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# Stock Assessment for the Southern and Eastern Scalefish and Shark Fishery: 2016 and 2017

PART
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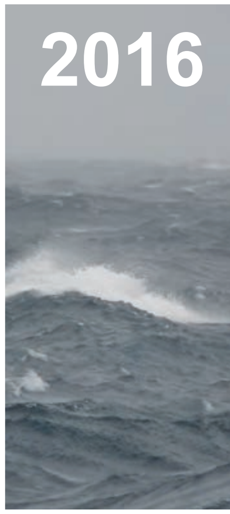


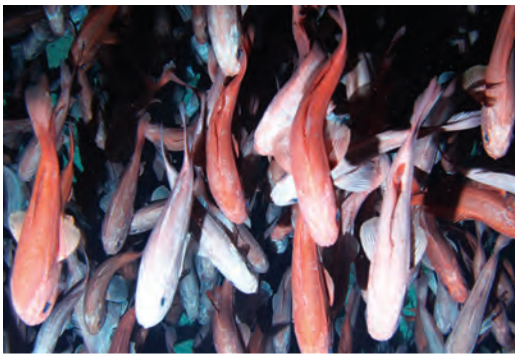

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***Cover photographs***

*Front cover, jackass morwong, orange roughy, blue grenadier, and flathead.*

***Report structure***

*Parts 1 and 2 of this report describe the assessments of 2016 and 2017 respectively.*

# Stock Assessment for the Southern and Eastern Scalefish and Shark Fishery 2016 and 2017

Part 1: 2016

G.N. Tuck
June 2018
Report 2015/0817

Australian Fisheries Management Authority

# Stock Assessment for the Southern and Eastern Scalefish and Shark Fishery: 2016

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# 1. Non-Technical Summary

*Stock Assessment for the Southern and Eastern Scalefish and Shark Fishery 2016 and 2017*

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**OBJECTIVES:**

- Provide quantitative and qualitative species assessments in support of the four SESSFRAG assessment groups, including RBC calculations within the SESSF harvest strategy framework
- 2016: Provide Tier 1 assessments for Deepwater flathead, Gummy shark, Tiger flathead, Eastern gemfish (subject to SESSFRAG advice) and School whiting data analysis; and Tier 4 assessments for Blue eye trevalla and Mirror dory
- 2017: Provide Tier 1 assessments for Blue grenadier, Redfish, East Roughy and School whiting; Tier 3 for Alfonsino, John Dory; Tier 4 for E/W Deepwater shark, Ocean Perch, Oreo basket, Ribaldo, Royal Red Prawn, and Silver Trevally

***Outcomes Achieved***

The 2016 assessments of stock status of the key Southern and Eastern Scalefish and Shark fishery (SESSF) species are based on the methods presented in this report. Documented are the latest quantitative assessments for the SESSF quota species. Typical assessment results provide indications of current stock status, in addition to an application of the recently introduced Commonwealth fishery harvest control rules that determine a Recommended Biological Catch (RBC). These assessment outputs are a critical component of the management and Total Allowable Catch (TAC) setting process for these fisheries. The results from these studies are being used by SESSFRAG, industry and management to help manage the fishery in accordance with agreed sustainability objectives.

## 1.1 General

*Examination of catch rate indices to determine whether to break out of a multi-year TAC*

Due to the increasing number of stocks that are being placed under multi-year TACs (MYTAC), indicators that might suggest that the stock is not following the projected or predicted trajectory of the last accepted Tier 1 stock assessment are impotant. Such indicators may include catch rates, biological surveys, recruitment indices (age or length composition data), or discarding. If a statistical comparison between the observed and predicted indicator suggests that the stock is not behaving in a manner consistent with the stock assessment, then this may be grounds to break-out from the MYTAC and, following RAG discussion and approval, conduct a Tier 1 assessment. Analyses for all Tier 1 assessed stocks of the time series of projected (expected) catch rates against those determined in the catch rate update were examined. The observations lay within the 95% confidence region for the forecasts for school whiting, blue grenadier, and silver warehou in the west (only just). The most recent CPUE observation (i.e. 2015) for redfish, jackass morwong and silver warehou in the east all lay below the forecast prediction intervals.

For the GAB, standard CPUE breakout analyses were conducted for Bight Redfish in the GAB. The species was not close to the edge of the 95% confidence intervals around the CPUE predicted from the projected Tier 1 assessment from 2015. In the 2014/2015 season the FIS breakout rule came close to being triggered but the model predicted standard errors were large and hence no breakout occurred.

*Catch rate standardisations*

Catch-per-unit-effort (CPUE) data is an important input to many of the stock assessments conducted within the South East and Southern Shark Fishery (SESSF), where it is used as an index of relative abundance through time. The catch and effort logbook data from the SESSF, which is the source of CPUE data, constitutes shot by shot data derived from a wide range of vessels, areas (zones), months, depths, and fishing gears. Catch rates used in the assessments are standardized to reduce the effects of factors such as which vessel fished, where and when fishing occurred, the gear used, at what depths fishing was conducted, and whether fishing occurred during the day or night. The intent is to focus on any changes in catch rates that occurred between years as a result of changes in stock size rather than changes that occur in any of these other factors. This intent is not always realized when there are unknown influential factors or factors for which we have no data, so interpretation of the catch rate trends should not necessarily be taken at face value. This is especially the case when there have been major management changes, such as the introduction of quotas or the more recent structural adjustment. Such large events can greatly influence fishing behaviour, which in turn influences catch rates. Because these changes affected the whole fleet at the same time it is not possible to standardize for their effects.

Catch rates, generally as kilograms per hour fished (though sometimes as catch per shot *e.g.* Danish Seine, or non-trawl methods), were natural log-transformed to normalize the data and stabilize the variance before standardization. A General Linear Model was used rather than using a Generalized Linear Model with a log-link. This simple analytical approach means that the exact same methods can be applied to all species/stock combinations in a relatively robust manner. The statistical models fitted were of the form: LnCE = Year + Vessel + Month + Depth Category + Zone + DayNight. There were interaction terms which could sometimes be fitted, such as Month:Zone or Month:Depth_Category. Data from all vessels reporting catches of a species were included although a preliminary data selection was made on a given depth range for each species for the zones of interest to focus attention on those depths contributing significantly to the fishery for each assumed stock and to reduce the number of empty categories within the statistical models.

Documented are the statistical standardization of the commercial catch and effort data for 23 species, distributed across 43 different combinations of stocks and fisheries ready for inclusion in the annual round of stock assessments. These include School Whiting, Eastern Gemfish, Jackass Morwong, Flathead, Redfish, Silver Trevally, Royal Red Prawn, Blue Eye, Blue Grenadier, Spotted/Silver

Warehou, Blue Warehou, Pink Ling, Western Gemfish, Ocean Perch, John Dory, Mirror Dory, Ribaldo, Ocean Jackets, Deepwater Flathead and Bight Redfish.

Summary graphs are provided across all species as well as more detailed information for each stock. Out of 43 stocks, there were eight whose catch rates have increased; 8 stocks where catch rates were stable and 27 stocks whose catch rates have declined over the last 10 years. There were nine stocks whose catch rates have increased since the 2007 corresponding to the structural adjustment and introduction of the Harvest Strategy Policy; five stocks whose catch rates were stable and 29 stocks whose catch rates have declined. The results from the standardisations are a key input to Tier 4 and Tier 1 assessments.

*Tier 4 analyses 1986 - 2015*

The Tier 4 harvest control rule is applied to species for which there is no reliable information on either current biomass levels or current exploitation rates. Ideally, in line with the notion of being more precautionary in the absence of information, the outcome from these analyses should be more conservative than those available from higher Tier analyses; this is now explicitly implemented by imposing a 15% discount factor on the RBC as a precautionary measure, unless there are good reasons for not imposing such an discount on particular species. The default procedure will now be to apply the discount factor unless RAGs generate advice that alternative and equivalent precautionary measures are in place (such as spatial or temporal closures) or that there is evidence of historical stability of the stock at current catch levels. Tier 4 analyses require, as a minimum, knowledge of the time series of total catches and of catch rates, either standardized or simple geometric mean catch rates. This year, only standardized catch rates were used except where discards were explicitly included in the analyses.

Mirror Dory East, Mirror Dory East including discards into the CPUE, Mirror Dory West, Western Gemfish and Blue-eye Trevalla have been assessed using the Tier 4 methodology in 2016. The Mirror Dory analyses treat the west and east as separate stocks, and also include the high levels of discards that occur in the east. Mirror dory RBCs for the east were either 222t or 173t (without or with discards) and for the west was 104t. For western gemfish, the RBCs were 423t or 139t (with or without discards). The Tier 4 analysis for Blue-Eye is based on the CPUE, as catch-per-hook, from SESSF zones 20 – 50 but the catches that go towards generating the target catch include all areas and methods except the GAB. This is a reflection of the hypothesis that the Blue-Eye in the GAB constitute a separate stock. The RBC from the analysis based on catch-per-hook catch rates is now 526t. This is a relatively large change in the RBC from last year, which is a reflection of the potential behaviour of the Tier 4 when CPUE is recovering from a relatively low period.

## 1.2 Slope, Shelf and Deepwater Species

*Eastern Gemfish*

The potential effects of updating the stock assessment in Stock Synthesis for eastern gemfish was considered in 2016. As in the last full assessment in 2009, Stock Synthesis provides a standardised platform for conducting stock assessments. Catch data were incorporated from 1968, state catches were included, and length-frequency data dating back to 1975 were used. This update included (a) the estimation of the growth parameters within the assessment, (b) the use of conditional age-at-length data, (c) the addition of updated length-frequencies, catches and catch-rates to 2015, (d) the inclusion of discards and (e) allowance for ageing error.

With the latest data to the end of 2015, the spawning stock biomass is 8.3% of the average unfished level. Similar to the previous assessment, a large spawning event was estimated to have occurred in 2002, which has led to slight recovery of biomass. A relatively high recruitment event is apparent in 2013, although this event simply returns to the long-term average rather than the depressed level of recruitment that has been experienced in recent times.

*Tiger flathead*

The tiger flathead assessment was updated in 2016 with the inclusion of data up to the end of 2015, comprising an additional three years of catch, discard, CPUE, length and age data and ageing error updates since the last assessment. An additional survey point was included from the Fishery Independent Survey and length frequencies have been included from all four years of the Fishery Independent Survey. A range of sensitivities were explored, including splitting the Fishery Independent Survey into two fleets to match the fleet structure in the assessment, and lowering the final year of recruitment estimation from 2012 to 2009.

The base-case assessment estimates that current spawning stock biomass is 43% of unexploited stock biomass (SSB0). Under the agreed 20:35:40 harvest control rule, the 2017 recommended biological catch (RBC) is 2,971 t, and remains above the long term yield (assuming average recruitment in the future) of 2,765 t. The average RBC over the three year period 2017-2019 is 2,936 t and over the five year period 2017-2021, the average RBC is 2,909 t.

*Blue eye*

Alternative catch rate units for the standardisation of blue eye (*Hyperoglyphe antarctica*) were considered in 2016. One of the foundations of the current Tier 4 Blue-Eye assessments is that the CPUE for drop-line and auto-line can be combined. This is the case because both have used catch-per-record (or day) as their unit of CPUE and on that basis their CPUE was comparable. The combination was required because, in 2009, each method alone only had a rather short time-series of usable CPUE (sufficient catches, records and representative coverage of the fishery) that could be used for assessment purposes. Catch-per-day was used because early use of the log-books had often mixed up the reporting of lines and hooks-per-line making their direct use invalid.

An objective of this work was to set up a more easily repeatable analysis for the generation of total-hooks-set and hence be more open to future correction and critical examination. Separate data selection rules and database manipulations (separate algorithms) were developed for Drop-Line and Auto-Line data sets such that the outcome was a more reliable estimate of the total number of hooks set for each record. These data were used to generate catch-per-hook catch rate data which were in turn used in catch rate standardizations for the two methods.

The effect of using catch-per-hook rather than catch-per-record is marked with the catch-per-record exhibiting a recent CPUE recovery not seen in the catch-per-record. It does not seem to matter greatly whether the analysis of catch-per-hook is restricted to zones 20 – 50 or extended to include the GAB zones 83, 84, and 85.

The Tier 4 analysis for blue-eye is based on the CPUE, as catch-per-hook, from SESSF zones 20 – 50 but the catches that go towards generating the target catch include all areas and methods except the GAB. This is a reflection of the hypothesis that the blue-eye in the GAB constitute a separate stock. However, currently in the GHT fishery, the blue-eye quota also applies in the GAB, so there is some confusion over the assessment and management details that may require attention.

The effect of the CPUE standardization is, as expected, to reduce the variation exhibited by the nominal catch rates seen in the fishery. However, in more recent years there still remains some relatively large rises and falls in catch rate over relatively short periods. This seems likely to reflect the fact that there are very few Auto-Line vessels that make large contributions to the fishery so if they alter their fishing patterns (perhaps in response to whale depredation or some other factor) then large changes in catch rates can occur. Such large changes over short periods are certainly not a direct reflection of equivalent changes in the stock size in such a long-lived species. For greater stability in the RBC predicted from the Tier 4 analysis it might be necessary to increase the number of years over which the more recent CPUE is averaged for comparison with the target.

The RBC from the analysis based on catch-per-hook catch rates is now 526 t.

## 1.3 GAB Species

*Deepwater flathead*

A Tier 1 analysis for GAB Deepwater flathead was conducted in 2016. For the first time the ISMP data was divided into the on-board and Port based samples, the length and age composition data from the FIS was used for the first time, and the Industry collected length composition data was also used for the first time.

The base-case assessment estimates that the female spawning stock biomass at the start of 2016/2017 was 45.0% of unexploited female spawning stock biomass ($SSB_0$). The 2017/2018 recommended biological catch (RBC) under the agreed 20:35:43 harvest control rule is 1155 t and the long-term yield (assuming average recruitment in the future) is 1093 t. Averaging the RBC over the three year period 2017/2018 – 2019/2020, generates a three year RBC of 1128 t and over the five year period 2016/2017 – 2020/2021, the average RBC would be 1115 t.

*Bight redfish*

Standard CPUE breakout analyses were conducted for Bight Redfish in the GAB. The species was not close to the edge of the 95% confidence intervals around the CPUE predicted from the projected Tier 1 assessment from 2015. In the 2014/2015 season the FIS breakout rule came close to being triggered but the model predicted standard errors were large and hence no breakout occurred.

Predicted catch-rates for Bight Redfish have been rising gently since 2009/2010 while the standardized CPUE first declined from 2009/2010 – 2013/2014 but since then have been rising and running parallel to the predicted CPUE. However, the 95% confidence intervals around the predicted CPUE easily encompass the standardized CPUE values so no breakout was observed. It should be noted, however, that the predicted CPUE has now been above the observed CPUE for the past four years, although currently the two trends appear to be running in parallel.

## 1.4 Shark Species

*Gummy shark*

An updated Tier 1 assessment for gummy shark (*Mustelus antarcticus*) was provided in 2016. The assessment of gummy shark was updated based on available information to 2015. The model on which the assessment is based was modified in three ways: (a) the dynamics are now based on a population dynamics equation that assumes that the catches by the various gear-types occur simultaneously rather than sequentially, (b) the "hook fleet" included in previous assessments is now separated into shark longline, trawl, and scalefish longline gear-types, with size-specific selectivity estimated for each gear-type, and (c) allowance is now made for age-reading error. The assessment includes revised catch and length-composition data based on the most recent extractions from the AFMA database, new age composition data, and updated catch-rate indices. The catch-rate indices for 1997 onwards are based on the method commonly applied for SESSF species, with the pre-1997 catch-rates appended to those for 1997 onwards by calibrating the catch-rates for the period of overlap. The assessment includes catch-rate indices for the trawl and shark longline for the first time.

A reference case model was presented that fits to all available data. The fits are all reasonable and the assessment outputs indicate that gummy shark in Bass Strait, and off South Australia and Tasmania are above the management target of 48% of unfished pup production. The Recommended Biological Catches for 2016, 2017 and 2018 from the reference case model are 2080t, 1878t, and 1807t.

*Shark catch rate standardisations*

Data from years 1997 – 2015 available in the Commonwealth logbook database were used to standardise catch rates for shark species. Reported catches of school shark are relatively low and those from trawling do not appear to be targeted, as evidenced by the large proportion of < 30 kg shots present in the logbook data. Nevertheless, the areas where they are caught have not changed greatly and yet the standardized catch-per-unit effort (CPUE) has begun to increase significantly, with the exception of 2014. This is a positive sign, which when combined with the observation of increased proportions of smaller school sharks in the ISMP sampling are a first clear evidence of school sharks showing some signs of recovery.

There has been an increase in reported gillnet catches of gummy shark and standardized CPUE in South Australia and Bass Strait during 2015. By contrast, standardized CPUE of gillnet caught gummy shark around Tasmania remained flat since 2014. Reported catches by bottom line remained at 229 t for both 2013 and 2014, and dropped to 192 t in 2015, while there was a drop of ~8 t reported (i.e. 92 t to 84 t) in 2015 relative to 2014 for trawl. Standardized CPUE for bottom line and trawl have increased steadily since 2013, remaining above the long-term average.

Like school shark, elephant fish are a non-targeted species, as indicated by the large proportion of small shots (i.e. <30 kg). Gillnet standardized CPUE is flat and noisy, and decreased in 2015. However this analysis ignores discarding and uses number of shots instead of net length as a unit of effort. In recent years discard rates for elephant fish have been very high, which may imply that their CPUE is in fact increasing. It would be desirable, in the future to perform analyses that account for discards.

Sawshark are considered to be a bycatch group which is supported by the high proportion of < 30 kg. Catches are reported by both gillnets and trawls. Standardized CPUE for gillnets exhibits a steady decline since about 2001. However, a detailed analysis should be considered that uses net length as an effort unit instead of shot. Trawl caught sawshark standardized indices exhibit a noisy but flat trend, with an increase in 2014 reaching the long term average. By contrast, sawshark standardized CPUE by Danish seine (which has the highest proportion of shots < 30 kg among methods) has been flat since 2006 and increased about the long-term mean in 2015. However, this species group is also discarded (13% to 28%; discarded for 2011-2014) no estimate available for 2015) may artficially inflate these estimates.

KEYWORDS: fishery management, southern and eastern scalefish and shark fishery, stock assessment, trawl fishery, non-trawl fishery

## 2. Background

The Southern and Eastern Scalefish and Shark Fishery (SESSF) is a Commonwealth-managed, multi-species and multi-gear fishery that catches over 80 species of commercial value and is the main provider of fresh fish to the Sydney and Melbourne markets. Precursors of this fishery have been operating for more than 85 years. Catches are taken from both inshore and offshore waters, as well as offshore seamounts, and the fishery extends from Fraser Island in Queensland to south west Western Australia.

Management of the SESSF is based on a mixture of input and output controls, with over 20 commercial species or species groups currently under quota management. For the previous South East Fishery (SEF), there were 17 species or species groups managed using TACs. Five of these species had their own species assessment groups (SAGs) – orange roughy (ORAG), eastern gemfish (EGAG), blue grenadier (BGAG), blue warehou (BWAG), and redfish (RAG). The assessment groups comprise scientists, fishers, managers and (sometimes) conservation members, meeting several times in a year, and producing an annual stock assessment report based on quantitative species assessments. The previous Southern Shark Fishery (SSF), with its own assessment group (SharkRAG), harvested two main species (gummy and school shark), but with significant catches of saw shark and elephantfish.

In 2003, these assessment groups were restructured and their terms of reference redefined. Part of the rationale for the amalgamation of the previous separately managed fisheries was to move towards a more ecosystem-based system of fishery management (EBFM) for this suite of fisheries, which overlap in area and exploit a common set of species. The restructure of the assessment groups was undertaken to better reflect the ecological system on which the fishery rests. To that end, the assessment group structure now comprises:

- SESSFRAG (an umbrella assessment group for the whole SESSF)
- South East Resource Assessment Group (Slope, Shelf and Deep RAG)
- Shark Resource Assessment Group (Shark RAG)
- Great Australian Bight Resource Assessment Group (GAB RAG)

Each of the depth-related assessment groups is responsible for undertaking stock assessments for a suite of key species, and for reporting on the status of those species to SESSFRAG. The plan for the resource assessment groups (South East, GAB and Shark RAGs) is to focus on suites of species, rather than on each species in isolation. This approach has helped to identify common factors affecting these species (such as environmental conditions), as well as consideration of marketing and management factors on key indicators such as catch rates.

The quantitative assessments produced annually by the Resource Assessment Groups are a key component of the TAC setting process for the SESSF. For assessment purposes, stocks of the SESSF currently fall under a Tier system whereby those with better quality data and more robust assessments fall under Tier 1, while those with less reliable available information are in Tiers 3 and 4. To support the assessment work of the four Resource Assessment Groups, the aims of the work conducted in this report were to develop new assessments if necessary (under all Tier levels), and update and improve existing ones for priority species in the SESSF.

# 3. Need

A stock assessment that includes the most up-to-date information and considers a range of hypotheses about the resource dynamics and the associated fisheries is a key need for the management of a resource. In particular, the information contained in a stock assessment is critical for selecting harvest strategies and setting Total Allowable Catches.

# 4. Objectives

- Provide quantitative and qualitative species assessments in support of the four SESSFRAG assessment groups, including RBC calculations within the SESSF harvest strategy framework
- 2016: Provide Tier 1 assessments for Deepwater flathead, Gummy shark, Tiger flathead, Eastern gemfish (subject to SESSFRAG advice) and School whiting data analysis; and Tier 4 assessments for Blue eye trevalla and Mirror dory
- 2017: Provide Tier 1 assessments for Blue grenadier, Redfish, East Roughy and School whiting; Tier 3 for Alfonsino, John Dory; Tier 4 for E/W Deepwater shark, Ocean Perch, Oreo basket, Ribaldo, Royal Red Prawn, and Silver Trevally

# 5. SESSF Tier 1 CPUE forecasts for multi-year TAC review triggers, 2016

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## 5.1 Summary

Annual standardized observed CPUE were compared with forecast abundance from the most recent Tier 1 stock assessment models for redfish, school whiting, blue grenadier, jackass morwong and silver warehou. The observations lay within the 95% confidence region for the forecasts for blue grenadier, school whiting, and silver warehou in the west (only just). The most recent CPUE observation (i.e. 2015) for redfish, jackass morwong and silver warehou in the east all lay below the forecast prediction intervals (PI).

## 5.2 Introduction

A number of Southern and Eastern Scalefish and Shark Fishery (SESSF) quota species on Tier 1 are managed on Multi-Year Total Allowable Catches (MYTACs) so that stock assessments are performed for those species at 3-5 year intervals. The most recently accepted base case stock assessment for each MYTAC stock is used to set future Recommended Biological Catches (RBCs) for the stock during the MYTAC period. Each year, to evaluate the continuing accuracy of the model predictions, actual catches are entered into the model and predicted catch rates are forecast. If recent observed catch rates fall outside of a 95% prediction interval around the forecast catch rates, this suggests that the model no longer accurately reflects observed reality and most likely needs to be updated. Note that this method aims to test the applicability of the TAC that was set, therefore it is important to project the assessment model under the same set of assumptions as those originally used to set the TAC e.g. the future recruitment scenario (high, average, low) should be the same.

When recent standardized CPUE falls outside of the 95% prediction interval for forecast abundance, this triggers management attention for the stock. One of the considerations for management must be whether the recent observed (and standardized) CPUE accurately reflects stock abundance. This may be particularly questionable for stocks that are no longer targeted, such as eastern gemfish.

During 2016 CPUE forecasts were calculated for the stocks shown in Table 5.1.

Table 5.1. Stocks for which CPUE forecasts were performed, the name of the CSIRO scientist responsible for projecting the assessment, and final year of data available to the original stock assessment model, after this year the model is forecasting.

| Stock | Assessment scientist | Final assessment year | Reference |
|---|---|---|---|
| Redfish | Geoff Tuck | 2013 | Tuck & Day (2014) |
| School whiting | Jemery Day | 2008 | Day (2009) |
| Blue Grenadier | Geoff Tuck | 2012 | Tuck (2014) |
| Jackass morwong | Geoff Tuck | 2014 | Tuck & Day (2015) |
| Spotted warehou | Jemery Day | 2014 | Day & Thomson (2015) |

## 5.3 Methods

The process of calculating review triggers involves the following steps:

1. Standardize the CPUE for the stock of interest (including the most recent data).
2. Obtain the recent catch history for the stock (i.e. the catches taken from the stock during the years since the stock assessment model was last updated).
3. Use the base case stock assessment model to project the stock to the current year, given the catches from step 2.
4. Adjust the CPUE series from step 1 to match the CPUE series used to tune the assessment model, calculate 95% prediction bounds (PI) around the forecast CPUE, and determine whether the most recent observed CPUE points fall within the PI.

Each of these steps is described in more detail below.

### 5.3.1 *Updated CPUE*

Reported catch and effort data are standardized to take account of factors affecting catch rates (such as fishing depth, season, vessel and zone). Standardized catch rates for the 9 fleets (6 stocks) considered in this report were obtained from Miriana Sporcic (CSIRO, pers commn).

### 5.3.2 *Recent catch history*

Logbook catch records from the GENLOG database, held at CSIRO, were used to calculate catch ratios between the fleets used by each stock assessment. For example, the eastern flathead assessment model incorporates a trawl fleet in zones 10 and 20, and another in eastern Tasmania (zone 30). The ratio of the logbook catches for these fleets was used to split up the verified landed catch (taken from the Catch Disposal Record, CDR, database) and this was used in the stock assessment projection. The exception was eastern gemfish, for which the historical split between the non-spawning summer and the winter spawning fleets was applied to the CDR data.

#### 5.3.3 *Stock assessment forecast*

All of the stocks considered here were assessed using the stock synthesis model, version 3.x (SS3). SS3 does not produce expected values for each CPUE index in standard forecasts, so assessment authors were provided with the following instructions:

***Edit starter.ss***

1 # 0=use init values in control file; 1=use ss3.par

0 # Turn off estimation for parameters entering after this phase

***Edit ss3.dat***

Change end year on line 3 to the most recently available data e.g. 2015.

Obtain the most recent actual catch estimates available for years that have elapsed since the assessment model was last run. Add these to the catch series using the attached Catch_History.csv file and – assume fleet splits as per you're the attached R code that calculates logbook totals. You will need to increase the number of lines of catch data.

Add lines to the end of recent abundance indices so that they finish in 2015. Please use values of 1.0 and a CV of 999.0.

***Edit ss3.par***

Add another 0.0000000000 to the end of recruitment deviations for every extra year of data you have added.

***Run ss3 –nohess***

Look in report.sso under the heading INDEX_2 and there should be estimates of CPUE for all years to 2015 for recent abundance indices.

#### 5.3.4 *Matching two standardized CPUE series*

Two standardized CPUE time series are used here: (a) the standardized CPUE series that was used to tune the stock assessment model during the last model update, and (b) the updated standardized CPUE time series that used a slightly longer catch and effort time series than that used by (a). On the whole, the two series correspond very closely with one another, apart from the greater length of series (b). However, there are always slight differences so series (b) must be scaled to match series (a). There are a number of ways that these two series can be matched, e.g. by dividing both series by their means, or by shifting (b) up or down so that any given year from series (b) matches the corresponding value from series (a). The method chosen by Klaer et al (2014) is to scale to the final year of series (a). Thus, the updated time series ($B$) is rescaled (yielding series $\tilde{B}$) by multiplying each element of $B$ by the ratio of the value of the historical time series $A$, in its final year $A_y$, by the value of updated series $B$ in the same year ($B_y$):

$$\tilde{B} = B\,\frac{A_y}{B_y}$$

The final year of the historical time series ($y$) for each stock is shown in Table 5.1.

#### 5.3.5 *Prediction interval around forecast CPUE*

A 95% prediction interval for the forecast CPUE points was generated by assuming a log normal distribution for the residuals of the observed and expected CPUE. Thus the standard error $s_y$ for a given year $y$ were given by the standard error of the residuals $r_y$ over the whole (historical part) of the time series

$$r_y = \ln(B_y) - \ln(E_y)$$

where $E_y$ is the expected catch rate from the stock assessment model.

The plots shown in this report use the same method to calculate the PIs shown for all years, even though the stock assessment models do provide annual standard errors for the historical period. The PI for the forecast period is used to assess whether or not the observed CPUE falls within acceptable bounds. Alternative methods for calculating PIs for the model forecasts include projecting the model a large number of times using parameter values drawn from the model posterior by the Markov Chain Monte Carlo (MCMC) method; or approximating the standard errors using the Laplace approximation.

## 5.4 Results

The recent observed CPUE for trawl catches of eastern redfish lie below the lower prediction bound in 2015 and is particularly close to the lower bound in 2014 (Figure 5.1). Interestingly, the two earlier CPUE values (for 2012 and 2013) both lie below the lower prediction bound, despite being part of the historical period to which the assessment model was tuned.

The seven observed CPUE points for school whiting caught by Danish seine all fall within the model PI (Figure 5.2), indicating no need to trigger a review for this species.

The recent observed CPUE values for blue grenadier all lie close to the expected values, and well within the 95% PI (Figure 5.3).

The recent observed CPUE value for eastern jackass morwong is below the PI in both the combined Victoria and NSW region, and in eastern Tasmania (Figure 5.4). The 2015 CPUE point for western jackass morwong lies within the PI bound but is very close to the lower bound (Figure 5.5).

The 2015 CPUE for silver warehou in the east is just below the lower bound, and only just above it in the west (Figure 5.6).

A summary of the results for all fleets and stocks is shown in Table 5.2.

Table 5.2. Summary of comparison between observed and forecast CPUE for all fleets and stocks considered. *Green* shading indicates an observation well within the PI; *orange* indicates within, but close to the lower bound; *red* indicates below the lower bound.

| Stock | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 |
|---|---|---|---|---|---|---|---|
| Redfish | | | | | | | |
| School whiting | | | | | | | |
| Blue Grenadier | | | | | | | |
| Morwong 10&20 | | | | | | | |
| Morwong East 30 | | | | | | | |
| Jackass morwong West | | | | | | | |
| Silver warehou East | | | | | | | |
| Silver warehou West | | | | | | | |

### 5.4.1 *Redfish*

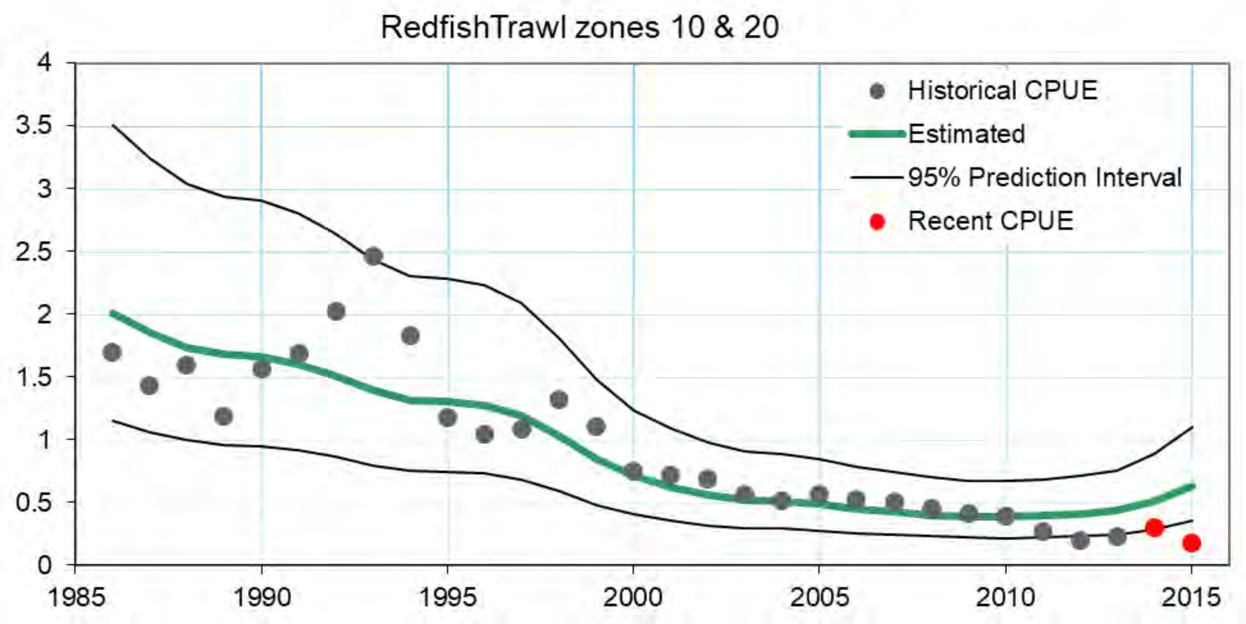



Figure 5.1. Redfish CPUE in zones 10 and 20 caught by trawl. The historical CPUE to which the stock assessment model was tuned is shown as *grey dots* and the recent observed CPUE (scaled to match the older series) as *red dots*. Model estimated catch rates, projected to 2015, are shown as a *green line*, with a corresponding 95% prediction interval (*black line*).

### 5.4.2 *School whiting*

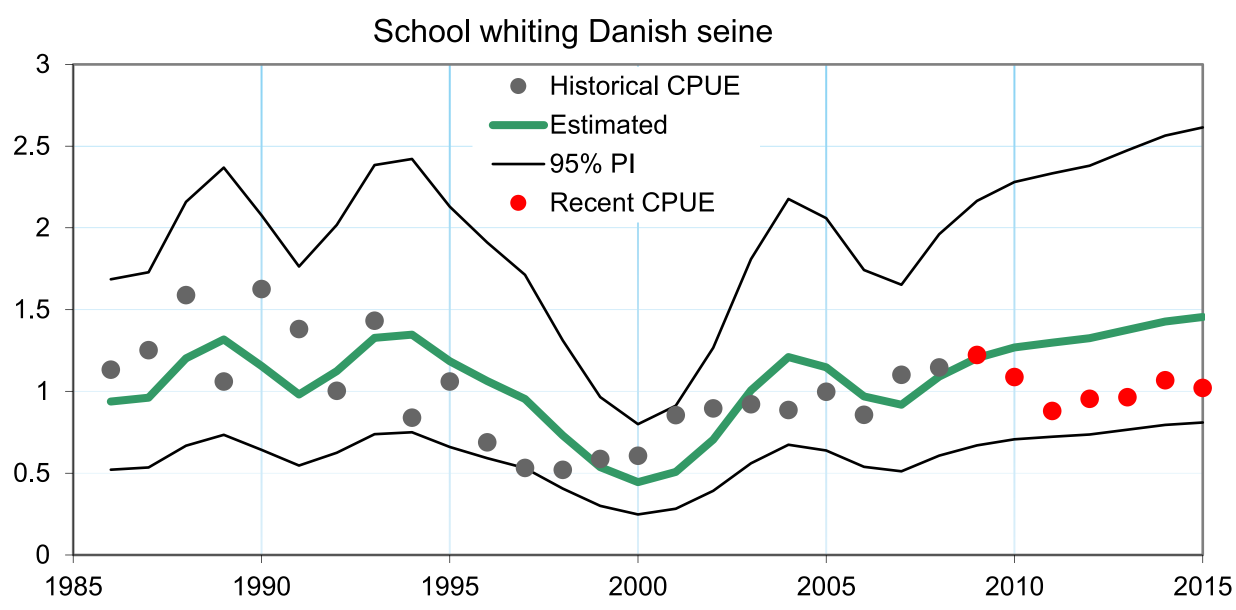



Figure 5.2. School whiting CPUE for Danish seine. The historical CPUE to which the stock assessment model was tuned is shown as *grey dots* and the recent observed CPUE (scaled to match the older series) as *red dots*. Model estimated catch rates, projected to 2015, are shown as a *green line*, with a corresponding 95% prediction interval (*black line*).

### 5.4.3 *Blue grenadier*

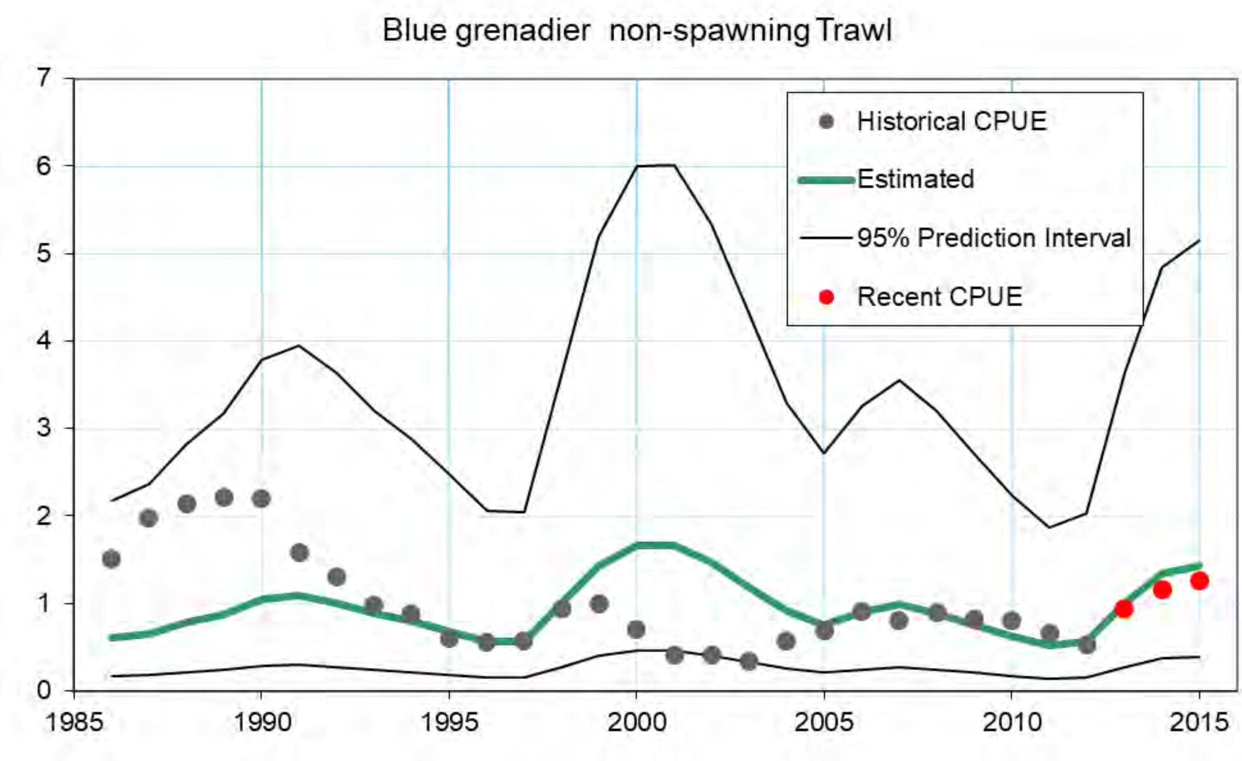
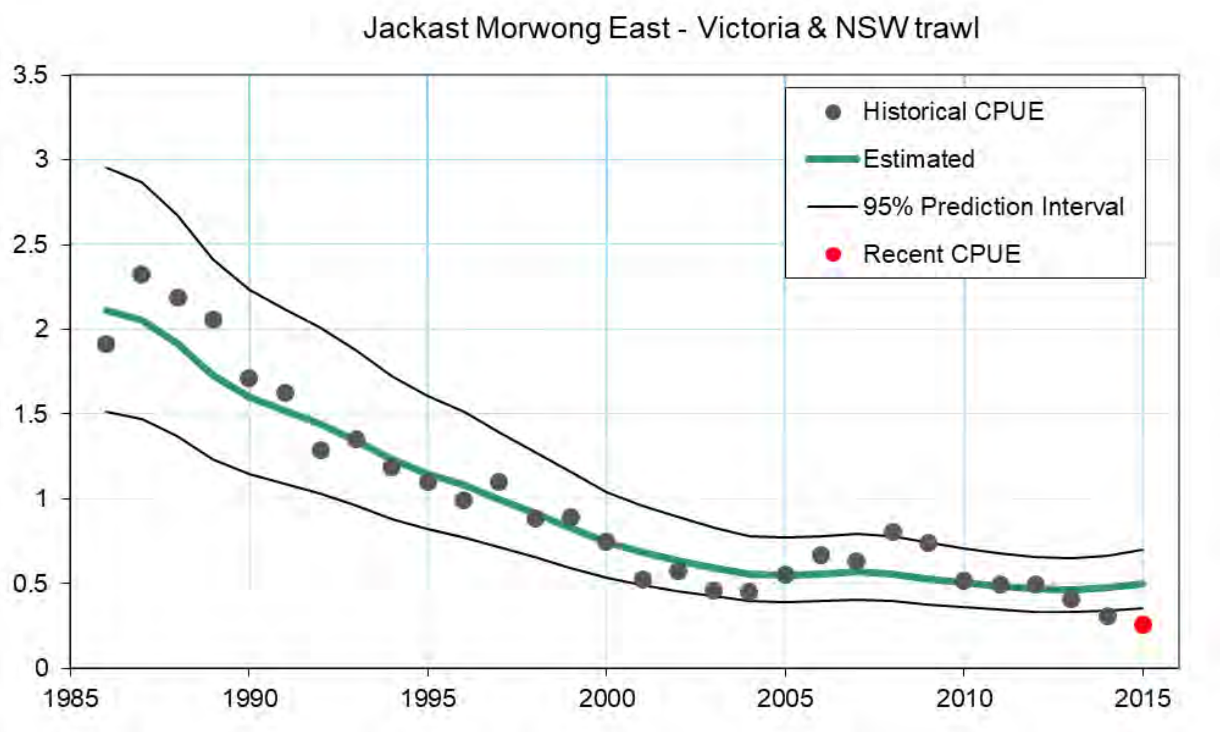



Figure 5.3. Blue grenadier CPUE caught by trawl in the non-spawning fishery (all times and zones except zone 40 during June-Aug). The historical CPUE to which the stock assessment model was tuned is shown as *grey dots* and the recent observed CPUE (scaled to match the older series) as *red dots*. Model estimated catch rates, projected to 2015, are shown as a *green line*, with a corresponding 95% prediction interval (*black line*).

### 5.4.4 *Jackass Morwong East*



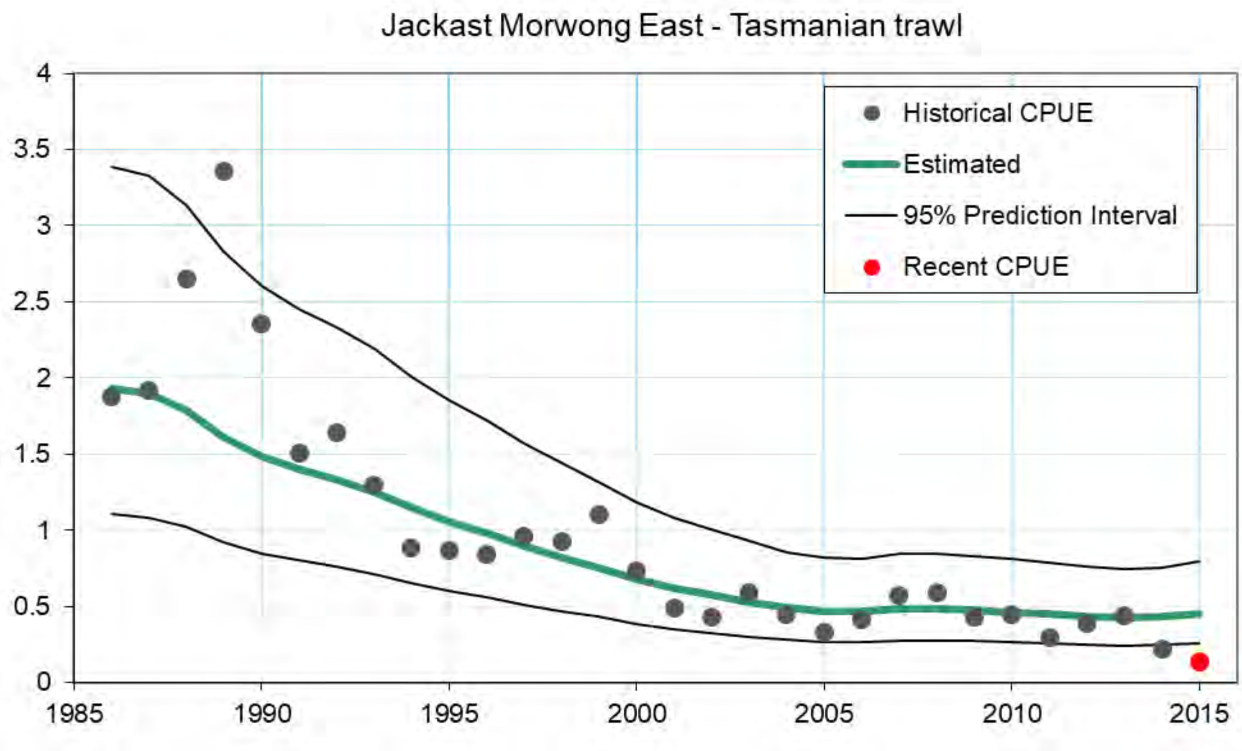




Figure 5.4. Jackass morwong CPUE for trawl catches in the east: Victoria and NSW (zones 10, 20) (upper plot), and Tasmania (zone 30) (lower plot). The historical CPUE to which the stock assessment model was tuned is shown as *grey dots* and the recent observed CPUE (scaled to match the older series) as *red dots*. Model estimated catch rates, projected to 2015, are shown as a *green line*, with a 95% prediction interval (*black line*).

### 5.4.5 *Jackass Morwong West*

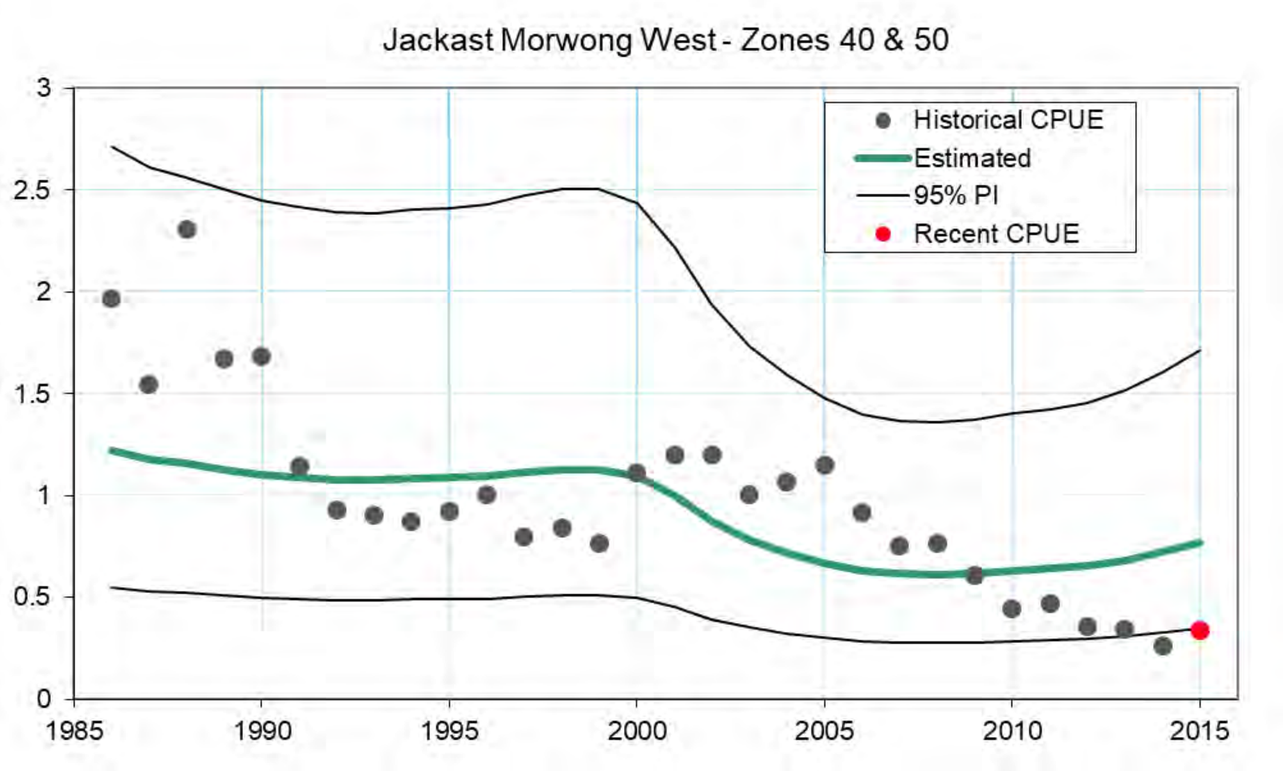



Figure 5.5. Jackass morwong CPUE for trawl catches in the west (zones 40 & 50). The historical CPUE to which the stock assessment model was tuned is shown as *grey dots* and the recent observed CPUE (scaled to match the older series) as *red dots*. Model estimated catch rates, projected to 2015, are shown as a *green line*, with a 95% prediction interval (*black line*).

### 5.4.6 *Silver warehou*

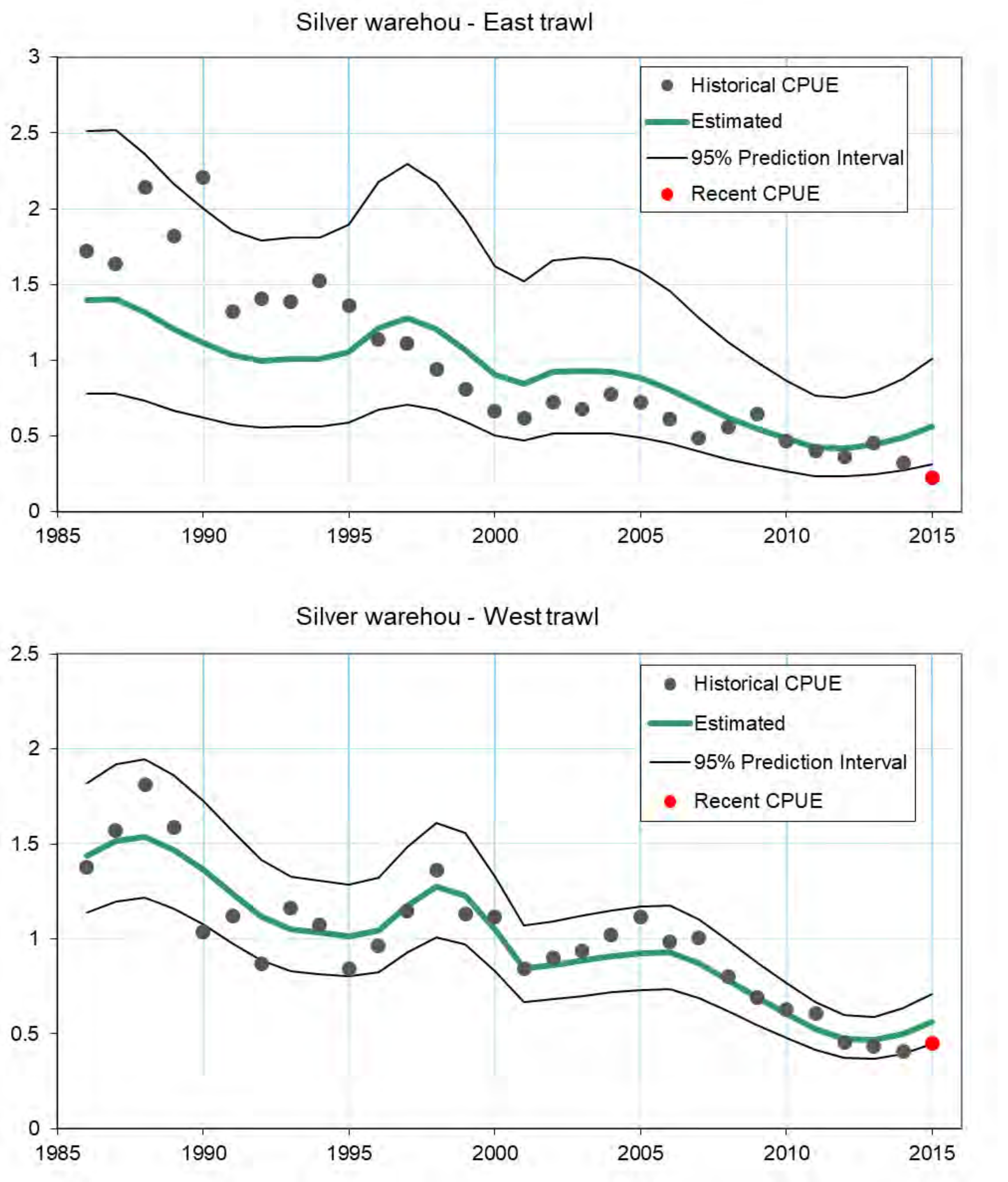
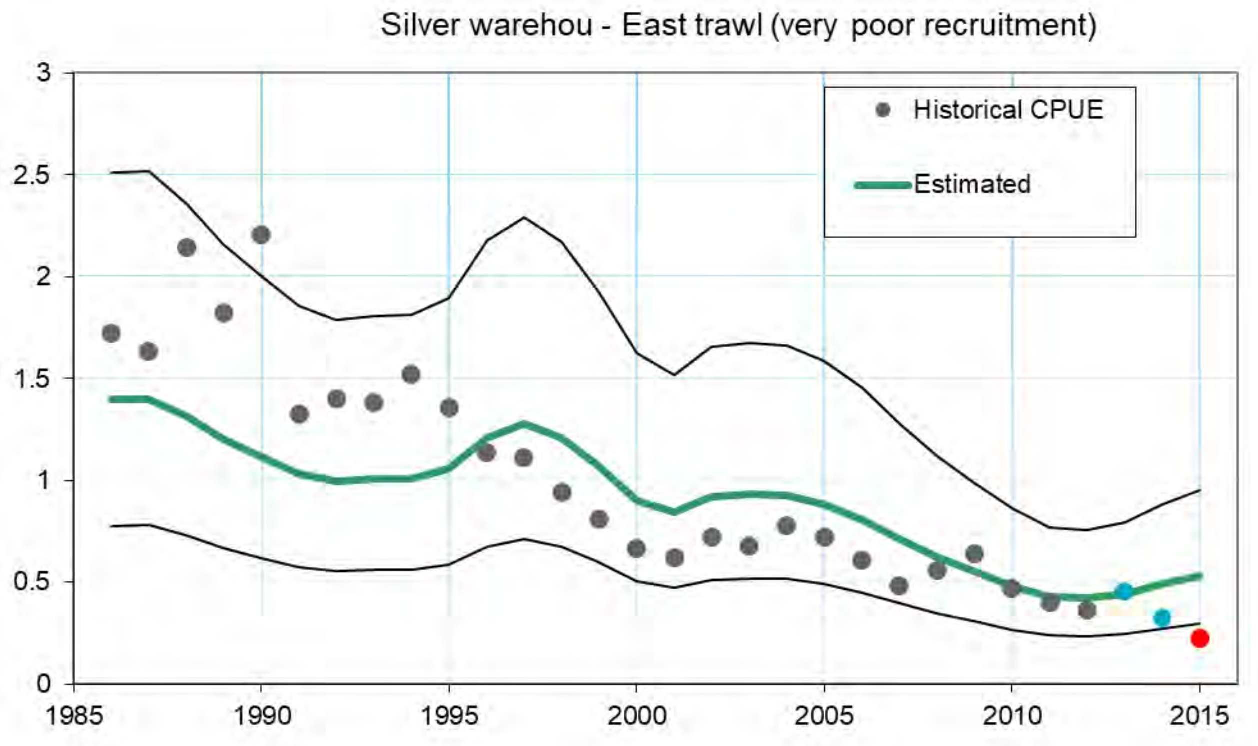



Figure 5.6. Silver warehou CPUE for trawl catches in the east (upper plot) and west (lower plot). The historical CPUE to which the stock assessment model was tuned is shown as *grey dots* and the recent observed CPUE (scaled to match the older series) as *red dots*. Model estimated catch rates, projected to 2015, are shown as a *green line*, with a 95% prediction interval (*black line*).

### 5.4.7 *Silver warehou under poor recruitment*



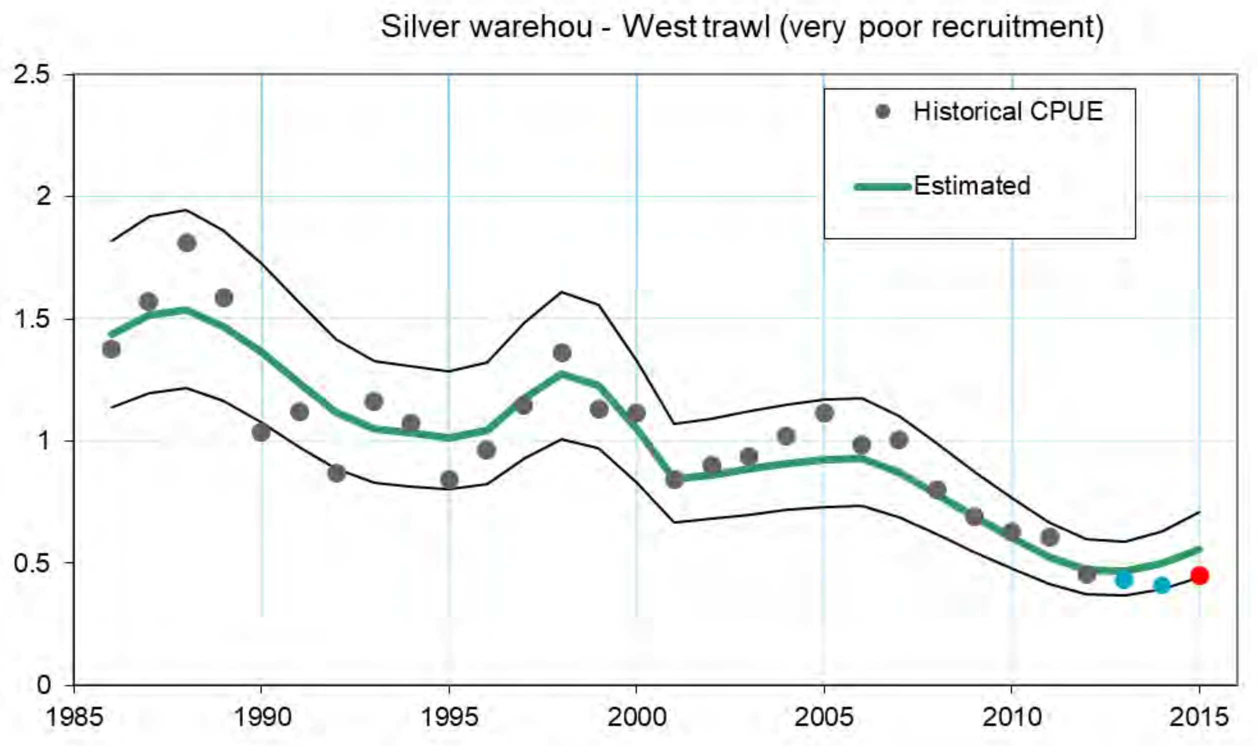




Figure 5.7. Silver warehou CPUE for trawl catches in the east (upper plot) and west (lower plot) under a poor recruitment assumption from 2013 onwards.

#### 5.4.8 *Silver warehou under very poor recruitment*

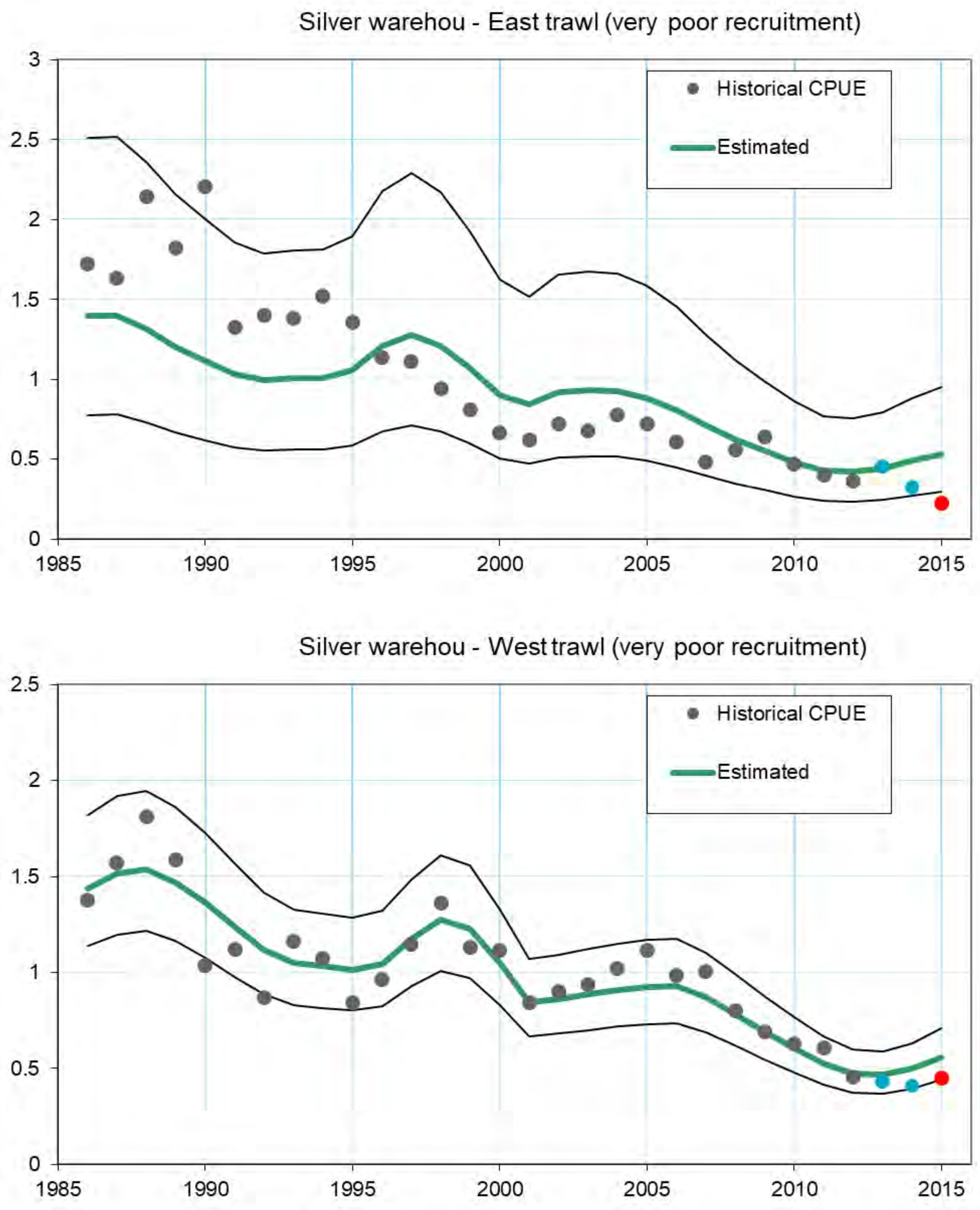



Figure 5.8. Silver warehou CPUE for trawl catches in the east (upper plot) and west (lower plot) under a very poor recruitment assumption from 2013 onwards.

### 5.5 References

Day J (2010) School whiting (*Sillago flindersi*) stock assessment based on data up to 2008. In Tuck, G.N. (ed.) 2010. *Stock Assessment for the Southern and Eastern Scalefish and Shark Fishery 2009*. Part 1. Australian Fisheries Management Authority and CSIRO Marine and Atmospheric Research, Hobart. p 190-249.

Day J, Thomson RB & Tuck GN (2015) Silver Warehou (*Seriolella punctata*) stock assessment based on data up to 2014. Version 2 – updated after presentation to SlopeRAG. 10 November 2015. 68pp.

Tuck GN (2014) Stock assessment of blue grenadier *Macruronus novaezelandiae* based on data up to 2012. In Tuck, G.N. (ed.) 2014. *Stock Assessment for the Southern and Eastern Scalefish and Shark Fishery 2013*. Part 1. Australian Fisheries Management Authority and CSIRO Marine and Atmospheric Research, Hobart. p 61-115.

Tuck GN, Day J & Wayte, S (2015) Development of a base-case Tier 1 assessment of eastern Jackass Morwong (*Nemadactylus macropterus*) based on data up to 2014. Presented to ShelfRAG 22 September 2015. Hobart. 35pp.

Tuck GN & Day J (2015) Stock assessment of redfish *Centroberyx affinis* based on data up to 2013. In Tuck, G.N. (ed.) 2015. *Stock Assessment for the Southern and Eastern Scalefish and Shark Fishery 2014*. Part 1. Australian Fisheries Management Authority and CSIRO Marine and Atmospheric Research, Hobart. p 103-147.

# 6. Multi-Year Breakout Analyses for Bight Redfish in the GAB (2015/16)

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## 6.1 Executive Summary

Standard CPUE breakout analyses were conducted for Bight Redfish in the GAB. The species was not close to the edge of the 95% confidence intervals around the CPUE predicted from the projected Tier 1 assessment from 2015. In the 2014/2015 season the FIS breakout rule came close to being triggered but the model predicted standard errors were large and hence no breakout occurred.

Predicted catch-rates for Bight Redfish has been rising gently since 2009/2010 while the standardized CPUE first declined from 2009/2010 – 2013/2014 but since then have been rising and running parallel to the predicted CPUE. However, the 95% confidence intervals around the predicted CPUE easily encompass the standardized CPUE values so no breakout was observed. It should be noted, however, that the predicted CPUE has now been above the observed CPUE for the past four years, although currently the two trends appear to be running in parallel.

No changes to current management arrangements for Bight Redfish are indicated.

## 6.2 Introduction

Multi-Year TACs were introduced in 2012 after discussions through 2011 (Tuck *et al*., 2012). In the absence of formal stock assessments within the period of a multi-year TAC, breakout tests are conducted to determine whether the species not assessed had begun to deviate from their expected trajectories through the period of their multi-year TACs. In the Great Australian Bight (GAB) trawl fishery the quota species not assessed this year is Bight Redfish (*Centroberyx gerrardi*). This year a new Tier 1 assessment for Deepwater Flathead is being developed and an updated base-case Tier 1 assessment is being attempted with Western Gemfish (*Rexea solandri*); so this report focusses only on Bight Redfish.

## 6.3 Methods

### 6.3.1 *TIER 1 Breakout Rules*

Standard breakout rules for Tier 1 species were adopted in the GAB for Deepwater Flathead and Bight Redfish. These rules, along with multi-year TACs remain untested in terms of the risks they entail, which relate to their potential to lead to a failure to act when the stock really is declining significantly and yet does not breakout below the selected 95% confidence intervals around the projected predicted CPUE (a false negative result). False positives might be where the breakout has the observed CPUE rising above the projected predicted CPUE. This may entail potential risks to fishing opportunities but at least such possible events indicate little risk to the stock. The agreed breakout rules used are identical to those used last year (Haddon, 2015). Both are repeated here for reference.

#### *6.3.1.1 Bight Redfish*

The breakout rule is triggered:

- if the most recent observed value for the standardised CPUE falls outside of the 95% confidence interval of the value for the CPUE predicted by the most recent Tier 1 stock assessment;

  or

- if the most recent observed value for the CPUE from the fishery independent survey falls outside of the 95% confidence interval of the value for the CPUE predicted from the fishery independent survey (when survey values are available).

#### *6.3.1.2 Deepwater Flathead*

The breakout rule is triggered:

- if the most recent observed value for the standardised CPUE falls outside of the 95% confidence interval of the value for the CPUE predicted by the most recent Tier 1 stock assessment;

  or

- if the most recent observed value for biomass from the fishery independent survey falls outside of the 95% confidence interval of the value for the biomass predicted from the fishery independent survey (when survey values are available).

#### *6.3.1.3 Western Gemfish*

A breakout rule for western gemfish was decided upon by the RAG in August 2014:

Western Gemfish will have broken out:

- if the observed standardised CPUE falls outside of the 95% CI of standardised CPUE over the last 10 years.

This rule, remains un-tested and, for the 2013/2014 assessment (Haddon, 2015), was found to be sensitive to the level of discarding of western gemfish, which remains high. Nevertheless, last year it was possible to apply a form of weight-of-evidence argument to claim that the stock showed no signs of stress. The argument had the form that the standardized CPUE was not deviating significantly from the long term average and that considering there had been relatively high levels of discarding then the CPUE should have been higher than represented by the log-book records. Hence the available data indicated that the stock was not having problems. The discarding levels were reportedly due to marketing issues.

## 6.4 Results and Discussion

### 6.4.1 ***Bight Redfish*** *(Centroberyx gerrardi)*

The latest Tier1 assessment for Bight Redfish was based on data up to and including the 2012/2013 (Haddon, 2015a). The standardized catch rates are now available for the 2015/2016 year (Sporcic and Haddon, 2016), although these have been re-run here to only include the years 89/90 – 15/16, and these are used in the breakout rules agreed to by the GAB RAG in August 2014 listed in the methods. By including the latest landed catch into the Tier 1 assessment and projecting the dynamics forward the model predicted CPUE can be produced and compared with the standardized value. If the latest year is outside the 95% confidence intervals then the fishery will be said to have broken out of its expected trajectory.

There is no indication that the Bight Redfish fishery has broken out of its expected trajectory (Figure 6.1 and Table 6.1), although for the last four years the predicted CPUE has been below the standardized CPUE. The standardization has little effect upon the CPUE trend over the last ten years (Sporcic, 2015).

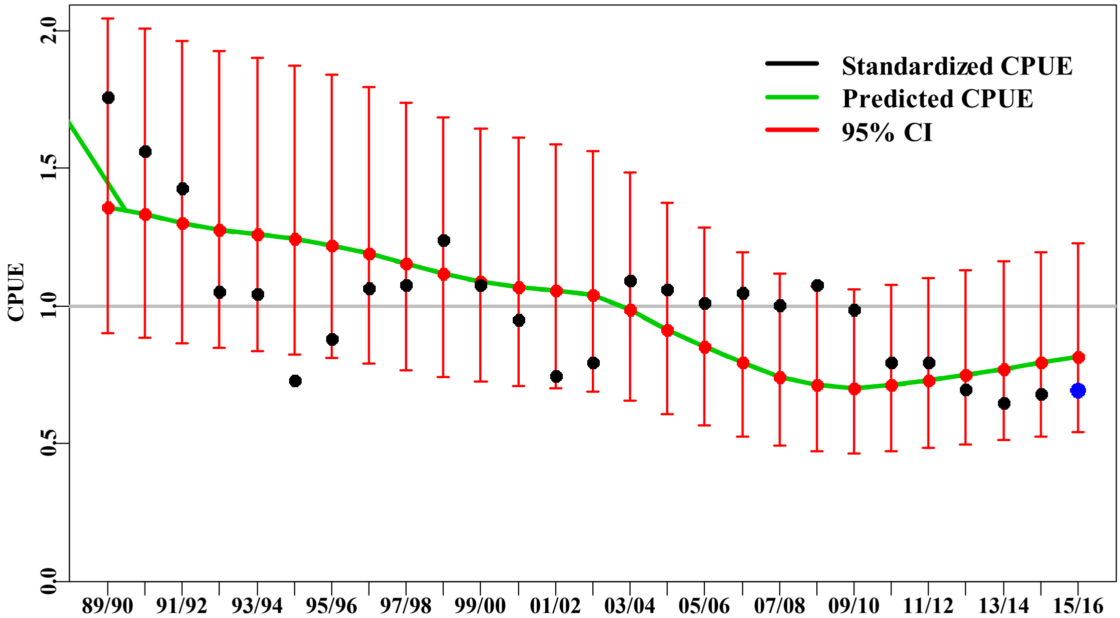


Figure 6.1. The predicted trajectory of Bight Redfish CPUE (red line) obtained from projecting the previous Tier 1 assessment forward through 2013/2014 and 2014/2015 for comparison with the recently observed CPUE data. The black dots represent the mean standardized CPUE while the red line and dots, with their associated 95% confidence intervals represent the expected CPUE from the Tier 1 model. The blue dots are the CPUE projected since the last stock assessment.

#### *6.4.1.1 Catches and Catch Rates*

Discard estimates since 2007/2008 are now included (Table 6.1; Upston and Thomson, 2016), although in some years with very low discard levels the estimates are highly uncertain. In all years they remain a very minor component of the catch.

Table 6.1. A comparison of the standardized observed CPUE for Bight Redfish and that predicted from projecting the previous Tier 1 assessment (Haddon, 2015a). The standard error estimate for the CPUE from the Tier 1 model was 0.209 Figure 6.1.

| Year | Standardized | Predicted | Catch |
|---|---|---|---|
| 1989/1990 | 1.7578 | 1.3483 | 170.833 |
| 1990/1991 | 1.5612 | 1.3239 | 281.808 |
| 1991/1992 | 1.4278 | 1.2705 | 265.612 |
| 1992/1993 | 1.0539 | 1.2352 | 120.698 |
| 1993/1994 | 1.0439 | 1.1837 | 107.472 |
| 1994/1995 | 0.7300 | 1.1119 | 157.803 |
| 1995/1996 | 0.8829 | 1.0632 | 173.922 |
| 1996/1997 | 1.0665 | 1.0319 | 327.177 |
| 1997/1998 | 1.0784 | 0.9081 | 372.617 |
| 1998/1999 | 1.2391 | 0.7890 | 437.788 |
| 1999/2000 | 1.0784 | 0.7077 | 323.641 |
| 2000/2001 | 0.9514 | 0.7093 | 387.879 |
| 2001/2002 | 0.7459 | 0.7443 | 262.613 |
| 2002/2003 | 0.7935 | 0.7893 | 424.672 |
| 2003/2004 | 1.0911 | 1.3483 | 946.477 |
| 2004/2005 | 1.0584 | 1.2935 | 937.456 |
| 2005/2006 | 1.0114 | 1.2543 | 789.704 |
| 2006/2007 | 1.0488 | 1.2130 | 1023.908 |
| 2007/2008 | 1.0039 | 1.1481 | 808.024 |
| 2008/2009 | 1.0775 | 1.0842 | 681.885 |
| 2009/2010 | 0.9869 | 1.0482 | 469.696 |
| 2010/2011 | 0.7941 | 0.9808 | 297.596 |
| 2011/2012 | 0.7970 | 0.8483 | 341.481 |
| 2012/2013 | 0.6993 | 0.7373 | 273.451 |
| 2013/2014 | 0.6477 | 0.6985 | 207.051 |
| 2014/2015 | 0.6794 | 0.7264 | 238.327 |
| 2015/2016 | 0.6937 | 0.7669 | 179.879 |

#### *6.4.1.2 FIS Breakout Rule*

The GAB breakout rules include a clause concerning the FIS results and implications (Figure 6.2 and Table 6.2). In this case there was no FIS in 2015/2016 as the most recent survey occurred in March and April 2015. Like the Deepwater Flathead estimates the Bight Redfish abundance estimate was the lowest ever recorded in the FIS. The inter-annual variation was already large leading to extremely wide confidence intervals which suggest that even with the low value in 2014/2015 there was no breakout.

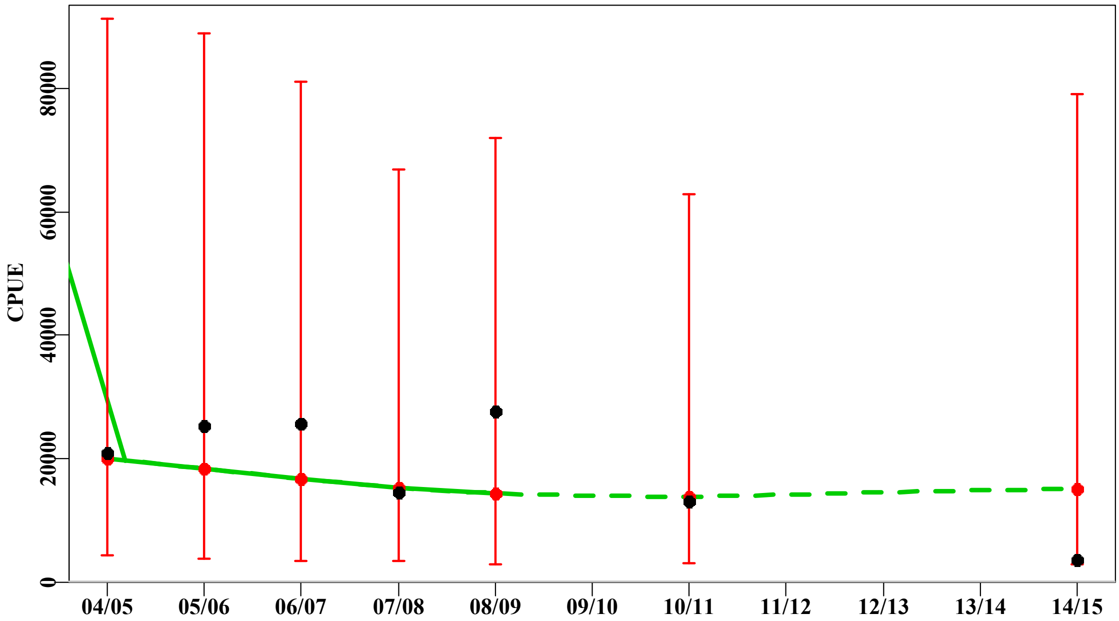


Figure 6.2. The GAB FIS as exploited within the projected Bight Redfish assessment.

This is consistent with the Tier 1 assessment last year but highlights that the FIS estimate for the Bight Redfish is potentially flawed.

Table 6.2. The observed and predicted FIS abundance indices for the Bight Redfish in the GAB. The standard errors are those derived from the assessment not the survey. There was no survey in 2015/2016.

| Year | Obs | Exp | StErr |
|---|---|---|---|
| 2004/2005 | 20887.0 | 20102.3 | 0.772 |
| 2005/2006 | 25380.0 | 18465.3 | 0.802 |
| 2006/2007 | 25713.0 | 16826.1 | 0.802 |
| 2007/2008 | 14591.0 | 15333.8 | 0.752 |
| 2008/2009 | 27610.0 | 14355.5 | 0.822 |
| 2009/2010 | | | |
| 2010/2011 | 13189.0 | 13843.7 | 0.772 |
| 2011/2012 | | | |
| 2012/2013 | | | |
| 2013/2014 | | | |
| 2014/2015 | 3633.0 | 15180.6 | 0.842 |

### 6.5 References


Haddon, M. (2015) Multi-Year Breakout Analyses for Deepwater Flathead and Western Gemfish in the GAB (2013/14). pp 10 – 18 *in* Tuck, G.N. (ed.) *Stock Assessment for the Southern and Eastern Scalefish and Shark Fishery 2014. Part 2.* Australian Fisheries Management Authority and CSIRO Oceans and Atmosphere Flagship, Hobart. 432 p.

Haddon, M. (2015a) *Bight redfish (Centroberyx gerrardi) stock assessment based on data up to 2014/2015.* Report to November 2013 GAB RAG meeting. CSIRO, Oceans and Atmosphere, Australia. 40p.

Klaer, N., Day, J., Tuck, G., Little, R., and S. Wayte (2014) Tier 1 CPUE forecasts for multi-year TAC breakout. Draft paper presented to SLOPE and SHELF RAGs July 2014. 11p.

Sporcic, M and M. Haddon (2016) Catch rate standardizations for selected SESSF species (data to 2015). CSIRO Oceans and Atmosphere Flagship, Hobart. 206p.

Tuck, G., Klaer, N., Haddon, M., Thomson, R., Day, J., Fay, G., Little, R., Upston, J. and S. Wayte (2012) Multi-Year TACs in the SESSF pp *in* Tuck, G.N. (ed.) *Stock Assessment for the Southern and Eastern Scalefish and Shark Fishery 2011. Part 2.* Australian Fisheries Management Authority and CSIRO Marine and Atmospheric Research, Hobart. 507 p.

Upston, J. and R. Thomson (2016) Integrated Scientific Monitoring Program for the Southern and Eastern Scalefish and Shark Fishery – Discard estimation 2015 DRAFT. CSIRO Oceans and Atmosphere, Australian Fisheries Management Authority. 56p.

## 6.6 Appendix: SS3 Methods

To generate forecast CPUE from stock synthesis version 3.x (SS) requires a run of the most recent stock assessment, updated with recent actual catches and catch rates. In the GAB results can be sought for Bight Redfish and Deepwater Flathead.

Running this kind of forecast is very fast because no estimation is required. However, there is a small amount of set-up time. SS3 does not produce expected values for each CPUE index in standard forecasts, so assessment authors were provided with the following instructions:

**Edit starter.ss** Modified from Klaer et al., (2014).
1 # 0=use init values in control file; 1=use ss3.par

0 # Turn off estimation for parameters entering after this phase

**Edit ss3.dat**

Change end year, usually on line 3 to the most recently available data.

Add the most recent actual catch estimates to the catch series using CDR results (including discards, especially if these are significant) assume fleet splits as per your last projections. Increase the expected number of lines of catch data accordingly.

Add lines to the end of recent abundance indices so that they finish in the same end year as the catches. Once can use values of 1.0 and a CV of 999.0 - here are examples used for fleet 9 for tiger flathead:

```
2007 1 9 1.137 0.1539
2008 1 9 1.0583 0.1538
2009 1 9 1.0346 0.1553
2010 1 9 1.0000 999.0
2011 1 9 1.0000 999.0
```

The actual observed standardized CPUE values for those years can also be used, but retain the enlarged CVs.

**`Edit ss3.par`**

Add another 0.00 to the end of recruitment deviates for every extra year of data you have added.
Run ss3 -nohess

Look in report.sso under the heading INDEX_2 and there should be estimates of CPUE for all years to 2011 for recent abundance indices. Alternatively, the output list from the use of SS_output (from r4ss) contains $cpue which is a data.frame containing the required columns of Observed and expected CPUE.

# 7. Assigning SESSF logbook shots to "Day", "Night", or "Mixed"

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## 7.1 Background

Management protocols for Southern and Eastern and Scalefish and Shark Fishery (SESSF) quota species require standardized time series of catch-per-unit effort (CPUE) data from the commercial fishery. These standardizations seek to remove the effects of known covariates such as fishing depth, and individual vessel power, from CPUE times series so that any temporal change in the standardized CPUE series results from the abundance of the fish stock (and from unquantifiable or unknown covariates). It is widely held amongst the fishing community that the time of day or night can affect the catch rates for at least some SESSF species. Early CPUE standardizations in the SESSF did not account for daylight, but later a "day-night" field was added to the logbook database and has been included in CPUE standardization work ever since.

The "day-night" field for SESSF logbook data has, until recently, been generated using routines developed in the database system dBase by Neil Klaer. During 2015 Neil kindly generated the field for the last time, despite having already left CSIRO. New routines have now been developed using the more widely available R software (R Core Team, 2016). These improve on the older method in that (1) the code could be run by anyone; (2) R has built in time-date functions that account for daylight savings times in all states of Australia (and around the world); (3) libraries are available for R that accurately calculate sunrise and sunset times throughout the years. The DBASE routines are only accessible to Neil Klaer, they do not account for daylight savings time, and they use a routine for calculating sunrise / sunset time that is only guaranteed to be accurate until 2010.

## 7.2 Methods

Apart from the calculating of sunrise / sunset times and the accounting for daylight savings times, all efforts were made to use the same methodology as that used by Neil Klaer. The start time, and end time, for each fishing shot are assigned to *day* if they take place after sunrise and before sunset, to *night* if they take place between sunset and sunrise, and *unknown* if a time and date is not recorded in the database (or cannot be estimated). A second field is then generated, containing "D" if both start and end time took place during the day, "N"ight if both were nighttime, "M"ixed if one was daytime and the other nighttime; or "U"nknown if either or both are missing.

A mixed shot can therefore be one that started one minute before sunrise, or that ended one minute after sunrise. These will not be distinguished from a shot that occurred entirely during twilight. Shots that occur closer to the equator will experience shorter twilight periods than those close to the poles. Alternative schemes that seek to calculate "dayness" as the proportion of the shot that occurred during daylight hours or total or mean irradiance can be conceived. Such alternatives are not the scope of this paper, which seeks to match the work of Neil Klaer as closely as possible, and to quantify the effect on the result of improving the calculation of sunrise and sunset times relative to the time reported by the vessel (which might be influenced by local time zone and zone shifts due to daylight saving).

Given a fishing position (latitude-longitude) the assignment of a fishing shot to day, night, mixed or unknown requires the following steps:

1. Establish a local time zone for the shot.

2. If the start time is known but the end time is unknown, use the mean shot duration for that gear type and fishery to calculate a likely end time, if the mean value is available for that combination of the gear type and the fishery.

3. Establish sunrise/set time at the reported position.

4. Compare start and end position for the shot with sunrise/set time to assign each to day or night.

5. Assign "D" if both start and end are "day"; "N" if both are "night"; "M" if either is "day" and the other "night" and "U" if either is unknown.

The assignment of a local time zone to each fishing shot (step 1 above), by the old DBASE method involved the following definitions:

WA: lon <= 129
SA: 129 < lon <= 141
E Aus: lon > 141
QLD: lat < 29 (and lon > 141)

The new method was based on the old definitions, but adds TAS & VIC/NSW and changes QLD:

Lon <=129: "Australia/Perth"
Lon > 129 and lon <= 141: "Australia/Adelaide"
Lon > 141 and lat <= -40: "Australia/Hobart"
Lon > 141 and (lat <= -37.5 and lat > -40): "Australia/Melbourne"
Lon > 141 and (lat > -37.5 and lat <= -28.16): "Australia/Sydney"
Lon > 141 and lat > -28.16: "Australia/Brisbane"

Both old and new methods assume each shot to a time zone corresponding to a nearby Australian State. It is conceivable that a vessel departing from and returning to a port in a particular state, but, fishing the waters of an adjacent state, might keep the time zone of the port of origin throughout the trip. Refinement of the method could be considered in the future.

Step (2) was introduced by Neil Klaer because end times are most often missing from the logbook database. End times are tricky to work with because the shot date is taken to correspond to the start time, but the date for the end time will differ if the shot spans midnight. Accurate calculation of shot duration must be preceded by accurate calculation of start and end dates. The built-in R class "POSIXct" was used to store dates and times. The POSIXct class tracks date and time in Coordinated Universal Time (UTC) and can report these in any required local time zone including daylight saving zones.

Calculation of average shot duration for a gear involved pooling shot duration data over all years. It was noted (not shown) the average duration versus year shows trends for some gears. Future version of the method could consider year specific shot duration, for those gears for which sufficient data, and an apparent trend, exist. This would involve interpolation, and often extrapolation, to years for which end times are reported.

The assumptions were made that (a) the shot date corresponds with the start time, not necessarily the end time; (b) if the end time appears to occur earlier in the day than the start time, the end time corresponds to the following day. Mean shot durations were typically less than 11 hours so it seems a reasonable assumption that shots never spanned more than one day.

A variation was introduced to the method used by Klaer, who seems to have pooled data across fisheries. Instead, we calculated mean shot duration separately for each fishery – gear combination. This resulted in more shots with unknown end times, than Klaer had, because there are fishery-gear combinations that have no reported end times from which shot duration can be calculated. The number of reported end times for each fishery-gear combination is shown in Table 7.1.

Table 7.1. Number of shots that reported shot end time for every fishery and gear type reported in the logbook database.

| Fishery | AL | BL | DL | DLH | DLM | DS | FP | GN | HL | J | LLP | PL | TL | TR | TW |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CSF | 883 | 722 | 1064 | 5262 | 110 | 0 | 3453 | 0 | 91 | 0 | 0 | 0 | 272 | 20 | 1532 |
| CSIRO | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1327 |
| ECD | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3725 |
| ECH | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 89 | 0 | 0 | 0 | 0 |
| ECT | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 507074 | 0 | 0 | 0 | 0 |
| FGN | 307 | 0 | 0 | 0 | 0 | 0 | 0 | 110281 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| FSQ | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 61075 | 0 | 0 | 0 | 0 | 0 |
| FTR | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 331922 |
| GAB | 0 | 0 | 0 | 0 | 0 | 80 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 336812 |
| HSN | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 15 |
| HSS | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 167 | 0 | 0 | 0 | 0 |
| HST | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 7212 |
| JMF | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 151 |
| NFO | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 38 |
| NPF | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 9436 |
| NWS | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 46771 |
| SE | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| SEN | 705 | 2599 | 7224 | 0 | 0 | 0 | 972 | 85122 | 268 | 0 | 0 | 8 | 71 | 0 | 0 |
| SET | 0 | 0 | 31 | 0 | 0 | 405300 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2950732 |
| SPF | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1770 |
| SSG | 0 | 46 | 34 | 0 | 0 | 0 | 0 | 25850 | 28 | 0 | 0 | 0 | 0 | 0 | 0 |
| SSH | 0 | 421 | 0 | 0 | 0 | 0 | 0 | 18 | 2 | 0 | 0 | 0 | 0 | 0 | 0 |
| STR | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 469 |
| TUN | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 26317 | 0 | 0 | 0 | 41546 |
| VIT | 0 | 0 | 0 | 0 | 0 | 2539 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 7592 |
| WDW | 0 | 0 | 0 | 0 | 0 | 5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 22312 |
| WTB | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 11859 | 0 | 0 | 0 | 0 |
| WTF | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 77404 | 0 | 0 | 0 | 0 |

## 7.3 Results

As expected, categorization using the new method did not always give the same result as the old DBASE methods. The majority of records were given the same assignment, however, a relatively large proportion were not (Table 7.2).

Table 7.2. Number of records (for logbook data to partial 2015) assigned to D/M/N/U by the new method (rows) and the old method (columns). The percentage of corresponding records is shown in the RH Columns. Shaded cells are those that had the same assignment by both methods.

| | D | M | N | U | D | M | N | U |
|---|---|---|---|---|---|---|---|---|
| NA | 0 | 0 | 0 | 2671 | 0 | 0 | 0 | 100 |
| D | 3369678 | 857504 | 65481 | 379751 | 72 | 18 | 1 | 8 |
| M | 242752 | 1077933 | 513289 | 301670 | 11 | 50 | 24 | 14 |
| N | 9788 | 160727 | 969527 | 199837 | 1 | 12 | 72 | 15 |
| U | 6 | 17454 | 79031 | 1024433 | 0 | 2 | 7 | 91 |

Nine sets of example results are shown below along with the sunrise and sunset times calculated using the new method (Table 7.2). Position and local time zones are not shown, but were an important part of the calculation. Examples were deliberately chosen amongst those cases where the new (R) and old (DBASE) methods yield different results.

Table 7.3. Shot start *Start* and end *End* times, corresponding *Sunrise* and *Sunset* times and "D"ay or "N"ight assignments to the start *S* and end *E* times for ten example scenarios. The overall assignment of "D", "N" or "M" is given for the *New* R method and the *Old* DBASE method.

| | Start | End | Sunrise | Sunset | S | E | **New** | **Old** |
|---|---|---|---|---|---|---|---|---|
| 1 | 10/11/2000 15:00 | 10/11/2000 18:00 | 4:43 | 18:14 | D | D | **D** | **M** |
| 2 | 1/10/2000 16:19 | 1/10/2000 18:29 | 5:54 | 18:09 | D | N | **M** | **D** |
| 3 | 25/07/2000 17:00 | 26/07/2000 6:30 | 6:34 | 17:49 | D | N | M | D |
| 4 | 23/02/1998 8:00 | 24/02/1998 6:00 | 5:30 | 18:12 | D | N | **M** | **D** |
| 5 | 13/05/2000 18:39 | 13/05/2000 21:59 | 6:03 | 17:08 | N | N | **N** | **M** |
| 6 | 22/05/2000 18:00 | 23/05/2000 4:00 | 6:28 | 17:51 | N | N | **N** | **M** |
| 7 | 11/08/2005 19:00 | 12/08/2005 16:00 | 6:27 | 17:56 | N | D | **M** | **D** |
| 8 | 2/03/2001 2:30 | 2/03/2001 5:30 | 5:41 | 18:29 | N | N | **N** | **M** |
| 9 | 2/05/2000 5:00 | 2/05/2000 10:00 | 6:11 | 17:42 | N | D | **M** | **D** |
| 10 | 17/07/2005 5:45 | 17/07/2005 17:54 | 6:29 | 17:44 | N | D | **M** | **D** |

Most of the examples in Table 7.2 have either the start or the end time of the shot within roughly 1.5 hours of either sunrise or sunset. Examples 3 and 4 seem to result from incorrect accounting by the dBase method for a shot that spans midnight.

Although we know the overall assignment given to each shot (D/N/M/U) by the old method, the assignment of the start and end positions is only known for the new method. For all records whose overall assignment differed, we calculated the proportion belonging to each of X possible "types" based on a unique combination of overall assignment by the new or old method, and the assignment of the start and end times by the new method (Table 7.3).

Table 7.4. Every unique combination of old and new results, and the count and proportion of the shots that fell into each category (ordered from greatest to least 'proportion').

| Rank | New_DayNight | Old_DayNight | StartShotDateTime_DN | EndShotDateTime_DN | Count | Proportion |
|---|---|---|---|---|---|---|
| 1 | Unknown | Day | Day | NA | 107909 | 0.159 |
| 2 | Mix | Day | Night | Day | 107763 | 0.159 |
| 3 | Night | Mix | Night | Night | 106957 | 0.158 |
| 4 | Mix | Day | Day | Night | 65547 | 0.097 |
| 5 | Unknown | Night | Night | NA | 50082 | 0.074 |
| 6 | Day | Mix | Day | Day | 49280 | 0.073 |
| 7 | Unknown | Mix | Night | NA | 42337 | 0.062 |
| 8 | Unknown | Mix | Day | NA | 37794 | 0.056 |
| 9 | Night | Unknown | Day | NA | 23094 | 0.034 |
| 10 | Mix | Night | Night | Day | 21257 | 0.031 |
| 11 | Night | Day | Night | Night | 20559 | 0.030 |
| 12 | Unknown | Day | Night | NA | 19238 | 0.028 |
| 13 | Mix | Night | Day | Night | 12419 | 0.018 |
| 14 | Mix | Unknown | Night | Day | 6221 | 0.009 |
| 15 | Unknown | Night | Day | NA | 4265 | 0.006 |
| 16 | Day | Night | Day | Day | 3712 | 0.005 |
| 17 | Unknown | Mix | NA | NA | 55 | 0.000 |
| 18 | Unknown | Night | NA | NA | 42 | 0.000 |
| 19 | Unknown | Day | NA | NA | 13 | 0.000 |
| 20 | Day | Unknown | Day | Day | 1 | 0.000 |
| 21 | Mix | Unknown | Day | Night | 1 | 0.000 |

### 7.3.1 *End time has been lost*

The scenarios ranked 1, 5, 7, 8, 12, 15, 17, 18 and 19 have unknown end time for the shot and therefore "U" overall assignment using the new method however the old method gave "D", "N" or "M". The end shot time was therefore not unknown. This occurred because the new method does not pool for a given gear type across fisheries in order to calculate average shot duration, instead it calculated shot duration for each fishery-gear combination. This results in more unknowns because some fishery-gear combinations had no reported end times.

### 7.3.2 *D/N/M has changed*

Here we discuss shots that were not considered "U" under either the old or new methods, but that have changed their overall assignment. Only the overall D/N/M result is available for the old method, not the assignments given to the start and end times. Therefore these can only be known for the shots that had an overall assignment of "D" or "N" where both the start and end positions must have had the corresponding assignment. Cases where the old method gave "M" were not investigated further because there is no way of knowing whether the start, the end or both assignments have changed.

Shots that were "D" or "N" but are classified as "M" under the new method typically have a start time that is close to the nearest sunrise or sunset (Figure 7.1, top RHS and bottom LHS). This suggests that the change in designation is most likely to be due to the use of a more accurate sunrise/set calculator or due to taking 1 hour daylight saving times into account. A batch of shots, predominantly from South Australia, show a 5 hour difference (Figure 7.1, top RHS) suggesting a more serious error in the assignment of a local time zone.

Those shots whose end time designation changed typically ended approximately 3 hours before or after the nearest sunrise or sunset (Figure 7.1, top LHS and bottom RHS). While shot start time will have been the same for both the old and new methods, the end time is most often calculated using average shot duration and average shot duration will change every time the dataset is updated (and more shots of known duration are added). Any trend or overall change in shot duration over the years (which we know has happened) will lead to a shift to the right of the mode in these plots (Figure 7.1, top RHS and bottom LHS).

Cases where a designation of "M" changed to "D" or "N" could not be investigated, but are likely to show similar patterns to those that were investigated. In summary, causes for a change in designation for shots that are not designated "U", are:

a. Due to small differences in the more accurate sunrise / set calculator, affecting shots that start or end very close to sunrise or sunset;

b. Due to better accounting for local time zone including daylight savings times (again, for shots that occur close to sunrise/set);

c. Due to ongoing shifts in the mean duration of shots – this would result in changes to the D/N/M assignment whenever new data become available, even without any change in the method used to assign D/N/M.

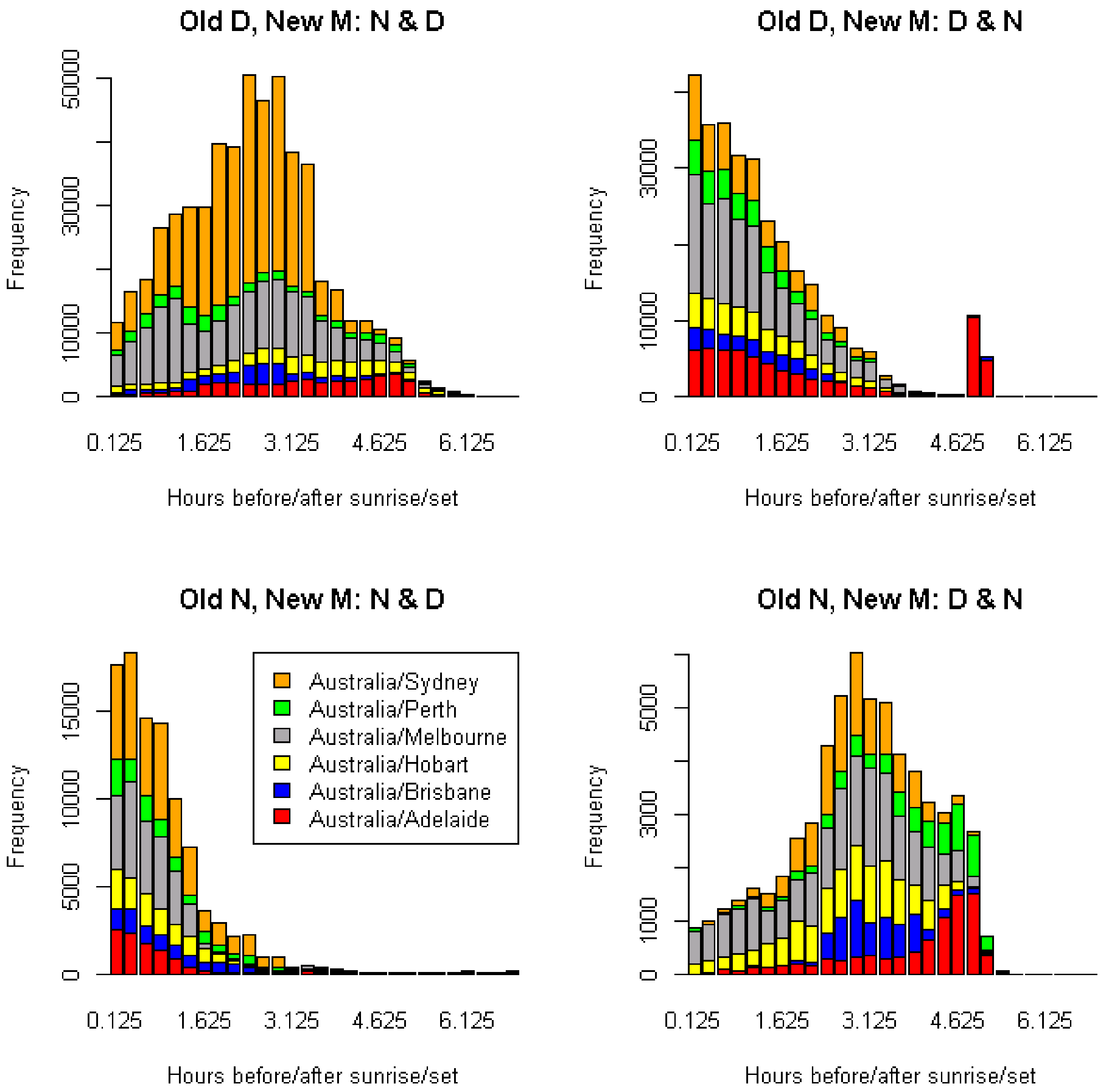


Figure 7.1. *Top: Top left*: Histogram of the number of hours to the nearest sunrise or sunset for (*top left*, and *bottom right*) the start time, or (*top right* and *bottom left*) the end time of all shots whose classification was "D" (*top plots*) or "N" (*bottom plots*) for the old method but is "M" for the new method. In every case, only one of the start or end times has been reclassified.

## 7.4 Discussion

Future work includes:

1. Exploration of those fisheries for which mean shot duration cannot be accounted for – it might be reasonable to 'borrow' mean shot duration from a similar fishery;

2. Allowing mean shot duration to change with time (an estimated trend would probably be needed to overcome the problem of years for which few or no end times are recorded);

3. Calculating a "dayness" statistic that reflects how much of the shot occurred during the daytime, as opposed to assigning a time that occurs 1 second after sunset to "night" and one second before sunset to "day".

## 7.5 Reference

R Core Team (2016). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL https://www.R-project.org/.

# 8. Statistical CPUE standardizations for selected SESSF species (data to 2015)

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## 8.1 Executive Summary

Catch-per-unit-effort (CPUE) data is an important input to many of the stock assessments conducted within the South East and Southern Shark Fishery (SESSF), where it is used as an index of relative abundance through time. The catch and effort logbook data from the SESSF, which is the source of CPUE data, constitutes shot by shot data derived from a wide range of vessels, areas (zones), months, depths, and fishing gears. Catch rates used in the assessments are standardized to reduce the effects of factors such as which vessel fished, where and when fishing occurred, the gear used, at what depths fishing was conducted, and whether fishing occurred during the day or night. The intent is to focus on any changes in catch rates that occurred between years as a result of changes in stock size rather than changes that occur in any of these other factors. This intent is not always realized when there are unknown influential factors or factors for which we have no data, so interpretation of the catch rate trends should not necessarily be taken at face value. This is especially the case when there have been major management changes, such as the introduction of quotas or the more recent structural adjustment. Such large events can greatly influence fishing behaviour, which in turn influences catch rates. Because these changes affected the whole fleet at the same time it is not possible to standardize for their effects.

Catch rates, generally as kilograms per hour fished (though sometimes as catch per shot *e.g.* Danish Seine, or non-trawl methods), were natural log-transformed to normalize the data and stabilize the variance before standardization. A General Linear Model was used rather than using a Generalized Linear Model with a log-link. This simple analytical approach means that the exact same methods can be applied to all species/stock combinations in a relatively robust manner. The statistical models fitted were of the form: LnCE = Year + Vessel + Month + Depth Category + Zone + DayNight. There were interaction terms which could sometimes be fitted, such as Month:Zone or Month:Depth_Category. Data from all vessels reporting catches of a species were included although a preliminary data selection was made on a given depth range for each species for the zones of interest to focus attention on those depths contributing significantly to the fishery for each assumed stock and to reduce the number of empty categories within the statistical models. The statistical package R was used, based on the 'biglm' library, which was necessary because of the large amount of data available for some species. Despite the large numbers of observations available in most analyses, the use of the AIC was able to discriminate between the more complex models. In fact, the visual difference between the CPUE trends exhibited by the top few models tends to be only minor.

This document reports the statistical standardization of the commercial catch and effort data for 23 species (including species groups), distributed across 43 different combinations of stocks and fisheries ready for inclusion in the annual round of stock assessments. These include School Whiting, Eastern Gemfish, Jackass Morwong, Flathead, Redfish, Silver Trevally, Royal Red Prawn, Blue Eye, Blue Grenadier, Spotted/Silver Warehou, Blue Warehou, Pink Ling, Western Gemfish, Ocean Perch, John Dory, Mirror Dory, Ribaldo, Ocean Jackets, Deepwater Flathead and Bight Redfish.

Summary graphs are provided across all species (Figure 8.2 and Figure 8.3), as well as more detailed information for each stock. Out of 43 stocks, there were eight whose catch rates have increased; eight stocks where catch rates were stable and 27 stocks whose catch rates have declined over the last 10 years. Since 2007, there were nine stocks whose catch rates have increased; five stocks whose catch rates were stable and 29 stocks whose catch rates have declined. The first year, 2007 corresponds to the structural adjustment and introduction of the Harvest Strategy Policy. Many of the species were also examined for trends in catches and geometric catch rates between zones; this was to provide a check that there were only minor Year x Zone interactions (differences in catch rate trends between zones).

## 8.2 Introduction

Commercial catch and effort (CPUE) data are used in very many fishery stock assessments in Australia as an index of relative abundance. This is based on the assumption that there is a direct relationship between catch rates and exploitable biomass. However, many other factors can influence catch rates, including vessel, gear, depth, season, area, and time of fishing (e.g. day or night). The use of catch rates as an index of relative abundance requires the removal of the effects of variation due to changes in these factors on the assumption that what remains will provide a better estimate of the underlying biomass. This process of adjusting the time series for the effects of other factors is known as standardization and the accepted way of doing this is to use some statistical modelling procedure that focuses attention onto the annual average catch rates adjusted for the variation in the averages brought about by all the other factors identified. The diversity of species and methods in the SESSF fishery means that each fishery/stock for which standardized catch rates are required entails its own set of conditions and selection of data. This report updates standardized indices (based on data to 2014 inclusive) for over 40 different stocks.

### 8.2.1 *Limits of Standardization*

The use of commercial CPUE as an index of relative abundance of exploitable biomass can breakdown when there are factors that significantly influence CPUE which cannot be accounted for and employed in a GLM standardization analysis. Over the last two decades there have been a number of major management interventions in the South East Scalefish and Shark Fishery (SESSF) including the introduction of the quota management system in 1992 and that of the Harvest Strategy Policy (HSP) and associated structural adjustment in 2005 – 2007. The combination of limited quotas and the HSP is now controlling catches in such a way that many fishers have been altering their fishing behaviour to take into account the availability of quota and their own access to quota needed to land the species taken in the mixed species SESSF.

Some stocks, such as flathead, are currently near or around their target stock size and catch rates are at historically good levels. As a result of this success, some fishers report having to avoid catching species, such as flathead, so as to avoid having to discard and to stay within the bounds of their own quota holdings. Such influences on catch rates tend to bias the catch rates downwards, or at very least add noise to any CPUE signal, which could lead to misinformation passing to any assessment. Currently, there is no way to handle this issue but care needs to be taken not to provide incorrectly conservative advice or inappropriately high catch targets. Included in the management changes is the on-going introduction of numerous area closures imposed for a range of different reasons.

Another example of catch rates not necessarily reflecting the stock dynamics can be found with Blue Eye Trevalla Auto Line catch rates. Some of the closures (e.g. the gulper closures north east of Flinders Island) cover areas where auto-line catch rates were previously relatively high. Fishing continues mostly along the western edge of the St Helens Hill closure (even though this closure is open to Auto Line vessels) but the catch rates on the periphery are only about 2/3 the catch rates previously exhibited on the St Helens Hill itself. The geographical scale of these changes is much finer than that already included in the analyses and so the impression gained is that catch rates in general have declined whereas this may be much more about exactly where the fishing is occurring than what the stock is doing. A FRDC funded research project began last year to examine the influence of closures on stock assessments and this exploration is on-going. A second FRDC funded project is also examining how best to use CPUE data in Australian fisheries and is attempting to investigate the impacts of major management interventions (such as the introduction of quotas) on CPUE trends. The preliminary findings of both these projects, indicate that again, great care needs to be taken when trying to interpret the outcomes of the catch rate standardization.

## *8.3 Methods*

### 8.3.1 *Catch Rate Standardization*

#### *8.3.1.1 Preliminary Data Selection*

The methods used when standardizing commercial catch and effort data in the SESSF continue to be discussed in the Commonwealth stock assessment RAGs because the catch rate time series (and associated standardized indices are very influential in many of the assessments. Data were initially selected by fishery (e.g. SET, GHT, GAB, etc), within a specified depth range and method (e.g. trawl, Auto Line, Danish seine etc) in specified statistical zones (e.g. Figure 8.1) within the years specified for the analysis (Table 8.1). This was based on a standard set of database queries, both from ACCESS and ORACLE, designed to identify shots containing the species of interest in each case.

#### *8.3.1.2 General Linear Modelling*

In each case, catch rates, generally as kilograms per hour fished (though sometimes as catch per shot *e.g.* School Whiting caught by Danish Seine), were natural log-transformed. A General Linear Model was used rather than using a Generalized Linear Model with a log-link; this has advantages in terms of normalizing the data while stabilizing the variance, which the Generalized Linear Model approach does not always achieve appropriately (Venables & Dichmont, 2004). This relatively simple analytical approach means that the exact same methods can be applied to all species in a relatively robust manner. The statistical models were variants on the form: Ln(*CPUE*) = Year + Vessel + Month + Depth Category + Zone + DayNight. Gear type was also included for some fisheries, as well as method of fishing (e.g. Blue eye Trevalla caught by Auto Line and Drop Line). In addition, there were interaction terms which could sometimes be fitted, such as Month:Zone and/or Month:DepthCategory. Thus, the CPUE, conditioned on positive catches of the species of interest, was statistically modelled with a normal GLM on log-transformed CPUE data:

$$\text{Ln}\left(CPUE_i\right) = \alpha_0 + \alpha_1 x_{i,1} + \alpha_2 x_{i,2} + \sum_{j=3}^{N} \alpha_j x_{ij} + \varepsilon_i \tag{1}$$

where Ln($CPUE_i$) is the natural logarithm of the catch rate (usually kg/hr, but sometimes kg/shot) for the $i$-th shot, $x_{ij}$ are the values of the explanatory variables $j$ for the $i$-th shot and the $\alpha_j$ are the coefficients for the $N$ factors $j$ to be estimated ($\alpha_0$ is the intercept, $\alpha_1$ is the coefficient for the first factor, *etc*.).

*8.3.1.3 The Overall Year Effect*

For the lognormal model the expected back-transformed year effect involves a bias-correction to account for the log-normality; this then focuses on the mean of the distribution rather than the median:

$$CPUE_t = e^{\left(\gamma_t + \sigma_t^2/2\right)} \tag{2}$$

$\gamma_t$ is the Year coefficient for year $t$ and $\sigma_t$ is the standard deviation of the log transformed data (obtained from the analysis). The year coefficients were all divided by the average of the year coefficients to simplify the visual comparison of catch rate changes:

$$CE_t = \frac{CPUE_t}{\left(\sum CPUE_t\right)/n} \tag{3}$$

$CPUE_t$ is the yearly coefficients from the standardization, ($\Sigma CPUE_t$)/$n$ is the arithmetic average of the yearly coefficients, $n$ is the number of years of observations, and $CE_t$ is the final time series of yearly index of relative abundance.

Analyses were performed in the statistical software *R* (R Development Core Team, 2009), using the library 'biglm', due to the large size of the datasets for many species.

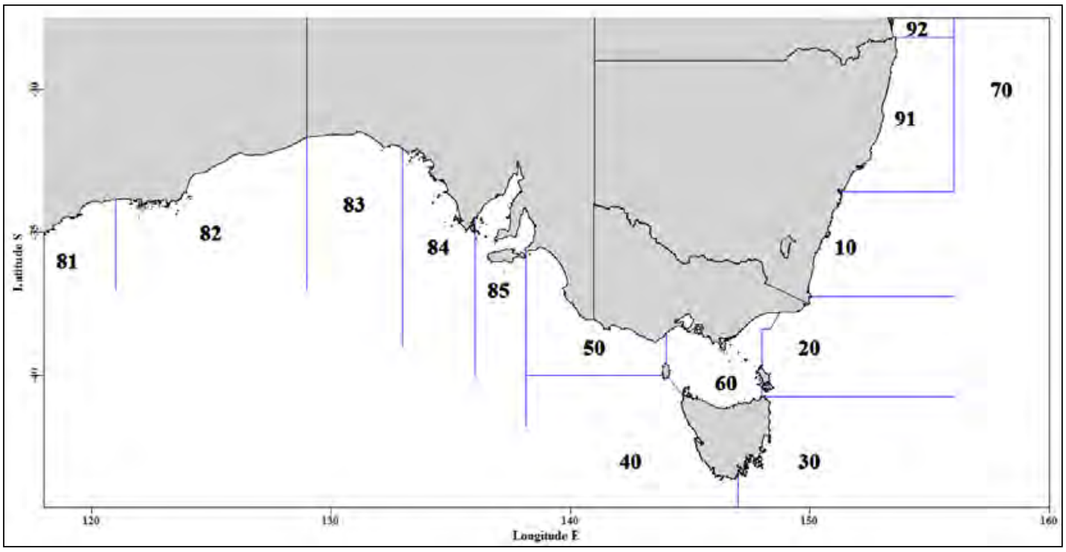



Figure 8.1. A schematic diagram depicting the statistical reporting zones in the SESSF, as used in this document. The GAB fishery is to the west of zone 50. The main SESSF trawl zones are zones 10 – 50. Each zone extends out to the boundary of the EEZ, except for zones 50 and 60, and for zones 92 and 91, which are bounded by zone 70.

Plots of the unstandardized geometric mean catch rate along with the optimum statistical model representing the standardized time series are depicted for each species and/or species groups. This provides a visual indication of whether the standardization changes any trend away from the nominal catch rate. The time series have all been scaled relative to the average of each time series of yearly indices, which means that the overall average in each case equates to one; this centres the vertical location of each series but does not change the relative trends through time. In all cases the differences between this year's analysis and last years' were minimal; both are illustrated in the individual stock graphs. In addition, for most analyses there is a graph of the relative contribution made by the different factors considered to the changes in the trend between the geometric mean and the optimum model. The scale of the changes introduced by a factor is not always in the same order as the relative proportion of the variation accounted for by a particular factor. These influence plots illustrate the fact that for most species while the best statistical model can involve many factors and possibly interaction terms, the influence of many of the later factors tends to be either minor or possibly relates to noisy data rather than trend changes. In many species the difference between the final "fullish" model and one with the first three or four factors is trivial.

## 8.4 Results

Table 8.1. Data characteristics for each analysis. Records show the number of records, depths, zones and other details used in the data analyses.

| | Name | Zone(s) | Depth (m) | Comment | Records |
|---|---|---|---|---|---|
| 1 | School Whiting | 60 | 0-100 | Danish Seine, catch per shot. | 84942 |
| 2 | Eastern Gemfish | 10-30,40/2 | 300-500 | June-Sept 93 onwards, Spawning | 15256 |
| 3 | Eastern Gemfish | 10-30,40/2 | 0-600 | Oct-May 86-09 0-600m, Jun-Sep <300m | 38290 |
| 4 | Jackass Morwong | 10-50 | 70-360 | | 151892 |
| 5 | Jackass Morwong | 10,20 | 70-300 | | 115026 |
| 6 | Jackass Morwong | 30 | 70-300 | | 20301 |
| 7 | Jackass Morwong | 40,50 | 70-360 | | 13650 |
| 8 | Flathead | 10,20 | 0-400 | Trawl | 270430 |
| 9 | Flathead | 30 | 0-400 | Trawl | 22757 |
| 10 | Flathead | 20,60 | 0-200 | Danish Seine, catch per shot | 205230 |
| 11 | Redfish | 10,20 | 0-400 | | 100681 |
| 12 | Silver Trevally | 10,20 | 0-200 | Remove State waters and MPAs^ | 39526 |
| 13 | Silver Trevally | 10,20 | 0-200 | Including State waters and MPAs | 58424 |
| 14 | Royal Red Prawn | 10 | 200-700 | | 24930 |
| 15 | Blue Eye Trevalla | 20,30, 40, 50 | 0-1000 | | 25604 |
| 16 | Blue Eye Trevalla | 20, 30 | 0-1000 | | 12555 |
| 17 | Blue Eye Trevalla | 40, 50 | 0-1000 | | 13043 |
| 18 | Blue Grenadier | 10-60 | 0-1000 | Except Zone 40 Jun-Aug; non spawning | 138468 |
| 19 | Silver Warehou | 10-50 | 0-600 | | 134099 |
| 20 | Silver Warehou | 10-30 | 0-600 | | 72455 |
| 21 | Silver Warehou | 40-50 | 0-600 | | 61644 |
| 22 | Blue Warehou | 10-30 | 0-400 | | 37111 |
| 23 | Blue Warehou | 40,50 | 0-600 | | 13160 |
| 24 | Blue Warehou | 10-50 | 0-600 | | 50784 |
| 25 | Pink Ling East | 10-30 | 250-600 | | 99717 |
| 26 | Pink Ling West | 40,50 | 200-800 | | 78213 |
| 27 | Western Gemfish | 40,50,GAB | 100-600 | | 43701 |
| 28 | Western Gemfish | 40,50 | 100-600 | | 33311 |
| 29 | Western Gemfish | GAB | 100-600 | Only 1995 onwards | 9781 |
| 30 | Offshore Ocean Perch | 10,20 | 200-700 | | 80724 |
| 31 | Inshore Ocean Perch | 10,20 | 0-200 | | 16513 |
| 32 | John Dory | 10,20 | 0-200 | | 140918 |
| 33 | Mirror Dory | 10-50 | 0-600 | | 124719 |
| 34 | Mirror Dory East | 10-30 | 0-600 | | 93160 |
| 35 | Mirror Dory West | 40,50 | 0-600 | | 31524 |
| 36 | Ribaldo (RBD) | 10-50 | 0-1000 | | 22063 |
| 37 | Ribaldo | 10-50,81-85 | 0-1000 | Auto Line | 5362 |
| 38 | Ocean Jackets | 10-50 | 0-300 | | 87495 |
| 39 | Ocean Jackets | 82-83 | 80-220 | | 51841 |
| 40 | Deepwater Flathead | GAB | 0-1000 | | 75394 |
| 41 | Bight Redfish | GAB | 0-1000 | | 50416 |
| 42 | Eastern deepwater sharks | ORZones | 600-1250 | | 11275 |
| 43 | Western deepwater sharks | ORZones | 600-1100 | | 21410 |
| 44 | Mixed oreos | ORZones | 500-1200 | | 27624 |

^ not plotted in Figs. 2 & 3.

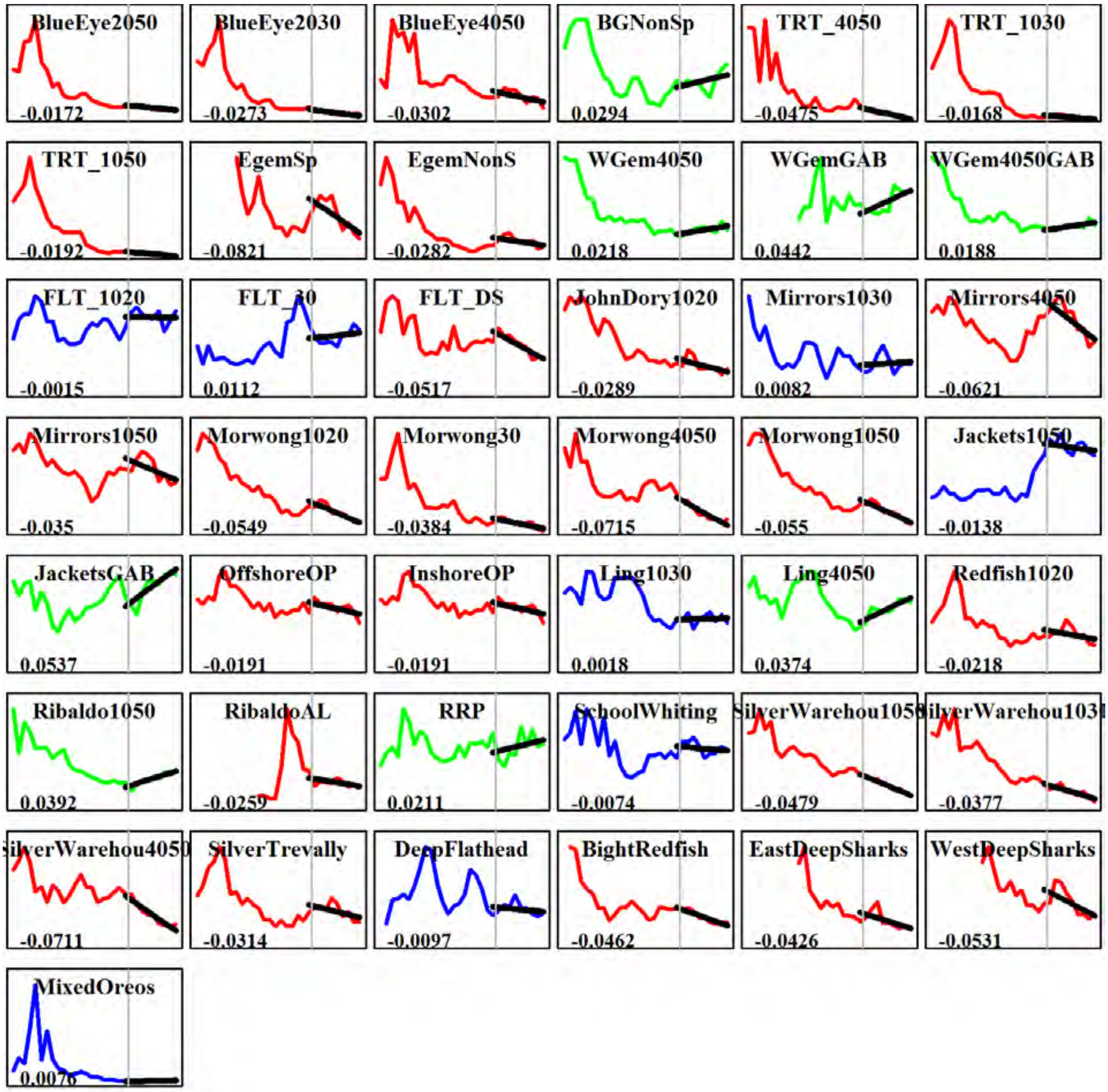



Figure 8.2. Summary graph of the optimum standardizations for 23 species (including grouped species) and 43 different stocks, methods, or fisheries, each with a linear regression across the last ten years (2005-2014). The gradient is at bottom left in each graph and the line colour reflects the gradient: green indicates a positive gradient > 0.015, blue a flat line with a gradient between 0.0149 and – 0.0149, the red indicates a negative gradient < 0.015. There were 8 selections with a positive gradient, 8 selections with a flat gradient, and 27 selections with a negative gradient.

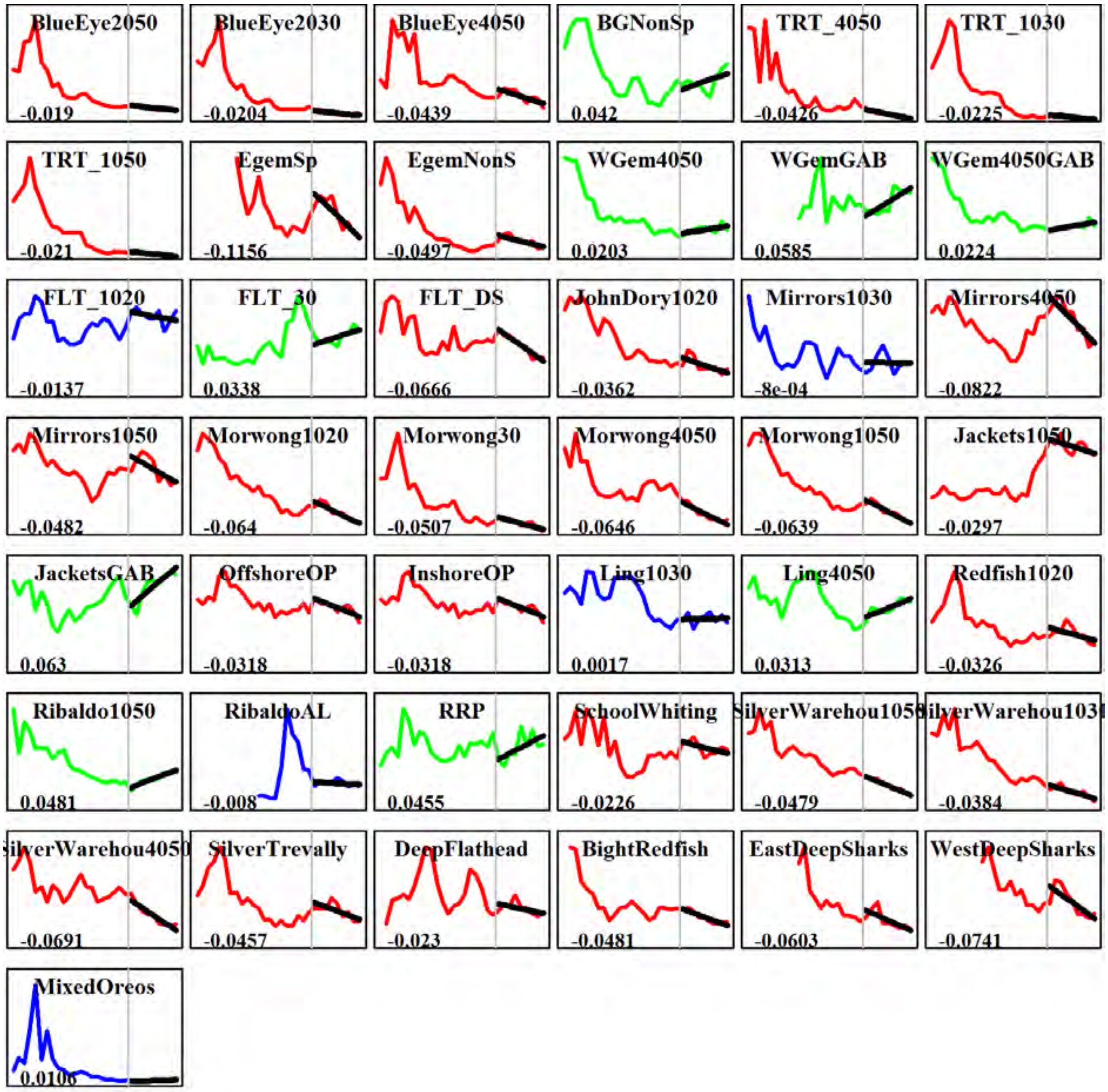



Figure 8.3. Summary graph of the optimum standardizations for 23 species (including grouped species) and 43 different stocks, methods, or fisheries, each with a linear regression across the last nine years (2007-2015). The gradient is at bottom left in each graph and the line colour reflects the gradient: green indicates a positive gradient > 0.015, blue a flat line with a gradient between 0.0149 and – 0.0149, the red indicates a negative gradient < 0.015. There were 9 selections with a positive gradient, 5 selections with a flat gradient, and 29 selections with a negative gradient. The starting year, 2007 was the year after the structural adjustment and the year of introducing the Harvest Strategy Policy.

Table 8.2. Summary of linear regressions (LR) of the annual standardized catch rates corresponding to the last nine years (Nine Year LR) for 43 stocks. Colour reflects the gradient: a positive gradient > 0.015 (green), a flat line with a gradient between 0.0149 and – 0.0149 (blue), a negative gradient < -0.015 (red). See also Figures 2 and 3. N refers to a change in slope from either a green to blue or blue to red comparing last year's to this year's LRs. Y refers to a change in slope from a red to blue or blue to green comparing last year's to this year's LRs.

| **Name** | **Zone(s)** | **Depth (m)** | **Nine Year LR** |
|---|---:|---:|:---:|
| School Whiting - DS | 60 | 0-100 | Y |
| Eastern Gemfish SP | 10-30,40/2 | 300-500 | |
| Eastern Gemfish - NSpawn | 10-30,40/2 | 0-600 | |
| Jackass Morwong | 10,20 | 70-300 | |
| Jackass Morwong | 30 | 70-300 | |
| Jackass Morwong | 40,50 | 70-360 | |
| Jackass Morwong | 10-50 | 70-360 | |
| Flathead | 10,20 | 0-400 | Y |
| Flathead | 30 | 0-400 | |
| Flathead - DS | 20,60 | 0-200 | |
| Redfish | 10 | 0-400 | |
| Silver Trevally | 10,20 | 0-200 | |
| Royal Red Prawn | 10 | 200-700 | |
| Blue Eye Trevalla | 20,30 | 0-1000 | |
| Blue Eye Trevalla | 40,50 | 0-1000 | |
| Blue Eye Trevalla | 20-50 | 0-1000 | |
| Blue Grenadier – NSpawn | 10-60 | 0-1000 | |
| Silver Warehou | 10-30 | 0-600 | |
| Silver Warehou | 40,50 | 0-600 | |
| Silver Warehou | 10-50 | 0-600 | |
| Blue Warehou | 10-30 | 0-400 | |
| Blue Warehou | 40,50 | 0-600 | |
| Blue Warehou | 10-50 | 0-600 | |
| Pink Ling | 10-30 | 250-600 | |
| Pink Ling | 40,50 | 200-800 | |
| Western Gemfish | 40,50,GAB | 100-600 | |
| Western Gemfish | 40,50 | 100-600 | |
| Western Gemfish | GAB | 100-600 | |
| Offshore Ocean Perch | 10,20 | 200-700 | N |
| Inshore Ocean Perch | 10,20 | 0-200 | N |
| John Dory | 10,20 | 0-200 | |
| Mirror Dory East | 10-30 | 0-600 | Y |
| Mirror Dory West | 40,50 | 0-600 | N |
| Mirror Dory | 10-50 | 0-600 | |
| Ribaldo (RBD) | 10-50 | 0-1000 | |
| Ribaldo - AL | 10-50,81-85 | 0-1000 | |
| Ocean Jackets | 10-50 | 0-300 | |
| Ocean Jackets - GAB | 82-83 | 80-220 | |
| Deepwater Flathead | GAB | 0-1000 | |
| Bight Redfish | GAB | 0-1000 | |
| Eastern Deepwater Sharks | OR Zones | 600-1250 | |
| Western Deepwater Sharks | OR Zones | 600-1100 | |
| Mixed oreos | OR Zones | 500-1200 | |

### 8.4.1 *School Whiting Z60 Danish Seine (WHS – 37330014 – Sillago flindersi)*

School Whiting are taken primarily by Danish Seine (and within State waters). In Commonwealth waters, catches are primarily in zone 60, and in depths less than or equal to 100 m. All vessels and all records were included in the analysis. Catch rates were expressed as the natural log of catch per shot (catch/shot). There were 86,537 records for analysis.

Table 8.3. School Whiting from zone 60 in depths 0 to 100 m by Danish Seine. Total catch (TotCatch; t) is the total reported in the database, number of records used in the analysis (Records), reported catch (CatchT; t) in zone 60 and depth used in the analysis and number of vessels used in the analysis (Vessels). GeoMean is the geometric mean of catch rates (kg/shot). The optimum model is DepC:Month and standard deviation (StDev) relates to the data in the optimum model.

| Year | TotCatch | Records | CatchT | Vessels | GeoMean | DepC:Month | StDev |
|---|---|---|---|---|---|---|---|
| 1986 | 1302.4100 | 5667 | 1181.5830 | 26 | 112.3054 | 1.1326 | 0.0000 |
| 1987 | 995.9650 | 4125 | 923.6450 | 23 | 131.3547 | 1.2497 | 0.0294 |
| 1988 | 1255.6880 | 3820 | 1177.8310 | 25 | 168.3341 | 1.5885 | 0.0300 |
| 1989 | 1061.5130 | 4449 | 995.4680 | 27 | 126.9691 | 1.0568 | 0.0289 |
| 1990 | 1930.3680 | 6268 | 1860.4630 | 24 | 165.2136 | 1.6240 | 0.0269 |
| 1991 | 1630.2550 | 4881 | 1520.4040 | 26 | 164.1953 | 1.4385 | 0.0289 |
| 1992 | 854.1060 | 2980 | 777.5240 | 23 | 124.7066 | 1.0390 | 0.0328 |
| 1993 | 1694.8960 | 4925 | 1548.5810 | 24 | 153.6107 | 1.4838 | 0.0287 |
| 1994 | 946.2010 | 4501 | 878.8520 | 24 | 93.9105 | 0.8682 | 0.0291 |
| 1995 | 1212.5610 | 4234 | 1059.6120 | 21 | 123.3912 | 1.1017 | 0.0295 |
| 1996 | 898.2130 | 4214 | 706.7910 | 22 | 81.2686 | 0.7222 | 0.0298 |
| 1997 | 697.3800 | 3218 | 461.7700 | 20 | 64.1314 | 0.5499 | 0.0322 |
| 1998 | 594.1530 | 2958 | 462.2970 | 20 | 66.5496 | 0.5306 | 0.0329 |
| 1999 | 681.2520 | 1914 | 418.9110 | 21 | 83.7522 | 0.6016 | 0.0385 |
| 2000 | 700.8800 | 1926 | 345.9230 | 18 | 66.7223 | 0.6284 | 0.0380 |
| 2001 | 890.9250 | 1997 | 429.4455 | 19 | 93.6854 | 0.8854 | 0.0391 |
| 2002 | 788.3307 | 2192 | 429.2183 | 20 | 90.8874 | 0.8764 | 0.0374 |
| 2003 | 866.2327 | 2355 | 463.5434 | 20 | 86.7848 | 0.9138 | 0.0369 |
| 2004 | 604.8859 | 1771 | 334.6310 | 20 | 79.7648 | 0.8424 | 0.0397 |
| 2005 | 662.6840 | 1750 | 311.4275 | 20 | 77.2502 | 0.9441 | 0.0413 |
| 2006 | 667.5046 | 1428 | 270.2720 | 18 | 76.2250 | 0.8429 | 0.0433 |
| 2007 | 535.3580 | 1488 | 347.0490 | 14 | 89.2381 | 1.1060 | 0.0422 |
| 2008 | 502.2450 | 1260 | 317.0575 | 15 | 92.3448 | 1.0949 | 0.0452 |
| 2009 | 462.5905 | 1569 | 350.7230 | 15 | 93.6200 | 1.1677 | 0.0420 |
| 2010 | 408.9007 | 1179 | 272.8700 | 15 | 88.6885 | 1.0387 | 0.0464 |
| 2011 | 373.9361 | 1579 | 260.2995 | 14 | 72.0269 | 0.8415 | 0.0416 |
| 2012 | 435.7716 | 1566 | 302.4675 | 14 | 80.0853 | 0.9118 | 0.0418 |
| 2013 | 510.6307 | 1791 | 339.7765 | 14 | 82.5661 | 0.9218 | 0.0404 |
| 2014 | 698.5380 | 2071 | 485.4330 | 14 | 99.4276 | 1.0204 | 0.0399 |
| 2015 | 734.6875 | 2461 | 564.6785 | 14 | 93.4423 | 0.9768 | 0.0376 |

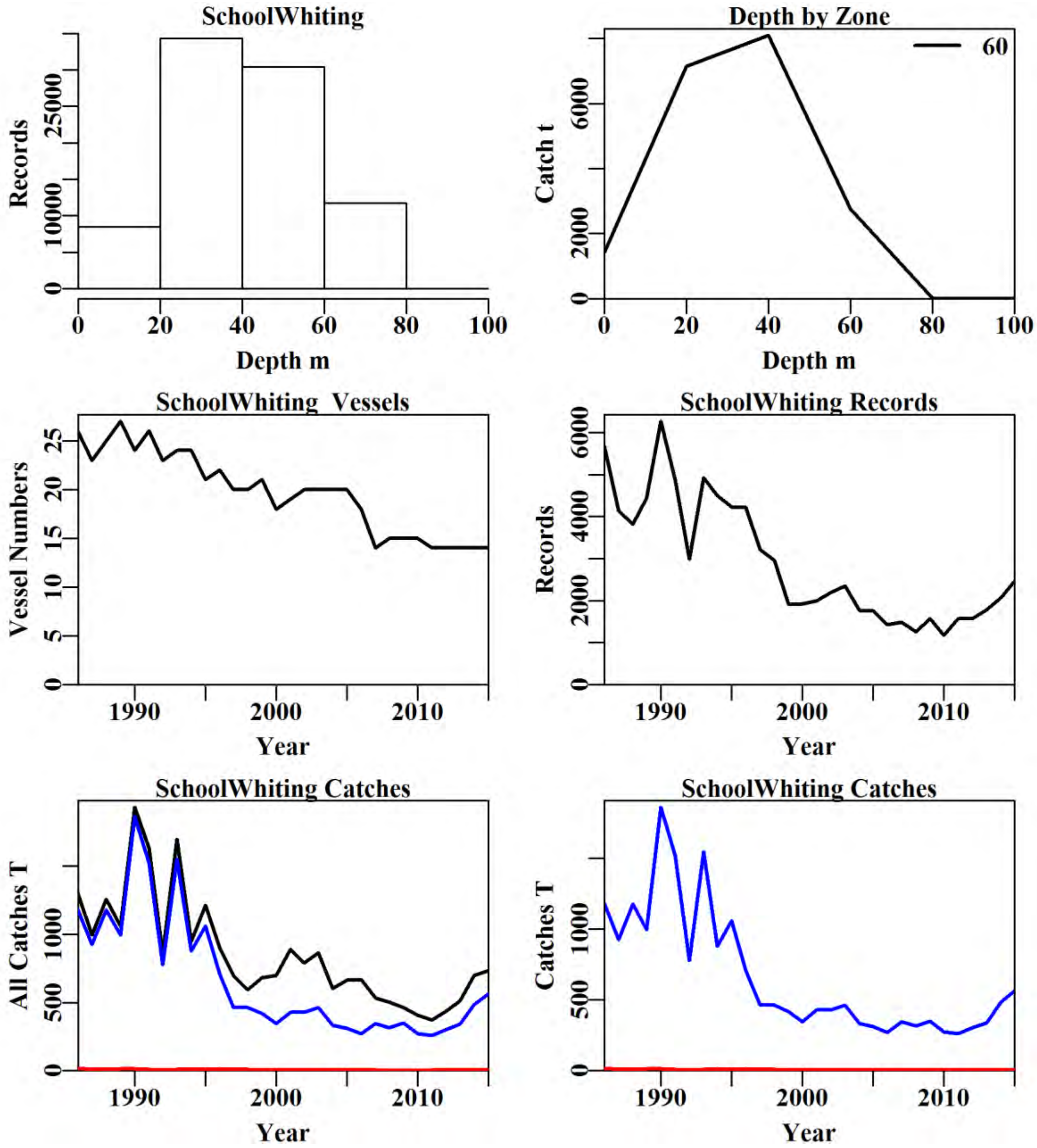
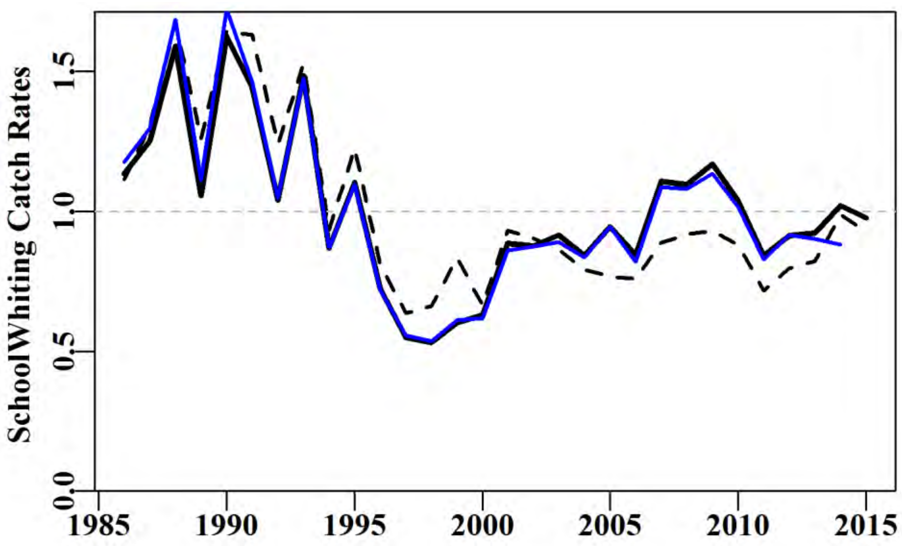



Figure 8.4. School Whiting in zone 60 in depths 0 to 100 m taken by Danish Seine. The top left plot depicts the depth distribution of shots containing School Whiting from zone 60 in depths 0 – 100 m. The top right plot depicts the distribution of catch by depth within zone 60. The middle left plot depicts the number of vessels through time. The middle right plot contains the number of records used in analysis. The bottom left plot contains School Whiting catches (top black line: total catches, middle blue line: catches used in the analysis; bottom red line: catches < 30 kg) and bottom right plot contains School Whiting catches (blue line: catches used in the analysis; red line: catches < 30 kg).



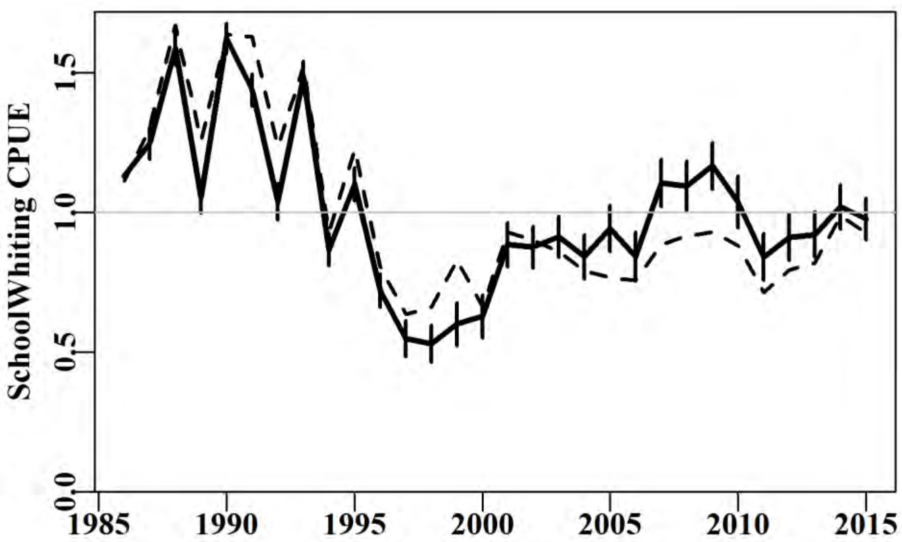




Figure 8.5. School Whiting in zone 60 in depths 0 to 100 m taken by Danish Seine. Upper plot: the dashed black line represents the geometric mean catch rate and the solid black line the standardized catch rates (relative to the mean of the standardized catch rates). The blue line corresponds to last year's standardized catch rates. Lower plot: Standardized catch rates (solid black line), 95% CI (vertical lines) and geometric mean (dashed black line).

Table 8.4. School Whiting from zone 60 in depths 0 to 100 m by Danish Seine. Statistical model structures used in this analysis. DepCat is a series of 20 metre depth categories.

| | |
|---|---|
| Model 1 | LnCE ~ Year |
| Model 2 | LnCE ~ Year + Vessel |
| Model 3 | LnCE ~ Year + Vessel + DayNight |
| Model 4 | LnCE ~ Year + Vessel + DayNight + Month |
| Model 5 | LnCE ~ Year + Vessel + DayNight + Month + DepCat |
| Model 6 | LnCE ~ Year + Vessel + DayNight + Month + DepCat + DayNight:DepCat |
| Model 7 | LnCE ~ Year + Vessel + DayNight + Month + DepCat + DepCat:Month |
| Model 8 | LnCE ~ Year + Vessel + DayNight + Month + DepCat + DayNight:Month |

Table 8.5. School Whiting from zone 60 in depths 0 to 100 m by Danish Seine. Model selection criteria include the Akaike Information Criterion (AIC), residual sum of squares (RSS), model sum of squares (MSS), number of usable observations (Nobs), number of parameters (Npars), adjusted $R^2$ (adj_$R^2$) and the change in adjusted $R^2$ (%Change). The optimum model was Model 7 (DepC:Month). Depth category: DepC; DayNight:DN.

| | Year | Vessel | DN | Month | DepC | DN:DepC | DepC:Month | DN:Month |
|---|---|---|---|---|---|---|---|---|
| AIC | 62229 | 59969 | 56108 | 54962 | 53548 | 53277 | 53019 | 53295 |
| RSS | 177503 | 172736 | 165185 | 162972 | 159190 | 158626 | 157995 | 158593 |
| MSS | 7827 | 12595 | 20145 | 22358 | 26140 | 26704 | 27335 | 26737 |
| Nobs | 86537 | 86537 | 86537 | 86537 | 84942 | 84942 | 84942 | 84942 |
| Npars | 30 | 78 | 81 | 92 | 97 | 112 | 152 | 130 |
| adj_$R^2$ | 4.191 | 6.713 | 10.787 | 11.972 | 14.008 | 14.297 | 14.597 | 14.297 |
| %Change | 0.000 | 2.521 | 4.075 | 1.184 | 2.036 | 0.289 | 0.300 | -0.301 |

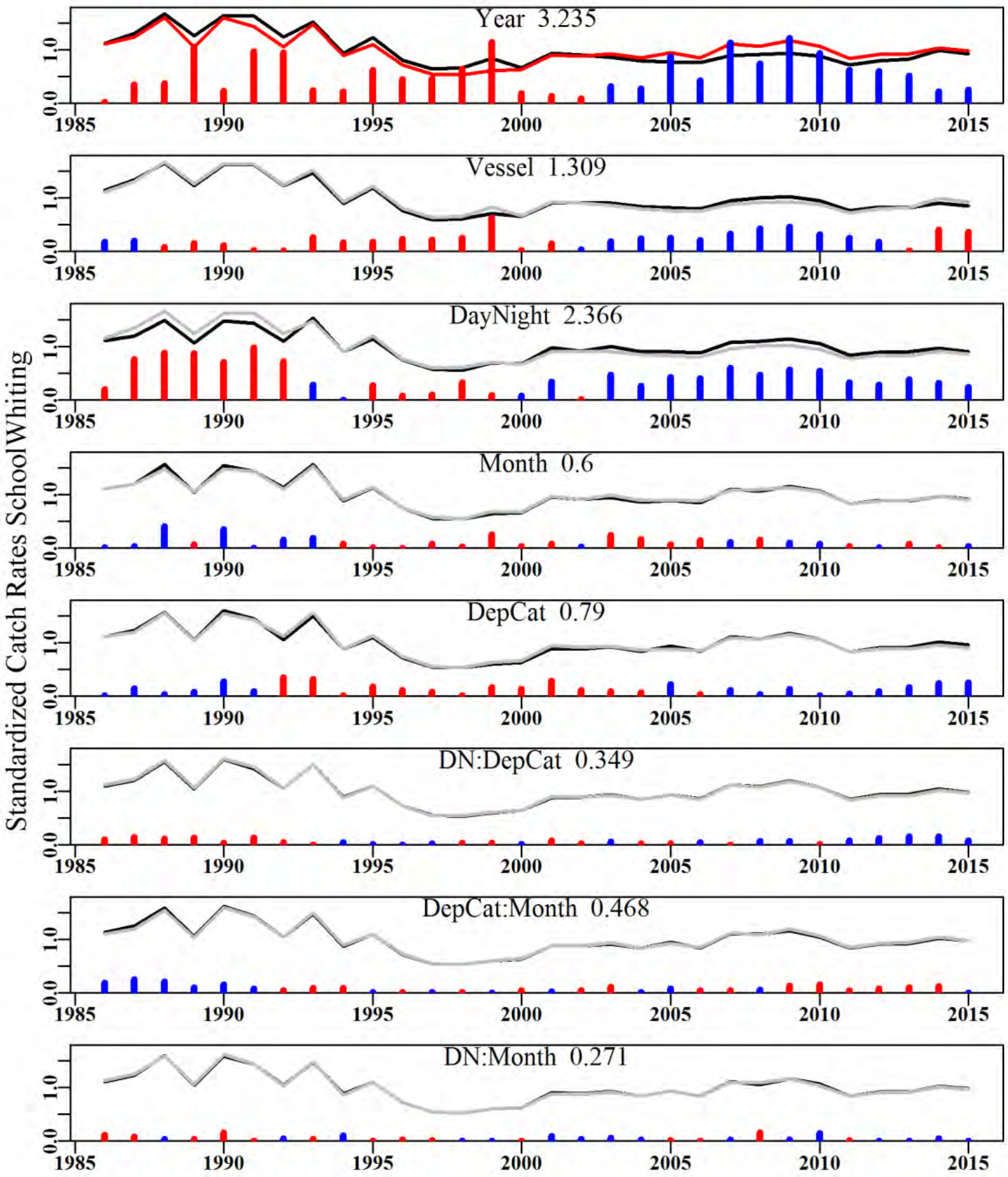



Figure 8.6. The relative influence of each factor used on the final trend in the optimal standardization for School Whiting in zone 60. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by the vertical bars with blue bars indicating the optimum model is higher than the geometric mean and red bars indicating it is lower. The top graph bars are the sum of all the bars in the graphs below. The graphs for individual factors are cumulative. Thus the second graph has the geometric mean (grey line) and the effect of adding Year + factor2 (Model 2). In the third graph, the grey line represents Model 2 and the black line the effect of adding factor3 to the model. The remaining graphs continue in the same cumulative manner except for the interaction terms which are added singularly to the final single factor model.

### 8.4.2 *Eastern Gemfish Spawning (GEM – 37439002 – Rexea solandri)*

Eastern Gemfish are taken by Trawl in the spawning season from June to September in zones 10, 20 and 30, in the bottom half of zone 40 (i.e. below 42°S; west coast of Tasmania) and between depths of 300 to 500 m. There were 15,364 records for analysis. The spawning run of Eastern Gemfish is considered to be a by-catch fishery. Particular records in the database relating to the Eastern Gemfish surveys in 2007 and 2008 were removed from the data set prior to the analysis.

Table 8.6. Eastern Gemfish, spawning fishery in depths between 300 – 500 m, taken by Trawl. Total catch (TotCatch; t) is the total reported in the database, number of records used in the analysis (Records), reported catch (CatchT; t) in the area and depth used in the analysis and number of vessels used in the analysis (Vessels). GeoMean is the geometric mean of catch rates (kg/hr). The optimum model is Zone:Month and standard deviation (StDev) relates to the data in the optimum model.

| Year | TotCatch | Records | CatchT | Vessels | GeoMean | Zone:Month | StDev |
|---|---|---|---|---|---|---|---|
| 1993 | 353.4100 | 824 | 133.2310 | 50 | 17.7598 | 2.1882 | 0.0000 |
| 1994 | 232.1790 | 819 | 49.0380 | 47 | 11.8880 | 1.4361 | 0.0622 |
| 1995 | 181.7460 | 657 | 21.8650 | 48 | 7.3973 | 0.9633 | 0.0656 |
| 1996 | 382.1960 | 769 | 135.1320 | 49 | 10.9438 | 1.2051 | 0.0633 |
| 1997 | 571.9758 | 1232 | 268.5900 | 48 | 18.9829 | 1.7876 | 0.0586 |
| 1998 | 404.8147 | 883 | 144.6760 | 46 | 11.5921 | 1.1903 | 0.0628 |
| 1999 | 448.6767 | 1065 | 87.9210 | 45 | 8.4120 | 0.9846 | 0.0611 |
| 2000 | 336.4642 | 1178 | 37.0190 | 44 | 4.8857 | 0.6722 | 0.0613 |
| 2001 | 331.4862 | 855 | 32.8390 | 47 | 4.7369 | 0.6888 | 0.0650 |
| 2002 | 195.8983 | 924 | 22.4530 | 42 | 3.5080 | 0.4945 | 0.0644 |
| 2003 | 267.9710 | 967 | 31.5869 | 48 | 4.5797 | 0.6971 | 0.0633 |
| 2004 | 568.8517 | 631 | 19.7705 | 44 | 4.2927 | 0.6629 | 0.0705 |
| 2005 | 511.7585 | 652 | 21.6200 | 40 | 4.5977 | 0.5874 | 0.0693 |
| 2006 | 544.8936 | 571 | 34.7529 | 35 | 7.7674 | 0.9126 | 0.0719 |
| 2007 | 580.6498 | 308 | 25.3560 | 19 | 8.9499 | 1.1418 | 0.0867 |
| 2008 | 257.6855 | 447 | 35.2582 | 23 | 10.4210 | 1.3744 | 0.0791 |
| 2009 | 194.8654 | 413 | 37.0383 | 22 | 9.3924 | 1.2649 | 0.0802 |
| 2010 | 220.6510 | 390 | 41.7925 | 24 | 10.5969 | 1.3639 | 0.0812 |
| 2011 | 147.7397 | 413 | 27.4315 | 21 | 7.3130 | 0.9633 | 0.0794 |
| 2012 | 168.5996 | 381 | 28.0095 | 21 | 6.0729 | 0.6253 | 0.0826 |
| 2013 | 103.8201 | 296 | 16.1220 | 20 | 7.2970 | 0.7971 | 0.0884 |
| 2014 | 130.2023 | 368 | 11.2463 | 19 | 4.1031 | 0.5647 | 0.0822 |
| 2015 | 86.3213 | 321 | 7.8913 | 20 | 3.5519 | 0.4340 | 0.0865 |

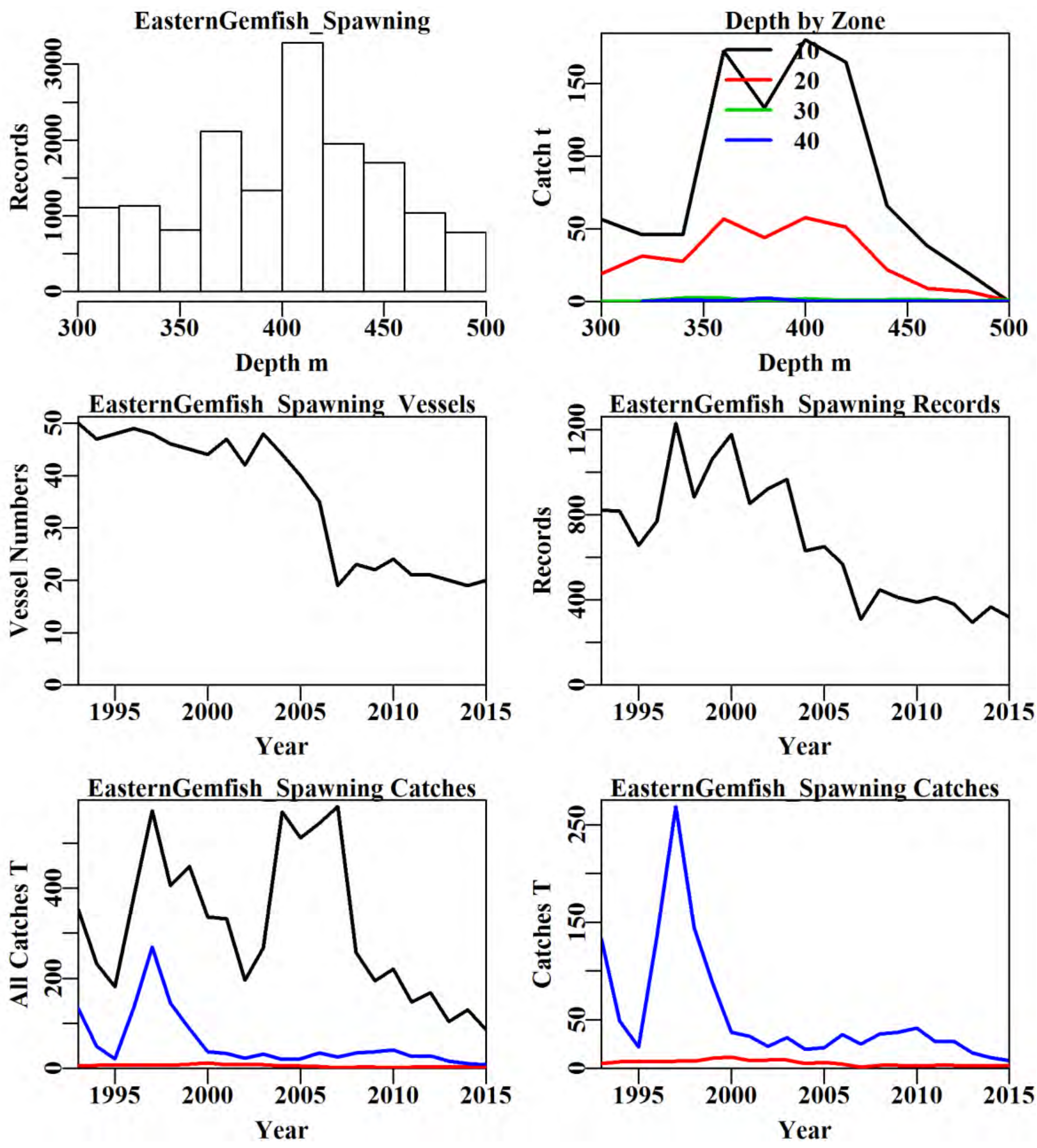



Figure 8.7. Eastern Gemfish, spawning fishery in depths between 300 – 500 m, taken by Trawl. The top left plot depicts the depth distribution of shots containing Eastern Gemfish from zones 10 to 40 in depths 300 – 500 m by Trawl. The top right plot depicts the distribution of catch by depth within zones 10 to 40. The middle left plot depicts the number of vessels through time. The middle right plot contains the number of records used in analysis. The bottom left plot contains Eastern Gemfish catches (top black line: total catches for all gemfish (Eastern and Western), middle blue line: catches used in the analysis; bottom red line: catches < 30 kg) and bottom right plot contains Eastern Gemfish catches (blue line: catches used in the analysis; red line: catches < 30 kg).

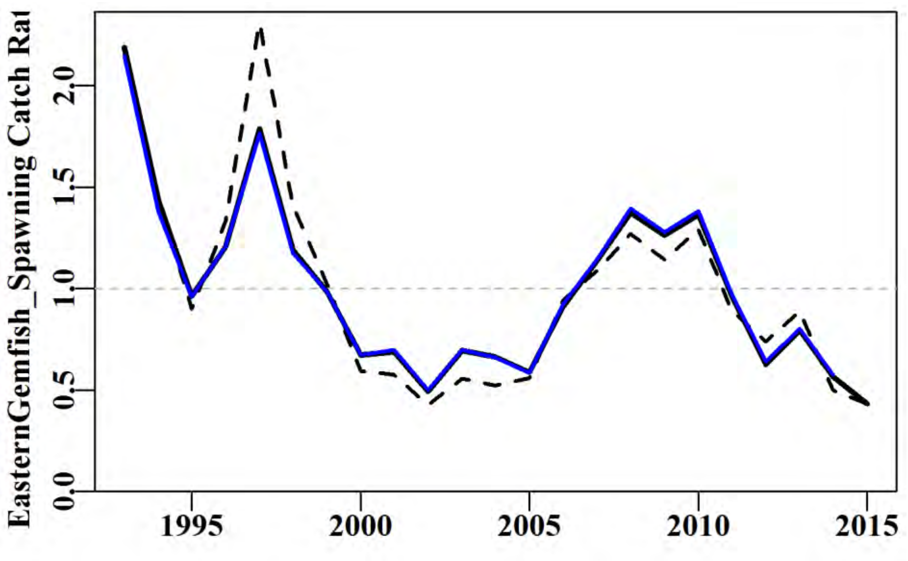



Figure 8.8. Eastern Gemfish, spawning fishery in depths between 300 – 500 m, taken by Trawl. The dashed black line represents the geometric mean catch rate and the solid black line the standardized catch rates (relative to the mean of the standardized catch rates). The blue line is last year's optimum standardization.

Table 8.7. Eastern Gemfish, spawning fishery in depths between 300 – 500 m, taken by Trawl. Statistical model structures used in this analysis. DepCat is a series of 20 metre depth categories.

| | |
|---|---|
| Model 1 | LnCE~Year |
| Model 2 | LnCE~Year+Vessel |
| Model 3 | LnCE~Year+Vessel+Month |
| Model 4 | LnCE~Year+Vessel+Month +DepCat |
| Model 5 | LnCE~Year+Vessel+Month +DepCat +DayNight |
| Model 6 | LnCE~Year+Vessel+Month +DepCat +DayNight+Zone |
| Model 7 | LnCE~Year+Vessel+Month +DepCat +DayNight+Zone+Zone:Month |
| Model 8 | LnCE~Year+Vessel+Month +DepCat +DayNight+Zone+Zone:DepCat |

Table 8.8. Eastern Gemfish, spawning fishery in depths between 300 – 500 m, taken by Trawl. Model selection criteria include the Akaike Information Criterion (AIC), residual sum of squares (RSS), model sum of squares (MSS), number of usable observations (Nobs), number of parameters (Npars), adjusted $R^2$ (adj_$R^2$) and the change in adjusted $R^2$ (%Change). The optimum model is Model 7 (Zone:Month). Depth category: DepC.

| | Year | Vessel | Month | DepC | DayNight | Zone | Zone:Month | Zone:DepC |
|---|---|---|---|---|---|---|---|---|
| AIC | 8927 | 7200 | 6358 | 5978 | 5879 | 5872 | 5602 | 5866 |
| RSS | 27386 | 24152 | 22856 | 22170 | 22017 | 21998 | 21588 | 21904 |
| MSS | 4113 | 7348 | 8644 | 9330 | 9483 | 9502 | 9912 | 9596 |
| Nobs | 15364 | 15364 | 15364 | 15256 | 15256 | 15256 | 15256 | 15256 |
| Npars | 23 | 125 | 128 | 138 | 141 | 144 | 153 | 174 |
| adj_$R^2$ | 12.934 | 22.702 | 26.837 | 28.982 | 29.456 | 29.503 | 30.776 | 29.665 |
| %Change | 0.000 | 9.768 | 4.135 | 2.145 | 0.474 | 0.047 | 1.273 | -1.111 |

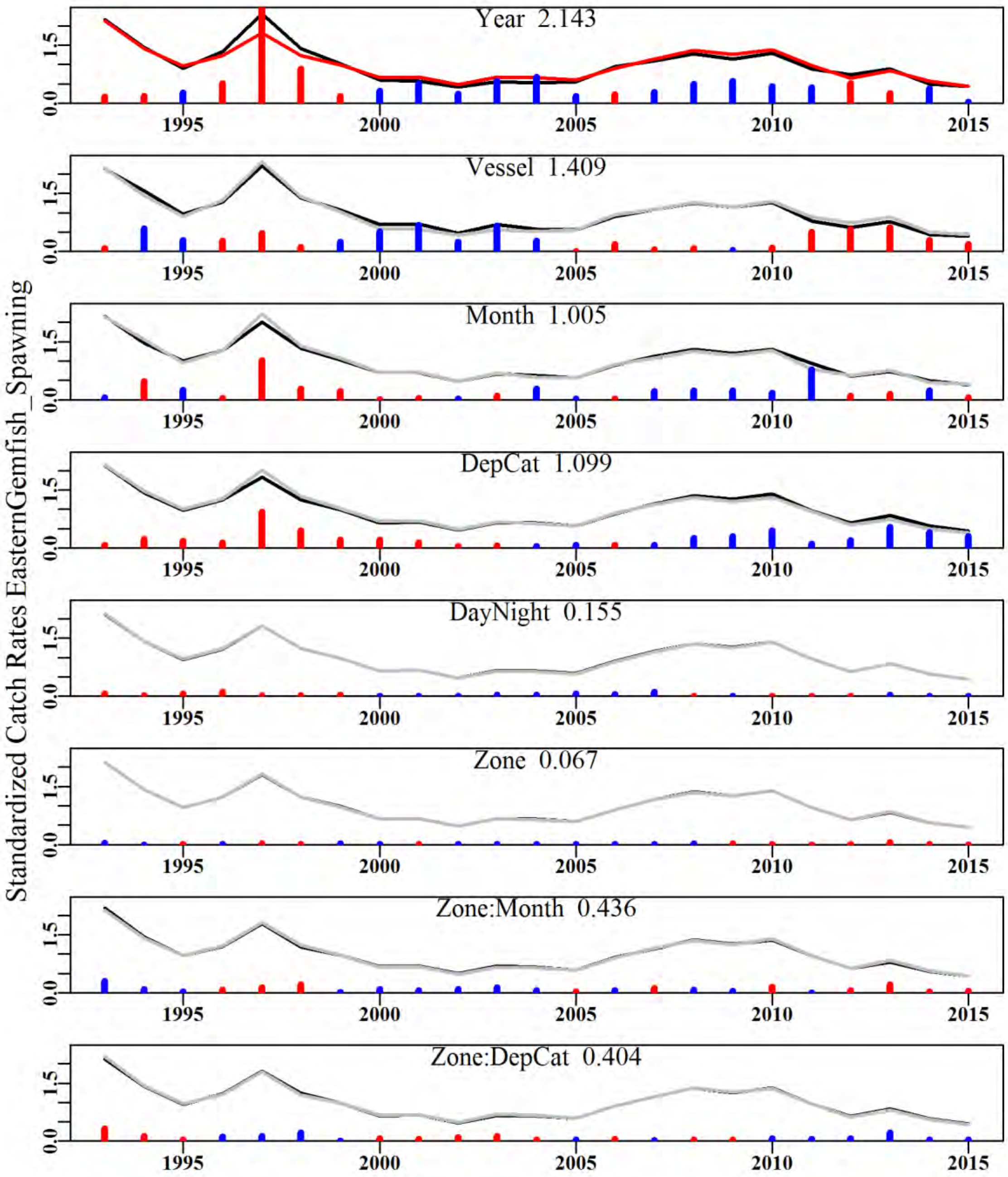



Figure 8.9. The relative influence of each factor used on the final trend in the optimal standardization for the Eastern Gemfish spawning fishery. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by the vertical bars with blue bars indicating the optimum model is higher than the geometric mean and red bars indicating it is lower. The top graph bars are the sum of all the bars in the graphs below. The graphs for individual factors are cumulative. Thus the second graph has the geometric mean (grey line) and the effect of adding Year + factor2 (Model 2). In the third graph, the grey line represents Model 2 and the black line the effect of adding factor3 to the model. The remaining graphs continue in the same cumulative manner except for the interaction terms which are added singularly to the final single factor model.

### 8.4.3 *Eastern Gemfish Non-Spawning (GEM – 37439002 – Rexea solandri)*

Data selected for analysis were based on records from zones 10-30 from October to May 1986-2014, all depths to 600 m; and from June to September in depths less than 300 m. Also, records below 42°S on the west coast of Tasmania (zone 40) were used. Particular records in the database relating to the Eastern Gemfish surveys in 2007 and 2008 were removed from the data set prior to the analysis.

Table 8.9. Non-spawning Eastern Gemfish from the SET in depths between 0 – 600 m, taken by Trawl. Total catch (TotCatch; t) is the total reported in the database, number of records used in the analysis (Records), reported catch (CatchT; t) in the area and depth used in the analysis and number of vessels used in the analysis (Vessels). GeoMean is the geometric mean of catch rates (kg/hr). The optimum model is Zone:DepCat and standard deviation (StDev) relates to the data in the optimum model.

| Year | TotCatch | Records | CatchT | Vessels | GeoMean | Zone:DepCat | StDev |
|---|---|---|---|---|---|---|---|
| 1986 | 3639.9550 | 2030 | 390.3560 | 86 | 14.5833 | 2.5612 | 0.0000 |
| 1987 | 4660.4470 | 1894 | 770.1410 | 74 | 25.6322 | 3.4759 | 0.0430 |
| 1988 | 3515.8190 | 2203 | 509.5870 | 77 | 20.2775 | 2.9134 | 0.0430 |
| 1989 | 1778.3250 | 1434 | 148.4000 | 69 | 11.5170 | 1.9420 | 0.0476 |
| 1990 | 1206.8970 | 758 | 104.1350 | 69 | 12.7467 | 1.9483 | 0.0574 |
| 1991 | 580.3220 | 731 | 65.9950 | 71 | 8.7585 | 1.2878 | 0.0586 |
| 1992 | 494.4410 | 695 | 135.1640 | 50 | 11.2643 | 1.7772 | 0.0594 |
| 1993 | 353.4100 | 1536 | 94.3200 | 58 | 8.9703 | 1.3939 | 0.0480 |
| 1994 | 232.1790 | 1832 | 63.8120 | 55 | 6.3021 | 0.9653 | 0.0461 |
| 1995 | 181.7460 | 1685 | 49.9770 | 54 | 5.5810 | 0.8699 | 0.0469 |
| 1996 | 382.1960 | 1947 | 55.7080 | 61 | 4.1794 | 0.6671 | 0.0460 |
| 1997 | 571.9758 | 1786 | 66.0200 | 58 | 4.3644 | 0.6985 | 0.0484 |
| 1998 | 404.8147 | 1246 | 45.6350 | 50 | 4.3330 | 0.6569 | 0.0510 |
| 1999 | 448.6767 | 1344 | 30.3190 | 53 | 2.9242 | 0.4803 | 0.0504 |
| 2000 | 336.4642 | 1718 | 32.3180 | 57 | 2.7962 | 0.4385 | 0.0481 |
| 2001 | 331.4862 | 1642 | 32.2460 | 50 | 2.0644 | 0.3562 | 0.0490 |
| 2002 | 195.8983 | 1617 | 19.0340 | 50 | 1.5969 | 0.2743 | 0.0493 |
| 2003 | 267.9710 | 1583 | 20.0334 | 48 | 1.7225 | 0.3011 | 0.0496 |
| 2004 | 568.8517 | 1771 | 38.5647 | 54 | 2.6317 | 0.4227 | 0.0489 |
| 2005 | 511.7585 | 1745 | 40.9667 | 48 | 2.8254 | 0.4538 | 0.0485 |
| 2006 | 544.8936 | 1325 | 32.1506 | 43 | 2.9591 | 0.4807 | 0.0517 |
| 2007 | 580.6498 | 788 | 28.1400 | 22 | 4.2429 | 0.6499 | 0.0590 |
| 2008 | 257.6855 | 840 | 35.4670 | 26 | 5.7070 | 0.8661 | 0.0581 |
| 2009 | 194.8654 | 514 | 27.2266 | 27 | 6.6449 | 0.8984 | 0.0683 |
| 2010 | 220.6510 | 704 | 22.8883 | 23 | 4.1931 | 0.6459 | 0.0614 |
| 2011 | 147.7397 | 800 | 22.8895 | 22 | 3.8396 | 0.5807 | 0.0602 |
| 2012 | 168.5996 | 709 | 21.9958 | 23 | 3.5107 | 0.5557 | 0.0621 |
| 2013 | 103.8201 | 596 | 23.4630 | 23 | 4.5973 | 0.6370 | 0.0659 |
| 2014 | 130.2023 | 521 | 9.7232 | 23 | 2.4041 | 0.3743 | 0.0676 |
| 2015 | 86.3213 | 622 | 16.6003 | 24 | 2.8876 | 0.4272 | 0.0649 |

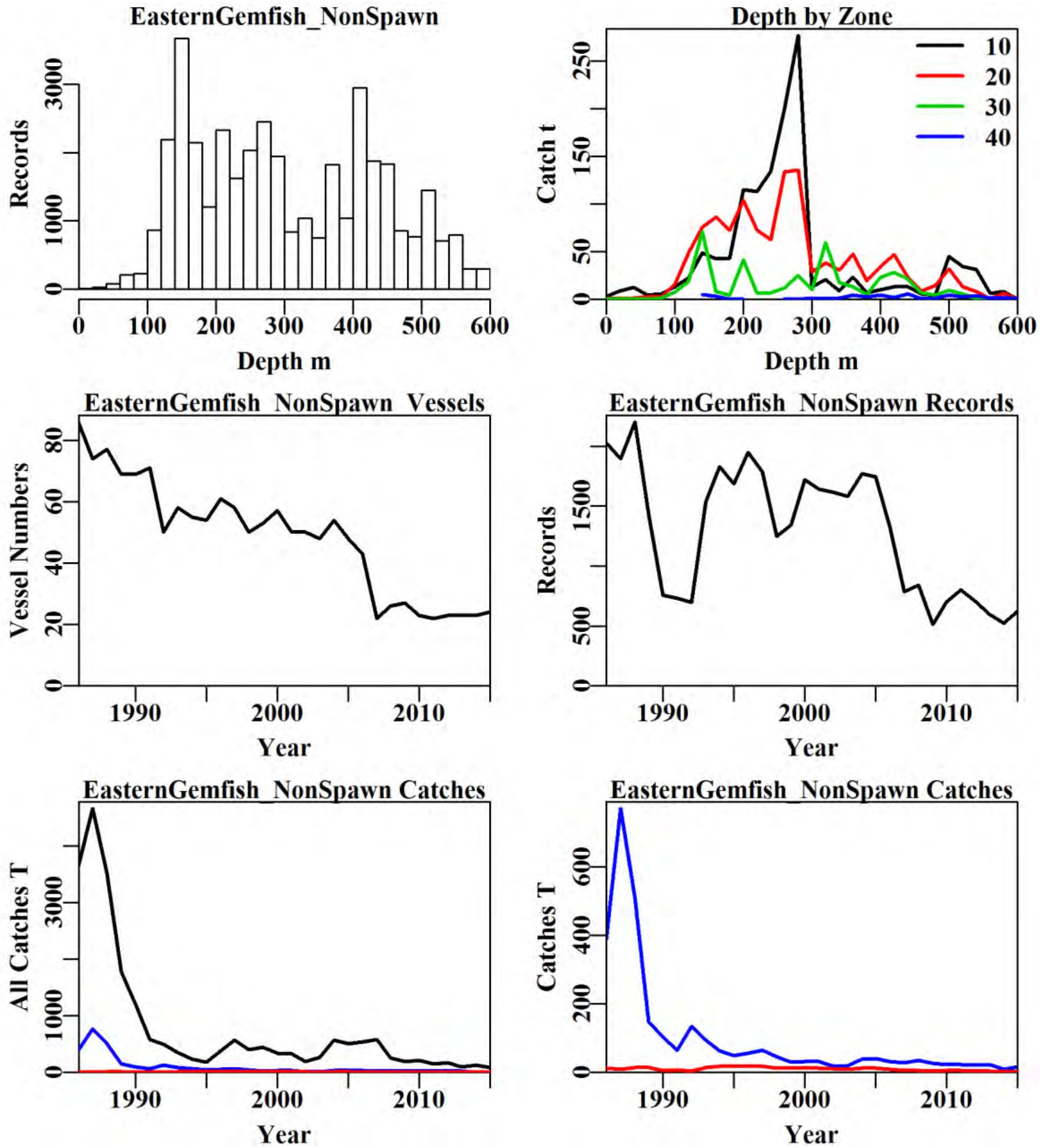



Figure 8.10. Non-spawning Eastern Gemfish from the SET in depths between 0 – 600 m, taken by Trawl. The top left plot depicts the depth distribution of shots containing non-spawning Eastern Gemfish from zones 10 to 40 in depths 0 – 600 m by Trawl. The top right plot depicts the distribution of catch by depth within zones 10 to 40. The middle left plot depicts the number of vessels through time. The middle right plot contains the number of records used in analysis. The bottom left plot contains non-spawning Eastern Gemfish catches (top black line: total catches, middle blue line: catches used in the analysis; bottom red line: catches < 30 kg) and bottom right plot contains non-spawning Eastern Gemfish catches (blue line: catches used in the analysis; red line: catches < 30 kg).

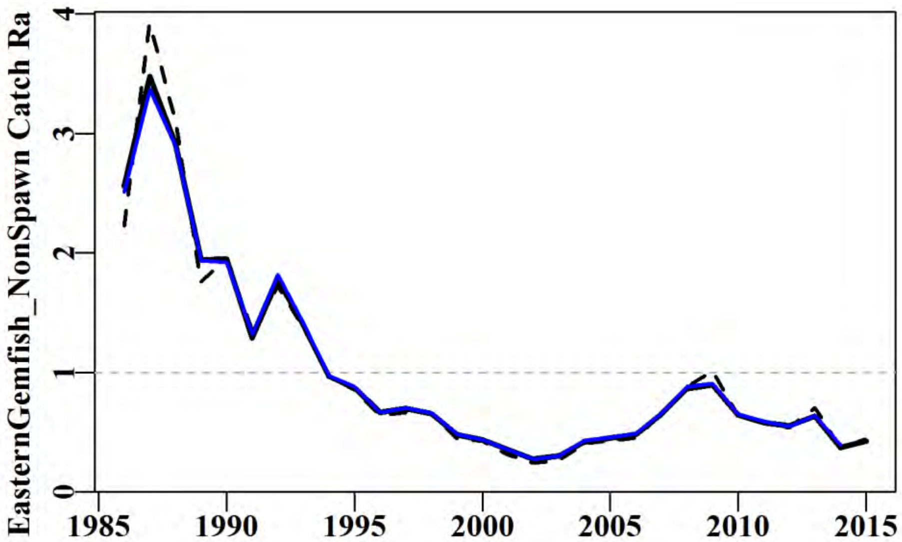



Figure 8.11. Non-spawning Eastern Gemfish from the SET in depths between 0 – 600 m, taken by Trawl. The dashed black line represents the geometric mean catch rate and the solid black line the standardized catch rates (relative to the mean of the standardized catch rates). The blue line is last year's optimum standardization.

Table 8.10. Non-spawning Eastern Gemfish from the SET in depths between 0 – 600 m, taken by Trawl. Statistical model structures used in this analysis. DepCat is a series of 20 metre depth categories.

| | |
|---|---|
| Model 1 | LnCE~Year |
| Model 2 | LnCE~Year+Vessel |
| Model 3 | LnCE~Year+Vessel+DepCat |
| Model 4 | LnCE~Year+Vessel+DepCat+Month |
| Model 5 | LnCE~Year+Vessel+DepCat+Month+ DayNight |
| Model 6 | LnCE~Year+Vessel+DepCat+Month+ DayNight + Zone |
| Model 7 | LnCE~Year+Vessel+DepCat+Month+ DayNight + Zone+ Zone:Month |
| Model 8 | LnCE~Year+Vessel+DepCat+Month+ DayNight + Zone+ Zone:DepCat |

Table 8.11. Non-spawning Eastern Gemfish from the SET in depths between 0 – 600 m, taken by Trawl. Model selection criteria include the Akaike Information Criterion (AIC), residual sum of squares (RSS), model sum of squares (MSS), number of usable observations (Nobs), number of parameters (Npars), adjusted $R^2$ (adj_$R^2$) and the change in adjusted $R^2$ (%Change). The optimum model is Model 8 (Zone:DepCat). Depth category: DepC.

| | Year | Vessel | DepC | Month | DayNight | Zone | Zone:Month | Zone:DepC |
|---|---|---|---|---|---|---|---|---|
| AIC | 24689 | 19211 | 17091 | 16625 | 16320 | 16037 | 15736 | 15577 |
| RSS | 73073 | 62798 | 59066 | 58317 | 57845 | 57411 | 56863 | 56459 |
| MSS | 23314 | 33589 | 37322 | 38071 | 38542 | 38977 | 39525 | 39928 |
| Nobs | 38616 | 38616 | 38290 | 38290 | 38290 | 38290 | 38290 | 38290 |
| Npars | 30 | 217 | 247 | 258 | 261 | 264 | 297 | 354 |
| adj_$R^2$ | 24.131 | 34.482 | 38.324 | 39.089 | 39.577 | 40.025 | 40.546 | 40.880 |
| %Change | 0.000 | 10.351 | 3.843 | 0.764 | 0.488 | 0.449 | 0.521 | 0.333 |

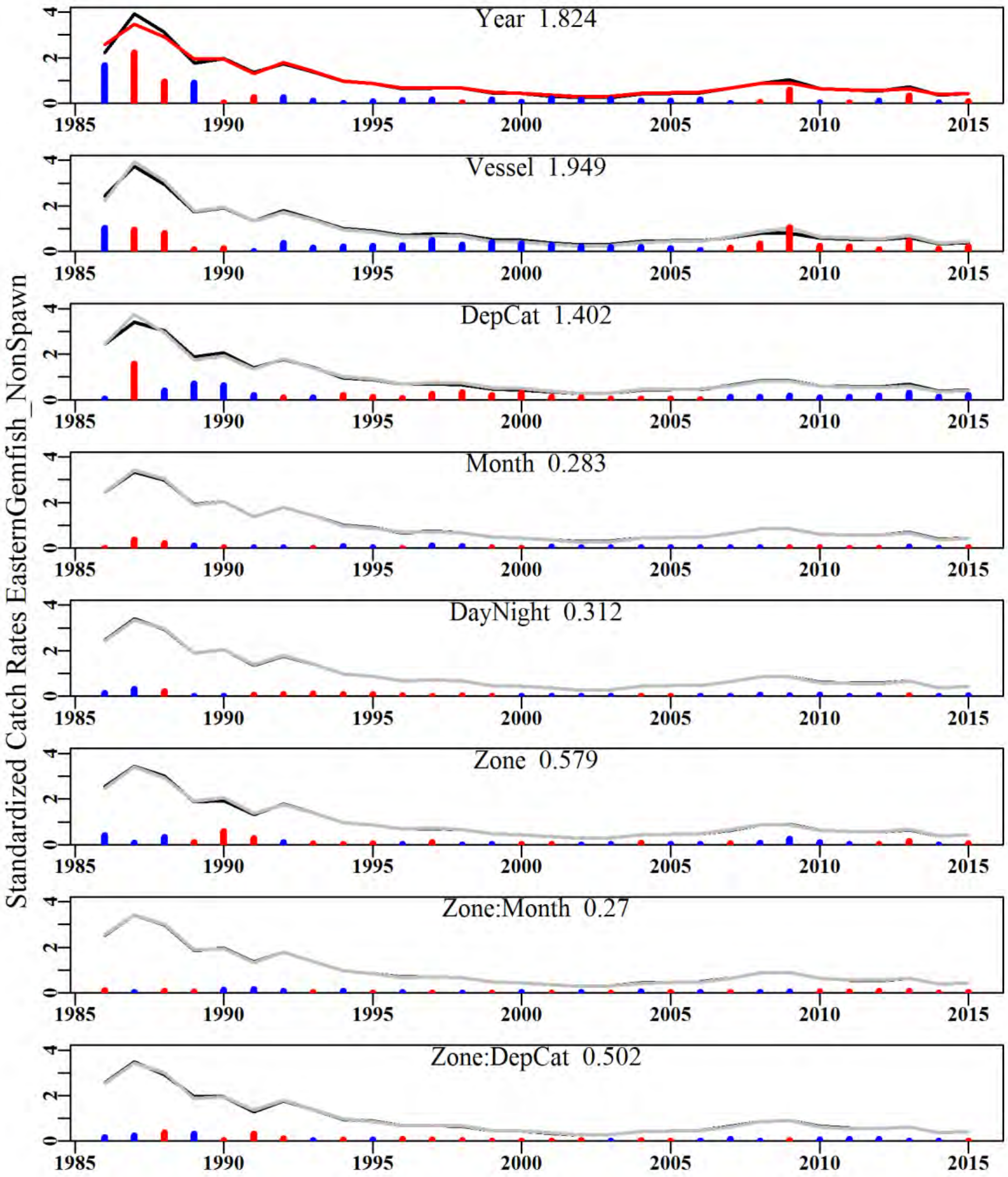



Figure 8.12. The relative influence of each factor used on the final trend in the optimal standardization for Non-spawning Eastern Gemfish. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by the vertical bars with blue bars indicating the optimum model is higher than the geometric mean and red bars indicating it is lower. The top graph bars are the sum of all the bars in the graphs below. The graphs for individual factors are cumulative. Thus the second graph has the geometric mean (grey line) and the effect of adding Year + factor2 (Model 2). In the third graph, the grey line represents Model 2 and the black line the effect of adding factor3 to the model. The remaining graphs continue in the same cumulative manner except for the interaction terms which are added singularly to the final single factor model.

### 8.4.4 *Jackass Morwong Z10-50 (MOR – 37377003 Nemadactylus macropterus)*

Trawl data selected for analysis corresponded to records from zones 10 to 50 in depths 70 – 360 m.

Table 8.12. Jackass Morwong from zones 10 to 50 in depths 70 – 360 m by Trawl. Total catch (TotCatch; t) is the total reported in the database, number of records used in the analysis (Records), reported catch (CatchT; t) in the area and depth used in the analysis and number of vessels used in the analysis (Vessels). GeoMean is the geometric mean of catch rates (kg/hr). The optimum model is Zone:Month and standard deviation (StDev) relates to the data in the optimum model.

| Year | TotCatch | Records | CatchT | Vessels | GeoMean | Zone:Month | StDev |
|---|---|---|---|---|---|---|---|
| 1986 | 982.8110 | 5771 | 873.1790 | 106 | 22.5642 | 2.0002 | 0.0000 |
| 1987 | 1087.6900 | 4948 | 1000.0540 | 104 | 26.1917 | 2.2616 | 0.0267 |
| 1988 | 1483.5120 | 5983 | 1313.7970 | 102 | 29.1474 | 2.2349 | 0.0261 |
| 1989 | 1667.3730 | 5434 | 1500.6040 | 89 | 33.9001 | 2.1776 | 0.0268 |
| 1990 | 1001.4140 | 5022 | 837.3570 | 86 | 24.2137 | 1.8250 | 0.0278 |
| 1991 | 1138.0700 | 5233 | 899.6850 | 85 | 21.1174 | 1.5862 | 0.0277 |
| 1992 | 758.2540 | 3512 | 525.2990 | 64 | 19.0586 | 1.3307 | 0.0309 |
| 1993 | 1014.9853 | 4731 | 821.8510 | 73 | 21.3564 | 1.3659 | 0.0290 |
| 1994 | 818.4180 | 5657 | 684.5450 | 71 | 18.0741 | 1.1565 | 0.0277 |
| 1995 | 789.5280 | 5852 | 705.4090 | 63 | 16.3623 | 1.0827 | 0.0274 |
| 1996 | 827.1910 | 7535 | 749.5740 | 70 | 13.8607 | 0.9926 | 0.0263 |
| 1997 | 1063.3630 | 7560 | 933.9260 | 70 | 16.1580 | 1.0657 | 0.0268 |
| 1998 | 876.4054 | 5941 | 688.7050 | 65 | 13.4363 | 0.9154 | 0.0277 |
| 1999 | 961.2618 | 5800 | 779.6130 | 66 | 14.1564 | 0.9428 | 0.0279 |
| 2000 | 945.0978 | 6811 | 730.9400 | 77 | 10.3611 | 0.8001 | 0.0271 |
| 2001 | 790.1902 | 6686 | 643.7060 | 70 | 8.4334 | 0.5959 | 0.0274 |
| 2002 | 811.1362 | 7777 | 692.3930 | 65 | 8.3261 | 0.6300 | 0.0269 |
| 2003 | 774.5778 | 6537 | 600.9390 | 64 | 7.9043 | 0.5466 | 0.0276 |
| 2004 | 765.5049 | 6483 | 604.4761 | 70 | 8.6153 | 0.5446 | 0.0278 |
| 2005 | 784.1607 | 6376 | 597.4155 | 58 | 8.9785 | 0.5876 | 0.0279 |
| 2006 | 811.2979 | 5446 | 616.1015 | 49 | 11.5427 | 0.6766 | 0.0287 |
| 2007 | 607.8702 | 3812 | 443.3657 | 30 | 12.2504 | 0.6879 | 0.0312 |
| 2008 | 700.4393 | 4491 | 546.6400 | 33 | 13.7889 | 0.8002 | 0.0302 |
| 2009 | 454.3668 | 3384 | 344.4442 | 27 | 11.4694 | 0.7046 | 0.0321 |
| 2010 | 380.0247 | 3432 | 291.8870 | 30 | 8.5531 | 0.5161 | 0.0322 |
| 2011 | 427.9796 | 3524 | 303.3383 | 28 | 8.5407 | 0.4951 | 0.0320 |
| 2012 | 395.5938 | 3145 | 305.2530 | 29 | 8.9426 | 0.4965 | 0.0328 |
| 2013 | 323.9461 | 2518 | 238.6190 | 26 | 8.7131 | 0.4341 | 0.0348 |
| 2014 | 216.4660 | 2161 | 140.3600 | 26 | 5.5073 | 0.3049 | 0.0361 |
| 2015 | 152.3598 | 1721 | 80.2410 | 27 | 4.4077 | 0.2417 | 0.0389 |

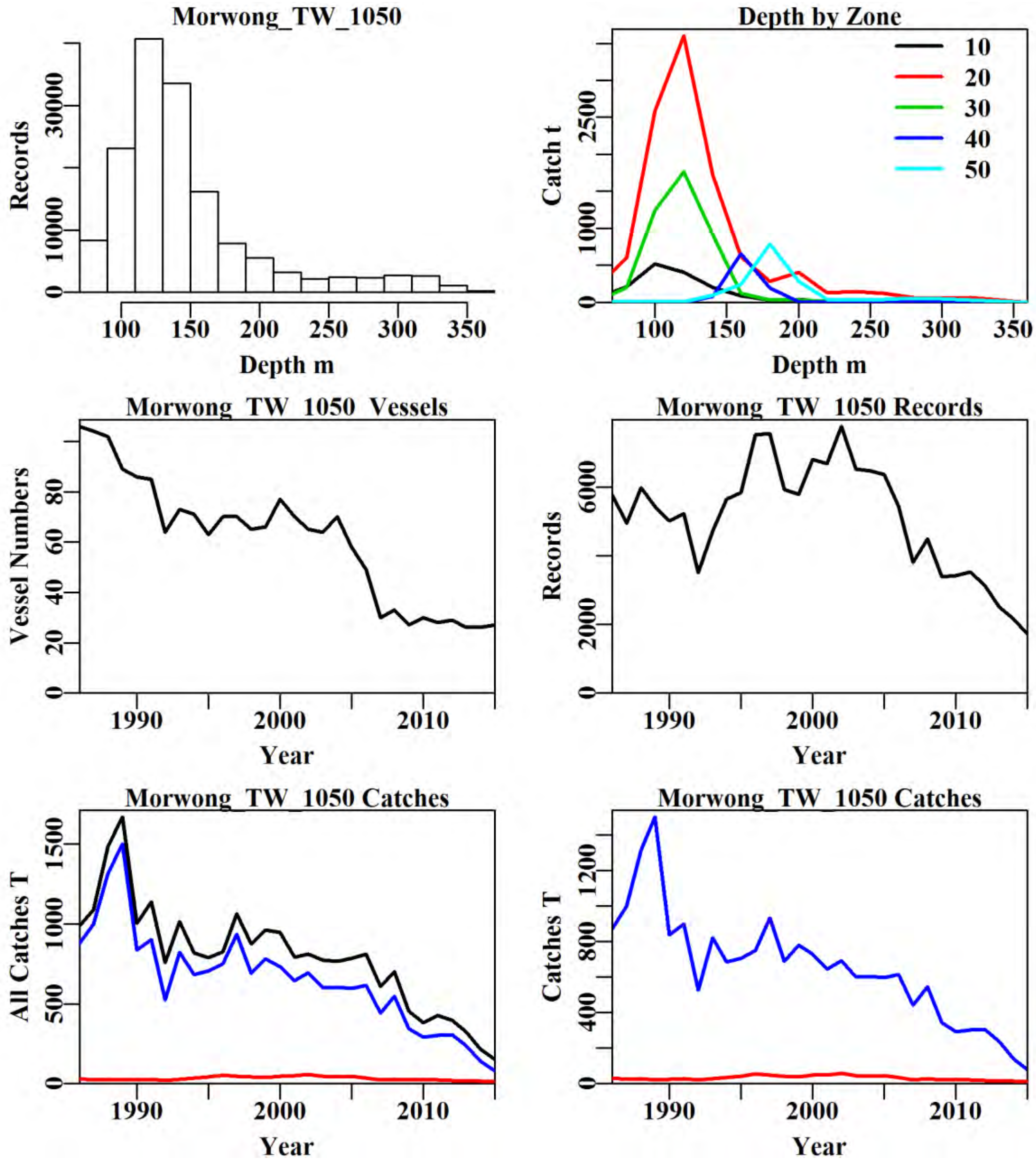



Figure 8.13. Jackass Morwong from zones 10 to 50 in depths 70 – 360 m by Trawl. The top left plot depicts the depth distribution of shots containing Jackass Morwong from zones 10 to 50 in depths 70 – 360 m by Trawl. The top right plot depicts the distribution of catch by depth within zones 10 to 50. The middle left plot depicts the number of vessels through time. The middle right plot contains the number of records used in analysis. The bottom left plot contains Jackass Morwong catches (top black line: total catches, middle blue line: catches used in the analysis; bottom red line: catches < 30 kg) and bottom right plot contains Jackass Morwong catches (blue line: catches used in the analysis; red line: catches < 30 kg).

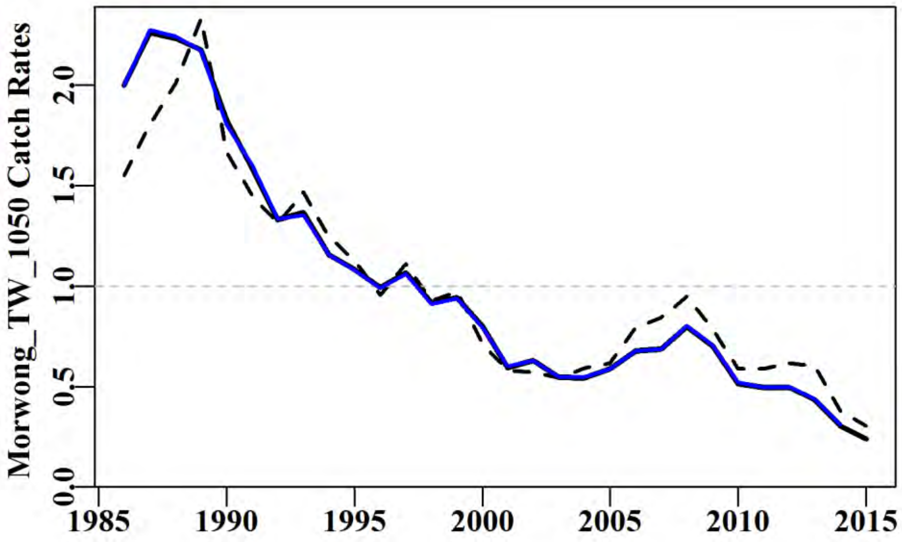



Figure 8.14. Jackass Morwong from zones 10 to 50 in depths 70 – 360 m by Trawl. The dashed black line represents the geometric mean catch rate and the solid black line the standardized catch rates. The graph standardizes catch rates relative to the mean of the standardized catch rates. The blue line is last year's optimum standardization.

Table 8.13. Jackass Morwong from zones 10 to 50 in depths 70 – 360 m by Trawl. Statistical model structures used in this analysis. DepCat is a series of 20 metre depth categories.

| | |
|---|---|
| Model 1 | LnCE ~ Year |
| Model 2 | LnCE ~ Year + Vessel |
| Model 3 | LnCE ~ Year + Vessel + Month |
| Model 4 | LnCE ~ Year + Vessel + Month + DepCat |
| Model 5 | LnCE ~ Year + Vessel + Month + DepCat + Zone |
| Model 6 | LnCE ~ Year + Vessel + Month + DepCat + Zone + DayNight |
| Model 7 | LnCE ~ Year + Vessel + Month + DepCat + Zone + DayNight + Zone:Month |
| Model 8 | LnCE ~ Year + Vessel + Month + DepCat + Zone + DayNight + Zone:DepCat |

Table 8.14. . Jackass Morwong from zones 10 to 50 in depths 70 – 360 m by Trawl. Model selection criteria include the Akaike Information Criterion (AIC), residual sum of squares (RSS), model sum of squares (MSS), number of usable observations (Nobs), number of parameters (Npars), adjusted $R^2$ (adj_$R^2$) and the change in adjusted $R^2$ (%Change). The optimum model was Model 7 (Zone:Month). Depth category: DepC.

| | Year | Vessel | Month | DepC | Zone | DayNight | Zone:Month | Zone:DepC |
|---|---|---|---|---|---|---|---|---|
| AIC | 118352 | 96403 | 89521 | 85051 | 80317 | 78823 | 76699 | 77334 |
| RSS | 331626 | 286563 | 273942 | 264937 | 256793 | 254270 | 250594 | 251590 |
| MSS | 31622 | 76685 | 89306 | 98310 | 106454 | 108977 | 112654 | 111657 |
| Nobs | 153283 | 153283 | 153283 | 151892 | 151892 | 151892 | 151892 | 151892 |
| Npars | 30 | 249 | 260 | 275 | 279 | 282 | 326 | 342 |
| adj_$R^2$ | 8.688 | 20.983 | 24.458 | 26.932 | 29.177 | 29.871 | 30.865 | 30.583 |
| %Change | 0.000 | 12.295 | 3.475 | 2.475 | 2.244 | 0.694 | 0.994 | -0.282 |

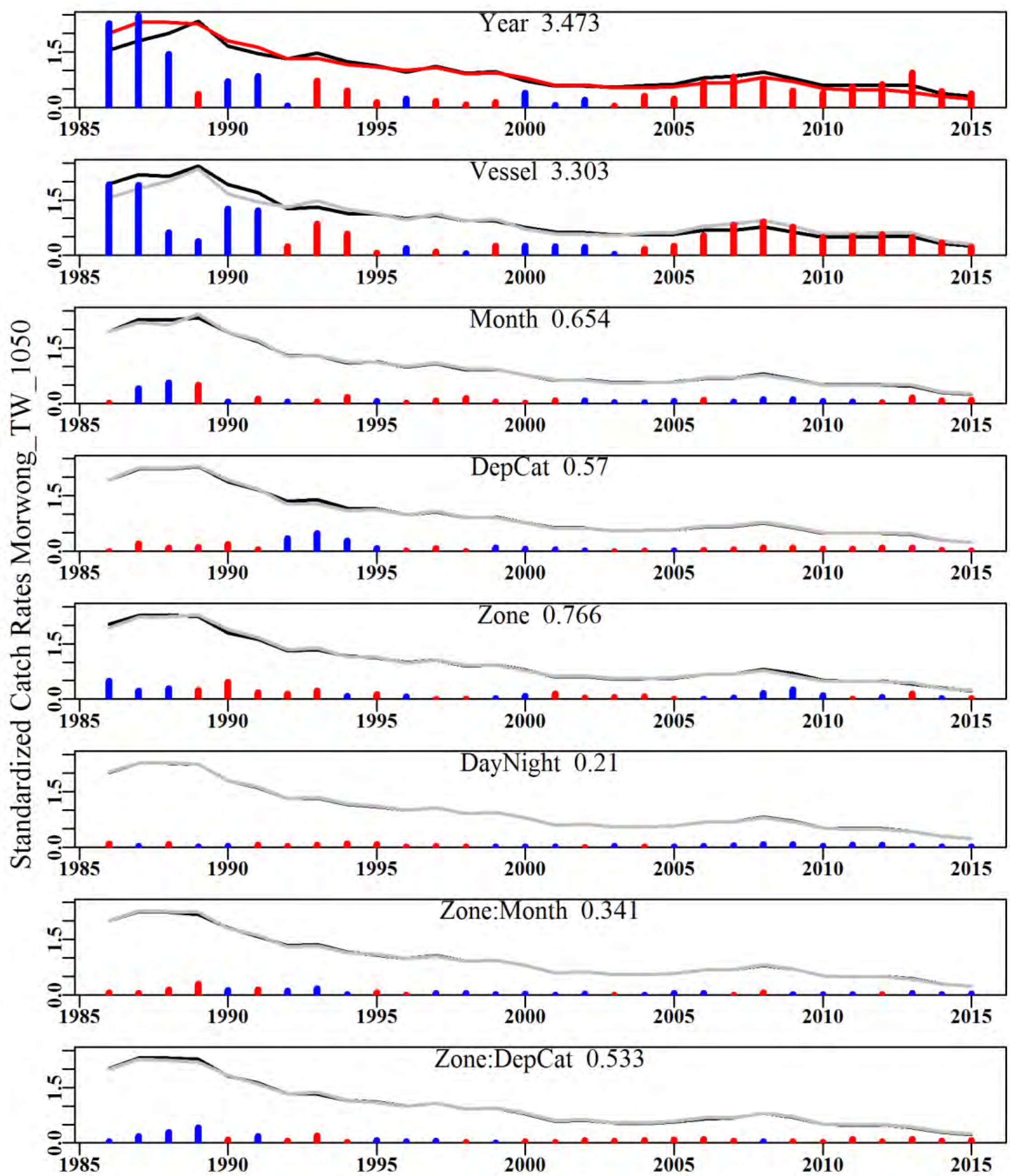



Figure 8.15. The relative influence of each factor used on the final trend in the optimal standardization for Jackass Morwong in zones 10 – 50. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by the vertical bars with blue bars indicating the optimum model is higher than the geometric mean and red bars indicating it is lower. The top graph bars are the sum of all the bars in the graphs below. The graphs for individual factors are cumulative. Thus the second graph has the geometric mean (grey line) and the effect of adding Year + factor2 (Model 2). In the third graph, the grey line represents Model 2 and the black line the effect of adding factor3 to the model. The remaining graphs continue in the same cumulative manner except for the interaction terms which are added singularly to the final single factor model.

Table 8.15. The split of reported catches in tonnes by zone as taken by Trawl in the identified depths. GAB includes zones 82, 83, 84, and 85.

| Year | 10 | 20 | 30 | 40 | 50 | 60 | GAB |
|---|---|---|---|---|---|---|---|
| 1986 | 17.028 | 189.137 | 40.259 | 1.710 | 42.833 | 1.079 | 0.000 |
| 1987 | 153.320 | 597.844 | 32.287 | 0.400 | 152.246 | 27.109 | 16.565 |
| 1988 | 143.635 | 769.633 | 80.446 | 13.775 | 46.426 | 19.748 | 12.820 |
| 1989 | 181.161 | 918.844 | 213.955 | 16.700 | 51.072 | 57.580 | 41.430 |
| 1990 | 80.174 | 896.639 | 505.097 | 50.770 | 34.226 | 39.482 | 51.348 |
| 1991 | 82.778 | 606.580 | 158.494 | 14.701 | 68.417 | 22.015 | 45.693 |
| 1992 | 108.783 | 689.849 | 225.715 | 14.382 | 33.105 | 22.191 | 32.921 |
| 1993 | 56.655 | 443.724 | 132.726 | 27.490 | 34.501 | 7.577 | 45.160 |
| 1994 | 109.032 | 420.051 | 344.380 | 4.474 | 21.107 | 26.708 | 46.599 |
| 1995 | 109.510 | 431.722 | 185.204 | 4.641 | 18.665 | 18.074 | 46.811 |
| 1996 | 79.732 | 385.563 | 187.464 | 67.835 | 10.855 | 3.863 | 52.929 |
| 1997 | 100.470 | 472.702 | 162.715 | 10.917 | 27.350 | 6.867 | 45.263 |
| 1998 | 64.784 | 649.778 | 205.295 | 29.995 | 27.213 | 14.151 | 66.733 |
| 1999 | 59.853 | 440.336 | 193.305 | 45.258 | 12.961 | 13.462 | 72.571 |
| 2000 | 45.971 | 443.839 | 249.027 | 64.502 | 16.404 | 9.217 | 102.751 |
| 2001 | 49.815 | 475.111 | 126.249 | 107.740 | 13.703 | 20.428 | 73.115 |
| 2002 | 37.154 | 273.619 | 112.989 | 137.773 | 149.603 | 17.561 | 52.075 |
| 2003 | 76.130 | 291.396 | 110.840 | 98.844 | 156.460 | 15.729 | 48.200 |
| 2004 | 32.855 | 239.895 | 196.687 | 62.151 | 114.646 | 12.053 | 98.563 |
| 2005 | 31.203 | 223.494 | 205.915 | 48.383 | 141.840 | 7.189 | 104.330 |
| 2006 | 37.018 | 289.029 | 151.947 | 36.915 | 162.915 | 8.309 | 96.863 |
| 2007 | 30.714 | 289.117 | 166.045 | 24.665 | 167.622 | 6.735 | 121.021 |
| 2008 | 14.548 | 230.969 | 118.917 | 25.839 | 96.708 | 5.620 | 109.069 |
| 2009 | 38.791 | 327.492 | 122.652 | 29.875 | 74.678 | 6.366 | 91.719 |
| 2010 | 27.420 | 230.783 | 55.928 | 20.819 | 45.113 | 3.843 | 64.330 |
| 2011 | 21.832 | 190.898 | 59.890 | 13.603 | 27.351 | 3.445 | 39.384 |
| 2102 | 17.680 | 184.606 | 51.254 | 35.147 | 51.226 | 11.685 | 30.838 |
| 2013 | 22.588 | 170.102 | 94.482 | 20.303 | 16.295 | 4.139 | 26.905 |
| 2014 | 7.630 | 103.087 | 105.968 | 21.596 | 16.065 | 4.128 | 25.447 |
| 2015 | 10.590 | 74.923 | 54.188 | 1.966 | 9.250 | 1.941 | 33.464 |

### 8.4.5 *Jackass Morwong Z1020 (MOR–37377003 – Nemadactylus macropterus)*

Trawl data selected for analysis corresponded to records from zones 10 and 20 and depths between 70 and 300 m (i.e. Danish Seine vessels were excluded).

Table 8.16. Jackass Morwong from zones 10 and 20 in depths 70 – 300 m by Trawl. Total catch (TotCatch; t) is the total reported in the database, number of records used in the analysis (Records), reported catch (CatchT; t) in the area and depth used in the analysis and number of vessels used in the analysis (Vessels). GeoMean is the geometric mean of catch rates (kg/hr). The optimum model is Zone:Month and standard deviation (StDev) relates to the data in the optimum model.

| Year | TotCatch | Records | CatchT | Vessels | GeoMean | Zone:Month | StDev |
|---|---|---|---|---|---|---|---|
| 1986 | 982.8110 | 5044 | 686.1930 | 87 | 21.2727 | 1.9632 | 0.0000 |
| 1987 | 1087.6900 | 4266 | 858.4750 | 79 | 26.2295 | 2.3769 | 0.0293 |
| 1988 | 1483.5120 | 5146 | 1024.6560 | 79 | 27.6649 | 2.2351 | 0.0286 |
| 1989 | 1667.3730 | 4325 | 929.4090 | 65 | 27.9306 | 2.1179 | 0.0296 |
| 1990 | 1001.4140 | 4127 | 600.5530 | 59 | 21.9897 | 1.7850 | 0.0305 |
| 1991 | 1138.0700 | 4436 | 661.7960 | 55 | 19.4029 | 1.6456 | 0.0304 |
| 1992 | 758.2540 | 2871 | 380.1120 | 47 | 17.2369 | 1.3114 | 0.0341 |
| 1993 | 1014.9853 | 3362 | 464.9250 | 49 | 17.0150 | 1.3958 | 0.0329 |
| 1994 | 818.4180 | 4467 | 473.1680 | 49 | 16.1904 | 1.2159 | 0.0308 |
| 1995 | 789.5280 | 4600 | 435.2090 | 47 | 14.0323 | 1.1290 | 0.0305 |
| 1996 | 827.1910 | 6218 | 544.8280 | 51 | 12.3880 | 1.0229 | 0.0290 |
| 1997 | 1063.3630 | 6030 | 672.0670 | 53 | 14.8967 | 1.1311 | 0.0297 |
| 1998 | 876.4054 | 4790 | 435.7790 | 46 | 11.3605 | 0.9127 | 0.0307 |
| 1999 | 961.2618 | 4428 | 447.7570 | 50 | 11.3304 | 0.9174 | 0.0313 |
| 2000 | 945.0978 | 5627 | 478.2770 | 54 | 8.9093 | 0.7729 | 0.0299 |
| 2001 | 790.1902 | 4808 | 252.5370 | 47 | 5.8922 | 0.5272 | 0.0308 |
| 2002 | 811.1362 | 5718 | 329.1130 | 44 | 6.3693 | 0.5905 | 0.0302 |
| 2003 | 774.5778 | 4584 | 237.0400 | 47 | 5.3333 | 0.4709 | 0.0313 |
| 2004 | 765.5049 | 4196 | 220.2786 | 52 | 5.4124 | 0.4637 | 0.0321 |
| 2005 | 784.1607 | 4378 | 262.6155 | 39 | 6.8948 | 0.5659 | 0.0318 |
| 2006 | 811.2979 | 3417 | 275.5010 | 36 | 8.8173 | 0.6832 | 0.0335 |
| 2007 | 607.8702 | 2437 | 212.3727 | 20 | 9.2385 | 0.6520 | 0.0369 |
| 2008 | 700.4393 | 3167 | 321.5780 | 25 | 11.2739 | 0.8296 | 0.0348 |
| 2009 | 454.3668 | 2448 | 228.4745 | 19 | 10.4038 | 0.7600 | 0.0370 |
| 2010 | 380.0247 | 2589 | 193.6210 | 19 | 7.6365 | 0.5240 | 0.0367 |
| 2011 | 427.9796 | 2400 | 170.9440 | 18 | 7.4002 | 0.5114 | 0.0377 |
| 2012 | 395.5938 | 2166 | 175.1280 | 19 | 7.6279 | 0.5040 | 0.0383 |
| 2013 | 323.9461 | 1409 | 97.4370 | 15 | 6.8977 | 0.4174 | 0.0434 |
| 2014 | 216.4660 | 1516 | 75.9770 | 17 | 5.0266 | 0.3097 | 0.0422 |
| 2015 | 152.3598 | 1094 | 42.3390 | 20 | 3.9053 | 0.2578 | 0.0471 |

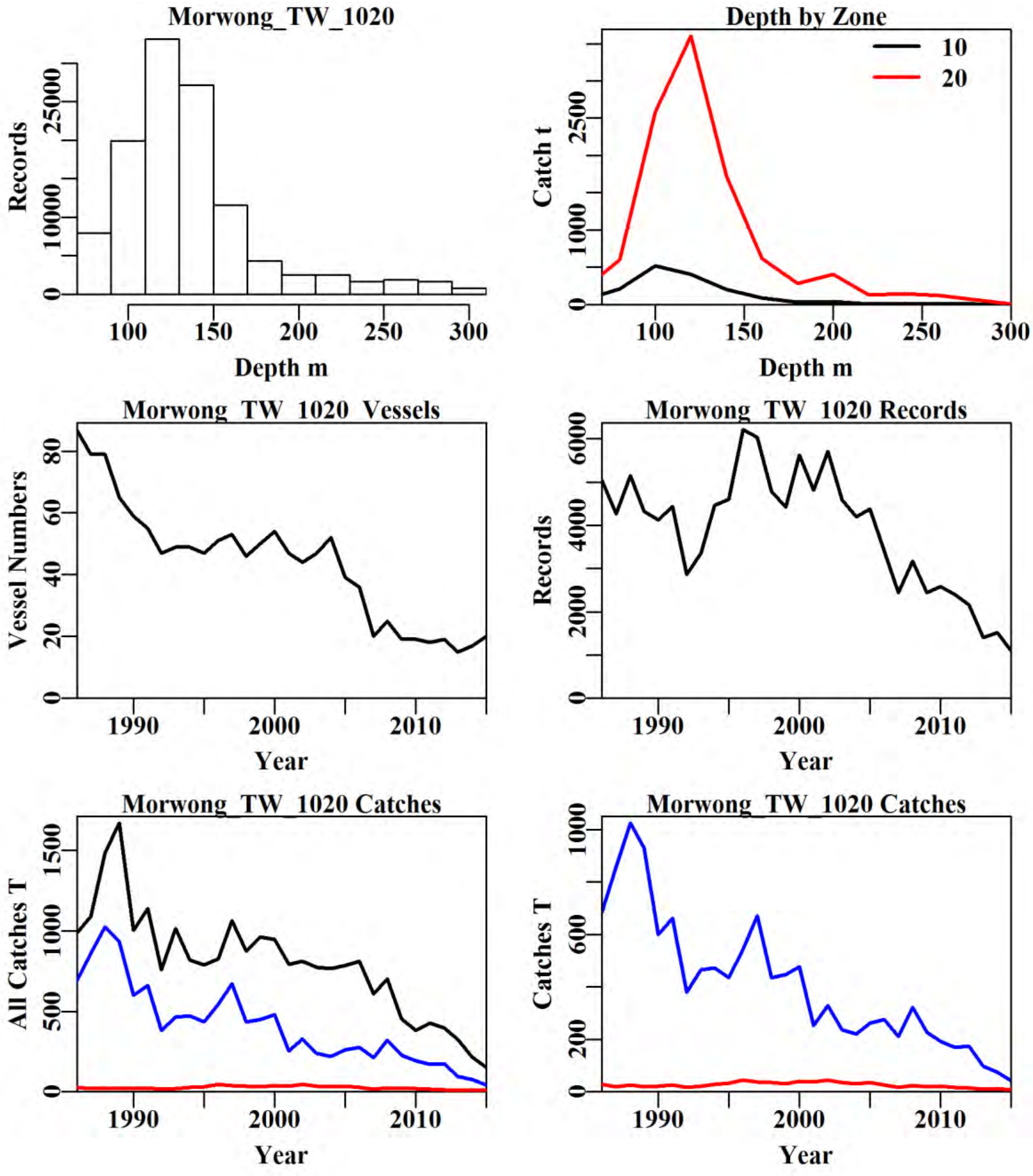



Figure 8.16. Jackass Morwong from zones 10 and 20 in depths 70 – 300 m by Trawl. The top left plot depicts the depth distribution of shots containing Jackass Morwong from zones 10 and 20 in depths 70 – 300 m by Trawl. The top right plot depicts the distribution of catch by depth within zones 10 and 20 (Zone 20 is the top red line). The middle left plot depicts the number of vessels through time. The middle right plot contains the number of records used in analysis. The bottom left plot contains Jackass Morwong catches (top black line: total catches, middle blue line: catches used in the analysis; bottom red line: catches < 30 kg) and bottom right plot contains Jackass Morwong catches (blue line: catches used in the analysis; red line: catches < 30 kg).

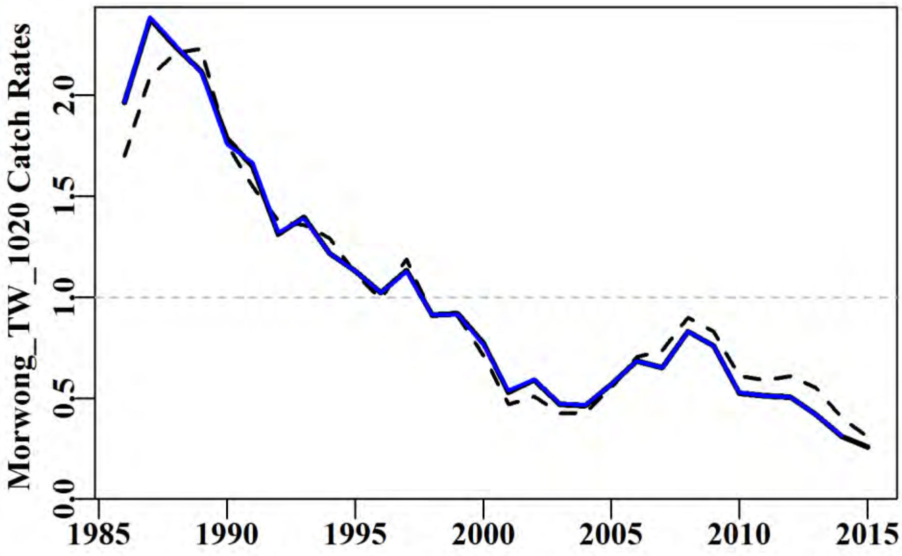



Figure 8.17. Jackass Morwong from zones 10 and 20 in depths 70 – 300 m by Trawl. The dashed black line represents the geometric mean catch rate and the solid black line the standardized catch rates. The graph standardizes catch rates relative to the mean of the standardized catch rates. The blue line is last year's optimum standardization.

Table 8.17. Jackass Morwong from zones 10 and 20 in depths 70 – 300 m by Trawl. Statistical model structures used in this analysis. DepCat is a series of 20 metre depth categories.

| | |
|---|---|
| Model 1 | LnCE ~ Year |
| Model 2 | LnCE ~ Year + Vessel |
| Model 3 | LnCE ~ Year + Vessel + Month |
| Model 4 | LnCE ~ Year + Vessel + Month + DepCat |
| Model 5 | LnCE ~ Year + Vessel + Month + DepCat + Zone |
| Model 6 | LnCE ~ Year + Vessel + Month + DepCat + Zone + DayNight |
| Model 7 | LnCE ~ Year + Vessel + Month + DepCat + Zone + DayNight + Zone:Month |
| Model 8 | LnCE ~ Year + Vessel + Month + DepCat + Zone + DayNight + Zone:DepCat |

Table 8.18. Jackass Morwong from zones 10 and 20 in depths 70 – 300 m by Trawl. Model selection criteria include the Akaike Information Criterion (AIC), residual sum of squares (RSS), model sum of squares (MSS), number of usable observations (Nobs), number of parameters (Npars), adjusted $R^2$ (adj_$R^2$) and the change in adjusted $R^2$ (%Change). The optimum model was Model 7 (Zone:Month). Depth category: DepC.

| | Year | Vessel | Month | DepC | Zone | DayNight | Zone:Month | Zone:DepC |
|---|---|---|---|---|---|---|---|---|
| AIC | 83954 | 69680 | 66650 | 64347 | 62497 | 61124 | 60209 | 60815 |
| RSS | 239121 | 210812 | 205341 | 200458 | 197258 | 194906 | 193325 | 194343 |
| MSS | 32307 | 60615 | 66086 | 70970 | 74170 | 76521 | 78102 | 77085 |
| Nobs | 116064 | 116064 | 116064 | 115026 | 115026 | 115026 | 115026 | 115026 |
| Npars | 30 | 205 | 216 | 228 | 229 | 232 | 243 | 244 |
| adj_$R^2$ | 11.880 | 22.195 | 24.207 | 26.001 | 27.182 | 28.048 | 28.624 | 28.248 |
| %Change | 0.000 | 10.315 | 2.012 | 1.794 | 1.181 | 0.866 | 0.577 | -0.376 |

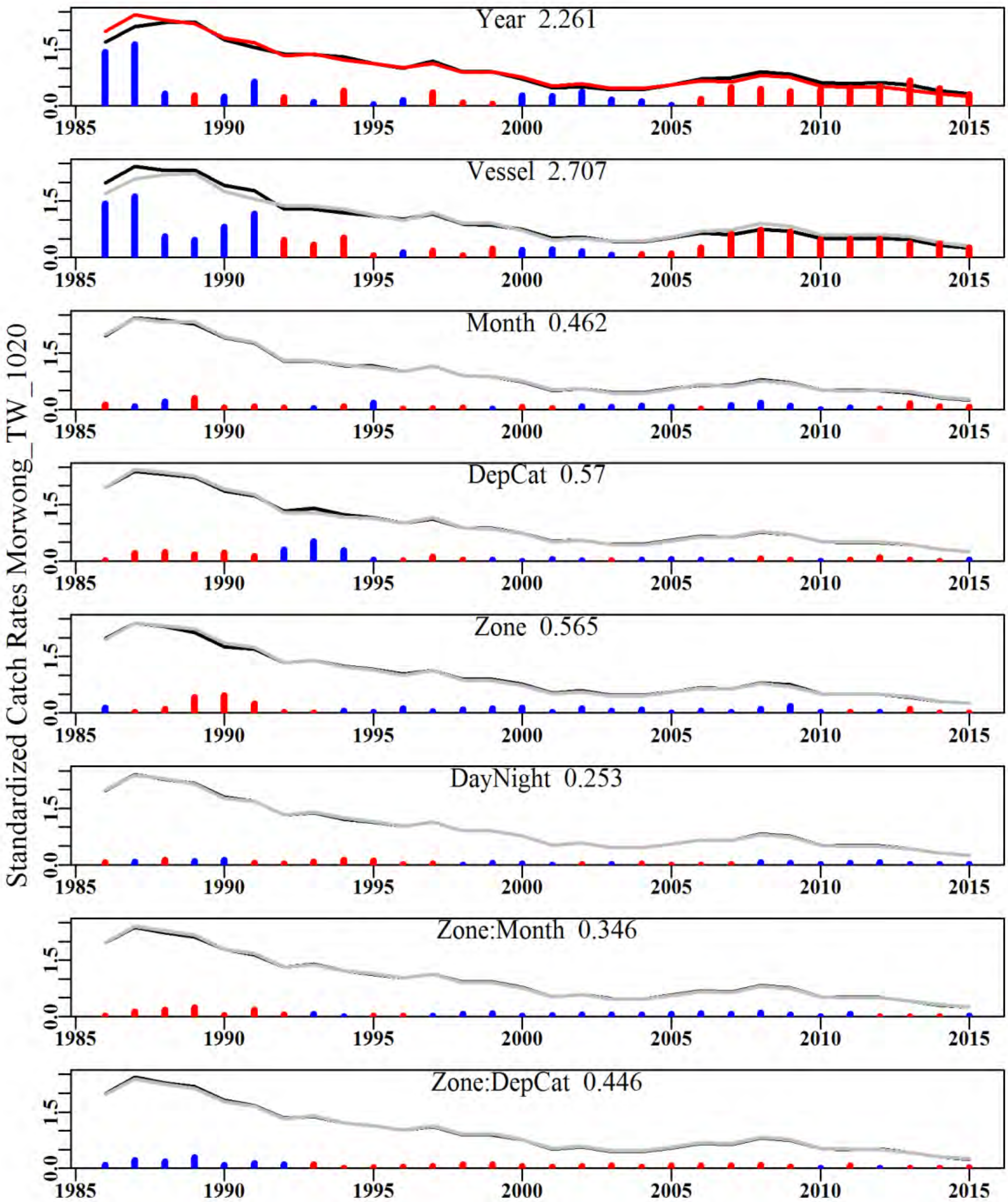



Figure 8.18. The relative influence of each factor used on the final trend in the optimal standardization for Jackass Morwong in Zones 10 – 20. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by the vertical bars with blue bars indicating the optimum model is higher than the geometric mean and red bars indicating it is lower. The top graph bars are the sum of all the bars in the graphs below. The graphs for individual factors are cumulative. Thus the second graph has the geometric mean (grey line) and the effect of adding Year + factor2 (Model 2). In the third graph, the grey line represents Model 2 and the black line the effect of adding factor3 to the model. The remaining graphs continue in the same cumulative manner except for the interaction terms which are added singularly to the final single factor model.

### 8.4.6 *Jackass Morwong Z30 (MOR – 37377003 – Nemadactylus macropterus)*

Trawl data selected for analysis corresponded to records from zone 30 and depths between 70 and 300 m.

Table 8.19. Jackass Morwong from zone 30 in depths 70 – 300 m by Trawl. Total catch (TotCatch; t) is the total reported in the database, number of records used in the analysis (Records), reported catch (CatchT; t) in the area and depth used in the analysis and number of vessels used in the analysis (Vessels). GeoMean is the geometric mean of catch rates (kg/hr). The optimum model is Month:DepC and standard deviation (StDev) relates to the data in the optimum model.

| Year | TotCatch | Records | CatchT | Vessels | GeoMean | Month:DepC | StDev |
|---|---|---|---|---|---|---|---|
| 1986 | 982.8110 | 69 | 29.8870 | 6 | 52.3193 | 1.8988 | 0.0000 |
| 1987 | 1087.6900 | 210 | 57.4760 | 13 | 45.8807 | 1.9294 | 0.1805 |
| 1988 | 1483.5120 | 283 | 207.9350 | 13 | 90.9064 | 2.7498 | 0.1752 |
| 1989 | 1667.3730 | 687 | 475.0390 | 19 | 125.0172 | 3.4424 | 0.1683 |
| 1990 | 1001.4140 | 386 | 148.8570 | 26 | 64.6762 | 2.4175 | 0.1691 |
| 1991 | 1138.0700 | 427 | 189.5340 | 29 | 68.3860 | 1.5604 | 0.1672 |
| 1992 | 758.2540 | 335 | 106.8190 | 18 | 50.3448 | 1.7238 | 0.1721 |
| 1993 | 1014.9853 | 1042 | 325.8730 | 27 | 49.6567 | 1.3671 | 0.1620 |
| 1994 | 818.4180 | 762 | 180.1850 | 22 | 40.3411 | 0.9234 | 0.1630 |
| 1995 | 789.5280 | 826 | 185.2820 | 19 | 36.4017 | 0.9086 | 0.1639 |
| 1996 | 827.1910 | 890 | 161.4020 | 19 | 29.4500 | 0.8890 | 0.1630 |
| 1997 | 1063.3630 | 940 | 202.3890 | 15 | 32.4284 | 1.0063 | 0.1624 |
| 1998 | 876.4054 | 772 | 191.7330 | 15 | 38.4649 | 0.9730 | 0.1631 |
| 1999 | 961.2618 | 855 | 246.9130 | 17 | 46.7614 | 1.1503 | 0.1635 |
| 2000 | 945.0978 | 552 | 123.7850 | 23 | 30.7755 | 0.7582 | 0.1654 |
| 2001 | 790.1902 | 812 | 110.7990 | 19 | 16.3003 | 0.5081 | 0.1623 |
| 2002 | 811.1362 | 1044 | 108.9440 | 15 | 13.9509 | 0.4329 | 0.1619 |
| 2003 | 774.5778 | 1126 | 187.0530 | 19 | 20.4814 | 0.5984 | 0.1609 |
| 2004 | 765.5049 | 1500 | 201.2780 | 15 | 18.1516 | 0.4516 | 0.1602 |
| 2005 | 784.1607 | 1159 | 137.7100 | 17 | 12.3142 | 0.3367 | 0.1614 |
| 2006 | 811.2979 | 1127 | 154.4820 | 14 | 17.6164 | 0.4225 | 0.1620 |
| 2007 | 607.8702 | 714 | 111.6250 | 8 | 22.5650 | 0.5866 | 0.1643 |
| 2008 | 700.4393 | 768 | 119.0200 | 9 | 24.1797 | 0.5998 | 0.1642 |
| 2009 | 454.3668 | 463 | 54.3427 | 10 | 16.5669 | 0.4325 | 0.1677 |
| 2010 | 380.0247 | 372 | 58.1890 | 9 | 19.1085 | 0.4532 | 0.1707 |
| 2011 | 427.9796 | 451 | 48.2553 | 8 | 12.0083 | 0.3034 | 0.1683 |
| 2012 | 395.5938 | 561 | 92.4940 | 7 | 16.4181 | 0.3981 | 0.1668 |
| 2013 | 323.9461 | 599 | 103.4190 | 10 | 17.1218 | 0.4417 | 0.1656 |
| 2014 | 216.4660 | 366 | 53.6290 | 9 | 8.6955 | 0.2064 | 0.1700 |
| 2015 | 152.3598 | 456 | 30.5960 | 11 | 5.6240 | 0.1302 | 0.1676 |

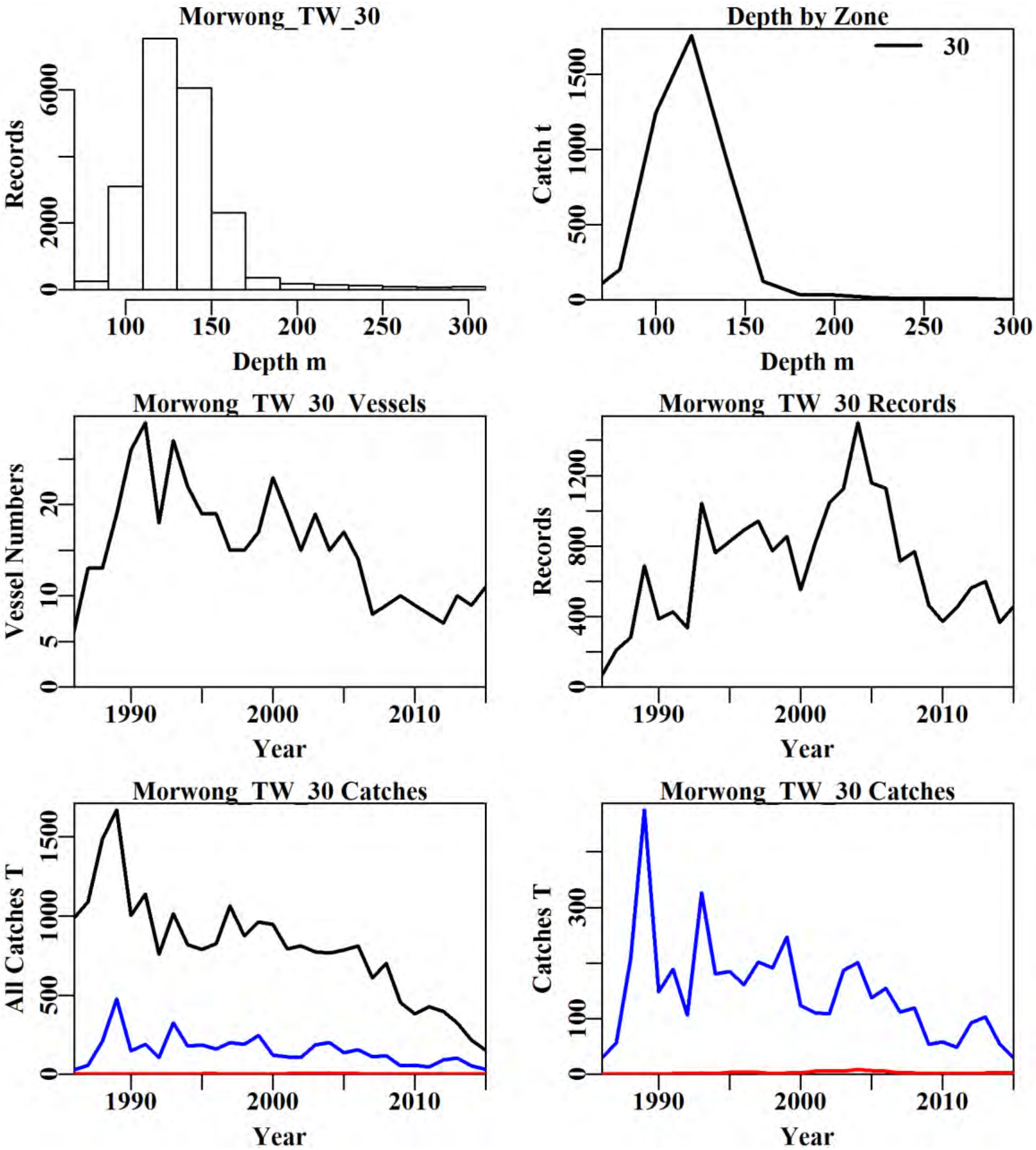



Figure 8.19. Jackass Morwong from zone 30 in depths 70 – 300 m by Trawl. The top left plot depicts the depth distribution of shots containing Jackass Morwong from zone 30 in depths 70 – 300 m by Trawl. The top right plot depicts the catch distribution by depth within zone 30. The middle left plot depicts the number of vessels through time and middle right plot contains the number of records used in analysis. The bottom left plot contains Jackass Morwong catches (top black line: total catches, middle blue line: catches used in the analysis; bottom red line: catches < 30 kg) and bottom right plot contains Jackass Morwong catches (blue line: catches used in the analysis; red line: catches < 30 kg).

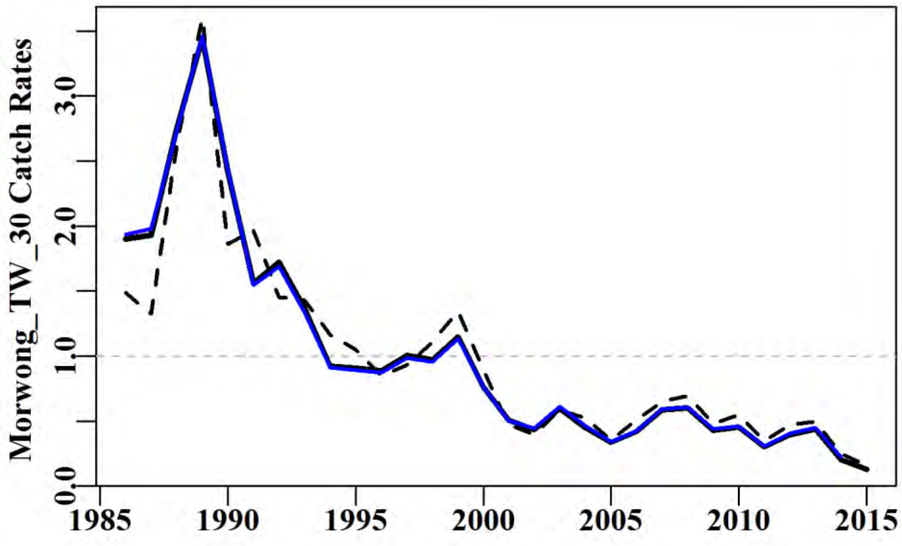



Figure 8.20. Jackass Morwong from zone 30 in depths 70 – 300 m by Trawl. The dashed black line represents the geometric mean catch rate and the solid black line the standardized catch rates (relative to the mean of the standardized catch rates). The blue line is last year's optimum standardization.

Table 8.20. Jackass Morwong from zone 30 in depths 70 – 300 m by Trawl. Statistical model structures used in this analysis. DepCat is a series of 20 metre depth categories.

| | |
|---|---|
| Model 1 | LnCE ~ Year |
| Model 2 | LnCE ~ Year + Month |
| Model 3 | LnCE ~ Year + Month + Vessel |
| Model 4 | LnCE ~ Year + Month + Vessel+ DepCat |
| Model 5 | LnCE ~ Year + Month + Vessel+ DepCat + DayNight |
| Model 6 | LnCE ~ Year + Month + Vessel+ DepCat + DayNight + DayNight:Month |
| Model 7 | LnCE ~ Year + Month + Vessel+ DepCat + DayNight + Month:DepCat |
| Model 8 | LnCE ~ Year + Month + Vessel+ DepCat + DayNight + DayNight:DepCat |

Table 8.21. Jackass Morwong from zone 30 in depths 70 – 300 m by Trawl. Model selection criteria include the Akaike Information Criterion (AIC), residual sum of squares (RSS), model sum of squares (MSS), number of usable observations (Nobs), number of parameters (Npars), adjusted $R^2$ (adj_$R^2$) and the change in adjusted $R^2$ (%Change). The optimum was model was Model 7 (Month:DepC). Depth category: DepC; DayNight: DN.

| | Year | Month | Vessel | DepC | DN | DN:Month | Month:DepC | DN:DepC |
|---|---|---|---|---|---|---|---|---|
| AIC | 11098 | 9238 | 8024 | 7327 | 7108 | 7070 | 7008 | 7138 |
| RSS | 35166 | 32089 | 29977 | 28709 | 28392 | 28248 | 27888 | 28334 |
| MSS | 8064 | 11141 | 13253 | 14521 | 14838 | 14982 | 15342 | 14896 |
| Nobs | 20554 | 20554 | 20554 | 20301 | 20301 | 20301 | 20301 | 20301 |
| Npars | 30 | 41 | 134 | 146 | 149 | 182 | 281 | 185 |
| adj_$R^2$ | 18.540 | 25.626 | 30.206 | 33.111 | 33.840 | 34.069 | 34.587 | 33.857 |
| %Change | 0.000 | 7.087 | 4.580 | 2.905 | 0.729 | 0.229 | 0.518 | -0.730 |

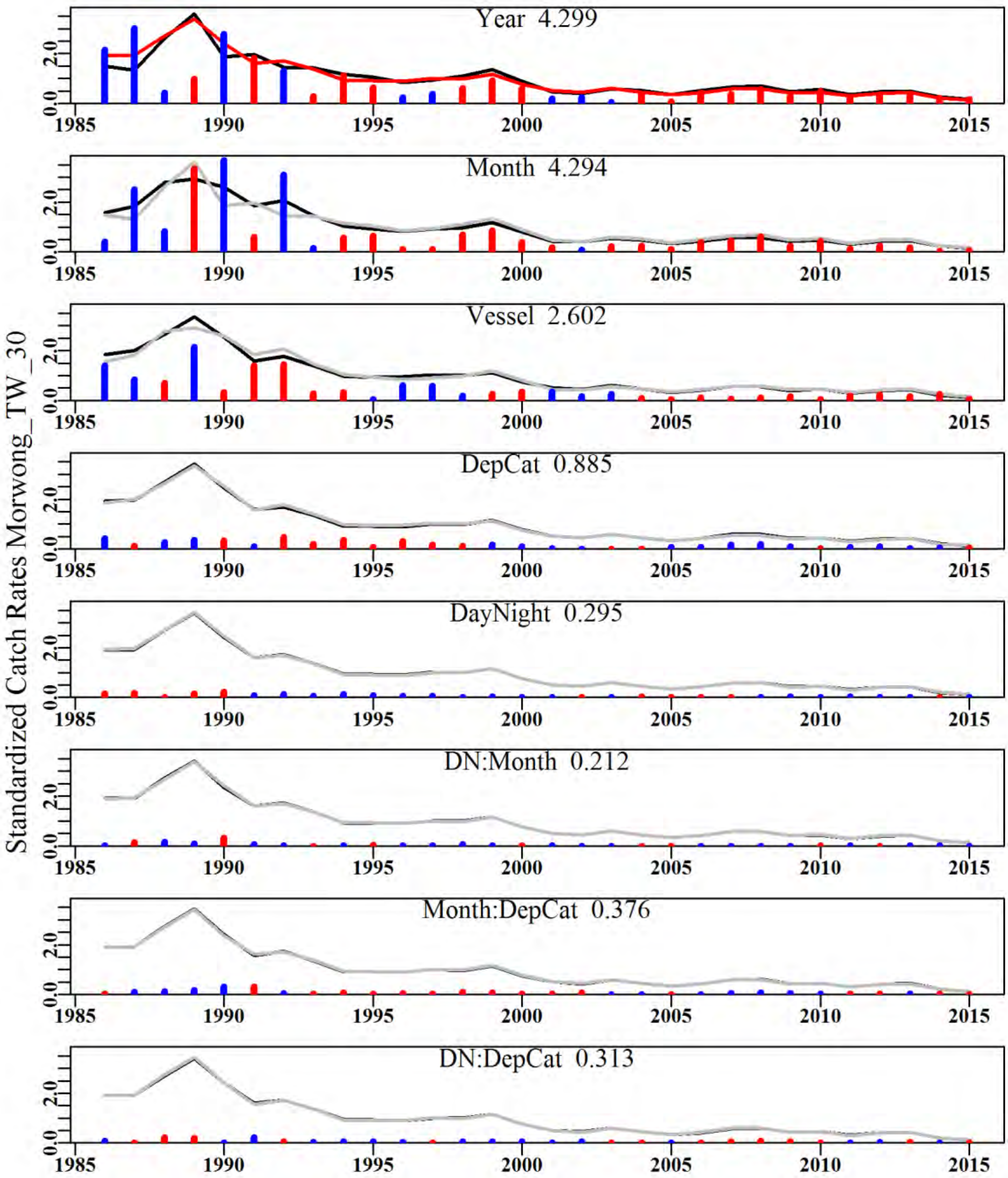



Figure 8.21. The relative influence of each factor used on the final trend in the optimal standardization for Jackass Morwong in zone 30. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by the vertical bars with blue bars indicating the optimum model is higher than the geometric mean and red bars indicating it is lower. The top graph bars are the sum of all the bars in the graphs below. The graphs for individual factors are cumulative. Thus the second graph has the geometric mean (grey line) and the effect of adding Year + factor2 (Model 2). In the third graph, the grey line represents Model 2 and the black line the effect of adding factor3 to the model. The remaining graphs continue in the same cumulative manner except for the interaction terms which are added singularly to the final single factor model.

### 8.4.7 *Jackass Morwong Z4050 (MOR – 3737700 – N. macropterus 70-360 m)*

Data selected for analysis corresponded to records from zones 40 and 50 and depths between 70 and 360 m.

Table 8.22. Jackass Morwong from zones 40 and 50 in depths 70 – 360 m by Trawl. Total catch (TotCatch; t) is the total reported in the database, number of records used in the analysis (Records), reported catch (CatchT; t) in the area and depth used in the analysis and number of vessels used in the analysis (Vessels). GeoMean is the geometric mean of catch rates (kg/hr). The optimum model is Zone:Month and standard deviation (StDev) relates to the data in the optimum model.

| Year | TotCatch | Records | CatchT | Vessels | GeoMean | Zone:Month | StDev |
|---|---|---|---|---|---|---|---|
| 1986 | 982.8110 | 551 | 149.2610 | 19 | 40.7569 | 1.9980 | 0.0000 |
| 1987 | 1087.6900 | 350 | 58.4640 | 21 | 24.4475 | 1.5678 | 0.0867 |
| 1988 | 1483.5120 | 402 | 65.4440 | 19 | 32.2567 | 2.3425 | 0.0871 |
| 1989 | 1667.3730 | 346 | 83.2030 | 21 | 32.2213 | 1.6876 | 0.0916 |
| 1990 | 1001.4140 | 412 | 80.6570 | 22 | 28.9610 | 1.7091 | 0.0931 |
| 1991 | 1138.0700 | 281 | 40.3800 | 26 | 18.6097 | 1.1598 | 0.0974 |
| 1992 | 758.2540 | 252 | 28.8780 | 14 | 15.3915 | 0.9410 | 0.1002 |
| 1993 | 1014.9853 | 248 | 24.9710 | 17 | 15.5454 | 0.9021 | 0.1014 |
| 1994 | 818.4180 | 312 | 22.6790 | 16 | 14.6606 | 0.8843 | 0.0945 |
| 1995 | 789.5280 | 295 | 77.6150 | 17 | 21.5262 | 0.9299 | 0.0955 |
| 1996 | 827.1910 | 346 | 37.0710 | 17 | 15.3414 | 1.0295 | 0.0928 |
| 1997 | 1063.3630 | 489 | 53.8510 | 20 | 12.8371 | 0.8212 | 0.0862 |
| 1998 | 876.4054 | 267 | 54.6300 | 19 | 14.8359 | 0.8636 | 0.0982 |
| 1999 | 961.2618 | 383 | 77.2350 | 17 | 15.5951 | 0.7780 | 0.0909 |
| 2000 | 945.0978 | 430 | 118.9080 | 26 | 22.5459 | 1.1328 | 0.0909 |
| 2001 | 790.1902 | 920 | 276.7930 | 25 | 34.4490 | 1.2353 | 0.0800 |
| 2002 | 811.1362 | 860 | 251.7490 | 22 | 33.1596 | 1.2427 | 0.0802 |
| 2003 | 774.5778 | 655 | 171.7260 | 24 | 30.9832 | 1.0439 | 0.0836 |
| 2004 | 765.5049 | 681 | 176.6765 | 25 | 30.6678 | 1.0926 | 0.0827 |
| 2005 | 784.1607 | 722 | 190.7030 | 21 | 28.0502 | 1.1867 | 0.0821 |
| 2006 | 811.2979 | 818 | 183.2035 | 19 | 21.6176 | 0.9490 | 0.0811 |
| 2007 | 607.8702 | 594 | 115.4050 | 15 | 19.7196 | 0.7851 | 0.0840 |
| 2008 | 700.4393 | 473 | 101.9450 | 16 | 24.9533 | 0.7890 | 0.0873 |
| 2009 | 454.3668 | 413 | 59.1540 | 13 | 14.8023 | 0.6242 | 0.0901 |
| 2010 | 380.0247 | 410 | 38.3110 | 13 | 10.0420 | 0.4625 | 0.0898 |
| 2011 | 427.9796 | 622 | 82.8770 | 14 | 12.6506 | 0.4884 | 0.0845 |
| 2012 | 395.5938 | 345 | 34.7220 | 14 | 10.2040 | 0.3640 | 0.0933 |
| 2013 | 323.9461 | 466 | 36.1660 | 13 | 8.0350 | 0.3492 | 0.0889 |
| 2014 | 216.4660 | 252 | 10.1490 | 13 | 5.2197 | 0.2802 | 0.1008 |
| 2015 | 152.3598 | 155 | 7.0190 | 9 | 5.4323 | 0.3599 | 0.1157 |

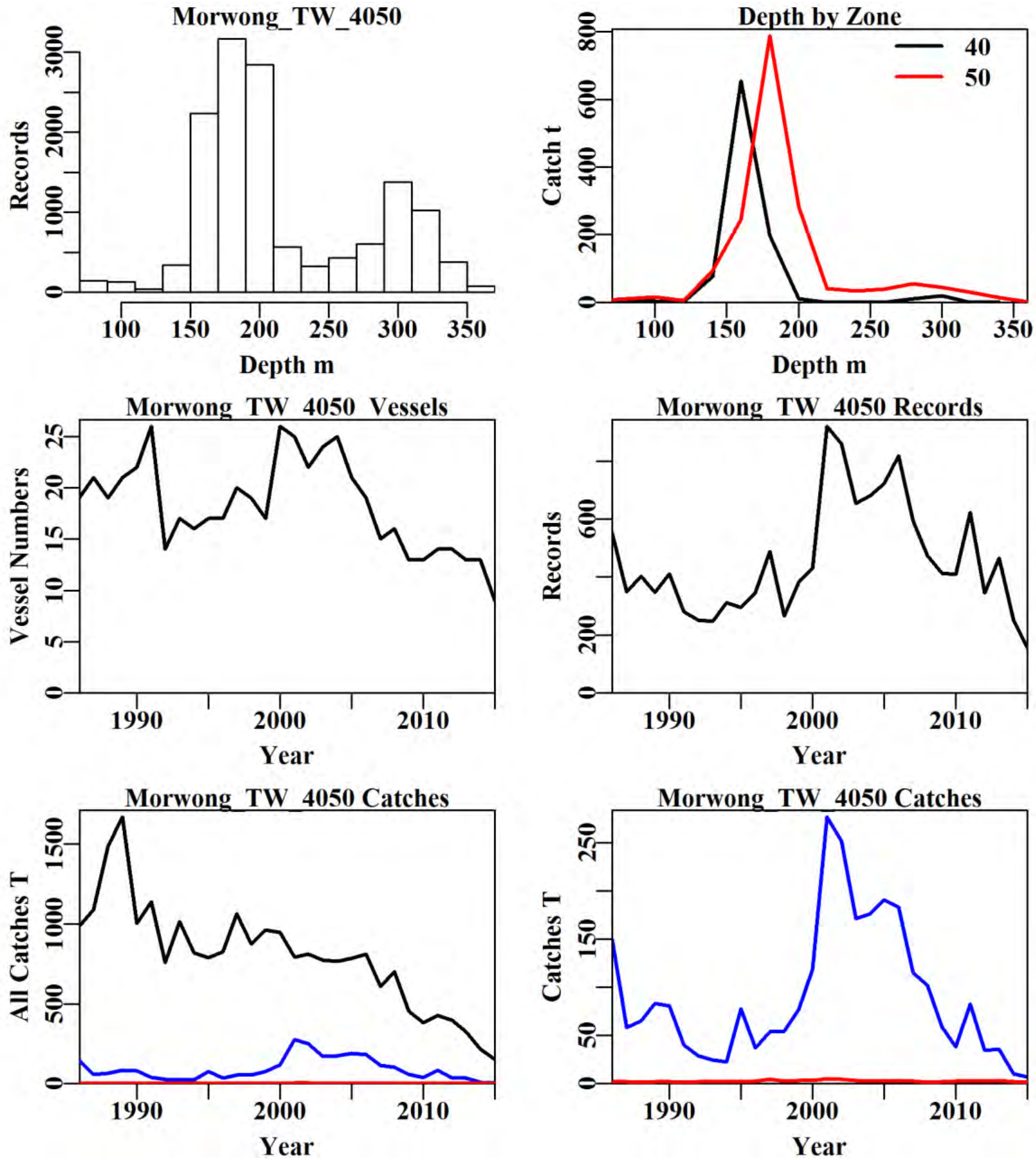



Figure 8.22. Jackass Morwong from zones 40 and 50 in depths 70 – 360 m by Trawl. The top left plot depicts the depth distribution of shots containing Jackass Morwong from zones 40 and 50 in depths 70 – 360 m by Trawl. The top right plot depicts the catch distribution by depth within zones 40 and 50. The middle left plot depicts the number of vessels through time and middle right plot contains the number of records used in analysis. The bottom left plot contains Jackass Morwong catches (top black line: total catches, middle blue line: catches used in the analysis; bottom red line: catches < 30 kg) and bottom right plot contains Jackass Morwong catches (blue line: catches used in the analysis; red line: catches < 30 kg).

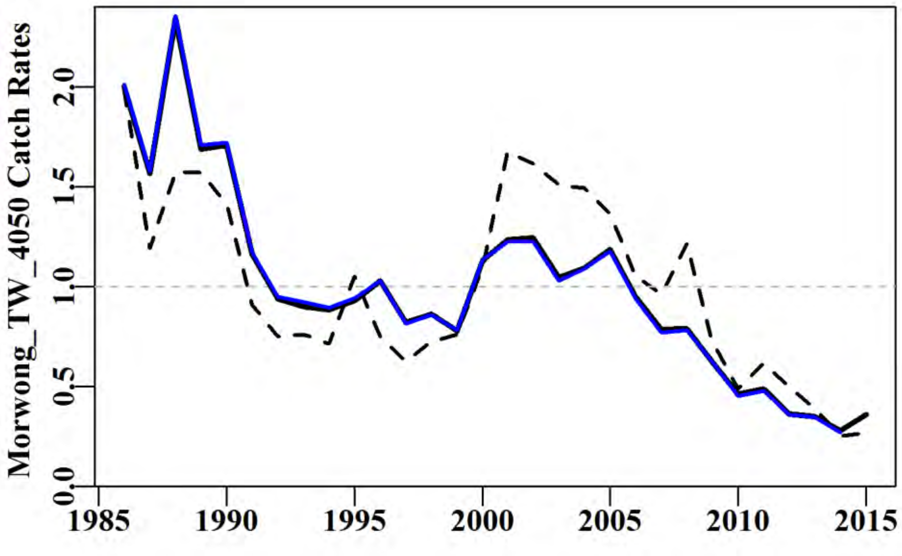



Figure 8.23. Jackass Morwong from zones 40 and 50 in depths 70 – 360 m by Trawl. The dashed black line represents the geometric mean catch rate and the solid black line the standardized catch rates. The graph standardizes catch rates relative to the mean of the standardized catch rates. The blue line is last year's optimum standardization.

Table 8.23. Jackass Morwong from zones 40 and 50 in depths 70 – 360 m by Trawl. Statistical model structures used in this analysis. DepCat is a series of 20 metre depth categories.

| | |
|---|---|
| Model 1 | LnCE~Year |
| Model 2 | LnCE~Year+DepCat |
| Model 3 | LnCE~Year+DepCat+Month |
| Model 4 | LnCE~Year+DepCat+Month+Vessel |
| Model 5 | LnCE~Year+DepCat+Month+Vessel+DayNight |
| Model 6 | LnCE~Year+DepCat+Month+Vessel+DayNight+Zone |
| Model 7 | LnCE~Year+DepCat+Month+Vessel+DayNight+Zone+Zone:Month |
| Model 8 | LnCE~Year+DepCat+Month+Vessel+DayNight+Zone+Zone:DepCat |

Table 8.24. Jackass Morwong from zones 40 and 50 in depths 70 – 360 m by Trawl. Model selection criteria include the Akaike Information Criterion (AIC), residual sum of squares (RSS), model sum of squares (MSS), number of usable observations (Nobs), number of parameters (Npars), adjusted $R^2$ (adj_$R^2$) and the change in adjusted $R^2$ (%Change). The optimum was Model 7 (Zone:Month). Depth category: DepC.

| | Year | DepC | Month | Vessel | DayNight | Zone | Zone:Month | Zone:DepC |
|---|---|---|---|---|---|---|---|---|
| AIC | 8029 | 5693 | 4512 | 3882 | 3754 | 3617 | 3471 | 3525 |
| RSS | 24547 | 20577 | 18842 | 17767 | 17594 | 17415 | 17201 | 17260 |
| MSS | 3229 | 7199 | 8934 | 10010 | 10183 | 10361 | 10575 | 10516 |
| Nobs | 13750 | 13650 | 13650 | 13650 | 13650 | 13650 | 13650 | 13650 |
| Npars | 30 | 45 | 56 | 142 | 145 | 146 | 157 | 161 |
| adj_$R^2$ | 11.438 | 25.678 | 31.891 | 35.368 | 35.984 | 36.628 | 37.356 | 37.124 |
| %Change | 0.000 | 14.239 | 6.213 | 3.477 | 0.615 | 0.644 | 0.728 | -0.232 |

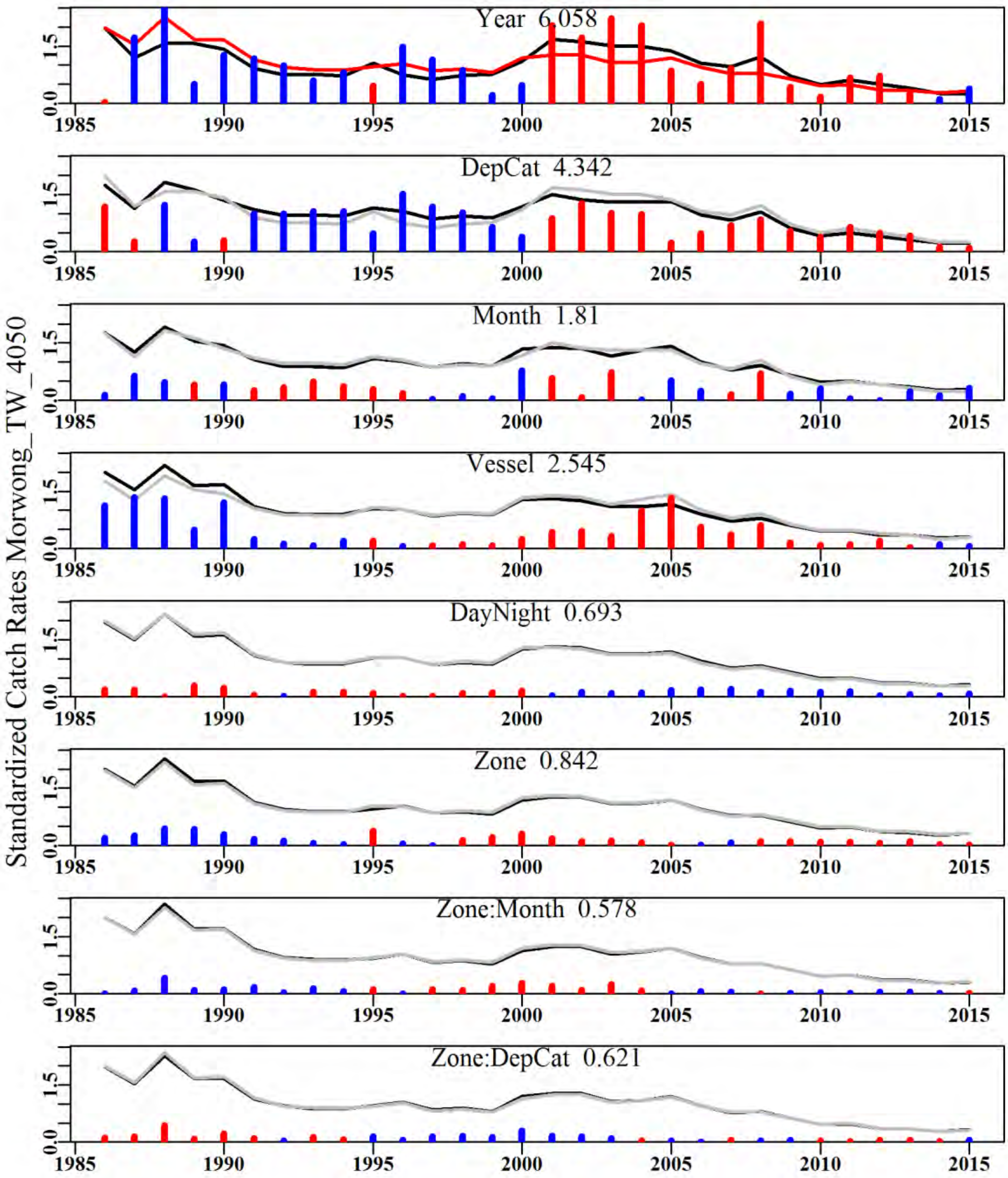



Figure 8.24. The relative influence of each factor used on the final trend in the optimal standardization for Jackass Morwong in zones 40 and 50. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by the vertical bars with blue bars indicating the optimum model is higher than the geometric mean and red bars indicating it is lower. The top graph bars are the sum of all the bars in the graphs below. The graphs for individual factors are cumulative. Thus the second graph has the geometric mean (grey line) and the effect of adding Year + factor2 (Model 2). In the third graph, the grey line represents Model 2 and the black line the effect of adding factor3 to the model. The remaining graphs continue in the same cumulative manner except for the interaction terms which are added singularly to the final single factor model.

### 8.4.8 *Flathead Trawl (FLT – 37296001 and 37296000 – Neoplatycephalus richardsoni and Platycephalidae)*

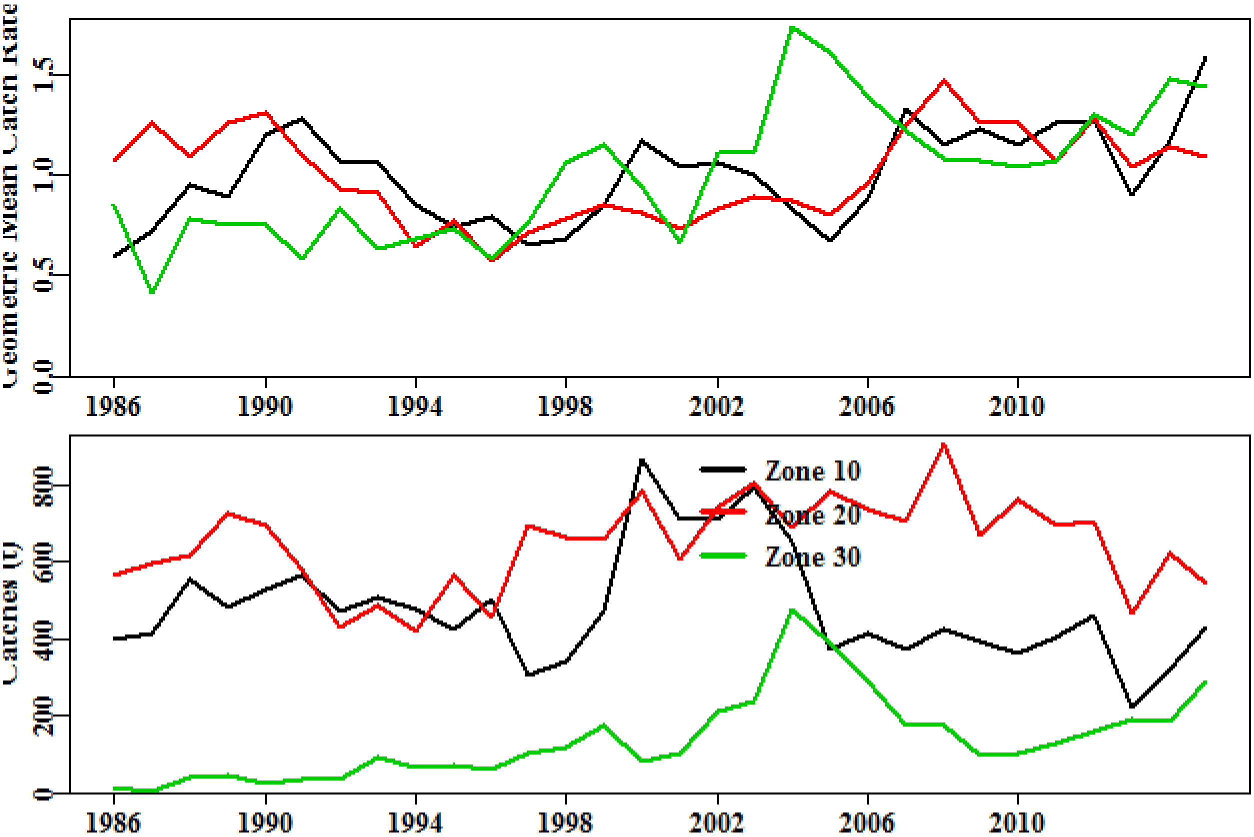



Figure 8.25. The trends in catches and geometric mean catch rates for flathead taken by Trawl in zones 10 to 30. The catch rate trends in 10 and 20 are similar to each other but are different from that expressed in zone 30. For this reason, zones 10 and 20 are standardized separately from Zone 30.

### 8.4.9 *Flathead Trawl Z1020 (FLT – 37296001 and 37296000 – Neoplatycephalus richardsoni and Platycephalidae)*

Trawl data selected for analysis corresponded to records from zones 10 and 20 and depths less than 400 m. The family group code 37296000 was included in this analysis as tiger flathead has been recorded as both 37296001 and 37296000 from electronic logbooks.

Table 8.25. Flathead from zones 10 and 20 in depths 0 – 400 m by Trawl. Total catch (TotCatch; t) is the total reported in the database, number of records used in the analysis (Records), reported catch (CatchT; t) in the area and depth used in the analysis and number of vessels used in the analysis (Vessels). GeoMean is the geometric mean of catch rates (kg/hr). The optimum model is Zone:DepC and standard deviation (StDev) relates to the data in the optimum model.

| Year | TotCatch | Records | CatchT | Vessels | GeoMean | Zone:DepC | StDev |
|---|---|---|---|---|---|---|---|
| 1986 | 1911.4140 | 10507 | 968.7960 | 95 | 30.9411 | 0.7877 | 0.0000 |
| 1987 | 2471.7310 | 8360 | 1011.4140 | 88 | 40.7456 | 1.0463 | 0.0157 |
| 1988 | 2482.7610 | 9471 | 1176.9760 | 86 | 41.1818 | 1.1251 | 0.0155 |
| 1989 | 2609.0370 | 9154 | 1214.6890 | 74 | 43.5936 | 1.1337 | 0.0156 |
| 1990 | 2041.6530 | 7883 | 1224.4950 | 64 | 51.7660 | 1.3771 | 0.0164 |
| 1991 | 2236.1810 | 7926 | 1147.2150 | 57 | 51.4599 | 1.2851 | 0.0166 |
| 1992 | 2377.3580 | 6961 | 905.0140 | 54 | 43.8529 | 1.0215 | 0.0173 |
| 1993 | 1881.0370 | 8816 | 994.1750 | 57 | 38.6305 | 1.0317 | 0.0164 |
| 1994 | 1710.8930 | 10254 | 900.2990 | 55 | 29.9070 | 0.7564 | 0.0158 |
| 1995 | 1805.8140 | 10286 | 990.8940 | 54 | 31.6202 | 0.7945 | 0.0158 |
| 1996 | 1880.1650 | 11070 | 957.3650 | 59 | 29.2083 | 0.7093 | 0.0156 |
| 1997 | 2356.2450 | 10396 | 996.6780 | 61 | 31.0897 | 0.7080 | 0.0160 |
| 1998 | 2306.6670 | 9995 | 999.6910 | 52 | 32.5302 | 0.7531 | 0.0160 |
| 1999 | 3118.6710 | 10398 | 1129.6700 | 57 | 36.2399 | 0.9077 | 0.0158 |
| 2000 | 2947.7940 | 12945 | 1646.2780 | 59 | 51.7059 | 0.9992 | 0.0153 |
| 2001 | 2600.5370 | 11733 | 1316.4230 | 52 | 39.6288 | 0.9655 | 0.0155 |
| 2002 | 2876.8260 | 12421 | 1451.9000 | 49 | 39.2389 | 1.0556 | 0.0155 |
| 2003 | 3232.3520 | 12952 | 1595.7950 | 52 | 41.3288 | 1.0394 | 0.0153 |
| 2004 | 3227.3880 | 12296 | 1344.3095 | 52 | 36.2381 | 0.9038 | 0.0155 |
| 2005 | 2846.7890 | 10729 | 1155.9940 | 49 | 34.1559 | 0.7814 | 0.0159 |
| 2006 | 2586.0240 | 9140 | 1148.9090 | 46 | 40.2812 | 0.9421 | 0.0164 |
| 2007 | 2648.3710 | 6336 | 1076.4633 | 25 | 55.0735 | 1.1485 | 0.0181 |
| 2008 | 2913.1230 | 7300 | 1330.8200 | 27 | 56.4532 | 1.2151 | 0.0175 |
| 2009 | 2460.8730 | 6311 | 1060.7127 | 26 | 51.5876 | 1.1181 | 0.0182 |
| 2010 | 2502.3350 | 6876 | 1124.3520 | 25 | 49.0289 | 1.0767 | 0.0178 |
| 2011 | 2466.5740 | 6777 | 1096.4995 | 24 | 52.0010 | 1.0592 | 0.0179 |
| 2012 | 2780.8310 | 6887 | 1162.4942 | 24 | 54.3703 | 1.1652 | 0.0178 |
| 2013 | 1941.1480 | 5643 | 689.4606 | 24 | 37.4147 | 0.8862 | 0.0186 |
| 2014 | 2370.0560 | 6361 | 945.9275 | 25 | 45.9575 | 1.0355 | 0.0180 |
| 2015 | 2667.8090 | 6387 | 987.6740 | 31 | 48.3417 | 1.1716 | 0.0181 |

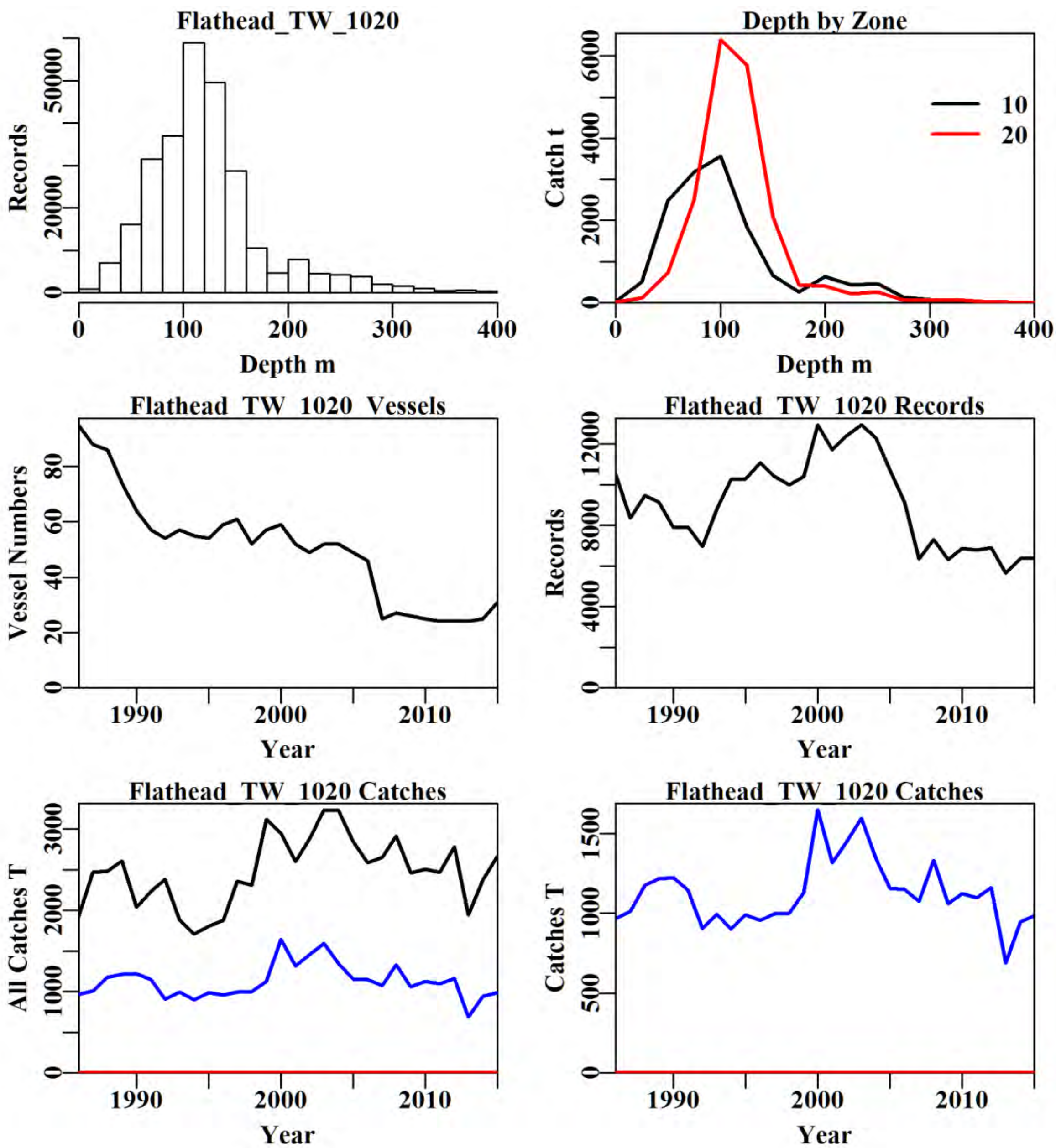



Figure 8.26. Flathead from zones 10 and 20 in depths 0 – 400 m by Trawl. The top left plot depicts the depth distribution of shots containing Flathead from zones 10 and 20 in depths 0 – 400 m by Trawl. The top right plot depicts the catch distribution by depth from zones 10 and 20 (top red line: zone 20). The middle left plot depicts the number of vessels through time and middle right plot contains the number of records used in analysis. The bottom left plot contains Flathead catches (top black line: total catches, middle blue line: catches used in the analysis; bottom red line: catches < 30 kg) and bottom right plot contains Flathead catches (blue line: catches used in the analysis; red line: catches < 30 kg).

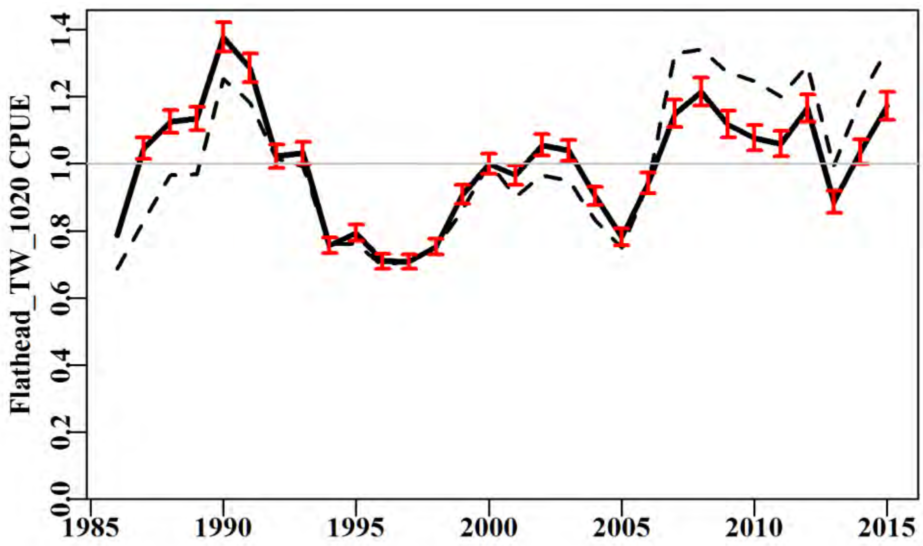



Figure 8.27. Flathead from zones 10 and 20 in depths 0 – 400m by Trawl. Standardized catch rates (solid black line), 95% CI (vertical lines) and geometric mean (dashed black line).

Table 8.26. Flathead from zones 10 and 20 in depths 0 – 400 m by Trawl. Statistical model structures used in this analysis. DepCat is a series of 20 metre depth categories.

| | |
|---|---|
| Model 1 | LnCE~Year |
| Model 2 | LnCE~Year+Vessel |
| Model 3 | LnCE~Year+Vessel+DepCat |
| Model 4 | LnCE~Year+Vessel+DepCat+Month |
| Model 5 | LnCE~Year+Vessel+DepCat+Month+DayNight |
| Model 6 | LnCE~Year+Vessel+DepCat+Month+DayNight+Zone |
| Model 7 | LnCE~Year+Vessel+DepCat+Month+DayNight+Zone+Zone:Month |
| Model 8 | LnCE~Year+Vessel+DepCat+Month+DayNight+Zone+Zone:DepCat |

Table 8.27. Flathead from zones 10 and 20 in depths 0 – 400 m by Trawl. Model selection criteria include the Akaike Information Criterion (AIC), residual sum of squares (RSS), model sum of squares (MSS), number of usable observations (Nobs), number of parameters (Npars), adjusted $R^2$ (adj_$R^2$) and the change in adjusted $R^2$ (%Change). The optimum model was Model 8 (Zone:DepC) Depth category: DepC.

| | Year | Vessel | DepC | Month | DayNight | Zone | Zone:Month | Zone:DepC |
|---|---|---|---|---|---|---|---|---|
| AIC | 46185 | 15833 | 7325 | 6421 | 6078 | 6008 | 3829 | 3079 |
| RSS | 322828 | 288415 | 277379 | 276431 | 276074 | 276000 | 273763 | 272995 |
| MSS | 11475 | 45888 | 56925 | 57873 | 58229 | 58303 | 60540 | 61308 |
| Nobs | 272571 | 272571 | 270430 | 270430 | 270430 | 270430 | 270430 | 270430 |
| Npars | 30 | 216 | 232 | 243 | 246 | 247 | 258 | 263 |
| adj_$R^2$ | 3.422 | 13.658 | 16.957 | 17.237 | 17.343 | 17.365 | 18.031 | 18.260 |
| %Change | 0.000 | 10.236 | 3.298 | 0.280 | 0.106 | 0.022 | 0.667 | 0.228 |

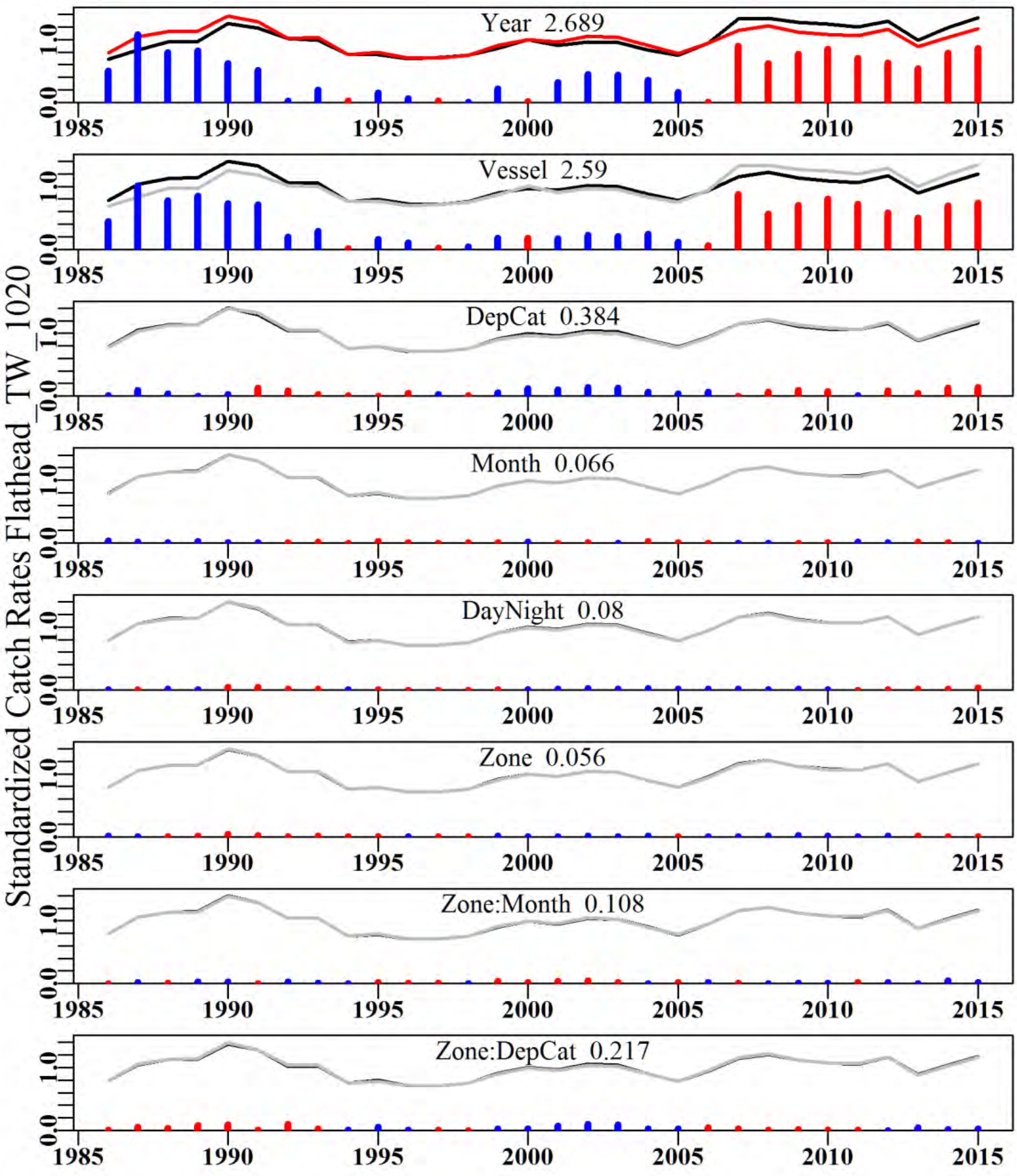



Figure 8.28. The relative influence of each factor used on the final trend in the optimal standardization for Flathead in zones 10 and 20. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by the vertical bars with blue bars indicating the optimum model is higher than the geometric mean and red bars indicating it is lower. The top graph bars are the sum of all the bars in the graphs below. The graphs for individual factors are cumulative. Thus the second graph has the geometric mean (grey line) and the effect of adding Year + factor2 (Model 2). In the third graph, the grey line represents Model 2 and the black line the effect of adding factor3 to the model. The remaining graphs continue in the same cumulative manner except for the interaction terms which are added singularly to the final single factor model.

### 8.4.10 *Flathead Trawl Z30 (FLT – 37296001 and 37296000 – Neoplatycephalus richardsoni and Platycephalidae)*

Data selected for analysis corresponded to records from zone 30 and depths less than 400 m.

Table 8.28. Flathead from zone 30 in depths 0 – 400 m by Trawl. Total catch (TotCatch; t) is the total reported in the database, number of records used in the analysis (Records), reported catch (CatchT; t) in the area and depth used in the analysis and number of vessels used in the analysis (Vessels). GeoMean is the geometric mean of catch rates (kg/hr). The optimum model is Month:DepC and standard deviation (StDev) relates to the data in the optimum model.

| Year | TotCatch | Records | CatchT | Vessels | GeoMean | Month:DepC | StDev |
|---|---|---|---|---|---|---|---|
| 1986 | 1911.4140 | 71 | 16.7540 | 6 | 65.6462 | 0.9491 | 0.0000 |
| 1987 | 2471.7310 | 90 | 5.1550 | 9 | 18.2409 | 0.6198 | 0.1888 |
| 1988 | 2482.7610 | 200 | 40.2560 | 9 | 50.5790 | 0.9453 | 0.1693 |
| 1989 | 2609.0370 | 517 | 48.4730 | 19 | 29.3197 | 0.6935 | 0.1627 |
| 1990 | 2041.6530 | 253 | 24.6190 | 27 | 34.8979 | 0.7211 | 0.1648 |
| 1991 | 2236.1810 | 316 | 33.4130 | 29 | 28.3326 | 0.7154 | 0.1602 |
| 1992 | 2377.3580 | 272 | 33.8970 | 15 | 37.5785 | 0.6389 | 0.1648 |
| 1993 | 1881.0370 | 902 | 92.0790 | 24 | 30.3152 | 0.6095 | 0.1562 |
| 1994 | 1710.8930 | 612 | 64.4870 | 17 | 31.6721 | 0.6493 | 0.1573 |
| 1995 | 1805.8140 | 694 | 71.3490 | 17 | 31.3923 | 0.6922 | 0.1575 |
| 1996 | 1880.1650 | 714 | 61.4250 | 17 | 26.6946 | 0.6303 | 0.1573 |
| 1997 | 2356.2450 | 885 | 104.8750 | 14 | 42.7214 | 0.8179 | 0.1562 |
| 1998 | 2306.6670 | 707 | 118.5520 | 14 | 55.5228 | 0.9458 | 0.1567 |
| 1999 | 3118.6710 | 770 | 175.0520 | 17 | 68.3373 | 1.0199 | 0.1569 |
| 2000 | 2947.7940 | 520 | 83.6640 | 21 | 50.0166 | 0.8539 | 0.1581 |
| 2001 | 2600.5370 | 934 | 102.7490 | 17 | 31.5441 | 0.7411 | 0.1551 |
| 2002 | 2876.8260 | 1367 | 212.1580 | 15 | 46.7614 | 1.3840 | 0.1542 |
| 2003 | 3232.3520 | 1454 | 240.1100 | 21 | 47.4346 | 1.4364 | 0.1536 |
| 2004 | 3227.3880 | 1923 | 477.4160 | 15 | 80.1510 | 1.8854 | 0.1532 |
| 2005 | 2846.7890 | 1540 | 388.3250 | 18 | 77.1294 | 1.6647 | 0.1537 |
| 2006 | 2586.0240 | 1315 | 287.9680 | 13 | 60.1538 | 1.3593 | 0.1546 |
| 2007 | 2648.3710 | 823 | 173.1554 | 8 | 64.5088 | 1.1231 | 0.1561 |
| 2008 | 2913.1230 | 874 | 173.7390 | 11 | 60.9613 | 1.0002 | 0.1559 |
| 2009 | 2460.8730 | 600 | 100.2251 | 10 | 49.6587 | 1.0080 | 0.1575 |
| 2010 | 2502.3350 | 537 | 104.1860 | 10 | 55.6875 | 1.0175 | 0.1584 |
| 2011 | 2466.5740 | 623 | 131.2742 | 9 | 64.4316 | 0.9416 | 0.1575 |
| 2012 | 2780.8310 | 756 | 160.7460 | 8 | 58.6972 | 1.1783 | 0.1567 |
| 2013 | 1941.1480 | 833 | 191.3445 | 11 | 65.4567 | 1.1522 | 0.1561 |
| 2014 | 2370.0560 | 769 | 183.6865 | 11 | 67.0661 | 1.3544 | 0.1566 |
| 2015 | 2667.8090 | 1171 | 292.8885 | 13 | 68.8997 | 1.2521 | 0.1551 |

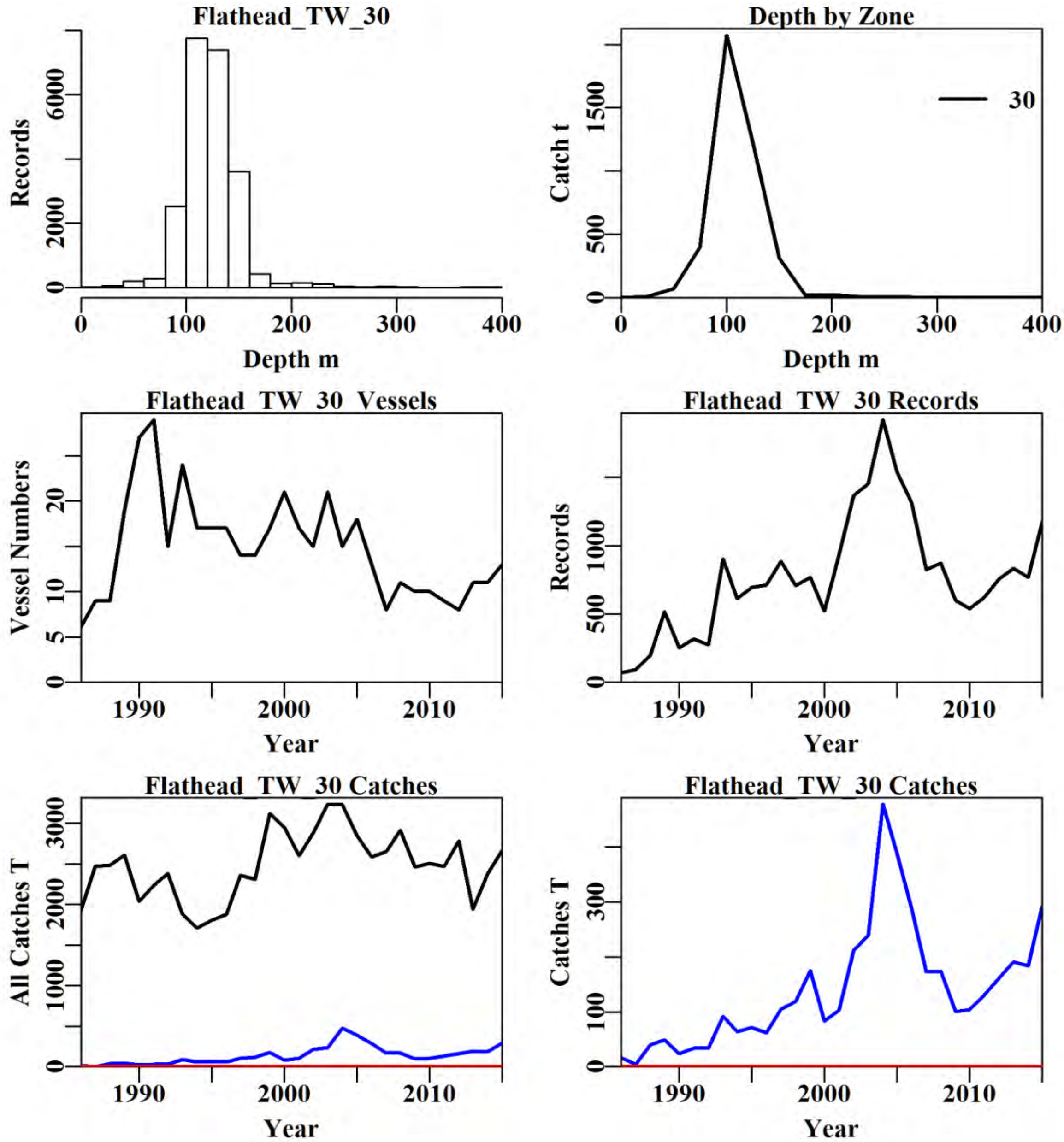



Figure 8.29. Flathead from zone 30 in depths 0 – 400m by Trawl. The top left plot depicts the depth distribution of shots containing Flathead from zones 10 and 20 in depths 0 – 400 m by Trawl. The top right plot depicts the catch distribution by depth from zone 30. The middle left plot depicts the number of vessels through time and middle right plot contains the number of records used in analysis. The bottom left plot contains Flathead catches (top black line: total catches, middle blue line: catches used in the analysis; bottom red line: catches < 30 kg) and bottom right plot contains Flathead catches (blue line: catches used in the analysis; red line: catches < 30 kg).

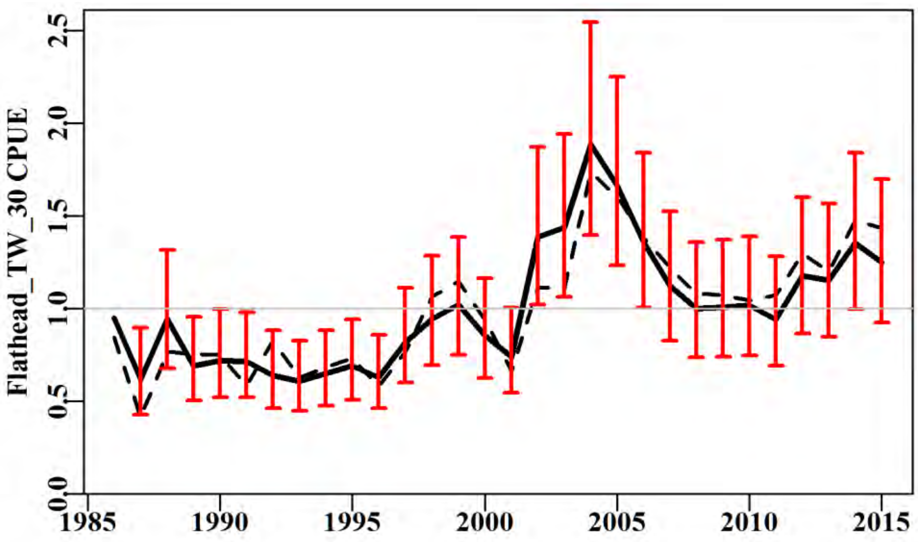



Figure 8.30. Flathead from zone 30 in depths 0 – 400 m by Trawl. Standardized catch rates (solid black line), 95% CI (vertical lines) and geometric mean (dashed black line).

Table 8.29. Flathead from zone 30 in depths 0 – 400 m by Trawl. Statistical model structures used in this analysis. DepCat is a series of 20 metre depth categories.

| | |
|---|---|
| Model 1 | LnCE~Year |
| Model 2 | LnCE~Year+Vessel |
| Model 3 | LnCE~Year+Vessel+DepCat |
| Model 4 | LnCE~Year+Vessel+DepCat+DayNight |
| Model 5 | LnCE~Year+Vessel+DepCat+DayNight+Month |
| Model 6 | LnCE~Year+Vessel+DepCat+DayNight+Month+DayNight:Month |
| Model 7 | LnCE~Year+Vessel+DepCat+DayNight+Month+Month:DepCat |
| Model 8 | LnCE~Year+Vessel+DepCat+DayNight+Month+DayNight:DepCat |

Table 8.30. Flathead from zone 30 in depths 0 – 400 m by Trawl. Model selection criteria include the Akaike Information Criterion (AIC), residual sum of squares (RSS), model sum of squares (MSS), number of usable observations (Nobs), number of parameters (Npars), adjusted $R^2$ (adj_$R^2$) and the change in adjusted $R^2$ (%Change). The optimum was Model 7 (Mth:DepC). Depth category: DepC; DayNight: DN; Month: Mth.

| | Year | Vessel | DepC | DN | Mth | DN:Mth | Mth:DepC | DN:DepC |
|---|---|---|---|---|---|---|---|---|
| AIC | 3272 | 1599 | 75 | -270 | -519 | -540 | -906 | -577 |
| RSS | 26489 | 24439 | 22559 | 22214 | 21951 | 21867 | 21249 | 21803 |
| MSS | 2422 | 4472 | 6353 | 6698 | 6961 | 7044 | 7662 | 7109 |
| Nobs | 23042 | 23042 | 22757 | 22757 | 22757 | 22757 | 22757 | 22757 |
| Npars | 30 | 121 | 137 | 140 | 151 | 184 | 327 | 199 |
| adj_$R^2$ | 8.263 | 15.026 | 21.504 | 22.694 | 23.572 | 23.751 | 25.434 | 23.926 |
| %Change | 0.000 | 6.763 | 6.479 | 1.190 | 0.878 | 0.179 | 1.683 | -1.509 |

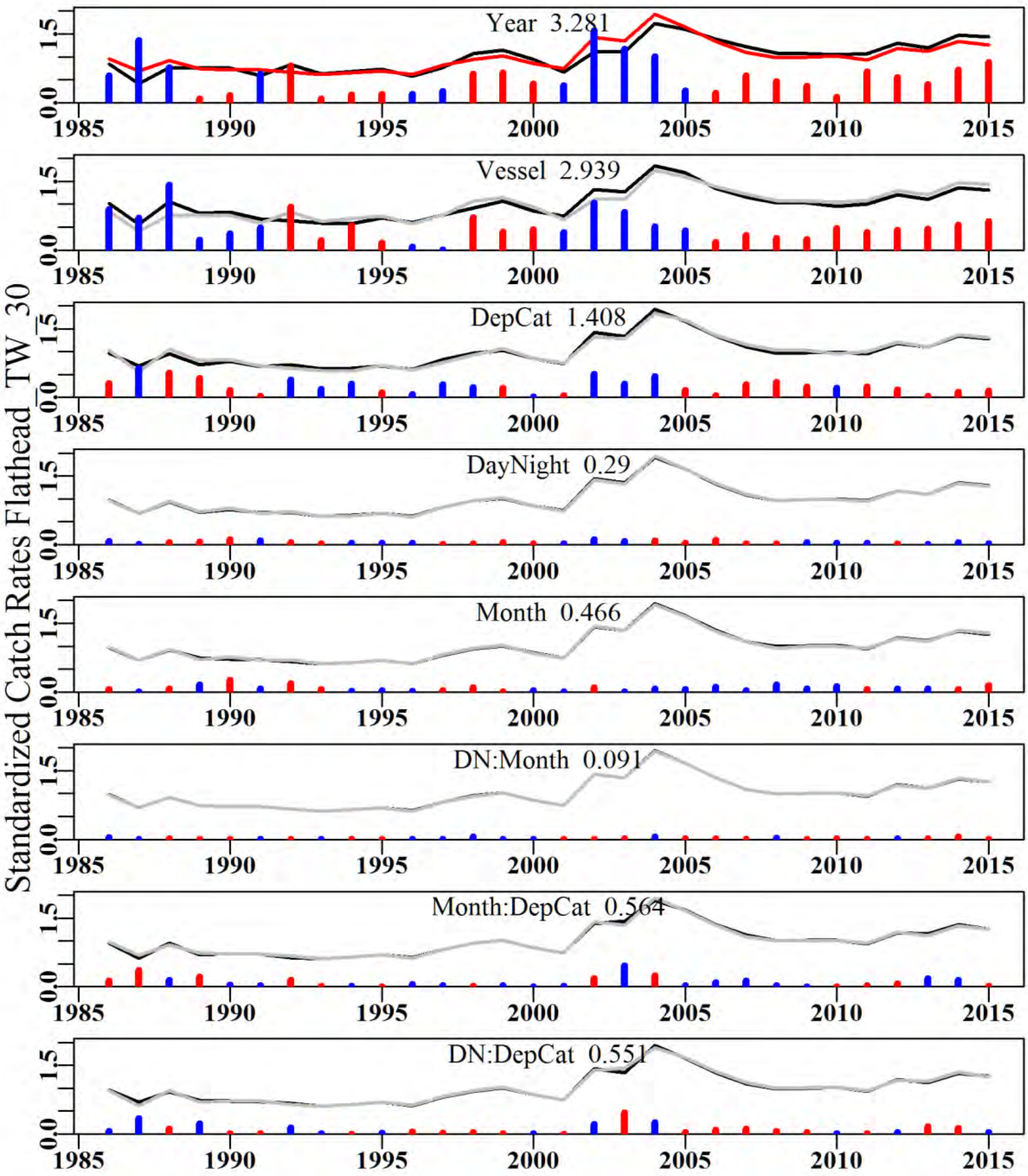



Figure 8.31. The relative influence of each factor used on the final trend in the optimal standardization for Flathead from zone 30. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by the vertical bars with blue bars indicating the optimum model is higher than the geometric mean and red bars indicating it is lower. The top graph bars are the sum of all the bars in the graphs below. The graphs for individual factors are cumulative. Thus the second graph has the geometric mean (grey line) and the effect of adding Year + factor2 (Model 2). In the third graph, the grey line represents Model 2 and the black line the effect of adding factor3 to the model. The remaining graphs continue in the same cumulative manner except for the interaction terms which are added singularly to the final single factor model.

### 8.4.11 *Flathead Danish Seine (FLT – 37296001 and 37296000 – Neoplatycephalus richardsoni and Platycephalidae)*

Data selected for analysis corresponded to records from zones 20 and 60, for Danish Seine vessels only (i.e. excluded Otter Trawl vessels), and depths less than 200 m. The additional generic flathead group code was added as a result of a change in recording Tiger flathead as 37296000 in electronic logbooks since 2013.

Table 8.31. Flathead from zones 20 and 60 in depths 0 – 200 m by Danish Seine. Total catch (TotCatch; t) is the total reported in the database, number of records used in the analysis (Records), reported catch (CatchT; t) in the area and depth used in the analysis and number of vessels used in the analysis (Vessels). GeoMean is the geometric mean of catch rates (kg/shot). The optimum model is Zone:Month and standard deviation (StDev) relates to the data in the optimum model.

| Year | TotCatch | Records | CatchT | Vessels | GeoMean | Zone:Month | StDev |
|---|---|---|---|---|---|---|---|
| 1986 | 1911.4140 | 5988 | 774.2420 | 26 | 183.8017 | 1.0947 | 0.0000 |
| 1987 | 2471.7310 | 5922 | 1373.1520 | 23 | 336.7735 | 1.6044 | 0.0224 |
| 1988 | 2482.7610 | 6171 | 1104.2320 | 25 | 262.7225 | 1.7212 | 0.0222 |
| 1989 | 2609.0370 | 5602 | 1147.1690 | 27 | 289.3552 | 1.6220 | 0.0226 |
| 1990 | 2041.6530 | 4778 | 588.8310 | 25 | 150.6150 | 1.0619 | 0.0240 |
| 1991 | 2236.1810 | 4741 | 777.3800 | 28 | 215.7827 | 1.3400 | 0.0242 |
| 1992 | 2377.3580 | 6674 | 1218.3790 | 23 | 233.9066 | 1.3756 | 0.0222 |
| 1993 | 1881.0370 | 6162 | 557.3410 | 25 | 114.6268 | 0.8305 | 0.0227 |
| 1994 | 1710.8930 | 7330 | 649.4750 | 25 | 125.4864 | 0.7199 | 0.0218 |
| 1995 | 1805.8140 | 5660 | 658.1740 | 21 | 192.4334 | 0.7671 | 0.0231 |
| 1996 | 1880.1650 | 7615 | 748.3220 | 22 | 137.2817 | 0.7235 | 0.0217 |
| 1997 | 2356.2450 | 8408 | 1149.9340 | 20 | 193.6332 | 0.9375 | 0.0214 |
| 1998 | 2306.6670 | 9876 | 1134.3800 | 21 | 147.9208 | 0.7929 | 0.0209 |
| 1999 | 3118.6710 | 8750 | 1702.1270 | 23 | 269.0891 | 1.1942 | 0.0213 |
| 2000 | 2947.7940 | 7354 | 1092.4630 | 19 | 199.9414 | 0.8323 | 0.0222 |
| 2001 | 2600.5370 | 7858 | 1084.5430 | 19 | 196.9445 | 0.7881 | 0.0221 |
| 2002 | 2876.8260 | 8218 | 1144.0750 | 22 | 181.7925 | 0.8893 | 0.0219 |
| 2003 | 3232.3520 | 9006 | 1210.2330 | 23 | 168.5926 | 0.9534 | 0.0217 |
| 2004 | 3227.3880 | 7784 | 1253.0260 | 22 | 193.6549 | 0.9239 | 0.0222 |
| 2005 | 2846.7890 | 7212 | 1125.7530 | 22 | 183.9055 | 0.9777 | 0.0226 |
| 2006 | 2586.0240 | 5563 | 968.0510 | 21 | 232.4380 | 0.9379 | 0.0239 |
| 2007 | 2648.3710 | 5551 | 1182.0670 | 15 | 294.1158 | 1.1678 | 0.0238 |
| 2008 | 2913.1230 | 6214 | 1283.4890 | 15 | 280.3483 | 1.0327 | 0.0234 |
| 2009 | 2460.8730 | 5499 | 1168.9280 | 15 | 318.3953 | 1.0518 | 0.0239 |
| 2010 | 2502.3350 | 6050 | 1167.4060 | 15 | 273.8728 | 0.9450 | 0.0235 |
| 2011 | 2466.5740 | 6889 | 1122.3150 | 14 | 207.9269 | 0.8876 | 0.0229 |
| 2012 | 2780.8310 | 7214 | 1382.3340 | 14 | 298.7905 | 0.8473 | 0.0228 |
| 2013 | 1941.1480 | 7265 | 937.0370 | 14 | 168.7580 | 0.6376 | 0.0228 |
| 2014 | 2370.0560 | 8374 | 1165.2170 | 14 | 186.1502 | 0.6716 | 0.0225 |
| 2015 | 2667.8090 | 8668 | 1323.3520 | 15 | 196.6040 | 0.6704 | 0.0225 |

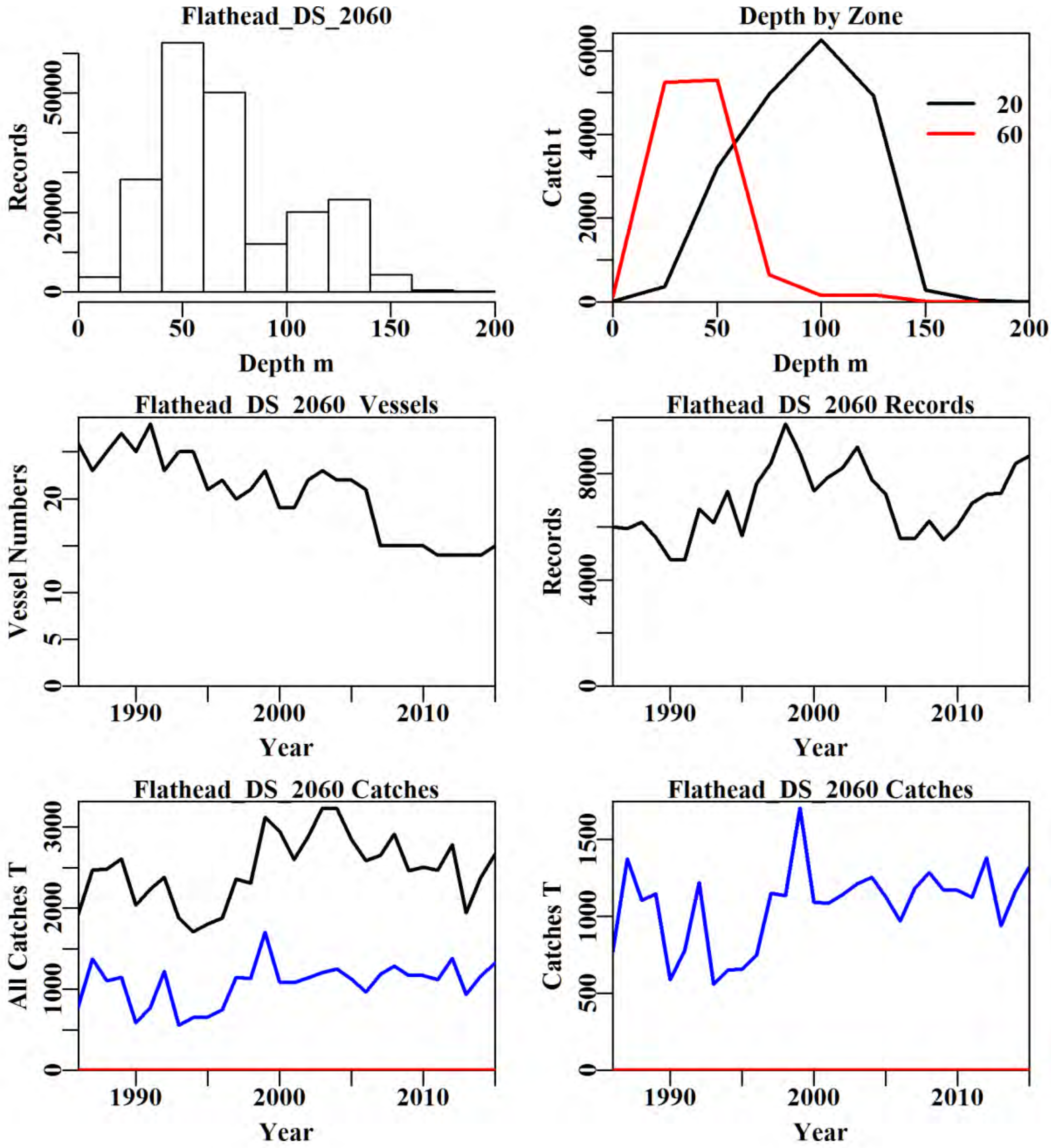



Figure 8.32. Flathead from zones 20 and 60 in depths 0 – 200 m by Danish Seine. The top left plot depicts the depth distribution of shots containing Flathead from zones 20 and 60 in depths 0 – 200 m by Danish Seine. The top right plot depicts the catch distribution by depth from zones 20 and 60. The middle left plot depicts the number of vessels through time and middle right plot contains the number of records used in analysis. The bottom left plot contains Flathead catches (top black line: total catches, middle blue line: catches used in the analysis; bottom red line: catches < 30 kg) and bottom right plot contains Flathead catches (blue line: catches used in the analysis; red line: catches < 30 kg).

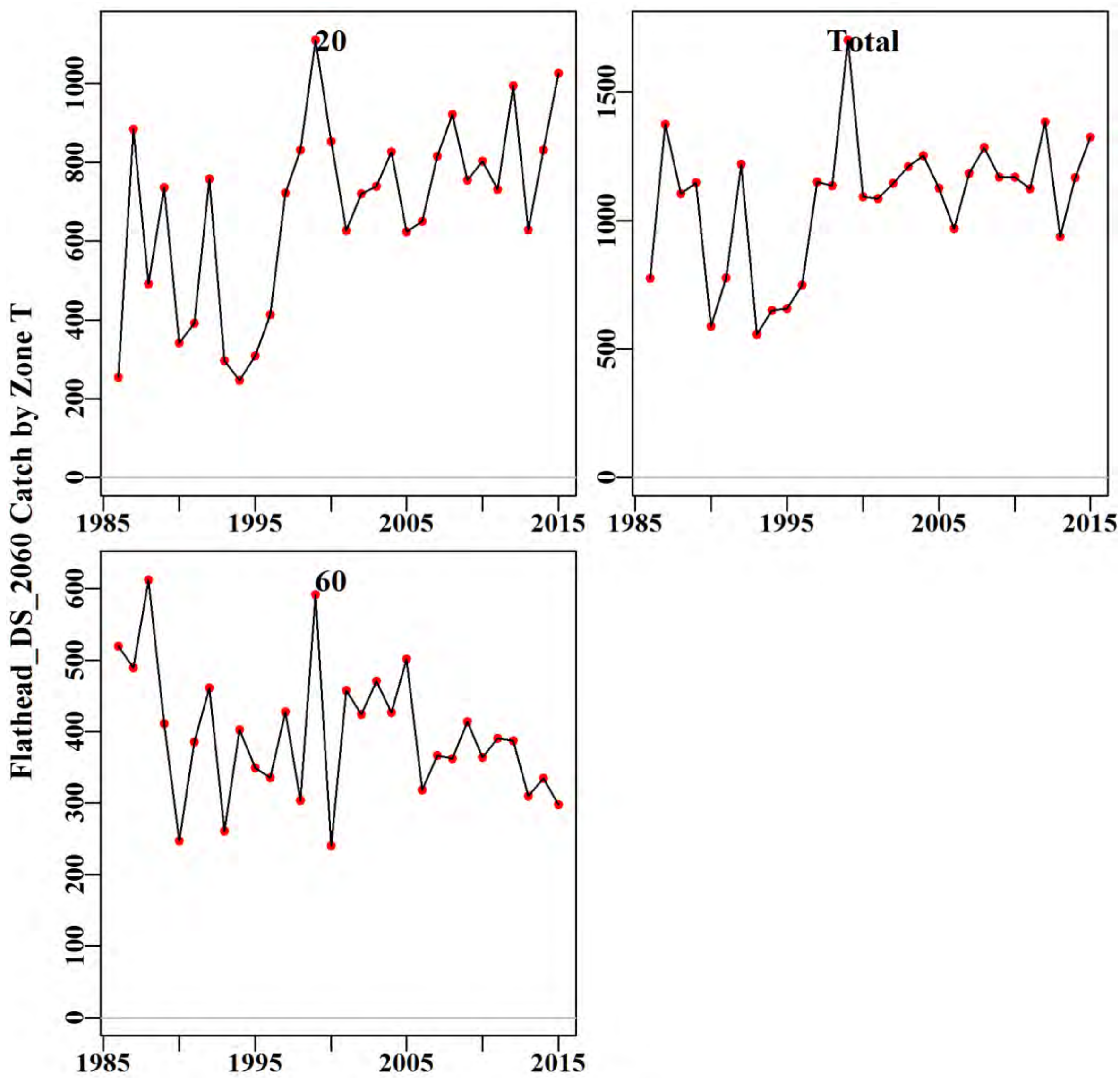



Figure 8.33. Annual flathead catches among the reporting zones 20, 60 and combined (20 & 60).

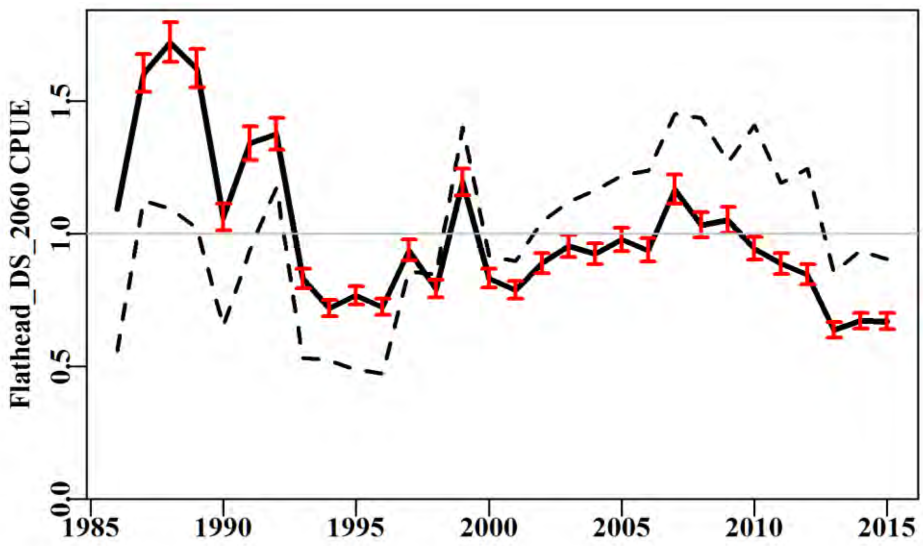



Figure 8.34. Flathead from zones 20 and 60 in depths 0 – 200 m by Danish Seine. Standardized catch rates (solid black line), 95% CI (vertical lines) and geometric mean (dashed black line).

Table 8.32. Flathead from zones 20 and 60 in depths 0 – 200 m by Danish Seine. Statistical model structures used in this analysis. DepCat is a series of 20 metre depth categories.

| | |
|---|---|
| Model 1 | LnCE~Year |
| Model 2 | LnCE~Year+Zone |
| Model 3 | LnCE~Year+Zone+DepCat |
| Model 4 | LnCE~Year+Zone+DepCat+Month |
| Model 5 | LnCE~Year+Zone+DepCat+Month+Vessel |
| Model 6 | LnCE~Year+Zone+DepCat+Month+Vessel+DayNight |
| Model 7 | LnCE~Year+Zone+DepCat+Month+Vessel+DayNight+Zone:Month |
| Model 8 | LnCE~Year+Zone+DepCat+Month+Vessel+DayNight+Zone:DepCat |

Table 8.33. Flathead from zones 20 and 60 in depths 0 – 200 m by Danish Seine. Model selection criteria include the Akaike Information Criterion (AIC), residual sum of squares (RSS), model sum of squares (MSS), number of usable observations (Nobs), number of parameters (Npars), adjusted $R^2$ (adj_$R^2$) and the change in adjusted $R^2$ (%Change). The optimum was Model 7 (Zone:Month). Depth category: DepC.

| | Year | Zone | DepC | Month | Vessel | DayNight | Zone:Month | Zone:DepC |
|---|---|---|---|---|---|---|---|---|
| AIC | 161635 | 123854 | 92796 | 84562 | 72068 | 65845 | 61919 | 65349 |
| RSS | 452491 | 377459 | 322437 | 309596 | 291280 | 282572 | 277189 | 281868 |
| MSS | 21390 | 96423 | 151445 | 164286 | 182602 | 191310 | 196693 | 192014 |
| Nobs | 208396 | 208396 | 205230 | 205230 | 205230 | 205230 | 205230 | 205230 |
| Npars | 30 | 31 | 39 | 92 | 103 | 106 | 117 | 114 |
| adj_$R^2$ | 4.501 | 20.336 | 31.946 | 34.639 | 38.503 | 40.340 | 41.474 | 40.487 |
| %Change | 0.000 | 15.835 | 11.610 | 2.693 | 3.864 | 1.838 | 1.133 | -0.987 |

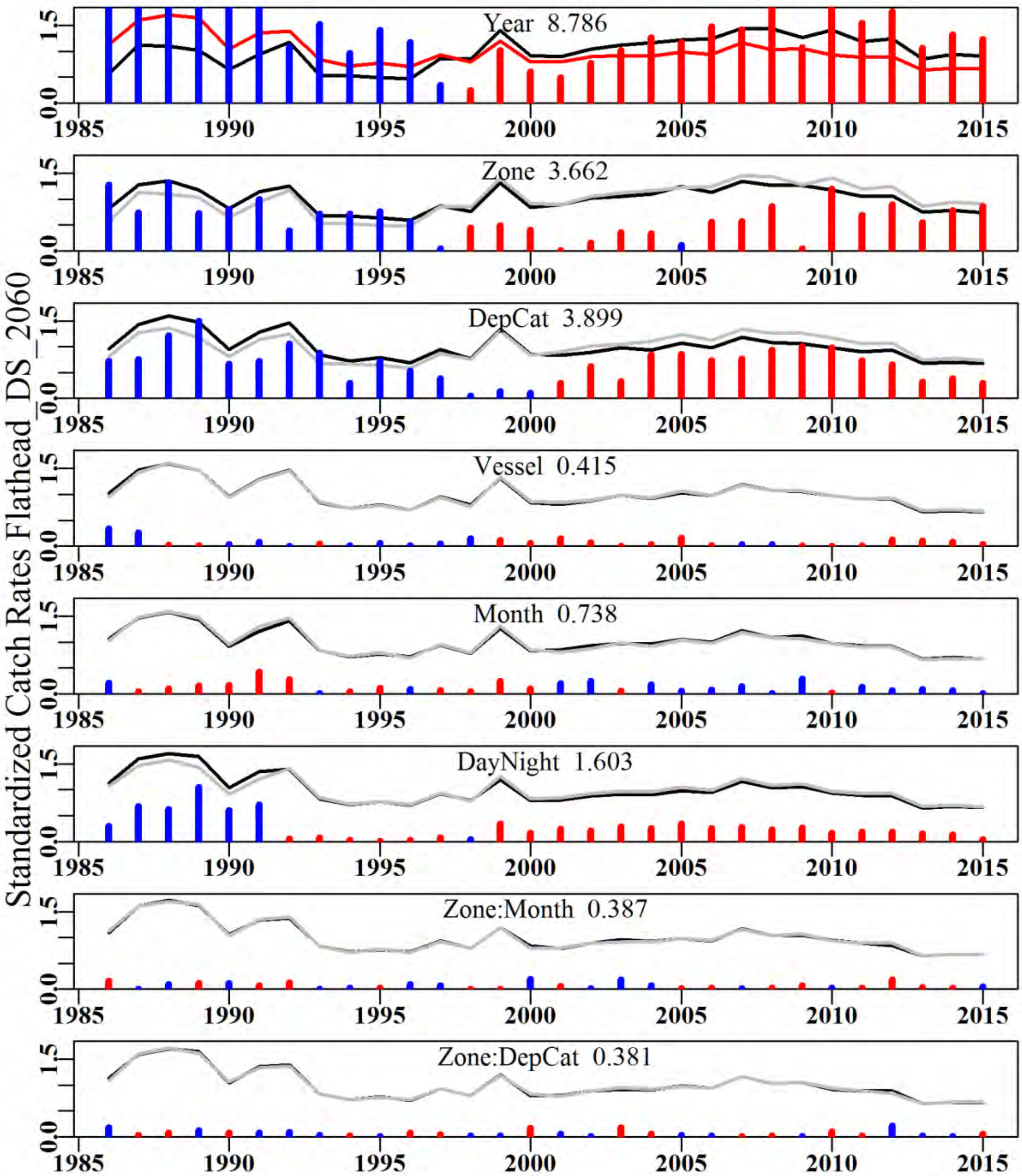



Figure 8.35. The relative influence of each factor used on the final trend in the optimal standardization for Flathead by Danish Seine in zones 20 and 60. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by the vertical bars with blue bars indicating the optimum model is higher than the geometric mean and red bars indicating it is lower. The top graph bars are the sum of all the bars in the graphs below. The graphs for individual factors are cumulative. Thus the second graph has the geometric mean (grey line) and the effect of adding Year + factor2 (Model 2). In the third graph, the grey line represents Model 2 and the black line the effect of adding factor3 to the model. The remaining graphs continue in the same cumulative manner except for the interaction terms which are added singularly to the final single factor model.

### 8.4.12 *Redfish Z1020 (RED – 37258003 – Centroberyx affinis)*

Trawl data selected for analysis corresponded to records from zones 10 and 20 from depths less than 400 m.

Table 8.34. Redfish from zones 10 and 20 in depths 0 – 400 m by Trawl. Total catch (TotCatch; t) is the total reported in the database, number of records used in the analysis (Records), reported catch (CatchT; t) in the area and depth used in the analysis and number of vessels used in the analysis (Vessels). GeoMean is the geometric mean of catch rates (kg/hr). The optimum model is Month:DepC and standard deviation (StDev) relates to the data in the optimum model.

| Year | TotCatch | Records | CatchT | Vessels | GeoMean | Month:DepC | StDev |
|---|---|---|---|---|---|---|---|
| 1986 | 1687.4710 | 5338 | 1598.2390 | 87 | 32.2541 | 1.7593 | 0.0000 |
| 1987 | 1252.6580 | 3931 | 1185.3720 | 79 | 32.2363 | 1.5002 | 0.0338 |
| 1988 | 1125.4920 | 3972 | 1078.8020 | 75 | 32.8369 | 1.6835 | 0.0343 |
| 1989 | 714.3160 | 2723 | 644.4320 | 72 | 25.1327 | 1.2682 | 0.0382 |
| 1990 | 931.3700 | 2593 | 794.8440 | 58 | 29.8742 | 1.6026 | 0.0392 |
| 1991 | 1570.6070 | 3352 | 1238.0430 | 52 | 33.6518 | 1.7660 | 0.0369 |
| 1992 | 1636.6870 | 3207 | 1523.6760 | 48 | 40.0168 | 2.1732 | 0.0380 |
| 1993 | 1921.3470 | 3785 | 1767.5710 | 53 | 46.1788 | 2.6451 | 0.0364 |
| 1994 | 1487.7170 | 5477 | 1340.8060 | 53 | 31.9323 | 1.9648 | 0.0337 |
| 1995 | 1240.6170 | 5697 | 1195.6930 | 52 | 24.0992 | 1.2657 | 0.0329 |
| 1996 | 1344.0490 | 5805 | 1305.1470 | 56 | 20.6510 | 1.1044 | 0.0329 |
| 1997 | 1397.3280 | 4406 | 1354.0270 | 58 | 23.1410 | 1.1564 | 0.0351 |
| 1998 | 1553.7182 | 4309 | 1528.0160 | 49 | 29.8256 | 1.3813 | 0.0350 |
| 1999 | 1116.4030 | 3943 | 1091.8070 | 53 | 24.3438 | 1.1392 | 0.0356 |
| 2000 | 758.2751 | 4668 | 737.1360 | 52 | 14.6627 | 0.7553 | 0.0348 |
| 2001 | 742.2683 | 4576 | 725.4900 | 47 | 13.0540 | 0.7473 | 0.0348 |
| 2002 | 807.1325 | 5215 | 774.5375 | 49 | 12.2185 | 0.7055 | 0.0344 |
| 2003 | 615.5584 | 4119 | 555.8542 | 51 | 10.7368 | 0.6029 | 0.0358 |
| 2004 | 475.2044 | 3965 | 449.3740 | 50 | 10.2028 | 0.5392 | 0.0363 |
| 2005 | 483.5160 | 3796 | 453.1700 | 46 | 11.0542 | 0.5921 | 0.0367 |
| 2006 | 325.4821 | 2589 | 302.6810 | 42 | 10.7454 | 0.5461 | 0.0403 |
| 2007 | 216.2794 | 1880 | 208.9890 | 23 | 10.7721 | 0.5292 | 0.0451 |
| 2008 | 183.7567 | 1932 | 179.7953 | 25 | 10.0057 | 0.4625 | 0.0449 |
| 2009 | 160.5248 | 1619 | 154.3370 | 23 | 9.0193 | 0.4065 | 0.0474 |
| 2010 | 152.8285 | 1871 | 147.4586 | 24 | 7.8240 | 0.3953 | 0.0453 |
| 2011 | 87.3052 | 1408 | 84.1147 | 22 | 5.4792 | 0.2881 | 0.0496 |
| 2012 | 66.4453 | 1354 | 62.3310 | 21 | 4.6073 | 0.2031 | 0.0500 |
| 2013 | 62.6740 | 1137 | 60.4391 | 20 | 5.5583 | 0.2623 | 0.0531 |
| 2014 | 86.7989 | 1415 | 82.8054 | 22 | 7.4969 | 0.3447 | 0.0493 |
| 2015 | 49.7984 | 1153 | 47.7200 | 22 | 4.8070 | 0.2100 | 0.0534 |

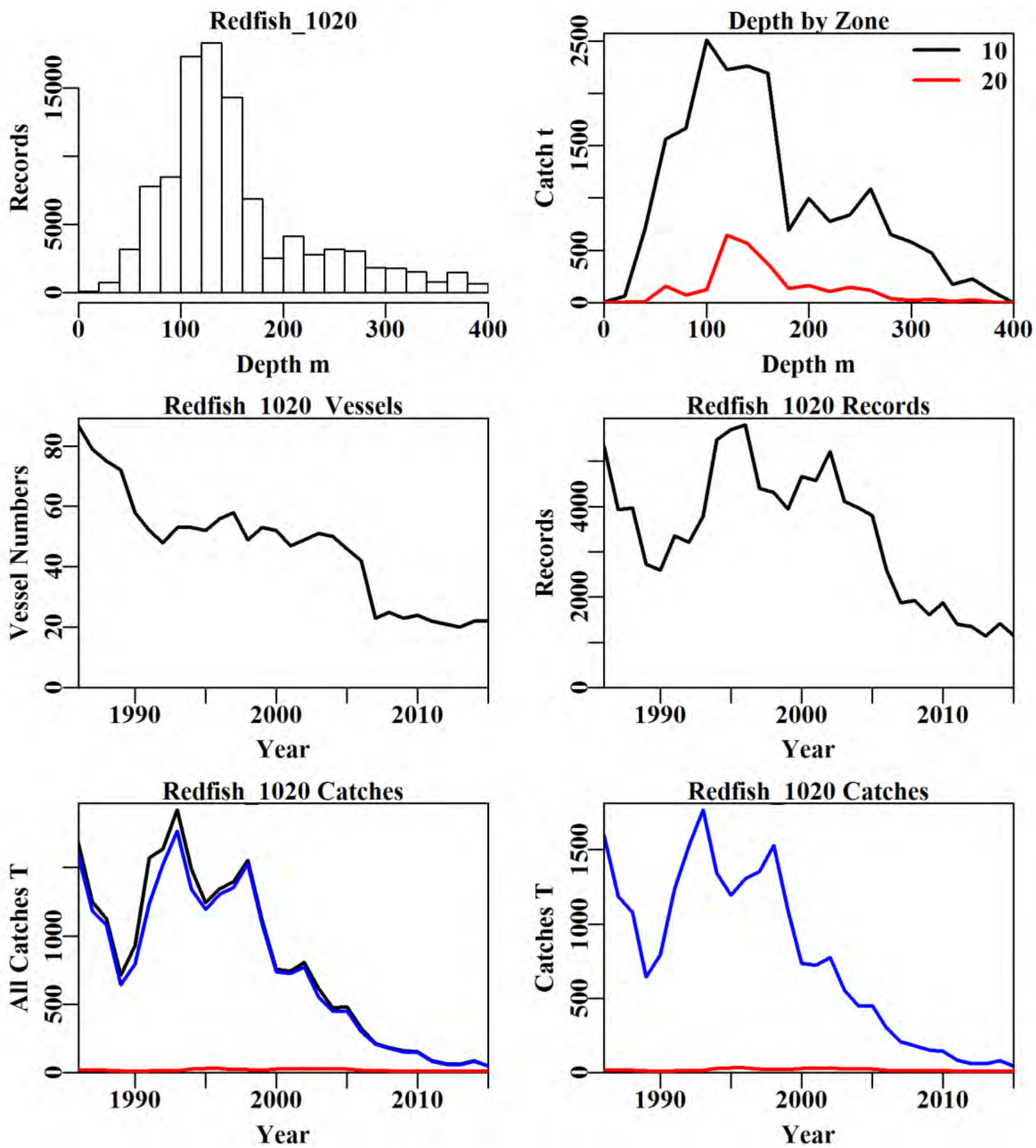
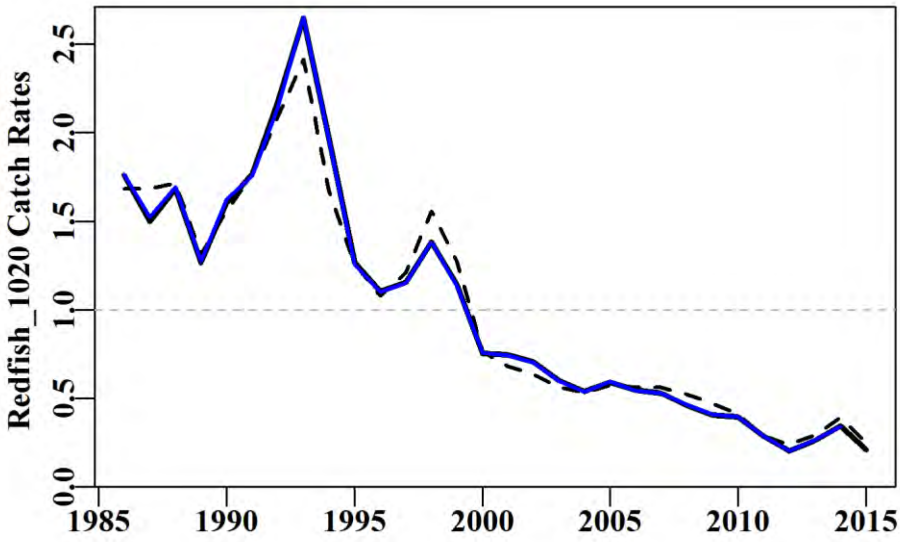



Figure 8.36. Redfish from zones 10 and 20 in depths 0 – 400 m by Trawl. The top left plot depicts the depth distribution of shots containing Redfish from zones 10 and 20 in depths 0 – 400 m by Trawl. The top right plot depicts the catch distribution by depth from zones 10 and 20. The middle left plot depicts the number of vessels through time and middle right plot contains the number of records used in analysis. The bottom left plot contains Redfish catches (top black line: total catches, middle blue line: catches used in the analysis; bottom red line: catches < 30 kg) and bottom right plot contains Redfish catches (blue line: catches used in the analysis; red line: catches < 30 kg).



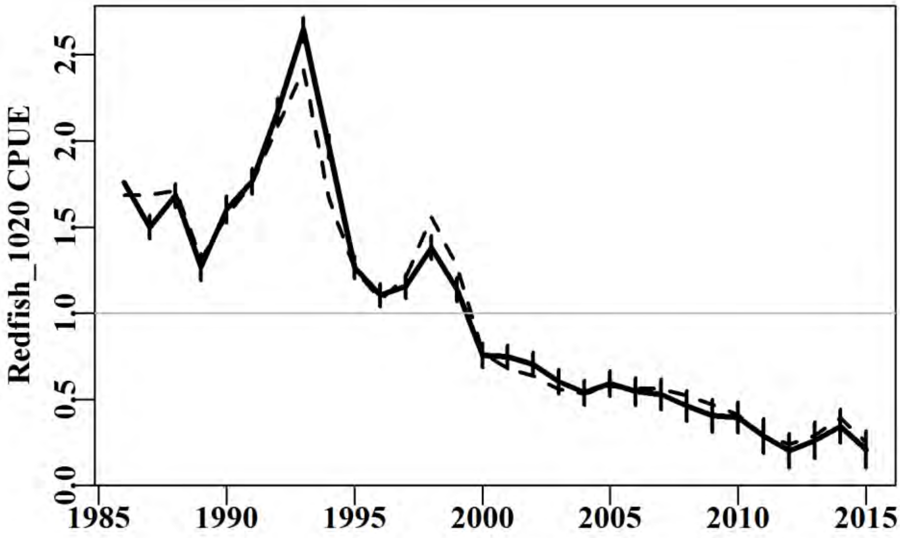




Figure 8.37. Redfish from zones 10 and 20 in depths 0 – 400 m by Trawl. Top plot: The dashed black line represents the geometric mean catch rate and the solid black line the standardized catch rates (relative to the mean of the standardized catch rates). The blue line corresponds to last year's standardized catch rates. Lower plot: Standardized catch rates (solid black line), 95% CI (vertical lines) and geometric mean (dashed black line).

Table 8.35. Redfish from zone 10 in depths 0 – 400m by Trawl. Statistical model structures used in this analysis. DepCat is a series of 20 metre depth categories.

| | |
|---|---|
| Model 1 | LnCE~Year |
| Model 2 | LnCE~Year+Vessel |
| Model 3 | LnCE~Year+Vessel+DepCat |
| Model 4 | LnCE~Year+Vessel+DepCat+Zone |
| Model 5 | LnCE~Year+Vessel+DepCat+Zone+Month |
| Model 6 | LnCE~Year+Vessel+DepCat+Zone+Month+DayNight |
| Model 7 | LnCE~Year+Vessel+DepCat+Zone+Month+DayNight+DayNight:Month |
| Model 8 | LnCE~Year+Vessel+DepCat+Zone+Month+DayNight+Month:DepCat |
| Model 9 | LnCE~Year+Vessel+DepCat+Zone+Month+DayNight+ DayNight:DepCat |

Table 8.36. Redfish from zone 10 in depths 0 – 400 m by Trawl. Model selection criteria include the Akaike Information Criterion (AIC), residual sum of squares (RSS), model sum of squares (MSS), number of usable observations (Nobs), number of parameters (Npars), adjusted $R^2$ (adj_$R^2$) and the change in adjusted $R^2$ (%Change). The optimum model was Model 8 (Month:DepC). Depth category: DepC; DayNight: DN.

| | Year | Vessel | DepC | Zone | DN | Month | DN:Month | Month:DepC | DN:DepC |
|---|---|---|---|---|---|---|---|---|---|
| AIC | 110085 | 92872 | 86796 | 85539 | 84884 | 84556 | 84307 | 83065 | 83593 |
| RSS | 300146 | 252437 | 237448 | 234500 | 232965 | 232155 | 231429 | 227746 | 229671 |
| MSS | 34080 | 81789 | 96778 | 99727 | 101261 | 102071 | 102797 | 106480 | 104556 |
| Nobs | 101235 | 101235 | 100681 | 100681 | 100681 | 100681 | 100681 | 100681 | 100681 |
| Npars | 30 | 186 | 206 | 207 | 210 | 221 | 254 | 441 | 281 |
| adj_$R^2$ | 10.171 | 24.333 | 28.811 | 29.694 | 30.152 | 30.388 | 30.582 | 31.560 | 31.091 |
| %Change | 0.000 | 14.162 | 4.478 | 0.883 | 0.458 | 0.235 | 0.195 | 0.977 | -0.468 |

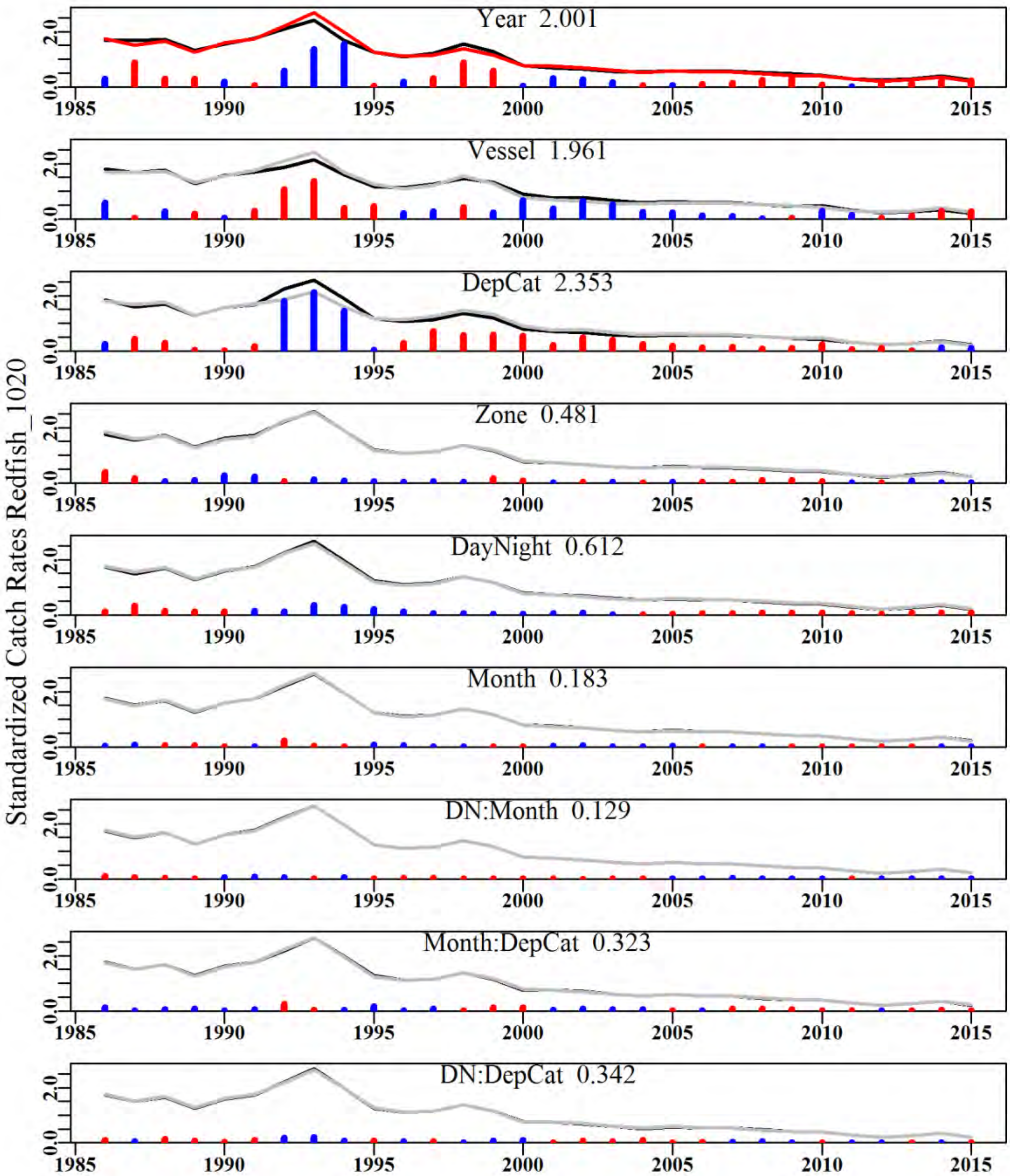



Figure 8.38. The relative influence of each factor used on the final trend in the optimal standardization for Redfish in zones 10 and 20. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by the vertical bars with blue bars indicating the optimum model is higher than the geometric mean and red bars indicating it is lower. The top graph bars are the sum of all the bars in the graphs below. The graphs for individual factors are cumulative. Thus the second graph has the geometric mean (grey line) and the effect of adding Year + factor2 (Model 2). In the third graph, the grey line represents Model 2 and the black line the effect of adding factor3 to the model. The remaining graphs continue in the same cumulative manner except for the interaction terms which are added singularly to the final single factor model.

### 8.4.13 *Silver Trevally Z1020 (TRE – 37337062 – Pseudocaranx dentex)*

Trawl data from zones 10 and 20 corresponding to depths less than 200 m were used. In order to discount the influence of catches taken within the Batemans Bay MPA, all data in Commonwealth waters within the MPA have been excluded from the analysis. The selection of which records to exclude is improved over earlier year's analysis through the use of improved GIS.

Table 8.37. Silver Trevally from zones 10 and 20 in depths 0 to 200 m, excluding data taken in State waters (Bateman's Bay MPA). Total catch (TotCatch; t) is the total reported in the database, number of records used in the analysis (Records), reported catch (CatchT; t) in the area and depth used in the analysis and number of vessels used in the analysis (Vessels). GeoMean is the geometric mean of catch rates (kg/hr). The optimum model is Zone:Month and standard deviation (StDev) relates to the data in the optimum model.

| Year | TotCatch | Records | CatchT | Vessels | GeoMean | Zone:Month | StDev |
|---|---|---|---|---|---|---|---|
| 1986 | 469.5080 | 1763 | 282.9590 | 74 | 17.0570 | 1.1634 | 0.0000 |
| 1987 | 198.4900 | 1083 | 122.0060 | 62 | 17.8442 | 1.3987 | 0.0607 |
| 1988 | 278.5410 | 1257 | 226.6600 | 53 | 23.8537 | 1.8021 | 0.0563 |
| 1989 | 376.1960 | 1847 | 282.4840 | 62 | 22.9733 | 1.9208 | 0.0511 |
| 1990 | 450.3910 | 1851 | 296.5230 | 52 | 22.7736 | 2.2587 | 0.0522 |
| 1991 | 340.6830 | 1960 | 218.1340 | 49 | 17.6957 | 1.9870 | 0.0529 |
| 1992 | 296.4930 | 1371 | 175.9210 | 45 | 13.2643 | 1.2114 | 0.0574 |
| 1993 | 377.6730 | 1415 | 152.2810 | 48 | 13.7212 | 1.2436 | 0.0570 |
| 1994 | 392.8280 | 2082 | 176.6310 | 47 | 10.2235 | 0.9870 | 0.0525 |
| 1995 | 413.4390 | 1938 | 177.7140 | 44 | 10.9856 | 1.1061 | 0.0533 |
| 1996 | 340.6160 | 2168 | 174.4590 | 49 | 8.6881 | 0.9655 | 0.0528 |
| 1997 | 328.8385 | 1657 | 115.7470 | 50 | 6.9074 | 0.9005 | 0.0562 |
| 1998 | 210.1360 | 1217 | 62.0900 | 42 | 5.7847 | 0.6412 | 0.0592 |
| 1999 | 166.0182 | 1028 | 49.3970 | 40 | 5.2214 | 0.6511 | 0.0623 |
| 2000 | 154.7527 | 1241 | 54.0240 | 45 | 3.9720 | 0.5018 | 0.0590 |
| 2001 | 270.1751 | 2010 | 120.6810 | 43 | 5.1258 | 0.6133 | 0.0529 |
| 2002 | 232.7870 | 1819 | 99.0780 | 40 | 3.6655 | 0.4973 | 0.0549 |
| 2003 | 337.8967 | 1554 | 91.2558 | 49 | 4.1196 | 0.5030 | 0.0559 |
| 2004 | 458.0749 | 1891 | 152.3540 | 43 | 6.4738 | 0.7251 | 0.0541 |
| 2005 | 290.9402 | 1028 | 98.7435 | 41 | 6.8153 | 0.6224 | 0.0618 |
| 2006 | 247.2843 | 704 | 80.4700 | 37 | 8.1280 | 0.7991 | 0.0687 |
| 2007 | 172.7180 | 571 | 80.8040 | 20 | 10.4198 | 0.9151 | 0.0743 |
| 2008 | 128.3861 | 912 | 81.7890 | 23 | 8.7006 | 0.8833 | 0.0646 |
| 2009 | 164.0519 | 962 | 110.6100 | 23 | 9.9383 | 0.8841 | 0.0633 |
| 2010 | 240.2269 | 1078 | 156.1683 | 24 | 12.6408 | 1.1247 | 0.0621 |
| 2011 | 193.4736 | 953 | 155.3153 | 20 | 11.5056 | 0.9834 | 0.0641 |
| 2012 | 139.6903 | 741 | 99.5880 | 21 | 8.1453 | 0.7163 | 0.0686 |
| 2013 | 122.7757 | 575 | 78.3730 | 20 | 13.7412 | 0.8238 | 0.0734 |
| 2014 | 106.3265 | 697 | 67.6660 | 20 | 10.2789 | 0.5858 | 0.0695 |
| 2015 | 67.9840 | 429 | 45.5280 | 20 | 10.6513 | 0.5845 | 0.0816 |

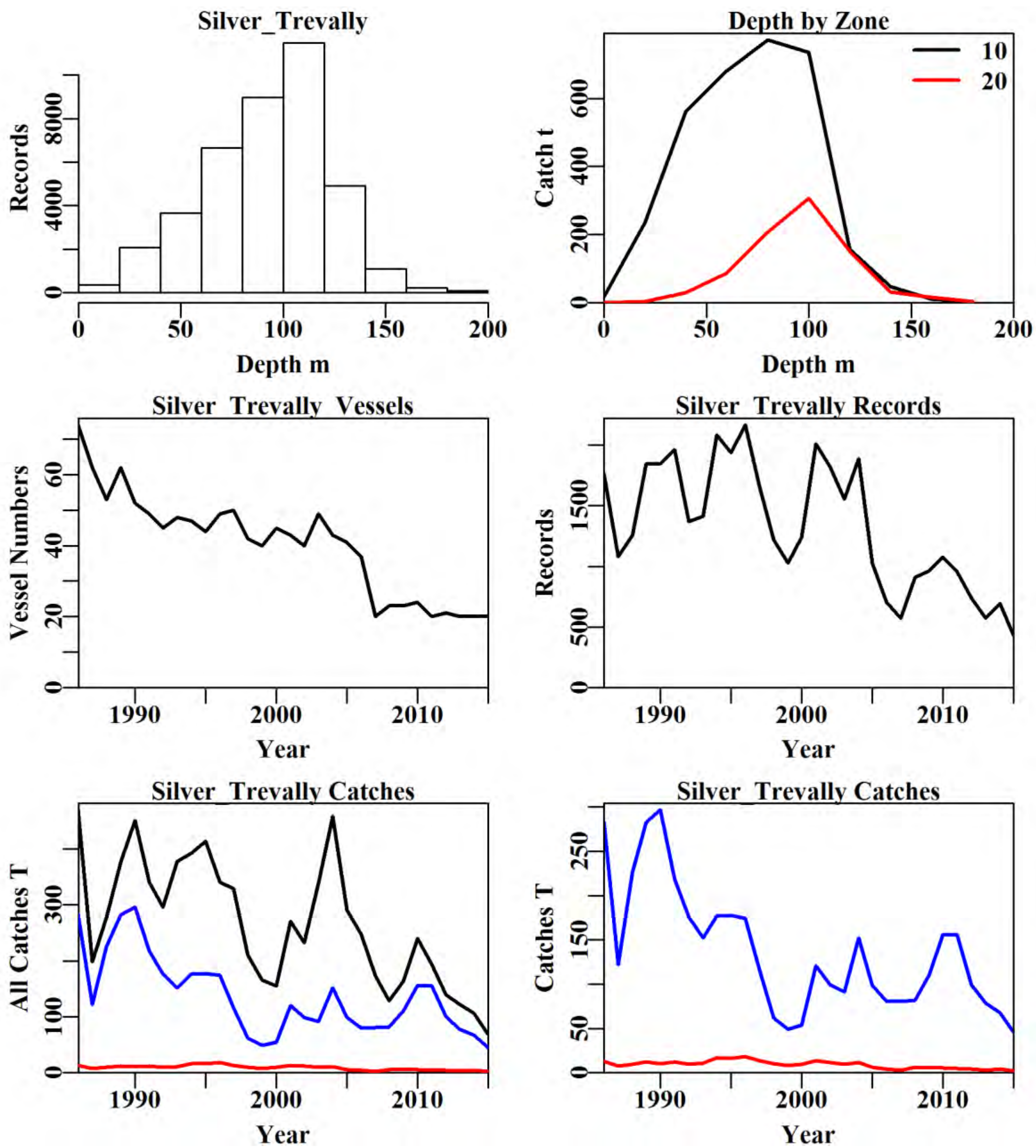



Figure 8.39. Silver Trevally from Zones 10 and 20 in depths 0 to 200 m, excluding data from State waters (Bateman's Bay MPA). The top left plot depicts the depth distribution of shots containing Silver Trevally from zones 10 and 20 in depths 0 to 200 m by Trawl, excluding data from State waters (Bateman's Bay MPA). The top right plot depicts the catch distribution by depth within zones 10 and 20 (20 is bottom red line). The middle left plot depicts the number of vessels through time and middle right plot contains the number of records used in analysis. The bottom left plot contains Silver Trevally catches (top black line: total catches, middle blue line: catches used in the analysis; bottom red line: catches < 30 kg) and bottom right plot contains Silver Trevally catches (blue line: catches used in the analysis; red line: catches < 30 kg).

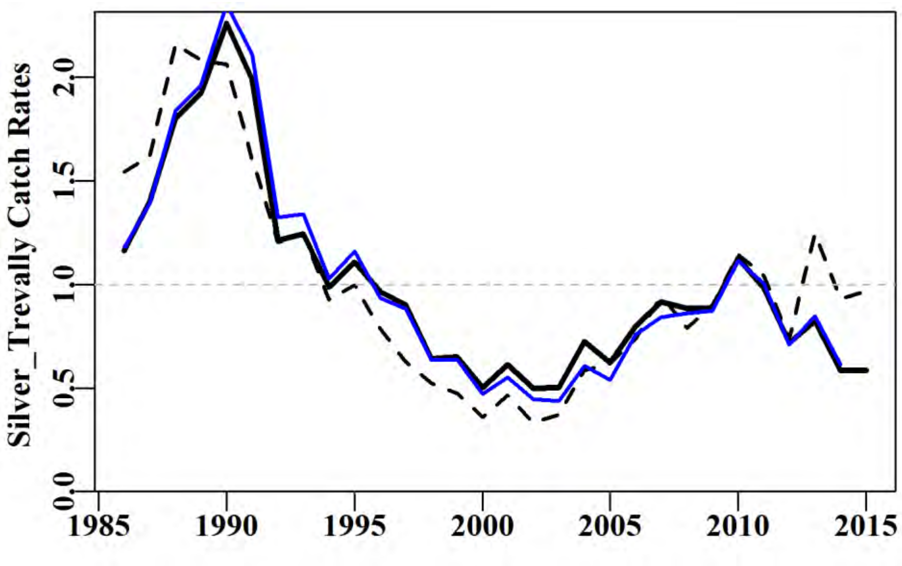



Figure 8.40. Silver Trevally from zones 10 and 20 in depths 0 to 200 m, excluding data taken in State waters (Bateman's Bay MPA). The dashed black line represents the geometric mean catch rate and the solid black line the standardized catch rates (relative to the mean of the standardized catch rates). The blue line corresponds to last year's standardized indices.

Table 8.38. Silver Trevally from Zones 10 and 20 in depths 0 to 200 m, excluding data taken in State waters (Bateman's Bay MPA). Statistical model structures used in this analysis. DepCat is a series of 20 metre depth categories.

| | |
|---|---|
| Model 1 | LnCE~Year |
| Model 2 | LnCE~Year+Vessel |
| Model 3 | LnCE~Year+Vessel+DepCat |
| Model 4 | LnCE~Year+Vessel+DepCat+Month |
| Model 5 | LnCE~Year+Vessel+DepCat+Month+DayNight |
| Model 6 | LnCE~Year+Vessel+DepCat+Month+DayNight+Zone |
| Model 7 | LnCE~Year+Vessel+DepCat+Month+DayNight+Zone+Zone:Month |
| Model 8 | LnCE~Year+Vessel+DepCat+Month+DayNight+Zone+Zone:DepCat |

Table 8.39. Silver Trevally from Zones 10 and 20 in depths 0 to 200 m, excluding data taken in State waters (Bateman's Bay MPA). Model selection criteria include the Akaike Information Criterion (AIC), residual sum of squares (RSS), model sum of squares (MSS), number of usable observations (Nobs), number of parameters (Npars), adjusted $R^2$ (adj_$R^2$) and the change in adjusted $R^2$ (%Change). The optimum model is Model 7 (Zone:Month). Depth category: DepC.

| | Year | Vessel | DepC | Month | DayNight | Zone | Zone:Month | Zone:DepC |
|---|---|---|---|---|---|---|---|---|
| AIC | 39106 | 30425 | 29034 | 28313 | 27714 | 27658 | 27564 | 27629 |
| RSS | 106158 | 84713 | 81609 | 80090 | 78874 | 78757 | 78527 | 78664 |
| MSS | 12033 | 33478 | 36581 | 38101 | 39316 | 39434 | 39664 | 39526 |
| Nobs | 39802 | 39802 | 39526 | 39526 | 39526 | 39526 | 39526 | 39526 |
| Npars | 30 | 180 | 189 | 200 | 203 | 204 | 215 | 213 |
| adj_$R^2$ | 10.115 | 28.001 | 30.621 | 31.894 | 32.922 | 33.020 | 33.198 | 33.084 |
| %Change | 0.000 | 17.886 | 2.620 | 1.273 | 1.028 | 0.098 | 0.177 | -0.114 |

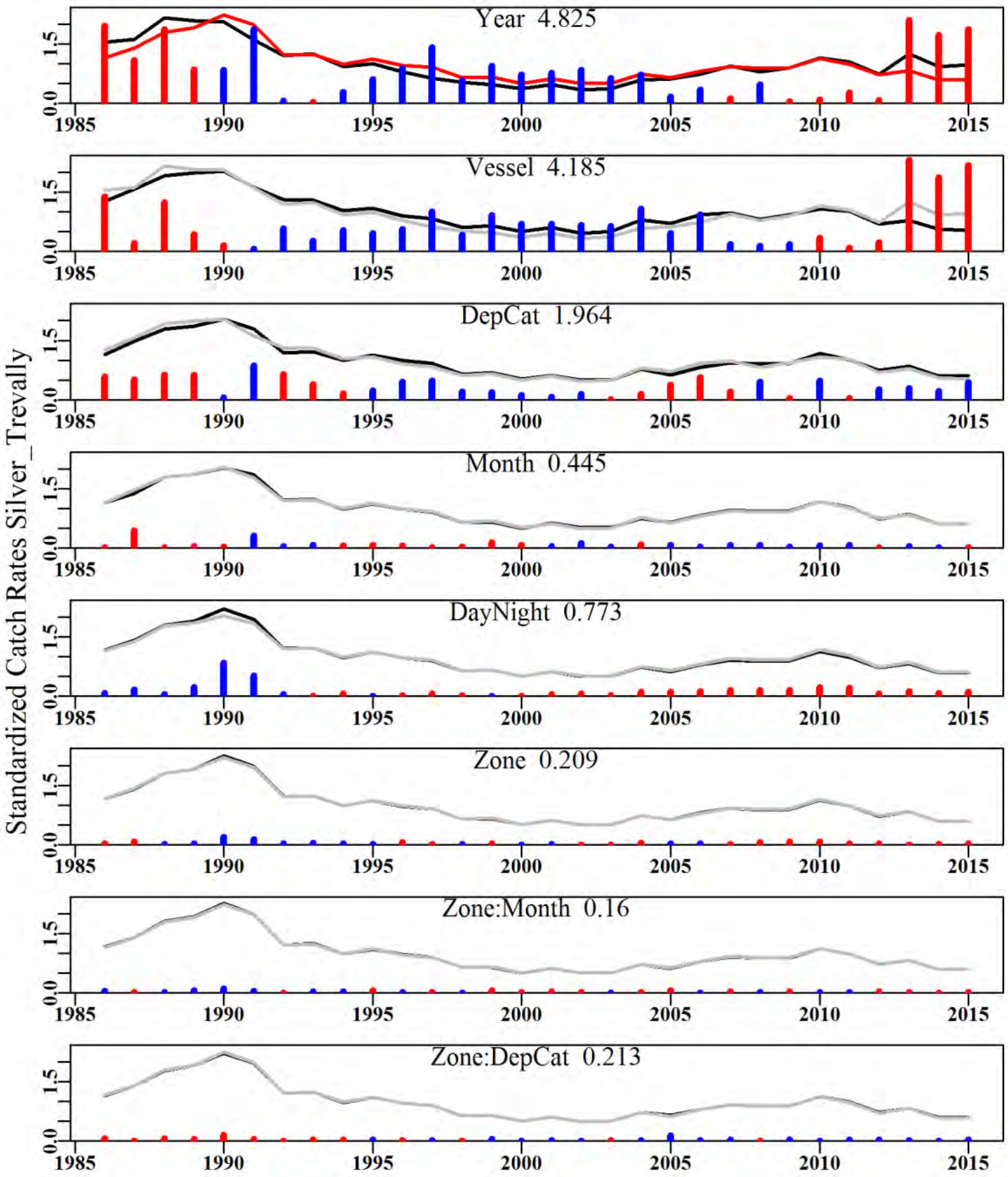



Figure 8.41. The relative influence of each factor used on the final trend in the optimal standardization for Silver Trevally in zones 10 and 20. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by the vertical bars with blue bars indicating the optimum model is higher than the geometric mean and red bars indicating it is lower. The top graph bars are the sum of all the bars in the graphs below. The graphs for individual factors are cumulative. Thus the second graph has the geometric mean (grey line) and the effect of adding Year + factor2 (Model 2). In the third graph, the grey line represents Model 2 and the black line the effect of adding factor3 to the model. The remaining graphs continue in the same cumulative manner except for the interaction terms which are added singularly to the final single factor model.

### 8.4.14 *Silver Trevally – 37337062 (TREAlternative Treatments of the MPA)*

The current Tier 4 analysis uses all the Silver Trevally catches but the catch rates relate only to records taken outside the MPA. It has been proposed to run the Tier 4 in three ways, 1) All catches and CPUE from outside the MPA, 2) all catches and CPUE from all records inside and outside the MPA, and 3) catches and CPUE from records outside the MPA. This means a further CPUE analysis using all available records for the CPUE is required.

Table 8.40. Silver Trevally from Zones 10 and 20 in depths 0 to 200 m, including all data taken in State waters (Bateman's Bay MPA). Total catch (TotCatch; t) is the total reported in the database, number of records used in the analysis (Records), reported catch (CatchT; t) in the area and depth used in the analysis and number of vessels used in the analysis (Vessels). GeoMean is the geometric mean of catch rates (kg/hr). The optimum model is Zone:Month and standard deviation (StDev) relates to the data in the optimum model.

| Year | TotCatch | Records | CatchT | Vessels | GeoMean | Zone:Month | StDev |
|---|---|---|---|---|---|---|---|
| 1986 | 469.5080 | 1976 | 306.2840 | 74 | 17.5398 | 1.0756 | 0.0000 |
| 1987 | 198.4900 | 1259 | 134.9090 | 64 | 17.4100 | 1.2693 | 0.0573 |
| 1988 | 278.5410 | 1582 | 243.9510 | 56 | 20.1927 | 1.4518 | 0.0522 |
| 1989 | 376.1960 | 2196 | 332.8420 | 62 | 24.3012 | 1.8486 | 0.0483 |
| 1990 | 450.3910 | 2101 | 349.0320 | 53 | 24.1445 | 2.1736 | 0.0496 |
| 1991 | 340.6830 | 2225 | 251.6620 | 50 | 18.0432 | 1.8847 | 0.0501 |
| 1992 | 296.4930 | 1711 | 255.6020 | 45 | 14.4696 | 1.1501 | 0.0529 |
| 1993 | 377.6730 | 2279 | 282.0230 | 49 | 15.1303 | 1.1564 | 0.0499 |
| 1994 | 392.8280 | 3299 | 360.8900 | 48 | 12.9941 | 0.9823 | 0.0467 |
| 1995 | 413.4390 | 3342 | 379.2420 | 48 | 14.3443 | 1.1131 | 0.0464 |
| 1996 | 340.6160 | 3233 | 315.3390 | 54 | 10.9106 | 1.0087 | 0.0469 |
| 1997 | 328.8385 | 2868 | 297.5130 | 56 | 11.5187 | 0.9862 | 0.0480 |
| 1998 | 210.1360 | 2281 | 177.4570 | 46 | 9.4406 | 0.7516 | 0.0495 |
| 1999 | 166.0182 | 1856 | 115.1350 | 45 | 8.3688 | 0.7344 | 0.0519 |
| 2000 | 154.7527 | 2009 | 122.6470 | 48 | 6.0450 | 0.5687 | 0.0509 |
| 2001 | 270.1751 | 3236 | 227.9205 | 45 | 7.6394 | 0.6847 | 0.0465 |
| 2002 | 232.7870 | 2777 | 209.1290 | 44 | 5.9953 | 0.6442 | 0.0482 |
| 2003 | 337.8967 | 2761 | 281.9697 | 49 | 8.0171 | 0.6870 | 0.0479 |
| 2004 | 458.0749 | 3338 | 367.6270 | 45 | 10.6787 | 0.8404 | 0.0467 |
| 2005 | 290.9402 | 2324 | 242.1420 | 43 | 11.1271 | 0.7310 | 0.0500 |
| 2006 | 247.2843 | 1687 | 209.1645 | 39 | 13.2846 | 0.7949 | 0.0531 |
| 2007 | 172.7180 | 835 | 115.5430 | 21 | 11.8089 | 0.7691 | 0.0644 |
| 2008 | 128.3861 | 1065 | 95.8960 | 23 | 9.1077 | 0.8848 | 0.0602 |
| 2009 | 164.0519 | 1152 | 136.0260 | 23 | 10.5189 | 0.8822 | 0.0588 |
| 2010 | 240.2269 | 1264 | 191.9942 | 24 | 13.7770 | 1.1387 | 0.0577 |
| 2011 | 193.4736 | 1125 | 179.4593 | 20 | 12.5672 | 0.9752 | 0.0594 |
| 2012 | 139.6903 | 966 | 131.5530 | 21 | 11.0919 | 0.7677 | 0.0617 |
| 2013 | 122.7757 | 723 | 112.8740 | 20 | 16.1023 | 0.8225 | 0.0669 |
| 2014 | 106.3265 | 890 | 98.1320 | 20 | 12.0879 | 0.6244 | 0.0630 |
| 2015 | 67.9840 | 515 | 62.3410 | 21 | 11.6200 | 0.5980 | 0.0754 |

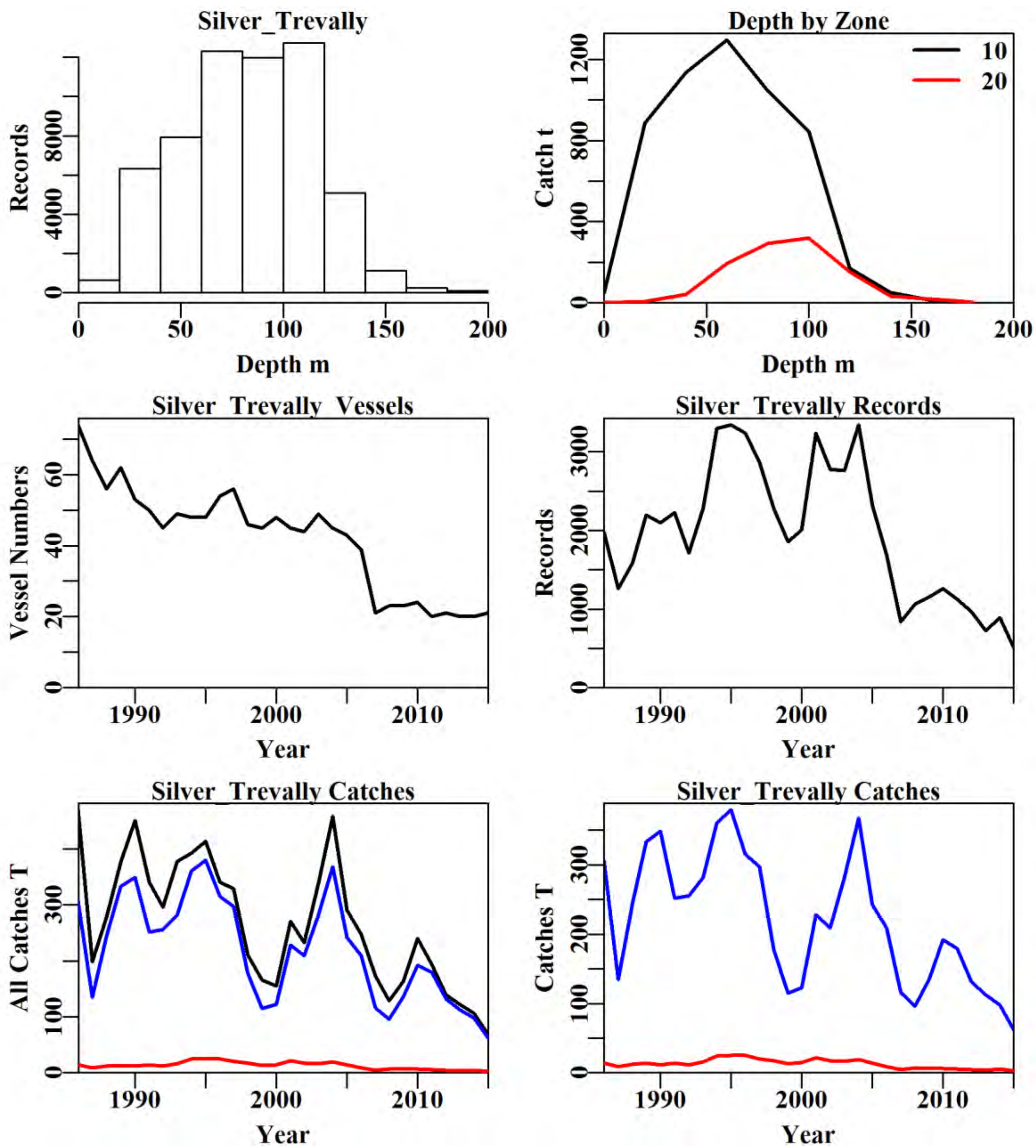



Figure 8.42. Silver Trevally from Zones 10 and 20 in depths 0 to 200 m, including all from State waters (Bateman's Bay MPA). The top left plot depicts the depth distribution of shots containing Silver Trevally from zones 10 and 20 in depths 0 to 200 m by Trawl, including data from State waters (Bateman's Bay MPA). The top right plot depicts the catch distribution by depth within zones 10 and 20 (20 is bottom red line). The middle left plot depicts the number of vessels through time and middle right plot contains the number of records used in analysis. The bottom left plot contains Silver Trevally catches (top black line: total catches, middle blue line: catches used in the analysis; bottom red line: catches < 30 kg) and bottom right plot contains Silver Trevally catches (blue line: catches used in the analysis; red line: catches < 30 kg).

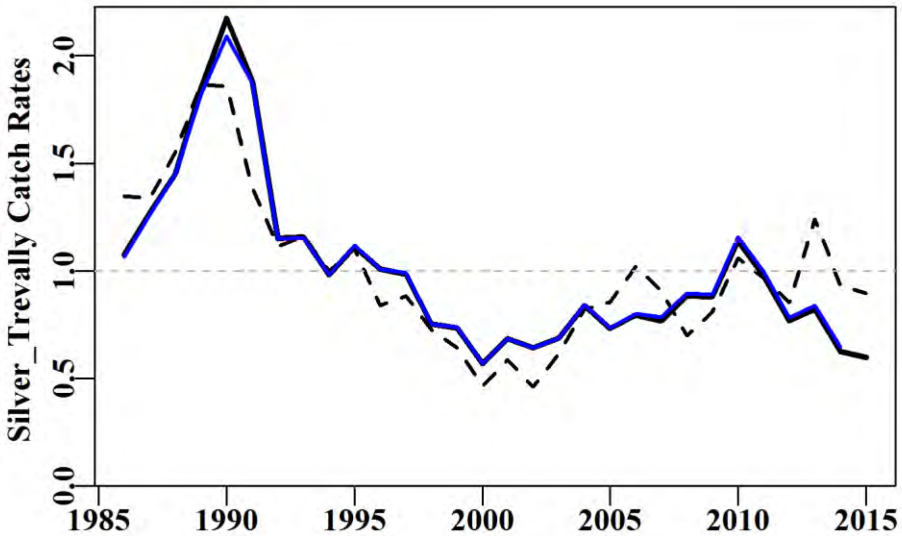



Figure 8.43. Silver Trevally from zones 10 and 20 in depths 0 to 200 m, including data from State waters (Bateman's Bay MPA). The dashed black line represents the geometric mean catch rate and the solid black line the standardized catch rates (relative to the mean of the standardized catch rates). The blue line corresponds to last year's standardized indices.

Table 8.41. Silver Trevally from zones 10 and 20 in depths 0 to 200 m, including data from State waters (Bateman's Bay MPA). Statistical model structures used in this analysis. DepCat is a series of 20 metre depth categories.

| | |
|---|---|
| Model 1 | LnCE~Year |
| Model 2 | LnCE~Year+Vessel |
| Model 3 | LnCE~Year+Vessel+DepCat |
| Model 4 | LnCE~Year+Vessel+DepCat+Month |
| Model 5 | LnCE~Year+Vessel+DepCat+Month+DayNight |
| Model 6 | LnCE~Year+Vessel+DepCat+Month+DayNight+Zone |
| Model 7 | LnCE~Year+Vessel+DepCat+Month+DayNight+Zone+Zone:Month |
| Model 8 | LnCE~Year+Vessel+DepCat+Month+DayNight+Zone+Zone:DepCat |

Table 8.42. Silver Trevally from Zones 10 and 20 in depths 0 to 200 m, excluding data taken in State waters (Bateman's Bay MPA). Model selection criteria include the Akaike Information Criterion (AIC), residual sum of squares (RSS), model sum of squares (MSS), number of usable observations (Nobs), number of parameters (Npars), adjusted $R^2$ (adj_$R^2$) and the change in adjusted $R^2$ (%Change). The optimum model is Model 7 (Zone:Month). Depth category: DepC.

| | Year | Vessel | DepC | Month | DayNight | Zone | Zone:Mth | Zone:DepC |
|---|---|---|---|---|---|---|---|---|
| AIC | 61888 | 48070 | 44517 | 43809 | 42992 | 42961 | 42814 | 42931 |
| RSS | 168270 | 132380 | 124351 | 122808 | 121091 | 121023 | 120673 | 120923 |
| MSS | 7756 | 43646 | 51674 | 53218 | 54935 | 55003 | 55353 | 55103 |
| Nobs | 58875 | 58875 | 58424 | 58424 | 58424 | 58424 | 58424 | 58424 |
| Npars | 30 | 183 | 192 | 203 | 206 | 207 | 218 | 216 |
| adj_$R^2$ | 4.359 | 24.562 | 29.124 | 29.991 | 30.966 | 31.004 | 31.190 | 31.050 |
| %Change | 0.000 | 20.203 | 4.562 | 0.866 | 0.975 | 0.038 | 0.186 | -0.140 |

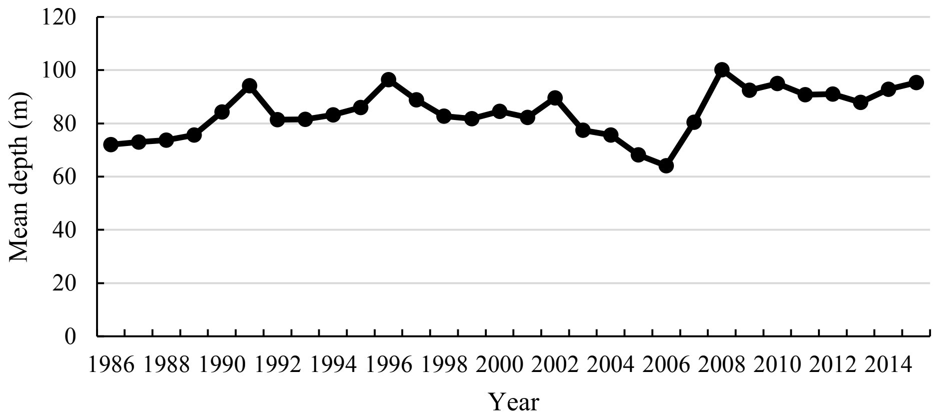



Figure 8.44. Average reported depth of trawling for Silver Trevally from Zones 10 and 20 in depths 0 to 200 m, including data from State waters (Bateman's Bay MPA). The effect of the introduction of the Bateman's Bay MPA in increasing the average depth fished is apparent from 2008 onwards.

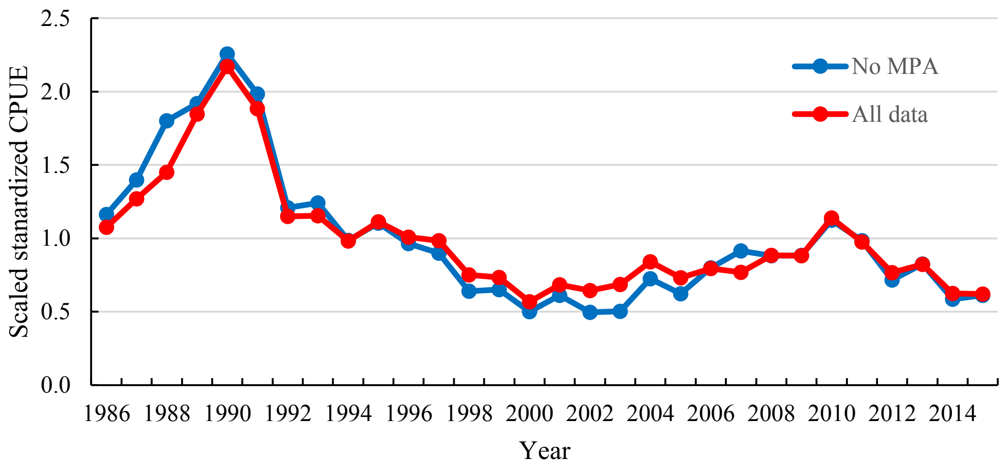



Figure 8.45. Comparison of the CPUE series with and without the data from inside the MPA. The All data series is less variable than the series that excludes data from the MPA.

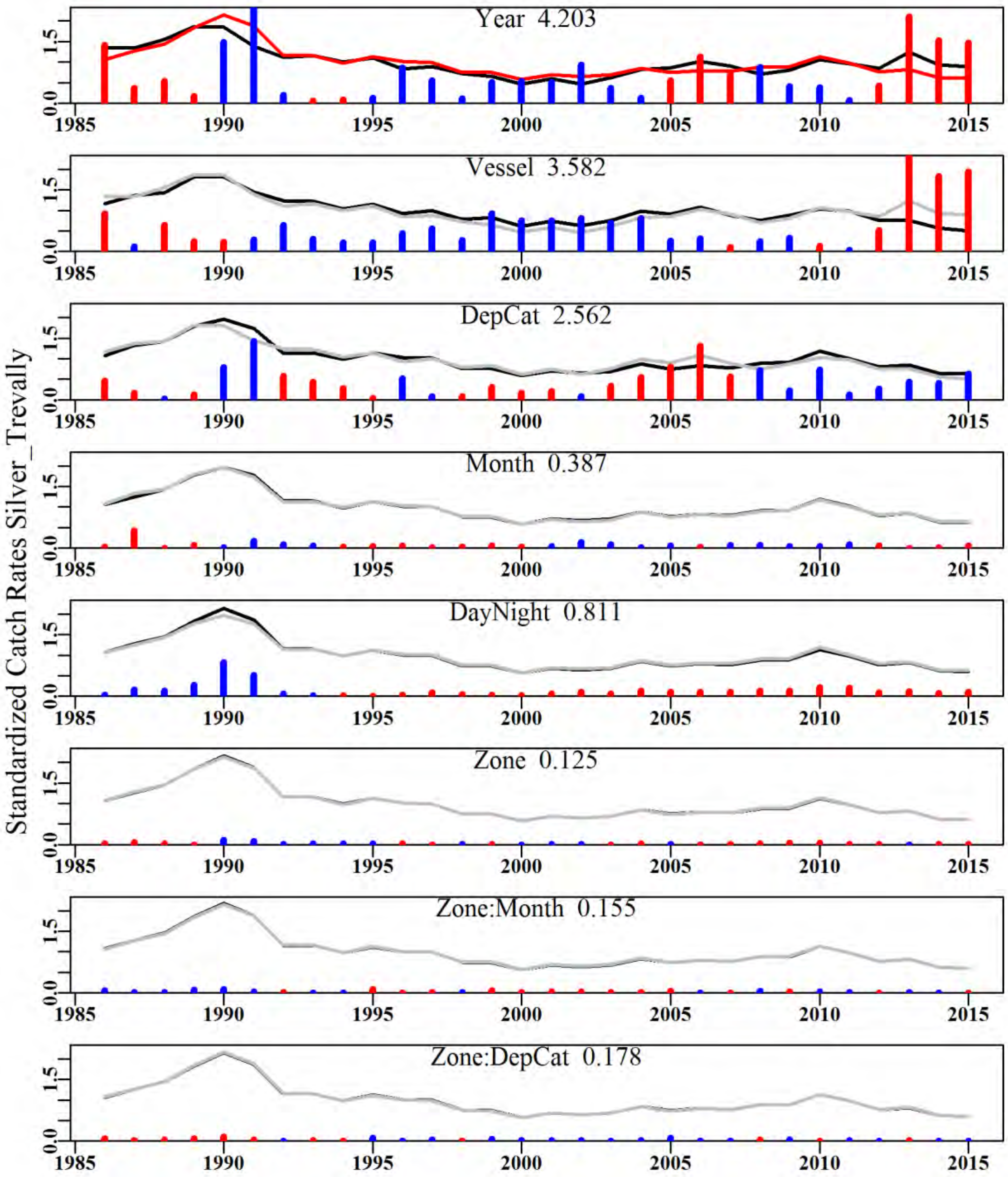



Figure 8.46. The relative influence of each factor used on the final trend in the optimal standardization for Silver Trevally in zones 10 and 20 (including MPA records). The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by the vertical bars with blue bars indicating the optimum model is higher than the geometric mean and red bars indicating it is lower. The top graph bars are the sum of all the bars in the graphs below. The graphs for individual factors are cumulative. Thus the second graph has the geometric mean (grey line) and the effect of adding Year + factor2 (Model 2). In the third graph, the grey line represents Model 2 and the black line the effect of adding factor3 to the model. The remaining graphs continue in the same cumulative manner except for the interaction terms which are added singularly to the final single factor model.

### 8.4.15 *Royal Red Prawn (PRR – 28714005 – Haliporoides sibogae)*

Trawl data selected for analysis corresponded to records from zone 10 in depths between 200 – 700 m.

Table 8.43. Royal Red Prawn from zone 10 in depths 200 – 700 m by Trawl. Total catch (TotCatch; t) is the total reported in the database, number of records used in the analysis (Records), reported catch (CatchT; t) in the area and depth used in the analysis and number of vessels used in the analysis (Vessels). GeoMean is the geometric mean of catch rates (kg/hr). The optimum model is Month:DepC and standard deviation (StDev) relates to the data in the optimum model.

| Year | TotCatch | Records | CatchT | Vessels | GeoMean | Month:DepC | StDev |
|---|---|---|---|---|---|---|---|
| 1986 | 277.7170 | 1592 | 231.8440 | 47 | 71.7065 | 0.7001 | 0.0000 |
| 1987 | 351.2940 | 1764 | 324.7160 | 47 | 93.0098 | 0.8947 | 0.0382 |
| 1988 | 362.5050 | 1395 | 344.4570 | 41 | 124.6161 | 0.9791 | 0.0412 |
| 1989 | 329.2540 | 1143 | 310.7600 | 39 | 139.2891 | 0.8409 | 0.0431 |
| 1990 | 337.1340 | 727 | 311.1180 | 25 | 174.4921 | 1.5841 | 0.0496 |
| 1991 | 334.1340 | 734 | 299.3700 | 29 | 182.9425 | 1.3996 | 0.0504 |
| 1992 | 166.8600 | 434 | 146.0810 | 19 | 166.4494 | 1.0234 | 0.0586 |
| 1993 | 298.7970 | 673 | 232.7740 | 21 | 172.5386 | 1.2238 | 0.0500 |
| 1994 | 359.8303 | 661 | 240.3630 | 26 | 170.4137 | 1.1783 | 0.0502 |
| 1995 | 335.5920 | 1070 | 252.9050 | 25 | 105.0529 | 0.9175 | 0.0440 |
| 1996 | 360.7760 | 1216 | 272.6750 | 25 | 95.4163 | 0.8147 | 0.0425 |
| 1997 | 252.6930 | 855 | 166.7030 | 21 | 86.8573 | 0.7715 | 0.0467 |
| 1998 | 233.2980 | 1234 | 190.7320 | 23 | 67.9917 | 0.7929 | 0.0430 |
| 1999 | 367.0420 | 1607 | 348.8040 | 25 | 84.2022 | 0.8152 | 0.0409 |
| 2000 | 434.9308 | 1540 | 398.6840 | 27 | 127.1453 | 1.0164 | 0.0412 |
| 2001 | 276.7855 | 1314 | 229.5490 | 22 | 76.3486 | 0.8416 | 0.0433 |
| 2002 | 484.2085 | 1740 | 417.3700 | 23 | 131.5076 | 1.0520 | 0.0404 |
| 2003 | 230.8050 | 801 | 163.1840 | 26 | 115.5988 | 1.0379 | 0.0493 |
| 2004 | 193.8510 | 579 | 170.6810 | 22 | 207.4067 | 1.0812 | 0.0540 |
| 2005 | 173.8960 | 601 | 159.8050 | 21 | 153.2133 | 0.9879 | 0.0539 |
| 2006 | 192.2620 | 455 | 178.5790 | 17 | 297.7054 | 1.2025 | 0.0585 |
| 2007 | 121.5453 | 324 | 116.4300 | 9 | 252.8144 | 0.7996 | 0.0665 |
| 2008 | 75.7990 | 252 | 70.6050 | 8 | 221.0994 | 0.6954 | 0.0748 |
| 2009 | 68.7850 | 250 | 67.6070 | 9 | 158.9600 | 0.8903 | 0.0790 |
| 2010 | 96.7650 | 343 | 82.8210 | 9 | 138.3098 | 0.8581 | 0.0664 |
| 2011 | 110.9230 | 291 | 108.9600 | 8 | 206.3570 | 1.3081 | 0.0708 |
| 2012 | 126.5190 | 363 | 122.7770 | 9 | 169.2764 | 0.9949 | 0.0654 |
| 2013 | 212.1670 | 428 | 208.2470 | 9 | 286.9174 | 1.2637 | 0.0690 |
| 2014 | 121.7380 | 351 | 118.5350 | 11 | 176.3687 | 1.0048 | 0.0664 |
| 2015 | 125.8350 | 345 | 119.7550 | 8 | 219.9117 | 1.0298 | 0.0694 |

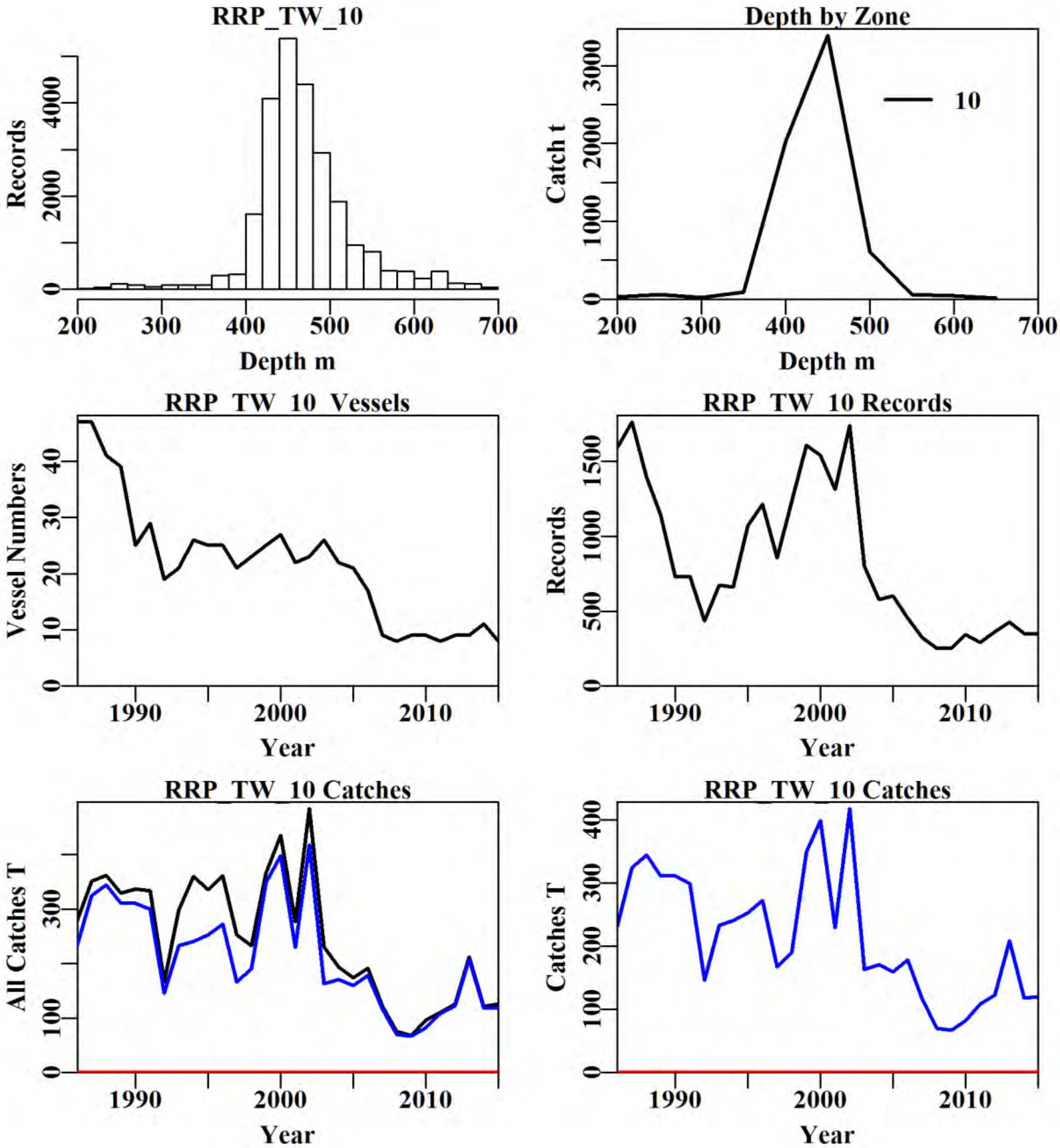



Figure 8.47. Royal Red Prawn from zone 10 in depths 200 – 700m by Trawl. The top left plot depicts the depth distribution of shots containing Royal red Prawn from zone 10 in depths 200 to 700 m by Trawl. The top right plot depicts the catch distribution by depth within zone 10. The middle left plot depicts the number of vessels through time and middle right plot contains the number of records used in analysis. The bottom left plot contains Royal Red Prawn catches (top black line: total catches, middle blue line: catches used in the analysis; bottom red line: catches < 30 kg) and bottom right plot contains Royal Red Prawn catches (blue line: catches used in the analysis; red line: catches < 30 kg).

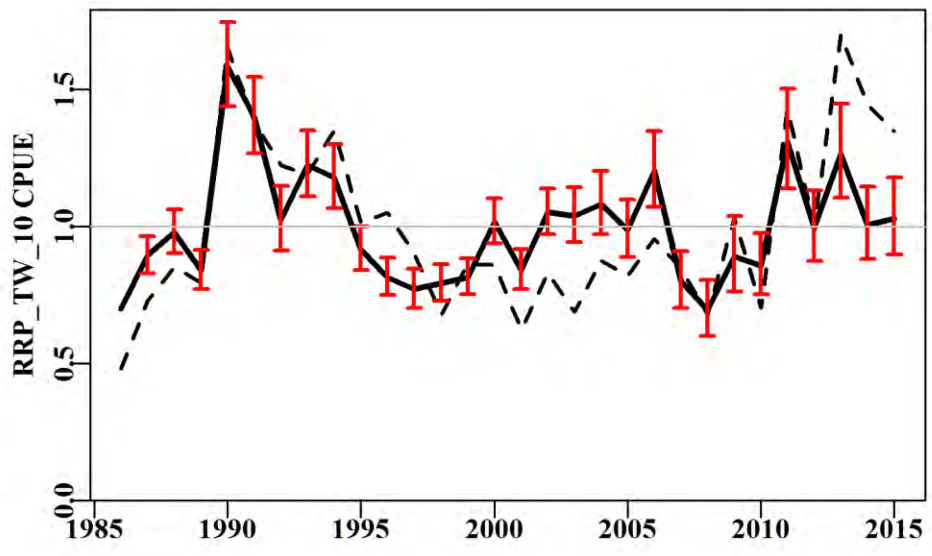



Figure 8.48. Royal Red Prawn from zone 10 in depths 200 – 700 m by Trawl. Standardized catch rates (solid black line), 95% CI (vertical lines) and geometric mean (dashed black line).

Table 8.44. Royal Red Prawn from zone 10 in depths 200 – 700 m by Trawl. Statistical model structures used in this analysis. DepCat is a series of 20 metre depth categories.

| | |
|---|---|
| Model 1 | LnCE~Year |
| Model 2 | LnCE~Year+DepCat |
| Model 3 | LnCE~Year+DepCat+Vessel |
| Model 4 | LnCE~Year+DepCat+Vessel+Month |
| Model 5 | LnCE~Year+DepCat+Vessel+Month+DayNight |
| Model 6 | LnCE~Year+DepCat+Vessel+Month+DayNight+DayNight:DepCat |
| Model 7 | LnCE~Year+DepCat+Vessel+Month+DayNight+Month:DepCat |
| Model 8 | LnCE~Year+DepCat+Vessel+Month+DayNight+DayNight:DepCat |

Table 8.45. Royal Red Prawn from zone 10 in depths 200 – 700 m by Trawl. Model selection criteria include the Akaike Information Criterion (AIC), residual sum of squares (RSS), model sum of squares (MSS), number of usable observations (Nobs), number of parameters (Npars), adjusted $R^2$ (adj_$R^2$) and the change in adjusted $R^2$ (%Change). The optimum was Model 7: Month:DepC. Depth category: DepC; DayNight: DN.

| | Year | DepC | Vessel | Month | DN | DN:Month | Month:DepC | DN:DepC |
|---|---|---|---|---|---|---|---|---|
| AIC | 14037 | 9671 | 3865 | 2074 | 1881 | 1876 | 1450 | 1782 |
| RSS | 43790 | 36630 | 28820 | 26799 | 26585 | 26510 | 25923 | 26423 |
| MSS | 2124 | 9283 | 17093 | 19114 | 19328 | 19403 | 19990 | 19490 |
| Nobs | 25082 | 24930 | 24930 | 24930 | 24930 | 24930 | 24930 | 24930 |
| Npars | 30 | 39 | 125 | 136 | 139 | 172 | 238 | 166 |
| adj_$R^2$ | 4.515 | 20.097 | 36.916 | 41.313 | 41.775 | 41.861 | 42.997 | 42.067 |
| %Change | 0.000 | 15.582 | 16.818 | 4.397 | 0.462 | 0.086 | 1.136 | -0.930 |

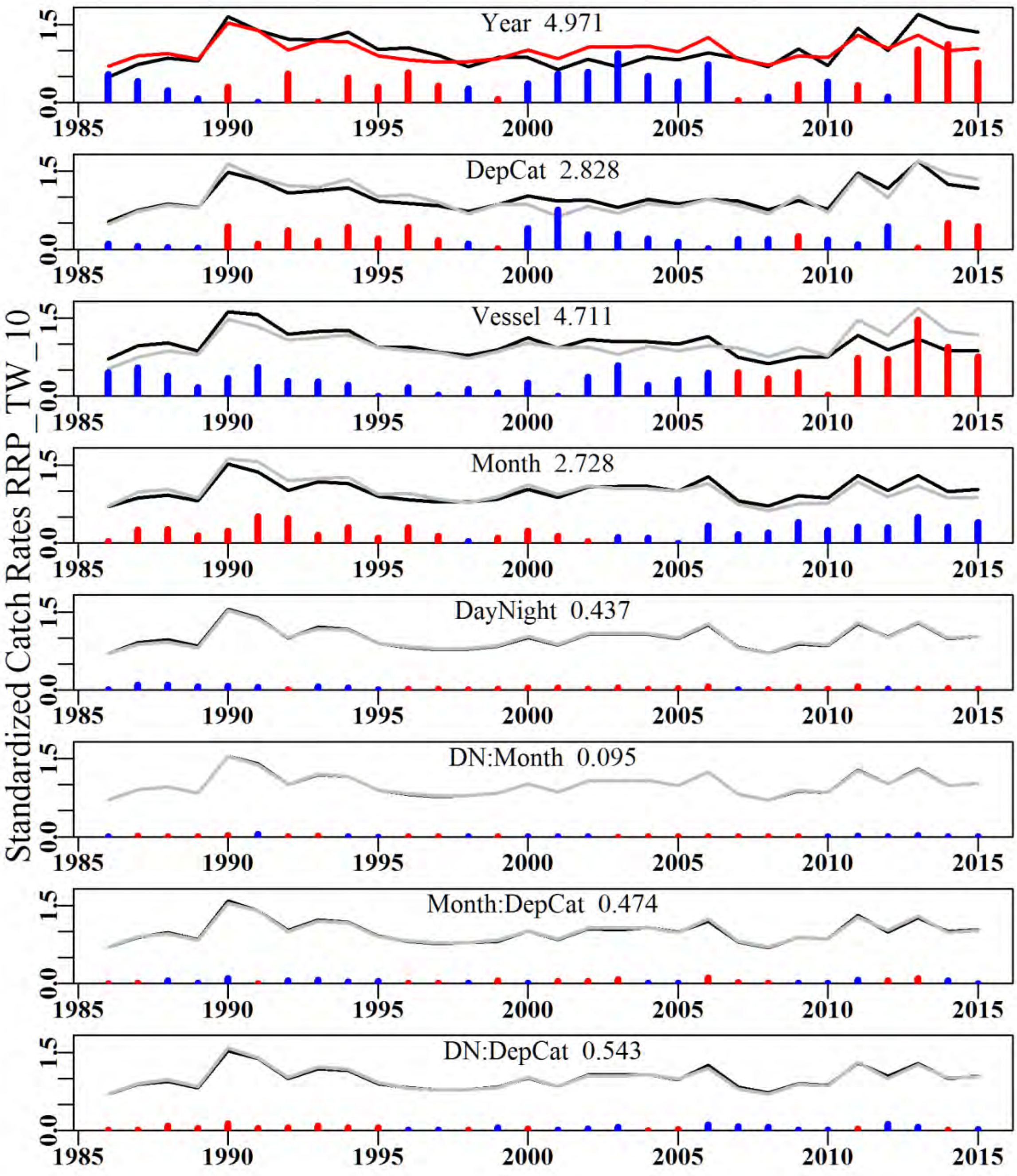



Figure 8.49. The relative influence of each factor used on the final trend in the optimal standardization for Royal Red Prawn in zone 10. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by the vertical bars with blue bars indicating the optimum model is higher than the geometric mean and red bars indicating it is lower. The top graph bars are the sum of all the bars in the graphs below. The graphs for individual factors are cumulative. Thus the second graph has the geometric mean (grey line) and the effect of adding Year + factor2 (Model 2). In the third graph, the grey line represents Model 2 and the black line the effect of adding factor3 to the model. The remaining graphs continue in the same cumulative manner except for the interaction terms which are added singularly to the final single factor model.

### 8.4.16 *Blue Eye Trevalla Z20-50 (TBE – 37445001 – Hyperoglyphe antarctica)*

Trawl data from zones 20, 30, 40 and 50 and depths less than 1000 m were analysed.

Table 8.46. Blue Eye Trevalla from zones 20, 30, 40 and 50 in depths 0 – 1000 m by Trawl. Total catch (TotCatch; t) is the total reported in the database, number of records used in the analysis (Records), reported catch (CatchT; t) in the area and depth used in the analysis and number of vessels used in the analysis (Vessels). GeoMean is the geometric mean of catch rates (kg/hr). The optimum model is Zone:DepC and standard deviation (StDev) relates to the data in the optimum model.

| Year | TotCatch | Records | CatchT | Vessels | GeoMean | Zone:DepC | StDev |
|---|---|---|---|---|---|---|---|
| 1986 | 37.9620 | 360 | 25.0720 | 34 | 24.6441 | 1.6980 | 0.0000 |
| 1987 | 15.4950 | 246 | 13.1710 | 27 | 18.1060 | 1.6435 | 0.1054 |
| 1988 | 105.1770 | 449 | 95.8430 | 33 | 66.8545 | 2.6081 | 0.0977 |
| 1989 | 88.0660 | 551 | 77.2410 | 51 | 58.3218 | 2.6560 | 0.0955 |
| 1990 | 79.2980 | 421 | 70.7550 | 50 | 82.3640 | 3.3408 | 0.1016 |
| 1991 | 76.0240 | 602 | 47.8930 | 49 | 23.9199 | 1.9238 | 0.0961 |
| 1992 | 49.3050 | 442 | 42.8750 | 36 | 54.1822 | 1.6874 | 0.1010 |
| 1993 | 59.6540 | 1020 | 55.8080 | 44 | 18.6846 | 1.1495 | 0.0915 |
| 1994 | 109.9750 | 1202 | 105.2900 | 45 | 30.7446 | 1.2590 | 0.0908 |
| 1995 | 58.5720 | 986 | 54.6590 | 39 | 14.6967 | 0.8538 | 0.0922 |
| 1996 | 71.6840 | 1167 | 65.6070 | 46 | 17.3499 | 0.7691 | 0.0914 |
| 1997 | 471.4664 | 1390 | 102.2800 | 44 | 16.4663 | 0.7504 | 0.0909 |
| 1998 | 475.9652 | 1251 | 77.6040 | 39 | 13.3570 | 0.9009 | 0.0920 |
| 1999 | 574.4838 | 1508 | 88.0240 | 40 | 13.0810 | 0.8997 | 0.0906 |
| 2000 | 667.0558 | 1766 | 82.3900 | 50 | 11.4731 | 0.6836 | 0.0895 |
| 2001 | 647.5307 | 1669 | 68.7090 | 44 | 10.2481 | 0.6221 | 0.0901 |
| 2002 | 843.8591 | 1503 | 66.0295 | 45 | 13.2793 | 0.5466 | 0.0907 |
| 2003 | 605.3019 | 1113 | 25.0763 | 42 | 7.1185 | 0.5031 | 0.0927 |
| 2004 | 606.2500 | 1475 | 46.4366 | 42 | 10.9467 | 0.4689 | 0.0912 |
| 2005 | 755.1858 | 1010 | 30.6695 | 36 | 11.4233 | 0.4639 | 0.0937 |
| 2006 | 573.7189 | 860 | 53.0610 | 29 | 16.9679 | 0.5139 | 0.0945 |
| 2007 | 937.1424 | 785 | 36.7948 | 22 | 11.9171 | 0.4901 | 0.0956 |
| 2008 | 398.9433 | 758 | 30.0251 | 21 | 20.9032 | 0.5531 | 0.0959 |
| 2009 | 520.8777 | 589 | 38.6428 | 20 | 25.5479 | 0.5277 | 0.0986 |
| 2010 | 437.3987 | 624 | 42.5536 | 21 | 20.6240 | 0.4788 | 0.0981 |
| 2011 | 554.2188 | 608 | 22.5124 | 21 | 8.4139 | 0.4197 | 0.0983 |
| 2012 | 463.8349 | 411 | 10.3400 | 19 | 3.6741 | 0.3644 | 0.1050 |
| 2013 | 398.3768 | 351 | 22.7978 | 22 | 15.5137 | 0.4008 | 0.1068 |
| 2014 | 460.5264 | 336 | 29.2876 | 19 | 29.6746 | 0.4431 | 0.1079 |
| 2015 | 295.0238 | 295 | 25.0471 | 19 | 141.6765 | 0.3802 | 0.1125 |

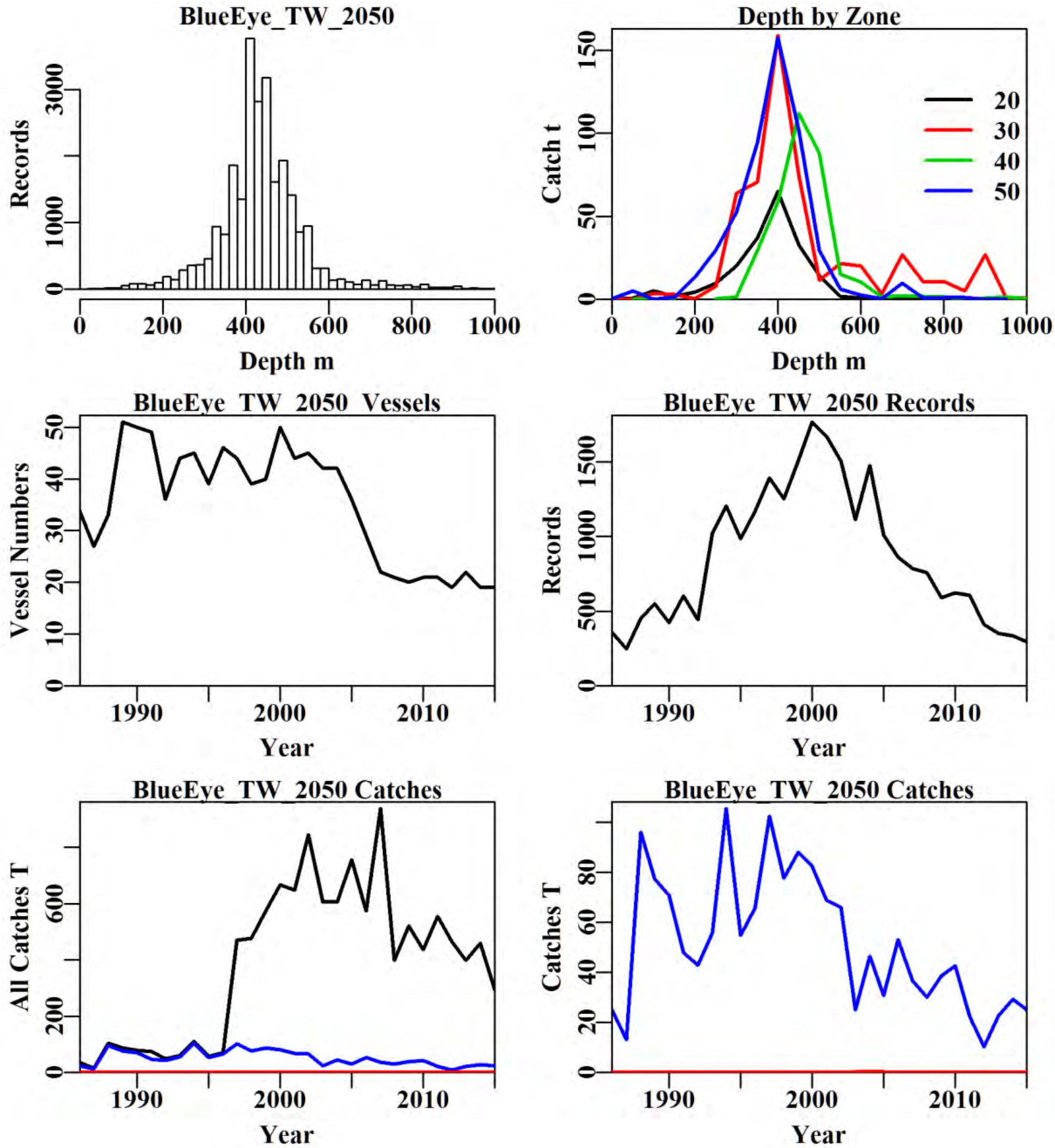



Figure 8.50. Blue Eye Trevalla from zones 20 through to 50 in depths 0 – 1000 m by Trawl. The top left plot depicts the depth distribution of shots containing Blue Eye Trevalla from each zone in depths 0 to 1000 m by Trawl. The top right plot depicts the catch distribution by depth within each zone. The middle left plot depicts the number of vessels through time and middle right plot contains the number of records used in analysis. The bottom left plot contains Blue Eye Trevalla catches (top black line: total catches, middle blue line: catches used in the analysis; bottom red line: catches < 30 kg) and bottom right plot contains Blue Eye Trevalla catches (blue line: catches used in the analysis; red line: catches < 30 kg).

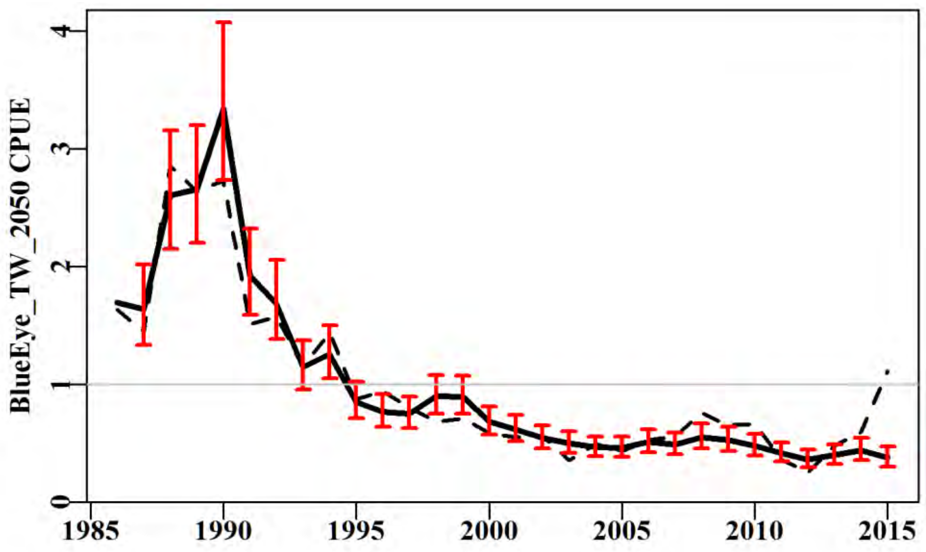



Figure 8.51. Blue Eye Trevalla from zones 20 through to 50 in depths 0 – 1000 m by Trawl. Standardized catch rates (solid black line), 95% CI (vertical lines) and geometric mean (dashed black line). Mean standardized catch rate (grey line).

Table 8.47. Blue Eye Trevalla from zones 20, 30, 40 and 50 in depths 0 – 1000 m by Trawl. Statistical model structures used in this analysis. DepCat is a series of 20 metre depth categories.

| | |
|---|---|
| Model 1 | LnCE~Year |
| Model 2 | LnCE~Year+Vessel |
| Model 3 | LnCE~Year+Vessel+Zone |
| Model 4 | LnCE~Year+Vessel+Zone+DepCat |
| Model 5 | LnCE~Year+Vessel+Zone+DepCat+DayNight |
| Model 6 | LnCE~Year+Vessel+Zone+DepCat+DayNight+Month |
| Model 7 | LnCE~Year+Vessel+Zone+DepCat+DayNight+Month+Zone:Month |
| Model 8 | LnCE~Year+Vessel+Zone+DepCat+DayNight+Month+Zone:DepCat |

Table 8.48. Blue Eye Trevalla from zones 20, 30, 40 and 50 in depths 0 – 1000 m by Trawl. Model selection criteria include the Akaike Information Criterion (AIC), residual sum of squares (RSS), model sum of squares (MSS), number of usable observations (Nobs), number of parameters (Npars), adjusted $R^2$ (adj_$R^2$) and the change in adjusted $R^2$ (%Change). The optimum was Model 8: Zone:DepC. Depth category: DepC.

| | Year | Vessel | Zone | DepC | DayNight | Month | Zone:Month | Zone:DepC |
|---|---|---|---|---|---|---|---|---|
| AIC | 21184 | 10323 | 8720 | 8385 | 8253 | 8109 | 8062 | 7697 |
| RSS | 58485 | 37919 | 35622 | 34972 | 34783 | 34559 | 34406 | 33848 |
| MSS | 6699 | 27264 | 29562 | 30212 | 30401 | 30625 | 30778 | 31336 |
| Nobs | 25748 | 25748 | 25748 | 25604 | 25604 | 25604 | 25604 | 25604 |
| Npars | 30 | 178 | 181 | 201 | 204 | 215 | 248 | 275 |
| adj_$R^2$ | 10.176 | 41.424 | 44.968 | 45.927 | 46.212 | 46.536 | 46.703 | 47.511 |
| %Change | 0.000 | 31.248 | 3.543 | 0.959 | 0.285 | 0.324 | 0.167 | 0.809 |

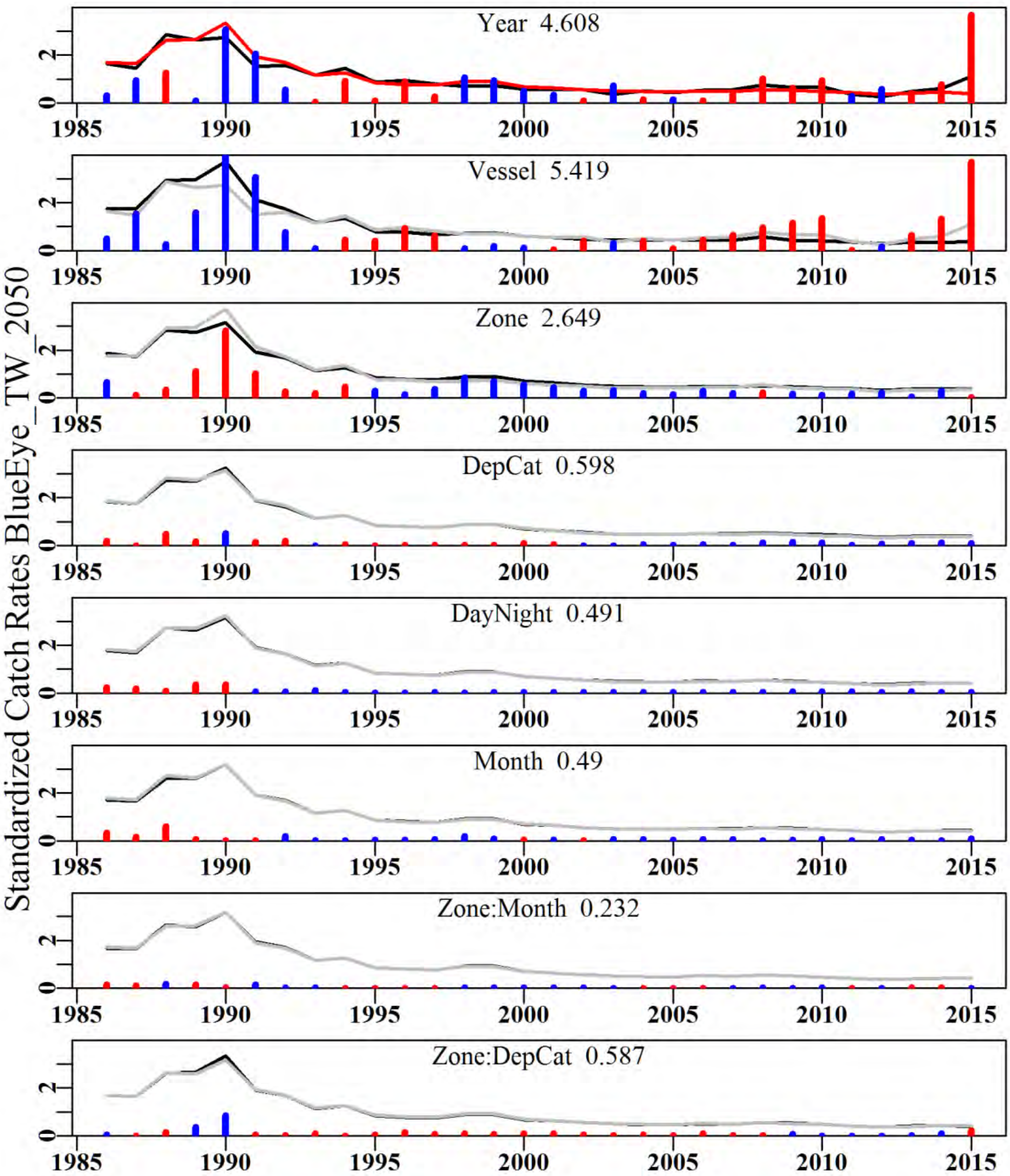



Figure 8.52. The relative influence of each factor used on the final trend in the optimal standardization for Blue Eye Trevalla in zones 20 – 50. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by the vertical bars with blue bars indicating the optimum model is higher than the geometric mean and red bars indicating it is lower. The top graph bars are the sum of all the bars in the graphs below. The graphs for individual factors are cumulative. Thus the second graph has the geometric mean (grey line) and the effect of adding Year + factor2 (Model 2). In the third graph, the grey line represents Model 2 and the black line the effect of adding factor3 to the model. The remaining graphs continue in the same cumulative manner except for the interaction terms which are added singularly to the final single factor model.

### 8.4.17 *Blue Eye Trevalla Z2030 (TBE – 37445001 – Hyperoglyphe antarctica)*

Trawl data from zones 20, 30 and depths less than 1000 m were analysed.

Table 8.49. Blue Eye Trevalla from zones 20, 30 in depths 0 – 1000 m by Trawl. Total catch (TotCatch; t) is the total reported in the database, number of records used in the analysis (Records), reported catch (CatchT; t) in the area and depth used in the analysis and number of vessels used in the analysis (Vessels). GeoMean is the geometric mean of catch rates (kg/hr). The optimum model is Zone:DepC and standard deviation (StDev) relates to the data in the optimum model.

| Year | TotCatch | Records | CatchT | Vessels | GeoMean | Zone:DepC | StDev |
|---|---|---|---|---|---|---|---|
| 1986 | 37.9620 | 166 | 9.1170 | 17 | 10.0553 | 2.2460 | 0.0000 |
| 1987 | 15.4950 | 190 | 10.0260 | 14 | 9.8390 | 2.0967 | 0.1373 |
| 1988 | 105.1770 | 307 | 19.4330 | 21 | 14.4132 | 2.6542 | 0.1299 |
| 1989 | 88.0660 | 313 | 33.2560 | 32 | 14.6076 | 2.9716 | 0.1324 |
| 1990 | 79.2980 | 264 | 39.8450 | 36 | 24.1892 | 3.7996 | 0.1348 |
| 1991 | 76.0240 | 474 | 29.1890 | 37 | 9.3594 | 2.0068 | 0.1270 |
| 1992 | 49.3050 | 313 | 14.2320 | 23 | 8.3976 | 1.4946 | 0.1341 |
| 1993 | 59.6540 | 731 | 37.6990 | 31 | 8.0165 | 1.2192 | 0.1241 |
| 1994 | 109.9750 | 854 | 89.0080 | 33 | 10.7333 | 1.3858 | 0.1234 |
| 1995 | 58.5720 | 486 | 28.2780 | 29 | 5.8486 | 0.9303 | 0.1282 |
| 1996 | 71.6840 | 644 | 35.4230 | 29 | 5.7724 | 0.7454 | 0.1258 |
| 1997 | 471.4664 | 602 | 19.9090 | 31 | 4.6913 | 0.6814 | 0.1278 |
| 1998 | 475.9652 | 471 | 18.6580 | 24 | 4.1372 | 0.7916 | 0.1301 |
| 1999 | 574.4838 | 631 | 41.7210 | 27 | 3.6101 | 0.8100 | 0.1269 |
| 2000 | 667.0558 | 657 | 37.6610 | 34 | 2.7104 | 0.5178 | 0.1247 |
| 2001 | 647.5307 | 700 | 25.1710 | 24 | 2.2528 | 0.4547 | 0.1250 |
| 2002 | 843.8591 | 700 | 33.7320 | 28 | 3.0245 | 0.4505 | 0.1269 |
| 2003 | 605.3020 | 722 | 14.0635 | 25 | 2.2528 | 0.4513 | 0.1263 |
| 2004 | 606.2500 | 623 | 15.1709 | 28 | 2.7224 | 0.4447 | 0.1279 |
| 2005 | 755.1858 | 502 | 17.9194 | 26 | 2.6091 | 0.4438 | 0.1311 |
| 2006 | 573.7189 | 327 | 36.7820 | 17 | 3.9453 | 0.5463 | 0.1353 |
| 2007 | 937.1424 | 247 | 10.6065 | 11 | 3.1151 | 0.4335 | 0.1411 |
| 2008 | 398.9433 | 434 | 13.6537 | 15 | 5.6341 | 0.4118 | 0.1346 |
| 2009 | 520.8777 | 246 | 22.8489 | 14 | 5.4891 | 0.3950 | 0.1423 |
| 2010 | 437.3987 | 197 | 11.5432 | 13 | 3.3742 | 0.2659 | 0.1476 |
| 2011 | 554.2188 | 227 | 7.8041 | 12 | 2.1952 | 0.2792 | 0.1445 |
| 2012 | 463.8349 | 150 | 1.3334 | 11 | 1.6617 | 0.2466 | 0.1540 |
| 2013 | 398.3268 | 147 | 4.1109 | 11 | 3.6018 | 0.2242 | 0.1557 |
| 2014 | 460.1404 | 120 | 20.5533 | 11 | 7.7831 | 0.2984 | 0.1629 |
| 2015 | 294.6678 | 189 | 22.3964 | 14 | 17.4973 | 0.3032 | 0.1533 |

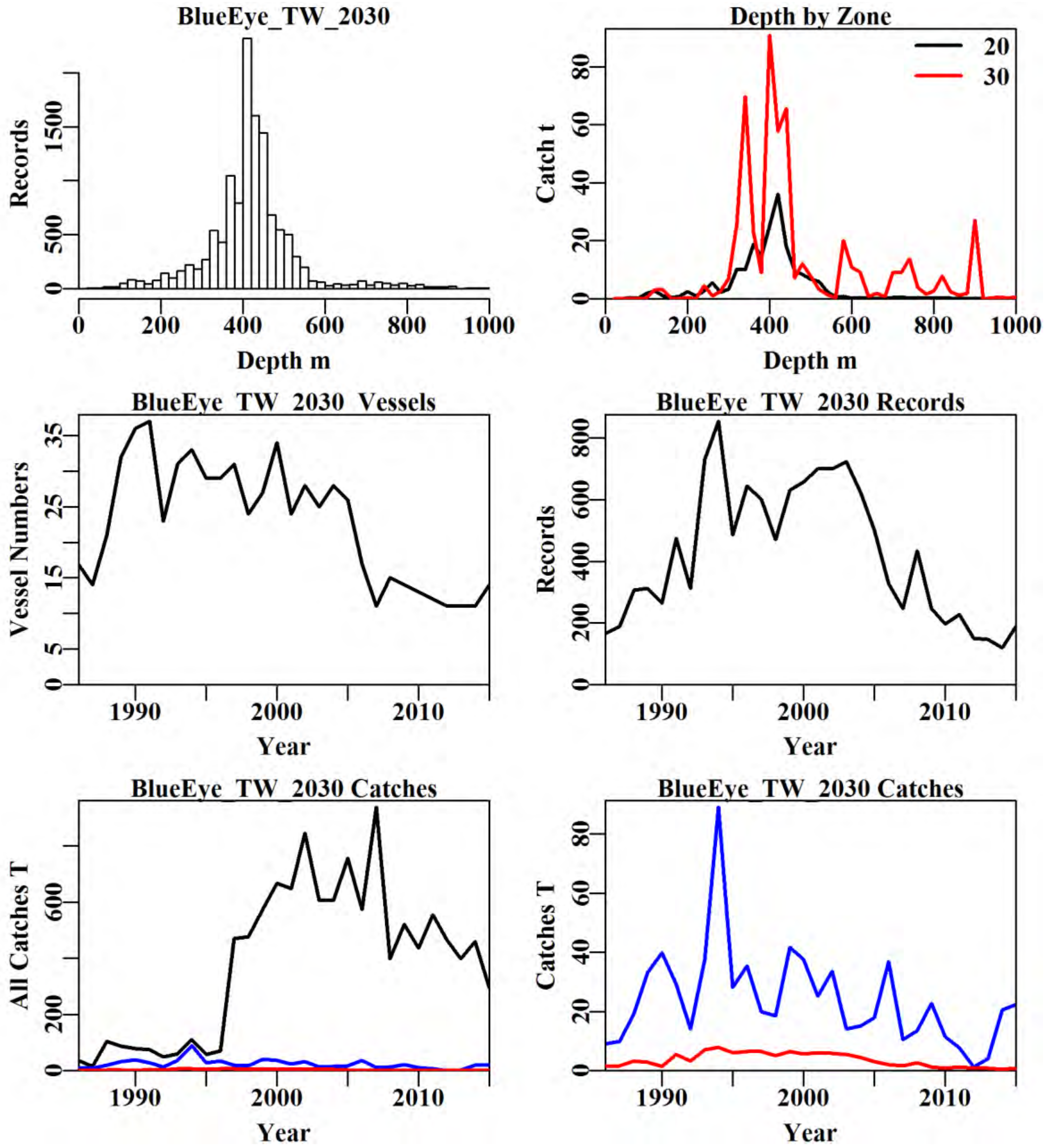



Figure 8.53. Blue Eye Trevalla from zones 20, 30 in depths 0 – 1000 m by Trawl. The top left plot depicts the depth distribution of shots containing Blue Eye Trevalla from each zone in depths 0 to 1000 m by Trawl. The top right plot depicts the catch distribution by depth within each zone. The middle left plot depicts the number of vessels through time and middle right plot contains the number of records used in analysis. The bottom left plot contains Blue Eye Trevalla catches (top black line: total catches, middle blue line: catches used in the analysis; bottom red line: catches < 30 kg) and bottom right plot contains Blue Eye Trevalla catches (blue line: catches used in the analysis; red line: catches < 30 kg).

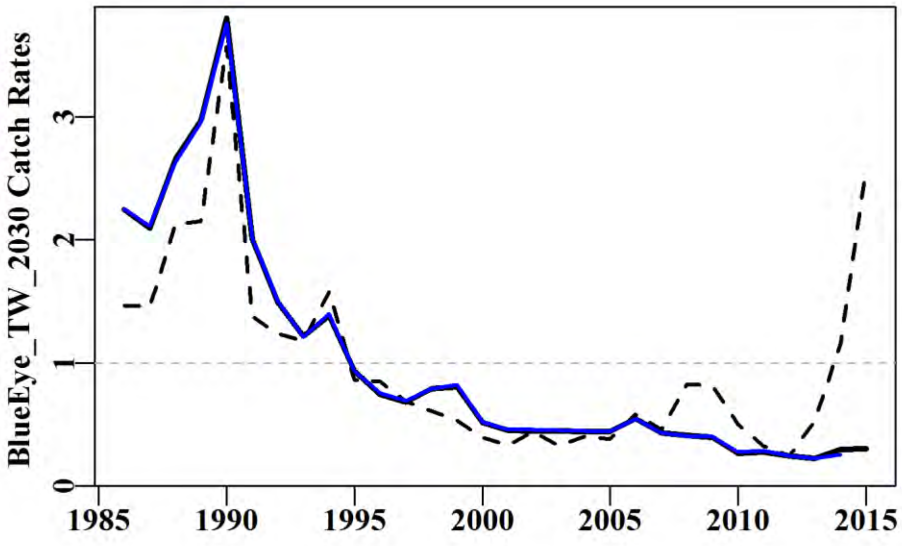



Figure 8.54. Blue Eye Trevalla from zones 20 and 30 in depths 0 – 1000 m by Trawl. Standardized catch rates (solid black line). The dashed black line represents the geometric mean catch rate (relative to the mean standardized catch rates). The blue line corresponds to last year's standardized catch rates. Mean standardized catch rate (grey line).

Table 8.50. Blue Eye Trevalla from zones 20, 30 in depths 0 – 1000 m by Trawl. Statistical model structures used in this analysis. DepCat is a series of 20 metre depth categories.

| | |
|---|---|
| Model 1 | LnCE~Year |
| Model 2 | LnCE~Year+Vessel |
| Model 3 | LnCE~Year+Vessel+Zone |
| Model 4 | LnCE~Year+Vessel+Zone+DepCat |
| Model 5 | LnCE~Year+Vessel+Zone+DepCat+DayNight |
| Model 6 | LnCE~Year+Vessel+Zone+DepCat+DayNight+Month |
| Model 7 | LnCE~Year+Vessel+Zone+DepCat+DayNight+Month+Zone:Month |
| Model 8 | LnCE~Year+Vessel+Zone+DepCat+DayNight+Month+Zone:DepCat |

Table 8.51. Blue Eye Trevalla from zones 20, 30 in depths 0 – 1000 m by Trawl. Model selection criteria include the Akaike Information Criterion (AIC), residual sum of squares (RSS), model sum of squares (MSS), number of usable observations (Nobs), number of parameters (Npars), adjusted $R^2$ (adj_$R^2$) and the change in adjusted $R^2$ (%Change). The optimum was Model 8: Zone:DepC. Depth category: DepC.

| | Year | Vessel | Zone | DepC | DayNight | Month | Zone:Month | Zone:DepC |
|---|---|---|---|---|---|---|---|---|
| AIC | 11640 | 4763 | 4357 | 4244 | 4225 | 4183 | 4151 | 3986 |
| RSS | 31593 | 17984 | 17413 | 17053 | 17018 | 16932 | 16860 | 16542 |
| MSS | 5119 | 18728 | 19299 | 19659 | 19694 | 19781 | 19852 | 20170 |
| Nobs | 12634 | 12634 | 12634 | 12555 | 12555 | 12555 | 12555 | 12555 |
| Npars | 30 | 151 | 152 | 200 | 203 | 214 | 225 | 262 |
| adj_$R^2$ | 13.745 | 50.424 | 51.994 | 52.801 | 52.887 | 53.084 | 53.242 | 53.984 |
| %Change | 0.000 | 36.680 | 1.570 | 0.807 | 0.086 | 0.197 | 0.157 | 0.743 |

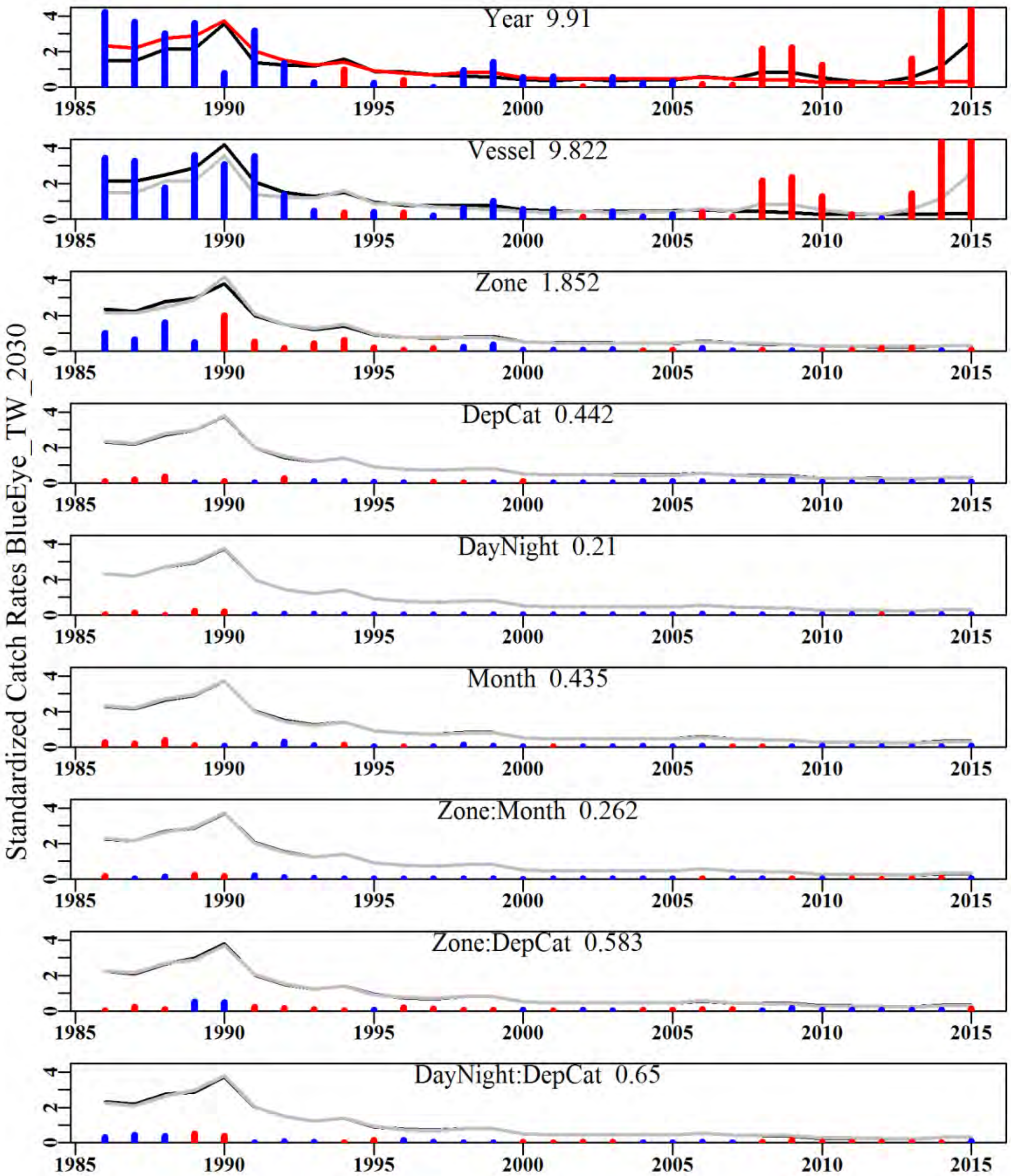



Figure 8.55. The relative influence of each factor used on the final trend in the optimal standardization for Blue Eye Trevalla in zones 20 and 30. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by the vertical bars with blue bars indicating the optimum model is higher than the geometric mean and red bars indicating it is lower. The top graph bars are the sum of all the bars in the graphs below. The graphs for individual factors are cumulative. Thus the second graph has the geometric mean (grey line) and the effect of adding Year + factor2 (Model 2). In the third graph, the grey line represents Model 2 and the black line the effect of adding factor3 to the model. The remaining graphs continue in the same cumulative manner except for the interaction terms which are added singularly to the final single factor model.

### 8.4.18 *Blue Eye Trevalla Z4050 (TBE – 37445001 – Hyperoglyphe antarctica)*

Trawl data from zones 40 and 50 and depths less than 1000 m were analysed.

Table 8.52. Blue Eye Trevalla from zones 40 and 50 in depths 0 – 1000 m by Trawl. Total catch (TotCatch; t) is the total reported in the database, number of records used in the analysis (Records), reported catch (CatchT; t) in the area and depth used in the analysis and number of vessels used in the analysis (Vessels). GeoMean is the geometric mean of catch rates (kg/hr). The optimum model is Zone:DepC and standard deviation (StDev) relates to the data in the optimum model.

| Year | TotCatch | Records | CatchT | Vessels | GeoMean | Zone:DepC | StDev |
|---|---|---|---|---|---|---|---|
| 1986 | 37.9620 | 194 | 15.9550 | 18 | 13.1296 | 1.0210 | 0.0000 |
| 1987 | 15.4950 | 56 | 3.1450 | 14 | 11.6895 | 0.8171 | 0.1771 |
| 1988 | 105.1770 | 142 | 76.4100 | 15 | 41.5696 | 2.4948 | 0.1566 |
| 1989 | 88.0660 | 238 | 43.9850 | 24 | 25.5841 | 2.0845 | 0.1380 |
| 1990 | 79.2980 | 157 | 30.9100 | 16 | 13.0702 | 2.1783 | 0.1588 |
| 1991 | 76.0240 | 128 | 18.7040 | 18 | 17.2513 | 1.7207 | 0.1584 |
| 1992 | 49.3050 | 129 | 28.6430 | 15 | 21.8842 | 2.1452 | 0.1567 |
| 1993 | 59.6540 | 289 | 18.1090 | 19 | 8.5334 | 0.9348 | 0.1400 |
| 1994 | 109.9750 | 348 | 16.2820 | 19 | 8.8991 | 0.9629 | 0.1364 |
| 1995 | 58.5720 | 500 | 26.3810 | 21 | 6.4723 | 0.8627 | 0.1326 |
| 1996 | 71.6840 | 523 | 30.1840 | 24 | 8.0361 | 0.9020 | 0.1333 |
| 1997 | 471.4664 | 788 | 82.3710 | 18 | 6.5139 | 0.9223 | 0.1299 |
| 1998 | 475.9652 | 780 | 58.9460 | 19 | 5.3540 | 1.1001 | 0.1313 |
| 1999 | 574.4838 | 877 | 46.3030 | 19 | 6.4046 | 1.1276 | 0.1302 |
| 2000 | 667.0558 | 1109 | 44.7290 | 23 | 5.2927 | 0.9810 | 0.1293 |
| 2001 | 647.5307 | 969 | 43.5380 | 26 | 5.8514 | 0.9418 | 0.1309 |
| 2002 | 843.8591 | 803 | 32.2975 | 26 | 5.0569 | 0.7866 | 0.1310 |
| 2003 | 605.3020 | 391 | 11.0128 | 25 | 3.1904 | 0.6955 | 0.1377 |
| 2004 | 606.2500 | 852 | 31.2657 | 24 | 4.2140 | 0.6152 | 0.1312 |
| 2005 | 755.1858 | 508 | 12.7502 | 22 | 3.6280 | 0.5767 | 0.1345 |
| 2006 | 573.7189 | 533 | 16.2790 | 17 | 3.6218 | 0.5837 | 0.1341 |
| 2007 | 937.1424 | 538 | 26.1883 | 16 | 4.4303 | 0.6199 | 0.1341 |
| 2008 | 398.9433 | 324 | 16.3714 | 14 | 4.9605 | 0.8210 | 0.1394 |
| 2009 | 520.8777 | 343 | 15.7939 | 13 | 4.0546 | 0.7737 | 0.1391 |
| 2010 | 437.3987 | 427 | 31.0104 | 14 | 5.4788 | 0.7831 | 0.1362 |
| 2011 | 554.2188 | 381 | 14.7083 | 14 | 2.8223 | 0.6106 | 0.1373 |
| 2012 | 463.8349 | 261 | 9.0066 | 11 | 1.8380 | 0.4542 | 0.1457 |
| 2013 | 398.3268 | 203 | 18.6619 | 15 | 3.2600 | 0.5932 | 0.1478 |
| 2014 | 460.1404 | 211 | 8.6683 | 13 | 3.0568 | 0.5611 | 0.1477 |
| 2015 | 294.6678 | 106 | 2.6507 | 9 | 1.8727 | 0.3288 | 0.1686 |

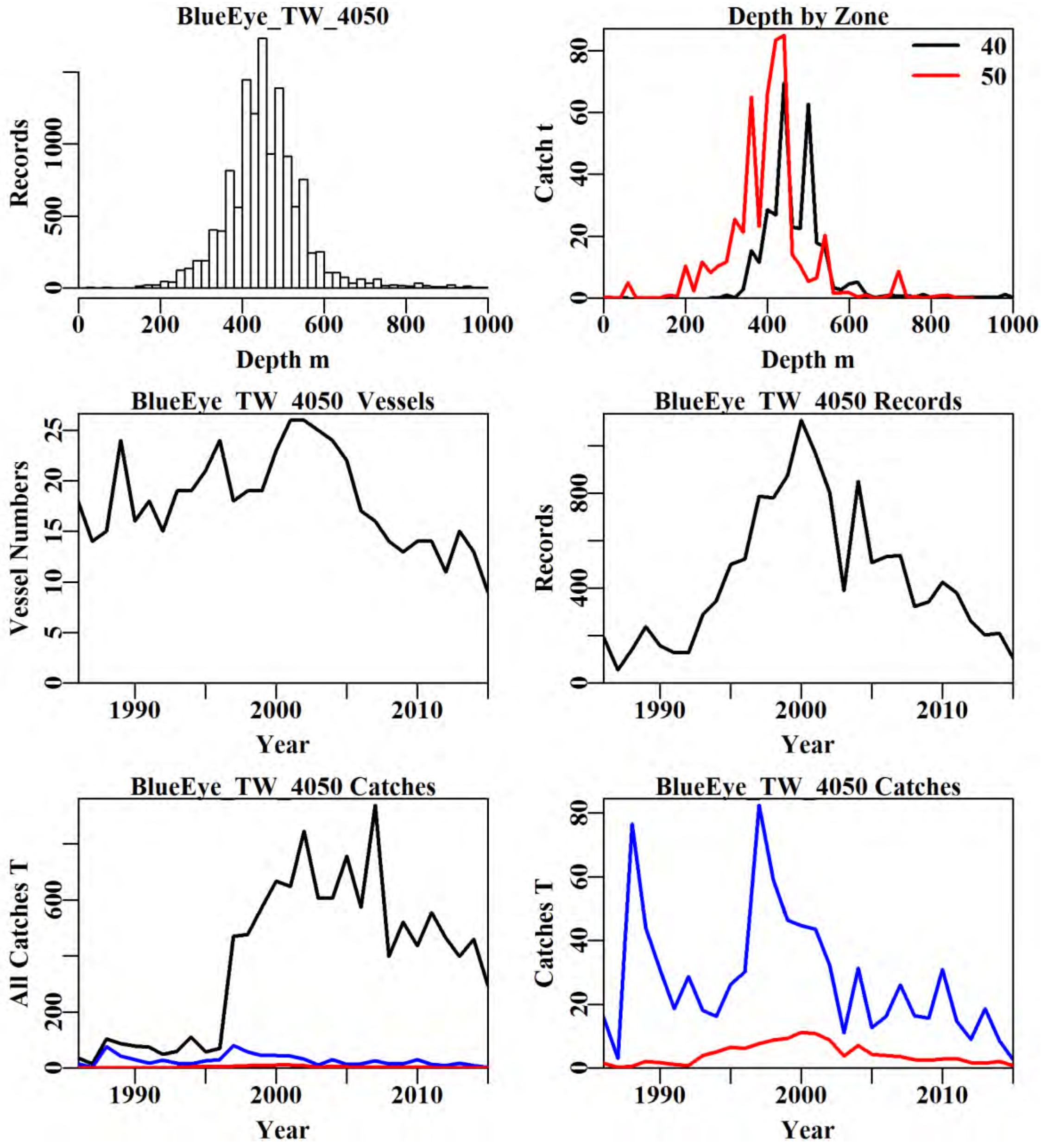



Figure 8.56. Blue Eye Trevalla from zones 40 and 50 in depths 0 – 1000 m by Trawl. The top left plot depicts the depth distribution of shots containing Blue Eye Trevalla from each zone in depths 0 to 1000 m by Trawl. The top right plot depicts the catch distribution by depth within each zone. The middle left plot depicts the number of vessels through time and middle right plot contains the number of records used in analysis. The bottom left plot contains Blue Eye Trevalla catches (top black line: total catches, middle blue line: catches used in the analysis; bottom red line: catches < 30 kg) and bottom right plot contains Blue Eye Trevalla catches (blue line: catches used in the analysis; red line: catches < 30 kg).

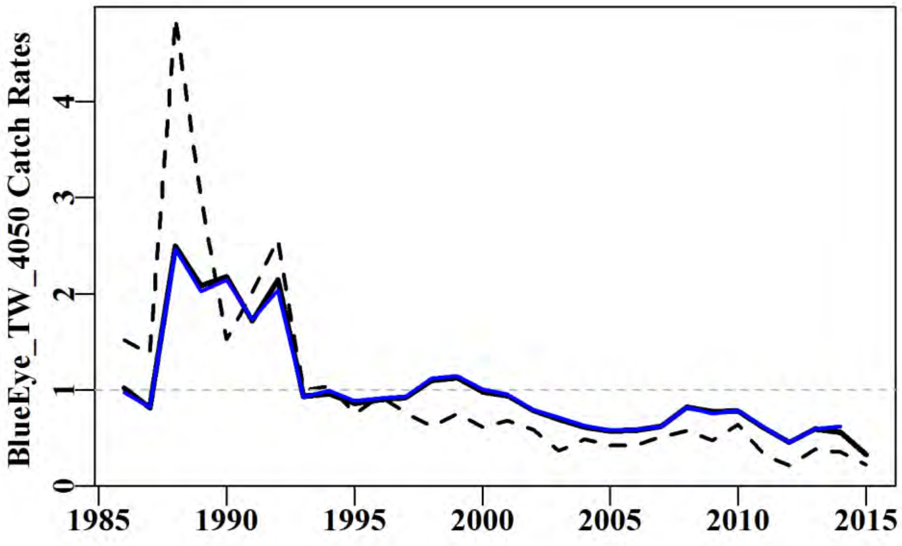



Figure 8.57. Blue Eye Trevalla from zones 40 and 50 in depths 0 – 1000 m by Trawl. Standardized catch rates (solid black line). The dashed black line represents the geometric mean catch rate (relative to the mean standardized catch rates). The blue line corresponds to last year's standardized catch rates. Mean standardized catch rate (grey line).

Table 8.53. Blue Eye Trevalla from zones 40 and 50 in depths 0 – 1000 m by Trawl. Statistical model structures used in this analysis. DepCat is a series of 20 metre depth categories.

| | |
|---|---|
| Model 1 | LnCE~Year |
| Model 2 | LnCE~Year+Vessel |
| Model 3 | LnCE~Year+Vessel+Zone |
| Model 4 | LnCE~Year+Vessel+Zone+DepCat |
| Model 5 | LnCE~Year+Vessel+Zone+DepCat+DayNight |
| Model 6 | LnCE~Year+Vessel+Zone+DepCat+DayNight+Month |
| Model 7 | LnCE~Year+Vessel+Zone+DepCat+DayNight+Month+Zone:Month |
| Model 8 | LnCE~Year+Vessel+Zone+DepCat+DayNight+Month+Zone:DepCat |

Table 8.54. Blue Eye Trevalla from zones 40 and 50 in depths 0 – 1000 m by Trawl. Model selection criteria include the Akaike Information Criterion (AIC), residual sum of squares (RSS), model sum of squares (MSS), number of usable observations (Nobs), number of parameters (Npars), adjusted $R^2$ (adj_$R^2$) and the change in adjusted $R^2$ (%Change). The optimum was Model 8: Zone:DepC. Depth category: DepC.

| | Year | Vessel | Zone | DepC | DayNight | Month | Zone:Month | Zone:DepC |
|---|---|---|---|---|---|---|---|---|
| AIC | 8562 | 3225 | 2776 | 2670 | 2564 | 2514 | 2512 | 2493 |
| RSS | 25075 | 16478 | 15741 | 15606 | 15454 | 15392 | 15364 | 15252 |
| MSS | 3284 | 11881 | 12618 | 12753 | 12905 | 12967 | 12995 | 13107 |
| Nobs | 13108 | 13108 | 13043 | 13043 | 13043 | 13043 | 13043 | 13043 |
| Npars | 30 | 113 | 162 | 165 | 176 | 177 | 188 | 226 |
| adj_$R^2$ | 11.385 | 41.394 | 43.800 | 44.269 | 44.766 | 44.981 | 45.036 | 45.275 |
| %Change | 0.000 | 30.009 | 2.406 | 0.469 | 0.497 | 0.215 | 0.055 | 0.239 |

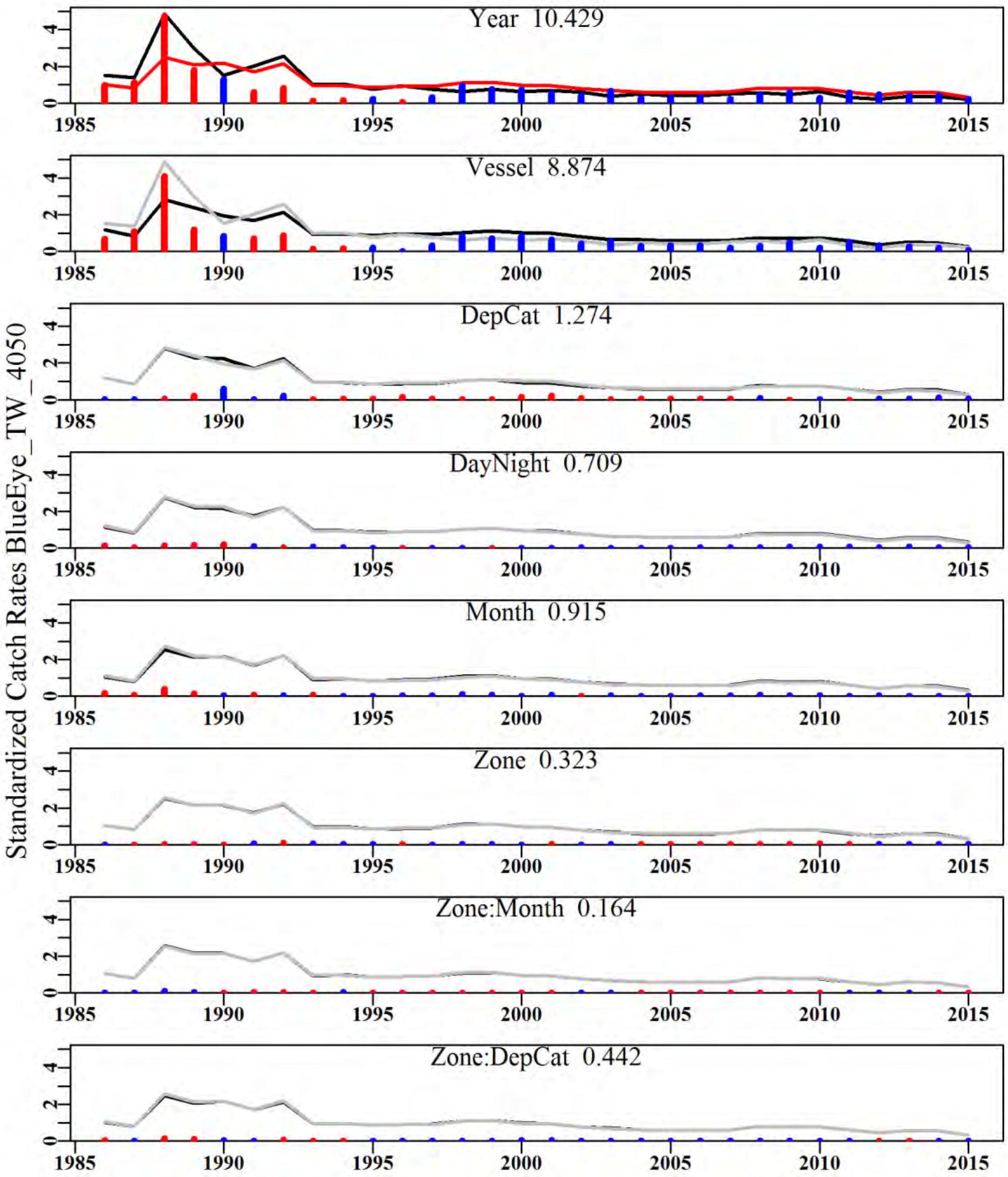



Figure 8.58. The relative influence of each factor used on the final trend in the optimal standardization for Blue Eye Trevalla in zones 40 and 50. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by the vertical bars with blue bars indicating the optimum model is higher than the geometric mean and red bars indicating it is lower. The top graph bars are the sum of all the bars in the graphs below. The graphs for individual factors are cumulative. Thus the second graph has the geometric mean (grey line) and the effect of adding Year + factor2 (Model 2). In the third graph, the grey line represents Model 2 and the black line the effect of adding factor3 to the model. The remaining graphs continue in the same cumulative manner except for the interaction terms which are added singularly to the final single factor model.

### 8.4.19 *Blue Grenadier Non-Spawning (GRE – 37227001 Macruronus novaezelandiae)*

Trawl data selected for analysis corresponded to records from zones 10 to 60 except in zone 40 from June to August. Depths greater than 0 m and less than 1000 m were also included in the analysis.

Table 8.55. Blue Grenadier from the SET in depths between 0 – 1000 m, taken by Trawl, omitting the Spawning fishery (zone 40 between June and August). Total catch (TotCatch; t) is the total reported in the database, number of records used in the analysis (Records), reported catch (CatchT; t) in the area and depth used in the analysis and number of vessels used in the analysis (Vessels). GeoMean is the geometric mean of catch rates (kg/hr). The optimum model is Zone:Month and standard deviation (StDev) relates to the data in the optimum model.

| Year | TotCatch | Records | CatchT | Vessels | GeoMean | Zone:Month | StDev |
|---|---|---|---|---|---|---|---|
| 1986 | 1451.7780 | 3189 | 1183.3070 | 92 | 141.8895 | 1.5710 | 0.0000 |
| 1987 | 2244.8280 | 3569 | 1437.4340 | 91 | 135.1891 | 2.0092 | 0.0338 |
| 1988 | 1849.1470 | 3961 | 1470.1960 | 102 | 128.9817 | 2.1785 | 0.0339 |
| 1989 | 1890.8550 | 4309 | 1813.5010 | 99 | 151.1360 | 2.1892 | 0.0338 |
| 1990 | 2280.4710 | 3577 | 1625.1460 | 92 | 156.6999 | 2.1833 | 0.0358 |
| 1991 | 3669.0360 | 4307 | 2392.2870 | 86 | 208.2422 | 1.5556 | 0.0344 |
| 1992 | 2474.5460 | 3235 | 1505.8140 | 62 | 178.0744 | 1.2589 | 0.0366 |
| 1993 | 2482.2700 | 4203 | 1619.0490 | 63 | 125.3869 | 0.9515 | 0.0351 |
| 1994 | 2315.4900 | 4491 | 1309.5630 | 66 | 93.9576 | 0.8599 | 0.0346 |
| 1995 | 1931.0460 | 5075 | 1015.1610 | 61 | 58.5788 | 0.5953 | 0.0338 |
| 1996 | 2304.2340 | 5370 | 1055.3400 | 73 | 56.2697 | 0.5409 | 0.0337 |
| 1997 | 3654.6590 | 6194 | 994.6040 | 73 | 43.7798 | 0.5654 | 0.0332 |
| 1998 | 4226.1770 | 6598 | 1452.3520 | 65 | 74.7536 | 0.9120 | 0.0331 |
| 1999 | 7573.0180 | 8046 | 2051.9760 | 65 | 89.7587 | 0.9601 | 0.0323 |
| 2000 | 7503.1400 | 7680 | 1751.2315 | 70 | 73.5207 | 0.6884 | 0.0326 |
| 2001 | 8370.7990 | 7344 | 1023.0800 | 60 | 40.3410 | 0.3936 | 0.0330 |
| 2002 | 7976.8590 | 6347 | 1124.6527 | 57 | 54.7338 | 0.3944 | 0.0336 |
| 2003 | 7947.1150 | 5676 | 669.6359 | 56 | 33.7578 | 0.3298 | 0.0339 |
| 2004 | 6091.1790 | 6393 | 1204.7328 | 56 | 56.3464 | 0.5537 | 0.0337 |
| 2005 | 4506.6460 | 5346 | 1174.7071 | 54 | 65.8646 | 0.6650 | 0.0343 |
| 2006 | 3544.3540 | 4362 | 1308.8400 | 42 | 84.5394 | 0.8842 | 0.0355 |
| 2007 | 3127.3930 | 3659 | 1203.7072 | 27 | 86.4721 | 0.7915 | 0.0365 |
| 2008 | 4150.1920 | 3406 | 1274.3986 | 26 | 110.9800 | 0.8742 | 0.0370 |
| 2009 | 3874.2100 | 3443 | 1128.4378 | 23 | 89.0993 | 0.8118 | 0.0369 |
| 2010 | 4551.2510 | 3314 | 1136.1358 | 25 | 81.8686 | 0.8100 | 0.0373 |
| 2011 | 4476.9130 | 3969 | 897.7095 | 26 | 49.2213 | 0.6470 | 0.0362 |
| 2012 | 4483.2820 | 3210 | 613.6124 | 29 | 40.8033 | 0.5232 | 0.0377 |
| 2013 | 4217.1500 | 3052 | 742.0920 | 26 | 58.2177 | 0.9262 | 0.0381 |
| 2014 | 1265.5160 | 3042 | 920.7774 | 28 | 77.9687 | 1.1383 | 0.0380 |
| 2015 | 1462.1300 | 2959 | 1050.0345 | 29 | 106.4365 | 1.2382 | 0.0383 |

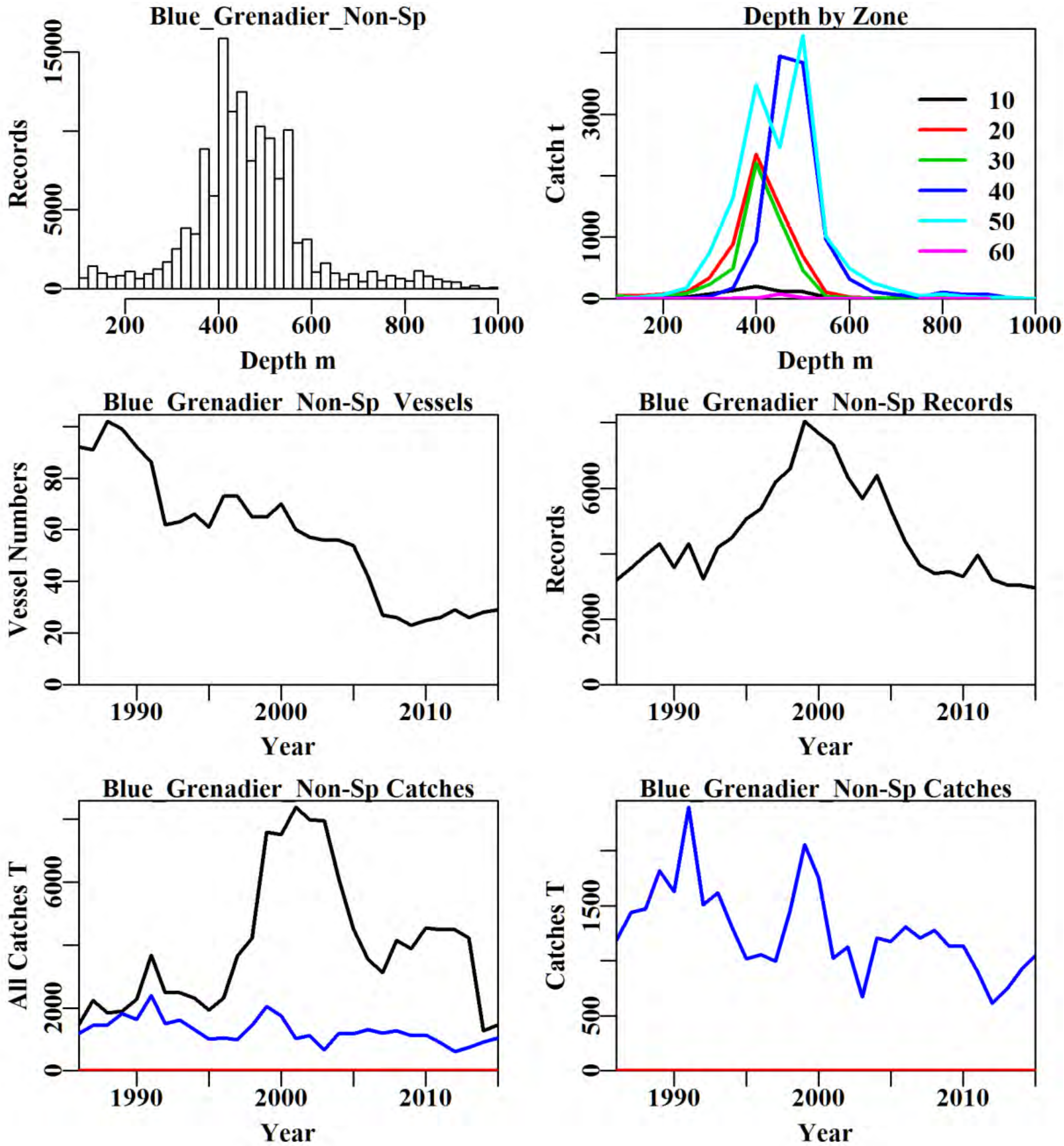



Figure 8.59. Blue Grenadier from the SET in depths between 0 – 1000 m, taken by Trawl, omitting the Spawning fishery (zone 40 between June and August). The top left plot depicts the depth distribution of shots containing Blue Grenadier from the SET omitting the Spawning fishery (zone 40 between June and August) in depths 0 – 1000 m by Trawl. The top right plot depicts the catch distribution by depth by zone. The middle left plot depicts the number of vessels through time and middle right plot contains the number of records used in analysis. The bottom left plot contains Blue Grenadier catches (top black line: total catches, middle blue line: catches used in the analysis; bottom red line: catches < 30 kg) and bottom right plot contains Blue Grenadier catches (blue line: catches used in the analysis; red line: catches < 30 kg).

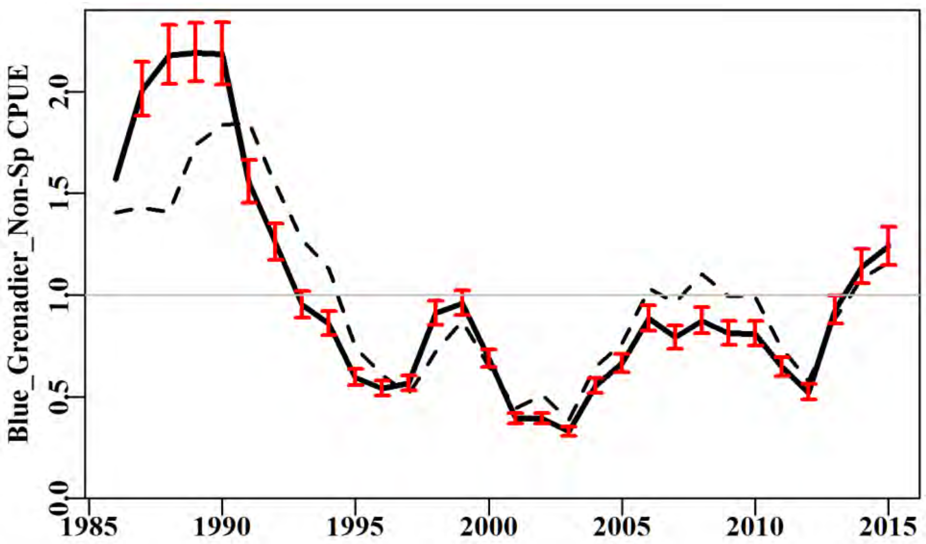



Figure 8.60. Blue Grenadier from the SET in depths between 0 – 1000 m, taken by Trawl, omitting the Spawning fishery (zone 40 between June and August). The dashed black line represents the geometric mean catch rate and the solid black line the standardized catch rates (relative to the mean of the standardized catch rates), and 95% CI (vertical lines).

Table 8.56. Blue Grenadier from the SET in depths between 0 – 1000 m, taken by Trawl, omitting the Spawning fishery (zone 40 between June and August). Statistical model structures used in this analysis. DepCat is a series of 20 metre depth categories.

| | |
|---|---|
| Model 1 | LnCE~Year |
| Model 2 | LnCE~Year+Vessel |
| Model 3 | LnCE~Year+Vessel+DepCat |
| Model 4 | LnCE~Year+Vessel+DepCat+Month |
| Model 5 | LnCE~Year+Vessel+DepCat+Month+Zone |
| Model 6 | LnCE~Year+Vessel+DepCat+Month+Zone+DayNight |
| Model 7 | LnCE~Year+Vessel+DepCat+Month+Zone+DayNight+Zone:Month |
| Model 8 | LnCE~Year+Vessel+DepCat+Month+Zone+DayNight+Zone:DepCat |

Table 8.57. Blue Grenadier from the SET in depths between 0 – 1000 m, taken by Trawl, omitting the Spawning fishery (zone 40 between June and August). Model selection criteria include the Akaike Information Criterion (AIC), residual sum of squares (RSS), model sum of squares (MSS), number of usable observations (Nobs), number of parameters (Npars), adjusted $R^2$ (adj_$R^2$) and the change in adjusted $R^2$ (%Change). The optimum is Model 7 (Zone:Month). Depth category: DepC.

| | Year | Vessel | DepC | Month | Zone | DayNight | Zone:Month | Zone:DepC |
|---|---|---|---|---|---|---|---|---|
| AIC | 127710 | 103612 | 88804 | 83594 | 80527 | 77613 | 74341 | 76042 |
| RSS | 348282 | 292129 | 262016 | 252300 | 246755 | 241607 | 235777 | 238570 |
| MSS | 25479 | 81632 | 111745 | 121461 | 127006 | 132154 | 137984 | 135191 |
| Nobs | 139326 | 139326 | 138468 | 138468 | 138468 | 138468 | 138468 | 138468 |
| Npars | 30 | 229 | 247 | 258 | 263 | 266 | 321 | 356 |
| adj_$R^2$ | 6.798 | 21.713 | 29.773 | 32.371 | 33.855 | 35.234 | 36.772 | 36.006 |
| %Change | 0.000 | 14.915 | 8.060 | 2.599 | 1.484 | 1.378 | 1.538 | 0.772 |

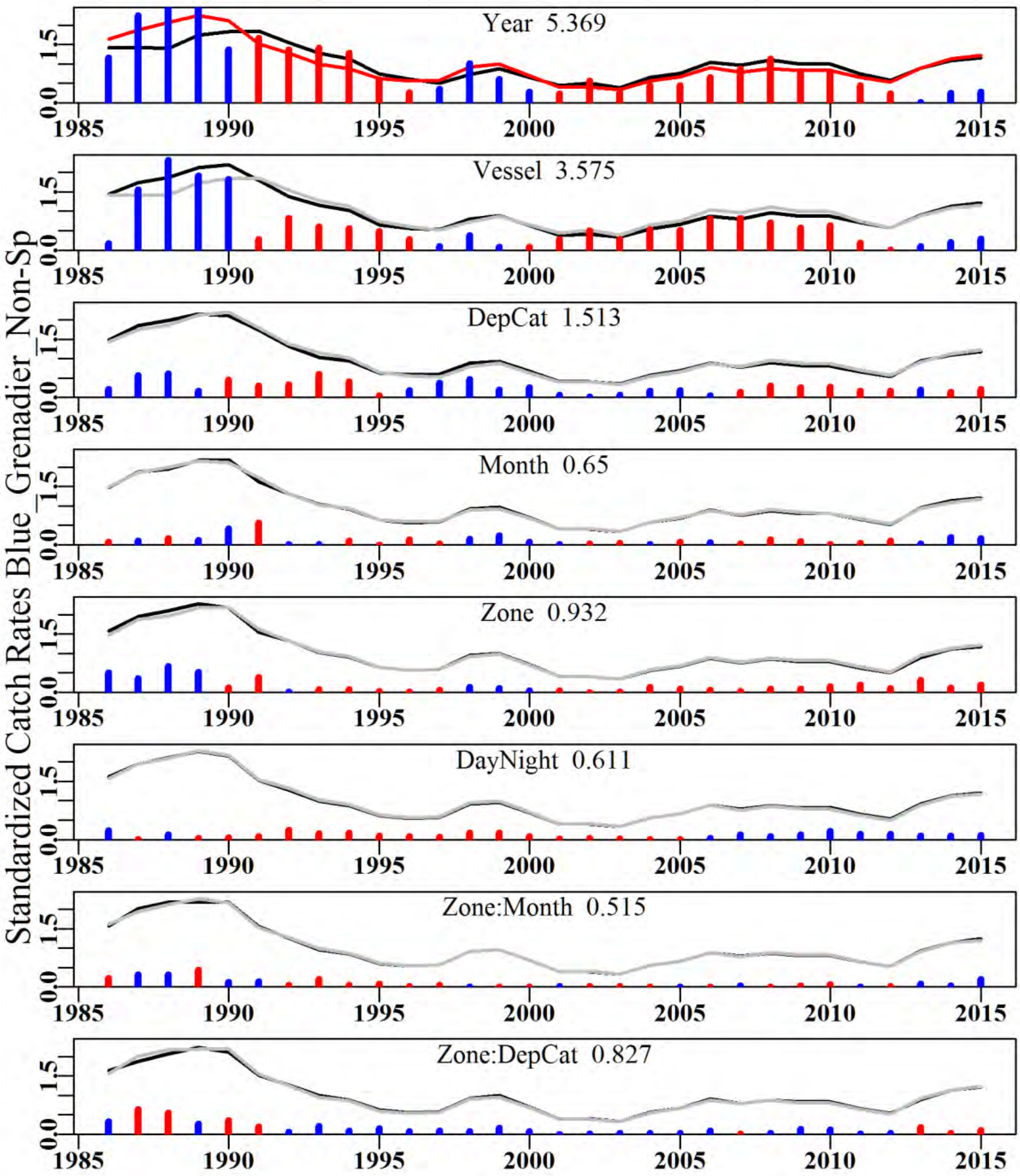



Figure 8.61. The relative influence of each factor used on the final trend in the optimal standardization for Blue Grenadier non-spawning fishery. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by the vertical bars with blue bars indicating the optimum model is higher than the geometric mean and red bars indicating it is lower. The top graph bars are the sum of all the bars in the graphs below. The graphs for individual factors are cumulative. Thus the second graph has the geometric mean (grey line) and the effect of adding Year + factor2 (Model 2). In the third graph, the grey line represents Model 2 and the black line the effect of adding factor3 to the model. The remaining graphs continue in the same cumulative manner except for the interaction terms which are added singularly to the final single factor model.

### 8.4.20 *Silver Warehou Z10-50 (TRS – 37445006 – Seriolella punctata)*

Trawl data selected for analysis corresponded to records from zones 10 to 50 and depths between 0 – 600 m.

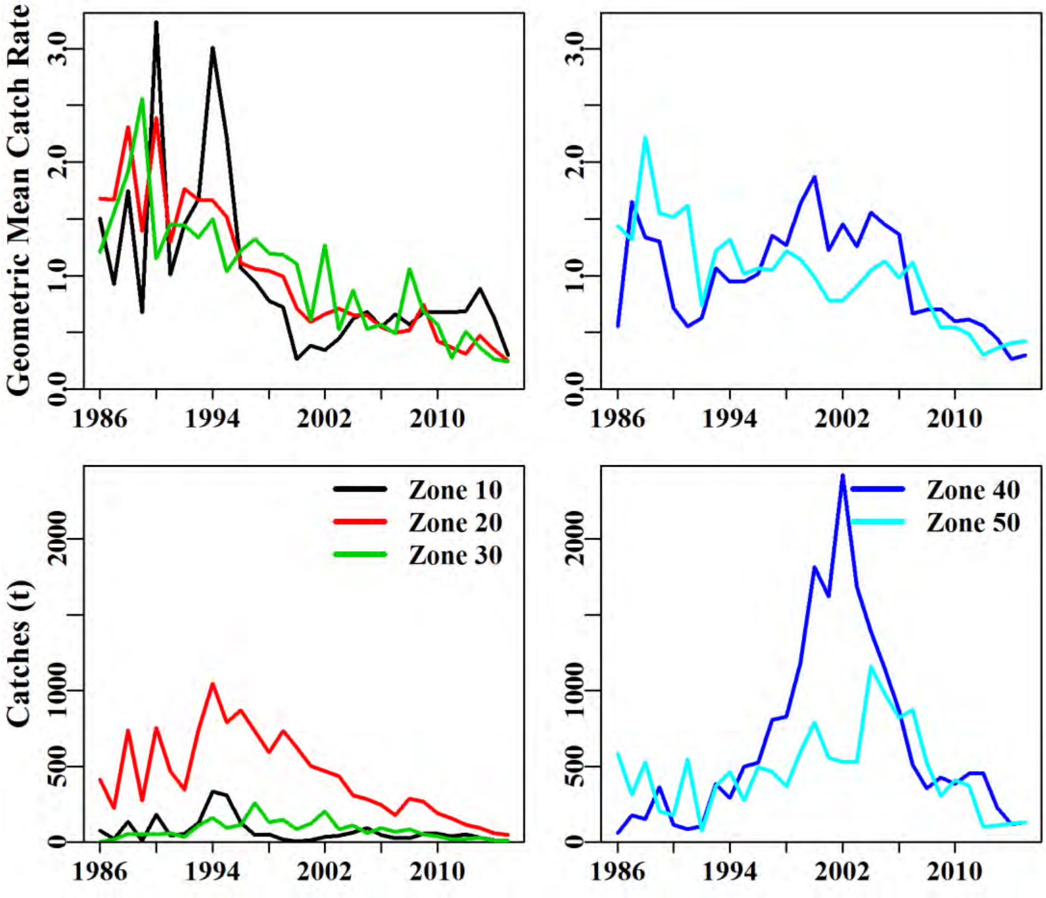



Figure 8.62. The trends in catches and catch rates for zones 10 – 50, split east and west.

Catch rates in the east show approximately similar trends, though there are some differences between 2000 and 2003. In the west the pattern in catch rates are noisy but relatively flat from 1992 to 2006 followed by a decline. Trends appear to be different between the east and west.

Table 8.58. Silver Warehou from Zones 10 to 50 and depths 0 – 600 m by Trawl. Total catch (TotCatch; t) is the total reported in the database, number of records used in the analysis (Records), reported catch (CatchT; t) in the area and depth used in the analysis and number of vessels used in the analysis (Vessels). GeoMean is the geometric mean of catch rates (kg/hr). The optimum model is Zone:Month and standard deviation (StDev) relates to the data in the optimum model.

| Year | TotCatch | Records | CatchT | Vessels | GeoMean | Zone:Month | StDev |
|---|---|---|---|---|---|---|---|
| 1986 | 1156.5330 | 2438 | 1135.2960 | 86 | 32.2897 | 1.6137 | 0.0000 |
| 1987 | 782.1510 | 1509 | 757.2980 | 76 | 35.5040 | 1.6663 | 0.0561 |
| 1988 | 1646.1870 | 2249 | 1617.2400 | 87 | 42.9346 | 2.1278 | 0.0509 |
| 1989 | 926.2570 | 2049 | 907.4200 | 80 | 30.7291 | 1.7120 | 0.0537 |
| 1990 | 1346.5850 | 1983 | 1290.9590 | 81 | 40.6488 | 1.8580 | 0.0542 |
| 1991 | 1453.1690 | 2290 | 1207.4810 | 78 | 25.6943 | 1.2661 | 0.0531 |
| 1992 | 733.7670 | 1858 | 625.2760 | 56 | 27.9497 | 1.1138 | 0.0555 |
| 1993 | 1815.8010 | 3864 | 1735.0090 | 61 | 33.3011 | 1.2694 | 0.0485 |
| 1994 | 2309.5100 | 4519 | 2300.0830 | 57 | 34.7142 | 1.3482 | 0.0474 |
| 1995 | 2002.8810 | 5015 | 1968.6070 | 58 | 29.7678 | 1.2207 | 0.0468 |
| 1996 | 2188.2440 | 6080 | 2137.3730 | 67 | 22.7319 | 1.1414 | 0.0461 |
| 1997 | 2562.0160 | 5765 | 2305.7850 | 61 | 25.3481 | 1.1729 | 0.0467 |
| 1998 | 2166.0212 | 4702 | 1976.6670 | 57 | 26.6416 | 1.1254 | 0.0476 |
| 1999 | 2834.0520 | 5147 | 2685.6730 | 58 | 31.2497 | 0.9627 | 0.0472 |
| 2000 | 3401.5633 | 6735 | 3325.0720 | 63 | 26.1343 | 0.8732 | 0.0460 |
| 2001 | 2970.4067 | 7345 | 2816.4640 | 58 | 21.8403 | 0.7340 | 0.0458 |
| 2002 | 3841.4390 | 8423 | 3659.2765 | 57 | 23.0006 | 0.7933 | 0.0453 |
| 2003 | 2910.0946 | 7405 | 2782.8079 | 64 | 20.4602 | 0.7933 | 0.0458 |
| 2004 | 3202.0836 | 7861 | 3036.7484 | 58 | 23.3439 | 0.8796 | 0.0456 |
| 2005 | 2647.9671 | 6920 | 2558.2815 | 56 | 20.0277 | 0.8657 | 0.0461 |
| 2006 | 2191.1968 | 5663 | 2076.2746 | 47 | 18.2145 | 0.7606 | 0.0470 |
| 2007 | 1816.5165 | 4657 | 1665.2355 | 33 | 20.1239 | 0.7148 | 0.0481 |
| 2008 | 1381.1590 | 4400 | 1279.9289 | 32 | 16.1202 | 0.6492 | 0.0484 |
| 2009 | 1285.3059 | 4387 | 1109.6456 | 28 | 15.8837 | 0.6709 | 0.0484 |
| 2010 | 1189.4336 | 4484 | 1082.6024 | 28 | 13.2592 | 0.5548 | 0.0484 |
| 2011 | 1108.7509 | 4940 | 1042.7738 | 30 | 12.6164 | 0.5138 | 0.0479 |
| 2012 | 781.1541 | 3768 | 750.5568 | 29 | 10.4075 | 0.4218 | 0.0497 |
| 2013 | 584.0728 | 2979 | 502.9518 | 29 | 11.6081 | 0.4613 | 0.0515 |
| 2014 | 356.8551 | 2891 | 333.4079 | 27 | 9.3123 | 0.3791 | 0.0517 |
| 2015 | 367.8410 | 2665 | 332.9070 | 28 | 7.9890 | 0.3363 | 0.0525 |

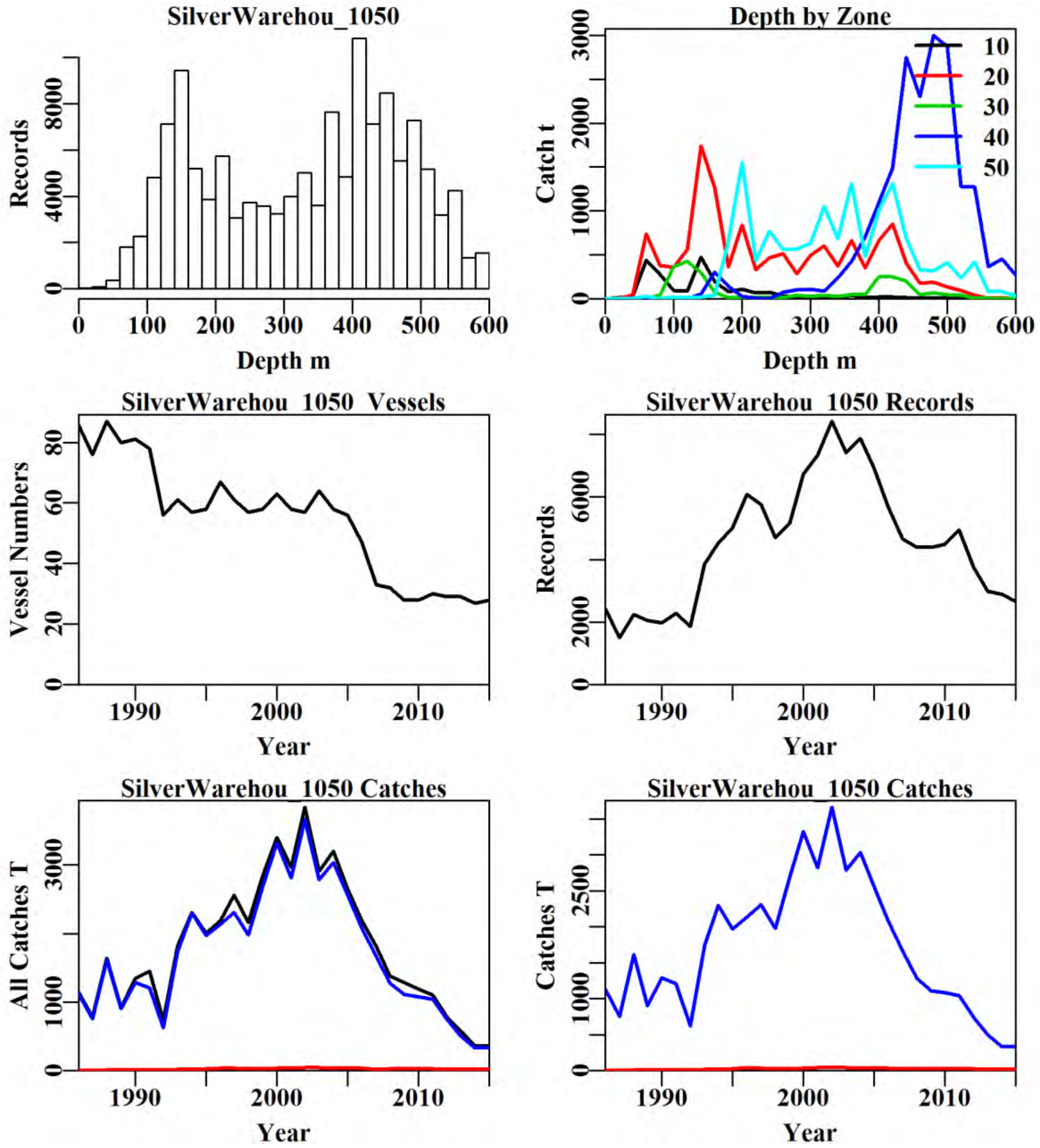



Figure 8.63. Silver Warehou from zones 10 to 50 and depths 0 – 600 m by Trawl. The top left plot depicts the depth distribution of shots containing Silver Warehou from zones 10 to 50 in depths 0 – 600 m by Trawl. The top right plot depicts the catch distribution by depth by zone. The middle left plot depicts the number of vessels through time and middle right plot contains the number of records used in analysis. The bottom left plot contains Silver Warehou catches (top black line: total catches, middle blue line: catches used in the analysis; bottom red line: catches < 30 kg) and bottom right plot contains Silver Warehou catches (blue line: catches used in the analysis; red line: catches < 30 kg).

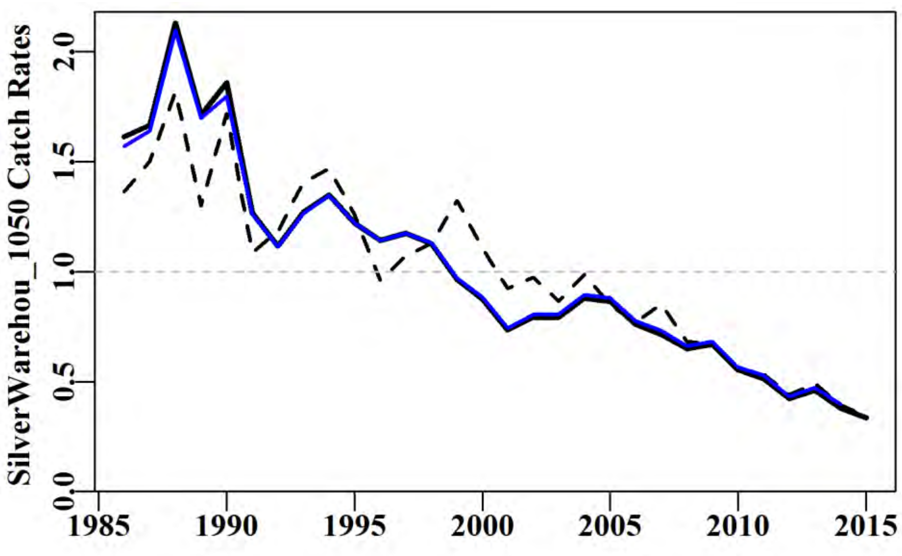



Figure 8.64. Silver Warehou from Zones 10 to 50 and depths 0 – 600 m by Trawl. The dashed black line represents the geometric mean catch rate and the solid black line the standardized catch rates (relative to the mean of the standardized catch rates). The blue line corresponds to last year's standardized indices.

Table 8.59. Silver Warehou from Zones 10 to 50 and depths 0 – 600 m by Trawl. Statistical model structures used in this analysis. DepCat is a series of 20 metre depth categories.

| | |
|---|---|
| Model 1 | LnCE~Year |
| Model 2 | LnCE~Year+Vessel |
| Model 3 | LnCE~Year+Vessel+Month |
| Model 4 | LnCE~Year+Vessel+Month+Zone |
| Model 5 | LnCE~Year+Vessel+Month+Zone+DepCat |
| Model 6 | LnCE~Year+Vessel+Month+Zone+DepCat+DayNight |
| Model 7 | LnCE~Year+Vessel+Month+Zone+DepCat+DayNight+Zone:Month |
| Model 8 | LnCE~Year+Vessel+Month+Zone+DepCat+DayNight+Zone:DepCat |

Table 8.60. Silver Warehou from Zones 10 to 50 and depths 0 – 600 m by Trawl. Model selection criteria include the Akaike Information Criterion (AIC), residual sum of squares (RSS), model sum of squares (MSS), number of usable observations (Nobs), number of parameters (Npars), adjusted $R^2$ (adj_$R^2$) and the change in adjusted $R^2$ (%Change). The optimum is Zone:Month (Model 7). Depth Category: DepC.

| | Year | Vessel | Month | Zone | DepC | DayNight | Zone:Month | Zone:DepC |
|---|---|---|---|---|---|---|---|---|
| AIC | 160044 | 137623 | 131317 | 128813 | 125927 | 125887 | 123995 | 124365 |
| RSS | 441578 | 372889 | 355814 | 349010 | 341559 | 341443 | 336437 | 336984 |
| MSS | 18090 | 86779 | 103853 | 110658 | 118109 | 118225 | 123231 | 122684 |
| Nobs | 134991 | 134991 | 134991 | 134099 | 134099 | 134099 | 134099 | 134099 |
| Npars | 30 | 231 | 242 | 272 | 276 | 279 | 323 | 399 |
| adj_$R^2$ | 3.915 | 18.740 | 22.455 | 23.920 | 25.542 | 25.565 | 26.633 | 26.471 |
| %Change | 0.000 | 14.825 | 3.714 | 1.465 | 1.622 | 0.024 | 1.067 | -0.161 |

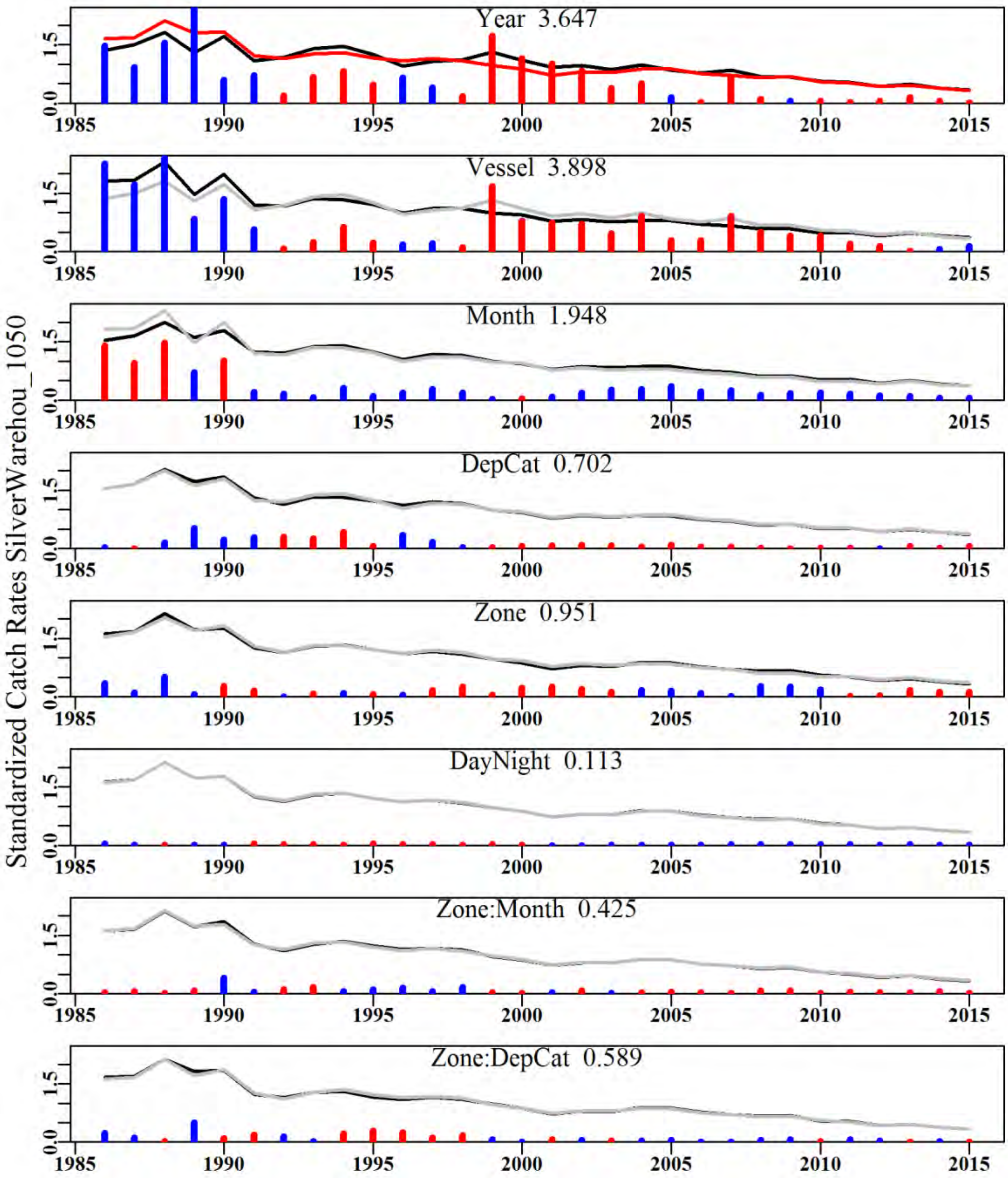



Figure 8.65. The relative influence of each factor used on the final trend in the optimal standardization for Silver Warehou in zones 10 – 50. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by the vertical bars with blue bars indicating the optimum model is higher than the geometric mean and red bars indicating it is lower. The top graph bars are the sum of all the bars in the graphs below. The graphs for individual factors are cumulative. Thus the second graph has the geometric mean (grey line) and the effect of adding Year + factor2 (Model 2). In the third graph, the grey line represents Model 2 and the black line the effect of adding factor3 to the model. The remaining graphs continue in the same cumulative manner except for the interaction terms which are added singularly to the final single factor model.

### 8.4.21 *Silver Warehou Z10-30 (TRS – 37445006 – Seriolella punctata)*

Table 8.61. Silver Warehou from Zones 10 to 30 and depths 0 – 600 m by Trawl. Total catch (TotCatch; t) is the total reported in the database, number of records used in the analysis (Records), reported catch (CatchT; t) in the area and depth used in the analysis and number of vessels used in the analysis (Vessels). GeoMean is the geometric mean of catch rates (kg/hr). The optimum model is Zone:DepC and standard deviation (StDev) relates to the data in the optimum model.

| Year | TotCatch | Records | CatchT | Vessels | GeoMean | Zone:DepC | StDev |
|---|---|---|---|---|---|---|---|
| 1986 | 1156.5330 | 1318 | 491.7080 | 66 | 26.2914 | 1.7747 | 0.0000 |
| 1987 | 782.1510 | 784 | 266.3420 | 56 | 24.5689 | 1.7074 | 0.0780 |
| 1988 | 1646.1870 | 1675 | 932.7990 | 69 | 36.4292 | 2.2083 | 0.0659 |
| 1989 | 926.2570 | 1399 | 337.8800 | 63 | 22.5921 | 1.8764 | 0.0695 |
| 1990 | 1346.5850 | 1414 | 992.2860 | 59 | 39.7032 | 2.3326 | 0.0705 |
| 1991 | 1453.1690 | 1584 | 578.0110 | 64 | 21.0464 | 1.3769 | 0.0704 |
| 1992 | 733.7670 | 1274 | 438.2490 | 41 | 28.4491 | 1.4644 | 0.0733 |
| 1993 | 1815.8010 | 2318 | 982.5520 | 49 | 27.6682 | 1.4399 | 0.0664 |
| 1994 | 2309.5100 | 2866 | 1541.9790 | 46 | 30.3557 | 1.5810 | 0.0650 |
| 1995 | 2002.8810 | 3335 | 1194.4620 | 45 | 25.9959 | 1.3995 | 0.0636 |
| 1996 | 2188.2440 | 4514 | 1116.6110 | 53 | 18.6397 | 1.1687 | 0.0622 |
| 1997 | 2562.0160 | 3883 | 1036.5460 | 48 | 19.2212 | 1.1463 | 0.0637 |
| 1998 | 2166.0212 | 2849 | 779.0660 | 43 | 17.8248 | 0.9671 | 0.0652 |
| 1999 | 2834.0520 | 2400 | 905.8040 | 43 | 17.6648 | 0.8339 | 0.0669 |
| 2000 | 3401.5633 | 3162 | 722.0340 | 49 | 12.0589 | 0.6736 | 0.0648 |
| 2001 | 2970.4067 | 3155 | 637.3550 | 40 | 10.0296 | 0.6284 | 0.0650 |
| 2002 | 3841.4390 | 3989 | 709.3435 | 42 | 11.2474 | 0.7268 | 0.0639 |
| 2003 | 2910.0946 | 3986 | 569.4015 | 50 | 10.4670 | 0.6786 | 0.0638 |
| 2004 | 3202.0836 | 3587 | 488.1205 | 46 | 11.0406 | 0.7804 | 0.0644 |
| 2005 | 2647.9671 | 3840 | 441.7305 | 42 | 10.6058 | 0.7253 | 0.0640 |
| 2006 | 2191.1968 | 2968 | 389.8176 | 35 | 9.2290 | 0.6120 | 0.0657 |
| 2007 | 1816.5165 | 1870 | 275.1950 | 23 | 8.8816 | 0.4851 | 0.0697 |
| 2008 | 1381.1590 | 2326 | 401.1699 | 24 | 9.9089 | 0.5602 | 0.0678 |
| 2009 | 1285.3059 | 2330 | 375.0856 | 23 | 11.8427 | 0.6408 | 0.0679 |
| 2010 | 1189.4336 | 2137 | 286.2760 | 20 | 8.2239 | 0.4680 | 0.0688 |
| 2011 | 1108.7509 | 2027 | 218.1696 | 22 | 6.8693 | 0.4011 | 0.0694 |
| 2012 | 781.1541 | 1863 | 190.1950 | 20 | 6.7481 | 0.3613 | 0.0701 |
| 2013 | 584.0728 | 1452 | 158.9600 | 21 | 8.6082 | 0.4539 | 0.0728 |
| 2014 | 356.8551 | 1346 | 88.9805 | 22 | 6.2581 | 0.3115 | 0.0736 |
| 2015 | 367.8410 | 1286 | 64.7780 | 22 | 4.3431 | 0.2161 | 0.0743 |

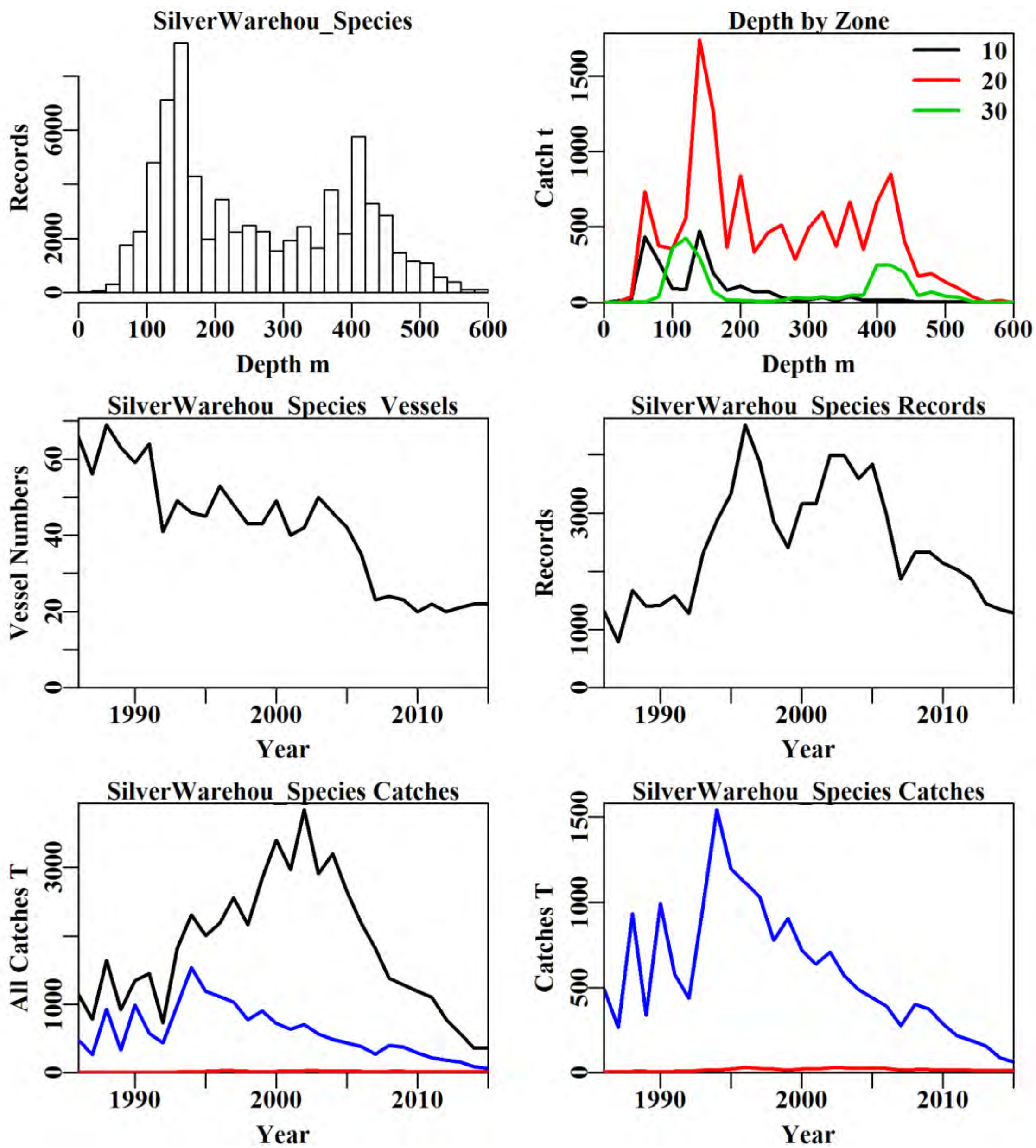



Figure 8.66. Silver Warehou from zones 10 to 30 and depths 0 – 600 m by Trawl. The top left plot depicts the depth distribution of shots containing Silver Warehou from zones 10 to 30 in depths 0 – 600 m by Trawl. The top right plot depicts the catch distribution by depth by zone. The middle left plot depicts the number of vessels through time and middle right plot contains the number of records used in analysis. The bottom left plot contains Silver Warehou catches (top black line: total catches, middle blue line: catches used in the analysis; bottom red line: catches < 30 kg) and bottom right plot contains Silver Warehou catches (blue line: catches used in the analysis; red line: catches < 30 kg).

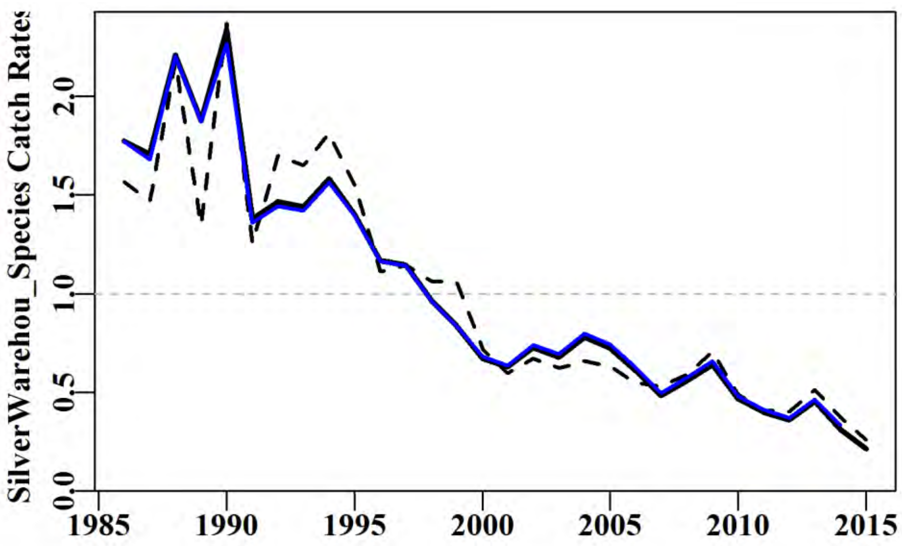



Figure 8.67. Silver Warehou from Zones 10 to 50 and depths 0 – 600 m by Trawl. The dashed black line represents the geometric mean catch rate and the solid black line the standardized catch rates (relative to the mean of the standardized catch rates). The blue line corresponds to last year's standardized indices.

Table 8.62. Silver Warehou from Zones 10 to 50 and depths 0 – 600 m by Trawl. Statistical model structures used in this analysis. DepCat is a series of 20 metre depth categories.

| | |
|---|---|
| Model 1 | LnCE~Year |
| Model 2 | LnCE~Year+Vessel |
| Model 3 | LnCE~Year+Vessel+Month |
| Model 4 | LnCE~Year+Vessel+Month+Zone |
| Model 5 | LnCE~Year+Vessel+Month+Zone+DepCat |
| Model 6 | LnCE~Year+Vessel+Month+Zone+DepCat+DayNight |
| Model 7 | LnCE~Year+Vessel+Month+Zone+DepCat+DayNight+Zone:Month |
| Model 8 | LnCE~Year+Vessel+Month+Zone+DepCat+DayNight+Zone:DepCat |

Table 8.63. Silver Warehou from Zones 10 to 50 and depths 0 – 600 m by Trawl. Model selection criteria include the Akaike Information Criterion (AIC), residual sum of squares (RSS), model sum of squares (MSS), number of usable observations (Nobs), number of parameters (Npars), adjusted $R^2$ (adj_$R^2$) and the change in adjusted $R^2$ (%Change). The optimum is Zone:DepC (Model 8). Depth Category: DepC.

| | Year | Vessel | Month | Zone | DepC | DayNight | Zone:Month | Zone:DepC |
|---|---|---|---|---|---|---|---|---|
| AIC | 81122 | 75037 | 71375 | 69737 | 69443 | 69427 | 68478 | 68435 |
| RSS | 221627 | 202890 | 192895 | 188398 | 187625 | 187566 | 185013 | 184711 |
| MSS | 18485 | 37222 | 47216 | 51714 | 52487 | 52545 | 55098 | 55400 |
| Nobs | 72937 | 72937 | 72937 | 72455 | 72455 | 72455 | 72455 | 72455 |
| Npars | 30 | 209 | 220 | 250 | 252 | 255 | 277 | 315 |
| adj_$R^2$ | 7.662 | 15.260 | 19.422 | 21.267 | 21.588 | 21.609 | 22.652 | 22.738 |
| %Change | 0.000 | 7.598 | 4.162 | 1.844 | 0.321 | 0.021 | 1.043 | 0.086 |

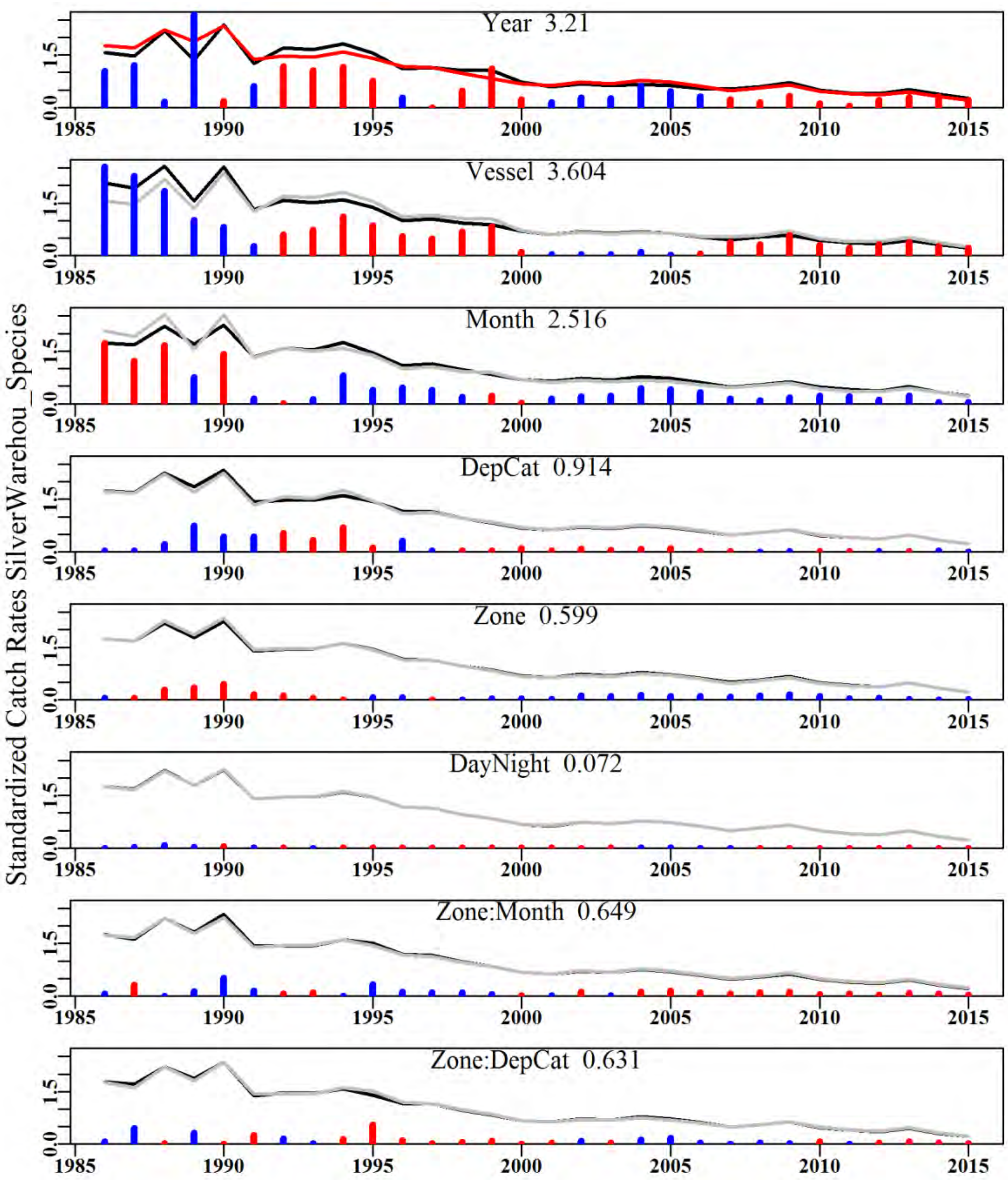



Figure 8.68. The relative influence of each factor used on the final trend in the optimal standardization for Silver Warehou in zones 10 – 30. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by the vertical bars with blue bars indicating the optimum model is higher than the geometric mean and red bars indicating it is lower. The top graph bars are the sum of all the bars in the graphs below. The graphs for individual factors are cumulative. Thus the second graph has the geometric mean (grey line) and the effect of adding Year + factor2 (Model 2). In the third graph, the grey line represents Model 2 and the black line the effect of adding factor3 to the model. The remaining graphs continue in the same cumulative manner except for the interaction terms which are added singularly to the final single factor model.

### 8.4.22 *Silver Warehou Z4050 (TRS – 37445006 – Seriolella punctata)*

Table 8.64. Silver Warehou from Zones 40 and 50 and depths 0 – 600 m by Trawl. Total catch (TotCatch; t) is the total reported in the database, number of records used in the analysis (Records), reported catch (CatchT; t) in the area and depth used in the analysis and number of vessels used in the analysis (Vessels). GeoMean is the geometric mean of catch rates (kg/hr). The optimum model is Zone:Month and standard deviation (StDev) relates to the data in the optimum model.

| Year | TotCatch | Records | CatchT | Vessels | GeoMean | Zone:Month | StDev |
|---|---|---|---|---|---|---|---|
| 1986 | 1156.5330 | 1120 | 643.5880 | 23 | 41.1238 | 1.4596 | 0.0000 |
| 1987 | 782.1510 | 725 | 490.9560 | 26 | 52.8667 | 1.6261 | 0.0830 |
| 1988 | 1646.1870 | 574 | 684.4410 | 27 | 69.3486 | 1.8895 | 0.0881 |
| 1989 | 926.2570 | 650 | 569.5400 | 27 | 59.5779 | 1.6075 | 0.0903 |
| 1990 | 1346.5850 | 569 | 298.6730 | 26 | 43.0973 | 1.0505 | 0.0899 |
| 1991 | 1453.1690 | 706 | 629.4700 | 29 | 40.2037 | 1.1417 | 0.0858 |
| 1992 | 733.7670 | 584 | 187.0270 | 21 | 26.8907 | 0.8673 | 0.0888 |
| 1993 | 1815.8010 | 1546 | 752.4570 | 23 | 43.9668 | 1.1739 | 0.0737 |
| 1994 | 2309.5100 | 1653 | 758.1040 | 26 | 43.8060 | 1.0816 | 0.0716 |
| 1995 | 2002.8810 | 1680 | 774.1450 | 24 | 38.9540 | 0.8550 | 0.0716 |
| 1996 | 2188.2440 | 1566 | 1020.7620 | 26 | 40.2805 | 0.9816 | 0.0727 |
| 1997 | 2562.0160 | 1882 | 1269.2390 | 24 | 44.8612 | 1.1659 | 0.0707 |
| 1998 | 2166.0212 | 1853 | 1197.6010 | 22 | 49.4206 | 1.3781 | 0.0712 |
| 1999 | 2834.0520 | 2747 | 1779.8690 | 24 | 51.4384 | 1.1423 | 0.0681 |
| 2000 | 3401.5633 | 3573 | 2603.0380 | 28 | 51.8176 | 1.1309 | 0.0668 |
| 2001 | 2970.4067 | 4190 | 2179.1090 | 29 | 39.2417 | 0.8619 | 0.0660 |
| 2002 | 3841.4390 | 4434 | 2949.9330 | 27 | 43.7767 | 0.9131 | 0.0657 |
| 2003 | 2910.0946 | 3419 | 2213.4064 | 28 | 44.6963 | 0.9503 | 0.0671 |
| 2004 | 3202.0836 | 4274 | 2548.6279 | 25 | 43.7609 | 1.0361 | 0.0660 |
| 2005 | 2647.9671 | 3080 | 2116.5510 | 24 | 44.2429 | 1.1357 | 0.0679 |
| 2006 | 2191.1968 | 2695 | 1686.4570 | 21 | 38.5112 | 0.9990 | 0.0687 |
| 2007 | 1816.5165 | 2787 | 1390.0405 | 16 | 34.8382 | 1.0216 | 0.0684 |
| 2008 | 1381.1590 | 2074 | 878.7590 | 17 | 27.8222 | 0.8090 | 0.0704 |
| 2009 | 1285.3059 | 2057 | 734.5600 | 13 | 22.1498 | 0.7006 | 0.0706 |
| 2010 | 1189.4336 | 2347 | 796.3264 | 14 | 20.4833 | 0.6373 | 0.0696 |
| 2011 | 1108.7509 | 2913 | 824.6042 | 17 | 19.2600 | 0.6144 | 0.0683 |
| 2012 | 781.1541 | 1905 | 560.3618 | 15 | 15.8987 | 0.4608 | 0.0720 |
| 2013 | 584.0728 | 1527 | 343.9918 | 16 | 15.4251 | 0.4354 | 0.0741 |
| 2014 | 356.8551 | 1545 | 244.4274 | 14 | 13.1656 | 0.4175 | 0.0740 |
| 2015 | 367.8410 | 1379 | 268.1290 | 13 | 14.1038 | 0.4560 | 0.0756 |

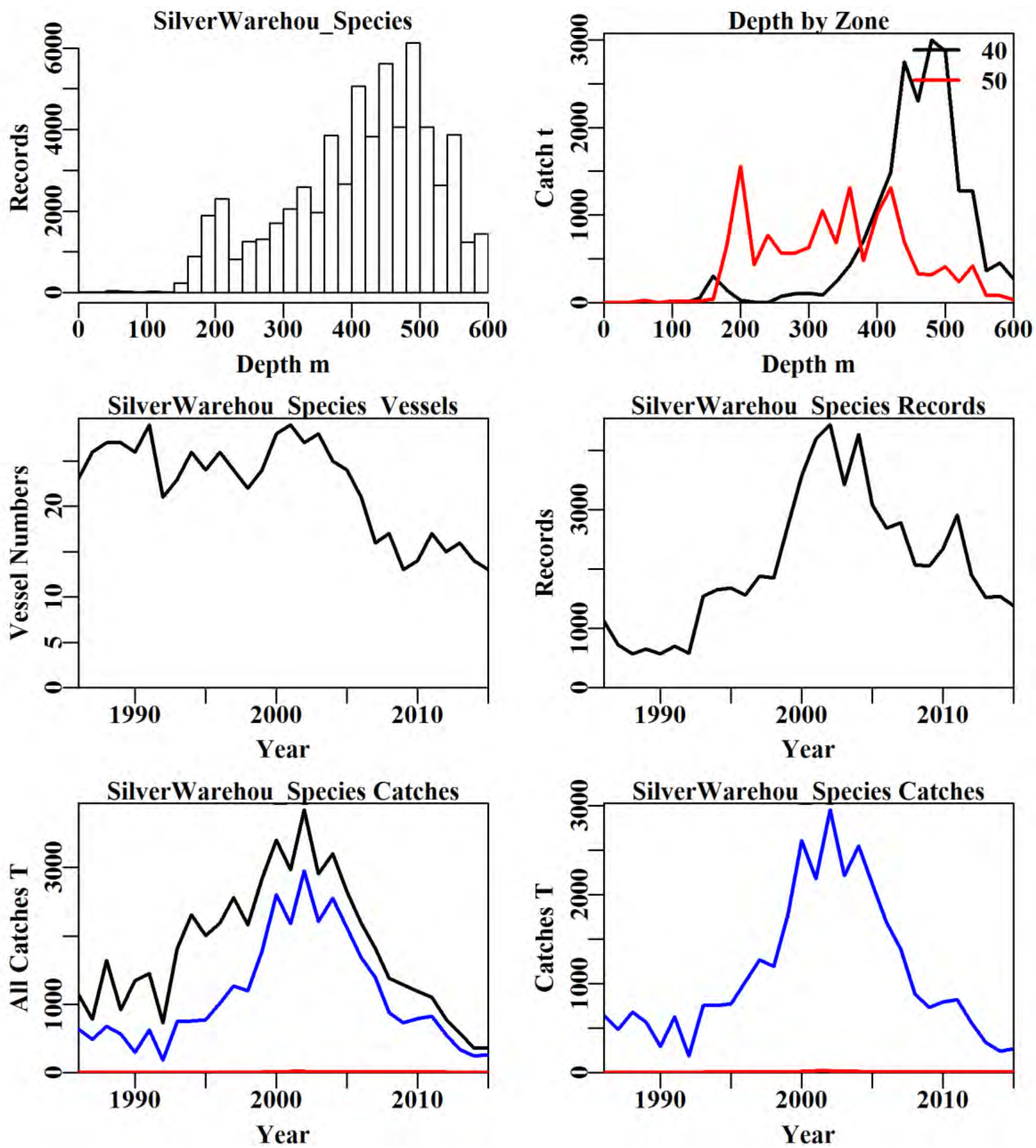



Figure 8.69. Silver Warehou from zones 40 and 50 and depths 0 – 600 m by Trawl. The top left plot depicts the depth distribution of shots containing Silver Warehou from zones 40 and 50 in depths 0 – 600 m by Trawl. The top right plot depicts the catch distribution by depth by zone. The middle left plot depicts the number of vessels through time and middle right plot contains the number of records used in analysis. The bottom left plot contains Silver Warehou catches (top black line: total catches, middle blue line: catches used in the analysis; bottom red line: catches < 30 kg) and bottom right plot contains Silver Warehou catches (blue line: catches used in the analysis; red line: catches < 30 kg).

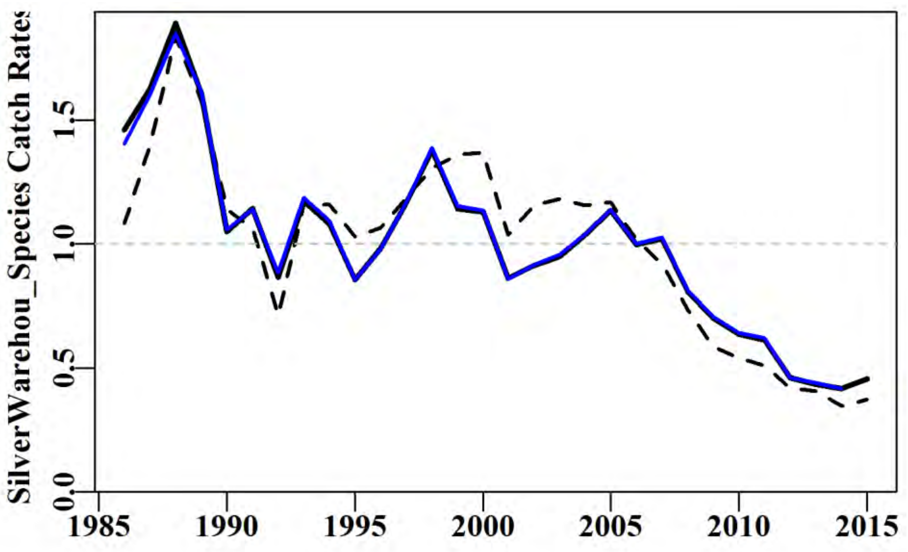



Figure 8.70. Silver Warehou from Zones 40 and 50 and depths 0 – 600 m by Trawl. The dashed black line represents the geometric mean catch rate and the solid black line the standardized catch rates (relative to the mean of the standardized catch rates). The blue line corresponds to last year's standardized indices.

Table 8.65. Silver Warehou from Zones 40 and 50 and depths 0 – 600 m by Trawl. Statistical model structures used in this analysis. DepCat is a series of 20 metre depth categories.

| | |
|---|---|
| Model 1 | LnCE~Year |
| Model 2 | LnCE~Year+Vessel |
| Model 3 | LnCE~Year+Vessel+Month |
| Model 4 | LnCE~Year+Vessel+Month+Zone |
| Model 5 | LnCE~Year+Vessel+Month+Zone+DepCat |
| Model 6 | LnCE~Year+Vessel+Month+Zone+DepCat+DayNight |
| Model 7 | LnCE~Year+Vessel+Month+Zone+DepCat+DayNight+Zone:Month |
| Model 8 | LnCE~Year+Vessel+Month+Zone+DepCat+DayNight+Zone:DepCat |

Table 8.66. Silver Warehou from Zones 40 and 50 and depths 0 – 600 m by Trawl. Model selection criteria include the Akaike Information Criterion (AIC), residual sum of squares (RSS), model sum of squares (MSS), number of usable observations (Nobs), number of parameters (Npars), adjusted $R^2$ (adj_$R^2$) and the change in adjusted $R^2$ (%Change). The optimum is Zone:Month (Model 7). Depth Category: DepC.

| | Year | Vessel | Month | Zone | DepC | DayNight | Zone:Month | Zone:DepC |
|---|---|---|---|---|---|---|---|---|
| AIC | 66542 | 58833 | 55930 | 54397 | 53565 | 53270 | 53035 | 53078 |
| RSS | 181156 | 159489 | 152146 | 148166 | 146176 | 145463 | 144858 | 144870 |
| MSS | 10159 | 31827 | 39169 | 43149 | 45140 | 45852 | 46458 | 46445 |
| Nobs | 62054 | 62054 | 62054 | 61644 | 61644 | 61644 | 61644 | 61644 |
| Npars | 30 | 128 | 139 | 169 | 170 | 173 | 184 | 203 |
| adj_$R^2$ | 5.266 | 16.465 | 20.296 | 22.342 | 23.384 | 23.754 | 24.058 | 24.028 |
| %Change | 0.000 | 11.199 | 3.832 | 2.046 | 1.042 | 0.370 | 0.304 | -0.030 |

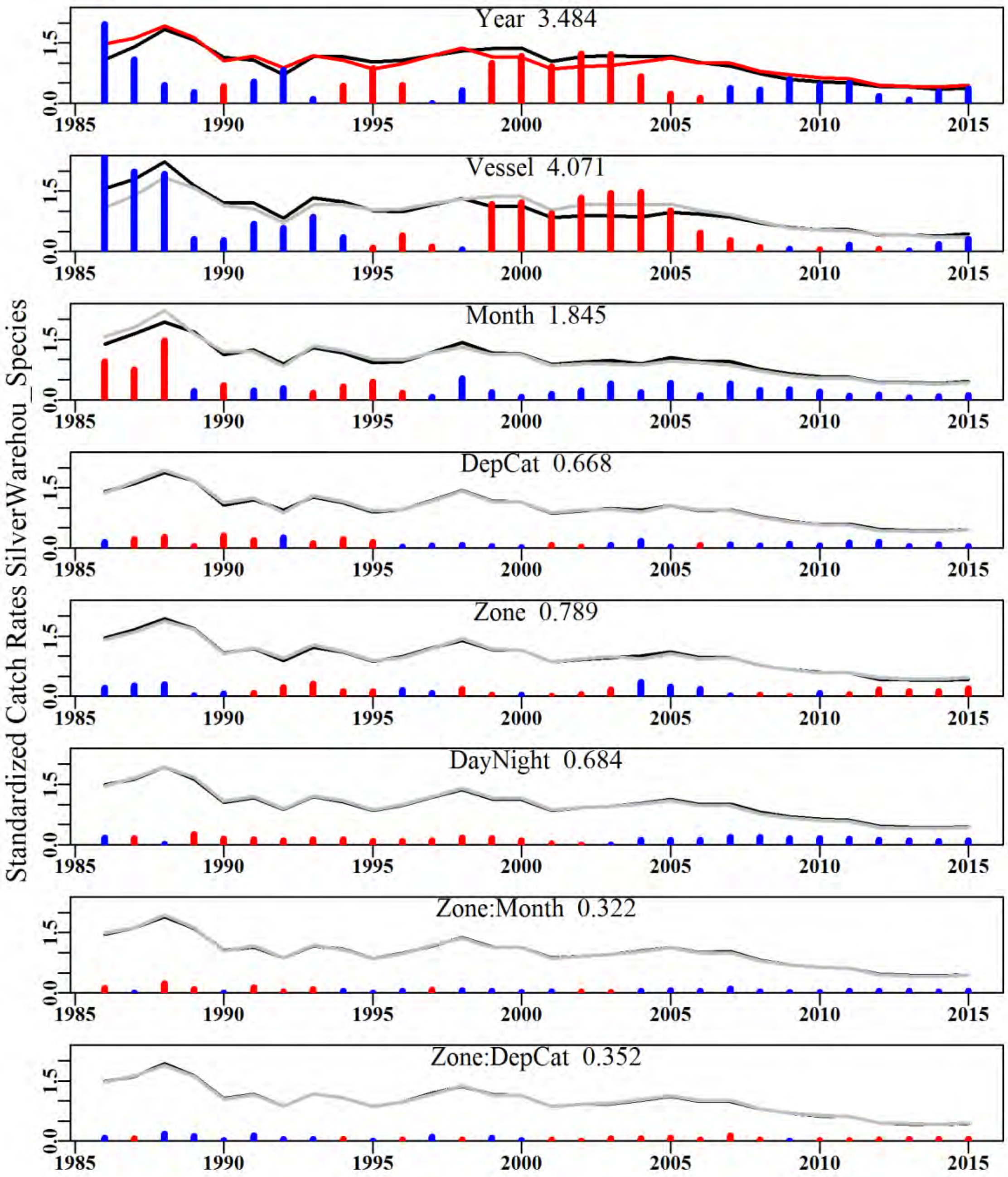



Figure 8.71. The relative influence of each factor used on the final trend in the optimal standardization for Silver Warehou in zones 40 and 50. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by the vertical bars with blue bars indicating the optimum model is higher than the geometric mean and red bars indicating it is lower. The top graph bars are the sum of all the bars in the graphs below. The graphs for individual factors are cumulative. Thus the second graph has the geometric mean (grey line) and the effect of adding Year + factor2 (Model 2). In the third graph, the grey line represents Model 2 and the black line the effect of adding factor3 to the model. The remaining graphs continue in the same cumulative manner except for the interaction terms which are added singularly to the final single factor model.

### 8.4.23 *Blue Warehou Z10–30 (TRT – 37445005 – Seriolella brama)*

Trawl data selected for analysis corresponded to records from zones 10, 20, and 30 from depths less than or equal to 400 m.

Table 8.67. Blue Warehou from zones 10 to 30 in depths 0 – 400 m by Trawl. Total catch (TotCatch; t) is the total reported in the database, number of records used in the analysis (Records), reported catch (CatchT; t) in the area and depth used in the analysis and number of vessels used in the analysis (Vessels). GeoMean is the geometric mean of catch rates (kg/hr). The optimum model is Zone:DepC and standard deviation (StDev) relates to the data in the optimum model.

| Year | TotCatch | Records | CatchT | Vessels | GeoMean | Zone:DepC | StDev |
|---|---|---|---|---|---|---|---|
| 1986 | 211.8770 | 701 | 138.7900 | 40 | 22.9634 | 2.1208 | 0.0000 |
| 1987 | 405.8510 | 457 | 168.1520 | 40 | 23.2716 | 2.5966 | 0.1047 |
| 1988 | 543.9760 | 775 | 334.0470 | 33 | 34.8726 | 3.1977 | 0.0953 |
| 1989 | 776.0410 | 1178 | 664.7090 | 41 | 52.6588 | 4.0194 | 0.0926 |
| 1990 | 881.3530 | 826 | 508.2700 | 42 | 46.5510 | 3.7240 | 0.0975 |
| 1991 | 1284.1940 | 1567 | 465.1580 | 54 | 23.0208 | 1.9626 | 0.0922 |
| 1992 | 934.4050 | 1351 | 407.0970 | 40 | 24.1440 | 1.5937 | 0.0928 |
| 1993 | 829.5730 | 2192 | 431.5160 | 45 | 20.7168 | 1.2686 | 0.0896 |
| 1994 | 944.8050 | 2443 | 473.1760 | 43 | 17.5991 | 1.2233 | 0.0886 |
| 1995 | 815.3840 | 2643 | 464.3400 | 44 | 15.3167 | 1.1139 | 0.0885 |
| 1996 | 724.4080 | 3550 | 531.1030 | 49 | 14.6399 | 1.1452 | 0.0876 |
| 1997 | 935.1594 | 2481 | 404.2950 | 42 | 11.8800 | 1.1166 | 0.0898 |
| 1998 | 903.2421 | 2555 | 457.2320 | 39 | 13.8638 | 1.0473 | 0.0893 |
| 1999 | 590.9751 | 1642 | 131.5910 | 39 | 5.7056 | 0.5784 | 0.0923 |
| 2000 | 470.2475 | 2221 | 185.5790 | 41 | 5.0089 | 0.4800 | 0.0903 |
| 2001 | 285.4641 | 1475 | 57.3440 | 33 | 2.7894 | 0.2861 | 0.0938 |
| 2002 | 290.4765 | 1858 | 62.9810 | 36 | 2.2078 | 0.2172 | 0.0923 |
| 2003 | 233.9681 | 1324 | 42.0775 | 38 | 1.8331 | 0.1677 | 0.0953 |
| 2004 | 232.4455 | 1249 | 52.0505 | 38 | 2.7248 | 0.2291 | 0.0970 |
| 2005 | 289.0633 | 830 | 21.2863 | 33 | 1.8011 | 0.1534 | 0.1014 |
| 2006 | 379.5272 | 776 | 25.7195 | 28 | 2.2327 | 0.1818 | 0.1026 |
| 2007 | 177.7756 | 584 | 16.7583 | 14 | 1.8647 | 0.1906 | 0.1075 |
| 2008 | 163.2600 | 738 | 27.4410 | 18 | 2.6539 | 0.2672 | 0.1032 |
| 2009 | 135.2235 | 447 | 36.8840 | 15 | 3.5956 | 0.3146 | 0.1122 |
| 2010 | 129.3300 | 372 | 12.0425 | 15 | 2.0876 | 0.1977 | 0.1178 |
| 2011 | 103.2946 | 435 | 9.8117 | 13 | 1.7081 | 0.1626 | 0.1136 |
| 2012 | 52.2722 | 356 | 9.9005 | 14 | 1.6727 | 0.1352 | 0.1188 |
| 2013 | 67.9643 | 166 | 3.6740 | 17 | 1.6983 | 0.1246 | 0.1475 |
| 2014 | 15.3153 | 89 | 1.7870 | 12 | 1.0422 | 0.0821 | 0.1834 |
| 2015 | 5.4345 | 55 | 1.5870 | 9 | 1.5278 | 0.1019 | 0.2227 |

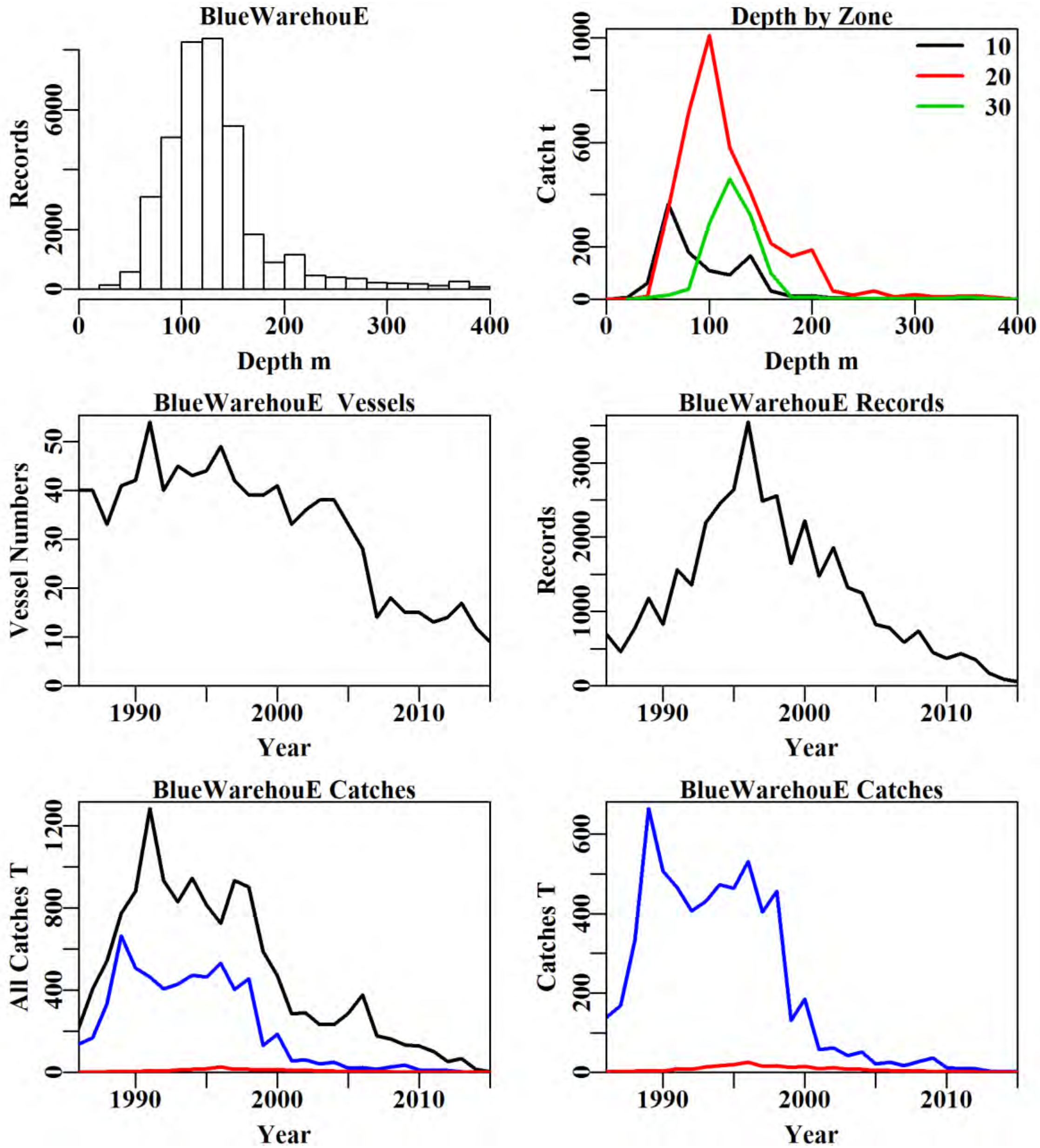



Figure 8.72. Blue Warehou from zones 10 to 30 in depths 0 – 400 m by Trawl. The top left plot depicts the depth distribution of shots containing Blue Warehou from zones 10 to 30 in depths 0 – 400 m by Trawl. The top right plot depicts the catch distribution by depth by zone. The middle left plot depicts the number of vessels through time and middle right plot contains the number of records used in analysis. The bottom left plot contains Blue Warehou catches (top black line: total catches, middle blue line: catches used in the analysis; bottom red line: catches < 30 kg) and bottom right plot contains Blue Warehou catches (blue line: catches used in the analysis; red line: catches < 30 kg).

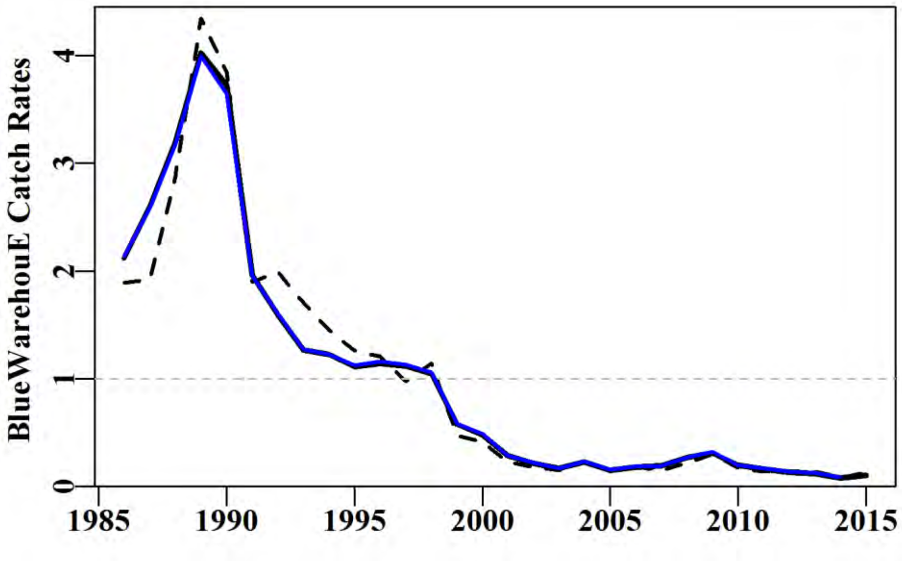



Figure 8.73. Blue Warehou from zones 10 to 30 in depths 0 – 400 m by Trawl. The dashed black line represents the geometric mean catch rate and the solid black line the standardized catch rates (relative to the mean of the standardized catch rates). The blue line corresponds to last year's standardized indices.

Table 8.68. Blue Warehou from zones 10 to 30 in depths 0 – 400 m by Trawl. Statistical model structures used in this analysis. DepCat is a series of 20 metre depth categories.

| | |
|---|---|
| Model 1 | LnCE~Year |
| Model 2 | LnCE~Year+Vessel |
| Model 3 | LnCE~Year+Vessel+DepCat |
| Model 4 | LnCE~Year+Vessel+DepCat+Month |
| Model 5 | LnCE~Year+Vessel+DepCat+Month+Zone |
| Model 6 | LnCE~Year+Vessel+DepCat+Month+Zone+DayNight |
| Model 7 | LnCE~Year+Vessel+DepCat+Month+Zone+DayNight+Zone:Month |
| Model 8 | LnCE~Year+Vessel+DepCat+Month+Zone+DayNight+Zone:DepCat |

Table 8.69. Blue Warehou from zones 10 to 30 in depths 0 – 400 m by Trawl Model selection criteria include the Akaike Information Criterion (AIC), residual sum of squares (RSS), model sum of squares (MSS), number of usable observations (Nobs), number of parameters (Npars), adjusted $R^2$ (adj_$R^2$) and the change in adjusted $R^2$ (%Change). The optimum is Zone:DepC (Model 8). Depth Category: DepC.

| | Year | Vessel | DepC | Month | Zone | DayNight | Zone:Month | Zone:DepC |
|---|---|---|---|---|---|---|---|---|
| AIC | 37392 | 32685 | 32029 | 31761 | 31382 | 31296 | 31048 | 31005 |
| RSS | 101479 | 88686 | 86970 | 86334 | 85405 | 85193 | 84527 | 84348 |
| MSS | 38494 | 51287 | 53004 | 53640 | 54568 | 54780 | 55447 | 55625 |
| Nobs | 37336 | 37336 | 37111 | 37111 | 37111 | 37111 | 37111 | 37111 |
| Npars | 30 | 192 | 212 | 214 | 225 | 228 | 250 | 268 |
| adj_$R^2$ | 27.445 | 36.315 | 37.512 | 37.965 | 38.614 | 38.761 | 39.204 | 39.303 |
| %Change | 0.000 | 8.870 | 1.197 | 0.454 | 0.649 | 0.147 | 0.443 | 0.099 |

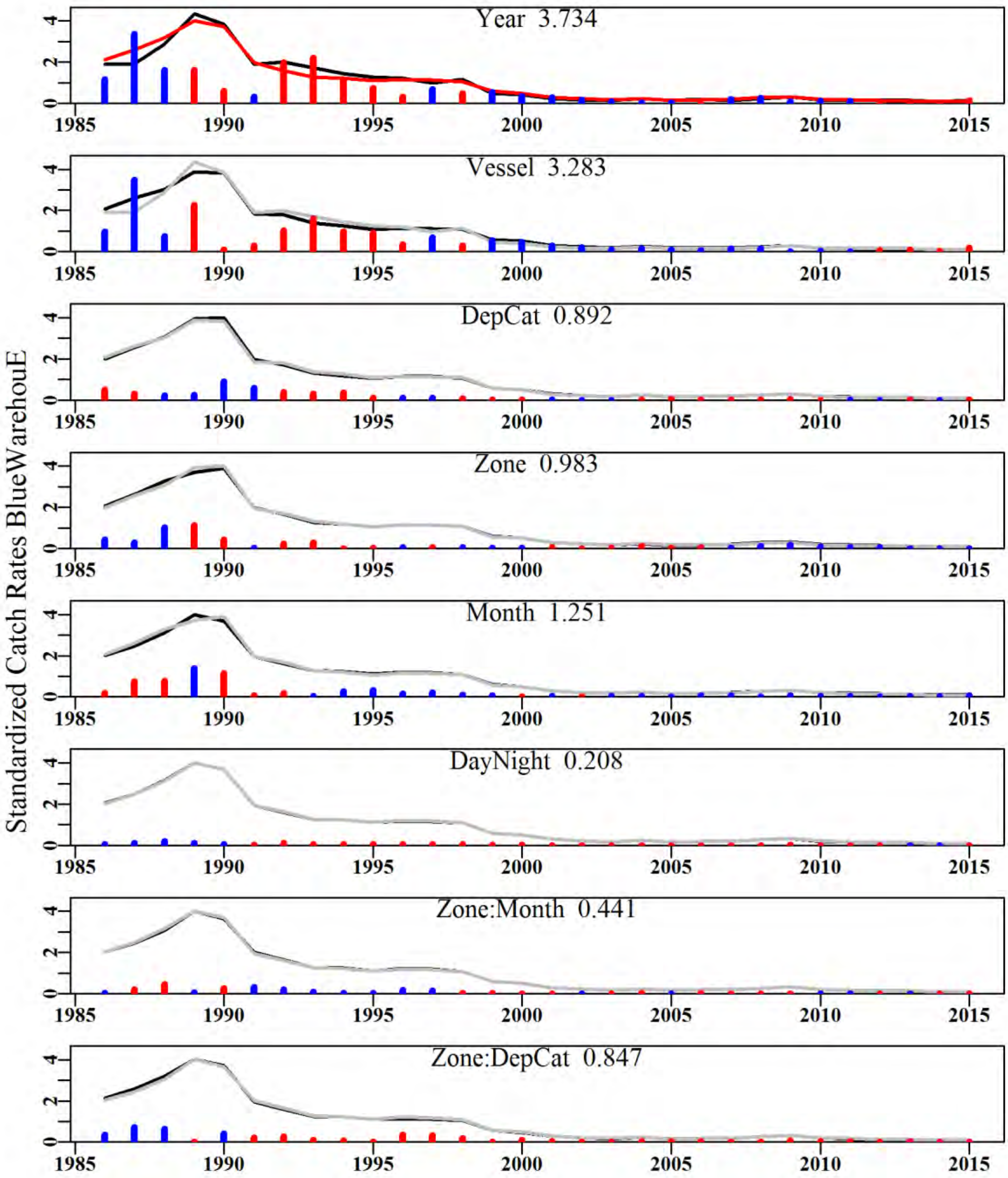



Figure 8.74. The relative influence of each factor used on the final trend in the optimal standardization for Blue Warehou in zone 10 – 30. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by the vertical bars with blue bars indicating the optimum model is higher than the geometric mean and red bars indicating it is lower. The top graph bars are the sum of all the bars in the graphs below. The graphs for individual factors are cumulative. Thus the second graph has the geometric mean (grey line) and the effect of adding Year + factor2 (Model 2). In the third graph, the grey line represents Model 2 and the black line the effect of adding factor3 to the model. The remaining graphs continue in the same cumulative manner except for the interaction terms which are added singularly to the final single factor model.

### 8.4.24 *Blue Warehou Z4050 (TRT – 37445005 – Seriolella brama)*

Trawl data corresponding to zones 40 and 50 from depths less than or equal to 600 m were analysed.

Table 8.70. Blue Warehou from zones 40 and 50 in depths 0 – 600 m by Trawl. Total catch (TotCatch; t) is the total reported in the database, number of records used in the analysis (Records), reported catch (CatchT; t) in the area and depth used in the analysis and number of vessels used in the analysis (Vessels). GeoMean is the geometric mean of catch rates (kg/hr). The optimum model is Zone:Month and standard deviation (StDev) relates to the data in the optimum model.

| Year | TotCatch | Records | CatchT | Vessels | GeoMean | Zone:Month | StDev |
|---|---|---|---|---|---|---|---|
| 1986 | 211.8770 | 159 | 71.3890 | 14 | 34.3927 | 3.5560 | 0.0000 |
| 1987 | 405.8510 | 183 | 215.6450 | 10 | 153.6342 | 3.4959 | 0.2440 |
| 1988 | 543.9760 | 180 | 197.9890 | 12 | 104.5294 | 1.4993 | 0.2519 |
| 1989 | 776.0410 | 56 | 81.3430 | 13 | 91.5270 | 3.8418 | 0.3122 |
| 1990 | 881.3530 | 444 | 298.2960 | 14 | 55.8069 | 1.6072 | 0.2379 |
| 1991 | 1284.1940 | 597 | 647.5370 | 18 | 159.6429 | 2.5887 | 0.2359 |
| 1992 | 934.4050 | 538 | 430.1330 | 17 | 88.9759 | 1.4507 | 0.2375 |
| 1993 | 829.5730 | 495 | 362.8540 | 21 | 92.3447 | 1.0914 | 0.2389 |
| 1994 | 944.8050 | 824 | 449.9010 | 21 | 67.3117 | 1.1900 | 0.2343 |
| 1995 | 815.3840 | 825 | 325.1500 | 22 | 45.1964 | 0.8057 | 0.2319 |
| 1996 | 724.4080 | 700 | 183.5500 | 24 | 26.4215 | 0.5465 | 0.2334 |
| 1997 | 935.1594 | 431 | 243.5470 | 23 | 35.6095 | 0.5740 | 0.2390 |
| 1998 | 903.2421 | 582 | 354.4830 | 19 | 58.9967 | 0.8917 | 0.2373 |
| 1999 | 590.9751 | 688 | 174.3760 | 19 | 32.5226 | 0.4955 | 0.2366 |
| 2000 | 470.2475 | 652 | 203.6200 | 24 | 28.2022 | 0.3953 | 0.2368 |
| 2001 | 285.4641 | 686 | 194.1760 | 23 | 27.6016 | 0.4215 | 0.2357 |
| 2002 | 290.4765 | 531 | 218.1070 | 23 | 35.4283 | 0.5487 | 0.2381 |
| 2003 | 233.9681 | 362 | 175.4480 | 19 | 28.2126 | 0.4881 | 0.2440 |
| 2004 | 232.4455 | 437 | 159.2550 | 21 | 28.4995 | 0.5403 | 0.2407 |
| 2005 | 289.0633 | 461 | 257.8010 | 18 | 53.5991 | 0.8403 | 0.2412 |
| 2006 | 379.5272 | 695 | 337.4725 | 16 | 31.8482 | 0.5851 | 0.2375 |
| 2007 | 177.7756 | 466 | 148.6395 | 16 | 22.9820 | 0.4988 | 0.2412 |
| 2008 | 163.2600 | 353 | 117.7735 | 12 | 20.3955 | 0.3990 | 0.2436 |
| 2009 | 135.2235 | 308 | 89.0030 | 11 | 18.4388 | 0.2936 | 0.2457 |
| 2010 | 129.3300 | 407 | 105.2905 | 12 | 17.5511 | 0.3453 | 0.2411 |
| 2011 | 103.2946 | 519 | 77.9065 | 14 | 14.3950 | 0.3101 | 0.2396 |
| 2012 | 52.2722 | 262 | 32.7576 | 14 | 8.1485 | 0.1826 | 0.2507 |
| 2013 | 67.9643 | 305 | 57.9275 | 13 | 12.4449 | 0.2445 | 0.2470 |
| 2014 | 15.3153 | 60 | 11.6460 | 9 | 9.3797 | 0.1917 | 0.3078 |
| 2015 | 5.4345 | 18 | 0.5810 | 5 | 2.6356 | 0.0806 | 0.4405 |

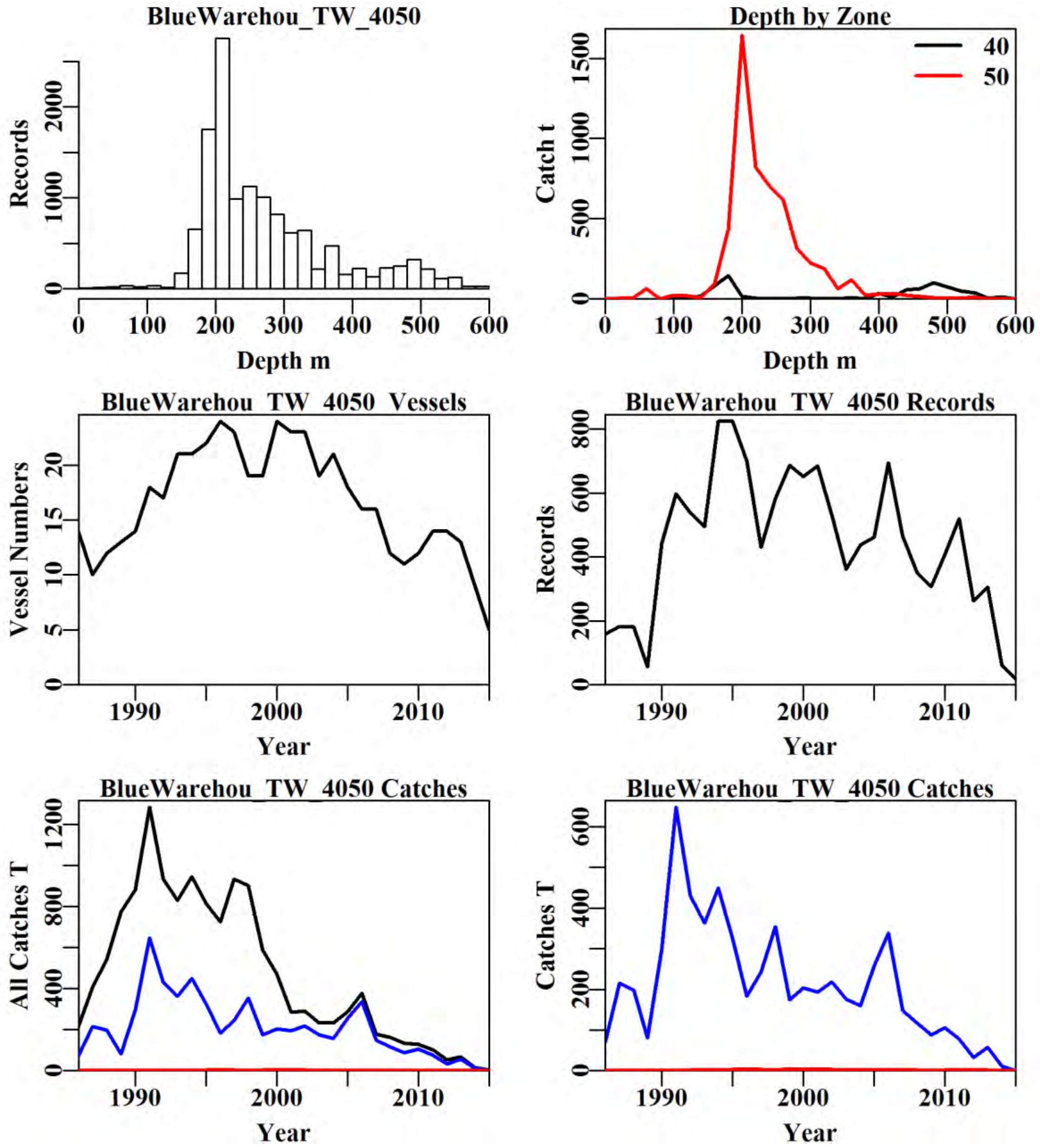



Figure 8.75. Blue Warehou from zones 40 and 50 in depths 0 – 600 m by Trawl. The top left plot depicts the depth distribution of shots containing Blue Warehou from zones 40 and 50 in depths 0 – 600 m by Trawl. The top right plot depicts the catch distribution by depth by zone. The middle left plot depicts the number of vessels through time and middle right plot contains the number of records used in analysis. The bottom left plot contains Blue Warehou catches (top black line: total catches, middle blue line: catches used in the analysis; bottom red line: catches < 30 kg) and bottom right plot contains Blue Warehou catches (blue line: catches used in the analysis; red line: catches < 30 kg).

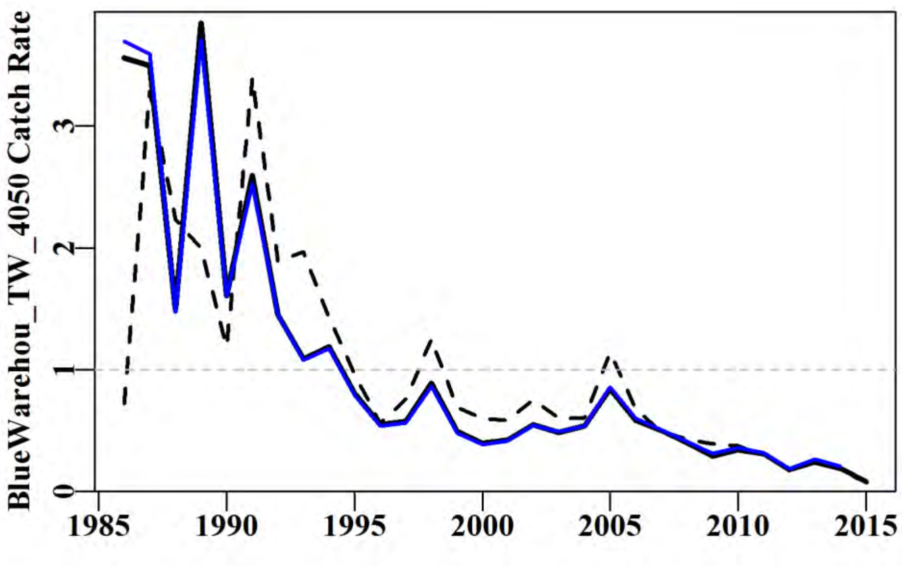



Figure 8.76. Blue Warehou from zones 40 and 50 in depths 0 – 600 m by Trawl. The dashed black line represents the geometric mean catch rate and the solid black line the standardized catch rates (relative to the mean of the standardized catch rates). The blue line corresponds to last year's standardized indices.

Table 8.71. Blue Warehou from zones 40 and 50 in depths 0 – 600 m by Trawl. Statistical model structures used in this analysis. DepCat is a series of 20 metre depth categories.

| | |
|---|---|
| Model 1 | LnCE~Year |
| Model 2 | LnCE~Year+Vessel |
| Model 3 | LnCE~Year+Vessel+Month |
| Model 4 | LnCE~Year+Vessel+Month+DepCat |
| Model 5 | LnCE~Year+Vessel+Month+DepCat+DayNight |
| Model 6 | LnCE~Year+Vessel+Month+DepCat+DayNight+Zone |
| Model 7 | LnCE~Year+Vessel+Month+DepCat+DayNight+Zone+Zone:Month |
| Model 8 | LnCE~Year+Vessel+Month+DepCat+DayNight+Zone+Zone:DepCat |

Table 8.72. Blue Warehou from zones 40 and 50 in depths 0 – 600m by Trawl. Model selection criteria include the Akaike Information Criterion (AIC), residual sum of squares (RSS), model sum of squares (MSS), number of usable observations (Nobs), number of parameters (Npars), adjusted $R^2$ (adj_$R^2$) and the change in adjusted $R^2$ (%Change). The optimum is Model 7 (Zone:Month). Depth category: DepC.

| | Year | Vessel | Month | DepC | DayNight | Zone | Zone:Month | Zone:DepC |
|---|---|---|---|---|---|---|---|---|
| AIC | 14702 | 13550 | 12522 | 11725 | 11671 | 11667 | 11631 | 11644 |
| RSS | 40017 | 36229 | 33466 | 31345 | 31203 | 31189 | 31050 | 30993 |
| MSS | 5847 | 9635 | 12398 | 14519 | 14661 | 14675 | 14814 | 14871 |
| Nobs | 13224 | 13224 | 13224 | 13160 | 13160 | 13160 | 13160 | 13160 |
| Npars | 30 | 111 | 122 | 152 | 155 | 156 | 167 | 186 |
| adj_$R^2$ | 12.557 | 20.345 | 26.359 | 30.863 | 31.161 | 31.186 | 31.435 | 31.461 |
| %Change | 0.000 | 7.787 | 6.014 | 4.505 | 0.298 | 0.025 | 0.248 | 0.026 |

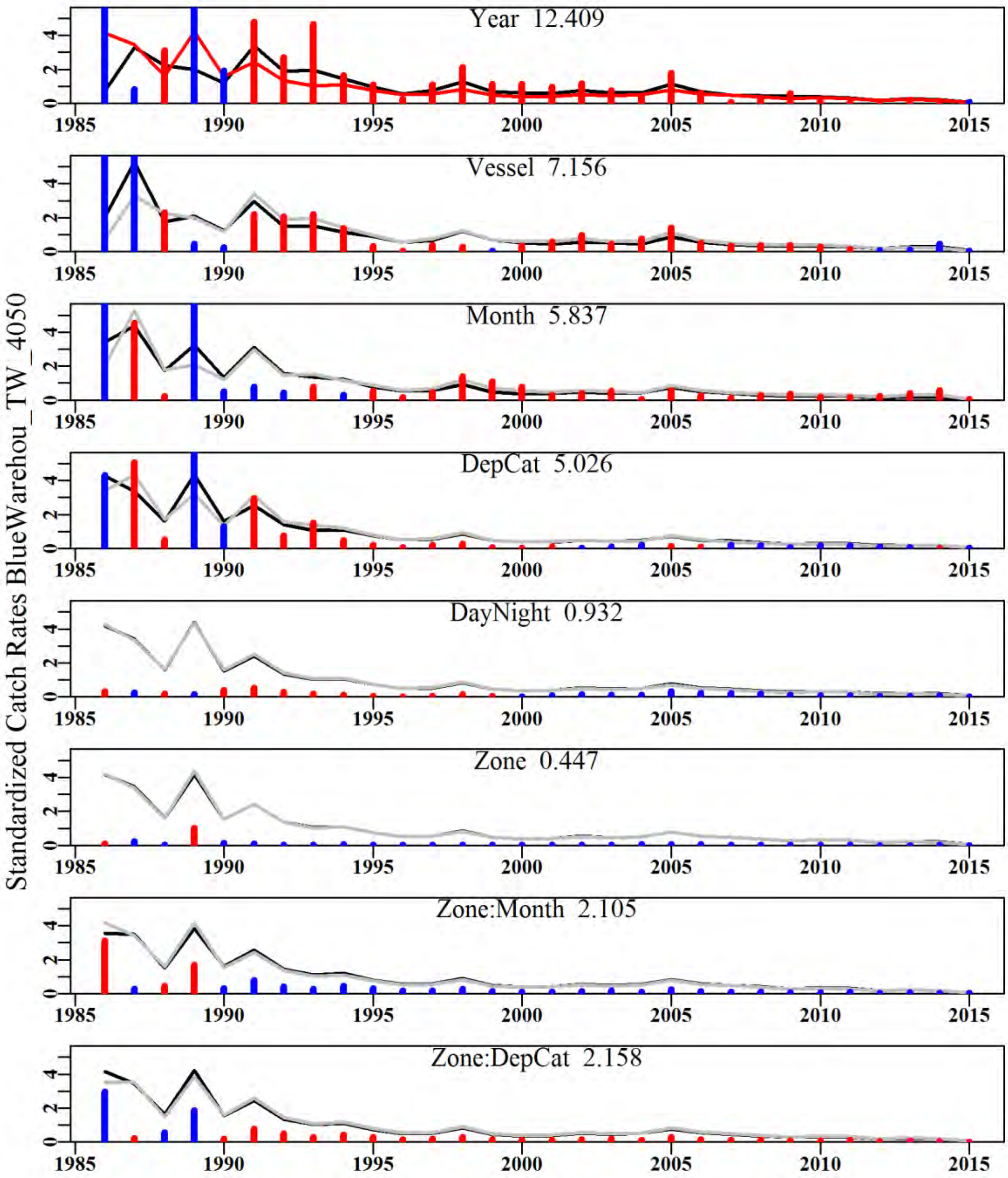



Figure 8.77. The relative influence of each factor used on the final trend in the optimal standardization for Blue Warehou in zone 40 – 50. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by the vertical bars with blue bars indicating the optimum model is higher than the geometric mean and red bars indicating it is lower. The top graph bars are the sum of all the bars in the graphs below. The graphs for individual factors are cumulative. Thus the second graph has the geometric mean (grey line) and the effect of adding Year + factor2 (Model 2). In the third graph, the grey line represents Model 2 and the black line the effect of adding factor3 to the model. The remaining graphs continue in the same cumulative manner except for the interaction terms which are added singularly to the final single factor model.

#### 8.4.25 *Blue Warehou Z10–50 (TRT – 37445005 – Seriolella brama)*

Trawl data corresponding to zones 10 to 50 in depths 0 – 600 m and vessels present in the fishery for more than two years were analysed.

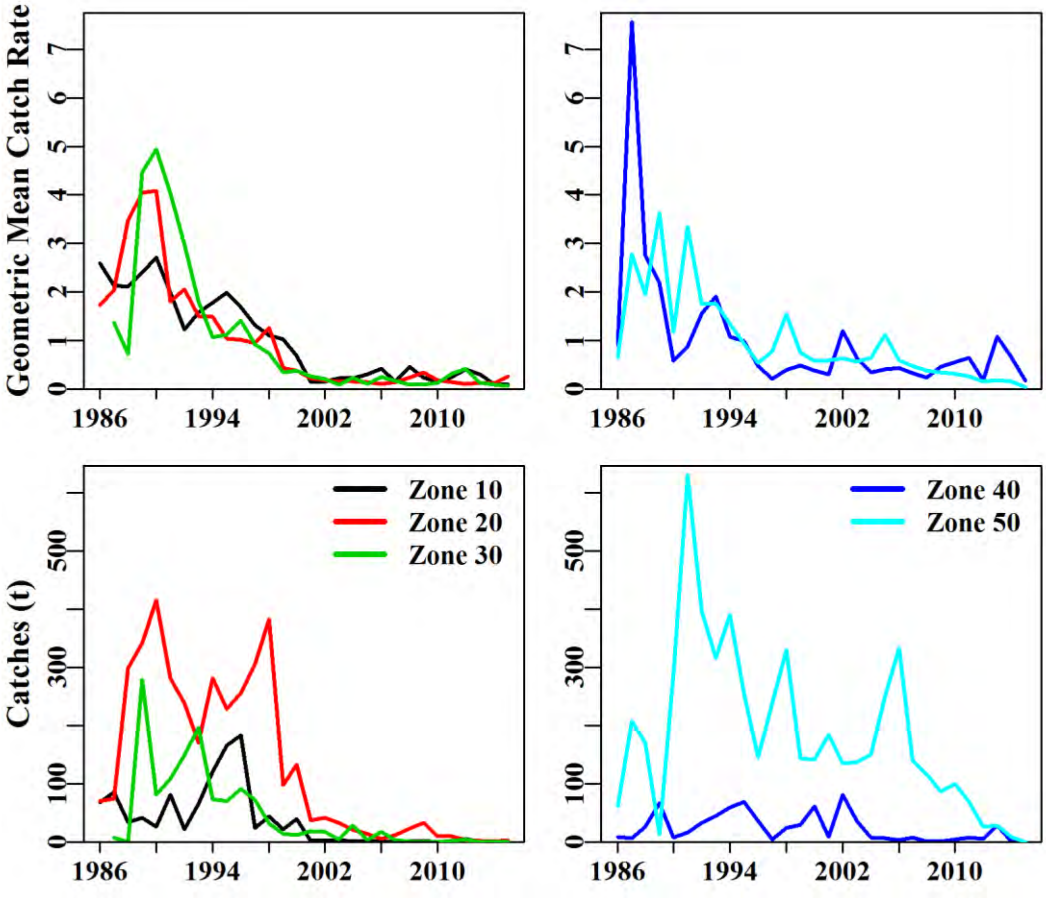



Figure 8.78. Trends in the catches and geometric mean catch rates for Blue Warehou across each of the zones 10 – 50, split east and west. The extreme catch rates in zone 40 reflect very small catches.

The severe depletion in the east is evident but in the west the catch rates are noisy then flat. They are depressed primarily because of early high values that reflect very low catches or relatively high catches. Zone 50 is the main part of the western Blue Warehou fishery.

Table 8.73. Blue Warehou from zones 10 to 50 in depths 0 – 600 m by Trawl. Total catch (TotCatch; t) is the total reported in the database, number of records used in the analysis (Records), reported catch (CatchT; t) in the area and depth used in the analysis and number of vessels used in the analysis (Vessels). GeoMean is the geometric mean of catch rates (kg/hr). The optimum model is Zone:Month and standard deviation (StDev) relates to the data in the optimum model.

| Year | TotCatch | Records | CatchT | Vessels | GeoMean | Zone:Month | StDev |
|---|---|---|---|---|---|---|---|
| 1986 | 211.8770 | 862 | 210.2890 | 54 | 24.6804 | 2.2862 | 0.0000 |
| 1987 | 405.8510 | 655 | 384.5560 | 51 | 38.9818 | 2.6160 | 0.0923 |
| 1988 | 543.9760 | 963 | 532.3580 | 45 | 42.2791 | 2.9372 | 0.0894 |
| 1989 | 776.0410 | 1239 | 746.1520 | 50 | 53.5132 | 4.0117 | 0.0879 |
| 1990 | 881.3530 | 1284 | 822.4190 | 56 | 49.3618 | 2.8641 | 0.0891 |
| 1991 | 1284.1940 | 2193 | 1119.7880 | 66 | 38.9026 | 2.2386 | 0.0850 |
| 1992 | 934.4050 | 1910 | 840.6520 | 57 | 34.6593 | 1.6326 | 0.0858 |
| 1993 | 829.5730 | 2714 | 797.0890 | 58 | 27.0343 | 1.2922 | 0.0837 |
| 1994 | 944.8050 | 3294 | 926.5050 | 57 | 24.5529 | 1.2411 | 0.0825 |
| 1995 | 815.3840 | 3494 | 791.2120 | 58 | 19.7089 | 1.0447 | 0.0823 |
| 1996 | 724.4080 | 4277 | 715.6340 | 66 | 16.0435 | 1.0578 | 0.0818 |
| 1997 | 935.1594 | 2925 | 648.1530 | 57 | 13.9067 | 1.0573 | 0.0840 |
| 1998 | 903.2421 | 3151 | 813.7120 | 50 | 18.0398 | 1.0513 | 0.0834 |
| 1999 | 590.9751 | 2371 | 309.6460 | 57 | 9.5296 | 0.5643 | 0.0852 |
| 2000 | 470.2475 | 2905 | 390.3170 | 59 | 7.3031 | 0.4863 | 0.0840 |
| 2001 | 285.4641 | 2215 | 253.4310 | 52 | 5.6332 | 0.3270 | 0.0860 |
| 2002 | 290.4765 | 2411 | 281.2400 | 53 | 4.0510 | 0.2758 | 0.0857 |
| 2003 | 233.9681 | 1708 | 218.3395 | 51 | 3.2829 | 0.2215 | 0.0883 |
| 2004 | 232.4455 | 1700 | 211.5094 | 51 | 4.9660 | 0.3044 | 0.0889 |
| 2005 | 289.0633 | 1297 | 279.4293 | 45 | 6.0446 | 0.2834 | 0.0913 |
| 2006 | 379.5272 | 1474 | 363.2420 | 36 | 7.8259 | 0.2853 | 0.0903 |
| 2007 | 177.7756 | 1052 | 165.4073 | 25 | 5.6675 | 0.2597 | 0.0938 |
| 2008 | 163.2600 | 1100 | 145.3175 | 27 | 5.0903 | 0.2942 | 0.0930 |
| 2009 | 135.2235 | 766 | 126.2322 | 24 | 6.9116 | 0.2940 | 0.0979 |
| 2010 | 129.3300 | 783 | 117.5180 | 22 | 6.3064 | 0.2343 | 0.0978 |
| 2011 | 103.2946 | 966 | 91.4787 | 23 | 5.5254 | 0.2205 | 0.0951 |
| 2012 | 52.2722 | 633 | 46.4206 | 25 | 3.2664 | 0.1578 | 0.1020 |
| 2013 | 67.9643 | 492 | 62.5255 | 26 | 6.0280 | 0.1873 | 0.1076 |
| 2014 | 15.3153 | 159 | 14.2100 | 18 | 2.7908 | 0.1411 | 0.1478 |
| 2015 | 5.4345 | 80 | 4.5055 | 13 | 2.2595 | 0.1325 | 0.1929 |

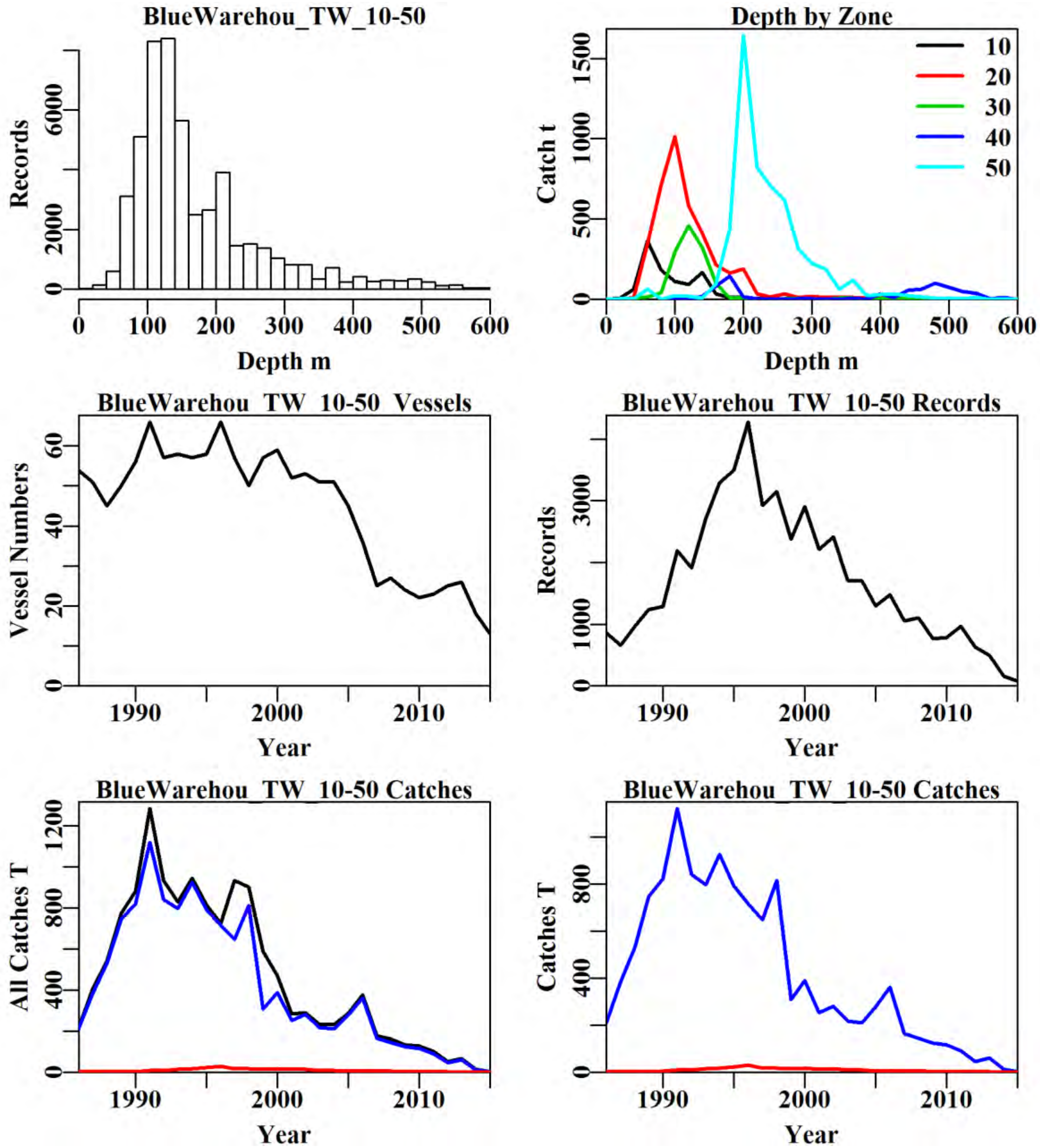



Figure 8.79. Blue Warehou from zones 10 to 50 in depths 0 – 600 m by Trawl. The top left plot depicts the depth distribution of shots containing Blue Warehou from zones 10 to 50 in depths 0 – 600 m by Trawl. The top right plot depicts the catch distribution by depth by zone. The middle left plot depicts the number of vessels through time and middle right plot contains the number of records used in analysis. The bottom left plot contains Blue Warehou catches (top black line: total catches, middle blue line: catches used in the analysis; bottom red line: catches < 30 kg) and bottom right plot contains Blue Warehou catches (blue line: catches used in the analysis; red line: catches < 30 kg).

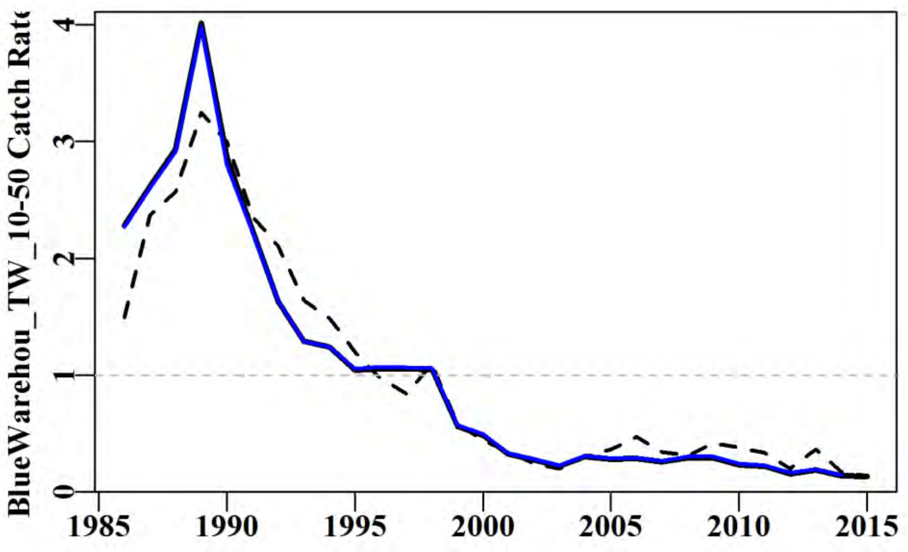



Figure 8.80. Blue Warehou from zones 10 to 50 in depths 0 – 600 m by Trawl. The dashed black line represents the geometric mean catch rate and the solid black line the standardized catch rates (relative to the mean of the standardized catch rates). The blue line corresponds to last year's standardized indices.

Table 8.74. Blue Warehou from zones 10 to 50 in depths 0 – 600 m by Trawl. Statistical model structures used in this analysis. DepCat is a series of 20 metre depth categories.

| | |
|---|---|
| Model 1 | LnCE~Year |
| Model 2 | LnCE~Year+Vessel |
| Model 3 | LnCE~Year+Vessel+DepCat |
| Model 4 | LnCE~Year+Vessel+DepCat+Zone |
| Model 5 | LnCE~Year+Vessel+DepCat+Zone+Month |
| Model 6 | LnCE~Year+Vessel+DepCat+Zone+Month+DayNight |
| Model 7 | LnCE~Year+Vessel+DepCat+Zone+Month+DayNight+Zone:Month |
| Model 8 | LnCE~Year+Vessel+DepCat+Zone+Month+DayNight+Zone:DepCat |

Table 8.75. Blue Warehou from zones 10 to 50 in depths 0 – 600 m by Trawl. Model selection criteria include the Akaike Information Criterion (AIC), residual sum of squares (RSS), model sum of squares (MSS), number of usable observations (Nobs), number of parameters (Npars), adjusted $R^2$ (adj_$R^2$) and the change in adjusted $R^2$ (%Change). The optimum is Zone:Month (Model 7). Depth category: DepC.

| | Year | Vessel | DepC | Zone | Month | DayNight | Zone:Month | Zone:DepC |
|---|---|---|---|---|---|---|---|---|
| AIC | 63016 | 49075 | 47768 | 46574 | 45866 | 45825 | 44798 | 45052 |
| RSS | 175199 | 132350 | 128801 | 125788 | 123992 | 123879 | 121187 | 121432 |
| MSS | 32856 | 75706 | 79254 | 82267 | 84063 | 84176 | 86868 | 86623 |
| Nobs | 51073 | 51073 | 50784 | 50784 | 50784 | 50784 | 50784 | 50784 |
| Npars | 30 | 222 | 252 | 256 | 267 | 270 | 314 | 390 |
| adj_$R^2$ | 15.744 | 36.111 | 37.785 | 39.236 | 40.090 | 40.141 | 41.391 | 41.184 |
| %Change | 0.000 | 20.367 | 1.675 | 1.450 | 0.855 | 0.051 | 1.250 | -0.207 |

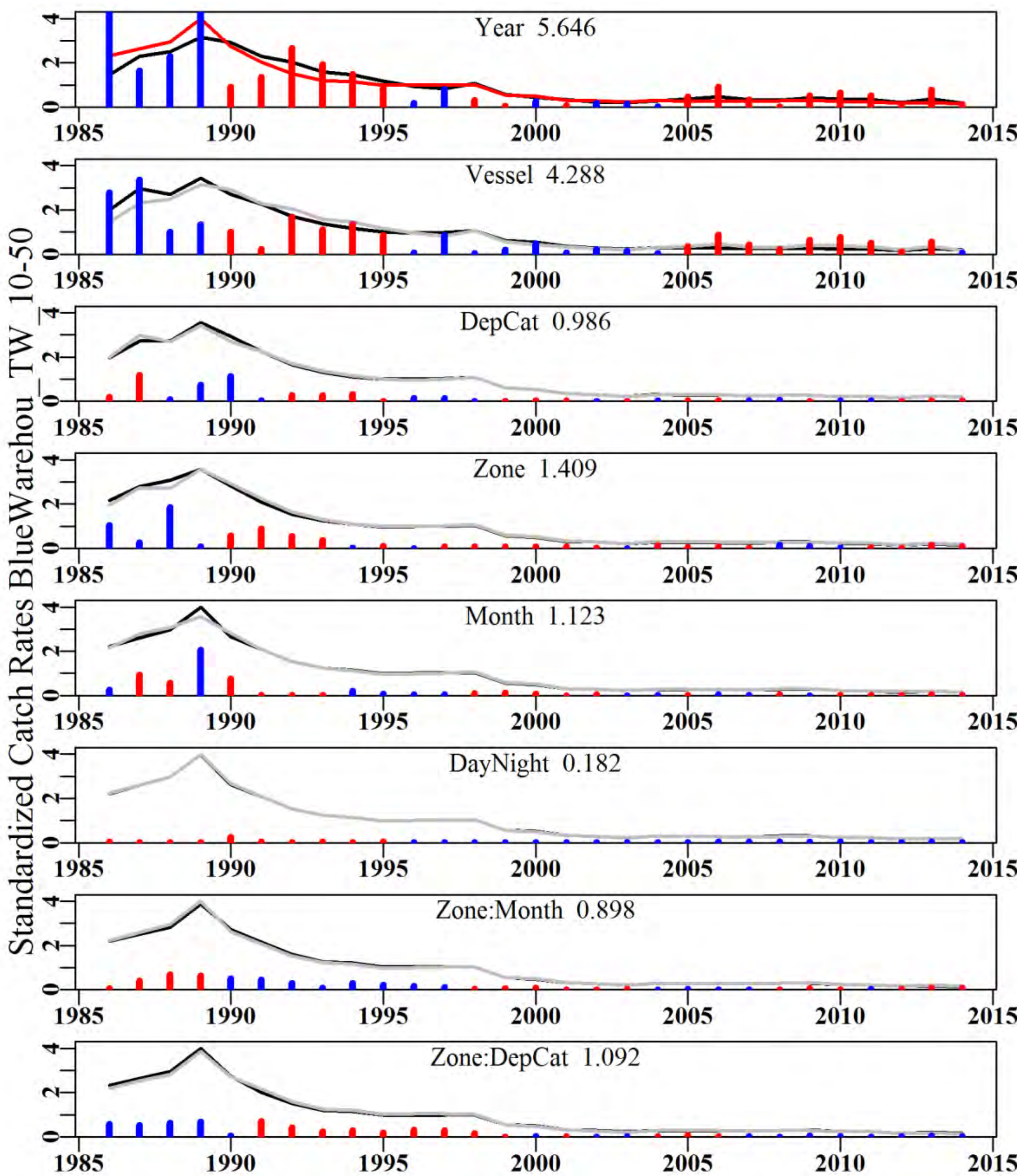



Figure 8.81. The relative influence of each factor used on the final trend in the optimal standardization for Blue Warehou in zone 10 – 50. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by the vertical bars with blue bars indicating the optimum model is higher than the geometric mean and red bars indicating it is lower. The top graph bars are the sum of all the bars in the graphs below. The graphs for individual factors are cumulative. Thus the second graph has the geometric mean (grey line) and the effect of adding Year + factor2 (Model 2). In the third graph, the grey line represents Model 2 and the black line the effect of adding factor3 to the model. The remaining graphs continue in the same cumulative manner except for the interaction terms which are added singularly to the final single factor model.

#### 8.4.26 *Pink Ling TW (LIG – 37228002 – Genypterus blacodes)*

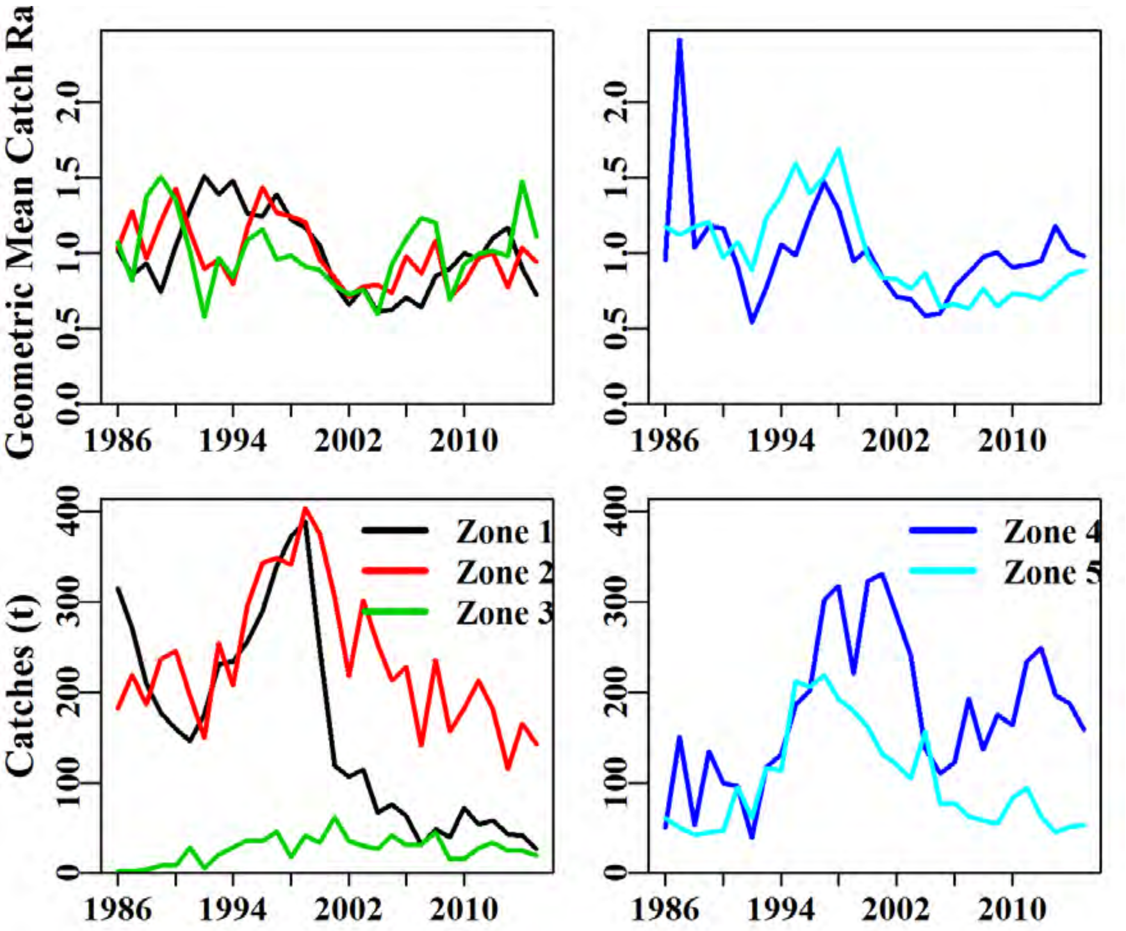



Figure 8.82. Trends in the catches and geometric mean catch rates for Pink Ling taken by Trawler across zones 10 – 50 split between east and west.

The trends in the geometric mean catch rates in the east all follow approximately the same trajectory, albeit with some noise (Figure 8.82). In the west, however, zones 40 and 50 appear to follow rather different trajectories with rates increasing since 2005 in zone 40 while staying flat in zone 50. However, this may simply reflect that catches were increasing in zone 40 and were decreasing in zone 50.

### 8.4.27 *Pink Ling Z10–30 (LIG – 37228002 – Genypterus blacodes)*

Trawl data corresponding to zones 10, 20 and 30 from depths greater than 250 m and less than 600 m were analysed.

Table 8.76. Pink Ling from zones 10 to 30 in depths between 250 – 600 m by Trawl. Total catch (TotCatch; t) is the total reported in the database, number of records used in the analysis (Records), reported catch (CatchT; t) in the area and depth used in the analysis and number of vessels used in the analysis (Vessels). GeoMean is the geometric mean of catch rates (kg/hr). The optimum model is Zone:DepC and standard deviation (StDev) relates to the data in the optimum model.

| Year | TotCatch | Records | CatchT | Vessels | GeoMean | Zone:DepC | StDev |
|---|---|---|---|---|---|---|---|
| 1986 | 678.9770 | 4512 | 498.2980 | 80 | 20.6651 | 1.1405 | 0.0000 |
| 1987 | 765.0660 | 4260 | 492.3140 | 77 | 19.4237 | 1.2312 | 0.0223 |
| 1988 | 583.0770 | 3613 | 400.0770 | 77 | 20.2595 | 1.1591 | 0.0234 |
| 1989 | 678.8960 | 3879 | 422.0770 | 77 | 19.1575 | 0.9908 | 0.0232 |
| 1990 | 674.4790 | 2794 | 413.0820 | 68 | 26.8201 | 1.4647 | 0.0254 |
| 1991 | 736.8030 | 2938 | 370.2970 | 72 | 26.3050 | 1.4412 | 0.0254 |
| 1992 | 568.3080 | 2437 | 331.3060 | 58 | 25.0704 | 1.1202 | 0.0267 |
| 1993 | 892.7960 | 3525 | 504.4740 | 59 | 25.3075 | 1.0577 | 0.0244 |
| 1994 | 895.4310 | 4066 | 470.2650 | 63 | 23.5158 | 1.0831 | 0.0235 |
| 1995 | 1208.8930 | 4361 | 586.6860 | 57 | 25.8106 | 1.3677 | 0.0230 |
| 1996 | 1233.2650 | 4268 | 667.5830 | 63 | 27.6570 | 1.3576 | 0.0232 |
| 1997 | 1696.8475 | 4808 | 732.6540 | 62 | 27.9375 | 1.3850 | 0.0228 |
| 1998 | 1592.3980 | 4909 | 730.4580 | 57 | 26.0156 | 1.3719 | 0.0226 |
| 1999 | 1651.5715 | 5964 | 832.6550 | 59 | 25.2286 | 1.2526 | 0.0221 |
| 2000 | 1507.3786 | 5112 | 660.3260 | 62 | 22.4167 | 1.1025 | 0.0230 |
| 2001 | 1392.8101 | 4569 | 485.6305 | 53 | 19.0505 | 0.8505 | 0.0238 |
| 2002 | 1330.1940 | 3902 | 360.5923 | 52 | 15.8480 | 0.7521 | 0.0246 |
| 2003 | 1353.1029 | 4310 | 445.7625 | 57 | 18.2826 | 0.7702 | 0.0242 |
| 2004 | 1495.1340 | 3359 | 347.2374 | 54 | 16.7949 | 0.6900 | 0.0257 |
| 2005 | 1203.1954 | 3454 | 329.9497 | 51 | 16.3326 | 0.6405 | 0.0253 |
| 2006 | 1069.2001 | 2593 | 323.1010 | 38 | 21.3189 | 0.7683 | 0.0273 |
| 2007 | 875.9218 | 1652 | 204.3070 | 23 | 20.5015 | 0.7465 | 0.0313 |
| 2008 | 980.2672 | 2382 | 329.0357 | 24 | 25.1511 | 0.8704 | 0.0284 |
| 2009 | 775.0457 | 1947 | 212.3617 | 27 | 18.2953 | 0.6273 | 0.0301 |
| 2010 | 906.2231 | 1991 | 271.1322 | 23 | 20.7020 | 0.7755 | 0.0297 |
| 2011 | 1081.9062 | 2201 | 294.8960 | 22 | 23.4304 | 0.8158 | 0.0290 |
| 2012 | 1030.9058 | 1972 | 273.3230 | 24 | 24.3541 | 0.8741 | 0.0300 |
| 2013 | 735.6858 | 1561 | 183.9784 | 22 | 21.3662 | 0.7373 | 0.0320 |
| 2014 | 850.4257 | 1614 | 231.8756 | 24 | 24.5893 | 0.8401 | 0.0314 |
| 2015 | 716.7958 | 1656 | 189.3976 | 24 | 21.6332 | 0.7157 | 0.0316 |

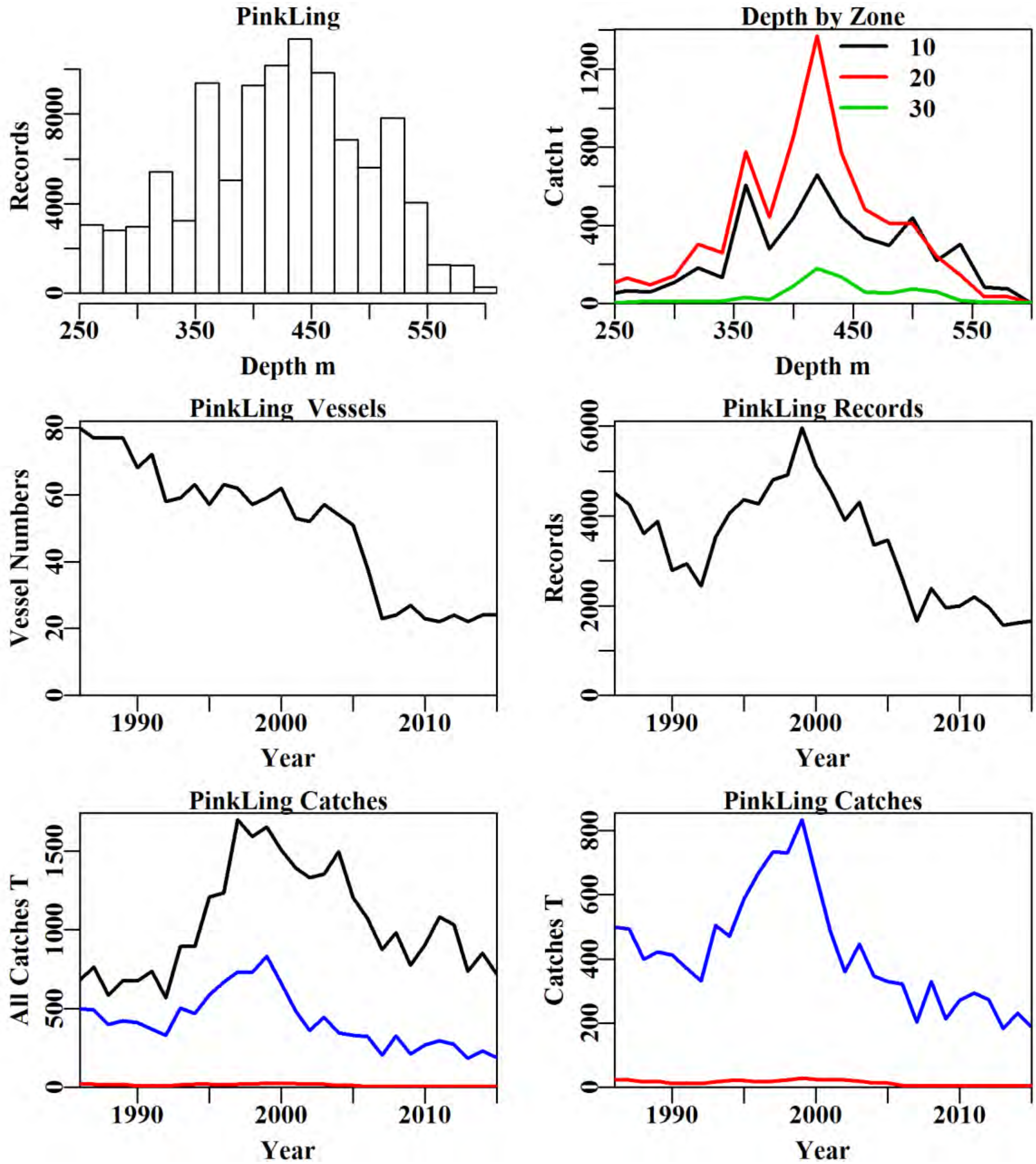



Figure 8.83. Pink Ling from zones 10 to 30 in depths between 250 – 600 m by Trawl. The top left plot depicts the depth distribution of shots containing Pink Ling from zones 10 to 30 in depths 250 – 600 m by Trawl. The top right plot depicts the catch distribution by depth by zone. The middle left plot depicts the number of vessels through time and middle right plot contains the number of records used in analysis. The bottom left plot contains Pink Ling catches (top black line: total catches, middle blue line: catches used in the analysis; bottom red line: catches < 30 kg) and bottom right plot contains Pink Ling catches (blue line: catches used in the analysis; red line: catches < 30 kg).

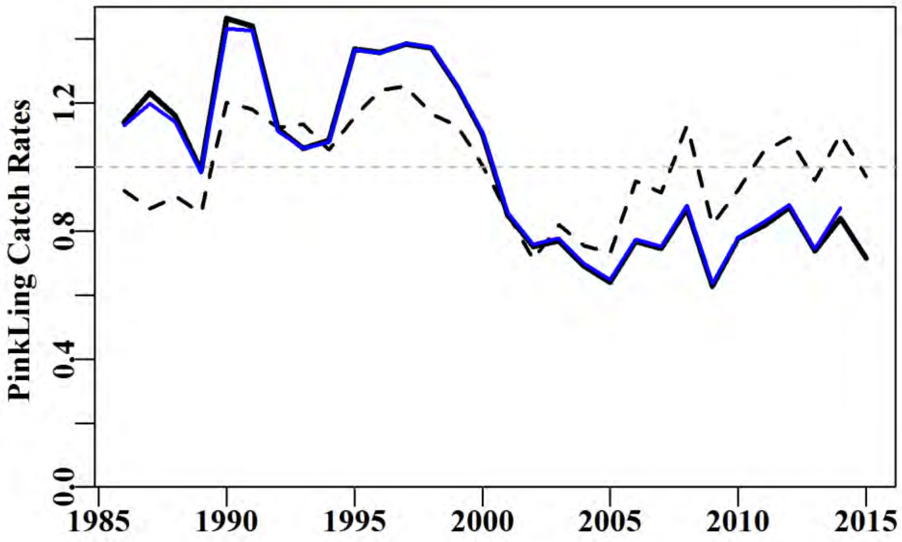



Figure 8.84. Pink Ling from zones 10 to 30 in depths between 250 – 600 m by Trawl. The dashed black line represents the geometric mean catch rate and the solid black line the standardized catch rates (relative to the mean of the standardized catch rates). The blue line corresponds to last year's standardized indices.

Table 8.77. Pink Ling from zones 10 to 30 in depths between 250 – 600 m by Trawl. Statistical model structures used in this analysis. DepCat is a series of 20 metre depth categories.

| | |
|---|---|
| Model 1 | LnCE~Year |
| Model 2 | LnCE~Year+DepCat |
| Model 3 | LnCE~Year+ Vessel+DepCat |
| Model 4 | LnCE~Year+Vessel+DepCat+Zone |
| Model 5 | LnCE~Year+Vessel+DepCat+Zone+Month |
| Model 6 | LnCE~Year+ Vessel+DepCat+Zone+Month+DayNight |
| Model 7 | LnCE~Year+ Vessel+DepCat+Zone+Month+DayNight+Zone:Month |
| Model 8 | LnCE~Year+ Vessel+DepCat+Zone+Month+DayNight+Zone:DepCat |

Table 8.78. Pink Ling from zones 10 to 30 in depths between 250 – 600 m by Trawl. Model selection criteria include the Akaike Information Criterion (AIC), residual sum of squares (RSS), model sum of squares (MSS), number of usable observations (Nobs), number of parameters (Npars), adjusted $R^2$ (adj_$R^2$) and the change in adjusted $R^2$ (%Change). The optimum is Zone:DepC (Model 8). Depth category: DepC.

| | Year | DepC | Vessel | Month | Zone | DayNight | Zone:Month | Zone:DepC |
|---|---|---|---|---|---|---|---|---|
| AIC | 33822 | 16626 | 4296 | 599 | 480 | -106 | -1185 | -2231 |
| RSS | 140727 | 118184 | 103618 | 99830 | 99705 | 99117 | 98007 | 96914 |
| MSS | 2765 | 25307 | 39874 | 43662 | 43787 | 44375 | 45484 | 46578 |
| Nobs | 100609 | 100609 | 99717 | 99717 | 99717 | 99717 | 99717 | 99717 |
| Npars | 30 | 214 | 235 | 243 | 246 | 248 | 270 | 306 |
| adj_$R^2$ | 1.898 | 17.462 | 27.618 | 30.259 | 30.344 | 30.753 | 31.514 | 32.253 |
| %Change | 0.000 | 15.564 | 10.156 | 2.640 | 0.085 | 0.409 | 0.760 | 0.739 |

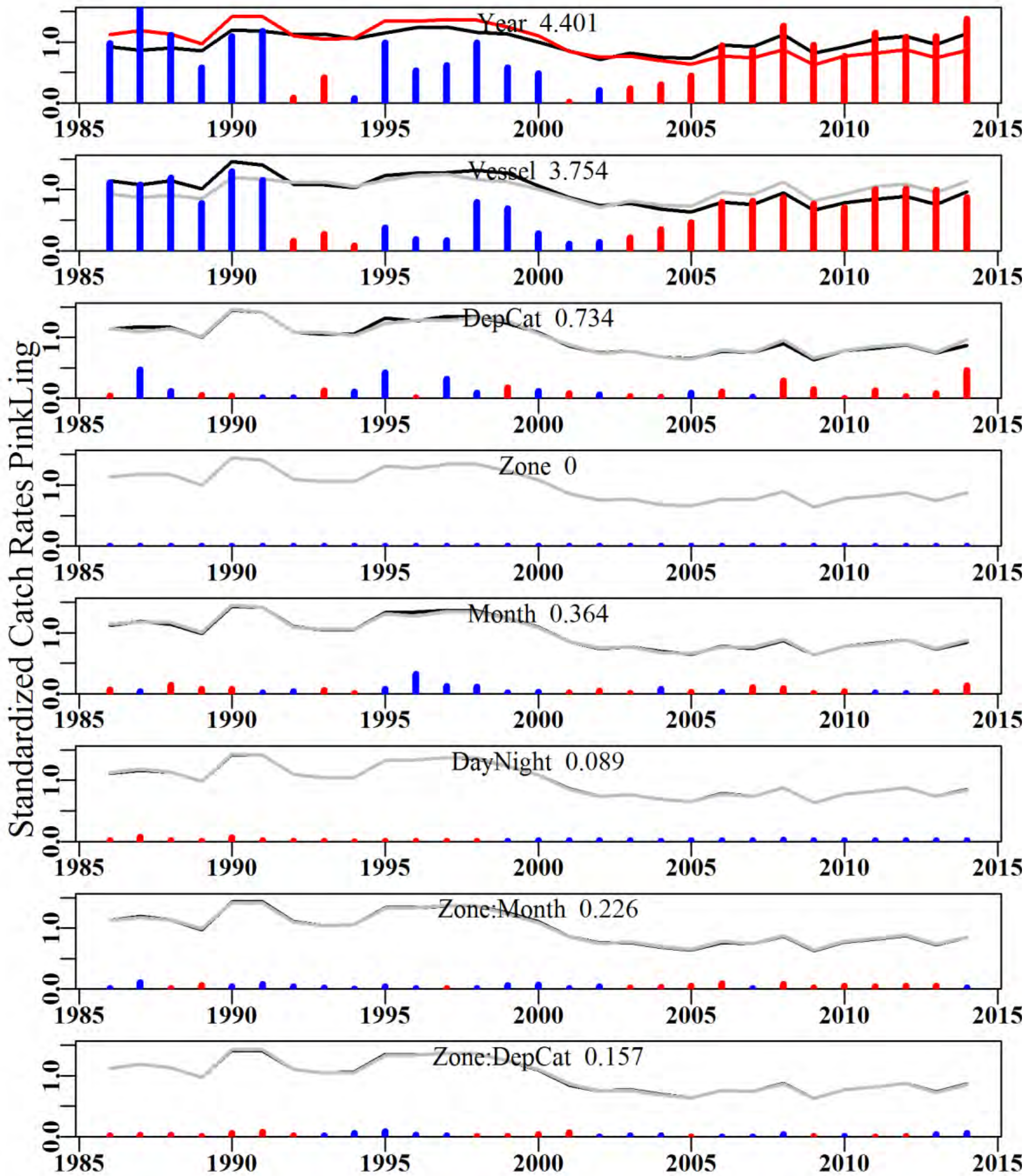



Figure 8.85. The relative influence of each factor used on the final trend in the optimal standardization for Pink Ling from zones 10 to 30. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by the vertical bars with blue bars indicating the optimum model is higher than the geometric mean and red bars indicating it is lower. The top graph bars are the sum of all the bars in the graphs below. The graphs for individual factors are cumulative. Thus the second graph has the geometric mean (grey line) and the effect of adding Year + factor2 (Model 2). In the third graph, the grey line represents Model 2 and the black line the effect of adding factor3 to the model. The remaining graphs continue in the same cumulative manner except for the interaction terms which are added singularly to the final single factor model.

### 8.4.28 *Pink Ling Z4050 (LIG – 37228002 – Genypterus blacodes)*

Trawl data selected for analysis corresponded to records from zones 40 and 50 in depths greater than 200 m and less or equal to 800 m.

Table 8.79. Pink Ling from zones 40 and 50 in depths between 200 – 800 m by Trawl. Total catch (TotCatch; t) is the total reported in the database, number of records used in the analysis (Records), reported catch (CatchT; t) in the area and depth used in the analysis and number of vessels used in the analysis (Vessels). GeoMean is the geometric mean of catch rates (kg/hr). The optimum model is Zone:DepC and standard deviation (StDev) relates to the data in the optimum model.

| Year | TotCatch | Records | CatchT | Vessels | GeoMean | Zone:DepC | StDev |
|---|---|---|---|---|---|---|---|
| 1986 | 678.9770 | 1265 | 112.9440 | 23 | 17.1417 | 1.1978 | 0.0000 |
| 1987 | 765.0660 | 1310 | 206.3410 | 28 | 24.0155 | 1.3479 | 0.0370 |
| 1988 | 583.0770 | 1026 | 95.7030 | 32 | 17.6676 | 1.0508 | 0.0402 |
| 1989 | 678.8960 | 1469 | 183.1210 | 34 | 21.9840 | 1.0769 | 0.0381 |
| 1990 | 674.4790 | 1524 | 147.4120 | 32 | 16.9021 | 0.9691 | 0.0388 |
| 1991 | 736.8030 | 1896 | 198.9250 | 37 | 16.4027 | 1.0376 | 0.0370 |
| 1992 | 568.3080 | 1632 | 102.0640 | 24 | 11.9918 | 0.7713 | 0.0380 |
| 1993 | 892.7960 | 2253 | 235.4850 | 24 | 17.1332 | 1.0455 | 0.0367 |
| 1994 | 895.4310 | 2110 | 247.7930 | 24 | 20.5621 | 1.2599 | 0.0365 |
| 1995 | 1208.8930 | 3515 | 426.8070 | 25 | 20.0607 | 1.2893 | 0.0343 |
| 1996 | 1233.2650 | 3403 | 448.0440 | 26 | 19.9984 | 1.3655 | 0.0347 |
| 1997 | 1696.8475 | 3732 | 577.4340 | 24 | 21.1891 | 1.4330 | 0.0343 |
| 1998 | 1592.3980 | 3709 | 558.5210 | 21 | 22.4124 | 1.4107 | 0.0346 |
| 1999 | 1651.5715 | 3794 | 427.9200 | 24 | 18.0495 | 1.1182 | 0.0345 |
| 2000 | 1507.3786 | 4656 | 509.3340 | 28 | 16.3658 | 0.9981 | 0.0341 |
| 2001 | 1392.8101 | 5100 | 502.3720 | 28 | 14.7225 | 0.8904 | 0.0340 |
| 2002 | 1330.1940 | 4633 | 429.5610 | 27 | 13.4055 | 0.7707 | 0.0341 |
| 2003 | 1353.1029 | 3822 | 360.2349 | 27 | 12.6257 | 0.7747 | 0.0345 |
| 2004 | 1495.1340 | 3901 | 306.2357 | 25 | 11.7174 | 0.7279 | 0.0346 |
| 2005 | 1203.1954 | 2663 | 195.7375 | 23 | 9.9452 | 0.6069 | 0.0359 |
| 2006 | 1069.2001 | 2322 | 209.9851 | 21 | 10.6509 | 0.6430 | 0.0366 |
| 2007 | 875.9218 | 2532 | 287.3451 | 16 | 12.6778 | 0.7052 | 0.0362 |
| 2008 | 980.2672 | 1795 | 214.2319 | 17 | 14.6108 | 0.9135 | 0.0377 |
| 2009 | 775.0457 | 1976 | 260.6090 | 13 | 14.0039 | 0.8895 | 0.0372 |
| 2010 | 906.2231 | 2337 | 272.1558 | 14 | 13.1460 | 0.8653 | 0.0364 |
| 2011 | 1081.9062 | 2792 | 356.8662 | 16 | 13.2635 | 0.8565 | 0.0358 |
| 2012 | 1030.9058 | 2342 | 344.9726 | 14 | 14.5232 | 0.9152 | 0.0368 |
| 2013 | 735.6858 | 1720 | 272.2423 | 17 | 15.6511 | 1.0396 | 0.0385 |
| 2014 | 850.4257 | 1849 | 278.7479 | 15 | 16.3305 | 1.0334 | 0.0379 |
| 2015 | 716.7958 | 1628 | 235.0769 | 13 | 15.4463 | 0.9965 | 0.0389 |

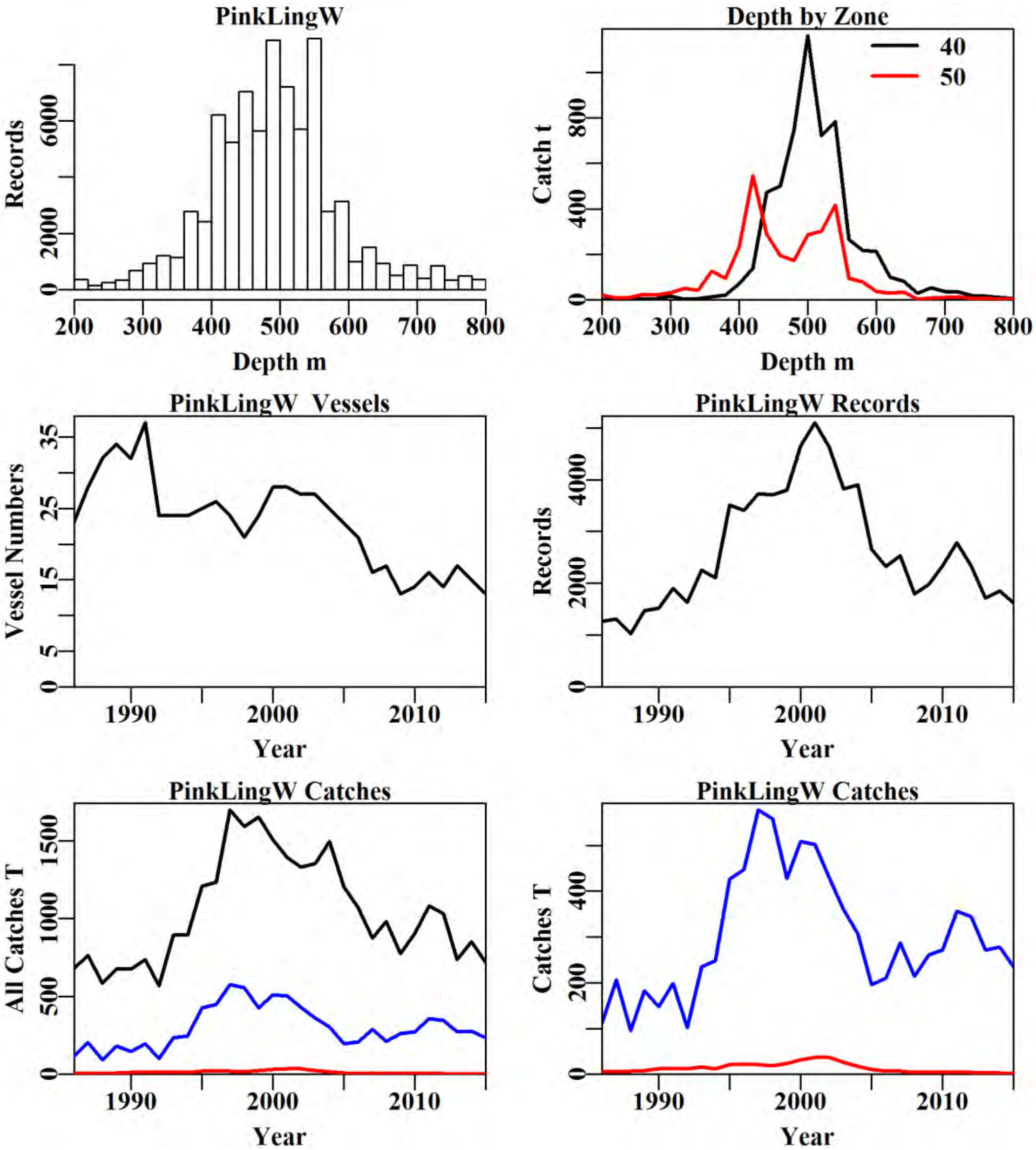



Figure 8.86. Pink Ling from zones 40 and 50 in depths between 200 – 800 m by Trawl. The top left plot depicts the depth distribution of shots containing Pink Ling from zones 40 and 50 in depths 200 – 800 m by Trawl. The top right plot depicts the catch distribution by depth by zone. The middle left plot depicts the number of vessels through time and middle right plot contains the number of records used in analysis. The bottom left plot contains Pink Ling catches (top black line: total catches, middle blue line: catches used in the analysis; bottom red line: catches < 30 kg) and bottom right plot contains Pink Ling catches (blue line: catches used in the analysis; red line: catches < 30 kg).

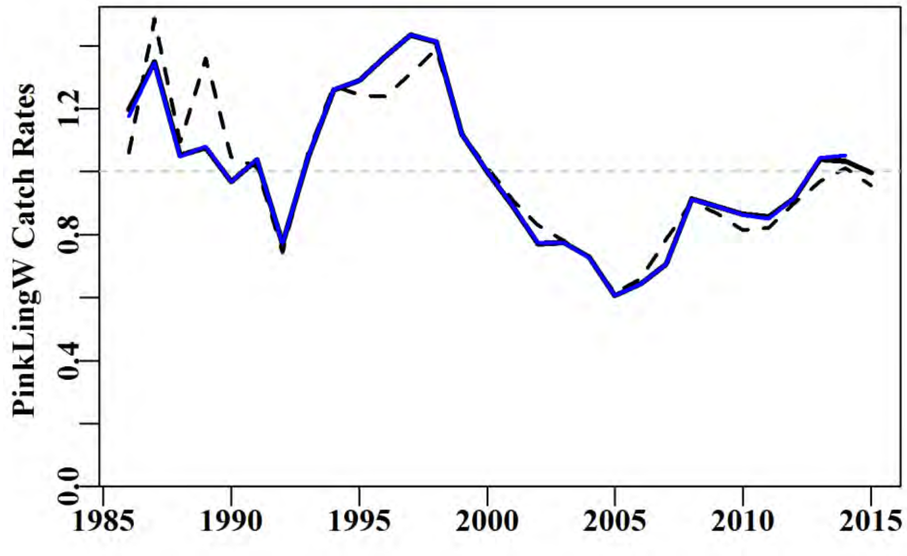



Figure 8.87. Pink Ling from zones 40 and 50 in depths between 200 – 800 m by Trawl. The dashed black line represents the geometric mean catch rate and the solid black line the standardized catch rates (relative to the mean of the standardized catch rates). The blue line corresponds to last year's standardized catch rates.

Table 8.80. Pink Ling from zones 40 and 50 in depths between 200 – 800 m by Trawl. Statistical model structures used in this analysis. DepCat is a series of 20 metre depth categories.

| | |
|---|---|
| Model 1 | LnCE~Year |
| Model 2 | LnCE~Year+DepCat |
| Model 3 | LnCE~Year+DepCat+Vessel |
| Model 4 | LnCE~Year+DepCat+Vessel+Month |
| Model 5 | LnCE~Year+DepCat+Vessel+Month+Zone |
| Model 6 | LnCE~Year+DepCat+Vessel+Month+Zone+DayNight |
| Model 7 | LnCE~Year+DepCat+Vessel+Month+Zone+DayNight+Zone:Month |
| Model 8 | LnCE~Year+DepCat+Vessel+Month+Zone+DayNight+Zone:DepCat |

Table 8.81. Pink Ling from zones 40 and 50 in depths between 200 – 800 m by Trawl. Model selection criteria include the Akaike Information Criterion (AIC), residual sum of squares (RSS), model sum of squares (MSS), number of usable observations (Nobs), number of parameters (Npars), adjusted $R^2$ (adj_$R^2$) and the change in adjusted $R^2$ (%Change). The optimum is Zone:DepC (Model 8). Depth category: DepC.

| | Year | DepC | Vessel | Month | Zone | DayNight | Zone:Month | Zone:DepC |
|---|---|---|---|---|---|---|---|---|
| AIC | 142 | -11047 | -17527 | -20187 | -21241 | -21269 | -22760 | -22116 |
| RSS | 78788 | 67806 | 62262 | 60163 | 59357 | 59331 | 58194 | 58646 |
| MSS | 3902 | 14884 | 20428 | 22527 | 23334 | 23359 | 24496 | 24044 |
| Nobs | 78706 | 78213 | 78213 | 78213 | 78213 | 78213 | 78213 | 78213 |
| Npars | 30 | 60 | 156 | 167 | 168 | 171 | 182 | 201 |
| adj_$R^2$ | 4.684 | 17.938 | 24.555 | 27.088 | 28.065 | 28.093 | 29.461 | 28.895 |
| %Change | 0.000 | 13.254 | 6.617 | 2.533 | 0.976 | 0.028 | 1.368 | -0.565 |

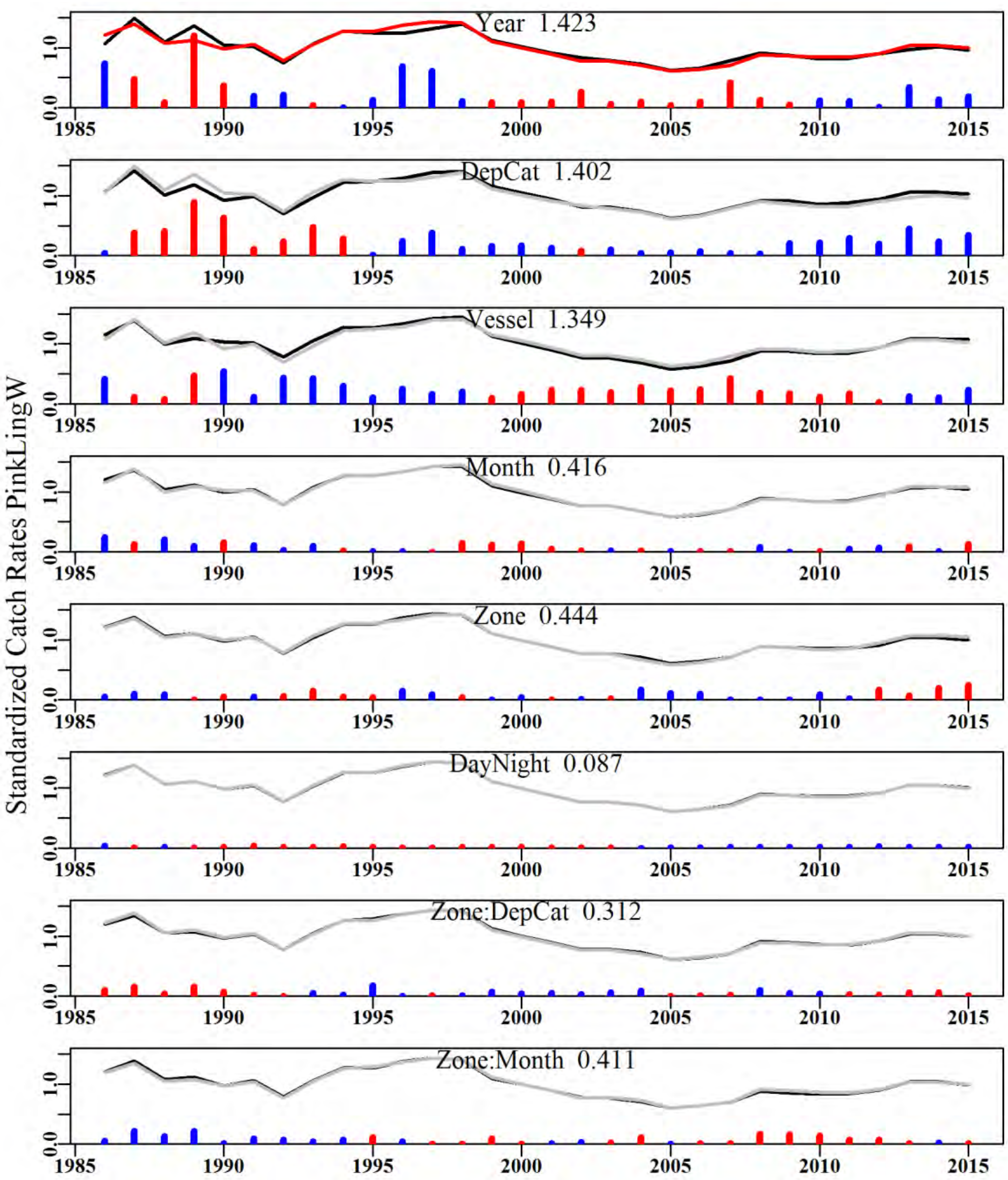



Figure 8.88. The relative influence of each factor used on the final trend in the optimal standardization for Pink Ling from zones 40 and 50. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by the vertical bars with blue bars indicating the optimum model is higher than the geometric mean and red bars indicating it is lower. The top graph bars are the sum of all the bars in the graphs below. The graphs for individual factors are cumulative. Thus the second graph has the geometric mean (grey line) and the effect of adding Year + factor2 (Model 2). In the third graph, the grey line represents Model 2 and the black line the effect of adding factor3 to the model. The remaining graphs continue in the same cumulative manner except for the interaction terms which are added singularly to the final single factor model.

### 8.4.29 *Western Gemfish and GAB (GEM – 37439002 – Rexea solandri)*

Trawl data selected for analysis corresponded to records from zones 40 and 50 with 82, 83, 84, and 85 (the GAB) above -42° S, in depths greater than 100 and less than or equal to 600 m.

Table 8.82. Western Gemfish from zones 40 and 50, and the GAB in depths between 100 – 600 m by Trawl (now represented by TW and TDO). Total catch (TotCatch; t) is the total reported in the database, number of records used in the analysis (Records), reported catch (CatchT; t) in the area and depth used in the analysis and number of vessels used in the analysis (Vessels). GeoMean is the geometric mean of catch rates (kg/hr). The optimum model is Zone:Month and standard deviation (StDev) relates to the data in the optimum model.

| Year | TotCatch | Records | CatchT | Vessels | GeoMean | Zone:Month | StDev |
|---|---|---|---|---|---|---|---|
| 1986 | 3639.9550 | 1698 | 306.4910 | 25 | 29.2406 | 2.2764 | 0.0000 |
| 1987 | 4660.4470 | 1280 | 261.6060 | 29 | 30.7446 | 2.1692 | 0.0458 |
| 1988 | 3515.8190 | 1399 | 255.4090 | 36 | 25.3713 | 2.0431 | 0.0481 |
| 1989 | 1778.3250 | 1396 | 184.4330 | 37 | 19.1431 | 1.5556 | 0.0489 |
| 1990 | 1206.8970 | 1241 | 145.5200 | 35 | 14.4402 | 1.3691 | 0.0529 |
| 1991 | 580.3220 | 1568 | 279.2890 | 32 | 19.1549 | 1.3425 | 0.0496 |
| 1992 | 494.4410 | 799 | 96.8810 | 21 | 15.1631 | 0.9905 | 0.0567 |
| 1993 | 353.4100 | 896 | 108.2890 | 21 | 11.5326 | 0.8467 | 0.0557 |
| 1994 | 232.1790 | 1041 | 109.8960 | 24 | 11.4211 | 0.8734 | 0.0533 |
| 1995 | 181.7460 | 1285 | 106.8040 | 26 | 9.1790 | 0.8259 | 0.0509 |
| 1996 | 382.1960 | 1573 | 161.7360 | 32 | 9.5346 | 0.9634 | 0.0491 |
| 1997 | 571.9758 | 2088 | 214.0380 | 28 | 8.9720 | 0.8553 | 0.0470 |
| 1998 | 404.8147 | 1958 | 206.7570 | 26 | 10.2560 | 1.0244 | 0.0479 |
| 1999 | 448.6767 | 2337 | 322.9730 | 24 | 12.0677 | 1.0222 | 0.0467 |
| 2000 | 336.4642 | 2325 | 260.6825 | 30 | 9.7749 | 0.8757 | 0.0471 |
| 2001 | 331.4862 | 2326 | 258.4500 | 30 | 10.0470 | 0.8219 | 0.0472 |
| 2002 | 195.8983 | 1746 | 128.4288 | 28 | 6.4820 | 0.6300 | 0.0490 |
| 2003 | 267.9710 | 1612 | 201.0612 | 33 | 8.8661 | 0.6876 | 0.0499 |
| 2004 | 568.8517 | 1931 | 478.0203 | 30 | 10.6711 | 0.7411 | 0.0497 |
| 2005 | 511.7585 | 1796 | 368.5067 | 27 | 12.7461 | 0.7358 | 0.0504 |
| 2006 | 544.8936 | 1591 | 434.7030 | 26 | 11.9765 | 0.6941 | 0.0514 |
| 2007 | 599.1098 | 1380 | 415.0929 | 21 | 11.0165 | 0.6368 | 0.0524 |
| 2008 | 294.8605 | 1225 | 155.5205 | 19 | 6.7358 | 0.6460 | 0.0530 |
| 2009 | 194.8654 | 1255 | 104.8608 | 16 | 5.8844 | 0.7000 | 0.0526 |
| 2010 | 220.6510 | 1663 | 127.5652 | 18 | 6.1259 | 0.7509 | 0.0501 |
| 2011 | 147.7397 | 1258 | 73.2852 | 16 | 5.7046 | 0.7419 | 0.0527 |
| 2012 | 168.5996 | 1028 | 99.0475 | 18 | 6.4833 | 0.8053 | 0.0559 |
| 2013 | 103.8201 | 684 | 47.0844 | 20 | 6.4814 | 0.6946 | 0.0612 |
| 2014 | 130.2023 | 809 | 87.7275 | 17 | 9.9349 | 0.9350 | 0.0587 |
| 2015 | 86.3213 | 700 | 49.7927 | 14 | 6.3453 | 0.7455 | 0.0622 |

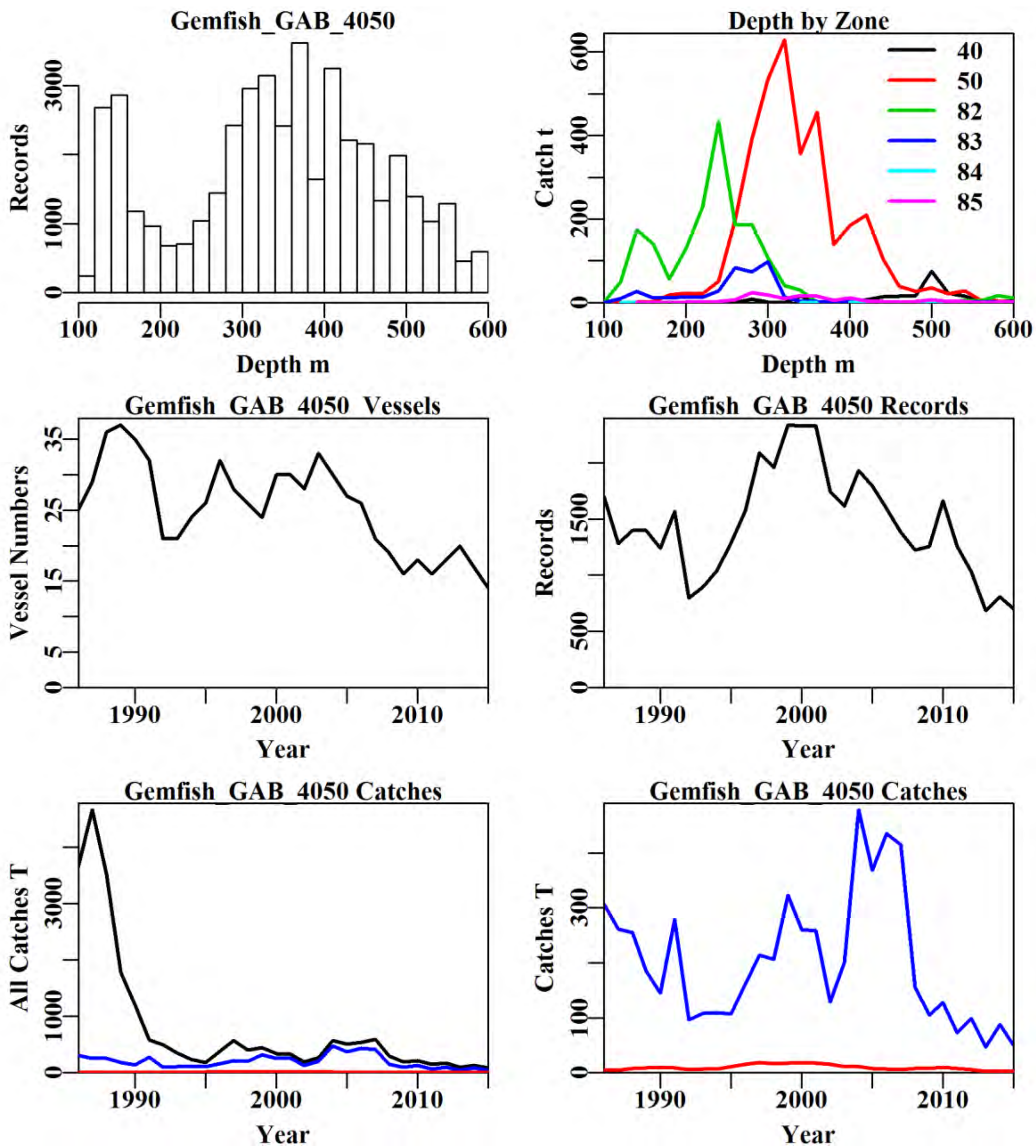



Figure 8.89. Western Gemfish from zones 40 and 50, and the GAB (zones 82, 83, 84, and 85) in depths between 100 – 600 m by Trawl. The top left plot depicts the depth distribution of shots containing Western Gemfish from zones 40 and 50, and the GAB (zones 82, 83, 84, and 85) in depths 100 – 600 m by Trawl. The top right plot depicts the catch distribution by depth by zone. The middle left plot depicts the number of vessels through time and middle right plot contains the number of records used in analysis. The bottom left plot contains Gemfish catches across east and west regions (top black line: total catches, middle blue line: catches used in the analysis; bottom red line: catches < 30 kg) and bottom right plot contains Gemfish catches across east and west regions (blue line: catches used in the analysis; red line: catches < 30 kg).

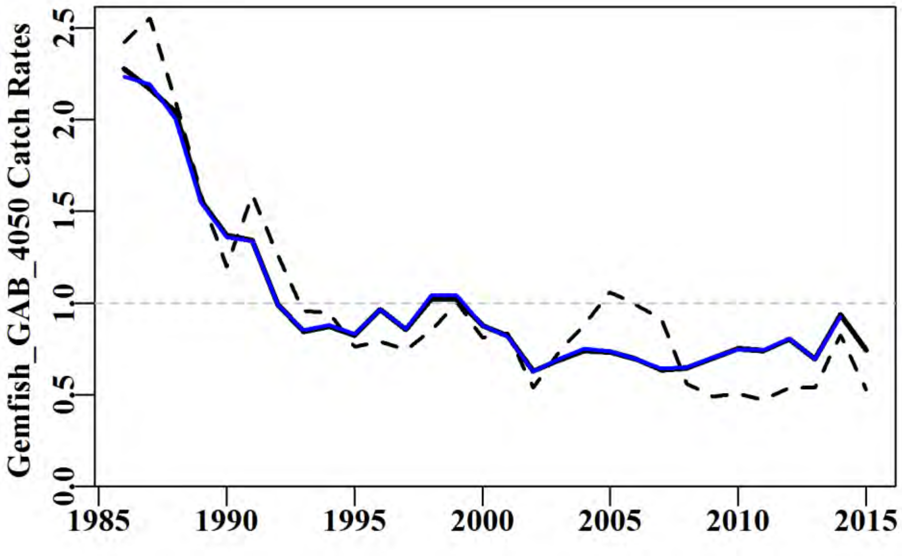



Figure 8.90. Western Gemfish from zones 40 and 50, and the GAB (zones 82, 83, 84, and 85) in depths between 100 – 600 m by Trawl. The dashed black line represents the geometric mean catch rate, solid black line the standardized catch rates and solid blue line the standardized catch rates from last year's analysis. The graph standardizes catch rates relative to the mean of the standardized catch rates.

Table 8.83. Western Gemfish from zones 40 and 50, and the GAB (zones 82, 83, 84, and 85) in depths between 100 – 600 m by Trawl. Statistical model structures used in this analysis. DepCat is a series of 20 metre depth categories.

| | |
|---|---|
| Model 1 | LnCE~Year |
| Model 2 | LnCE~Year+DepCat |
| Model 3 | LnCE~Year+DepCat+Vessel |
| Model 4 | LnCE~Year+DepCat+Vessel+Zone |
| Model 5 | LnCE~Year+DepCat+Vessel+Zone+DayNight |
| Model 6 | LnCE~Year+DepCat+Vessel+Zone+DayNight+Month |
| Model 7 | LnCE~Year+DepCat+Vessel+Zone+DayNight+Month+Zone:Month |
| Model 8 | LnCE~Year+DepCat+Vessel+Zone+DayNight+Month+Zone:DepCat |

Table 8.84. Western Gemfish from zones 40 and 50, and the GAB (zones 82, 83, 84, and 85) in depths between 100 – 600 m by Trawl. Model selection criteria include the Akaike Information Criterion (AIC), residual sum of squares (RSS), model sum of squares (MSS), number of usable observations (Nobs), number of parameters (Npars), adjusted $R^2$ (adj_$R^2$) and the change in adjusted $R^2$ (%Change). The optimum is Zone:Month (Model 7). Depth category: DepC.

| | Year | DepC | Vessel | Zone | DayNight | Month | Zone:Month | Zone:DepC |
|---|---|---|---|---|---|---|---|---|
| AIC | 37234 | 23463 | 15973 | 14919 | 14208 | 14011 | 12805 | 13434 |
| RSS | 102376 | 74570 | 62513 | 61015 | 60016 | 59716 | 57945 | 58597 |
| MSS | 8493 | 36299 | 48357 | 49855 | 50853 | 51154 | 52925 | 52272 |
| Nobs | 43888 | 43701 | 43701 | 43701 | 43701 | 43701 | 43701 | 43701 |
| Npars | 30 | 55 | 164 | 167 | 172 | 183 | 238 | 308 |
| adj_$R^2$ | 7.600 | 32.657 | 43.405 | 44.757 | 45.655 | 45.913 | 47.451 | 46.774 |
| %Change | 0.000 | 25.058 | 10.747 | 1.353 | 0.897 | 0.259 | 1.537 | -0.677 |

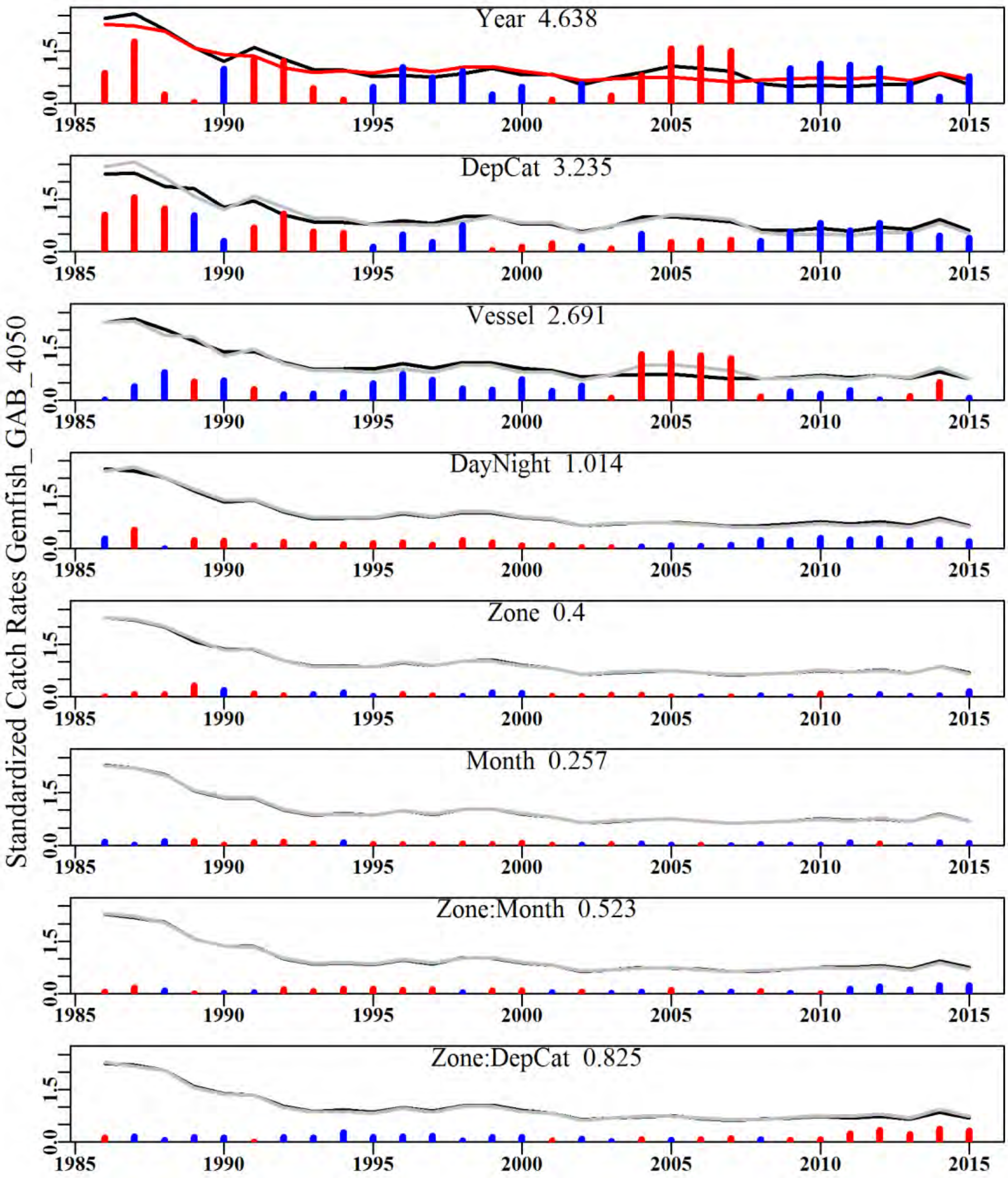



Figure 8.91. The relative influence of each factor used on the final trend in the optimal standardization for Western Gemfish from zones 40 and 50 and the GAB. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by the vertical bars with blue bars indicating the optimum model is higher than the geometric mean and red bars indicating it is lower. The top graph bars are the sum of all the bars in the graphs below. The graphs for individual factors are cumulative. Thus the second graph has the geometric mean (grey line) and the effect of adding Year + factor2 (Model 2). In the third graph, the grey line represents Model 2 and the black line the effect of adding factor3 to the model. The remaining graphs continue in the same cumulative manner except for the interaction terms which are added singularly to the final single factor model.

### 8.4.30 *Western Gemfish Z4050 (GEM – 37439002 – Rexea solandri)*

Trawl data selected for analysis corresponded to records from zones 40 and 50 in depths between 100 and 600 m.

Table 8.85. Western Gemfish from zones 40 and 50 in depths between 100 – 600m by Trawl. Total catch (TotCatch; t) is the total reported in the database, number of records used in the analysis (Records), reported catch (CatchT; t) in the area and depth used in the analysis and number of vessels used in the analysis (Vessels). GeoMean is the geometric mean of catch rates (kg/hr). The optimum model is Zone:Month and standard deviation (StDev) relates to the data in the optimum model.

| Year | TotCatch | Records | CatchT | Vessels | GeoMean | Zone:Month | StDev |
|---|---|---|---|---|---|---|---|
| 1986 | 3639.9550 | 1687 | 306.8610 | 24 | 29.5835 | 2.3624 | 0.0000 |
| 1987 | 4660.4470 | 1209 | 248.8790 | 26 | 31.5896 | 2.2926 | 0.0450 |
| 1988 | 3515.8190 | 1235 | 226.9560 | 27 | 26.9924 | 2.3013 | 0.0472 |
| 1989 | 1778.3250 | 1082 | 156.5780 | 29 | 23.3363 | 1.8505 | 0.0494 |
| 1990 | 1206.8970 | 1057 | 136.0850 | 29 | 15.9031 | 1.4359 | 0.0528 |
| 1991 | 580.3220 | 1384 | 249.4150 | 28 | 22.0062 | 1.3854 | 0.0494 |
| 1992 | 494.4410 | 665 | 80.9300 | 15 | 16.7792 | 0.9587 | 0.0576 |
| 1993 | 353.4100 | 718 | 102.4890 | 17 | 16.5820 | 0.9235 | 0.0570 |
| 1994 | 232.1790 | 839 | 95.3780 | 20 | 16.2263 | 0.9943 | 0.0542 |
| 1995 | 181.7460 | 990 | 84.6880 | 21 | 12.0017 | 0.8791 | 0.0519 |
| 1996 | 382.1960 | 1182 | 145.5880 | 26 | 13.4563 | 0.9632 | 0.0499 |
| 1997 | 571.9758 | 1389 | 153.5890 | 21 | 13.2702 | 0.8583 | 0.0483 |
| 1998 | 404.8147 | 1259 | 121.6610 | 20 | 13.2167 | 0.9092 | 0.0498 |
| 1999 | 448.6767 | 1694 | 176.3230 | 19 | 12.8407 | 0.8665 | 0.0474 |
| 2000 | 336.4642 | 1933 | 228.9645 | 28 | 12.5253 | 0.9343 | 0.0472 |
| 2001 | 331.4862 | 1711 | 170.7050 | 27 | 12.1527 | 0.7582 | 0.0482 |
| 2002 | 195.8983 | 1418 | 85.6338 | 24 | 7.1142 | 0.5782 | 0.0494 |
| 2003 | 267.9710 | 1076 | 122.4803 | 24 | 11.1647 | 0.6711 | 0.0520 |
| 2004 | 568.8517 | 1232 | 105.5549 | 24 | 7.9006 | 0.6521 | 0.0521 |
| 2005 | 511.7585 | 1073 | 117.6765 | 18 | 10.5982 | 0.6897 | 0.0531 |
| 2006 | 544.8936 | 889 | 101.4170 | 18 | 8.9869 | 0.5575 | 0.0558 |
| 2007 | 599.1098 | 715 | 61.0609 | 16 | 7.4736 | 0.5345 | 0.0582 |
| 2008 | 294.8605 | 770 | 53.0883 | 16 | 7.5204 | 0.6104 | 0.0570 |
| 2009 | 194.8654 | 925 | 56.8320 | 12 | 6.4884 | 0.6897 | 0.0545 |
| 2010 | 220.6510 | 1364 | 86.8772 | 14 | 6.3620 | 0.7212 | 0.0505 |
| 2011 | 147.7397 | 1158 | 57.9422 | 13 | 5.6504 | 0.7507 | 0.0523 |
| 2012 | 168.5996 | 820 | 50.6973 | 14 | 5.3756 | 0.6983 | 0.0576 |
| 2013 | 103.8201 | 582 | 38.7114 | 15 | 5.5756 | 0.6099 | 0.0623 |
| 2014 | 130.2023 | 691 | 70.5258 | 14 | 8.8163 | 0.8816 | 0.0595 |
| 2015 | 86.3213 | 706 | 47.7637 | 13 | 5.7229 | 0.6817 | 0.0606 |

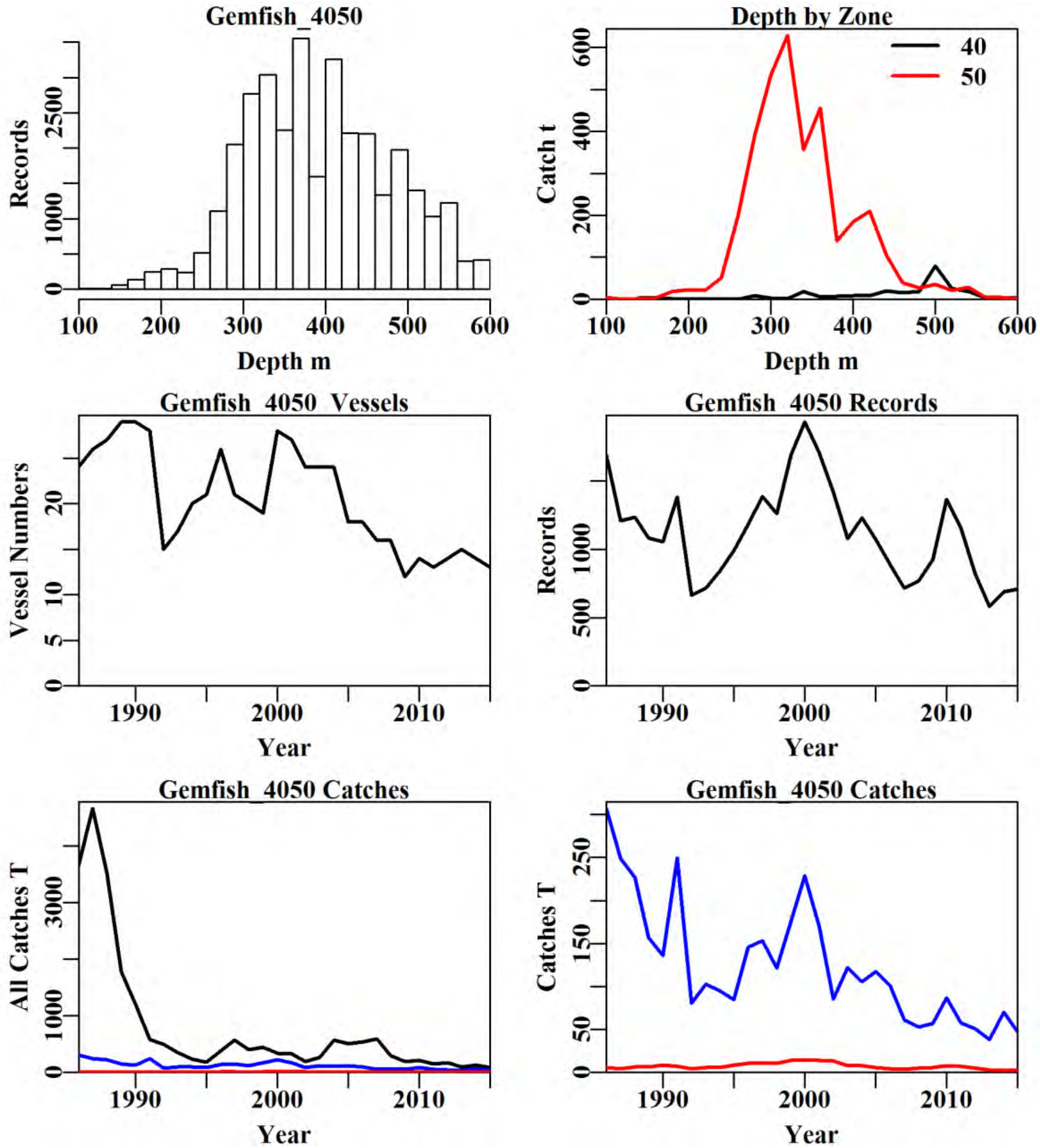



Figure 8.92. Western Gemfish from zones 40 and 50 in depths between 100 – 600 m by Trawl. The top left plot depicts the depth distribution of shots containing Western Gemfish from zones 40 and 50 in depths 100 – 600 m by Trawl. The top right plot depicts the catch distribution by depth by zone. The middle left plot depicts the number of vessels through time and middle right plot contains the number of records used in analysis. The bottom left plot contains Western Gemfish catches (top black line: total catches, middle blue line: catches used in the analysis; bottom red line: catches < 30 kg) and bottom right plot contains Western Gemfish catches (blue line: catches used in the analysis; red line: catches < 30 kg).

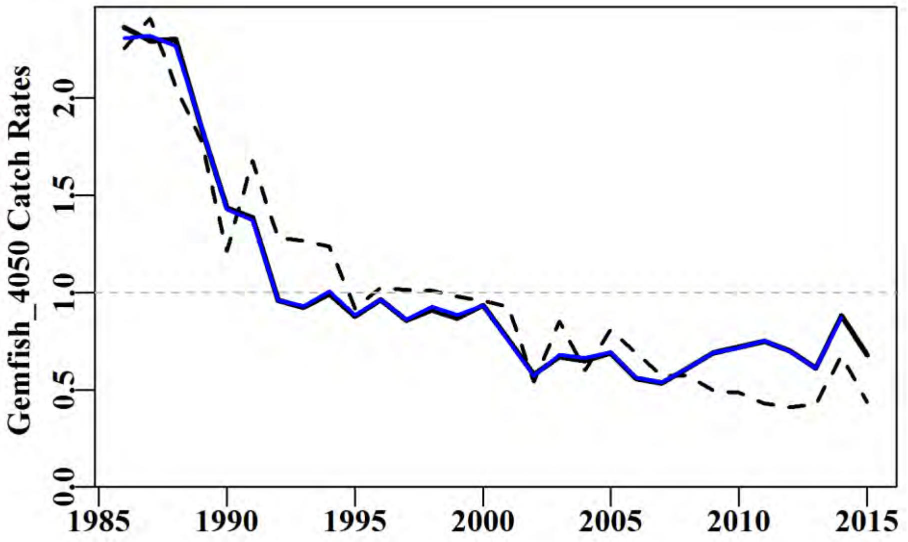



Figure 8.93. Western Gemfish from zones 40 and 50 in depths between 100 – 600 m by Trawl. The dashed black line represents the geometric mean catch rate, solid black line the standardized catch rates and solid blue line standardized catch rates from last year's analysis. The graph standardizes catch rates relative to the mean of the standardized catch rates.

Table 8.86. Western Gemfish from zones 40 and 50 in depths between 100 – 600 m by Trawl. Statistical model structures used in this analysis. DepCat is a series of 20 metre depth categories.

| | |
|---|---|
| Model 1 | LnCE~Year |
| Model 2 | LnCE~Year+Vessel |
| Model 3 | LnCE~Year+Vessel+DepCat |
| Model 4 | LnCE~Year+Vessel+DepCat+DayNight |
| Model 5 | LnCE~Year+Vessel+DepCat+DayNight+Month |
| Model 6 | LnCE~Year+Vessel+DepCat+DayNight+Month+Zone |
| Model 7 | LnCE~Year+Vessel+DepCat+DayNight+Month+Zone+Zone:Month |
| Model 8 | LnCE~Year+Vessel+DepCat+DayNight+Month+Zone+Zone:DepCat |

Table 8.87. Western Gemfish from zones 40 and 50 in depths between 100 – 600 m by Trawl. Model selection criteria include the Akaike Information Criterion (AIC), residual sum of squares (RSS), model sum of squares (MSS), number of usable observations (Nobs), number of parameters (Npars), adjusted $R^2$ (adj_$R^2$) and the change in adjusted $R^2$ (%Change). The optimum is Zone:Month (Model 7). Depth category: DepC.

| | Year | Vessel | DepC | DayNight | Month | Zone | Zone:Month | Zone:DepC |
|---|---|---|---|---|---|---|---|---|
| AIC | 22704 | 15045 | 8459 | 7896 | 7527 | 7524 | 7182 | 7278 |
| RSS | 65828 | 52066 | 42561 | 41841 | 41351 | 41346 | 40897 | 40980 |
| MSS | 8573 | 22334 | 31839 | 32559 | 33049 | 33055 | 33504 | 33420 |
| Nobs | 33453 | 33453 | 33311 | 33311 | 33311 | 33311 | 33311 | 33311 |
| Npars | 30 | 123 | 148 | 151 | 162 | 163 | 174 | 188 |
| adj_$R^2$ | 11.446 | 29.762 | 42.541 | 43.508 | 44.150 | 44.156 | 44.745 | 44.609 |
| %Change | 0.000 | 18.317 | 12.779 | 0.967 | 0.642 | 0.006 | 0.588 | -0.136 |

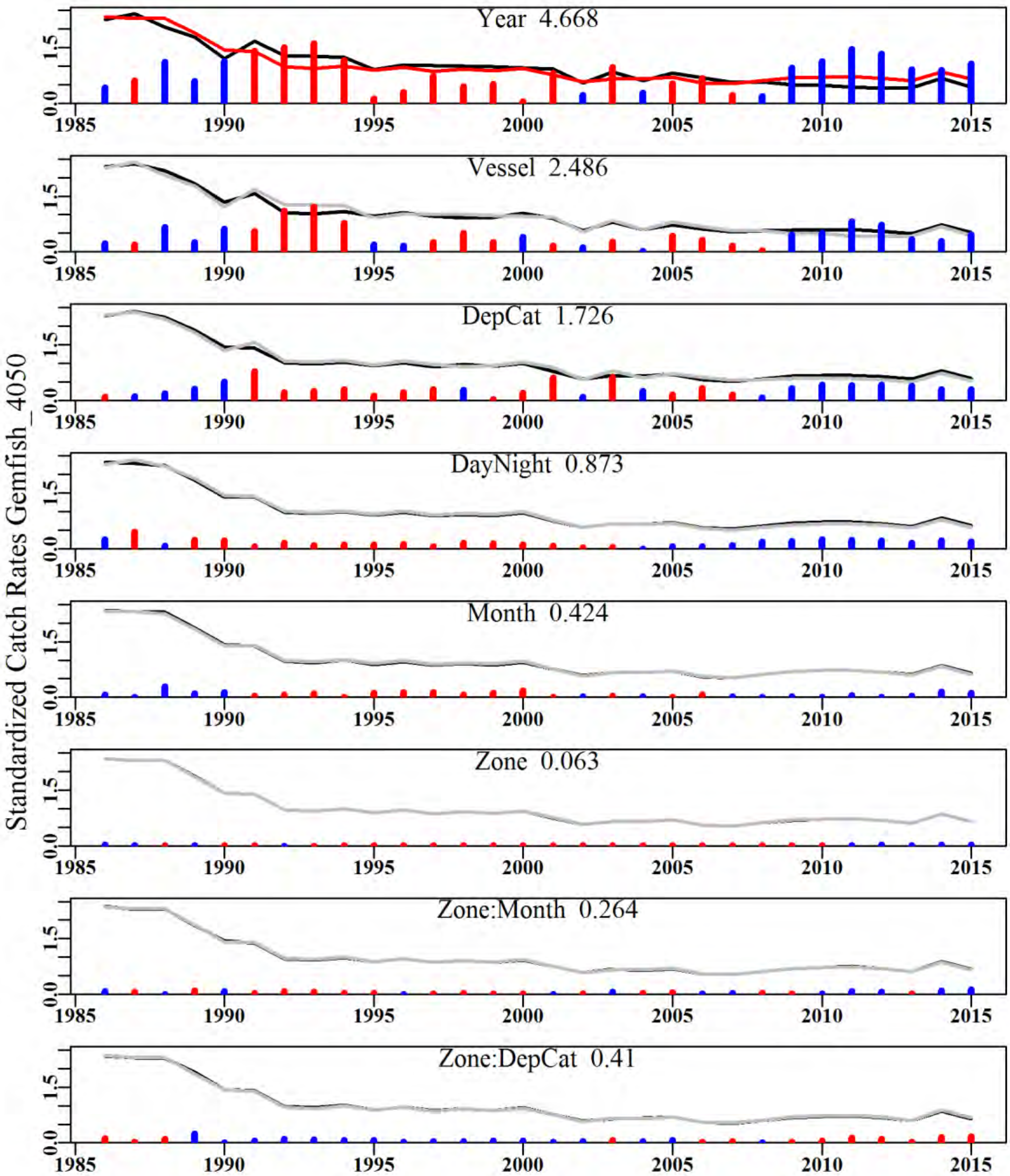



Figure 8.94. The relative influence of each factor used on the final trend in the optimal standardization for Western Gemfish from zones 40 and 50. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by the vertical bars with blue bars indicating the optimum model is higher than the geometric mean and red bars indicating it is lower. The top graph bars are the sum of all the bars in the graphs below. The graphs for individual factors are cumulative. Thus the second graph has the geometric mean (grey line) and the effect of adding Year + factor2 (Model 2). In the third graph, the grey line represents Model 2 and the black line the effect of adding factor3 to the model. The remaining graphs continue in the same cumulative manner except for the interaction terms which are added singularly to the final single factor model.

### 8.4.31 *Western Gemfish GAB (GEM – 37439002 – Rexea solandri)*

Trawl data selected for analysis corresponded to records from all vessels, zones 82, 83, 84, and 85 (the GAB) and depths between 100 and 600 m.

Table 8.88. Western Gemfish in the GAB in depths between 100 and 600 m by Trawl. Total catch (TotCatch; t) is the total reported in the database, number of records used in the analysis (Records), reported catch (CatchT; t) in the area and depth used in the analysis and number of vessels used in the analysis (Vessels). GeoMean is the geometric mean of catch rates (kg/hr). The optimum model is Zone:Month and standard deviation (StDev) relates to the data in the optimum model.

| Year | TotCatch | Records | CatchT | Vessels | GeoMean | Zone:Month | StDev |
|---|---|---|---|---|---|---|---|
| 1995 | 181.7460 | 326 | 22.8450 | 6 | 3.8779 | 0.6884 | 0.0000 |
| 1996 | 382.1960 | 449 | 19.2390 | 7 | 3.8858 | 0.9075 | 0.0930 |
| 1997 | 571.9758 | 717 | 61.7730 | 9 | 4.2096 | 0.8931 | 0.0884 |
| 1998 | 404.8147 | 708 | 85.2200 | 8 | 6.3801 | 1.4515 | 0.0903 |
| 1999 | 448.6767 | 653 | 146.9330 | 7 | 10.0539 | 1.7468 | 0.0929 |
| 2000 | 336.4642 | 427 | 32.1620 | 6 | 2.8433 | 0.6315 | 0.0986 |
| 2001 | 331.4862 | 669 | 90.2810 | 8 | 5.7470 | 1.0710 | 0.0926 |
| 2002 | 195.8983 | 353 | 43.3413 | 8 | 4.3575 | 0.9221 | 0.1017 |
| 2003 | 267.9710 | 565 | 79.3545 | 11 | 5.4980 | 0.8444 | 0.0971 |
| 2004 | 568.8517 | 720 | 372.9160 | 10 | 17.0005 | 1.1049 | 0.0972 |
| 2005 | 511.7585 | 743 | 253.8402 | 10 | 16.0998 | 0.9321 | 0.0986 |
| 2006 | 544.8936 | 709 | 333.2422 | 11 | 16.7217 | 0.9530 | 0.0974 |
| 2007 | 599.1098 | 697 | 358.0045 | 10 | 15.2782 | 0.8371 | 0.0958 |
| 2008 | 294.8605 | 495 | 104.3260 | 7 | 5.4956 | 0.8169 | 0.0978 |
| 2009 | 194.8654 | 350 | 48.9613 | 4 | 4.5291 | 0.7693 | 0.1042 |
| 2010 | 220.6510 | 339 | 42.6375 | 4 | 4.9524 | 0.8460 | 0.1046 |
| 2011 | 147.7397 | 218 | 20.2225 | 4 | 5.2471 | 0.8244 | 0.1171 |
| 2012 | 168.5996 | 305 | 52.2863 | 5 | 9.0523 | 1.2742 | 0.1087 |
| 2013 | 103.8201 | 148 | 9.6908 | 6 | 8.7711 | 1.1884 | 0.1320 |
| 2014 | 130.2023 | 167 | 19.1975 | 5 | 12.5046 | 1.1455 | 0.1359 |
| 2015 | 86.3213 | 65 | 3.9625 | 2 | 7.7844 | 1.1518 | 0.1761 |

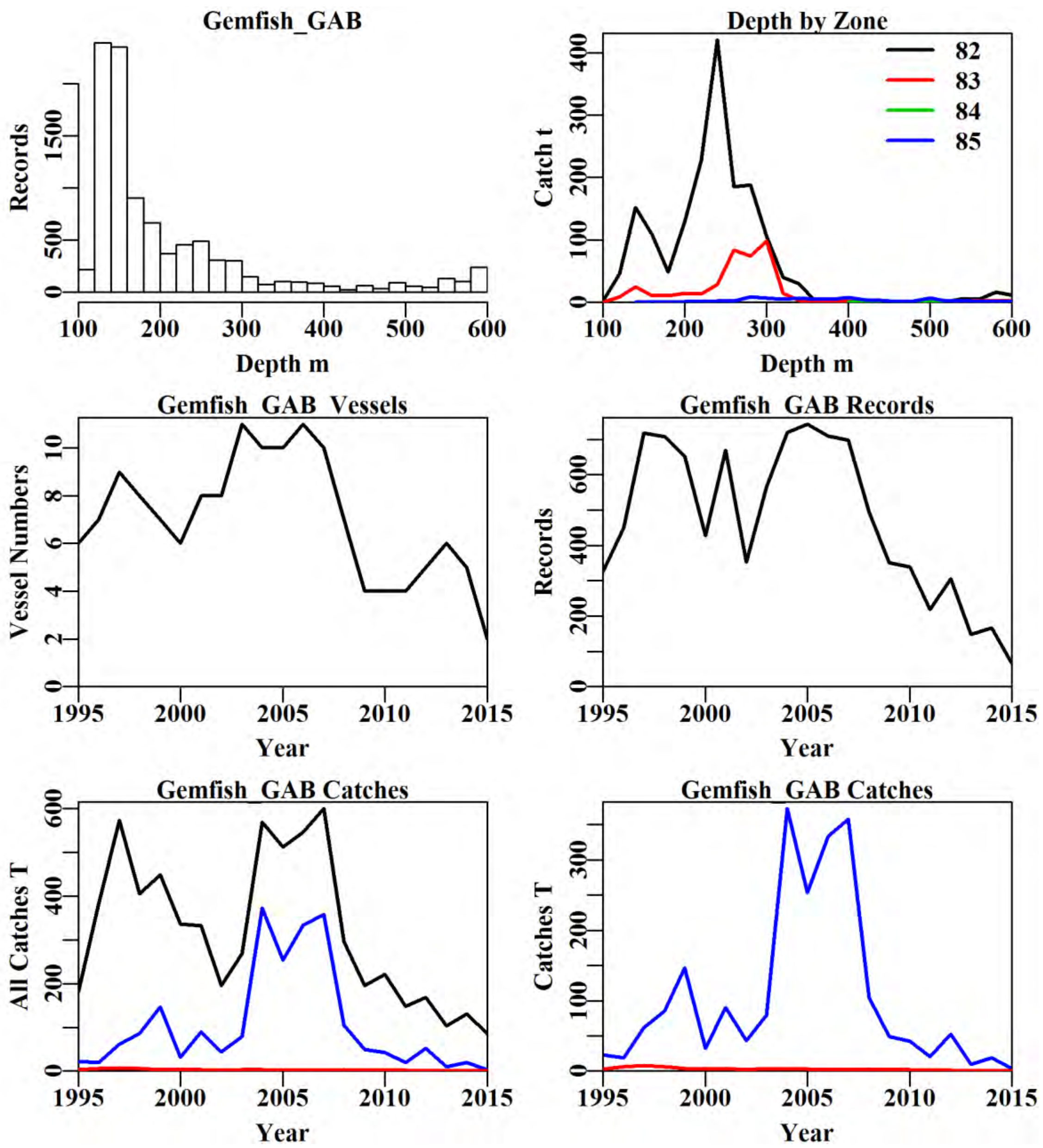
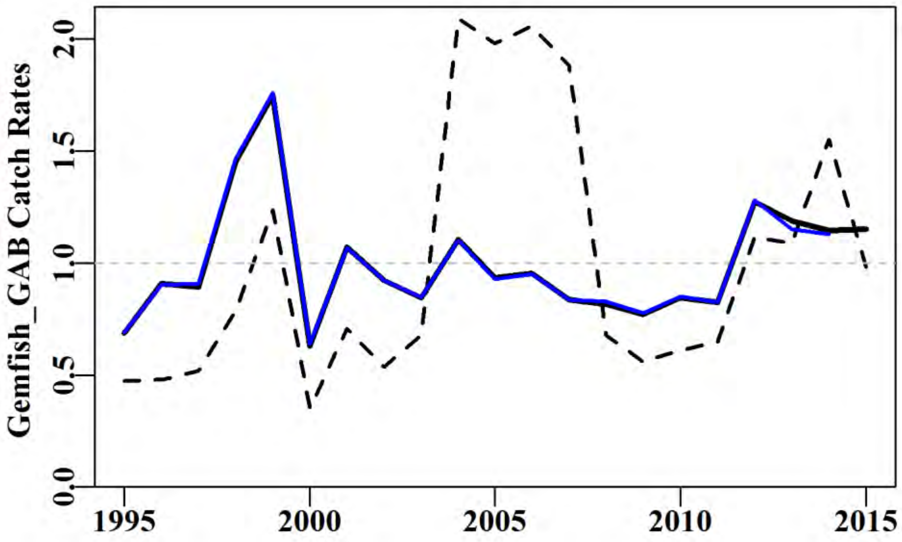



Figure 8.95. Western Gemfish in the GAB (zones 82, 83, 84, and 85) in depths between 100 and 600 m by Trawl. The top left plot depicts the depth distribution of shots containing Western Gemfish from zones in the GAB (zones 82, 83, 84, and 85) in depths 100 – 600 m by Trawl. The top right plot depicts the catch distribution by depth by zone. The middle left plot depicts the number of vessels through time and middle right plot contains the number of records used in analysis. The bottom left plot contains Western Gemfish catches (top black line: total catches, middle blue line: catches used in the analysis; bottom red line: catches < 30 kg) and bottom right plot contains Western Gemfish catches (blue line: catches used in the analysis; red line: catches < 30 kg).



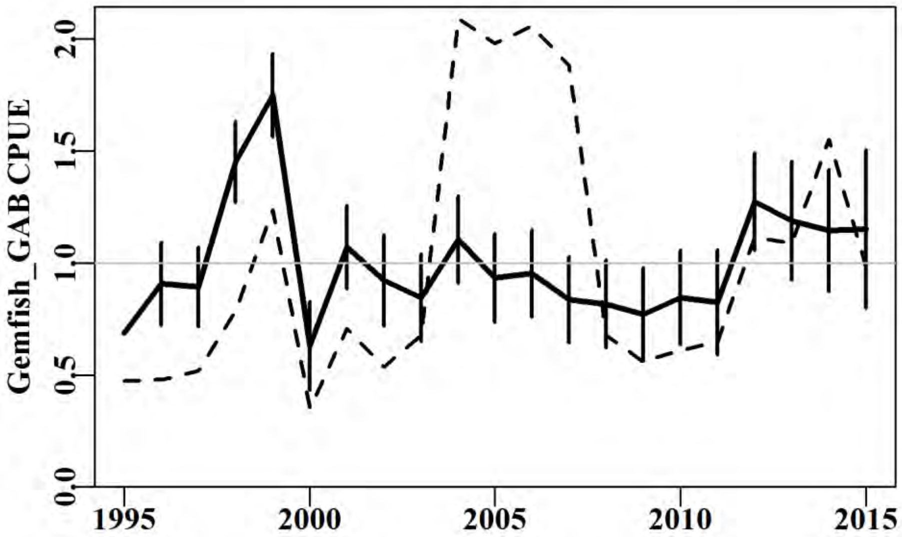




Figure 8.96. Western Gemfish in the GAB (zones 82, 83, 84, and 85) in depths between 100 and 600 m by Trawl. Upper graph: The dashed black line represents the geometric mean catch rate and the solid black line the standardized catch rates (relative to the mean of the standardized catch rates). The blue line corresponds to last year's standardized indices. Lower graph: Standardized indices (solid black line), 95% CI (vertical lines) and geometric mean (dashed black line). The graph standardizes catch rates relative to the mean of the standardized catch rates.

Table 8.89. Western Gemfish in the GAB (zones 82, 83, 84, and 85) in depths between 100 and 600 m by Trawl. Statistical model structures used in this analysis. DepCat is a series of 20 metre depth categories.

| | |
|---|---|
| Model 1 | LnCE~Year |
| Model 2 | LnCE~Year+DepCat |
| Model 3 | LnCE~Year+DepCat+Vessel |
| Model 4 | LnCE~Year+DepCat+Vessel+Month |
| Model 5 | LnCE~Year+DepCat+Vessel+Month+DayNight |
| Model 6 | LnCE~Year+DepCat+Vessel+Month+DayNight+Zone |
| Model 7 | LnCE~Year+DepCat+Vessel+Month+DayNight+Zone+Zone:Month |
| Model 8 | LnCE~Year+DepCat+Vessel+Month+DayNight+Zone+Zone:DepCat |

Table 8.90. Western Gemfish in the GAB (zones 82, 83, 84, and 85) in depths between 100 and 600 m by Trawl. Model selection criteria include the Akaike Information Criterion (AIC), residual sum of squares (RSS), model sum of squares (MSS), number of usable observations (Nobs), number of parameters (Npars), adjusted $R^2$ (adj_$R^2$) and the change in adjusted $R^2$ (%Change). The optimum is Zone:Month (Model 7). Depth category: DepC.

| | Year | DepC | Vessel | Month | DayNight | Zone | Zone:Month | Zone:DepC |
|---|---|---|---|---|---|---|---|---|
| AIC | 11023 | 7137 | 5711 | 5029 | 4780 | 4553 | 4244 | 4495 |
| RSS | 30043 | 20099 | 17277 | 16077 | 15664 | 15296 | 14720 | 14973 |
| MSS | 3263 | 13206 | 16029 | 17228 | 17641 | 18010 | 18585 | 18333 |
| Nobs | 9823 | 9781 | 9781 | 9781 | 9781 | 9781 | 9781 | 9781 |
| Npars | 21 | 46 | 73 | 84 | 87 | 90 | 123 | 165 |
| adj_$R^2$ | 9.613 | 39.373 | 47.742 | 51.314 | 52.550 | 53.653 | 55.244 | 54.277 |
| %Change | 0.000 | 29.760 | 8.370 | 3.572 | 1.236 | 1.103 | 1.591 | -0.967 |

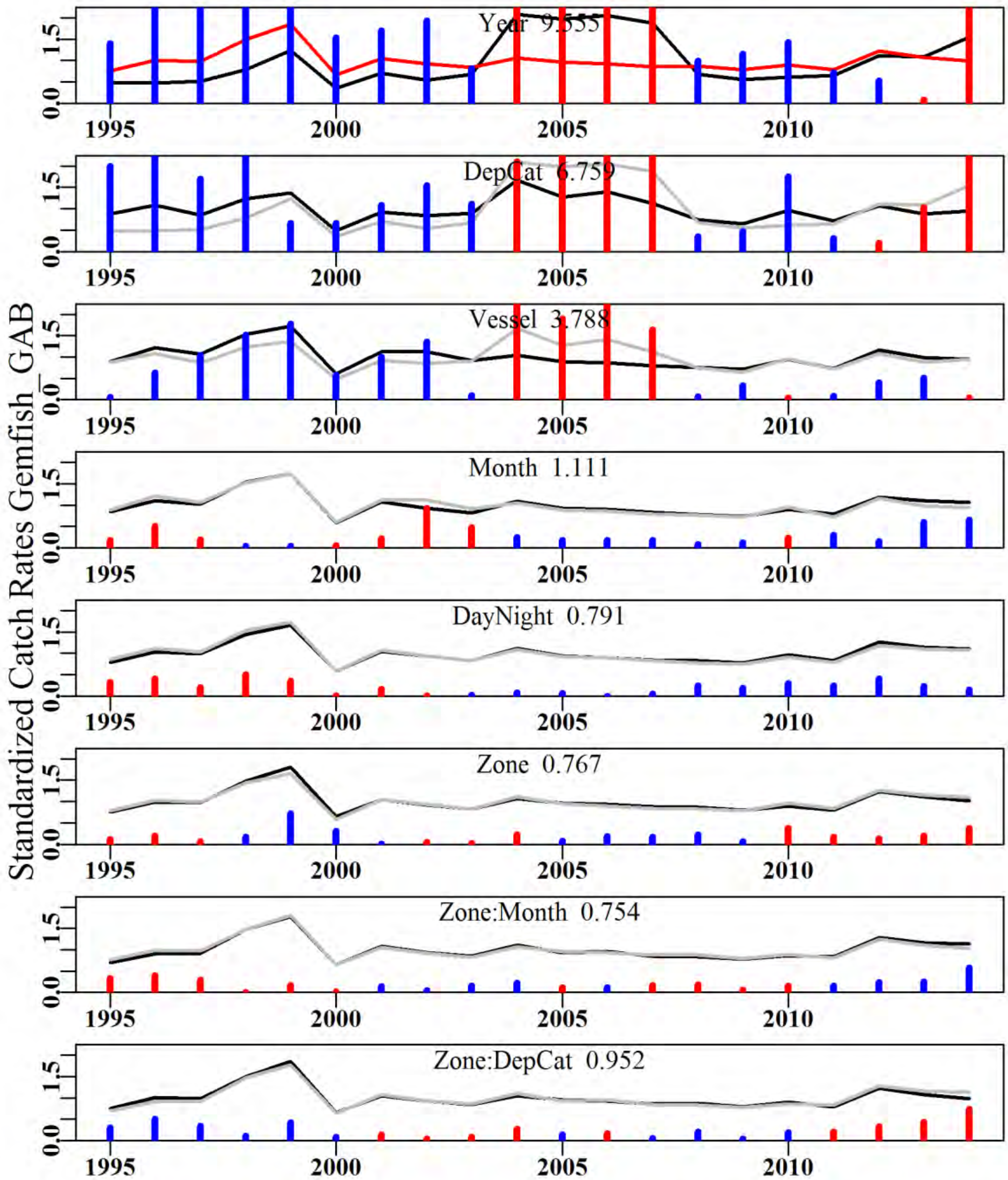



Figure 8.97. The relative influence of each factor used on the final trend in the optimal standardization for Western Gemfish in the GAB (zones 82, 83, 84, and 85). The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by the vertical bars with blue bars indicating the optimum model is higher than the geometric mean and red bars indicating it is lower. The top graph bars are the sum of all the bars in the graphs below. The graphs for individual factors are cumulative. Thus the second graph has the geometric mean (grey line) and the effect of adding Year + factor2 (Model 2). In the third graph, the grey line represents Model 2 and the black line the effect of adding factor3 to the model. The remaining graphs continue in the same cumulative manner except for the interaction terms which are added singularly to the final single factor model.

### 8.4.32 *Offshore Ocean Perch Z1020 (REG – 37287001 Helicolenus percoides; 200 m)*

The depth distribution of offshore Ocean Perch was revised to 300-700 m to avoid overlap with inshore Ocean Perch following a Slope RAG meeting (Nov. 2009). However, this decision was reversed in 2010 and the analysis was repeated using 200-700 m.

Table 8.91. Offshore Ocean Perch from zones 10 and 20 in depths 200 – 700 m by Trawl. Total catch (TotCatch; t) is the total reported in the database, number of records used in the analysis (Records), reported catch (CatchT; t) in the area and depth used in the analysis and number of vessels used in the analysis (Vessels). GeoMean is the geometric mean of catch rates (kg/hr). The optimum model is Zone:Month and standard deviation (StDev) relates to the data in the optimum model.

| Year | TotCatch | Records | CatchT | Vessels | GeoMean | Zone:Month | StDev |
|---|---|---|---|---|---|---|---|
| 1986 | 262.4460 | 3479 | 207.3630 | 77 | 12.1440 | 1.0506 | 0.0000 |
| 1987 | 198.3470 | 3140 | 132.7970 | 70 | 8.9237 | 0.9752 | 0.0257 |
| 1988 | 186.7120 | 2808 | 150.7650 | 73 | 10.5074 | 1.0881 | 0.0268 |
| 1989 | 206.2580 | 3036 | 160.0040 | 67 | 10.6494 | 1.0426 | 0.0266 |
| 1990 | 180.5600 | 1970 | 115.9430 | 57 | 12.0207 | 1.3930 | 0.0299 |
| 1991 | 223.1880 | 2093 | 138.9910 | 53 | 13.4339 | 1.4545 | 0.0296 |
| 1992 | 169.6690 | 1855 | 114.3790 | 48 | 11.8942 | 1.2305 | 0.0305 |
| 1993 | 259.3100 | 2924 | 199.1860 | 53 | 12.9555 | 1.2385 | 0.0272 |
| 1994 | 257.2410 | 3014 | 180.9550 | 49 | 11.8001 | 1.1500 | 0.0269 |
| 1995 | 239.9510 | 3146 | 150.3410 | 50 | 10.4874 | 1.0391 | 0.0266 |
| 1996 | 263.2350 | 3411 | 176.8080 | 53 | 9.8364 | 0.9325 | 0.0262 |
| 1997 | 296.3336 | 3725 | 193.7730 | 54 | 9.7119 | 0.9964 | 0.0259 |
| 1998 | 292.0978 | 3850 | 194.6290 | 49 | 9.4285 | 0.8781 | 0.0257 |
| 1999 | 290.6426 | 4406 | 219.0650 | 52 | 9.7566 | 0.9847 | 0.0254 |
| 2000 | 269.8270 | 4180 | 180.9002 | 53 | 7.5503 | 0.7876 | 0.0258 |
| 2001 | 281.5414 | 4063 | 184.8160 | 43 | 8.3993 | 0.8847 | 0.0260 |
| 2002 | 255.3073 | 3648 | 150.6642 | 45 | 7.3691 | 0.8373 | 0.0268 |
| 2003 | 322.7355 | 3960 | 185.0060 | 53 | 7.6242 | 0.8930 | 0.0265 |
| 2004 | 316.1390 | 3129 | 150.4585 | 46 | 8.0648 | 0.8908 | 0.0278 |
| 2005 | 316.7690 | 3089 | 170.0795 | 46 | 9.3641 | 1.0031 | 0.0277 |
| 2006 | 237.6008 | 2326 | 113.1680 | 39 | 7.8433 | 0.8583 | 0.0296 |
| 2007 | 180.5792 | 1528 | 94.9000 | 22 | 9.9183 | 1.0781 | 0.0334 |
| 2008 | 184.2667 | 1843 | 101.8360 | 23 | 9.1917 | 0.9908 | 0.0319 |
| 2009 | 173.8793 | 1694 | 99.6075 | 23 | 9.0355 | 0.9823 | 0.0328 |
| 2010 | 195.5993 | 1759 | 118.1070 | 21 | 9.8647 | 0.9838 | 0.0323 |
| 2011 | 186.7935 | 1874 | 116.6955 | 22 | 9.0998 | 0.8747 | 0.0318 |
| 2012 | 180.5639 | 1693 | 114.1412 | 22 | 9.9671 | 0.9321 | 0.0326 |
| 2013 | 166.4426 | 1232 | 100.1720 | 20 | 12.0121 | 0.9690 | 0.0359 |
| 2014 | 141.2040 | 1170 | 95.5290 | 20 | 11.1743 | 0.8659 | 0.0364 |
| 2015 | 124.7333 | 1107 | 87.421 | 19 | 9.2999 | 0.7148 | 0.0375 |

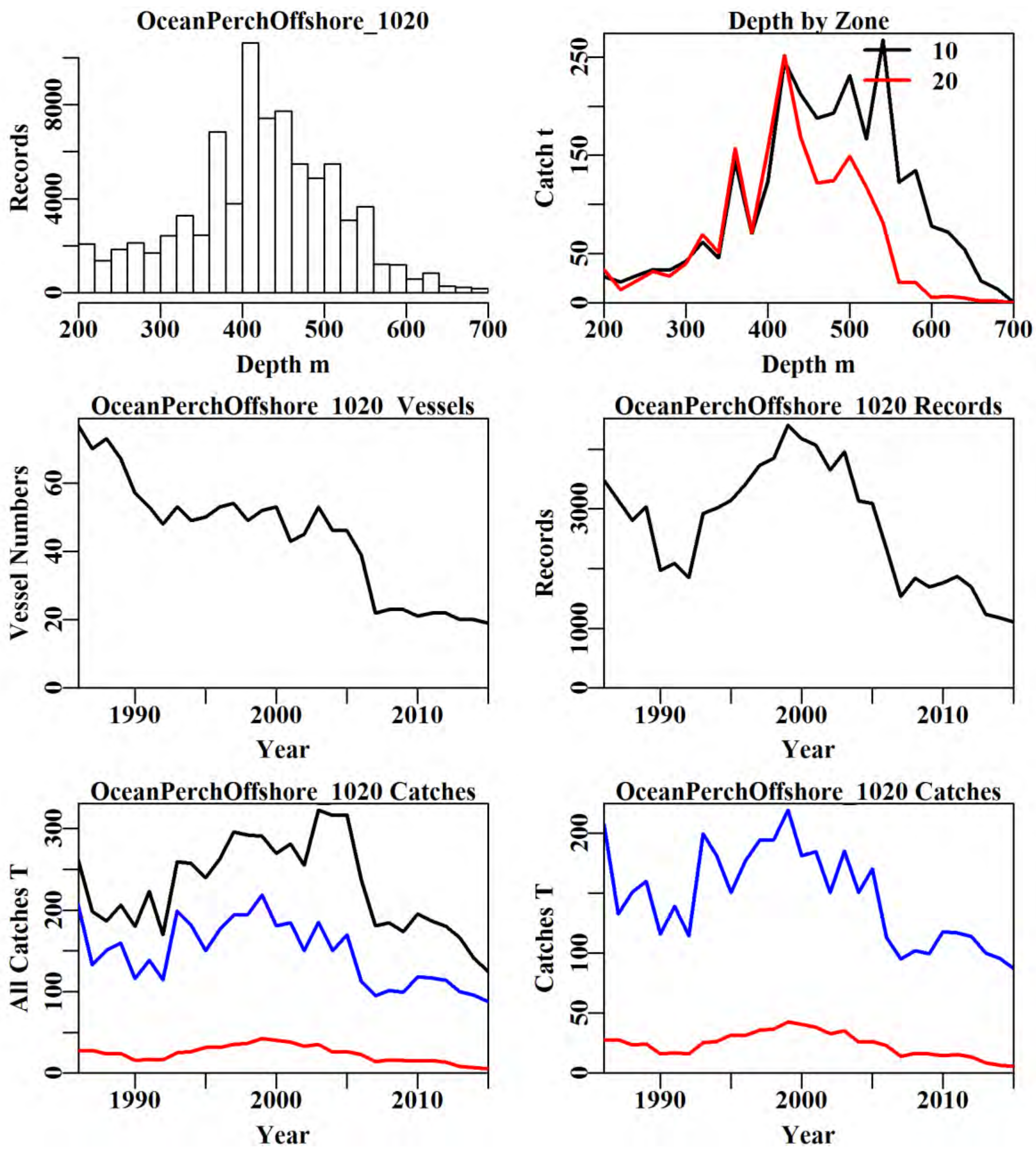



Figure 8.98. Offshore Ocean Perch from zones 10 and 20 in depths 200 – 700 m by Trawl. The top left plot depicts the depth distribution of shots containing Offshore Ocean Perch from zones 10 and 20 in depths 200 – 700m by Trawl. The top right plot depicts the catch distribution by depth by zone. The middle left plot depicts the number of vessels through time and middle right plot contains the number of records used in analysis. The bottom left plot contains Offshore Ocean Perch catches (top black line: total catches, middle blue line: catches used in the analysis; bottom red line: catches < 30 kg) and bottom right plot contains Offshore Ocean Perch catches (blue line: catches used in the analysis; red line: catches < 30 kg).

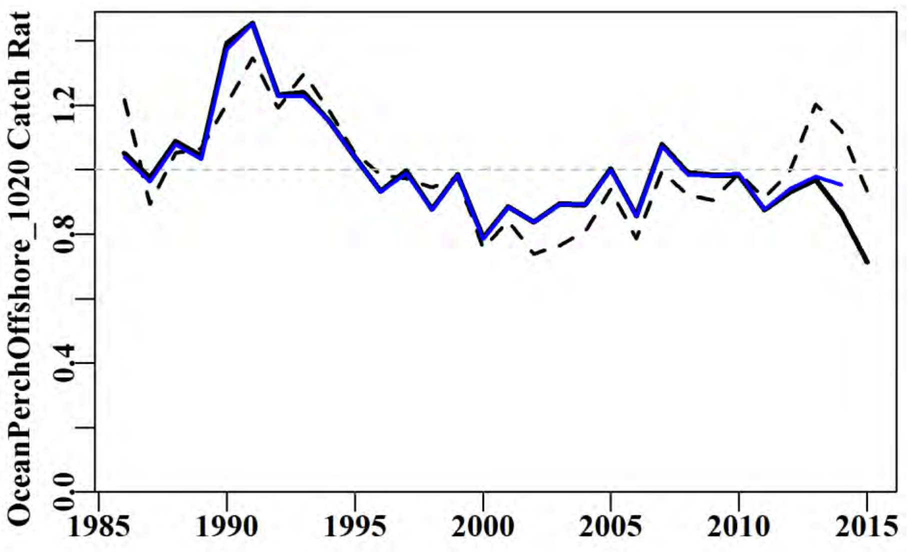



Figure 8.99. Offshore Ocean Perch from zones 10 and 20 in depths 200 – 700 m by Trawl. The dashed black line represents the geometric mean catch rate, solid black line the standardized catch rates and solid blue line standardized catch rates from last year's analysis. The graph standardizes catch rates relative to the mean of the standardized catch rates.

Table 8.92. Offshore Ocean Perch from zones 10 and 20 in depths 200 – 700 m by Trawl. Statistical model structures used in this analysis. DepCat is a series of 20 metre depth categories.

| | |
|---|---|
| Model 1 | LnCE~Year |
| Model 2 | LnCE~Year+DepCat |
| Model 3 | LnCE~Year+DepCat+Vessel |
| Model 4 | LnCE~Year+DepCat+Vessel+Month |
| Model 5 | LnCE~Year+DepCat+Vessel+Month+DayNight |
| Model 6 | LnCE~Year+DepCat+Vessel+Month+DayNight+Zone |
| Model 7 | LnCE~Year+DepCat+Vessel+Month+DayNight+Zone+Zone:Month |
| Model 8 | LnCE~Year+DepCat+Vessel+Month+DayNight+Zone+Zone:DepCat |

Table 8.93. Offshore Ocean Perch from zones 10 and 20 in depths 200 – 700 m by Trawl. Model selection criteria include the Akaike Information Criterion (AIC), residual sum of squares (RSS), model sum of squares (MSS), number of usable observations (Nobs), number of parameters (Npars), adjusted $R^2$ (adj_$R^2$) and the change in adjusted $R^2$ (%Change). The optimum is Zone:Month (Model 7). Depth category: DepC.

| | Year | DepC | Vessel | Month | DayNight | Zone | Zone:Month | Zone:DepC |
|---|---|---|---|---|---|---|---|---|
| AIC | 24958 | 12380 | 3328 | 1110 | 591 | 549 | -1544 | 184 |
| RSS | 110292 | 93975 | 83677 | 81386 | 80860 | 80815 | 78725 | 80401 |
| MSS | 2186 | 18502 | 28801 | 31091 | 31618 | 31662 | 33752 | 32077 |
| Nobs | 81152 | 80724 | 80724 | 80724 | 80724 | 80724 | 80724 | 80724 |
| Npars | 30 | 55 | 214 | 225 | 228 | 229 | 240 | 254 |
| adj_$R^2$ | 1.908 | 16.394 | 25.409 | 27.441 | 27.908 | 27.946 | 29.800 | 28.294 |
| %Change | 0.000 | 14.486 | 9.015 | 2.032 | 0.467 | 0.039 | 1.854 | -1.507 |

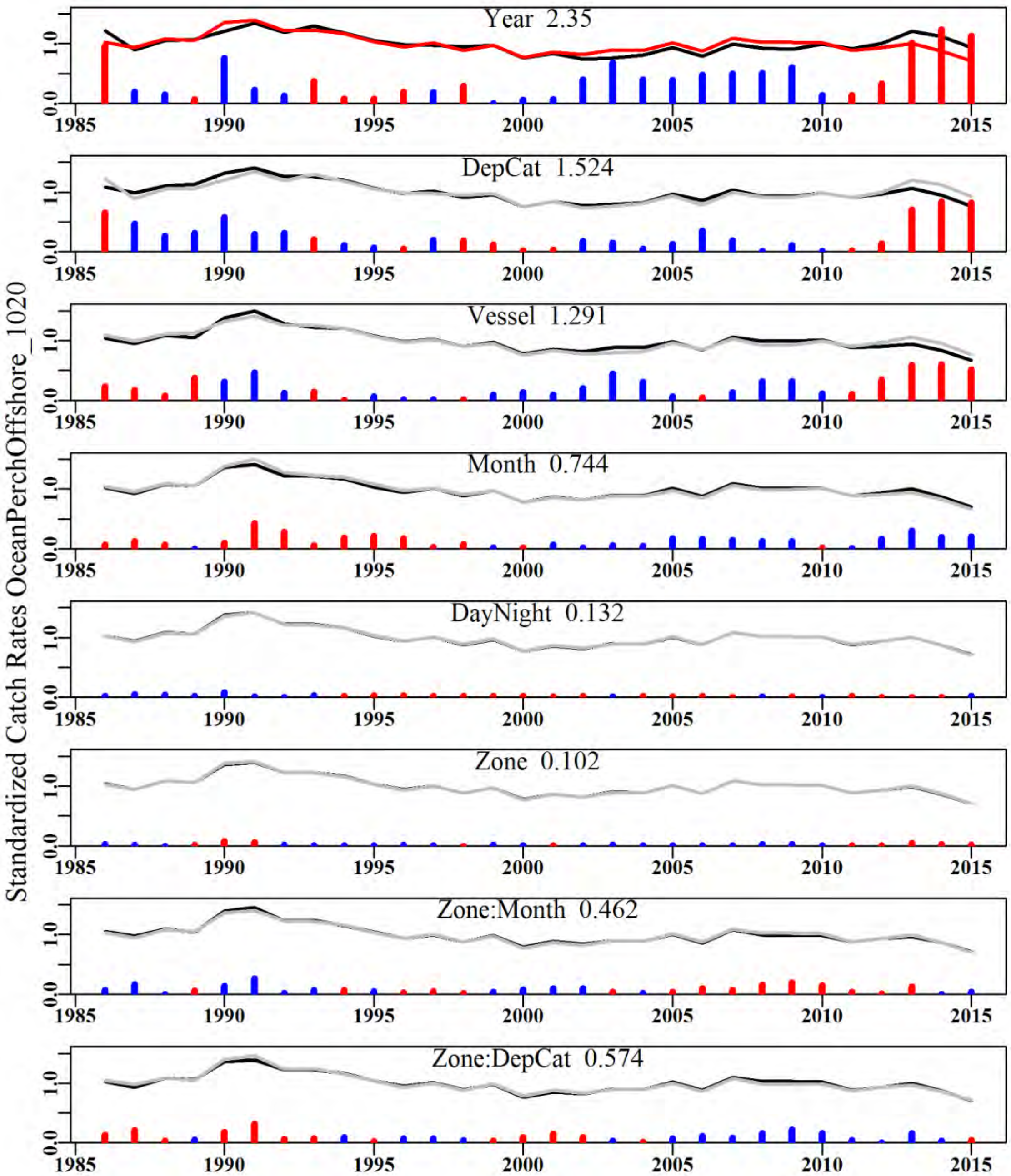
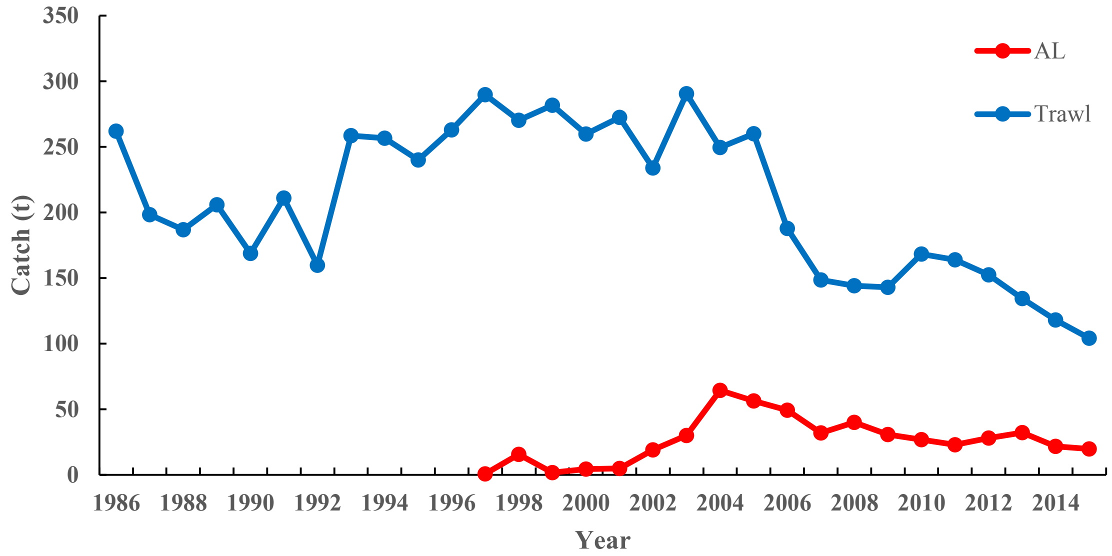



Figure 8.100. The relative influence of each factor used on the final trend in the optimal standardization for Offshore Ocean Perch from zones 10 and 20. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by the vertical bars with blue bars indicating the optimum model is higher than the geometric mean and red bars indicating it is lower. The top graph bars are the sum of all the bars in the graphs below. The graphs for individual factors are cumulative. Thus the second graph has the geometric mean (grey line) and the effect of adding Year + factor2 (Model 2). In the third graph, the grey line represents Model 2 and the black line the effect of adding factor3 to the model. The remaining graphs continue in the same cumulative manner except for the interaction terms which are added singularly to the final single factor model.



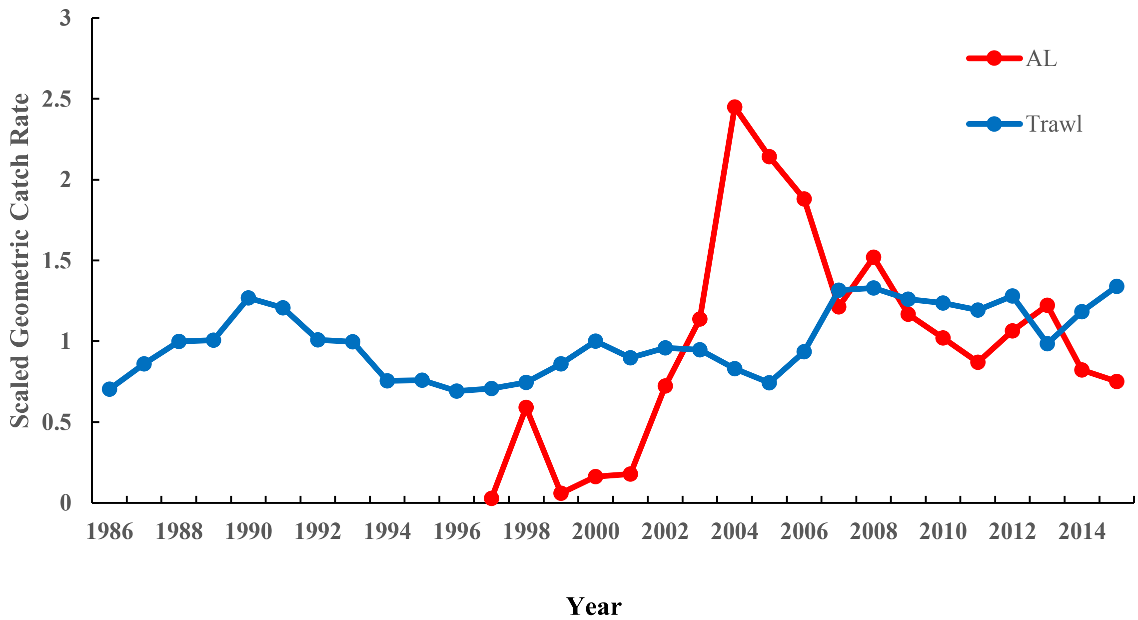




Figure 8.101. Offshore Ocean Perch, depths > 200 m for Trawl and Auto Line (AL), in zones 10 and 20 between 1986 and 2015. Upper plot: Catches through time taken by Trawl and by Auto Line. Some of the decline in trawl catches in recent years have been made up by the Auto Long Lining. Lower plot: Geometric mean catch rates for Offshore Ocean Perch in depth 200 – 700 m for both trawl and Auto Line scaled to the mean of each series for comparison.

### 8.4.33 *Inshore Ocean Perch Z1020 (REG – 37287001 – H. percoides; 0–200m)*

A separate analysis was required for Inshore Ocean Perch following a Slope RAG meeting (Nov. 2009). These were defined as all those Ocean Perch reported as caught between 0-299 m to avoid overlap with Offshore Ocean Perch. However, in 2010 this decision was reversed and the analysis was repeated for depths 0-200 m.

Table 8.94. Inshore Ocean Perch from zones 10 and 20 in depths 0 – 200 m by Trawl. Total catch (TotCatch; t) is the total reported in the database, number of records used in the analysis (Records), reported catch (CatchT; t) in the area and depth used in the analysis and number of vessels used in the analysis (Vessels). GeoMean is the geometric mean of catch rates (kg/hr). The optimum model is Zone:DepC and standard deviation (StDev) relates to the data in the optimum model.

| Year | TotCatch | Records | CatchT | Vessels | GeoMean | Zone:DepC | StDev |
|---|---|---|---|---|---|---|---|
| 1986 | 262.4460 | 3479 | 207.3630 | 77 | 12.1440 | 1.0506 | 0.0000 |
| 1987 | 198.3470 | 3140 | 132.7970 | 70 | 8.9237 | 0.9752 | 0.0257 |
| 1988 | 186.7120 | 2808 | 150.7650 | 73 | 10.5074 | 1.0881 | 0.0268 |
| 1989 | 206.2580 | 3036 | 160.0040 | 67 | 10.6494 | 1.0426 | 0.0266 |
| 1990 | 180.5600 | 1970 | 115.9430 | 57 | 12.0207 | 1.3930 | 0.0299 |
| 1991 | 223.1880 | 2093 | 138.9910 | 53 | 13.4339 | 1.4545 | 0.0296 |
| 1992 | 169.6690 | 1855 | 114.3790 | 48 | 11.8942 | 1.2305 | 0.0305 |
| 1993 | 259.3100 | 2924 | 199.1860 | 53 | 12.9555 | 1.2385 | 0.0272 |
| 1994 | 257.2410 | 3014 | 180.9550 | 49 | 11.8001 | 1.1500 | 0.0269 |
| 1995 | 239.9510 | 3146 | 150.3410 | 50 | 10.4874 | 1.0391 | 0.0266 |
| 1996 | 263.2350 | 3411 | 176.8080 | 53 | 9.8364 | 0.9325 | 0.0262 |
| 1997 | 296.3336 | 3725 | 193.7730 | 54 | 9.7119 | 0.9964 | 0.0259 |
| 1998 | 292.0978 | 3850 | 194.6290 | 49 | 9.4285 | 0.8781 | 0.0257 |
| 1999 | 290.6426 | 4406 | 219.0650 | 52 | 9.7566 | 0.9847 | 0.0254 |
| 2000 | 269.8270 | 4180 | 180.9002 | 53 | 7.5503 | 0.7876 | 0.0258 |
| 2001 | 281.5414 | 4063 | 184.8160 | 43 | 8.3993 | 0.8847 | 0.0260 |
| 2002 | 255.3073 | 3648 | 150.6642 | 45 | 7.3691 | 0.8373 | 0.0268 |
| 2003 | 322.7355 | 3960 | 185.0060 | 53 | 7.6242 | 0.8930 | 0.0265 |
| 2004 | 316.1390 | 3129 | 150.4585 | 46 | 8.0648 | 0.8908 | 0.0278 |
| 2005 | 316.7690 | 3089 | 170.0795 | 46 | 9.3641 | 1.0031 | 0.0277 |
| 2006 | 237.6008 | 2326 | 113.1680 | 39 | 7.8433 | 0.8583 | 0.0296 |
| 2007 | 180.5792 | 1528 | 94.9000 | 22 | 9.9183 | 1.0781 | 0.0334 |
| 2008 | 184.2667 | 1843 | 101.8360 | 23 | 9.1917 | 0.9908 | 0.0319 |
| 2009 | 173.8793 | 1694 | 99.6075 | 23 | 9.0355 | 0.9823 | 0.0328 |
| 2010 | 195.5993 | 1759 | 118.1070 | 21 | 9.8647 | 0.9838 | 0.0323 |
| 2011 | 186.7935 | 1874 | 116.6955 | 22 | 9.0998 | 0.8747 | 0.0318 |
| 2012 | 180.5639 | 1693 | 114.1412 | 22 | 9.9671 | 0.9321 | 0.0326 |
| 2013 | 166.4426 | 1232 | 100.1720 | 20 | 12.0121 | 0.9690 | 0.0359 |
| 2014 | 141.2040 | 1170 | 95.5290 | 20 | 11.1743 | 0.8659 | 0.0364 |
| 2015 | 124.7333 | 1107 | 87.4210 | 19 | 9.2999 | 0.7148 | 0.0375 |

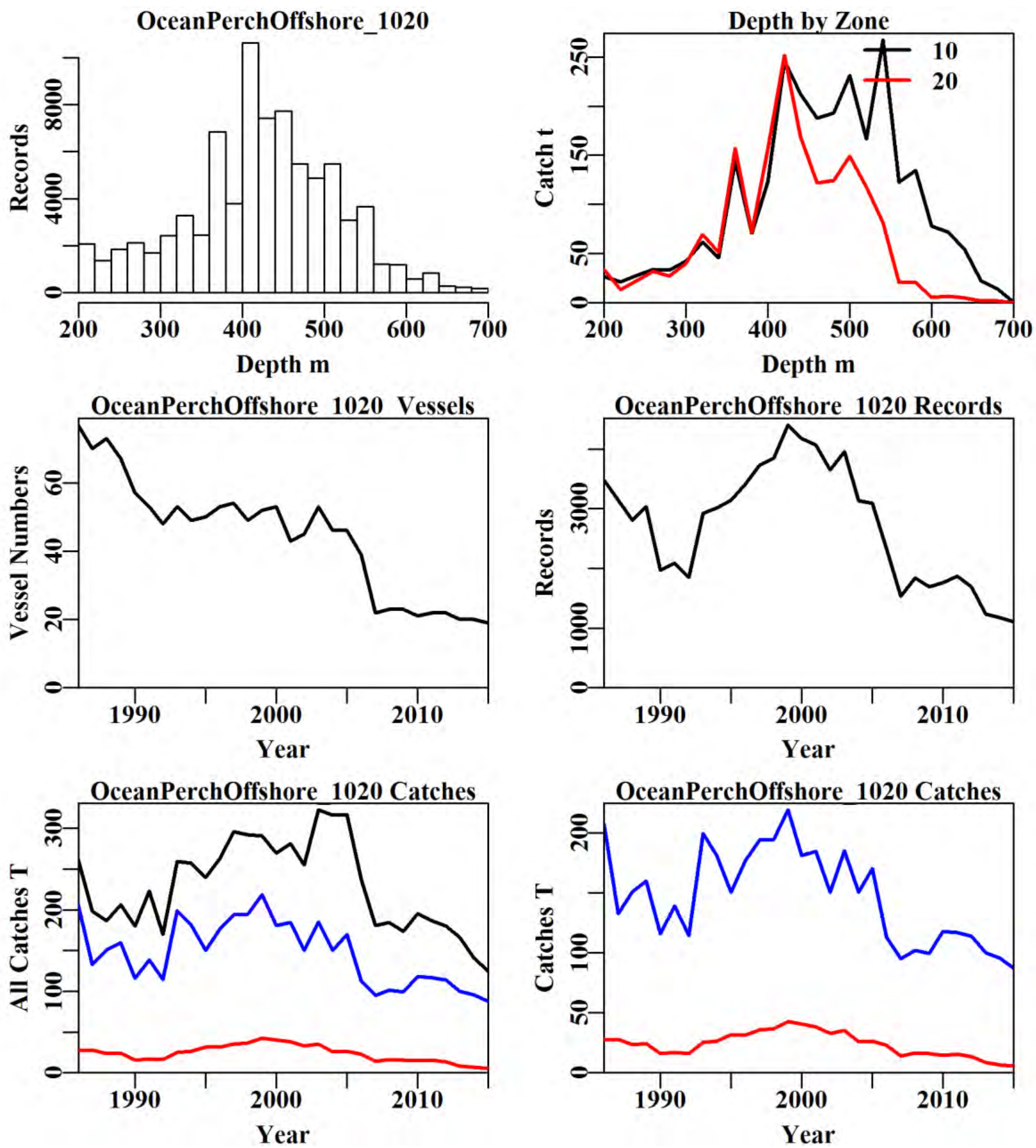



Figure 8.102. Inshore Ocean Perch from zones 10 and 20 in depths 0 – 200 m by Trawl. The top left plot depicts the depth distribution of shots containing Offshore Ocean Perch from zones 10 and 20 in depths 0 – 200 m by Trawl. The top right plot depicts the catch distribution by depth by zone. The middle left plot depicts the number of vessels through time and middle right plot contains the number of records used in analysis. The bottom left plot contains Offshore Ocean Perch catches (top black line: total catches, middle blue line: catches used in the analysis; bottom red line: catches < 30 kg) and bottom right plot contains Offshore Ocean Perch catches (blue line: catches used in the analysis; red line: catches < 30 kg).

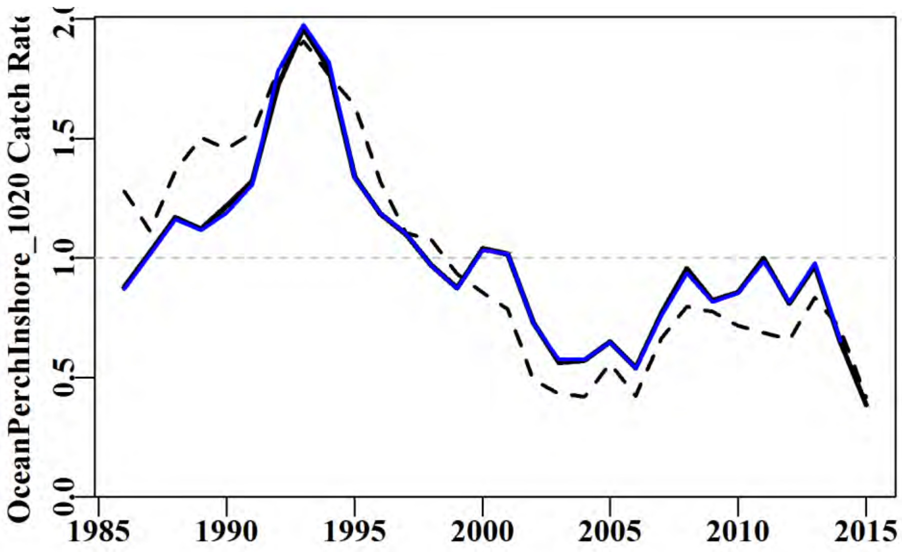



Figure 8.103. Inshore Ocean Perch from zones 10 and 20 in depths 0 – 200 m by Trawl. The dashed black line represents the geometric mean catch rate, solid black line the standardized catch rates and solid blue line standardized catch rates from last year's analysis. The graph standardizes catch rates relative to the mean of the standardized catch rates.

Table 8.95. Inshore Ocean Perch from zones 10 and 20 in depths 0 – 200 m by Trawl. Statistical model structures used in this analysis. DepCat is a series of 20 metre depth categories.

| | |
|---|---|
| Model 1 | LnCE~Year |
| Model 2 | LnCE~Year+Vessel |
| Model 3 | LnCE~Year+Vessel+DepCat |
| Model 4 | LnCE~Year+Vessel+DepCat+Month |
| Model 5 | LnCE~Year+Vessel+DepCat+Month+DayNight |
| Model 6 | LnCE~Year+Vessel+DepCat+Month+DayNight+Zone |
| Model 7 | LnCE~Year+Vessel+DepCat+Month+DayNight+Zone+Zone:Month |
| Model 8 | LnCE~Year+Vessel+DepCat+Month+DayNight+Zone+Zone:DepCat |

Table 8.96. Inshore Ocean Perch from zones 10 and 20 in depths 0 – 200 m by Trawl. Model selection criteria include the Akaike Information Criterion (AIC), residual sum of squares (RSS), model sum of squares (MSS), number of usable observations (Nobs), number of parameters (Npars), adjusted $R^2$ (adj_$R^2$) and the change in adjusted $R^2$ (%Change). The optimum is Zone:DepC (Model 8). Depth category: DepC.

| | Year | Vessel | DepC | Month | DayNight | Zone | Zone:DepC | Zone:Month |
|---|---|---|---|---|---|---|---|---|
| AIC | 6018 | 2540 | 1588 | 1511 | 1438 | 1365 | 1280 | 1365 |
| RSS | 24081 | 19279 | 17777 | 17671 | 17591 | 17507 | 17395 | 17483 |
| MSS | 3869 | 8671 | 10173 | 10279 | 10359 | 10443 | 10554 | 10466 |
| Nobs | 16941 | 16941 | 16513 | 16513 | 16513 | 16513 | 16513 | 16513 |
| Npars | 30 | 175 | 185 | 196 | 197 | 200 | 210 | 211 |
| adj_$R^2$ | 13.694 | 30.306 | 35.681 | 36.021 | 36.306 | 36.600 | 36.964 | 36.642 |
| %Change | 0.000 | 16.613 | 5.374 | 0.341 | 0.285 | 0.294 | 0.364 | -0.322 |

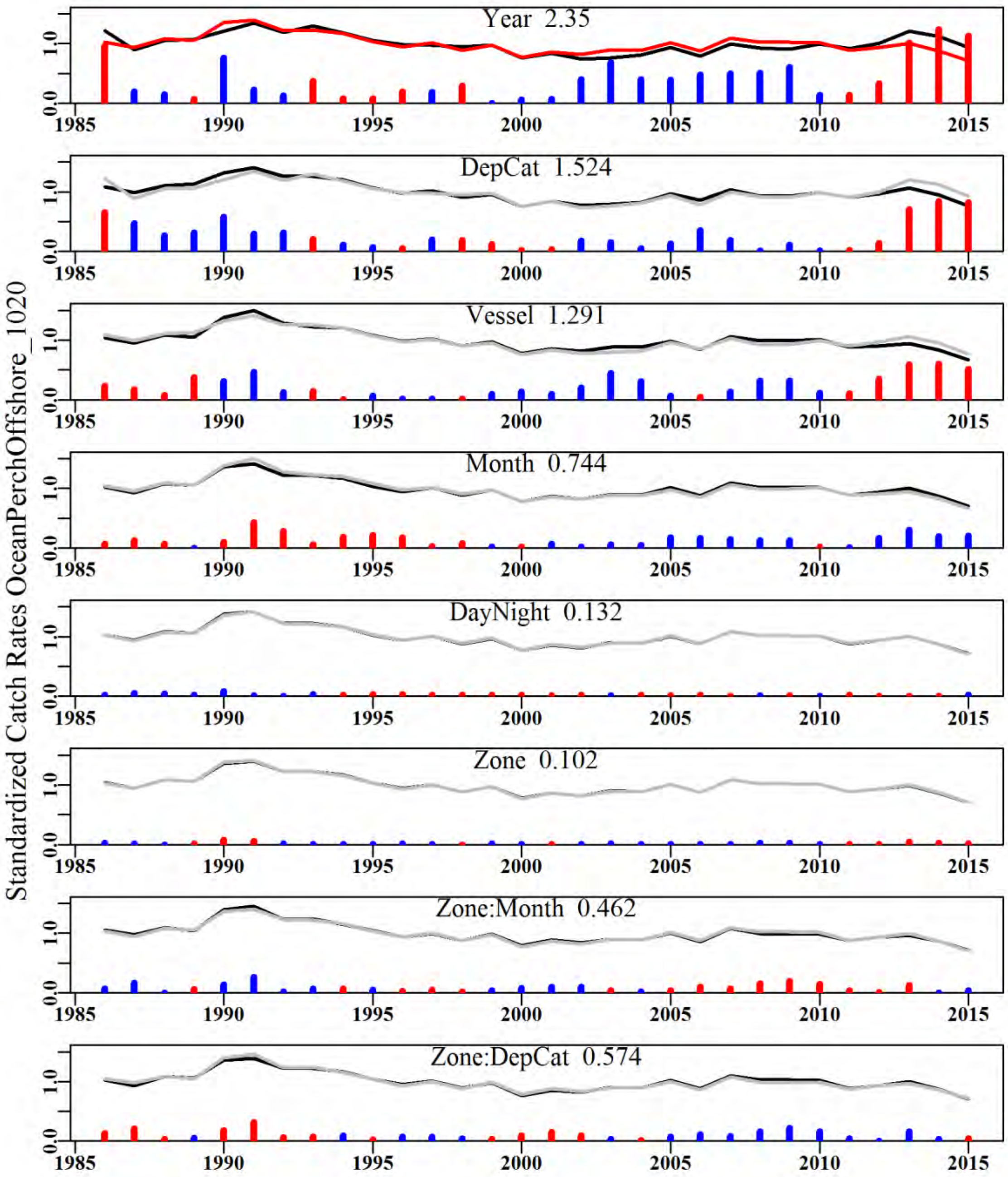



Figure 8.104. The relative influence of each factor used on the final trend in the optimal standardization for Inshore Ocean Perch from zones 10 and 20. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by the vertical bars with blue bars indicating the optimum model is higher than the geometric mean and red bars indicating it is lower. The top graph bars are the sum of all the bars in the graphs below. The graphs for individual factors are cumulative. Thus the second graph has the geometric mean (grey line) and the effect of adding Year + factor2 (Model 2). In the third graph, the grey line represents Model 2 and the black line the effect of adding factor3 to the model. The remaining graphs continue in the same cumulative manner except for the interaction terms which are added singularly to the final single factor model.

### 8.4.34 *John Dory Z1020 (DOJ – 37264004 – Zeus faber)*

Trawl data corresponding to zones 10 and 20 in depths 0 – 200 m were analysed.

Table 8.97. John Dory from zones 10 and 20 in depths 0 to 200 m by Trawl. Total catch (TotCatch; t) is the total reported in the database, number of records used in the analysis (Records), reported catch (CatchT; t) in the area and depth used in the analysis and number of vessels used in the analysis (Vessels). GeoMean is the geometric mean of catch rates (kg/hr). The optimum model is Zone:DepC and standard deviation (StDev) relates to the data in the optimum model.

| Year | TotCatch | Records | CatchT | Vessels | GeoMean | Zone:DepC | StDev |
|---|---|---|---|---|---|---|---|
| 1986 | 231.7150 | 6417 | 202.2230 | 90 | 12.0754 | 1.6922 | 0.0000 |
| 1987 | 206.0900 | 4662 | 181.5810 | 78 | 14.5313 | 1.9540 | 0.0209 |
| 1988 | 181.9840 | 4540 | 161.6280 | 73 | 13.4584 | 1.8114 | 0.0212 |
| 1989 | 217.9240 | 4814 | 188.4680 | 70 | 14.2742 | 1.9801 | 0.0211 |
| 1990 | 167.8530 | 3701 | 136.7740 | 60 | 12.9727 | 1.8086 | 0.0231 |
| 1991 | 172.2910 | 4041 | 126.6960 | 53 | 11.8881 | 1.4447 | 0.0228 |
| 1992 | 130.8493 | 3938 | 109.1163 | 49 | 9.5571 | 1.2149 | 0.0230 |
| 1993 | 240.4380 | 5431 | 181.0670 | 55 | 11.6096 | 1.5267 | 0.0215 |
| 1994 | 267.8680 | 6556 | 209.3850 | 55 | 11.0915 | 1.4423 | 0.0205 |
| 1995 | 185.6720 | 6043 | 167.2860 | 52 | 10.0702 | 1.2238 | 0.0206 |
| 1996 | 160.7530 | 6391 | 146.3450 | 59 | 8.4122 | 0.9629 | 0.0205 |
| 1997 | 87.7655 | 4468 | 79.1930 | 60 | 6.2670 | 0.7489 | 0.0225 |
| 1998 | 109.0292 | 5091 | 98.4870 | 53 | 6.9524 | 0.7773 | 0.0216 |
| 1999 | 132.8421 | 5547 | 120.9940 | 56 | 7.7587 | 0.9178 | 0.0213 |
| 2000 | 164.0530 | 6962 | 147.3445 | 58 | 7.2348 | 0.8504 | 0.0204 |
| 2001 | 129.2998 | 6627 | 116.3130 | 50 | 5.7830 | 0.7136 | 0.0206 |
| 2002 | 150.9738 | 6688 | 136.4103 | 49 | 6.7049 | 0.6996 | 0.0208 |
| 2003 | 156.9439 | 6558 | 137.3210 | 51 | 6.7367 | 0.6782 | 0.0207 |
| 2004 | 166.0275 | 7094 | 147.6960 | 51 | 6.7630 | 0.7173 | 0.0204 |
| 2005 | 107.3895 | 4934 | 88.6397 | 48 | 5.7083 | 0.5947 | 0.0222 |
| 2006 | 85.4007 | 3727 | 71.6251 | 43 | 5.8304 | 0.6674 | 0.0238 |
| 2007 | 62.4793 | 2844 | 51.6850 | 23 | 5.9518 | 0.6076 | 0.0258 |
| 2008 | 116.7894 | 3852 | 102.9915 | 26 | 8.7102 | 0.9115 | 0.0239 |
| 2009 | 91.7065 | 3148 | 79.7460 | 23 | 8.3442 | 0.8407 | 0.0251 |
| 2010 | 61.9744 | 3078 | 52.4480 | 24 | 5.3200 | 0.5361 | 0.0255 |
| 2011 | 74.8052 | 3428 | 57.4000 | 22 | 5.2685 | 0.5607 | 0.0247 |
| 2012 | 67.1300 | 3387 | 56.5785 | 22 | 5.3487 | 0.5529 | 0.0246 |
| 2013 | 63.4930 | 2685 | 48.9130 | 23 | 5.6624 | 0.5811 | 0.0261 |
| 2014 | 46.5936 | 2648 | 35.4220 | 23 | 3.8079 | 0.4330 | 0.0263 |
| 2015 | 73.5552 | 2800 | 54.7662 | 29 | 5.6939 | 0.5497 | 0.0260 |

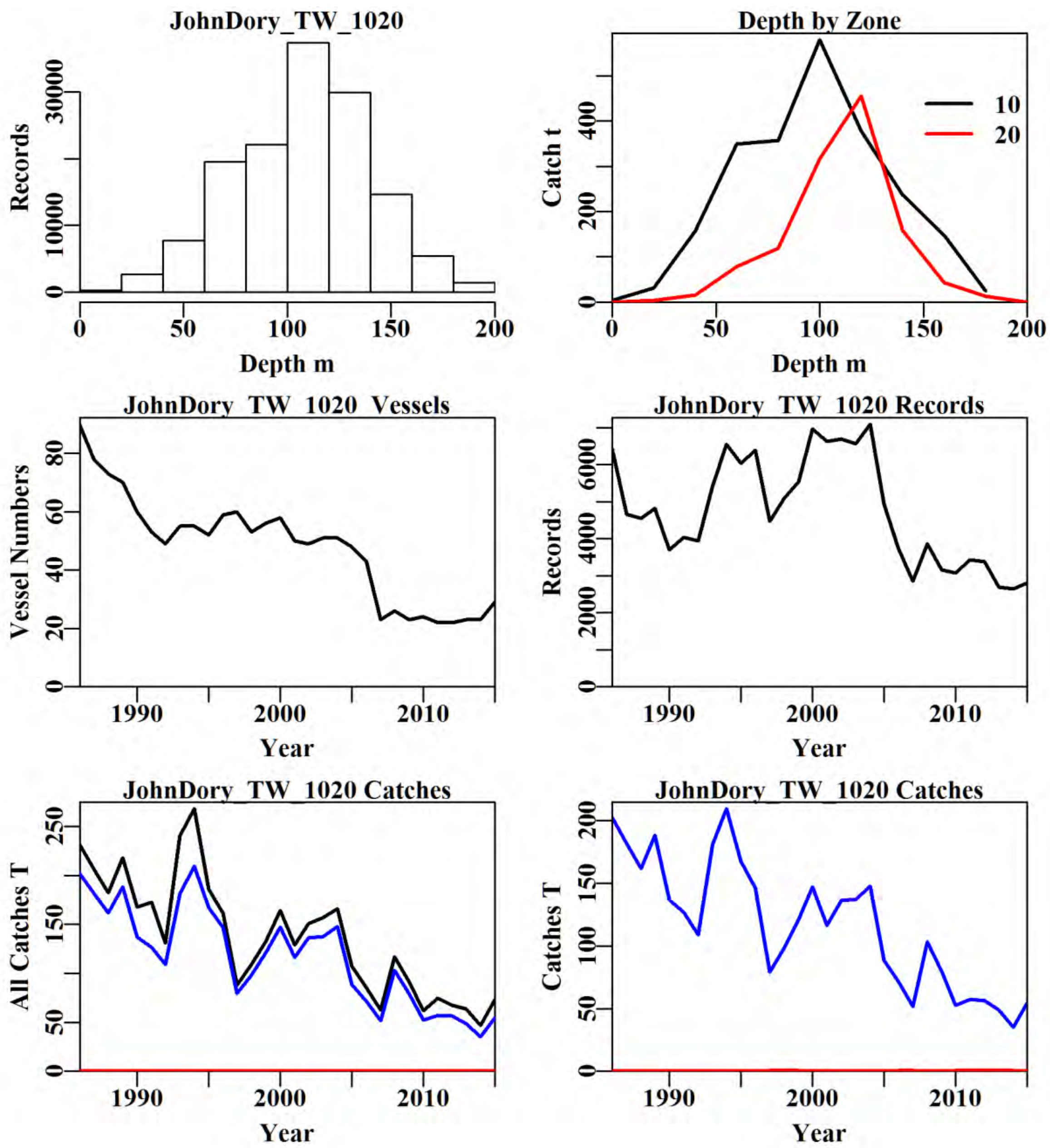



Figure 8.105. John Dory from Zones 10 and 20 in depths 0 to 200 m by Trawl. The top left plot depicts the depth distribution of shots containing John Dory zones 10 and 20 in depths 0 to 200 m by Trawl. The top right plot depicts the catch distribution by depth by zone. The middle left plot depicts the number of vessels through time and middle right plot contains the number of records used in analysis. The bottom left plot contains John Dory catches (top black line: total catches, middle blue line: catches used in the analysis; bottom red line: catches < 30 kg) and bottom right plot contains John Dory catches (blue line: catches used in the analysis; red line: catches < 30 kg).

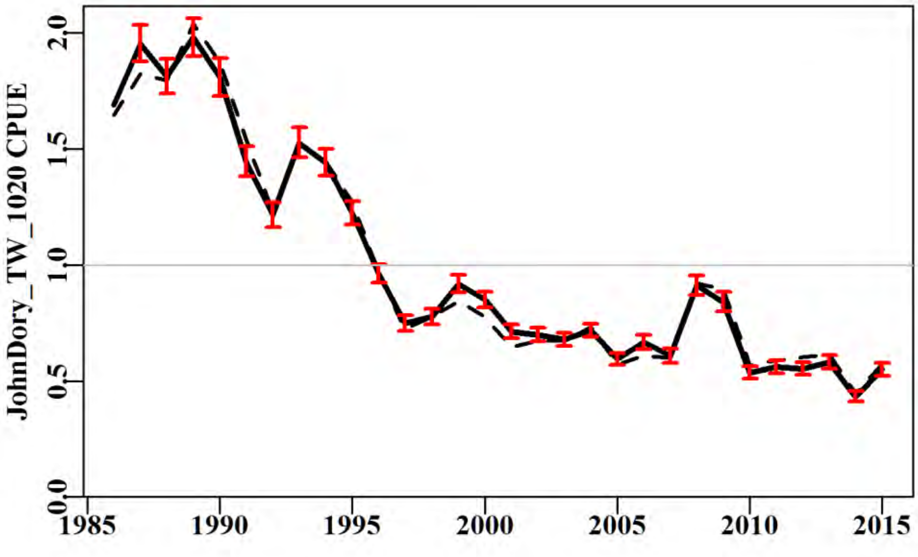



Figure 8.106. John Dory from Zones 10 and 20 in depths 0 to 200 m by Trawl. The graph standardizes catch rates relative to the mean of the standardized catch rates. Standardized catch rates (solid black line), 95% CI (vertical lines) and geometric mean (dashed black line).

Table 8.98. John Dory from Zones 10 and 20 in depths 0 to 200 m by Trawl. Statistical model structures used in this analysis. DepCat is a series of 20 metre depth categories.

| | |
|---|---|
| Model 1 | LnCE~Year |
| Model 2 | LnCE~Year+Vessel |
| Model 3 | LnCE~Year+Vessel+DepCat |
| Model 4 | LnCE~Year+Vessel+DepCat+DayNight |
| Model 5 | LnCE~Year+Vessel+DepCat+DayNight+Month |
| Model 6 | LnCE~Year+Vessel+DepCat+DayNight+Month+Zone |
| Model 7 | LnCE~Year+Vessel+DepCat+DayNight+Month+Zone+Zone:Month |
| Model 8 | LnCE~Year+Vessel+DepCat+DayNight+Month+Zone+Zone:DepCat |

Table 8.99. John Dory from Zones 10 and 20 in depths 0 to 200 m by Trawl. Model selection criteria include the Akaike Information Criterion (AIC), residual sum of squares (RSS), model sum of squares (MSS), number of usable observations (Nobs), number of parameters (Npars), adjusted $R^2$ (adj_$R^2$) and the change in adjusted $R^2$ (%Change). The optimum is Zone:DepC (Model 8). Depth category: DepC.

| | Year | Vessel | DepC | DayNight | Month | Zone | Zone:Month | Zone:DepC |
|---|---|---|---|---|---|---|---|---|
| AIC | 29433 | 13717 | 12008 | 9741 | 8559 | 8525 | 7842 | 7359 |
| RSS | 174729 | 156070 | 153004 | 150556 | 149275 | 149237 | 148493 | 147987 |
| MSS | 25911 | 44571 | 47636 | 50084 | 51366 | 51403 | 52148 | 52654 |
| Nobs | 142100 | 142100 | 140918 | 140918 | 140918 | 140918 | 140918 | 140918 |
| Npars | 30 | 196 | 206 | 209 | 220 | 221 | 232 | 231 |
| adj_$R^2$ | 12.897 | 22.107 | 23.631 | 24.851 | 25.485 | 25.503 | 25.869 | 26.122 |
| %Change | 0.000 | 9.211 | 1.524 | 1.220 | 0.634 | 0.018 | 0.366 | 0.253 |

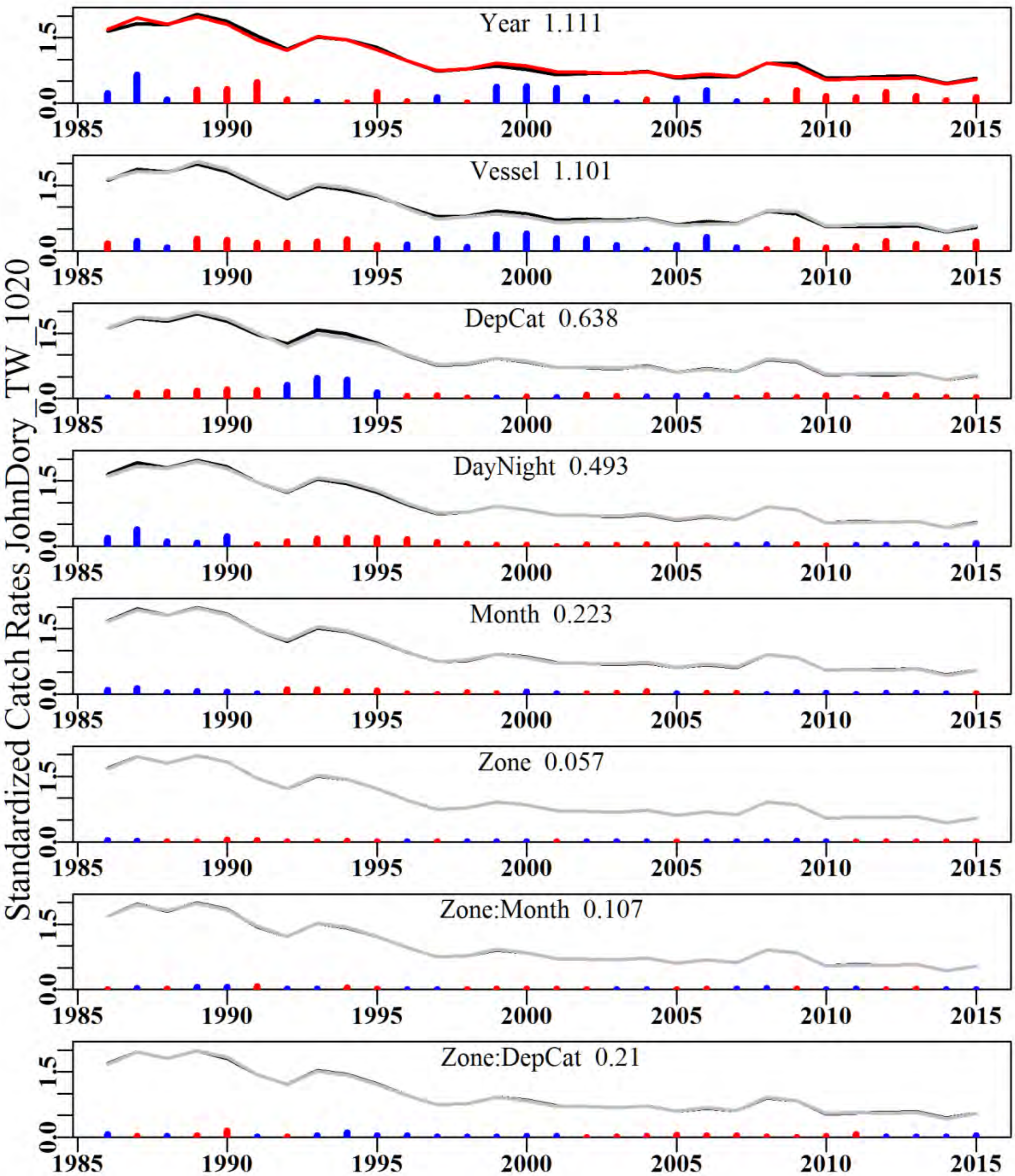



Figure 8.107. The relative influence of each factor used on the final trend in the optimal standardization for John Dory from zones 10 and 20. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by the vertical bars with blue bars indicating the optimum model is higher than the geometric mean and red bars indicating it is lower. The top graph bars are the sum of all the bars in the graphs below. The graphs for individual factors are cumulative. Thus the second graph has the geometric mean (grey line) and the effect of adding Year + factor2 (Model 2). In the third graph, the grey line represents Model 2 and the black line the effect of adding factor3 to the model. The remaining graphs continue in the same cumulative manner except for the interaction terms which are added singularly to the final single factor model.

#### 8.4.35 *Mirror Dory Z10-50 (DOM – 37264003 – Zenopsis nebulosus)*

Trawl data corresponding to zones 10 to 50 in depths 0 – 600 m and all vessels reporting Mirror Dory were analysed.

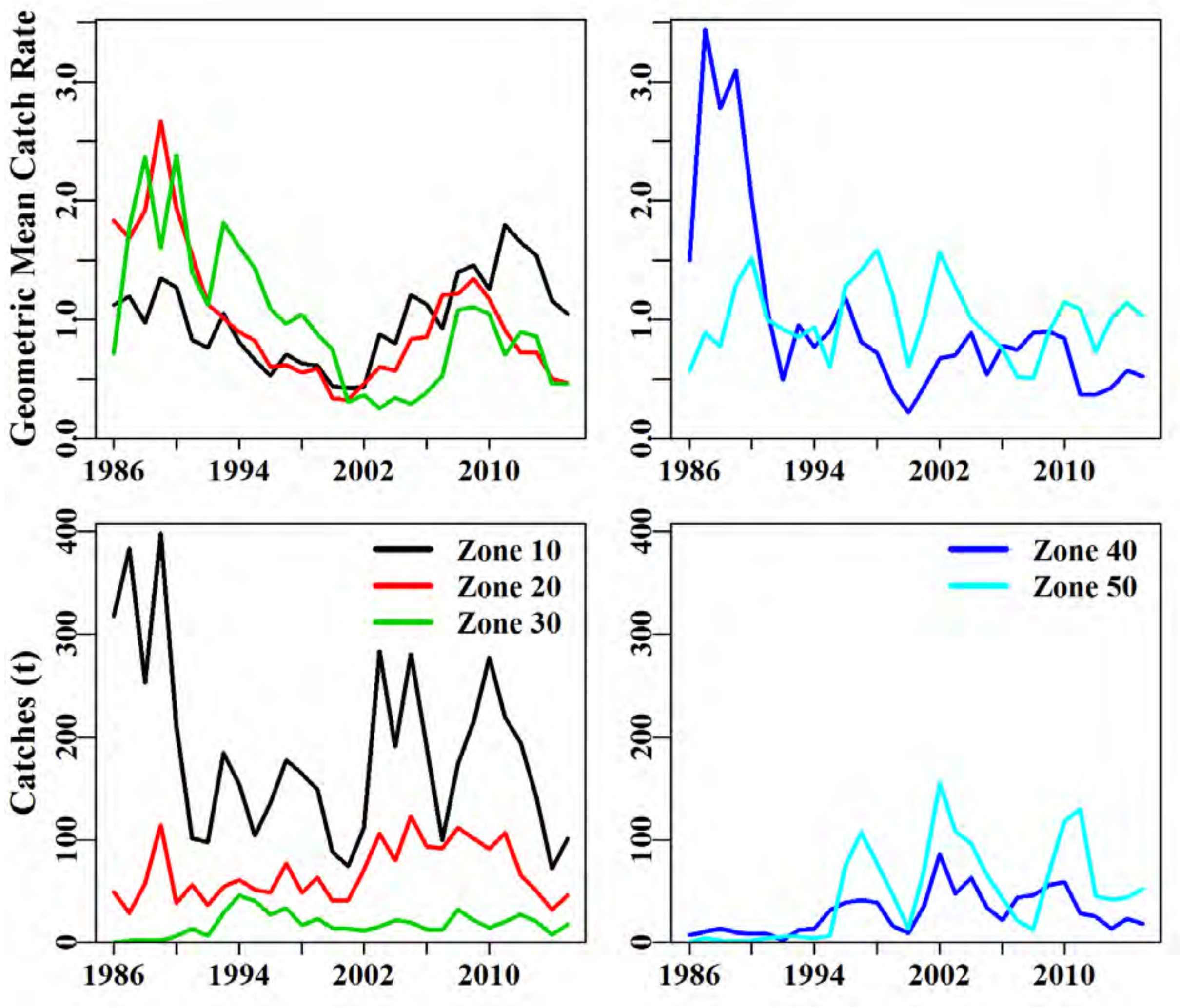



Figure 8.108. The catches and geometric mean catch rates from 1986 – 2012 for Mirror Dory split between east (zones 10 -30) and west (zones 40 and 50). The general trends in catch rates, in periods of significant catches, are similar across zones within the east and west. This implies that the assumption that there are no Year x Zone interactions is valid.

Table 8.100. Mirror Dory from zones 10 to 50 in depths 0 to 600 m by Trawl. Total catch (TotCatch; t) is the total reported in the database, number of records used in the analysis (Records), reported catch (CatchT; t) in the area and depth used in the analysis and number of vessels used in the analysis (Vessels). GeoMean is the geometric mean of catch rates (kg/hr). The optimum model is Zone:Month and standard deviation (StDev) relates to the data in the optimum model.

| Year | TotCatch | Records | CatchT | Vessels | GeoMean | Zone:Month | StDev |
|---|---|---|---|---|---|---|---|
| 1986 | 402.0480 | 3198 | 375.3350 | 91 | 39.2923 | 1.2628 | 0.0000 |
| 1987 | 450.7660 | 3103 | 429.0900 | 92 | 40.5389 | 1.3563 | 0.0310 |
| 1988 | 346.0140 | 3189 | 328.2200 | 88 | 33.8322 | 1.2321 | 0.0310 |
| 1989 | 591.6310 | 3068 | 524.8630 | 84 | 54.1685 | 1.5189 | 0.0315 |
| 1990 | 295.7640 | 1906 | 264.3460 | 73 | 36.4669 | 1.4181 | 0.0362 |
| 1991 | 240.3130 | 2229 | 183.6870 | 77 | 26.1034 | 1.1876 | 0.0348 |
| 1992 | 166.9803 | 2245 | 149.2240 | 72 | 21.6080 | 1.0305 | 0.0349 |
| 1993 | 306.2200 | 3289 | 285.1910 | 72 | 30.8083 | 1.1148 | 0.0318 |
| 1994 | 297.2680 | 3826 | 280.1780 | 70 | 24.7710 | 1.0037 | 0.0310 |
| 1995 | 244.9240 | 4207 | 234.4100 | 69 | 20.4951 | 0.9274 | 0.0305 |
| 1996 | 352.7220 | 5831 | 327.3160 | 84 | 18.6495 | 0.8969 | 0.0291 |
| 1997 | 459.6263 | 6681 | 436.4460 | 80 | 21.1399 | 0.9536 | 0.0288 |
| 1998 | 355.7935 | 5572 | 346.7060 | 68 | 21.7227 | 0.8579 | 0.0294 |
| 1999 | 309.4810 | 5543 | 298.1670 | 74 | 18.7583 | 0.6994 | 0.0296 |
| 2000 | 171.0664 | 5581 | 165.1355 | 79 | 10.6637 | 0.4960 | 0.0298 |
| 2001 | 243.3623 | 7013 | 235.1330 | 74 | 11.9013 | 0.5812 | 0.0292 |
| 2002 | 449.5550 | 8204 | 435.3746 | 69 | 18.8684 | 0.7799 | 0.0287 |
| 2003 | 613.8621 | 7797 | 560.9170 | 71 | 27.0358 | 0.9415 | 0.0287 |
| 2004 | 507.3770 | 6484 | 452.6005 | 69 | 24.2230 | 0.9012 | 0.0295 |
| 2005 | 579.8856 | 6190 | 523.8135 | 66 | 28.8815 | 1.0015 | 0.0296 |
| 2006 | 419.5564 | 4293 | 363.0748 | 54 | 29.0772 | 0.9839 | 0.0312 |
| 2007 | 289.6026 | 3400 | 268.1030 | 33 | 26.0002 | 0.9458 | 0.0329 |
| 2008 | 396.2424 | 3377 | 376.3640 | 34 | 37.5237 | 1.1347 | 0.0329 |
| 2009 | 476.5154 | 3567 | 461.7812 | 32 | 38.8778 | 1.2461 | 0.0326 |
| 2010 | 579.9761 | 3702 | 561.2296 | 32 | 46.7110 | 1.1935 | 0.0325 |
| 2011 | 514.5297 | 3921 | 506.2050 | 33 | 41.2284 | 1.1030 | 0.0321 |
| 2012 | 365.4882 | 2757 | 357.9945 | 33 | 41.9667 | 0.7959 | 0.0344 |
| 2013 | 279.8848 | 2172 | 261.8533 | 32 | 45.7026 | 0.9058 | 0.0362 |
| 2014 | 189.9533 | 1601 | 131.9813 | 29 | 31.2560 | 0.7435 | 0.0393 |
| 2015 | 240.3220 | 1463 | 147.1550 | 28 | 39.9183 | 0.7865 | 0.0410 |

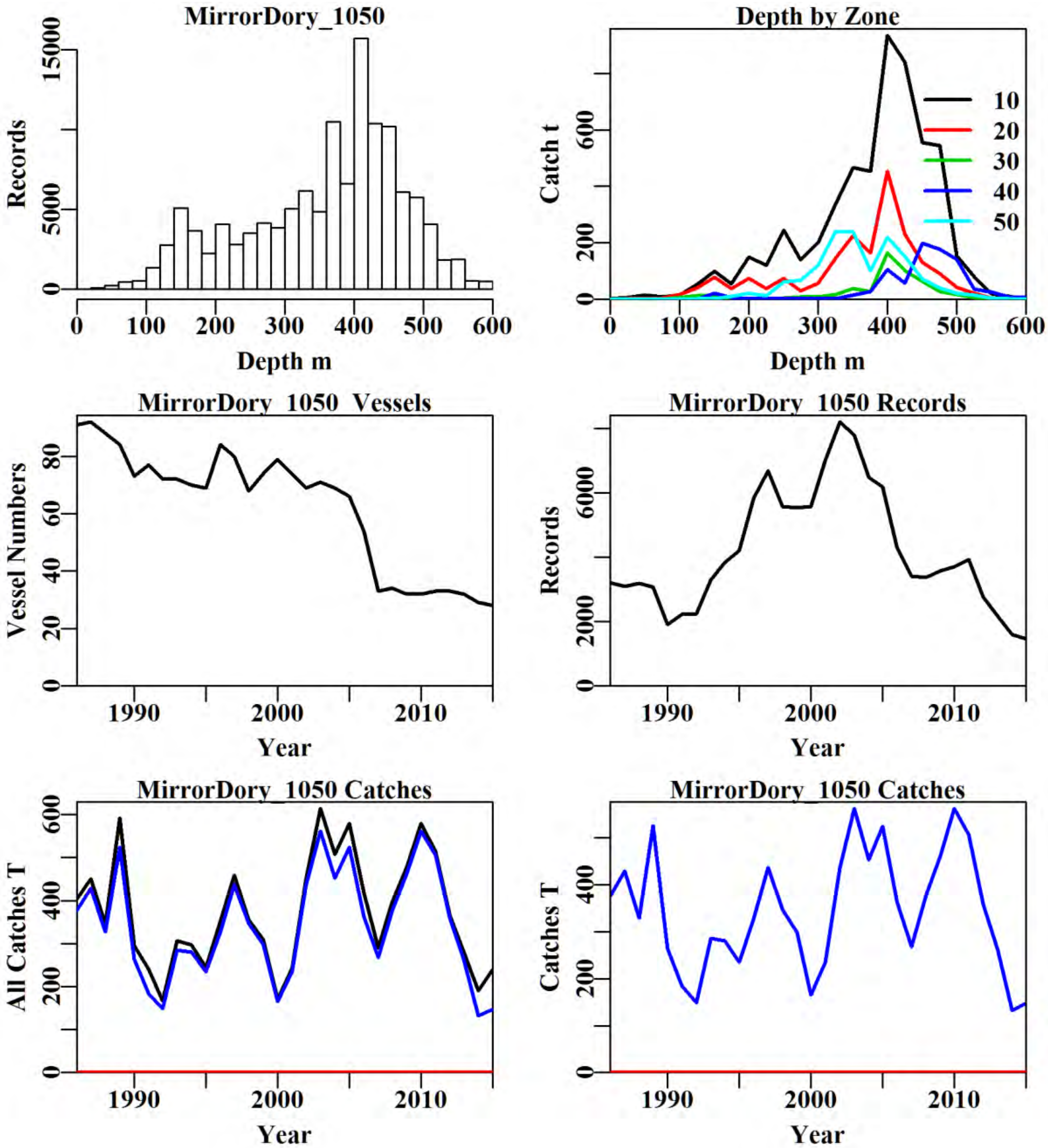



Figure 8.109. Mirror Dory from zones 10 to 50 in depths 0 to 600 m by Trawl. The top left plot depicts the depth distribution of shots containing Mirror Dory zones 10 to 50 in depths 0 to 600 m by Trawl. The top right plot depicts the catch distribution by depth by zone. The middle left plot depicts the number of vessels through time and middle right plot contains the number of records used in analysis. The bottom left plot contains Mirror Dory catches (top black line: total catches, middle blue line: catches used in the analysis; bottom red line: catches < 30 kg) and bottom right plot contains Mirror Dory catches (blue line: catches used in the analysis; red line: catches < 30 kg).

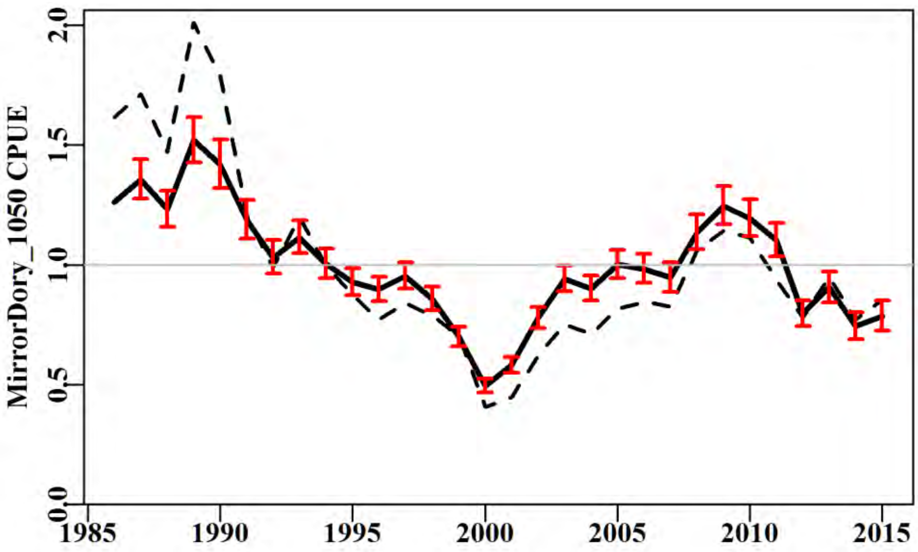



Figure 8.110. Mirror Dory from Zones 10 to 50 in depths 0 to 600 m by Trawl. The graph standardizes catch rates relative to the mean of the standardized catch rates. Standardized catch rates (solid black line), 95% CI (vertical lines) and geometric mean (dashed black line).

Table 8.101. Mirror Dory from zones 10 to 50 in depths 0 to 600 m by Trawl. Statistical model structures used in this analysis. DepCat is a series of 20 metre depth categories.

| | |
|---|---|
| Model 1 | LnCE~Year |
| Model 2 | LnCE~Year+Vessel |
| Model 3 | LnCE~Year+Vessel+Month |
| Model 4 | LnCE~Year+Vessel+Month+DepCat |
| Model 5 | LnCE~Year+Vessel+Month+DepCat+DayNight |
| Model 6 | LnCE~Year+Vessel+Month+DepCat+DayNight+Zone |
| Model 7 | LnCE~Year+Vessel+Month+DepCat+DayNight+Zone+Zone:Month |
| Model 8 | LnCE~Year+Vessel+Month+DepCat+DayNight+Zone+Zone:DepCat |

Table 8.102. Mirror Dory from zones 10 to 50 in depths 0 to 600 m by Trawl. Model selection criteria include the Akaike Information Criterion (AIC), residual sum of squares (RSS), model sum of squares (MSS), number of usable observations (Nobs), number of parameters (Npars), adjusted $R^2$ (adj_$R^2$) and the change in adjusted $R^2$ (%Change). The optimum is Zone:Month (Model 7). Depth category: DepC.

| | Year | Vessel | DepC | Month | DayNight | Zone | Zone:Month | Zone:DepC |
|---|---|---|---|---|---|---|---|---|
| AIC | 80759 | 58249 | 56393 | 45062 | 43609 | 42712 | 38112 | 41706 |
| RSS | 238667 | 198801 | 195847 | 178224 | 176152 | 174877 | 168427 | 173205 |
| MSS | 16132 | 55998 | 58952 | 76575 | 78647 | 79922 | 86373 | 81594 |
| Nobs | 125409 | 125409 | 125409 | 124719 | 124719 | 124719 | 124719 | 124719 |
| Npars | 30 | 235 | 246 | 270 | 273 | 277 | 321 | 373 |
| adj_$R^2$ | 6.310 | 21.831 | 22.986 | 29.902 | 30.715 | 31.214 | 33.728 | 31.819 |
| %Change | 0.000 | 15.522 | 1.155 | 6.916 | 0.813 | 0.499 | 2.514 | -1.909 |

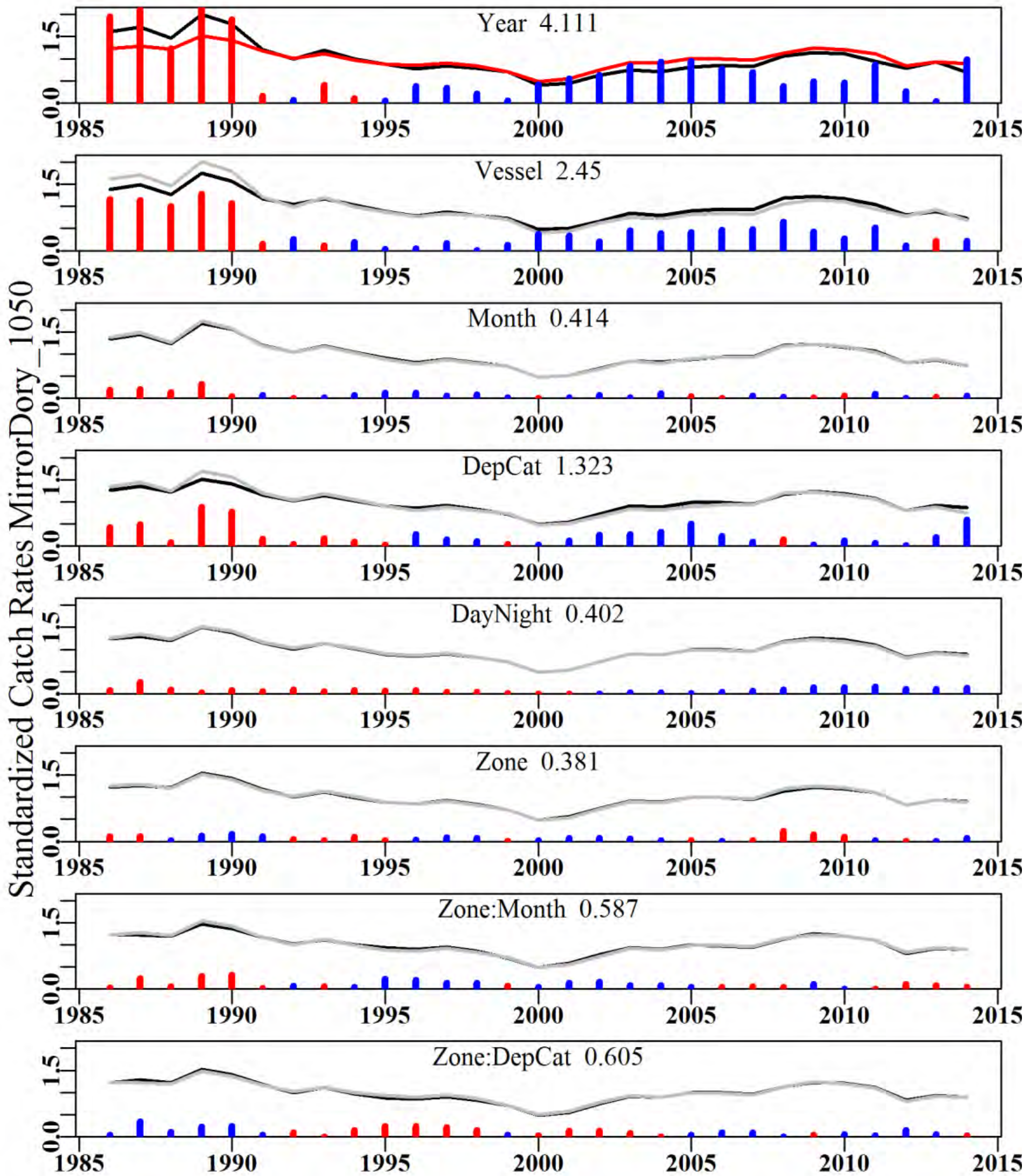



Figure 8.111. The relative influence of each factor used on the final trend in the optimal standardization for Mirror Dory from zones 10 to 50. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by the vertical bars with blue bars indicating the optimum model is higher than the geometric mean and red bars indicating it is lower. The top graph bars are the sum of all the bars in the graphs below. The graphs for individual factors are cumulative. Thus the second graph has the geometric mean (grey line) and the effect of adding Year + factor2 (Model 2). In the third graph, the grey line represents Model 2 and the black line the effect of adding factor3 to the model. The remaining graphs continue in the same cumulative manner except for the interaction terms which are added singularly to the final single factor model.

### 8.4.36 *Mirror Dory East (DOM – 37264003 – Zenopsis nebulosus)*

Trawl data selected for analysis corresponded to records from zones 10 to 30 in depths 0 – 600 m and all vessels reporting Mirror Dory.

Table 8.103. Mirror Dory from Zones 10 to 30 in depths 0 to 600 m by Trawl. Total catch (TotCatch; t) is the total reported in the database, number of records used in the analysis (Records), reported catch (CatchT; t) in the area and depth used in the analysis and number of vessels used in the analysis (Vessels). GeoMean is the geometric mean of catch rates (kg/hr). The optimum model is Zone:Month and standard deviation (StDev) relates to the data in the optimum model.

| Year | TotCatch | Records | CatchT | Vessels | GeoMean | Zone:Month | StDev |
|---|---|---|---|---|---|---|---|
| 1986 | 402.0480 | 3140 | 367.9350 | 80 | 39.3096 | 1.1963 | 0.0000 |
| 1987 | 450.7660 | 2961 | 413.5710 | 70 | 40.7350 | 1.2945 | 0.0324 |
| 1988 | 346.0140 | 3067 | 313.2370 | 77 | 33.7080 | 1.1718 | 0.0323 |
| 1989 | 591.6310 | 2997 | 513.7360 | 70 | 54.4064 | 1.4137 | 0.0328 |
| 1990 | 295.7640 | 1811 | 254.3800 | 61 | 36.4032 | 1.3418 | 0.0378 |
| 1991 | 240.3130 | 2020 | 170.9040 | 68 | 27.1227 | 1.1572 | 0.0372 |
| 1992 | 166.9803 | 2039 | 140.9250 | 57 | 22.3554 | 1.0060 | 0.0371 |
| 1993 | 306.2200 | 3012 | 267.0610 | 62 | 32.4231 | 1.0875 | 0.0337 |
| 1994 | 297.2680 | 3496 | 262.0160 | 62 | 25.9551 | 0.9607 | 0.0328 |
| 1995 | 244.9240 | 3498 | 196.2670 | 58 | 21.7028 | 0.8703 | 0.0327 |
| 1996 | 352.7220 | 4393 | 212.1710 | 69 | 16.7077 | 0.7656 | 0.0315 |
| 1997 | 459.6263 | 4775 | 288.1360 | 65 | 19.4994 | 0.8116 | 0.0314 |
| 1998 | 355.7935 | 4103 | 230.4950 | 55 | 19.4367 | 0.7302 | 0.0319 |
| 1999 | 309.4810 | 4225 | 234.8730 | 59 | 19.2731 | 0.6485 | 0.0321 |
| 2000 | 171.0664 | 4601 | 142.6745 | 63 | 11.3498 | 0.5081 | 0.0320 |
| 2001 | 243.3623 | 4544 | 128.9480 | 54 | 10.0086 | 0.5074 | 0.0323 |
| 2002 | 449.5550 | 5041 | 194.5926 | 53 | 14.0316 | 0.6385 | 0.0318 |
| 2003 | 613.8621 | 5363 | 405.7085 | 58 | 29.9382 | 0.9328 | 0.0313 |
| 2004 | 507.3770 | 4274 | 292.6610 | 57 | 25.8699 | 0.8851 | 0.0326 |
| 2005 | 579.8856 | 4417 | 423.6310 | 55 | 37.1607 | 1.1323 | 0.0324 |
| 2006 | 419.5564 | 3230 | 297.5593 | 44 | 35.2650 | 1.1329 | 0.0342 |
| 2007 | 289.6026 | 2223 | 203.1620 | 22 | 33.8239 | 1.2242 | 0.0375 |
| 2008 | 396.2424 | 2495 | 317.7050 | 26 | 47.8049 | 1.3596 | 0.0369 |
| 2009 | 476.5154 | 2232 | 338.4877 | 27 | 55.3346 | 1.4319 | 0.0378 |
| 2010 | 579.9761 | 2105 | 383.4800 | 25 | 70.8452 | 1.1972 | 0.0382 |
| 2011 | 514.5297 | 2254 | 347.0670 | 26 | 64.2791 | 1.1995 | 0.0377 |
| 2012 | 365.4882 | 1739 | 287.7780 | 24 | 67.2055 | 0.9408 | 0.0403 |
| 2013 | 279.8848 | 1569 | 207.8363 | 24 | 59.1746 | 0.9742 | 0.0413 |
| 2014 | 189.9533 | 1084 | 83.9653 | 23 | 35.4959 | 0.7039 | 0.0461 |
| 2015 | 240.3220 | 954 | 107.1480 | 24 | 59.8964 | 0.7759 | 0.0492 |

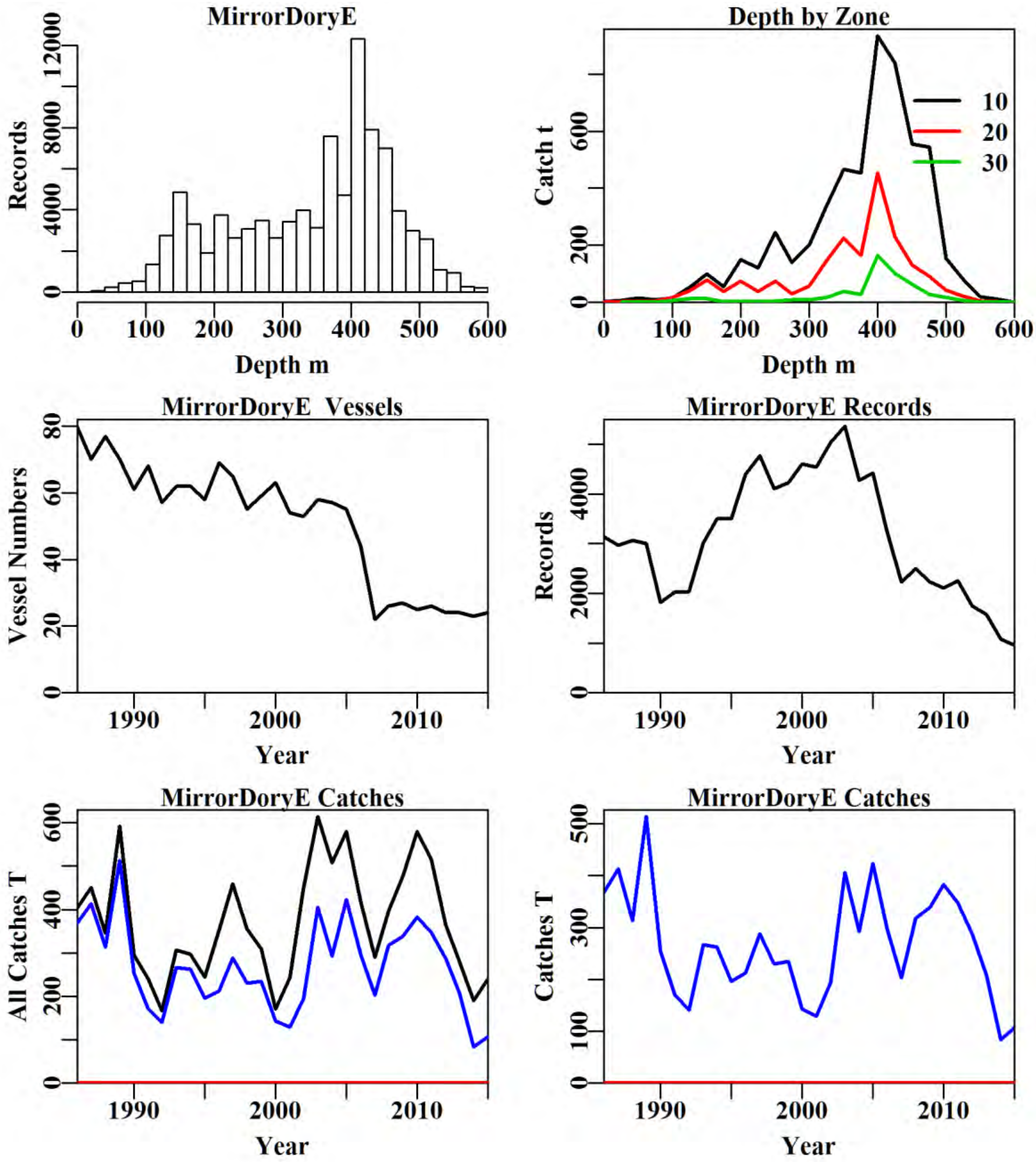



Figure 8.112. Mirror Dory from zones 10 to 30 in depths 0 to 600 m by Trawl. The top left plot depicts the depth distribution of shots containing Mirror Dory zones 10 to 30 in depths 0 to 600 m by Trawl. The top right plot depicts the catch distribution by depth by zone. The middle left plot depicts the number of vessels through time and middle right plot contains the number of records used in analysis. The bottom left plot contains Mirror Dory catches (top black line: total catches, middle blue line: catches used in the analysis; bottom red line: catches < 30 kg) and bottom right plot contains Mirror Dory catches (blue line: catches used in the analysis; red line: catches < 30 kg).

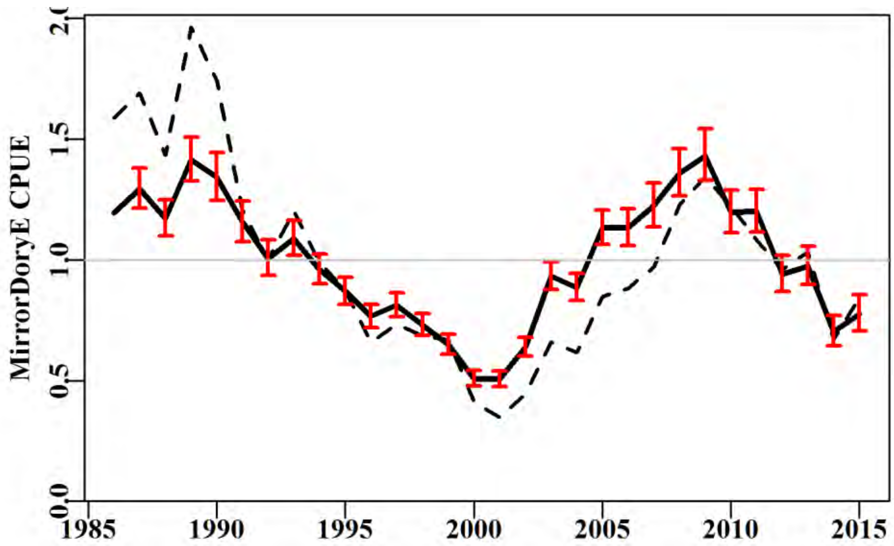



Figure 8.113. Mirror Dory from Zones 10 to 30 in depths 0 to 600 m by Trawl. The dashed black line represents the geometric mean catch rate, solid black line the standardized catch rates and solid blue line the standardized catch rates from last year's analysis. The graph standardizes catch rates relative to the mean of the standardized catch rates.

Table 8.104. Mirror Dory from Zones 10 to 30 in depths 0 to 600 m by Trawl. Statistical model structures used in this analysis. DepCat is a series of 20 metre depth categories.

| | |
|---|---|
| Model 1 | LnCE~Year |
| Model 2 | LnCE~Year+Vessel |
| Model 3 | LnCE~Year+Vessel+DepCat |
| Model 4 | LnCE~Year+Vessel+DepCat+Month |
| Model 5 | LnCE~Year+Vessel+DepCat+Month+DayNight |
| Model 6 | LnCE~Year+Vessel+DepCat+Month+DayNight+Zone |
| Model 7 | LnCE~Year+Vessel+DepCat+Month+DayNight+Zone+Zone:Month |
| Model 8 | LnCE~Year+Vessel+DepCat+Month+DayNight+Zone+Zone:DepCat |

Table 8.105. Mirror Dory from zones 10 to 30 in depths 0 to 600 m by Trawl. Model selection criteria include the Akaike Information Criterion (AIC), residual sum of squares (RSS), model sum of squares (MSS), number of usable observations (Nobs), number of parameters (Npars), adjusted $R^2$ (adj_$R^2$) and the change in adjusted $R^2$ (%Change). The optimum is Zone:Month (Model 7). Depth category: DepC.

| | Year | Vessel | DepC | Month | DayNight | Zone | Zone:Month | Zone:DepC |
|---|---|---|---|---|---|---|---|---|
| AIC | 66003 | 49268 | 38672 | 36812 | 36145 | 35361 | 33780 | 34978 |
| RSS | 189378 | 157794 | 140397 | 137589 | 136598 | 135448 | 133105 | 134753 |
| MSS | 18447 | 50031 | 67428 | 70236 | 71227 | 72377 | 74720 | 73072 |
| Nobs | 93662 | 93662 | 93160 | 93160 | 93160 | 93160 | 93160 | 93160 |
| Npars | 30 | 207 | 231 | 242 | 245 | 247 | 269 | 295 |
| adj_$R^2$ | 8.848 | 23.906 | 32.277 | 33.624 | 34.100 | 34.654 | 35.768 | 34.955 |
| %Change | 0.000 | 15.059 | 8.371 | 1.347 | 0.476 | 0.554 | 1.115 | -0.813 |

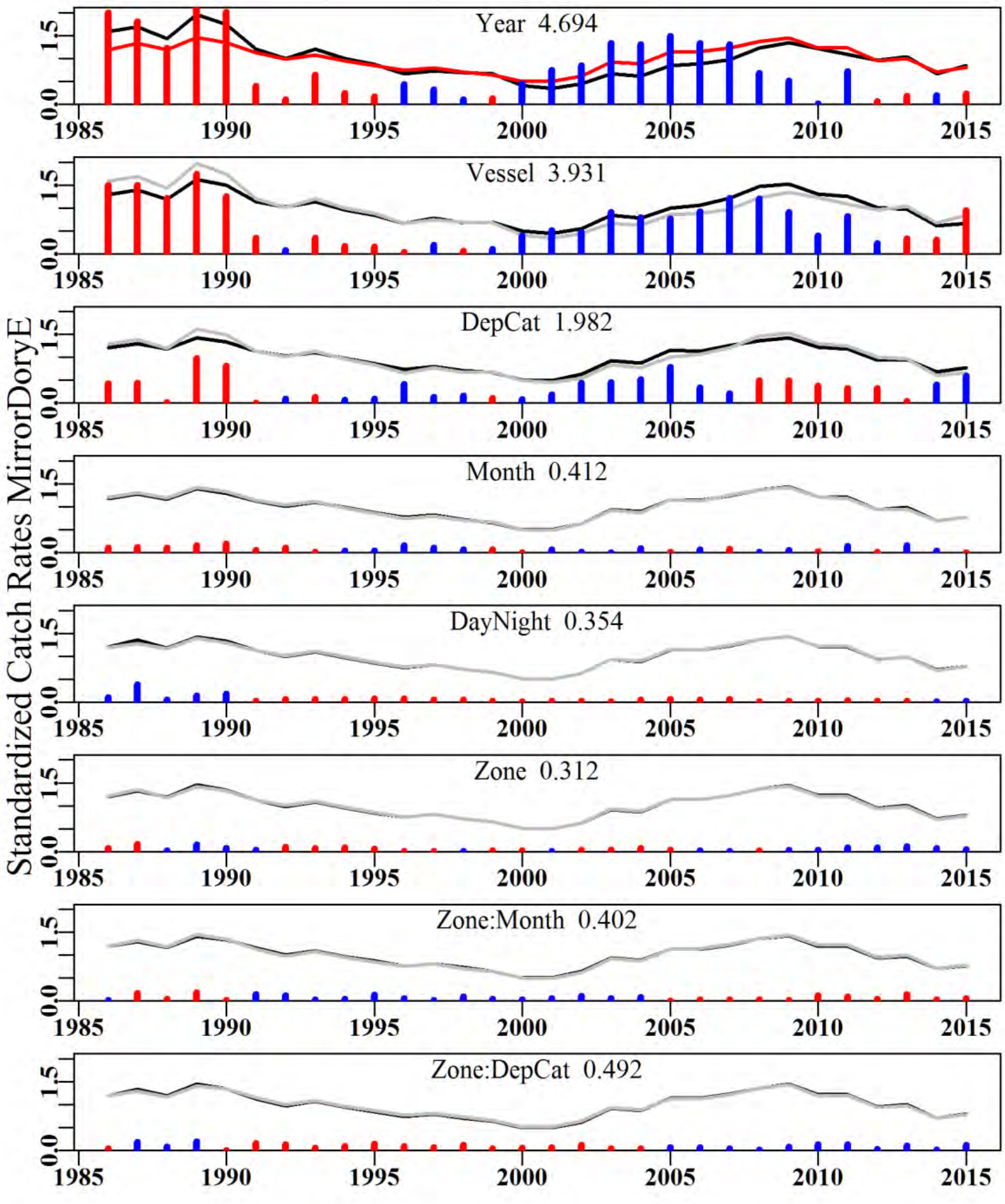



Figure 8.114. The relative influence of each factor used on the final trend in the optimal standardization for Mirror Dory from zones 10 to 30. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by the vertical bars with blue bars indicating the optimum model is higher than the geometric mean and red bars indicating it is lower. The top graph bars are the sum of all the bars in the graphs below. The graphs for individual factors are cumulative. Thus the second graph has the geometric mean (grey line) and the effect of adding Year + factor2 (Model 2). In the third graph, the grey line represents Model 2 and the black line the effect of adding factor3 to the model. The remaining graphs continue in the same cumulative manner except for the interaction terms which are added singularly to the final single factor model.

### 8.4.37 *Mirror Dory West (DOM – 37264003 – Zenopsis nebulosus)*

Trawl data selected for analysis corresponded to records from zones 40 and 50 in depths 0 – 600 m and all vessels reporting Mirror Dory.

Table 8.106. Mirror Dory from Zones 40 to 50 in depths 0 to 600 m by Trawl. Total catch (TotCatch; t) is the total reported in the database, number of records used in the analysis (Records), reported catch (CatchT; t) in the area and depth used in the analysis and number of vessels used in the analysis (Vessels). GeoMean is the geometric mean of catch rates (kg/hr). The optimum model is Zone:Month and standard deviation (StDev) relates to the data in the optimum model.

| Year | TotCatch | Records | CatchT | Vessels | GeoMean | Zone:Month | StDev |
|---|---|---|---|---|---|---|---|
| 1986 | 402.0480 | 57 | 7.3740 | 10 | 37.8926 | 2.4182 | 0.0000 |
| 1987 | 450.7660 | 142 | 15.5190 | 23 | 36.0604 | 1.6631 | 0.1876 |
| 1988 | 346.0140 | 122 | 14.9830 | 17 | 37.1811 | 1.3527 | 0.1981 |
| 1989 | 591.6310 | 71 | 11.1270 | 15 | 45.3237 | 1.6690 | 0.2099 |
| 1990 | 295.7640 | 95 | 9.9660 | 14 | 37.8770 | 1.1784 | 0.2141 |
| 1991 | 240.3130 | 209 | 12.7830 | 17 | 17.7768 | 0.8254 | 0.1861 |
| 1992 | 166.9803 | 205 | 8.2890 | 20 | 14.5194 | 0.6867 | 0.1880 |
| 1993 | 306.2200 | 276 | 18.0100 | 18 | 16.7714 | 0.7900 | 0.1835 |
| 1994 | 297.2680 | 330 | 18.1620 | 20 | 14.7748 | 0.7171 | 0.1815 |
| 1995 | 244.9240 | 709 | 38.1430 | 23 | 15.3638 | 0.9072 | 0.1781 |
| 1996 | 352.7220 | 1438 | 115.1450 | 26 | 23.4103 | 1.2887 | 0.1779 |
| 1997 | 459.6263 | 1906 | 148.3100 | 24 | 24.4653 | 1.3047 | 0.1775 |
| 1998 | 355.7935 | 1469 | 116.2110 | 20 | 27.5790 | 1.2403 | 0.1779 |
| 1999 | 309.4810 | 1318 | 63.2940 | 23 | 17.1138 | 0.7984 | 0.1781 |
| 2000 | 171.0664 | 980 | 22.4610 | 28 | 7.8627 | 0.4514 | 0.1790 |
| 2001 | 243.3623 | 2469 | 106.1850 | 29 | 14.1812 | 0.7926 | 0.1772 |
| 2002 | 449.5550 | 3158 | 240.4320 | 28 | 24.8208 | 1.1652 | 0.1769 |
| 2003 | 613.8621 | 2429 | 154.8985 | 27 | 20.6958 | 0.9774 | 0.1772 |
| 2004 | 507.3770 | 2208 | 159.8094 | 25 | 20.4507 | 0.9851 | 0.1774 |
| 2005 | 579.8856 | 1769 | 100.0055 | 23 | 15.1798 | 0.7727 | 0.1777 |
| 2006 | 419.5564 | 1061 | 65.3505 | 19 | 15.7843 | 0.6580 | 0.1789 |
| 2007 | 289.6026 | 1177 | 64.9410 | 16 | 14.4232 | 0.5877 | 0.1786 |
| 2008 | 396.2424 | 879 | 58.5330 | 17 | 16.1944 | 0.6699 | 0.1792 |
| 2009 | 476.5154 | 1333 | 123.2455 | 14 | 20.0140 | 1.0251 | 0.1780 |
| 2010 | 579.9761 | 1596 | 177.5496 | 14 | 26.4545 | 1.2380 | 0.1777 |
| 2011 | 514.5297 | 1662 | 157.8060 | 16 | 21.5957 | 0.9415 | 0.1777 |
| 2012 | 365.4882 | 1018 | 70.2165 | 15 | 16.6445 | 0.5561 | 0.1789 |
| 2013 | 279.8848 | 602 | 53.7610 | 15 | 22.1155 | 0.7475 | 0.1808 |
| 2014 | 189.9533 | 516 | 47.8960 | 10 | 22.8337 | 0.8163 | 0.1814 |
| 2015 | 240.3220 | 508 | 39.9920 | 10 | 18.7325 | 0.7759 | 0.1820 |

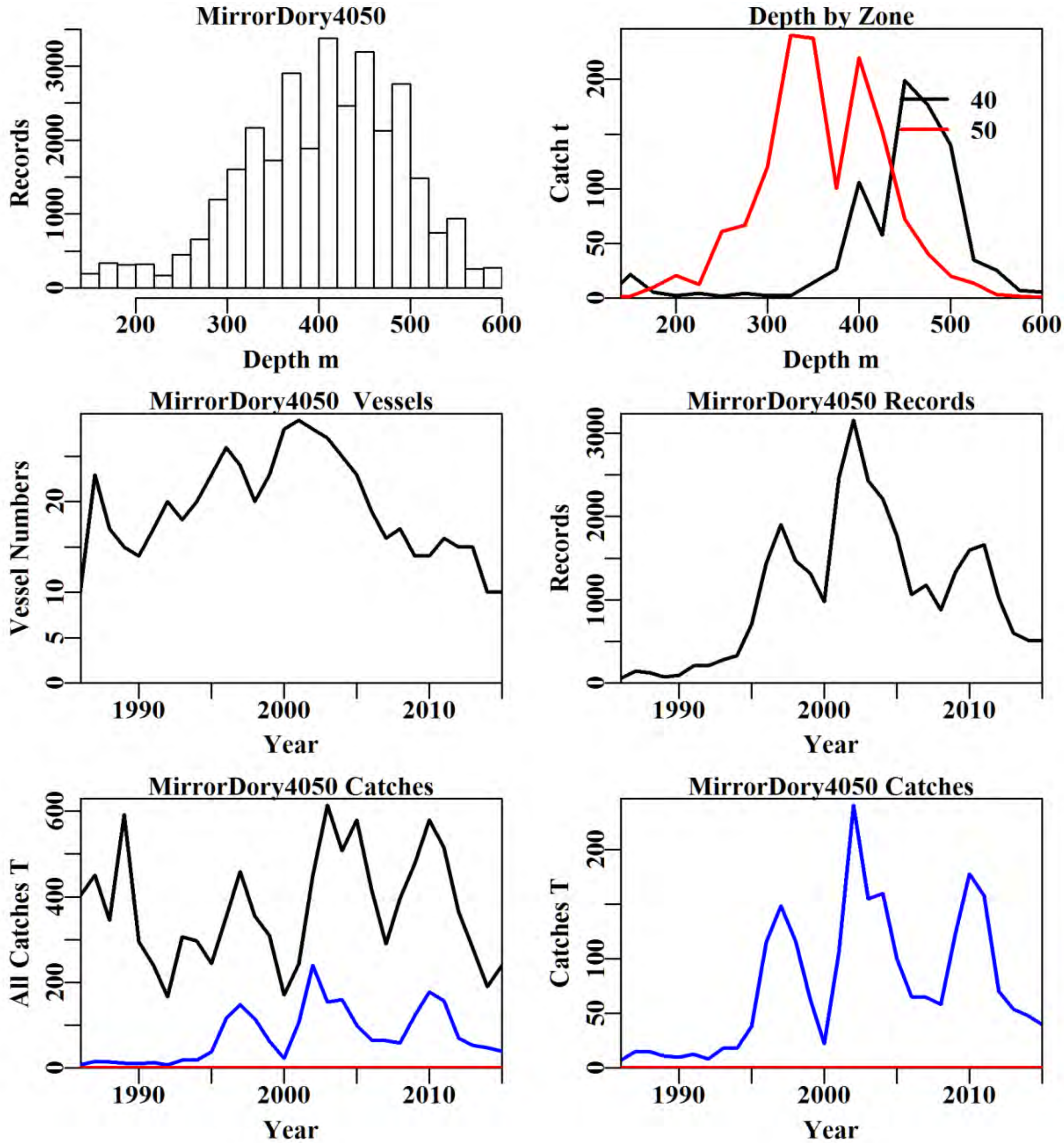



Figure 8.115. Mirror Dory from zones 40 to 50 in depths 0 to 600 m by Trawl. The top left plot depicts the depth distribution of shots containing Mirror Dory zones 40 to 50 in depths 0 to 600 m by Trawl. The top right plot depicts the catch distribution by depth by zone. The middle left plot depicts the number of vessels through time and middle right plot contains the number of records used in analysis. The bottom left plot contains Mirror Dory catches (top black line: total catches, middle blue line: catches used in the analysis; bottom red line: catches < 30 kg) and bottom right plot contains Mirror Dory catches (blue line: catches used in the analysis; red line: catches < 30 kg).

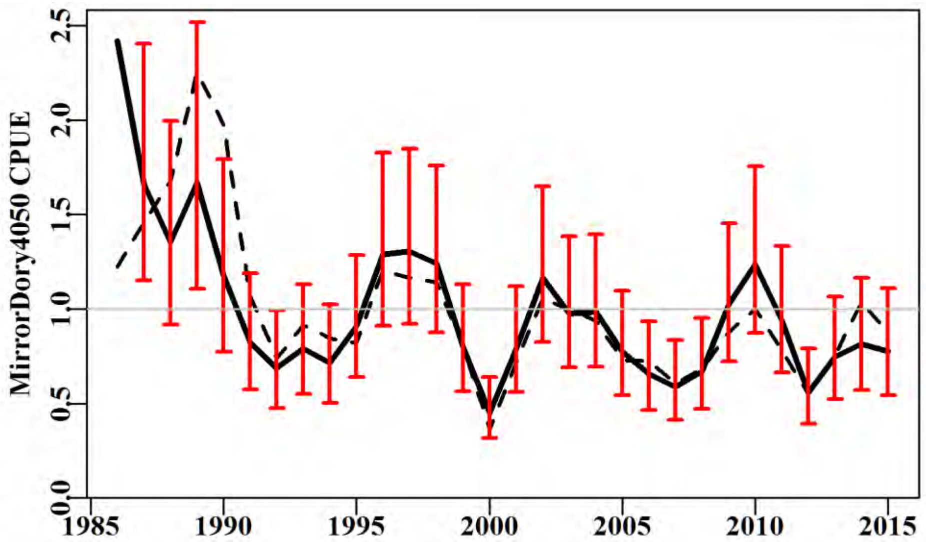



Figure 8.116. Mirror Dory from zones 40 to 50 in depths 0 to 600 m by Trawl. Standardized indices (solid black line), 95% CI (vertical lines) and geometric mean (dashed black line).

Table 8.107. Mirror Dory from Zones 40 to 50 in depths 0 to 600 m by Trawl. Statistical model structures used in this analysis. DepCat is a series of 20 metre depth categories.

| | |
|---|---|
| Model 1 | LnCE~Year |
| Model 2 | LnCE~Year+Vessel |
| Model 3 | LnCE~Year+Vessel+Month |
| Model 4 | LnCE~Year+Vessel+Month+DepCat |
| Model 5 | LnCE~Year+Vessel+Month+DepCat+DayNight |
| Model 6 | LnCE~Year+Vessel+Month+DepCat+DayNight+Zone |
| Model 7 | LnCE~Year+Vessel+Month+DepCat+DayNight+Zone+Zone:Month |
| Model 8 | LnCE~Year+Vessel+Month+DepCat+DayNight+Zone+Zone:DepCat |

Table 8.108. Mirror Dory from zones 40 to 50 in depths 0 to 600 m by Trawl. Model selection criteria include the Akaike Information Criterion (AIC), residual sum of squares (RSS), model sum of squares (MSS), number of usable observations (Nobs), number of parameters (Npars), adjusted $R^2$ (adj_$R^2$) and the change in adjusted $R^2$ (%Change). The optimum is Zone:Month (Model 7). Depth category: DepC.

| | Year | Vessel | Month | DepC | DayNight | Zone | Zone:Month | Zone:DepC |
|---|---|---|---|---|---|---|---|---|
| AIC | 10894 | 3940 | 2374 | 886 | -105 | -484 | -834 | -535 |
| RSS | 44626 | 35634 | 33894 | 32114 | 31114 | 30740 | 30379 | 30654 |
| MSS | 2260 | 11252 | 12993 | 14773 | 15773 | 16146 | 16508 | 16233 |
| Nobs | 31712 | 31712 | 31712 | 31524 | 31524 | 31524 | 31524 | 31524 |
| Npars | 30 | 121 | 132 | 151 | 154 | 155 | 166 | 174 |
| adj_$R^2$ | 4.733 | 23.710 | 27.411 | 31.180 | 33.316 | 34.115 | 34.866 | 34.261 |
| %Change | 0.000 | 18.977 | 3.701 | 3.769 | 2.136 | 0.799 | 0.751 | -0.606 |

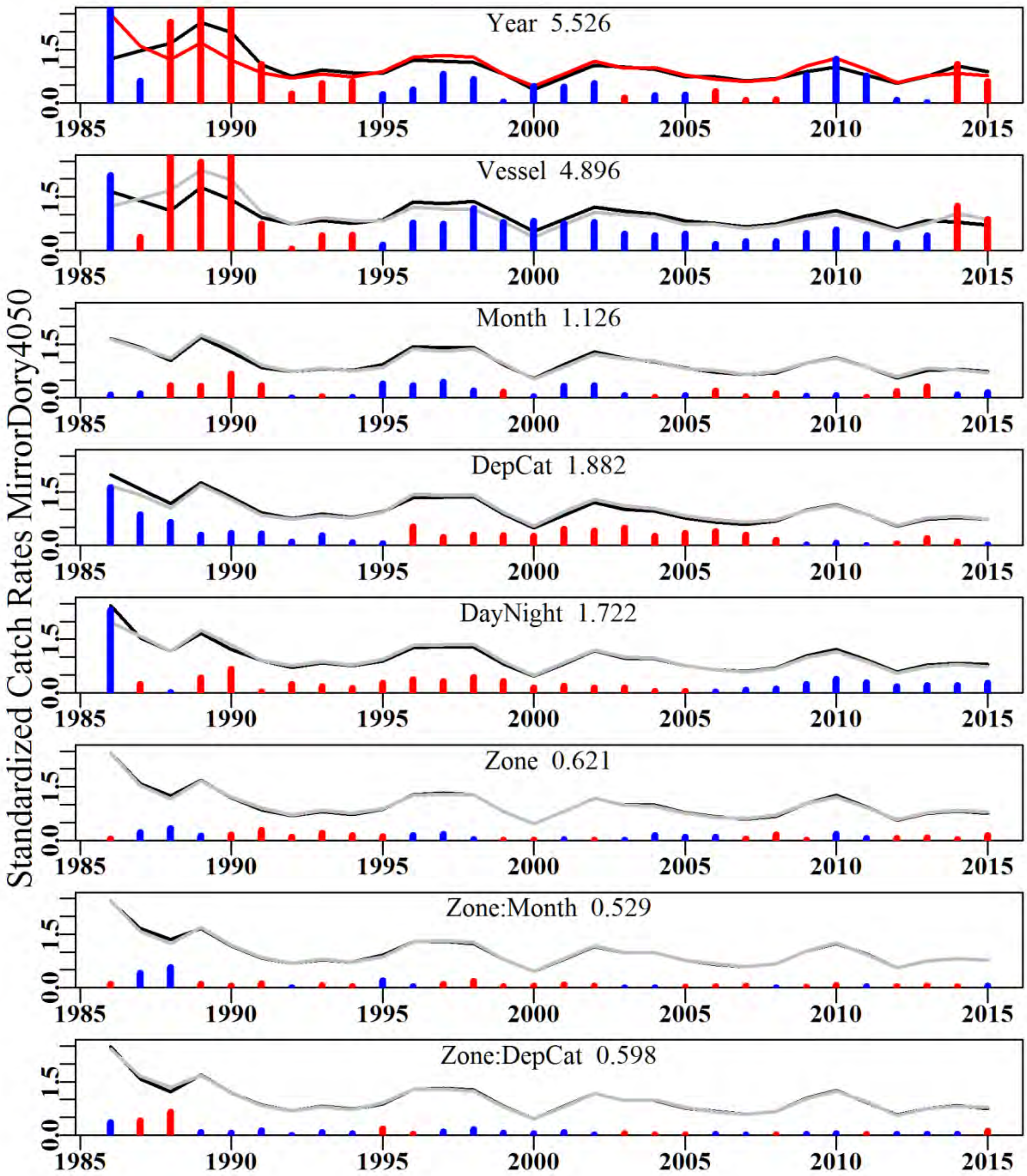



Figure 8.117. The relative influence of each factor used on the final trend in the optimal standardization for Mirror Dory from zones 40 – 50. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by the vertical bars with blue bars indicating the optimum model is higher than the geometric mean and red bars indicating it is lower. The top graph bars are the sum of all the bars in the graphs below. The graphs for individual factors are cumulative. Thus the second graph has the geometric mean (grey line) and the effect of adding Year + factor2 (Model 2). In the third graph, the grey line represents Model 2 and the black line the effect of adding factor3 to the model. The remaining graphs continue in the same cumulative manner except for the interaction terms which are added singularly to the final single factor model.

### 8.4.38 *Ribaldo Z10-50 (RBD – 37224002 – Mora moro)*

Trawl data corresponding to zones 10 to 50 in depths 0 – 1000 m were analysed.

Table 8.109. Ribaldo from zones 10 to 50 in depths 0 to 1000 m by Trawl. Total catch (TotCatch; t) is the total reported in the database, number of records used in the analysis (Records), reported catch (CatchT; t) in the area and depth used in the analysis and number of vessels used in the analysis (Vessels). GeoMean is the geometric mean of catch rates (kg/hr). The optimum model is Zone:Month and standard deviation (StDev) relates to the data in the optimum model.

| Year | TotCatch | Records | CatchT | Vessels | GeoMean | Zone:Month | StDev |
|---|---|---|---|---|---|---|---|
| 1986 | 4.1040 | 72 | 3.5240 | 11 | 14.6630 | 2.2732 | 0.0000 |
| 1987 | 7.9410 | 158 | 7.2920 | 14 | 10.2593 | 1.2769 | 0.1378 |
| 1988 | 10.8980 | 123 | 8.0490 | 22 | 16.5570 | 1.9794 | 0.1530 |
| 1989 | 11.3420 | 136 | 7.7110 | 14 | 18.2556 | 1.7824 | 0.1510 |
| 1990 | 3.6680 | 58 | 2.2590 | 11 | 8.9113 | 1.3914 | 0.1717 |
| 1991 | 7.8080 | 145 | 5.1620 | 22 | 7.9930 | 1.3958 | 0.1507 |
| 1992 | 13.3330 | 226 | 11.6890 | 26 | 9.7616 | 1.3904 | 0.1419 |
| 1993 | 22.7770 | 330 | 19.7620 | 37 | 11.2449 | 1.1616 | 0.1419 |
| 1994 | 41.9380 | 423 | 23.6220 | 30 | 11.8156 | 1.2821 | 0.1395 |
| 1995 | 90.3230 | 1147 | 86.2990 | 26 | 12.3128 | 1.3672 | 0.1359 |
| 1996 | 82.2780 | 1492 | 77.0120 | 32 | 10.1757 | 1.0388 | 0.1357 |
| 1997 | 103.1154 | 1714 | 96.5670 | 30 | 9.8023 | 0.9093 | 0.1353 |
| 1998 | 99.9134 | 1666 | 91.9750 | 33 | 9.6723 | 0.8781 | 0.1355 |
| 1999 | 72.1498 | 1133 | 59.6680 | 32 | 8.7093 | 0.8075 | 0.1362 |
| 2000 | 66.7914 | 1174 | 53.8450 | 38 | 7.4217 | 0.7456 | 0.1361 |
| 2001 | 82.4788 | 1129 | 52.6190 | 37 | 6.7580 | 0.6991 | 0.1361 |
| 2002 | 157.8426 | 1142 | 57.2360 | 30 | 6.7896 | 0.6426 | 0.1363 |
| 2003 | 180.8106 | 1307 | 65.9550 | 35 | 6.6903 | 0.6297 | 0.1360 |
| 2004 | 180.9607 | 1257 | 66.4169 | 33 | 7.2233 | 0.6896 | 0.1362 |
| 2005 | 90.3599 | 671 | 30.0311 | 32 | 6.3449 | 0.6069 | 0.1381 |
| 2006 | 122.5935 | 637 | 32.0832 | 34 | 6.3304 | 0.6367 | 0.1381 |
| 2007 | 78.3142 | 404 | 15.5712 | 24 | 3.2493 | 0.4394 | 0.1410 |
| 2008 | 78.4750 | 367 | 17.6183 | 24 | 4.7326 | 0.5982 | 0.1416 |
| 2009 | 104.9600 | 572 | 33.4102 | 20 | 5.6978 | 0.6686 | 0.1387 |
| 2010 | 91.9240 | 681 | 37.1429 | 22 | 5.5961 | 0.7010 | 0.1379 |
| 2011 | 93.9468 | 863 | 44.4726 | 20 | 5.8293 | 0.7061 | 0.1369 |
| 2012 | 107.2292 | 759 | 42.4445 | 19 | 6.1631 | 0.7128 | 0.1377 |
| 2013 | 122.3639 | 928 | 68.9605 | 23 | 8.5808 | 0.8607 | 0.1370 |
| 2014 | 134.0078 | 815 | 55.8475 | 22 | 7.8160 | 0.8717 | 0.1373 |
| 2015 | 99.1166 | 739 | 50.5253 | 25 | 7.5382 | 0.8574 | 0.1379 |

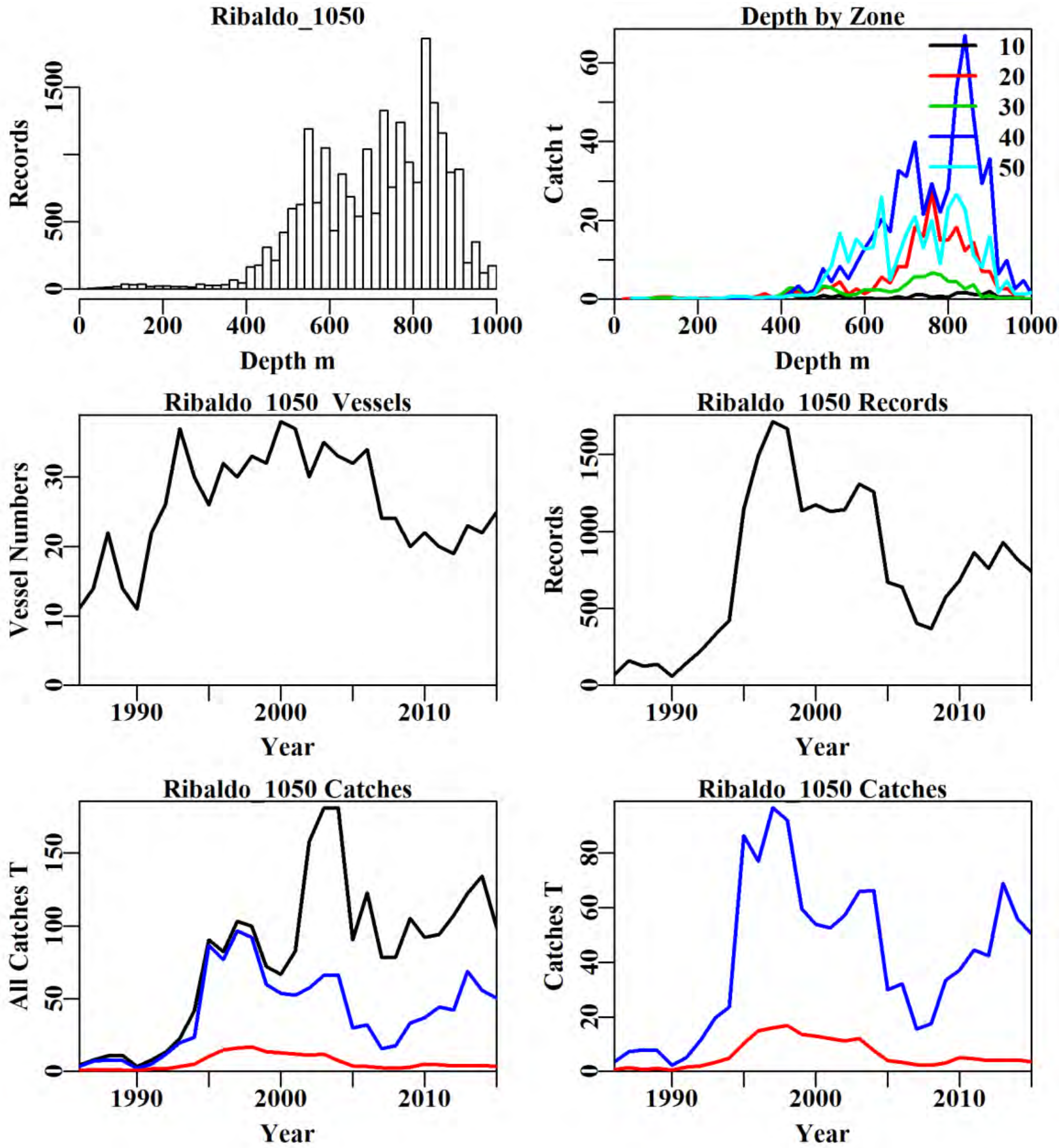



Figure 8.118. Ribaldo from zones 10 to 50 in depths 0 to 1000 m by Trawl. The top left plot depicts the depth distribution of shots containing Ribaldo from zones 10 to 50 in depths 0 to 1000 m by Trawl. The top right plot depicts the catch distribution by depth by zone. The middle left plot depicts the number of vessels through time and middle right plot contains the number of records used in analysis. The bottom left plot contains Ribaldo catches (top black line: total catches, middle blue line: catches used in the analysis; bottom red line: catches < 30 kg) and bottom right plot contains Ribaldo catches (blue line: catches used in the analysis; red line: catches < 30 kg).

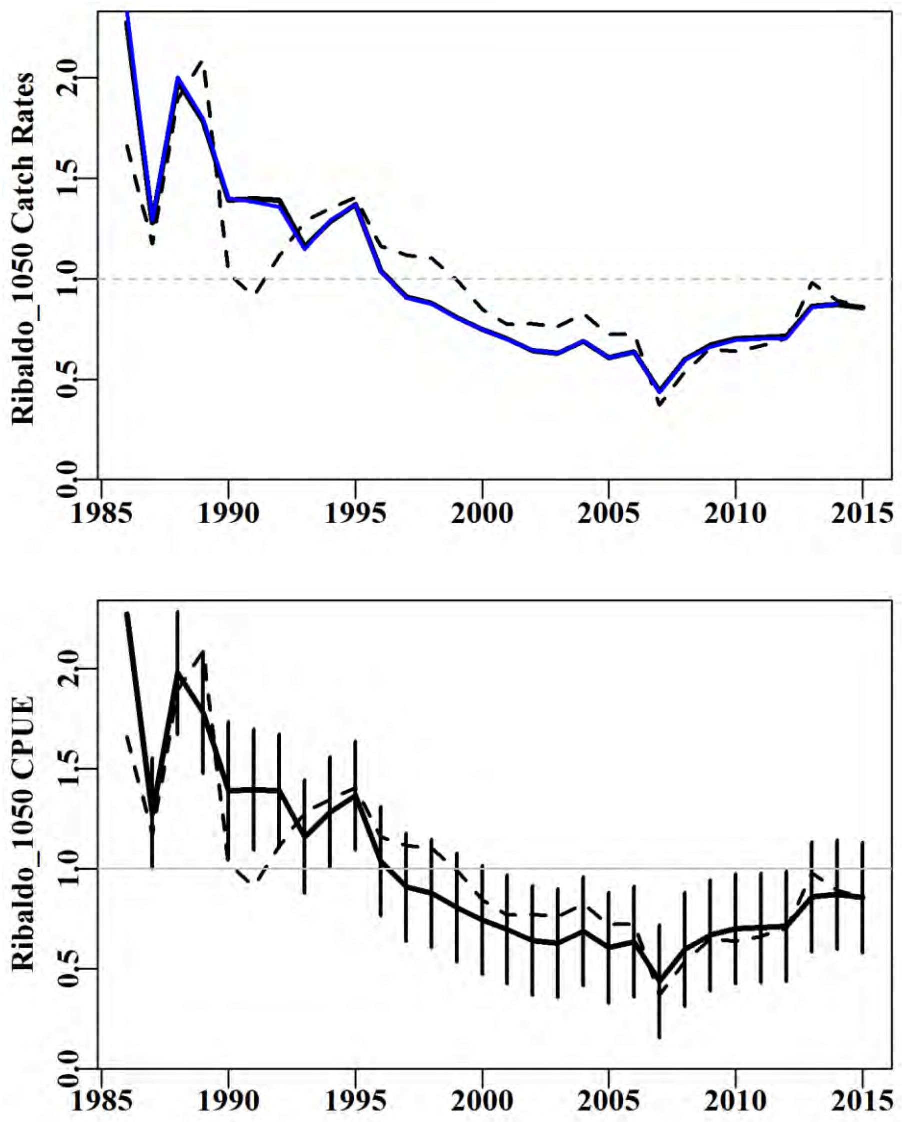



Figure 8.119. Ribaldo from zones 10 to 50 in depths 0 to 1000 m by Trawl. Upper graph: The dashed black line represents the geometric mean catch rate and the solid black line the standardized catch rates (relative to the mean of the standardized catch rates). The blue line corresponds to last year's standardized catch rates. Lower graph: Standardized indices (solid black line), 95% CI (vertical lines) and geometric mean (dashed black line). This illustrates the impact on the relative uncertainty of the relatively small number of records, especially in the early years.

Table 8.110. Ribaldo from zones 10 to 50 in depths 0 to 1000 m by Trawl. Statistical model structures used in this analysis. DepCat is a series of 50 metre depth categories.

| | |
|---|---|
| Model 1 | LnCE~Year |
| Model 2 | LnCE~Year+Vessel |
| Model 3 | LnCE~Year+Vessel+DepCat |
| Model 4 | LnCE~Year+Vessel+DepCat+Zone |
| Model 5 | LnCE~Year+Vessel+DepCat+Zone+DayNight |
| Model 6 | LnCE~Year+Vessel+DepCat+Zone+DayNight+Month |
| Model 7 | LnCE~Year+Vessel+DepCat+Zone+DayNight+Month+Zone:Month |
| Model 8 | LnCE~Year+Vessel+DepCat+Zone+DayNight+Month+Zone:DepCat |

Table 8.111. Ribaldo from zones 10 to 50 in depths 0 to 1000 m by Trawl. Model selection criteria include the Akaike Information Criterion (AIC), residual sum of squares (RSS), model sum of squares (MSS), number of usable observations (Nobs), number of parameters (Npars), adjusted $R^2$ (adj_$R^2$) and the change in adjusted $R^2$ (%Change). The optimum is Zone:Month (Model 7). Depth category: DepC.

| | Year | Vessel | DepC | Zone | DayNight | Month | Zone:Month | Zone:DepC |
|---|---|---|---|---|---|---|---|---|
| AIC | -1731 | -5436 | -6669 | -7416 | -7542 | -7600 | -8185 | -7928 |
| RSS | 20547 | 17120 | 16006 | 15467 | 15375 | 15320 | 14859 | 14822 |
| MSS | 1662 | 5088 | 6203 | 6741 | 6833 | 6889 | 7349 | 7386 |
| Nobs | 22268 | 22063 | 22063 | 22063 | 22063 | 22063 | 22063 | 22063 |
| Npars | 30 | 80 | 206 | 210 | 213 | 224 | 268 | 424 |
| adj_$R^2$ | 7.361 | 22.634 | 27.253 | 29.687 | 30.097 | 30.314 | 32.271 | 31.952 |
| %Change | 0.000 | 15.273 | 4.619 | 2.434 | 0.409 | 0.217 | 1.956 | -0.319 |

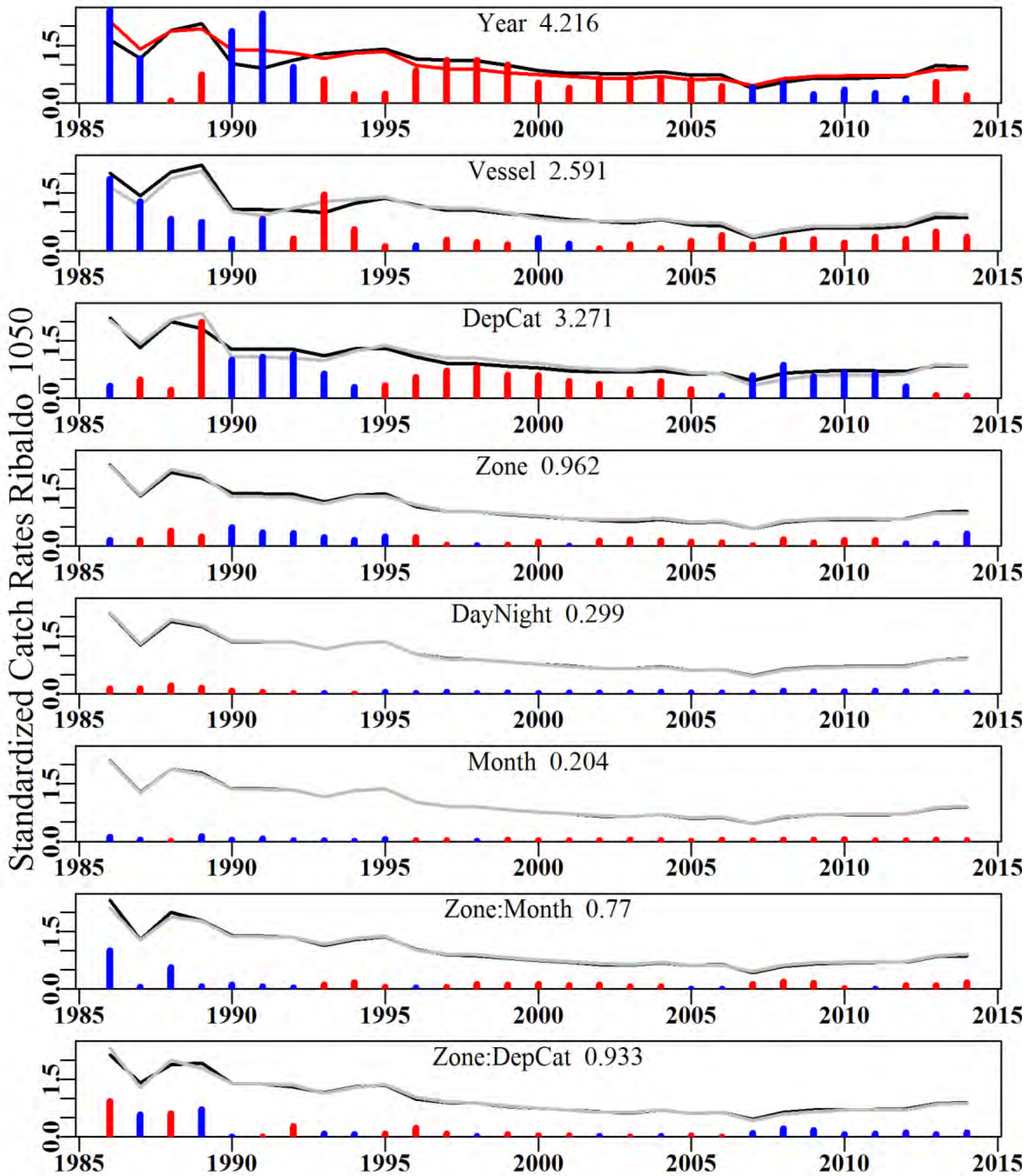



Figure 8.120. The relative influence of each factor used on the final trend in the optimal standardization for Ribaldo from zones 10 to 50. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by the vertical bars with blue bars indicating the optimum model is higher than the geometric mean and red bars indicating it is lower. The top graph bars are the sum of all the bars in the graphs below. The graphs for individual factors are cumulative. Thus the second graph has the geometric mean (grey line) and the effect of adding Year + factor2 (Model 2). In the third graph, the grey line represents Model 2 and the black line the effect of adding factor3 to the model. The remaining graphs continue in the same cumulative manner except for the interaction terms which are added singularly to the final single factor model.

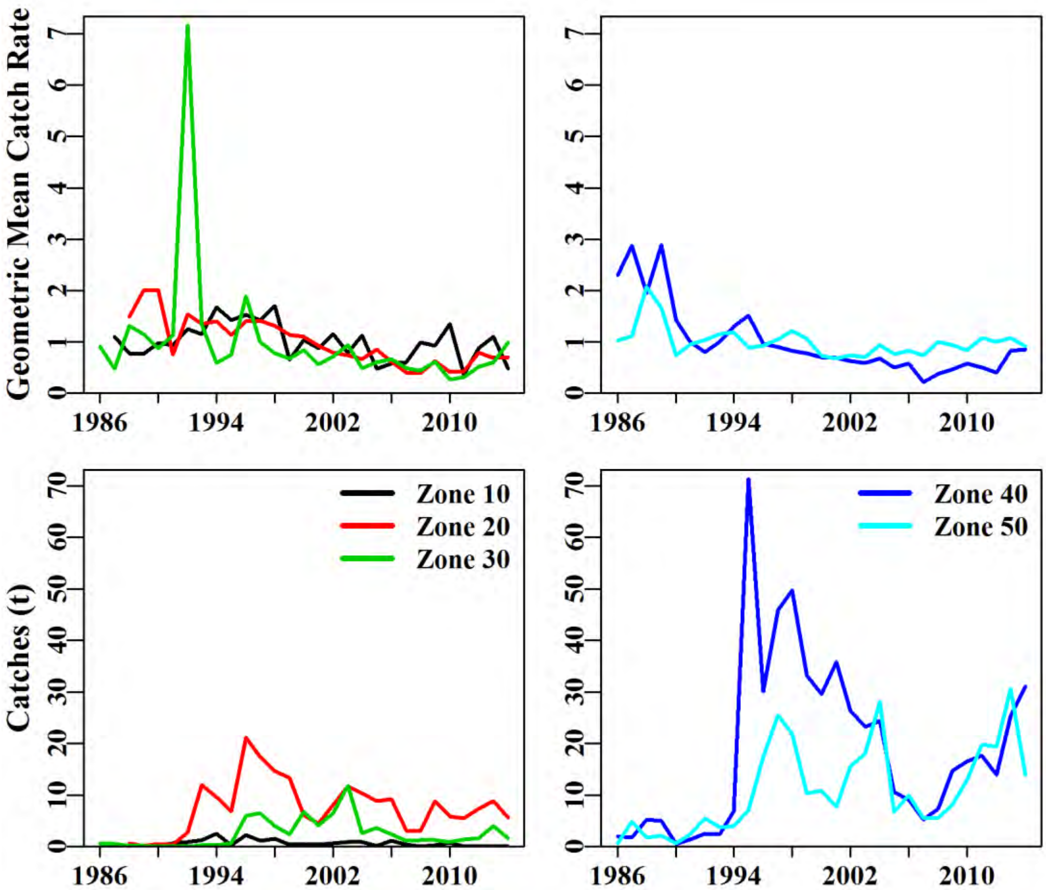



Figure 8.121. Ribaldo from zones 10 to 50 in depths 0 to 1000 m by Trawl. Geometric mean catch rate and catch (t) by zones 10-30 (left plots) and zone 40, 50 (right plots).

### 8.4.39 *Ribaldo AL Z10-50 GAB (RBD – 37224002 – Mora moro)*

Auto Line Ribaldo data selected for analysis corresponded to records from zones 10 – 50 and the GAB in depths 0 to 1000 m. The DayNight factor was not employed in the standardization analysis.

Table 8.112. Ribaldo taken by Auto Line in zones 10, 20, 30 40, 50 and the GAB in depths 0 to 1000 m. Total catch (TotCatch; t) is the total reported in the database, number of records used in the analysis (Records), reported catch (CatchT; t) in the area and depth used in the analysis and number of vessels used in the analysis (Vessels). GeoMean is the geometric mean of catch rates (kg/shot). The optimum model is Zone:Month and standard deviation (StDev) relates to the data in the optimum model.

| Year | TotCatch | Records | CatchT | Vessels | GeoMean | Zone:Month | StDev |
|---|---|---|---|---|---|---|---|
| 1997 | 103.1154 | 22 | 1.4050 | 1 | 50.5984 | 0.4255 | 0.0000 |
| 1998 | 99.9134 | 13 | 1.7530 | 2 | 88.6126 | 0.4263 | 0.4488 |
| 1999 | 72.1498 | 24 | 1.9470 | 1 | 40.6973 | 0.3522 | 0.3814 |
| 2000 | 66.7914 | 43 | 9.0390 | 1 | 96.6841 | 0.3405 | 0.3390 |
| 2001 | 82.4788 | 63 | 15.7200 | 2 | 157.4316 | 1.2321 | 0.3143 |
| 2002 | 157.8426 | 259 | 95.4965 | 4 | 135.9460 | 2.8714 | 0.2856 |
| 2003 | 180.8106 | 337 | 102.8823 | 7 | 75.0323 | 2.1583 | 0.2832 |
| 2004 | 180.9607 | 714 | 96.5886 | 11 | 51.6307 | 1.9305 | 0.2804 |
| 2005 | 90.3599 | 308 | 37.1892 | 7 | 44.5029 | 1.1682 | 0.2849 |
| 2006 | 122.5935 | 605 | 65.3525 | 8 | 39.5723 | 1.1415 | 0.2806 |
| 2007 | 78.3142 | 393 | 28.1252 | 6 | 25.0254 | 0.6992 | 0.2823 |
| 2008 | 78.4750 | 401 | 56.7722 | 6 | 39.2440 | 0.8160 | 0.2809 |
| 2009 | 104.9600 | 433 | 68.2730 | 6 | 49.5683 | 0.8080 | 0.2801 |
| 2010 | 91.9240 | 381 | 51.6696 | 5 | 47.4481 | 0.7682 | 0.2812 |
| 2011 | 93.9468 | 356 | 46.4764 | 5 | 45.6603 | 0.9184 | 0.2811 |
| 2012 | 107.2292 | 295 | 58.8469 | 6 | 60.9351 | 0.8502 | 0.2820 |
| 2013 | 122.3639 | 275 | 49.8231 | 5 | 48.7494 | 0.6671 | 0.2831 |
| 2014 | 134.0078 | 265 | 66.2288 | 5 | 57.9143 | 0.7407 | 0.2838 |
| 2015 | 99.1166 | 194 | 34.8787 | 3 | 51.9909 | 0.6857 | 0.2866 |

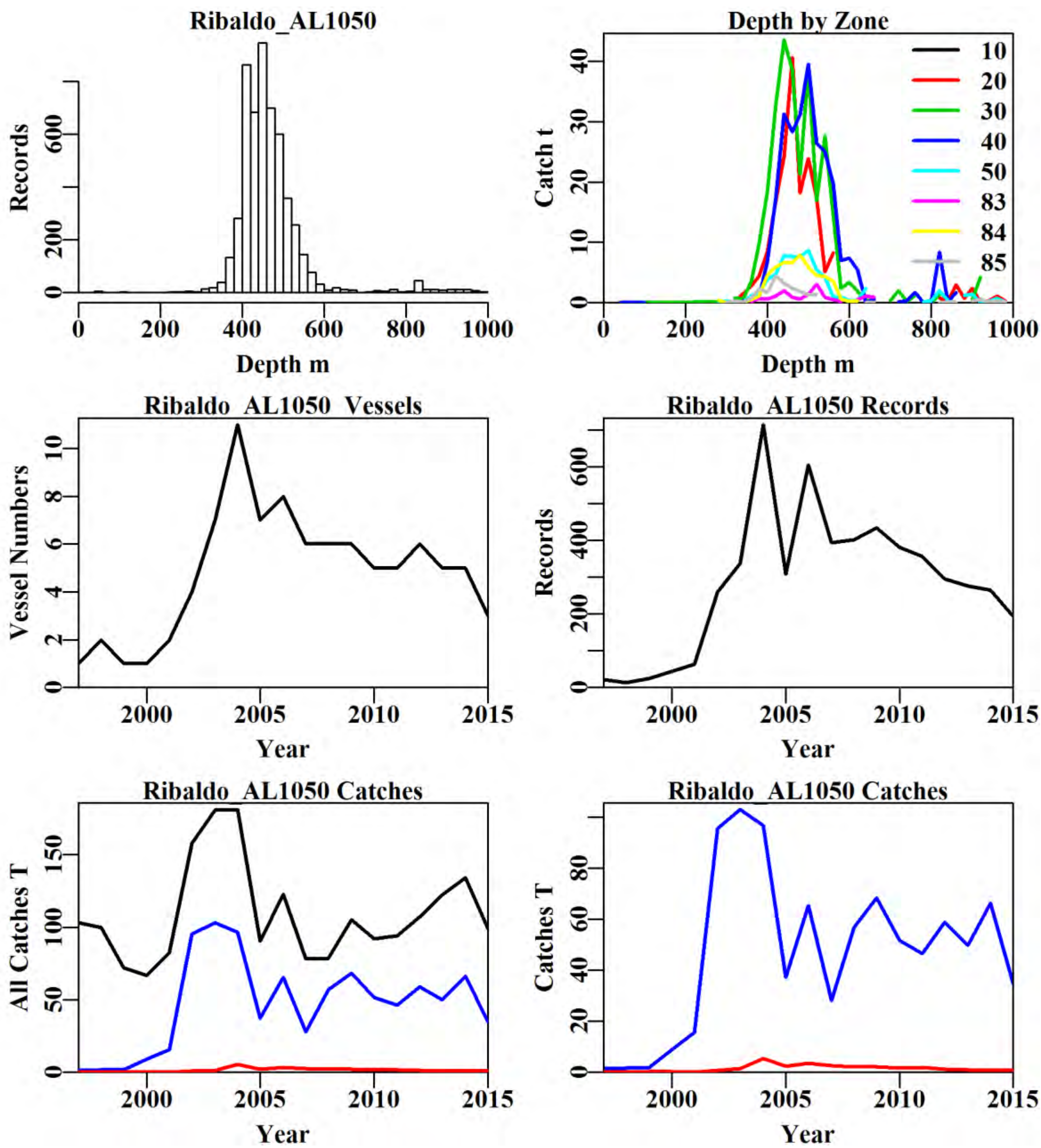
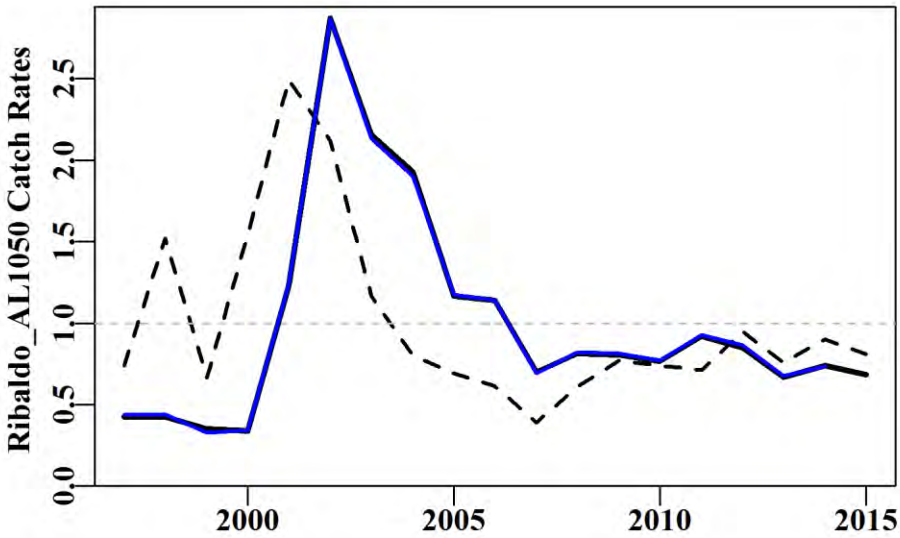



Figure 8.122. Ribaldo by Auto Line. The top left plot depicts the depth distribution of shots containing Ribaldo from zones 10 to 50 and the GAB in depths 0 to 1000 m by Auto Line employed in the standardization analysis. The top right plot depicts the catch distribution by depth by zone. The middle left plot depicts the number of vessels through time and middle right plot contains the number of records used in analysis. The bottom left plot contains Ribaldo catches (top black line: total catches, middle blue line: catches used in the analysis; bottom red line: catches < 30 kg) and bottom right plot contains Ribaldo catches (blue line: catches used in the analysis; red line: catches < 30 kg).



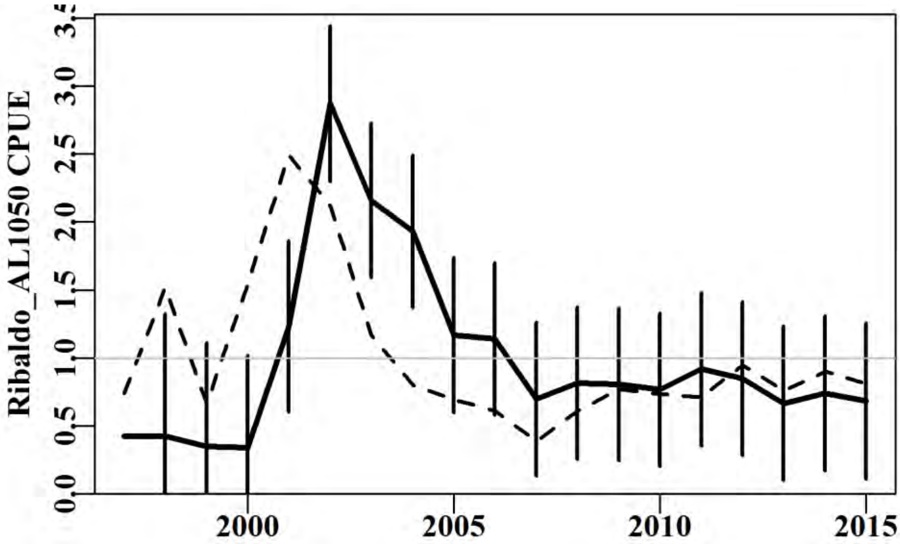




Figure 8.123. Standardized catch rates for Ribaldo by Auto Line. Upper graph: The dashed black line represents the geometric mean catch rate and the solid black line the standardized catch rates (relative to the mean of the standardized catch rates). The blue line corresponds to last year's standardized indices. Lower graph: Standardized indices (solid black line), 95% CI (vertical lines) and geometric mean (dashed black line). The graph standardizes catch rates relative to the mean of the standardized catch rates.The same statistical models that were used for the trawl analysis were also used here (Table 8.113).

Table 8.113. Ribaldo from zones 10 to 50 in depths 0 to 1000 m by Auto Line. Statistical model structures used in this analysis. DepCat is a series of 20 metre depth categories.

| | |
|---|---|
| Model 1 | LnCE~Year |
| Model 2 | LnCE~Year+Vessel |
| Model 3 | LnCE~Year+Vessel+DepCat |
| Model 4 | LnCE~Year+Vessel+DepCat+Zone |
| Model 5 | LnCE~Year+Vessel+DepCat+Zone+Month |
| Model 6 | LnCE~Year+Vessel+DepCat+Zone+Month |
| Model 7 | LnCE~Year+Vessel+DepCat+Zone+Month+Zone:Month |
| Model 8 | LnCE~Year+Vessel+DepCat+Zone+Month+Zone:DepCat |

Table 8.114. Ribaldo taken by Auto Line. Model selection criteria include the Akaike Information Criterion (AIC), residual sum of squares (RSS), model sum of squares (MSS), number of usable observations (Nobs), number of parameters (Npars), adjusted $R^2$ (adj_$R^2$) and the change in adjusted $R^2$ (%Change). The optimum is Zone:Month (Model 7). Depth category: DepC.

| | Year | Vessel | DepC | Zone | Month | Zone:Month | Zone:DepC |
|---|---|---|---|---|---|---|---|
| AIC | 5176 | 3128 | 2734 | 2642 | 2600 | 2445 | 2664 |
| RSS | 13982 | 9509 | 8692 | 8522 | 8421 | 7949 | 7459 |
| MSS | 693 | 5166 | 5983 | 6153 | 6254 | 6726 | 7216 |
| Nobs | 5381 | 5381 | 5362 | 5362 | 5362 | 5362 | 5362 |
| Npars | 19 | 32 | 72 | 79 | 90 | 167 | 447 |
| adj_$R^2$ | 4.402 | 34.829 | 39.976 | 41.069 | 41.650 | 44.106 | 44.561 |
| %Change | 0.000 | 30.427 | 5.147 | 1.093 | 0.581 | 2.455 | 0.456 |

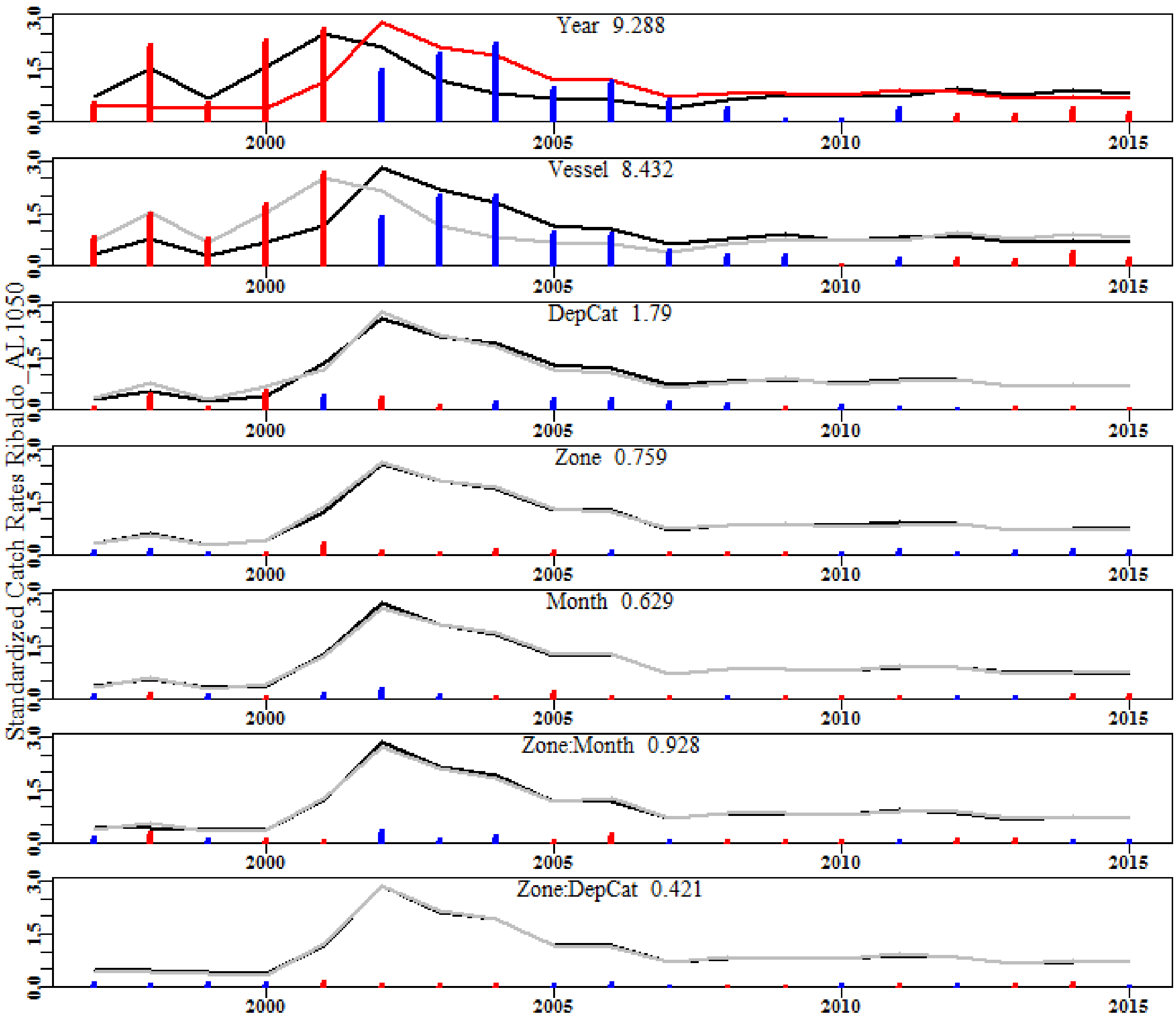



Figure 8.124. The relative influence of each factor used on the final trend in the optimal standardization for Ribaldo from zones 10 to 50 and the GAB. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by the vertical bars with blue bars indicating the optimum model is higher than the geometric mean and red bars indicating it is lower. The top graph bars are the sum of all the bars in the graphs below. The graphs for individual factors are cumulative. Thus the second graph has the geometric mean (grey line) and the effect of adding Year + factor2 (Model 2). In the third graph, the grey line represents Model 2 and the black line the effect of adding factor3 to the model. The remaining graphs continue in the same cumulative manner except for the interaction terms which are added singularly to the final single factor model.

### 8.4.40 *Ocean Jackets Z1050 (LTC – 37465006 – Nelusetta ayraudi)*

**Alternate: Leather Jackets (LTH – 37465000)**

Trawl data from zones 10 to 50 in depths 0 – 300 m and all vessels and records reporting leatherjackets were included. This is the second year this data has been considered

Table 8.115. Ocean Jackets from zones 10 to 50 in depths 0 to 300 m by Trawl. Total catch (TotCatch; t) is the total reported in the database, number of records used in the analysis (Records), reported catch (CatchT; t) in the area and depth used in the analysis and number of vessels used in the analysis (Vessels). GeoMean is the geometric mean of catch rates (kg/hr). The optimum model is Zone:DepCat and standard deviation (StDev) relates to the data in the optimum model.

| Year | TotCatch | Records | CatchT | Vessels | GeoMean | Zone:DepCat | StDev |
|---|---|---|---|---|---|---|---|
| 1986 | 56.4290 | 2472 | 44.6950 | 75 | 5.0326 | 0.6460 | 0.0000 |
| 1987 | 53.3540 | 1445 | 28.1510 | 61 | 5.1085 | 0.6866 | 0.0368 |
| 1988 | 66.3040 | 1911 | 45.7250 | 66 | 6.2067 | 0.8269 | 0.0342 |
| 1989 | 71.6660 | 1808 | 32.7780 | 65 | 4.8860 | 0.7127 | 0.0348 |
| 1990 | 90.9690 | 1548 | 33.1570 | 46 | 4.9715 | 0.7007 | 0.0367 |
| 1991 | 170.4810 | 1329 | 24.7880 | 46 | 4.4265 | 0.6070 | 0.0387 |
| 1992 | 88.8840 | 1207 | 24.9160 | 41 | 4.8188 | 0.6239 | 0.0397 |
| 1993 | 71.8970 | 1342 | 29.2450 | 42 | 5.0852 | 0.6728 | 0.0393 |
| 1994 | 74.4380 | 1449 | 34.8850 | 45 | 5.9751 | 0.7592 | 0.0378 |
| 1995 | 140.1790 | 2222 | 59.0530 | 41 | 6.0061 | 0.7585 | 0.0343 |
| 1996 | 199.5710 | 2571 | 72.1980 | 54 | 6.3291 | 0.7798 | 0.0335 |
| 1997 | 177.4190 | 2007 | 52.4820 | 51 | 5.4556 | 0.7075 | 0.0352 |
| 1998 | 189.8986 | 2488 | 68.0120 | 44 | 5.2611 | 0.7041 | 0.0337 |
| 1999 | 202.8050 | 2681 | 88.1900 | 52 | 7.0007 | 0.8236 | 0.0332 |
| 2000 | 198.8111 | 2981 | 73.1510 | 52 | 5.1869 | 0.6609 | 0.0328 |
| 2001 | 222.5697 | 3190 | 64.2490 | 55 | 4.1918 | 0.5879 | 0.0326 |
| 2002 | 378.4963 | 4875 | 199.4070 | 61 | 5.4889 | 0.6992 | 0.0307 |
| 2003 | 482.3066 | 5504 | 187.3785 | 58 | 5.0841 | 0.6652 | 0.0302 |
| 2004 | 692.5927 | 6213 | 313.1105 | 60 | 8.3073 | 1.0824 | 0.0298 |
| 2005 | 890.6138 | 5162 | 342.8585 | 54 | 9.8912 | 1.2445 | 0.0306 |
| 2006 | 741.5297 | 4636 | 301.7370 | 50 | 10.2758 | 1.3759 | 0.0311 |
| 2007 | 564.8329 | 3092 | 285.3964 | 27 | 14.0314 | 1.6420 | 0.0334 |
| 2008 | 490.3988 | 3554 | 318.3140 | 29 | 13.7134 | 1.5577 | 0.0329 |
| 2009 | 609.9797 | 3260 | 376.1120 | 28 | 16.0145 | 1.7454 | 0.0333 |
| 2010 | 483.8922 | 3259 | 300.1655 | 29 | 13.2397 | 1.4447 | 0.0333 |
| 2011 | 487.4438 | 3224 | 277.1800 | 29 | 12.3456 | 1.3667 | 0.0333 |
| 2012 | 519.6479 | 3443 | 343.8395 | 30 | 14.4818 | 1.5709 | 0.0330 |
| 2013 | 488.2250 | 2835 | 264.7285 | 28 | 13.7429 | 1.5781 | 0.0340 |
| 2014 | 511.8626 | 3374 | 273.1295 | 28 | 12.0639 | 1.4088 | 0.0331 |
| 2015 | 411.1243 | 3004 | 244.9400 | 31 | 11.7216 | 1.3604 | 0.0337 |

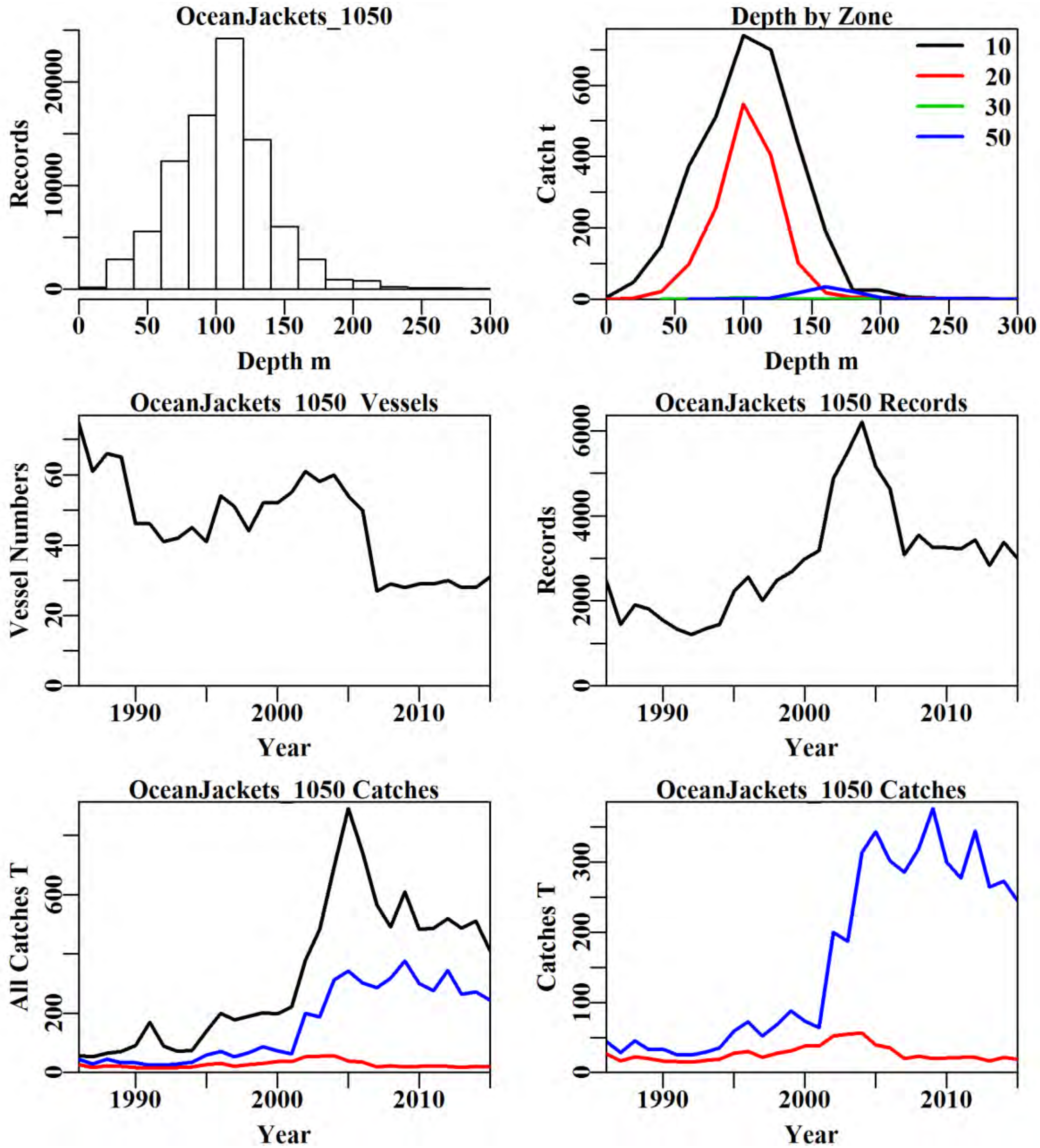



Figure 8.125. Ocean Jackets from zones 10 to 50 in depths 0 to 300 m by Trawl. The top left plot depicts the depth distribution of shots containing Ocean Jackets from zones 10 to 50 in depths 0 to 300 m by Trawl employed in the analysis. The top right plot depicts the catch distribution by depth by zone. The middle left plot depicts the number of vessels through time and middle right plot contains the number of records used in analysis. The bottom left plot contains Ocean Jackets catches (top black line: total catches, middle blue line: catches used in the analysis; bottom red line: catches < 30 kg) and bottom right plot contains Ocean Jackets catches (blue line: catches used in the analysis; red line: catches < 30 kg).

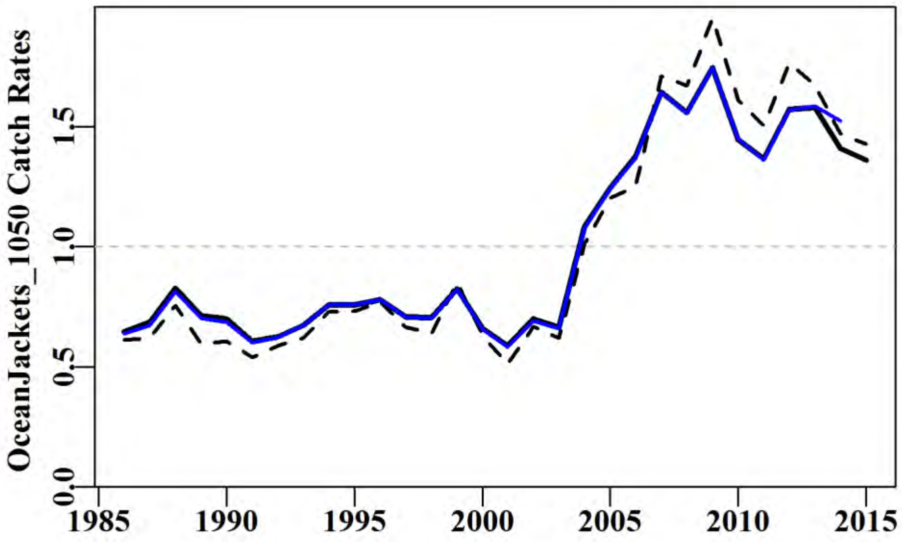



Figure 8.126. Ocean Jackets from zones 10 to 50 in depths 0 to 300 m by Trawl. The dashed black line represents the geometric mean catch rate, solid black line the standardized catch rates and solid blue line the standardized catch rates from last year's analysis. The graph standardizes catch rates relative to the mean of the standardized catch rates.

Table 8.116. Ocean Jackets from Zones 10 to 50 in depths 0 to 300 m by Trawl. Statistical model structures used in this analysis. DepCat is a series of 20 metre depth categories.

| | |
|---|---|
| Model 1 | LnCE~Year |
| Model 2 | LnCE~Year+Vessel |
| Model 3 | LnCE~Year+Vessel+DepCat |
| Model 4 | LnCE~Year+Vessel+DepCat+Month |
| Model 5 | LnCE~Year+Vessel+DepCat+Month+Zone |
| Model 6 | LnCE~Year+Vessel+DepCat+Month+Zone+DayNight |
| Model 7 | LnCE~Year+Vessel+DepCat+Month+Zone+DayNight +Zone:Month |
| Model 8 | LnCE~Year+Vessel+DepCat+Month+Zone+DayNight +Zone:DepCat |

Table 8.117. Ocean Jackets from Zones 10 to 50 in depths 0 to 300 m by Trawl. Model selection criteria include the Akaike Information Criterion (AIC), residual sum of squares (RSS), model sum of squares (MSS), number of usable observations (Nobs), number of parameters (Npars), adjusted $R^2$ (adj_$R^2$) and the change in adjusted $R^2$ (%Change). The optimum is Zone:DepC (Model 8). Depth category: DepC.

| | Year | Vessel | DepC | Month | Zone | DayNight | Zone:Month | Zone:DepC |
|---|---|---|---|---|---|---|---|---|
| AIC | 19643 | 6620 | 6088 | 5316 | 4556 | 4382 | 3157 | 4184 |
| RSS | 110017 | 94527 | 93336 | 92492 | 91686 | 91498 | 90133 | 91222 |
| MSS | 16322 | 31812 | 33003 | 33847 | 34653 | 34841 | 36206 | 35117 |
| Nobs | 88086 | 88086 | 87495 | 87495 | 87495 | 87495 | 87495 | 87495 |
| Npars | 30 | 202 | 217 | 228 | 231 | 234 | 279 | 267 |
| adj_$R^2$ | 12.890 | 25.009 | 25.940 | 26.600 | 27.237 | 27.384 | 28.430 | 27.575 |
| %Change | 0.000 | 12.119 | 0.931 | 0.660 | 0.637 | 0.147 | 1.046 | -0.855 |

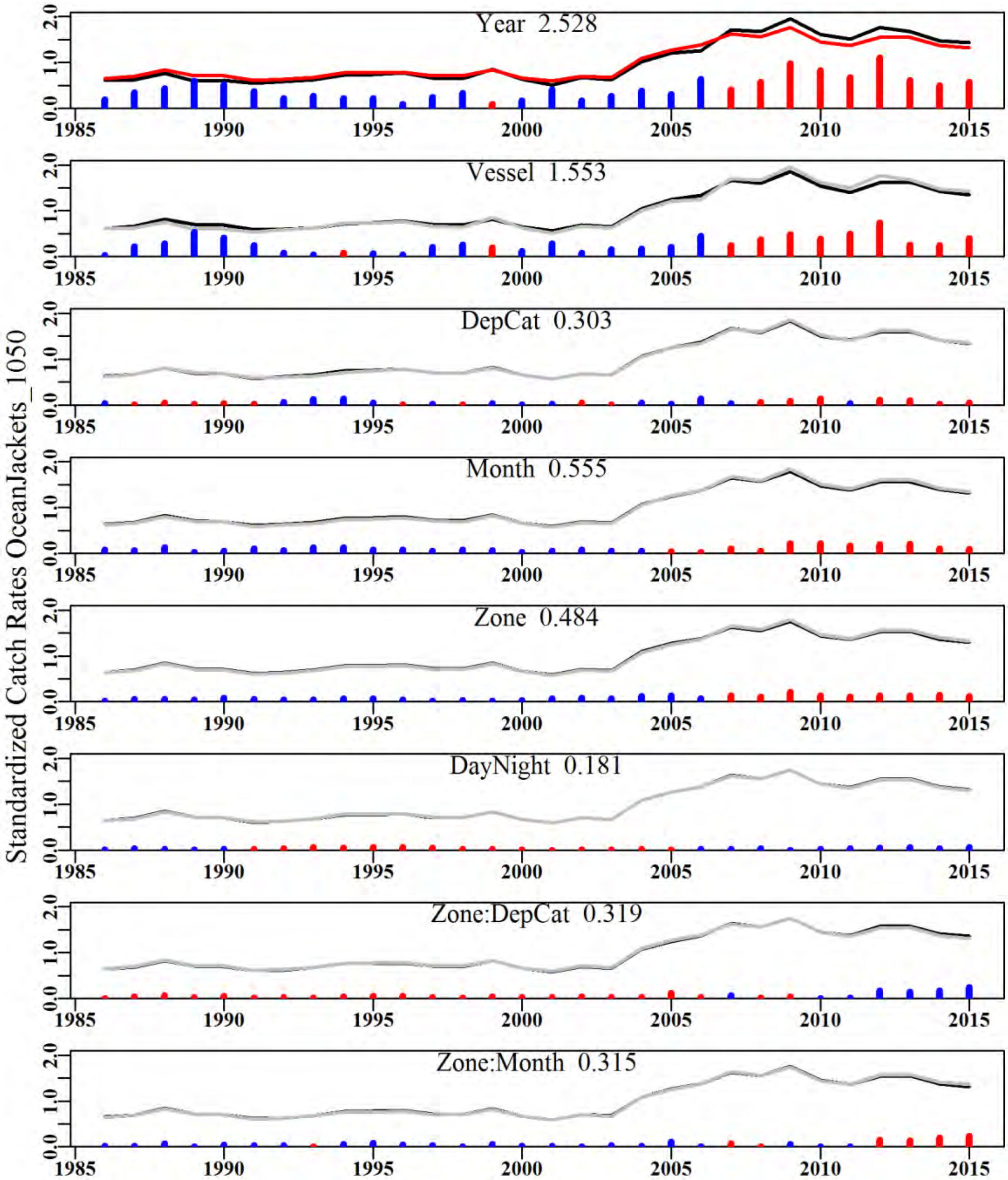



Figure 8.127. The relative influence of each factor used on the final trend in the optimal standardization for Ocean Jackets from Zones 10 to 50. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by the vertical bars with blue bars indicating the optimum model is higher than the geometric mean and red bars indicating it is lower. The top graph bars are the sum of all the bars in the graphs below. The graphs for individual factors are cumulative. Thus the second graph has the geometric mean (grey line) and the effect of adding Year + factor2 (Model 2). In the third graph, the grey line represents Model 2 and the black line the effect of adding factor3 to the model. The remaining graphs continue in the same cumulative manner except for the interaction terms which are added singularly to the final single factor model.

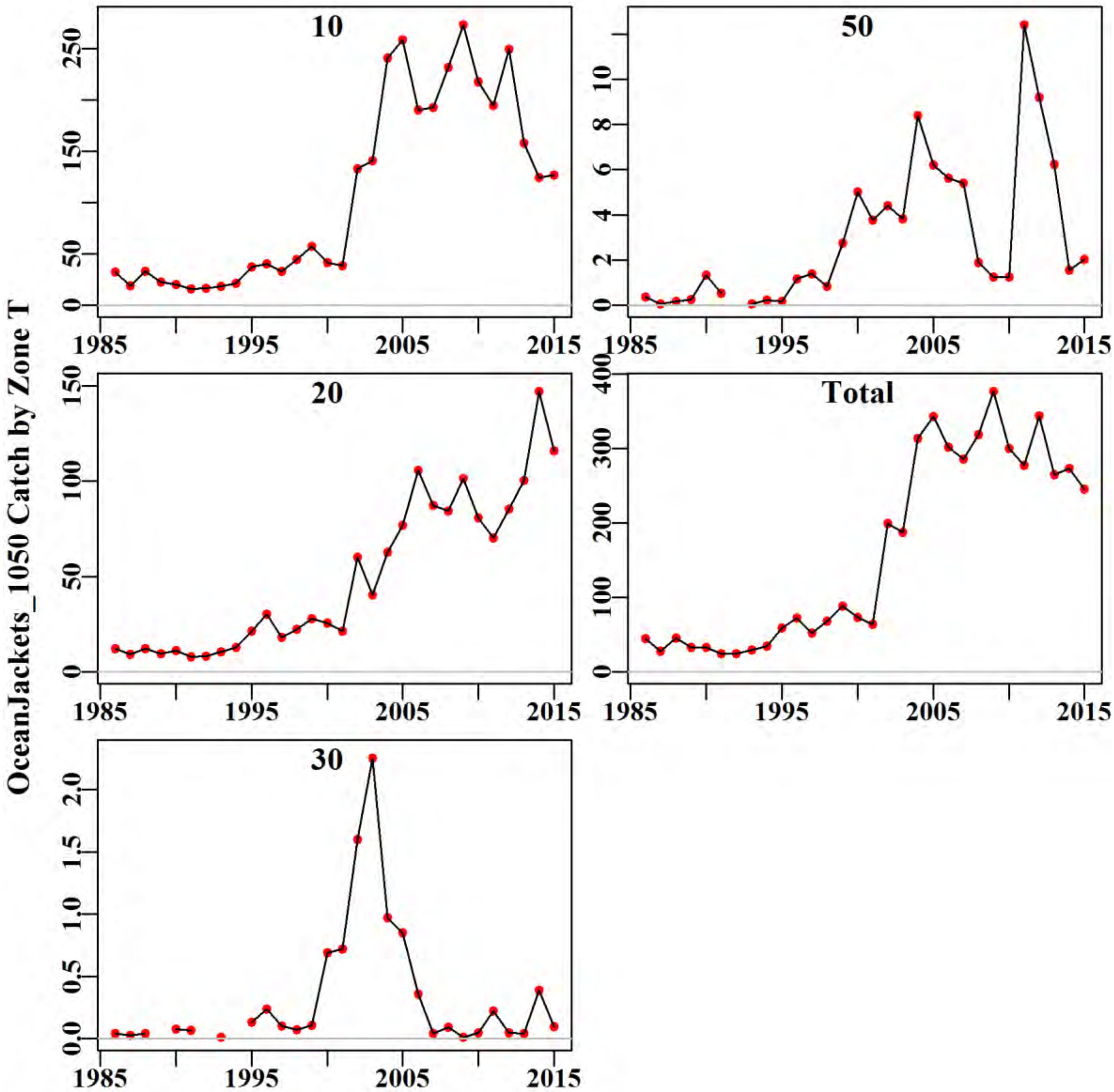



Figure 8.128. Ocean Jackets from Zones 10 to 50 in depths 0 to 300 m by Trawl. The catches taken in each of the four main SESSF zones is depicted with the total catch across these zones. The scales on the y-axis changes between graphs.

### 8.4.41 *Ocean Jackets GAB (LTC – 37465006 – Nelusetta ayraudi)*

**Alternate: Leatherjackets (LTH – 37465000)**

Data from zones 82 and 83 in the GAB in depths 0 – 300 m by Trawl and all vessels and records reporting leatherjackets were included. This is the second year this data has been considered.

Table 8.118. Ocean Jackets from zones 82 and 83 in depths 80 to 220 m by Trawl. Total catch (TotCatch; t) is the total reported in the database, number of records used in the analysis (Records), reported catch (CatchT; t) in the area and depth used in the analysis and number of vessels used in the analysis (Vessels). GeoMean is the geometric mean of catch rates (kg/hr). The optimum model is Zone:Month and standard deviation (StDev) relates to the data in the optimum model.

| Year | TotCatch | Records | CatchT | Vessels | GeoMean | Zone:Month | StDev |
|---|---|---|---|---|---|---|---|
| 1986 | 56.4290 | 141 | 8.4900 | 1 | 11.5206 | 1.2151 | 0.0000 |
| 1987 | 53.3540 | 212 | 22.6320 | 3 | 13.7002 | 1.0210 | 0.1068 |
| 1988 | 66.3040 | 245 | 15.5900 | 7 | 14.0350 | 1.1758 | 0.1868 |
| 1989 | 71.6660 | 576 | 34.7140 | 7 | 11.9652 | 1.2139 | 0.1851 |
| 1990 | 90.9690 | 920 | 51.3800 | 11 | 11.1086 | 0.8285 | 0.1827 |
| 1991 | 170.4810 | 1252 | 139.7970 | 8 | 15.0694 | 1.0644 | 0.1821 |
| 1992 | 88.8840 | 954 | 59.5340 | 7 | 9.0287 | 0.9154 | 0.1820 |
| 1993 | 71.8970 | 819 | 38.7640 | 4 | 6.3105 | 0.6199 | 0.1820 |
| 1994 | 74.4380 | 745 | 36.6600 | 5 | 5.7741 | 0.5435 | 0.1827 |
| 1995 | 140.1790 | 1316 | 78.8320 | 5 | 6.2242 | 0.7093 | 0.1813 |
| 1996 | 199.5710 | 1725 | 123.4690 | 6 | 7.8262 | 0.8285 | 0.1810 |
| 1997 | 177.4190 | 2135 | 121.0640 | 9 | 6.4622 | 0.6869 | 0.1810 |
| 1998 | 189.8986 | 1799 | 116.4370 | 9 | 7.1373 | 0.7496 | 0.1810 |
| 1999 | 202.8050 | 1585 | 108.9700 | 7 | 7.8084 | 0.8565 | 0.1814 |
| 2000 | 198.8111 | 1552 | 122.3260 | 5 | 7.8146 | 0.8759 | 0.1815 |
| 2001 | 222.5697 | 1993 | 146.1530 | 6 | 8.6637 | 0.9136 | 0.1813 |
| 2002 | 378.4963 | 1798 | 148.3705 | 6 | 9.0807 | 0.9641 | 0.1814 |
| 2003 | 482.3066 | 2837 | 279.6050 | 9 | 10.8621 | 1.1028 | 0.1811 |
| 2004 | 692.5927 | 3433 | 364.4399 | 9 | 12.7575 | 1.2024 | 0.1810 |
| 2005 | 890.6138 | 4317 | 522.9095 | 10 | 13.9012 | 1.2802 | 0.1810 |
| 2006 | 741.5297 | 3609 | 408.4483 | 11 | 12.0564 | 0.9937 | 0.1810 |
| 2007 | 564.8329 | 2647 | 254.8505 | 8 | 10.2989 | 0.8926 | 0.1813 |
| 2008 | 490.3988 | 2351 | 146.3620 | 6 | 7.4758 | 0.7642 | 0.1814 |
| 2009 | 609.9797 | 2160 | 219.9650 | 4 | 10.4196 | 1.0585 | 0.1814 |
| 2010 | 483.8922 | 1792 | 168.2025 | 4 | 12.6091 | 1.2018 | 0.1817 |
| 2011 | 487.4438 | 1856 | 190.9830 | 4 | 13.1259 | 1.2246 | 0.1816 |
| 2012 | 519.6479 | 1712 | 154.6335 | 5 | 12.8980 | 1.1694 | 0.1818 |
| 2013 | 488.2250 | 2209 | 203.8610 | 6 | 13.9358 | 1.2876 | 0.1815 |
| 2014 | 511.8626 | 2006 | 206.0260 | 6 | 14.5330 | 1.3440 | 0.1816 |
| 2015 | 411.1243 | 1570 | 148.6155 | 3 | 14.6190 | 1.2965 | 0.1820 |

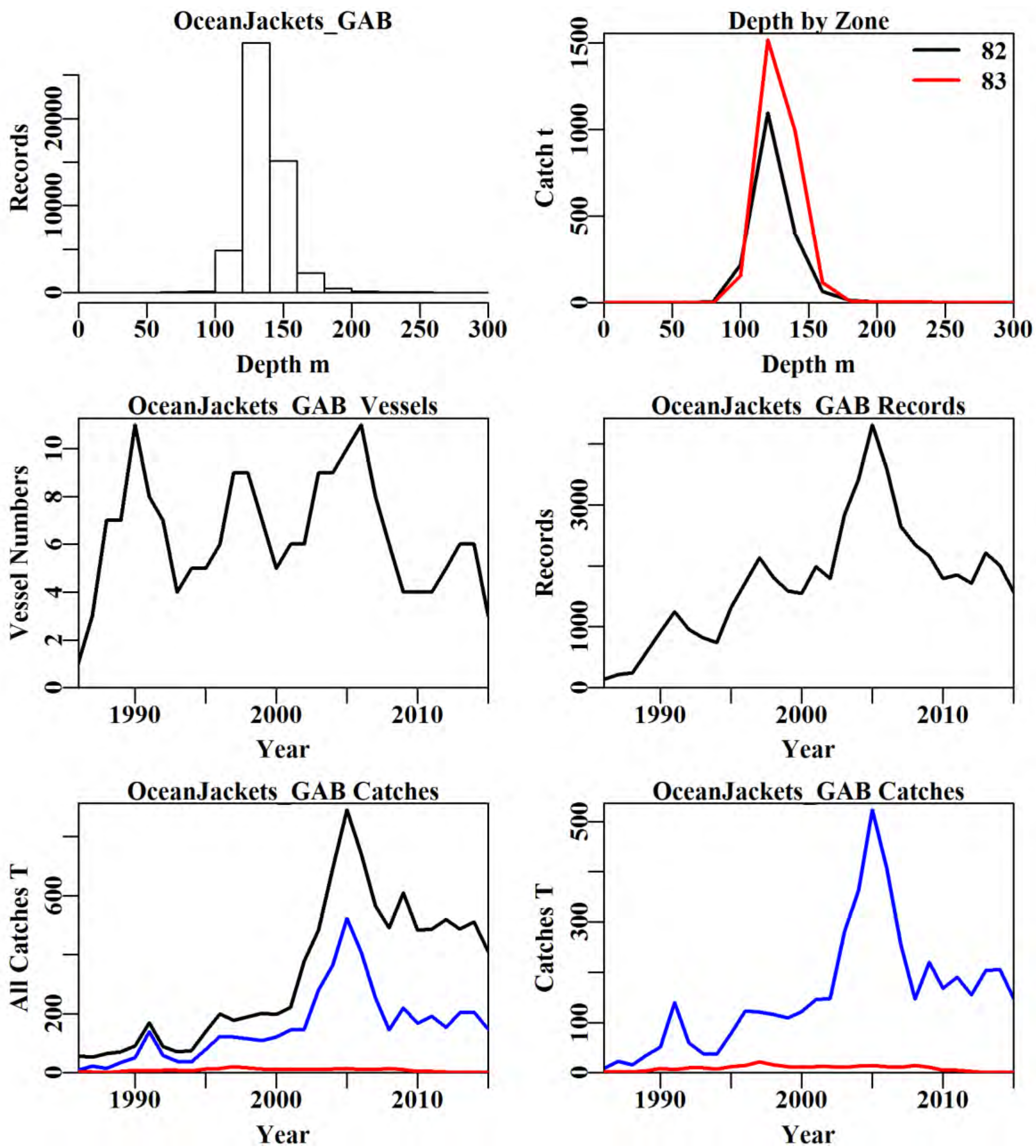



Figure 8.129. Ocean Jackets from zones 82 and 83 in depths 80 to 220 m by Trawl. The top left plot depicts the depth distribution of shots containing Ocean Jackets from Zones 82 and 83 in depths 80 to 220 m by Trawl. The top right plot depicts the catch distribution by depth by zone. The middle left plot depicts the number of vessels through time and middle right plot contains the number of records used in analysis. The bottom left plot contains Ocean Jackets catches (top black line: total catches, middle blue line: catches used in the analysis; bottom red line: catches < 30 kg) and bottom right plot contains Ocean Jackets catches (blue line: catches used in the analysis; red line: catches < 30 kg).

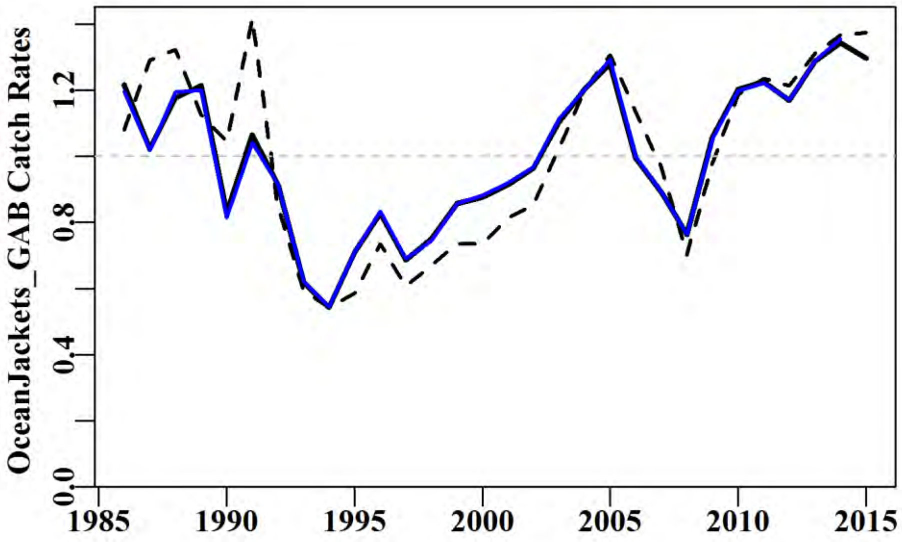



Figure 8.130. Ocean Jackets from zones 82 and 83 in depths 80 to 220 m by Trawl. The dashed black line represents the geometric mean catch rate, solid black line the standardized catch rates and blue line the standardized catch rates based on last year's analysis. The graph standardizes catch rates relative to the mean of the standardized catch rates.

Table 8.119. Ocean Jackets from zones 82 and 83 in depths 80 to 220 m by Trawl. Statistical model structures used in this analysis. DepCat is a series of 20 metre depth categories.

| | |
|---|---|
| Model 1 | LnCE~Year |
| Model 2 | LnCE~Year+DayNight |
| Model 3 | LnCE~Year+Daynight+DepCat |
| Model 4 | LnCE~Year+DayNight+DepCat+Vessel |
| Model 5 | LnCE~Year+DayNight+DepCat+Vessel+Month |
| Model 6 | LnCE~Year+DayNight+DepCat+Vessel+Month+Zone |
| Model 7 | LnCE~Year+DayNight+DepCat+Vessel+Month+Zone+Zone:Month |
| Model 8 | LnCE~Year+DayNight+DepCat+Vessel+Month+Zone+Zone:DepCat |

Table 8.120. Ocean Jackets from zones 82 and 83 in depths 80 to 220 m by Trawl. Model selection criteria include the Akaike Information Criterion (AIC), residual sum of squares (RSS), model sum of squares (MSS), number of usable observations (Nobs), number of parameters (Npars), adjusted $R^2$ (adj_$R^2$) and the change in adjusted $R^2$ (%Change). The optimum is Zone:Month (Model 8). Depth category: DepC.

| | Year | DayNight | DepC | Zone | Vessel | Month | Zone:Month | Zone:DepC |
|---|---|---|---|---|---|---|---|---|
| AIC | 2409 | -3149 | -5858 | -8322 | -9659 | -9681 | -9905 | -9683 |
| RSS | 54669 | 49148 | 46216 | 44008 | 42869 | 42850 | 42647 | 42823 |
| MSS | 3979 | 9499 | 12431 | 14639 | 15778 | 15797 | 16001 | 15824 |
| Nobs | 52266 | 52266 | 51841 | 51841 | 51841 | 51841 | 51841 | 51841 |
| Npars | 30 | 33 | 48 | 85 | 96 | 97 | 108 | 112 |
| adj_$R^2$ | 6.732 | 16.146 | 21.125 | 24.839 | 26.769 | 26.801 | 27.133 | 26.826 |
| %Change | 0.000 | 9.414 | 4.979 | 3.714 | 1.930 | 0.031 | 0.332 | -0.307 |

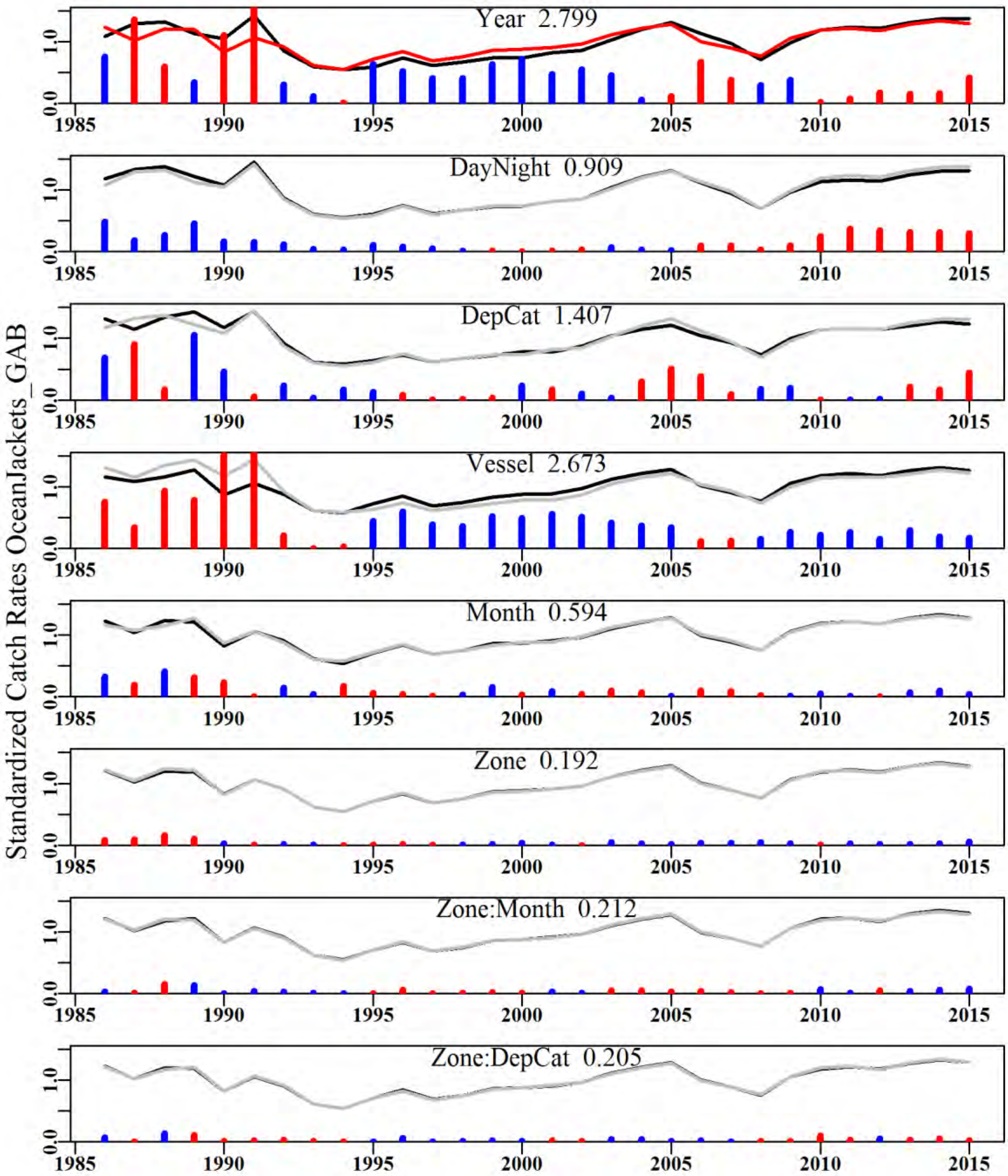



Figure 8.131. The relative influence of each factor used on the final trend in the optimal standardization for Ocean Jackets from zones 82 and 83. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by the vertical bars with blue bars indicating the optimum model is higher than the geometric mean and red bars indicating it is lower. The top graph bars are the sum of all the bars in the graphs below. The graphs for individual factors are cumulative. Thus the second graph has the geometric mean (grey line) and the effect of adding Year + factor2 (Model 2). In the third graph, the grey line represents Model 2 and the black line the effect of adding factor3 to the model. The remaining graphs continue in the same cumulative manner except for the interaction terms which are added singularly to the final single factor model.

### 8.4.42 *Deepwater Flathead (FLD – 37296002 – Platycephalus conatus)*

Data from the GAB fishery, depths between 0 – 1000 m, taken by Trawl. Previous analyses have restricted analyses to vessels present for more than two years and which caught an average annual catch > 4 t. However, these data filters have only very minor effects upon the observed trend in catch rates, so all Trawl data between 0 – 1000 m were used in the analysis. Catches in 1986/1987 corresponded to the first four months of the year, were relatively low and only taken by a single vessel, so were omitted from analyses.

Table 8.121. Deepwater Flathead taken by Trawl in the GAB in depths between 0 – 1000 m. Total catch (TotCatch; t) is the total reported in the database, number of records used in the analysis (Records), reported catch (CatchT; t) in the area and depth used in the analysis and number of vessels used in the analysis (Vessels). GeoMean is the geometric mean of catch rates (kg/hr). The optimum model is Zone:Ves and standard deviation (StDev) relates to the data in the optimum model.

| Year | TotCatch | Records | CatchT | Vessels | GeoMean | Zone:Ves | StDev |
|---|---|---|---|---|---|---|---|
| 1987/1988 | 80.3340 | 453 | 76.8400 | 9 | 27.6907 | 0.4679 | 0.0000 |
| 1988/1989 | 317.2490 | 815 | 314.0740 | 9 | 56.0806 | 0.9390 | 0.0502 |
| 1989/1990 | 402.5570 | 1126 | 397.4970 | 7 | 53.0361 | 0.9633 | 0.0507 |
| 1990/1991 | 430.2310 | 1501 | 423.2260 | 11 | 49.0776 | 1.0404 | 0.0497 |
| 1991/1992 | 621.1150 | 1781 | 611.2140 | 13 | 54.5388 | 0.9522 | 0.0481 |
| 1992/1993 | 524.0620 | 984 | 509.2170 | 4 | 76.9248 | 1.2104 | 0.0500 |
| 1993/1994 | 593.1100 | 900 | 585.6450 | 7 | 91.4997 | 1.5531 | 0.0504 |
| 1994/1995 | 1285.9330 | 1745 | 1258.8930 | 6 | 106.3058 | 1.9671 | 0.0478 |
| 1995/1996 | 1585.1240 | 1862 | 1559.4390 | 5 | 125.2137 | 1.9094 | 0.0477 |
| 1996/1997 | 1499.2260 | 2784 | 1466.6360 | 8 | 79.3934 | 1.2654 | 0.0469 |
| 1997/1998 | 1029.9880 | 2908 | 1012.4710 | 10 | 50.9703 | 0.8971 | 0.0467 |
| 1998/1999 | 690.3890 | 2558 | 682.1710 | 7 | 34.6696 | 0.6678 | 0.0471 |
| 1999/2000 | 571.0500 | 2102 | 545.8370 | 7 | 39.1315 | 0.8121 | 0.0482 |
| 2000/2001 | 846.6200 | 2413 | 775.5200 | 6 | 43.0405 | 0.8781 | 0.0477 |
| 2001/2002 | 973.9438 | 2448 | 912.9710 | 6 | 51.5431 | 1.0460 | 0.0477 |
| 2002/2003 | 1711.5006 | 3144 | 1632.1305 | 8 | 73.4099 | 1.5175 | 0.0472 |
| 2003/2004 | 2272.7170 | 4536 | 2188.2269 | 10 | 68.4174 | 1.4288 | 0.0470 |
| 2004/2005 | 2158.9205 | 5551 | 2100.1866 | 10 | 55.0520 | 1.1513 | 0.0467 |
| 2005/2006 | 1433.1321 | 5349 | 1358.4065 | 11 | 37.5227 | 0.7493 | 0.0468 |
| 2006/2007 | 1015.4786 | 4254 | 969.1785 | 11 | 32.9286 | 0.6430 | 0.0467 |
| 2007/2008 | 1041.3325 | 4003 | 971.1735 | 7 | 35.9047 | 0.7236 | 0.0472 |
| 2008/2009 | 813.9210 | 3118 | 775.7370 | 5 | 40.6974 | 0.8516 | 0.0475 |
| 2009/2010 | 849.8300 | 3205 | 829.7290 | 4 | 39.1349 | 0.8012 | 0.0474 |
| 2010/2011 | 970.0015 | 2805 | 930.2880 | 4 | 50.8864 | 1.0292 | 0.0477 |
| 2011/2012 | 965.0510 | 3270 | 788.7420 | 4 | 38.5448 | 0.7888 | 0.0475 |
| 2012/2013 | 1017.8855 | 3611 | 876.1815 | 5 | 37.9414 | 0.7753 | 0.0473 |
| 2013/2014 | 882.6720 | 3304 | 672.6200 | 7 | 31.9933 | 0.6695 | 0.0474 |
| 2014/2015 | 544.6340 | 2572 | 484.7460 | 4 | 29.3345 | 0.6183 | 0.0480 |
| 2015/2016^ | 491.0775 | 996 | 231.2270 | 3 | 34.3758 | 0.6832 | 0.0513 |

^ subject to change, incomplete financial year

Table 8.122. Reported catch of Deepwater Flathead by method across all methods and years.

| Year | AL | BL | DL | DS | GN | OTT | PTB | TDO | TW |
|---|---|---|---|---|---|---|---|---|---|
| 1987/1988 | | | | | | | | | 80.3340 |
| 1988/1989 | | | | | | | | | 317.2490 |
| 1989/1990 | | | | | | | | | 402.5570 |
| 1990/1991 | | | | | | | | | 429.8560 |
| 1991/1992 | | | | | | | | | 620.2830 |
| 1992/1993 | | | | | | | | | 523.6620 |
| 1993/1994 | | | | | | | | | 593.1100 |
| 1994/1995 | | | | | | | | | 1278.8130 |
| 1995/1996 | | | | | | | | | 1582.3740 |
| 1996/1997 | | | | | | | | | 1497.8160 |
| 1997/1998 | | | | | | | | | 1029.8980 |
| 1998/1999 | | | 0.01 | | | | | | 690.0790 |
| 1999/2000 | | | | | | | | | 570.9100 |
| 2000/2001 | | | | | 0.0010 | | | | 846.6190 |
| 2001/2002 | | | | | 0.0033 | | | | 973.9405 |
| 2002/2003 | | | | | 0.0091 | | | | 1711.4915 |
| 2003/2004 | | | | | 0.0091 | | | | 2272.7079 |
| 2004/2005 | 0.001 | 0.021 | | | 0.1120 | | | | 2158.7865 |
| 2005/2006 | | | | | 0.0021 | | | | 1433.1300 |
| 2006/2007 | | | | | 0.0011 | | | | 1015.4775 |
| 2007/2008 | | | | | | | | | 1041.3325 |
| 2008/2009 | | | | | | | | | 813.9210 |
| 2009/2010 | | | | | | | | | 849.8300 |
| 2010/2011 | | | | 5.3030 | | | | 24.5290 | 940.1695 |
| 2011/2012 | | | | 136.6770 | | 13.5050 | | 606.9670 | 207.9020 |
| 2012/2013 | | | | 103.4930 | | 0.6500 | | 512.3310 | 401.4115 |
| 2013/2014 | | | | 83.7710 | | 5.3700 | 11.090 | 542.9380 | 239.5030 |
| 2014/2015 | | | | 18.8850 | | | | 490.4950 | 35.2540 |
| 2015/2016^ | | | | 79.4555 | | | | 389.5470 | 22.0750 |

^ subject to change, incomplete financial year

An examination of the depth distribution of catches suggests that this could be modified to become 100 – 300 m with essentially no loss of information and the outcomes do not differ from the base case adopted here (Figure 8.132; All vessels and 0 – 1000 m).

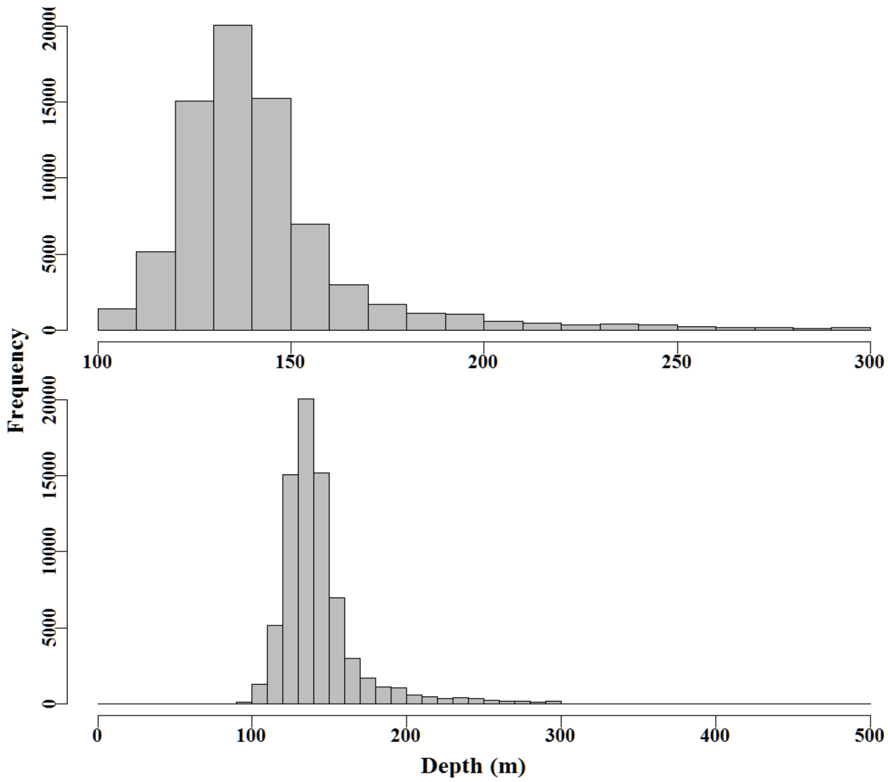



Figure 8.132. The depth distribution of records for the Deepwater Flathead fishery taken by Trawl in the GAB.

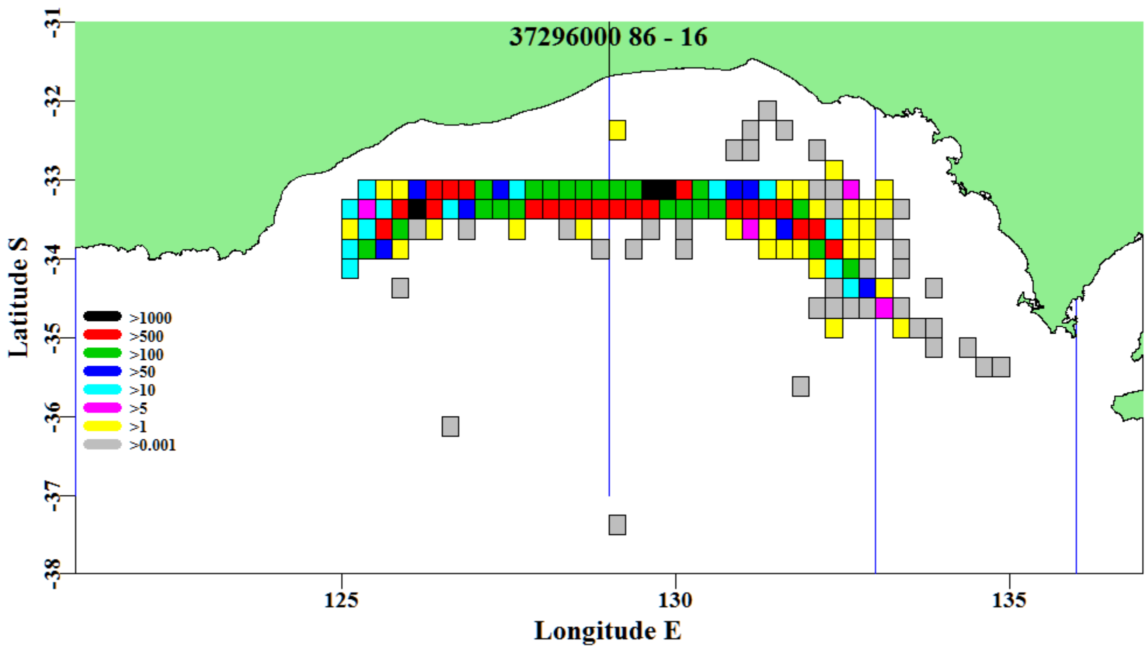



Figure 8.133. Schematic map of the distribution of catches of Deepwater Flathead from 1987/1988 to 2011/2012 taken by all methods (Table 8.122).

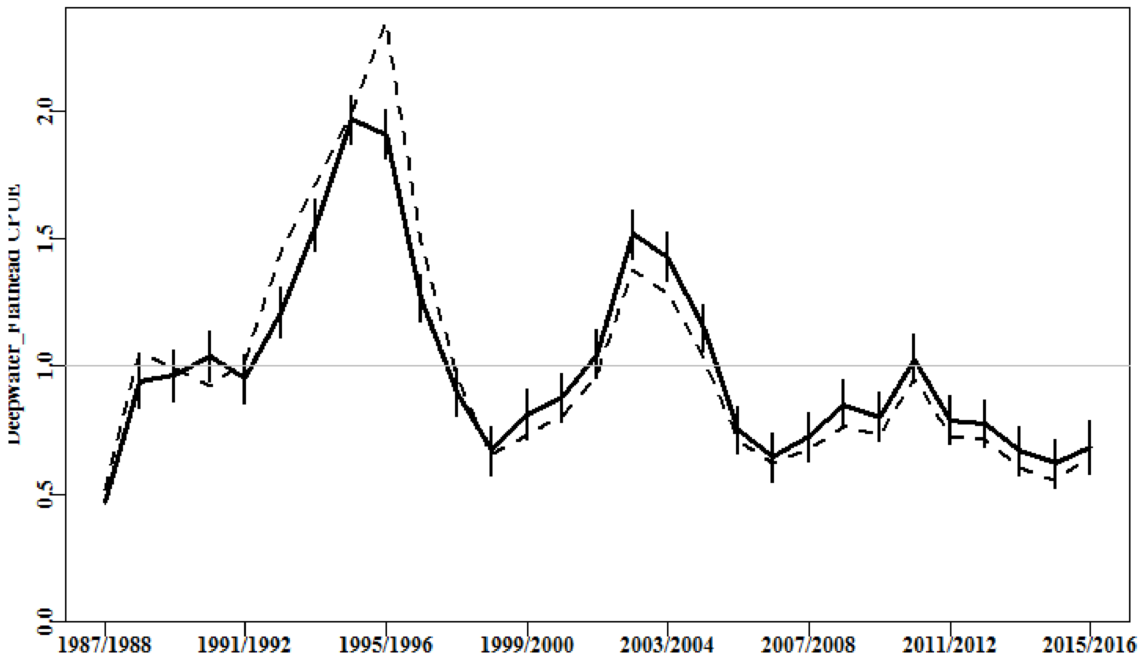



Figure 8.134. The standardized CPUE for Deepwater Flathead from the trawl fishery in the GAB. The dashed black line represents the geometric mean catch rate, solid black line the standardized catch rates and blue line the standardized catch rates based on last year's analysis. The graph standardizes catch rates relative to the mean of the standardized catch rates.

Table 8.123. Deepwater Flathead from the trawl fishery in the GAB by Trawl from 0 – 1000 m. Statistical model structures used in this analysis. DepCat is a series of 50 metre depth categories.

| | |
|---|---|
| Model 1 | LnCE~Year |
| Model 2 | LnCE~Year+Vessel |
| Model 3 | LnCE~Year+Vessel + Zone |
| Model 4 | LnCE~Year+Vessel + Zone + Month |
| Model 5 | LnCE~Year+Vessel + Zone + Month +DepCat |
| Model 6 | LnCE~Year+Vessel + Zone + Month +DepCat +DayNight |
| Model 7 | LnCE~Year+Vessel + Zone + Month +DepCat +DayNight + Zone:Month |
| Model 8 | LnCE~Year+Vessel + Zone + Month +DepCat +DayNight + Zone:Vessel |
| Model 9 | LnCE~Year+Vessel + Zone + Month +DepCat +DayNight + Zone:DepCat |

Table 8.124. Deepwater Flathead from the trawl fishery in the GAB by Trawl from 0 – 1000 m. Model selection criteria include the Akaike Information Criterion (AIC), residual sum of squares (RSS), model sum of squares (MSS), number of usable observations (Nobs), number of parameters (Npars), adjusted $R^2$ (adj_$R^2$) and the change in adjusted $R^2$ (%Change). The optimum model is Zone:Ves (Model 8). Depth category: DepC; Vessel: Ves; Month: Mth.

| | Year | Ves | Zone | Month | DepC | DayNight | Zone:Mth | Zone:Ves | Zone:DepC |
|---|---|---|---|---|---|---|---|---|---|
| AIC | -31062 | -37097 | -41900 | -45582 | -47351 | -49182 | -50204 | -51160 | -49866 |
| RSS | 50556 | 46650 | 43755 | 41676 | 40091 | 39126 | 38532 | 37859 | 38496 |
| MSS | 9074 | 12980 | 15874 | 17954 | 19538 | 20503 | 21097 | 21770 | 21133 |
| Nobs | 76098 | 76098 | 76060 | 76060 | 75394 | 75394 | 75394 | 75394 | 75394 |
| Npars | 29 | 71 | 76 | 88 | 133 | 136 | 202 | 388 | 406 |
| adj_$R^2$ | 15.186 | 21.695 | 26.548 | 30.029 | 32.648 | 34.267 | 35.208 | 36.182 | 35.092 |
| %Change | 0.000 | 6.510 | 4.853 | 3.480 | 2.619 | 1.619 | 0.942 | 0.974 | -1.090 |

### 8.4.43 *Bight Redfish (FLD – 37258004 – Centroberyx gerrardi)*

Data from the GAB fishery used in the analysis was based on depths between 0 – 1000 m, taken by Trawl. Also, analyses were restricted to vessels present for more than two years and which caught an average annual catch > 4 t, and that trawled for more than one hour but less than 10 hours. Instead of 5 degree zones across the GAB, 2.5 degree zones were employed to allow better resolution of location based differences in CPUE. An examination of the depth distribution of catches suggests that this could be modified to become 100 – 250 m with essentially no loss of information and the outcomes do not differ from the base case adopted here Figure 8.135; All vessels and 0 – 1000 m). Catches in 1986/1987 were relatively low and only taken by a single vessel and so were omitted from analysis.

Table 8.125. Bight Redfish taken by Trawl in the GAB in depths between 0 – 1000 m. Total catch (TotCatch; t) is the total reported in the database, number of records used in the analysis (Records), reported catch (CatchT; t) in the area and depth used in the analysis and number of vessels used in the analysis (Vessels). GeoMean is the geometric mean of catch rates (kg/hr). The optimum model is Zone:DepC and standard deviation (StDev) relates to the data in the optimum model.

| Year | TotCatch | Records | CatchT | Vessels | GeoMean | Zone:DepC | StDev |
|---|---|---|---|---|---|---|---|
| 1987/1988 | 47.4340 | 184 | 32.7530 | 4 | 29.2533 | 2.3930 | 0.0000 |
| 1988/1989 | 87.9610 | 492 | 85.8800 | 6 | 32.9965 | 2.3184 | 0.1015 |
| 1989/1990 | 173.5590 | 827 | 171.5770 | 7 | 31.8857 | 1.5813 | 0.0996 |
| 1990/1991 | 290.1385 | 1023 | 250.2255 | 8 | 36.6457 | 1.4044 | 0.0980 |
| 1991/1992 | 274.0490 | 1101 | 240.4430 | 7 | 27.4447 | 1.2844 | 0.0962 |
| 1992/1993 | 132.0980 | 718 | 120.1880 | 3 | 18.3377 | 0.9481 | 0.0985 |
| 1993/1994 | 108.6860 | 695 | 107.4180 | 5 | 16.2182 | 0.9391 | 0.0990 |
| 1994/1995 | 163.5980 | 1282 | 159.9070 | 6 | 11.9237 | 0.6567 | 0.0946 |
| 1995/1996 | 176.9320 | 1395 | 175.2770 | 5 | 11.8016 | 0.7942 | 0.0947 |
| 1996/1997 | 334.0670 | 2036 | 329.7770 | 6 | 15.3383 | 0.9594 | 0.0930 |
| 1997/1998 | 375.8710 | 1930 | 365.9310 | 7 | 16.0229 | 0.9701 | 0.0933 |
| 1998/1999 | 442.2460 | 1812 | 440.2960 | 7 | 20.2349 | 1.1147 | 0.0933 |
| 1999/2000 | 328.3430 | 1478 | 324.4210 | 7 | 17.1853 | 0.9701 | 0.0955 |
| 2000/2001 | 398.7389 | 1697 | 387.5310 | 5 | 15.6494 | 0.8559 | 0.0947 |
| 2001/2002 | 232.9888 | 1637 | 225.6420 | 5 | 10.8567 | 0.6710 | 0.0949 |
| 2002/2003 | 378.0266 | 2118 | 364.3121 | 8 | 13.4661 | 0.7138 | 0.0937 |
| 2003/2004 | 862.0778 | 3154 | 841.7250 | 10 | 20.1099 | 0.9815 | 0.0933 |
| 2004/2005 | 889.9464 | 3808 | 758.0925 | 9 | 18.3742 | 0.9521 | 0.0929 |
| 2005/2006 | 802.9481 | 3553 | 722.8482 | 10 | 17.4248 | 0.9098 | 0.0930 |
| 2006/2007 | 961.6332 | 3293 | 873.7396 | 10 | 21.7750 | 0.9435 | 0.0927 |
| 2007/2008 | 759.0168 | 2743 | 683.5350 | 6 | 20.0988 | 0.9031 | 0.0935 |
| 2008/2009 | 665.4162 | 2443 | 648.7860 | 4 | 21.9054 | 0.9693 | 0.0941 |
| 2009/2010 | 463.7251 | 2298 | 445.7170 | 4 | 17.3788 | 0.8878 | 0.0941 |
| 2010/2011 | 286.5087 | 1851 | 277.8890 | 4 | 14.2664 | 0.7144 | 0.0948 |
| 2011/2012 | 330.9570 | 2188 | 322.8650 | 4 | 14.4195 | 0.7170 | 0.0945 |
| 2012/2013 | 266.9629 | 1873 | 255.7050 | 4 | 15.2641 | 0.6291 | 0.0950 |
| 2013/2014 | 199.6347 | 1494 | 187.5580 | 4 | 14.6071 | 0.5827 | 0.0959 |
| 2014/2015 | 239.2200 | 1396 | 233.3710 | 4 | 16.9298 | 0.6112 | 0.0966 |
| 2015/2016^ | 144.3841 | 389 | 41.1280 | 3 | 12.2527 | 0.6240 | 0.1087 |

^ subject to change; incomplete financial year

Table 8.126. Reported catch of Bight Redfish by method and years.

| Year | Line | GN | PS | DS | Trawl |
|---|---|---|---|---|---|
| 1987/1988 | | | | | 317.3330 |
| 1988/1989 | | | | | 314.5200 |
| 1989/1990 | | | | | 0.2280 |
| 1990/1991 | | | | | 3.4320 |
| 1991/1992 | | | | | 58.7140 |
| 1992/1993 | | | | | 22.0120 |
| 1993/1994 | | | | | 47.4340 |
| 1994/1995 | | | | | 87.9610 |
| 1995/1996 | | | | | 173.5590 |
| 1996/1997 | | | | | 290.1385 |
| 1997/1998 | | | | | 274.0490 |
| 1998/1999 | | | | 0.0100 | 131.4380 |
| 1999/2000 | | | | | 108.6860 |
| 2000/2001 | | | | | 162.3110 |
| 2001/2002 | | | | | 176.9020 |
| 2002/2003 | | | | | 334.0470 |
| 2003/2004 | | | | | 375.8110 |
| 2004/2005 | | | | | 442.2160 |
| 2005/2006 | | | | | 328.3430 |
| 2006/2007 | | 1.0369 | | | 397.7020 |
| 2007/2008 | 0.6440 | 3.1238 | | | 229.2210 |
| 2008/2009 | 0.0035 | 3.3255 | | | 374.6956 |
| 2009/2010 | 0.0170 | 4.9658 | | | 857.0920 |
| 2010/2011 | 0.0040 | 5.2114 | | 0.0040 | 884.7160 |
| 2011/2012 | 0.2452 | 6.4947 | 30 | | 766.2082 |
| 2012/2013 | 0.1821 | 7.9965 | | | 953.4546 |
| 2013/2014 | 0.1512 | 7.7796 | | | 751.0860 |
| 2014/2015 | 0.0550 | 8.1033 | | | 657.2580 |
| 2015/2016^ | 0.0880 | 5.3801 | | | 458.2570 |

^ subject to change

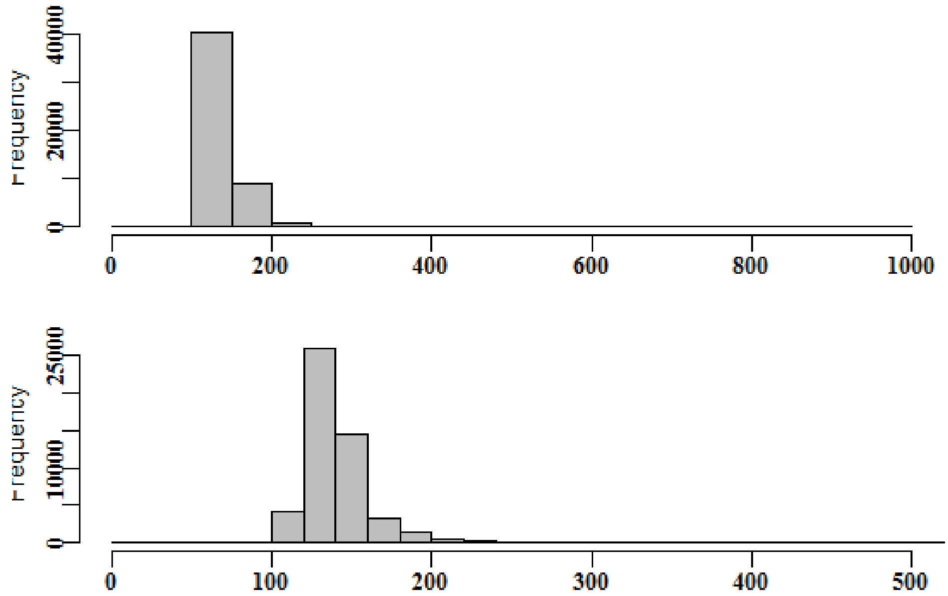


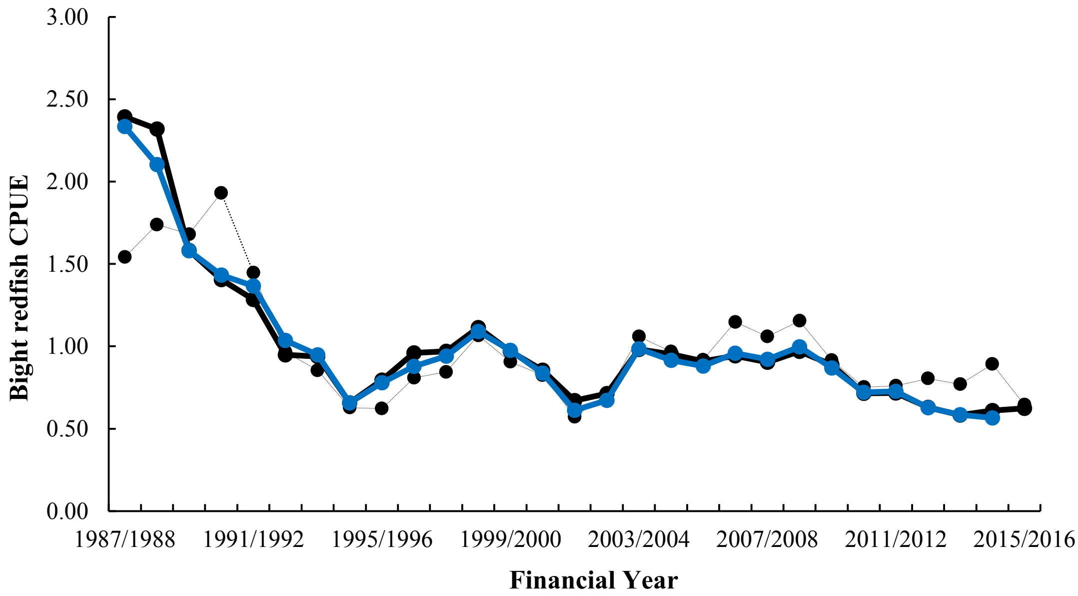

Figure 8.135. The depth (m) distribution of records for the Bight Redfish fishery taken by Trawl in the GAB.

Table 8.127. Bight Redfish in the GAB by Trawl from 0 – 1000 m. Statistical model structures used in this analysis. DepCat is a series of 20 metre depth categories.

| | |
|---|---|
| Model 1 | LnCE~Year |
| Model 2 | LnCE~Year+ DayNight |
| Model 3 | LnCE~Year+ DayNight + Zone |
| Model 4 | LnCE~Year+ DayNight + Zone + Month |
| Model 5 | LnCE~Year+ DayNight + Zone + Month +Vessel |
| Model 6 | LnCE~Year+ DayNight + Zone + Month + Vessel + DepCat |
| Model 7 | LnCE~Year+ DayNight + Zone + Month + Vessel + DepCat + Zone:Month |
| Model 8 | LnCE~Year+ DayNight + Zone + Month + Vessel + DepCat + Zone:Vessel |
| Model 9 | LnCE~Year+ DayNight + Zone + Month + Vessel + DepCat + Zone:DepCat |

Table 8.128. Bight Redfish in the GAB by Trawl from 0 – 1000 m. Model selection criteria include the Akaike Information Criterion (AIC), residual sum of squares (RSS), model sum of squares (MSS), number of usable observations (Nobs), number of parameters (Npars), adjusted $R^2$ (adj_$R^2$) and the change in adjusted $R^2$ (%Change). The optimum model is Zone:DepC (Model 7). Depth category: DepC; Vessel: Ves.

| | Year | DayNight | Zone | Month | Ves | DepC | Zone:Month | Zone:Ves | Zone:DepC |
|---|---|---|---|---|---|---|---|---|---|
| AIC | 31551 | 25575 | 20318 | 16271 | 15018 | 14484 | 13655 | 13976 | 13148 |
| RSS | 94504 | 84027 | 75759 | 69940 | 68186 | 66913 | 65592 | 65823 | 64443 |
| MSS | 3063 | 13539 | 21808 | 27626 | 29381 | 30653 | 31974 | 31743 | 33123 |
| Nobs | 50908 | 50908 | 50908 | 50908 | 50908 | 50416 | 50416 | 50416 | 50416 |
| adj_$R^2$ | 3.086 | 13.825 | 22.292 | 28.245 | 30.017 | 31.275 | 32.513 | 32.178 | 33.441 |
| %Change | 0.000 | 10.739 | 8.467 | 5.953 | 1.773 | 1.257 | 1.239 | -0.335 | 1.263 |



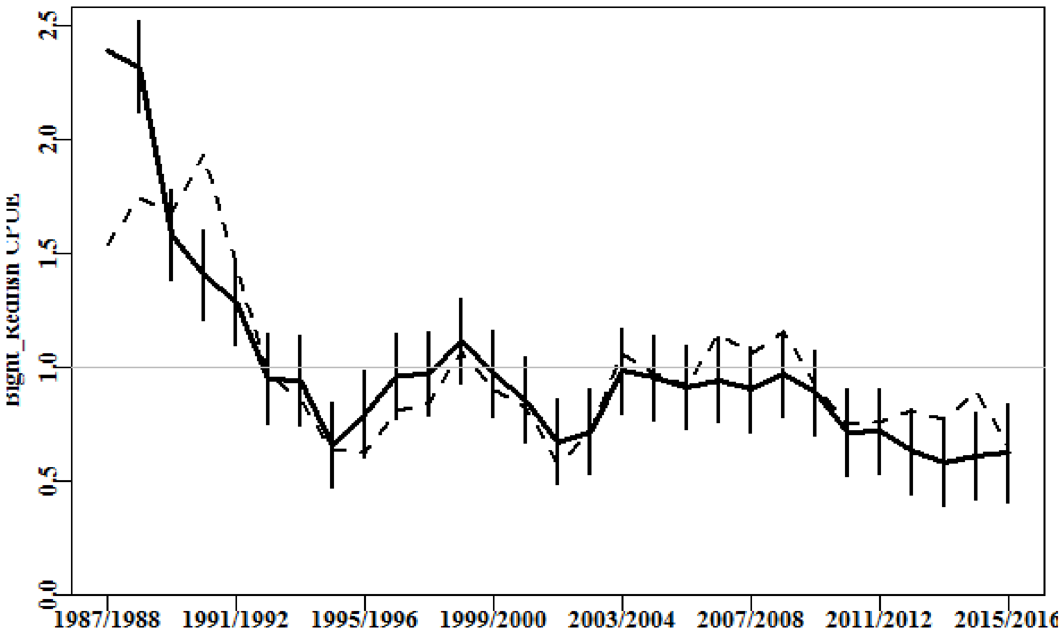




Figure 8.136. The standardized CPUE for Bight Redfish from the trawl fishery in the GAB. Upper graph: The solid black line corresponds to the standardized catch rates (relative to the mean of the standardized catch rates). The blue line corresponds to last year's standardized catch rates and geometric mean (dashed black line). Lower graph: Standardized catch rates (solid black line), 95% CI (vertical lines) and geometric mean (dashed black line).

## 8.5 Deepwater species

Catch rates for deepwater sharks and oreos are considered here. Both mixed oreos (a basket of oreo species), as well as smooth oreos requires attention however (Table 8.129).

Table 8.129. End of season catches obtained from the summary Catch-Watch data on the AFMA website. These catches are for the May through to April rather than the calendar years of the CPUE analyses.

| Common name | Agreed TAC (t) | TAC with over & under-catch (t) | Catch (t) | Available TAC (%) | TAC caught (%) | Available TAC (%) |
|---|---|---|---|---|---|---|
| Deepwater Sharks East | 47 | 50.762 | 22.285 | 28.477 | 44 | 56 |
| Deepwater Sharks West | 215 | 231.059 | 68.250 | 162.809 | 30 | 70 |
| Orange Roughy (Albany-Esperance) | 50 | 50.000 | 0.000 | 50.000 | 0 | 100 |
| Orange Roughy (Cascade Plateau) | 500 | 549.744 | 2.009 | 547.735 | 0 | 100 |
| Orange Roughy (Eastern) | 465 | 465.000 | 436.384 | 28.617 | 94 | 6 |
| Orange Roughy (Southern) | 66 | 66.000 | 57.225 | 8.775 | 87 | 13 |
| Orange Roughy (Western) | 60 | 60.000 | 22.297 | 37.703 | 37 | 63 |
| Oreos | 128 | 140.296 | 111.040 | 29.256 | 79 | 21 |
| Smooth Oreos (Cascade Plateau) | 150 | 165.000 | 0.000 | 165.000 | 0 | 100 |
| Smooth Oreos (other) | 23 | 25.177 | 21.337 | 3.840 | 85 | 15 |

### 8.5.1 *Eastern Deepwater Sharks*

Table 8.130. The names of the various species identified in the catch and effort database.

| CAAB Code | Common Name | Scientific Name |
|---|---|---|
| 37020000 | Dogfish | Squalidae |
| 37020002 | Black | *Dalatias licha* |
| 37020003 | Brier | *Deania calcea* |
| 37020004 | Platypus | *Deania quadrispinosa* |
| 37020013 | Plunket's Dogfish | *Centroscymnus plunketi* |
| 37020904 | Roughskin | *Centroscymnus & Deania sps.* |
| 37020905 | Pearl | *Deania calcea & D. quadrispinosa* |
| 37020906 | Black (roughskin) | *Centroscymnus sps.* |
| 37990003 | Other Sharks | Other Sharks |

This basket quota group is made up of many recognized species but only ten have any records, and only eight of these have any significant catches. Dogfish and Other Sharks dominate catches until about 2000. The Black Shark is possibly confounded with two group categories, the Roughskin and the Black Shark – Roughskin. Plunket's Dogfish is possibly confounded with the Roughskin Shark group. Similarly, the Pearl Shark group is a combination of the Brier and Platypus Sharks. The reported distributions of the Brier shark, the Roughskin Shark, and especially the Plunket's Dogfish categories are much less widespread than the others. A number of the fishery characteristics for eastern deepwater sharks have been described in Haddon (2014a).

Table 8.131. Statistical model structures used with Deepwater Sharks. DepCat is a series of 20 metre depth categories. Deep relates to whether the area is open or closed. DayNight reduced the quality of fit.

| | |
|---|---|
| Model 1 | LnCE ~ Year |
| Model 2 | LnCE ~ Year + Vessel |
| Model 3 | LnCE ~ Year + Vessel + DepCat |
| Model 4 | LnCE ~ Year + Vessel + DepCat + ORZone |
| Model 5 | LnCE ~ Year + Vessel + DepCat + ORZone + Month |
| Model 6 | LnCE ~ Year + Vessel + DepCat + ORZone + Month + deep |
| Model 7 | LnCE ~ Year + Vessel + DepCat + ORZone + Month + deep + ORZone:Month |
| Model 8 | LnCE ~ Year + Vessel + DepCat + ORZone + Month + deep + Vessel:Month |

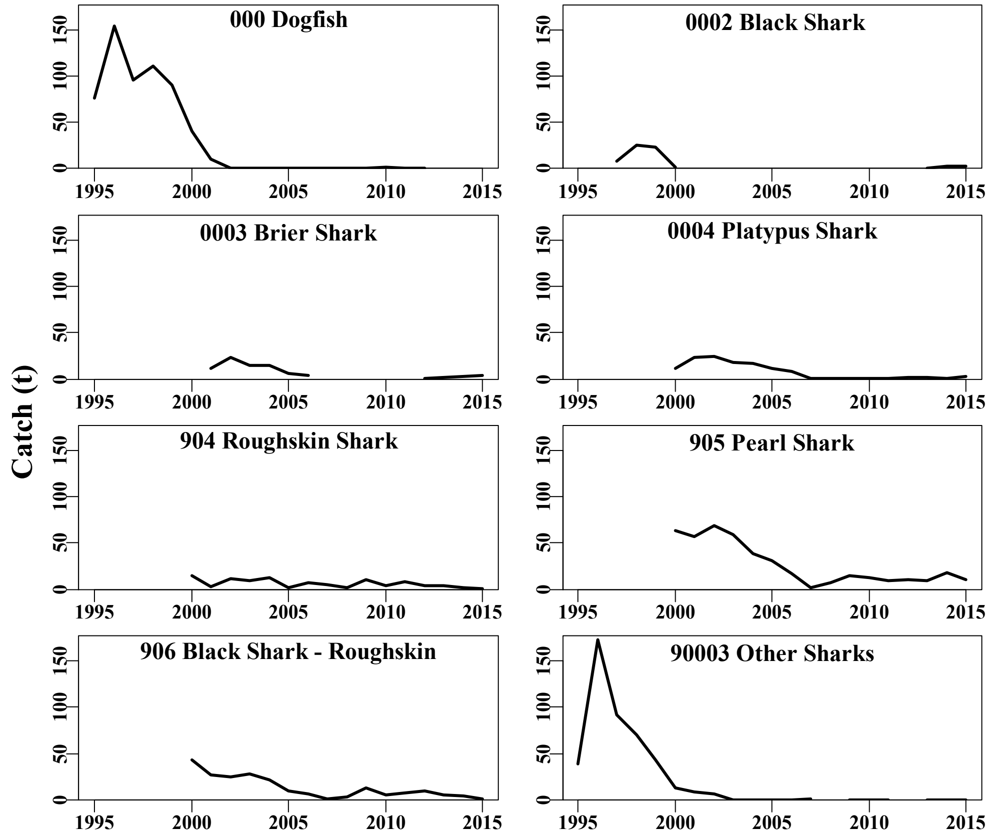



Figure 8.137. Annual catch (t) of deepwater sharks in the east.

Table 8.132. Eastern deepwater sharks. Model selection criteria include the Akaike Information Criterion (AIC), residual sum of squares (RSS), model sum of squares (MSS), number of usable observations (Nobs), number of parameters (Npars), adjusted $R^2$ (adj_$R^2$) and the increment in adjusted $R^2$ (D $R^2$). The model including the ORZone:Mth interaction term (Model 7) was optimal. There was a trivial effect of being in the open or closed areas (Deep) on the statistical model fit. Year, Vessel, and DepCat dominated the analysis. The DayNight factor was omitted because it detracted from the fit. Depth category: DepC; Month: Mth.

| | Year | Vessel | DepC | ORZone | Month | Deep | ORZone:Mth | Vessel:Month |
|---|---|---|---|---|---|---|---|---|
| AIC | 3720 | 2059 | 1153 | 1139 | 991 | 986 | 957 | 1950 |
| RSS | 15869 | 13556 | 12246 | 12206 | 12038 | 12031 | 11907 | 11255 |
| MSS | 2654 | 4967 | 6278 | 6317 | 6485 | 6492 | 6616 | 7268 |
| Nobs | 11537 | 11537 | 11275 | 11275 | 11275 | 11275 | 11275 | 11275 |
| Npars | 21 | 99 | 111 | 122 | 126 | 127 | 171 | 985 |
| adj_$R^2$ | 14.179 | 26.189 | 33.239 | 33.388 | 34.280 | 34.313 | 34.733 | 33.428 |
| % $R^2$ | 0.000 | 12.010 | 7.051 | 0.148 | 0.893 | 0.032 | 0.421 | -1.305 |

Table 8.133. Number of records where Eastern Deepwater Sharks are reported from trawling in OR Zones 10, 20, 21, and 50, in depths 600 to 1250 m. Vessel represents the count of vessels reporting eastern deepwater sharks. Yield is the total reported catch in tonnes. The geometric mean CE is the raw unstandardized catch rate in kg/hour. The left hand five columns represent all data, the right hand five columns represent the areas left open following the 700m closure.

| Year | Yield | Records | Effort | Vessels | Geom | YieldO | RecordsO | EffortO | VesselsO | GeomO |
|---|---|---|---|---|---|---|---|---|---|---|
| 1986 | 28.926 | 254 | 1051.900 | 25 | 11.827 | 26.601 | 215 | 913.070 | 25 | 11.936 |
| 1987 | 5.792 | 97 | 326.630 | 26 | 8.745 | 4.705 | 84 | 280.930 | 21 | 8.721 |
| 1988 | 5.246 | 38 | 137.000 | 18 | 14.679 | 4.735 | 30 | 110.100 | 15 | 15.285 |
| 1989 | 5.106 | 69 | 219.600 | 16 | 13.865 | 4.493 | 60 | 191.100 | 14 | 13.310 |
| 1990 | 5.352 | 42 | 124.600 | 17 | 16.157 | 2.383 | 22 | 67.100 | 15 | 7.275 |
| 1991 | 18.574 | 105 | 316.030 | 19 | 24.887 | 8.922 | 70 | 212.300 | 18 | 21.914 |
| 1992 | 62.977 | 103 | 467.380 | 18 | 36.871 | 4.465 | 39 | 210.030 | 13 | 12.201 |
| 1993 | 93.604 | 258 | 967.800 | 19 | 47.054 | 22.347 | 94 | 356.570 | 16 | 23.760 |
| 1994 | 110.394 | 420 | 1604.940 | 25 | 37.705 | 38.693 | 210 | 809.550 | 23 | 30.290 |
| 1995 | 114.285 | 359 | 1452.710 | 17 | 50.193 | 63.009 | 219 | 850.220 | 16 | 49.853 |
| 1996 | 326.351 | 952 | 3712.390 | 26 | 52.295 | 263.351 | 775 | 2978.510 | 23 | 50.875 |
| 1997 | 194.116 | 903 | 4091.140 | 24 | 30.823 | 141.462 | 699 | 3130.440 | 22 | 29.977 |
| 1998 | 205.896 | 1102 | 4989.310 | 24 | 27.601 | 175.869 | 947 | 4174.520 | 23 | 27.799 |
| 1999 | 156.767 | 1008 | 4668.600 | 25 | 22.184 | 135.044 | 867 | 3968.760 | 23 | 22.016 |
| 2000 | 187.075 | 889 | 4252.450 | 29 | 27.855 | 150.603 | 700 | 3311.090 | 25 | 28.334 |
| 2001 | 140.686 | 892 | 4119.220 | 27 | 19.961 | 114.661 | 725 | 3291.450 | 26 | 21.440 |
| 2002 | 160.721 | 891 | 4230.080 | 28 | 23.381 | 129.724 | 737 | 3423.110 | 26 | 23.016 |
| 2003 | 128.789 | 963 | 4744.890 | 25 | 16.848 | 92.133 | 732 | 3483.100 | 22 | 16.950 |
| 2004 | 103.248 | 716 | 3459.050 | 29 | 17.959 | 75.417 | 564 | 2696.830 | 26 | 18.117 |
| 2005 | 61.376 | 477 | 2470.230 | 16 | 15.739 | 48.839 | 371 | 1915.540 | 14 | 16.143 |
| 2006 | 43.227 | 408 | 1959.920 | 21 | 11.414 | 34.263 | 287 | 1316.920 | 20 | 14.861 |
| 2007 | 8.418 | 106 | 493.530 | 17 | 10.127 | 8.378 | 104 | 484.040 | 17 | 10.304 |
| 2008 | 12.904 | 100 | 658.310 | 10 | 10.800 | 11.734 | 95 | 619.650 | 10 | 10.259 |
| 2009 | 38.892 | 230 | 1226.840 | 14 | 16.957 | 38.068 | 224 | 1181.760 | 14 | 17.134 |
| 2010 | 24.806 | 244 | 1264.020 | 13 | 10.087 | 22.826 | 230 | 1162.540 | 13 | 10.256 |
| 2011 | 25.171 | 242 | 1351.790 | 15 | 10.976 | 23.614 | 233 | 1307.570 | 15 | 10.651 |
| 2012 | 25.926 | 278 | 1544.690 | 16 | 8.911 | 25.663 | 271 | 1494.620 | 16 | 9.085 |
| 2013 | 20.775 | 252 | 1362.100 | 15 | 8.595 | 18.728 | 225 | 1206.170 | 15 | 8.702 |
| 2014 | 30.646 | 283 | 1833.230 | 13 | 11.289 | 29.491 | 273 | 1748.730 | 13 | 11.369 |
| 2015 | 22.379 | 242 | 1532.490 | 13 | 9.001 | 21.859 | 238 | 1497.710 | 13 | 8.973 |

Table 8.134. The standardized catch rates for the alternative statistical models for Eastern Deepwater Sharks in OR zones10, 20, 21, and 50, in depths 600 to 1250 m. The optimal model was Model 7 (ORZone:Mth). St Err is the estimate of standard error for the optimum model. Values are relative to the mean of the standardized catch rates. The models for Deep and Vessel:Month were omitted for brevity.

| Year | Year | Vessel | DepCat | ORzone | Month | Deep | ORZone:Mth | StErr |
|---|---|---|---|---|---|---|---|---|
| 1995 | 2.5444 | 2.2206 | 2.0409 | 2.0590 | 2.0988 | 2.1302 | 2.1026 | 0.0000 |
| 1996 | 2.6579 | 2.9169 | 2.9018 | 2.9112 | 2.5329 | 2.5437 | 2.5265 | 0.0727 |
| 1997 | 1.5667 | 1.6120 | 1.4546 | 1.4567 | 1.3935 | 1.4004 | 1.4192 | 0.0708 |
| 1998 | 1.4027 | 1.3214 | 1.1854 | 1.1917 | 1.2087 | 1.2071 | 1.2192 | 0.0701 |
| 1999 | 1.1275 | 1.1274 | 0.9850 | 0.9863 | 1.0088 | 1.0073 | 0.9936 | 0.0702 |
| 2000 | 1.4159 | 1.3791 | 1.2043 | 1.1953 | 1.2080 | 1.2056 | 1.1875 | 0.0715 |
| 2001 | 1.0146 | 1.0755 | 0.9853 | 0.9801 | 1.0331 | 1.0284 | 1.0382 | 0.0724 |
| 2002 | 1.1884 | 1.1656 | 1.0850 | 1.0956 | 1.1365 | 1.1340 | 1.1278 | 0.0723 |
| 2003 | 0.8563 | 0.8721 | 0.7848 | 0.7834 | 0.7999 | 0.8015 | 0.8093 | 0.0720 |
| 2004 | 0.9130 | 0.8581 | 0.7881 | 0.7829 | 0.8149 | 0.8149 | 0.8187 | 0.0742 |
| 2005 | 0.8006 | 0.7947 | 0.7605 | 0.7611 | 0.7775 | 0.7788 | 0.7734 | 0.0800 |
| 2006 | 0.5807 | 0.5635 | 0.6775 | 0.6724 | 0.6717 | 0.6723 | 0.6780 | 0.0827 |
| 2007 | 0.5177 | 0.4993 | 0.7643 | 0.7594 | 0.7743 | 0.7684 | 0.7656 | 0.1286 |
| 2008 | 0.5523 | 0.6119 | 0.9589 | 0.9587 | 0.9811 | 0.9775 | 0.9733 | 0.1275 |
| 2009 | 0.8638 | 0.9315 | 1.1493 | 1.1444 | 1.1435 | 1.1378 | 1.1461 | 0.0971 |
| 2010 | 0.5138 | 0.5722 | 0.6172 | 0.6136 | 0.6336 | 0.6298 | 0.6312 | 0.0944 |
| 2011 | 0.5590 | 0.5504 | 0.6100 | 0.6106 | 0.6419 | 0.6365 | 0.6457 | 0.0962 |
| 2012 | 0.4537 | 0.4687 | 0.5290 | 0.5312 | 0.5617 | 0.5569 | 0.5649 | 0.0919 |
| 2013 | 0.4377 | 0.4332 | 0.4901 | 0.4899 | 0.4967 | 0.4947 | 0.5077 | 0.0930 |
| 2014 | 0.5748 | 0.5605 | 0.5500 | 0.5384 | 0.5814 | 0.5771 | 0.5780 | 0.0889 |
| 2015 | 0.4585 | 0.4655 | 0.4780 | 0.4782 | 0.5014 | 0.4971 | 0.4934 | 0.0946 |

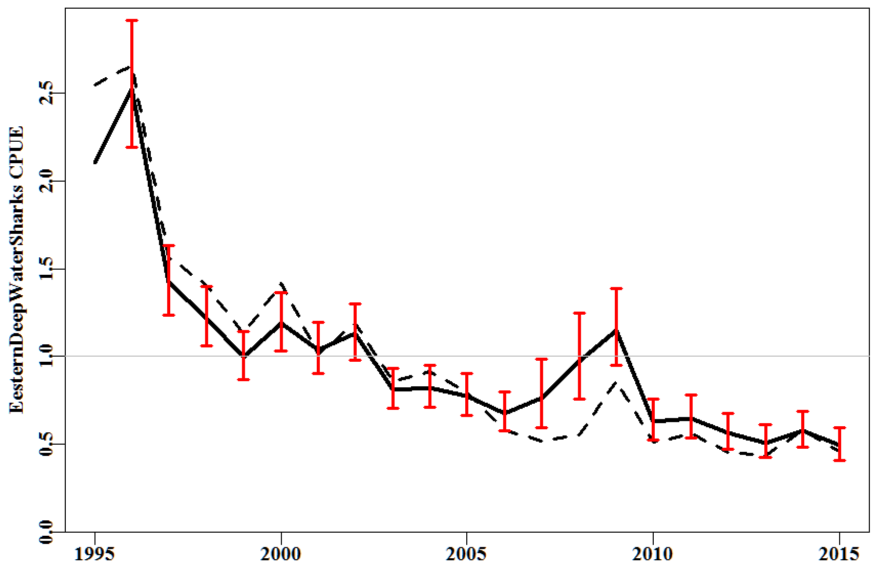



Figure 8.138. Eastern Deepwater Sharks reported from trawling in OR Zones 10, 20, 21, and 50, in depths 600 to 1250 m. The black dashed line from 86-14 represents the geometric mean catch rate and the solid black line the optimum standardized catch rates (Model 7). The graph scales the catch rates relative to the mean of the standardized catch rates (depicted by the horizontal grey line at 1.0).

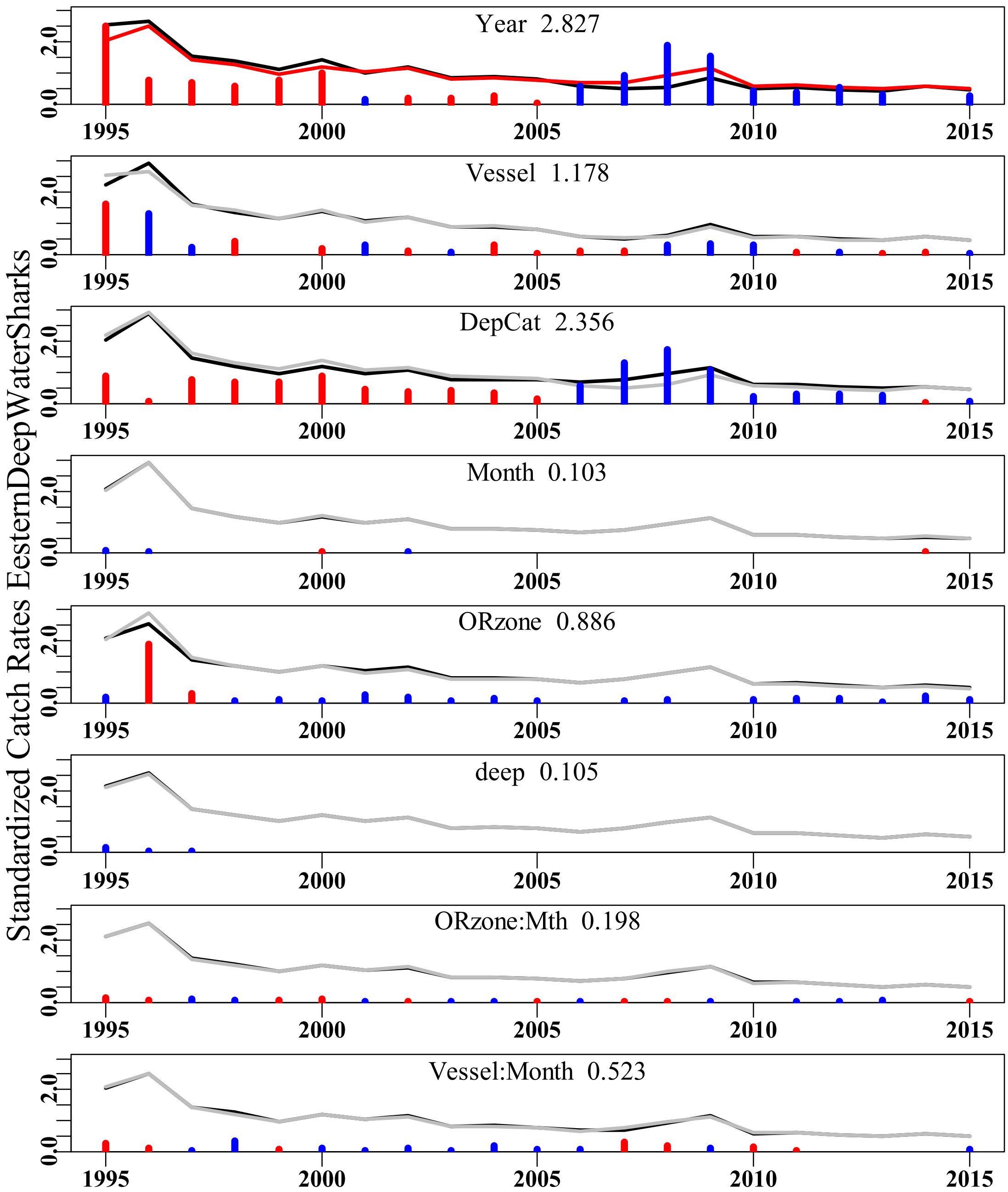



Figure 8.139. The relative impact of the different factors on the changes in the standardized trend. The major effects of both the structural adjustment that occurred across Nov 2005 – Nov 2006, with its change of vessels, and the deepwater closures is clear.

### 8.5.2 *Western Deepwater Sharks*

There are numerous species grouped together into the Western Deepwater Sharks (Table 8.135) but only some have data and even fewer have significant catches reported.

Table 8.135. The names of the various species identified in the catch and effort database.

| CAAB Code | Common Name | Scientific Name |
|---|---|---|
| 37020000 | Dogfish | Squalidae |
| 37020002 | Black | *Dalatias licha* |
| 37020003 | Brier | *Deania calcea* |
| 37020004 | Platypus | *Deania quadrispinosa* |
| 37020904 | Roughskin | *Centroscymnus & Deania sps.* |
| 37020905 | Pearl | *Deania calcea & D. quadrispinosa* |
| 37020906 | Black (roughskin) | *Centroscymnus sps.* |
| 37990003 | Other Sharks | Other Sharks |

This basket quota group is made up of many recognized species but only seven have any records, and only four have any significant catches reported recently. The Black Shark is possibly confounded with two group categories, the Roughskin and the Black Shark – Roughskin. Similarly, the Pearl Shark is a combination of the Brier and Platypus Sharks.

Table 8.136. Statistical model structures used with Western Deepwater Sharks. DepCat is a series of 20 metre depth categories. Deep relates to whether the area is open or closed.

| | |
|---|---|
| Model 1 | Year |
| Model 2 | Year + Vessel |
| Model 3 | Year + Vessel + DepCat |
| Model 4 | Year + Vessel + DepCat + Month |
| Model 5 | Year + Vessel + DepCat + Month + DayNight |
| Model 6 | Year + Vessel + DepCat + Month + DayNight + Deep |
| Model 7 | Year + Vessel + DepCat + Month + DayNight + Deep + Vessel:Month |

Table 8.137. Statistical model structures used with Western Deepwater Sharks. DepCat is a series of 20 metre depth categories. Deep relates to whether the area is open or closed.

| Year | Yield | Records | Effort | Vessels | Geom | YieldO | RecordsO | EffortO | VesselsO | GeomO |
|---|---|---|---|---|---|---|---|---|---|---|
| 1986 | 1.030 | 14 | 56.400 | 3 | 13.861 | 0.600 | 8 | 30.800 | 3 | 13.346 |
| 1987 | 0.558 | 19 | 61.500 | 4 | 7.496 | 0.453 | 15 | 48.000 | 3 | 7.444 |
| 1988 | 0.525 | 4 | 11.000 | 2 | 46.530 | 0.100 | 1 | 2.000 | 1 | 50.000 |
| 1989 | 1.200 | 13 | 40.000 | 2 | 28.124 | 0.490 | 6 | 19.500 | 2 | 23.730 |
| 1990 | 0.250 | 4 | 13.000 | 3 | 9.554 | 0.250 | 4 | 13.000 | 3 | 9.554 |
| 1991 | 0.315 | 5 | 17.600 | 3 | 12.628 | 0.195 | 2 | 5.300 | 2 | 20.226 |
| 1992 | 3.580 | 20 | 94.160 | 3 | 32.371 | 3.440 | 18 | 86.160 | 3 | 34.984 |
| 1993 | 1.785 | 17 | 60.750 | 3 | 21.610 | 1.635 | 14 | 50.750 | 3 | 23.369 |
| 1994 | 1.512 | 22 | 127.810 | 3 | 9.830 | 0.472 | 8 | 42.660 | 2 | 10.314 |
| 1995 | 95.256 | 596 | 2945.980 | 10 | 19.689 | 51.951 | 315 | 1529.980 | 9 | 20.276 |
| 1996 | 185.827 | 957 | 4497.240 | 23 | 23.740 | 107.731 | 598 | 2737.720 | 18 | 24.240 |
| 1997 | 326.165 | 1980 | 10122.680 | 19 | 19.644 | 173.944 | 1177 | 5818.150 | 19 | 19.148 |
| 1998 | 396.302 | 2901 | 16201.930 | 18 | 16.498 | 176.832 | 1390 | 7427.930 | 18 | 16.153 |
| 1999 | 313.300 | 2218 | 12578.150 | 19 | 16.590 | 131.936 | 1105 | 6023.580 | 18 | 14.837 |
| 2000 | 311.139 | 1870 | 10466.010 | 18 | 20.996 | 135.762 | 895 | 4682.040 | 18 | 20.826 |
| 2001 | 241.687 | 1833 | 10406.490 | 19 | 15.555 | 111.133 | 938 | 5215.410 | 19 | 14.746 |
| 2002 | 251.380 | 1622 | 10168.040 | 17 | 16.598 | 124.184 | 831 | 5057.740 | 17 | 16.130 |
| 2003 | 163.645 | 1423 | 9022.050 | 16 | 12.058 | 81.568 | 740 | 4589.350 | 16 | 12.139 |
| 2004 | 207.836 | 1723 | 10907.720 | 15 | 12.985 | 107.515 | 889 | 5443.170 | 14 | 13.606 |
| 2005 | 81.425 | 805 | 4815.850 | 13 | 10.785 | 40.669 | 426 | 2472.380 | 12 | 10.247 |
| 2006 | 70.907 | 607 | 3806.420 | 12 | 11.730 | 41.657 | 354 | 2159.470 | 12 | 12.343 |
| 2007 | 8.362 | 109 | 681.820 | 9 | 6.326 | 6.462 | 90 | 545.960 | 9 | 6.420 |
| 2008 | 15.245 | 117 | 784.100 | 8 | 12.183 | 12.210 | 98 | 636.210 | 8 | 11.864 |
| 2009 | 32.803 | 221 | 1486.740 | 10 | 12.503 | 28.336 | 194 | 1298.560 | 9 | 12.031 |
| 2010 | 35.240 | 265 | 1641.080 | 10 | 11.690 | 30.988 | 237 | 1440.450 | 10 | 11.624 |
| 2011 | 37.562 | 304 | 2085.220 | 11 | 10.439 | 32.748 | 269 | 1853.300 | 11 | 10.204 |
| 2012 | 36.848 | 391 | 2580.970 | 10 | 8.870 | 32.848 | 356 | 2312.290 | 10 | 8.890 |
| 2013 | 65.370 | 629 | 4442.420 | 12 | 9.689 | 44.329 | 490 | 3215.970 | 12 | 9.338 |
| 2014 | 55.428 | 544 | 4240.540 | 9 | 8.799 | 35.596 | 387 | 2689.250 | 9 | 9.305 |
| 2015 | 48.327 | 388 | 3081.470 | 8 | 9.754 | 37.682 | 332 | 2546.300 | 8 | 9.273 |

Table 8.138. Western deepwater sharks. Model selection criteria include the Akaike Information Criterion (AIC), residual sum of squares (RSS), model sum of squares (MSS), number of usable observations (Nobs), number of parameters (Npars), adjusted $R^2$ (adj_$R^2$) and the increment in adjusted $R^2$ (D $R^2$). Model 6 was optimal (Deep). The effect of being in the open or closed areas (Deep) was minor. Depth category: DepC.

| | Year | DepC | Vessel | Month | DayNight | Deep | Vessel:Month |
|---|---|---|---|---|---|---|---|
| AIC | 901 | -130 | -2624 | -2814 | -2824 | -2573 | 901 |
| RSS | 22380 | 21245 | 18805 | 18620 | 18609 | 17996 | 22380 |
| MSS | 1499 | 2634 | 5074 | 5259 | 5269 | 5883 | 1499 |
| Nobs | 21503 | 21503 | 21410 | 21410 | 21410 | 21410 | 21503 |
| Npars | 21 | 65 | 77 | 88 | 89 | 573 | 21 |
| adj_ $R^2$ | 6.191 | 10.765 | 20.969 | 21.706 | 21.746 | 22.568 | 6.191 |
| $\Delta R^2$ | 0.000 | 4.574 | 10.204 | 0.737 | 0.040 | 0.822 | 0.000 |

Table 8.139. The standardized catch rates for the alternative statistical models for Western Deepwater Sharks in OR zone 30, in depths 600 to 1100 m. The optimal model was Model 6. St Err is the estimate of standard error for the optimum model. Values are relative to the mean of the standardized catch rates.

| Year | Year | DepCat | Vessel | Month | DayNight | Deep | Vessel:Month | StErr |
|---|---|---|---|---|---|---|---|---|
| 1995 | 1.4376 | 1.4980 | 1.5131 | 1.5685 | 1.5622 | 1.5860 | 1.4376 | 0.0000 |
| 1996 | 1.7358 | 1.8634 | 1.8054 | 1.7783 | 1.7712 | 1.8638 | 1.7358 | 0.0507 |
| 1997 | 1.4359 | 1.5337 | 1.3925 | 1.3875 | 1.3818 | 1.4461 | 1.4359 | 0.0459 |
| 1998 | 1.2059 | 1.3293 | 1.1232 | 1.0976 | 1.0902 | 1.0762 | 1.2059 | 0.0447 |
| 1999 | 1.2126 | 1.3378 | 1.1015 | 1.0909 | 1.0852 | 1.0592 | 1.2126 | 0.0456 |
| 2000 | 1.5348 | 1.5627 | 1.2835 | 1.2615 | 1.2548 | 1.2331 | 1.5348 | 0.0465 |
| 2001 | 1.1370 | 1.1448 | 0.9776 | 0.9752 | 0.9716 | 0.9782 | 1.1370 | 0.0467 |
| 2002 | 1.2133 | 1.1659 | 1.0618 | 1.0606 | 1.0581 | 1.0606 | 1.2133 | 0.0471 |
| 2003 | 0.8815 | 0.8631 | 0.7784 | 0.7788 | 0.7757 | 0.7900 | 0.8815 | 0.0477 |
| 2004 | 0.9492 | 0.9440 | 0.7948 | 0.7879 | 0.7858 | 0.7902 | 0.9492 | 0.0470 |
| 2005 | 0.7886 | 0.7465 | 0.7067 | 0.6848 | 0.6832 | 0.6785 | 0.7886 | 0.0526 |
| 2006 | 0.8579 | 0.8896 | 0.8575 | 0.8391 | 0.8377 | 0.8305 | 0.8579 | 0.0569 |
| 2007 | 0.4645 | 0.4742 | 0.8225 | 0.8204 | 0.8203 | 0.8241 | 0.4645 | 0.1014 |
| 2008 | 0.8943 | 0.7881 | 1.2941 | 1.3319 | 1.3338 | 1.2510 | 0.8943 | 0.0978 |
| 2009 | 0.9158 | 0.8811 | 1.2188 | 1.2130 | 1.2240 | 1.2136 | 0.9158 | 0.0761 |
| 2010 | 0.8560 | 0.8143 | 0.9882 | 1.0080 | 1.0201 | 1.0208 | 0.8560 | 0.0720 |
| 2011 | 0.7642 | 0.7025 | 0.8511 | 0.8554 | 0.8659 | 0.8692 | 0.7642 | 0.0676 |
| 2012 | 0.6491 | 0.5961 | 0.6023 | 0.6191 | 0.6261 | 0.6225 | 0.6491 | 0.0673 |
| 2013 | 0.7086 | 0.6267 | 0.6252 | 0.6254 | 0.6289 | 0.6239 | 0.7086 | 0.0587 |
| 2014 | 0.6436 | 0.5990 | 0.5739 | 0.5769 | 0.5786 | 0.5507 | 0.6436 | 0.0602 |
| 2015 | 0.7137 | 0.6392 | 0.6277 | 0.6389 | 0.6449 | 0.6318 | 0.7137 | 0.0651 |

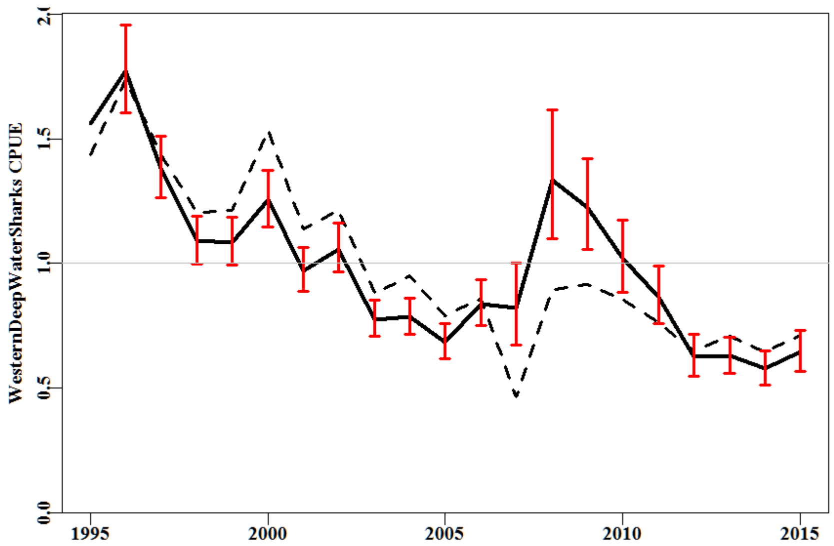



Figure 8.140. Western Deepwater Sharks reported from trawling in OR Zone 30, in depths 600 to 1100 m. The black dashed line represents the geometric mean catch rate and the solid black line the optimum standardized catch rates (Model 5). The graph standardizes catch rates relative to the mean of the standardized catch rates, represented by the horizontal fine grey line.

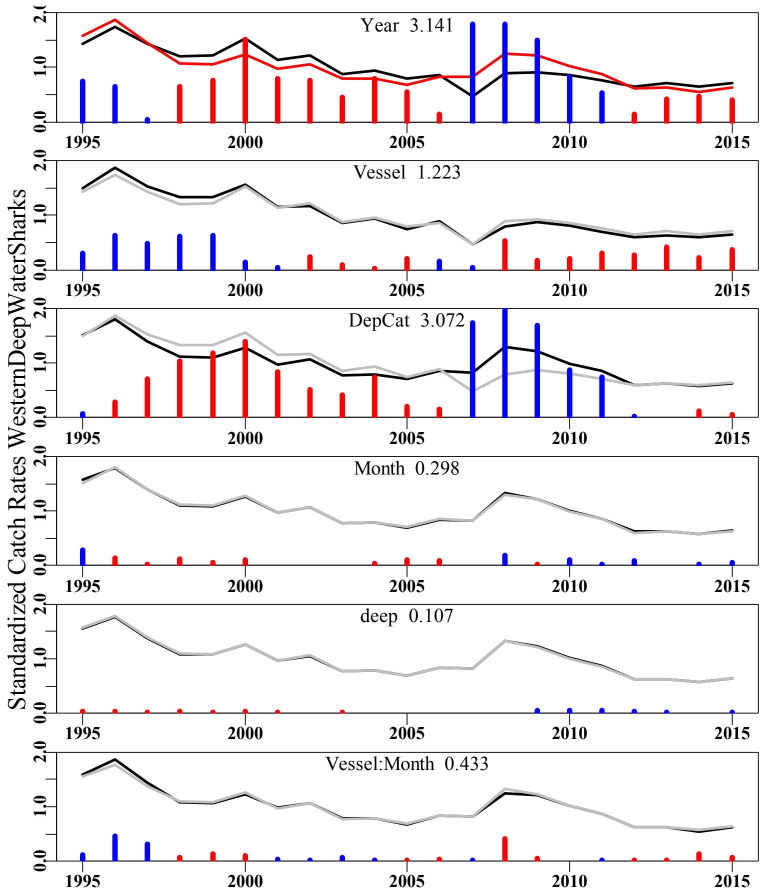



Figure 8.141. The relative impact of the different factors on the changes in the standardized trend. The major effects of both the structural adjustment, with its change of vessels, and the deepwater closures is clear.

### 8.5.3 Mixed Oreos Basket (spikey, warty, rough, black, & Oreo Dory)

Spikey (*Neocyttus rhomboidalis*), Oxeye (*Oreosoma atlanticum*) warty (*Allocyttus verrucosus*), rough (*Neocyttus psilorhynchus*) and black (*Allocyttus niger*) and grouped oreo dories (i.e. group of oreo species) were considered for analysis. CAAB codes were 37266001, 37266002, 37266004, 37266005, 37266006 and 37266902 (group code). Only spikey, warty and grouped oreo dories were used in the analysis since the other species were seldom caught in very low catches. The 2007, 2012 and 2013 estimated discard rates were 66.9 %, 9.7% (CV = 2.6%) and 18.5% (CV = 6.5%) respectively (Upston and Klaer 2013; Upston 2014). The estimated discard rate of mixed oeros for 2015 is 45.35% (Thomson and Upston 2016). Approximately, 89% of the reported catch is given as spikey oreo (*Neocyttus rhomboidalis*), 2.5% as warty oreo (*Allocyttus verrucosus*), and 6.4% as oreo dories (37266902).

Table 8.140. Number of records where Mixed Oreos are reported from trawling in OR Zones 10, 20, 21, 30, and 50, in depths 500 to 1200 m. Vessels represents the count of vessels reporting mixed oreos. Yield is the reported catch (t) of mixed Oreos. The geometric mean CE is the raw unstandardized catch rate in Kg/tow. Columns 2-6 represent all data while the right hand five columns represent the areas left open following the 700m closure.

| Year | Records | Vessels | Effort | Yield | Geom | RecordsO | VesselsO | EffortO | YieldO | GeomO |
|---|---|---|---|---|---|---|---|---|---|---|
| 1986 | 166 | 9 | 366.590 | 50.966 | 65.148 | 94 | 8 | 258.690 | 33.456 | 55.224 |
| 1987 | 138 | 16 | 353.000 | 58.029 | 64.754 | 55 | 10 | 156.200 | 11.200 | 47.936 |
| 1988 | 159 | 12 | 371.700 | 31.844 | 46.006 | 27 | 5 | 81.500 | 6.310 | 44.856 |
| 1989 | 350 | 18 | 497.400 | 179.209 | 194.500 | 77 | 7 | 192.900 | 17.580 | 61.084 |
| 1990 | 248 | 22 | 171.700 | 243.868 | 822.430 | 16 | 9 | 39.200 | 4.690 | 48.613 |
| 1991 | 208 | 22 | 532.290 | 81.019 | 51.915 | 77 | 13 | 300.250 | 14.378 | 26.859 |
| 1992 | 567 | 31 | 848.380 | 604.251 | 266.324 | 114 | 17 | 350.320 | 62.815 | 54.879 |
| 1993 | 819 | 38 | 1621.350 | 274.839 | 88.478 | 156 | 23 | 542.800 | 47.437 | 36.280 |
| 1994 | 1057 | 34 | 2493.820 | 283.074 | 58.626 | 187 | 23 | 715.320 | 65.146 | 41.645 |
| 1995 | 1752 | 29 | 6060.430 | 479.955 | 36.706 | 580 | 21 | 2287.930 | 203.136 | 40.106 |
| 1996 | 2091 | 33 | 6898.420 | 419.817 | 30.411 | 592 | 30 | 2207.330 | 122.200 | 25.010 |
| 1997 | 2273 | 34 | 9606.900 | 572.797 | 30.506 | 719 | 26 | 3168.970 | 154.515 | 25.315 |
| 1998 | 2337 | 33 | 9872.990 | 666.374 | 38.720 | 565 | 26 | 2505.450 | 168.488 | 31.043 |
| 1999 | 1910 | 33 | 7905.280 | 440.687 | 35.087 | 407 | 27 | 1776.120 | 105.103 | 30.333 |
| 2000 | 1722 | 39 | 7738.930 | 375.744 | 28.005 | 414 | 31 | 1821.610 | 106.794 | 31.204 |
| 2001 | 1937 | 37 | 8684.480 | 402.390 | 28.168 | 562 | 33 | 2482.820 | 106.099 | 24.431 |
| 2002 | 1452 | 36 | 7180.720 | 212.986 | 18.087 | 433 | 31 | 2121.860 | 69.128 | 16.950 |
| 2003 | 1447 | 30 | 7401.700 | 224.924 | 17.965 | 393 | 23 | 1925.540 | 64.188 | 15.806 |
| 2004 | 1428 | 30 | 7501.770 | 179.164 | 15.838 | 368 | 26 | 1871.930 | 48.965 | 16.391 |
| 2005 | 805 | 22 | 4270.530 | 100.586 | 13.983 | 241 | 20 | 1184.730 | 32.694 | 16.618 |
| 2006 | 635 | 23 | 3229.610 | 79.570 | 12.610 | 183 | 19 | 906.180 | 21.671 | 11.840 |
| 2007 | 378 | 17 | 2026.240 | 57.776 | 12.844 | 229 | 16 | 1282.770 | 27.628 | 8.171 |
| 2008 | 302 | 16 | 1751.380 | 48.294 | 13.979 | 194 | 14 | 1077.190 | 22.209 | 10.938 |
| 2009 | 488 | 17 | 2743.410 | 72.164 | 13.385 | 229 | 17 | 1312.820 | 23.740 | 9.046 |
| 2010 | 499 | 15 | 2895.100 | 75.217 | 12.443 | 236 | 15 | 1363.800 | 24.254 | 9.720 |
| 2011 | 566 | 17 | 3514.480 | 77.279 | 13.395 | 254 | 16 | 1535.400 | 25.545 | 10.412 |
| 2012 | 492 | 15 | 3020.500 | 58.668 | 10.953 | 172 | 13 | 1057.670 | 17.913 | 8.384 |
| 2013 | 705 | 16 | 4328.870 | 138.179 | 14.166 | 226 | 15 | 1360.680 | 48.632 | 12.364 |
| 2014 | 570 | 16 | 3994.320 | 108.082 | 14.307 | 161 | 11 | 999.800 | 27.882 | 11.742 |
| 2015 | 312 | 13 | 1796.410 | 48.577 | 22.694 | 185 | 11 | 873.680 | 27.799 | 28.303 |

Table 8.141. The catch in tonnes of Mixed Oreos by Orange Roughy (OR) Zone, and, across OR Zones in the current open and closed areas. All data included in the OR Zones.

| Year | Total | 10 | 20 | 21 | 30 | 50 | Open | Closed |
|---|---|---|---|---|---|---|---|---|
| 1986 | 50.966 | 0.160 | 30.520 | | 20.278 | 0.008 | 33.456 | 17.510 |
| 1987 | 58.029 | 0.130 | 6.470 | | 51.429 | | 11.200 | 46.829 |
| 1988 | 31.844 | 0.020 | 0.150 | | 31.584 | 0.090 | 6.310 | 25.534 |
| 1989 | 179.209 | | 88.650 | 37.090 | 53.409 | 0.060 | 17.580 | 161.629 |
| 1990 | 243.868 | 3.990 | 170.283 | 62.765 | 6.700 | 0.130 | 4.690 | 239.178 |
| 1991 | 81.019 | 3.091 | 47.720 | 13.251 | 16.572 | 0.385 | 14.378 | 66.641 |
| 1992 | 604.251 | 31.596 | 352.104 | 187.494 | 31.561 | 1.496 | 62.815 | 541.436 |
| 1993 | 274.839 | 1.392 | 102.822 | 34.641 | 106.719 | 29.265 | 47.437 | 227.402 |
| 1994 | 283.074 | 0.882 | 90.447 | 34.289 | 135.657 | 21.799 | 65.146 | 217.928 |
| 1995 | 479.955 | 1.178 | 63.472 | 8.029 | 401.029 | 6.247 | 203.136 | 276.819 |
| 1996 | 419.817 | 8.507 | 92.409 | 3.451 | 278.425 | 37.025 | 122.200 | 297.617 |
| 1997 | 572.797 | 43.955 | 129.834 | 1.390 | 377.317 | 20.301 | 154.515 | 418.282 |
| 1998 | 666.374 | 33.714 | 130.832 | 1.492 | 379.179 | 121.157 | 168.488 | 497.886 |
| 1999 | 440.687 | 13.860 | 126.159 | 1.265 | 241.254 | 58.149 | 105.103 | 335.584 |
| 2000 | 375.744 | 25.925 | 111.417 | 0.775 | 212.965 | 24.662 | 106.794 | 268.950 |
| 2001 | 402.390 | 19.096 | 135.779 | 7.885 | 219.587 | 20.043 | 106.099 | 296.291 |
| 2002 | 212.986 | 35.898 | 59.174 | 1.025 | 106.132 | 10.757 | 69.128 | 143.858 |
| 2003 | 224.924 | 30.992 | 56.615 | 7.550 | 116.664 | 13.103 | 64.188 | 160.736 |
| 2004 | 179.164 | 11.947 | 40.235 | 1.520 | 113.860 | 11.602 | 48.965 | 130.198 |
| 2005 | 100.586 | 5.907 | 22.152 | 1.500 | 61.909 | 9.118 | 32.694 | 67.892 |
| 2006 | 79.570 | 8.231 | 12.259 | 0.270 | 56.615 | 2.195 | 21.671 | 57.899 |
| 2007 | 57.776 | 2.100 | 18.507 | 1.194 | 34.665 | 1.310 | 27.628 | 30.148 |
| 2008 | 48.294 | 2.262 | 16.934 | | 26.437 | 2.661 | 22.209 | 26.085 |
| 2009 | 72.164 | 4.105 | 17.181 | 0.058 | 46.692 | 4.128 | 72.164 | |
| 2010 | 75.217 | 4.944 | 24.926 | 5.860 | 37.206 | 2.281 | 75.217 | |
| 2011 | 77.279 | 3.615 | 19.941 | 1.990 | 47.829 | 3.904 | 77.279 | |
| 2012 | 58.668 | 2.258 | 19.275 | 0.022 | 33.426 | 3.687 | 58.668 | |
| 2013 | 138.179 | 6.566 | 48.362 | 0.180 | 80.896 | 2.175 | 138.179 | |
| 2014 | 108.082 | 1.273 | 47.763 | 0.375 | 57.634 | 1.037 | 108.082 | |
| 2015 | 48.577 | 12.349 | 9.252 | 2.568 | 20.830 | 3.578 | 48.577 | |
| Total | 6646.328 | 319.942 | 2091.643 | 417.929 | 3404.461 | 412.353 | 2093.996 | 4552.332 |

In the last five years, 52% of the catch has been reported as Oreo Dory, 31% as spikey dory, 12% as oxeye dory and the remainder warty and rough oreos. Only data from OR Zones 10, 20, 21, 30, 50, in depths 500 – 1200 m were used in the analysis. All vessels recording mixed oreos were included in the analysis. Orange Roughy zones 40, 60, 70 and unknown were removed.

Table 8.142. Statistical model structures used with Mixed Oreos. DepCat is a series of 50 metre depth categories. Closure relates to whether the area is open or closed.

| | |
|---|---|
| Model 1 | LnCE ~ Year |
| Model 2 | LnCE ~ Year + Vessel |
| Model 3 | LnCE ~ Year + Vessel + DepCat |
| Model 4 | LnCE ~ Year + Vessel + DepCat + ORzone |
| Model 5 | LnCE ~ Year + Vessel + DepCat + ORzone + DayNight |
| Model 6 | LnCE ~ Year + Vessel + DepCat + ORzone + DayNight + Month |
| Model 7 | LnCE ~ Year + Vessel + DepCat + ORzone + DayNight + Month + Closure |
| Model 8 | LnCE ~ Year + Vessel + DepCat + ORzone + DayNight + Month + Closure + |
| Model 9 | LnCE ~ Year + Vessel + DepCat + ORzone + DayNight + Month + Closure + |

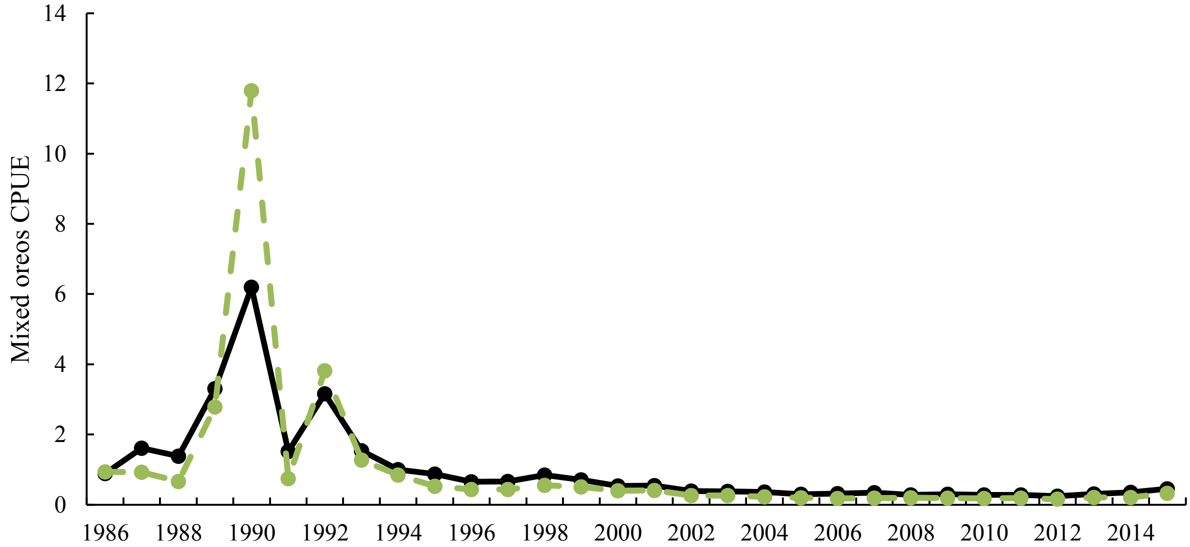



Figure 8.142. The standardized catch rates of mixed oreos showing the optimum model (solid black line) and the geometric mean catch rate (grey dashed line) each scaled to the mean of each time series.

Table 8.143. Mixed oreos. Model selection criteria include the Akaike Information Criterion (AIC), residual sum of squares (RSS), model sum of squares (MSS), number of usable observations (Nobs), number of parameters (Npars), adjusted $R^2$ (adj_$R^2$) and the increment in adjusted $R^2$ (D $R^2$). Model 9 (DepC:Month) was optimal. The effect of being in the open or closed areas (Closure) was minor (Figure 8.143). Depth category: DepC; Month: Mth.

| | Year | Vessel | DepC | ORZone | DayNight | Month | Closure | Vessel:Month | DepC:Mth |
|---|---|---|---|---|---|---|---|---|---|
| AIC | 19521 | 15465 | 13458 | 12508 | 11535 | 10946 | 10947 | 10653 | 10653 |
| RSS | 55992 | 48016 | 44468 | 42953 | 41458 | 40550 | 40549 | 36785 | 39676 |
| MSS | 13627 | 21603 | 25150 | 26666 | 28161 | 29068 | 29070 | 32834 | 29943 |
| Nobs | 27813 | 27813 | 27624 | 27624 | 27624 | 27624 | 27624 | 27624 | 27624 |
| Npars | 30 | 139 | 153 | 157 | 160 | 171 | 172 | 1371 | 326 |
| adj_$R^2$ | 19.490 | 30.686 | 35.772 | 37.952 | 40.106 | 41.393 | 41.393 | 44.405 | 42.332 |
| $\Delta R^2$ | 0.000 | 11.196 | 5.086 | 2.180 | 2.154 | 1.287 | 0.000 | 3.013 | -2.074 |

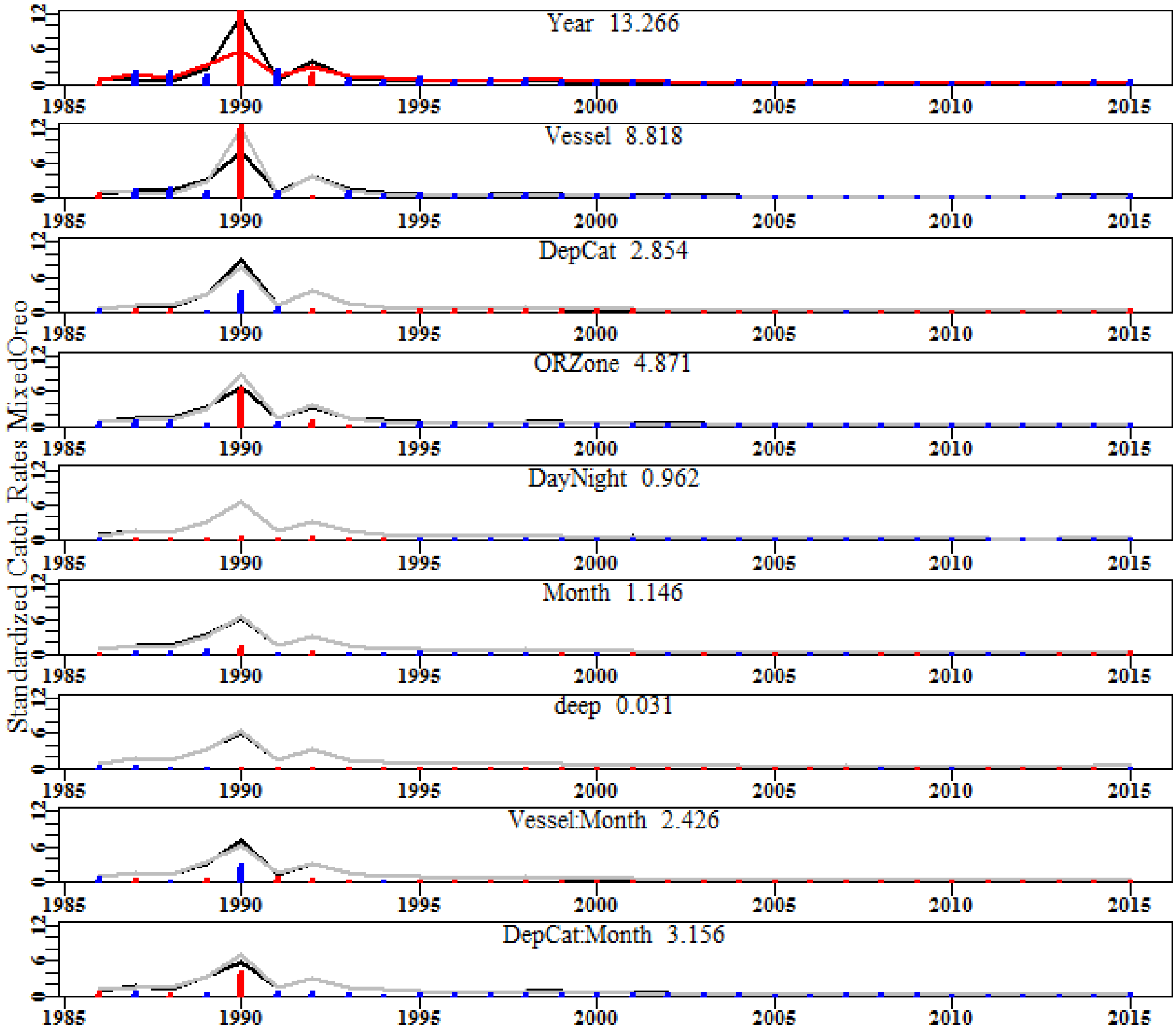



Figure 8.143. Relative impact of each factor on the final trend. Blue bars indicate the standardization is above the previous model, red bars indicate it is below. Closures appear to have only a very small effect.

Table 8.144. Reported catches (t) by CAAB code for the data analysed. Up until 2011 the group code Oreo Dory (37266902) had been omitted from the analysis because of confusion with Black Oreo (37266901). The 37266902 reporting code (grouped Oreo dories) appears only to have been introduced in 2005 when quotas were first applied to Mixed Oreos.

| | 37266001 | 37266002 | 37266004 | 37266902 | |
|---|---|---|---|---|---|
| Year | Spikey | Oxeye | Warty | Oreo Dory | Total |
| 1986 | 20.565 | 3.608 | 32.463 | | 56.636 |
| 1987 | 45.771 | 18.706 | 19.200 | | 83.677 |
| 1988 | 46.386 | 10.830 | 23.541 | | 80.757 |
| 1989 | 372.495 | 33.817 | 17.420 | | 423.732 |
| 1990 | 274.056 | 4.080 | 2.257 | | 280.393 |
| 1991 | 117.596 | 2.722 | 0.528 | | 120.846 |
| 1992 | 743.462 | 12.285 | 1.050 | | 756.797 |
| 1993 | 409.933 | 4.110 | 3.071 | | 417.114 |
| 1994 | 351.801 | 3.103 | 18.900 | | 373.804 |
| 1995 | 486.155 | 17.195 | 14.750 | | 518.100 |
| 1996 | 431.104 | 0.900 | 15.956 | | 447.960 |
| 1997 | 1080.351 | 4.927 | 21.000 | | 1106.278 |
| 1998 | 1297.604 | 0.940 | 24.806 | | 1323.350 |
| 1999 | 554.449 | 0.080 | 11.275 | | 565.804 |
| 2000 | 474.784 | 0.030 | 30.987 | | 505.801 |
| 2001 | 513.634 | 0.400 | 6.090 | | 520.124 |
| 2002 | 305.093 | 0.095 | 1.595 | | 306.783 |
| 2003 | 456.249 | NA | 0.800 | | 457.049 |
| 2004 | 362.796 | 0.120 | 1.570 | | 364.486 |
| 2005 | 183.308 | 3.549 | NA | 7.573 | 194.430 |
| 2006 | 67.263 | 10.490 | NA | 48.496 | 126.249 |
| 2007 | 21.435 | 11.983 | NA | 56.832 | 90.250 |
| 2007 | 8.558 | 1.182 | NA | 54.874 | 64.614 |
| 2009 | 110.205 | 2.145 | NA | 75.238 | 187.588 |
| 2010 | 54.371 | 1.282 | NA | 74.136 | 129.789 |
| 2011 | 15.764 | 7.951 | NA | 77.348 | 101.063 |
| 2012 | 8.825 | 13.821 | NA | 58.193 | 80.839 |
| 2013 | 22.664 | 15.497 | NA | 125.016 | 163.177 |
| 2014 | 72.887 | 22.871 | 2.895 | 49.835 | 148.488 |
| 2015 | 76.561 | 19.666 | 0.000 | 21.515 | 117.742 |
| Total | 8986.123 | 228.385 | 250.154 | 649.056 | 10113.718 |

Table 8.145. The standardized catch rates for the alternative statistical models for Mixed Oreos in OR Zones 10, 20, 21, 30, and 50, in depths 500 to 1200 m. The optimal model was DepC:Mth. St Err is the estimate of standard error for the optimum model. Values are relative to the mean of the standardized catch rates.

| Year | Year | Vessel | DepC | ORZone | DN | Month | Closure | Vessel:Mth | DepC:Mth | StErr |
|---|---|---|---|---|---|---|---|---|---|---|
| 1986 | 0.9259 | 0.6333 | 0.6936 | 0.8420 | 0.9225 | 0.8844 | 0.8911 | 1.1006 | 0.8753 | 0.00000 |
| 1987 | 0.9327 | 1.3812 | 1.2567 | 1.5599 | 1.5128 | 1.6053 | 1.6112 | 1.4987 | 1.6430 | 0.19495 |
| 1988 | 0.6620 | 1.2362 | 1.0848 | 1.3173 | 1.2716 | 1.3846 | 1.3854 | 1.3960 | 1.3114 | 0.20945 |
| 1989 | 2.7891 | 3.0942 | 3.1202 | 3.1730 | 3.1360 | 3.3092 | 3.3098 | 3.2212 | 3.3189 | 0.18767 |
| 1990 | 11.8076 | 7.7643 | 8.8689 | 6.7189 | 6.5843 | 6.2004 | 6.1969 | 7.1295 | 5.8615 | 0.19086 |
| 1991 | 0.7459 | 1.1331 | 1.3460 | 1.5253 | 1.5163 | 1.5218 | 1.5211 | 1.3493 | 1.5379 | 0.19390 |
| 1992 | 3.8149 | 3.7416 | 3.6090 | 3.3370 | 3.2136 | 3.1599 | 3.1590 | 3.0061 | 3.1787 | 0.17463 |
| 1993 | 1.2667 | 1.6294 | 1.5896 | 1.5760 | 1.5146 | 1.5422 | 1.5399 | 1.4767 | 1.5739 | 0.17654 |
| 1994 | 0.8391 | 0.9525 | 0.9159 | 1.0013 | 0.9786 | 1.0038 | 1.0025 | 1.0628 | 1.0630 | 0.17445 |
| 1995 | 0.5251 | 0.7563 | 0.6498 | 0.7919 | 0.8191 | 0.8743 | 0.8738 | 0.8379 | 0.9204 | 0.17243 |
| 1996 | 0.4350 | 0.5883 | 0.4918 | 0.6376 | 0.6482 | 0.6500 | 0.6493 | 0.6017 | 0.6545 | 0.17284 |
| 1997 | 0.4364 | 0.6087 | 0.5220 | 0.6341 | 0.6541 | 0.6659 | 0.6652 | 0.6236 | 0.6752 | 0.17223 |
| 1998 | 0.5539 | 0.7871 | 0.6834 | 0.8013 | 0.8168 | 0.8414 | 0.8404 | 0.7852 | 0.8683 | 0.17236 |
| 1999 | 0.5020 | 0.6787 | 0.6002 | 0.6903 | 0.7081 | 0.7076 | 0.7065 | 0.6559 | 0.7216 | 0.17255 |
| 2000 | 0.4007 | 0.5130 | 0.4542 | 0.5243 | 0.5350 | 0.5366 | 0.5363 | 0.4929 | 0.5478 | 0.17272 |
| 2001 | 0.4030 | 0.5340 | 0.4773 | 0.5436 | 0.5627 | 0.5473 | 0.5470 | 0.5075 | 0.5636 | 0.17271 |
| 2002 | 0.2588 | 0.3575 | 0.3310 | 0.3787 | 0.3905 | 0.3924 | 0.3922 | 0.3643 | 0.4014 | 0.17357 |
| 2003 | 0.2571 | 0.3428 | 0.3164 | 0.3640 | 0.3819 | 0.3775 | 0.3773 | 0.3454 | 0.3892 | 0.17352 |
| 2004 | 0.2266 | 0.3036 | 0.2840 | 0.3387 | 0.3545 | 0.3581 | 0.3579 | 0.3324 | 0.3652 | 0.17369 |
| 2005 | 0.2002 | 0.2674 | 0.2476 | 0.2993 | 0.3118 | 0.3017 | 0.3015 | 0.2867 | 0.3134 | 0.17579 |
| 2006 | 0.1806 | 0.2518 | 0.2331 | 0.2833 | 0.3058 | 0.3155 | 0.3152 | 0.3000 | 0.3239 | 0.17745 |
| 2007 | 0.1841 | 0.2388 | 0.2619 | 0.3110 | 0.3325 | 0.3468 | 0.3467 | 0.3153 | 0.3485 | 0.18186 |
| 2008 | 0.2005 | 0.2360 | 0.2283 | 0.2723 | 0.2876 | 0.2806 | 0.2807 | 0.2570 | 0.2877 | 0.18506 |
| 2009 | 0.1918 | 0.2344 | 0.2128 | 0.2755 | 0.2999 | 0.2952 | 0.2951 | 0.2686 | 0.3102 | 0.17937 |
| 2010 | 0.1783 | 0.2147 | 0.2043 | 0.2453 | 0.2685 | 0.2757 | 0.2757 | 0.2532 | 0.2805 | 0.17887 |
| 2011 | 0.1919 | 0.2316 | 0.2078 | 0.2514 | 0.2745 | 0.2770 | 0.2769 | 0.2620 | 0.2812 | 0.17804 |
| 2012 | 0.1569 | 0.2063 | 0.1870 | 0.2218 | 0.2404 | 0.2422 | 0.2421 | 0.2211 | 0.2486 | 0.18089 |
| 2013 | 0.2028 | 0.2993 | 0.2604 | 0.3032 | 0.3170 | 0.3069 | 0.3066 | 0.3035 | 0.3184 | 0.17743 |
| 2014 | 0.2049 | 0.3103 | 0.2804 | 0.3226 | 0.3494 | 0.3491 | 0.3487 | 0.3289 | 0.3561 | 0.17893 |
| 2015 | 0.3255 | 0.4734 | 0.3816 | 0.4589 | 0.4914 | 0.4466 | 0.4480 | 0.4160 | 0.4607 | 0.18600 |

### 8.5.4 *Smooth oreo – Cascade and non-Cascade (37266003 – Pseudocyttus maculatus)*

There were very small reported catches of smooth oreos from the Cascade Plateau since 2012 (0.03 t) and 2015 (0.5 t). Reported catches of smooth oreos from the non-Cascade Plateau were consistently less than 10 t annually over the last five years. Therefore, these were excluded from standardization analyses.

Table 8.146. Smooth oreo catch (t) by Trawl across Orange Roughy zones.

| | Orange roughy zone | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Year | 10 | 20 | 21 | 30 | 40 | 50 | 60 | 70 |
| 1987 | | 1.67 | | 0.71 | | | | |
| 1988 | 0.10 | 0.65 | | 14.66 | | | | |
| 1990 | 0.25 | 85.45 | 11.22 | 4.46 | 64.23 | | | 0.02 |
| 1991 | 34.29 | 176.75 | 186.10 | 0.78 | 48.97 | 0.13 | | 0.20 |
| 1992 | 16.26 | 49.78 | 293.39 | 1.35 | 0.45 | 1.47 | | |
| 1993 | 263.00 | 161.68 | 538.60 | 20.90 | 4.65 | 0.36 | 1.35 | |
| 1994 | 0.09 | 71.85 | 157.82 | 34.62 | 1.52 | 0.25 | | |
| 1995 | 0.86 | 70.34 | 198.96 | 1.71 | 44.67 | 2.40 | | 1.20 |
| 1996 | 4.70 | 12.28 | 153.38 | 70.46 | 6.90 | | | |
| 1997 | 6.30 | 10.13 | 40.12 | 23.90 | 71.32 | 0.60 | | 4.50 |
| 1998 | 3.70 | 15.38 | 18.91 | 32.44 | 168.91 | 0.50 | | 286.91 |
| 1999 | 1.46 | 7.55 | 30.91 | 21.68 | 63.40 | 4.76 | 0.12 | 236.07 |
| 2000 | 0.70 | 1.42 | 8.68 | 23.22 | 39.56 | | | 71.90 |
| 2001 | 10.24 | 4.31 | 8.57 | 22.92 | 132.18 | | | 91.19 |
| 2002 | 8.13 | 31.75 | 80.26 | 44.90 | 187.02 | | | 4.46 |
| 2003 | 1.86 | 10.82 | 24.18 | 68.24 | 176.91 | 0.58 | | 0.20 |
| 2004 | 1.60 | 2.49 | 5.90 | 41.54 | 39.62 | 3.69 | | 13.20 |
| 2005 | 0.86 | 4.75 | 1.91 | 49.09 | 57.20 | 2.76 | | 3.50 |
| 2006 | 0.80 | 5.87 | 6.65 | 10.43 | 31.77 | 0.51 | | |
| 2007 | 0.25 | 8.13 | 2.70 | 2.60 | 41.37 | 0.00 | | |
| 2008 | | 0.03 | 0.34 | | 7.49 | | | |
| 2009 | | | | 0.90 | 7.26 | | | |
| 2010 | 0.09 | 0.14 | | 0.59 | 0.05 | 0.11 | | |
| 2011 | | 0.06 | | 0.06 | 0.80 | | | |
| 2012 | | 1.10 | | 0.32 | | | | |
| 2013 | 0.04 | 0.15 | 0.02 | 0.24 | 0.03 | | | |
| 2014 | | 0.05 | | 0.20 | | 0.01 | | |
| 2015 | 0.20 | 0.58 | | 0.05 | | 0.00 | | |

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# 9. Blue-Eye Auto-Line and Drop-Line CPUE Characterization and Catch-per-Hook 1997-2015

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## *9.1 Executive Summary*

In 2013 the stock status for Blue-Eye (*Hyperoglyphe antarctica*) was assessed using a standardized catch-per-unit-effort (CPUE) time series for the auto-line and drop-line fisheries, which were combined for the purpose so as to extend the length of the time-series available (Haddon, 2010). At that time CPUE was estimated as catch-per-record rather than catch-per-hook. The focus was on the Drop-Line and Auto-Line fisheries because these generated the greatest catches, with the Auto-Line fishery increasing when the Drop-Line fishery declined.

The 2013 CPUE standardizations for Blue-Eye, and the Tier 4 analyses dependent upon them, are no longer considered to provide an adequate representation of trends across and within the Blue-Eye fishery, which could leave the stock status uncertain. The catch-per-record was no longer thought to be representative due to the advent of a number of issues: 1) a reported expansion of whale depredations on auto-line catches in association with the changed behaviour of the fishing vessels in the presence of whales, 2) a restriction of fishing location options due to an increase in the number of marine closures over known Blue-Eye fishing grounds, and 3) a recent movement of fishing effort much further north off the east coast of New South Wales and Queensland has altered the reliability of the current CPUE analyses as an indicator of Blue-Eye relative abundance across the range of the fishery.

Given the extensive spatial heterogeneity of both the Blue-Eye fishery and of the biological properties of the Blue-Eye populations across its spatial distribution, the CPUE analyses conducted were in need of a complete review and possible revision.

Catch-per-record has been used for the CPUE since 2009 (Haddon, 2010). In 2009, the log book records of effort in the two methods was a mixture of total number of hooks, number of lines with number of hooks per line, and other combinations plus errors (this confused mixture was the main reason for moving to catch-per-record in the first place). Since then the data entry has been more consistent leading the way for an attempt at generating CPUE as catch-per-hook, a measure of catch rate deemed to be more realistic and closer to the reality of the fishery. As with the catch-per-record this will generate two time-series, an early one for drop-line that over-laps one for auto-line, but the time-series are now of sufficient length that the general trends should be apparent.

Catches in what is now the GHT made up the majority of the fishery prior to 1997 but records from then are poor and there are multiple estimates of total catches and none are available with any reliable spatial detail. In the last four to five years, related to the move of a larger proportion of the total catch away from the east coast of Tasmania, the use of alternative line methods (rod-reel, hand-line, and others) has increased, although, possibly in response to reductions in the available quota, catches by these methods have started to decline again. In some years, notably 2002, 2005, 2007, and 2011 – 2014 catches in the High Seas fisheries also increased markedly.

There are some important assumptions in the earlier CPUE analyses. The first is that CPUE reflects changes in the relative stock abundance rather than either the influence of the structural adjustment, or reduced catch rates through whale depredations or from whale avoidance behaviour from shifting into less optimal CPUE areas. In addition, it is assumed the various closures in the south-east have had little or only minor effects on catch rates. In fact, all of these factors are likely to have had some effect.

In reality, the recent relatively large shift in effort and catch to the north-eastern sea-mounts is a change whose impact is difficult to assess. It is the case that examination of the CPUE from the minor line methods (Rod-and-Reel, and Hand-Line) indicates no particular trends in CPUE across the relatively short time-series of such catches, but to make those analyses required amalgamation of data across seamounts so the possibility of serial depletion cannot be excluded. Now that quota is less available these catches seem to have declined again to relatively low levels (Haddon, 2014c; Haddon, 2015).

One of the foundations of the current Tier 4 Blue-Eye assessments is that the CPUE for drop-line and auto-line can be combined. This is the case because both have used catch-per-record (or day) as their unit of CPUE and on that basis their CPUE was comparable (Haddon, 2010). The combination was required because, in 2009, each method alone only had a rather short time-series of usable CPUE (sufficient catches, records and representative coverage of the fishery) that could be used for assessment purposes. Catch-per-day was used because early use of the log-books had often mixed up the reporting of lines and hooks-per-line making their direct use invalid.

An objective of the current work is to set up a more easily repeatable analysis for the generation of total-hooks-set and hence be more open to future correction and critical examination. Separate data selection rules and database manipulations (separate algorithms) were developed for Drop-Line and Auto-Line data sets such that the outcome was a more reliable estimate of the total number of hooks set for each record. These data were used to generate catch-per-hook catch rate data which were in turn used in catch rate standardizations for the two methods.

The two time series of CPUE were combined using catch waiting and scaling the two series to the same mean CPUE of 1.0 for the period of 2002 – 2006, which was the period of overlap. For the catch-per-hook data to be acceptable required there to be sufficient records to provide a reasonable spatial coverage of the fishery as well as reasonably precise estimates of the annual mean values. Drop-Line CPUE were consider acceptable from 1997 – 2006 and Auto-Line data were acceptable from 2002 – 2015.

The effect of using catch-per-hook rather than catch-per-record is marked with the catch-per-record exhibiting a recent CPUE recovery not seen in the catch-per-record. It does not seem to matter greatly whether the analysis of catch-per-hook is restricted to zones 20 – 50 or extended to include the GAB zones 83, 84, and 85. Whatever the case the reduced decline in perceived CPUE has implications for any subsequent Tier 4 analysis

## 9.2 Introduction

Blue-Eye trevalla (*Hyperoglyphe antarctica*) is managed as a single stock but its stock status is difficult to assess because, as a species, its adults are widely but patchily distributed, although its juveniles stages are widely dispersed. Not only is it patchily distributed but the fishery differs markedly by area through the application of different methods and histories of exploitation. The differences in exploitation history along with sampling different areas in different years may have been sufficient to have led to the appearance of heterogeneity in the biological characteristics of different populations.

There is little consistency between consecutive years in the age structure and length structure of samples (Figure 9.1); for example, cohort progression is difficult or impossible to follow. This lack of consistency has thwarted previous attempts at applying a Tier 1 integrated assessment to Blue-Eye and has made the application of the Tier 3 catch-curve approach equally problematical (Fay, 2007a, b). Such spatial heterogeneity has recently been reviewed and further evidence presented, all of which supported the notion that there were spatially structured differences between Blue-Eye populations between regions around the south-east of Australia (Williams *et al*., 2016).

Table 9.1. The number of records and catches per year for auto-line, drop-line, and trawl vessels reporting catches of Blue-Eye Trevalla from 1997 – 2015. Data filters were to restrict the fisheries included to SET, GAB, SEN, GHT, SSF, SSG, and SSH. Methods were limited to AL, DL, TW, and TDO. Finally only CAAB code = 37445001 that identifies *Hyperoglyphe antarctica* were included.

| Year | AL Catch | AL Record | DL Catch | DL Record | TW Catch | TW Record |
|---|---|---|---|---|---|---|
| 1997 | 0.267 | 3 | 271.942 | 575 | 104.567 | 1500 |
| 1998 | 27.253 | 50 | 343.505 | 738 | 82.074 | 1398 |
| 1999 | 61.590 | 77 | 377.032 | 971 | 100.329 | 1712 |
| 2000 | 90.932 | 93 | 384.409 | 1075 | 95.042 | 1893 |
| 2001 | 47.884 | 76 | 335.873 | 797 | 90.218 | 1809 |
| 2002 | 134.067 | 234 | 223.074 | 619 | 67.998 | 1548 |
| 2003 | 219.676 | 487 | 221.649 | 587 | 28.918 | 1210 |
| 2004 | 329.608 | 1338 | 158.491 | 515 | 48.767 | 1558 |
| 2005 | 301.303 | 1142 | 93.779 | 363 | 42.969 | 1169 |
| 2006 | 354.582 | 1087 | 114.639 | 327 | 66.105 | 924 |
| 2007 | 455.097 | 667 | 46.011 | 127 | 38.321 | 834 |
| 2008 | 281.384 | 612 | 15.549 | 76 | 36.046 | 806 |
| 2009 | 325.893 | 578 | 30.158 | 105 | 39.386 | 618 |
| 2010 | 236.620 | 488 | 42.023 | 225 | 43.480 | 647 |
| 2011 | 267.318 | 562 | 59.381 | 230 | 23.268 | 624 |
| 2012 | 217.816 | 465 | 34.107 | 119 | 10.792 | 424 |
| 2013 | 190.515 | 360 | 7.762 | 47 | 22.893 | 358 |
| 2014 | 227.041 | 305 | 10.242 | 68 | 29.381 | 340 |
| 2015 | 198.232 | 282 | 46.711 | 92 | 25.128 | 301 |

The Blue-Eye fishery has a relatively long history and while there is a long history of catches by trawl the majority of the catch has always been taken by line-methods (generally less than 10% of catches are taken by trawl since 2003; Table 9.1). Unfortunately, fisheries data from line methods, in the GHT fishery, only began to be collected comprehensively from late in 1997 onwards (Table 9.1). In addition, in 1997 Auto-Line fishing was introduced as an accepted method in the SESSF although only very little fishing was conducted in 1997 and only in the last two months (Table 9.1, Figure 9.2). Auto-line related effort and catches increased from 2002 – 2003 onwards at the same time that drop-line records and catches began to decline (Figure 9.2; Table 9.1).

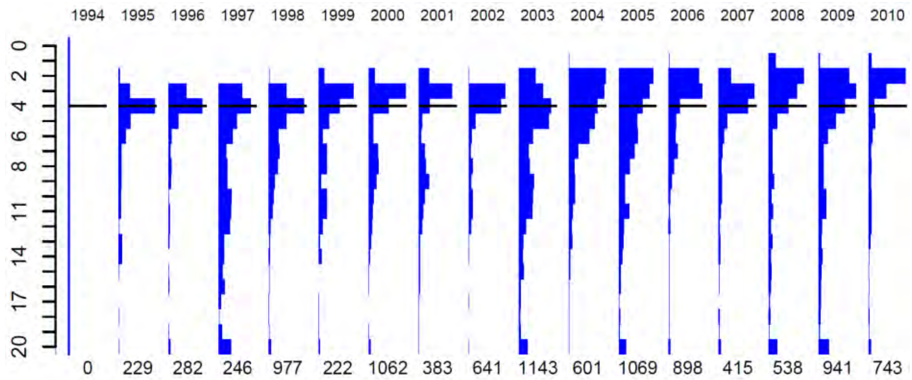


Figure 9.1. Age distributions sampled from the catches of Blue-Eye (*Hyperoglyphe antarctica*;) for the years 1995 – 2010 (Thomson *et al*, 2016), illustrating the variation between years. The sample sizes in the bottom row of numbers should be sufficient to provide a good representation if the stock were homogeneous in its properties. Blue-Eye shows inconsistencies every year with annual progressions of year classes being vague and ephemeral at best.

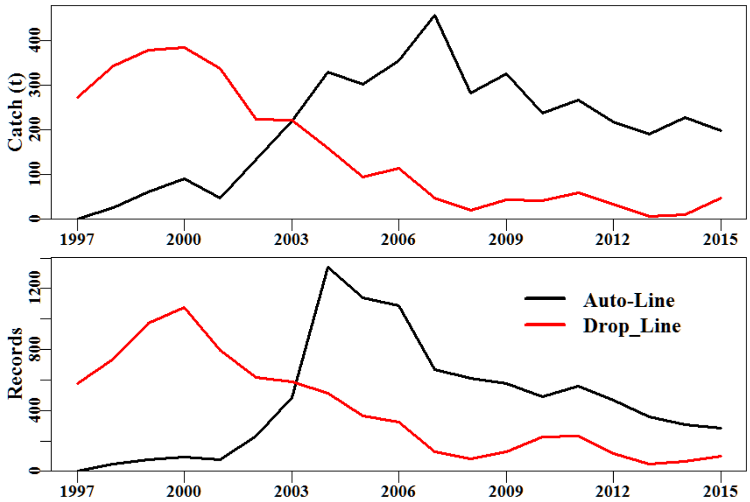


Figure 9.2. The trends in the number of records and the catches of Blue-Eye from 1997 – 2015 by the two main line methods (Table 9.1); most catches are now taken by auto-line.

In the two years, 2013 – 2014, the drop-line catches dropped to 10 t or less while auto-line catches continue to dominate the fishery. However, in 2015, drop-line catches increased to about 47 t, while auto-line catches dropped by about 30 t from the previous year (Table 9.1; Figure 9.2).

### 9.2.1 *Current Management*

When the Harvest Strategy Policy was implemented in 2007 (DAFF, 2007) a Tier 4 assessment was used to provide advice on annual recommended biological catch (RBC) levels for Blue-Eye instead of a Tier 1 assessment (after both a Tier 1 statistical catch-at-age model and a Tier 3 catch-curve approach were rejected; Fay, 2007a, b). The Tier 4 uses standardized CPUE as an empirical performance measure of relative abundance that is assumed to be representative of the whole stock. The average CPUE across a target period is selected by the RAG to provide the target reference point, which implies a limit CPUE reference point (0.41667 x target reference point) below which target fishing is to stop. In between the target and the limit there is a harvest control rule that reduces the RBC as CPUE declines. The appropriate characterization of CPUE is therefore very important in this fishery (Little et al., 2011; Haddon, 2014b).

By 2007 the auto-line fishery was already dominating the Blue-Eye fishery but the time series of significant catches by that method was relatively short (only six years from 2002 – 2007; Table 9.1 and Figure 9.2). At that time some way of extending the time series was required to allow for the application of the Tier 4 methodology. Unfortunately, in the log-book records there was, and still is, often confusion in how to record effort (in terms of number of lines and number of hooks per line, or number of line drops, or length of main line) so it was not feasible at that time to estimate CPUE as a catch-per-hook. Instead CPUE was based on catch-per-record, which was equivalent to catch-per-day. The CPUE standardization conducted in 2008 on data from 1997 – 2007 (Haddon, 2009) was the first time that the catch-per-day data from drop-line was combined with auto-line catch-per-day data, with a justification presented to the RAGs. This was followed in 2009 by a summary of the separate auto-line and drop-line CPUE and a more detailed defence for their combination (Haddon, 2010). While it was appreciated that the two methods are very different, the intent of combining their data was always to extent the time series of line-caught Blue-Eye back to 1997 rather than 2002. Despite this extension of time, the early Tier 4 Blue-Eye analyses had overlap between the reference period (1997 – 2006) and the CPUE grad over the final four years (2004 – 2007); it took three more years for that overlap to cease.

Table 9.2. Catch by SESSF Zone. Data filtered as for **Error! Reference source not found.**. Only Zones 20, 0, 40, 50, 83, 84, 85, 91, and 92 have significant catches.

| Year | 10 | **20** | **30** | **40** | **50** | 60 | 70 | 82 | **83** | **84** | **85** | **91** | **92** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1997 | 3.345 | 89.408 | 92.819 | 83.255 | 86.142 | 3.270 | | | 0.030 | | 6.947 | 5.505 | |
| 1998 | 1.647 | 79.892 | 170.828 | 97.873 | 66.657 | 2.182 | | | 0.100 | | 4.129 | 1.590 | |
| 1999 | 1.893 | 75.715 | 225.703 | 91.531 | 86.576 | 1.386 | | | | | 5.794 | 21.590 | 0.050 |
| 2000 | 0.985 | 45.090 | 275.350 | 128.207 | 95.639 | 0.045 | | | | 0.357 | 9.554 | 1.100 | 0.750 |
| 2001 | 0.264 | 28.590 | 239.652 | 100.091 | 59.845 | 0.022 | 0.188 | | 0.150 | 2.854 | 23.735 | 3.186 | 4.740 |
| 2002 | 0.489 | 39.713 | 180.660 | 75.521 | 76.950 | | 0.100 | | | 1.561 | 6.530 | 33.664 | 7.850 |
| 2003 | 1.288 | 52.263 | 153.536 | 124.815 | 43.311 | 0.039 | | | | 27.664 | 6.568 | 57.910 | 2.400 |
| 2004 | 0.222 | 73.836 | 148.512 | 113.269 | 63.711 | 0.742 | 0.400 | 0.946 | 12.713 | 61.283 | 54.842 | 5.045 | 0.180 |
| 2005 | 1.601 | 88.195 | 119.790 | 64.249 | 51.496 | 0.256 | 1.550 | 0.057 | 19.552 | 29.273 | 50.756 | 5.901 | 4.700 |
| 2006 | 0.192 | 69.824 | 157.401 | 83.899 | 41.087 | 0.930 | 2.420 | 0.169 | 31.511 | 43.438 | 89.189 | 10.375 | 2.500 |
| 2007 | 0.271 | 53.777 | 235.551 | 48.514 | 47.451 | 0.552 | 0.700 | | 29.876 | 107.069 | 15.594 | | |
| 2008 | 0.117 | 46.524 | 129.679 | 55.478 | 26.535 | 0.077 | | 0.015 | 28.943 | 32.267 | 13.346 | | |
| 2009 | 0.133 | 52.751 | 158.909 | 86.619 | 47.509 | 0.175 | 5.060 | | 1.633 | 15.369 | 15.415 | 10.515 | 1.350 |
| 2010 | 0.109 | 26.136 | 98.273 | 54.924 | 97.551 | 0.100 | 1.153 | | 6.549 | 9.532 | 15.929 | 7.932 | 3.935 |
| 2011 | 0.195 | 31.725 | 99.592 | 45.207 | 30.612 | 0.001 | 10.440 | | 20.576 | 40.692 | 14.159 | 33.689 | 23.081 |
| 2012 | 0.188 | 21.728 | 67.388 | 77.448 | 21.092 | | | | 8.428 | 9.736 | 3.752 | 42.938 | 10.017 |
| 2013 | 0.015 | 13.387 | 55.375 | 98.820 | 18.995 | 0.164 | 3.252 | | 0.465 | 16.158 | 13.250 | 1.131 | |
| 2014 | 0.005 | 4.218 | 91.440 | 91.993 | 26.010 | | | | 2.107 | 33.759 | 11.640 | 4.505 | 0.510 |
| 2015 | 0.012 | 9.793 | 75.974 | 73.330 | 26.186 | 0.546 | 0.750 | | 2.490 | 22.160 | 3.621 | 37.833 | 9.872 |
| Total | 12.97 | 902.56 | 2776.43 | 1595.04 | 1013.35 | 10.49 | 26.01 | 1.19 | 165.12 | 453.17 | 364.75 | 284.41 | 71.93 |

In 2013 the stock status for Blue-Eye (*Hyperoglyphe antarctica*) was assessed using a standardized CPUE time series from the combined auto-line and drop-line fisheries, which combined data from the two methods from 8 zones (SESSF zone 10 – 50 with 83 – 85; Figure 9.3). In addition, the time series of CPUE for trawls, relating to SESSF zones 20 – 30 (eastern Bass Strait and eastern Tasmania) and 40 – 50 (western Tasmania and western Bass Strait) were examined, although these trawl fisheries only relate to a small fraction of the total fishery so less attention is given them (Haddon, 2014 a, b). This was repeated in 2014 (Sporcic and Haddon, 2014), however, because of the unaccounted influences of factors such as the introduction of closures (both all methods and solely for auto-line), depredations by whales, and having to ignore significant catches taken with other new methods, these standardizations, and the Tier 4 analyses dependent upon them, were no longer considered to provide an adequate representation of trends within, and hence the status of, the Blue-Eye fishery.

One outcome of this was the determination to re-examine the available data to determine whether it would be possible to generate a CPUE series based upon some measure of catch-per-hook rather than catch-per-day. The use of catch-per-hook would allow more fine detail to be discerned and might provide a more informative time-series, although the two methods were no longer likely to be able to be combined. However, the length of time-series for auto-line is now sufficiently long that such a combination is now no longer a requirement. This was conducted last year (Haddon, 2015b) but now needs to be repeated in a manner that will ideally be repeatable by anyone.

### 9.2.2 *Fishery Changes*

The fishery as a whole has included a number of large-scale changes in fishing methods and the area of focus for the fishery. Catches in what is now the GHT were significant prior to 1997 but detailed data for that earlier period are not readily available. Catch estimates, have been derived from combining State with Commonwealth estimates, taken from earlier assessment summaries (Tilzey, 1999; Smith and Wayte, 2002; Table 9.3; Figure 9.4) and have the status of being an agreed catch history. While trawl catches have continued at a low (< 10%) but steady level since 2003 there has been a switch from drop-line (alternatively demersal-line) to auto-line. Also, related to the move of a proportion of the total catch away from the east coast up to the north-east seamount region, in the last three to four years the use of alternative line methods (rod-reel, hand-line, etc) has increased, although perhaps now that the TAC is decreasing the proportion of the total catch being taken by these ‘minor line’ methods is declining again (Figure 9.4 and Figure 9.5; Table 9.4).

Multiple issues have combined to cast doubt on the use of the combined auto-line and drop-line CPUE data; the issues included reported whale depredations, the effects of closures, and the advent of a number of new line fishing methods north of -35° S, all of which have, or have been reported to have, increased since the increase in use of the auto-line method. In amongst a detailed consideration of the CPUE for all areas and methods (Haddon, 2015) a preliminary examination of the line data was made to determine whether it would be possible to go through the database records for the Blue-Eye fishery and generate a catch-per-hook index to see if the use of the rather crude catch-per-day index was affecting the outcome of the standardization.

## 9.3 Objectives

The intent of this report is to attempt to estimate the Blue-Eye Trevalla CPUE in terms of catch-per-hook for both the drop-line and the auto-line fisheries. The specific objectives were to:

1. Review and amend the database records for the drop-line fishery to allow for the calculation of a catch-per-hook CPUE.

2. Review and amend the database records for the auto-line fishery to allow for the calculation of a catch-per-hook CPUE.
3. Compare the catch-per-hook standardized data for the two fisheries with that from the catch-per-day standardization across both species.

### 9.3.1 *Report Structure*

There will be four main sections to the results:

1. The report will first of all review the current distribution of catches across all methods and areas.
2. Secondly, it will consider the current arrangements with auto-line and drop-line data illustrating the current form of CPUE standardization, which combines the catch-per-shot data from both methods.
3. In the analysis of catch-per-hook first the drop-line fishery data will be considered, the database amended in a defensible manner, and a re-analysis of the CPUE using catch-per-hook made.
4. The same process of amending the database where appropriate followed by a reanalysis will be applied to the auto-line fishery.

The implications of these analyses will be examined in the discussion

## 9.4 Methods

### 9.4.1 *Catch Rate Standardization*

#### *9.4.1.1 Data Selection*

Blue-Eye catches were selected by method and area for CPUE analyses. CPUE from these specific areas were standardized using the methods described below and reported elsewhere (Haddon, 2014a).

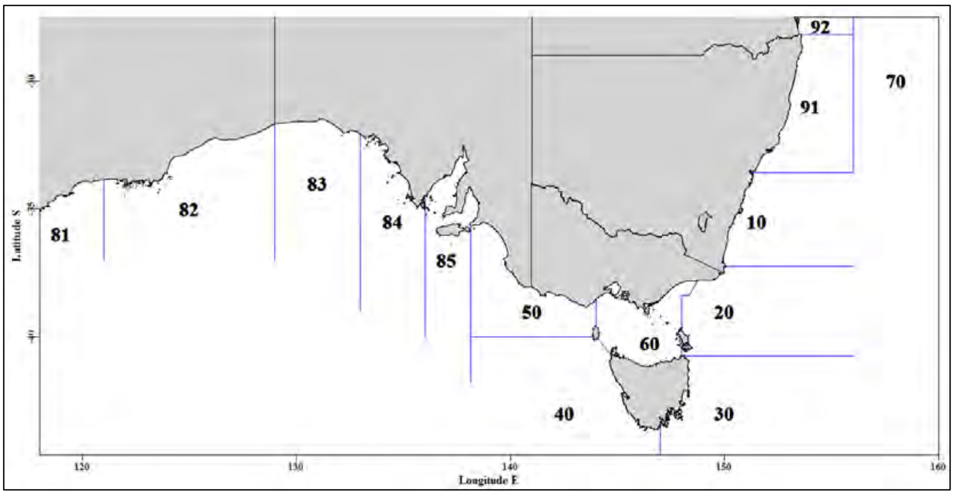


Figure 9.3. A schematic diagram depicting the statistical reporting zones in the SESSF, as used in this document. The GAB fishery is to the west of Zone 50. The main SESSF trawl zones are zones 10 – 50. Each zone extends out to the boundary of the EEZ, except for zones 50 and 60, and for zones 92 and 91, which are bounded by zone 70.

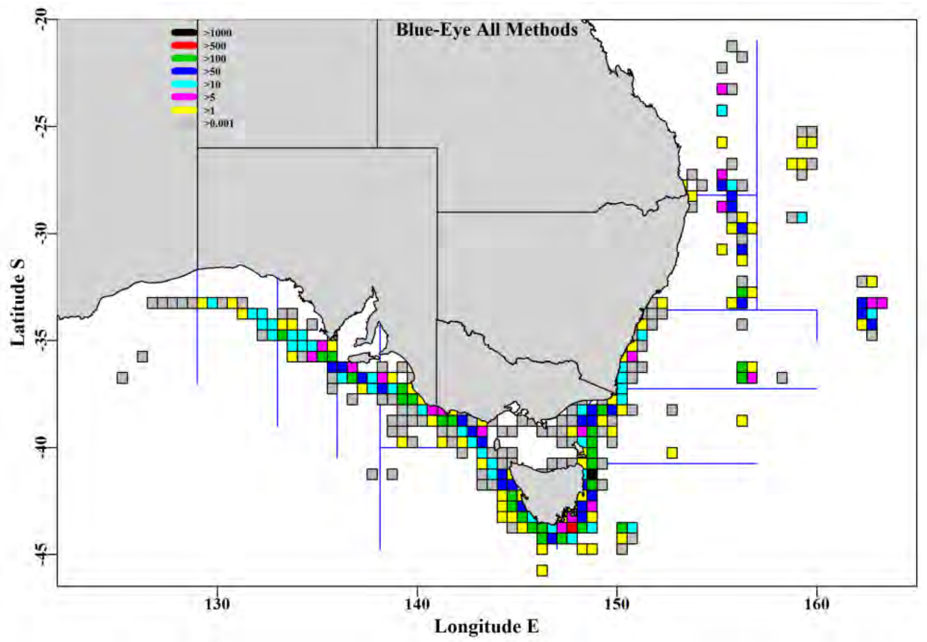


Figure 9.4. All reported catches of Blue-Eye by all methods from 1986 – 2015 in 0.5 degree squares. At least two records per square were required for inclusion. The legend units are in tonnes summed across all years.

#### *9.4.1.2 General Linear Modelling*

Where trawling was the method used, catch rates were kilograms per hour fished; except for the analyses later in this document all other methods were as catch-per-shot because the various line and net methods record effort in widely varying ways (the number of hooks, the number of lines of hooks, or the number of line drops etc; there is greater consistency in more recent years but still sufficient heterogeneity to make the use of catch-per-hook unreliable). Once the database records were amended for internal consistency, then analyses based on catch-per-hook were conducted. All catch rates were natural log-transformed and a General Linear Model was used rather than using a Generalized Linear Model with a log-link on the untransformed data; this has advantages in terms of normalizing the data while stabilizing the variance, which the Generalized Linear Model approach does not always achieve appropriately (Venables & Dichmont, 2004). The statistical models were variants on the form: LnCE = Year + Vessel + Month + DepthCategory + Zone + Daynight. In addition, there were interaction terms which could sometimes be fitted, such as Month:Zone or Month: DepthCategory, although with the use of finer spatial areas other simpler models or more idiosyncratic terms were occasionally used. Thus, the CPUE, conditioned on positive catches of the species of interest, was statistically modelled with a normal GLM on log-transformed CPUE data:

$$\mathrm{Ln}\left(CPUE_i\right) = \alpha_0 + \alpha_1 x_{i,1} + \alpha_2 x_{i,2} + \sum_{j=3}^{N} \alpha_j x_{ij} + \varepsilon_i \qquad (4)$$

where Ln($CPUE_i$) is the natural logarithm of the catch rate (either kg/h, kg/shot, or kg/hook) for the $i$-th shot, $x_{ij}$ are the values of the explanatory variables $j$ for the $i$-th shot and the $\alpha_j$ are the coefficients for the $N$ factors $j$ to be estimated ($\alpha_0$ is the intercept, $\alpha_1$ is the coefficient for the first factor, *etc*.).

*9.4.1.3 The Year Effect*

For the lognormal model the expected back-transformed year effect involves a bias-correction to account for the log-normality; this then focuses on the mean of the distribution rather than the median:

$$CPUE_t = e^{\left(\gamma_t + \sigma_t^2/2\right)} \tag{5}$$

where $\gamma_t$ is the Year coefficient for year $t$ and $\sigma_t$ is the standard deviation of the log transformed data (obtained from the analysis). The year coefficients were all divided by the average of the year coefficients to simplify the visual comparison of catch rate changes:

$$CE_t = \frac{CPUE_t}{\left(\sum CPUE_t\right)/n} \tag{6}$$

where $CPUE_t$ is the yearly coefficients from the standardization, $(\Sigma CPUE_t)/n$ is the arithmetic average of the yearly coefficients, n is the number of years of observations, and $CE_t$ is the final time series of yearly index of relative abundance

## *9.5 Results*

### 9.5.1 *Reported Catches*

Blue-Eye have been a target species before the formation of the SESSF, with large catches reported from eastern Tasmania taken primarily by drop-line. The estimates of total catch through time vary in their completeness and quality and earlier reviews have generated different values (Table 9.3). In particular, prior to 1997, non-trawl catches were only poorly recorded. At very least these early estimates indicate the significant scale of fishing mainly by drop-line, prior to the introduction of auto-line vessels.

Table 9.3. Early estimates of total Blue-Eye Trevalla catches, tonnes, across all methods within the SET area. The North Barrenjoey is included as being extra South-East Trawl area catches. Tilzey (1998) is only for catches north of Barrenjoey. Recent catches from 2005 are derived from Catch Documentation Records (CDR).

| Year | Recent | Tilzey (1998) | Tilzey (1999) | Smith & Wayte (2002) |
|---|---|---|---|---|
| 1980 | | | 207 | 207 |
| 1981 | | | 257 | 257 |
| 1982 | | | 276 | 276 |
| 1983 | | | 236 | 236 |
| 1984 | | 7 | 388 | 350 |
| 1985 | | 9 | 510 | 525 |
| 1986 | | 38 | 285 | 341 |
| 1987 | | 105 | 345 | 468 |
| 1988 | | 210 | 505 | 725 |
| 1989 | | 174 | 531 | 717 |
| 1990 | | 243 | 647 | 819 |
| 1991 | | 181 | 599 | 717 |
| 1992 | | 60 | 633 | 643 |
| 1993 | | 38 | 634 | 628 |
| 1994 | 801.327 | 27 | 729 | 730 |
| 1995 | 740.046 | 19 | 716 | 725 |
| 1996 | 893.428 | 16 | 868 | 890 |
| 1997 | 733.985 | | 1040 | 989 |
| 1998 | 472.287 | | | 566 |
| 1999 | 572.689 | | | 651 |
| 2000 | 656.847 | | | 710 |
| 2001 | 586.572 | | | 648 |
| 2002 | 512.111 | | | |
| 2003 | 588.064 | | | |
| 2004 | 633.794 | | | |
| 2005 | 496.316 | | | |
| 2006 | 546.700 | | | |
| 2007 | 740.396 | | | |
| 2008 | 438.611 | | | |
| 2009 | 418.548 | | | |
| 2010 | 393.971 | | | |
| 2011 | 354.600 | | | |
| 2012 | 332.397 | | | |
| 2013 | 354.972 | | | |
| 2014 | 269.331 | | | |
| 2015 | 299.075 | | | |

### 9.5.2 *Catch by Method*

In the catch and effort log book database there are 15 fishing methods listed that report catches of Blue-Eye, although six of those, along with the 'unknown' category only account for about 0.2% of total catches from 1986 to 2014 (Table 9.4), although in 1991 and 1992 they constitute up to 8% of catches (all of which was in 'unknown' method and so was likely by trawl, which was the only method reported in detail at the time). Only six methods have each accounted for more than 1% of total reported catches through that period; data have only been collected for methods other than trawl since 1998, with incomplete data collection in 1997 (Figure 9.5).

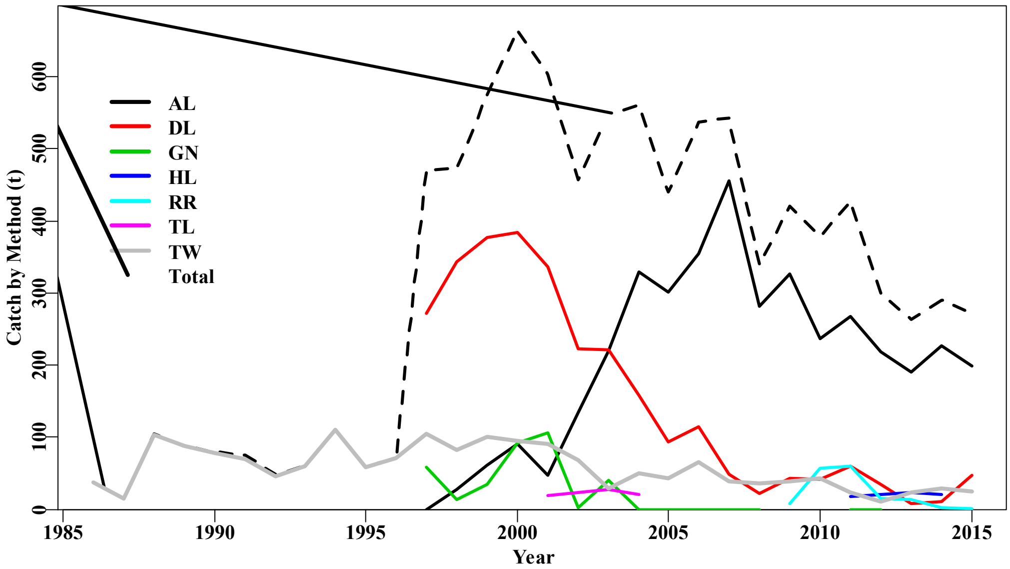


Figure 9.5. Catches of seven methods that together account for about 98.6% of all reported catches of Blue-Eye (Table 9.4) from 1996 – 2015. The codes are AL – auto-line, DL – drop-line, TW – trawl, GN – gill net, TL – trot line, RR – Rod and Reel, and HL – Hand Line. The dominance of drop-line and then auto-line is apparent.

Recently, on the northern sea mounts off the east coast the use of hydraulic reels and hand lines (RR and HL) have expanded (Figure 9.4, Figure 9.5), although these have now declined while drop-line catches have increased in the latest year. This latter may be because of the return to the use of drop-line gear in the South Australian shark fishery increasing the opportunity to use the gear in other fisheries.

The trawl fishery averaged about 75t from 1986 to 2002 and about 51t from 2003 to 2012 and averaged about 16% of the total fishery from 1998 to 2002, and about 7.8% of the fishery from 2003 - 2014; in 2011 catches by trawl reduced by ~20 t but estimated discard rates remained low (Upston, 2014), the 2012 trawl catch was the lowest recorded at only about 11 t. The non-trawl fishery has always taken the largest proportion of the total catch but useful data have only become available since 1997, with more complete data only being available from 1998 (see Table 9.3 for a previously agreed upon catch history back to 1980). In 1997 auto-lining was introduced as an accepted method in the SESSF and its catches grew to take over from drop-lining, which had been the dominant method used up until then (Figure 9.5, Figure 9.10). The time series for auto-line is truncated to start in 2001 or 2002 as catches only started to be taken over a wider area and in appreciable total amounts after that time (Table 9.4; Figure 9.9); before that time catches were very patchy and varied by location from year to year.

Table 9.4. Reported annual catches of Blue-Eye from 1986 – 2014 by method, Auto-Line, Drop-Line, Trawl, Gill Net, Rod and Reel, Trot Line, Bottom Line, and Hand Line. Other includes unknown, pole and line, fish trap, Danish seine, pelagic longline, and trolling. The landings relate to annual formal landings against quota

but differ from those reported in AFMA's Catch-Watch which relate to fishing seasons (May – April). TAC is the Agreed TAC; from 1992 – 1997 the TAC in trawl only, a non-trawl allocation of 530 t was included in 1998. The season in 2007 was 16 months long, which is why the landings and TAC appear high relative to surrounding seasons.

| Year | AL | DL | TW | GN | RR | TL | BL | HL | Other | Total | Landing | TAC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1986 | | | 37.774 | | | | | | 0.188 | 37.962 | | |
| 1987 | | | 15.495 | | | | | | | 15.495 | | |
| 1988 | | 0.160 | 103.969 | | | | | | 1.048 | 105.177 | | |
| 1989 | | | 88.066 | | | | | | | 88.066 | | |
| 1990 | | | 78.686 | | | | | | 0.612 | 79.298 | | |
| 1991 | | | 69.576 | | | | | | 6.448 | 76.024 | | |
| 1992 | | 0.415 | 46.055 | | | | | | 2.835 | 49.305 | | |
| 1993 | | | 59.598 | | | | | | 0.056 | 59.654 | | |
| 1994 | | | 109.839 | | | | | | 0.016 | 109.975 | | |
| 1995 | | | 58.533 | | | | | | 0.039 | 58.572 | | |
| 1996 | | | 71.148 | | | | | | 0.444 | 71.684 | | |
| 1997 | 0.267 | 271.942 | 104.567 | 59.022 | | 6.148 | 28.382 | | 0.281 | 471.466 | | |
| 1998 | 27.253 | 343.505 | 82.074 | 14.282 | | | 4.526 | 0.100 | 1.001 | 475.965 | | 630 |
| 1999 | 61.590 | 377.032 | 100.329 | 34.711 | | 0.030 | 0.889 | | 0.294 | 574.984 | | 630 |
| 2000 | 90.932 | 384.409 | 95.042 | 92.406 | | | 1.739 | | 0.678 | 671.352 | | 630 |
| 2001 | 47.884 | 335.873 | 90.218 | 106.679 | | 19.600 | 3.326 | | 0.023 | 648.321 | | 630 |
| 2002 | 134.067 | 223.074 | 67.998 | 1.951 | | 23.415 | 6.493 | | 0.001 | 843.859 | | 630 |
| 2003 | 219.676 | 221.649 | 28.918 | 40.846 | | 28.080 | 8.589 | | | 605.272 | | 690 |
| 2004 | 329.608 | 158.491 | 49.659 | 0.171 | | 20.116 | 2.318 | | 0.003 | 612.260 | | 621 |
| 2005 | 301.303 | 93.779 | 43.194 | 0.016 | | | 1.941 | | 0.400 | 755.186 | 496.316 | 621 |
| 2006 | 354.582 | 114.639 | 66.105 | 0.002 | | | 1.187 | | | 573.727 | 546.700 | 560 |
| 2007 | 455.097 | 48.011 | 38.321 | 0.003 | | | 0.632 | | | 937.142 | 740.396 | 785 |
| 2008 | 281.384 | 21.449 | 36.046 | 0.016 | | | 0.724 | | 0.070 | 398.941 | 438.611 | 560 |
| 2009 | 325.893 | 43.378 | 39.386 | | 7.550 | | 1.740 | | 3.162 | 521.038 | 418.548 | 560 |
| 2010 | 236.620 | 42.073 | 43.480 | | 56.788 | | 0.022 | | | 437.399 | 393.971 | 428 |
| 2011 | 267.318 | 59.381 | 23.268 | 0.111 | 59.962 | | 0.049 | 17.118 | | 554.219 | 354.600 | 326 |
| 2012 | 217.818 | 34.107 | 10.792 | 0.003 | 14.792 | | 1.377 | 21.171 | | 463.835 | 332.397 | 388 |
| 2013 | 190.515 | 7.762 | 22.893 | | 14.125 | | 3.311 | 24.083 | 0.002 | 398.377 | 354.972 | 388 |
| 2014 | 227.041 | 10.242 | 29.381 | | 2.600 | | 0.377 | 20.233 | | 460.526 | 269.331 | 335 |
| 2015 | 198.286 | 46.857 | 25.128 | | 0.925 | 0.404 | 0.168 | | 0.701 | 295.024 | 299.075 | 335 |

### 9.5.3 *Catches by Fishery*

Most catches are taken in the gillnet, hook and trap fishery, then the south east trawl fishery, and finally the East coast deepwater and high seas fisheries (Table 9.5).

Table 9.5. Reported catches by fishery and the landings against quota. Total is all fisheries combined, SET is the south east trawl, GHT is the gillnet, hook and trap fishery (combined with the southeast non-trawl, the southern shark fishery, southern shark gillnet fishery, and the southern shark hook fishery). ECD & HS is the

combined catches of the east coast deep-water fishery and the high seas trawl and high seas non-trawl. Other combines 8 other fisheries, which only account for about 0.28% of total catches from 1994 to 2015.

| Year | Landings | Total | SET | GHT | GAB | ECD+HST+HSN | Other |
|---|---|---|---|---|---|---|---|
| 1986 | | 37.962 | 37.962 | | | | |
| 1987 | | 15.495 | 15.467 | | 0.028 | | |
| 1988 | | 105.177 | 101.767 | 0.160 | 3.250 | | |
| 1989 | | 88.066 | 87.691 | | 0.375 | | |
| 1990 | | 79.298 | 76.373 | | 2.925 | | |
| 1991 | | 76.024 | 75.716 | | 0.308 | | |
| 1992 | | 49.305 | 49.275 | | 0.030 | | |
| 1993 | | 59.654 | 59.519 | | 0.135 | | |
| 1994 | | 109.975 | 109.730 | | 0.125 | | 0.120 |
| 1995 | | 58.572 | 57.967 | | 0.605 | | |
| 1996 | | 71.684 | 71.245 | | 0.347 | | 0.092 |
| 1997 | | 471.466 | 103.464 | 365.945 | 1.199 | | 0.858 |
| 1998 | | 475.965 | 79.878 | 390.601 | 2.261 | | 3.225 |
| 1999 | | 574.984 | 95.572 | 474.482 | 4.822 | | 0.108 |
| 2000 | | 671.352 | 84.204 | 570.152 | 10.850 | 5.408 | 0.738 |
| 2001 | | 648.321 | 69.535 | 513.378 | 20.690 | 35.284 | 9.434 |
| 2002 | | 843.859 | 66.849 | 389.000 | 1.150 | 371.351 | 15.510 |
| 2003 | | 605.302 | 27.108 | 518.839 | 1.810 | 57.022 | 0.523 |
| 2004 | 496.316 | 612.260 | 46.939 | 510.704 | 2.723 | 51.549 | 0.346 |
| 2005 | 546.700 | 755.186 | 34.497 | 397.439 | 8.698 | 314.499 | 0.054 |
| 2006 | 740.396 | 573.727 | 54.136 | 470.410 | 11.968 | 37.196 | 0.016 |
| 2007 | 438.611 | 937.142 | 37.362 | 503.743 | 0.960 | 394.673 | 0.405 |
| 2008 | 418.548 | 398.943 | 35.969 | 303.573 | 0.147 | 58.947 | 0.308 |
| 2009 | 393.971 | 521.038 | 39.410 | 381.699 | | 99.609 | 0.320 |
| 2010 | 354.600 | 437.399 | 43.480 | 335.502 | | 58.327 | 0.090 |
| 2011 | 332.397 | 554.219 | 23.268 | 403.940 | | 124.670 | 2.341 |
| 2012 | 354.972 | 463.835 | 10.781 | 289.268 | 0.011 | 162.453 | 1.322 |
| 2013 | 269.331 | 398.377 | 22.895 | 239.796 | | 134.908 | 0.778 |
| 2014 | 299.075 | 460.526 | 29.370 | 260.493 | 0.011 | 169.951 | 0.702 |
| 2015 | 496.316 | 295.024 | 25.150 | 247.318 | | 22.370 | 0.186 |

### 9.5.4 *Catch by Zone*

The fishery has been focussed largely around the south-east for many years, especially off the east and west coasts of Tasmania. In the last four years zones 70, 91, and 92 have increased in their importance to the fishery, although the reduction in TAC has seen a drop in the absolute catches from the area. The limited number of years in the north-east with available data restricts the possibilities for analysis, and this is further restricted by a proliferation of different fishing methods associated with this shift off effort and catch (Table 9.6; Figure 9.6).

Table 9.6. Catches in tonnes of Blue-Eye taken by all methods by zone (Figure 9.3). 80 includes all the GAB catches. The zones are arranged approximately from north-east to south-west.

| | 70 | 91 | 92 | 10 | 20 | 30 | 40 | 50 | 60 | 80 |
|---|---|---|---|---|---|---|---|---|---|---|
| 1986 | | 0.020 | | 12.712 | 5.771 | 3.346 | 4.927 | 11.058 | 0.128 | |
| 1987 | | | | 1.882 | 6.881 | 3.269 | 0.214 | 2.931 | 0.250 | 0.068 |
| 1988 | | 0.585 | | 3.076 | 18.841 | 1.460 | 23.834 | 53.101 | 1.020 | 3.250 |
| 1989 | | 0.101 | | 9.506 | 10.088 | 23.654 | 24.905 | 19.080 | 0.031 | 0.375 |
| 1990 | | | | 4.201 | 11.622 | 29.411 | 14.880 | 16.030 | 0.139 | 2.925 |
| 1991 | | | | 14.119 | 20.771 | 18.256 | 7.871 | 13.986 | 0.120 | 0.308 |
| 1992 | | | | 2.498 | 13.663 | 3.408 | 7.739 | 21.679 | 0.063 | 0.030 |
| 1993 | | 0.015 | | 2.360 | 14.582 | 24.092 | 5.892 | 12.567 | 0.001 | 0.135 |
| 1994 | 0.115 | 0.030 | | 2.886 | 14.894 | 74.892 | 8.140 | 8.842 | 0.046 | 0.125 |
| 1995 | | 0.080 | | 2.778 | 8.719 | 19.763 | 12.605 | 13.791 | 0.201 | 0.635 |
| 1996 | | 0.075 | | 4.927 | 9.842 | 25.660 | 9.134 | 21.450 | 0.192 | 0.347 |
| 1997 | | 10.835 | 0.140 | 6.046 | 149.869 | 92.819 | 83.333 | 100.036 | 4.149 | 16.843 |
| 1998 | | 1.590 | | 1.820 | 93.370 | 171.130 | 97.903 | 66.989 | 4.211 | 7.967 |
| 1999 | | 21.590 | 0.050 | 1.893 | 106.166 | 225.832 | 91.532 | 86.924 | 5.109 | 7.044 |
| 2000 | 5.408 | 1.100 | 0.750 | 0.985 | 129.528 | 275.937 | 129.247 | 95.971 | 8.559 | 9.923 |
| 2001 | 34.930 | 3.186 | 4.740 | 0.264 | 86.447 | 239.668 | 100.831 | 60.290 | 0.708 | 48.991 |
| 2002 | 7.469 | 33.664 | 7.850 | 0.489 | 41.624 | 180.660 | 75.524 | 77.538 | 0.012 | 37.437 |
| 2003 | 14.668 | 57.910 | 2.400 | 1.288 | 91.447 | 153.646 | 124.815 | 43.761 | 1.567 | 70.485 |
| 2004 | 36.796 | 10.045 | 0.180 | 0.222 | 73.957 | 148.512 | 113.269 | 64.437 | 0.745 | 152.432 |
| 2005 | 2.607 | 7.451 | 4.700 | 1.601 | 88.198 | 119.790 | 64.249 | 51.935 | 0.267 | 100.616 |
| 2006 | 2.540 | 10.375 | 2.516 | 0.192 | 69.824 | 157.401 | 83.899 | 41.217 | 0.932 | 165.364 |
| 2007 | 16.174 | | | 0.271 | 53.777 | 235.939 | 48.581 | 47.631 | 0.552 | 152.539 |
| 2008 | 8.100 | | | 0.170 | 46.583 | 130.524 | 55.478 | 26.535 | 0.110 | 74.574 |
| 2009 | 7.631 | 12.615 | 22.758 | 0.133 | 54.023 | 159.609 | 86.619 | 47.601 | 0.195 | 32.416 |
| 2010 | 1.797 | 34.124 | 34.027 | 0.109 | 26.136 | 98.273 | 54.924 | 97.572 | 0.100 | 32.010 |
| 2011 | 14.271 | 79.995 | 52.926 | 0.195 | 31.830 | 99.656 | 45.235 | 30.612 | 0.012 | 75.426 |
| 2012 | 15.079 | 74.673 | 13.189 | 0.188 | 21.728 | 67.578 | 77.448 | 22.012 | | 22.196 |
| 2013 | 5.546 | 37.203 | 1.138 | 0.015 | 13.389 | 58.686 | 98.820 | 19.005 | 0.164 | 29.874 |
| 2014 | | 24.379 | 0.918 | 0.005 | 6.339 | 103.029 | 94.445 | 26.010 | | 49.222 |
| 2015 | 0.750 | 38.423 | 11.212 | 0.012 | 9.793 | 77.010 | 76.218 | 27.388 | 0.568 | 30.108 |
| Total | 173.880 | 460.062 | 159.494 | 76.842 | 1329.701 | 3022.909 | 1722.511 | 1227.978 | 30.150 | 1123.665 |

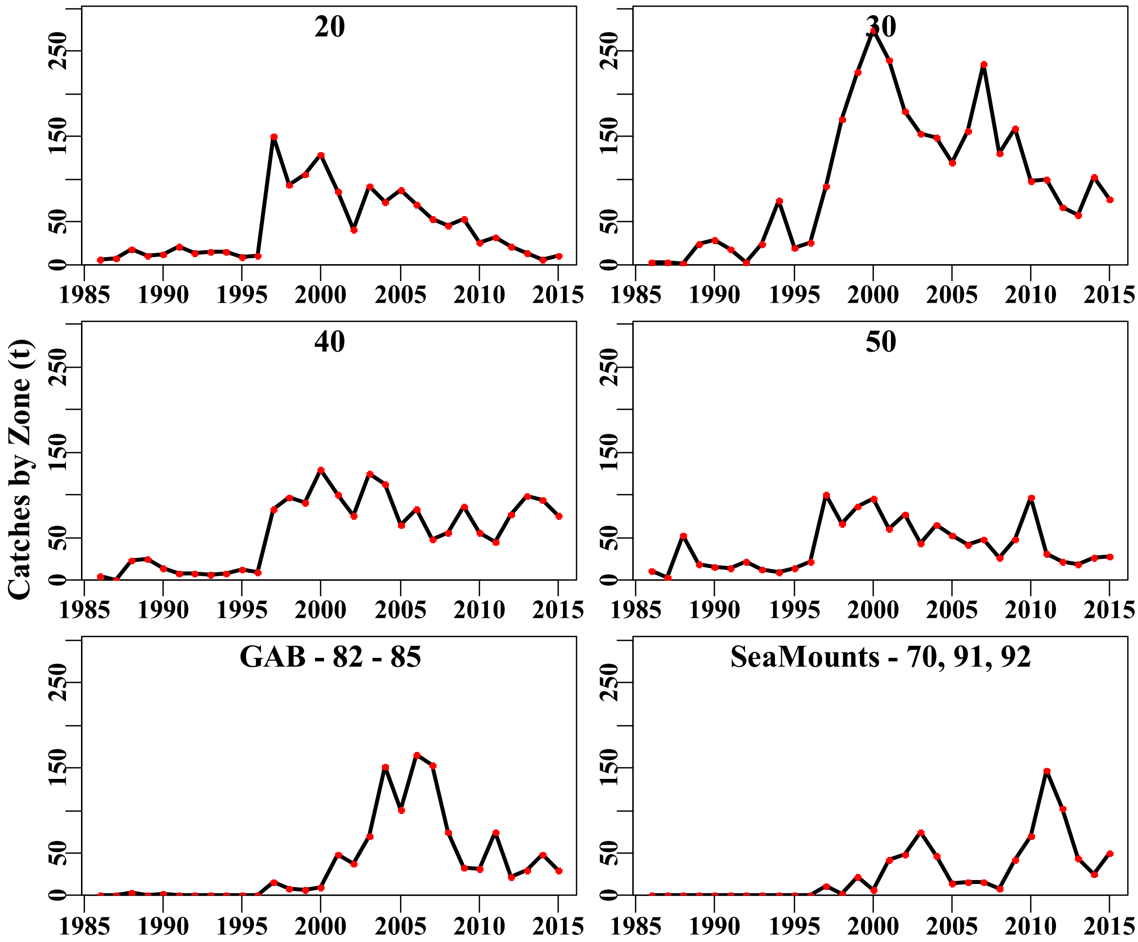


Figure 9.6. Annual catch in Blue-Eye in the four zones 20, 30, 40, and 50, the GAB (zones 82 – 85) and the Seamounts (zones 91, 92, and 70 from 1986 – 2015.

In 1998 one global TAC of 630 t was introduced to cover both the trawl and the GHT fisheries; this was divided 100t for trawl and 530 t for GHT. An increase in effort and catch, particularly in the drop-line fishery on the east coast of Tasmania is reported to be a response in anticipation of that management change, with fishers believing that increasing their catch history would lead to an increase in their allocation of quota. Since 1997 total catches have declined to just over one third of the agreed catches in 1997 (Figure 9.7). The distribution of catches in different regions indicate the changes in the intensity of fishing (Figure 9.6) with the proportion changes occurring through time showing the dominance of zone 30 as well as that changes in the location of fishing can occur rapidly from year to year (Figure 9.9).

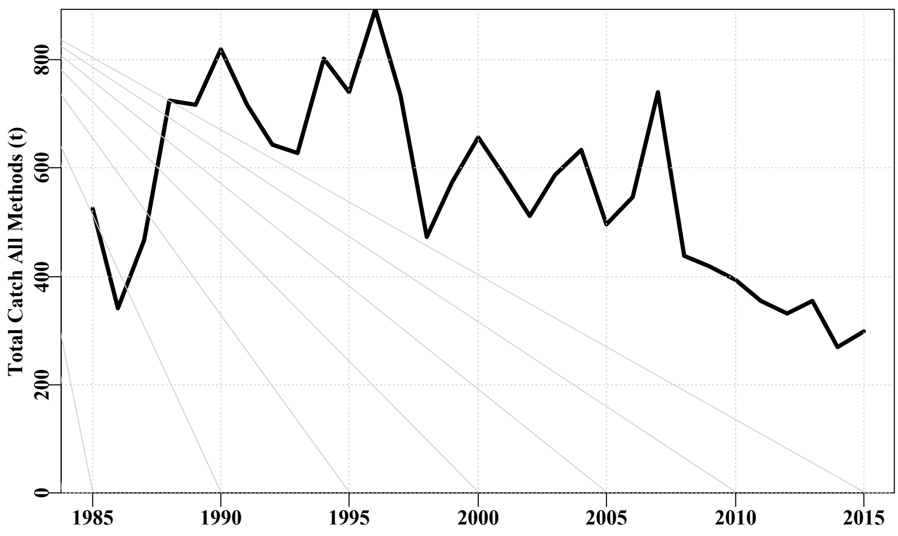


Figure 9.7. Total historical catches of Blue-Eye (not including high-seas catches), with estimates from 1985 – 1999 from Smith and Wayte (2002); see Table 9.3. The apparent spike of catches in 2007 relates to the 16 month season represented by that point.

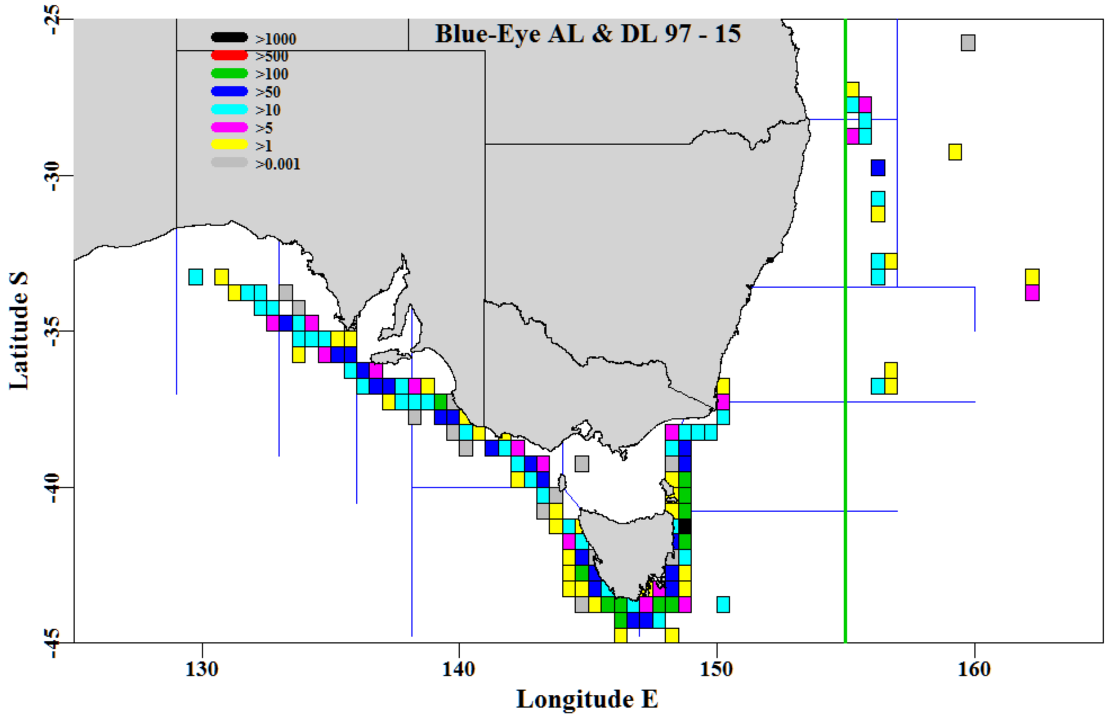


Figure 9.8. Schematic map of the distribution of Blue-Eye catches taken by AL and DL between 1997 – 2015. The zones (Figure 9.3) are used to discern the distribution of catches. A comparison with Figure 9.4 illustrate the different areas fished by different methods. Data east of the Longitude 155°E (the vertical green line) are currently excluded from the assessment of the GHT fishery.

### 9.5.5 *Auto-Line and Drop-Line Catches*

Blue-Eye catches taken with Auto-Line and Drop-Line are patchily distributed and the distribution of those catches has changed through time (Figure 9.8). Only the catches from the north-east region near and around the off-shore sea-mounts are excluded from the assessment of Blue-Eye (those west of Longitude 155°E. The catches and effort have been so variable and patchily distributed across the different sea-mounts and sub-regions that obtaining a valid CPUE index for the areas is currently not plausible (Haddon, 2015). As a result only zones 20, 30, 40, 50, and 83, 84, and 85 are used. The zones 83, 84, and 85 are in the GAB (see Figure 9.3).

Table 9.7. Catch by zone of Blue-Eye taken by Auto Line and Drop Line. This omits zones 10, 60, and 82, which had 3.5, 10.1, and 0.6 tonnes of reported catch respectively.

| Year | 20 | 30 | 40 | 50 | 83 | 84 | 85 | 70 | 91 | 92 |
|---|---|---|---|---|---|---|---|---|---|---|
| 1997 | 78.856 | 80.730 | 40.189 | 45.057 | | | 5.778 | | 3.745 | |
| 1998 | 72.375 | 158.987 | 62.428 | 40.616 | | | 1.968 | | 1.100 | |
| 1999 | 64.394 | 194.861 | 74.856 | 51.698 | | | 0.972 | | 16.910 | 0.050 |
| 2000 | 38.200 | 193.204 | 113.492 | 59.732 | | 0.332 | 5.234 | | 0.350 | 0.750 |
| 2001 | 20.659 | 214.492 | 87.241 | 28.957 | 0.15 | 2.364 | 3.935 | 0.06 | 3.186 | 4.740 |
| 2002 | 34.257 | 151.014 | 63.101 | 56.757 | | 1.561 | 5.08 | | 30.164 | 7.850 |
| 2003 | 46.296 | 142.138 | 75.155 | 33.329 | | 27.313 | 4.875 | | 57.890 | 2.400 |
| 2004 | 62.288 | 123.851 | 82.704 | 46.213 | 5.738 | 58.988 | 36.367 | 0.4 | 4.945 | 0.180 |
| 2005 | 85.093 | 100.828 | 59.423 | 42.908 | 19.258 | 29.173 | 42.215 | 1.55 | 4.881 | 4.700 |
| 2006 | 67.115 | 117.711 | 80.403 | 27.980 | 31.135 | 43.306 | 77.221 | 2.42 | 10.375 | 2.500 |
| 2007 | 50.186 | 227.145 | 41.324 | 28.367 | 29.801 | 100.647 | 15.337 | 0.7 | | |
| 2008 | 44.439 | 111.803 | 50.407 | 13.668 | 27.543 | 32.267 | 13.214 | | | |
| 2009 | 48.524 | 136.003 | 79.413 | 36.219 | 1.633 | 15.369 | 14.826 | 5.06 | 10.515 | 1.150 |
| 2010 | 25.422 | 83.915 | 47.662 | 69.919 | 6.549 | 9.532 | 15.929 | 1.153 | 7.932 | 3.495 |
| 2011 | 30.838 | 92.203 | 41.476 | 18.131 | 20.576 | 40.527 | 14.159 | 10.44 | 31.289 | 22.010 |
| 2012 | 21.176 | 65.587 | 71.830 | 17.454 | 8.417 | 9.736 | 3.752 | | 39.805 | 10.017 |
| 2013 | 13.151 | 51.497 | 84.457 | 14.244 | 0.465 | 16.152 | 13.25 | 3.252 | 1.131 | |
| 2014 | 3.878 | 69.016 | 87.153 | 20.619 | 2.107 | 33.103 | 11.629 | | 4.505 | 0.510 |
| 2015 | 9.031 | 52.005 | 72.576 | 24.076 | 2.49 | 21.672 | 3.621 | 0.75 | 35.272 | 9.872 |
| Total | 816.176 | 2366.989 | 1315.288 | 675.943 | 155.862 | 442.042 | 289.362 | 25.785 | 263.994 | 70.223 |

The focus of this work is the auto-line and drop-line fisheries and there have been large changes in these in terms of both catches and location of those catches (Figure 9.9).

The catch rate time series for both methods are now relatively long but catches were relatively low and the number of records was below 70 each year for auto-line before 2001. Drop-line catches have been <= 10 t and with 54 and 65 records in the past two years (Table 9.1; Figure 9.10). By excluding those years of minimum data from the auto-line and drop-line data, when it is combined, not surprisingly, the current standardization, based on catch-per-day shows greater similarities to the drop-line trajectory early on and the auto-line trajectory later on (Figure 9.10). Based on catch-per-day, the auto-line CPUE by itself is now indicating a return to the longer term average CPUE, having completely recovered the decline that appeared to have occurred in 2010. This by itself needs discussion for its management implications but the notion of pursuing CPUE as catch-per-hook remains more intuitively plausible and more likely to reflect changes in the fishery if they have occurred.

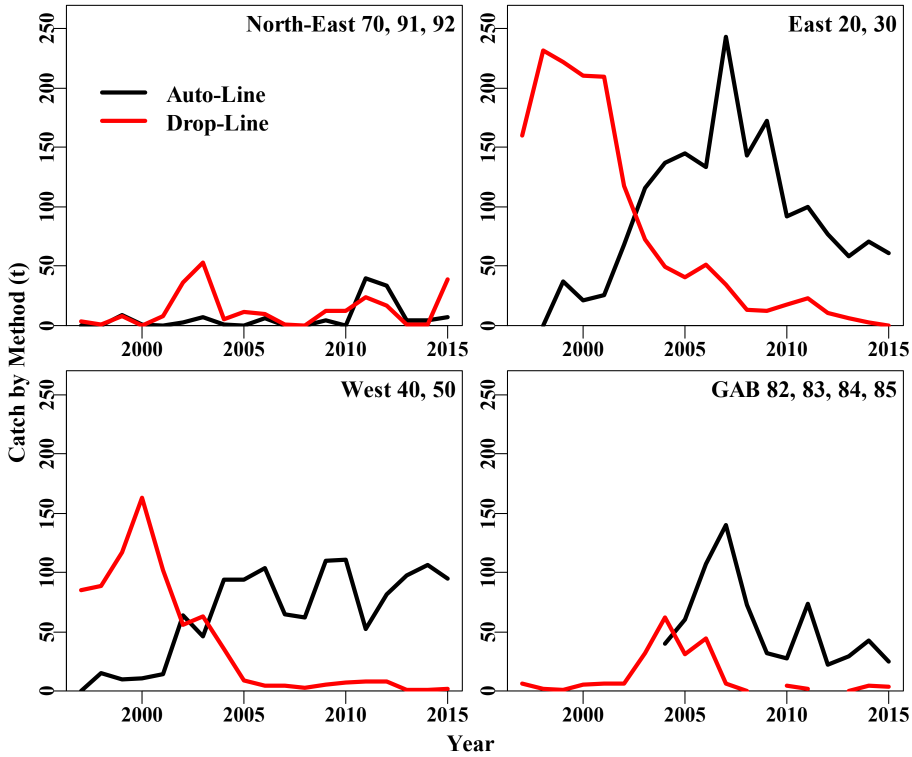


Figure 9.9. Distribution of each year's catch across regions. All graphs are on the same vertical scale. Fishery changes occurred in 2007 (the introduction of the HSP) and 2010 (beginning of TAC reduction).

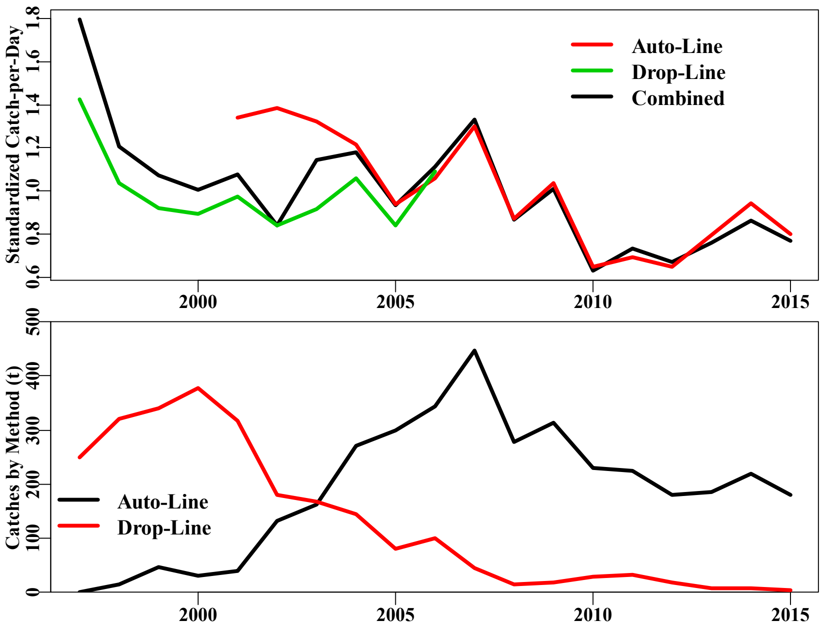


Figure 9.10. A comparison of the standardization for Blue-Eye catch-per-day across zones 20 – 50 and 83 – 85 combined and conducted separately for auto-line from 2001 – 2015 and drop-line from 1997 – 2006. The respective catches across those zones at the same time show the changeover from one method to the other.


Figure 9.11. Standardized CPUE for the auto-line and drop-line fisheries combined using catch-per-record as the unit of catch rate. The dashed line is the unstandardized geometric mean CPUE. The red bars are the 95% confidence intervals around the mean estimates (their asymmetry reflects the log-normal distribution of the CPUE data. Each time series is called to its own mean value so both series now have a mean of 1.0 for ease of visual comparison of trends. Data filtered to include only drop-line and auto-line from between 200 – 600 m depth and zones 20 – 50 and 83 – 85.

### 9.5.6 *CPUE from the Drop Line Fishery*

Currently the stock status of Blue-Eye is determined using a SESSF Tier 4 harvest strategy, and in practice this would use the combined CPUE of the drop-line and the auto-line fisheries to provide a time series. The most recent CPUE analysis of catch-per-record (catch-per-day; Figure 9.11) indicates that after a relatively strong decline between 2009 – 2010 the CPUE is rising, with the error bounds now once again encompassing the longer term rescaled average of 1.0.

While the overall distribution of CPUE from the two methods (as catch-per-record) were sufficiently similar in 2007 and 2008 to allow combination (Haddon, 2010) it is clear that the proportional distribution of each method has changed through time, with catches by drop-line being replaced by auto-line catches following 2001 (Figure 9.5, Figure 9.10; Table 9.1). Given the large area over which fishing could occur, most of the catches tend to be focused in zones 20 – 50 with an occasionally significant fishery developing in the GAB and a couple of years of auto-line effort in the northeast. There were two years of auto-line fishing on the Cascade Plateau but that is currently closed to auto-line fishing. Both auto-line and drop-line catches and effort move between zones a good deal (Figure 9.9 and Table 9.7), although zone 30 (east Tasmania) has often been a favoured fishing area, with reports that this was especially the case before 1997 for Drop-Line.

The early period from 1997 onwards is especially important to the CPUE analysis as the initial relatively high level of CPUE in 1997 is influential on the perceived changes in catch rate since then. Of course, in 1997 the catches were essentially all from drop-line as only 0.27t were taken by Autoline, and that was only in a very restricted area on the west coast of Tasmania in the months of November and December. The reason the CPUE was estimated as catch-per-record is because with the drop-line vessels, for example, the fields in the logbook for recording the number of lines and the number of hooks were mixed up in a large number of instances. To determine whether the very high CPUE in the drop-line fishery in 1997 was being affected by the use of catch-per-day all drop-line data for zones 20 – 50 plus 83, 84, and 85 were extracted and the effort fields examined (in fact labelled effort_unit_value and effort_unit_sub_code_value). It was possible to discover the records which had most likely been mixed across each other (for example, 2000 lines of 5 hooks was deemed an error as were 80 drops of 5 hooks) and these were reversed so that more plausible effort estimates in terms of number of lines and number of hooks per line, were available. In the current database there are a few erroneous records with a few combinations of unknown Units or Sub-Units (Table 9.8). Fortunately, out of a total reported catch of 2880.446t only 10.934t are not reported using units of NLD with sub-units of AHL; thus 99.62% of all catches are accounted for with such a selection.

Table 9.8. The catch (t) and number of records (in parentheses) of effort Units (as rows) and effort SubUnits (as columns). NLD is 'number of line lifts per day', THS is 'total number of hooks set', AHL is 'average number of hooks per line', and TLM is 'total length of mainline used (kms)'. FA, HRS, and M are not known.

| | Unknown | AHL | HRS | TLM |
|---|---|---|---|---|
| Unknown | 1.4 (6) | 0 | 0 | 0 |
| FA | 0 | 0 | 1.324 (11) | 0 |
| HRS | 0 | 0.789 (8) | 0 | 0 |
| M | 0 | 0 | 3.471 (23) | 0 |
| NLD | 0 | 2869.512 (7793) | 0.8 (4) | 0 |
| THS | 0 | 0 | 0 | 3.15 (3) |

#### *9.5.6.1 Data Selection Criteria*

To analyse the Drop-Line catch and effort data requires various data selections to be made. Obviously a selection for 'Method' = "DL" is required. But in addition other selections for zone, depth and fishery are required (Table 9.9).

Table 9.9. The data selection criteria used to isolate those records relating to Drop-Line catches. Previous analyses of CPUE have not used zones 91 and 92 so separate analyses will need to be conducted with and without these.

| | |
|---|---|
| Method | DL |
| Catch | > 0 |
| Start Year | 1997 |
| Final Year | 2015 |
| CAAB code | 37445001 |
| Lower Depth | 200 |
| Deepest Depth | 600 |
| Effort Unit | NLD |
| Effort Sub-Unit | AHL |
| Fishery | SEN, SSF, SSG, GHT |
| SESSF Zone | 20, 30, 40, 50, 84, 85, 91, 92 |

In any analysis of fisheries data using categorical variables, such as depth categories or regional zones, it is very common for there to be some levels within a variable that will be empty or contain very few observations. The linear models used to characterize the general trends in CPUE, while attempting to remove the effect of variables other than the stock size, generates expected values for each level or cell of each categorical variable (e.g. a mean for each month in an attempt to account for seasonality). An ideal statistical analysis would have equal numbers of observations within each cell. Properly designed experiments obtain great statistical power to detect differences from having such balanced data. Instead, within fisheries, statistical analyses rely on large numbers of observations to reduce the effects of having blatantly unbalanced data. Nevertheless, removal of empty and almost empty levels from categorical variables can reduce the number of empty cells in such analyses and improve their stability.

After review of the individual data fields some data selection was clearly required to remove very minor numbers of observations. For example, there were Blue-Eye catches in zones 10, 60, 70, and 83 but they were all minor (Table 9.22; Figure 9.12) and so these were omitted from the analysis.

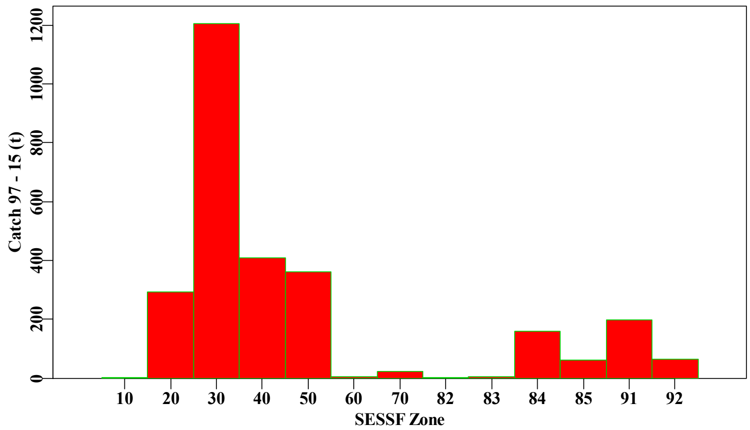


Figure 9.12. Catch (t) of Blue-Eye by SESSF zone taken by Drop-Line between 1997 – 2015

Similarly, catches at depths other than those between 200 – 600m were relatively minor although there were even records out to 3000 m (assumed erroneous) so both presumed erroneous as well as minor depth values were omitted (Figure 9.13).

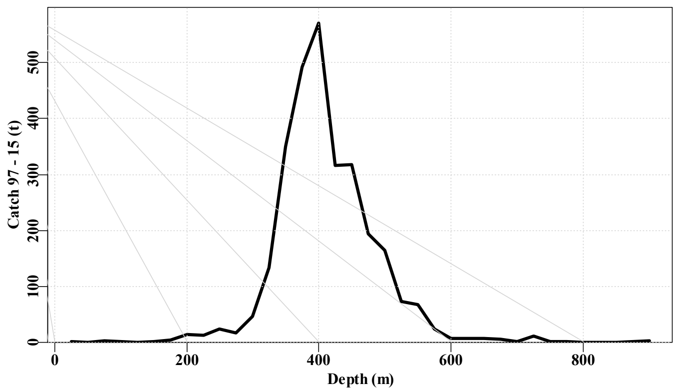


Figure 9.13. The catch at depth of Blue-Eye from 1997 – 2015 taken by Drop-Line.

The initial data selection based on the criteria listed (Table 9.9) constrained the analysis down to about 13.0% of the records and 23.0% of the catches of Blue-Eye (Table 9.10).

Table 9.10. The number of records and catches associated with applying each selection criterion. The Effort categories effectively identify the Method, which is why Method has so little effect. The two 'Delta' rows designate the difference between columns. The effect of selecting on depth, years, zones, and fishery was to lose 6.8% of DL catches.

| Statistic | Total | Effort | Depth | Years | Zones | Method | Fishery |
|---|---|---|---|---|---|---|---|
| Records | 52302 | 7824 | 7626 | 7603 | 7263 | 7262 | 7258 |
| DeltaR | 0 | 44478 | 198 | 23 | 340 | 1 | 4 |
| Catch | 11569.4 | 2877.369 | 2815.878 | 2808.625 | 2684.48 | 2684.03 | 2682.849 |
| DeltaC | 0 | 8692.034 | 61.491 | 7.253 | 124.145 | 0.450 | 1.181 |

There were also extreme values in some of the fields such as the number of line drops and average number of hooks per line (Figure 9.14), which entailed searching for the most reasonable values above which to eliminate further data as implausible.

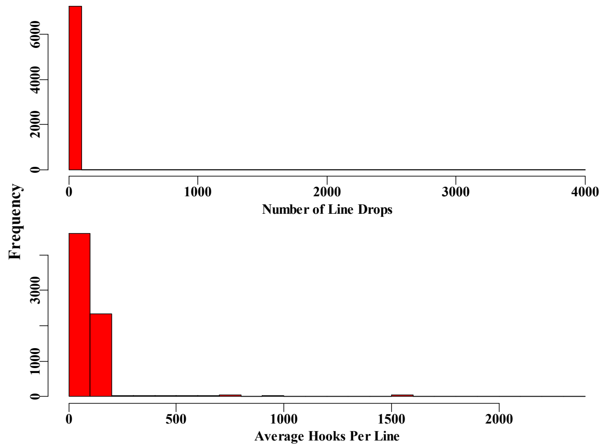


Figure 9.14. The number of line-drops and the average number of hooks per line reported by each vessel in individual records before editing implausible combinations. There were, for example, 2 records of 4000 line drops and 2 records of 2400 Hooks per Line.

Initially an upper limit of 100 line drops and 300 hooks per line were considered (Figure 9.15), however, the resulting data cloud suggested a final range of 1 – 40 for the number of line drops and 1 – 200 for the number of hooks (Figure 9.16; Table 9.11).

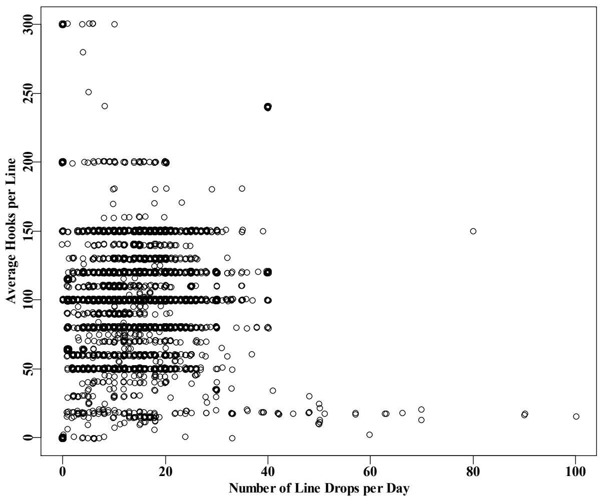


Figure 9.15. Number of hooks per line (generally there is an inverse relationship between number of lines and number of hooks). Limits used were 100 drops/lines and 300 hooks. Values were jittered to illustrate local concentrations of points.

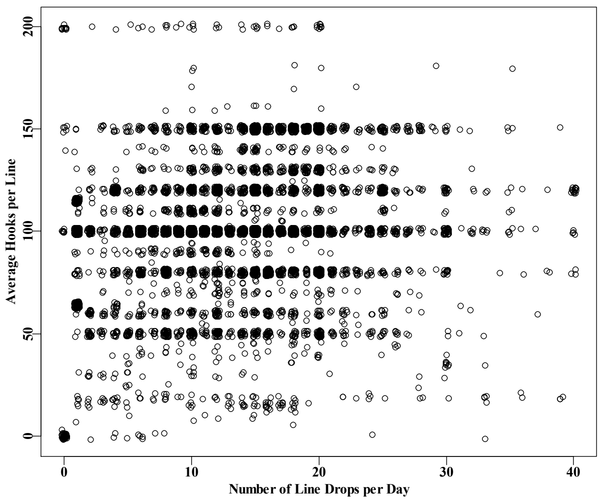


Figure 9.16. The final selection criteria for the number of line drops (or lifts) per day and the average number of hooks per line. Final limits used were 1 – 40 drops/lines and 1 – 200 hooks inclusive. Values were jittered to illustrates local concentrations of points.

Table 9.11. The effect of data selection in terms of number of line drops and average number of hooks per line. The removal of records with missing data removed ~0.6% of catch, and with the removal of records with > 40 line drops a day and > 200 hooks per line there was a total loss of 3.27% of all catches by drop-line.

| | Remove Zeros | <=100; <= 300 | <=40; <= 200 |
|---|---|---|---|
| Total | 2682.849 | 2666.989 | 2666.989 |
| Selection | 2666.989 | 2601.283 | 2579.87 |
| Data Retained | 0.9941 | 0.9754 | 0.9673 |
| Data Rejected | 0.0059 | 0.0246 | 0.0327 |
| Catch Difference | 15.8605 | 65.7055 | 87.1185 |

Prior to the adjustment and data selection the frequency distribution of the number of lines used was extremely skewed (Figure 9.14), while after the data processing peaks were observed at 1, 10, 15, and 20 line drops a day and 50, 75, 100, 120, and 150 hooks per line (Figure 9.17). These rounding effects when recording the data are the reason it typically takes on a grid like appearance when catches are plotted against effort (Figure 9.15, Figure 9.16). This grid like property of the CPUE data can influence the stability of the standardization. The number or records and total catch omitted remains minor with those up at 40 NLD and 200 AHL also being minor (Figure 9.17; Table 9.11).

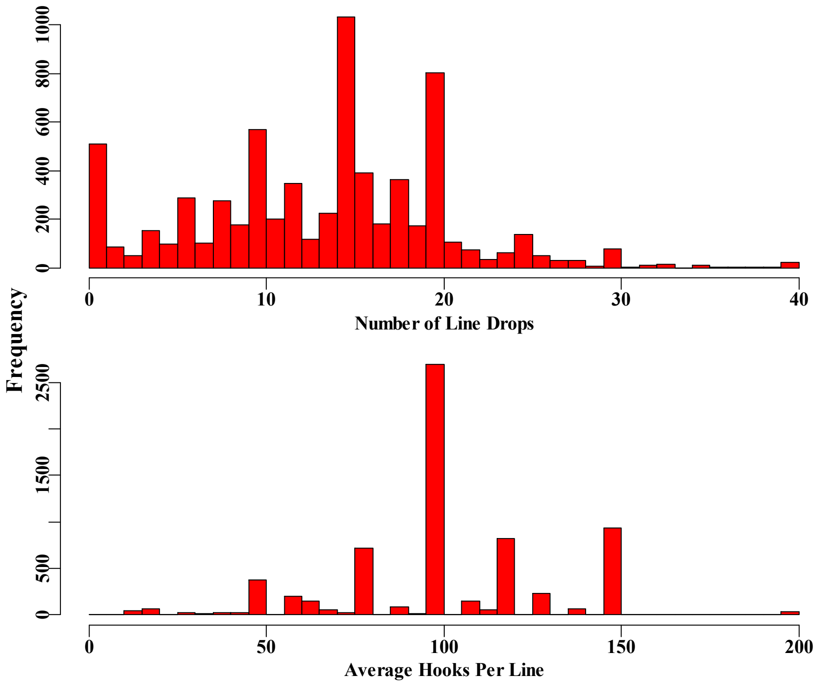


Figure 9.17. The distributions of the number of line drops (NLD) and the average number of hooks per line (AHL) after cleaning and removal of data with NLD values > 40 and AHL values > 200.

#### *9.5.6.2 Single Line Drops*

The relatively high frequency of single line drops (Figure 9.17) was unexpected so this was explored further. When the number of records per zone is compared to the number of records per zone where only single line drops were reported it is clear that large changes in reporting practices occurred but only in zones 30 and 50 and only in some years (Table 9.12).

The effect of the records reporting only one line drop can be quite marked. They only make up a small proportion of the total catches up to 2005 (a maximum of 3%) and so are less influential but from 2006 onwards, except for 2014 and 2015, makes up more than 27% and up to 63% of all catches (Table 9.13). When all CPUE data are plotted, post-2005 reveals a bimodal distribution relative to the pre-2006 distribution, which is a direct reflection of this increased percentage of single line reports (Figure 9.18; the bimodality largely disappears when the single line drop records are removed, and the data from the two periods become more comparable).

Even if the catch-per-hook analysis is not accepted to replace the catch-per-shot analysis the impact of these single shots is enough to make the distributions of the catch-per-shot differ between the auto-line and drop-line and so would need to be removed or the combination no longer used.

Table 9.12. The total number of records for the selected Drop-Line records compared with the number of records reporting only single line drops in zones 20 to 91. '>1' is the number of records that list more than one line drop while the column labelled '1' are the list of records that only report one line drop. The other columns report the zone records of single line drops.

| Year | > 1 | 1 | 20 | 30 | 40 | 50 | 84 | 91 |
|---|---|---|---|---|---|---|---|---|
| 1997 | 451 | | | | | | | |
| 1998 | 662 | | | | | | | |
| 1999 | 745 | 23 | 2 | | | 21 | | |
| 2000 | 896 | 51 | | | | 50 | | 1 |
| 2001 | 660 | 45 | | | | 45 | | |
| 2002 | 586 | 24 | | | | 20 | 4 | |
| 2003 | 577 | 2 | | 1 | | 1 | | |
| 2004 | 486 | 1 | | 1 | | | | |
| 2005 | 343 | | | | | | | |
| 2006 | 251 | 67 | | 65 | 2 | | | |
| 2007 | 86 | 38 | | 37 | 1 | | | |
| 2008 | 21 | 50 | | 50 | | | | |
| 2009 | 61 | 51 | | 50 | | 1 | | |
| 2010 | 149 | 61 | | 61 | | | | |
| 2011 | 154 | 57 | | 53 | 4 | | | |
| 2012 | 97 | 22 | | 20 | 2 | | | |
| 2013 | 27 | 16 | | 15 | 1 | | | |
| 2014 | 55 | 1 | | | | 1 | | |
| 2015 | 67 | | | | | | | |

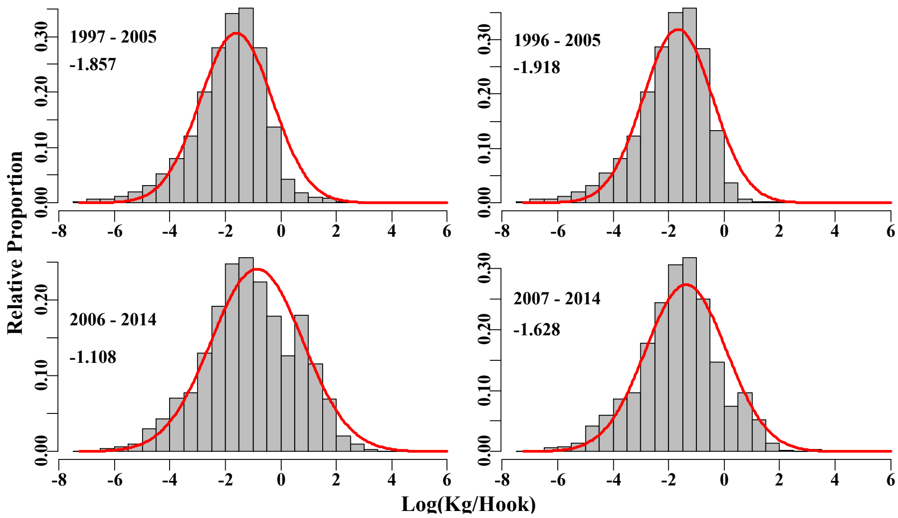


Figure 9.18. The log-transformed CPUE (catch/[line-drops x hooks]) from 1997 – 2005 and 2006 – 2015, both with (left columns) and without single drops (right column). The mode of relatively high log( catch-per-hook) results from single line drops. The negative value is the estimated mean of the fitted normal distribution.

Table 9.13. The catches and number of records taken by Drop-Line in zones 20 - 50 where either 1 line was reported or > 1 line. The %Records and %Catch indicate a large change occurs from 2006 onwards.

| Year | Catch (L > 1) | Records (L > 1) | Catch (L = 1) | Records (L = 1) | %Catch (L = 1) | %Records (L = 1) | Vessels |
|---|---|---|---|---|---|---|---|
| 1997 | 227.666 | 429 | | | | | 33 |
| 1998 | 313.473 | 647 | | | | | 26 |
| 1999 | 319.579 | 730 | 2.945 | 23 | 0.91 | 3.05 | 26 |
| 2000 | 347.112 | 873 | 7.610 | 50 | 2.15 | 5.42 | 28 |
| 2001 | 295.627 | 621 | 9.174 | 45 | 3.01 | 6.76 | 23 |
| 2002 | 170.335 | 517 | 3.178 | 20 | 1.83 | 3.72 | 20 |
| 2003 | 134.966 | 446 | 0.066 | 2 | 0.05 | 0.45 | 20 |
| 2004 | 81.265 | 312 | 0.030 | 1 | 0.04 | 0.32 | 16 |
| 2005 | 48.481 | 206 | | | | | 14 |
| 2006 | 37.604 | 101 | 18.065 | 67 | 32.45 | 39.88 | 10 |
| 2007 | 16.926 | 65 | 21.841 | 38 | 56.34 | 36.89 | 9 |
| 2008 | 5.177 | 20 | 8.803 | 50 | 62.97 | 71.43 | 5 |
| 2009 | 7.827 | 30 | 9.991 | 51 | 56.07 | 62.96 | 9 |
| 2010 | 15.468 | 101 | 9.241 | 61 | 37.40 | 37.65 | 9 |
| 2011 | 16.916 | 96 | 13.017 | 57 | 43.49 | 37.25 | 9 |
| 2012 | 13.029 | 71 | 4.898 | 22 | 27.32 | 23.66 | 8 |
| 2013 | 4.608 | 24 | 2.303 | 16 | 33.32 | 40.00 | 5 |
| 2014 | 3.257 | 31 | 0.260 | 1 | 7.39 | 3.13 | 4 |
| 2015 | 1.086 | 19 | | | | | 5 |

The records reporting single lines post-2006 have a major impact on the perceived CPUE. Post-2006 (following the structural adjustment), the proportion of single lines increases to > 50% and catches from > 1 lines reduce to no more than 17t and generally no more than 64 records per year at most (although there were 101 records in 2010; Table 9.13). A comparison of the standardized CPUE for drop-line catches from 1997 – 2006, with and without the single line records illustrates the very large effect these single lines have on records following 2005 (compare Figure 9.19, Figure 9.20, and Figure 9.21). The inclusion of records reporting single lines leads to a similarly noisy but flat time-series after the transition in effort reporting through 2006, however, as evidenced by the wider confidence intervals the later observations are based on far fewer record numbers (Table 9.13). It is apparent that the structural adjustment and associated changes in fishing behaviour (and reporting behaviour) have broken the drop-line CPUE time-series. Of most importance to this is the almost complete changeover in the vessels doing the drop-line fishing. Only one of the significant fishers remained after the structural adjustment and an array of new vessels entered the fishery. It is recommended that the post-2006 drop-line data not be used in future in conjunction with the earlier data as it is too sparse, and has a completely different character. If used alone it is also clear that it is effectively flat but is so noisy (sparse data) that it would be uninformative to any stock assessment that tried to use it.

A final confirmation that the character of the CPUE changed when single line drops were recorded is provided by examining the records of individual vessels (Table 9.14).

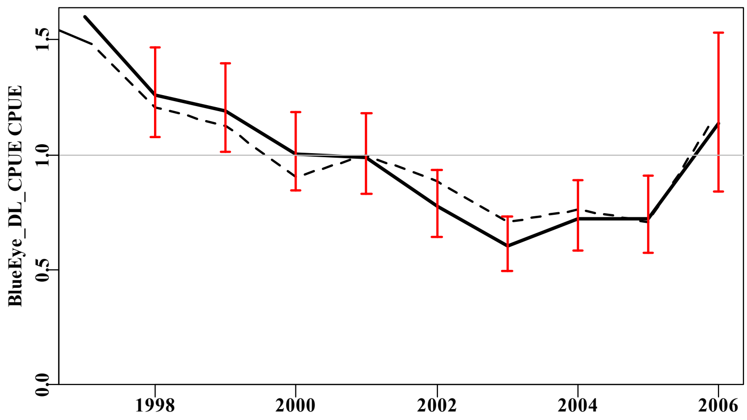


Figure 9.19. The standardized drop-line CPUE from which all records reporting a single line are removed. The low catches and number of records following 2006 (Table 9.13) would make an extension out to 2014 unreliable.

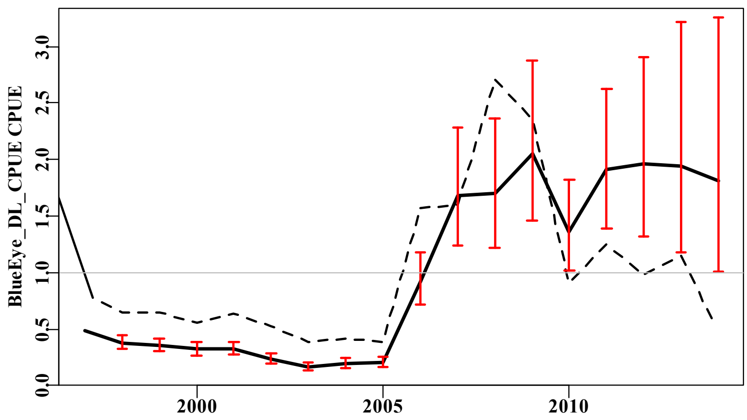


Figure 9.20. The standardized drop-line CPUE from which all records reporting a single line are retained. This time series is extended to 2014 to illustrate the expanded impact of the increased proportion of single lines post-2005; although the small number of records and very low catches in the last two years makes this even less reliable.

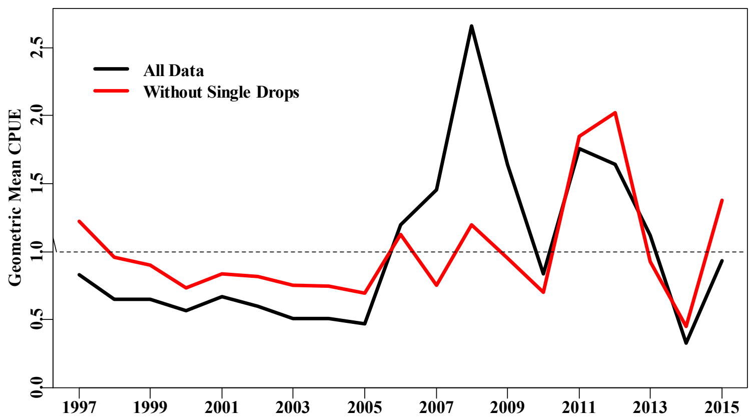


Figure 9.21. The geometric mean CPUE (catch-per-hook) with and without single drops. The numbers of records in the later years become relatively few but the distortion in the general trend brought about by single drops is apparent. Standardization fails because of an almost complete change-over of vessels doing the fishing after 2006/2007.

When most of the data is made up of single line drops then the CPUE tends to be > 1.0 and when it is mostly or only made up of > 1 line drop then it tends to be below 1.0 (Table 9.14). Such a change in recording implies the data has a mixture of two categories.

Table 9.14. The bias corrected geometric mean CPUE for three individual vessels from the Drop-Line fleet. The CPUE is in the V1, V2, and V3 columns, while the number of records with >1 line-drops is in V#_0 and the records with single NLD values is in V#_1 columns. V1 in 1998 has a high CPUE but has only 5 records all with > 1 NLD. However, these were made up of four records of 4 line drops and one record with only 2 line drops (of 50 hooks each) so these were exceptionally high.

| Year | V1 | V1_0 | V1_1 | V2 | V2_0 | V2_1 | V3 | V3_0 | V3_1 |
|---|---|---|---|---|---|---|---|---|---|
| 1997 | | | | 0.3518 | 19 | | | | |
| 1998 | 1.4417 | 5 | | 0.3979 | 61 | | | | |
| 1999 | 1.3905 | 21 | 20 | 0.2970 | 76 | | | | |
| 2000 | 2.6199 | | 50 | 0.2000 | 84 | | | | |
| 2001 | 3.4965 | | 44 | 0.1918 | 72 | | | | |
| 2002 | 1.7530 | 25 | 20 | 0.1247 | 51 | | | | |
| 2003 | 0.3140 | 29 | 1 | 0.1701 | 52 | | | | |
| 2004 | 0.2404 | 26 | | 0.1570 | 55 | | | | |
| 2005 | 0.2173 | 11 | | 0.1115 | 59 | | | | |
| 2006 | 0.3059 | 5 | | 2.9587 | 1 | 66 | | | |
| 2007 | | | | 6.5619 | | 33 | | | |
| 2008 | | | | 2.0312 | 6 | 50 | | | |
| 2009 | | | | 2.9143 | | 48 | | | |
| 2010 | | | | 1.9730 | 6 | 61 | | | |
| 2011 | | | | 2.7616 | 9 | 34 | 2.5565 | | 23 |
| 2012 | | | | 2.5848 | 1 | 4 | 3.9952 | 3 | 18 |
| 2013 | | | | | | | 2.5946 | | 16 |

The catch rate trajectory described when effort is taken to be the corrected hooks by lines differs from that obtained when using catch-per-day (Figure 9.22; see Sporcic and Haddon, 2014 for standard methods). When using all hook x line data (ignoring the single line drop problem) the increase in single line records would lead to a lower total catch-per-day but a higher catch-per-hook-line. Once the impact of the rise in single lines being reported is identified this difference becomes significant.

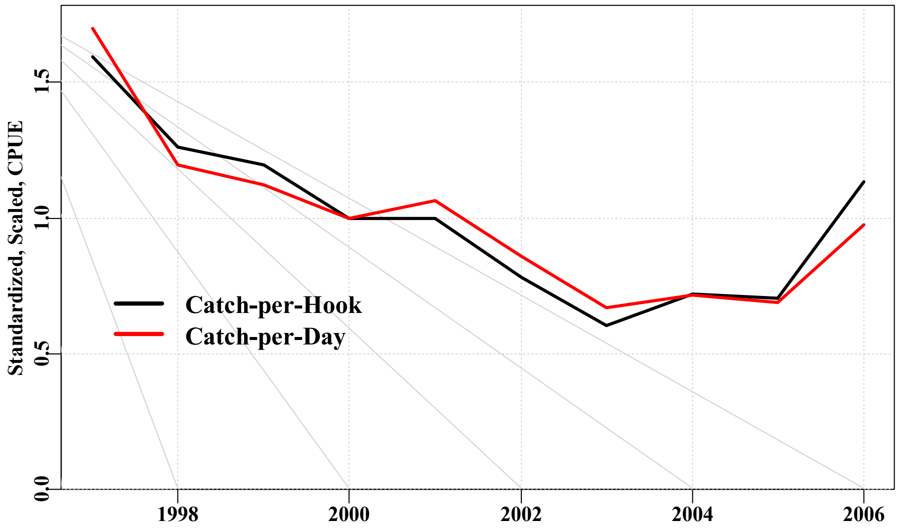


Figure 9.22. A comparison of drop-line CPUE using catch-per-hook (from Figure 9.19) with drop-line CPUE using catch-per-day from the four zones 20 – 50.

The catch-per-hook trend line begins at a lower level and ends at a higher level than the catch-per-day series (Figure 9.22). However, both have wide uncertainty bars (e.g Figure 9.19 and Figure 9.20). Both time series can be considered to be noisy and uncertain even while oscillating around the mean of 1.0. If all SESSF zones in which significant catches have been taken are included then the same pattern emerges in the standardization except that both trends are lower in 2006 and the catch-per-hook is closer to the lower value of catch-per-day in 2006 (Figure 9.23; Figure 9.23).

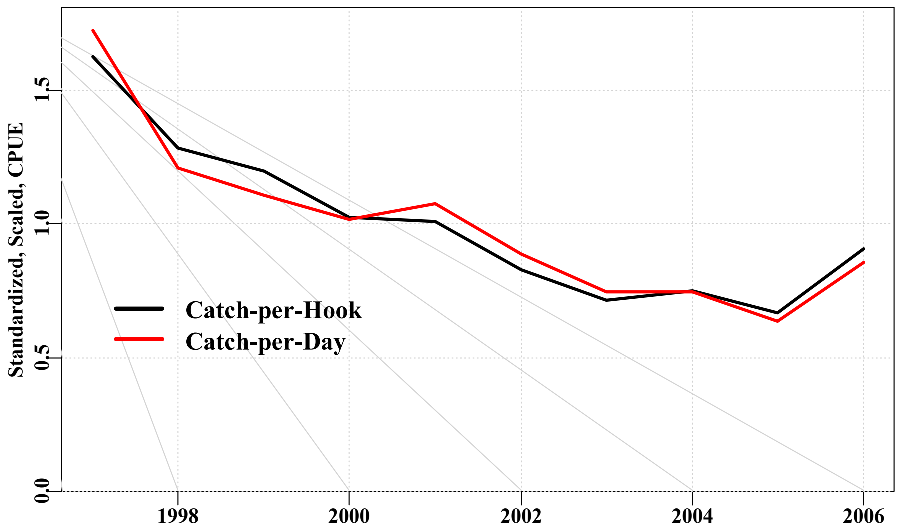


Figure 9.23. A comparison of drop-line CPUE using catch-per-hook (from Figure 9.19) with drop-line CPUE using catch-per-day from all zones 20 – 50, 83 – 85, and 91 and 92.

### 9.5.7 *CPUE from the Auto Line Fishery*

Auto-line vessels only gained licenses to operate in the SESSF from 1997 although they only began operations in November 1997 on the west coast of Tasmania. Catches in the North East by auto-line only increased since the TAC within the SESSF has declined in recent years (Figure 9.24), although auto-line is now excluded from Zones 70 and 92.

Table 9.15. Catches of Blue-Eye (tonnes) reported as being taken by Auto-line since 1997 for those zones where catches are continuous and potentially amenable to a CPUE analysis. See Figure 9.3 for the block descriptions; zone 0 includes catches from zones 10, 60, 70, 91, and 92, as well as outside the SESSF and includes the High Seas Non-Trawl fishery. The high catch purporting to be in Zone 30 in 2000 actually included over 50 tonnes from the Cascade Plateau.

| Year | Total | 0 | 20 | 30 | 40 | 50 | 83 | 84 | 85 |
|---|---|---|---|---|---|---|---|---|---|
| 1997 | 0.267 | | | | 0.267 | | | | |
| 1998 | 27.253 | 12.064 | | 0.233 | 14.956 | | | | |
| 1999 | 61.040 | 12.809 | 35.575 | 1.725 | 10.932 | | | | |
| 2000 | 90.756 | 7.061 | 12.243 | 56.804 | 14.648 | | | | |
| 2001 | 47.884 | 0.242 | 2.000 | 31.044 | 14.598 | | | | |
| 2002 | 133.747 | 2.100 | 2.640 | 65.131 | 42.576 | 21.300 | | | |
| 2003 | 219.676 | 7.260 | 20.634 | 97.288 | 84.594 | 9.900 | | | |
| 2004 | 324.805 | 2.152 | 62.886 | 91.921 | 82.155 | 26.754 | 11.981 | 15.316 | 31.641 |
| 2005 | 300.602 | 1.815 | 84.953 | 60.283 | 57.163 | 36.472 | 19.058 | 5.145 | 35.715 |
| 2006 | 353.763 | 8.569 | 67.075 | 67.257 | 77.940 | 25.672 | 31.144 | 0.330 | 75.777 |
| 2007 | 448.511 | 0.550 | 48.019 | 195.532 | 41.074 | 23.907 | 29.791 | 94.300 | 15.337 |
| 2008 | 279.398 | 0.017 | 44.450 | 98.763 | 51.837 | 11.408 | 27.543 | 32.167 | 13.214 |
| 2009 | 323.923 | 4.655 | 50.874 | 124.045 | 79.579 | 32.355 | 1.633 | 15.369 | 15.415 |
| 2010 | 236.620 | 0.100 | 25.642 | 69.142 | 50.841 | 63.093 | 5.764 | 7.153 | 14.884 |
| 2011 | 266.793 | 40.196 | 30.835 | 69.502 | 38.459 | 14.160 | 20.576 | 40.127 | 12.939 |
| 2012 | 213.670 | 33.644 | 21.176 | 55.333 | 70.428 | 11.183 | 8.417 | 9.736 | 3.752 |
| 2013 | 190.515 | 4.175 | 13.151 | 45.406 | 84.451 | 13.684 | 0.465 | 16.158 | 13.025 |
| 2014 | 225.853 | 4.950 | 3.867 | 67.697 | 87.153 | 19.442 | 0.607 | 31.049 | 11.089 |
| 2015 | 192.101 | 11.365 | 9.031 | 51.862 | 72.641 | 22.563 | 0.541 | 20.487 | 3.611 |
| Total | 3937.176 | 153.723 | 535.049 | 1248.968 | 976.289 | 331.893 | 157.519 | 287.336 | 246.398 |
| %Total | 100.0 | 3.9 | 13.6 | 31.7 | 24.8 | 8.4 | 4.0 | 7.3 | 6.3 |

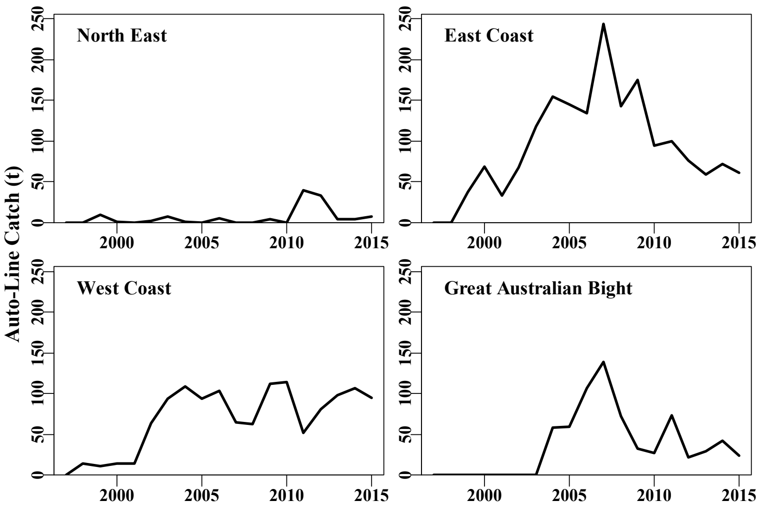


Figure 9.24. Total reported catches of Blue-Eye by auto-line by region. The North East includes zones 70, 91, and 92, the east coast is zones 20 – 30, the west coast is 40 – 50, and the GAB is 83 – 85.

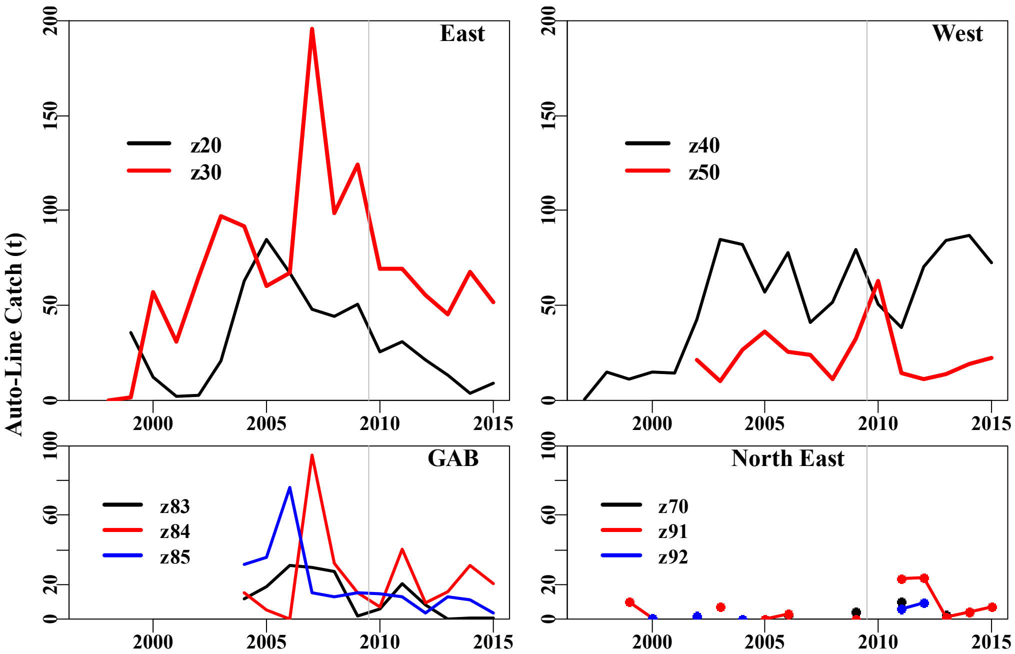


Figure 9.25. A change in catches by auto-line by specific zone within regions. Note the vertical scales are the same in each case so all plots are comparable. Dots are included in the North-East as some zones are not necessarily fished every year.

The east coast of Tasmania and eastern Bass Strait (Horseshoe and Flinders Island) have dominated catches, although since about 2002 catches off western Tasmania have been approximately 100 t per annum and since 2004 catches from the GAB have featured, although these have declined since 2009 (Figure 9.24).

The auto-line fishery for Blue-Eye exhibits some clear seasonal trends around Tasmania but the trend in the GAB is less clear (Figure 9.25 and Figure 9.26), which may be related to the recently reduced catches.

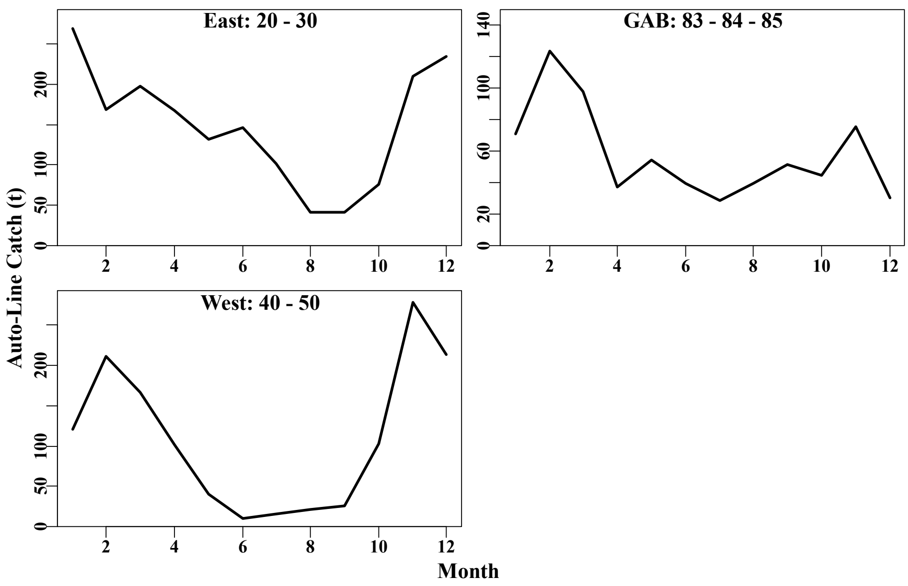


Figure 9.26. The total catch per month across years 1997 - 2015 for three main regions. Seasonality is less apparent in the GAB but is still present. In the North East catches are scattered through the years and there is insufficient data to describe any seasonality.

The specification of depth bounds of 200 – 600 metres might appear intuitively as being relatively narrow, however, a consideration of the catch of Blue-Eye at depth by Auto-Line indicates these to be sensible bounds to use in practice (**Error! Reference source not found.**).

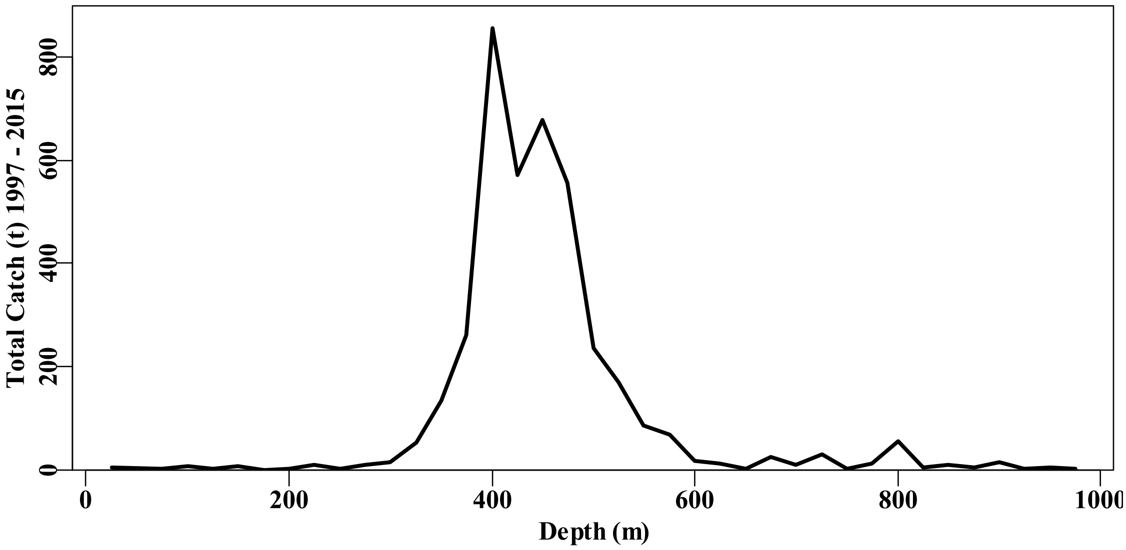


Figure 9.27. The catch at depth by Auto-Line vessels from 1997 p 2015 across zones 20 – 50 and 83 – 85.

Just as with Drop-Line the effort reporting is in terms of the main Unit of effort with a Sub-Unit of effort included. There are two main codes although there are also 55 with unknown Unit and Sub-Unit. Initially in 1997 and 1998 the main unit of effort was the Number-of-Lines-Set, however, as this could lead to confusion of whether total hooks set meant per line set or the total for the day it is fortunate that NLS was made obsolete sometime in 1999. This in turn led to the major issue with the Auto-Line effort reporting being that the Total Hooks Set switched from being a Sub-Unit code to being a Unit code sometime in 1999 (Table 9.16 and Table 9.17). This source of confusion appears to have propagated confusion in the log-book entries for a number of years following the changes and is the main reason this data needs review.

Table 9.16. A tabulation of the different Unit types identified (rows) and Sub-Units codes identified (columns). NLS is number of lines per shot (obsolete after 1999) and THS is Total Number of Hooks per Shot, finally TLM is Total Length of Mainline used.

| Unit | Unknown | THS | TLM |
|---|---|---|---|
| Unknown | 55 | 0 | 0 |
| NLS | 0 | 71 | 0 |
| THS | 0 | 0 | 8286 |

Even before editing the database confusions such that the Total-Hooks-Set was corrected as best it could be the number of records available for CPUE standardization only rose above 100 in 2002 onwards. From 1997 – 2001 the number of records were sparse as was the geographical spread of the distribution of catch. In 2000 the catches and records are also distorted by relatively high catches being taken down on the Cascade Plateau.

Table 9.17. The number of records in each year under the different Unit and Sub-Unit codes. NLS is number of lines per shot (obsolete after 1999) and THS is Total Number of Hooks per Shot, and TLM is Total Length of Mainline used. 'Final' are the final number of records per year after the Total-Hooks-Set was corrected for database confusions.

| | | Unit | | Sub-Unit | | |
|---|---|---|---|---|---|---|
| Year | Unknown | NLS | THS | THS | TLM | Final |
| 1997 | 0 | 3 | 0 | 3 | 0 | 3 |
| 1998 | 0 | 28 | 0 | 28 | 0 | 28 |
| 1999 | 0 | 40 | 9 | 40 | 9 | 45 |
| 2000 | 0 | 0 | 29 | 0 | 29 | 28 |
| 2001 | 0 | 0 | 65 | 0 | 65 | 63 |
| 2002 | 0 | 0 | 226 | 0 | 226 | 226 |
| 2003 | 0 | 0 | 433 | 0 | 433 | 432 |
| 2004 | 55 | 0 | 1135 | 0 | 1135 | 1125 |
| 2005 | 0 | 0 | 1127 | 0 | 1127 | 1116 |
| 2006 | 0 | 0 | 1064 | 0 | 1064 | 1062 |
| 2007 | 0 | 0 | 652 | 0 | 652 | 652 |
| 2008 | 0 | 0 | 603 | 0 | 603 | 600 |
| 2009 | 0 | 0 | 544 | 0 | 544 | 541 |
| 2010 | 0 | 0 | 482 | 0 | 482 | 482 |
| 2011 | 0 | 0 | 524 | 0 | 524 | 522 |
| 2012 | 0 | 0 | 425 | 0 | 425 | 425 |
| 2013 | 0 | 0 | 349 | 0 | 349 | 349 |
| 2014 | 0 | 0 | 292 | 0 | 292 | 292 |
| 2015 | 0 | 0 | 250 | 0 | 250 | 250 |

A total of 14 vessels have reported catches of Blue-Eye caught using Auto-Line since 1997, although a maximum of 11 report in any single year (Figure 9.28). The active fleet expanded between 2002 – 2004. The structural adjustment occurred from November 2005 to Nov 2006 and that (along with TAC changes) appears to have stabilized numbers at about six vessels, with only three or four contributing in recent years. However, the four lowest catching vessels, across all years 1997 – 2015, have only landed totals of either 0.815, 3.55, 6.0, or 6.256 t of Blue-Eye in between 1 – 6 years of fishing. By selecting those vessels catching more than 10 tonnes a more representative number of vessels reporting significant catches per year is obtained (Figure 9.28). However, for the standardization analysis no selection on minimum catch was made.

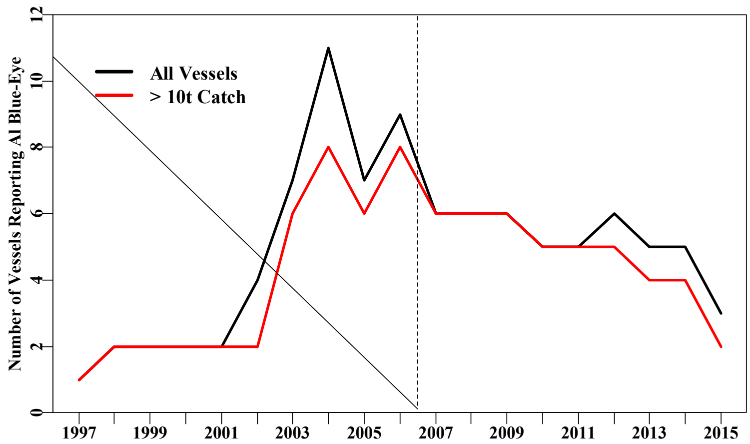


Figure 9.28. The number of auto-line vessels reporting Blue-Eye catches per year of the fishery compared with the number of vessels that caught more than a total of 10 tonnes over the 19 years from 1997 – 2015. Vertical dashed line is 2006.5, identifying the structural adjustment.

### *9.5.7.1 Auto-Line Catch-per-Hook*

There remain numerous confusions in the database, especially in the early years. There was an early change in the database which mixed up a large number of the unit-code-values and sub-unit-code-values so that the 'total-hooks-set' (THS) field might contain '15000' or perhaps just '2'. Other errors occurred but the most important were such transposition errors. The main field used is 'total-hooks-set', so the focus was on making the values in that field defensible for as many records as possible (Figure 9.29).

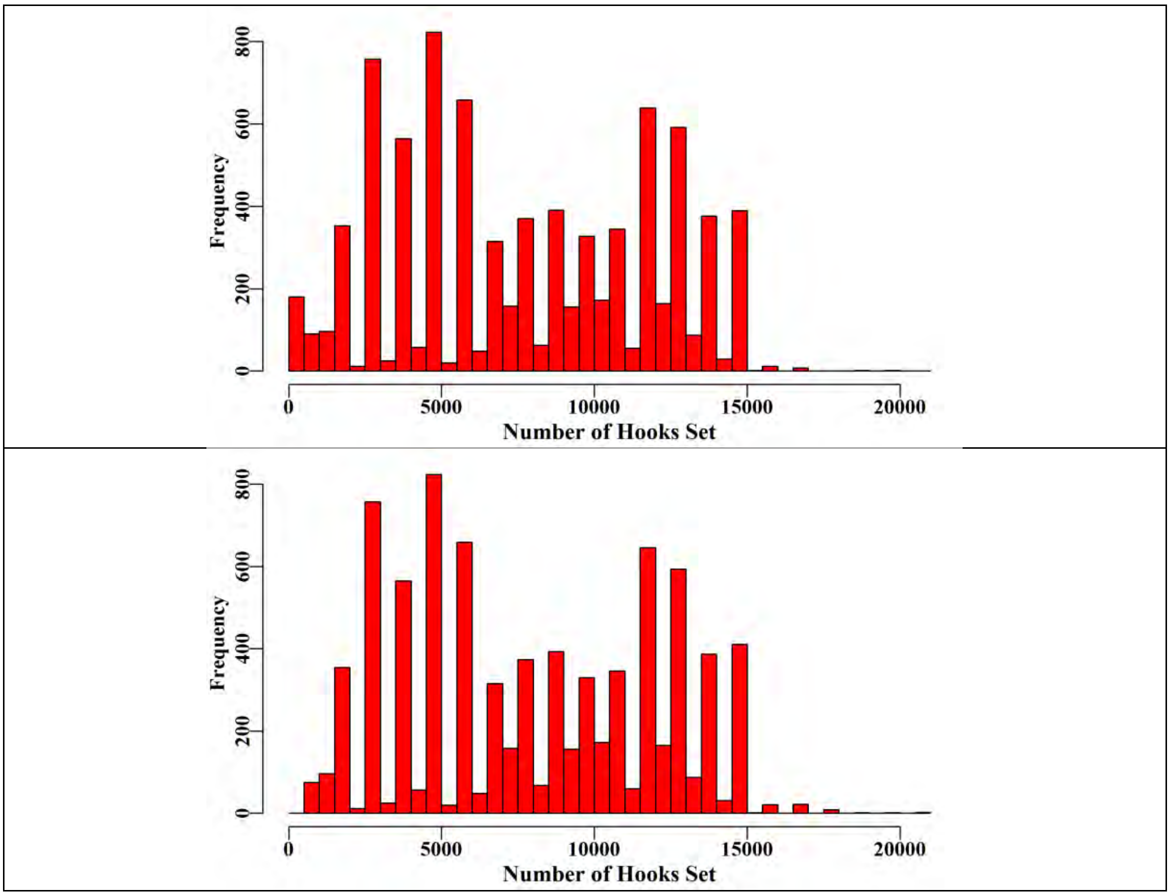


Figure 9.29. A naïve generation of catch rate in terms of the log(catch/Sub-Unit-Value) in the top panel where Sub-Unit-Value is supposedly the total-hooks-set (THS). The spread of values includes a few hundred with low values, which lead to elevated catch-rates. After passing through the reorganisation and selection algorithm (Table 9.18) the result is the lower panel which has far fewer smaller values with only minor changes elsewhere. These plots relate to all years combined.

There were some records which appeared to be more representative of drop-line fishing than auto-line (e.g. a unit-value = 20, and subunit-value = 100), such potential errors may need clarification by examination of the original data-sheets or by tracing back records for the individual vessels involved to determine their usual fishing methods at the same times and places to determine whether they are actually Drop-Line records.

Even when the uncertainty generated in the analyses of catch-per-hook by flawed data are managed through data editing or exclusion, it became evident that there have been other sources of change that could influence fishing behaviour, in terms of hooks set, and hence CPUE (Figure 9.30). For example, in 1999 – 2000 it is clear that operators reported setting more than 15,000 hooks. However, from 2001 – 2009 it would appear that something led to them using up to 15,000 hooks, and then from 2010 onwards that maximum appears to have decreased to 13,000 hooks (Figure 9.30). Numerous other changes have occurred in the auto-line fishery with catches only being more evenly distributed among multiple fishers following the structural adjustment (Nov 2005 – Nov 2006). The structural adjustment also had the effect, or removing primarily those who had been catching the least, and with so few vessels in the fishery this too can influence CPUE of the remaining vessels, which thus cannot be captured by a standardization.

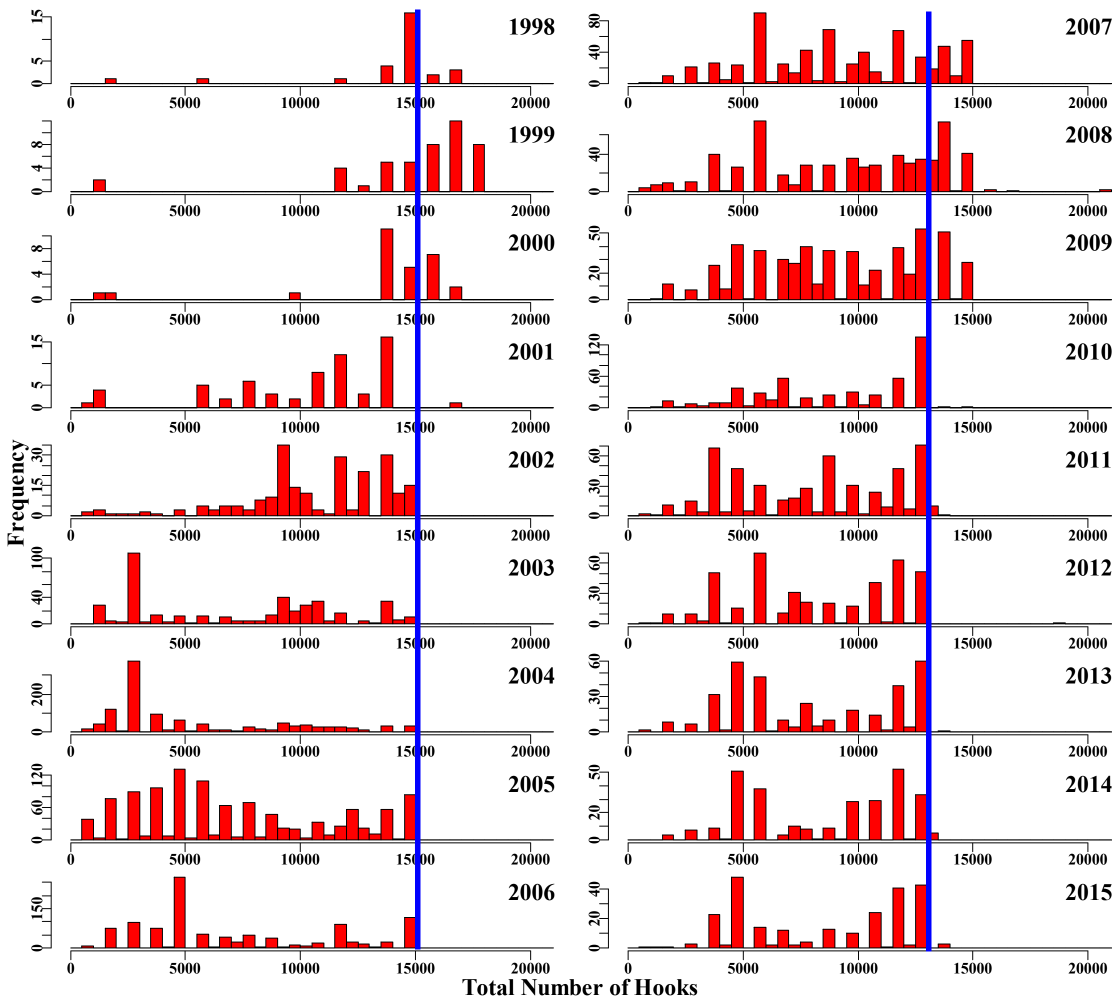


Figure 9.30. The frequency distribution of total number of hooks set each year from 1998 – 2015, after correcting the database so that Total-Hooks-Set was no longer mixed up with other records.

An attempt was made to generate a repeatable algorithm to make the changes required to the database to isolate the total-hooks-set from among the confusions currently expressed within the effort related fields. Introducing new columns titled 'hooks', 'CE', and 'LnCE' incremental steps were applied checking the distribution of hooks, the corresponding log transformed CPUE, and visually inspecting the effort fields in the database at each step to clarify the next steps if any (Figure 9.31).

The generation of a cleaner representation of the total-hooks-set per record involves both selecting and manipulating data fields in the current database (Table 9.18 and Table 9.19).

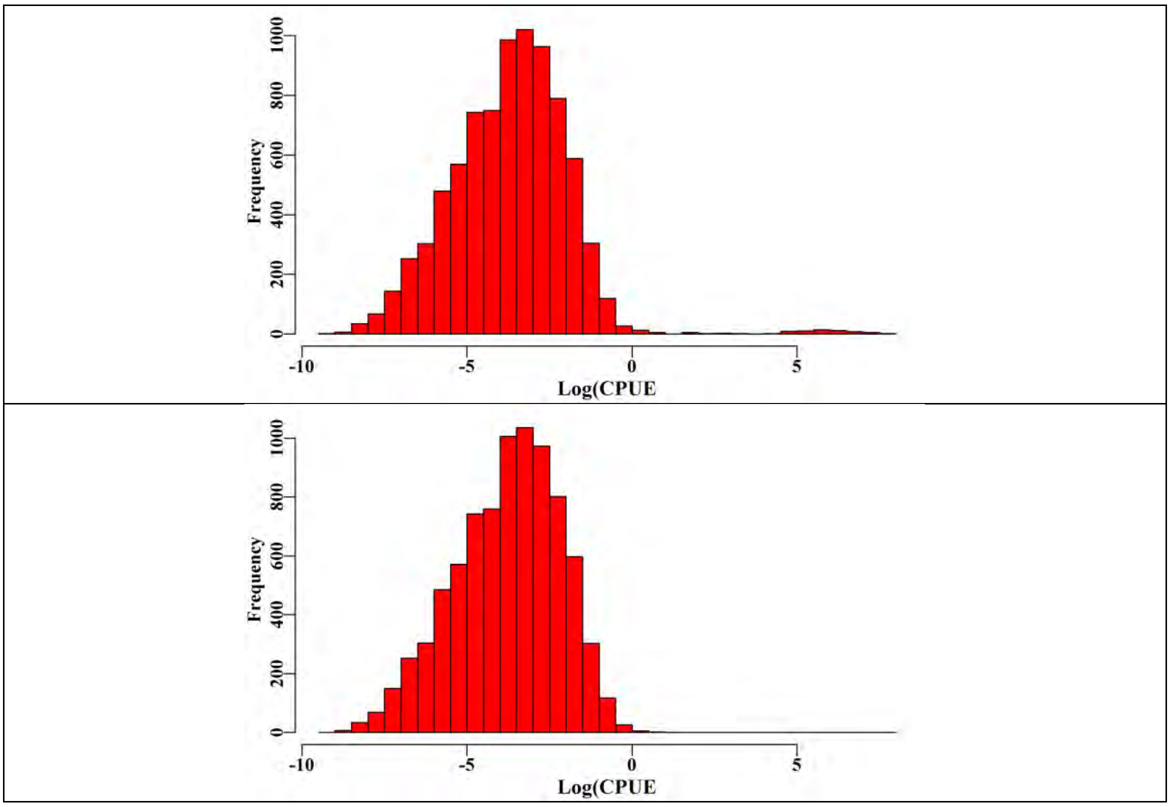


Figure 9.31. The distribution of the log-transformed CPUE (kg/hook) with the top panel using the naïve Unit-Values as representing total-hooks-set. The bottom panel, set on the same scales, uses the total-hooks-set after the different selections and database manipulations (see Figure 9.29 for the total-hooks-set in each case).

Table 9.18. The data selection criteria used followed by the steps in the database manipulations that were used to generate a relatively clean column of total-hooks-set for Auto-Line. UV = Unit-Value and SUV – Sub-Unit-Value within the database (see Table 9.19).

| Step | Description |
|---|---|
| Total | All Blue-Eye records in the AFMA catch and Effort database |
| Method | Only those records reporting a method of "AL" |
| Depth | Only depths between 200 – 600 metres |
| Years | Only data from 1997 – 2015 |
| Zones | Only records reporting zones 20, 30, 40, 50, 83, 84, 85 |
| Fishery | Only records reporting either "SEN" or "GHT" |
| U-THS | Transfer the UV to hooks |
| 9798SUV | Transfer SUV recorded as THS to hooks |
| H0-SUVgt0 | Transfer the SUV if it was > 0 and the UV = 0 |
| noEffort | Remove records with no effort; neither UV nor SUV |
| SUVgtUV | Transfer SUV which are > UV where UV > 1000 and hooks > 20 |
| CEgt10 | Remove 2 remaining records with CPUE > 10Kg/hook |
| Hlt1000 | Remove 2 records with fewer than 1000 hooks. |

Table 9.19. The sequence of data selection and editing and their effects on the amount of Blue-Eye catch and number of records. Codes below *Fishery* are described in Table 9.18.

| | Records | Difference | Catch (t) | ΔCatch | %AL |
|---|---|---|---|---|---|
| Total | 52302 | 0 | 11569.400 | 0 | |
| Method | 9545 | 42757 | 4261.211 | 7308.192 | 100 |
| Depth | 9000 | 545 | 4001.779 | 259.432 | 93.91 |
| Years | 8836 | 164 | 3900.517 | 101.262 | 91.54 |
| Zones | 8365 | 471 | 3611.321 | 289.196 | 84.75 |
| Fishery | 8335 | 30 | 3591.132 | 20.189 | 84.27 |
| U-THS | 8335 | 0 | 3591.132 | 0 | 84.27 |
| 9798SUV | 8335 | 0 | 3591.132 | 0 | 84.27 |
| H0-SUVgt0 | 8335 | 0 | 3591.132 | 0 | 84.27 |
| noEffort | 8254 | 81 | 3584.629 | 6.502 | 84.12 |
| SUVgtUV | 8254 | 0 | 3584.629 | 0 | 84.12 |
| CEgt10 | 8252 | 2 | 3578.829 | 5.800 | 83.99 |
| Hlt1000 | 8250 | 2 | 3575.779 | 3.050 | 83.91 |

Once catch-per-hook CPUE data were available these could then be standardized using standard methods (Figure 9.32). Standardizations only begin in 2002 after which sufficient data to be representative are available.

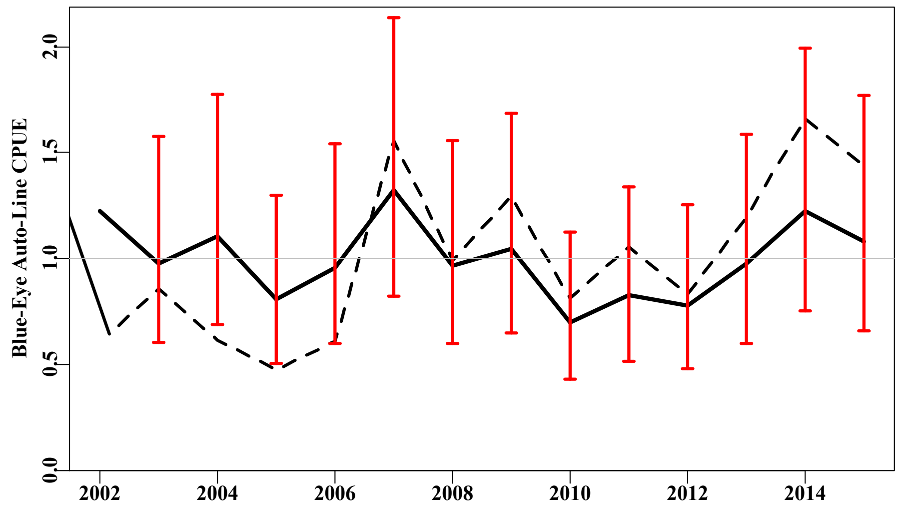


Figure 9.32. The standardized CPUE for Blue-Eye taken by Auto-Line from 2002 – 2015 from zones 20, 30, 40, 50, 83, 84, and 85. While the error bars are wide note the difference between the solid standardized trend and the unstandardized geometric mean (dashed line).

The optimum statistical model fitted to the available data from 2002 – 2015 was LnCE = Year + Vessel + Month + Zone + DepCat + DayNight + Month:Zone in each case. Catch-per-hook from zones 20 – 85 and from zones 20 – 50, were compared with the catch-per-day analysis from zones 20 – 50 (Table 9.20; Figure 9.33). Only minor differences are apparent between the inclusion of the GAB data (zones 83 – 85) and considering only zones 20 – 50. However, the catch-per-hook estimates generate a flatter trend than that deriving from the catch-per-day analysis.

Table 9.20. The geometric mean unstandardized CPUE (Geom), and the optimum models from standardizations of all Auto-Line Blue-Eye catches as catch-per-hook (cph) from zones 20 – 85 (y2085), zones 20 – 50 (y2050), and as catch-per-day (cpd) for zones 20 – 50 (yCPD). The final column is the total reported catch from the records included in The AL CPUE analyses.

| Year | Geom-cph | Geom-cpd | y2050 | y2085 | yCPD | AL Catch |
|---|---|---|---|---|---|---|
| 2002 | 0.6024 | 0.7863 | 0.7681 | 0.7982 | 0.9336 | 131.366 |
| 2003 | 0.8589 | 0.6567 | 0.9814 | 1.0105 | 1.2881 | 156.966 |
| 2004 | 0.6139 | 0.3394 | 1.0614 | 1.1473 | 1.2039 | 227.589 |
| 2005 | 0.4759 | 0.4114 | 0.9160 | 0.8383 | 1.0908 | 237.854 |
| 2006 | 0.6088 | 0.6967 | 1.0275 | 0.9948 | 1.2125 | 237.218 |
| 2007 | 1.5558 | 1.5810 | 1.3542 | 1.3757 | 1.3300 | 308.245 |
| 2008 | 0.9909 | 1.1665 | 1.1093 | 1.0029 | 1.0921 | 205.017 |
| 2009 | 1.2935 | 1.5166 | 1.1114 | 1.0829 | 1.1223 | 279.887 |
| 2010 | 0.8120 | 0.9249 | 0.7405 | 0.7201 | 0.6945 | 202.140 |
| 2011 | 1.0567 | 0.8874 | 0.8374 | 0.8604 | 0.7237 | 151.689 |
| 2012 | 0.8343 | 0.8147 | 0.7511 | 0.7998 | 0.6852 | 158.120 |
| 2013 | 1.1956 | 1.0478 | 0.9227 | 1.0044 | 0.7661 | 156.342 |
| 2014 | 1.6616 | 1.7500 | 1.3410 | 1.2563 | 1.0191 | 176.813 |
| 2015 | 1.4398 | 1.4206 | 1.0780 | 1.1084 | 0.8383 | 155.946 |

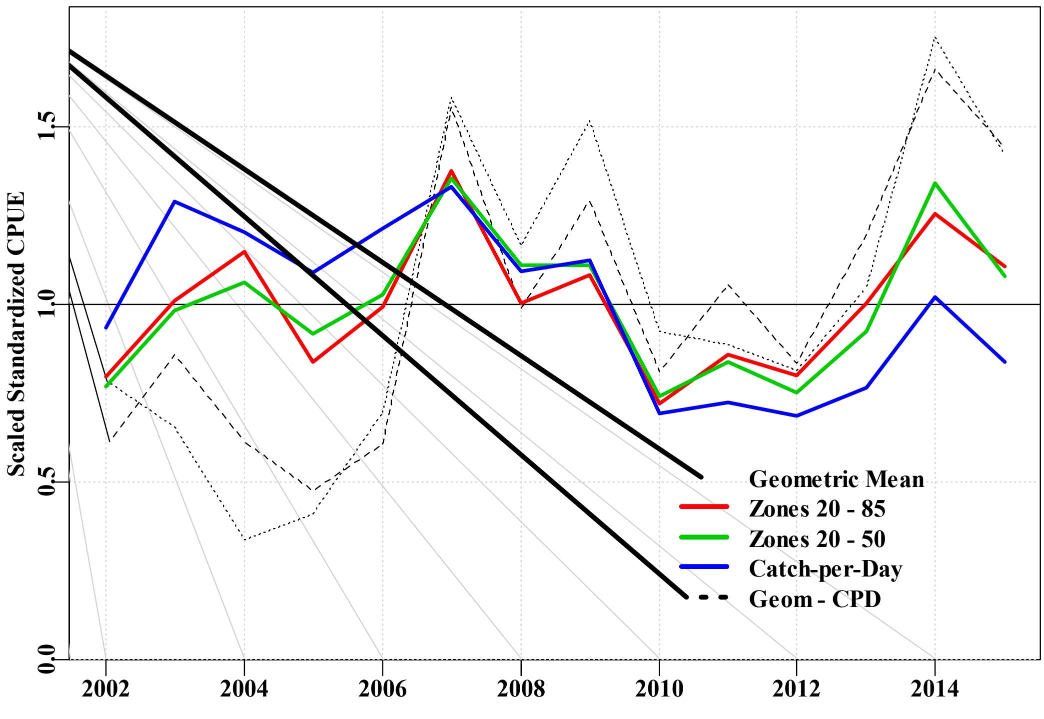


Figure 9.33. A comparison of the standardized catch rates for auto-line vessels using catch-per-day (blue line and dotted black line), and catch-per-hook (red, green, and dashed black line). All three main lines have high levels of uncertainty (e.g. Figure 9.32), but the relative flattening of the catch-per-hook trajectory is clear. All trends were scaled to an average of 1.0.

### 9.5.8 *Compare Drop-Line and Auto-Line*

With a standardized Drop-Line CPUE index available for 1997 – 2006, and an Auto-Line index from 2002 – 2014 the two could also be compared (Figure 9.34). Whether they can be combined to permit a standard Tier 4 analysis to continue (using 1997 – 2006 as a reference period) still needs to be decided. However, the standardized time series in each case are both scaled to have a mean of 1.0 during the overlap period of 2002 - 2006, and both series (using catch-per-hook CPUE) exhibit similar variation around the longer term average of 1.0. For the provision of management advice it would be possible to use a catch-weighted average of the two lines over the period of overlap (Figure 9.34; Table 9.21).

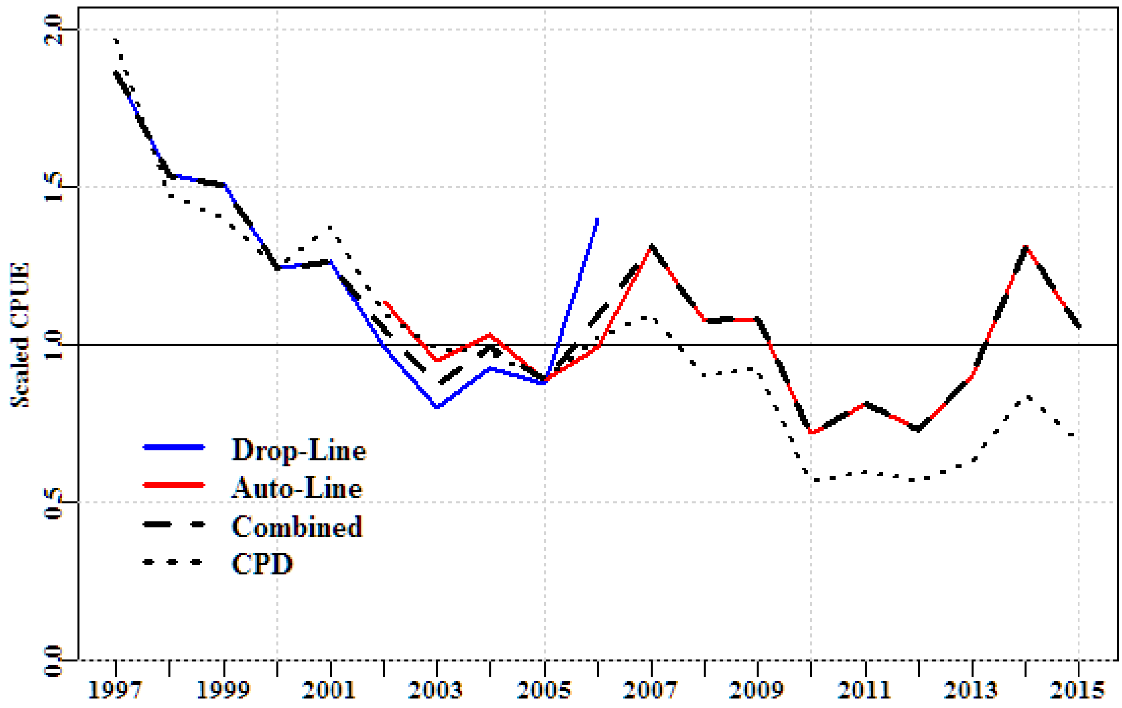


Figure 9.34. A comparison of Blue-Eye standardized catch-per-hook estimates for Drop-Line and Auto-Line catches of Blue-Eye from zones 20 – 50. A catch-weighted average of the lines from the two methods leads to a compromise in the years 2002 – 2006. If the 2001 auto-line estimates had been included this would have raised the average in 2001 slightly but at that point in time Drop-Line catches still dominated (Table 9.21). Catch-per-Day across the combined Drop-Line and Auto-Line catches is include as a dotted line.

Table 9.21. The optimum standardized CPUE (scaled to a mean of 1.0) for both drop-line, DL, and auto-line, AL. These are re-scaled so that the average CPUE between 2002 – 2006 = 1.0 in both cases (the columns with a 'Scale'postfix. The catch weighted CPUE (CWtCE) is only catch weighted over the 2002 – 2006 overlap period.

| Year | DropLine | AutoLine | DLScale | ALScale | Combined | AL Catch | DL Catch |
|---|---|---|---|---|---|---|---|
| 1997 | 1.4977 | | 1.8589 | | 1.8589 | 0.267 | 271.942 |
| 1998 | 1.2406 | | 1.5398 | | 1.5398 | 27.253 | 346.557 |
| 1999 | 1.2115 | | 1.5036 | | 1.5036 | 61.590 | 377.140 |
| 2000 | 1.0037 | | 1.2457 | | 1.2457 | 90.932 | 384.504 |
| 2001 | 1.0179 | | 1.2634 | | 1.2634 | 49.681 | 341.384 |
| 2002 | 0.8013 | 1.1351 | 0.9945 | 1.1351 | 1.0502 | 151.397 | 230.814 |
| 2003 | 0.6441 | 0.9527 | 0.7994 | 0.9528 | 0.8752 | 219.937 | 224.989 |
| 2004 | 0.7456 | 1.0291 | 0.9254 | 1.0291 | 0.9946 | 335.648 | 167.621 |
| 2005 | 0.7079 | 0.8877 | 0.8786 | 0.8877 | 0.8855 | 301.303 | 98.349 |
| 2006 | 1.1297 | 0.9952 | 1.4021 | 0.9952 | 1.0942 | 364.916 | 117.344 |
| 2007 | | 1.3106 | | 1.3107 | 1.3107 | 470.439 | 49.016 |
| 2008 | | 1.0743 | | 1.0743 | 1.0743 | 284.412 | 24.155 |
| 2009 | | 1.0793 | | 1.0793 | 1.0793 | 329.683 | 43.378 |
| 2010 | | 0.7194 | | 0.7194 | 0.7194 | 241.202 | 43.443 |
| 2011 | | 0.8114 | | 0.8114 | 0.8114 | 286.419 | 59.381 |
| 2012 | | 0.7338 | | 0.7338 | 0.7338 | 229.068 | 34.487 |
| 2013 | | 0.9009 | | 0.9009 | 0.9009 | 231.541 | 7.762 |
| 2014 | | 1.3149 | | 1.3149 | 1.3149 | 263.423 | 10.242 |
| 2015 | | 1.0558 | | 1.0559 | 1.0559 | 219.761 | 47.938 |

## 9.6 Discussion

### 9.6.1 Assumptions about CPUE

There are some important assumptions in the analyses previously conducted on Blue-Eye Trevalla and those conducted in this document. These assumptions apply to all species whose stock status assessments rely on CPUE. The first is that changes in CPUE directly reflect changes in the relative stock abundance rather than the influence of other factors such as the structural adjustment, or reduced catch rates through whale depredations or from whale avoidance behaviour from shifting into less optimal CPUE areas. In addition, the various closures in the south-east are assumed to have little or only minor effects on catch rates as are the recent reductions in TAC, which mostly coincide with the introduction of important Blue-Eye closures on the east coast of Tasmania. In addition there would appear to have been large and sudden changes in the fishing behaviours with regard the total number of hooks set in a shot. CPUE reflects fishing behaviour and, potentially, any factor that may lead to a change in fishing behaviour may affect CPUE. Such things are confounded with stock size changes. That is, a change in the CPUE brought about by a management change, can easily be confused for a change in the stock. Catch rate standardization is a method of using statistical methods in an attempt to take account of such external factors, with common examples of important potentially influential factors being which vessel is fishing, where they are fishing, at what depth they are fishing, and what month they are fishing. The process of standardization is completely dependent upon the availability of quality data concerning the factors being considered.

### 9.6.2 *Other Factors Affecting CPUE*

There are some influential factors whose potential effects upon CPUE would be difficult to identify and isolate as a confounding effect with stock size. Any influence that occurs as an apparently instant transition so that for a sequence of years it is not there but after a given date it is present (such as the introduction of a closure, or a change in almost all the vessels fishing following the structural adjustment, or a limitation placed on maximum effort or catch per day) is very difficult to correct for, if at all.

In the case of a closure, if the closure is on favoured fishing grounds then there will undoubtedly be a change in fishing behaviour (which, in the case of Blue-Eye is confounded with reductions in TAC). While it is known where the vessels would not be operating it is not known where effort that would have been expended in the now closed region will be transferred to.

The structural adjustment between Nov 2005 – Nov 2006 led to a reduction in the number of vessels operating in the Blue-Eye fishery and this is very apparent in the trawl fleet and the drop-line fleet, both of which decline significantly in numbers from 2005 - 2007 onwards. Such a reduction in vessel numbers, and which vessels are actually fishing, may have altered fishing behaviour in ways that are not characterized in the standardization. In the case of Blue-Eye drop-line vessels, a major change did occur in how effort was being reported with the proportion of records reporting single lines instead of multiple lines increasing dramatically. This is mixed up with the big change in the vessels actually fishing with most significant fishers leaving the fishery after the structural adjustment (one remained). Such transitions invalidate application of the statistical standardization and almost the only thing that can be done is to treat the different periods separately.

One large issue with the analysis of any of the line and hook methods is uncertainty over the representativeness of any single year's data for the fishery. The minor-line methods are still patchily distributed over different sea-mounts and off-shore areas and even auto-line and drop-line have widely varying coverage across the different important statistical reporting zones within the SESSF. This is especially the case with auto-line following its adoption in 1997; for example, there were significant catches in only four zones, 20 – 50, from 2002 onwards and catching in the GAB only started to become important from 2003/2004 onwards. Similarly, although also inversely, after 2006 reducing catches by drop-lining meant they did not occur consistently every year in all four zones 20 – 50 and have remained at low and declining levels (< 20t) throughout that period.

### 9.6.3 *Catch-per-Record vs Catch-per-Hook*

The use of catch-per-day or record stemmed from early records of effort data being confused so that for example, with drop-lines the number of separate lines used and the number of hooks per line were sometime placed in each other's fields on the log-books and thereby in the database. For a single and particular species in particular areas it was, however, possible to examine what appeared to be atypical data and reverse obvious errors (for example cases of 200 lines each of 10 hooks, should obviously be reversed). This use of a different measure of effort gives a very different time-series of CPUE than when catch-per-day or record is used. The use of catch-per-day avoids the issue of the remarkable change in effort reporting that appears to have followed the structural adjustment. Intuitively, however, catch-per-hook appears a more realistic reflection of the variation of practice within the fishery. It is certainly an area that requires further analysis and consideration.

Using catch-per-record means that when significant changes occur in fishing behaviour these would be missed. By missing such major changes, inappropriate data can continue to be used as still representing the fishery. Thus, if catch-per-record data is to continue being used for the provision of management advice then some extra data selection will need to be made to focus on those fishing events that are more typical of the fishery.

One very influential change in how effort was reported occurred with the proportion of single drops (in the drop-line fishery) increasing dramatically following 2006; this is directly related to the advent of an array of new vessels entering the fishery. In terms of catch-per-hook these greatly distort the CPUE although if they are removed from consideration the geometric mean CPUE flattens remarkably and is very different from when all data are considered together. This, plus the almost complete change in the fleet of vessels doing the drop-lining fishing, along with the major reduction in the number of drop-line records available post-2006, justify only using the drop-line CPUE from 1997 – 2006 when examining catch-per-hook, and similar arguments apply to the use of catch-per-record.

The auto-line fleet only began to expand and distribute catches from about 2002 onwards, other changes include the first gear limitation (to 15,000 hooks maximum) in 2001 and the rapid expansion of the auto-line fleet from 2002 onwards. The data up to 2000/2001 are not widely distributed spatially each year and are not distributed among many vessels. For this reason it is difficult to justify using the auto-line data before 2002.

## 9.7 Conclusion

The diversity of methods used to fish for Blue-Eye and the patchy nature of the fishing grounds mean that there is no simple, catch-all analysis that can be used to summarize the fishery as a whole. Nevertheless, it remains possible to focus on the methods that lead to the greatest proportion of the catches.

1. It has proven possible to develop relatively simple algorithms, which if followed lead to the clarification of effort in terms of total hooks set that in turn allows for an alternative, intuitively more realistic measure of CPUE.
2. Separate and different algorithms for handing the Drop-Line and Auto-Line data within the catch and effort database were required to enable effort in each case to be characterized in terms of total number of hooks set.
3. Using those algorithms the Drop-Line and Auto-Line data were re-structured and catch-rates estimates in terms of kg/hook for both methods.
4. As has been done previously, it was possible to combine the two, using a catch weighted approach over the overlap period. When this was done for both the catch-per-hook and catch-per-day data the outcome of the standardization was rather different; with the standardized data recovering from 2012, which is a trend not seen in the catch-per-day trend.

There is now sufficient evidence that the validity of the catch-per-day analyses conducted on Blue-Eye catch rates should now be questioned. There are undoubted uncertainties that were not previously accounted for in the CPUE time-series that were used for earlier management advice, but at the time there were few useful alternatives. Alternatives are now available and by following the algorithms described in this results section these analyses should be repeatable when more data becomes available.

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## *9.9 Appendix: Extra Tables and Figures*

Table 9.22. Reported catch in each SESSF Zone, only those with bold headers were analysed in the standardization.

| Year | 10 | 20 | 30 | 40 | 50 | 60 | 70 | 82 | 83 | 84 | 85 | 91 | 92 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1997 | 2.361 | 81.546 | 80.730 | 40.722 | 45.977 | 3.270 | | | | | 5.778 | 5.503 | |
| 1998 | 0.050 | 72.375 | 158.954 | 49.692 | 40.856 | 2.150 | | | | | 1.968 | 1.590 | |
| 1999 | | 29.061 | 193.339 | 65.244 | 55.078 | 0.348 | | | | | 0.972 | 11.470 | 0.050 |
| 2000 | | 26.170 | 187.555 | 104.457 | 59.822 | | | | | 0.357 | 5.504 | 0.520 | |
| 2001 | | 18.659 | 191.312 | 72.643 | 29.127 | | 0.060 | | 0.150 | 2.814 | 4.345 | 3.186 | 4.740 |
| 2002 | | 31.617 | 87.014 | 20.530 | 35.487 | | 4.700 | | | 1.561 | 5.380 | 33.664 | 5.750 |
| 2003 | | 25.822 | 47.450 | 33.081 | 29.464 | | 1.300 | | | 27.547 | 4.875 | 50.680 | 2.400 |
| 2004 | | 6.332 | 42.729 | 12.169 | 23.579 | 0.060 | 0.120 | 0.850 | 0.026 | 45.762 | 21.725 | 5.045 | |
| 2005 | | 0.140 | 42.590 | 2.261 | 6.651 | | 1.550 | 0.350 | 0.200 | 24.128 | 6.500 | 4.870 | 4.700 |
| 2006 | | 0.290 | 55.118 | 2.463 | 2.308 | | 0.120 | | | 42.976 | 1.444 | 7.240 | 2.500 |
| 2007 | | 2.174 | 32.071 | 0.250 | 4.460 | | 2.700 | | 0.010 | 6.347 | | | |
| 2008 | 0.051 | | 13.319 | | 2.260 | | 8.100 | | | 0.100 | | | |
| 2009 | | 0.150 | 11.958 | 0.010 | 5.700 | | 1.060 | | | | | 12.430 | 12.070 |
| 2010 | | | 17.803 | 0.165 | 6.826 | | 1.153 | | 0.785 | 2.379 | 1.045 | 7.932 | 4.075 |
| 2011 | | 0.003 | 23.158 | 3.615 | 3.971 | | 0.100 | | | 0.400 | 1.220 | 9.993 | 16.921 |
| 2012 | | | 10.254 | 1.403 | 6.271 | | | | | | | 15.496 | 0.683 |
| 2013 | | | 6.091 | 0.007 | 0.910 | | 0.529 | | | | 0.225 | | |
| 2014 | | 0.011 | 2.665 | | 2.547 | | | | 1.500 | 2.469 | 0.540 | | 0.510 |
| 2015 | | | 0.215 | | 1.521 | | 0.750 | | 1.949 | 1.185 | 0.010 | 28.193 | 10.937 |
| Total | 2.462 | 294.349 | 1204.327 | 408.709 | 362.815 | 5.828 | 22.242 | 1.200 | 4.620 | 158.025 | 61.531 | 197.812 | 65.336 |

Table 9.23. Catch in tonnes of Blue-Eye by fishing method. AL – auto-line, DL – drop-line, TW – trawl, GN – gillnet, RR – rod-and-reel, TL – trot-line, HL – hand-line, BL – bottom-line, PL – pole-and-line, FP – fish-trap, LDR – new code, DS – Danish seine. The data are restricted to the years 1997 – 2015 and in the fisheries: GHT, SEN, SSF, SSG, SSH, SET, and GAB.

| Year | AL | DL | TW | GN | RR | TL | HL | BL | PL | FP | LDR | Unknown | DS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1997 | 0.267 | 271.942 | 104.567 | 59.022 | | 6.148 | | 28.382 | | 0.165 | | 0.055 | 0.061 |
| 1998 | 27.253 | 343.505 | 82.074 | 14.282 | | | 0.100 | 4.526 | | 0.936 | | 0.030 | 0.035 |
| 1999 | 61.590 | 377.032 | 100.329 | 34.711 | | 0.030 | | 0.889 | | 0.229 | | 0.041 | 0.024 |
| 2000 | 90.932 | 384.409 | 95.042 | 92.406 | | | | 1.739 | | 0.666 | | | 0.012 |
| 2001 | 47.884 | 335.873 | 90.218 | 106.679 | | 19.600 | | 3.326 | | 0.016 | | | 0.007 |
| 2002 | 134.067 | 223.074 | 67.998 | 1.951 | | 23.415 | | 6.493 | | | | | 0.001 |
| 2003 | 219.676 | 221.649 | 28.918 | 40.846 | | 28.080 | | 8.589 | | | | | |
| 2004 | 329.608 | 158.491 | 49.659 | 0.171 | | 20.116 | | 2.318 | | | | | 0.003 |
| 2005 | 301.303 | 93.779 | 43.194 | 0.016 | | | | 1.941 | | | | 0.400 | |
| 2006 | 354.582 | 114.639 | 66.105 | 0.002 | | | | 1.187 | | | | | |
| 2007 | 455.097 | 48.011 | 38.321 | 0.003 | | | | 0.632 | | | | | |
| 2008 | 281.384 | 21.449 | 36.046 | 0.016 | | | | 0.724 | | | | | 0.070 |
| 2009 | 325.893 | 43.378 | 39.386 | | 7.550 | | | 1.740 | 3.138 | | | | 0.024 |
| 2010 | 236.620 | 42.073 | 43.480 | | 56.788 | | | 0.022 | | | | | |
| 2011 | 267.318 | 59.381 | 23.268 | 0.111 | 59.962 | | 17.118 | 0.049 | | | | | |
| 2012 | 217.818 | 34.107 | 10.792 | 0.003 | 14.792 | | 21.171 | 1.377 | | | | | |
| 2013 | 190.515 | 7.762 | 22.893 | | 14.125 | | 24.083 | 3.311 | | | | | 0.002 |
| 2014 | 227.041 | 10.242 | 29.381 | | 2.600 | | 20.233 | 0.377 | | | | | |
| 2015 | 198.286 | 46.857 | 25.128 | | 0.925 | 0.404 | | 0.168 | | | 0.679 | | 0.022 |
| Total | 3967.132 | 2837.653 | 996.797 | 350.219 | 156.742 | 97.792 | 82.706 | 67.791 | 3.138 | 2.012 | 0.679 | 0.526 | 0.261 |

Table 9.24. Number of records in the AFMA database relating to each method. AL – auto-line, DL – drop-line, TW – trawl, GN – gillnet, RR – rod-and-reel, TL – trot-line, HL – hand-line, BL – bottom-line, PL – pole-and-line, FP – fish-trap, LDR – new code, DS – Danish seine. The data are restricted to the years 1997 – 2015 and in the fisheries: GHT, SEN, SSF, SSG, SSH, SET, and GAB.

| Year | AL | DL | TW | GN | RR | TL | HL | BL | PL | FP | LDR | Unknown | DS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1997 | 3 | 575 | 1500 | 364 | 0 | 14 | 0 | 251 | 0 | 3 | 0 | 4 | 2 |
| 1998 | 50 | 738 | 1398 | 176 | 0 | 0 | 1 | 66 | 0 | 9 | 0 | 1 | 7 |
| 1999 | 77 | 971 | 1712 | 231 | 0 | 2 | 0 | 22 | 0 | 16 | 0 | 3 | 4 |
| 2000 | 93 | 1075 | 1893 | 328 | 0 | 0 | 0 | 27 | 0 | 13 | 0 | 0 | 4 |
| 2001 | 76 | 797 | 1809 | 348 | 0 | 41 | 0 | 27 | 0 | 1 | 0 | 0 | 3 |
| 2002 | 234 | 619 | 1548 | 33 | 0 | 63 | 0 | 34 | 0 | 0 | 0 | 0 | 1 |
| 2003 | 487 | 587 | 1210 | 137 | 0 | 94 | 0 | 36 | 0 | 0 | 0 | 0 | 0 |
| 2004 | 1338 | 515 | 1568 | 10 | 0 | 59 | 0 | 23 | 0 | 0 | 0 | 0 | 2 |
| 2005 | 1142 | 363 | 1170 | 4 | 0 | 0 | 0 | 9 | 0 | 0 | 0 | 1 | 0 |
| 2006 | 1087 | 327 | 924 | 1 | 0 | 0 | 0 | 8 | 0 | 0 | 0 | 0 | 0 |
| 2007 | 667 | 130 | 834 | 2 | 0 | 0 | 0 | 5 | 0 | 0 | 0 | 0 | 0 |
| 2008 | 612 | 84 | 806 | 6 | 0 | 0 | 0 | 10 | 0 | 0 | 0 | 0 | 2 |
| 2009 | 578 | 131 | 618 | 0 | 11 | 0 | 0 | 10 | 5 | 0 | 0 | 0 | 3 |
| 2010 | 488 | 226 | 647 | 0 | 79 | 0 | 0 | 3 | 0 | 0 | 0 | 0 | 0 |
| 2011 | 562 | 230 | 624 | 4 | 95 | 0 | 59 | 3 | 0 | 0 | 0 | 0 | 0 |
| 2012 | 466 | 119 | 424 | 1 | 29 | 0 | 43 | 15 | 0 | 0 | 0 | 0 | 0 |
| 2013 | 360 | 47 | 358 | 0 | 22 | 0 | 43 | 4 | 0 | 0 | 0 | 0 | 1 |
| 2014 | 305 | 68 | 340 | 0 | 25 | 0 | 51 | 2 | 0 | 0 | 0 | 0 | 0 |
| 2015 | 283 | 98 | 301 | 0 | 8 | 20 | 0 | 9 | 0 | 0 | 3 | 0 | 2 |

Table 9.25. Other fisheries in which catches of Blue-Eye are reported in the AFMA catch-effort database. HST – High-Sea Trawl, HSN – High-Sea Non-Trawl, ECD – East Coast Deepwater Trawl, CSF – Coral Sea Fishery, NFO – Norfolk Island Offshore Demersal Finfish Fishery, TUN – Tuna Fishery, ECT - Eastern Tuna & Billfish Fishery, WDW – Western Deepwater Trawl fishery, STR - South Tasman Rise Fishery, JMF - Jack Mackerel Fishery, VIT – Victorian Inshore Trawl Fishery, WTF - Southern & Western Tuna & Billfish Fishery.

| Year | HST | HSN | ECD | CSF | NFO | TUN | ECT | WDW | STR | JMF | VIT | WTF | Unknown |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1994 | | | | | | | | 0.120 | | | | | |
| 1995 | | | | | | | | | | | | | |
| 1996 | | | | | | 0.065 | | 0.027 | | | | | |
| 1997 | | | | | | 0.858 | | | | | | | |
| 1998 | | | | 3.052 | | 0.173 | | | | | | | |
| 1999 | | | | 0.100 | | | | | | | | | 0.008 |
| 2000 | | | 5.408 | 0.095 | | | | 0.543 | | 0.100 | | | |
| 2001 | | | 35.284 | 0.014 | 8.686 | | | | 0.720 | | | 0.014 | |
| 2002 | 273.747 | 95.214 | 2.390 | 11.300 | 4.210 | | | | | | | | |
| 2003 | 0.013 | 43.640 | 13.368 | 0.273 | 0.240 | | | | | | 0.010 | | |
| 2004 | 0.843 | 14.930 | 35.776 | 0.246 | | | | 0.100 | | | | | |
| 2005 | 307.936 | 4.570 | 1.992 | 0.006 | | | | | | | 0.048 | | |
| 2006 | 24.158 | 13.039 | | | | | 0.016 | | | | | | |
| 2007 | 365.284 | 16.343 | 13.046 | 0.005 | | | 0.400 | | | | | | |
| 2008 | 53.509 | 5.438 | | 0.125 | | | 0.183 | | | | | | |
| 2009 | 93.649 | 3.790 | 2.171 | | | | 0.320 | | | | | | |
| 2010 | 52.465 | 5.862 | | 0.090 | | | | | | | | | |
| 2011 | 104.913 | 16.800 | 2.957 | 2.336 | | | | | | | 0.005 | | |
| 2012 | 138.072 | 10.463 | 13.918 | 1.322 | | | | | | | | | |
| 2013 | 92.982 | 40.258 | 1.668 | 0.768 | | | | | | | 0.010 | | |
| 2014 | 134.270 | 35.681 | | 0.702 | | | | | | | | | |
| 2015 | | 22.370 | | 0.186 | | | | | | | | | |
| Total | 1641.840 | 328.396 | 127.979 | 20.619 | 13.136 | 1.096 | 0.919 | 0.790 | 0.720 | 0.100 | 0.073 | 0.014 | 0.008 |

Table 9.26. The annual catches of Blue-Eye, as tonnes, reported in the AFMA catch-effort database for the various fisheries. GAB – Great Australian Bight, GHT – Gillnet Hook and Trap, SEN – South-East Non-Trawl, SSF, SSG, and SSH – Southern Shark Fishery, Gillnet fishery, and Hook fishery respectively, and SET – South-East Trawl.

| Year | GAB | GHT | SEN | SSF | SSG | SSH | SET | Total |
|---|---|---|---|---|---|---|---|---|
| 1997 | 1.199 | | 365.945 | | | | 103.464 | 470.608 |
| 1998 | 2.261 | | 390.536 | | 0.063 | 0.002 | 79.878 | 472.740 |
| 1999 | 4.822 | | 471.878 | 0.995 | 1.609 | | 95.572 | 574.876 |
| 2000 | 10.850 | | 564.351 | 5.801 | | | 84.204 | 665.206 |
| 2001 | 20.690 | | 512.679 | 0.699 | | | 69.535 | 603.603 |
| 2002 | 1.150 | 0.027 | 388.327 | 0.646 | | | 66.849 | 456.998 |
| 2003 | 1.810 | 518.839 | | | | | 27.108 | 547.757 |
| 2004 | 2.723 | 510.704 | | | | | 46.939 | 560.365 |
| 2005 | 8.698 | 397.439 | | | | | 34.497 | 440.633 |
| 2006 | 11.968 | 470.410 | | | | | 54.136 | 536.515 |
| 2007 | 0.960 | 503.743 | | | | | 37.362 | 542.064 |
| 2008 | 0.147 | 303.573 | | | | | 35.969 | 339.689 |
| 2009 | | 381.699 | | | | | 39.410 | 421.109 |
| 2010 | | 335.502 | | | | | 43.480 | 378.982 |
| 2011 | | 403.940 | | | | | 23.268 | 427.208 |
| 2012 | 0.011 | 289.268 | | | | | 10.781 | 300.060 |
| 2013 | | 239.796 | | | | | 22.895 | 262.691 |
| 2014 | 0.011 | 260.493 | | | | | 29.370 | 289.874 |
| 2015 | | 247.318 | | | | | 25.150 | 272.468 |
| Total | 67.300 | 4862.751 | 2693.715 | 8.141 | 1.672 | 0.002 | 929.864 | 8563.446 |

Table 9.27. Number of records for Blue-Eye in each fishery reported in the AFMA catch-effort database. See Table 9.26 for fishery names.

| Year | GAB | GHT | SEN | SET | SSF | SSG | SSH | Total |
|---|---|---|---|---|---|---|---|---|
| 1997 | 39 | 0 | 1212 | 1465 | 0 | 0 | 0 | 2716 |
| 1998 | 53 | 0 | 1034 | 1353 | 0 | 5 | 1 | 2446 |
| 1999 | 100 | 0 | 1262 | 1619 | 31 | 26 | 0 | 3038 |
| 2000 | 44 | 0 | 1496 | 1853 | 40 | 0 | 0 | 3433 |
| 2001 | 98 | 0 | 1279 | 1714 | 11 | 0 | 0 | 3102 |
| 2002 | 4 | 1 | 967 | 1545 | 15 | 0 | 0 | 2532 |
| 2003 | 24 | 1341 | 0 | 1186 | 0 | 0 | 0 | 2551 |
| 2004 | 52 | 1945 | 0 | 1518 | 0 | 0 | 0 | 3515 |
| 2005 | 105 | 1519 | 0 | 1065 | 0 | 0 | 0 | 2689 |
| 2006 | 27 | 1423 | 0 | 897 | 0 | 0 | 0 | 2347 |
| 2007 | 25 | 804 | 0 | 809 | 0 | 0 | 0 | 1638 |
| 2008 | 4 | 712 | 0 | 804 | 0 | 0 | 0 | 1520 |
| 2009 | 0 | 735 | 0 | 621 | 0 | 0 | 0 | 1356 |
| 2010 | 0 | 796 | 0 | 647 | 0 | 0 | 0 | 1443 |
| 2011 | 0 | 953 | 0 | 624 | 0 | 0 | 0 | 1577 |
| 2012 | 1 | 673 | 0 | 423 | 0 | 0 | 0 | 1097 |
| 2013 | 0 | 476 | 0 | 359 | 0 | 0 | 0 | 835 |
| 2014 | 1 | 451 | 0 | 339 | 0 | 0 | 0 | 791 |
| 2015 | 0 | 421 | 0 | 303 | 0 | 0 | 0 | 724 |

# 10. CPUE standardizations for selected shark SESSF species (data to 2015)

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## *10.1 Executive Summary*

This report focuses on data from years 1997 – 2015 available in the Commonwealth logbook database. The logbook database contains records relating to all methods and areas and allow for a detailed analysis, which is required to provide a complete view of the current state of the fishery.

Reported catches of school shark are relatively low and those from trawling do not appear to be targeted, as evidenced by the large proportion of < 30 kg shots present in the logbook data. Nevertheless, the areas where they are caught have not changed greatly and yet the standardized catch-per-unit effort (CPUE) has begun to increase significantly, with the exception of 2014. This is a positive sign, which when combined with the observation of increased proportions of smaller school sharks in the ISMP sampling are a first clear evidence of school sharks showing some signs of recovery.

There has been an increase in reported gillnet catches of gummy shark and standardized CPUE in South Australia and Bass Strait during 2015. By contrast, standardized CPUE of gillnet caught gummy shark around Tasmania remained flat since 2014. Reported catches by bottom line remained at 229 t for both 2013 and 2014, and dropped to 192 t in 2015, while there was a drop of ~8 t reported (i.e. 92 t to 84 t) in 2015 relative to 2014 for trawl. Standardized CPUE for bottom line and trawl have increased steadily since 2013, remaining above the long-term average. These analyses used number of operations as the effort unit, and ignore zero catches. It would be desirable, in future, to perform analyses that include (i) alternative effort unit(s), e.g. total net length and (ii) targeted gummy shark shots with no associated catches.

Like school shark, elephant fish are a non-targeted species, as indicated by the large proportion of small shots (i.e. <30 kg). Gillnet standardized CPUE is flat and noisy, and decreased in 2015. However this analysis ignores discarding and uses number of shots instead of net length as a unit of effort. In recent years discard rates for elephant fish have been very high, which may imply that their CPUE is in fact increasing. It would be desirable, in the future to perform analyses that account for discards.

Sawshark are considered to be a bycatch group which is supported by the high proportion of < 30 kg. Catches are reported by both gillnets and trawls. Standardized CPUE for gillnets exhibits a steady decline since about 2001. However, a detailed analysis should be considered that uses net length as an effort unit instead of shot. Trawl caught sawshark standardized indices exhibit a noisy but flat trend, with an increase in 2014 reaching the long term average. By contrast, sawshark standardized CPUE by Danish seine (which has the highest proportion of shots < 30 kg among methods) has been flat since 2006 and increased about the long-term mean in 2015. However, this species group is also discarded (13% to 28%; discarded for 2011-2014) no estimate available for 2015) may artficially inflate these estimates.

## 10.2 Introduction

Commercial catch-per-unit effort (CPUE) data are used in very many fishery stock assessments in Australia as an index of relative abundance. This is based on the assumption that there is a direct relationship between CPUE and exploitable biomass. However, many other factors can influence CPUE, including vessel, gear, depth, season, area, and time of fishing (e.g. day or night). The use of CPUE as an index of relative abundance requires the removal of the effects of variation due to changes in these factors on the assumption that what remains will provide a better estimate of the underlying biomass. This process of adjusting the time series for the effects of other factors is known as standardization and the accepted way of doing this is to use a statistical modelling procedure that focuses attention onto the annual average CPUE adjusted for the (average) variation brought about by all the other measureable factors identified. The diversity of species and methods in the SESSF fishery means that each fishery/stock for which standardized CPUE are required requires its own set of conditions and selection of data. This report updates and extends standardized indices (based on data to 2014 inclusive) for 10 different stocks.

### 10.2.1 *Limits of Standardization*

The use of commercial CPUE as an index of relative abundance of exploitable biomass can breakdown when there are factors that significantly influence CPUE which cannot be accounted for and employed in a GLM standardization analysis. Over the last two decades there have been a number of major management interventions in the South East Scalefish and Shark Fishery (SESSF) including the introduction of the quota management system in 1992 and that of the Harvest Strategy Policy (HSP) and associated structural adjustment in 2005 – 2007. The combination of limited quotas and the HSP is now controlling catches in such a way that many fishers have been altering their fishing behaviour to take into account the availability of quota and their own access to quota needed to land the species taken in the mixed species SESSF. As such, this may bias standardized CPUE.

## 10.3 Methods

The southern shark fishery extends from New South Wales, around Tasmania, and across to Western Australia (Table 10.1, Figure 10.1).

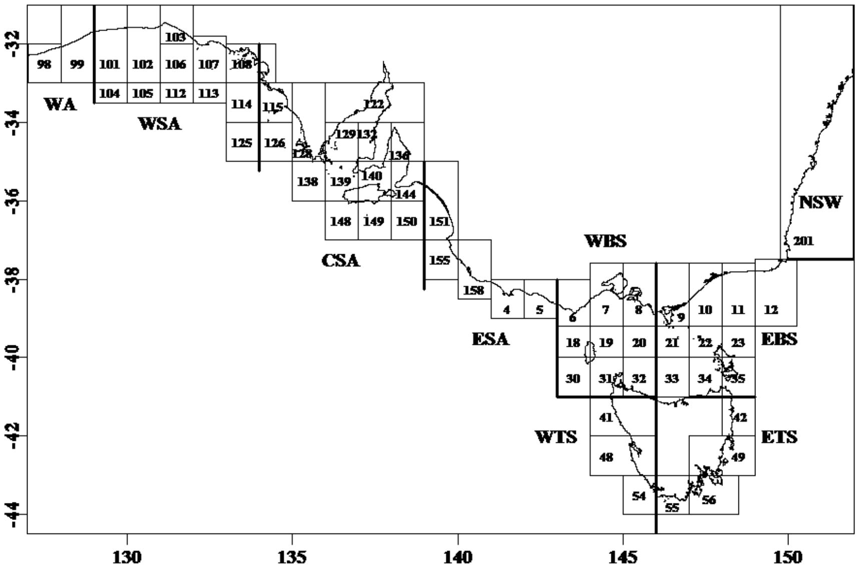



Figure 10.1. Shark statistical reporting areas and statistical regions. WA is Western Australia, WSA is Western South Australia, CSA is Central South Australia, ESA is Eastern South Australia (sometimes known as SAV – South Australia Victoria), WBS is Western Bass Strait, EBS is Eastern Bass Strait, NSW is New South Wales, ETS is Eastern Tasmania and WTS is Western Tasmania.

Table 10.1. Shark regions and corresponding shark zones used in the analysis.

| Shark region | Shark region name | Shark zone |
|---|---|---|
| WA | Western Australia | 10 |
| WSA | Western South Australia | 1 |
| CSA | Central South Australia | 2 |
| SAV-E | Southern Australia-Victoria East | 3 |
| WBS | Western Bass Strait | 4 |
| WT | Western Tasmania | 6 |
| ET | Eastern Tasmania | 7 |
| EBS | Eastern Bass Strait | 5 |
| NSW | New South Wales | 8 |
| SAV-W | Southern Australia-Victoria West | 9 |

### 10.3.1 *Catch-per-unit effort Standardization*

Data used in the following analyses applies to only the SESSF logbook data. Data from 1997 – 2015 inclusive is used for most species. Catch-per-unit effort (CPUE) was calculated, where there were positive non-zero catches and associated positive non-zero effort levels. These were also log transformed in preparation for the log-linear modelling. Depth of fishing was sub-divided into 20 metre depth categories for inclusion in statistical standardizations (the size of the depth classes varied with fishing method (e.g. 25 m depth classes (out to 600 m) for trawl caught school sharks).

### 10.3.1.1 The Overall Year Effect

The expected back-transformed year effect for the lognormal model involves a bias-correction to account for the log-normality; this correction returns the mean of the distribution rather than the median:

$$CPUE_t = e^{\left(\gamma_t + \sigma_t^2/2\right)} \tag{7}$$

$\gamma_t$ is the Year coefficient for year $t$ and $\sigma_t$ is the standard deviation of the log transformed data (obtained from the analysis). The year coefficients were all divided by the average of the Year coefficients to simplify the visual comparison of CPUE changes:

$$CE_t = \frac{CPUE_t}{\left(\sum CPUE_t\right)/n} \tag{8}$$

$CPUE_t$ is the yearly coefficient from the standardization, (□$CPUE_t$)/$n$ is the arithmetic average of the yearly coefficients, $n$ is the number of years of observations, and $CE_t$ is the final time series yielding the yearly index of relative abundance.

Analyses were performed in the statistical software *R* (R Development Core Team, 2009), using the library 'biglm', which is able to analyse the large size datasets available for many of the species considered in this report. It incorporates classical statistical linear model techniques (e.g. GLMs; McCullagh and Nelder, 1989).

The optimum model chosen was the model which contained the lowest estimated AIC statistic (Burnham and Anderson 2002).

### 10.3.1.2 Factors Considered

Factors considered in the analyses (i.e. categorical variables) were:

| | |
|---|---|
| Year | standard calendar year |
| Vessel | each vessel is uniquely and confidentially identified |
| Month | standard calendar months |
| Shark Zone | standard shark statistical reporting blocks (see Table 10.1) |
| SharkArea | an alternative to shark zone, essential 1 degree squares (see Table 10.1) |
| Gear | gillnets, trawl, bottom line, or Danish seine as appropriate |
| DepCat | 20 m categories (or variants depending on species) |
| DayNight | day, night, mixed, unknown categories |
| DayNight:DepCat | an interaction term including depth changes through the day |
| DepCat:Month | an interaction term used to include any seasonal changes across areas |
| DayNight:Month | an interaction term used to include any seasonal changes across when fishing occurred during each day |

The DayNight term is availavle for trawl gear, but was not available for non-trawl gears.

#### *10.3.1.3 Presentation of Time Series*

Plots of the unstandardized geometric mean CPUE along with the optimum statistical model representing the standardized time series are depicted for each species and/or species groups. This provides a visual indication of whether the standardization alters the trend away from the nominal CPUE. The time series have all been scaled relative to the average of each time series of yearly indices, which means that the overall average in each case equates to one; this centres the vertical location of each series but does not change the relative trends through time.

### 10.3.2 ***Data Selection for Different Shark Species***

Shark records corresponding to 1997 – 2015 were analysed, except for gummy shark - bottom line (from 1998), gummy shark – trawl (from 1996) and school shark – trawl (1996-2015). The selection of data by fishery, gear type, depth and shark zones for each species is listed in Table 10.2 through to Table 10.5. The small number of records for which no effort data were available (effort = -1 or 0 could not be included in the standardization.

#### *10.3.2.1 Gummy Sharks (Mustelus antarcticus)*

Table 10.2. Data selection criteria for gummy shark standardization caught by gillnets, trawl and bottom line.

| Criteria | Values |
|---|---|
| CSIRO CODE | 37017001 |
| *Gillnet*: | |
| Gear Types | 6”, 6.5”, and 7” mesh gillnet (GN) |
| Depth | 20 m depth classes 1 – 160 m |
| Shark zones | SA: 1,2,3,9; TAS: 4,5; BS: 6,7 |
| Years | 1996 – 2015 |
| *Trawl:* | |
| Gear type | TW, TDO, OTT* |
| Depth | 20 m depth classes 0 – 500 m |
| Shark zones | SA: 1,2,3,9; TAS: 4,5; BS: 6,7 NSW: 8; WA: 10 |
| Years | 1996 – 2015 |
| *Bottom line*: | |
| Gear type | BL |
| Depth | 20 m depth classes 0 – 200 m |
| Shark zones | 1–10 inclusive |
| Years | 1998 – 2015 |

* “TW” otter trawl; “TDO” otter trawl reported by elog; “OTT” bottom otter twin trawls

#### *10.3.2.2 School Shark (Galeorhinus galeus)*

Given the change from targeting, to increasingly active avoidance of school sharks by gillnet fishers during the available time series, an analysis of gillnet CPUE would be invalid and misleading. However, the trawl fishery is unlikely to have targeted school shark at any time, providing a consistent time series of catch and effort data. These were standardized using classical statistical methods

(Haddon, 2014c). There were various data selections made with respect to gear types, depths, and years prior to data analysis (Table 10.3).

Table 10.3. Data selection criteria for trawl caught school shark standardization.

| Criteria | Values |
|---|---|
| Gear Type(s) | Trawl (TW, TDO, OTT); but catches by other methods summarized. |
| Depth | 25 m depth classes 0 – 600 m |
| Shark zones | 1 – 7: WSA, CSA, ESA, WBS, EBS, WTS, ETS |
| Years | 1997 - 2015 |

#### *10.3.2.3 Sawshark*

Sawshark are considered to be primarily a bycatch species and are taken mostly by gillnets, trawl and Danish seine. The amounts landed by each of these methods are sufficient to allow a standardization for each method with comparison of outcomes. In each case, the same set of years was used but usually a different set of gears, depths, and shark zones were selected on the basis of the number of fishing operations available (Table 10.4).

Table 10.4. Data selection criteria for sawshark standardizations for gillnet, trawl and Danish seine fisheries.

| Criteria | Values |
|---|---|
| CSIRO CODE(S) | 37023000, 37023001, 37023002, 37023900 |
| Years | 1997 - 2015 |
| *Gillnet:* | |
| Gear Type | GN |
| Depth | 0 – 150 m |
| Shark zones | 1 – 7: WSA, CSA, ESA, WBS, EBS, WTS, ETS |
| *Trawl:* | |
| Gear Type(s) | TW and TDO; OTT but catches for all methods summarized. |
| Depth | 20 m depth classes 0 – 500 m |
| Shark zones | 1, 3 – 8: WSA, ESA, WBS, EBS, WTS, ETS, NSW |
| *Danish seine:* | |
| Gear Type | DS |
| Depth | 0 – 240 m |
| Shark zones | 4 – 5: WBS, EBS |

#### *10.3.2.4 Elephant Fish (Callorhinchus milii)*

While there are reported catches of elephant fish in the trawl and Danish seine fisheries most catches are reported by the gillnet fishery so a standardization for that that only fishery is undertaken. There are relatively high levels of discarding of elephant fish so an analysis that generates a CPUE series that attempts to include the influence of discard levels as well as reported catches is produced.

The data selection criteria for elephant fish (Table 10.5), attempt to eliminate deeper water chimaerid species that are sometimes grouped under the codes used for elephant fish.

Table 10.5. Criteria for selecting which records to include in the standardization of elephant fish.

| Criteria | Values |
|---|---|
| CSIRO CODE(S) | 37043001, 37043000, 37043002, 37043900, 37043901 |
| Gear Types | Gillnet (GN); but catches for all methods are summarized. |
| Depth | 20 m depth classes 0 – 160 m |
| Shark zones | 2 – 7: CSA, ESA, WBS, EBS, WTS, ETS |
| Years | 1997 - 2015 |

## *10.4 Results*

### 10.4.1 *South Australian gummy shark: Gillnet*

Positive non-zero records of catch per shot were employed in the statistical standardization analyses for gummy shark caught by gillnets. Further investigation should be considered to determine whether total net length could be used as an alternative effort unit in standardization analyses.

Table 10.6. Gummy shark taken by gillnet across shark zones from South Australia between of 0 to 160 m in the period 1997 - 2015. Total catch (TotCatch; t) is the total reported in the database across all gears, TotCat (t) is the total catch reported in the SESSF across all gears, number of records used in the analysis (Records), reported catch (CatchT; t) in the area and depth used in the analysis and number of vessels used in the analysis (Vessels). GeoMean is the geometric mean of CPUE (kg/shot). The optimum model is Model 7 (Table 10.8). SharkZone:DepC and standard deviation (StDev) are the coefficients from the optimum model.

| Year | TotCatch | Records | CatchT | Vessels | GeoMean | SharkZone:DepC | StDev |
|---|---|---|---|---|---|---|---|
| 1997 | 952.0854 | 4837 | 432.3829 | 56 | 46.9392 | 1.0783 | 0.0000 |
| 1998 | 1401.0623 | 7370 | 522.5191 | 53 | 34.7557 | 0.8411 | 0.0219 |
| 1999 | 1878.4663 | 6429 | 615.0027 | 48 | 47.8909 | 1.0463 | 0.0229 |
| 2000 | 2349.5960 | 5109 | 807.3709 | 37 | 83.0107 | 1.7457 | 0.0246 |
| 2001 | 1669.7930 | 5074 | 394.3000 | 36 | 42.6727 | 0.8741 | 0.0250 |
| 2002 | 1494.9734 | 5289 | 409.6034 | 32 | 46.2709 | 0.9287 | 0.0249 |
| 2003 | 1618.2742 | 5429 | 473.1045 | 37 | 50.1198 | 1.0521 | 0.0253 |
| 2004 | 1656.3767 | 5435 | 476.4703 | 40 | 50.3723 | 1.0932 | 0.0257 |
| 2005 | 1570.5199 | 5044 | 485.8724 | 29 | 53.0656 | 1.1114 | 0.0261 |
| 2006 | 1577.1332 | 5993 | 552.8931 | 28 | 53.0288 | 1.0864 | 0.0253 |
| 2007 | 1574.9505 | 4555 | 438.9615 | 29 | 56.2384 | 1.1259 | 0.0263 |
| 2008 | 1727.7449 | 4883 | 543.5174 | 23 | 64.0944 | 1.3222 | 0.0263 |
| 2009 | 1500.9008 | 5160 | 418.4865 | 23 | 47.4737 | 0.9910 | 0.0263 |
| 2010 | 1404.7877 | 5268 | 390.3654 | 29 | 41.4997 | 0.8771 | 0.0265 |
| 2011 | 1364.7051 | 3279 | 229.1685 | 19 | 38.6818 | 0.7759 | 0.0297 |
| 2012 | 1304.2189 | 1371 | 83.0395 | 15 | 31.3816 | 0.5944 | 0.0379 |
| 2013 | 1307.6117 | 800 | 60.4970 | 18 | 35.9230 | 0.6221 | 0.0467 |
| 2014 | 1381.4137 | 1476 | 126.7239 | 20 | 49.9737 | 0.8483 | 0.0389 |
| 2015 | 1544.2091 | 1571 | 154.2236 | 15 | 57.6206 | 0.9859 | 0.0395 |

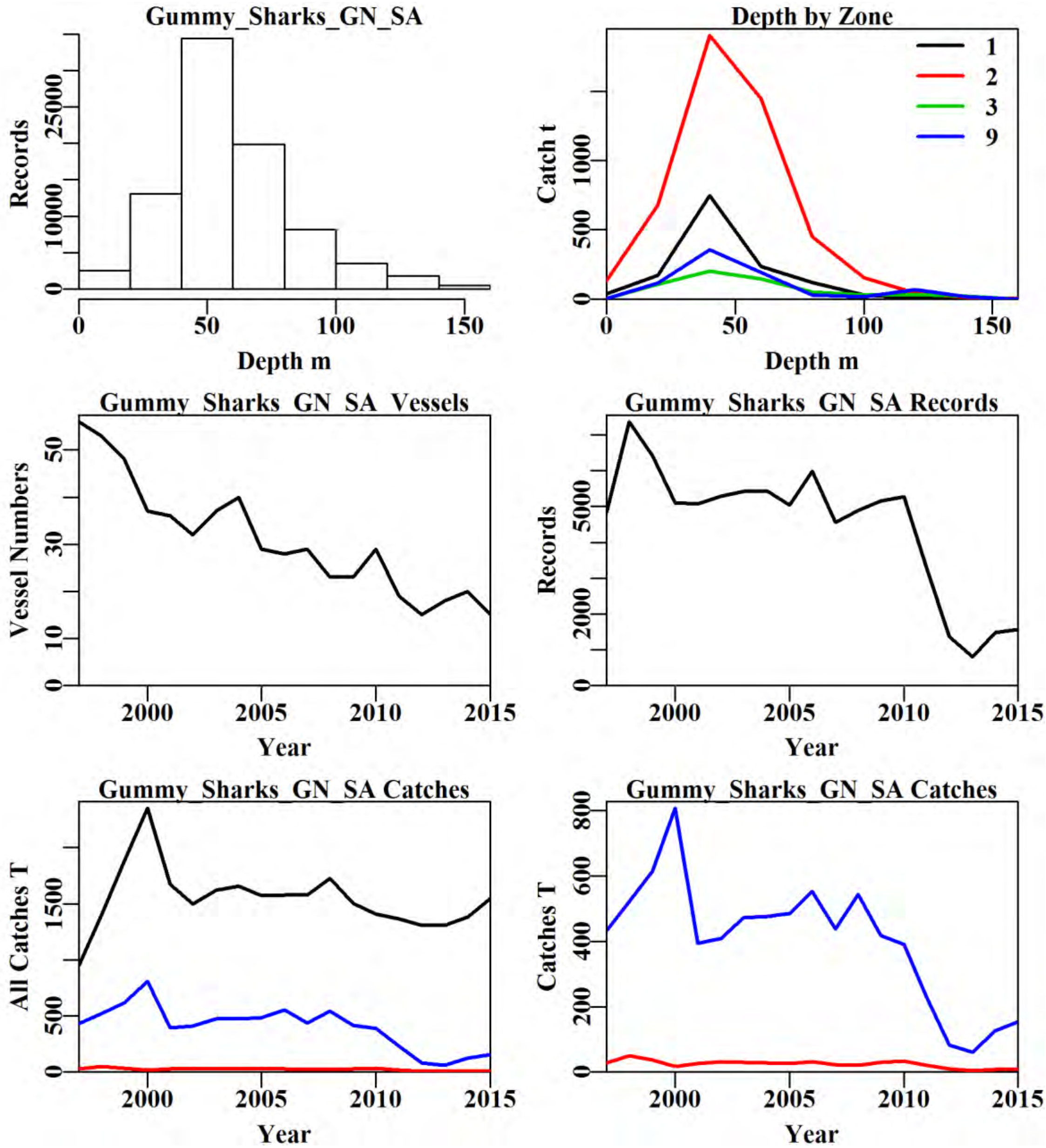



Figure 10.2. Gummy shark in South Australia in depths 0 to 160 m taken by gillnet. The top left plot depicts the depth distribution of shots containing gummy shark from shark zone 1, 2, 3 and 9 in depths 0 – 160 m. The top right plot depicts the distribution of catch by depth within shark zones 1, 2, 3 and 9. The middle left plot depicts the number of vessels through time. The middle right plot contains the number of records used in analysis. The bottom left plot contains gummy shark catches (top black line: total catches, middle blue line: catches used in the analysis; bottom red line: catches < 30 kg) and bottom right plot contains gummy shark catches (blue line: catches used in the analysis; red line: catches < 30 kg).

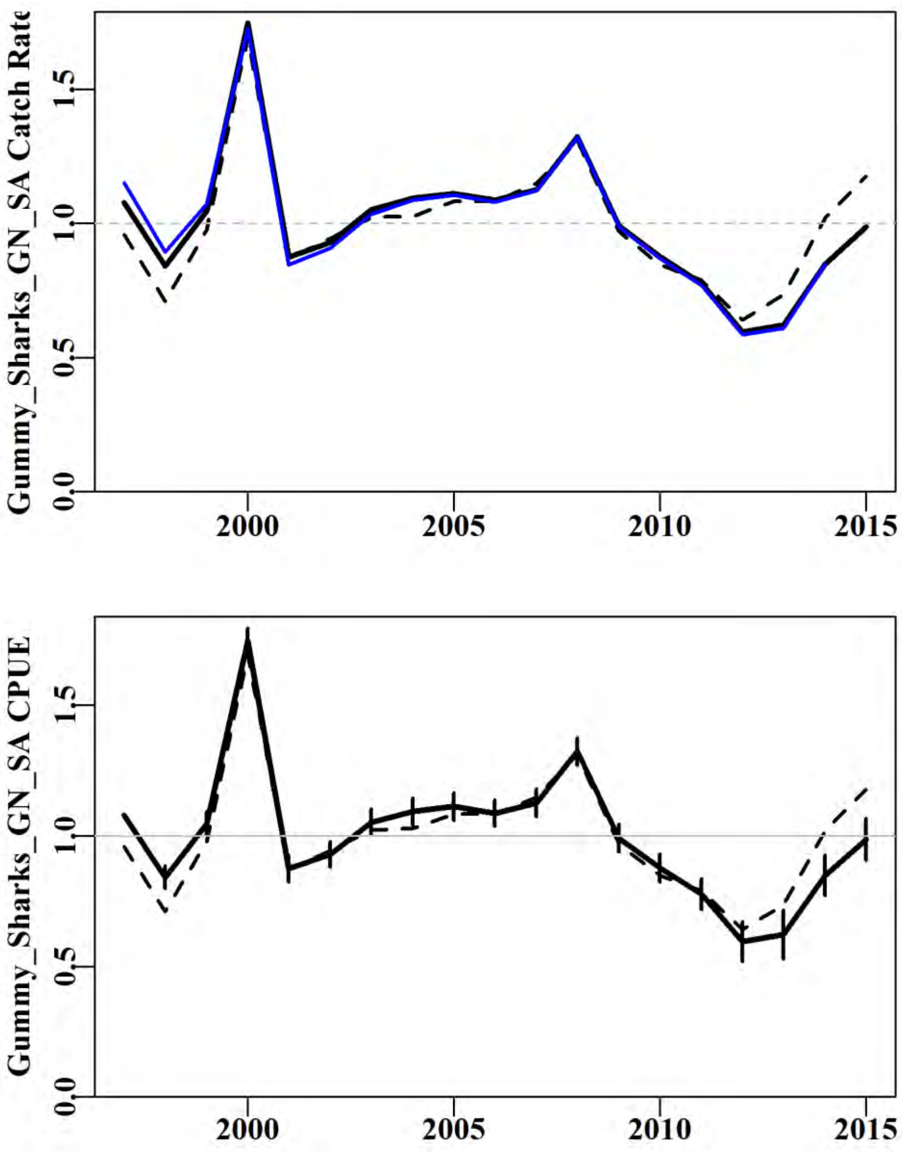



Figure 10.3. Gummy shark taken by gillnet in South Australia. Upper plot: The dashed black line represents the geometric mean CPUE and the solid black line the standardized catch rates (each scaled to the mean of each time series). The blue line corresponds to last year's standardized CPUE. Lower plot: Standardized CPUE (solid black line), two times the standard error (vertical lines) and geometric mean (dashed black line).

Table 10.7. Gummy shark from across shark zones in depths 0 to 160 m by gillnet. Statistical model structures used in this analysis. DepCat is a series of 20 metre depth categories.

| | |
|---|---|
| Model 1 | LnCE ~ Year |
| Model 2 | LnCE ~ Year +Vessel |
| Model 3 | LnCE ~ Year +Vessel +DepCat |
| Model 4 | LnCE ~ Year +Vessel +DepCat + SharkZone |
| Model 5 | LnCE ~ Year +Vessel +DepCat + SharkZone + Month |
| Model 6 | LnCE ~ Year +Vessel +DepCat + SharkZone + Month + SharkZone:Month |
| Model 7 | LnCE ~ Year +Vessel +DepCat + SharkZone + Month + SharkZone:DepC |

Table 10.8. Gummy shark taken by gillnet across shark zones from South Australia at depths 0 to 160 m in the period 1997 - 2015. Model selection criteria, include the AIC, the adjusted $R^2$ (adj_ $R^2$) and the change in adjusted $R^2$ (%Change). The optimum model is Model 7 (SharkZone:DepC). Depth category: DepC.

| | Year | Vessel | DepCat | SharkZone | Month | SharkZone:Month | SharkZone:DepC |
|---|---|---|---|---|---|---|---|
| AIC | 24365 | 20055 | 18841 | 17715 | 17166 | 16756 | 16164 |
| RSS | 112569 | 106616 | 104486 | 103065 | 102383 | 101803 | 101108 |
| MSS | 3653 | 9606 | 11736 | 13158 | 13839 | 14419 | 15114 |
| Nobs | 84372 | 84372 | 83768 | 83768 | 83768 | 83768 | 83768 |
| Npars | 19 | 156 | 164 | 175 | 178 | 211 | 202 |
| adj_$R^2$ | 3.122 | 8.096 | 9.923 | 11.136 | 11.721 | 12.186 | 12.796 |
| %Change | 0.000 | 4.974 | 1.827 | 1.214 | 0.584 | 0.466 | 0.609 |

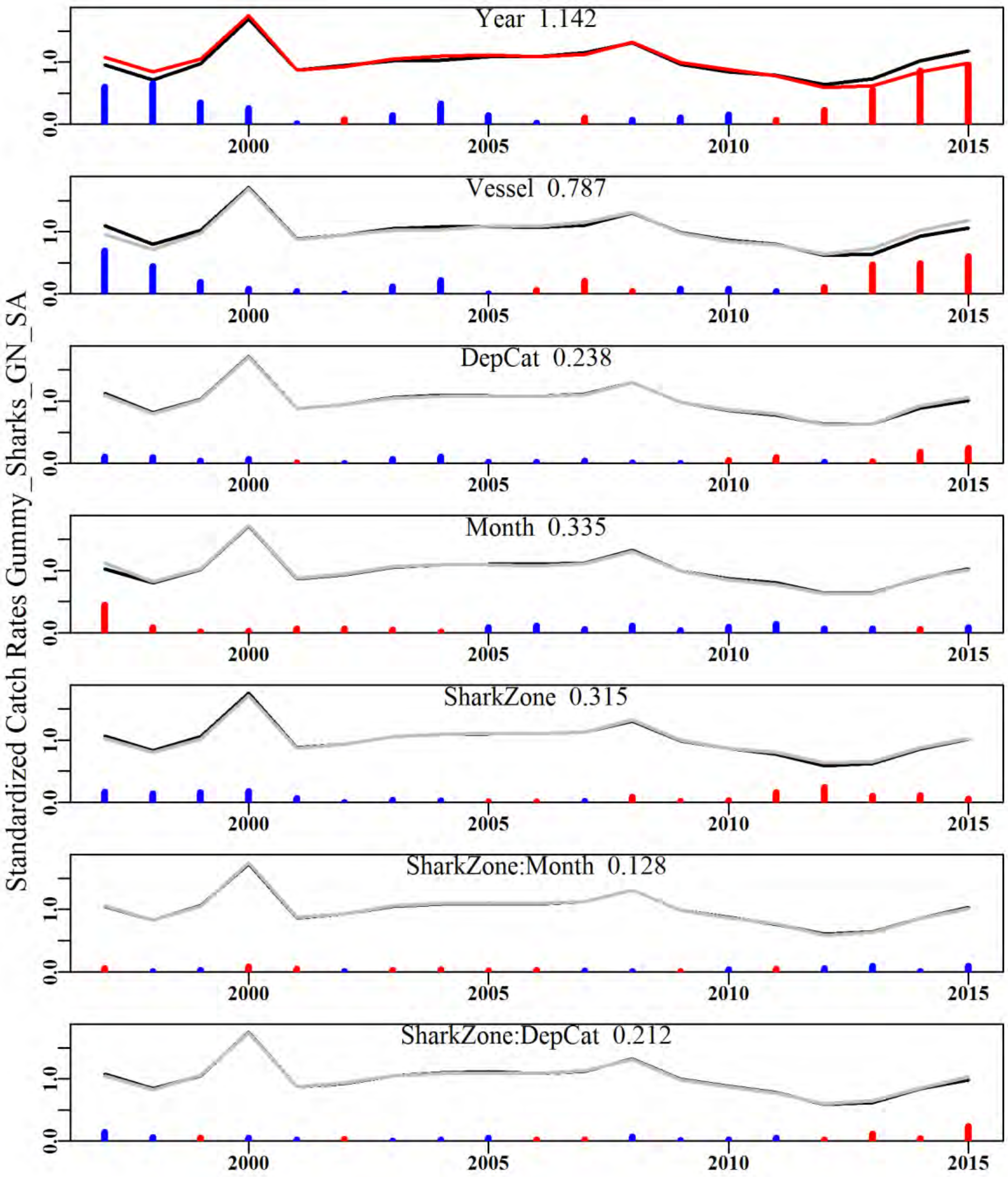



Figure 10.4. The relative influence of each factor on the final trend in the optimal standardization for the South Australian gummy shark gillnet fishery. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by the vertical bars with blue bars indicating the optimum model is higher than the geometric mean and red bars indicating it is lower. The top graph's bars are the sum of all the bars in the graphs below. The graphs for individual factors are cumulative. Thus the second graph has the geometric mean (grey line) and the effect of adding Year + factor2 (Model 2, black line). In the third graph, the grey line represents Model 2 and the black line the effect of adding factor3 to the model. The remaining graphs continue in the same cumulative manner except for the interaction terms which are added singularly to the final single factor model.

### 10.4.2 *Bass Strait gummy shark: Gillnet*

Positive non-zero records of catch per shot were employed in the statistical standardization analyses for gummy shark caught by gillnets. Further investigation should be considered to determine whether total net length could be used as an alternative effort unit in standardization analyses.

Table 10.9. Gummy shark taken by gillnet across shark zones in Bass Strait between depths of 0 to 160 m in the period 1997 - 2015. Total catch (TotCatch; t) is the total reported catch in the database across all gears, number of records used in the analysis (Records), reported catch (CatchT; t) in the area and depth used in the analysis and number of vessels used in the analysis (Vessels). GeoMean is the geometric mean of CPUE (kg/shot). The optimum model is model 6 (Table 10.11). SharkZone:Month and standard deviation (StDev) are the coefficients from the optimum model.

| Year | TotCatch | Records | CatchT | Vessels | GeoMean | SharkZone:Month | StDev |
|---|---|---|---|---|---|---|---|
| 1997 | 952.0854 | 4384 | 419.4455 | 50 | 53.1660 | 0.5967 | 0.0000 |
| 1998 | 1401.0623 | 5901 | 716.5877 | 51 | 66.9520 | 0.7342 | 0.0236 |
| 1999 | 1878.4663 | 6481 | 1041.8043 | 54 | 84.5960 | 0.9773 | 0.0236 |
| 2000 | 2349.5960 | 6386 | 1275.3329 | 49 | 107.2786 | 1.1832 | 0.0236 |
| 2001 | 1669.7930 | 5928 | 1069.9627 | 48 | 98.9225 | 1.0539 | 0.0241 |
| 2002 | 1494.9734 | 5920 | 840.8233 | 47 | 81.4804 | 0.8658 | 0.0242 |
| 2003 | 1618.2742 | 6076 | 888.4635 | 44 | 84.4294 | 0.8776 | 0.0241 |
| 2004 | 1656.3767 | 5921 | 883.7388 | 41 | 89.4380 | 0.9313 | 0.0243 |
| 2005 | 1570.5199 | 5059 | 817.3180 | 39 | 101.9002 | 1.0433 | 0.0252 |
| 2006 | 1577.1332 | 4087 | 735.5516 | 33 | 106.9539 | 1.1002 | 0.0265 |
| 2007 | 1574.9505 | 3485 | 875.1630 | 25 | 138.6657 | 1.3419 | 0.0275 |
| 2008 | 1727.7449 | 3671 | 954.5525 | 26 | 144.0312 | 1.4432 | 0.0274 |
| 2009 | 1500.9008 | 4091 | 833.4100 | 28 | 120.9260 | 1.2585 | 0.0267 |
| 2010 | 1404.7877 | 4423 | 744.0505 | 31 | 97.6047 | 1.0059 | 0.0263 |
| 2011 | 1364.7051 | 5171 | 798.1138 | 32 | 83.7931 | 0.9047 | 0.0257 |
| 2012 | 1304.2189 | 5445 | 780.8977 | 37 | 79.8678 | 0.8742 | 0.0257 |
| 2013 | 1307.6117 | 5341 | 758.7125 | 36 | 79.7234 | 0.8385 | 0.0255 |
| 2014 | 1381.4137 | 5249 | 811.8250 | 36 | 84.2759 | 0.8925 | 0.0257 |
| 2015 | 1544.2091 | 4970 | 983.6490 | 30 | 107.0144 | 1.0773 | 0.0260 |

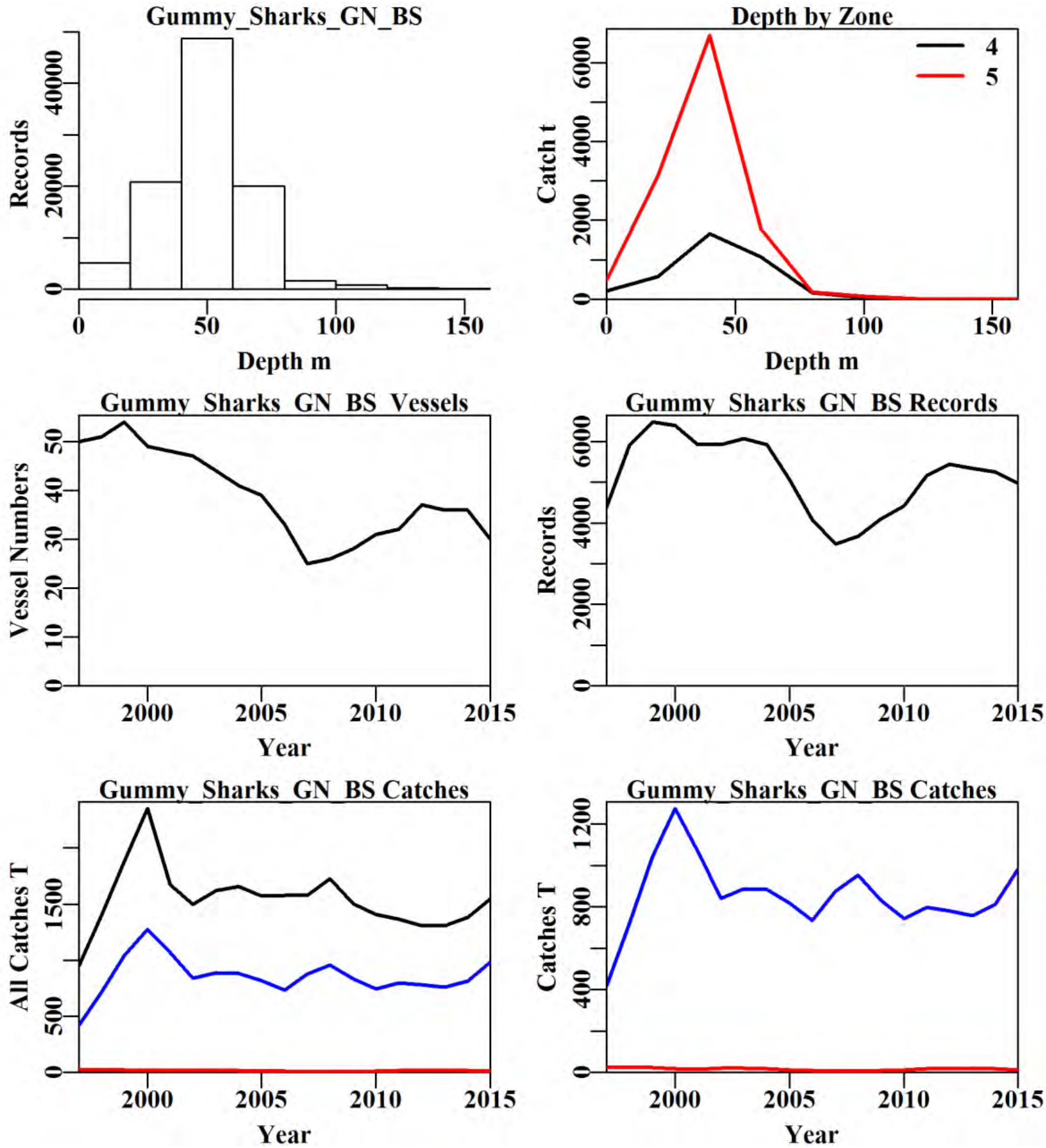



Figure 10.5. Gummy shark taken by gillnet in Bass Strait at depths 0 to 160 m. The top left plot depicts the depth distribution of shots containing gummy shark from zone 4 and 5 in depths 0 – 160 m. The top right plot depicts the distribution of catch by depth within shark zones 4 and 5. The middle left plot depicts the number of vessels through time. The middle right plot contains the number of records used in analysis. The bottom left plot contains gummy shark catches (top black line: total catches, middle blue line: catches used in the analysis; bottom red line: catches < 30 kg) and bottom right plot contains gummy shark catches (blue line: catches used in the analysis; red line: catches < 30 kg).

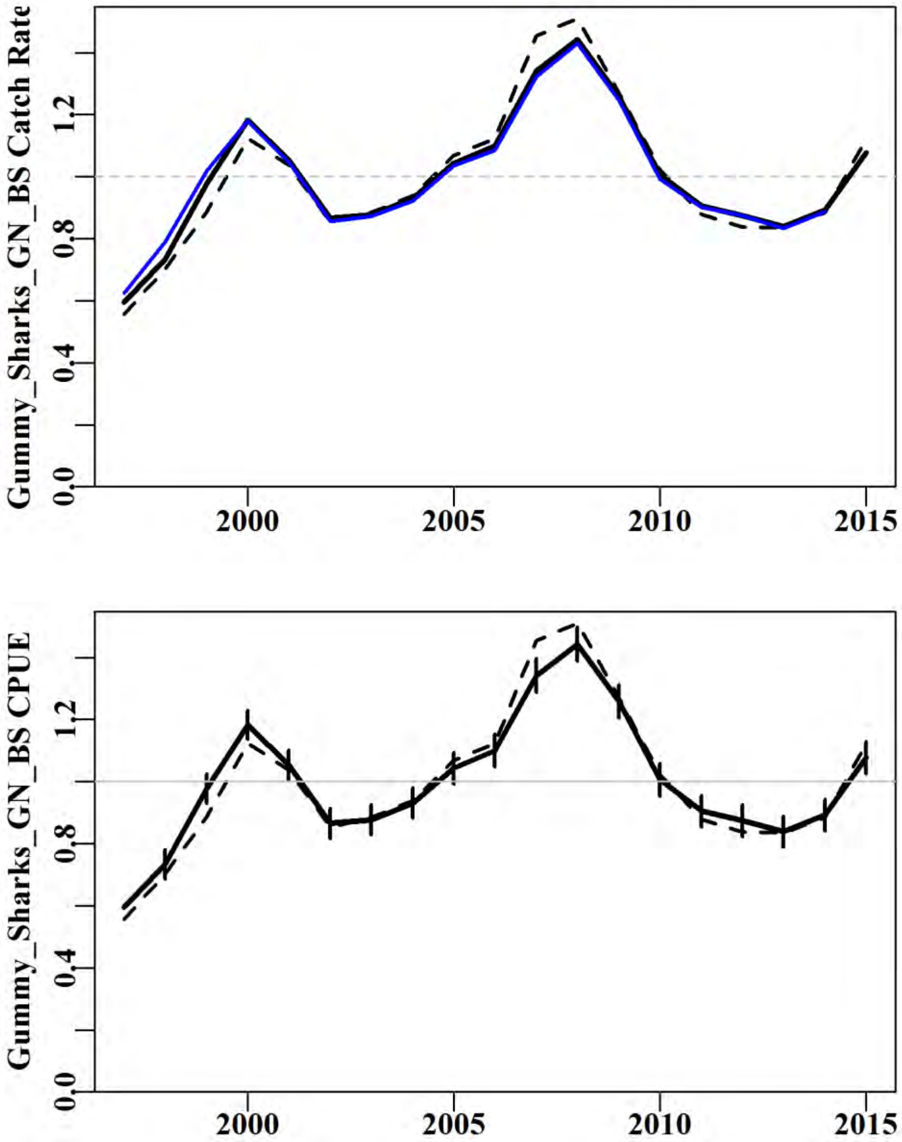



Figure 10.6. Gummy shark taken by gillnet in Bass Strait. Upper plot: The dashed black line represents the geometric mean CPUE and the solid black line the standardized catch rates (each scaled to the mean of each time series). The blue line corresponds to last year's standardized CPUE. Lower plot: Standardized CPUE (solid black line), two times the standard error (vertical lines) and geometric mean (dashed black line).

Table 10.10. Gummy shark from across shark zones in Bass Strait in depths 0 to 160 m by gillnet. Statistical model structures used in this analysis. DepCat is a series of 20 metre depth categories.

| | |
|---|---|
| Model 1 | LnCE ~ Year |
| Model 2 | LnCE ~ Year +Vessel |
| Model 3 | LnCE ~ Year +Vessel +DepCat |
| Model 4 | LnCE ~ Year +Vessel +DepCat + SharkZone |
| Model 5 | LnCE ~ Year +Vessel +DepCat + SharkZone + Month |
| Model 6 | LnCE ~ Year +Vessel +DepCat + SharkZone + Month + SharkZone:Month |
| Model 7 | LnCE ~ Year +Vessel +DepCat + SharkZone + Month + SharkZone:DepC |

Table 10.11. Gummy shark taken by gillnet across shark zones from Bass Strait at depths 0 to 160 m during 1997 - 2015. Model selection criteria, include the AIC, the adjusted $R^2$ (adj_ $R^2$) and the change in adjusted $R^2$ (%Change). The optimum model is Model 6 (SharkZone:Month). Depth category: DepC.

| | Year | Vessel | DepCat | SharkZone | Month | SharkZone:Month | SharkZone:DepC |
|---|---|---|---|---|---|---|---|
| AIC | 32400 | 25479 | 24414 | 23737 | 23735 | 23471 | 23652 |
| RSS | 136335 | 126743 | 124779 | 123886 | 123881 | 123518 | 123755 |
| MSS | 4478 | 14070 | 16034 | 16926 | 16932 | 17295 | 17057 |
| Nobs | 97989 | 97989 | 97394 | 97394 | 97394 | 97394 | 97394 |
| Npars | 19 | 133 | 141 | 152 | 153 | 164 | 161 |
| adj_$R^2$ | 3.162 | 9.870 | 11.259 | 11.884 | 11.887 | 12.135 | 11.969 |
| %Change | 0.000 | 6.708 | 1.389 | 0.625 | 0.003 | 0.248 | -0.166 |

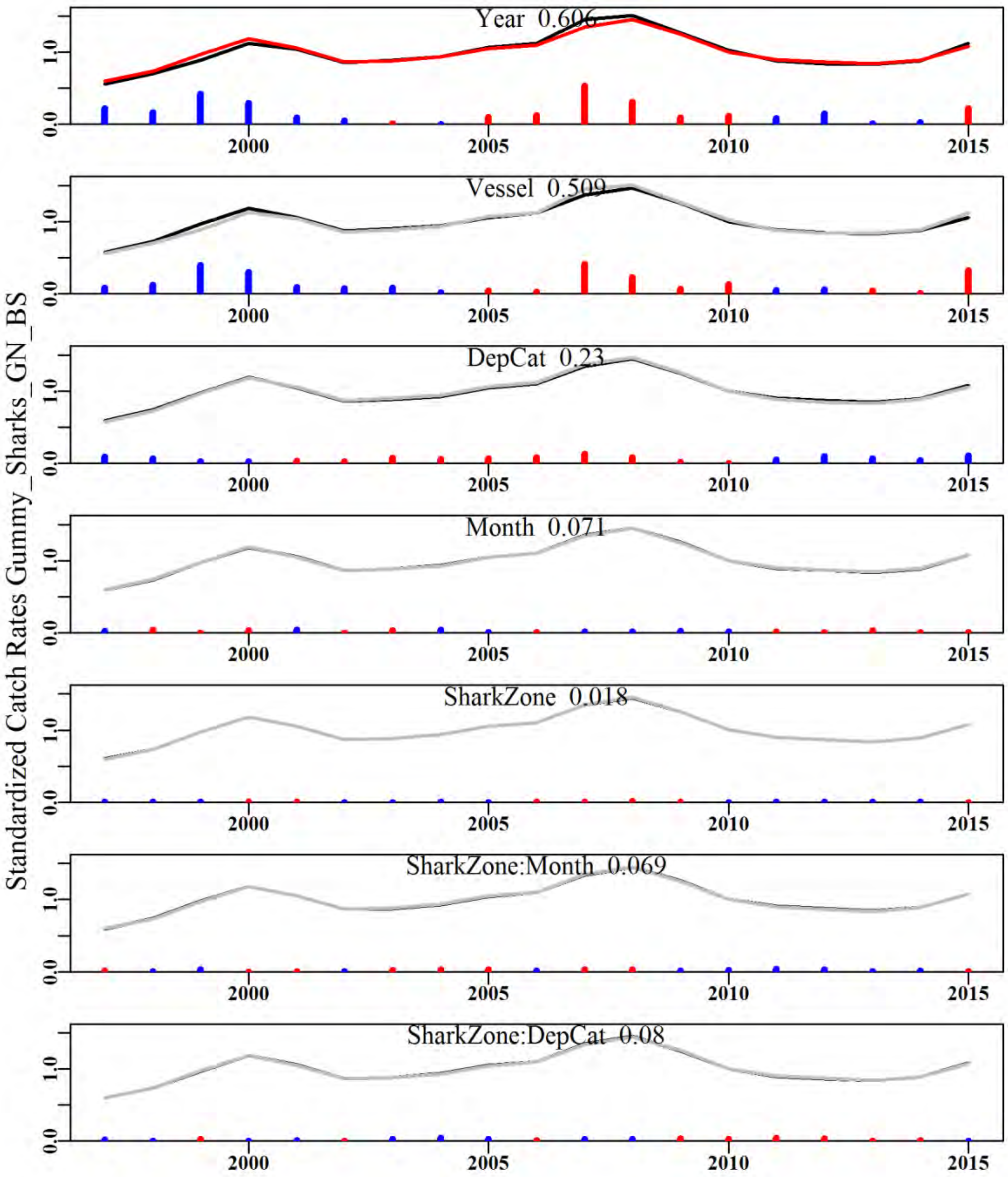



Figure 10.7. The relative influence of each factor on the final trend in the optimal standardization for the Bass Strait gummy shark gillnet fishery. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by the vertical bars with blue bars indicating the optimum model is higher than the geometric mean and red bars indicating it is lower. The top graph bars are the sum of all the bars in the graphs below. The graphs for individual factors are cumulative. Thus the second graph has the geometric mean (grey line) and the effect of adding Year + factor2 (Model 2, black line). In the third graph, the grey line represents Model 2 and the black line the effect of adding factor3 to the model. The remaining graphs continue in the same cumulative manner except for the interaction terms which are added singularly to the final single factor model.

### 10.4.3 *Tasmanian gummy shark: Gillnet*

Non-zero records of catch per shot were employed in the statistical standardization analyses for gummy shark caught by gillnets. Further investigation should be considered to determine whether total net length could be used as an alternative effort unit in standardization analyses.

Table 10.12. Gummy shark taken by gillnet across shark zones in Tasmania between depths of 0 to 160 m in the period 1997 - 2015. Total catch (TotCatch; t) is the total reported in the database across all gears, TotCat (t) is the total catch reported in the SESSF across all gears, number of records used in the analysis (Records), reported catch (CatchT; t) in the area and depth used in the analysis and number of vessels used in the analysis (Vessels). GeoMean is the geometric mean of CPUE (kg/shot). The optimum model is Model 6 (Table 10.14). SharkZone:Month and standard deviation (StDev) are the coefficients from the optimum model.

| Year | TotCatch | Records | CatchT | Vessels | GeoMean | SharkZone:Month | StDev |
|---|---|---|---|---|---|---|---|
| 1997 | 952.0854 | 203 | 17.2860 | 14 | 45.4643 | 0.7412 | 0.0000 |
| 1998 | 1401.0623 | 547 | 58.1410 | 14 | 48.8017 | 0.6813 | 0.1070 |
| 1999 | 1878.4663 | 797 | 98.3318 | 18 | 64.0234 | 0.9038 | 0.1061 |
| 2000 | 2349.5960 | 507 | 81.5136 | 18 | 86.2155 | 1.1453 | 0.1134 |
| 2001 | 1669.7930 | 565 | 66.2423 | 21 | 66.0826 | 1.1731 | 0.1169 |
| 2002 | 1494.9734 | 778 | 103.7533 | 26 | 61.7342 | 1.1586 | 0.1159 |
| 2003 | 1618.2742 | 799 | 90.9151 | 23 | 58.5075 | 1.2877 | 0.1172 |
| 2004 | 1656.3767 | 884 | 122.1803 | 26 | 64.4966 | 1.2361 | 0.1160 |
| 2005 | 1570.5199 | 660 | 86.1055 | 15 | 69.0883 | 1.0865 | 0.1189 |
| 2006 | 1577.1332 | 700 | 117.1630 | 15 | 92.2733 | 1.2185 | 0.1187 |
| 2007 | 1574.9505 | 835 | 95.3450 | 14 | 57.5239 | 1.0439 | 0.1177 |
| 2008 | 1727.7449 | 635 | 61.8030 | 14 | 52.8743 | 0.9075 | 0.1196 |
| 2009 | 1500.9008 | 533 | 68.6330 | 14 | 66.1554 | 1.1003 | 0.1247 |
| 2010 | 1404.7877 | 534 | 75.5120 | 14 | 75.8358 | 1.0986 | 0.1244 |
| 2011 | 1364.7051 | 686 | 102.7250 | 13 | 87.1495 | 0.9077 | 0.1273 |
| 2012 | 1304.2189 | 1121 | 130.0615 | 18 | 49.5438 | 0.9550 | 0.1234 |
| 2013 | 1307.6117 | 910 | 96.5810 | 15 | 55.4671 | 0.7937 | 0.1266 |
| 2014 | 1381.4137 | 481 | 61.0560 | 13 | 68.1559 | 0.7781 | 0.1369 |
| 2015 | 1544.2091 | 360 | 53.4210 | 11 | 78.9707 | 0.7830 | 0.1390 |

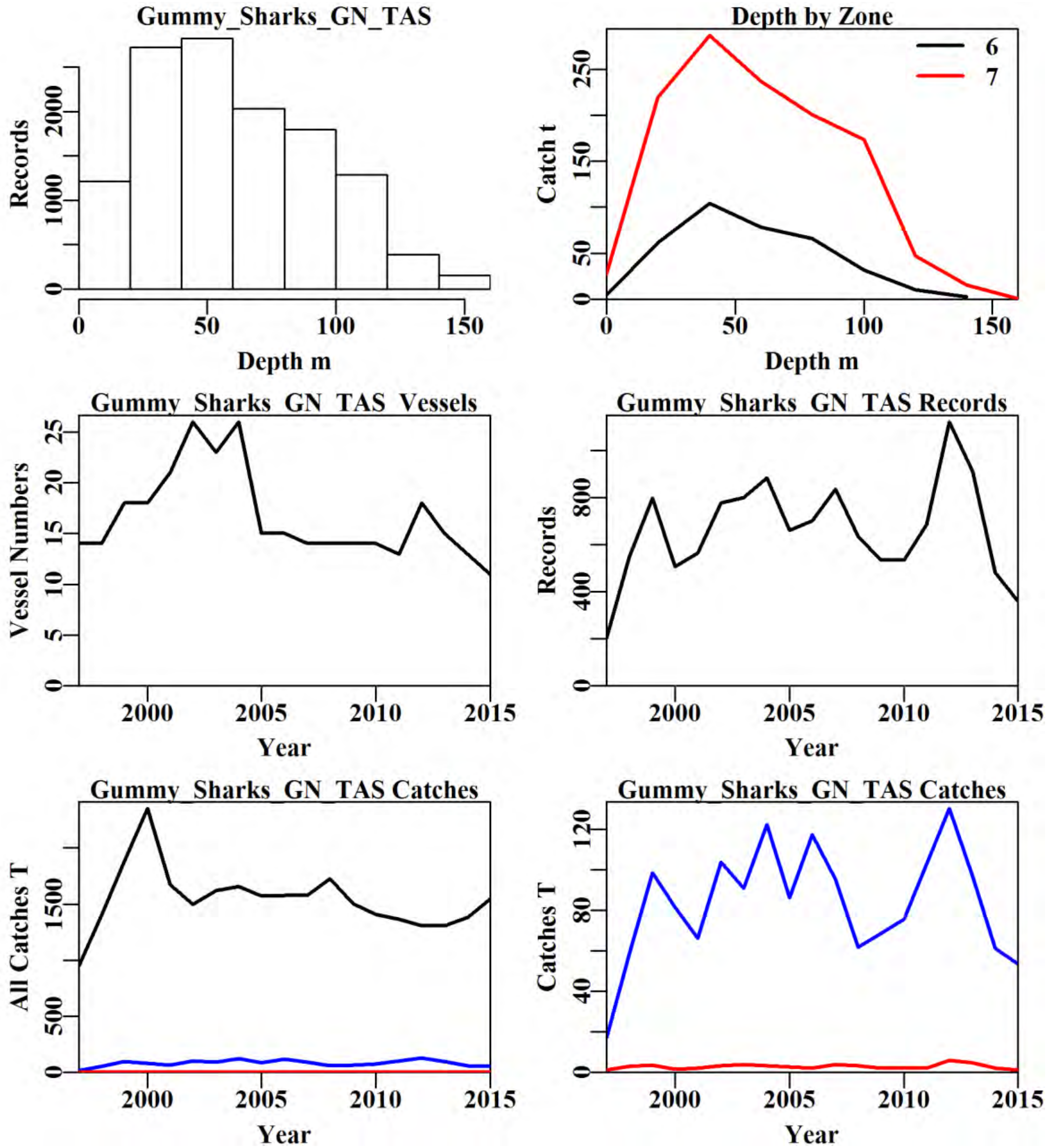



Figure 10.8. Gummy shark taken by gillnet in Tasmania at depths 0 – 160 m. The top left plot depicts the depth distribution of shots containing gummy shark from shark zones 6 and 7 at depths 0 – 160 m. The top right plot depicts the distribution of catch by depth within shark zones 6 and 7. The middle left plot depicts the number of vessels through time. The middle right plot contains the number of records used in analysis. The bottom left plot contains gummy shark catches (top black line: total catches, middle blue line: catches used in the analysis; bottom red line: catches < 30 kg) and bottom right plot contains gummy shark catches (blue line: catches used in the analysis; red line: catches < 30 kg).

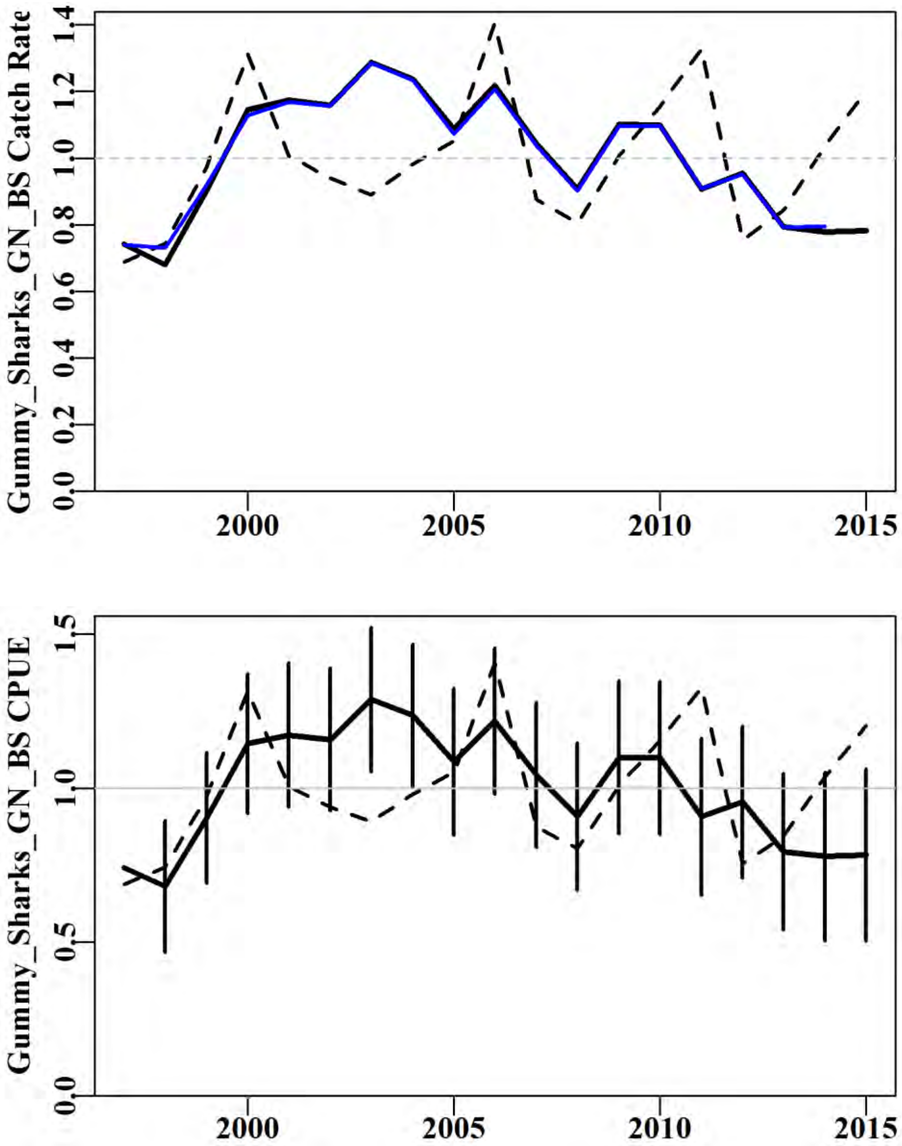



Figure 10.9. Gummy shark taken by gillnet surrounding Tasmania. Upper plot: The dashed black line represents the geometric mean CPUE and the solid black line the standardized catch rates (each scaled to the mean of each time series). The blue line corresponds to last year's standardized CPUE. Lower plot: Standardized CPUE (solid black line), two times the standard error (vertical lines) and geometric mean (dashed black line).

Table 10.13. Gummy shark from across shark zones surrounding Tasmania in depths 0 to 160 m by gillnet. Statistical model structures used in this analysis. DepCat is a series of 20 metre depth categories.

| | |
|---|---|
| Model 1 | LnCE ~ Year |
| Model 2 | LnCE ~ Year +Vessel |
| Model 3 | LnCE ~ Year +Vessel +DepCat |
| Model 4 | LnCE ~ Year +Vessel +DepCat + SharkZone |
| Model 5 | LnCE ~ Year +Vessel +DepCat + SharkZone + Month |
| Model 6 | LnCE ~ Year +Vessel +DepCat + SharkZone + Month + SharkZone:Month |
| Model 7 | LnCE ~ Year +Vessel +DepCat + SharkZone + Month + SharkZone:DepC |

Table 10.14. Gummy shark taken by gillnet across shark zones surrounding Tasmania at depths 0 to 160 m during 1997 – 2015. Model selection criteria, include the AIC, the adjusted $R^2$ (adj_$R^2$) and the change in adjusted $R^2$ (%Change). The optimum model is Model 6 (SharkZone:Month). Depth category: DepC.

| | Year | Vessel | DepCat | SharkZone | Month | SharkZone:Month | SharkZone:DepC |
|---|---|---|---|---|---|---|---|
| AIC | 6203 | 908 | 919 | 638 | 628 | 548 | 589 |
| RSS | 20499 | 13269 | 13145 | 12829 | 12816 | 12712 | 12759 |
| MSS | 438 | 7668 | 7792 | 8109 | 8121 | 8226 | 8178 |
| Nobs | 12535 | 12535 | 12416 | 12416 | 12416 | 12416 | 12416 |
| Npars | 19 | 97 | 105 | 116 | 117 | 128 | 125 |
| adj_$R^2$ | 1.953 | 36.135 | 36.686 | 38.155 | 38.212 | 38.660 | 38.445 |
| %Change | 0.000 | 34.182 | 0.551 | 1.469 | 0.057 | 0.448 | -0.215 |

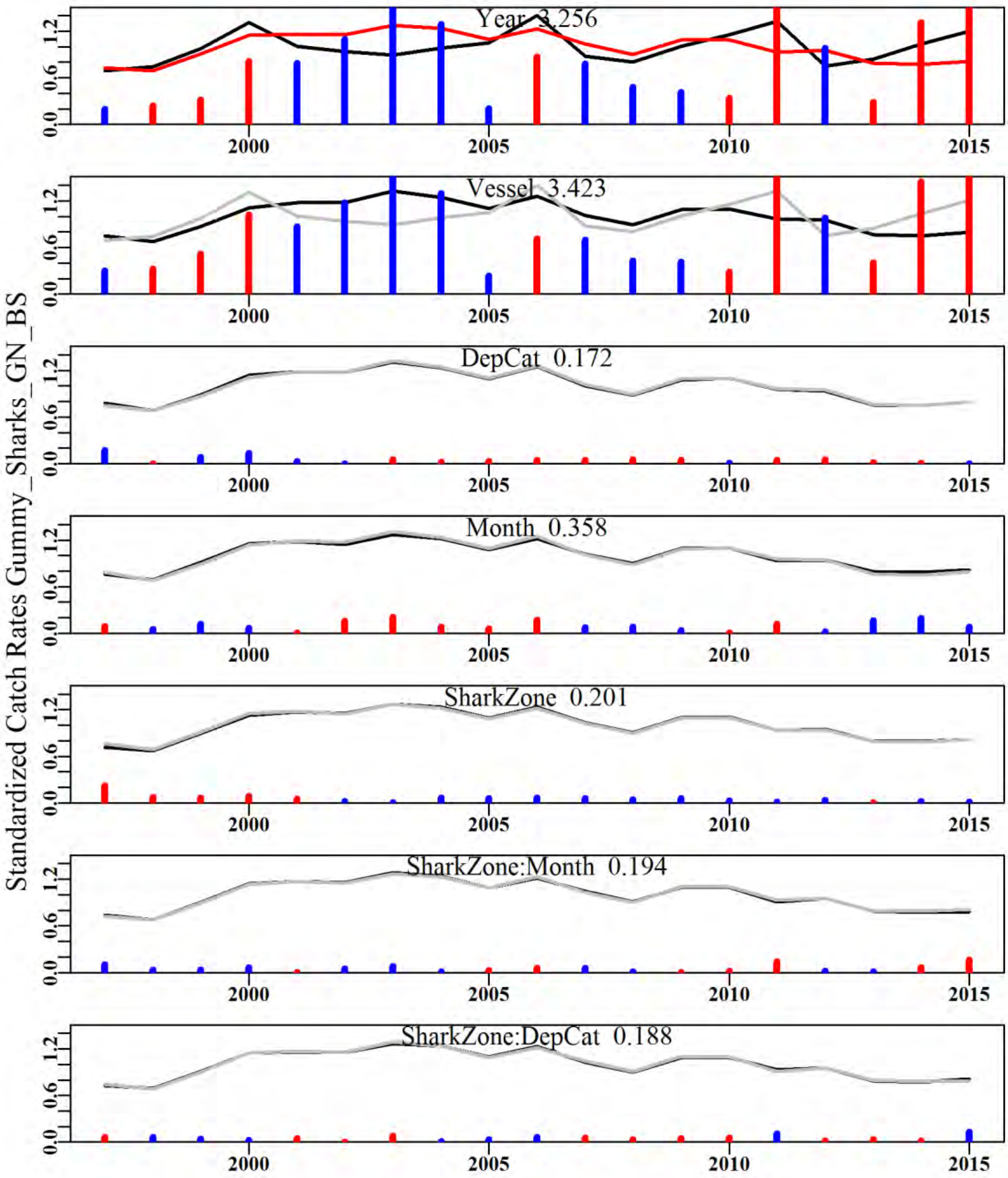



Figure 10.10. The relative influence of each factor on the final trend in the optimal standardization for the Tasmanian gummy shark gillnet fishery. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by the vertical bars with blue bars indicating the optimum model is higher than the geometric mean and red bars indicating it is lower. The top graph bars are the sum of all the bars in the graphs below. The graphs for individual factors are cumulative. Thus the second graph has the geometric mean (grey line) and the effect of adding Year + factor2 (Model 2, black line). In the third graph, the grey line represents Model 2 and the black line the effect of adding factor3 to the model. The remaining graphs continue in the same cumulative manner except for the interaction terms which are added singularly to the final single factor model.

### 10.4.4 *Gummy shark: Trawl*

CPUE (catch/hour) analysis used shots that reported catches of gummy shark (non zero shots), and included a factor for shark zones, more consistent with gillnet and line standardizations than the SESSF trawl zones previously considered (Haddon, 2014). The proportion of zero gummy shark catches reported by trawl (based on all records) is >60%. Since gummy shark are not targeted by trawl vessels, it is inappropriate to include zero catches in the analysis.

Table 10.15. Gummy shark taken by trawl across shark zones between depths of 0 to 500 m in the period 1996 - 2015. Total catch (TotCatch; t) is the total reported in the database across all gears, number of records used in the analysis (Records), reported catch (CatchT; t) in the area and depth used in the analysis and number of vessels used in the analysis (Vessels). GeoMean is the geometric mean of CPUE (kg/hr). The optimum model is Model 7 (Table 10.17). SharkZone:Month and standard deviation (StDev) are the coefficients from the optimum model.

| Year | TotCatch | Records | CatchT | Vessels | GeoMean | SharkZone:Month | StDev |
|---|---|---|---|---|---|---|---|
| 1996 | 49.3660 | 2254 | 41.0720 | 74 | 3.1006 | 1.0478 | 0.0000 |
| 1997 | 952.0854 | 2795 | 43.9650 | 77 | 2.5780 | 0.9181 | 0.0277 |
| 1998 | 1401.0623 | 2465 | 39.2090 | 62 | 2.6347 | 0.9144 | 0.0287 |
| 1999 | 1878.4663 | 2399 | 38.2530 | 69 | 2.6006 | 0.9459 | 0.0292 |
| 2000 | 2349.5960 | 3145 | 50.5350 | 74 | 2.5729 | 0.8287 | 0.0281 |
| 2001 | 1669.7930 | 3372 | 56.6135 | 64 | 2.5298 | 0.8162 | 0.0276 |
| 2002 | 1494.9734 | 4015 | 61.3995 | 67 | 2.3216 | 0.7746 | 0.0269 |
| 2003 | 1618.2742 | 4612 | 81.3464 | 73 | 2.4624 | 0.8290 | 0.0265 |
| 2004 | 1656.3767 | 4834 | 90.3284 | 73 | 2.5926 | 0.8437 | 0.0264 |
| 2005 | 1570.5199 | 5101 | 96.8855 | 70 | 2.7457 | 0.8597 | 0.0263 |
| 2006 | 1577.1332 | 4951 | 103.1047 | 62 | 2.8071 | 0.8877 | 0.0265 |
| 2007 | 1574.9505 | 3655 | 86.4725 | 37 | 2.9373 | 0.9099 | 0.0279 |
| 2008 | 1727.7449 | 3819 | 87.8080 | 36 | 3.0002 | 1.0736 | 0.0275 |
| 2009 | 1500.9008 | 3549 | 88.7385 | 31 | 3.4595 | 1.1727 | 0.0278 |
| 2010 | 1404.7877 | 3755 | 92.5170 | 33 | 3.2692 | 1.1589 | 0.0276 |
| 2011 | 1364.7051 | 4380 | 101.8220 | 32 | 3.1341 | 1.0539 | 0.0270 |
| 2012 | 1304.2189 | 3870 | 102.4883 | 31 | 3.4623 | 1.1593 | 0.0276 |
| 2013 | 1307.6117 | 3524 | 97.0122 | 34 | 4.0329 | 1.3069 | 0.0280 |
| 2014 | 1381.4137 | 3165 | 91.3406 | 34 | 4.1016 | 1.2686 | 0.0285 |
| 2015 | 1544.2091 | 2941 | 82.9910 | 36 | 3.7848 | 1.2306 | 0.0289 |

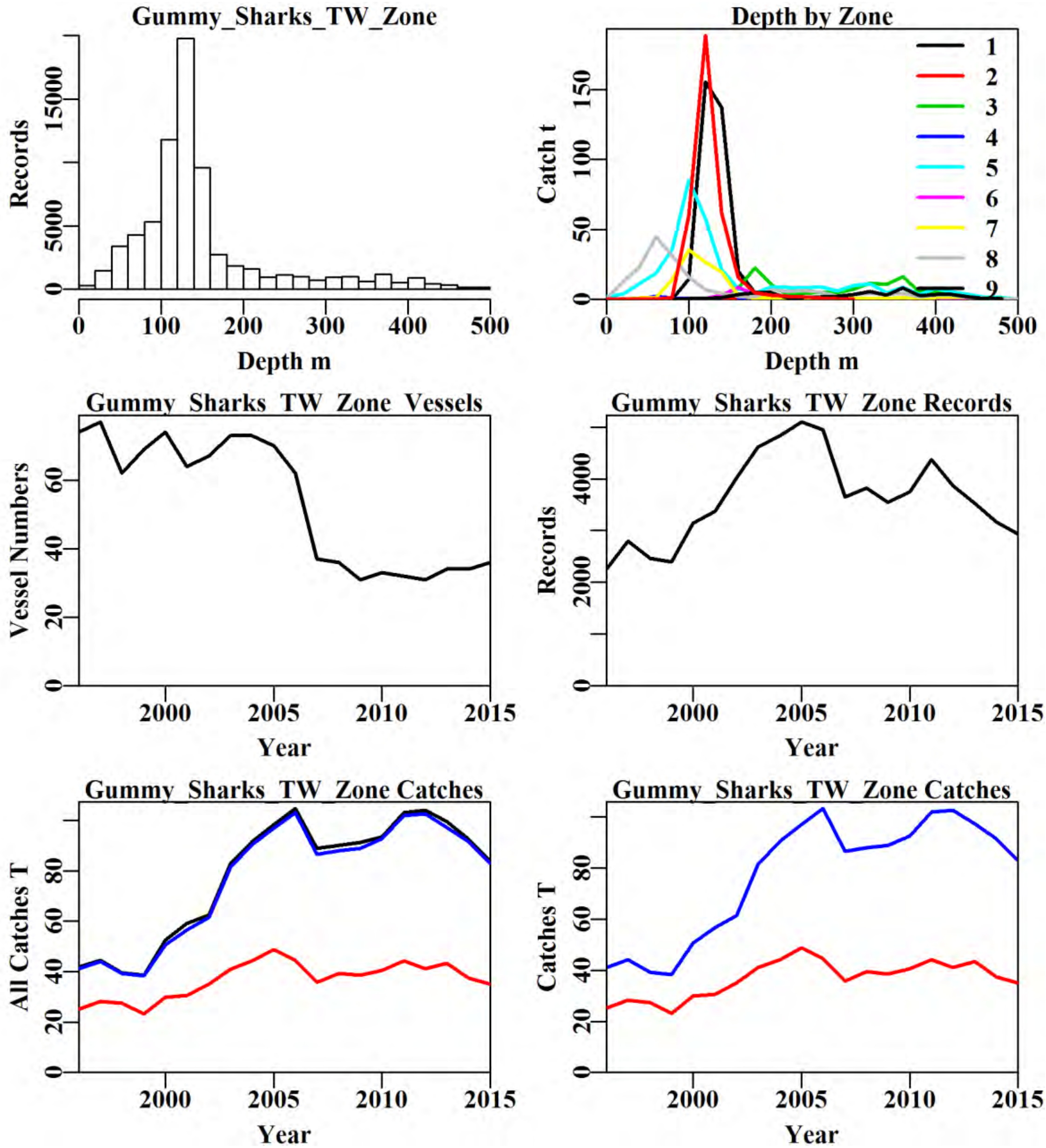



Figure 10.11. Gummy shark in depths 0 to 160 m taken by trawl. The top left plot depicts the depth distribution of shots containing gummy shark from shark zone 6 and 7 in depths 0 – 160 m. The top right plot depicts the distribution of catch by depth within shark zones 6 and 7. The middle left plot depicts the number of vessels through time. The middle right plot contains the number of records used in analysis. The bottom left plot contains gummy shark catches (top black line: total catches, middle blue line: catches used in the analysis; bottom red line: catches < 30 kg) and bottom right plot contains gummy shark catches (blue line: catches used in the analysis; red line: catches < 30 kg).

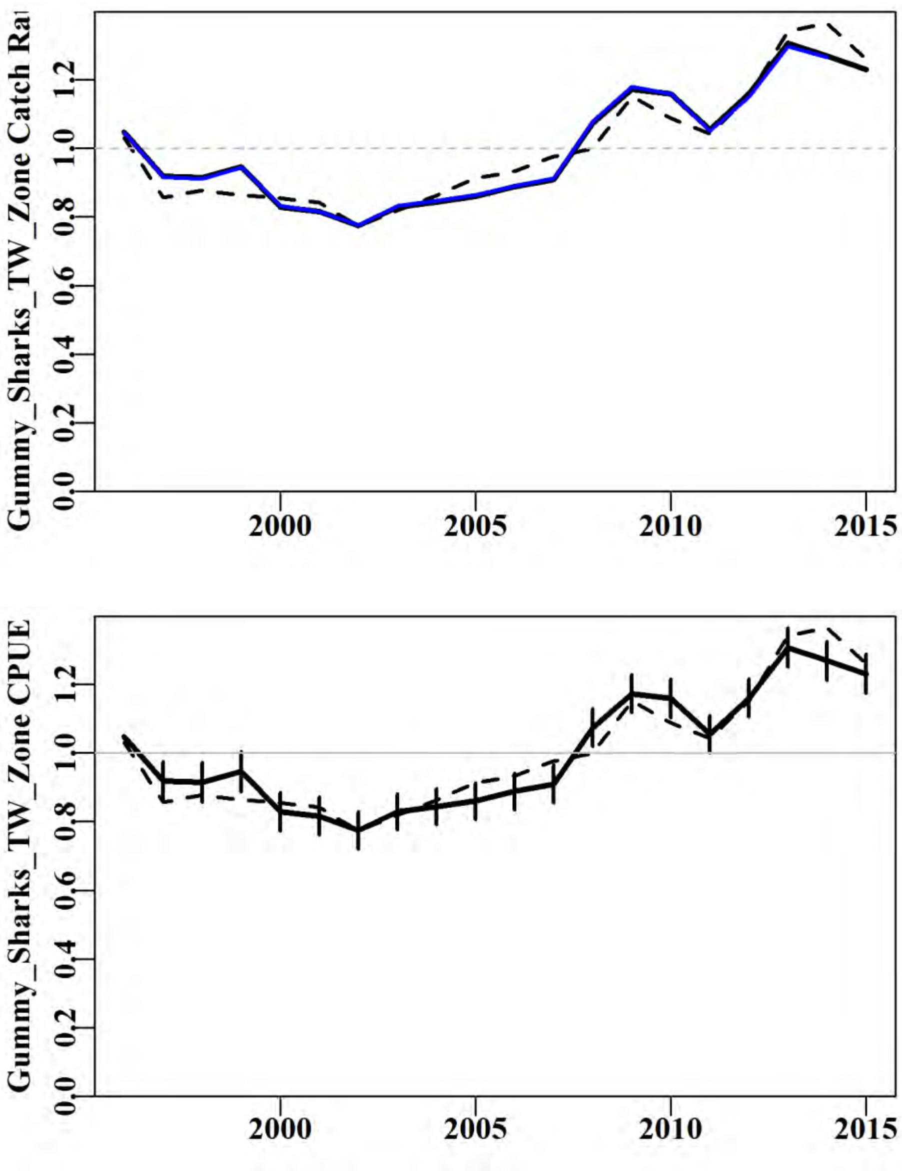



Figure 10.12. Gummy shark taken by Trawl. Upper plot: The dashed black line represents the geometric mean CPUE and the solid black line the standardized catch rates (each scaled to the mean of each time series). The blue line corresponds to last year's standardized CPUE. Lower plot: Standardized CPUE (solid black line), two times the standard error (vertical lines) and geometric mean (dashed black line).

Table 10.16. Gummy shark from across shark zones in depths 0 to 160 m by Trawl. Statistical model structures used in this analysis. DepCat is a series of 20 metre depth categories.

| | |
|---|---|
| Model 1 | LnCE ~ Year |
| Model 2 | LnCE ~ Year +Vessel |
| Model 3 | LnCE ~ Year +Vessel +DepCat |
| Model 4 | LnCE ~ Year +Vessel +DepCat + Month |
| Model 5 | LnCE ~ Year +Vessel +DepCat + Month + SharkZone |
| Model 6 | LnCE ~ Year +Vessel +DepCat + Month + SharkZone + DayNight |
| Model 7 | LnCE ~ Year +Vessel +DepCat + Month + SharkZone + DayNight + |
| Model 8 | LnCE ~ Year +Vessel +DepCat + Month + SharkZone + DayNight + |

Table 10.17. Gummy shark taken by trawl across shark zones at depths 0 to 160 m during 1997 - 2015. Model selection criteria, include the AIC, the adjusted $R^2$ (adj_$R^2$) and the change in adjusted $R^2$ (%Change). The optimum model is Model 7 (SharkZone:Month). Depth category: DepC.

| | Year | Vessel | Month | DepCat | DayNight | SharkZone | SharkZone:Month | SharkZone:DepC |
|---|---|---|---|---|---|---|---|---|
| AIC | 9040 | -2828 | -4318 | -5608 | -6728 | -7865 | -9136 | -8390 |
| RSS | 82183 | 69541 | 68108 | 66132 | 65104 | 64065 | 62550 | 63425 |
| MSS | 1882 | 14523 | 15957 | 17933 | 18961 | 19999 | 21514 | 20640 |
| Nobs | 72601 | 72601 | 72601 | 71868 | 71868 | 71868 | 71868 | 71868 |
| Npars | 20 | 149 | 160 | 185 | 188 | 197 | 422 | 296 |
| adj_$R^2$ | 2.213 | 17.107 | 18.804 | 21.130 | 22.353 | 23.582 | 25.154 | 24.241 |
| %Change | 0.000 | 14.895 | 1.696 | 2.326 | 1.223 | 1.229 | 1.572 | -0.913 |

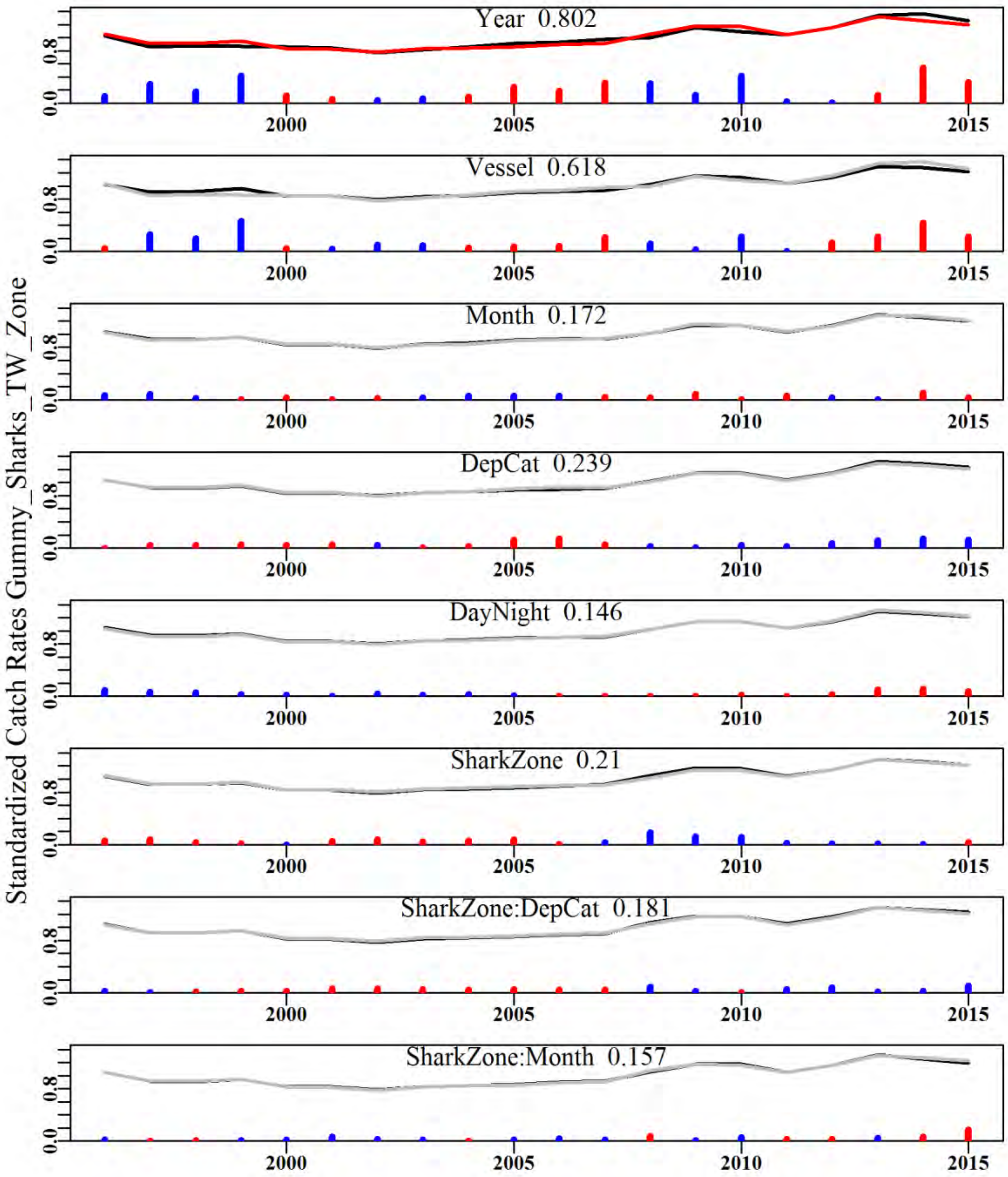



Figure 10.13. The relative influence of each factor on the final trend in the optimal standardization for the Tasmanian gummy shark trawl fishery. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by the vertical bars with blue bars indicating the optimum model is higher than the geometric mean and red bars indicating it is lower. The top graph bars are the sum of all the bars in the graphs below. The graphs for individual factors are cumulative. Thus the second graph has the geometric mean (grey line) and the effect of adding Year + factor2 (Model 2, black line). In the third graph, the grey line represents Model 2 and the black line the effect of adding factor3 to the model. The remaining graphs continue in the same cumulative manner except for the interaction terms which are added singularly to the final single factor model.

### 10.4.5 *Gummy shark: Bottom Line*

Records pertaining to shark zones 8 and 10 were omitted from analysis since they contributed very little to the overall catch (8: 0.02 %; 10: 0.007 %; less than one tonne in each shark zone). Furthermore, non-zero catches per shot were employed in the statistical standardization analyses for gummy shark caught by bottom line.

Currently, effort units are recorded inconsistently in the logbook database for bottom line caught gummy shark. Any of three alternative pairs of units can be recorded for a shot:

(i) THS (total hooks per set) and TLM (total length of mainline used); (ii) NLP (number of lines per shot) and THS (total number of hooks per set); and (iii) NLS (total number lines per shot) and THS (total number of hooks per shot) and/or HRS (hours). No clear method was apparent for including these inconsistent effort units in a single standardization. However the alternative is to assume that every fishing operation has the same probability of catching sharks, regardless of the number of hooks used, length of line, or soak time. A detailed analysis of these effort units should be investigated to determine whether (i) through to (iii) or some combination could be used as an altenative effort unit in the standardization analyses.

Table 10.18. Gummy shark taken by bottom line across shark zones at depths of 0 to 200 m in the period 1996 - 2015. TotCat (t) is the total catch reported in the SESSF across all gears, number of records used in the analysis (Records), reported catch (CatchT; t) in the area and depth used in the analysis and number of vessels used in the analysis (Vessels). GeoMean is the geometric mean of CPUE (kg/shot). The optimum model is Model 6 (Table 10.20). SharkZone:Month and standard deviation (StDev) are the coefficients from the optimum model.

| Year | TotCat | Records | CatchT | Vessels | GeoMean | SharkZone:Month | StDev |
|---|---|---|---|---|---|---|---|
| 1998 | 1401.0620 | 72 | 8.4820 | 3 | 89.4931 | 0.6518 | 0.0000 |
| 1999 | 1878.4660 | 335 | 46.9247 | 13 | 95.5411 | 0.9046 | 0.1475 |
| 2000 | 2349.5960 | 483 | 112.5767 | 14 | 142.8284 | 1.3184 | 0.1524 |
| 2001 | 1669.7930 | 543 | 59.1420 | 23 | 55.1650 | 0.8261 | 0.1514 |
| 2002 | 1494.9730 | 507 | 59.8912 | 22 | 61.1717 | 0.9142 | 0.1522 |
| 2003 | 1618.2740 | 629 | 66.1515 | 27 | 61.3844 | 0.7888 | 0.1514 |
| 2004 | 1656.3770 | 593 | 59.2260 | 24 | 56.8428 | 0.8334 | 0.1517 |
| 2005 | 1570.5200 | 585 | 61.1477 | 25 | 57.8756 | 0.9736 | 0.1531 |
| 2006 | 1577.1330 | 494 | 48.8603 | 19 | 50.4682 | 1.0675 | 0.1550 |
| 2007 | 1574.9510 | 627 | 54.5186 | 19 | 40.7575 | 0.9664 | 0.1539 |
| 2008 | 1727.7450 | 599 | 50.0818 | 16 | 36.0171 | 0.7291 | 0.1562 |
| 2009 | 1500.9010 | 822 | 67.1229 | 15 | 37.5970 | 0.8309 | 0.1549 |
| 2010 | 1404.7880 | 684 | 71.9608 | 19 | 48.2002 | 0.9870 | 0.1554 |
| 2011 | 1364.7050 | 1051 | 87.9336 | 28 | 46.2099 | 1.1251 | 0.1550 |
| 2012 | 1304.2190 | 1407 | 124.1840 | 24 | 52.7575 | 1.1440 | 0.1544 |
| 2013 | 1307.6120 | 2519 | 228.7894 | 26 | 50.3615 | 1.3581 | 0.1544 |
| 2014 | 1381.4140 | 2791 | 226.9177 | 28 | 40.8349 | 1.1255 | 0.1545 |
| 2015 | 1544.2090 | 1958 | 188.4015 | 28 | 51.9165 | 1.4556 | 0.1552 |

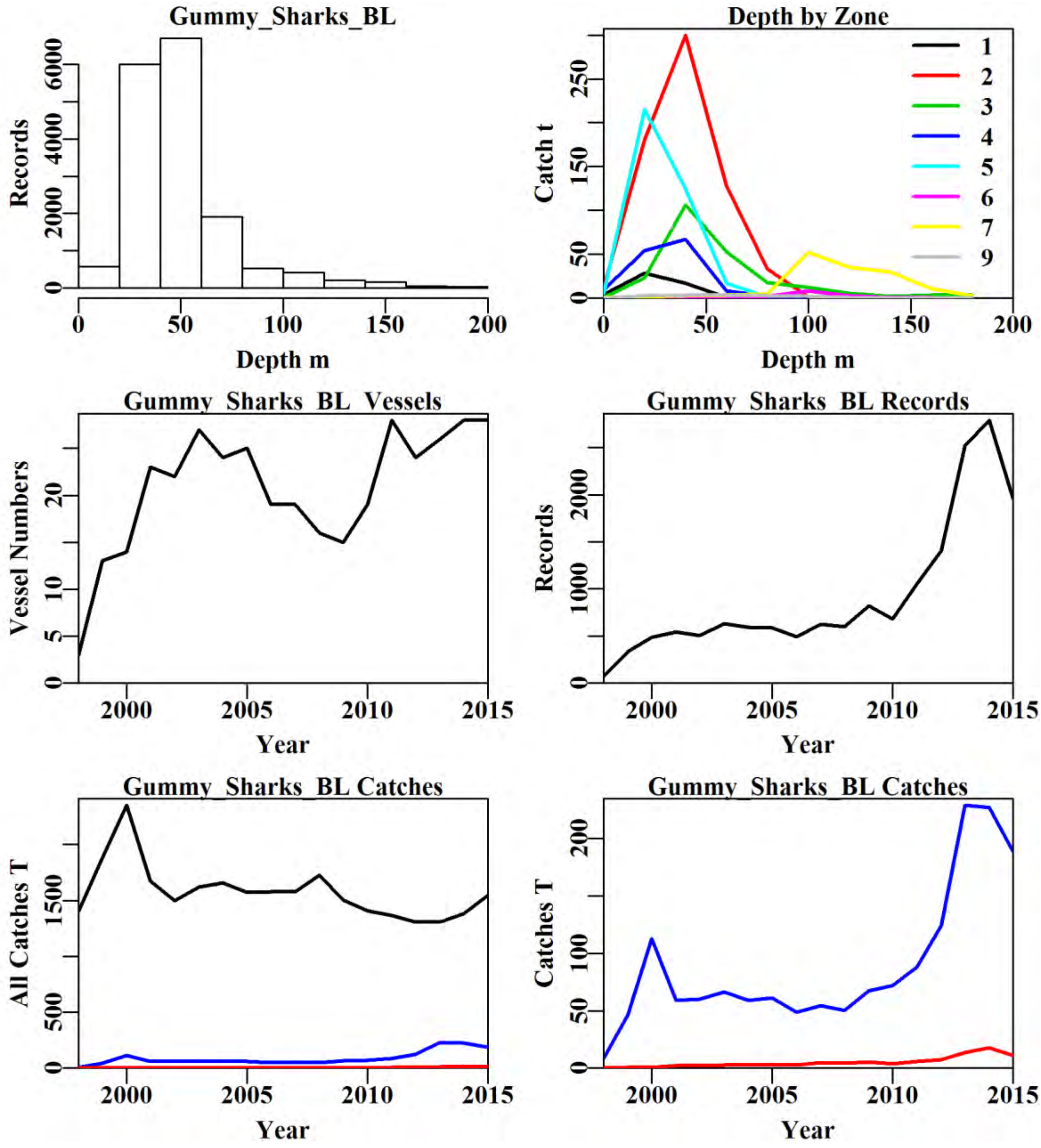



Figure 10.14. Gummy shark in depths 0 to 200 m taken by bottom line. The top left plot depicts the depth distribution of shots containing gummy shark from shark zone 1-7, 9 in depths 0 – 200 m. The top right plot depicts the distribution of catch by depth within shark zones 1-7 and 9. The middle left plot depicts the number of vessels through time. The middle right plot contains the number of records used in analysis. The bottom left plot contains gummy shark catches (top black line: total catches, middle blue line: catches used in the analysis; bottom red line: catches < 30 kg) and bottom right plot contains gummy shark catches (blue line: catches used in the analysis; red line: catches < 30 kg).

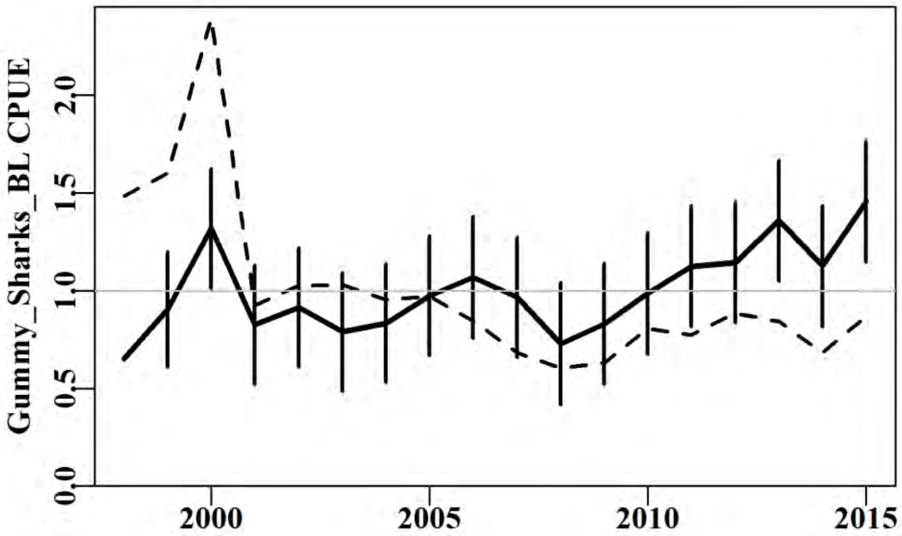



Figure 10.15. The standardized CPUE for gummy sharks taken by bottom line showing the optimum model (solid black line) and the geometric mean CPUE (dashed line) each scaled to the mean of each time series. The vertical bars are two times the standard error.

Table 10.19. Gummy shark from across shark zones at depths 0 to 160 m by bottom line. Statistical model structures used in this analysis. DepCat is a series of 20 metre depth categories.

| | |
|---|---|
| Model 1 | LnCE ~ Year |
| Model 2 | LnCE ~ Year +Vessel |
| Model 3 | LnCE ~ Year +Vessel +DepCat |
| Model 4 | LnCE ~ Year +Vessel +DepCat + Month |
| Model 5 | LnCE ~ Year +Vessel +DepCat + Month + SharkZone |
| Model 6 | LnCE ~ Year +Vessel +DepCat + Month + SharkZone + SharkZone:Month |
| Model 7 | LnCE ~ Year +Vessel +DepCat + Month + SharkZone + SharkZone:DepC |

Table 10.20. Gummy shark taken by bottom line across shark zones at depths 0 to 200 m during 1998 - 2015. Model selection criteria, include the AIC, the adjusted $R^2$ (adj_ $R^2$) and the change in adjusted $R^2$ (%Change). The optimum model is Model 6 (SharkZone:Month). Depth category: DepC.

| | Year | Vessel | DepCat | SharkZone | Month | SharkZone:Month | SharkZone:DepC |
|---|---|---|---|---|---|---|---|
| AIC | 6502 | -346 | -430 | -468 | -499 | -624 | -543 |
| RSS | 24596 | 16092 | 15865 | 15816 | 15765 | 15502 | 15604 |
| MSS | 1057 | 9560 | 9787 | 9836 | 9887 | 10150 | 10048 |
| Nobs | 16699 | 16699 | 16570 | 16570 | 16570 | 16570 | 16570 |
| Npars | 18 | 136 | 145 | 152 | 163 | 240 | 226 |
| adj_$R^2$ | 4.021 | 36.757 | 37.609 | 37.779 | 37.937 | 38.685 | 38.332 |
| %Change | 0.000 | 32.736 | 0.852 | 0.170 | 0.158 | 0.748 | -0.352 |

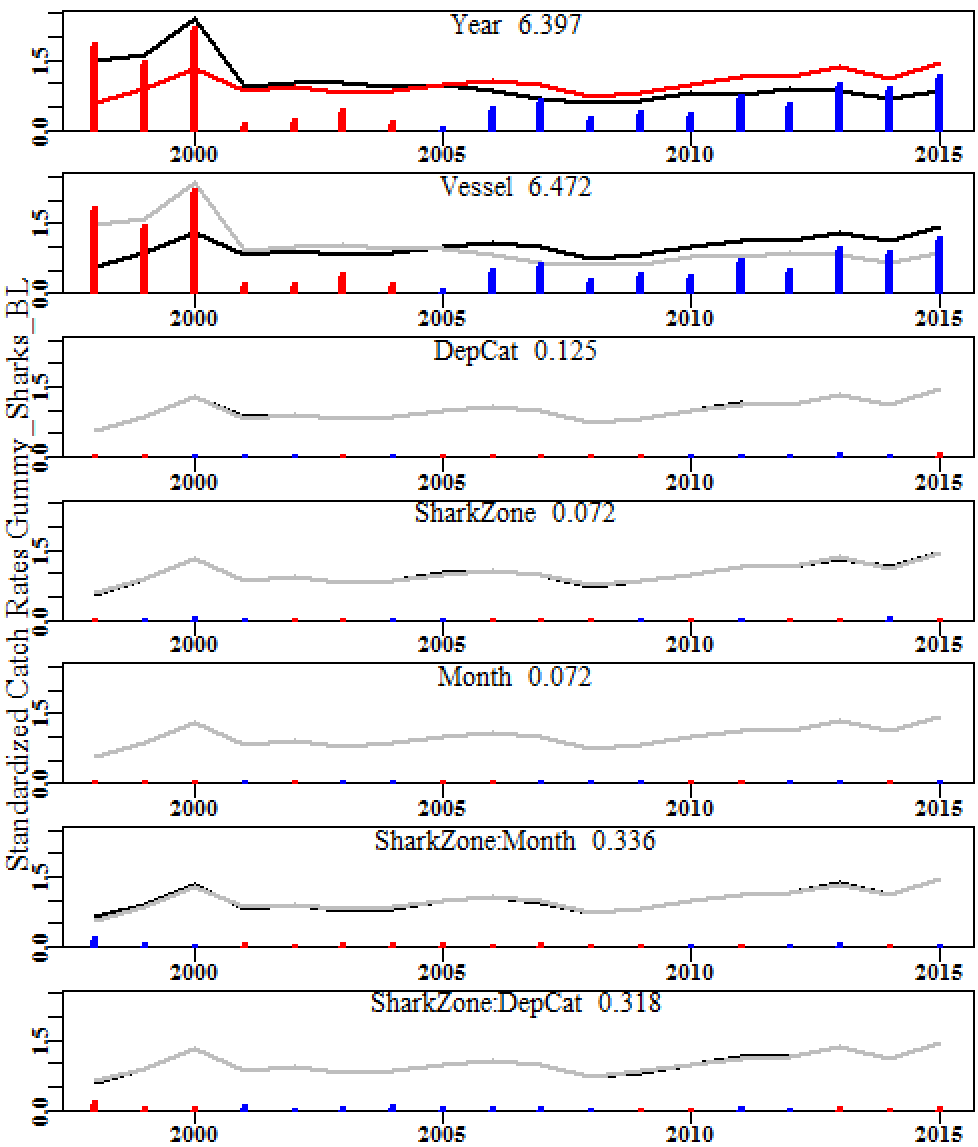



Figure 10.16. The relative influence of each factor on the final trend in the optimal standardization for the gummy shark bottom line fishery. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by the vertical bars with blue bars indicating the optimum model is higher than the geometric mean and red bars indicating it is lower. The top graph bars are the sum of all the bars in the graphs below. The graphs for individual factors are cumulative. Thus the second graph has the geometric mean (grey line) and the effect of adding Year + factor2 (Model 2, black line). In the third graph, the grey line represents Model 2 and the black line the effect of adding factor3 to the model. The remaining graphs continue in the same cumulative manner except for the interaction terms which are added singularly to the final single factor model.

### 10.4.6 *School shark: Trawl*

Positive non-zero records of catch per hour were employed in the statistical standardization analyses for reported school shark caught by trawl. Shark zones used in the analysis were 1-8 and 10. This analysis excludes State catches (Table 10.24; Figure 10.20).

Table 10.21. School shark taken by trawl across shark zones between depths of 0 to 200 m during 1996 - 2015. Total catch (TotCatch; t) is the total reported in the database across all gears, number of records used in the analysis (Records), reported catch (CatchT; t) in the area and depth used in the analysis and number of vessels used in the analysis (Vessels). GeoMean is the geometric mean of CPUE (kg/hr). The optimum model is Model 7 (Table 10.23). SharkZone:Month and standard deviation (StDev) are the coefficients from the optimum model.

| Year | TotCatch | Records | CatchT | Vessels | GeoMean | SharkZone:Month | StDev |
|---|---|---|---|---|---|---|---|
| 1996 | 29.1410 | 922 | 24.4410 | 67 | 4.2798 | 1.1974 | 0.0000 |
| 1997 | 363.6533 | 1193 | 23.6930 | 60 | 3.5138 | 1.0398 | 0.0435 |
| 1998 | 560.0518 | 962 | 19.8990 | 51 | 3.3436 | 1.0399 | 0.0460 |
| 1999 | 485.5591 | 764 | 14.2330 | 51 | 3.4120 | 0.9537 | 0.0504 |
| 2000 | 451.1087 | 921 | 16.6700 | 68 | 2.6861 | 0.8139 | 0.0485 |
| 2001 | 182.5977 | 860 | 15.7240 | 47 | 2.8884 | 0.8301 | 0.0492 |
| 2002 | 205.1494 | 948 | 17.0350 | 57 | 3.0584 | 0.8548 | 0.0484 |
| 2003 | 208.2442 | 773 | 13.2407 | 59 | 2.7186 | 0.7919 | 0.0516 |
| 2004 | 197.7008 | 699 | 13.3534 | 54 | 2.6630 | 0.7916 | 0.0533 |
| 2005 | 208.8549 | 521 | 8.3496 | 45 | 2.4624 | 0.8392 | 0.0571 |
| 2006 | 212.0395 | 573 | 10.9540 | 47 | 2.6022 | 0.8256 | 0.0560 |
| 2007 | 197.7974 | 350 | 7.3560 | 32 | 2.7737 | 0.8467 | 0.0650 |
| 2008 | 234.3531 | 406 | 8.9945 | 30 | 2.9491 | 0.9375 | 0.0610 |
| 2009 | 253.0733 | 444 | 13.6965 | 28 | 3.2235 | 1.0327 | 0.0591 |
| 2010 | 180.1430 | 437 | 12.8640 | 26 | 3.2832 | 0.9944 | 0.0604 |
| 2011 | 182.4215 | 453 | 13.8320 | 28 | 3.2958 | 1.1084 | 0.0596 |
| 2012 | 136.0453 | 346 | 11.0003 | 27 | 3.7005 | 1.1462 | 0.0650 |
| 2013 | 150.0228 | 375 | 18.3260 | 33 | 5.0015 | 1.3417 | 0.0645 |
| 2014 | 199.8103 | 395 | 11.2510 | 26 | 3.8274 | 1.2397 | 0.0621 |
| 2015 | 146.7326 | 334 | 12.4380 | 25 | 4.1185 | 1.3748 | 0.0656 |

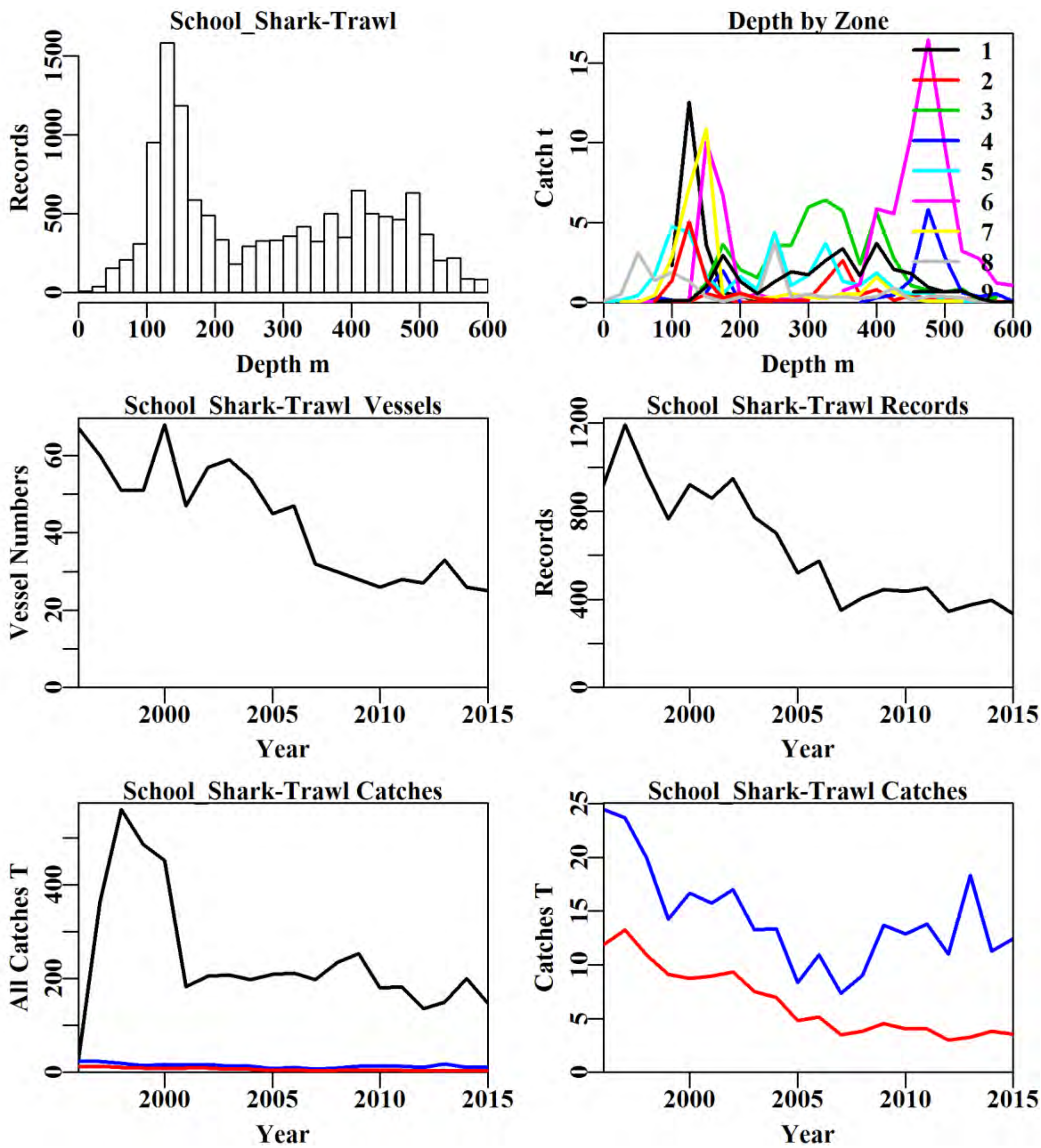



Figure 10.17. School shark in depths 0 to 600 m taken by trawl. The top left plot depicts the depth distribution of shots containing school shark from shark zones 1-8, 10 in depths 0 – 600 m. The top right plot depicts the distribution of catch by depth within shark zones 1-8 and 10. The middle left plot depicts the number of vessels through time. The middle right plot contains the number of records used in analysis. The bottom left plot contains school shark catches (top black line: total catches, middle blue line: catches used in the analysis; bottom red line: catches < 30 kg) and bottom right plot contains school shark catches (blue line: catches used in the analysis; red line: catches < 30 kg).

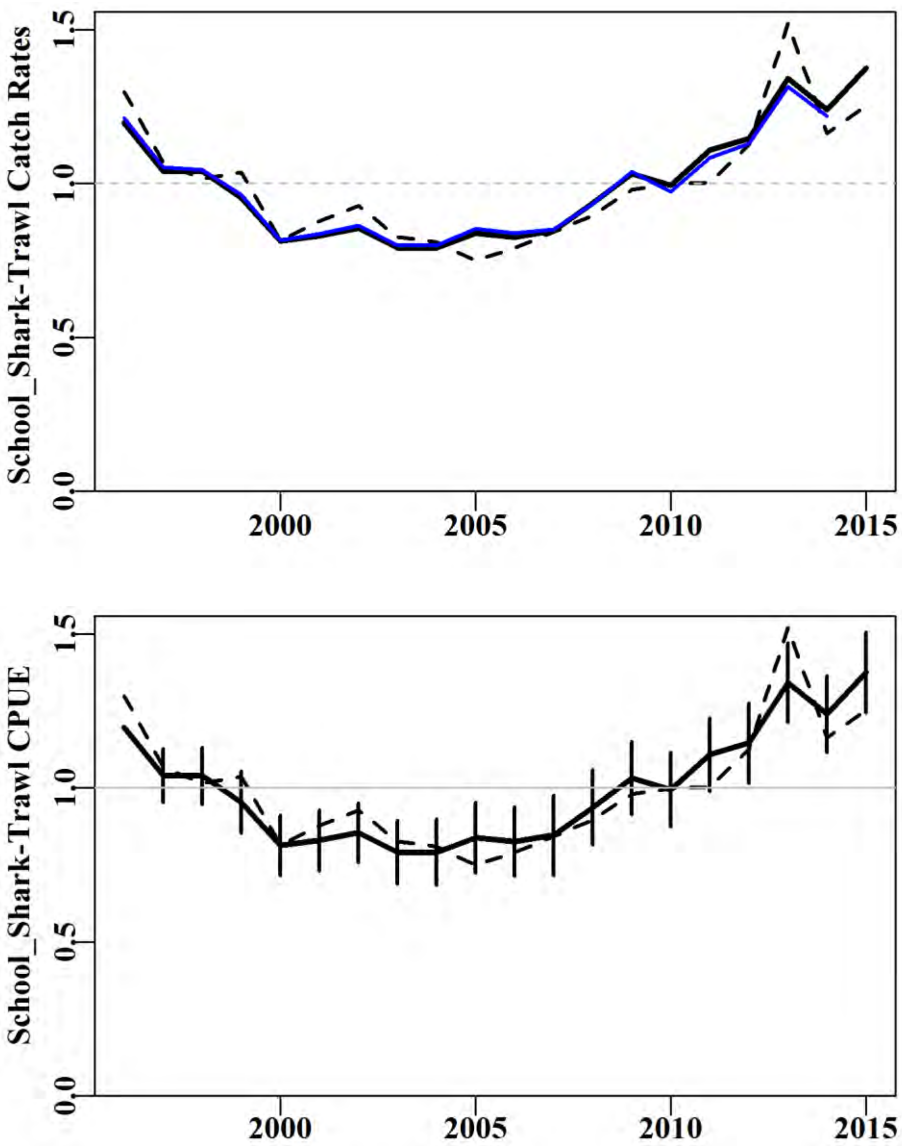



Figure 10.18. The standardized CPUE for school sharks taken by trawl showing the optimum model (solid black line) and the geometric mean CPUE (dashed line) each scaled to the mean of each time series. The vertical bars are two times the standard error.

Table 10.22. School shark from across shark zones in depths 0 to 600 m by trawl. Statistical model structures used in this analysis. DepCat is a series of 25 metre depth categories.

| | |
|---|---|
| Model 1 | LnCE ~ Year |
| Model 2 | LnCE ~ Year +Vessel |
| Model 3 | LnCE ~ Year +Vessel +DepCat |
| Model 4 | LnCE ~ Year +Vessel +DepCat + Month |
| Model 5 | LnCE ~ Year +Vessel +DepCat + Month + SharkZone |
| Model 6 | LnCE ~ Year +Vessel +DepCat + Month + SharkZone + DayNight |
| Model 7 | LnCE ~ Year +Vessel +DepCat + Month + SharkZone + DayNight + SharkZone:Month |
| Model 8 | LnCE ~ Year +Vessel +DepCat + Month + SharkZone + DayNight + SharkZone:DepC |

Table 10.23. School shark taken by trawl across shark zones at depths 0 to 600 m during 1996 - 2015. Model selection criteria, include the AIC, the adjusted $R^2$ (adj_$R^2$) and the change in adjusted $R^2$ (%Change). The optimum model is Model 7 (SharkZone:Month). Depth category: DepC.

| | Year | Vessel | DepCat | SharkZone | Month | DayNight | SharkZone:Month | SharkZone:DepC |
|---|---|---|---|---|---|---|---|---|
| AIC | 2666 | -684 | -1284 | -1369 | -1407 | -1407 | -1433 | -1427 |
| RSS | 15594 | 11724 | 11069 | 10975 | 10937 | 10935 | 10894 | 10876 |
| MSS | 364 | 4233 | 4888 | 4982 | 5020 | 5022 | 5064 | 5081 |
| Nobs | 12676 | 12676 | 12605 | 12605 | 12605 | 12605 | 12605 | 12605 |
| Npars | 20 | 153 | 177 | 188 | 191 | 192 | 203 | 216 |
| adj_$R^2$ | 2.132 | 25.637 | 29.649 | 30.184 | 30.413 | 30.416 | 30.621 | 30.657 |
| %Change | 0.000 | 23.505 | 4.012 | 0.535 | 0.228 | 0.004 | 0.205 | 0.036 |

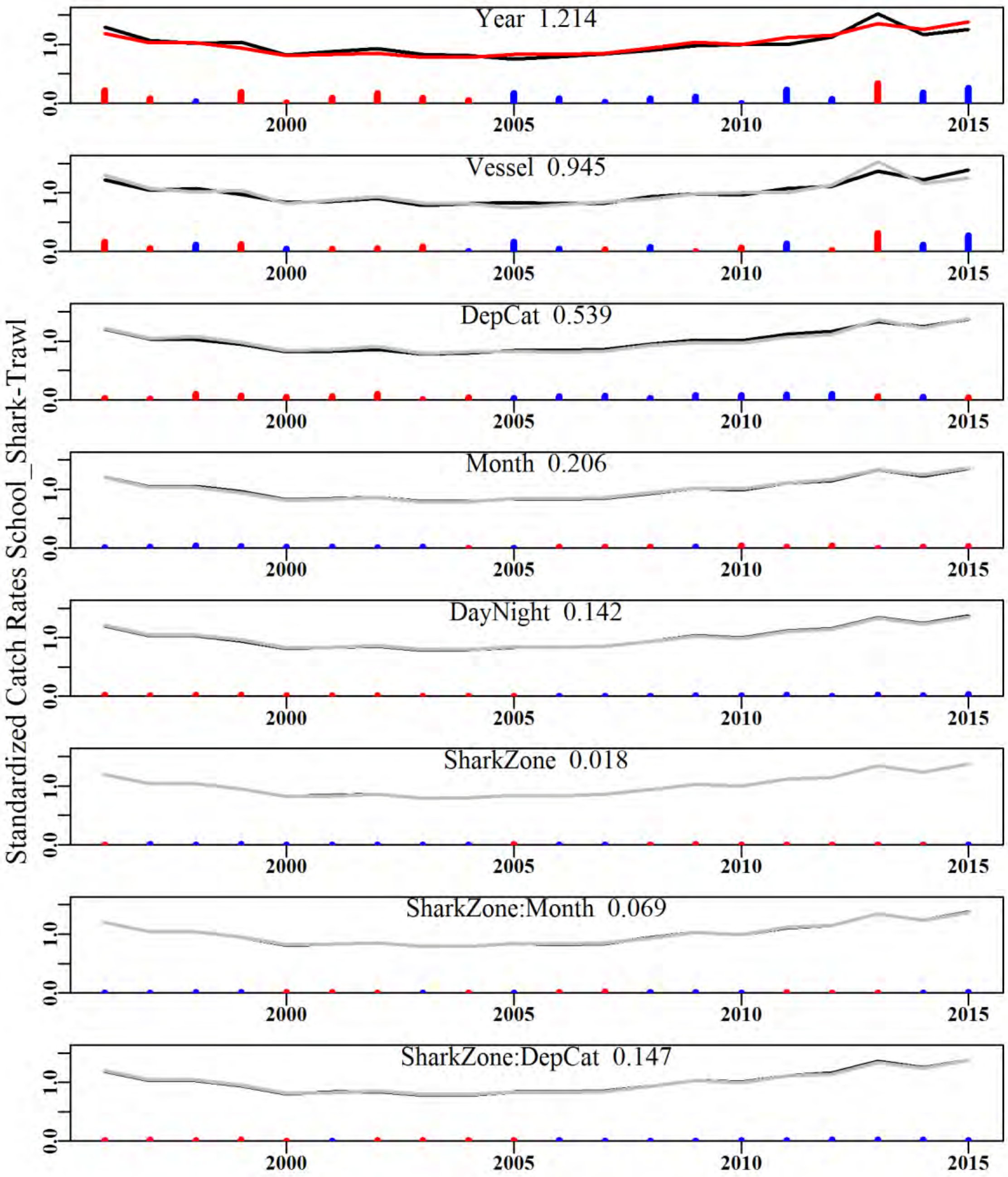
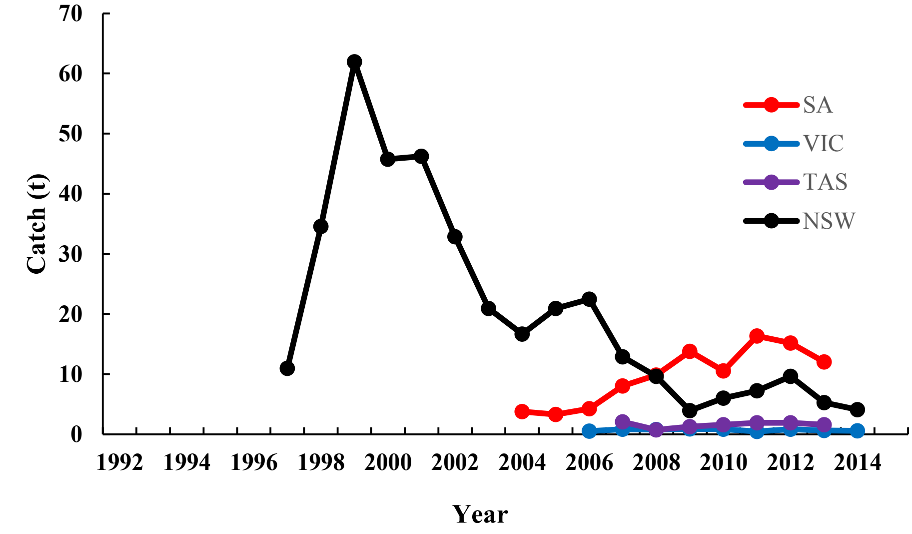



Figure 10.19. The relative influence of each factor on the final trend in the optimal standardization for the school shark trawl fishery. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by the vertical bars with blue bars indicating the optimum model is higher than the geometric mean and red bars indicating it is lower. The top graph bars are the sum of all the bars in the graphs below. The graphs for individual factors are cumulative. Thus the second graph has the geometric mean (grey line) and the effect of adding Year + factor2 (Model 2, black line). In the third graph, the grey line represents Model 2 and the black line the effect of adding factor3 to the model. The remaining graphs continue in the same cumulative manner except for the interaction terms which are added singularly to the final single factor model.



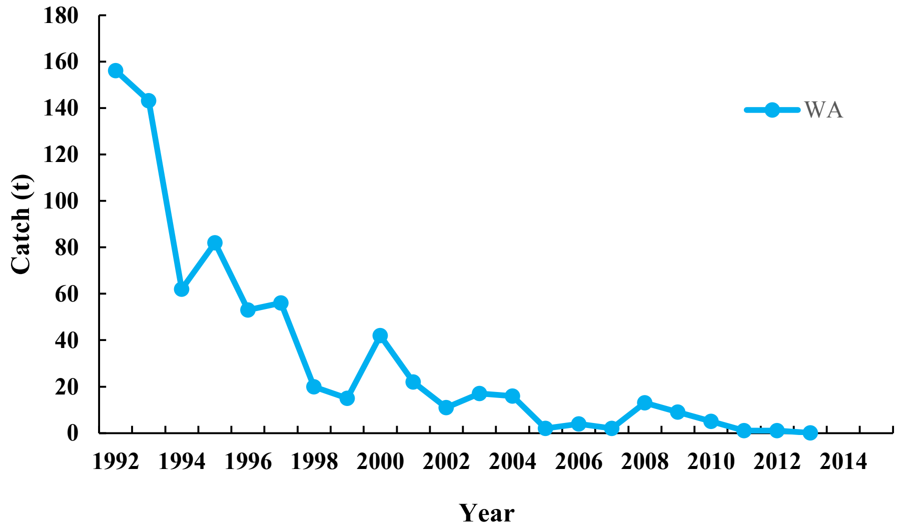




Figure 10.20. Reported State catches of school sharks. Western Australia is on a separate graph due to the different y-axis scale. Estimates are pending from (i) SA, TAS and WA for 2014 and 2015 and (ii) from Vic and NSW for 2015.

Table 10.24. Reported total State catches of school sharks (t). Estimates are pending from (i) SA, TAS and WA for 2014 and 2015 and (ii) from Vic and NSW for 2015. Extracted from Thomson and Upston (2016).

| Year | WA | SA | Vic | Tas | NSW |
|---|---|---|---|---|---|
| 1992 | 156.1 | | | | |
| 1993 | 143.1 | | | | |
| 1994 | 62 | | | | |
| 1995 | 82 | | | | |
| 1996 | 53 | | | | |
| 1997 | 56 | | | | 10.985 |
| 1998 | 20 | | | | 34.584 |
| 1999 | 15 | | | | 61.947 |
| 2000 | 42 | | | | 45.729 |
| 2001 | 22 | | | | 46.229 |
| 2002 | 11 | | | | 32.88 |
| 2003 | 17.1 | | | | 20.909 |
| 2004 | 16 | 3.794 | | | 16.674 |
| 2005 | 2 | 3.321 | | | 20.913 |
| 2006 | 4 | 4.275 | 0.544 | | 22.456 |
| 2007 | 2 | 8.063 | 0.836 | 2.104 | 12.868 |
| 2008 | 13 | 9.855 | 0.791 | 0.728 | 9.618 |
| 2009 | 9 | 13.813 | 0.916 | 1.304 | 3.961 |
| 2010 | 5 | 10.544 | 0.836 | 1.605 | 6.017 |
| 2011 | 1 | 16.358 | 0.489 | 1.903 | 7.221 |
| 2012 | 1 | 15.179 | 0.877 | 1.935 | 9.666 |
| 2013 | 0.1 | 12.02 | 0.627 | 1.577 | 5.298 |
| 2014 | | | 0.605 | | 4.119 |
| 2015 | | | | | |

### 10.4.7 *Elephant fish: Gillnet*

The proportion of catches recording < 30 kg is relatively high in elephant fish reports, indicating that elephant fish are not a primary target species and tend to be caught in small numbers and weights in each shot (**Error! Reference source not found.**). The preliminary estimate of the proportion discarded or 2015 is 0.75, corresponding to 182.66 t (Thomson and Upston 2016). Given the high proportion of discards, it is questionable as to whether an analysis including zero catches would be valid. Therefore, only non-zero shots were analysed. The use of effort in units of net length should be investigated for future analyses. Exploratory analyses shows inconsistency in the recording of gillnet effort units in the logbook database, particularly in 1997 and 1998 compared to later years. A detailed effort analsyis is required towards utilizing this in subsequent standardizations (see discussion in Section 10.4.5).

Table 10.25. Elephant fish taken by gillnet across shark zones from Central South Australia (CSA) to Eastern Bass Strait (EBS) at depths of 0 to 160 m and during 1997 - 2015. Total catch (TotCatch; t) is the total reported in the database across all gears, number of records used in the analysis (Records), reported catch (CatchT; t) in the area and depth used in the analysis and number of vessels used in the analysis (Vessels). GeoMean is the geometric mean of CPUE (kg/shot). The optimum model is Model 6 (Table 10.27). SharkZone:Month and standard deviation (StDev) are the coefficients from the optimum model.

| Year | TotCatch | Records | CatchT | Vessels | GeoMean | SharkZone:Month | StDev |
|---|---|---|---|---|---|---|---|
| 1997 | 32.0257 | 1482 | 25.9637 | 56 | 6.2883 | 0.9238 | 0.0000 |
| 1998 | 51.9470 | 2234 | 42.9950 | 57 | 6.1209 | 0.8549 | 0.0466 |
| 1999 | 67.7428 | 2940 | 59.0129 | 63 | 6.8456 | 1.0142 | 0.0456 |
| 2000 | 77.4971 | 2867 | 67.5423 | 57 | 8.3170 | 1.2764 | 0.0455 |
| 2001 | 87.6935 | 2913 | 76.9756 | 63 | 9.3138 | 1.3123 | 0.0461 |
| 2002 | 59.2784 | 2251 | 39.6659 | 64 | 6.1646 | 0.9379 | 0.0479 |
| 2003 | 70.5919 | 2219 | 45.7141 | 61 | 5.9048 | 0.9220 | 0.0484 |
| 2004 | 64.7651 | 1869 | 32.9099 | 52 | 5.8738 | 0.8765 | 0.0501 |
| 2005 | 66.3701 | 1977 | 34.2006 | 40 | 6.2019 | 0.9144 | 0.0495 |
| 2006 | 53.2590 | 1708 | 31.6755 | 43 | 6.1036 | 0.9862 | 0.0516 |
| 2007 | 51.6930 | 1808 | 34.0480 | 38 | 6.6645 | 1.0669 | 0.0512 |
| 2008 | 61.4437 | 2066 | 39.9947 | 34 | 7.0127 | 1.1405 | 0.0497 |
| 2009 | 65.3126 | 2138 | 44.0663 | 35 | 8.2736 | 1.2814 | 0.0498 |
| 2010 | 56.7397 | 2287 | 34.8855 | 36 | 6.1679 | 1.0001 | 0.0499 |
| 2011 | 50.4971 | 2693 | 33.8475 | 35 | 5.3919 | 0.8812 | 0.0495 |
| 2012 | 65.9296 | 2730 | 44.7281 | 38 | 6.5543 | 1.0183 | 0.0490 |
| 2013 | 61.9402 | 2494 | 38.2604 | 34 | 6.7187 | 0.9438 | 0.0492 |
| 2014 | 47.2474 | 2249 | 30.5315 | 31 | 5.9065 | 0.8464 | 0.0496 |
| 2015 | 49.3108 | 1862 | 28.6513 | 27 | 5.6910 | 0.8028 | 0.0514 |

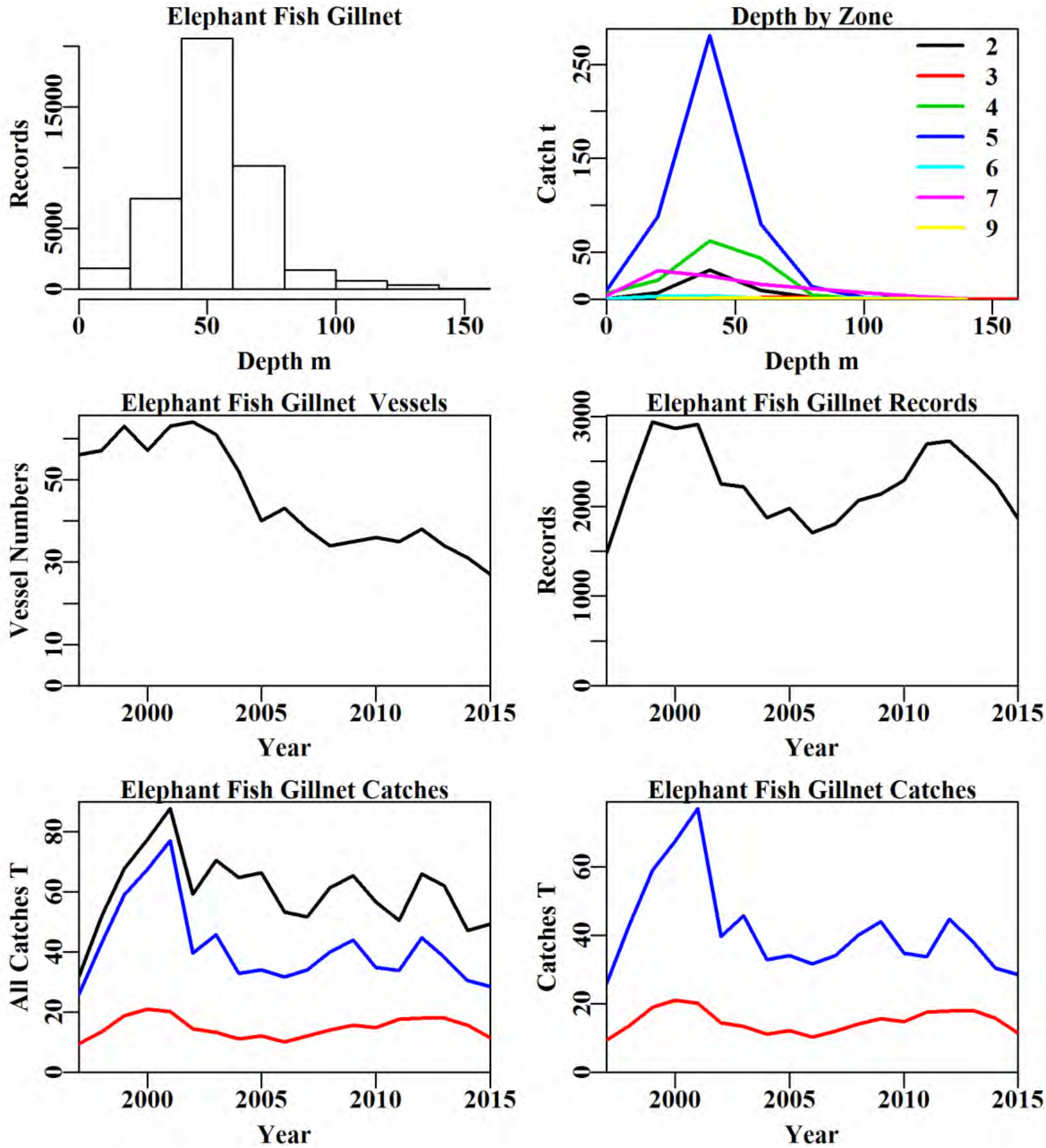
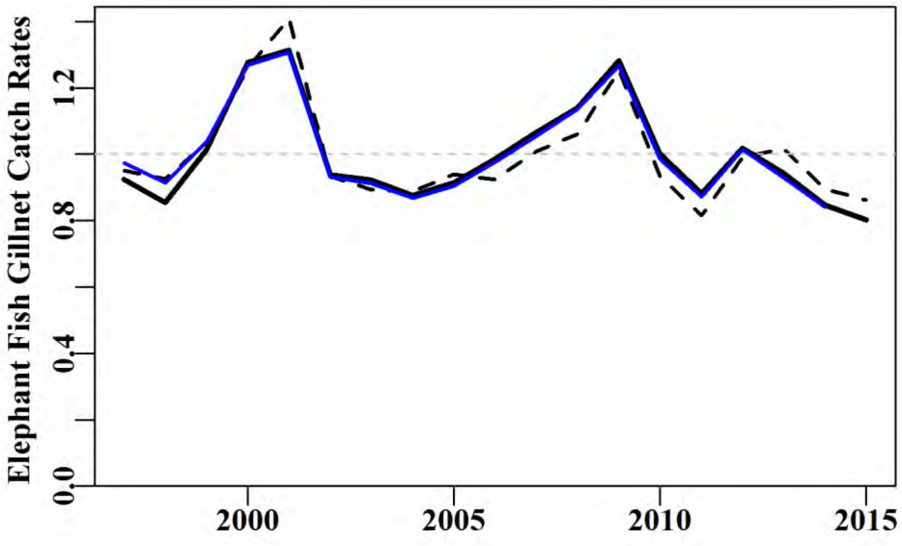



Figure 10.21. Elephant fish taken by gillnet at depths 0 to 100 m in zone 60. The top left plot depicts the depth distribution of shots containing elephant fish from shark zones 2-7 and 9 in depths 0 – 160 m. The top right plot depicts the distribution of catch by depth within zone 60. The middle left plot depicts the number of vessels through time. The middle right plot contains the number of records used in analysis. The bottom left plot contains elephant fish catches (top black line: total catches, middle blue line: catches used in the analysis; bottom red line: catches < 30 kg) and bottom right plot contains elephant fish catches (blue line: catches used in the analysis; red line: catches < 30 kg).



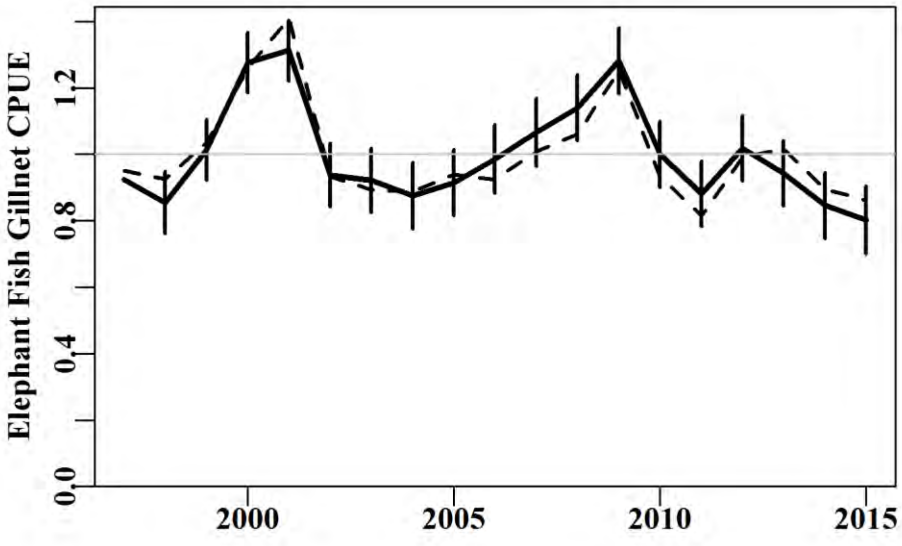




Figure 10.22. Elephant fish taken by gillnet from shark zones 2-7 and 9 in depths of 0 to 160 m. Upper plot: The dashed black line represents the geometric mean CPUE and the solid black line the standardized catch rates (each scaled to the mean of each time series). The blue line corresponds to last year's standardized CPUE. Lower plot: Standardized CPUE (solid black line), two times the standard error (vertical lines) and geometric mean (dashed black line).

Table 10.26. Elephant fish by gillnet at depths 0 to 160 m from shark zones 2-7 and 9. Statistical model structures used in this analysis. DepCat is a series of 20 metre depth categories.

| | |
|---|---|
| Model 1 | LnCE ~ Year |
| Model 2 | LnCE ~ Year +Vessel |
| Model 3 | LnCE ~ Year +Vessel +Month |
| Model 4 | LnCE ~ Year +Vessel +Month + DepCat |
| Model 5 | LnCE ~ Year +Vessel +Month + DepCat + SharkZone |
| Model 6 | LnCE ~ Year +Vessel +Month + DepCat + SharkZone + SharkZone:Month |
| Model 7 | LnCE ~ Year +Vessel +Month + DepCat + SharkZone + SharkZone:DepC |

Table 10.27. Elephant fish taken by gillnet across shark regions from CSA to EBS at depths 0 to 160 m during 1997 - 2015. Model selection criteria, include the AIC, the adjusted $R^2$ (adj_$R^2$) and the change in adjusted $R^2$ (%Change). The optimum model is Model 7 (SharkZone:Month). Depth category: DepC.

| | Year | Vessel | Month | DepC | SharkZone | SharkZone:Month | SharkZone:DepC |
|---|---|---|---|---|---|---|---|
| AIC | 25085 | 21855 | 21613 | 21515 | 21365 | 20967 | 21182 |
| RSS | 76832 | 70744 | 70309 | 69940 | 69674 | 68813 | 69219 |
| MSS | 907 | 6995 | 7431 | 7799 | 8066 | 8927 | 8521 |
| Nobs | 42787 | 42787 | 42787 | 42567 | 42567 | 42567 | 42567 |
| Npars | 19 | 170 | 181 | 189 | 195 | 261 | 243 |
| adj_$R^2$ | 1.125 | 8.638 | 9.176 | 9.633 | 9.965 | 10.939 | 10.452 |
| %Change | 0.000 | 7.512 | 0.539 | 0.457 | 0.332 | 0.975 | -0.487 |

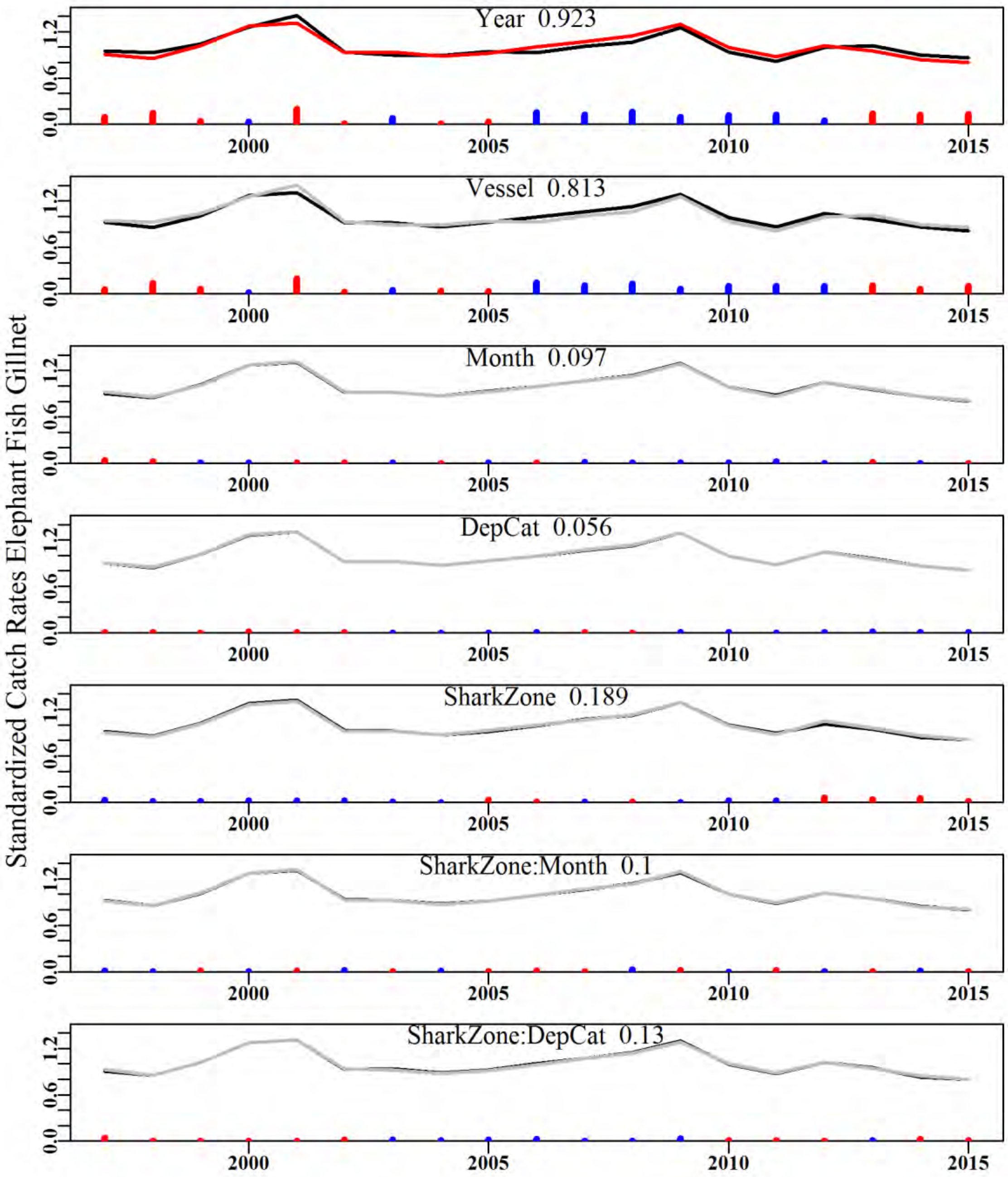



Figure 10.23. The relative influence of each factor on the final trend in the optimal standardization for the elephant fish gillnet fishery. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by the vertical bars with blue bars indicating the optimum model is higher than the geometric mean and red bars indicating it is lower. The top graph bars are the sum of all the bars in the graphs below. The graphs for individual factors are cumulative. Thus the second graph has the geometric mean (grey line) and the effect of adding Year + factor2 (Model 2, black line). In the third graph, the grey line represents Model 2 and the black line the effect of adding factor3 to the model. The remaining graphs continue in the same cumulative manner except for the interaction terms which are added singularly to the final single factor model.

Table 10.28. Reported elephant fish catches by method (t) from the Commonwealth Logbook (GENLOG) database across all regions and methods from 1997. Total is the total catch from 1997 – 2015 (across method). Total catch by gear across the years (Total_Gear; t). Discards are not included.

| Year | AL | BL | DL | DS | GA | GN | TDO | TW | Total (t) |
|---|---|---|---|---|---|---|---|---|---|
| 1997 | | 0.005 | 0.011 | 4.963 | | 26.057 | | 0.790 | 31.826 |
| 1998 | | 0.076 | | 7.141 | | 43.076 | | 1.654 | 51.947 |
| 1999 | | 0.021 | 0.033 | 5.625 | | 59.264 | | 2.800 | 67.743 |
| 2000 | 0.045 | 0.047 | 0.046 | 6.715 | 0.026 | 68.028 | | 2.590 | 77.497 |
| 2001 | 0.035 | 0.120 | 0.073 | 6.456 | | 77.369 | | 3.640 | 87.693 |
| 2002 | 0.004 | 0.123 | 0.006 | 11.689 | | 39.666 | | 7.792 | 59.278 |
| 2003 | 0.647 | 0.088 | 0.026 | 12.302 | | 45.752 | | 11.777 | 70.592 |
| 2004 | 1.888 | 0.525 | | 15.157 | | 33.172 | | 14.023 | 64.765 |
| 2005 | 2.065 | | | 12.839 | | 34.229 | | 17.238 | 66.370 |
| 2006 | 0.762 | 0.003 | | 5.396 | | 32.528 | | 14.571 | 53.259 |
| 2007 | 0.271 | 0.037 | | 7.399 | | 34.460 | | 9.526 | 51.693 |
| 2008 | | 0.007 | | 10.325 | | 40.464 | | 10.649 | 61.444 |
| 2009 | | 0.002 | | 8.502 | | 44.134 | | 12.675 | 65.313 |
| 2010 | | 0.004 | | 10.156 | | 35.020 | | 11.560 | 56.740 |
| 2011 | | 0.025 | | 7.629 | | 33.881 | | 8.963 | 50.497 |
| 2012 | | 0.046 | | 10.126 | | 44.841 | | 10.917 | 65.930 |
| 2013 | 0.052 | 0.024 | | 12.983 | | 38.295 | 1.169 | 9.417 | 61.940 |
| 2014 | 0.003 | | | 6.581 | | 30.626 | 3.955 | 6.083 | 47.247 |
| 2015 | | 0.009 | | 9.005 | | 28.883 | 6.612 | 4.802 | 49.311 |
| Total_Gear (t) | 5.772 | 1.161 | 0.195 | 170.984 | 0.026 | 789.744 | 11.736 | 161.466 | 1141.085 |

Table 10.29. Catch (t) of elephant fish by shark reporting zones taken by gillnets. Discards are not included.

| Year | WestSA | CentSA | EastSA | WestBS | EastBS | WestTas | EastTas | NSW | WestTas | Total |
|---|---|---|---|---|---|---|---|---|---|---|
| 1997 | | 0.932 | 1.831 | 13.958 | 13.627 | 0.434 | 0.206 | 0.078 | 0.857 | 31.921 |
| 1998 | 0.042 | 2.093 | 0.235 | 18.335 | 24.526 | 1.743 | 4.754 | 0.015 | 0.165 | 51.907 |
| 1999 | 1.003 | 4.885 | 1.327 | 17.794 | 35.153 | 0.833 | 6.080 | 0.035 | 0.537 | 67.647 |
| 2000 | 0.285 | 6.200 | 0.841 | 15.298 | 44.207 | 1.032 | 9.336 | 0.028 | 0.217 | 77.445 |
| 2001 | 0.128 | 9.758 | 0.929 | 9.672 | 52.168 | 2.492 | 11.709 | 0.093 | 0.435 | 87.384 |
| 2002 | 0.127 | 2.170 | 1.233 | 11.557 | 34.244 | 1.328 | 7.755 | 0.299 | 0.425 | 59.137 |
| 2003 | 1.498 | 4.459 | 0.840 | 12.470 | 38.542 | 2.978 | 6.944 | 1.156 | 0.713 | 69.601 |
| 2004 | 1.395 | 2.935 | 2.385 | 11.748 | 35.006 | 2.215 | 7.402 | 0.961 | 0.438 | 64.483 |
| 2005 | 1.305 | 2.448 | 1.115 | 13.978 | 36.616 | 2.241 | 6.541 | 0.947 | 0.640 | 65.831 |
| 2006 | 2.022 | 1.813 | 0.638 | 7.274 | 32.505 | 2.486 | 5.624 | 0.577 | 0.185 | 53.122 |
| 2007 | 1.939 | 2.976 | 0.698 | 4.606 | 29.838 | 1.840 | 8.827 | 0.759 | 0.147 | 51.629 |
| 2008 | 1.013 | 2.829 | 1.182 | 6.875 | 39.453 | 1.927 | 6.601 | 0.615 | 0.424 | 60.918 |
| 2009 | 0.495 | 3.357 | 1.835 | 10.528 | 42.268 | 0.909 | 5.227 | 0.441 | 0.155 | 65.215 |
| 2010 | 0.243 | 3.295 | 0.532 | 12.894 | 33.721 | 0.512 | 4.440 | 0.721 | 0.257 | 56.615 |
| 2011 | 0.119 | 4.379 | 0.494 | 8.446 | 29.839 | 1.018 | 4.384 | 0.745 | 0.893 | 50.317 |
| 2012 | 0.003 | 0.098 | 0.264 | 12.145 | 44.952 | 1.408 | 6.034 | 0.523 | 0.499 | 65.925 |
| 2013 | 0.165 | 0.246 | 0.392 | 13.697 | 40.169 | 1.397 | 4.560 | 0.743 | 0.560 | 61.928 |
| 2014 | 0.027 | 0.135 | 0.208 | 10.305 | 30.144 | 1.247 | 4.102 | 0.891 | 0.122 | 47.180 |
| 2015 | | 0.236 | 0.273 | 7.605 | 37.927 | 0.335 | 2.009 | 0.667 | 0.017 | 49.069 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Total | 11.807 | 55.243 | 17.251 | 219.181 | 674.904 | 28.373 | 112.534 | 10.293 | 7.685 | 1137.273 |

### 10.4.8 *Sawshark: Gillnet*

Non-zero records of catch per shot were employed in the statistical standardization analyses for sawshark caught by gillnets. Further investigation should be considered to determine whether total net length could be used as an alternative effort unit in standardization analyses.

Table 10.30. Sawshark taken by gillnet across shark regions from Central South Australia to Eastern Bass Strait between depths of 0 to 150 m and during 1997 - 2014. Total catch (TotCatch; t) is the total reported in the database across all gears, number of records used in the analysis (Records), reported catch (CatchT; t) in the area and depth used in the analysis and number of vessels used in the analysis (Vessels). GeoMean is the geometric mean of CPUE (kg/shot). The optimum model is model 6 (Table 10.34). SharkZone:Month and standard deviation (StDev) are the coefficients from the optimum model.

| Year | TotCatch | Records | CatchT | Vessels | GeoMean | SharkZone:Month | StDev |
|---|---|---|---|---|---|---|---|
| 1997 | 214.1599 | 4346 | 129.5441 | 80 | 13.3998 | 1.1414 | 0.0000 |
| 1998 | 284.1927 | 6573 | 212.2422 | 80 | 12.2238 | 1.1593 | 0.0234 |
| 1999 | 292.1391 | 6941 | 211.1770 | 81 | 12.6922 | 1.2648 | 0.0235 |
| 2000 | 352.3844 | 6342 | 257.9544 | 74 | 17.5508 | 1.6804 | 0.0240 |
| 2001 | 338.1462 | 5921 | 249.7963 | 80 | 17.2911 | 1.7724 | 0.0245 |
| 2002 | 255.7574 | 5665 | 144.7214 | 77 | 10.6221 | 1.0254 | 0.0248 |
| 2003 | 318.8120 | 6354 | 174.8317 | 79 | 10.3777 | 1.0397 | 0.0244 |
| 2004 | 314.6146 | 6103 | 180.1242 | 71 | 11.4436 | 1.1068 | 0.0246 |
| 2005 | 296.6669 | 5263 | 148.3160 | 59 | 10.3383 | 0.9875 | 0.0254 |
| 2006 | 317.6979 | 4806 | 124.4204 | 54 | 9.1939 | 0.9857 | 0.0260 |
| 2007 | 214.5345 | 4447 | 95.0295 | 43 | 7.3232 | 0.8719 | 0.0266 |
| 2008 | 211.6896 | 4379 | 105.4135 | 44 | 8.8781 | 0.9940 | 0.0268 |
| 2009 | 191.4528 | 4666 | 82.5688 | 43 | 7.1489 | 0.8327 | 0.0264 |
| 2010 | 192.5017 | 4776 | 84.7280 | 47 | 7.3529 | 0.8136 | 0.0265 |
| 2011 | 197.0364 | 5022 | 98.8135 | 45 | 7.9242 | 0.8013 | 0.0263 |
| 2012 | 158.5591 | 4285 | 69.6699 | 42 | 6.9015 | 0.6391 | 0.0276 |
| 2013 | 165.6645 | 4051 | 67.1830 | 39 | 7.8626 | 0.5881 | 0.0275 |
| 2014 | 166.7128 | 3895 | 77.1952 | 38 | 8.6437 | 0.6604 | 0.0277 |
| 2015 | 162.5917 | 3824 | 71.6147 | 34 | 8.3240 | 0.6354 | 0.0279 |

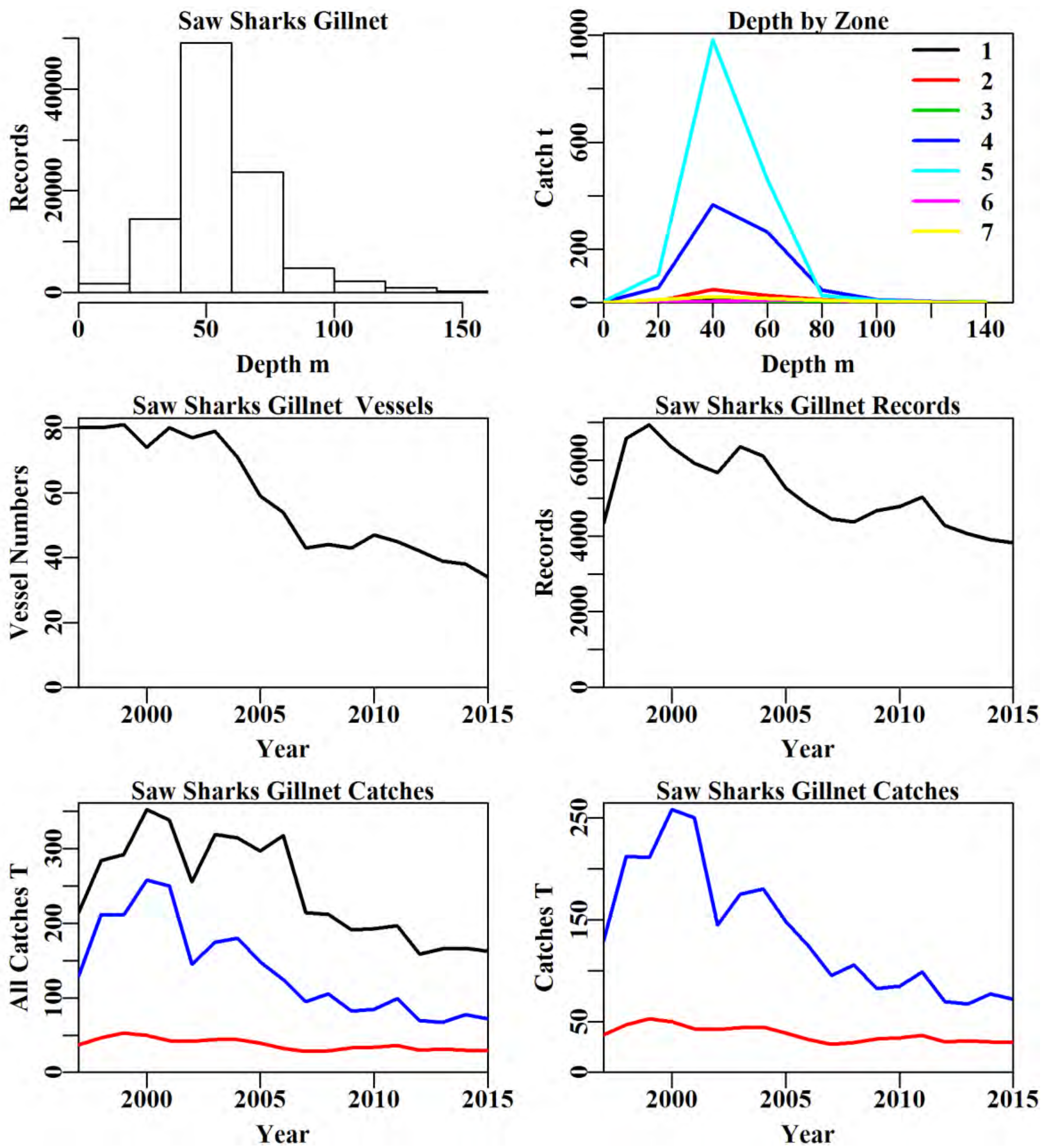



Figure 10.24. Sawshark in shark zones 1-7 in depths 0 to 150 m taken by gillnet. The top left plot depicts the depth distribution of shots containing sawshark from shark zones 1-7 in depths 0 – 150 m. The top right plot depicts the distribution of catch by depth within shark zones 1-7. The middle left plot depicts the number of vessels through time. The middle right plot contains the number of records used in analysis. The bottom left plot contains sawshark catches (top black line: total catches, middle blue line: catches used in the analysis; bottom red line: catches < 30 kg) and bottom right plot contains sawshark catches (blue line: catches used in the analysis; red line: catches < 30 kg).

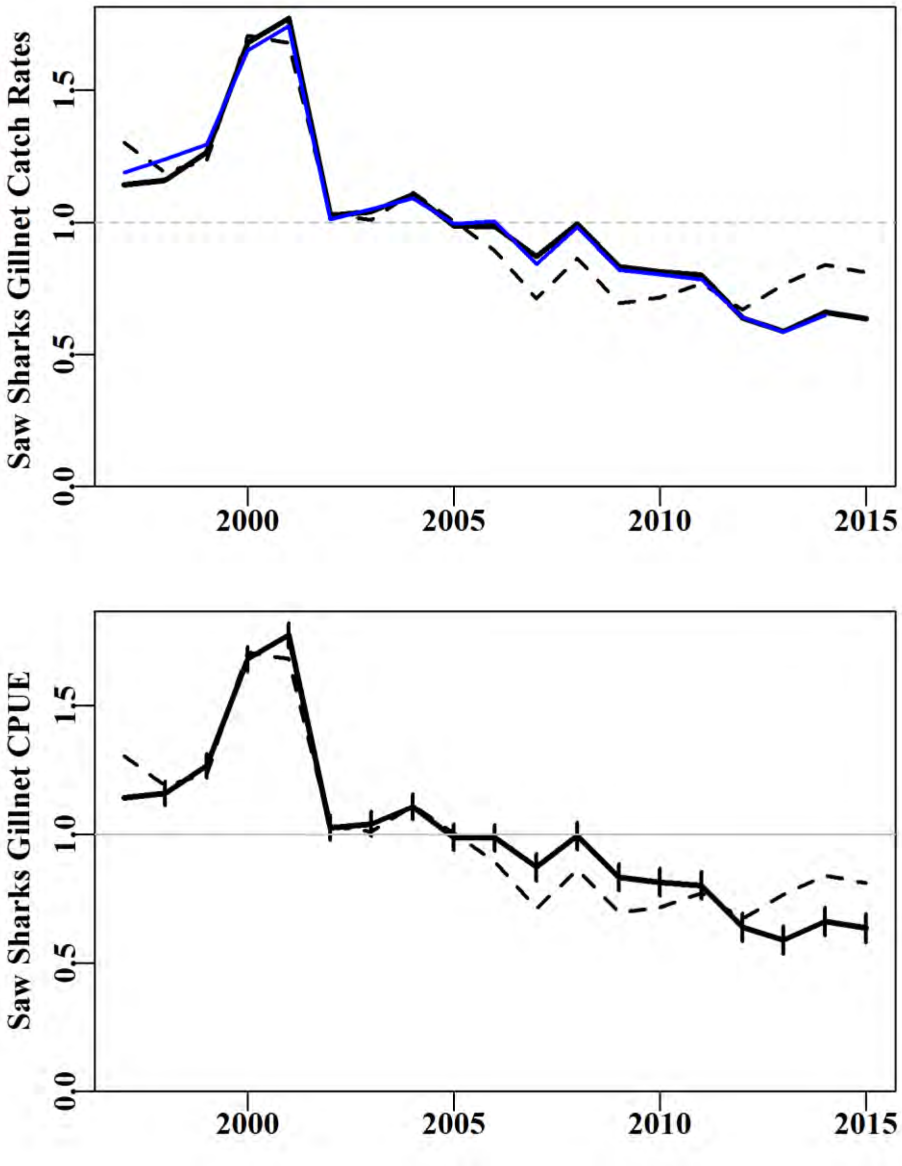



Figure 10.25. Sawshark taken by gillnet. Upper plot: The dashed black line represents the geometric mean CPUE and the solid black line the standardized catch rates (each scaled to the mean of each time series). The blue line corresponds to last year's standardized CPUE. Lower plot: Standardized CPUE (solid black line), two times the standard error (vertical lines) and geometric mean (dashed black line).

Table 10.31. Sawshark from shark zones 1-7 at depths 0 to 150 m by gillnet. Statistical model structures used in this analysis. DepCat is a series of 20 metre depth categories.

| | |
|---|---|
| Model 1 | LnCE ~ Year |
| Model 2 | LnCE ~ Year +Vessel |
| Model 3 | LnCE ~ Year +Vessel +Month |
| Model 4 | LnCE ~ Year +Vessel +Month + DepCat |
| Model 5 | LnCE ~ Year +Vessel +Month + DepCat + SharkZone |
| Model 6 | LnCE ~ Year +Vessel +Month + DepCat + SharkZone + SharkZone:Month |
| Model 7 | LnCE ~ Year +Vessel +Month + DepCat + SharkZone + SharkZone:DepC |

Table 10.32. Sawshark taken by gillnet across shark zones 1-7 at depths 0 to 150 m during 1997 - 2015. Model selection criteria, include the AIC, the adjusted $R^2$ (adj_$R^2$) and the change in adjusted $R^2$ (%Change). The optimum model is Model 6 (SharkZone:Month). Depth category: DepC.

| | Year | Vessel | Month | DepC | SharkZone | SharkZone:Month | SharkZone:DepC |
|---|---|---|---|---|---|---|---|
| AIC | 61582 | 38850 | 33234 | 29309 | 27289 | 23219 | 25478 |
| RSS | 183401 | 144787 | 136158 | 130747 | 128027 | 122604 | 125552 |
| MSS | 7718 | 46333 | 54962 | 60373 | 63093 | 68516 | 65567 |
| Nobs | 97659 | 97659 | 97101 | 97101 | 97101 | 97101 | 97101 |
| Npars | 19 | 197 | 204 | 210 | 221 | 287 | 263 |
| adj_$R^2$ | 4.021 | 24.090 | 28.609 | 31.441 | 32.860 | 35.660 | 34.129 |
| %Change | 0.000 | 20.070 | 4.518 | 2.833 | 1.419 | 2.800 | -1.531 |

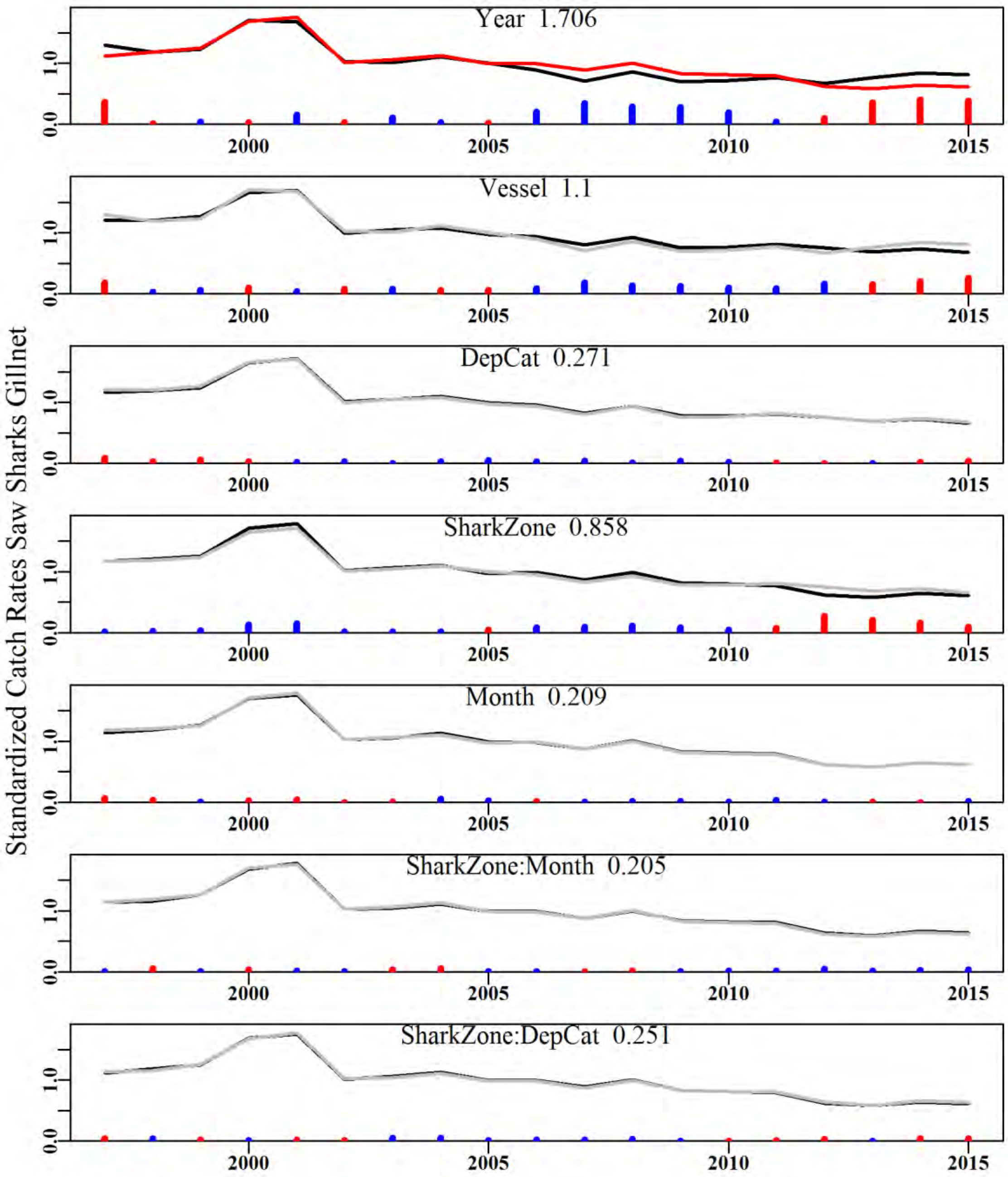



Figure 10.26. The relative influence of each factor on the final trend in the optimal standardization for the sawshark gillnet fishery. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by the vertical bars with blue bars indicating the optimum model is higher than the geometric mean and red bars indicating it is lower. The top graph bars are the sum of all the bars in the graphs below. The graphs for individual factors are cumulative. Thus the second graph has the geometric mean (grey line) and the effect of adding Year + factor2 (Model 2, black line). In the third graph, the grey line represents Model 2 and the black line the effect of adding factor3 to the model. The remaining graphs continue in the same cumulative manner except for the interaction terms which are added singularly to the final single factor model.

### 10.4.9 *Sawshark: Trawl (using Shark Zone)*

Non-zero records of catch per hour were employed in the statistical standardization analyses for sawshark caught by trawl.

Table 10.33. Sawshark taken by trawl across shark regions from Central South Australia to Eastern Bass Strait between depths of 0 to 500 m and during 1997 - 2015. Total catch (TotCatch; t) is the total reported in the database across all gears, number of records used in the analysis (Records), reported catch (CatchT; t) in the area and depth used in the analysis and number of vessels used in the analysis (Vessels). GeoMean is the geometric mean of CPUE (kg/hr). The optimum model is Model 7 (Table 10.35). SharkZone:Month and standard deviation (StDev) are the coefficients from the optimum model.

| Year | TotCatch | Records | CatchT | Vessels | GeoMean | SharkZone:Month | StDev |
|---|---|---|---|---|---|---|---|
| 1997 | 214.1599 | 2025 | 45.9350 | 59 | 3.0297 | 1.1418 | 0.0000 |
| 1998 | 284.1927 | 1485 | 34.2000 | 54 | 2.8938 | 1.0731 | 0.0361 |
| 1999 | 292.1391 | 1561 | 38.4520 | 50 | 3.7791 | 1.2849 | 0.0359 |
| 2000 | 352.3844 | 2094 | 55.6710 | 65 | 4.1146 | 1.1626 | 0.0353 |
| 2001 | 338.1462 | 2070 | 49.0660 | 58 | 3.0880 | 1.1268 | 0.0353 |
| 2002 | 255.7574 | 3096 | 62.2622 | 75 | 2.7652 | 0.9910 | 0.0326 |
| 2003 | 318.8120 | 3957 | 80.1817 | 76 | 2.3522 | 0.8649 | 0.0314 |
| 2004 | 314.6146 | 3906 | 80.4314 | 77 | 2.5885 | 0.8649 | 0.0315 |
| 2005 | 296.6669 | 4428 | 90.9200 | 72 | 2.5786 | 0.8735 | 0.0307 |
| 2006 | 317.6979 | 4073 | 111.3040 | 64 | 2.8887 | 0.9878 | 0.0313 |
| 2007 | 214.5345 | 2205 | 63.6195 | 39 | 2.7224 | 0.8551 | 0.0353 |
| 2008 | 211.6896 | 2562 | 58.3463 | 40 | 2.5111 | 0.9187 | 0.0346 |
| 2009 | 191.4528 | 2545 | 69.2425 | 34 | 3.3781 | 1.1497 | 0.0345 |
| 2010 | 192.5017 | 2654 | 59.1161 | 37 | 2.7260 | 0.9806 | 0.0345 |
| 2011 | 197.0364 | 2678 | 58.2292 | 36 | 2.5914 | 0.9185 | 0.0344 |
| 2012 | 158.5591 | 2334 | 56.7883 | 35 | 2.8468 | 0.8956 | 0.0355 |
| 2013 | 165.6645 | 2303 | 59.0716 | 36 | 3.1325 | 1.0077 | 0.0355 |
| 2014 | 166.7128 | 2024 | 53.8859 | 36 | 3.2138 | 0.9822 | 0.0363 |
| 2015 | 162.5917 | 2093 | 52.8783 | 35 | 2.9129 | 0.9205 | 0.0362 |

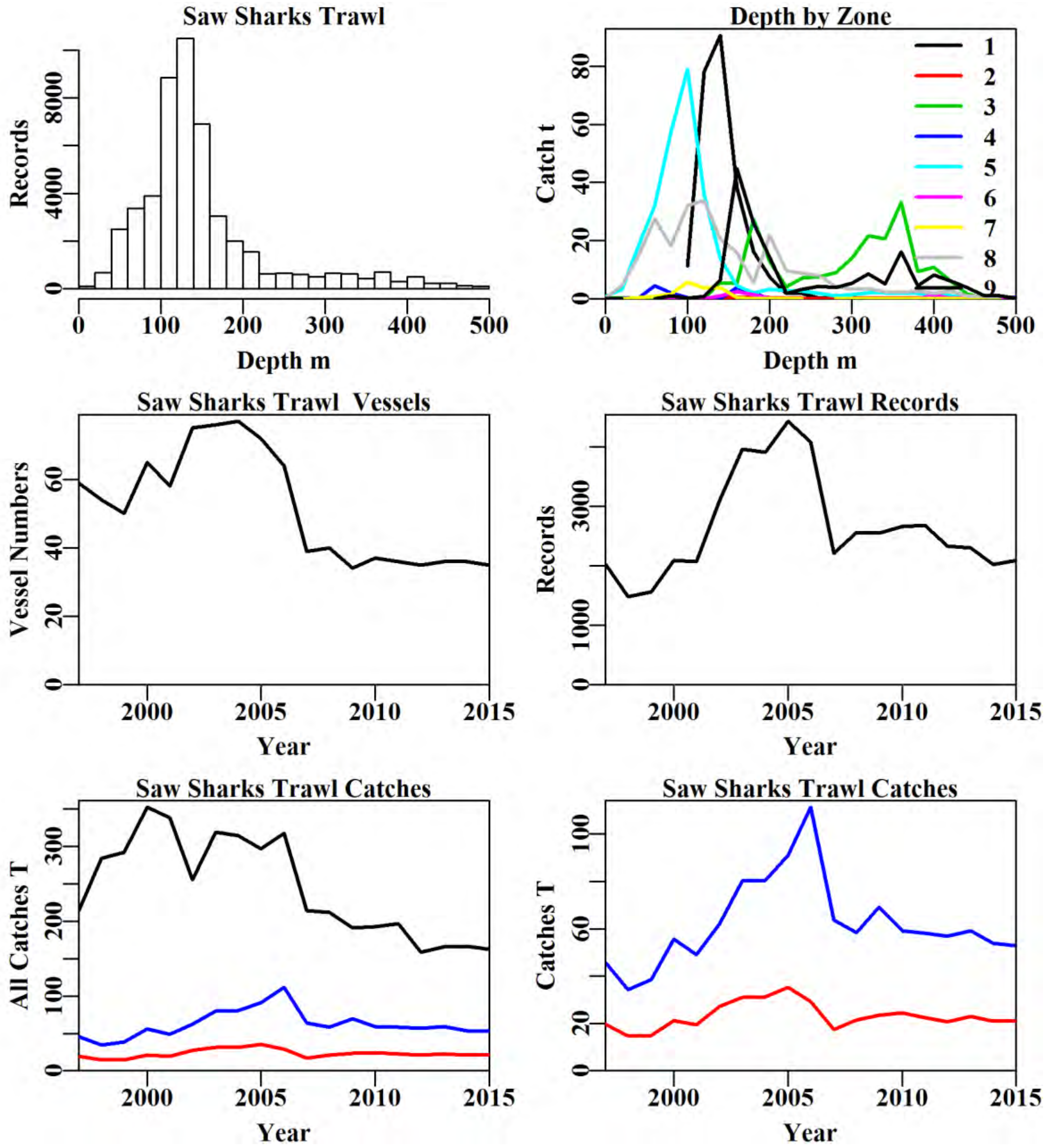



Figure 10.27. Sawshark taken by Trawl. The top left plot depicts the depth distribution of shots containing sawshark from shark zones 1-9 in depths 0 – 500 m. The top right plot depicts the distribution of catch by depth within zone 60. The middle left plot depicts the number of vessels through time. The middle right plot contains the number of records used in analysis. The bottom left plot contains sawshark catches (top black line: total catches, middle blue line: catches used in the analysis; bottom red line: catches < 30 kg) and bottom right plot contains sawshark catches (blue line: catches used in the analysis; red line: catches < 30 kg).

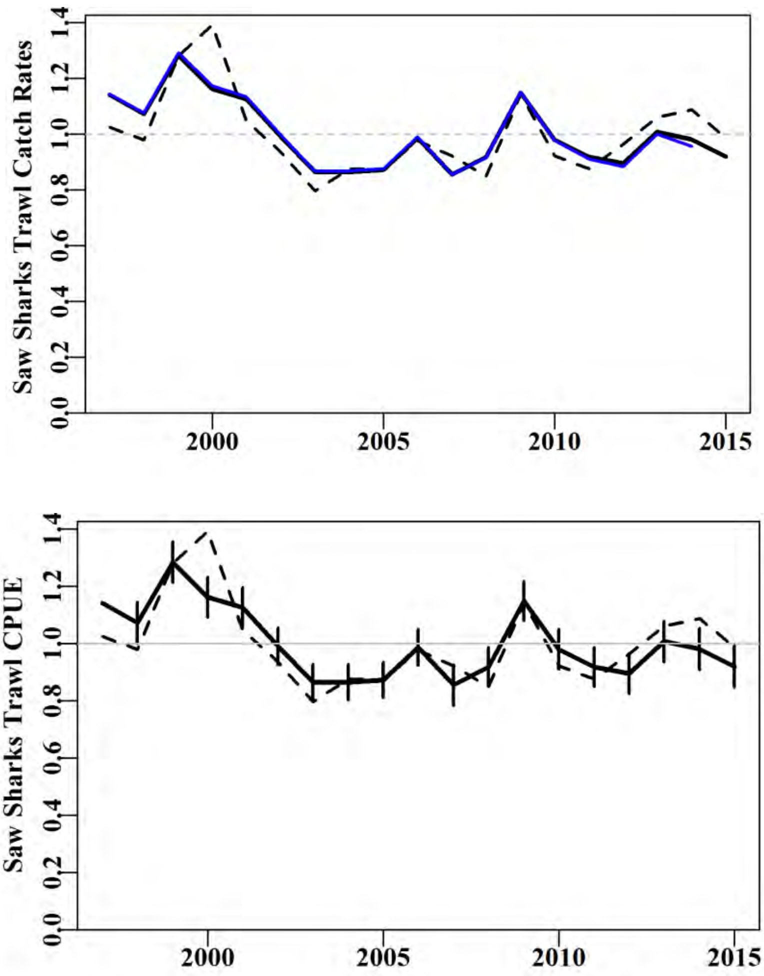



Figure 10.28. Sawshark taken by trawl. Upper plot: The dashed black line represents the geometric mean CPUE and the solid black line the standardized catch rates (each scaled to the mean of each time series). The blue line corresponds to last year's standardized CPUE. Lower plot: Standardized CPUE (solid black line), two times the standard error (vertical lines) and geometric mean (dashed black line).

Table 10.34. Sawshark from across shark zones in depths 0 to 500 m by Trawl. Statistical model structures used in this analysis. DepCat is a series of 20 metre depth categories.

| | |
|---|---|
| Model 1 | LnCE ~ Year |
| Model 2 | LnCE ~ Year +Vessel |
| Model 3 | LnCE ~ Year +Vessel +DepCat |
| Model 4 | LnCE ~ Year +Vessel +DepCat + SharkZone |
| Model 5 | LnCE ~ Year +Vessel +DepCat + SharkZone + Month |
| Model 6 | LnCE ~ Year +Vessel +DepCat + SharkZone + Month + DayNight |
| Model 7 | LnCE ~ Year +Vessel +DepCat + SharkZone + Month + DayNight + SharkZone:Month |
| Model 8 | LnCE ~ Year +Vessel +DepCat + SharkZone + Month + DayNight + SharkZone:DepC |

Table 10.35. Sawshark taken by trawl across shark zones at depths 0 to 500 m from Western South Australia to Eastern Bass Strait during 1997 - 2015. Model selection criteria, include the AIC, the adjusted $R^2$ (adj_$R^2$) and the change in adjusted $R^2$ (%Change). The optimum model is Model 7 (SharkZone:Month). Depth category: DepC.

| | Year | Vessel | DepCat | SharkZone | Month | DayNight | SharkZone:Month | SharkZone:DepC |
|---|---|---|---|---|---|---|---|---|
| AIC | 23140 | 7431 | 5700 | 4306 | 3357 | 3257 | 2164 | 2301 |
| RSS | 79445 | 57750 | 55257 | 53709 | 52668 | 52556 | 51228 | 51139 |
| MSS | 857 | 22553 | 25046 | 26594 | 27634 | 27747 | 29075 | 29164 |
| Nobs | 50093 | 50093 | 49615 | 49615 | 49615 | 49615 | 49615 | 49615 |
| Npars | 19 | 153 | 178 | 186 | 197 | 200 | 288 | 400 |
| adj_$R^2$ | 1.032 | 27.866 | 30.943 | 32.867 | 34.153 | 34.289 | 35.835 | 35.801 |
| %Change | 0.000 | 26.834 | 3.077 | 1.924 | 1.286 | 0.137 | 1.546 | -0.034 |

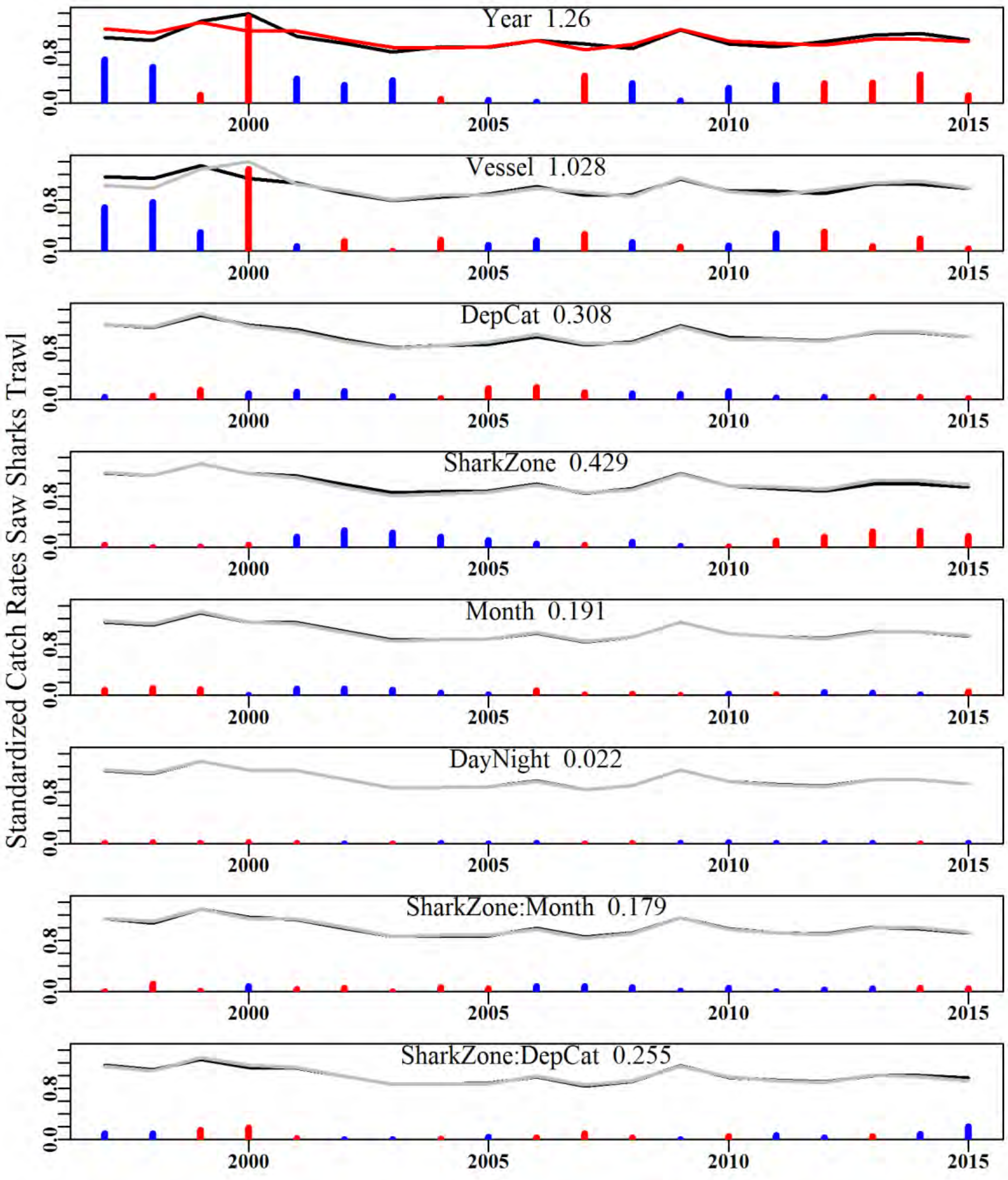



Figure 10.29. The relative influence of each factor on the final trend in the optimal standardization for the sawshark trawl fishery. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by the vertical bars with blue bars indicating the optimum model is higher than the geometric mean and red bars indicating it is lower. The top graph bars are the sum of all the bars in the graphs below. The graphs for individual factors are cumulative. Thus the second graph has the geometric mean (grey line) and the effect of adding Year + factor2 (Model 2, black line). In the third graph, the grey line represents Model 2 and the black line the effect of adding factor3 to the model. The remaining graphs continue in the same cumulative manner except for the interaction terms which are added singularly to the final single factor model.

### 10.4.10 *Sawshark: Trawl (using Shark Area)*

Non-zero records of catch per shot were employed in the statistical standardization analyses for sawshark caught by trawl. This analysis considers the factor SharkArea instead of SharkZone.

Table 10.36. Sawshark taken by trawl across shark areas from Western South Australia to Eastern Bass Strait between depths of 0 to 500 m and during 1997 - 2015. Total catch (TotCatch; t) is the total reported in the database across all gears, number of records used in the analysis (Records), reported catch (CatchT; t) in the area and depth used in the analysis and number of vessels used in the analysis (Vessels). GeoMean is the geometric mean of CPUE (kg/hr). The optimum model is Model 7 (Table 10.38). SharkArea:Month and standard deviation (StDev) are the coefficients from the optimum model.

| Year | TotCatch | Records | CatchT | Vessels | GeoMean | SharkArea:Month | StDev |
|---|---|---|---|---|---|---|---|
| 1997 | 214.1599 | 2025 | 45.9350 | 59 | 3.0297 | 1.1753 | 0.0000 |
| 1998 | 284.1927 | 1485 | 34.2000 | 54 | 2.8938 | 1.0320 | 0.0367 |
| 1999 | 292.1391 | 1561 | 38.4520 | 50 | 3.7791 | 1.2375 | 0.0365 |
| 2000 | 352.3844 | 2094 | 55.6710 | 65 | 4.1146 | 1.1809 | 0.0357 |
| 2001 | 338.1462 | 2070 | 49.0660 | 58 | 3.0880 | 1.1410 | 0.0358 |
| 2002 | 255.7574 | 3096 | 62.2622 | 75 | 2.7652 | 1.0328 | 0.0330 |
| 2003 | 318.8120 | 3957 | 80.1817 | 76 | 2.3522 | 0.8884 | 0.0318 |
| 2004 | 314.6146 | 3906 | 80.4314 | 77 | 2.5885 | 0.8572 | 0.0320 |
| 2005 | 296.6669 | 4428 | 90.9200 | 72 | 2.5786 | 0.8726 | 0.0312 |
| 2006 | 317.6979 | 4073 | 111.3040 | 64 | 2.8887 | 1.0077 | 0.0319 |
| 2007 | 214.5345 | 2205 | 63.6195 | 39 | 2.7224 | 0.8679 | 0.0356 |
| 2008 | 211.6896 | 2562 | 58.3463 | 40 | 2.5111 | 0.9101 | 0.0350 |
| 2009 | 191.4528 | 2545 | 69.2425 | 34 | 3.3781 | 1.1340 | 0.0348 |
| 2010 | 192.5017 | 2654 | 59.1161 | 37 | 2.7260 | 0.9769 | 0.0348 |
| 2011 | 197.0364 | 2678 | 58.2292 | 36 | 2.5914 | 0.9172 | 0.0347 |
| 2012 | 158.5591 | 2334 | 56.7883 | 35 | 2.8468 | 0.8821 | 0.0358 |
| 2013 | 165.6645 | 2303 | 59.0716 | 36 | 3.1325 | 0.9775 | 0.0357 |
| 2014 | 166.7128 | 2024 | 53.8859 | 36 | 3.2138 | 0.9872 | 0.0366 |
| 2015 | 162.5917 | 2093 | 52.8783 | 35 | 2.9129 | 0.9215 | 0.0364 |

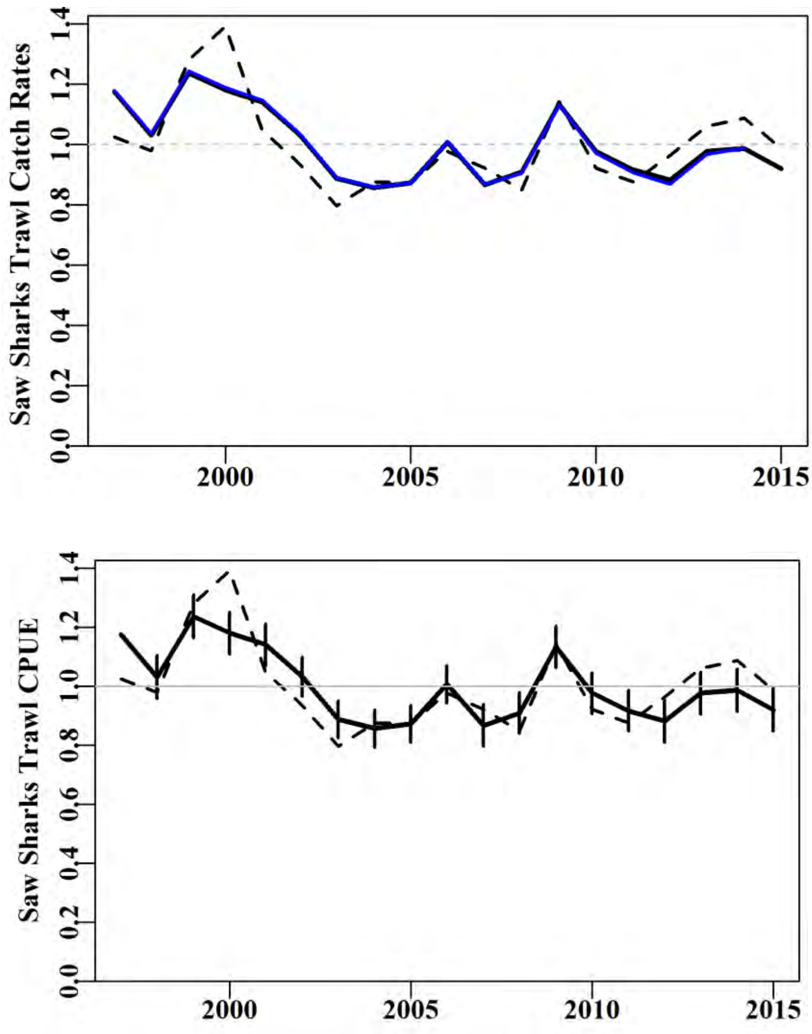



Figure 10.30. Sawshark taken by trawl. Upper plot: The dashed black line represents the geometric mean CPUE and the solid black line the standardized catch rates (each scaled to the mean of each time series). The blue line corresponds to last year's standardized CPUE. Lower plot: Standardized CPUE (solid black line), two times the standard error (vertical lines) and geometric mean (dashed black line).

Table 10.37. Sawshark from across shark zones in depths 0 to 500 m by Trawl. Statistical model structures used in this analysis. DepCat is a series of 20 metre depth categories.

| | |
|---|---|
| Model 1 | LnCE ~ Year |
| Model 2 | LnCE ~ Year +Vessel |
| Model 3 | LnCE ~ Year +Vessel +DepCat |
| Model 4 | LnCE ~ Year +Vessel +DepCat + SharkArea |
| Model 5 | LnCE ~ Year +Vessel +DepCat + SharkArea + Month |
| Model 6 | LnCE ~ Year +Vessel +DepCat + SharkArea + Month + DayNight |
| Model 7 | LnCE ~ Year +Vessel +DepCat + SharkArea + Month + DayNight + SharkArea:Month |
| Model 8 | LnCE ~ Year +Vessel +DepCat + SharkArea + Month + DayNight + SharkArea:DepC |

Table 10.38. Sawshark taken by trawl across shark zones at depths 0 to 500 m from Western South Australia to Eastern Bass Strait during 1997 - 2015. Model selection criteria, include the AIC, the adjusted $R^2$ (adj_$R^2$) and the change in adjusted $R^2$ (%Change). The optimum model is Model 7 (SharkArea:Month). Depth category: DepC.

| | Year | Vessel | DepCat | SharkArea | Month | DayNight | SharkArea:Month | SharkArea:DepC |
|---|---|---|---|---|---|---|---|---|
| AIC | 23140 | 7431 | 5700 | 3415 | 2450 | 2361 | 1212 | 2472 |
| RSS | 79445 | 57750 | 55257 | 52507 | 51469 | 51371 | 49261 | 49345 |
| MSS | 857 | 22553 | 25046 | 27795 | 28834 | 28932 | 31042 | 30958 |
| Nobs | 50093 | 50093 | 49615 | 49441 | 49441 | 49441 | 49441 | 49441 |
| Npars | 19 | 153 | 178 | 220 | 231 | 234 | 696 | 1284 |
| adj_$R^2$ | 1.032 | 27.866 | 30.943 | 34.322 | 35.607 | 35.725 | 37.781 | 36.914 |
| %Change | 0.000 | 26.834 | 3.077 | 3.380 | 1.284 | 0.119 | 2.056 | -0.867 |

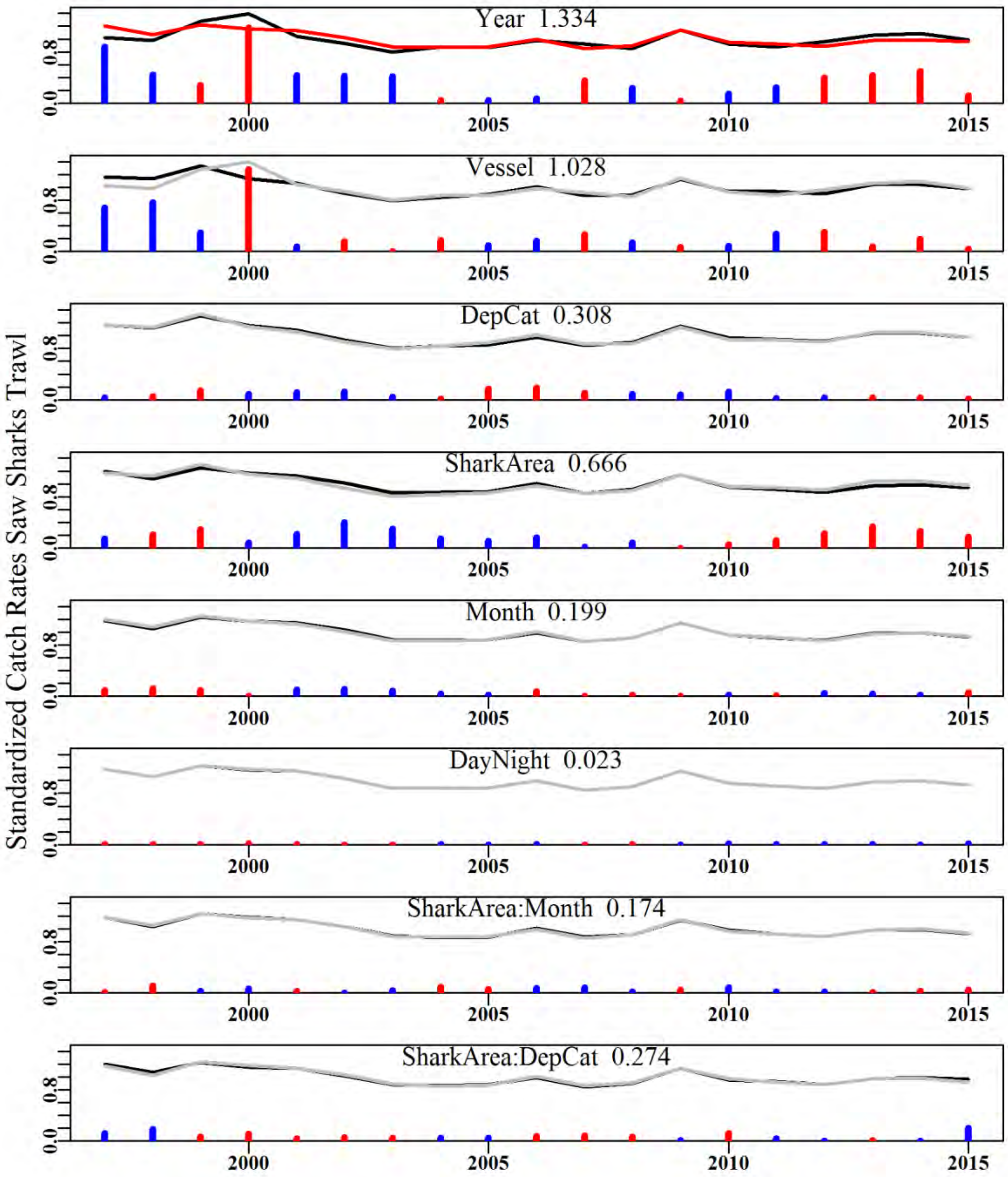



Figure 10.31. The relative influence of each factor on the final trend in the optimal standardization for the sawshark trawl fishery. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by the vertical bars with blue bars indicating the optimum model is higher than the geometric mean and red bars indicating it is lower. The top graph bars are the sum of all the bars in the graphs below. The graphs for individual factors are cumulative. Thus the second graph has the geometric mean (grey line) and the effect of adding Year + factor2 (Model 2, black line). In the third graph, the grey line represents Model 2 and the black line the effect of adding factor3 to the model. The remaining graphs continue in the same cumulative manner except for the interaction terms which are added singularly to the final single factor model.

### 10.4.11 *Sawshark: Danish seine (using Shark Zone)*

A large proportion of records contain missing effort entries, so CPUE used in the analyses was kg/shot. Data pertaining to Shark Zones 4 and 5 (Western and Eastern Bass Strait respectively) were used in the analysis.

Table 10.39. Sawshark taken by danish seine across shark regions from Western Bass Strait to Eastern Bass Strait between depths of 0 to 240 m and during 1997 - 2015. Total catch (TotCatch; t) is the total reported in the database across all gears, number of records used in the analysis (Records), reported catch (CatchT; t) in the area and depth used in the analysis and number of vessels used in the analysis (Vessels). GeoMean is the geometric mean of CPUE (kg/shot). The optimum model is Model 7 (Table 10.41). SharkZone:Month and standard deviation (StDev) are the coefficients from the optimum model.

| Year | TotCatch | Records | CatchT | Vessels | GeoMean | SharkZone:Month | StDev |
|---|---|---|---|---|---|---|---|
| 1997 | 214.1599 | 436 | 4.0180 | 13 | 6.6325 | 1.4116 | 0.0000 |
| 1998 | 284.1927 | 485 | 6.7500 | 12 | 8.3699 | 1.6272 | 0.0673 |
| 1999 | 292.1391 | 613 | 6.4640 | 13 | 6.7292 | 1.2873 | 0.0641 |
| 2000 | 352.3844 | 398 | 7.1650 | 11 | 10.3938 | 1.8941 | 0.0720 |
| 2001 | 338.1462 | 508 | 7.0290 | 12 | 8.6081 | 1.0746 | 0.0709 |
| 2002 | 255.7574 | 2705 | 24.4030 | 22 | 4.5931 | 0.8910 | 0.0565 |
| 2003 | 318.8120 | 3057 | 22.1803 | 22 | 3.8527 | 0.7871 | 0.0565 |
| 2004 | 314.6146 | 3228 | 24.3190 | 22 | 3.7264 | 0.7296 | 0.0563 |
| 2005 | 296.6669 | 2666 | 17.3475 | 22 | 3.2825 | 0.6555 | 0.0569 |
| 2006 | 317.6979 | 2254 | 17.9365 | 20 | 3.9417 | 0.7593 | 0.0578 |
| 2007 | 214.5345 | 2299 | 21.5465 | 16 | 4.3883 | 0.8525 | 0.0578 |
| 2008 | 211.6896 | 2484 | 22.5495 | 15 | 4.6027 | 0.9027 | 0.0576 |
| 2009 | 191.4528 | 2844 | 21.1270 | 15 | 3.9010 | 0.8591 | 0.0573 |
| 2010 | 192.5017 | 2405 | 17.0375 | 15 | 3.9924 | 0.8834 | 0.0578 |
| 2011 | 197.0364 | 2885 | 25.3570 | 14 | 4.4635 | 0.8643 | 0.0571 |
| 2012 | 158.5591 | 2196 | 20.2490 | 14 | 4.5630 | 0.8413 | 0.0581 |
| 2013 | 165.6645 | 2531 | 20.7945 | 14 | 4.3873 | 0.8602 | 0.0577 |
| 2014 | 166.7128 | 1732 | 13.1949 | 14 | 4.1010 | 0.7539 | 0.0598 |
| 2015 | 162.5917 | 2139 | 24.1762 | 15 | 5.4819 | 1.0651 | 0.0591 |

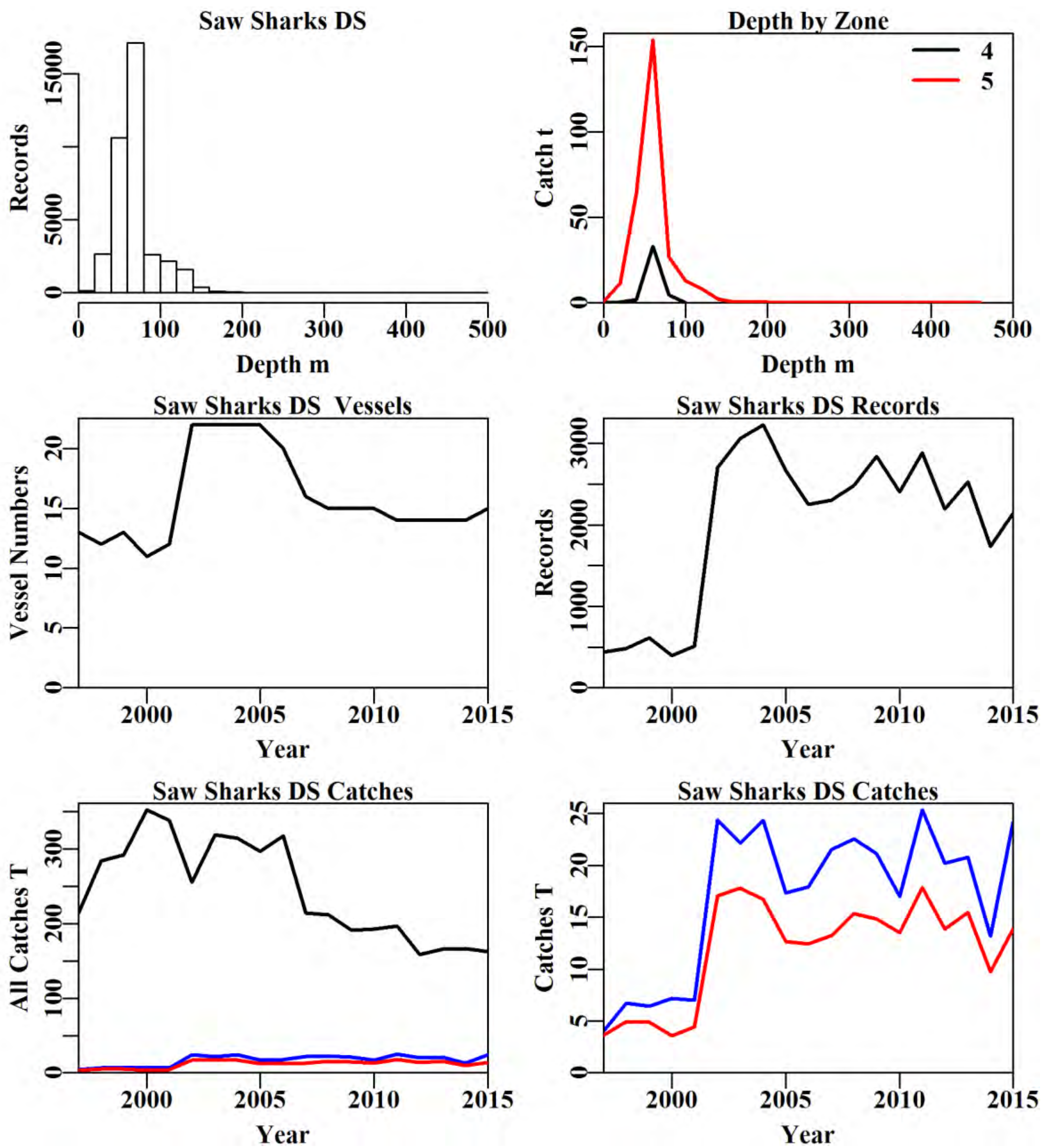



Figure 10.32. Sawshark taken by Danish seine. The top left plot depicts the depth distribution of shots containing sawshark from shark zones 4, 5 in depths 0 – 240 m. The top right plot depicts the distribution of catch by depth within zone 4 and 5. The middle left plot depicts the number of vessels through time. The middle right plot contains the number of records used in analysis. The bottom left plot contains sawshark catches (top black line: total catches, middle blue line: catches used in the analysis; bottom red line: catches < 30 kg) and bottom right plot contains sawshark catches (blue line: catches used in the analysis; red line: catches < 30 kg).

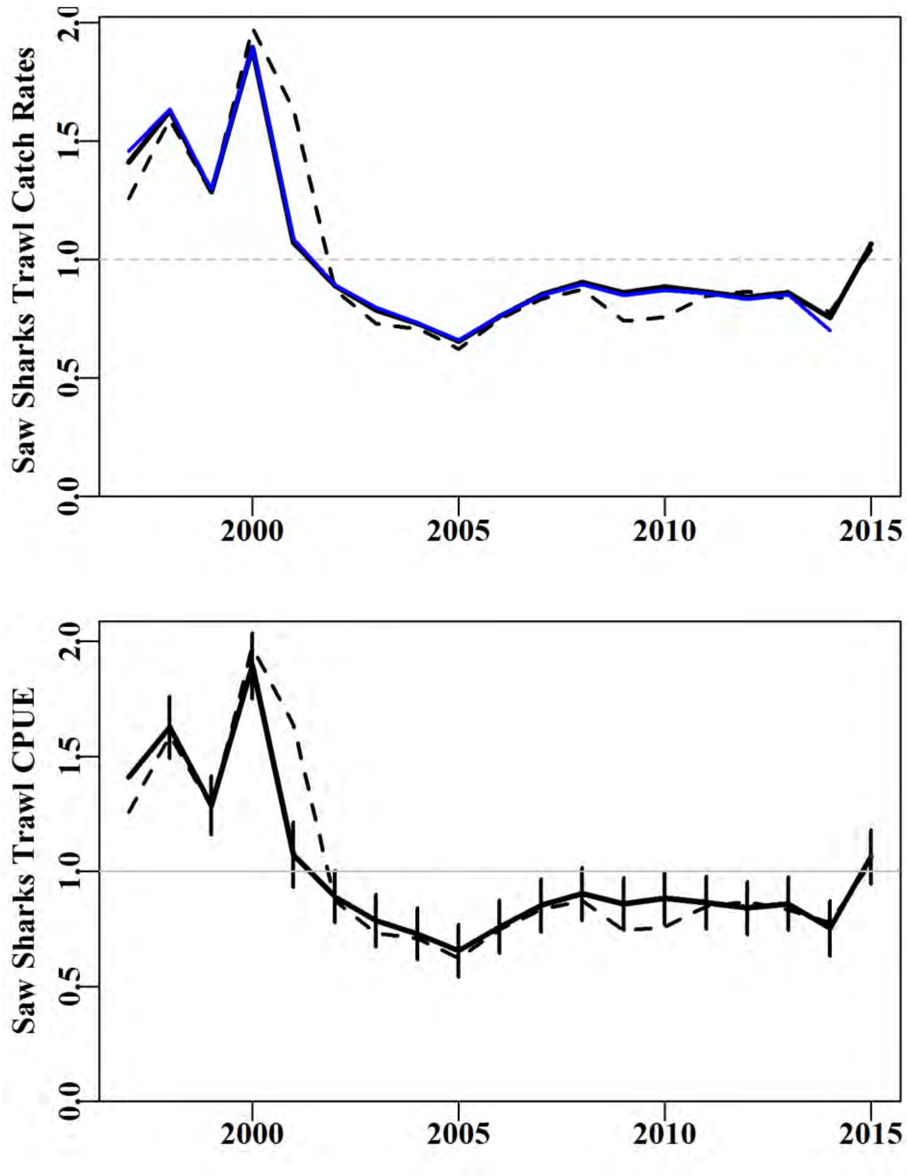



Figure 10.33. Sawshark taken by Danish Seine in shark zones 4 and 5. Upper plot: The dashed black line represents the geometric mean CPUE and the solid black line the standardized catch rates (each scaled to the mean of each time series). The blue line corresponds to last year's standardized CPUE. Lower plot: Standardized CPUE (solid black line), two times the standard error (vertical lines) and geometric mean (dashed black line).

Table 10.40. Sawshark from across shark zones in depths 0 to 240 m by Danish seine. Statistical model structures used in this analysis. DepCat is a series of 20 metre depth categories.

| | |
|---|---|
| Model 1 | LnCE ~ Year |
| Model 2 | LnCE ~ Year +DepCat |
| Model 3 | LnCE ~ Year +DepCat + Vessel |
| Model 4 | LnCE ~ Year + DepCat +Vessel + Month |
| Model 5 | LnCE ~ Year + DepCat +Vessel + Month + SharkZone |
| Model 6 | LnCE ~ Year + DepCat +Vessel + Month + SharkZone + DayNight |
| Model 7 | LnCE ~ Year + DepCat +Vessel + Month + SharkZone + DayNight + SharkZone:Month |
| Model 8 | LnCE ~ Year + DepCat +Vessel + Month + SharkZone + DayNight + SharkZone:DepC |

Table 10.41. Sawshark taken by Danish seine across shark zones at depths 0 to 240 m from Western Bass Strait to Eastern Bass Strait during 1997 - 2015. Model selection criteria, include the AIC, the adjusted $R^2$ (adj_$R^2$) and the change in adjusted $R^2$ (%Change). The optimum model is Model 7 (SharkZone:Month). Depth category: DepCat.

| | Year | DepCat | Vessel | Month | SharkZone | DayNight | SharkZone:Month | SharkZone:DepC |
|---|---|---|---|---|---|---|---|---|
| AIC | 5005 | 2545 | 1254 | 730 | 595 | 531 | 328 | 373 |
| RSS | 43172 | 39912 | 38488 | 37929 | 37791 | 37720 | 37493 | 37527 |
| MSS | 1491 | 4752 | 6176 | 6735 | 6873 | 6944 | 7171 | 7137 |
| Nobs | 37865 | 37355 | 37355 | 37355 | 37355 | 37355 | 37355 | 37355 |
| Npars | 19 | 36 | 69 | 80 | 81 | 84 | 95 | 101 |
| adj_$R^2$ | 3.293 | 10.556 | 13.670 | 14.899 | 15.206 | 15.358 | 15.843 | 15.754 |
| %Change | 0.000 | 7.263 | 3.114 | 1.229 | 0.307 | 0.152 | 0.484 | -0.089 |

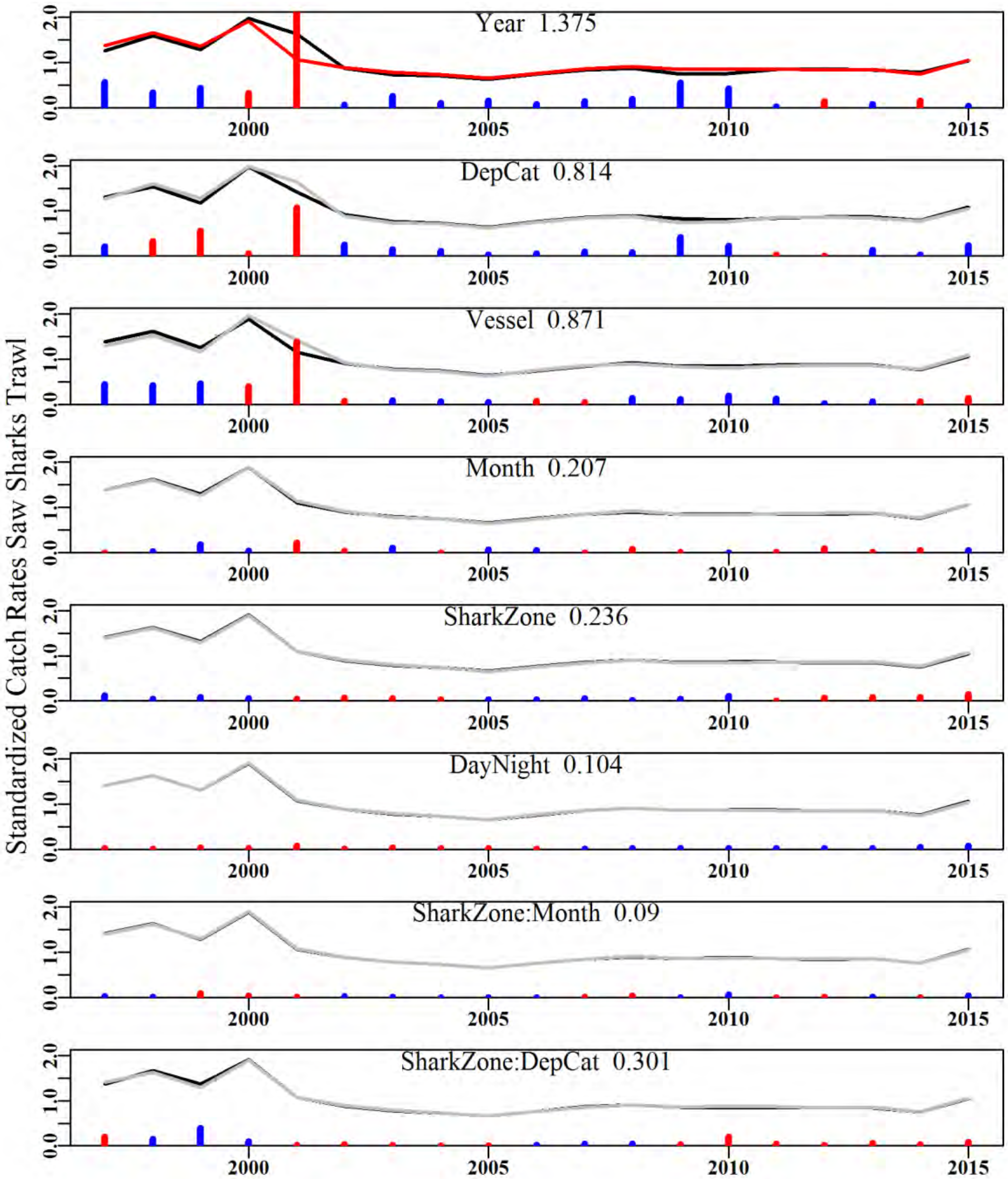



Figure 10.34. The relative influence of each factor on the final trend in the optimal standardization for the sawshark Danish seine fishery. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by the vertical bars with blue bars indicating the optimum model is higher than the geometric mean and red bars indicating it is lower. The top graph bars are the sum of all the bars in the graphs below. The graphs for individual factors are cumulative. Thus the second graph has the geometric mean (grey line) and the effect of adding Year + factor2 (Model 2, black line). In the third graph, the grey line represents Model 2 and the black line the effect of adding factor3 to the model. The remaining graphs continue in the same cumulative manner except for the interaction terms which are added singularly to the final single factor model.

### 10.4.12 *Sawshark: Danish seine (using Shark Area)*

This analysis in this section is similar to that of the previous section, except that Shark Area was used instead of Shark Zone.

Table 10.42. Sawshark taken by Danish seine across shark areas from Western Western Bass Strait to Eastern Bass Strait between depths of 0 to 240 m and during 1997 - 2015. Total catch (TotCatch; t) is the total reported in the database across all gears, number of records used in the analysis (Records), reported catch (CatchT; t) in the area and depth used in the analysis and number of vessels used in the analysis (Vessels). GeoMean is the geometric mean of CPUE (kg/shot). The optimum model is Model 7 (Table 10.44). SharkArea:Month and standard deviation (StDev) are the coefficients from the optimum model.

| Year | TotCatch | Records | CatchT | Vessels | GeoMean | SharkArea:Month | StDev |
|---|---|---|---|---|---|---|---|
| 1997 | 214.1599 | 435 | 4.0130 | 13 | 6.6369 | 1.4093 | 0.0000 |
| 1998 | 284.1927 | 482 | 6.7250 | 12 | 8.3726 | 1.6045 | 0.0675 |
| 1999 | 292.1391 | 612 | 6.4610 | 13 | 6.7381 | 1.2321 | 0.0643 |
| 2000 | 352.3844 | 397 | 7.1600 | 11 | 10.4130 | 1.7860 | 0.0720 |
| 2001 | 338.1462 | 508 | 7.0290 | 12 | 8.6081 | 1.0807 | 0.0709 |
| 2002 | 255.7574 | 2693 | 24.1670 | 22 | 4.5827 | 0.8886 | 0.0568 |
| 2003 | 318.8120 | 3027 | 21.8343 | 22 | 3.8597 | 0.7879 | 0.0568 |
| 2004 | 314.6146 | 3221 | 24.2960 | 22 | 3.7301 | 0.7417 | 0.0565 |
| 2005 | 296.6669 | 2658 | 17.3015 | 22 | 3.2812 | 0.6706 | 0.0570 |
| 2006 | 317.6979 | 2244 | 17.8885 | 20 | 3.9523 | 0.7890 | 0.0580 |
| 2007 | 214.5345 | 2296 | 21.5415 | 16 | 4.3941 | 0.8794 | 0.0580 |
| 2008 | 211.6896 | 2483 | 22.5435 | 15 | 4.6022 | 0.9196 | 0.0578 |
| 2009 | 191.4528 | 2843 | 21.1220 | 15 | 3.9007 | 0.8651 | 0.0575 |
| 2010 | 192.5017 | 2397 | 17.0055 | 15 | 3.9936 | 0.9167 | 0.0581 |
| 2011 | 197.0364 | 2879 | 25.3350 | 14 | 4.4682 | 0.8940 | 0.0575 |
| 2012 | 158.5591 | 2196 | 20.2490 | 14 | 4.5630 | 0.8505 | 0.0583 |
| 2013 | 165.6645 | 2530 | 20.7845 | 14 | 4.3859 | 0.8797 | 0.0579 |
| 2014 | 166.7128 | 1728 | 13.1579 | 14 | 4.0963 | 0.7613 | 0.0600 |
| 2015 | 162.5917 | 2134 | 24.0882 | 15 | 5.4797 | 1.0435 | 0.0594 |

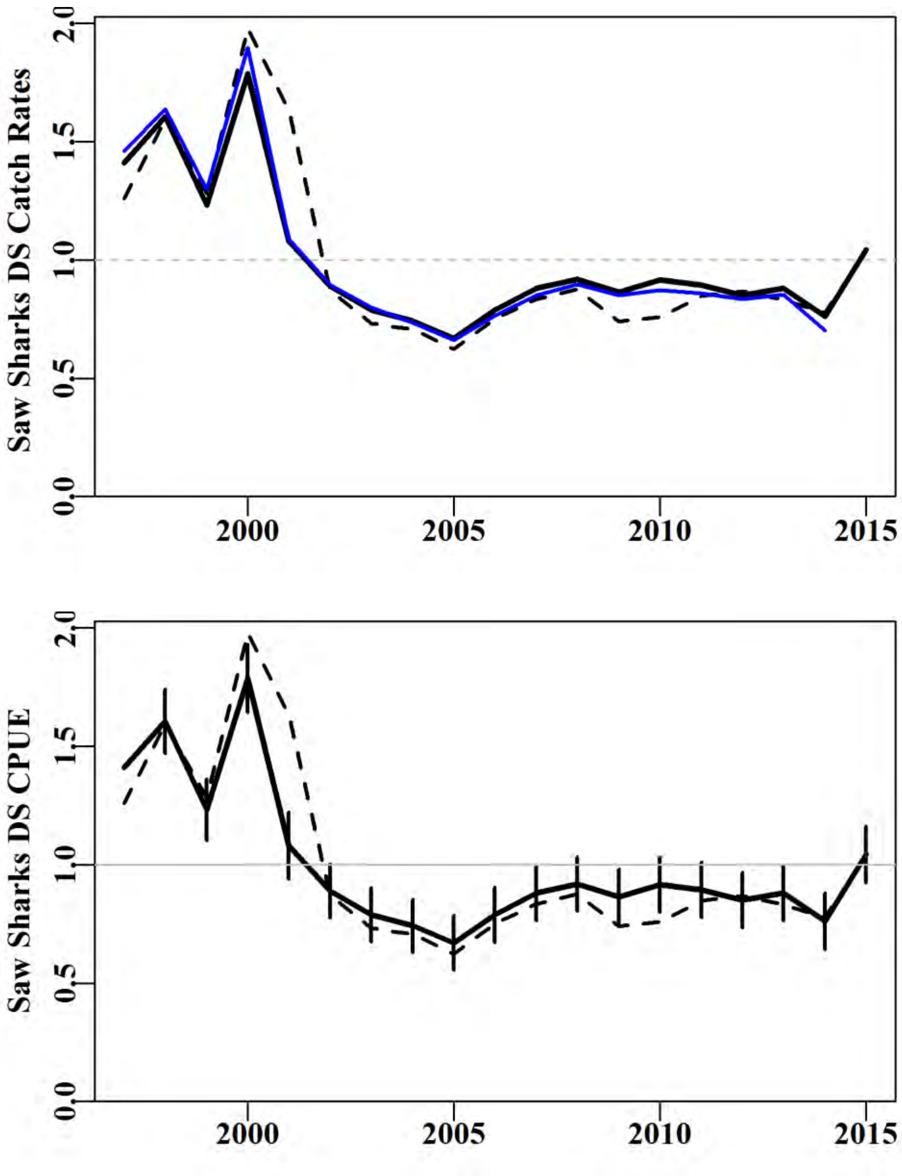



Figure 10.35. Sawshark taken by Danish Seine in shark zones 4 and 5. Upper plot: The dashed black line represents the geometric mean CPUE and the solid black line the standardized catch rates (each scaled to the mean of each time series). The blue line corresponds to last year's standardized CPUE. Lower plot: Standardized CPUE (solid black line), two times the standard error (vertical lines) and geometric mean (dashed black line).

Table 10.43. Sawshark from across shark zones in depths 0 to 240 m by Danish seine. Statistical model structures used in this analysis. DepCat is a series of 20 metre depth categories.

| | |
|---|---|
| Model 1 | LnCE ~ Year |
| Model 2 | LnCE ~ Year +Vessel |
| Model 3 | LnCE ~ Year +Vessel +DepCat |
| Model 4 | LnCE ~ Year +Vessel +DepCat + SharkArea |
| Model 5 | LnCE ~ Year +Vessel +DepCat + SharkArea + Month |
| Model 6 | LnCE ~ Year +Vessel +DepCat + SharkArea + Month + DayNight |
| Model 7 | LnCE ~ Year +Vessel +DepCat + SharkArea + Month + DayNight + SharkArea:Month |
| Model 8 | LnCE ~ Year +Vessel +DepCat + SharkArea + Month + DayNight + SharkArea:DepC |

Table 10.44. Sawshark taken by Danish seine across shark areas at depths 0 to 240 m from Western Bass Strait to Eastern Bass Strait during 1997 - 2015. Model selection criteria, include the AIC, the adjusted $R^2$ (adj_$R^2$) and the change in adjusted $R^2$ (%Change). The optimum model is Model 7 (SharkArea:Month). Depth category: DepCat.

| | Year | Vessel | DepCat | SharkArea | Month | DayNight | SharkArea:Month | SharkArea:DepC |
|---|---|---|---|---|---|---|---|---|
| AIC | 4449 | 2107 | 993 | 456 | 99 | 98 | -435 | -85 |
| RSS | 40106 | 37025 | 35793 | 35224 | 34836 | 34829 | 33978 | 34321 |
| MSS | 1363 | 4444 | 5676 | 6245 | 6632 | 6640 | 7491 | 7148 |
| Nobs | 35406 | 34915 | 34915 | 34915 | 34915 | 34915 | 34915 | 34915 |
| Npars | 18 | 29 | 63 | 74 | 89 | 92 | 257 | 257 |
| adj_$R^2$ | 3.241 | 10.645 | 13.534 | 14.881 | 15.781 | 15.792 | 17.458 | 16.626 |
| %Change | 0.000 | 7.404 | 2.889 | 1.347 | 0.900 | 0.011 | 1.666 | -0.832 |

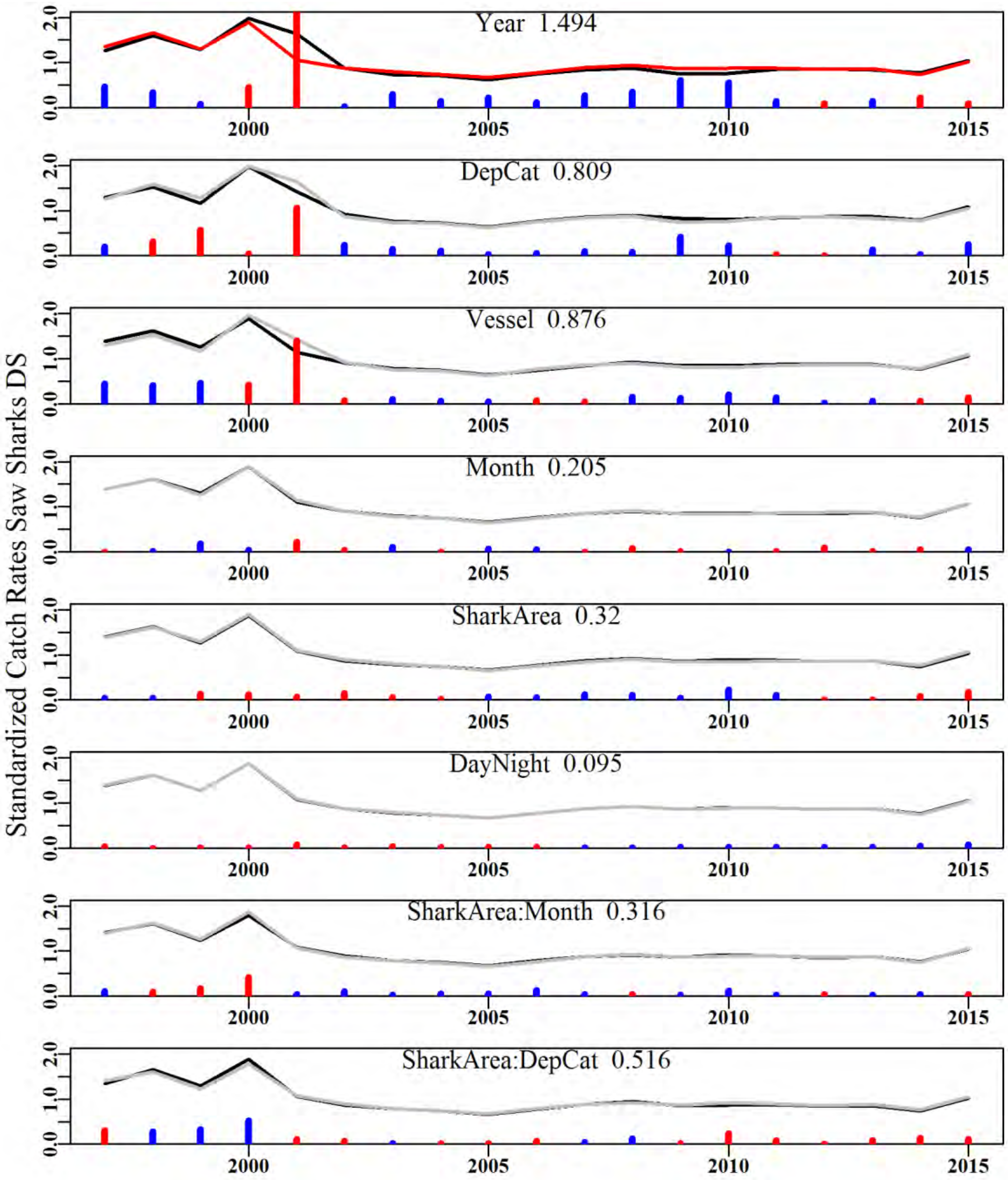
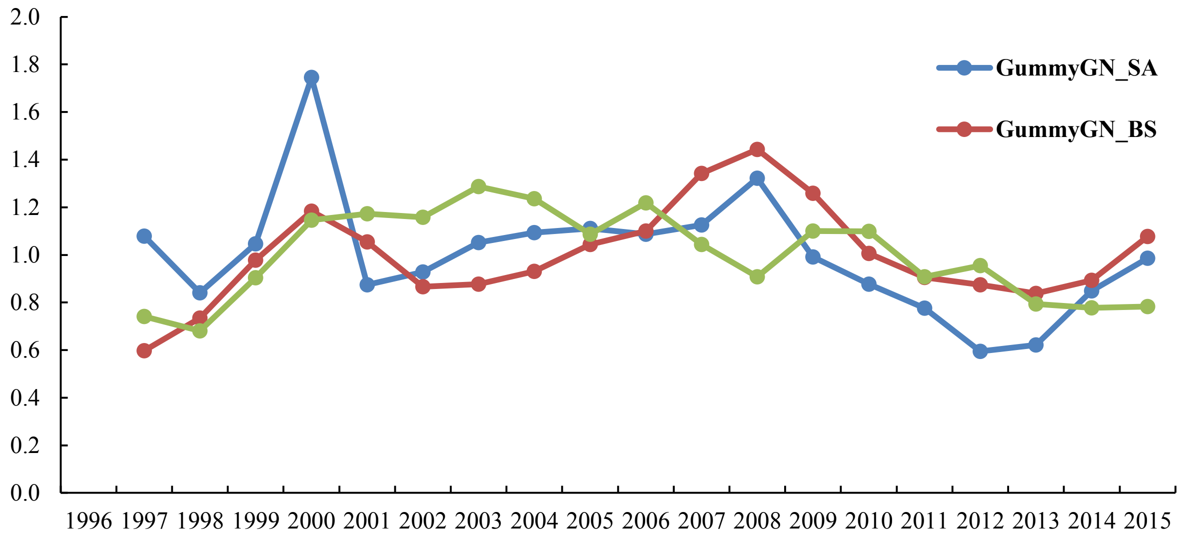



Figure 10.36. The relative influence of each factor on the final trend in the optimal standardization for the sawshark Danish seine fishery. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by the vertical bars with blue bars indicating the optimum model is higher than the geometric mean and red bars indicating it is lower. The top graph bars are the sum of all the bars in the graphs below. The graphs for individual factors are cumulative. Thus the second graph has the geometric mean (grey line) and the effect of adding Year + factor2 (Model 2, black line). In the third graph, the grey line represents Model 2 and the black line the effect of adding factor3 to the model. The remaining graphs continue in the same cumulative manner except for the interaction terms which are added singularly to the final single factor model.



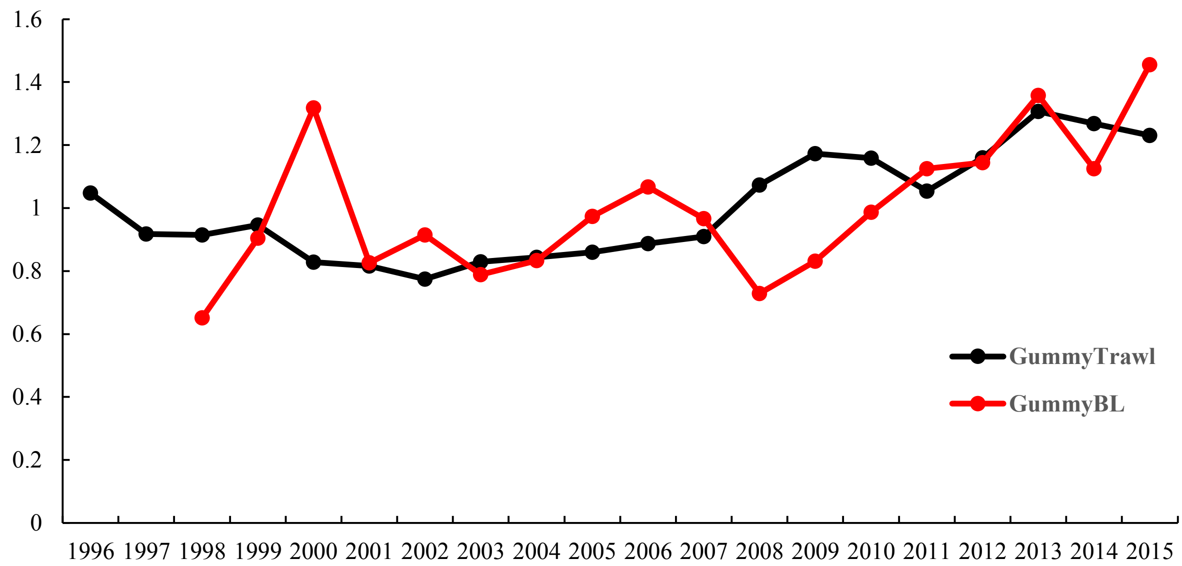




Figure 10.37. Annual standardized indices of gummy shark (i) gillnet-CPUE for SA, TAS and BS (upper plot). Annual standardized indices of gummy shark for trawl-CPUE and bottom line (BL) CPUE (lower plot).

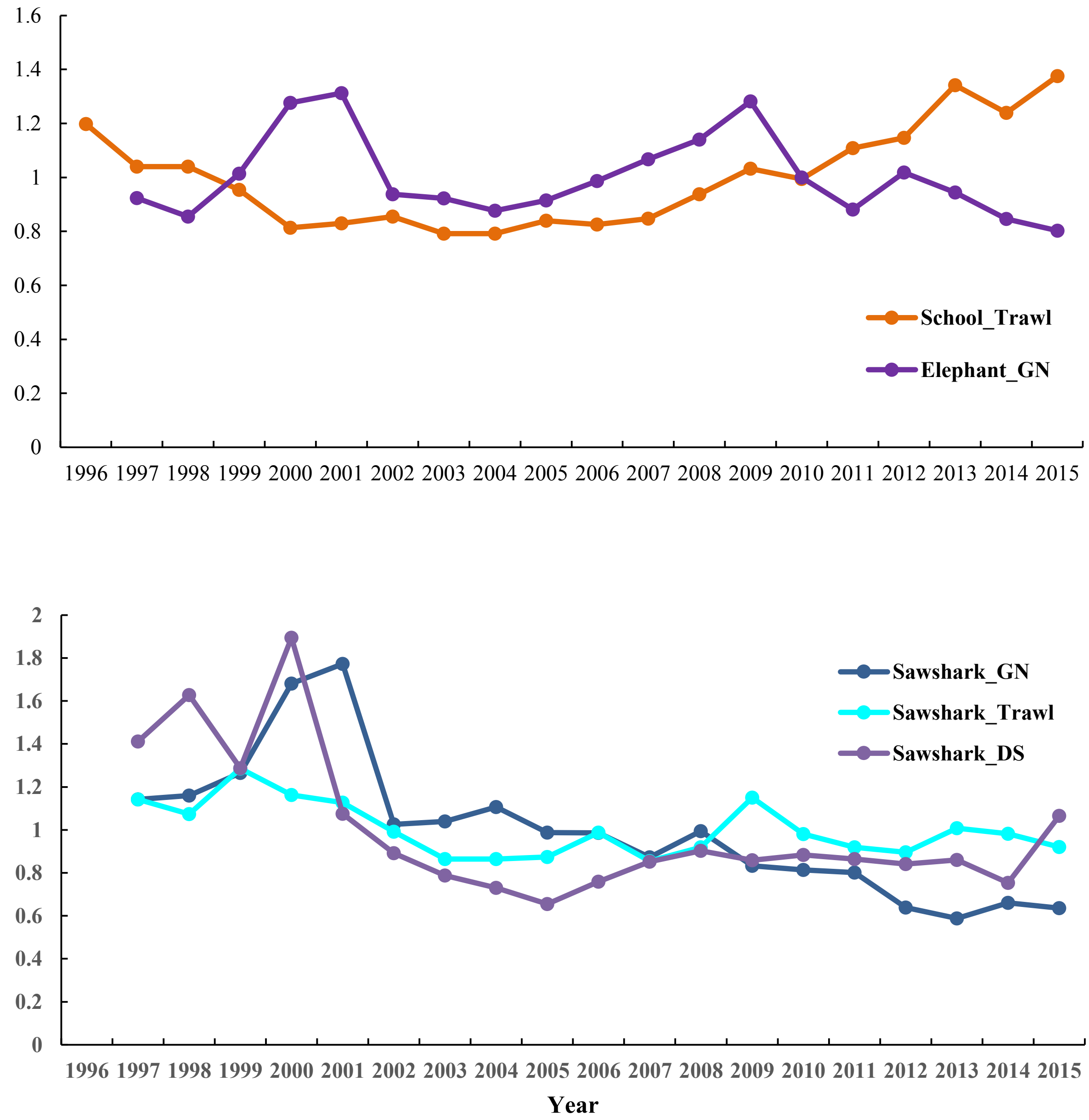



Figure 10.38. Annual standardized indices of school shark for trawl-CPUE and elephant fish gillnet-CPUE (upper plot). Annual standardized indices of sawshark for trawl-CPUE, gillnet-CPUE and Danish seine-CPUE (lower plot).

## 10.5 Discussion and Conclusions

### 10.5.1 *Gummy shark – Gillnet*

Most gummy shark catches are taken by gillnets (25,520 t; 1997-2015), followed by trawl (1,519 t; 1997-2015) and bottom line (1,716 t; 1997-2015). For consistency with the stock assessment model for gummy shark, the gillnet analysis considered Bass Strait, South Australia and Tasmania separately. Catches are greatest in Bass Strait and least in Tasmania.

Large scale closures to gillnet gear were imposed after 2010 to reduce the risk of interactions with marine mammals. In response, reported gillnet catches of gummy shark fell steadily from 2010 to 2013 (from 390 t to 60 t), in South Australia while bottom line catches decreased (from 72 t in 2010 to 229 t in 2013). By contrast, gillnet catches in South Australia increased in 2014 (127 t) and again in 2015 (154 t) while bottom line catches in the region decreased (227 t in 2014 and 188 t in 2015). This might reflect learning as fishers find new ways to use the more profitable gillnets in the region. This reduced fishing for gummy shark in areas of historical high CPUE has led to apparent changes in the CPUE for gillnets in South Australia. The impact on catches and numbers of records is obvious (Figure 10.2). Such changes may cast some doubt as to whether this series can be considered a reliable indicator of the stock's status in South Australia. Increases in standardized CPUE since 2012 may reflect a real change in abundance, or may reflect learning as the industry adapt to fishing in areas previously unfamiliar to them (Figure 10.3).

Gillnet catches of gummy shark in Bass Strait have been relatively stable (~800 t) in recent years and ~981 t in 2015. Standardized indices increased in the last two years relative to 2013, with the 2015 estimate above the overall long-term average (Figure 10.6). There has been an overall decline since 2008, with increases in the last two years. How much of this decline is due to the avoidance of school shark areas would be difficult to determine.

Tasmania has a relatively minor gummy shark catch and the standardized CPUE has been noisy but relatively flat since 1997 (Figure 10.9). However, the relatively few fishing operations performed in this region result in wide confidence intervals for the standardized CPUE indices.

### 10.5.2 *Gummy shark – Bottom Line*

Associated with recent increases in gillnet catches in South Australia, hook catches have decreased in 2015 (Table 10.18). The point estimate of the standardized CPUE increased markedly in 2013 relative to 2012, declined in 2014 and increased in 2015 (above the long-term average. However, taking into account the wide and overlapping confidence bands, there is no difference in the standardized CPUE indices for these years (Figure 10.15).

A CPUE standardization on the bottom line catches (using catch per shot) exhibits much broader confidence intervals owing to the smaller numbers of records relative to gillnet records. Nevertheless, the standardization has a large effect on the geometric mean CPUE, primarily due to the vessel effect (Figure 10.16). Since about 2010, standardized CPUE has been rising above the long term average (with a possible decline in 2014).

### 10.5.3 *School shark*

Industry avoidance of school sharks is reasonably successful, although there are reports that a scarcity of quota for leasing at economic prices is making it difficult for operators to land school shark, consequently unmeasured discarding may be occurring. Reports of high school shark availability (SharkRAG No. 1, Meeting Minutes 2014) may also have made it difficult for industry to keep the bycatch ratio of school shark to gummy shark catches below 20%. Discard levels were not estimated from the ISMP in 2015.

There has been a shift within line fishing methods with a greater catch by bottom long-line than by auto-line (e.g. during 2015, ~12.1 t auto-line compared to ~38.3 t bottom line). Reported trawl catches in 2014 and 2015 have remained similar (i.e. ~11.3 t and ~12.5 t) (but note that this excludes discards), despite a similar number of records (Table 10.21). Approximately, 83 t of school shark were reported caught by gillnets in 2015, a reduction of ~ 25 t from 2014.

Due to the change in behaviour of the gillnet industry in moving from targeting school sharks to increasing avoidance, their CPUE cannot be taken to be indicative of the stock status in any way. By contrast, although trawl catches are low, fishers do not appear to have changed their behaviour during 1996-2015. The trend in school shark standardized CPUE taken by trawl is gradually increasing (except for 2014); not as rapidly as for gummy sharks, but it has a similar trend (Figure 10.18). However, inspection of the on-board sampling for length frequencies suggests that there has been an increased proportion of smaller school sharks being measured in 2012, 2014 and 2015, although not evident from the 2013 sample, despite the large sample size (across all methods; Thomson et al. 2016, page 258).

### 10.5.4 *Gummy shark – Trawl*

Reported gummy shark catches by trawl of less than 30 kg have been consistently more frequent they are in the gillnet fishery (Figure 10.11), indicating that gummy shark are not targeted by trawl. Most trawl catches are taken from shark zones ESB, WA and WSA. Standardized trawl CPUE has increased by 24% since 2007 (Figure 10.12) and presents a strong contrast to all of the gillnet CPUE trends (Figure 10.3, Figure 10.6, Figure 10.9).

### 10.5.5 *Elephant fish*

Elephant fish are predominately taken by gillnet (Table 10.28). Catches are predominately taken in roughly 50 m of water (Figure 10.21). The number of vessels reporting gillnet catches of elephant fish dropped strongly just before the structural adjustment from about 56 vessels down to about 27, and has remained roughly stable since. A high proportion of reported catches are less than 30 kg, which is suggests that the species is rarely if ever targeted (Figure 10.21). There is no trend through time in the proportion of these small catches. Much of the reported catch is from Eastern Bass Strait (Table 10.29). Industry members have indicated that catches made at great distance from markets are seldom landed due to the cost of transportation relative to the low market value of this fish (David Stone, pers comm.).

Reported catches by trawl have remained stable at ~ 10 t in recent years (Table 10.28), providing insufficient information for a useable standardization. Similarly, Danish seine catches have been consistent but low across the years and are therefore currently not suitable for a useful standardization (Table 10.28).

Standardized CPUE (not adjusted for discards) of gillnet caught elephant fish show occasional rises and falls about the longer term average (Figure 10.22). There is no evidence of an overall rise or fall apparent in the data. The factor having the greatest influence on the CPUE appears to be which vessels are fishing with a major change in the CPUE pattern following the structural adjustment (Figure 10.23).

### 10.5.6 *Sawshark*

Sawshark catches have been split primarily between gillnets and trawls, with a lesser quantity taken by Danish seine. Discarding, which has only really been examined in the context of CPUE in recent years, was relatively high (13 – ~28%) from 2011 to 2014 (Thomson et al. 2016; page 270). There is no discard estimate for 2015. The structural adjustment certainly affected vessel numbers reporting catches of sawshark with number of gillnet vessels dropping from 79 in 2003 down to 43 in 2007 (Table 10.30). The number of trawl vessels reporting sawshark also approximately halved from about 65 in 2000 (i.e. pre-2007) to about 36 post-2006 (Table 10.33). Danish Seine vessels reporting sawshark dropped from about 22 vessels a year down to about 16 vessels each year (Table 10.39).

For all methods, the average proportion of the catch reported to come from shots of < 30 kg is also relatively high (~70% for Danish seine, 31% for gillnet and 38% for trawl). This indicates that sawshark are not a primary target species and that few individuals are landed from each shot, especially in the Danish seine fishery.

The standardized CPUE for gillnet caught sawshark has been declining since 2004 (except for 2014), although the standardization does not account for the level of discarding that occurred. If discarding has been increasing over time, the inclusion of discarding may lead to an increase in the CPUE exhibited by the fishery. The effect of the South Australian closures can be seen from the impact of the shark zone factors (Figure 10.26). Discard rates have not been calculated by gear type (Thomson 2016) so this question can not be examined.

Trawl catches are taken in a much wider depth range (0-500 m) than gillnet catches (0-150 m). Standardized CPUE varies around an average of 1.0, ranging between 0.9 and 1.3 since 1997; it is flat and noisy (Figure 10.28). The impact of the introduction of closures to gillnetting in 2010 is evidenced by the influence of the shark zone factor (Figure 10.29). The use of shark area rather than shark zone for both trawl and Danish seine caught sawshark caused no differences in standardized CPUE indicating that both factors capture the same information.

Danish seine catches tend to be more focussed in shallower depths i.e. less than 100 m. Following an initial high standardized CPUE during 1997-2001, a period when reported catches were consistently < 8 tonnes, the standardized Danish seine CPUE is essentially flat from 2001 to 2013 apart from a small decrease in 2014 and an increase above the long-term average in 2015 (Figure 10.33).

Over the period 2001 – 2013 Danish seine and trawl based sawshark CPUE follow essentially the same trajectory when placed on the same scale. If these CPUEs are indexing stock status, there is no indication of a change in the relative abundance, despite the downward trend exhibited by gillnet-CPUE (Figure 10.38).

## 10.6 References

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# 11. Tier 4 Analyses of Selected Species from the SESSF. Data from 1986 – 2015

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## *11.1 Executive Summary*

Four fisheries have been assessed using the Tier 4 methodology in 2016: Mirror Dory East, Mirror Dory East including discards into the CPUE, Mirror Dory West, and Western Gemfish. The Mirror Dory analyses treat the west and east as separate stocks, and also include the high levels of discards that occur in the east. The Western Gemfish analysis contrasts the Tier 4 obtained with and without the inclusion of the recently very high levels of discards.

The TIER 4 analyses conducted this year used the analytical method developed and tested in 2008 and 2009. This has the capacity to provide advice that will manage a fishery in such a manner that it should achieve the target catch rate derived from the chosen reference period. However, the TIER 4 control rule can only succeed if catch rates do in fact reflect stock size. Many factors could contribute to make this assumption fail so care needs to be taken when applying this control rule. It should be made clear that the control rule works to achieve the selected target but there is no guarantee that this truly corresponds to the HSP proxy target for MEY of 48% $B_0$.

The inclusion of discards into the CPUE makes the assumption that there were no complete shots discarded; in other words only part of some or all hauls were discarded and no shots were completely discarded. The analyses depend on adjusting the total catch in each instance while not adjusting the effort. However, if complete shots are discarded then the total effort will be under-estimated biasing the discard CPUE high. Given that some shots may be completely discarded the analysis with discards is thus expected to be biased high, whereas if discards have been variable through time, but are not included in an analysis, then the CPUE from that analysis would be expected to be biased low. Both together bound the possibilities and both need to be considered when setting the TAC.

Table 11.1. Summary of the Tier 4 analyses for Mirror Dory. The target catches are those from the Tier 4 analyses. The Mirror Dory RBCs for east and west need to be combined to obtain the overall RBC.

| Mirror Dory | East | East + Discards | West | Total |
|---|---|---|---|---|
| Scaling | 0.5977 | 0.4664 | 0.5551 | |
| TAC | 437 | 437 | 437 | 437 |
| Target E Catch | 372.739 | 372.739 | 187.647 | 560.386 |
| RBC | **222.781** | **173.828** | **104.171** | **277.999** |

Table 11.2. A comparison of the RBC for Mirror Dory from the last three Tier 4 assessments. The reduction in RBC as a reflection of the relatively rapid changes in CPUE exhibited by the Mirror Dory fisheries is clear. The years designate the last year of data in each case.

| Mirror Dory | 2012 | 2013 | 2015 |
|---|---|---|---|
| East + Discards | 497.134 | 523.107 | 198.278 |
| East | 465.000 | 392.696 | 222.781 |
| West | 183.118 | 160.809 | 104.171 |
| Total (E Discard + W) | 680.252 | 683.916 | 302.449 |
| Total (E & W) | 648.118 | 553.505 | 326.952 |

The Western Gemfish RBC lies somewhere between 139 – 423 t depending on the recent incidence of the discarding if complete shots. If all discarding was of complete shots then the lower value is correct, if all discarding was of total shots then the larger number is correct. It is to be expected that the more appropriate value will lies somewhere in between.

Table 11.3. Summary of the Tier 4 analyses for Western Gemfish. The target catches are those from the Tier 4 analyses.

| Western Gemfish | West + Discards | West |
|---|---|---|
| Scaling | 1.9663 | 0.6462 |
| TAC | 247 | 247 |
| Target Catch | 215.124 | 215.124 |
| RBC | **422.997** | **139.024** |

## 11.2 Introduction

### 11.2.1 *Tier 4 Harvest Control Rule*

The TIER 4 harvest control rules are the default procedure applied to species for which only limited information is available; specifically no reliable information on either current biomass levels or current exploitation rates.

Ideally, in line with the notion of being more precautionary in the absence of information, the outcome from these analyses should be more conservative than those available from higher TIER analyses; this is now explicitly implemented by imposing a 15% discount factor on the RBC as a precautionary measure unless there are good reasons for not imposing such a discount on particular species. The application of the discount factor will occur unless RAGs generate explicit advice that alternative equivalent precautionary measures are in place (such as spatial or temporal closures) or that there is evidence of historical stability of the stock at current catch levels (AFMA, 2009).

In essence TIER 4 analyses require, as a minimum, a time series of total catches and of standardized catch rates.

The current TIER 4 analysis and control rule underwent Management Strategy Evaluation (Wayte, 2009, Little *et al*, 2011a), which demonstrated its advantages over an earlier implementation used in 2007 and 2008. Further work has since demonstrated that as long as there is a limit on increases and decreases to the RBC of no more than 50% then the notion of including a maximum RBC (at 1.25 times the target) is redundant (Little *et al*, 2011b).

## 11.3 Methods

### 11.3.1 TIER 4 Harvest Control Rule

The data required are time series of catches and catch rates. The analyses have been conducted on total catches across the entire SESSF (including State catches, SEF2 landing records, and any discards). For some species, where there is only a single stock and a single primary fishing method, analyses are presented using standardized CPUE data (Haddon, 2013). For other species, there may be multiple stocks or areas or multiple methods and selecting which time series of catch rates to use in the analyses is not always straightforward. In those cases, the standardized time series for the method now accounting for the majority of current catch was used.

All data between 1986 – 2015, relating to catches and discards, from both State waters and SEF2 data sets, were provided by AFMA and the various State agencies, with initial processing by Dr Robin Thomson and Dr Judy Upston of CSIRO. All catch rate data were derived from the standard commercial catch and effort database processed from the AFMA data by CSIRO Hobart and CSIRO Brisbane.

Standard analyses were set up in the statistical software, R (2016) and included in the r4sessf R package, which is currently under development. These standard analyses provide the tables and graphs required for the TIER4 analyses. All data and results for each analysis are presented for complete transparency. The TIER 4 harvest control rule formulation essentially uses a ratio of current catch rates with respect to the selected limit and target reference points to calculate a scaling factor for the current year ($SF_t$). This scaling factor is applied to the target catch to generate an RBC. To generate a TAC, known discards and State catches are first removed and then, if applicable, the 15% discount is applied. The TAC calculations are conducted by AFMA. This report focusses on providing the estimates of the Recommended Biological Catches.

$$\text{Scaling Factor } = SF_t = \max\left(0, \frac{\overline{CPUE} - CPUE_{\text{lim}}}{CPUE_{\text{targ}} - CPUE_{\text{lim}}}\right) \tag{9}$$

$$RBC = C_{\text{targ}} \times SF_t \tag{10}$$

If new data becomes available, for example, more State data has become available this year, or other large changes occur in the catch rates then the RBC could undergo large changes. Such changes are constrained by the following limits:

$$\begin{array}{l|l} RBC_y = 1.5RBC_{y-1} & RBC_y > 1.5RBC_{y-1} \\ RBC_y = 0.5RBC_{y-1} & RBC_y < 0.5RBC_{y-1} \end{array} \tag{11}$$

where

| | |
|---|---|
| $RBC_y$ | is the RBC in year *y* |
| $CPUE_{targ}$ | is the target CPUE for the species; Eq. (13) |

| | |
|---|---|
| $CPUE_{lim}$ | is the limit CPUE for the species = either (0.2/0.48) * $CPUE_{targ}$ or (0.2/0.40) * $CPUE_{targ}$ depending on the selected target for the species |
| $\overline{CPUE}$ | the average CPUE over the past *m* years; *m* tends to be the most recent four years. |
| $C_{targ}$ | is a catch target derived from a period of historical catch that has been identified as a desirable target in terms of CPUE, catches and status of the fishery, e.g. 1986 – 1995 (Table 11.4). This is an average of the total removals for the selected reference period, including any discards; Eq. (12). |

$$C_{\text{targ}} = \frac{\sum_{y=yr1}^{yr2} L_y}{\left(yr2 - yr1 + 1\right)} \tag{12}$$

where $L_y$ represents the landings in year *y*.

$$CPUE_{\text{targ}} = \frac{\sum_{y=yr1}^{yr2} CPUE_y}{\left(yr2 - yr1 + 1\right)} \tag{13}$$

where $CPUE_y$ is the catch rate in year *y*, *yr2* and *yr1* represent the last and the first years in the reference period respectively.

For each species a table of landings and of standardized catch rates was assembled. These included all catches (Commonwealth landings, Non-trawl catches, combined State catches, and discards). The State catches are available back to 1994 and non-trawl catches are from 1998. Catches prior to 1994 are either taken from an historical catch database or, if no data are available for the species, then they are taken from the AFMA GenLog Catch and Effort database as processed by CSIRO. The catch rates are standardized, usually from 1986, using methods described in Haddon (2014).

Percent discards are estimated from ISMP observations from 1998 to the current year. Discards for earlier years, prior to ISMP sampling, are estimated by taking the overall average percent discard from 1998 to the 2006 and applying that discard rate to the reported landings for the earlier years. The year 2006 was selected as the final year as discarding practices altered at about that time following the structural adjustment and the introduction of the Harvest Strategy Policy. For Eastern Gemfish the average discard rate was determined for 1998-2002 to allow for the non-target nature of the fishery following 2002. The calculation of the earlier discards is done so that the total catches can be estimated even though only the landed catches are available. To calculate the discards for a given year we used

$$D_y = \frac{C_y \bar{D}_{98-06}}{\left(1 - \bar{D}_{98-06}\right)} \tag{14}$$

Discard proportions for the projected year for which the RBC is being calculated are taken as a weighted mean of the previous four years:

$$D_{CUR} = (1.0D_{y-1} + 0.5D_{y-2} + 0.25D_{y-3} + 0.125D_{y-4})/1.875 \tag{15}$$

Where $D_{CUR}$ is the estimated discard rate for the coming year *y*, $D_{y-1}$ is the discards rate in year *y-1*. The discard rate in year *y* is the ratio of discards to the sum of landed catches plus those discards (this can vary between 0 – 100%):

$$D_y = \frac{Discard_y}{\left(Catches_y + Discard_y\right)} \tag{16}$$

For each species, reference years were selected by the RAGs to generate estimates of target catches and target catch rates. In addition, a decision was required as to whether the fishery could be considered as fully developed or otherwise (**Error! Reference source not found.**). Where a fishery was not onsidered to be fully developed the target catch rate, $CPUE_{targ}$, was divided by two as a proxy for expected changes to catch rates as the fishery develops and the resource stock size declines towards the target of 48% unfished biomass.

Plots are given of the total removals illustrating the target catch level. In addition, the standardized catch rates are illustrated with the target catch rate and the limit catch rate. Finally, where the data are available, plots are given of the Total removals contrasted with State removals, and of discards and non-trawl catches.

### 11.3.2 *Data Manipulations*

The default reference years were 1986-1995, but various species required different reference years to account for the specific development of each fishery; these are noted in each analysis. In addition, Silver Warehou and Ribaldo were two fisheries where the state of development was such that the exhibited catch rates were unlikely to be representative of a developed fishery and so the target catch rates were halved; these details are provided in Table 11.4.

### 11.3.3 *The Inclusion of Discards*

Some species, especially redfish (*Centroberyx affinis*), inshore Ocean Perch (*Helicolenus percoides*), and Mirror Dory (*Zenopsis nebulosus*), have experienced high levels of discarding but the reported catch rates relate only to the estimated landed weights. In those species where discarding makes up a significant proportion of the catch (in some years more redfish were discarded than landed and more inshore ocean perch tend to be discarded than landed) it is reasonable to ask how the discards would have affected catch rates. This is an important question because standardized commercial catch rates are used in Australian stock assessments as an index of relative abundance (Haddon, 2010); if ignoring discards leads to a consistent bias this could affect the outcome of the assessments and thus, the assessments should become aware of the effects of discards.

Catch rates are used in assessments as an index of relative abundance through time and it is the trends exhibited by the catch rates that are important rather than their absolute values. If the discard levels are relatively constant through time and evenly distributed amongst the fleet, then their inclusion would not be expected to influence the trends in catch rates except to add noise. In all cases the discard rates are estimates based on sub-sampling the fleet of vessels. That the estimates are uncertain can be seen simply by considering the summary data tables in this document; where discards rates are not low they are very variable between years. Redfish provide an extreme where in 1998 the estimate was 2324 t, which was nearly 56 % of the total catch, while in 1999 discards estimated at only 69 t, making up on about 5 % of the total catch. So in those cases where discard levels are low, adding discards to the estimation of catch rates is not expected to alter outcomes.

For those species, such as redfish and ocean perch, where discard rates are much higher it was decided to include those estimated catches to determine their effect on the outcome of the Tier 4 analyses. In 2010 it was concluded that while the inclusion of discards contributed a great deal of noise to the analyses, for those species where discarding made up significant proportions of the overall catch the discard augmented catch rates should be examined each year as a sensitivity analysis to contrast with the outcome from the un-augmented catch rates (Haddon, 2010).

### 11.3.4 *The Analyses Including Discards*

Discard rates cannot simply be added to known catches on the way to calculating catch rates. The standardized catch rates are estimated from individual catch and effort records but the estimates of discards are summary estimates for each fishery. While a method for incrementing the standardized catch rates has been developed it should be noted that this ignores all complications relating to unknown aspects of discarding behaviour (is the discard rate constant across all catch sizes, across all vessels, across all areas? etc). This means that including discard catches into the annual catch rate estimates introduces an unknown amount of uncertainty into the analysis. It should also be noted that the discard estimates are highly variable from year to year and derive from relatively small samples of all trips contributing to catches.

The method developed was to find the multiplier needed to adjust ratio mean catch rates and apply that to the standardized catch rates (Haddon, 2010). The ratio mean catch rates require the annual sum of catches for the fishery along with the sum of effort and ratio means calculated for each year. The discard estimates from the fishery can be added to the catch totals and new ratio means calculated and compared. The multiplier needed to make the same changes to the ratio mean catch rates can then be developed and applied to the standardized catch rates.

The ratio mean is simply the sum of all catches divided by the sum of effort

$$\hat{I}_{R,t} = \frac{\sum C_t}{\sum E_t} \tag{17}$$

where $\hat{I}_{R,t}$ is the ratio mean catch rate for year $t$, $\Sigma C_t$ is the sum of landed catches in year $t$, and $\Sigma E_t$ is the sum of effort (as hours trawled) in year $t$. If $\Sigma D_t$ is the sum of discards in year $t$ then the discard incremented ratio mean catch rate would be

$$\hat{I}_{D,t} = \frac{\sum C_t + \sum D_t}{\sum E_t} \tag{18}$$

The same values of $\hat{I}_{D,t}$ can also be obtained using the following multiplier

$$\hat{I}_{D,t} = \left[ \left( \sum D_t / \sum C_t \right) + 1 \right] \times I_t \tag{19}$$

where $I_t$ is the catch rate estimate to be modified by the inclusion of discards. If this is the ratio mean from Equ (17) then the augmented catch rates would be identical to those produced by Equ (18). In practice, the catch rates used with the multiplier are the standardized catch rates from Haddon (2010).

In the case of redfish and inshore ocean perch the discard augmented standardized mean catch rates were calculated, and compared visually with the geometric mean and original standardized catch rates. After the re-analysis of the catch rates these can be introduced into the TIER 4 analysis for Inshore Ocean Perch using the standard methods as described in Haddon (2010b).

If discarding is variable through time then it may be worthwhile including those discards into the CPUE calculations. It should be noted that the objective of doing this is to attempt to account for the CPUE being biased low through the actual catches being higher than those reported and those used in the usual CPUE calculations. However, there is a risk that if there were many shots that were totally discarded then including those discards into the CPUE will in fact bias the resulting CPUE high! Because any estimates of the proportion of discarding of complete shots of a species are invariably poor, this means that when including discards into a CPUE analysis to obtain a full appreciation of the effects of discard it is necessary to contract the analysis without discards with the analysis that includes discards. The actual CPUE will be bracketed by the two time series.

Table 11.4. Characteristics used in the TIER 4 method. If a species is not considered to be fully fished during the reference period then the target catch rate is to be divided by two.

| Species | Reference Years | Fully Fished by Reference Period | First year with catches > 100t. | Target CPUE |
|---|---|---|---|---|
| Mirror Dory | 1986-1995 | 1 | 1986 | 0.48 |
| Mirror Dory East | 1986-1995 | 1 | 1986 | 0.48 |
| Mirror Dory West | 1996-2005 | 1 | 1996 | 0.48 |
| Western Gemfish Discard | 1992-2001 | 1 | 1994 | 0.48 |

### 11.3.5 *Selection of Reference Periods*

The Tier 4 requires a reference period to be selected in order to establish target and limit levels of catch rates and associated target levels of catch that are deemed by the RAG to act as a proxy for the desired state for the fishery. These act as a proxy for the Harvest Strategy Policy reference points of 48% and 20% unfished spawning biomass. The original Tier 4 rule that used a linear regression of the last four year's catch rates to determine whether catches increase or decrease was not able to rebuild a resource towards a desired target level and the current approach was developed so as to be able to manage a fishery towards a target and away from a limit.

The essence of the Tier 4 control rule is that it sets a RAG agreed target catch rate, which has an associated target catch. An estimate of current catch rates (usually the average of the last four years) is compared with the target and a multiplier is estimated which is to be applied to the target catch to generate the recommended biological catch.

To select a reference period requires a time series of comparable catch rates. For this reason the use of standardized catch rates should be an improvement over using, for example, the observed arithmetic or geometric mean catch rates. Catch rate data is available in the SESSF for all targeted species from 1986 - 2011, although it needs to be noted that the character of the fishery has changed markedly during that period. Little *et al.* (2009) provide a discussion on how reference periods might be selected.

They proposed a default ten year period of 1986 – 1995, stating: "We have assumed that the average CPUE from 1986 to 1995 corresponds to that which would be attained if the stock were at the level that provides the maximum economic yield, $B_{MEY}$. The limit CPUE is 40% of this CPUE." (Little *et al.*, 2009, p 234).

For each species, reference years were selected by the RAGs to generate estimates of target catches and target catch rates. In addition, a decision was required as to whether the fishery could be considered as fully developed or otherwise during the reference period or not. Where a fishery was not considered to be fully developed the target catch rate, $CPUE_{targ}$, was divided by two as a proxy for expected changes to catch rates as the fishery develops and the resource stock size declines towards the assumed proxy target for 48% unfished biomass.

Little *et al.* (2009) proposed three rules used to estimate the CPUE target:

1. The CPUE target for stocks fully exploited at or prior to 1986 is based on the average CPUE from 1986-1995.
2. Where fishing exploitation up to 1986 is thought to be minimal, the CPUE determined in step 1 is halved (to provide a catch rate proxy for $B_{MEY}$).
3. Where fishing exploitation after 1986 is low, the first year in which catches are above 100t signifies the start of the 10 year period for which CPUE targeted is calculated.

Once the average CPUE for the reference period has been selected as the target CPUE then the limit CPUE is defined as 40% of the target. All of these rules make the assumption that the target catch rates have achieved an equilibrium with the target catches. In other words, if the target catch was maintained long enough the target catch rate would be the result.

### 11.3.6 *Treatment of Non-Target Species*

In 2012, the SESSF RAG determined that the assessments of those species which do not constitute the economic drivers for a fishery might use the proxy for $B_{MSY}$ as the target instead of $B_{MEY}$. In practice this means that the target is assumed to be a proxy for $B_{40}$ rather than $B_{48}$. For the Tier 4, this means modifying the control rule used to estimate the RBC by multiplying the target catch rate by 5/6. If the original target was a proxy for 48% $B_0$, then 5/6$^{th}$ or 0.83333 of this target would be a proxy for $B_{40\%}$. This option may possibly become more important when the new revised harvest strategy policy that is being developed is implemented.

### 11.3.7 *The Tier 4 Assumptions*

All stock assessments involve a series of assumptions (Table 11.5). More attention is needed to these assumptions to ensure that the limitations of the Tier 4 assessments are understood.

Table 11.5. The assumptions that need to be met for the Tier 4 assessment to be valid. This list is not necessarily exhaustive and will be added to in future years.

| Title | Description |
|---|---|
| **Informative CPUE** | There is a linear relationship between catch rates and exploitable biomass; *if there is hyper-stability (catch rates remain stable while stock size changes) or hyper-depletion (catch rates decline much faster than stock size changes) then the standard Tier 4 analysis would provide biased results.* |
| **Consistent CPUE through time** | The character of the estimated catch rates has not changed in significant ways through the period from the start of the reference period to the end of the most recent year; *If there has been significant effort creep altering the catchability, or there have been changes to the fleet that have altered the relative efficiency of the vessels fishing, or the catchability of the species by the fleet has been altered by other changes then the comparability of recent catch rates with the target period may be compromised. Such changes would obviously reduce the responsiveness of the Tier 4 method to change and may generate completely inappropriate management advice. Included in this clause are the effects of targeting or not targeting of deep water or aggregated species. When catch rates are extremely variable through time, such that mean estimates become unreliable measures of stock status, then the Tier 4 approach cannot be validly applied.* |
| **Plausible target reference period** | The reference period provides a good estimate of the stock when at a depletion level of 48% unfished spawning biomass; *the Tier 4 method is based on catch rates and thus relates to exploitable biomass and not spawning biomass. As a minimum the reference period will refer to a period when the stock was in an acceptable, productive and sustainable state. But there can be no guarantees that the target aimed for is really $B_{48\%}$.* |
| **Accurate total catch history** | Accurate estimates are required for all catches from the stock under consideration during the accepted target period, irrespective of what method was used or whether it was retained or discarded. |

## 11.4 Results for Tier 4 species

### 11.4.1 *Mirror Dory East (DOM – 37264003 – Zenopsis nebulosus)*

Mirror Dory East relates to catches of Mirror Dory taken in SESSF zones 10, 20 and 30.

Table 11.6. Mirror Dory data for the TIER 4 calculations. Total is the sum of Discards, State, Non Trawl and SEF2 catches. All values in Tonnes. CE is the standardized catch rate for Zones 10 to 30 in depths 0 – 600m (Sporcic and Haddon, 2016). GeoMean is the geometric mean catch rates. Discards are estimates from 1998 to present. The ratio of discards to catch over the 1998 – 2006 period was used to estimate the discards between 1986 and 1997, the proportion of which is the PDiscard. The greyed cells represent the reference period.

| Year | Catch | Discards | Total | PDiscard | CE | GeoMean |
|---|---|---|---|---|---|---|
| 1986 | 367.985 | 91.091 | 459.076 | 0.198 | 1.1970 | 1.6108 |
| 1987 | 413.571 | 102.375 | 515.946 | 0.198 | 1.3068 | 1.7147 |
| 1988 | 313.237 | 77.539 | 390.776 | 0.198 | 1.1788 | 1.4520 |
| 1989 | 513.736 | 127.170 | 640.906 | 0.198 | 1.4157 | 1.9914 |
| 1990 | 254.380 | 62.969 | 317.349 | 0.198 | 1.3416 | 1.7676 |
| 1991 | 170.954 | 42.318 | 213.272 | 0.198 | 1.1554 | 1.2213 |
| 1992 | 140.441 | 34.765 | 175.206 | 0.198 | 1.0048 | 1.0146 |
| 1993 | 267.091 | 66.116 | 333.207 | 0.198 | 1.0881 | 1.2209 |
| 1994 | 303.620 | 75.158 | 378.777 | 0.198 | 0.9552 | 1.0060 |
| 1995 | 242.777 | 60.097 | 302.874 | 0.198 | 0.8680 | 0.8853 |
| 1996 | 262.435 | 64.963 | 327.398 | 0.198 | 0.7589 | 0.6702 |
| 1997 | 361.397 | 89.460 | 450.857 | 0.198 | 0.8024 | 0.7430 |
| 1998 | 291.383 | 76.246 | 367.629 | 0.207 | 0.7236 | 0.6959 |
| 1999 | 299.692 | 40.790 | 340.482 | 0.120 | 0.6480 | 0.6767 |
| 2000 | 186.698 | 79.861 | 266.558 | 0.300 | 0.5029 | 0.4157 |
| 2001 | 167.701 | 159.648 | 327.348 | 0.488 | 0.5026 | 0.3512 |
| 2002 | 243.363 | 43.250 | 286.613 | 0.151 | 0.6295 | 0.4523 |
| 2003 | 533.382 | 118.276 | 651.658 | 0.182 | 0.9158 | 0.6678 |
| 2004 | 405.706 | 110.066 | 515.772 | 0.213 | 0.8766 | 0.6245 |
| 2005 | 536.383 | 42.614 | 578.998 | 0.074 | 1.1240 | 0.8592 |
| 2006 | 402.464 | 22.031 | 424.496 | 0.052 | 1.1288 | 0.8932 |
| 2007 | 254.469 | 48.904 | 303.373 | 0.161 | 1.2094 | 0.9842 |
| 2008 | 391.325 | 75.650 | 466.976 | 0.162 | 1.3340 | 1.2430 |
| 2009 | 411.469 | 270.788 | 682.256 | 0.397 | 1.4220 | 1.3625 |
| 2010 | 432.522 | 188.472 | 620.994 | 0.304 | 1.1899 | 1.2381 |
| 2011 | 390.628 | 170.216 | 560.844 | 0.304 | 1.1962 | 1.0964 |
| 2012 | 338.672 | 147.576 | 486.248 | 0.304 | 0.9370 | 0.9714 |
| 2013 | 249.475 | 2.629 | 252.103 | 0.010 | 0.9644 | 1.0172 |
| 2014 | 136.620 | 38.534 | 175.154 | 0.220 | 0.8095 | 0.6075 |
| 2015 | 190.385 | 1.230 | 191.615 | 0.006 | 0.8131 | 0.5455 |

Table 11.7. RBC calculations for Mirror Dory East. $C_{targ}$ and $CPUE_{targ}$ relate to the period 1986-1995, $CPUE_{Lim}$ is 20% of the $B_0$ proxy, and $\overline{\boldsymbol{CPUE}}$ is the average catch rate over the last four years. The RBC calculation does not account for predicted discards of predicted State catches. Wt_Discard is the weighted average discards from the last four years, as with Equ (15).

| | |
|---:|---:|
| Ref_Year | 1986 - 1995 |
| CE_Targ | 1.1511 |
| CE_Lim | 0.4796 |
| CE_Recent | 0.881 |
| Wt_Discard | 11.229 |
| Scaling | 0.5977 |
| Last Year's TAC | 437 |
| $C_{targ}$ | 372.739 |
| **RBC** | **222.781** |

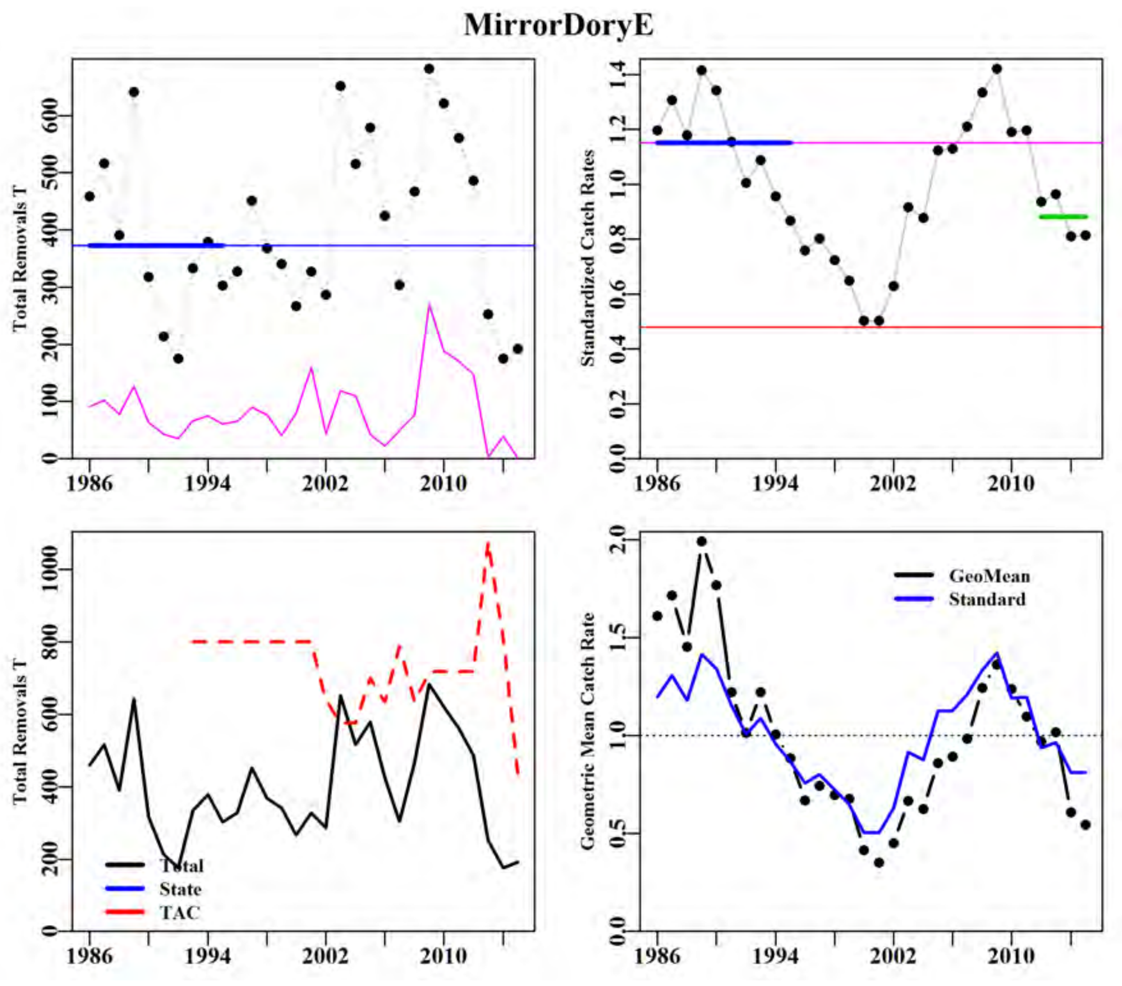


Figure 11.1. Mirror Dory. Top left is the total removals with the fine line illustrating the target catch. Top right represents the standardized catch rates with the upper fine line representing the target catch rate and the lower line the limit catch rate. Thickened lines represents the reference period for catches, catch rates, and the recent average catch rate.

### 11.4.2 *Mirror Dory East – Discards*

Following instructions from the RAG an alternative Tier 4 analysis for the eastern Mirror Dory was performed to determine the impact of recent high levels of discard rate on the catch rates. In this case there was a marked effect, especially in some of the last eight years, the last four are used in the estimate of current CPUE. The effect of this is to alter the estimate of the RBC from about 465 t to 497 t. This enables the reduction to the RBC due to the increased discard levels to be accounted for in the calculation of the TAC.

Table 11.8. Mirror Dory data for the TIER 4 calculations. Total is the sum of Discards, State, Non Trawl, SEF2, and ECDW catches. All values in Tonnes. StandCE is the standardized catch rate for all Zones 10 to 50 in depths 0 – 1000m (Haddon, 2013). GeoMean is the geometric mean catch rates. (D/C) +1 is the multiplier used with StandCE to generate DiscCE (see the Methods).

| Year | Catch | Discards | Total | (D/C)+1 | StandCE | DiscCE | GeoMean | TAC |
|---|---|---|---|---|---|---|---|---|
| 1986 | 367.985 | 91.091 | 459.076 | 1.2475 | 1.1970 | 1.1849 | 1.6108 | |
| 1987 | 413.571 | 102.375 | 515.946 | 1.2475 | 1.3068 | 1.2936 | 1.7147 | |
| 1988 | 313.237 | 77.539 | 390.776 | 1.2475 | 1.1788 | 1.1668 | 1.4520 | |
| 1989 | 513.736 | 127.170 | 640.906 | 1.2475 | 1.4157 | 1.4013 | 1.9914 | |
| 1990 | 254.380 | 62.969 | 317.349 | 1.2475 | 1.3416 | 1.3280 | 1.7676 | |
| 1991 | 170.954 | 42.318 | 213.272 | 1.2475 | 1.1554 | 1.1437 | 1.2213 | |
| 1992 | 140.441 | 34.765 | 175.206 | 1.2475 | 1.0048 | 0.9946 | 1.0146 | |
| 1993 | 267.091 | 66.116 | 333.207 | 1.2475 | 1.0881 | 1.0771 | 1.2209 | 800 |
| 1994 | 303.620 | 75.158 | 378.777 | 1.2475 | 0.9552 | 0.9455 | 1.0060 | 800 |
| 1995 | 242.777 | 60.097 | 302.874 | 1.2475 | 0.8680 | 0.8592 | 0.8853 | 800 |
| 1996 | 262.435 | 64.963 | 327.398 | 1.2475 | 0.7589 | 0.7512 | 0.6702 | 800 |
| 1997 | 361.397 | 89.460 | 450.857 | 1.2475 | 0.8024 | 0.7943 | 0.7430 | 800 |
| 1998 | 291.383 | 76.246 | 367.629 | 1.2617 | 0.7236 | 0.7243 | 0.6959 | 800 |
| 1999 | 299.692 | 40.790 | 340.482 | 1.1361 | 0.6480 | 0.5841 | 0.6767 | 800 |
| 2000 | 186.698 | 79.861 | 266.558 | 1.4278 | 0.5029 | 0.5697 | 0.4157 | 800 |
| 2001 | 167.701 | 159.648 | 327.348 | 1.9520 | 0.5026 | 0.7784 | 0.3512 | 800 |
| 2002 | 243.363 | 43.250 | 286.613 | 1.1777 | 0.6295 | 0.5883 | 0.4523 | 640 |
| 2003 | 533.382 | 118.276 | 651.658 | 1.2217 | 0.9158 | 0.8878 | 0.6678 | 576 |
| 2004 | 405.706 | 110.066 | 515.772 | 1.2713 | 0.8766 | 0.8842 | 0.6245 | 576 |
| 2005 | 536.383 | 42.614 | 578.998 | 1.0794 | 1.1240 | 0.9627 | 0.8592 | 700 |
| 2006 | 402.464 | 22.031 | 424.496 | 1.0547 | 1.1288 | 0.9447 | 0.8932 | 634 |
| 2007 | 254.469 | 48.904 | 303.373 | 1.1922 | 1.2094 | 1.1441 | 0.9842 | 788 |
| 2008 | 391.325 | 75.650 | 466.976 | 1.1933 | 1.3340 | 1.2631 | 1.2430 | 634 |
| 2009 | 411.469 | 270.788 | 682.256 | 1.6581 | 1.4220 | 1.8708 | 1.3625 | 718 |
| 2010 | 432.522 | 188.472 | 620.994 | 1.4358 | 1.1899 | 1.3555 | 1.2381 | 718 |
| 2011 | 390.628 | 170.216 | 560.844 | 1.4358 | 1.1962 | 1.3627 | 1.0964 | 718 |
| 2012 | 338.672 | 147.576 | 486.248 | 1.4358 | 0.9370 | 1.0674 | 0.9714 | 718 |
| 2013 | 249.475 | 2.629 | 252.103 | 1.0105 | 0.9644 | 0.7733 | 1.0172 | 1077 |
| 2014 | 136.620 | 38.534 | 175.154 | 1.2821 | 0.8095 | 0.8187 | 0.6075 | 808 |
| 2015 | 190.385 | 1.230 | 191.615 | 1.0065 | 0.8131 | 0.6493 | 0.5455 | 437 |

Discards make up approximately 19.84 % of the catch over the 1998-2006 period, but this is an estimate for the combined east and west. According to an earlier RAG decision this value multiplied by proportion of catch taken in the east, was used to estimate the discards for the years 1986 – 1997.

Table 11.9. RBC calculations for Mirror Dory East, with Discards. $C_{targ}$ and $CPUE_{targ}$ relate to the period 1986-1995, $CPUE_{Lim}$ is 20% of the $B_0$ proxy, and $\overline{\boldsymbol{CPUE}}$is the average catch rate over the last four years. The RBC calculation does not account for predicted discards of predicted State catches. Wt_Discard is the weighted average discards from the last four years, as with Equ (15).

| | |
|---|---|
| Ref_Year | 1986-1995 |
| CE_Targ | 1.1329 |
| CE_Lim | 0.472 |
| CE_Recent | 0.8236 |
| Wt_Discard | 21.121 |
| Scaling | 0.5319 |
| Last Year's TAC | 437 |
| $C_{targ}$ | 372.739 |
| **RBC** | **198.278** |

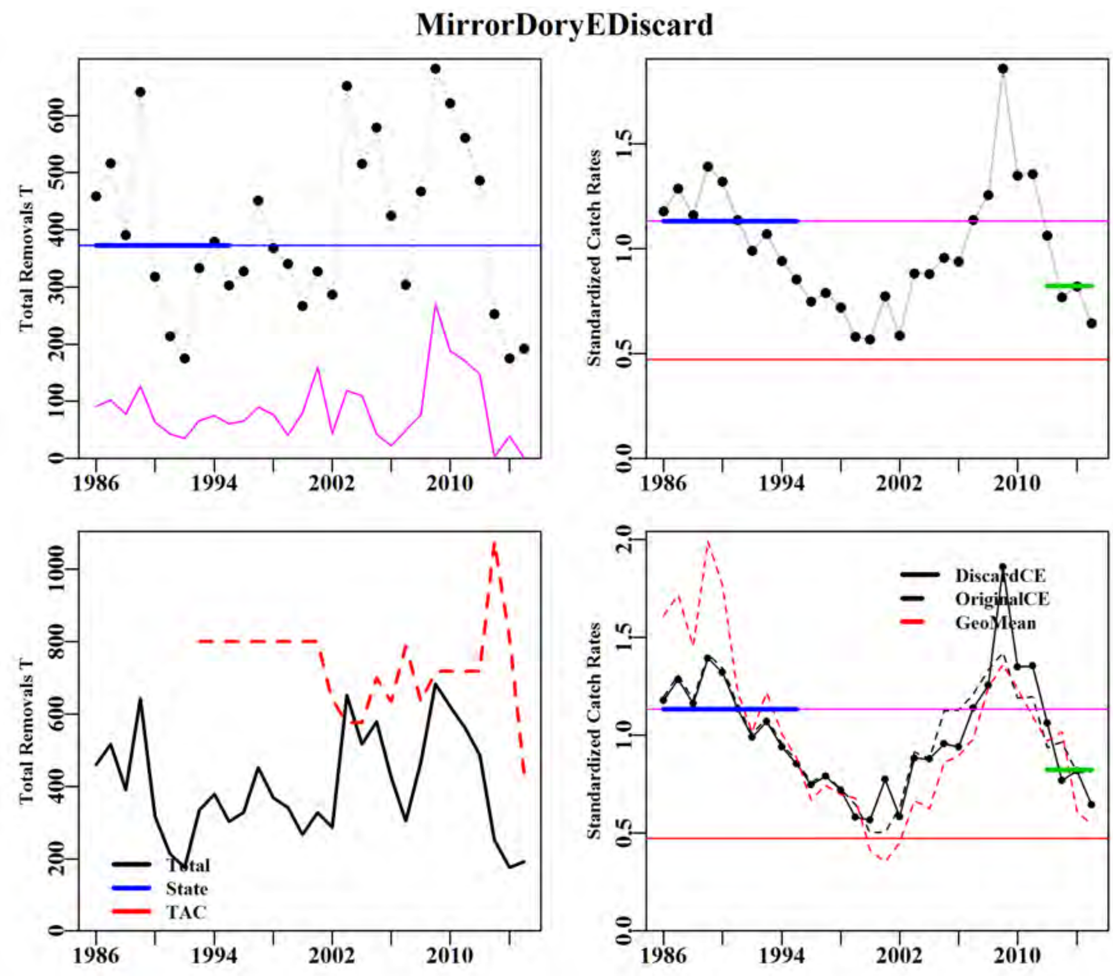


Figure 11.2. Mirror Dory. Top left is the total removals with the fine line illustrating the target catch. Top right represents the standardized catch rates with the upper fine line representing the target catch rate and the lower line the limit catch rate. Thickened lines represents the reference period for catches, catch rates, and the recent average catch rate.

### 11.4.3 *Dory West (DOM – 37264003 – Z. nebulosus)*

Table 11.10. Mirror Dory West data for the TIER 4 calculations. Total is the sum of Discards, State, Non Trawl and SEF2 catches. All values in Tonnes. CE is the standardized catch rate for Zones 40 to 50 in depths 0 – 600m (Sporcic & Haddon, 2016). GeoMean is the geometric mean catch rates. Discards are estimates from 1998 to present. The ratio of discards to catch over the 1998 – 2006 period was used to estimate the discards between 1986 and 1997, the proportion of which is the PDiscard.

| Year | Catch | Discards | Total | State | PDiscard | CE | GeoMean |
|---|---|---|---|---|---|---|---|
| 1986 | 5.911 | 1.463 | 7.374 | | 0.198 | 2.4182 | 37.8926 |
| 1987 | 12.44 | 3.079 | 15.519 | | 0.198 | 1.6631 | 36.0604 |
| 1988 | 12.01 | 2.973 | 14.983 | | 0.198 | 1.3527 | 37.1811 |
| 1989 | 8.919 | 2.208 | 11.127 | | 0.198 | 1.6690 | 45.3237 |
| 1990 | 7.989 | 1.977 | 9.966 | | 0.198 | 1.1784 | 37.8770 |
| 1991 | 10.247 | 2.536 | 12.783 | | 0.198 | 0.8254 | 17.7768 |
| 1992 | 7.377 | 1.826 | 9.204 | | 0.198 | 0.6867 | 14.5194 |
| 1993 | 14.753 | 3.652 | 18.404 | | 0.198 | 0.7900 | 16.7714 |
| 1994 | 14.844 | 3.675 | 18.519 | 1.414 | 0.198 | 0.7171 | 14.7748 |
| 1995 | 30.848 | 7.636 | 38.484 | 3.632 | 0.198 | 0.9072 | 15.3638 |
| 1996 | 93.491 | 23.143 | 116.634 | 7.634 | 0.198 | 1.2887 | 23.4103 |
| 1997 | 120.196 | 29.753 | 149.949 | 7.365 | 0.198 | 1.3047 | 24.4653 |
| 1998 | 146.909 | 38.442 | 185.351 | 9.046 | 0.207 | 1.2403 | 27.5790 |
| 1999 | 80.762 | 10.992 | 91.754 | 7.835 | 0.120 | 0.7984 | 17.1138 |
| 2000 | 29.391 | 12.572 | 41.964 | 1.512 | 0.300 | 0.4514 | 7.8627 |
| 2001 | 138.097 | 131.465 | 269.562 | 4.655 | 0.488 | 0.7926 | 14.1812 |
| 2002 | 300.692 | 53.438 | 354.13 | 11.966 | 0.151 | 1.1652 | 24.8208 |
| 2003 | 203.644 | 45.157 | 248.801 | 18.918 | 0.181 | 0.9774 | 20.6958 |
| 2004 | 221.538 | 60.102 | 281.64 | 37.575 | 0.213 | 0.9851 | 20.4507 |
| 2005 | 126.623 | 10.06 | 136.682 | 14.026 | 0.074 | 0.7727 | 15.1798 |
| 2006 | 88.39 | 4.839 | 93.228 | 15.384 | 0.052 | 0.6580 | 15.7843 |
| 2007 | 81.341 | 15.632 | 96.973 | 6.957 | 0.161 | 0.5877 | 14.4232 |
| 2008 | 72.097 | 13.938 | 86.034 | 3.439 | 0.162 | 0.6699 | 16.1944 |
| 2009 | 149.818 | 98.595 | 248.414 | 9.372 | 0.397 | 1.0251 | 20.0140 |
| 2010 | 200.256 | 87.261 | 287.517 | 3.807 | 0.303 | 1.2380 | 26.4545 |
| 2011 | 177.612 | 77.395 | 255.007 | 1.904 | 0.304 | 0.9415 | 21.5957 |
| 2012 | 82.634 | 36.008 | 118.642 | 1.195 | 0.303 | 0.5561 | 16.6445 |
| 2013 | 64.532 | 0.68 | 65.212 | 1.251 | 0.010 | 0.7475 | 22.1155 |
| 2014 | 77.931 | 0.821 | 78.753 | 0.050 | 0.010 | 0.8163 | 22.8337 |
| 2015 | 71.06 | 0.459 | 71.519 | | 0.006 | 0.7759 | 18.7325 |

Discards make up approximately 19.84 % of the catch over the 1998-2006 period, used for estimating discard rates for 1986 – 1997. Discard rates for 2013 – 2015 are draft estimates.

Table 11.11. RBC calculations for Mirror Dory West. $C_{targ}$ and $CPUE_{targ}$ relate to the period 1996-2005, $CPUE_{Lim}$ is 20% of the $B_0$ proxy, and $\overline{CPUE}$ is the average catch rate over the last four years. The RBC calculation does not account for predicted discards of predicted State catches. Wt_Discard is the weighted average discards from the last four years, as with Equ (15).

| | |
|---|---|
| Ref_Year | 1996-2005 |
| CE_Targ | 0.9776 |
| CE_Lim | 0.4074 |
| CE_Recent | 0.7240 |
| Wt_Discard | 2.955 |
| Scaling | 0.5551 |
| Last Year's TAC | 437 |
| $C_{targ}$ | 187.647 |
| **RBC** | **104.171** |

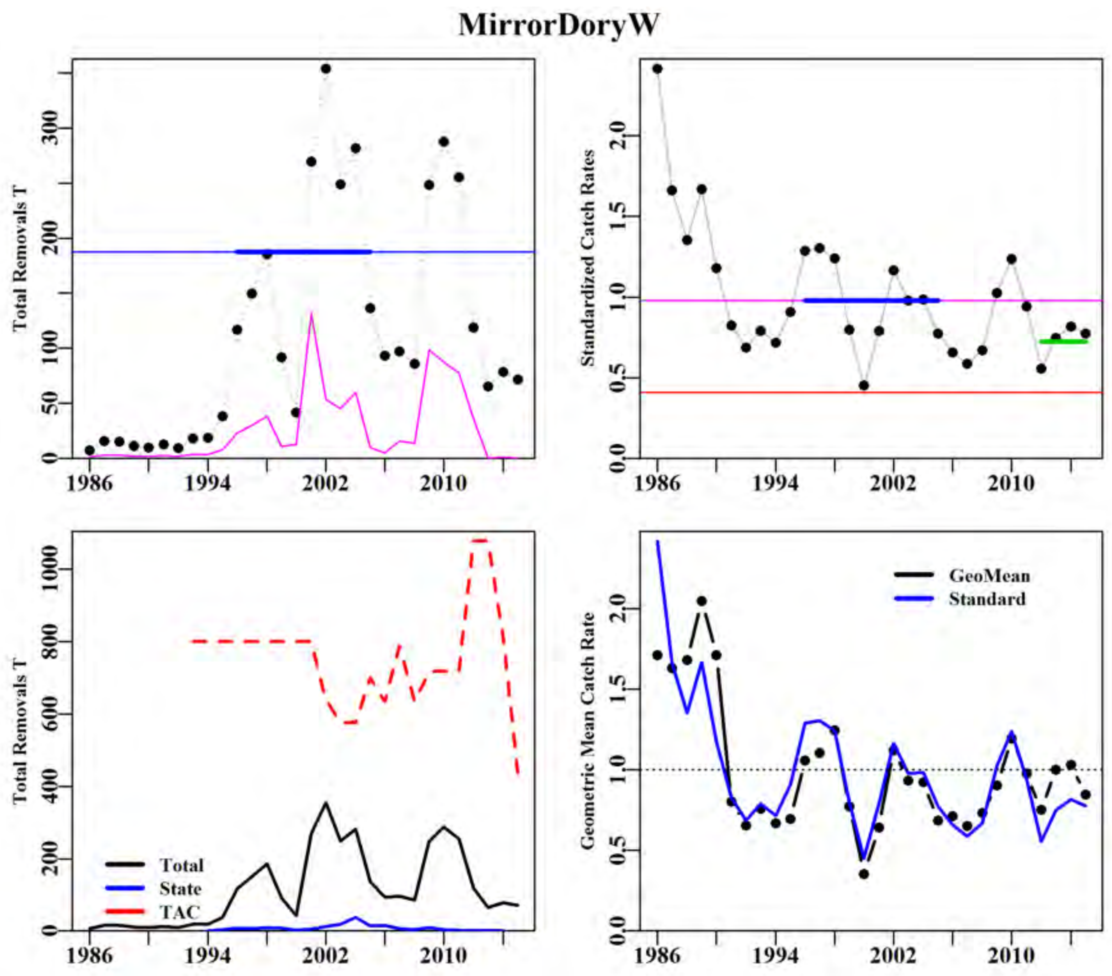


Figure 11.3. Mirror Dory. Top left is the total removals with the fine line illustrating the target catch. Top right represents the standardized catch rates with the upper fine line representing the target catch rate and the lower line the limit catch rate. Thickened lines represents the reference period for catches, catch rates, and the recent average catch rate.

### 11.4.4 *Western Gemfish (GEM – 37439002 – Rexea solandri)*

Western Gemfish occurs both in the GAB and in the SESSF, but only the SESSF fishery component has a set TAC and quota. This year a Tier 1 assessment is being developed for the Western Gemfish stock but that is currently defined as including those fish in the GAB and those taken in SESSF Zone 50. A specific mechanism for converting the outcome of that Tier 1 assessment into a quota setting RBC for the SESSF has still to be agreed upon. In the meantime, to ensure that TAC setting is possible a Tier 4 analysis of the western gemfish catches taken in the SESSF is presented here. The data (Table 11.12) can be used to conduct both an ordinary Tier 4 analysis as well as the Tier 4 including discards which modifies the CPUE time-series in an attempt to include discarded fish (Table 11.13; Figure 11.4 and Figure 11.5).

Table 11.12. Western Gemfish data from SESSF zones 40 and 50 for the TIER 4 calculations. Total is the sum of Discards, State, Non Trawl and SEF2 catches. All values in Tonnes. CE is the standardized catch rate for Zones 40 to 50 in depths 0 – 600m (Sporcic & Haddon, 2016). GeoMean is the geometric mean catch rates. Both scaled to a mean of 1.0 between 1992 – 2015. Discards are estimates from 1998 to 2006. The ratio of discards to catch over the 1998 – 2006 period was used to estimate the discards between 1992 and 1997, the proportion of which is the PDiscard. (D/C) +1 is the multiplier used with StandCE to generate DiscCE (see the Methods).

| Year | Catch | Discards | Total | (D/C)+1 | StandCE | DiscCE | GeoMean |
|---|---|---|---|---|---|---|---|
| 1992 | 84.384 | 3.820 | 88.204 | 1.0453 | 1.2524 | 1.0099 | 1.6518 |
| 1993 | 90.489 | 4.097 | 94.586 | 1.0453 | 1.2064 | 0.9728 | 1.6323 |
| 1994 | 153.086 | 6.930 | 160.016 | 1.0453 | 1.2989 | 1.0474 | 1.5973 |
| 1995 | 146.940 | 6.652 | 153.592 | 1.0453 | 1.1484 | 0.9261 | 1.1815 |
| 1996 | 228.378 | 10.339 | 238.717 | 1.0453 | 1.2583 | 1.0146 | 1.3247 |
| 1997 | 288.838 | 13.076 | 301.914 | 1.0453 | 1.1212 | 0.9041 | 1.3063 |
| 1998 | 185.314 | 11.996 | 197.310 | 1.0647 | 1.1877 | 0.9756 | 1.3011 |
| 1999 | 270.981 | 4.995 | 275.976 | 1.0184 | 1.1319 | 0.8893 | 1.2641 |
| 2000 | 348.854 | 29.965 | 378.818 | 1.0859 | 1.2205 | 1.0225 | 1.2330 |
| 2001 | 253.121 | 8.990 | 262.111 | 1.0355 | 0.9905 | 0.7912 | 1.1963 |
| 2002 | 138.694 | 9.120 | 147.814 | 1.0658 | 0.7553 | 0.6210 | 0.7003 |
| 2003 | 177.360 | 12.574 | 189.934 | 1.0709 | 0.8767 | 0.7243 | 1.0991 |
| 2004 | 149.555 | 8.905 | 158.461 | 1.0595 | 0.8519 | 0.6963 | 0.7777 |
| 2005 | 156.447 | 1.580 | 158.027 | 1.0101 | 0.9010 | 0.7021 | 1.0433 |
| 2006 | 159.639 | 0.545 | 160.184 | 1.0034 | 0.7283 | 0.5638 | 0.8847 |
| 2007 | 99.359 | 5.119 | 104.479 | 1.0515 | 0.6982 | 0.5664 | 0.7357 |
| 2008 | 86.396 | 9.006 | 95.401 | 1.1042 | 0.7974 | 0.6793 | 0.7403 |
| 2009 | 87.488 | 51.008 | 138.496 | 1.5830 | 0.9010 | 1.1003 | 0.6387 |
| 2010 | 121.226 | 31.837 | 153.064 | 1.2626 | 0.9421 | 0.9177 | 0.6263 |
| 2011 | 79.705 | 120.438 | 200.143 | 2.5110 | 0.9807 | 1.8997 | 0.5562 |
| 2012 | 59.962 | 28.486 | 88.448 | 1.4751 | 0.9122 | 1.0381 | 0.5292 |
| 2013 | 43.768 | 99.628 | 143.396 | 3.2763 | 0.7967 | 2.0138 | 0.5489 |
| 2014 | 73.430 | 23.383 | 96.812 | 1.3184 | 1.1517 | 1.1714 | 0.8679 |
| 2015 | 50.364 | 78.093 | 128.458 | 2.5506 | 0.8905 | 1.7523 | 0.5634 |

Discards make up approximately 4.3 % of the catch over the 1998-2006 period, used for estimating discard rates for 1986 – 1997. Discard rates for 2015 are draft estimates.

Table 11.13. RBC calculations for Western Gemfish. $C_{targ}$ and $CPUE_{targ}$ relate to the period 1992-2001, $CPUE_{Lim}$ is 20% of the $B_0$ proxy, and $\overline{CPUE}$ is the average catch rate over the last four years. The RBC calculation does not account for predicted discards of predicted State catches. Wt_Discard is the weighted average discards from the last four years, as with Equ (15).

| | With Discards | Without Discards |
|---|---|---|
| Ref_Year | 1992 – 2001 | 1992 – 2001 |
| CE_Targ | 0.9554 | 1.1816 |
| CE_Lim | 0.3981 | 0.4923 |
| CE_Recent | 1.4939 | 0.9378 |
| Wt_Discard | 63.068 | 63.068 |
| Scaling | 1.9663 | 0.6462 |
| Last Year's TAC | 247 | 247 |
| $C_{targ}$ | 215.124 | 215.124 |
| **RBC** | **422.997** | **139.024** |

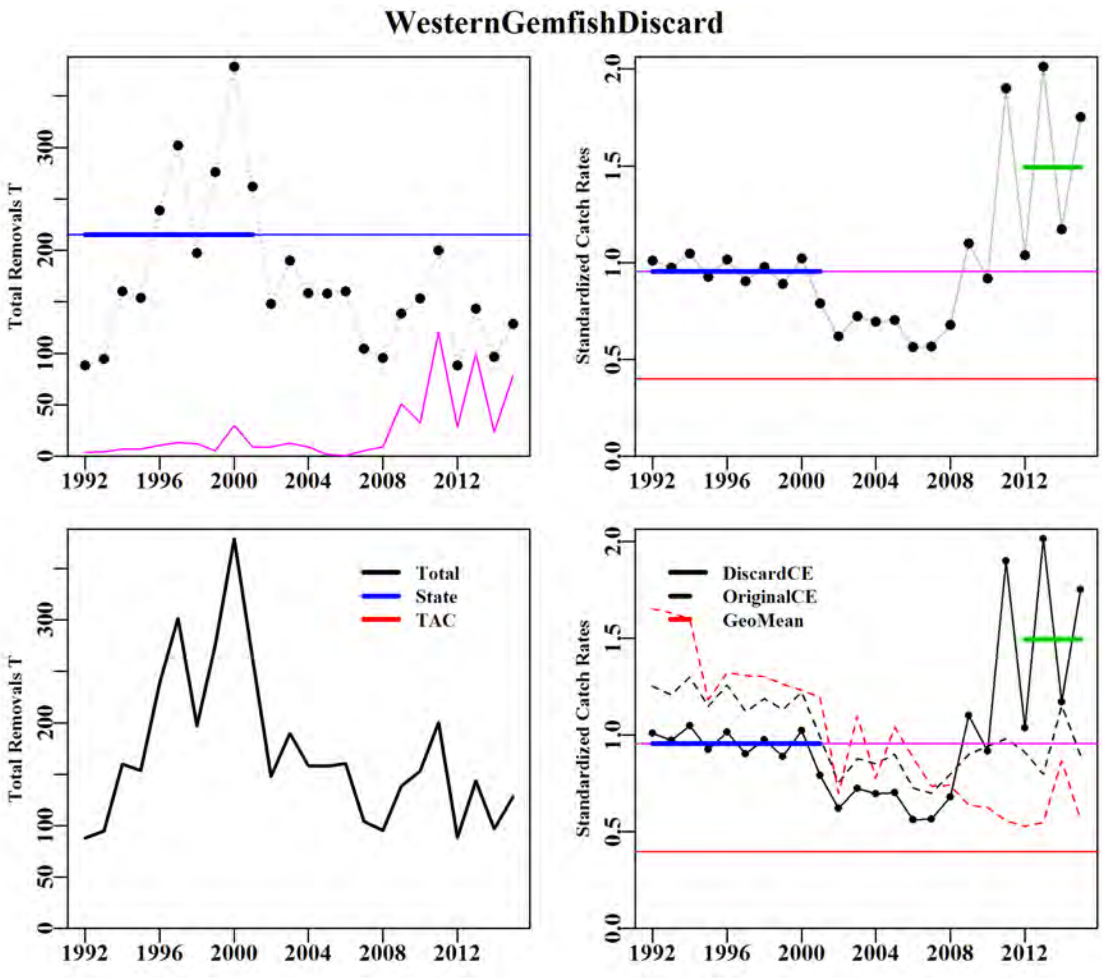


Figure 11.4. Western Gemfish (Zones 40 and 50) with inclusion of discards (the fine pink line in the top left graph). Top left is the total removals with the fine line illustrating the target catch. Top right represents the standardized catch rates with the upper fine line representing the target catch rate and the lower line the limit catch rate. Thickened lines represents the reference period for catches, catch rates, and the recent average catch rate.

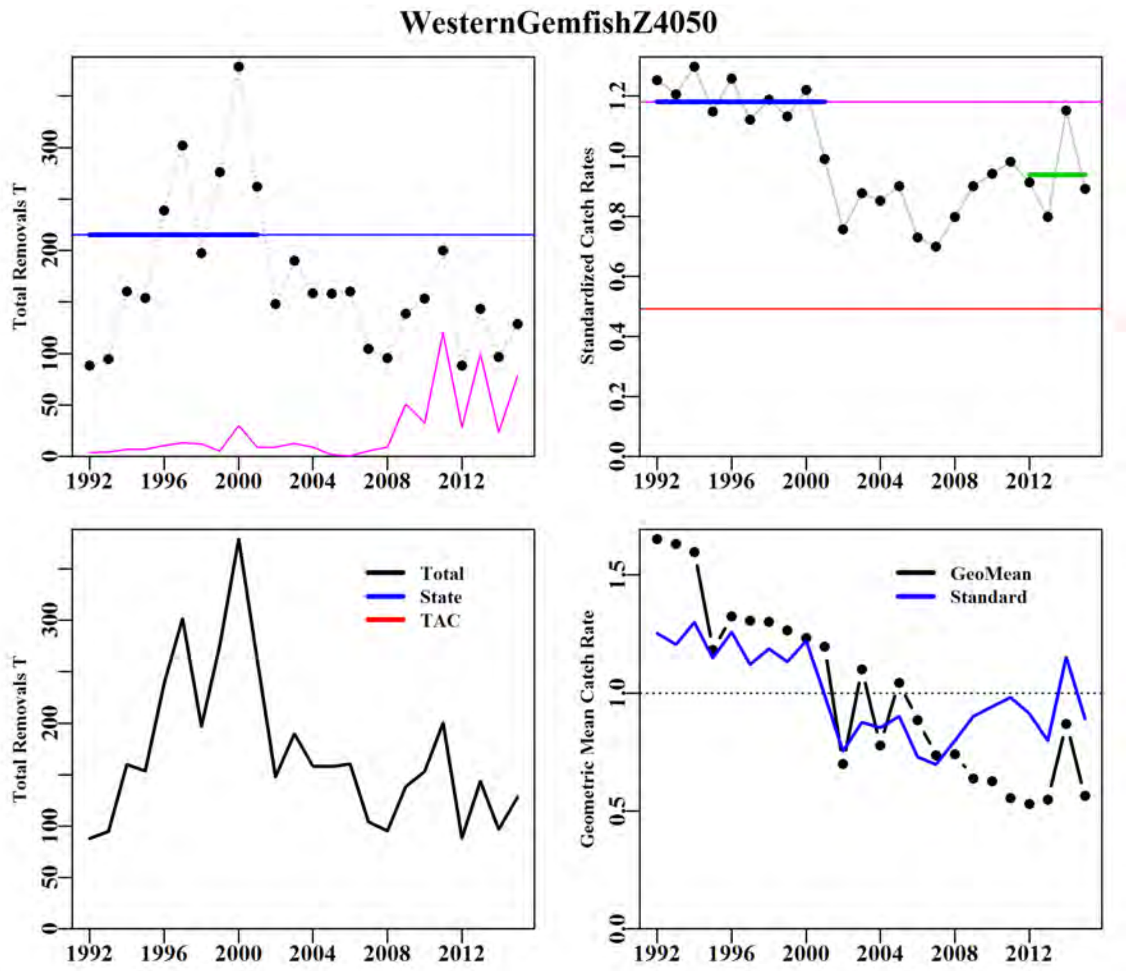


Figure 11.5. Western Gemfish (Zones 40 and 50) without the inclusion of discards (the fine pink line in the top left graph). Top left is the total removals with the fine line illustrating the target catch. Top right represents the standardized catch rates with the upper fine line representing the target catch rate and the lower line the limit catch rate. Thickened lines represents the reference period for catches, catch rates, and the recent average catch rate.

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# 12. Blue-Eye (*Hyperoglyphe antarctica*) Tier 4 Analysis using Catch-per-Hook for Auto-Line and Drop-Line from 1997 – 2015

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## *12.1 Executive Summary*

The Tier 4 analysis for Blue-Eye (*Hyperoglyphe antarctica*) is based on the CPUE, as catch-per-hook, from SESSF zones 20 – 50 but the catches that go towards generating the target catch include all areas and methods except the GAB. This is a reflection of the hypothesis that the Blue-Eye in the GAB constitute a separate stock. However, currently in the GHT fishery, the Blue-Eye quota also applies in the GAB, so there is some confusion over the assessment and management details that may require attention.

The effect of the CPUE standardization is, as expected, to reduce the variation exhibited by the nominal catch rates seen in the fishery. However, in more recent years there still remains some relatively large rises and falls in catch rate over relatively short periods. This seems likely to reflect the fact that there are very few Auto-Line vessels that make large contributions to the fishery so if they alter their fishing patterns (perhaps in response to whale depredation or some other factor) then large changes in catch rates can occur. Such large changes over short periods are certainly not a direct reflection of equivalent changes in the stock size in such a long-lived species. For greater stability in the RBC predicted from the Tier 4 analysis it might be necessary to increase the number of years over which the more recent CPUE is averaged for comparison with the target.

The RBC from the analysis based on catch-per-hook catch rates is now 526 t.

This is a relatively large change in the RBC from last year, which is a reflection of the potential behaviour of the Tier 4 when CPUE is recovering from a relatively low period. The Tier 4 uses the last four years of the time-series to compare with the CPUE observed in the target period. In the most recent year, even though the CPUE has dropped from 2014, the 2015 figure remains much higher than the 2010 value that it has replaced in the four-year average, hence the recent increase. If such variation is deemed undesirable this too could be smoothed out by increasing the number of years over which to take the recent average.

## *12.2 Introduction*

Blue-Eye trevalla (*Hyperoglyphe antarctica*) is currently managed as a single stock but its stock status is difficult to assess because, as a species, its adults are widely but patchily distributed, although its juveniles stages are widely dispersed. Not only is it patchily distributed but the fishery differs markedly by area through the application of different methods and histories of exploitation. The differences in exploitation history along with sampling different areas in different years may have been sufficient to have led to the appearance of heterogeneity in the biological characteristics of different populations. It is certainly the case that there is little consistency between consecutive years in the age structure and length structure of samples (Figure 12.1). Expected cohort progression is difficult or impossible to follow using current data. This lack of consistency has thwarted previous attempts at applying a Tier 1 integrated assessment to Blue-Eye and has made the application of the Tier 3 catch-curve approach equally problematical (Fay, 2007a, b). Such spatial heterogeneity has recently been reviewed and further evidence presented, which supported the hypothesis that spatially structured differences existed between Blue-Eye populations around the south-east of Australia (Williams *et al*., 2016).

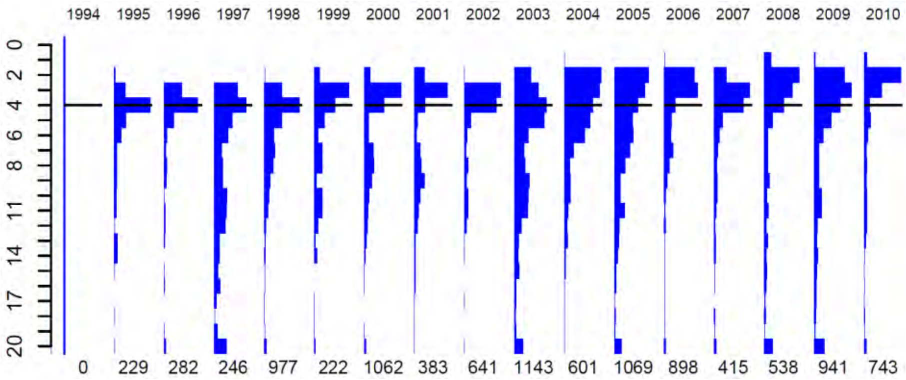


Figure 12.1. Age distributions sampled from the catches of Blue-Eye (*Hyperoglyphe antarctica*;) for the years 1995 – 2010 (Thomson *et al*, 2016), illustrating the variation between years. The sample sizes in the bottom row of numbers should be sufficient to provide a good representation if the stock were homogeneous in its properties. Blue-Eye shows inconsistencies every year with annual progressions of year classes being vague and ephemeral at best.

The Blue-Eye fishery has a relatively long history especially around Tasmania, however, while there is a long history of catches by trawl the majority of the catch has always been taken by line-methods (generally less than 10% of all catches have been taken by trawl since 2003; Table 12.1). Unfortunately, fisheries data from line methods, in the GHT fishery, only began to be collected comprehensively from late in 1997 onwards (Table 12.1). In addition, in 1997 Auto-Line fishing was introduced as an accepted method in the SESSF although very little fishing was conducted in 1997 and only in the last two months (Table 12.1, Figure 12.2). Auto-line related effort and catches increased from 2002 – 2003 onwards at the same time that drop-line records and catches began to decline (Figure 12.2; Table 12.1).

In the two years, 2013 – 2014, the drop-line catches dropped to 10 t or less while auto-line catches continue to dominate the fishery. However, in 2015, drop-line catches increased again to about 47 t, while auto-line catches dropped by about 30 t from the previous year (Table 12.1; Figure 12.2).

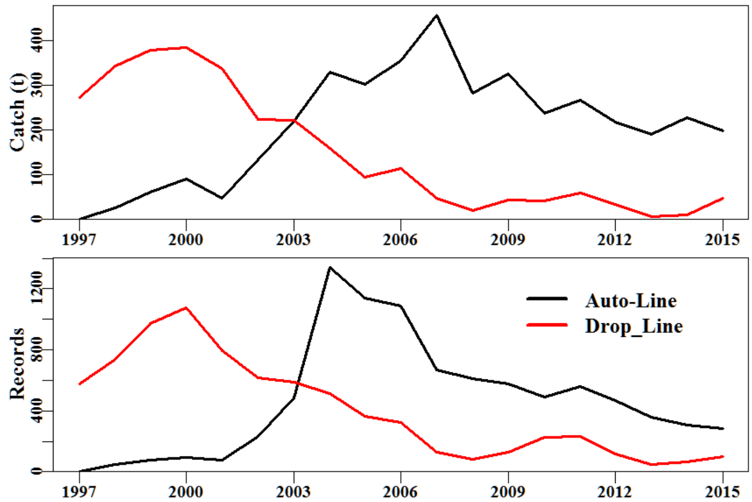


Figure 12.2. The trends in the number of records and the catches of Blue-Eye from 1997 – 2015 by the two main line methods (Table 12.1); most catches are now taken by auto-line.

Table 12.1. The number of records and catches per year for auto-line, drop-line, and trawl vessels reporting catches of Blue-Eye Trevalla from 1997 – 2015. Data filters were to restrict the fisheries included to SET, GAB, SEN, GHT, SSF, SSG, and SSH. Methods were limited to AL, DL, TW, and TDO. Finally only CAAB code = 37445001 that identifies *Hyperoglyphe antarctica* were included.

| Year | AL Catch | AL Record | DL Catch | DL Record | TW Catch | TW Record |
|---|---|---|---|---|---|---|
| 1997 | 0.267 | 3 | 271.942 | 575 | 104.567 | 1500 |
| 1998 | 27.253 | 50 | 343.505 | 738 | 82.074 | 1398 |
| 1999 | 61.590 | 77 | 377.032 | 971 | 100.329 | 1712 |
| 2000 | 90.932 | 93 | 384.409 | 1075 | 95.042 | 1893 |
| 2001 | 47.884 | 76 | 335.873 | 797 | 90.218 | 1809 |
| 2002 | 134.067 | 234 | 223.074 | 619 | 67.998 | 1548 |
| 2003 | 219.676 | 487 | 221.649 | 587 | 28.918 | 1210 |
| 2004 | 329.608 | 1338 | 158.491 | 515 | 48.767 | 1558 |
| 2005 | 301.303 | 1142 | 93.779 | 363 | 42.969 | 1169 |
| 2006 | 354.582 | 1087 | 114.639 | 327 | 66.105 | 924 |
| 2007 | 455.097 | 667 | 46.011 | 127 | 38.321 | 834 |
| 2008 | 281.384 | 612 | 15.549 | 76 | 36.046 | 806 |
| 2009 | 325.893 | 578 | 30.158 | 105 | 39.386 | 618 |
| 2010 | 236.620 | 488 | 42.023 | 225 | 43.480 | 647 |
| 2011 | 267.318 | 562 | 59.381 | 230 | 23.268 | 624 |
| 2012 | 217.816 | 465 | 34.107 | 119 | 10.792 | 424 |
| 2013 | 190.515 | 360 | 7.762 | 47 | 22.893 | 358 |
| 2014 | 227.041 | 305 | 10.242 | 68 | 29.381 | 340 |
| 2015 | 198.232 | 282 | 46.711 | 92 | 25.128 | 301 |

### 12.2.1 *Current Assessment and Management*

When the Harvest Strategy Policy was implemented in 2007 (DAFF, 2007) a Tier 4 assessment was used to provide advice on annual recommended biological catch (RBC) levels for Blue-Eye instead of a Tier 1 assessment (after both using a Tier 1 statistical catch-at-age model or a Tier 3 catch-curve approach were rejected; Fay, 2007a, b). The Tier 4 uses standardized CPUE as an empirical performance measure of relative abundance that is assumed to be representative of the impact of catches on the whole stock. The average CPUE across a target period is selected by the RAG to provide the target reference point, which implies a limit CPUE reference point (0.41667 x target reference point; 0.41667 * 0.48 = 0.2) below which targeted fishing is to stop. In between the target and the limit there is a harvest control rule that reduces the RBC as CPUE declines. The appropriate characterization of CPUE is therefore very important in this fishery (Little et al., 2011; Haddon, 2014b).

By 2007 the auto-line fishery was already dominating the Blue-Eye fishery but the time-series of significant catches by that method was relatively short (only six years of useful data from 2002 – 2007; Table 12.1 and Figure 12.2). At that time some way of extending the time series was required to allow for the application of the Tier 4 methodology. Unfortunately, in the log-book records there was, and still is, often confusion in how to record effort (in terms of number of lines and number of hooks per line, or number of line drops, or length of main line, etc.) so it was not feasible at that time to estimate CPUE as a catch-per-hook. Instead CPUE was based on catch-per-record, which was equivalent to catch-per-day. The CPUE standardization conducted in 2008 on data from 1997 – 2007 (Haddon, 2009) was the first time that the catch-per-day data from drop-line was combined with auto-line catch-per-day data, with a justification presented to the RAGs. This was followed in 2009 by a summary of the separate auto-line and drop-line CPUE and a more detailed defence for their combination (Haddon, 2010). While it was appreciated that the two methods are very different, the intent of combining their data was always to extent the time series of line-caught Blue-Eye back to 1997 rather than 2002; a difficulty brought about by the switch from Drop-Line fishing to Auto-Line fishing (Figure 12.2). Despite the extension of the time-series, the first few Tier 4 Blue-Eye analyses had overlap between the reference period (1997 – 2006) and the CPUE grad over the final four years (2004 – 2007); it took three more years for that overlap to cease.

Table 12.2. Blue-Eye catch by SESSF Zone. Data filtered as for Table 12.1; restrict the fisheries included to SET, GAB, SEN, GHT, SSF, SSG, and SSH. Methods were limited to AL, DL, TW, and TDO. Only Zones 20, 30, 40, 50, 83, 84, 85, 91, and 92 have significant catches across all methods.

| Year | 10 | **20** | **30** | **40** | **50** | 60 | 70 | 82 | **83** | **84** | **85** | **91** | **92** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1997 | 3.345 | 89.408 | 92.819 | 83.255 | 86.142 | 3.270 | | | 0.030 | | 6.947 | 5.505 | |
| 1998 | 1.647 | 79.892 | 170.828 | 97.873 | 66.657 | 2.182 | | | 0.100 | | 4.129 | 1.590 | |
| 1999 | 2.593 | 75.715 | 225.703 | 91.531 | 86.576 | 1.386 | 0.507 | | | | 5.794 | 21.590 | 0.050 |
| 2000 | 0.985 | 45.090 | 275.350 | 128.207 | 95.664 | 0.045 | | | | 0.357 | 9.554 | 1.100 | 0.750 |
| 2001 | 0.264 | 28.590 | 239.652 | 100.091 | 59.845 | 0.022 | 0.188 | | 0.150 | 2.854 | 23.735 | 3.186 | 4.740 |
| 2002 | 0.489 | 39.713 | 180.660 | 75.521 | 76.950 | | 0.100 | | | 1.561 | 6.530 | 33.664 | 7.850 |
| 2003 | 1.318 | 52.263 | 153.536 | 125.145 | 43.361 | 0.039 | | | | 27.664 | 6.568 | 57.910 | 2.400 |
| 2004 | 0.222 | 73.836 | 148.512 | 113.323 | 63.726 | 0.742 | 0.400 | 0.946 | 12.713 | 61.283 | 54.842 | 5.045 | 0.180 |
| 2005 | 1.601 | 88.195 | 119.790 | 64.249 | 51.686 | 0.256 | 1.550 | 0.057 | 19.552 | 29.273 | 50.756 | 5.901 | 4.700 |
| 2006 | 1.732 | 69.824 | 157.401 | 83.899 | 41.087 | 0.930 | 2.420 | 0.169 | 31.511 | 43.438 | 89.189 | 10.375 | 2.500 |
| 2007 | 0.271 | 53.777 | 235.551 | 48.514 | 47.451 | 0.552 | 0.700 | | 29.876 | 107.069 | 15.594 | | |
| 2008 | 0.117 | 46.524 | 129.679 | 55.478 | 26.535 | 0.077 | | 0.015 | 28.943 | 32.267 | 13.346 | | |
| 2009 | 0.133 | 52.751 | 158.909 | 86.619 | 47.509 | 0.175 | 5.060 | | 1.633 | 15.369 | 15.415 | 10.515 | 1.350 |
| 2010 | 0.109 | 26.136 | 98.273 | 54.924 | 97.551 | 0.100 | 1.153 | | 6.549 | 9.532 | 15.929 | 7.932 | 3.935 |
| 2011 | 0.195 | 31.725 | 99.592 | 45.207 | 30.612 | 0.001 | 10.440 | | 20.576 | 40.692 | 14.159 | 33.689 | 23.081 |
| 2012 | 0.188 | 21.728 | 67.388 | 77.448 | 21.092 | | | | 8.428 | 9.736 | 3.752 | 42.938 | 10.017 |
| 2013 | 0.015 | 13.387 | 55.375 | 98.820 | 18.995 | 0.164 | 3.252 | | 0.465 | 16.158 | 13.250 | 1.131 | |
| 2014 | 0.005 | 4.218 | 91.440 | 91.993 | 26.010 | | | | 2.107 | 33.759 | 11.640 | 4.505 | 0.510 |
| 2015 | 0.012 | 9.793 | 75.974 | 73.330 | 26.186 | 0.546 | 0.750 | | 2.490 | 22.160 | 3.621 | 37.833 | 9.872 |
| Total | 15.240 | 902.563 | 2776.430 | 1595.427 | 1013.633 | 10.487 | 26.520 | 1.188 | 165.122 | 453.171 | 364.750 | 284.408 | 71.934 |

In 2013 the stock status for Blue-Eye (*Hyperoglyphe antarctica*) was assessed using a standardized CPUE time series from the combined auto-line and drop-line fisheries (catch-per-day), which combined data from the two methods from 8 zones (SESSF zone 10 – 50 with 83 – 85). In addition, the time series of CPUE for trawls, relating to SESSF zones 20 – 30 (eastern Bass Strait and eastern Tasmania) and 40 – 50 (western Tasmania and western Bass Strait) were examined, although these trawl fisheries only relate to a small fraction of the total fishery so less attention is given them (Haddon, 2014 a, b).

This Blue-Eye analysis based on catch-per-day was repeated in 2014 (using data to the end of 2013; Sporcic and Haddon, 2015), however, because of the unaccounted influences of factors such as the introduction of closures (both all methods and solely for auto-line), depredations by whales, and having to ignore significant catches taken with other new methods, these standardizations, and the Tier 4 analyses dependent upon them, were no longer considered to provide an adequate representation of trends within, and hence the status of, the Blue-Eye fishery.

One outcome was the decision to re-examine available data to determine if it would be possible to generate a CPUE series based upon some measure of catch-per-hook rather than catch-per-day. The use of catch-per-hook would allow more fine detail to be discerned and might provide a more informative time-series, although it was no longer guaranteed that data from the two methods would still be able to be combined. However, the length of time-series for auto-line is now sufficiently long that such a combination is now no longer a requirement (although selecting a new target period might still be an issue). This catch-per-hook analysis was conducted last year and repeated this year (Haddon, 2015, 2016), with the intent of making the analysis easily repeatable.

#### 12.2.2 *Tier 4 Assessments*

Blue-Eye (*Hyperoglyphe antarctica*) is a valuable and iconic species within the SESSF with most of the catches from 1997 – 2015 being taken in the Gillnet, Hook, and Trap fishery (GHT) using the Drop-Line and Auto-line methods.

The TIER 4 harvest control rules are the default procedure applied to species for which only limited information is available; specifically no reliable information on either current biomass levels or current exploitation rates. The Tier 4 assessment is the basis for an empirical harvest strategy that uses standardized catch rates as the fishery performance measure upon which a control rule is based (Little *et al*, 2011; Haddon, 2014b).

Ideally, in line with the notion of being more precautionary in the absence of information, the outcome from these analyses should be more conservative than those available from higher TIER analyses; this is now explicitly implemented by imposing a 15% discount factor on the RBC as a precautionary measure unless there are good reasons for not imposing such a discount on particular species. The application of the discount factor will occur unless RAGs generate explicit advice that alternative equivalent precautionary measures are in place (such as spatial or temporal closures) or that there is evidence of historical stability of the stock at current catch levels (AFMA, 2009).

In essence TIER 4 analyses require, as a minimum, a time series of total catches and of standardized catch rates.

## 12.3 Methods

#### 12.3.1 *Catch-per-Hook rather than Catch-per-Day*

##### *12.3.1.1 Catch-per-Day*

Estimating the catch-per-day is simple. The database records are first filtered as appropriate for the species, the method, the regions, the depths, etc, and then catch rates are set as the daily catches and these are log-transformed when included in the CPUE standardizations.

An apparent advantage of catch-per-day is that it is less sensitive to changes in the routines used when data recording. For example, as will be seen in the Drop-Line effort data the NLD = number of line drops field held the value of 1 infrequently up to about 2006 but after that date the proportion of such records in the data increased markedly. This has almost no effect on the trend taken from catch-per-day but introduced an enormous bias when using catch-per-hook, which meant the time series for catch-per-hook needed to cut shorter than when using catch-per-day.

On the other hand, this only seems to be an advantage and is really a weakness as it makes clear that using catch-per-day has the potential to obscure or hide major changes in fishing behaviour (at least the recording of it) through time.

*12.3.1.2 Catch-per-Hook*

Given that Auto-Line and Drop-Line fishing methods are very different it is not surprising that different approaches are needed to manipulate the database records to generate an acceptable time-series of total-hooks-set per day. An objective of this work was to produce a repeatable algorithm of steps required to obtain the total-hooks-set by method. The process of exploring the data to sort out such an algorithm for both Drop-Line and Auto-Line was described in detail in Haddon (2016). Here only the algorithms and the resulting standardizations will be presented.

The standardization methods have been described previously (Haddon, 2014a) but the essentials are provided here to allow this document to be stand-alone.

### 12.3.2 *Catch Rate Standardization*

*12.3.2.1 General Linear Modelling*

Where trawling was the method used, catch rates were kilograms per hour fished; except for the analyses later in this document all other methods were as catch-per-shot because the various line and net methods record effort in widely varying ways (the number of hooks, the number of lines of hooks, or the number of line drops etc; there is greater consistency in more recent years but still sufficient heterogeneity to make the use of catch-per-hook unreliable). Once the database records were amended for internal consistency, then analyses based on catch-per-hook were conducted. All catch rates were natural log-transformed and a General Linear Model was used rather than using a Generalized Linear Model with a log-link on the untransformed data; this has advantages in terms of normalizing the data while stabilizing the variance, which the Generalized Linear Model approach does not always achieve appropriately (Venables & Dichmont, 2004). The statistical models were variants on the form: LnCE = Year + Vessel + Month + DepthCategory + Zone + Daynight. In addition, there were interaction terms which could sometimes be fitted, such as Month:Zone or Month: DepthCategory, although with the use of finer spatial areas other simpler models or more idiosyncratic terms were occasionally used. Thus, the CPUE, conditioned on positive catches of the species of interest, was statistically modelled with a normal GLM on log-transformed CPUE data:

$$\text{Ln}\left(CPUE_i\right) = \alpha_0 + \alpha_1 x_{i,1} + \alpha_2 x_{i,2} + \sum_{j=3}^{N} \alpha_j x_{ij} + \varepsilon_i \tag{20}$$

where Ln($CPUE_i$) is the natural logarithm of the catch rate (either kg/h, kg/shot, or kg/hook) for the *i*-th shot, $x_{ij}$ are the values of the explanatory variables *j* for the *i*-th shot and the $\alpha_j$ are the coefficients for the *N* factors *j* to be estimated ($\alpha_0$ is the intercept, $\alpha_1$ is the coefficient for the first factor, *etc*.).

*12.3.2.2 The Year Effect*

For the lognormal model the expected back-transformed year effect involves a bias-correction to account for the log-normality; this then focuses on the mean of the distribution rather than the median:

$$CPUE_t = e^{\left(\gamma_t + \sigma_t^2/2\right)} \tag{21}$$

where $\gamma_t$ is the Year coefficient for year $t$ and $\sigma_t$ is the standard deviation of the log transformed data (obtained from the analysis). The year coefficients were all divided by the average of the year coefficients to simplify the visual comparison of catch rate changes:

$$CE_t = \frac{CPUE_t}{\left(\sum CPUE_t\right)/n} \tag{22}$$

where $CPUE_t$ is the yearly coefficients from the standardization, $(\Sigma CPUE_t)/n$ is the arithmetic average of the yearly coefficients, n is the number of years of observations, and $CE_t$ is the final time series of yearly index of relative abundance.

*12.3.2.3 Major Factors in Standardizations*

The CPUE standardizations are linear models that consider linear relationships between the various factors included in the statistical models and the natural log and catch rates (LnCE). The specific model that was found to be optimum in all cases was:

LnCE = Year + Vessel + Month + Zone + DepCat + Month:Zone

Generally, irrespective of the detail of the Blue-Eye data being analysed the order of the variables reflected the relative amount of data variation each factor accounted for in the statistical models. The SESSF zones do not follow a consistent sequence all around the coast (Figure 12.3).

A total of seven separate standardizations were conducted on the catch-per-hook data (Table 12.3). In line with the RAG minutes from last year the only combination of Auto-Line and Drop-Line standardizations which were amalgamated were those where only zones 20 – 50 were included in the analysis, although some alternative are discussed. Rather than try to amalgamate separate standardizations alternatives were also considered which treated fishing method as a factor, and in addition, a further analysis was attempted which treated the Number of Line Drops as a two value factor (1 or >1). The combined analyses were compared with a single catch-per-day standardization (for zones 20 – 50).

Table 12.3. The characteristics of the five factors included in the standardizations. The two time-series only overlap in the period 2002 – 2006. Seven separate standardizations were conducted consisting of three zone combinations for Drop-Line (all omitted records containing number-line-drops = 1), and two combinations for Auto-Line. In addition, a separate standardization was conducted where all data was combined but Method was included as a factor. Finally the combined analysis was repeated but including the ‘ones’ variable as a factor instead of removing those records with 1 line drop recorded.

| Factor | Drop-Line | Auto-Line |
|---|---|---|
| Year | 1997 - 2006 | 2002 - 2015 |
| Vessel | 96 unique vessels | 14 unique vessels |
| Month | 1 - 12 | 1 - 12 |
| Zone | 20-50, +(84,85), + 91 | 20-50, +(83-85) |
| DepCat | 200 - 600 | 200 - 600 |
| Method | DL | AL |
| ones | 0, 1 | 0 |

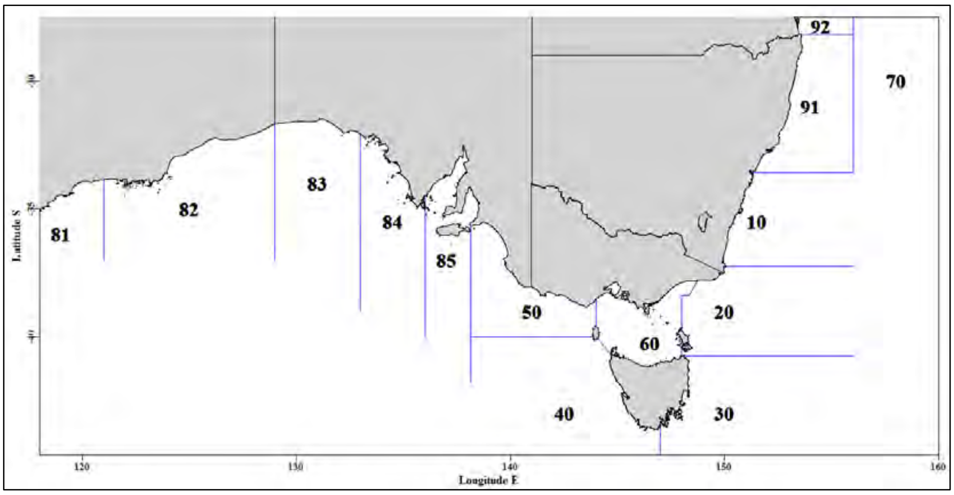


Figure 12.3. A schematic diagram depicting the statistical reporting zones in the SESSF, as used in this document. The GAB fishery is to the west of Zone 50. The main SESSF trawl zones are zones 10 – 50. Each zone extends out to the boundary of the EEZ, except for zones 50 and 60, and for zones 92 and 91, which are bounded by zone 70.

### 12.3.3 *TIER 4 Harvest Control Rule*

The standardizations are developed for use in the Tier 4 harvest control rule (Little et al, 2011; Haddon, 2014b). The data required to conduct a Tier 4 assessment are time series of catches and catch rates. For some species, where there is only a single stock and a single primary fishing method, analyses are presented using standardized CPUE data (Haddon, 2014b). For other species, there may be multiple stocks or areas or multiple methods and selecting which time series of catch rates to use in the analyses is not always straightforward. In those cases, the standardized time series for the method now accounting for the majority of current catch was used. With Blue-Eye, in order to obtain a time-series of sufficient length the catch rates from Drop-Line and Auto-Line have been combined.

Standard analyses were set up in the statistical software, R Core Team (2016). These standard analyses provide the tables and graphs required for the Tier 4 analyses. All data and results for each analysis are presented for complete transparency. The TIER 4 harvest control rule formulation essentially uses a ratio of current catch rates with respect to the selected limit and target reference points to calculate a scaling factor for the current year ($SF_t$). This scaling factor is applied to the target catch to generate an RBC. To generate a TAC, known discards and State catches are first removed and then, if applicable, the 15% discount is applied. The TAC calculations are conducted by AFMA. This report focusses on providing the estimates of the Recommended Biological Catches.

$$\text{Scaling Factor } = SF_t = \max\left(0, \frac{\overline{CPUE} - CPUE_{\text{lim}}}{CPUE_{\text{targ}} - CPUE_{\text{lim}}}\right) \tag{23}$$

$$RBC = C_{\text{targ}} \times SF_t \tag{24}$$

If new data becomes available, for example, more State data has become available this year, or other large changes occur in the catch rates then the RBC could undergo large changes. Such changes are constrained by the following limits:

$$\begin{array}{l|l} RBC_y = 1.5RBC_{y-1} & RBC_y > 1.5RBC_{y-1} \\ RBC_y = 0.5RBC_{y-1} & RBC_y < 0.5RBC_{y-1} \end{array} \tag{25}$$

where

| | |
|---|---|
| $RBC_y$ | is the RBC in year $y$ |
| $CPUE_{targ}$ | is the target CPUE for the species; Eq. (13) |
| $CPUE_{lim}$ | is the limit CPUE for the species = either (0.2/0.48) * $CPUE_{targ}$ or (0.2/0.40) * $CPUE_{targ}$ depending on the selected target for the species |
| $\overline{CPUE}$ | the average CPUE over the past *m* years; *m* tends to be the most recent four years. |
| $C_{targ}$ | is a catch target derived from a period of historical catch that has been identified as a desirable target in terms of CPUE, catches and status of the fishery, e.g. 1986 – 1995 (For Blue-Eye this is set at 1997 - 2006). This is an average of the total removals for the selected reference period, including any discards; Eq. (12). |

$$C_{\text{targ}} = \frac{\sum_{y=yr1}^{yr2} L_y}{\left(yr2 - yr1 + 1\right)} \tag{26}$$

where $L_y$ represents the landings in year $y$.

$$CPUE_{\text{targ}} = \frac{\sum_{y=yr1}^{yr2} CPUE_y}{\left(yr2 - yr1 + 1\right)} \tag{27}$$

where $CPUE_y$ is the catch rate in year $y$, $yr2$ and $yr1$ represent the last and the first years in the reference period respectively.

For each species a table of landings and of standardized catch rates was assembled. These included all catches (Commonwealth landings, Non-trawl catches, combined State catches, and discards). The standardization CPUE are those provided in the current document and are set as catch-per-hook (contrasted with a single catch-per-day standardization.

Percent discards are estimated from ISMP observations from 1998 to the current year. Fortunately, discard rates for Blue-Eye are invariably low (Upston and Thomson, 2016).

#### *12.3.3.1 Reference Points*

For each species, reference years were selected by the RAGs to generate estimates of target catches and target catch rates. In the case of Blue-Eye in Zones 20 – 50 this period was assumed to be 1997 – 2006 (the first ten years of the improved data collection period).

Plots are given of the total removals illustrating the target catch level. In addition, the standardized catch rates are illustrated with the target catch rate and the limit catch rate.

#### *12.3.3.2 Tier 4 Specification*

The Tier 4 analysis for Blue-Eye in 2016 will be:

- based upon the catch-per-hook time series of Drop-Line and Auto-Line data.
- the Drop-Line time-series will extend from 1997 – 2006 and the Auto-Line time-series will extend from 2002 – 2015.
- the two time-series will be combined by setting the mean standardized CPUE in the period 2002 – 2006 to 1.0 and using the catch-weighted average trend across the two in the period of overlap.
- the Blue-Eye catch will include all catches from all zones and all methods but not the catch-rates.
- only data from the SET, SEN, and GHT will be included.

#### *12.3.3.3 The Tier 4 Assumptions*

All stock assessments involve a series of assumptions (Table 12.4). More attention is needed to these assumptions to ensure that the limitations of the Tier 4 assessments are understood.

Table 12.4. The assumptions that need to be met for the Tier 4 assessment to be valid. This list is not necessarily exhaustive and will be added to in future years.

| Title | Description |
|---|---|
| **Informative CPUE** | There is a linear relationship between catch rates and exploitable biomass; *if there is hyper-stability (catch rates remain stable while stock size changes) or hyper-depletion (catch rates decline much faster than stock size changes) then the standard Tier 4 analysis would provide biased results.* |
| **Consistent CPUE through time** | The character of the estimated catch rates has not changed in significant ways through the period from the start of the reference period to the end of the most recent year; *If there has been significant effort creep altering the catchability, or there have been changes to the fleet that have altered the relative efficiency of the vessels fishing, or the catchability of the species by the fleet has been altered by other changes then the comparability of recent catch rates with the target period may be compromised. Such changes would obviously reduce the responsiveness of the Tier 4 method to change and may generate completely inappropriate management advice. Included in this clause are the effects of targeting or not targeting of deep water or aggregated species. When catch rates are extremely variable through time, such that mean estimates become unreliable measures of stock status, then the Tier 4 approach cannot be validly applied.* |
| **Plausible target reference period** | The reference period provides a good estimate of the stock when at a depletion level of 48% unfished spawning biomass; *the Tier 4 method is based on catch rates and thus relates to exploitable biomass and not spawning biomass. As a minimum the reference period will refer to a period when the stock was in an acceptable, productive and sustainable state. But there can be no guarantees that the target aimed for is really* $B_{48\%}$. |
| **Accurate total catch history** | Accurate estimates are required for all catches from the stock under consideration during the accepted target period, irrespective of what method was used or whether it was retained or discarded. |

## 12.4 Results

### 12.4.1 *Blue-Eye CPUE Standardization*

#### *12.4.1.1 Drop-Line*

Only relatively minor differences were obtained between the geometric mean Drop-Line CPUE (as catch-per-hook) and the standardized CPUE. There was a clear decline from 1997 to 2005 after which the trend reversed, although the precision of the mean estimate also declined in 2006, as evidenced by the wider confidence intervals (Figure 12.4). While the details differ between the geometric mean and the standardized time-series the beginning and end points of the Drop-Line CPUE are essentially the same.

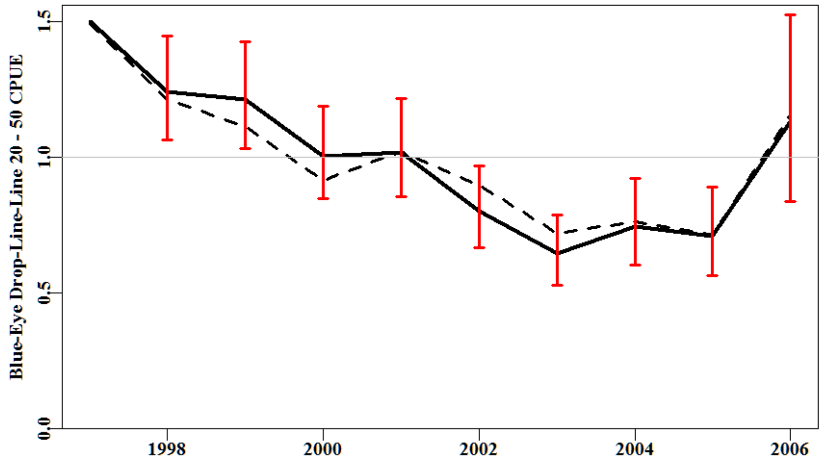


Figure 12.4. The standardization of Blue-Eye catches taken by Drop-Line in zones 20 – 50, excluding records which recorded single line drops.

If the GAB zones 84 and 85 are included in the analysis then the trend is greatly modified with the standardized trend exhibiting a higher starting point in 1997 and a lower end point in 2006 (Figure 12.5). If Zone 91 is included (not shown) this barely differs visually from the analysis that includes the GAB zones. This is not surprising considering that the catches in the GAB and up in zone 91 (Figure 12.3; Table 12.8) are only very minor up until about 2002.

Catch-per-day CPUE for zones 20 – 50 is similar to the catch-per-hook CPUE for 20 – 50 except for 2006 when it ends somewhat lower than the catch-per-hook, though not as low as when the GAB is included.

A comparison of the Drop-Line standardizations illustrates that the differences between the time series all lie within the 95% confidence intervals of the primary standardization within zone 20 – 50.

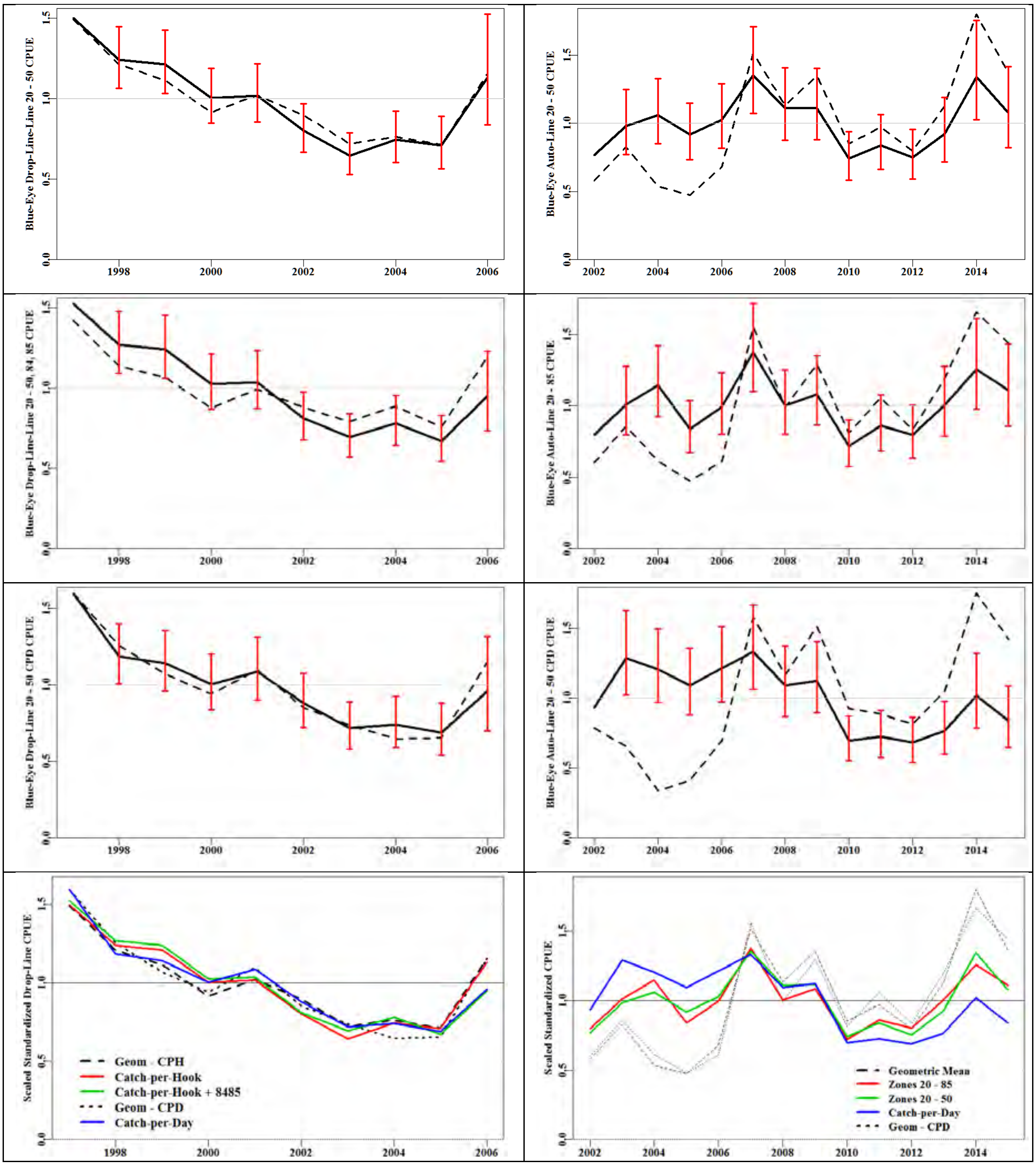


Figure 12.5. The separate standardizations for Drop-Line (left column) and Auto-Line (right column) with three separate analyses being the zones 20 – 50 in the top row, the same zones but with the GAB included in the second row, and the Catch-per-Day standardization for zones 20 – 50 in the third row. The bottom row combines all three plus the two geometric mean trends for zones 20 – 50, one for catch-per-hook and the other for catch-per-day.

### *12.4.1.2 Auto-Line*

The standardization of catch-per-hook data (and catch-per-day) for the Auto-Line fishery for Blue-Eye has a marked effect on the trend relative to that expressed by the geometric mean (Figure 12.6). The overall effect on the trend in CPUE is that the extremes of the lows and highs are moderated so that the trend varies both below and above the mean of 1.0. Some of these variations about the mean of 1.0

are greater than the predicted 95% confidence intervals as are some of the differences between the standardized and geometric mean CPUE trends.

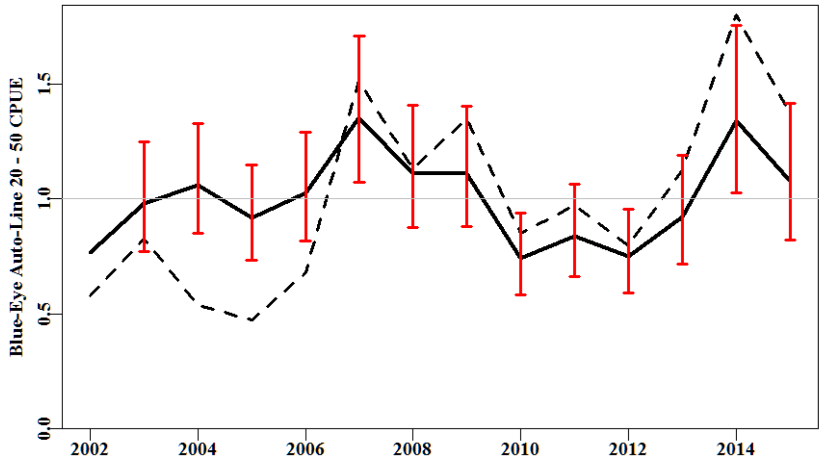


Figure 12.6. The standardization of Blue-Eye catches taken by Auto-Line in zones 20 – 50 (single line drops are not an issue for Auto-Line).

The inclusion of the GAB zones (83, 84, and 85) does lead to changes but the general trend of the two time-series is approximately the same (Figure 12.5).

Unlike the Drop-Line analysis, with the Auto-Line data the standardization of catch-per-hook differs significantly from the catch-per-day analysis (Figure 12.5). The overall effect is to flatten the trend of CPUE through time. This means that when the three are compared (Figure 12.5) the contrast between the unstandardized CPUE, and the standardized catch-per-hook and catch-per-day becomes very clear.

### 12.4.2 *Combining Drop-Line with Auto-Line CPUE*

The specification for the Tier 4 analysis this year requires that the two time-series (Drop-Line and Auto-Line) be combined in a particular manner. The Drop-Line time-series extends from 1997 – 2006 and that for Auto-Line from 2002 – 2015. The accepted approach to combining them is to set the mean standardized CPUE in 2002 – 2006 to 1.0 and then using the catch-weighted average trend across the two in the period of overlap (Table 12.5; Figure 12.7).

Table 12.5. The optimum standardizations of the catch-per-hook data for Blue-Eye for both Drop-Line and Auto-Line. DLAL is the catch-weighted CPUE. Catches are in tonnes. ReScale is merely the Combined DLAL CPUE scaled to a mean of 1.0 ready for the Tier 4 analysis.

| Years | DL2050 | AL2050 | DL Catch | AL Catch | DLAL | ReScale |
|---|---|---|---|---|---|---|
| 1997 | 1.8596 | | 254.478 | 0.267 | 1.8596 | 1.4964 |
| 1998 | 1.5404 | | 323.466 | 15.189 | 1.5404 | 1.2395 |
| 1999 | 1.5037 | | 354.242 | 58.902 | 1.5037 | 1.2100 |
| 2000 | 1.2458 | | 378.548 | 85.201 | 1.2458 | 1.0024 |
| 2001 | 1.2642 | | 319.727 | 47.642 | 1.2642 | 1.0172 |
| 2002 | 0.9952 | 0.8078 | 219.013 | 134.067 | 0.9240 | 0.7435 |
| 2003 | 0.7989 | 1.0321 | 192.327 | 219.646 | 0.9232 | 0.7429 |
| 2004 | 0.9251 | 1.1162 | 90.028 | 273.947 | 1.0689 | 0.8602 |
| 2005 | 0.8785 | 0.9633 | 62.951 | 239.181 | 0.9456 | 0.7609 |
| 2006 | 1.4024 | 1.0806 | 70.039 | 246.289 | 1.1519 | 0.9269 |
| 2007 | | 1.4242 | 39.654 | 309.325 | 1.4242 | 1.1460 |
| 2008 | | 1.1667 | 15.579 | 207.044 | 1.1667 | 0.9388 |
| 2009 | | 1.1689 | 30.158 | 293.927 | 1.1689 | 0.9406 |
| 2010 | | 0.7788 | 37.904 | 208.718 | 0.7788 | 0.6267 |
| 2011 | | 0.8807 | 57.761 | 206.679 | 0.8807 | 0.7086 |
| 2012 | | 0.7899 | 34.107 | 197.659 | 0.7899 | 0.6356 |
| 2013 | | 0.9704 | 7.537 | 170.274 | 0.9704 | 0.7808 |
| 2014 | | 1.4102 | 5.733 | 198.945 | 1.4102 | 1.1348 |
| 2015 | | 1.1337 | 41.405 | 171.833 | 1.1337 | 0.9123 |

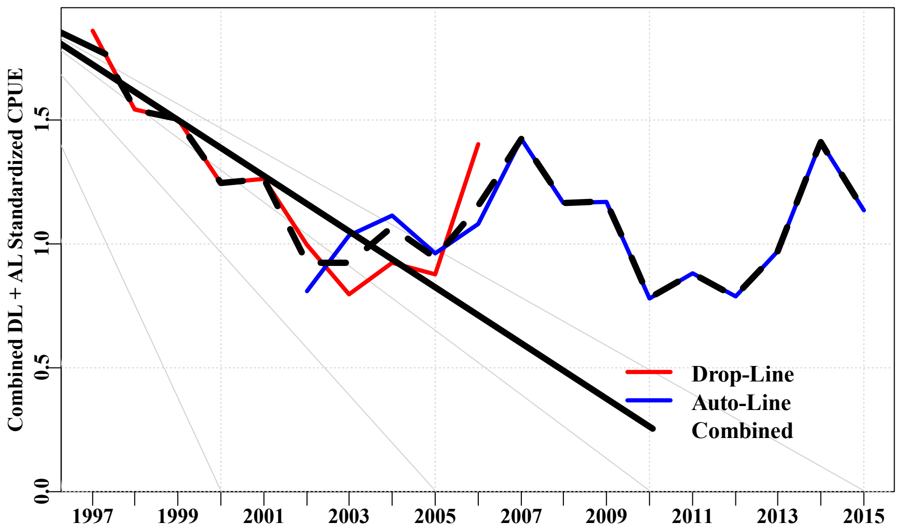


Figure 12.7. The combined standardized CPUE for Drop-Line and Auto-Line for zones 20 – 50 (Table 12.4), where the CPUE between 2002 – 2006 is the catch-weighted values combined, while from 1997 – 2001 it is the Drop-Line CPUE and from 2007 – 2015 it is the Auto-Line CPUE.

*12.4.2.1 Alternative Analysis*

The current approach has only been adopted because the approach of combining two disparate line methods by analysing them separately and then combining them was adopted originally in 2009 and 2010 (Haddon, 2010). However, instead of independent treatment and then catch-weighting the period of overlap it is also possible to use the catch-per-hook data and include 'Method' as a factor in the standardization:

LnCE ~ Year + Method + Vessel + Month + Zone + DepCat + Month:Zone

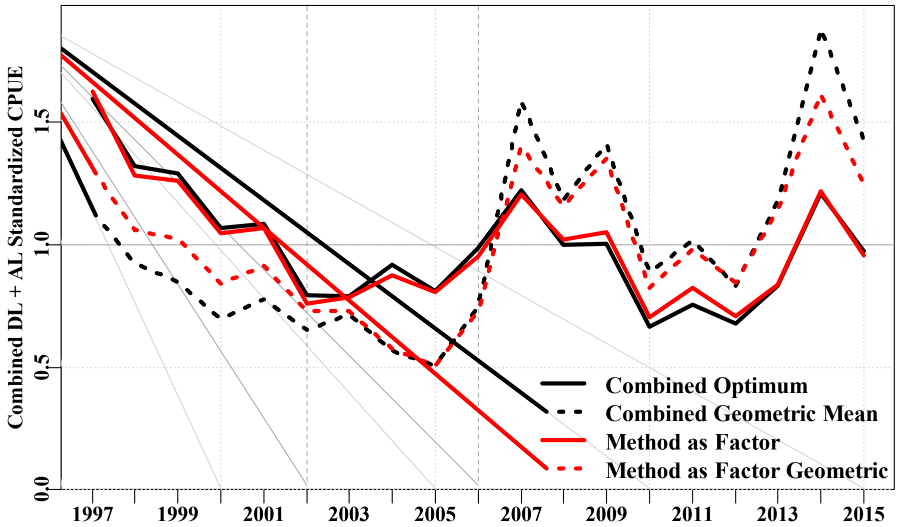


Figure 12.8. The standardization of catch-per-hook using the Drop-Line and Auto-Line time-series separately and then combing them, and using the total data set but including 'Method' as a factor in the analysis. All lines are scaled to a mean of 1.0. The period of overlap for the independent time-series by method was 2002 – 2006 which are marked by fine vertical grey lines.

When 'Method' is included in the analysis the outcome is very similar to the outcome of the combined analysis (Figure 12.8). This more straightforward analysis might be preferable as an approach to providing the CPUE time-series. The geometric mean for that comparison needs to include method (i.e. use LnCE ~ Year + Method rather than LnCE ~ Year) so as to account for the different scale on which the methods operate. When the parameter describing the difference between the effectiveness of the two methods is examined it estimates that Drop-Line catch-per-hook is about 3.24 times that of Auto-Line.

*12.4.2.2 The effect of Closures*

A number of relatively large closures have been imposed upon the SESSF, including on the Blue-Eye fishery. In particular the closure off Flinders Island effectively removed a favoured fishing ground.

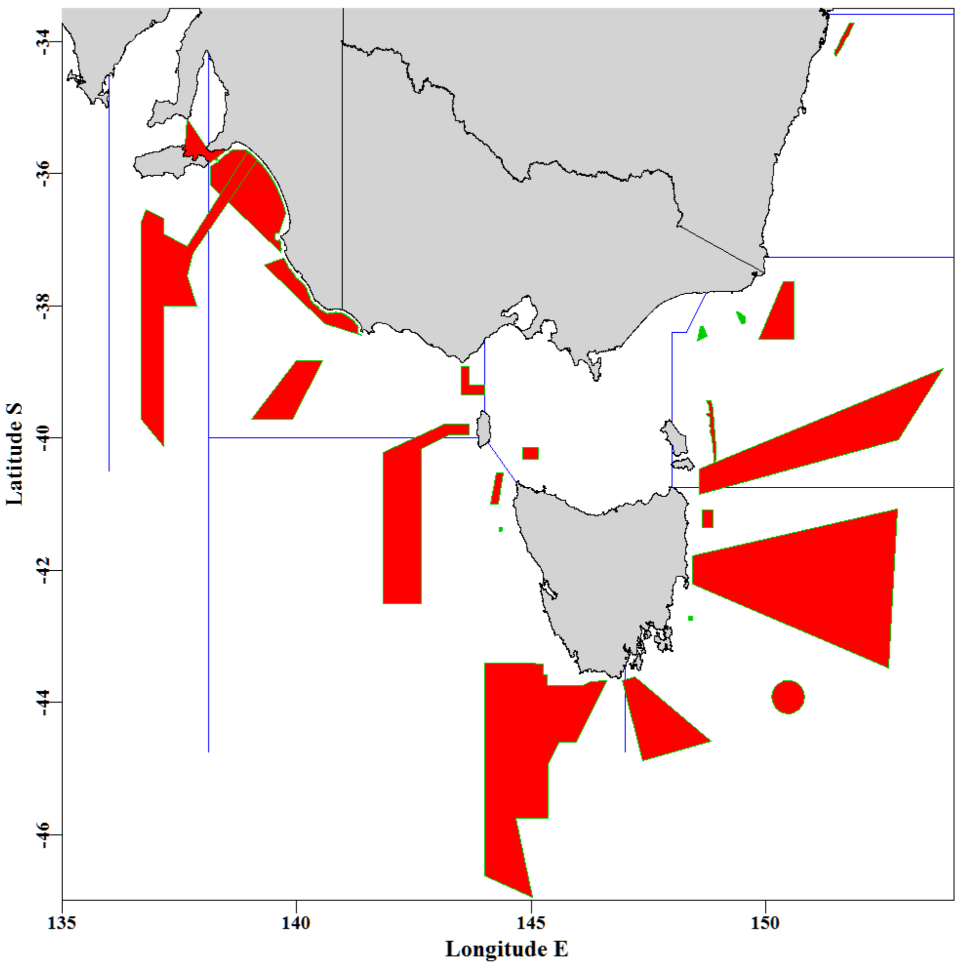


Figure 12.9. A schematic map of an array of the closures installed in the south-east SESSF region. The red closures are permanent while the four much smaller green areas are seasonal and not present in all years. In all cases trawling is banned within the closed areas, although other methods might be acceptable. Missing from this plot are the very extensive deepwater closures where all waters < 700m depth were closed (although this was revised after two years to open a few subsets of that area) and the trawl closure in Bass Strait.

While it is possible that some of these closures would have displaced effort the effect upon catch rates has still to be explored for a catch-per-hook analysis. Three analyses were conducted which were: 1) ignore the closure, 2) include the closure as a factor in the standardization, and 3) remove all catches originally taken within the closures. Only zones 20 and 30 were considered as these included some relatively high proportions of catch through time within areas that became closed.

The only analytical treatment that led to changes in the expressed trends was when all data from within the closures were removed from the analysis (Figure 12.9).

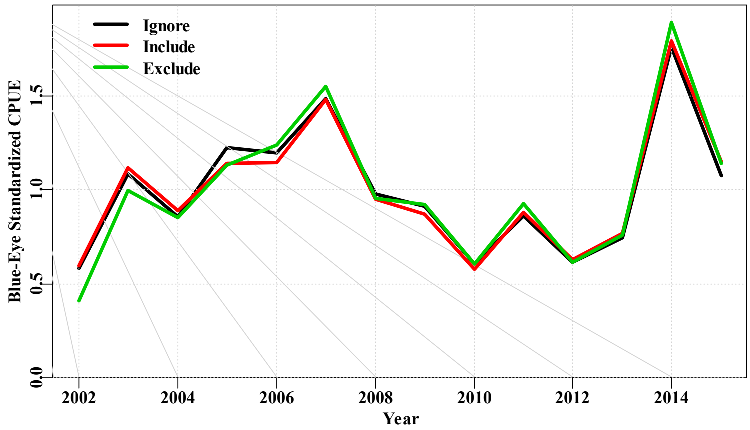


Figure 12.10. Three scenarios where Blue-Eye catch-per-hook data were analysed to determine the effect of closures on catch rates.

### 12.4.3 *Tier 4 Analysis*

The Tier 4 data included the total catches, total discards, and the standardized CPUE. The CPUE series used was only for the Drop-Line and Auto-Line fisheries from SESSF zones 20, 30, 40 and 50, but the catches relate to the whole fishery (Table 12.6) excluding the GAB.

Table 12.6. Blue-Eye data for the TIER 4 calculations. Total is the sum of Discards, State, CDR Landings and derives from Thomson and Upston (2016). All values in Tonnes. CE is the standardized catch rate for Zones 20 to 50 in depths 200 – 600m based on catch-per-hook (Haddon, 2016). GeoMean is the geometric mean catch rates. The proportion of discards are in the PDiscard column. The greyed cells represent the reference period. Both the combined CE and the geometric mean have been scaled to an average of 1.0 for ease of visual comparison of trends. TAC in 2016 = 410 t.

| Year | Catch | Discards | Total | State | Pdiscard | CE | GeoMean | TAC |
|---|---|---|---|---|---|---|---|---|
| 1997 | 829.002 | | 829.002 | 623.141 | | 1.5951 | 1.0462 | 125 |
| 1998 | 602.299 | 0.006 | 602.305 | 130.012 | 0.00001 | 1.3213 | 0.8386 | 630 |
| 1999 | 712.297 | 0.007 | 712.304 | 139.608 | 0.00001 | 1.2898 | 0.7845 | 630 |
| 2000 | 756.41 | 37.638 | 794.048 | 99.563 | 0.04740 | 1.0686 | 0.6449 | 630 |
| 2001 | 683.185 | 33.919 | 717.104 | 96.613 | 0.04730 | 1.0843 | 0.7307 | 630 |
| 2002 | 629.472 | 0.126 | 629.598 | 117.362 | 0.00020 | 0.7926 | 0.6360 | 630 |
| 2003 | 646.688 | 0.129 | 646.817 | 58.623 | 0.00020 | 0.7919 | 0.7311 | 690 |
| 2004 | 711.251 | 1.425 | 712.676 | 77.457 | 0.00200 | 0.9169 | 0.6021 | 621 |
| 2005 | 564.442 | 0.006 | 564.448 | 71.557 | 0.00001 | 0.8111 | 0.5216 | 621 |
| 2006 | 620.945 | 0.062 | 621.007 | 57.095 | 0.00010 | 0.9880 | 0.7645 | 560 |
| 2007 | 653.412 | 2.888 | 656.300 | 68.102 | 0.00440 | 1.2216 | 1.6266 | 785 |
| 2008 | 415.027 | 0.998 | 416.025 | 41.980 | 0.00240 | 1.0007 | 1.2152 | 560 |
| 2009 | 481.452 | 0.005 | 481.457 | 38.090 | 0.00001 | 1.0026 | 1.4479 | 560 |
| 2010 | 450.183 | 0.144 | 450.327 | 50.287 | 0.00032 | 0.6680 | 0.9122 | 428 |
| 2011 | 504.001 | 7.513 | 511.514 | 45.465 | 0.01469 | 0.7554 | 1.0408 | 326 |
| 2012 | 360.059 | 5.045 | 365.104 | 35.317 | 0.01382 | 0.6775 | 0.8555 | 388 |
| 2013 | 266.548 | 1.015 | 267.563 | 22.335 | 0.00379 | 0.8323 | 1.2067 | 388 |
| 2014 | 315.35 | 0.481 | 315.831 | 18.820 | 0.00152 | 1.2097 | 1.9305 | 335 |
| 2015 | 287.163 | 0.255 | 287.418 | 18.820 | 0.00089 | 0.9725 | 1.4641 | 335 |

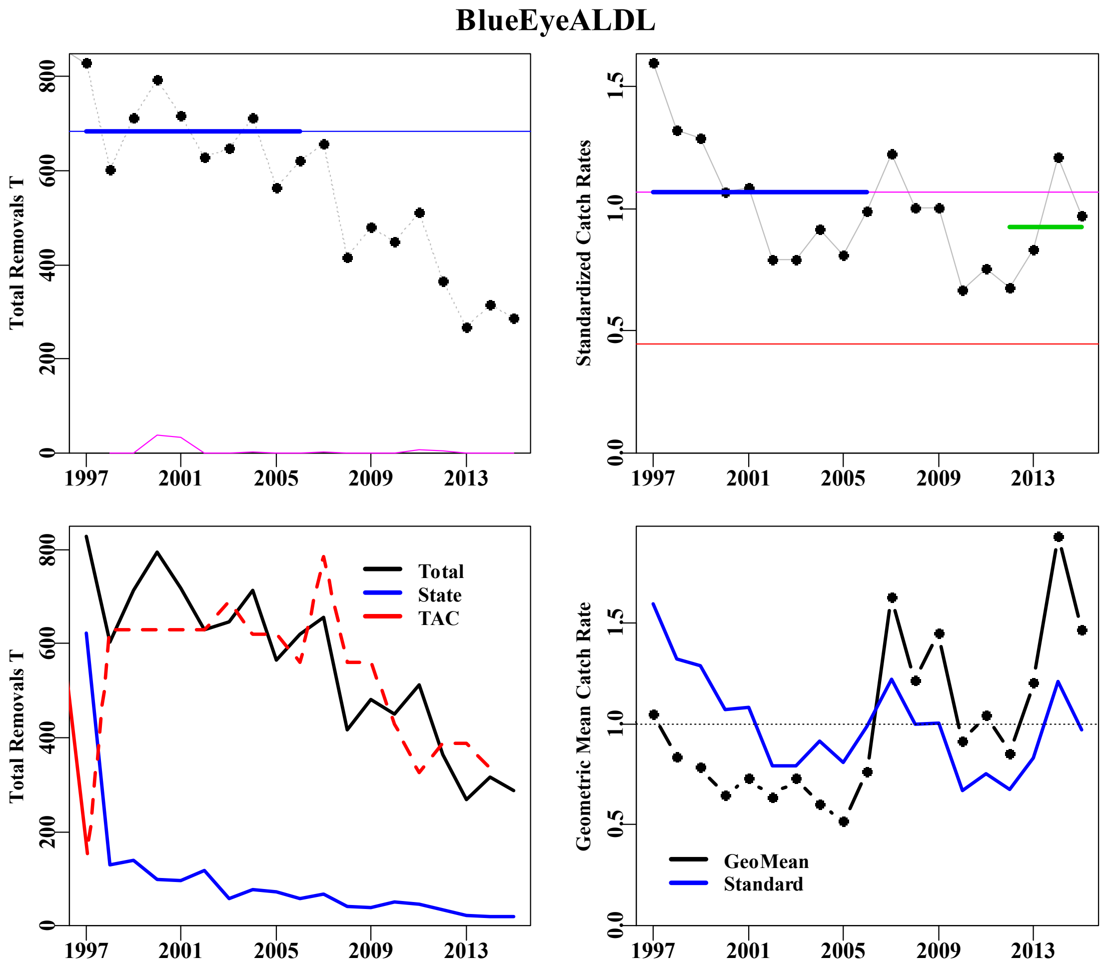


Figure 12.11. Blue Eye Trevalla. Top left is the total removals from the fishery (except for catches in the GAB) with the fine line illustrating the target catch. Top right represents the standardized catch rates (combined Drop-Line and Auto-Line catch-per-hook) with the upper fine line representing the target catch rate and the lower line the limit catch rate. Thickened lines represents the reference period for catches, catch rates, and the recent average catch rate.

Table 12.7. RBC calculations for Blue Eye. C*(target) and CE_Targ relate to the period 1997-2006, CE_Lim is 41.66% of the target, and CPUE is the average catch rate over the last four years. The RBC calculation does not account for predicted discards of predicted State catches. Wt_Discard is the weighted average discards from the last four years.

| BlueEyeALDL | 1997 - 2015 |
|---|---|
| Ref_Year | 1997 - 2006 |
| CE_Targ | 1.0660 |
| CE_Lim | 0.4442 |
| CE_Recent | 0.9230 |
| Wt_Discard | 0.736 |
| Scaling | 0.7701 |
| Current TAC | 335 |
| C*(target) | 682.931 |
| RBC | **525.923** |

## 12.5 Discussion

The generation of catch-per-hook catch rate data from the Blue-Eye catch and effort database has produced a time series of combined Drop-Line and Auto-Line CPUE which intuitively provides a better description of what actually occurs in the fishery. Drop-Line catch rates are about three times higher in terms of catch-per-hook than Auto-Line catches. There has been discussion of the possible effects of closures and that of whale depredation. Preliminary analyses of the effects of closures on catch-per-hook indicate that the effects are minimal after standardization of any CPUE time-series (involving only one method). Whale depredations continue to be a difficulty until a concerted effort is made to gather spatially detailed data on whale interactions. Some indications have been possible with the sparse data currently available but a detailed consideration is not currently feasible. Whatever the case, whale depredation would tend to bias the catch rates low (because part of the catch-per-hook was taken by whales), but also the total catch would also be biased low, implying that true fishing related mortality is also biased low.

Despite the difficulties it was possible to combine the two time-series from the two methods to produce a time-series from 1997 – 2015 based on catch-per-hook. This was then used within the standard Tier 4 analysis to generate an expected Recommended Biological Catch.

The Tier 4 analysis is based in the CPUE from SESSF zones 20 – 50 but the catches that go towards generating the target catch include all areas and methods except the GAB. This is a reflection of the hypothesis that the Blue-Eye in the GAB constitute a separate stock. However, currently in the GHT fishery, the Blue-Eye quota they have also applies in the GAB, so there is some confusion over the assessment and management details that may require attention.

The effect of the standardization is, as expected, to reduce the variation exhibited by the catch rates seen in the fishery, although in more recent years there still remains some relatively large rises and falls in catch rate over relatively short periods. This seems likely to reflect the fact that there are very few Auto-Line vessels that make large contributions to the fishery so if they alter their fishing patterns (perhaps in response to whale depredation) then large changes in catch rates can occur. Such large changes over short periods are certainly not a direct reflection of equivalent changes in the stock size. For greater stability in the RBC predicted from the Tier 4 analysis it might be necessary to increase the number of years over which the more recent CPUE is averaged for comparison with the target.

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## 12.7 Supplementary Material

Table 12.8. Catches taken by Drop-Line included in the various standardizations (Table 12.3). The drop-off in catches, except in Zone 30 following 2006 is apparent. These data have removed all records where only one line drop was recorded and hence these values differ from those in Table 12.10.

| Year | 20 | 30 | 40 | 50 | 83 | 84 | 85 | 91 |
|---|---|---|---|---|---|---|---|---|
| 1997 | 76.435 | 79.630 | 36.092 | 32.973 | | | 3.870 | 3.745 |
| 1998 | 72.135 | 156.451 | 47.472 | 37.296 | | | 1.720 | 1.100 |
| 1999 | 27.234 | 191.741 | 64.494 | 38.765 | | | 0.560 | 8.110 |
| 2000 | 25.910 | 182.032 | 102.167 | 44.568 | | 0.332 | 4.150 | 0.100 |
| 2001 | 18.659 | 188.742 | 72.643 | 24.757 | 0.150 | 2.364 | 2.755 | 2.536 |
| 2002 | 31.617 | 85.914 | 20.525 | 35.457 | | 1.561 | 5.080 | 29.464 |
| 2003 | 25.722 | 46.850 | 32.881 | 29.359 | | 27.313 | 4.875 | 50.680 |
| 2004 | 5.722 | 40.475 | 11.203 | 22.599 | 0.026 | 43.428 | 16.275 | 4.945 |
| 2005 | 0.140 | 39.645 | 2.261 | 6.626 | 0.200 | 24.028 | 6.208 | 4.870 |
| 2006 | 0.040 | 50.858 | 2.463 | 2.308 | | 42.241 | 1.444 | 6.750 |
| 2007 | 2.174 | 31.883 | 0.250 | 4.190 | 0.010 | 6.347 | | |
| 2008 | | 11.719 | | 2.260 | | 0.100 | | |
| 2009 | 0.150 | 11.958 | 0.010 | 5.700 | | | | 9.230 |
| 2010 | | 17.718 | 0.165 | 6.826 | 0.785 | 2.379 | 1.045 | 7.932 |
| 2011 | 0.003 | 22.388 | 3.607 | 3.926 | | 0.400 | 1.220 | 4.902 |
| 2012 | | 10.254 | 1.403 | 6.271 | | | | 15.496 |
| 2013 | | 5.994 | 0.007 | 0.910 | | | 0.225 | |
| 2014 | 0.011 | 2.628 | | 0.877 | 1.500 | 2.054 | 0.540 | |
| 2015 | | 0.215 | | 0.871 | 1.949 | 0.535 | 0.010 | 9.609 |

Table 12.9. Auto-Line Catches. Zone 0 are either unknown or outside the SESSF.

| Year | 0 | 10 | 20 | 30 | 40 | 50 | 60 | 70 | 82 | 83 | 84 | 85 | 91 | 92 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1997 | | | | | 0.267 | | | | | | | | | |
| 1998 | 12.064 | | | 0.233 | 14.956 | | | | | | | | | |
| 1999 | 1.689 | | 35.575 | 1.725 | 11.482 | | 1.000 | | | | | | 10.120 | |
| 2000 | 5.731 | | 12.243 | 56.804 | 14.824 | | | | | | | | 0.580 | 0.750 |
| 2001 | 0.242 | | 2.000 | 31.044 | 14.598 | | | | | | | | | |
| 2002 | | | 2.640 | 65.351 | 42.576 | 21.400 | | | | | | | | 2.100 |
| 2003 | | | 20.634 | 97.288 | 84.594 | 9.900 | 0.030 | | | | | | 7.230 | |
| 2004 | 0.910 | | 63.236 | 94.791 | 82.677 | 27.164 | 0.662 | 0.400 | | 12.584 | 15.316 | 31.689 | | 0.180 |
| 2005 | 0.484 | 1.070 | 84.998 | 60.426 | 57.265 | 36.482 | 0.250 | | | 19.278 | 5.145 | 35.895 | 0.011 | |
| 2006 | 0.550 | 1.540 | 67.075 | 67.257 | 77.940 | 25.822 | 0.924 | 2.420 | | 31.405 | 0.330 | 76.184 | 3.135 | |
| 2007 | | | 48.019 | 196.324 | 41.074 | 23.907 | 0.550 | | | 29.791 | 100.094 | 15.337 | | |
| 2008 | | | 44.786 | 99.013 | 51.837 | 11.408 | 0.017 | | | 28.943 | 32.167 | 13.214 | | |
| 2009 | | 0.041 | 50.874 | 125.545 | 79.909 | 32.355 | 0.169 | 4.400 | | 1.633 | 15.369 | 15.415 | 0.185 | |
| 2010 | | | 25.642 | 69.142 | 50.841 | 63.093 | 0.100 | | | 5.764 | 7.153 | 14.884 | | |
| 2011 | | | 30.835 | 69.512 | 38.809 | 14.160 | | 10.340 | | 20.576 | 40.292 | 12.939 | 23.696 | 6.160 |
| 2012 | | | 21.176 | 56.348 | 70.428 | 11.183 | | | | 8.417 | 9.736 | 3.752 | 27.442 | 9.334 |
| 2013 | 0.157 | | 13.151 | 45.406 | 84.451 | 13.684 | 0.164 | 2.723 | | 0.465 | 16.158 | 13.025 | 1.131 | |
| 2014 | 0.446 | | 3.867 | 68.561 | 87.235 | 19.442 | | | | 0.607 | 31.290 | 11.089 | 4.505 | |
| 2015 | 4.356 | | 9.031 | 54.122 | 72.715 | 22.563 | 0.546 | | | 0.541 | 20.975 | 3.611 | 9.772 | |

Table 12.10. Drop-Line Catches. Zone 0 are either unknown or outside the SESSF.

| Year | 0 | 10 | 20 | 30 | 40 | 50 | 60 | 70 | 82 | 83 | 84 | 85 | 91 | 92 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1997 | 6.055 | 2.361 | 81.546 | 80.730 | 40.722 | 45.977 | 3.270 | | | | | 5.778 | 5.503 | |
| 1998 | 15.871 | 0.050 | 72.375 | 158.954 | 49.692 | 40.856 | 2.150 | | | | | 1.968 | 1.590 | |
| 1999 | 20.778 | 0.700 | 29.061 | 193.331 | 65.244 | 55.078 | 0.348 | | | | | 0.972 | 11.470 | 0.050 |
| 2000 | | | 26.170 | 187.555 | 104.457 | 59.847 | | | | | 0.357 | 5.504 | 0.520 | |
| 2001 | 8.837 | | 18.659 | 191.312 | 72.643 | 29.127 | | 0.060 | | 0.150 | 2.814 | 4.345 | 3.186 | 4.740 |
| 2002 | 2.070 | | 31.617 | 87.014 | 20.530 | 35.487 | | | | | 1.561 | 5.380 | 33.664 | 5.750 |
| 2003 | | | 25.822 | 47.450 | 33.411 | 29.464 | | | | | 27.547 | 4.875 | 50.680 | 2.400 |
| 2004 | 0.160 | | 6.332 | 42.729 | 12.223 | 23.579 | 0.060 | | 0.850 | 0.026 | 45.762 | 21.725 | 5.045 | |
| 2005 | | | 0.140 | 42.590 | 2.261 | 6.841 | | 1.550 | | 0.200 | 24.128 | 6.500 | 4.870 | 4.700 |
| 2006 | 0.300 | | 0.290 | 55.118 | 2.463 | 2.308 | | | | | 42.976 | 1.444 | 7.240 | 2.500 |
| 2007 | | | 2.174 | 32.071 | 0.250 | 4.460 | | 0.700 | | 0.010 | 6.347 | | | |
| 2008 | | | | 13.189 | | 2.260 | | | | | 0.100 | | | |
| 2009 | | | 0.150 | 11.958 | 0.010 | 5.700 | | 0.660 | | | | | 10.330 | 1.350 |
| 2010 | | | | 17.803 | 0.165 | 6.826 | | 1.153 | | 0.785 | 2.379 | 1.045 | 7.932 | 3.935 |
| 2011 | | | 0.003 | 23.158 | 3.615 | 3.971 | | 0.100 | | | 0.400 | 1.220 | 9.993 | 16.921 |
| 2012 | | | | 10.254 | 1.403 | 6.271 | | | | | | | 15.496 | 0.683 |
| 2013 | | | | 6.091 | 0.007 | 0.910 | | 0.529 | | | | 0.225 | | |
| 2014 | | | 0.011 | 2.665 | | 2.547 | | | | 1.500 | 2.469 | 0.540 | | 0.510 |
| 2015 | 3.148 | | | 0.215 | | 1.521 | | 0.750 | | 1.949 | 1.185 | 0.010 | 28.061 | 9.872 |

# 13. Tiger flathead (*Neoplatycephalus richardsoni*) stock assessment based on data up to 2015 – development of a preliminary base case

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## *13.1 Executive Summary*

This document presents a suggested base case for an updated quantitative Tier 1 tiger flathead (*Neoplatycephalus richardsoni*) assessment for presentation at the first SERAG meeting in 2016. The last full assessment was presented in Day and Klaer (2013). The preliminary base case has been updated by the inclusion of data up to the end of 2015, which entails an additional 3 years of catch, discard, CPUE, length and age data and ageing error updates since the 2013 assessment and incorporation of survey results from the Fishery Independent Survey from 2008-2014. This document describes the process used to develop a preliminary base case for tiger flathead through the sequential updating of recent data to the stock assessment, using the stock assessment package Stock Synthesis (SS-V3.24Z).

Changes to the last stock assessment include: separating length frequencies into onboard and port collected components, with a joint selectivity pattern estimated; including FIS abundance indices separated into Eastern (SESSF Zones 10 and 20) and Tasmanian (SESSF Zone 30) fleets; weighting length frequencies by shots and trips rather than fish measured; and using a new tuning method.

Results show reasonably good fits to the catch rate data, length data and conditional age-at-length data. This assessment estimates that the projected 2017 spawning stock biomass will be 43% of virgin stock biomass (projected assuming 2015 catches in 2016), compared to 50% at the start of 2014 from the last assessment (Day and Klaer 2013).

## *13.2 Introduction*

### 13.2.1 *Bridging from 2013 to 2016 assessments*

The previous full quantitative assessment for tiger flathead was performed in 2013 (Day and Klaer, 2013) using Stock Synthesis (version SS-V3.24f, Methot, August 2012). The 2016 assessment uses the current version of Stock Synthesis (version SS-V3.24Z, Methot, 2015), which has few changes to SS_V3.24f.

As a first step in the process of bridging to a new model, the data used in the 2013 assessment was used in the new software (SS-V3.24Z) and minor updates were made to the 2001-2012 catch history. This was followed by including the data from 2013-2015 into the model. This additional data included new catch, discard, CPUE, length frequency and age-at-length data for 2013, 2014 and 2015 and FIS for 2014. The last year of recruitment estimation was extended to 2012 (2009 in the 2013 assessment). The use of updated software and the inclusion of additional data resulted in some differences in the fits to CPUE, age and length data. The usual process of bridging to a new model by adding new data piecewise and analysing which components of the data could be attributed to changes in the assessment outcome was conducted with the details outlined below.

#### 13.2.2 *Update to Stock Synthesis SSV-3.24Z and updated catch history*

The 2013 tiger flathead assessment (2013BaseCase) was initially converted to the most recent version of the software, Stock Synthesis version SS-V3.24Z (Base2013NoHessian).

The next step included updated catch history in the 2013 assessment, which involved minor revisions to the catch history from 2001-2011 and using updated data for 2012 and 2013 to replace the preliminary 2012 and 2013 data used in the 2013 assessment. This includes some corrections to allocations of catches between fleets before 2011 and updates to recent state catches, and replacing the estimated 2013 catch with actual catches. These changes in catch history (B2UpdateCatch01-11) were included after the transition to SS-V3.24Z. There were negligible changes to the spawning biomass and recruitment time series for any of these steps. When these time series are plotted together, it is very difficult to see any difference between them (Figure 13.1and Figure 13.2).

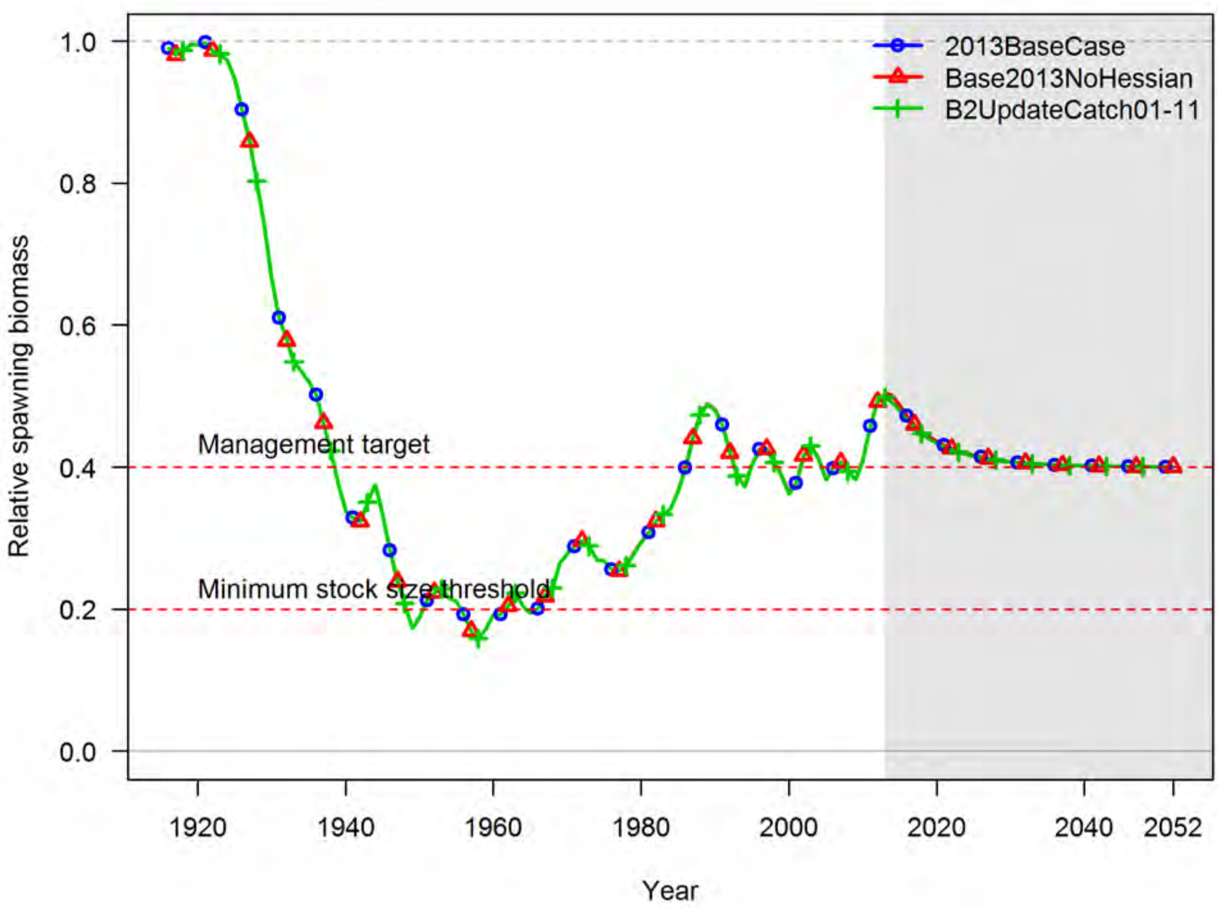


Figure 13.1. Comparison of the spawning biomass time series for the 2013 assessment (2013BaseCase) and a model converted to SS-V3.24Z (Base2013NoHessian) and updates to the 2001-2013 catches to include data which was unavailable to the 2013 assessment (B2UpdateCatch01-11).

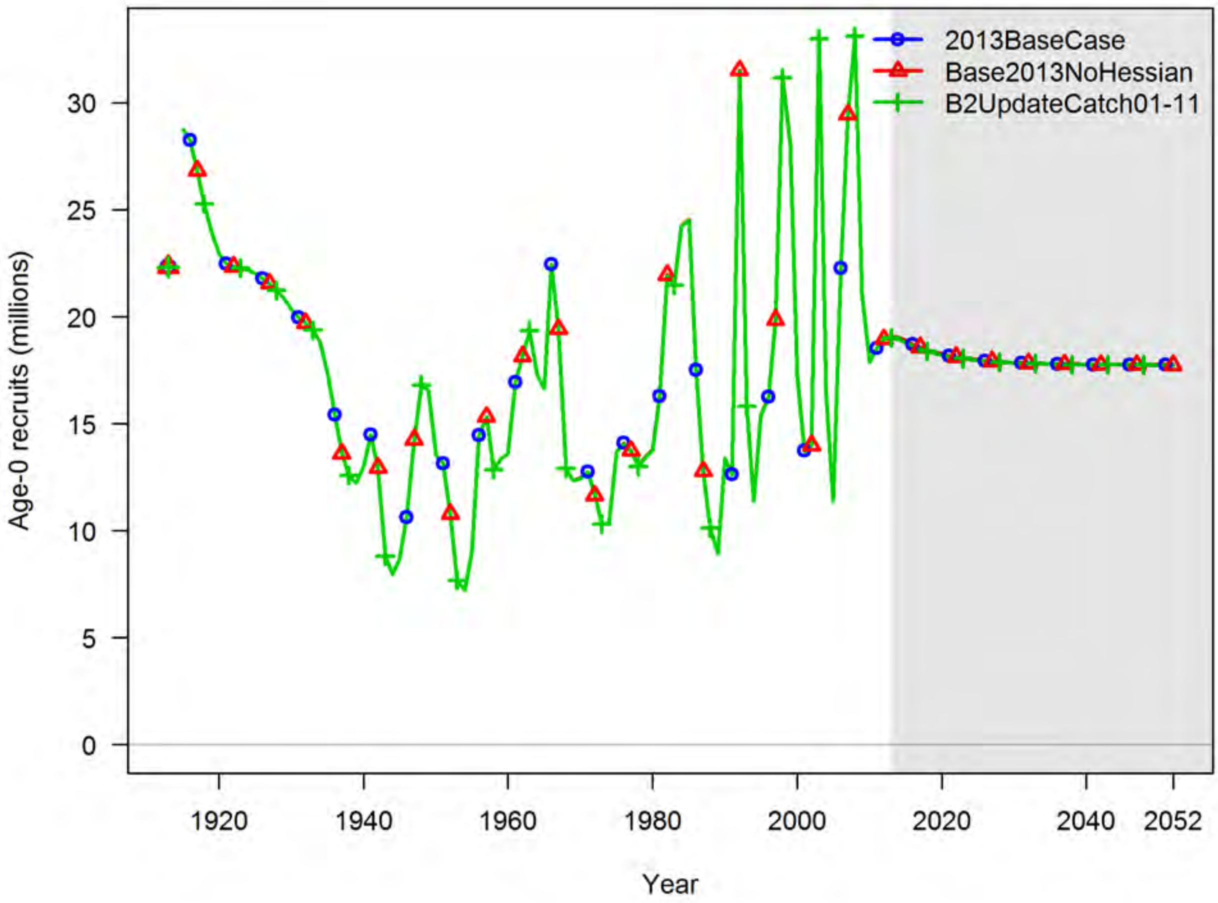


Figure 13.2. Comparison of the recruitment time series for the 2013 assessment (2013BaseCase) and a model converted to SS-V3.24Z (Base2013NoHessian) and updates to the 2001-2013 catches to include data which was unavailable to the 2013 assessment (B2UpdateCatch01-11).

### 13.2.3 *Inclusion of new data: 2013-2015*

Starting from the converted 2013 base case model with updated catch history, (B2UpdateCatch01-11), additional data from 2013-2015 were added sequentially to develop a preliminary base case for the 2016 assessment:

1. Change final assessment year to 2015, add catch to 2015 (B3).
2. Add CPUE to 2015 (from Sporcic and Haddon (2016)) (B4).
3. Add FIS indices for 2014, with the FIS abundance index split into two indices to match the spatial zones corresponding to the Eastern trawl and Tasmanian trawl fleets (B6).
4. Add updated discard fraction estimates to 2015 (B7).
5. Update length frequency data, this time including both port and onboard length frequencies for historical data and weighting these length frequencies by number of shots or trips, rather than number of fish (B12).
6. Add updated age error matrix and age-at-length data to 2015 (B13).

7. Change the final year for which recruitments are estimated from 2009 to 2012 (B15).
8. Retune using latest tuning protocols, including Francis weighting on lengths and ages, and without using lambda=0.1 to down weight the age and length likelihood (T7_2016Base).

Inclusion of the new data resulted in gradual changes to the estimates of recruitment and the relative spawning biomass time series. Including the new CPUE data resulted in reduced recent recruitment estimates and reduced 2017 relative spawning biomass, with further reductions due to the length and age data. Estimating an additional three years of recruitments (to 2012) resulted in three years of above average recruitment producing a slight increase to the relative spawning biomass in 2017, although at a level below that predicted by the 2013 assessment.

The final tuned model produced changes to the relative spawning biomass from around 1940 onwards, with a reduction in the earlier years, from around 1940-1990, but with an increase to the relative spawning biomass from 1990 onwards. Tuning also resulted in considerable changes to the recruitment time series from around 1940 onwards.

Since the 2013 assessment, standard changes to the procedures used in the Stock Synthesis assessments in the SESSF include:

1. Including both port and onboard length frequency data.
2. Weighting length frequency data by shot or trip numbers rather than fish measured.
3. Modification to the tuning procedures including use of Francis weighting for length and age data.
4. separating the FIS data into areas to match fleets used in the assessments, so in this case separating to an eastern trawl FIS (Zones 10 and 20) and a Tasmanian trawl FIS (Zone 30).

These are considerable changes to the tuning procedures used in the 2013 assessment, so it is not surprising that tuning resulted in considerable changes. Previous tiger flathead assessments have applied a lambda of 0.1 to length and age frequency data to down weight the likelihood from these sources relative to the likelihood from the CPUE and survey data. Weighting these frequencies by shot rather than numbers of fish measured, and using the latest tuning protocols including Francis weighting has allowed these lambdas to be returned to 1. If it can be avoided, it is preferable to set the lambdas at 1, rather than make somewhat adhoc decision to balance the likelihood from different data sources and somewhat arbitrarily down weight length and age data.

Inclusion of the new data had relatively minor impacts on the estimates of recruitment and the spawning biomass time series. With recruitment estimated up until 2012, this resulted in the recruitments estimated from 2007-2009 to be revised down, compared to the 2013 assessment. However, the three new years of estimated recruitment (2010, 2011 and 2012) are all above average. These recruitment events appear to be supported by the recent length data and have resulted in an estimate of the depletion at the start of 2017 of 43% of unexploited stock biomass, $SSB_0$. While the most recent recruitments are well estimated, they should be treated with some caution as it is possible for future data to result in modifications to estimates of recent recruitment events, as occurred with the 2007-2009 recruitment estimates from the 2013 assessment. In that assessment, when recruitment was only estimated to 2007, excluding the above average recruitment estimates in 2008 and 2009, the spawning biomass was estimated to be 40% of $SSB_0$. Since 2005 various values have been used for the target and the breakpoint in the Tier 1 harvest control rule. In 2009, AFMA directed that the 20:35:40 ($B_{lim}$: $B_{MSY}$: $F_{targ}$) form of the harvest control rule is used for tiger flathead.


Figure 13.3. Comparison of the spawning biomass time series for the 2013 assessment model converted to SS-V3.24Z (2013BaseCase) and various bridging models leading to a proposed 2016 tuned base case model (T7).

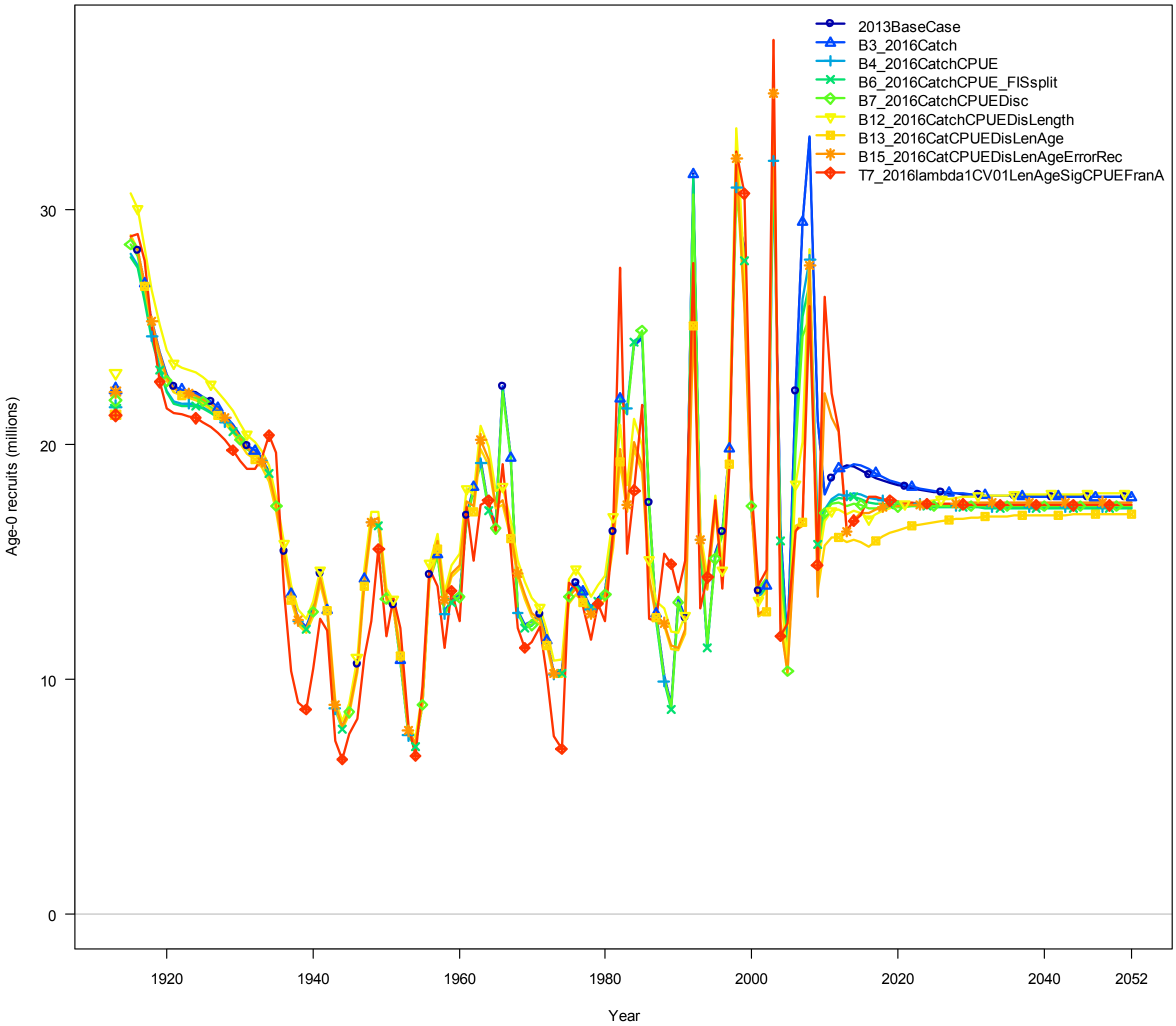


Figure 13.4. Comparison of the recruitment time series for the 2013 assessment model converted to SS-V3.24Z (2013BaseCase) and various bridging models leading to a proposed 2016 tuned base case model (T7).

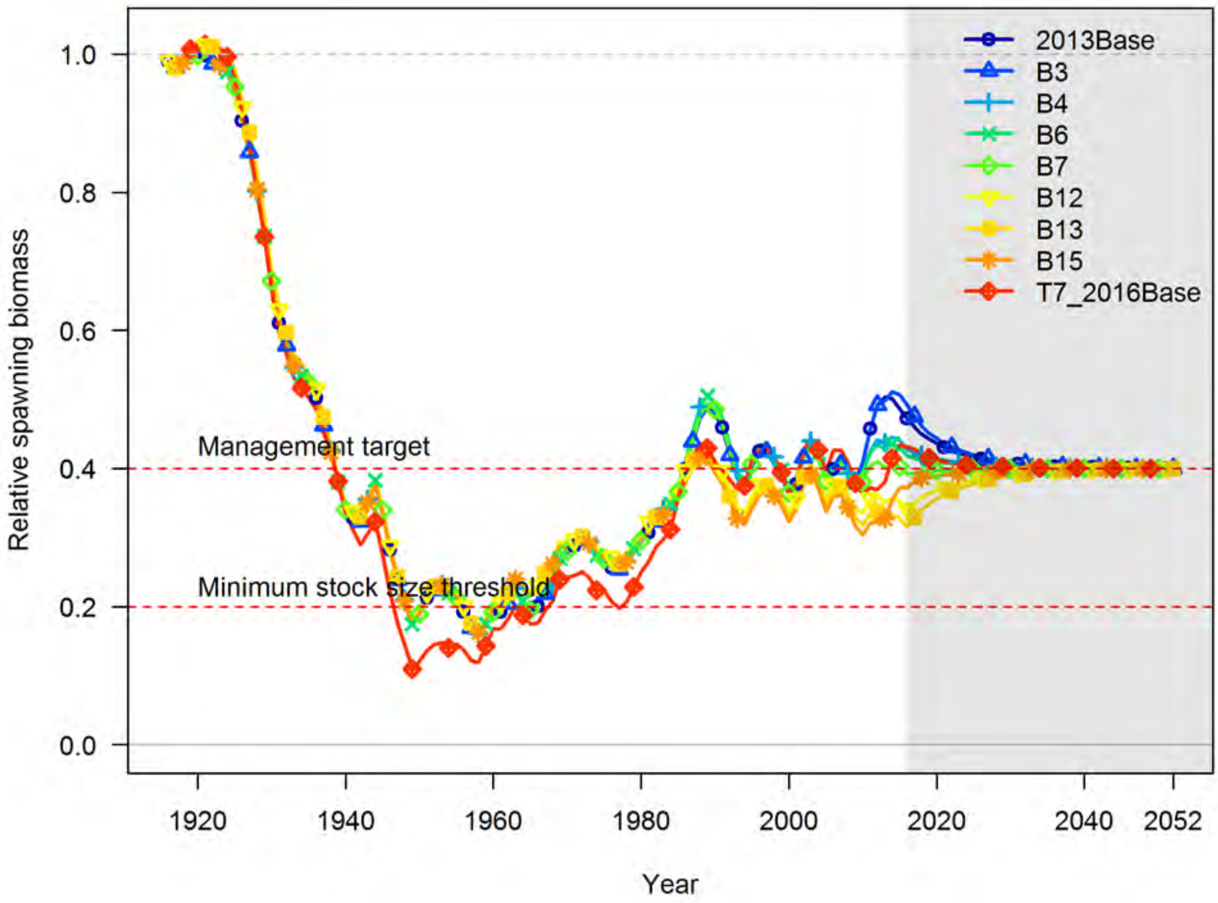


Figure 13.5. Comparison of the spawning biomass time series for the 2013 assessment model converted to SS-V3.24Z (2013Base) and various bridging models leading to a proposed 2016 tuned base case model (T7).

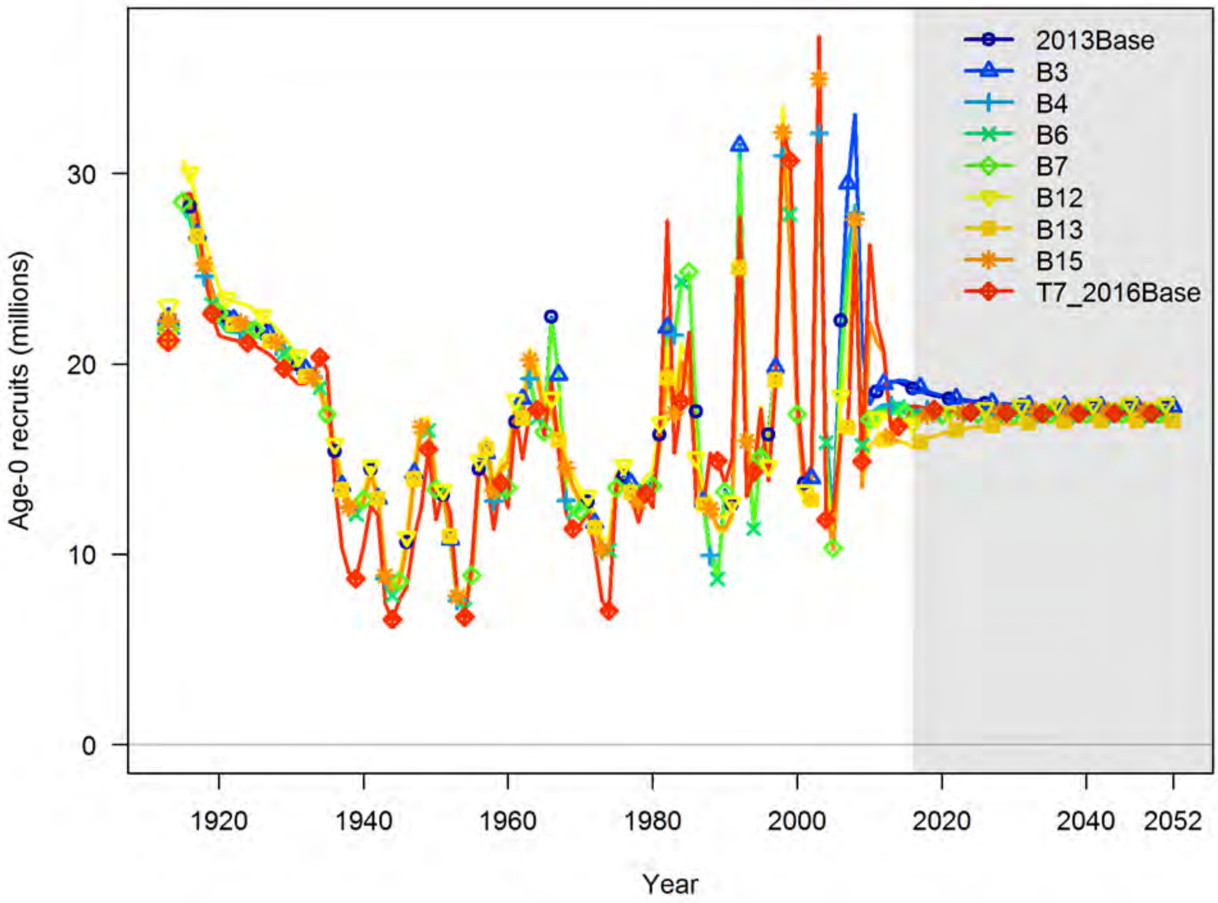


Figure 13.6. Comparison of the recruitment time series for the 2013 assessment model converted to SS-V3.24Z (2013Base) and various bridging models leading to a proposed 2016 tuned base case model (T7).

### *13.3 Acknowledgements*

Age data was provided by Kyne Krusic-Golub (Fish Ageing Services), ISMP and AFMA logbook and CDR data were provided by John Garvey (AFMA). Mike Fuller, Roy Deng and Franzis Althaus (CSIRO) pre-processed the data. Athol Whitten provided very useful R code for organising plots. Robin Thomson, Geoff Tuck, Rich Little, Miriana Sporcic, Malcolm Haddon and Judy Upston are thanked for helpful discussions on this work.

### *13.4 References*

Day J and Klaer N (2013) Tiger flathead (*Neoplatycephalus richardsoni*) stock assessment based on data up to 2012. Unpublished report to Shelf RAG. 70 pp.

Methot RD (2012) User manual for Stock Synthesis. Model Version 3.24f. NOAA Fisheries Service, Seattle. 150 pp.

Methot RD (2015) User manual for Stock Synthesis. Model Version 3.24s. NOAA Fisheries Service, Seattle. 152 pp.

Sporcic M and Haddon M (2016). Catch rate standardizations for selected SESSF Species (data to 2015). Unpublished report to SERAG Data, 11-13 October 2015, Hobart. 214 p.

## *13.5 Appendix: Preliminary base case diagnostics*

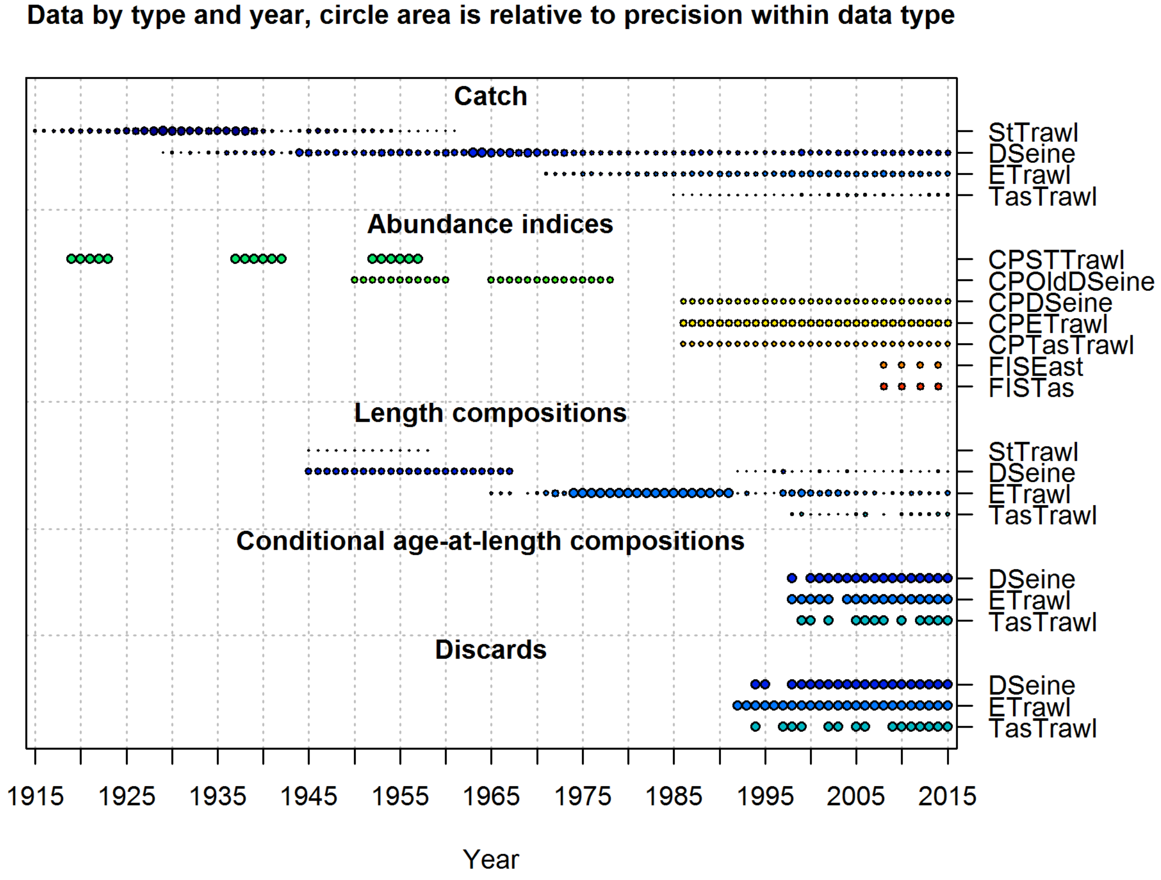


Figure A 13.1. Summary of data sources for tiger flathead stock assessment.

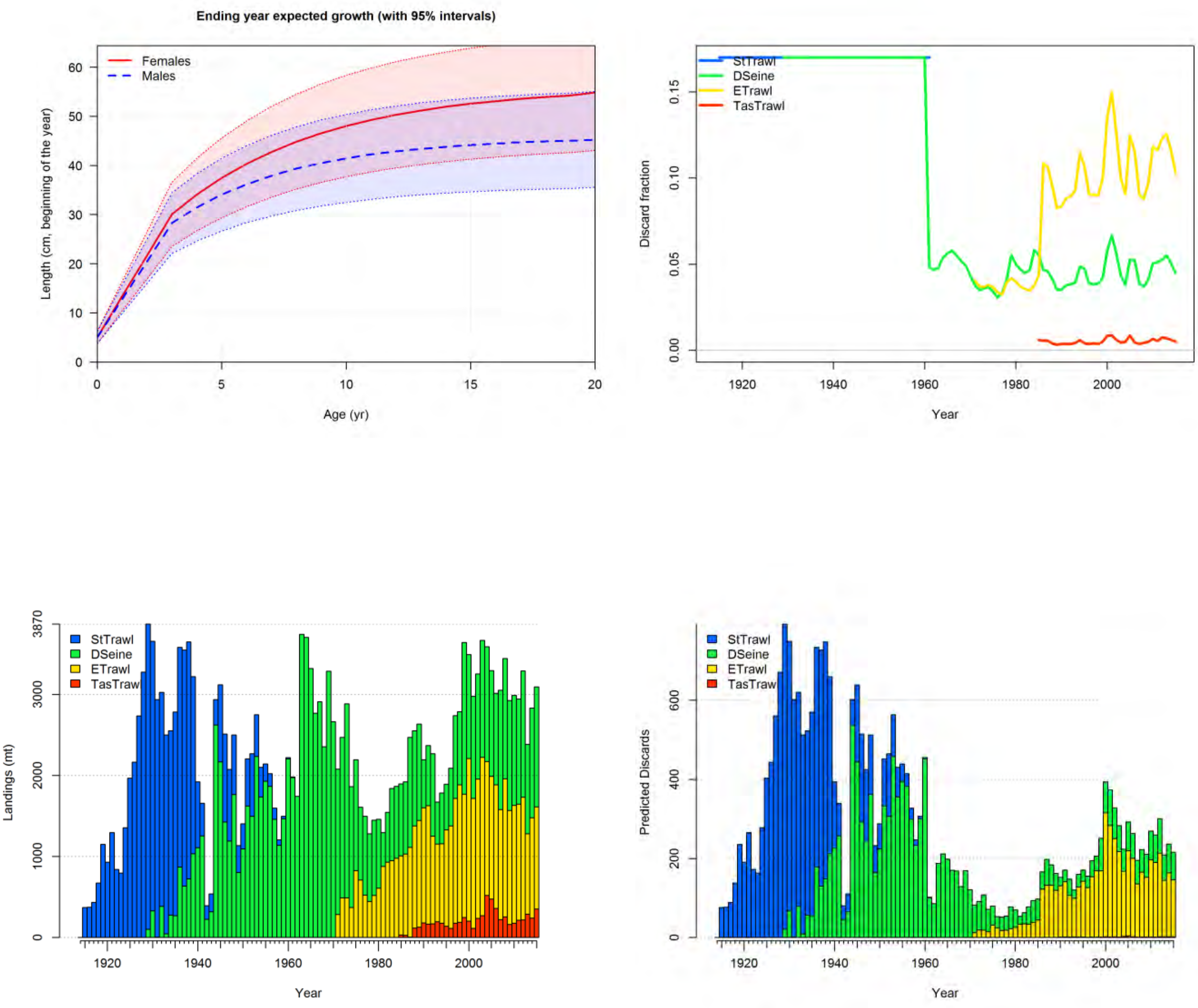


Figure A 13.2. Growth, discard fraction estimates, landings by fleet and predicted discards by fleet for tiger flathead.

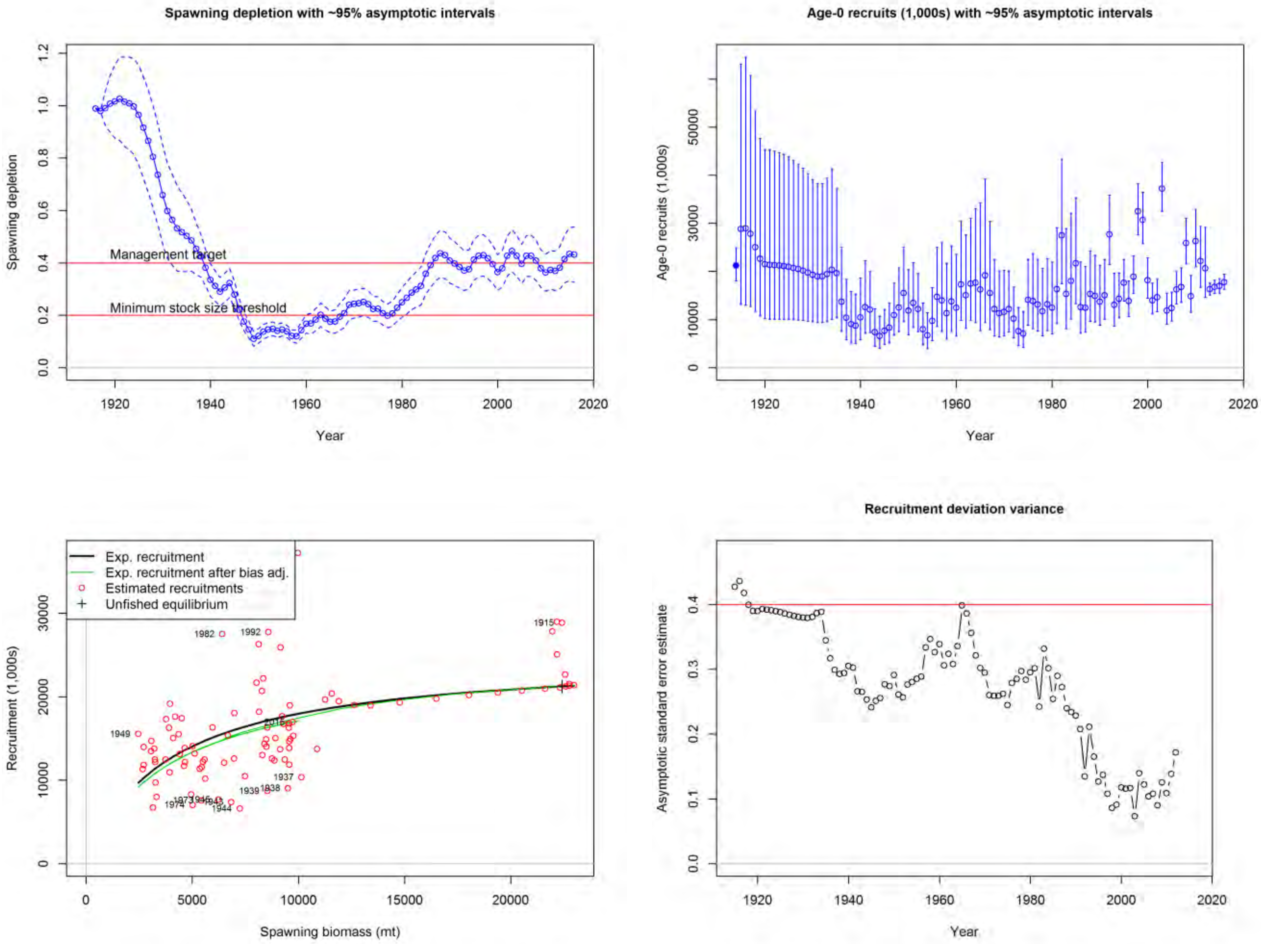


Figure A 13.3. Time series showing depletion of spawning biomass with confidence intervals, recruitment estimates with confidence intervals, stock recruitment curve and recruitment deviation variance check for tiger flathead.

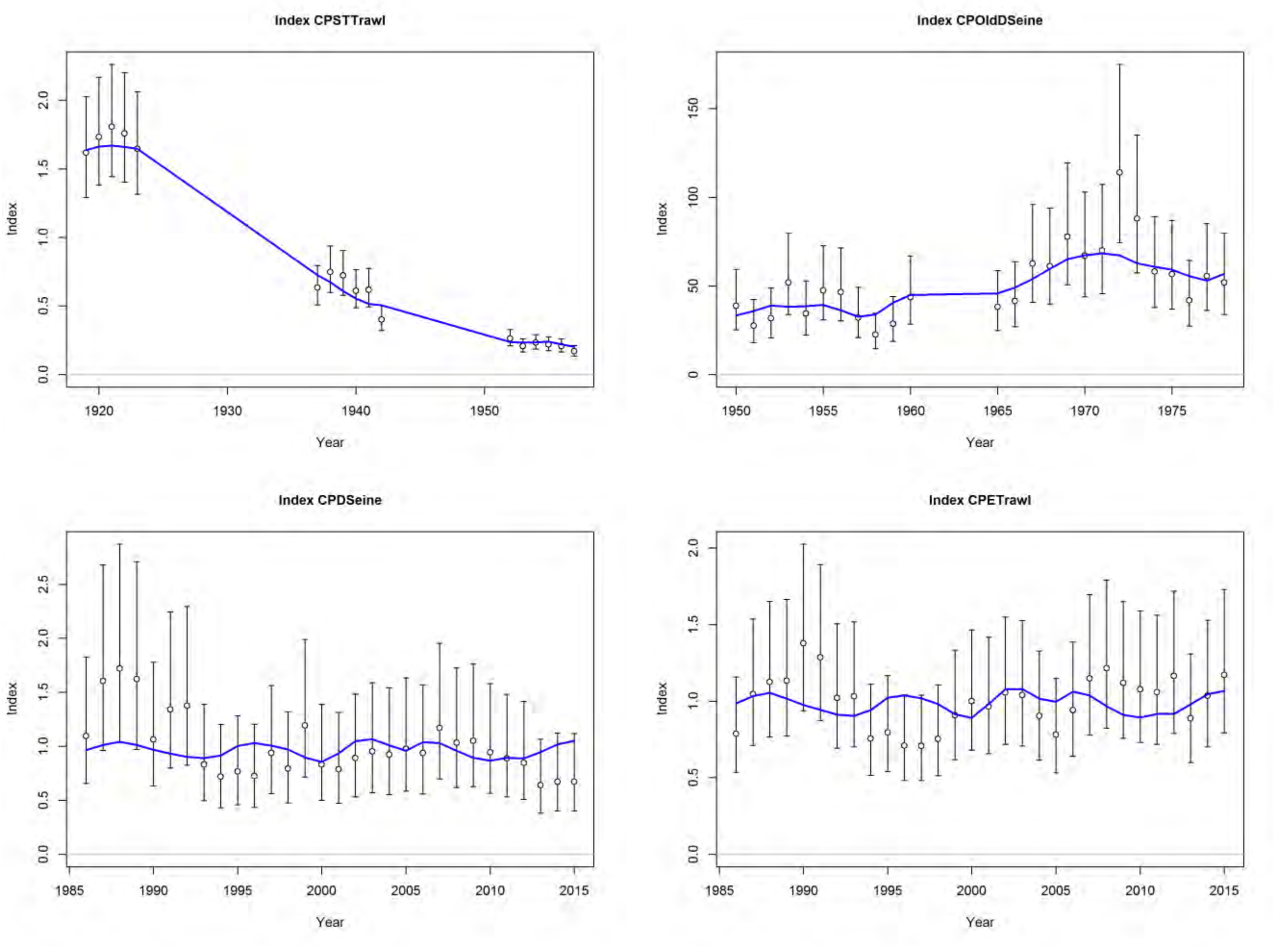


Figure A 13.4. Fits to CPUE by fleet for tiger flathead: steam trawl, old Danish seine, Danish seine, eastern trawl.

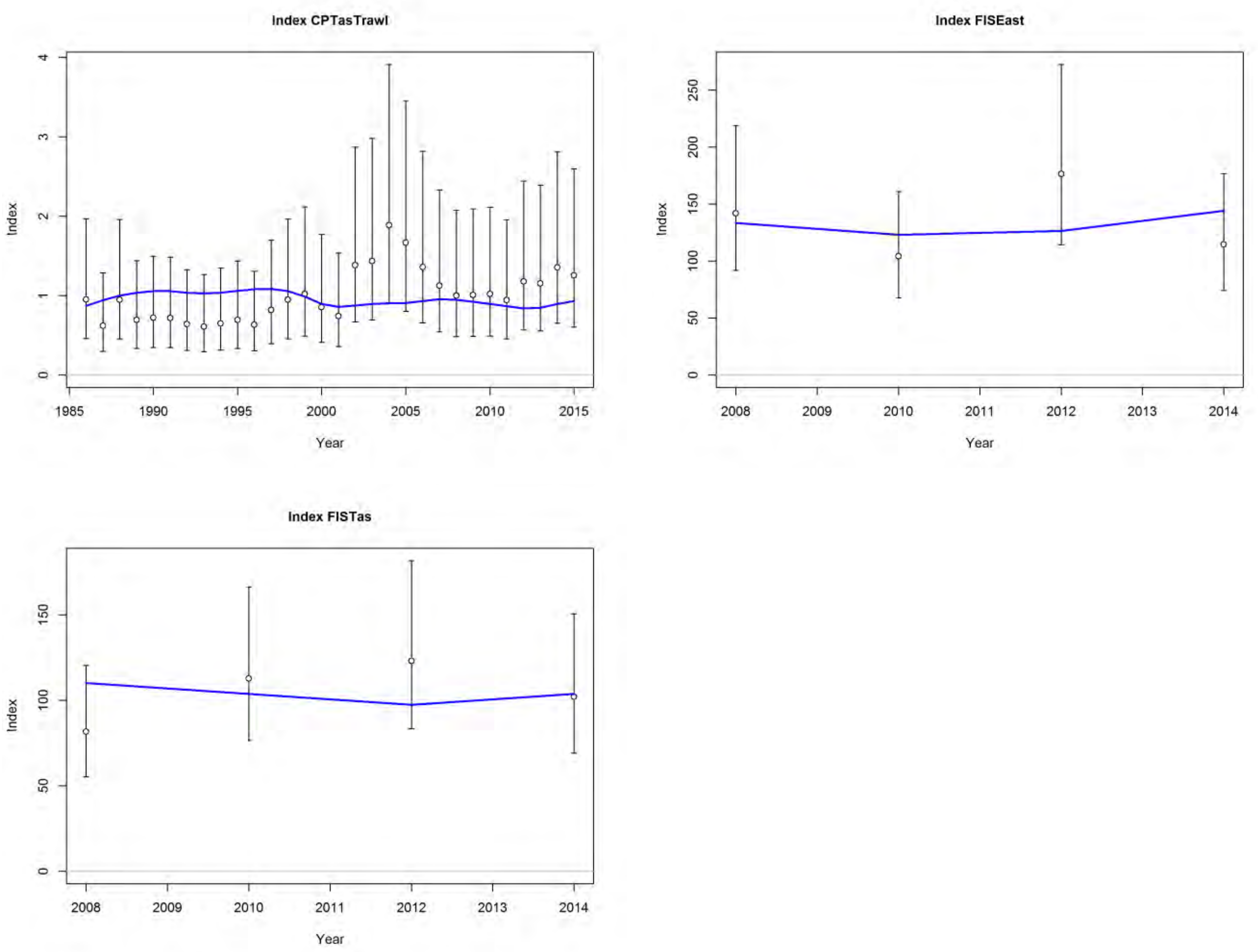


Figure A 13.5. Fits to CPUE by fleet for tiger flathead: Tasmanian trawl and the Fishery Independent Survey.

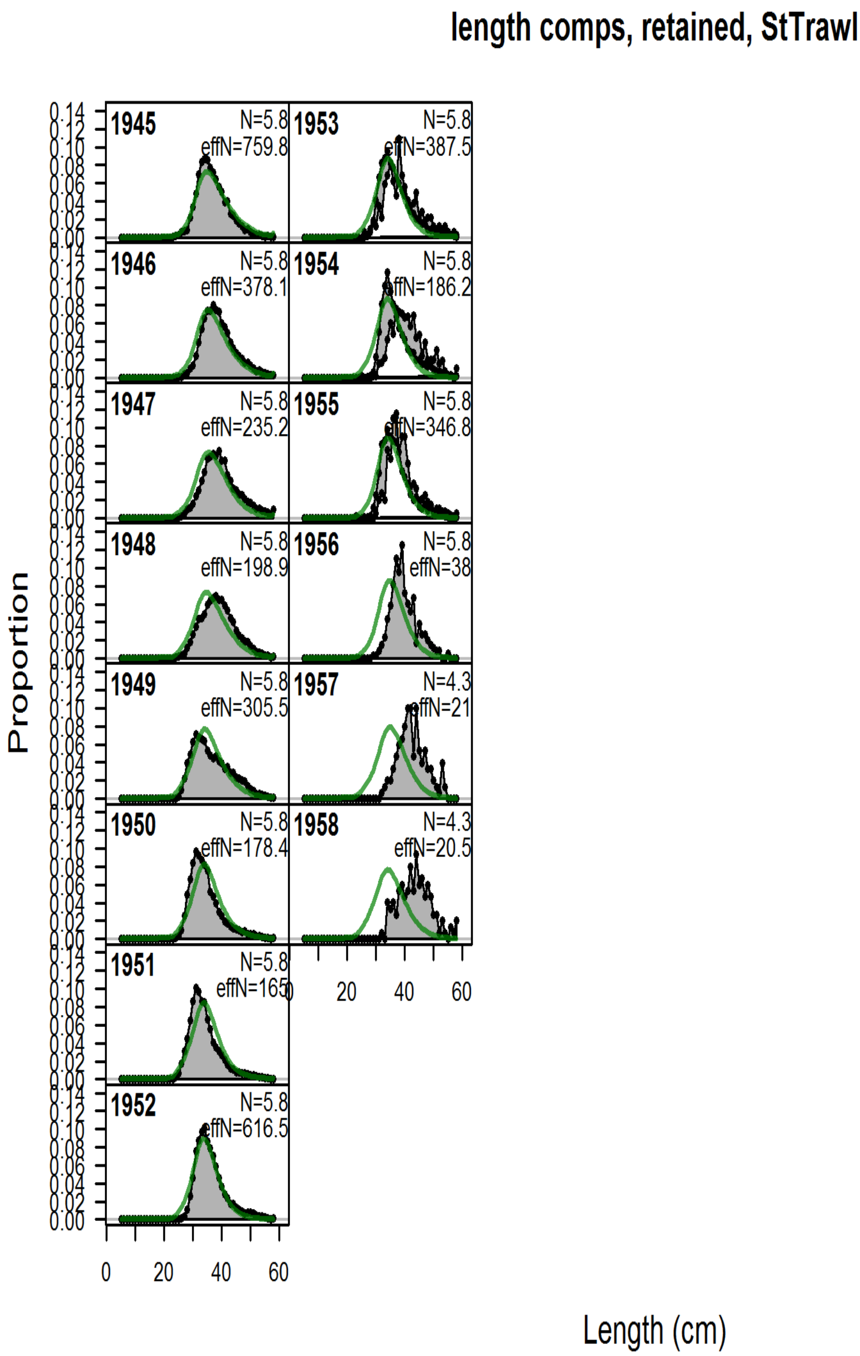


Figure A 13.6. Tiger flathead length composition fits: steam trawl retained.

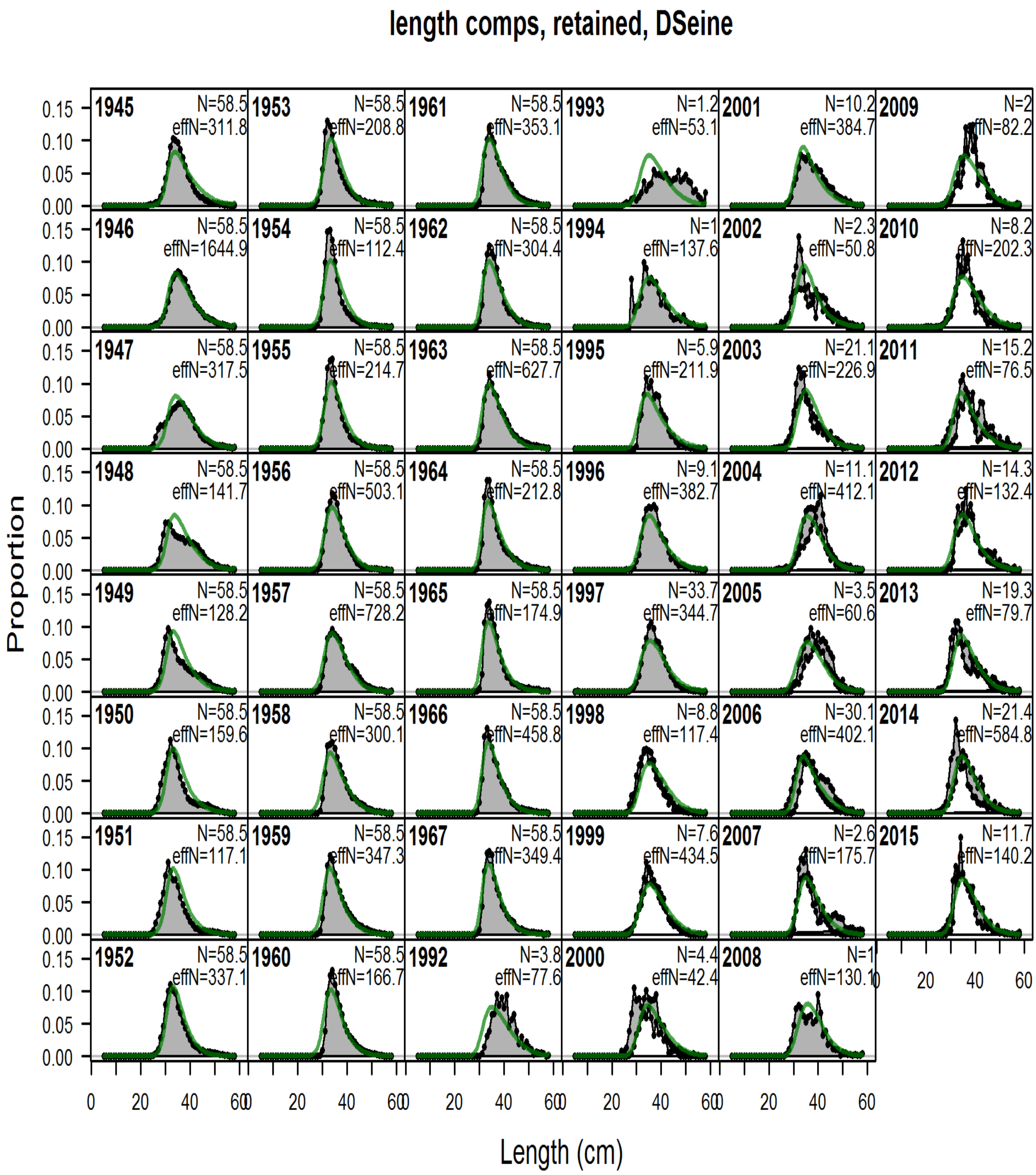


Figure A 13.7. Tiger flathead length composition fits: Danish seine retained.

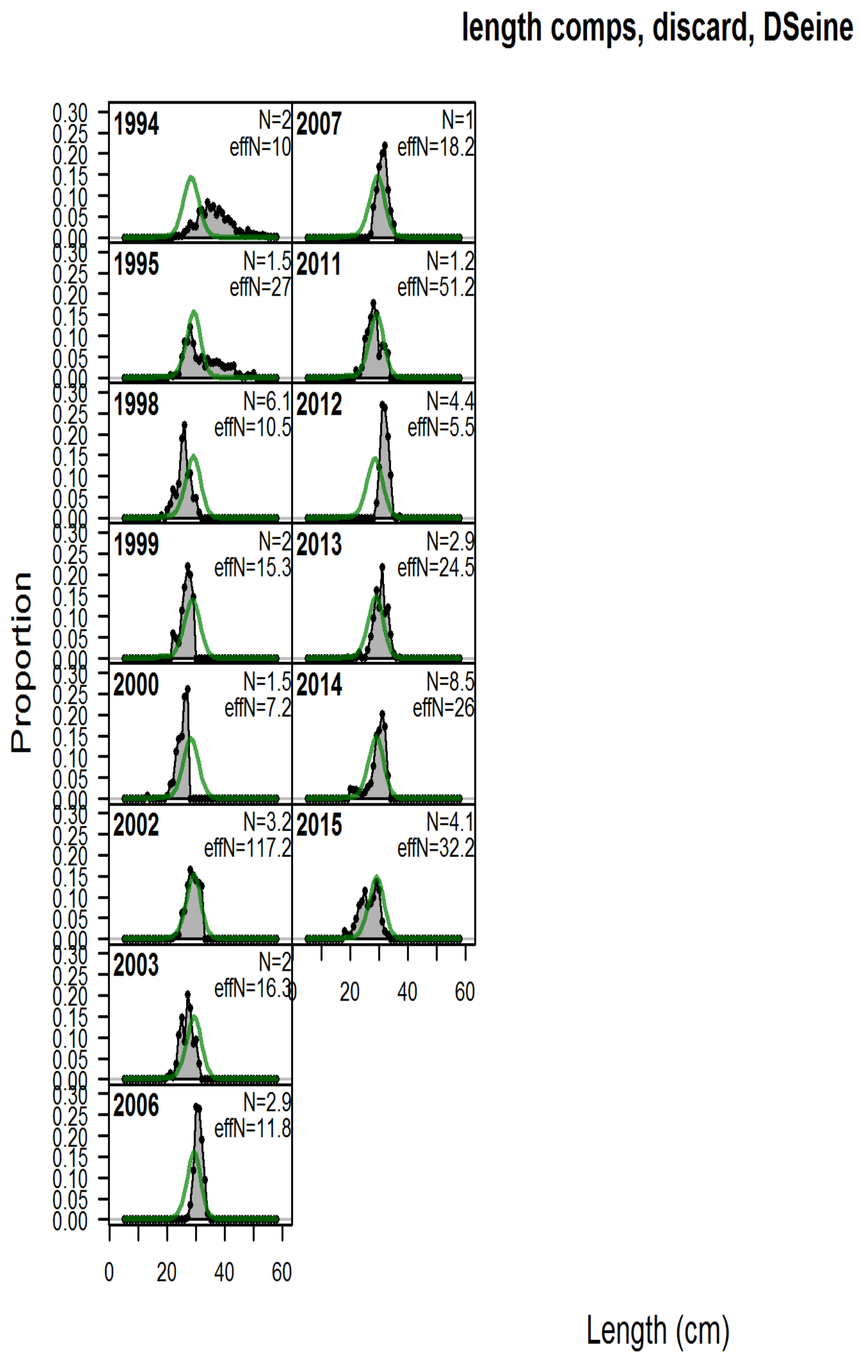


Figure A 13.8. Tiger flathead length composition fits: Danish seine discarded.

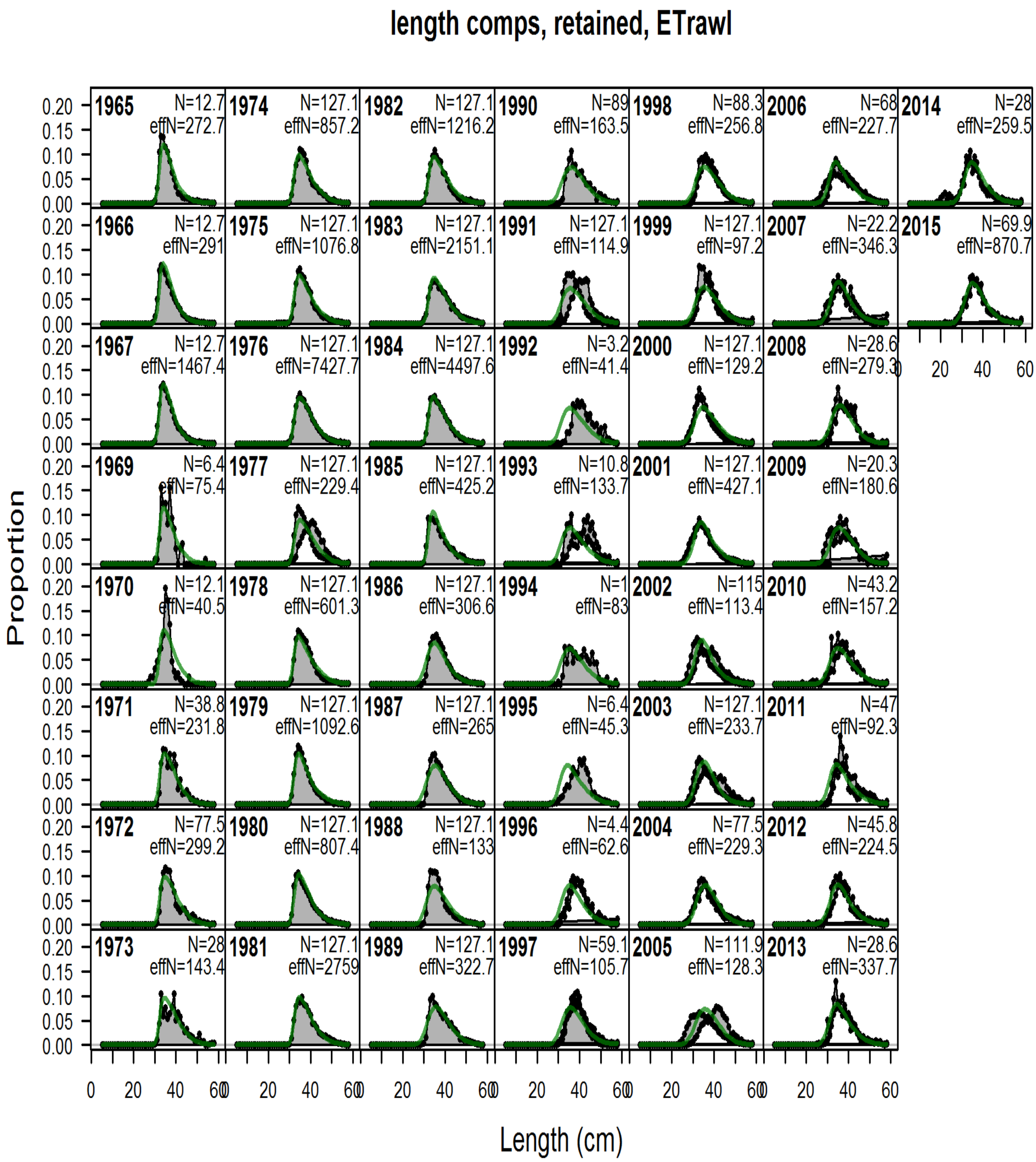


Figure A 13.9. Tiger flathead length composition fits: eastern trawl retained.

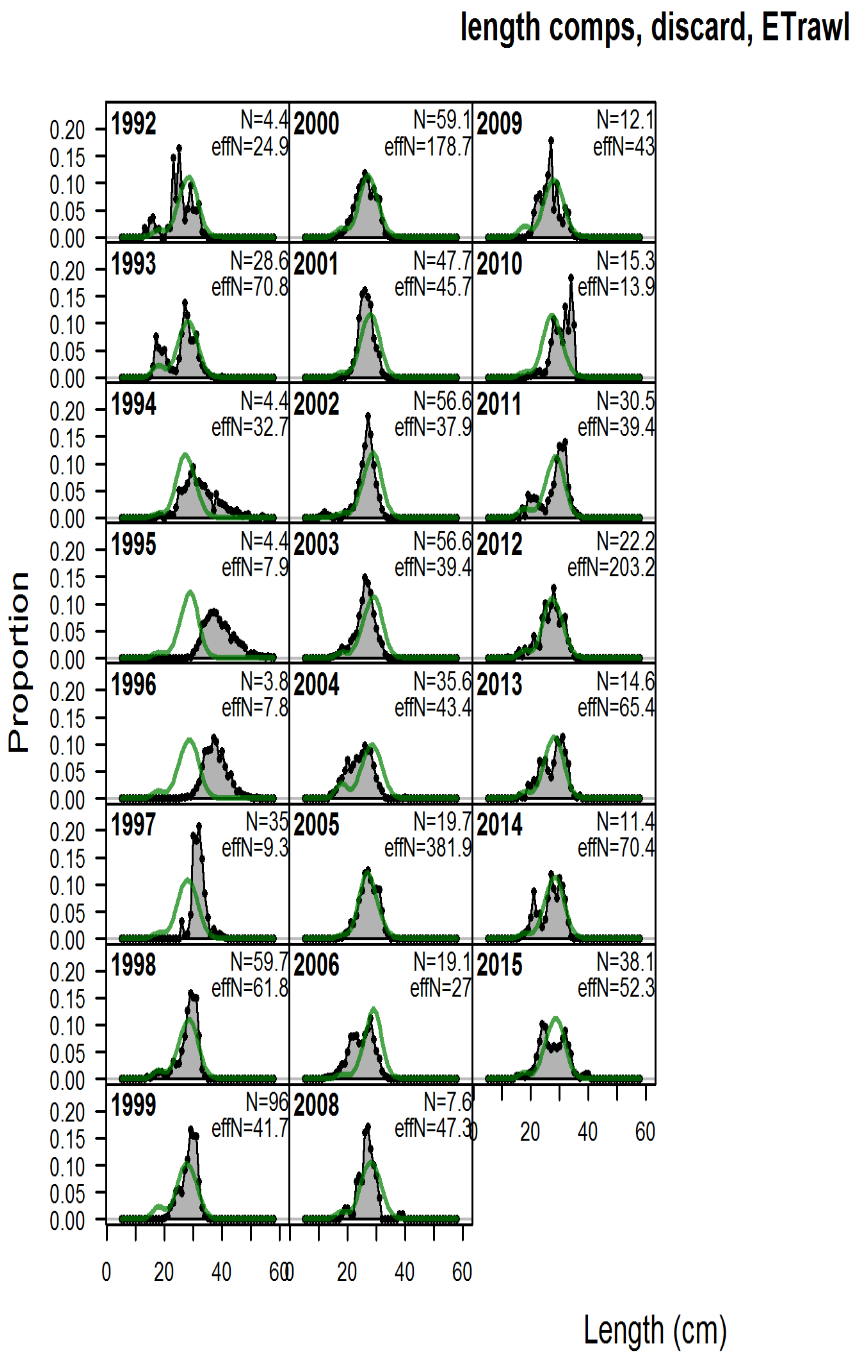


Figure A 13.10. Tiger flathead length composition fits: eastern trawl discarded.

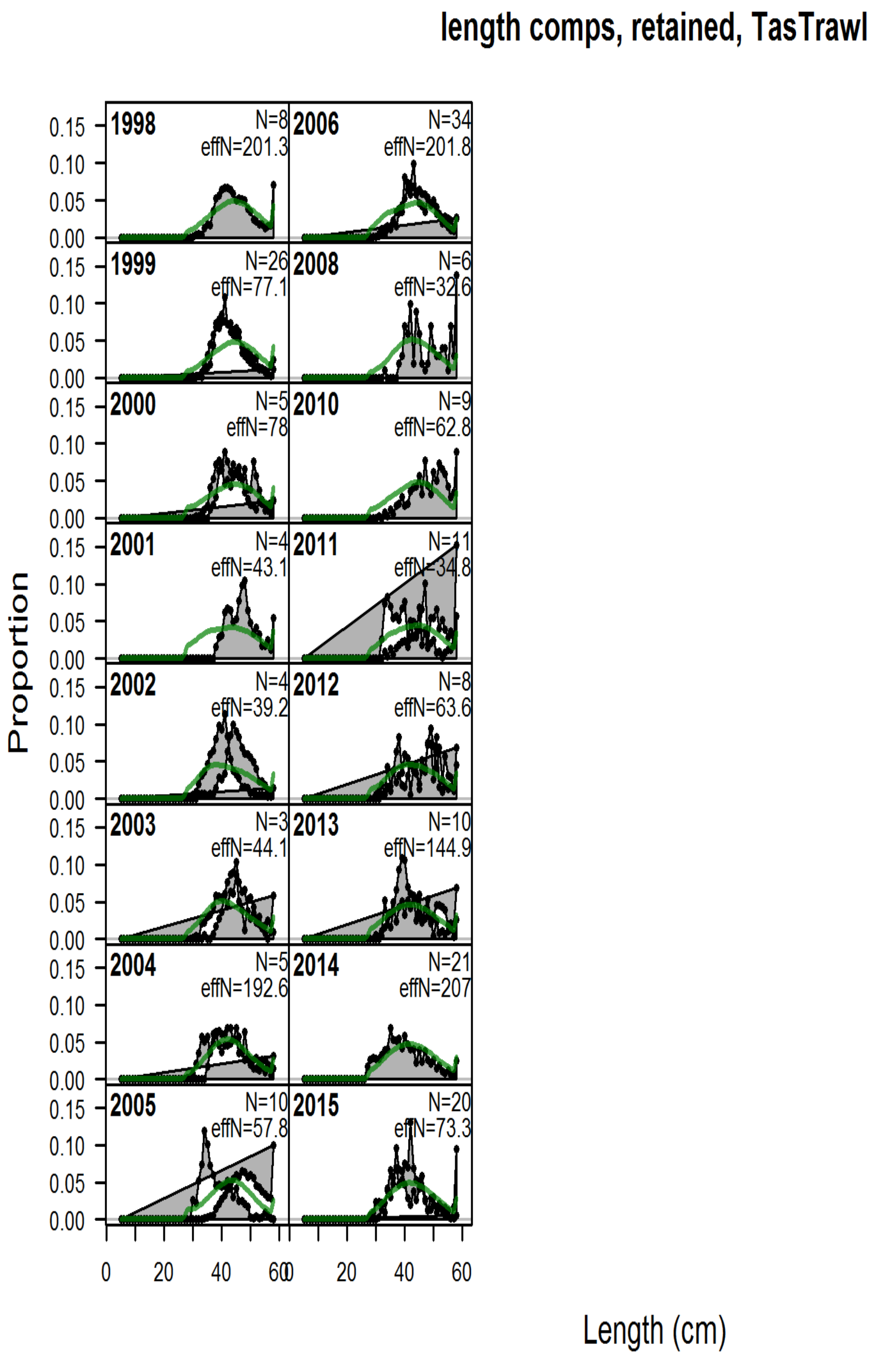


Figure A 13.11. Tiger flathead length composition fits: Tasmanian trawl retained.

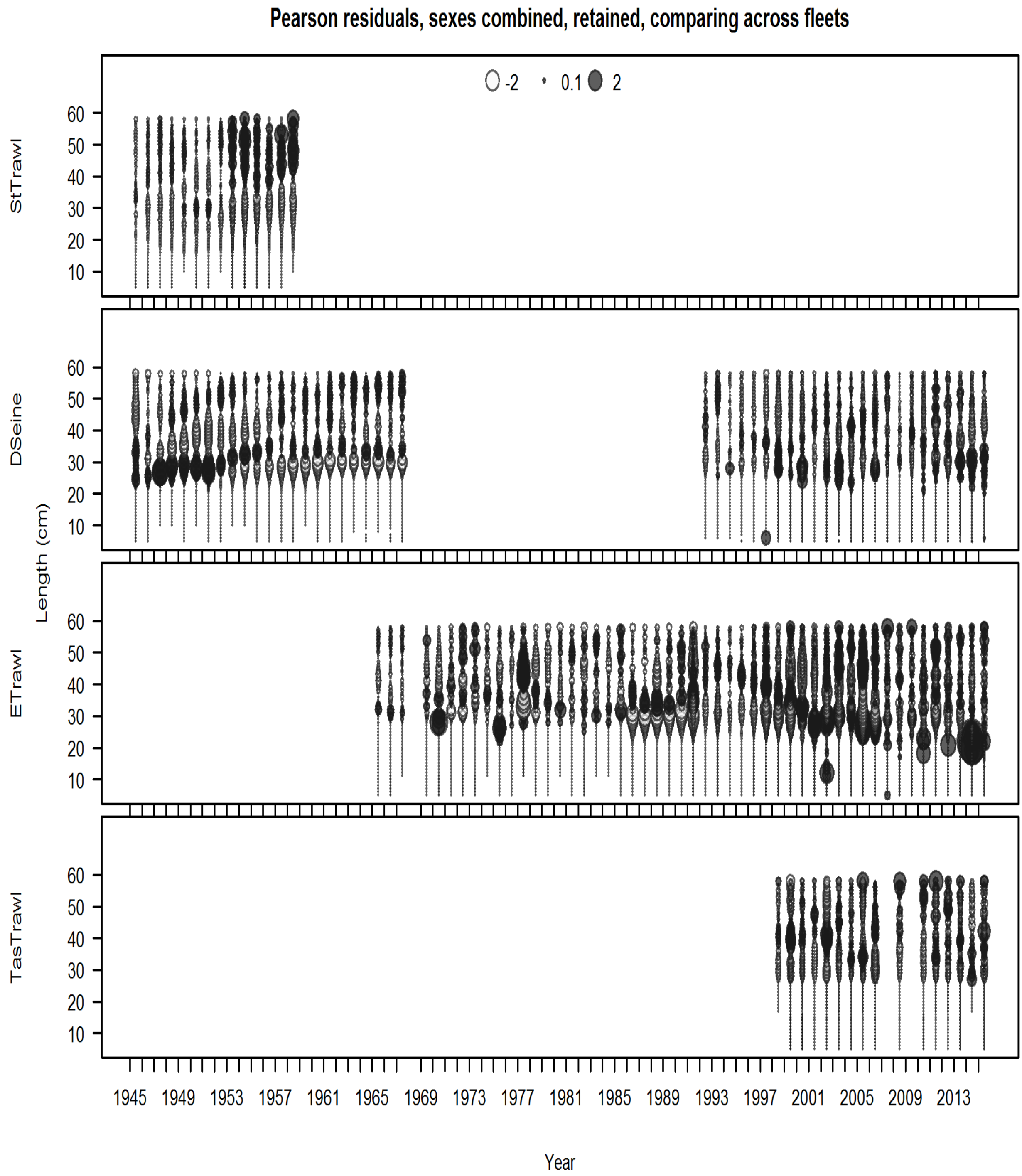


Figure A 13.12. Residuals from the annual length compositions (retained) for tiger flathead displayed by year and fleet.

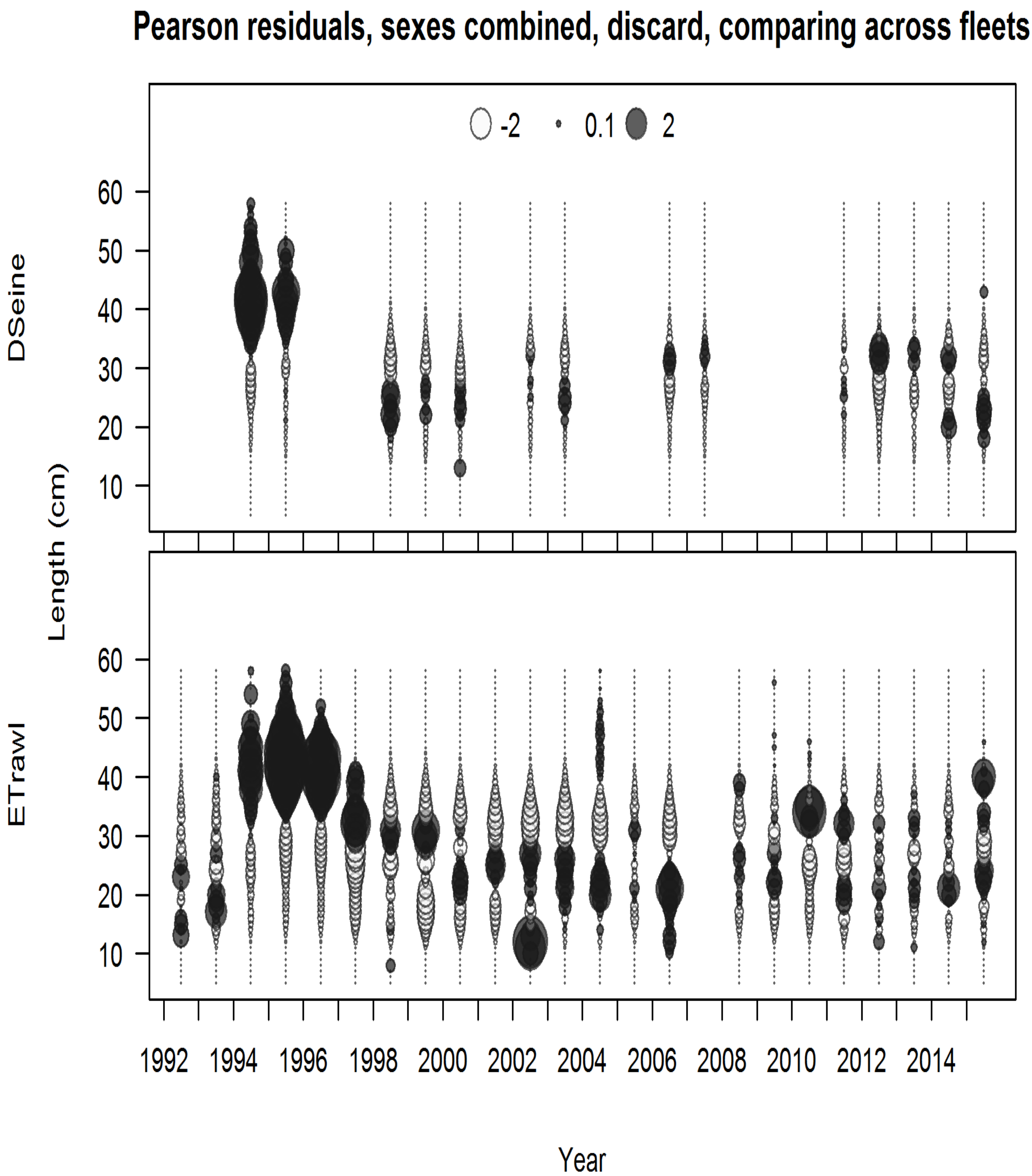


Figure A 13.13. Residuals from the annual length compositions (discarded) for tiger flathead displayed by year and fleet.

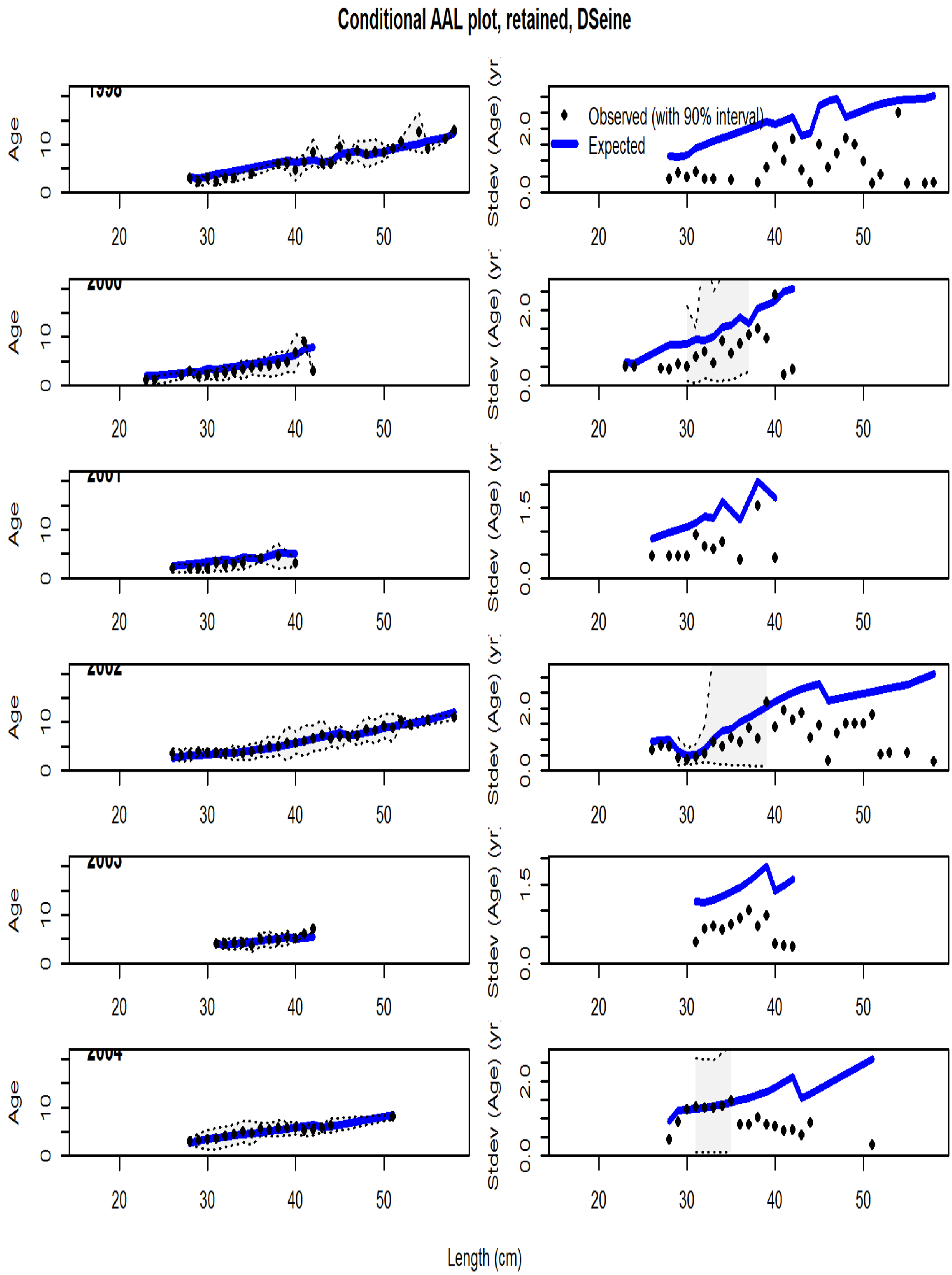


Figure A 13.14. Tiger flathead conditional age-at-length fits: Danish seine part 1.

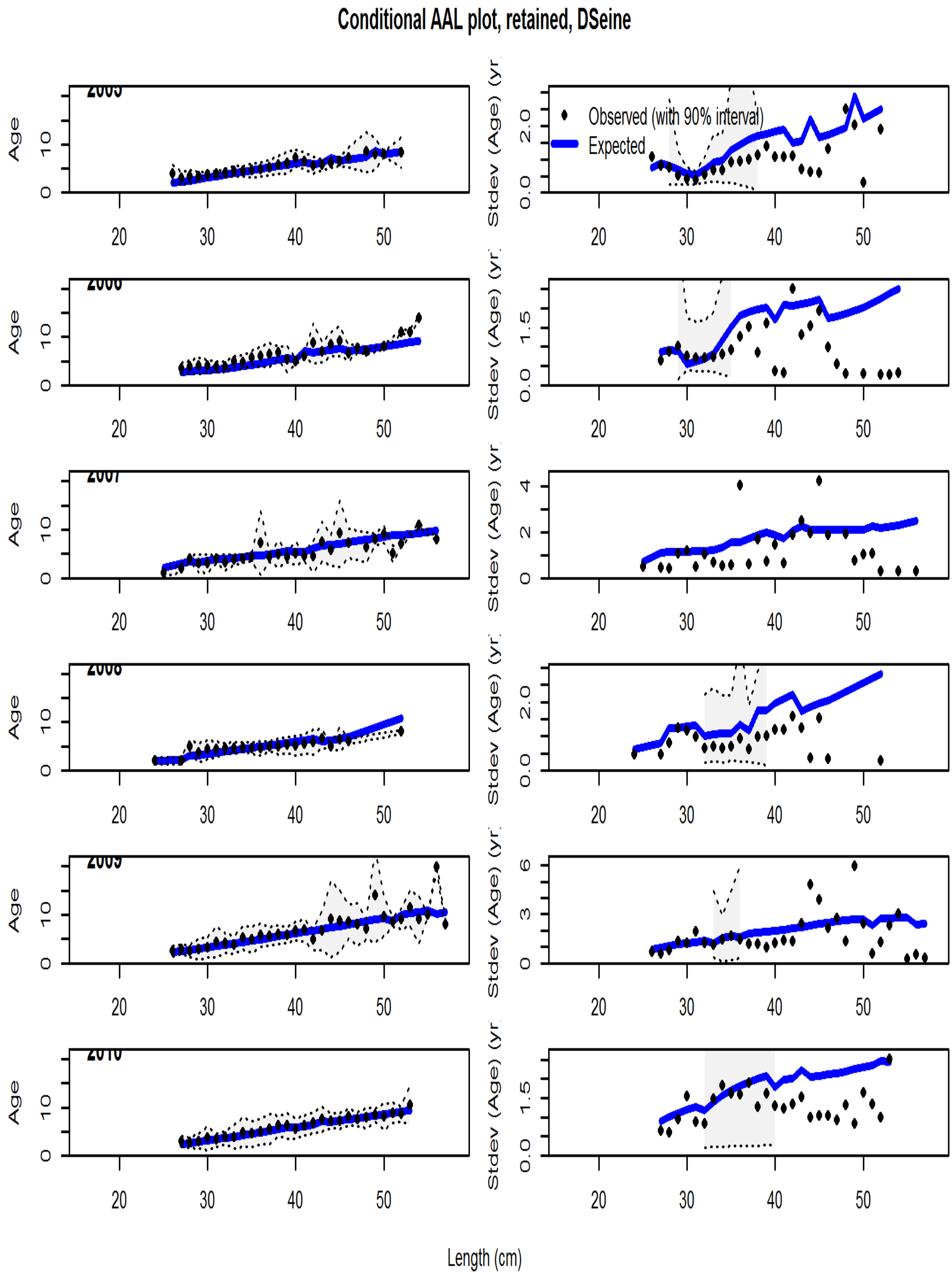


Figure A 13.15. Tiger flathead conditional age-at-length fits: Danish seine part 2.

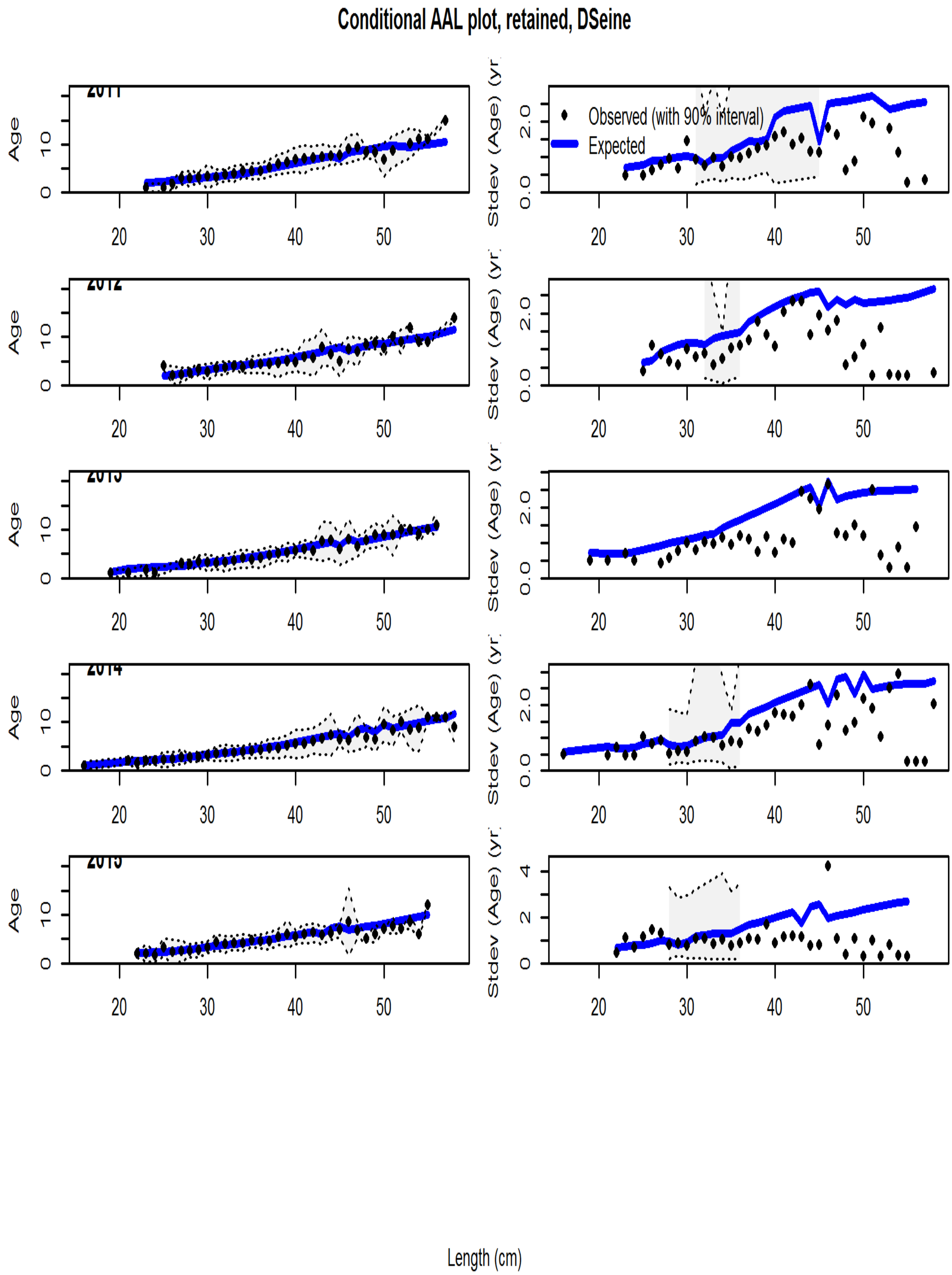


Figure A 13.16. Tiger flathead conditional age-at-length fits: Danish seine part 3.

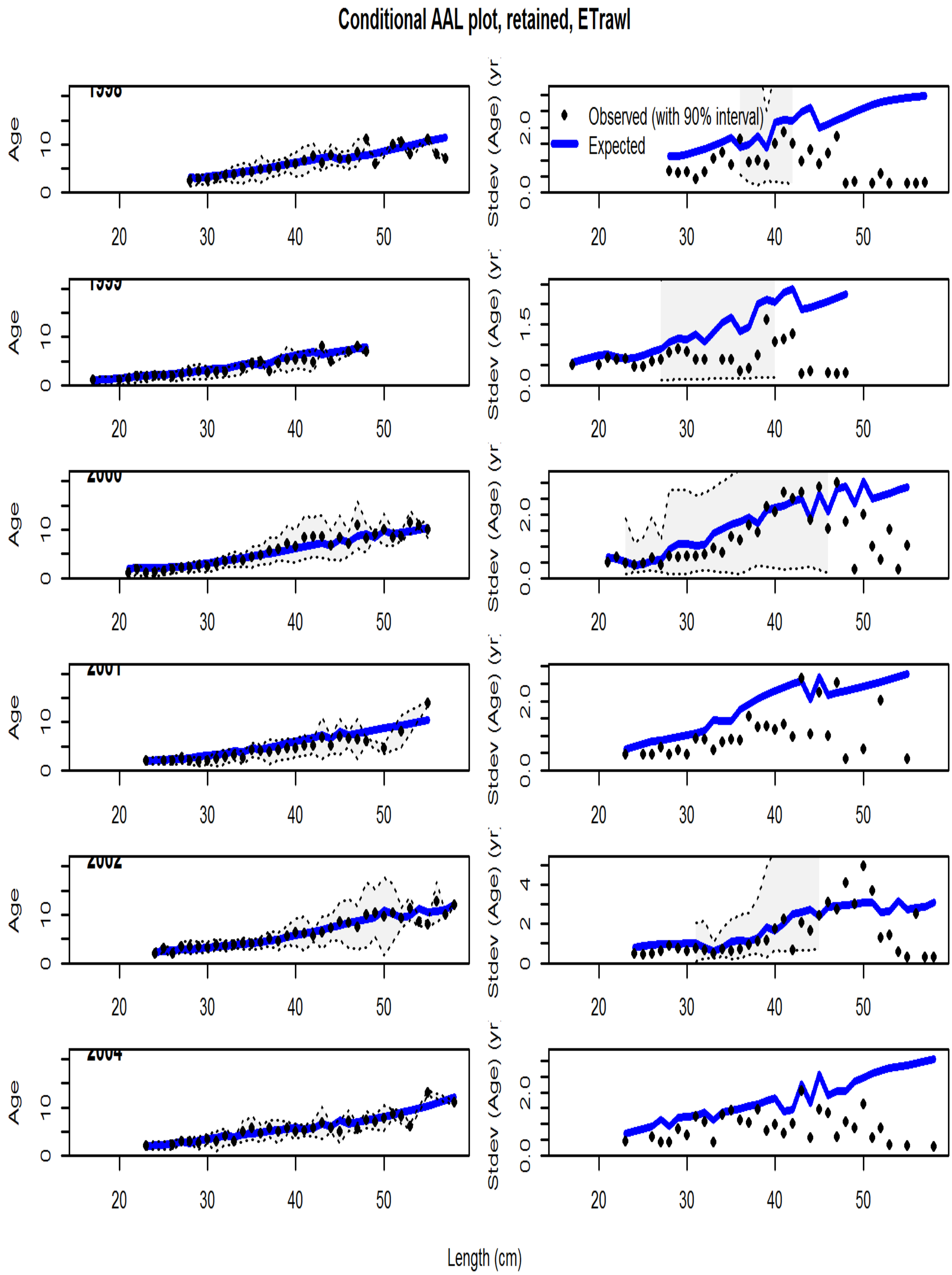


Figure A 13.17. Tiger flathead conditional age-at-length fits: eastern trawl part 1.

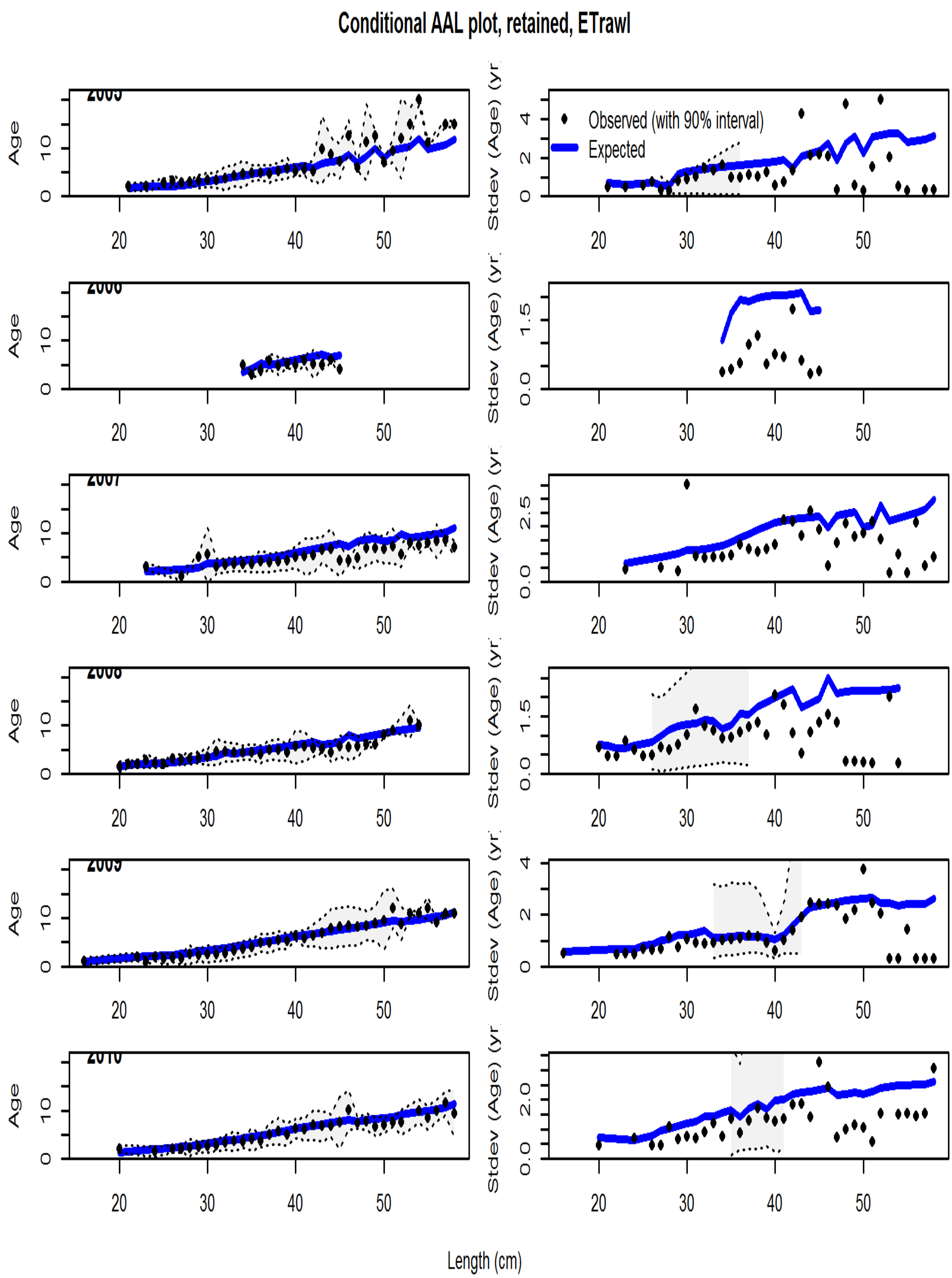


Figure A 13.18. Tiger flathead conditional age-at-length fits: eastern trawl part 2.

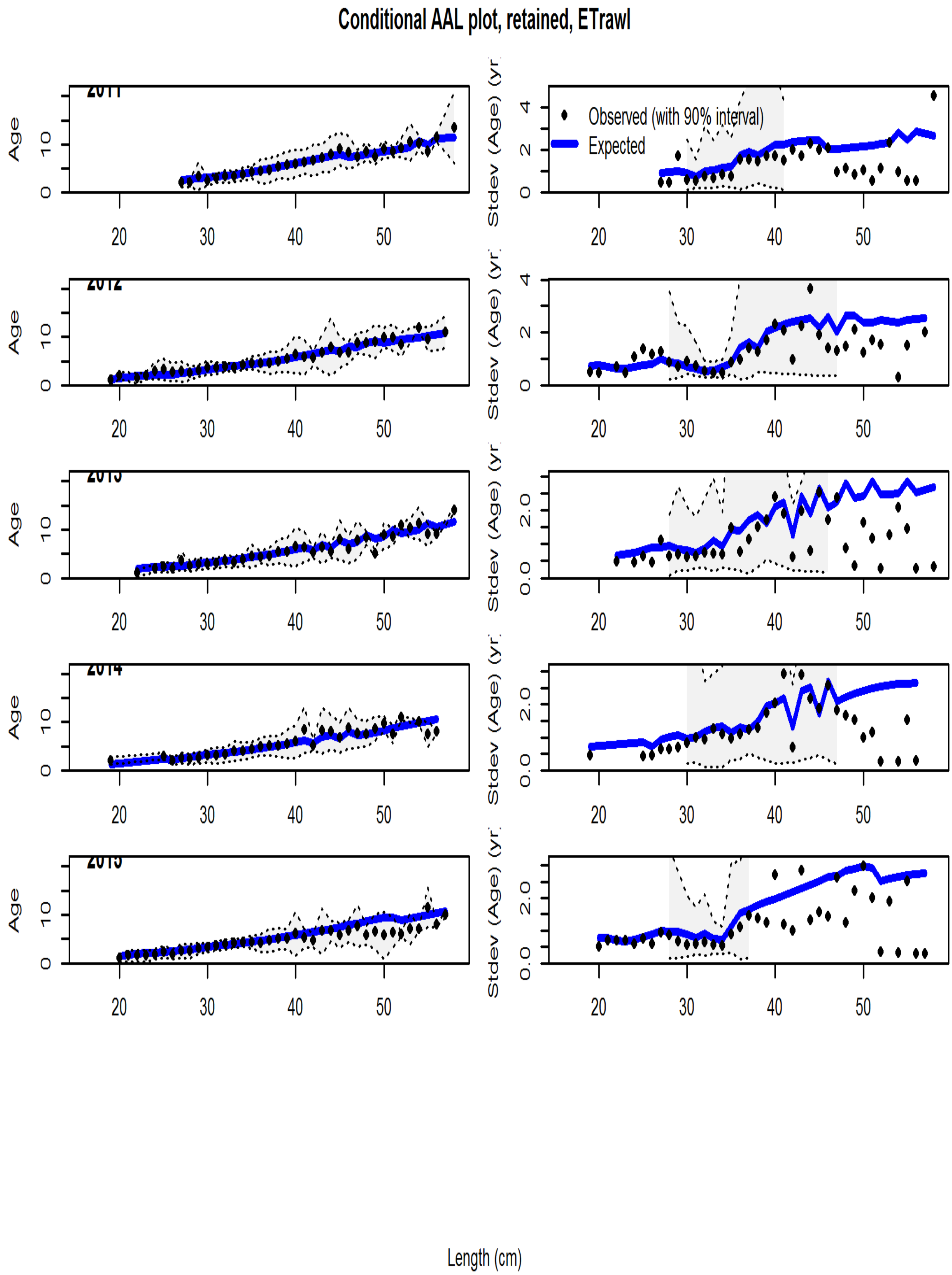


Figure A 13.19. Tiger flathead conditional age-at-length fits: eastern trawl part 3.

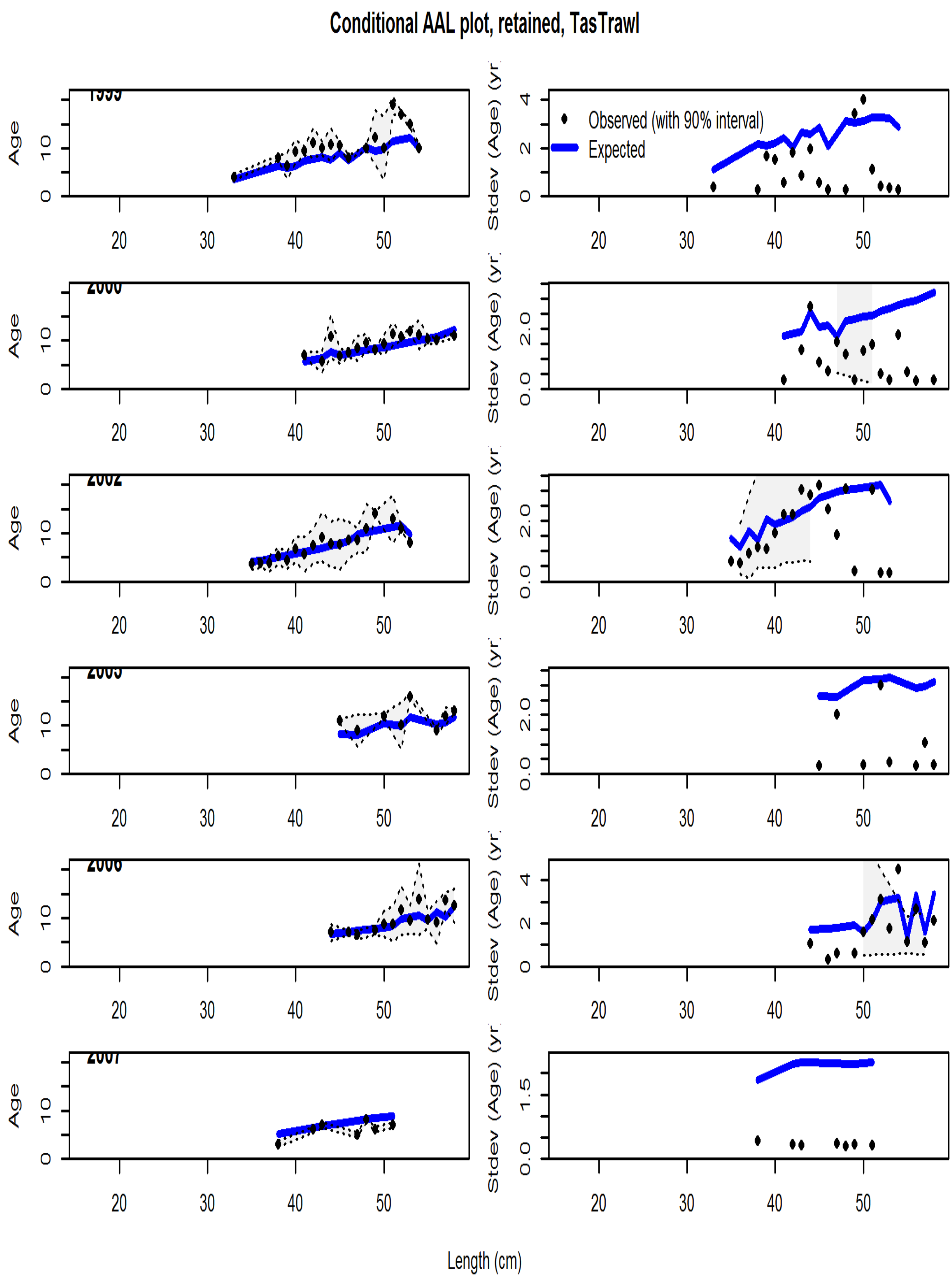


Figure A 13.20. Tiger flathead conditional age-at-length fits: Tasmanian trawl part 1.

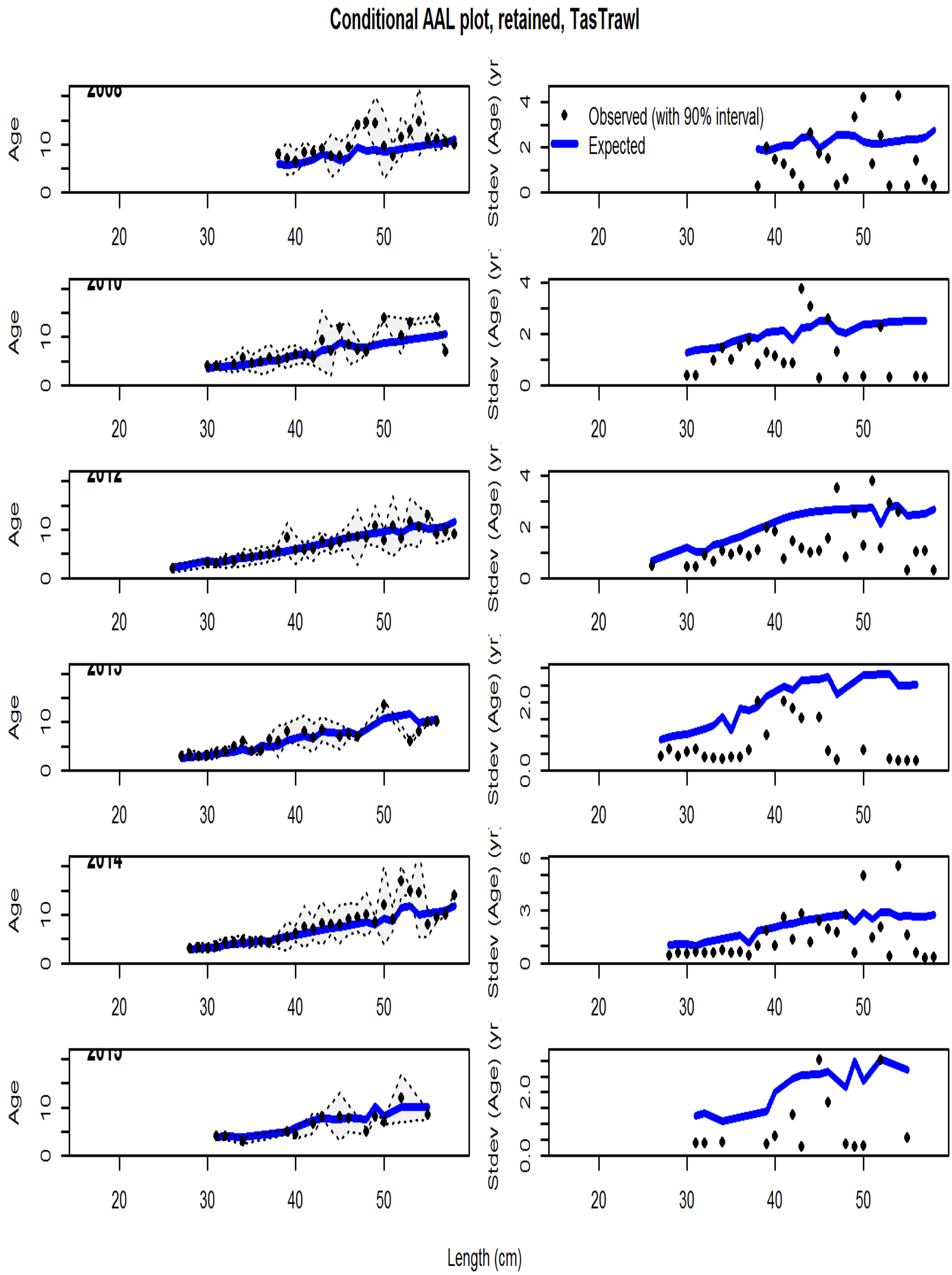


Figure A 13.21. Tiger flathead conditional age-at-length fits: Tasmanian trawl part 2.

# 14. Tiger flathead (*Neoplatycephalus richardsoni*) stock assessment based on data up to 2015

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## 14.1 Executive Summary

This document updates the 2013 assessment of tiger flathead (*Neoplatycephalus richardsoni*) to provide estimates of stock status in the SESSF at the start of 2017. This assessment was performed using the stock assessment package Stock Synthesis (version SS-V3.24Z). The 2013 stock assessment has been updated with the inclusion of data up to the end of 2015, comprising an additional three years of catch, discard, CPUE, length and age data and ageing error updates. An additional survey point is included from the Fishery Independent Survey and length frequencies have been included from all four years of the Fishery Independent Survey. A range of sensitivities were explored, including splitting the Fishery Independent Survey into two fleets to match the fleet structure in the assessment, and lowering the final year of recruitment estimation from 2012 to 2009.

The base-case assessment estimates that current spawning stock biomass is 43% of unexploited stock biomass ($SSB_0$). Under the agreed 20:35:40 harvest control rule, the 2017 recommended biological catch (RBC) is 2,971 t, and remains above the long term yield (assuming average recruitment in the future) of 2,765 t. The average RBC over the three year period 2017-2019 is 2,936 t and over the five year period 2017-2021, the average RBC is 2,909 t.

Exploration of model sensitivity showed a variation in spawning biomass from 26% to 51% of $SSB_0$ when natural mortality was fixed at values of 0.22 and 0.32 respectively. When recruitment is only estimated to 2009, excluding the three above average recruitment estimates in 2010-2012, the spawning biomass was estimated to be 31% of $SSB_0$. For all other sensitivities explored, the variation in spawning biomass was much narrower, ranging between 39% and 45%.

Changes to the last stock assessment include: separating length frequencies into onboard and port collected components, with a joint selectivity pattern estimated; including FIS length frequencies; weighting length frequencies by shots and trips rather than fish measured; and using a new tuning method. The reduction in spawning biomass compared to the last assessment appear to be largely driven by the new data and the resulting modification to the estimates of recent recruitment, in particular to recruitment in the years 2004, 2006, 2007 and 2009.

## 14.2 Introduction

### 14.2.1 *The Fishery*

Tiger flathead have been caught commercially in the south eastern region of Australia since the development of the trawl fishery in 1915. They are endemic to Australian waters and are caught mainly on the continental shelf and upper slope waters from northern NSW to Tasmania and through Bass Strait. Historical records (e.g. Fairbridge, 1948; Allen, 1989; Klaer, 2005) show that steam trawlers caught tiger flathead from 1915 to about 1960. A Danish seine trawl fishery developed in the 1930s (Allen, 1989) and continues to the present day. Modern diesel trawling commenced in the 1970s.

### 14.2.2 *Previous Assessments*

Prior to 2001, the previous quantitative assessment for tiger flathead was from the late 1980s (Allen, 1989). In that report, the assessment for tiger flathead was conducted based on catch and effort data using a surplus production model. The estimate of Maximum Sustainable Yield, MSY, for NSW and eastern Bass Strait was about 2,500 t.

Between 1989 and 2001, assessments of tiger flathead involved examination of trends in catches, catch rates, and in age and length data, but no quantitative assessments were undertaken. Assessments from 1993 to 2001 can be found in the annual reports of SEFAG (the South East Fishery Assessment Group). For example, the 1993 assessment noted that tiger flathead catches from south-east Tasmanian waters contained higher proportions of larger, older fish than those from eastern Bass Strait. This suggested that tiger flathead resources off Tasmania were either more lightly fished than those in the main fishing areas, or that there was a separate stock with different population characteristics off Tasmania.

During the period 2001-2004, data for tiger flathead were collated, summarized and presented at workshops (see Cui *et al*. (2004) for a detailed summary of these workshops and the analyses presented to them). These workshops led to revisions of the data series, analyses of the data, and to suggestions for revisions to the data sets and research priorities. The 2004 assessment (Cui *et al.*, 2004) used 89 years (1915–2003) of data to estimate the virgin spawning stock biomass and the 2004 spawning stock biomass relative to that in 1915 and provided, for the first time, a complete picture of the dynamics of the tiger flathead fishery.

A number of changes to both the input data and some model structural changes were made and presented in the assessments developed in 2005 (Punt 2005a, Punt 2005b). These assessments considered tiger flathead caught off eastern Tasmania in SEF zone 30 as either separate to, or part of the same stock in zones 10 (E NSW), 20 (E Bass Strait) and 60 (Bass Strait) combined. In the scenario where eastern Tasmanian flathead are part of the same stock, a separate fleet was constructed to account for catches made there. Modifications to estimates of historical catches from Klaer (2005) were incorporated into catch series used in the assessments. Length-frequency data for 1945-1967 and 1971-1984 were obtained, and uncertainty in discard rates was estimated using a bootstrap procedure.

Part of the intention for the 2006 assessment (Klaer, 2006a) was initially to duplicate as far as possible the assessment results from 2005 (Punt, 2005a, Punt 2005b) while implementing the assessment using the Stock Synthesis (SS2) framework. The same assumptions were made about stock structure, i.e. tiger flathead off eastern Tasmania may or may not be the same stock as those off NSW and Victoria. Steepness was treated as an estimable parameter and annual age frequencies were added directly into the model as samples independent to length frequencies. The 2006 Shelf RAG selected the model that treated Tasmanian trawl as a separate fleet fishing the same east coast stock as the most appropriate base case.

The 2009 assessment (Klaer, 2009) moved the model from Stock Synthesis version SS-V2.1.21 (June 2006) to Stock Synthesis version SS-V3.03 (May 2009). Major changes to previous assessments were the use of age-at-length data to estimate growth parameters, correction to discard estimation for steam trawl, allowing selectivity change in 1985 for diesel trawl and 1978 for Danish seine, and estimation of recruitment 3 years prior to the last year (2005) for the 2009 assessment that used data to the end of 2008.

The 2009 assessment was updated in 2010 (Klaer, 2010) using Stock Synthesis version SS-V3.11a, (Methot September 2010). For the 2010 assessment, changes were made to the treatment of discards prior to 1980, an additional growth parameter was estimated and the assumed value for natural mortality, M, was changed from 0.22 to 0.27.

The most recent full quantitative assessment for tiger flathead was performed in 2013 (Day and Klaer, 2013) using Stock Synthesis version SS-V3.24f, (Methot August 2011). Results from three years of the winter fishery independent survey (FIS) were included as an additional abundance index in the 2013 assessment, but no FIS length data were included.

#### 14.2.3 *Modifications to the Previous Assessments*

This assessment uses the current version of Stock Synthesis, version SS-V3.24Z, (Methot 2015).The number of growth parameters estimated and assumptions about mortality and early discarding rates in this assessment are identical to the 2013 assessment (Day and Klaer, 2013). Three growth parameters are estimated (CV, $K$ and $l_{min}$), natural mortality is assumed to be 0.27 and the discarded catch for steam trawl and for Danish seine prior to 1960 is assumed to be 20% of the retained catch, which translates to a discard ratio (disc/[ret+disc]) of 17%.

An abundance index from the fishery independent survey (FIS) for the winter surveys for four years: 2008, 2010, 2012 and 2014 (Knuckey *et al.*, 2015) was included in the 2013 assessment and this index is retained in this assessment with an additional data point. As the summer FIS was discontinued after 2012, the summer FIS abundance index has not been included in sensitivities in this assessment.

Updates to data used in the previous assessment resulted from improvements in the automatic processing of data and filtering of records. However, some historical length frequency data used in the 2013 assessment are not present in the automatic processing. These length frequencies are included in the current assessment, by using data from the 2013 assessment for the following retained length frequencies:

1. Steam Trawl, Sydney Fish Market – 1953-1958.
2. Eastern Trawl, Sydney Fish Market – 1965-1967.
3. Danish seine, onboard – 1993-1994.

In addition to this historical data, retained for this assessment, there appear to be some changes in the Tasmanian Trawl length frequencies in 2009 and 2010 which may warrant future investigation. Only one shot was recorded from each of the 2009 and 2010 onboard samples, so these length frequencies were excluded, as they were unlikely to be representative. Similarly, the 2009 port length frequency came from less than 100 fish so this length frequency was also excluded. These sample sizes are different to those produced by the 2013 automatic processing, so this may require further investigation.

Discard length frequencies from Danish seine in 1994 and 1995 and eastern trawl from 1994-1996 were excluded in previous assessments as these appear to have unrepresentative distributions. These discard length frequencies were also excluded from the current assessment.

Other substantial changes from the 2013 assessment include:

1. Including both port and onboard length frequency data.
2. Weighting length frequency data by shot or trip numbers rather than numbers of fish measured.
3. Modifications to the tuning procedures including use of Francis weighting for length and age data.
4. Inclusion of length frequency data from the fishery independent surveys from 2008, 2010, 2012 and 2014.

Previous tiger flathead assessments have applied a lambda of 0.1 to length and age frequency data to down weight the likelihood from these sources relative to the likelihood from the CPUE and survey data. Weighting these frequencies by shot rather than numbers of fish measured, and using the latest protocols including Francis weighting has allowed these lambdas to be returned to 1. If it can be avoided, it is preferable to set the lambdas at 1, rather than make somewhat adhoc decisions to balance the likelihood from different data sources and somewhat arbitrarily down weight length and age data.

Updates to data used in the previous assessment resulted from improvements and corrections in the automatic processing of data and filtering of records. Including both port and onboard length frequencies resulted in additional length frequencies, and weighting these by shot or trip numbers altered the relative weighting between years. When shots or trip were not known (Sydney Fish Market, Kapala or Blackburn data), the number of fish measured was divided by 10 and capped at 200. When the number of trips or shots was available, a cap of 120 trips and 200 shots was used to set an upper limit on the sample size, although the limit on trip numbers was never exceeded.

The data updates produced minor modifications to estimates of discards. An updated estimate of the ageing error matrix constructed from the new ageing data was used. As in the 2013 assessment, age-at-length frequency distributions were only used when the gender was known. The only changes to age-at-length data were the addition of three years of new data from 2013 to 2015. Minor revisions were made to the catch history from 2001 onwards, with minor modifications to recent state catch history and some reallocation of catch between fleets due to misclassification of some vessels. Updates to the preliminary 2012 and assumed 2013 catches were made and new 2014 and 2015 catch data was included, with the 2016 catch data (required to calculate a 2017 RBC) assumed to be the same as the 2015 catch data.

Inclusion of the new data had relatively minor impacts on the estimates of recruitment and the spawning biomass time series. With recruitment estimated up until 2012, this resulted in several of the recruitments estimated from 2004-2009 to be revised down, compared to the 2013 assessment. The general recruitment trend before 2004 was unchanged in the new assessment.

The usual process of bridging to a new model by adding new data piecewise and analysing which components of the data could be contributing to changes in the assessment outcome was conducted (Day, 2016).

## 14.3 Methods

### 14.3.1 *The Data and Model Inputs*

#### *14.3.1.1 Biological Parameters*

As male and female tiger flathead have different growth patterns (females are substantially larger), a two-sex model has been used.

The parameters of the Von Bertalanffy growth equation are estimated by sex within the model-fitting procedure from age-at-length data. This approach accounts for the impact of gear selectivity on the age-at-length data collected from the fishery and the impact of ageing error. Three growth parameters are estimated (CV, $K$ and $l_{\min}$), with only one growth parameter fixed ($l_{\max}$ = 55.9), with this valued based on the estimate of $l_\infty$ obtained by Punt(2005a) by fitting von Bertalanffy growth curves to data from SESSF Zones 10 and 20 (NSW and eastern Bass Strait).

Estimates of the rate of natural mortality, $M$, reported in the literature vary from 0.21 to 0.46 $yr^{-1}$. This assessment uses a value of 0.27 $yr^{-1}$ as the base-case estimate of $M$ as used in the previous assessment (Day and Klaer, 2013) and as previously agreed to by Shelf RAG. Sensitivity to this value is tested. The steepness of the stock-recruitment relationship, $h$, is estimated by the model, and for the base case is estimated to be 0.62.

Female tiger flathead become sexually mature at about three years of age, which corresponds to a length of about 30 cm (Klaer, 2010). Maturity is modelled as a logistic function, with 50% maturity at 30 cm. Fecundity-at-length is assumed to be proportional to weight-at-length.

The parameters of the length-weight relationship are the same as those used in the previous assessment $a$=5.88 x $10^{-6}$, $b$=3.31 (Day and Klaer, 2013), with these parameters originally obtained by fitting von Bertalanffy growth curves to data from SESSF Zones 10 and 20, NSW and eastern Bass Strait (Punt, 2005a).

#### *14.3.1.2 Fleets*

The assessment data for tiger flathead have been separated into five 'fleets', which represent one or more gear, regional, or temporal differences in the fishery. Landings data from eastern Tasmania were separated from the catches from the other regions in the east, because the length compositions of catches from this area indicate that it lands larger fish.

1. Steam trawl – steam trawlers (1915 – 1961).
2. Danish seine – Danish seine from NSW, eastern Victoria and Bass Strait (1929 – 2015).
3. Eastern trawl – diesel otter trawlers from NSW, eastern Victoria and Bass Strait (1971 – 2015).
4. Tasmanian trawl – diesel otter trawlers from eastern Tasmania (1985 – 2015).
5. Fishery Independent Survey – (2008-2014).

#### *14.3.1.3 Landed Catches*

A landed catch history for tiger flathead, separated into the four 'fleets', is available for all years from 1915 to 2015 (Table 14.1, Figure 14.1 and Figure 14.2). Landings from the FIS fleet were assumed to be zero, with the actual FIS catch included in the scaling up of logbook catches to landed catches.

Klaer (2005) describes the sources of information used to construct the historical landed catch record for each of the fleets to 1986. Quotas were introduced into the fishery in 1992, and from then onwards, records of landed catches as well as estimated catches from the logbook are available. The landings data give a more accurate measure of the landed catch than do the logbook data, but the logbook data contain more detail. For example, it is usually possible to separate logbook records, but not landing records, by fleet. The logbook catches for each fleet from 1992 onwards have been scaled up by the ratio of landed catches to logbook catches in each year (Thomson, 2002). Prior to 1992, the unscaled logbook catches are used.

In 2007 the quota year was changed from calendar year to the year extending from 1 May to 30 April, however the assessment is based on calendar years. All catches for recent years continue to be those made by calendar year, which may conflict with the fishing year TACs.

Small quantities of tiger flathead are caught in state waters. NSW and Victorian state catches have been added to the eastern trawl fleet, and Tasmanian state catches have been added to the Tasmanian fleet.

In order to calculate the Recommended Biological Catch (RBC) for 2017, it is necessary to estimate the Commonwealth calendar year catch for 2016. The TAC (Table 14.2) was almost unchanged from 2015 to 2016 and the state catches are unknown for 2016. Hence, assuming that the same ratio of the TAC will be caught in 2016 as in 2015, with the same state catches as 2015, is equivalent to assuming that the catch in 2016 is identical to the 2015 catch. This gives estimated 2016 catches for the eastern fleet, the Tasmanian fleet, and the Danish seine fleet of 1,245 t, 349 t and 1,479 t, respectively.

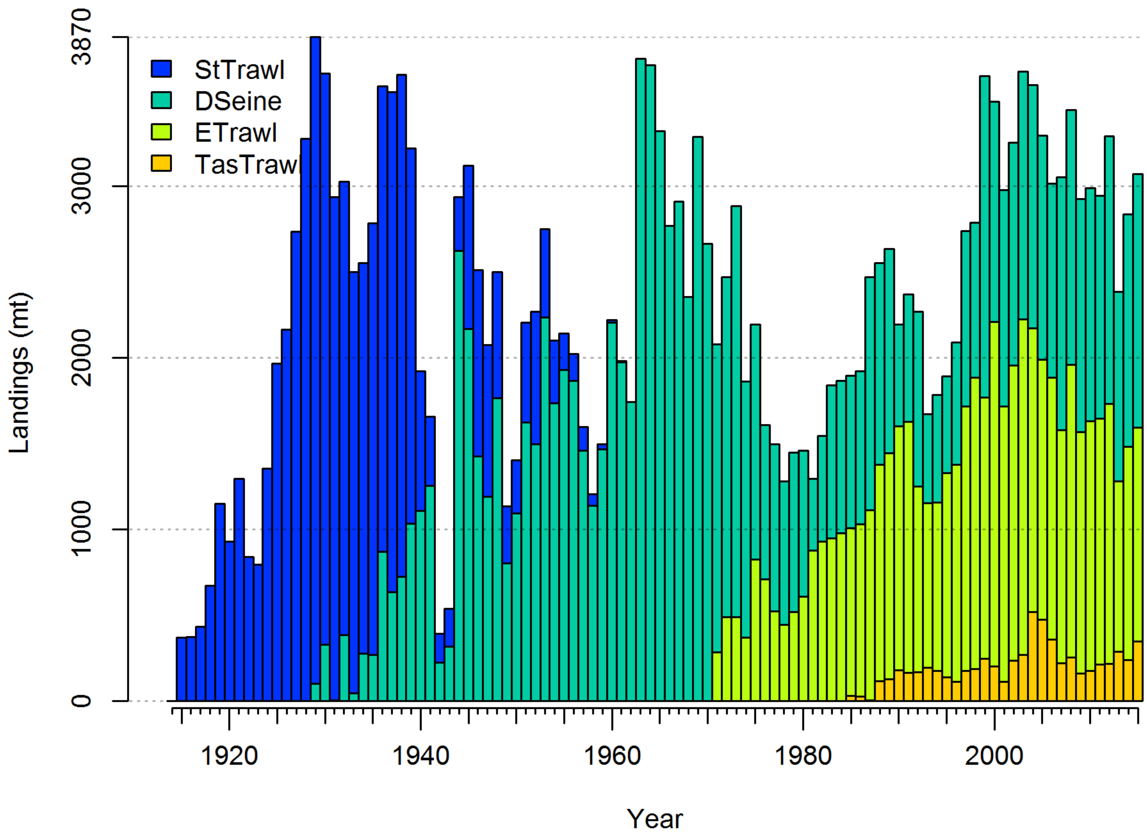


Figure 14.1. Total landed catch of tiger flathead by fleet (stacked) from 1915-2015.

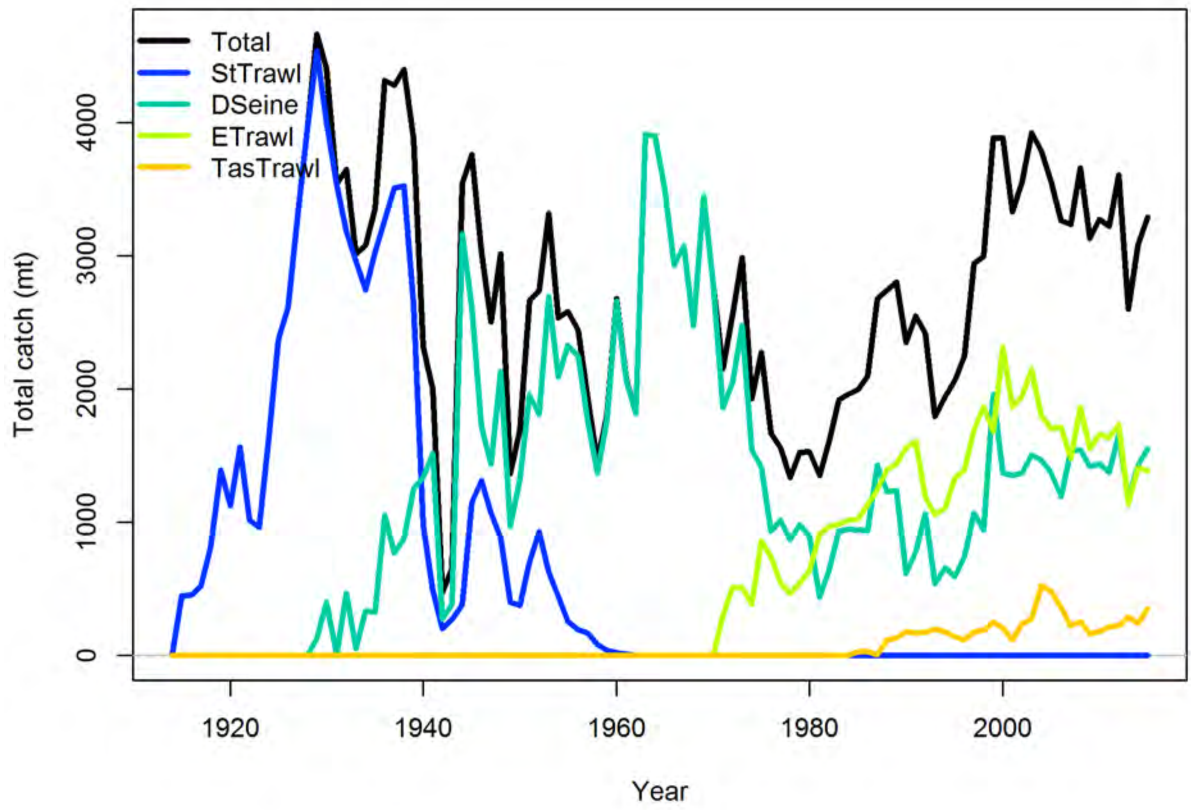


Figure 14.2. Total landed catch of tiger flathead by fleet from 1915-2015.

Table 14.1. Total retained catches (tonnes) of tiger flathead per fleet for calendar years from 1915-2016.

| Year | Fleet St Trawl | D Seine | E Trawl | Tas Trawl | Year | Fleet St Trawl | D Seine | E Trawl | Tas Trawl | Year | Fleet St Trawl | D Seine | E Trawl | Tas Trawl |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1915 | 371 | 0 | 0 | 0 | 1951 | 583 | 1,625 | 0 | 0 | 1987 | 0 | 1,358 | 1,109 | 6 |
| 1916 | 373 | 0 | 0 | 0 | 1952 | 769 | 1,499 | 0 | 0 | 1988 | 0 | 1,177 | 1,263 | 116 |
| 1917 | 432 | 0 | 0 | 0 | 1953 | 517 | 2,235 | 0 | 0 | 1989 | 0 | 1,189 | 1,318 | 128 |
| 1918 | 671 | 0 | 0 | 0 | 1954 | 366 | 1,737 | 0 | 0 | 1990 | 0 | 591 | 1,425 | 178 |
| 1919 | 1,151 | 0 | 0 | 0 | 1955 | 211 | 1,932 | 0 | 0 | 1991 | 0 | 746 | 1,461 | 166 |
| 1920 | 931 | 0 | 0 | 0 | 1956 | 157 | 1,868 | 0 | 0 | 1992 | 0 | 1,019 | 1,080 | 170 |
| 1921 | 1,297 | 0 | 0 | 0 | 1957 | 139 | 1,459 | 0 | 0 | 1993 | 0 | 516 | 962 | 194 |
| 1922 | 840 | 0 | 0 | 0 | 1958 | 68 | 1,138 | 0 | 0 | 1994 | 0 | 626 | 982 | 178 |
| 1923 | 796 | 0 | 0 | 0 | 1959 | 32 | 1,467 | 0 | 0 | 1995 | 0 | 564 | 1,189 | 139 |
| 1924 | 1,356 | 0 | 0 | 0 | 1960 | 15 | 2,206 | 0 | 0 | 1996 | 0 | 711 | 1,265 | 114 |
| 1925 | 1,969 | 0 | 0 | 0 | 1961 | 9 | 1,974 | 0 | 0 | 1997 | 0 | 1,023 | 1,542 | 175 |
| 1926 | 2,167 | 0 | 0 | 0 | 1962 | 0 | 1,742 | 0 | 0 | 1998 | 0 | 905 | 1,700 | 186 |
| 1927 | 2,735 | 0 | 0 | 0 | 1963 | 0 | 3,745 | 0 | 0 | 1999 | 0 | 1,873 | 1,520 | 248 |
| 1928 | 3,277 | 0 | 0 | 0 | 1964 | 0 | 3,707 | 0 | 0 | 2000 | 0 | 1,286 | 2,006 | 203 |
| 1929 | 3,768 | 102 | 0 | 0 | 1965 | 0 | 3,322 | 0 | 0 | 2001 | 0 | 1,261 | 1,602 | 114 |
| 1930 | 3,329 | 330 | 0 | 0 | 1966 | 0 | 2,769 | 0 | 0 | 2002 | 0 | 1,299 | 1,722 | 235 |
| 1931 | 2,932 | 4 | 0 | 0 | 1967 | 0 | 2,912 | 0 | 0 | 2003 | 0 | 1,447 | 1,954 | 270 |
| 1932 | 2,642 | 385 | 0 | 0 | 1968 | 0 | 2,355 | 0 | 0 | 2004 | 0 | 1,417 | 1,654 | 521 |
| 1933 | 2,456 | 44 | 0 | 0 | 1969 | 0 | 3,289 | 0 | 0 | 2005 | 0 | 1,307 | 1,515 | 476 |
| 1934 | 2,278 | 276 | 0 | 0 | 1970 | 0 | 2,667 | 0 | 0 | 2006 | 0 | 1,133 | 1,526 | 359 |
| 1935 | 2,514 | 270 | 0 | 0 | 1971 | 0 | 1,793 | 286 | 0 | 2007 | 0 | 1,476 | 1,357 | 221 |
| 1936 | 2,712 | 872 | 0 | 0 | 1972 | 0 | 1,981 | 491 | 0 | 2008 | 0 | 1,487 | 1,705 | 255 |
| 1937 | 2,912 | 637 | 0 | 0 | 1973 | 0 | 2,397 | 490 | 0 | 2009 | 0 | 1,356 | 1,406 | 163 |
| 1938 | 2,924 | 725 | 0 | 0 | 1974 | 0 | 1,493 | 369 | 0 | 2010 | 0 | 1,359 | 1,456 | 175 |
| 1939 | 2,185 | 1,035 | 0 | 0 | 1975 | 0 | 1,367 | 827 | 0 | 2011 | 0 | 1,300 | 1,433 | 214 |
| 1940 | 815 | 1,108 | 0 | 0 | 1976 | 0 | 900 | 712 | 0 | 2012 | 0 | 1,562 | 1,515 | 217 |
| 1941 | 403 | 1,255 | 0 | 0 | 1977 | 0 | 977 | 522 | 0 | 2,013 | 0 | 1,103 | 995 | 287 |
| 1942 | 167 | 225 | 0 | 0 | 1978 | 0 | 836 | 446 | 0 | 2,014 | 0 | 1,354 | 1,244 | 239 |
| 1943 | 223 | 317 | 0 | 0 | 1979 | 0 | 928 | 520 | 0 | 2,015 | 0 | 1,479 | 1,245 | 349 |
| 1944 | 315 | 2,624 | 0 | 0 | 1980 | 0 | 851 | 609 | 0 | 2016* | 0 | 1,479 | 1,245 | 349 |
| 1945 | 953 | 2,168 | 0 | 0 | 1981 | 0 | 418 | 877 | 0 | | | | | |
| 1946 | 1,088 | 1,425 | 0 | 0 | 1982 | 0 | 615 | 930 | 0 | | | | | |
| 1947 | 884 | 1,193 | 0 | 0 | 1983 | 0 | 889 | 950 | 0 | | | | | |
| 1948 | 735 | 1,767 | 0 | 0 | 1984 | 0 | 890 | 978 | 0 | | | | | |
| 1949 | 330 | 804 | 0 | 0 | 1985 | 0 | 890 | 978 | 30 | | | | | |
| 1950 | 310 | 1,095 | 0 | 0 | 1986 | 0 | 892 | 1,005 | 26 | | | | | |

*2016 catches are estimated

Table 14.2. Total allowable catch (t) from 1992 to 2016/17.

| Year | TAC Agreed |
|---|---|
| 1992 | 3000 |
| 1993 | 3000 |
| 1994 | 3500 |
| 1995 | 3500 |
| 1996 | 3500 |
| 1997 | 3500 |
| 1998 | 3500 |
| 1999 | 3500 |
| 2000 | 3500 |
| 2001 | 3500 |
| 2002 | 3500 |
| 2003 | 3500 |
| 2004 | 3500 |
| 2005 | 3150 |
| 2006 | 3000 |
| 2007 | 3015 |
| 2008-09 | 2850 |
| 2009-10 | 2850 |
| 2010-11 | 2750 |
| 2011-12 | 2750 |
| 2012-13 | 2750 |
| 2013-14 | 2750 |
| 2014-15 | 2878 |
| 2015-16 | 2860 |
| 2016-17 | 2882 |

*14.3.1.4 Discard Rates*

Information on the discarding rate of tiger flathead was available from the PIRVic-run Integrated Scientific Monitoring Program (ISMP) for 1992-2006. From 2007 the ISMP was run by AFMA. The discard data are summarised in Table 14.3. Generally, discards of tiger flathead were in the order of 8% for Danish seine, 10% for eastern trawl and 1% for Tasmanian trawl.

There is limited information on discarding for the early steam trawl fleet (1915-61) and the early Danish seine fleet (1929-67). However, it is known that total discards for all species from steam trawl in the 1920s was in the order of 20% of the retained catch (Klaer, 2001). As there is no way to determine the species catch composition of the discards, Shelf RAG made the decision to apply this ratio to tiger flathead, which translates to a discard fraction of 17%. For the base-case, all steam trawl (1915-1961) and early Danish seine (1929-1960) were assigned a constant discard fraction of 17% to apply equally to all selected fish (Figure 14.3). The discard fraction for Danish seine from 1961 to present was set using recent observed discard ratios since 1994. Recent observations were used to estimate discard fractions for the east coast and Tasmanian diesel trawl fleets.

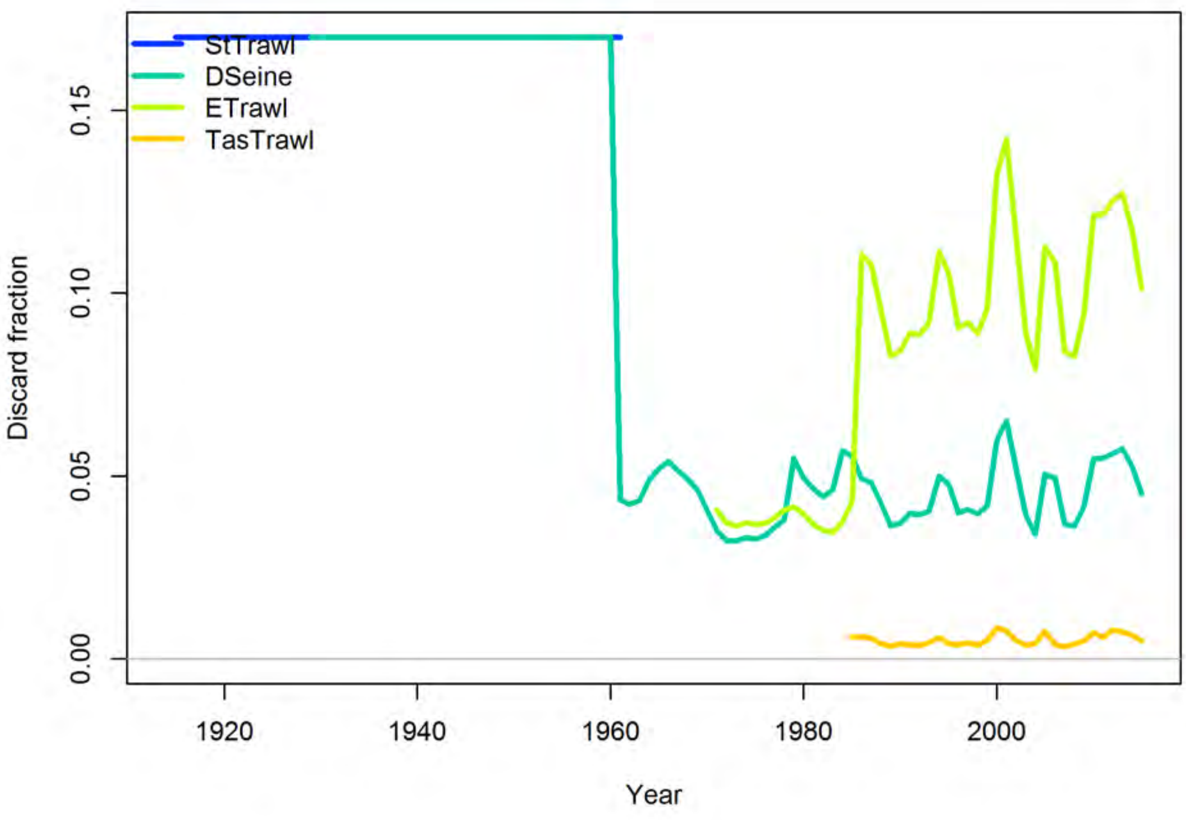


Figure 14.3. Model estimates of discard fractions per fleet.

Table 14.3. Proportion of catch discarded by fleet, with sample sizes.

| Year | Fleet D Seine | n | E Trawl | n | Tas Trawl | n |
|---|---|---|---|---|---|---|
| 1992 | | | 0.087868 | 11 | | |
| 1993 | | | 0.101798 | 195 | | |
| 1994 | 0.040297 | 79 | 0.129968 | 267 | 0.081380 | 18 |
| 1995 | 0.123334 | 44 | 0.127717 | 129 | | |
| 1996 | | | 0.122627 | 240 | | |
| 1997 | | | 0.031345 | 383 | 0.000956 | 10 |
| 1998 | 0.053599 | 23 | 0.118566 | 246 | 0.000245 | 27 |
| 1999 | 0.015437 | 34 | 0.199701 | 382 | 0.002363 | 48 |
| 2000 | 0.071560 | 27 | 0.114977 | 395 | | |
| 2001 | 0.006871 | 41 | 0.075192 | 457 | | |
| 2002 | 0.112531 | 30 | 0.067438 | 385 | 0.006729 | 8 |
| 2003 | 0.014414 | 113 | 0.072940 | 470 | 0.005699 | 10 |
| 2004 | 0.001241 | 39 | 0.099207 | 387 | | |
| 2005 | 0.049008 | 61 | 0.105351 | 461 | 0.001489 | 16 |
| 2006 | 0.023315 | 125 | 0.132521 | 369 | 0.000582 | 59 |
| 2007 | 0.106470 | 47 | 0.030259 | 106 | | |
| 2008 | 0.030943 | 37 | 0.020926 | 214 | | |
| 2009 | 0.136644 | 32 | 0.113514 | 200 | 0.052681 | 8 |
| 2010 | 0.151653 | 75 | 0.117542 | 171 | 0.029486 | 20 |
| 2011 | 0.255459 | 124 | 0.141128 | 140 | 0.002131 | 22 |
| 2012 | 0.069183 | 70 | 0.095674 | 127 | 0.009509 | 27 |
| 2013 | 0.041523 | 102 | 0.118683 | 128 | 0.016985 | 22 |
| 2014 | 0.170019 | 109 | 0.106842 | 128 | 0.006047 | 36 |
| 2015 | 0.045976 | 72 | 0.148704 | 231 | 0.003959 | 49 |

#### *14.3.1.5 Catch Rate Indices*

A standardised catch rate (CPUE) index is available for the historical steam trawl fleet for the years 1919-23, 1937-42, and 1952-57 (Klaer, 2006b; Table 14.4). An unstandardised catch rate index for early Danish seine has been used in tiger flathead assessments since Cui *et al.* (2004) (Table 14.5).

Catch and effort information from the SEF1 logbook database from the period 1986-2015 were standardised using GLM analysis to obtain indices of relative abundance for recent Danish seine, eastern and Tasmanian trawl fleets (Sporcic and Haddon, 2016; Table 14.6).

Abundance indices from the Fishery Independent Survey from 2008-2014 were also used, with either zones 10, 20 and 30 combined, or separated into zones 10 and 20, to match the eastern trawl fleet, and zone 30, to match the Tasmanian trawl fleet (Table 14.7).

Table 14.4. Standardised catch rates for the steam trawl fleet (Klaer 2006b).

| Year | Value | CV |
|---|---|---|
| 1919 | 1.618 | 0.31 |
| 1920 | 1.732 | 0.31 |
| 1921 | 1.806 | 0.31 |
| 1922 | 1.758 | 0.31 |
| 1923 | 1.646 | 0.31 |
| 1937 | 0.635 | 0.31 |
| 1938 | 0.749 | 0.31 |
| 1939 | 0.723 | 0.31 |
| 1940 | 0.611 | 0.31 |
| 1941 | 0.618 | 0.31 |
| 1942 | 0.401 | 0.31 |
| 1952 | 0.262 | 0.31 |
| 1953 | 0.208 | 0.31 |
| 1954 | 0.232 | 0.31 |
| 1955 | 0.219 | 0.31 |
| 1956 | 0.208 | 0.31 |
| 1957 | 0.169 | 0.31 |

Table 14.5. Unstandardised catch rates for the early Danish seine fleet.

| Year | Value | CV |
|---|---|---|
| 1950 | 38.7 | 0.33 |
| 1951 | 27.6 | 0.33 |
| 1952 | 31.8 | 0.33 |
| 1953 | 52.0 | 0.33 |
| 1954 | 34.4 | 0.33 |
| 1955 | 47.4 | 0.33 |
| 1956 | 46.5 | 0.33 |
| 1957 | 32.1 | 0.33 |
| 1958 | 22.5 | 0.33 |
| 1959 | 28.7 | 0.33 |
| 1960 | 43.6 | 0.33 |
| 1965 | 38.2 | 0.33 |
| 1966 | 41.5 | 0.33 |
| 1967 | 62.5 | 0.33 |
| 1968 | 61.2 | 0.33 |
| 1969 | 77.8 | 0.33 |
| 1970 | 67.1 | 0.33 |
| 1971 | 69.9 | 0.33 |
| 1972 | 114.0 | 0.33 |
| 1973 | 88.0 | 0.33 |
| 1974 | 58.1 | 0.33 |
| 1975 | 56.6 | 0.33 |
| 1976 | 41.9 | 0.33 |
| 1977 | 55.5 | 0.33 |
| 1978 | 51.9 | 0.33 |

Table 14.6. Standardised catch rates for the Danish seine, Eastern and Tasmanian diesel trawl fleets from 1986-2015.

| Year | Fleet D Seine | CV | E Trawl | CV | Tas Trawl | CV |
|---|---|---|---|---|---|---|
| 1986* | 1.0947 | 0.0226 | 0.7877 | 0.0166 | 0.9491 | 0.1587 |
| 1987 | 1.6044 | 0.0224 | 1.0463 | 0.0157 | 0.6198 | 0.1888 |
| 1988 | 1.7212 | 0.0222 | 1.1251 | 0.0155 | 0.9453 | 0.1693 |
| 1989 | 1.6220 | 0.0226 | 1.1337 | 0.0156 | 0.6935 | 0.1627 |
| 1990 | 1.0619 | 0.0240 | 1.3771 | 0.0164 | 0.7211 | 0.1648 |
| 1991 | 1.3400 | 0.0242 | 1.2851 | 0.0166 | 0.7154 | 0.1602 |
| 1992 | 1.3756 | 0.0222 | 1.0215 | 0.0173 | 0.6389 | 0.1648 |
| 1993 | 0.8305 | 0.0227 | 1.0317 | 0.0164 | 0.6095 | 0.1562 |
| 1994 | 0.7199 | 0.0218 | 0.7564 | 0.0158 | 0.6493 | 0.1573 |
| 1995 | 0.7671 | 0.0231 | 0.7945 | 0.0158 | 0.6922 | 0.1575 |
| 1996 | 0.7235 | 0.0217 | 0.7093 | 0.0156 | 0.6303 | 0.1573 |
| 1997 | 0.9375 | 0.0214 | 0.7080 | 0.0160 | 0.8179 | 0.1562 |
| 1998 | 0.7929 | 0.0209 | 0.7531 | 0.0160 | 0.9458 | 0.1567 |
| 1999 | 1.1942 | 0.0213 | 0.9077 | 0.0158 | 1.0199 | 0.1569 |
| 2000 | 0.8323 | 0.0222 | 0.9992 | 0.0153 | 0.8539 | 0.1581 |
| 2001 | 0.7881 | 0.0221 | 0.9655 | 0.0155 | 0.7411 | 0.1551 |
| 2002 | 0.8893 | 0.0219 | 1.0556 | 0.0155 | 1.3840 | 0.1542 |
| 2003 | 0.9534 | 0.0217 | 1.0394 | 0.0153 | 1.4364 | 0.1536 |
| 2004 | 0.9239 | 0.0222 | 0.9038 | 0.0155 | 1.8854 | 0.1532 |
| 2005 | 0.9777 | 0.0226 | 0.7814 | 0.0159 | 1.6647 | 0.1537 |
| 2006 | 0.9379 | 0.0239 | 0.9421 | 0.0164 | 1.3593 | 0.1546 |
| 2007 | 1.1678 | 0.0238 | 1.1485 | 0.0181 | 1.1231 | 0.1561 |
| 2008 | 1.0327 | 0.0234 | 1.2151 | 0.0175 | 1.0002 | 0.1559 |
| 2009 | 1.0518 | 0.0239 | 1.1181 | 0.0182 | 1.0080 | 0.1575 |
| 2010 | 0.9450 | 0.0235 | 1.0767 | 0.0178 | 1.0175 | 0.1584 |
| 2011 | 0.8876 | 0.0229 | 1.0592 | 0.0179 | 0.9416 | 0.1575 |
| 2012 | 0.8473 | 0.0228 | 1.1652 | 0.0178 | 1.1783 | 0.1567 |
| 2013 | 0.6376 | 0.0228 | 0.8862 | 0.0186 | 1.1522 | 0.1561 |
| 2014 | 0.6716 | 0.0225 | 1.0355 | 0.0180 | 1.3544 | 0.1566 |
| 2015 | 0.6704 | 0.0225 | 1.1716 | 0.0181 | 1.2521 | 0.1551 |

* CV values for 1986 were set to the average of all other years

Table 14.7. Abundance indices for the fishery independent survey: combined (zones 10, 20 and 30); with eastern trawl fleet (zones 10 and 20); and Tasmanian trawl fleet (zone 30).

| Year | FIS Z 10, 20, 30 | CV | FIS East Z 10, 20 | CV | FIST Tas Z 30 | CV |
|---|---|---|---|---|---|---|
| 2008 | 93.06 | 0.11 | 141.65 | 0.13 | 81.6400 | 0.1900 |
| 2010 | 91.06 | 0.12 | 104.18 | 0.13 | 112.7200 | 0.2000 |
| 2012 | 152.36 | 0.11 | 176.39 | 0.12 | 123.0900 | 0.2000 |
| 2014 | 97.22 | 0.10 | 114.39 | 0.12 | 102.06 | 0.18 |

#### *14.3.1.6 Age Composition Data*

An estimate of the standard deviation of age reading error was calculated by Andre Punt (pers. comm., 2016) from data supplied by Kyne Krusic-Golub of Fish Ageing Services (Table 14.8).

Age-at-length measurements, based on sectioned otoliths, provided by Fish Ageing Services, were available for the years 1998, 2000-2015 for the Danish seine fleet; 1998-2002, 2004-2015 for the eastern diesel trawl fleet; and 1999, 2000, 2002, 2005-2008, 2010 and 2012 for the Tasmanian diesel trawl fleet (Table 14.9). Years for which the total number of fish aged was less than 10 were not used. No age information was available for the earlier fleets.

Table 14.8. Standard deviation of age reading error (A Punt pers. comm. 2016).

| Age | sd |
|---|---|
| 0.5 | 0.245117 |
| 1.5 | 0.271087 |
| 2.5 | 0.296930 |
| 3.5 | 0.322645 |
| 4.5 | 0.348233 |
| 5.5 | 0.373695 |
| 6.5 | 0.399031 |
| 7.5 | 0.424243 |
| 8.5 | 0.449330 |
| 9.5 | 0.474293 |
| 10.5 | 0.499133 |
| 11.5 | 0.523850 |
| 12.5 | 0.548446 |
| 13.5 | 0.572920 |
| 14.5 | 0.597273 |
| 15.5 | 0.621507 |
| 16.5 | 0.645621 |
| 17.5 | 0.669615 |
| 18.5 | 0.693492 |
| 19.5 | 0.717251 |
| 20.5 | 0.740892 |

#### *14.3.1.7 Length Composition Data*

Length composition information for the onboard retained components of catches is available for: the Danish seine fleet 1993-1994, 1998-2007 and 2009-2015; the eastern trawl fleet from 1977, 1993, 1996-2015; and the Tasmanian trawl fleet for 1998-2006, 2008, 2010-2015 along with the numbers of fish measured and numbers of shots in each year (Table 14.10). Length composition information from port data is available for: the steam trawl fleet from 1945-1958; the Danish seine fleet from 1945-1967, 1992 and 1994-2015; the eastern trawl fleet from 1965-1967, 1969-2015; and the Tasmanian trawl fleet for 1999-2000, 2002-2006, 2009-2013 and 2015, along with the numbers of fish measured and numbers of trips in each year (Table 14.11 and Table 14.12). Length composition information from the ISMP for the discarded components of catches is available for: the Danish seine fleet 1998-2003, 2006-2007 and 2011-2015; and the eastern trawl fleet from 1992-2006 and 2008-2015; along with the numbers of fish measured and numbers of shots in each year (Table 14.13). In line with current standard practice in the SESSF, both port and onboard length frequencies are used when they are available.

Table 14.9. Number of age-length otolith samples included in the base case assessment by fleet 1998-2015.

| Year | Fleet | | Tas | |
|---|---|---|---|---|
| | D Seine | E Trawl | Trawl | Total |
| 1998 | 101 | 211 | | 312 |
| 1999 | | 169 | 46 | 215 |
| 2000 | 192 | 521 | 56 | 769 |
| 2001 | 30 | 180 | | 210 |
| 2002 | 558 | 588 | 149 | 1,295 |
| 2003 | 102 | | | 102 |
| 2004 | 174 | 152 | | 326 |
| 2005 | 603 | 268 | 11 | 882 |
| 2006 | 312 | 64 | 141 | 517 |
| 2007 | 159 | 302 | 8 | 469 |
| 2008 | 363 | 277 | 66 | 706 |
| 2009 | 596 | 698 | | 1,294 |
| 2010 | 259 | 444 | 88 | 791 |
| 2011 | 715 | 410 | | 1,125 |
| 2012 | 336 | 813 | 131 | 1,280 |
| 2013 | 299 | 434 | 65 | 798 |
| 2014 | 573 | 461 | 162 | 1,196 |
| 2015 | 394 | 735 | 23 | 1,152 |

Table 14.10. Number of onboard retained lengths and number of shots for length frequencies included in the base case assessment by fleet 1977-2015.

| Year | Fleet | # fish | | Fleet | # shots | |
|---|---|---|---|---|---|---|
| | D Seine | E Trawl | Tas Trawl | D Seine | E Trawl | Tas Trawl |
| 1977 | | 2,136 | | | 200 | |
| 1993 | 356 | 1,347 | | 4 | 17 | |
| 1994 | 1,950 | | | 20 | | |
| 1996 | | 494 | | | 7 | |
| 1997 | | 6,797 | | | 191 | |
| 1998 | 1,706 | 9,364 | 959 | 30 | 139 | 8 |
| 1999 | 1,765 | 18,771 | 3,066 | 26 | 259 | 26 |
| 2000 | 707 | 21,686 | 492 | 15 | 235 | 5 |
| 2001 | 238 | 21,952 | 383 | 3 | 213 | 4 |
| 2002 | 332 | 17,229 | 477 | 8 | 181 | 4 |
| 2003 | 4,158 | 18,187 | 399 | 72 | 201 | 3 |
| 2004 | 3,595 | 11,836 | 562 | 26 | 122 | 5 |
| 2005 | 5,353 | 18,745 | 1,692 | 38 | 176 | 10 |
| 2006 | 13,202 | 12,137 | 4,588 | 103 | 107 | 34 |
| 2007 | 1,593 | 1,243 | | 9 | 35 | |
| 2008 | | 1,482 | 101 | | 45 | 6 |
| 2009 | 672 | 1,374 | | 11 | 32 | |
| 2010 | 678 | 1,909 | 239 | 28 | 68 | 9 |
| 2011 | 1,303 | 1,881 | 334 | 52 | 74 | 11 |
| 2012 | 1,821 | 2,226 | 348 | 49 | 72 | 8 |
| 2013 | 2,479 | 1,880 | 410 | 66 | 45 | 10 |
| 2014 | 2,064 | 1,999 | 972 | 73 | 44 | 21 |
| 2015 | 1,925 | 4,393 | 741 | 40 | 110 | 20 |

Table 14.11. Number of port retained lengths and number of trips used for length frequencies included in the base case assessment by fleet 1945-1991.

| Year | Fleet | # fish | | Fleet | # trips | |
|---|---|---|---|---|---|---|
| | St Trawl | D Seine | E Trawl | St Trawl | D Seine | E Trawl |
| 1945 | 5,076 | 21,735 | | 200 | 200 | |
| 1946 | 10,916 | 26,475 | | 200 | 200 | |
| 1947 | 15,488 | 20,287 | | 200 | 200 | |
| 1948 | 11,973 | 20,721 | | 200 | 200 | |
| 1949 | 10,863 | 23,316 | | 200 | 200 | |
| 1950 | 18,057 | 16,640 | | 200 | 200 | |
| 1951 | 25,843 | 21,423 | | 200 | 200 | |
| 1952 | 32,188 | 28,941 | | 200 | 200 | |
| 1953 | 14,880 | 16,264 | | 200 | 200 | |
| 1954 | 13,167 | 26,263 | | 200 | 200 | |
| 1955 | 2,313 | 9,966 | | 200 | 200 | |
| 1956 | 343 | 14,878 | | 34 | 200 | |
| 1957 | 150 | 15,283 | | 15 | 200 | |
| 1958 | 149 | 17,291 | | 15 | 200 | |
| 1959 | | 20,354 | | | 200 | |
| 1960 | | 25,334 | | | 200 | |
| 1961 | | 18,623 | | | 200 | |
| 1962 | | 20,255 | | | 200 | |
| 1963 | | 15,988 | | | 200 | |
| 1964 | | 17,882 | | | 200 | |
| 1965 | | 17,861 | 14,310 | | 200 | 200 |
| 1966 | | 19,101 | 23,222 | | 200 | 200 |
| 1967 | | 7,233 | 11,798 | | 200 | 200 |
| 1969 | | | 96 | | | 10 |
| 1970 | | | 187 | | | 19 |
| 1971 | | | 610 | | | 61 |
| 1972 | | | 1,223 | | | 122 |
| 1973 | | | 435 | | | 44 |
| 1974 | | | 5,590 | | | 200 |
| 1975 | | | 11,684 | | | 200 |
| 1976 | | | 14,881 | | | 200 |
| 1977 | | | 18,017 | | | 200 |
| 1978 | | | 16,335 | | | 200 |
| 1979 | | | 12,189 | | | 200 |
| 1980 | | | 8,757 | | | 200 |
| 1981 | | | 6,184 | | | 200 |
| 1982 | | | 5,893 | | | 200 |
| 1983 | | | 5,140 | | | 200 |
| 1984 | | | 6,702 | | | 200 |
| 1985 | | | 2,633 | | | 200 |
| 1986 | | | 12,513 | | | 200 |
| 1987 | | | 8,154 | | | 200 |
| 1988 | | | 6,274 | | | 200 |
| 1989 | | | 3,999 | | | 200 |
| 1990 | | | 1,398 | | | 140 |
| 1991 | | | 4,040 | | | 200 |

Table 14.12. Number of port retained lengths and number of trips used for length frequencies included in the base case assessment by fleet 1992-2015.

| Year | Fleet | # fish | | Fleet | # trips | |
|---|---|---|---|---|---|---|
| | D Seine | E Trawl | Tas Trawl | D Seine | E Trawl | Tas Trawl |
| 1992 | 1,442 | 873 | | 13 | 5 | |
| 1993 | | 502 | | | 3 | |
| 1994 | 292 | 156 | | 3 | 1 | |
| 1995 | 1,566 | 1,418 | | 20 | 10 | |
| 1996 | 3,760 | 2,520 | | 31 | 16 | |
| 1997 | 11,857 | 5,106 | | 115 | 26 | |
| 1998 | 11,346 | 11,302 | | 112 | 84 | |
| 1999 | 5,079 | 12,747 | 519 | 22 | 94 | 3 |
| 2000 | 3,566 | 6,698 | 362 | 20 | 53 | 2 |
| 2001 | 5,690 | 11,087 | | 35 | 88 | |
| 2002 | 3,569 | 6,208 | 5,201 | 32 | 35 | 27 |
| 2003 | 1,896 | 4,686 | 649 | 11 | 35 | 6 |
| 2004 | 4,280 | 10,247 | 1,520 | 38 | 71 | 7 |
| 2005 | 3,542 | 13,035 | 769 | 12 | 74 | 3 |
| 2006 | 1,375 | 13,029 | 1,323 | 5 | 116 | 6 |
| 2007 | 505 | 3,024 | | 3 | 20 | |
| 2008 | 435 | 132 | | 3 | 1 | |
| 2009 | 428 | 735 | 87 | 7 | 7 | 1 |
| 2010 | 751 | 2,107 | 64 | 15 | 17 | 1 |
| 2011 | 1,066 | 1,061 | 204 | 35 | 24 | 6 |
| 2012 | 884 | 771 | 188 | 32 | 22 | 4 |
| 2013 | 1,055 | 885 | 185 | 41 | 26 | 3 |
| 2014 | 1,691 | 1,288 | | 52 | 22 | |
| 2015 | 2,401 | 1,099 | 232 | 54 | 19 | 3 |

Table 14.13. Number of discarded lengths and number of shots included in the base case assessment by fleet 1992-2015.

| Year | Fleet | # fish | Fleet | # shots |
|---|---|---|---|---|
| | D Seine | E Trawl | D Seine | E Trawl |
| 1992 | | 131 | | 7 |
| 1993 | | 896 | | 45 |
| 1997 | | 139 | | 55 |
| 1998 | 126 | 2,155 | 21 | 94 |
| 1999 | 104 | 3,988 | 7 | 151 |
| 2000 | 110 | 2,890 | 5 | 93 |
| 2002 | 235 | 2,834 | 11 | 89 |
| 2003 | 102 | 2,622 | 7 | 89 |
| 2004 | | 3,098 | | 56 |
| 2005 | | 1,478 | | 31 |
| 2006 | 119 | 2,116 | 10 | 30 |
| 2007 | 218 | | 1 | |
| 2008 | | 99 | | 12 |
| 2009 | | 376 | | 19 |
| 2010 | | 175 | | 24 |
| 2011 | 132 | 546 | 4 | 48 |
| 2012 | 212 | 388 | 15 | 35 |
| 2013 | 125 | 477 | 10 | 23 |
| 2014 | 254 | 700 | 29 | 18 |
| 2015 | 175 | 1,504 | 14 | 60 |

*14.3.1.8 Fishery Independent Survey (FIS) Estimates*

Abundance indices for tiger flathead for the FIS surveys conducted in 2008, 2010, 2012 and 2014 are provided in Knuckey et al. (2015). As well as the standard tiger flathead FIS abundance indices (covering SESSF zones 10, 20 and 30 only), indices from the FIS were re-estimated for the eastern fleet (SESSF zones 10 and 20) and the Tasmanian fleet (SESSF zone 30) with coefficients of variation calculated for each fleet (Table 14.14). The length composition data from the FIS are included in this assessment and this allows the selectivity of the various partitions of the FIS fleet to be estimated within the assessment. Small numbers of tiger flathead are caught in the FIS from zones 40 and 50, but this data is excluded from the calculation of the FIS abundance indices and is excluded from the assessment.

Table 14.14. FIS derived abundance indices for tiger flathead with corresponding coefficient of variation (cv) for a single FIS fleet, and for split FIS fleets.

| Year | FIS | | FIS East | | FIST Tas | |
|---|---|---|---|---|---|---|
| | Z 10, 20, 30 | CV | Z 10, 20 | CV | Z 30 | CV |
| 2008 | 93.06 | 0.11 | 141.65 | 0.13 | 81.6400 | 0.19 |
| 2010 | 91.06 | 0.12 | 104.18 | 0.13 | 112.7200 | 0.20 |
| 2012 | 152.36 | 0.11 | 176.39 | 0.12 | 123.0900 | 0.20 |
| 2014 | 97.22 | 0.10 | 114.39 | 0.12 | 102.0600 | 0.18 |

The number of length measurements and the number of shots with tiger flathead from each year of the FIS are listed in Table 14.15. These are also separated into a single FIS fleet (zones 10, 20 and 30) and into two FIS fleets: eastern FIS (zones 10 and 20) and Tasmanian FIS (zone 30 only).

Table 14.15. Number of FIS length measurements and number of shots containing tiger flathead by fleet and year.

| Year | FIS | (10,20,30) | FIS East | (10,20) | FIST Tas | (30) |
|---|---|---|---|---|---|---|
| | # fish | # shots | # fish | # shots | # fish | # shots |
| 2008 | 5222 | 65 | 3952 | 47 | 1270 | 18 |
| 2010 | 8298 | 101 | 6426 | 75 | 1872 | 26 |
| 2012 | 6494 | 88 | 5397 | 71 | 1097 | 17 |
| 2014 | 3991 | 44 | 3403 | 39 | 588 | 5 |

*14.3.1.9 Input Data Summary*

The data used in this assessment is summarised in Figure 14.4, indicating which years the various data types were available.

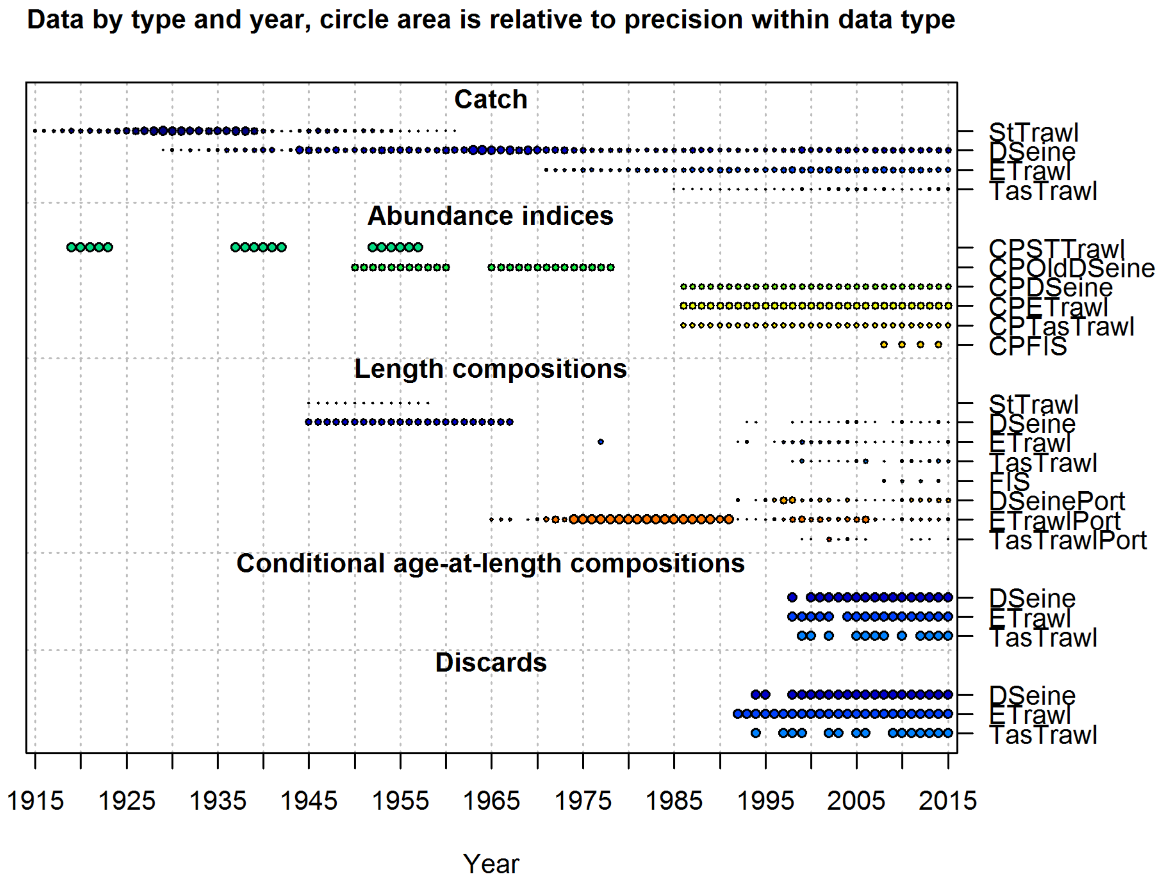


Figure 14.4. Summary of input data used for the tiger flathead assessment.

### 14.3.2 *Stock Assessment Method*

#### *14.3.2.1 Population Dynamics Model and Parameter Estimation*

A two-sex stock assessment for tiger flathead was conducted using the software package Stock Synthesis version SS-V3.24Z, (Methot, 2015). Stock Synthesis is a statistical age- and length-structured model which allows multiple fishing fleets and can be fitted simultaneously to the range of data available for tiger flathead. The population dynamics model, and the statistical approach used in the fitting of the model to the various types of data, are given fully in the SS technical description (Methot, 2005) and are not reproduced here. Some key features of the population dynamics model underlying Stock Synthesis which are pertinent to this assessment are discussed below.

A single stock of tiger flathead is assumed to occur from zone 10 off Sydney, through zone 20 (eastern Bass Strait), zone 60 (Bass Strait) and zone 30 (eastern Tasmania). The stock is assumed to be unexploited at the start of 1915 when the steam trawl fishery commenced. Catches prior to this are thought to have been minimal. The assessment models the impact of four fishing fleets on the tiger flathead population. The input CVs of the catch rate indices for the pre-1986 fleets were set to fixed values which are largely arbitrary due to the process of iterative reweighting. For the post-1986 fleets, the standard errors calculated from the catch-rate standardisation are used in the model (Haddon, 2013). Iterative reweighting is used to adjust the standard errors so their average equals those estimated by the model.

Selectivity is assumed to vary among fleets, but the selectivity pattern for each fleet is modelled as time-invariant except for two changes. The selectivity for Danish seine is allowed to change in 1978, and eastern diesel trawl in 1985. Selectivity is modelled as a function of length. Separate logistic functions are used for the selectivity ogives for each fleet. The two parameters of the selectivity function for each fleet are estimated within the assessment. Retention is also defined as a logistic function of length, and the inflection and slope of this function are estimated for those fleets where discard information is available (Danish seine, eastern trawl and Tasmanian trawl).

The rate of natural mortality, $M$, is assumed to be constant with age, and also time-invariant. The natural mortality for the base-case analysis is fixed to 0.27 $yr^{-1}$ as in the previous assessment (Day and Klaer, 2013).

Recruitment is assumed to follow a Beverton-Holt type stock-recruitment relationship, parameterised by the average recruitment at unexploited spawning biomass, $R_0$, and the steepness parameter, $h$. Steepness for the base-case analysis is estimated at 0.62. Deviations from the average recruitment at a given spawning biomass (recruitment deviations) are estimated for 1915 to 2012. The value of the parameter determining the magnitude of the process error in annual recruitment, $\sigma_R$ , was set equal to 0.4, which is greater than the amount of error estimated by the model.

A plus-group is modelled at age 20. Growth of tiger flathead is assumed to be time-invariant, that is there has been no change over time in the mean size-at-age, with the distribution of size-at-age determined from fitting the growth curve within the assessment using the age-at-length data. Differences in growth by gender are modelled.

#### *14.3.2.2 Relative Data Weighting*

Iterative reweighting of input and output CVs or input and effective sample sizes is an imperfect but objective method for ensuring that the expected variation is comparable to the input. This makes the model internally consistent, although some argue against this approach, particularly if it is believed that the input variance is well measured and potentially accurate. It is not necessarily good to down weight a data series just because the model does not fit it, if in fact, that series is reliably measured. On the other hand, most of the indices we deal with in fisheries underestimate the true variance by only reporting measurement and not process error.

Data series with a large number of individual measurements such as length or weight frequencies tend to swamp the combined likelihood value with poor fits to noisy data when fitting is highly partitioned by area, time or fishing method. These misfits to small samples mean that simple series such as a single CPUE might be almost completely ignored in the fitting process. This model behaviour is not optimal, because we know, for example, that the CPUE values are in fact derived from a very large number of observations. If there is reason to believe that the length and age data are noisy at the level fitted, it has been recommended in similar circumstances (e.g. see sablefish: Schirripa 2007, pacific sardine: Hill *et. al* 2005) that the length and age data be down weighted to allow the model to better fit other data sources.

Previous tiger flathead assessments dealt with this issue by capping length frequency sample sizes at 200 and reducing both the age and length components of the total likelihood by a factor of 10 for the base case. This procedure was modified in this assessment to avoid making arbitrary changes to particular likelihood components, through using trip and shot numbers, where available, instead of numbers of fish measured and by adopting the Francis weighting method for age and length composition data.

Shot or trip number is not available for all data, especially for some of the early length frequency data, which often had very large sample sizes (numbers of fish measured). To balance sample sizes for numbers of fish measured, these cases were divided by 10 and capped at 200. The number of trips were also capped at 120 and the number of shots capped at 200. Samples with less than 100 fish measured per year were excluded.

The sample sizes for the recent fleets are also individually tuned so that the input sample size is equal to the effective sample size calculated by the model.

*14.3.2.3 Tuning Procedure*

The tuning procedure used (Andre Punt pers comm.) was to:

1. Set the coefficients of variation to 0.1 for all CPUE and index fleets. This encourages an initial good fit to the abundance indices.
2. Simultaneously tune the sample size multipliers for the length frequencies using Francis weights and the age-at-length frequencies using Francis B. Iterate to convergence.
3. Adjust the recruitment bias ramp.
4. Tune to $\sigma_R$ with a lower bound of 0.4 – replace with the RMSE and iterate to convergence (and adjust the bias ramp if required).
5. Tune the CPUE and FIS abundance indices using the variance adjustment factors and iterate to convergence, checking bias ramp and length frequencies.
6. Perform a single tuning to the Francis A method on age-at-length data (no iteration).
7. Re-tune CPUE and check recruitment bias ramp.

*14.3.2.4 Calculating the RBC*

The SESSF Harvest Strategy Framework (HSF) was developed during 2005 (Smith *et al.*2008) and has been used as a basis for providing advice on TACs in the SESSF quota management system for fishing years 2006-2016. The HSF uses harvest control rules to determine a recommended biological catch (RBC) for each stock in the SESSF quota management system. Each stock is assigned to one of four Tier levels depending on the basis used for assessing stock status or exploitation level for that stock. Tiger flathead is classified as a Tier 1 stock as it has an agreed quantitative stock assessment.

The Tier 1 harvest control rule specifies a target and a limit biomass reference point, as well as a target fishing mortality rate. Since 2005 various values have been used for the target and the breakpoint in the rule. In 2009, AFMA directed that the 20:40:40 ($B_{lim}$: $B_{MSY}$: $F_{targ}$) form of the rule is used up to where fishing mortality reaches $F_{48}$. Once this point is reached, the fishing mortality is set at $F_{48}$. Day (2008) determined that for most SESSF stocks where the proxy values of $B_{40}$ and $B_{48}$ are used for $B_{MSY}$ and $B_{MEY}$ respectively, this form of the rule is equivalent to a 20:35:48 ($B_{lim}$: Inflection point: $F_{targ}$) strategy.

Previously, a preliminary economic analysis was used as a basis for using a 20:35:41 rule for tiger flathead (Klaer 2010). As steepness is an estimated parameter in the tiger flathead assessment, it is one of the few SESSF stocks where an MSY estimate may be taken from the base-case stock assessment. SESSFRAG in 2010 determined that a tiger flathead RBC may be calculated using a rule that incorporates application of the default 1.2 multiplier to the MSY depletion level to determine a minimum value for an MEY depletion level. It was also agreed at SESSFRAG that if this level was below 40% of $B_0$, that the 40% level be used to generate an RBC to maintain the biological precaution implicit in the 40% level. As with the 2013 assessment, SERAG agreed that the default RBC for tiger flathead is calculated under the 20:35:40 strategy.

*14.3.2.5 Sensitivity Tests and Alternative Models*

1. $M = 0.22$ yr$^{-1}$.
2. $M = 0.32$ yr$^{-1}$.
3. 50% maturity at 27cm.
4. 50% maturity at 33 cm.
5. $\sigma_R$ set to 0.35.
6. $\sigma_R$ set to 0.45.
7. Double the weighting on the length composition data.
8. Halve the weighting on the length composition data.
9. Double the weighting on the age-at-length data.
10. Halve the weighting on the age-at-length data.
11. Double the weighting on the survey (CPUE) data.
12. Halve the weighting on the survey (CPUE) data.
13. Fix steepness ($h$) at 0.75 and estimate natural mortality ($M$).
14. Estimate recruitment only until 2009 (exclude the 2010, 2011 and 2012 recruitment estimates). This assumes average recruitment from 2010-2012, lower recruitment than estimated in these years in the base case.
15. Split the fishery independent survey (FIS) data into two fleets, to match the eastern and Tasmanian trawl fleets (one in SESSF zones 10 and 20 and another in SESSF zone 30 only). This included splitting both the FIS abundance index and the FIS length frequency data.

The results of the sensitivity tests are summarized by the following quantities (Table 14.19):

1. $SSB_0$: the average unexploited female spawning biomass.
2. $SSB_{2017}$: the female spawning biomass at the start of 2017.
3. $SSB_{2017}/SSB_0$: the female spawning biomass depletion level at the start of 2017.
4. Steepness: the estimated steepness of the stock-recruitment relationship.
5. $SSB_{MSY}/SSB_0$: the female spawning biomass depletion level at maximum sustainable yield (MSY).
6. $RBC_{2017}$: the recommended biological catch (RBC) for 2017.

7. $RBC_{2017\text{-}9}$: the mean RBC over the three years from 2017-2019.
8. $RBC_{2017\text{-}21}$: the mean RBC over the five years from 2017-2021.
9. $RBC_{longterm}$: the longterm RBC.

The RBC values are calculated for tuned models only, which are the base case and the final sensitivity where the FIS is split into two fleets (sensitivity 15). While SERAG requested a single FIS fleet, when the length frequencies were separated between Zone 30 and Zones 10 and 20, it was clear that larger fish are being caught off Eastern Tasmania (Zone 30). This same reason is used to separate the commercial fleets. As this seems a plausible alternative model, this sensitivity was also fully tuned with RBCs reported.

It is possible that the Eastern Tasmanian part of the stock could have different growth to the rest of the stock, and this option could be explored in future assessments. The current assessment assumes a single growth curve for the whole stock, an assumption also made in previous assessments.

## 14.4 Results and Discussion

### 14.4.1 *The Base-Case Analysis*

#### *14.4.1.1 Parameter Estimates*

Figure 14.5 shows the estimated growth curve for female and male tiger flathead. All growth parameters are estimated by the model except for $l_{max}$ (parameter values are listed in Table 14.16).

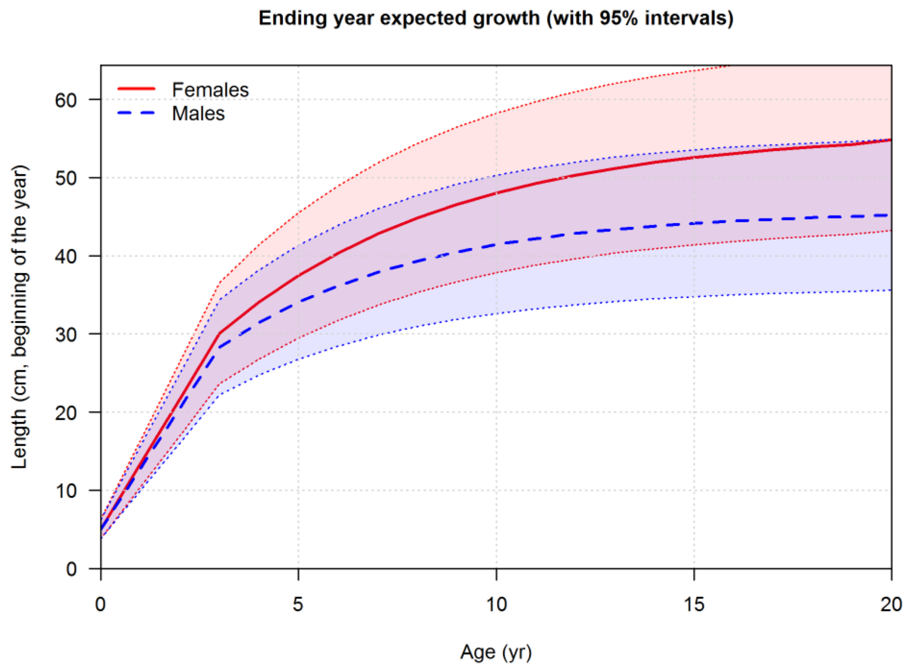


Figure 14.5. The model-estimated growth curves.

Table 14.16. Summary of parameters of the base case model.

| Feature | Details | |
|---|---|---|
| Fleets | Steam trawl | Fixed discard rate of 17% |
| | Danish seine | Fixed discard rate of 17% to 1960, fitted thereafter |
| | | Selectivity change in 1978 from early to modern Danish seine |
| | East coast trawl | Selectivity change in 1985 from early to modern diesel trawl |
| | Tasmanian trawl | Diesel trawl in Zone 30 |
| Natural mortality *M* | fixed | 0.27 |
| Steepness *h* | estimated | 0.62 |
| $\sigma_R$ in | fixed | 0.40 |
| Recruitment devs | estimated | 1915-2012, bias adjustment ramps 1928-1943 and 2015 |
| CV growth | estimated | 0.106 |
| Growth *K* | estimated | Female 0.168 |
| Growth $l_{min}$ | estimated | Female age 2 29.73 |
| Growth $l_{max}$ | fixed | Female 55.9 |

Selectivity is assumed to be logistic for all fleets. The parameters that define the selectivity function are the length at 50% selection and the spread (the difference between length at 50% and length at 95% selection). Figure 14.6 shows the selectivity and retention functions for each of the commercial fleets. Figure 14.7 shows the selectivity for the combined FIS fleet (zones 10, 20 and 30) and Figure 14.8 shows the selectivity for the two FIS fleets when they are split into an eastern fleet (zones 10 and 20) and a Tasmanian fleet (Zone 30). The difference in the selectivity patterns when the FIS fleet is split suggests different characteristics in the fish caught by the FIS in Zone 30 from fish caught by the FIS in zones 10 and 20, reflecting similar pattern as is seen in the commercial trawl data in these regions.

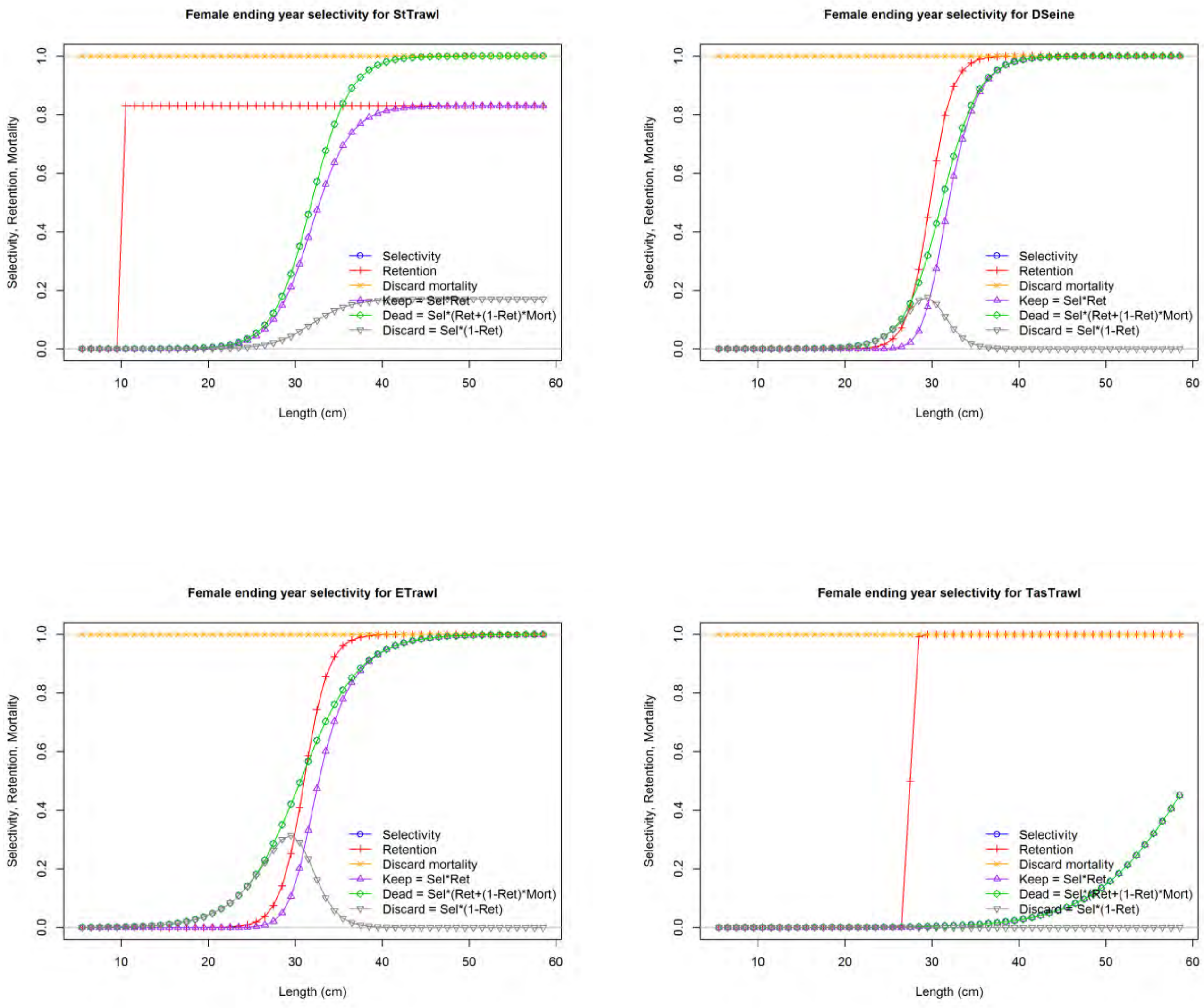


Figure 14.6. Selectivity (blue/green) and retention (red) functions for the four commercial fleets.

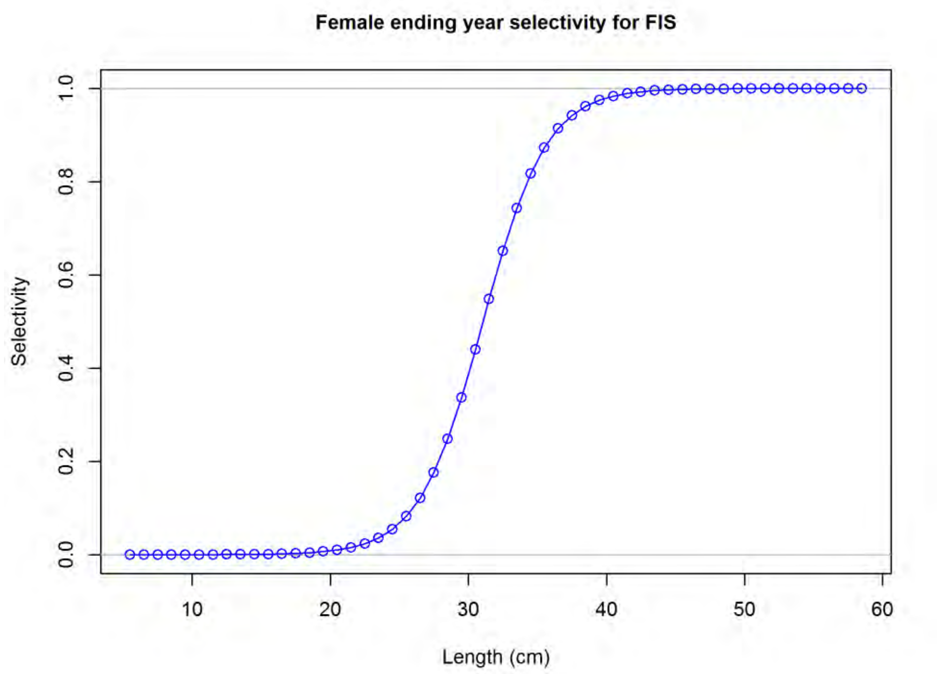


Figure 14.7. Selectivity for the single FIS fleet.

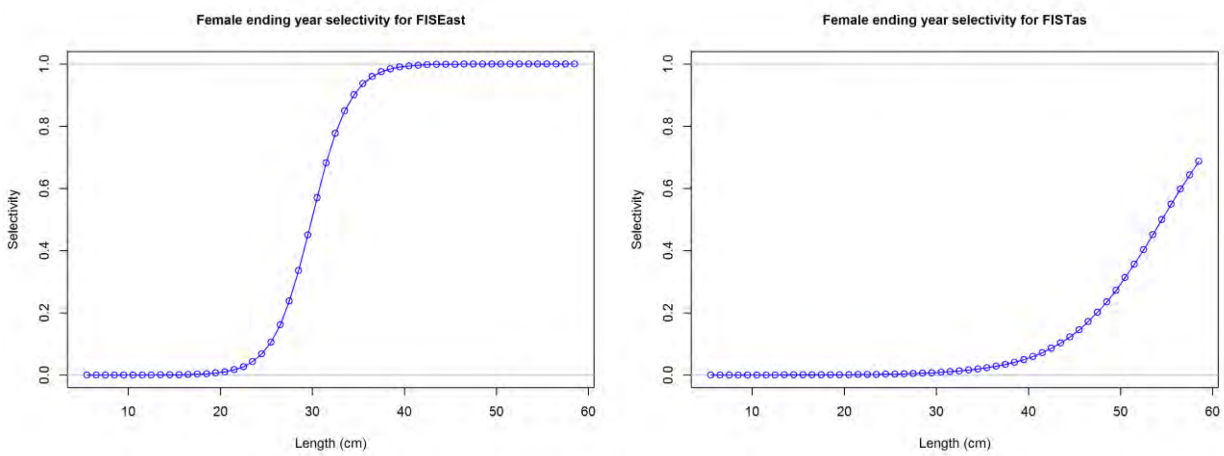


Figure 14.8. Selectivity for the eastern (left) and Tasmanian (right) FIS fleets when the FIS length frequencies are separated into zones.

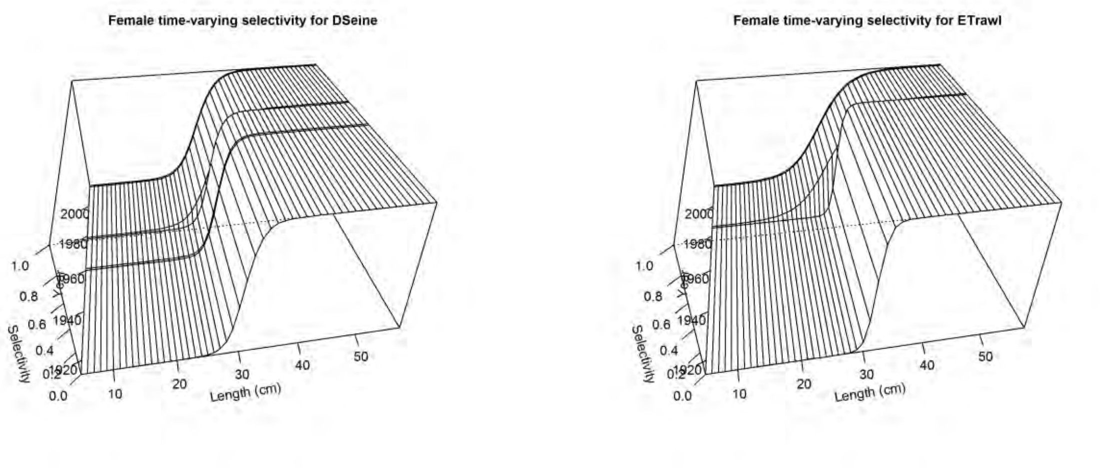


Figure 14.9. Time variation in selectivity for Danish seine and eastern diesel trawl.

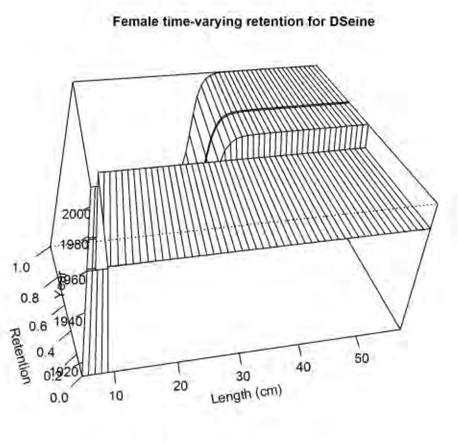


Figure 14.10. Time variation in retention for Danish seine.

*14.4.1.2 Fits to the Data*

The fits to the catch rate indices (Figure 14.11) are variable in quality. The catch rate indices for the steam trawl fleet shows a considerable decline from 1915 to 1950, consistent with overexploitation during that time (see Fairbridge 1948, Klaer 2006b). The early Danish seine index from 1950 to 1978 was relatively flat or increasing over that period. Recent abundance indices from 1986 to present also show reasonably flat trends. The Tasmanian trawl fleet index is the worst fit for the recent indices, but the catch contribution by that fleet is also the smallest. The fit to the single FIS fleet is adequate, but the relatively high 2012 abundance estimate relative to the others makes it difficult to achieve a better fit to these data points.

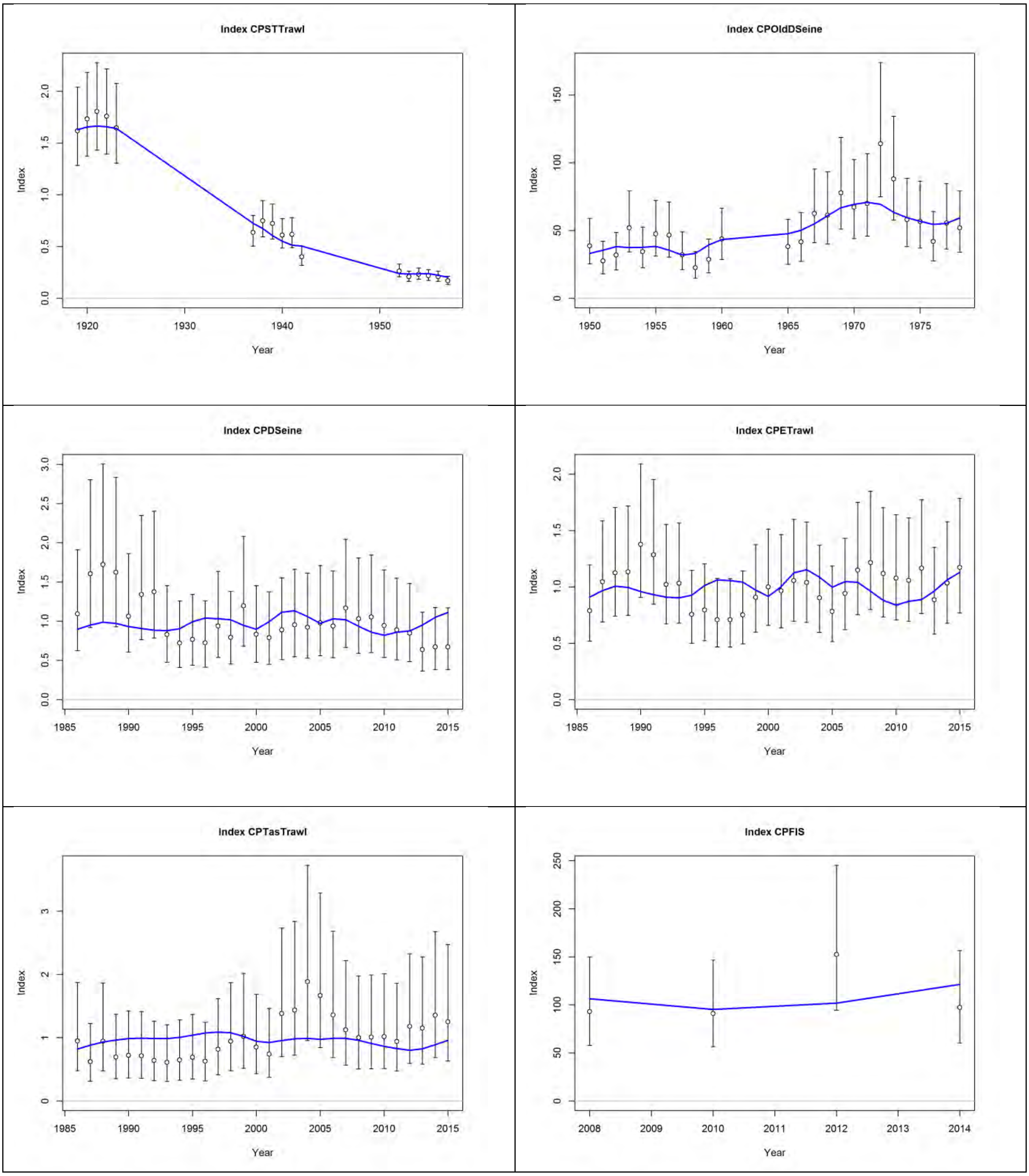


Figure 14.11. Observed (circles) and model-estimated (lines) catch rates vs year, with approx 95% asymptotic intervals.

The fits to the FIS abundance indices when this index is separated into and eastern (zones 10 and 20) and Tasmanian (zone 30) fleet are shown in Figure 14.12. As with the fits to the single FIS abundance index, variability between years and inconsistent patterns between the two regions makes it difficult to achieve any better fit to these data points, and the fits do not appear to be much better than for the single FIS fleet (Figure 14.11).

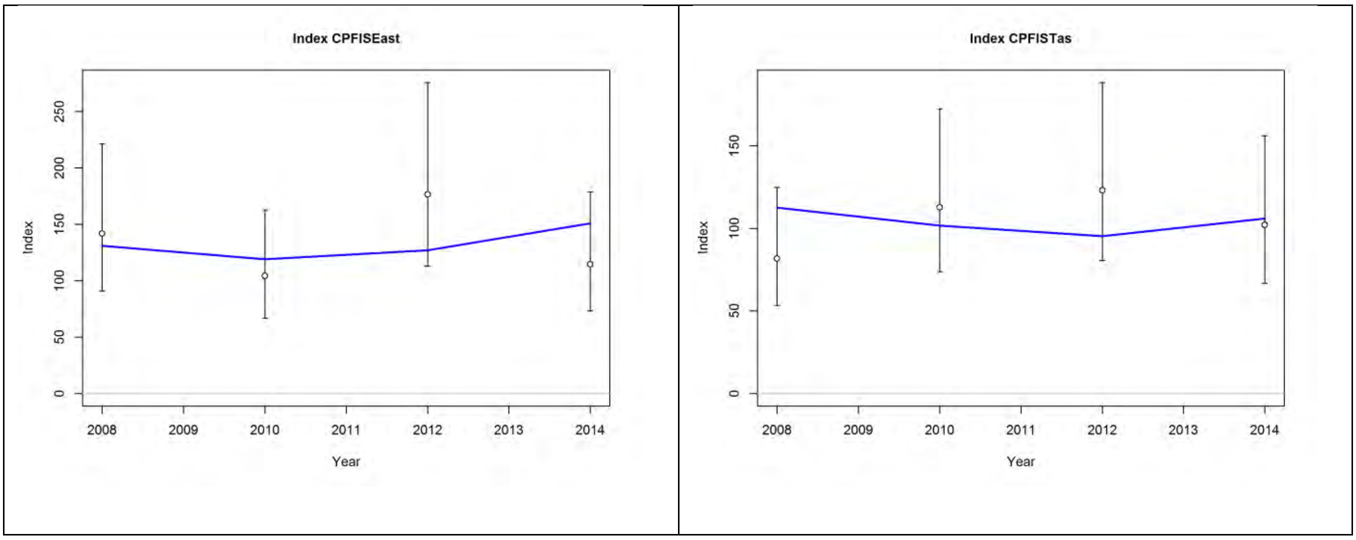


Figure 14.12. Observed (circles) and model-estimated (lines) catch rates vs year, with approx 95% asymptotic intervals for the FIS abundance index separated into Eastern (zones 10 and 20) and Tasmanian (zone 30) fleets.

The fits to the discard fractions (Figure 14.13) are reasonable given the variability in the data, with some very low data points (less than 1%) and others up to 20% for Danish seine and eastern trawl and up to 8% for Tasmanian trawl. The fits to the discard fractions for the Eastern trawl and Danish seine fleets are considerably better than in the 2013 assessment.

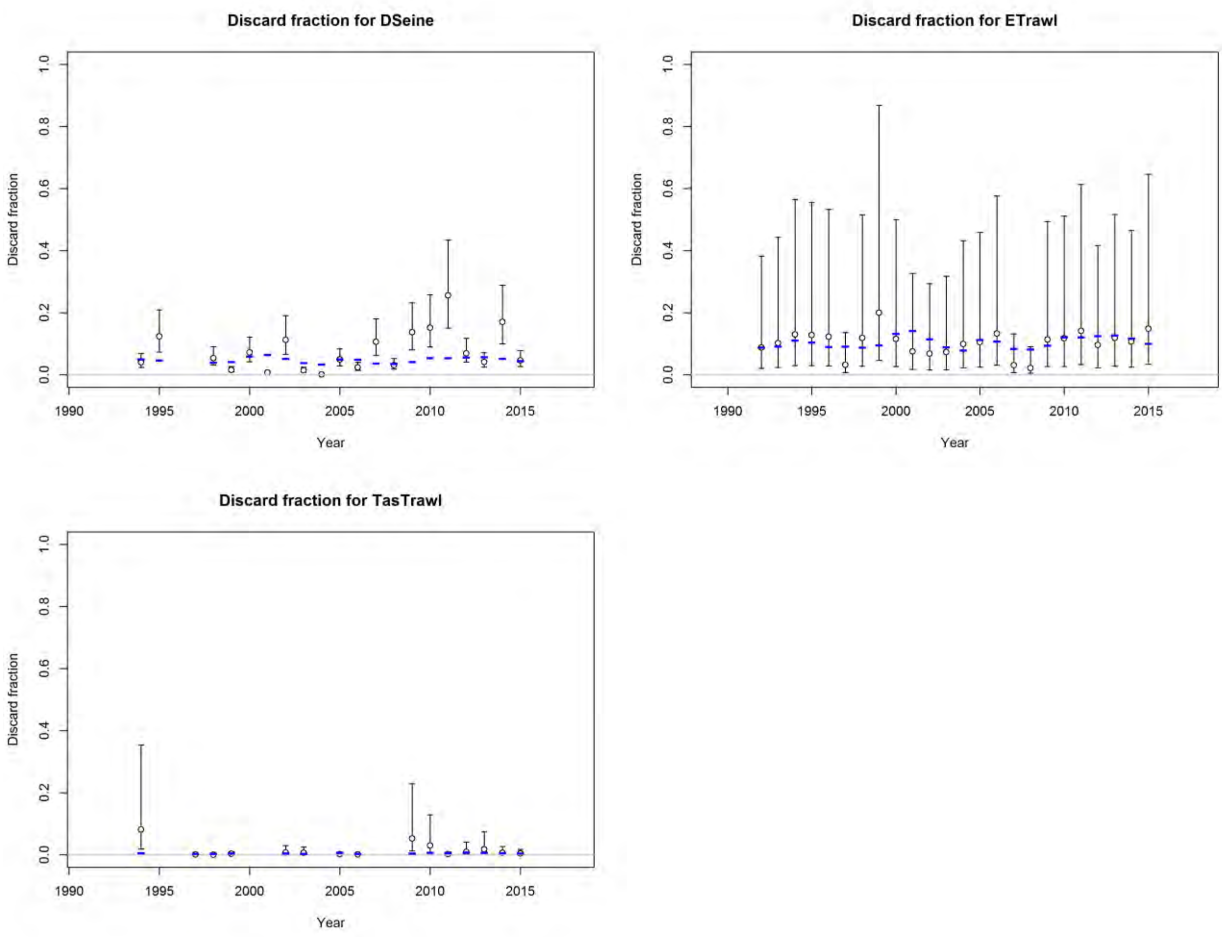


Figure 14.13. Observed (circles) and model-estimated (blue lines) discard estimates versus year, with approximate 95% asymptotic intervals.

The base-case model is able to mimic the retained length-frequency distributions adequately (Figure 14.14 and Appendix A), with the exception of the Tasmanian trawl fleet, for which the actual sample sizes are relatively small. The fits to the historical steam trawl and early Danish seine fleets are better than those for the more recent data (except for steam trawl in 1957 and 1958). The number of fish measured for the historical data is generally very high, which leads to smoother observed distributions. The fits to the discarded length compositions are variable (Figure 14.15 and Appendix A). This is not surprising, as the observed discard length frequencies are quite variable from year to year, and actual sample sizes are small in comparison to the retained length frequencies.

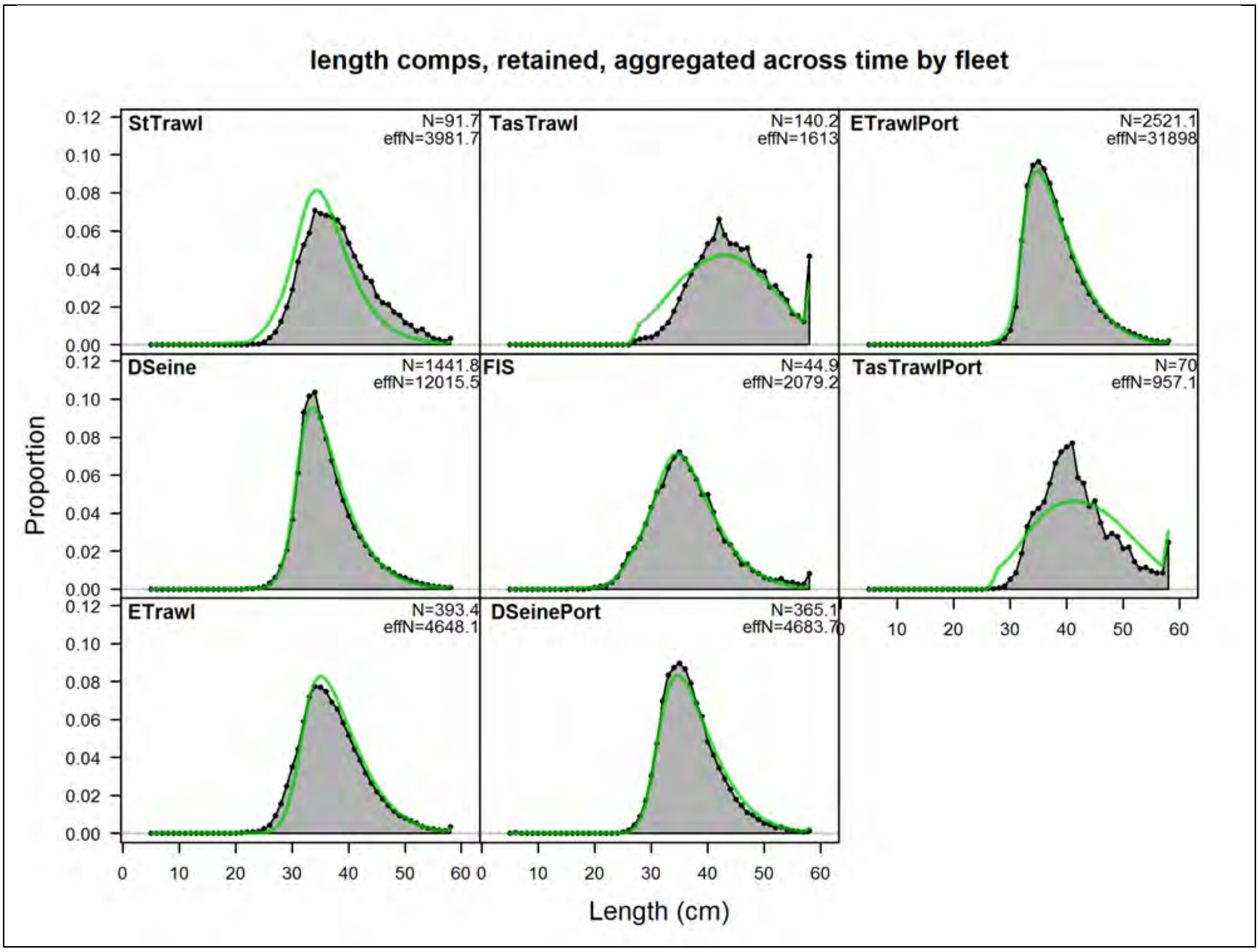


Figure 14.14. Fits to retained length compositions by fleet, separated by port and onboard samples, aggregated across all years. Observed data are grey and the fitted value is the green line.

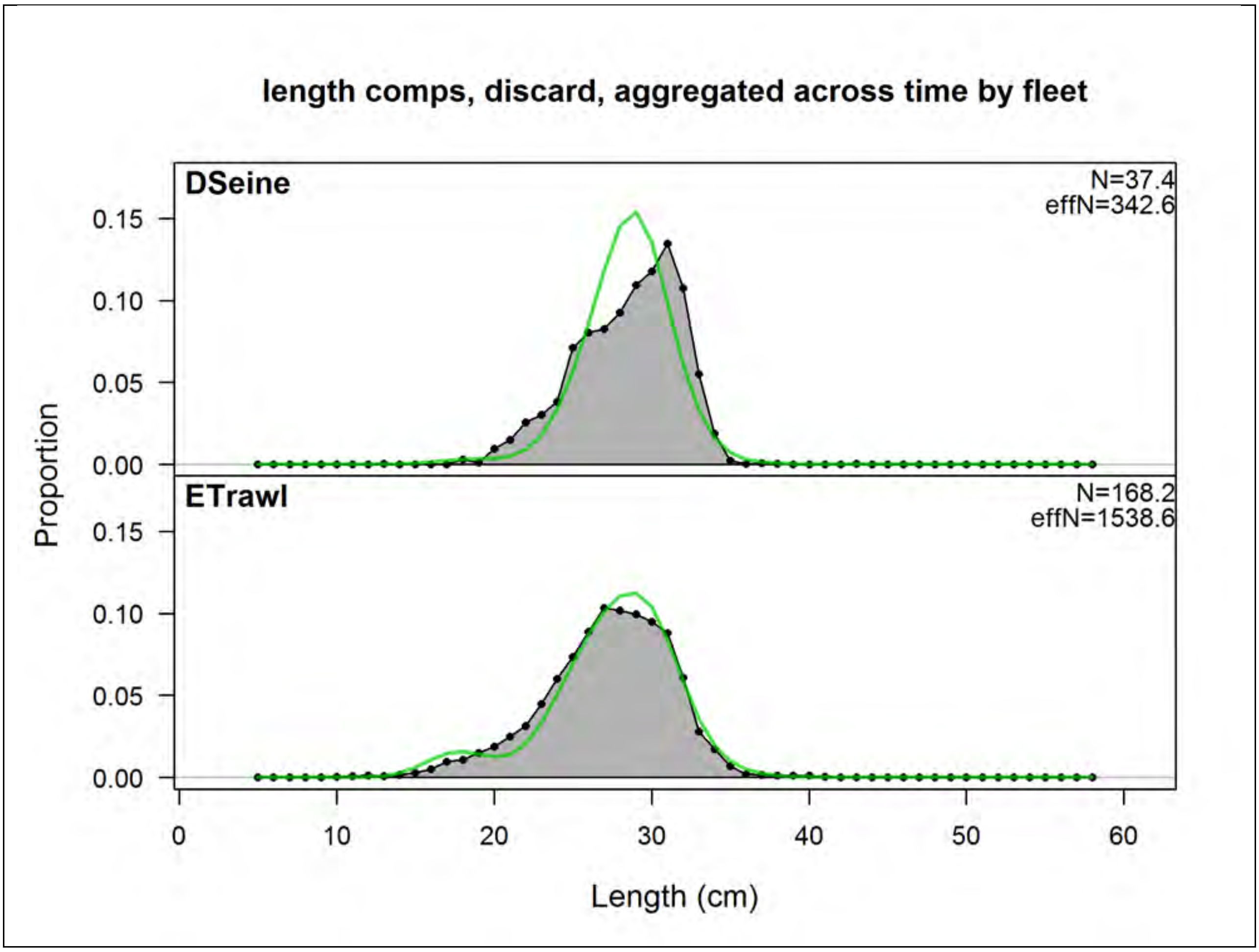


Figure 14.15. Fits to discarded length compositions by fleet, aggregated across all years. Observed data are grey and the fitted value is the green line.

The implied fits to the age composition data are shown in Appendix B. The age compositions were not fitted to directly, as age-at-length data were used. However, the model is capable of outputting the implied fits to these data for years where length frequency data are also available, even though they are not included directly in the assessment. The model mimics the observed age data reasonably well for all three recent fleets.

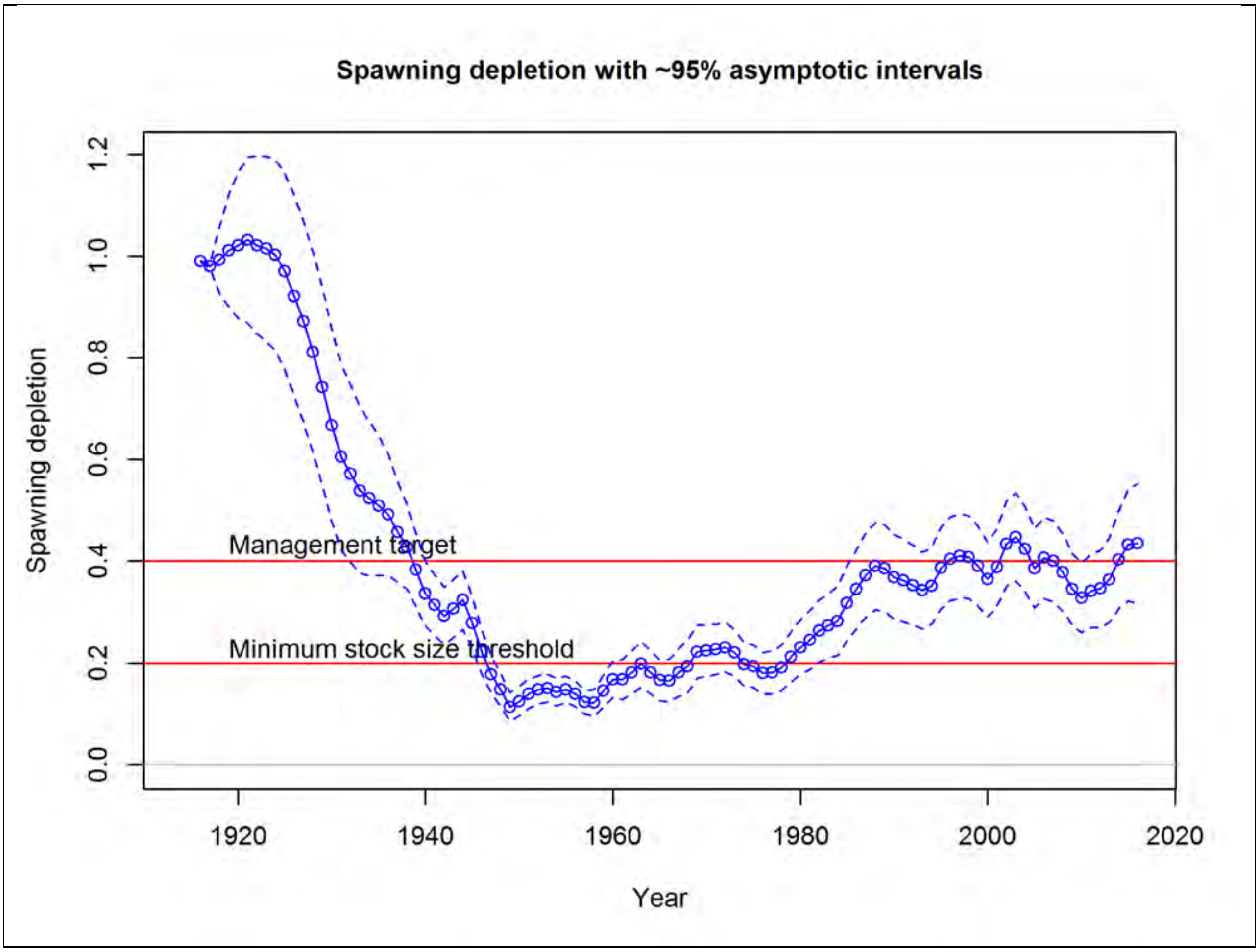


Figure 14.16. Time-trajectory of spawning biomass depletion (with approximate 95% asymptotic intervals) corresponding to the MPD estimates for the base-case analysis for tiger flathead (single FIS fleet).

*14.4.1.3 Assessment Outcomes*

Figure 14.16 shows the trajectory of spawning stock depletion. The stock declines substantially from the beginning of the fishery in 1915 to 1950, fluctuates near the minimum threshold of 20% $SSB_0$ during the 1950s, 1960s and 1970s, before an increase to near 40% $SSB_0$ by the 1990 This increase in the 1980s was driven by a combination of favourable recruitments (Figure 14.17) and total landings of less than 2,000t in the late 1970s and early 1980s. The stock has fluctuated near 40% $SSB_0$ since around 1990 with a slight increase in the last few years.

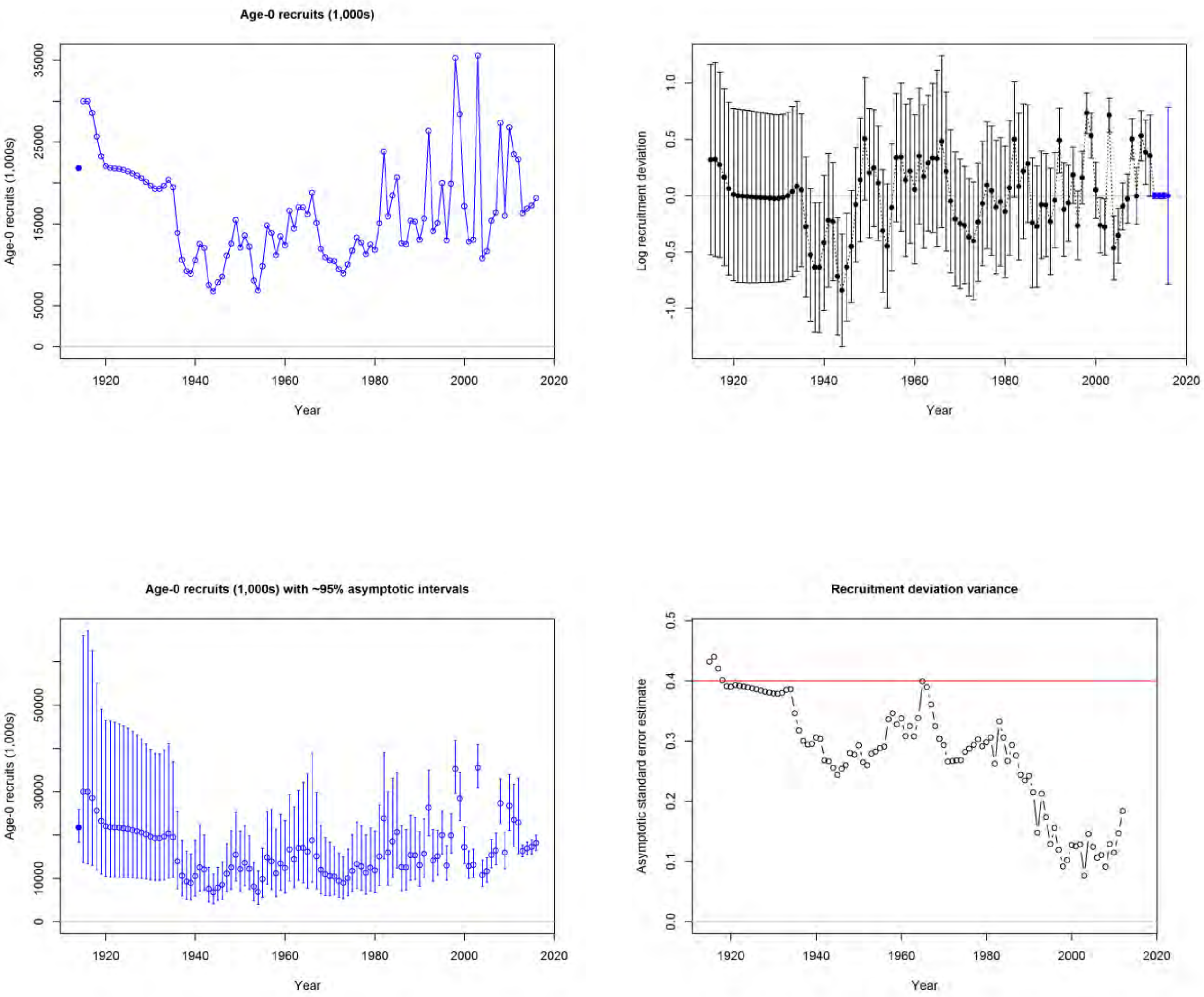


Figure 14.17. Recruitment estimation for the base case analysis. Top left : Time-trajectories of estimated recruitment numbers; top right : time trajectory of estimated recruitment deviations; bottom left : time-trajectories of estimated recruitment numbers with approximate 95% asymptotic intervals; bottom right: the standard errors of recruitment deviation estimates.

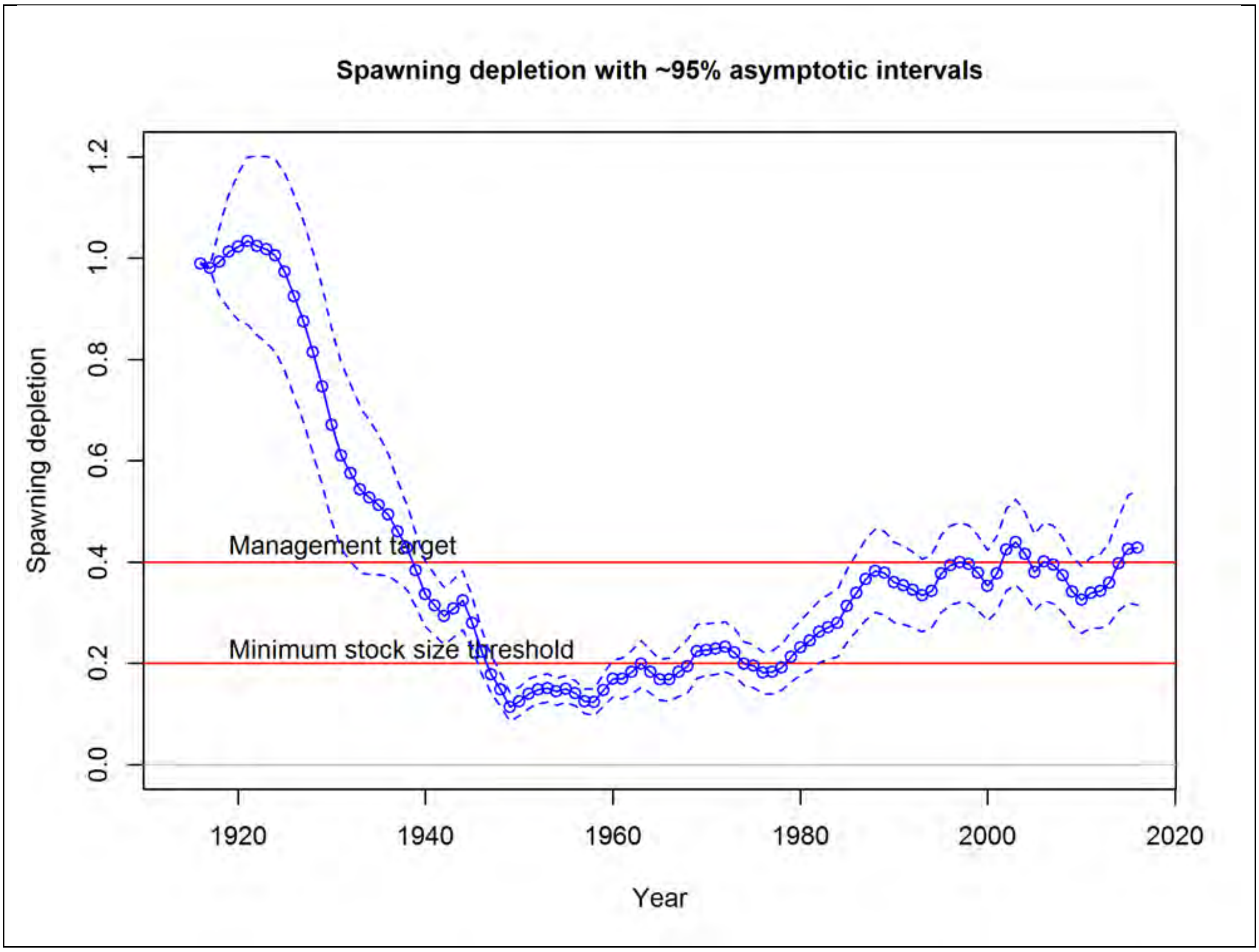


Figure 14.18. Time-trajectory of spawning biomass depletion (with approximate 95% asymptotic intervals) corresponding to the MPD estimates for sensitivity 15 with two FIS fleets for tiger flathead.

Figure 14.18 shows the trajectory of spawning stock depletion for sensitivity 15 with two FIS fleets. The differences between the trajectories in Figure 14.16 and Figure 14.18 are very small, illustrating the very minor impact on the spawning biomass from modelling two FIS fleets, rather than just one.

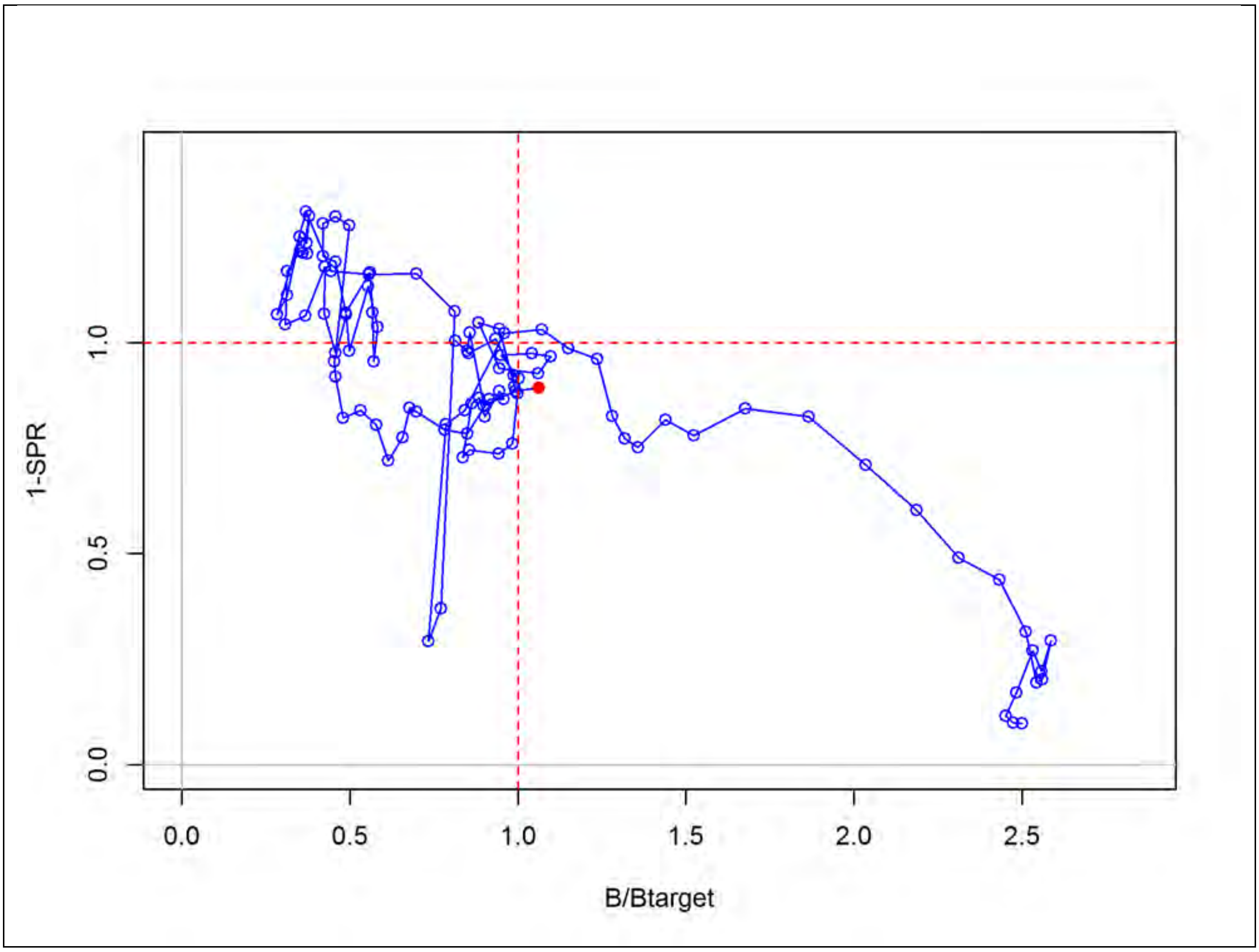


Figure 14.19. Kobe plot for sensitivity 15 with two FIS fleets, showing the trajectory of spawning biomass (relative to B0) plotted against 1-SPR, which is a proxy for fishing mortality, essentially integrating fishing mortality across fleets in the fishery.

Figure 14.19 shows a Kobe plot for sensitivity 15, with two FIS fleets. This plot shows a time series of spawning biomass plotted against spawning potential ratio, which provides a measure of overall fishing mortality, and shows the stepwise movement in this space from the start of the fishery, in the bottom right corner, when there was low fishing mortality and high biomass to the present day (the red dot) where the biomass is just above the target (to the right of the vertical red dashed line) and the fishing mortality is below the target fishing level (below the horizontal red dashed line). This trajectory shows an increase in overall fishing mortality and a decrease in biomass from 1915 to about 1950, with movement from the bottom right corner to the top left corner, when the biomass was well below the target and the fishing mortality was above the target rate. The years 1942 and 1943 stand out in this trajectory when fishing effort dropped notably, with the biomass at around 75% of the target (or 30% of $B_0$). Apart from this short period of reduced fishing effort during World War II, fishing mortality stayed above the target rate until 1978, when fishing mortality reduced considerably, and stayed around or below the target until the late 1990s. This allowed the spawning biomass to recover to near the target (40% of $B_0$) in the late 1990s. Since the late 1990s, fishing mortality has increased again, with a slight drop in the last 3 years. This period has been supported by relatively strong recruitment.

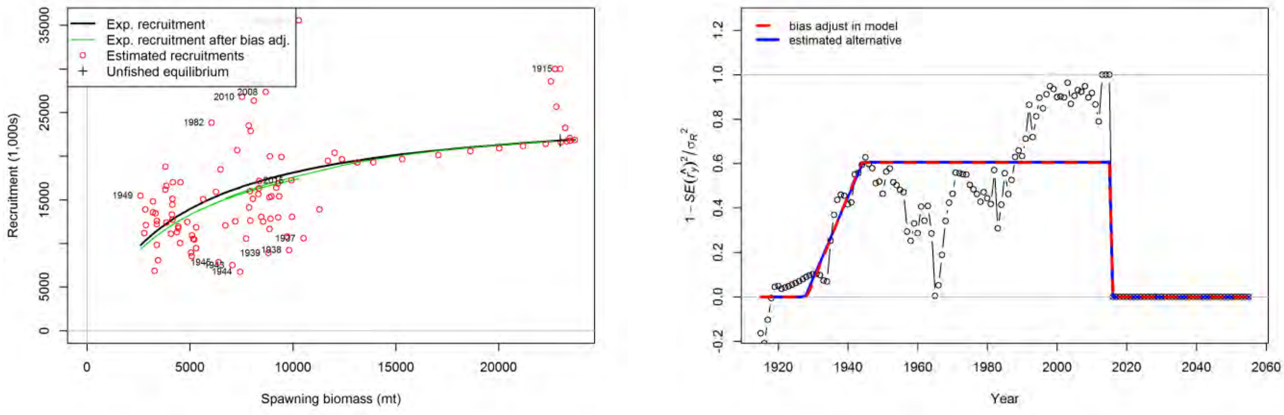


Figure 14.20. Recruitment estimation for the base case analysis. Left: the stock-recruit curve and estimated recruitments; right: bias adjustment.

The time-trajectories of recruitment and recruitment deviation are shown in Figure 14.17. Estimates of recruitments since about 1940 are generally variable, but periods of above and below average recruitment levels appear for periods of up to 12 years. Long-term regular cycles are not evident however. Recruitment in the past 15 years has been highly variable, with both average or above average recruitment for the last 6 estimated years of recruitment. The variability in estimated recent recruitment is likely to be a result of the model attempting to fit the increased quantity of data in recent years, particularly the age data.

The base-case assessment estimates that current spawning stock biomass is 43% of unexploited stock biomass ($SSB_0$). The 2017 recommended biological catch (RBC) under the 20:35:40 harvest control rule is 2,971 t (Table 14.17) and the long term yield (assuming average recruitment in the future) is 2,765 t (Table 14.19). Averaging the RBC over the three year period 2017-2019, the average RBC is 2,936 t (Table 14.17) and over the five year period 2017-2021, the average RBC is 2,909 t (Table 14.19). The RBCs for each individual year from 2017-2021 are listed in Table 14.17 for both the base case and for the sensitivity with two FIS fleets.

Table 14.17. Yearly projected RBCs (tonnes) across all fleets under the 20:35:40 harvest control rules: assuming average recruitment from 2013 (base case, column 2); and for the sensitivity when the FIS has two fleets (sensitivity 15, column 3), assuming average recruitment from 2013.

| RBCs<br>Year | Base<br>1 FIS | Sens 15<br>2 FIS |
|---|---|---|
| 2017 | 2,971 | 2,929 |
| 2018 | 2,934 | 2,900 |
| 2019 | 2,903 | 2,876 |
| 2020 | 2,879 | 2,857 |
| 2021 | 2,860 | 2,841 |

#### *14.4.1.4 Discard Estimates*

Model estimates for discards for the period 2017-21 with the 20:35:40 Harvest Control Rule are listed in Table 14.18 for the base case, with a range of 163 to 167 t, and for the sensitivity with two FIS fleets, with a range of 159 to 163 t.

Table 14.18. Yearly projected discards (tonnes) across all fleets under the 20:35:40 harvest control rules with catches set to the calculated RBC for each year from 2017 to 2021: assuming average recruitment from 2013 (base case, column 2); and for the sensitivity when the FIS has two fleets (sensitivity 15, column 3), assuming average recruitment from 2013.

| Discards<br>Year | Base<br>1 FIS | Sens 15<br>2 FIS |
|---|---|---|
| 2017 | 163 | 159 |
| 2018 | 164 | 160 |
| 2019 | 166 | 162 |
| 2020 | 167 | 163 |
| 2021 | 167 | 163 |

### 14.4.2 *Sensitivity Tests and Alternative Models*

Results of the sensitivity tests are shown in Table 14.19. The results are very sensitive to the assumed value for natural mortality (*M*). Much of this variability is due to the estimated current depletion level, which can be as low as 26% $SSB_0$ when *M* is 0.22. For all other standard sensitivities, there is much less variability in current depletion. The one exception to this result for a non-standard sensitivity is when recruitment is only estimated to 2009, and not estimated in 2010, 2011 and 2012.

Unweighted likelihood components for the base case and differences for the sensitivities reveal several points (Table 14.20). The overall likelihood is not improved for a smaller value of *M*, in contrast to the results from Day and Klaer (2013), but in line with earlier results in Klaer (2010). Steepness and *M* are highly correlated, and it is normally not possible to estimate both of these parameters. The base-case is essentially uninformative about the value of *M*, which needs to be sourced independently of the stock assessment if steepness is estimated, but these results suggests that *M* should not be reduced.

In contrast to the 2013 assessment, none of the sensitivities show an overall improvement to the fit, which suggests the model is remarkably stable and well balanced.

In addition to the standard sensitivities, (cases 1-13 in Table 14.19), two additional sensitivities were investigated.

The last three estimated recruitment events (2010-2012) were all above average. Recruitment events at the end of the tie series can often be modified with the addition of future data, which may be more informative, so it is useful to explore the possible effect of lower recruitment over this time period. If these recruitment events are assumed to be average, which reduces all three of these recruitment events, the depletion in 2017 would be 31%, and the fits to the discards and age compositions would be worse (Table 14.20). This suggests that the age and discard data support these good recent recruitment events.

Splitting the FIS into two fleets, made very little difference to the depletion estimate, improved the fit to the surveys slightly and resulted in poorer fits to the length frequency data. None of these results are surprising. The influence of the FIS data is relatively small given the quantity of other data in the assessment, so structural changes to this fleet are unlikely to have much impact. Separating the length frequencies allowed the larger fish caught in zone 30 to have a little more influence, and not surprisingly, these were subsequently harder to fit.

Exploration of model sensitivity showed a variation in spawning biomass from 26% to 51% of $SSB_0$ when natural mortality was fixed at values of 0.22 and 0.32 respectively. When recruitment is only estimated to 2009, excluding the above average recruitment estimates in 2010, 2011 and 2012, the spawning biomass was estimated to be 31% of $SSB_0$. For all other sensitivities explored, the variation in spawning biomass was much narrower, ranging between 39% and 45%.

For the base-case (20:35:40 Harvest Control Rule with recruitment estimated to 2012), $SSB_{\mathrm{MSY}}$ is estimated to be 31% of $SSB_0$. If the standard MEY proxy multiplier of 1.2 is applied to this MSY estimate, the $SSB_{\mathrm{MEY}}$ estimate for the base case is 37% of $SSB_0$. This proxy for $SSB_{\mathrm{MEY}}$ is rounded up to 40% of $SSB_0$ by agreement at SESSFRAG, with a 20:35:40 Harvest Control Rule used for tiger flathead.

### 14.4.3 *Future Work*

#### *14.4.3.1 Danish Seine Mesh Size*

The Danish seine fleet has made changes to the mesh size used for the flathead gear in recent years, with a transition to a slightly larger mesh size possibly starting sometime between 2010 and 2013, with the full transition taking around three years. While there is little evidence in the length frequency data to suggest a large change to selectivity as a result, it would be possible to use a time block with a transitional period and examine the resulting selectivity. The impact of such a change on both the selectivity and the spawning biomass could be explored in a future assessment. Given that the Danish seine length frequency distributions do not seem to have changed in this period, it would be surprising if this produced very different results.

#### *14.4.3.2 Summer FIS Length Frequencies*

All length frequency distributions included in this assessment from the FIS from 2008, 2010 and 2012 included measurements from both the winter and the summer surveys. In 2014 there was only a winter survey, so this length frequency distribution does not include fish caught in summer. These summer and winter FIS length frequencies could be separated in a future assessment, initially to check if there are any differences. Decisions could then be made as to whether to simply exclude the summer FIS length frequencies from the assessment or whether to include these in the assessment as yet another fleet, albeit a fairly short-lived fleet.

#### *14.4.3.3 Tasmanian Trawl Growth Parameters*

In 2006, Shelf RAG selected the model that treated Tasmanian trawl as a separate fishing fleet fishing the same east coast stock as the most appropriate base case. It appears that growth may differ for the fish caught by the Tasmanian trawl and the Tasmanian FIS fleets, so the assumption for this model of the stock could be revisited in future. Options to consider include modelling the Tasmanian stock as a separate stock, estimating growth independently for the Tasmanian stock and excluding the Tasmanian data from the assessment.

*14.4.3.4 Historical Length Frequencies*

Some historical length frequencies from the 2013 assessment appear to have been lost from the automatic processing. These distributions were included in this assessment, by using the dame data used in 2013. This issue need to be investigated to make sure the original data is not lost for future assessments.

*14.4.3.5 Steam Trawl Length Frequencies*

Length frequency data from the steam trawl fleet in the 1950s includes two sources of data which overlap for the period 1953-1955. Fits to the Sydney Fish Market data (1953-1958) are not as good as the fits to the Blackburn data (1945-1955), but there is some conflict between the data from these two sources. These data sources could potentially be treated differently to improve these fits to the steam trawl fleet.

Table 14.19. Summary of results for the base-case and sensitivity tests. Recommended biological catches (RBCs) are only shown for tuned models (cases 0 & 17).

| Case | | $SSB_0$ | $SSB_{2017}$ | $SSB_{2017}/SSB_0$ | Steepness | $SSB_{MSY}/SSB_0$ | $RBC_{2017}$ | $RBC_{2017-9}$ | $RBC_{2017-21}$ | $RBC_{longterm}$ |
|---|---|---|---|---|---|---|---|---|---|---|
| 0 | base case 20:35:40 *M* 0.27 | 22,987 | 9,972 | 0.43 | 0.62 | 0.31 | 2,971 | 2,936 | 2,909 | 2,765 |
| 1 | *M* 0.22 | 22,041 | 5,728 | 0.26 | 0.75 | 0.27 | | | | |
| 2 | *M* 0.32 | 25,095 | 12,898 | 0.51 | 0.50 | 0.35 | | | | |
| 3 | 50% maturity at 27cm | 24,182 | 10,661 | 0.44 | 0.60 | 0.32 | | | | |
| 4 | 50% maturity at 33cm | 21,333 | 9,032 | 0.42 | 0.64 | 0.30 | | | | |
| 5 | $\sigma_R = 0.35$ | 22,795 | 9,799 | 0.43 | 0.61 | 0.31 | | | | |
| 6 | $\sigma_R = 0.45$ | 23,151 | 10,092 | 0.44 | 0.62 | 0.31 | | | | |
| 7 | wt x 2 length comp | 23,271 | 9,815 | 0.42 | 0.61 | 0.31 | | | | |
| 8 | wt x 0.5 length comp | 22,619 | 9,993 | 0.44 | 0.63 | 0.30 | | | | |
| 9 | wt x 2 age comp | 23,126 | 9,717 | 0.42 | 0.61 | 0.31 | | | | |
| 10 | wt x 0.5 age comp | 22,838 | 10,187 | 0.45 | 0.63 | 0.31 | | | | |
| 11 | wt x 2 CPUE | 22,653 | 10,067 | 0.44 | 0.63 | 0.31 | | | | |
| 12 | wt x 0.5 CPUE | 22,803 | 9,531 | 0.42 | 0.62 | 0.31 | | | | |
| 13 | estimate *M* (0.232), *h* 0.75 | 21,592 | 8,413 | 0.39 | 0.75 | 0.26 | | | | |
| 14 | recruitment est to 2009 | 22,705 | 7,032 | 0.31 | 0.61 | 0.31 | | | | |
| 15 | Two FIS fleets | 23,100 | 9,877 | 0.43 | 0.61 | 0.31 | 2,929 | 2,901 | 2,880 | 2,766 |

Table 14.20. Summary of likelihood components for the base-case and sensitivity tests. Likelihood components are unweighted, and cases 1-17 are shown as differences from the base case. A negative value indicates a better fit, a positive value a worse fit.

| Case | | Likelihood TOTAL | Survey | Discard | Length comp | Age comp | Recruitment | Parm_priors |
|---|---|---|---|---|---|---|---|---|
| 0 | base case 20:35:40 M 0.27 | 2834.33 | -129.41 | 187.76 | 404.01 | 2383.26 | -14.30 | 2.94 |
| 1 | M 0.22 | 9.85 | 11.72 | -1.52 | -1.43 | 1.68 | -1.79 | -0.07 |
| 2 | M 0.32 | 0.57 | -2.03 | 0.55 | -0.09 | 0.04 | 1.56 | 0.43 |
| 3 | 50% maturity at 27cm | 6.80 | -0.03 | -0.01 | -0.01 | 0.00 | -0.21 | 7.07 |
| 4 | 50% maturity at 33cm | 7.35 | 0.04 | 0.01 | 0.02 | 0.00 | 0.29 | 6.99 |
| 5 | $\sigma_R = 0.35$ | 2.22 | 1.69 | 0.63 | 1.72 | 0.06 | -1.89 | 0.00 |
| 6 | $\sigma_R = 0.45$ | -1.00 | -1.23 | -0.46 | -1.30 | -0.01 | 2.00 | 0.00 |
| 7 | wt x 2 length comp | 4.55 | 1.08 | 5.08 | -10.10 | 3.36 | 5.11 | 0.02 |
| 8 | wt x 0.5 length comp | 2.77 | 0.14 | -2.77 | 9.90 | -1.34 | -3.13 | -0.02 |
| 9 | wt x 2 age comp | 3.65 | 3.85 | 5.59 | 2.83 | -9.10 | 0.45 | 0.02 |
| 10 | wt x 0.5 age comp | 4.20 | -2.36 | -6.63 | -1.38 | 14.24 | 0.34 | -0.02 |
| 11 | wt x 2 CPUE | 4.38 | -10.22 | 4.50 | 0.95 | 4.32 | 4.84 | -0.02 |
| 12 | wt x 0.5 CPUE | 3.70 | 12.78 | -3.44 | -0.10 | -2.19 | -3.34 | 0.00 |
| 13 | estimate M (0.232), h 0.75 | 0.75 | 1.65 | -0.53 | 0.36 | -0.02 | -0.60 | -0.07 |
| 14 | recruitment est to 2009 | 13.00 | 0.79 | 5.68 | 1.19 | 7.44 | -2.20 | 0.01 |
| 15 | Two FIS fleets | 12.13 | -4.43 | 1.34 | 13.48 | -0.61 | -0.14 | 0.17 |

## 14.5 Acknowledgements

Age data was provided by Kyne Krusic-Golub (Fish Ageing Services), ISMP and AFMA logbook and CDR data were provided by John Garvey (AFMA). Mike Fuller, Roy Deng, Franzis Althaus and Robin Thomson (CSIRO) pre-processed the data. Athol Whitten provided very useful R code for organising plots. Robin Thomson, Geoff Tuck, Rich Little, Miriana Sporcic, Malcolm Haddon and Judy Upston are thanked for helpful discussions on this work.

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## 14.7 Appendix

### A1 Data source summary and fits to length composition data

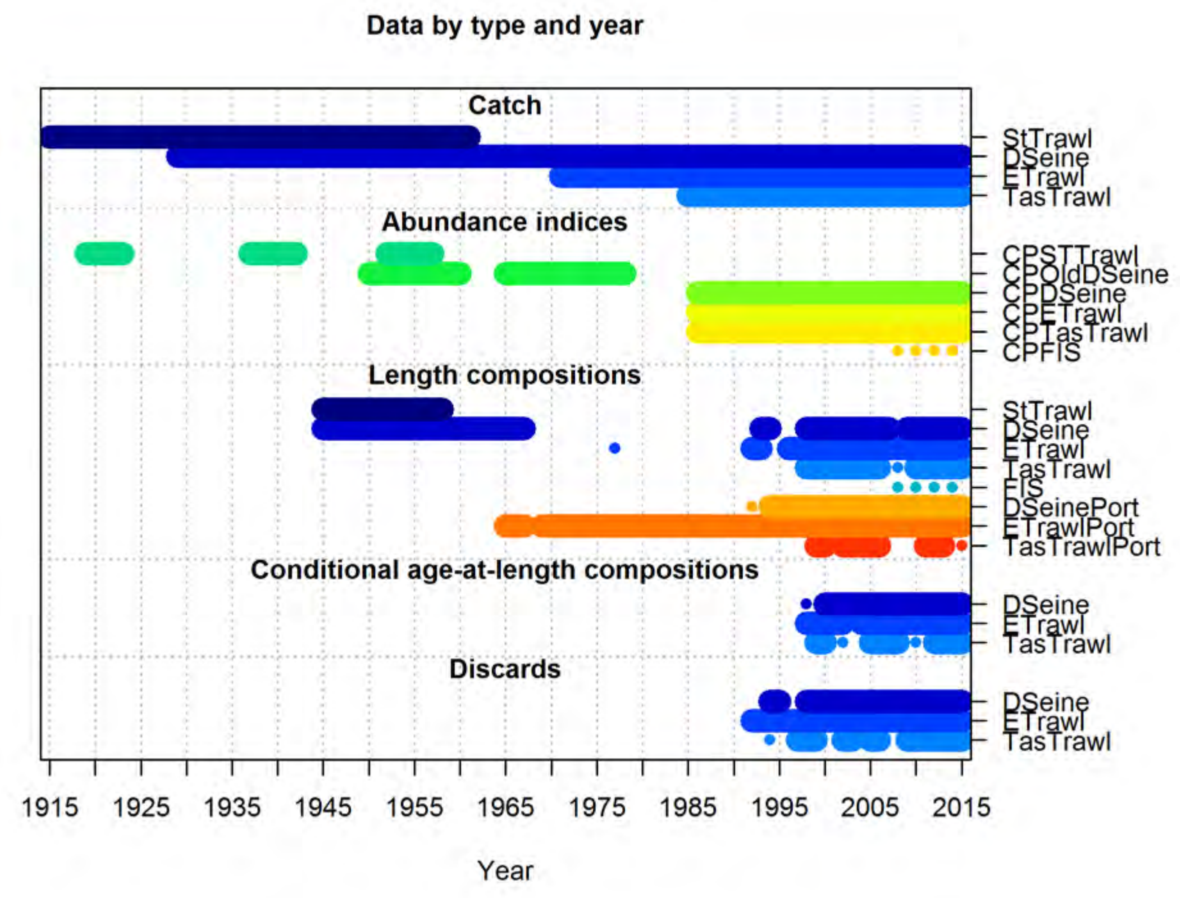


Figure A 14.1. Summary of data sources for tiger flathead stock assessment.

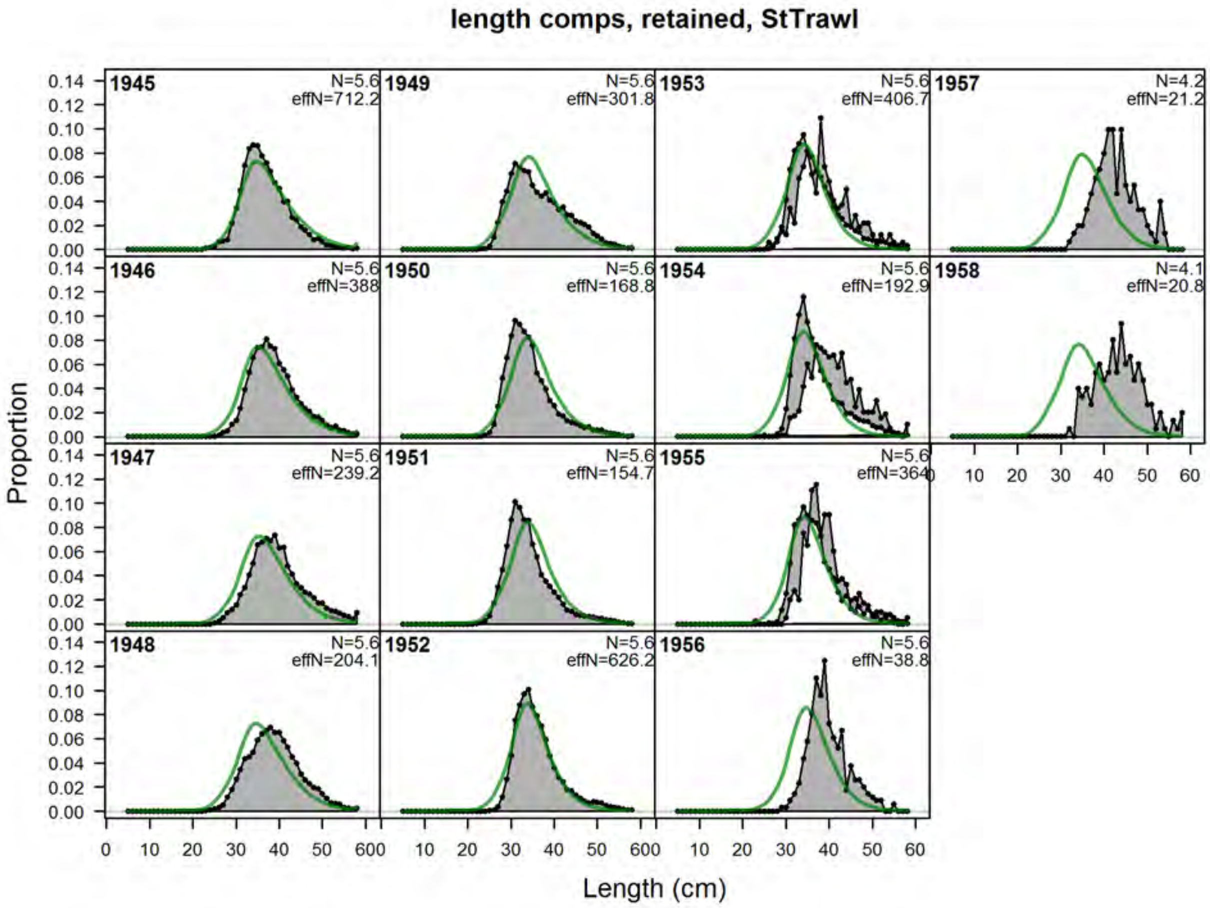


Figure A 14.2. Tiger flathead length composition fits: steam trawl retained.

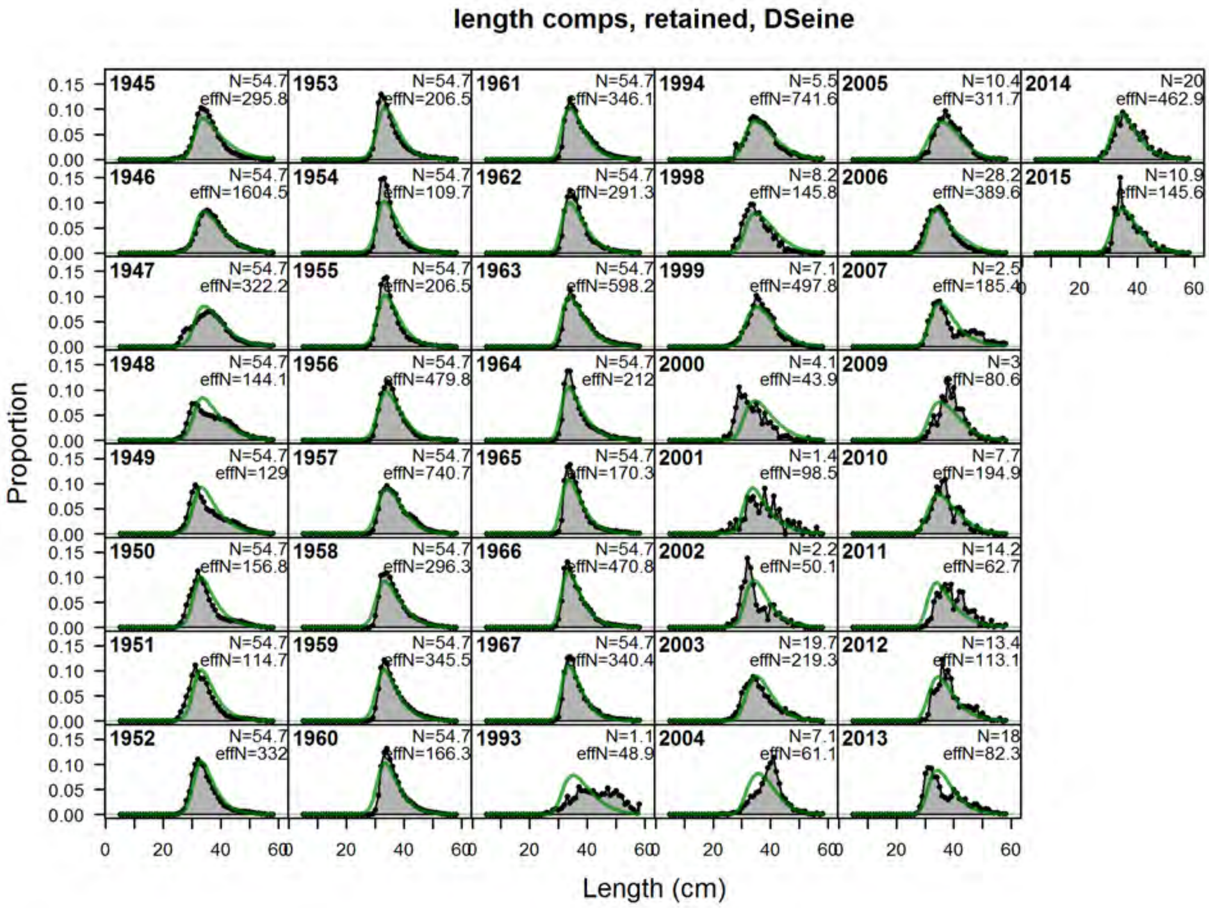

Figure A 14.3. Tiger flathead length composition fits: Danish seine retained onboard.

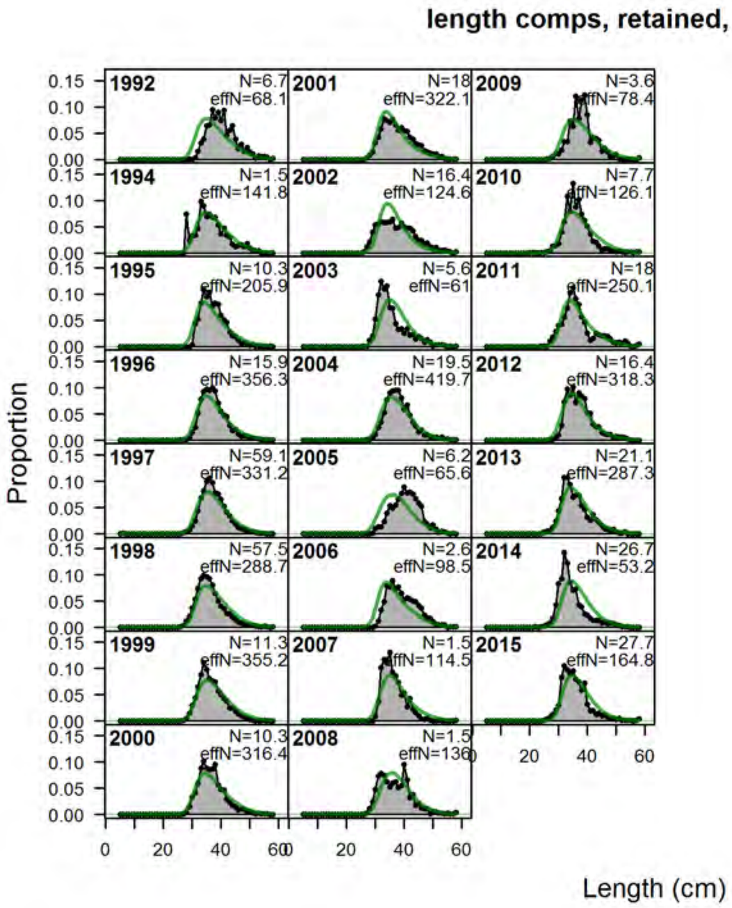


Figure A 14.4. Tiger flathead length composition fits: Danish seine retained port.

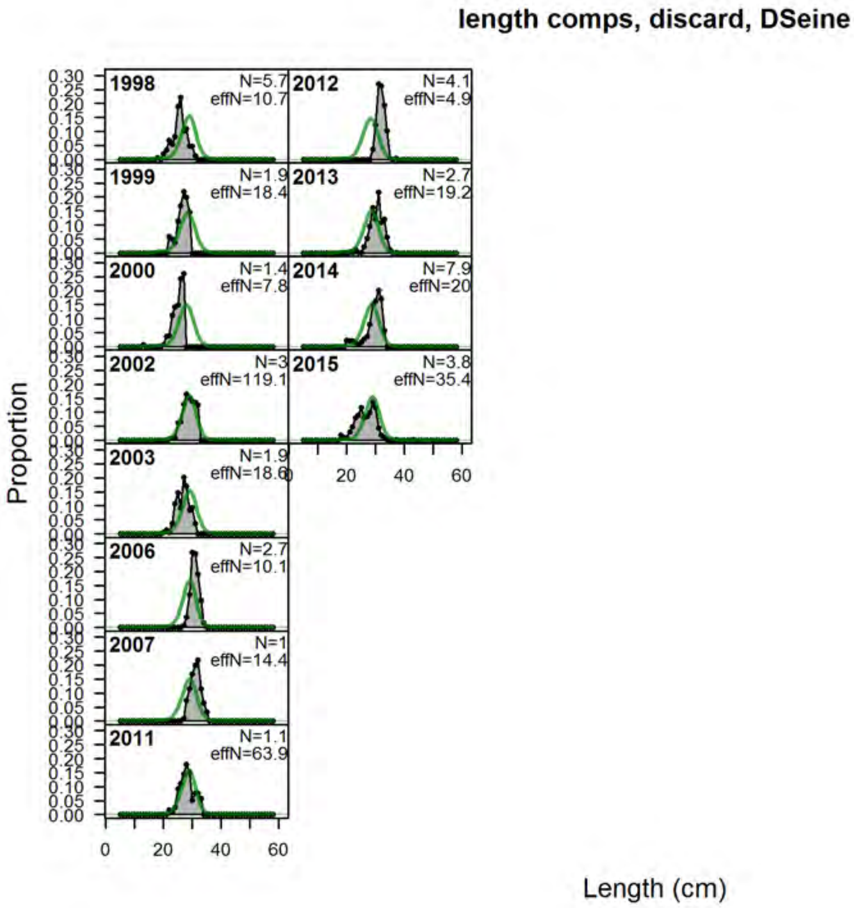


Figure A 14.5. Tiger flathead length composition fits: Danish seine discarded.

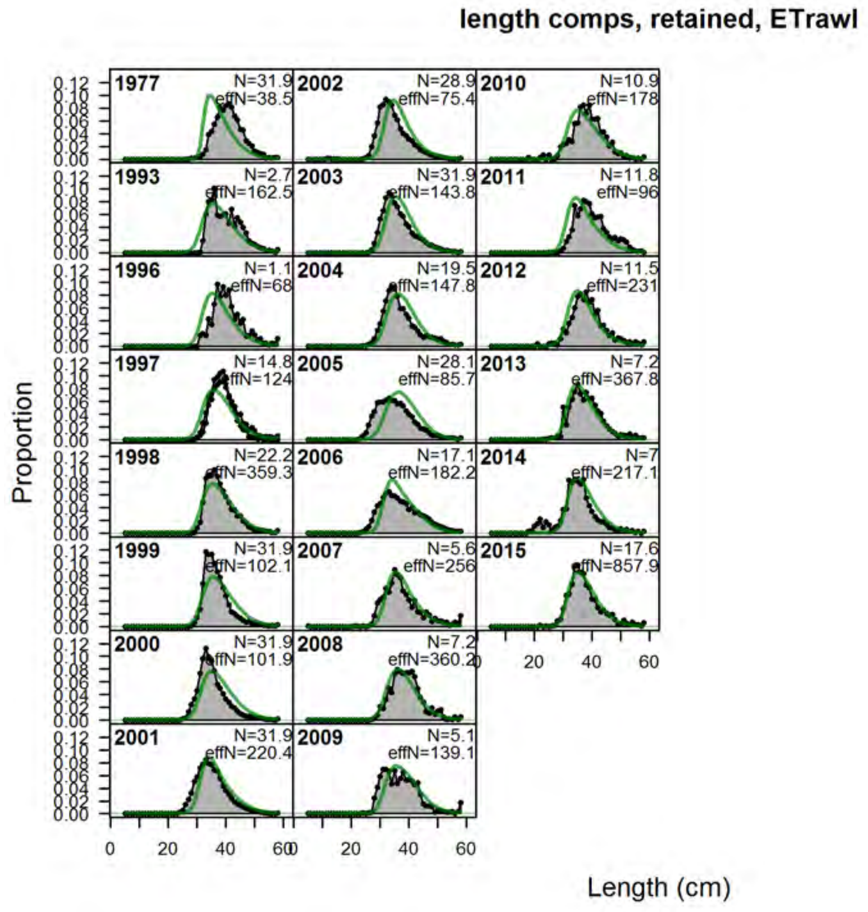


Figure A 14.6. Tiger flathead length composition fits: eastern trawl retained onboard.

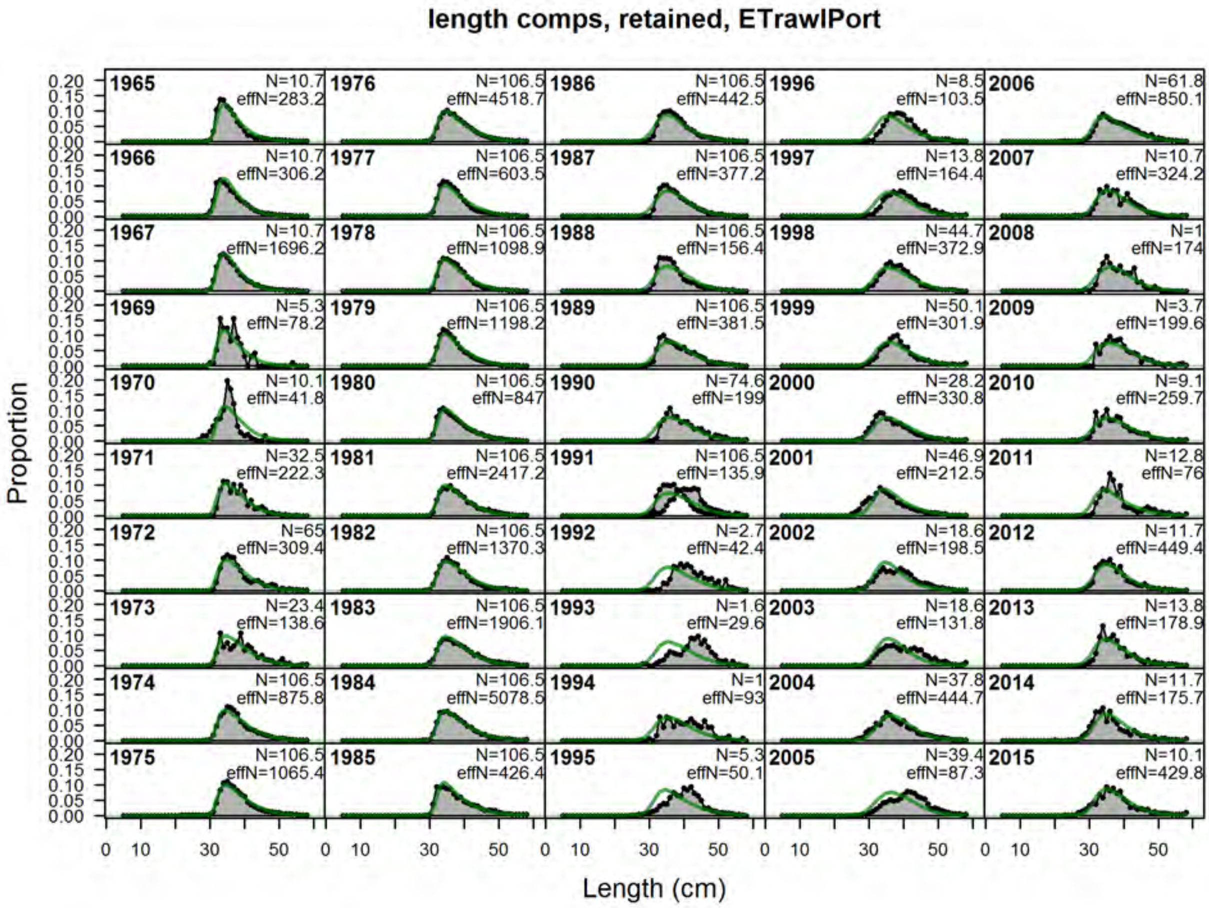


Figure A 14.7. Tiger flathead length composition fits: eastern trawl retained port .

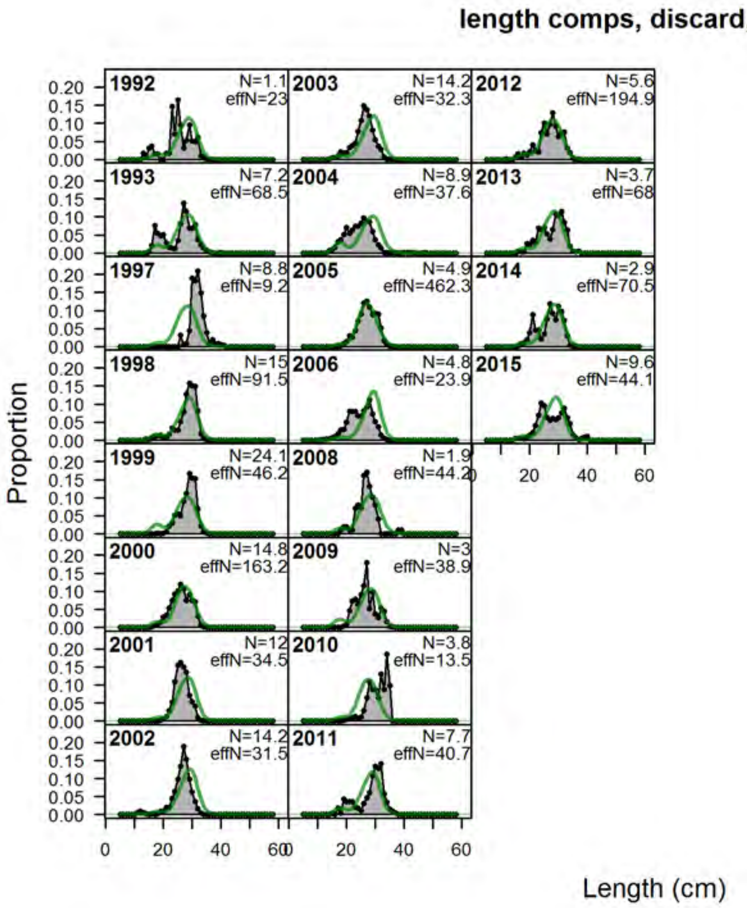


Figure A 14.8. Tiger flathead length composition fits: eastern trawl discarded.

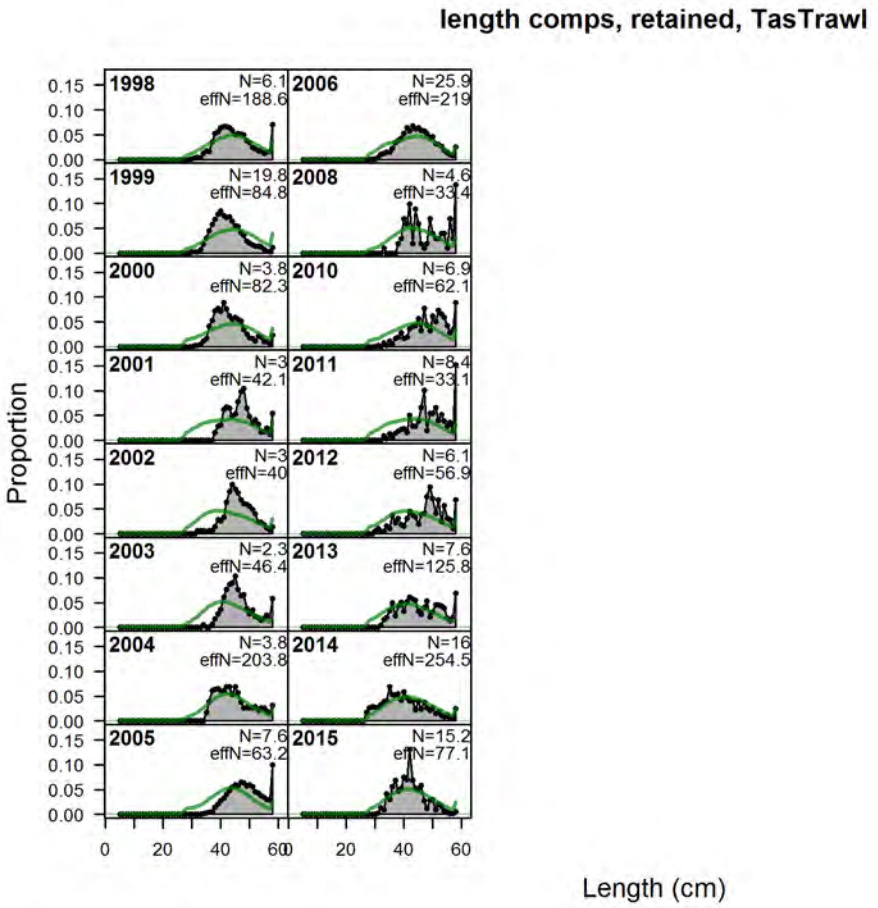


Figure A 14.9. Tiger flathead length composition fits: Tasmanian trawl retained onboard.

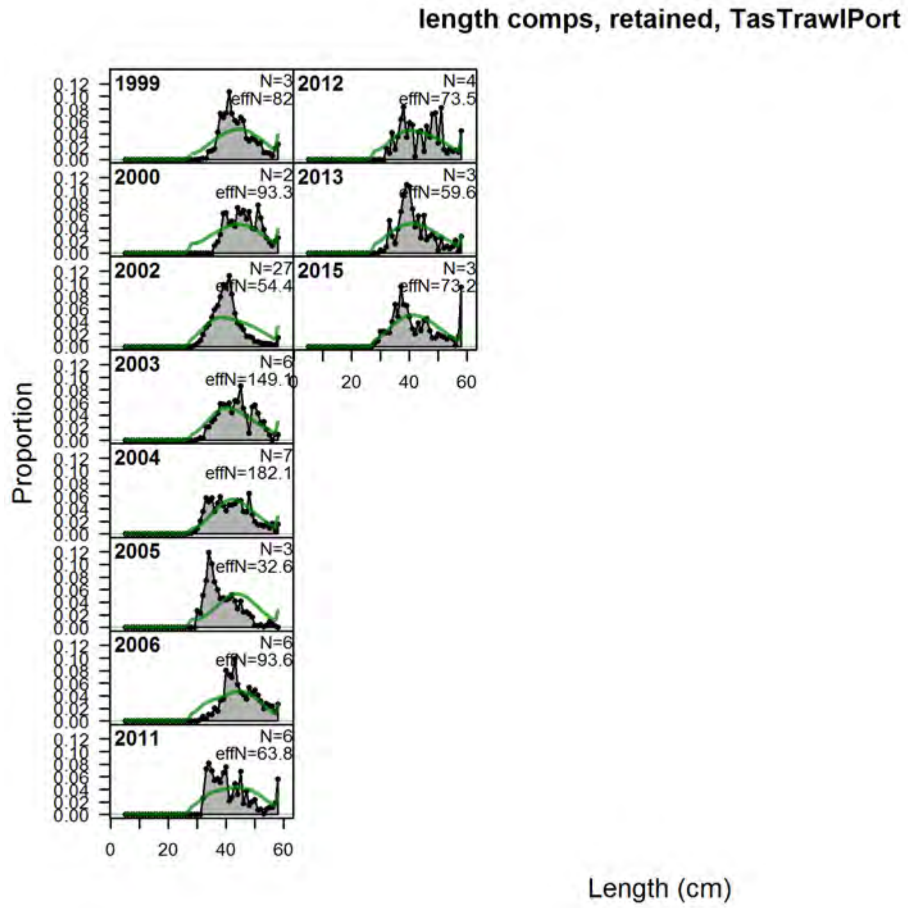


Figure A 14.10. Tiger flathead length composition fits: Tasmanian trawl retained port.

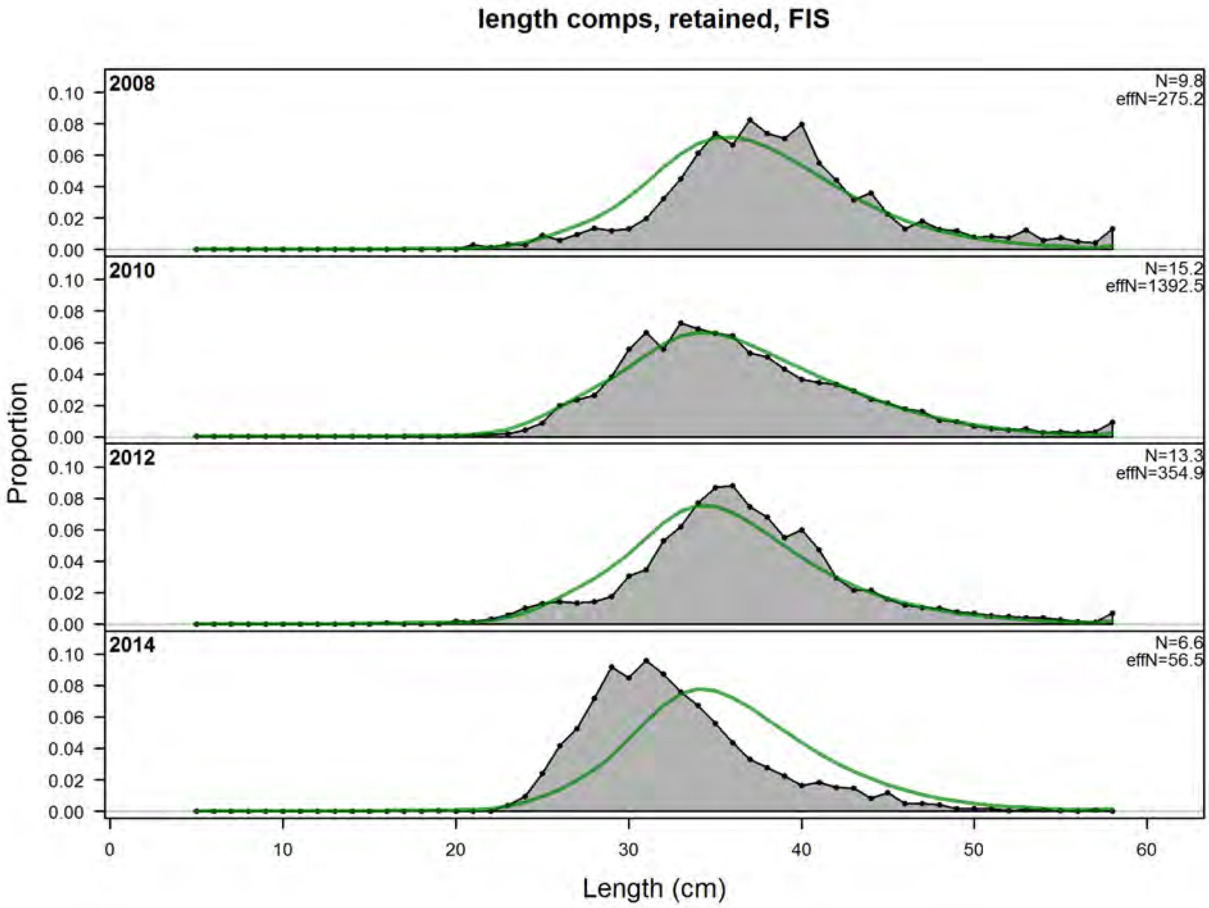


Figure A 14.11. Tiger flathead length composition fits: FIS (zones 10, 20 and 30).

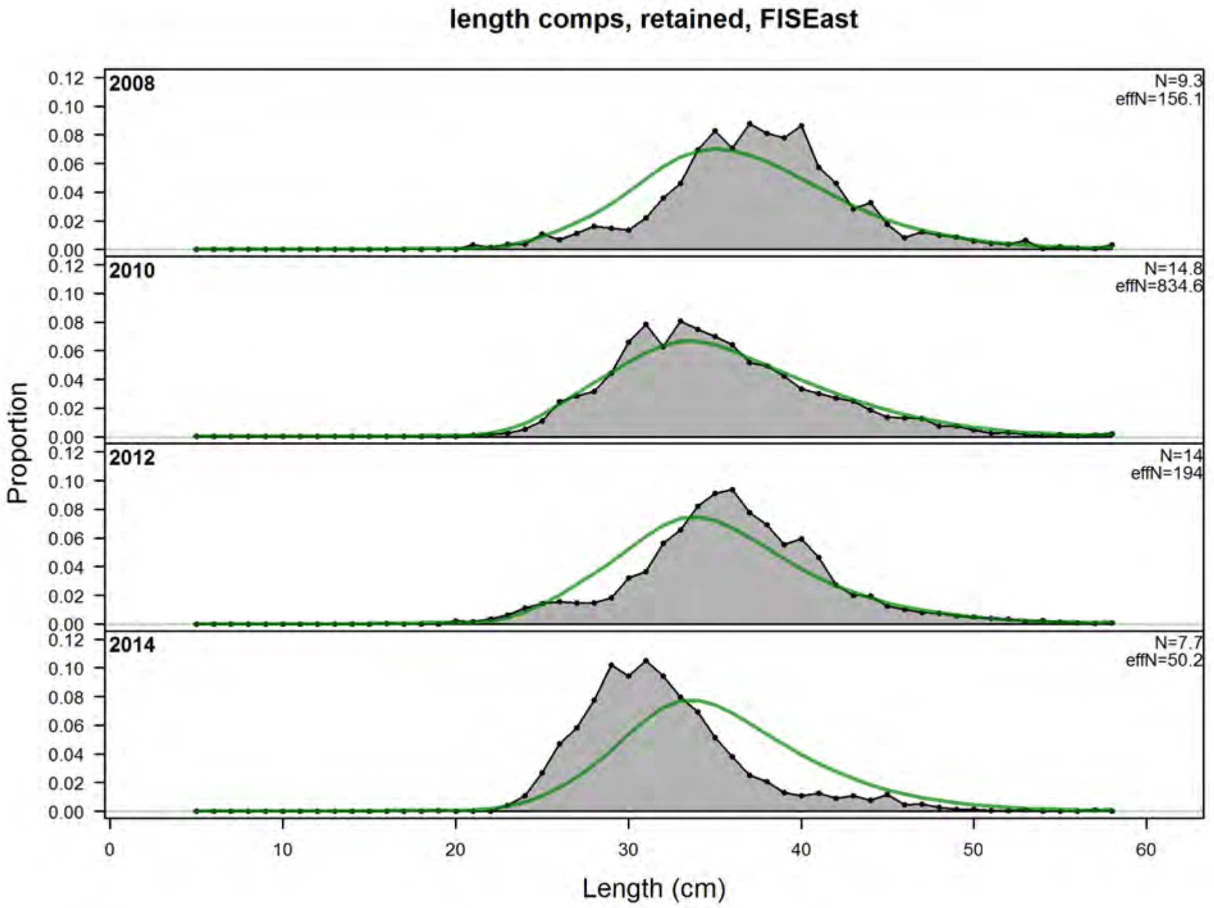


Figure A 14.12. Tiger flathead length composition fits: Eastern FIS (zones 10 and 20).

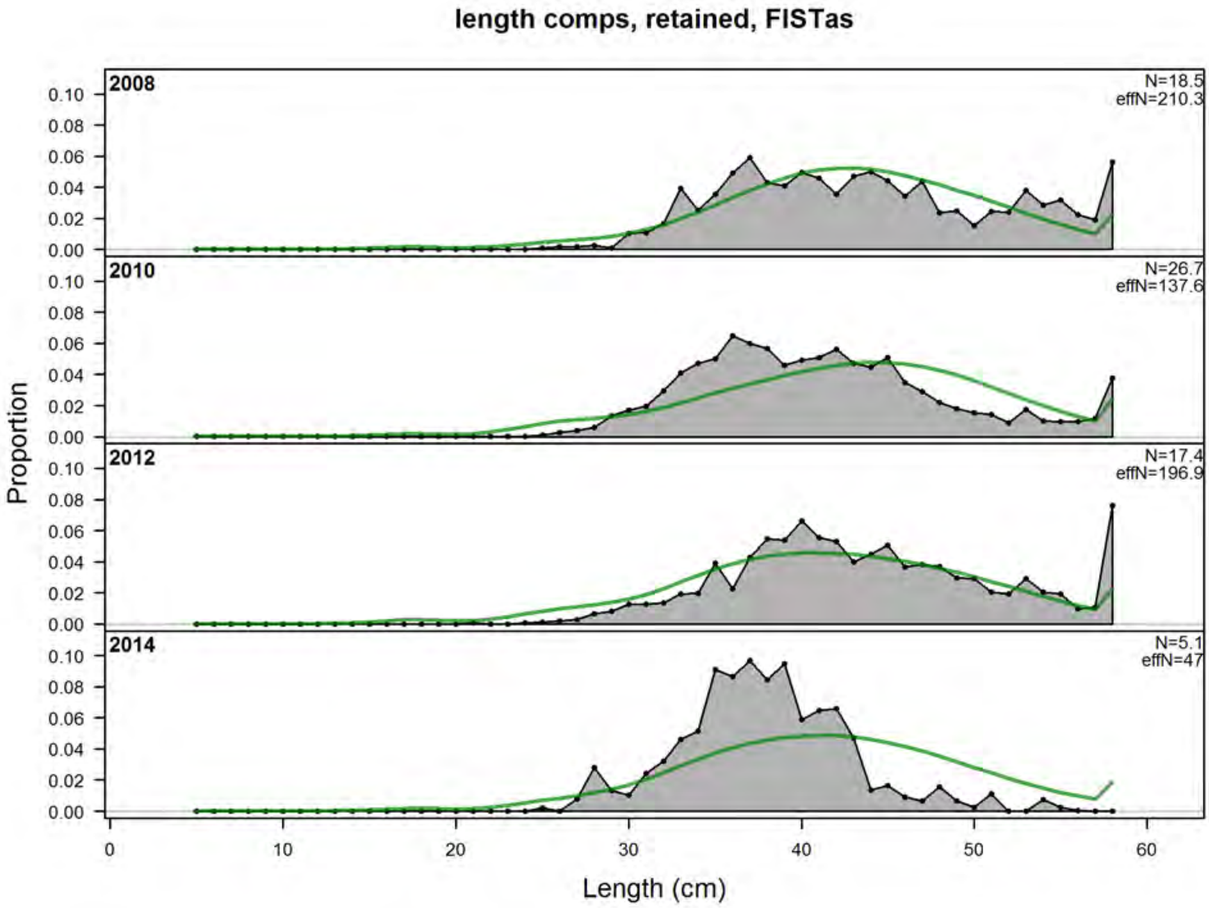


Figure A 14.13. Tiger flathead length composition fits: Tasmanian FIS (zone 30 only).

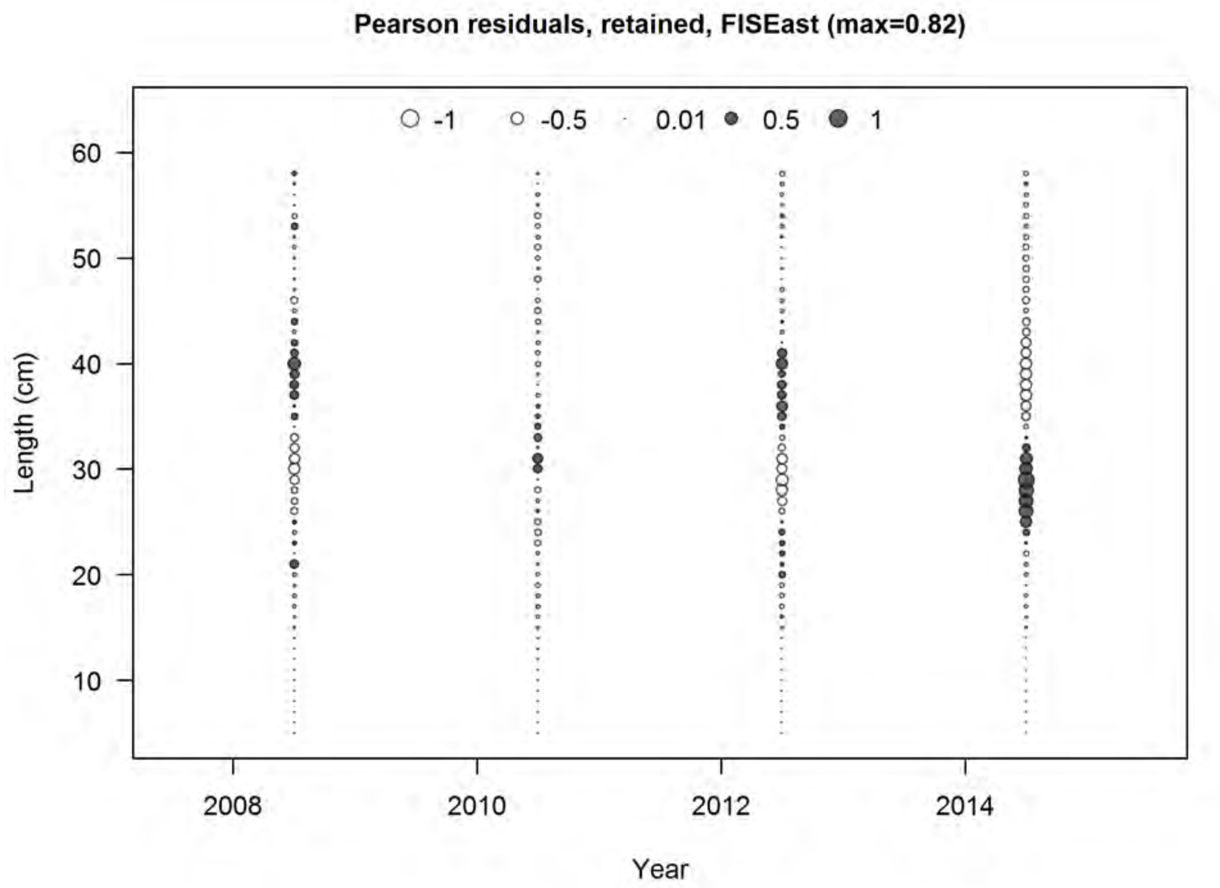


Figure A 14.14. Tiger flathead length composition fits: Eastern FIS (zones 10 and 20).

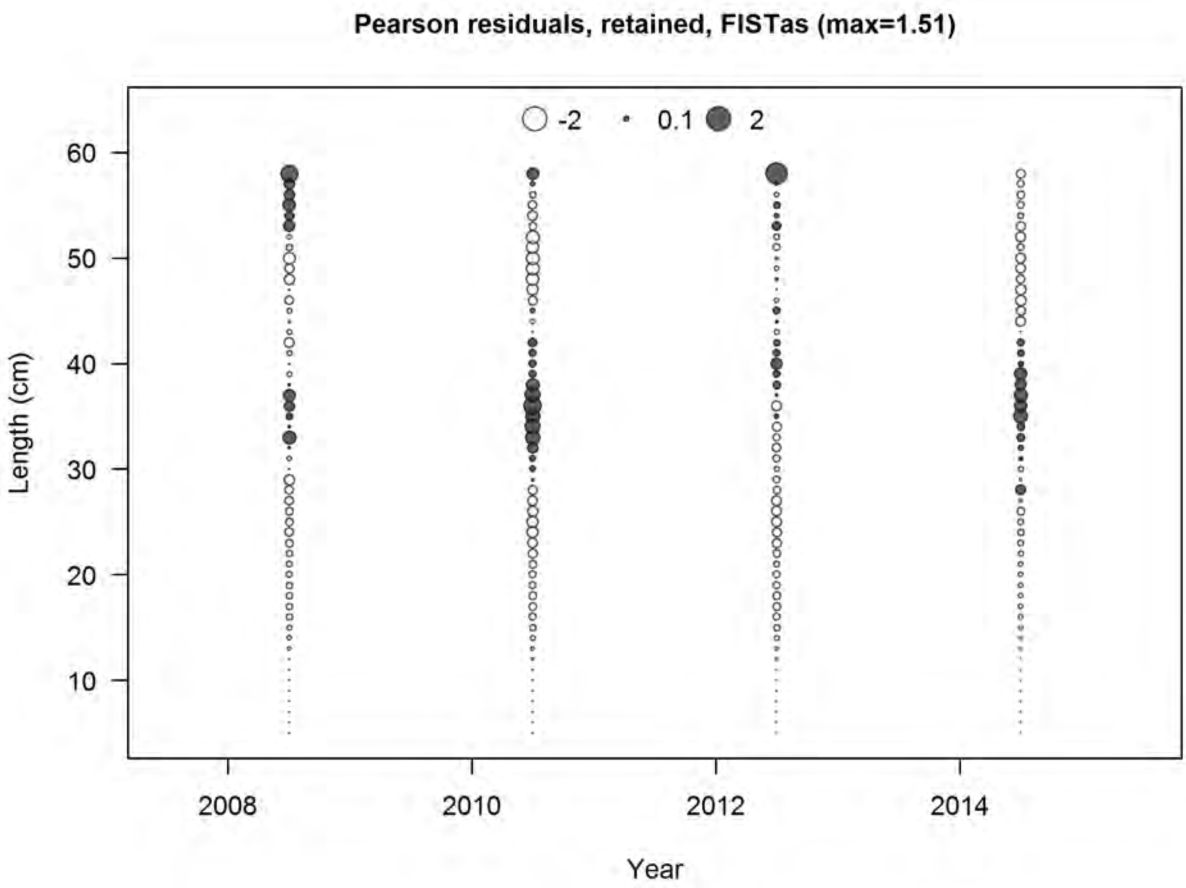


Figure A 14.15. Tiger flathead length composition fits: Tasmanian FIS (zone 30 ony).

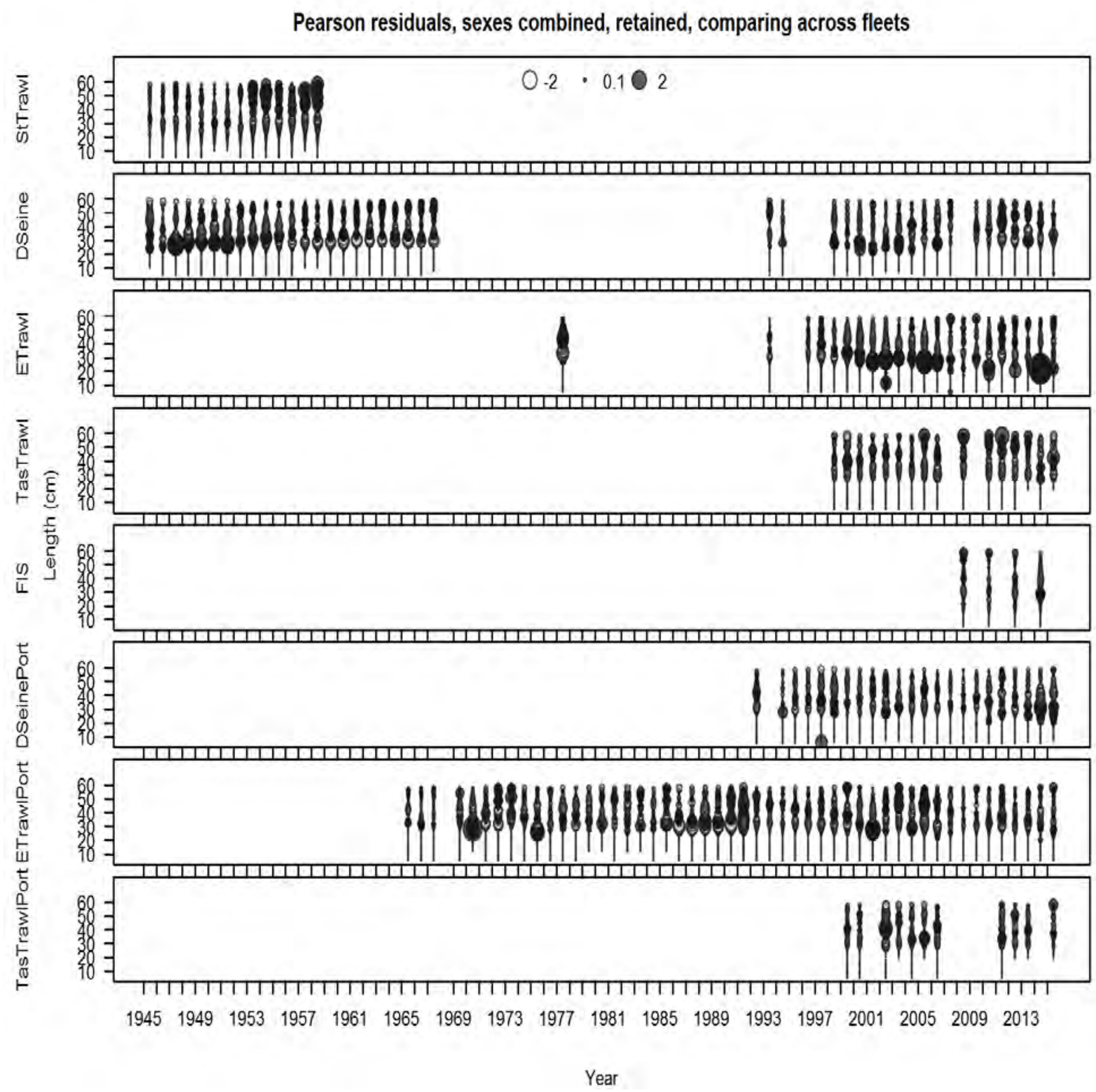


Figure A 14.16. Residuals from the annual length compositions (retained) for tiger flathead displayed by year and fleet.

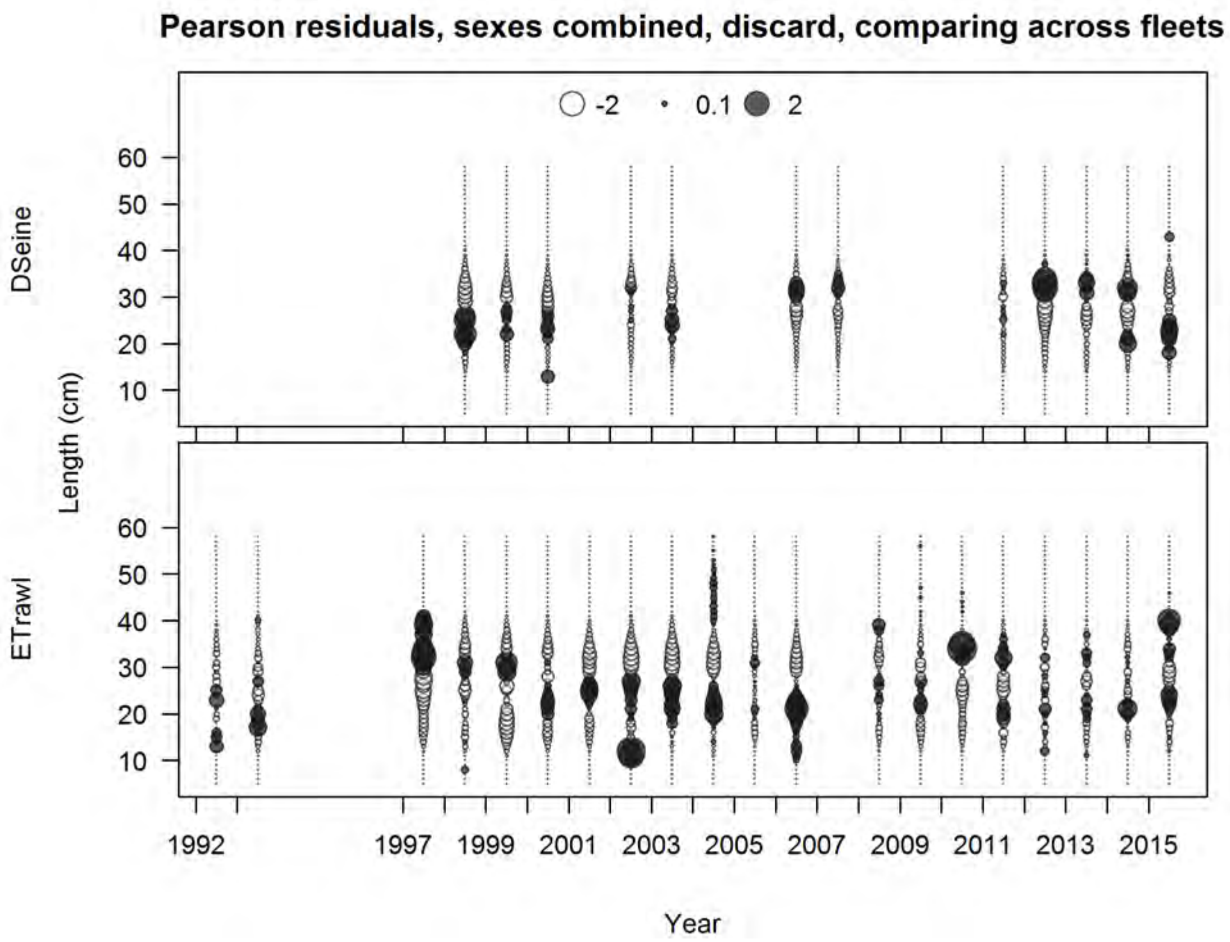


Figure A 14.17. Residuals from the annual length compositions (discarded) for tiger flathead displayed by year and fleet.

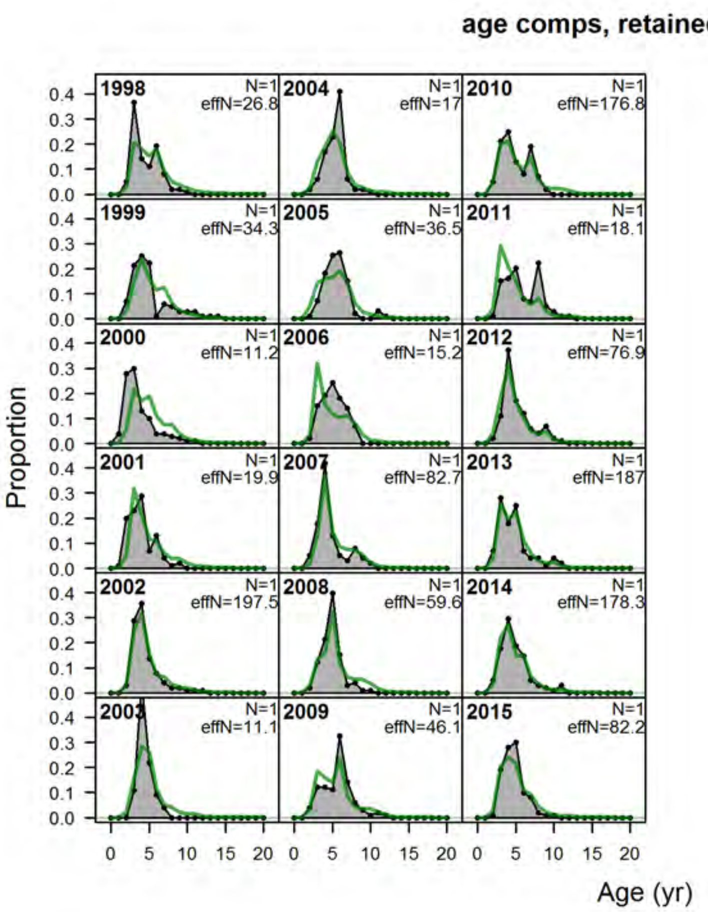


Figure A 14.18. Implied fits to age compositions for tiger flathead Danish seine (retained).

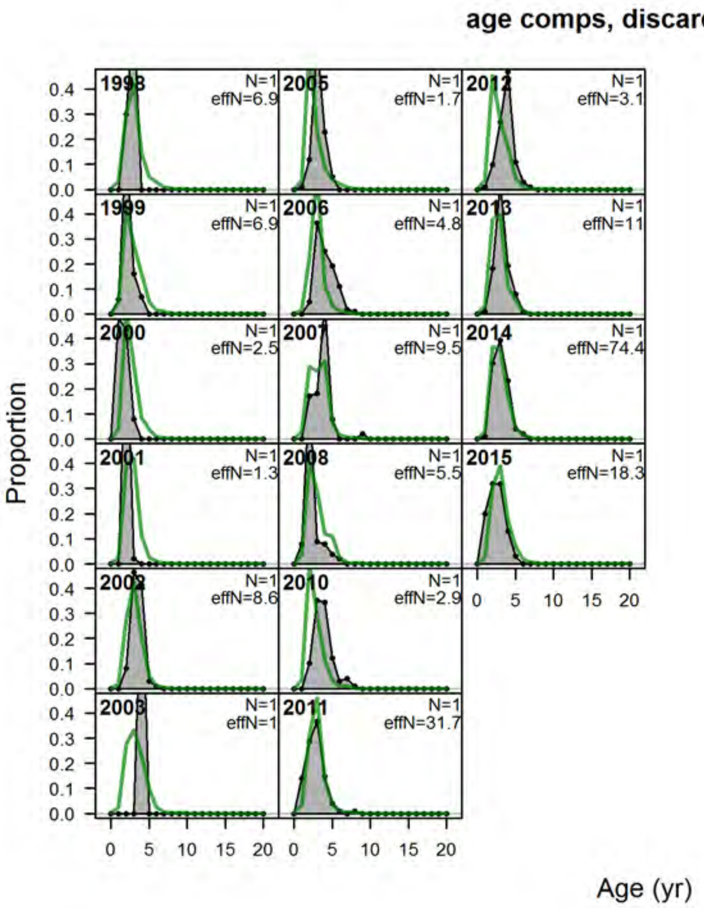


Figure A 14.19. Implied fits to age compositions for tiger flathead Danish seine (discarded).

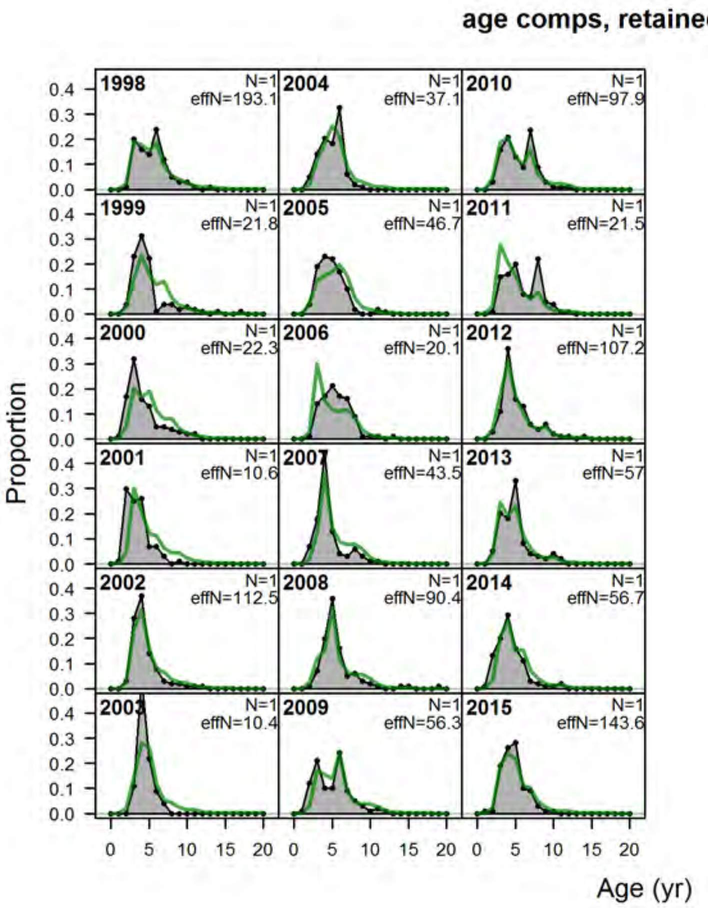


Figure A 14.20. Implied fits to age compositions for tiger flathead eastern trawl (retained).

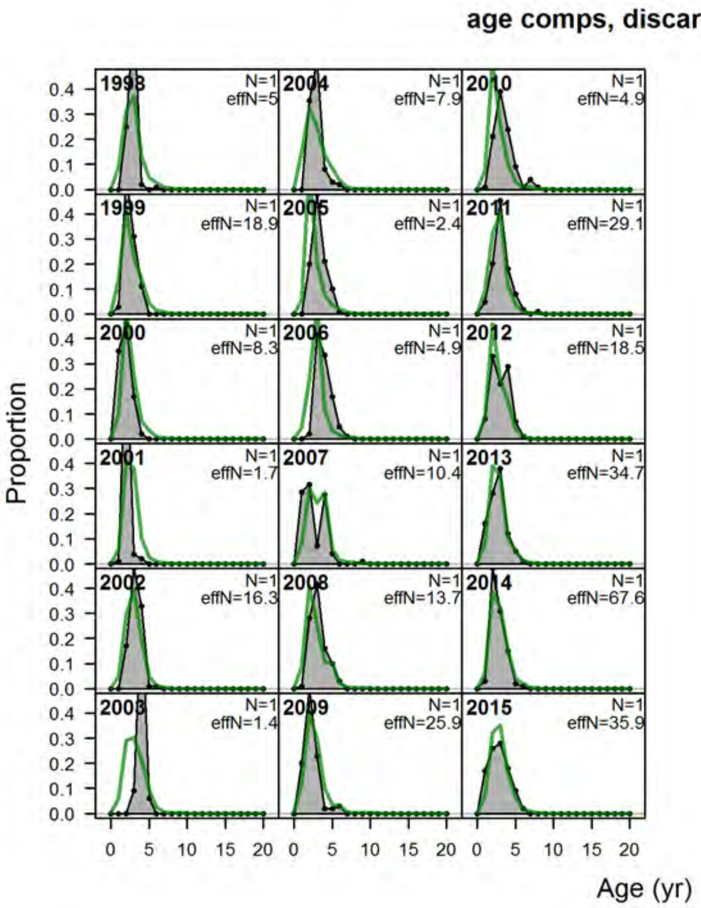


Figure A 14.21. Implied fits to age compositions for tiger flathead eastern trawl (discarded).

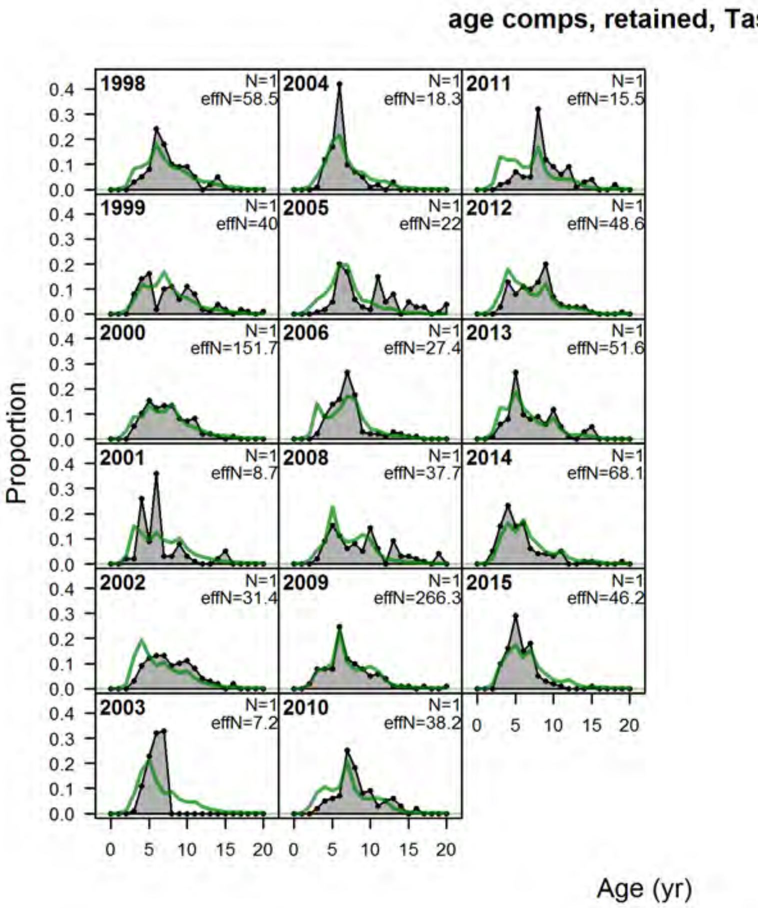


Figure A 14.22. Implied fits to age compositions for tiger flathead Tasmanian trawl (retained).

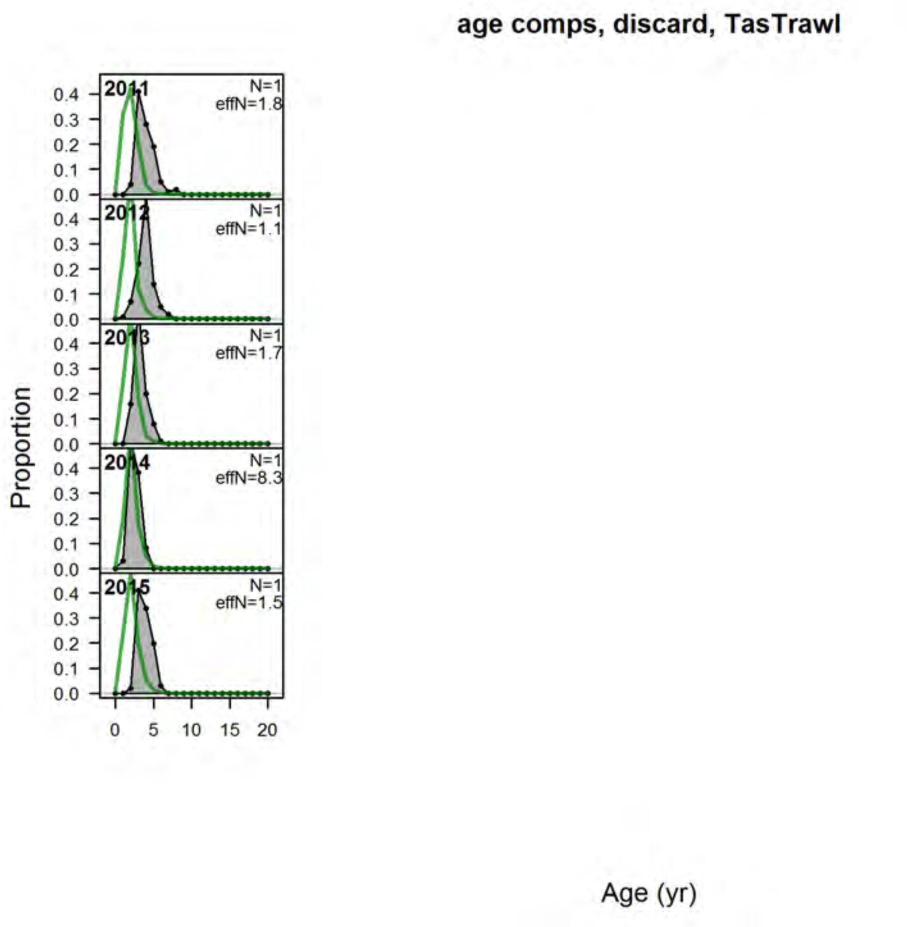


Figure A 14.23. Implied fits to age compositions for tiger flathead Tasmanian trawl (discarded).

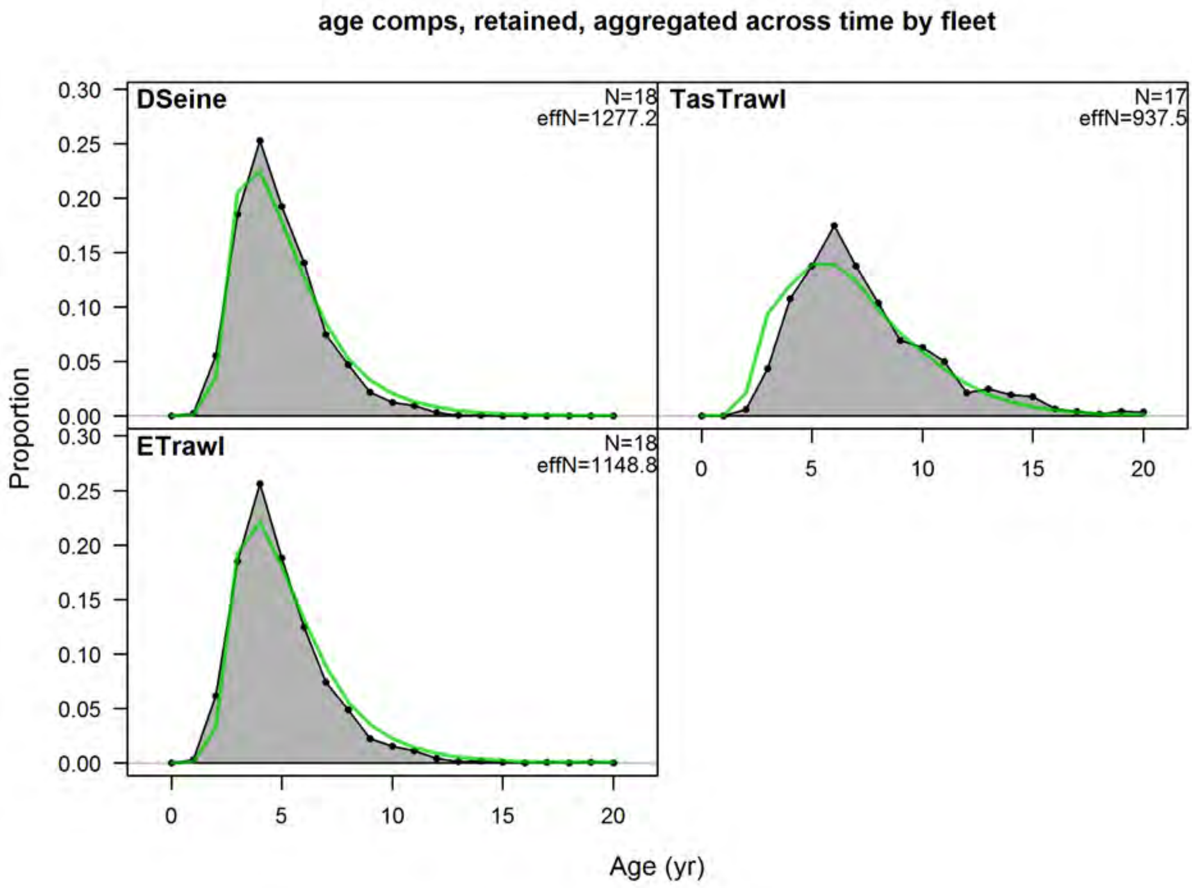


Figure A 14.24. Implied fits to age compositions for tiger flathead aggregated across time by fleet (retained).

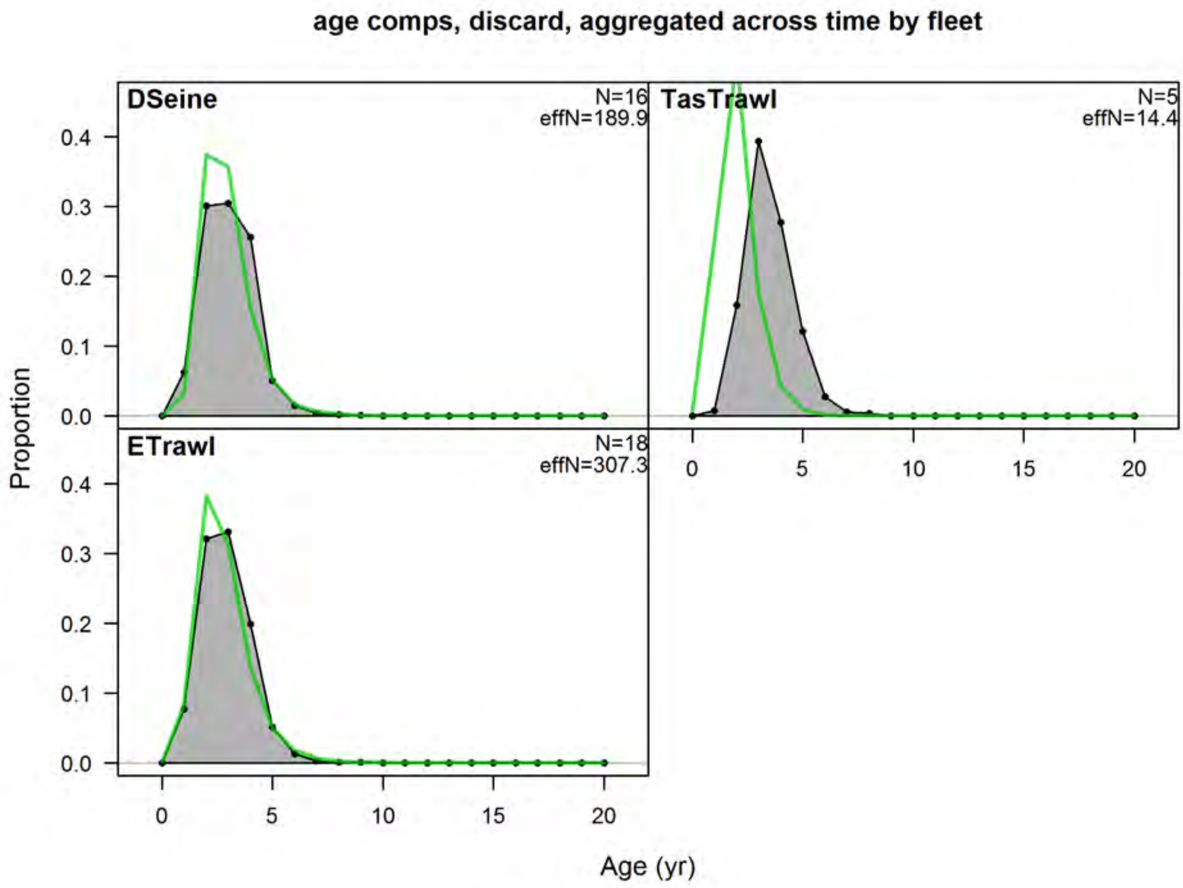


Figure A 14.25. Implied fits to age compositions for tiger flathead aggregated across time by fleet (discarded).

# 15. Updated RBC calculations for Tiger flathead (*Neoplatycephalus richardsoni*) stock assessment based on data up to 2015

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## *15.1 2017 updates to tiger flathead RBCs*

### 15.1.1 *Updated RBCs from 2016 tiger flathead assessment*

RBC calculations were made for the 2016 tiger flathead assessment (Day 2016), with the usual assumption that the 2016 catch data was identical to the 2015 catch data, in the absence of actual catch data for 2016. The projected 2016 catch data allows the spawning biomass and RBC to be calculated at the start of 2017 year, allowing an updated TAC to be implemented in 2017. Stock Synthesis (Methot 2015) was largely developed in the USA, using a different set of harvest control rules to those used in Australia. The code has been modified to incorporate the Australian harvest control rules, and there are some clear differences between these sets of rules. For example, in SESSF assessments, the projected 2016 catch figures are included as a "forecast" quantity in the forecast.sso file, as they fall outside the range of data input to the assessment, which ends in 2015.

In 2016, advice was received to modify one of the parameters in the forecast file, so that forecast catches comply more closely with the Australian rules rather than the American rules. Unfortunately, this resulted in some unintended side effects where the catch that was used in the projections was not that which was specified in the forecast file. Instead, it was calculated by the harvest control rule, assuming that those results were known in advance. This resulted in a lower projected catch for 2016 than was expected (with a total retained catch of 2769t in 2016 when it should have been 3074t). This would affect the forecast spawning biomass trajectory and calculation of the RBC for 2017. If the correct 2016 catch is considered, a different spawning biomass level at the start of 2017 would result, and consequently a different series of RBC values from 2017.

To ensure that the appropriate catch is taken in 2016, we have reverted to the process used in previous assessments. However, this ensures that the correct 2016 catch is applied, and is consistent with procedures used in SESSF assessments prior to 2016.

When this correction is made, the estimated depletion at the start of 2017 changes from the 43% reported in Day (2016) to 42%. The RBCs calculated from 2017 to 2021, listed in Table 17 in Day (2016), are updated below (Table 15.1), along with the incorrect RBCs reported at the November 2016 SERAG meeting for the base case for tiger flathead adopted at the November SERAG meeting (with two FIS fleets). The correct RBC for 2017 is 43t less than that reported previously, 35t less in 2018 and 28 t less in 2019. The updated spawning depletion trajectory is plotted against the incorrect version in Figure 15.1.

Table 15.1. Yearly projected RBCs (tonnes) across all fleets under the 20:35:40 harvest control rules: assuming average recruitment from 2013. The updated RBCs appear in column 2, with the superseded values (as reported at the November 2016 SERAG meeting) in column 3 for comparison. These RBCs include the sum of retained catches and discard estimates.

| RBCs Year | Updated RBC | Nov 2016 RBC |
|---|---|---|
| 2017 | 2,886 | 2,929 |
| 2018 | 2,865 | 2,900 |
| 2019 | 2,848 | 2,876 |
| 2020 | 2,834 | 2,857 |
| 2021 | 2,823 | 2,841 |

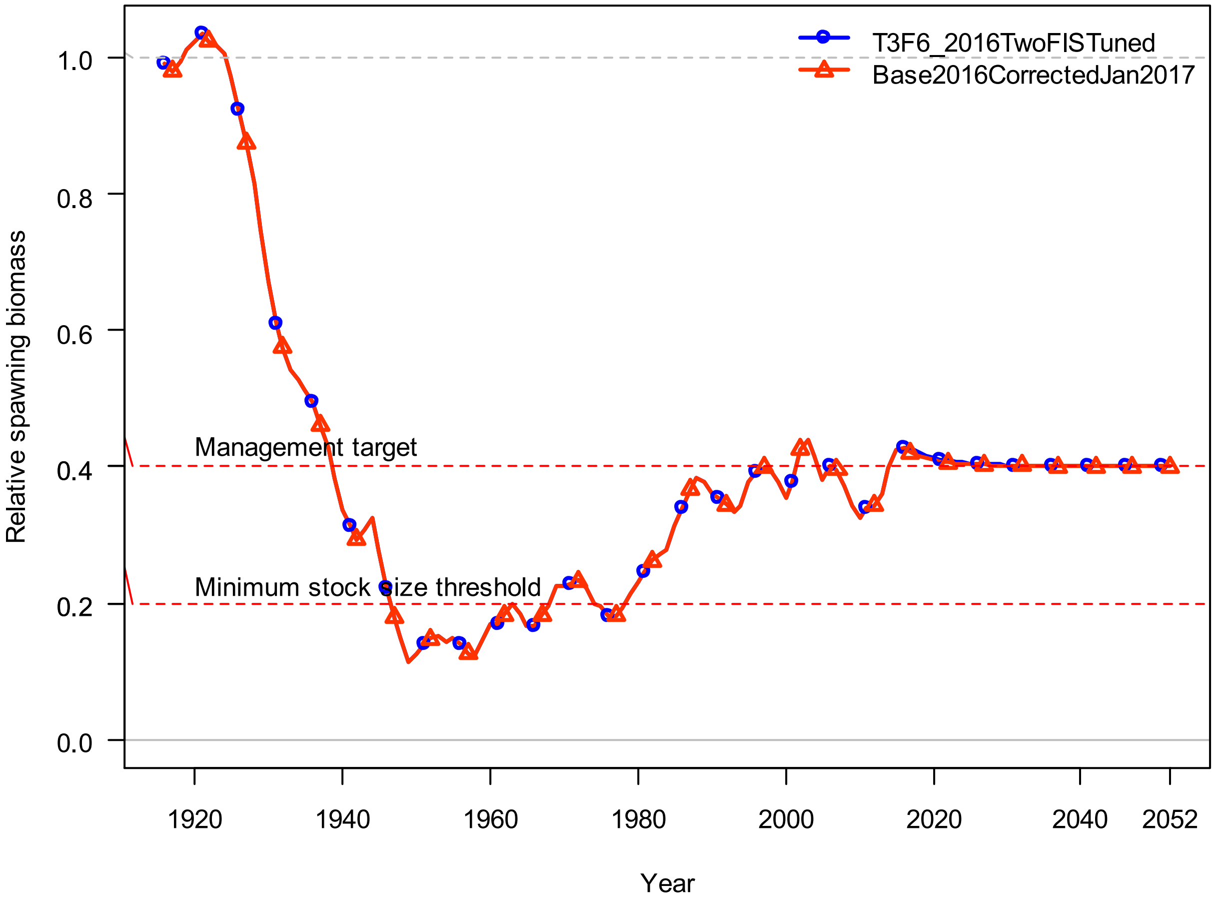


Figure 15.1. Corrected (red) and November 2016 (blue) relative spawning biomass trajectories. These trajectories are identical up to 2016 and there is a very small difference from 2016 onwards, with the corrected trajectory marginally lower than the November 2016 trajectory.

### 15.1.2 *RBCs from variations to the standard harvest control rule used for the 2016 updated base case*

Alternative scenarios are also considered where total catches (including discards) between 2017 and 2019 are fixed at particular values, reflecting either a 50% reduction in the TAC cut phased over one or two years and a 33% reduction per year phased over 3 years (Table 15.2).

Scenario 1

- A 50 % cut in the proposed reduction in TAC for 2017

Scenario 2

- A 50 % cut in the proposed reduction in TAC for 2017, with the remaining 50% to be deducted in 2018

Scenario 3

- A 33.33 % cut in the proposed reduction in TAC each year over three years from 2017-2019.

Spawning biomass trajectories comparing the updated base case with scenario 1 is shown in Figure 15.2 and the updated base case compared to scenario 3 in Figure 15.3. The spawning biomass trajectory approaches the target faster than the base case in both scenarios, as expected, but the difference is hard to discern on this scale.

Table 15.2 shows the fixed total catches (retained plus discards) used for scenarios 1-3 and the resulting depletion level and the RBC calculated for the years after the catch is fixed. Depletion is listed to 3 significant figures so that the differences can be seen. RBCs used in Table 15.2 for years 2017-2019 are individual yearly RBCs rather than the three year mean of the RBC for that period.

Table 15.2. New projections comparing the updated RBCs and depletions for the base case with the fixed catches and resulting depletions from the three different scenarios. All catches and RBCs in this table are total catches (retained plus discard estimates).

| Year | | Base Case | | | 50% 1 year | | | 50% 2 years | | | 33% 3 years | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Dep | Catch | RBC | Dep | Catch | RBC | Dep | Catch | RBC | Dep | Catch | RBC |
| 2016 | 0.428 | 3259 | | 0.428 | 3259 | | 0.428 | 3259 | | 0.428 | 3259 | |
| 2017 | 0.421 | | 2886 | 0.421 | 3089 | | 0.421 | 3089 | | 0.421 | 3157 | |
| 2018 | 0.416 | | 2865 | 0.412 | | 2837 | 0.412 | 2868 | | 0.410 | 3004 | |
| 2019 | 0.412 | | 2848 | 0.409 | | 2826 | 0.408 | | 2821 | 0.404 | 2854 | |
| 2020 | 0.410 | | 2834 | 0.407 | | 2817 | 0.406 | | 2812 | 0.402 | | 2783 |
| 2021 | 0.408 | | 2823 | 0.406 | | 2809 | 0.405 | | 2805 | 0.401 | | 2781 |

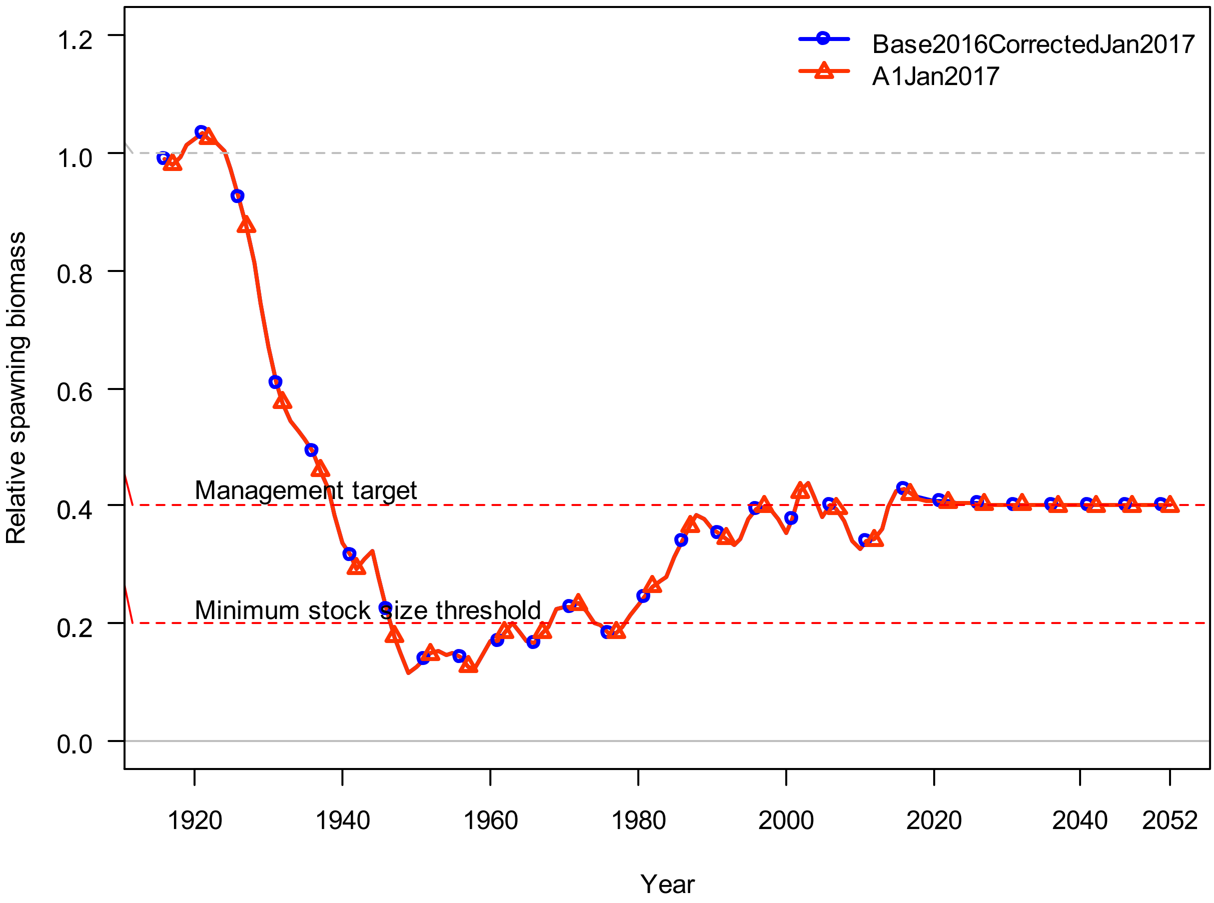


Figure 15.2. Corrected (blue) and Scenario1 (blue) relative spawning biomass trajectories. These trajectories are identical up to 2016 and there is a very small difference from 2016 onwards.

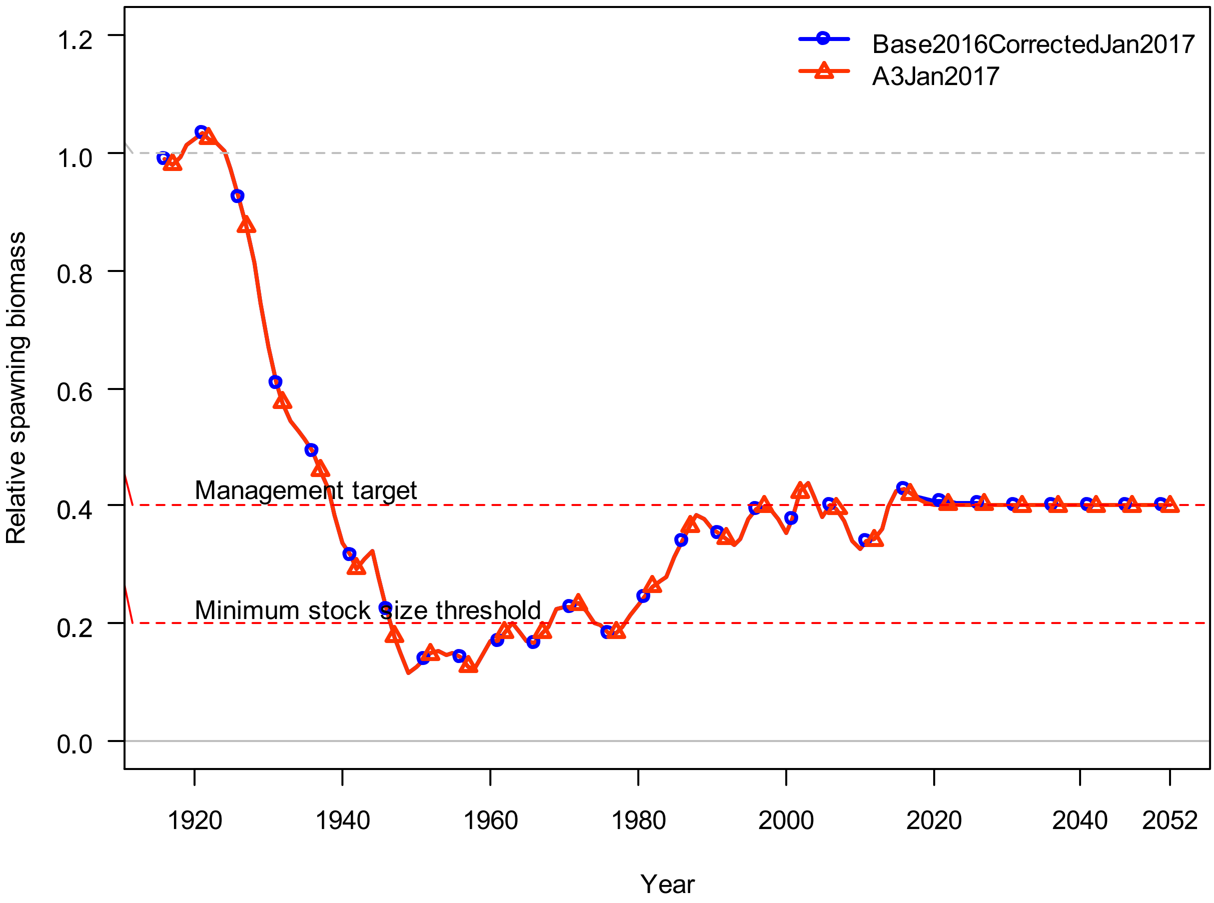


Figure 15.3. Corrected (blue) and Scenario 3 (blue) relative spawning biomass trajectories. These trajectories are identical up to 2016. Scenario 3 approaches the management target faster than the base case

## *15.2 References*

Day J 2016. Tiger flathead (*Neoplatycephalus richardsoni*) stock assessment based on data up to 2015. Unpublished report to SERAG. 80 pp.

Methot RD (2015) User manual for Stock Synthesis. Model Version 3.24s. NOAA Fisheries Service, Seattle. 152 pp.

# 16. Deepwater Flathead (*Neoplatycephalus conatus*) stock assessment using data to 2015/2016

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## *16.1 Summary*

This document updates the 2013 assessment of Deepwater Flathead (*Platycephalus conatus*) by including new data from 2012/2013 – 2014/2015) to provide estimates of stock status in the Great Australian Bight at the start of 2016/17 (end of 2015/2016). This assessment was performed using the stock assessment package Stock Synthesis (v3.24z) and included data from AFMA log-books, the ISMP sampling program, the ageing facility, and from Industry sampling programs and the GAB Fishery Independent Trawl Survey. For the first time the ISMP data was divided into the on-board and Port based samples, the length and age composition data from the FIS was used for the first time, and the Industry collected length composition data was also used for the first time.

The base-case assessment estimates that the female spawning stock biomass at the start of 2016/2017 was 45.0% of unexploited female spawning stock biomass ($SSB_0$). The 2017/2018 recommended biological catch (RBC) under the agreed 20:35:43 harvest control rule is 1155 t and the long-term yield (assuming average recruitment in the future) is 1093 t. Averaging the RBC over the three year period 2017/2018 – 2019/2020, generates a three year RBC of 1128 t and over the five year period 2016/2017 – 2020/2021, the average RBC would be 1115 t. The reduction reflects the gradually declining RBC predicted when projecting the assessment model forward to a depletion level of 43%$B_0$. As expected lower RBCs are generated using a 20:35:48 harvest control rule.

The unexploited female spawning biomass in 2016/2017 was estimated as 11,046 t. While this is an increase of 1719 t over the estimate made in 2012 there has been little change in the stock status with the stock still estimated to be at 45% unfished biomass (2% above the estimate MEY value).

| The Forecast RBCs for Deepwater Flathead based on the 20:35:43 Harvest Control Rule | |
|---|---|
| Forecast | 20:43 |
| 2017/2018 RBC | 1155 |
| 17/18 – 19/20 RBC | 1128 |
| 17/18 – 19/20 RBC | 1115 |
| Long Term Yield | 1093 |

## *16.2 Introduction*

### 16.2.1 *The Fishery*

The trawl fishery in the GAB primarily targets two species, Bight Redfish (*Centroberyx gerrardi*) and Deepwater Flathead (*Neoplatycephalus conatus*), and these have been fished sporadically in the Great

Australian Bight (GAB) since the early 1900s (Kailola *et al*., 1993). The GAB trawl fishery (GABTF) was set up and managed as a developmental fishery in 1988, and since then a permanent fishery has been established with increasing catches of both species, although catches of Bight Redfish have declined recently. Deepwater Flathead are endemic to Australia and inhabit waters from NW Tasmania, west to north of Geraldton in WA in depths from 70m to more than 510m (Kailola *et al*., 1993; Gomon *et al*., 2008; www.fishbase.org). Bight Redfish are also endemic to southern Australia, occurring from off Lancelin in WA to Bass Strait in depths from 10m to 500m. The two species are often caught in the same trawl tows although Bight Redfish is most commonly taken in the east of the GAB. This document focusses on the stock assessment for Deepwater Flathead.

### 16.2.2 *Previous Assessments*

An initial stock assessment workshop for the GABTF held in 1992 focused on the status of Deepwater Flathead and Bight Redfish. Sources of information for the workshop included historical data, logbook catch data, observer data and biological information. With so few years of data available at that time catch-per-unit-area (kg/km$^2$) was calculated for quarter-degree squares and then scaled to the total area in which the species had been recorded. The approximate exploitable biomass estimates for Deepwater Flathead and Bight Redfish obtained by this relatively informal method were 32,000t and 12,000t respectively (Tilzey and Wise 1999). Error bounds on these estimates could not be calculated.

Wise and Tilzey (2000) summarised the data for the GABTF focusing on Deepwater Flathead and Bight Redfish, the two principle commercial species in shelf waters. They produced the first attempt to assess the status of these Deepwater Flathead and Bight Redfish populations using age- and sex-structured stock assessment models. The virgin total biomass estimates for the Deepwater Flathead base case model were 53,760t (95% confidence interval is 2,488-105,032t). In 2002 an updated assessment was carried out including data up to 2001. The unexploited biomass estimates for the Deepwater Flathead base case model was then 12,876t (95%CI=11,928-13,824).

GABTF assessments in 2005 (Wise and Klaer, 2006; Klaer, 2007) used a custom-designed integrated assessment model developed using the AD Model Builder software (Fournier *et al*., 2012). A series of fishery-independent resource surveys was also commenced in 2005, providing a single annual biomass estimate for Bight Redfish and Deepwater Flathead (Knuckey *et al*., 2015), plus extra samples of length and age composition data. Initially, attempts were made to make absolute abundance estimates using classical swept area methods from the survey data. The unexploited biomass levels estimated for the base case models from the assessment models were 20,418t and 13,932t for Deepwater Flathead and Bight Redfish, respectively. The absolute biomass estimate from the survey at that time was consistent with other fishery data for deepwater flathead, but was much greater than the biomass modelled without the survey for Bight redfish. Survey estimates are now treated as indices of relative abundance separate from that obtained from the standardized Commercial catch-per-unit-effort data.

The 2006 assessment (Klaer and Day, 2007) duplicated as far as possible the assessment results from 2005 using the Stock Synthesis (SS) framework. Although it was possible to replicate 2005 results reasonably well, there were a few differences in the model structure implemented in SS2 most importantly the calculation of recruitment residuals independently and allowing recruitment residuals to occur prior to the commencement of the fishery.

An attempt was made to incorporate as much previously unused data as possible into the 2007 assessment - particularly length-frequencies (Klaer, 2007). Age-frequencies were no longer used explicitly but conditional age-at-length distributions were obtained from age-length keys. In addition, the model used original age-at-length measurements to fit growth curves within the model, to better allow for the interaction between selectivity and the growth parameters. The depletion of Deepwater Flathead in 2007 was estimated at 56%, and the unexploited female spawning biomass was estimated at 8,836t (Klaer, 2007).

The 2010 assessment (Klaer 2011a, b) included all available port and on-board collected length data combined. Following agreement by the RAG, the 2010 assessment included the FIS as a relative index for the first time. Unexploited female spawning biomass was estimated as 10,366t and current depletion at 62% of B0. The long-term RBC estimate was 1,137t. This assessment indicated that the stock had been more depleted than previously predicted in 2005/06, being down near the 20% B0 limit. Previous assessments had all indicated a stock in fish-down, but always above the target biomass.

The Deepwater Flathead assessment was repeated again in 2012 (Klaer 2013a, b) with the base case estimating an unexploited spawning stock biomass of 8,921t and a depletion at that time of 39% of $SSB_0$. The 2013/14 recommended biological catch (RBC) under the 20:35:43 harvest control rule was 979t and the long-term yield (assuming average recruitment in the future) was 1,051 t.

Finally, the latest Deepwater Flathead assessment was conducted using data to the end of 2012/2013 (Klaer, 2014a, b). This estimated the unexploited spawning stock biomass of 9,320t and a depletion at the start of 2014/2015 of 45% of $SSB_0$. The 2014/15 recommended biological catch (RBC) under the 20:35:43 harvest control rule is 1,146t and the long-term yield (assuming average recruitment in the future) is 1,105 t (Table 16.1).

Table 16.1. A summary of previous stock assessment outcomes for Deepwater Flathead. The year of assessment usually relates to the final year of data collection, which is the fishing year involved (thus, 2011 is for the year 2010/2011). B0 is the unfished female spawning biomass. The yield is the RBC for the following year with the long term estimated sustainable yield in brackets for some years (prior to 2009 these are MSY estimates). The 1999 biomass estimate is of exploitable biomass while the rest reflect female spawning biomass.

| Year | Authors | B0 (t) | Depletion | RBC (LTY) (t) |
|---|---|---|---|---|
| 1999 | Tilzey and Wise(1999) | ~32,000 | - | |
| 2000 | Wise and Tilzey(2000) | 53,760 | | |
| 2002 | Wise and Tilzey | 12,876 | | |
| 2005 | Wise and Klaer (2006) | 20,418 | >79% | (670) |
| 2006 | Klaer and Day (2007) | 10,084 | 50 | 1,070 () |
| 2007 | Klaer (2007) | 8,841 | 56 | 1,524 () |
| 2010 | Klaer (2011b) | 10,366 | 62 | 1,463 (1,137) |
| 2012 | Klaer (2013b) | 9,320 | 45 | 1,146 (1,105) |

### 16.2.3 *Modifications to the previous assessment*

An initial base case was developed and presented to the GAB RAB on 3rd November 2016; this was used to describe the changes wrought on the previous assessment by the sequential addition of the new data now available (known as a bridging analysis) along with other structural changes.
The latest version of the SS3 software was applied (SS3.24z; Methot and Wetzel, 2013; Methot, 2015) and then an array of data updates were made, including some data streams that had not been used previously. Importantly, there has been a change in general advice with regard the emphasis to be placed on the indices of relative abundance (standardized commercial CPUE and the Trawl Survey indices; Francis, 2011) relative to that placed on the age and length composition data. This relates to

the proportional emphasis given to the different data streams available when fitting the model and, in this case, different arrangements can lead to different assessment outcomes in terms of estimates of female spawning biomass and depletion levels. There was also discussion in earlier GAB RAGs concerning the validity of the 2015/2016 trawl survey indices of relative abundance so especial attention was paid to the influence of including that single new data point into that time series. The bridging analysis therefore included the usual incremental addition of new data to the earlier assessment but included two extra final analyses where either all FIS related data was removed or only the final year's survey index was removed.

The changes are described in a set different manipulations and changes to the old assessment (Table 16.2).

Table 16.2. The 11 different analyses conducted as part of the bridging analysis that revised the assessment conducted in 2013 to the current assessment that includes all new available data. An alternative basecase analyses in which the data stream variances have been fully rebalanced except the FIS survey data for 2014/2015 was removed.

| Title | Description |
|---|---|
| origbase24f | Repeat the assessment from 2013 using the original software version SS3.24f |
| origbas24z | Use the newer version of SS3 (SS3.24z) to test the effect of using new software. |
| newCatCE | Add catch and commercial CPUE to 2015/16. |
| newsurvCE | Add the latest 2015/16 survey CPUE (a single new data point) |
| newRecs | Extend estimation of recruitment deviates from 2009 to 2012, and accept the recruitment bias adjustments suggested by SS3. |
| newLenComp | Include new length composition data – separate data from ISMP Port and on-board samples, and from Industry length composition data. |
| newAAL | Include new conditional age-at-length data for 2013 - 2015 |
| ageingerror | Include a newly revised ageing error matrix |
| LenAgeFIS | Include FIS length composition data and age-at-length data and estimate the FIS selectivity |
| balancedCE | Re-balanced variances, with emphasis placed on CPUE and Survey |
| balnoFIS1415 | Re-balanced variances, removing only the 2014/2015 survey index. |

As adding significant amounts of new data can disturb the balance between different data sets and thus disturb the apparent mode outcomes (depletion estimation, etc) some rebalancing of the variances of the different data streams was conducted at each stage. At the final stage the variance of the different length and age composition data and the CPUE data were balanced until they all reached equilibrium to generate the initial base case. The balancing procedure this year attempts to apply more emphasis to the CPUE time series. The model balancing also involved temporarily increasing the maximum recruitment variation from 0.5 to 0.55 for the four steps 'newLenComp', 'newAAL', 'ageingerror', and 'LenAgeFIS' as further bias adjustments were required after adjusting the variance estimates on different data streams. However, for the final 'balancedCE' basecase the SigmaR (recruitment variation) was returned to the assumed 0.5.

### *16.2.3.1 Estimation of RBC and Long Term RBC*

Once the base case was completed its dynamics were projected forwards for 40 years to estimate the long term RBC that would, at equilibrium, keep the stock to the MEY proxy target of 43%$B_0$ (Kompas *et al*., 2011).

Following the projections, 16 sensitivity analyses were conducted to provide a test of the structural assumptions made in the formulation of the assessment model.

## 16.3 Methods

### 16.3.1 *The Data and Model Inputs*

#### *16.3.1.1 Biological Parameters*

Male and female Deepwater Flathead are assumed to have the same biological parameters except for their growth and the length-weight relationship (Table 16.3).

Three of the four parameters relating to the Von Bertalanffy growth equation are estimated within the model-fitting procedure from the observed age-at-length data; all male growth parameters are fitted as offsets to the female parameters. Fitting growth within the assessment model attempts to account for the impact of gear selectivity on the age-at-length data collected from the fishery and any impacts of ageing error.

The rate of natural mortality per year, *M*, is estimated in the base-case model, with the estimated value being close to 0.235; the model outcomes are sensitive to this parameter and a likelihood profile, where *M* is given a series of fixed values and all other parameters are re-fitted to determine the effect on the total likelihood and other model outputs was conducted. Maturity is modelled as a logistic function, with 50% maturity at about 40 cm. Changing the size at maturity has almost no effect on the quality of the model fit but has an effect on the estimates of stock biomass and status so a likelihood profile of size-at-maturity was also conducted. Fecundity-at-length is assumed to be proportional to weight-at-length.

The assessment data for Deepwater Flathead comes from a single trawl fleet; although there is now a Danish seine vessel operating and some pair-trawling occurring in the GAB (Table 16.4).

Table 16.3. Summary of selected parameters from the base case model for Deepwater Flathead. Sources: (1) Analyses of biological samples collected during the 2004 GAB reproductive study (Brown and Sivakumaran, 2007), (2) length and age samples collected between 2000-2003 and (3) length samples collected during the 2001 FRDC project. Years represent the first year of each financial year i.e. 2015 = 2015/2016.

| Description | Source | Parameter | Combined Male/Female | |
|---|---|---|---|---|
| Years | | y | 1988-2015 | |
| Recruitment Deviates | | *r* | estimated 1980 - 2012 | |
| Fleets | | | 1 trawl only | |
| Discards | | | none significant, not Fitted | |
| Age classes | | *a* | 0 – 29 years | |
| Sex ratio | | $p_s$ | 0.5 (1:1) | |
| Natural mortality | | *M* | estimated (0.235) per year | |
| Steepness | | *h* | 0.75 | |
| Recruitment variation | | $\sigma_r$ | 0.55 | |
| Female maturity | 1 | | 40 cm (TL) | |
| Growth | 2 | $L_{max}$ | 65.0258 cm (TL) | fitted |
| | | *K* | fitted | fitted |
| | | $L_{min}$ | fitted | fitted |
| | | CV | Fitted (M & F assumed equal) | |
| | | | Female | Male |
| Length-weight (based | 3 | $f_1$ | 0.002 cm (TL)/gm | 0.002 |
| on standard length) | | $f_2$ | 3.332 | 3.339 |

*16.3.1.2 Available Data*

An array of different data sources are available for the Deepwater Flathead assessment including catch (landings plus discards), standardized commercial CPUE, an index of relative abundance from the Fishery Independent Survey (FIS), age composition data from the Integrated Scientific Monitoring Program (ISMP) and from the FIS, and length composition data from four sources: the ISMP (keeping port sampling separate from the on-board sampling), from the FIS, and from on-board crew sampling (Figure 16.1). Age-at-length composition data for the fleet designated Trawl and the FIS were calculated from the available length compositions and conditional age-at-length data (age-length keys). These do not comprise additional data and are not included in the fitting of the model but are shown for information.

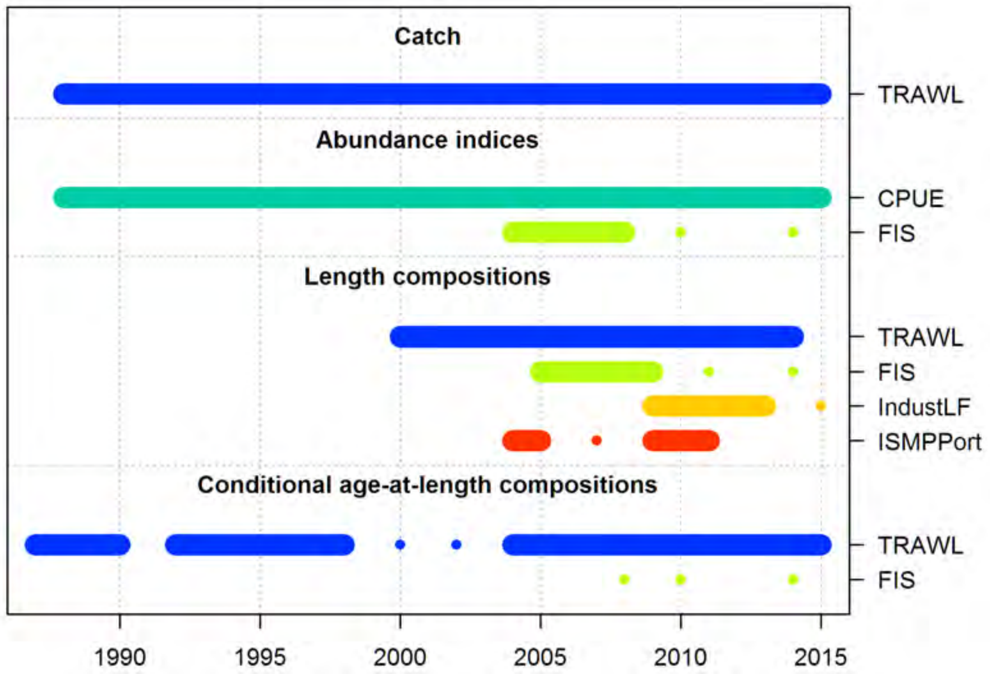


Figure 16.1. Data availability by type and year. The year axis denotes the first year of the financial year, thus 1995 = 1995/1996. This illustrates the full data set as used in the balancedCE basecase scenario.

A landed catch history for Deepwater Flathead is available for the years from 1988/1989 to 2015/2016 (Figure 16.2; Table 16.4). Landed catches were derived from GAB logbook records for the years to about 2000, and catch disposal records have been the source of total landings since then. All landings were aggregated by financial year. In all figures, where single years are illustrated these represent the first year of the financial year.

In 2007 the quota year was changed from calendar year to the year extending from 1 May to 30 April. As the assessment is conducted according to financial year, the recent quota year change has resulted in closer alignment of the assessment and quota years. In the intervening year the quota year was extended to 16 months to allow for this change, which is one reason catches were elevated in the 2006/2007 year (Table 16.4).

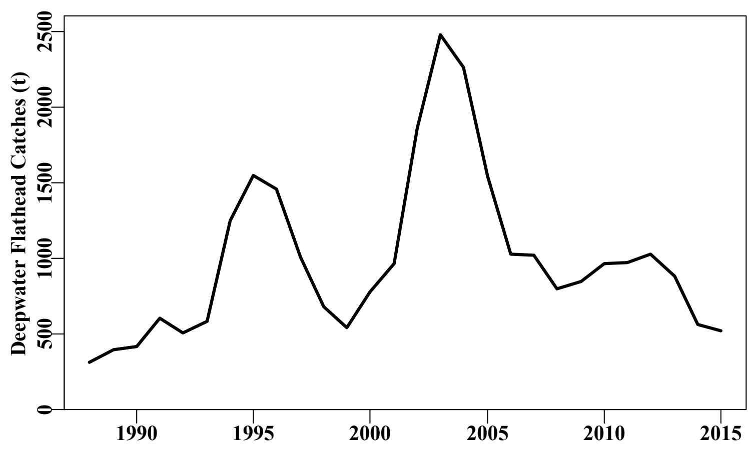


Figure 16.2. Total reported landed catch of Deepwater Flathead 1988/1989 – 2015/2016 (the final year's data is incomplete; see Table 16.4).

Table 16.4. Financial year values and estimates of catch by method, total catch, the geometric mean CPUE, the standardized Trawl CPUE, and the number of trawl vessels reporting Deepwater Flathead in the GAB from 1988/1989 – 2015/2016. Discards are assumed to be trivial. Standardized CPUE is from Sporcic and Haddon (2016), scaled to 88/89 – 15/16.

| Season | DS | PTB | TDO | TW | Total | GeoMetric | Stand | Vessels | Records |
|---|---|---|---|---|---|---|---|---|---|
| 88/89 | | | | 316.559 | 316.559 | 56.081 | 0.9390 | 9 | 815 |
| 89/90 | | | | 400.852 | 400.852 | 53.036 | 0.9633 | 7 | 1126 |
| 90/91 | | | | 429.221 | 429.221 | 49.078 | 1.0404 | 11 | 1501 |
| 91/92 | | | | 618.749 | 618.749 | 54.539 | 0.9522 | 13 | 1781 |
| 92/93 | | | | 523.312 | 523.312 | 76.925 | 1.2104 | 4 | 984 |
| 93/94 | | | | 591.010 | 591.010 | 91.500 | 1.5531 | 7 | 900 |
| 94/95 | | | | 1266.045 | 1266.045 | 106.306 | 1.9671 | 6 | 1745 |
| 95/96 | | | | 1574.134 | 1574.134 | 125.214 | 1.9094 | 5 | 1862 |
| 96/97 | | | | 1475.916 | 1475.916 | 79.393 | 1.2654 | 8 | 2784 |
| 97/98 | | | | 1017.668 | 1017.668 | 50.970 | 0.8971 | 10 | 2908 |
| 98/99 | | | | 684.414 | 684.414 | 34.670 | 0.6678 | 7 | 2558 |
| 99/00 | | | | 555.256 | 555.256 | 39.132 | 0.8121 | 7 | 2102 |
| 00/01 | | | | 782.697 | 782.697 | 43.041 | 0.8781 | 6 | 2413 |
| 01/02 | | | | 917.556 | 917.556 | 51.543 | 1.0460 | 6 | 2448 |
| 02/03 | | | | 1657.349 | 1657.349 | 73.410 | 1.5175 | 8 | 3144 |
| 03/04 | | | | 2235.568 | 2235.568 | 68.417 | 1.4288 | 10 | 4536 |
| 04/05 | | | | 2111.130 | 2111.130 | 55.052 | 1.1513 | 10 | 5551 |
| 05/06 | | | | 1378.191 | 1378.191 | 37.523 | 0.7493 | 11 | 5349 |
| 06/07 | | | | 983.135 | 983.135 | 32.929 | 0.6430 | 11 | 4254 |
| 07/08 | | | | 980.210 | 980.210 | 35.905 | 0.7236 | 7 | 4003 |
| 08/09 | | | | 783.241 | 783.241 | 40.697 | 0.8516 | 5 | 3118 |
| 09/10 | | | | 834.012 | 834.012 | 39.135 | 0.8012 | 4 | 3205 |
| 10/11 | 5.303 | | 24.529 | 910.447 | 940.279 | 50.886 | 1.0292 | 4 | 2805 |
| 11/12 | 136.677 | | 621.692 | 172.010 | 930.379 | 38.545 | 0.7888 | 4 | 3270 |
| 12/13 | 103.493 | | 514.951 | 368.480 | 986.924 | 37.941 | 0.7753 | 5 | 3611 |
| 13/14 | 83.771 | 11.090 | 456.954 | 220.269 | 772.084 | 31.993 | 0.6695 | 7 | 3304 |
| 14/15 | 61.376 | | 478.565 | 23.594 | 563.535 | 29.335 | 0.6183 | 4 | 2572 |
| 15/16 | 79.353 | | 380.044 | 14.040 | 473.437 | 34.376 | 0.6832 | 3 | 996 |

#### *16.3.1.3 Catch Rate Indices*

In earlier assessments, commercial catch rates have been standardised using Generalised Additive Models (GAMs) (Hobsbawn et al. 2002a, 2002b) and a log-linear model (Klaer, 2007). Standardisations for a range of SESSF species are carried out each year (see Haddon, 2014a,b; Sporcic, 2015; Sporcic and Haddon, 2016) and Deepwater Flathead is now included in the list of species routinely analysed each year.

"Data from the GAB fishery used in the analysis was based on depths between 0 – 1000 m, taken by Trawl. Also, analyses were restricted to vessels present for more than two years and which caught an average annual catch > 4 t, and that trawled for more than one hour but less than 10 hours. Instead of

5 degree zones across the GAB, 2.5 degree zones were employed to allow better resolution of location based differences in CPUE. An examination of the depth distribution of catches suggests that this could be modified to become 100 – 250 m with essentially no loss of information and the outcomes do not differ from the base case adopted here; All vessels and 0 – 1000 m). Catches in 1986/1987 were relatively low and only taken by a single vessel and so were omitted from analysis." (Sporcic, 2015, p209). In 1987/1988 over 95% of catches were taken in zone 82 and there were only 453 records so that year was also omitted.

The point about the depth categories used is important, as the inclusion of relatively empty depth categories introduces more noise than information into an analysis (Table 16.5). It is recommended that the depth range used in the standardization should be reduced at least to 0 – 500m in future analyses.

Table 16.5. The number of records and catch reported by different depth categories. Approximately 8.315 t of catch has ever been reported from below 1000m across the duration of the fishery, and 20.433 t has ever been reported from depths greater than 500m.

| Depth | Records | Catch | Cum% | Depth | Records | Catch |
|---|---|---|---|---|---|---|
| 0 | 21 | 6.559 | 0.025 | 0 | 33 | 9.23 |
| 25 | 12 | 2.671 | 0.035 | 50 | 208 | 52.171 |
| 50 | 53 | 7.134 | 0.062 | 100 | 55515 | 18741.84 |
| 75 | 155 | 45.037 | 0.234 | 150 | 17973 | 6147.604 |
| 100 | 9815 | 2907.111 | 11.324 | 200 | 2672 | 922.5073 |
| 125 | 45700 | 15834.724 | 71.730 | 250 | 1091 | 270.145 |
| 150 | 14805 | 5253.466 | 91.771 | 300 | 377 | 34.8415 |
| 175 | 3168 | 894.139 | 95.182 | 350 | 179 | 8.0765 |
| 200 | 1764 | 585.957 | 97.417 | 400 | 93 | 5.20965 |
| 225 | 908 | 336.551 | 98.701 | 450 | 27 | 1.315 |
| 250 | 712 | 188.916 | 99.422 | 500 | 15 | 1.11775 |
| 275 | 379 | 81.230 | 99.731 | 550 | 8 | 0.432 |
| 300 | 279 | 29.089 | 99.842 | 600 | 9 | 1.35525 |
| 325 | 98 | 5.753 | 99.864 | 650 | 3 | 0.496 |
| 350 | 140 | 6.725 | 99.890 | 700 | 6 | 2.47 |
| 375 | 39 | 1.352 | 99.895 | 750 | 3 | 0.276 |
| 400 | 83 | 3.945 | 99.910 | 800 | 2 | 3.66 |
| 425 | 10 | 1.265 | 99.915 | 850 | 2 | 2.24 |
| 450 | 23 | 1.226 | 99.920 | 900 | 3 | 0.2985 |
| 475 | 4 | 0.090 | 99.920 | 950 | 1 | 0.18 |
| 500 | 13 | 0.538 | 99.922 | 1000 | 1 | 0.13 |

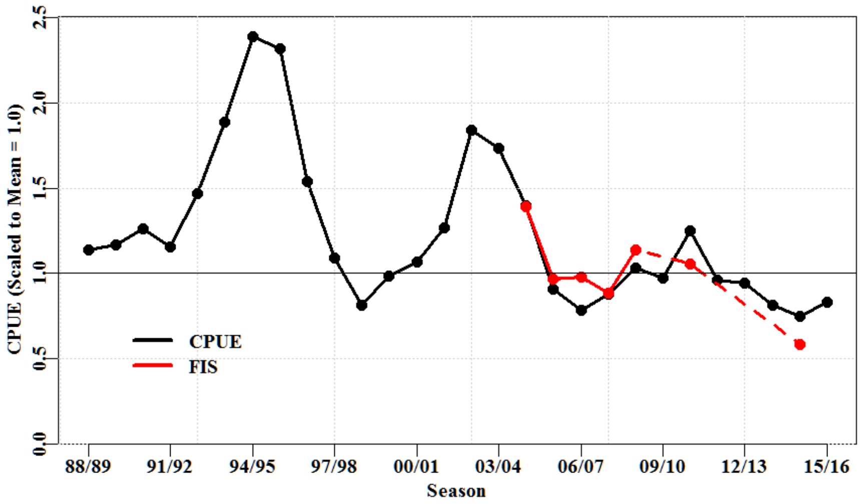


Figure 16.3. The standardized CPUE for Deepwater Flathead from the trawl fishery in the GAB (data from Sporcic and Haddon, 2016, p 183) with the index of relative abundance from the Fishery Independent Survey. Both time-series have been scaled so that over the years of the survey indices the mean of both series is 1.0 to make them directly comparable (see **Error! Reference source not found.** and **Error! Reference source not und.**). Note the most recent survey index is exceptionally low.

### *16.3.1.4 Fishery Independent Survey Abundance Estimates*

There are now seven estimates of relative abundance from the Fishery Independent trawl Survey (Table 16.6; Knuckey, *et al*., 2015). The CV estimates for the individual abundance estimates are used initially, but in the process of balancing the output variability with that input, these values were greatly expanded. The last estimate for the season conducted in 2015 is the lowest estimate ever and only uses the samples taken in the second trip (Knuckey et al, (2015). The sampling on the first trip may have been compromised by a large scale acoustic survey that occurred at the same time. It is unknown whether the sampling for relative abundance during second trip was also compromised. The effect of including this single new point is explored in two runs of the bridging analysis, which focussed attention solely on the effect of this single survey (Table 16.2; see newsurvCE and balnoFIS1415).

Table 16.6. FIS relative abundance estimates for Deepwater Flathead, with each survey estimate's coefficient of variation (taken from Knuckey *et al*., (2015). The 2014/2015 estimate only uses the results from trip two so as to avoid the potential for interference from a proximate seismic acoustic survey.

| Year | 2004/2005 | 2005/2006 | 2006/2007 | 2007/2008 | 2008/2009 | 2010/2011 | 2014/2015 |
|---|---|---|---|---|---|---|---|
| Estimate | 12,152 | 8,415 | 8,540 | 7,725 | 9,942 | 9,227 | 5,065 |
| CV | 0.05 | 0.06 | 0.05 | 0.06 | 0.05 | 0.05 | 0.09 |

### *16.3.1.5 Age Composition Data*

Previously (Klaer, 2012), age composition data from the ISMP sampling was mixed up with three years of FIS age data. In this current assessment the ISMP age composition data is included as previously but now the ageing data from three years of the FIS are included separately (2008/2009, 2010/2011, and 2014/2015).

Since about 2000/2001 the proportion of older fish in the ISMP samples has declined (Figure 16.4) although they appear to be noticeably returning since about 2012/2013. A comparison of the age composition seen in the FIS years and the ISMP samples from the same financial year (Figure 16.5) suggests similarities although it is clear that the FIS samples have a lower mean age than those from the ISMP. The difference inmean age reflects the different selectivity of the gear used to collect the FIS samples relative to that of the whole fleet from which the ISMP samples were collected (Figure 16.4, Figure 16.5; Table 16.7).

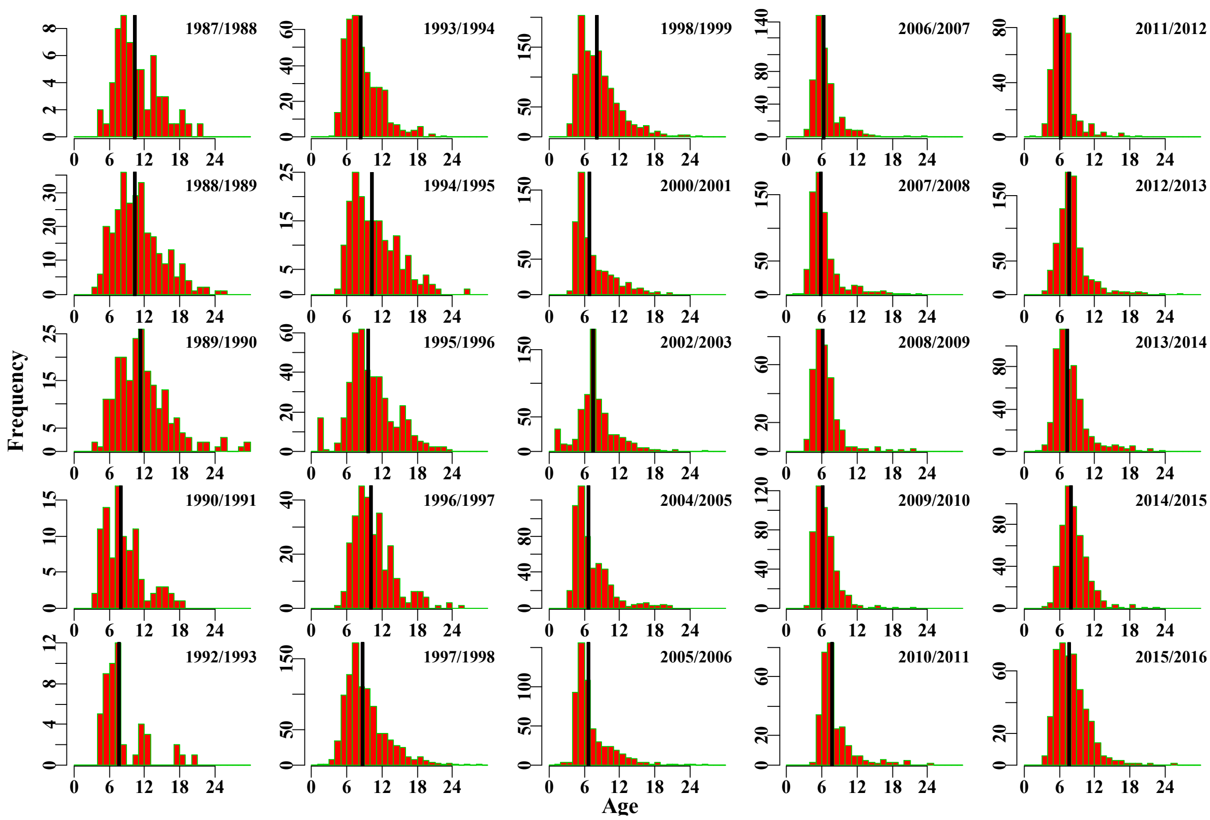


Figure 16.4. All ISMP Deepwater Flathead ageing data used by year, illustrating the relative sample size and the relatively recent contraction in the older age classes. (see Table 16.7).

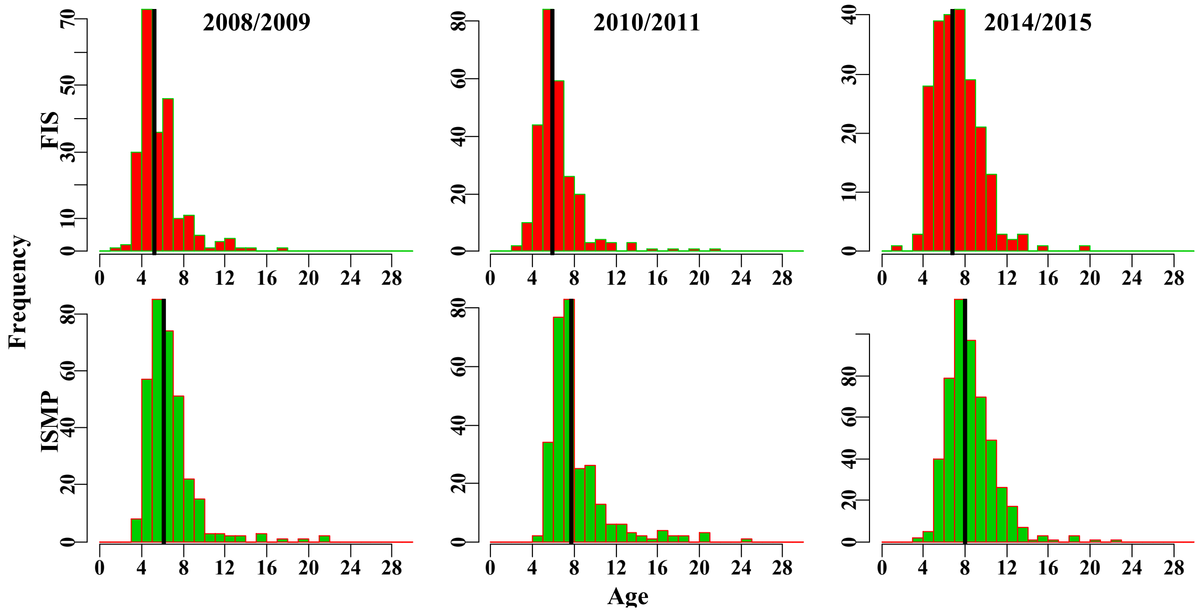


Figure 16.5. All ISMP Deepwater Flathead ageing data used by year, illustrating the relative sample size and the relatively recent contraction in the older age classes. (see Table 16.7).

Table 16.7. The mean age and number of observations of each season's ageing data from the ISMP sampling and the sampling during the FIS, as used in the Deepwater Flathead assessment.

| Season | ISMP Mean Age | ISMP Nobs | Season | ISMP Mean Age | ISMP Nobs | FIS Mean Age | FIS Nobs |
|---|---|---|---|---|---|---|---|
| 1987/1988 | 10.34 | 61 | 2004/2005 | 6.67 | 563 | | |
| 1988/1989 | 10.42 | 290 | 2005/2006 | 6.73 | 555 | | |
| 1989/1990 | 11.28 | 214 | 2006/2007 | 6.28 | 484 | | |
| 1990/1991 | 8.03 | 97 | 2007/2008 | 5.87 | 650 | | |
| 1992/1993 | 7.74 | 50 | 2008/2009 | 6.16 | 329 | 5.25 | 225 |
| 1993/1994 | 8.30 | 407 | 2009/2010 | 6.16 | 465 | | |
| 1994/1995 | 10.24 | 178 | 2010/2011 | 7.67 | 290 | 5.87 | 262 |
| 1995/1996 | 9.66 | 430 | 2011/2012 | 6.26 | 367 | | |
| 1996/1997 | 10.07 | 287 | 2012/2013 | 7.61 | 787 | | |
| 1997/1998 | 8.77 | 972 | 2013/2014 | 7.36 | 528 | | |
| 1998/1999 | 8.06 | 1163 | 2014/2015 | 8.03 | 519 | 6.78 | 225 |
| 2000/2001 | 6.88 | 600 | 2015/2016 | 7.63 | 478 | | |
| 2002/2003 | 7.48 | 640 | | | | | |

### *16.3.1.6 Length Composition Data*

Previously (Klaer, 2012), only used length composition data from the ISMP, and port and on-board samples were considered together, which was standard practice at the time. In this current assessment the port and on-board ISMP length samples are kept separate, and there are further length composition data available from the FIS and from crew-member collected data (Figure 16.1). Separating the on-board and ISMP samples makes explicit the fact that port based samples are often of sorted (or graded) samples. In Deepwater Flathead there are only two grades 'All' and 'Unk', with 'All' dominating in numbers. Mostly the sample weights were between 30 – 32 kg (the expected weight of a single fish bin full of fish). Currently the options for whether or not to apply catch weighting modified by grade data and or location data, to generate a combined length composition for each year in the context of changes in the sampling regime of the ISMP through time remains under investigation. This is not such an issue for Deepwater Flathead, which, by using 'All', appears to assume there has been no grading for landed fish. However, in some species, such as Western Gemfish there are numerous grades landed and how best to weight these data requires further exploration.

The crew collected length composition data exhibited consistent length composition data spread from across the fishery, however, an unusual and atypical distribution was exhibited by the sample from 2014/2015 and this was therefore omitted from consideration while the source of this deviation from the more typical composition was explored (Figure 16.6), however, the data from 2009/20110 to 2015/2016 were included using the same selectivity as for the ISMP data. The anomalous data may be a result of sampling is shallower water than normal, or may be due to a measurement error.

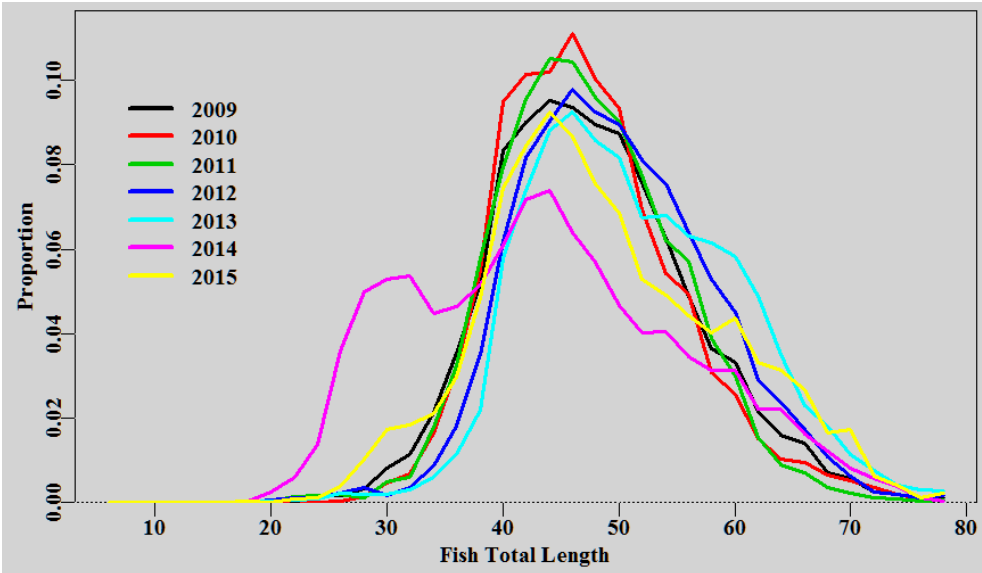


Figure 16.6. Length composition data for Deepwater Flathead obtained from crew sampling on-board. The data for 2014/2015 was exceptional and constituted a sample size only 3/5th the usual samples size. It unusual form led to it being omitted from consideration prior to discussion in the November 2016 GAB RAG meeting, and further analyses attempting to explain its anomalous shape.

The length composition data from the FIS also exhibits variation through time (Figure 16.7) with some large changes between 2010/2011 and 2014/2015.

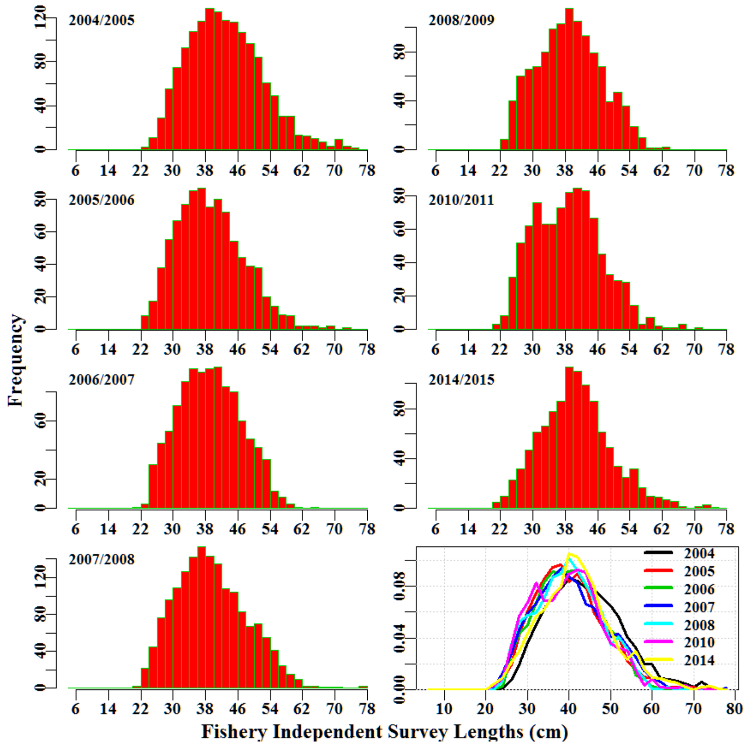


Figure 16.7. The length composition data of Deepwater Flathead from the seven FIS that have occurred in the GAB. The plot at bottom right illustrates the contrast between years, with the legend showing only the first year of the season.

The length composition data from the ISMP also varies considerably from year to year in both the on-board and port data (Figure 16.8, Figure 16.9).

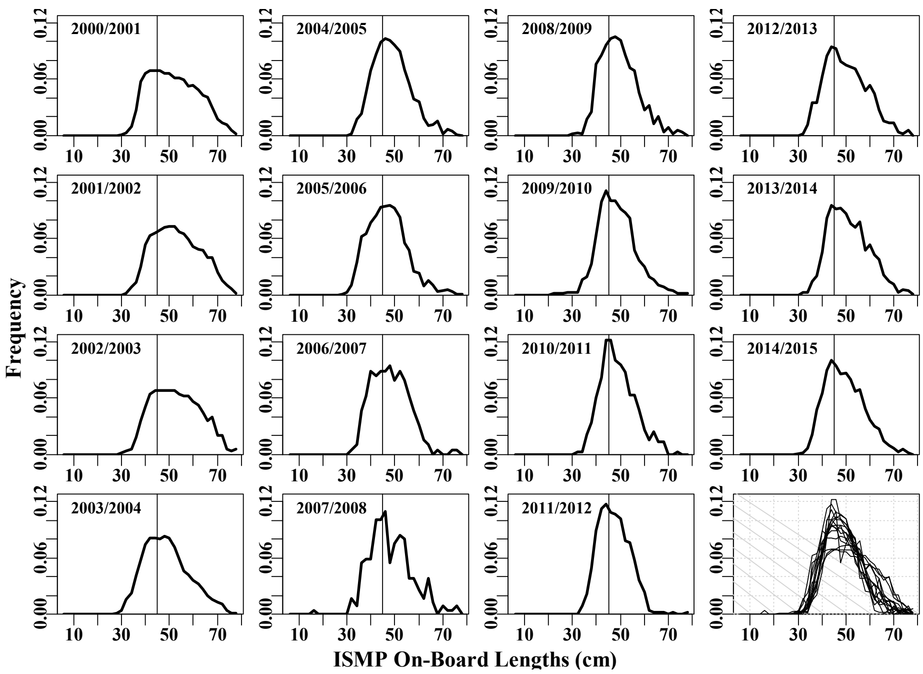


Figure 16.8. The proportional distribution of on-board length composition data for Deepwater Flathead from the ISMP. The vertical grey line at 45cm is to ease visual comparisons. The plot at bottom right is a combination of all the plots to illustrate the variation between years.

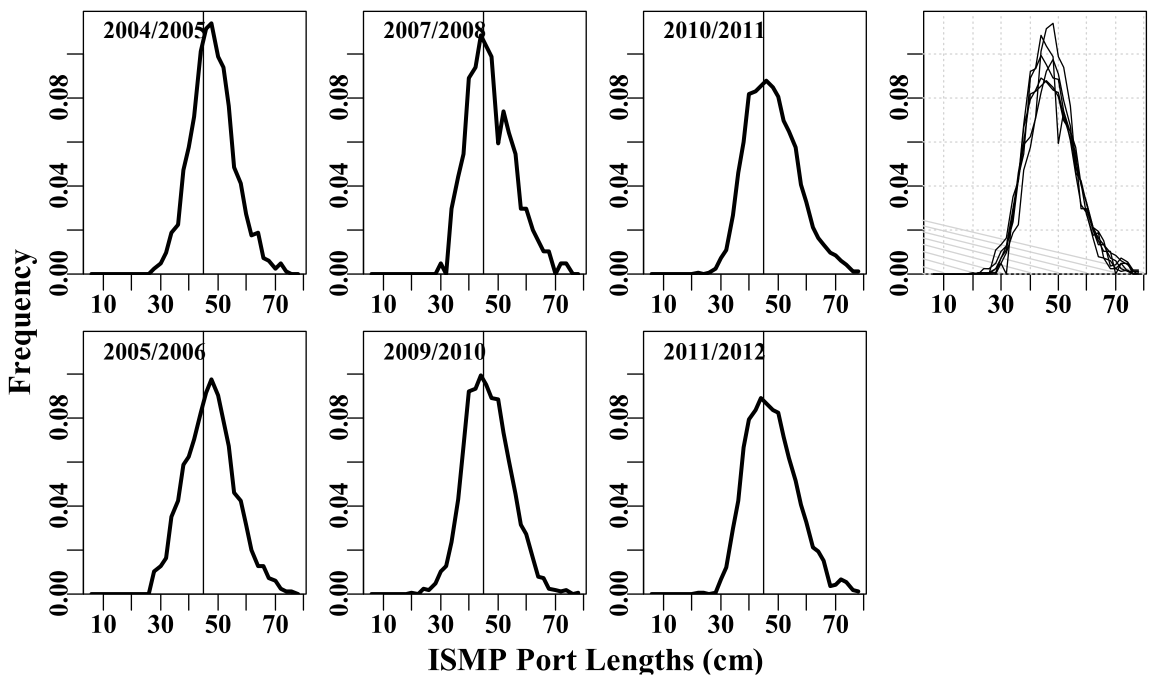


Figure 16.9. The proportional distribution of Port sampled length composition data for Deepwater Flathead from the ISMP. The vertical grey line at 45cm is to ease visual comparisons. The plot at bottom right is a combination of all the plots to illustrate the variation between years.

Table 16.8. Original sample sizes for the length and age composition data for Deepwater Flathead. There were thus four length composition data streams and two age composition data streams. Note the very large sample sizes from the Industry sampling.

| Season | ISMP Ages | Season | ISMP Ages | FIS Ages | ISMP On-Board | ISMP Port | FIS LF | Industry LF |
|---|---|---|---|---|---|---|---|---|
| 1987/1988 | 61 | 2000/2001 | 600 | | 1867 | | | |
| 1988/1989 | 290 | 2001/2002 | | | 1467 | | | |
| 1989/1990 | 214 | 2002/2003 | 640 | | 496 | | | |
| 1990/1991 | 97 | 2003/2004 | | | 715 | | | |
| 1991/1992 | | 2004/2005 | 563 | | 1009 | 854 | 1495 | |
| 1992/1993 | 50 | 2005/2006 | 555 | | 1125 | 851 | 897 | |
| 1993/1994 | 407 | 2006/2007 | 484 | | 191 | | 1046 | |
| 1994/1995 | 178 | 2007/2008 | 650 | | 238 | 203 | 1635 | |
| 1995/1996 | 430 | 2008/2009 | 329 | 225 | 750 | | 1140 | |
| 1996/1997 | 287 | 2009/2010 | 465 | | 676 | 2507 | | 5957 |
| 1997/1998 | 972 | 2010/2011 | 290 | 262 | 378 | 3339 | 915 | 5931 |
| 1998/1999 | 1163 | 2011/2012 | 367 | | 471 | 4647 | | 5376 |
| 1999/2000 | | 2012/2013 | 787 | | 522 | | | 5645 |
| | | 2013/2014 | 528 | | 846 | | | 5047 |
| | | 2014/2015 | 519 | 225 | 1269 | | 1074 | 3336 |
| | | 2015/2016 | 478 | | | | | 8361 |

*16.3.1.7 Age-Reading Error*

The age estimates are assumed to be unbiased but subject to random age-reading errors (Punt et al., 2008). Standard deviations for aging error by reader have been estimated, producing the age-reading error matrix (A.E. Punt, pers. comm.). Selectivity is low for ages below 4.

Table 16.9. The estimated standard deviation of normal variation (age-reading error) around age-estimates for the different age classes of Deepwater Flathead.

| Age | StDev. | Age | StDev. | Age | StDev. |
|---|---|---|---|---|---|
| 0 | 0.2017 | 10 | 0.5495 | 20 | 0.6594 |
| 1 | 0.2570 | 11 | 0.5669 | 21 | 0.6650 |
| 2 | 0.3063 | 12 | 0.5825 | 22 | 0.6699 |
| 3 | 0.3502 | 13 | 0.5964 | 23 | 0.6743 |
| 4 | 0.3894 | 14 | 0.6088 | 24 | 0.6782 |
| 5 | 0.4243 | 15 | 0.6198 | 25 | 0.6817 |
| 6 | 0.4554 | 16 | 0.6297 | 26 | 0.6817 |
| 7 | 0.4831 | 17 | 0.6385 | 27 | 0.6817 |
| 8 | 0.5078 | 18 | 0.6463 | 28 | 0.6817 |
| 9 | 0.5298 | 19 | 0.6532 | 29 | 0.6817 |

### 16.3.2 *Stock Assessment*

*16.3.2.1 Population Dynamics Model and Parameter Estimation*

A two-sex stock assessment for Deepwater Flathead has been implemented using the software package Stock Synthesis (SS, version 3.24z; Methot and Wetzel, 2013). However, differences by gender are restricted to growth and weight at length. SS is a statistical age- and length-structured model that can be used to fit the various data streams now available for Deepwater Flathead, simultaneously. The population dynamics model, and the statistical approach used in the fitting of the model to the various types of data, are described in the SS operating manual (Methot, 2015) and technical description (Methot and Wetzel, 2013) and are not reproduced here.

A single stock of Deepwater Flathead was assumed to occur across the GAB. The stock was assumed to have been unexploited prior to 1988/1989, although minor catches have been recorded back to 1986/1987. The input CVs of the catch rate index and the biomass survey were initially set to fixed values which are effectively arbitrary in the final phase of the model fitting. These values are revised using an iterative process to reweight the variances of the different data streams once parameter estimates have been obtained. Within each abundance index, the variation of all of the annual estimates is assumed to be equal.

The selectivity pattern for the trawl fleet was modelled as not changing through time; although this might be questioned as more spatially explicit data is collected. The two parameters of the selectivity function were estimated within the assessment. Now that FIS length and age composition data are included as data streams a separate selectivity was able to be estimated for the FIS, and this selectivity was found to differ from the rest of the trawl fishery.

The rate of natural mortality, *M*, was assumed to be constant with age, and also constant through time. The natural mortality rate is estimated in the base-case analysis.

Recruitment was assumed to follow a Beverton-Holt type stock-recruitment relationship, parameterised by the average recruitment at unexploited spawning biomass, $R_0$, and the steepness parameter, *h*. Steepness for the base-case analysis was assumed to be 0.75. Deviations from the average recruitment at a given spawning biomass (recruitment deviations) were estimated from 1980/1981 to 2011/2012. The value of the parameter determining the magnitude of the potential variation in annual recruitment, $\sigma_R$ (SigmaR) was set equal to 0.5 to begin with, it required to be extended to 0.55 during the addition of extra composition data, however, after complete balancing and recruitment deviate bias adjustment (Methot and Taylor, 2011) it again ended at 0.5. During the rebalancing of variances the model continued to suggest reducing the SigmaR value so it could have been reduced to 0.45 and well below, however, this would have constrained the recruitment variability implausibly and so the value was fixed at 0.5. The recruitment deviates for more recent years cannot be estimated well because it can take 3 – 4 years for larval fish to grow and then enter the fishery. Hence, it can take 4 years before information about relative recruitment levels becomes available to the model.

Age 29 is treated as a plus group into which all animals predicted to survive to ages greater than 29 are accumulated. Growth of Deepwater Flathead was also assumed to be time-invariant, that is there has been no change over time in the expected mean size-at-age, with the distribution of size-at-age being determined from the fitting of the growth curve within the assessment using the age-at-length data. The potential for age-reading errors (Punt *et al*., 2008) is accounted for within the model by the inclusion of an age-reading error matrix (Table 16.9). Differences in growth by sex were in terms of both the $L_\infty$ and the *K* parameters of the von Bertalanffy curve and the length-weight relationship.

*16.3.2.2 Relative Data Weighting*

Iterative rescaling (reweighting) of input and output CVs or input and effective sample sizes is a repeatable method for ensuring that the expected variation of the different data streams is comparable to what is input. Most of the indices (CPUE, composition data) used in fisheries underestimate their true variance by only reporting measurement or estimation error and not including process error.

In iterative reweighting, the effective annual sample sizes are tuned/adjusted so that the input sample size was equal to the effective sample size calculated by the model.
An automated tuning procedure was used0:

1. Set the CV for the commercial CPUE values and the FIS values to 0.1 for all years (this relatively low value is used to encourage a good fit to the abundance data).

Then iterate through the following:

2. Adjust the recruitment variance ($\sigma_R$) by replacing it with the RMSE or a defnied set minimum (in this case 0.5) and iterating to convergence (keep altering the recruitment bias adjustment ramps appropriately at the same time).
3. Simultaneously tune the sample size multipliers for the length frequencies and age at length using Francis weights for the LFs and Francis B (the larger of the Francis A and B factors, Francis 2011).
4. Weight the commercial CPUE and FIS abundance indices by replacing these with the relevant variance adjustment factors derived from SS3.
5. Repeat steps 2 to 4, until all are converged and stable.

This procedure may change in the future.

*16.3.2.3 Calculating the RBC*

The SESSF Harvest Strategy Framework (HSF) was developed during 2005 (Smith *et al.*2008) and has been used as a basis for providing advice on TACs in the SESSF quota management system for fishing years 2006-2015. The HSF uses harvest control rules to determine a recommended biological catch (RBC) for each stock in the SESSF quota management system. Within the SESSF tier system (Smith et al., 2014) Deepwater Flathead is classified as a Tier 1 stock as it has an agreed quantitative stock assessment.

The Tier 1 harvest control rule specifies a target and a limit biomass reference point, as well as a target fishing mortality rate. Since 2005 various values have been used for the target and the breakpoint in the rule. In 2009, AFMA directed that the 20:40:40 ($B_{lim}$: $B_{MSY}$: $F_{targ}$) form of the rule be used up to where fishing mortality reaches $F_{48}$. Once this point is reached, the fishing mortality is set at $F_{48}$. Day (2009) determined that for most SESSF stocks where the proxy values of $B_{40}$ and $B_{48}$ are used for $B_{MSY}$ and $B_{MEY}$ respectively, this form of the rule is equivalent to a 20:35:48 ($B_{lim}$: $B_{Inflection\ point}$ : $F_{targ}$) strategy. An economic analysis was used as a basis for using a 20:35:43 rule for Deepwater Flathead (Kompas et al., 2012).

Estimating the following year's RBC entails calculating the catch that would be equivalent to a fishing mortality that would, at equilibrium, give rise to a spawning biomass depletion level of 43%$B_0$. Estimating the long term RBC entails projecting the stock assessment forward imposing catches calculated using the Tier 1 harvest control rule (Day, 2009) until the target of 43%$B_0$ is achieved and citing that final catch level.

*16.3.2.4 The Development of the Base-Case Assessment*

Eleven sequential changes were made to the 2013 assessment (Table 16.2). It was possible to closely match the original assessment spawning biomass time-series (Klaer, 2014a, b) using the SS3.24f version and there was almost no difference to the outcome when the latest version of SS3 (SS3.24z) was used.

Table 16.10. The 11 sequential changes made to the 2013 assessment model. The final base-case is either the balancedCE or balnoFIS1415 models (see Table 16.2).

| N | Name | Description |
|---|---|---|
| 1 | origbase24f | Repeat the assessment from 2013 using the original software version SS3.24f |
| 2 | origbas24z | Use the newer version of SS3 (SS3.24z) to test the effect of using new software. |
| 3 | newCatCE | Add catch and commercial CPUE to 2015/16. |
| 4 | newsurvCE | Add the latest 2015/16 survey CPUE (a single new data point) |
| 5 | newRecs | Extend estimation of recruitment deviates from 2009 to 2012, and accept the recruitment bias adjustments suggested by SS3. |
| 6 | newLenComp | Include new length composition data – separate data from ISMP Port and on-board samples, and from Industry length composition data. |
| 7 | newAAL | Include new conditional age-at-length data for 2013 - 2015 |
| 8 | ageingerror | Include a newly revised ageing error matrix |
| 9 | LenAgeFIS | Include FIS length composition data and age-at-length data and estimate the FIS selectivity |
| 10 | balancedCE | Re-balanced variances, with emphasis placed on CPUE and Survey |
| 11 | balnoFIS1415 | Re-balanced variances, removing only the 2014/2015 survey index. |

*16.3.2.5 Sensitivity Tests*

A number of tests were used to examine the sensitivity of the results of the model to some of the assumptions and data inputs (Table 16.11). In addition, the assessment outcomes were sensitive to the value of natural mortality, so a further likelihood profile (Venzon and Moolgavkar, 1988) was made for that parameter.

Table 16.11. Changes used to test the model's sensitivity to modified assumptions and data inputs.

| | |
|---|---|
| 1. | M = 0.141 $yr^{-1}$. (relative to the base-case model estimate of 0.191) |
| 2. | M = 0.241 $yr^{-1}$ |
| 3. | 50% maturity at 35cm. (relative to that assumed in the model of 40cm) |
| 4. | 50% maturity at 45 cm. |
| 5. | $\sigma_R$ set to 0.4 (relative to that assumed in the model of 0.5) |
| 6. | $\sigma_R$ set to 0.6 |
| 7. | Double the weighting on the length composition data. |
| 8. | Halve the weighting on the length composition data. |
| 9. | Double the weighting on the age-at-length data. |
| 10. | Halve the weighting on the age-at-length data. |
| 11. | Double the weighting on the abundance (CPUE) data. |
| 12. | Halve the weighting on the abundance (CPUE) data. |
| 13. | Derive the RBC using the 20:35:48 harvest control rule, rather than the 20:35:43. This is not a sensitivity on the assessment but on the forecast RBC values. |
| 14. | Fix steepness (h) at 0.65 (relative to model assumed 0.75) |
| 15. | Fix steepness (h) at 0.85 |
| 16. | No Survey Data (remove all FIS index, age- and length-composition data) |

The results of the sensitivity tests are summarized by the effects on the absolute likelihoods associated with each data stream, the total likelihoods, which includes the effect of changes to the Lambdas or weights applied, and the following quantities (see Table 16.16):

| | |
|---|---|
| 1. | SSB0: the average unexploited female spawning biomass. |
| 2. | $SSB_{2015}$: the female spawning biomass at the start of 2015/2016. |
| 3. | $SSB_{2015}/SSB_0$: female spawning biomass depletion at the start of 2015/2016 |
| 4. | M: natural mortality |
| 5. | $RBC_{2016/2017}$ |

## 16.4 Results and Discussion

### 16.4.1 *The Base-Case Analysis*

Stepping sequentially through the different scenarios leading from the 2013 assessment to the current base-case the general result was that most scenarios, that had an observable influence on the outcome, led to declines in the estimated unfished spawning biomass. Generally this occurred because the addition of new data meant the balance between variances and effective sample sizes as well as the recruitment bias adjustments became badly out of balance. BY conducting a limited variance rebalance then the effect of adding the extra data could become more clear. The trend of reducing biomass reversed with the final balancing of variances between the data streams and adjustment of the recruitment bias adjustment and variation of recruitment deviates (balancedCE). While the final estimated female unfished spawning biomass was 11,046 t relative to 9,320 t in 2013, the spawning biomass depletion level was essentially the same at 0.45 which was nearly identical with the 0.45 in 2013 (Table 16.1 and Table 16.12). With the addition of large numbers of new samples (the Industry LF samples alone contribute more than 35,000 extra records; Table 16.8) and the sub-division of both the length and ageing data into their component parts the imbalance with the relative weights attributed to the different data streams became extreme. For this reason some limited rebalancing started with the newLenComp scenario so as to obtain more sensible and more comparable results (Table 16.12).

Table 16.12. The spawning biomass (B0), at the end of 2015/2016, with the spawning biomass depletion (Depl), and the natural mortality estimate (M) obtained during the development of the 2015/2016 variance balanced base-case assessment for Deepwater Flathead. The four right-hand columns relate to the likelihood contributions from the Indices (both the commercial CPUE and the FIS abundance index), AgeComp relates to the conditional Age at Length data for the ISMP onboard, the Port, the Industry sampling, and the FIS, the LenComp includes the ISMP onboard, ISMP Port, Industry LF samples, and the FIS LF samples, finally Recruit is the contribution from the recruitment residuals. The final year of estimating recruitment residuals increased from 2008 to 2011 in the newRecs scenario. SigmaR needed to increase from 0.5 to 0.55 with the newAAL scenario and then returned to 0.5 for the balancedCE The inclusion of the FIS ageing and length composition data began with LenAgeFIS.

| Scenario | B0 | Depl | M | Indices | AgeComp | LenComp | Recruit |
|---|---|---|---|---|---|---|---|
| origbase24f | 9201 | 0.474 | 0.236 | -17.43 | 333.71 | 214.87 | -10.18 |
| origbase24z | 9067 | 0.471 | 0.236 | -17.44 | 333.73 | 214.88 | -10.14 |
| newCatCE | 8921 | 0.432 | 0.234 | -19.02 | 334.11 | 215.37 | -10.01 |
| newsurvCE | 8502 | 0.348 | 0.228 | -15.96 | 334.88 | 217.05 | -9.98 |
| newRecs | 8330 | 0.313 | 0.228 | -17.35 | 334.50 | 216.96 | -10.02 |
| newLenComp | 9390 | 0.240 | 0.165 | -21.80 | 246.45 | 76.82 | -7.11 |
| newAAL | 11534 | 0.489 | 0.191 | -29.30 | 178.05 | 45.77 | -4.15 |
| ageingerror | 11534 | 0.489 | 0.191 | -29.30 | 178.05 | 45.77 | -4.15 |
| LenAgeFIS | 11439 | 0.456 | 0.198 | -27.89 | 231.49 | 71.05 | -9.77 |
| balancedCE | 11046 | 0.450 | 0.191 | -27.52 | 290.23 | 84.68 | -10.46 |
| balnoFIS1415 | 11069 | 0.451 | 0.187 | -29.66 | 289.05 | 86.01 | -10.72 |

The addition of new composition data and the rebalancing led to improvements (likelihoods getting smaller) in the fitting to all data streams. Importantly, the estimate of natural mortality declined once the new composition data was added, which in turn led to the increase in unfished biomass (Table 16.12).

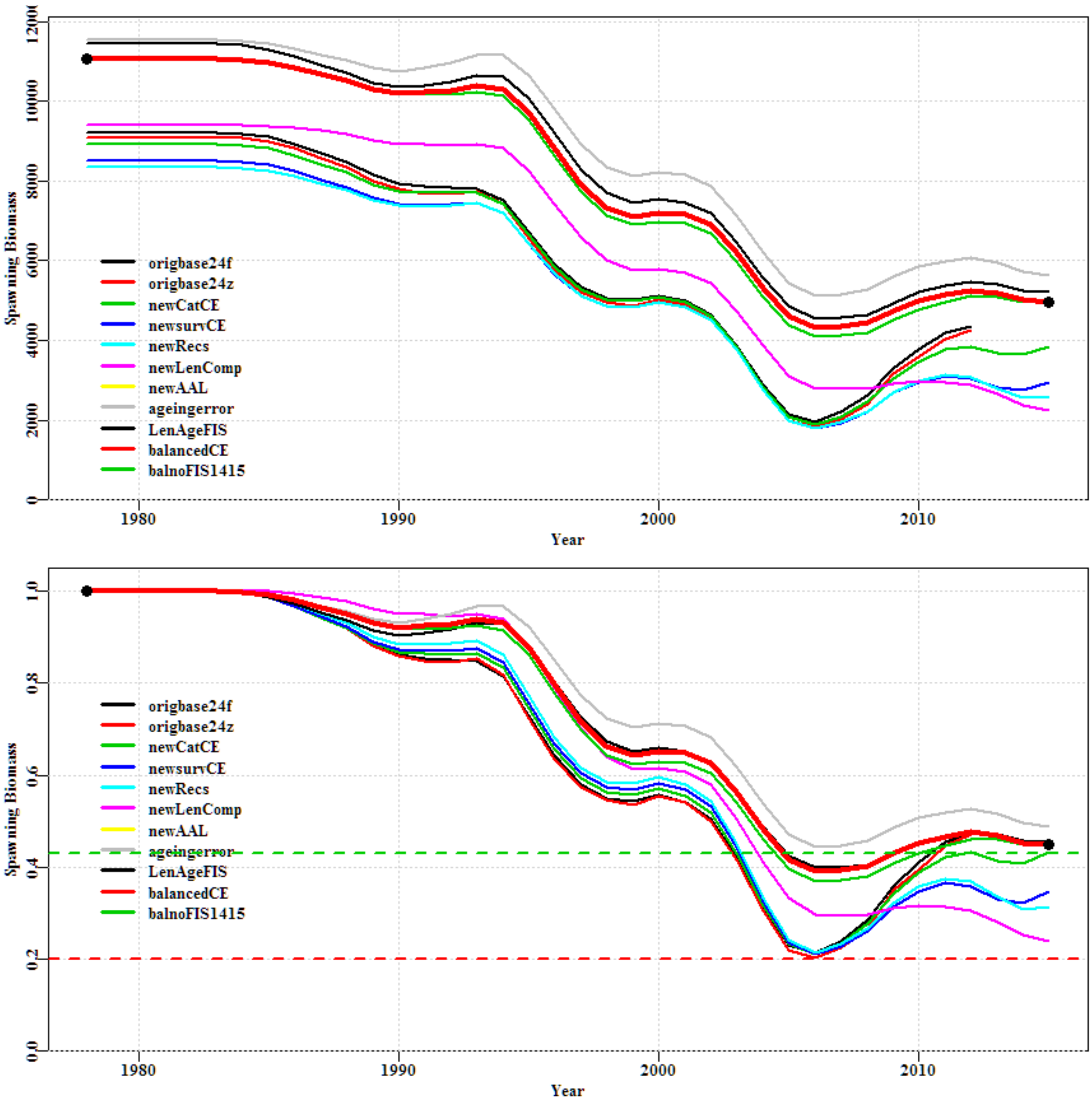


Figure 16.10. The predicted female spawning biomass and relative depletion level for the main scenarios describing the inclusion of different data and alternative assessment software. Some lines sit almost exactly on top of each other (for example the origbase24f and origbase24z), the thicker red line with the black dots is the balanced outcome from the base-case (see Table 16.10 for an explanation of each scenario).

Despite catches being relatively low recently (Table 16.4; Figure 16.3) the estimated spawning biomass trajectory suggests a very gradual decline since 2012/2013. It remains, however, just (2%) above the target reference point for spawning biomass depletion.

An alternative base-case was considered which removed the final index of abundance from the FIS data series. This retained the length and age composition data from the FIS plus the first six FIS indices of abundance while only removing the final, possibly compromised index from the 2014/2015 survey (Figure 16.11). Given that only a single data point has been removed the impact of that single point altered the likelihood for the indices and the length composition data but had little effect on the final biomass depletion level (Table 16.12). The predicted trajectory followed by the stock is very similar to that of the balancedCE scenario that includes the final FIS data point.

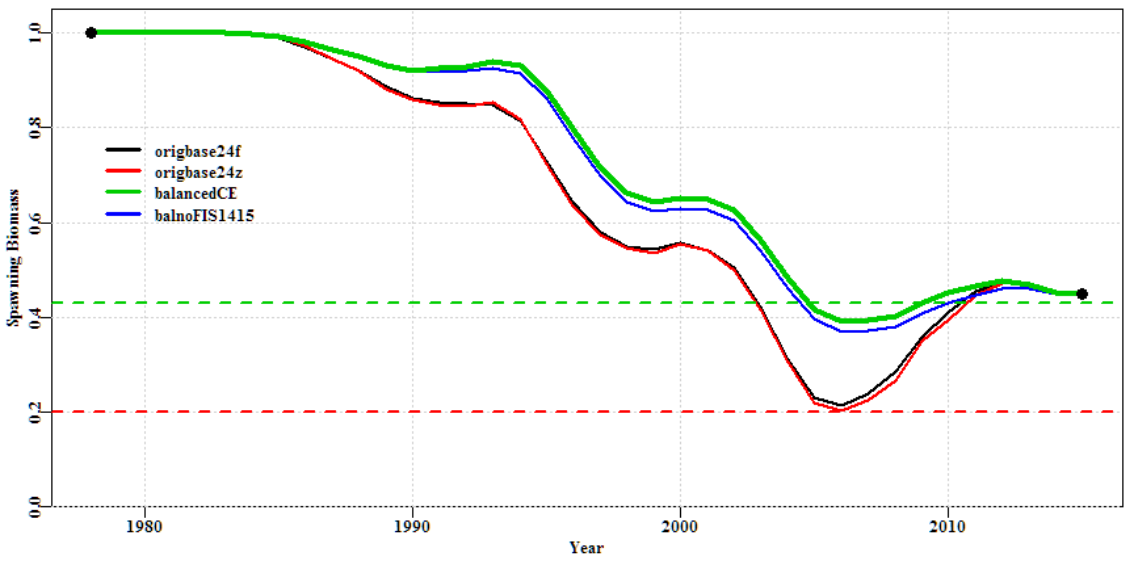


Figure 16.11. The predicted female spawning biomass depletion level for Deepwater Flathead comparing the final two balanced base-case candidates with the original assessment outcome from 2013. The optimum here is the thicker green line.

The November 2016 RAG considered the two alternative basecase scenarios and accepted that even though the final FIS relative abundance index was the lowest ever, and possibly biased, it was within the range of previous variation and had very little effect against the weight of other data included in the assessment. The expectation is that if there is another survey then the outcome would help correct the trend of the FIS index. The conclusion was to accept the balencedCE as the basecase scenario and proceed with the sensitivities based on that.

### 16.4.2 *Model Fits*

The estimated growth curve for female and male Deepwater Flathead is assumed to be the same (Figure 16.12). All growth parameters are estimated by the model except for $L_{max}$ (Table 16.13). With only a trawl fleet and Trawl run FIS, selectivity is assumed to be logistic. The parameters that define the selectivity function are the length at 50% selection and the spread (the difference between length at 50% and length at 95% selection). A different selectivity was found to be required to appropriately describe the FIS length and age data (Figure 16.12; Table 16.13). In addition to these results the different contributions to the total likelihood also provides insights into the relative fit (Table 16.12), although, not all scenarios are directly comparable because their different structures mean there are different numbers of parameters and the re-balancing also makes comparisons invalid.

Table 16.13. Estimates for parameters other than recruitment deviates, with some fixed parameters for clarity. St.Dev is the approximate standard deviation for each estimate.

| Parameter/Feature | Value | St.Dev. | C.V. | Comment |
|---|---|---|---|---|
| Natural mortality *M* | 0.191 | 0.0247 | 10.6 | estimated |
| Recruitment | | | | |
| $\sigma_R$ | 0.5 | | | Fixed |
| deviates | 1980 – 2011 | | | estimated |
| Ln(R0) | 8.9413 | 0.313 | 3.5 | estimated |
| First bias adjustment | 1962 – 2005 | | | estimated |
| Final bias adjustment | 2007 – 2017 | | | estimated |
| maximum bias adjustment | 0.8764 | | | estimated |
| Growth | | | | |
| CV | 0.1414 | 0.0034 | 2.4 | estimated |
| K | 0.2354 | 0.0003 | 0.1 | estimated |
| $L_{min}$ | 18.016 | 0.7364 | 8.4 | estimated |
| $L_{max}$ | 65.0258 | | | fixed |
| Selectivity | | | | |
| Trawl L50 | 39.716 | 0.6823 | 1.7 | estimated |
| Trawl inter-quartile | 8.595 | 0.7076 | 8.2 | estimated |
| FIS L50 | 29.093 | 0.6931 | 2.4 | estimated |
| FIS inter-quartile | 5.261 | 0.7572 | 14.4 | estimated |

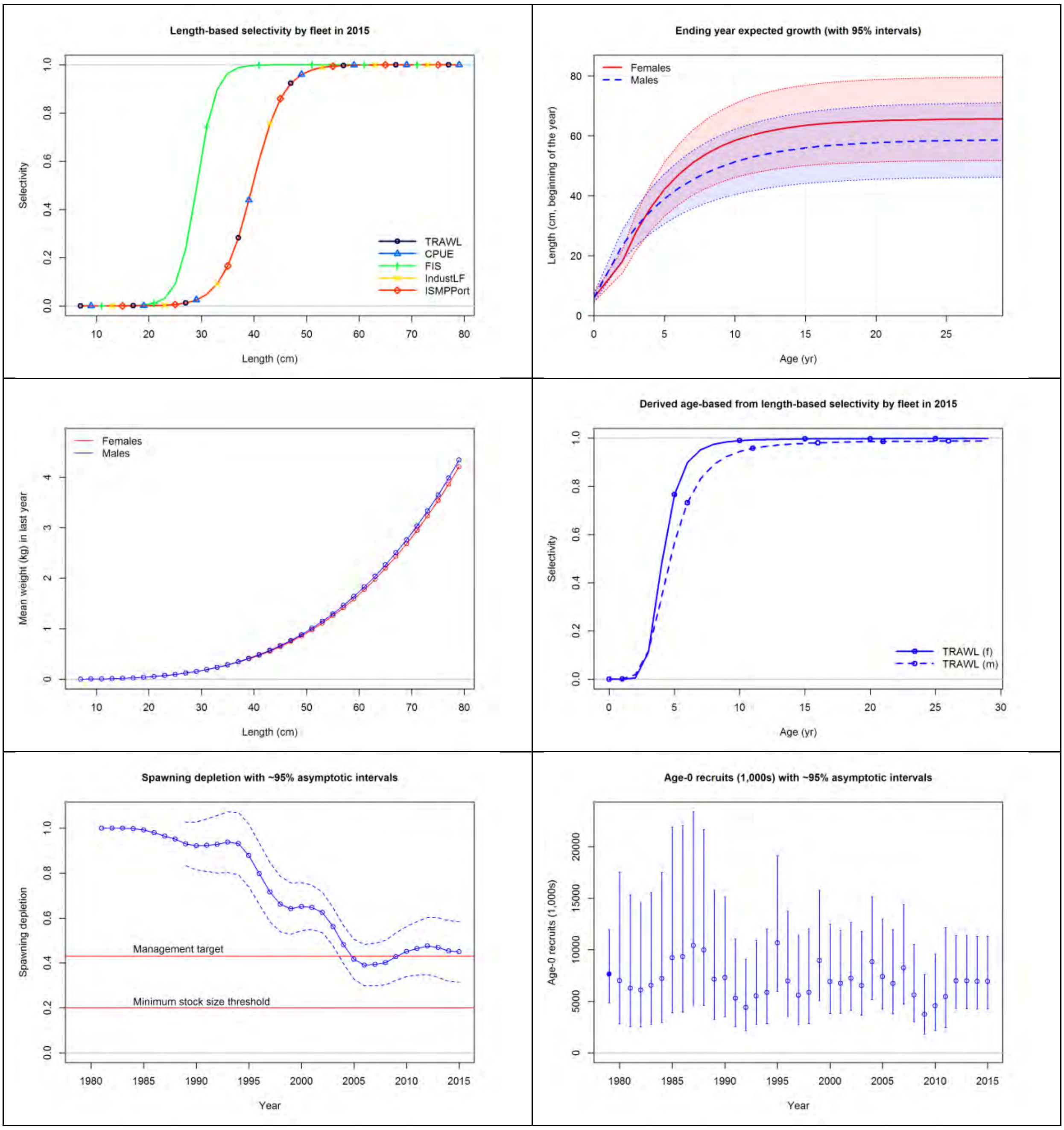


Figure 16.12. The selectivity curves for the trawl fishery and related length frequency data and of the FIS, and the predicted expected growth curves for females and males. The predicted mean weight at length, and derived age-based, length-based selectivity, the predicted depletion level of the balanced model with the 95% asymptotic confidence intervals, and the Age-0 recruit levels, again with the 95% asymptotic confidence intervals.

### 16.4.3 *Fits to the Data*

*16.4.3.1 CPUE Data*

At first consideration the fits to the catch rate indices (Figure 16.13) appear reasonable with the predicted commercial CPUE trajectory reflecting the ups and downs of the full time series although with less dramatic changes in the predicted mean than observed in the fishery. The FIS relative abundance index essentially follows the same trend as the commercial CPUE until the very latest survey (Figure 16.3). Even with an expanded Coefficient of Variation during the rebalancing process it was not possible to fit the last data point in the FIS index without disrupting the relative fit of the FIS length and age composition data and the other composition data.

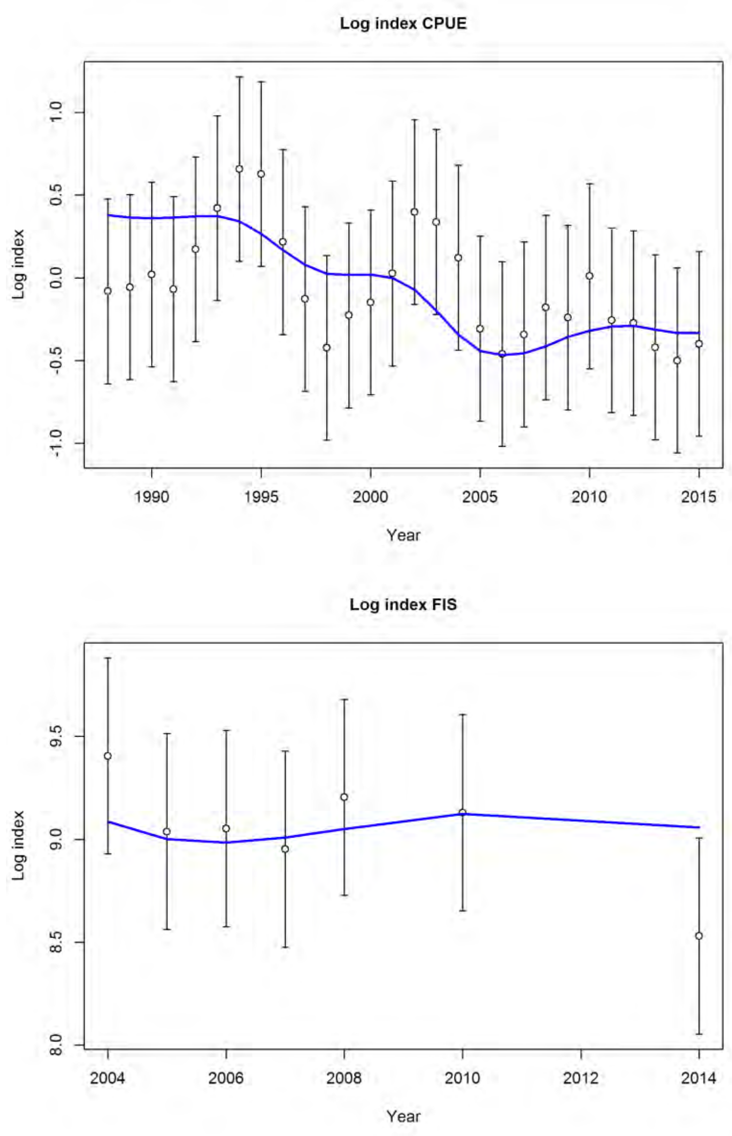


Figure 16.13. The balanced model fit to the commercial CPUE index of relative abundance and to the FIS index of relative abundance. Each year in the figures relates to the first year of each financial year combinations; e.g. 2001 = 2001/2002. The plots are of the natural Log Index because log-normal residual errors were used to fit the model to the abundance index data.

Such model fits are only relative to other possible fits. To illustrate this the model fit to CPUE and the FIS index for the current base-case (balancedCE) is compared with the equivalent model fits to the 2013 assessment and to the alternative base-case (balnoFIS1415). To make such a comparison valid each time-series of the observed and expected CPUE needed to be scaled to 1.0 over the years they had in common. Given that the 2013 assessment used commercial CPUE data from 1988/1989 - 2010/2011 and the FIS shared the years 2004/2005 – 2010/2011 in common, each of the three time-series were scaled to a mean of 1.0 over those years. Comparisons of the sum of their absolute residuals from the similarly scaled observed values were also calculated only for the years of overlap. In this way their relative fit could be ascertained both visually and quantitatively.

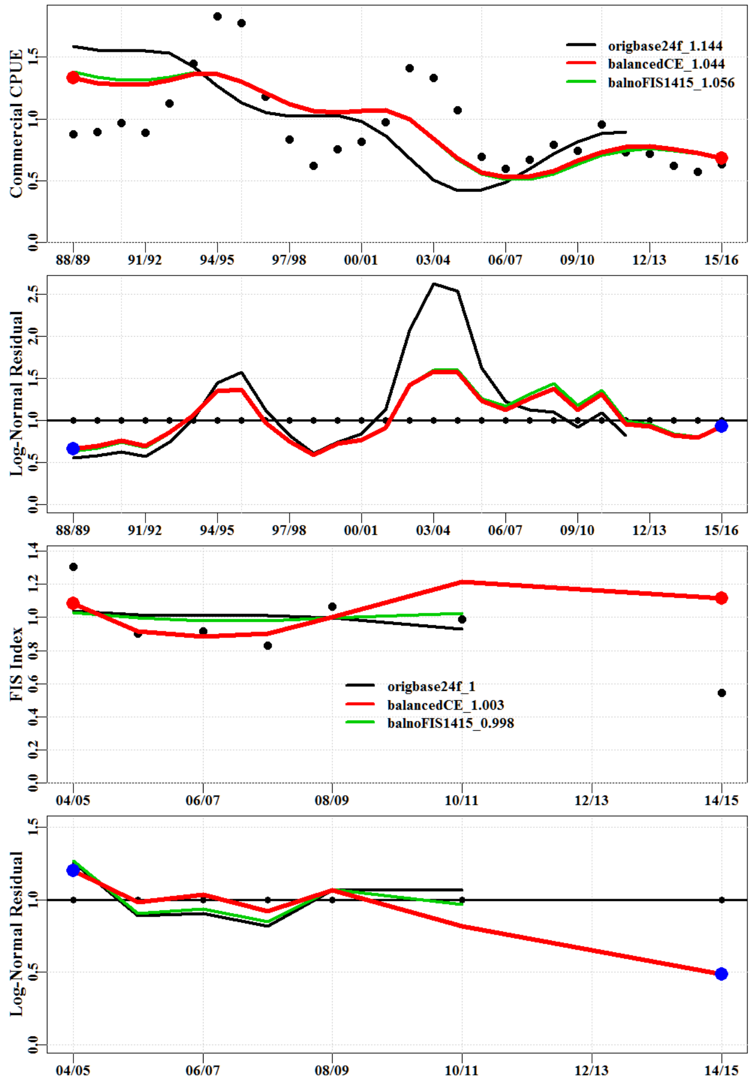


Figure 16.14. A comparison of the Index trends from the commercial CPUE and the FIS for the 2013 base-case (origbase24f) and the two alternative base-cases considered here (balancedCE and balnoFIS1415). Each time series is scaled to a mean of 1.0 over the years of overlap in each case. The numbers associated with each name in each legend are the mean log-normal residual between the expected and observed over the period of common overlap (closest to 1.0 is best). In the top panel balancedCE is closest to 1.0 while with the FIS index the 2013 mode was best over the 04/05 – 10/11 period but all are close and balanceCE follows the early trend better. The exceptional nature of the most recent estimate is clear.

The current approach used when fitting assessment models is to attempt to place emphasis on the relative index of abundance data (Francis, 2011). This is a major reason the quality of model fit to the different indices of relative abundance is better in the 2016 assessment than that in the 2013 assessment. The effect of omitting the final FIS index is only minor on the commercial CPUE (including it flattened the time-series slightly), but its effect on the fit to the FIS data is marked. It is also clear just how exceptional the last data point in the FIS is relative to all the other data in the assessment.

The commercial catch rates exhibit some relatively extreme variation through time. This reflects the changing conditions in the fishery, which has seen catches vary from about 500 t a year up to 1500t down again to 500 t, then up to nearly 2500 t, and then down to 1000t or less (Figure 16.2). Such changes are also reflected in the catch per vessel and in the number of vessels operating in the fishery (which has also been affected by the licence buyout associated with the structural adjustment during November 2005 to November 2006 (Figure 16.15).

Such changes may have contributed to the commercial CPUE exhibiting residual differences between the observed and expected CPUE with a distinct pattern of first being above the center line and then being below it (Figure 16.14). Such serial correlation demonstrates that some important factor has been missed in the standardization.  The sequence of residuals lying either side of the expected in a pattern of up and down. In this case the pronounced negative residuals reflect the periods of greatly elevated catches (Figure 16.2), which suggests that fishing behaviour was considerably altered during these periods. Such behavioural changes are difficult to capture within a CPUE standardization.

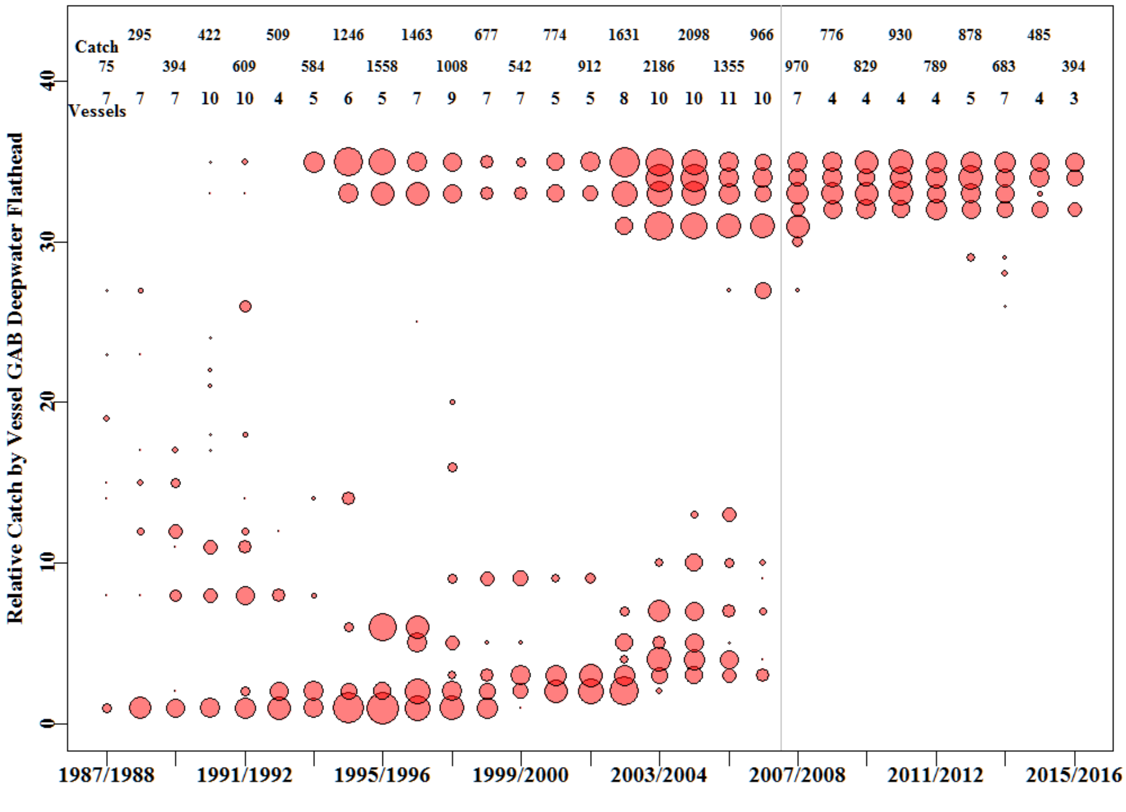


Figure 16.15. The relative catch (square root of catch) of Deepwater Flathead per trawl vessel in the GAB fishery, with the vertical line depicting the advent of the structural adjustment. The lowest of the top three lines lists the number of vessels reporting > 1 t across all years, and the other two lines are the reported catches, staggered to improve readability.

*16.4.3.2 Length Composition Data*

The length composition data from the FIS shows that those fish were slightly larger on average than those from the commercial fishery (Figure 16.17) and this is reflected in their respective selectivity curves (Figure 16.12). Deepwater Flathead tend to be selected at about 25cm and above implying that they can be 10 years or older before they are strongly selected by the fishery. This is about the same size and age at which they mature, which implies there is a proportion of the mature population not selected by the fishery and this should give the population an extra degree of resilience (Figure 16.12). There are some years of ISMP sampling, both on-board and port samples, that appear to be inconsistent with previous and following years (on-board 2004/2005 – 2006/2007, and port 1992/1993 and 2005/2006; Figure 16.17), however the data from the FIS and the crew-member samples are more sequentially consistent, although they sometimes fail to meet the same peak levels of relative frequency. Despite these internal inconsistencies the relative fit to the length composition data, when considered across all years is close in all data streams (Figure 16.17). Further illustrations of the relative fit to the length-composition data are provided in the Appendix.

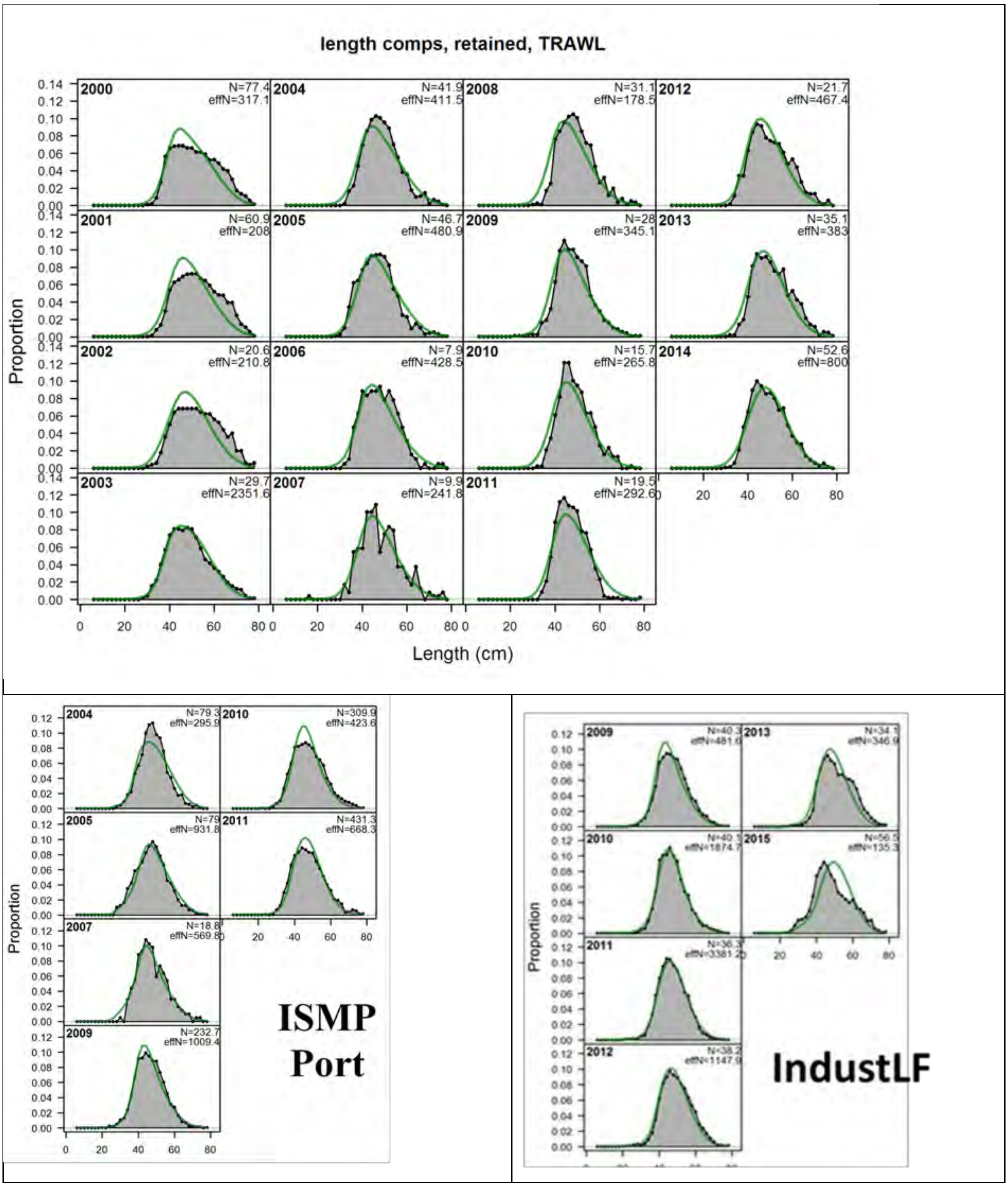


Figure 16.16. The base-case (balancedCE) fit to the ISMP collected length composition data from on-board. Numbers of observations in each case are listed in Table 16.8. The listed year relates to the first of the financial year pair. The samples from 2006/2007 and 2007/2008 were especially small, hence their spikiness.

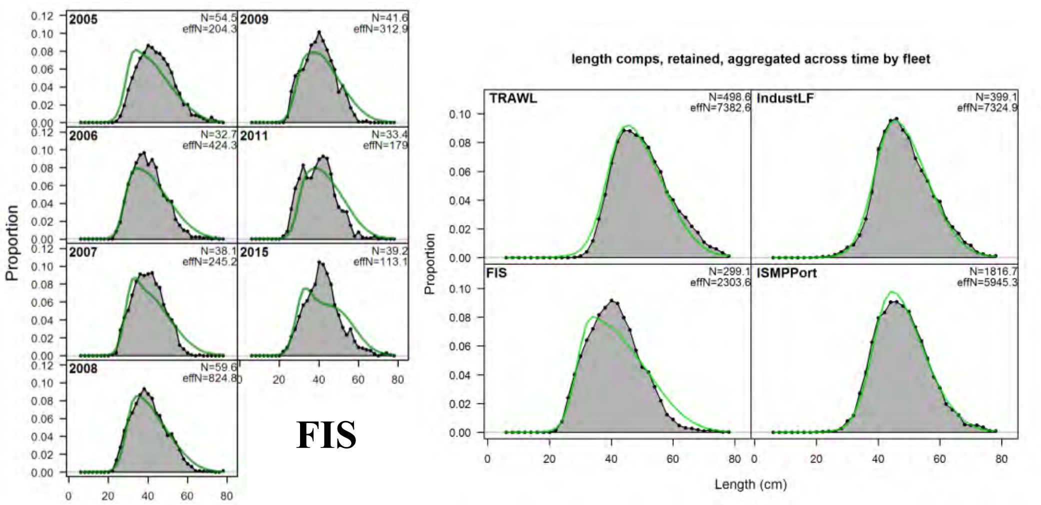


Figure 16.17. The base-case model fit to the different time-series of length-frequency composition data for the FIS data, the industry on-board data (industLF), the ISMP Port data, and the summary across years for each data set. Each year in the figures relates to the first of the financial year combinations; e.g. 2001 = 2001/2002.

### 16.4.4 *Base-Case Assessment Outcomes*

The stock depletion level at the end of 2015/2016 is estimated to be approximately 4,993 t or 45%$B_0$, (Figure 16.18), while the estimated, approximate MEY biomass level is 43%$B_0$ (Kompas *et al*., 2011). The asymptotic confidence intervals, and the standard deviation and CVs around the biomass estimates, are likely to under-estimate the true uncertainty about the estimated biomass levels (Figure 16.18). This is why the confidence bounds are relatively tight about the median estimated spawning biomass levels. The upturn in spawning biomass following the reduction in catches from 2009/2010 is driven by reduced fishing pressure and not by greater recruitment as recruitment during this period is lower than average predicted by the stock recruitment curve in the years 2007/2008 – 2011/2012 (Figure 16.19), although fish spawned in those years would only just have entered the fishery. In addition, recruitment levels are not particularly variable (Figure 16.19).

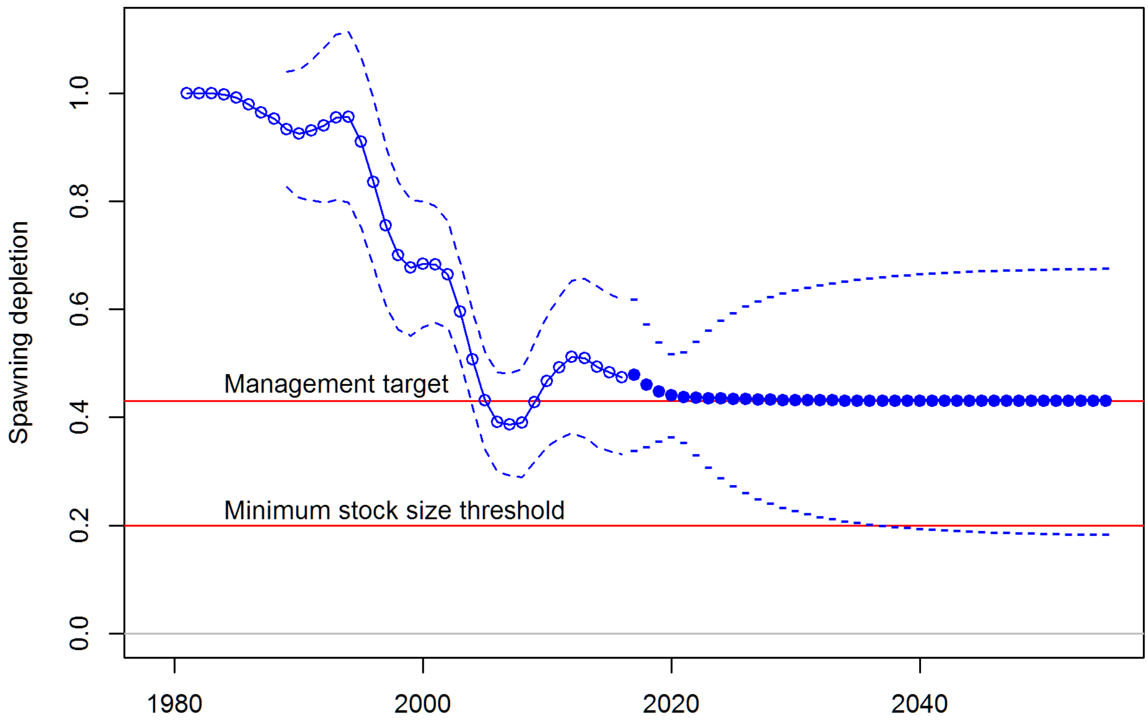


Figure 16.18. The trajectory of spawning stock depletion, including 40 years of projection used to estimate the current RBC and the long-term RBC. The stock only begins to decline slowly when fishing first begins and then accelerates downwards once catches reach about 800 – 1000t per year. With the more recent drop in catches from about 2009/2010, the stock is predicted to have increased to the present day until it ended at about 45%$B_0$ at the end of 2015/2016. If catches adhere to the predicted RBCs then it will take approximately 40 years for the stock to decline to the estimate MEY at 43%$B_0$.

The predicted trajectory in the 40 projections depends upon the estimated RBC being caught each year, which, given recent catches and reports of difficulty in catching the fish, seems unlikely.

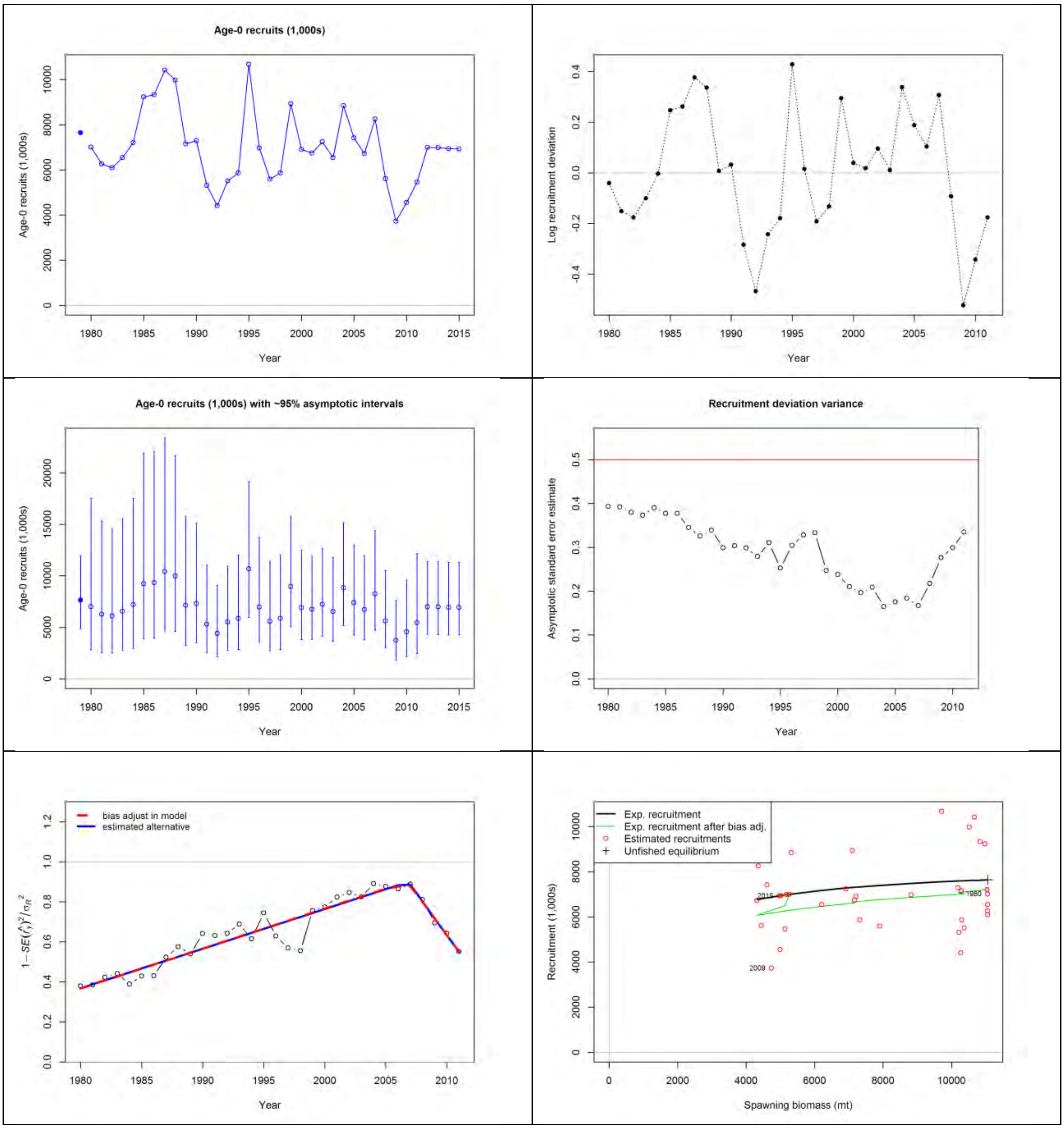


Figure 16.19. Estimation of recruitment and recruitment deviates for the base-case assessment with time trajectories given in both nominal and log-space. The final nine deviates in the middle left are not estimated but are estimated by the implied Beverton-Holt stock recruitment curve. The asymptotic standard errors of the recruitment deviates (middle right) are sufficiently low to indicate that all estimated deviates have sufficient data to allow for an adequate estimate. The bias-adjustment graph illustrates the degree to which the estimates of recruitment deviates require correction for their level of variation (Methot and Taylor, 2011). The implied stock recruitment curve (bottom right) illustrates that the stock depletion level has not been sufficient to alter the average recruitment levels significantly.

The predicted recruitment dynamics differ from those previously estimated, which appears to be related to the advent of more ageing data from the FIS and additional length-composition data streams.

The inclusion of recruitment estimates for more recent years also, not surprisingly, indicates some relatively low and some relatively high values. There are now no prolonged periods of high or low recruitment apparent in the time series (Figure 16.20).

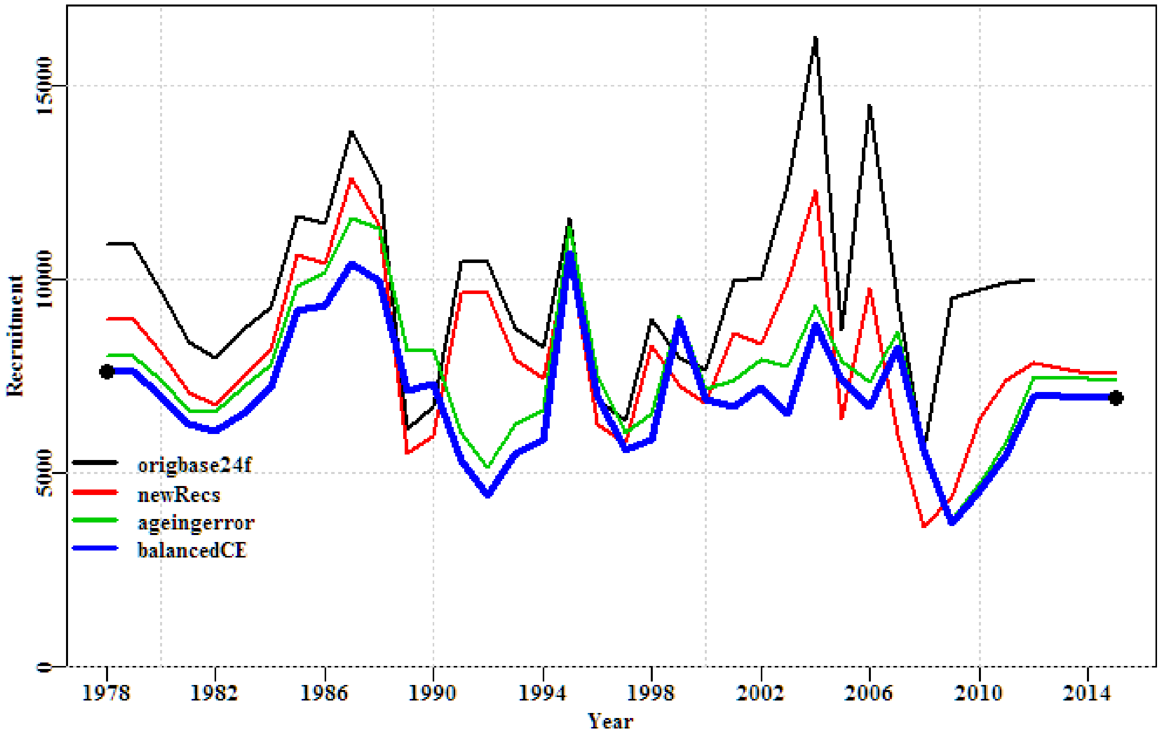


Figure 16.20. The sequence of expected recruitment levels through time for five different scenarios (more becomes uninterpretable). The difference between the 'newRecs' series and he base-case 'balancedCE' illustrates the differences that the rebalancing can bring about.

The recruitment levels and recruitment deviates through the period of the fishery have not varied to any extreme extent (Figure 16.20). There have been no extensive periods of below or above average recruitment levels predicted throughout the fishery. The effect of increasing and decreasing this variation is examined in the sensitivities (Table 16.16).

#### *16.4.4.1 Recommended Biological Catches*

The 2017/2018 recommended biological catch (RBC) under the 20:35:43 harvest control rule is 1155 t and the long term yield (assuming average recruitment in the future) is 1093 t (Table 16.14). Averaging the RBC over the three year period 2017/2018 – 2019/2020, the average RBC is 1128 t and over the five year period 2017/2018 – 2021/2022, the average RBC is 1115t (Table 16.14).

The forecast estimates of future RBCs are dependent upon first predicting the catch in the incomplete season 2016/2017 so that the predicted catch that is equivalent to $F_{43\%}$ can be generated for the 2017/2018 onwards. The basecase projection is based upon the assumption that the catch in 2016/2107 will be the same as happened in 2015/2016. In the December RAG this was questioned and alternative possible catches were suggested so that projections were made assuming 600t and 1000t (Table 16.15). As expected these led to small reductions in the 1, 3, and 5 year RBCs although, again as expected, the Long Term Yield remained at 1093 t.

Table 16.14. The predicted total exploitable biomass, the Female Spawning Biomass, and the observed and predicted catches from the forecast projections. The bolded rows represent the predicted RBCs for the 2017/2018 fishing year and the long-term RBC that should maintain the stock at the target of 43%$B_0$. See Table 16.18 for the projection outcomes for all years.

| Year | Total Exploitable Biomass | Spawning Biomass | Catch | Depletion |
|---|---|---|---|---|
| Unfished | 21058 | 11046 | 0 | 1 |
| 1979 | 21058 | 11046 | 0 | 1 |
| 1980 | 21057 | 11046 | 0 | 1 |
| 1981 | 21050 | 11046 | 0 | 1 |
| 1982 | 21018 | 11046 | 0 | 1 |
| | | | | |
| 2014 | 10260 | 4992 | 567 | 0.452 |
| 2015 | 10379 | 4951 | 523 | 0.448 |
| 2016 | 10611 | 4993 | 523 | 0.450 |
| **2017** | 10910 | 5123 | 1155 | 0.464 |
| **2018** | 10668 | 4966 | 1125 | 0.450 |
| **2019** | 10514 | 4859 | 1106 | 0.440 |
| **2020** | 10427 | 4790 | 1096 | 0.434 |
| **2021** | 10384 | 4752 | 1092 | 0.430 |
| | | | | |
| 2051 | 10398 | 4745 | 1093 | 0.430 |
| 2052 | 10398 | 4745 | 1093 | 0.430 |
| 2053 | 10399 | 4746 | 1093 | 0.430 |
| 2054 | 10399 | 4746 | 1093 | 0.430 |
| **2055** | 10400 | 4746 | 1093 | 0.430 |

Table 16.15. The forecast one year, three year, and five year RBCs are listed for the 20:35:43 harvest control rule and the original 20:35:48 harvest control rule to illustrate the difference between the proxy for MEY being 48%$B_0$ relative to the estimate of 43%$B_0$. These are based on a predicted catch in 2016/2017 assumed equal to that in 2015/2016. To test the sensitivity of the outcome to this assumption alternative assumed catches of 600t and 1000t in 2016/2017.

| Forecast | 20:43 | 20:48 | 16/17 = 600t | 16/17=1000t |
|---|---|---|---|---|
| 2017/2018 RBC | 1155 | 939 | 1146 | 1102 |
| 17/18 – 19/20 RBC | 1128 | 938 | 1121 | 1085 |
| 17/18 – 19/20 RBC | 1115 | 945 | 1109 | 1078 |
| Long Term Yield | 1093 | 1029 | 1093 | 1093 |

### 16.4.5 *Sensitivity Tests*

The sensitivity tests demonstrate that the assessment outcomes are very sensitive to the assumed value for *M*, the natural mortality (Figure 16.21; Table 16.16). In addition, although not as extreme as the effects of the natural mortality altering the size at median maturity and doubling the weight on CPUE were also influential on the absolute estimates of $B_0$ and hence of the final depletion.

The other sensitivities considered remained grouped relatively closely around the balanced base-case outcomes (Figure 16.21; Table 16.16). This is also a reflection of the limited rebalancing of variances conducted once large amounts of new data began to be added to the model. Without such rebalancing the advent of the new age data, for example, appeared to drop the spawning stock biomass down to just above 20%$B_0$, which was merely an artefact of enormous weight being given to the ageing data through the addition of hundred of new observations.

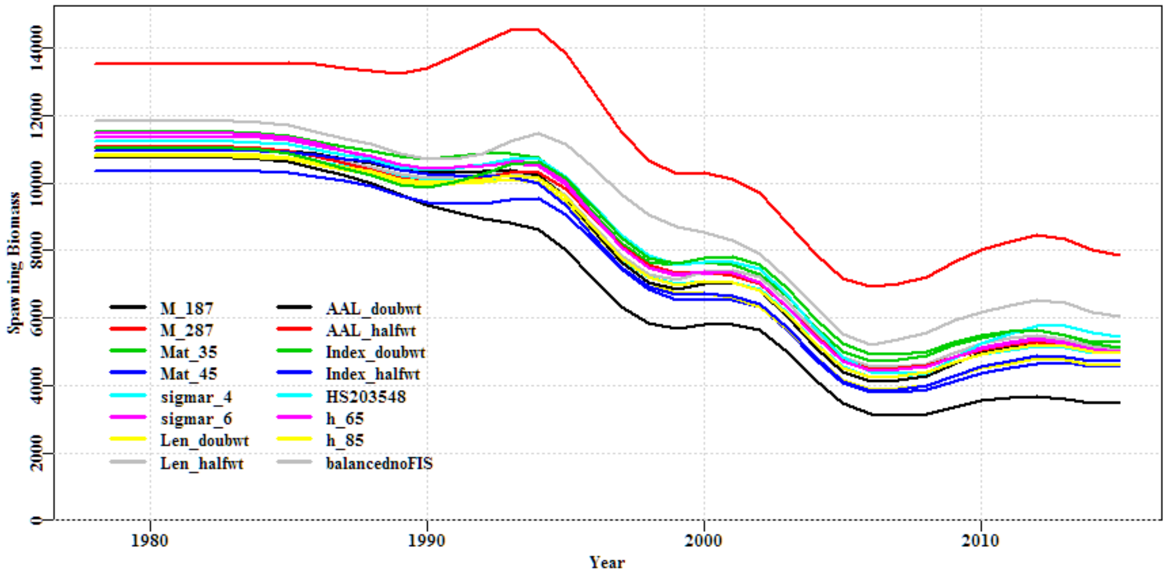


Figure 16.21. The effect on the predicted spawning biomass trajectory of the sensitivity tests on different assumptions and data weightings. The sensitivity to different assumed values of natural mortality is apparent.

In the sensitivities altering the weights on the different data streams had some effects on the model outcomes especially the halving and doubling the weights on the age composition data, (Table 16.16). However, by changing the weight given to each data stream it is no longer valid to compare the likelihoods from such sensitivity tests. The overall fit of the model improved with greater weight on the length and age composition data and declined with a lower weight.

With the different weights on the CPUE indices (log-books and FIS) the reverse was true in that the model fit improved when less weight was placed on the CPUE. Care is needed with such statements however. A consideration of the different weights applied to the age-composition data illustrate the reasons why total likelihood comparisons can be misleading (and are invalid). Because the age-related likelihoods are large to start with including a multiplier alters their values enormously even though they have only a small effect on the biomass related model outcomes (Table 16.16).

The sensitivity tests on the particular parameters in the model (steepness, natural mortality, size at 50% maturity, and the permissible variation of the recruitment deviates (SigmaR) are directly comparable, although it needs to be remembered that the sensitivities are not rebalanced and so the comparisons remain only approximate.

The effect of varying steepness was relatively minor on both the likelihoods and the stock status, while the effect of varying the size at 50% maturity was also very minor.

The effect of changing the SigmaR value alters how variable the recruitment deviates can be from year to year. However, once again the effect on the stock depletion status is minor varying the estimate from 44.1% – 45.9%.

Far more influential is the effect of varying the natural mortality. As one of the major factors affecting productivity this influenced the likelihoods for all data streams although it did so in different directions. A higher *M* value improved the fit to the two CPUE series and to the age-composition data but decreased the quality of fit to the length-composition data, and visa-versa when *M* was reduced. More importantly, the higher the M the greater the degree of depletion so increasing M by 0.05 led to the depletion changing from 45% down to 32% while decreasing it by 0.05 changed depletion from 45% to 58%. The influence of the natural mortality estimate is clear.

When all data from the FIS was removed this alters the model structure, which means it is no longer directly comparable with the full basecase. Nevertheless, the effect is to alter depletion from 45% to 51%, so the FIS is clearly generating information about the stock, particularly about the smaller fish.

All other sensitivities had only small effects on the outcome of the assessment with the final depletion ranging only 1 – 2 % from the basecase depletion. This may be a reflection of the strong contrast in the fishery where it was fished hard in the mid-1990s and the early 2000s with far reduced catches in between. Such fishing behaviour may provide difficult marketing conditions but it does provide information on how a stock responds to widely different fishing mortality levels and provides insight into its potential productivity.

#### *16.4.5.1 Likelihood Profile on Natural Mortality*

By fixing the value of natural mortality over an array of different values and re-fitting the assessment model so that all other parameters (except natural mortality) are re-estimated, it is possible to both determine the relative precision of the natural mortality estimate as well as the consequences for the stock and its status if different natural mortality values were used (Table 16.17 and Figure 16.22).

The profile likelihood enables approximate 95% confidence intervals to be generated (Venzon and Moolgavkar (1988). By searching for the natural mortality values that match the minimum obtained from the balancedCE scenario + 1.92 this provides approximate 95% intervals on natural mortality: 0.1628 – 0.1914 – 0.2285. This implies a range of depletion from 38 – 54% (Table 16.17; Figure 16.22), which is rather a wide range. Clearly, like most species, the natural mortality is a highly influential factor in the biology of Deepwater Flathead.

Table 16.16. Summary of the outcomes for the base-case and sensitivity tests. Recommended biological catches (RBCs) are only shown for tuned models (base-case and RBC48). The likelihoods in the italicized cases should not be compared with the other sensitivities.

| Case | | $SSB_0$ | $SSB_{2016}$ | $SSB_{2016}/SSB_0$ | M | TotalLL | Index | AgeComp | LenComp | Recruit |
|---|---|---|---|---|---|---|---|---|---|---|
| **Base-Case** | **base case 20:35:43** | **11046** | **4974** | **0.450** | **0.191** | **336.92** | **-27.52** | **290.23** | **84.68** | **-10.46** |
| MHigh | $M =$ 0.241 | 10757 | 3461 | 0.322 | 0.141 | -7.78 | -4.41 | -2.95 | 0.87 | -1.29 |
| MLow | $M =$ 0.141 | 13509 | 7854 | 0.581 | 0.241 | -3.58 | 1.76 | -3.19 | -1.80 | -0.35 |
| MatHigh | 50% maturity at 45cm | 11512 | 5282 | 0.459 | 0.191 | 0.00 | -0.02 | 0.00 | 0.01 | 0.00 |
| MatLow | 50% maturity at 35cm | 10332 | 4537 | 0.439 | 0.192 | 0.01 | 0.03 | 0.00 | -0.02 | 0.01 |
| SigRHigh | $\sigma_R = 0.6$ | 10796 | 4954 | 0.459 | 0.189 | 2.94 | -0.23 | -0.73 | -0.04 | 3.95 |
| SigRLow | $\sigma_R = 0.4$ | 11459 | 5050 | 0.441 | 0.194 | -2.70 | 0.08 | 0.38 | -0.03 | -3.14 |
| *LFwtx2* | wt x 2 length comp | *10773* | *4617* | *0.429* | *0.186* | *-82.63* | *-2.11* | *-2.94* | -77.18 | -0.40 |
| *LFwtx0.5* | wt x 0.5 length comp | *11040* | *5060* | *0.458* | *0.196* | *43.34* | *1.44* | *1.99* | 40.08 | -0.16 |
| *agewtx2* | wt x 2 age comp | *10954* | *4982* | *0.455* | *0.189* | *-288.08* | *-1.13* | *-282.64* | -3.27 | -1.05 |
| *agewtx0.5* | wt x 0.5 age comp | *11074* | *4990* | *0.451* | *0.195* | *146.07* | *0.85* | *142.88* | 1.80 | 0.54 |
| *cpuewtx2* | wt x 2 CPUE | *11033* | *5113* | *0.463* | *0.202* | *29.55* | *34.40* | *-1.52* | -2.30 | -1.04 |
| *cpuewtx0.5* | wt x 0.5 CPUE | *10953* | *4747* | *0.433* | *0.184* | *-13.13* | *-15.29* | *0.56* | 1.31 | 0.29 |
| hHigh | Fix steepness $h = 0.85$ | 11364 | 5009 | 0.441 | 0.194 | -0.11 | 0.11 | -0.02 | -0.16 | -0.04 |
| hLow | Fix steepness $h = 0.65$ | 10839 | 4962 | 0.458 | 0.189 | 0.05 | -0.08 | 0.01 | 0.11 | 0.01 |
| *noSurvey* | No Survey data | *11825* | *6042* | *0.511* | *0.202* | *202.53* | *-4.48* | *188.74* | 22.81 | -4.54 |

Table 16.17. The outcome from the profile likelihood conducted on natural mortality including the influence on the different likelihood components and on the Unfished spawning biomass ($B_0$), the current biomass, and the depletion.

| M | TotalLike | TotalCE | TotalLF | TotalAge | CPUE | FISCE | TrawlLF | FISLF | IndustLF | PortLF | TrawlAge | FISAge | B0 | Bcurr | Depletion |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0.14 | 354.184 | -22.989 | 83.814 | 293.359 | -15.983 | -7.006 | 24.009 | 20.376 | 10.267 | 29.161 | 2527.530 | 406.065 | 10765.500 | 3438.060 | 0.319 |
| 0.145 | 352.747 | -23.616 | 83.809 | 292.554 | -16.689 | -6.927 | 24.316 | 20.205 | 10.211 | 29.077 | 2518.790 | 406.752 | 10727.100 | 3555.420 | 0.331 |
| 0.15 | 351.525 | -24.195 | 83.831 | 291.889 | -17.342 | -6.853 | 24.616 | 20.048 | 10.159 | 29.008 | 2511.470 | 407.417 | 10701.400 | 3677.930 | 0.344 |
| 0.155 | 350.497 | -24.730 | 83.877 | 291.349 | -17.946 | -6.784 | 24.909 | 19.903 | 10.112 | 28.953 | 2505.430 | 408.061 | 10689.000 | 3806.170 | 0.356 |
| 0.16 | 349.642 | -25.223 | 83.943 | 290.922 | -18.504 | -6.719 | 25.196 | 19.770 | 10.068 | 28.909 | 2500.540 | 408.684 | 10690.400 | 3940.730 | 0.369 |
| **0.165** | 348.948 | -25.677 | 84.027 | 290.598 | -19.019 | -6.658 | 25.475 | 19.648 | 10.028 | 28.877 | 2496.690 | 409.289 | 10706.200 | 4082.280 | 0.381 |
| 0.17 | 348.396 | -26.095 | 84.125 | 290.366 | -19.494 | -6.601 | 25.747 | 19.535 | 9.990 | 28.854 | 2493.790 | 409.874 | 10737.100 | 4231.530 | 0.394 |
| 0.175 | 347.976 | -26.479 | 84.237 | 290.218 | -19.931 | -6.548 | 26.012 | 19.430 | 9.955 | 28.839 | 2491.740 | 410.442 | 10783.800 | 4389.250 | 0.407 |
| 0.18 | 347.676 | -26.831 | 84.360 | 290.147 | -20.333 | -6.499 | 26.271 | 19.334 | 9.922 | 28.833 | 2490.480 | 410.993 | 10847.200 | 4556.320 | 0.420 |
| 0.185 | 347.485 | -27.154 | 84.494 | 290.145 | -20.702 | -6.453 | 26.524 | 19.244 | 9.892 | 28.834 | 2489.920 | 411.530 | 10928.100 | 4733.670 | 0.433 |
| 0.19 | 347.393 | -27.450 | 84.637 | 290.206 | -21.039 | -6.411 | 26.771 | 19.161 | 9.863 | 28.841 | 2490.010 | 412.051 | 11027.800 | 4922.360 | 0.446 |
| **0.1913** | 347.384 | -27.523 | 84.676 | 290.232 | -21.123 | -6.400 | 26.835 | 19.141 | 9.856 | 28.845 | 2490.130 | 412.187 | 11057.300 | 4974.120 | 0.450 |
| 0.195 | 347.393 | -27.720 | 84.788 | 290.325 | -21.348 | -6.372 | 27.012 | 19.084 | 9.836 | 28.855 | 2490.690 | 412.560 | 11147.300 | 5123.540 | 0.460 |
| 0.2 | 347.478 | -27.966 | 84.947 | 290.497 | -21.630 | -6.337 | 27.249 | 19.013 | 9.811 | 28.875 | 2491.910 | 413.057 | 11288.100 | 5338.530 | 0.473 |
| 0.205 | 347.640 | -28.190 | 85.113 | 290.717 | -21.886 | -6.305 | 27.480 | 18.946 | 9.788 | 28.900 | 2493.620 | 413.544 | 11451.700 | 5568.770 | 0.486 |
| 0.21 | 347.872 | -28.394 | 85.285 | 290.981 | -22.118 | -6.276 | 27.707 | 18.883 | 9.765 | 28.930 | 2495.790 | 414.021 | 11640.100 | 5815.890 | 0.500 |
| 0.215 | 348.172 | -28.579 | 85.464 | 291.287 | -22.328 | -6.250 | 27.931 | 18.824 | 9.744 | 28.965 | 2498.380 | 414.490 | 11855.100 | 6081.710 | 0.513 |
| 0.22 | 348.531 | -28.746 | 85.648 | 291.629 | -22.518 | -6.228 | 28.150 | 18.768 | 9.724 | 29.005 | 2501.340 | 414.953 | 12099.300 | 6368.250 | 0.526 |
| **0.225** | 348.948 | -28.897 | 85.838 | 292.007 | -22.688 | -6.209 | 28.367 | 18.715 | 9.705 | 29.050 | 2504.660 | 415.412 | 12375.300 | 6677.800 | 0.540 |
| 0.23 | 349.416 | -29.033 | 86.033 | 292.416 | -22.840 | -6.193 | 28.581 | 18.665 | 9.687 | 29.100 | 2508.300 | 415.867 | 12686.000 | 7012.880 | 0.553 |
| 0.235 | 349.934 | -29.155 | 86.233 | 292.856 | -22.975 | -6.180 | 28.792 | 18.617 | 9.670 | 29.154 | 2512.240 | 416.322 | 13034.900 | 7376.290 | 0.566 |
| 0.24 | 350.497 | -29.264 | 86.438 | 293.323 | -23.095 | -6.170 | 29.001 | 18.570 | 9.654 | 29.214 | 2516.450 | 416.777 | 13425.800 | 7771.120 | 0.579 |
| 0.245 | 351.103 | -29.362 | 86.649 | 293.816 | -23.200 | -6.163 | 29.208 | 18.525 | 9.638 | 29.278 | 2520.920 | 417.236 | 13862.700 | 8200.710 | 0.592 |
| 0.25 | 351.749 | -29.450 | 86.865 | 294.334 | -23.291 | -6.159 | 29.414 | 18.481 | 9.623 | 29.348 | 2525.640 | 417.702 | 14350.200 | 8668.670 | 0.604 |
| 0.255 | 352.433 | -29.529 | 87.087 | 294.875 | -23.371 | -6.158 | 29.619 | 18.436 | 9.608 | 29.423 | 2530.570 | 418.177 | 14893.000 | 9178.720 | 0.616 |
| 0.26 | 353.154 | -29.599 | 87.314 | 295.439 | -23.440 | -6.159 | 29.824 | 18.392 | 9.594 | 29.504 | 2535.720 | 418.667 | 15496.100 | 9734.640 | 0.628 |

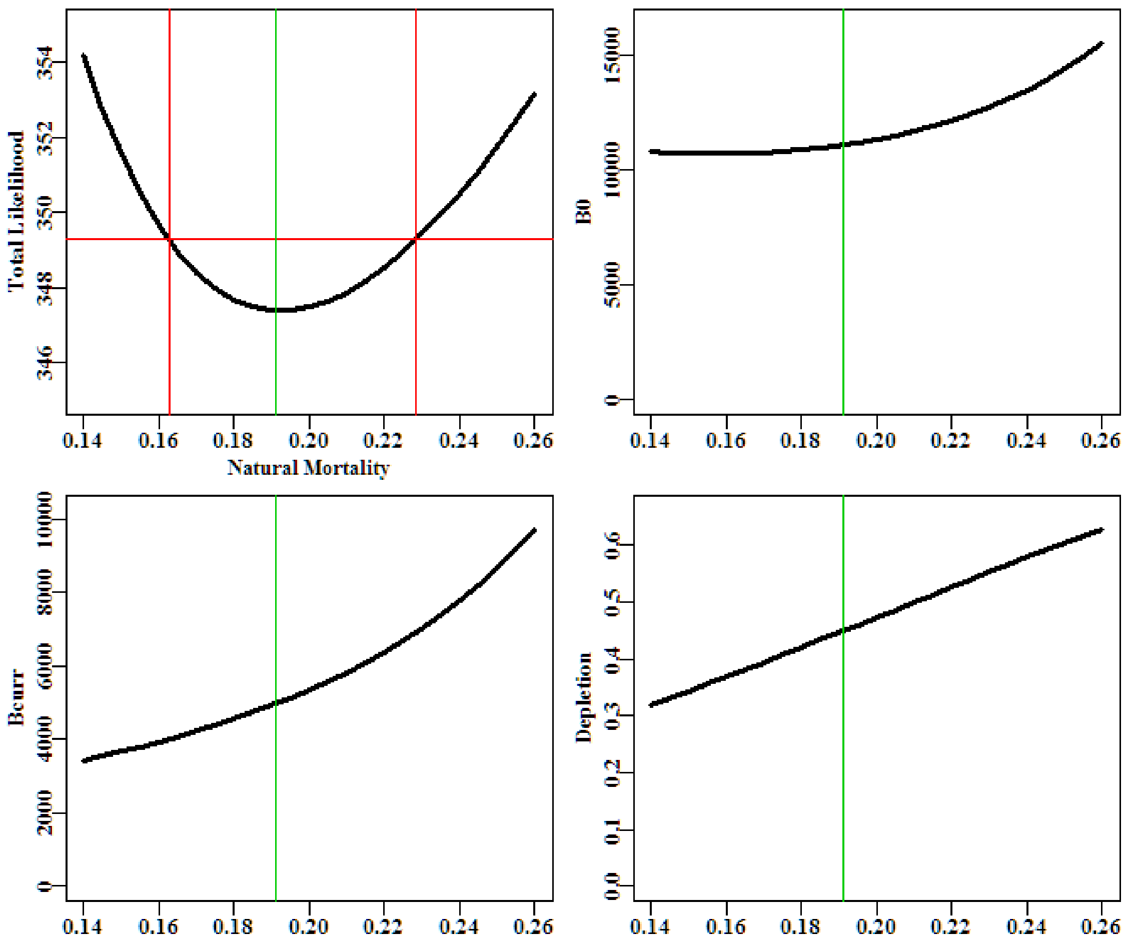


Figure 16.22. The likelihood profile for natural mortality (top right) with its implications for the unfished spawning biomass ($B_0$), the Current biomass and the state of depletion. The green line depicts the optimum estimate of natural mortality in all cases. In the likelihood profile the red lines bound the approximate likelihood profile 95% confidence bounds.

Table 16.18. Tabulated deterministic output from the projections. The filled dots in Figure 16.18 are the year and Depletion column values (as proportions not percentages).

| Year | Total Biomass | Spawning Biomass | Recruitment | Depletion | TAC |
|---|---|---|---|---|---|
| 2016 | 11164 | 5318 | 6612 | 0.475 | 1171 |
| 2017 | 10783 | 5019 | 6549 | 0.448 | 1120 |
| 2018 | 10572 | 4858 | 6513 | 0.434 | 1093 |
| 2019 | 10475 | 4780 | 6495 | 0.427 | 1082 |
| 2020 | 10445 | 4754 | 6488 | 0.424 | 1079 |
| 2021 | 10448 | 4755 | 6489 | 0.424 | 1081 |
| 2022 | 10462 | 4766 | 6491 | 0.425 | 1084 |
| 2023 | 10479 | 4777 | 6494 | 0.426 | 1086 |
| 2024 | 10494 | 4785 | 6496 | 0.427 | 1088 |
| 2025 | 10506 | 4792 | 6497 | 0.428 | 1090 |
| 2026 | 10516 | 4796 | 6498 | 0.428 | 1091 |
| 2027 | 10524 | 4800 | 6499 | 0.428 | 1092 |
| 2028 | 10530 | 4803 | 6500 | 0.429 | 1092 |
| 2029 | 10535 | 4805 | 6501 | 0.429 | 1093 |
| 2030 | 10540 | 4807 | 6501 | 0.429 | 1093 |
| 2031 | 10543 | 4809 | 6502 | 0.429 | 1094 |
| 2032 | 10546 | 4810 | 6502 | 0.429 | 1094 |
| 2033 | 10549 | 4812 | 6502 | 0.429 | 1095 |
| 2034 | 10551 | 4813 | 6502 | 0.429 | 1095 |
| 2035 | 10553 | 4814 | 6503 | 0.430 | 1095 |
| 2036 | 10554 | 4814 | 6503 | 0.430 | 1095 |
| 2037 | 10555 | 4815 | 6503 | 0.430 | 1095 |
| 2038 | 10556 | 4816 | 6503 | 0.430 | 1095 |
| 2039 | 10557 | 4816 | 6503 | 0.430 | 1095 |
| 2040 | 10558 | 4816 | 6503 | 0.430 | 1096 |
| 2041 | 10559 | 4817 | 6503 | 0.430 | 1096 |
| 2042 | 10559 | 4817 | 6503 | 0.430 | 1096 |
| 2043 | 10560 | 4817 | 6503 | 0.430 | 1096 |
| 2044 | 10560 | 4818 | 6504 | 0.430 | 1096 |
| 2045 | 10560 | 4818 | 6504 | 0.430 | 1096 |
| 2046 | 10561 | 4818 | 6504 | 0.430 | 1096 |
| 2047 | 10561 | 4818 | 6504 | 0.430 | 1096 |
| 2048 | 10561 | 4818 | 6504 | 0.430 | 1096 |
| 2049 | 10561 | 4818 | 6504 | 0.430 | 1096 |
| 2050 | 10562 | 4818 | 6504 | 0.430 | 1096 |
| 2051 | 10562 | 4818 | 6504 | 0.430 | 1096 |
| 2052 | 10562 | 4818 | 6504 | 0.430 | 1096 |
| 2053 | 10562 | 4818 | 6504 | 0.430 | 1096 |
| 2054 | 10562 | 4818 | 6504 | 0.430 | 1096 |
| 2055 | 10562 | 4818 | 6504 | 0.430 | 1096 |

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## 16.6 Appendix

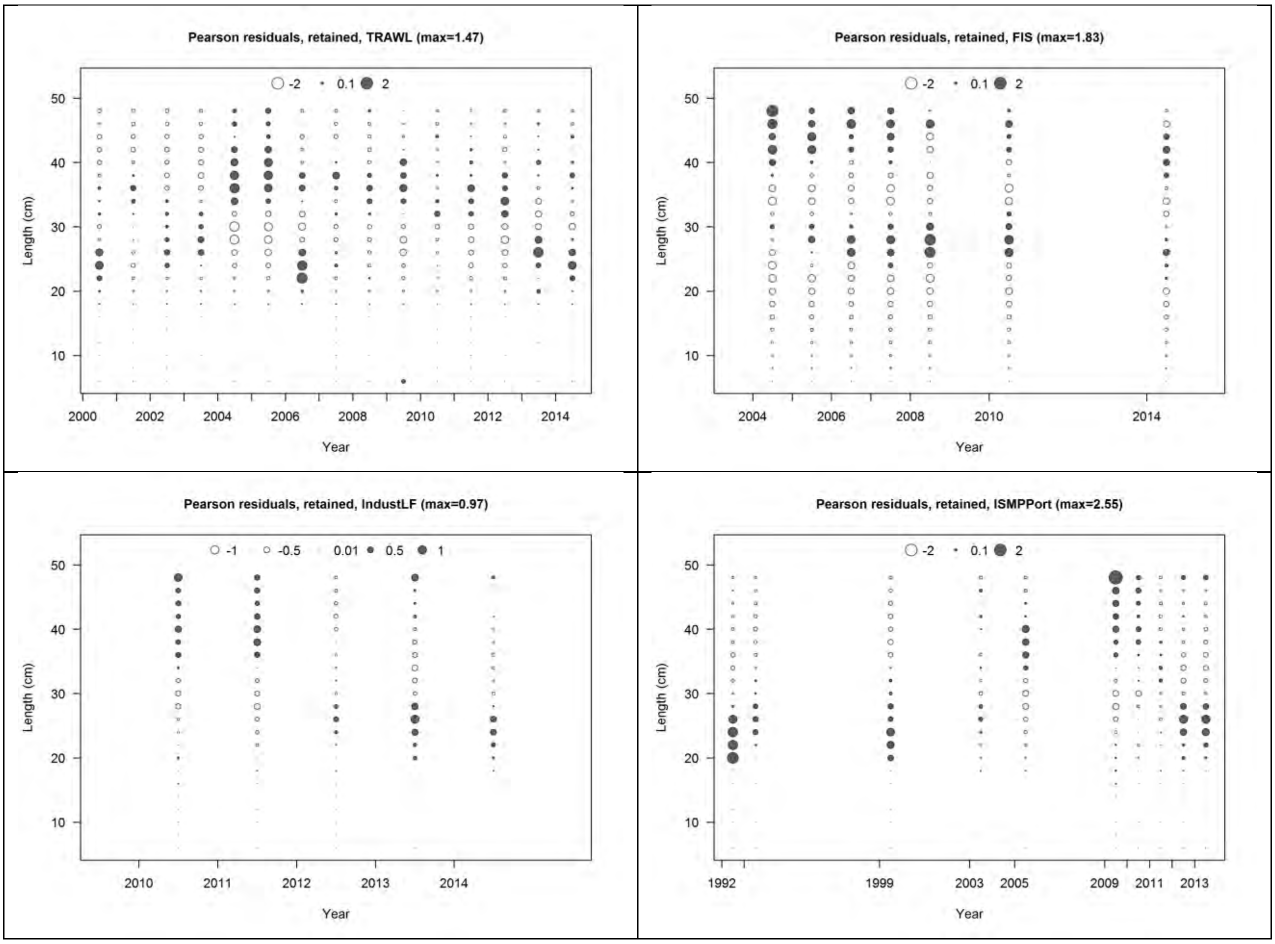


Figure 16.23. Residuals from the annual length composition data (retained) for Deepwater Flathead displayed by year and fleet (TRAWL – ISMP_onboard).

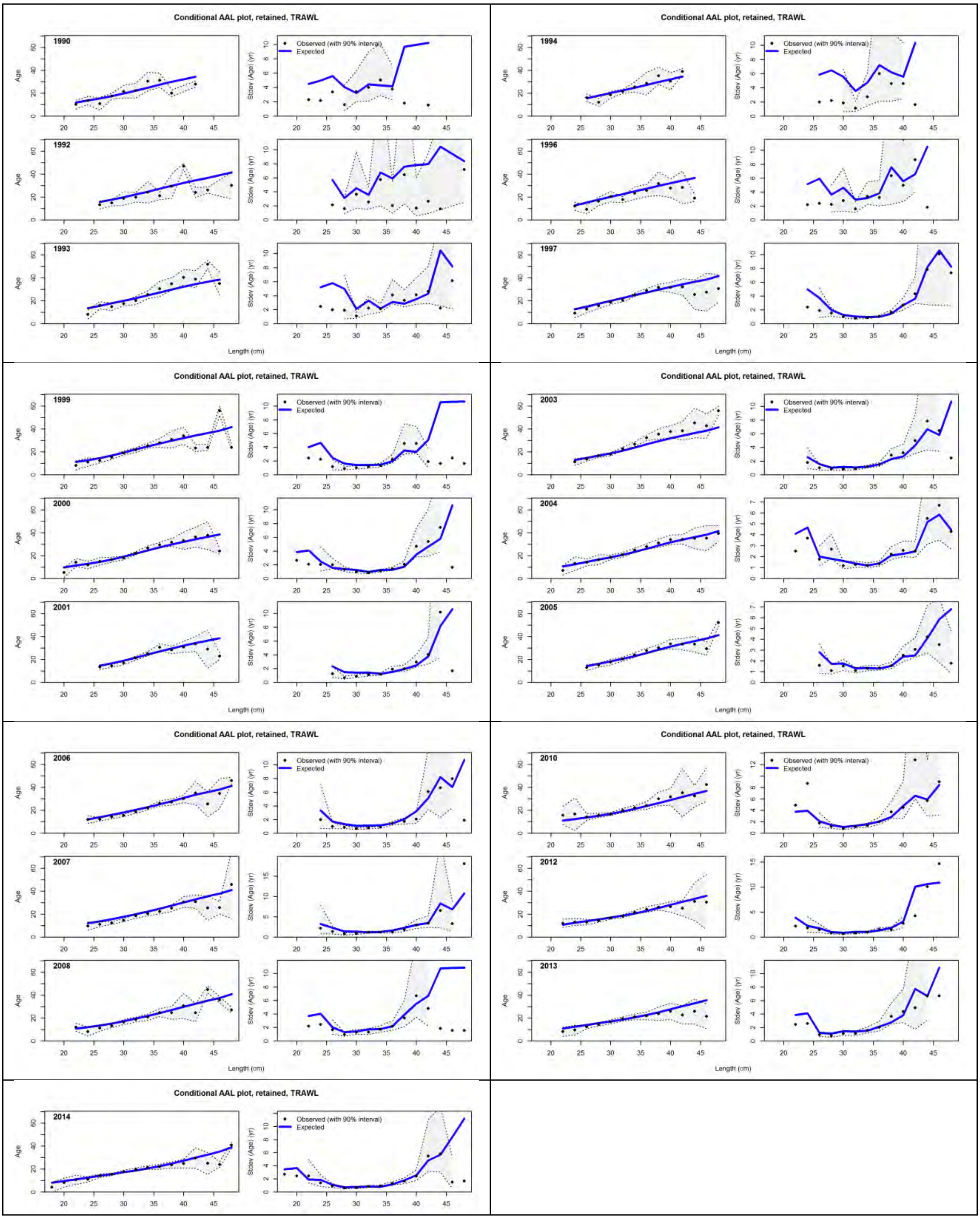


Figure 16.24. Conditional age-at-length plots illustrating the ages expected each year from the sampled length composition data and the age-length key for the year.

# 17. Gummy shark assessment update for 2016, using data to the end of 2015

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## *17.1 Executive Summary*

The assessment of gummy shark (*Mustelus antarcticus*) is updated based on available information to 2015. The model on which the assessment is based is modified in three ways: (a) the dynamics are now based on a population dynamics equation that assumes that the catches by the various gear-types occur simultaneously rather than sequentially, (b) the "hook fleet" included in previous assessments is now separated into shark longline, trawl, and scalefish longline gear-types, with size-specific selectivity estimated for each gear-type, and (c) allowance is now made for age-reading error. The assessment includes revised catch and length-composition data based on the most recent extractions from the AFMA database, new age composition data, and updated catch-rate indices. The catch-rate indices for 1997 onwards are based on the method commonly applied for SESSF species, with the pre-1997 catch-rates appended to those for 1997 onwards by calibrating the catch-rates for the period of overlap. The assessment includes catch-rate indices for the trawl and shark longline for the first time.

A reference case model is presented that fits to all available data. The fits are all reasonable and the assessment outputs indicate that gummy shark in Bass Strait, and off South Australia and Tasmania are above the management target of 48% of unfished pup production. The Recommended Biological Catches for 2016, 2017 and 2018 from the reference case model are 2080t, 1878t, and 1807t.

## *17.2 Introduction*

Gummy shark are considered to be relatively sedentary and not to undertake spawning or feeding migrations. Any management region could therefore be thought of as a separate stock. However, management regions should be chosen so there is sufficient length and catch-rate information to allow the values for the parameters of the population dynamics model to be estimated with reasonable precision[1]. Stock boundaries have been chosen to allow sufficient data for assessment, and to encompass possible spatial differences in fishery and stock characteristics. The analyses of this report treat gummy shark as three separate stocks: South Australia (SA), Victoria (Vic) and Tasmania (Tas) (Figure 17.1).

Several assessments of gummy shark have been conducted, with the assessments conducted since 2004 (Punt *et al.* 2004) having been based on the approach of Pribac *et al*. (2005), modified inter alia by Punt and Thomson (2010). The most recent assessment update for gummy shark used data to 2012 (Thomson and Sporcic, 2014). The code implementing the gummy shark assessment was one of the

[1] Unlike other SESSF assessments (e.g. for western and eastern gemfish), multiple management regions are assessed simultaneously for gummy shark, with the values for some parameters (e.g., the rate of natural mortality and the parameter determining density-dependence) assumed to be the same for multiple regions.

earliest developed using AD Model Builder (Fournier *et al*., 2012), and was consequently set up to be as simple (and fast) as possible. One of the key simplifications that had to be made was that the catches by each of the five gear types ("hooks" and four gillnet mesh gears) are instantaneous (i.e., half of natural mortality occurs then all the fisheries, and then the remainder of natural mortality), and that the fisheries are sequential (i.e., within each year, catches by hooks occur first, then those by 6.0-inch gill nets, 6.5-inch gillnets, etc). These assumptions would be inconsequential if fishing morality was always low, but if fishing mortality was highish (roughly $0.4yr^{-1}$ and higher on fully-selected animals, as was likely the case in Bass Strait in the 1970s and 1980s), they could have a major impact on estimates of population age-structure.

The population dynamics model on which this assessment was based was therefore reformulated as a continuous model (i.e., fishing mortality occurs throughout the year and all fisheries occur at the same time), making it consistent with stock assessments for sharks conducted elsewhere in the world (e.g., for spiny dogfish, *Squalus suckleyi*, Gertseva and Taylor, 2012), as well as the assessments for other fish species in the SESSF. The original model assumed that tags were released just before the fishery operated (mid-year). The revised model assumes that tags are released at the start of the year (so there is some (instantaneous) tag-loss before the fishery can catch the tags). Section 3 of this report therefore illustrates the consequences of changing the population dynamics model on which the assessment is based, along with other changes to the assessment methodology resulting from changes to the data that have become available since the time of the 2013 assessment. The outcome of Section 3 is a model (denoted Model 4A), that uses essentially the same data as the 2013 assessment, but is based on updated methodology.

Section 4 of the report updates Model 4A to include data subsequent to 2012, specifically:

- landings information for the seven gear-types included in the assessment (6-inch gillnets, 6.5-inch gillnets, 7-inch gillnets, 8-inch gillnets, shark longline, trawl, and scalefish longline – although the catches by 7-inch gillnets and 8-inch gillnets are negligible and are likely data recording errors);
- length-composition information for the seven gear-types;
- age-composition data for 1995, 1997, 2002 and 2003 (these data were previously unavailable); and
- updated catch-rate data.

Section 5 of the report summaries the Recommended Biological Catches for the next few years, along with the results of projections based on various assumptions about future catches, in particular the split of the RBC by region to gear-type.

## 17.3 Overview of the Data Types and Pre-Processing

### 17.3.1 *Landings Data*

The fishery for gummy shark started in Bass Strait, as a bycatch of the hook fishery for school shark. The fishery moved to South Australia and Tasmania, with the first catches off South Australia recorded in 1938 and off Tasmania in 1942. The fishery moved to gillnets in the 1960s. Catches were initially taken using 7-inch and 8-inch gillnets, but over time smaller mesh sizes predominated. Catches in Bass Strait have been taken predominantly using 6-inch gillnets from 1973. Catches off South Australia were dominated by those taken using 7-inch gillnets until 1997 when the predominant gear-type changed to 6.5-inch gillnets. Since 2012, the bulk of the catches off South Australia have been taken using line gear. Catches off Tasmania were taken using a range of gear-types, but 6-inch mesh has been the predominant gear since 1996.

The landings data on which this assessment is based for the years before 2000 are identical to those on which the 2013 assessment was based. The catches from 2001 to 2015 were recalculated based on updated information and all landed catches were converted to total catches by accounting for estimated discard rates (Appendix A). The time-series of catches used in the final assessment are shown in Figure 17.2.

### 17.3.2 *Catch-Rate Indices*

Catch-rates, along with tagging data, provide the key measures of relative abundance in the assessment for gummy shark. Two approaches for developing catch-rate indices have been applied to data for gummy shark. The catch-rates used in previous assessments were derived using the method of CPUE standardization for gummy shark that was developed by SharkRAG, and first outlined by Punt *et al*. (2000) and that evolved during a subsequent application (Punt, 2004). The method used for the last assessment is summarised by Punt and Gason (2006) and Thomson and Sporcic (2016). This method analyses the catch and effort data using the spatial cells identified by SharkRAG, modelling the probability of a non-zero catch-rate using a binomial distribution and the catch rate, given there is some catch, using a negative binomial distribution. The resulting model estimates are then combined, weighting the catch-rate indices by cell using a measure of the habitat area of the cell. There are cells for which catch-rate indices are missing, and an algorithm was developed by SharkRAG to specify these missing catch-rate indices. However, the software on which this method is based is no longer supported within R, and the SESSF has moved to a common approach to constructing standardized catch-rate indices for the use in stock assessments.

An alternative approach for standardizing catch and effort (Haddon, 2013) involves analysing all of the catch and effort data using standard methodology. Sporcic (2016) provides the most recent application of this method to sharks, which involves analysing records for 1997 onwards for which both catch and effort are non-zero. The best model, based on a log-normal GLM, is selected using AIC based on factors for year, vessel, month, Shark Zone (e.g. western and eastern Bass Strait), SharkArea (the blocks developed for previous catch-rate standardizations), gear, 25m depth category and DayNight (whether the record occurred during day, at night or was mixed between these - trawl only), as well as interactions between DayNight and Day, between Depth and Month, and between DayNight and Month. Sporcic (2016) conducted analyses separately for gillnets, trawl and bottom line.

### 17.3.3 *Length-Composition Data*

Gummy shark length-composition data from commercial catches were collected by MAFRI until 2006 and used in the 2006 assessment (Punt *et al*., 2006), as well as in the current update. Responsibility for the collection of commercial length-composition data has now moved to the AFMA Observer Program, which has yielded length-composition information from 2008 to 2015.

Until June 2015, the Observer Program collected length information onboard gillnet and line vessels (mostly as total length (TOT), but also significant amounts as fork length (LCF) or in port (all partial length (PAR)). Sample sizes are greatest for the onboard data, but the validity of the historical conversion formula for PAR to TOT is in doubt (i.e., TOT (cm) = 2.65 + 1.61PAR (cm)), Walker and Gason 2009). This doubt arises from converting partial lengths to total length and then comparing the converted length frequencies with the whole length frequencies (Thomson and Sporcic, 2014). Consequently, the Observer Program collected dual TOT and PAR measurements as well as LCF and TOT measurements from gummy, school shark, sawshark and elephantfish, and new conversion factors were calculated (most recently by Thomson 2015). Cameras have now replaced observers onboard shark fishing vessels so these measurements are no longer being collected, although trials are underway to collect length information from camera footage. Port data are not used in the assessment for the reasons outlined in Thomson and Sporcic (2014).

Length frequencies were catch-weighted before they were summed: first to the total weight for the shot, and then to year by gear and shark zone. Criteria for including length measurements made on board vessels were: (a) length code must be TOT, PAR or LCF (converted to TOT using the newly available conversion formulae; Thomson, 2015); and (c) measurements that were tagged as "discarded" were ignored. The size of gillnet was not recorded for these data so the mesh size was assumed to be that which led to the largest catch in the region from which the data were collected (i.e., 6-inch in Bass Strait and Tasmania and 6.5-inch in South Australia). The length-composition data for gillnets were restricted to those for which the annual sample size was at least 400 (for consistency with the 2013 assessment). Sample sizes for shark and scalefish longline and trawl are small (Table 17.1) so no minimum was imposed on these data, but these data were down-weighted prior to their inclusion in the assessment.

### 17.3.4 *Age-Composition Data*

Age data used by Punt and Thomson (2010) were included in this assessment and the previous assessment, even though they were derived from 2007 and 2008 surveys, not from commercial fishing. These data were supplemented with new age-readings from vertebrae collected during 1995, 1997, 2002, and 2003. Some of the new age data had to be ignored for this assessment. In particular, age data for which the gear used to catch the animals was missing, the age estimate was -99, or the animal was caught using bottom longline. In principle, age data from bottom longline could be used in the assessment, but the sample size (9) was too small for this to be the case this year. Data were aggregated to ages 1 – 10+ for consistency with the previous assessment. Table 17.2 lists the sample sizes for the age-composition data.

### 17.3.5 *Tagging Data*

It is not known whether any new tag-recaptures have been reported since 2008. Reporting rates have probably decreased in recent years and have probably been effectively close to zero from 2005 onwards.

## *17.4 Modifications to the Assessment*

Most of the specifications of the assessment match those of Thomson and Sporcic (2014). In particular:

- allowance is made for gear saturation when calculating the catchability coefficient that relates exploitable biomass to catch-rates;
- account is taken of availability as well as selectivity;
- discards are ignored;

- the likelihood for the tagging data is truncated at 2005;
- catch-rates for South Australia are truncated in 2009; and
- the last five recruitment deviations are not estimated.

As in the assessment of Thomson and Sporcic (2014), the reference case of this assessment assumes that (i) density-dependence is a function of total (1+) biomass, (ii) density-dependence impacts the rate of natural mortality for animals aged 0-30 years, and (iii) gear competition is modelled using Equation 1a of Punt and Thomson (2010):

$$U_y^a = q^a \, B_y^{e,a} \, \frac{1}{1+\gamma^a E_y^a} \, e^{\varepsilon_y^a}$$

where $U_y^a$ is the catch-rate for region *a* (Bass Strait, South Australia, or Tasmania) and year *y*, $q^a$ is the catchability coefficient for region *a*, $B_y^{e,a}$ is the exploitable biomass for region *a* and year *y*, $E_y^a$ is the nominal effort for region *a* and year *y*, $\gamma^a$ is the parameter that determines the extent of effort saturation / gear competition for region *a* (no gear competition if $\gamma^a$=0, with increasing amounts of gear competition as $\gamma^a$ is increased), and $\varepsilon_y^a$ is the observation error for region *a* and year *y* (assumed for consistency with past assessments to be normal with mean 0 and standard deviation 0.15). 'Gear competition' has been postulated for the fishery for gummy shark off southern Australia based on the observation that catches have been relatively insensitive to large changes in fishing effort (Pribac *et al.*, 2015).

The population dynamics model includes both length-specific gear-selectivity and age-specific availability. The values for the parameters of the selectivity functions are based on experimental results (Kirkwood and Walker, 1986). Differentiating availability from selectivity allows animals to be vulnerable to the gear (i.e., the selectivity of the gear allows them to be captured), but not to be available to the fishery (e.g., because they are not where the fishery operates) and hence not to be caught. Empirical evidence for non-uniform availability arises from analyses of length-composition data collected during fishery-independent surveys (A. E. Punt, unpubl. data, cited by Pribac *et al.*, 2005). Non-uniform availability may be a consequence of behavioral changes associated with ontogenetic changes in prey preference (Pribac *et al.*, 2005).

Table 17.3 lists the full set of models considered in the assessment, including the ‘bridging’ models used to modify the assessment specifications and data from the reference case model from that of the 2013 assessment to the reference case model for this assessment.

### 17.4.1 *Moving to a Continuous Model Formulation*

Figure 17.3 compares the time-trajectories of pup production in absolute terms and pup production relative to that in 1927 for Bass Strait, South Australia, and Tasmania, along with the fits to the catch-rate indices used in the 2013 assessment (Model 0) as well as for a variant of Model 0 in which the population dynamics model is continuous rather than discrete (Model 1A). The numbers of pups are consistently lower when the assessment is based on the continuous model. The relative pup production (pup production relative to the unfished level) is also lower (particularly for Bass Strait) when the assessment is based on the continuous model (Figure 17.3, center panels). Given the theoretical support for continuous dynamics, the remaining analyses are based on the Model 1A and variants thereof.

The estimate of natural mortality in the 2013 assessment (Model 0) was 0.177 $yr^{-1}$ (SD 0.013), which resulted in a MSY rate[2] of 0.22 to 0.24 depending on region, and given a value for the density-dependence parameter of 0.893 (Table 17.4). The estimate of natural mortality in Model 1A is almost the same as that for Model 0 (0.176$yr^{-1}$, SD 0.013) as is the estimate of the density-dependence parameter (0.973).

### 17.4.2 *Inclusion of Additional Fleets to the Model*

The 2013 assessment (and Model 1A) is based on five gear-types (four gillnet fleets; 6-inch, 6.5-inch, 7-inch and 8-inch, and shark longline). The shark longline gear (denoted "the hook fleet" in previous assessments) combines catches by shark longline and other gears (including trawl). Shark and scalefish longline are defined as being shallow and deeper than 183m, respectively. The legislative distinction between these gear types was removed during 2015, but will be preserved for the gummy shark stock assessment because the size composition of sharks landed by these gears differ. Using a combined line and trawl gear fleet was a defensible approach in past assessments given there were no catch-rate indices nor length and age data for catches by longlines and trawl. However, Sporcic (2016) provided catch-rate indices for trawl gear, and for bottom longlines (for which catches shallower then 183m predominate). In addition, length-composition data for gummy shark from onboard sampling are now available for trawl catches, catches by longlines targeted towards sharks and by longlines targeted towards scalefish (see Table 17.1 for sample sizes). The current "hook fleet" was consequently split into three fleets: trawl, shark longline, and scalefish longline (Figure A 17.1; Figure 17.2). Given there were no length, age and catch-rate data for the "hook fleet" in the 2013 assessment, the results of the assessment are unchanged from those from the 2013 assessment when the catches of the "hook fleet" are simply split into those for the three gear-types. Similarly, the results of Model 1A are insensitive to splitting the catches by the "hook fleet".

Appendix A shows that updated information changed the catches from 2007 onwards. Model 1B (Figure 17.3) shows that updating the catches in Model 1A to the revised catches does not have a large impact on the estimates of pup production, and the fits to the catch-rate data. The remaining analyses in this section are based on the catches used in Model 1B.

### 17.4.3 *Splitting the Catch-Rate Series for the Gillnet Fishery*

Figure 17.4 compares the catch-rate indices for 1997-2012 based on the SharkRAG approach and those developed by Sporcic (2016) by region (Bass Strait, South Australia and Tasmania). The indices for Bass Strait are very similar and those for Tasmania exhibit quite similar trends (the results for Tasmania would not be expected to be identical, owing to low catches, and hence likely sensitivity to changes to methodology). The trends in catch-rate for South Australia are qualitatively similar (no trend between 1999 and 2012), but there are some notable differences for particular years, most noticeably for 2001. The exact reasons for the differences are not clear (and given the major differences in approach, cannot be resolved by changing each step of the Punt *et al*. (2000) approach until it matches that of Sporcic (2016)), but the reasons probably relate to how the spatial distribution of catches off South Australia has changed over time.

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[2] MSYR - the ratio of MSY to the biomass at which MSY is achieved when exploitation is uniform on mature animals.

One way to move from the previous approach to one based on the standard methodology for constructing standardized catch-rate indices is as follows: (a) develop 'legacy' catch-rate series for Bass Strait (1976-1996), South Australia (1984-1996), and Tasmania (1990-1996) based on the original method for constructing catch rate indices (Punt *et al*., 2000; Punt 2004) by truncating the series used by Thomson and Sporcic (2014) in 1996; and (b) base the catch-rate indices for 1997 onwards on the standard methodology.

The potential implications of this change in methodology are evaluated using three new model variants:

- Model 1B: which uses the catch-rate indices on which the 2013 assessment was based.
- Model 2A: Model 1B, except the catch-rate series developed by Sporcic (2016) are used for the 1997-2012, and the catch-rate indices for the years prior to 1997 are based on those used by Thomson and Sporcic (2014), with the extent to which catchability changes with effort assumed to be constant over time (i.e. no effort saturation).
- Model 2B: Model 1B, except the catch-rates for 1997 onwards are replaced by those from Sporcic (2016), with the mean catch-rate for the Sporcic (2016) series set to equal to those for the original series to create a "spliced" series (Figure 17.4; dashed lines).
- Model 2C: Model 2B, but with the catch-rate series for the trawl and longline[3] gear-types included in the assessment.

The catch-rate series for trawl and shark longline gear are not disaggregated to region so are assumed to relate to all regions combined (with the possibility of gear saturation consequently ignored). The estimates of pup production from Model 2A are more pessimistic than those for Models 1B, 2B and 2C (Figure 17.5; Table 17.4). There is little difference in results between models 2B and 2C, including in terms of the fits to the gillnet catch-rate data. The fits to the catch-rate series for trawl and shark longline (Figure 17.6) are not very good, but it is hard to draw definitive conclusions given the short duration of these series.

#### 17.4.4 *Length-Composition Data*

The length-composition data from 2007 onwards have been updated since the last assessment. Gillnet mesh size is not available for the post-2007 length-composition data. Therefore, the length-composition data for Bass Strait and Tasmania were assumed to relate to catch by 6-inch mesh, and those for South Australia to 6.5-inch mesh, reflecting an assumption also made for the 2013 assessment that the length-composition data pertain to the gear-type that took the bulk of the catch. Figure 17.7 compares the length-composition data used in the 2013 assessment with the updated data. There is generally good agreement between the two sources of data, but this is not always the case (e.g. the length-composition data for 2008 off South Australia). In the absence of information to justify using the earlier data, the remaining analyses of this report are based on the revised data.

Figure 17.8 compares the estimates of the pup production and the fits to the catch-rate series for Model 2C and three model variants that modify the length-composition data used in the assessment.

[3] The longline catch-rate series was assumed to pertain to shark longline as the bulk of the catches by longline gear are from shark longline.

- Model 3A: As for Model 2C, except that the gill-net length-composition data are updated.
- Model 3B: As for Model 3A, except that the assessment includes the length-composition data for shark longline, trawl and scalefish longline. Longline and trawl selectivity is knife-edged.
- Model 3C: As for Model 3B, except that selectivity for shark longline, trawl and scalefish longline is assumed to be a logistic function of length (resulting in six additional estimable parameters).
- Model 3D: As for Model 3C, except that availability is assumed to be constant.

The results of the models 2C, and 3A-3C are all qualitatively similar. However, model 3D leads to markedly lower estimates of pup production in absolute terms and when expressed relative the 1927 level (Figure 17.8). The lower estimates of pup production for Model 3D are not surprising because this model assumes that the entire population is vulnerable to the gillnet sector, unlike the remaining models that allow for a "refuge" due to declining availability with size. Figure 17.9 shows the fits to the length-composition data when these data are aggregated over time. The improvement in fit by Models 3C and 3D over Model 3B is clearly evident in Figure 17.9. Models 3B, 3C and 3D are fitted to the same data, which means that the values for the negative log-likelihood function (including penalties) are comparable. These values are 1506, 1271, and 1337. Model 3C has six more parameters than Model 3B (the addition of these parameters is highly significant, $p$=1e$^{-98}$), while Model 3D has one fewer parameter than Model 3C (the retention of this parameter is also highly significant, $p$=8e$^{-31}$). Comparisons among the models need to be conducted with care, but there is strong evidence against models 3B and 3D and in favour of Model 3C. Figure 17.10 contrasts the estimated selectivity patterns for models 3B, 3C and 3D.

### 17.4.5 *Age-Reading Error*

Previous assessments of gummy shark have assumed that the age-estimates are exact, i.e. the differences between the observed and model-predicted age distributions are due only to sampling error. Appendix B analyses data from a double-read experiment to estimate the coefficient of variation of age-reading error, which is estimated to be 0.092 (SD 0.00468). Model 4A extends Model 3C by including age-reading error. Including age-reading error (but not the new age data), leads to slightly lower estimates of pup production in absolute terms, but negligible differences in pup production relative to the 1927 level (Figure 17.11).

## *17.5 Reference Case Model and Sensitivity Tests*

### 17.5.1 *Reference Case Analysis and Further Bridging Analyses*

Table 17.5 lists the number of parameters on which the reference case analysis is based. Compared to the 2013 assessment, there are 9 additional pup survival deviations (one for each of 2011, 2012 and 2013 for Bass Strait, South Australia, and Tasmania), and 6 additional selectivity parameters, with the total number of estimable parameters equal to 267. Table 17.6 lists the weights assigned to the length- and age-composition data. The weights (the average effective sample sizes) are set to 10 for those combinations of sex, region, gear-type for which the sample sizes are very low (i.e., below 50) – sufficiently low to allow selectivity to be estimated but not too large to influence final outcomes. A value of 25 was used for larger length frequency sample sizes, and a value of 50 for the combinations of sex, region and gear-type with the largest sample sizes.

The revised catch-rate indices (Sporcic, pers. commn) are shown in the upper panels of Figure 17.12. The overall catch-rate indices in this assessment are constructed using the "splicing" approach on which the catch-rate data used for Model 2B were based. The assessment also requires data on the total gillnet effort in a region to compute the extent of gear saturation, as well as the breakdown of the records used for catch-rate standardization by mesh size.

Figure 17.13 provides the results of the bridging analyses in which the updated catch (Model 5A), new length-composition (Model 5B), new age-composition (Model 5C) and new / updated catch-rates (Model 5D) are included in the assessment in turn. The analysis with all the new data (Model 5D) is the reference case analysis. The analyses that use the new age data (Model 5C) and the revised catch-rate indices (Model 5D) are more optimistic that Models 4A, 5A and 5B in absolute terms, as well as in a relative sense. Figure 17.13 shows asymptotic 90% confidence intervals for pup production (in absolute terms and relative to the 1927 level), as well as recruitment for the reference case analysis. As expected, the estimates of pup production in absolute terms are less precise than pup production in relative terms, which can be attributed in large part to uncertainty about historical recruitment (Figure 17.13, lower panels). It is noteworthy that the estimates are more precise for the regions (Bass Strait and South Australia) with more size- and age-composition data.

Figure 17.14, Figure 17.15, Figure 17.16 and Figure 17.17 show the fits to the catch-rate, length-composition, age-composition and tagging data for Model 5D. The fits to the gillnet catch-rate indices are generally satisfactory (Figure 17.14). The residual standard deviations for the gillnet catch-rate indices for Bass Strait and Tasmania (0.16 and 0.12) are close to the assumed value (0.15), as are the residual standard deviations for the trawl and shark longline indices (0.17 and 0.19), even though these indices are not very informative. However, the residual standard deviation for South Australia is larger than assumed (0.35 compared to 0.15). This due to several periods of poor fits (e.g. 1995-2001) and to some outliers (e.g. for 2001).

The model is able to mimic the size-composition data well, particularly for the combinations of sex, gear-type, and region with large sample sizes (Figure 17.15). However, the fits to the shark longline and particularly trawl length-compositions are fairly poor. The model is able to mimic the general pattern of the age-composition data, but given small sample sizes the fits are not very good in some cases. Appendix C shows the fits to the length- and age-composition data by year, sex, gear-type and region for Model 5D. As in previous assessments, the fits to the tagging data (Figure 17.17) are good.

All three stocks are assessed (according to the reference model, Model 5D) to have been above the management target of $0.48B_0$ (in terms of pup production) at the start of 2016: $0.59B_0$ (Bass Strait), $0.69B_0$ (South Australia), $0.83B_0$ (Tasmania), with no evidence (in point estimate terms) that the stocks were ever below the management target. The base-case estimate for the effort saturation parameter for South Australia is 50 (the upper limit for this parameter). A value for "50" implies high effort saturation, but values from approximately 10 and above all imply this – the specific value of "50" is the best estimate, but is fairly imprecise. Sensitivity results (Model 6B; Section 4.2) suggest that the results in terms of pup production are not very sensitive to allowing for effort saturation, but doing so leads to quite markedly better fits to the data (-LnL value of 1673 for sensitivity Model 6B compared to 1610 for the reference case model).

Appendix D provides the variance co-variance matrix for the leading parameters (i.e. ignoring the annual recruitment deviations) and suggests fairly low correlation among the parameters (no correlations of 0.7 and higher in absolute terms). Figure 17.18 compares the estimates of pup production to those of female spawning biomass. As expected, there is a close to linear relationship between the model outputs.

### 17.5.2 *Sensitivity Analyses*

Table 17.3 lists the sensitivity analyses used to examine the sensitivity of the results to key uncertainties. Table 17.7 lists the values for some key model outputs. The sensitivity tests explore the sensitivity of the results to some key assumptions (Models 6B-6Q) and to inclusion and weighting of data (Models 6A, and 6R-6V). Models 6D and 6E were introduced to attempt to fit the length-frequency data better and to test the support for the availability function. The aggregated summaries in Figure 17.15 are suggestive of systematic lack of fit to some combinations of region and gear-type. Models 6D and 6E involve estimating the values for the two parameters that determine the gill-net selectivity patterns (assumed to be the same spatially).

In general, the results are insensitive to varying the assumptions of the model. The sensitivity tests that lead to notable (>10% change in estimated 2016 depletion) changes to the results involve (a) ignoring the availability functions [Models 6C and 6E] (but this leads to poor fits to the data), (b) assuming density dependence impacts only younger ages (0-2 and 0-4; Models 6J, 6M, 6N, and 6O), and (c) assuming that density-dependence impacts fecundity (tests 6P, and 6Q). Models 6J, 6M, 6N 6O, 6P, and 6Q all fit the data better than the reference case model, primarily owing to better fits to the catch-rate series (Table 17.7). The model fits to the length-composition data were slightly better when selectivity was estimated, but the effect was fairly minor (Models 6D and 6E).

## *17.6 Projections and Management Quantities*

### 17.6.1 *Recommended Biological Catches*

The Recommended Biological Catches (RBCs) are calculated for each projection year by first computing the fully-selected fishing mortality corresponding to reducing (or rebuilding) the pup production to 48% of unfished pup production when the relative split of fully-selected fishing mortality among gear-types matches that for 2015 (the last year with catches). This fishing mortality is then reduced if pup production is less than 35% of the unfished level and used to compute the catch for each future year. The projections are based on the assumption that pup production equals the value from the stock-recruitment relationship.

Table 17.8 lists the RBCs for 2016-2025, along with the catches for 2014 and 2015 by region, while Table 17.9 lists the RBCs for 2016-2025 by region and gear-type. Figure 17.19 shows the time-trajectories of RBC for a 30-year projection period. The values in Table 17.8 and Table 17.9 are total RBCs (i.e. included the impact of discards). The long-term RBCs (i.e., the total catch when the pup production by region are 48% of unfished pup production) by region are 1098t (Bass Strait), 650t (South Australia), and 213t (Tasmania) (Figure 17.19).

### 17.6.2 *Alternative Projections*

10-year projections are undertaken for the reference case model for the following the scenarios:

1. Status quo (project using the parameter values of the base case assessment, and the RBC catch levels in Table 17.8 and Table 17.9).
2. All future catches are taken by shark longline (with the total annual catches by region set to those for the status-quo).

3. The longline catch in South Australia increases so the total catch off South Australia equals maximum historical catch; the catches by region for the remaining regions are set to the reference case values.
4. All catch is by 6.5” gillnets (with the total annual catches by region set to those for the status-quo).
5. All catch is shark longline (with the total annual catches by region set to those for the status-quo).
6. All catch is by scalefish longline (with the total annual catches by region set to those for the status-quo).
7. The total catch for each future year is set to 2052t (the current TAC, 1836t, plus recent average State catches, 120t, and discards 96t), with the split to region and gear-type based on the data for 2015.
8. The total catch for each future year is set to 1961t (the long-term RBC), with the split to region and gear-type based on the data for 2015.
9. The total catch for each future year is set to 1922t (the average of the RBCs over the first three years, 2016, 2017, 2018), with the split to region and gear-type based on the data for 2015.

Table 17.10 lists the catches by year and region for the nine projection scenarios. Note that the catches by region are the same for some of the cases (e.g. 4, 5 and 6) because these cases change the split of the catch by region to gear-type and not the total catch by region. The results of the projections are summarized by pup production relative to unfished pup production in 2017, 2019, 2012 and 2016 (i.e. after 1, 3, 5 and 10 years; Table 17.11). These sensitivities examine the relative impact of each gear type on the stock.

## 17.7 General Discussion

### 17.7.1 *Future Work*

- Selectivity: Sensitivity tests 6D and 6E are more general than the reference case model. However, the estimated selectivity patterns are not very general. Future work should consider more general functional forms (e.g. double logistic), and with parameters that vary among regions.
- The model pre-specifies growth and its variation. The model should be extended to include the data on which the growth curves are based and hence to estimate growth within the model.
- The values for the effective sample sizes (length- and age-composition data) are pre-specified and the assumed standard deviations for the catch-rate indices are based on auxiliary analyses conducted many years ago. Approaches (e.g., Francis, 2011) now exist for providing a more objective way to set effective sample sizes and residual standard deviations, and these warrant further exploration in future assessments.
- The models in which density-dependence acts on a narrower range of ages lead to better fits. Future assessments should consider whether these models provide a better basis for a reference case analysis. The current assumptions regarding density-dependence are based on earlier decisions by SharkRAG.
- A fishery independent trawl survey has been conducted in the Great Australian Bight (GAB FIS) since 2005 (Knuckey *et al*. 2015). Gummy shark are caught in this survey in relatively small

numbers that are nevertheless sufficient to provide an index of abundance in the GAB with a relatively low annual CV. This offers an alternative to the gillnet CPUE series, which is no longer providing a consistent index of abundance due to sea lion closures. To use the GAB FIS index in the stock assessment, a selectivity curve would need to be estimated or assumed. Fewer than 100 gummy shark are caught in the survey each year, and although all are measured, there is little information from which to estimate a selectivity curve. The assumption cannot be made that the selectivity of the survey matches that of the commercial trawl fishery because the survey is operationally too different (Ian Knuckey, Fishwell Consulting, pers comm). An abundance index based on fewer than 100 animals per year is questionable. Together with the lack of a selectivity curve, SharkRAG concluded that the GAB FIS index could not be used in the gummy shark stock assessment model.

- Another trawl fishery-independent survey, in the region of the SESSF not conducted in the GAB (SET FIS) is also available. CVs of below 0.3 are available for gummy shark for some regions and years, along with length frequency data. However, the inter-annual variation in the SET FIS estimates is higher than is biologically reasonable. The survey does not operate in the core area of shark fishing. SharkRAG decided against using these data in the gummy assessment.

#### 17.7.2 *Utility of Collecting Vertebrae*

SharkRAG requested that simulations be conducted to evaluate the utility of collecting vertebrae for ages, including the evaluation of alternative sample sizes and sampling frequencies (annual, biennual, triennial). Such an investigation is outside the scope of a stock assessment. More details of the procedure that would be involved, and information requirements for such a procedure, are shown in Appendix E.

#### 17.7.3 *Final Note*

The Australian sea lion (ASL) closures in South Australia led to greatly reduced catches by gillnets. However, that trend showed a slight reversal in 2015. Members of the shark fishing industry suggest that this is due to greater confidence by skippers in their ability to fish closer to ASL closures without triggering bycatch limits that would shut the fishery.

## 17.8 Acknowledgements

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Table 17.1. Sample sizes for new (shark longline, trawl, scalefish longline, gillnet since 2013) and revised (2007-2012; gillnet) length-composition data. Entries indicated by asterisks are combinations of region, gillnet mesh size and year not included in the assessment because the sample size is less than 400.

| | Bass Strait | | South Australia | | Tasmania | |
|---|---|---|---|---|---|---|
| | Female | Male | Female | Male | Female | Male |
| Shark longline | | | | | | |
| 2004 | 158 | 64 | 0 | 0 | 0 | 0 |
| 2012 | 0 | 0 | 397 | 189 | 209 | 136 |
| 2013 | 303 | 206 | 507 | 62 | 97 | 56 |
| 2014 | 0 | 0 | 1368 | 772 | 513 | 174 |
| 2015 | 0 | 0 | 35 | 14 | 0 | 0 |
| 2016 | 0 | 0 | 49 | 16 | 0 | 0 |
| Gillnet | | | | | | |
| 2007 | 0 | 0 | 136* | 132* | 0 | 0 |
| 2008 | 803 | 1828 | 412 | 581 | 0 | 0 |
| 2009 | 2193 | 1464 | 1063 | 562 | 0 | 0 |
| 2010 | 1535 | 2746 | 1304 | 391* | 146* | 436 |
| 2011 | 5052 | 8739 | 1978 | 955 | 293* | 271* |
| 2012 | 5693 | 11808 | 1082 | 443 | 564 | 996 |
| 2013 | 5739 | 10362 | 400 | 1127 | 442 | 905 |
| 2014 | 4811 | 5761 | 1093 | 354* | 274* | 558 |
| 2015 | 1834 | 2229 | 147* | 606 | 30* | 243* |
| Trawl | | | | | | |
| 1995 | 7 | 0 | 0 | 0 | 0 | 0 |
| 2003 | 10 | 11 | 0 | 0 | 0 | 0 |
| 2014 | 7 | 0 | 0 | 0 | 0 | 0 |
| Scalefish longline | | | | | | |
| 2003 | 0 | 0 | 0 | 0 | 28 | 13 |
| 2004 | 0 | 0 | 0 | 0 | 16 | 11 |
| 2009 | 0 | 0 | 77 | 17 | 6 | 0 |
| 2010 | 45 | 42 | 0 | 0 | 28 | 8 |
| 2011 | 0 | 0 | 19 | 7 | 0 | 0 |
| 2012 | 0 | 17 | 0 | 0 | 9 | 7 |
| 2013 | 49 | 80 | 0 | 0 | 144 | 117 |
| 2014 | 0 | 0 | 13 | 9 | 0 | 0 |

Table 17.2. Summary of the available age-composition data. Asterisks indicate samples that are new to this assessment.

| | Bass Strait | | South Australia | |
|---|---|---|---|---|
| | Female | Male | Female | Male |
| 6-inch mesh | | | | |
| 1986 | 72 | 76 | 0 | 0 |
| 1987 | 39 | 27 | 0 | 0 |
| 1990 | 43 | 83 | 0 | 0 |
| 1991 | 179 | 141 | 0 | 0 |
| 1992 | 68 | 70 | 0 | 0 |
| 1993 | 190 | 184 | 0 | 0 |
| 1995* | 77 | 50 | 0 | 0 |
| 1997* | 0 | 0 | 69 | 108 |
| 2002* | 0 | 0 | 7 | 47 |
| 2003* | 96 | 98 | 0 | 0 |
| 2007 | 0 | 0 | 70 | 54 |
| 2008 | 41 | 35 | 10 | 44 |
| 6.5-inch mesh | | | | |
| 1995* | 32 | 66 | 26 | 34 |
| 1997* | 0 | 0 | 10 | 10 |
| 2002* | 0 | 0 | 13 | 54 |
| 7-inch mesh | | | | |
| 1986 | 0 | 0 | 56 | 23 |
| 1990 | 0 | 0 | 54 | 10 |
| 1992 | 0 | 0 | 79 | 81 |
| 1993 | 0 | 0 | 76 | 69 |
| 1995* | 0 | 0 | 37 | 56 |

Table 17.3. Alternative models (including sensitivity tests – models 6A-6V).

| Model No | Description |
|---|---|
| 0 | 2013 base model |
| 1A | Replace discrete model with continuous model |
| 1B | Model 1A with updated catches (Appendix A) |
| 2A | Model 1B, but including the Sporcic (2016) CPUE |
| 2B | Model 1B, but including the spliced CPUE approach |
| 2C | Model 2B, but with trawl and line CPUE |
| 3A | Model 2C with updated gill-net length-composition data |
| 3B | Model 3A with trawl and line length-composition data |
| 3C | Model 3B with trawl and line selectivity estimated |
| 3D | Model 3C with constant availability |
| 4A | Model 3C with ageing error matrices |
| 5A | Model 4A with updated catches for 2001-12 and the 2013-15 catches |
| 5B | Model 5A with the length-composition data for 2013-15 |
| 5C | Model 5B with new catch-rate indices for 2007-15 |
| 5D | Model 5C with new age-composition data (Table 4) [**the reference case model**] |
| | |
| 6A | Model 5D with CPUE data for South Australia to 2015 |
| 6B | Model 5D with effort saturation eliminated |
| 6C | Model 5D with constant availability |
| 6D | Model 5D with gillnet selectivity estimated |
| 6E | Model 5D with gillnet selectivity estimated and constant availability |
| 6F | Model 5D, but with *M* fixed at 0.14$yr^{-1}$ |
| 6H | Model 5D, but with *M* fixed at 0.16 $yr^{-1}$ |
| 6I | Model 5D with density-dependence on *M* for ages 0-15 based on 1+ biomass |
| 6J | Model 5D with density-dependence on *M* for ages 0-4 based on 1+ biomass |
| 6K | Model 5D with density-dependence on *M* for ages 0-30 based on mature biomass |
| 6L | Model 5D with density-dependence on *M* for ages 0-15 based on mature biomass |
| 6M | Model 5D with density-dependence on *M* for ages 0-4 based on mature biomass |
| 6N | Model 5D with density-dependence on *M* for ages 0-2 based on 1+ biomass |
| 6O | Model 5D with density-dependence on *M* for ages 0-2 based on mature biomass |
| 6P | Model 5D with density-dependence on fecundity based on 1+ biomass |
| 6Q | Model 5D with density-dependence on fecundity based on mature biomass |
| 6R | Half weight on CPUE data |
| 6S | Half weight on length-composition data |
| 6T | Half weight on age-composition data |
| 6U | Half weight on tagging data |
| 6V | Double weight on CPUE data |

Table 17.4. Estimates of various quantities of importance from the bridging models, showing adult natural mortality rate “$M_a$”, pup production in year ‘X’ compared with pristine “PembryoX” (%), the effort saturation parameter value for each population “effort sat’n”, and the negative log likelihood “-LnL” and its constituent components. A brief description of each sensitivity test is provided in the last column.

| # | $M_a$ | $B_0$ | | | MSYR | | | Pembryo73 | | | Pembryo13 | | | Effort sat’n | | | -LnL | -LnL components | | | | | Brief description |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | BS | SA | TS | BS | SA | TS | BS | SA | TS | BS | SA | TS | BS | SA | TS | | CPUE | Len | Age | Tag | Prior | of sensitivity test |
| 0 | 0.18 | 9864 | 5492 | 2253 | 0.22 | 0.24 | 0.22 | 65 | 71 | 91 | *59* | *69* | *83* | 25.5 | 8.6 | 0 | 1028 | 85 | 457 | 151 | 297 | 37 | 2013 base case |
| 1A | 0.18 | 8299 | 4862 | 1876 | 0.25 | 0.27 | 0.25 | 60 | 67 | 89 | 49 | 64 | 79 | 18.8 | 8.9 | 0 | 1033 | 89 | 452 | 151 | 303 | 38 | With continuous dynamics |
| 1B | 0.17 | 8941 | 5377 | 2005 | 0.24 | 0.27 | 0.24 | 60 | 68 | 88 | 45 | 54 | 76 | 14.6 | 8.1 | 0 | 1039 | 92 | 450 | 155 | 302 | 40 | With revised catches |
| 2A | 0.19 | 9004 | 5145 | 2040 | 0.21 | 0.23 | 0.21 | 58 | 65 | 88 | 35 | 44 | 76 | 0 | 0 | 0 | 1012 | 83 | 443 | 162 | 292 | 32 | With Sporcic CPUE |
| 2B | 0.18 | 9196 | 5416 | 2049 | 0.23 | 0.25 | 0.23 | 60 | 68 | 89 | 44 | 54 | 77 | 5.80 | 1.51 | 0 | 1062 | 106 | 452 | 157 | 304 | 43 | With spliced Sporcic CPUE |
| 2C | 0.18 | 9016 | 5310 | 2004 | 0.24 | 0.26 | 0.24 | 61 | 68 | 89 | 45 | 54 | 77 | 4.75 | 2.21 | 0 | 1089 | 123 | 451 | 165 | 305 | 44 | With trawl and line CPUE |
| 3A | 0.18 | 9139 | 5415 | 2032 | 0.23 | 0.25 | 0.23 | 59 | 67 | 88 | 49 | 54 | 76 | 1.06 | 1.62 | 0 | 1110 | 119 | 481 | 161 | 302 | 46 | Updated length gillnet data |
| 3B | 0.18 | 9185 | 5440 | 1975 | 0.23 | 0.25 | 0.23 | 60 | 67 | 88 | 50 | 55 | 76 | 1.13 | 1.71 | 0 | 1506[a] | 118 | 874 | 165 | 302 | 48 | With trawl and line length data |
| 3C | 0.18 | 9129 | 5388 | 1877 | 0.23 | 0.25 | 0.23 | 60 | 67 | 87 | 50 | 54 | 75 | 1.09 | 1.84 | 0 | 1271[a] | 120 | 640 | 165 | 300 | 47 | Estimated trawl and line selectivity |
| 3D | 0.3 | 6825 | 4368 | 1314 | 0.24 | 0.26 | 0.24 | 46 | 63 | 81 | 32 | 40 | 62 | 2.00 | 1.86 | 0 | 1337[a] | 132 | 683 | 168 | 290 | 65 | With constant availability |
| 4A | 0.18 | 8994 | 5240 | 1844 | 0.23 | 0.25 | 0.23 | 59 | 67 | 87 | 50 | 53 | 75 | 1.03 | 1.88 | 0 | 1269 | 117 | 639 | 166 | 298 | 49 | With updated age data |

a: comparable negative log-likelihoods.

Table 17.5. Estimable parameters of the reference case model. The values in parenthesis indicate the bounds on the parameters.

| Parameter | Number of parameters<br>Bass Strait | South Australia | Tasmania | Total |
|---|---|---|---|---|
| Unfished pup numbers | 1<br>(-15, 25) | 1<br>(-15, 25) | 1<br>(-15,25) | 3 |
| Adult natural mortality | | 1 (shared)<br>(0.1,0.3) | | 1 |
| Density-dependence parameter | | 1 (shared)<br>(0,1) | | 1 |
| Gear saturation parameters | 1<br>(0, 50) | 1<br>(0, 50) | 1<br>(0, 50) | 3 |
| Pup survival deviations | 84<br>(-5,5) | 84<br>(-5.5) | 84<br>(-5.5) | 252 |
| Gear selectivity | | 6 (shared)<br>($L_{50}$: 600, 2000; Slope: -20, 1) | | 6 |
| Total | | | | 267 |

Table 17.6. The weights assigned to the length- and age-composition data. “N/A” denotes that there are no data of the type concerned.

| | Bass Strait | South Australia | Tasmania |
|---|---|---|---|
| *(a) Length data* | | | |
| Shark Longline | 10 | 10 | 10 |
| 6” gillnet | 50 | N/A | 10 |
| 6.5” gillnet | N/A | 25 | N/A |
| 7” gillnet | 50 | 25 | 10 |
| 8” gillnet | N/A | N/A | N/A |
| Trawl | 10 | 10 | N/A |
| Scalefish longline | 10 | 10 | 10 |
| *(b) Age data* | | | |
| Shark Longline | N/A | N/A | N/A |
| 6” gillnet | 25 | 25 | N/A |
| 6.5” gillnet | 25 | 25 | N/A |
| 7” gillnet | N/A | 25 | N/A |
| 8” gillnet | N/A | N/A | N/A |
| Trawl | N/A | N/A | N/A |
| Scalefish longline | N/A | N/A | N/A |

Table 17.7. Estimates of various quantities of importance, showing adult natural mortality rate “$M_a$”, pup production in year ‘X’ compared with pristine “PembryoX” (%), the effort saturation parameter value for each population “effort sat’n”, and the negative log likelihood “-LnL” and its constituent components. A brief description of each sensitivity test is provided in the last column. Numbers (italics) under “Pembryo16” refer to depletion in 2013 not 2016.

| # | $M_a$ | $B_0$ | | | MSYR | | | Pembryo73 | | | Pembryo16 | | | Effort sat’n | | | -LnL | -LnL components | | | | | Brief description |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | BS | SA | TS | BS | SA | TS | BS | SA | TS | BS | SA | TS | BS | SA | TS | | CPUE | Len | Age | Tag | Prior | of sensitivity est |
| 0 | 0.18 | 9864 | 5492 | 2253 | 0.22 | 0.24 | 0.22 | 65 | 71 | 91 | *59* | *69* | *83* | 25.5 | 8.56 | 0 | 1028 | 85 | 457 | 151 | 297 | 37 | 2013 base case |
| 4A | 0.18 | 8994 | 5240 | 1844 | 0.23 | 0.25 | 0.23 | 59 | 67 | 87 | *50* | *53* | *75* | 1.03 | 1.88 | 0 | 1269 | 117 | 639 | 166 | 298 | 49 | 2013 base case with model updates |
| 5A | 0.19 | 9010 | 5255 | 1837 | 0.23 | 0.25 | 0.23 | 59 | 67 | 87 | 47 | 52 | 73 | 1.10 | 1.89 | 0 | 1265 | 117 | 634 | 166 | 298 | 50 | With the addition of catch data |
| 5B | 0.19 | 8796 | 5243 | 1820 | 0.23 | 0.25 | 0.23 | 58 | 67 | 87 | 45 | 55 | 72 | 1.18 | 1.81 | 0 | 1370 | 113 | 743 | 166 | 299 | 50 | With the addition of length data |
| 5C | 0.16 | 9171 | 6023 | 2054 | 0.25 | 0.27 | 0.25 | 60 | 71 | 89 | 51 | 63 | 77 | 1.64 | 2.25 | 0 | 1638 | 146 | 747 | 378 | 319 | 46 | With the addition of age data |
| **5D** | **0.16** | **9406** | **6104** | **1949** | **0.25** | **0.27** | **0.25** | **61** | **71** | **88** | **53** | **63** | **75** | **4.38** | **50** | **0** | **1610** | **129** | **751** | **366** | **315** | **48[a]** | **With the addition of catch-rate data** |
| 6A | 0.16 | 9630 | 6199 | 1987 | 0.24 | 0.26 | 0.24 | 61 | 71 | 88 | 53 | 64 | 75 | 4.81 | 50 | 0 | 1621 | 137 | 751 | 369 | 316 | 49 | SA CPUE to 2015 |
| 6B | 0.16 | 9794 | 6509 | 2011 | 0.22 | 0.25 | 0.22 | 60 | 72 | 88 | 52 | 64 | 74 | 0 | 0 | 0 | 1673 | 164 | 759 | 380 | 310 | 61[a] | No effort saturation |
| 6C | 0.27 | 7117 | 4891 | 1321 | 0.25 | 0.27 | 0.25 | 47 | 66 | 81 | 35 | 51 | 59 | 4.3 | 50 | 0 | 1676 | 138 | 808 | 373 | 290 | 67[a] | Constant availability |
| 6D | 0.15 | 9550 | 6245 | 2148 | 0.24 | 0.27 | 0.24 | 62 | 73 | 90 | 53 | 65 | 78 | 5.02 | 50 | 0 | 1604 | 129 | 742 | 361 | 324 | 48[a] | Estimate gillnet selectivity |
| 6E | 0.21 | 8065 | 5351 | 1481 | 0.25 | 0.28 | 0.25 | 54 | 67 | 82 | 46 | 54 | 64 | 3.83 | 50 | 0 | 1641 | 133 | 783 | 375 | 297 | 54[a] | Estimate gillnet selectivity; const availability |
| 6F | 0.14 | 10104 | 6483 | 2225 | 0.25 | 0.27 | 0.25 | 63 | 72 | 89 | 55 | 65 | 78 | 4.54 | 50 | 0 | 1612 | 128 | 748 | 362 | 327 | 47[a] | $M = 0.14y^{-1}$ |
| 6H | 0.18 | 8953 | 5863 | 1777 | 0.25 | 0.27 | 0.25 | 59 | 71 | 87 | 52 | 62 | 73 | 4.26 | 50 | 0 | 1611 | 131 | 753 | 371 | 307 | 49[a] | $M = 0.18y^{-1}$ |
| 6I | 0.16 | 9495 | 6131 | 1973 | 0.26 | 0.28 | 0.26 | 57 | 67 | 86 | 46 | 59 | 70 | 4.04 | 50 | 0 | 1609 | 129 | 754 | 364 | 314 | 49[a] | Dens dep M; ages 0-15 on 1+ biomass |
| 6J | 0.12 | 10968 | 6988 | 2365 | 0.23 | 0.25 | 0.23 | 51 | 61 | 84 | 34 | 53 | 64 | 5.5 | 50 | 0 | 1604 | 126 | 746 | 357 | 332 | 44[a] | Dens dep M; ages 0-4 on 1+ biomass |
| 6K | 0.17 | 8149 | 5473 | 1788 | 0.2 | 0.22 | 0.2 | 54 | 91 | 88 | 57 | 88 | 74 | 6.93 | 50 | 0 | 1583 | 104 | 743 | 368 | 320 | 47[a] | Dens dep M; ages 0-30 on mature biomass |
| 6L | 0.18 | 8039 | 5369 | 1744 | 0.19 | 0.21 | 0.19 | 50 | 92 | 87 | 52 | 87 | 70 | 6.48 | 47.92 | 0 | 1580 | 103 | 747 | 366 | 317 | 47[a] | Dens dep M; ages 0-15 on mature biomass |
| 6M | 0.14 | 7882 | 5133 | 1917 | 0.18 | 0.2 | 0.18 | 37 | 92 | 85 | 41 | 89 | 70 | 10.09 | 50 | 0 | 1576 | 104 | 735 | 359 | 331 | 46[a] | Dens dep M; ages 0-4 on mature biomass |
| 6N | 0.12 | 11329 | 7097 | 2286 | 0.22 | 0.24 | 0.22 | 48 | 60 | 82 | 31 | 52 | 59 | 6.57 | 50 | 0 | 1597 | 125 | 739 | 357 | 330 | 46[a] | Dens dep M; ages 0-2 on 1+ biomass |
| 6O | 0.15 | 6483 | 4316 | 1545 | 0.19 | 0.21 | 0.19 | 25 | 90 | 82 | 39 | 90 | 66 | 19.4 | 50 | 0 | 1562 | 106 | 724 | 363 | 325 | 45[a] | Dens dep M; ages 0-2 on mature biomass |
| 6P | 0.14 | 7664 | 5217 | 1371 | 0.16 | 0.15 | 0.16 | 49 | 67 | 77 | 38 | 54 | 60 | 7.41 | 50 | 0.02 | 1602 | 128 | 750 | 359 | 319 | 46[a] | Dens dep fecundity on 1+ biomass |
| 6Q | 0.13 | 7812 | 4579 | 1413 | 0.13 | 0.13 | 0.13 | 31 | 99 | 90 | 40 | 100 | 79 | 7.97 | 50 | 0 | 1562 | 100 | 740 | 359 | 327 | 36[a] | Dens dep fecundity on mature biomass |
| 6R | 0.17 | 9095 | 5957 | 1905 | 0.26 | 0.28 | 0.26 | 60 | 72 | 88 | 53 | 62 | 75 | 3.72 | 50 | 0 | 1537 | 168 | 753 | 350 | 306 | 44 | Half weight on CPUE data |
| 6S | 0.17 | 10070 | 5925 | 1873 | 0.23 | 0.26 | 0.23 | 63 | 69 | 87 | 55 | 59 | 72 | 4.54 | 50 | 0 | 1223 | 130 | 806 | 347 | 299 | 45 | Half weight on length-comp data |
| 6T | 0.18 | 8973 | 5464 | 1804 | 0.24 | 0.27 | 0.24 | 60 | 69 | 87 | 51 | 59 | 73 | 2.69 | 50 | 0 | 1411 | 112 | 739 | 435 | 298 | 46 | Half weight on age-comp data |
| 6U | 0.12 | 9561 | 7037 | 2309 | 0.26 | 0.29 | 0.26 | 60 | 73 | 89 | 51 | 69 | 80 | 10.54 | 50 | 0 | 1436 | 123 | 728 | 347 | 388 | 44 | Half weight on tagging data |
| 6V | 0.16 | 9893 | 6331 | 1968 | 0.23 | 0.25 | 0.23 | 61 | 70 | 87 | 51 | 64 | 73 | 5.42 | 50 | 0 | 1718 | 92 | 753 | 394 | 327 | 60 | Double weight on CPUE data |

Table 17.8. Catches by region (2014 and 2015), and projected recommended biological catches (2016-2015) based on Model 5D.

| Year | Bass Strait | South Australia | Tasmania | Total |
|---|---|---|---|---|
| 2014 | 1077.1 | 528.7 | 121.7 | 1727.5 |
| 2015 | 1280.8 | 533.7 | 93.7 | 1908.3 |
| 2016 | 1080.3 | 743.8 | 255.6 | 2079.6 |
| 2017 | 1002.3 | 648.2 | 227.5 | 1878.1 |
| 2018 | 995.2 | 600.8 | 211.6 | 1807.6 |
| 2019 | 1028.1 | 585.9 | 202.9 | 1816.9 |
| 2020 | 1070.1 | 598.5 | 203.1 | 1871.7 |
| 2021 | 1100.4 | 625.7 | 208.5 | 1934.7 |
| 2022 | 1113.9 | 653.5 | 215.0 | 1982.4 |
| 2023 | 1115.2 | 672.6 | 219.6 | 2007.4 |
| 2024 | 1111.1 | 680.3 | 221.8 | 2013.2 |
| 2025 | 1107.1 | 678.7 | 221.9 | 2007.6 |

Table 17.9. Projected recommended biological catches (2016-2025) by region and gear-type based on Model 5D. 'Depletion' refers to pup production relative to unfished pup production.

| | | | Gear type | | | | |
|---|---|---|---|---|---|---|---|
| Year | Depletion | Total | Shark Longline | 6" gillnet | 6.5" gillnet | Trawl | Scalefish longline |
| Bass Strait | | | | | | | |
| 2016 | 53.0 | 1080.3 | 9.4 | 1007.9 | 0.0 | 62.6 | 0.4 |
| 2017 | 53.2 | 1002.3 | 8.8 | 933.1 | 0.0 | 60.1 | 0.3 |
| 2018 | 53.2 | 995.2 | 8.7 | 925.7 | 0.0 | 60.4 | 0.4 |
| 2019 | 53.0 | 1028.1 | 8.8 | 957.1 | 0.0 | 61.8 | 0.4 |
| 2020 | 52.8 | 1070.1 | 8.9 | 997.7 | 0.0 | 63.1 | 0.4 |
| 2021 | 52.4 | 1100.4 | 9.1 | 1027.2 | 0.0 | 63.8 | 0.4 |
| 2022 | 52.0 | 1113.9 | 9.1 | 1040.6 | 0.0 | 63.9 | 0.4 |
| 2023 | 51.7 | 1115.2 | 9.1 | 1042.0 | 0.0 | 63.7 | 0.4 |
| 2024 | 51.4 | 1111.1 | 9.1 | 1038.3 | 0.0 | 63.4 | 0.4 |
| 2025 | 51.1 | 1107.1 | 9.0 | 1034.5 | 0.0 | 63.3 | 0.4 |
| South Australia | | | | | | | |
| 2016 | 63.2 | 743.8 | 416.7 | 150.4 | 102.9 | 68.8 | 5.0 |
| 2017 | 62.5 | 648.2 | 367.2 | 127.9 | 87.2 | 61.3 | 4.5 |
| 2018 | 62.0 | 600.8 | 341.8 | 117.9 | 78.5 | 58.4 | 4.3 |
| 2019 | 61.2 | 585.9 | 331.9 | 116.7 | 74.7 | 58.3 | 4.3 |
| 2020 | 60.0 | 598.5 | 335.7 | 122.6 | 75.6 | 60.1 | 4.4 |
| 2021 | 58.5 | 625.7 | 346.9 | 132.1 | 79.6 | 62.5 | 4.6 |
| 2022 | 56.9 | 653.5 | 358.9 | 140.9 | 84.6 | 64.4 | 4.7 |
| 2023 | 55.2 | 672.6 | 367.2 | 146.5 | 88.6 | 65.4 | 4.8 |
| 2024 | 53.8 | 680.3 | 370.7 | 148.5 | 90.8 | 65.5 | 4.8 |
| 2025 | 52.7 | 678.7 | 370.0 | 147.6 | 91.3 | 65.0 | 4.7 |
| Tasmania | | | | | | | |
| 2016 | 75.0 | 255.6 | 44.4 | 160.2 | 0.0 | 42.8 | 8.1 |
| 2017 | 71.7 | 227.5 | 39.9 | 142.0 | 0.0 | 38.4 | 7.3 |
| 2018 | 69.0 | 211.6 | 37.2 | 131.4 | 0.0 | 36.1 | 6.9 |
| 2019 | 66.7 | 202.9 | 35.5 | 125.6 | 0.0 | 35.1 | 6.7 |
| 2020 | 64.6 | 203.1 | 35.1 | 126.0 | 0.0 | 35.3 | 6.7 |
| 2021 | 62.5 | 208.5 | 35.4 | 130.4 | 0.0 | 35.9 | 6.8 |
| 2022 | 60.6 | 215.0 | 35.9 | 135.6 | 0.0 | 36.5 | 7.0 |
| 2023 | 58.8 | 219.6 | 36.3 | 139.5 | 0.0 | 36.8 | 7.0 |
| 2024 | 57.2 | 221.8 | 36.5 | 141.3 | 0.0 | 36.9 | 7.0 |
| 2025 | 55.9 | 221.9 | 36.5 | 141.6 | 0.0 | 36.7 | 7.0 |

Table 17.10. Catch by region for the nine projection cases.

| Year | Base-case | | | | Case 2 | | | | Case 3 | | | | Case 4 | | | | Case 5 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | BS | SA | TAS | Total | BS | SA | TAS | Total | BS | SA | TAS | Total | BS | SA | TAS | Total | BS | SA | TAS | Total |
| 2016 | 1080 | 744 | 256 | 2080 | 1080 | 744 | 256 | 2080 | 1080 | 744 | 256 | 2080 | 1080 | 744 | 256 | 2080 | 1080 | 744 | 256 | 2080 |
| 2017 | 1002 | 648 | 228 | 1878 | 1002 | 648 | 228 | 1878 | 1002 | 744 | 228 | 1974 | 1002 | 648 | 228 | 1878 | 1002 | 648 | 228 | 1878 |
| 2018 | 995 | 601 | 212 | 1808 | 995 | 601 | 212 | 1808 | 995 | 744 | 212 | 1951 | 995 | 601 | 212 | 1808 | 995 | 601 | 212 | 1808 |
| 2019 | 1028 | 586 | 203 | 1817 | 1028 | 586 | 203 | 1817 | 1028 | 744 | 203 | 1975 | 1028 | 586 | 203 | 1817 | 1028 | 586 | 203 | 1817 |
| 2020 | 1070 | 598 | 203 | 1872 | 1070 | 598 | 203 | 1872 | 1070 | 744 | 203 | 2017 | 1070 | 598 | 203 | 1872 | 1070 | 598 | 203 | 1872 |
| 2021 | 1100 | 626 | 209 | 1935 | 1100 | 626 | 209 | 1935 | 1100 | 744 | 209 | 2053 | 1100 | 626 | 209 | 1935 | 1100 | 626 | 209 | 1935 |
| 2022 | 1114 | 653 | 215 | 1982 | 1114 | 653 | 215 | 1982 | 1114 | 744 | 215 | 2073 | 1114 | 653 | 215 | 1982 | 1114 | 653 | 215 | 1982 |
| 2023 | 1115 | 673 | 220 | 2007 | 1115 | 673 | 220 | 2007 | 1115 | 744 | 220 | 2079 | 1115 | 673 | 220 | 2007 | 1115 | 673 | 220 | 2007 |
| 2024 | 1111 | 680 | 222 | 2013 | 1111 | 680 | 222 | 2013 | 1111 | 744 | 222 | 2077 | 1111 | 680 | 222 | 2013 | 1111 | 680 | 222 | 2013 |
| 2025 | 1107 | 679 | 222 | 2008 | 1107 | 679 | 222 | 2008 | 1107 | 744 | 222 | 2073 | 1107 | 679 | 222 | 2008 | 1107 | 679 | 222 | 2008 |
| 2026 | 1105 | 672 | 221 | 1998 | 1105 | 672 | 221 | 1998 | 1105 | 744 | 221 | 2070 | 1105 | 672 | 221 | 1998 | 1105 | 672 | 221 | 1998 |
| 2027 | 1105 | 664 | 220 | 1989 | 1105 | 664 | 220 | 1989 | 1105 | 744 | 220 | 2069 | 1105 | 664 | 220 | 1989 | 1105 | 664 | 220 | 1989 |
| 2028 | 1107 | 657 | 218 | 1982 | 1107 | 657 | 218 | 1982 | 1107 | 744 | 218 | 2069 | 1107 | 657 | 218 | 1982 | 1107 | 657 | 218 | 1982 |
| 2029 | 1108 | 653 | 218 | 1978 | 1108 | 653 | 218 | 1978 | 1108 | 744 | 218 | 2069 | 1108 | 653 | 218 | 1978 | 1108 | 653 | 218 | 1978 |
| 2030 | 1108 | 652 | 217 | 1977 | 1108 | 652 | 217 | 1977 | 1108 | 744 | 217 | 2069 | 1108 | 652 | 217 | 1977 | 1108 | 652 | 217 | 1977 |
| 2031 | 1108 | 652 | 217 | 1976 | 1108 | 652 | 217 | 1976 | 1108 | 744 | 217 | 2068 | 1108 | 652 | 217 | 1976 | 1108 | 652 | 217 | 1976 |
| 2032 | 1107 | 653 | 216 | 1976 | 1107 | 653 | 216 | 1976 | 1107 | 744 | 216 | 2067 | 1107 | 653 | 216 | 1976 | 1107 | 653 | 216 | 1976 |
| 2033 | 1106 | 654 | 216 | 1975 | 1106 | 654 | 216 | 1975 | 1106 | 744 | 216 | 2066 | 1106 | 654 | 216 | 1975 | 1106 | 654 | 216 | 1975 |
| 2034 | 1105 | 654 | 215 | 1974 | 1105 | 654 | 215 | 1974 | 1105 | 744 | 215 | 2064 | 1105 | 654 | 215 | 1974 | 1105 | 654 | 215 | 1974 |
| 2035 | 1104 | 654 | 215 | 1973 | 1104 | 654 | 215 | 1973 | 1104 | 744 | 215 | 2063 | 1104 | 654 | 215 | 1973 | 1104 | 654 | 215 | 1973 |

Table 17.10. Continued.

| Year | Case 6 | | | | Case 7 | | | | Case 8 | | | | Case 9 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | BS | SA | TAS | Total | BS | SA | TAS | Total | BS | SA | TAS | Total | BS | SA | TAS | Total |
| 2016 | 1080 | 744 | 256 | 2080 | 1377 | 574 | 101 | 2052 | 1316 | 548 | 96 | 1961 | 1290 | 538 | 94 | 1922 |
| 2017 | 1002 | 648 | 228 | 1878 | 1377 | 574 | 101 | 2052 | 1316 | 548 | 96 | 1961 | 1290 | 538 | 94 | 1922 |
| 2018 | 995 | 601 | 212 | 1808 | 1377 | 574 | 101 | 2052 | 1316 | 548 | 96 | 1961 | 1290 | 538 | 94 | 1922 |
| 2019 | 1028 | 586 | 203 | 1817 | 1377 | 574 | 101 | 2052 | 1316 | 548 | 96 | 1961 | 1290 | 538 | 94 | 1922 |
| 2020 | 1070 | 598 | 203 | 1872 | 1377 | 574 | 101 | 2052 | 1316 | 548 | 96 | 1961 | 1290 | 538 | 94 | 1922 |
| 2021 | 1100 | 626 | 209 | 1935 | 1377 | 574 | 101 | 2052 | 1316 | 548 | 96 | 1961 | 1290 | 538 | 94 | 1922 |
| 2022 | 1114 | 653 | 215 | 1982 | 1377 | 574 | 101 | 2052 | 1316 | 548 | 96 | 1961 | 1290 | 538 | 94 | 1922 |
| 2023 | 1115 | 673 | 220 | 2007 | 1377 | 574 | 101 | 2052 | 1316 | 548 | 96 | 1961 | 1290 | 538 | 94 | 1922 |
| 2024 | 1111 | 680 | 222 | 2013 | 1377 | 574 | 101 | 2052 | 1316 | 548 | 96 | 1961 | 1290 | 538 | 94 | 1922 |
| 2025 | 1107 | 679 | 222 | 2008 | 1377 | 574 | 101 | 2052 | 1316 | 548 | 96 | 1961 | 1290 | 538 | 94 | 1922 |
| 2026 | 1105 | 672 | 221 | 1998 | 1377 | 574 | 101 | 2052 | 1316 | 548 | 96 | 1961 | 1290 | 538 | 94 | 1922 |
| 2027 | 1105 | 664 | 220 | 1989 | 1377 | 574 | 101 | 2052 | 1316 | 548 | 96 | 1961 | 1290 | 538 | 94 | 1922 |
| 2028 | 1107 | 657 | 218 | 1982 | 1377 | 574 | 101 | 2052 | 1316 | 548 | 96 | 1961 | 1290 | 538 | 94 | 1922 |
| 2029 | 1108 | 653 | 218 | 1978 | 1377 | 574 | 101 | 2052 | 1316 | 548 | 96 | 1961 | 1290 | 538 | 94 | 1922 |
| 2030 | 1108 | 652 | 217 | 1977 | 1377 | 574 | 101 | 2052 | 1316 | 548 | 96 | 1961 | 1290 | 538 | 94 | 1922 |
| 2031 | 1108 | 652 | 217 | 1976 | 1377 | 574 | 101 | 2052 | 1316 | 548 | 96 | 1961 | 1290 | 538 | 94 | 1922 |
| 2032 | 1107 | 653 | 216 | 1976 | 1377 | 574 | 101 | 2052 | 1316 | 548 | 96 | 1961 | 1290 | 538 | 94 | 1922 |
| 2033 | 1106 | 654 | 216 | 1975 | 1377 | 574 | 101 | 2052 | 1316 | 548 | 96 | 1961 | 1290 | 538 | 94 | 1922 |
| 2034 | 1105 | 654 | 215 | 1974 | 1377 | 574 | 101 | 2052 | 1316 | 548 | 96 | 1961 | 1290 | 538 | 94 | 1922 |
| 2035 | 1104 | 654 | 215 | 1973 | 1377 | 574 | 101 | 2052 | 1316 | 548 | 96 | 1961 | 1290 | 538 | 94 | 1922 |

Table 17.11. Results of 10-year projections (pup production as a percentage of unfished pup production) under various scenarios regarding future catches.

| Region | 2017 | 2019 | 2021 | 2026 |
|---|---|---|---|---|
| Base case: catches equal RBCs | | | | |
| Bass Strait | 53.2 | 53.0 | 52.4 | 50.9 |
| South Australia | 62.5 | 61.2 | 58.5 | 51.8 |
| Tasmania | 71.7 | 66.7 | 62.5 | 54.7 |
| Case 2: All catch by shark longline in South Australia | | | | |
| Bass Strait | 53.2 | 53.0 | 52.4 | 50.9 |
| South Australia | 61.5 | 59.1 | 55.8 | 48.1 |
| Tasmania | 71.7 | 66.7 | 62.5 | 54.7 |
| Case 3: Longline catch in South Australia increases so total catch equals maximum historical catch | | | | |
| Bass Strait | 53.2 | 53.0 | 52.4 | 50.9 |
| South Australia | 62.5 | 58.5 | 52.3 | 42.8 |
| Tasmania | 71.7 | 66.7 | 62.5 | 54.7 |
| Case 4: All catch by 6.5” gillnets | | | | |
| Bass Strait | 53.2 | 53.1 | 52.4 | 50.9 |
| South Australia | 62.9 | 62.4 | 60.3 | 53.4 |
| Tasmania | 71.9 | 67.2 | 63.1 | 55.1 |
| Case 5: All catch by shark longline | | | | |
| Bass Strait | 51.9 | 50.0 | 48.9 | 48.0 |
| South Australia | 63.4 | 63.2 | 61.3 | 56.8 |
| Tasmania | 71.3 | 66.2 | 62.4 | 56.0 |
| Case 6: All catch by scalefish longline | | | | |
| Bass Strait | 50.3 | 46.6 | 44.2 | 40.1 |
| South Australia | 61.5 | 59.1 | 55.8 | 48.1 |
| Tasmania | 69.0 | 61.4 | 56.4 | 47.7 |
| Case 7: Total catch = 2052t; split by region and gear according to 2015 catch | | | | |
| Bass Strait | 51.8 | 47.1 | 41.9 | 34.2 |
| South Australia | 63.9 | 63.9 | 61.8 | 57.2 |
| Tasmania | 75.3 | 76.9 | 79.3 | 82.3 |
| Case 8: Total catch = 1961t; split by region and gear according to 2015 catch | | | | |
| Bass Strait | 52.1 | 48.2 | 43.9 | 37.6 |
| South Australia | 64.1 | 64.6 | 63.1 | 59.2 |
| Tasmania | 75.4 | 77.2 | 79.9 | 83.3 |
| Case 9: Total catch = 1922t; split by region and gear according to 2015 catch | | | | |
| Bass Strait | 52.2 | 48.7 | 44.7 | 39.0 |
| South Australia | 64.2 | 64.9 | 63.6 | 60.1 |
| Tasmania | 75.5 | 77.4 | 80.1 | 83.8 |

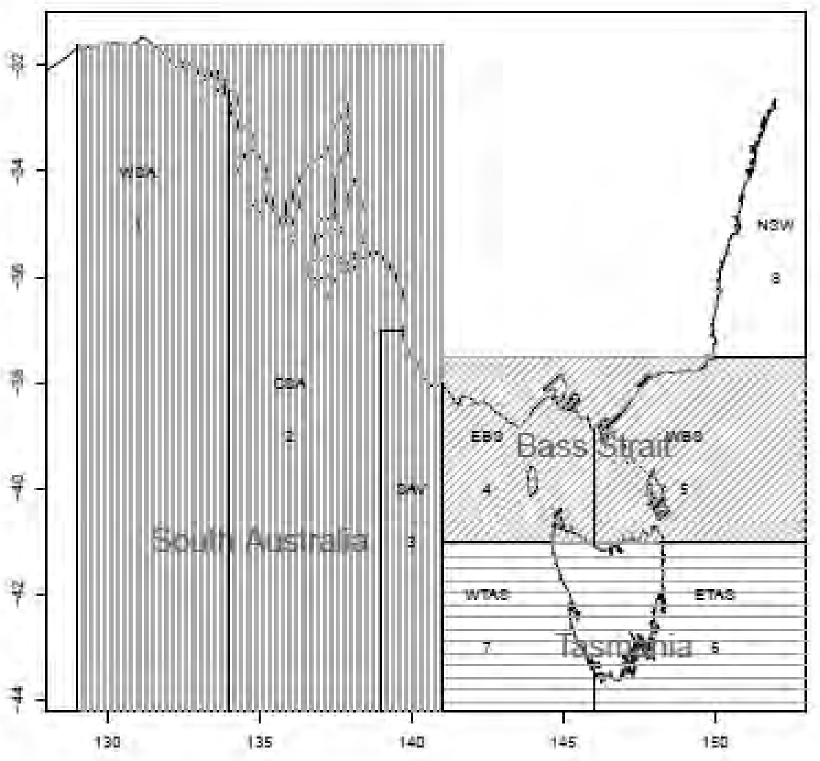



Figure 17.1. The three gummy shark management regions, each assigned to a separate stock (from Punt and Thomson, 2010).

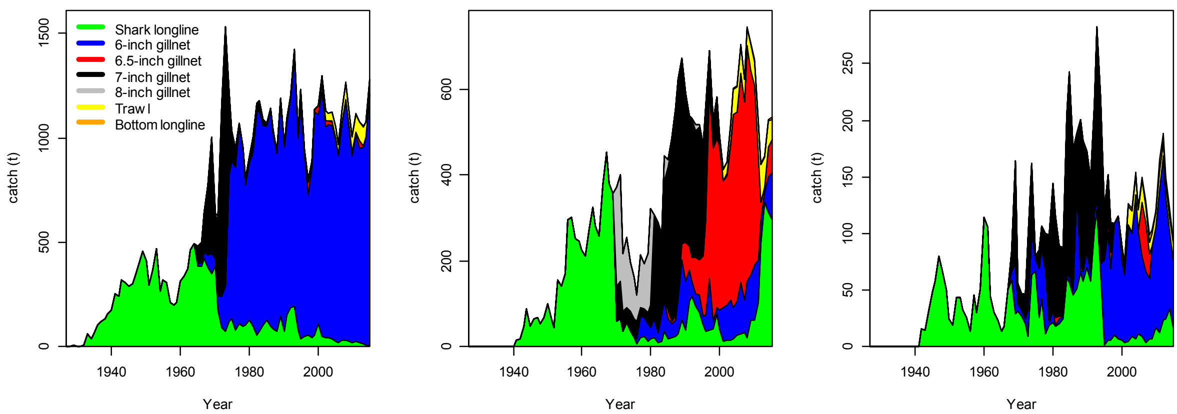



Figure 17.2. Catch time-series by region used in the assessment.

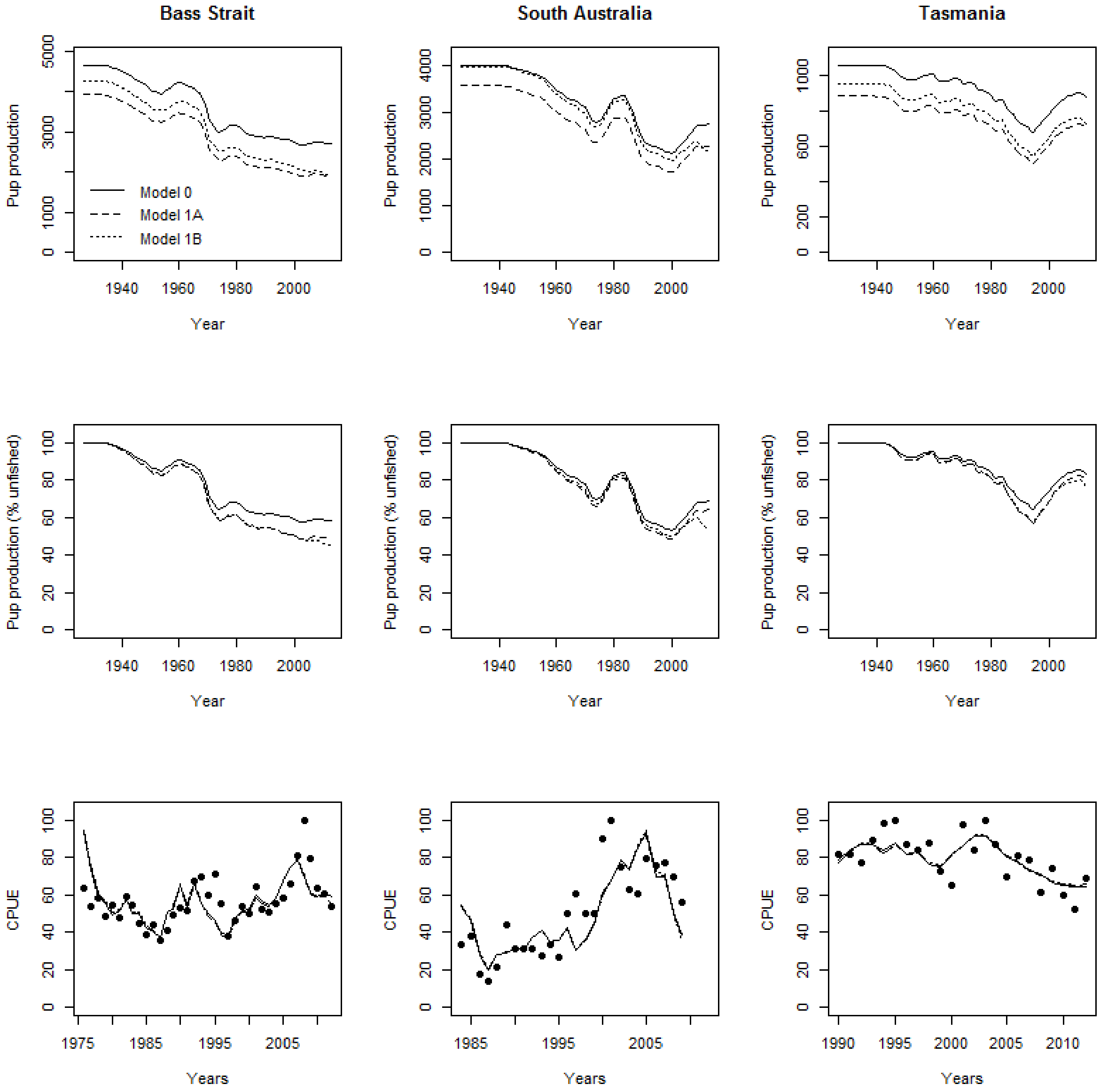



Figure 17.3. Estimates of pup production and pup production relative to the 1927 levels (upper and center panels), and fits to the catch-rate indices on which the 2013 assessment was based (lower panels). Results are shown for three model variants.

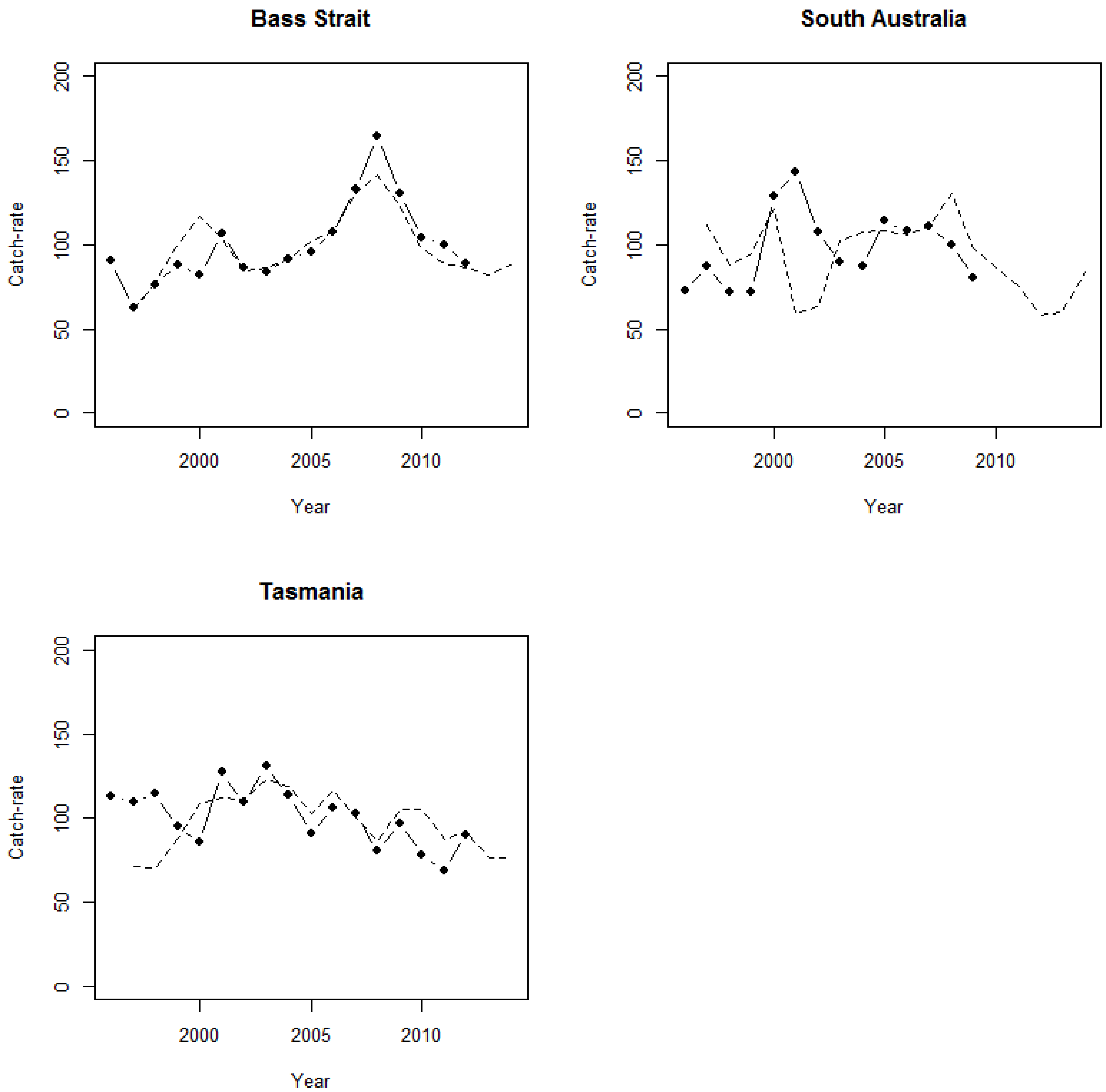



Figure 17.4. Catch-rate indices on which the 2013 assessment was based (solid lines) and the catch-rate indices of abundance developed by Sporcic (2016) scaled so that the means for the two series since 1997 are the same (dashed lines). For Bass Strait (top left), South Australia (top right), and Tasmania (bottom).

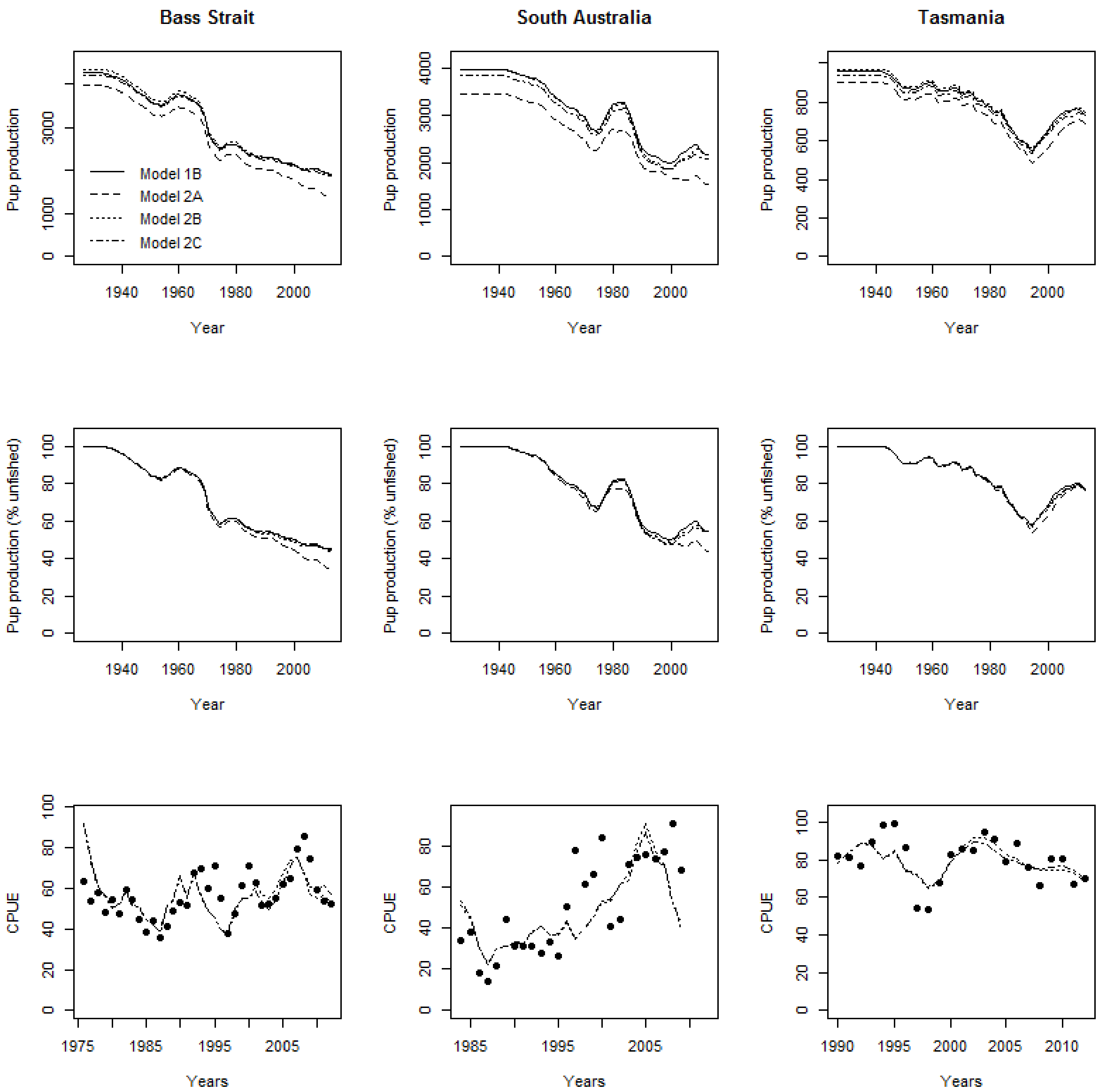



Figure 17.5. Estimates of pup production and pup production relative to the 1927 level (upper and centre panels), and fits of models 2B and 2C to the catch-rate indices based on attaching the Sporcic (2016) indices to the earlier catch-rate indices (lower panels). Results are shown for four model variants.

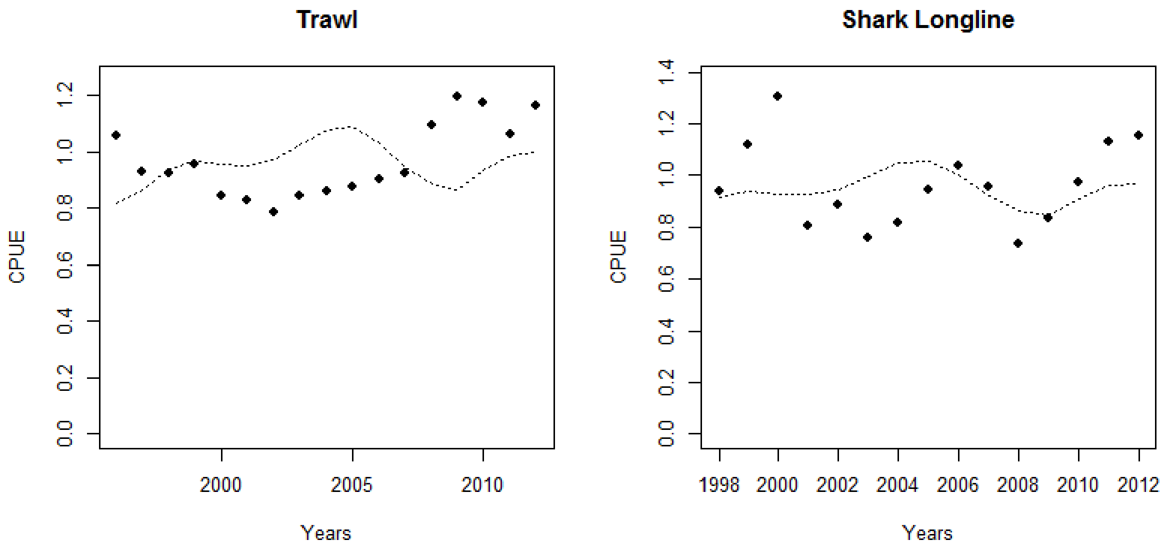



Figure 17.6. Fit of Model 2C to the catch-rate series for trawl and shark longline.

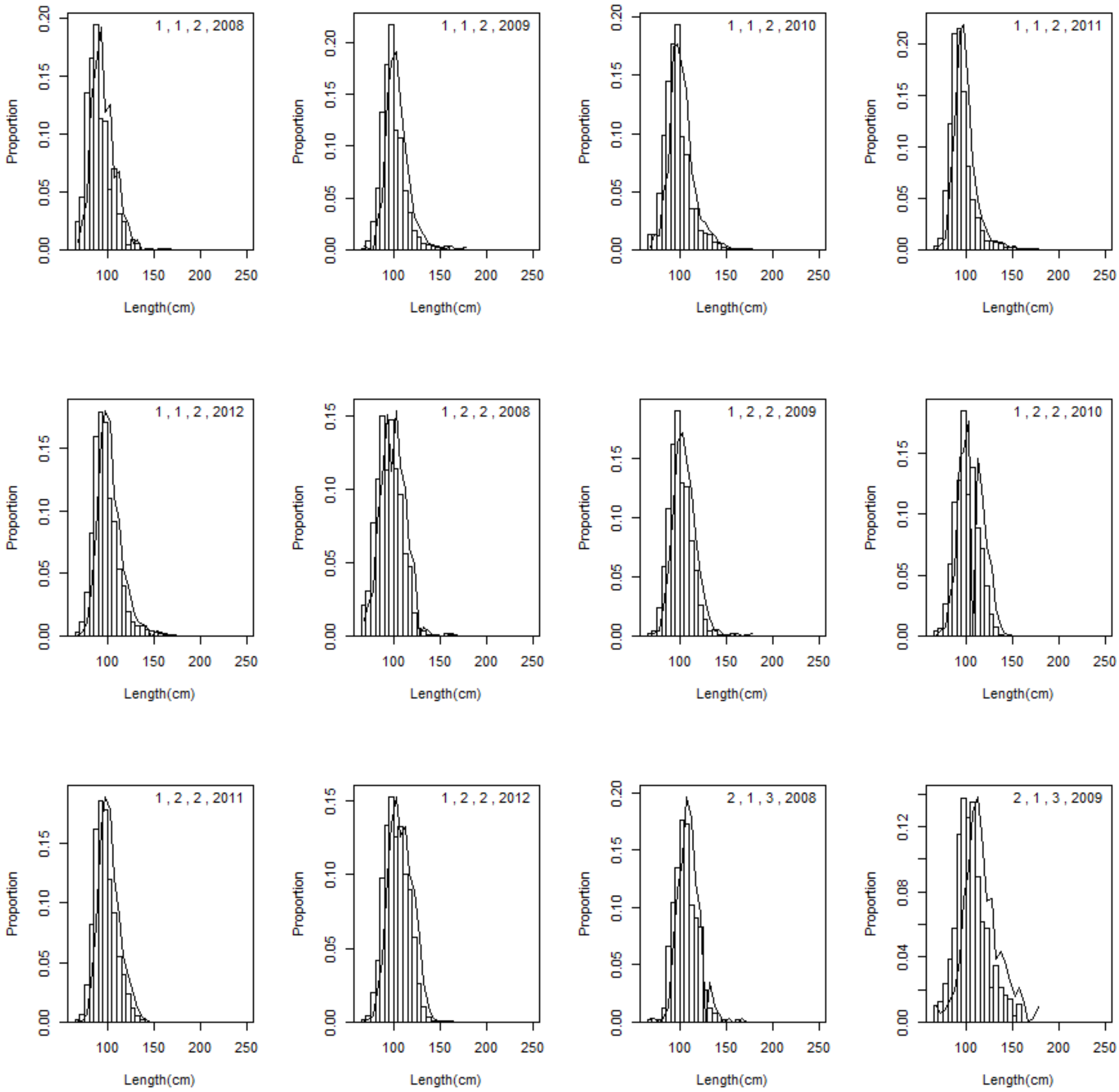



Figure 17.7. Comparison of the length-composition data used in the 2013 assessment (bars) with the updated length-composition data for the same years (lines). The notation for each panel is (region - 1: Bass Strait; 2:South Australia; 3:Tasmania, sex -1:female; 2: male , gear-type – 2: 6-inch mesh; 3: 6.5-inch mesh; 4: 7-inch mesh, year).

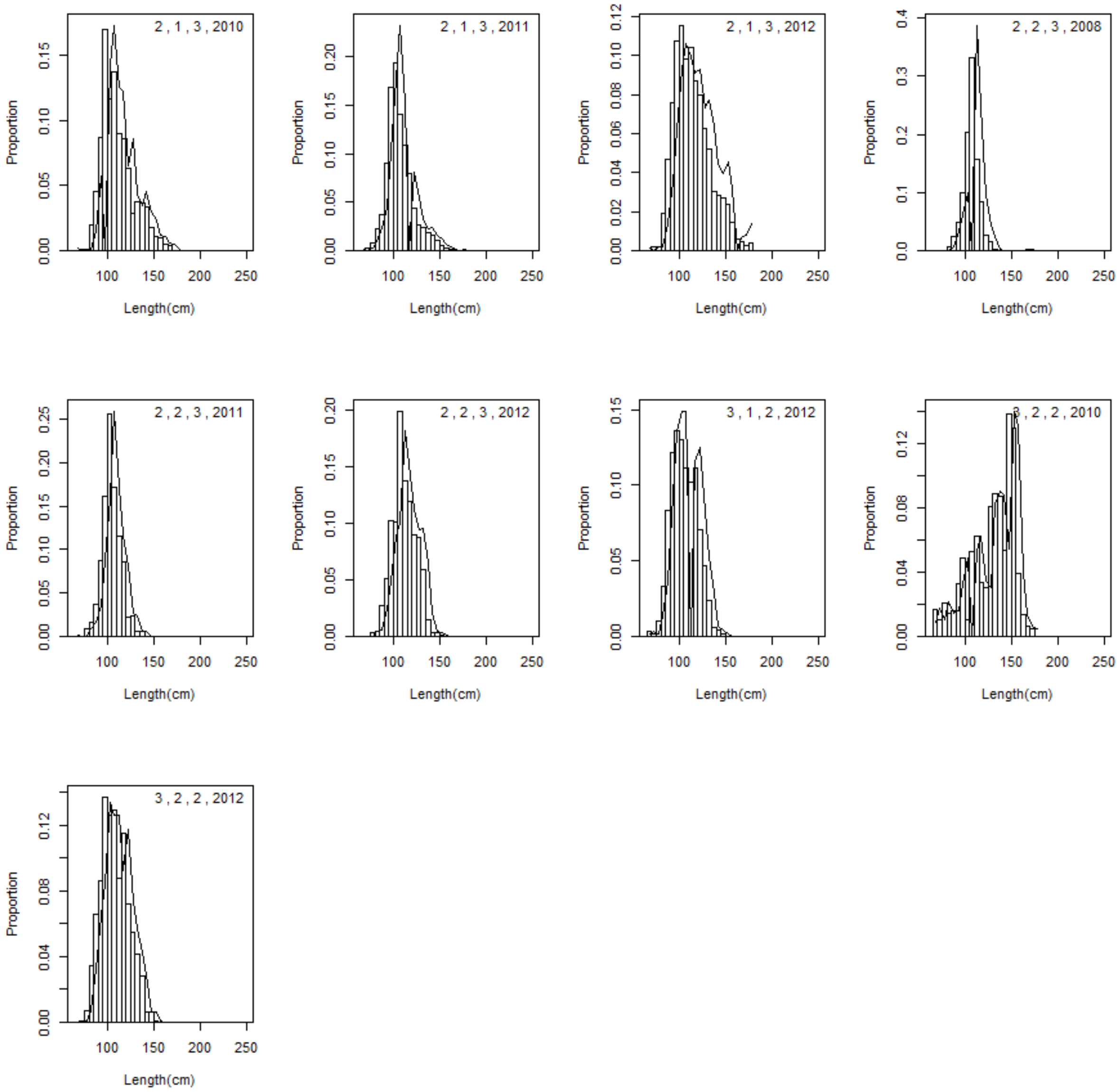



Figure 17.7. Continued.

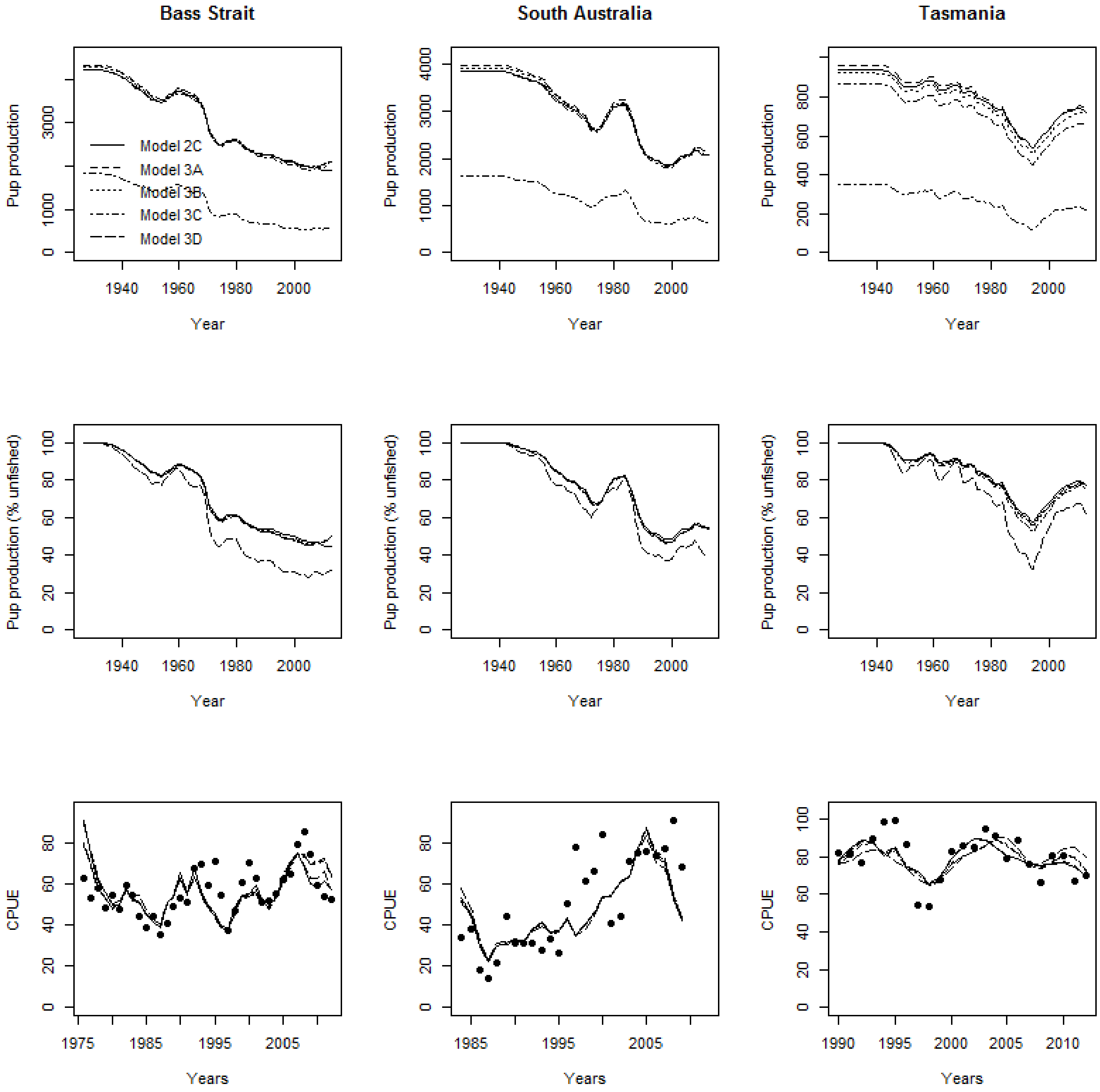



Figure 17.8. Estimates of pup production and pup production relative to the 1927 level (upper and centre panels), and fits to the catch-rate indices based on attaching the Sporcic (2016) indices to the earlier catch-rate indices (lower panels). Results are shown for five model variants.

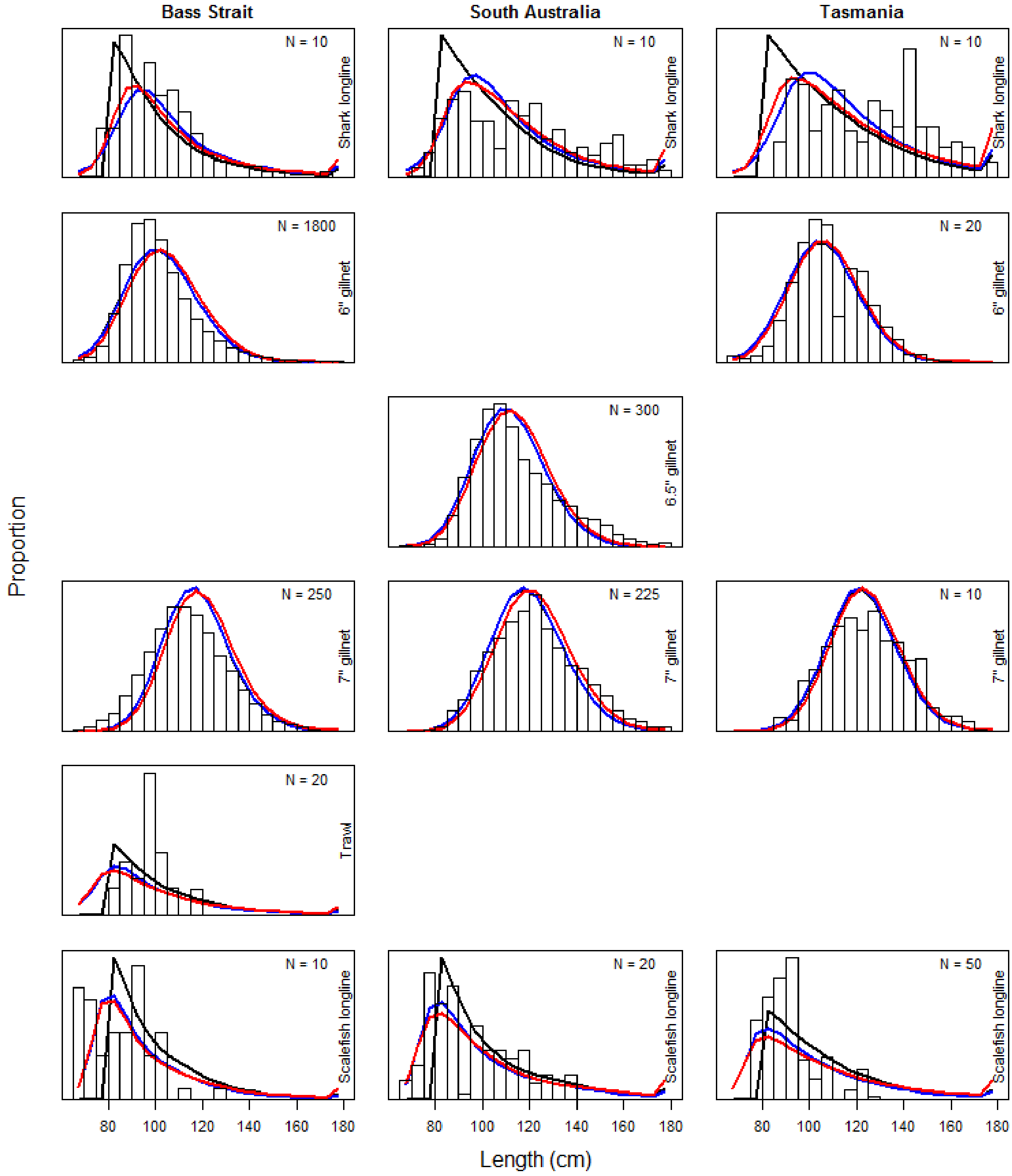



Figure 17.9. Observed and the model-predicted length-frequencies for females (black: Model 3B, blue: Model 3C, and red: Model 3D). The observations and predictions are summed over years to ease presentation.

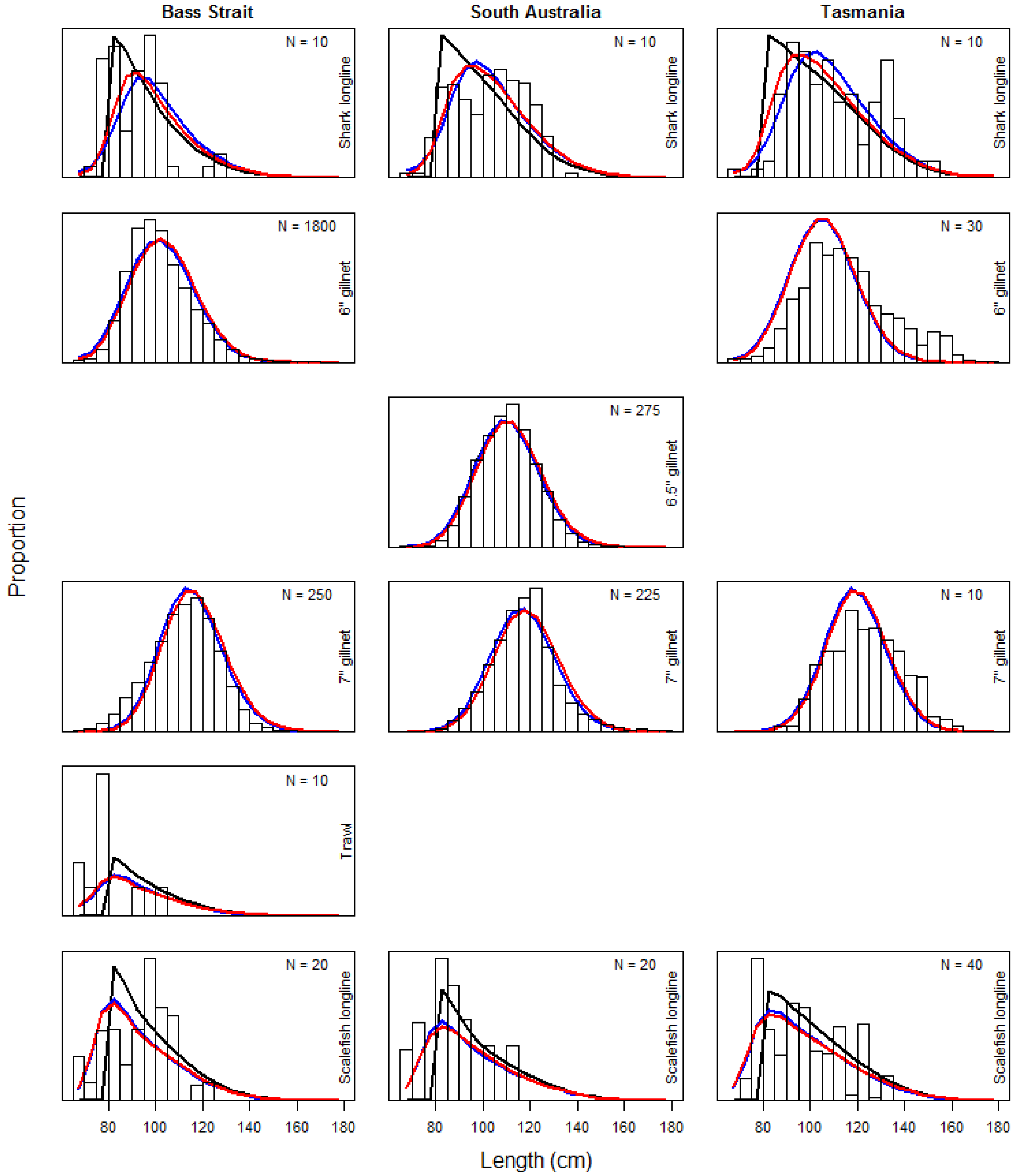



Figure 17.9. Continued: males.

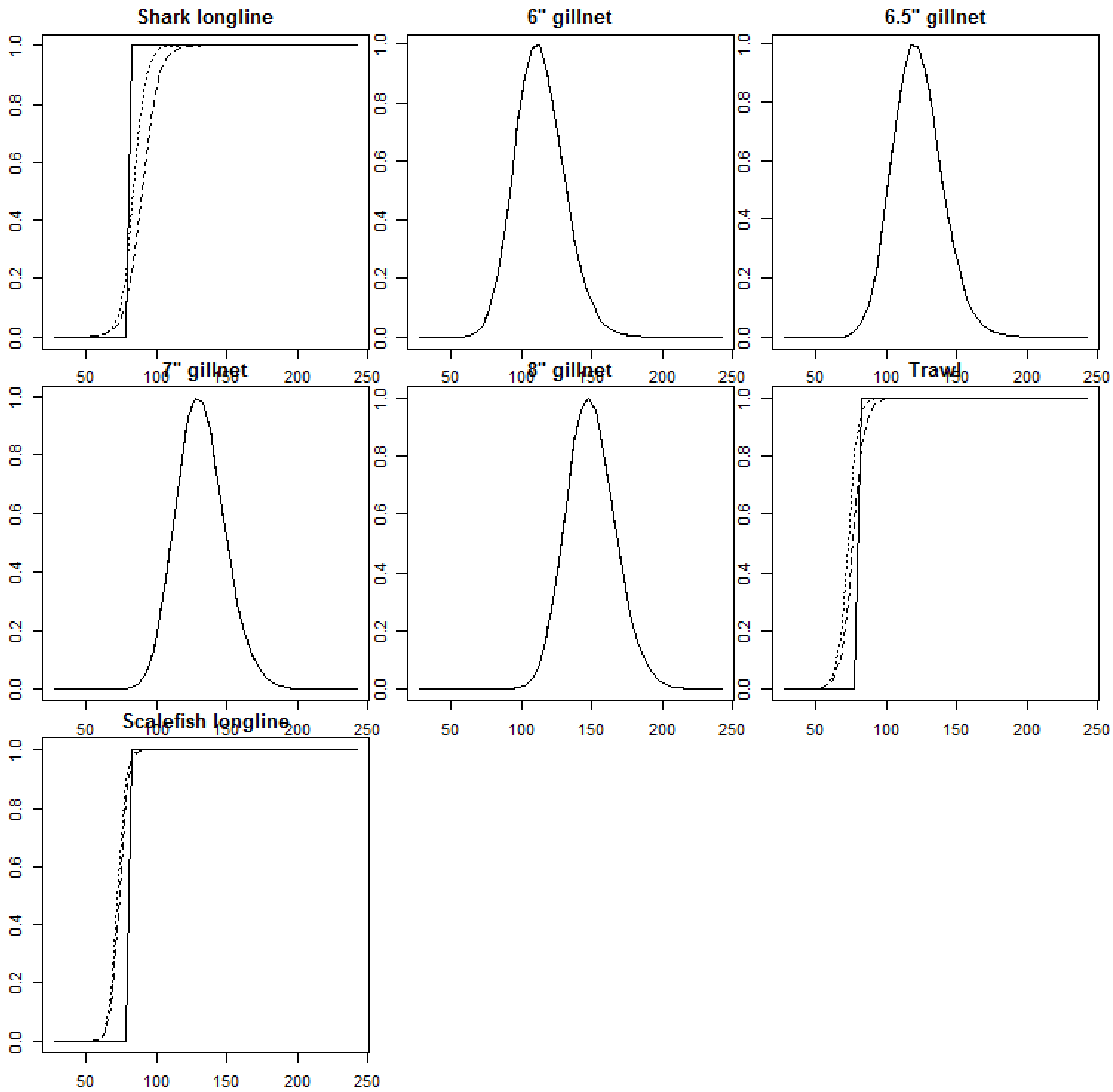



Figure 17.10. Estimated length-specific selectivity patterns based on three model variants (solid: Model 3B, dashed: Model 3C, and dotted: Model 3D). Note that selectivity for gill-nets is pre-specified so is the same for the three model variants.

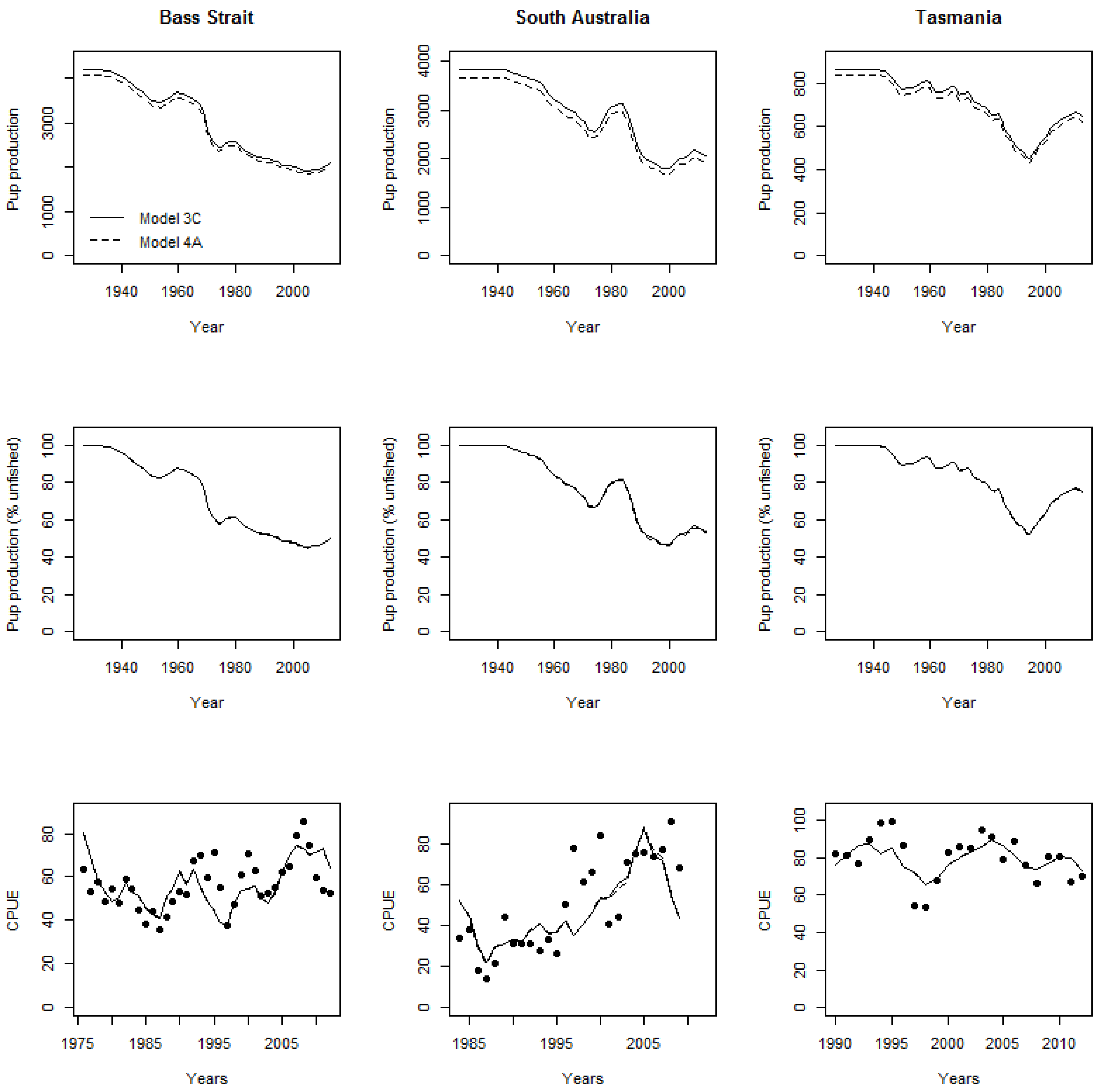



Figure 17.11. Estimates of pup production and pup production relative to the 1927 level (upper and centre panels), and fits to the catch-rate indices based on attaching the Sporcic (2016) indices to the earlier catch-rate indices (lower panels). Results are shown for two model variants.

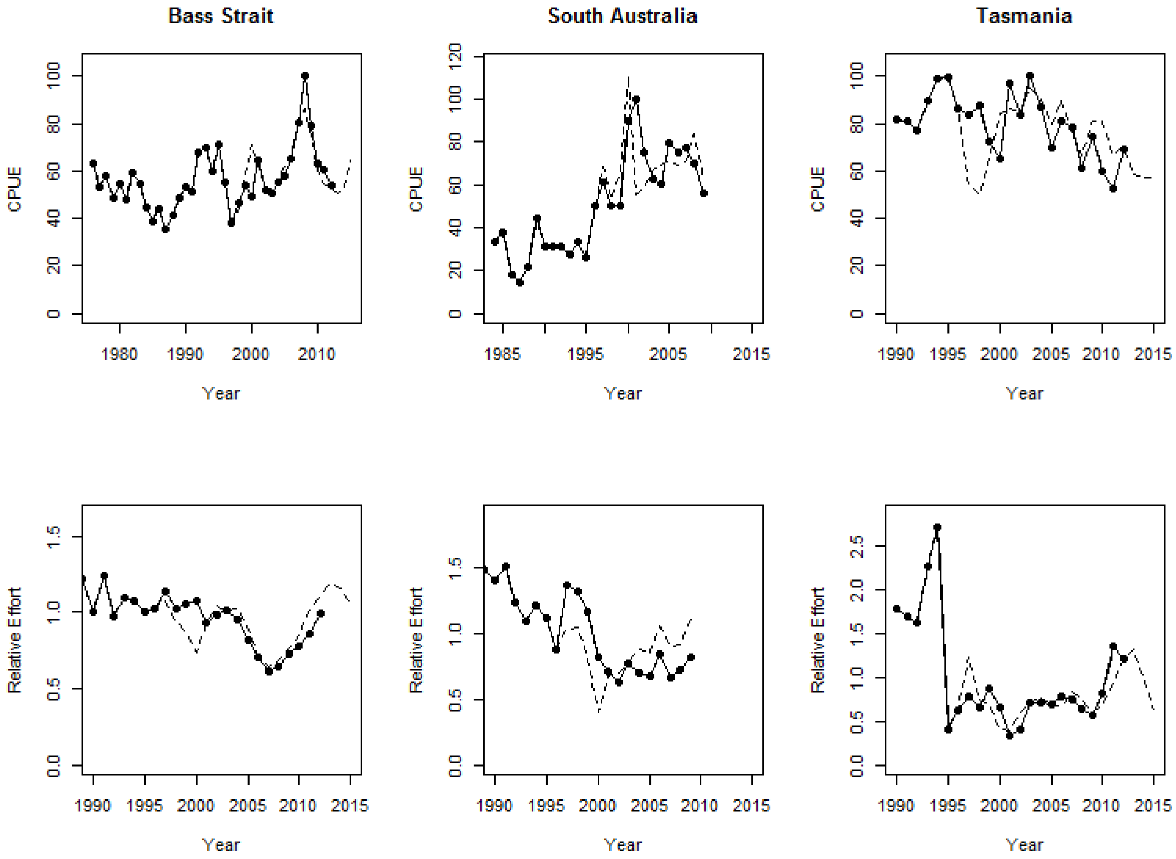



Figure 17.12. The revised catch rate indices (Sporcic pers comm) (upper panels) and total gillnet effort (lower plot) in each region. Time series were combined using the "splicing" approach using the catch rate data for Model 2B.

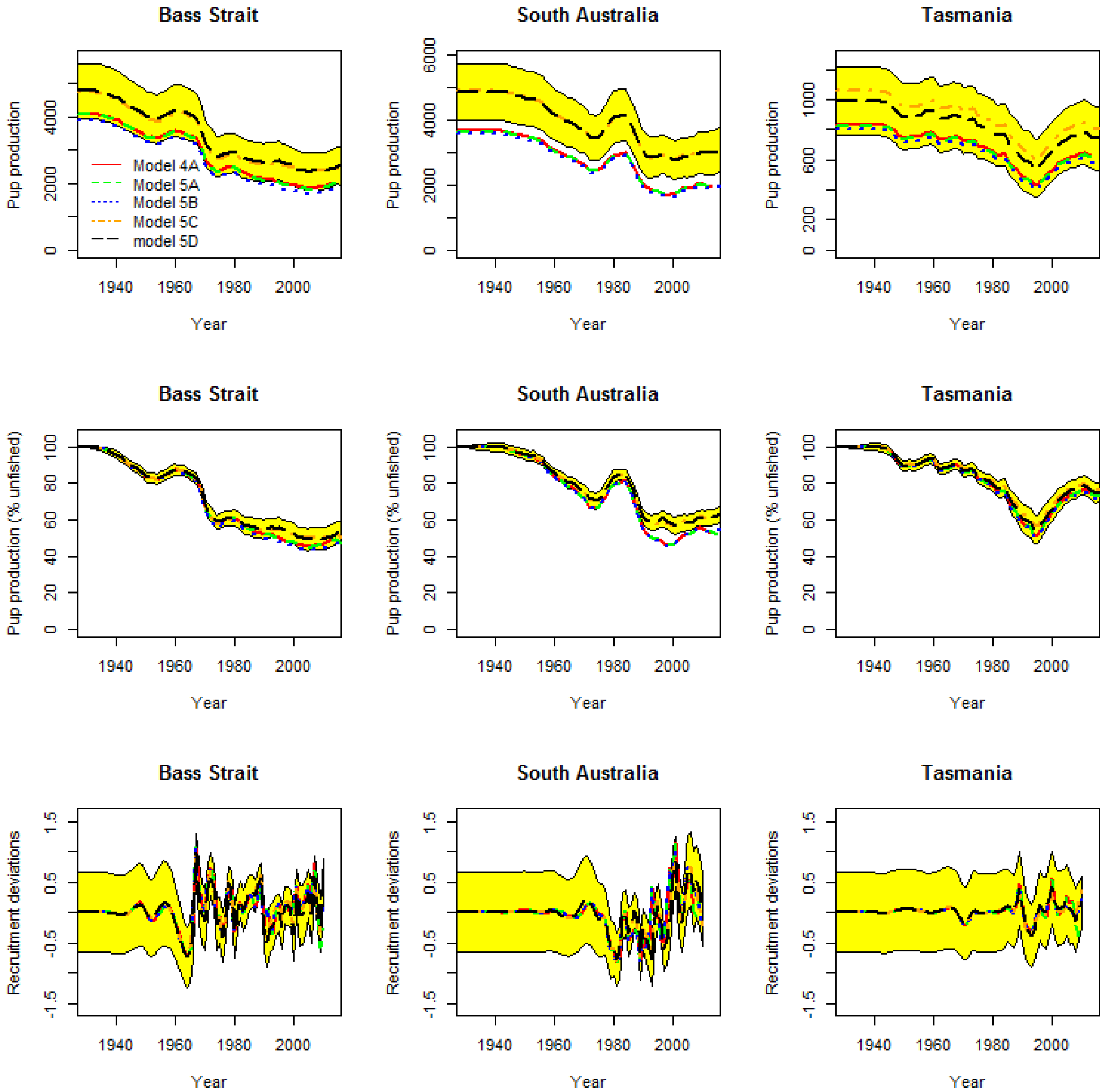



Figure 17.13. Estimates of pup production and pup production relative to the 1927 level (upper and centre panels), and recruitment (lower panels). Results are shown for five model variants. The yellow shading indicates asymptotic 90% confidence intervals about the results from Model 5D.

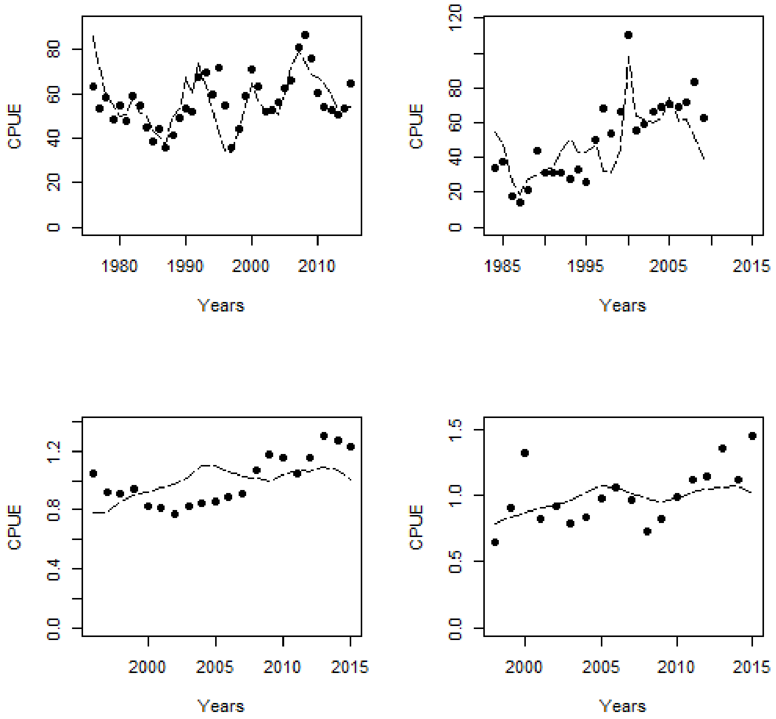



Figure 17.14. Model 5D fits to the catch-rate indices.

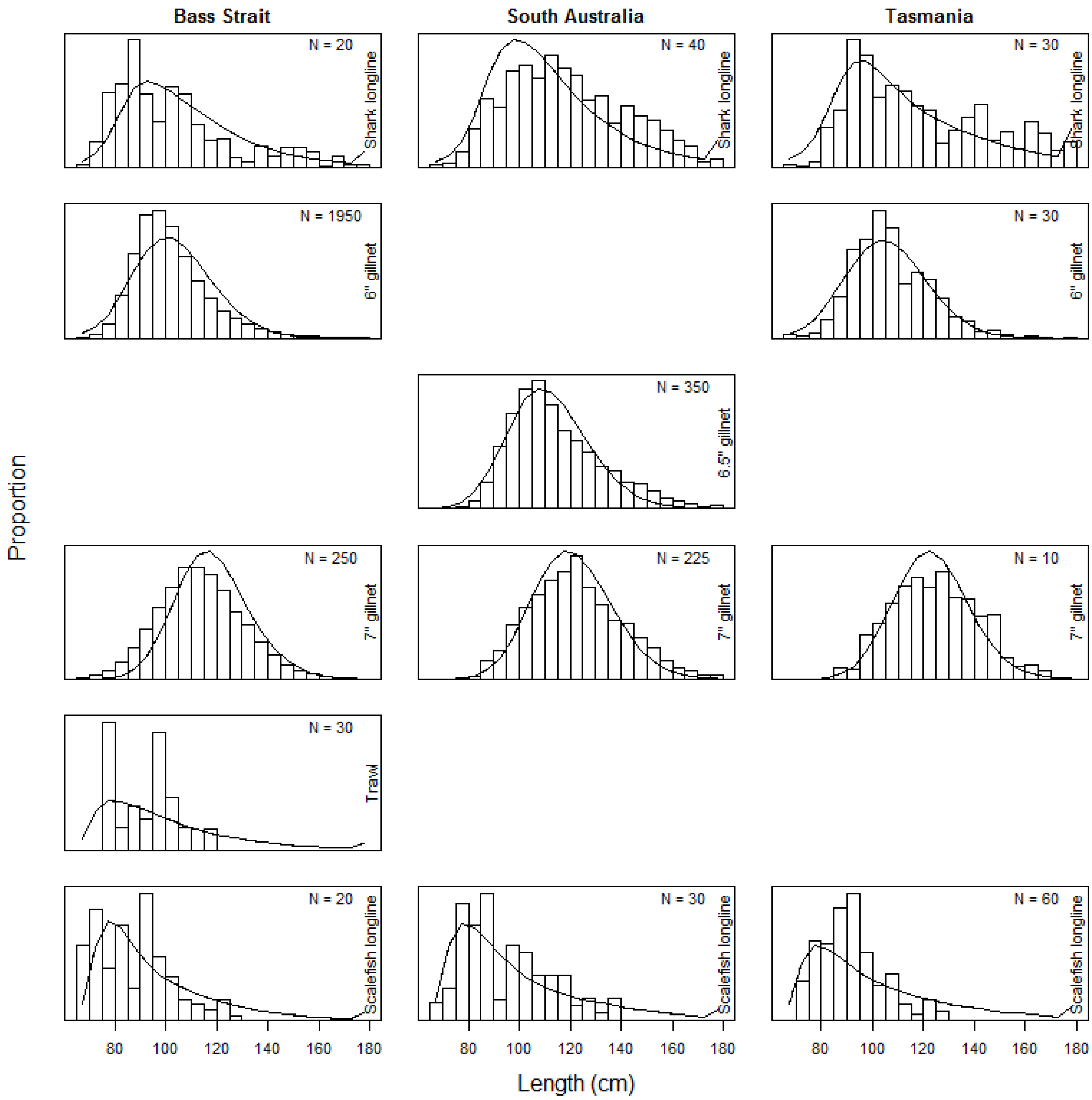



Figure 17.15. Observed and Model 5D-predicted length-frequencies for females. The observations and predictions are summed over years to ease presentation.

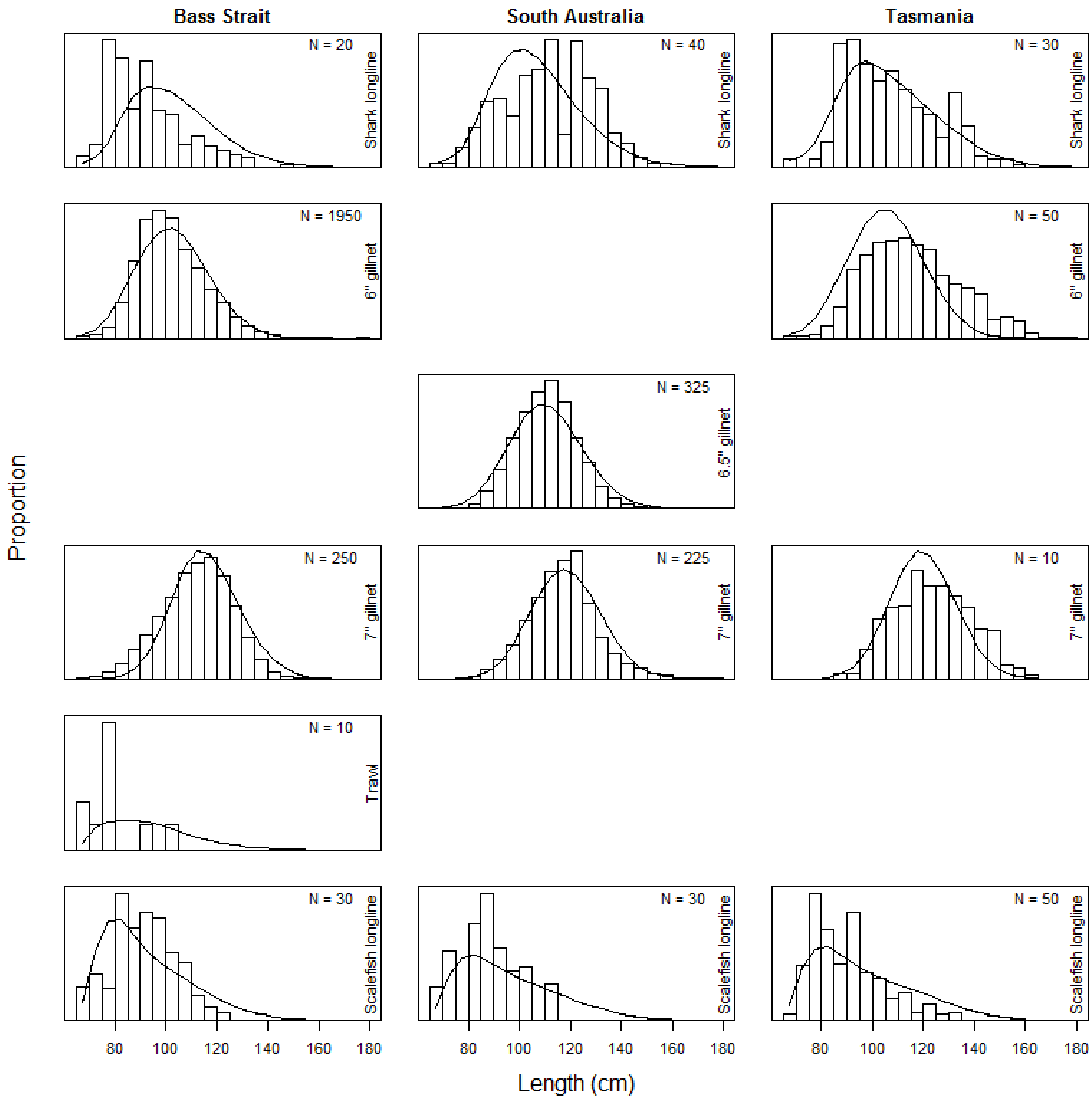



Figure 17.15. Continued: males.

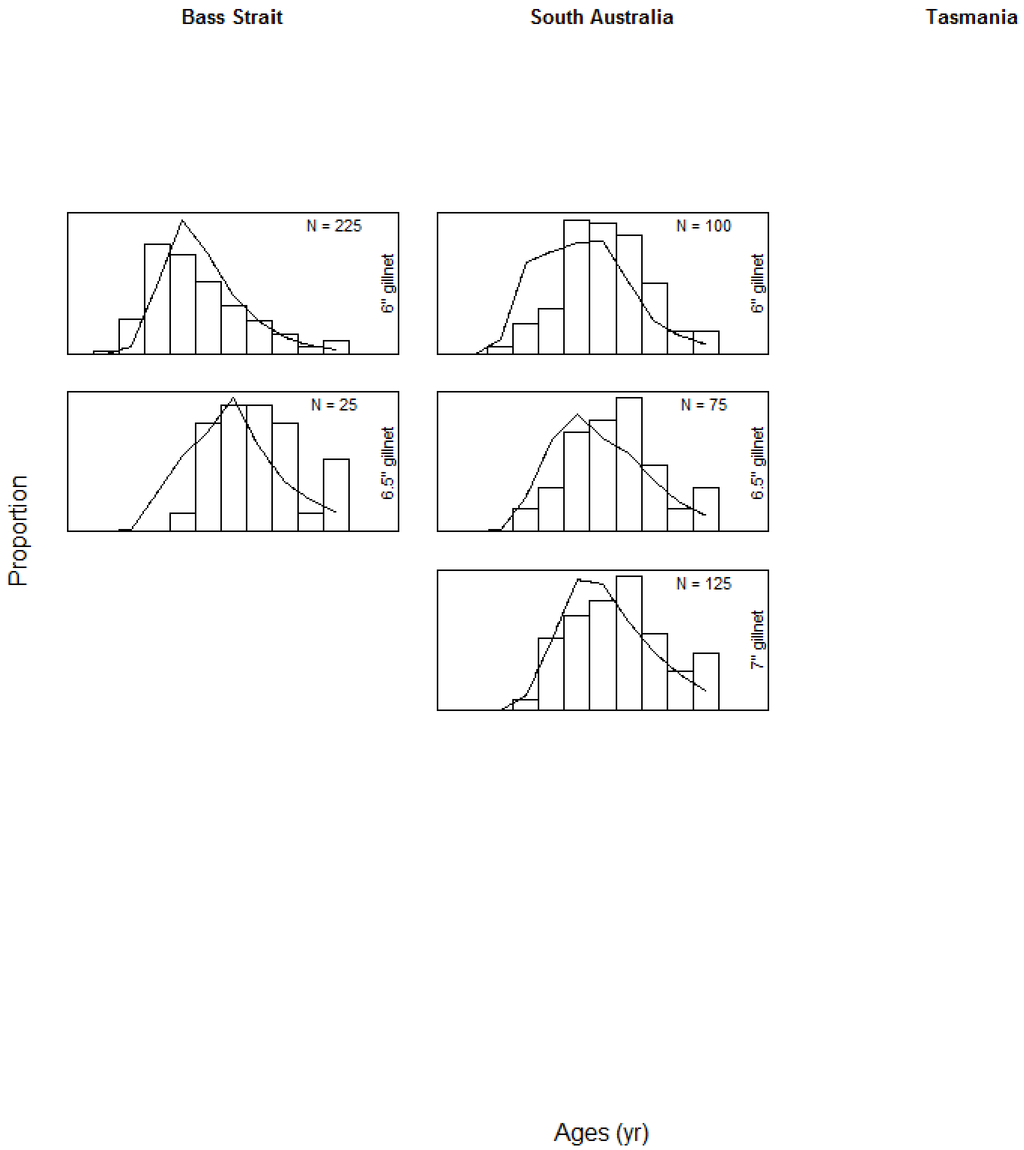



Figure 17.16. Observed and Model 5D-predicted age-frequencies for females. The observations and predictions are summed over years to ease presentation.

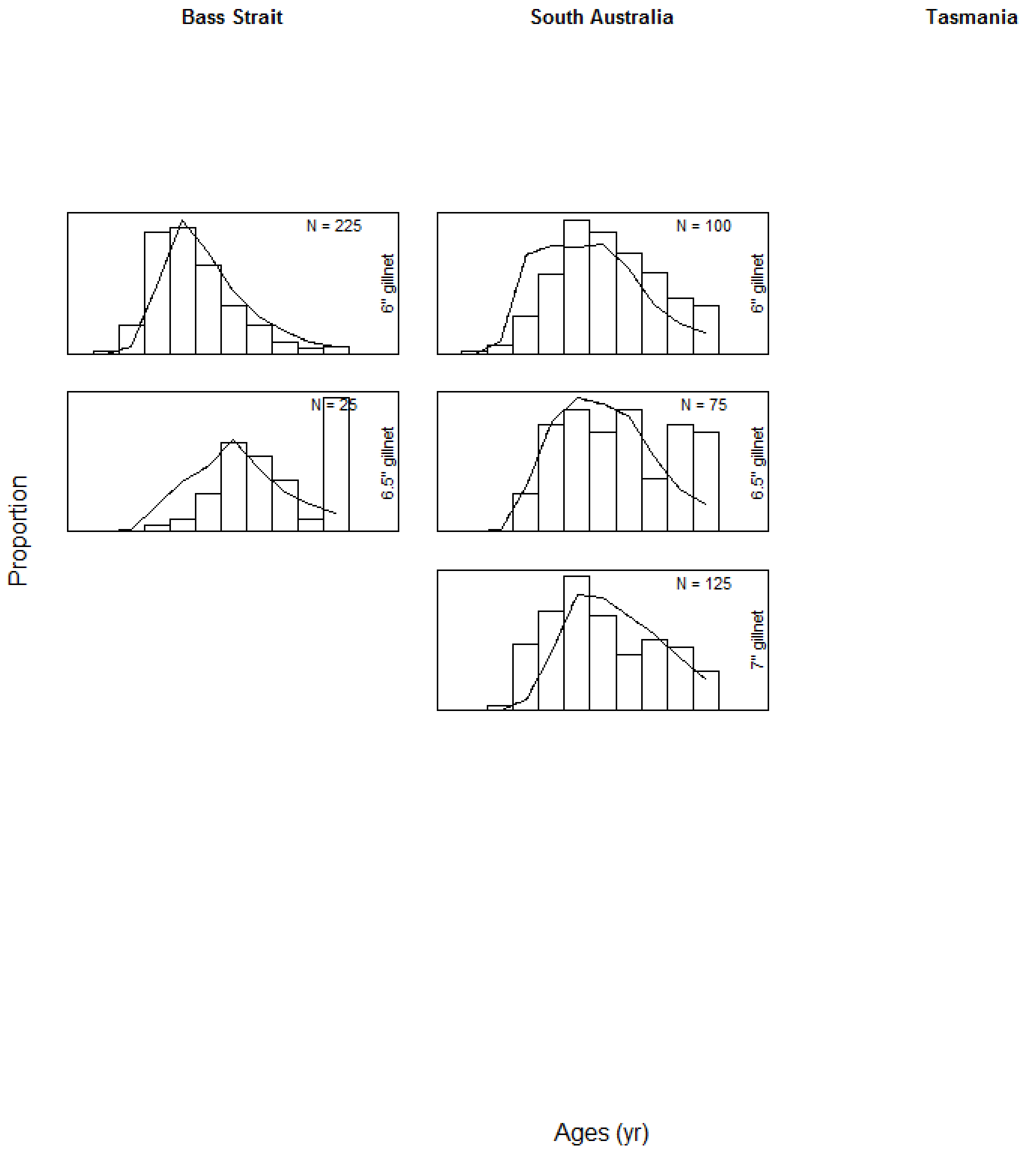



Figure 17.16. Continues: males.

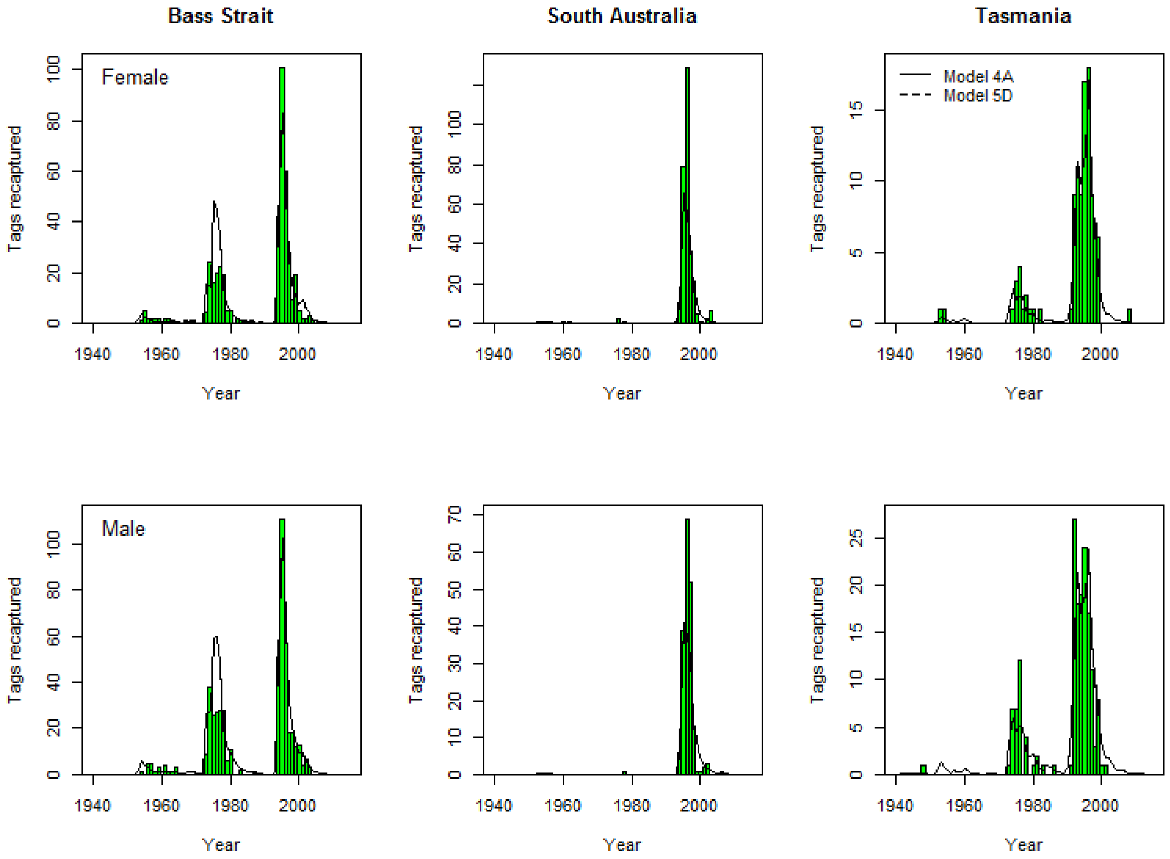



Figure 17.17. Observed and the Model 5D-predicted tag-recoveries.

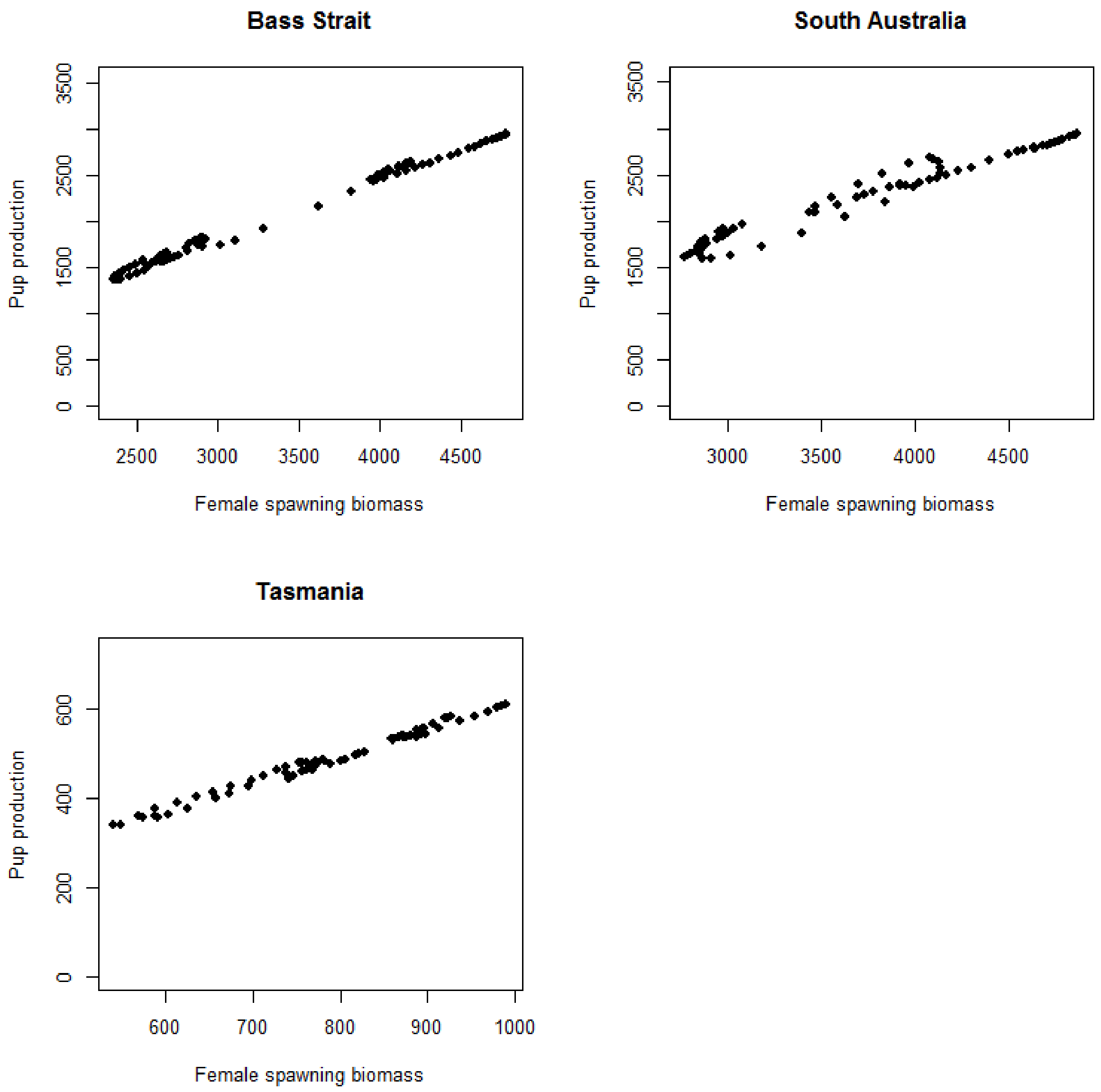



Figure 17.18. Female spawning biomass vs pup production for the reference case model (Model 5D).

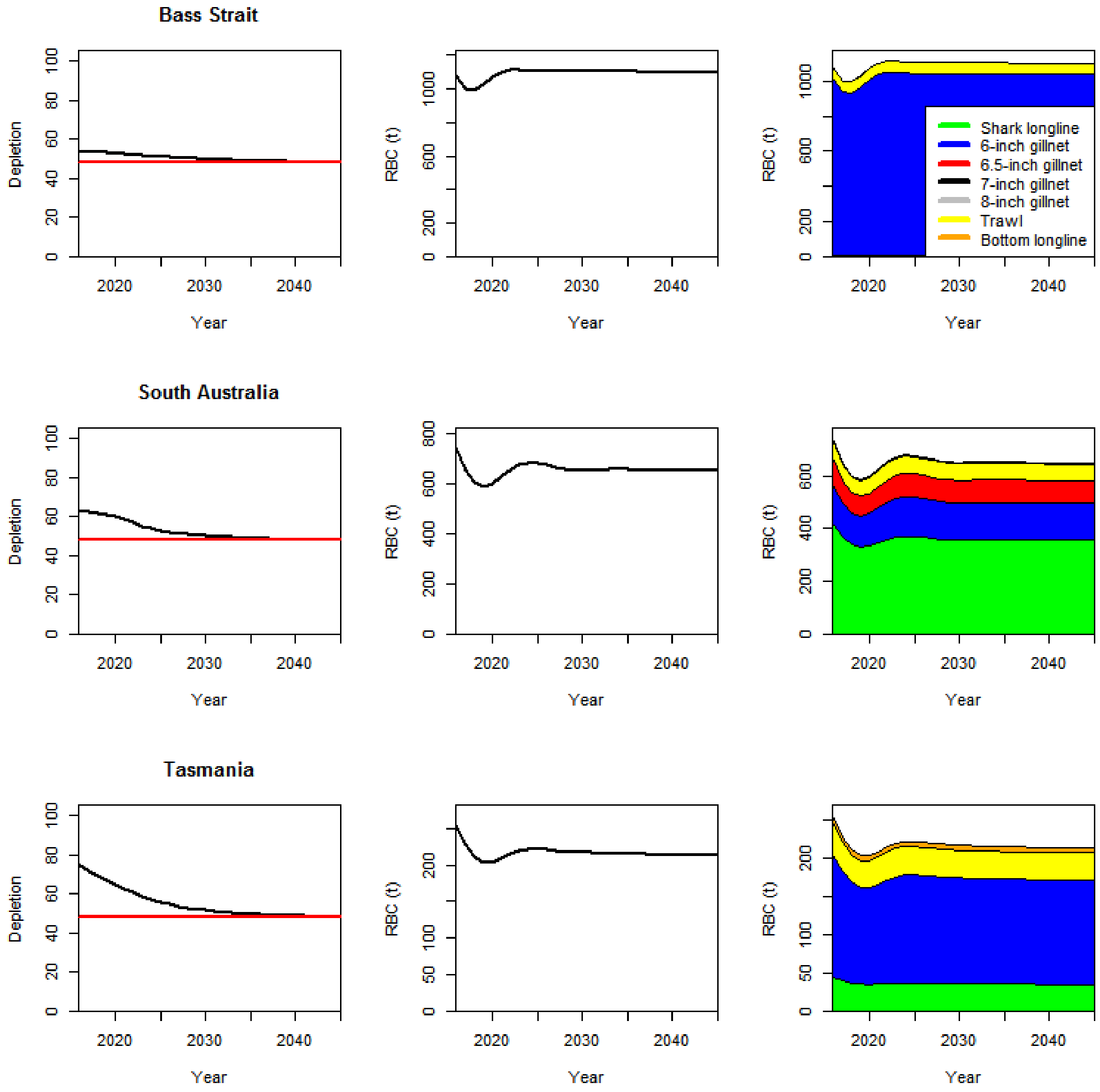



Figure 17.19. Time-trajectories of depletion (pup production relative to unfished pup production) (left panels), Recommended Biological Catch (center panels), and Recommended Biological Catch by gear-type (right panels) for projections based on Model 5D (the reference case model).

## 17.10 Appendix A: Catch data for 2001-2015

Previous (before 2010) assessments of gummy shark were based on catches that were extracted by AFMA for the “hook” gear-type (where the “hook” gear-type included shark longline, trawl and scalefish longline). This assessment is based on revised data for the years 2001 onwards where the catches by gear-type are based on an extraction from a version of the AFMA database that is stored at CSIRO, with state catches added. The algorithm for constructing the catches by gear-type, region (Bass Strait, South Australia and Tasmania), and year was as follows:

- The data were extracted to form catch time-series by gear-type and region, with additional categories for unknown mesh gear, unknown gear, and unknown region.
- The catches for unknown mesh gear by year and region (including the “unknown” region catches) were allocated to the four mesh gears (6-inch, 6.5-inch, 7-inch and 8-inch) proportional to the recorded catches by mesh gear by year and region.
- The catches for unknown gear-type by year and region were allocated to the seven gear-types (the four mesh gear-types, “shark longline”, “trawl”, and “scalefish longline”) in proportion to the recorded catches by gear-type by year and region.
- The catches for unknown region by year and gear-type were allocated to the seven gear-types (the four mesh gear-types, “shark longline”, “trawl”, and “scalefish longline”) in proportion to the inferred catches by region by year and gear-type.
- The state catches by year were allocated to gear-type in proportion of the catch by gear-type.
- The resulting landed catches are scaled upwards to account for the estimated discard rates:

| Year | 2011 | 2012 | 2013 | 2014 | 2015 | Others |
|---|---|---|---|---|---|---|
| Discard rate | 0.063561 | 0.032478 | 0.032924 | 0.051360 | 0.059462 | 0.047957 |

The AFMA database does not store mesh size in integer numbers of inches (or half inches). Instead, the mesh size is given in (a wide range) of millimetres (mm). These were converted to 6-, 6.5-, 7- or 8-inches by converting the sizes in mm to inches, and then rounding to the nearest half inch and then using only those data that emerged as one of the known gear-types.

Figure A 17.1 compares the catches for 2001-2015 based on the 2013 assessment (results for 2001-2012 only) as well as those based on the algorithm outlined above. The catches by mesh gear for Bass Strait and Tasmania are about 5% larger than those used in the previous assessments (owing to the accounting for discard), but the catches by mesh gear off South Australia are larger (inter alia because of the inclusion of state catch data). The catches by shark longline, trawl and scalefish longline combined in this assessment exceed the “hook” catches used in previous assessments, particularly for Bass Strait, but also for Tasmania.

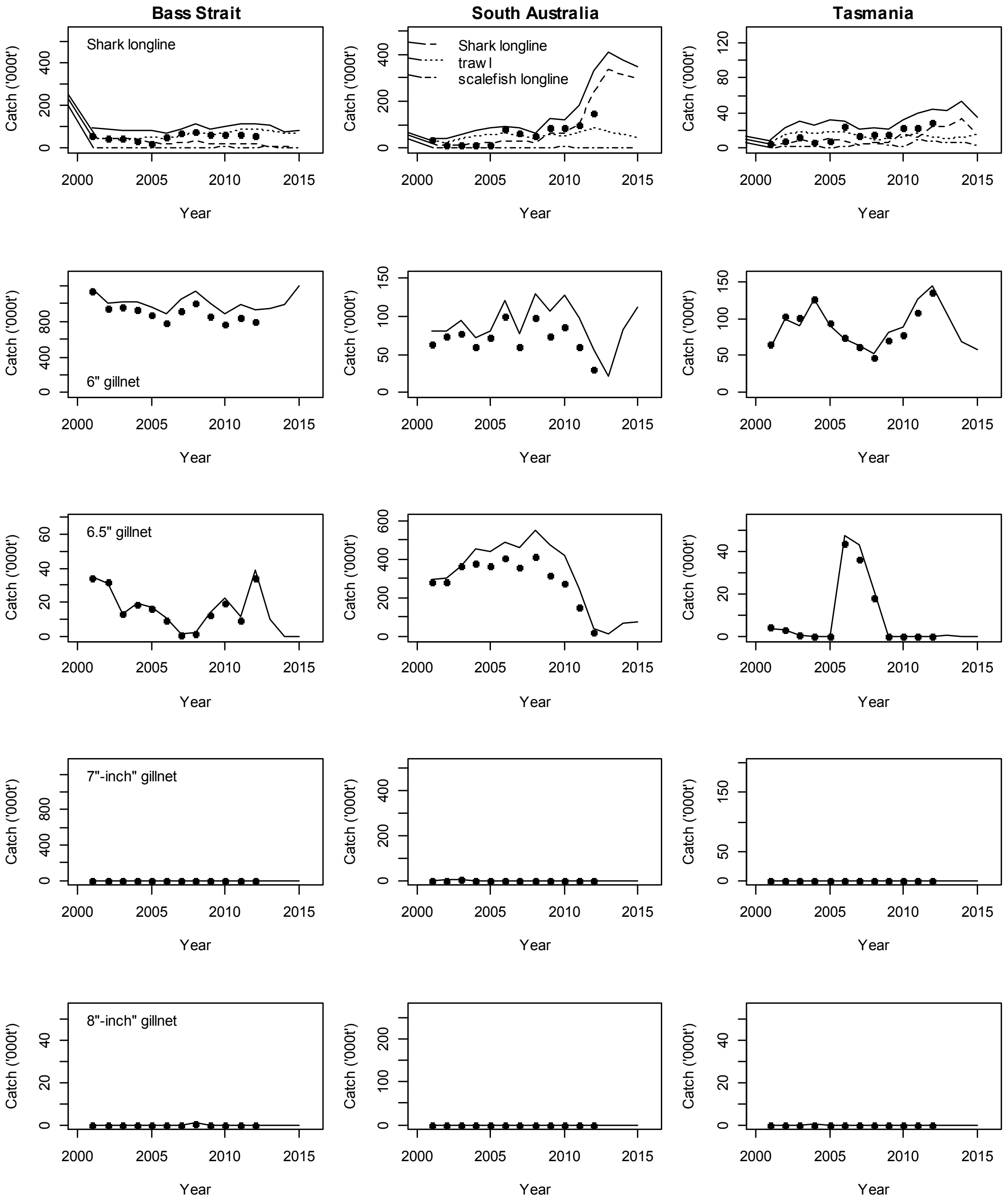



Figure A 17.1. Catches used in the 2013 assessment by region and gear-type (dots), with the catches for shark longline, trawl and scalefish longline combined, and the revised catches based on the algorithm outlined above (lines). The upper panels show the breakdown of the "hook" catch into its constituent gear-types.

## 17.11 Appendix B: Age-reading Error for Gummy Shark

Vertebrae for 256 gummy sharks were read twice to allow age-reading error to be evaluated. Given there is no way to validate the age-readings, the analysis was based on the assumption that age-readings are unbiased (i.e., on average the estimate of age is correct, although there may be random error about age estimates). The method of analysis (see Punt *et al*., 2008 for details) also assumes that errors when assigning ages are random. Two models were fitted to the data, one in which the CV of error reading error is independent of age and another in which it is governed by the Michaelis-Menton equation. Given the small sample size, the data do not support the more complex Michaelis-Menton equation. Consequently, the estimates of age-reading error are based on the constant CV model (Figure B 17.1(a)). Figure B 17.1(b)-(g) illustrate the observed ages by the second read as a function of that for the first read (e.g. Figure B 17.1(b) plots the ages assigned during the second read against those vertebrae that were assigned to be age 5 on the first read). The model fit to the ages with the largest sample sizes (ages 5, 6 and 7) are very good. The estimate of overdispersion is 0.798, which is good for analyses of data from double-read experiments.

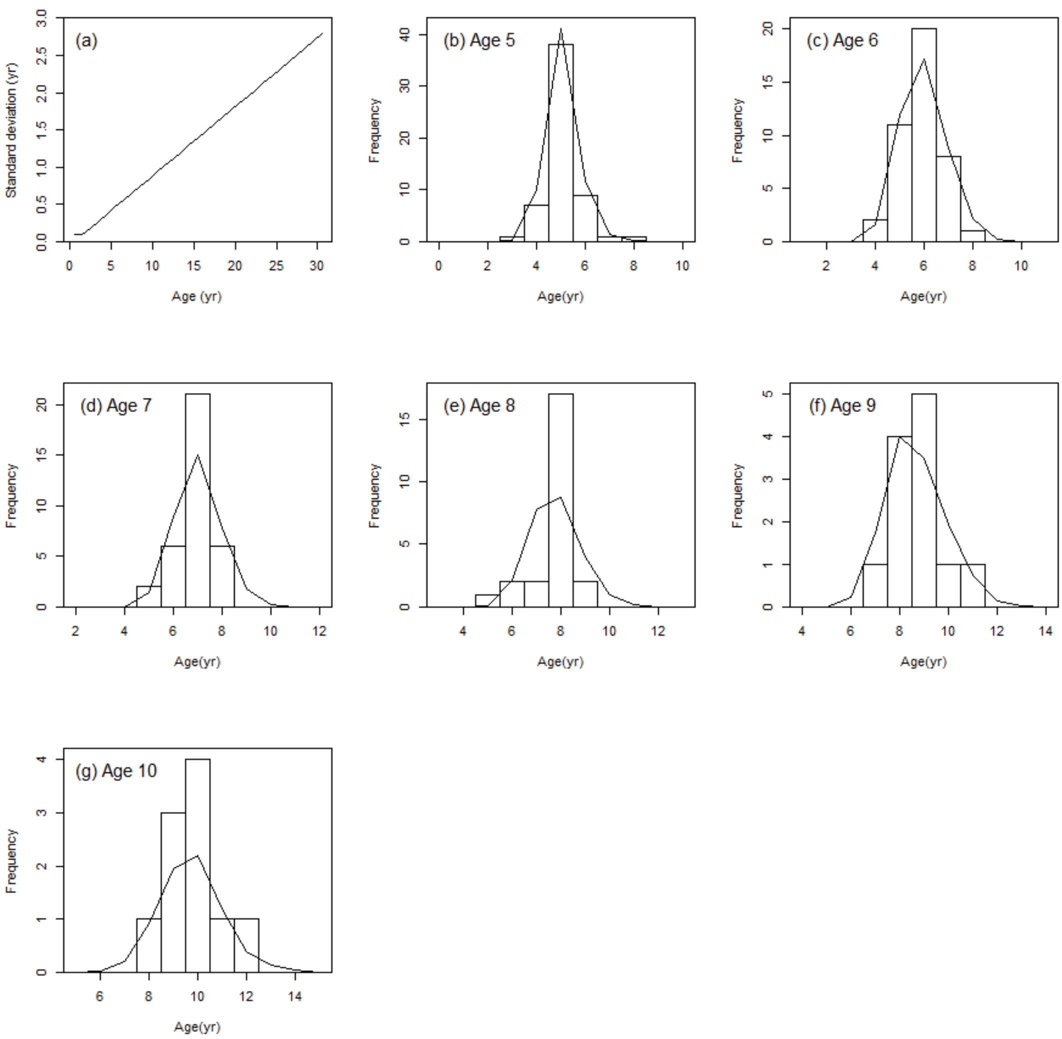



Figure B 17.1. Diagnostics for the fit to the age-reading error model.

## *17.12 Appendix C: Fits of the reference case model to the year-specific length- and age-composition data*


The numbers in the headers for each panel are the number of animals sized/aged scaled to the assumed effective sample sizes (Table 17.1 and Table 17.2).

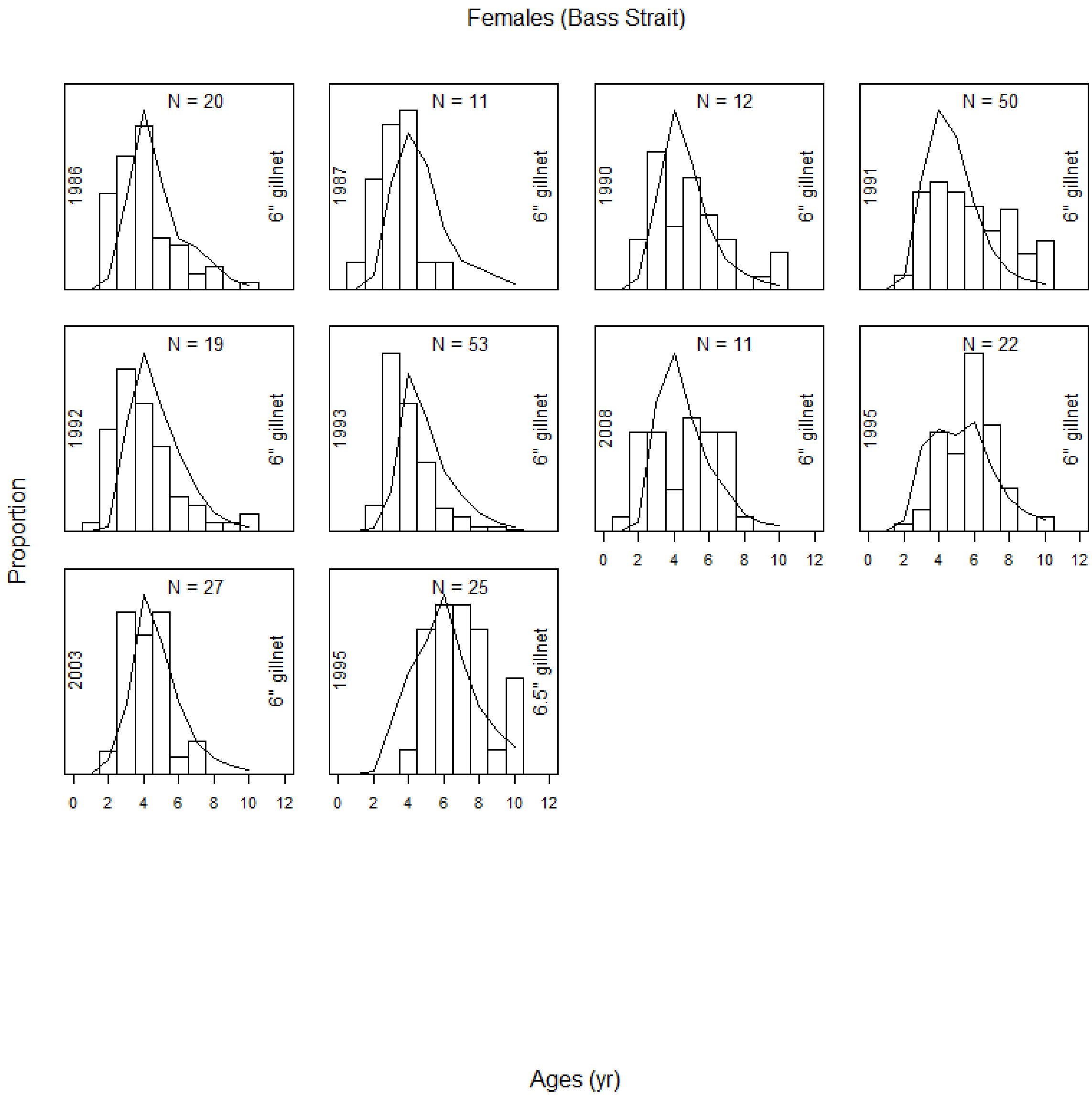

Females (South Australia)
2012 N = 7 Shark longline
2013 N = 9 Shark longline
2014 N = 24 Shark longline
2015 N = 1 Shark longline
1997 N = 8 6.5" gillnet
1998 N = 46 6.5" gillnet
1999 N = 85 6.5" gillnet
2000 N = 33 6.5" gillnet
2001 N = 38 6.5" gillnet
2002 N = 34 6.5" gillnet
2003 N = 16 6.5" gillnet
2008 N = 5 6.5" gillnet
2009 N = 13 6.5" gillnet
2010 N = 16 6.5" gillnet
2011 N = 24 6.5" gillnet
2012 N = 13 6.5" gillnet
2013 N = 5 6.5" gillnet
2014 N = 13 6.5" gillnet
1986 N = 6 7" gillnet
1987 N = 51 7" gillnet
1988 N = 18 7" gillnet
1990 N = 10 7" gillnet
1992 N = 25 7" gillnet
1993 N = 54 7" gillnet
1994 N = 22 7" gillnet
1995 N = 22 7" gillnet
1996 N = 16 7" gillnet
2009 N = 21 Scalefish longline
2011 N = 5 Scalefish longline
2014 N = 4 Scalefish longline
50 100 200
Proportion
Length (cm)

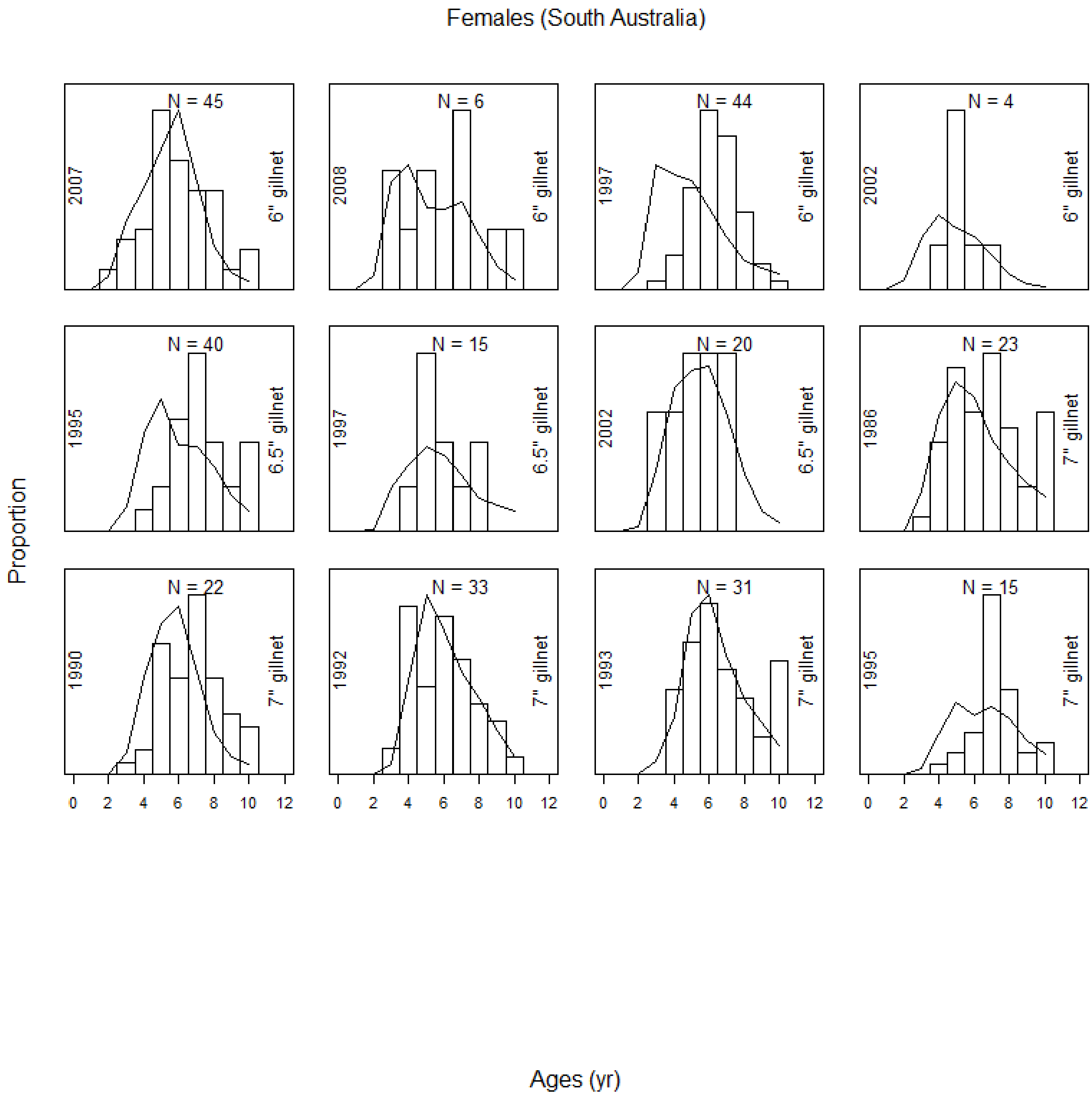

Females (Tasmania)
N = 8
2012
Shark longline
N = 4
2013
Shark longline
N = 19
2014
Shark longline
N = 9
1995
6" gillnet
N = 9
2013
6" gillnet
N = 12
2012
6" gillnet
N = 10
1996
7" gillnet
N = 7
2003
N = 4
2004
N = 2
2009
N = 7
2010
N = 2
2012
N = 37
2013
50
100
200
Proportion
Length (cm)

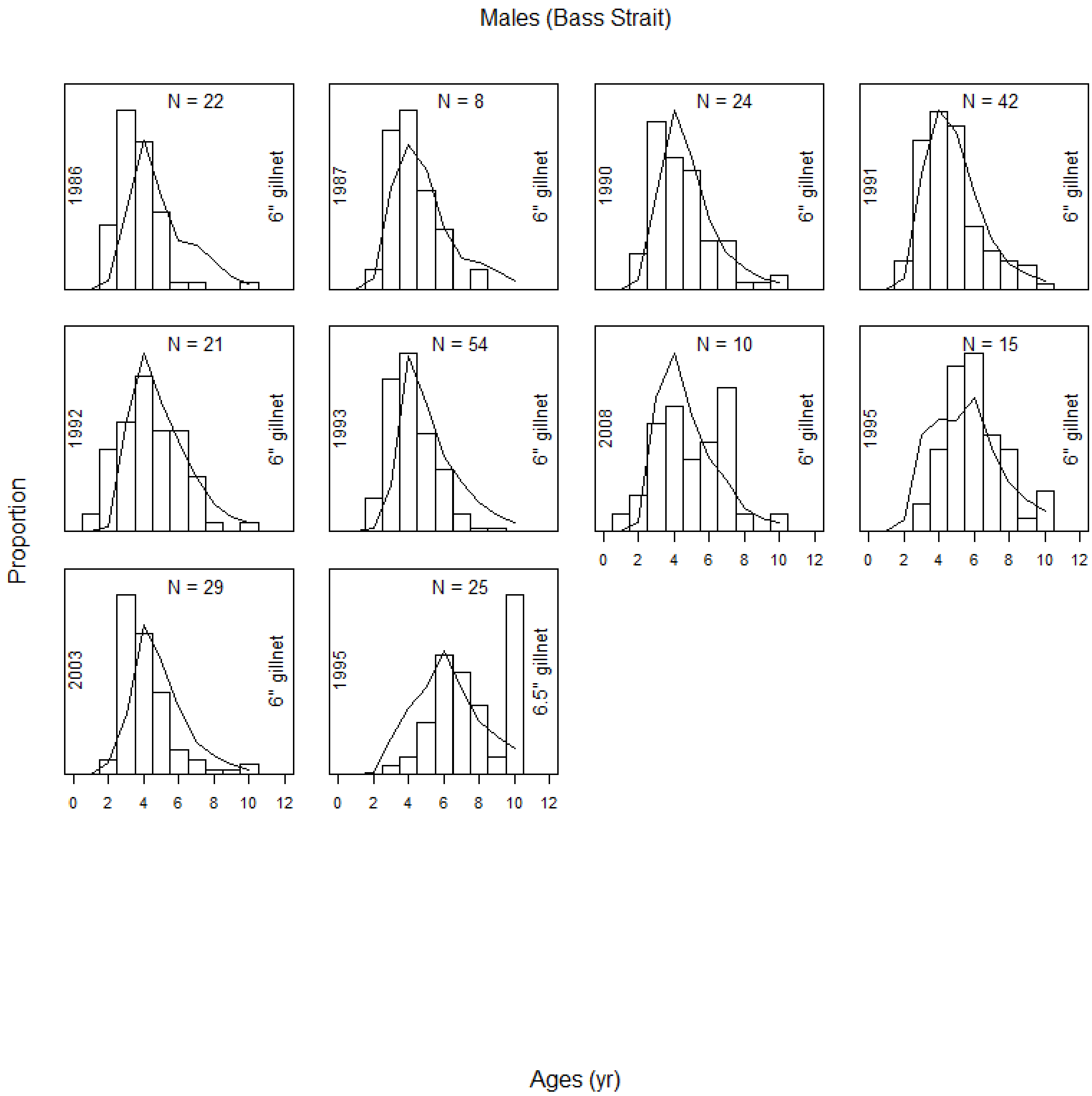

Males (Bass Strait)
Proportion
Length (cm)

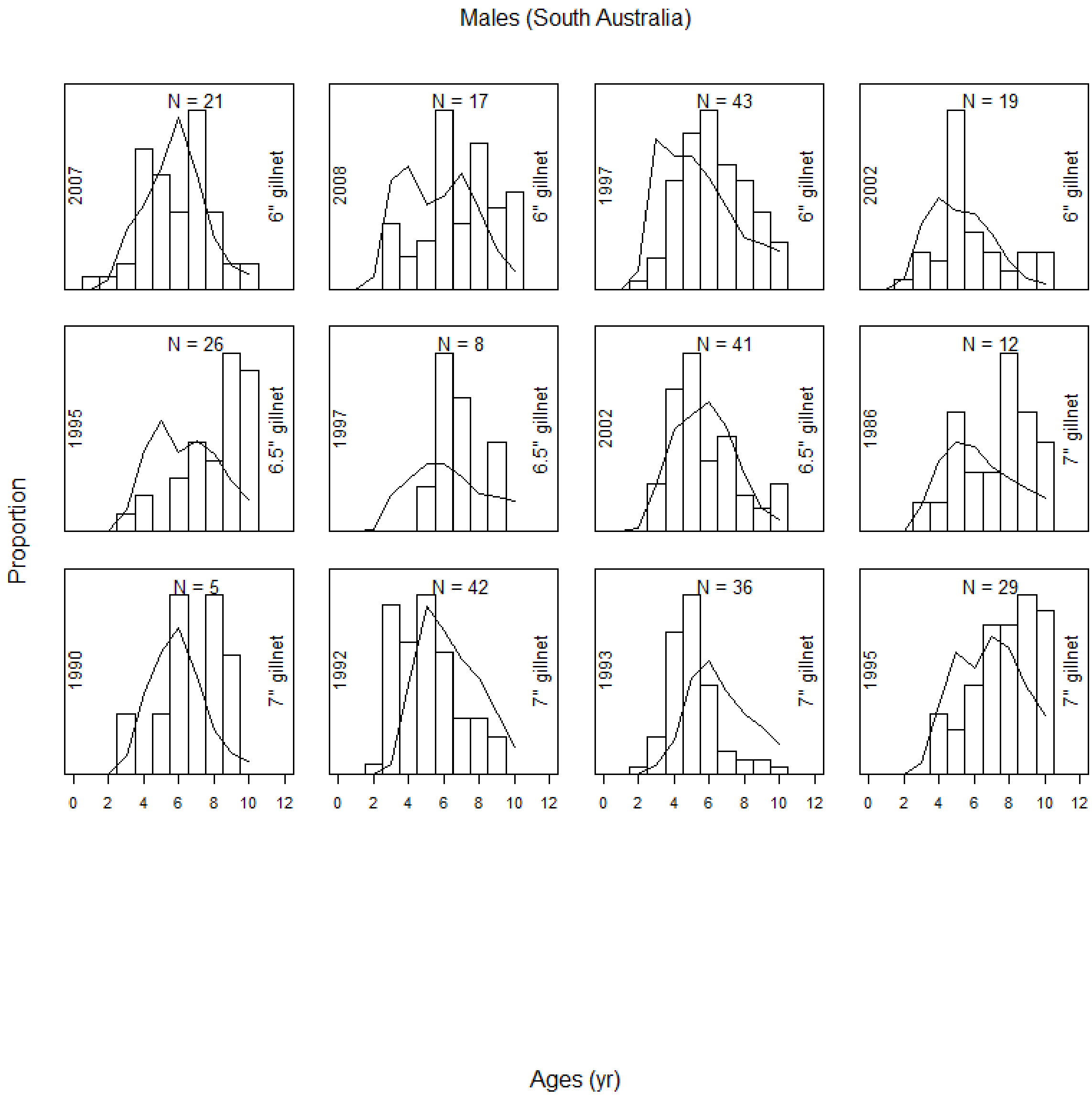

Males (South Australia)
N = 7
2012
N = 2
2013
N = 30
2014
N = 1
2015
N = 9
1997
N = 49
1998
N = 74
1999
N = 26
2000
N = 36
2001
N = 26
2002
N = 9
2003
N = 13
2008
N = 13
2009
N = 22
2011
N = 10
2012
N = 25
2013
N = 14
2015
N = 14
1986
N = 46
1987
N = 17
1988
N = 13
1990
N = 18
1992
N = 35
1993
N = 28
1994
N = 38
1995
N = 16
1996
N = 15
2009
N = 6
2011
N = 8
2014
50 100 200
Proportion
Length (cm)


Males (Tasmania)
Proportion
Length (cm)


Females (Bass Strait)
Proportion
N = 20
1986
6" gillnet
N = 11
1987
6" gillnet
N = 12
1990
6" gillnet
N = 50
1991
6" gillnet
N = 19
1992
6" gillnet
N = 53
1993
6" gillnet
N = 11
2008
6" gillnet
N = 22
1995
6" gillnet
N = 27
2003
6" gillnet
N = 25
1995
6.5" gillnet
0 2 4 6 8 10 12
Ages (yr)


Females (South Australia)
N = 45
2007
6" gillnet
N = 6
2008
6" gillnet
N = 44
1997
6" gillnet
N = 4
2002
6" gillnet
N = 40
1995
6.5" gillnet
N = 15
1997
6.5" gillnet
N = 20
2002
6.5" gillnet
N = 23
1986
7" gillnet
N = 22
1990
7" gillnet
N = 33
1992
7" gillnet
N = 31
1993
7" gillnet
N = 15
1995
7" gillnet
Proportion
0 2 4 6 8 10 12
Ages (yr)


Males (Bass Strait)
N = 22
1986
6" gillnet
N = 8
1987
6" gillnet
N = 24
1990
6" gillnet
N = 42
1991
6" gillnet
N = 21
1992
6" gillnet
N = 54
1993
6" gillnet
N = 10
2008
6" gillnet
N = 15
1995
6" gillnet
N = 29
2003
6" gillnet
N = 25
1995
6.5" gillnet
Proportion
0 2 4 6 8 10 12
Ages (yr)


Males (South Australia)
N = 21
2007
6" gillnet
N = 17
2008
6" gillnet
N = 43
1997
6" gillnet
N = 19
2002
6" gillnet
N = 26
1995
6.5" gillnet
N = 8
1997
6.5" gillnet
N = 41
2002
6.5" gillnet
N = 12
1986
7" gillnet
N = 5
1990
7" gillnet
N = 42
1992
7" gillnet
N = 36
1993
7" gillnet
N = 29
1995
7" gillnet
0 2 4 6 8 10 12
Proportion
Ages (yr)

## 17.13 Appendix D: Correlation matrix for the leading parameters of reference case model

| | Estimate | SE | Correlation | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
| 1 Log($R_0$) (Bass Strait) | 9.156 | 0.066 | | | | | | | | | | | | | | |
| 2. Log($R_0$) (South Australia) | 8.724 | 0.062 | 0.6512 | | | | | | | | | | | | | |
| 3. Log($R_0$) (Tasmania) | 7.582 | 0.099 | 0.5127 | 0.4361 | | | | | | | | | | | | |
| 4. $M_{adult}$ | 0.161 | 0.011 | -0.4978 | -0.4365 | -0.6126 | | | | | | | | | | | |
| 5. Length-at-50%-availability | 123.5 | 5.861 | -0.6580 | -0.5355 | -0.4980 | 0.5961 | | | | | | | | | | |
| 6. Length-at-50% selectivity (shark longline) | 870.7 | 28.409 | -0.0030 | -0.0246 | -0.1928 | 0.0985 | -0.1124 | | | | | | | | | |
| 7. Length-at-50% selectivity (trawl longline) | 719.1 | 19.022 | 0.0106 | 0.0220 | 0.0151 | -0.0212 | -0.0456 | 0.0222 | | | | | | | | |
| 8. Length-at-50% selectivity (scalefish longline) | 711.0 | 12.131 | 0.0366 | 0.0216 | -0.0272 | 0.0217 | -0.0920 | 0.0431 | -0.0005 | | | | | | | |
| 9. Log(selectivity slope) (shark longline) | -3.976 | 0.200 | 0.0342 | 0.0434 | 0.1605 | -0.0940 | 0.0391 | -0.8047 | -0.0146 | -0.0218 | | | | | | |
| 10. Log(selectivity slope) (trawl) | -3.029 | 0.326 | 0.0013 | 0.0012 | -0.0004 | 0.0021 | 0.0021 | 0.0029 | -0.2928 | 0.0017 | -0.0009 | | | | | |
| 11. Log(selectivity slope) (scalefish longline) | -2.990 | 0.274 | -0.0182 | -0.0100 | 0.0163 | -0.0089 | 0.0499 | -0.0258 | 0.0010 | -0.7052 | 0.0137 | -0.0011 | | | | |
| 12. $\gamma$ (Bass Strait) | 4.376 | 4.290 | 0.0361 | 0.0144 | 0.0145 | -0.0176 | -0.0044 | 0.0034 | -0.0374 | -0.0017 | -0.0041 | -0.0005 | -0.0014 | | | |
| 13. $\gamma$ (South Australia) | 50.000 | 0.028 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | | |
| 14. $\gamma$ (Tasmania) | 0.000 | 0.000 | 0.0000 | 0.0000 | -0.0001 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | |
| 15. Density-dependence parameter | 0.964 | 0.077 | -0.6871 | -0.5577 | -0.2852 | 0.0799 | 0.1684 | -0.0073 | -0.0126 | -0.0071 | -0.0069 | -0.0023 | 0.0039 | -0.0461 | 0.0000 | 0.0000 |

## *17.14 Appendix E: Evaluating sampling strategies for collecting future vertebrate*

SharkRAG requested an evaluation of alternative sampling strategies for the collection (and reading) of vertebrae. Such an evaluation cannot be conducted within the context of an assessment, but needs to be conducted using a simulation-estimation analysis. This would involve projecting the assessment model forward under a range of future catches, generating future deviations in pup numbers, generating future data (catch-rates, length-composition and [in particular] age-composition), applying the assessment method to the generated data and summarizing the results using various metrics of estimation performance. This process would be repeated for various alternative sampling schemes for collecting age-composition data (such as every second year, only from gillnet catches, from a variety of gears etc). Unfortunately conducting these calculations is beyond the scope of an assessment. Moreover, before it could be conducted, the following additional information would be needed:

- the specific alternative schemes to evaluate (including sample sizes);
- the metrics to evaluate estimation success (e.g. the bias and precision of incoming recruitment, how well RBCs are estimated, etc.); and
- information on the proportion of vertebrae that are collected, but cannot be aged.

Finally, the value of ageing data depends on the extent of ageing error. Appendix B provides a preliminary analysis in this regard, but there would be value in having additional data to better quantify ageing error.

# 18. Benefits

The results of this project have had a direct bearing on the management of the Southern and Eastern Scalefish and Shark Fishery. Direct benefits to the commercial fishing industry in the SESSF have arisen from improvements to, or the development of, assessments under the various Tier Rules of the Commonwealth Harvest Strategy Policy for selected quota and non-quota species. Information from the stock assessments has fed directly into the TAC setting process for SESSF quota species. As specific and agreed harvest strategies are being developed for SESSF species (a process required by and agreed to under EPBC approval for the fishery), improvements in the assessments developed under this project have had direct and immediate impacts on quota levels or other fishery management measures (in the case of non-quota species).

Participation by the project's staff on the SESSF Resource Assessment Groups has enabled the production of critical assessment reports and clear communication of the reports' results to a wide audience (including managers, industry). Project staff's scientific advice on quantitative and qualitative matters is also clearly valued.

The stock assessments presented in this report have provided managers and industry greater confidence when making key commercial and sustainability decisions for species in the SESSF. These assessments have provided the most up-to-date information, in terms of data and methods, to facilitate the management of the Southern and Eastern Scalefish and Shark Fishery.

# 19. Conclusion

- Provide quantitative and qualitative species assessments in support of the four SESSFRAG assessment groups, including RBC calculations within the SESSF harvest strategy framework.

The 2016 assessment of the stock status of key Southern and Eastern Scalefish and Shark fishery species is based on the methods presented in this report. Documented are the latest quantitative assessments (Tier 1) for key quota species (gummy shark, deepwater flathead, tiger flathead and an update of eastern gemfish), as well as cpue standardisations for shelf, slope, deepwater and shark species and Tier 4 analyses. Typical assessment outputs provided indications of current stock status and an application of the Commonwealth Harvest Strategy framework. This framework is based on a set of assessment methods and associated harvest control rules, with the decision to apply a particular combination dependent on the type and quality of information available to determine stock status (Tiers 1 to 4).

The assessment outputs from this project are a critical component of the management and TAC setting process for these fisheries. The results from these studies are being used by SESSFRAG, industry and management to help manage the fishery in accordance with agreed sustainability objectives.

**Stock status and Recommended Biological Catch (RBC) conclusions:**

The 2016 assessment for tiger flathead was updated by the inclusion of data to the end of 2015. This assessment also included Fishery Independent Survey (FIS) data and length frequencies from all four years of the FIS. The base-case assessment estimates that current spawning stock biomass is 43% of unexploited stock biomass (SSB0). Under the agreed 20:35:40 harvest control rule, the 2017 recommended biological catch (RBC) is 2,971 t, and remains above the long term yield (assuming average recruitment in the future) of 2,765 t. The average RBC over the three year period 2017-2019 is 2,936 t and over the five year period 2017-2021, the average RBC is 2,909 t.

The 2016 assessment of deepwater flathead included ISMP data that were divided into the on-board and port based samples, the length and age composition data from the FIS were used for the first time, and the industry collected length composition data were also used for the first time. The base-case assessment estimates that the female spawning stock biomass at the start of 2016/2017 was 45.0% of unexploited female spawning stock biomass ($SSB_0$). The 2017/2018 RBC under the agreed 20:35:43 harvest control rule is 1155 t and the long-term yield (assuming average recruitment in the future) is 1093 t. Averaging the RBC over the three year period 2017/2018 – 2019/2020, generates a three year RBC of 1128 t and over the five year period 2016/2017 – 2020/2021, the average RBC would be 1115 t.

The assessment for gummy shark (*Mustelus antarcticus*) was updated based on available information to 2015. The model on which the assessment is based was modified in three ways: (a) the dynamics are now based on a population dynamics equation that assumes that the catches by the various gear-types occur simultaneously rather than sequentially, (b) the "hook fleet" included in previous assessments is now separated into shark longline, trawl, and scalefish longline gear-types, with size-specific selectivity estimated for each gear-type, and (c) allowance is now made for age-reading error. A reference case model was presented with fits that are all reasonable and the assessment outputs indicate that gummy shark in Bass Strait, and off South Australia and Tasmania are above the management target of 48% of unfished pup production. The RBC for 2016, 2017 and 2018 from the reference case model are 2080t, 1878t, and 1807t.

An update of the eastern gemfish assessment was conducted in 2016. Catch data were incorporated from 1968, state catches were included, and length-frequency data dating back to 1975 were used. This update included (a) the estimation of the growth parameters within the assessment, (b) the use of conditional age-at-length data, (c) the addition of updated length-frequencies, catches and catch-rates to 2015, (d) the inclusion of discards and (e) allowance for ageing error. With the latest data to the end of 2015, the spawning stock biomass is 8.3% of the average unfished level. Similar to the previous assessment, a large spawning event was estimated to have occurred in 2002, which has led to slight recovery of biomass. A relatively high recruitment event is apparent in 2013, although this event simply returns to the long-term average rather than the depressed level of recruitment that has been experienced in recent times.

The Tier 4 harvest control rule is applied to species for which there is no reliable information on either current biomass levels or current exploitation rates. Mirror Dory East, Mirror Dory East including discards into the CPUE, Mirror Dory West, Western Gemfish and Blue-eye Trevalla have been assessed using the Tier 4 methodology in 2016. The Mirror Dory analyses treat the west and east as separate stocks, and also include the high levels of discards that occur in the east. Mirror dory RBCs for the east were either 222t or 173t (without or with discards) and for the west was 104t. For western gemfish, the RBCs were 423t or 139t (with or without discards). The Tier 4 analysis for blue-eye is based on the CPUE, as catch-per-hook, from SESSF zones 20 – 50 but the catches that go towards generating the target catch include all areas and methods except the GAB. This is a reflection of the hypothesis that the blue-eye in the GAB constitute a separate stock. The RBC from the analysis based on catch-per-hook catch rates is now 526t. This is a relatively large change in the RBC from last year, which is a reflection of the potential behaviour of the Tier 4 when CPUE is recovering from a relatively low period.

# 20. Appendix: Intellectual Property

No intellectual property has arisen from the project that is likely to lead to significant commercial benefits, patents or licenses.

# 21. Appendix: Project Staff

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