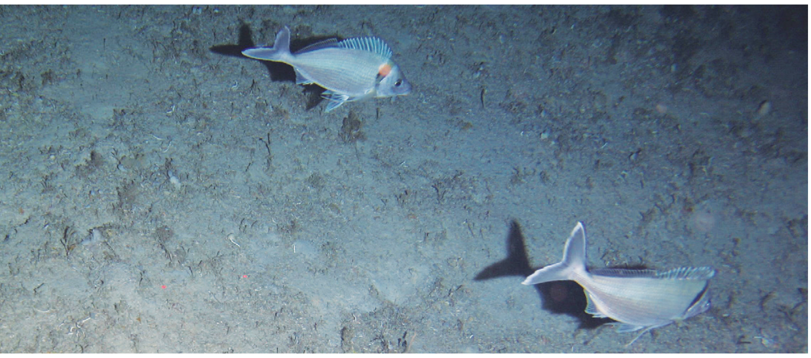
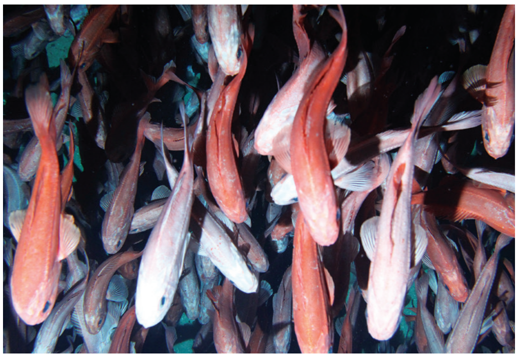
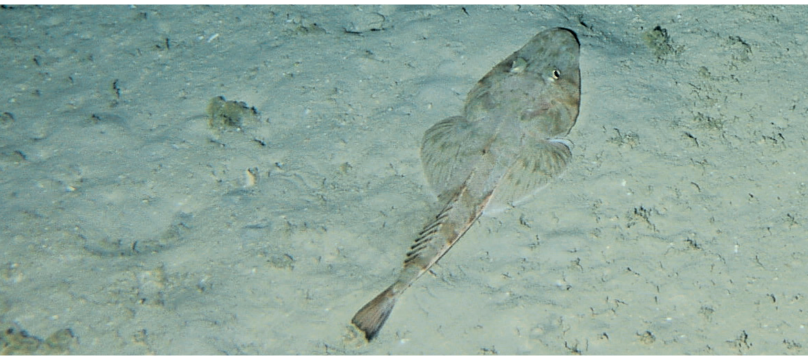
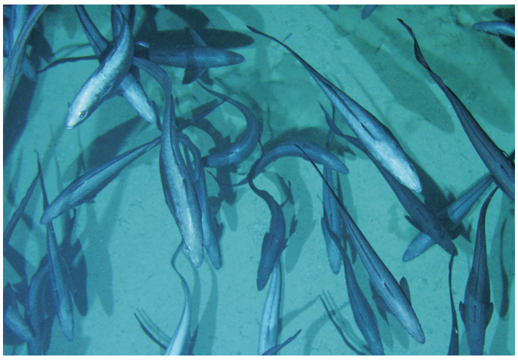
Australian Government
Australian Fisheries Management Authority

2011/0814 June 2014

# Stock Assessment for the Southern and Eastern Scalefish and Shark Fishery: 2013

PART 2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***Acknowledgements***

*All authors wish to thank the science, management and industry members of the slope-deepwater, shelf, GAB and shark resource assessment groups for their contributions to the work presented in this report. Authors also acknowledge support from Fish Ageing Services (for fish ageing data) and AFMA (for the on-board and port length-frequencies, and in particular John Garvey, for the log book data). Jemery Day and Louise Bell are also greatly thanked for their assistance with the production of this report and Tim Ryan and Bruce Barker for the cover photographs of SESSF fish. Sally Wayte and Neil Klaer are thanked for their enormous contribution to the assessment and management of SESSF stocks.*

***Cover photographs***

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

***Report structure***

*Part 1 of this report describes the Tier 1 assessments of 2013. Part 2 describes the Tier 3 and Tier 4 assessments, catch rate standardisations and other general work contributing to the assessment and management of SESSF stocks in 2013.*

# Stock Assessment for the Southern and Eastern Scalefish and Shark Fishery: 2013

## Part 2: Tier 3 and Tier 4, catch rate standardisations and other work contributing to the assessment and management of SESSF stocks in 2013

G.N. Tuck
June 2014
Report 2011/0814

Australian Fisheries Management Authority

# Stock Assessment for the Southern and Eastern Scalefish and Shark Fishery: 2013 Part 2

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# 15. Tier 1 CPUE forecasts for multi-year TAC breakout

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## 15.1 Summary

This chapter examines whether recent actual CPUE trends are consistent with projected trends from the most recent Tier 1 stock assessments. Only species not planned for assessment this year are examined, to allow RAG judgement of whether as assessment may be warranted. Of the species examined, only two showed actual CPUE trends that fell outside of the 95% confidence bounds projected from the stock assessment – jackass morwong and silver warehou. Jackass morwong had results for two areas, and it was the result from the area with the least catch that fell just outside of the bounds, so this species was judged not to have broken out. Silver warehou however, only had one CPUE indicator series, and this had unambiguously broken out for the past two years.

## 15.2 Methods

To generate forecast CPUE from stock synthesis version 3 (SS) requires a run of the most recent stock assessment, updated with recent actual catches. Results were sought for SESSF school whiting, morwong and silver warehou. CPUE was not used for orange roughy, and shark assessments do not use SS, so this procedure does not apply to those.

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

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 - this year it is 2011.

Add the most recent actual catch estimates for the years to 2011 to the catch series using the attached CDRsum.xlsx file - assume fleet splits as per your last projections (don't forget to increase the number of lines of catch data.

Add lines to the end of recent abundance indices so that they finish in 2011. Please use values of 1.0 and a CV of 999.0 - here are examples used for index 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
```

Edit ss3.par

Add another 0.0000000000 to the end of rec devs 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.

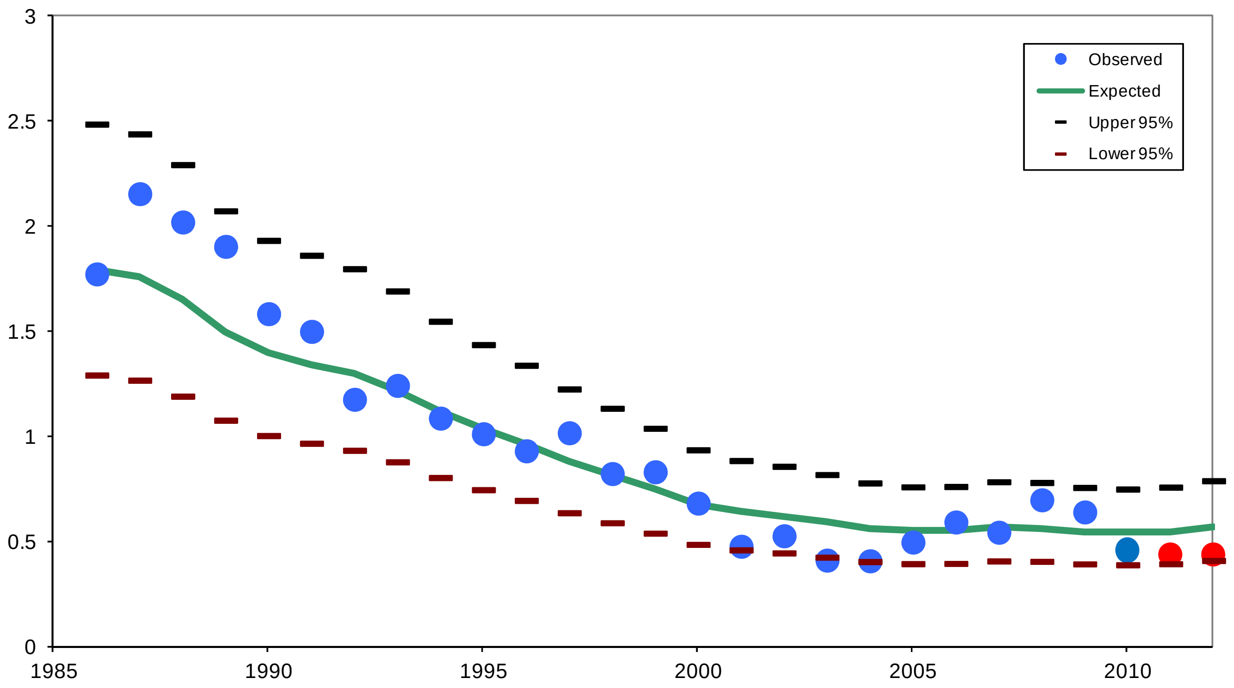
## 15.3 Results

Observed CPUE values used for the last stock assessment are shown as blue circles. Observed values as calculated in 2013 (Haddon 2013) for years since those used in the assessment are shown as red circles. The red series has been rescaled to the value of the last point in the blue series.

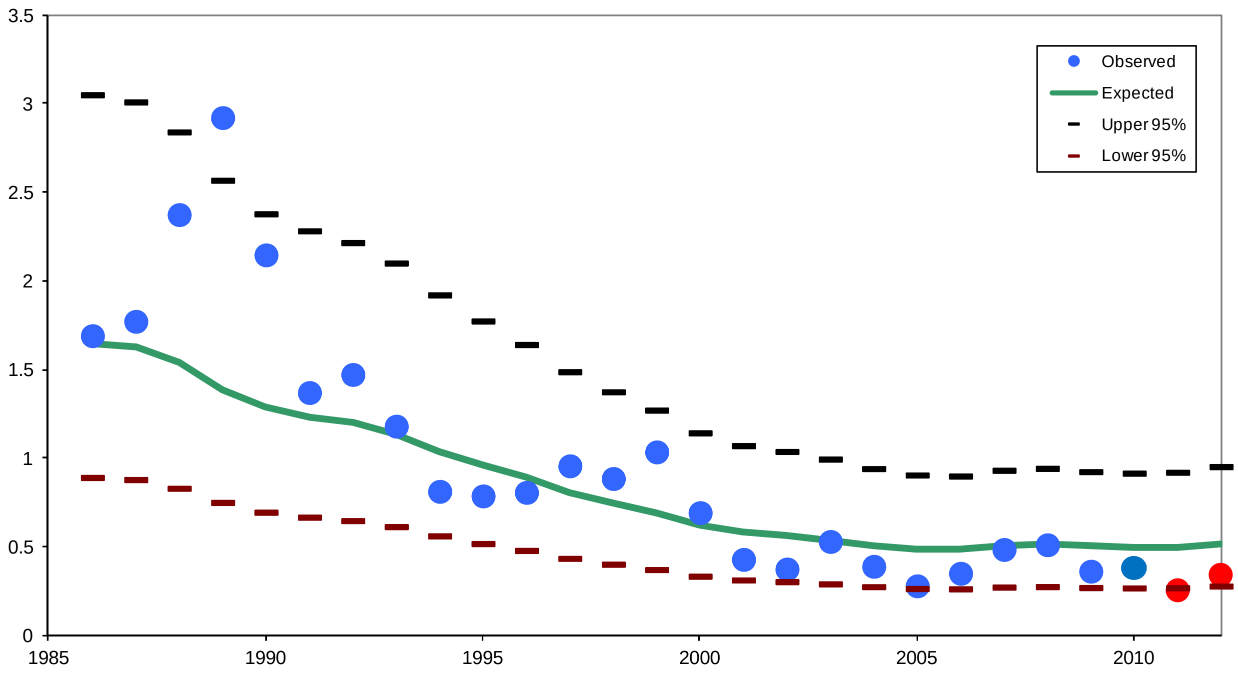
The only series that have been examined where recent observed CPUE values have landed outside of the 95% confidence interval of the data as predicted by the last stock assessment are for jackass morwong Tas trawl, and silver warehou trawl. As only one third of the catch of jackass morwong was taken by the Tas trawl fleet, and the NSW and Vic trawl index was not broken out, a case may be made for not breaking out jackass morwong. However, the breakout for silver warehou is clear and unambiguous.

### *15.3.1 Jackass morwong*

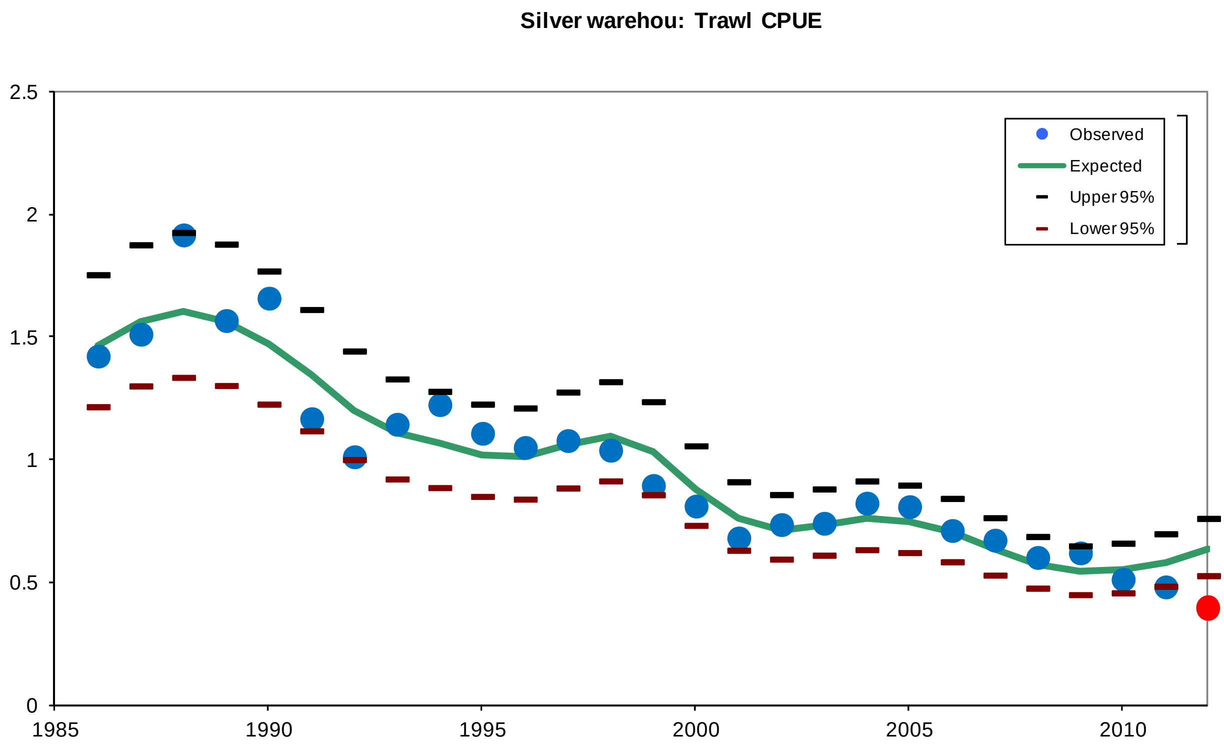
**Jackass morwong: NSW Vic trawl CPUE**



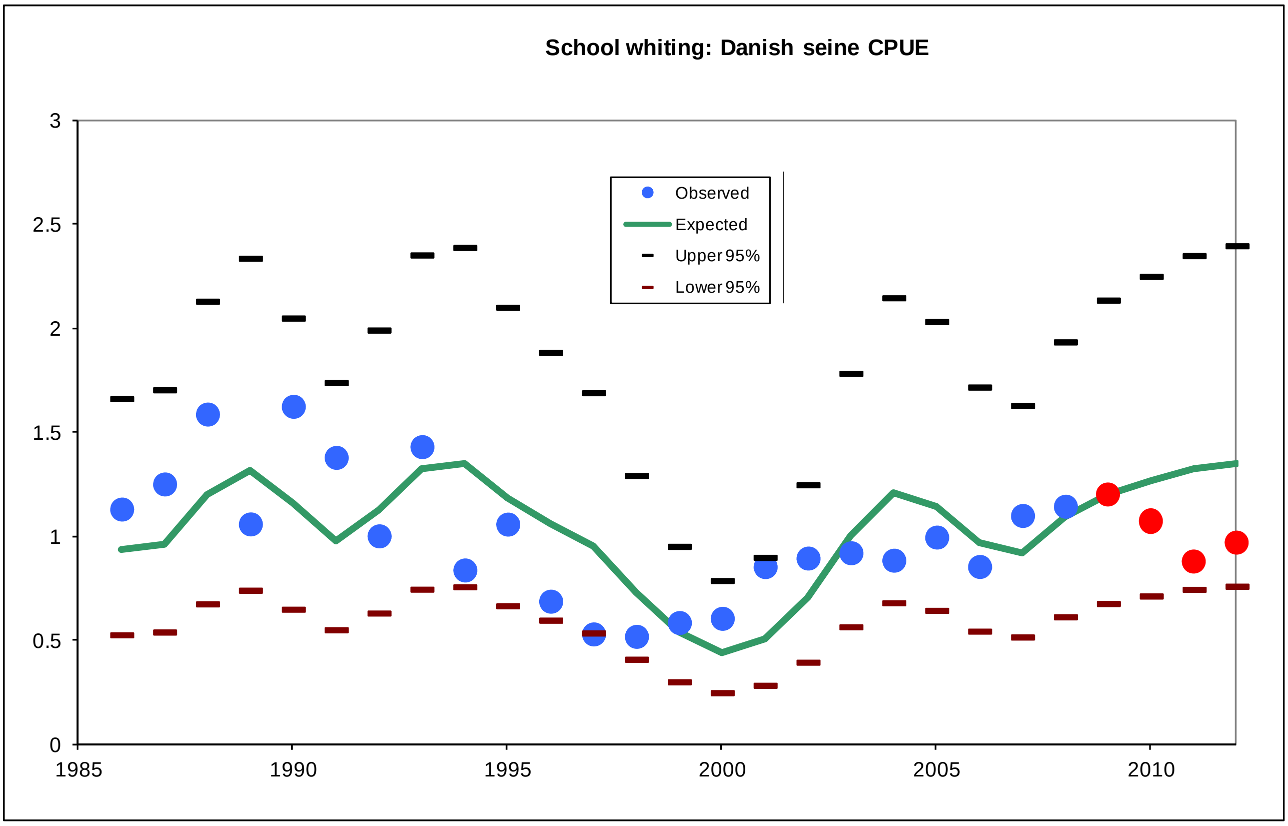

**Jackass morwong: Tas trawl CPUE**



### *15.3.2 Silver warehou*



### *15.3.3* School whiting




## *15.4 Acknowledgements*

Thanks to all of the Tier 1 stock assessment authors for providing forecast CPUE estimates: Geoff Tuck, Sally Wayte, Jemery Day, Rich Little.

## *15.5 References*

Haddon 2013. Catch Rate Standardizations for Selected Species from the SESSF (data 1986 – 2012). Draft report the Shelf and Slope RAG, 2013.

# 16. Estimated conversion coefficients for LCF to TOT length measurements for gummy shark, school shark, elephant fish and discussion of further needs

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## *16.1 Introduction*

The AFMA Observer Program and its predecessor the Integrated Scientific Monitoring Program (e.g. Knuckey et al. 2001; Talman et al. 2003) collected length information from commercial catches for quota species to facilitate stock assessments. Length information for the four shark quota species: school shark, gummy shark, elephant fish and saw shark have been collected using a range of measurements, of which total length (TOT), partial length (PAR) and LCF (fork length) predominate (Figure 16.1 and Table 16.1).

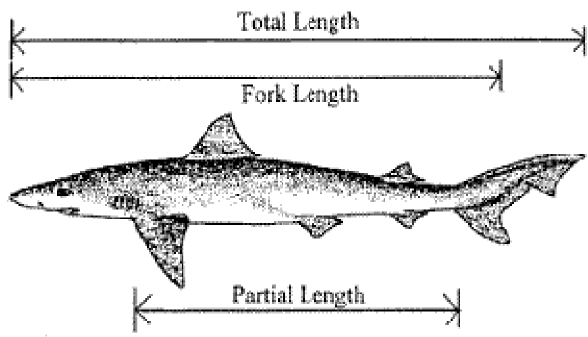


Figure 16.1. Partial length (PAR), fork length (LCF) and total length (TOT) as measured by the AFMA Observer Program (taken from the 'GHATF – Gillnet Observers Manual 2008, AFMA Observer Program'; GHATF, 2008).

Table 16.1. Number of sharks measured by the AFMA Observer Program over all years, regions, gear types and for both sexes (and sex unknown). The type of measurement (see Figure 16.1) is shown. Blanks indicate zero samples. Grey shading indicate samples that can now be used in stock assessments.

| Type | School shark | | Gummy shark | | Elephant fish | | Sawsharks | |
|---|---|---|---|---|---|---|---|---|
| | Port | Onboard | Port | Onboard | Port | Onboard | Port | Onboard |
| TOT | | 3114 | | 48848 | | 6775 | | 9663 |
| PAR | 18513 | 642 | 55645 | 2095 | 7804 | 2 | 2847 | 354 |
| LCF | 1492 | 1519 | 4640 | 10060 | | 1272 | | 947 |
| Unknown | 2 | 2 | 931* | 39 | | | | 10 |
| STL | | | 204 | 36 | | | | 1 |
| Other | | | | 4 | | | | 5 |

* All net captures, 794 sharks measured in Streaky Bay captured in Central South Australia during 2009 and 137 unsexed sharks measured in an unknown port from an unknown zone of capture during 1999.

In order to use length data in stock assessments, it is necessary to convert all length measurements to a single type (TOT), for which growth curves are available. It is evident that estimated conversion coefficients are required for (i) PAR to TOT and (ii) LCF to TOT for all four shark quota species (Table 16.1). These coefficients are available for PAR to TOT for school and gummy shark (Walker et al. 2009) but until now (this document) none were available for LCF to TOT. However, when all PAR measurements for school and gummy shark are converted to TOT, and plotted alongside the length frequency for TOT measurements, the length frequencies differ more than would be expected (Figure 16.2). This may be due to changes, over time, in (i) the way sharks are processed before landing (ii) how a PAR length measurement is made, or (iii) other factors which may influence which fish are landed and which are measured onboard. It would be desirable to estimate new PAR to TOT conversion coefficients for school and gummy sharks to investigate this apparent change.

## 16.2 Data & methods

Observer data collected by the AFMA Observer Program under the banner “biological samples” were provided by John Garvey (AFMA, Canberra). The data included a unique identifying code for each individual shark “Bio.Id”, which was used to identify LCF and TOT measurements taken from single individuals. Apart from one gummy shark that had a PAR measurement, all measurements were of type LCF and TOT. See Figure 16.1 for the three measurements used. Note that the data shown in Table 16.1 and Figure 16.2 relate to commercially caught sharks, sampled by the Observer Program, for which a single measurement were taken. The data shown in Table 16.2 and Figure 16.3 relate to sharks for which dual measurements were taken. Whether or not these measurements were also included in the main Observer Program database (and if so, whether each individual shark appears once, or twice) is unknown.

Apart from one gummy shark measured in January 2007, and one school shark measured in September 2009, data for all species were collected between 2011 and 2013. All but eight gummy sharks were measured during 7-10 Feb 2013 or 6-27 Oct 2012. All but five school shark samples were measured between 6 Oct-20 Nov 2012 and 7-10 Feb 2013. Apart from four elephant fish samples taken on January 2011, all were sampled between 19-27 Oct 2012.

Gummy shark were mostly sampled from Eastern Bass Strait, while school shark were mostly sampled from Western Bass Strait (Table 16.2). By contrast, elephant fish were equally sampled from Eastern Bass Strait and Eastern Tasmania (Table 16.2).

Table 16.2. Sample sizes by shark region (zone) of capture. WSA: Western South Australia; CSA: Central South Australia; WBS: Western Bass Strait; EBS: Eastern Bass Strait; WTas: Western Tasmania; ETas: Eastern Tasmania

| Region | Gummy shark | School shark | Elephant fish |
|---|---|---|---|
| WSA | 1 | 1 | |
| CSA | 2 | | 4 |
| WBS | 43 | 24 | 4 |
| EBS | 110 | 20 | 16 |
| WTas | 7 | 5 | |
| ETas | 65 | 2 | 16 |

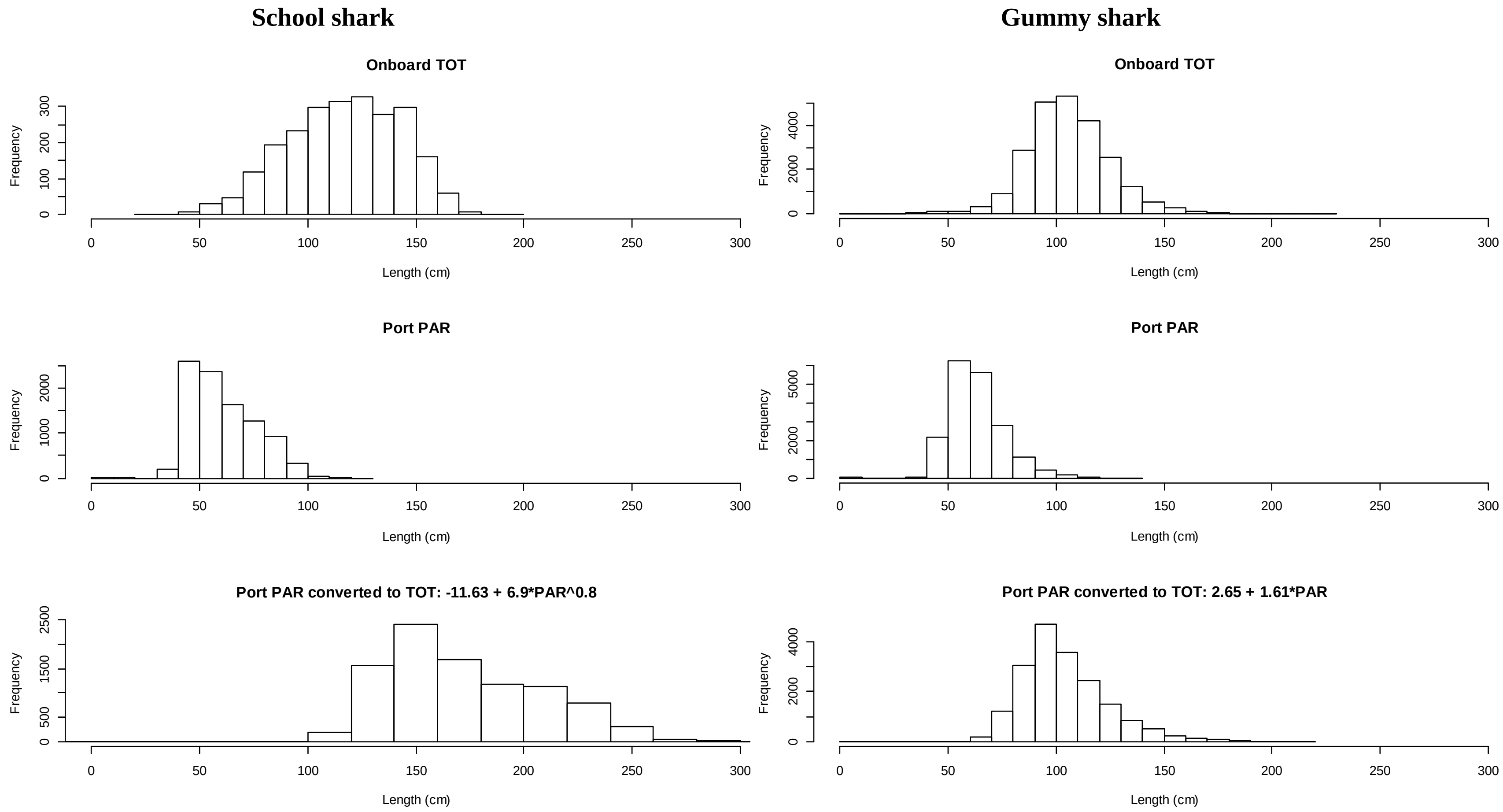


Figure 16.2. Length frequencies for school shark and gummy shark collected by the AFMA Observer program. Top panel: All data collected as total length (TOT);middle panel: All data collected using partial length (PAR), and bottom panel: PAR measurements after conversation to TOT.

The R statistical software was used to fit linear regressions based on Ordinary Least Squares to all double-measured gummy shark (Mustelus antarcticus), school shark (Galeorhinus galeus) and elephant fish (Callorhinchus mili). Estimated parameters (a; b) were used to convert LCF length (cm) to TOT length (cm) for stock assessment purposes using the formula: TOTi = a + b LCFi, for shark i (Table 16.3).

### 16.3 Results & conclusions

The estimated conversion coefficients for gummy shark and school shark appear reliable, with $R^2$ statistics close to 1 – these can be used with confidence to convert LCF to TOT lengths for stock assessment purposes (Table 16.3; Figure 16.3).

Table 16.3. Estimated coefficients of linear regressions between LCF and TOT measurements for gummy shark school shark and elephant fish. $R^2$ statistics and sample sizes are also shown. “na”: not available (no samples)

| Common name | Intercept (*a*) | Slope (*b*) | $R^2$ | Sample size |
|---|---|---|---|---|
| Gummy shark | 5.166 | 1.085 | 0.99 | 228 |
| School shark | 2.915 | 1.107 | 0.98 | 52 |
| Elephant fish | 14.185 | 1.004 | 0.85 | 40 |
| Saw shark | na | na | na | 0 |

Estimated coeffcients for saw shark could not be obtained because this species was not sampled. The sample size for elephant fish is relatively small and measurements show greater variability than those of other two species. In particular, two measurements with low LCF appear unduly influential (Figure 16.3). Therefore, the estimated coefficients should not be used to convert from LCF to TOT lengths for elephant fish.

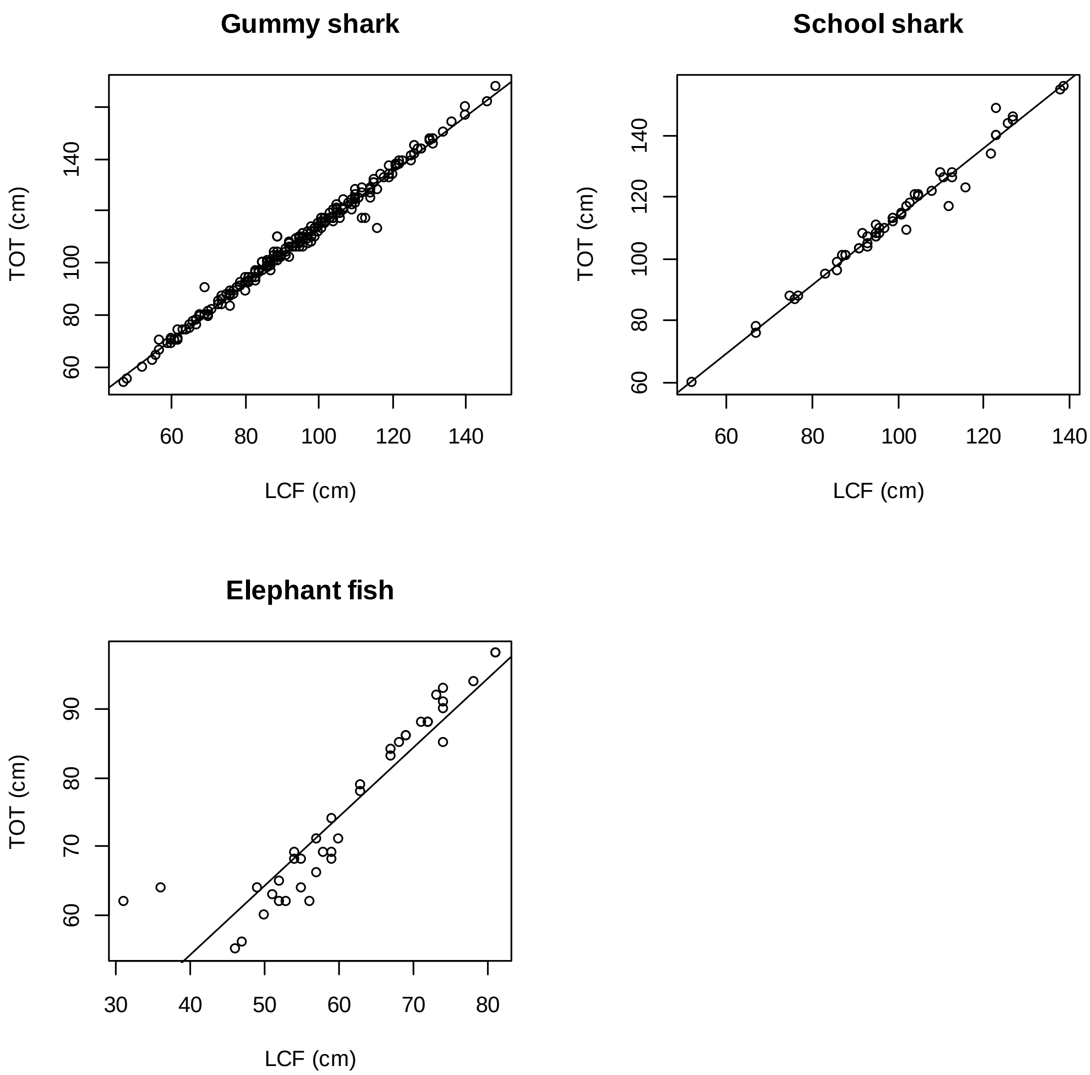


Figure 16.3. Length measurements (cm) of the LCF and TOT type for individual sharks (circles) and an estimated -linear regression (line) for gummy shark, school shark and elephant fish.

### *16.4 Further work*

1. The variability in the relationship between LCF and TOT for elephant fish presumably relates to differences in the way these sharks are processed. It would be useful for sharkRAG to discuss what factors might influence processing (e.g. different methods on different boats, or at different ports or different sized fish). A larger sample size which records any factor that may influence processing would be of use.
2. A sawshark relationship, using dual LCF-TOT measurements made for these sharks, would be of great value to any future assessment of these (two) species.
3. Dual PAR-TOT measurements for all four species would be of value to stock assessments as the port length collections cannot (at present) be used.

### 16.5 Acknowledgents

Thanks to both John Garvey (AFMA) and Selvy Coundjidapadam (AFMA) for providing the data on which this work is based.

### 16.6 References

GHATF (2008). GHATF – Gillnet Observers Manual 2008, AFMA Observer Program.

Knuckey, I. and Gason, A.S.H. (2001). Development of a "design model" for an adaptive ISMP sampling regime. Marine and Freshwater Resources Institute Integrated Scientific Monitoring Program. Final report to the Australian Fisheries Management Authority December 2001. ARF Project R99/1502

Talman, S.G., Brown, L.P., Gason, A.S.H., and Berrie, S. (2003). Gillnet, Hook and Trap Fishery Integrated Scientific Monitoring Program 2002/2003 Report to the Australian Fisheries Management Authority.

Walker, T. I., and Gason, A. S. (2009). SESSF monitoring data management, reporting and Documentation 2006/07. Final report to Australian Fisheries Management Authority Project No. R2006/812. (June 2009). vii + 177 pp. (Marine and Freshwater Fisheries Research Institute, Fisheries Victoria, Department of Primary Industries: Queenscliff, Victoria, Australia).

# 17. Yield, total mortality values and Tier 3 estimates for selected shelf and slope species in the SESSF 2013

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## *17.1 Summary*

This chapter updates yield analyses presented in Klaer (2012) for major commercial species caught in the Southern and Eastern Scalefish and Shark Fishery (SESSF) on the shelf and slope. Much of the data processing and analysis has been automated, following procedures documented particularly in Thomson (2002a) and Klaer *et al*. (2008).

Yield and total mortality estimates are provided for major commercial fish species from the shelf and slope in the South East Fishery. Yield estimates were made using a yield-per-recruit model with the following input: selectivity-at-age, length-at-age, weight-at-age, age-at-maturity, and natural mortality. Total mortality values corresponding to various reference equilibrium biomass depletions were calculated for each species.

Recent average total mortality was estimated from catch curves constructed from length frequency information. Length frequency data were from ISMP port and/or onboard measurements. The method used to estimate total mortality also estimates average fishery selectivity.

Tier 3 calculations use the estimates of total mortality, natural mortality and average recent catches to decide the Recommended Biological Catch (RBC) for next year. The method used to calculate the Tier 3 RBC is described in Klaer *et al*. 2008 and Wayte and Klaer (2010). An average length procedure was developed and tested (Klaer *et al*., 2012) for species where only length data and no age samples are available. The average length method is described here, but results not presented because all current Tier 3 species have recent length at age data.

Tier 3 calculations were applied to all SESSF quota species with sufficient available information, regardless of the actual Tier that applies to the species because (a) the Tier that will apply to each species in the current year is decided by the Resource Assessment Groups and (b) it is useful to compare Tier 3 results with those from other Tiers to check performance of the methods.

At the SESSFRAG meeting in early 2012 it was agreed to allow the investigation of an *M*-based threshold to limit the size of the RBC multiplier produced by Tier 3 analyses. In the results here, $F_{cur}$ has been limited to a lowest possible value of $M/10$. Alfonsino was the only species to reach this threshold (last year was alfonsino, John dory and mirror dory).

RBC values for alfonsino, John dory and redfish were greater than reference average catches (p>1). The RBC for mirror dory is lower than the reference catch (p<1) which is a result very different to that presented in 2012. The reason is a considerable shift in the average *Z* fit for catch curves in the east (Figure 17.26) caused by a change in emphasis in the overall fit from younger to older fish. This highlights the possible catch variability inherent in a data-poor procedure such as the Tier 3.

## 17.2 Methods

### 17.2.1 Zoning

The fishery region and zones referred to here are as shown in Figure 17.1.

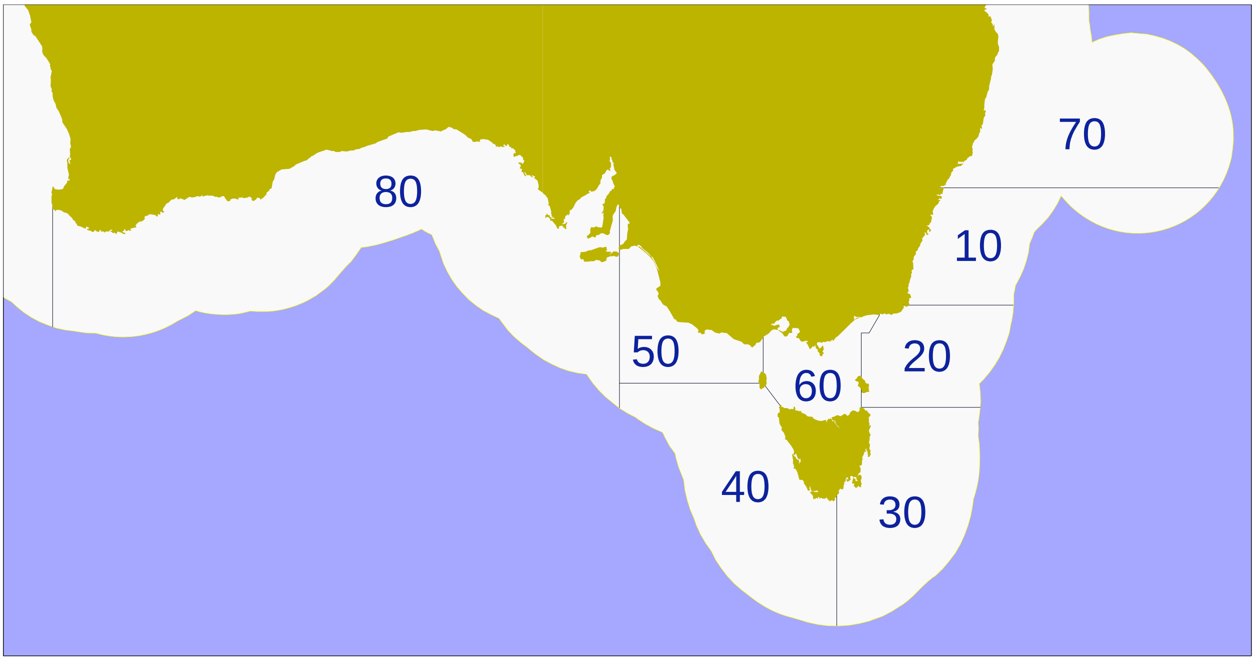


Figure 17.1. Map of the SESSF showing 8 statistical zones used in analyses here.

### 17.2.2 Yield analysis

The information required for this calculation was: selectivity-at-age, length-at-age, weight-at-age; age-at-maturity; and natural mortality. The parameters used are shown in Table 17.1. A mix of shelf and slope quota species has been considered and results are presented where the automated process appears to have produced sensible results, and where sufficient data were available.

Table 17.1. Population parameters used for yield analysis.

| Species | $M$ | $h$ | $L_\infty$ | $k$ | $t_0$ | $a$ | $b$ | $l_{25}$ | $l_{50}$ | $l_{mat}$ | $a_{max}$ | $cc_{amax}$ | $S_{25}$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Alfonsino | 0.22 | 0.75 | 54.3 | 0.099 | -3.83 | 0.019 | 3.061 | 20 | 25 | 19 | 20 | 10 | 0.8102 |
| John Dory | 0.36 | 0.45 | 53.2 | 0.15 | -1 | 0.0458 | 2.9 | 15.54 | 30 | 31.5 | 20 | 19 | 1.303 |
| Mirror Dory | 0.3 | 0.75 | 57.44 | 0.2345 | 0 | 0.0164 | 3 | 15.54 | 40 | 35 | 20 | 19 | 1.345 |
| Tiger Flathead | 0.22 | 0.62 | 50.87 | 0.168 | -3.053 | 0.0059 | 3.31 | 27.93 | 31.02 | 30 | 20 | 19 | 1.688 |
| Gemfish E | 0.47 | 0.75 | 109.4 | 0.18 | -0.61 | 0.0014 | 3.39 | 26.95 | 31.7 | 70 | 20 | 19 | 0.9612 |
| Gemfish W | 0.47 | 0.75 | 109.4 | 0.18 | -0.61 | 0.0014 | 3.39 | 26.95 | 31.7 | 70 | 20 | 12 | 0.9612 |
| Blue Grenadier | 0.189 | 0.9 | 101 | 0.18 | 0.58 | 0.0038 | 3.013 | 37.8 | 50.73 | 70 | 20 | 19 | 3.185 |
| Pink Ling | 0.268 | 0.8 | 103.4 | 0.166 | 3.139 | 0.0029 | 3.139 | 39.9 | 43 | 67 | 20 | 19 | 6.078 |
| Jackass Morwong E | 0.15 | 0.7 | 36.39 | 0.34 | -0.45 | 0.0429 | 3 | 21.94 | 21.95 | 22 | 25 | 20 | 2.266 |
| Jackass Morwong W | 0.15 | 0.7 | 36.39 | 0.34 | -0.45 | 0.0429 | 3 | 21.94 | 21.95 | 22 | 25 | 20 | 2.266 |
| Redfish | 0.1 | 0.75 | 25.28 | 0.224 | -0.719 | 0.0577 | 2.77 | 15.94 | 17.25 | 19 | 40 | 20 | 3.727 |
| Ocean Perch | 0.1 | 0.75 | 43.72 | 0.114 | 0 | 0.0118 | 2.997 | 15.93 | 18.23 | 31 | 40 | 20 | 3.975 |
| Blue-eye Trevalla | 0.1 | 0.75 | 96 | 0.08 | -5.25 | 0.018 | 3.016 | 48 | 50 | 62 | 20 | 19 | 3.414 |
| Silver Trevally | 0.1 | 0.8 | 63.16 | 0.051 | -6.47 | 0.0443 | 2.786 | 22.31 | 22.32 | 28 | 20 | 19 | 2.074 |
| Silver Warehou | 0.3 | 0.75 | 51.25 | 0.464 | -0.65 | 0.0153 | 3 | 31.05 | 40 | 37 | 23 | 20 | 1.357 |
| Blue Warehou | 0.45 | 0.75 | 54.65 | 0.37 | -0.67 | 0.03 | 2.9 | 17.61 | 35 | 33.4 | 25 | 20 | 0.3812 |
| School Whiting | 0.6 | 0.75 | 26 | 0.25 | -1.15 | 0.0132 | 2.93 | 14 | 15 | 16 | 6 | 5 | 1.943 |

For species for which a recent stock assessment has been performed, the population parameters used in the assessment were used here. Otherwise, the primary source of information on population parameters was Smith and Wayte (2002) or, failing that, the Fishbase website (http://www.fishbase.com). A meta-analysis performed by Koopman *et al.* (2001) was used to provide values for steepness.

#### *17.2.2.1 Length- and weight-at-age*

Length-at-age was calculated using the von Bertalanffy growth equation (parameters are $l_\infty$, $k$ and $t_0$) and the weight-at-age using the allometric length-weight relationship (parameters are $a$ and $b$). The von Bertalanffy parameters were calculated using length and age data supplied by the Fish Ageing Services (FAS, Kyne Krusic-Golub pers com). The type of length measurement (e.g. standard length or total length) used was specified in the data. It is assumed the parameters of the length-weight relationship (Smith and Wayte, 2002) use the same measures. The units for these parameters are not specified and do not all appear to use the same units. These were manipulated until the results appeared to be in kg per cm. Parameters that were not available from Smith and Wayte (2002) were obtained from the Fishbase website (http://www.fishbase.org), using values that had been calculated from Australian fish or, if necessary, New Zealand fish.

#### *17.2.2.2 Female length-at-maturity*

Length-at-maturity for females ($l_{mat}$) (which is converted into a knife-edged function of age using the calculated lengths-at-age) was obtained, where possible, from Wayte and Smith (2002). If separate values were not available for males and females, that for both sexes combined was used. In some cases several different values were available and an arbitrary selection was made - when there were three of more values the median value was chosen.

#### *17.2.2.3 Natural mortality*

Natural mortality ($M$) values were obtained from Smith and Wayte (2002) or by calculating the median of the values presented by Bax and Knuckey (2001). The value of $M$ for John dory was updated by the Shelf Research Assessment Group in 2005 based on an additional meta-analysis performed by Matt Koopman. The value of $M$ for tiger flathead was updated for the 2010 stock assessment (Klaer, 2011b).

#### *17.2.2.4 Selectivity*

A logistic selectivity curve is assumed for all species. Selectivity parameters ($l_{25}$, $l_{50}$) were drawn from Bax and Knuckey's calculated selectivity factors. All parameters used in the present investigation apply to a 90mm trawl mesh (except for school whiting where 42mm has been assumed) and non-trawl gear types are not considered. Values were not available, from Bax and Knuckey, for John dory or silver trevally. Those for mirror dory were applied to John dory because, of all the quota species, mirror dory are most like John dory in shape.

The selectivity parameters used in this study have been estimated from an empirical relationship between fish size and mesh size derived from covered cod end (or trouser haul) experiments on a subset of the species. These pertain purely to gear selectivity, which is not the function often referred to in stock assessments as "selectivity". Fishers are able to target fish of a particular size by fishing in particular areas and in particular different depths -- all SEF quota shelf-associated species show a pattern of larger fish being caught at greater depths. No account is taken in this study of how trawl selectivity changes as a function of gear design or gear deployment (e.g. changing door separation with depth) that have been shown to exert large influences on overall selectivity in other studies.

It has been suggested that practices such as double bagging might reduce the selectivity of commercial trawls below that expected for a 90 mm mesh cod end, however there was no evidence for this, with the possible exception of school whiting and redfish off Eastern Victoria.
The "selectivity" estimated in stock assessment models is a function of both gear selectivity, targeting by the fishery and availability of fish to being caught.

#### *17.2.2.5 Maximum age*

Maximum observed age ($a_{\text{max}}$) values were selected after examining available aged otolith samples. As the maximum age is treated as a plus group, a maximum age for catch curve analysis ($cca_{\text{max}}$) is also required that is normally at least one age less than the maximum. This was chosen after examination of age samples from the last 5 years.

#### *17.2.2.6 Stock-recruit relationship*

A Beverton-Holt stock-recruit relationship is assumed using the single-parameter formulation suggested by Francis (1992a). The value of this parameter (steepness - *h*) was investigated by Koopman *et al*. (2001) using meta-population analysis. The histograms presented by Koopman *et al*. were examined and likely figures for steepness chosen. The default figure of 0.75 suggested by Francis (1992b) is used when the results of Koopman *et al*. do not suggest a clear pattern.

#### *17.2.2.7 Management reference points*

Using virgin biomass estimates provided by stock reduction analysis in combination with yield-per-recruit analysis, a number of common *F*-based management reference point values were calculated. While $F_{0.1}$ (Gulland and Boerema 1973) and $F_{\text{spr30}}$ (or $F_{30\%\text{SPR}}$, Gabriel *et al.* 1989) are reasonably widely known, the method used to calculate $F_{\text{msy}}$ is given below (from Klaer 2006).

Fisheries management decisions are often based on abundance relative to target and limit reference points. The most common reference point is the population size where maximum sustainable yield (MSY) is achieved. The fully-selected fishing mortality corresponding to MSY, $F_{\text{msy}}$, is defined as the instantaneous rate of fishing mortality at which yield is maximized, i.e.:

$$\left.\frac{dY(F)}{dF}\right|_{F_{MSY}} = 0$$

where $Y(F)$ is yield as a function of fully-selected fishing mortality, i.e.:

$$Y(F) = \tilde{Y}(F)\,R(F)$$

$\tilde{Y}(F)$ is yield-per-recruit as a function of *F*, and

$R(F)$ is recruitment as a function of *F*.

Yield-per-recruit is defined according to the formula:

$$\tilde{Y}(F) = \sum_s \sum_{a=0}^{x} w_a^s \frac{S_a^s F}{Z_a^s(F)} N_a^s(F)(1 - e^{-Z_a^s(F)})$$

where $w_a^s$ is the weight of an animal of sex *s* and age *a*,

$S_a^s$ is the selectivity for animals of sex *s* and age *a*,

$Z_a^s(F)$ is the total mortality on fish of sex *s* and age *a*,

$$Z_a^s(F) = M + S_a^s\, F$$

$N_a^s(F)$ is the number of fish of sex *s* and age *a* relative to the number of animals of age 0 (both sexes combined):

$$N_a^s(F) = \begin{cases} 0.5 & \text{if } a = 0 \\ N_{a-1}^s(F)\, e^{-Z_{a-1}^s(F)} & \text{if } 0 < a < x \\ N_{x-1}^s(F)\, e^{-Z_{x-1}^s(F)} / (1 - e^{-Z_x^s(F)}) & \text{if } a = x \end{cases}$$

$x$ is the maximum age-class.

The recruitment as a function of *F* depends on the assumed form of the stock-recruitment relationship, e.g.:

$$R(F) = \frac{S(F)}{\alpha + \beta\, S(F)}$$

where $S(F)$ is spawner biomass as a function of *F*:

$$S(F) = \tilde{S}(F)\, R(F)$$

$\tilde{S}(F)$ is spawner biomass-per-recruit as a function of *F*:

$$\tilde{S}(F) = \sum_{a=1}^{x} f_a\, N_a^{\text{fem}}(F)$$

$f_a$ is fecundity as a function of age.

### *17.2.3 Catch curves*

*17.2.3.1 Data*

This investigation used length frequency data from ISMP port measurements (eg Knuckey *et al*, 2001). For a given year, fleet and population (see below for further detail) length frequencies are catch-weighted and summed to give annual length frequencies.

Age and length data were obtained from the Central Ageing Facility. Age-length keys (ALKs) were constructed from these data.

Two methods were used to convert length frequencies data into age frequencies: ALKs and chopping. The ALK method was used, where possible, to generate age frequencies data by multiplying the length frequency for a given year by the ALK for that same year. No allowances were made for inadequate sampling of an ALK so that, if no age samples were taken from a particular length class then all samples from this length class in the length frequency were ignored. This occurs because the ALK has a zero for all ages for that length class so that the length frequency is always multiplied by zero. ‘Chopping’ involves using the von Bertalanffy to chop the length frequency into age classes. Catch curve analysis was applied to all resulting age frequencies. In the future it may be desirable to use a chopping method that allows variance in length-at-age about the von Bertalanffy curve.

Age samples from the 2010 and 2011 calendar years became available for both mirror dory and John dory during October 2011, and were used to provide age-based Tier 3 results here for both species. In both cases, all samples from 2010 and 2011 were used to provide an average age-length key that was applied to length data from the most recent 5 years.

*17.2.3.2 Fleets and Populations*

The difference between a fleet and a population is that although the length frequency data are separated for both, the ALK data are separated into populations but are combined across fleets.
For species except tiger flathead, redfish, spotted warehou and blue grenadier, the length frequency data were separated into trawl and non-trawl (including Danish seine) fleets. Tiger flathead was separated into trawl and Danish seine. Non-trawl data for redfish was ignored so that there was only one fleet - a trawl fleet. Spotted warehou was divided into trawl and non-trawl fleets but any Danish seine records were ignored. For blue grenadier the fleets were separated into the summer non-spawning trawl fishery and the winter spawning trawl fishery.

Redfish was divided into two populations – north and south of 36°S. Population 1 is north and Population 2 south of this latitude.

As there was no recent age data for redfish, all available age data was combined into a single average ALK for that species.

*17.2.3.3 Automated catch curve analysis*

The method of $F_{CUR}$ estimation used is an improved method of catch-curve estimation which involves fitting an equilibrium age-structured production model to the most recent five years of age-composition data to estimate $F_{CUR}$ and two selectivity parameters. This method accounts for selectivity-at-age, and integrates over all years used in the estimation. Estimated numbers at age in each year are fitted to the observed using simple sum of squares difference as a goodness of fit measure. The advantages of this method over traditional catch-curve methods are that averaging of annual mortality estimates is not required to obtain an estimate of $F_{CUR}$ and all selected ages are used, rather than just the assumed fully-selected ages, as selectivity is taken into account in the estimation.

Specifically, the population model is of the form:

$$N_a = \begin{cases} 1 & \text{if } a = 0 \\ N_{a-1} e^{-(s_{a-1} F_{CUR} + M)} & \text{if } 0 < a <= a_{\max} \end{cases}$$

where the $N_a$ are the numbers-at-age $a$, $s_a$ is the (estimated) selectivity-at-age (assumed to be asymptotic and to follow a logistic curve with two parameters, age at 50% and 95% selectivity), $a_{\max}$ is the maximum age used for catch curve analysis (a value less than maximum age), $F_{CUR}$ is the estimated rate of current fishing mortality, and $M$ is the assumed rate of natural mortality. The selectivity equation is:

$$s_a = 1/\left(1 + \exp\left(-Ln\left(19\right) * \left(a - a_{50}\right) / \left(a_{95} - a_{50}\right)\right)\right)$$

### *17.2.4 Average length method*

Catch curve analysis relies on measurement of the decline in numbers at age of a population in equilibrium under constant levels of fishing pressure. If equilibrium conditions apply, the slope of the right hand limb of an age frequency distribution can be used to estimate fishing mortality. For some SESSF fish populations, otoliths have not been collected or aged, sometimes because of the physical difficulty in doing so. Some species, for example, have very tiny otoliths that are both difficult to collect and age. Normally, however, all quota species are measured by onboard observers, or in the port data collection program, so we have reasonably large length frequency samples for most quota species in most years.

The current Tier 3 method for dealing with species with length samples but no age samples is to slice the length-frequency distribution into assumed ages based on the age transitions calculated from the von Bertalanffy parameters, and then apply the standard catch curve analysis to the derived age distribution. This method is not optimal compared to an analysis based on age samples at least because it does not account for the distribution of lengths at age – that the lengths of fish at any age follow a distribution that overlaps with lengths at age for adjacent aged fish.

A procedure has been developed as part of the Reducing Uncertainty in Stock Status (RUSS) project that uses length frequency samples alone to estimate fishing mortality, and is described in detail in Klaer *et al*. (2012). Management Strategy Evaluation (MSE) testing of the procedure indicated that it works in theory, and provides comparable results to the age-based catch curve method. The greatest disadvantage of the procedure determined by testing was that it produced more variable RBC values than standard catch curve analysis.

The key assumption of the average length method is that the relative number of large fish in the population will reduce as fishing pressure increases. This is intuitively true, and the determination of stock status indicators from average length measurements has a long history (e.g. see Pauly 1984).

The procedure implemented here first requires the selection of a reference length ($L_{ref}$) where the stock can be assumed to be fully selected. By default, $L_{ref}$ is assumed to be 2cm greater than the length at 50% selection ($S_{50}$), as most species are assumed to have relatively knife-edged selection for Tier 3 analyses. The intention was to select a reference length greater than where selectivity effects occur, but as low as possible to allow the largest sample sizes from existing fishery length-frequencies.

Using yield-per-recruit calculations, it is possible to calculate what the average length of the catch above $L_{ref}$ would be for any level of $F$ (Figure 17.2). To determine current $F$ ($F_{cur}$) that corresponds to $F_{cur}$ using catch curves, calculate the average length of the catch above $L_{ref}$, then use the relationship in Figure 17.2 to determine $F_{cur}$. The average length of the catch at the limit $F_{20}$ and target $F_{48}$ are shown as dotted lines in Figure 17.2.

As all current Tier 3 stocks have size at age data, results using the average length method have not been included in this document.

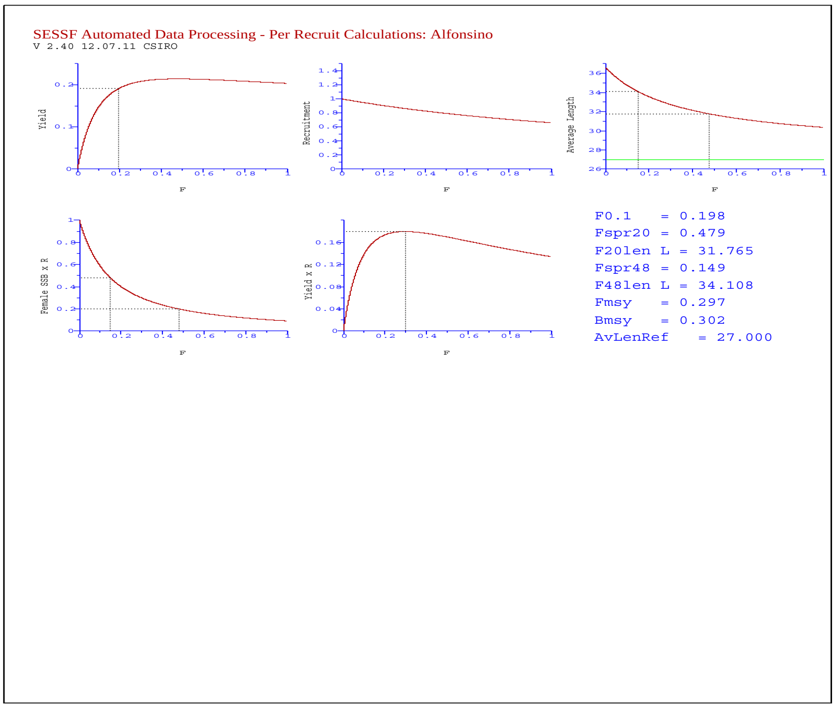


Figure 17.2. Average length reference point calculations.

### *17.2.5 Harvest control rule*

The method used to calculate the Tier 3 RBC has been improved and is described in Klaer *et al.* 2008 and Wayte and Klaer (2010). The new Tier 3 control rule that has limit and target fishing levels was implemented and applied for the first time for the 2008 stock assessments.

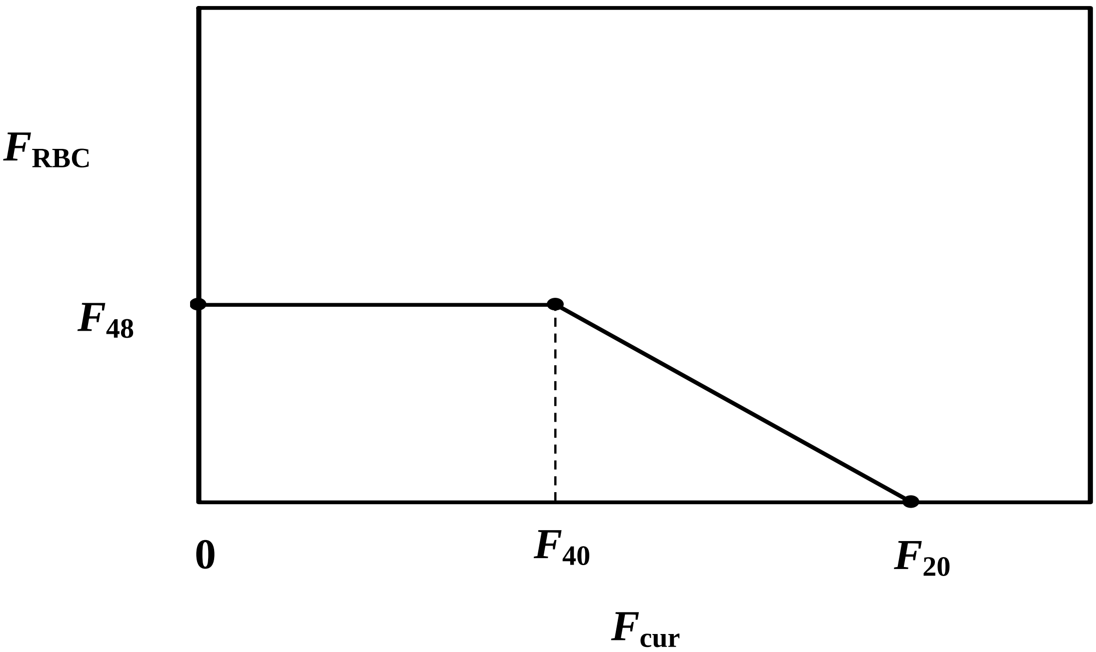


Figure 17.3. Method for selecting $F_{RBC}$ based on estimated $F_{cur}$.

Yield per recruit calculations were used to calculate $F$ values that will reduce the spawning biomass to 20% ($F_{20}$), 40% ($F_{40}$) and 48% ($F_{48}$) of the unexploited level. The relationship given in Figure

17.3 is then used to assign the value of $F_{RBC}$ using $F_{cur}$. This relationship has properties similar to the Tier 1 harvest control rule, with $F_{20}$ as the limit and $F_{48}$ as the target fishing mortality rate.

The following formula that adjusts current catch according to the ratio of the intended and current exploitation rates is then used to calculate $C_{RBC}$:

$$C_{RBC} = \frac{(1 - e^{-F_{RBC}})}{(1 - e^{-F_{cur}})} C_{cur}$$

where $F_{cur}$ is the estimated current fishing mortality, $C_{cur}$ is current catch, $F_{RBC}$ is the selected $F$ for the recommended biological catch from the control rule, and $C_{RBC}$ is the recommended biological catch from the control rule.

It can be seen from the above formula that as the $F_{cur}$ estimate approaches zero, that the multiplier on $C_{cur}$ exponentially increases to infinity at $M$. Clearly, it is possible for the control rule to generate very large RBC values that are not realistic, and would not result in good behaviour of the HCR. One method for avoiding such behaviour would be to apply direct limits on possible values for the $C_{cur}$ multiplier. The upper limit of the multiplier on recent average catch was 1.2 in the previous and first implementation of Tier 3 in the SESSF (Klaer and Thomson 2007). To date there has been no agreement via the RAG process on what direct limits may be applied to the new implementation.

The current SESSF application of harvest control rules includes a TAC change limitation rule that was designed to dampen RBC changes from year to year. This applies to all TACs generated from RBCs. In testing the Tier 3 HCR (Wayte and Klaer 2010), the current SESSF catch change limitation rule was also included, which effectively limits the extreme values that may be generated by the Tier 3 HCR. Testing of the Tier 3 rule showed that it was effective in meeting expected management performance measures in the case where the TAC change limitation rule was applied. If such a change limitation rules was not applied, then it is likely that the Tier 3 behaviour would be considerably degraded.

Good performance of the Tier 3 HCR depends on the application of the catch change limitation rule to avoid extreme behaviour. In practice, when the Tier 3 HCR produces unrealistically high or low RBC values due to (1) noise in population age structure data (2) incorrect fixed value for M (3) incorrect biological assumptions in yield-per-recruit calculations (4) incorrect assumptions about fishery selectivity, the behaviour is limited by the TAC change control rule.

In the past, the actual RBC value generated by the Tier 3 HCR has been criticised if it was well above any of the known historical catch levels. The reason why such values are possible using the current HCR have been described here, and how they are correctly dealt with in the overall TAC setting framework. Unexpectedly large RBC values can be generated using the current HCR simply due to the imprecision in the method used to estimate $F_{cur}$, and it is probably not possible in a short time-frame to determine whether this is the main cause. To avoid misinterpretation of Tier 3 RBCs, both the RBC as generated by the harvest control rule and also the effectively limited values based on the most recent TAC are reported in this document. I can’t see where these are both reported.

A Tier 3 analysis that consistently produces inflated RBC values suggests either that the fishery is having a low impact on the stock, or that some assumptions of the method (e.g. M value) need to be re-examined.

## 17.3 Results

### 17.3.1 Yield per recruit analyses

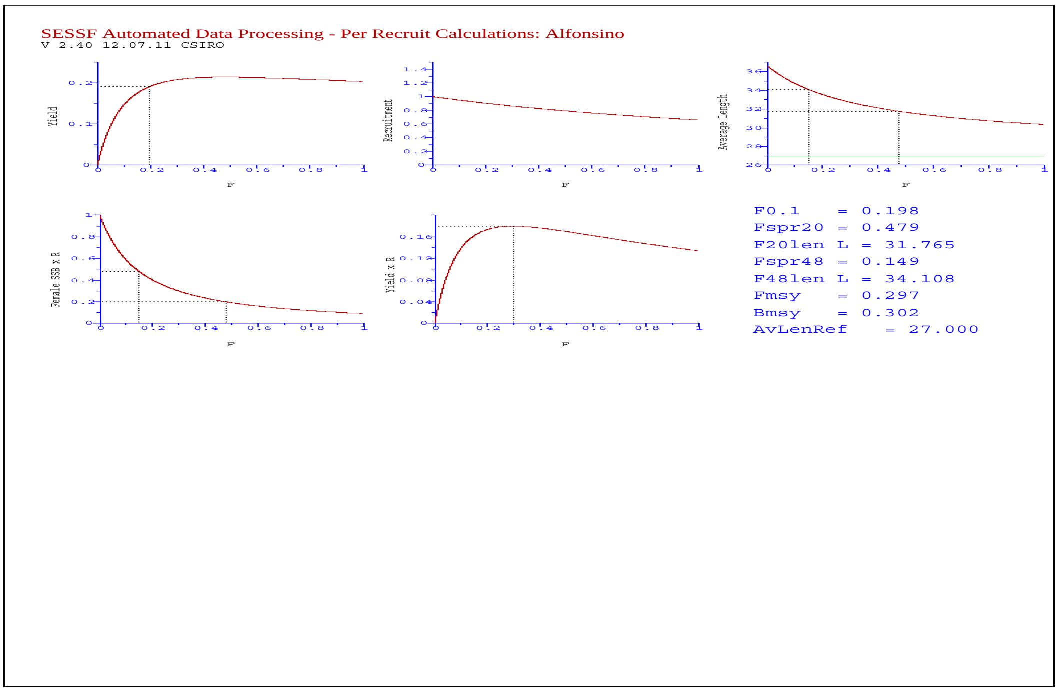


Figure 17.4. John dory yield per recruit reference point calculations.

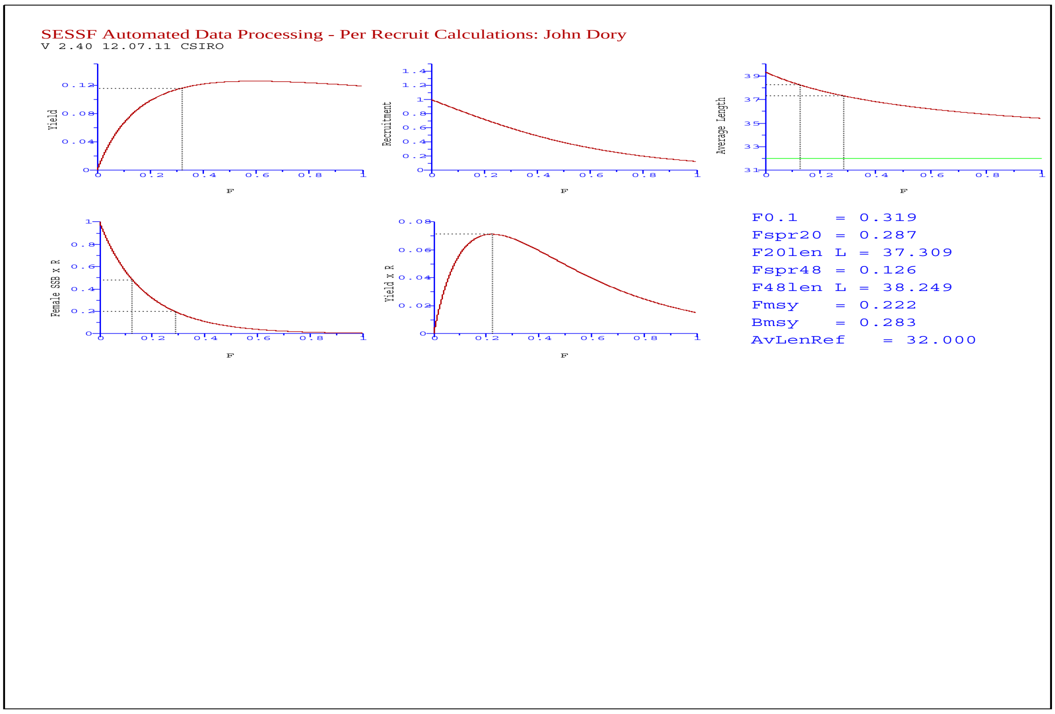


Figure 17.5. Alfonsino yield per recruit reference point calculations.

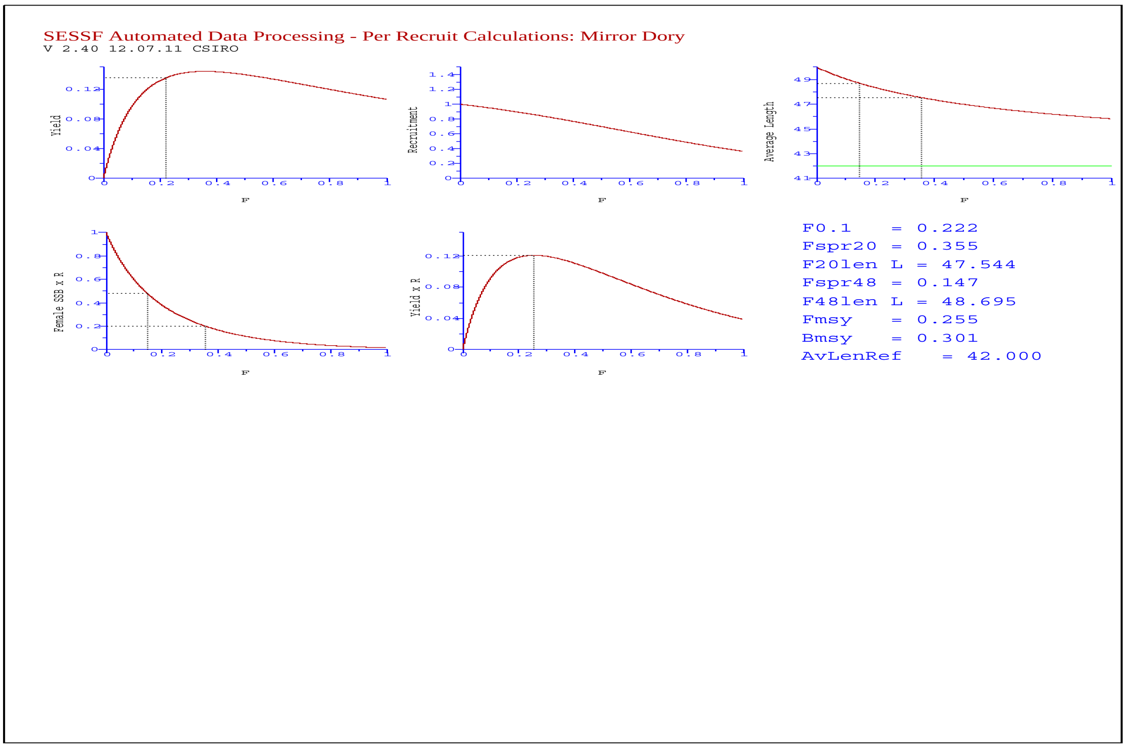


Figure 17.6. Mirror dory yield per recruit reference point calculations.

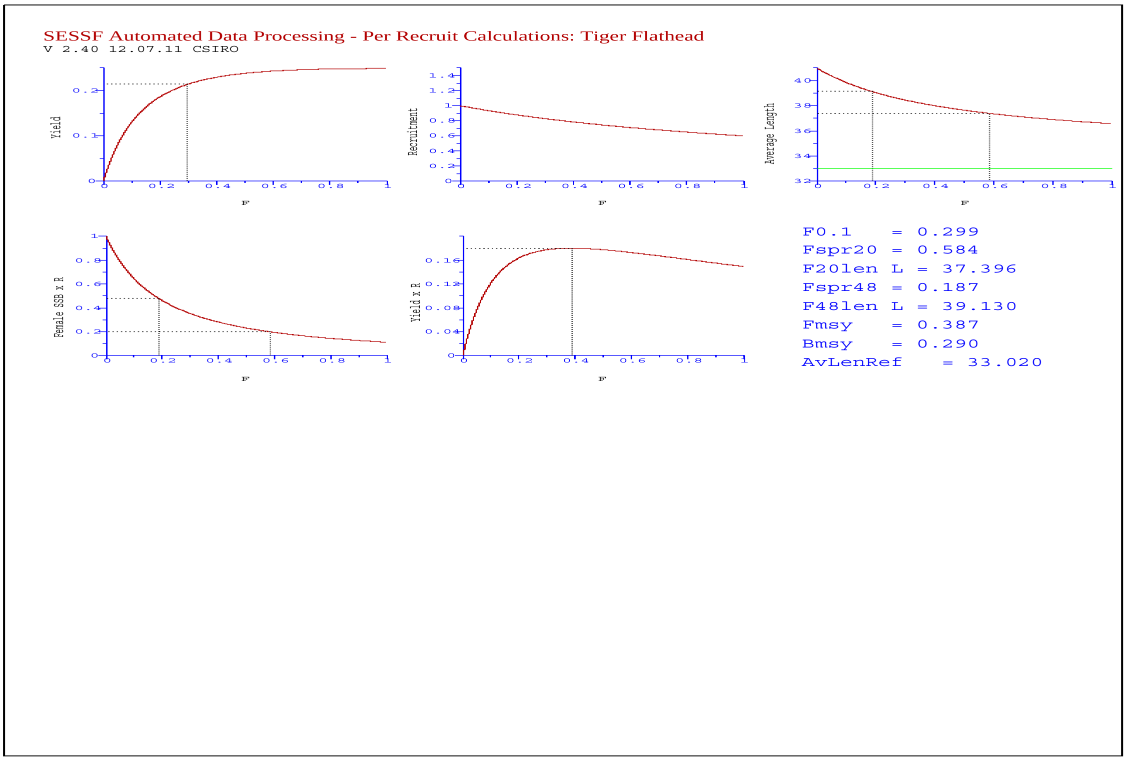


Figure 17.7. Tiger flathead yield per recruit reference point calculations.

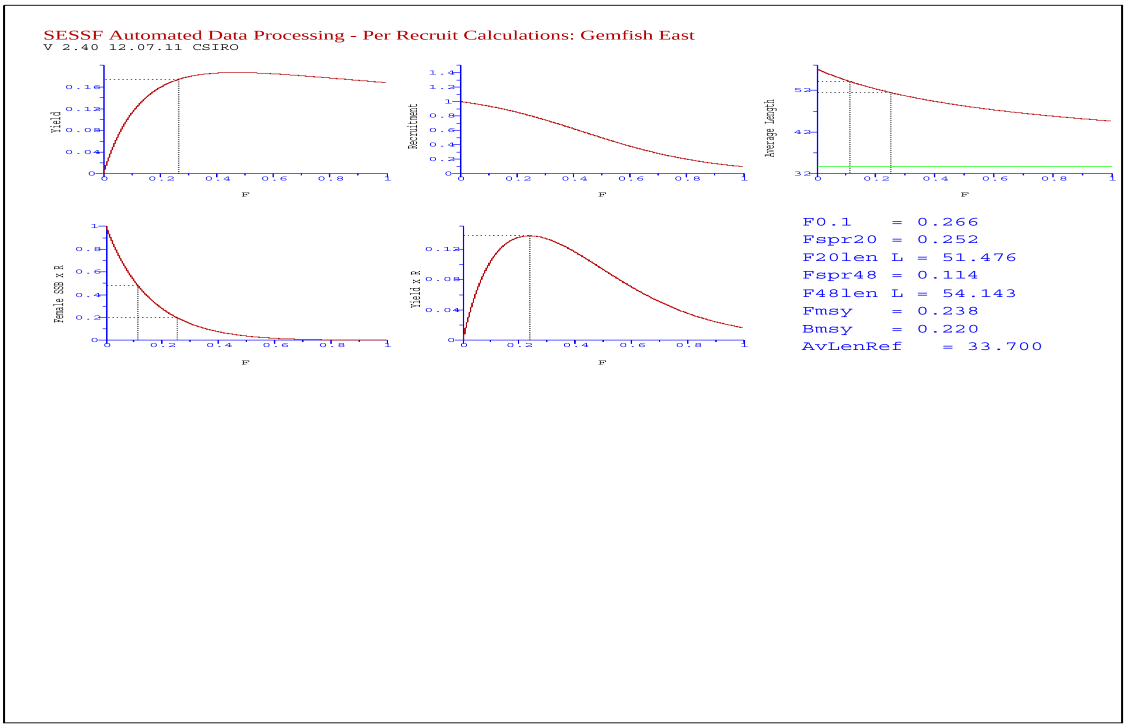


Figure 17.8. Gemfish east yield per recruit reference point calculations.

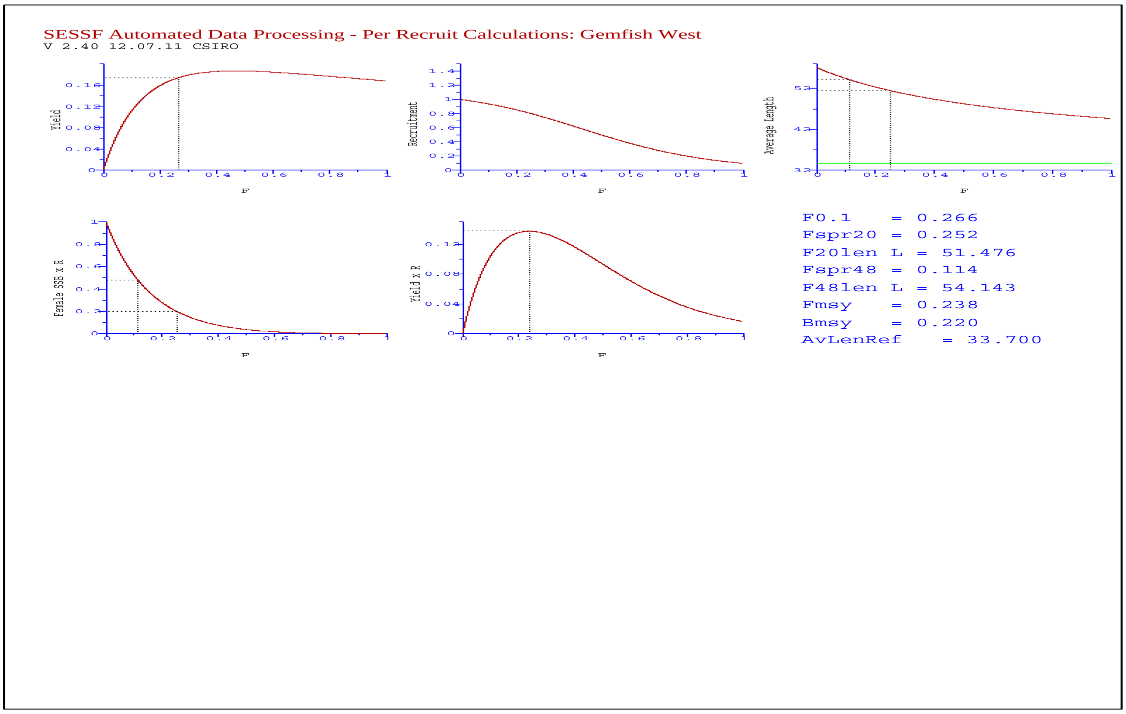


Figure 17.9. Gemfish west yield per recruit reference point calculations.

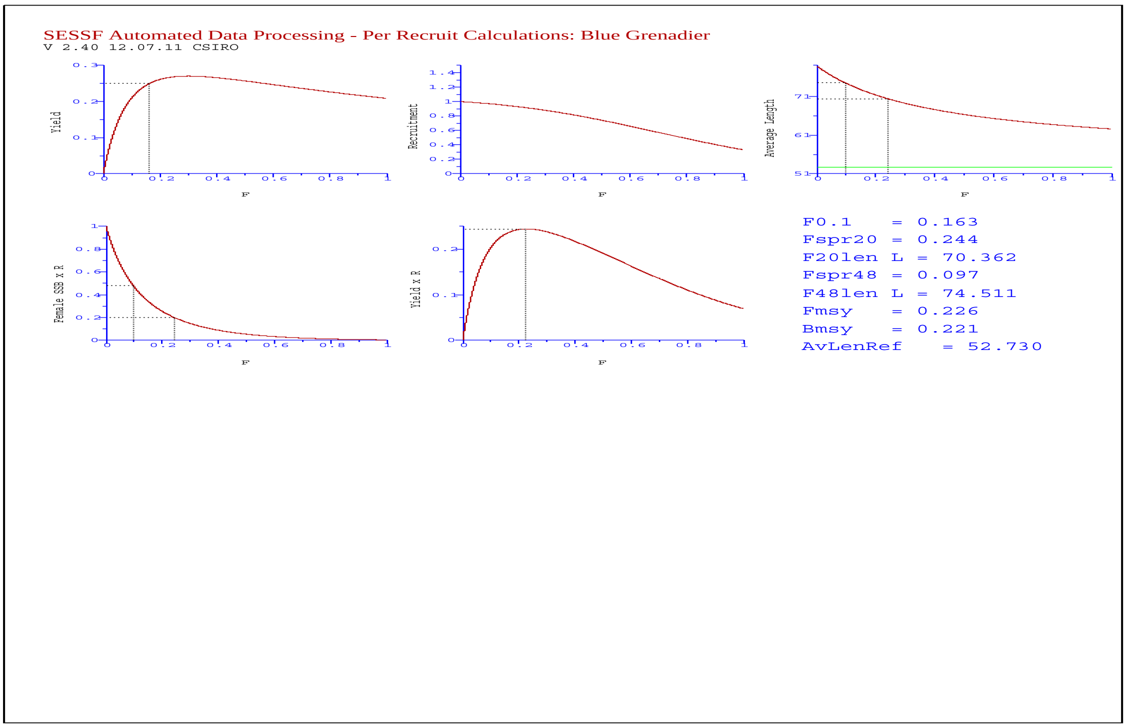


Figure 17.10. Blue grenadier yield per recruit reference point calculations.

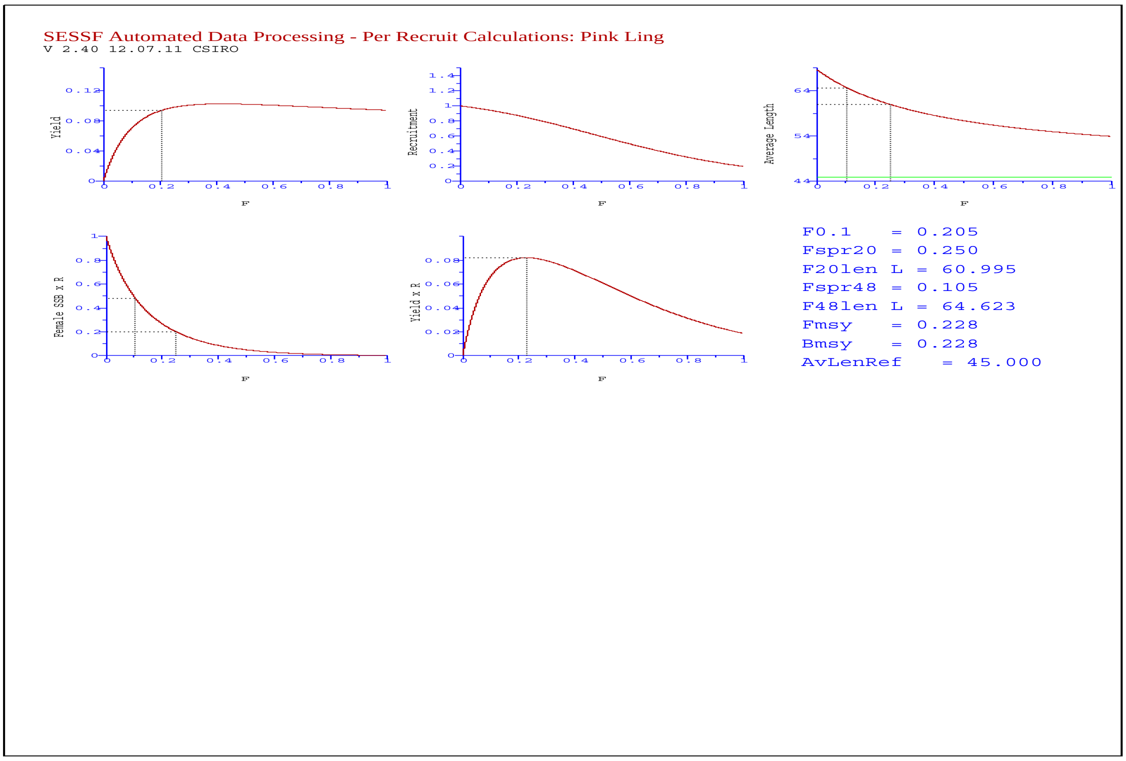


Figure 17.11. Pink ling yield per recruit reference point calculations.

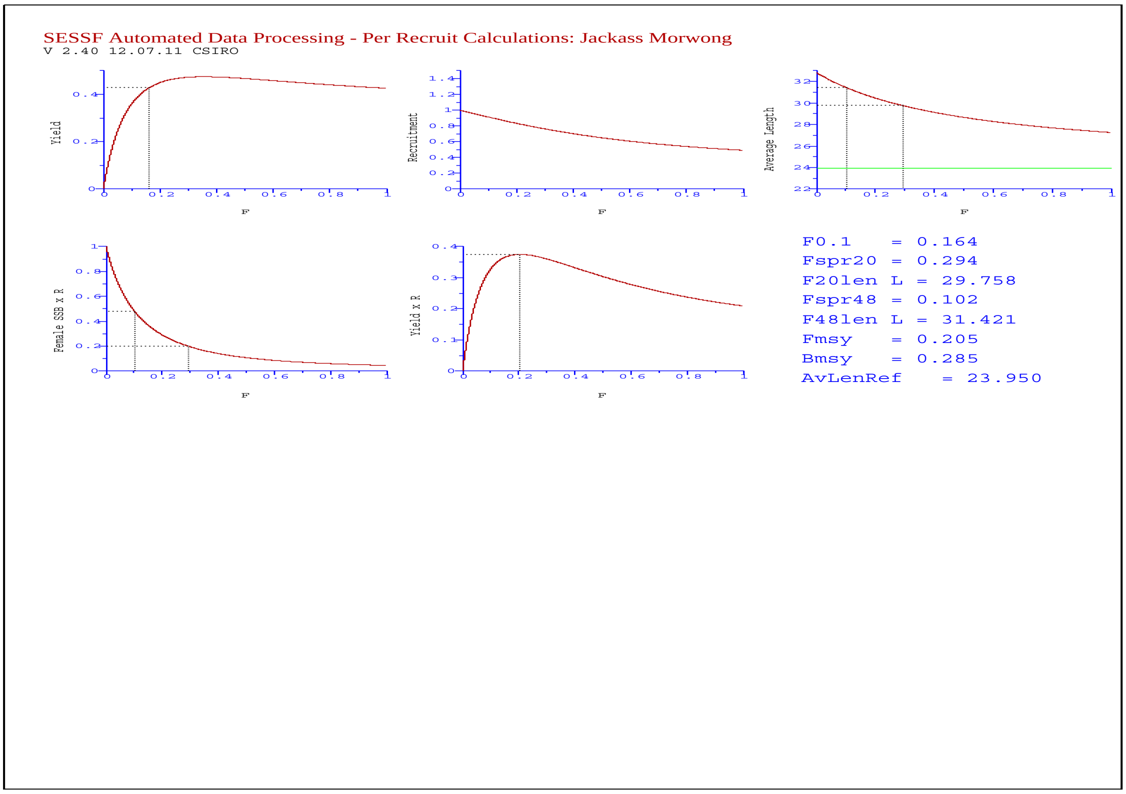


Figure 17.12. Jackass morwong yield per recruit reference point calculations.

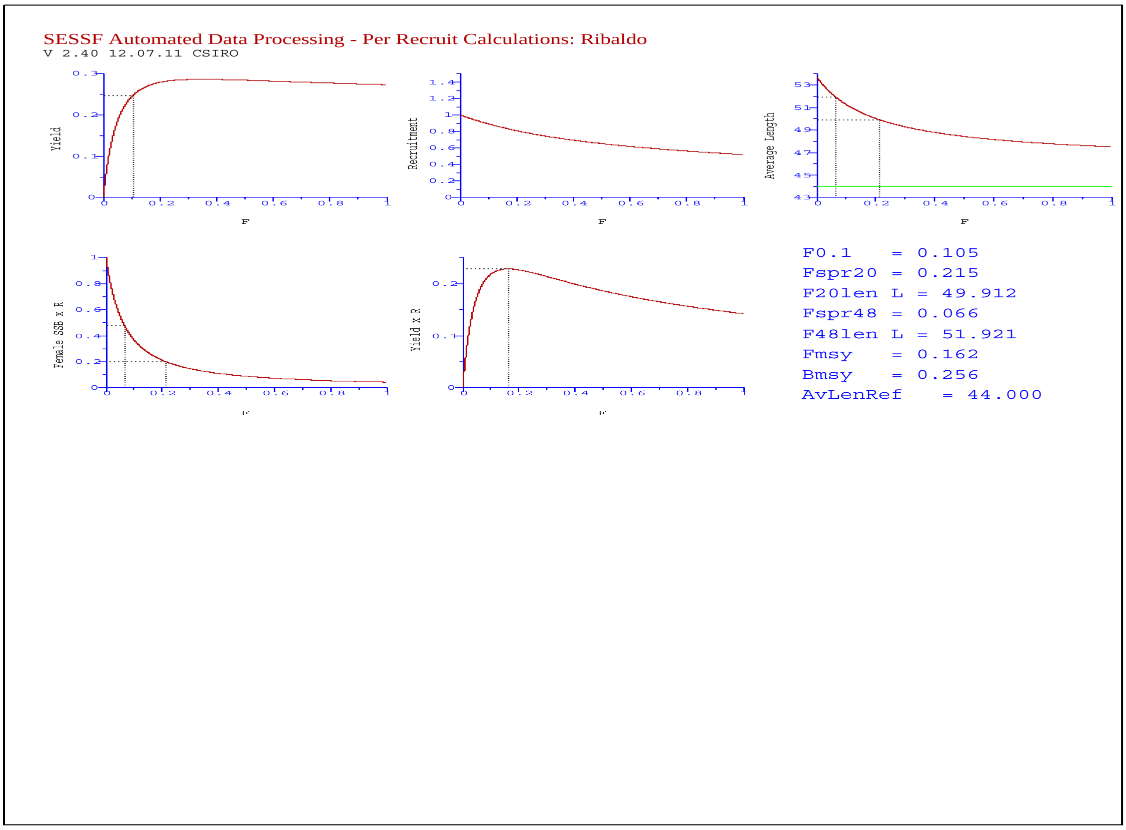


Figure 17.13. Ribaldo yield per recruit reference point calculations.

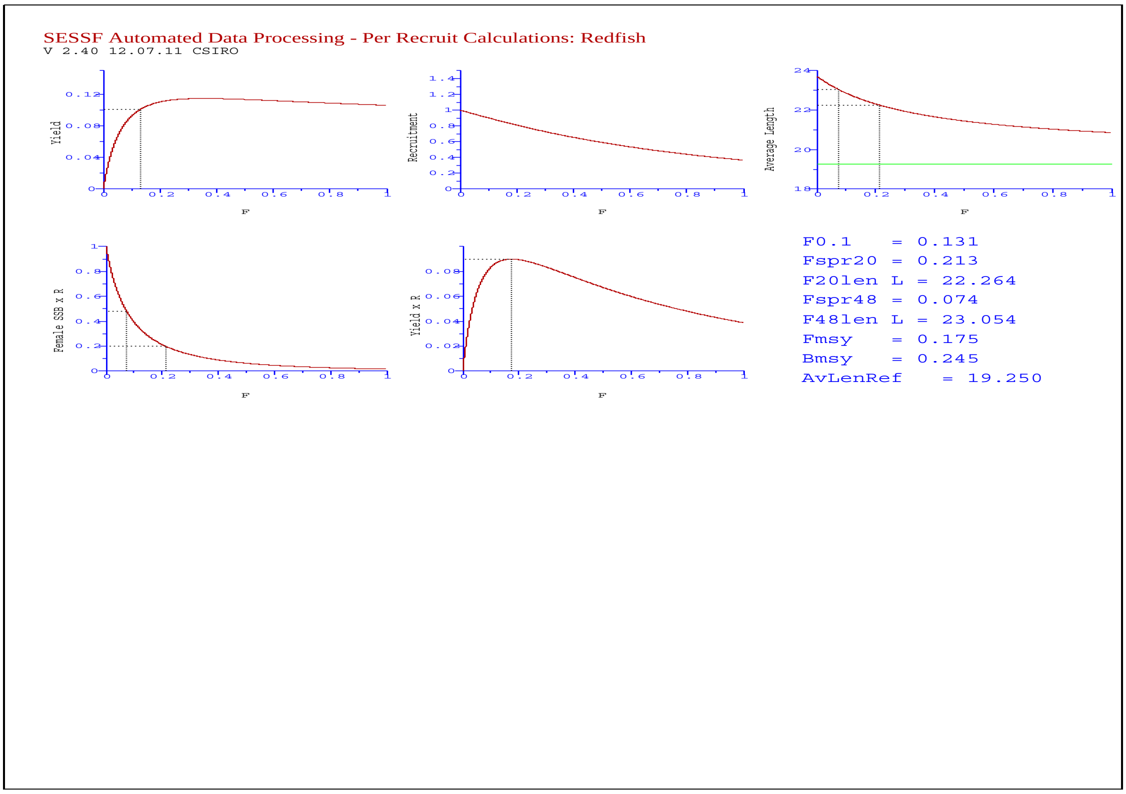


Figure 17.14. Redfish yield per recruit reference point calculations.

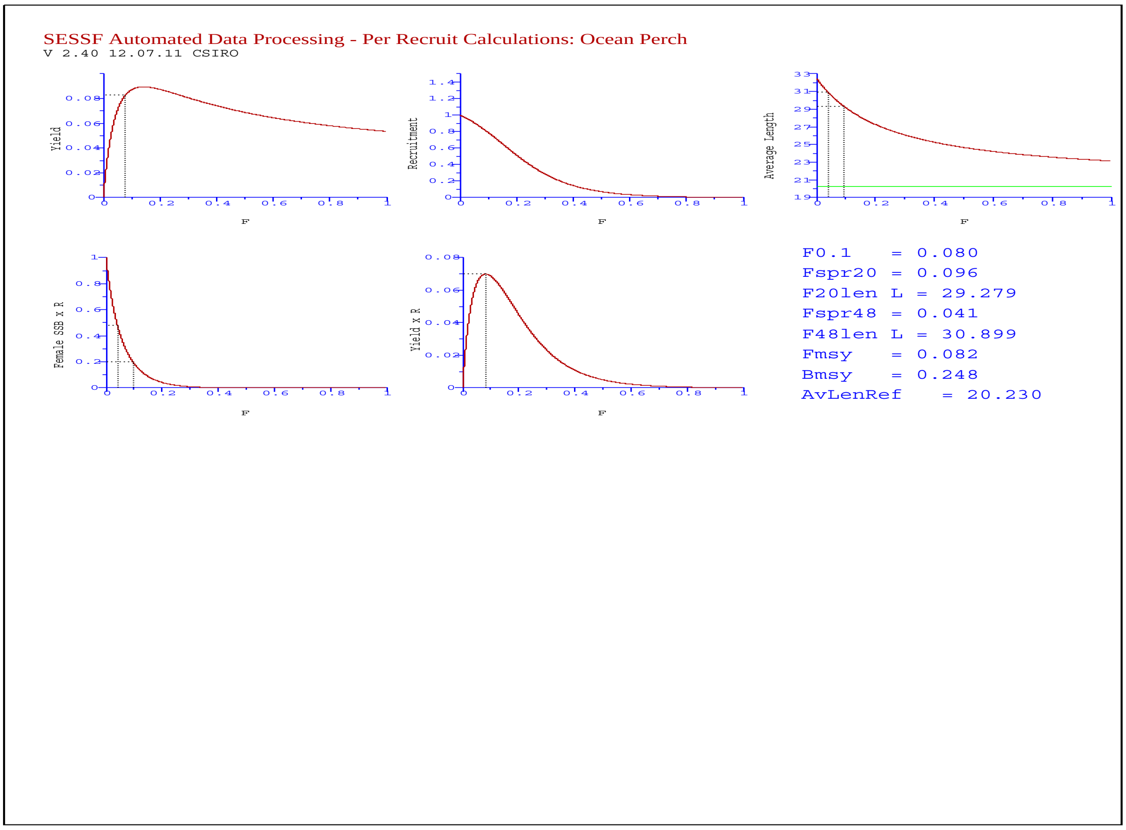


Figure 17.15. Ocean perch yield per recruit reference point calculations.

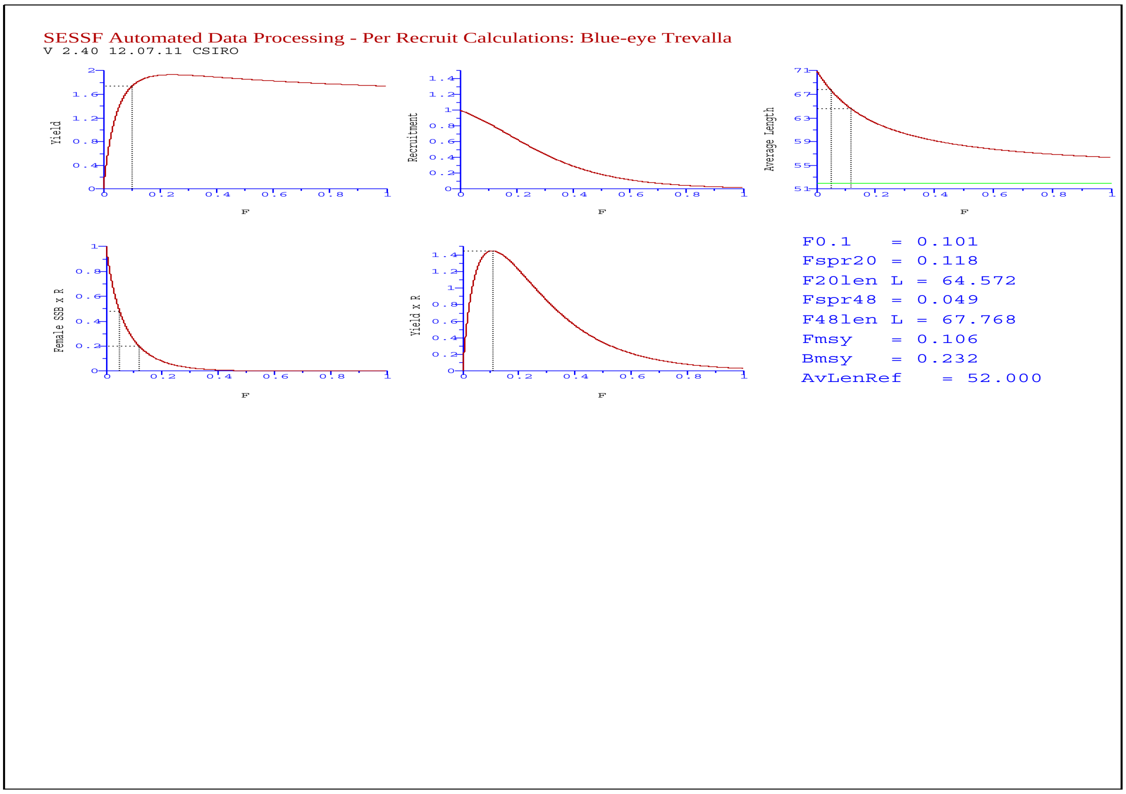


Figure 17.16. Blue-eye trevalla yield per recruit reference point calculations.

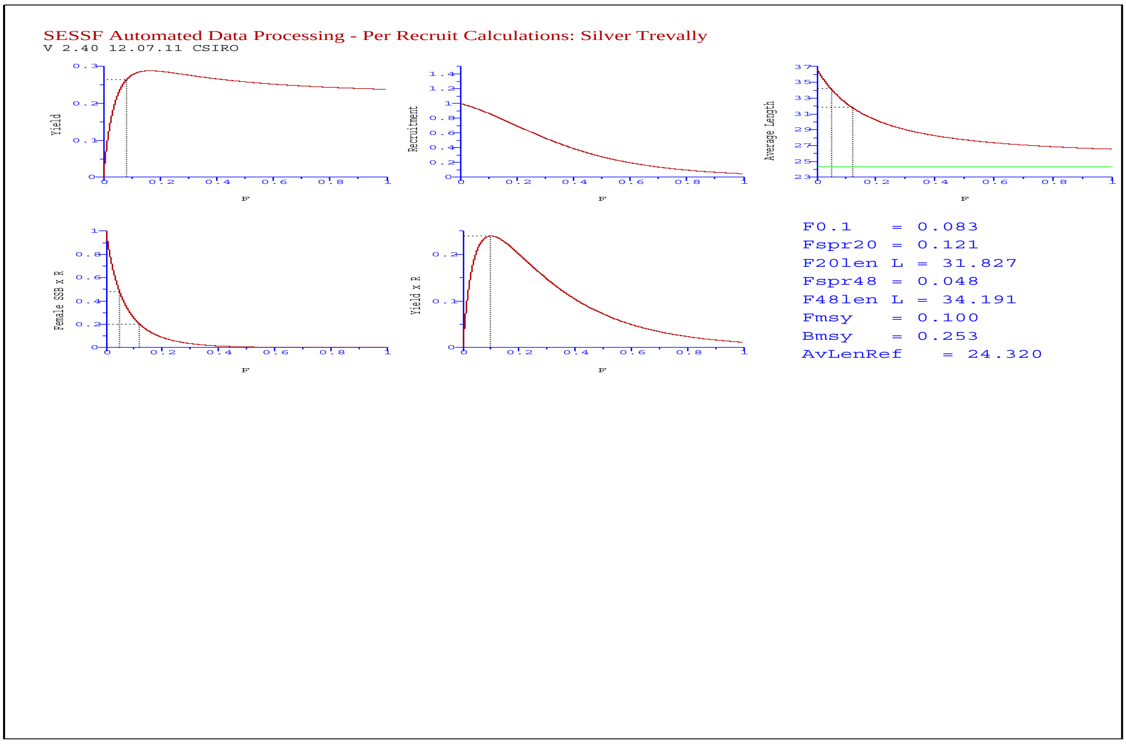


Figure 17 17. Silver trevally yield per recruit reference point calculations.

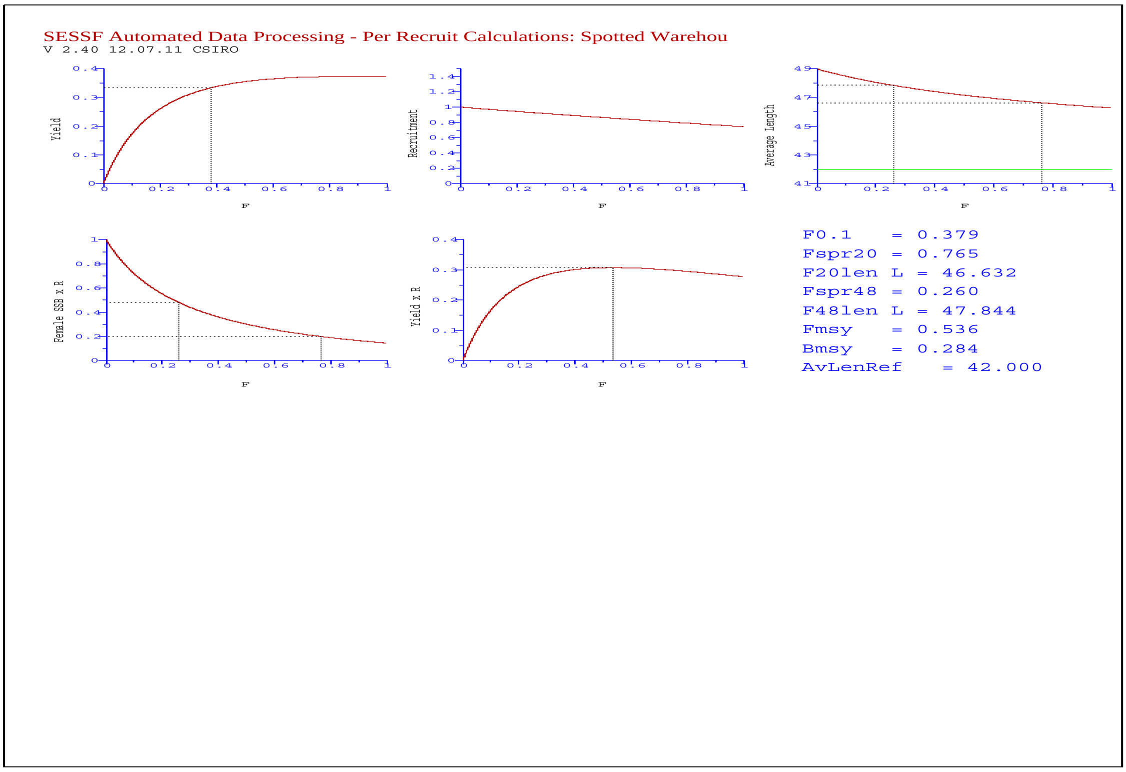


Figure 17.18. Silver warehou yield per recruit reference point calculations.

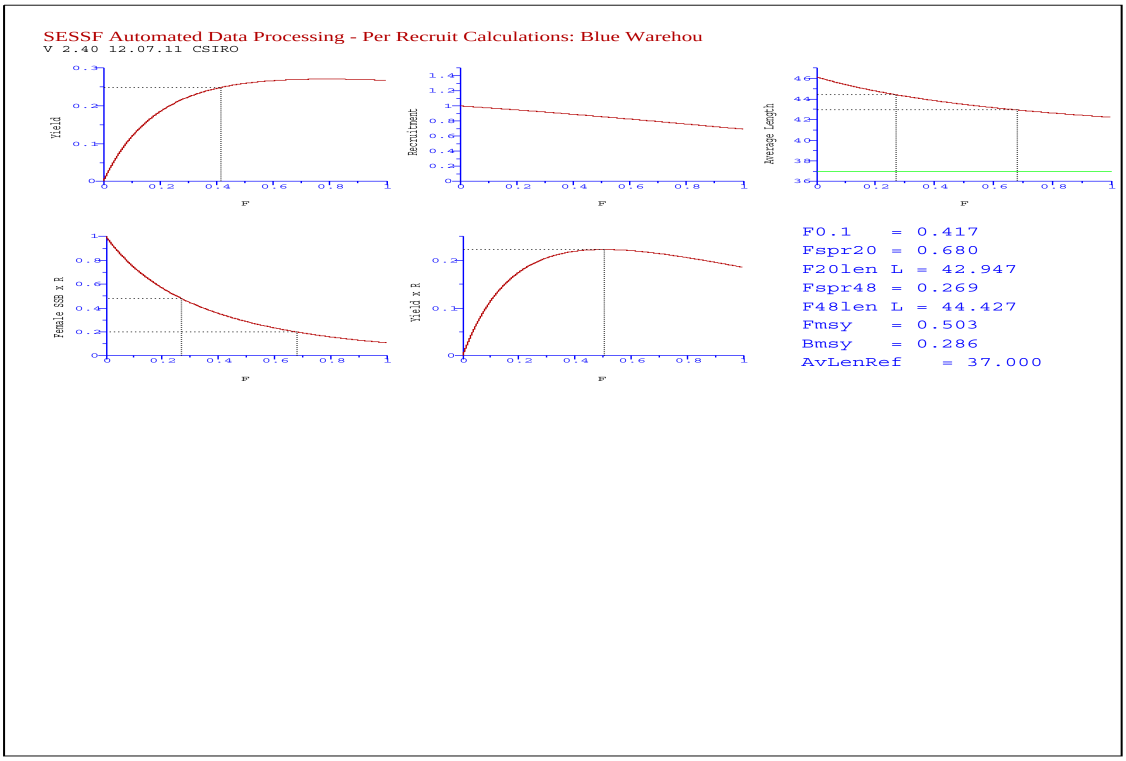


Figure 17.19. Blue warehou yield per recruit reference point calculations.

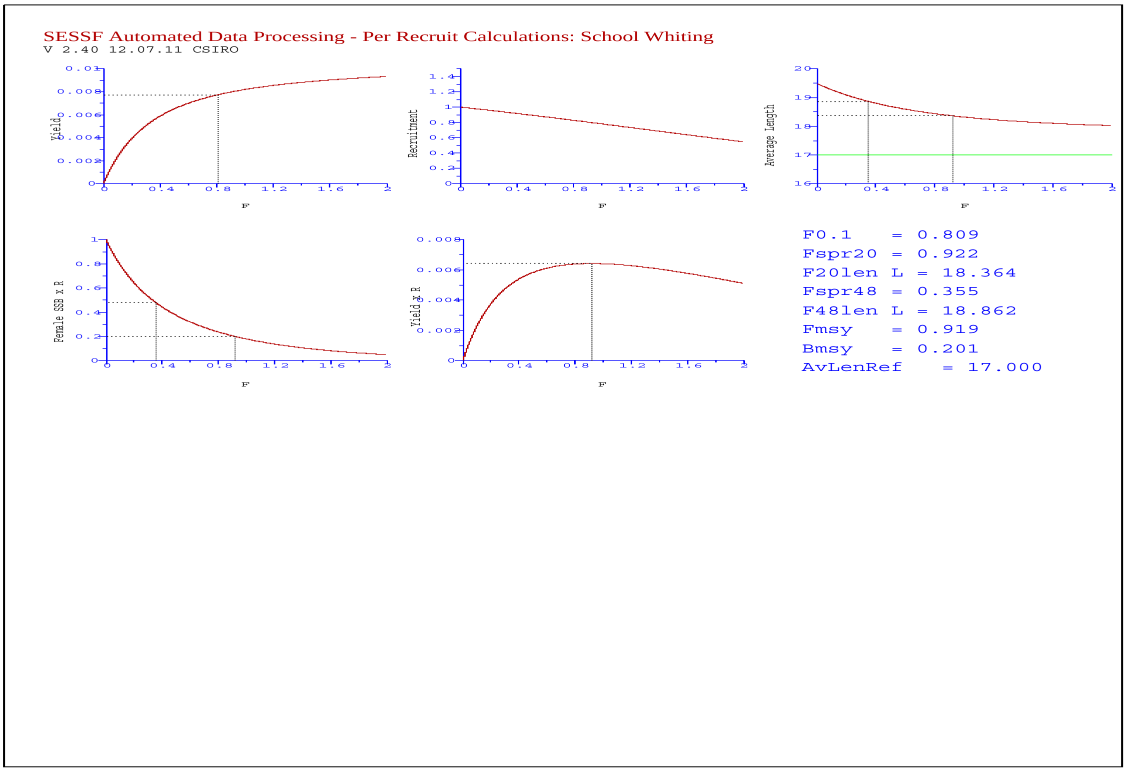


Figure 17.20. School whiting yield per recruit reference point calculations.

### *17.3.2 Catch curves*

The resulting estimates of *Z* are shown in Figure 17.21 to Figure 17.37. Average catch curve fits to annual age compositions are shown, as well as plots of the estimated *Z* value versus year per population and fleet.

The results of catch curve analysis are shown together with the total mortality figures (*Z*) that resulted in spawning biomasses of 20% and 48% of pristine (dotted horizontal lines).

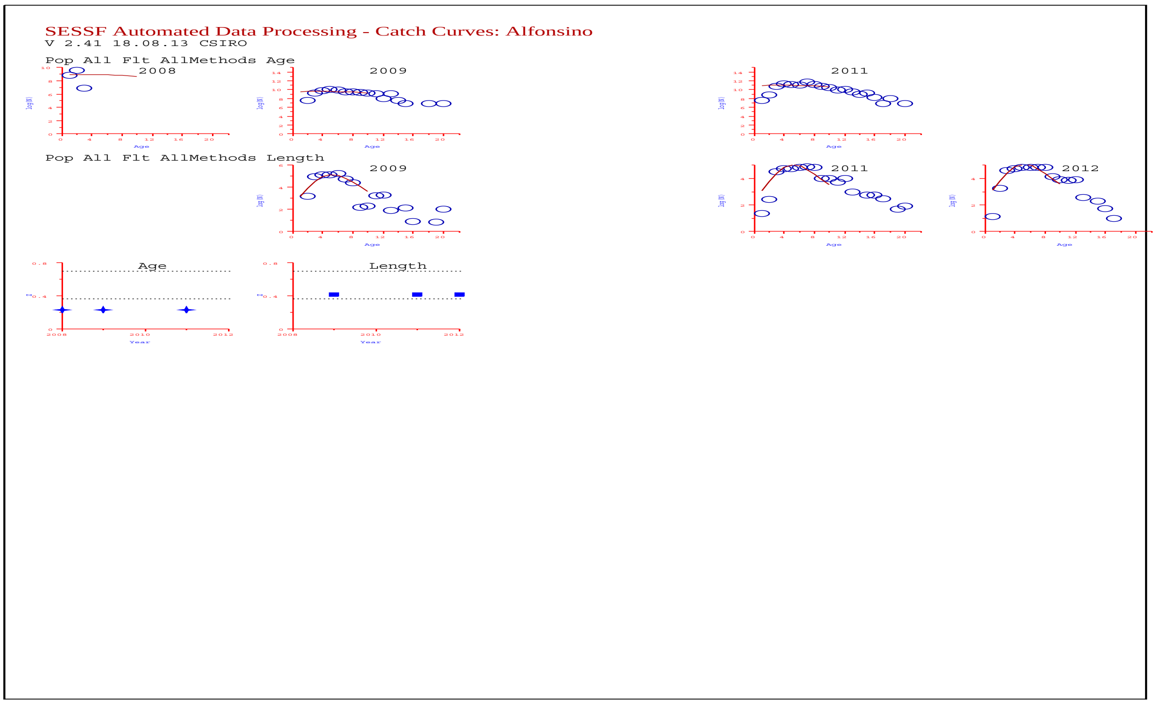


Figure 17.21. Alfonsino catch curve results.

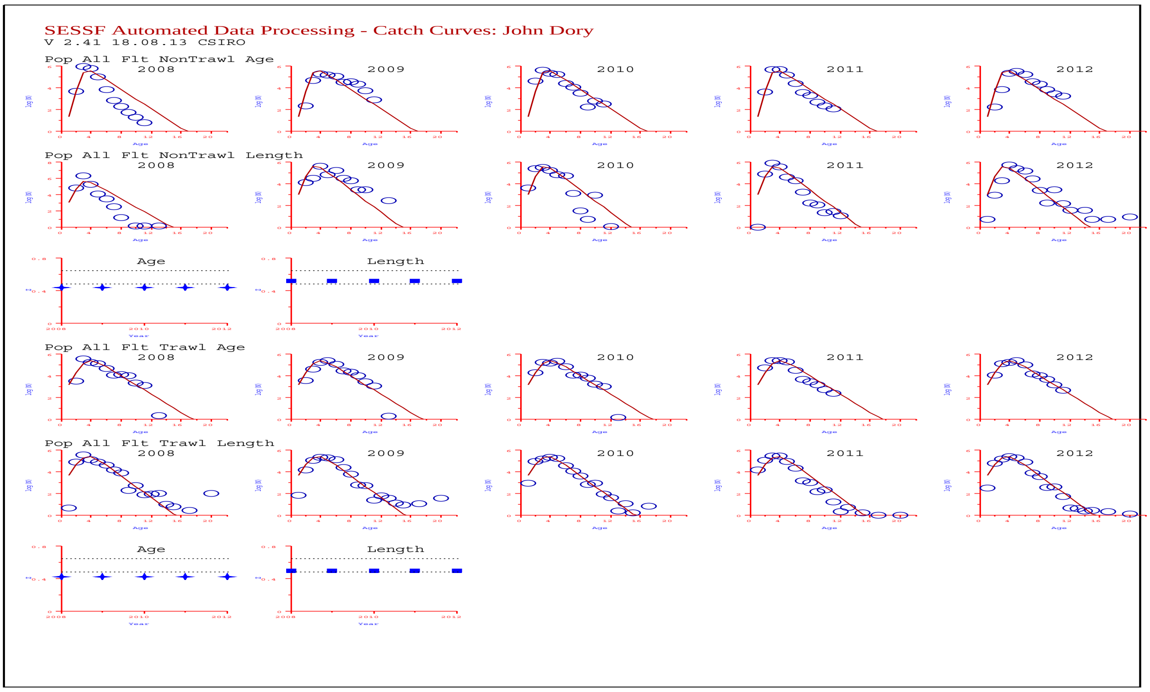


Figure 17.25. John dory catch curve results.

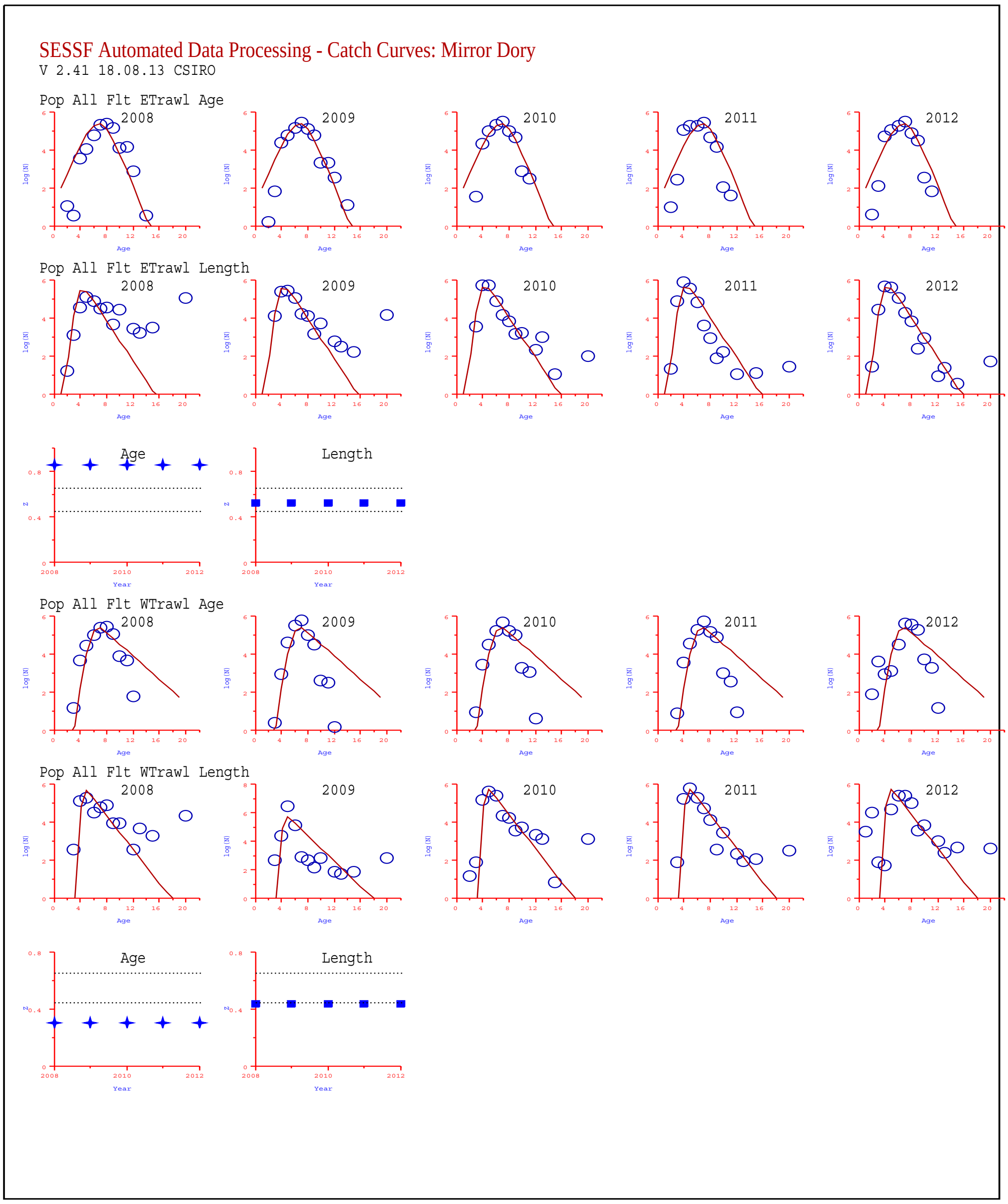


Figure 17.26. Mirror dory catch curve results.

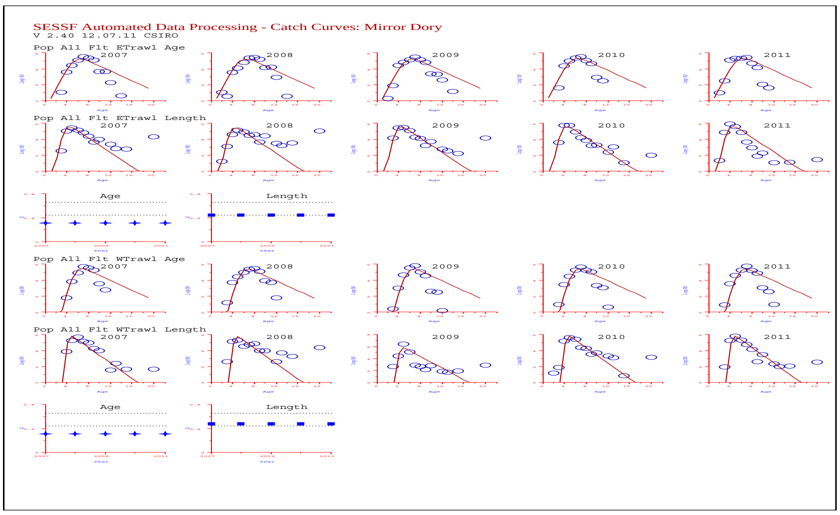


Figure 17.27. Mirror dory catch curve - previous 2012 result.

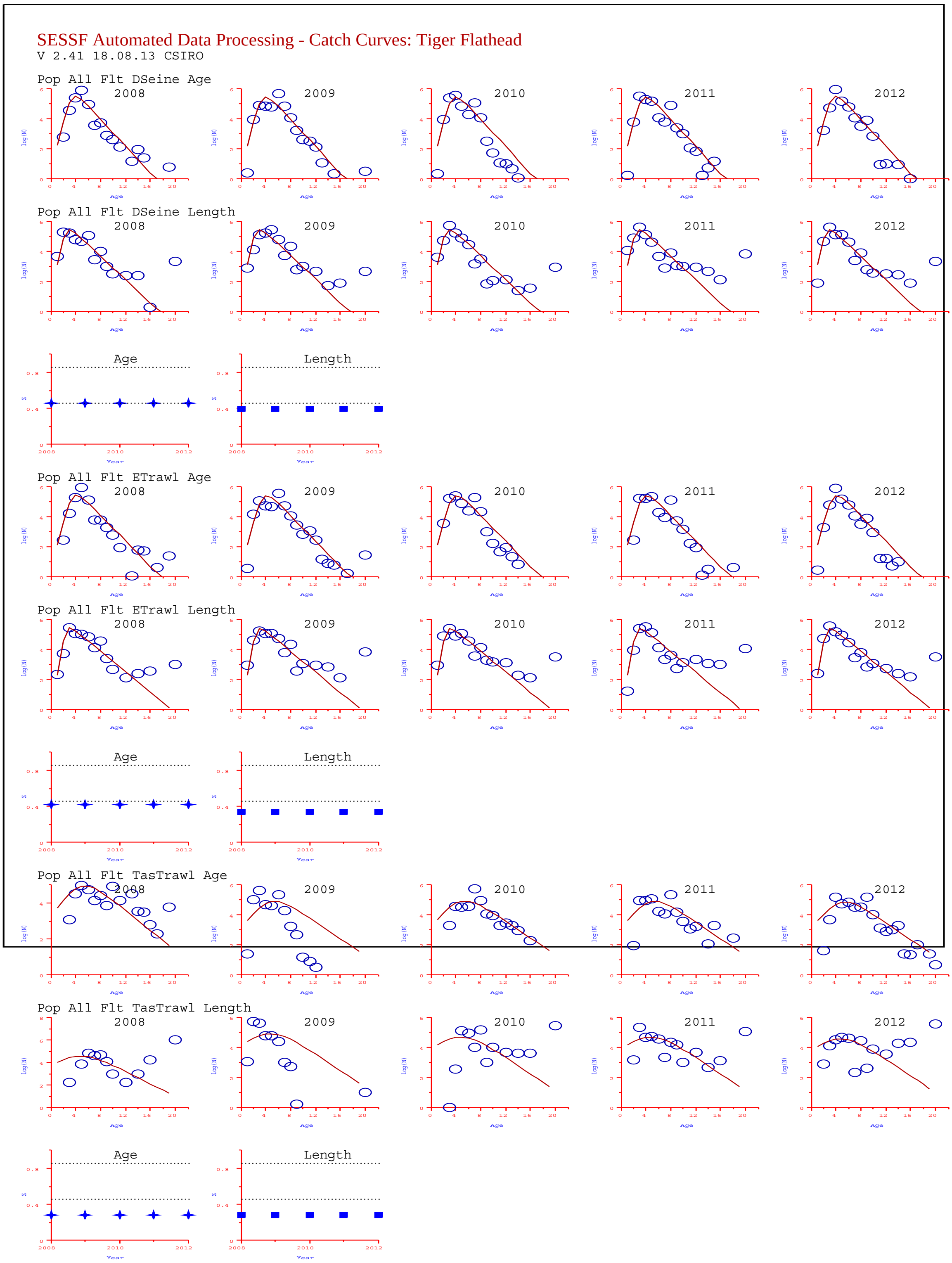


Figure 17.28. Flathead catch curve results.


Figure 17.29. Gemfish east catch curve results.

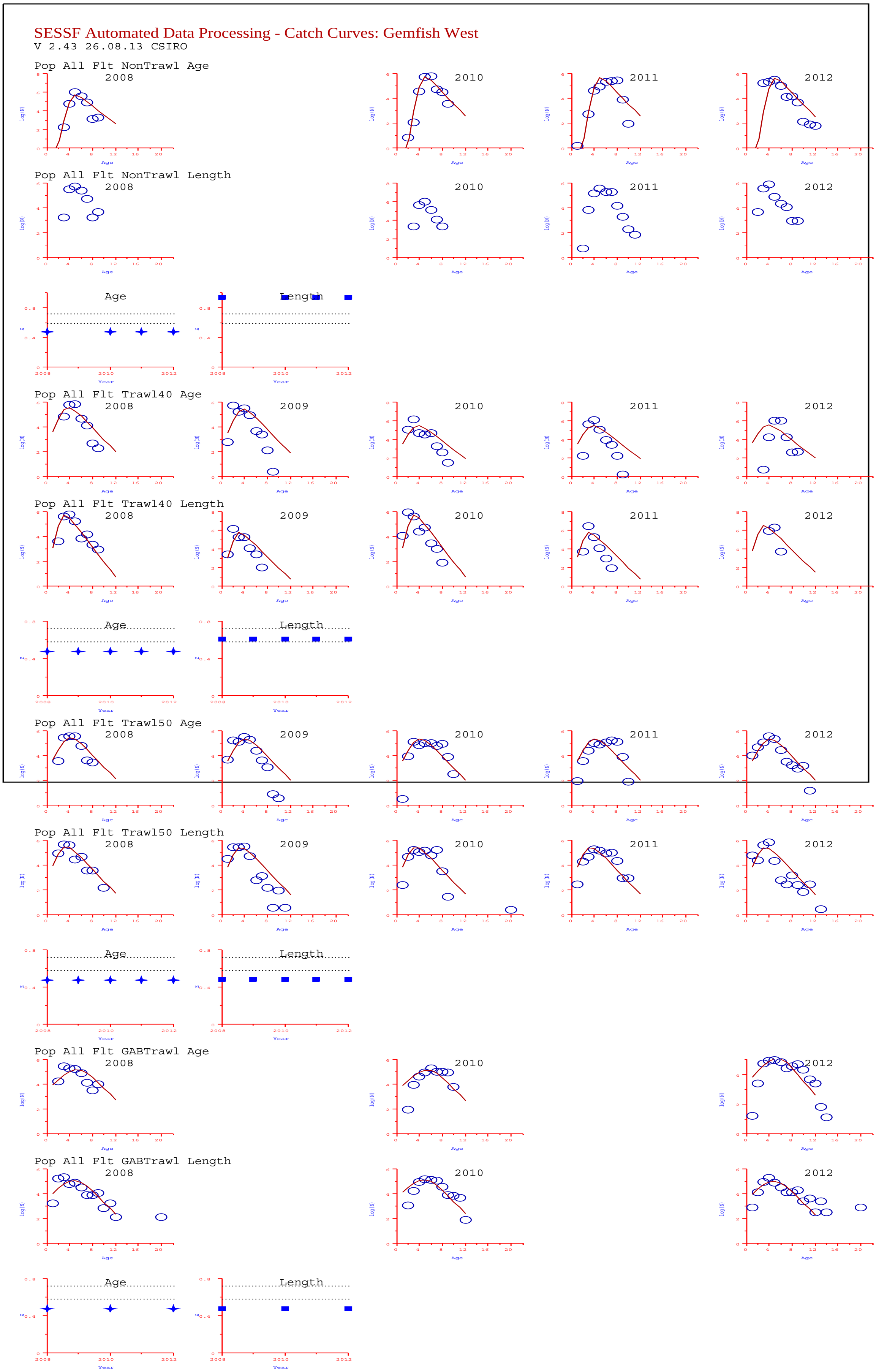


Figure 17.30. Gemfish west catch curve results

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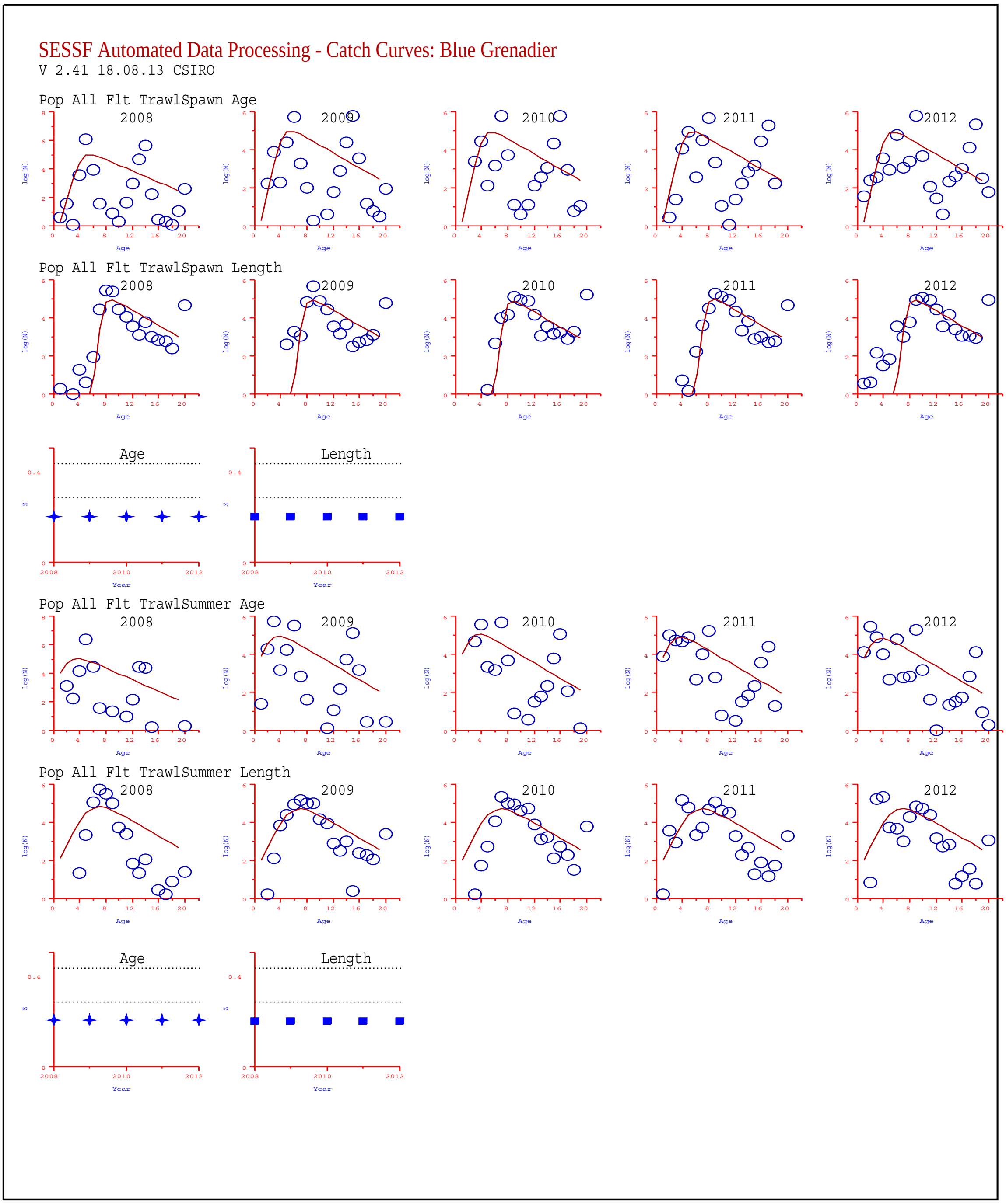


Figure 17.31. Blue grenadier catch curve results.


Figure 17.32. Pink ling catch curve results.

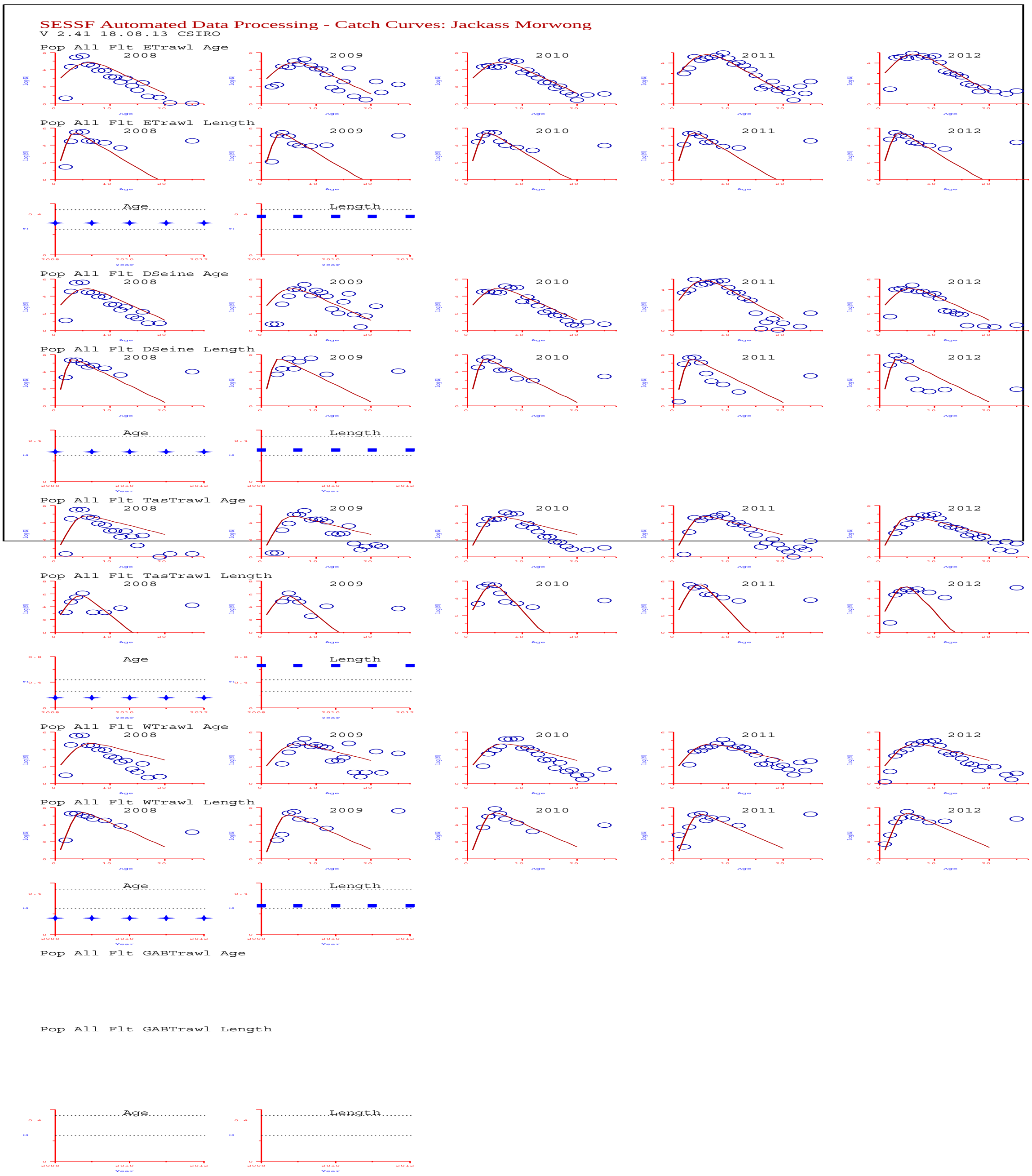


Figure 17.33. Jackass morwong catch curve results.

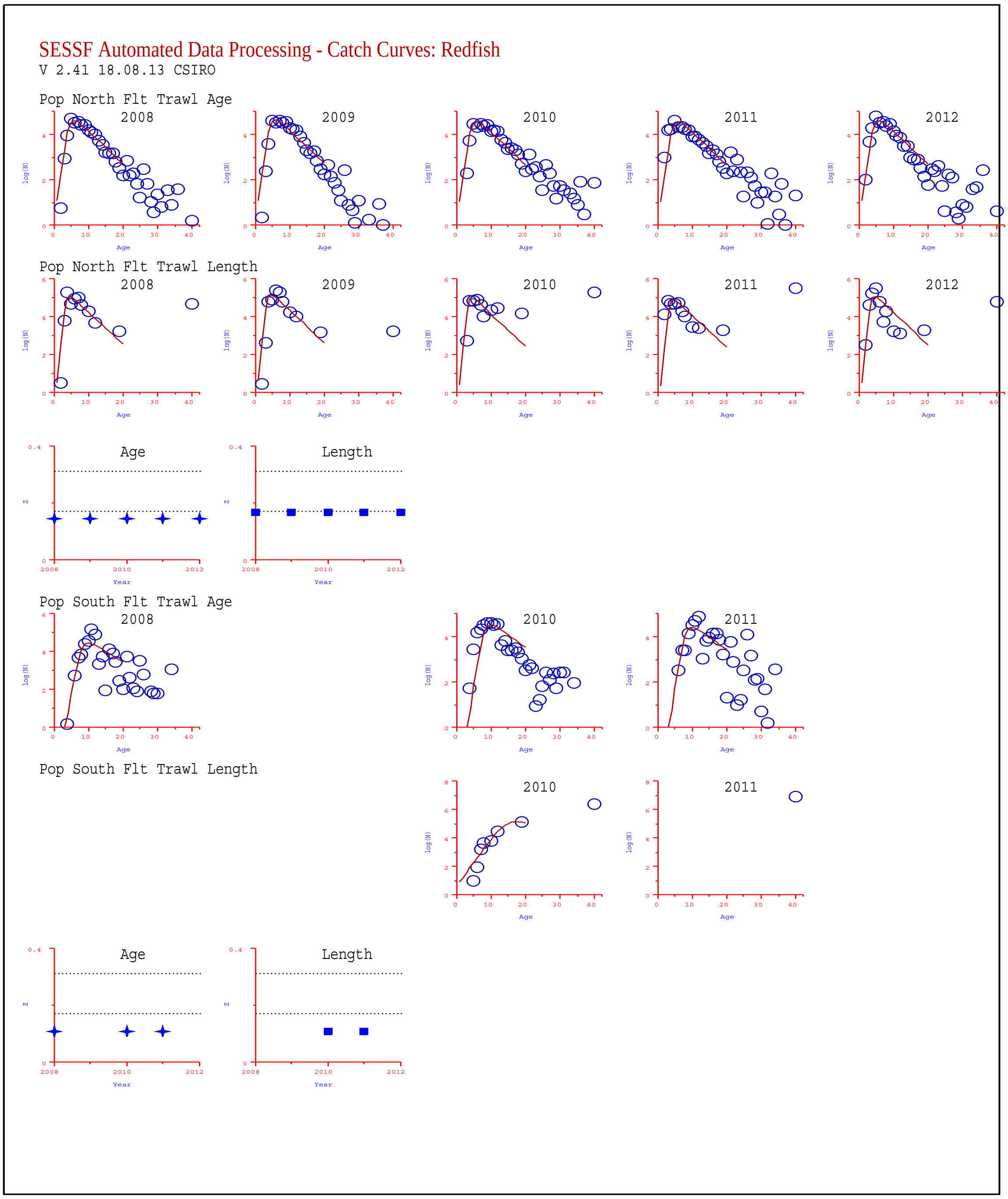


Figure 17.34. Redfish catch curve results

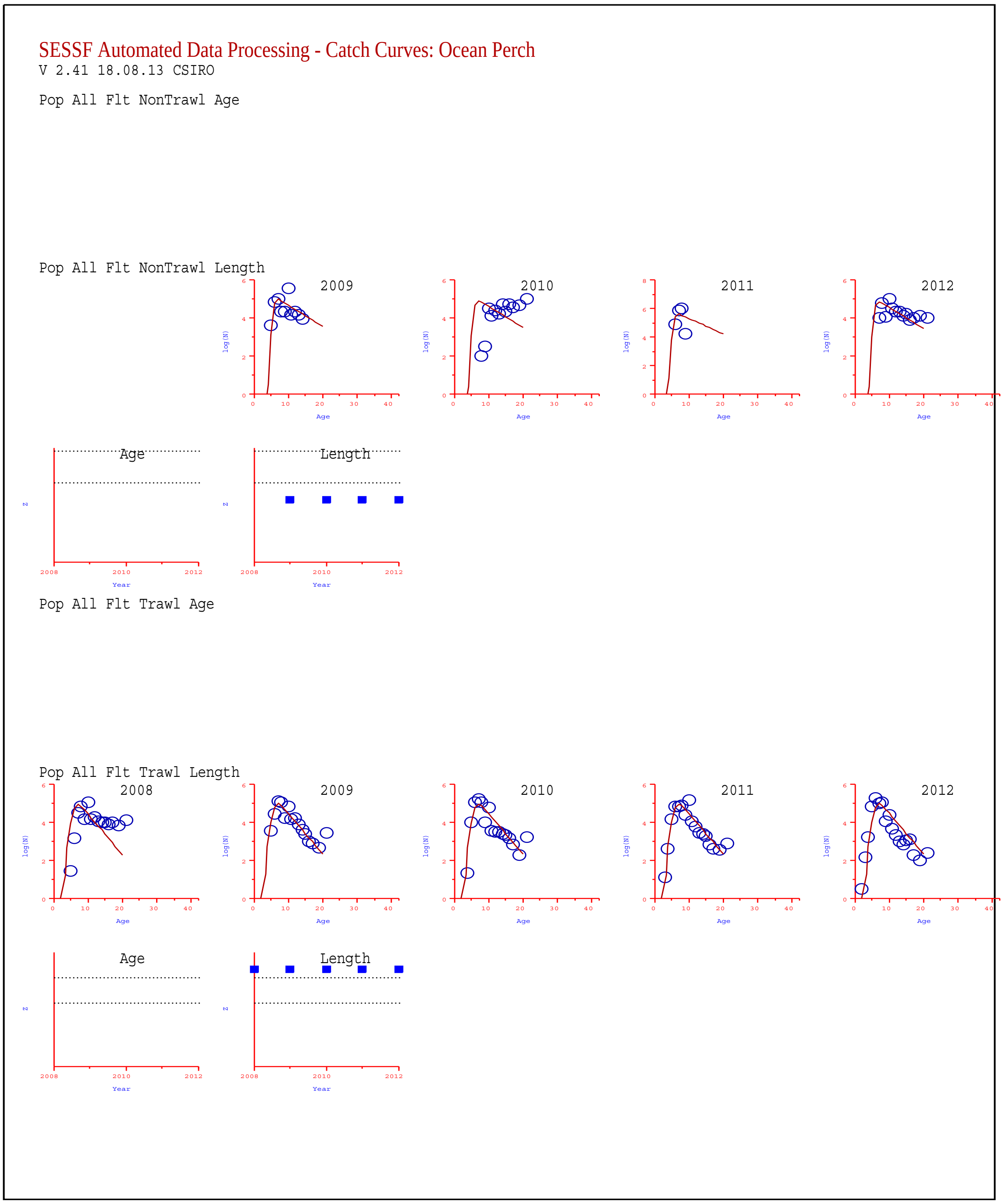


Figure 17.35. Ocean perch catch curve results – where are the SEF1 records?

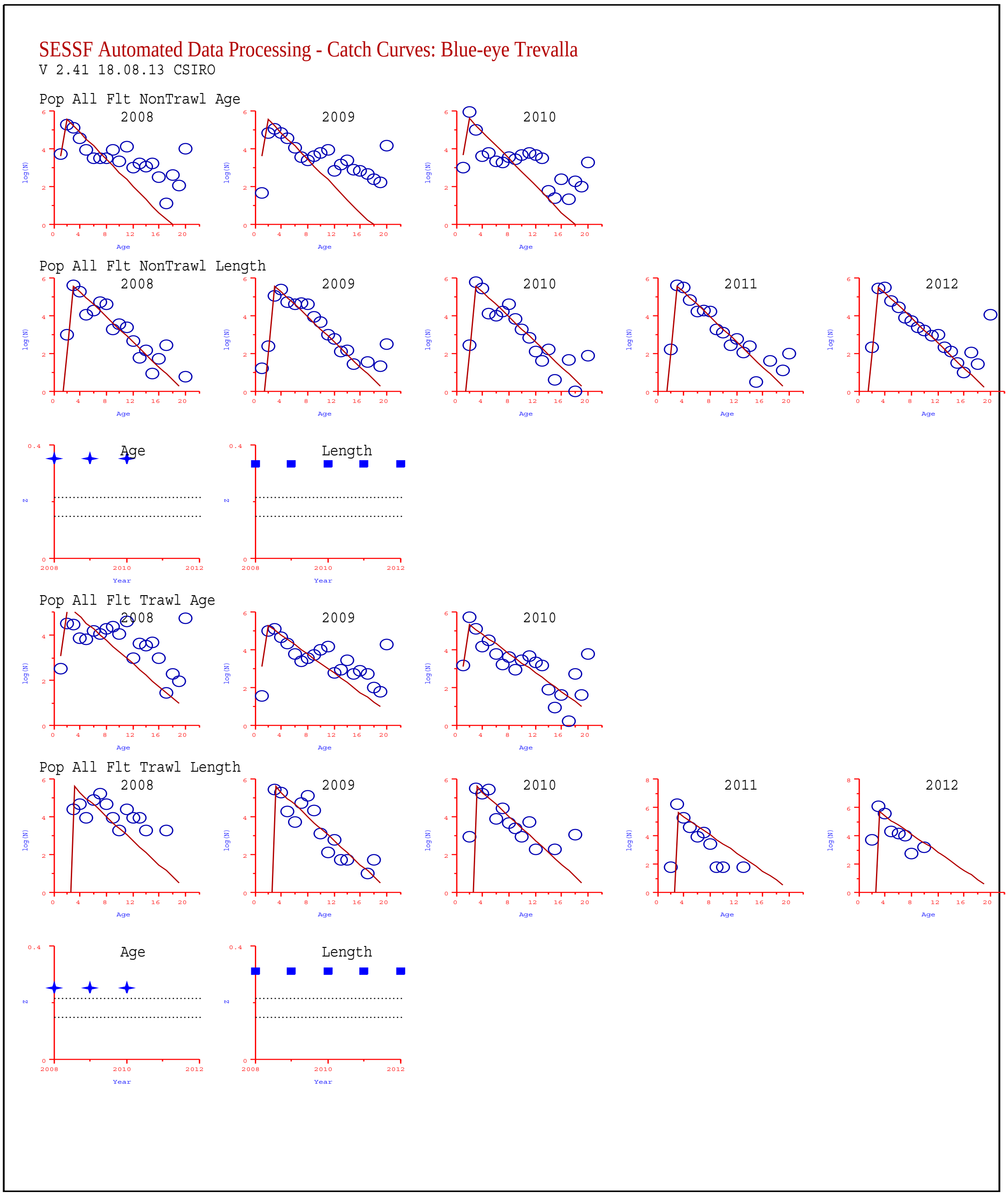


Figure 17.36. Blue-eye trevalla catch curve results.

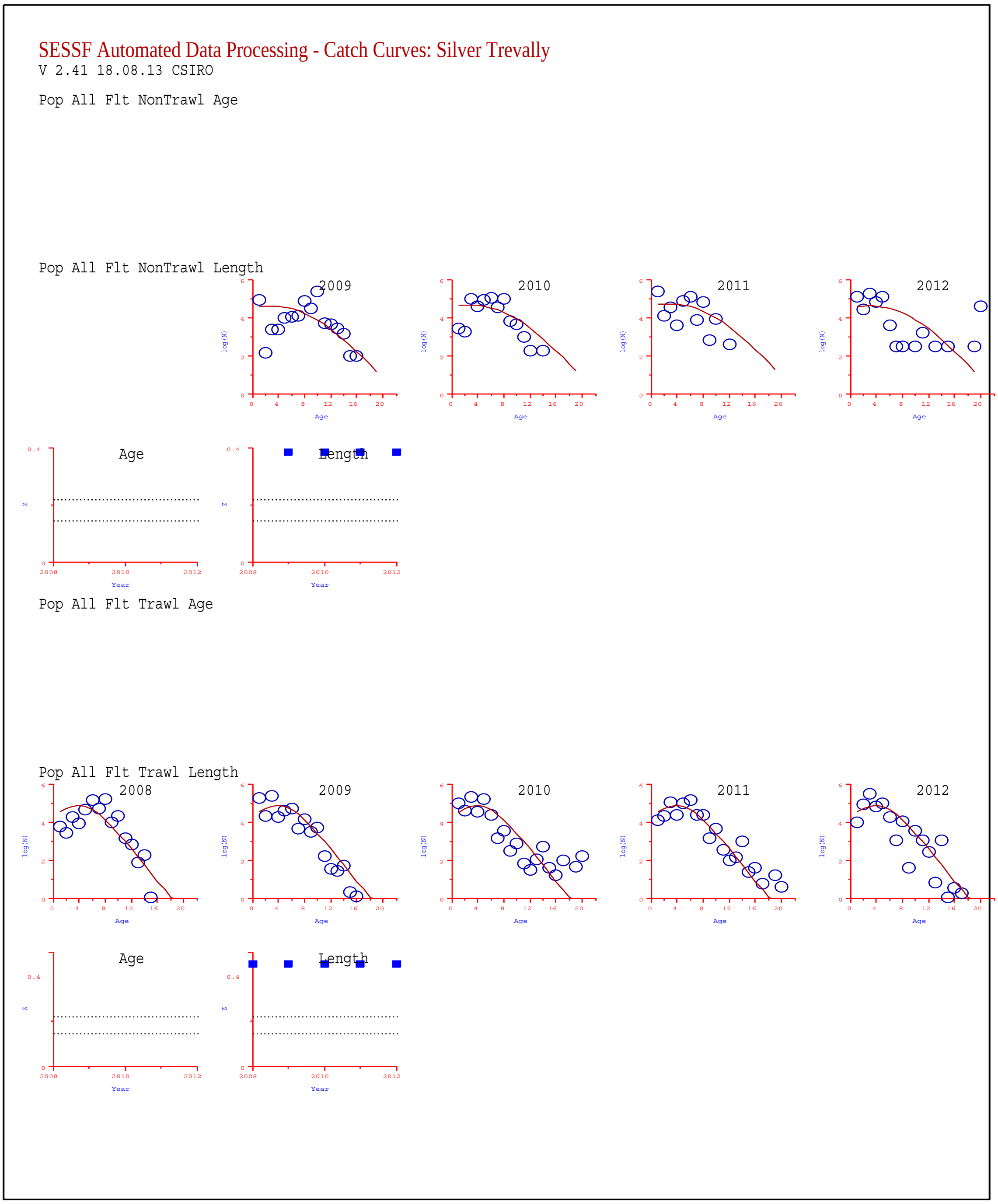


Figure 17.37. Silver trevally catch curve results.

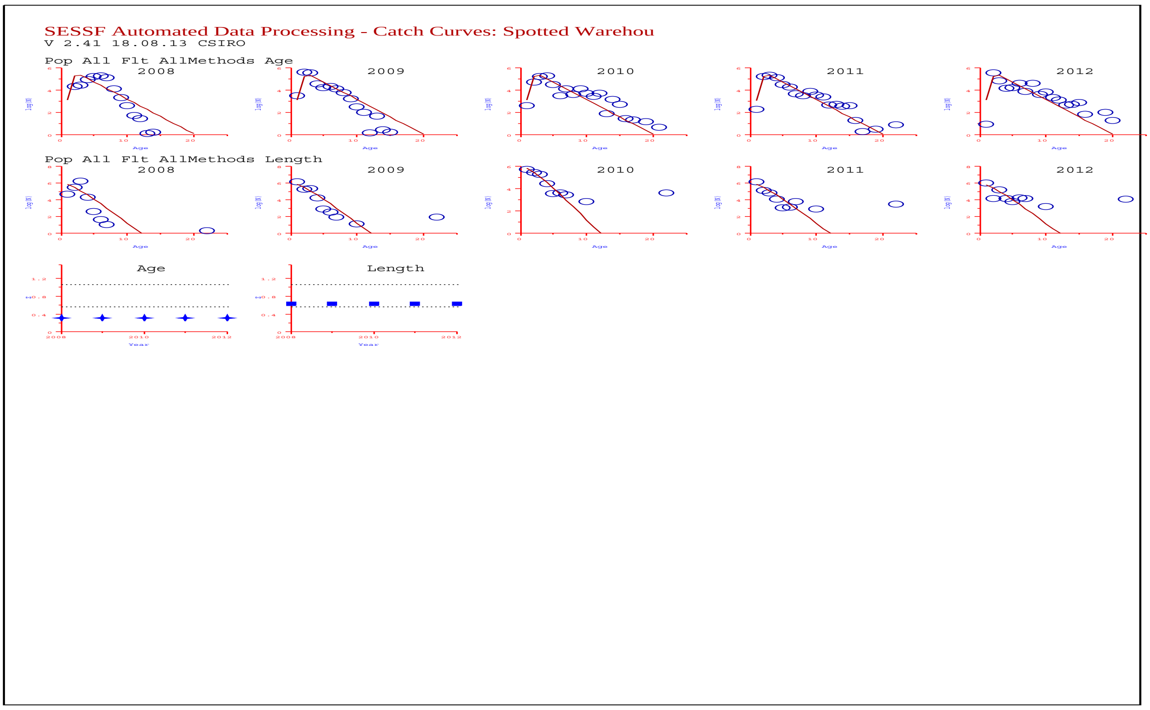


Figure 17.38. Silver warehou catch curve results.

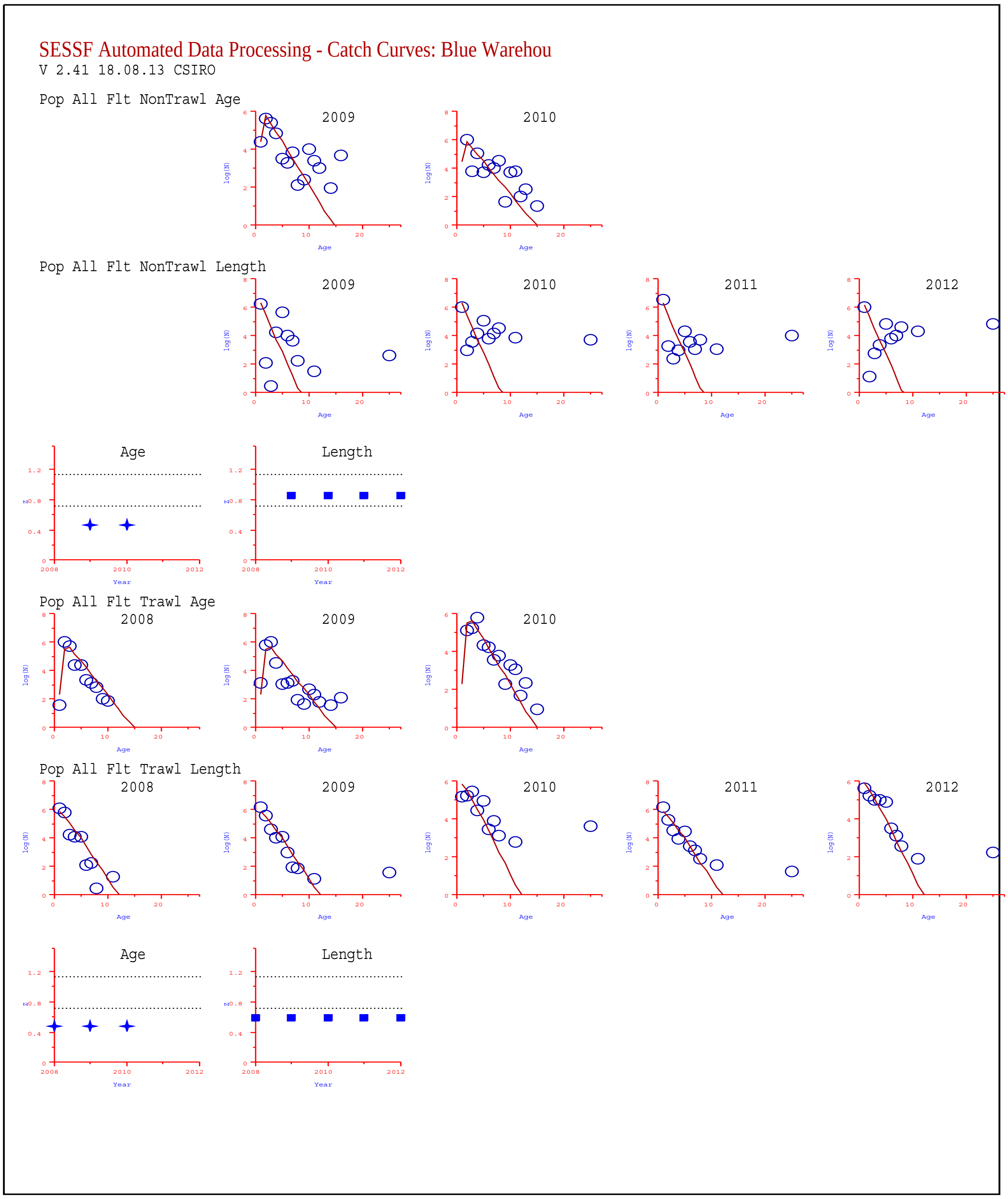


Figure 17.39 Blue warehou catch curve results (check SEF2 and SANSFR record counts).

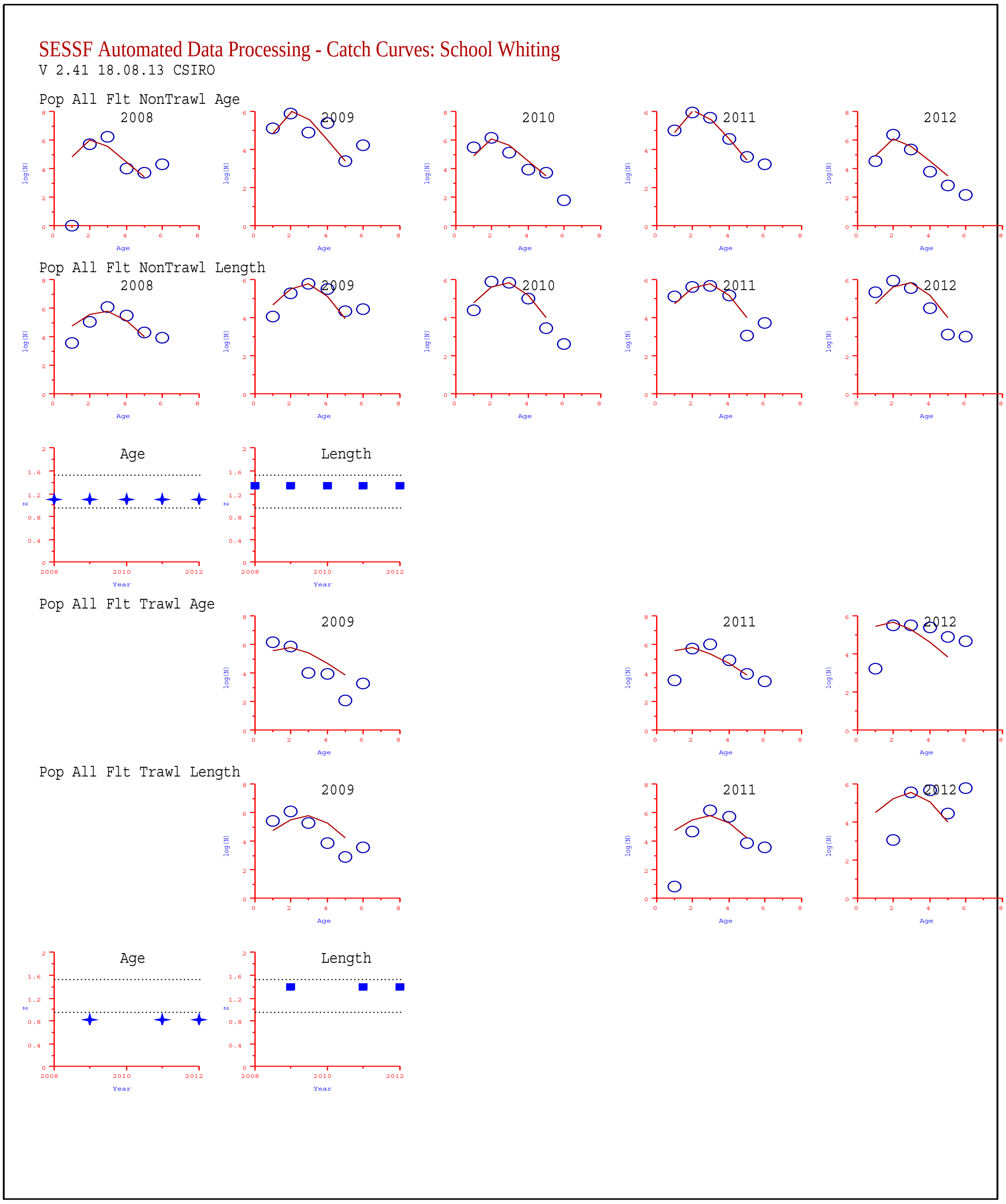


Figure 17.37. School whiting catch curve results.

### *17.3.3 RBC Calculations*

A summary of *Z* and current *F* estimates from catch curve analysis is given in Table 17.2, and the *F* values resulting in 20% and 48% depletion from the previous yield analysis are also shown. Recent *Z* estimates are taken from the values in Figure 17.21 to Figure 17.37 from age-based estimates from fleets that take the majority of catches. The actual values chosen for averaging are highlighted in Appendix 1.

At the SESSFRAG meeting in early 2012 it was agreed to allow the investigation of an *M*-based threshold to limit the size of the RBC multiplier produced by Tier 3 analyses. In the results here, $F_{cur}$ has been limited to a lowest possible value of *M*/10. Alfonsino, John dory and mirror dory all reached this threshold, so have had the RBC limited by this rule. In the Table limit=no means that particular Tier 3 was unaffected by the limit multiplier - not that it wasn't used. Without the limitation, the RBC values were 2,616t, 2,131t and 8,104t respectively.

At Shelf and Slope RAG October 2012 it was agreed to follow the advice from SESSFRAG in 2011 that non-target species MEY target values may be set to $F_{spr40}$ rather than $F_{spr48}$. In Table 17.2 the $F_{spr}$ target used for RBC calculations is highlighted in bold, and the targets for John dory, redfish, silver trevally and blue warehou are now $F_{spr40}$. Other species also agreed, but not included in the Tier 3 calculations below were ribaldo and elephant fish.

Table 17.2. *F* reference points, $Z_{cur}$, $C_{cur}$ and RBC estimates (ribaldo to be included). Limit=no means that particular Tier 3 was unaffected by the limit multiplier - not that it wasn't used

| Species | $F_{spr20}$ | $F_{spr40}$ | $F_{spr48}$ | $Z_{cur}$ | $F_{cur}$ | p | $y_{min}$ | $y_{max}$ | $C_{cur}$ | $F_{rbc}$ | Limit? | RBC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Alfonsino** | 0.479 | 0.201 | **0.149** | 0.230 | 0.022 | 6.362 | 2003 | 2012 | 289 | 0.149 | Yes | 1,838 |
| **John Dory** | 0.287 | **0.159** | 0.126 | 0.424 | 0.064 | 2.371 | 1994 | 2011 | 168 | 0.159 | No | 398 |
| **Mirror Dory** | 0.355 | 0.188 | **0.147** | 0.585 | 0.285 | 0.242 | 1994 | 2011 | 613 | 0.062 | No | 148 |
| Tiger Flathead | 0.585 | 0.251 | **0.187** | 0.438 | 0.168 | 1.104 | 1994 | 2011 | | | | |
| Gemfish E | 0.252 | 0.143 | **0.114** | 0.480 | 0.047 | 2.337 | 1994 | 2012 | | | | |
| Gemfish W | 0.252 | 0.143 | **0.114** | 0.480 | 0.047 | 2.337 | 2001 | 2012 | | | | |
| Blue Grenadier | 0.244 | 0.125 | **0.097** | 0.208 | 0.019 | 4.903 | 1994 | 2009 | | | | |
| Pink Ling E | 0.250 | 0.134 | **0.105** | 0.403 | 0.135 | 0.774 | 1994 | 2006 | | | | |
| Pink Ling W | 0.250 | 0.134 | **0.105** | 0.299 | 0.031 | 3.221 | 1994 | 2006 | | | | |
| Jackass Morwong | 0.294 | 0.135 | **0.102** | 0.311 | 0.161 | 0.550 | 1993 | 2010 | | | | |
| Redfish | 0.213 | **0.098** | 0.074 | 0.145 | 0.045 | 2.113 | 1993 | 2009 | 1,794 | 0.098 | No | 3,791 |
| Ocean Perch | 0.096 | 0.052 | **0.041** | 0.213 | 0.113 | 0.000 | 1993 | 2009 | | | | |
| Blue-eye Trevalla | 0.118 | 0.062 | **0.049** | 0.334 | 0.234 | 0.000 | 1994 | 2009 | | | | |
| Silver Trevally | 0.121 | **0.062** | 0.048 | 0.450 | 0.350 | 0.000 | 1994 | 2010 | | | | |
| Silver Warehou | 0.766 | 0.347 | **0.260** | 0.310 | 0.030 | 7.747 | 1993 | 2011 | | | | |
| Blue Warehou | 0.680 | **0.348** | 0.269 | 0.475 | 0.045 | 6.679 | 1993 | 2012 | | | | |
| School Whiting | 0.922 | 0.461 | **0.355** | 1.104 | 0.504 | 0.695 | 2008 | 2011 | | | | |

Note: Species that were Tier 3 in 2012 are highlighted in bold.

RBC values for alfonsino, John dory and redfish were greater than reference average catches (p>1). The RBC for mirror dory is lower than the reference catch (p<1) which is a result very different to that presented in 2012. The reason is a considerable shift in the average *Z* fit for catch curves in the east (Figure 17.26) caused by a change in emphasis in the overall fit from younger to older fish. This highlights the possible catch variability inherent in a data-poor procedure such as the Tier 3 (see Klaer and Wayte 2011).

Western gemfish, blue grenadier, pink ling, blue-eye trevalla and silver trevally were unable to be assessed using catch curves due to probable dome-shaped selectivity or high recruitment variability.

## 17.4 Acknowledgements

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## *17.6 Appendix 1 – details of values that were used as estimates of total Z (shown highlighted)*

| ALFCCRes | Pop | Flt | Year | Catch | CCType | Iage | Ilen | Zage | Zlen | SSa | SSl |
|---|---|---|---|---|---|---|---|---|---|---|---|
| ALFCCRes | All | AllMethods | 2008 | 0 | 1 | -99 | -99 | 0.23 | -99 | 23 | 0 |
| ALFCCRes | All | AllMethods | 2009 | 14.197 | 1 | -99 | -99 | 0.23 | 0.415458 | 148 | 473 |
| ALFCCRes | All | AllMethods | 2010 | 0.0135 | 1 | -99 | -99 | -99 | -99 | 0 | 0 |
| ALFCCRes | All | AllMethods | 2011 | 210.977 | 1 | -99 | -99 | 0.23 | 0.415458 | 640 | 25638 |
| ALFCCRes | All | AllMethods | 2012 | 330.211 | 1 | -99 | -99 | -99 | 0.415458 | 0 | 32788 |
| DOJCCRes | All | NonTrawl | 2008 | 6.90675 | 1 | -99 | -99 | 0.440459 | 0.521817 | 611 | 804 |
| DOJCCRes | All | NonTrawl | 2009 | 6.08687 | 1 | -99 | -99 | 0.440459 | 0.521817 | 611 | 64 |
| DOJCCRes | All | NonTrawl | 2010 | 4.819 | 1 | -99 | -99 | 0.440459 | 0.521817 | 611 | 450 |
| DOJCCRes | All | NonTrawl | 2011 | 11.0446 | 1 | -99 | -99 | 0.440459 | 0.521817 | 611 | 525 |
| DOJCCRes | All | NonTrawl | 2012 | 6.13983 | 1 | -99 | -99 | 0.440459 | 0.521817 | 611 | 242 |
| DOJCCRes | All | Trawl | 2008 | 106.212 | 1 | -99 | -99 | 0.423801 | 0.502959 | 611 | 1573 |
| DOJCCRes | All | Trawl | 2009 | 84.209 | 1 | -99 | -99 | 0.423801 | 0.502959 | 611 | 3363 |
| DOJCCRes | All | Trawl | 2010 | 55.1425 | 1 | -99 | -99 | 0.423801 | 0.502959 | 611 | 2603 |
| DOJCCRes | All | Trawl | 2011 | 60.3184 | 1 | -99 | -99 | 0.423801 | 0.502959 | 611 | 1890 |
| DOJCCRes | All | Trawl | 2012 | 59.0366 | 1 | -99 | -99 | 0.423801 | 0.502959 | 611 | 2552 |
| DOMCCRes | All | ETrawl | 2008 | 326.319 | 1 | -99 | -99 | 0.859399 | 0.524908 | 1634 | 1601 |
| DOMCCRes | All | ETrawl | 2009 | 343.905 | 1 | -99 | -99 | 0.859399 | 0.524908 | 1634 | 2318 |
| DOMCCRes | All | ETrawl | 2010 | 389.139 | 1 | -99 | -99 | 0.859399 | 0.524908 | 1634 | 2657 |
| DOMCCRes | All | ETrawl | 2011 | 354.116 | 1 | -99 | -99 | 0.859399 | 0.524908 | 1634 | 1757 |
| DOMCCRes | All | ETrawl | 2012 | 290.615 | 1 | -99 | -99 | 0.859399 | 0.524908 | 1634 | 1882 |
| DOMCCRes | All | WTrawl | 2008 | 66.053 | 1 | -99 | -99 | 0.310126 | 0.441789 | 1634 | 75 |
| DOMCCRes | All | WTrawl | 2009 | 131.066 | 1 | -99 | -99 | 0.310126 | 0.441789 | 1634 | 299 |
| DOMCCRes | All | WTrawl | 2010 | 187.747 | 1 | -99 | -99 | 0.310126 | 0.441789 | 1634 | 628 |
| DOMCCRes | All | WTrawl | 2011 | 161.886 | 1 | -99 | -99 | 0.310126 | 0.441789 | 1634 | 658 |
| DOMCCRes | All | WTrawl | 2012 | 71.9615 | 1 | -99 | -99 | 0.310126 | 0.441789 | 1634 | 423 |
| FLDCCRes | All | Trawl | 2008 | 783.441 | 1 | -99 | -99 | 0.51493 | 0.6982 | 554 | 1849 |
| FLDCCRes | All | Trawl | 2009 | 834.012 | 1 | -99 | -99 | 0.51493 | 0.6982 | 465 | 13911 |
| FLDCCRes | All | Trawl | 2010 | 916.38 | 1 | -99 | -99 | 0.51493 | 0.6982 | 552 | 3504 |
| FLDCCRes | All | Trawl | 2011 | 322.192 | 1 | -99 | -99 | 0.51493 | 0.6982 | 367 | 2284 |
| FLDCCRes | All | Trawl | 2012 | 338.257 | 1 | -99 | -99 | 0.51493 | 0.6982 | 396 | 2026 |
| FLDCCRes | All | Survey | 2008 | 0 | 1 | -99 | -99 | -99 | -99 | 0 | 0 |
| FLDCCRes | All | Survey | 2009 | 0 | 1 | -99 | -99 | -99 | -99 | 0 | 0 |
| FLDCCRes | All | Survey | 2010 | 0 | 1 | -99 | -99 | -99 | -99 | 0 | 0 |
| FLDCCRes | All | Survey | 2011 | 0 | 1 | -99 | -99 | -99 | -99 | 0 | 0 |
| FLDCCRes | All | Survey | 2012 | 0 | 1 | -99 | -99 | -99 | -99 | 0 | 0 |
| FLTCCRes | All | DSeine | 2008 | 1321.42 | 1 | -99 | -99 | 0.456433 | 0.389983 | 714 | 466 |
| FLTCCRes | All | DSeine | 2009 | 1221.38 | 1 | -99 | -99 | 0.456433 | 0.389983 | 1093 | 1100 |
| FLTCCRes | All | DSeine | 2010 | 1231.44 | 1 | -99 | -99 | 0.456433 | 0.389983 | 1134 | 1429 |
| FLTCCRes | All | DSeine | 2011 | 1170.06 | 1 | -99 | -99 | 0.456433 | 0.389983 | 1130 | 2369 |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| FLTCCRes | All | DSeine | 2012 | 1393.84 | 1 | -99 | -99 | 0.456433 | 0.389983 | 1080 | 2577 |
| FLTCCRes | All | ETrawl | 2008 | 1390.34 | 1 | -99 | -99 | 0.41916 | 0.34237 | 714 | 1614 |
| FLTCCRes | All | ETrawl | 2009 | 1126.35 | 1 | -99 | -99 | 0.41916 | 0.34237 | 1093 | 2109 |
| FLTCCRes | All | ETrawl | 2010 | 1157.05 | 1 | -99 | -99 | 0.41916 | 0.34237 | 1134 | 4016 |
| FLTCCRes | All | ETrawl | 2011 | 1158.72 | 1 | -99 | -99 | 0.41916 | 0.34237 | 1130 | 2942 |
| FLTCCRes | All | ETrawl | 2012 | 1216.35 | 1 | -99 | -99 | 0.41916 | 0.34237 | 1080 | 2997 |
| FLTCCRes | All | TasTrawl | 2008 | 175.732 | 1 | -99 | -99 | 0.280002 | 0.28 | 714 | 101 |
| FLTCCRes | All | TasTrawl | 2009 | 102.032 | 1 | -99 | -99 | 0.280002 | 0.28 | 1093 | 176 |
| FLTCCRes | All | TasTrawl | 2010 | 105.253 | 1 | -99 | -99 | 0.280002 | 0.28 | 1134 | 303 |
| FLTCCRes | All | TasTrawl | 2011 | 132.183 | 1 | -99 | -99 | 0.280002 | 0.28 | 1130 | 538 |
| FLTCCRes | All | TasTrawl | 2012 | 164.418 | 1 | -99 | -99 | 0.280002 | 0.28 | 1080 | 536 |
| GEECCRes | East | NonTrawl | 2008 | 15.9079 | 1 | -99 | -99 | 0.48 | 0.508587 | 625 | 37 |
| GEECCRes | East | NonTrawl | 2009 | 11.9662 | 1 | -99 | -99 | 0.48 | -99 | 396 | 0 |
| GEECCRes | East | NonTrawl | 2010 | 12.2595 | 1 | -99 | -99 | 0.48 | 0.508587 | 580 | 122 |
| GEECCRes | East | NonTrawl | 2011 | 7.258 | 1 | -99 | -99 | 0.48 | 0.508587 | 626 | 551 |
| GEECCRes | East | NonTrawl | 2012 | 6.14025 | 1 | -99 | -99 | 0.48 | 0.508587 | 405 | 363 |
| GEECCRes | East | SumTrawl | 2008 | 27.5237 | 1 | -99 | -99 | 0.48022 | 0.480324 | 625 | 1109 |
| GEECCRes | East | SumTrawl | 2009 | 18.6789 | 1 | -99 | -99 | 0.48022 | 0.480324 | 396 | 218 |
| GEECCRes | East | SumTrawl | 2010 | 15.0915 | 1 | -99 | -99 | 0.48022 | 0.480324 | 580 | 835 |
| GEECCRes | East | SumTrawl | 2011 | 13.6502 | 1 | -99 | -99 | 0.48022 | 0.480324 | 626 | 1281 |
| GEECCRes | East | SumTrawl | 2012 | 15.56 | 1 | -99 | -99 | 0.48022 | 0.480324 | 405 | 920 |
| GEECCRes | East | WinTrawl | 2008 | 79.0505 | 1 | -99 | -99 | 0.480624 | 0.48108 | 625 | 478 |
| GEECCRes | East | WinTrawl | 2009 | 43.5215 | 1 | -99 | -99 | 0.480624 | 0.48108 | 396 | 366 |
| GEECCRes | East | WinTrawl | 2010 | 48.6733 | 1 | -99 | -99 | 0.480624 | 0.48108 | 580 | 471 |
| GEECCRes | East | WinTrawl | 2011 | 31.1313 | 1 | -99 | -99 | 0.480624 | 0.48108 | 626 | 1201 |
| GEECCRes | East | WinTrawl | 2012 | 32.1955 | 1 | -99 | -99 | 0.480624 | 0.48108 | 405 | 689 |
| GEWCCRes | All | NonTrawl | 2008 | 9.5857 | 1 | -99 | -99 | 0.480072 | 0.94 | 625 | 76 |
| GEWCCRes | All | NonTrawl | 2009 | 7.2278 | 1 | -99 | -99 | -99 | -99 | 0 | 0 |
| GEWCCRes | All | NonTrawl | 2010 | 9.7671 | 1 | -99 | -99 | 0.480072 | 0.94 | 1167 | 34 |
| GEWCCRes | All | NonTrawl | 2011 | 12.7382 | 1 | -99 | -99 | 0.480072 | 0.94 | 925 | 321 |
| GEWCCRes | All | NonTrawl | 2012 | 5.2559 | 1 | -99 | -99 | 0.480072 | 0.94 | 999 | 50 |
| GEWCCRes | All | Trawl40 | 2008 | 4.105 | 1 | -99 | -99 | 0.480408 | 0.610007 | 625 | 105 |
| GEWCCRes | All | Trawl40 | 2009 | 5.25825 | 1 | -99 | -99 | 0.480408 | 0.610007 | 1002 | 129 |
| GEWCCRes | All | Trawl40 | 2010 | 11.5847 | 1 | -99 | -99 | 0.480408 | 0.610007 | 1167 | 137 |
| GEWCCRes | All | Trawl40 | 2011 | 14.872 | 1 | -99 | -99 | 0.480408 | 0.610007 | 925 | 334 |
| GEWCCRes | All | Trawl40 | 2012 | 9.2765 | 1 | -99 | -99 | 0.480408 | 0.610007 | 999 | 16 |
| GEWCCRes | All | Trawl50 | 2008 | 52.992 | 1 | -99 | -99 | 0.480078 | 0.48182 | 625 | 112 |
| GEWCCRes | All | Trawl50 | 2009 | 54.1895 | 1 | -99 | -99 | 0.480078 | 0.48182 | 1002 | 420 |
| GEWCCRes | All | Trawl50 | 2010 | 78.3824 | 1 | -99 | -99 | 0.480078 | 0.48182 | 1167 | 729 |
| GEWCCRes | All | Trawl50 | 2011 | 44.5025 | 1 | -99 | -99 | 0.480078 | 0.48182 | 925 | 118 |
| GEWCCRes | All | Trawl50 | 2012 | 44.1995 | 1 | -99 | -99 | 0.480078 | 0.48182 | 999 | 450 |
| GEWCCRes | All | GABTrawl | 2008 | 104.618 | 1 | -99 | -99 | 0.480001 | 0.480001 | 625 | 117 |
| GEWCCRes | All | GABTrawl | 2009 | 48.9613 | 1 | -99 | -99 | -99 | -99 | 0 | 0 |
| GEWCCRes | All | GABTrawl | 2010 | 42.7313 | 1 | -99 | -99 | 0.480001 | 0.480001 | 1167 | 140 |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| GEWCCRes | All | GABTrawl | 2011 | 21.5787 | 1 | -99 | -99 | -99 | -99 | 0 | 0 |
| GEWCCRes | All | GABTrawl | 2012 | 35.1163 | 1 | -99 | -99 | 0.480001 | 0.480001 | 999 | 161 |
| GRECCRes | All | TrawlSpawn | 2008 | 2837.64 | 1 | -99 | -99 | 0.199104 | 0.199208 | 1848 | 5366 |
| GRECCRes | All | TrawlSpawn | 2009 | 2723 | 1 | -99 | -99 | 0.199104 | 0.199208 | 2086 | 15241 |
| GRECCRes | All | TrawlSpawn | 2010 | 3383.55 | 1 | -99 | -99 | 0.199104 | 0.199208 | 1642 | 9206 |
| GRECCRes | All | TrawlSpawn | 2011 | 3553.82 | 1 | -99 | -99 | 0.199104 | 0.199208 | 2007 | 7484 |
| GRECCRes | All | TrawlSpawn | 2012 | 3837.58 | 1 | -99 | -99 | 0.199104 | 0.199208 | 1771 | 6821 |
| GRECCRes | All | TrawlSummer | 2008 | 1305.68 | 1 | -99 | -99 | 0.207941 | 0.19914 | 1848 | 1895 |
| GRECCRes | All | TrawlSummer | 2009 | 1144.23 | 1 | -99 | -99 | 0.207941 | 0.19914 | 2086 | 2979 |
| GRECCRes | All | TrawlSummer | 2010 | 1156.58 | 1 | -99 | -99 | 0.207941 | 0.19914 | 1642 | 2499 |
| GRECCRes | All | TrawlSummer | 2011 | 913.108 | 1 | -99 | -99 | 0.207941 | 0.19914 | 2007 | 3321 |
| GRECCRes | All | TrawlSummer | 2012 | 619.961 | 1 | -99 | -99 | 0.207941 | 0.19914 | 1771 | 2743 |
| GRWCCRes | All | TrawlSummer | 2008 | 3.321 | 1 | -99 | -99 | -99 | -99 | 0 | 0 |
| GRWCCRes | All | TrawlSummer | 2009 | 0.5625 | 1 | -99 | -99 | -99 | -99 | 0 | 0 |
| GRWCCRes | All | TrawlSummer | 2010 | 5.145 | 1 | -99 | -99 | -99 | -99 | 0 | 0 |
| GRWCCRes | All | TrawlSummer | 2011 | 4.8425 | 1 | -99 | -99 | -99 | -99 | 0 | 0 |
| GRWCCRes | All | TrawlSummer | 2012 | 2.415 | 1 | -99 | -99 | -99 | -99 | 0 | 0 |
| GRWCCRes | All | TrawlSpawn | 2008 | 0.27 | 1 | -99 | -99 | 0.538723 | 0.263261 | 1848 | 48 |
| GRWCCRes | All | TrawlSpawn | 2009 | 0 | 1 | -99 | -99 | -99 | -99 | 0 | 0 |
| GRWCCRes | All | TrawlSpawn | 2010 | 0.5925 | 1 | -99 | -99 | -99 | -99 | 0 | 0 |
| GRWCCRes | All | TrawlSpawn | 2011 | 0.5025 | 1 | -99 | -99 | -99 | -99 | 0 | 0 |
| GRWCCRes | All | TrawlSpawn | 2012 | 0.075 | 1 | -99 | -99 | -99 | -99 | 0 | 0 |
| LIECCRes | All | LongLine10 | 2008 | 0 | 1 | -99 | -99 | -99 | -99 | 0 | 0 |
| LIECCRes | All | LongLine10 | 2009 | 0.108 | 1 | -99 | -99 | -99 | -99 | 0 | 0 |
| LIECCRes | All | LongLine10 | 2010 | 0.0418 | 1 | -99 | -99 | -99 | -99 | 0 | 0 |
| LIECCRes | All | LongLine10 | 2011 | 0 | 1 | -99 | -99 | -99 | -99 | 0 | 0 |
| LIECCRes | All | LongLine10 | 2012 | 0.0198 | 1 | -99 | -99 | -99 | -99 | 0 | 0 |
| LIECCRes | All | LongLine20 | 2008 | 163.989 | 1 | -99 | -99 | 0.278188 | 0.278061 | 1054 | 249 |
| LIECCRes | All | LongLine20 | 2009 | 96.5261 | 1 | -99 | -99 | 0.278188 | 0.278061 | 1452 | 708 |
| LIECCRes | All | LongLine20 | 2010 | 102.562 | 1 | -99 | -99 | 0.278188 | 0.278061 | 1312 | 897 |
| LIECCRes | All | LongLine20 | 2011 | 86.2119 | 1 | -99 | -99 | 0.278188 | 0.278061 | 1505 | 446 |
| LIECCRes | All | LongLine20 | 2012 | 82.9846 | 1 | -99 | -99 | 0.278188 | 0.278061 | 1068 | 872 |
| LIECCRes | All | LongLine30 | 2008 | 66.0834 | 1 | -99 | -99 | 0.279525 | 0.278001 | 1054 | 7 |
| LIECCRes | All | LongLine30 | 2009 | 61.7725 | 1 | -99 | -99 | 0.279525 | 0.278001 | 1452 | 230 |
| LIECCRes | All | LongLine30 | 2010 | 37.6081 | 1 | -99 | -99 | 0.279525 | 0.278001 | 1312 | 338 |
| LIECCRes | All | LongLine30 | 2011 | 71.7383 | 1 | -99 | -99 | 0.279525 | 0.278001 | 1505 | 603 |
| LIECCRes | All | LongLine30 | 2012 | 82.1065 | 1 | -99 | -99 | 0.279525 | 0.278001 | 1068 | 242 |
| LIECCRes | All | Trawl10 | 2008 | 35.723 | 1 | -99 | -99 | 0.331802 | 0.302351 | 1054 | 200 |
| LIECCRes | All | Trawl10 | 2009 | 28.7143 | 1 | -99 | -99 | 0.331802 | 0.302351 | 1452 | 98 |
| LIECCRes | All | Trawl10 | 2010 | 42.7996 | 1 | -99 | -99 | 0.331802 | 0.302351 | 1312 | 254 |
| LIECCRes | All | Trawl10 | 2011 | 43.5719 | 1 | -99 | -99 | 0.331802 | 0.302351 | 1505 | 153 |
| LIECCRes | All | Trawl10 | 2012 | 38.6114 | 1 | -99 | -99 | 0.331802 | 0.302351 | 1068 | 220 |
| LIECCRes | All | Trawl20 | 2008 | 295.131 | 1 | -99 | -99 | 0.403479 | 0.332763 | 1054 | 1685 |
| LIECCRes | All | Trawl20 | 2009 | 199.448 | 1 | -99 | -99 | 0.403479 | 0.332763 | 1452 | 2233 |

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|---|---|---|---|---|---|---|---|---|---|---|---|
| LIECCRes | All | Trawl20 | 2010 | 238.584 | 1 | -99 | -99 | 0.403479 | 0.332763 | 1312 | 2150 |
| LIECCRes | All | Trawl20 | 2011 | 258.957 | 1 | -99 | -99 | 0.403479 | 0.332763 | 1505 | 2131 |
| LIECCRes | All | Trawl20 | 2012 | 229.095 | 1 | -99 | -99 | 0.403479 | 0.332763 | 1068 | 1444 |
| LIECCRes | All | Trawl30 | 2008 | 48.972 | 1 | -99 | -99 | 0.623457 | 0.476081 | 1054 | 179 |
| LIECCRes | All | Trawl30 | 2009 | 17.0742 | 1 | -99 | -99 | -99 | -99 | 0 | 0 |
| LIECCRes | All | Trawl30 | 2010 | 17.5107 | 1 | -99 | -99 | 0.623457 | 0.476081 | 1312 | 119 |
| LIECCRes | All | Trawl30 | 2011 | 29.146 | 1 | -99 | -99 | 0.623457 | 0.476081 | 1505 | 317 |
| LIECCRes | All | Trawl30 | 2012 | 35.052 | 1 | -99 | -99 | 0.623457 | 0.476081 | 1068 | 425 |
| LIWCCRes | All | LongLine40 | 2008 | 35.1416 | 1 | -99 | -99 | -99 | -99 | 0 | 0 |
| LIWCCRes | All | LongLine40 | 2009 | 44.7203 | 1 | -99 | -99 | -99 | -99 | 0 | 0 |
| LIWCCRes | All | LongLine40 | 2010 | 76.5216 | 1 | -99 | -99 | 0.305268 | 0.278001 | 1312 | 212 |
| LIWCCRes | All | LongLine40 | 2011 | 136.816 | 1 | -99 | -99 | -99 | -99 | 0 | 0 |
| LIWCCRes | All | LongLine40 | 2012 | 150.554 | 1 | -99 | -99 | 0.305268 | 0.278001 | 1068 | 805 |
| LIWCCRes | All | LongLine50 | 2008 | 2.567 | 1 | -99 | -99 | -99 | -99 | 0 | 0 |
| LIWCCRes | All | LongLine50 | 2009 | 7.202 | 1 | -99 | -99 | -99 | -99 | 0 | 0 |
| LIWCCRes | All | LongLine50 | 2010 | 16.0016 | 1 | -99 | -99 | -99 | -99 | 0 | 0 |
| LIWCCRes | All | LongLine50 | 2011 | 8.1297 | 1 | -99 | -99 | -99 | -99 | 0 | 0 |
| LIWCCRes | All | LongLine50 | 2012 | 8.0215 | 1 | -99 | -99 | -99 | -99 | 0 | 0 |
| LIWCCRes | All | LongLine80 | 2008 | 102.184 | 1 | -99 | -99 | 0.278008 | 0.278001 | 1054 | 134 |
| LIWCCRes | All | LongLine80 | 2009 | 45.766 | 1 | -99 | -99 | 0.278008 | 0.278001 | 1452 | 101 |
| LIWCCRes | All | LongLine80 | 2010 | 86.187 | 1 | -99 | -99 | 0.278008 | 0.278001 | 1312 | 1127 |
| LIWCCRes | All | LongLine80 | 2011 | 72.3042 | 1 | -99 | -99 | 0.278008 | 0.278001 | 1505 | 374 |
| LIWCCRes | All | LongLine80 | 2012 | 42.1772 | 1 | -99 | -99 | 0.278008 | 0.278001 | 1068 | 117 |
| LIWCCRes | All | Trawl40 | 2008 | 161.646 | 1 | -99 | -99 | 0.299437 | 0.278123 | 1054 | 113 |
| LIWCCRes | All | Trawl40 | 2009 | 210.365 | 1 | -99 | -99 | 0.299437 | 0.278123 | 1452 | 148 |
| LIWCCRes | All | Trawl40 | 2010 | 189.41 | 1 | -99 | -99 | 0.299437 | 0.278123 | 1312 | 314 |
| LIWCCRes | All | Trawl40 | 2011 | 260.476 | 1 | -99 | -99 | 0.299437 | 0.278123 | 1505 | 475 |
| LIWCCRes | All | Trawl40 | 2012 | 282.095 | 1 | -99 | -99 | 0.299437 | 0.278123 | 1068 | 308 |
| LIWCCRes | All | Trawl50 | 2008 | 64.4137 | 1 | -99 | -99 | 0.363393 | 0.279314 | 1054 | 20 |
| LIWCCRes | All | Trawl50 | 2009 | 61.2257 | 1 | -99 | -99 | 0.363393 | 0.279314 | 1452 | 110 |
| LIWCCRes | All | Trawl50 | 2010 | 92.0323 | 1 | -99 | -99 | 0.363393 | 0.279314 | 1312 | 180 |
| LIWCCRes | All | Trawl50 | 2011 | 108.134 | 1 | -99 | -99 | 0.363393 | 0.279314 | 1505 | 210 |
| LIWCCRes | All | Trawl50 | 2012 | 68.5638 | 1 | -99 | -99 | 0.363393 | 0.279314 | 1068 | 519 |
| LIWCCRes | All | Trawl80 | 2008 | 1.7864 | 1 | -99 | -99 | -99 | -99 | 0 | 0 |
| LIWCCRes | All | Trawl80 | 2009 | 0.132 | 1 | -99 | -99 | -99 | -99 | 0 | 0 |
| LIWCCRes | All | Trawl80 | 2010 | 4.699 | 1 | -99 | -99 | -99 | -99 | 0 | 0 |
| LIWCCRes | All | Trawl80 | 2011 | 3.8997 | 1 | -99 | -99 | -99 | -99 | 0 | 0 |
| LIWCCRes | All | Trawl80 | 2012 | 4.1075 | 1 | -99 | -99 | -99 | -99 | 0 | 0 |
| MOWCCRes | All | ETrawl | 2008 | 335.839 | 1 | -99 | -99 | 0.310755 | 0.377915 | 751 | 2475 |
| MOWCCRes | All | ETrawl | 2009 | 243.398 | 1 | -99 | -99 | 0.310755 | 0.377915 | 620 | 2425 |
| MOWCCRes | All | ETrawl | 2010 | 199.266 | 1 | -99 | -99 | 0.310755 | 0.377915 | 892 | 1973 |
| MOWCCRes | All | ETrawl | 2011 | 184.993 | 1 | -99 | -99 | 0.310755 | 0.377915 | 855 | 1362 |
| MOWCCRes | All | ETrawl | 2012 | 181.435 | 1 | -99 | -99 | 0.310755 | 0.377915 | 758 | 1806 |
| MOWCCRes | All | DSeine | 2008 | 36.779 | 1 | -99 | -99 | 0.287874 | 0.307332 | 751 | 635 |
| MOWCCRes | All | DSeine | 2009 | 18.538 | 1 | -99 | -99 | 0.287874 | 0.307332 | 620 | 50 |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| MOWCCRes | All | DSeine | 2010 | 17.3235 | 1 | -99 | -99 | 0.287874 | 0.307332 | 892 | 492 |
| MOWCCRes | All | DSeine | 2011 | 29.405 | 1 | -99 | -99 | 0.287874 | 0.307332 | 855 | 665 |
| MOWCCRes | All | DSeine | 2012 | 14.8215 | 1 | -99 | -99 | 0.287874 | 0.307332 | 758 | 216 |
| | | | | | | | | | | | |
| MOWCCRes | All | TasTrawl | 2008 | 121.07 | 1 | -99 | -99 | 0.160321 | 0.66122 | 751 | 43 |
| MOWCCRes | All | TasTrawl | 2009 | 55.8167 | 1 | -99 | -99 | 0.160321 | 0.66122 | 620 | 80 |
| MOWCCRes | All | TasTrawl | 2010 | 59.871 | 1 | -99 | -99 | 0.160321 | 0.66122 | 892 | 341 |
| MOWCCRes | All | TasTrawl | 2011 | 50.6332 | 1 | -99 | -99 | 0.160321 | 0.66122 | 855 | 555 |
| MOWCCRes | All | TasTrawl | 2012 | 93.961 | 1 | -99 | -99 | 0.160321 | 0.66122 | 758 | 771 |
| | | | | | | | | | | | |
| MOWCCRes | All | WTrawl | 2008 | 104.283 | 1 | -99 | -99 | 0.160001 | 0.282321 | 751 | 156 |
| MOWCCRes | All | WTrawl | 2009 | 64.9515 | 1 | -99 | -99 | 0.160001 | 0.282321 | 620 | 140 |
| MOWCCRes | All | WTrawl | 2010 | 40.5487 | 1 | -99 | -99 | 0.160001 | 0.282321 | 892 | 72 |
| MOWCCRes | All | WTrawl | 2011 | 85.874 | 1 | -99 | -99 | 0.160001 | 0.282321 | 855 | 208 |
| MOWCCRes | All | WTrawl | 2012 | 36.3215 | 1 | -99 | -99 | 0.160001 | 0.282321 | 758 | 318 |
| | | | | | | | | | | | |
| MOWCCRes | All | GABTrawl | 2008 | 89.7646 | 1 | -99 | -99 | -99 | -99 | 0 | 0 |
| MOWCCRes | All | GABTrawl | 2009 | 64.352 | 1 | -99 | -99 | -99 | -99 | 0 | 0 |
| MOWCCRes | All | GABTrawl | 2010 | 39.1475 | 1 | -99 | -99 | -99 | -99 | 0 | 0 |
| MOWCCRes | All | GABTrawl | 2011 | 24.7415 | 1 | -99 | -99 | -99 | -99 | 0 | 0 |
| MOWCCRes | All | GABTrawl | 2012 | 5.0125 | 1 | -99 | -99 | -99 | -99 | 0 | 0 |
| | | | | | | | | | | | |
| REBCCRes | All | Trawl | 2008 | 664.902 | 1 | -99 | -99 | 0.11 | 0.11 | 561 | 1875 |
| REBCCRes | All | Trawl | 2009 | 463.432 | 1 | -99 | -99 | 0.11 | 0.11 | 668 | 9093 |
| REBCCRes | All | Trawl | 2010 | 275.407 | 1 | -99 | -99 | 0.11 | 0.11 | 429 | 1926 |
| REBCCRes | All | Trawl | 2011 | 67.8018 | 1 | -99 | -99 | 0.11 | 0.11 | 353 | 2712 |
| REBCCRes | All | Trawl | 2012 | 38.6814 | 1 | -99 | -99 | 0.11 | 0.11 | 282 | 502 |
| | | | | | | | | | | | |
| REDCCRes | North | Trawl | 2008 | 165.35 | 1 | -99 | -99 | 0.144953 | 0.169955 | 7634 | 583 |
| REDCCRes | North | Trawl | 2009 | 145.515 | 1 | -99 | -99 | 0.144953 | 0.169955 | 7634 | 791 |
| REDCCRes | North | Trawl | 2010 | 136.367 | 1 | -99 | -99 | 0.144953 | 0.169955 | 7634 | 1066 |
| REDCCRes | North | Trawl | 2011 | 76.485 | 1 | -99 | -99 | 0.144953 | 0.169955 | 7634 | 479 |
| REDCCRes | North | Trawl | 2012 | 60.444 | 1 | -99 | -99 | 0.144953 | 0.169955 | 7634 | 592 |
| | | | | | | | | | | | |
| REDCCRes | South | Trawl | 2008 | 16.6653 | 1 | -99 | -99 | 0.110001 | -99 | 7892 | 0 |
| REDCCRes | South | Trawl | 2009 | 12.4443 | 1 | -99 | -99 | -99 | -99 | 0 | 0 |
| REDCCRes | South | Trawl | 2010 | 13.2126 | 1 | -99 | -99 | 0.110001 | 0.11 | 7892 | 160 |
| REDCCRes | South | Trawl | 2011 | 8.8597 | 1 | -99 | -99 | 0.110001 | 0.11 | 7892 | 3 |
| REDCCRes | South | Trawl | 2012 | 3.1062 | 1 | -99 | -99 | -99 | -99 | 0 | 0 |
| | | | | | | | | | | | |
| REGCCRes | All | NonTrawl | 2008 | 0 | 1 | -99 | -99 | -99 | -99 | 0 | 0 |
| REGCCRes | All | NonTrawl | 2009 | 0.035 | 1 | -99 | -99 | -99 | 0.110076 | 0 | 77 |
| REGCCRes | All | NonTrawl | 2010 | 0 | 1 | -99 | -99 | -99 | 0.110076 | 0 | 342 |
| REGCCRes | All | NonTrawl | 2011 | 0.005 | 1 | -99 | -99 | -99 | 0.110076 | 0 | 14 |
| REGCCRes | All | NonTrawl | 2012 | 0.04 | 1 | -99 | -99 | -99 | 0.110076 | 0 | 191 |
| | | | | | | | | | | | |
| REGCCRes | All | Trawl | 2008 | 0.844 | 1 | -99 | -99 | -99 | 0.213473 | 0 | 1414 |
| REGCCRes | All | Trawl | 2009 | 1.272 | 1 | -99 | -99 | -99 | 0.213473 | 0 | 2590 |
| REGCCRes | All | Trawl | 2010 | 1.32 | 1 | -99 | -99 | -99 | 0.213473 | 0 | 2746 |
| REGCCRes | All | Trawl | 2011 | 1.39 | 1 | -99 | -99 | -99 | 0.213473 | 0 | 2400 |
| REGCCRes | All | Trawl | 2012 | 1.562 | 1 | -99 | -99 | -99 | 0.213473 | 0 | 2200 |
| | | | | | | | | | | | |
| TBECCRes | All | NonTrawl | 2008 | 226.219 | 1 | -99 | -99 | 0.35477 | 0.333672 | 557 | 624 |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| TBECCRes | All | NonTrawl | 2009 | 310.741 | 1 | -99 | -99 | 0.35477 | 0.333672 | 960 | 1343 |
| TBECCRes | All | NonTrawl | 2010 | 238.743 | 1 | -99 | -99 | 0.35477 | 0.333672 | 743 | 2038 |
| TBECCRes | All | NonTrawl | 2011 | 187.119 | 1 | -99 | -99 | -99 | 0.333672 | 0 | 2581 |
| TBECCRes | All | NonTrawl | 2012 | 186.416 | 1 | -99 | -99 | -99 | 0.333672 | 0 | 2303 |
| TBECCRes | All | Trawl | 2008 | 35.8986 | 1 | -99 | -99 | 0.253298 | 0.314437 | 557 | 37 |
| TBECCRes | All | Trawl | 2009 | 39.3857 | 1 | -99 | -99 | 0.253298 | 0.314437 | 960 | 295 |
| TBECCRes | All | Trawl | 2010 | 44.4158 | 1 | -99 | -99 | 0.253298 | 0.314437 | 743 | 95 |
| TBECCRes | All | Trawl | 2011 | 23.3388 | 1 | -99 | -99 | -99 | 0.314437 | 0 | 162 |
| TBECCRes | All | Trawl | 2012 | 10.7808 | 1 | -99 | -99 | -99 | 0.314437 | 0 | 115 |
| TRECCRes | All | NonTrawl | 2008 | 1.99725 | 1 | -99 | -99 | -99 | -99 | 0 | 0 |
| TRECCRes | All | NonTrawl | 2009 | 1.0371 | 1 | -99 | -99 | -99 | 0.388319 | 0 | 247 |
| TRECCRes | All | NonTrawl | 2010 | 25.1141 | 1 | -99 | -99 | -99 | 0.388319 | 0 | 263 |
| TRECCRes | All | NonTrawl | 2011 | 0.2565 | 1 | -99 | -99 | -99 | 0.388319 | 0 | 212 |
| TRECCRes | All | NonTrawl | 2012 | 0.2492 | 1 | -99 | -99 | -99 | 0.388319 | 0 | 78 |
| TRECCRes | All | Trawl | 2008 | 101.855 | 1 | -99 | -99 | -99 | 0.450013 | 0 | 1135 |
| TRECCRes | All | Trawl | 2009 | 142.527 | 1 | -99 | -99 | -99 | 0.450013 | 0 | 2750 |
| TRECCRes | All | Trawl | 2010 | 203.268 | 1 | -99 | -99 | -99 | 0.450013 | 0 | 3085 |
| TRECCRes | All | Trawl | 2011 | 186.964 | 1 | -99 | -99 | -99 | 0.450013 | 0 | 1681 |
| TRECCRes | All | Trawl | 2012 | 133.151 | 1 | -99 | -99 | -99 | 0.450013 | 0 | 2459 |
| TRSCCRes | All | AllMethods | 2008 | 1378.06 | 1 | -99 | -99 | 0.31003 | 0.636699 | 547 | 1609 |
| TRSCCRes | All | AllMethods | 2009 | 1285.08 | 1 | -99 | -99 | 0.31003 | 0.636699 | 821 | 3521 |
| TRSCCRes | All | AllMethods | 2010 | 1188.8 | 1 | -99 | -99 | 0.31003 | 0.636699 | 822 | 4001 |
| TRSCCRes | All | AllMethods | 2011 | 1106.49 | 1 | -99 | -99 | 0.31003 | 0.636699 | 852 | 2861 |
| TRSCCRes | All | AllMethods | 2012 | 780.292 | 1 | -99 | -99 | 0.31003 | 0.636699 | 818 | 3221 |
| TRTCCRes | All | NonTrawl | 2008 | 6.6546 | 1 | -99 | -99 | -99 | -99 | 0 | 0 |
| TRTCCRes | All | NonTrawl | 2009 | 3.8073 | 1 | -99 | -99 | 0.460068 | 0.85204 | 274 | 357 |
| TRTCCRes | All | NonTrawl | 2010 | 11.3836 | 1 | -99 | -99 | 0.460068 | 0.85204 | 428 | 900 |
| TRTCCRes | All | NonTrawl | 2011 | 5.43365 | 1 | -99 | -99 | -99 | 0.85204 | 0 | 1093 |
| TRTCCRes | All | NonTrawl | 2012 | 4.3962 | 1 | -99 | -99 | -99 | 0.85204 | 0 | 341 |
| TRTCCRes | All | Trawl | 2008 | 159.262 | 1 | -99 | -99 | 0.475344 | 0.587272 | 597 | 1282 |
| TRTCCRes | All | Trawl | 2009 | 117.136 | 1 | -99 | -99 | 0.475344 | 0.587272 | 274 | 2412 |
| TRTCCRes | All | Trawl | 2010 | 123.18 | 1 | -99 | -99 | 0.475344 | 0.587272 | 428 | 2123 |
| TRTCCRes | All | Trawl | 2011 | 88.4417 | 1 | -99 | -99 | -99 | 0.587272 | 0 | 1994 |
| TRTCCRes | All | Trawl | 2012 | 42.7666 | 1 | -99 | -99 | -99 | 0.587272 | 0 | 1068 |
| WHSCCRes | All | NonTrawl | 2008 | 393.335 | 1 | -99 | -99 | 1.10427 | 1.33394 | 479 | 894 |
| WHSCCRes | All | NonTrawl | 2009 | 425.426 | 1 | -99 | -99 | 1.10427 | 1.33394 | 421 | 880 |
| WHSCCRes | All | NonTrawl | 2010 | 359.503 | 1 | -99 | -99 | 1.10427 | 1.33394 | 620 | 1179 |
| WHSCCRes | All | NonTrawl | 2011 | 308.165 | 1 | -99 | -99 | 1.10427 | 1.33394 | 581 | 1222 |
| WHSCCRes | All | NonTrawl | 2012 | 388.682 | 1 | -99 | -99 | 1.10427 | 1.33394 | 392 | 1263 |
| WHSCCRes | All | Trawl | 2008 | 69.1595 | 1 | -99 | -99 | -99 | -99 | 0 | 0 |
| WHSCCRes | All | Trawl | 2009 | 29.744 | 1 | -99 | -99 | 0.815239 | 1.40089 | 421 | 288 |
| WHSCCRes | All | Trawl | 2010 | 38.4377 | 1 | -99 | -99 | -99 | -99 | 0 | 0 |
| WHSCCRes | All | Trawl | 2011 | 50.7141 | 1 | -99 | -99 | 0.815239 | 1.40089 | 581 | 435 |
| WHSCCRes | All | Trawl | 2012 | 40.8341 | 1 | -99 | -99 | 0.815239 | 1.40089 | 392 | 46 |

# 18. Catch Rate Standardizations for Selected Species from the SESSF (data 1986 – 2012)

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## *18.1 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 log-book 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. The catch rates used in the assessments are standardized to reduce the effects of factors such as which vessel fished, where and when fishing occurred, what gear was 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 relatively 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 were variants on the form: LnCE = Year + Vessel + Month + DepthCategory + Zone + Daynight. For some fisheries weeknumber or gear type was also included. In addition, there were interaction terms which could sometimes be fitted, such as Month:Zone or Month:DepthCategory. The 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.

This chapter reports the statistical standardization of the commercial catch and effort data for 21 species, distributed across 50 different combinations of stocks and fisheries ready for inclusion in the annual round of stock assessments. These included 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. The statistical package R was used, with especial use being made of 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.

Summary graphs are provided across all species (Figure 18.2 and Figure 18.3), as well as more detailed information for each stock. Out of 36 stocks there were 10 whose catch rates have increased over the last 10 years, there were 13 stocks where catch rates were stable (two of which were stable and low; Blue Warehou 102030 and Jackass Morwong 30), and there were 7 stocks whose catch rates have declined over the last 10 years. Many of the species are 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).

## 18.2 Introduction

Commercial catch and effort data are used in in very many fishery stock assessments in Australia as an index of relative abundance through time. The assumption is made that there is a direct relationship between catch rates and the amount of exploitable biomass. However, many factors can influence catch rates, including who was fishing with what gear in what depth, in what season, in what area, and whether it was day or night (plus other factors). The use of catch rates as an index of relative abundance means that it would be best to remove the effects of variation due to changes in these other factors on the assumption that what remains will provide a better estimate of the dynamics of the underlying stock biomass. This process of adjusting the time series for the effects of other influential 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. The Resource Assessment Groups (RAGs) have direct input on what combinations of depths and area need to be used in the standardization of each species/stock.

### 18.2.1 The Limits of Standardization

The assumption behind using commercial catch rates in stock assessments is that they reflect the relative abundance of the exploitable biomass through time. The legitimacy behind using commercial catch rates can be questioned when there are factors significantly influencing catch rates which cannot be included in any standardization. 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 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 BlueEye Autoline 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 Autoline 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 has only recently begun to examine the influence of closures on stock assessments and this exploration is on-going. The preliminary findings, however, indicate that again, great care needs to be taken when trying to interpret the outcomes of the catch rate standardization.

## 18.3 Methods

### 18.3.1 Catch Rate Standardization

#### *18.3.1.1 Preliminary Data Selection*

The precise methods used when standardizing commercial catch and effort data in the SESSF continue to be discussed in the Commonwealth stock assessment RAGs. This discussion continues because the catch rate time series are very influential in many of the assessments. Previously, various filters were placed on the data available in a preliminary attempt to focus on those vessels that actively target a species. These data filters involved only using vessels that had taken the species for more than two years and those that had taken some minimum annual catch level. The objective of these selections was to remove noise from whatever signal was present in the available data. After examining the effects of these data selections they appear to have only very minor influences on the catch rate trends because the number of records involved was only minor (often differences were not apparent in the graphs, i.e. less effect than the thickness of the lines) and so such selections are again not used this year. Far more influential were restrictions based upon depth of operation. In recognition that there are records which report activity in unlikely depths, there are usually restrictions placed on the depth range from which records could be validly reported. This is necessary as depth tends to be one of the most influential factors used in the statistical standardizations and rare outlying depths only served to confuse the analysis by introducing many combinations of factors that contained no data. In addition the choice of which particular reporting zones or areas are to be examined also leads to a prior selection of data.

Briefly, initial data selection for a particular species consists of using those data relating to a specific fishery (e.g. SET, GHT, GAB, etc), those data within a specified depth range and taken with a specified method in specified statistical zones within the years specified for the analysis.

The graphical representation of results includes the depiction of the unstandardized geometric mean catch rate along with the optimum statistical model representing the standardized time series. This provides a visual indication of whether the standardization changes any trend away from the nominal catch rate. To avoid visual distortions introduced by scaling the standardization relative to a particular year, 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.

#### *18.3.1.2 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: LnCE = Year + Vessel + Month + DepthCategory + Zone + Daynight. For some fisheries weeknumber or gear type was also included. In addition, there were interaction terms which could sometimes be fitted, such as Month:Zone 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:

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

where Ln($CPUE_i$) is the natural logarithm of the catch rate (usually kg/h, 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*.).

*18.3.1.3 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:

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

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:

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

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.

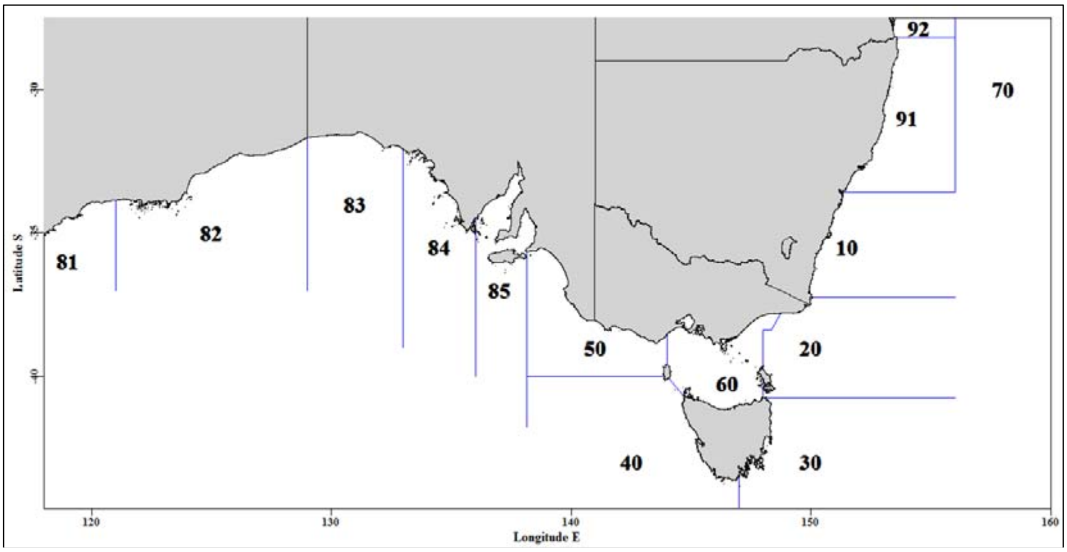



Figure 18.1. A schematic diagram depicting the statistical reporting zones in the SESSF, as used in this document. The GAB fishery is to the west of Zone 50. The main SESSF trawl zones are zones 10 – 50. Each zone extends out to the boundary of the EEZ, except for zones 50 and 60, and for zones 92 and 91, which are bounded by zone 70.

*18.3.1.4 Data Manipulations*

A standard set of database extracts were designed to identify positive shots containing the species of interest in each case. For each species the analyses were restricted to particular zones and depth ranges within a particular fishery and using a particular method (Table 18.1).

The statistical software *R* was used in all analyses (R Development Core Team, 2009), which, because of the large size of the datasets, required the use of the library “biglm”.

## 18.4 Results

Table 18.1. Data characteristics for each analysis. Records show the number of records, the depths, the zones, and other details used in the data selection for the analyses.

| | Species | Zone | Depths | Comment | Records |
|---|---|---|---|---|---|
| 1 | School Whiting | 60 | 0-100 | Danish Seine, catch per shot. | 78769 |
| 2 | Eastern Gemfish | 10-30,40/2 | 200-500 | June-Sept 93 onwards, Spawning | 14277 |
| 3 | Eastern Gemfish | 10-30,40/2 | 0-600 | Oct-May 86-09 0-600m, Jun-Sep <300m | 36550 |
| 4 | Jackass Morwong | 10-50 | 70-360 | | 145693 |
| 5 | Jackass Morwong | 10,20 | 70-300 | | 111210 |
| 6 | Jackass Morwong | 30 | 70-300 | | 18879 |
| 7 | Jackass Morwong | 40,50 | 70-360 | | 12433 |
| 8 | Flathead | 10,20 | 0-400 | Trawl | 250688 |
| 9 | Flathead | 30 | 0-400 | | 19983 |
| 10 | Flathead DS | 20,60 | 0-200 | Danish Seine, catch per shot | 178743 |
| 11 | RedFish | 10 | 0-400 | | 70520 |
| 12 | RedFish | 20 | 0-400 | | 26423 |
| 13 | Silver Trevally | 10,20 | 0-200 | Remove State waters and MPAs | 32889 |
| 14 | Royal Red Prawn | 10 | 200-700 | | 23812 |
| 15 | Blue Eye | 20,30 | 0-1000 | | 12124 |
| 16 | Blue Eye | 40,50 | 0-1000 | | 12516 |
| 17 | Blue Eye | 10-50,83-85 | 200-600 | Autolining and Droplining 1997 onwards | 14246 |
| 18 | Blue Grenadier | 10-60 | 0-1000 | Except Zone 40 Jun-Aug | 129373 |
| 19 | Silver Warehou | 10-50 | 0-600 | | 125519 |
| 20 | Blue Warehou | 10-30 | 0-400 | | 36804 |
| 21 | Blue Warehou | 40,50 | 0-600 | | 12775 |
| 22 | Blue Warehou | 10-50 | 0-600 | | 50053 |
| 23 | Pink Ling | 10-30 | 250-600 | | 94864 |
| 24 | Pink Ling | 40,50 | 200-800 | | 73010 |
| 25 | Pink Ling | 10 | 250-600 | For use in disaggregated analyses | 43966 |
| 26 | Pink Ling | 20 | 250-600 | " | 42901 |
| 27 | Pink Ling | 30 | 250-600 | " | 7997 |
| 28 | Pink Ling | 40 | 350-800 | " | 30455 |
| 29 | Pink Ling | 50 | 200-800 | " | 42357 |
| 30 | Western Gemfish | 40,50,GAB | 100-600 | | 42103 |
| 31 | Western Gemfish | 40,50 | 200-600 | | 31327 |
| 32 | Western Gemfish | GAB | 100-600 | Only 1995 onwards | 9219 |
| 33 | Off-Ocean Perch | 10,20 | 200-700 | | 77185 |
| 34 | In-Ocean Perch | 10,20 | 0-200 | | 16017 |
| 35 | John Dory | 10,20 | 0-200 | | 133067 |
| 36 | Mirror Dory | 10-50 | 0-600 | | 119543 |
| 37 | Mirror Dory East | 10-30 | 0-600 | | 89626 |
| 38 | Mirror Dory West | 40,50 | 0-600 | | 29885 |
| 39 | Ribaldo (RBD) | 10-50 | 0-1000 | | 19597 |
| 40 | Ribaldo | 20-50,81-85 | 0-1000 | Autoline | 4236 |
| 41 | Ocean Jackets | 10-50 | 0-300 | | 78257 |
| 42 | Ocean Jackets | 82-83 | 0-300 | | 44831 |
| 43 | DeepWater Flathead | GAB | 0-1000 | Trawl only, new more detailed analysis | 61685 |
| 44 | Bight Redfish | GAB | 0-1000 | Trawl only, new more detailed analysis | 45374 |

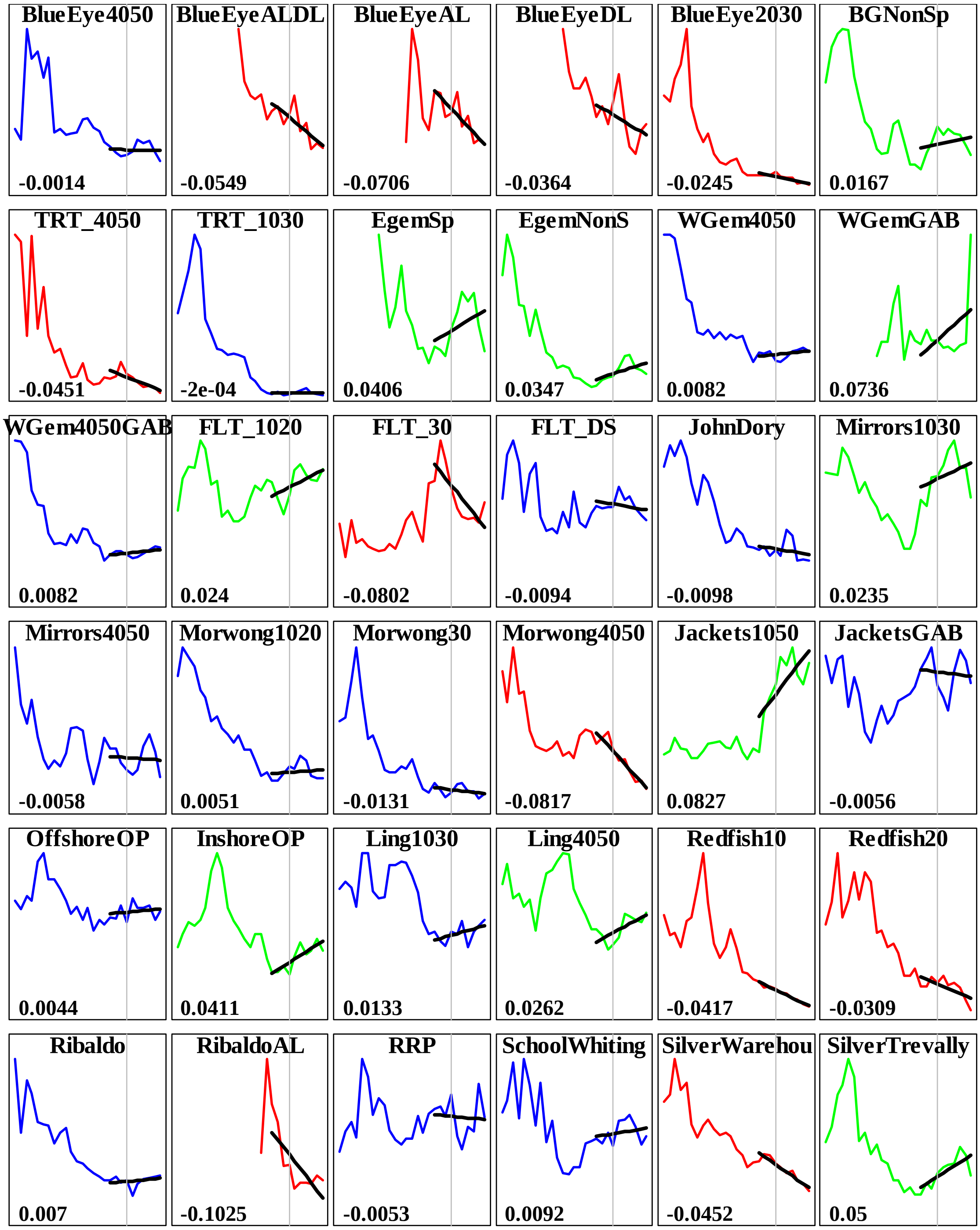



Figure 18.2. Summary graph of the optimum standardizations for 19 species and 36 different stocks, methods, or fisheries, each with a linear regression across the last six years (2003-2012). The gradient is at bottom left in each graph and the line colour reflects the gradient: green indicates a positive gradient > 0.015, blue a flat line with a gradient between 0.0149 and – 0.0149, and red indicates a negative gradient < -0.015. There were 10 selections with a positive gradient, 15 selections with a flat gradient, and 11 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. Composite selections, such as MirrorDory10-50 and TotalOceanPerch are omitted.

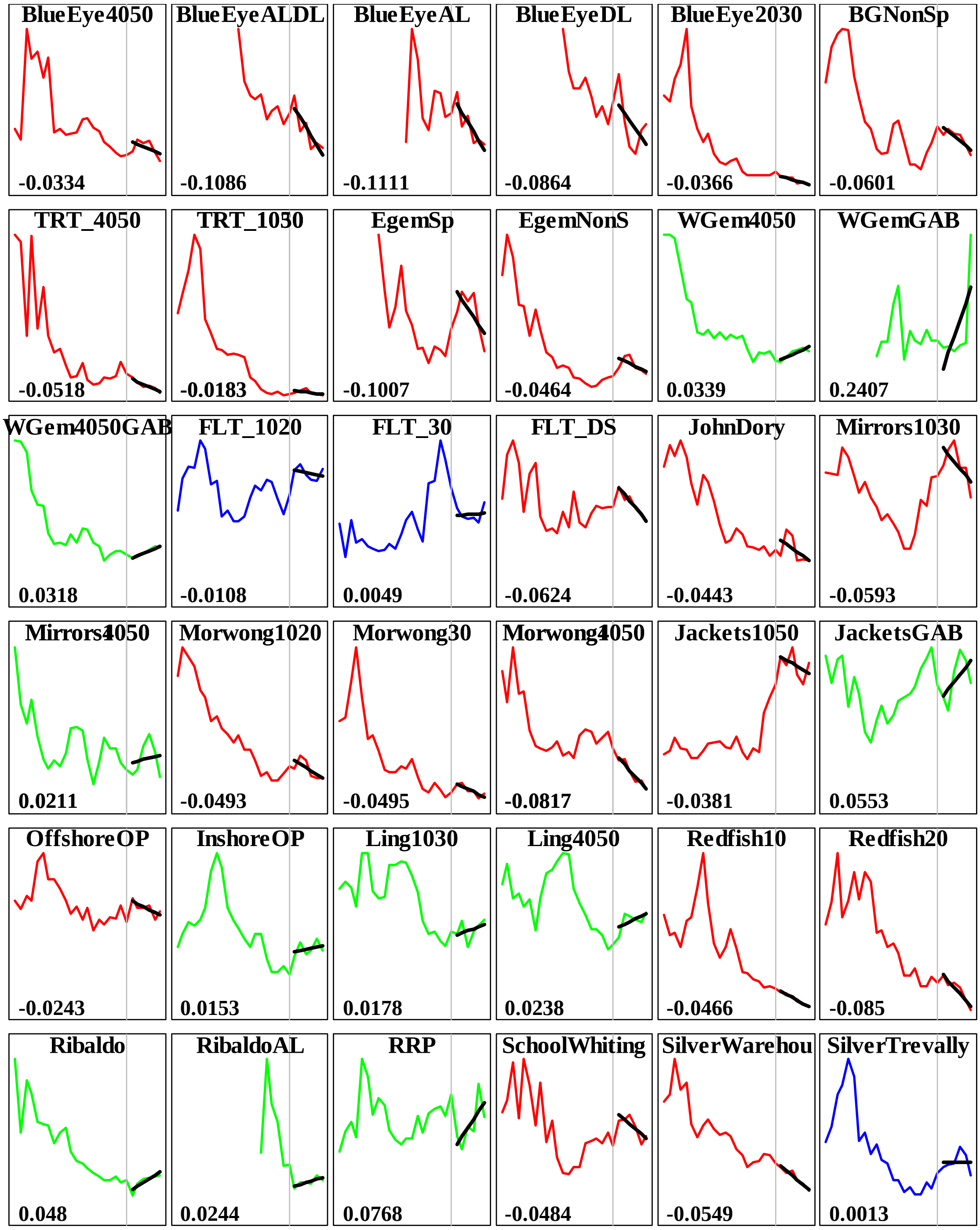



Figure 18.3. Summary graph of the optimum standardizations for 19 species and 36 different stocks, methods, or fisheries, each with a linear regression across the last six years (2007-2012). The gradient is at bottom left in each graph and the line colour reflects the gradient: green indicates a positive gradient > 0.015, blue a flat line with a gradient between 0.0149 and – 0.0149, and red indicates a negative gradient < -0.015. There were 11 selections with a positive gradient, 3 selections with a flat gradient, and 22 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.

#### *18.4.1 School Whiting (WHS – 37330014) Sillago flindersi*

School Whiting are taken primarily by Danish Seine (and within State waters). In Commonwealth waters the catches are primarily within 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. There were a total of 80,294 records used.

Table 18.2. School Whiting from Zone 60 in depths 0 to 100 m by Danish Seine. Total Catch is the total reported in the database, Records are the number used in the analysis, CatchT is the reported catch in the area and depth used in the analysis, Vessels relates to all vessels used in the analysis. Geomean is the geometric mean of catch rates (kg/hr). Mth:DepC is the optimum model and StDev is the standard deviation relating to the data in the optimum model.

| Year | TotCatch | Records | CatchT | Vessels | GeoMean | Mth:DepC | StDev |
|---|---|---|---|---|---|---|---|
| 1986 | 1299.306 | 5667 | 1181.583 | 26 | 112.3054 | 1.1634 | 0.0000 |
| 1987 | 995.251 | 4119 | 920.495 | 23 | 131.1624 | 1.2824 | 0.0293 |
| 1988 | 1251.758 | 3815 | 1177.456 | 25 | 168.5490 | 1.6623 | 0.0299 |
| 1989 | 1060.763 | 4440 | 994.408 | 27 | 127.0438 | 1.0976 | 0.0288 |
| 1990 | 1928.558 | 6263 | 1859.923 | 24 | 165.2959 | 1.7010 | 0.0269 |
| 1991 | 1622.185 | 4871 | 1517.794 | 26 | 164.1905 | 1.4401 | 0.0285 |
| 1992 | 843.104 | 2980 | 777.524 | 23 | 124.7066 | 1.0249 | 0.0327 |
| 1993 | 1675.025 | 4696 | 1471.559 | 23 | 152.4819 | 1.4595 | 0.0289 |
| 1994 | 940.481 | 4503 | 879.162 | 24 | 93.9314 | 0.8526 | 0.0290 |
| 1995 | 1211.626 | 4270 | 1065.934 | 21 | 122.4731 | 1.0721 | 0.0294 |
| 1996 | 893.769 | 4297 | 718.814 | 22 | 81.4339 | 0.7020 | 0.0296 |
| 1997 | 696.620 | 3314 | 481.660 | 20 | 64.5619 | 0.5436 | 0.0319 |
| 1998 | 593.943 | 2988 | 464.154 | 20 | 66.0158 | 0.5241 | 0.0328 |
| 1999 | 678.265 | 2044 | 452.215 | 21 | 84.3634 | 0.5996 | 0.0376 |
| 2000 | 700.465 | 1913 | 335.075 | 17 | 65.1233 | 0.6039 | 0.0380 |
| 2001 | 888.820 | 1980 | 425.095 | 18 | 93.2089 | 0.8466 | 0.0392 |
| 2002 | 787.413 | 2192 | 429.218 | 20 | 90.8874 | 0.8685 | 0.0375 |
| 2003 | 864.291 | 2352 | 463.528 | 20 | 87.1013 | 0.8882 | 0.0368 |
| 2004 | 601.813 | 1771 | 334.631 | 20 | 79.7648 | 0.8380 | 0.0396 |
| 2005 | 660.934 | 1750 | 311.428 | 20 | 77.2502 | 0.9476 | 0.0412 |
| 2006 | 664.547 | 1428 | 270.272 | 18 | 76.2250 | 0.8179 | 0.0431 |
| 2007 | 535.083 | 1488 | 347.049 | 14 | 89.2381 | 1.0781 | 0.0421 |
| 2008 | 502.245 | 1260 | 317.058 | 15 | 92.3448 | 1.0854 | 0.0451 |
| 2009 | 461.891 | 1569 | 350.723 | 15 | 93.6200 | 1.1373 | 0.0418 |
| 2010 | 408.306 | 1179 | 273.470 | 15 | 88.7190 | 1.0153 | 0.0461 |
| 2011 | 372.096 | 1579 | 260.300 | 14 | 72.0269 | 0.8322 | 0.0415 |
| 2012 | 434.952 | 1566 | 302.468 | 14 | 80.0853 | 0.9157 | 0.0418 |

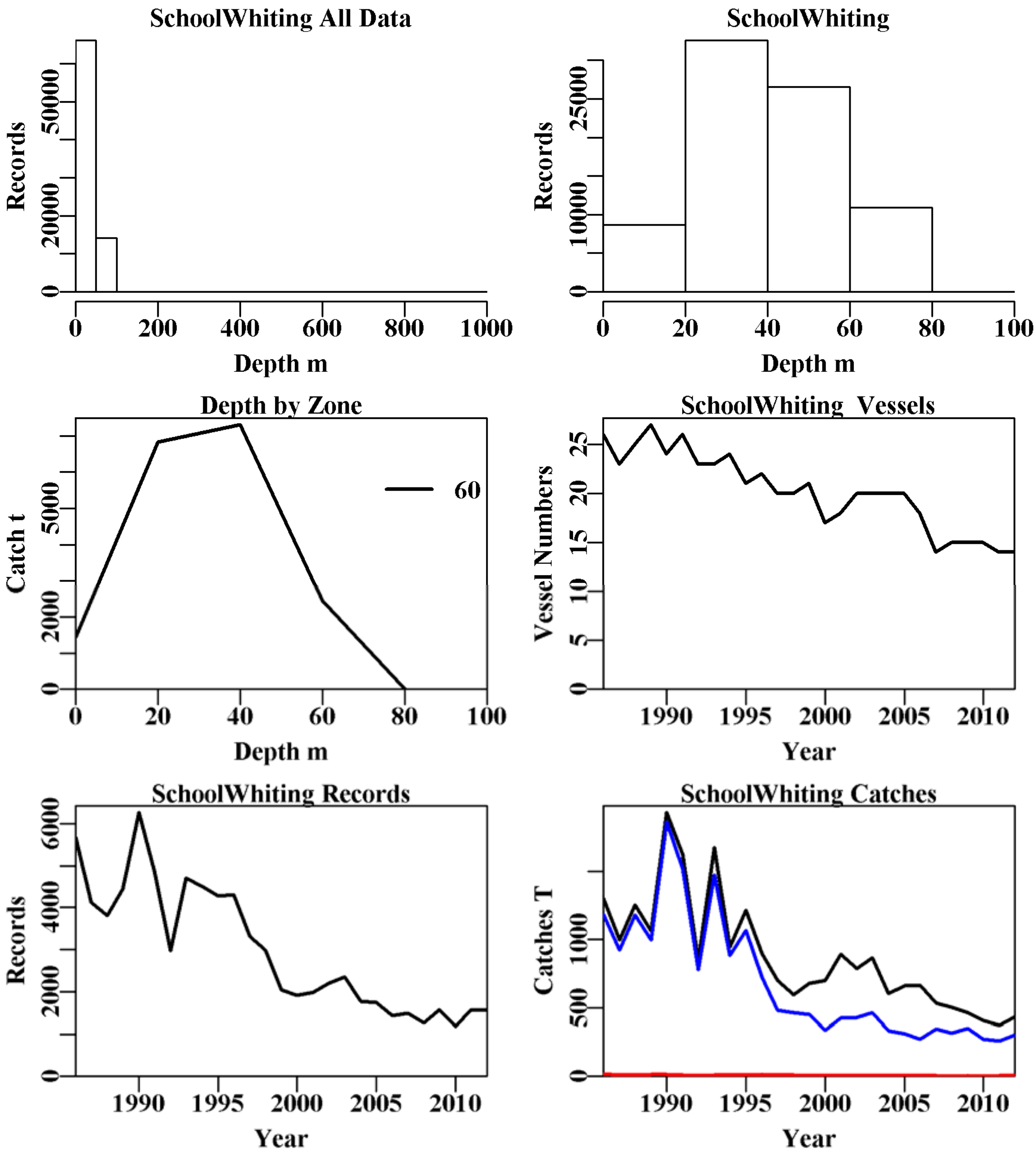



Figure 18.4. School Whiting in zone 60 in depths 0 to 100 m taken by Danish Seine. The top left is the depth distribution of all records reporting School Whiting, the top right graph depicts the depth distribution of shots containing School Whiting in Zone 60 and depths 0-100 m. The middle left diagram depicts the distribution of catch by depth within zone 60 across all years, the middle right hand graph depicts the number of vessels through time. The bottom left reflects the number of records used in analysis, and bottom right is the School Whiting catches (top line, black is total catches, middle line, blue, are those used in the analysis, and bottom, red, are catches < 30Kg).

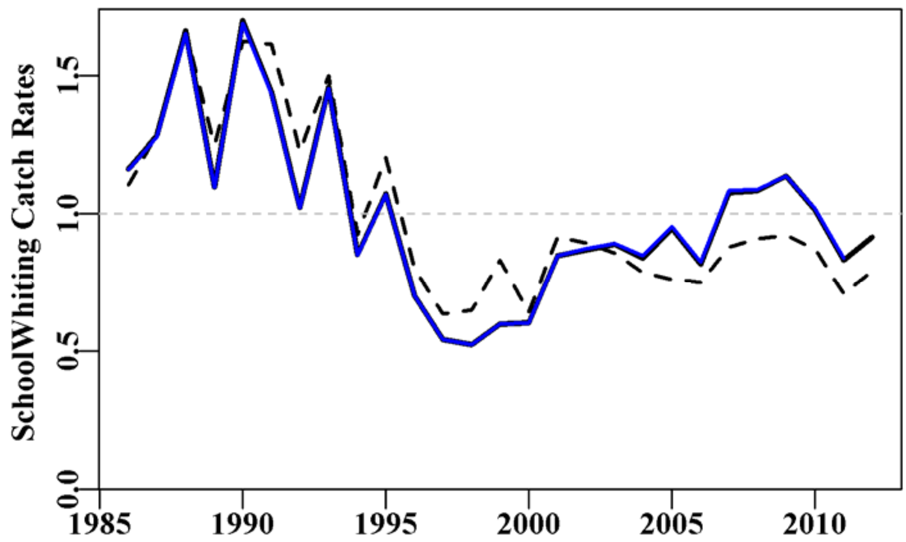



Figure 18.5. School Whiting in zone 60 in depths 0 to 100 m by Danish Seine. The dashed black line represents the geometric mean catch rate, the solid black line the standardized catch rates, and the blue line is last year's analysis. The graph standardizes catch rates relative to the mean of the standardized catch rates.

Table 18.3. 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. DN is DayNight

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

Table 18.4. School Whiting from Zone 60 in depths 0 to 100 m by Danish Seine. Model selection criteria, including the AIC, the adjusted $r^2$ and the change in adjusted $r^2$. The optimum was model 7. DN is DayNight, DepC is depth category and Mth is Month.

| | Year | Vessel | DayNight | Month | DepCat | DN:DepC | **DepC:Mth** | DN:Mth |
|---|---|---|---|---|---|---|---|---|
| AIC | 56785 | 54742 | 52485 | 50417 | 48942 | 48779 | **48408** | 48793 |
| RSS | 162753 | 158483 | 154078 | 150120 | 146284 | 145936 | **145133** | 145885 |
| MSS | 7667 | 11938 | 16342 | 20300 | 24136 | 24484 | **25287** | 24535 |
| Nobs | 80294 | 80294 | 80294 | 80294 | 78769 | 78769 | **78769** | 78769 |
| Npars | 27 | 73 | 76 | 87 | 91 | 103 | **135** | 124 |
| adj_r2 | 4.468 | 6.921 | 9.505 | 11.817 | 14.064 | 14.256 | **14.693** | 14.263 |
| %Change | 0.000 | 2.454 | 2.583 | 2.313 | 2.247 | 0.191 | **0.437** | -0.430 |

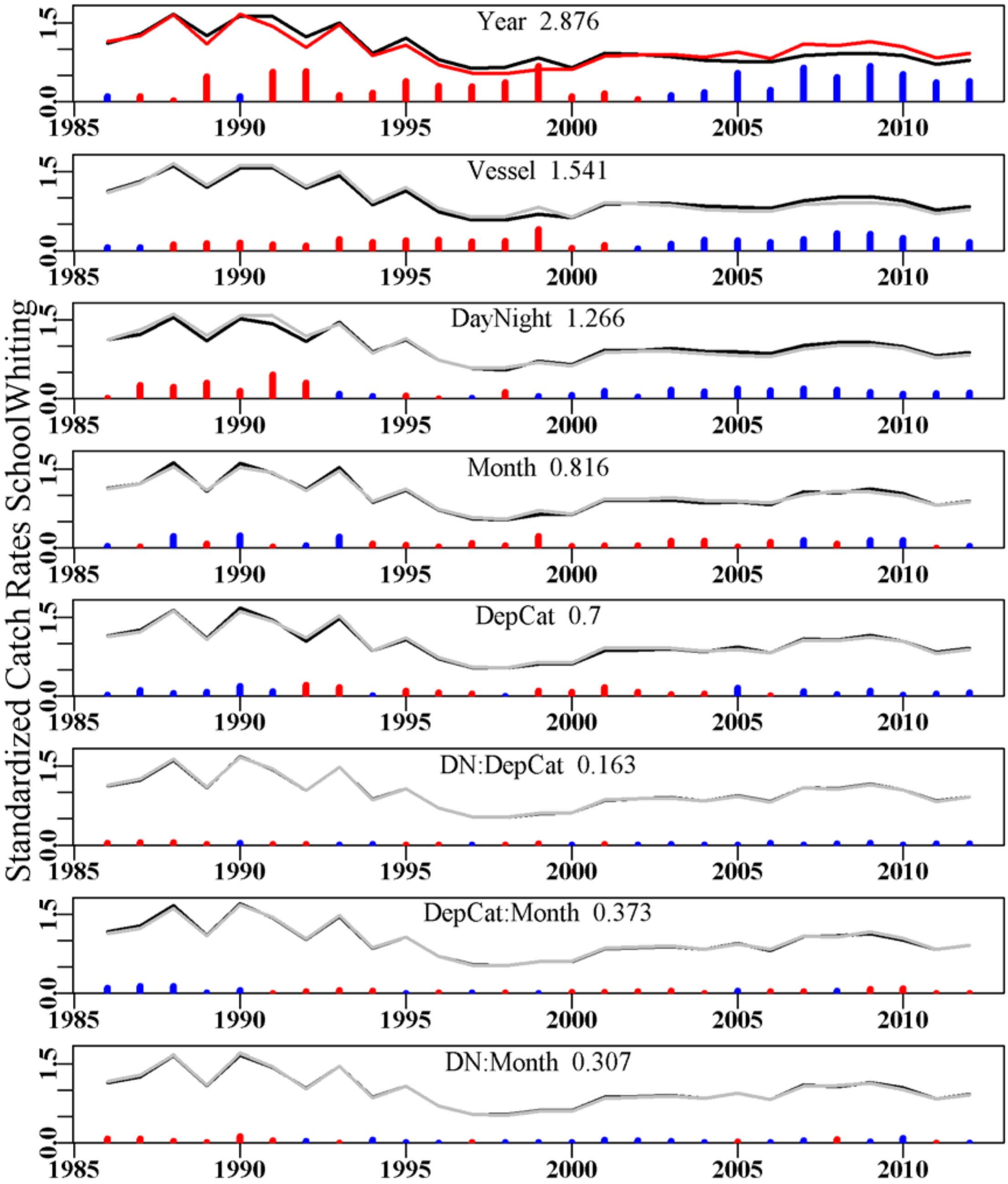



Figure 18.6. The relative influence of each factor used on the final trend in the optimal standardization for School Whiting in Zone 60. The top graph depicts the geometric mean (the black line) and the optimum model (the red line). The difference between them is illustrated by the vertical bars with 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.

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

Only use June through September from 1993 – 2012, 300-500m depth, Catch effort > 0.0, Zones 10 – 30 plus below 42 degrees on the west coast of Tasmania (zone 40).

Eastern Gemfish are taken by trawl in the spawning season from June to September in Zones 10, 20, 30, in the bottom half of 40 and between depths of 300 to 500 m. There were 14,377 records used. The spawning run of Eastern Gemfish is considered to be a bycatch fishery. Particular records in the database relating to the Eastern Gemfish surveys in 2007 and 2008 are removed from the data set prior to the analysis.

Table 18.5. Eastern Gemfish, spawning fishery in depths between 300 – 500m, taken by trawl. Total Catch is the total reported in the database, Records is the number of records used in the analysis, CatchT is the reported catch in the area and depth used in the analysis, and Vessels relates to all vessels used in the analysis. Geomean is the geometric mean of catch rates (kg/hr). Zone:Month is the optimum model and StDev is the standard deviation relating to the data in the optimum model.

| Year | TotCatch | Records | CatchT | Vessels | GeoMean | Zone:Mth | StDev |
|---|---|---|---|---|---|---|---|
| 1993 | 178.702 | 824 | 133.231 | 50 | 17.7598 | 2.0231 | 0.0000 |
| 1994 | 64.153 | 819 | 49.038 | 47 | 11.8880 | 1.3376 | 0.0622 |
| 1995 | 33.597 | 657 | 21.865 | 48 | 7.3973 | 0.8978 | 0.0656 |
| 1996 | 150.790 | 769 | 135.132 | 49 | 10.9438 | 1.1347 | 0.0632 |
| 1997 | 308.735 | 1232 | 268.590 | 48 | 18.9829 | 1.6483 | 0.0585 |
| 1998 | 153.176 | 883 | 144.676 | 46 | 11.5921 | 1.1003 | 0.0628 |
| 1999 | 102.124 | 1065 | 87.921 | 45 | 8.4120 | 0.9279 | 0.0610 |
| 2000 | 46.189 | 1178 | 37.019 | 44 | 4.8857 | 0.6347 | 0.0613 |
| 2001 | 43.598 | 854 | 32.809 | 47 | 4.7139 | 0.6491 | 0.0650 |
| 2002 | 29.059 | 922 | 22.438 | 42 | 3.5128 | 0.4665 | 0.0644 |
| 2003 | 38.392 | 967 | 31.587 | 48 | 4.5797 | 0.6604 | 0.0633 |
| 2004 | 29.601 | 631 | 19.771 | 44 | 4.2927 | 0.6203 | 0.0705 |
| 2005 | 36.899 | 652 | 21.620 | 40 | 4.5977 | 0.5494 | 0.0693 |
| 2006 | 46.131 | 571 | 34.753 | 35 | 7.7674 | 0.8783 | 0.0719 |
| 2007 | 32.799 | 308 | 25.356 | 19 | 8.9499 | 1.0890 | 0.0868 |
| 2008 | 49.565 | 447 | 35.258 | 23 | 10.4210 | 1.3265 | 0.0792 |
| 2009 | 47.203 | 413 | 37.038 | 22 | 9.3924 | 1.2145 | 0.0803 |
| 2010 | 50.948 | 391 | 41.807 | 24 | 10.5766 | 1.3142 | 0.0812 |
| 2011 | 33.197 | 413 | 27.432 | 21 | 7.3130 | 0.9187 | 0.0795 |
| 2012 | 33.045 | 381 | 28.010 | 21 | 6.0729 | 0.6087 | 0.0827 |

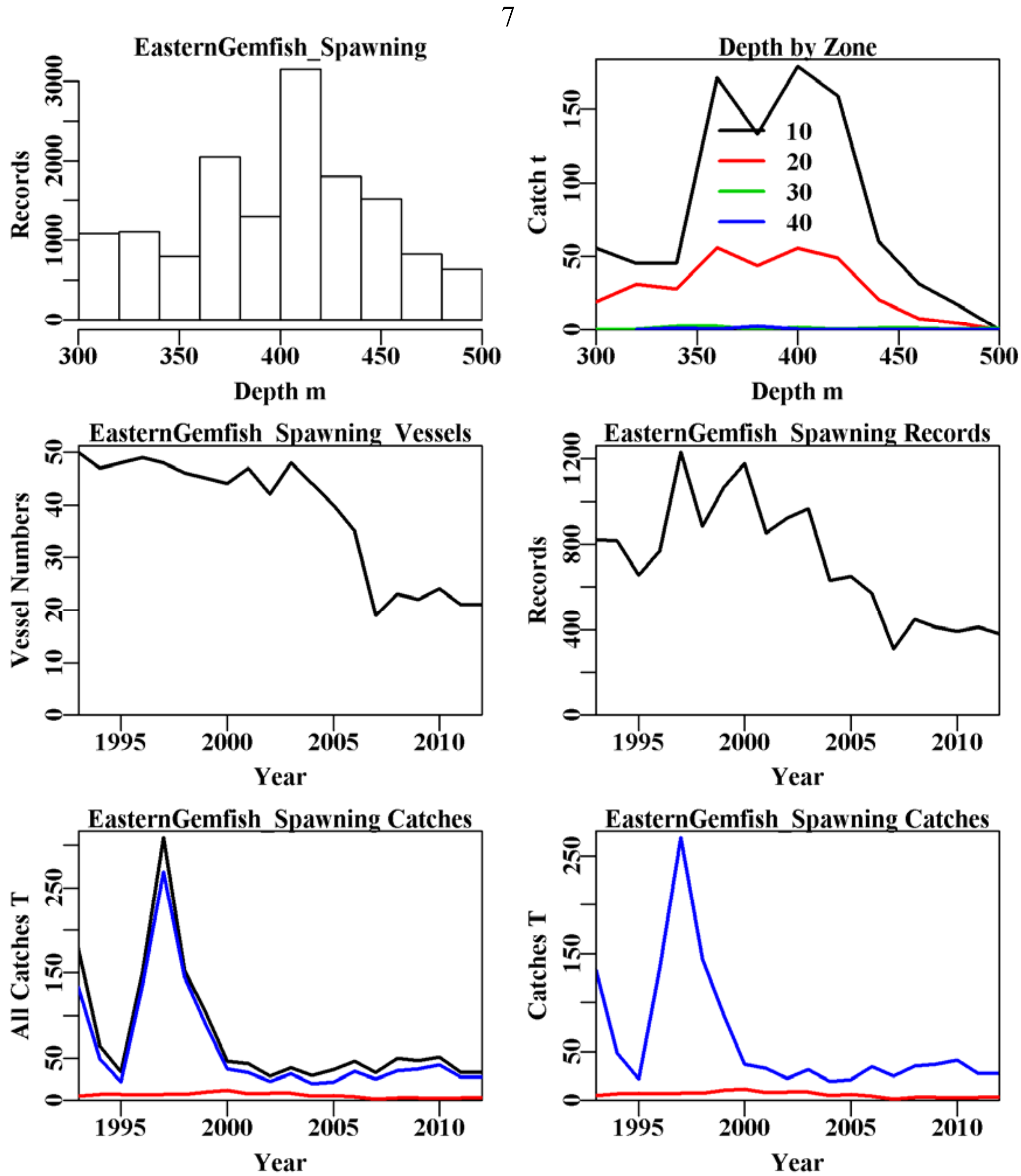



Figure 18.7. Eastern Gemfish, spawning fishery in depths between 300 – 500m, taken by trawl. The top left is the depth distribution of all records reporting Eastern Gemfish, the top right graph depicts the depth distribution of shots containing Eastern Gemfish, spawning fishery in depths between 300 – 500m, taken by trawl. The middle left diagram depicts the distribution of catch by depth by SESSF zone, the middle right hand graph depicts the number of vessels through time. The bottom left reflects the number of records used in analysis, and bottom right is the Eastern Gemfish catches (top line, black is total catches, middle line, blue, are those used in the analysis, and bottom, red, are catches < 30Kg).

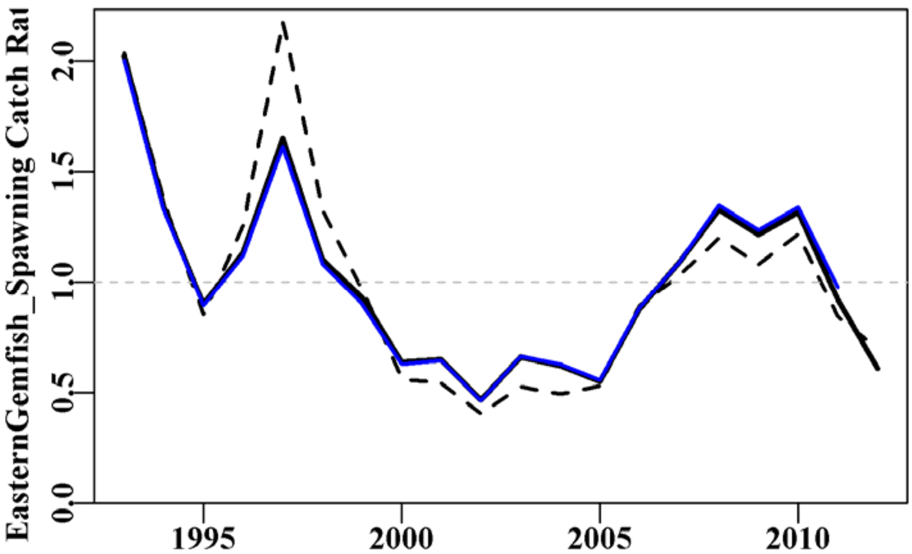



Figure 18.8. Eastern Gemfish, spawning fishery in depths between 300 – 500m, taken by trawl. The dashed black line represents the geometric mean catch rate and the solid black line the standardized catch rates. The graph standardizes catch rates relative to the mean of the standardized catch rates.

Table 18.6. Eastern Gemfish, spawning fishery in depths between 300 – 500m, 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 18.7. Eastern Gemfish, spawning fishery in depths between 300 – 500m, taken by trawl. Model selection criteria, including the AIC, the deviance and the change in deviance. The optimum is model Zone:Month.

| | Year | Vessel | DepCat | Month | DayNight | Zone | **Zone:Mth** | Zone:DepC |
|---|---|---|---|---|---|---|---|---|
| AIC | 8425 | 6762 | 5971 | 5564 | 5525 | 5508 | **5229** | 5495 |
| RSS | 25761 | 22629 | 21410 | 20692 | 20627 | 20593 | **20169** | 20489 |
| MSS | 3774 | 6907 | 8126 | 8844 | 8909 | 8943 | **9366** | 9047 |
| Nobs | 14377 | 14377 | 14377 | 14277 | 14277 | 14277 | **14277** | 14277 |
| Npars | 20 | 120 | 123 | 133 | 136 | 139 | **148** | 169 |
| adj_r2 | 12.663 | 22.744 | 26.892 | 29.290 | 29.496 | 29.598 | **31.001** | 29.804 |
| %Change | 0.000 | 10.081 | 4.148 | 2.398 | 0.207 | 0.101 | **1.404** | -1.197 |

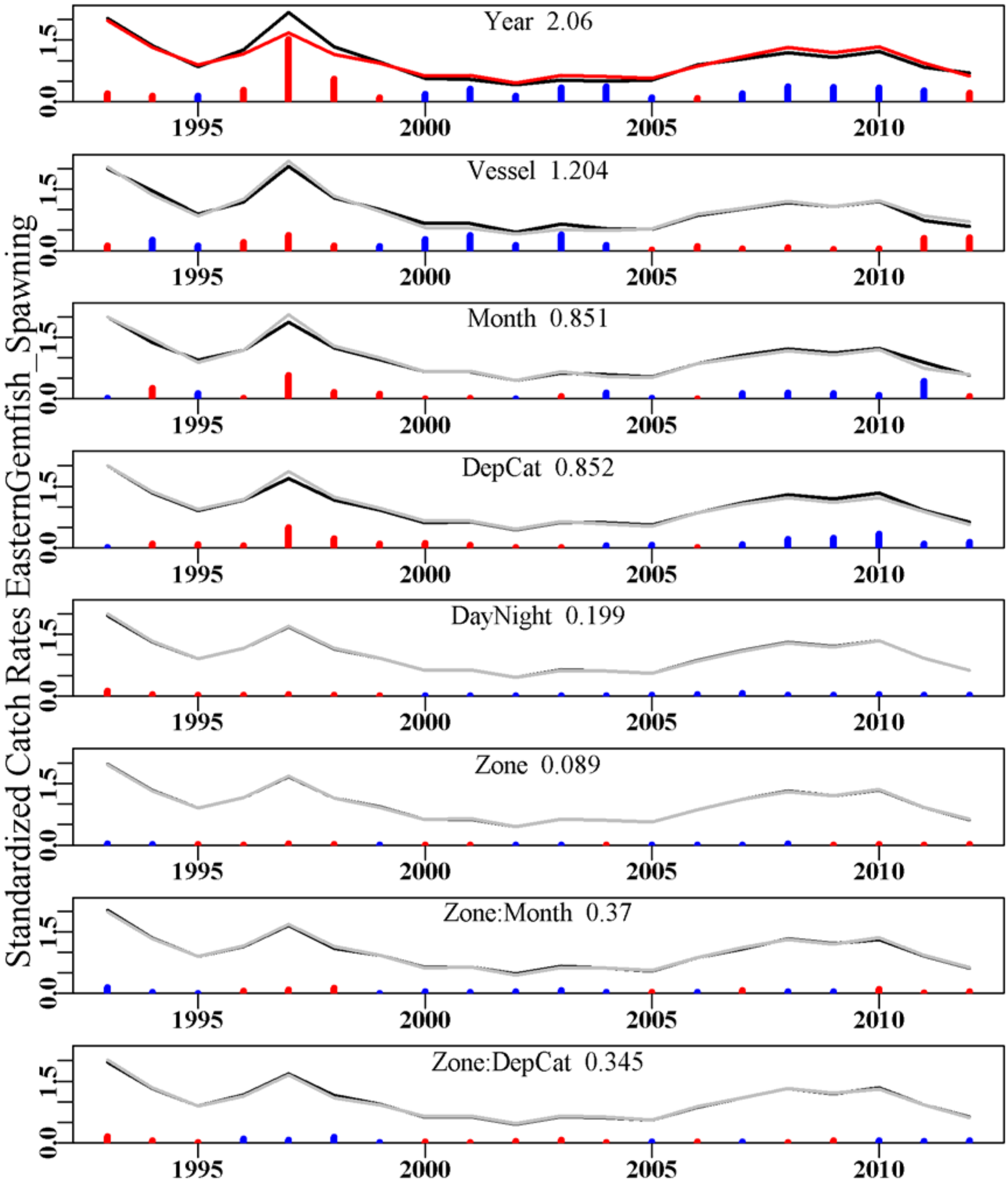



Figure 18.9. The relative influence of each factor used on the final trend in the optimal standardization for the eastern gemfish spawning fishery. The top graph depicts the geometric mean (the black line) and the optimum model (the red line). The difference between them is illustrated by the vertical 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.

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

Use October to May 1986-2012, all depths to 600m, June to September, < 300m depth, Zones 10 – 30 plus below 42 on the west coast of Tasmania (zone 40).

Table 18.8. Non-spawning Eastern Gemfish from the SET in depths between 0 – 600m, taken by trawl. Total Catch is the total reported in the database, Records is the number of records used in the analysis, CatchT is the reported catch in the area and depth used in the analysis, and Vessels relates to all vessels used in the analysis. Geomean is the geometric mean of catch rates (kg/hr). Zone:DepCat is the optimum model and StDev is the standard deviation relating to the data in the optimum model.

| Year | TotCatch | Records | CatchT | Vessels | GeoMean | **Zone:DepC** | StDev |
|---|---|---|---|---|---|---|---|
| 1986 | 3639.705 | 2030 | 390.356 | 86 | 14.5833 | 2.3736 | 0.0000 |
| 1987 | 4654.845 | 1894 | 770.141 | 74 | 25.6322 | 3.1365 | 0.0429 |
| 1988 | 3515.132 | 2203 | 509.587 | 77 | 20.2775 | 2.7031 | 0.0429 |
| 1989 | 1773.801 | 1434 | 148.400 | 69 | 11.5170 | 1.8111 | 0.0474 |
| 1990 | 1206.660 | 758 | 104.135 | 69 | 12.7467 | 1.8021 | 0.0572 |
| 1991 | 578.584 | 731 | 65.995 | 71 | 8.7585 | 1.2263 | 0.0585 |
| 1992 | 485.696 | 693 | 135.106 | 49 | 11.2867 | 1.7144 | 0.0592 |
| 1993 | 353.153 | 1536 | 94.320 | 58 | 8.9703 | 1.3372 | 0.0478 |
| 1994 | 232.154 | 1832 | 63.812 | 55 | 6.3021 | 0.9164 | 0.0459 |
| 1995 | 181.686 | 1685 | 49.977 | 54 | 5.5810 | 0.8339 | 0.0467 |
| 1996 | 381.614 | 1947 | 55.708 | 61 | 4.1794 | 0.6333 | 0.0459 |
| 1997 | 571.679 | 1786 | 66.020 | 58 | 4.3644 | 0.6651 | 0.0483 |
| 1998 | 404.594 | 1246 | 45.635 | 50 | 4.3330 | 0.6289 | 0.0508 |
| 1999 | 448.384 | 1344 | 30.319 | 53 | 2.9242 | 0.4601 | 0.0502 |
| 2000 | 336.404 | 1716 | 32.310 | 57 | 2.7970 | 0.4177 | 0.0480 |
| 2001 | 330.838 | 1621 | 32.019 | 51 | 2.0726 | 0.3438 | 0.0491 |
| 2002 | 195.597 | 1617 | 19.034 | 50 | 1.5969 | 0.2644 | 0.0493 |
| 2003 | 268.577 | 1585 | 20.047 | 48 | 1.7227 | 0.2907 | 0.0496 |
| 2004 | 524.293 | 1771 | 38.563 | 54 | 2.6319 | 0.4134 | 0.0489 |
| 2005 | 448.035 | 1745 | 40.971 | 48 | 2.8266 | 0.4417 | 0.0485 |
| 2006 | 508.681 | 1325 | 32.151 | 43 | 2.9593 | 0.4689 | 0.0517 |
| 2007 | 458.482 | 788 | 28.140 | 22 | 4.2429 | 0.6383 | 0.0589 |
| 2008 | 251.708 | 840 | 35.467 | 26 | 5.7070 | 0.8546 | 0.0582 |
| 2009 | 189.831 | 514 | 27.227 | 27 | 6.6449 | 0.8814 | 0.0683 |
| 2010 | 218.885 | 704 | 22.850 | 23 | 4.1887 | 0.6351 | 0.0614 |
| 2011 | 147.297 | 801 | 22.831 | 22 | 3.8210 | 0.5807 | 0.0604 |
| 2012 | 147.746 | 709 | 21.996 | 23 | 3.5107 | 0.5270 | 0.0624 |

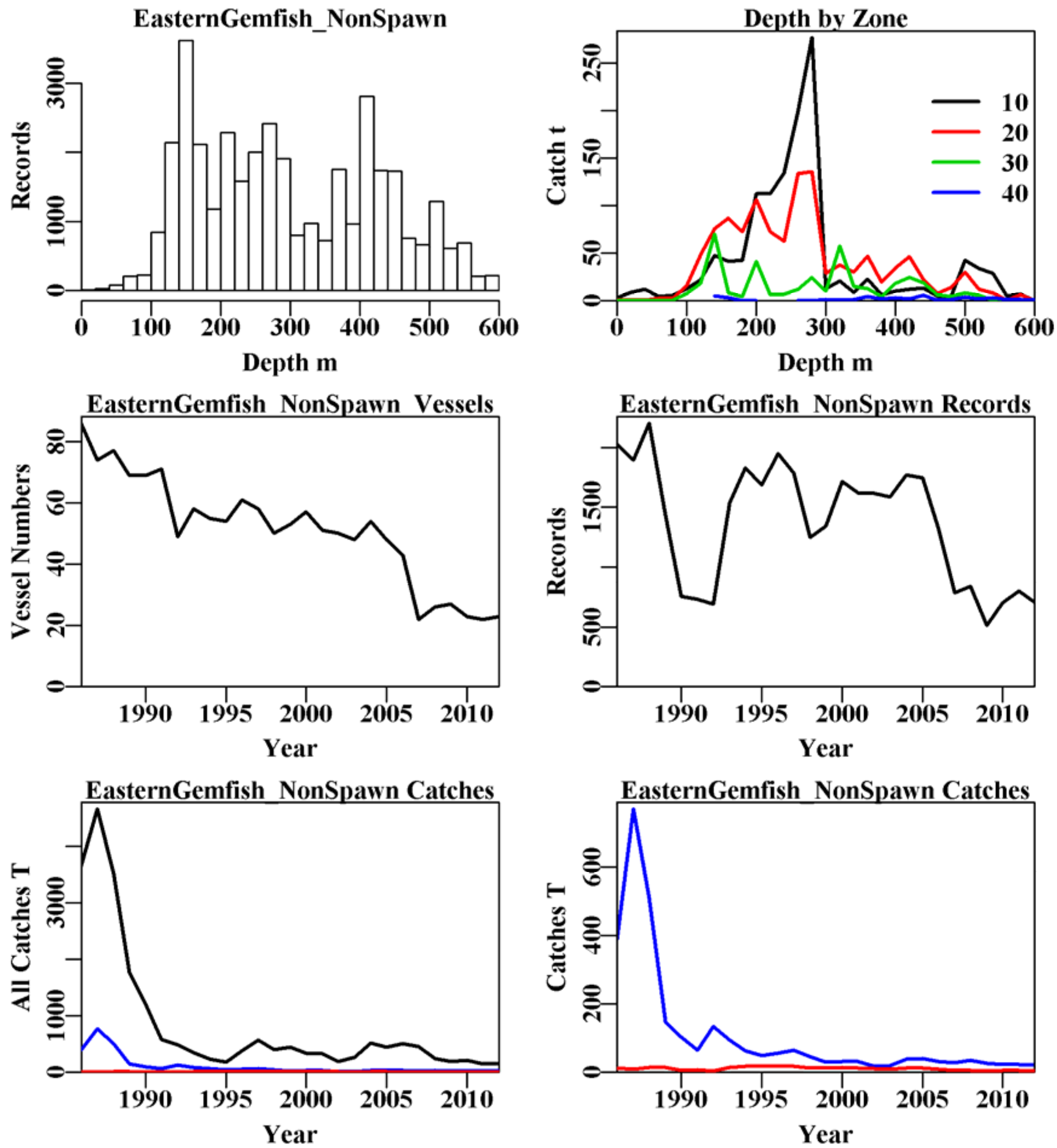



Figure 18.10. Non-spawning Eastern Gemfish from the SET in depths between 0 – 600m, taken by trawl. The top left is the depth distribution of all records reporting Eastern Gemfish, the top right graph depicts the depth distribution of shots containing Non-spawning Eastern Gemfish from the SET in depths between 0 – 600m, taken by trawl. The middle left diagram depicts the distribution of catch by depth by SESSF zone, the middle right hand graph depicts the number of vessels through time. The bottom left reflects the number of records used in analysis, and bottom right is the Eastern Gemfish catches (top line, black is total catches, middle line, blue, are those used in the analysis, and bottom, red, are catches < 30Kg).

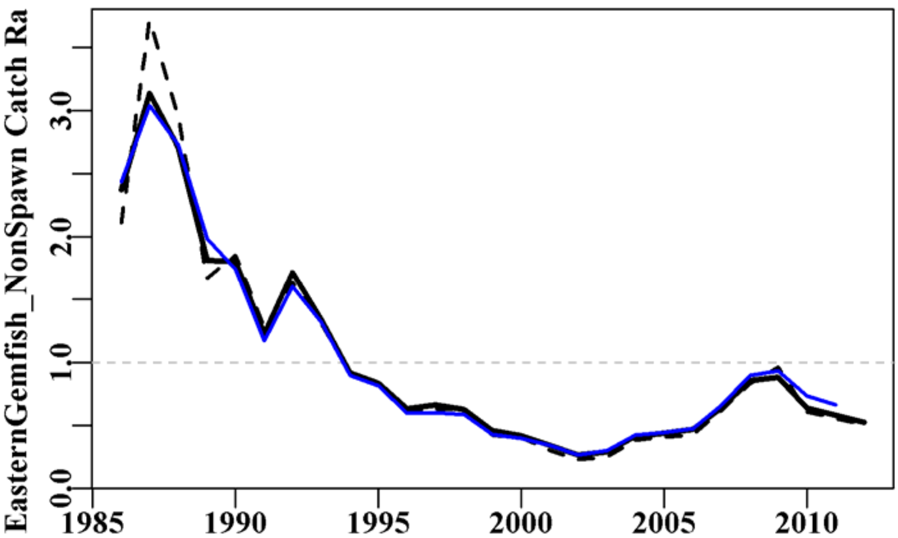



Figure 18.11. Non-spawning Eastern Gemfish from the SET in depths between 0 – 600m, taken by trawl. The dashed black line represents the geometric mean catch rate and the solid black line the standardized catch rates. The blue line is last year's optimum standardization. The graph standardizes catch rates relative to the mean of the standardized catch rates.

Table 18.9. Non-spawning Eastern Gemfish from the SET in depths between 0 – 600m, 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+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 18.10. Nonspawning Eastern Gemfish from the SET in depths between 0 – 600m, taken by trawl. Model selection criteria, including the AIC, the deviance and the change in deviance. The optimum is model Zone:DepCat.

| | Year | Vessel | DepCat | Month | Zone | DayNight | Zone:Mth | **Zone:DepC** |
|---|---|---|---|---|---|---|---|---|
| AIC | 23211 | 18145 | 15968 | 15522 | 15295 | 14991 | 14739 | **14590** |
| RSS | 69084 | 59617 | 55836 | 55126 | 54776 | 54314 | 53843 | **53457** |
| MSS | 22748 | 32215 | 35996 | 36706 | 37056 | 37518 | 37988 | **38375** |
| Nobs | 36855 | 36855 | 36550 | 36550 | 36550 | 36550 | 36550 | **36550** |
| Npars | 27 | 210 | 240 | 251 | 254 | 257 | 290 | **347** |
| adj_r2 | 24.718 | 34.710 | 38.798 | 39.557 | 39.936 | 40.438 | 40.900 | **41.232** |
| %Change | 0.000 | 9.992 | 4.088 | 0.760 | 0.379 | 0.502 | 0.462 | **0.332** |

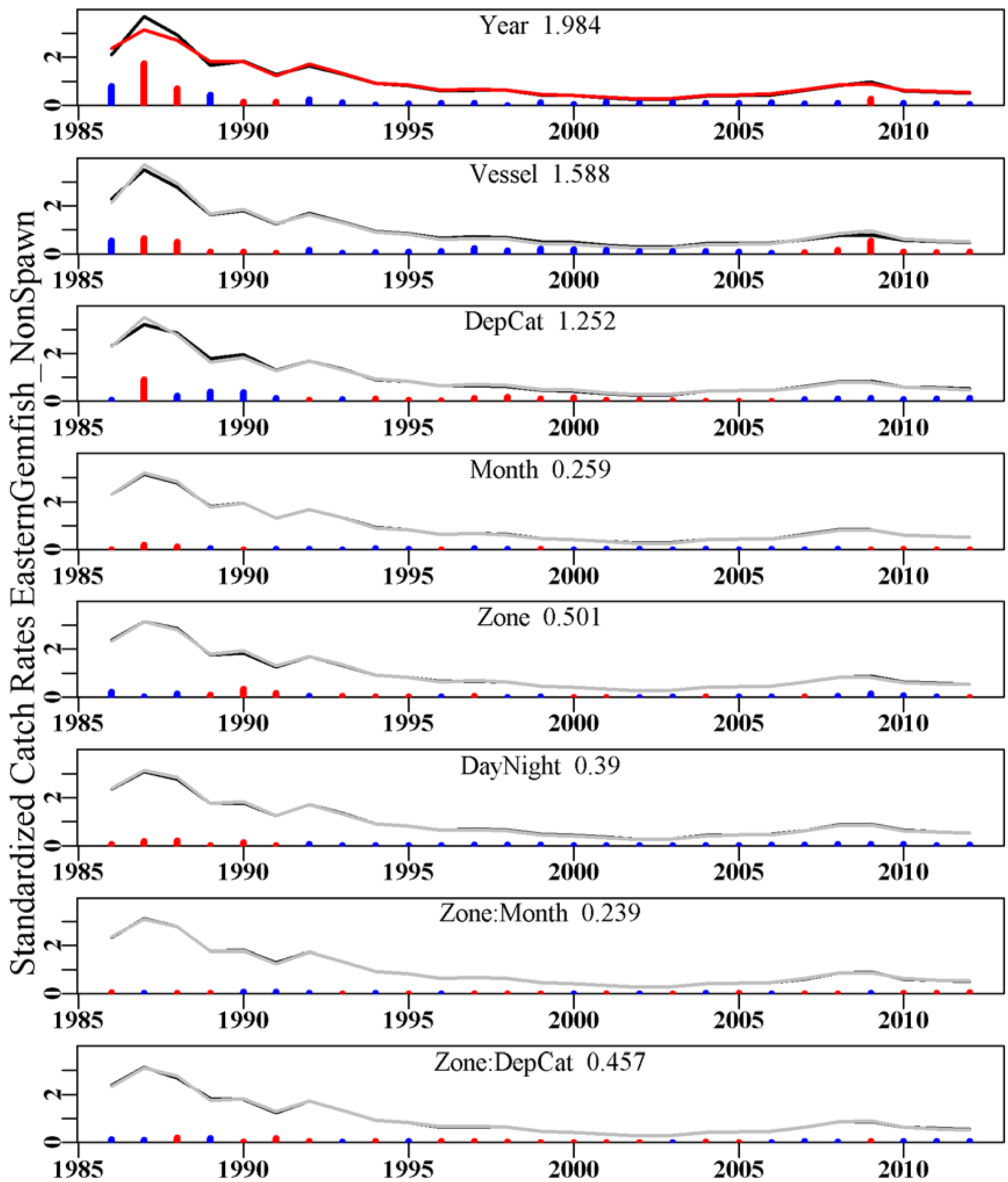



Figure 18.12. The relative influence of each factor used on the final trend in the optimal standardization for Non-spawning Eastern Gemfish. The top graph depicts the geometric mean (the black line) and the optimum model (the red line). The difference between them is illustrated by the vertical bars 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.

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

Only data from Zones 10 to 50 in depths 70 – 360m taken by trawl.

Table 18.11. Jackass Morwong from zones 10 to 50 in depths 70 – 360m by trawl. Total Catch is the total reported in the database, Records is the number of records used in the analysis, CatchT is the reported catch in the area and depth used in the analysis, and Vessels relates to all vessels used in the analysis. Geomean is the geometric mean of catch rates (kg/hr). Zone:Mth is the optimum model and StDev is the standard deviation relating to the data in the optimum model.

| Year | TotCatch | Records | CatchT | Vessels | GeoMean | Zone:Mth | StDev |
|---|---|---|---|---|---|---|---|
| 1986 | 982.811 | 5772 | 873.211 | 106 | 22.5592 | 1.8636 | 0.0000 |
| 1987 | 1087.450 | 4948 | 1000.054 | 104 | 26.1917 | 2.1150 | 0.0266 |
| 1988 | 1481.882 | 5984 | 1314.397 | 102 | 29.1554 | 2.0887 | 0.0259 |
| 1989 | 1659.362 | 5434 | 1500.604 | 89 | 33.9001 | 2.0266 | 0.0267 |
| 1990 | 1000.682 | 5022 | 837.357 | 86 | 24.2137 | 1.6782 | 0.0277 |
| 1991 | 1127.911 | 5233 | 899.685 | 85 | 21.1181 | 1.4883 | 0.0275 |
| 1992 | 755.788 | 3483 | 523.779 | 63 | 19.1937 | 1.2362 | 0.0307 |
| 1993 | 1012.730 | 4732 | 821.881 | 73 | 21.3530 | 1.2543 | 0.0288 |
| 1994 | 818.025 | 5660 | 684.800 | 71 | 18.0744 | 1.0712 | 0.0274 |
| 1995 | 789.528 | 5852 | 705.409 | 63 | 16.3623 | 1.0034 | 0.0272 |
| 1996 | 827.151 | 7535 | 749.574 | 70 | 13.8607 | 0.9215 | 0.0261 |
| 1997 | 1060.409 | 7561 | 934.001 | 70 | 16.1581 | 0.9853 | 0.0266 |
| 1998 | 838.174 | 5941 | 688.705 | 65 | 13.4363 | 0.8471 | 0.0275 |
| 1999 | 932.828 | 5801 | 779.703 | 66 | 14.1587 | 0.8733 | 0.0277 |
| 2000 | 866.393 | 6902 | 732.188 | 78 | 10.1983 | 0.7379 | 0.0269 |
| 2001 | 781.582 | 6786 | 644.178 | 71 | 8.3295 | 0.5590 | 0.0272 |
| 2002 | 798.666 | 7761 | 691.282 | 65 | 8.3275 | 0.5880 | 0.0268 |
| 2003 | 758.467 | 6538 | 601.484 | 64 | 7.9077 | 0.5102 | 0.0275 |
| 2004 | 764.786 | 6483 | 604.476 | 70 | 8.6153 | 0.5097 | 0.0277 |
| 2005 | 784.116 | 6376 | 597.416 | 58 | 8.9785 | 0.5486 | 0.0277 |
| 2006 | 806.510 | 5446 | 616.102 | 49 | 11.5427 | 0.6298 | 0.0286 |
| 2007 | 601.674 | 3812 | 443.366 | 30 | 12.2504 | 0.6369 | 0.0311 |
| 2008 | 691.699 | 4491 | 546.640 | 33 | 13.7889 | 0.7480 | 0.0301 |
| 2009 | 448.242 | 3383 | 344.429 | 27 | 11.4713 | 0.6605 | 0.0320 |
| 2010 | 356.916 | 3438 | 292.104 | 30 | 8.5497 | 0.4886 | 0.0320 |
| 2011 | 377.016 | 3526 | 303.344 | 28 | 8.5284 | 0.4623 | 0.0319 |
| 2012 | 333.477 | 3145 | 305.253 | 30 | 8.9426 | 0.4679 | 0.0327 |

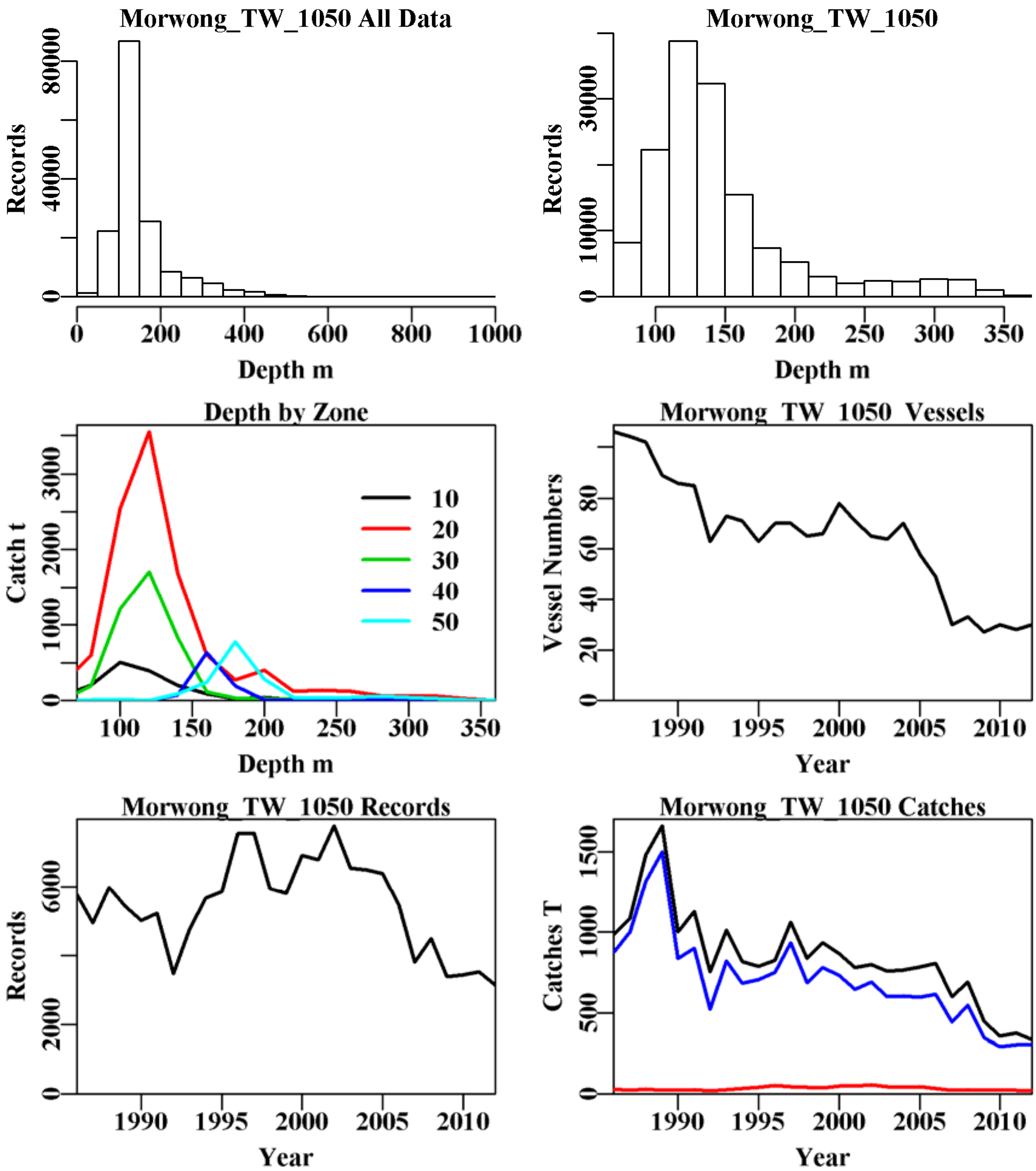



Figure 18.13. Jackass Morwong from zones 10 to 50 in depths 70 – 360m by trawl. The top left is the depth distribution of all records reporting Jackass Morwong, the top right graph depicts the depth distribution of shots containing Jackass Morwong from zones 10 to 50 in depths 70 – 360m by trawl. The middle left diagram depicts the distribution of catch by depth within zones 10 to 50, the middle right hand graph depicts the number of vessels through time. The bottom left reflects the number of records used in analysis, and bottom right is the Jackass Morwong catches (top line, black is total catches, middle line, blue, are those used in the analysis, and bottom, red, are catches < 30Kg).

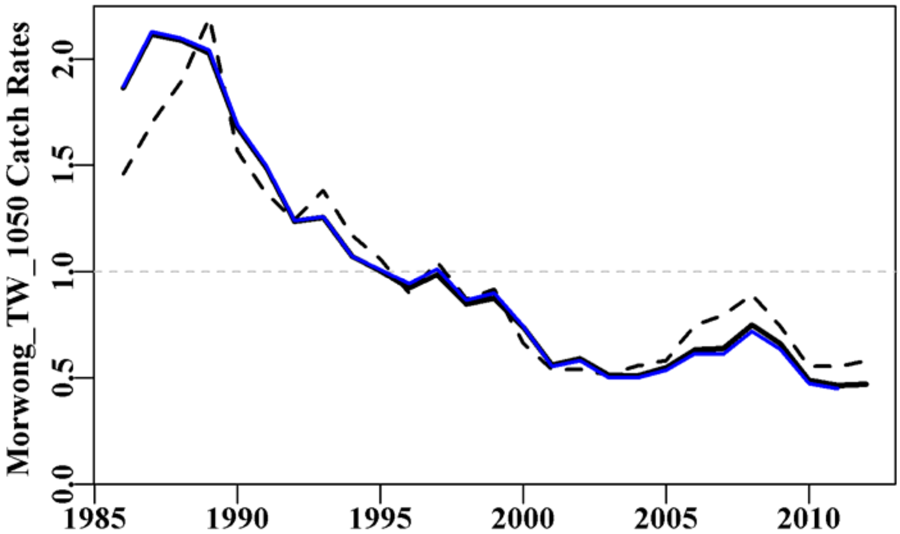



Figure 18.14. Jackass Morwong from zones 10 to 50 in depths 70 – 360m by trawl. The dashed black line represents the geometric mean catch rate and the solid black line the standardized catch rates. The graph standardizes catch rates relative to the mean of the standardized catch rates.

Table 18.12. Jackass Morwong from zones 10 to 50 in depths 70 – 360m 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 18.13. Jackass Morwong from zones 10 to 50 in depths 70 – 360m by trawl. Model selection criteria, including the AIC, the adjusted $r^2$ and the change in adjusted $r^2$. The optimum was model Zone:Month.

| | Year | Vessel | Month | DepCat | Zone | DayNight | **Zone:Month** | Zone:DepCat |
|---|---|---|---|---|---|---|---|---|
| AIC | 112806 | 90946 | 84493 | 80255 | 75285 | 73966 | **71843** | 72482 |
| RSS | 316564 | 272034 | 260315 | 251807 | 243349 | 241144 | **237513** | 238504 |
| MSS | 27262 | 71792 | 83511 | 92019 | 100477 | 102681 | **106313** | 105321 |
| Nobs | 147045 | 147045 | 147045 | 145693 | 145693 | 145693 | **145693** | 145693 |
| Npars | 27 | 243 | 254 | 269 | 273 | 276 | **320** | 336 |
| adj_r2 | 7.913 | 20.750 | 24.158 | 26.628 | 29.091 | 29.732 | **30.769** | 30.472 |
| %Change | 0.000 | 12.837 | 3.408 | 2.470 | 2.463 | 0.641 | **1.037** | -0.297 |

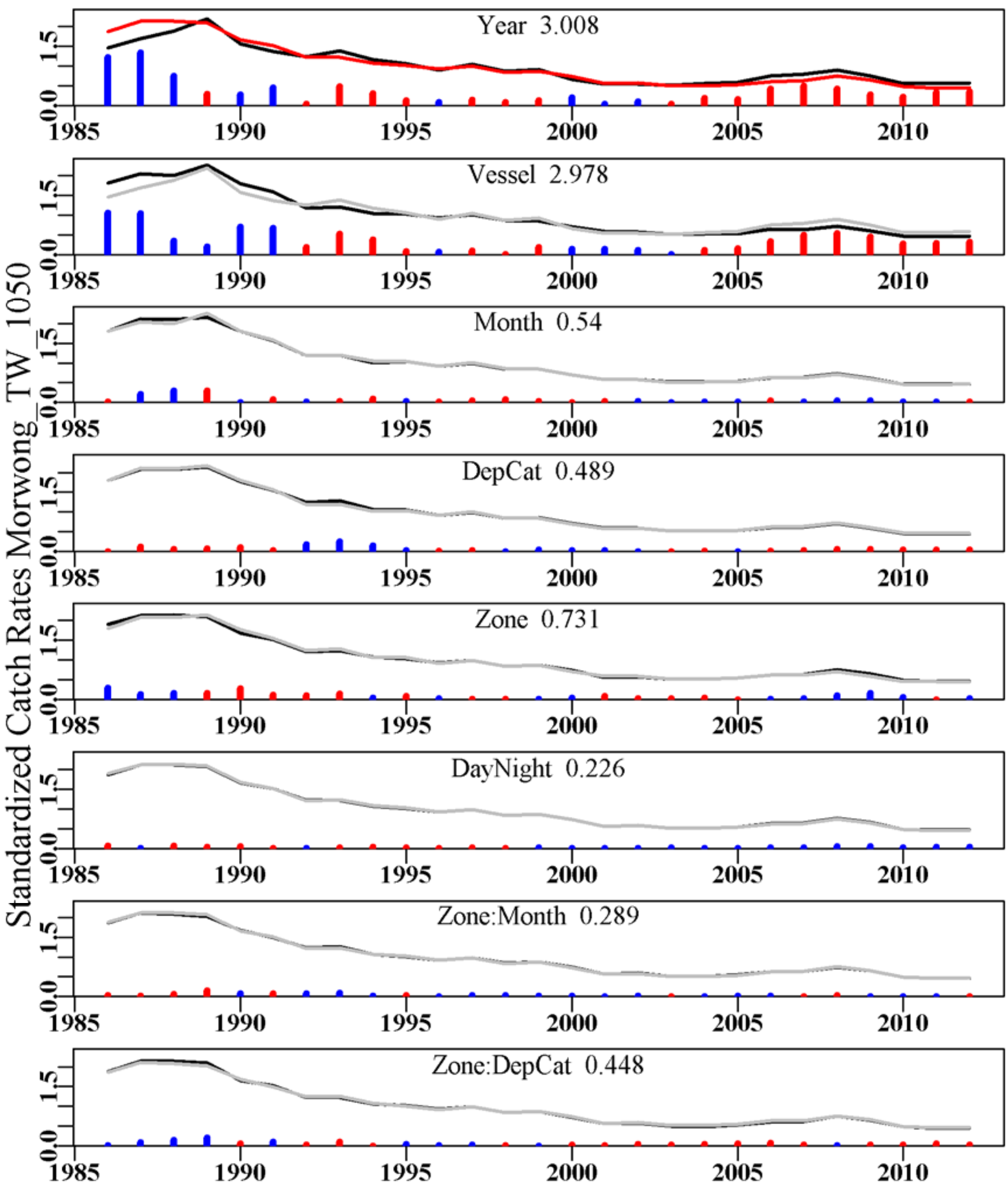



Figure 18.15. The relative influence of each factor used on the final trend in the optimal standardization for Jackass Morwong in Zones 10 – 50. The top graph depicts the geometric mean (the black line) and the optimum model (the red line). The difference between them is illustrated by the vertical bars 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.

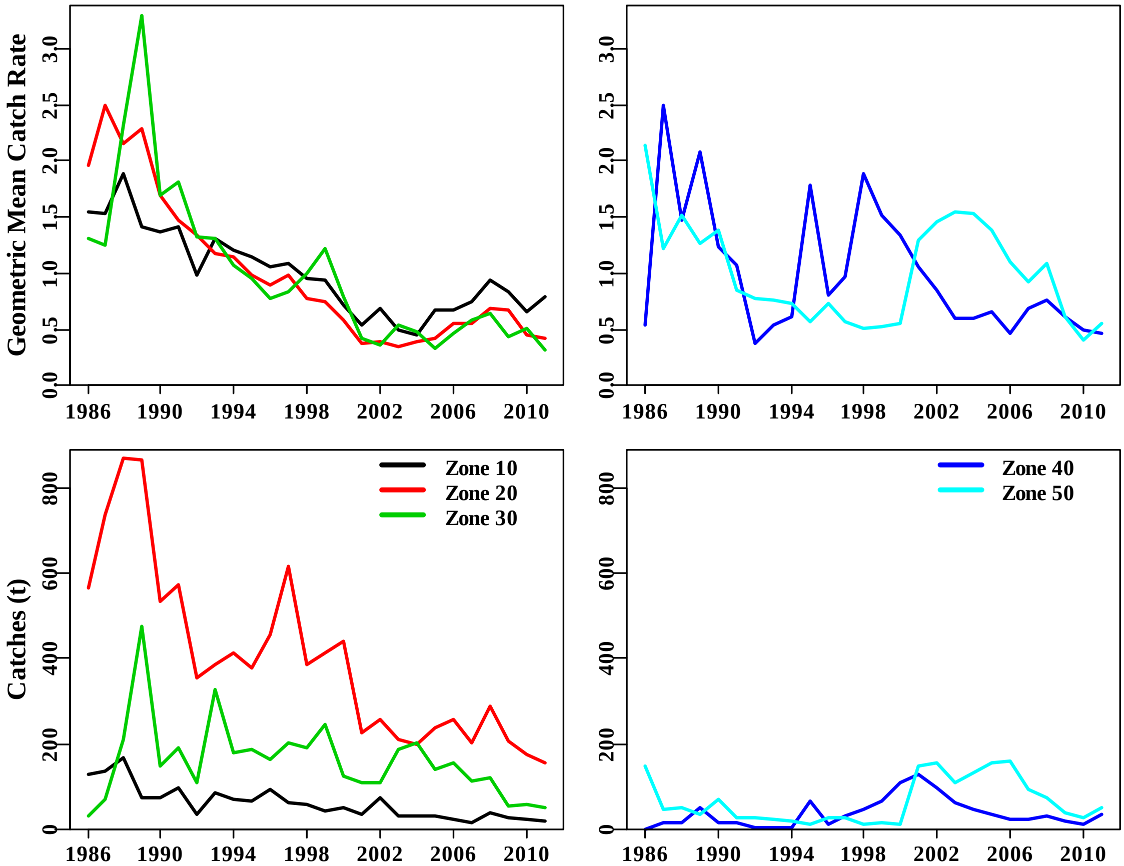



Figure 18.16. The trends in catch and geometric mean catch rates for Jackass Morwong taken by trawl across SESSF zones 10 – 50. The catch rate trends across zones 10 – 30 are very similar, whilst those for zones 40 to 50 are noisy due to low catches until after 1996.

Table 18.14. 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 | 1937.491 | 1345.901 | 2.152 | 28.394 | 280.900 | 3.993 | 1.200 |
| 1987 | 3471.444 | 814.932 | 76.887 | 17.139 | 233.879 | 2.152 | 13.517 |
| 1988 | 1408.400 | 1675.268 | 74.923 | 36.368 | 193.848 | 69.071 | 36.741 |
| 1989 | 1067.449 | 474.894 | 22.890 | 42.192 | 114.786 | 4.198 | 28.676 |
| 1990 | 838.855 | 183.976 | 24.321 | 5.954 | 130.706 | 3.308 | 10.978 |
| 1991 | 154.864 | 108.371 | 6.202 | 9.788 | 260.438 | 0.100 | 31.430 |
| 1992 | 282.921 | 45.515 | 1.101 | 0.374 | 89.302 | 0.090 | 16.016 |
| 1993 | 164.685 | 65.712 | 5.149 | 12.764 | 90.140 | 0.253 | 6.912 |
| 1994 | 56.539 | 45.209 | 11.232 | 6.081 | 90.272 | 0.061 | 14.815 |
| 1995 | 35.218 | 27.316 | 8.903 | 2.545 | 82.313 | 0.108 | 22.881 |
| 1996 | 146.237 | 31.378 | 10.480 | 6.374 | 139.626 | 0.332 | 20.049 |
| 1997 | 208.555 | 125.046 | 19.249 | 4.229 | 150.014 | 0.076 | 61.912 |
| 1998 | 126.852 | 45.949 | 21.314 | 0.682 | 121.874 | 0.306 | 85.736 |
| 1999 | 79.236 | 34.113 | 10.387 | 1.537 | 175.645 | 0.178 | 147.039 |
| 2000 | 33.049 | 32.722 | 5.443 | 2.887 | 229.426 | 0.158 | 32.230 |
| 2001 | 26.235 | 28.548 | 10.269 | 6.377 | 164.878 | 0.051 | 91.424 |
| 2002 | 18.604 | 17.914 | 7.911 | 2.931 | 84.183 | 0.077 | 43.836 |
| 2003 | 26.824 | 20.973 | 5.880 | 2.185 | 122.703 | 0.076 | 84.758 |
| 2004 | 24.023 | 20.924 | 16.445 | 2.461 | 105.490 | 0.108 | 337.274 |
| 2005 | 27.457 | 22.799 | 16.462 | 8.070 | 111.122 | 0.049 | 260.273 |
| 2006 | 33.590 | 25.816 | 13.485 | 2.543 | 102.359 | 0.021 | 322.633 |
| 2007 | 21.458 | 19.083 | 17.422 | 5.079 | 59.061 | 0.127 | 330.092 |
| 2008 | 28.365 | 32.561 | 23.380 | 4.117 | 53.580 | 0.965 | 108.368 |
| 2009 | 30.093 | 31.033 | 12.954 | 6.121 | 56.041 | 0.063 | 53.486 |
| 2010 | 36.475 | 25.576 | 13.515 | 12.277 | 80.655 | 0.359 | 49.525 |
| 2011 | 24.061 | 16.288 | 11.347 | 16.205 | 45.389 | 0.881 | 31.708 |
| 2102 | 19.056 | 20.761 | 13.509 | 10.761 | 45.122 | 0.410 | 37.905 |

### 18.4.5 Jackass Morwong Z1020 (MOR–37377003 *N. macropterus*)

Only data from zone 10 and 20 were used for trawl vessels only (i.e. exclude Danish Seine vessels), and depths between 70 and 300 m.

Table 18.15. Jackass Morwong from zones 10 and 20 in depths 70 – 300m by trawl. Total Catch is the total reported in the database, Records is the number of reported records used in the analysis, CatchT is the reported catch in the area and depth used in the analysis, and Vessels relates to all vessels used in the analysis. Geomean is the geometric mean of catch rates (kg/hr). Zone:Mth is the optimum model and StDev is the standard deviation relating to the data in the optimum model.

| Year | TotCatch | Records | CatchT | Vessels | GeoMean | Zone:Mth | StDev |
|---|---|---|---|---|---|---|---|
| 1986 | 982.811 | 5045 | 686.225 | 87 | 21.2677 | 1.8269 | 0.0000 |
| 1987 | 1087.450 | 4266 | 858.475 | 79 | 26.2295 | 2.2168 | 0.0292 |
| 1988 | 1481.882 | 5147 | 1025.256 | 79 | 27.6740 | 2.0875 | 0.0284 |
| 1989 | 1659.362 | 4325 | 929.409 | 65 | 27.9306 | 1.9635 | 0.0294 |
| 1990 | 1000.682 | 4127 | 600.553 | 59 | 21.9897 | 1.6331 | 0.0304 |
| 1991 | 1127.911 | 4436 | 661.796 | 55 | 19.4037 | 1.5462 | 0.0302 |
| 1992 | 755.788 | 2842 | 378.592 | 46 | 17.3690 | 1.2245 | 0.0340 |
| 1993 | 1012.730 | 3363 | 464.955 | 49 | 17.0123 | 1.2876 | 0.0326 |
| 1994 | 818.025 | 4470 | 473.423 | 49 | 16.1919 | 1.1287 | 0.0306 |
| 1995 | 789.528 | 4600 | 435.209 | 47 | 14.0323 | 1.0491 | 0.0302 |
| 1996 | 827.151 | 6218 | 544.828 | 51 | 12.3880 | 0.9501 | 0.0288 |
| 1997 | 1060.409 | 6031 | 672.142 | 53 | 14.8970 | 1.0479 | 0.0295 |
| 1998 | 838.174 | 4790 | 435.779 | 46 | 11.3605 | 0.8474 | 0.0305 |
| 1999 | 932.828 | 4429 | 447.847 | 50 | 11.3334 | 0.8504 | 0.0311 |
| 2000 | 866.393 | 5719 | 479.565 | 55 | 8.7637 | 0.7127 | 0.0298 |
| 2001 | 781.582 | 4930 | 258.551 | 48 | 5.8826 | 0.5006 | 0.0307 |
| 2002 | 798.666 | 5702 | 328.002 | 44 | 6.3660 | 0.5550 | 0.0301 |
| 2003 | 758.467 | 4585 | 237.585 | 47 | 5.3371 | 0.4401 | 0.0312 |
| 2004 | 764.786 | 4196 | 220.279 | 52 | 5.4124 | 0.4346 | 0.0320 |
| 2005 | 784.116 | 4378 | 262.616 | 39 | 6.8948 | 0.5298 | 0.0317 |
| 2006 | 806.510 | 3417 | 275.501 | 36 | 8.8173 | 0.6363 | 0.0333 |
| 2007 | 601.674 | 2437 | 212.373 | 20 | 9.2385 | 0.6017 | 0.0368 |
| 2008 | 691.699 | 3167 | 321.578 | 25 | 11.2739 | 0.7707 | 0.0348 |
| 2009 | 448.242 | 2447 | 228.460 | 19 | 10.4057 | 0.7088 | 0.0369 |
| 2010 | 356.916 | 2593 | 193.811 | 19 | 7.6433 | 0.4980 | 0.0366 |
| 2011 | 377.016 | 2401 | 170.945 | 18 | 7.3903 | 0.4780 | 0.0376 |
| 2012 | 333.477 | 2166 | 175.128 | 19 | 7.6279 | 0.4743 | 0.0382 |

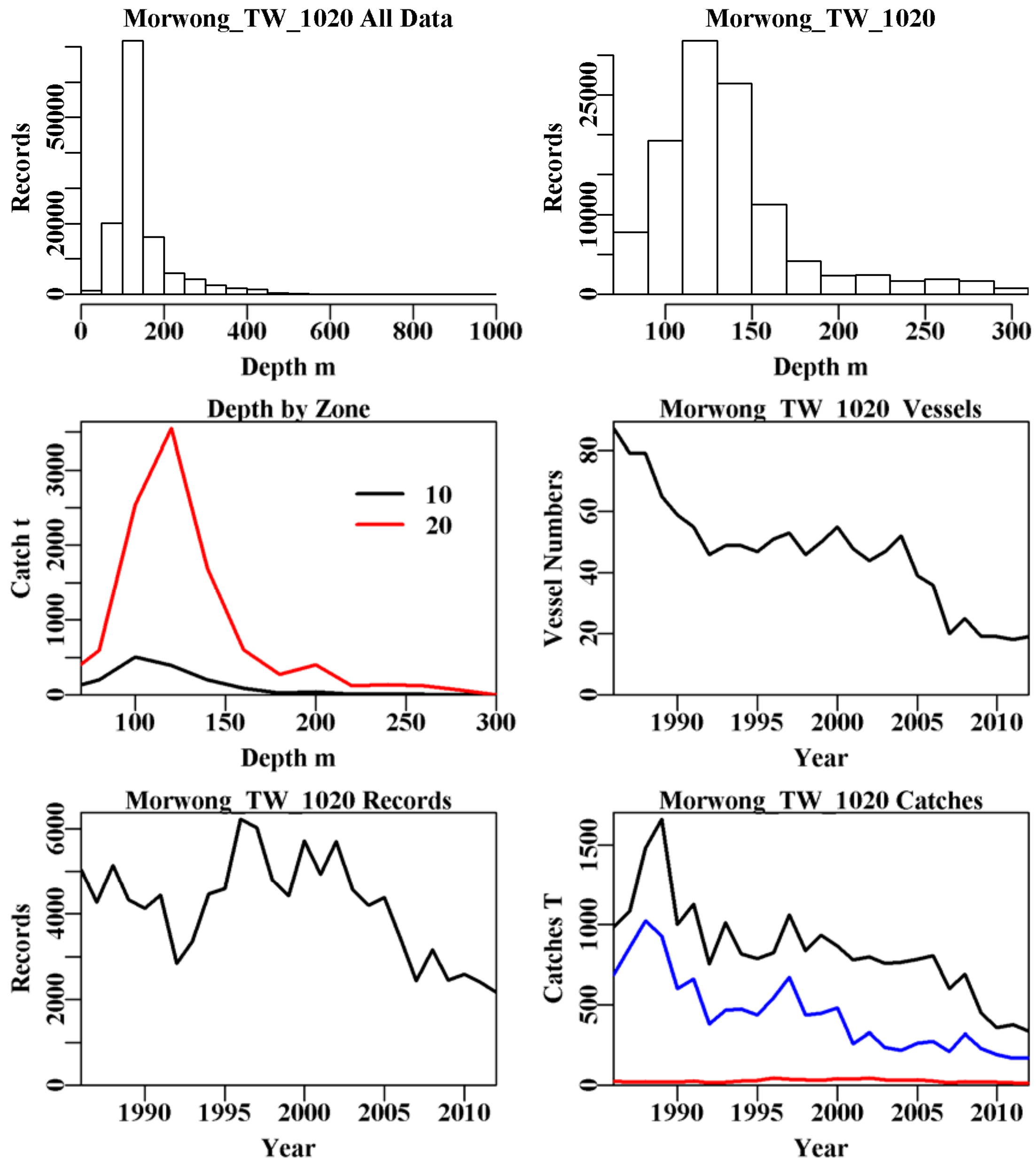



Figure 18.17. Jackass Morwong from zones 10 and 20 in depths 70 – 300m by trawl. The top left is the depth distribution of all records reporting Jackass Morwong, the top right graph depicts the depth distribution of shots containing Jackass Morwong from zones 10 and 20 in depths 70 – 300m by trawl. The middle left diagram depicts the distribution of catch by depth within zones 10 and 20 (20 is top red line), the middle right hand graph depicts the number of vessels through time. The bottom left reflects the number of records used in analysis, and bottom right is the Jackass Morwong catches (top line, black is total catches, middle line, blue, are those used in the analysis, and bottom, red, are catches < 30Kg).

Table 18.16. Jackass Morwong from zones 10 and 20 in depths 70 – 300m 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 |

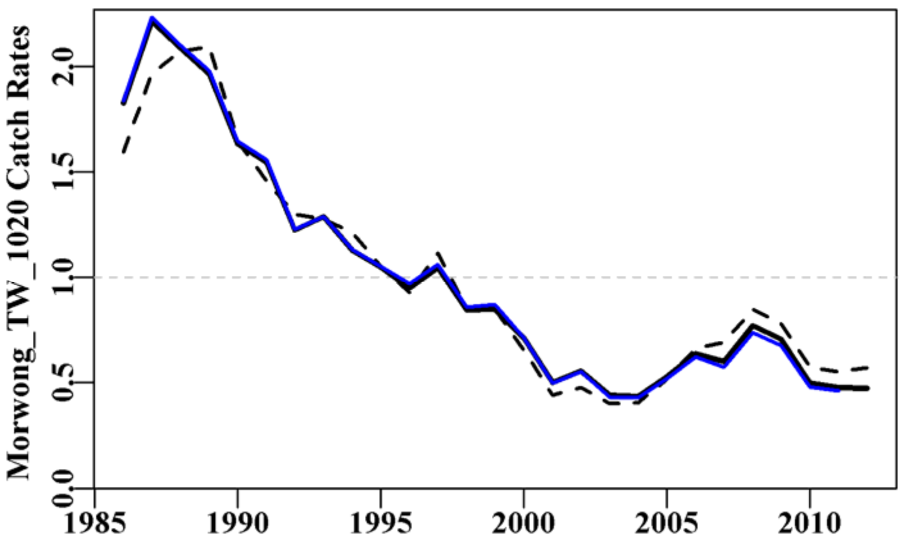



Figure 18.18. Jackass Morwong from zones 10 and 20 in depths 70 – 300m by trawl. The dashed black line represents the geometric mean catch rate and the solid black line the standardized catch rates. The graph standardizes catch rates relative to the mean of the standardized catch rates.

Table 18.17. Jackass Morwong from zones 10 and 20 in depths 70 – 300m by trawl. Model selection criteria, including the AIC, the adjusted $r^2$ and the change in adjusted $r^2$. The optimum was model Zone:Month.

| | Year | Vessel | Month | DepCat | Zone | DayNight | **Zone:Mth** | Zone:DepC |
|---|---|---|---|---|---|---|---|---|
| AIC | 80338 | 66125 | 63348 | 61193 | 59303 | 58043 | **57188** | 57728 |
| RSS | 229497 | 201577 | 196610 | 192031 | 188791 | 186654 | **185188** | 186086 |
| MSS | 29575 | 57496 | 62462 | 67041 | 70281 | 72418 | **73884** | 72986 |
| Nobs | 112227 | 112227 | 112227 | 111210 | 111210 | 111210 | **111210** | 111210 |
| Npars | 27 | 200 | 211 | 223 | 224 | 227 | **238** | 239 |
| adj_r2 | 11.395 | 22.055 | 23.968 | 25.729 | 26.982 | 27.806 | **28.366** | 28.018 |
| %Change | 0.000 | 10.659 | 1.913 | 1.762 | 1.252 | 0.825 | **0.560** | -0.348 |

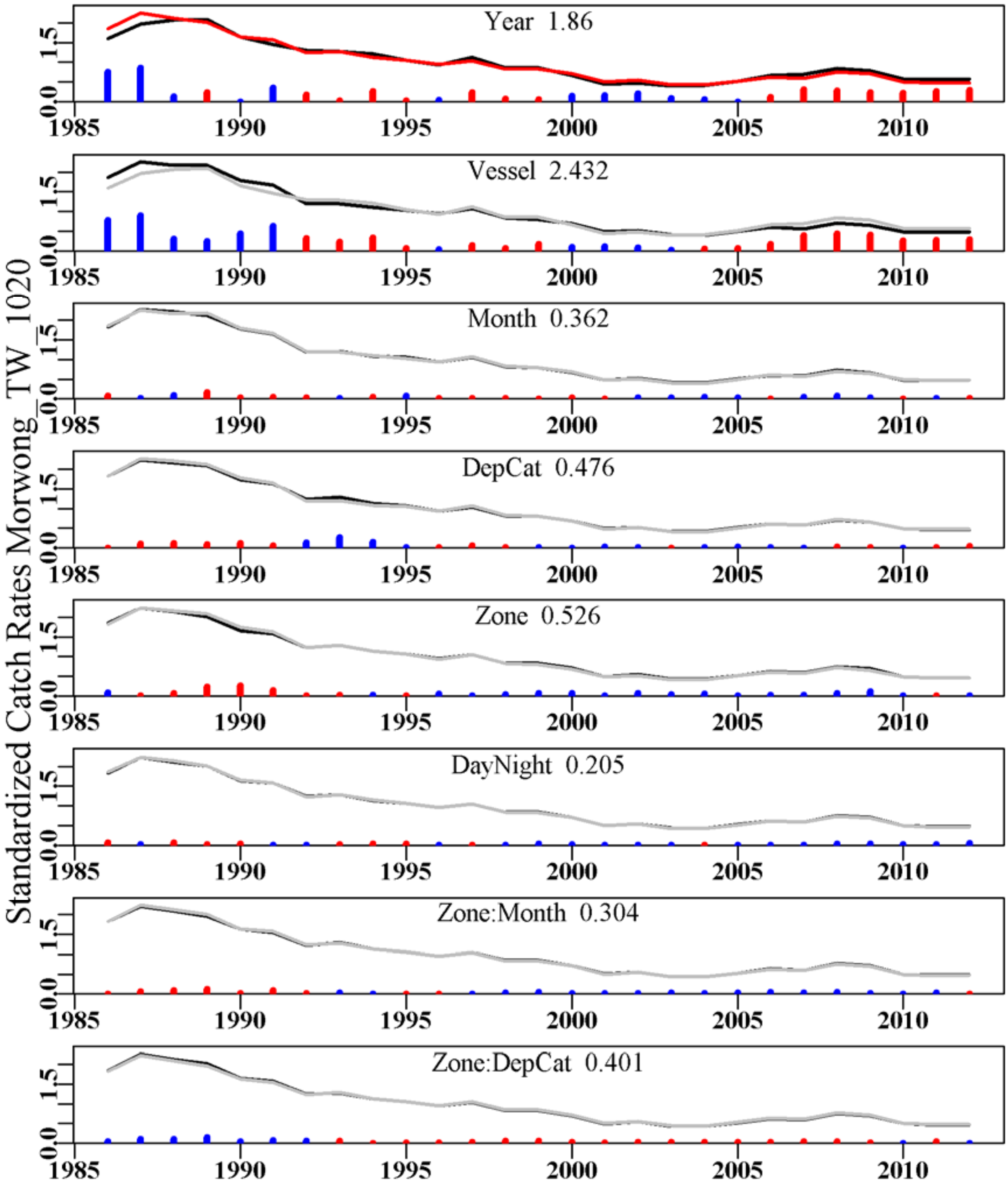



Figure 18.19. The relative influence of each factor used on the final trend in the optimal standardization for Jackass Morwong in Zones 10 – 20. The top graph depicts the geometric mean (the black line) and the optimum model (the red line). The difference between them is illustrated by the vertical bars 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.

### 18.4.6 Jackass Morwong Z30 (MOR – 37377003 N. macropterus)

Only data from zone 30 were used, depths between 70 and 300 m taken by trawl.

Table 18.18. Jackass Morwong from zone 30 in depths 70 – 300m by trawl. Total Catch is the total reported in the database, Records is the number of records used in the analysis, CatchT is the reported catch in the area and depth used in the analysis, and Vessels relates to all vessels used in the analysis. Geomean is the geometric mean of catch rates (kg/hr). Month:DepCat is the optimum model and StDev is the standard deviation relating to the data in the optimum model.

| Year | TotCatch | Records | CatchT | Vessels | GeoMean | Month:DepC | StDev |
|---|---|---|---|---|---|---|---|
| 1986 | 982.811 | 69 | 29.887 | 6 | 52.3193 | 1.7824 | 0.0000 |
| 1987 | 1087.450 | 210 | 57.476 | 13 | 45.8807 | 1.8363 | 0.1774 |
| 1988 | 1481.882 | 283 | 207.935 | 13 | 90.9064 | 2.5434 | 0.1721 |
| 1989 | 1659.362 | 687 | 475.039 | 19 | 125.0173 | 3.2012 | 0.1653 |
| 1990 | 1000.682 | 386 | 148.857 | 26 | 64.6762 | 2.2250 | 0.1661 |
| 1991 | 1127.911 | 427 | 189.534 | 29 | 68.3860 | 1.4313 | 0.1644 |
| 1992 | 755.788 | 335 | 106.819 | 18 | 50.3448 | 1.5121 | 0.1692 |
| 1993 | 1012.730 | 1042 | 325.873 | 27 | 49.6567 | 1.2018 | 0.1592 |
| 1994 | 818.025 | 762 | 180.185 | 22 | 40.3412 | 0.8330 | 0.1602 |
| 1995 | 789.528 | 826 | 185.282 | 19 | 36.4017 | 0.8056 | 0.1611 |
| 1996 | 827.151 | 890 | 161.402 | 19 | 29.4500 | 0.8022 | 0.1602 |
| 1997 | 1060.409 | 940 | 202.389 | 15 | 32.4284 | 0.9044 | 0.1595 |
| 1998 | 838.174 | 772 | 191.733 | 15 | 38.4649 | 0.8725 | 0.1603 |
| 1999 | 932.828 | 855 | 246.913 | 17 | 46.7614 | 1.0366 | 0.1606 |
| 2000 | 866.393 | 552 | 123.785 | 23 | 30.7755 | 0.7016 | 0.1625 |
| 2001 | 781.582 | 796 | 108.097 | 19 | 16.1559 | 0.4677 | 0.1594 |
| 2002 | 798.666 | 1044 | 108.944 | 15 | 13.9509 | 0.4161 | 0.1591 |
| 2003 | 758.467 | 1126 | 187.053 | 19 | 20.4814 | 0.5830 | 0.1582 |
| 2004 | 764.786 | 1500 | 201.278 | 15 | 18.1516 | 0.4423 | 0.1575 |
| 2005 | 784.116 | 1159 | 137.710 | 17 | 12.3142 | 0.3197 | 0.1587 |
| 2006 | 806.510 | 1127 | 154.482 | 14 | 17.6164 | 0.4018 | 0.1593 |
| 2007 | 601.674 | 714 | 111.625 | 8 | 22.5650 | 0.5578 | 0.1616 |
| 2008 | 691.699 | 768 | 119.020 | 9 | 24.1797 | 0.5880 | 0.1614 |
| 2009 | 448.242 | 463 | 54.343 | 10 | 16.5669 | 0.4215 | 0.1650 |
| 2010 | 356.916 | 372 | 58.189 | 9 | 19.1085 | 0.4350 | 0.1678 |
| 2011 | 377.016 | 452 | 48.260 | 8 | 11.9546 | 0.2903 | 0.1655 |
| 2012 | 333.477 | 561 | 92.494 | 8 | 16.4181 | 0.3873 | 0.1640 |

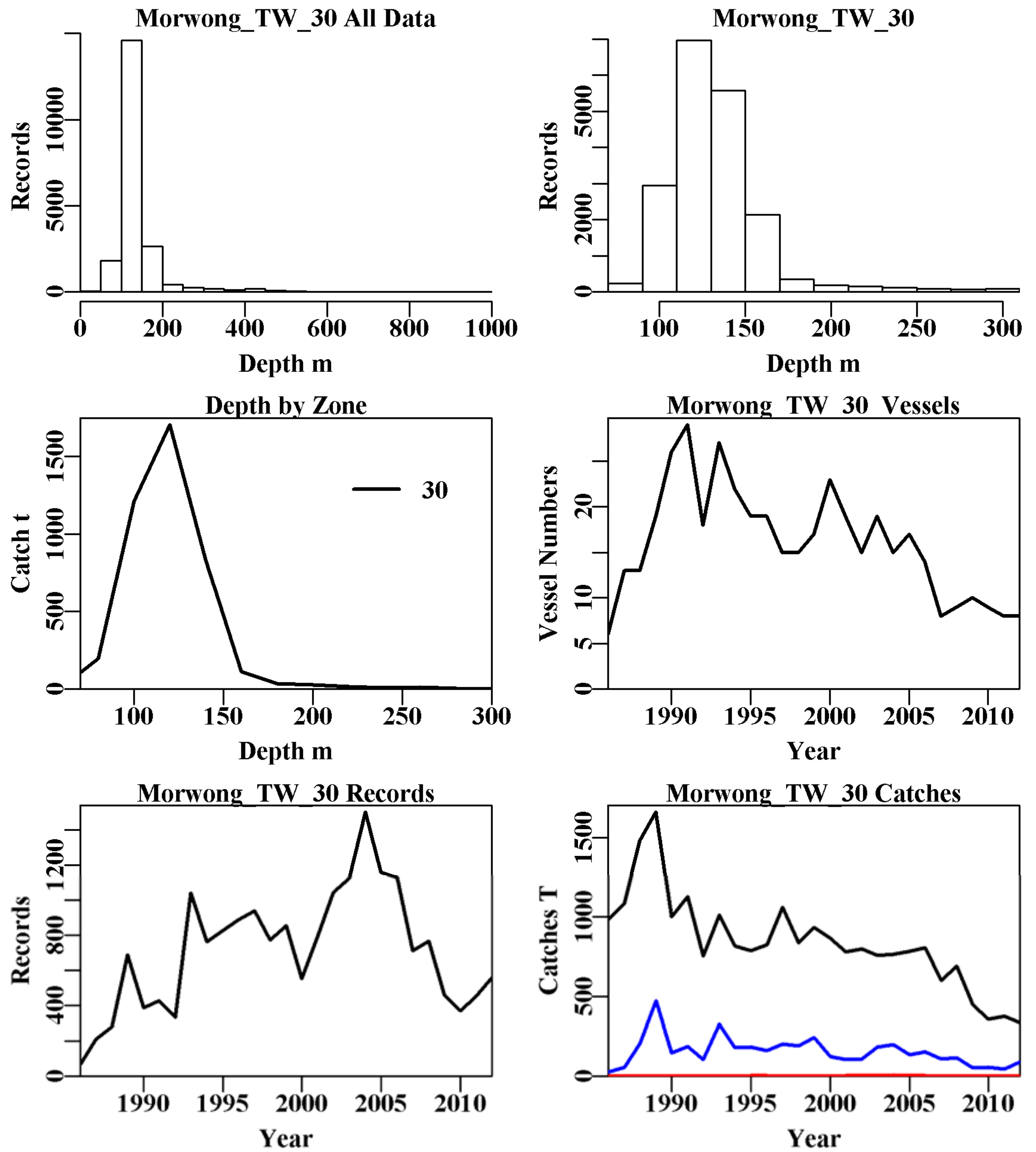



Figure 18.20. Jackass Morwong from zone 30 in depths 70 – 300m by trawl. The top left is the depth distribution of all records reporting Jackass Morwong, the top right graph depicts the depth distribution of shots containing Jackass Morwong from zone 30 in depths 70 – 300m by trawl. The middle left diagram depicts the distribution of catch by depth within zone 30, the middle right hand graph depicts the number of vessels through time. The bottom left reflects the number of records used in analysis, and bottom right is the Jackass Morwong catches (top line, black is total catches, middle line, blue, are those used in the analysis, and bottom, red, are catches < 30Kg).

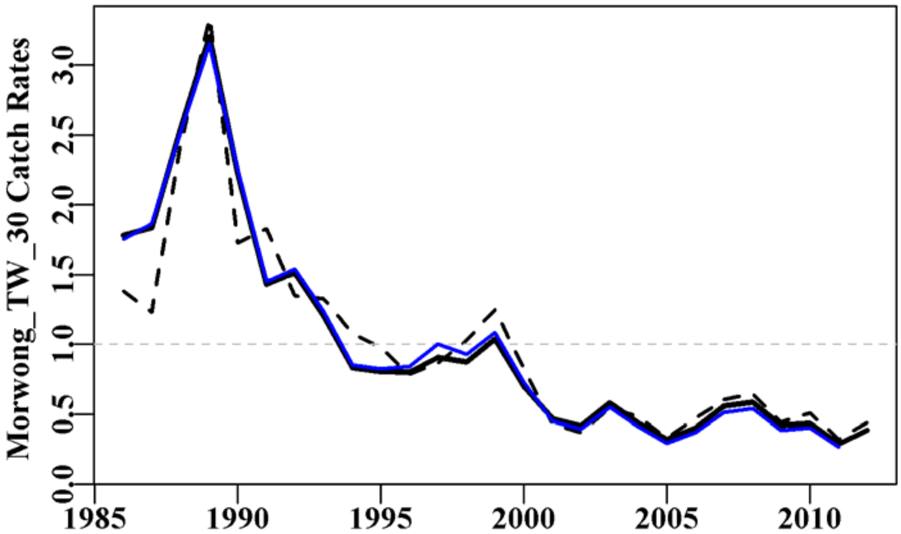



Figure 18.21. Jackass Morwong from zone 30 in depths 70 – 300m by trawl. The dashed black line represents the geometric mean catch rate and the solid black line the standardized catch rates. The graph standardizes catch rates relative to the mean of the standardized catch rates.

Table 18.19. Jackass Morwong from zone 30 in depths 70 – 300m 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 18.20. Jackass Morwong from zone 30 in depths 70 – 300m by trawl. Model selection criteria, including the AIC, the adjusted $r^2$ and the change in adjusted $r^2$. The optimum was model Month:DepCat.

| | Year | Month | Vessel | DepC | DN | DN:Mth | **Mth:DepC** | DN:DepC |
|---|---|---|---|---|---|---|---|---|
| AIC | 9601 | 7753 | 6632 | 6048 | 5906 | 5859 | **5836** | 5944 |
| RSS | 31501 | 28565 | 26683 | 25622 | 25423 | 25271 | **24977** | 25377 |
| MSS | 6432 | 9367 | 11250 | 12310 | 12510 | 12662 | **12955** | 12555 |
| Nobs | 19118 | 19118 | 19118 | 18879 | 18879 | 18879 | **18879** | 18879 |
| Npars | 27 | 38 | 129 | 141 | 144 | 177 | **276** | 180 |
| adj_r2 | 16.843 | 24.548 | 29.183 | 31.948 | 32.467 | 32.753 | **33.180** | 32.458 |
| %Change | 0.000 | 7.706 | 4.635 | 2.765 | 0.519 | 0.286 | **0.428** | -0.722 |

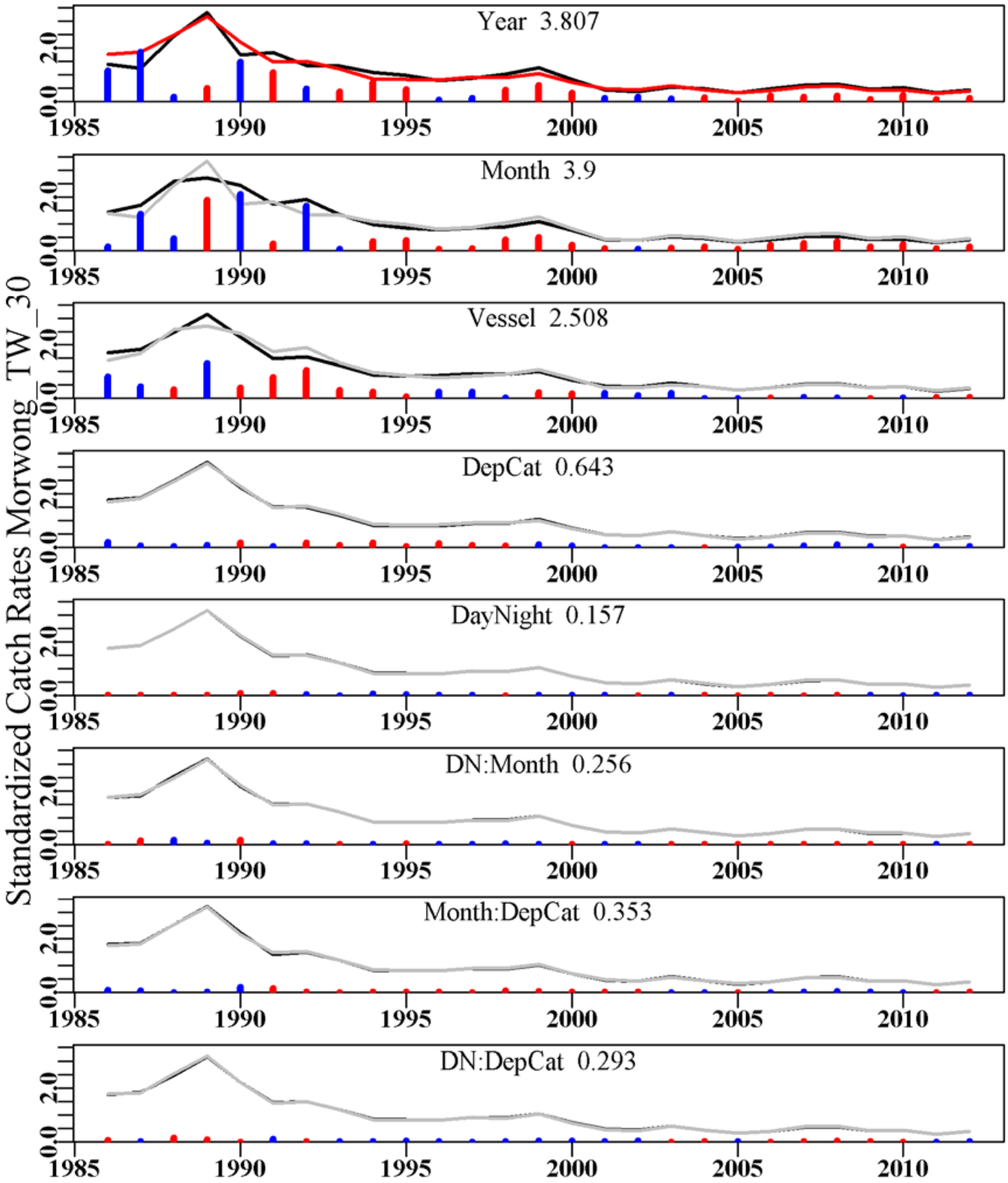



Figure 18.22. The relative influence of each factor used on the final trend in the optimal standardization for Jackass Morwong in Zone 30. The top graph depicts the geometric mean (the black line) and the optimum model (the red line). The difference between them is illustrated by the vertical bars with 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.

### *18.4.7 Jackass Morwong Z4050 OT (MOR – 37377003 N. macropterus)*

The data restrictions used in selecting the data for analysis were, depths between 70 and 360 m.

Table 18.21. Jackass Morwong from zones 40 and 50 in depths 70 – 360m by trawl. Total Catch is the total reported in the database, Records is the number of records used in the analysis, CatchT is the reported catch in the area and depth used in the analysis, and Vessels relates to all vessels used in the analysis. Geomean is the geometric mean of catch rates (kg/hr). Zone:Mth is the optimum model and StDev is the standard deviation relating to the data in the optimum model.

| Year | TotCatch | Records | CatchT | Vessels | GeoMean | Zone:Mth | StDev |
|---|---|---|---|---|---|---|---|
| 1986 | 982.811 | 551 | 149.261 | 19 | 40.7569 | 1.8892 | 0.0000 |
| 1987 | 1087.450 | 350 | 58.464 | 21 | 24.4475 | 1.4796 | 0.0873 |
| 1988 | 1481.882 | 402 | 65.444 | 19 | 32.2567 | 2.2158 | 0.0875 |
| 1989 | 1659.362 | 346 | 83.203 | 21 | 32.2213 | 1.5988 | 0.0923 |
| 1990 | 1000.682 | 412 | 80.657 | 22 | 28.9610 | 1.6166 | 0.0937 |
| 1991 | 1127.911 | 281 | 40.380 | 26 | 18.6097 | 1.1066 | 0.0979 |
| 1992 | 755.788 | 252 | 28.878 | 14 | 15.3915 | 0.8955 | 0.1008 |
| 1993 | 1012.730 | 248 | 24.971 | 17 | 15.5454 | 0.8713 | 0.1020 |
| 1994 | 818.025 | 312 | 22.679 | 16 | 14.6606 | 0.8407 | 0.0953 |
| 1995 | 789.528 | 295 | 77.615 | 17 | 21.5262 | 0.8822 | 0.0963 |
| 1996 | 827.151 | 346 | 37.071 | 17 | 15.3414 | 0.9678 | 0.0935 |
| 1997 | 1060.409 | 489 | 53.851 | 20 | 12.8372 | 0.7684 | 0.0869 |
| 1998 | 838.174 | 267 | 54.630 | 19 | 14.8359 | 0.8109 | 0.0989 |
| 1999 | 932.828 | 383 | 77.235 | 17 | 15.5951 | 0.7358 | 0.0916 |
| 2000 | 866.393 | 429 | 118.868 | 26 | 22.5254 | 1.0370 | 0.0919 |
| 2001 | 781.582 | 914 | 273.953 | 25 | 34.2135 | 1.1113 | 0.0809 |
| 2002 | 798.666 | 860 | 251.749 | 22 | 33.1596 | 1.0946 | 0.0813 |
| 2003 | 758.467 | 655 | 171.726 | 24 | 30.9832 | 0.9318 | 0.0846 |
| 2004 | 764.786 | 681 | 176.677 | 25 | 30.6678 | 1.0005 | 0.0836 |
| 2005 | 784.116 | 722 | 190.703 | 21 | 28.0502 | 1.0810 | 0.0830 |
| 2006 | 806.510 | 818 | 183.204 | 19 | 21.6176 | 0.8697 | 0.0821 |
| 2007 | 601.674 | 594 | 115.405 | 15 | 19.7196 | 0.7116 | 0.0850 |
| 2008 | 691.699 | 473 | 101.945 | 16 | 24.9534 | 0.7162 | 0.0881 |
| 2009 | 448.242 | 413 | 59.154 | 13 | 14.8023 | 0.5708 | 0.0911 |
| 2010 | 356.916 | 411 | 38.336 | 13 | 10.0135 | 0.4198 | 0.0907 |
| 2011 | 377.016 | 622 | 82.877 | 14 | 12.6506 | 0.4429 | 0.0859 |
| 2012 | 333.477 | 345 | 34.722 | 14 | 10.2040 | 0.3336 | 0.0943 |

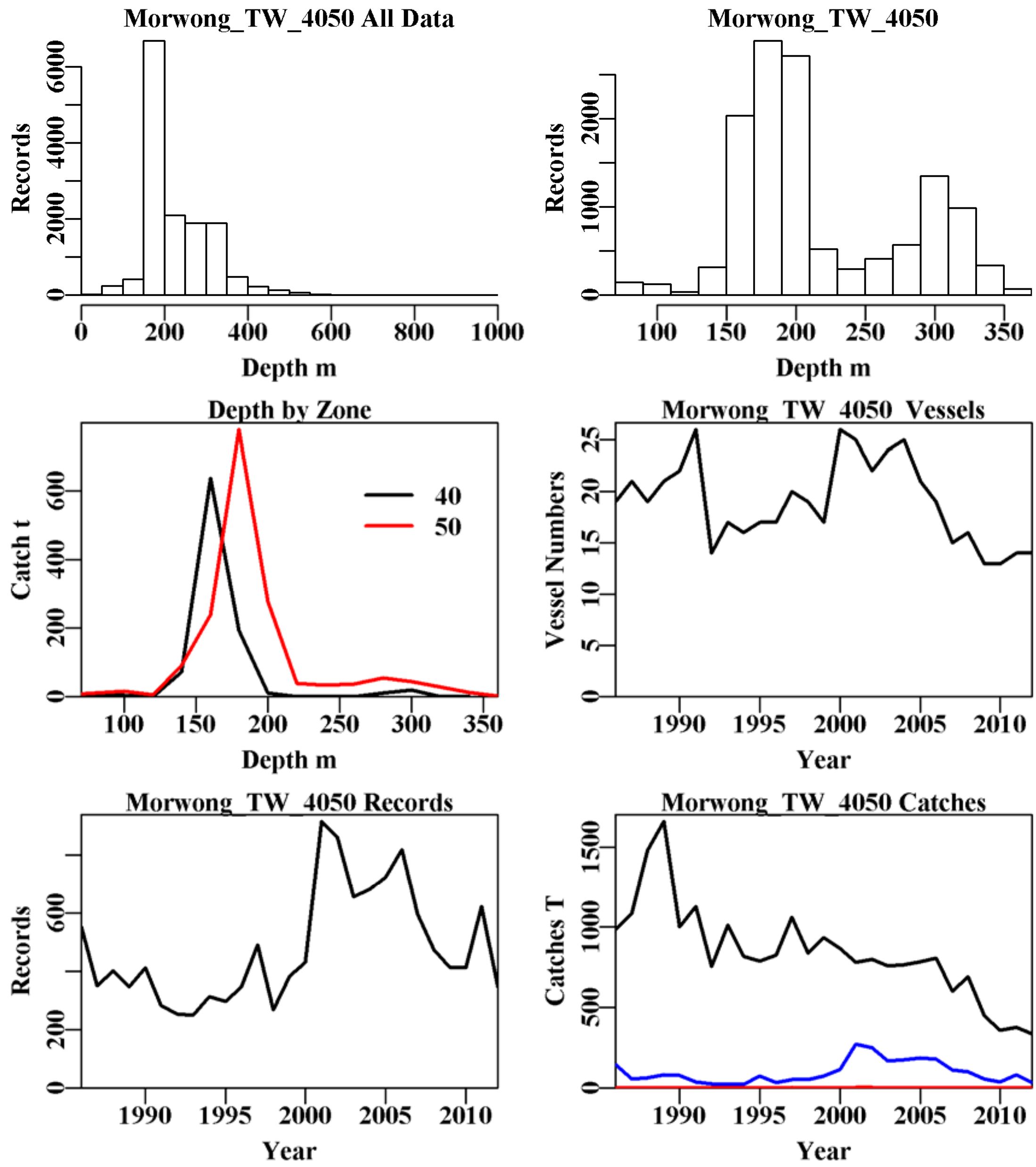



Figure 18.23. Jackass Morwong from zones 40 and 50 in depths 70 – 360m by trawl. The top left is the depth distribution of all records reporting Jackass Morwong, the top right graph depicts the depth distribution of shots containing Jackass Morwong from zone 40 and 50 in depths 70 – 360m by trawl. The middle left diagram depicts the distribution of catch by depth within zone40 and 50 (50 is top red line), the middle right hand graph depicts the number of vessels through time. The bottom left reflects the number of records used in analysis, and bottom right is the Jackass Morwong catches (top line, black is total catches, middle line, blue, are those used in the analysis, and bottom, red, are catches < 30Kg).

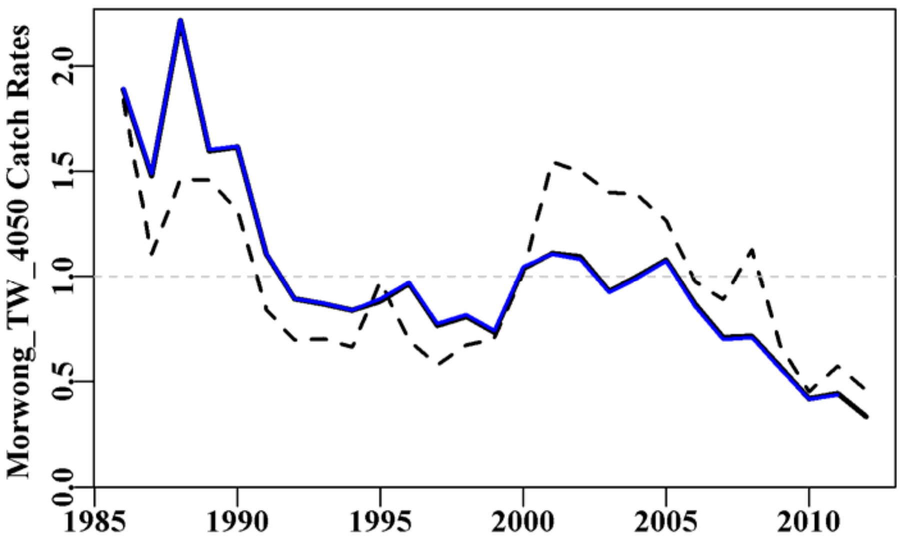



Figure 18.24. Jackass Morwong from zones 40 and 50 in depths 70 – 360m by trawl. The dashed black line represents the geometric mean catch rate and the solid black line the standardized catch rates. The graph standardizes catch rates relative to the mean of the standardized catch rates.

Table 18.22. Jackass Morwong from zones 40 and 50 in depths 70 – 360m 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 18.23. Jackass Morwong from zones 40 and 50 in depths 70 – 360m by trawl. Model selection criteria, including the AIC, the adjusted $r^2$ and the change in adjusted $r^2$.The optimum was model 7.

| | Year | DepCat | Month | Vessel | DayNight | Zone | **Zone:Mth** | Zone:DepC |
|---|---|---|---|---|---|---|---|---|
| AIC | 7635 | 5345 | 4160 | 3556 | 3478 | 3389 | **3246** | 3285 |
| RSS | 22946 | 18985 | 17229 | 16194 | 16086 | 15968 | **15758** | 15797 |
| MSS | 1783 | 5744 | 7500 | 8535 | 8643 | 8761 | **8971** | 8932 |
| Nobs | 12525 | 12433 | 12433 | 12433 | 12433 | 12433 | **12433** | 12433 |
| Npars | 26 | 41 | 52 | 135 | 138 | 139 | **150** | 154 |
| adj_r2 | 7.025 | 22.979 | 30.041 | 33.800 | 34.228 | 34.702 | **35.505** | 35.323 |
| %Change | 0.000 | 15.954 | 7.062 | 3.759 | 0.428 | 0.474 | **0.803** | -0.182 |

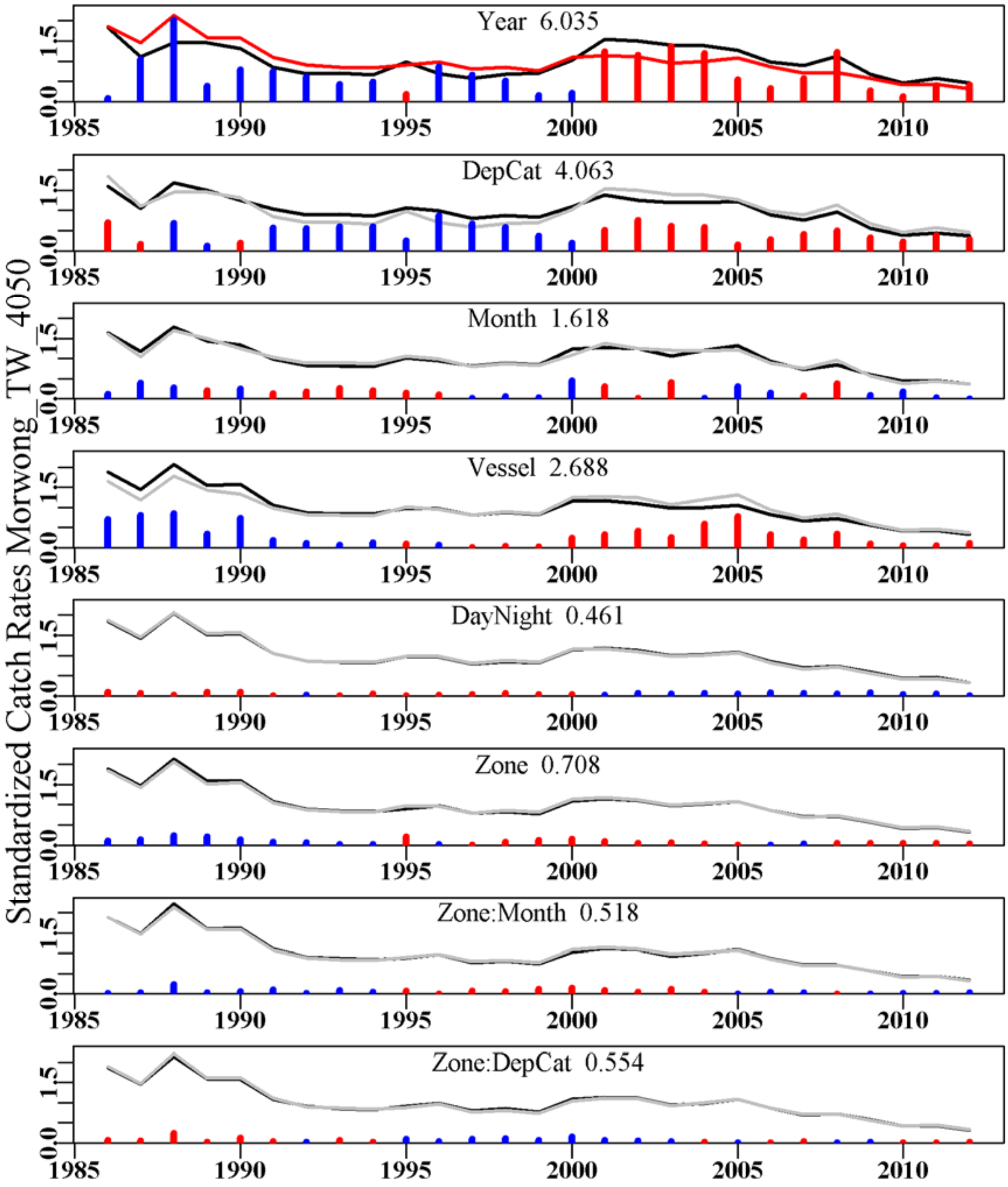



Figure 18.25. The relative influence of each factor used on the final trend in the optimal standardization for Jackass Morwong in Zones 40 – 50. The top graph depicts the geometric mean (the black line) and the optimum model (the red line). The difference between them is illustrated by the vertical bars 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.

### *18.4.8 Jackass Morwong Z4050 OT (in < 250 m depth)*

The data restrictions used in selecting the data for analysis were, depths between 70 and 250 m. This was a special request to determine the effect of the bump of catches between 250 and 360 m. However, doing this removes about 3,400 records from consideration and the fishery has only taken small amounts of catch up until about 2001 after which catches have declined markedly, so it seems possible that any decline in CPUE is being confounded by efforts to avoid catch Jackass Morwong.

Table 18.24. Jackass Morwong from zones 40 and 50 in depths 70 – 250m by trawl. Total Catch is the total reported in the database, Records is the number of records used in the analysis, CatchT is the reported catch in the area and depth used in the analysis, and Vessels relates to all vessels used in the analysis. Geomean is the geometric mean of catch rates (kg/hr). Zone:Mth is the optimum model and StDev is the standard deviation relating to the data in the optimum model.

| Year | TotCatch | Records | CatchT | Vessels | GeoMean | Zone:Mth | StDev |
|---|---|---|---|---|---|---|---|
| 1986 | 982.811 | 441 | 135.545 | 19 | 49.3798 | 1.8616 | 0.0000 |
| 1987 | 1087.450 | 257 | 52.140 | 20 | 32.6410 | 1.4896 | 0.1018 |
| 1988 | 1481.882 | 215 | 48.123 | 17 | 40.4386 | 1.5559 | 0.1111 |
| 1989 | 1659.362 | 214 | 76.518 | 21 | 51.8712 | 1.7655 | 0.1149 |
| 1990 | 1000.682 | 300 | 75.857 | 22 | 43.5691 | 1.8653 | 0.1113 |
| 1991 | 1127.911 | 141 | 29.892 | 23 | 32.8280 | 0.9821 | 0.1297 |
| 1992 | 755.788 | 116 | 21.881 | 14 | 23.0810 | 0.6850 | 0.1368 |
| 1993 | 1012.730 | 124 | 19.139 | 15 | 25.8778 | 0.7715 | 0.1335 |
| 1994 | 818.025 | 159 | 15.761 | 15 | 21.7099 | 0.7900 | 0.1224 |
| 1995 | 789.528 | 176 | 72.990 | 17 | 42.3529 | 1.0772 | 0.1183 |
| 1996 | 827.151 | 144 | 28.915 | 16 | 27.3737 | 0.9200 | 0.1259 |
| 1997 | 1060.409 | 206 | 45.296 | 18 | 24.6520 | 0.8443 | 0.1126 |
| 1998 | 838.174 | 130 | 50.245 | 16 | 30.3815 | 0.9320 | 0.1286 |
| 1999 | 932.828 | 209 | 57.680 | 15 | 25.6370 | 0.9416 | 0.1126 |
| 2000 | 866.393 | 264 | 113.242 | 23 | 38.0129 | 1.2375 | 0.1109 |
| 2001 | 781.582 | 719 | 260.825 | 23 | 46.2560 | 1.1839 | 0.0916 |
| 2002 | 798.666 | 685 | 244.364 | 22 | 46.0736 | 1.1053 | 0.0915 |
| 2003 | 758.467 | 507 | 163.474 | 24 | 42.9567 | 0.9263 | 0.0962 |
| 2004 | 764.786 | 536 | 157.248 | 23 | 35.0950 | 0.9491 | 0.0943 |
| 2005 | 784.116 | 540 | 174.706 | 21 | 35.8926 | 1.1190 | 0.0936 |
| 2006 | 806.510 | 663 | 170.238 | 19 | 25.6084 | 0.8827 | 0.0916 |
| 2007 | 601.674 | 497 | 107.175 | 15 | 22.1800 | 0.7178 | 0.0944 |
| 2008 | 691.699 | 393 | 95.471 | 16 | 29.4112 | 0.6982 | 0.0981 |
| 2009 | 448.242 | 356 | 56.737 | 13 | 17.3238 | 0.5833 | 0.1010 |
| 2010 | 356.916 | 338 | 34.851 | 13 | 10.4574 | 0.3994 | 0.1018 |
| 2011 | 377.016 | 541 | 78.345 | 14 | 13.8741 | 0.4222 | 0.0954 |
| 2012 | 333.477 | 284 | 32.301 | 14 | 11.6905 | 0.2935 | 0.1054 |

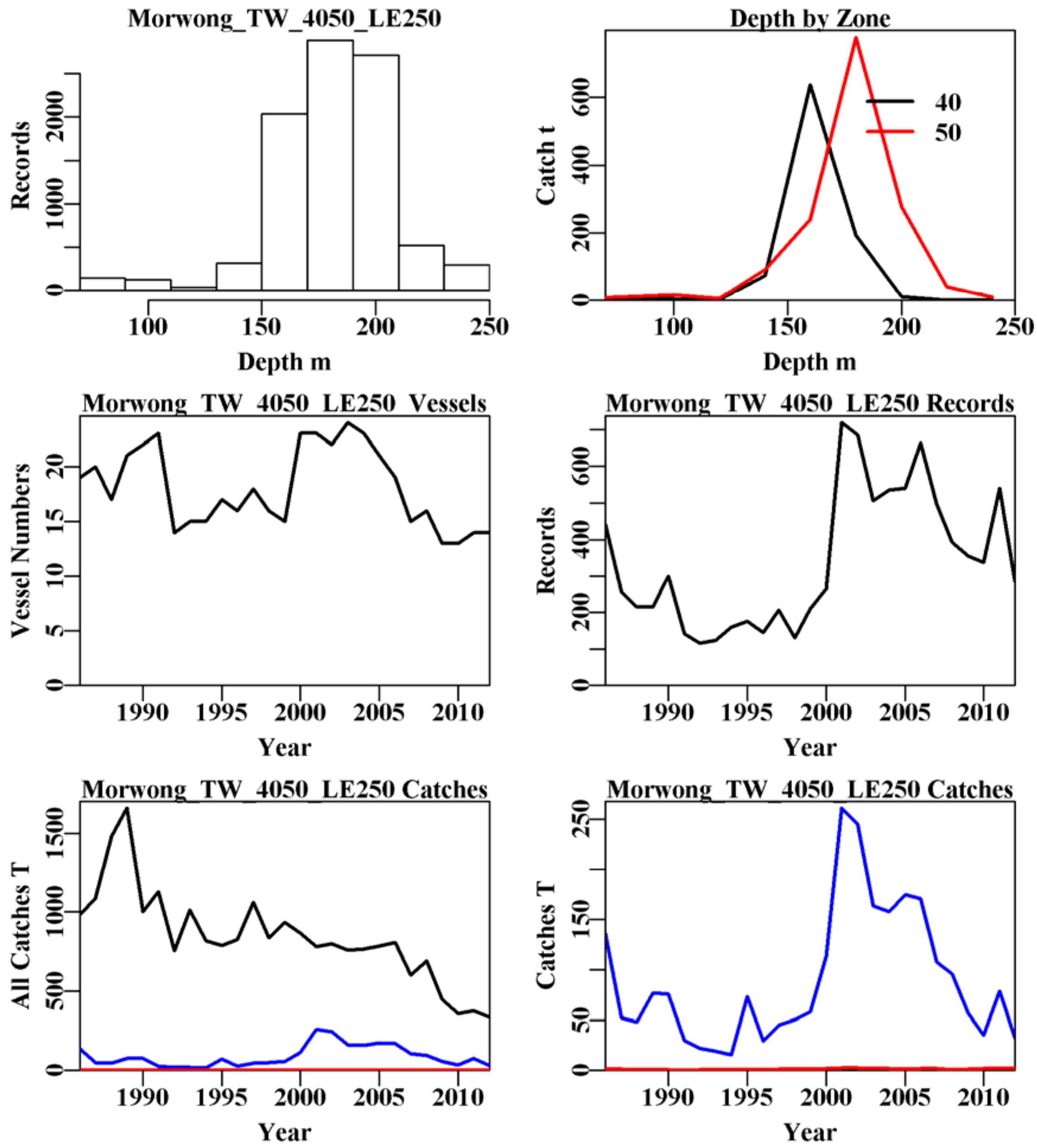



Figure 18.26. Jackass Morwong from zones 40 and 50 in depths 70 – 360m by trawl. The top left is the depth distribution of all records reporting Jackass Morwong, the top right graph depicts the depth distribution of shots containing Jackass Morwong from zone 40 and 50 in depths 70 – 360m by trawl. The middle left diagram depicts the distribution of catch by depth within zone40 and 50 (50 is top red line), the middle right hand graph depicts the number of vessels through time. The bottom left reflects the number of records used in analysis, and bottom right is the Jackass Morwong catches (top line, black is total catches, middle line, blue, are those used in the analysis, and bottom, red, are catches < 30Kg).

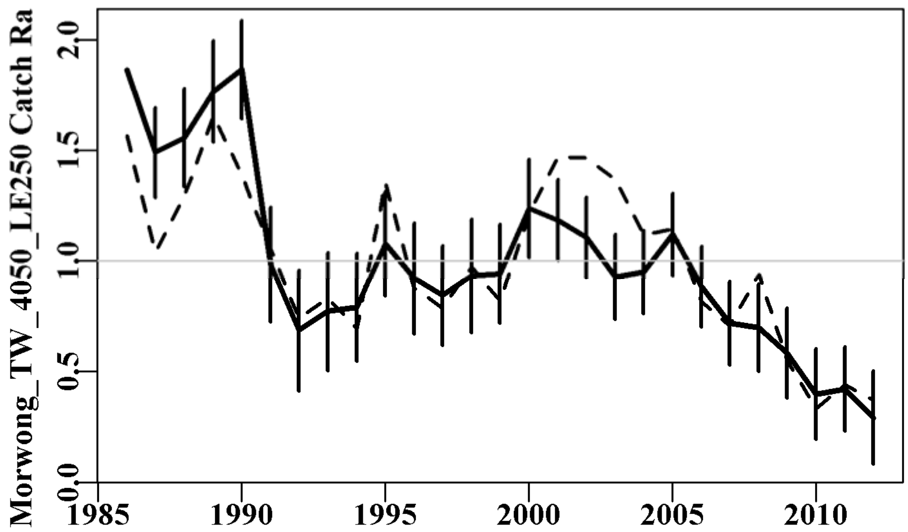



Figure 18.27. Jackass Morwong from zones 40 and 50 in depths 70 – 360m by trawl. The dashed black line represents the geometric mean catch rate and the solid black line the standardized catch rates. The graph standardizes catch rates relative to the mean of the standardized catch rates.

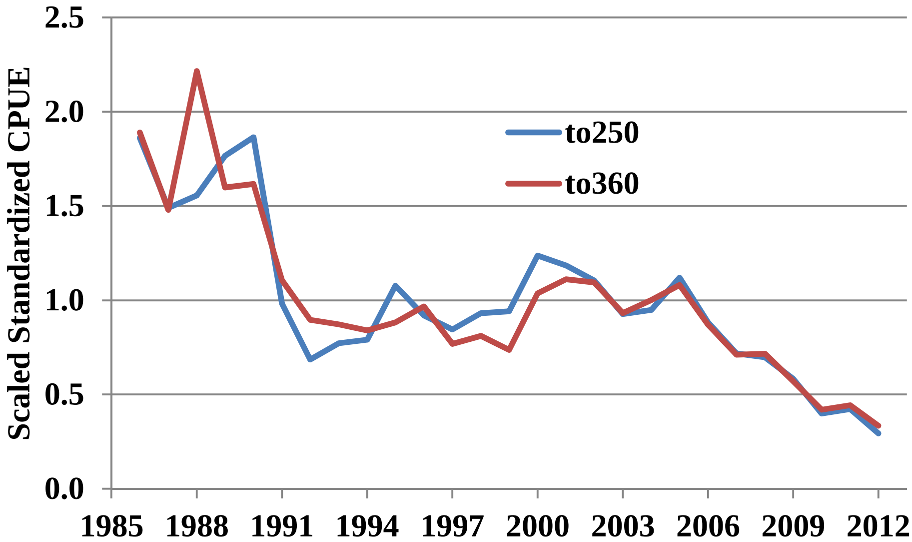



Figure 18.28. A comparison of the two standardizations, one excluding data from deeper than 250 m the other including data to 360 meters.

Table 18.25. Jackass Morwong from zones 40 and 50 in depths 70 – 360m 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 18.26. Jackass Morwong from zones 40 and 50 in depths 70 – 360m by trawl. Model selection criteria, including the AIC, the adjusted $r^2$ and the change in adjusted $r^2$.The optimum was model 7.

| | Year | DepCat | Month | Vessel | DayNight | Zone | **Zone:Mth** | Zone:DepC |
|---|---|---|---|---|---|---|---|---|
| AIC | 5461 | 3931 | 3349 | 2865 | 2722 | 2699 | **2432** | 2659 |
| RSS | 16526 | 13949 | 12854 | 12077 | 11880 | 11848 | **11476** | 11772 |
| MSS | 1790 | 4368 | 5462 | 6240 | 6437 | 6469 | **6841** | 6545 |
| Nobs | 9155 | 9155 | 9155 | 9059 | 9059 | 9059 | **9059** | 9059 |
| Npars | 27 | 38 | 121 | 130 | 133 | 134 | **145** | 143 |
| adj_r2 | 9.518 | 23.536 | 28.889 | 33.114 | 34.183 | 34.351 | **36.335** | 34.707 |
| %Change | | 14.019 | 5.353 | 4.225 | 1.069 | 0.168 | **1.984** | 0.356 |

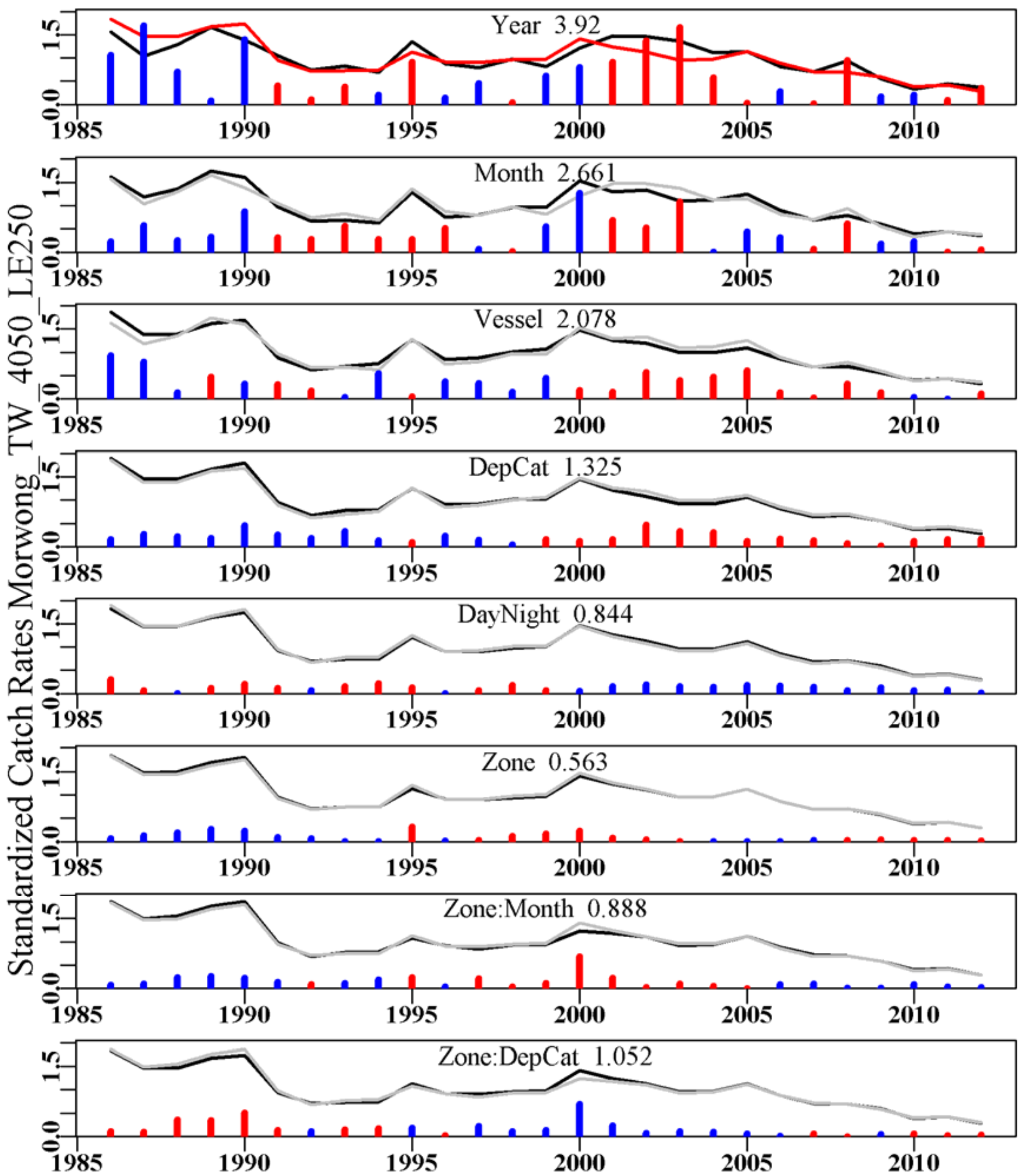



Figure 18.29. The relative influence of each factor used on the final trend in the optimal standardization for Jackass Morwong in Zones 40 – 50. The top graph depicts the geometric mean (the black line) and the optimum model (the red line). The difference between them is illustrated by the vertical bars 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.

### *18.4.9 Flathead Trawl (FLT – 37296001 – Neoplatycephalus richardsoni)*

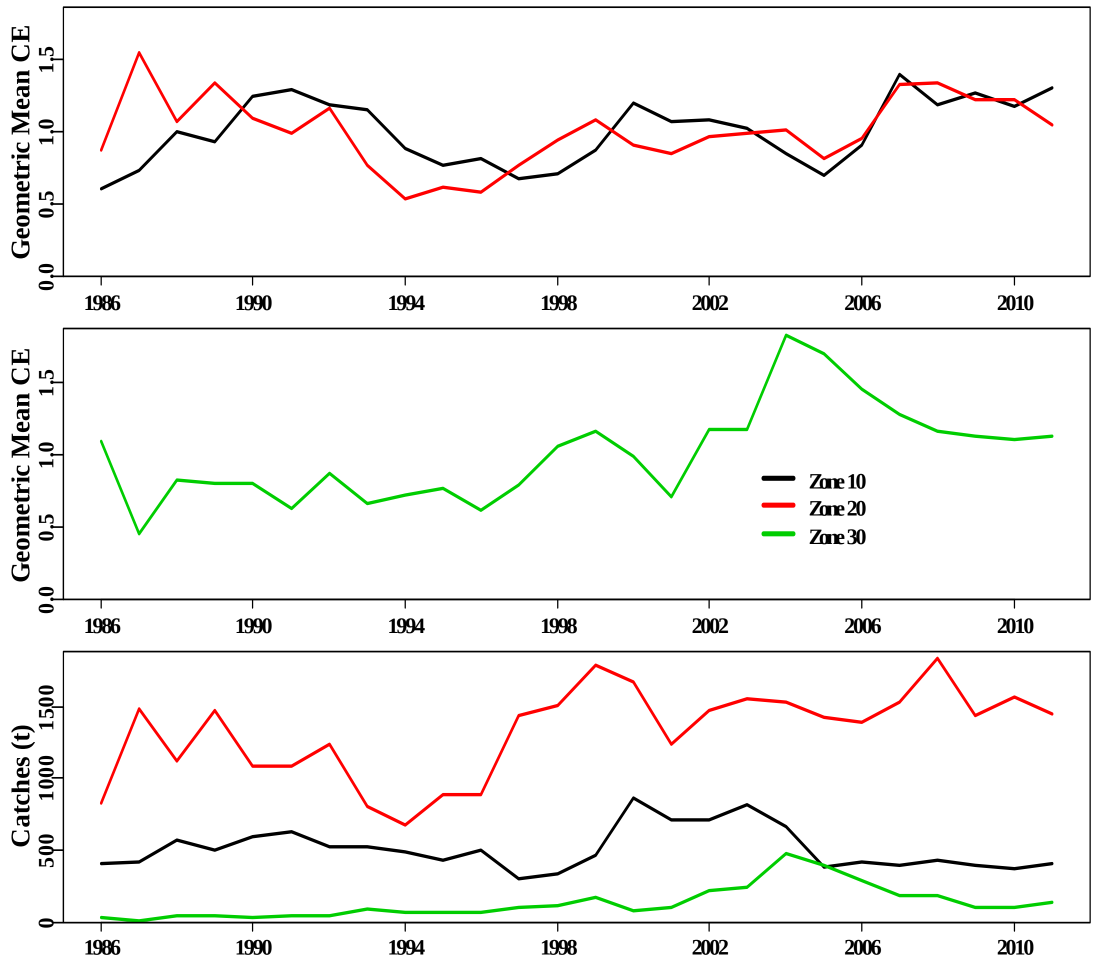



Figure 18.30. The trends in catches and geometric mean catch rates for flathead as taken by trawl in Zones 10 to 30. The catch rate trends in 10 and 20 are similar to each other but are different from that expressed in zone 30. For this reason, zones 10 and 20 are standardized separately from Zone 30.

### *18.4.10 Flathead Trawl Z1020(FLT – 37296001 – N. richardsoni)*

Only data from zones 10 and 20 were used, depths less than 400 m.

Table 18.27. Flathead from zones 10 and 20 in depths 0 – 400m by trawl. Total Catch is the total reported in the database, Records was the number of records used in the analysis, CatchT is the reported catch in the area and depth used in the analysis, and Vessels relates to all vessels used in the analysis. Geomean is the geometric mean of catch rates (kg/hr). Zone:DepCat is the optimum model and StDev is the standard deviation relating to the data in the optimum model.

| Year | TotCatch | Records | CatchT | Vessels | GeoMean | Zone:DepC | StDev |
|---|---|---|---|---|---|---|---|
| 1986 | 1889.485 | 10196 | 963.031 | 95 | 16.7357 | 0.7988 | 0.0000 |
| 1987 | 2458.130 | 8104 | 1008.332 | 86 | 20.4621 | 1.0669 | 0.0160 |
| 1988 | 2467.161 | 9175 | 1171.699 | 86 | 23.7988 | 1.1668 | 0.0158 |
| 1989 | 2587.762 | 8841 | 1210.472 | 74 | 23.9908 | 1.1636 | 0.0159 |
| 1990 | 2030.892 | 7765 | 1221.459 | 64 | 30.1854 | 1.3835 | 0.0168 |
| 1991 | 2207.959 | 7797 | 1145.652 | 57 | 28.7154 | 1.3128 | 0.0168 |
| 1992 | 2355.693 | 6810 | 871.934 | 53 | 23.8898 | 1.0246 | 0.0175 |
| 1993 | 1862.912 | 8782 | 998.146 | 58 | 23.8001 | 1.0470 | 0.0166 |
| 1994 | 1708.187 | 10280 | 902.906 | 56 | 17.9798 | 0.7592 | 0.0160 |
| 1995 | 1799.980 | 10305 | 994.134 | 54 | 18.0790 | 0.8038 | 0.0159 |
| 1996 | 1878.592 | 11089 | 958.779 | 59 | 16.4549 | 0.7163 | 0.0158 |
| 1997 | 2355.431 | 10395 | 997.137 | 60 | 16.8264 | 0.7162 | 0.0162 |
| 1998 | 2306.328 | 9986 | 999.535 | 52 | 17.7430 | 0.7588 | 0.0162 |
| 1999 | 3117.011 | 10377 | 1129.356 | 57 | 20.4344 | 0.9137 | 0.0160 |
| 2000 | 2944.056 | 13110 | 1696.814 | 60 | 24.4338 | 1.0085 | 0.0155 |
| 2001 | 2596.801 | 11957 | 1375.379 | 53 | 22.3118 | 0.9704 | 0.0157 |
| 2002 | 2874.139 | 12357 | 1444.049 | 49 | 22.8273 | 1.0586 | 0.0157 |
| 2003 | 3224.755 | 12879 | 1593.850 | 52 | 22.5536 | 1.0439 | 0.0155 |
| 2004 | 3215.761 | 12220 | 1343.072 | 52 | 19.7879 | 0.9029 | 0.0157 |
| 2005 | 2841.270 | 10703 | 1154.986 | 49 | 17.7159 | 0.7712 | 0.0162 |
| 2006 | 2582.725 | 9137 | 1148.779 | 46 | 22.2550 | 0.9342 | 0.0167 |
| 2007 | 2646.745 | 6337 | 1076.563 | 25 | 31.3544 | 1.1350 | 0.0184 |
| 2008 | 2910.286 | 7292 | 1330.559 | 27 | 31.6602 | 1.1909 | 0.0178 |
| 2009 | 2460.023 | 6311 | 1060.713 | 26 | 30.0219 | 1.0952 | 0.0185 |
| 2010 | 2495.298 | 6872 | 1124.212 | 25 | 29.4565 | 1.0558 | 0.0181 |
| 2011 | 2465.166 | 6768 | 1096.279 | 24 | 28.4013 | 1.0487 | 0.0182 |
| 2012 | 2780.222 | 6884 | 1162.354 | 25 | 30.4796 | 1.1529 | 0.0180 |

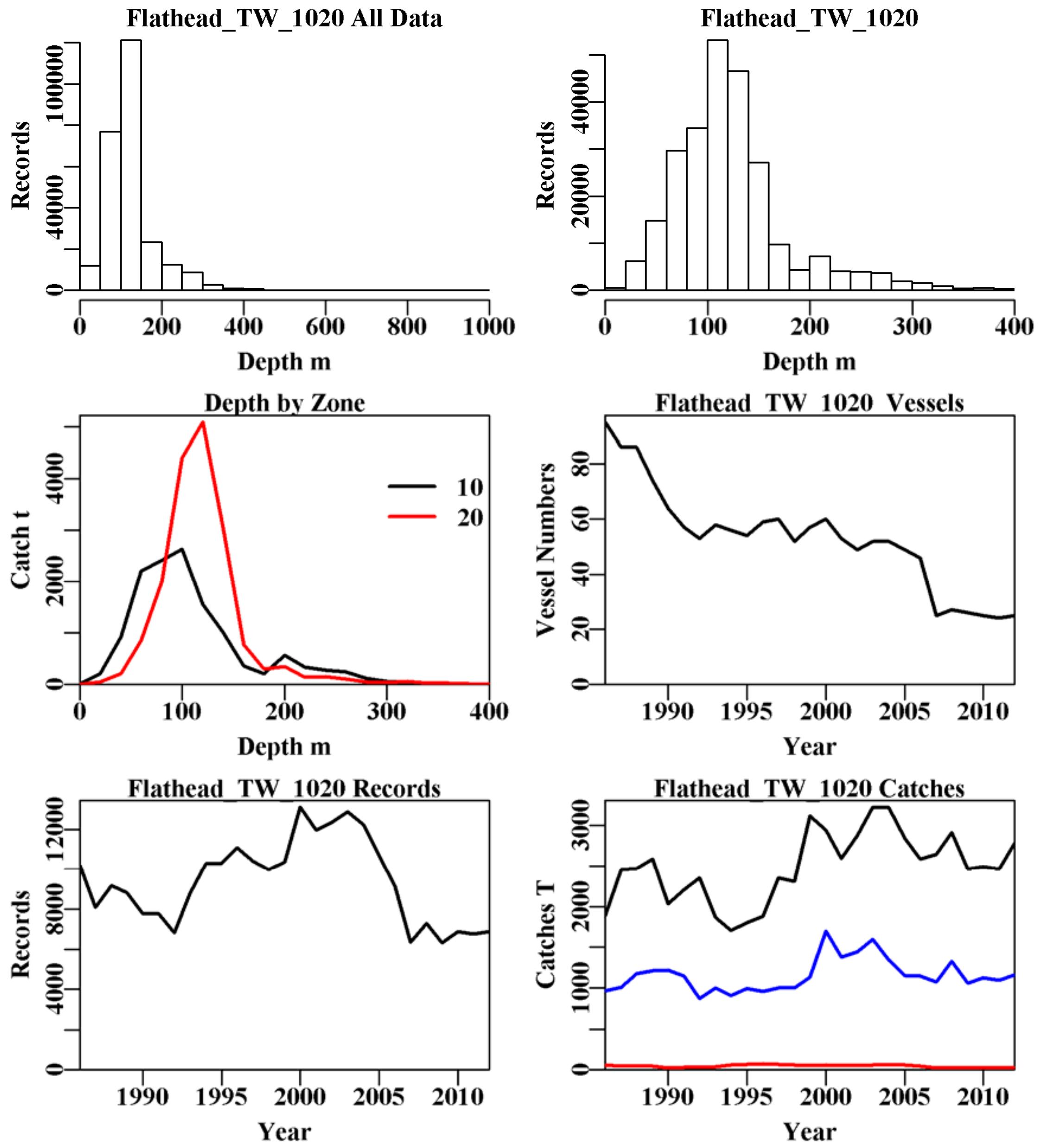



Figure 18.31. Flathead from zones 10 and 20 in depths 0 – 400m by trawl. The top left is the depth distribution of all records reporting Jackass Morwong, the top right graph depicts the depth distribution of shots containing Flathead from zones 10 and 20 in depths 0 – 400m by trawl. The middle left diagram depicts the distribution of catch by depth within zones 10 and 20 (20 is top red line), the middle right hand graph depicts the number of vessels through time. The bottom left reflects the number of records used in analysis, and bottom right is the Flathead catches (top line, black is total catches, middle line, blue, are those used in the analysis, and bottom, red, are catches < 30Kg).

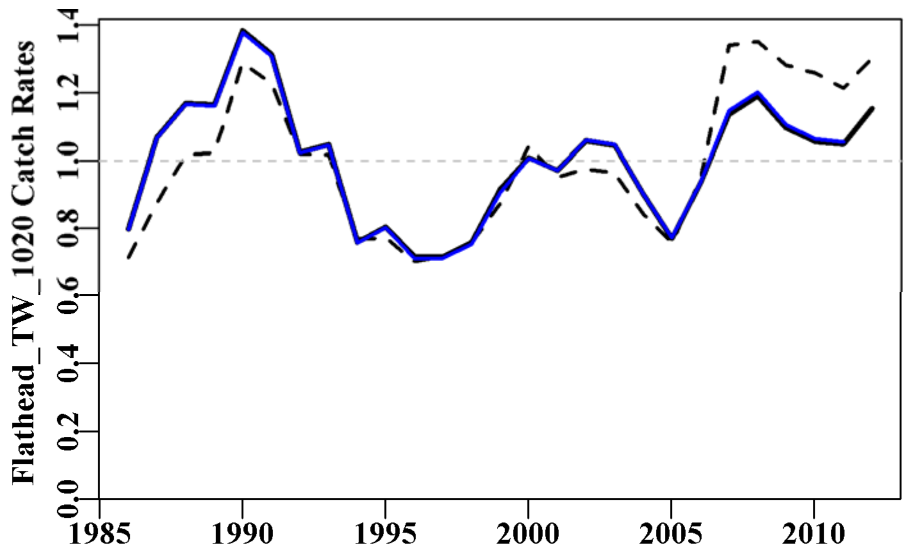



Figure 18.32. Flathead from zones 10 and 20 in depths 0 – 400m by trawl. The dashed black line represents the geometric mean catch rate and the solid black line the standardized catch rates. The graph standardizes catch rates relative to the mean of the standardized catch rates.

Table 18.28. Flathead from zones 10 and 20 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+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 18.29. Flathead from zones 10 and 20 in depths 0 – 400m by trawl. Model selection criteria, including the AIC, the adjusted $r^2$ and the change in adjusted $r^2$. The optimum was model Zone:DepCat.

| | Year | Vessel | DepCat | Month | DayNight | Zone | Zone:Month | **Zone:DepCat** |
|---|---|---|---|---|---|---|---|---|
| AIC | 45657 | 17343 | 9320 | 8467 | 8322 | 8274 | 6343 | **5201** |
| RSS | 302705 | 270236 | 259711 | 258806 | 258650 | 258598 | 256592 | **255407** |
| MSS | 10292 | 42762 | 53287 | 54192 | 54348 | 54399 | 56406 | **57591** |
| Nobs | 252729 | 252729 | 250688 | 250688 | 250688 | 250688 | 250688 | **250688** |
| Npars | 27 | 208 | 228 | 239 | 242 | 243 | 254 | **263** |
| adj_r2 | 3.278 | 13.591 | 16.950 | 17.235 | 17.284 | 17.300 | 17.938 | **18.314** |
| %Change | 0.000 | 10.313 | 3.358 | 0.286 | 0.049 | 0.016 | 0.638 | **0.376** |

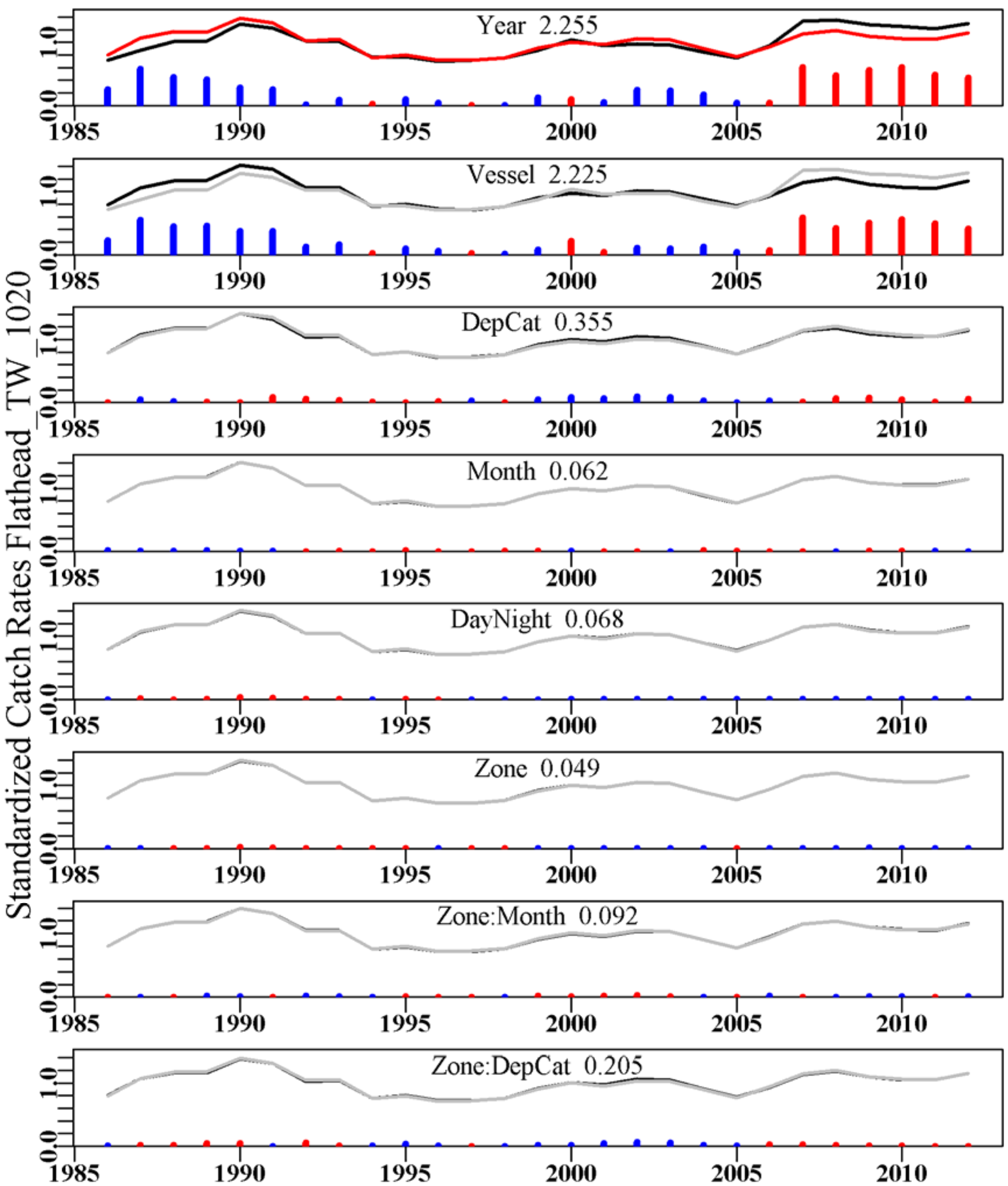



Figure 18.33. The relative influence of each factor used on the final trend in the optimal standardization for Flathead in Zones 10 – 20. The top graph depicts the geometric mean (the black line) and the optimum model (the red line). The difference between them is illustrated by the vertical bars with 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.

### *18.4.11 Flathead Trawl Z30 (FLT – 37296001 – N. richardsoni)*

Only data from zone 30 were used, depths less than 400 m.

Table 18.30. Flathead from zone 30 in depths 0 – 400m by trawl. Total Catch is the total reported in the database, Records was the number of records used in the analysis, CatchT is the reported catch in the area and depth used in the analysis, and Vessels relates to all vessels used in the analysis. Geomean is the geometric mean of catch rates (kg/hr). Month:DepCat is the optimum model and StDev is the standard deviation relating to the data in the optimum model.

| Year | TotCatch | Records | CatchT | Vessels | GeoMean | Mth:DepC | StDev |
|---|---|---|---|---|---|---|---|
| 1986 | 1889.485 | 71 | 16.754 | 6 | 23.1157 | 0.9552 | 0.0000 |
| 1987 | 2458.130 | 90 | 5.155 | 9 | 11.1912 | 0.5791 | 0.1897 |
| 1988 | 2467.161 | 193 | 39.976 | 9 | 21.2587 | 0.9973 | 0.1701 |
| 1989 | 2587.762 | 516 | 48.443 | 19 | 20.5177 | 0.7477 | 0.1625 |
| 1990 | 2030.892 | 253 | 24.619 | 27 | 20.3187 | 0.7835 | 0.1647 |
| 1991 | 2207.959 | 314 | 33.353 | 29 | 15.9189 | 0.7086 | 0.1608 |
| 1992 | 2355.693 | 272 | 33.897 | 15 | 22.4408 | 0.6741 | 0.1649 |
| 1993 | 1862.912 | 902 | 92.079 | 24 | 17.1065 | 0.6422 | 0.1563 |
| 1994 | 1708.187 | 612 | 64.487 | 17 | 18.5289 | 0.6649 | 0.1573 |
| 1995 | 1799.980 | 694 | 71.349 | 17 | 19.8905 | 0.7276 | 0.1576 |
| 1996 | 1878.592 | 714 | 61.425 | 17 | 15.7596 | 0.6716 | 0.1573 |
| 1997 | 2355.431 | 885 | 104.875 | 14 | 20.7052 | 0.8451 | 0.1562 |
| 1998 | 2306.328 | 707 | 118.552 | 14 | 28.8666 | 0.9967 | 0.1568 |
| 1999 | 3117.011 | 770 | 175.052 | 17 | 31.0992 | 1.0984 | 0.1570 |
| 2000 | 2944.056 | 520 | 83.664 | 21 | 25.4446 | 0.8899 | 0.1582 |
| 2001 | 2596.801 | 916 | 101.308 | 17 | 18.0579 | 0.7588 | 0.1552 |
| 2002 | 2874.139 | 1367 | 212.158 | 15 | 30.1174 | 1.4192 | 0.1544 |
| 2003 | 3224.755 | 1454 | 240.110 | 21 | 30.0485 | 1.4503 | 0.1538 |
| 2004 | 3215.761 | 1923 | 477.416 | 15 | 47.0053 | 1.9138 | 0.1534 |
| 2005 | 2841.270 | 1540 | 388.325 | 18 | 43.4956 | 1.6981 | 0.1540 |
| 2006 | 2582.725 | 1315 | 287.968 | 13 | 37.5195 | 1.3685 | 0.1548 |
| 2007 | 2646.745 | 823 | 173.155 | 8 | 33.0381 | 1.1339 | 0.1563 |
| 2008 | 2910.286 | 874 | 173.739 | 11 | 29.3148 | 1.0469 | 0.1562 |
| 2009 | 2460.023 | 600 | 100.225 | 10 | 29.0939 | 1.0169 | 0.1577 |
| 2010 | 2495.298 | 537 | 104.186 | 10 | 28.3260 | 1.0297 | 0.1587 |
| 2011 | 2465.166 | 623 | 131.274 | 9 | 29.1229 | 0.9714 | 0.1578 |
| 2012 | 2780.222 | 756 | 160.746 | 9 | 35.1418 | 1.2106 | 0.1570 |

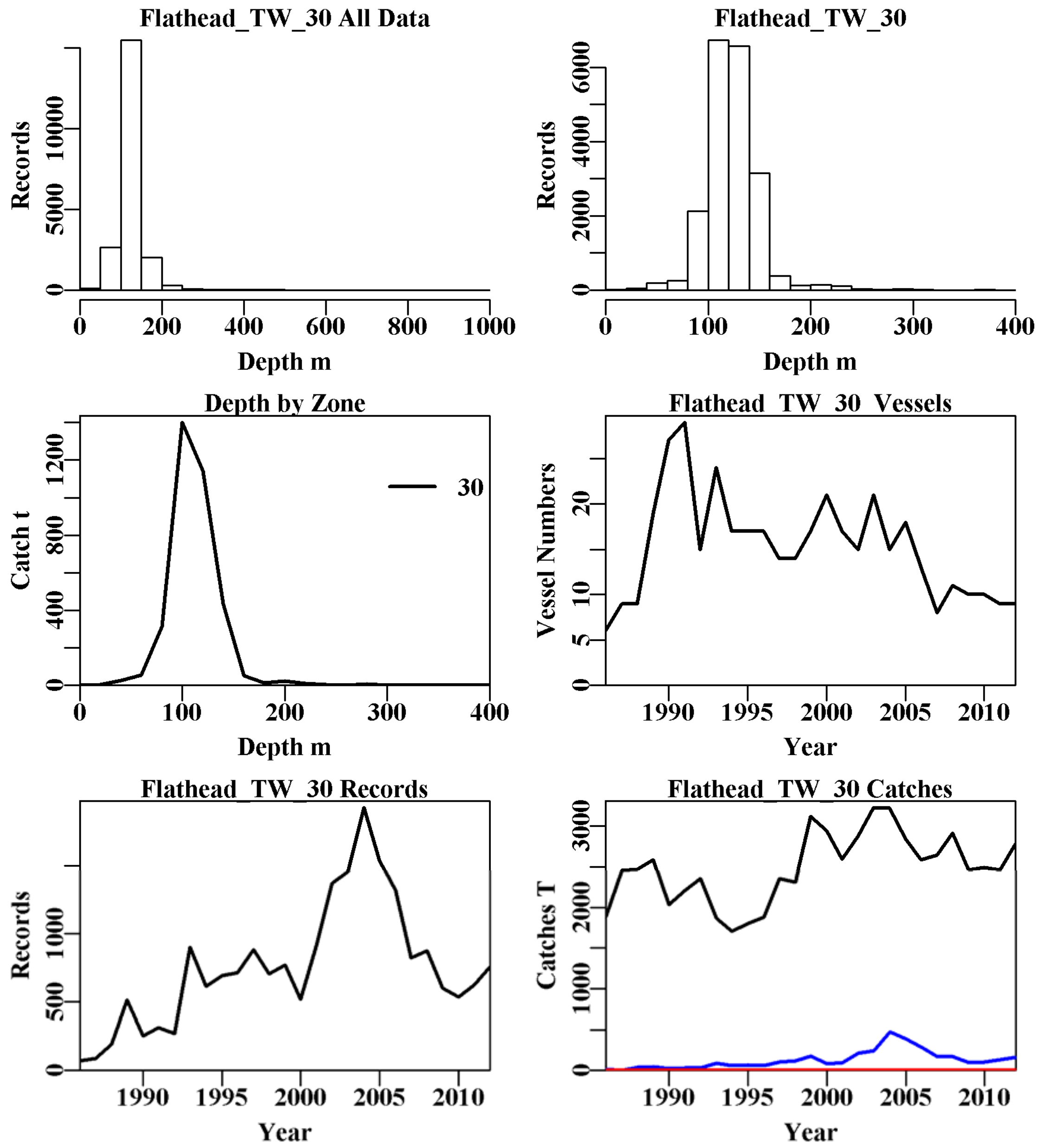



Figure 18.34. Flathead from zone 30 in depths 0 – 400m by trawl. The top left is the depth distribution of all records reporting Flathead, the top right graph depicts the depth distribution of shots containing Flathead from zone 30 in depths 0 – 400m by trawl. The middle left diagram depicts the distribution of catch by depth within zone 30, the middle right hand graph depicts the number of vessels through time. The bottom left reflects the number of records used in analysis, and bottom right is the Flathead catches (top line, black is total catches, middle line, blue, are those used in the analysis, and bottom, red, are catches < 30Kg).

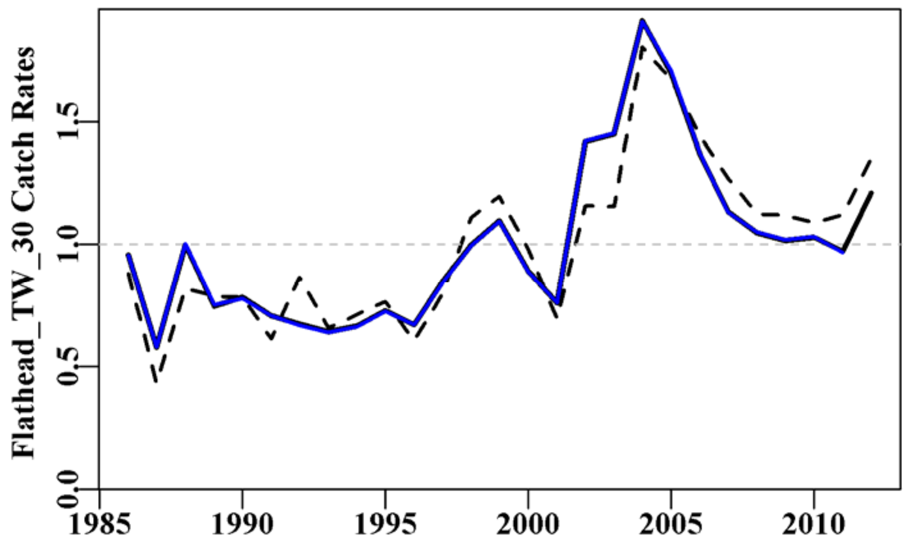



Figure 18.35. Flathead from zone 30 in depths 0 – 400m by trawl. The dashed black line represents the geometric mean catch rate and the solid black line the standardized catch rates. The graph standardizes catch rates relative to the mean of the standardized catch rates.

Table 18.31. Flathead from zone 30 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+DayNight |
| Model 5 | LnCE~Year+Vessel+DepCat+DayNight+Month |
| Model 6 | LnCE~Year+Vessel+DepCat+DayNight+Month+DayNight:DepCat |
| Model 7 | LnCE~Year+Vessel+DepCat+DayNight+Month+Month:DepCat |
| Model 8 | LnCE~Year+Vessel+DepCat+DayNight+Month+DayNight:DepCat |

Table 18.32. Flathead from zone 30 in depths 0 – 400m by trawl. Model selection criteria, including the AIC, the adjusted $r^2$ and the change in adjusted $r^2$. The optimum was model 7.

| | Year | Vessel | DepCat | DN | Mth | DN:Mth | **Mth:DepC** | DN:DepC |
|---|---|---|---|---|---|---|---|---|
| AIC | 2792 | 1089 | -12 | -357 | -650 | -702 | **-1102** | -755 |
| RSS | 23173 | 21116 | 19701 | 19358 | 19055 | 18943 | **18223** | 18842 |
| MSS | 2200 | 4258 | 5673 | 6016 | 6319 | 6430 | **7151** | 6532 |
| Nobs | 20241 | 20241 | 19983 | 19983 | 19983 | 19983 | **19983** | 19983 |
| Npars | 27 | 116 | 136 | 139 | 150 | 183 | **370** | 210 |
| adj_r2 | 8.555 | 16.304 | 21.828 | 23.179 | 24.339 | 24.656 | **26.830** | 24.958 |
| %Change | 0.000 | 7.749 | 5.524 | 1.350 | 1.160 | 0.318 | **2.174** | -1.872 |

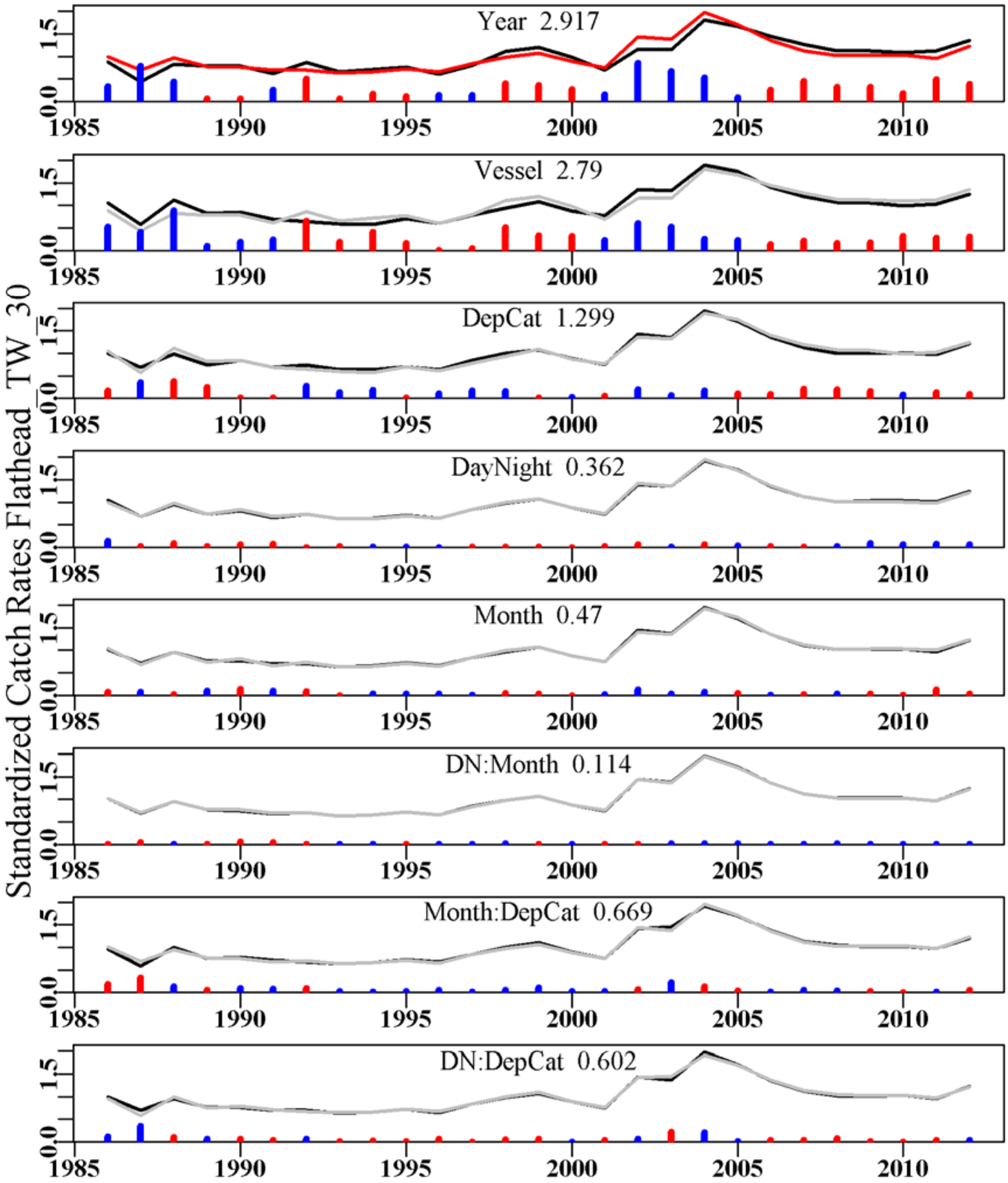



Figure 18.36. The relative influence of each factor used on the final trend in the optimal standardization for Flathead from zone 30. The top graph depicts the geometric mean (the black line) and the optimum model (the red line). The difference between them is illustrated by the vertical bars with blue 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.

### *18.4.12 Flathead Danish Seine (FLT – 37296001 – N. richardsoni)*

Only data from zones 20, and 60 were used, for Danish Seine vessels only (i.e. exclude Otter Trawl vessels), and depths less than 200 m.

Table 18.33. Flathead from zones 20 and 60 in depths 0 – 200m by Danish Seine. Total Catch is the total reported in the database, Records is the number of records used in the analysis, CatchT is the reported catch in the area and depth used in the analysis, and Vessels relates to all vessels used in the analysis. Geomean is the geometric mean of catch rates (kg/hr). Zone:Month is the optimum model and StDev is the standard deviation relating to the data in the optimum model.

| Year | TotCatch | Records | CatchT | Vessels | GeoMean | Zone:Mth | StDev |
|---|---|---|---|---|---|---|---|
| 1986 | 1889.485 | 5501 | 763.945 | 26 | 45.0535 | 1.0351 | 0.0000 |
| 1987 | 2458.130 | 5651 | 1366.944 | 23 | 88.6187 | 1.4551 | 0.0228 |
| 1988 | 2467.161 | 5823 | 1097.541 | 25 | 88.9194 | 1.5850 | 0.0226 |
| 1989 | 2587.762 | 5412 | 1142.708 | 27 | 78.4955 | 1.3782 | 0.0229 |
| 1990 | 2030.892 | 4653 | 586.018 | 25 | 48.3882 | 0.9073 | 0.0242 |
| 1991 | 2207.959 | 4670 | 775.768 | 28 | 69.8580 | 1.2672 | 0.0243 |
| 1992 | 2355.693 | 6643 | 1218.041 | 24 | 85.5977 | 1.3677 | 0.0223 |
| 1993 | 1862.912 | 5859 | 539.588 | 24 | 39.0251 | 0.8698 | 0.0230 |
| 1994 | 1708.187 | 7332 | 649.481 | 25 | 37.6721 | 0.7325 | 0.0219 |
| 1995 | 1799.980 | 5505 | 656.665 | 21 | 36.2337 | 0.7512 | 0.0233 |
| 1996 | 1878.592 | 7679 | 755.670 | 22 | 33.6052 | 0.7098 | 0.0219 |
| 1997 | 2355.431 | 8480 | 1150.436 | 21 | 60.3446 | 0.9134 | 0.0215 |
| 1998 | 2306.328 | 9904 | 1134.732 | 21 | 60.5323 | 0.7634 | 0.0210 |
| 1999 | 3117.011 | 8818 | 1702.605 | 23 | 98.4160 | 1.0990 | 0.0215 |
| 2000 | 2944.056 | 7092 | 1037.689 | 19 | 64.0436 | 0.8110 | 0.0225 |
| 2001 | 2596.801 | 7457 | 1004.507 | 18 | 62.0182 | 0.7585 | 0.0226 |
| 2002 | 2874.139 | 8218 | 1144.075 | 22 | 75.2709 | 0.9012 | 0.0222 |
| 2003 | 3224.755 | 9006 | 1210.597 | 23 | 80.7627 | 0.9628 | 0.0220 |
| 2004 | 3215.761 | 7784 | 1253.026 | 22 | 83.7818 | 0.9410 | 0.0225 |
| 2005 | 2841.270 | 7212 | 1125.753 | 22 | 87.7421 | 0.9586 | 0.0229 |
| 2006 | 2582.725 | 5563 | 968.051 | 21 | 89.1577 | 0.9493 | 0.0240 |
| 2007 | 2646.745 | 5551 | 1182.067 | 15 | 104.4620 | 1.1494 | 0.0239 |
| 2008 | 2910.286 | 6214 | 1283.489 | 15 | 103.2936 | 1.0271 | 0.0235 |
| 2009 | 2460.023 | 5499 | 1168.928 | 15 | 91.4234 | 1.0604 | 0.0239 |
| 2010 | 2495.298 | 6048 | 1166.861 | 15 | 101.4483 | 0.9420 | 0.0235 |
| 2011 | 2465.166 | 6890 | 1122.385 | 14 | 85.7899 | 0.8779 | 0.0230 |
| 2012 | 2780.222 | 7214 | 1382.334 | 14 | 89.5939 | 0.8261 | 0.0229 |

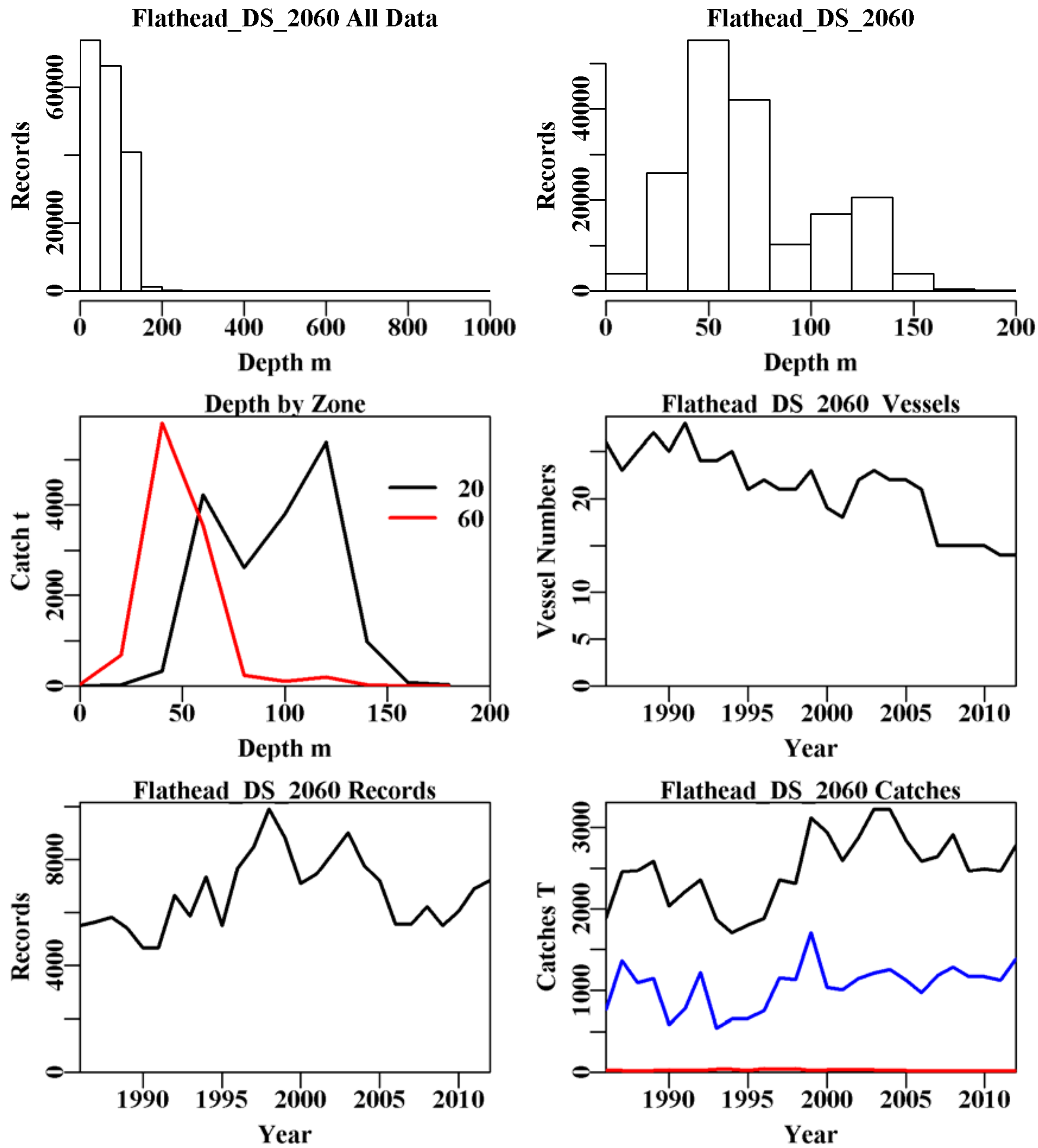



Figure 18.37. Flathead from zones 20 and 60 in depths 0 – 200m by Danish Seine. The top left is the depth distribution of all records reporting Flathead, the top right graph depicts the depth distribution of shots containing Flathead from zones 20 and 60 in depths 0 – 200m by Danish Seine. The middle left diagram depicts the distribution of catch by depth within zones 20 and 60, the middle right hand graph depicts the number of vessels through time. The bottom left reflects the number of records used in analysis, and bottom right is the Flathead catches (top line, black is total catches, middle line, blue, are those used in the analysis, and bottom, red, are catches < 30Kg).

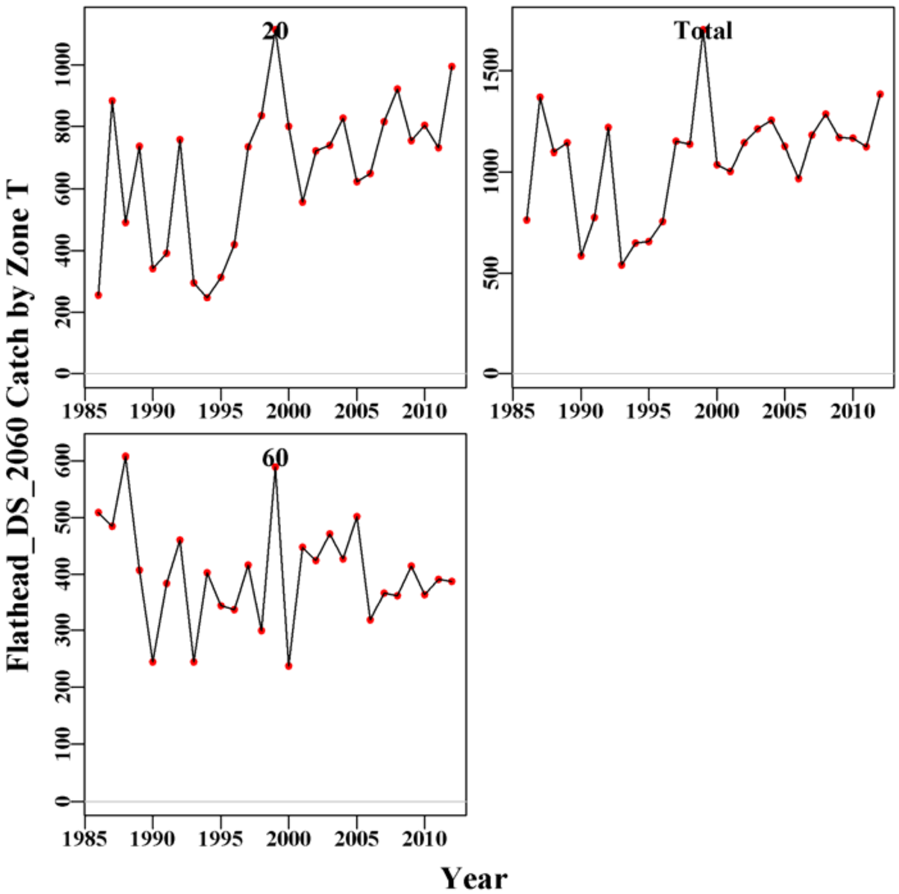



Figure 18.38. The distribution of catches among the reporting zones.

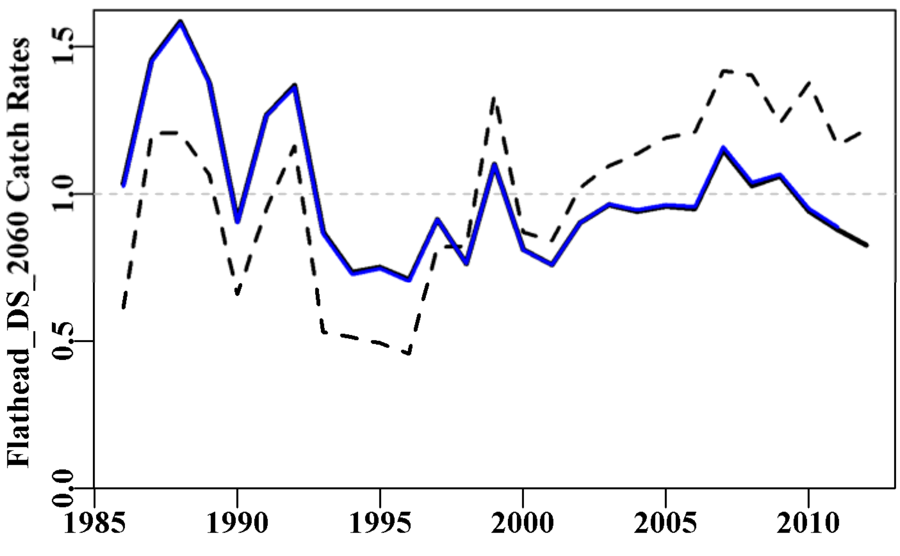



Figure 18.39. Flathead from zones 20 and 60 in depths 0 – 200m by Danish Seine. The dashed black line represents the geometric mean catch rate and the solid black line the standardized catch rates. The graph standardizes catch rates relative to the mean of the standardized catch rates.

Table 18.34. Flathead from zones 20 and 60 in depths 0 – 200m 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+Vessel |
| Model 5 | LnCE~Year+Zone+DepCat+Vessel+Month |
| Model 6 | LnCE~Year+Zone+DepCat+Vessel+Month+DayNight |
| Model 7 | LnCE~Year+Zone+DepCat+Vessel+Month+DayNight+Zone:Month |
| Model 8 | LnCE~Year+Zone+DepCat+Vessel+Month+DayNight+Zone:DepCat |

Table 18.35. Flathead from zones 20 and 60 in depths 0 – 200m by Danish Seine. Model selection criteria, including the AIC, the adjusted $r^2$ and the change in adjusted $r^2$. The optimum was model Zone:Month.

| | Year | Zone | DepCat | Vessel | Month | DayNight | **Zone:Mth** | Zone:DepC |
|---|---|---|---|---|---|---|---|---|
| AIC | 141241 | 106911 | 75064 | 67505 | 56079 | 53099 | **48396** | 52762 |
| RSS | 395189 | 327140 | 271916 | 260504 | 244342 | 240295 | **234026** | 239818 |
| MSS | 20564 | 88612 | 143837 | 155249 | 171411 | 175458 | **181727** | 175935 |
| Nobs | 181678 | 181678 | 178743 | 178743 | 178743 | 178743 | **178743** | 178743 |
| Npars | 27 | 28 | 37 | 89 | 100 | 103 | **114** | 112 |
| adj_r2 | 4.933 | 21.302 | 34.584 | 37.311 | 41.196 | 42.169 | **43.675** | 42.281 |
| %Change | 0.000 | 16.369 | 13.282 | 2.727 | 3.886 | 0.973 | **1.505** | -1.393 |

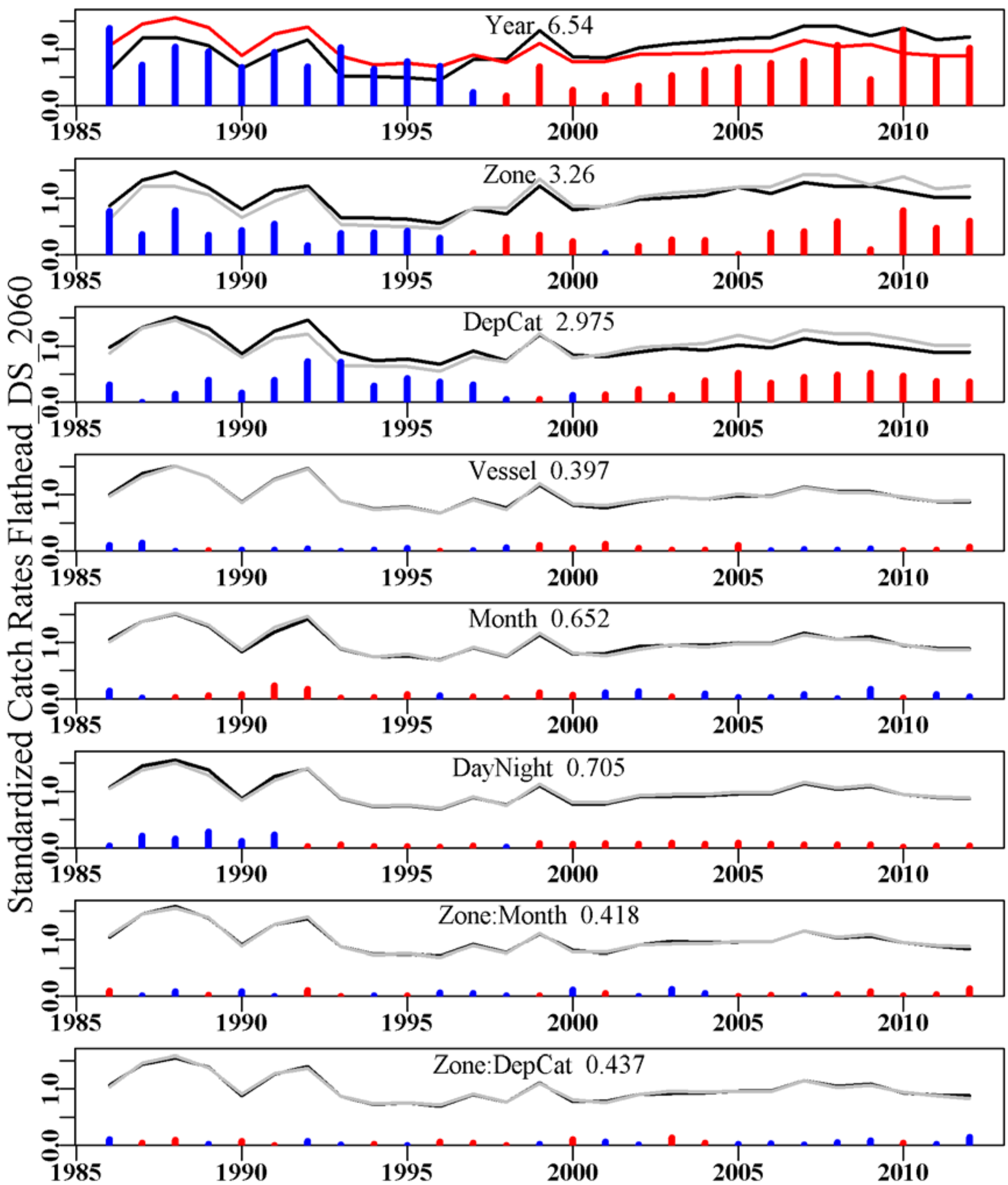



Figure 18.40. The relative influence of each factor used on the final trend in the optimal standardization for Flathead by Danish Seine in Zones 20 & 60. The top graph depicts the geometric mean (the black line) and the optimum model (the red line). The difference between them is illustrated by the vertical 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.

### *18.4.13 RedFish Zone 10 (RED – 37258003 – Centroberyx affinis)*

Only data from zone 10 were used, depths less than 400 m.

Table 18.36. Redfish from zone 10 in depths 0 – 400m by trawl. Total Catch is the total reported in the database, Records is the number of records used in the analysis, CatchT is the reported catch in the area and depth used in the analysis, and Vessels relates to all vessels used in the analysis. Geomean is the geometric mean of catch rates (kg/hr). Month:DepCat is the optimum model and StDev is the standard deviation relating to the data in the optimum model.

| Year | TotCatch | Records | CatchT | Vessels | GeoMean | Mth:DepC | StDev |
|---|---|---|---|---|---|---|---|
| 1986 | 1687.471 | 4503 | 1528.926 | 81 | 38.3044 | 1.6365 | 0.0000 |
| 1987 | 1247.550 | 3383 | 1114.805 | 73 | 35.9993 | 1.3134 | 0.0371 |
| 1988 | 1125.467 | 2966 | 904.361 | 70 | 37.3114 | 1.3632 | 0.0389 |
| 1989 | 694.060 | 2156 | 586.942 | 64 | 29.4122 | 1.1309 | 0.0431 |
| 1990 | 931.360 | 1894 | 699.754 | 49 | 37.2522 | 1.5351 | 0.0453 |
| 1991 | 1414.081 | 2467 | 1056.996 | 44 | 39.9367 | 1.5924 | 0.0421 |
| 1992 | 1624.316 | 2428 | 1393.725 | 41 | 50.0990 | 2.0517 | 0.0430 |
| 1993 | 1911.212 | 2960 | 1611.795 | 47 | 56.0385 | 2.5963 | 0.0407 |
| 1994 | 1486.623 | 4208 | 1140.891 | 49 | 35.8972 | 1.8208 | 0.0378 |
| 1995 | 1240.437 | 4397 | 1027.576 | 46 | 27.8589 | 1.1812 | 0.0368 |
| 1996 | 1342.798 | 4063 | 1094.993 | 50 | 26.2588 | 0.9638 | 0.0375 |
| 1997 | 1397.191 | 2952 | 1157.743 | 50 | 33.5183 | 1.1307 | 0.0405 |
| 1998 | 1553.528 | 3072 | 1363.404 | 43 | 43.1196 | 1.4172 | 0.0401 |
| 1999 | 1116.156 | 2998 | 969.424 | 44 | 32.7876 | 1.1127 | 0.0402 |
| 2000 | 757.894 | 3300 | 642.137 | 48 | 22.7760 | 0.7499 | 0.0398 |
| 2001 | 739.597 | 3209 | 607.215 | 41 | 17.8301 | 0.7333 | 0.0398 |
| 2002 | 802.192 | 3481 | 601.823 | 44 | 16.4201 | 0.6250 | 0.0395 |
| 2003 | 614.096 | 2690 | 478.879 | 43 | 17.0122 | 0.5978 | 0.0417 |
| 2004 | 474.517 | 2717 | 390.967 | 44 | 15.2541 | 0.5076 | 0.0416 |
| 2005 | 483.361 | 2443 | 360.961 | 41 | 16.1484 | 0.5194 | 0.0429 |
| 2006 | 323.977 | 1768 | 256.212 | 34 | 15.6812 | 0.4873 | 0.0472 |
| 2007 | 215.824 | 1207 | 149.288 | 18 | 15.4678 | 0.4341 | 0.0546 |
| 2008 | 183.757 | 1396 | 155.290 | 22 | 13.9780 | 0.4057 | 0.0523 |
| 2009 | 160.487 | 1171 | 123.810 | 20 | 11.3207 | 0.3285 | 0.0557 |
| 2010 | 152.661 | 1228 | 112.793 | 19 | 10.4815 | 0.3115 | 0.0546 |
| 2011 | 87.271 | 870 | 63.806 | 17 | 8.5118 | 0.2479 | 0.0614 |
| 2012 | 66.439 | 973 | 54.779 | 17 | 7.0022 | 0.2061 | 0.0587 |

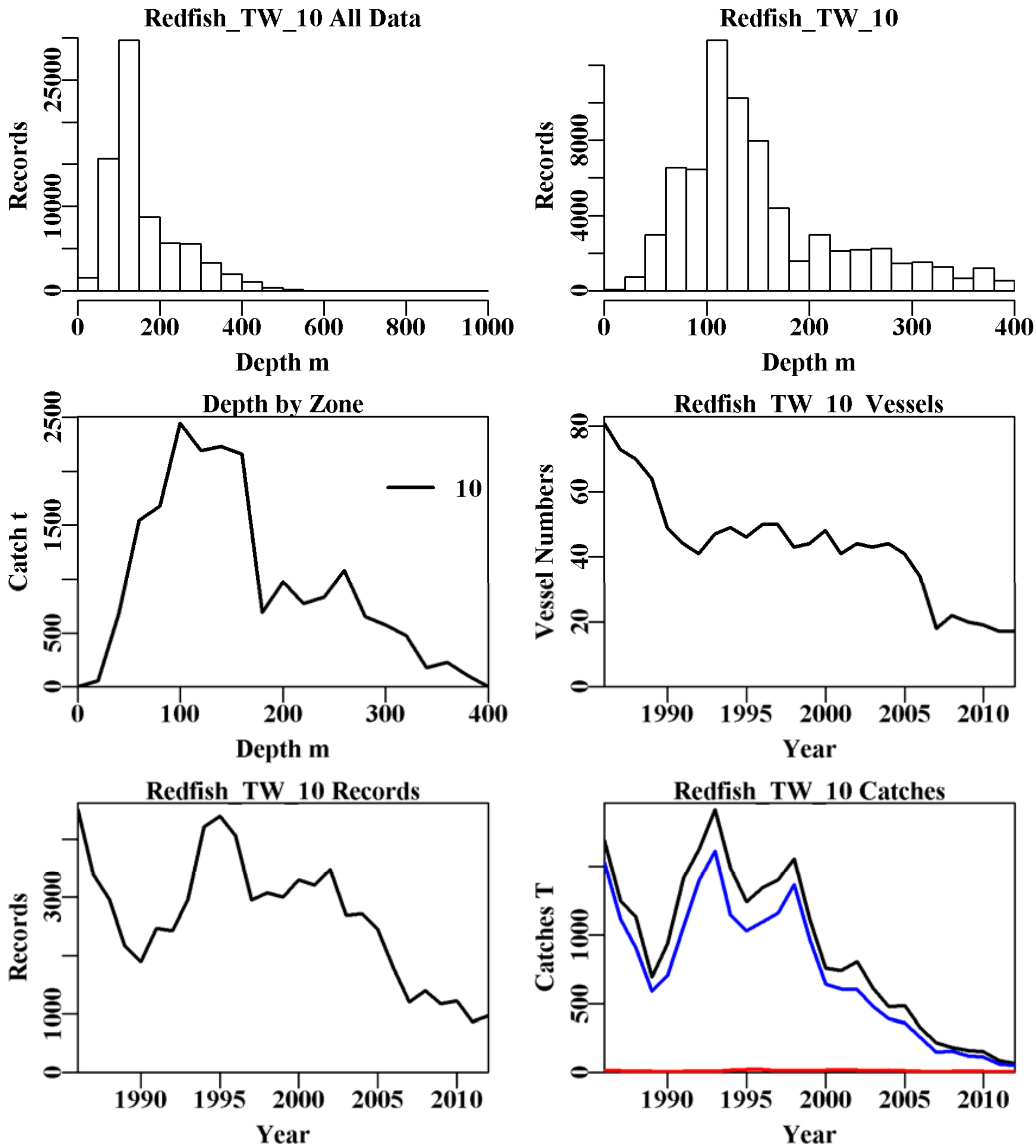



Figure 18.41. Redfish from zone 10 in depths 0 – 400m by trawl. The top left is the depth distribution of all records reporting Redfish, the top right graph depicts the depth distribution of shots containing Redfish from zone 10 in depths 0 – 400m by trawl. The middle left diagram depicts the distribution of catch by depth within zone 10, the middle right hand graph depicts the number of vessels through time. The bottom left reflects the number of records used in analysis, and bottom right is the Redfish catches (top line, black is total catches, middle line, blue, are those used in the analysis, and bottom, red, are catches < 30Kg).

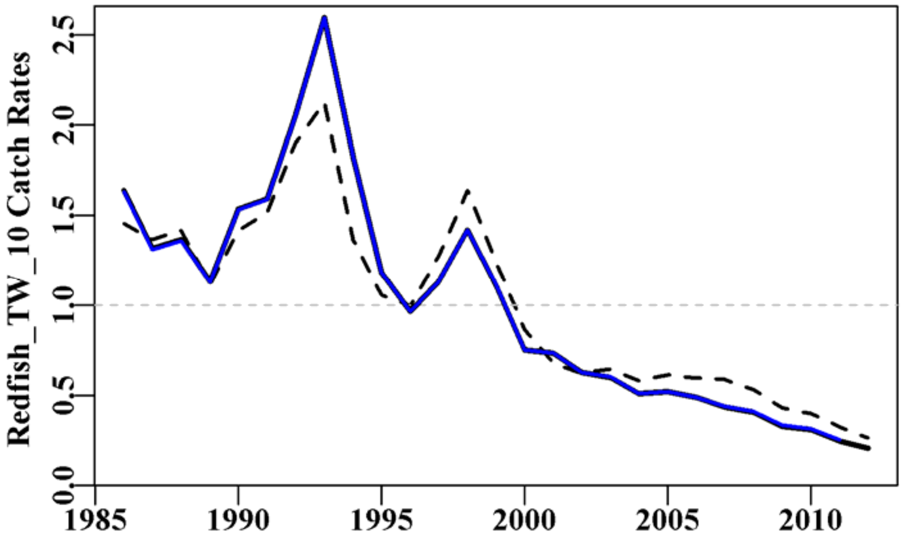



Figure 18 42. Redfish from zone 10 in depths 0 – 400m by trawl. The dashed black line represents the geometric mean catch rate and the solid black line the standardized catch rates. The graph standardizes catch rates relative to the mean of the standardized catch rates.

Table 18.37. 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+DayNight |
| Model 5 | LnCE~Year+Vessel+DepCat+DayNight+Month |
| Model 6 | LnCE~Year+Vessel+DepCat+DayNight+Month+DayNight:DepCat |
| Model 7 | LnCE~Year+Vessel+DepCat+DayNight+Month+Month:DepCat |
| Model 8 | LnCE~Year+Vessel+DepCat+DayNight+Month+DayNight:DepCat |

Table 18.38. Redfish from zone 10 in depths 0 – 400m by trawl. Model selection criteria, including the AIC, the adjusted $r^2$ and the change in adjusted $r^2$. The optimum was model Month:DepCat.

| | Year | Vessel | DepC | DN | Mth | DN:Mth | **Mth:DepC** | DN:DepC |
|---|---|---|---|---|---|---|---|---|
| AIC | 74949 | 66947 | 62011 | 61423 | 60926 | 60794 | **59651** | 60143 |
| RSS | 203899 | 181399 | 168987 | 167570 | 166342 | 165874 | **162344** | 164225 |
| MSS | 15491 | 37990 | 50402 | 51819 | 53048 | 53515 | **57045** | 55165 |
| Nobs | 70900 | 70900 | 70520 | 70520 | 70520 | 70520 | **70520** | 70520 |
| Npars | 27 | 171 | 191 | 194 | 205 | 238 | **425** | 265 |
| adj_r2 | 7.027 | 17.118 | 22.766 | 23.410 | 23.960 | 24.138 | **25.554** | 24.863 |
| %Change | 0.000 | 10.091 | 5.648 | 0.644 | 0.550 | 0.178 | **1.416** | -0.691 |

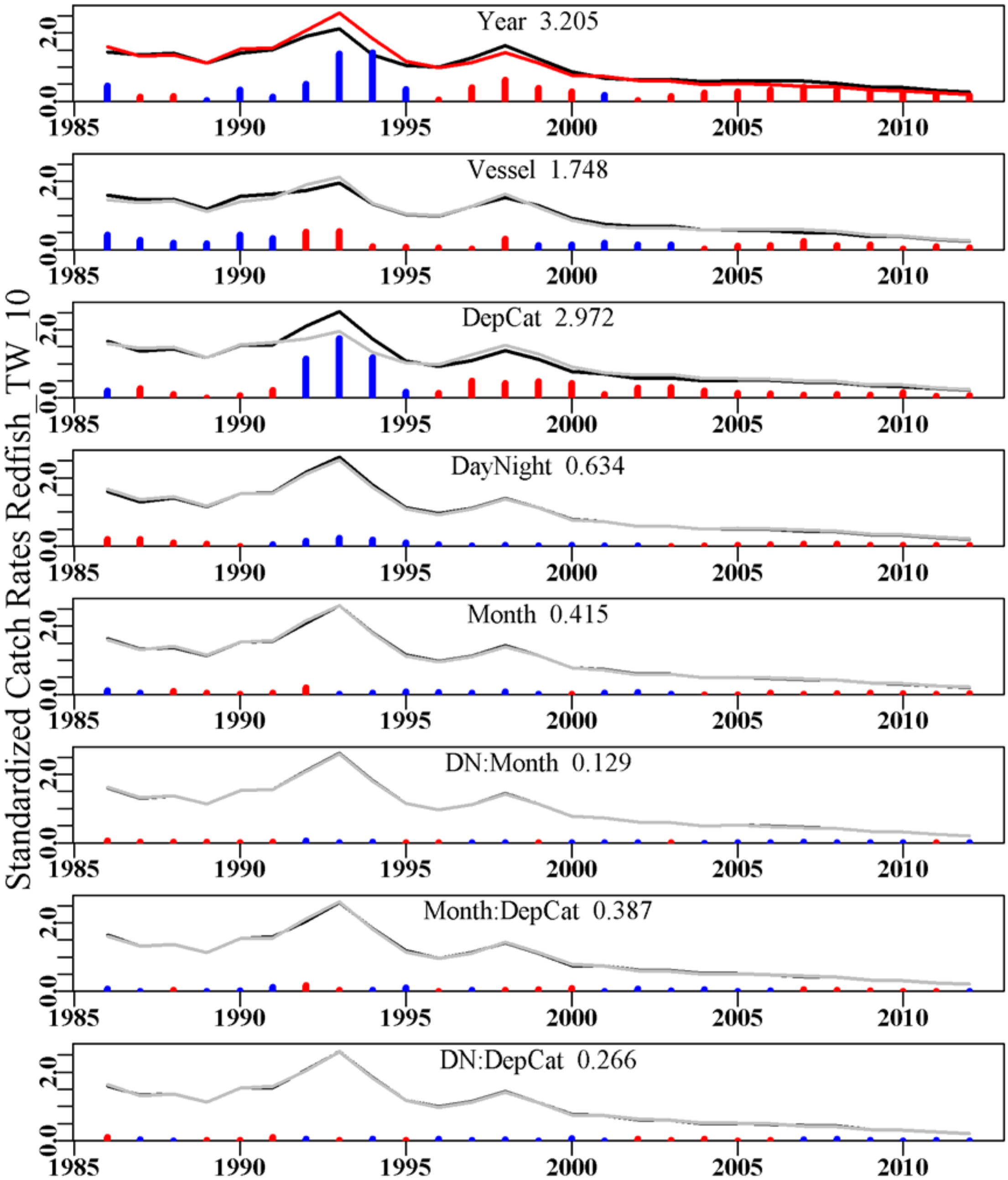



Figure 18.43. The relative influence of each factor used on the final trend in the optimal standardization for Redfish in Zone 10. The top graph depicts the geometric mean (the black line) and the optimum model (the red line). The difference between them is illustrated by the vertical bars with blue 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.

### *18.4.14 RedFish Zone 20 (RED – 37258003 – Centroberyx affinis)*

Only data from zone 20 were used, depths less than 400 m.

Table 18.39. Redfish from zone 20 in depths 0 – 400m by trawl. Total Catch is the total reported in the database, Records is the number of records used in the analysis, CatchT is the reported catch in the area and depth used in the analysis, and Vessels relates to all vessels used in the analysis. Geomean is the geometric mean of catch rates (kg/hr). Month:DepCat is the optimum model and StDev is the standard deviation relating to the data in the optimum model.

| Year | TotCatch | Records | CatchT | Vessels | GeoMean | Mth:DepC | StDev |
|---|---|---|---|---|---|---|---|
| 1986 | 1687.471 | 838 | 69.648 | 34 | 12.7888 | 1.2743 | 0.0000 |
| 1987 | 1247.550 | 548 | 70.567 | 28 | 16.3056 | 1.5868 | 0.0866 |
| 1988 | 1125.467 | 1008 | 174.671 | 35 | 22.5742 | 2.2402 | 0.0784 |
| 1989 | 694.060 | 567 | 57.490 | 32 | 13.8221 | 1.3698 | 0.0880 |
| 1990 | 931.360 | 699 | 95.090 | 34 | 16.4273 | 1.6000 | 0.0863 |
| 1991 | 1414.081 | 886 | 181.397 | 27 | 20.9240 | 1.9871 | 0.0851 |
| 1992 | 1624.316 | 691 | 100.149 | 25 | 18.2135 | 1.6212 | 0.0901 |
| 1993 | 1911.212 | 836 | 175.486 | 25 | 23.8774 | 1.9861 | 0.0870 |
| 1994 | 1486.623 | 1291 | 212.848 | 26 | 22.1556 | 1.8584 | 0.0819 |
| 1995 | 1240.437 | 1316 | 169.079 | 24 | 14.7891 | 1.1671 | 0.0804 |
| 1996 | 1342.798 | 1751 | 210.919 | 26 | 11.8255 | 1.2022 | 0.0788 |
| 1997 | 1397.191 | 1456 | 196.332 | 28 | 10.9003 | 0.9734 | 0.0811 |
| 1998 | 1553.528 | 1237 | 164.642 | 24 | 11.9357 | 1.0259 | 0.0821 |
| 1999 | 1116.156 | 947 | 122.433 | 25 | 9.4628 | 0.8961 | 0.0852 |
| 2000 | 757.894 | 1364 | 92.988 | 27 | 5.0564 | 0.5876 | 0.0824 |
| 2001 | 739.597 | 1345 | 113.456 | 24 | 5.9658 | 0.5992 | 0.0830 |
| 2002 | 802.192 | 1725 | 172.165 | 24 | 6.7628 | 0.6881 | 0.0818 |
| 2003 | 614.096 | 1428 | 77.081 | 26 | 4.5183 | 0.4434 | 0.0831 |
| 2004 | 474.517 | 1248 | 59.212 | 22 | 4.2622 | 0.4535 | 0.0854 |
| 2005 | 483.361 | 1353 | 92.209 | 20 | 5.5759 | 0.5760 | 0.0840 |
| 2006 | 323.977 | 821 | 46.469 | 21 | 4.7612 | 0.5045 | 0.0895 |
| 2007 | 215.824 | 673 | 59.701 | 11 | 5.6299 | 0.5859 | 0.0935 |
| 2008 | 183.757 | 536 | 24.505 | 17 | 4.1887 | 0.4690 | 0.0982 |
| 2009 | 160.487 | 448 | 30.527 | 12 | 4.9795 | 0.4900 | 0.1018 |
| 2010 | 152.661 | 644 | 34.686 | 15 | 4.4782 | 0.4279 | 0.0970 |
| 2011 | 87.271 | 538 | 20.309 | 11 | 2.6875 | 0.2539 | 0.0994 |
| 2012 | 66.439 | 381 | 7.552 | 11 | 1.5820 | 0.1324 | 0.1074 |

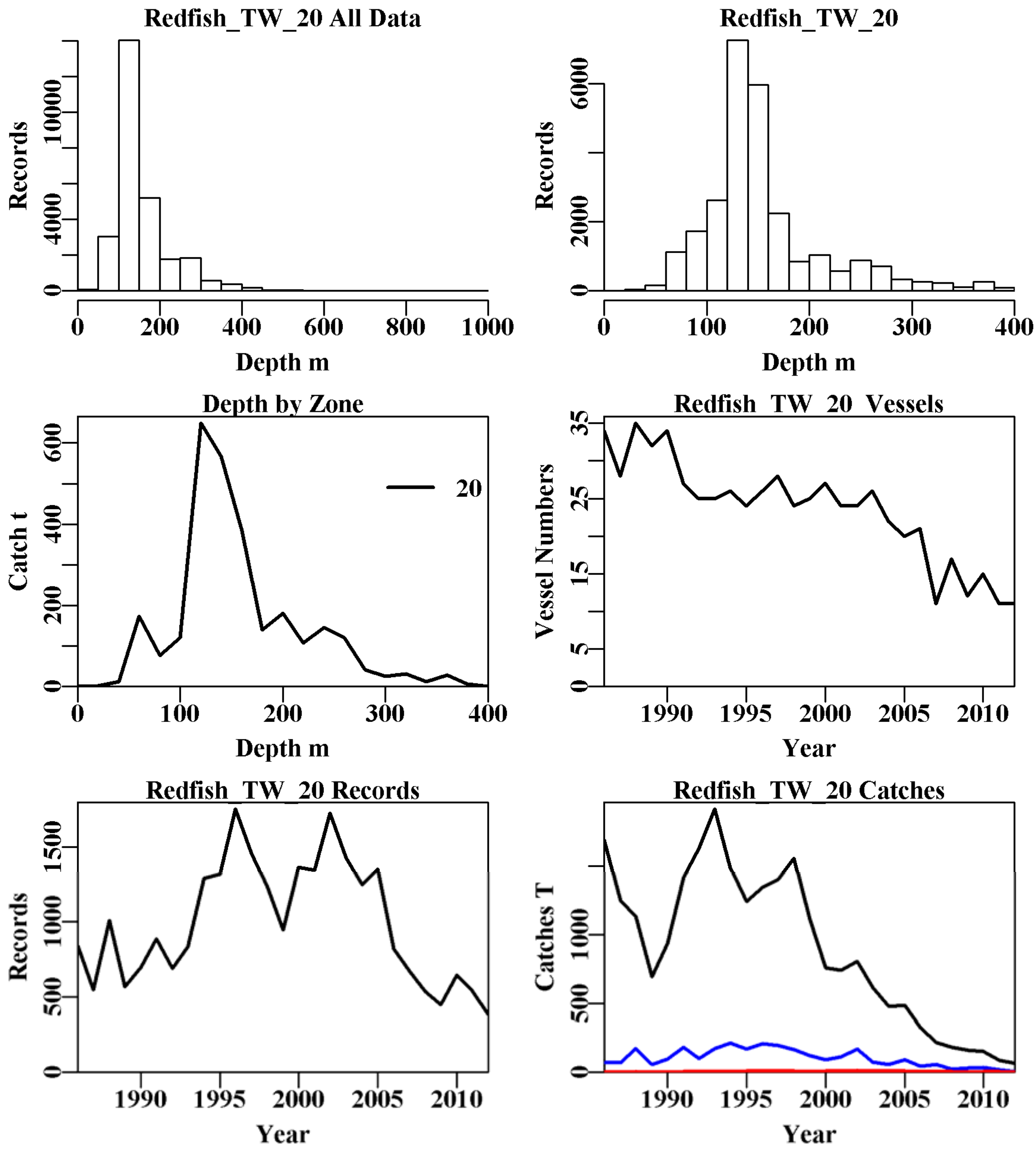



Figure 18.44. Redfish from zone 20 in depths 0 – 400m by trawl. The top left is the depth distribution of all records reporting Redfish, the top right graph depicts the depth distribution of shots containing Redfish from zone 20 in depths 0 – 400m by trawl. The middle left diagram depicts the distribution of catch by depth within zone 20, the middle right hand graph depicts the number of vessels through time. The bottom left reflects the number of records used in analysis, and bottom right is the Redfish catches (top line, black is total catches, middle line, blue, are those used in the analysis, and bottom, red, are catches < 30Kg).

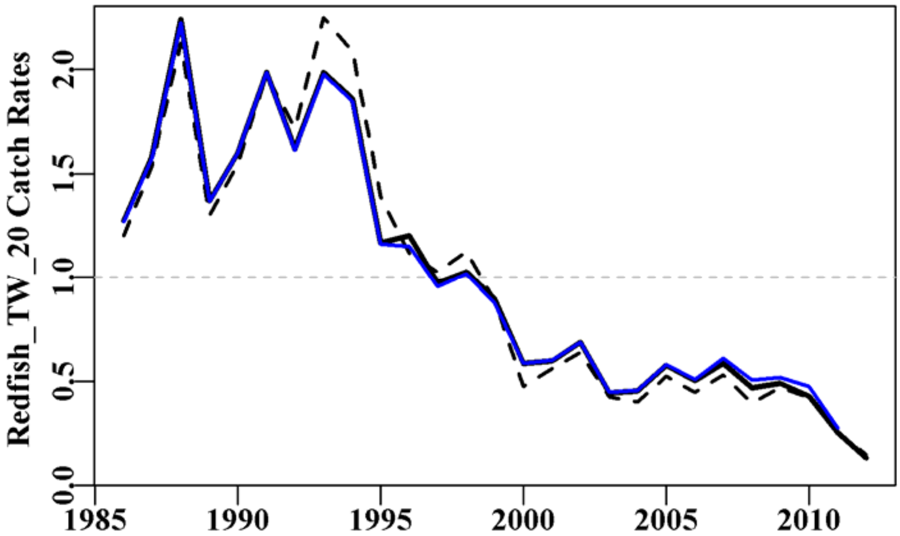



Figure 18.45. Redfish from zone 20 in depths 0 – 400m by trawl. The dashed black line represents the geometric mean catch rate and the solid black line the standardized catch rates. The graph standardizes catch rates relative to the mean of the standardized catch rates.

Table 18.40. Redfish from zone 20 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+DayNight |
| Model 5 | LnCE~Year+Vessel+DepCat+DayNight+Month |
| Model 6 | LnCE~Year+Vessel+DepCat+DayNight+Month+DayNight:DepCat |
| Model 7 | LnCE~Year+Vessel+DepCat+DayNight+Month+Month:DepCat |
| Model 8 | LnCE~Year+Vessel+DepCat+DayNight+Month+DayNight:DepCat |

Table 18.41. Redfish from zone 20 in depths 0 – 400m by trawl. Model selection criteria, including the AIC, the adjusted $r^2$ and the change in adjusted $r^2$. The optimum was model Month:DepCat.

| | Year | Vessel | DepCat | Mth | DayNight | DN:Mth | **Mth:DepCat** | DN:DepCat |
|---|---|---|---|---|---|---|---|---|
| AIC | 24544 | 21173 | 19404 | 18966 | 18929 | 18894 | **18682** | 18816 |
| RSS | 66786 | 58368 | 54440 | 53500 | 53413 | 53209 | **52043** | 52944 |
| MSS | 10637 | 19055 | 22982 | 23922 | 24009 | 24213 | **25380** | 24478 |
| Nobs | 26575 | 26575 | 26423 | 26423 | 26423 | 26423 | **26423** | 26423 |
| Npars | 27 | 132 | 152 | 163 | 166 | 199 | **386** | 226 |
| adj_r2 | 13.654 | 24.238 | 29.280 | 30.472 | 30.577 | 30.755 | **31.787** | 31.029 |
| %Change | 0.000 | 10.584 | 5.042 | 1.192 | 0.105 | 0.178 | **1.032** | -0.758 |

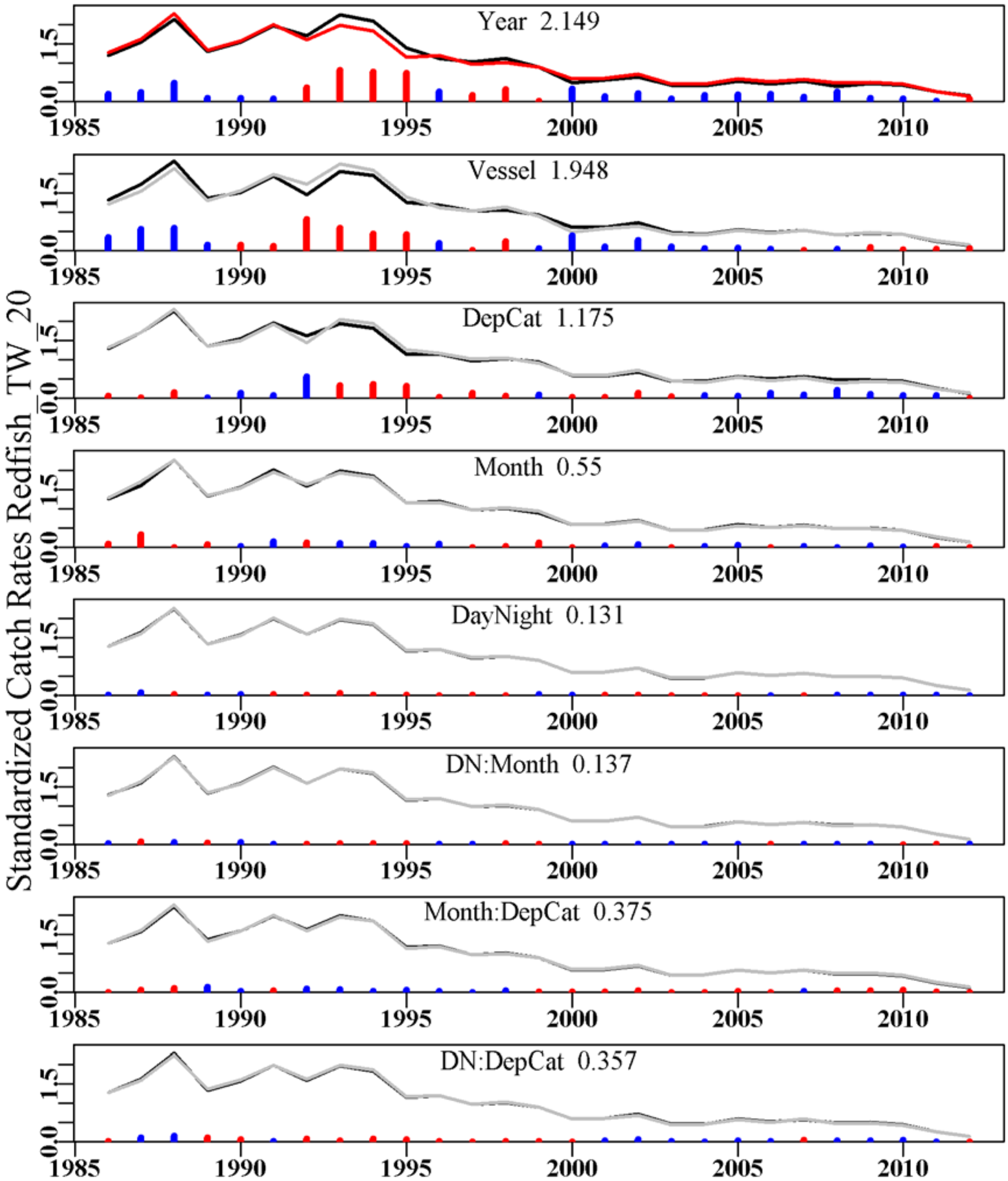



Figure 18.46. The relative influence of each factor used on the final trend in the optimal standardization for Redfish in Zone 20. The top graph depicts the geometric mean (the black line) and the optimum model (the red line). The difference between them is illustrated by the vertical bars with blue 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.

### *18.4.15 Silver Trevally (TRE – 37337062 – Pseudocaranx dentex)*

Only data from zones 10 and 20 combined were used, depths less than 200 m. 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 last year's analysis through the use of improved GIS.

Table 18.42. 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 is the total reported in the database, Records is the number of records used in the analysis, CatchT is the reported catch in the area and depth used in the analysis, and Vessels relates to all vessels used in the analysis. Geomean is the geometric mean of catch rates (kg/hr). Zone:Month is the optimum model and StDev is the standard deviation relating to the data in the optimum model.

| Year | TotCatch | Records | CatchT | Vessels | GeoMean | Zone:Mth | StDev |
|---|---|---|---|---|---|---|---|
| 1986 | 469.508 | 1765 | 278.628 | 74 | 17.0086 | 1.1540 | 0.0000 |
| 1987 | 197.212 | 1090 | 116.317 | 63 | 17.5072 | 1.3641 | 0.0596 |
| 1988 | 278.179 | 1299 | 226.620 | 52 | 23.7642 | 1.8041 | 0.0549 |
| 1989 | 373.313 | 1838 | 278.037 | 62 | 23.0657 | 1.9185 | 0.0503 |
| 1990 | 450.291 | 1841 | 288.809 | 52 | 23.2975 | 2.2806 | 0.0521 |
| 1991 | 328.521 | 1909 | 213.903 | 49 | 18.1137 | 2.0451 | 0.0524 |
| 1992 | 292.516 | 1194 | 108.366 | 44 | 12.0774 | 1.1704 | 0.0588 |
| 1993 | 375.426 | 1262 | 132.861 | 47 | 13.4863 | 1.2771 | 0.0578 |
| 1994 | 390.173 | 1839 | 139.154 | 46 | 9.4912 | 0.9802 | 0.0533 |
| 1995 | 413.434 | 1570 | 136.637 | 43 | 10.2789 | 1.1131 | 0.0554 |
| 1996 | 340.376 | 1883 | 129.536 | 47 | 7.5806 | 0.9028 | 0.0539 |
| 1997 | 328.647 | 1450 | 88.499 | 48 | 6.2012 | 0.8527 | 0.0575 |
| 1998 | 210.133 | 1023 | 48.972 | 40 | 5.2414 | 0.6199 | 0.0613 |
| 1999 | 165.978 | 882 | 41.568 | 39 | 4.9696 | 0.6205 | 0.0646 |
| 2000 | 154.748 | 1020 | 43.620 | 43 | 3.6777 | 0.4567 | 0.0618 |
| 2001 | 268.318 | 1536 | 82.085 | 43 | 4.1345 | 0.5340 | 0.0556 |
| 2002 | 232.562 | 1474 | 67.852 | 40 | 3.0864 | 0.4323 | 0.0574 |
| 2003 | 311.137 | 1124 | 57.733 | 45 | 3.3755 | 0.4233 | 0.0597 |
| 2004 | 440.997 | 1345 | 84.499 | 42 | 4.5401 | 0.5859 | 0.0581 |
| 2005 | 290.070 | 673 | 59.560 | 40 | 4.7971 | 0.5181 | 0.0694 |
| 2006 | 246.983 | 493 | 48.824 | 32 | 5.7178 | 0.7261 | 0.0769 |
| 2007 | 172.440 | 463 | 47.115 | 20 | 7.4274 | 0.8055 | 0.0798 |
| 2008 | 128.386 | 818 | 69.665 | 23 | 8.0833 | 0.8328 | 0.0662 |
| 2009 | 164.047 | 838 | 94.881 | 23 | 9.2632 | 0.8479 | 0.0654 |
| 2010 | 240.011 | 967 | 135.510 | 24 | 11.7000 | 1.0767 | 0.0637 |
| 2011 | 192.082 | 862 | 139.334 | 20 | 11.0895 | 0.9727 | 0.0656 |
| 2012 | 134.522 | 665 | 88.070 | 21 | 7.6670 | 0.6850 | 0.0706 |

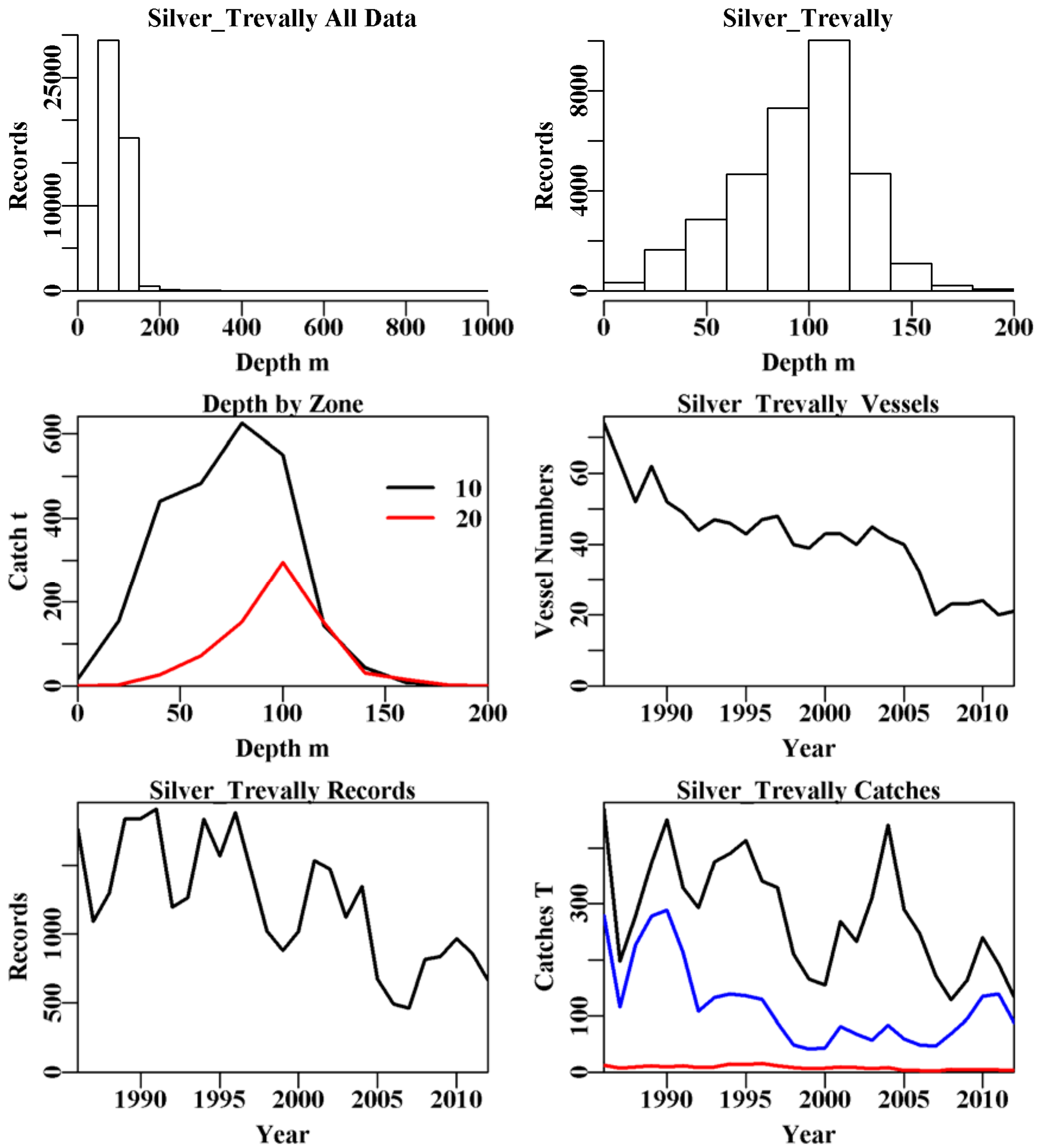



Figure 18.47. Silver Trevally from Zones 10 and 20 in depths 0 to 200 m, excluding data taken in State waters (Bateman's Bay MPA). The top left is the depth distribution of all records reporting Silver Trevally, the top right graph depicts the depth distribution of shots containing Silver Trevally from Zones 10 and 20 in depths 0 to 200 m by trawl, excluding data taken in State waters (Bateman's Bay MPA). The middle left diagram depicts the distribution of catch by depth within zones 10 and 20 (20 is top red line), the middle right hand graph depicts the number of vessels through time. The bottom left reflects the number of records used in analysis, and bottom right is the Silver Trevally catches (top line, black is total catches, middle line, blue, are those used in the analysis, and bottom, red, are catches < 30Kg).

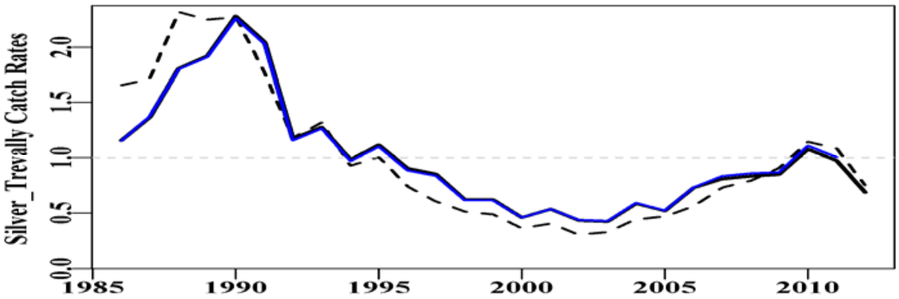



Figure 18.48. Silver Trevally from Zones 10 and 20 in depths 0 to 200 m, excluding data taken in State waters (Bateman's Bay MPA). The dashed black line represents the geometric mean catch rate and the solid black line the standardized catch rates. The blue line is last year's analysis. The graph standardizes catch rates relative to the mean of the standardized catch rates.

Table 18.43. 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 18.44. 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, including the AIC, the adjusted $r^2$ and the change in adjusted $r^2$. The optimum is model Zone:Month.

| | Year | Vessel | DepCat | Month | DayNight | Zone | **Zone:Mth** | Zone:DepC |
|---|---|---|---|---|---|---|---|---|
| AIC | 30754 | 24056 | 23041 | 22340 | 21970 | 21918 | **21846** | 21896 |
| RSS | 83687 | 67753 | 65523 | 64098 | 63369 | 63264 | **63084** | 63185 |
| MSS | 13492 | 29427 | 31656 | 33081 | 33810 | 33915 | **34095** | 33994 |
| Nobs | 33123 | 33123 | 32889 | 32889 | 32889 | 32889 | **32889** | 32889 |
| Npars | 27 | 176 | 186 | 197 | 200 | 201 | **212** | 211 |
| adj_r2 | 13.816 | 29.910 | 32.194 | 33.646 | 34.395 | 34.501 | **34.665** | 34.563 |
| %Change | 0.000 | 16.094 | 2.283 | 1.452 | 0.749 | 0.106 | **0.164** | 0.062 |

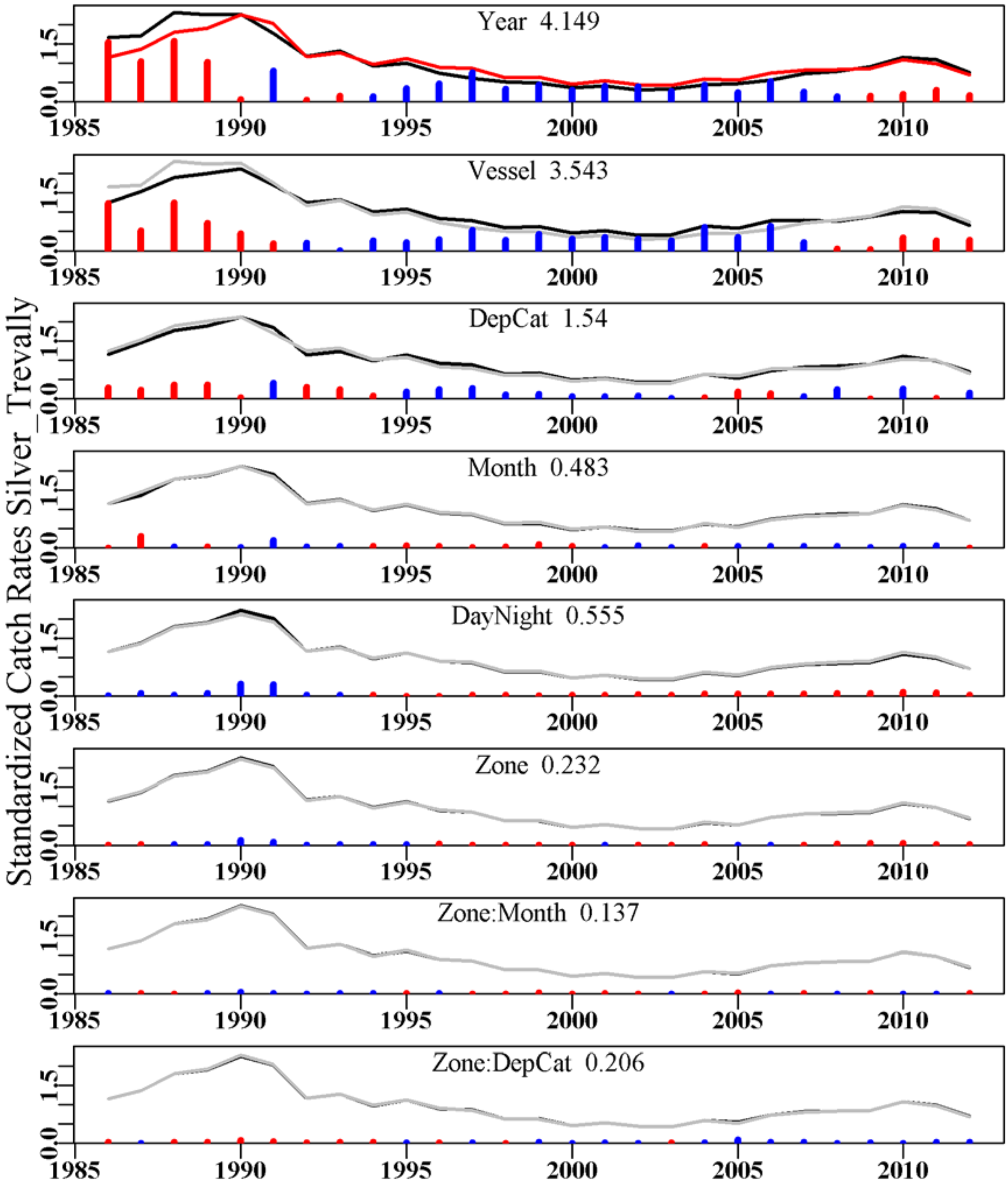



Figure 18.49. The relative influence of each factor used on the final trend in the optimal standardization for Silver Trevally in Zones 10 and 20. The top graph depicts the geometric mean (the black line) and the optimum model (the red line). The difference between them is illustrated by the vertical 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.

*18.4.15.1 Alternative 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 18.45. 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 is the total reported in the database, Records is the number of records used in the analysis, CatchT is the reported catch in the area and depth used in the analysis, and Vessels relates to all vessels used in the analysis. Geomean is the geometric mean of catch rates (kg/hr). Zone:Month is the optimum model and StDev is the standard deviation relating to the data in the optimum model.

| Year | TotCatch | Records | CatchT | Vessels | GeoMean | Zone:Mth | StDev |
|---|---|---|---|---|---|---|---|
| 1986 | 469.508 | 1978 | 306.504 | 74 | 17.5551 | 1.0402 | 0.0000 |
| 1987 | 197.212 | 1260 | 135.059 | 64 | 17.4271 | 1.2330 | 0.0572 |
| 1988 | 278.179 | 1581 | 243.906 | 56 | 20.1929 | 1.4170 | 0.0521 |
| 1989 | 373.313 | 2194 | 332.452 | 62 | 24.2894 | 1.7729 | 0.0482 |
| 1990 | 450.291 | 2101 | 349.032 | 53 | 24.1445 | 2.0276 | 0.0498 |
| 1991 | 328.521 | 2221 | 251.122 | 50 | 18.0221 | 1.8146 | 0.0500 |
| 1992 | 292.516 | 1620 | 195.772 | 44 | 13.4364 | 1.0322 | 0.0536 |
| 1993 | 375.426 | 2280 | 282.038 | 49 | 15.1230 | 1.1101 | 0.0497 |
| 1994 | 390.173 | 3307 | 361.967 | 48 | 13.0062 | 0.9447 | 0.0465 |
| 1995 | 413.434 | 3352 | 380.192 | 49 | 14.3268 | 1.0790 | 0.0462 |
| 1996 | 340.376 | 3237 | 315.198 | 54 | 10.8969 | 0.9774 | 0.0467 |
| 1997 | 328.647 | 2869 | 298.116 | 55 | 11.5325 | 0.9615 | 0.0479 |
| 1998 | 210.133 | 2281 | 177.057 | 46 | 9.4314 | 0.7327 | 0.0494 |
| 1999 | 165.978 | 1859 | 115.382 | 45 | 8.3770 | 0.7143 | 0.0517 |
| 2000 | 154.748 | 2010 | 122.637 | 49 | 6.0305 | 0.5512 | 0.0508 |
| 2001 | 268.318 | 3219 | 226.349 | 46 | 7.6285 | 0.6656 | 0.0465 |
| 2002 | 232.562 | 2766 | 207.474 | 44 | 5.9678 | 0.6240 | 0.0482 |
| 2003 | 311.137 | 2763 | 281.980 | 49 | 8.0079 | 0.6650 | 0.0478 |
| 2004 | 440.997 | 3339 | 367.812 | 45 | 10.6839 | 0.8146 | 0.0467 |
| 2005 | 290.070 | 2324 | 242.142 | 43 | 11.1271 | 0.7116 | 0.0500 |
| 2006 | 246.983 | 1687 | 209.165 | 39 | 13.2846 | 0.7714 | 0.0530 |
| 2007 | 172.440 | 836 | 115.558 | 22 | 11.7896 | 0.7619 | 0.0644 |
| 2008 | 128.386 | 1065 | 95.896 | 23 | 9.1077 | 0.8675 | 0.0602 |
| 2009 | 164.047 | 1154 | 136.726 | 23 | 10.5771 | 0.8627 | 0.0587 |
| 2010 | 240.011 | 1265 | 192.014 | 24 | 13.7711 | 1.1179 | 0.0578 |
| 2011 | 192.082 | 1125 | 179.459 | 20 | 12.5672 | 0.9676 | 0.0595 |
| 2012 | 134.522 | 966 | 131.553 | 21 | 11.0919 | 0.7617 | 0.0617 |

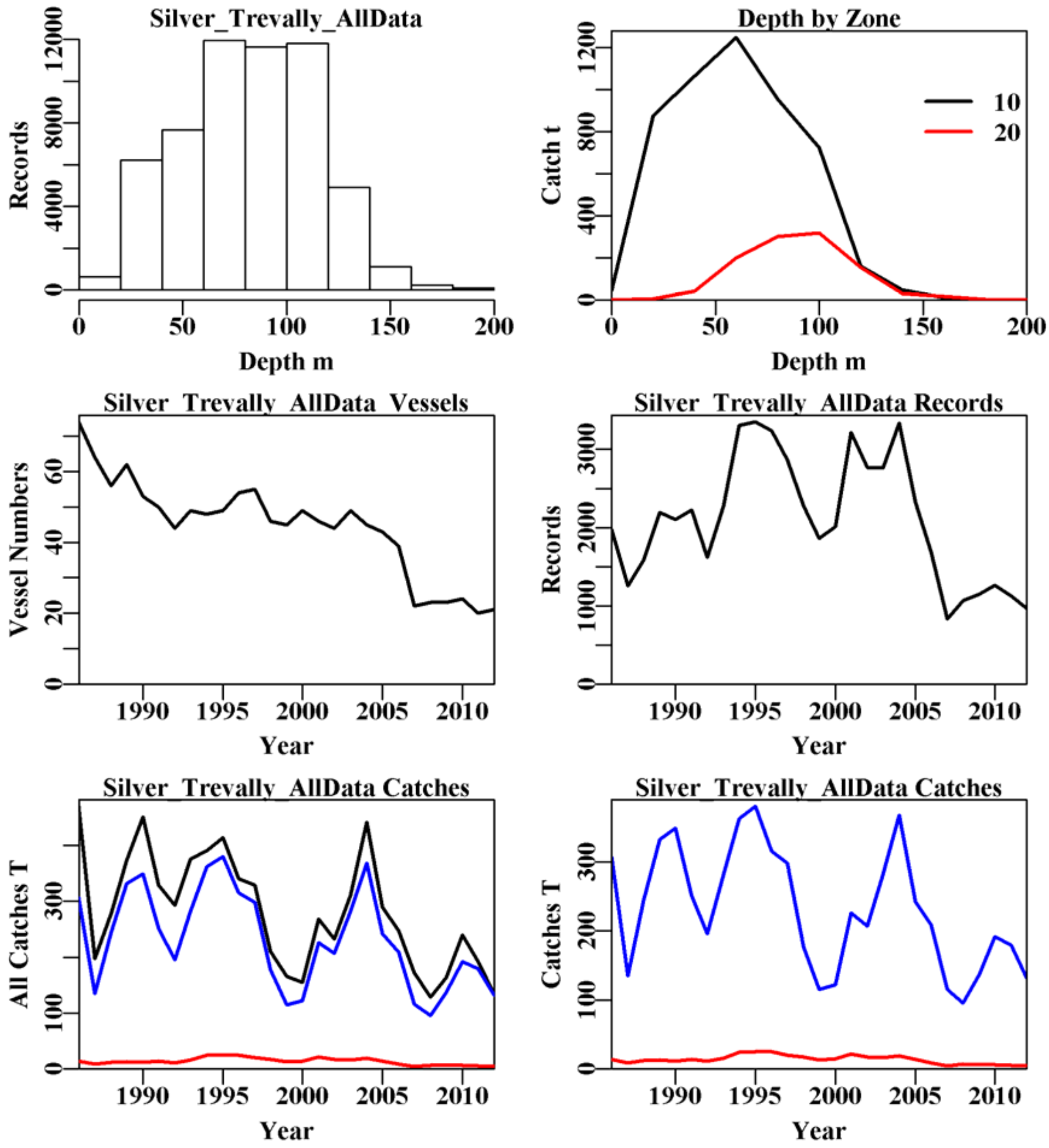



Figure 18.50. Silver Trevally from Zones 10 and 20 in depths 0 to 200 m, including all data taken in State waters (Bateman's Bay MPA). The top left is the depth distribution of all records reporting Silver Trevally, the top right graph depicts the depth distribution of shots containing Silver Trevally from Zones 10 and 20 in depths 0 to 200 m by trawl, including data taken in State waters (Bateman's Bay MPA). The middle left diagram depicts the distribution of catch by depth within zones 10 and 20 (20 is top red line), the middle right hand graph depicts the number of vessels through time. The bottom left reflects the number of records used in analysis, and bottom right is the Silver Trevally catches (top line, black is total catches, middle line, blue, are those used in the analysis, and bottom, red, are catches < 30Kg).

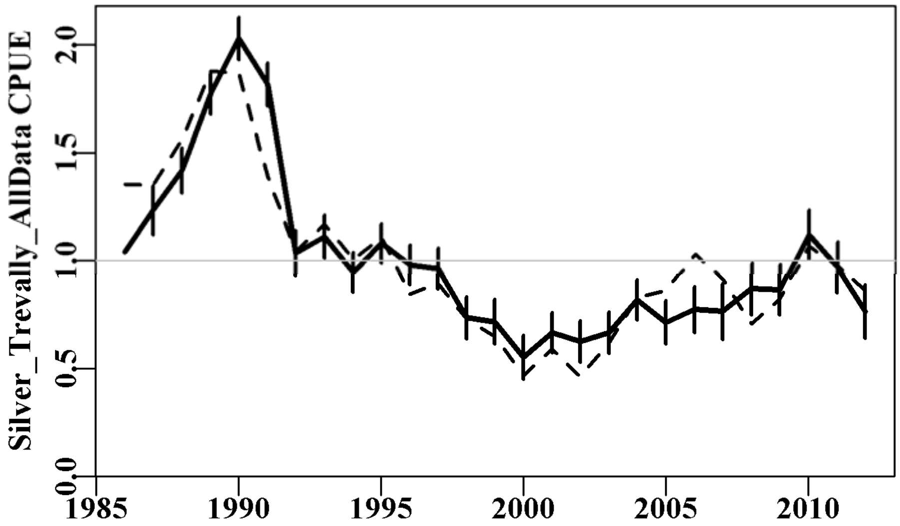



Figure 18.51. Silver Trevally from Zones 10 and 20 in depths 0 to 200 m, including data taken in State waters (Bateman's Bay MPA). The dashed black line represents the geometric mean catch rate and the solid black line the standardized catch rates. The graph standardizes catch rates relative to the mean of the standardized catch rates.

Table 18.46. Silver Trevally from Zones 10 and 20 in depths 0 to 200 m, including 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 18.47. 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, including the AIC, the adjusted $r^2$ and the change in adjusted $r^2$. The optimum is model Zone:Month.

| | Year | Vessel | DepCat | Month | DayNight | Zone | **Zone:Mth** | Zone:DepC |
|---|---|---|---|---|---|---|---|---|
| AIC | 59054 | 45874 | 42361 | 41667 | 41065 | 41051 | **40939** | 41015 |
| RSS | 160511 | 126518 | 118633 | 117133 | 115874 | 115840 | **115565** | 115725 |
| MSS | 7665 | 41658 | 49543 | 51043 | 52302 | 52336 | **52611** | 52451 |
| Nobs | 56659 | 56659 | 56222 | 56222 | 56222 | 56222 | **56222** | 56222 |
| Npars | 27 | 179 | 189 | 200 | 203 | 204 | **215** | 214 |
| adj_r2 | 4.514 | 24.534 | 29.222 | 30.103 | 30.851 | 30.870 | **31.021** | 30.926 |
| %Change | 0.000 | 20.020 | 4.689 | 0.881 | 0.748 | 0.019 | **0.151** | 0.056 |

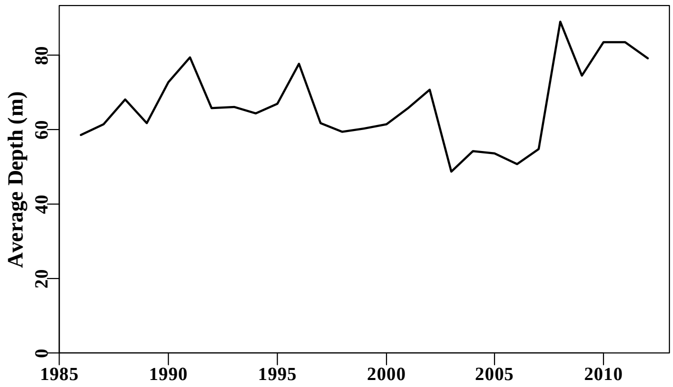



Figure 18.52. Average reported depth of trawling for Silver Trevally from Zones 10 and 20 in depths 0 to 200 m, including data taken in State waters (Bateman's Bay MPA). The effect of the introduction of the Batesman's Bay MPA in increasing the average depth fished is apparent from 2008 onwards.

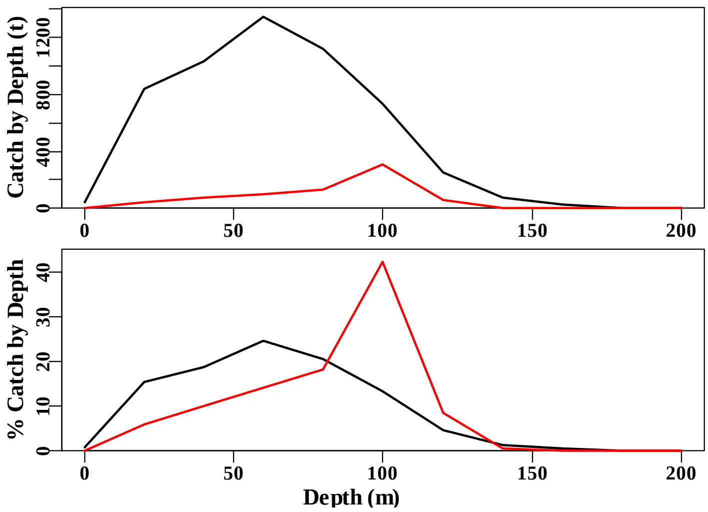



Figure 18.53. Catch by Depth for Silver Trevally from Zones 10 and 20 in depths 0 to 200 m, including data taken in State waters (Bateman's Bay MPA). The black lines are all data from 1986 – 2007 while the red line is data from 2008.

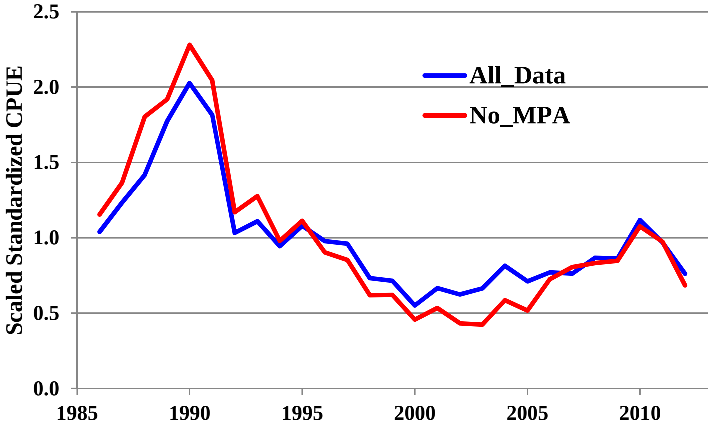



Figure 18 54. Comparison of the CPUE series with and without the data from inside the MPA. The All Data is less variable than the series that excludes data from the MPA.

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

Only data from Zone 10 were used, depths between 200 – 700 m.

Table 18.48. Royal Red Prawn from zone 10 in depths 200 – 700m by trawl. Total Catch is the total reported in the database, Records is the number of records used in the analysis, CatchT is the reported catch in the area and depth used in the analysis, and Vessels relates to all vessels used in the analysis. Geomean is the geometric mean of catch rates (kg/hr). Month:DepCat is the optimum model and StDev is the standard deviation relating to the data in the optimum model.

| Year | TotCatch | Records | CatchT | Vessels | GeoMean | Mth:DepC | StDev |
|---|---|---|---|---|---|---|---|
| 1986 | 277.717 | 1592 | 231.844 | 47 | 27.7627 | 0.6918 | 0.0000 |
| 1987 | 351.294 | 1764 | 324.716 | 47 | 41.9857 | 0.8829 | 0.0380 |
| 1988 | 362.445 | 1395 | 344.457 | 41 | 49.1496 | 0.9778 | 0.0409 |
| 1989 | 322.714 | 1143 | 310.760 | 39 | 45.8268 | 0.8333 | 0.0429 |
| 1990 | 335.111 | 727 | 311.118 | 25 | 95.1525 | 1.5634 | 0.0491 |
| 1991 | 334.061 | 734 | 299.370 | 29 | 79.4866 | 1.3943 | 0.0495 |
| 1992 | 166.860 | 434 | 146.081 | 19 | 70.3817 | 1.0408 | 0.0580 |
| 1993 | 298.749 | 673 | 232.774 | 21 | 68.5216 | 1.1942 | 0.0494 |
| 1994 | 359.830 | 661 | 240.363 | 26 | 77.7193 | 1.1348 | 0.0496 |
| 1995 | 334.852 | 1070 | 252.905 | 25 | 58.4998 | 0.9016 | 0.0436 |
| 1996 | 358.146 | 1216 | 272.675 | 25 | 60.5827 | 0.8127 | 0.0421 |
| 1997 | 252.693 | 855 | 166.703 | 21 | 51.9861 | 0.7652 | 0.0464 |
| 1998 | 233.298 | 1234 | 190.732 | 23 | 39.1713 | 0.8236 | 0.0428 |
| 1999 | 367.042 | 1607 | 348.804 | 25 | 49.7799 | 0.8162 | 0.0405 |
| 2000 | 434.931 | 1538 | 398.474 | 27 | 49.6136 | 1.0253 | 0.0409 |
| 2001 | 276.786 | 1307 | 228.699 | 22 | 35.9685 | 0.8726 | 0.0431 |
| 2002 | 484.129 | 1740 | 417.370 | 23 | 47.9208 | 1.0496 | 0.0402 |
| 2003 | 230.495 | 801 | 163.184 | 26 | 39.7063 | 1.0933 | 0.0491 |
| 2004 | 193.311 | 579 | 170.681 | 22 | 50.4687 | 1.1214 | 0.0536 |
| 2005 | 173.626 | 601 | 159.805 | 21 | 47.1225 | 1.0284 | 0.0536 |
| 2006 | 192.034 | 455 | 178.579 | 17 | 55.0038 | 1.2332 | 0.0581 |
| 2007 | 121.170 | 324 | 116.430 | 9 | 48.8072 | 0.8421 | 0.0662 |
| 2008 | 75.799 | 252 | 70.605 | 8 | 39.0864 | 0.7242 | 0.0749 |
| 2009 | 68.785 | 250 | 67.607 | 9 | 59.2670 | 0.9315 | 0.0787 |
| 2010 | 96.765 | 343 | 82.821 | 9 | 40.3732 | 0.8879 | 0.0662 |
| 2011 | 110.923 | 291 | 108.960 | 8 | 82.0762 | 1.3371 | 0.0706 |
| 2012 | 126.519 | 363 | 122.777 | 9 | 57.3988 | 1.0207 | 0.0652 |

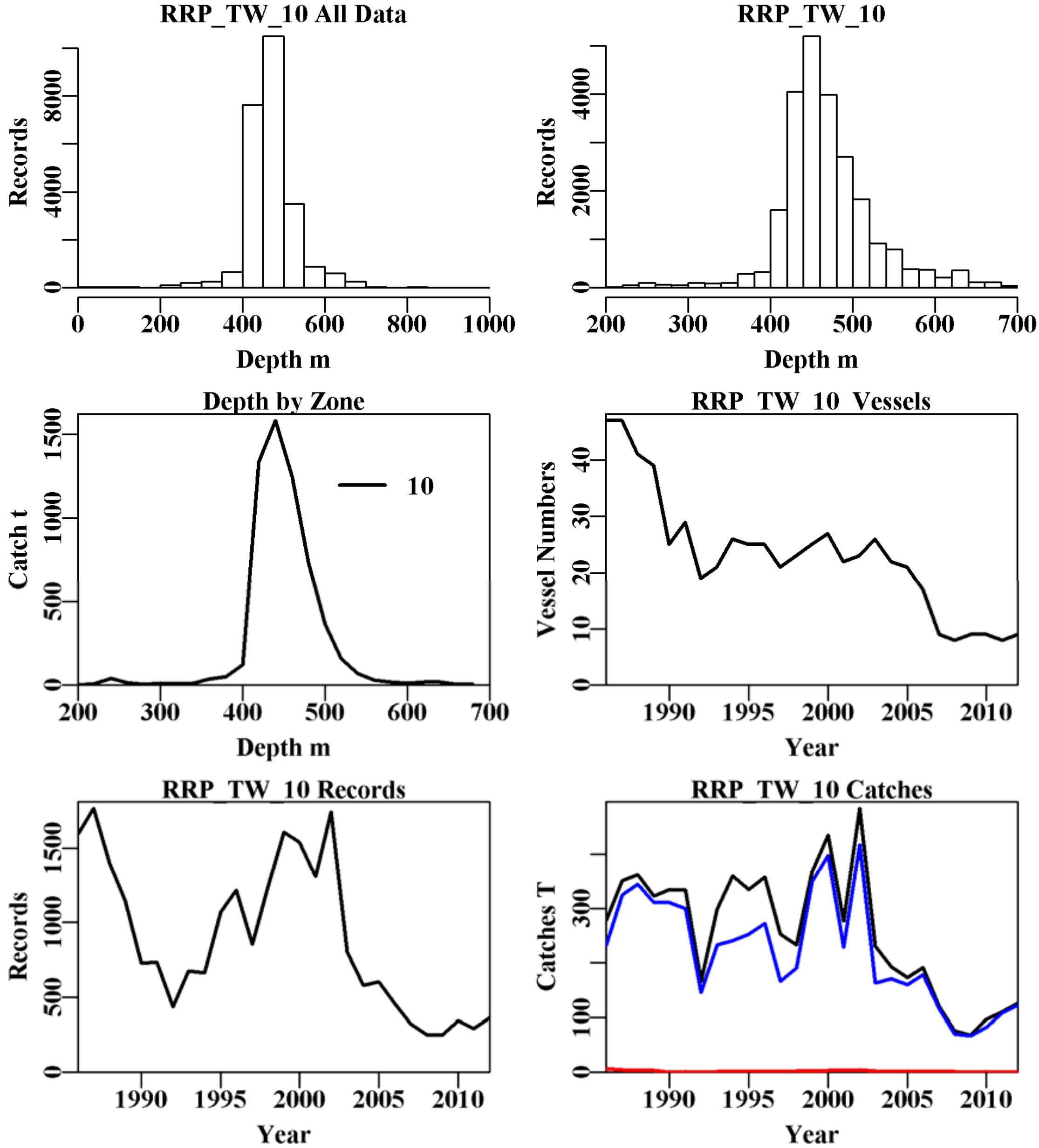



Figure 18.55. Royal Red Prawn from zone 10 in depths 200 – 700m by trawl. The top left is the depth distribution of all records reporting Royal Red Prawn, the top right graph depicts the depth distribution of shots containing Royal Red Prawn from zone 10 in depths 200 – 700m by trawl. The middle left diagram depicts the distribution of catch by depth within zone 10, the middle right hand graph depicts the number of vessels through time. The bottom left reflects the number of records used in analysis, and bottom right is the Royal Red Prawn catches (top line, black is total catches, middle line, blue, are those used in the analysis, and bottom, red, are catches < 30Kg).

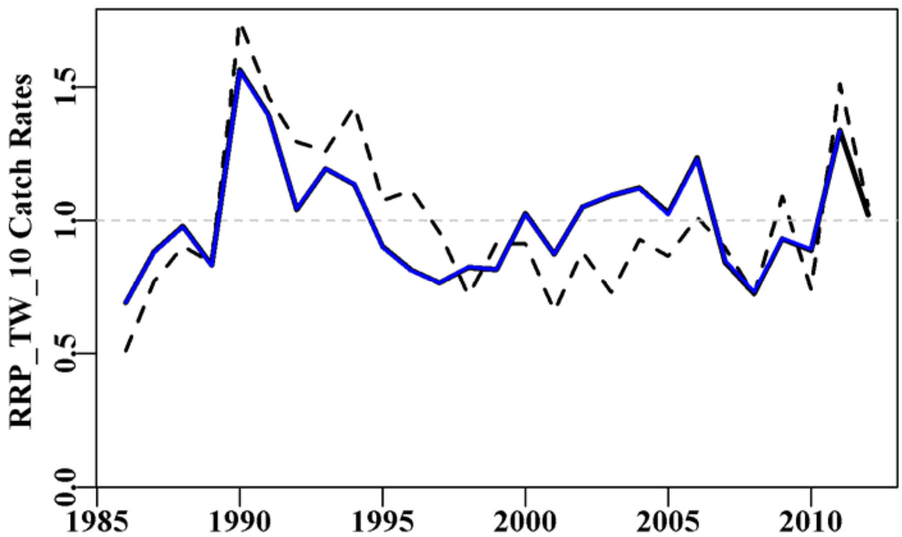



Figure 18.56. Royal Red Prawn from zone 10 in depths 200 – 700m by trawl. The dashed black line represents the geometric mean catch rate and the solid black line the standardized catch rates. The graph standardizes catch rates relative to the mean of the standardized catch rates.

Table 18.49. Royal Red Prawn from zone 10 in depths 200 – 700m 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 18.50. Royal Red Prawn from zone 10 in depths 200 – 700m by trawl. Model selection criteria, including the AIC, the adjusted $r^2$ and the change in adjusted $r^2$. The optimum was model Month:DepCat.

| | Year | DepCat | Vessel | Mth | DayNight | DN:Mth | **Mth:DepCat** | DN:DepCat |
|---|---|---|---|---|---|---|---|---|
| AIC | 13284 | 8313 | 3052 | 1442 | 1354 | 1320 | **833** | 1310 |
| RSS | 41611 | 33616 | 26765 | 24993 | 24894 | 24790 | **23821** | 24698 |
| MSS | 1770 | 9764 | 16615 | 18388 | 18487 | 18591 | **19560** | 18683 |
| Nobs | 23949 | 23812 | 23812 | 23812 | 23812 | 23812 | **23812** | 23812 |
| Npars | 27 | 51 | 134 | 145 | 148 | 181 | **412** | 220 |
| adj_r2 | 3.975 | 22.346 | 37.954 | 42.037 | 42.258 | 42.420 | **44.125** | 42.538 |
| %Change | 0.000 | 18.370 | 15.609 | 4.082 | 0.222 | 0.161 | **1.705** | -1.587 |

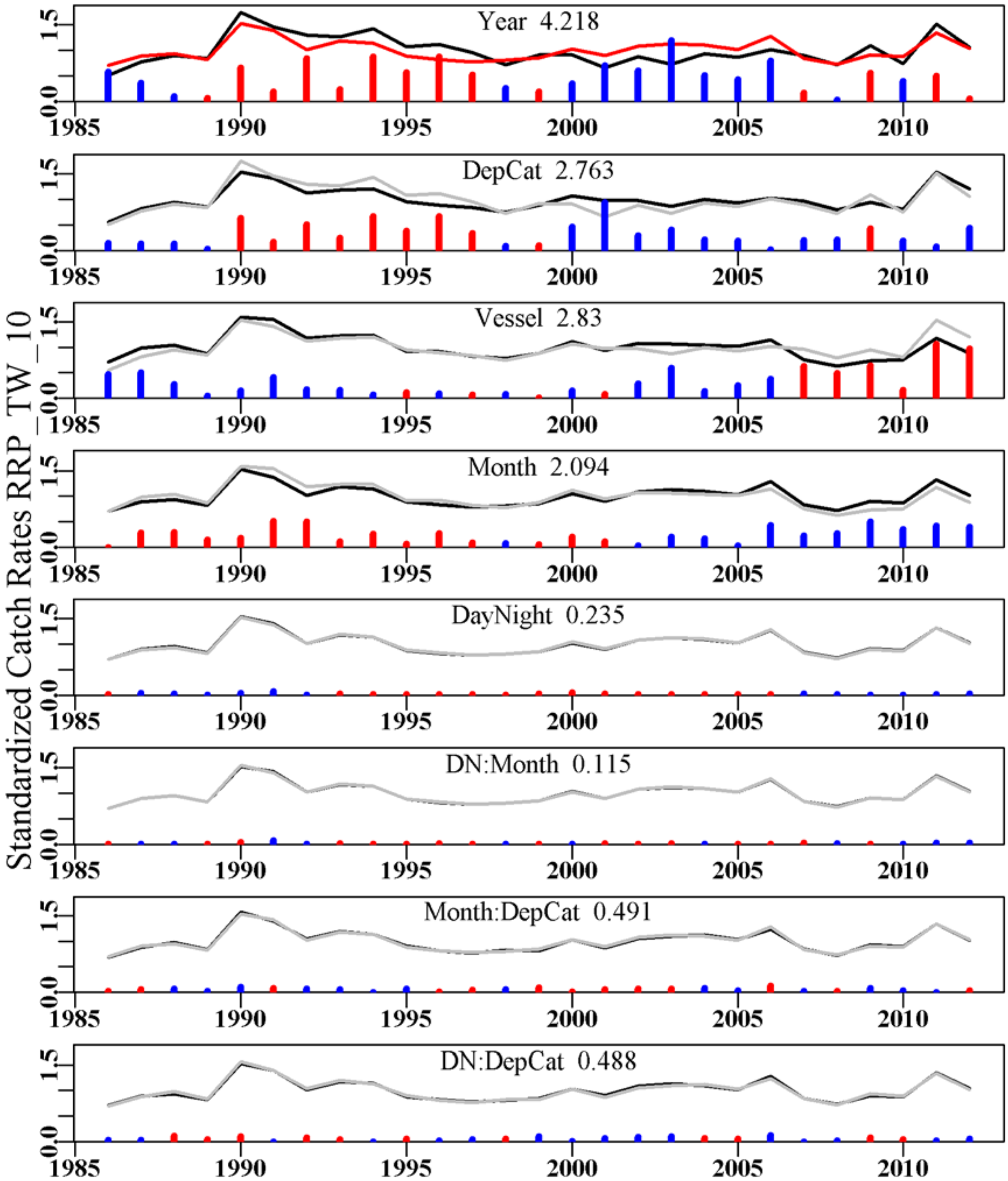



Figure 18.57. The relative influence of each factor used on the final trend in the optimal standardization for Royal Red Prawn in Zone 10. The top graph depicts the geometric mean (the black line) and the optimum model (the red line). The difference between them is illustrated by the vertical bars with 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.

*18.4.16.1 Comparison between Different Mesh Sizes*

Royal Red Prawns are targeted with so-called prawn nets that are significantly smaller meshed than usual trawl nets (Figure 18.58). The smaller mesh nets, < 60mm, have significantly higher catch rates than larger mesh nets with rates between 4 and 6 times higher than meshes > 80mm (Figure 18.59).

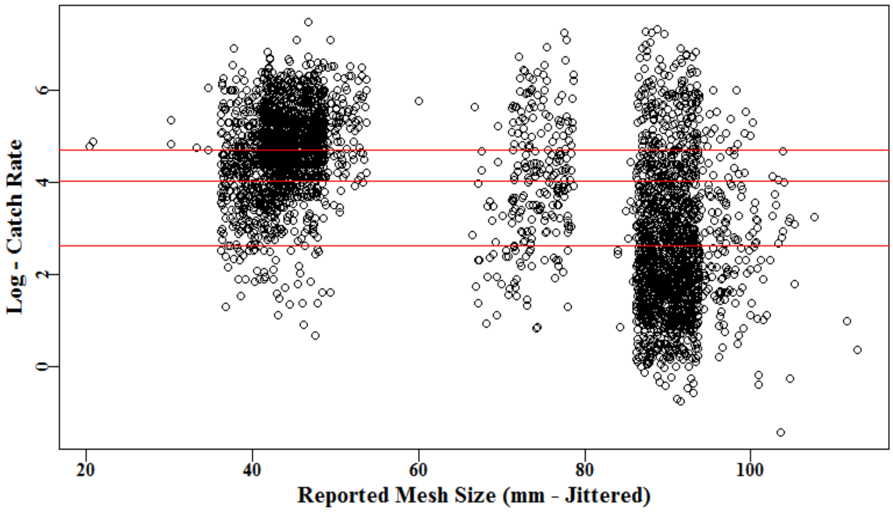



Figure 18.58. A scatter plot depicting the size distribution of reported mesh sizes used when Royal Red Prawn were landed. Each individual operation has been varied slightly (jittered) so as to illustrate the concentrations of mesh size and related catch rates. Thus, there are concentrations around 40 – 45mm, another at around 60 – 65mm, and another around 90mm. The three red lines depict the average log catch rates for the three clusters of data points, with the larger values relating to the clusters left to right.

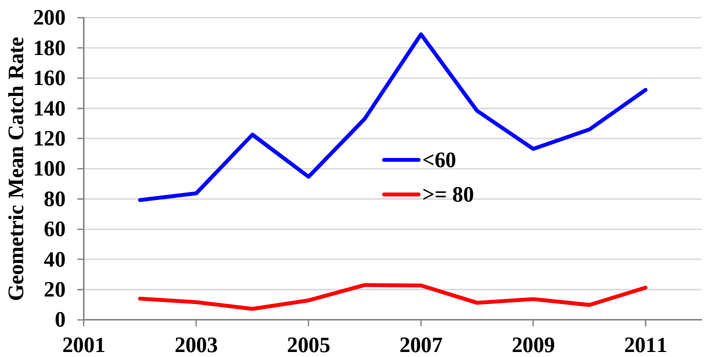



Figure 18.59. The geometric mean catch rates (kg/hr) of shots using nets with meshes less than 60mm and those with meshes greater than 80 mm.

While it is undoubtedly true that the absolute catch rates of Royal Red Prawn are much higher than when fishing with a normal trawl net the important aspect for the assessment of the relative abundance through time is any trend in the catch rates through time. By re-scaling all catch rates to a mean of 1.0 the trends in the catch rates from the different data sets can be directly compared (Figure 18.60).

The trends exhibited by the different data selections are noisy but essentially track a similar path. The optimum model, that uses all available data but doesn't distinguish between mesh sizes, is less variable than the smaller and larger mesh categories. Nevertheless, all series exhibit a rise between 2006 and 2007, and a further rise from average in 2011. These trend lines are clearly noisy about the average in each case, with the variation being greater from >=80mm, <60mm, and the Optimum series, which reflects the number of records in each data set. The conclusion remains that the use of the total dataset provides a good representation of the changes in the catch rates and can continue to be used in the Tier 4 assessment.

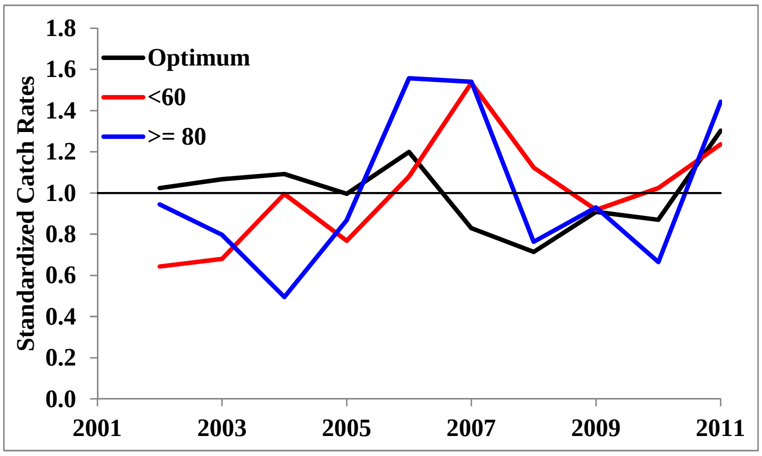



Figure 18.60. A comparison of the standardized catch rates, scaled to a mean of 1.0, for the optimum model using all data, and the separate statistical models for those data from meshes < 60mm and those > 80mm. The CV for the optimum series is 17.8%, for <60mm it is 26.9% and for the >=80mm it is 37.8%. The CVs in each case also reflect the relative amount of data available in each analysis.

Table 18.51. The scaled standardized catch rate data for different data selections. The Geomean and Optimum relate to all available data, < 60 relates to data from net meshes < 60mm, >=80 relate to data from meshes >=80mm, and BothMeshes relates to a standardization that includes data from both < 60 and >= 80 mm, using mesh size as a factor in the standardization, where it is, not surprisingly, highly influential. Columns 3 – 5 contain the data plotted in Figure 18.60.

| Year | GeoMean | Optimum | <60 | >= 80 | BothMeshes |
|---|---|---|---|---|---|
| 2002 | 0.93993 | 1.02359 | 0.64274 | 0.94438 | 1.03085 |
| 2003 | 0.77881 | 1.06722 | 0.67969 | 0.79677 | 0.98518 |
| 2004 | 0.98991 | 1.09235 | 0.99474 | 0.49541 | 1.03903 |
| 2005 | 0.92427 | 0.99593 | 0.76834 | 0.86704 | 0.94001 |
| 2006 | 1.07886 | 1.19880 | 1.08025 | 1.55634 | 1.15983 |
| 2007 | 0.95732 | 0.82842 | 1.53417 | 1.54000 | 1.02956 |
| 2008 | 0.76665 | 0.71378 | 1.12281 | 0.76311 | 0.82392 |
| 2009 | 1.16248 | 0.90847 | 0.91818 | 0.93033 | 0.80293 |
| 2010 | 0.79189 | 0.86951 | 1.02308 | 0.66411 | 0.88371 |
| 2011 | 1.60987 | 1.30193 | 1.23600 | 1.44252 | 1.30499 |

### *18.4.17 Blue Eye, Z2030 (TBE – 37445001 – Hyperoglyphe antarctica)*

Trawling data from zones 20 and 30, depths less than 1000 m.

Table 18.52. BlueEye from zones 20 and 30 in depths 0 – 1000m by trawl. Total Catch is the total reported in the database, Records is the number of records used in the analysis, CatchT is the reported catch in the area and depth used in the analysis, and Vessels relates to all vessels used in the analysis. Geomean is the geometric mean of catch rates (kg/hr). Zone:DepCat is the optimum model and StDev is the standard deviation relating to the data in the optimum model.

| Year | TotCatch | Records | CatchT | Vessels | GeoMean | Zone:DepC | StDev |
|---|---|---|---|---|---|---|---|
| 1986 | 37.962 | 166 | 9.117 | 17 | 10.0553 | 2.0812 | 0.0000 |
| 1987 | 15.495 | 190 | 10.026 | 14 | 9.8390 | 1.9572 | 0.1367 |
| 1988 | 105.177 | 307 | 19.433 | 21 | 14.4132 | 2.4327 | 0.1293 |
| 1989 | 87.740 | 315 | 33.371 | 32 | 14.6333 | 2.7395 | 0.1317 |
| 1990 | 79.208 | 264 | 39.845 | 36 | 24.1892 | 3.4875 | 0.1343 |
| 1991 | 75.681 | 474 | 29.189 | 37 | 9.3594 | 1.8698 | 0.1264 |
| 1992 | 49.280 | 313 | 14.232 | 23 | 8.3976 | 1.3942 | 0.1334 |
| 1993 | 59.644 | 736 | 37.789 | 31 | 7.9893 | 1.1168 | 0.1235 |
| 1994 | 109.975 | 855 | 89.033 | 33 | 10.7324 | 1.2935 | 0.1227 |
| 1995 | 58.572 | 489 | 28.335 | 29 | 5.8281 | 0.8610 | 0.1274 |
| 1996 | 71.684 | 648 | 35.518 | 29 | 5.7645 | 0.6964 | 0.1251 |
| 1997 | 463.319 | 604 | 19.921 | 31 | 4.6731 | 0.6382 | 0.1272 |
| 1998 | 448.146 | 475 | 18.704 | 24 | 4.1103 | 0.7277 | 0.1294 |
| 1999 | 548.067 | 633 | 41.733 | 27 | 3.5948 | 0.7572 | 0.1262 |
| 2000 | 653.775 | 657 | 37.661 | 34 | 2.7104 | 0.4821 | 0.1241 |
| 2001 | 579.726 | 692 | 25.038 | 24 | 2.2460 | 0.4230 | 0.1245 |
| 2002 | 476.739 | 700 | 33.732 | 28 | 3.0245 | 0.4227 | 0.1263 |
| 2003 | 565.203 | 723 | 14.094 | 25 | 2.2565 | 0.4224 | 0.1257 |
| 2004 | 598.770 | 623 | 15.171 | 28 | 2.7233 | 0.4141 | 0.1273 |
| 2005 | 447.053 | 502 | 17.919 | 26 | 2.6096 | 0.4092 | 0.1305 |
| 2006 | 544.834 | 327 | 36.782 | 17 | 3.9462 | 0.5016 | 0.1347 |
| 2007 | 559.007 | 248 | 10.629 | 11 | 3.1268 | 0.3940 | 0.1405 |
| 2008 | 342.397 | 434 | 13.654 | 15 | 5.6341 | 0.3674 | 0.1344 |
| 2009 | 424.099 | 246 | 22.849 | 14 | 5.4891 | 0.3698 | 0.1417 |
| 2010 | 380.558 | 199 | 11.939 | 13 | 3.5048 | 0.2541 | 0.1471 |
| 2011 | 458.658 | 228 | 7.870 | 12 | 2.2147 | 0.2635 | 0.1439 |
| 2012 | 340.782 | 150 | 1.333 | 11 | 1.6617 | 0.2232 | 0.1537 |

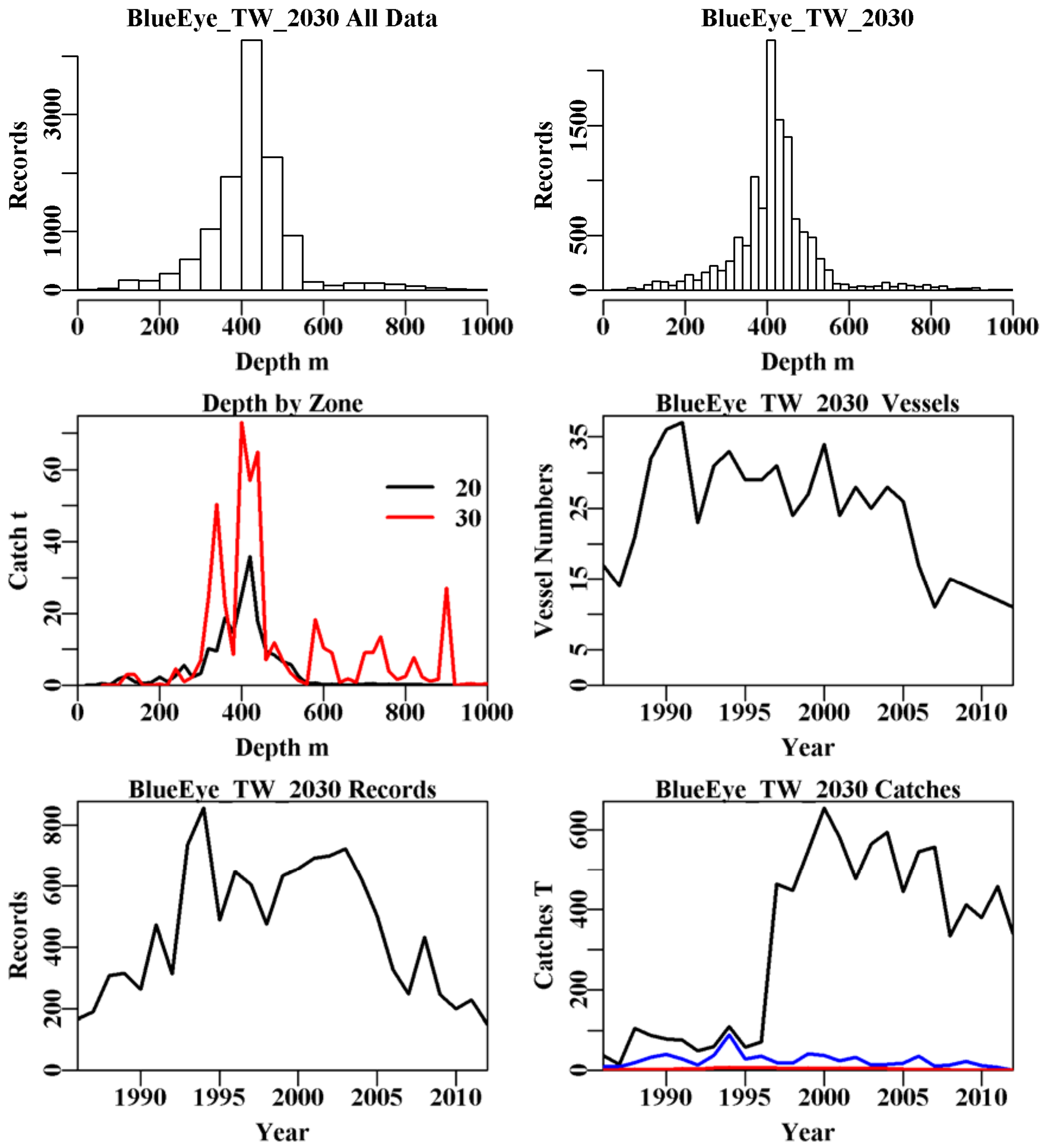



Figure 18.61. BlueEye from zones 20 and 30 in depths 0 – 1000m by trawl. The top left is the depth distribution of all records reporting BlueEye, the top right graph depicts the depth distribution of shots containing BlueEye from zones 20 and 30 in depths 0 – 1000m by trawl. The middle left diagram depicts the distribution of catch by depth within zones 20 and 30 (30 is top red line), the middle right hand graph depicts the number of vessels through time. The bottom left reflects the number of records used in analysis, and bottom right is the BlueEye catches (top line, black is total catches, middle line, blue, are those used in the analysis, and bottom, red, are catches < 30Kg).

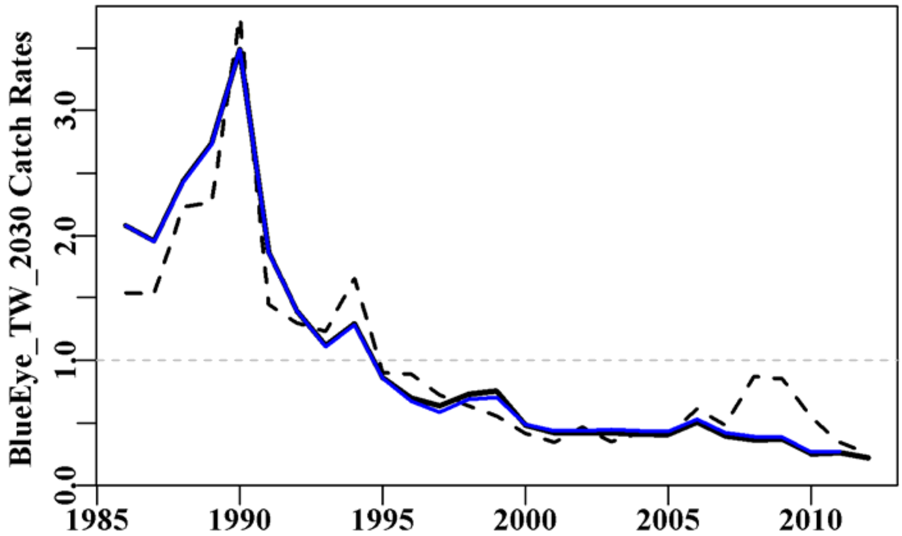



Figure 18.62. BlueEye from zones 20 and 30 in depths 0 – 1000m by trawl. The dashed black line represents the geometric mean catch rate and the solid black line the standardized catch rates. The graph standardizes catch rates relative to the mean of the standardized catch rates.

Table 18.53. BlueEye from zones 20 and 30 in depths 0 – 1000m 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 18.54. BlueEye from zones 20 and 30 in depths 0 – 1000m by trawl. Model selection criteria, including the AIC, the deviance and the change in deviance. The optimum was model Zone:DepCat.

| | Year | Vessel | Zone | DepCat | DayNight | Month | Zone:Mth | **Zone:DepC** |
|---|---|---|---|---|---|---|---|---|
| AIC | 10633 | 4566 | 4167 | 4054 | 3939 | 3925 | 3905 | **3729** |
| RSS | 29036 | 17317 | 16756 | 16402 | 16239 | 16191 | 16135 | **15806** |
| MSS | 4761 | 16481 | 17041 | 17395 | 17558 | 17606 | 17662 | **17991** |
| Nobs | 12198 | 12198 | 12198 | 12124 | 12124 | 12124 | 12124 | **12124** |
| Npars | 27 | 146 | 147 | 195 | 198 | 209 | 220 | **257** |
| adj_r2 | 13.902 | 48.147 | 49.821 | 50.680 | 51.159 | 51.257 | 51.381 | **52.224** |
| %Change | 0.000 | 34.245 | 1.674 | 0.859 | 0.479 | 0.098 | 0.125 | **0.843** |

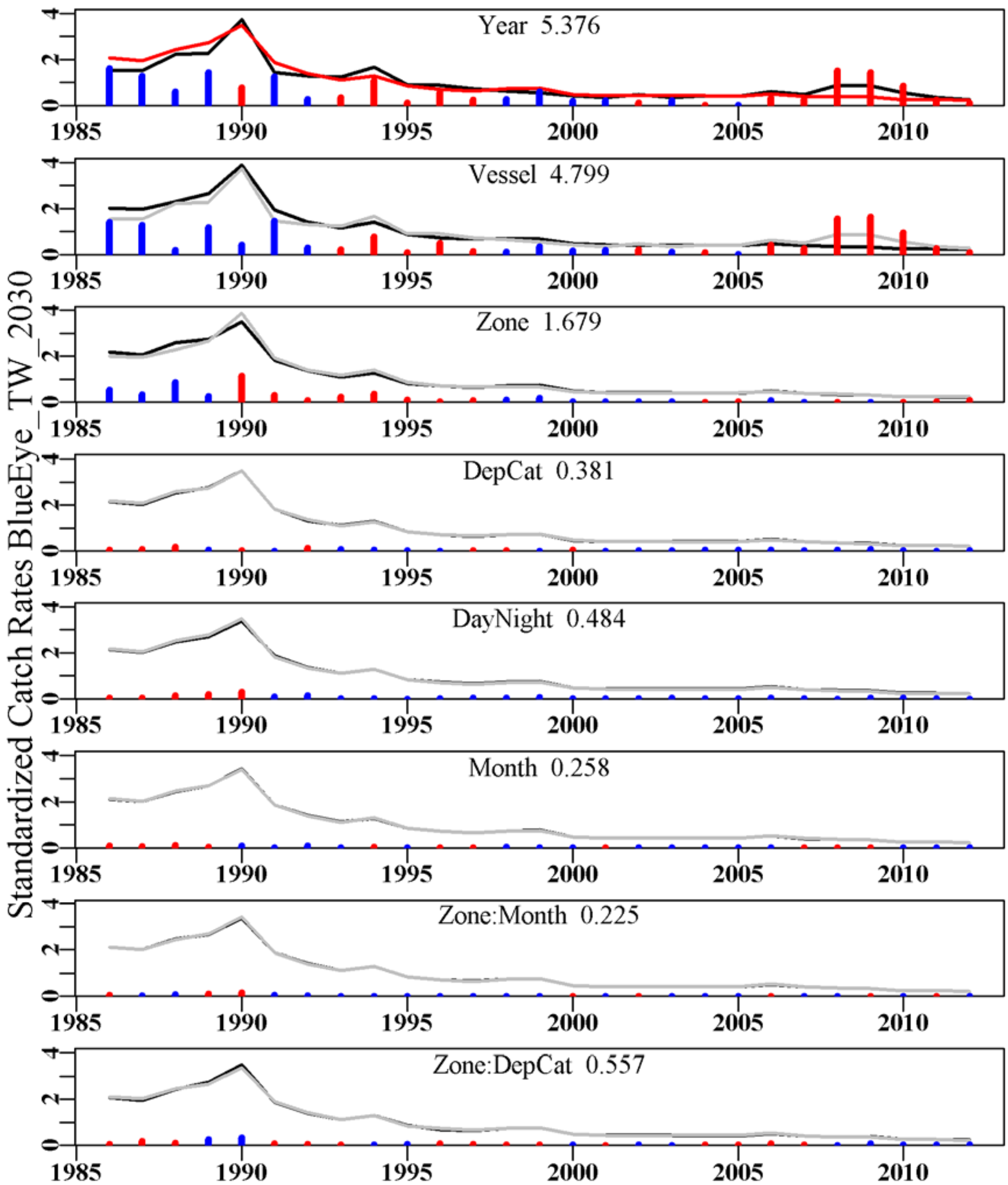



Figure 18.63. The relative influence of each factor used on the final trend in the optimal standardization for BlueEye in Zones 20 – 30. The top graph depicts the geometric mean (the black line) and the optimum model (the red line). The difference between them is illustrated by the vertical bars with 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.

### 18.4.18 *Blue Eye, Z4050 (TBE – 37445001 – H. antarctica)*

Data from zones 40 and 50, depths less than 1000 m.

Table 18.55. BlueEye from Zones 40 and 50 in depths 0 to 1000 m by Trawl. Total Catch is the total reported in the database, Records is the number of records used in the analysis, CatchT is the reported catch in the area and depth used in the analysis, and Vessels relates to all vessels used in the analysis. Geomean is the geometric mean of catch rates (kg/hr). Zone:Month is the optimum model and StDev is the standard deviation relating to the data in the optimum model.

| Year | TotCatch | Records | CatchT | Vessels | GeoMean | Zone:Mth | StDev |
|---|---|---|---|---|---|---|---|
| 1986 | 37.962 | 194 | 15.955 | 18 | 13.1296 | 0.9224 | 0.0000 |
| 1987 | 15.495 | 56 | 3.145 | 14 | 11.6895 | 0.7767 | 0.1754 |
| 1988 | 105.177 | 142 | 76.410 | 15 | 41.5696 | 2.3316 | 0.1559 |
| 1989 | 87.740 | 238 | 43.985 | 24 | 25.5841 | 1.9103 | 0.1376 |
| 1990 | 79.208 | 157 | 30.910 | 16 | 13.0702 | 2.0108 | 0.1580 |
| 1991 | 75.681 | 129 | 18.954 | 18 | 17.4424 | 1.6436 | 0.1563 |
| 1992 | 49.280 | 129 | 28.643 | 15 | 21.8842 | 1.9319 | 0.1562 |
| 1993 | 59.644 | 289 | 18.109 | 19 | 8.5334 | 0.8815 | 0.1399 |
| 1994 | 109.975 | 348 | 16.282 | 19 | 8.8991 | 0.9358 | 0.1365 |
| 1995 | 58.572 | 500 | 26.381 | 21 | 6.4723 | 0.8366 | 0.1327 |
| 1996 | 71.684 | 523 | 30.184 | 24 | 8.0361 | 0.8664 | 0.1333 |
| 1997 | 463.319 | 788 | 82.371 | 18 | 6.5139 | 0.8851 | 0.1300 |
| 1998 | 448.146 | 780 | 58.946 | 19 | 5.3540 | 1.0561 | 0.1314 |
| 1999 | 548.067 | 877 | 46.303 | 19 | 6.4046 | 1.0845 | 0.1303 |
| 2000 | 653.775 | 1109 | 44.729 | 23 | 5.2927 | 0.9462 | 0.1295 |
| 2001 | 579.726 | 955 | 42.188 | 26 | 5.7866 | 0.8893 | 0.1311 |
| 2002 | 476.739 | 802 | 32.268 | 26 | 5.0532 | 0.7470 | 0.1312 |
| 2003 | 564.693 | 392 | 11.023 | 25 | 3.1895 | 0.6814 | 0.1377 |
| 2004 | 594.290 | 852 | 31.296 | 24 | 4.2166 | 0.6014 | 0.1313 |
| 2005 | 444.114 | 508 | 12.750 | 22 | 3.6280 | 0.5534 | 0.1346 |
| 2006 | 544.834 | 533 | 16.279 | 17 | 3.6218 | 0.5682 | 0.1342 |
| 2007 | 556.619 | 538 | 26.188 | 16 | 4.4303 | 0.6054 | 0.1341 |
| 2008 | 334.297 | 324 | 16.371 | 14 | 4.9605 | 0.7811 | 0.1392 |
| 2009 | 411.616 | 343 | 15.751 | 13 | 4.0530 | 0.7226 | 0.1390 |
| 2010 | 380.394 | 430 | 31.436 | 14 | 5.5190 | 0.7586 | 0.1362 |
| 2011 | 458.642 | 381 | 14.696 | 14 | 2.8213 | 0.5975 | 0.1373 |
| 2012 | 340.633 | 261 | 9.007 | 11 | 1.8380 | 0.4746 | 0.1465 |

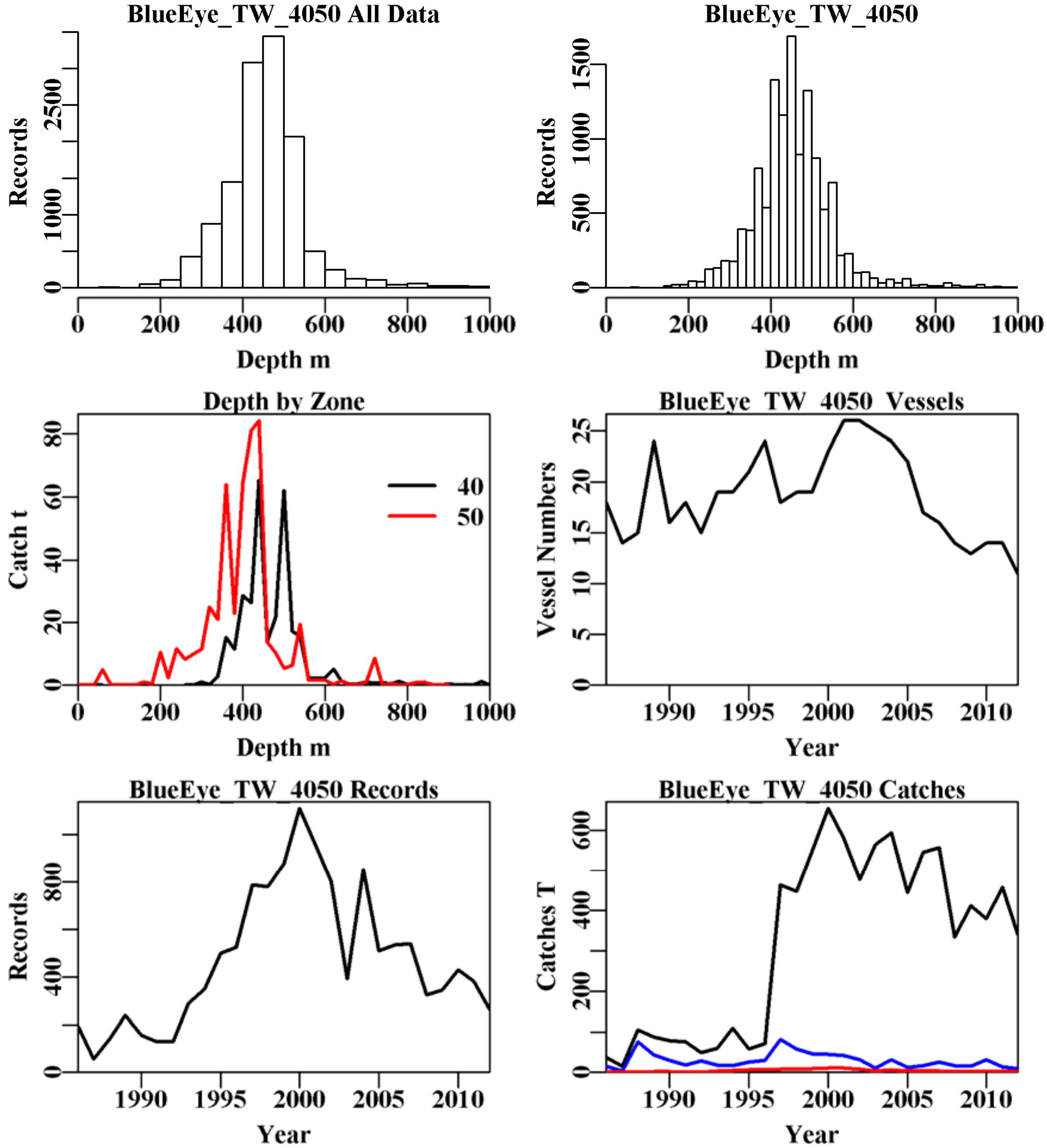



Figure 18.64. BlueEye from Zones 40 and 50 in depths 0 to 1000 m by Trawl. The top left is the depth distribution of all records reporting BlueEye, the top right graph depicts the depth distribution of shots containing BlueEye from Zones 40 and 50 in depths 0 to 1000 m by Trawl. The middle left diagram depicts the distribution of catch by depth within zones 40 and 50 (50 is top red line), the middle right hand graph depicts the number of vessels through time. The bottom left reflects the number of records used in analysis, and bottom right is the BlueEye catches (top line, black is total catches, middle line, blue, are those used in the analysis, and bottom, red, are catches < 30Kg).

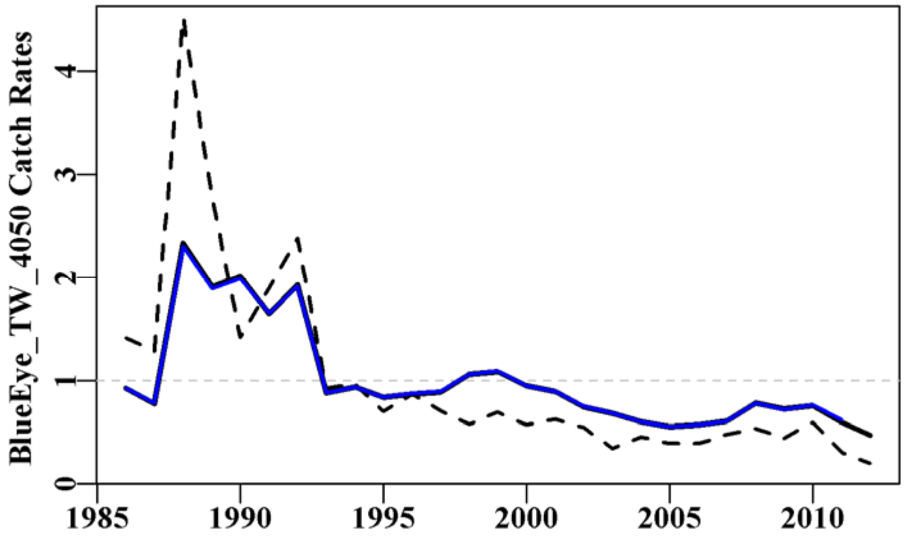



Figure 18.65. BlueEye from Zones 40 and 50 in depths 0 to 1000 m by Trawl. The dashed black line represents the geometric mean catch rate and the solid black line the standardized catch rates. The graph standardizes catch rates relative to the mean of the standardized catch rates.

Table 18.56. BlueEye from Zones 40 and 50 in depths 0 to 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+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 18.57. BlueEye from Zones 40 and 50 in depths 0 to 1000 m by Trawl. Model selection criteria, including the AIC, the adjusted $r^2$ and the change in adjusted $r^2$. The optimum was model Zone:DepCat.

| | Year | Vessel | DepCat | DayNight | Month | Zone | Zone:Mth | **Zone:DepC** |
|---|---|---|---|---|---|---|---|---|
| AIC | 8184 | 2817 | 2400 | 2153 | 2112 | 2057 | 2048 | **2040** |
| RSS | 24006 | 15467 | 14786 | 14490 | 14417 | 14352 | 14317 | **14221** |
| MSS | 3023 | 11562 | 12243 | 12539 | 12611 | 12677 | 12712 | **12808** |
| Nobs | 12578 | 12578 | 12516 | 12516 | 12516 | 12516 | 12516 | **12516** |
| Npars | 27 | 108 | 157 | 160 | 171 | 172 | 183 | **221** |
| adj_r2 | 11.001 | 42.284 | 44.606 | 45.701 | 45.925 | 46.167 | 46.250 | **46.444** |
| %Change | 0.000 | 31.283 | 2.322 | 1.095 | 0.224 | 0.242 | 0.084 | **0.194** |

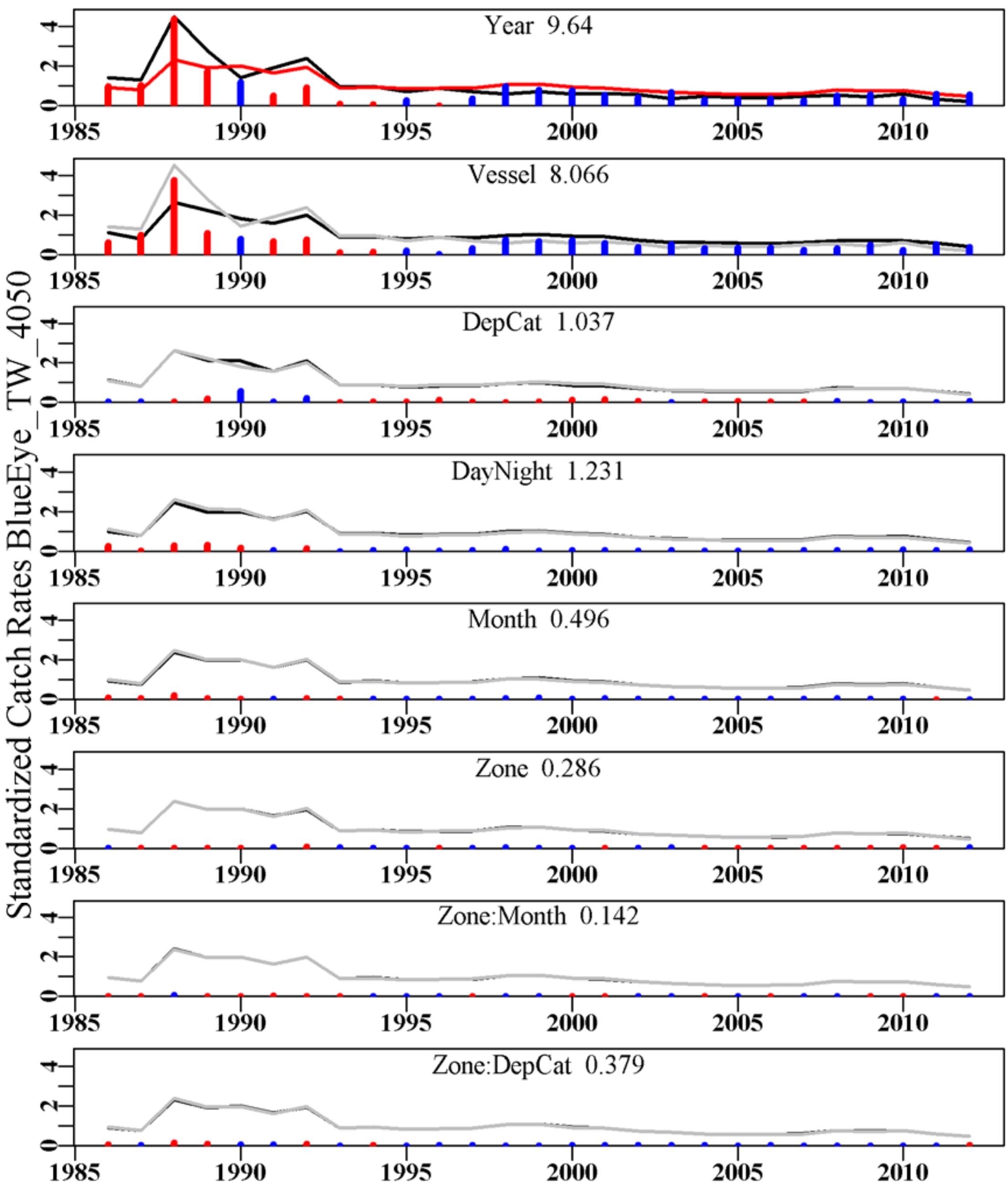



Figure 18.66. The relative influence of each factor used on the final trend in the optimal standardization for BlueEye in Zones 40 – 50. The top graph depicts the geometric mean (the black line) and the optimum model (the red line). The difference between them is illustrated by the vertical bars with 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.

### 18.4.19 Blue Eye, AL (TBE – 37445001 – H. antarctica)

Depths between 200-600m. All data from auto-longlining. 1997 was omitted as being unrepresentative due to very lower numbers of records.

Table 18.58. BlueEye from the SESSF in depths 200 – 600m by AutoLongLine. Total Catch is the total reported in the database, Records is the number of records used in the analysis, CatchT is the reported catch in the area and depth used in the analysis, and Vessels relates to all vessels used in the analysis. Geomean is the geometric mean of catch rates (kg/hr). Zone:DepCat is the optimum model and StDev is the standard deviation relating to the data in the optimum model.

| Year | TotCatch | Records | CatchT | Vessels | GeoMean | Zone:DepC | StDev |
|---|---|---|---|---|---|---|---|
| 1998 | 448.146 | 28 | 14.989 | 2 | 249.6862 | 0.6273 | 0.0000 |
| 1999 | 548.067 | 50 | 47.670 | 2 | 536.1933 | 1.9629 | 0.3311 |
| 2000 | 653.775 | 29 | 28.299 | 2 | 608.0267 | 1.5990 | 0.3683 |
| 2001 | 579.726 | 65 | 40.232 | 2 | 246.5002 | 0.9087 | 0.3184 |
| 2002 | 476.739 | 228 | 131.686 | 4 | 162.2961 | 0.7609 | 0.2906 |
| 2003 | 564.693 | 434 | 157.016 | 7 | 133.4303 | 1.2342 | 0.2932 |
| 2004 | 594.290 | 1145 | 268.210 | 11 | 71.8292 | 1.2049 | 0.2893 |
| 2005 | 444.114 | 1135 | 299.978 | 7 | 77.6456 | 0.9193 | 0.2893 |
| 2006 | 544.834 | 1067 | 345.481 | 9 | 102.2372 | 0.9642 | 0.2883 |
| 2007 | 556.619 | 658 | 453.819 | 6 | 364.8943 | 1.2126 | 0.2903 |
| 2008 | 334.297 | 604 | 277.917 | 6 | 232.1695 | 0.8136 | 0.2904 |
| 2009 | 411.616 | 550 | 313.987 | 6 | 289.6046 | 0.9347 | 0.2902 |
| 2010 | 380.394 | 483 | 230.042 | 5 | 184.8051 | 0.6099 | 0.2913 |
| 2011 | 458.642 | 526 | 225.716 | 5 | 209.8939 | 0.6487 | 0.2910 |
| 2012 | 340.633 | 427 | 180.740 | 6 | 170.2138 | 0.5991 | 0.2920 |

Table 18.59. BlueEye from the SESSF in depths 200 – 600m by Auto-LongLine. 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+DayNight |
| Model 6 | LnCE~Year+Vessel+Month+Zone+DayNight+DepCat |
| Model 7 | LnCE~Year+Vessel+Month+Zone+DayNight+DepCat+Zone:Month |
| Model 8 | LnCE~Year+Vessel+Month+Zone+DayNight+DepCat+Zone:DepCat |

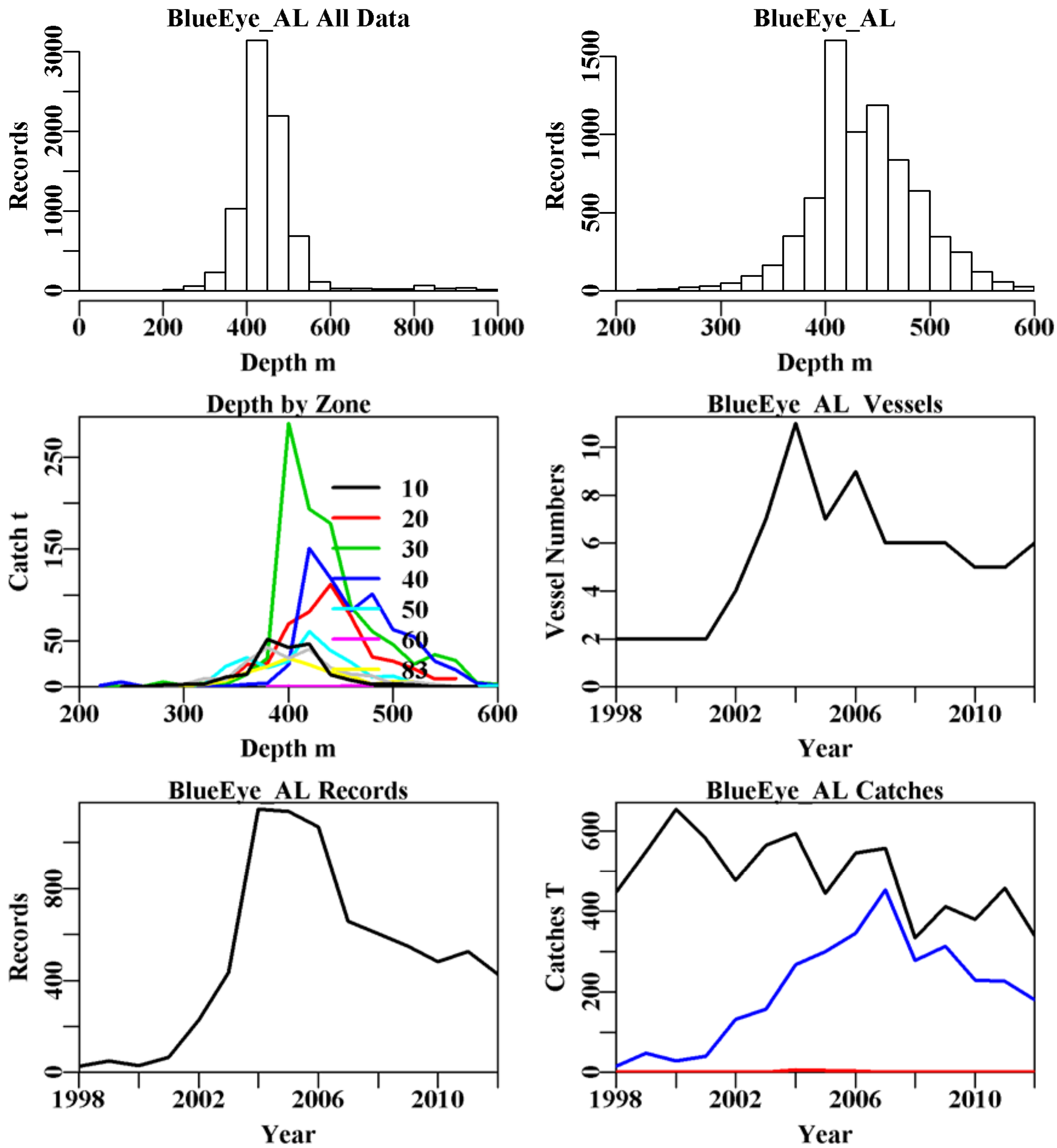
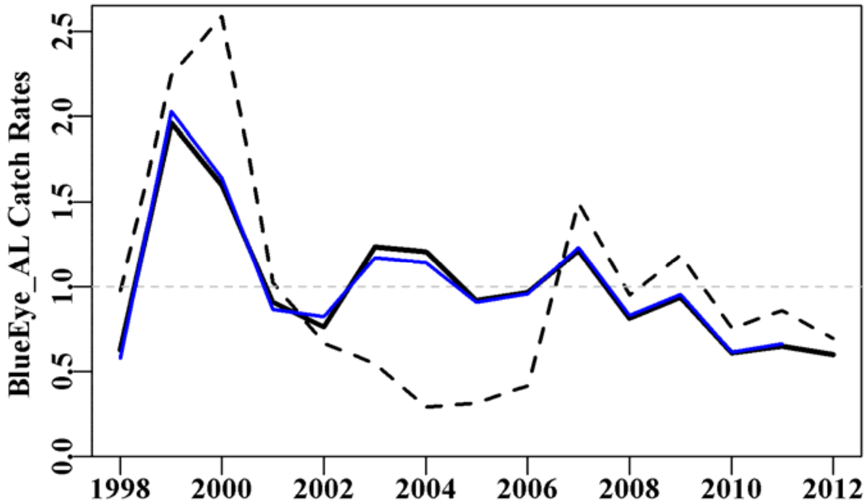



Figure 18.67. BlueEye from the SESSF in depths 200 – 600m by Auto-LongLine. The top left is the depth distribution of all records reporting BlueEye, the top right graph depicts the depth distribution of shots containing BlueEye from the SESSF in depths 200 – 600m by Auto-LongLine. The middle left diagram depicts the distribution of catch by depth across the zones of the SESSF, the middle right hand graph depicts the number of vessels through time. The bottom left reflects the number of records used in analysis, and bottom right is the BlueEye catches (top line, black is total catches, middle line, blue, are those used in the analysis, and bottom, red, are catches < 30Kg).



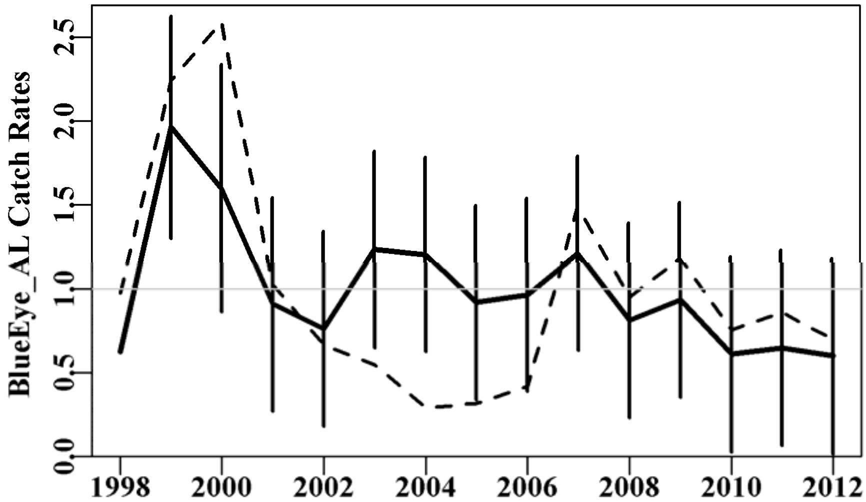




Figure 18.68. BlueEye from the SESSF in depths 200 – 600m by Auto-LongLine. The dashed black line represents the geometric mean catch rate and the solid black line the standardized catch rates. The graph standardizes catch rates relative to the mean of the standardized catch rates. The lower graph illustrates the impact on the relative uncertainty of the relatively small number of records, especially in the early years.

Table 18.60. BlueEye from the SESSF in depths 200 – 600m by Auto-LongLine. Model selection criteria, including the AIC, the adjusted $r^2$ and the change in adjusted $r^2$. The optimum was model Zone:Month.

| | Year | Vessel | Month | Zone | DayNight | DepCat | **Zone:Mth** | Zone:DepC |
|---|---|---|---|---|---|---|---|---|
| AIC | 6826 | 4788 | 4156 | 3995 | 3977 | 3944 | **3925** | 3950 |
| RSS | 18544 | 14051 | 12866 | 12585 | 12545 | 12403 | **12335** | 12346 |
| MSS | 2383 | 6877 | 8062 | 8342 | 8383 | 8524 | **8593** | 8582 |
| Nobs | 7429 | 7429 | 7429 | 7428 | 7428 | 7404 | **7404** | 7404 |
| Npars | 15 | 27 | 38 | 39 | 42 | 62 | **73** | 81 |
| adj_r2 | 11.221 | 32.623 | 38.215 | 39.552 | 39.724 | 40.239 | **40.480** | 40.362 |
| %Change | 0.000 | 21.402 | 5.592 | 1.337 | 0.171 | 0.515 | **0.241** | -0.118 |

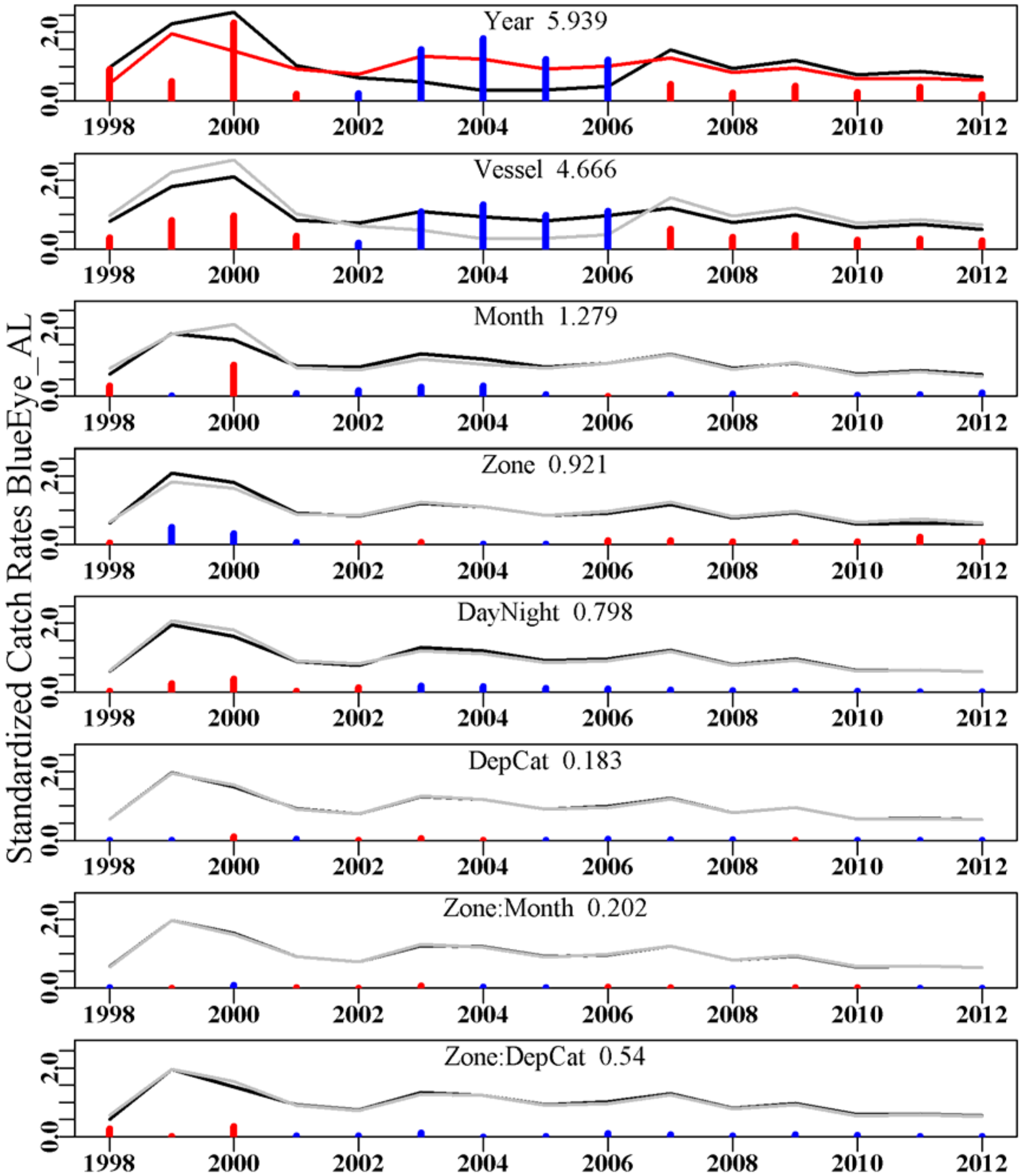



Figure 18.69. The relative influence of each factor used on the final trend in the optimal standardization for BlueEye in by Auto-Longline. The top graph depicts the geometric mean (the black line) and the optimum model (the red line). The difference between them is illustrated by the vertical bars with 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.

### *18.4.20 Blue Eye, DL (TBE – 37445001 – H. antarctica)*

Depths between 200-600m m. All data from Drop-lining. All vessels reporting blue eye by drop line are included. There is a slight change in the trajectory because depth data since 2005 has now been linked to Drop Line data.

Table 18.61. BlueEye from the SET and GHT fishery in depths between 200 – 600m, taken by Drop Line. Total Catch is the total reported in the database, Records is the number of records used in the analysis, CatchT is the reported catch in the area and depth used in the analysis, and Vessels relates to all vessels used in the analysis. Geomean is the geometric mean of catch rates (kg/hr). Zone:Month is the optimum model and StDev is the standard deviation relating to the data in the optimum model.

| Year | TotCatch | Records | CatchT | Vessels | GeoMean | Zone:Mth | StDev |
|---|---|---|---|---|---|---|---|
| 1997 | 463.319 | 542 | 254.094 | 38 | 261.5525 | 1.8101 | 0.0000 |
| 1998 | 448.146 | 730 | 325.907 | 29 | 225.2953 | 1.3460 | 0.0763 |
| 1999 | 548.067 | 876 | 339.371 | 29 | 178.7355 | 1.1628 | 0.0787 |
| 2000 | 653.775 | 1057 | 377.853 | 33 | 171.7160 | 1.1638 | 0.0825 |
| 2001 | 579.726 | 740 | 318.270 | 26 | 200.2441 | 1.2764 | 0.0864 |
| 2002 | 476.739 | 570 | 180.454 | 22 | 164.7123 | 1.0629 | 0.0919 |
| 2003 | 564.693 | 535 | 167.969 | 22 | 162.1292 | 0.8457 | 0.0996 |
| 2004 | 594.290 | 490 | 149.016 | 23 | 160.0459 | 0.9671 | 0.1026 |
| 2005 | 444.114 | 342 | 80.625 | 16 | 134.2685 | 0.7784 | 0.1111 |
| 2006 | 544.834 | 301 | 101.649 | 13 | 222.2480 | 1.0081 | 0.1189 |
| 2007 | 556.619 | 125 | 45.123 | 10 | 208.7957 | 1.3151 | 0.1440 |
| 2008 | 334.297 | 80 | 15.580 | 7 | 117.4039 | 0.7950 | 0.1641 |
| 2009 | 411.616 | 81 | 17.818 | 9 | 124.4663 | 0.5296 | 0.1761 |
| 2010 | 380.394 | 197 | 28.964 | 9 | 76.1903 | 0.4522 | 0.1478 |
| 2011 | 458.642 | 166 | 32.368 | 9 | 104.9216 | 0.7107 | 0.1588 |
| 2012 | 340.633 | 93 | 17.928 | 8 | 105.1590 | 0.7761 | 0.2005 |

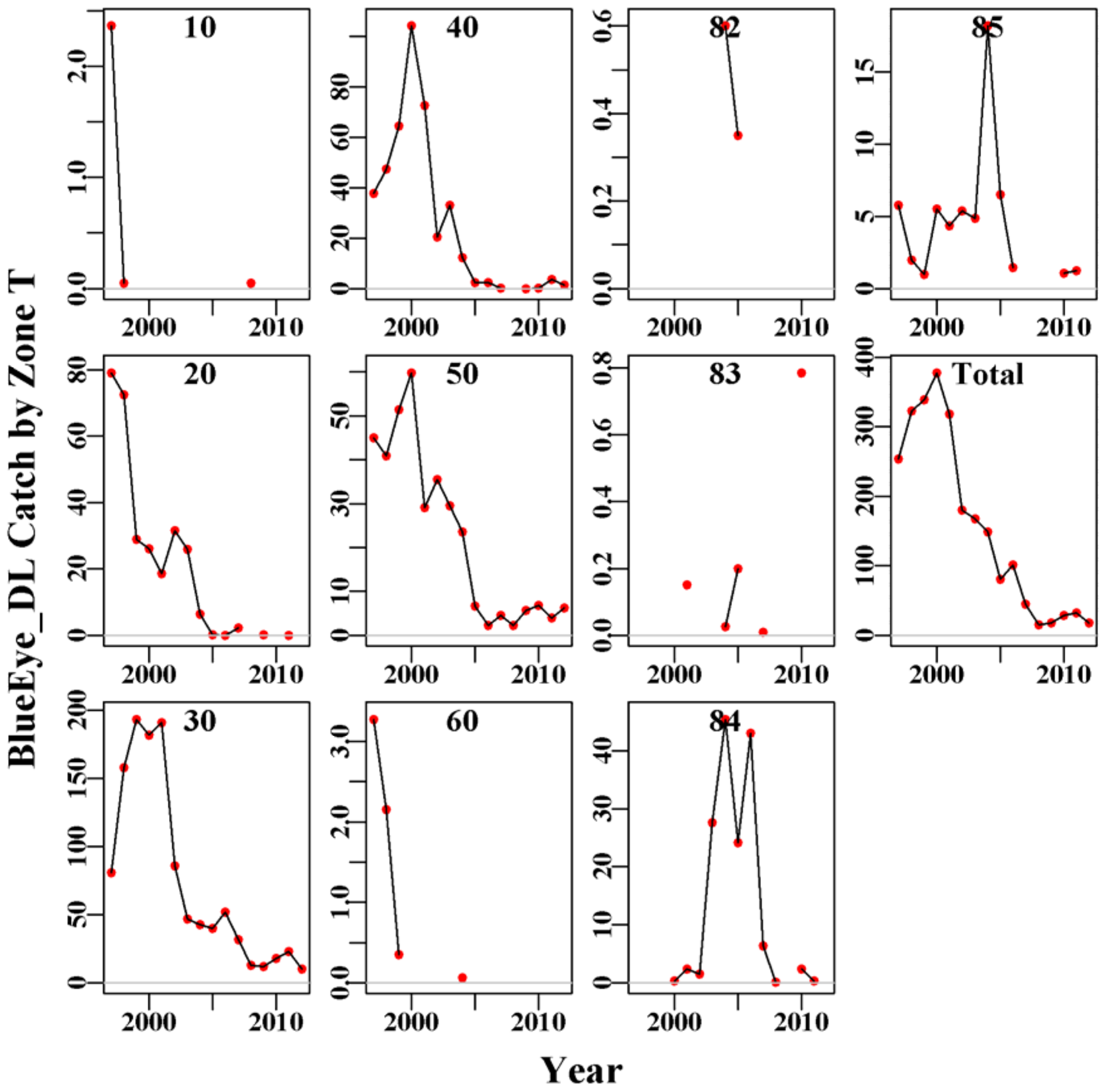



Figure 18.70. BlueEye catches by zone from the SESSF in depths 200 – 600m by DropLine.

Table 18.62. BlueEye from the SET and GHT fishery in depths between 200 – 600m, taken by Drop 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+Month |
| Model 4 | LnCE~Year+Vessel+Month+Zone |
| Model 5 | LnCE~Year+Vessel+Month+Zone+DayNight |
| Model 6 | LnCE~Year+Vessel+Month+Zone+DayNight+DepCat |
| Model 7 | LnCE~Year+Vessel+Month+Zone+DayNight+DepCat+Zone:Month |
| Model 8 | LnCE~Year+Vessel+Month+Zone+DayNight+DepCat+Zone:DepCat |

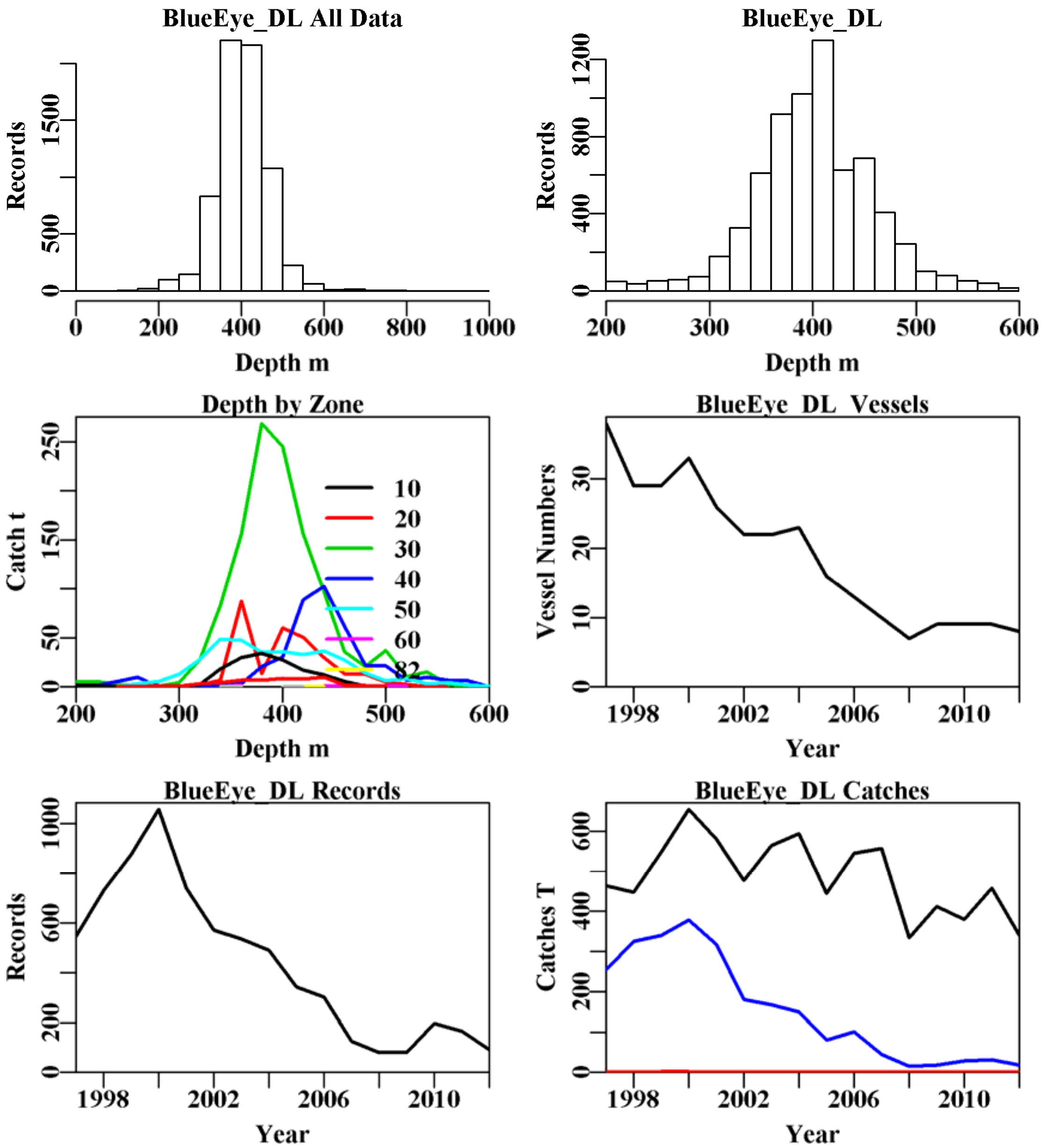



Figure 18.71. BlueEye from the SET and GHT fishery in depths between 200 – 600m, taken by Drop Line. The top left is the depth distribution of all records reporting BlueEye, the top right graph depicts the depth distribution of shots containing BlueEye from the SET and GHT fishery in depths between 200 – 600m, taken by Drop Line. The middle left diagram depicts the distribution of catch by depth by SESSF zone, the middle right hand graph depicts the number of vessels through time. The bottom left reflects the number of records used in analysis, and bottom right is the BlueEye catches (top line, black is total catches, middle line, blue, are those used in the analysis, and bottom, red, are catches < 30Kg).

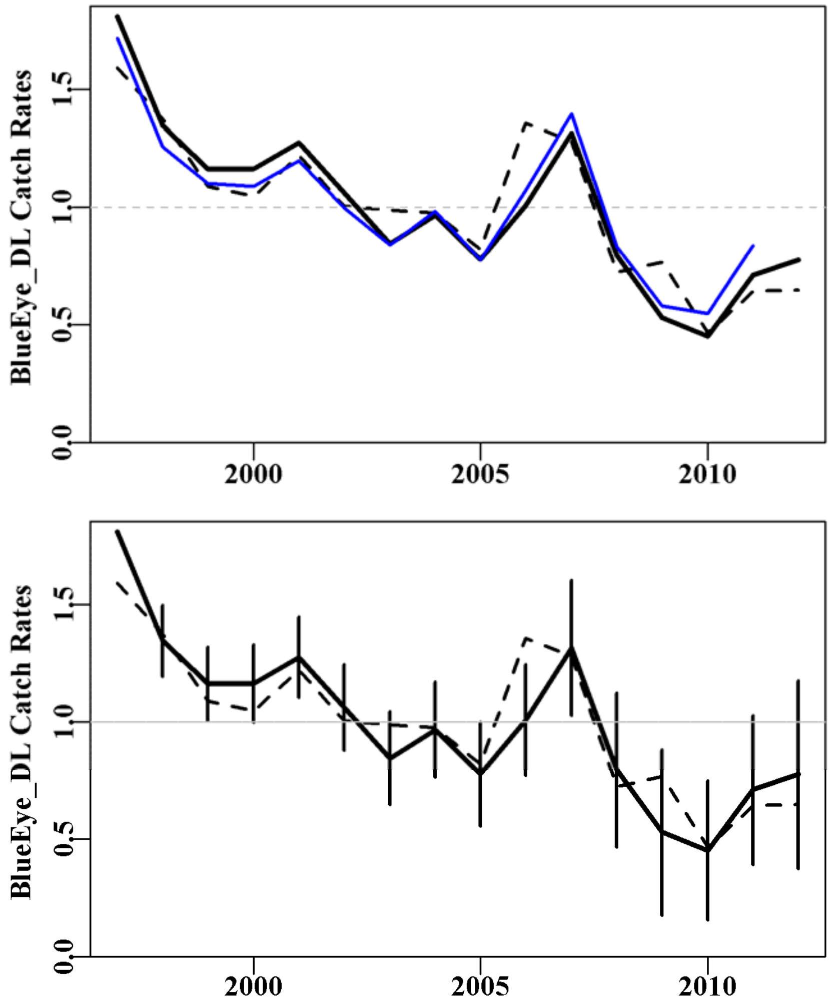



Figure 18.72. BlueEye from the SEN and GHT fishery in depths between 200 – 600m, taken by Drop Line. The dashed black line represents the geometric mean catch rate and the solid black line the standardized catch rates. The graph standardizes catch rates relative to the mean of the standardized catch rates.

Table 18.63. BlueEye from the SET and GHT fishery in depths between 200 – 600m, taken by Drop Line. Model selection criteria, including the AIC, the adjusted $r^2$ and the change in adjusted $r^2$. The optimum is Zone:Month.

| | Year | Vessel | Month | Zone | DayNight | DepCat | **Zone:Mth** | Zone:DepC |
|---|---|---|---|---|---|---|---|---|
| AIC | 4084 | 2955 | 2577 | 2574 | 2530 | 2478 | **2462** | 2472 |
| RSS | 12432 | 10278 | 9702 | 9662 | 9592 | 9418 | **9365** | 9354 |
| MSS | 428 | 2582 | 3158 | 3198 | 3268 | 3442 | **3495** | 3506 |
| Nobs | 6925 | 6925 | 6925 | 6890 | 6890 | 6839 | **6839** | 6839 |
| Npars | 16 | 110 | 121 | 122 | 125 | 145 | **156** | 165 |
| adj_r2 | 3.121 | 18.797 | 23.229 | 23.526 | 24.043 | 25.193 | **25.491** | 25.473 |
| %Change | 0.000 | 15.675 | 4.433 | 0.297 | 0.517 | 1.150 | **0.298** | -0.017 |

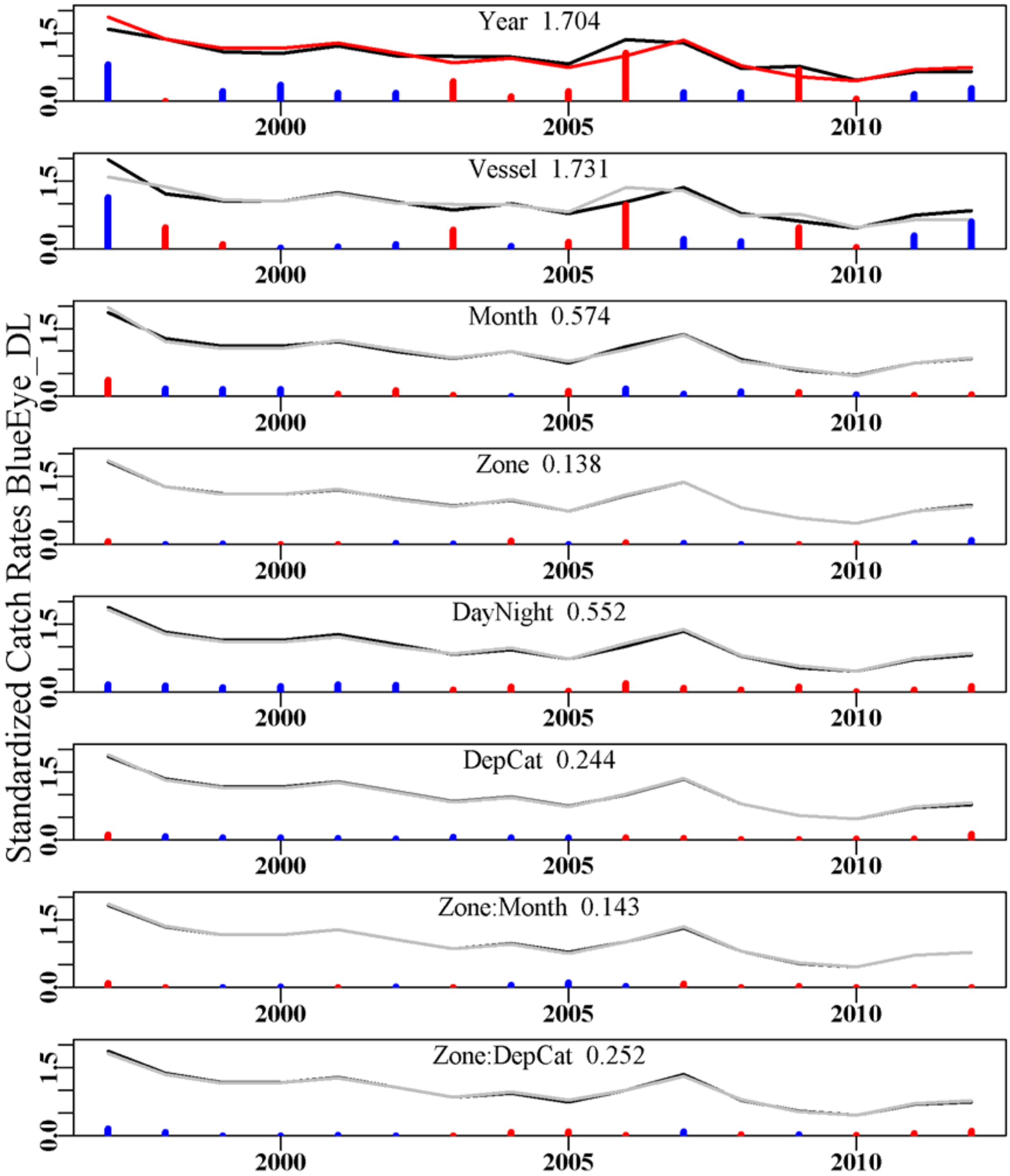



Figure 18.73. The relative influence of each factor used on the final trend in the optimal standardization for BlueEye in by Drop-line. The top graph depicts the geometric mean (the black line) and the optimum model (the red line). The difference between them is illustrated by the vertical bars with 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.

### *18.4.21 Blue Eye, AL & DL (TBE – 37445001 – H. antarctica)*

Depths between 200-600m m. All data from auto-longlining and droplining combined. Zones 20 – 50, and 83 – 85 included (83 – 85 are in the GAB ).

Table 18.64. BlueEye from the SEN and GHT in depths 200 – 600m by Auto Long Line and Drop Line. Total Catch is the total reported in the database, Records is the number of records used in the analysis, CatchT is the reported catch in the area and depth used in the analysis, and Vessels relates to all vessels used in the analysis. Geomean is the geometric mean of catch rates (kg/hr). Zone:Month is the optimum model and StDev is the standard deviation relating to the data in the optimum model.

| Year | TotCatch | Records | CatchT | Vessels | GeoMean | Zone:Mth | StDev |
|---|---|---|---|---|---|---|---|
| 1997 | 463.319 | 545 | 254.361 | 39 | 258.9752 | 1.9604 | 0.0000 |
| 1998 | 448.146 | 758 | 340.896 | 30 | 226.1524 | 1.3375 | 0.0797 |
| 1999 | 548.067 | 926 | 387.041 | 30 | 189.6587 | 1.1768 | 0.0817 |
| 2000 | 653.775 | 1086 | 406.152 | 34 | 177.6127 | 1.1240 | 0.0845 |
| 2001 | 579.726 | 805 | 358.502 | 27 | 203.6327 | 1.1817 | 0.0875 |
| 2002 | 476.739 | 798 | 312.140 | 24 | 164.0183 | 0.8899 | 0.0885 |
| 2003 | 564.693 | 969 | 324.984 | 25 | 148.5823 | 0.9941 | 0.0907 |
| 2004 | 594.290 | 1635 | 417.226 | 29 | 91.3225 | 1.0449 | 0.0885 |
| 2005 | 444.114 | 1477 | 380.603 | 23 | 88.1440 | 0.8302 | 0.0910 |
| 2006 | 544.834 | 1368 | 447.130 | 19 | 121.2856 | 0.9562 | 0.0916 |
| 2007 | 556.619 | 783 | 498.943 | 15 | 333.7817 | 1.1731 | 0.0966 |
| 2008 | 334.297 | 684 | 293.497 | 13 | 214.3734 | 0.7572 | 0.0978 |
| 2009 | 411.616 | 631 | 331.806 | 15 | 259.8521 | 0.8553 | 0.0988 |
| 2010 | 380.394 | 680 | 259.006 | 14 | 142.9654 | 0.5414 | 0.0988 |
| 2011 | 458.642 | 692 | 258.084 | 14 | 177.7306 | 0.6190 | 0.0987 |
| 2012 | 340.633 | 520 | 198.668 | 14 | 156.1670 | 0.5584 | 0.1031 |

Table 18.65. BlueEye from the SEN and GHT in depths 200 – 600m by Auto Long Line and Drop 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+DayNight |
| Model 6 | LnCE~Year+Vessel+DepCat+Month+DayNight+Zone |
| Model 7 | LnCE~Year+Vessel+DepCat+Month+DayNight+Zone+Method |
| Model 8 | LnCE~Year+Vessel+DepCat+Month+DayNight+Zone+Method+Zone:Month |
| Model 9 | LnCE~Year+Vessel+DepCat+Month+DayNight+Zone+Method+Zone:DepCat |
| Model 10 | LnCE~Year+Vessel+DepCat+Month+DayNight+Zone+Method+Zone:Method |
| Model 11 | LnCE~Year+Vessel+DepCat+Month+DayNight+Zone+Method+Month:Method |

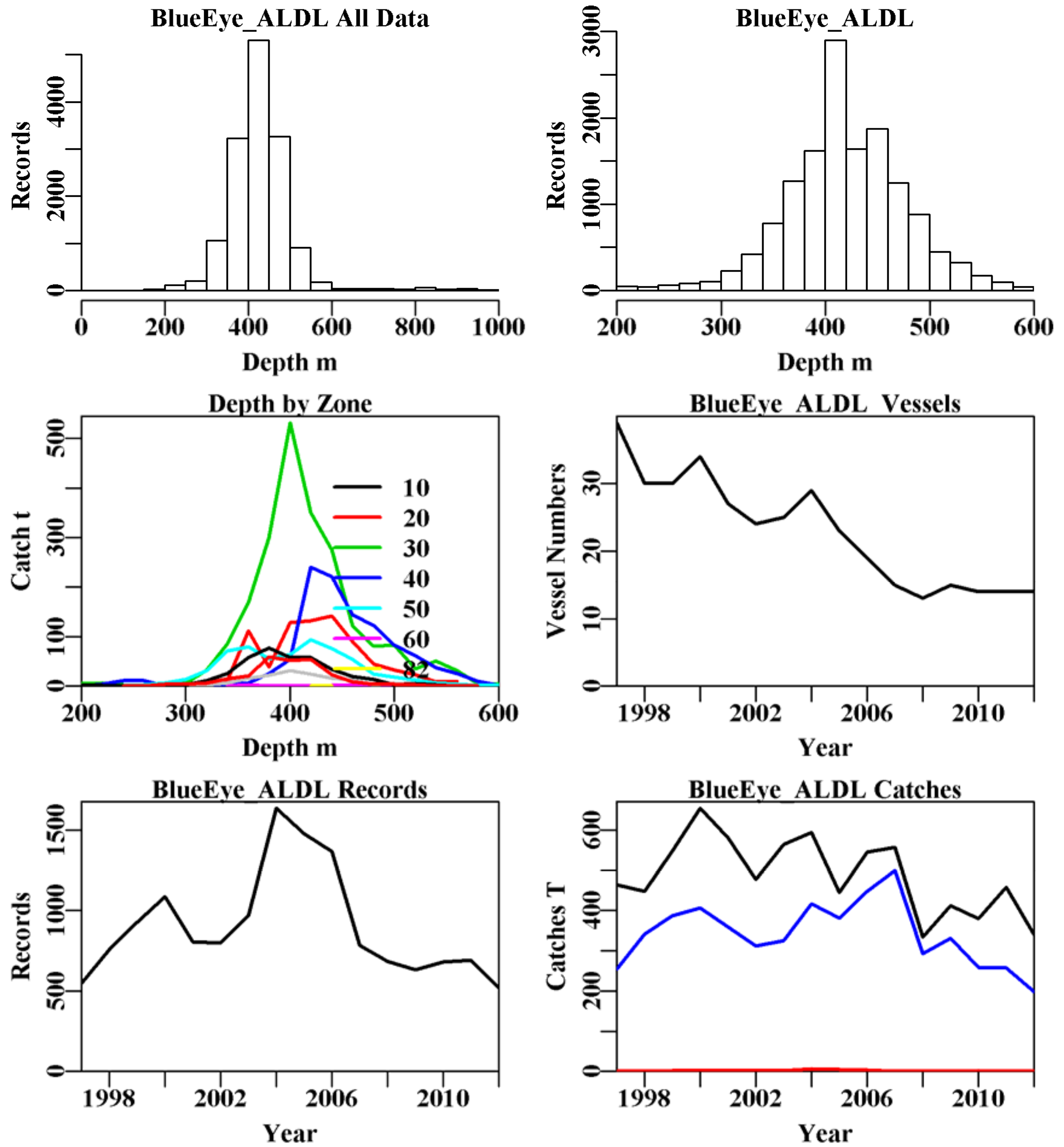
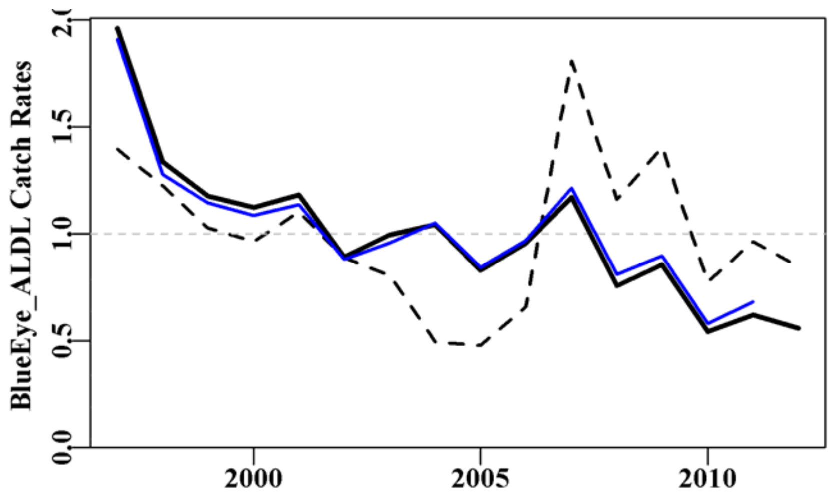



Figure 18.74. BlueEye from the SEN and GHT in depths 200 – 600m by Auto Long Line and Drop Line. The top left is the depth distribution of all records reporting BlueEye, the top right graph depicts the depth distribution of shots containing BlueEye from the SEN and GHT in depths 200 – 600m by Auto Long Line and Drop Line. The middle left diagram depicts the distribution of catch by depth, the middle right hand graph depicts the number of vessels through time. The bottom left reflects the number of records used in analysis, and bottom right is the BlueEye catches (top line, black is total catches, middle line, blue, are those used in the analysis, and bottom, red, are catches < 30Kg).



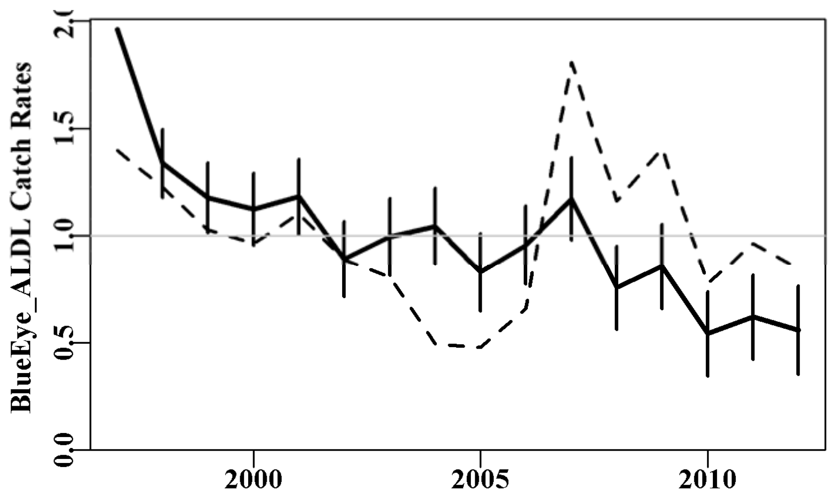




Figure 18.75. BlueEye from the SEN and GHT in depths 200 – 600m by Auto Long Line and Drop Line. The dashed black line represents the geometric mean catch rate and the solid black line the standardized catch rates. The graph standardizes catch rates relative to the mean of the standardized catch rates.

Table 18.66. BlueEye from the SEN and GHT in depths 200 – 600m by Auto Long Line and Drop Line. Model selection criteria, including the AIC, the adjusted $r^2$ and the change in adjusted $r^2$. The optimum is model Zone, though Zone:Month is very close. DepC is Depth Category, Mth is Month, DN is DayNight, Meth is Method and Zon is Zone.

| | Year | Vessel | DepC | Mth | DN | **Zone** | Meth | Zon:Mth | Zon:DepC | Zon:Meth | Mth:Meth |
|---|---|---|---|---|---|---|---|---|---|---|---|
| AIC | 11471 | 7966 | 7846 | 6996 | 6934 | **6756** | 6786 | 6758 | 6767 | 6773 | 6822 |
| RSS | 31849 | 24611 | 24279 | 22841 | 22732 | **22417** | 22417 | 22338 | 22324 | 22349 | 21959 |
| MSS | 2097 | 9335 | 9668 | 11105 | 11214 | **11530** | 11530 | 11608 | 11622 | 11597 | 11987 |
| Nobs | 14357 | 14357 | 14282 | 14282 | 14282 | **14246** | 14246 | 14246 | 14246 | 14246 | 14246 |
| Npars | 16 | 114 | 134 | 145 | 148 | **149** | 150 | 175 | 184 | 165 | 329 |
| adj_r2 | 6.080 | 26.925 | 27.807 | 32.028 | 32.339 | **33.271** | 33.267 | 33.381 | 33.381 | 33.397 | 33.787 |
| %Change | 0.000 | 20.845 | 0.882 | 4.221 | 0.311 | **0.932** | -0.004 | 0.114 | -0.001 | 0.016 | 0.390 |

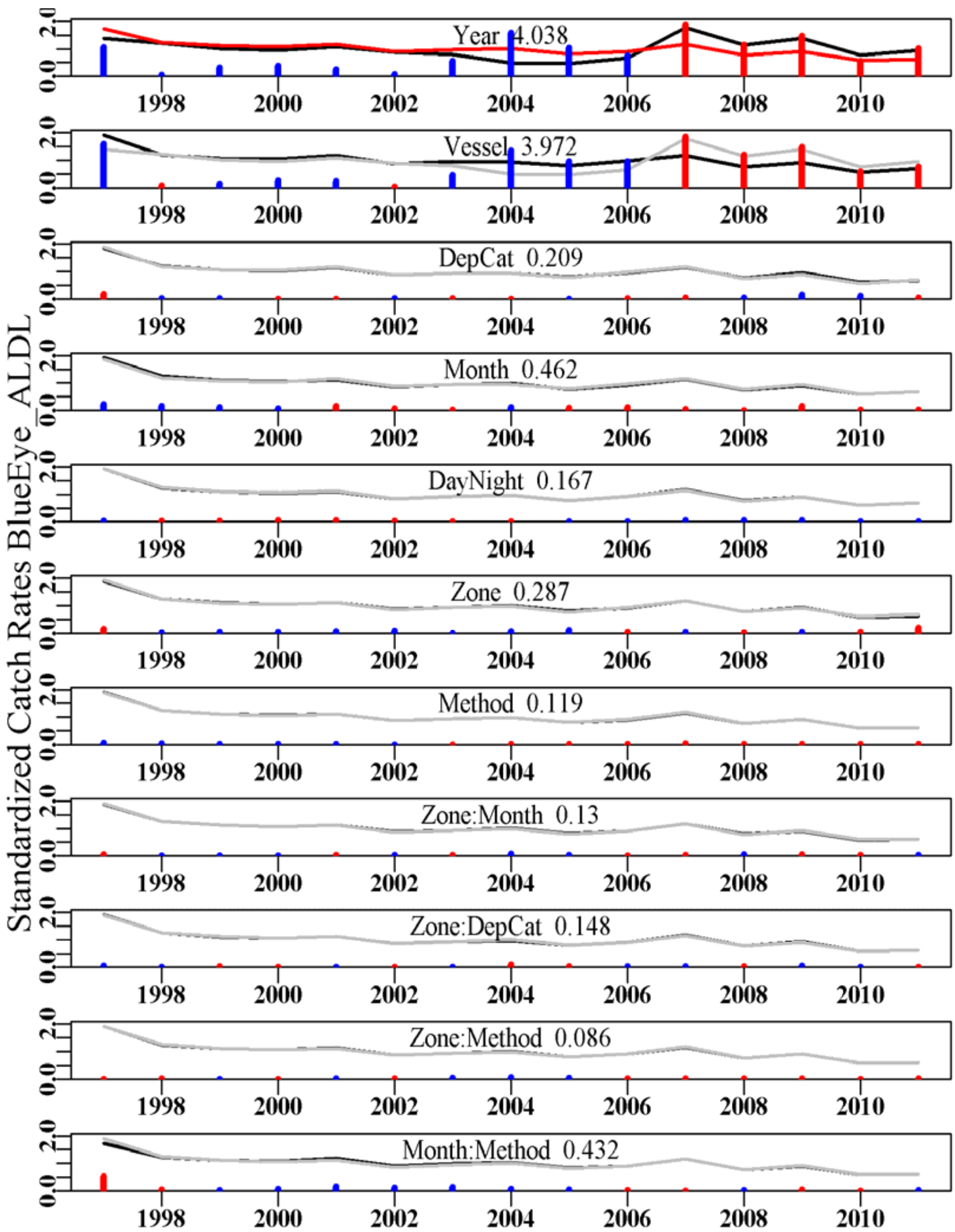



Figure 18.76. The relative influence of each factor used on the final trend in the optimal standardization for BlueEye by AL and DL. The top graph depicts the geometric mean (the black line) and the optimum model (the red line). The difference between them is illustrated by the vertical bars with blue 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.

#### *18.4.22 Blue Grenadier Non-Spawning (GRE – 37227001 – M. novaezelandiae)*

Data from zones 10 to 60 except Zone 40 in months June to August, depths less than 1000 m and greater than 0 m.

Table 18.67. Blue Grenadier from the SET in depths between 200 – 600m, taken by Trawl, omitting the Spawning fishery (zone 40 between June and August). Total Catch is the total reported in the database, Records is the number of records used in the analysis, CatchT is the reported catch in the area and depth used in the analysis, and Vessels relates to all vessels used in the analysis. Geomean is the geometric mean of catch rates (kg/hr). Zone:Month is the optimum model and StDev is the standard deviation relating to the data in the optimum model.

| Year | TotCatch | Records | CatchT | Vessels | GeoMean | Zone:Mth | StDev |
|---|---|---|---|---|---|---|---|
| 1986 | 1450.316 | 3189 | 1183.307 | 92 | 36.7375 | 1.5053 | 0.0000 |
| 1987 | 2244.428 | 3569 | 1437.434 | 91 | 37.3307 | 1.9781 | 0.0338 |
| 1988 | 1843.477 | 3961 | 1470.196 | 102 | 36.6778 | 2.1430 | 0.0338 |
| 1989 | 1887.630 | 4309 | 1813.501 | 99 | 45.3866 | 2.2189 | 0.0338 |
| 1990 | 2277.944 | 3577 | 1625.146 | 92 | 47.9497 | 2.1902 | 0.0357 |
| 1991 | 3647.541 | 4308 | 2392.687 | 86 | 48.2874 | 1.5761 | 0.0344 |
| 1992 | 2470.286 | 3228 | 1505.799 | 61 | 40.5408 | 1.2980 | 0.0367 |
| 1993 | 2474.305 | 4203 | 1619.049 | 63 | 33.2638 | 0.9795 | 0.0351 |
| 1994 | 2315.097 | 4491 | 1309.563 | 66 | 29.5414 | 0.8805 | 0.0346 |
| 1995 | 1930.333 | 5076 | 1015.261 | 61 | 19.4025 | 0.6073 | 0.0339 |
| 1996 | 2304.114 | 5370 | 1055.340 | 73 | 15.8910 | 0.5537 | 0.0337 |
| 1997 | 3654.671 | 6194 | 994.604 | 73 | 13.3293 | 0.5734 | 0.0333 |
| 1998 | 4224.977 | 6599 | 1452.552 | 65 | 18.8682 | 0.9410 | 0.0331 |
| 1999 | 7571.998 | 8045 | 2051.946 | 65 | 22.7820 | 0.9948 | 0.0324 |
| 2000 | 7503.080 | 7679 | 1751.230 | 70 | 16.8751 | 0.7095 | 0.0327 |
| 2001 | 8369.949 | 7279 | 1013.774 | 60 | 11.4735 | 0.4060 | 0.0331 |
| 2002 | 7977.284 | 6344 | 1125.943 | 57 | 13.3454 | 0.4074 | 0.0337 |
| 2003 | 7946.792 | 5675 | 670.745 | 56 | 10.1345 | 0.3407 | 0.0340 |
| 2004 | 6090.023 | 6393 | 1206.698 | 56 | 16.9690 | 0.5734 | 0.0338 |
| 2005 | 4505.559 | 5346 | 1174.711 | 54 | 19.8341 | 0.6857 | 0.0344 |
| 2006 | 3542.434 | 4362 | 1308.840 | 42 | 26.9839 | 0.9109 | 0.0356 |
| 2007 | 3125.396 | 3659 | 1204.518 | 27 | 25.1832 | 0.8113 | 0.0366 |
| 2008 | 4152.329 | 3407 | 1276.536 | 26 | 28.8353 | 0.8895 | 0.0371 |
| 2009 | 3874.659 | 3443 | 1128.896 | 23 | 25.9256 | 0.8260 | 0.0370 |
| 2010 | 4552.205 | 3308 | 1136.546 | 25 | 25.9279 | 0.8097 | 0.0374 |
| 2011 | 4476.805 | 3968 | 897.672 | 26 | 19.3008 | 0.6567 | 0.0365 |
| 2012 | 4464.290 | 3210 | 613.624 | 29 | 15.0049 | 0.5333 | 0.0379 |

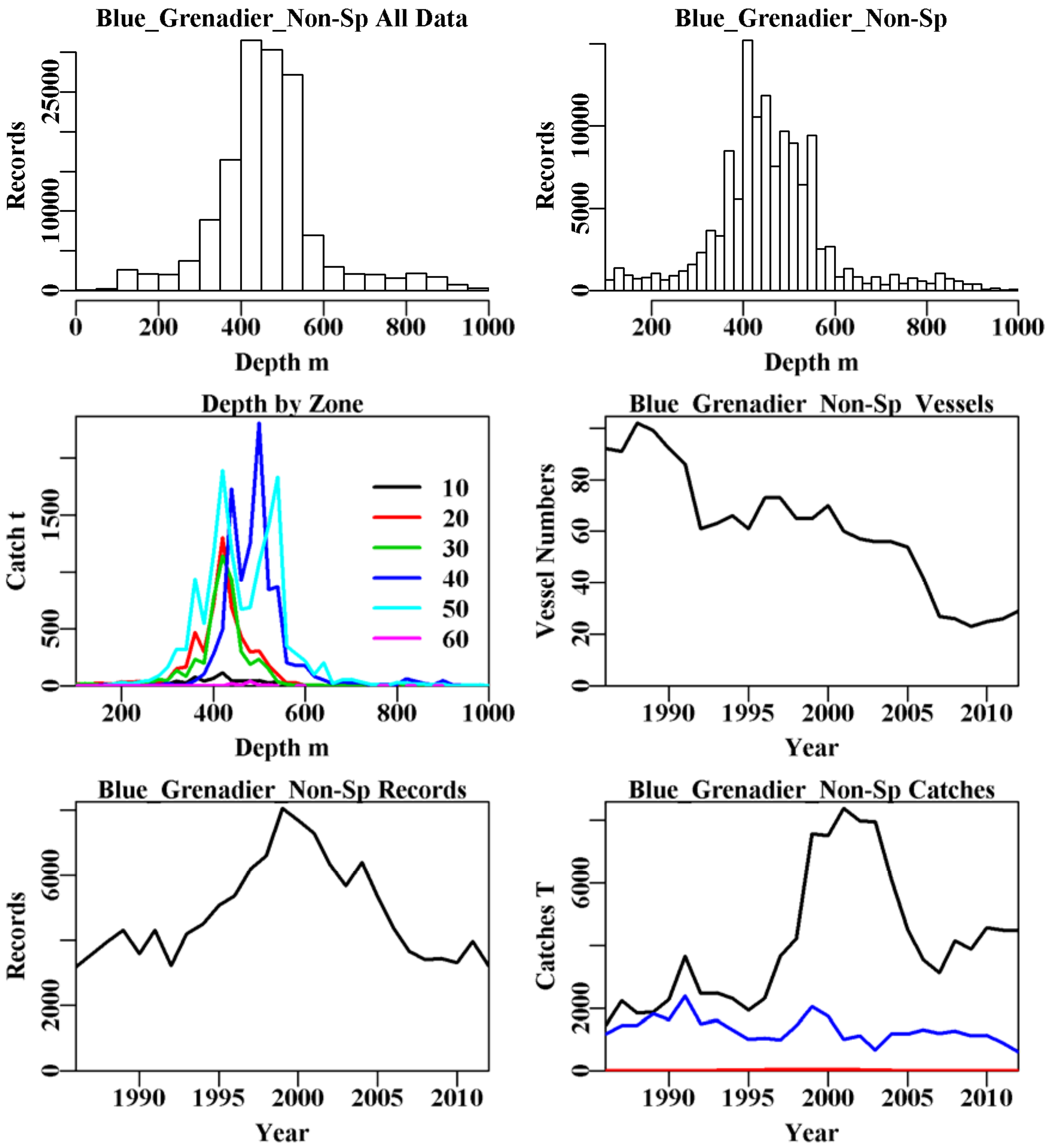



Figure 18.77. Blue Grenadier from the SET in depths between 200 – 600m, taken by Trawl, omitting the Spawning fishery (zone 40 between June and August). The top left is the depth distribution of all records reporting Blue Grenadier, the top right graph depicts the depth distribution of shots containing Blue Grenadier from the SET in depths between 200 – 600m, taken by Trawl, omitting the Spawning fishery (zone 40 between June and August). The middle left diagram depicts the distribution of catch by depth by SESSF zone, the middle right hand graph depicts the number of vessels through time. The bottom left reflects the number of records used in analysis, and bottom right is the Blue Grenadier catches (top line, black is total catches, middle line, blue, are those used in the analysis, and bottom, red, are catches < 30Kg).

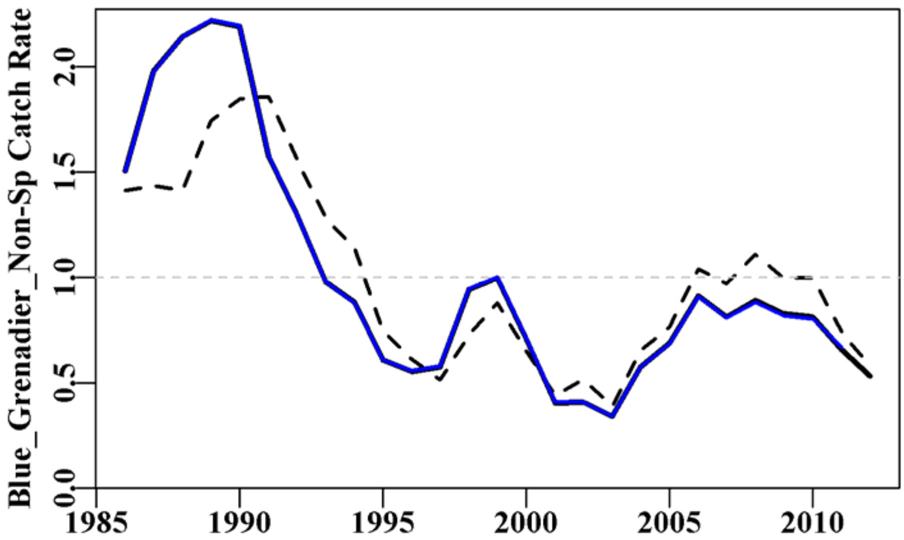



Figure 18.78. Blue Grenadier from the SET in depths between 200 – 600m, taken by Trawl, omitting the Spawning fishery (zone 40 between June and August). The dashed black line represents the geometric mean catch rate and the solid black line the standardized catch rates. The graph standardizes catch rates relative to the mean of the standardized catch rates.

Table 18.68. Blue Grenadier from the SET in depths between 200 – 600m, 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 18.69. Blue Grenadier from the SET in depths between 200 – 600m, taken by Trawl, omitting the Spawning fishery (zone 40 between June and August). Model selection criteria, including the AIC, the deviance and the change in deviance. The optimum is model 7.

| | Year | Vessel | DepCat | Month | Zone | DayNight | **Zone:Mth** | Zone:DepC |
|---|---|---|---|---|---|---|---|---|
| AIC | 120683 | 96414 | 82462 | 77356 | 74603 | 72212 | **68998** | 70859 |
| RSS | 328836 | 272107 | 243718 | 234248 | 229299 | 225089 | **219379** | 221974 |
| MSS | 24963 | 81692 | 110081 | 119551 | 124500 | 128710 | **134420** | 131825 |
| Nobs | 130192 | 130191 | 129373 | 129373 | 129373 | 129373 | **129373** | 129373 |
| Npars | 27 | 219 | 264 | 275 | 280 | 283 | **338** | 508 |
| adj_r2 | 7.037 | 22.961 | 30.974 | 33.650 | 35.050 | 36.241 | **37.831** | 37.013 |
| %Change | 0.000 | 15.924 | 8.013 | 2.676 | 1.399 | 1.191 | **1.591** | -0.818 |

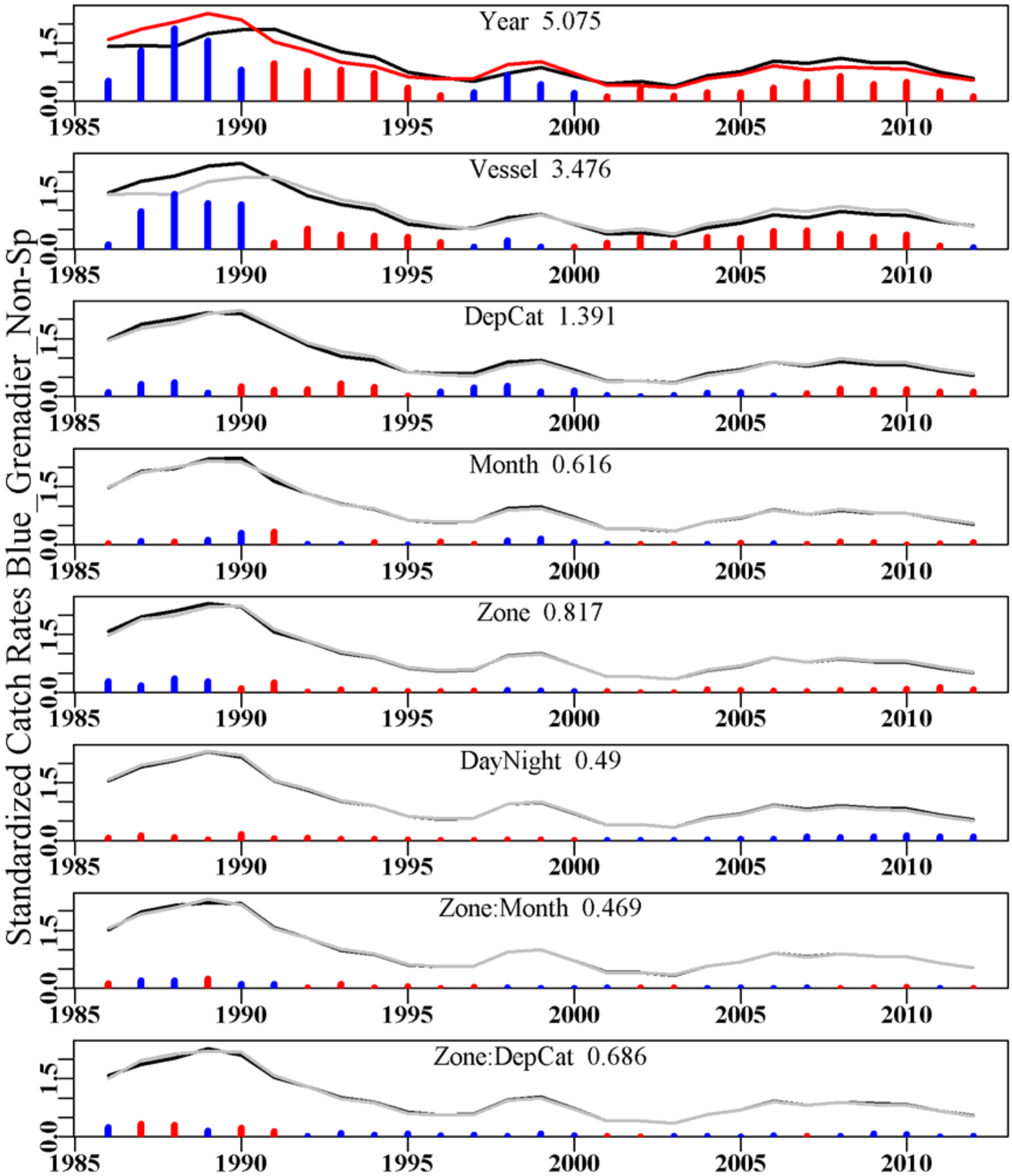



Figure 18.79. The relative influence of each factor used on the final trend in the optimal standardization for Blue Grenadier non-spawning fishery. The top graph depicts the geometric mean (the black line) and the optimum model (the red line). The difference between them is illustrated by the vertical 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.

### *18.4.23 Silver Warehou (TRS – 37445006 – Seriolella punctata)*

Data from zones 10 to 50, depths between 0 – 600 m.

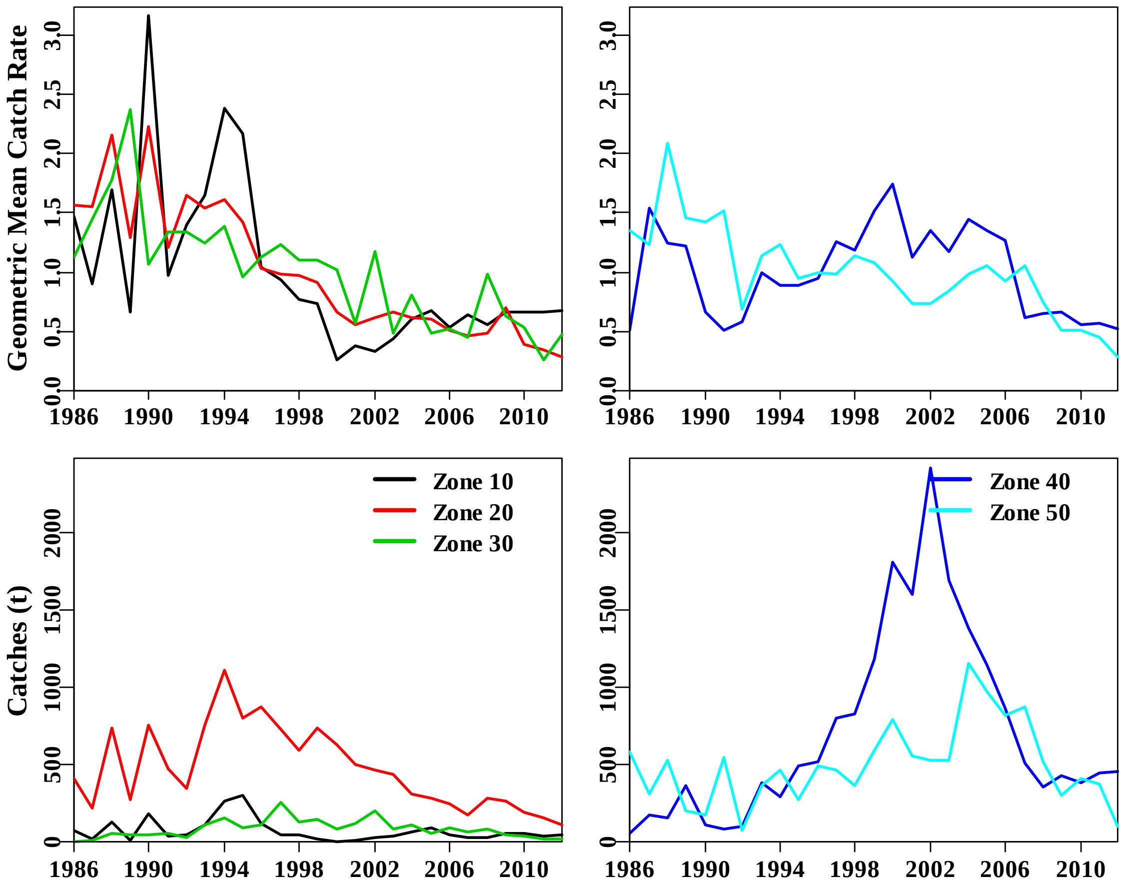



Figure 18.80. The trends in catches and catch rates for zones 10 – 50, split east and west.

The catch rates in the east show approximately the same trends, though there are some differences between 2000 and 2003. In the west the same pattern of noisy but flat from 1992 to 2006 followed by a decline are exhibited. But the trends are different between the east and west.

Table 18.70. Silver Warehou from Zones 10 to 50 and depths 0 – 600m by trawl. Total Catch is the total reported in the database, Records is the number of records use din the analysis, CatchT is the reported catch in the area and depth used in the analysis, and Vessels relates to all vessels used in the analysis. Geomean is the geometric mean of catch rates (kg/hr). Zone:Month is the optimum model and StDev is the standard deviation relating to the data in the optimum model.

| Year | TotCatch | Records | CatchT | Vessels | GeoMean | Zone:Mth | StDev |
|---|---|---|---|---|---|---|---|
| 1986 | 1149.503 | 2438 | 1135.296 | 86 | 32.2897 | 1.4578 | 0.0000 |
| 1987 | 782.151 | 1509 | 757.298 | 76 | 35.5040 | 1.5375 | 0.0562 |
| 1988 | 1646.027 | 2249 | 1617.240 | 87 | 42.9346 | 1.9596 | 0.0510 |
| 1989 | 925.352 | 2049 | 907.420 | 80 | 30.7291 | 1.5983 | 0.0539 |
| 1990 | 1346.441 | 1983 | 1290.959 | 81 | 40.6488 | 1.6895 | 0.0544 |
| 1991 | 1443.557 | 2289 | 1207.361 | 78 | 25.6848 | 1.1874 | 0.0532 |
| 1992 | 733.567 | 1857 | 625.074 | 55 | 27.9469 | 1.0405 | 0.0558 |
| 1993 | 1814.391 | 3866 | 1735.163 | 61 | 33.2988 | 1.1751 | 0.0487 |
| 1994 | 2309.000 | 4519 | 2300.083 | 57 | 34.7142 | 1.2561 | 0.0477 |
| 1995 | 2002.851 | 5016 | 1969.857 | 58 | 29.7825 | 1.1350 | 0.0470 |
| 1996 | 2188.244 | 6080 | 2137.373 | 67 | 22.7319 | 1.0664 | 0.0463 |
| 1997 | 2561.905 | 5765 | 2305.785 | 61 | 25.3481 | 1.0937 | 0.0469 |
| 1998 | 2166.021 | 4702 | 1976.667 | 57 | 26.6416 | 1.0527 | 0.0478 |
| 1999 | 2834.052 | 5148 | 2685.678 | 58 | 31.2330 | 0.9059 | 0.0474 |
| 2000 | 3399.963 | 6738 | 3324.009 | 64 | 26.0708 | 0.8281 | 0.0463 |
| 2001 | 2969.114 | 7293 | 2789.412 | 59 | 21.7853 | 0.6968 | 0.0461 |
| 2002 | 3830.902 | 8418 | 3656.597 | 57 | 22.9919 | 0.7532 | 0.0456 |
| 2003 | 2904.709 | 7402 | 2782.813 | 64 | 20.4815 | 0.7615 | 0.0461 |
| 2004 | 3195.654 | 7860 | 3032.860 | 58 | 23.3323 | 0.8452 | 0.0459 |
| 2005 | 2647.052 | 6920 | 2558.282 | 56 | 20.0277 | 0.8309 | 0.0464 |
| 2006 | 2190.930 | 5663 | 2076.280 | 47 | 18.2160 | 0.7316 | 0.0473 |
| 2007 | 1815.868 | 4657 | 1665.236 | 33 | 20.1239 | 0.6931 | 0.0484 |
| 2008 | 1380.959 | 4400 | 1279.929 | 32 | 16.1202 | 0.6233 | 0.0487 |
| 2009 | 1285.286 | 4387 | 1109.646 | 28 | 15.8837 | 0.6437 | 0.0488 |
| 2010 | 1189.318 | 4481 | 1082.522 | 28 | 13.2653 | 0.5328 | 0.0487 |
| 2011 | 1107.591 | 4940 | 1042.774 | 30 | 12.6164 | 0.4973 | 0.0483 |
| 2012 | 780.514 | 3768 | 750.557 | 29 | 10.4075 | 0.4068 | 0.0501 |

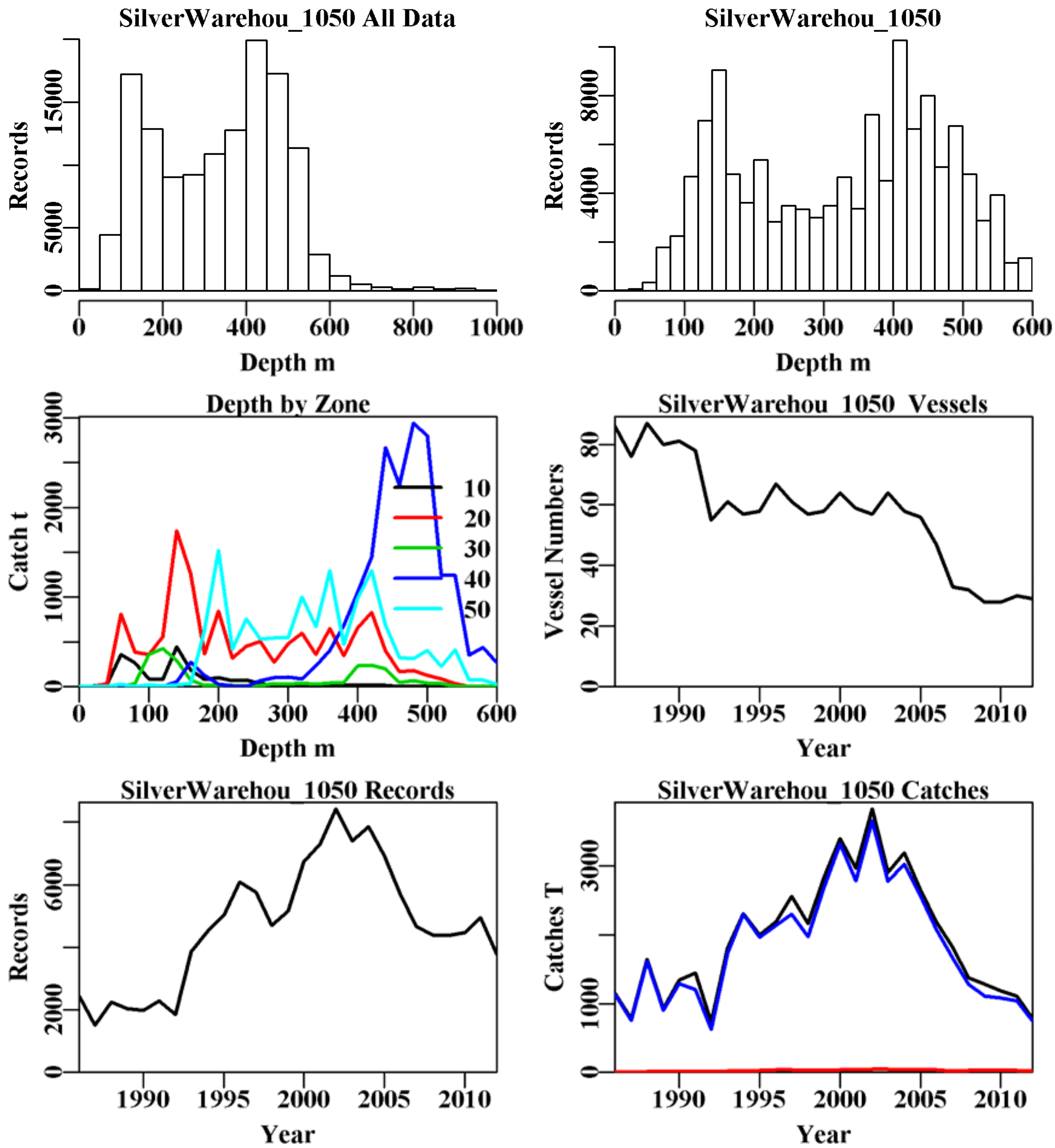



Figure 18.81. Silver Warehou from Zones 10 to 50 and depths 0 – 600m by trawl. The top left is the depth distribution of all records reporting Silver Warehou, the top right graph depicts the depth distribution of shots containing Silver Warehou from Zones 10 to 50 and depths 0 – 600m by trawl.. The middle left diagram depicts the distribution of catch by depth within zones 10 to 50, the middle right hand graph depicts the number of vessels through time. The bottom left reflects the number of records used in analysis, and bottom right is the Silver Warehou catches (top line, black is total catches, middle line, blue, are those used in the analysis, and bottom, red, are catches < 30Kg).

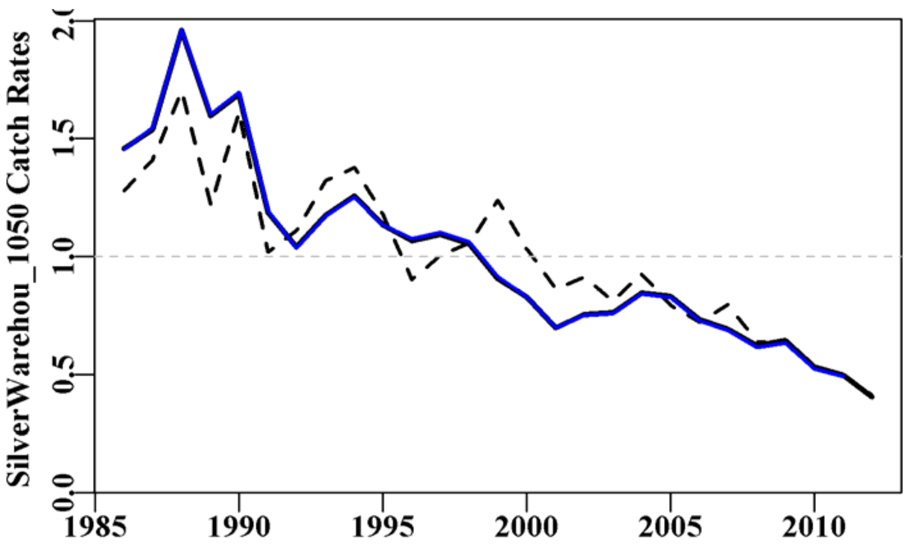



Figure 18.82. Silver Warehou from Zones 10 to 50 and depths 0 – 600m by trawl. The dashed black line represents the geometric mean catch rate and the solid black line the standardized catch rates. The graph standardizes catch rates relative to the mean of the standardized catch rates.

Table 18.71. Silver Warehou from Zones 10 to 50 and depths 0 – 600m 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 18.72. Silver Warehou from Zones 10 to 50 and depths 0 – 600m by trawl. Model selection criteria, including the AIC, the adjusted $r^2$ and the change in adjusted $r^2$. The optimum is Zone:Month (model 7).

| | Year | Vessel | Month | Zone | DepCat | DayNight | **Zone:Month** | Zone:DepCat |
|---|---|---|---|---|---|---|---|---|
| AIC | 151901 | 129881 | 123588 | 121315 | 118746 | 118519 | **116666** | 117144 |
| RSS | 420218 | 351943 | 334787 | 328571 | 321897 | 321299 | **316369** | 317191 |
| MSS | 12001 | 80276 | 97432 | 103648 | 110323 | 110920 | **115850** | 115028 |
| Nobs | 126397 | 126375 | 126375 | 125519 | 125519 | 125519 | **125519** | 125519 |
| Npars | 27 | 223 | 234 | 264 | 268 | 271 | **315** | 391 |
| adj_r2 | 2.757 | 18.430 | 22.399 | 23.821 | 25.366 | 25.503 | **26.620** | 26.385 |
| %Change | 0.000 | 15.673 | 3.969 | 1.422 | 1.545 | 0.137 | **1.117** | -0.235 |

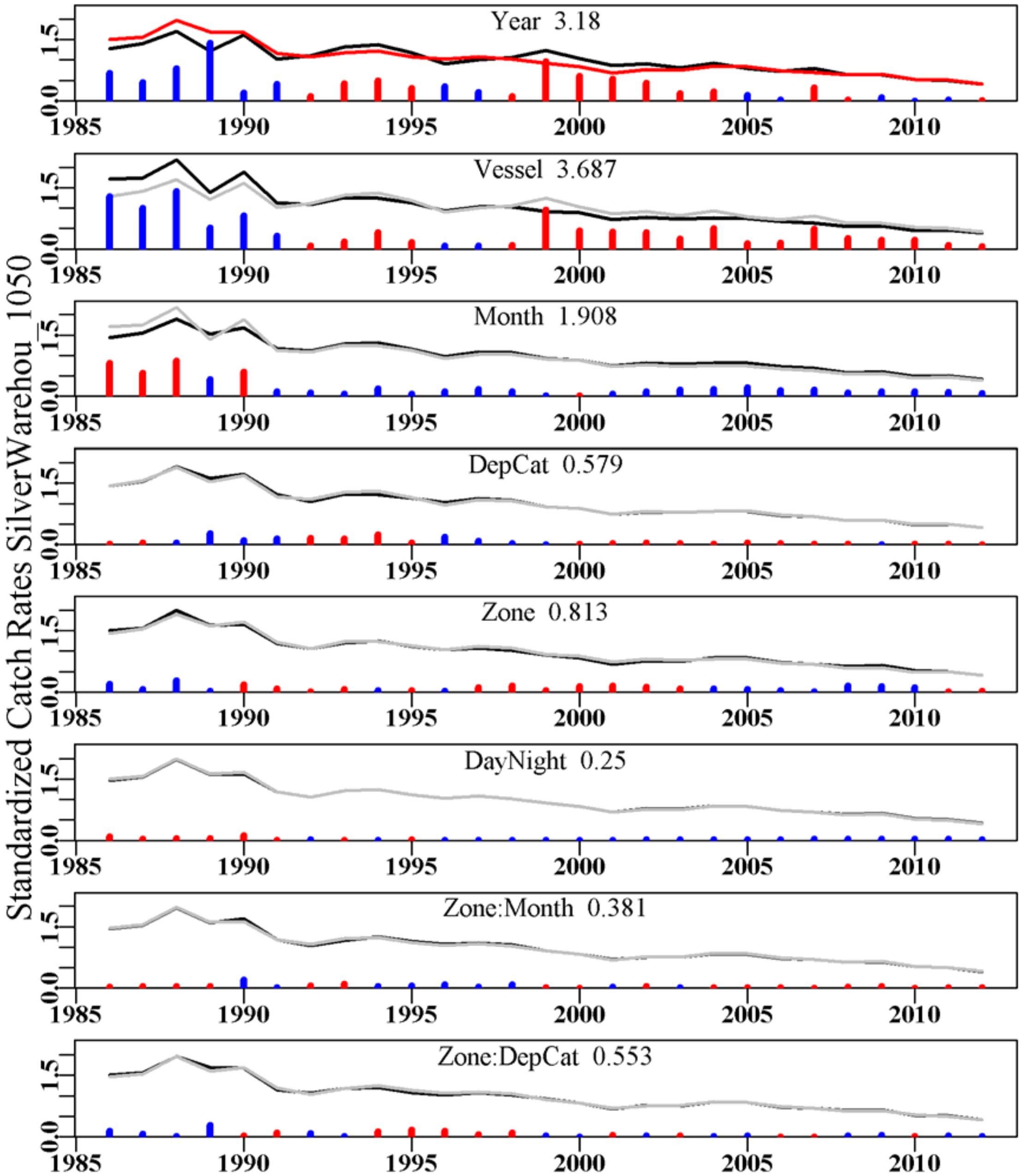



Figure 18.83. The relative influence of each factor used on the final trend in the optimal standardization for Silver Warehou in Zones 10 – 50. The top graph depicts the geometric mean (the black line) and the optimum model (the red line). The difference between them is illustrated by the vertical bars 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.

### *18.4.24 Blue Warehou Zones 10, 20, 30 (TRT – 37445005 – Seriolella brama)*

Data from zones 10, 20, and 30, depths less than or equal to 400 m.

Table 18.73. Blue Warehou from zones 10 to 30 in depths 0 – 400m by trawl. Total Catch is the total reported in the database, Records is the number of records used in the analysis, CatchT is the reported catch in the area and depth used in the analysis, and Vessels relates to all vessels used in the analysis. Geomean is the geometric mean of catch rates (kg/hr). Zone:DepCat is the optimum model and StDev is the standard deviation relating to the data in the optimum model.

| Year | TotCatch | Records | CatchT | Vessels | GeoMean | Zone:DepC | StDev |
|---|---|---|---|---|---|---|---|
| 1986 | 211.877 | 702 | 138.822 | 40 | 22.9216 | 1.9418 | 0.0000 |
| 1987 | 405.851 | 457 | 168.152 | 40 | 23.2716 | 2.3584 | 0.1047 |
| 1988 | 543.976 | 775 | 334.047 | 33 | 34.8726 | 2.8779 | 0.0953 |
| 1989 | 770.582 | 1178 | 664.709 | 41 | 52.6588 | 3.6492 | 0.0925 |
| 1990 | 872.888 | 826 | 508.270 | 42 | 46.5510 | 3.3387 | 0.0976 |
| 1991 | 1277.006 | 1567 | 465.158 | 54 | 23.0208 | 1.7949 | 0.0919 |
| 1992 | 933.335 | 1343 | 406.749 | 39 | 24.3304 | 1.4771 | 0.0925 |
| 1993 | 829.263 | 2195 | 431.735 | 45 | 20.7054 | 1.1518 | 0.0892 |
| 1994 | 943.873 | 2449 | 473.899 | 44 | 17.5997 | 1.1110 | 0.0881 |
| 1995 | 815.384 | 2646 | 467.825 | 44 | 15.3567 | 1.0166 | 0.0879 |
| 1996 | 724.128 | 3551 | 531.223 | 49 | 14.6415 | 1.0478 | 0.0872 |
| 1997 | 916.699 | 2481 | 404.281 | 42 | 11.8760 | 1.0217 | 0.0895 |
| 1998 | 903.212 | 2556 | 457.247 | 39 | 13.8592 | 0.9546 | 0.0890 |
| 1999 | 590.533 | 1643 | 131.641 | 39 | 5.7097 | 0.5292 | 0.0920 |
| 2000 | 470.238 | 2217 | 185.083 | 41 | 5.0072 | 0.4393 | 0.0901 |
| 2001 | 285.096 | 1470 | 57.242 | 33 | 2.7867 | 0.2615 | 0.0937 |
| 2002 | 290.256 | 1856 | 62.867 | 36 | 2.2036 | 0.1982 | 0.0922 |
| 2003 | 233.466 | 1324 | 42.078 | 38 | 1.8331 | 0.1538 | 0.0952 |
| 2004 | 232.060 | 1249 | 52.051 | 38 | 2.7248 | 0.2087 | 0.0969 |
| 2005 | 289.033 | 830 | 21.286 | 33 | 1.8011 | 0.1395 | 0.1013 |
| 2006 | 379.495 | 776 | 25.720 | 28 | 2.2327 | 0.1656 | 0.1025 |
| 2007 | 177.624 | 583 | 16.757 | 14 | 1.8677 | 0.1745 | 0.1074 |
| 2008 | 163.260 | 738 | 27.441 | 18 | 2.6539 | 0.2439 | 0.1031 |
| 2009 | 135.220 | 447 | 36.884 | 15 | 3.5956 | 0.2875 | 0.1121 |
| 2010 | 129.874 | 374 | 12.266 | 15 | 2.1227 | 0.1840 | 0.1175 |
| 2011 | 103.243 | 435 | 9.812 | 13 | 1.7081 | 0.1490 | 0.1135 |
| 2012 | 52.187 | 356 | 9.901 | 14 | 1.6727 | 0.1238 | 0.1188 |

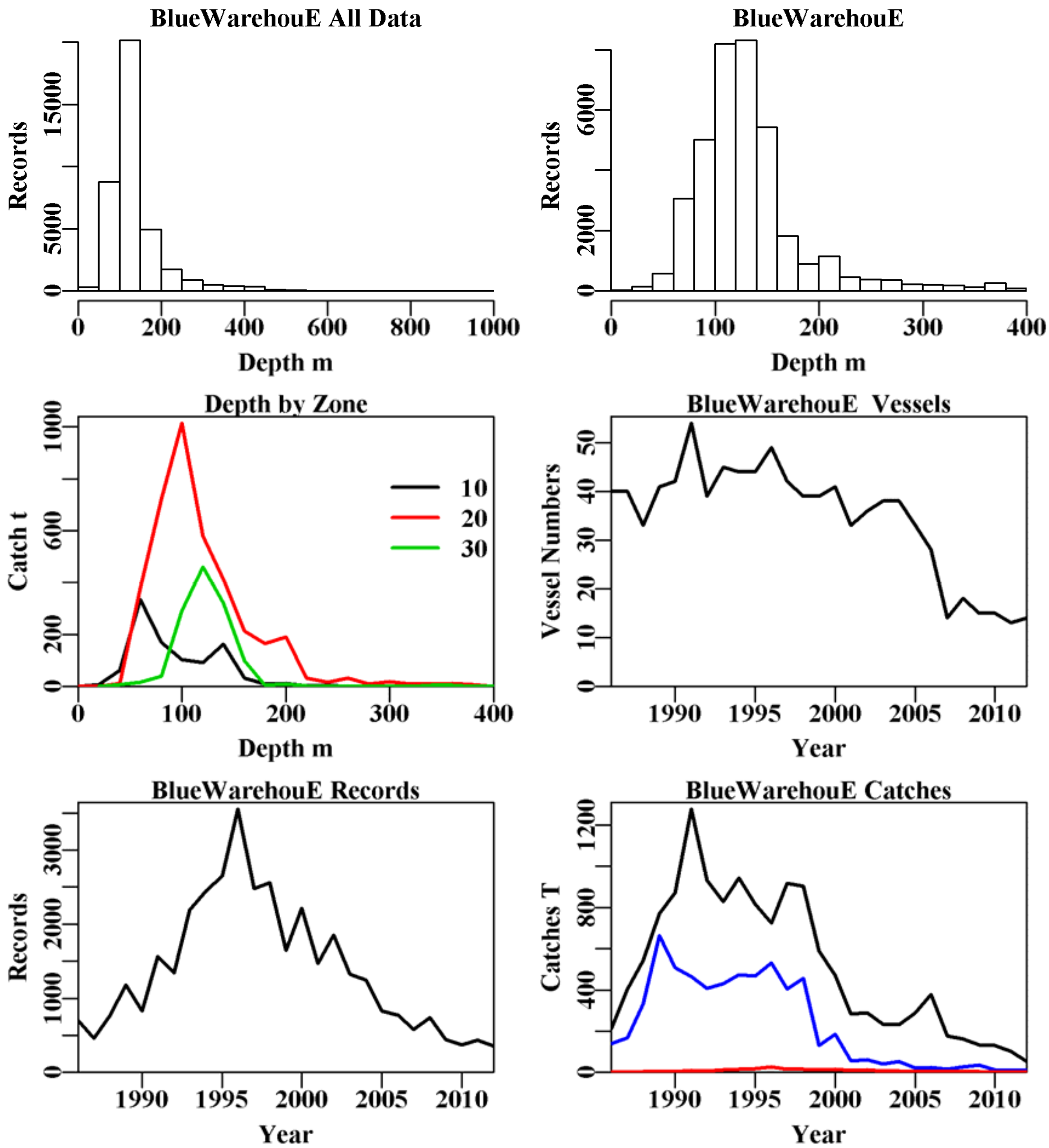



Figure 18.84. Blue Warehou from zones 10 to 30 in depths 0 – 400m by trawl. The top left is the depth distribution of all records reporting Blue Warehou, the top right graph depicts the depth distribution of shots containing Blue Warehou from zones 10 to 30 in depths 0 – 400m by trawl. The middle left diagram depicts the distribution of catch by depth within zones 10 to 30, the middle right hand graph depicts the number of vessels through time. The bottom left reflects the number of records used in analysis, and bottom right is the Blue Warehou catches (top line, black is total catches, middle line, blue, are those used in the analysis, and bottom, red, are catches < 30Kg).

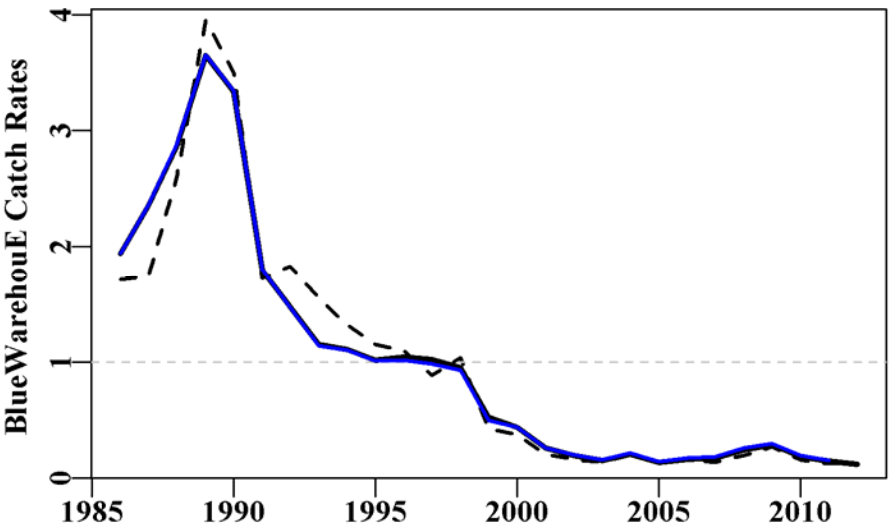



Figure 18.85. Blue Warehou from zones 10 to 30 in depths 0 – 400m by trawl. The dashed black line represents the geometric mean catch rate and the solid black line the standardized catch rates. The graph standardizes catch rates relative to the mean of the standardized catch rates.

Table 18.74. Blue Warehou from zones 10 to 30 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+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 18.75. Blue Warehou from zones 10 to 30 in depths 0 – 400m by trawl. Model selection criteria, including the AIC, the adjusted $r^2$ and the change in adjusted $r^2$. The optimum is Zone:DSepCat (model 8).

| | Year | Vessel | DepCat | Month | Zone | DayNight | Zone:Mth | **Zone:DepC** |
|---|---|---|---|---|---|---|---|---|
| AIC | 37094 | 32362 | 31717 | 31518 | 31048 | 31046 | 30791 | **30761** |
| RSS | 100684 | 87832 | 86144 | 85630 | 84533 | 84515 | 83832 | **83680** |
| MSS | 37450 | 50302 | 51990 | 52504 | 53601 | 53619 | 54302 | **54454** |
| Nobs | 37024 | 37024 | 36804 | 36804 | 36804 | 36804 | 36804 | **36804** |
| Npars | 27 | 189 | 209 | 220 | 222 | 225 | 247 | **265** |
| adj_r2 | 27.060 | 36.091 | 37.283 | 37.639 | 38.434 | 38.442 | 38.903 | **38.983** |
| %Change | 0.000 | 9.031 | 1.192 | 0.356 | 0.795 | 0.008 | 0.461 | **0.081** |

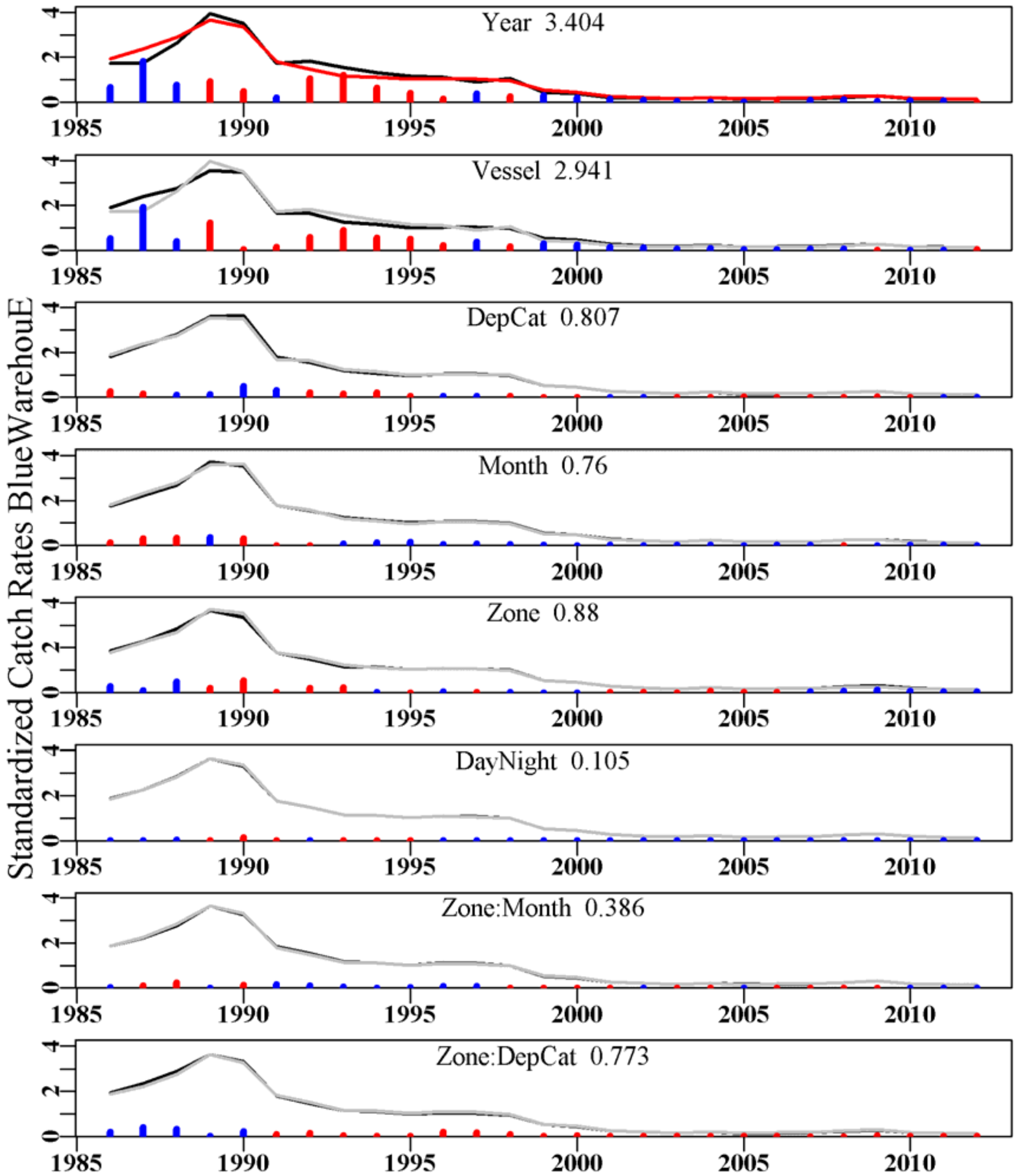



Figure 18.86. The relative influence of each factor used on the final trend in the optimal standardization for Blue Warehou in Zone 10 – 30. The top graph depicts the geometric mean (the black line) and the optimum model (the red line). The difference between them is illustrated by the vertical bars 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.

### *18.4.25 Blue Warehou Z4050 (TRT – 37445005 – S. brama)*

Data from zones 40 – 50 depths less than or equal to 600 m.

Table 18.76. Blue Warehou from zones 40 and 50 in depths 0 – 600m by trawl. Total Catch is the total reported in the database, Records is the number of records used in the analysis, CatchT is the reported catch in the area and depth used in the analysis, and Vessels relates to all vessels used in the analysis. Geomean is the geometric mean of catch rates (kg/hr). Zone:Month is the optimum model and StDev is the standard deviation relating to the data in the optimum model.

| Year | TotCatch | Records | CatchT | Vessels | GeoMean | Zone:Mth | StDev |
|---|---|---|---|---|---|---|---|
| 1986 | 211.877 | 159 | 71.389 | 14 | 34.3927 | 3.3898 | 0.0000 |
| 1987 | 405.851 | 183 | 215.645 | 10 | 153.6342 | 3.2398 | 0.2437 |
| 1988 | 543.976 | 180 | 197.989 | 12 | 104.5294 | 1.3376 | 0.2531 |
| 1989 | 770.582 | 56 | 81.343 | 13 | 91.5270 | 3.3688 | 0.3135 |
| 1990 | 872.888 | 444 | 298.296 | 14 | 55.8069 | 1.4738 | 0.2389 |
| 1991 | 1277.006 | 597 | 647.537 | 18 | 159.6429 | 2.3199 | 0.2369 |
| 1992 | 933.335 | 538 | 430.133 | 17 | 88.9759 | 1.3324 | 0.2389 |
| 1993 | 829.263 | 495 | 362.854 | 21 | 92.3447 | 0.9834 | 0.2403 |
| 1994 | 943.873 | 824 | 449.901 | 21 | 67.3117 | 1.0772 | 0.2360 |
| 1995 | 815.384 | 825 | 325.150 | 22 | 45.1964 | 0.7260 | 0.2336 |
| 1996 | 724.128 | 700 | 183.550 | 24 | 26.4215 | 0.4958 | 0.2351 |
| 1997 | 916.699 | 431 | 243.547 | 23 | 35.6095 | 0.5195 | 0.2405 |
| 1998 | 903.212 | 582 | 354.483 | 19 | 58.9967 | 0.7874 | 0.2390 |
| 1999 | 590.533 | 688 | 174.376 | 19 | 32.5226 | 0.4387 | 0.2383 |
| 2000 | 470.238 | 650 | 203.390 | 24 | 28.0473 | 0.3523 | 0.2385 |
| 2001 | 285.096 | 685 | 194.156 | 23 | 27.5825 | 0.3768 | 0.2374 |
| 2002 | 290.256 | 530 | 218.017 | 23 | 35.4216 | 0.4992 | 0.2400 |
| 2003 | 233.466 | 363 | 175.478 | 19 | 28.1023 | 0.4553 | 0.2457 |
| 2004 | 232.060 | 437 | 159.255 | 21 | 28.4995 | 0.5094 | 0.2424 |
| 2005 | 289.033 | 461 | 257.801 | 18 | 53.5991 | 0.8063 | 0.2428 |
| 2006 | 379.495 | 695 | 337.473 | 16 | 31.8482 | 0.5689 | 0.2393 |
| 2007 | 177.624 | 466 | 148.640 | 16 | 22.9820 | 0.4872 | 0.2430 |
| 2008 | 163.260 | 353 | 117.774 | 12 | 20.3955 | 0.3823 | 0.2453 |
| 2009 | 135.220 | 308 | 89.003 | 11 | 18.4388 | 0.2859 | 0.2476 |
| 2010 | 129.874 | 407 | 105.291 | 12 | 17.5511 | 0.3290 | 0.2429 |
| 2011 | 103.243 | 519 | 77.907 | 14 | 14.3950 | 0.2809 | 0.2418 |
| 2012 | 52.187 | 262 | 32.758 | 14 | 8.1485 | 0.1766 | 0.2529 |

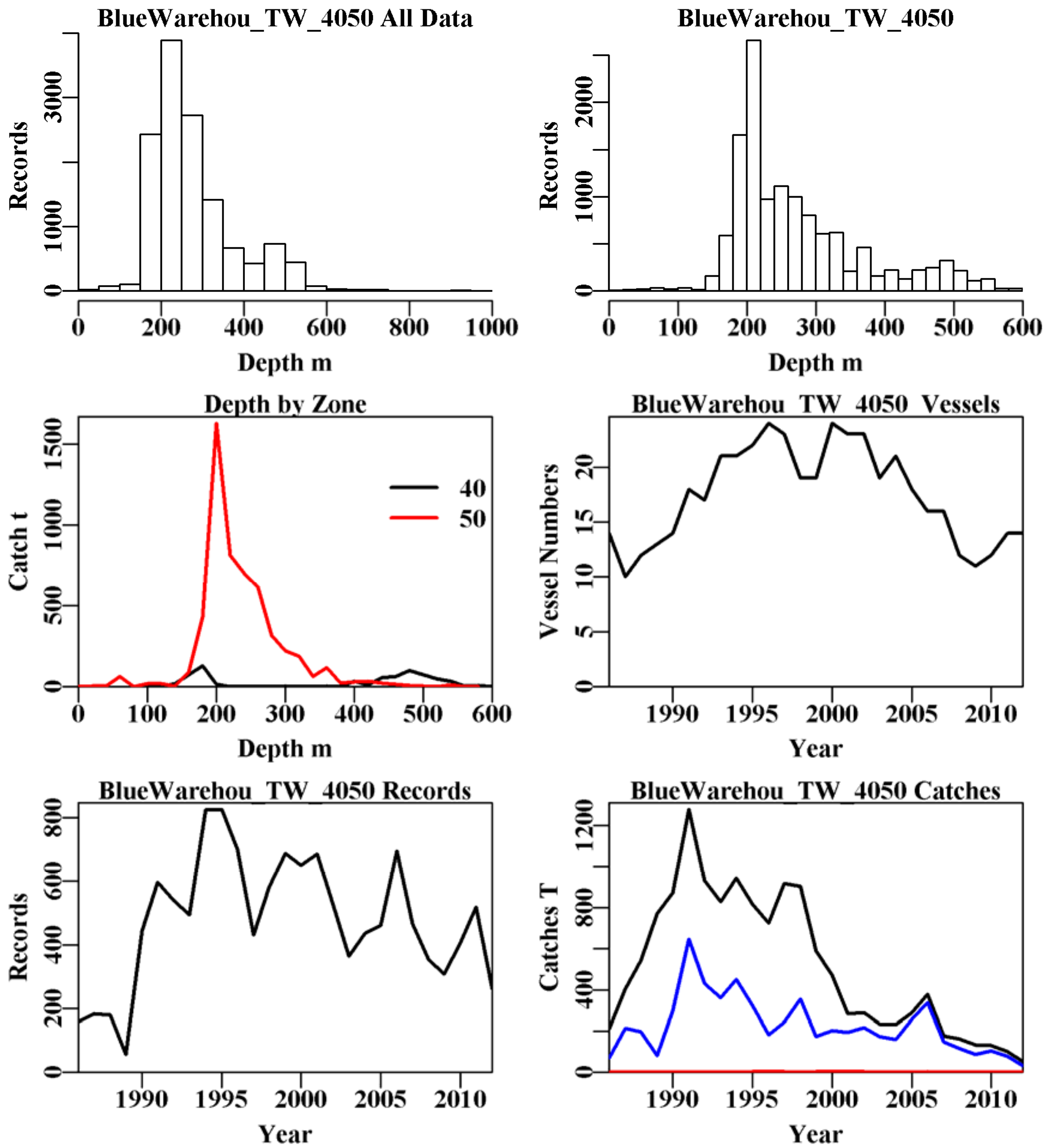



Figure 18.87. Blue Warehou from zones 40 and 50 in depths 0 – 600m by trawl. The top left is the depth distribution of all records reporting Blue Warehou, the top right graph depicts the depth distribution of shots containing Blue Warehou from zones 40 and 50 in depths 0 – 600m by trawl. The middle left diagram depicts the distribution of catch by depth within zones 40 and 50 (50 is top red line), the middle right hand graph depicts the number of vessels through time. The bottom left reflects the number of records used in analysis, and bottom right is the Blue Warehou catches (top line, black is total catches, middle line, blue, are those used in the analysis, and bottom, red, are catches < 30Kg).

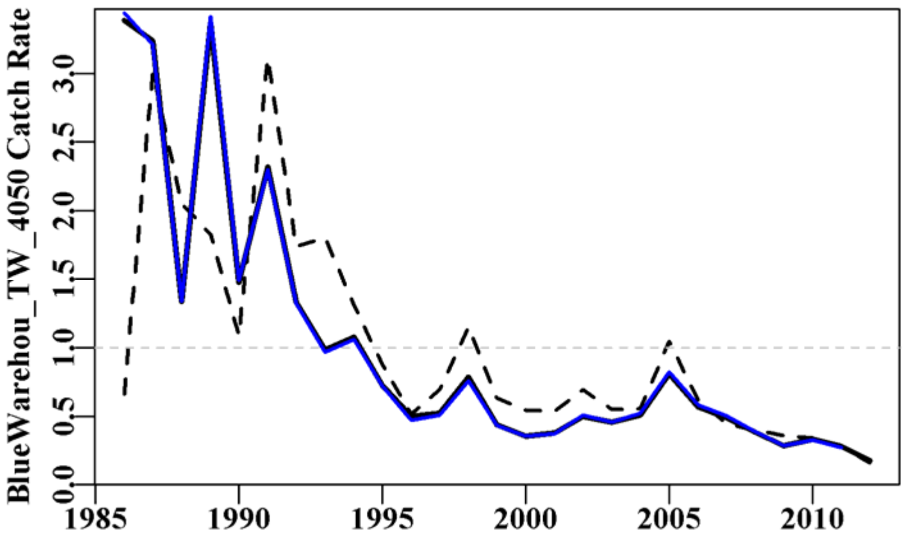



Figure 18.88. Blue Warehou from zones 40 and 50 in depths 0 – 600m by trawl. The dashed black line represents the geometric mean catch rate and the solid black line the standardized catch rates. The graph standardizes catch rates relative to the mean of the standardized catch rates.

Table 18.77. Blue Warehou from zones 40 and 50 in depths 0 – 600m 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 18.78. Blue Warehou from zones 40 and 50 in depths 0 – 600m by trawl. Model selection criteria, including the AIC, the adjusted $r^2$ and the change in adjusted $r^2$. The optimum is Zone:Month (model 7).

| | Year | Vessel | Month | DepCat | DayNight | Zone | **Zone:Mth** | Zone:DepC |
|---|---|---|---|---|---|---|---|---|
| AIC | 14361 | 13211 | 12188 | 11391 | 11229 | 11228 | **11183** | 11236 |
| RSS | 39128 | 35331 | 32569 | 30447 | 30049 | 30042 | **29885** | 29921 |
| MSS | 5218 | 9015 | 11778 | 13899 | 14297 | 14305 | **14461** | 14426 |
| Nobs | 12838 | 12837 | 12837 | 12775 | 12775 | 12775 | **12775** | 12775 |
| Npars | 27 | 107 | 118 | 148 | 151 | 152 | **163** | 182 |
| adj_r2 | 11.587 | 19.666 | 25.883 | 30.543 | 31.434 | 31.446 | **31.745** | 31.560 |
| %Change | 0.000 | 8.079 | 6.217 | 4.660 | 0.891 | 0.012 | **0.298** | -0.185 |

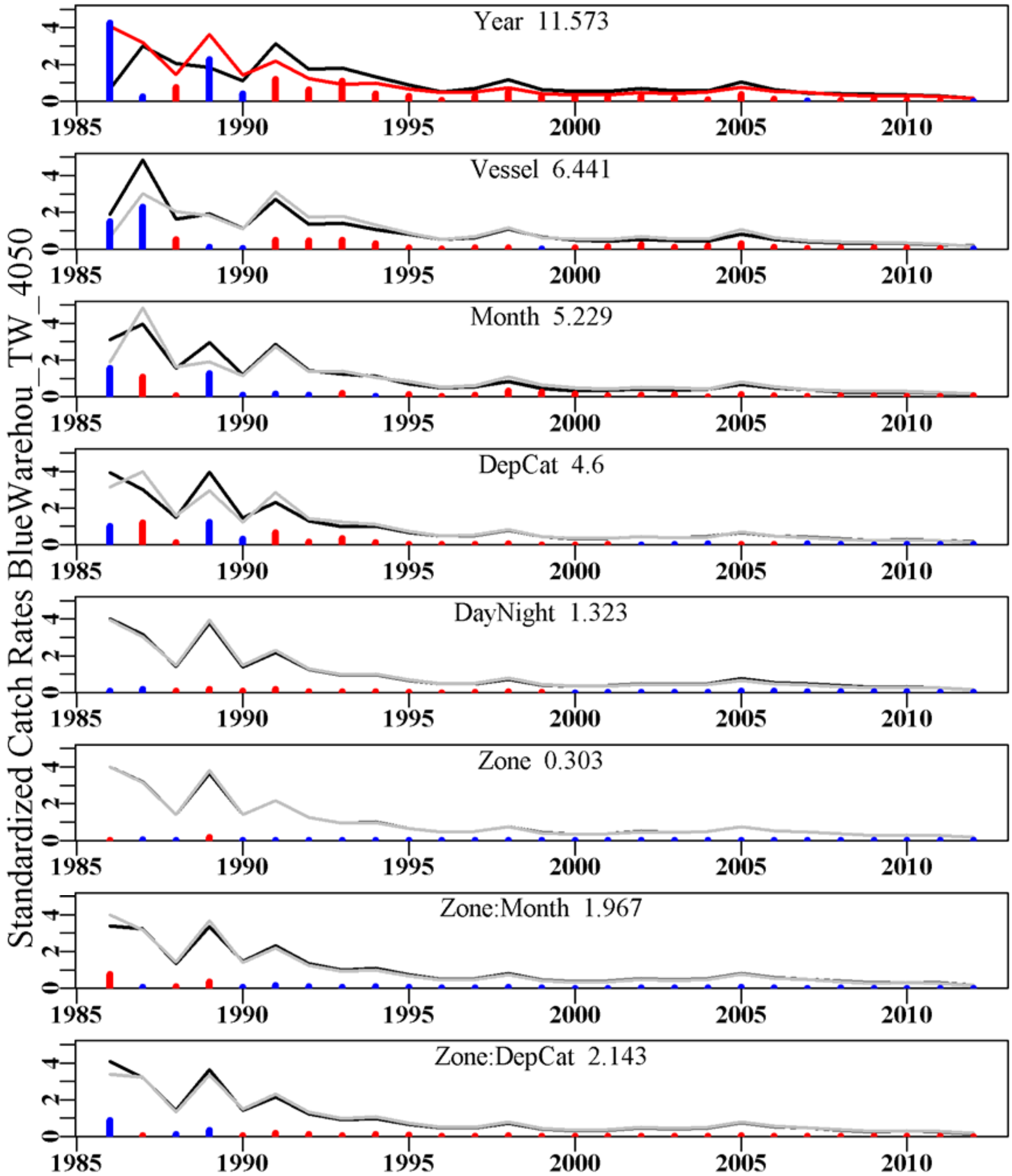



Figure 18.89. The relative influence of each factor used on the final trend in the optimal standardization for Blue Warehou in Zone 40 – 50. The top graph depicts the geometric mean (the black line) and the optimum model (the red line). The difference between them is illustrated by the vertical bars 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.

### *18.4.26 Blue Warehou Z10-50 (TRT – 37445005 – S. brama)*

Only data from Zones 10 to 50 in depths 0 – 600m. Only vessels present in the fishery for more than 2 years were included.

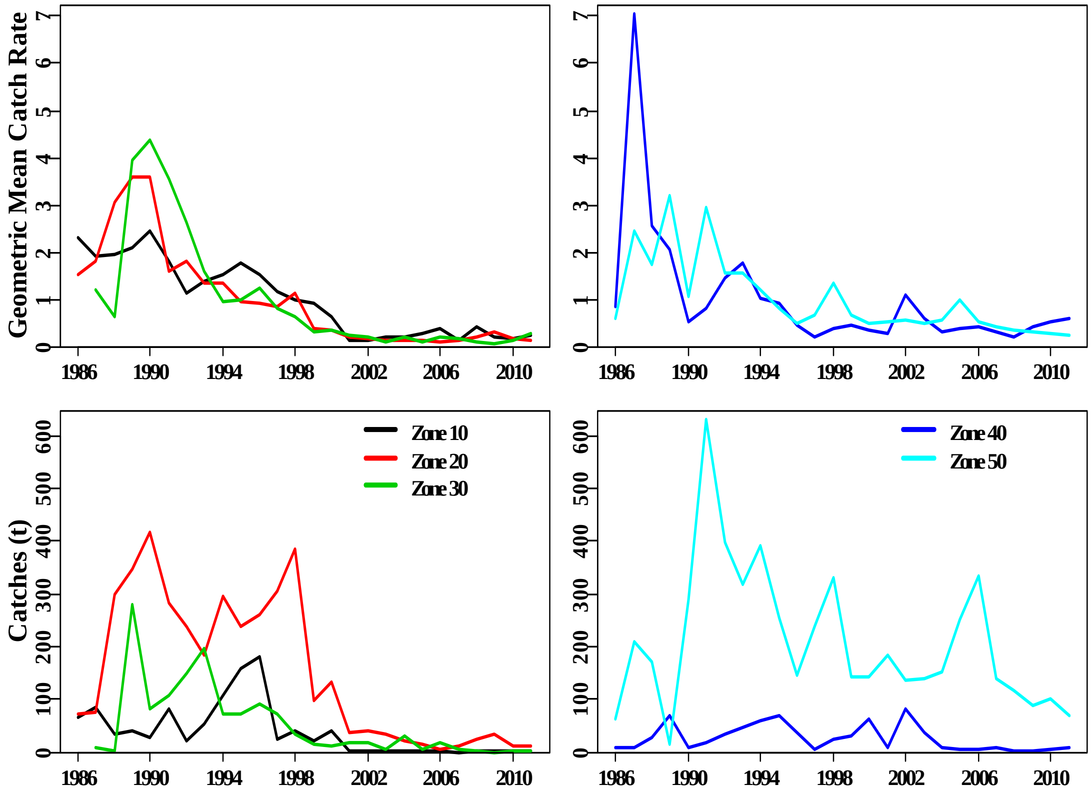



Figure 18.90. Trends in the catches and geometric mean catch rates for Blue Warehou across each of the zones 10 – 50, split east and west. The extreme catch rates in zone 40 reflect very small catches

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 18.79. Blue Warehou from zones 10 to 50 in depths 0 – 600m by trawl. Total Catch is the total reported in the database, Records is the number of records used in the analysis, CatchT is the reported catch in the area and depth used in the analysis, and Vessels relates to all vessels used in the analysis. Geomean is the geometric mean of catch rates (kg/hr). Zone:Mth is the optimum model and StDev is the standard deviation relating to the data in the optimum model.

| Year | TotCatch | Records | CatchT | Vessels | GeoMean | Zone:Mth | StDev |
|---|---|---|---|---|---|---|---|
| 1986 | 211.877 | 863 | 210.321 | 54 | 24.6419 | 2.0703 | 0.0000 |
| 1987 | 405.851 | 655 | 384.556 | 51 | 38.9818 | 2.3727 | 0.0921 |
| 1988 | 543.976 | 963 | 532.358 | 45 | 42.2791 | 2.6488 | 0.0892 |
| 1989 | 770.582 | 1239 | 746.152 | 50 | 53.5132 | 3.6574 | 0.0876 |
| 1990 | 872.888 | 1284 | 822.419 | 56 | 49.3618 | 2.5841 | 0.0889 |
| 1991 | 1277.006 | 2193 | 1119.788 | 66 | 38.9026 | 2.0552 | 0.0845 |
| 1992 | 933.335 | 1902 | 840.304 | 56 | 34.9011 | 1.5133 | 0.0854 |
| 1993 | 829.263 | 2717 | 797.308 | 58 | 27.0143 | 1.1760 | 0.0832 |
| 1994 | 943.873 | 3300 | 927.228 | 58 | 24.5388 | 1.1348 | 0.0820 |
| 1995 | 815.384 | 3497 | 794.697 | 58 | 19.7435 | 0.9631 | 0.0817 |
| 1996 | 724.128 | 4278 | 715.754 | 66 | 16.0446 | 0.9765 | 0.0813 |
| 1997 | 916.699 | 2925 | 648.139 | 57 | 13.9027 | 0.9728 | 0.0835 |
| 1998 | 903.212 | 3152 | 813.727 | 50 | 18.0335 | 0.9660 | 0.0829 |
| 1999 | 590.533 | 2372 | 309.696 | 57 | 9.5323 | 0.5210 | 0.0848 |
| 2000 | 470.238 | 2899 | 389.591 | 59 | 7.2891 | 0.4484 | 0.0837 |
| 2001 | 285.096 | 2208 | 253.279 | 53 | 5.6327 | 0.3021 | 0.0857 |
| 2002 | 290.256 | 2408 | 281.036 | 53 | 4.0433 | 0.2549 | 0.0854 |
| 2003 | 233.466 | 1709 | 218.370 | 51 | 3.2843 | 0.2065 | 0.0880 |
| 2004 | 232.060 | 1700 | 211.509 | 51 | 4.9660 | 0.2822 | 0.0887 |
| 2005 | 289.033 | 1297 | 279.429 | 45 | 6.0446 | 0.2635 | 0.0910 |
| 2006 | 379.495 | 1474 | 363.242 | 36 | 7.8259 | 0.2645 | 0.0900 |
| 2007 | 177.624 | 1051 | 165.406 | 25 | 5.6784 | 0.2444 | 0.0936 |
| 2008 | 163.260 | 1100 | 145.318 | 27 | 5.0903 | 0.2754 | 0.0927 |
| 2009 | 135.220 | 766 | 126.232 | 24 | 6.9116 | 0.2752 | 0.0976 |
| 2010 | 129.874 | 785 | 117.741 | 22 | 6.3388 | 0.2207 | 0.0975 |
| 2011 | 103.243 | 966 | 91.479 | 23 | 5.5254 | 0.2025 | 0.0950 |
| 2012 | 52.187 | 633 | 46.421 | 25 | 3.2664 | 0.1477 | 0.1019 |

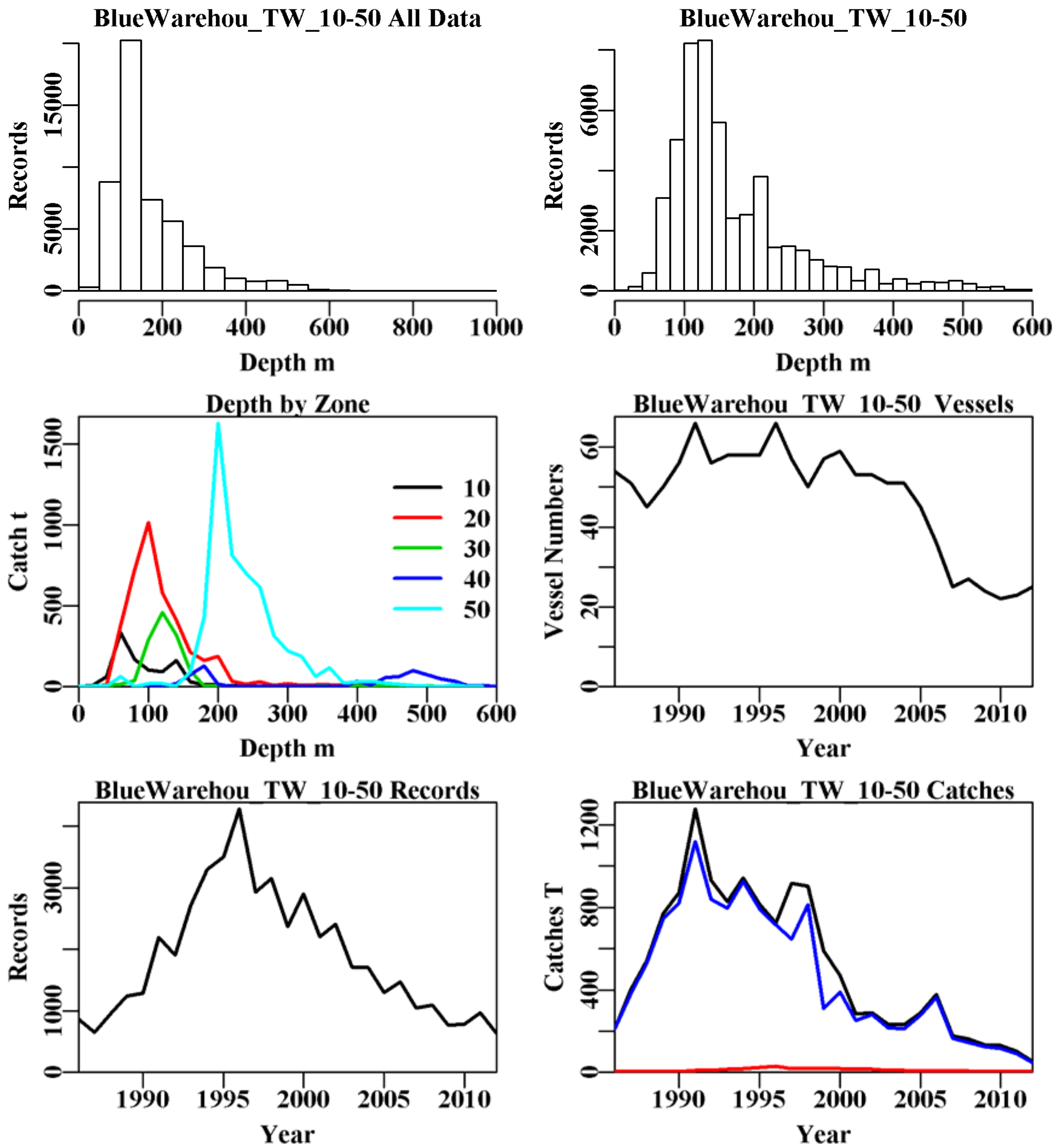



Figure 18.91. Blue Warehou from zones 10 to 50 in depths 0 – 400m by trawl. The top left is the depth distribution of all records reporting Blue Warehou, the top right graph depicts the depth distribution of shots containing Blue Warehou from zones 10 to 50 in depths 0 – 400m by trawl. The middle left diagram depicts the distribution of catch by depth within zones 10 50, the middle right hand graph depicts the number of vessels through time. The bottom left reflects the number of records used in analysis, and bottom right is the Blue Warehou catches (top line, black is total catches, middle line, blue, are those used in the analysis, and bottom, red, are catches < 30Kg)

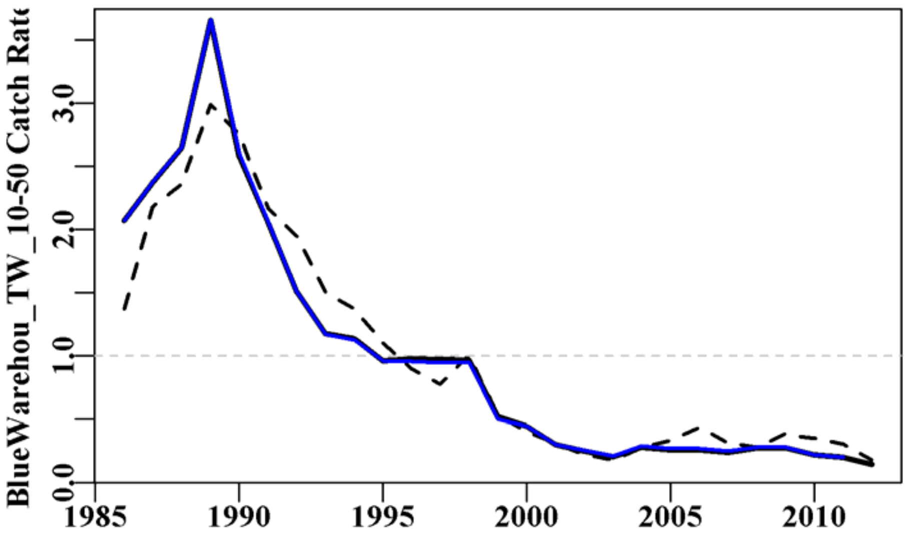



Figure 18.92. Blue Warehou from zones 10 to 50 in depths 0 – 400m by trawl. The dashed black line represents the geometric mean catch rate and the solid black line the standardized catch rates. The graph standardizes catch rates relative to the mean of the standardized catch rates.

Table 18.80. Blue Warehou from zones 10 to 50 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+Zone:Month |
| Model 8 | LnCE~Year+Vessel+DepCat+Zone+Month+DayNight+Zone:DepCat |

Table 18.81. Blue Warehou from zones 10 to 50 in depths 0 – 400m by trawl. Model selection criteria, including the AIC, the adjusted $r^2$ and the change in adjusted $r^2$. The optimum is Zone:Month (model 7).

| | Year | Vessel | DepCat | Zone | Month | DayNight | **Zone:Mth** | Zone:DepC |
|---|---|---|---|---|---|---|---|---|
| AIC | 62101 | 48148 | 46842 | 45746 | 45025 | 44957 | **43959** | 44262 |
| RSS | 172669 | 129872 | 126342 | 123584 | 121764 | 121584 | **118975** | 119333 |
| MSS | 31963 | 74759 | 78290 | 81047 | 82868 | 83047 | **85656** | 85299 |
| Nobs | 50336 | 50335 | 50053 | 50053 | 50053 | 50053 | **50053** | 50053 |
| Npars | 27 | 219 | 249 | 253 | 264 | 267 | **311** | 387 |
| adj_r2 | 15.576 | 36.257 | 37.951 | 39.301 | 40.182 | 40.266 | **41.497** | 41.231 |
| %Change | 0.000 | 20.681 | 1.694 | 1.349 | 0.881 | 0.085 | **1.230** | -0.266 |

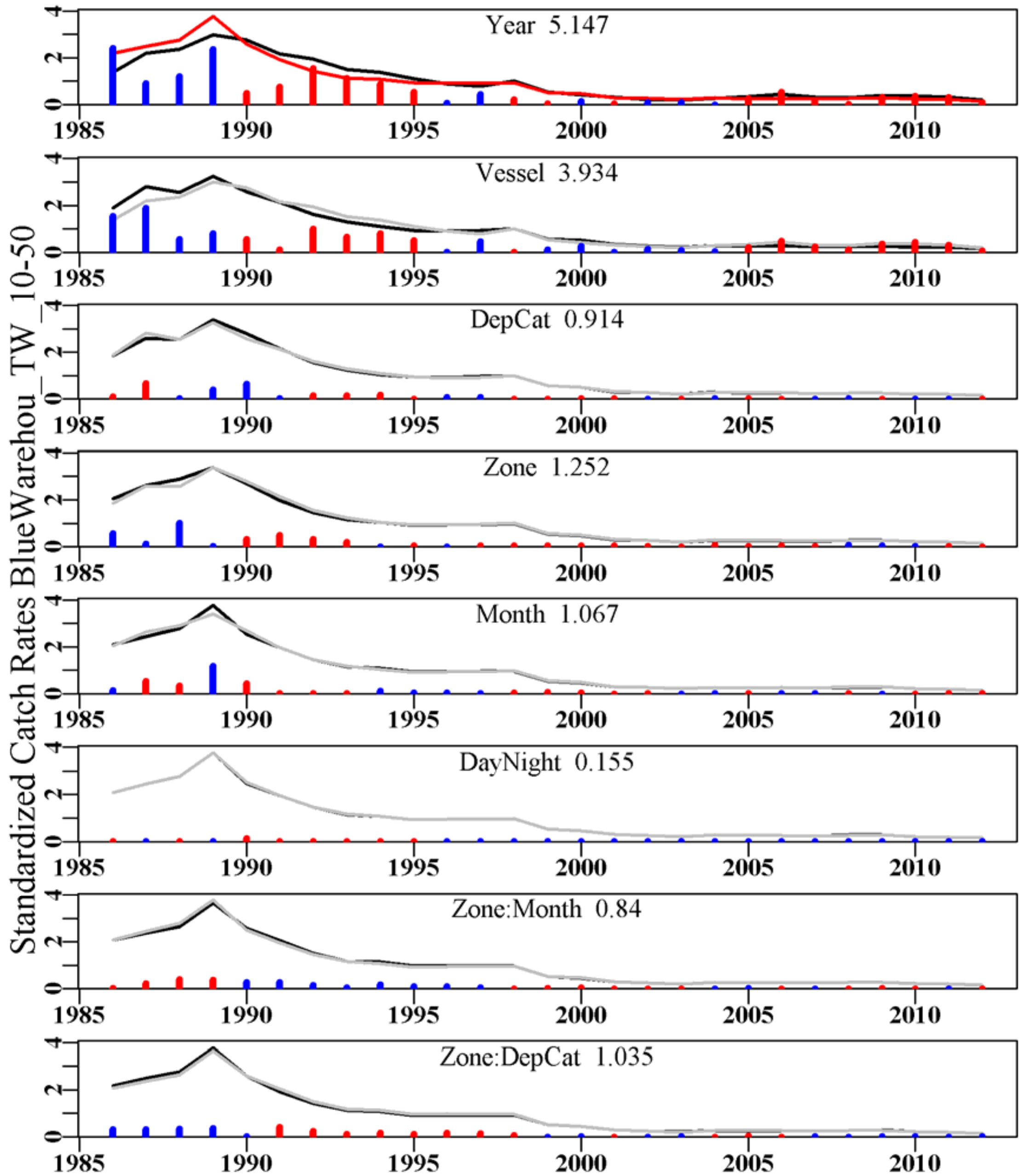



Figure 18.93. The relative influence of each factor used on the final trend in the optimal standardization for Blue Warehou in Zone 10 – 50. The top graph depicts the geometric mean (the black line) and the optimum model (the red line). The difference between them is illustrated by the vertical bars 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.

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

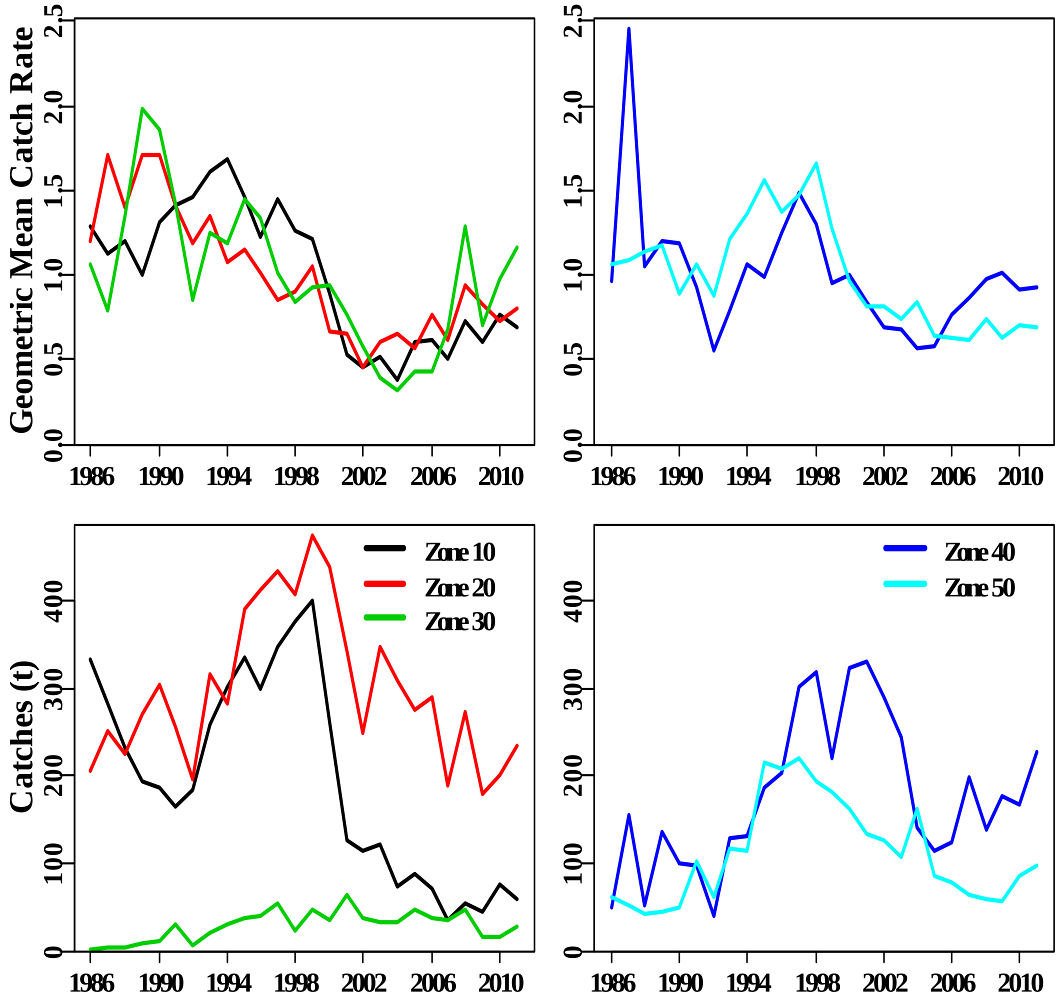



Figure 18.94. Trends in the catches and geometric mean catch rates for Pink Ling taken by trawler across zones 10 – 50 split between east and west.

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

### *18.4.28 Pink Ling, Z102030 (LIG – 37228002 – G. blacodes)*

Data from zones 10, 20 and 30, depths greater than 250 m and less than 600 m.

Table 18.82. Pink Ling from zones 10 to 30 in depths between 250 – 600m by trawl. Total Catch is the total reported in the database, Records is the number of records used in the analysis, CatchT is the reported catch in the area and depth used in the analysis, and Vessels relates to all vessels used in the analysis. Geomean is the geometric mean of catch rates (kg/hr). Zone:Month is the optimum model and StDev is the standard deviation relating to the data in the optimum model.

| Year | TotCatch | Records | CatchT | Vessels | GeoMean | Zone:Mth | StDev |
|---|---|---|---|---|---|---|---|
| 1986 | 678.801 | 4512 | 498.298 | 80 | 20.6651 | 1.1112 | 0.0000 |
| 1987 | 764.910 | 4260 | 492.314 | 77 | 19.4237 | 1.1786 | 0.0224 |
| 1988 | 582.895 | 3613 | 400.077 | 77 | 20.2595 | 1.1234 | 0.0235 |
| 1989 | 677.150 | 3879 | 422.077 | 77 | 19.1575 | 0.9652 | 0.0233 |
| 1990 | 673.624 | 2794 | 413.082 | 68 | 26.8201 | 1.4198 | 0.0256 |
| 1991 | 719.965 | 2938 | 370.297 | 72 | 26.3050 | 1.4201 | 0.0256 |
| 1992 | 567.627 | 2417 | 324.371 | 57 | 24.8497 | 1.0966 | 0.0269 |
| 1993 | 891.448 | 3525 | 504.474 | 59 | 25.3075 | 1.0313 | 0.0245 |
| 1994 | 894.766 | 4066 | 470.265 | 63 | 23.5158 | 1.0448 | 0.0236 |
| 1995 | 1208.577 | 4361 | 586.686 | 57 | 25.8106 | 1.3164 | 0.0231 |
| 1996 | 1233.106 | 4268 | 667.583 | 63 | 27.6570 | 1.3170 | 0.0233 |
| 1997 | 1693.734 | 4808 | 732.654 | 62 | 27.9375 | 1.3472 | 0.0229 |
| 1998 | 1591.848 | 4909 | 730.458 | 57 | 26.0156 | 1.3413 | 0.0227 |
| 1999 | 1651.457 | 5964 | 832.655 | 59 | 25.2286 | 1.2284 | 0.0222 |
| 2000 | 1507.199 | 5113 | 660.280 | 63 | 22.4049 | 1.0837 | 0.0231 |
| 2001 | 1392.361 | 4544 | 484.022 | 52 | 19.0624 | 0.8413 | 0.0239 |
| 2002 | 1329.946 | 3898 | 360.465 | 52 | 15.8660 | 0.7343 | 0.0248 |
| 2003 | 1351.687 | 4309 | 445.759 | 57 | 18.2929 | 0.7492 | 0.0243 |
| 2004 | 1492.255 | 3359 | 347.369 | 54 | 16.7984 | 0.6719 | 0.0259 |
| 2005 | 1202.739 | 3454 | 329.969 | 51 | 16.3335 | 0.6280 | 0.0255 |
| 2006 | 1069.111 | 2593 | 323.101 | 38 | 21.3189 | 0.7491 | 0.0274 |
| 2007 | 875.503 | 1652 | 204.307 | 23 | 20.5015 | 0.7292 | 0.0316 |
| 2008 | 980.268 | 2382 | 329.036 | 24 | 25.1511 | 0.8466 | 0.0287 |
| 2009 | 774.735 | 1947 | 212.362 | 27 | 18.2953 | 0.6172 | 0.0303 |
| 2010 | 905.925 | 1990 | 271.121 | 23 | 20.7211 | 0.7541 | 0.0300 |
| 2011 | 1081.607 | 2201 | 294.896 | 22 | 23.4304 | 0.7997 | 0.0293 |
| 2012 | 1024.601 | 1972 | 273.323 | 24 | 24.3541 | 0.8544 | 0.0302 |

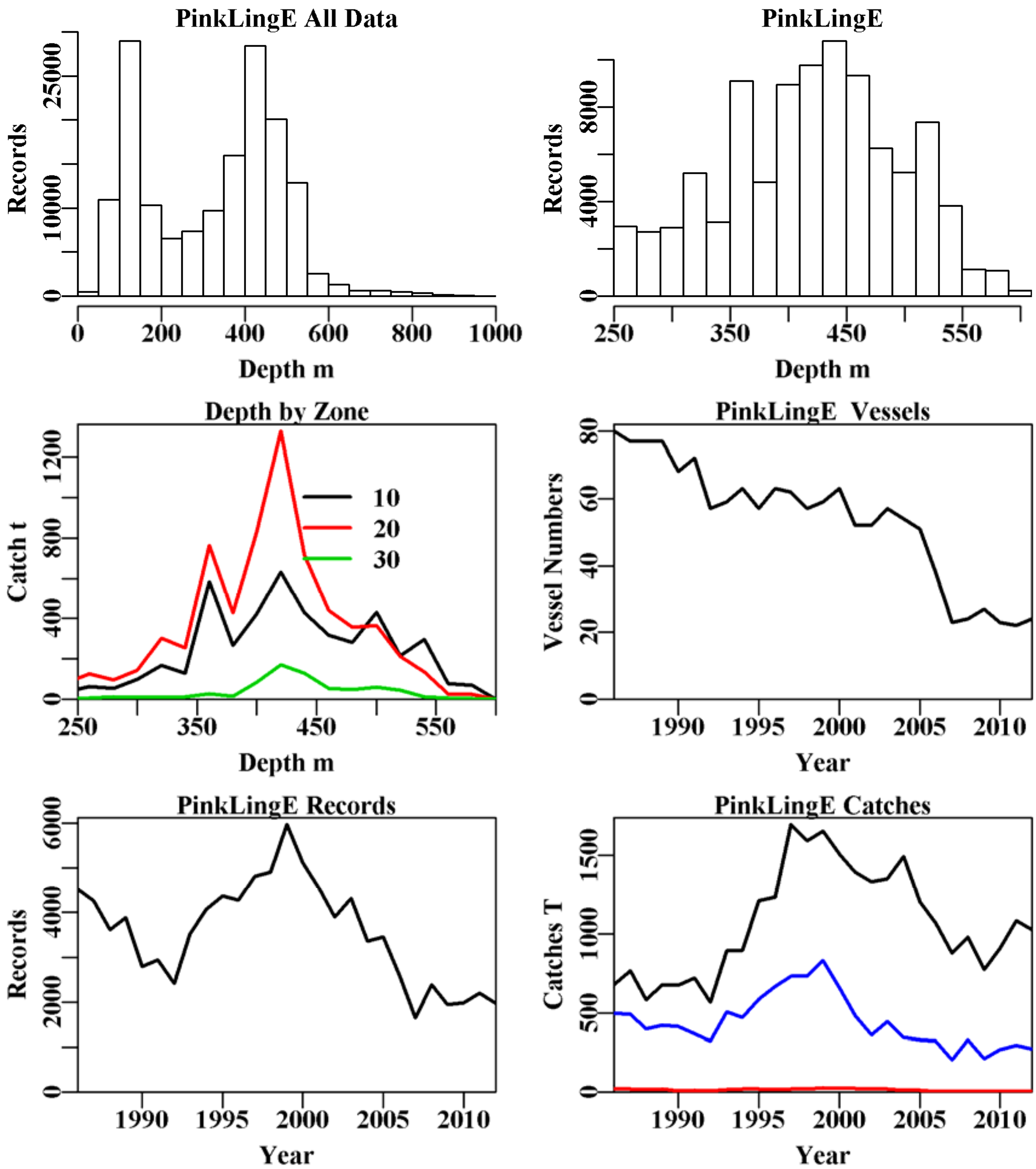



Figure 18.95. Pink Ling from zones 10 to 30 in depths between 250 – 600m by trawl. The top left is the depth distribution of all records reporting Pink Ling, the top right graph depicts the depth distribution of shots containing Pink Ling from zones 10 to 30 in depths between 250 – 600m by trawl. The middle left diagram depicts the distribution of catch by depth within zones 10 to 30, the middle right hand graph depicts the number of vessels through time. The bottom left reflects the number of records used in analysis, and bottom right is the Pink Ling catches (top line, black is total catches, middle line, blue, are those used in the analysis, and bottom, red, are catches < 30Kg).

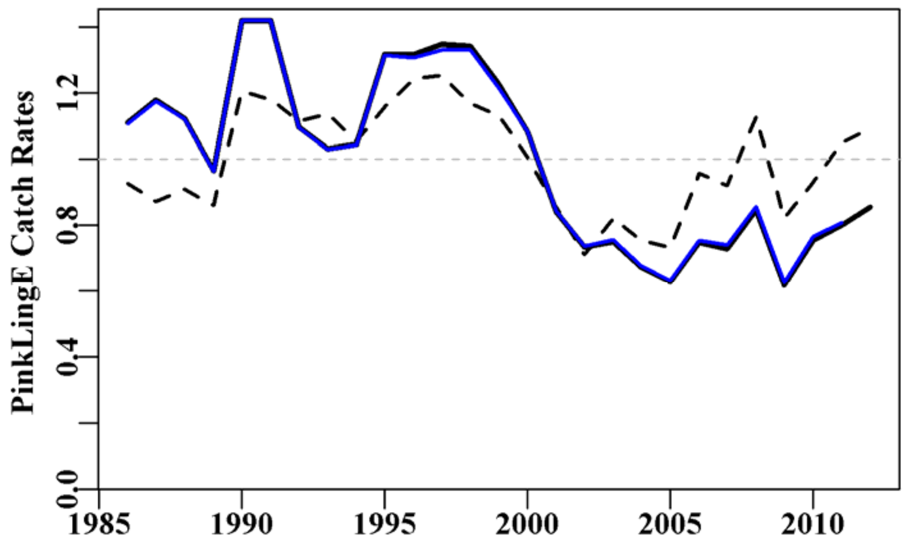



Figure 18.96. Pink Ling from zones 10 to 30 in depths between 250 – 600m by trawl. The dashed black line represents the geometric mean catch rate and the solid black line the standardized catch rates. The graph standardizes catch rates relative to the mean of the standardized catch rates.

Table 18.83. Pink Ling from zones 10 to 30 in depths between 250 – 600m 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 18.84. Pink Ling from zones 10 to 30 in depths between 250 – 600m by trawl. Model selection criteria, including the AIC, the adjusted $r^2$ and the change in adjusted $r^2$. The optimum is Zone:Month (model 7).

| | Year | DepCat | Vessel | Month | Zone | DayNight | **Zone:Mth** | Zone:DepC |
|---|---|---|---|---|---|---|---|---|
| AIC | 32436 | 25193 | 4487 | 663 | 39 | -3 | **-1120** | -994 |
| RSS | 134261 | 123602 | 98984 | 95051 | 94424 | 94376 | **93228** | 93324 |
| MSS | 2732 | 13390 | 38009 | 41942 | 42568 | 42616 | **43764** | 43668 |
| Nobs | 95728 | 94864 | 94864 | 94864 | 94864 | 94864 | **94864** | 94864 |
| Npars | 27 | 45 | 226 | 238 | 240 | 243 | **265** | 279 |
| adj_r2 | 1.967 | 9.733 | 27.573 | 30.442 | 30.899 | 30.932 | **31.756** | 31.676 |
| %Change | 0.000 | 7.765 | 17.841 | 2.869 | 0.457 | 0.033 | **0.824** | 0.744 |

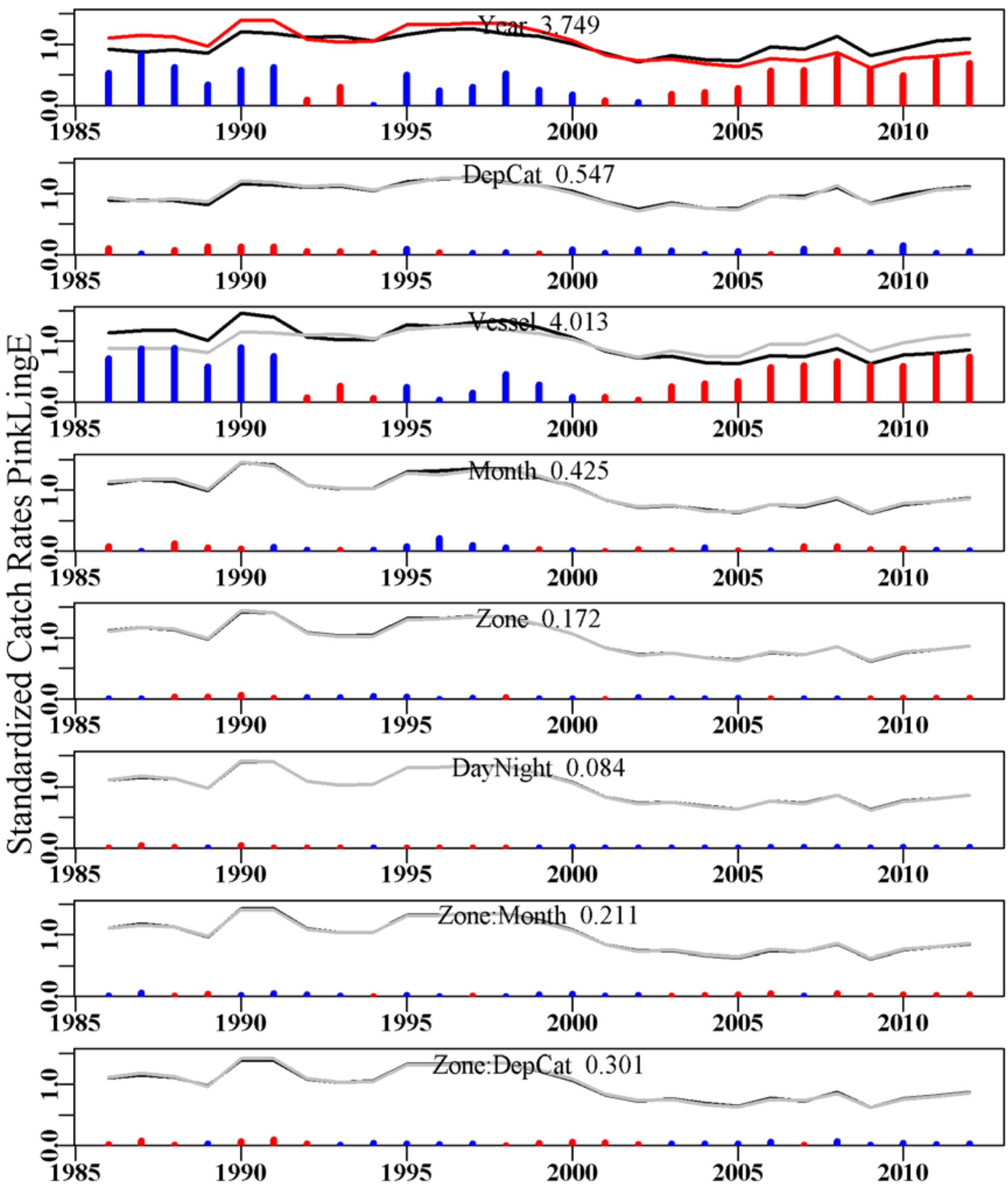



Figure 18.97. The relative influence of each factor used on the final trend in the optimal standardization for Pink Ling from zones 10 to 30. The top graph depicts the geometric mean (the black line) and the optimum model (the red line). The difference between them is illustrated by the vertical bars 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.

### *18.4.29 Pink Ling, Z4050 (LIG – 37228002 – G. blacodes)*

Data from zones 40 and 50, depths greater than 200 m and less or equal to 800 m.

Table 18.85. Pink Ling from zones 40 and 50 in depths between 200 – 800m by trawl. Total Catch is the total reported in the database, Records is the number of records used in the analysis, CatchT is the reported catch in the area and depth used in the analysis, and Vessels relates to all vessels used in the analysis. Geomean is the geometric mean of catch rates (kg/hr). Zone:Mth is the optimum model and StDev is the standard deviation relating to the data in the optimum model.

| Year | TotCatch | Records | CatchT | Vessels | GeoMean | Zone:Mth | StDev |
|---|---|---|---|---|---|---|---|
| 1986 | 678.801 | 1265 | 112.944 | 23 | 17.1417 | 1.1748 | 0.0000 |
| 1987 | 764.910 | 1310 | 206.341 | 28 | 24.0155 | 1.3485 | 0.0376 |
| 1988 | 582.895 | 1026 | 95.703 | 32 | 17.6676 | 1.0515 | 0.0406 |
| 1989 | 677.150 | 1469 | 183.121 | 34 | 21.9840 | 1.0854 | 0.0388 |
| 1990 | 673.624 | 1524 | 147.412 | 32 | 16.9021 | 0.9755 | 0.0393 |
| 1991 | 719.965 | 1897 | 198.945 | 37 | 16.3936 | 1.0397 | 0.0375 |
| 1992 | 567.627 | 1633 | 102.164 | 24 | 11.9963 | 0.7746 | 0.0385 |
| 1993 | 891.448 | 2253 | 235.485 | 24 | 17.1332 | 1.0500 | 0.0373 |
| 1994 | 894.766 | 2110 | 247.793 | 24 | 20.5621 | 1.2634 | 0.0372 |
| 1995 | 1208.577 | 3516 | 426.907 | 25 | 20.0613 | 1.2941 | 0.0350 |
| 1996 | 1233.106 | 3403 | 448.044 | 26 | 19.9984 | 1.3698 | 0.0353 |
| 1997 | 1693.734 | 3732 | 577.434 | 24 | 21.1891 | 1.4378 | 0.0350 |
| 1998 | 1591.848 | 3710 | 558.641 | 21 | 22.4111 | 1.4223 | 0.0353 |
| 1999 | 1651.457 | 3794 | 427.920 | 24 | 18.0495 | 1.1241 | 0.0351 |
| 2000 | 1507.199 | 4655 | 509.304 | 28 | 16.3679 | 1.0063 | 0.0347 |
| 2001 | 1392.361 | 5061 | 500.022 | 28 | 14.7513 | 0.8993 | 0.0346 |
| 2002 | 1329.946 | 4631 | 429.572 | 27 | 13.4100 | 0.7773 | 0.0347 |
| 2003 | 1351.687 | 3821 | 360.388 | 27 | 12.6444 | 0.7796 | 0.0351 |
| 2004 | 1492.255 | 3901 | 306.551 | 25 | 11.7195 | 0.7283 | 0.0353 |
| 2005 | 1202.739 | 2663 | 195.741 | 23 | 9.9467 | 0.6063 | 0.0365 |
| 2006 | 1069.111 | 2322 | 209.985 | 21 | 10.6509 | 0.6469 | 0.0373 |
| 2007 | 875.503 | 2532 | 287.345 | 16 | 12.6778 | 0.7116 | 0.0368 |
| 2008 | 980.268 | 1795 | 214.232 | 17 | 14.6108 | 0.9105 | 0.0383 |
| 2009 | 774.735 | 1976 | 260.609 | 13 | 14.0039 | 0.8931 | 0.0378 |
| 2010 | 905.925 | 2337 | 272.103 | 14 | 13.1465 | 0.8604 | 0.0371 |
| 2011 | 1081.607 | 2791 | 356.784 | 16 | 13.2647 | 0.8442 | 0.0366 |
| 2012 | 1024.601 | 2342 | 344.973 | 14 | 14.5232 | 0.9246 | 0.0376 |

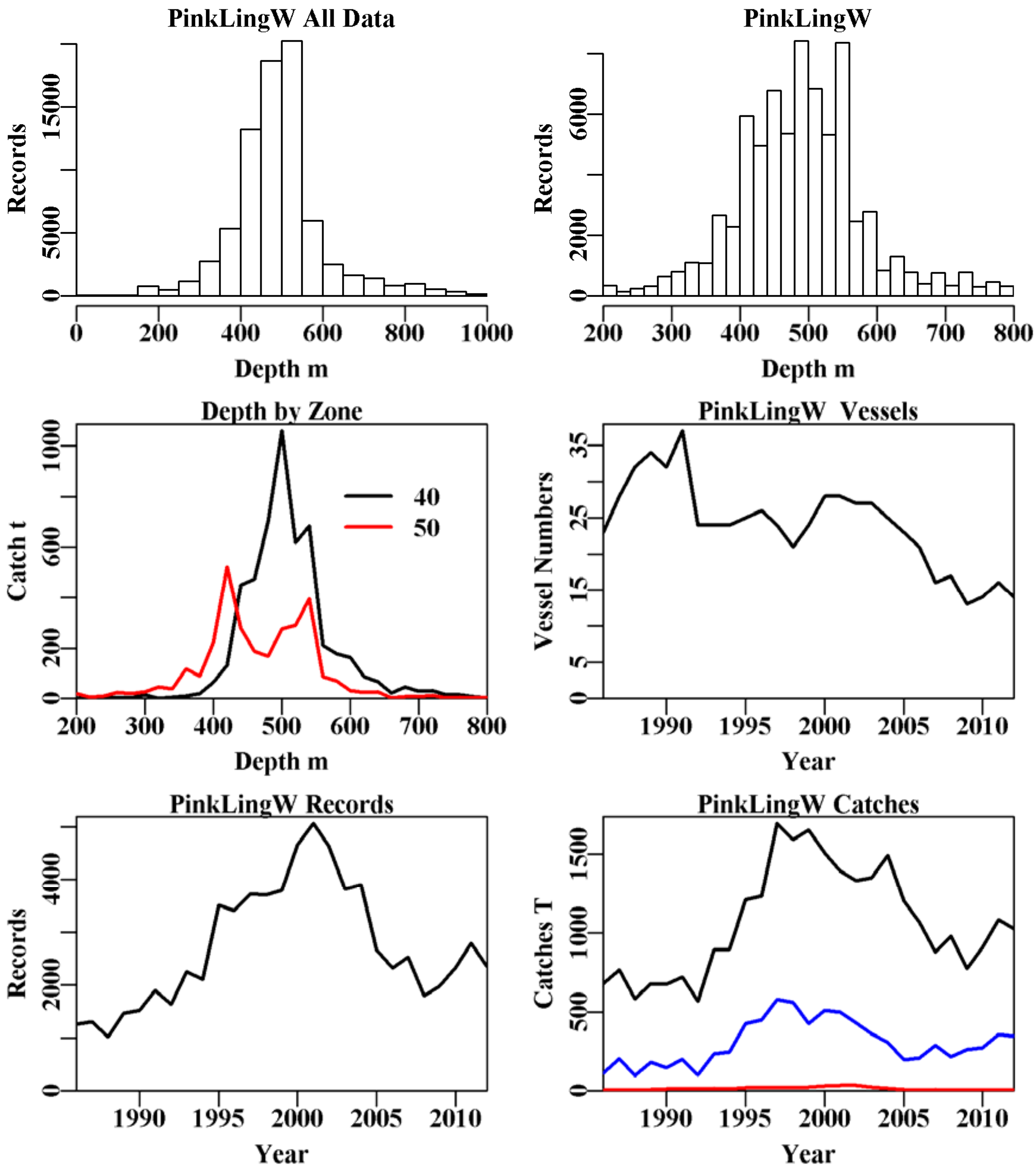



Figure 18.98. Pink Ling from zones 40 and 50 in depths between 200 – 800m by trawl. The top left is the depth distribution of all records reporting Pink Ling, the top right graph depicts the depth distribution of shots containing Pink Ling from zones 40 and 50 in depths between 200 – 800m by trawl. The middle left diagram depicts the distribution of catch by depth within zones 40 and 50 (50 is top red line), the middle right hand graph depicts the number of vessels through time. The bottom left reflects the number of records used in analysis, and bottom right is the Pink Ling catches (top line, black is total catches, middle line, blue, are those used in the analysis, and bottom, red, are catches < 30Kg).

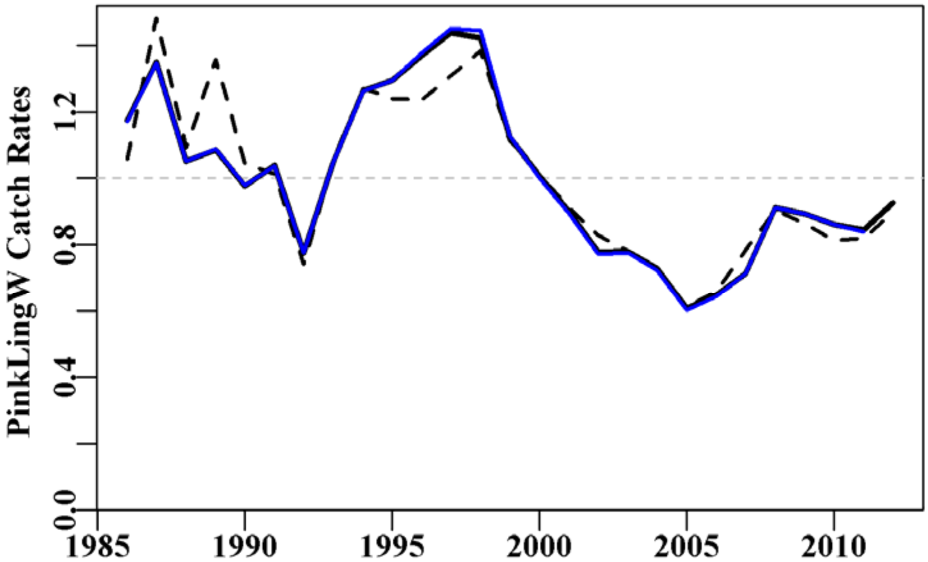



Figure 18.99. Pink Ling from zones 40 and 50 in depths between 200 – 800m by trawl. The dashed black line represents the geometric mean catch rate and the solid black line the standardized catch rates. The graph standardizes catch rates relative to the mean of the standardized catch rates.

Table 18.86. Pink Ling from zones 40 and 50 in depths between 200 – 800m 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 18.87. Pink Ling from zones 40 and 50 in depths between 200 – 800m by trawl. Model selection criteria, including the AIC, the adjusted $r^2$ and the change in adjusted $r^2$. The optimum is Zone:Month (model 7).

| | Year | DepCat | Vessel | Month | Zone | DayNight | **Zone:Mth** | Zone:DepC |
|---|---|---|---|---|---|---|---|---|
| AIC | 96 | -9960 | -16177 | -18501 | -19307 | -19330 | **-20667** | -20019 |
| RSS | 73511 | 63600 | 58260 | 56417 | 55797 | 55774 | **54746** | 55205 |
| MSS | 3893 | 13803 | 19144 | 20986 | 21607 | 21629 | **22658** | 22198 |
| Nobs | 73469 | 73010 | 73010 | 73010 | 73010 | 73010 | **73010** | 73010 |
| Npars | 27 | 57 | 150 | 161 | 162 | 165 | **176** | 195 |
| adj_r2 | 4.996 | 17.770 | 24.578 | 26.953 | 27.756 | 27.781 | **29.102** | 28.489 |
| %Change | 0.000 | 12.774 | 6.808 | 2.375 | 0.803 | 0.026 | **1.321** | -0.614 |

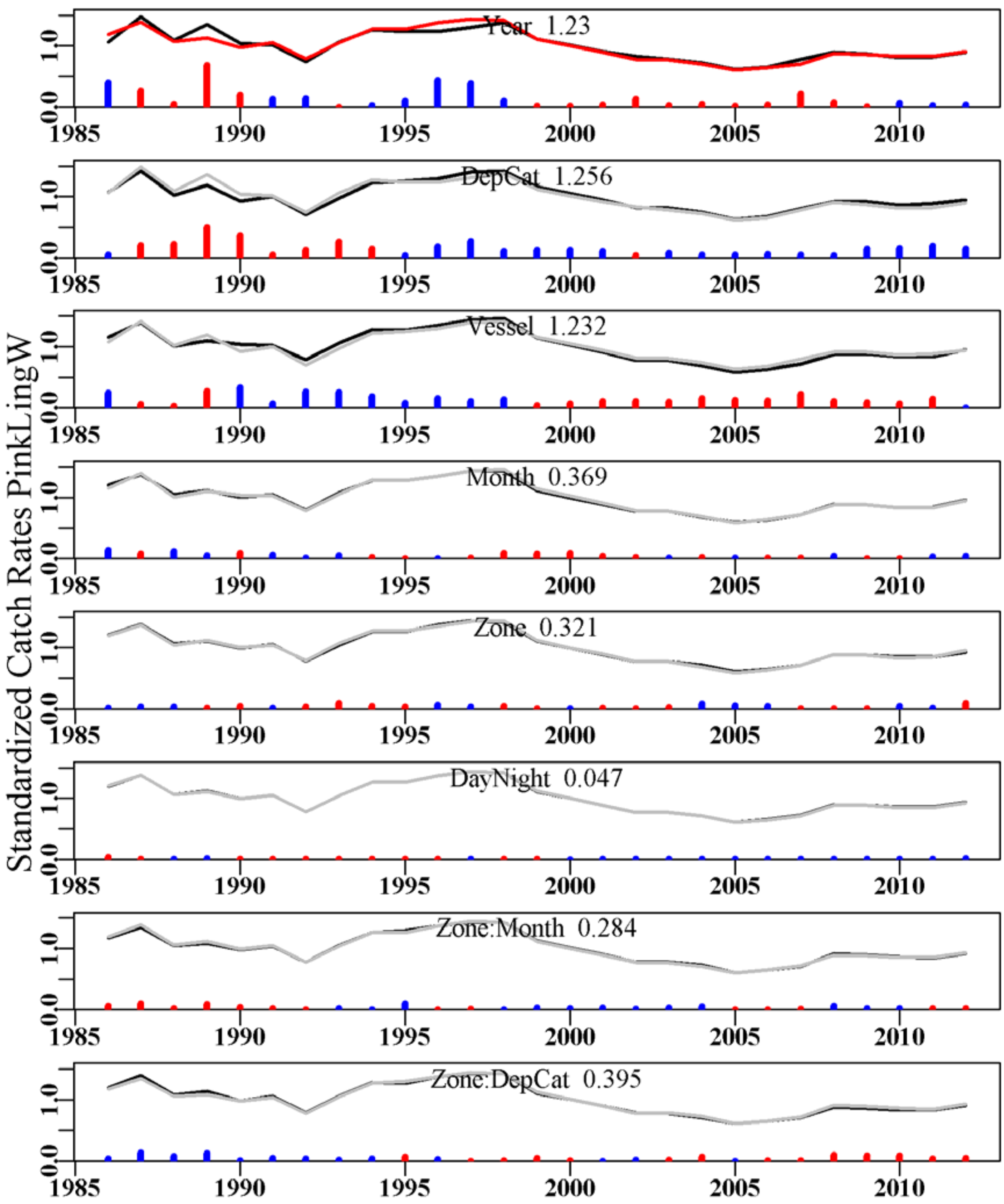



Figure 18.100. The relative influence of each factor used on the final trend in the optimal standardization for Pink Ling from zones 40 and 50. The top graph depicts the geometric mean (the black line) and the optimum model (the red line). The difference between them is illustrated by the vertical bars 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.

### *18.4.30 Pink Ling, Z10 (LIG – 37228002 – G. blacodes)*

Data from zone 10, depths greater than 250 m and less or equal to 600 m.

Table 18.88. Pink Ling from zone 10 in depths between 250 – 600m by trawl. Total Catch is the total Pink Ling catch from all zones reported in the database, Records is the number of records used in the analysis, CatchT is the reported catch in the area and depth used in this analysis, and Vessels relates to all vessels used in the analysis. Geomean is the unstandardized geometric mean of catch rates (kg/hr). Vessel:Mth is the optimum model and StDev is the standard deviation relating to the data in the optimum model.

| Year | TotCatch | Records | CatchT | Vessels | GeoMean | Vessel:Mth | StDev |
|---|---|---|---|---|---|---|---|
| 1986 | 678.801 | 3324 | 314.213 | 69 | 18.2806 | 1.1840 | 0.0000 |
| 1987 | 764.910 | 3017 | 270.907 | 65 | 15.1828 | 1.1356 | 0.0271 |
| 1988 | 582.895 | 2154 | 207.947 | 62 | 16.5795 | 1.1610 | 0.0296 |
| 1989 | 677.150 | 2356 | 177.865 | 61 | 13.2037 | 0.8887 | 0.0293 |
| 1990 | 673.624 | 1436 | 157.171 | 50 | 18.6577 | 1.2915 | 0.0332 |
| 1991 | 719.965 | 1319 | 145.022 | 39 | 23.1009 | 1.5801 | 0.0345 |
| 1992 | 567.627 | 1171 | 167.548 | 42 | 26.4272 | 1.4105 | 0.0357 |
| 1993 | 891.448 | 1613 | 224.873 | 43 | 24.5764 | 1.1705 | 0.0323 |
| 1994 | 894.766 | 1865 | 231.643 | 44 | 26.4614 | 1.4306 | 0.0308 |
| 1995 | 1208.577 | 2366 | 246.588 | 42 | 22.3982 | 1.5391 | 0.0290 |
| 1996 | 1233.106 | 2343 | 278.016 | 45 | 21.7797 | 1.3625 | 0.0291 |
| 1997 | 1693.734 | 2505 | 328.403 | 46 | 24.4094 | 1.4602 | 0.0287 |
| 1998 | 1591.848 | 2873 | 356.785 | 42 | 21.4118 | 1.4364 | 0.0280 |
| 1999 | 1651.457 | 3066 | 382.112 | 39 | 20.6881 | 1.3709 | 0.0279 |
| 2000 | 1507.199 | 2235 | 250.746 | 40 | 18.7962 | 1.1798 | 0.0305 |
| 2001 | 1392.361 | 1376 | 118.901 | 34 | 14.0899 | 0.8736 | 0.0351 |
| 2002 | 1329.946 | 1464 | 106.843 | 37 | 11.8033 | 0.7157 | 0.0343 |
| 2003 | 1351.687 | 1428 | 114.389 | 39 | 13.7771 | 0.6920 | 0.0350 |
| 2004 | 1492.255 | 1028 | 67.395 | 41 | 10.9097 | 0.5067 | 0.0382 |
| 2005 | 1202.739 | 1292 | 75.762 | 35 | 11.1472 | 0.4627 | 0.0353 |
| 2006 | 1069.111 | 795 | 63.499 | 27 | 12.5966 | 0.4744 | 0.0420 |
| 2007 | 875.503 | 397 | 31.023 | 16 | 11.4186 | 0.4903 | 0.0554 |
| 2008 | 980.268 | 559 | 48.896 | 17 | 15.1211 | 0.6017 | 0.0495 |
| 2009 | 774.735 | 421 | 39.817 | 15 | 15.9787 | 0.5314 | 0.0558 |
| 2010 | 905.925 | 636 | 72.524 | 15 | 17.9099 | 0.7021 | 0.0476 |
| 2011 | 1081.607 | 576 | 54.275 | 14 | 17.1346 | 0.6080 | 0.0486 |
| 2012 | 1024.601 | 577 | 58.242 | 15 | 19.5964 | 0.7401 | 0.0490 |

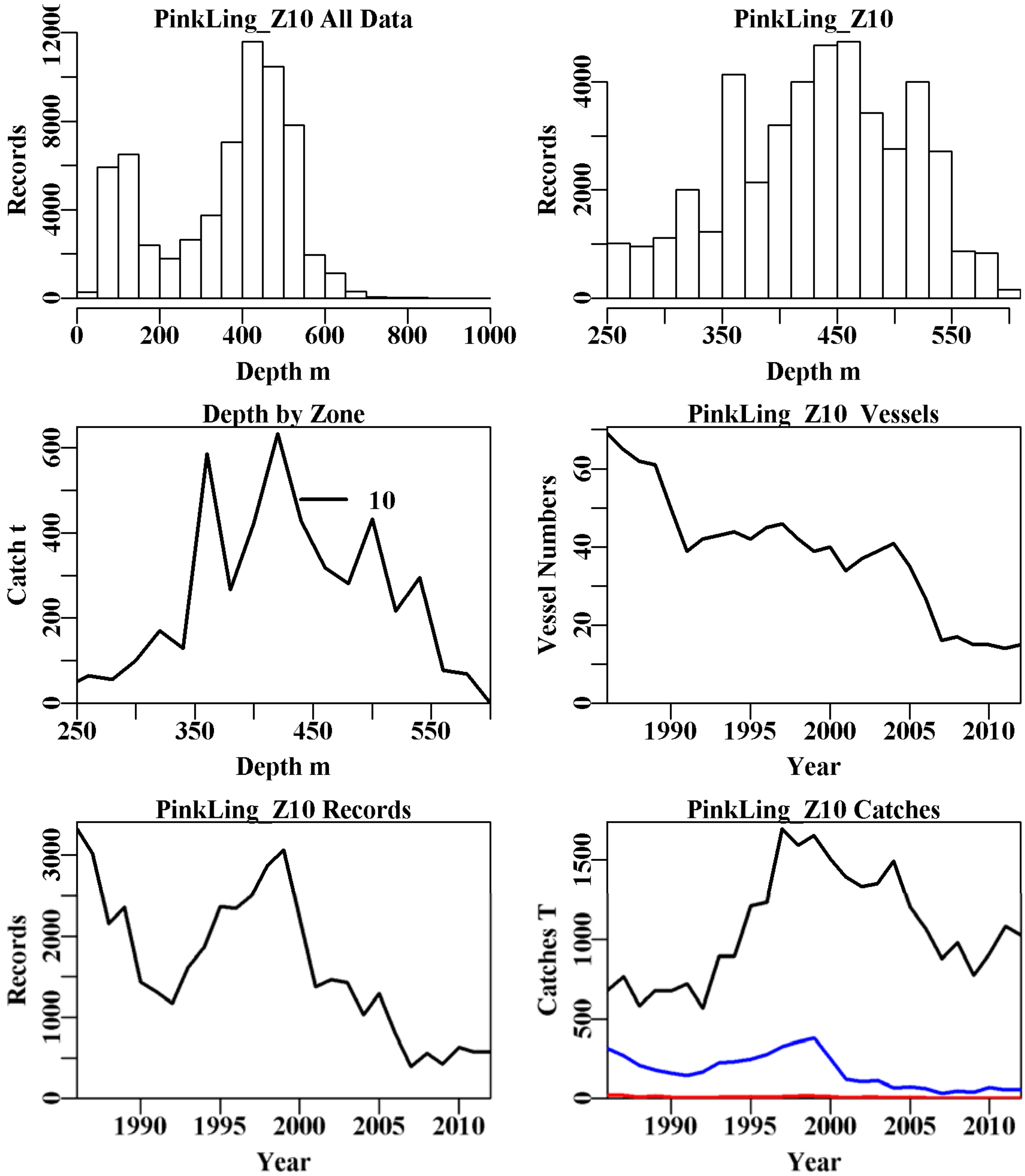



Figure 18.101. Pink Ling from zone 10 in depths between 250 – 600m by trawl. The top left is the depth distribution of all records reporting Pink Ling from zone 10 taken in the SET down to 1000m, the top right graph depicts the depth distribution of shots containing Pink Ling from zone 10 in depths between 250 – 600m by trawl. The middle left diagram depicts the distribution of catch by depth within zone 10, the middle right hand graph depicts the number of vessels reporting Pink Ling catches through time. The bottom left reflects the number of records used in analysis, and bottom right is the Pink Ling catches (top line, black is total catches, all zones, all methods, the middle line, blue, are those used in the analysis, and bottom, red, are catches < 30Kg).

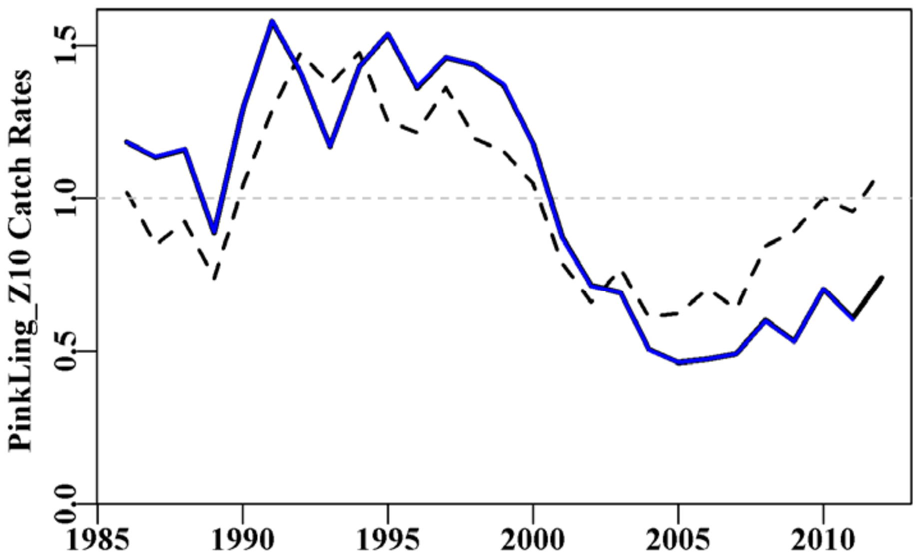



Figure 18.102. Pink Ling from zone 10 in depths between 250 – 600m by trawl. The dashed black line represents the geometric mean catch rate and the solid black line the standardized catch rates. The graph standardizes catch rates relative to the mean of the standardized catch rates; giving a mean for the series of 1.0.

Table 18.89. Pink Ling from zone 10 in depths between 250 – 600m 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+ Vessel:Month |
| Model 7 | LnCE~Year+Vessel +DepCat +Month +DayNight+ Month:DepCat |

Table 18.90. Pink Ling from zone 10 in depths between 250 – 600m by trawl. Model selection criteria, including the AIC, the adjusted $r^2$ and the change in adjusted $r^2$. The optimum is Vessel:Month (model 6).

| | Year | Vessel | DepCat | Month | DayNight | **Vessel:Month** | Month:DepCat |
|---|---|---|---|---|---|---|---|
| AIC | 19419 | 6644 | 2705 | -525 | -549 | **-1351** | -1184 |
| RSS | 68494 | 51000 | 46387 | 43080 | 43050 | **39630** | 42053 |
| MSS | 2808 | 20303 | 24916 | 28223 | 28253 | **31673** | 29250 |
| Nobs | 44192 | 44192 | 43966 | 43966 | 43966 | **43966** | 43966 |
| Npars | 27 | 156 | 174 | 185 | 188 | **1607** | 386 |
| adj_r2 | 3.882 | 28.222 | 34.686 | 39.328 | 39.366 | **42.312** | 40.501 |
| %Change | 0.000 | 24.340 | 6.464 | 4.642 | 0.037 | **2.947** | -1.811 |

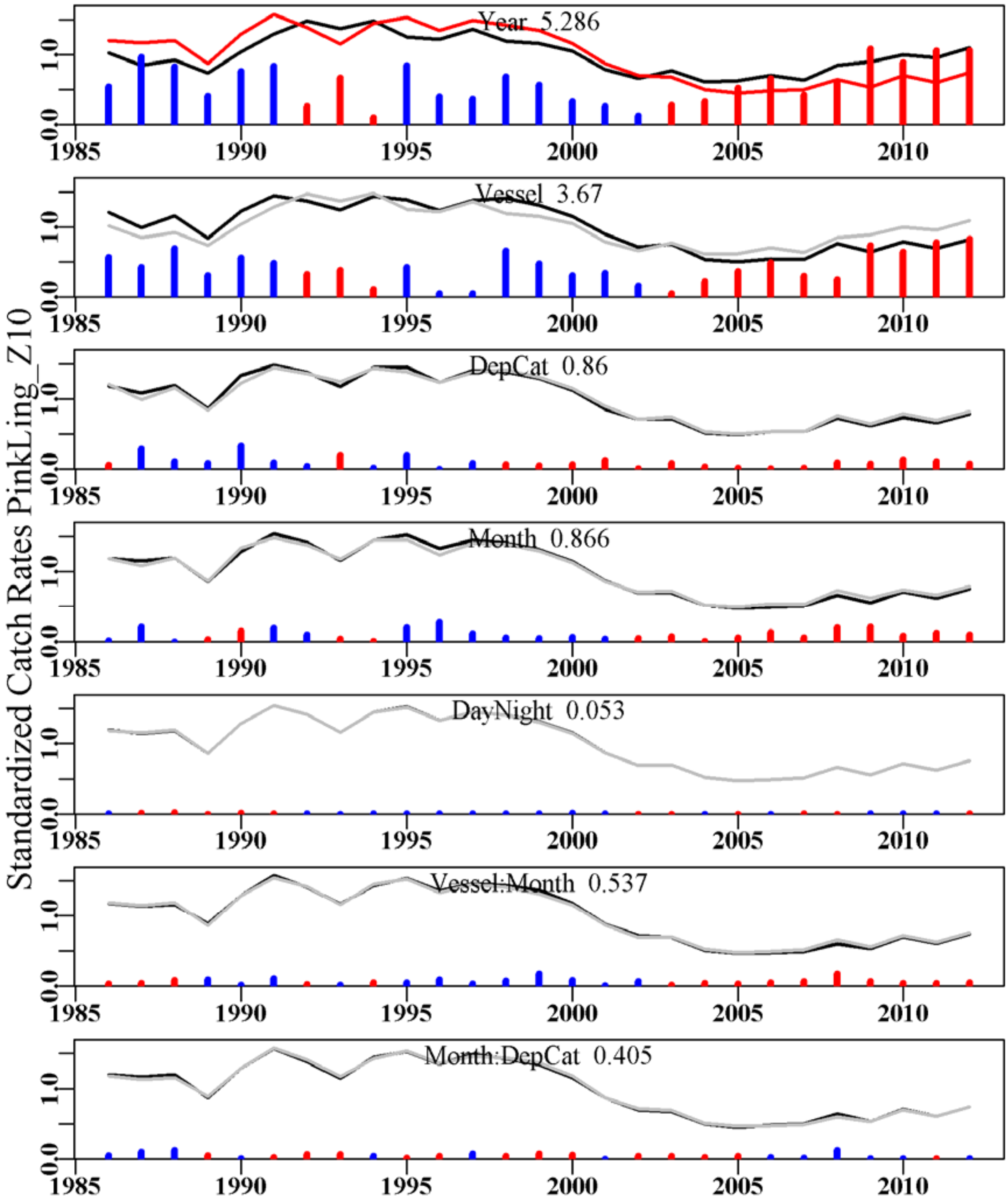



Figure 18.103. The relative influence of each factor used on the final trend in the optimal standardization for Pink Ling in Zone 10. The top graph depicts the geometric mean (the black line) and the optimum model (the red line). The difference between them is illustrated by the vertical bars with blue 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 for Vessel has the geometric mean (grey line) and the effect of adding Year + Vessel (model 2). In the third graph, for DepCat, the grey line represents model 2 and the black line the effect of adding DepCat 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.

### *18.4.31 Pink Ling, Z20 (LIG – 37228002 – G. blacodes)*

Data from zone 20, depths greater than 250 m and less or equal to 600 m.

Table 18.91. Pink Ling from zone 20 in depths between 250 – 600m by trawl. Total Catch is the total Pink Ling catch from all zones reported in the database, Records is the number of records used in the analysis, CatchT is the reported catch in the area and depth used in this analysis, and Vessels relates to all vessels used in the analysis. Geomean is the unstandardized geometric mean of catch rates (kg/hr).Mth:DepCat is the optimum model and StDev is the standard deviation relating to the data in the optimum model.

| Year | TotCatch | Records | CatchT | Vessels | GeoMean | Mth:DepCat | StDev |
|---|---|---|---|---|---|---|---|
| 1986 | 678.801 | 1173 | 182.189 | 38 | 29.2240 | 1.0127 | 0.0000 |
| 1987 | 764.910 | 1207 | 219.162 | 37 | 36.1063 | 1.4593 | 0.0431 |
| 1988 | 582.895 | 1409 | 187.752 | 39 | 27.1962 | 0.9889 | 0.0422 |
| 1989 | 677.150 | 1462 | 236.224 | 34 | 34.1990 | 1.0640 | 0.0420 |
| 1990 | 673.624 | 1253 | 247.526 | 33 | 40.5063 | 1.2793 | 0.0453 |
| 1991 | 719.965 | 1243 | 196.325 | 31 | 32.4251 | 1.0350 | 0.0461 |
| 1992 | 567.627 | 1112 | 151.017 | 25 | 25.4253 | 0.8514 | 0.0472 |
| 1993 | 891.448 | 1585 | 258.998 | 25 | 27.3764 | 0.8885 | 0.0444 |
| 1994 | 894.766 | 1713 | 210.108 | 24 | 22.5143 | 0.7882 | 0.0437 |
| 1995 | 1208.577 | 1584 | 303.948 | 24 | 33.0905 | 1.2646 | 0.0441 |
| 1996 | 1233.106 | 1544 | 353.759 | 26 | 41.1747 | 1.4004 | 0.0446 |
| 1997 | 1693.734 | 1860 | 358.577 | 28 | 36.3858 | 1.3060 | 0.0442 |
| 1998 | 1591.848 | 1870 | 355.885 | 23 | 35.8703 | 1.3513 | 0.0440 |
| 1999 | 1651.457 | 2421 | 409.166 | 26 | 34.3684 | 1.2096 | 0.0428 |
| 2000 | 1507.199 | 2493 | 375.436 | 32 | 27.0471 | 1.0389 | 0.0426 |
| 2001 | 1392.361 | 2427 | 304.034 | 24 | 23.7631 | 0.8141 | 0.0430 |
| 2002 | 1329.946 | 1934 | 218.025 | 24 | 20.1429 | 0.7759 | 0.0445 |
| 2003 | 1351.687 | 2473 | 301.477 | 30 | 22.0973 | 0.8268 | 0.0431 |
| 2004 | 1492.255 | 1954 | 253.007 | 25 | 22.4000 | 0.8540 | 0.0450 |
| 2005 | 1202.739 | 1768 | 212.464 | 24 | 20.8376 | 0.7847 | 0.0455 |
| 2006 | 1069.111 | 1542 | 228.071 | 20 | 27.6927 | 0.9660 | 0.0459 |
| 2007 | 875.503 | 1025 | 141.086 | 12 | 24.5067 | 0.8052 | 0.0494 |
| 2008 | 980.268 | 1458 | 235.294 | 13 | 30.6898 | 0.9527 | 0.0466 |
| 2009 | 774.735 | 1291 | 156.773 | 16 | 20.0214 | 0.6689 | 0.0475 |
| 2010 | 905.925 | 1175 | 182.205 | 13 | 22.6841 | 0.7740 | 0.0489 |
| 2011 | 1081.607 | 1363 | 212.576 | 13 | 27.4133 | 0.9032 | 0.0477 |
| 2012 | 1024.601 | 1104 | 181.406 | 14 | 28.3891 | 0.9363 | 0.0495 |

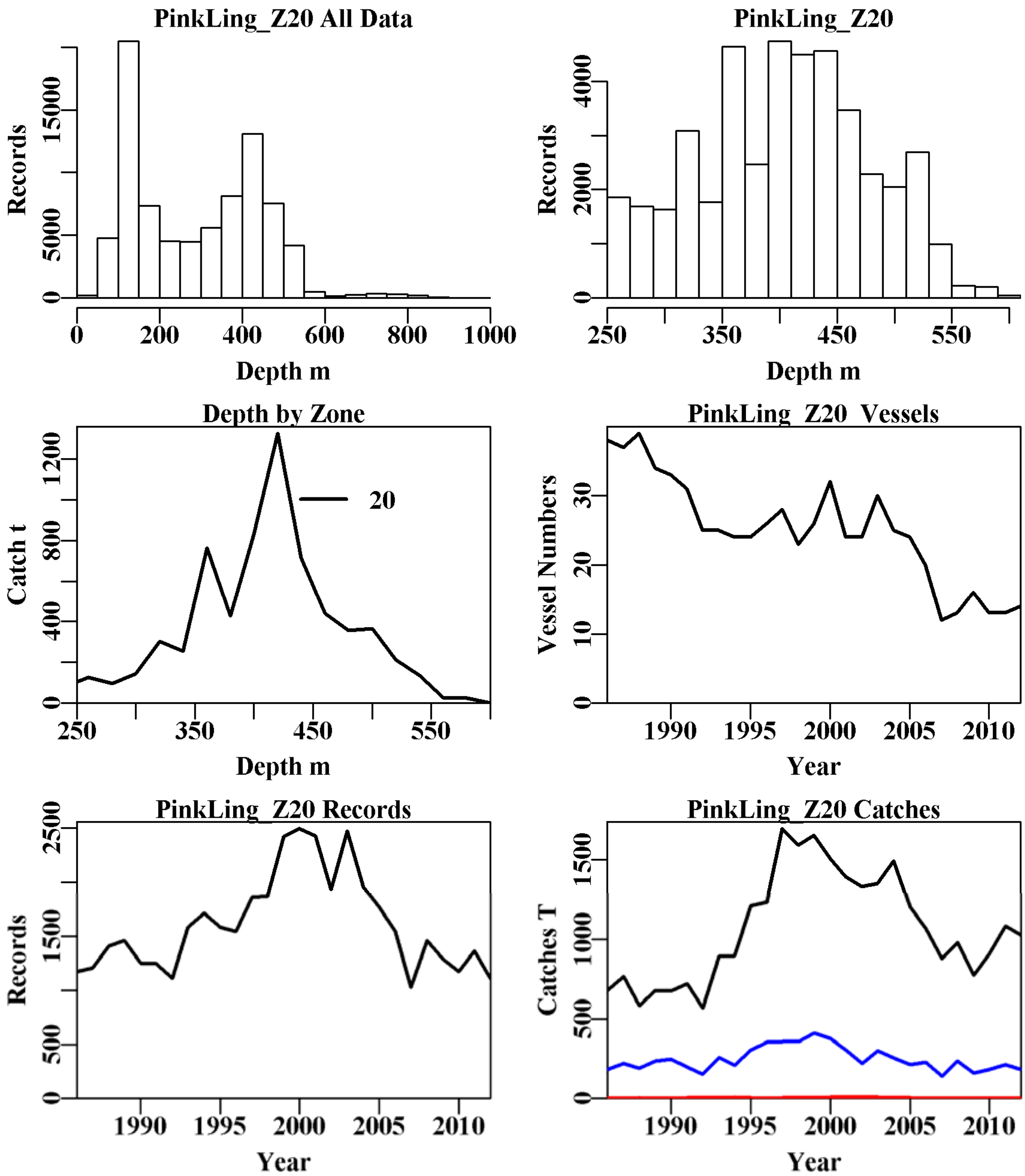



Figure 18.104. Pink Ling from zone 20 in depths between 250 – 600m by trawl. The top left is the depth distribution of all records reporting Pink Ling from zone 20 taken in the SET down to 1000m, the top right graph depicts the depth distribution of shots containing Pink Ling from zone 20 in depths between 250 – 600m by trawl. The middle left diagram depicts the distribution of catch by depth within zone 20, the middle right hand graph depicts the number of vessels reporting Pink Ling catches through time. The bottom left reflects the number of records used in analysis, and bottom right is the Pink Ling catches (top line, black is total catches, all zones, all methods, the middle line, blue, are those used in the analysis, and bottom, red, are catches < 30Kg).

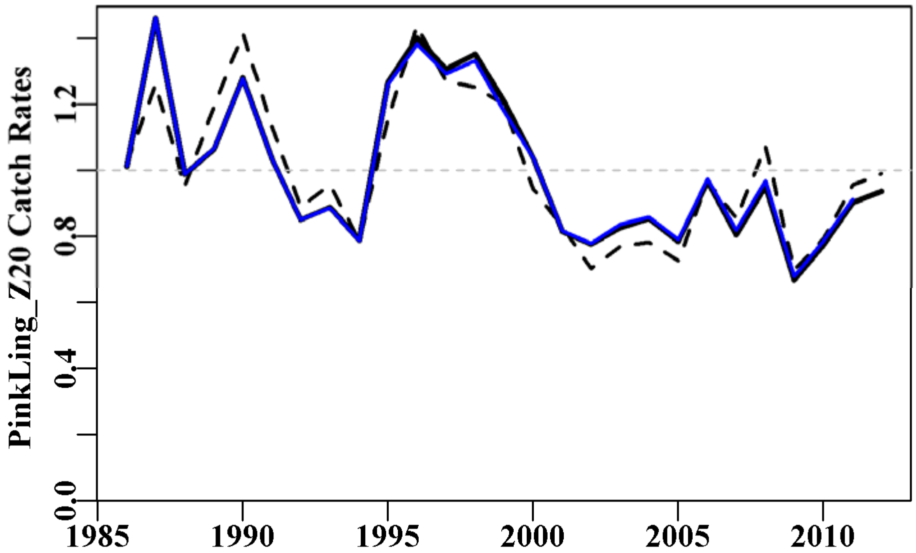



Figure 18.105. Pink Ling from zone 20 in depths between 250 – 600m by trawl. The dashed black line represents the geometric mean catch rate and the solid black line the standardized catch rates. The graph standardizes catch rates relative to the mean of the standardized catch rates; giving a mean for the series of 1.0.

Table 18.92. Pink Ling from zone 20 in depths between 250 – 600m 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+ Vessel:Month |
| Model 7 | LnCE~Year+Vessel +DepCat +Month +DayNight+ Month:DepCat |

Table 18.93. Pink Ling from zone 20 in depths between 250 – 600m by trawl. Model selection criteria, including the AIC, the adjusted $r^2$ and the change in adjusted $r^2$. The optimum is Month:DepCat (model 7).

| | Year | Vessel | DepCat | Month | DayNight | Vessel:Month | **Month:DepCat** |
|---|---|---|---|---|---|---|---|
| AIC | 8082 | -818 | -2150 | -3339 | -3432 | -3461 | **-3711** |
| RSS | 52261 | 42002 | 40486 | 39358 | 39268 | 36843 | **38655** |
| MSS | 1942 | 12201 | 13718 | 14845 | 14936 | 17361 | **15549** |
| Nobs | 43443 | 42901 | 42901 | 42901 | 42901 | 42901 | **42901** |
| Npars | 27 | 45 | 167 | 179 | 182 | 1535 | **380** |
| adj_r2 | 3.526 | 22.431 | 25.018 | 27.085 | 27.248 | 29.508 | **28.050** |
| %Change | 0.000 | 18.905 | 2.587 | 2.067 | 0.163 | 2.260 | **-1.457** |

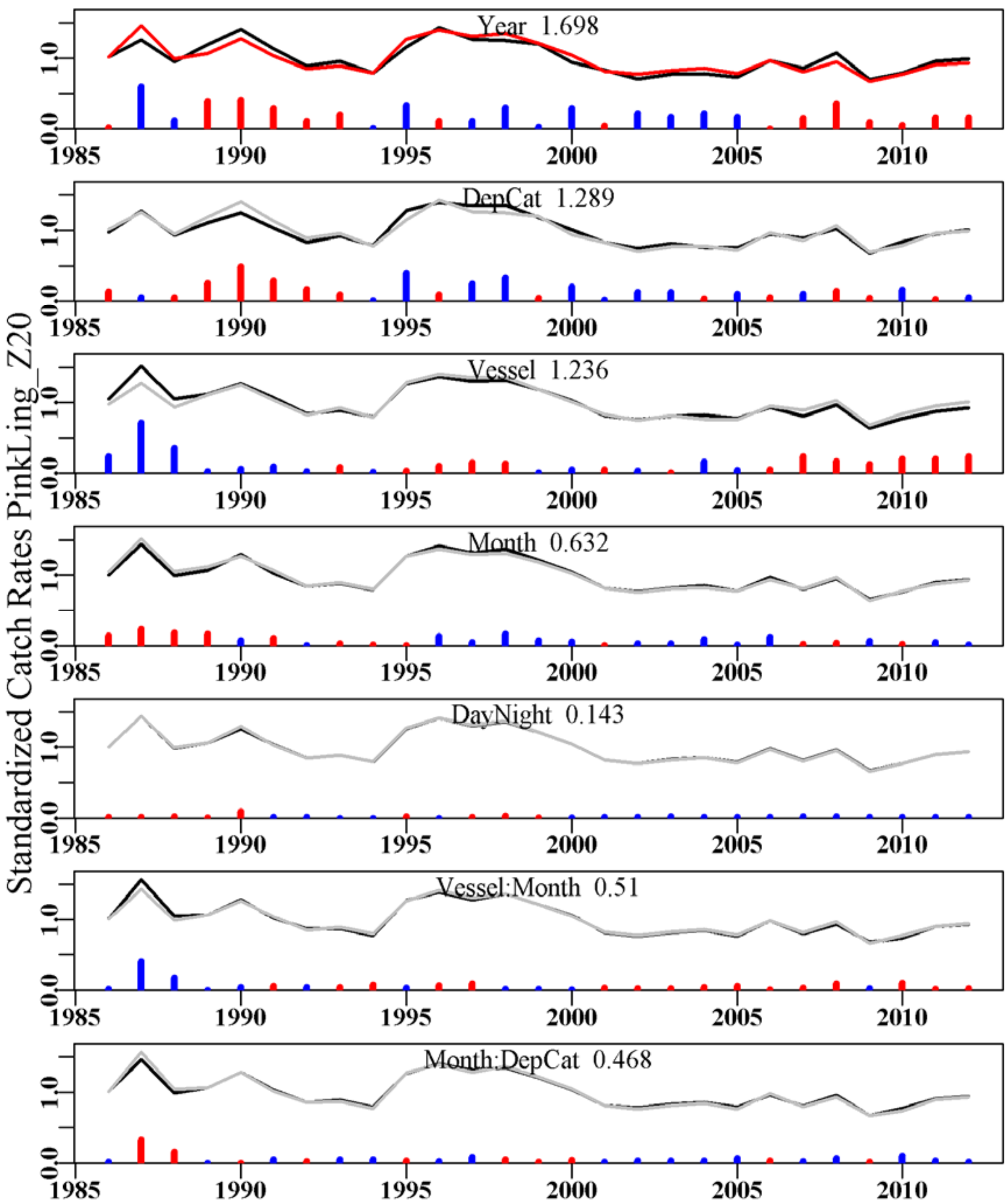



Figure 18.106. The relative influence of each factor used on the final trend in the optimal standardization for Pink Ling in Zone 20. The top graph depicts the geometric mean (the black line) and the optimum model (the red line). The difference between them is illustrated by the vertical bars with blue 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 for Vessel has the geometric mean (grey line) and the effect of adding Year + Vessel (model 2). In the third graph, for DepCat, the grey line represents model 2 and the black line the effect of adding DepCat 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.

### *18.4.32 Pink Ling, Z30 (LIG – 37228002 – G. blacodes)*

Data from zone 30, depths greater than 250 m and less or equal to 600 m.

Table 18.94. Pink Ling from zone 30 in depths between 250 – 600m by trawl. Total Catch is the total Pink Ling catch from all zones reported in the database, Records is the number of records used in the analysis, CatchT is the reported catch in the area and depth used in this analysis, and Vessels relates to all vessels used in the analysis. Geomean is the unstandardized geometric mean of catch rates (kg/hr). DayNight is the optimum model and StDev is the standard deviation relating to the data in the optimum model.

| Year | TotCatch | Records | CatchT | Vessels | GeoMean | DayNight | StDev |
|---|---|---|---|---|---|---|---|
| 1986 | 678.801 | 15 | 1.896 | 3 | 22.1580 | 2.0133 | 0.0000 |
| 1987 | 764.910 | 36 | 2.245 | 5 | 16.8408 | 1.0347 | 0.2888 |
| 1988 | 582.895 | 50 | 4.378 | 4 | 28.4036 | 2.1886 | 0.2768 |
| 1989 | 677.150 | 61 | 7.988 | 11 | 31.1539 | 1.3795 | 0.2730 |
| 1990 | 673.624 | 105 | 8.385 | 17 | 27.9919 | 1.5107 | 0.2518 |
| 1991 | 719.965 | 376 | 28.950 | 27 | 20.7784 | 0.9696 | 0.2409 |
| 1992 | 567.627 | 134 | 5.806 | 14 | 12.0005 | 0.5688 | 0.2463 |
| 1993 | 891.448 | 327 | 20.603 | 17 | 19.9815 | 0.9597 | 0.2381 |
| 1994 | 894.766 | 488 | 28.514 | 22 | 17.4518 | 0.7857 | 0.2360 |
| 1995 | 1208.577 | 411 | 36.150 | 17 | 22.4107 | 1.0328 | 0.2367 |
| 1996 | 1233.106 | 381 | 35.808 | 18 | 23.9592 | 1.1065 | 0.2372 |
| 1997 | 1693.734 | 443 | 45.674 | 17 | 19.7673 | 0.9230 | 0.2376 |
| 1998 | 1591.848 | 166 | 17.788 | 16 | 20.3063 | 0.9330 | 0.2424 |
| 1999 | 1651.457 | 477 | 41.377 | 15 | 18.8073 | 0.9816 | 0.2368 |
| 2000 | 1507.199 | 385 | 34.098 | 19 | 18.3481 | 0.8837 | 0.2364 |
| 2001 | 1392.361 | 741 | 61.087 | 19 | 16.2336 | 0.7975 | 0.2330 |
| 2002 | 1329.946 | 500 | 35.598 | 17 | 14.9854 | 0.7724 | 0.2347 |
| 2003 | 1351.687 | 408 | 29.893 | 19 | 15.6988 | 0.7402 | 0.2365 |
| 2004 | 1492.255 | 377 | 26.968 | 14 | 12.2641 | 0.6305 | 0.2364 |
| 2005 | 1202.739 | 394 | 41.743 | 14 | 19.1660 | 0.8846 | 0.2373 |
| 2006 | 1069.111 | 256 | 31.531 | 11 | 22.6012 | 0.8686 | 0.2402 |
| 2007 | 875.503 | 230 | 32.198 | 8 | 25.4173 | 1.0663 | 0.2407 |
| 2008 | 980.268 | 365 | 44.846 | 8 | 24.7573 | 1.0032 | 0.2388 |
| 2009 | 774.735 | 235 | 15.772 | 10 | 14.2097 | 0.5898 | 0.2409 |
| 2010 | 905.925 | 179 | 16.392 | 8 | 19.2029 | 0.7405 | 0.2427 |
| 2011 | 1081.607 | 262 | 28.045 | 7 | 20.6001 | 0.8384 | 0.2396 |
| 2012 | 1024.601 | 291 | 33.675 | 8 | 20.9485 | 0.7969 | 0.2397 |

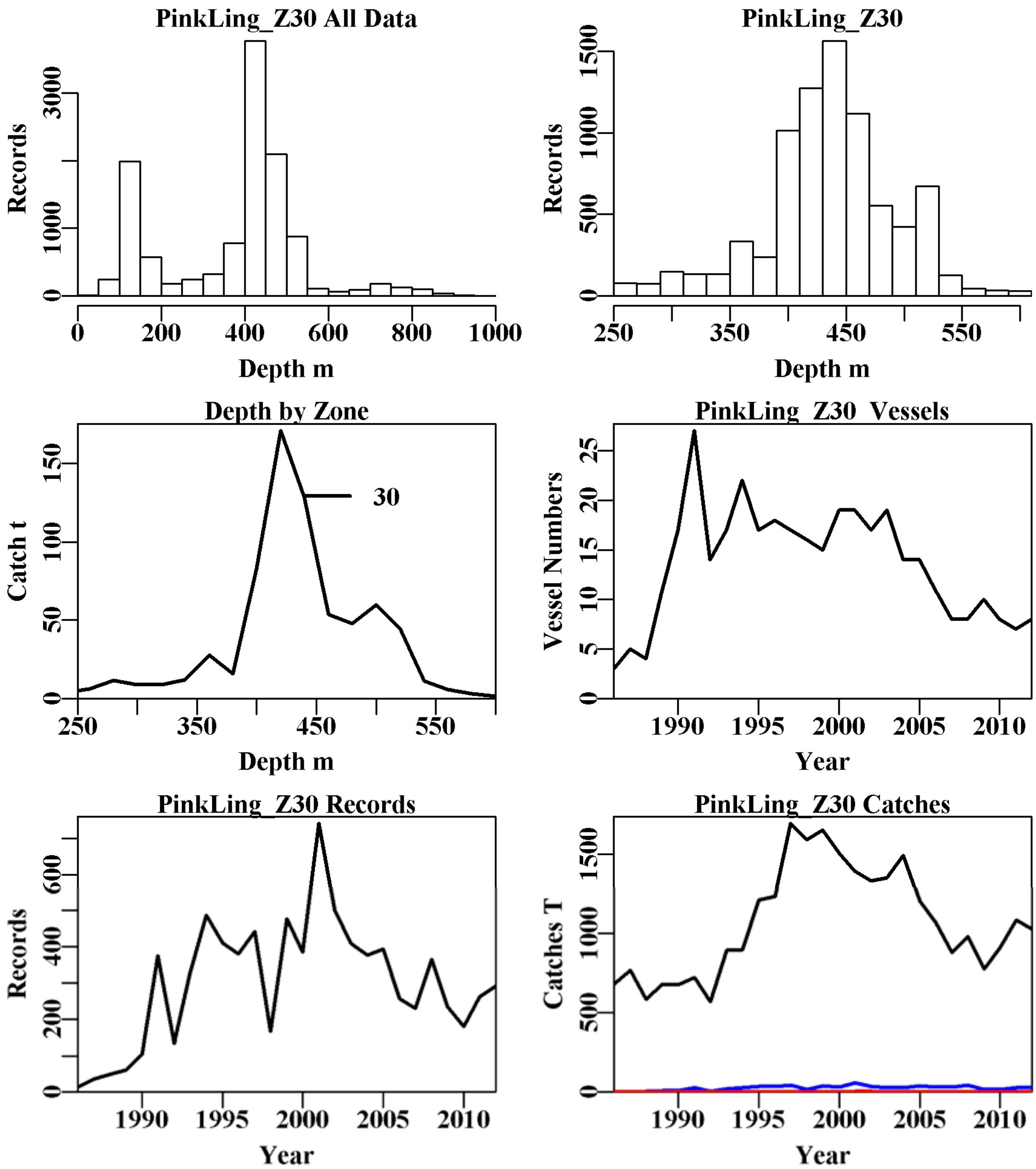



Figure 18.107. Pink Ling from zone 30 in depths between 250 – 600m by trawl. The top left is the depth distribution of all records reporting Pink Ling from zone 30 taken in the SET down to 1000m, the top right graph depicts the depth distribution of shots containing Pink Ling from zone 30 in depths between 250 – 600m by trawl. The middle left diagram depicts the distribution of catch by depth within zone 30, the middle right hand graph depicts the number of vessels reporting Pink Ling catches through time. The bottom left reflects the number of records used in analysis, and bottom right is the Pink Ling catches (top line, black is total catches, all zones, all methods, the middle line, blue, are those used in the analysis, and bottom, red, are catches < 30Kg).

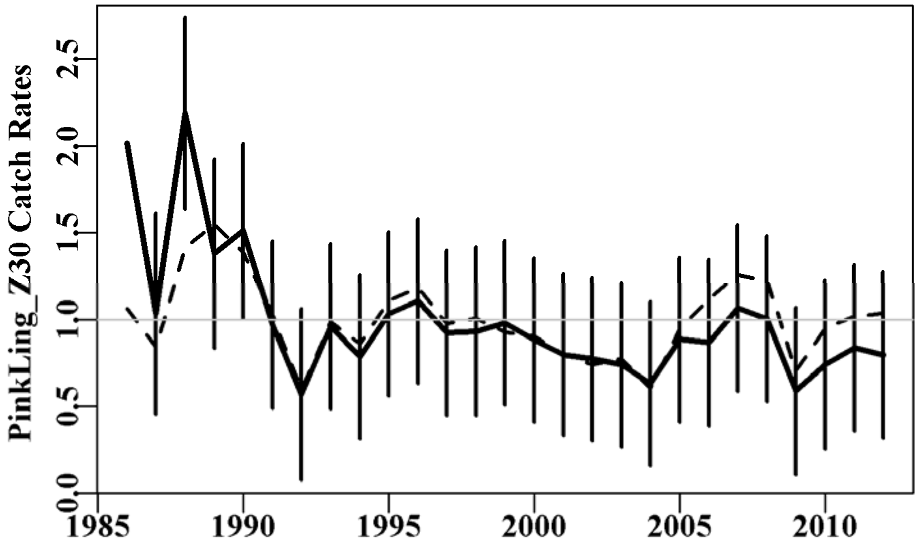



Figure 18.108. Pink Ling from zone 30 in depths between 250 – 600m by trawl. The dashed black line represents the geometric mean catch rate and the solid black line the standardized catch rates. The graph standardizes catch rates relative to the mean of the standardized catch rates; giving a mean for the series of 1.0. The confidence intervals are wider due to the relatively low number of records.

Table 18.95. Pink Ling from zone 30 in depths between 250 – 600m 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+ Vessel:Month |
| Model 7 | LnCE~Year+Vessel +DepCat +Month +DayNight+ Month:DepCat |

Table 18.96. Pink Ling from zone 30 in depths between 250 – 600m by trawl. Model selection criteria, including the AIC, the adjusted $r^2$ and the change in adjusted $r^2$. The optimum is DayNight (model 5).

| | Year | Vessel | DepCat | Month | **DayNight** | Vessel:Month | Month:DepCat |
|---|---|---|---|---|---|---|---|
| AIC | -1159 | -1817 | -2229 | -2295 | **-2357** | -1540 | -2277 |
| RSS | 6967 | 6304 | 5873 | 5809 | **5760** | 5189 | 5536 |
| MSS | 319 | 981 | 1413 | 1477 | **1526** | 2096 | 1749 |
| Nobs | 8093 | 8093 | 7997 | 7997 | **7997** | 7997 | 7997 |
| Npars | 27 | 102 | 120 | 131 | **134** | 959 | 332 |
| adj_r2 | 4.069 | 12.378 | 18.172 | 18.955 | **19.610** | 19.079 | 20.731 |
| %Change | 0.000 | 8.309 | 5.794 | 0.783 | **0.655** | -0.530 | 1.652 |

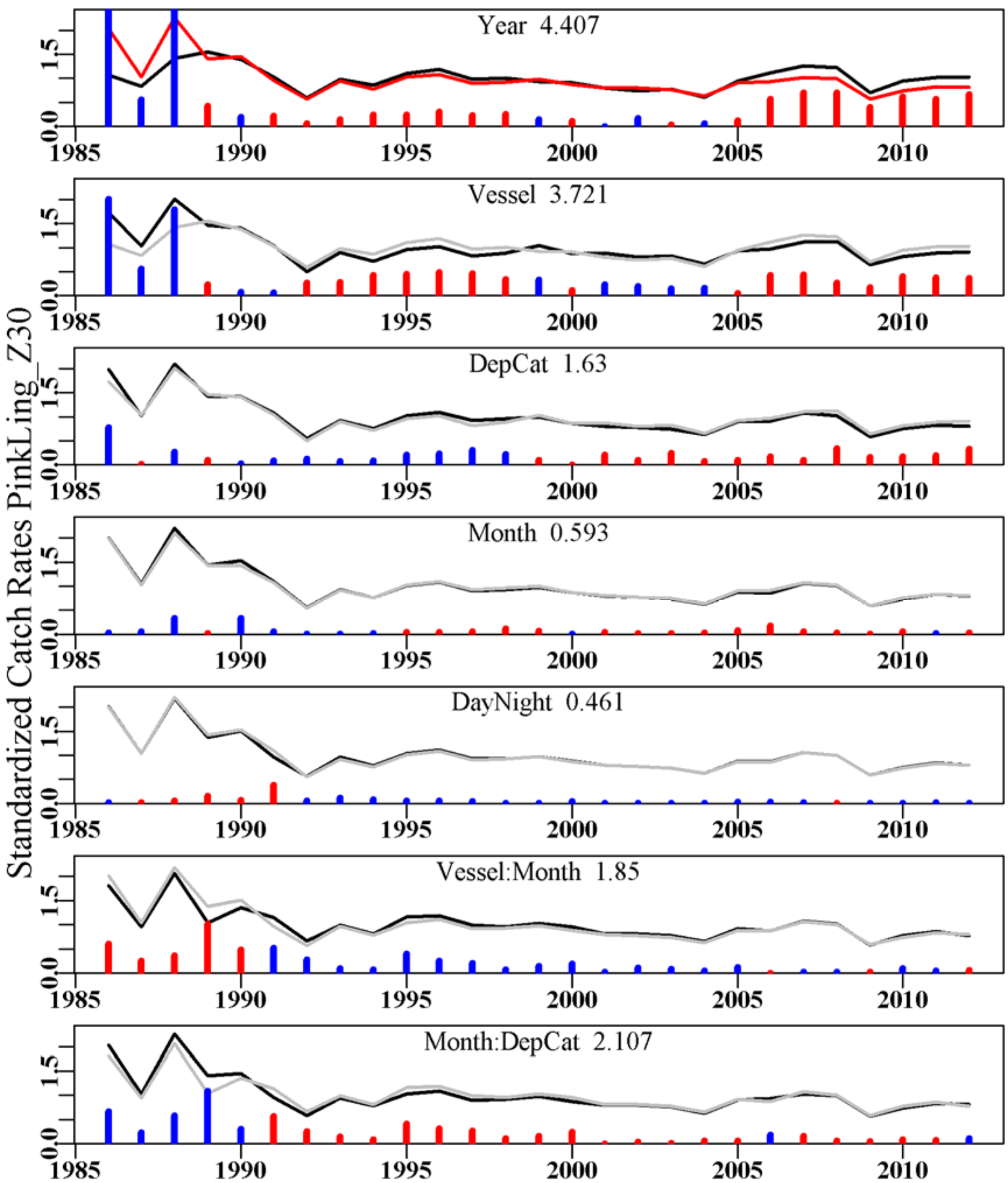



Figure 18.109. The relative influence of each factor used on the final trend in the optimal standardization for Pink Ling in Zone 30. The top graph depicts the geometric mean (the black line) and the optimum model (the red line). The difference between them is illustrated by the vertical bars with blue 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 for Vessel has the geometric mean (grey line) and the effect of adding Year + Vessel (model 2). In the third graph, for DepCat, the grey line represents model 2 and the black line the effect of adding DepCat 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.

### *18.4.33 Pink Ling, Z40 (LIG – 37228002 – G. blacodes)*

Data from zone 40, depths greater than 350 m and less or equal to 800 m.

Table 18.97. Pink Ling from zone 40 in depths between 350 – 800m by trawl. Total Catch is the total Pink Ling catch from all zones reported in the database, Records is the number of records used in the analysis, CatchT is the reported catch in the area and depth used in this analysis, and Vessels relates to all vessels used in the analysis. Geomean is the unstandardized geometric mean of catch rates (kg/hr). Mth:DepCat is the optimum model and StDev is the standard deviation relating to the data in the optimum model.

| Year | TotCatch | Records | CatchT | Vessels | GeoMean | Mth:DepCat | StDev |
|---|---|---|---|---|---|---|---|
| 1986 | 678.801 | 340 | 50.622 | 12 | 24.8664 | 1.1499 | 0.0000 |
| 1987 | 764.910 | 464 | 149.303 | 17 | 61.5525 | 1.7200 | 0.0811 |
| 1988 | 582.895 | 323 | 52.147 | 20 | 26.7665 | 0.9310 | 0.0852 |
| 1989 | 677.150 | 727 | 134.342 | 20 | 31.2668 | 0.9870 | 0.0783 |
| 1990 | 673.624 | 543 | 92.429 | 22 | 29.7271 | 0.9310 | 0.0784 |
| 1991 | 719.965 | 597 | 97.883 | 29 | 23.7829 | 0.8730 | 0.0770 |
| 1992 | 567.627 | 483 | 39.702 | 17 | 14.1316 | 0.5946 | 0.0799 |
| 1993 | 891.448 | 841 | 118.853 | 19 | 20.2159 | 0.8953 | 0.0755 |
| 1994 | 894.766 | 775 | 133.541 | 21 | 27.0651 | 1.1061 | 0.0756 |
| 1995 | 1208.577 | 1564 | 211.632 | 18 | 20.1818 | 1.0920 | 0.0718 |
| 1996 | 1233.106 | 1205 | 235.651 | 17 | 26.7059 | 1.2174 | 0.0746 |
| 1997 | 1693.734 | 1419 | 340.323 | 16 | 27.8818 | 1.3225 | 0.0734 |
| 1998 | 1591.848 | 1671 | 349.366 | 16 | 26.2074 | 1.2766 | 0.0731 |
| 1999 | 1651.457 | 1628 | 241.419 | 18 | 21.1431 | 0.9797 | 0.0729 |
| 2000 | 1507.199 | 2060 | 338.192 | 24 | 23.8936 | 1.0576 | 0.0724 |
| 2001 | 1392.361 | 2531 | 359.654 | 24 | 20.5368 | 0.9530 | 0.0720 |
| 2002 | 1329.946 | 2290 | 298.182 | 21 | 17.3590 | 0.7591 | 0.0721 |
| 2003 | 1351.687 | 1814 | 251.303 | 22 | 17.1223 | 0.7794 | 0.0729 |
| 2004 | 1492.255 | 1292 | 143.083 | 20 | 14.1120 | 0.6109 | 0.0744 |
| 2005 | 1202.739 | 966 | 114.114 | 18 | 14.2226 | 0.6051 | 0.0757 |
| 2006 | 1069.111 | 826 | 129.898 | 16 | 17.2693 | 0.7498 | 0.0766 |
| 2007 | 875.503 | 1254 | 221.488 | 15 | 20.4467 | 0.8852 | 0.0745 |
| 2008 | 980.268 | 806 | 151.663 | 14 | 24.2630 | 1.2056 | 0.0764 |
| 2009 | 774.735 | 965 | 200.785 | 13 | 24.1352 | 1.1457 | 0.0750 |
| 2010 | 905.925 | 947 | 182.003 | 10 | 22.1986 | 1.0330 | 0.0752 |
| 2011 | 1081.607 | 1168 | 251.898 | 12 | 22.2616 | 0.9763 | 0.0737 |
| 2012 | 1024.601 | 1259 | 276.501 | 13 | 22.6473 | 1.1632 | 0.0743 |

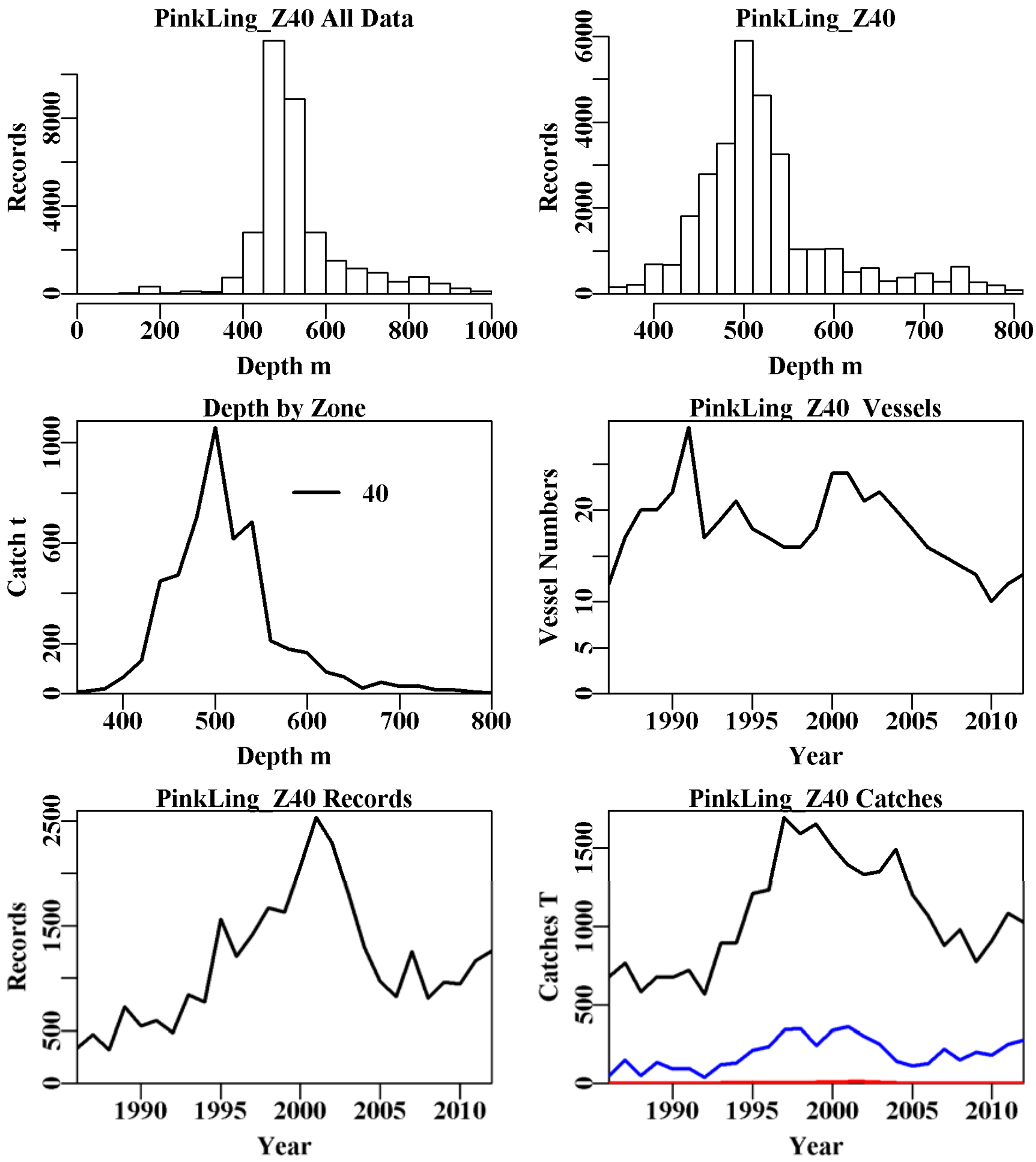



Figure 18.110. Pink Ling from zone 40 in depths between 350 – 800m by trawl. The top left is the depth distribution of all records reporting Pink Ling from zone 40 taken in the SET down to 1000m, the top right graph depicts the depth distribution of shots containing Pink Ling from zone 40 in depths between 350 – 800m by trawl. The middle left diagram depicts the distribution of catch by depth within zone 40, the middle right hand graph depicts the number of vessels reporting Pink Ling catches through time. The bottom left reflects the number of records used in analysis, and bottom right is the Pink Ling catches (top line, black is total catches, all zones, all methods, the middle line, blue, are those used in the analysis, and bottom, red, are catches < 30Kg).

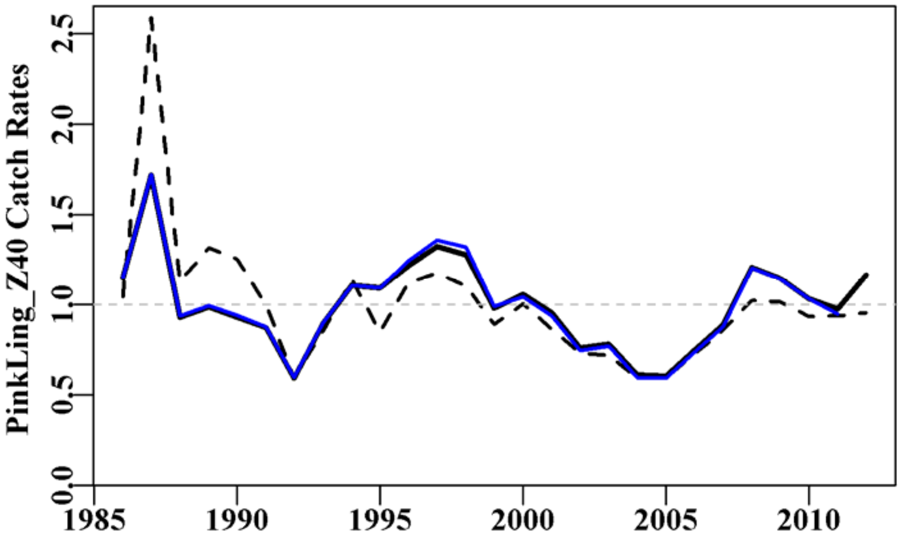



Figure 18.111. Pink Ling from zone 40 in depths between 350 – 800m by trawl. The dashed black line represents the geometric mean catch rate and the solid black line the standardized catch rates. The graph standardizes catch rates relative to the mean of the standardized catch rates; giving a mean for the series of 1.0. The confidence intervals are wider due to the relatively low number of records.

Table 18.98. Pink Ling from zone 40 in depths between 350 – 800m 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+ Vessel:Month |
| Model 7 | LnCE~Year+Vessel +DepCat +Month +DayNight+ Month:DepCat |

Table 18.99. Pink Ling from zone 40 in depths between 350 – 800m by trawl. Model selection criteria, including the AIC, the adjusted $r^2$ and the change in adjusted $r^2$. The optimum is Month:DepCat (model 7).

| | Year | Vessel | DepCat | Month | DayNight | Vessel:Month | **Month:DepCat** |
|---|---|---|---|---|---|---|---|
| AIC | 4132 | 543 | -2052 | -3377 | -3425 | -3177 | **-4715** |
| RSS | 35119 | 30901 | 28357 | 27000 | 26953 | 25573 | **25409** |
| MSS | 1748 | 5965 | 8509 | 9866 | 9914 | 11293 | **11458** |
| Nobs | 30758 | 30455 | 30455 | 30455 | 30455 | 30455 | **30455** |
| Npars | 27 | 50 | 61 | 145 | 148 | 1072 | **401** |
| adj_r2 | 4.660 | 16.046 | 22.929 | 26.415 | 26.536 | 28.105 | **30.162** |
| %Change | 0.000 | 11.386 | 6.883 | 3.485 | 0.122 | 1.569 | **2.057** |

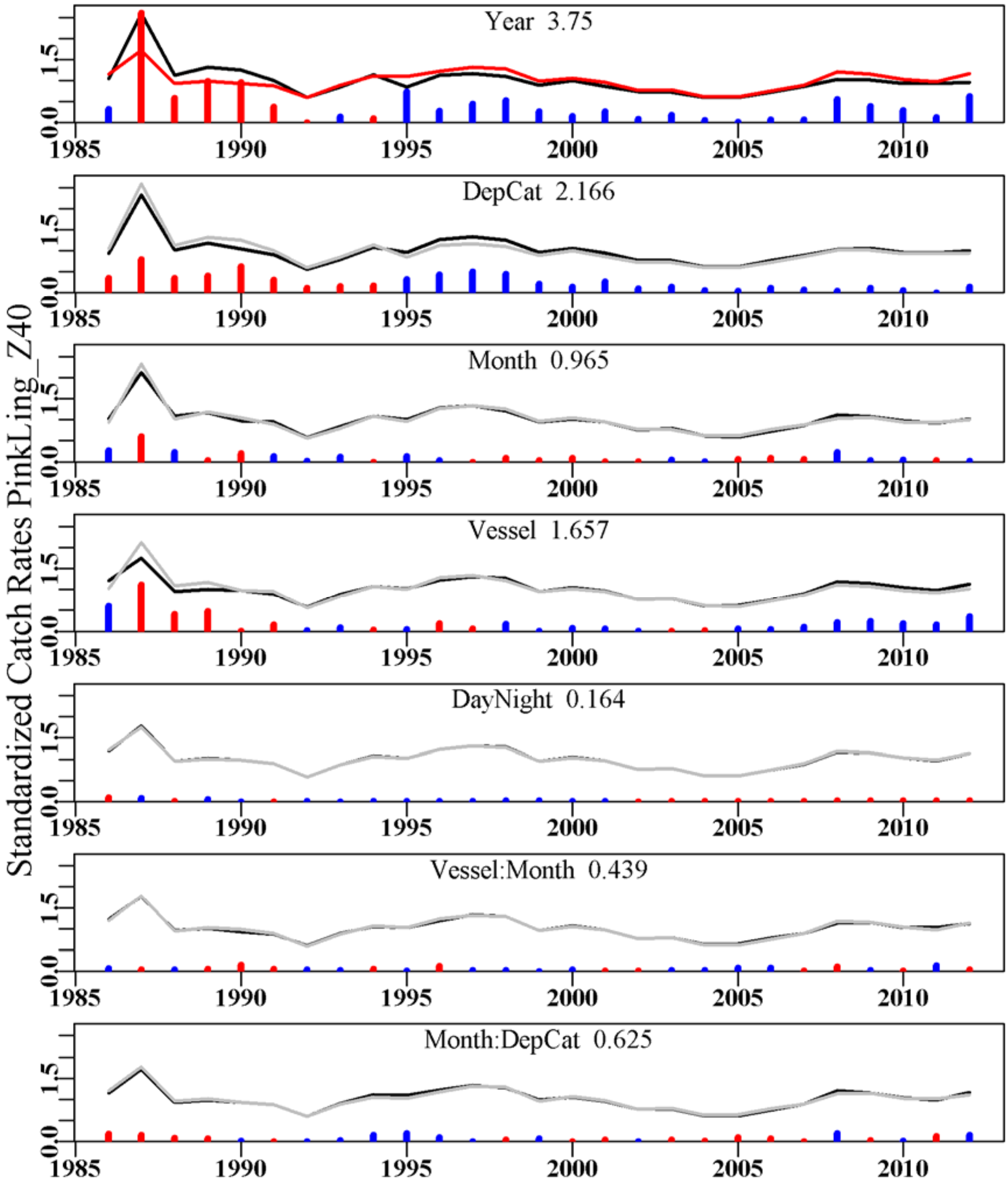



Figure 18.112. The relative influence of each factor used on the final trend in the optimal standardization for Pink Ling in Zone 40. The top graph depicts the geometric mean (the black line) and the optimum model (the red line). The difference between them is illustrated by the vertical bars with blue 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 for Vessel has the geometric mean (grey line) and the effect of adding Year + Vessel (model 2). In the third graph, for DepCat, the grey line represents model 2 and the black line the effect of adding DepCat 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. Note that the influence, which is simply the deviations between the two lines squared, are not always reflective of the adj-r2 for each factor.

### *18.4.34 Pink Ling, Z50 (LIG – 37228002 – G. blacodes)*

Data from zone 50, depths greater than 200 m and less or equal to 800 m.

Table 18.100. Pink Ling from zone 50 in depths between 200 – 800m by trawl. Total Catch is the total Pink Ling catch from all zones reported in the database, Records is the number of records used in the analysis, CatchT is the reported catch in the area and depth used in this analysis, and Vessels relates to all vessels used in the analysis. Geomean is the unstandardized geometric mean of catch rates (kg/hr). Vessel:Mth is the optimum model and StDev is the standard deviation relating to the data in the optimum model.

| Year | TotCatch | Records | CatchT | Vessels | GeoMean | Vessel:Mth | StDev |
|---|---|---|---|---|---|---|---|
| 1986 | 678.801 | 923 | 62.212 | 17 | 14.9346 | 1.1098 | 0.0000 |
| 1987 | 764.910 | 841 | 54.428 | 23 | 14.1775 | 1.1232 | 0.0398 |
| 1988 | 582.895 | 701 | 42.836 | 25 | 14.5280 | 1.1521 | 0.0437 |
| 1989 | 677.150 | 729 | 45.389 | 25 | 15.3818 | 1.1827 | 0.0435 |
| 1990 | 673.624 | 957 | 47.873 | 18 | 11.9104 | 0.9798 | 0.0434 |
| 1991 | 719.965 | 1294 | 100.787 | 20 | 13.8309 | 1.1309 | 0.0409 |
| 1992 | 567.627 | 1150 | 62.462 | 17 | 11.1987 | 0.8849 | 0.0414 |
| 1993 | 891.448 | 1410 | 116.532 | 12 | 15.5287 | 1.1969 | 0.0406 |
| 1994 | 894.766 | 1335 | 114.252 | 14 | 17.5302 | 1.4059 | 0.0402 |
| 1995 | 1208.577 | 1950 | 214.425 | 18 | 19.9408 | 1.5963 | 0.0381 |
| 1996 | 1233.106 | 2197 | 211.853 | 23 | 17.0478 | 1.4723 | 0.0378 |
| 1997 | 1693.734 | 2311 | 236.711 | 21 | 17.8914 | 1.5382 | 0.0376 |
| 1998 | 1591.848 | 2039 | 209.275 | 18 | 19.7137 | 1.5648 | 0.0383 |
| 1999 | 1651.457 | 2159 | 186.384 | 17 | 16.0778 | 1.2605 | 0.0380 |
| 2000 | 1507.199 | 2587 | 170.657 | 19 | 12.1381 | 0.9915 | 0.0376 |
| 2001 | 1392.361 | 2504 | 138.777 | 21 | 10.5409 | 0.8442 | 0.0379 |
| 2002 | 1329.946 | 2318 | 129.610 | 20 | 10.4073 | 0.8205 | 0.0380 |
| 2003 | 1351.687 | 1991 | 108.241 | 20 | 9.6163 | 0.7697 | 0.0384 |
| 2004 | 1492.255 | 2589 | 162.033 | 20 | 10.7076 | 0.7760 | 0.0378 |
| 2005 | 1202.739 | 1689 | 80.704 | 19 | 8.0776 | 0.5891 | 0.0395 |
| 2006 | 1069.111 | 1494 | 79.938 | 17 | 8.1572 | 0.5848 | 0.0404 |
| 2007 | 875.503 | 1270 | 64.909 | 13 | 7.8759 | 0.5731 | 0.0410 |
| 2008 | 980.268 | 987 | 62.435 | 14 | 9.6601 | 0.7242 | 0.0426 |
| 2009 | 774.735 | 1009 | 58.834 | 9 | 8.3008 | 0.6639 | 0.0426 |
| 2010 | 905.925 | 1382 | 89.591 | 12 | 9.1906 | 0.7145 | 0.0408 |
| 2011 | 1081.607 | 1618 | 104.411 | 13 | 9.1288 | 0.6855 | 0.0407 |
| 2012 | 1024.601 | 1079 | 67.990 | 10 | 8.6391 | 0.6647 | 0.0431 |

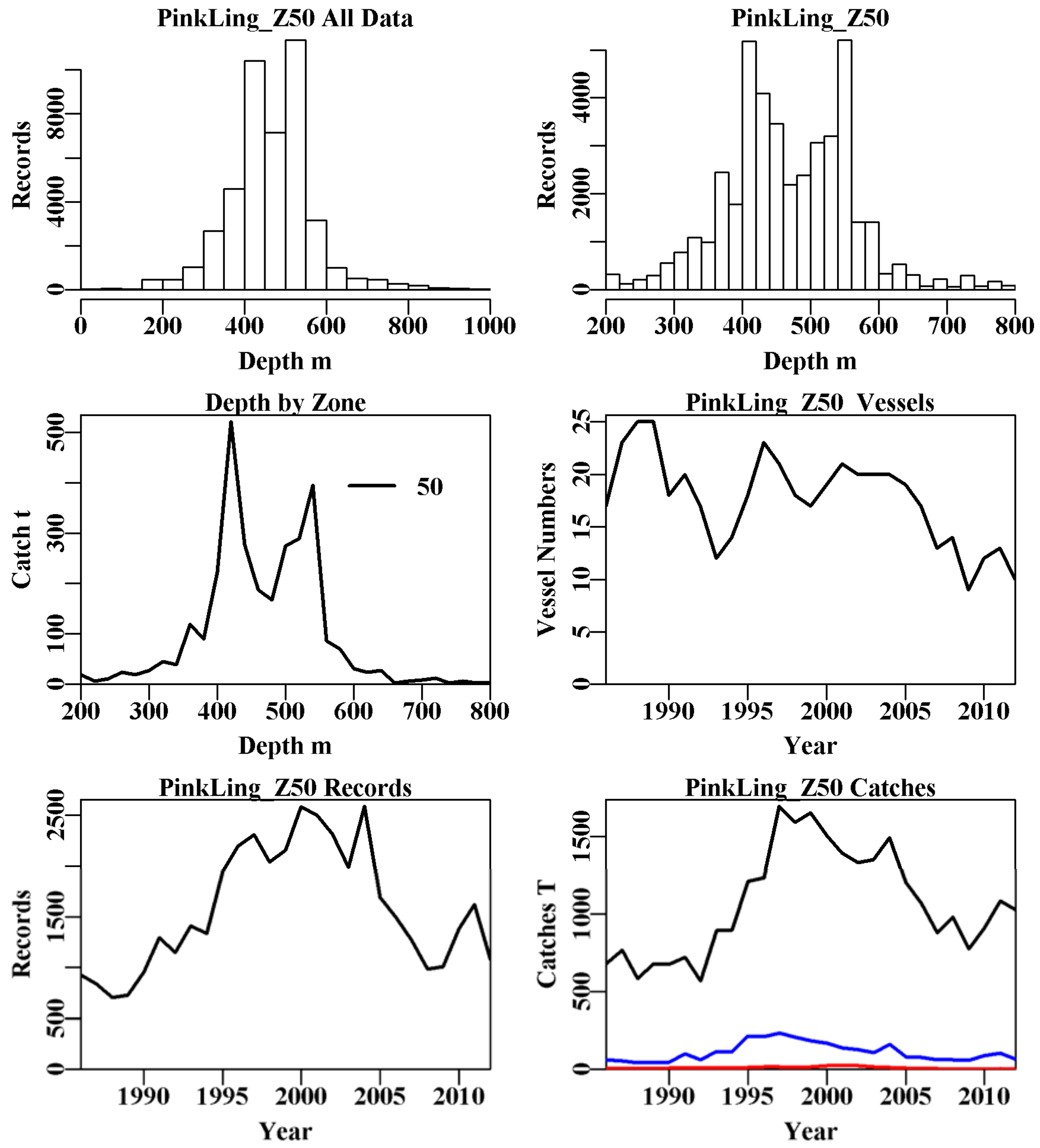



Figure 18.113. Pink Ling from zone 50 in depths between 200 – 800m by trawl. The top left is the depth distribution of all records reporting Pink Ling from zone 50 taken in the SET down to 1000m, the top right graph depicts the depth distribution of shots containing Pink Ling from zone 50 in depths between 200 – 800m by trawl. The middle left diagram depicts the distribution of catch by depth within zone 50, the middle right hand graph depicts the number of vessels reporting Pink Ling catches through time. The bottom left reflects the number of records used in analysis, and bottom right is the Pink Ling catches (top line, black is total catches, all zones, all methods, the middle line, blue, are those used in the analysis, and bottom, red, are catches < 30Kg).

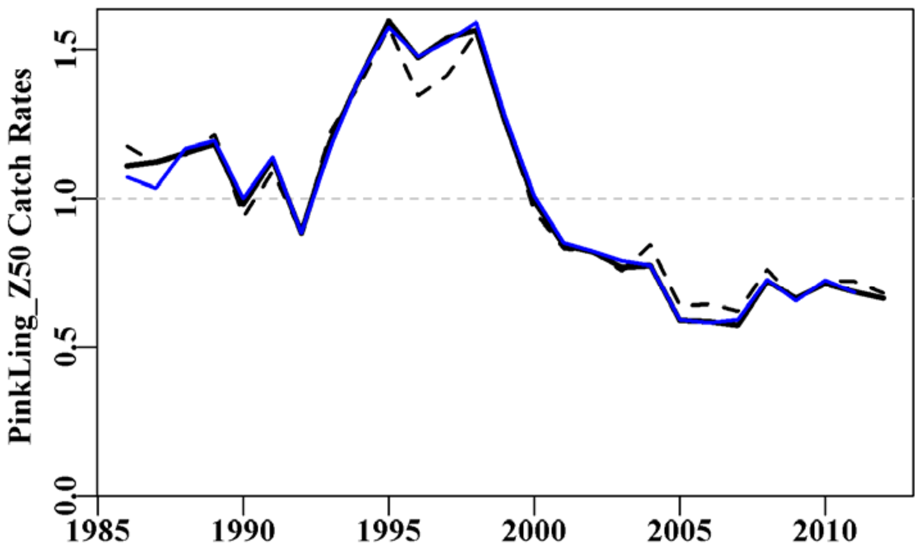



Figure 18.114. Pink Ling from zone 50 in depths between 200 – 800m by trawl. The dashed black line represents the geometric mean catch rate and the solid black line the standardized catch rates. The graph standardizes catch rates relative to the mean of the standardized catch rates; giving a mean for the series of 1.0. The confidence intervals are wider due to the relatively low number of records.

Table 18.101. Pink Ling from zone 50 in depths between 200 – 800m 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+ Vessel:Month |
| Model 7 | LnCE~Year+Vessel +DepCat +Month +DayNight+ Month:DepCat |

Table 18.102. Pink Ling from zone 50 in depths between 200 – 800m by trawl. Model selection criteria, including the AIC, the adjusted $r^2$ and the change in adjusted $r^2$. The optimum is Vessel:Month (model 6).

| | Year | Vessel | DepCat | Month | DayNight | **Vessel:Month** | Month:DepCat |
|---|---|---|---|---|---|---|---|
| AIC | -13693 | -18735 | -20971 | -21175 | -21299 | **-21495** | -21518 |
| RSS | 30767 | 27143 | 25658 | 25521 | 25443 | **24370** | 24921 |
| MSS | 3711 | 7335 | 8820 | 8956 | 9035 | **10107** | 9557 |
| Nobs | 42513 | 42357 | 42357 | 42357 | 42357 | **42357** | 42357 |
| Npars | 27 | 57 | 131 | 142 | 145 | **959** | 475 |
| adj_r2 | 10.709 | 21.169 | 25.353 | 25.730 | 25.952 | **27.680** | 26.902 |
| %Change | 0.000 | 10.460 | 4.184 | 0.377 | 0.222 | **1.728** | -0.778 |

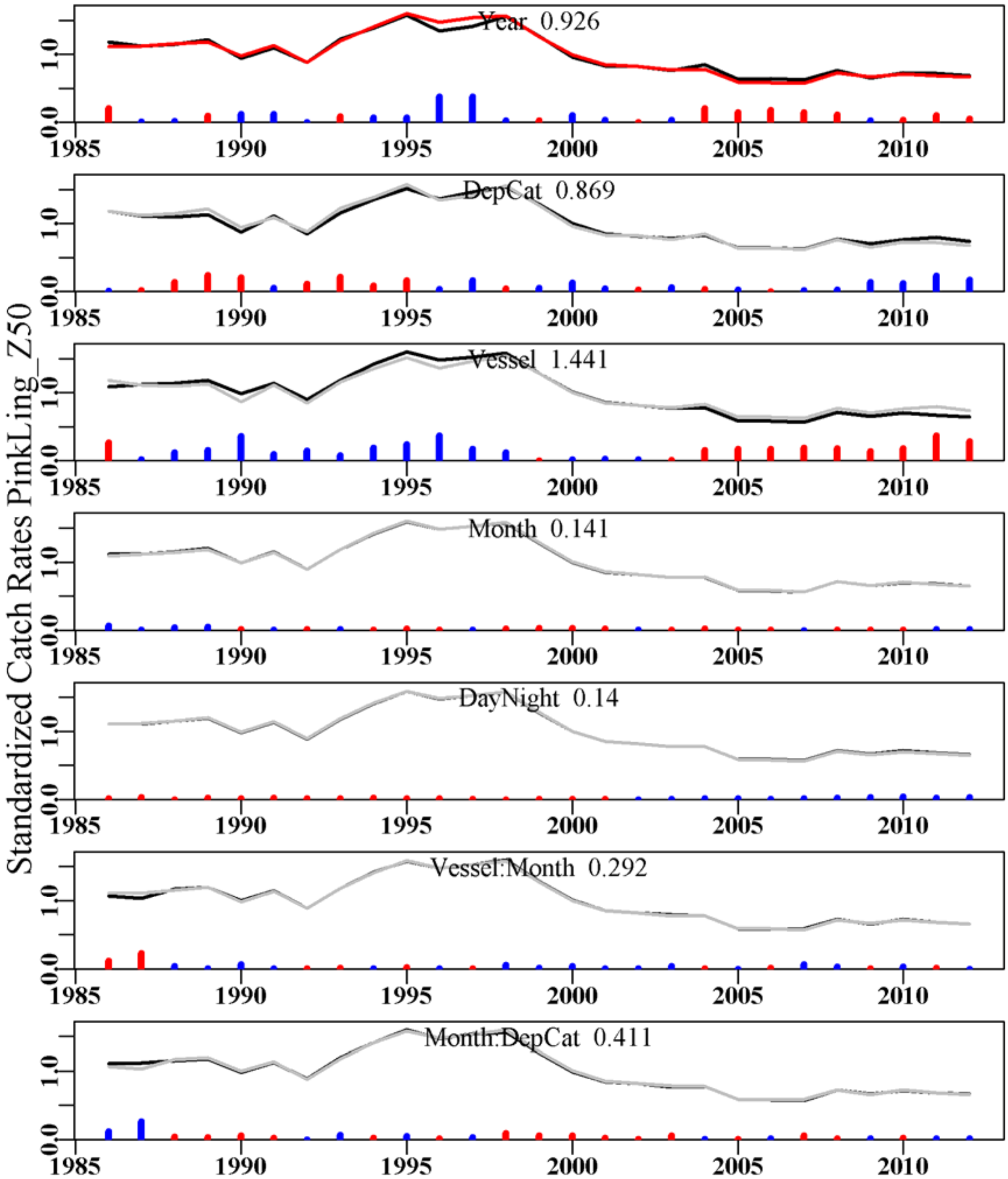



Figure 18.115. The relative influence of each factor used on the final trend in the optimal standardization for Pink Ling in Zone 50. The top graph depicts the geometric mean (the black line) and the optimum model (the red line). The difference between them is illustrated by the vertical bars with blue 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 for Vessel has the geometric mean (grey line) and the effect of adding Year + Vessel (model 2). In the third graph, for DepCat, the grey line represents model 2 and the black line the effect of adding DepCat 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. Note that the influence, which is simply the deviations between the two lines squared, are not always reflective of the adj-r2 for each factor.

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

Data from zones 40 and 50 with 82, 83, 84, and 85 (the GAB) above -42°, depths greater than 100 and less than or equal to 600 m.

Table 18.103. Western Gemfish from zones 40 and 50, and the GAB (zones 82, 83, 84, and 85) in depths between 200 – 600m by trawl (now represented by TW and TDO. Total Catch is the total reported in the database, Records is the number of records used in the analysis, CatchT is the reported catch in the area and depth used in the analysis, and Vessels relates to all vessels used in the analysis. Geomean is the geometric mean of catch rates (kg/hr). Zone:Mth is the optimum model and StDev is the standard deviation relating to the data in the optimum model.

| Year | TotCatch | Records | CatchT | Vessels | GeoMean | Zone:Mth | StDev |
|---|---|---|---|---|---|---|---|
| 1986 | 3639.705 | 1721 | 308.061 | 25 | 28.8362 | 2.1528 | 0.0000 |
| 1987 | 4654.845 | 1284 | 262.356 | 29 | 30.7827 | 2.1367 | 0.0460 |
| 1988 | 3515.132 | 1427 | 261.309 | 36 | 25.6522 | 2.0036 | 0.0478 |
| 1989 | 1773.801 | 1405 | 184.753 | 38 | 19.0566 | 1.5117 | 0.0489 |
| 1990 | 1206.660 | 1261 | 146.900 | 38 | 14.3866 | 1.3284 | 0.0527 |
| 1991 | 578.584 | 1592 | 280.530 | 35 | 19.1105 | 1.3073 | 0.0493 |
| 1992 | 485.696 | 801 | 96.906 | 21 | 15.0886 | 0.9604 | 0.0567 |
| 1993 | 353.153 | 902 | 109.371 | 21 | 11.5160 | 0.8198 | 0.0556 |
| 1994 | 232.154 | 1053 | 110.188 | 26 | 11.3093 | 0.8407 | 0.0531 |
| 1995 | 181.686 | 1316 | 107.533 | 26 | 9.0719 | 0.8050 | 0.0506 |
| 1996 | 381.614 | 1631 | 164.827 | 32 | 9.5592 | 0.9376 | 0.0488 |
| 1997 | 571.679 | 2106 | 215.362 | 28 | 8.9766 | 0.8402 | 0.0470 |
| 1998 | 404.594 | 1967 | 206.881 | 26 | 10.1690 | 1.0097 | 0.0478 |
| 1999 | 448.384 | 2347 | 323.256 | 25 | 11.9957 | 1.0104 | 0.0467 |
| 2000 | 336.404 | 2357 | 260.267 | 32 | 9.5636 | 0.8314 | 0.0472 |
| 2001 | 330.838 | 2335 | 255.222 | 31 | 9.9454 | 0.7822 | 0.0473 |
| 2002 | 195.597 | 1770 | 129.588 | 29 | 6.4625 | 0.6015 | 0.0490 |
| 2003 | 268.577 | 1642 | 203.076 | 34 | 8.8216 | 0.6781 | 0.0497 |
| 2004 | 524.293 | 1952 | 434.958 | 32 | 10.3074 | 0.7327 | 0.0497 |
| 2005 | 448.035 | 1816 | 359.400 | 27 | 12.3888 | 0.7310 | 0.0503 |
| 2006 | 508.681 | 1599 | 399.243 | 26 | 11.5504 | 0.6769 | 0.0513 |
| 2007 | 476.942 | 1412 | 382.551 | 22 | 10.3604 | 0.6378 | 0.0522 |
| 2008 | 288.883 | 1265 | 152.175 | 21 | 6.6254 | 0.6554 | 0.0527 |
| 2009 | 189.831 | 1275 | 105.771 | 16 | 5.8778 | 0.6932 | 0.0525 |
| 2010 | 218.885 | 1703 | 129.526 | 18 | 6.0572 | 0.7423 | 0.0499 |
| 2011 | 147.297 | 1376 | 77.795 | 17 | 5.5705 | 0.7792 | 0.0522 |
| 2012 | 147.746 | 974 | 83.610 | 19 | 5.9162 | 0.7941 | 0.0574 |

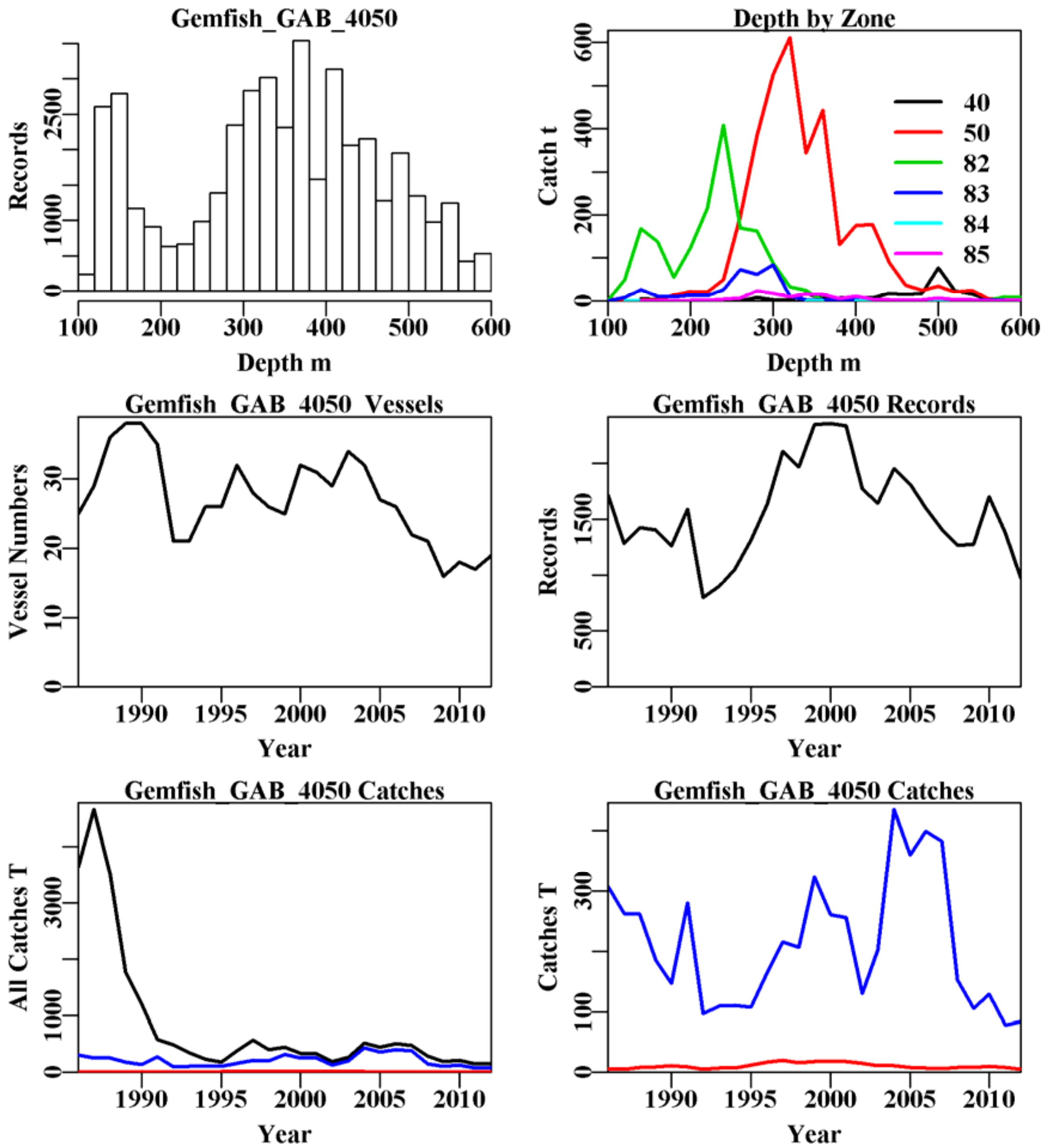



Figure 18.116. Western Gemfish from zones 40 and 50, and the GAB (zones 82, 83, 84, and 85) in depths between 200 – 600m by trawl. The top left depicts the depth distribution of shots containing Western Gemfish from zones 40 and 50, and the GAB (zones 82, 83, 84, and 85) in depths between 200 – 600m by trawl. The top right diagram depicts the distribution of catch by depth within zones, the middle left hand graph depicts the number of vessels through time. The middle right reflects the number of records used in analysis, bottom left is the Gemfish catches across east and west (top line, black is total catches, middle line, blue, are those used in the analysis, and bottom, red, are catches < 30Kg); western gemfish catches are given at bottom right but without total catches for that species.

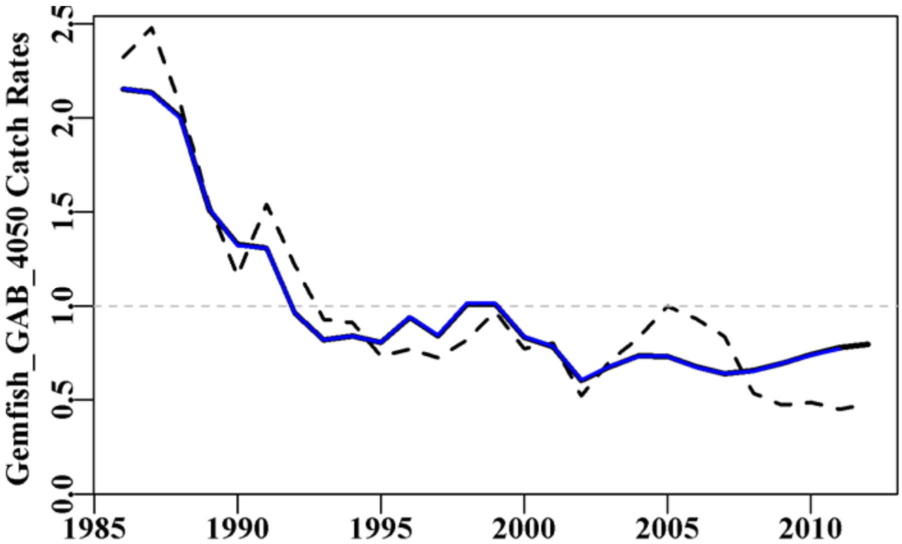



Figure 18.117. Western Gemfish from zones 40 and 50, and the GAB (zones 82, 83, 84, and 85) in depths between 200 – 600m by trawl. The dashed black line represents the geometric mean catch rate and the solid black line the standardized catch rates. The graph standardizes catch rates relative to the mean of the standardized catch rates.

Table 18.104. Western Gemfish from zones 40 and 50, and the GAB (zones 82, 83, 84, and 85) in depths between 200 – 600m 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 18.105. Western Gemfish from zones 40 and 50, and the GAB (zones 82, 83, 84, and 85) in depths between 200 – 600m by trawl. Model selection criteria, including the AIC, the deviance and the change in deviance. The optimum is Zone:Month (model 7).

| | Year | DepCat | Vessel | Zone | DayNight | Month | **Zone:Mth** | Zone:DepC |
|---|---|---|---|---|---|---|---|---|
| AIC | 36139 | 22340 | 15198 | 14421 | 13722 | 13334 | **12316** | 12689 |
| RSS | 99267 | 71397 | 59946 | 58836 | 57858 | 57299 | **55784** | 56093 |
| MSS | 8399 | 36269 | 47720 | 48830 | 49808 | 50367 | **51882** | 51573 |
| Nobs | 42289 | 42103 | 42103 | 42103 | 42103 | 42103 | **42103** | 42103 |
| Npars | 27 | 52 | 161 | 166 | 169 | 180 | **235** | 305 |
| adj_r2 | 7.745 | 33.606 | 44.110 | 45.139 | 46.046 | 46.554 | **47.899** | 47.522 |
| %Change | 0.000 | 25.862 | 10.504 | 1.029 | 0.907 | 0.508 | **1.345** | 0.968 |

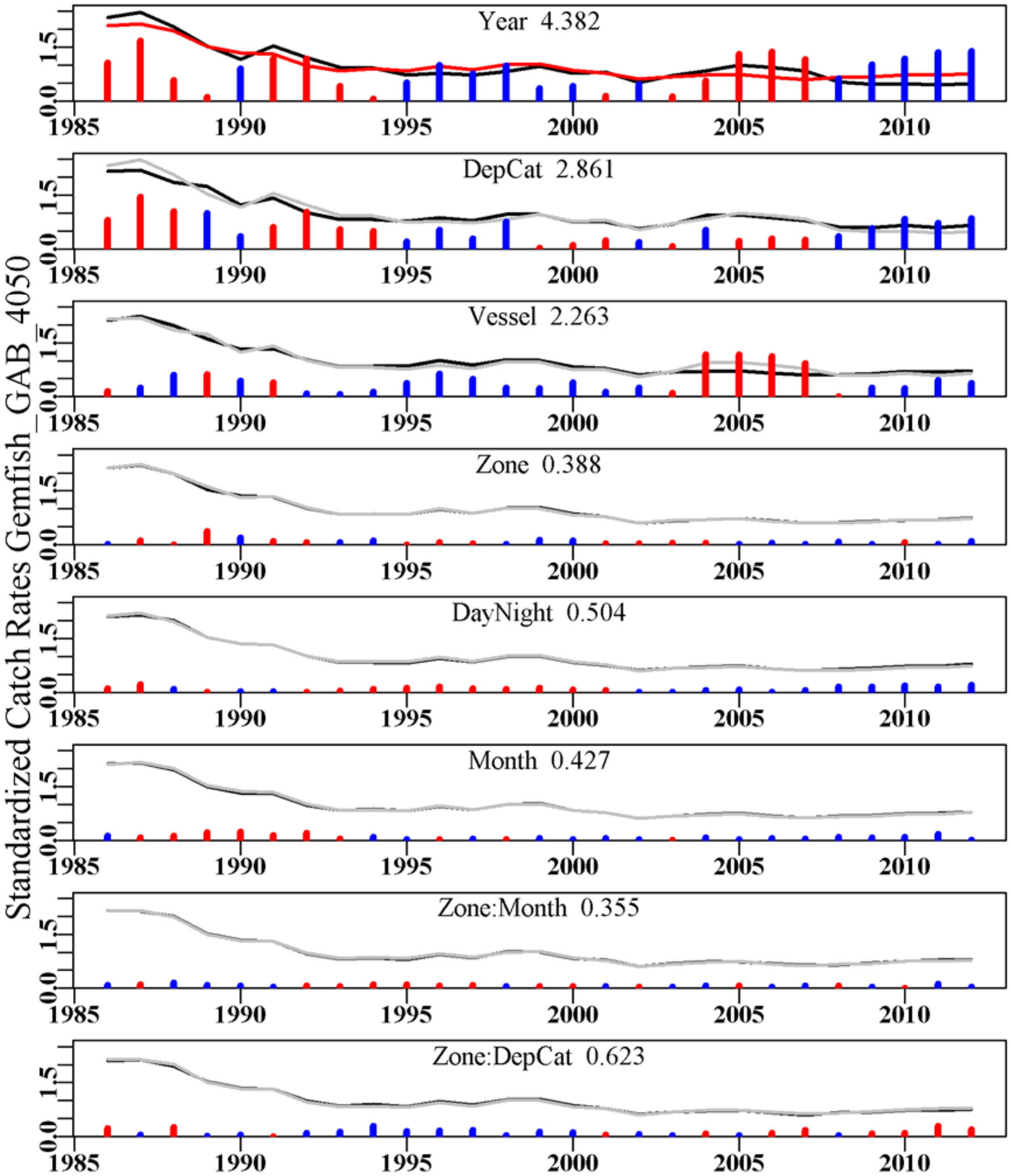



Figure 18.118. The relative influence of each factor used on the final trend in the optimal standardization for Western Gemfish from zones 40 and 50 and the GAB. The top graph depicts the geometric mean (the black line) and the optimum model (the red line). The difference between them is illustrated 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.

### *18.4.36 Western Gemfish Z4050 (GEM – 37439002 – R. solandri)*

Data from zones 40 and 50, depths greater than 200 and less than or equal to 600 m.

Table 18.106. Western Gemfish from zones 40 and 50 in depths between 200 – 600m by trawl. Total Catch is the total reported in the database, Records is the number of records used in the analysis, CatchT is the reported catch in the area and depth used in the analysis., and Vessels relates to all vessels used in the analysis. Geomean is the geometric mean of catch rates (kg/hr). Zone:Mth is the optimum model and StDev is the standard deviation relating to the data in the optimum model.

| Year | TotCatch | Records | CatchT | Vessels | GeoMean | Zone:Mth | StDev |
|---|---|---|---|---|---|---|---|
| 1986 | 3639.705 | 1687 | 306.861 | 24 | 29.5835 | 2.2547 | 0.0000 |
| 1987 | 4654.845 | 1209 | 248.879 | 26 | 31.5896 | 2.2580 | 0.0451 |
| 1988 | 3515.132 | 1235 | 226.956 | 27 | 26.9924 | 2.2045 | 0.0473 |
| 1989 | 1773.801 | 1082 | 156.578 | 29 | 23.3363 | 1.8127 | 0.0496 |
| 1990 | 1206.660 | 1057 | 136.085 | 29 | 15.9031 | 1.3844 | 0.0528 |
| 1991 | 578.584 | 1384 | 249.415 | 28 | 22.0062 | 1.3339 | 0.0493 |
| 1992 | 485.696 | 665 | 80.930 | 15 | 16.7792 | 0.9334 | 0.0575 |
| 1993 | 353.153 | 718 | 102.489 | 17 | 16.5820 | 0.9003 | 0.0570 |
| 1994 | 232.154 | 839 | 95.378 | 20 | 16.2263 | 0.9698 | 0.0543 |
| 1995 | 181.686 | 990 | 84.688 | 21 | 12.0017 | 0.8493 | 0.0520 |
| 1996 | 381.614 | 1182 | 145.588 | 26 | 13.4563 | 0.9350 | 0.0499 |
| 1997 | 571.679 | 1389 | 153.589 | 21 | 13.2702 | 0.8366 | 0.0484 |
| 1998 | 404.594 | 1259 | 121.661 | 20 | 13.2167 | 0.9026 | 0.0498 |
| 1999 | 448.384 | 1694 | 176.323 | 19 | 12.8407 | 0.8569 | 0.0475 |
| 2000 | 336.404 | 1932 | 228.165 | 28 | 12.4996 | 0.8804 | 0.0475 |
| 2001 | 330.838 | 1694 | 169.890 | 27 | 12.1589 | 0.7110 | 0.0484 |
| 2002 | 195.597 | 1418 | 86.261 | 24 | 7.1243 | 0.5418 | 0.0496 |
| 2003 | 268.577 | 1077 | 123.722 | 24 | 11.3050 | 0.6601 | 0.0521 |
| 2004 | 524.293 | 1232 | 105.674 | 24 | 7.9049 | 0.6457 | 0.0522 |
| 2005 | 448.035 | 1073 | 117.678 | 18 | 10.6004 | 0.6721 | 0.0532 |
| 2006 | 508.681 | 889 | 101.417 | 18 | 8.9869 | 0.5481 | 0.0560 |
| 2007 | 476.942 | 715 | 61.053 | 16 | 7.4717 | 0.5320 | 0.0583 |
| 2008 | 288.883 | 770 | 53.096 | 16 | 7.5220 | 0.5927 | 0.0571 |
| 2009 | 189.831 | 925 | 56.810 | 12 | 6.4871 | 0.6726 | 0.0546 |
| 2010 | 218.885 | 1364 | 86.888 | 14 | 6.3681 | 0.6984 | 0.0507 |
| 2011 | 147.297 | 1159 | 57.922 | 13 | 5.6449 | 0.7323 | 0.0528 |
| 2012 | 147.746 | 820 | 50.697 | 14 | 5.3756 | 0.6807 | 0.0587 |

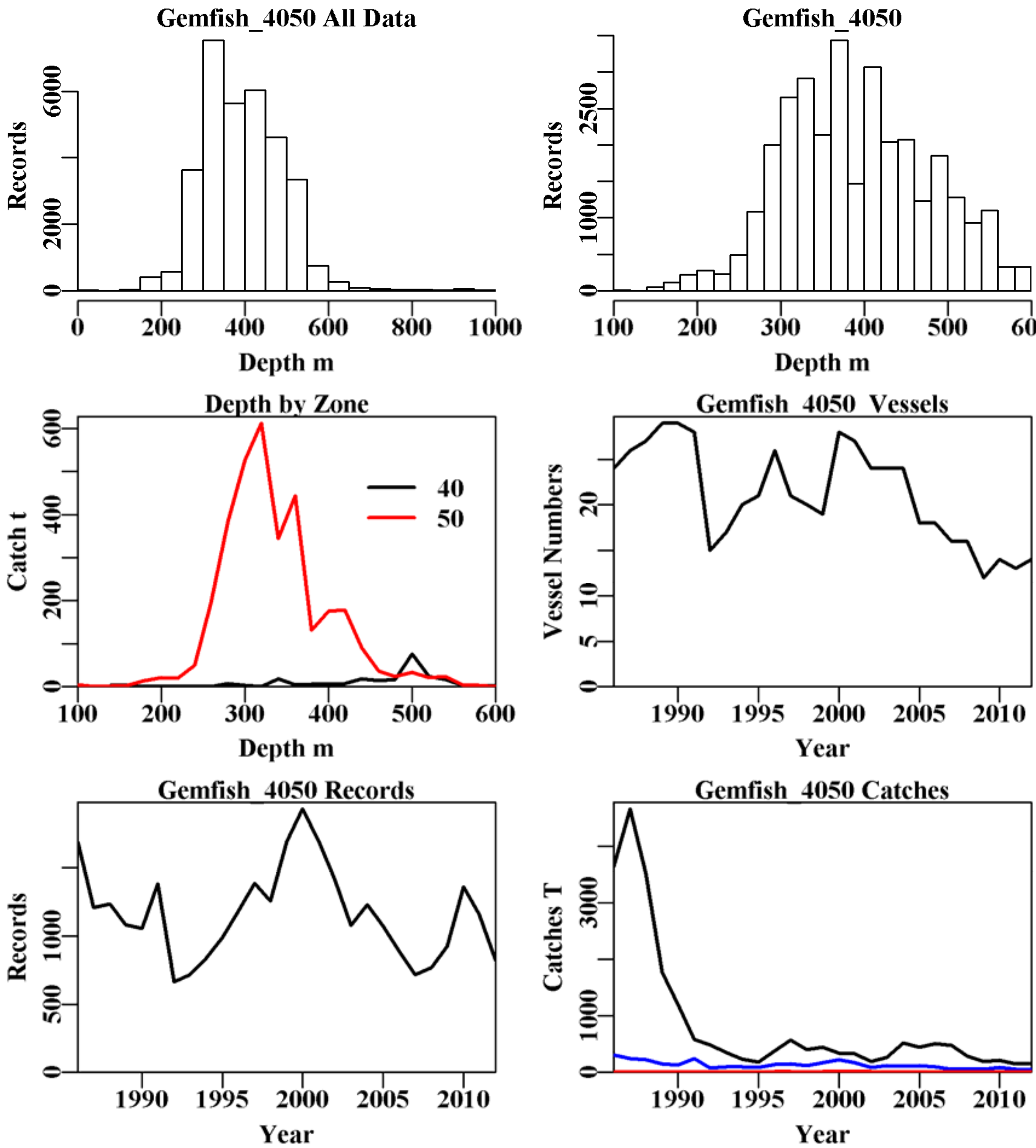



Figure 18.119. Western Gemfish from zones 40 and 50 in depths between 200 – 600m by trawl. The top left is the depth distribution of all records reporting Gemfish, the top right graph depicts the depth distribution of shots containing Western Gemfish from zones 40 and 50 in depths between 200 – 600m by trawl.. The middle left diagram depicts the distribution of catch by depth within zones 40 and 50 (50 is top red line), the middle right hand graph depicts the number of vessels through time. The bottom left reflects the number of records used in analysis, and bottom right is the Gemfish catches (top line, black is total catches, middle line, blue, are those used in the analysis, and bottom, red, are catches < 30Kg).

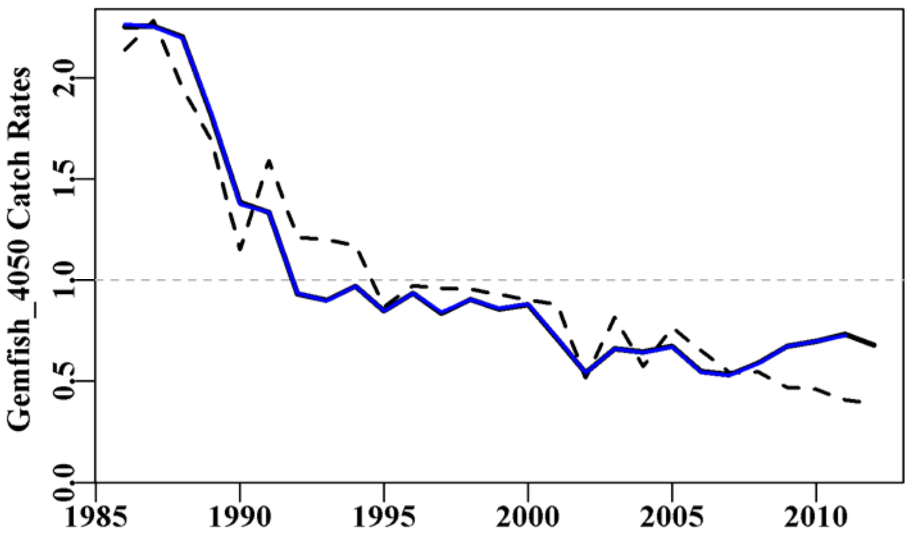



Figure 18.120. Western Gemfish from zones 40 and 50 in depths between 200 – 600m by trawl. The dashed black line represents the geometric mean catch rate and the solid black line the standardized catch rates. The graph standardizes catch rates relative to the mean of the standardized catch rates.

Table 18.107. Western Gemfish from zones 40 and 50 in depths between 200 – 600m 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 18.108. Western Gemfish from zones 40 and 50 in depths between 200 – 600m by trawl. Model selection criteria, including the AIC, the adjusted $r^2$ and the change in adjusted $r^2$. The optimum is Zone:Month (model 7).

| | Year | Vessel | DepCat | DayNight | Month | Zone | **Zone:Mth** | Zone:DepC |
|---|---|---|---|---|---|---|---|---|
| AIC | 21329 | 14035 | 7526 | 7013 | 6752 | 6752 | **6475** | 6592 |
| RSS | 61865 | 48783 | 39475 | 38826 | 38476 | 38475 | **38109** | 38217 |
| MSS | 7705 | 20788 | 30096 | 30745 | 31094 | 31096 | **31462** | 31354 |
| Nobs | 31458 | 31458 | 31327 | 31327 | 31327 | 31327 | **31327** | 31327 |
| Npars | 27 | 117 | 142 | 145 | 156 | 157 | **168** | 182 |
| adj_r2 | 11.002 | 29.621 | 43.003 | 43.934 | 44.420 | 44.420 | **44.929** | 44.748 |
| %Change | 0.000 | 18.619 | 13.382 | 0.932 | 0.485 | 0.000 | **0.509** | -0.181 |

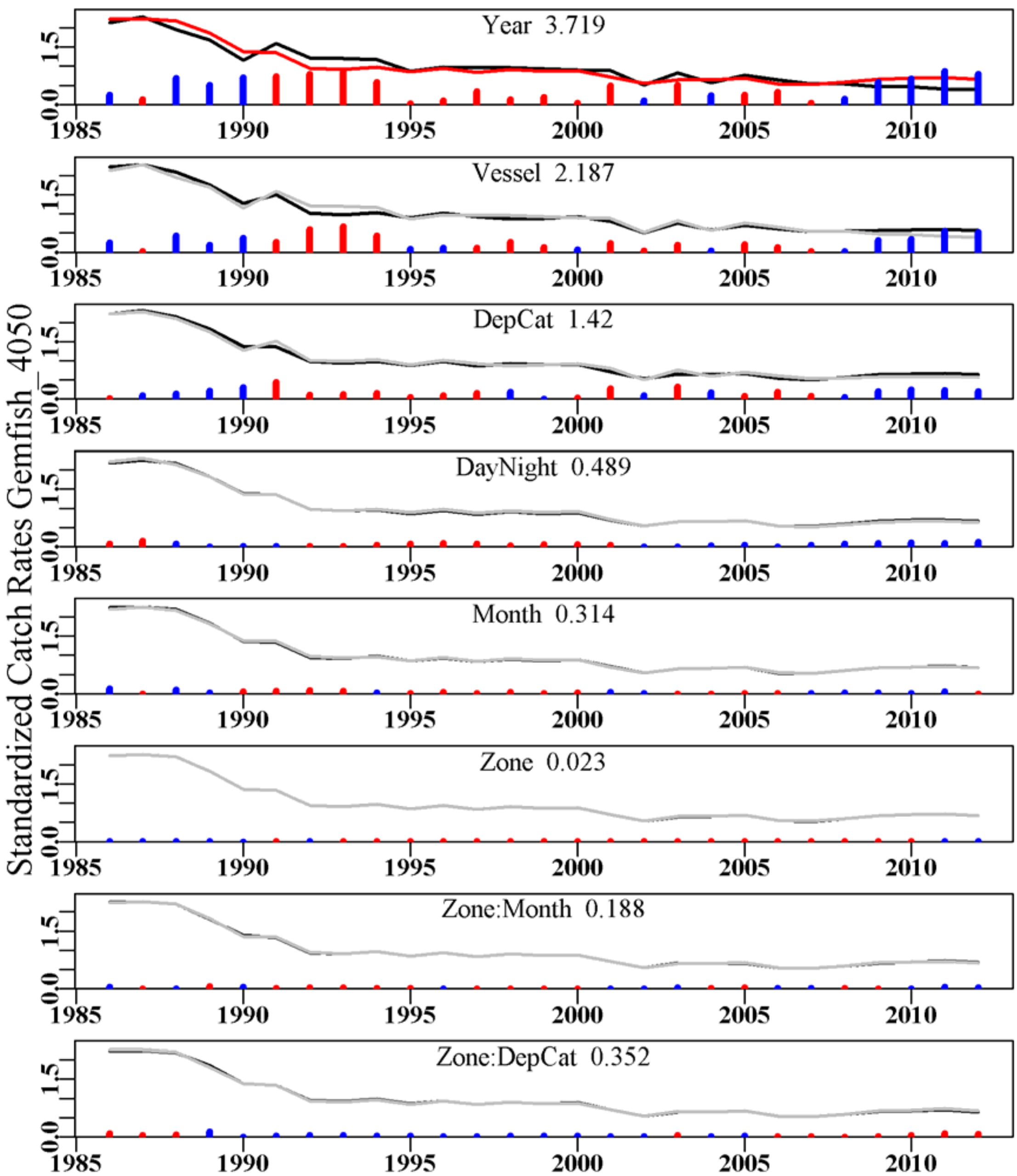



Figure 18.121. The relative influence of each factor used on the final trend in the optimal standardization for Western Gemfish from zones 40 and 50. The top graph depicts the geometric mean (the black line) and the optimum model (the red line). The difference between them is illustrated by the vertical 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.

### 18.4.37 Western Gemfish GAB (GEM – 37439002 – R. solandri)

Data from zones 82, 83, 84, and 85 (the GAB), depths greater than 100 and less than or equal to 600 m. All vessels included

Table 18.109. Western Gemfish in the GAB (zones 82, 83, 84, and 85) in depths between 100 and 600 m by trawl (codes TW and TDO. Total Catch is the total reported in the database, Records is the number of records used in the analysis, CatchT is the reported catch in the area and depth used in the analysis, and Vessels relates to all vessels used in the analysis. Geomean is the geometric mean of catch rates (kg/hr). Zone:Month is the optimum model and StDev is the standard deviation relating to the data in the optimum model.

| Year | TotCatch | Records | CatchT | Vessels | GeoMean | Zone:Mth | StDev |
|---|---|---|---|---|---|---|---|
| 1995 | 181.686 | 326 | 22.845 | 6 | 3.8779 | 0.7615 | 0.0000 |
| 1996 | 381.614 | 449 | 19.239 | 7 | 3.8858 | 1.0273 | 0.0945 |
| 1997 | 571.679 | 717 | 61.773 | 9 | 4.2096 | 1.0098 | 0.0902 |
| 1998 | 404.592 | 708 | 85.220 | 8 | 6.3801 | 1.5098 | 0.0921 |
| 1999 | 448.384 | 653 | 146.933 | 7 | 10.0539 | 1.9202 | 0.0943 |
| 2000 | 336.404 | 425 | 32.102 | 6 | 2.8318 | 0.6429 | 0.1004 |
| 2001 | 330.838 | 641 | 85.332 | 8 | 5.8477 | 1.0447 | 0.0952 |
| 2002 | 194.969 | 352 | 43.326 | 8 | 4.3633 | 0.9147 | 0.1033 |
| 2003 | 267.435 | 565 | 79.354 | 11 | 5.4980 | 0.8186 | 0.0984 |
| 2004 | 567.943 | 722 | 372.961 | 12 | 16.9525 | 1.0743 | 0.0988 |
| 2005 | 461.283 | 743 | 253.840 | 10 | 16.0998 | 0.9237 | 0.1004 |
| 2006 | 544.555 | 709 | 333.242 | 11 | 16.7217 | 0.8970 | 0.0988 |
| 2007 | 514.814 | 697 | 358.005 | 10 | 15.2782 | 0.8301 | 0.0976 |
| 2008 | 294.123 | 495 | 104.326 | 7 | 5.4956 | 0.8582 | 0.0999 |
| 2009 | 189.853 | 350 | 48.961 | 4 | 4.5291 | 0.7483 | 0.1062 |
| 2010 | 218.931 | 339 | 42.638 | 4 | 4.9524 | 0.9000 | 0.1070 |
| 2011 | 147.693 | 224 | 21.229 | 4 | 5.3076 | 0.7732 | 0.1186 |
| 2012 | 147.806 | 158 | 33.004 | 5 | 9.6345 | 1.3458 | 0.1323 |

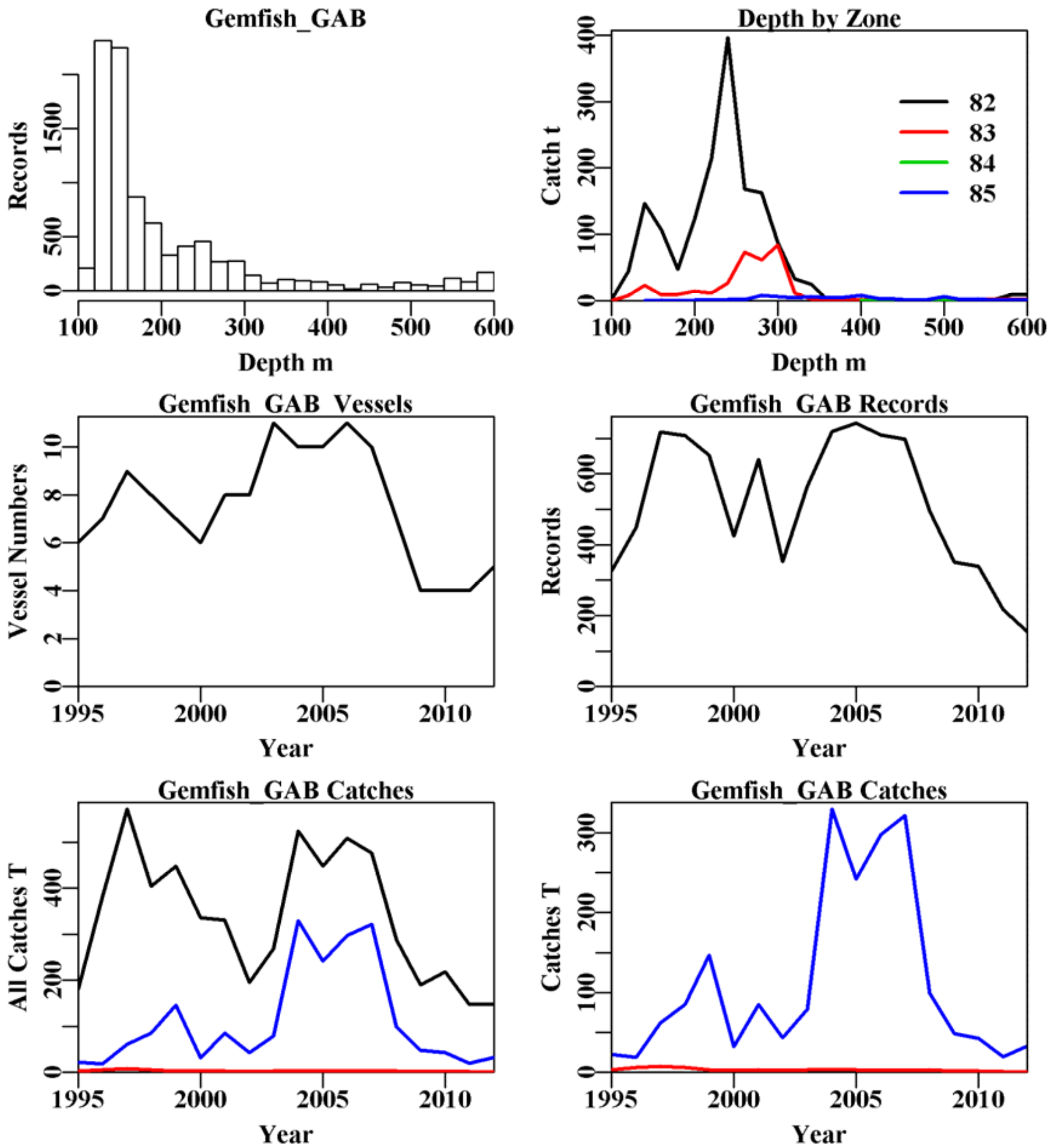



Figure 18.122. Western Gemfish in the GAB (zones 82, 83, 84, and 85) in depths between 100 and 600 m by trawl. The top left depicts the depth distribution of shots containing Western Gemfish from the GAB (zones 82, 83, 84, and 85) in depths between 100 – 600m by trawl. The top right diagram depicts the distribution of catch by depth within zones, the middle left hand graph depicts the number of vessels through time. The middle right reflects the number of records used in analysis, bottom left are all Western Gemfish catches (top line, black is total catches, middle line, blue, are those used in the analysis, and bottom, red, are catches < 30Kg); western gemfish catches in the GAB are given at bottom right but without total catches for that species.

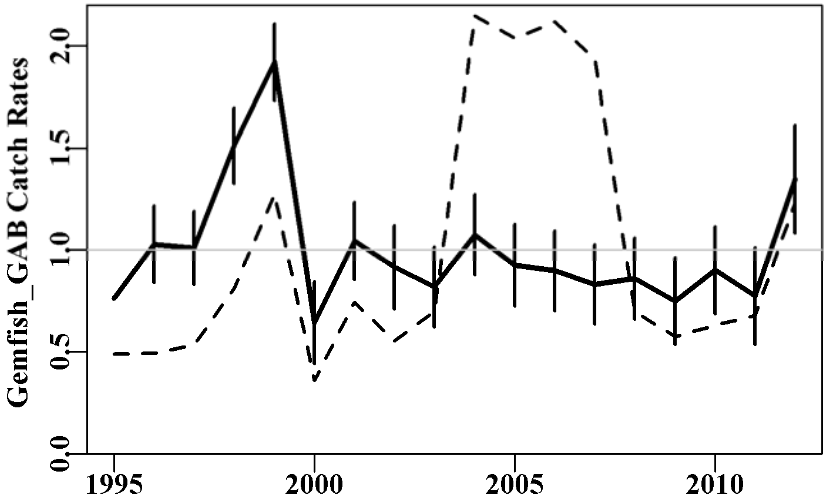



Figure 18.123. Western Gemfish in the GAB (zones 82, 83, 84, and 85) in depths between 100 and 600 m by trawl. The dashed black line represents the geometric mean catch rate and the solid black line the standardized catch rates. The graph standardizes catch rates relative to the mean of the standardized catch rates.

Table 18.110. 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 18.111. Western Gemfish in the GAB (zones 82, 83, 84, and 85) in depths between 100 and 600 m by trawl. Model selection criteria, including the AIC, the adjusted $r^2$ and the change in adjusted $r^2$. The optimum is Zone:Month (model 7).

| | Year | DepCat | Vessel | Month | DayNight | Zone | **Zone:Mth** | Zone:DepC |
|---|---|---|---|---|---|---|---|---|
| AIC | 10580 | 6796 | 5477 | 4863 | 4607 | 4378 | **4097** | 4302 |
| RSS | 28914 | 19088 | 16455 | 15357 | 14927 | 14551 | **14015** | 14200 |
| MSS | 3000 | 12826 | 15460 | 16557 | 16987 | 17363 | **17899** | 17714 |
| Nobs | 9260 | 9219 | 9219 | 9219 | 9219 | 9219 | **9219** | 9219 |
| Npars | 18 | 43 | 68 | 79 | 82 | 85 | **118** | 160 |
| adj_r2 | 9.235 | 39.915 | 48.064 | 51.469 | 52.813 | 53.987 | **55.521** | 54.725 |
| %Change | 0.000 | 30.680 | 8.149 | 3.405 | 1.344 | 1.173 | **1.535** | 0.738 |

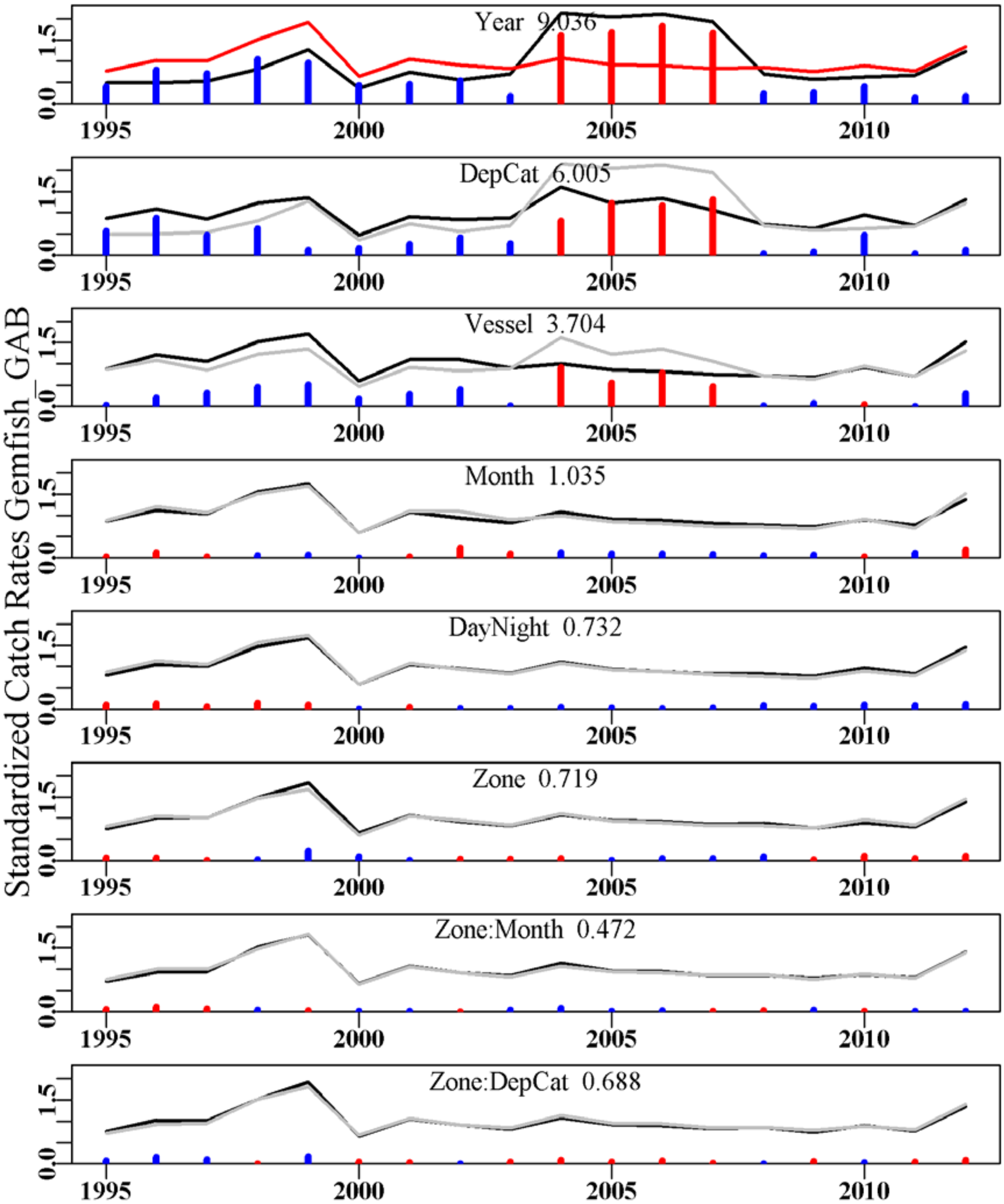



Figure 18.124. The relative influence of each factor used on the final trend in the optimal standardization for Western Gemfish in the GAB (zones 82, 83, 84, and 85). The top graph depicts the geometric mean (the black line) and the optimum model (the red line). The difference between them is illustrated 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.

#### *18.4.38 Offshore Ocean Perch, Z1020 (REG – 37287001 – H. percoides) 200m*

In the November 2009 Slope RAG meeting the depth distribution of offshore Ocean Perch was revised to 300-700m to avoid overlap with inshore Ocean Perch; however, this decision was reversed in 2010 and so the analysis was repeated using 200-700 m.

Table 18.112. Offshore Ocean Perch from zones 10 and 20 in depths 200 – 700m by trawl. Total Catch is the total reported in the database, Records is the number of records used in the analysis, CatchT is the reported catch in the area and depth used in the analysis, and Vessels relates to all vessels used in the analysis. Geomean is the geometric mean of catch rates (kg/hr). Zone:Month is the optimum model and StDev is the standard deviation relating to the data in the optimum model.

| Year | TotCatch | Records | CatchT | Vessels | GeoMean | Zone:Mth | StDev |
|---|---|---|---|---|---|---|---|
| 1986 | 262.042 | 3479 | 207.363 | 77 | 12.1440 | 1.0273 | 0.0000 |
| 1987 | 198.128 | 3140 | 132.797 | 70 | 8.9237 | 0.9524 | 0.0255 |
| 1988 | 186.616 | 2808 | 150.765 | 73 | 10.5074 | 1.0646 | 0.0265 |
| 1989 | 205.493 | 3036 | 160.004 | 67 | 10.6494 | 1.0226 | 0.0264 |
| 1990 | 180.438 | 1970 | 115.943 | 57 | 12.0207 | 1.3618 | 0.0296 |
| 1991 | 217.910 | 2093 | 138.991 | 53 | 13.4339 | 1.4388 | 0.0293 |
| 1992 | 169.419 | 1845 | 114.079 | 47 | 11.9264 | 1.2143 | 0.0302 |
| 1993 | 258.950 | 2924 | 199.186 | 53 | 12.9555 | 1.2142 | 0.0269 |
| 1994 | 256.441 | 3014 | 180.955 | 49 | 11.8001 | 1.1338 | 0.0266 |
| 1995 | 239.854 | 3146 | 150.341 | 50 | 10.4874 | 1.0258 | 0.0263 |
| 1996 | 262.985 | 3411 | 176.808 | 53 | 9.8364 | 0.9196 | 0.0259 |
| 1997 | 296.072 | 3725 | 193.773 | 54 | 9.7119 | 0.9729 | 0.0257 |
| 1998 | 277.782 | 3850 | 194.629 | 49 | 9.4285 | 0.8631 | 0.0254 |
| 1999 | 289.340 | 4406 | 219.065 | 52 | 9.7566 | 0.9696 | 0.0252 |
| 2000 | 269.170 | 4178 | 180.750 | 53 | 7.5464 | 0.7723 | 0.0256 |
| 2001 | 280.878 | 4038 | 183.911 | 43 | 8.3956 | 0.8676 | 0.0258 |
| 2002 | 253.420 | 3646 | 150.622 | 45 | 7.3709 | 0.8247 | 0.0265 |
| 2003 | 322.179 | 3960 | 185.006 | 53 | 7.6242 | 0.8799 | 0.0262 |
| 2004 | 314.899 | 3129 | 150.459 | 46 | 8.0648 | 0.8767 | 0.0276 |
| 2005 | 316.334 | 3089 | 170.080 | 46 | 9.3641 | 0.9852 | 0.0275 |
| 2006 | 236.835 | 2326 | 113.168 | 39 | 7.8433 | 0.8429 | 0.0294 |
| 2007 | 178.228 | 1528 | 94.900 | 22 | 9.9183 | 1.0503 | 0.0331 |
| 2008 | 182.642 | 1843 | 101.836 | 23 | 9.1917 | 0.9672 | 0.0316 |
| 2009 | 173.256 | 1694 | 99.608 | 23 | 9.0355 | 0.9630 | 0.0326 |
| 2010 | 194.732 | 1759 | 118.107 | 21 | 9.8647 | 0.9863 | 0.0321 |
| 2011 | 186.024 | 1874 | 116.696 | 22 | 9.0998 | 0.8673 | 0.0316 |
| 2012 | 177.420 | 1693 | 114.141 | 22 | 9.9671 | 0.9357 | 0.0324 |

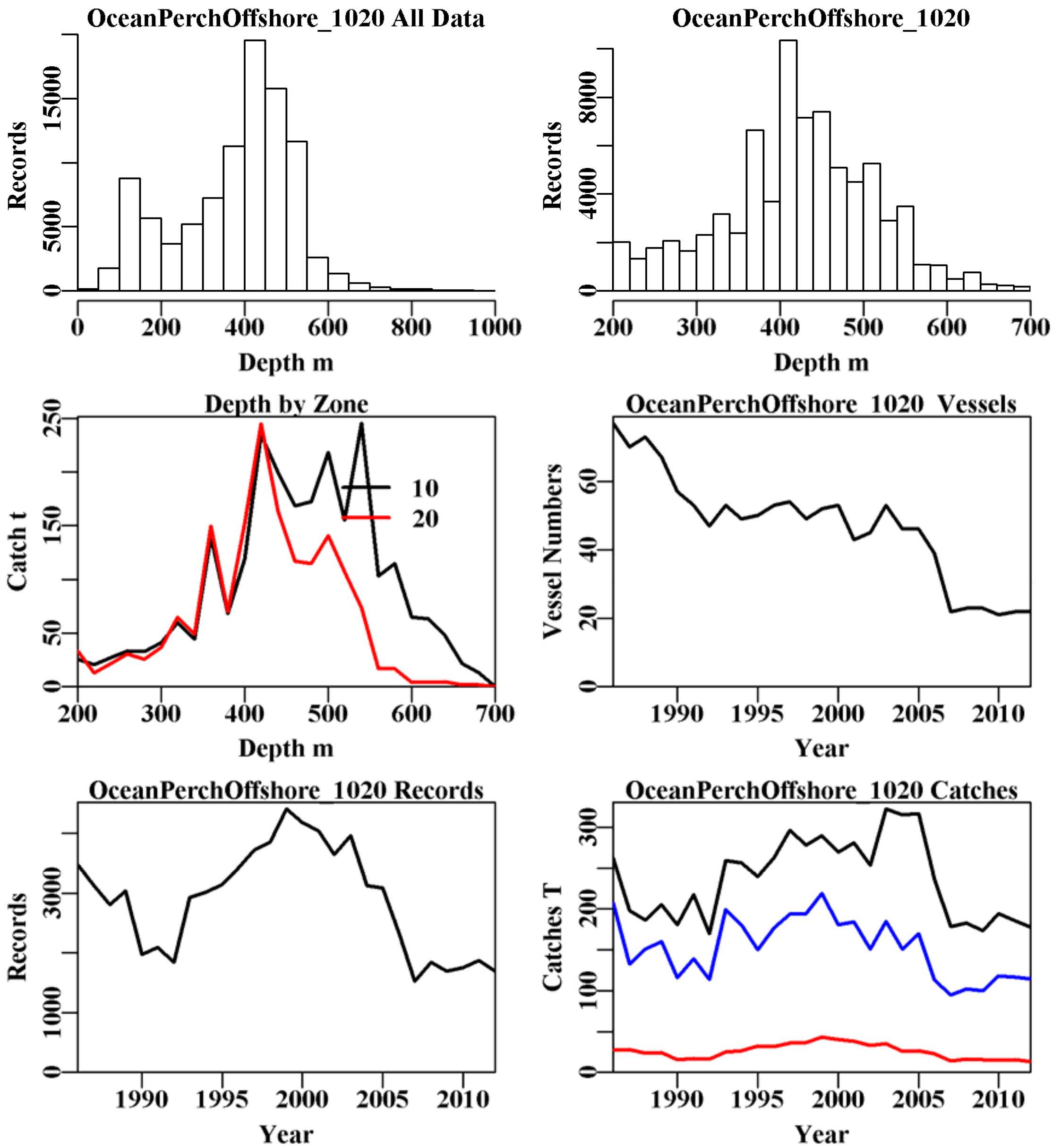



Figure 18.125. Offshore Ocean Perch from zones 10 and 20 in depths 200 – 700m by trawl. The top left is the depth distribution of all records reporting Ocean perch, the top right graph depicts the depth distribution of shots containing Offshore Ocean Perch from zones 10 and 20 in depths 200 – 700m by trawl. The middle left diagram depicts the distribution of catch by depth within zones 10 and 20 (20 is top red line), the middle right hand graph depicts the number of vessels through time. The bottom left reflects the number of records used in analysis, and bottom right is the Ocean Perch catches (top line, black is total catches, middle line, red, are those used in the analysis).

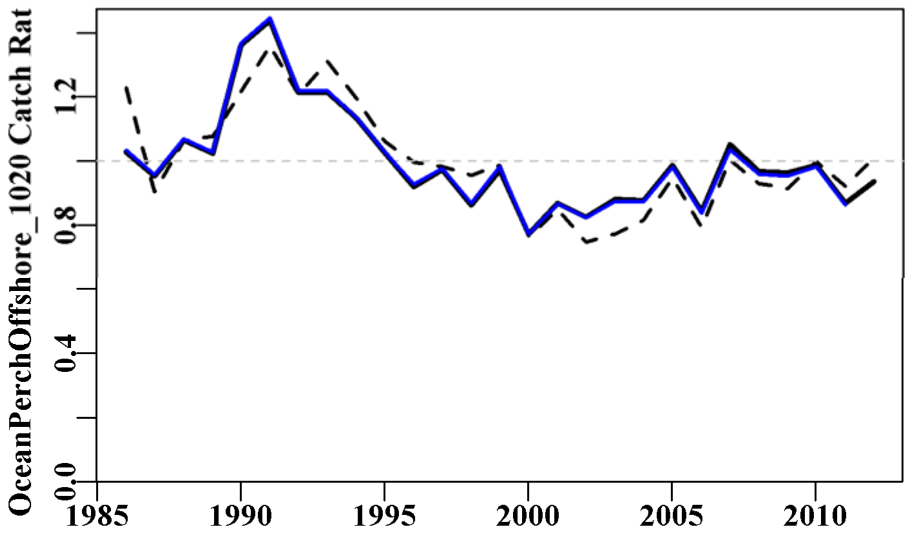



Figure 18.126. Offshore Ocean Perch from zones 10 and 20 in depths 200 – 700m by trawl. The dashed black line represents the geometric mean catch rate and the solid black line the standardized catch rates. The graph standardizes catch rates relative to the mean of the standardized catch rates.

Table 18.113. Offshore Ocean Perch from zones 10 and 20 in depths 200 – 700m 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 18.114. Offshore Ocean Perch from zones 10 and 20 in depths 200 – 700m by trawl. Model selection criteria, including the AIC, the adjusted $r^2$ and the change in adjusted $r^2$. The optimum is Zone:Month (model 7).

| | Year | DepCat | Vessel | Month | DayNight | Zone | **Zone:Mth** | Zone:DepC |
|---|---|---|---|---|---|---|---|---|
| AIC | 21365 | 9608 | 1220 | -894 | -1128 | -1159 | **-3118** | -1546 |
| RSS | 102128 | 87299 | 77991 | 75862 | 75627 | 75595 | **73679** | 75168 |
| MSS | 2100 | 16929 | 26237 | 28366 | 28601 | 28633 | **30549** | 29060 |
| Nobs | 77604 | 77185 | 77185 | 77185 | 77185 | 77185 | **77185** | 77185 |
| Npars | 27 | 52 | 209 | 220 | 223 | 224 | **235** | 249 |
| adj_r2 | 1.982 | 16.187 | 24.970 | 27.008 | 27.231 | 27.262 | **29.095** | 27.649 |
| %Change | 0.000 | 14.205 | 8.783 | 2.038 | 0.223 | 0.031 | **1.833** | -1.446 |

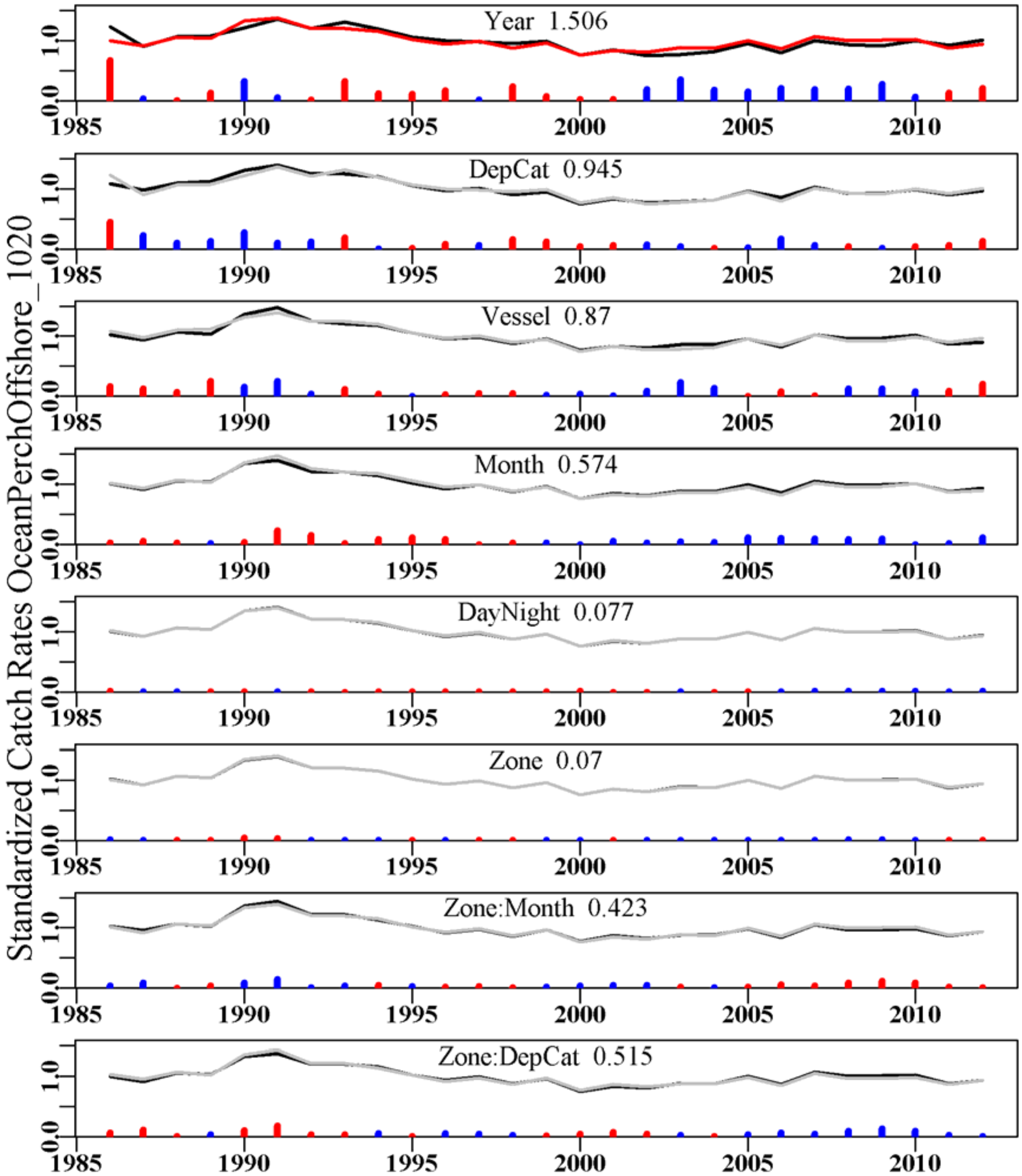



Figure 18.127. The relative influence of each factor used on the final trend in the optimal standardization for Offshore Ocean Perch from zones 10 and 20. The top graph depicts the geometric mean (the black line) and the optimum model (the red line). The difference between them is illustrated by the 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.

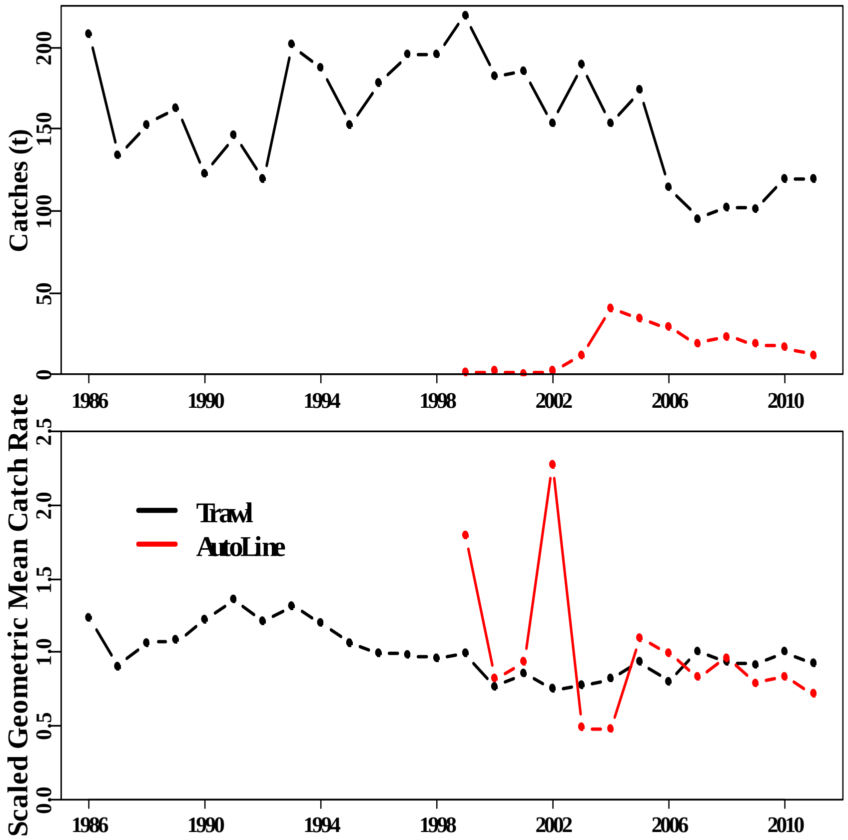



Figure 18.128. Offshore Ocean Perch, depths > 200 for trawl and AutoLongLine, in zones 10 and 20. Catches through time taken by trawl and by AutoLongLine. Some of the decline in trawl catches in recent years have been made up by the AutoLong Lining. Geometric mean catch rates for Offshore Ocean Perch in depth 200 – 700 metres for both trawl and autolongline; scaled to the mean of each series for comparison.

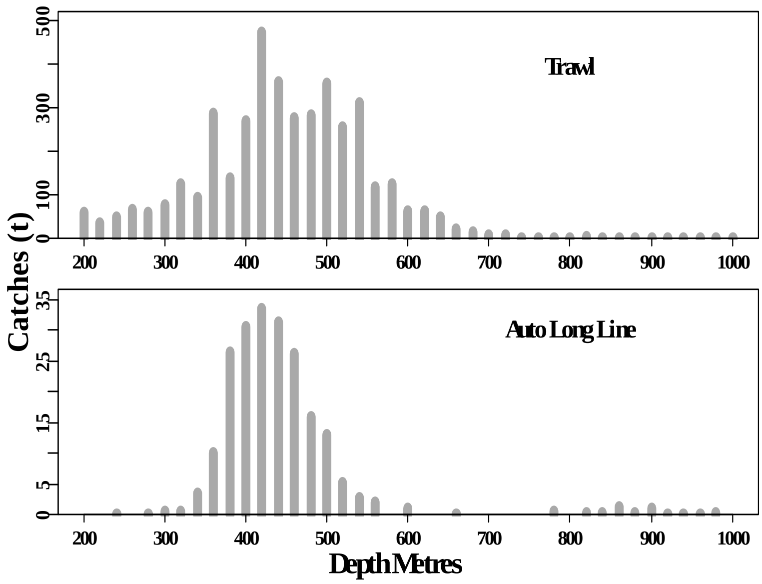



Figure 18.129. Depth distribution of catches of Offshore Ocean Perch, depths 200-700 for trawl, 0-1000m for AutoLongLine. Most catches by AutoLongLine are taken in the same depths as trawl catches.

### *18.4.39 Inshore Ocean Perch, Z1020 (REG – 37287001 – H. percoides) 0-200m*

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

Table 18.115. Inshore Ocean Perch from zones 10 and 20 in depths 0 – 200m by trawl. Total Catch is the total reported in the database, Records is the number of records used in the analysis, CatchT is the reported catch in the area and depth used in the analysis, and Vessels relates to all vessels used in the analysis. Geomean is the geometric mean of catch rates (kg/hr). Zone:DepCat is the optimum model and StDev is the standard deviation relating to the data in the optimum model.

| Year | TotCatch | Records | CatchT | Vessels | GeoMean | Zone:DepC | StDev |
|---|---|---|---|---|---|---|---|
| 1986 | 262.042 | 339 | 15.239 | 50 | 6.8543 | 0.8440 | 0.0000 |
| 1987 | 198.128 | 406 | 11.971 | 58 | 5.9511 | 0.9873 | 0.0920 |
| 1988 | 186.616 | 518 | 16.548 | 59 | 7.2891 | 1.1256 | 0.0885 |
| 1989 | 205.493 | 443 | 15.392 | 52 | 8.0367 | 1.0802 | 0.0925 |
| 1990 | 180.438 | 450 | 15.614 | 45 | 7.7738 | 1.1551 | 0.0937 |
| 1991 | 217.910 | 498 | 20.364 | 43 | 8.1374 | 1.2906 | 0.0928 |
| 1992 | 169.419 | 258 | 13.830 | 28 | 9.5229 | 1.7155 | 0.1043 |
| 1993 | 258.950 | 467 | 25.080 | 38 | 10.1873 | 1.9258 | 0.0957 |
| 1994 | 256.441 | 558 | 23.340 | 35 | 9.4326 | 1.7529 | 0.0926 |
| 1995 | 239.854 | 600 | 21.200 | 35 | 8.7548 | 1.2956 | 0.0902 |
| 1996 | 262.985 | 688 | 21.307 | 39 | 7.0539 | 1.1461 | 0.0898 |
| 1997 | 296.072 | 572 | 16.365 | 40 | 5.9056 | 1.0647 | 0.0925 |
| 1998 | 277.782 | 646 | 15.628 | 41 | 5.7524 | 0.9289 | 0.0911 |
| 1999 | 289.340 | 675 | 15.978 | 40 | 4.9974 | 0.8336 | 0.0903 |
| 2000 | 269.170 | 1326 | 30.551 | 39 | 4.5708 | 0.9928 | 0.0862 |
| 2001 | 280.878 | 1035 | 23.397 | 34 | 4.2075 | 0.9850 | 0.0879 |
| 2002 | 253.420 | 1422 | 25.185 | 36 | 2.6164 | 0.7049 | 0.0867 |
| 2003 | 322.179 | 1085 | 17.438 | 40 | 2.3132 | 0.5446 | 0.0876 |
| 2004 | 314.899 | 962 | 15.461 | 41 | 2.2440 | 0.5539 | 0.0892 |
| 2005 | 316.334 | 898 | 19.849 | 41 | 2.9880 | 0.6252 | 0.0899 |
| 2006 | 236.835 | 602 | 9.339 | 35 | 2.2501 | 0.5197 | 0.0931 |
| 2007 | 178.228 | 395 | 8.745 | 21 | 3.5455 | 0.7315 | 0.0995 |
| 2008 | 182.642 | 330 | 7.969 | 21 | 4.2486 | 0.8917 | 0.1033 |
| 2009 | 173.256 | 289 | 6.671 | 21 | 4.1335 | 0.7600 | 0.1069 |
| 2010 | 194.732 | 307 | 7.136 | 21 | 3.8363 | 0.8047 | 0.1055 |
| 2011 | 186.024 | 275 | 6.431 | 19 | 3.6642 | 0.9396 | 0.1079 |
| 2012 | 177.420 | 392 | 8.076 | 20 | 3.5117 | 0.8006 | 0.1005 |

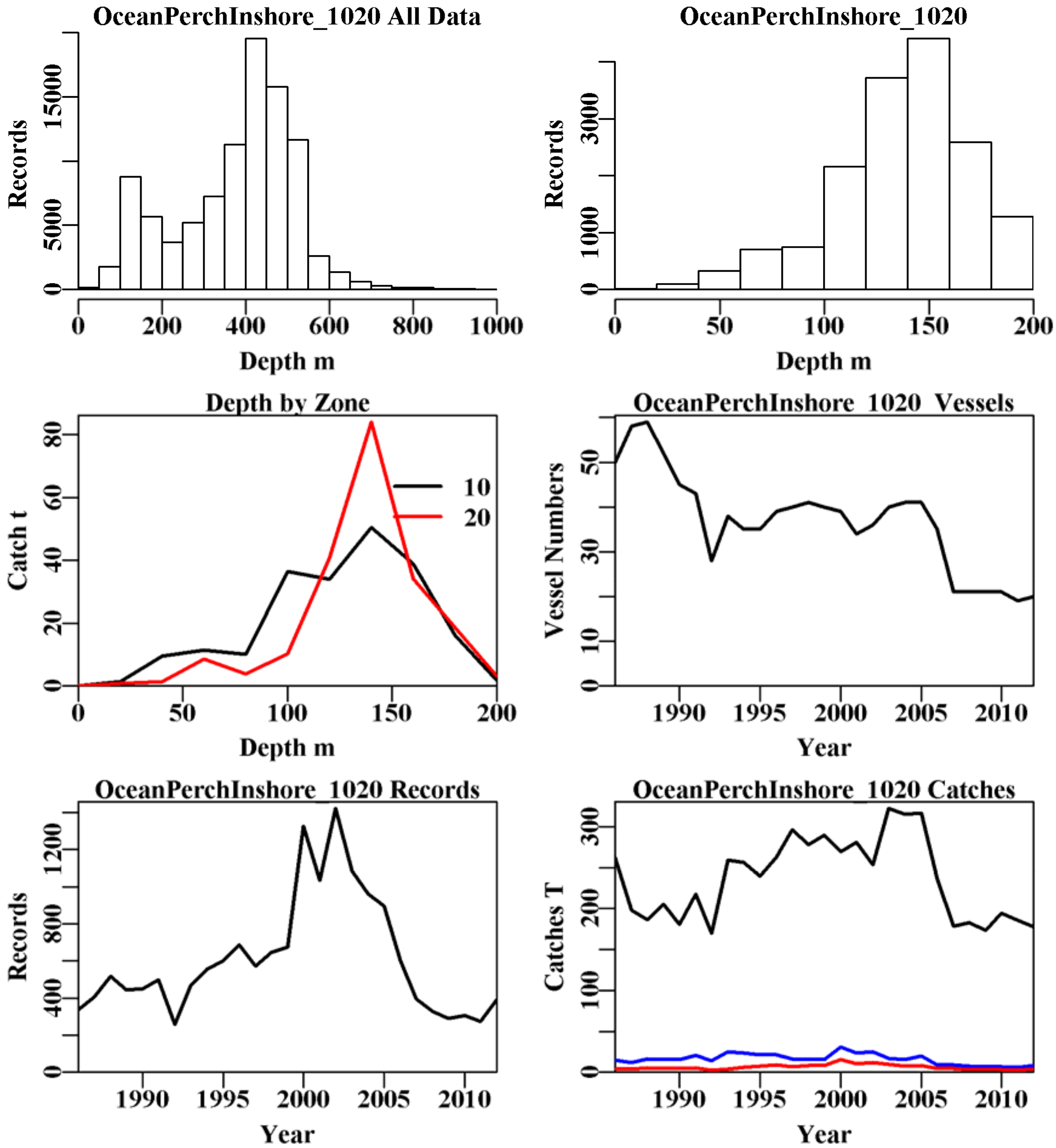



Figure 18.130. Inshore Ocean Perch from zones 10 and 20 in depths 0 – 200m by trawl. The top left is the depth distribution of all records reporting Ocean Perch, the top right graph depicts the depth distribution of shots containing Inshore Ocean Perch from zones 10 and 20 in depths 0 – 200m by trawl. The middle left diagram depicts the distribution of catch by depth within zones 10 and 20 (20 is top red line), the middle right hand graph depicts the number of vessels through time. The bottom left reflects the number of records used in analysis, and bottom right is the Ocean Perch catches (top line, black is total catches, middle line, red, are those used in the analysis.

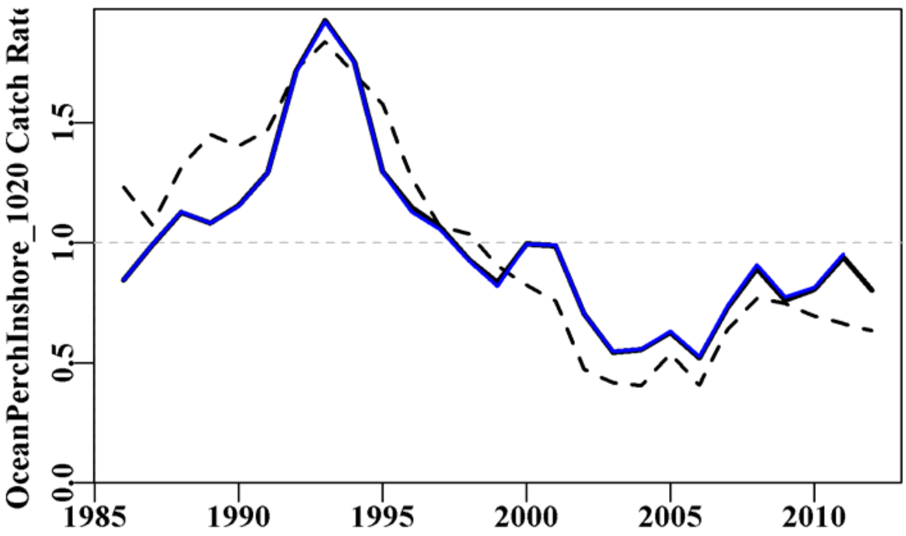



Figure 18.131. Inshore Ocean Perch from zones 10 and 20 in depths 0 – 200m by trawl. The dashed black line represents the geometric mean catch rate and the solid black line the standardized catch rates. The graph standardizes catch rates relative to the mean of the standardized catch rates.

Table 18.116. Inshore Ocean Perch from zones 10 and 20 in depths 0 – 200m 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 18.117. Inshore Ocean Perch from zones 10 and 20 in depths 0 – 200m by trawl. Model selection criteria, including the AIC, the adjusted $r^2$ and the change in adjusted $r^2$. The optimum is Zone:DepCat (model 8).

| | Year | Vessel | DepCat | Month | DayNight | Zone | Zone:Mth | **Zone:DepC** |
|---|---|---|---|---|---|---|---|---|
| AIC | 5856 | 2362 | 1423 | 1349 | 1299 | 1218 | 1217 | **1124** |
| RSS | 23394 | 18585 | 17114 | 17012 | 16952 | 16864 | 16840 | **16745** |
| MSS | 3804 | 8613 | 10085 | 10186 | 10246 | 10334 | 10358 | **10453** |
| Nobs | 16436 | 16436 | 16017 | 16017 | 16017 | 16017 | 16017 | **16017** |
| Npars | 27 | 171 | 181 | 192 | 195 | 196 | 207 | **206** |
| adj_r2 | 13.851 | 30.954 | 36.363 | 36.698 | 36.908 | 37.231 | 37.277 | **37.636** |
| %Change | 0.000 | 17.102 | 5.409 | 0.335 | 0.211 | 0.323 | 0.046 | **0.359** |

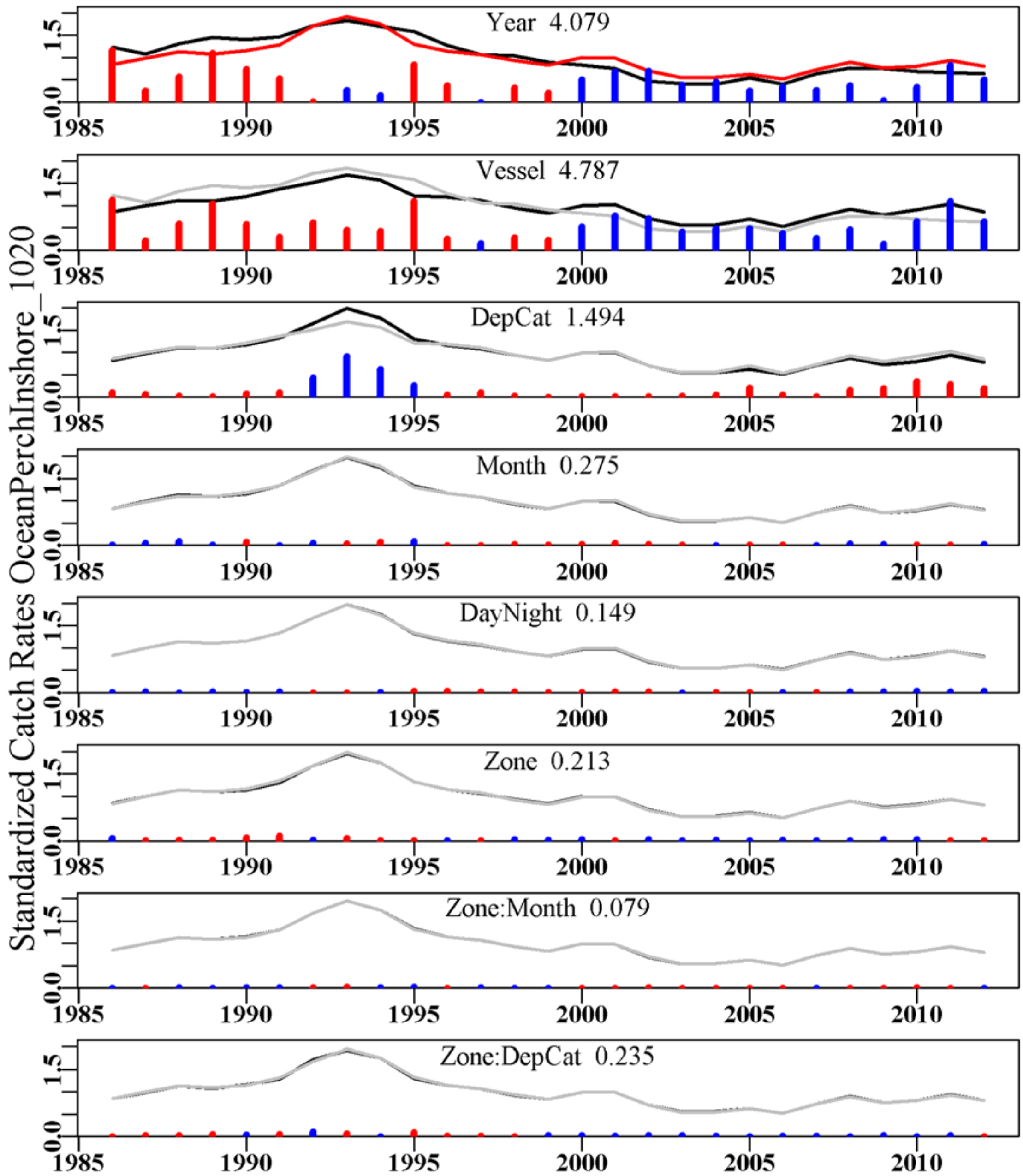



Figure 18.132. The relative influence of each factor used on the final trend in the optimal standardization for Inshore Ocean Perch from zones 10 and 20. The top graph depicts the geometric mean (the black line) and the optimum model (the red line). The difference between them is illustrated by the vertical 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.

### *18.4.40 John Dory (DOJ – 37264004) Zeus faber*

Zones 10 and 20 in depths 0 – 200m

Table 18.118. John Dory from Zones 10 and 20 in depths 0 to 200 m by trawl. Total Catch is the total reported in the database, Records is the number of records used in the analysis, CatchT is the reported catch in the area and depth used in the analysis, and Vessels relates to all vessels used in the analysis. Geomean is the geometric mean of catch rates (kg/hr). Zone:DepCat is the optimum model and StDev is the standard deviation relating to the data in the optimum model.

| Year | TotCatch | Records | CatchT | Vessels | GeoMean | Zone:DepC | StDev |
|---|---|---|---|---|---|---|---|
| 1986 | 231.654 | 6418 | 202.235 | 90 | 7.6948 | 1.5766 | 0.0000 |
| 1987 | 205.585 | 4663 | 181.591 | 78 | 8.5155 | 1.8050 | 0.0208 |
| 1988 | 181.874 | 4538 | 161.563 | 73 | 8.3856 | 1.6952 | 0.0211 |
| 1989 | 215.607 | 4813 | 188.443 | 70 | 9.5319 | 1.8594 | 0.0210 |
| 1990 | 167.764 | 3700 | 136.764 | 60 | 8.7451 | 1.6799 | 0.0230 |
| 1991 | 168.592 | 4041 | 126.696 | 53 | 7.1954 | 1.3793 | 0.0227 |
| 1992 | 129.762 | 3809 | 100.026 | 48 | 5.6282 | 1.1422 | 0.0231 |
| 1993 | 237.387 | 5446 | 181.622 | 56 | 7.0963 | 1.4786 | 0.0214 |
| 1994 | 267.438 | 6573 | 209.897 | 55 | 6.7516 | 1.3946 | 0.0204 |
| 1995 | 185.603 | 6070 | 168.531 | 52 | 5.9610 | 1.1844 | 0.0205 |
| 1996 | 160.332 | 6411 | 146.769 | 59 | 4.5279 | 0.9272 | 0.0204 |
| 1997 | 87.690 | 4473 | 79.224 | 60 | 3.3776 | 0.7205 | 0.0224 |
| 1998 | 108.987 | 5091 | 98.479 | 53 | 3.6350 | 0.7458 | 0.0215 |
| 1999 | 132.835 | 5553 | 121.021 | 56 | 3.9411 | 0.8748 | 0.0212 |
| 2000 | 164.043 | 7094 | 147.876 | 59 | 3.5716 | 0.8088 | 0.0203 |
| 2001 | 129.204 | 6789 | 116.224 | 51 | 2.9450 | 0.6769 | 0.0205 |
| 2002 | 150.867 | 6670 | 136.130 | 49 | 3.1506 | 0.6678 | 0.0208 |
| 2003 | 156.580 | 6559 | 137.336 | 51 | 3.1538 | 0.6480 | 0.0207 |
| 2004 | 165.431 | 7093 | 147.526 | 51 | 3.4191 | 0.6859 | 0.0204 |
| 2005 | 107.279 | 4934 | 88.640 | 48 | 2.6772 | 0.5702 | 0.0222 |
| 2006 | 85.241 | 3727 | 71.625 | 43 | 2.8463 | 0.6420 | 0.0237 |
| 2007 | 62.463 | 2844 | 51.685 | 23 | 2.8023 | 0.5811 | 0.0259 |
| 2008 | 116.789 | 3852 | 102.992 | 26 | 4.3014 | 0.8665 | 0.0239 |
| 2009 | 91.677 | 3148 | 79.746 | 23 | 4.1921 | 0.8057 | 0.0252 |
| 2010 | 61.689 | 3074 | 52.258 | 24 | 2.6414 | 0.5191 | 0.0256 |
| 2011 | 72.180 | 3428 | 57.400 | 22 | 2.7461 | 0.5402 | 0.0248 |
| 2012 | 65.944 | 3387 | 56.579 | 22 | 2.8174 | 0.5241 | 0.0246 |

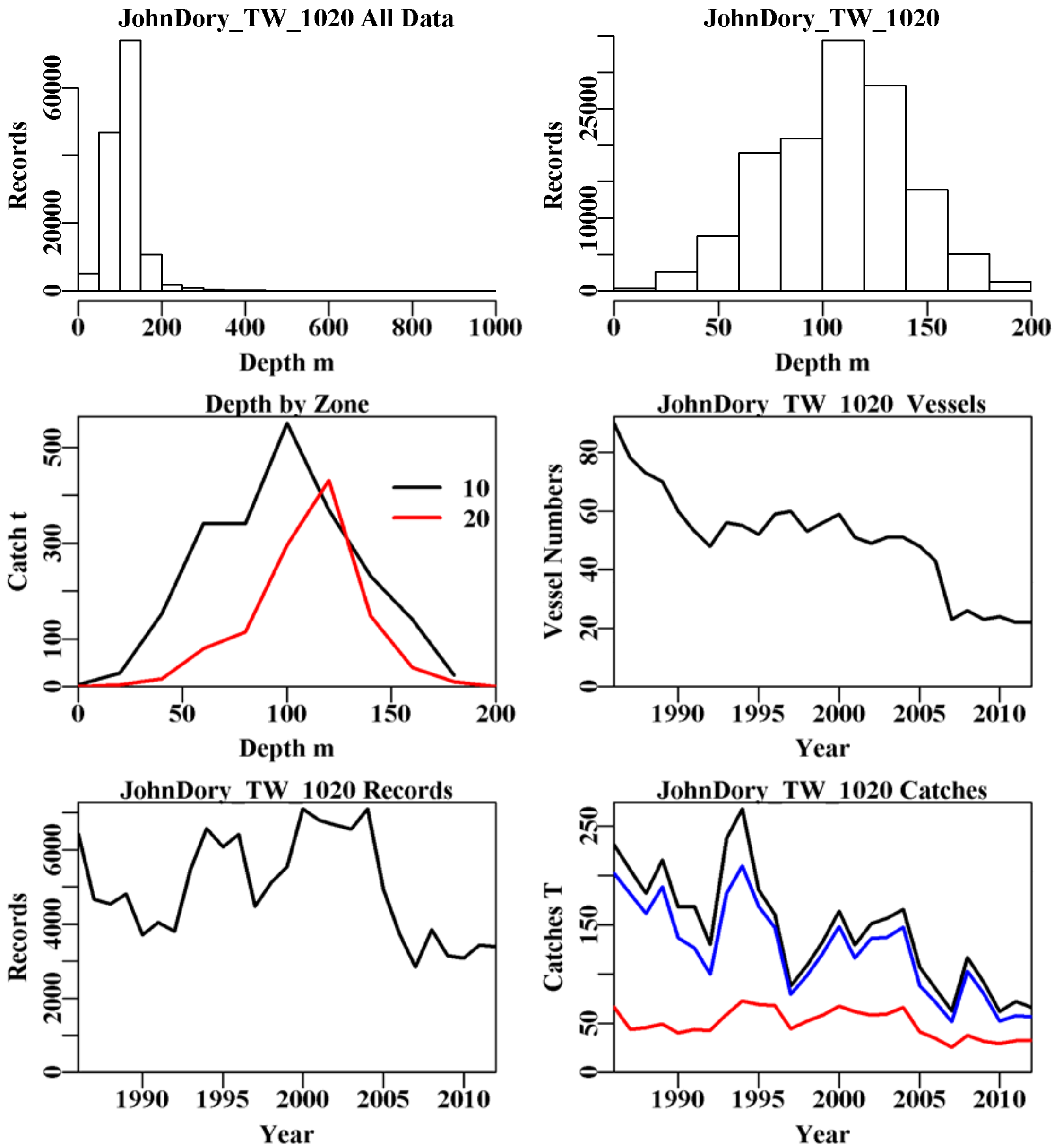



Figure 18.133. John Dory from Zones 10 and 20 in depths 0 to 200 m by trawl. The top left is the depth distribution of all records reporting John Dory, the top right graph depicts the depth distribution of shots containing John Dory from Zones 10 and 20 in depths 0 to 200 m by trawl. The middle left diagram depicts the distribution of catch by depth within zones 10 and 20 (20 is top red line), the middle right hand graph depicts the number of vessels through time. The bottom left reflects the number of records used in analysis, and bottom right is the John Dory catches (top line, black is total catches, middle line, blue, are those used in the analysis, and bottom, red, are catches < 30Kg).

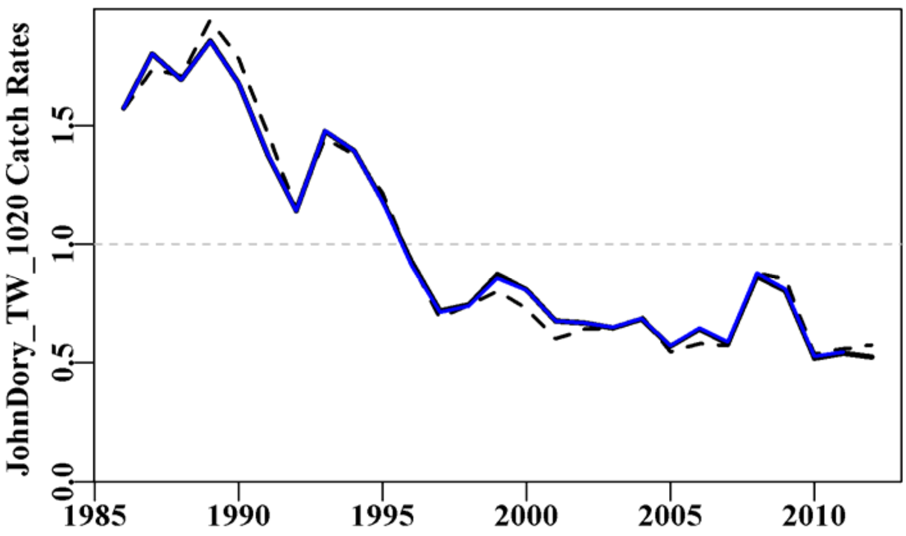



Figure 18.134. John Dory from Zones 10 and 20 in depths 0 to 200 m by trawl. The dashed black line represents the geometric mean catch rate and the solid black line the standardized catch rates. The graph standardizes catch rates relative to the mean of the standardized catch rates.

Table 18.119. 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 18.120. John Dory from Zones 10 and 20 in depths 0 to 200 m by trawl. Model selection criteria, including the AIC, the adjusted $r^2$ and the change in adjusted $r^2$. The optimum is Zone:DepCat (model 8).

| | Year | Vessel | DepCat | DayNight | Month | Zone | Zone:Mth | **Zone:DepC** |
|---|---|---|---|---|---|---|---|---|
| AIC | 26890 | 11360 | 9699 | 7968 | 7277 | 7238 | 6418 | **6049** |
| RSS | 163906 | 145642 | 142701 | 140850 | 140098 | 140055 | 139171 | **138787** |
| MSS | 23353 | 41617 | 44558 | 46409 | 47162 | 47205 | 48088 | **48472** |
| Nobs | 134198 | 134198 | 133067 | 133067 | 133067 | 133067 | 133067 | **133067** |
| Npars | 27 | 189 | 199 | 202 | 213 | 214 | 225 | **224** |
| adj_r2 | 12.454 | 22.115 | 23.681 | 24.670 | 25.066 | 25.088 | 25.555 | **25.761** |
| %Change | 0.000 | 9.661 | 1.566 | 0.988 | 0.396 | 0.022 | 0.466 | **0.206** |

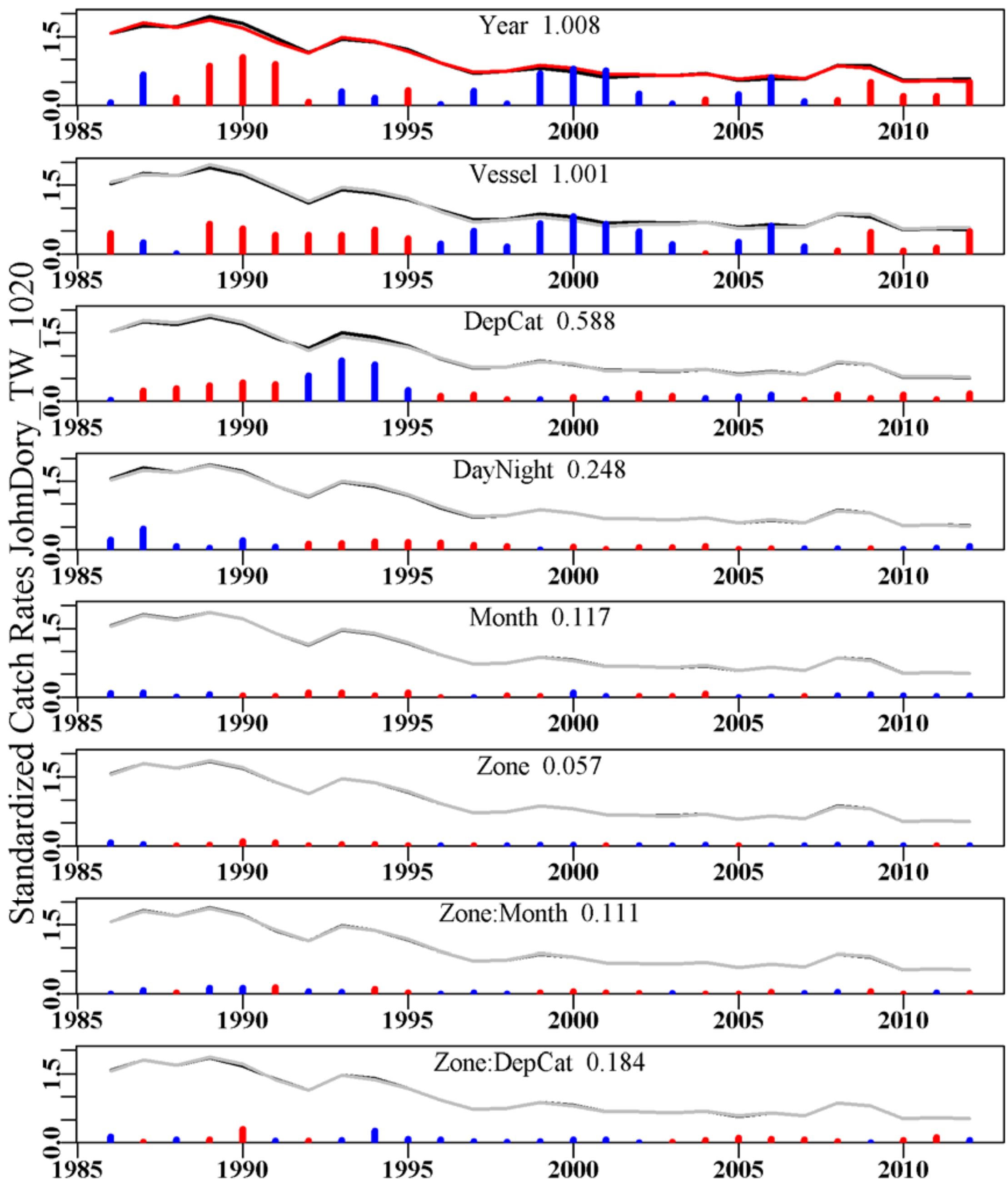



Figure 18.135. The relative influence of each factor used on the final trend in the optimal standardization for John Dory from Zones 10 and 20. The top graph depicts the geometric mean (the black line) and the optimum model (the red line). The difference between them is illustrated by the vertical bars 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.

### *18.4.41 Mirror Dory (DOM – 37264003 Zenopsis nebulosus)*

Only data from Zones 10 to 50 in depths 0 – 600m. All vessels reporting Mirror Dory were included.

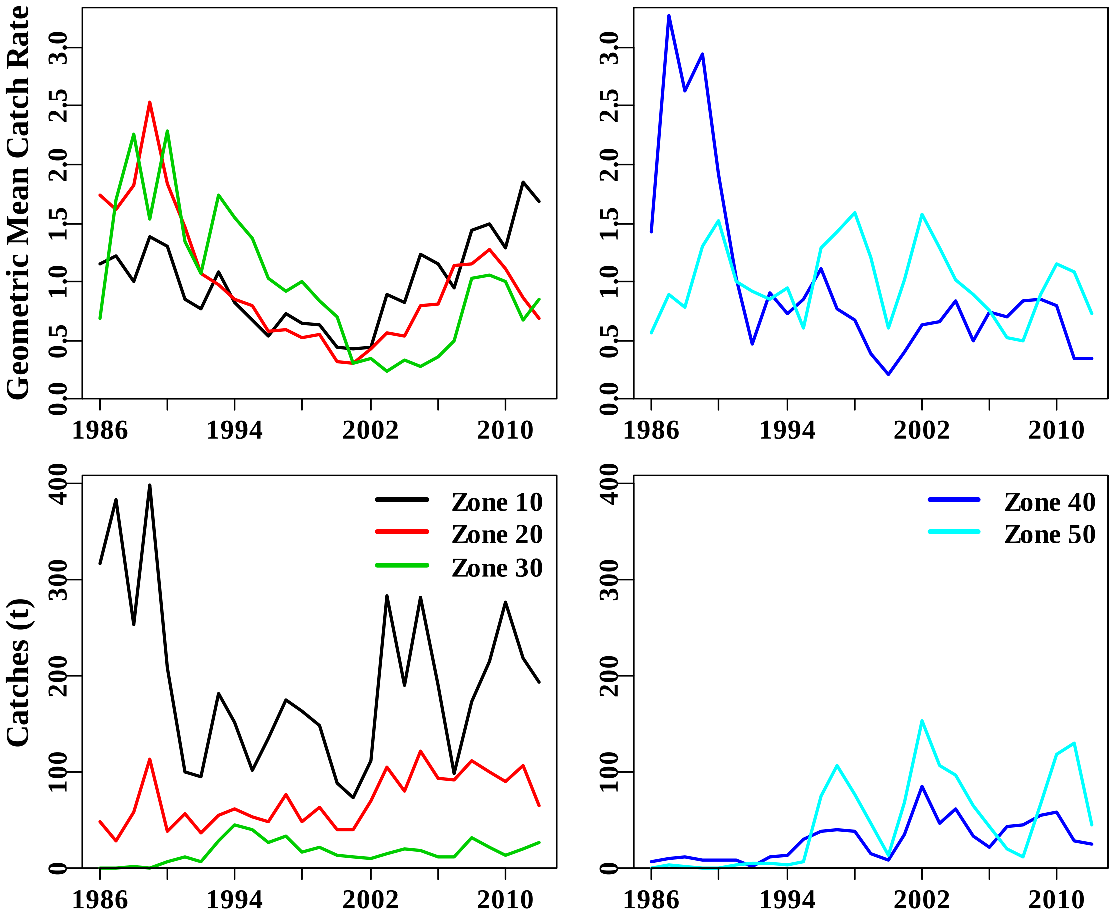



Figure 18.136. The catches and geometric mean catch rates from 1986 – 2012 for Mirror Dory split between east (Zones 10 -3 0) and west (zones 40 and 50. The general trends in catch rates, in periods of significant catches, are similar across zones within the east and west. This implies that the assumption that there are no year x zone interactions is valid.

Table 18.121. Mirror Dory from Zones 10 to 50 in depths 0 to 600 m by trawl. Total Catch is the total reported in the database, Records is the number of records used in the analysis, CatchT is the reported catch in the area and depth used in the analysis, and Vessels relates to all vessels used in the analysis. Geomean is the geometric mean of catch rates (kg/hr). Zone:Month is the optimum model and StDev is the standard deviation relating to the data in the optimum model.

| Year | TotCatch | Records | CatchT | Vessels | GeoMean | Zone:Mth | StDev |
|---|---|---|---|---|---|---|---|
| 1986 | 401.792 | 3199 | 375.385 | 91 | 18.6423 | 1.2143 | 0.0000 |
| 1987 | 449.654 | 3103 | 429.090 | 92 | 19.7476 | 1.2174 | 0.0310 |
| 1988 | 345.894 | 3189 | 328.220 | 88 | 16.9455 | 1.1918 | 0.0308 |
| 1989 | 589.920 | 3068 | 524.863 | 84 | 23.1957 | 1.4711 | 0.0313 |
| 1990 | 295.669 | 1906 | 264.346 | 73 | 20.6077 | 1.3573 | 0.0359 |
| 1991 | 230.138 | 2230 | 183.737 | 77 | 13.9567 | 1.1606 | 0.0345 |
| 1992 | 166.835 | 2228 | 147.170 | 71 | 11.3487 | 1.0060 | 0.0347 |
| 1993 | 305.379 | 3290 | 285.221 | 72 | 13.7999 | 1.1016 | 0.0316 |
| 1994 | 297.238 | 3828 | 280.195 | 70 | 11.4667 | 0.9869 | 0.0307 |
| 1995 | 244.924 | 4209 | 234.433 | 70 | 10.0782 | 0.9147 | 0.0302 |
| 1996 | 351.587 | 5835 | 327.514 | 84 | 8.9039 | 0.8809 | 0.0289 |
| 1997 | 459.626 | 6681 | 436.446 | 80 | 9.6820 | 0.9361 | 0.0286 |
| 1998 | 355.794 | 5572 | 346.706 | 68 | 9.0983 | 0.8501 | 0.0292 |
| 1999 | 309.471 | 5543 | 298.167 | 74 | 8.0995 | 0.6989 | 0.0294 |
| 2000 | 171.046 | 5613 | 165.229 | 80 | 4.6519 | 0.4882 | 0.0296 |
| 2001 | 243.341 | 7016 | 233.924 | 75 | 5.1157 | 0.5725 | 0.0290 |
| 2002 | 449.313 | 8199 | 435.035 | 69 | 7.1647 | 0.7646 | 0.0285 |
| 2003 | 612.264 | 7796 | 560.887 | 71 | 8.6661 | 0.9308 | 0.0285 |
| 2004 | 506.183 | 6485 | 452.616 | 69 | 8.2044 | 0.8942 | 0.0293 |
| 2005 | 579.706 | 6190 | 523.814 | 66 | 9.3924 | 0.9902 | 0.0294 |
| 2006 | 419.448 | 4293 | 363.075 | 54 | 9.7517 | 0.9763 | 0.0310 |
| 2007 | 289.571 | 3400 | 268.103 | 33 | 9.5152 | 0.9435 | 0.0327 |
| 2008 | 396.242 | 3377 | 376.364 | 34 | 12.2034 | 1.1278 | 0.0327 |
| 2009 | 476.503 | 3567 | 461.781 | 32 | 13.1797 | 1.2442 | 0.0324 |
| 2010 | 578.768 | 3702 | 561.230 | 32 | 12.8612 | 1.1866 | 0.0323 |
| 2011 | 516.299 | 3921 | 506.205 | 33 | 10.8184 | 1.0983 | 0.0319 |
| 2012 | 365.268 | 2757 | 357.995 | 33 | 8.9809 | 0.7952 | 0.0343 |

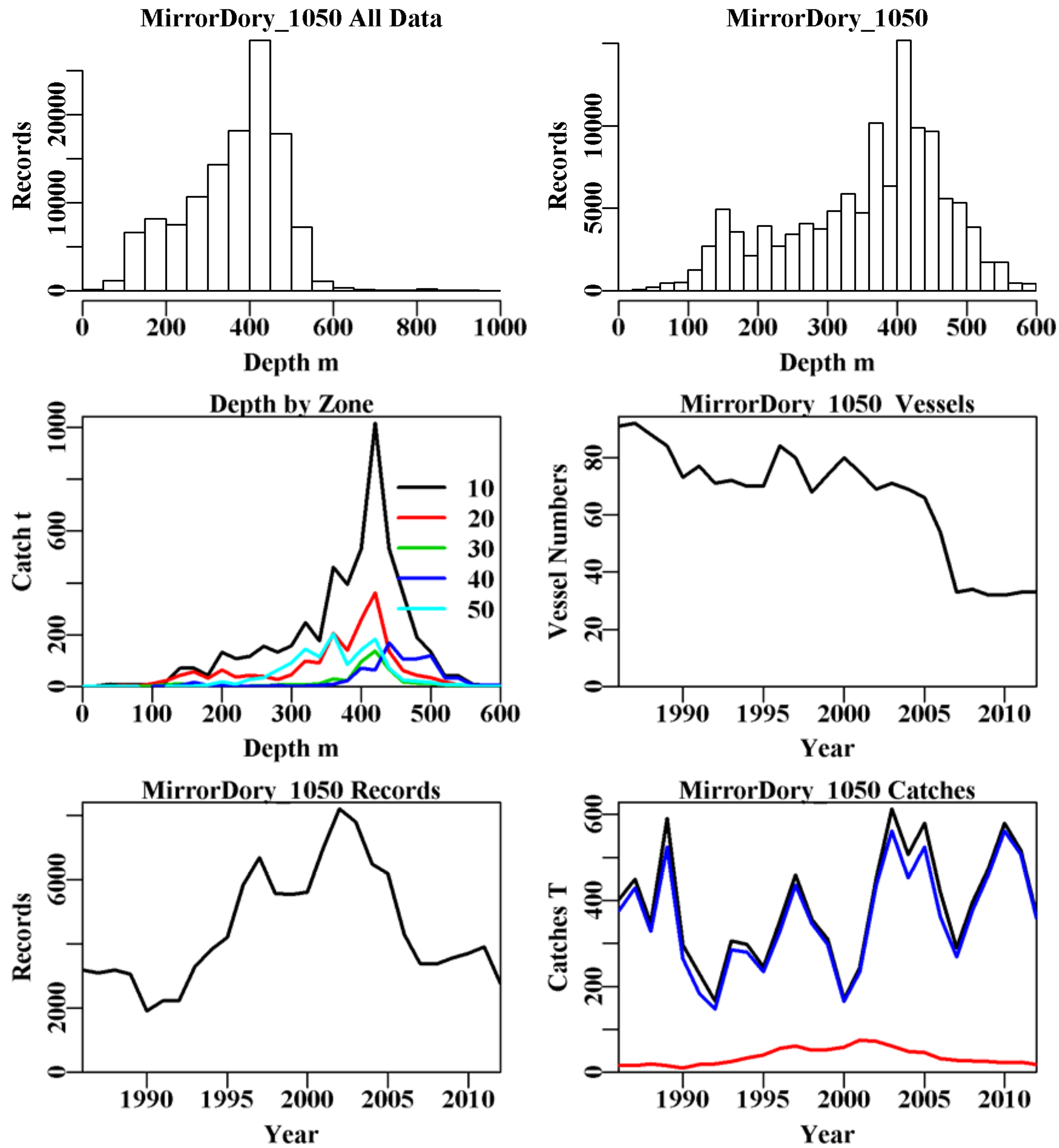



Figure 18.137. Mirror Dory from Zones 10 to 50 in depths 0 to 600 m by trawl. The top left is the depth distribution of all records reporting Mirror Dory, the top right graph depicts the depth distribution of shots containing Mirror Dory from Zones 10 to 50 in depths 0 to 600 m by trawl. The middle left diagram depicts the distribution of catch by depth within zones 10 to 50, the middle right hand graph depicts the number of vessels through time. The bottom left reflects the number of records used in analysis, and bottom right is the Mirror Dory catches (top line, black is total catches, middle line, blue, are those used in the analysis, and bottom, red, are catches < 30Kg).

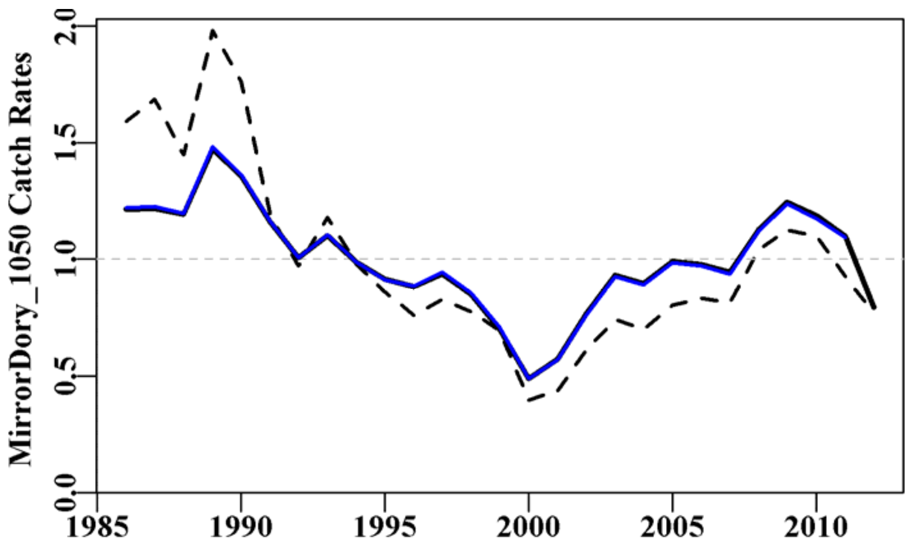



Figure 18.138. Mirror Dory from Zones 10 to 50 in depths 0 to 600 m by trawl. The dashed black line represents the geometric mean catch rate and the solid black line the standardized catch rates. The graph standardizes catch rates relative to the mean of the standardized catch rates.

Table 18.122. 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 18.123. Mirror Dory from Zones 10 to 50 in depths 0 to 600 m by trawl. Model selection criteria, including the AIC, the adjusted $r^2$ and the change in adjusted $r^2$. The optimum is Zone:Month (model 7).

| | Year | Vessel | DepCat | Month | DayNight | Zone | **Zone:Mth** | Zone:DepC |
|---|---|---|---|---|---|---|---|---|
| AIC | 75097 | 53633 | 51943 | 41088 | 39786 | 39061 | **34706** | 38143 |
| RSS | 224407 | 187082 | 184436 | 167819 | 165992 | 164978 | **158958** | 163387 |
| MSS | 16260 | 53585 | 56231 | 72849 | 74676 | 75690 | **81709** | 77280 |
| Nobs | 120197 | 120197 | 120197 | 119543 | 119543 | 119543 | **119543** | 119543 |
| Npars | 27 | 228 | 239 | 269 | 272 | 276 | **320** | 396 |
| adj_r2 | 6.736 | 22.118 | 23.213 | 30.113 | 30.872 | 31.292 | **33.774** | 31.886 |
| %Change | 0.000 | 15.382 | 1.095 | 6.900 | 0.759 | 0.420 | **2.482** | -1.889 |

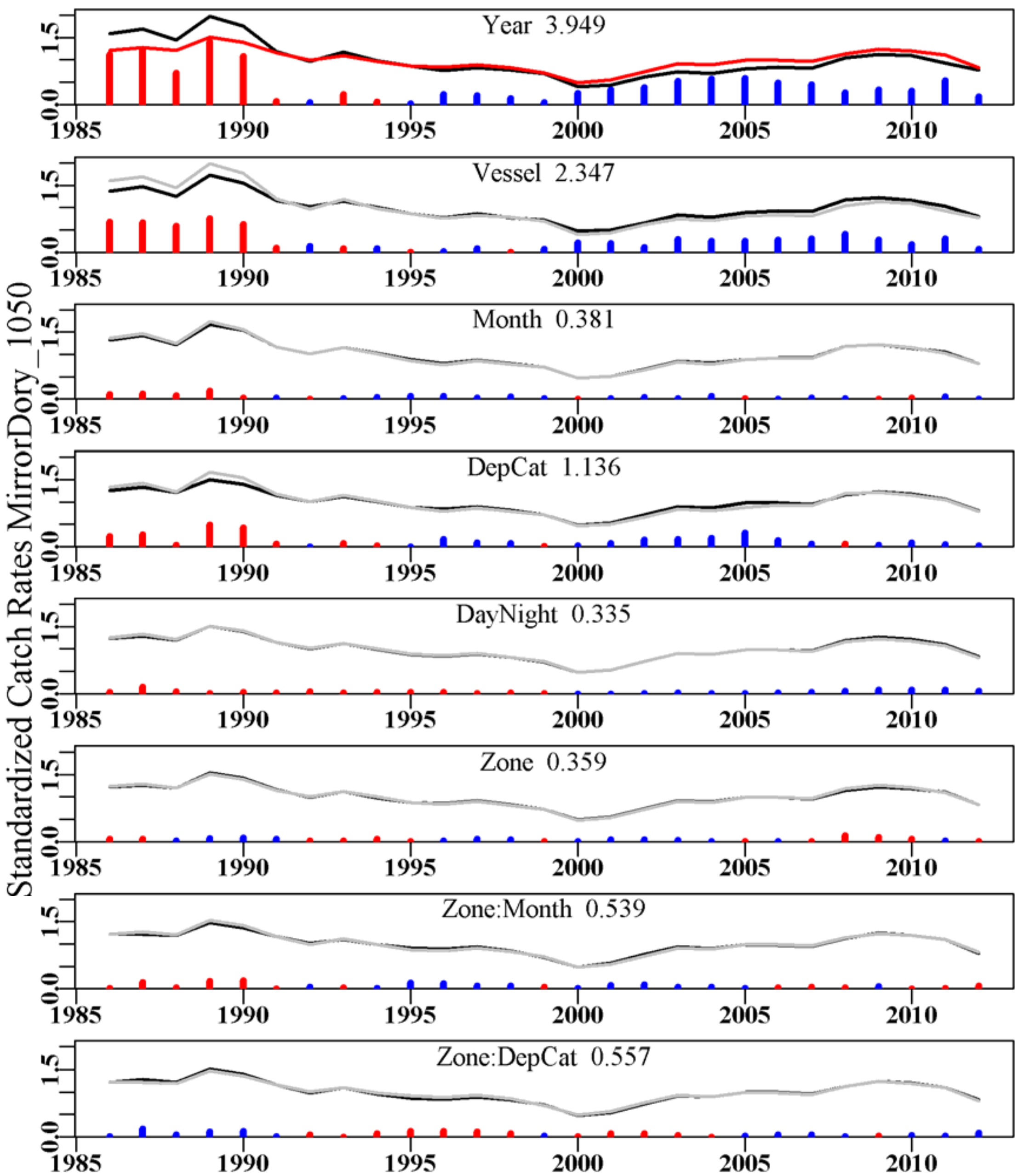



Figure 18.139. The relative influence of each factor used on the final trend in the optimal standardization for Mirror Dory from Zones 10 to 50. The top graph depicts the geometric mean (the black line) and the optimum model (the red line). The difference between them is illustrated by the vertical bars 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.

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

Only data from Zones 10 to 30 in depths 0 – 600m. All vessels reporting Mirror Dory were included.

Table 18.124. Mirror Dory from Zones 10 to 30 in depths 0 to 600 m by trawl. Total Catch is the total reported in the database, Records is the number of records used in the analysis, CatchT is the reported catch in the area and depth used in the analysis, and Vessels relates to all vessels used in the analysis. Geomean is the geometric mean of catch rates (kg/hr). Zone:Month is the optimum model and StDev is the standard deviation relating to the data in the optimum model.

| Year | TotCatch | Records | CatchT | Vessels | GeoMean | Zone:Mth | StDev |
|---|---|---|---|---|---|---|---|
| 1986 | 401.792 | 3141 | 367.985 | 80 | 18.7487 | 1.1544 | 0.0000 |
| 1987 | 449.654 | 2961 | 413.571 | 70 | 19.9429 | 1.1514 | 0.0324 |
| 1988 | 345.894 | 3067 | 313.237 | 77 | 16.8882 | 1.1314 | 0.0320 |
| 1989 | 589.92 | 2997 | 513.736 | 70 | 23.1617 | 1.3706 | 0.0325 |
| 1990 | 295.669 | 1811 | 254.38 | 61 | 20.5538 | 1.2855 | 0.0375 |
| 1991 | 230.138 | 2021 | 170.954 | 68 | 14.2052 | 1.1310 | 0.0368 |
| 1992 | 166.8353 | 2022 | 138.871 | 56 | 11.7312 | 0.9827 | 0.0369 |
| 1993 | 305.379 | 3013 | 267.091 | 62 | 14.1976 | 1.0769 | 0.0334 |
| 1994 | 297.238 | 3498 | 262.033 | 62 | 11.6924 | 0.9440 | 0.0325 |
| 1995 | 244.924 | 3500 | 196.29 | 59 | 10.2913 | 0.8593 | 0.0324 |
| 1996 | 351.587 | 4397 | 212.369 | 69 | 7.7998 | 0.7517 | 0.0312 |
| 1997 | 459.6263 | 4775 | 288.136 | 65 | 8.6425 | 0.7960 | 0.0311 |
| 1998 | 355.7935 | 4103 | 230.495 | 55 | 8.0944 | 0.7223 | 0.0317 |
| 1999 | 309.471 | 4225 | 234.873 | 59 | 7.8713 | 0.6464 | 0.0318 |
| 2000 | 171.0464 | 4633 | 142.7675 | 64 | 4.7885 | 0.4998 | 0.0317 |
| 2001 | 243.3413 | 4570 | 128.644 | 55 | 4.0443 | 0.5029 | 0.0320 |
| 2002 | 449.313 | 5038 | 194.4326 | 53 | 5.2594 | 0.6270 | 0.0315 |
| 2003 | 612.2641 | 5362 | 405.6785 | 58 | 7.7688 | 0.9220 | 0.0310 |
| 2004 | 506.183 | 4275 | 292.676 | 57 | 7.2635 | 0.8749 | 0.0323 |
| 2005 | 579.7056 | 4417 | 423.631 | 55 | 9.9946 | 1.1179 | 0.0321 |
| 2006 | 419.4475 | 3230 | 297.5593 | 44 | 10.3893 | 1.1214 | 0.0339 |
| 2007 | 289.5706 | 2223 | 203.162 | 22 | 11.4463 | 1.2150 | 0.0372 |
| 2008 | 396.2424 | 2495 | 317.705 | 26 | 14.4563 | 1.3541 | 0.0366 |
| 2009 | 476.5034 | 2232 | 338.4877 | 27 | 15.8458 | 1.4297 | 0.0376 |
| 2010 | 578.7681 | 2105 | 383.48 | 25 | 14.3976 | 1.1956 | 0.0379 |
| 2011 | 516.2987 | 2254 | 347.067 | 26 | 12.7502 | 1.1932 | 0.0374 |
| 2012 | 365.2682 | 1739 | 287.778 | 24 | 11.2957 | 0.9430 | 0.0400 |

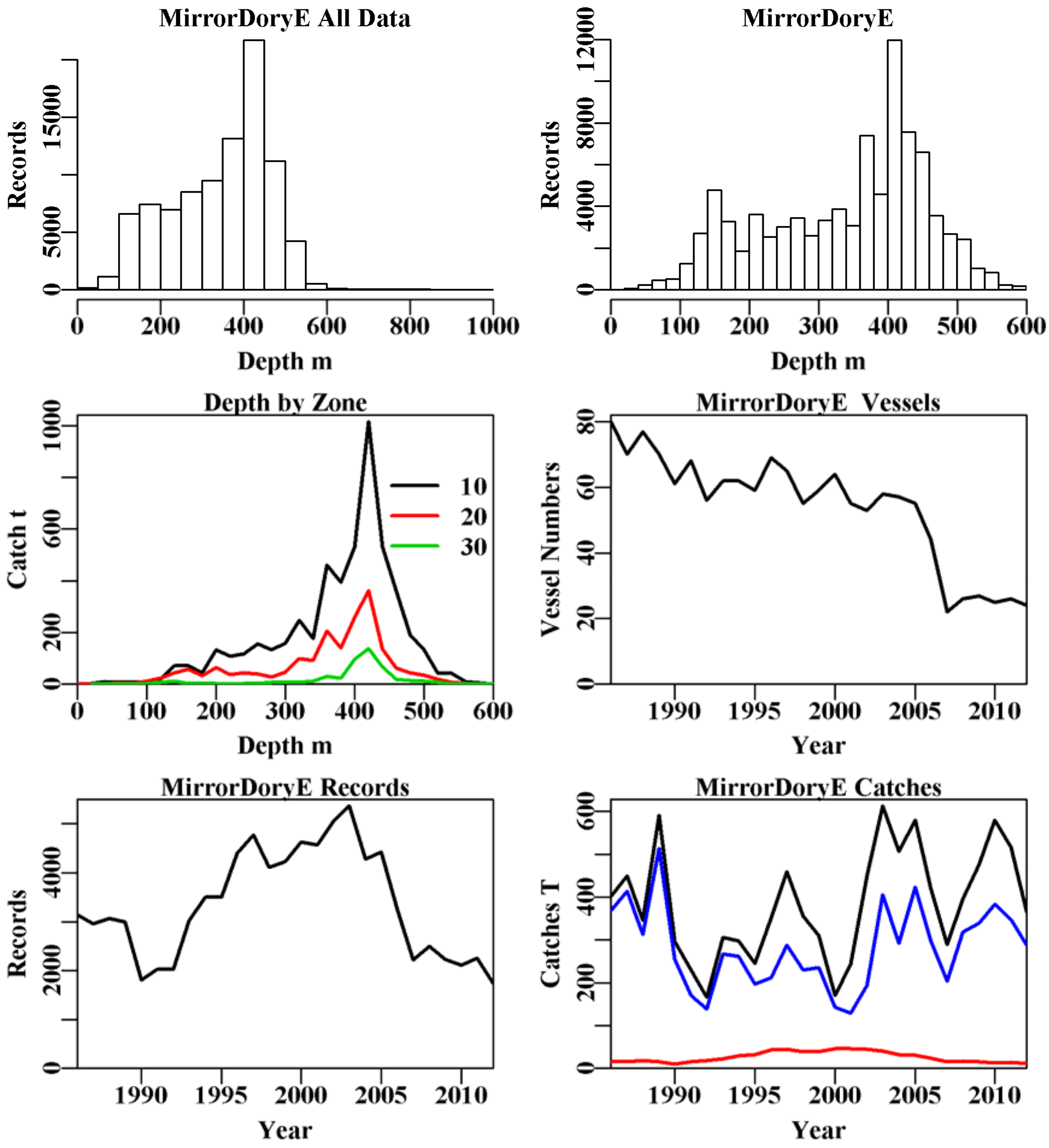



Figure 18.140. Mirror Dory from Zones 10 to 30 in depths 0 to 600 m by trawl. The top left is the depth distribution of all records reporting Mirror Dory, the top right graph depicts the depth distribution of shots containing Mirror Dory from Zones 10 to 30 in depths 0 to 600 m by trawl. The middle left diagram depicts the distribution of catch by depth within zones 10 to 30, the middle right hand graph depicts the number of vessels through time. The bottom left reflects the number of records used in analysis, and bottom right is the Mirror Dory catches (top line, black is total catches, middle line, blue, are those used in the analysis, and bottom, red, are catches < 30Kg).

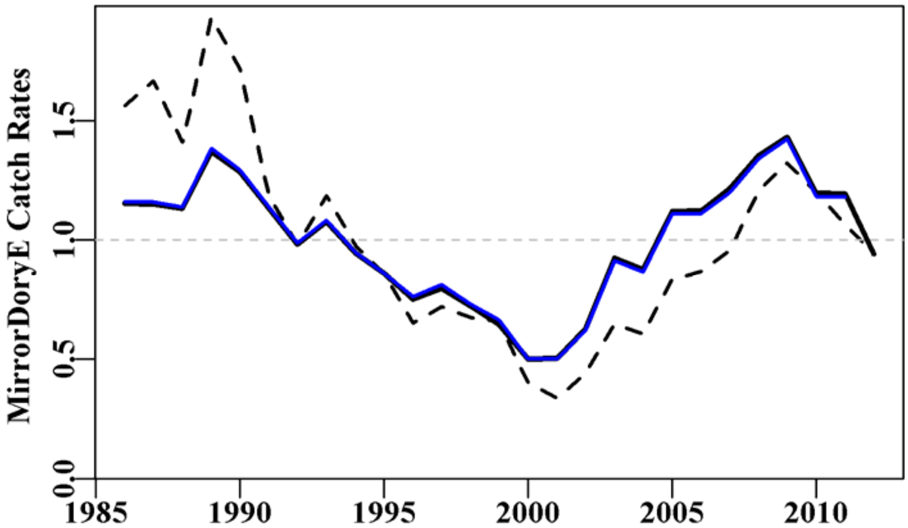



Figure 18.141. Mirror Dory from Zones 10 to 30 in depths 0 to 600 m by trawl. The dashed black line represents the geometric mean catch rate and the solid black line the standardized catch rates. The graph standardizes catch rates relative to the mean of the standardized catch rates.

Table 18.125. 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 18.126. Mirror Dory from Zones 10 to 30 in depths 0 to 600 m by trawl. Model selection criteria, including the AIC, the adjusted $r^2$ and the change in adjusted $r^2$. The optimum is Zone:Month (model 7).

| | Year | Vessel | DepCat | Month | DayNight | Zone | **Zone:Mth** | Zone:DepC |
|---|---|---|---|---|---|---|---|---|
| AIC | 61299 | 45584 | 35492 | 33794 | 33122 | 32432 | **30919** | 32166 |
| RSS | 177803 | 148768 | 132485 | 129966 | 128987 | 127993 | **125788** | 127442 |
| MSS | 18505 | 47540 | 63823 | 66342 | 67321 | 68315 | **70519** | 68866 |
| Nobs | 90104 | 90104 | 89626 | 89626 | 89626 | 89626 | **89626** | 89626 |
| Npars | 27 | 202 | 232 | 243 | 246 | 248 | **270** | 308 |
| adj_r2 | 9.400 | 24.048 | 32.337 | 33.616 | 34.113 | 34.620 | **35.730** | 34.857 |
| %Change | 0.000 | 14.647 | 8.290 | 1.278 | 0.498 | 0.507 | **1.110** | -0.873 |

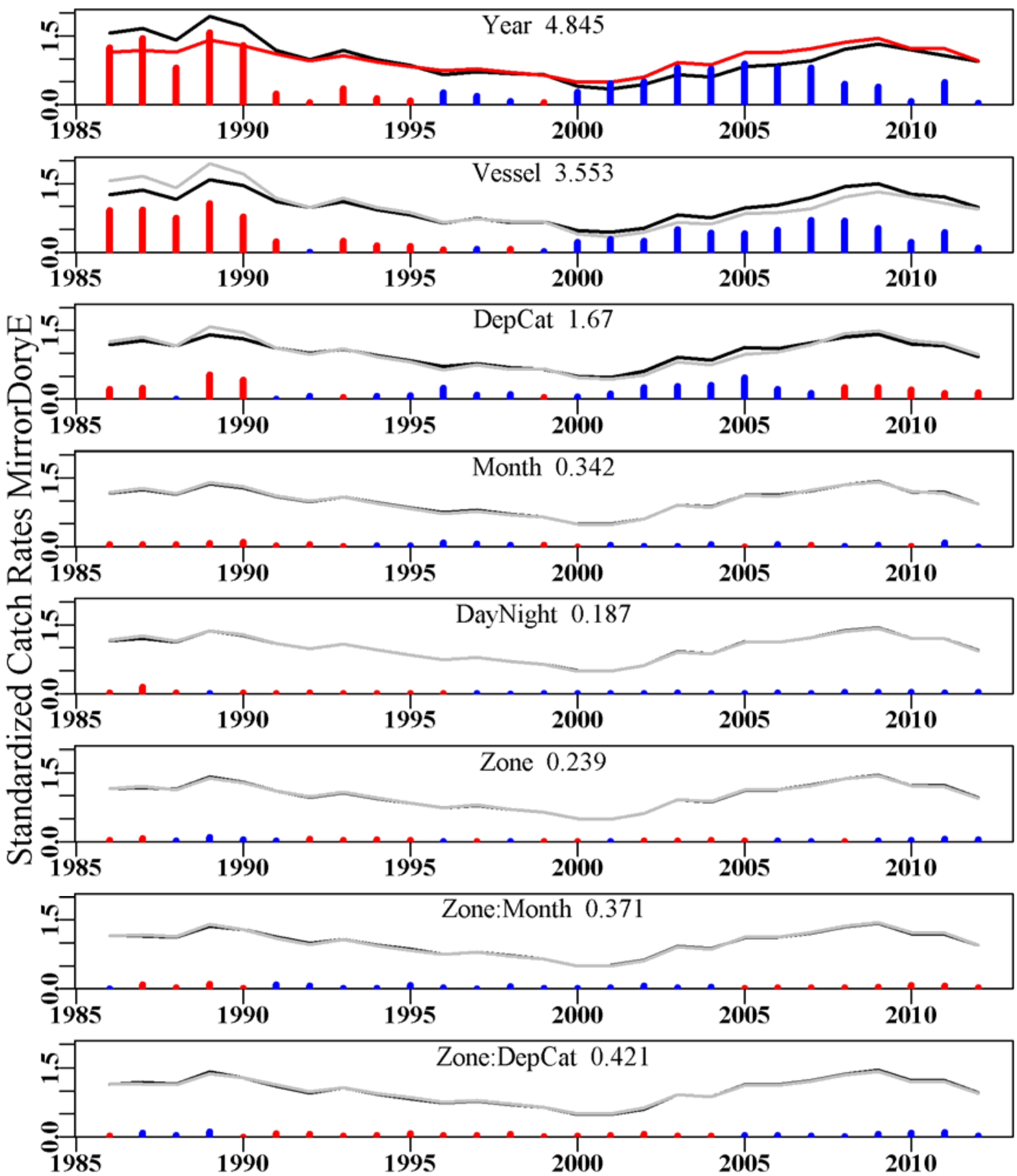



Figure 18.142. The relative influence of each factor used on the final trend in the optimal standardization for Mirror Dory from Zones 10 to 30. The top graph depicts the geometric mean (the black line) and the optimum model (the red line). The difference between them is illustrated by the vertical bars 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.

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

Only data from Zones 40 to 50 in depths 0 – 600m. All vessels reporting Mirror Dory were included.

Table 18.127. Mirror Dory from Zones 40 to 50 in depths 0 to 600 m by trawl. Total Catch is the total reported in the database, Records is the number of records used in the analysis, CatchT is the reported catch in the area and depth used in the analysis, and Vessels relates to all vessels used in the analysis. Geomean is the geometric mean of catch rates (kg/hr). Zone:Month is the optimum model and StDev is the standard deviation relating to the data in the optimum model.

| Year | TotCatch | Records | CatchT | Vessels | GeoMean | Zone:Mth | StDev |
|---|---|---|---|---|---|---|---|
| 1986 | 401.792 | 57 | 7.374 | 10 | 13.7130 | 2.4486 | 0.0000 |
| 1987 | 449.654 | 142 | 15.519 | 23 | 16.0832 | 1.6108 | 0.1997 |
| 1988 | 345.894 | 122 | 14.983 | 17 | 18.4525 | 1.3227 | 0.2085 |
| 1989 | 589.920 | 71 | 11.127 | 15 | 24.6757 | 1.6770 | 0.2200 |
| 1990 | 295.669 | 95 | 9.966 | 14 | 21.6631 | 1.1269 | 0.2236 |
| 1991 | 230.138 | 209 | 12.783 | 17 | 11.7670 | 0.8009 | 0.1971 |
| 1992 | 166.835 | 205 | 8.289 | 20 | 8.1608 | 0.6650 | 0.1987 |
| 1993 | 305.379 | 276 | 18.010 | 18 | 10.1017 | 0.7842 | 0.1939 |
| 1994 | 297.238 | 330 | 18.162 | 20 | 9.3264 | 0.6901 | 0.1924 |
| 1995 | 244.924 | 709 | 38.143 | 23 | 9.0896 | 0.8794 | 0.1894 |
| 1996 | 351.587 | 1438 | 115.145 | 26 | 13.3473 | 1.2517 | 0.1893 |
| 1997 | 459.626 | 1906 | 148.310 | 24 | 12.8686 | 1.2660 | 0.1888 |
| 1998 | 355.794 | 1469 | 116.211 | 20 | 12.6121 | 1.2261 | 0.1893 |
| 1999 | 309.471 | 1318 | 63.294 | 23 | 8.8763 | 0.8060 | 0.1895 |
| 2000 | 171.046 | 980 | 22.461 | 28 | 4.0569 | 0.4399 | 0.1904 |
| 2001 | 243.341 | 2446 | 105.280 | 29 | 7.9361 | 0.7588 | 0.1887 |
| 2002 | 449.313 | 3156 | 240.252 | 28 | 11.7181 | 1.1130 | 0.1884 |
| 2003 | 612.264 | 2429 | 154.899 | 27 | 11.0165 | 0.9545 | 0.1887 |
| 2004 | 506.183 | 2208 | 159.809 | 25 | 10.3786 | 0.9571 | 0.1889 |
| 2005 | 579.706 | 1769 | 100.006 | 23 | 8.0456 | 0.7563 | 0.1891 |
| 2006 | 419.448 | 1061 | 65.351 | 19 | 8.0395 | 0.6419 | 0.1902 |
| 2007 | 289.571 | 1177 | 64.941 | 16 | 6.7120 | 0.5779 | 0.1900 |
| 2008 | 396.242 | 879 | 58.533 | 17 | 7.5767 | 0.6475 | 0.1906 |
| 2009 | 476.503 | 1333 | 123.246 | 14 | 9.7010 | 0.9881 | 0.1894 |
| 2010 | 578.768 | 1596 | 177.550 | 14 | 11.0745 | 1.1728 | 0.1893 |
| 2011 | 516.299 | 1662 | 157.806 | 16 | 8.6510 | 0.8995 | 0.1892 |
| 2012 | 365.268 | 1018 | 70.217 | 15 | 6.0700 | 0.5376 | 0.1904 |

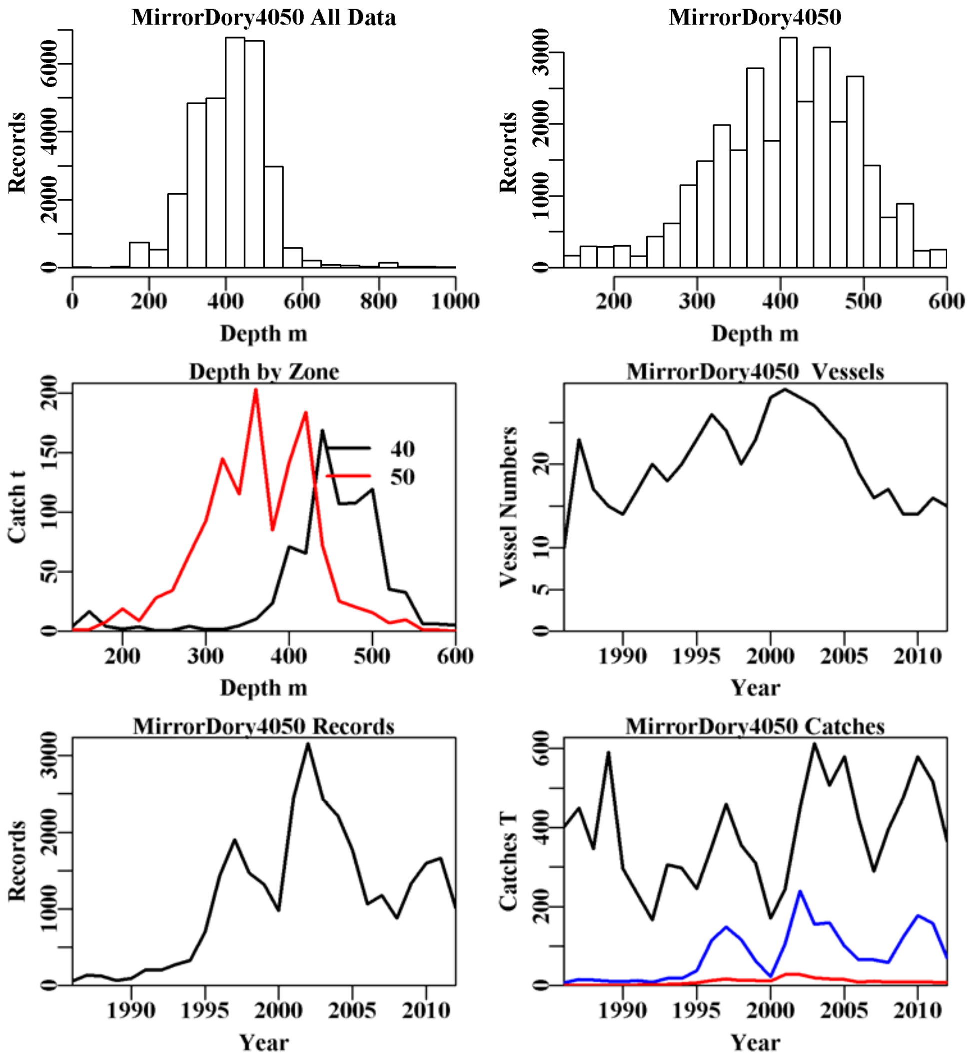



Figure 18.143. Mirror Dory from Zones 40 to 50 in depths 0 to 600 m by trawl. The top left is the depth distribution of all records reporting Mirror Dory, the top right graph depicts the depth distribution of shots containing Mirror Dory from Zones 40 to 50 in depths 0 to 600 m by trawl. The middle left diagram depicts the distribution of catch by depth within zones 40 to 50, the middle right hand graph depicts the number of vessels through time. The bottom left reflects the number of records used in analysis, and bottom right is the Mirror Dory catches (top line, black is total catches, middle line, blue, are those used in the analysis, and bottom, red, are catches < 30Kg).

Table 18.128. 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 |

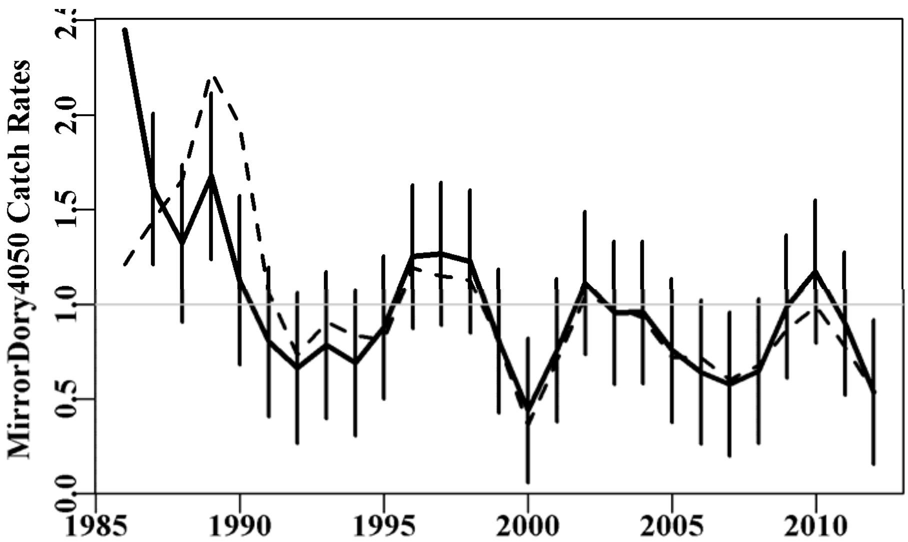



Figure 18.144. Mirror Dory from Zones 40 to 50 in depths 0 to 600 m by trawl. The dashed black line represents the geometric mean catch rate and the solid black line the standardized catch rates. The graph standardizes catch rates relative to the mean of the standardized catch rates.

Table 18.129. Mirror Dory from Zones 40 to 50 in depths 0 to 600 m by trawl. Model selection criteria, including the AIC, the adjusted $r^2$ and the change in adjusted $r^2$. The optimum is Zone:Month (model 7).

| | Year | Vessel | Month | DepCat | DayNight | Zone | **Zone:Mth** | Zone:DepC |
|---|---|---|---|---|---|---|---|---|
| AIC | 10144 | 3223 | 1721 | 433 | -253 | -605 | **-966** | -648 |
| RSS | 42050 | 33208 | 31567 | 30020 | 29333 | 28987 | **28619** | 28902 |
| MSS | 2231 | 11074 | 12715 | 14261 | 14948 | 15294 | **15663** | 15380 |
| Nobs | 30061 | 30061 | 30061 | 29885 | 29885 | 29885 | **29885** | 29885 |
| Npars | 27 | 115 | 126 | 149 | 152 | 153 | **164** | 176 |
| adj_r2 | 4.957 | 24.722 | 28.416 | 31.869 | 33.421 | 34.204 | **35.017** | 34.347 |
| %Change | 0.000 | 19.765 | 3.693 | 3.453 | 1.552 | 0.783 | **0.813** | -0.670 |

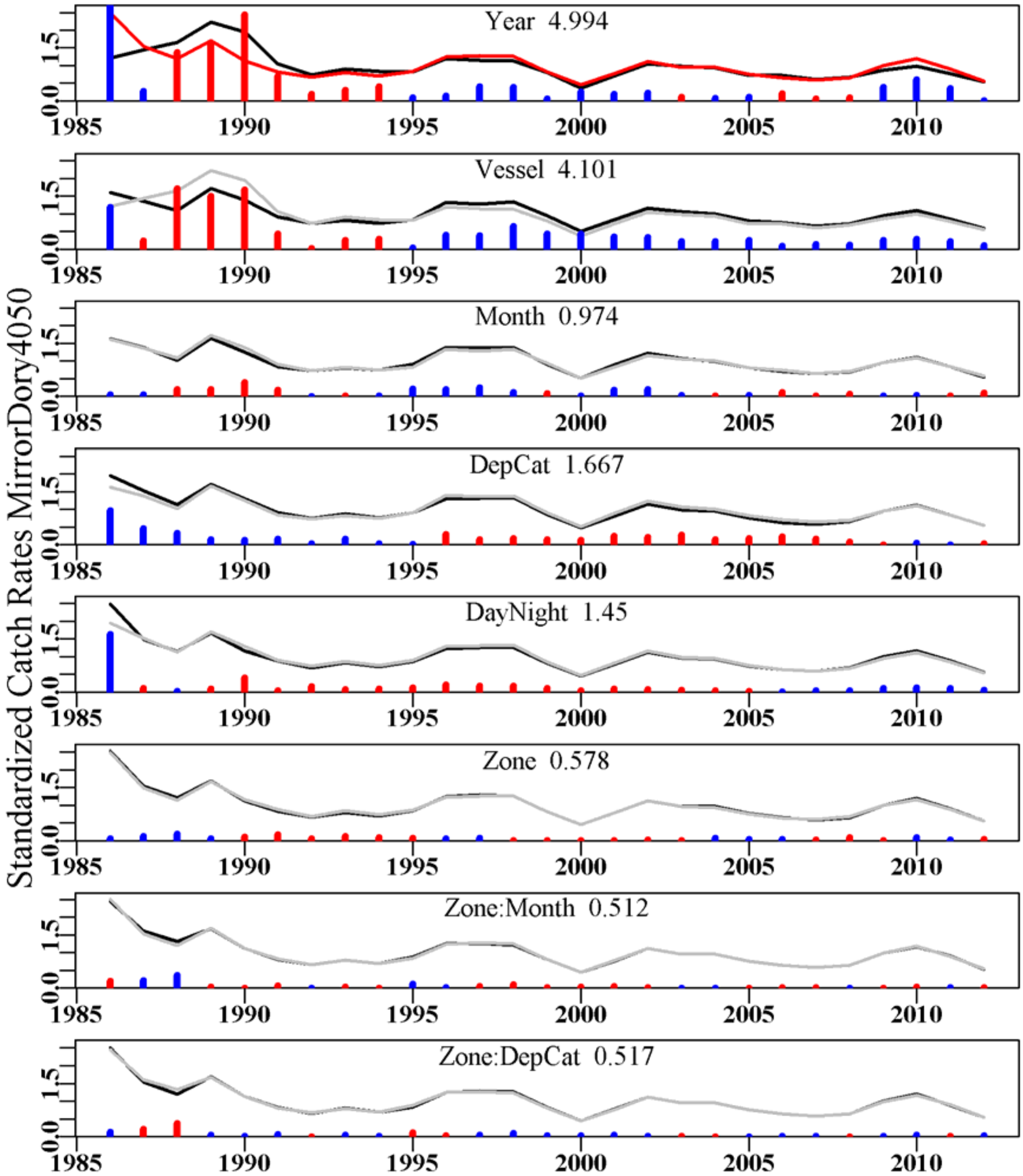



Figure 18.145. The relative influence of each factor used on the final trend in the optimal standardization for Mirror Dory from Zones 40 – 50. The top graph depicts the geometric mean (the black line) and the optimum model (the red line). The difference between them is illustrated by the vertical bars 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.

### *18.4.44 Ribaldo (RBD – 37224002 – Mora moro)*

Only data from Zones 10 to 50 in depths 0 – 1000m.

Table 18.130. Ribaldo from Zones 10 to 50 in depths 0 to 1000 m by trawl. Total Catch is the total reported in the database, Records is the number of records used in the analysis, CatchT is the reported catch in the area and depth used in the analysis, and Vessels relates to all vessels used in the analysis. Geomean is the geometric mean of catch rates (kg/hr). Zone:Mth is the optimum model and StDev is the standard deviation relating to the data in the optimum model.

| Year | TotCatch | Records | CatchT | Vessels | GeoMean | Zone:Mth | StDev |
|---|---|---|---|---|---|---|---|
| 1986 | 4.104 | 72 | 3.524 | 11 | 14.6630 | 2.2751 | 0.0000 |
| 1987 | 7.941 | 158 | 7.292 | 14 | 10.2593 | 1.2766 | 0.1388 |
| 1988 | 10.868 | 123 | 8.049 | 22 | 16.5570 | 1.9946 | 0.1552 |
| 1989 | 11.342 | 136 | 7.711 | 14 | 18.2556 | 1.8008 | 0.1535 |
| 1990 | 3.668 | 58 | 2.259 | 11 | 8.9113 | 1.4191 | 0.1740 |
| 1991 | 7.688 | 145 | 5.162 | 22 | 7.9930 | 1.3807 | 0.1532 |
| 1992 | 13.333 | 226 | 11.689 | 26 | 9.7616 | 1.3643 | 0.1450 |
| 1993 | 22.485 | 330 | 19.762 | 37 | 11.2449 | 1.1334 | 0.1448 |
| 1994 | 26.056 | 423 | 23.622 | 30 | 11.8156 | 1.2752 | 0.1424 |
| 1995 | 90.004 | 1147 | 86.299 | 26 | 12.3128 | 1.3346 | 0.1390 |
| 1996 | 82.278 | 1492 | 77.012 | 32 | 10.1757 | 1.0110 | 0.1388 |
| 1997 | 103.045 | 1714 | 96.567 | 30 | 9.8023 | 0.8805 | 0.1385 |
| 1998 | 99.824 | 1667 | 92.015 | 33 | 9.6696 | 0.8523 | 0.1386 |
| 1999 | 71.983 | 1133 | 59.668 | 32 | 8.7093 | 0.7859 | 0.1395 |
| 2000 | 66.536 | 1174 | 53.845 | 38 | 7.4217 | 0.7236 | 0.1394 |
| 2001 | 79.763 | 1122 | 52.390 | 37 | 6.7639 | 0.6772 | 0.1393 |
| 2002 | 157.033 | 1142 | 57.271 | 30 | 6.7944 | 0.6324 | 0.1395 |
| 2003 | 174.002 | 1310 | 66.180 | 35 | 6.7153 | 0.6250 | 0.1392 |
| 2004 | 180.109 | 1257 | 66.417 | 33 | 7.2233 | 0.6759 | 0.1395 |
| 2005 | 89.618 | 671 | 30.046 | 32 | 6.3488 | 0.5916 | 0.1413 |
| 2006 | 122.400 | 637 | 32.083 | 34 | 6.3304 | 0.6254 | 0.1414 |
| 2007 | 74.696 | 404 | 15.571 | 24 | 3.2493 | 0.4183 | 0.1441 |
| 2008 | 78.338 | 367 | 17.618 | 24 | 4.7326 | 0.5781 | 0.1447 |
| 2009 | 104.956 | 572 | 33.410 | 20 | 5.6978 | 0.6424 | 0.1419 |
| 2010 | 92.079 | 685 | 37.305 | 22 | 5.5851 | 0.6603 | 0.1410 |
| 2011 | 94.025 | 864 | 44.555 | 20 | 5.8331 | 0.6703 | 0.1401 |
| 2012 | 103.062 | 759 | 42.445 | 19 | 6.1631 | 0.6954 | 0.1410 |

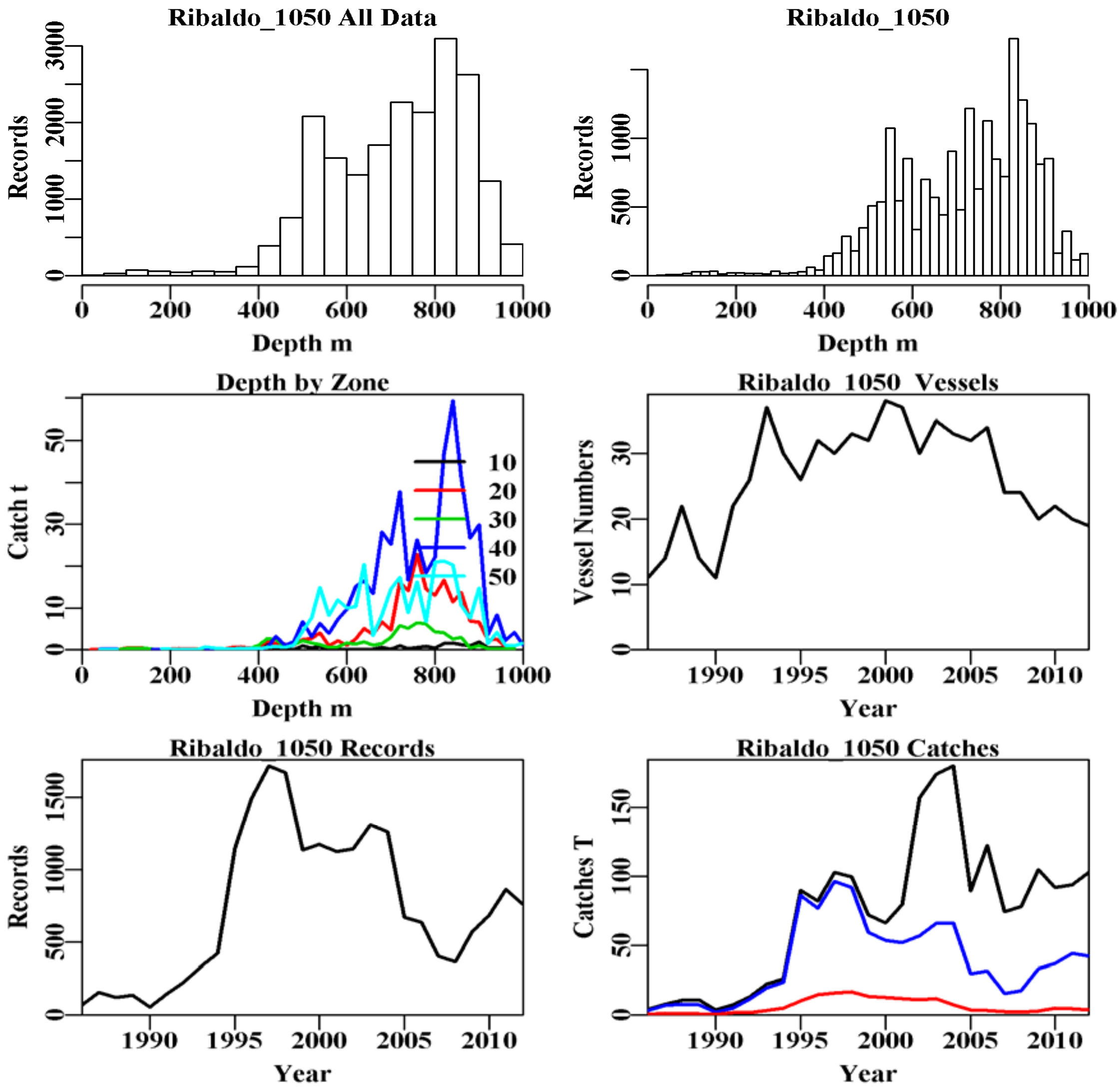



Figure 18.146. Ribaldo from Zones 10 to 50 in depths 0 to 1000 m by trawl. The top left is the depth distribution of all records reporting Ribaldo, the top right graph depicts the depth distribution of shots containing Ribaldo from Zones 10 to 50 in depths 0 to 1000 m by trawl. The middle left diagram depicts the distribution of catch by depth within zones 10 to 50, the middle right hand graph depicts the number of vessels through time. The bottom left reflects the number of records used in analysis, and bottom right is the Ribaldo catches (top line, black is total catches, middle line, blue, are those used in the analysis, and bottom, red, are catches < 30Kg).

Table 18.131. 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 |

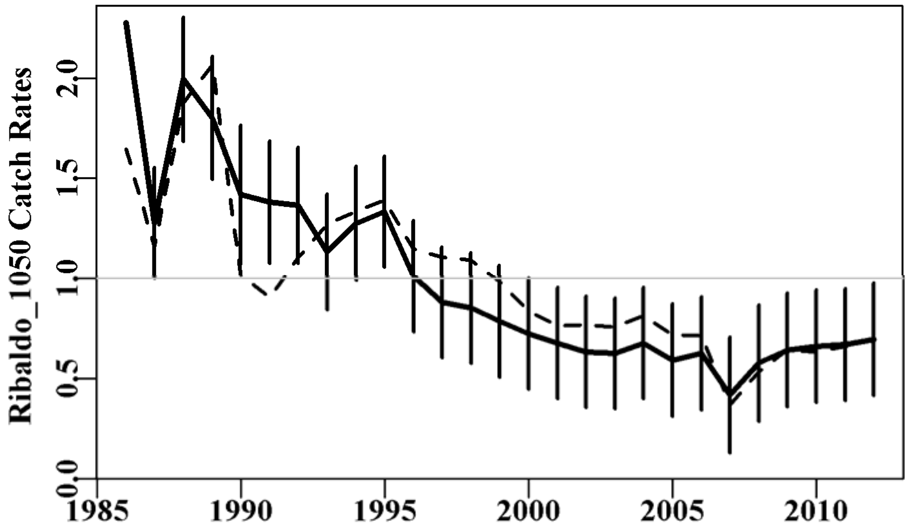



Figure 18.147. Ribaldo from Zones 10 to 50 in depths 0 to 1000 m by trawl. The dashed black line represents the geometric mean catch rate and the solid black line the standardized catch rates. The graph standardizes catch rates relative to the mean of the standardized catch rates.

Table 18.132. Ribaldo from Zones 10 to 50 in depths 0 to 1000 m by trawl. Model selection criteria, including the AIC, the adjusted $r^2$ and the change in adjusted $r^2$. The optimum is Zone:Month (model 7).

| | Year | Vessel | DepCat | Zone | DayNight | Month | **Zone:Mth** | Zone:DepC |
|---|---|---|---|---|---|---|---|---|
| AIC | -1879 | -3714 | -6250 | -6953 | -7057 | -7087 | **-7592** | -7382 |
| RSS | 17946 | 16157 | 13962 | 13465 | 13389 | 13354 | **12956** | 12888 |
| MSS | 1652 | 3441 | 5636 | 6133 | 6209 | 6244 | **6642** | 6710 |
| Nobs | 19788 | 19785 | 19597 | 19597 | 19597 | 19597 | **19597** | 19597 |
| Npars | 27 | 147 | 197 | 201 | 204 | 215 | **259** | 415 |
| adj_r2 | 8.308 | 16.945 | 28.039 | 30.586 | 30.966 | 31.110 | **33.009** | 32.817 |
| %Change | 0.000 | 8.638 | 11.093 | 2.547 | 0.379 | 0.145 | **1.899** | -0.192 |

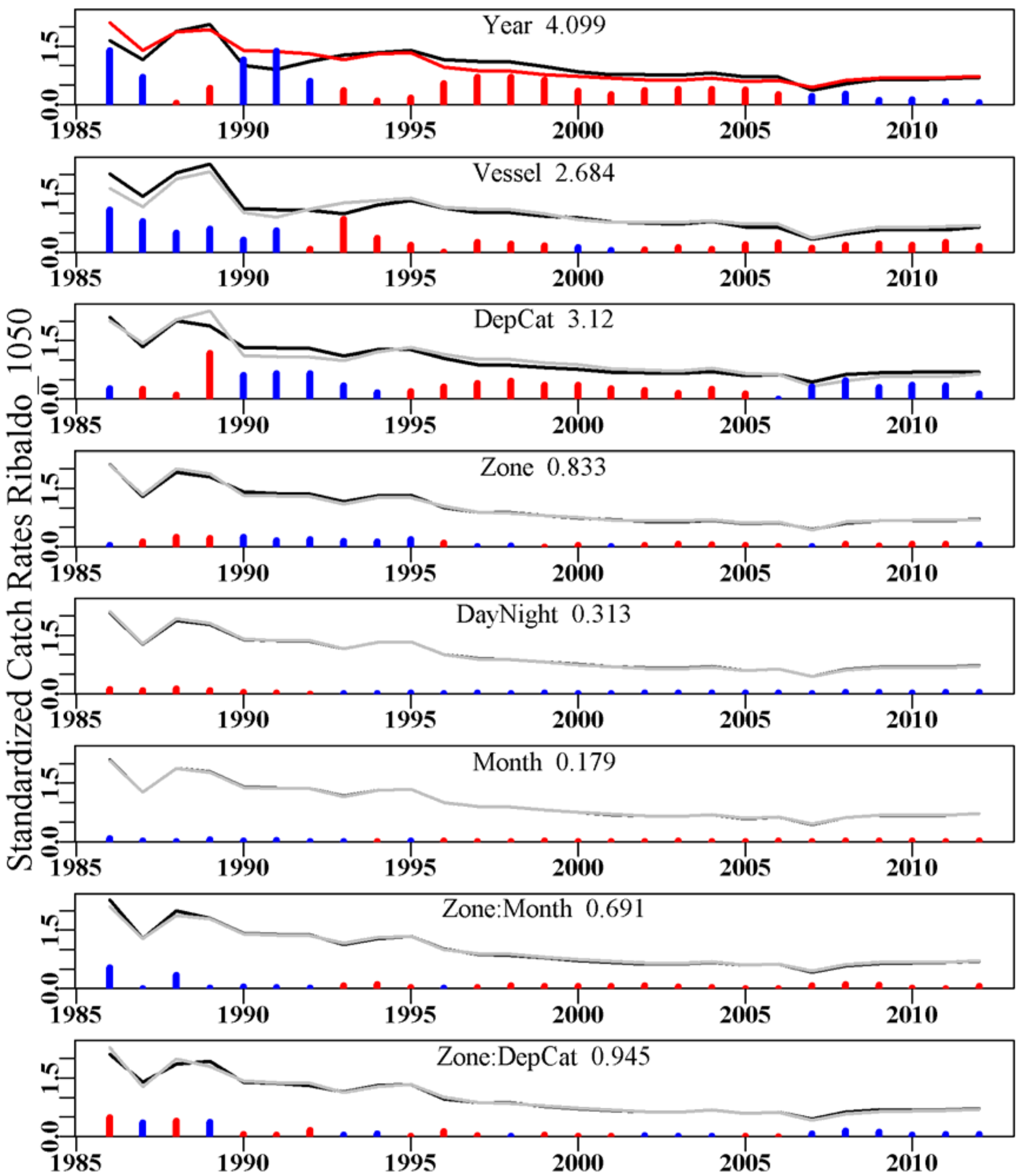
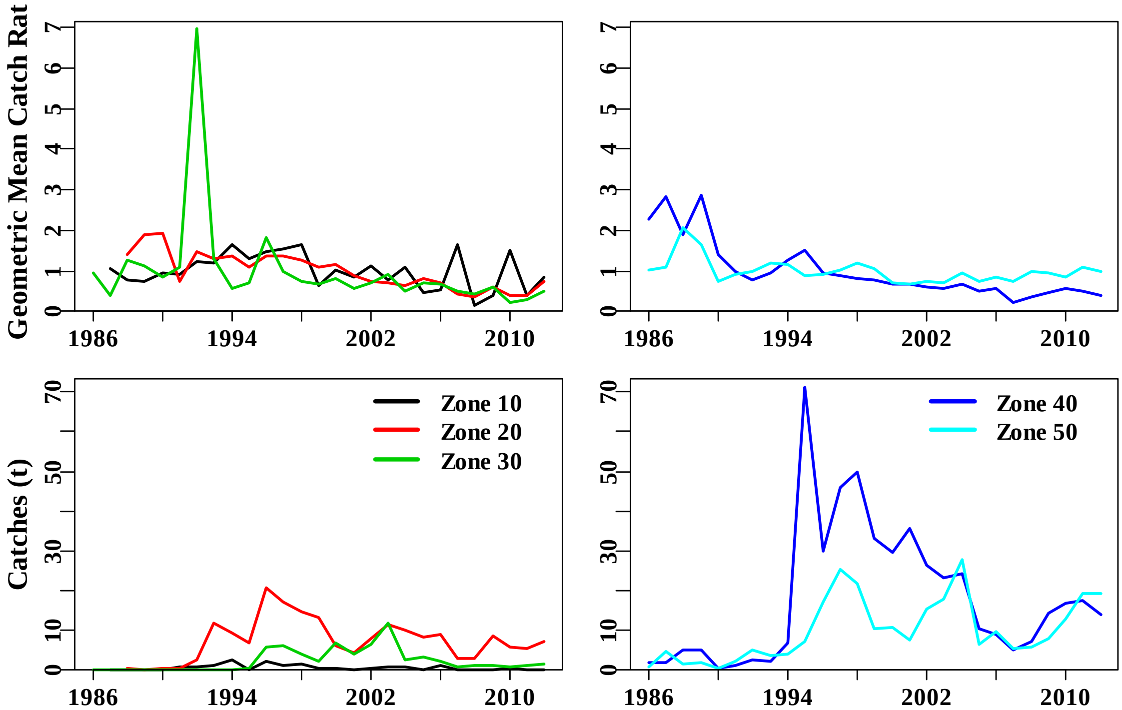



Figure 18.148. The relative influence of each factor used on the final trend in the optimal standardization for Ribaldo from Zones 10 to 50. The top graph depicts the geometric mean (the black line) and the optimum model (the red line). The difference between them is illustrated by the vertical bars 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.



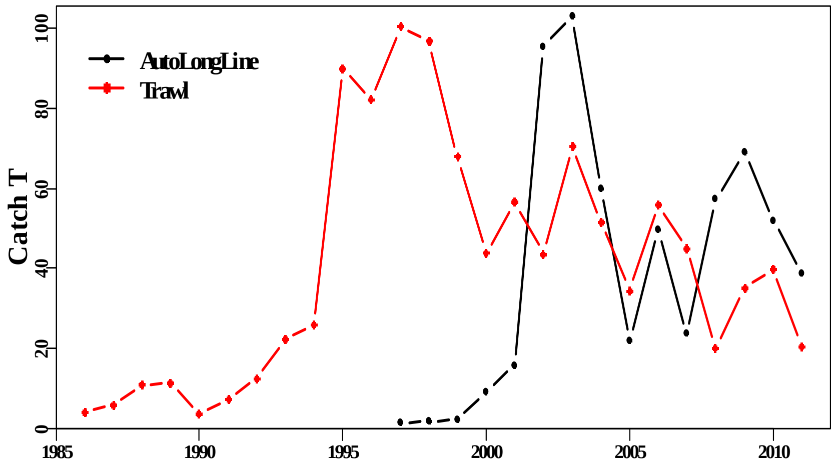




Figure 18.149. Ribaldo, all zones 10-50, plus the GAB and north of Barrenjoey. Catches by the two main methods, trawl and AutoLongLine. As with trawling, most catches by AutoLongLine are taken in zones 20-50.

### *18.4.44.1 The Effect of Closures*

An alternative analysis was conducted (Haddon (2010) that included a factor for inside and outside of the current deepwater closures. After the other single factors had been included in the standardization there was no significant effect of being inside or outside of a closure.

By considering the current deepwater closures and identifying each shot with respect to its starting position the catches within and outside the closures can be characterized (Figure 18.150, Figure 18.151,Table 18.133).

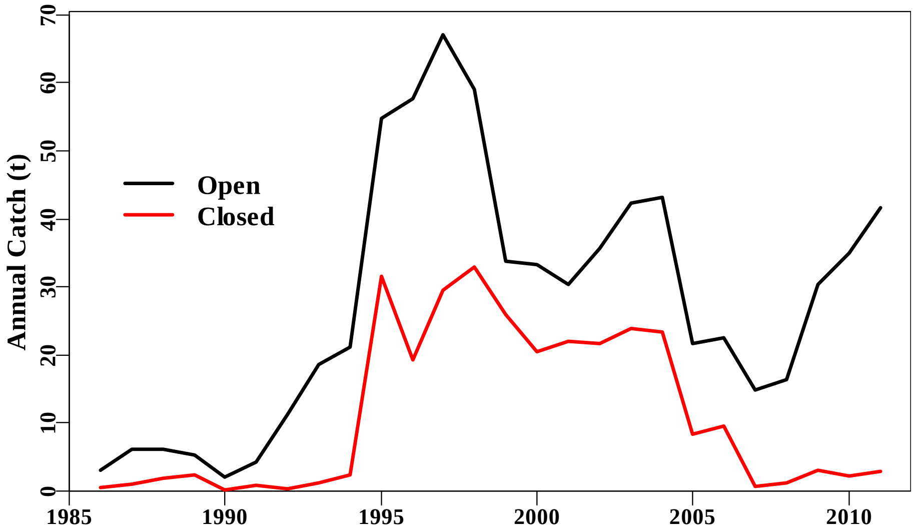



Figure 18.150. The annual catches of Ribaldo taken by trawl inside and outside of declared deepwater closures. The low catches taken from 2008 onwards derive from the precision of the available location data to discern all shots that are taken along the outer edge of a closure.

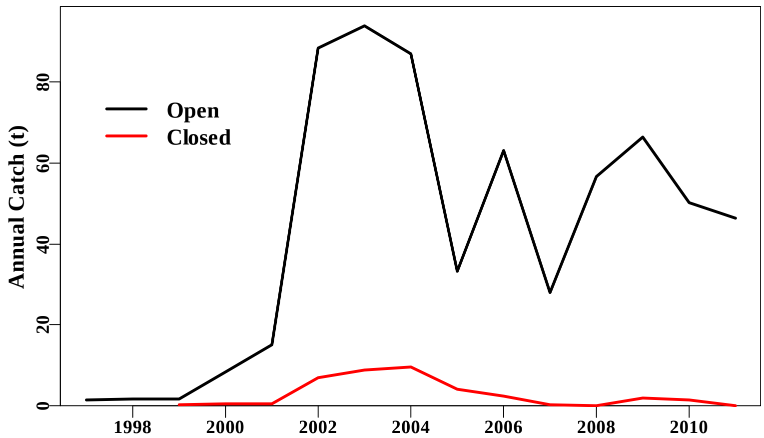



Figure 18.151. The annual catches of Ribaldo taken by AutoLine inside and outside of declared deepwater closures. The low catches taken from 2008 onwards derive from the precision of the available location data to discern all shots that are taken along the outer edge of a closure.

Table 18.133. Catches of Ribaldo by Trawl and AutoLine in open and closed areas.

| | Trawl | | AutoLine | |
|---|---|---|---|---|
| Year | Open | Closed | Open | Closed |
| 1986 | 3.054 | 0.470 | | |
| 1987 | 6.173 | 1.119 | | |
| 1988 | 6.082 | 1.967 | | |
| 1989 | 5.266 | 2.445 | | |
| 1990 | 2.144 | 0.115 | | |
| 1991 | 4.278 | 0.884 | | |
| 1992 | 11.354 | 0.335 | | |
| 1993 | 18.539 | 1.223 | | |
| 1994 | 21.175 | 2.447 | | |
| 1995 | 54.787 | 31.512 | | |
| 1996 | 57.647 | 19.365 | | |
| 1997 | 67.066 | 29.501 | 1.375 | 0.030 |
| 1998 | 59.008 | 33.007 | 1.753 | |
| 1999 | 33.724 | 25.944 | 1.687 | 0.260 |
| 2000 | 33.332 | 20.513 | 8.486 | 0.553 |
| 2001 | 30.350 | 22.040 | 15.110 | 0.610 |
| 2002 | 35.577 | 21.695 | 88.474 | 7.023 |
| 2003 | 42.289 | 23.891 | 93.960 | 8.922 |
| 2004 | 43.108 | 23.309 | 87.052 | 9.537 |
| 2005 | 21.626 | 8.421 | 33.177 | 4.013 |
| 2006 | 22.564 | 9.520 | 63.046 | 2.329 |
| 2007 | 14.802 | 0.769 | 27.887 | 0.239 |
| 2008 | 16.348 | 1.271 | 56.655 | 0.118 |
| 2009 | 30.393 | 3.017 | 66.447 | 1.827 |
| 2010 | 35.040 | 2.265 | 50.216 | 1.472 |
| 2011 | 41.630 | 2.925 | 46.364 | 0.113 |

### 18.4.45 Ribaldo (RBD – 37224002 – Mora moro) AutoLine

Table 18.134. Ribaldo taken by Autoline in Zones 20,30 40,50,81,82,83,84,85 in depths 0 to 1000 m. Total Catch is the total reported in the database, Records is the number of records used in the analysis, CatchT is the reported catch in the area and depth used in the analysis, and Vessels relates to all vessels used in the analysis. Geomean is the geometric mean of catch rates (kg/hr). Zone:Month is the optimum model and StDev is the standard deviation relating to the data in the optimum model.

| Year | TotCatch | Records | CatchT | Vessels | GeoMean | Zone:Month | StDev |
|---|---|---|---|---|---|---|---|
| 2001 | 79.763 | 63 | 15.720 | 2 | 157.4316 | 1.0324 | 0.0000 |
| 2002 | 157.033 | 259 | 95.497 | 4 | 135.9460 | 2.3532 | 0.3821 |
| 2003 | 174.002 | 337 | 102.882 | 7 | 75.0323 | 1.7211 | 0.3901 |
| 2004 | 180.109 | 714 | 96.589 | 11 | 51.6307 | 1.4747 | 0.3879 |
| 2005 | 89.618 | 308 | 37.189 | 7 | 44.5029 | 0.8430 | 0.3919 |
| 2006 | 122.400 | 605 | 65.374 | 8 | 39.5786 | 0.8635 | 0.3879 |
| 2007 | 74.696 | 393 | 28.125 | 6 | 25.0254 | 0.5236 | 0.3908 |
| 2008 | 78.338 | 401 | 56.772 | 6 | 39.2440 | 0.6206 | 0.3879 |
| 2009 | 104.956 | 433 | 68.273 | 6 | 49.5683 | 0.6195 | 0.3883 |
| 2010 | 92.079 | 381 | 51.687 | 5 | 47.4986 | 0.5930 | 0.3890 |
| 2011 | 94.025 | 356 | 46.476 | 5 | 45.6603 | 0.7078 | 0.3889 |
| 2012 | 103.062 | 295 | 58.847 | 6 | 60.9351 | 0.6476 | 0.3887 |

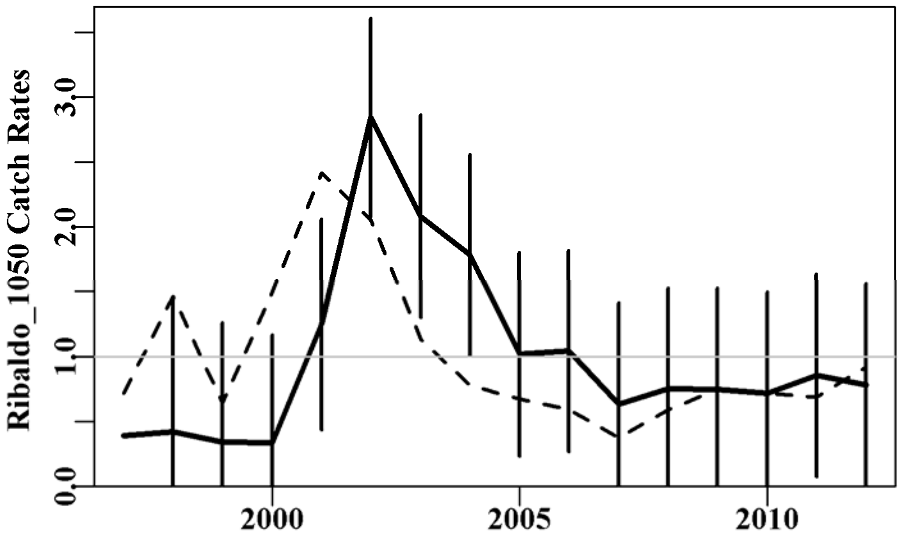



Figure 18.152. Standardized catch rates for Ribaldo by Autoline. The dashed black line represents the geometric mean catch rate and the solid black line the standardized catch rates. The graph standardizes catch rates relative to the mean of the standardized catch rates. The vertical black lines represent 1.96 times the standard errors. The same statistical models that were used for the trawl analysis were also used here (Table 18.131).

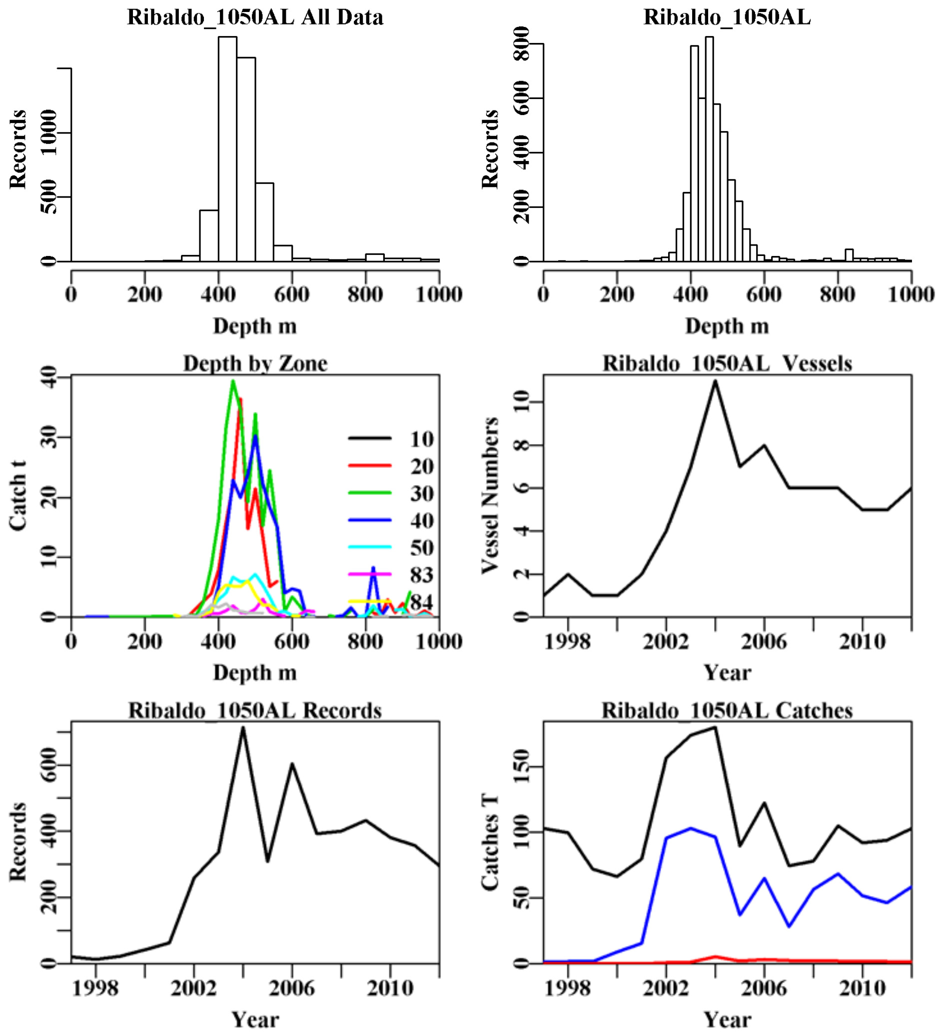



Figure 18.153. Ribaldo by Autoline. The top left is the depth distribution of all records reporting Ribaldo taken by autoline, the top right graph depicts the depth distribution of shots containing Ribaldo taken by Autoline as used in the standardization. The middle left diagram depicts the distribution of catch by depth within each zone, the middle right hand graph depicts the number of vessels through time. The bottom left reflects the number of records used in analysis, and bottom right is the Ribaldo catches (top line, black is total catches, middle line, blue, are those used in the analysis, and bottom, red, are catches < 30Kg).

Table 18.135. Ribaldo taken by Autoline. Model selection criteria, including the AIC, the adjusted $r^2$ and the change in adjusted $r^2$. The optimum is Zone:Month (model 7).

| | Year | Vessel | DepCat | Zone | DayNight | Month | **Zone:Mth** | Zone:DepC |
|---|---|---|---|---|---|---|---|---|
| AIC | 3784 | 2277 | 1991 | 1925 | 1903 | 1841 | 1707 | 2113 |
| RSS | 10300 | 7185 | 6580 | 6455 | 6413 | 6287 | 5874 | 5875 |
| MSS | 648 | 3764 | 4369 | 4493 | 4536 | 4661 | 5074 | 5074 |
| Nobs | 4250 | 4250 | 4236 | 4236 | 4236 | 4236 | 4236 | 4236 |
| Npars | 11 | 23 | 63 | 70 | 73 | 84 | 161 | 364 |
| adj_r2 | 5.700 | 34.036 | 39.011 | 40.063 | 40.413 | 41.428 | 44.240 | 41.314 |
| %Change | 0.000 | 28.337 | 4.974 | 1.053 | 0.350 | 1.014 | 2.812 | -0.114 |

### 18.4.46 Ocean Jackets (LTC – 37465006 – Nelusetta ayraudi) Alternate: LeatherJackets (LTH – 37465000)

Only data from Zones 10 to 50 in depths 0 – 300m. All vessels and records reporting leatherjackets are included. This is the first year this data has been considered.

Table 18.136. Ocean Jackets from Zones 10 to 50 in depths 0 to 300 m by trawl. Total Catch is the total reported in the database, Records is the number of records used in the analysis, CatchT is the reported catch in the area and depth used in the analysis, and Vessels relates to all vessels used in the analysis. Geomean is the geometric mean of catch rates (kg/hr). Zone:DepCat is the optimum model and StDev is the standard deviation relating to the data in the optimum model.

| Year | TotCatch | Records | CatchT | Vessels | GeoMean | Zone:DepCat | StDev |
|---|---|---|---|---|---|---|---|
| 1986 | 56.429 | 2473 | 44.715 | 75 | 5.0337 | 0.6676 | 0.0000 |
| 1987 | 53.249 | 1445 | 28.151 | 61 | 5.1085 | 0.7043 | 0.0361 |
| 1988 | 66.199 | 1911 | 45.725 | 66 | 6.2067 | 0.8544 | 0.0335 |
| 1989 | 70.961 | 1808 | 32.778 | 65 | 4.8860 | 0.7349 | 0.0341 |
| 1990 | 90.954 | 1548 | 33.157 | 46 | 4.9715 | 0.7195 | 0.0360 |
| 1991 | 170.170 | 1329 | 24.788 | 46 | 4.4265 | 0.6269 | 0.0379 |
| 1992 | 88.453 | 1127 | 22.074 | 40 | 4.7352 | 0.6250 | 0.0396 |
| 1993 | 71.645 | 1342 | 29.245 | 42 | 5.0852 | 0.6997 | 0.0384 |
| 1994 | 74.338 | 1455 | 35.044 | 45 | 5.9717 | 0.7850 | 0.0370 |
| 1995 | 140.159 | 2237 | 59.316 | 42 | 5.9904 | 0.7934 | 0.0334 |
| 1996 | 199.569 | 2576 | 72.307 | 54 | 6.3230 | 0.8183 | 0.0327 |
| 1997 | 177.394 | 2009 | 52.492 | 51 | 5.4540 | 0.7433 | 0.0344 |
| 1998 | 189.864 | 2488 | 68.017 | 44 | 5.2603 | 0.7352 | 0.0330 |
| 1999 | 202.805 | 2691 | 88.415 | 52 | 7.0029 | 0.8601 | 0.0325 |
| 2000 | 198.801 | 2983 | 73.176 | 52 | 5.1836 | 0.6873 | 0.0322 |
| 2001 | 222.507 | 3160 | 63.794 | 55 | 4.2040 | 0.6095 | 0.0320 |
| 2002 | 377.963 | 4863 | 199.088 | 61 | 5.4894 | 0.7270 | 0.0301 |
| 2003 | 482.065 | 5503 | 187.624 | 58 | 5.0890 | 0.6933 | 0.0296 |
| 2004 | 691.983 | 6214 | 313.391 | 60 | 8.3226 | 1.1299 | 0.0292 |
| 2005 | 890.143 | 5162 | 342.889 | 54 | 9.8920 | 1.3135 | 0.0301 |
| 2006 | 741.356 | 4636 | 301.737 | 50 | 10.2758 | 1.4563 | 0.0306 |
| 2007 | 564.345 | 3092 | 285.396 | 27 | 14.0314 | 1.7657 | 0.0329 |
| 2008 | 490.402 | 3554 | 318.317 | 29 | 13.7150 | 1.6679 | 0.0324 |
| 2009 | 609.940 | 3260 | 376.112 | 28 | 16.0145 | 1.8741 | 0.0328 |
| 2010 | 482.686 | 3258 | 300.273 | 29 | 13.2712 | 1.5658 | 0.0328 |
| 2011 | 487.064 | 3224 | 277.268 | 29 | 12.3518 | 1.4520 | 0.0328 |
| 2012 | 417.243 | 3443 | 343.840 | 30 | 14.4818 | 1.6902 | 0.0326 |

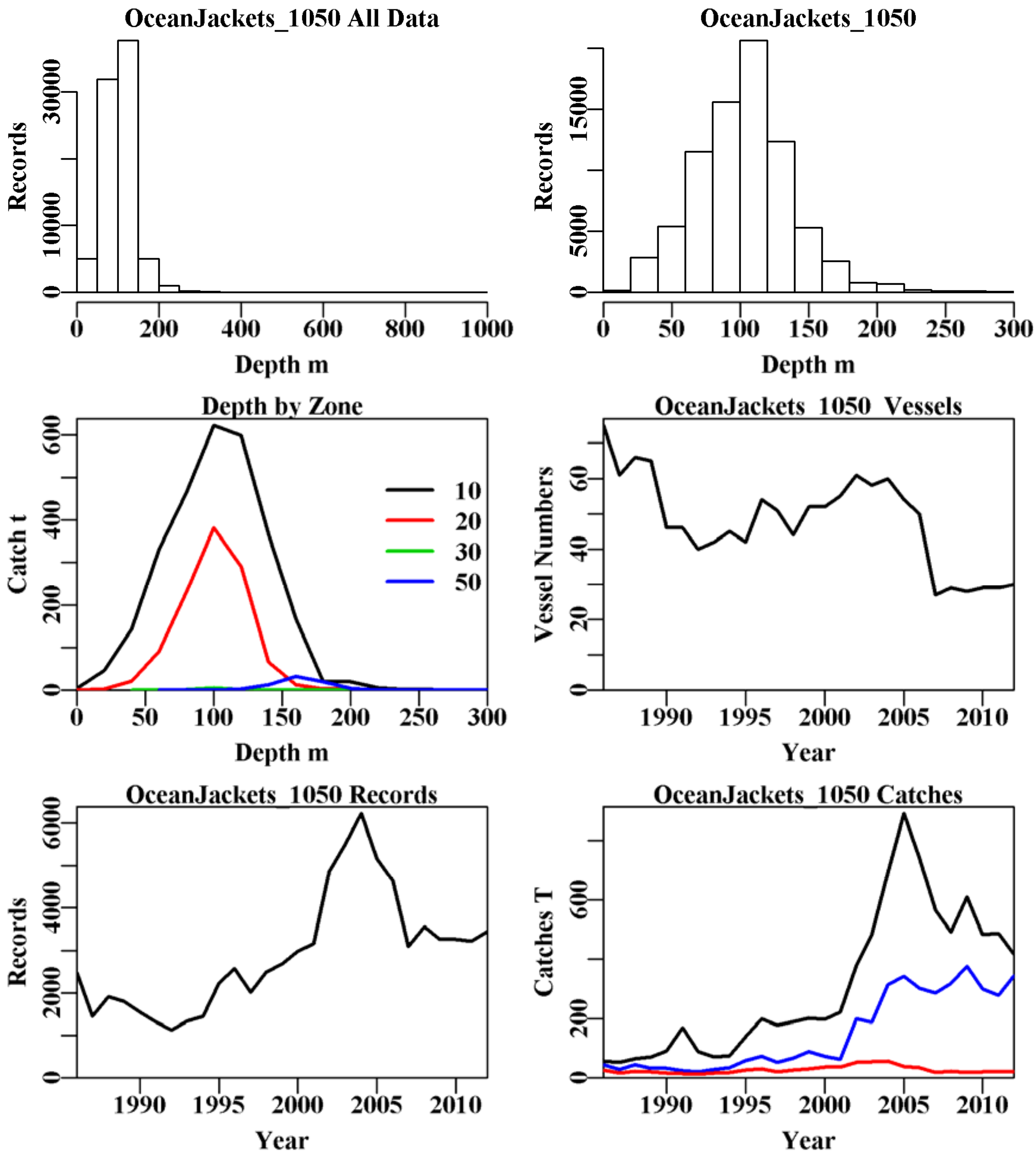



Figure 18.154. Ocean Jackets from Zones 10 to 50 in depths 0 to 300 m by trawl. The top left is the depth distribution of all records reporting Leatherjackets, the top right graph depicts the depth distribution of shots containing Ocean Jackets from Zones 10 to 50 in depths 0 to 300 m by trawl. The middle left diagram depicts the distribution of catch by depth within zones 10 to 50, the middle right hand graph depicts the number of vessels through time. The bottom left reflects the number of records used in analysis, and bottom right is the Leatherjacket catches (top line, black is total catches, middle line, blue, are those used in the analysis, and bottom, red, are catches < 30Kg).

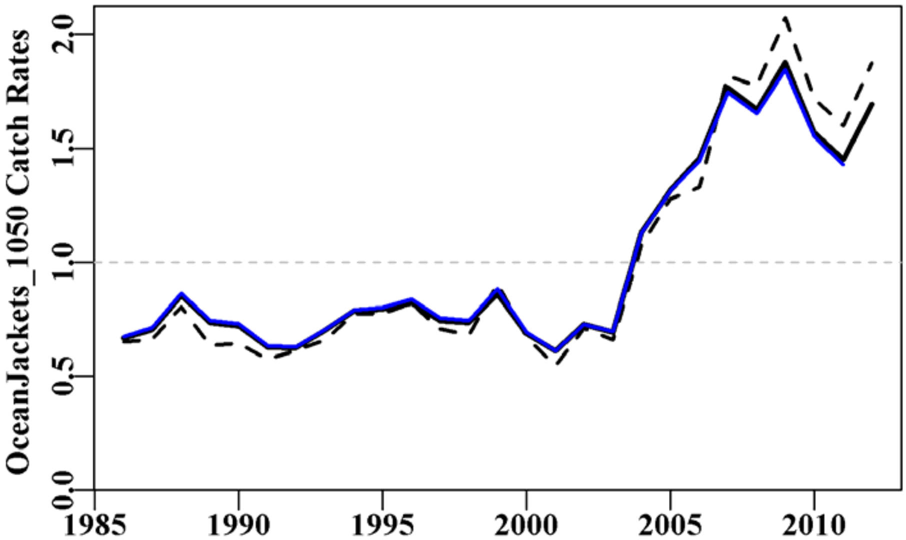



Figure 18.155. Ocean Jackets from Zones 10 to 50 in depths 0 to 300 m by trawl. The dashed black line represents the geometric mean catch rate and the solid black line the standardized catch rates. The graph standardizes catch rates relative to the mean of the standardized catch rates. The fine vertical lines are the 95% confidence intervals. The horizontal blue line is at one, which is the average of the time series. If the standardization is only applied to data from Zones 10 and 20 differences occur only at the third decimal place in the standardization.

Table 18.137. 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 18.138. Ocean Jackets from Zones 10 to 50 in depths 0 to 300 m by trawl. Model selection criteria, including the AIC, the adjusted $r^2$ and the change in adjusted $r^2$. The optimum is Zone:DepCat (model 8).

| | Year | Vessel | DepCat | Month | Zone | DayNight | Zone:Mth | **Zone:DepC** |
|---|---|---|---|---|---|---|---|---|
| AIC | 15796 | 2294 | 1908 | 1324 | 850 | 802 | 620 | **-30** |
| RSS | 96216 | 80720 | 79761 | 79146 | 78662 | 78608 | 78359 | **77687** |
| MSS | 14282 | 29778 | 30737 | 31352 | 31835 | 31889 | 32138 | **32810** |
| Nobs | 78791 | 78791 | 78257 | 78257 | 78257 | 78257 | 78257 | **78257** |
| Npars | 27 | 194 | 209 | 220 | 223 | 226 | 259 | **271** |
| adj_r2 | 12.896 | 26.769 | 27.624 | 28.172 | 28.608 | 28.654 | 28.850 | **29.450** |
| %Change | 0.000 | 13.873 | 0.855 | 0.548 | 0.436 | 0.046 | 0.196 | **0.599** |

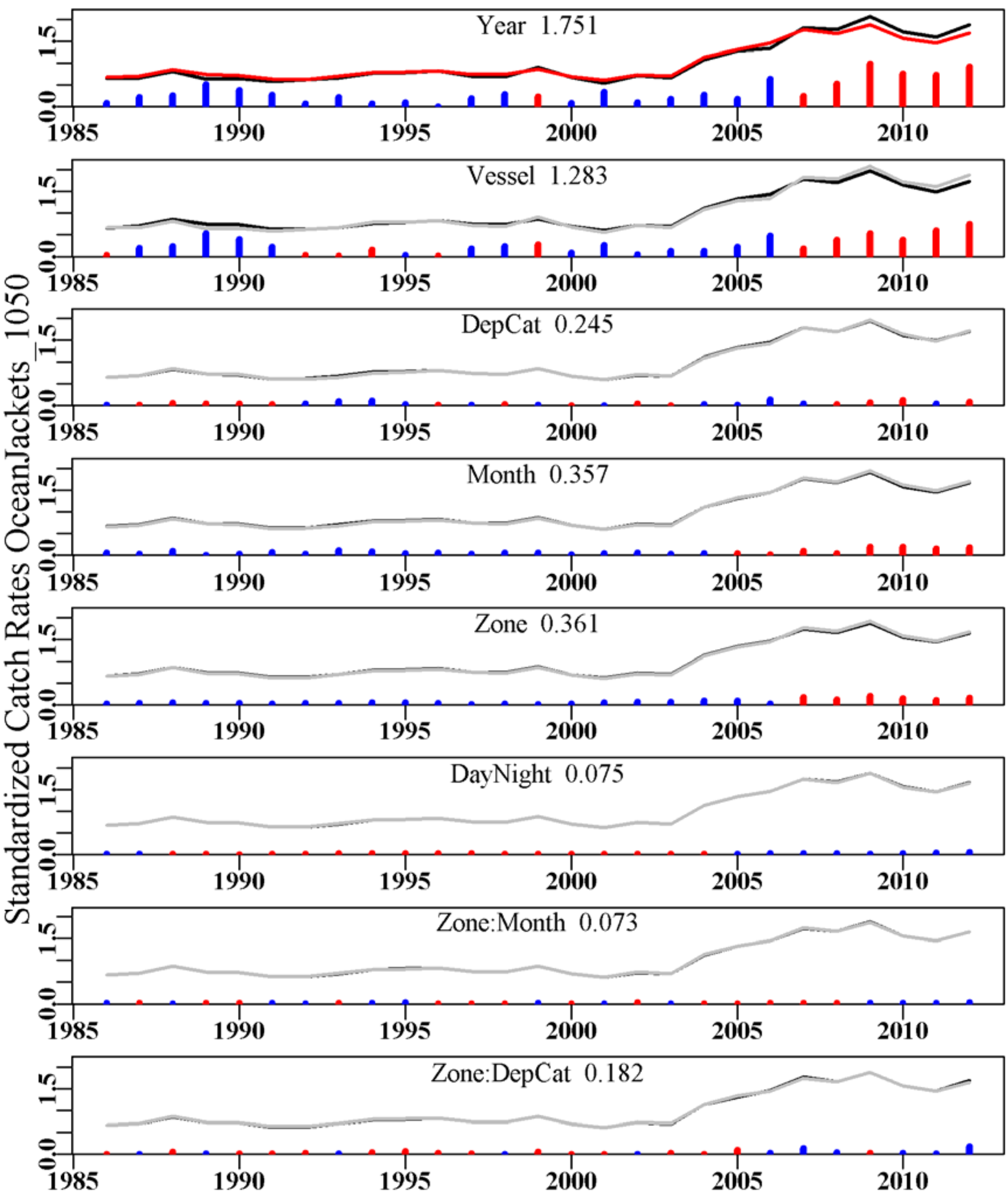



Figure 18.156. The relative influence of each factor used on the final trend in the optimal standardization for Ocean Jackets from Zones 10 to 50. The top graph depicts the geometric mean (the black line) and the optimum model (the red line). The difference between them is illustrated by the vertical 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.

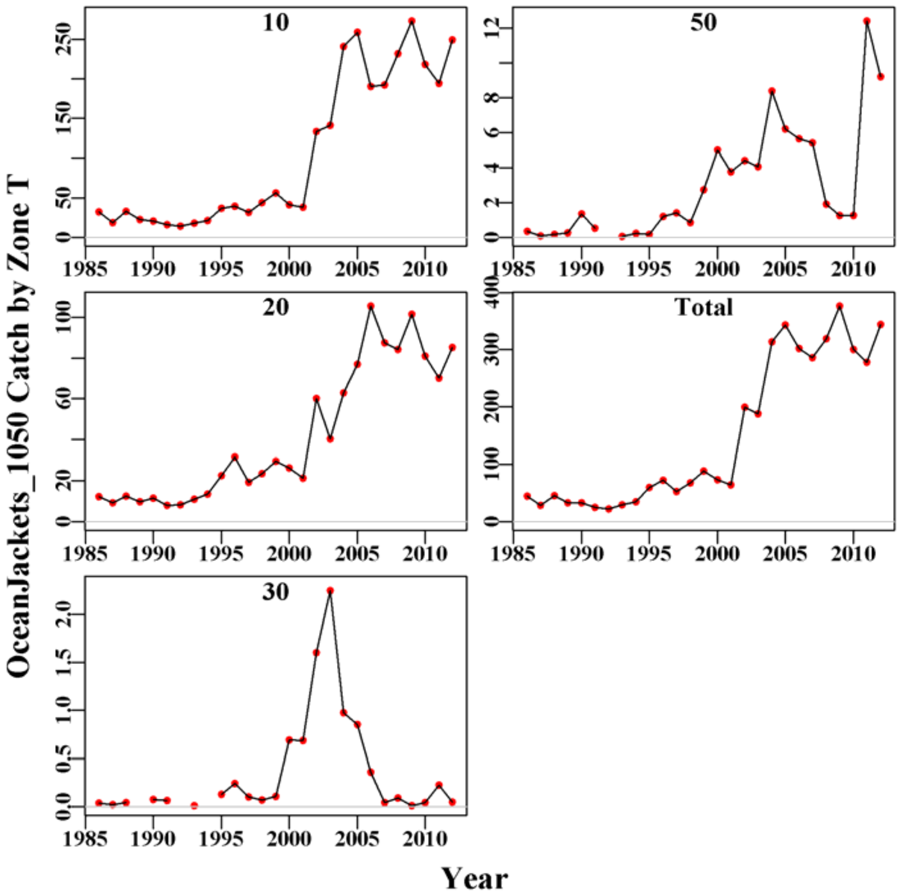



Figure 18.157. Ocean Jackets from Zones 10 to 50 in depths 0 to 300 m by trawl. The catches taken in each of the four main SESSF zones is depicted with the total catch across these zones. The scale on the - axis changes between graphs.

### 18.4.47 Ocean Jackets – GAB (LTC – 37465006 – N. ayraudi) Alternate: LeatherJackets (LTH – 37465000)

Only data from Zones 82 and 83 in the GAB in depths 0 – 300m. All vessels and records reporting leatherjackets are included. This is the first year this data has been considered.

Table 18.139. Ocean Jackets from Zones 82 and 83 in depths 80 to 220 m by trawl. Total Catch is the total reported in the database, Records is the number of records used in the analysis, CatchT is the reported catch in the area and depth used in the analysis, and Vessels relates to all vessels used in the analysis. Geomean is the geometric mean of catch rates (kg/hr). Zone:Month is the optimum model and StDev is the standard deviation relating to the data in the optimum model.

| Year | TotCatch | Records | CatchT | Vessels | GeoMean | Zone:Month | StDev |
|---|---|---|---|---|---|---|---|
| 1986 | 56.429 | 141 | 8.490 | 1 | 11.5206 | 1.2715 | 0.0000 |
| 1987 | 53.249 | 212 | 22.632 | 3 | 13.7002 | 1.0553 | 0.1111 |
| 1988 | 66.199 | 245 | 15.590 | 7 | 14.0350 | 1.2370 | 0.1943 |
| 1989 | 70.961 | 576 | 34.714 | 7 | 11.9652 | 1.2531 | 0.1926 |
| 1990 | 90.954 | 920 | 51.380 | 11 | 11.1086 | 0.8494 | 0.1901 |
| 1991 | 170.170 | 1252 | 139.797 | 8 | 15.0694 | 1.0859 | 0.1895 |
| 1992 | 88.453 | 954 | 59.534 | 7 | 9.0287 | 0.9544 | 0.1894 |
| 1993 | 71.645 | 819 | 38.764 | 4 | 6.3105 | 0.6511 | 0.1893 |
| 1994 | 74.338 | 745 | 36.660 | 5 | 5.7741 | 0.5640 | 0.1901 |
| 1995 | 140.159 | 1316 | 78.832 | 5 | 6.2242 | 0.7423 | 0.1887 |
| 1996 | 199.569 | 1725 | 123.469 | 6 | 7.8262 | 0.8645 | 0.1883 |
| 1997 | 177.394 | 2135 | 121.064 | 9 | 6.4622 | 0.7165 | 0.1883 |
| 1998 | 189.864 | 1799 | 116.437 | 9 | 7.1373 | 0.7774 | 0.1884 |
| 1999 | 202.805 | 1585 | 108.970 | 7 | 7.8084 | 0.8977 | 0.1887 |
| 2000 | 198.801 | 1540 | 121.614 | 5 | 7.8119 | 0.9227 | 0.1889 |
| 2001 | 222.507 | 1877 | 138.429 | 6 | 8.7175 | 0.9532 | 0.1888 |
| 2002 | 377.963 | 1788 | 147.551 | 6 | 9.0818 | 1.0050 | 0.1888 |
| 2003 | 482.065 | 2837 | 279.605 | 9 | 10.8621 | 1.1472 | 0.1885 |
| 2004 | 691.983 | 3433 | 364.440 | 9 | 12.7575 | 1.2347 | 0.1884 |
| 2005 | 890.143 | 4317 | 522.910 | 10 | 13.9012 | 1.3257 | 0.1884 |
| 2006 | 741.356 | 3609 | 408.448 | 11 | 12.0564 | 1.0220 | 0.1885 |
| 2007 | 564.345 | 2647 | 254.851 | 8 | 10.2989 | 0.9186 | 0.1887 |
| 2008 | 490.402 | 2351 | 146.362 | 6 | 7.4758 | 0.8009 | 0.1888 |
| 2009 | 609.940 | 2160 | 219.965 | 4 | 10.4196 | 1.1030 | 0.1888 |
| 2010 | 482.686 | 1792 | 168.203 | 4 | 12.6091 | 1.2590 | 0.1892 |
| 2011 | 487.064 | 1849 | 190.713 | 4 | 13.1684 | 1.2726 | 0.1891 |
| 2012 | 417.243 | 623 | 53.039 | 5 | 12.2457 | 1.1153 | 0.1920 |

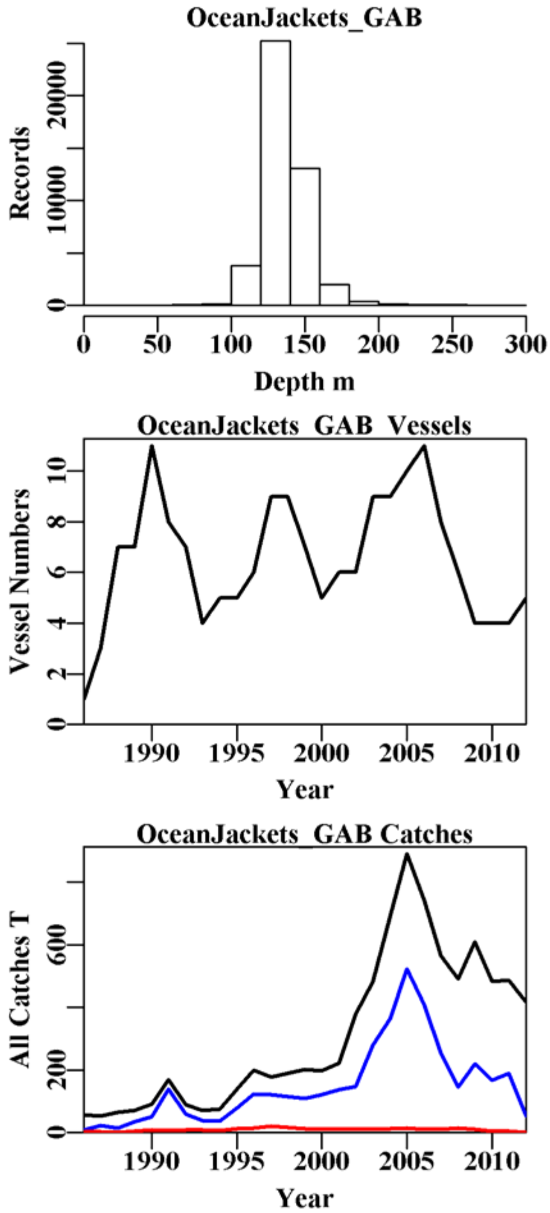



Figure 18.158. Ocean Jackets from Zones 82 and 83 in depths 80 to 220 m by trawl. The top left graph depicts the depth distribution of shots containing Ocean Jackets from Zones 82 and 83 in depths 80 to 220 m by trawl. The top right diagram depicts the distribution of catch by depth within zones 82 and 83, the middle left hand graph depicts the number of vessels through time and the middle right reflects the number of records used in analysis, bottom left are all catches of Leatherjackets (top line, black is total catches, middle line, blue, are those used in the analysis, and bottom, red, are catches < 30Kg), and bottom right focuses only on catches within the GAB.

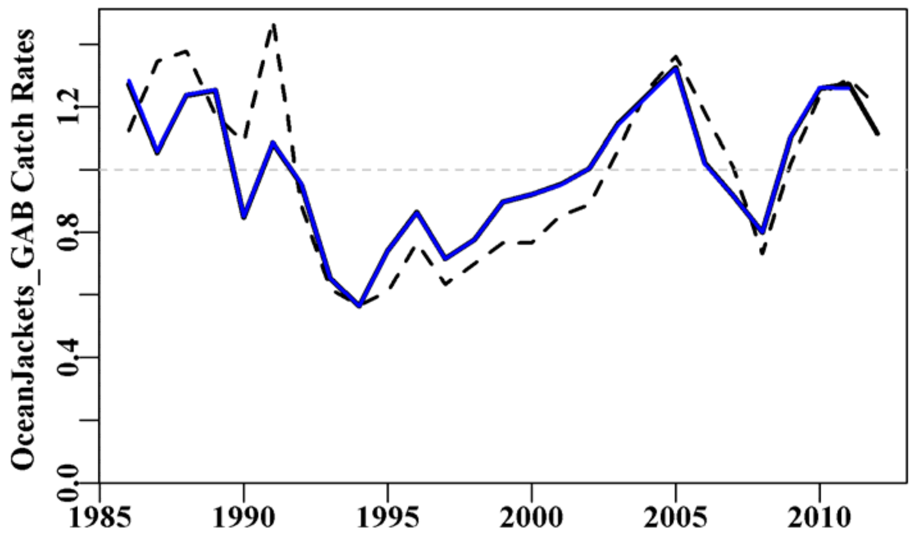



Figure 18.159. Ocean Jackets from Zones 82 and 83 in depths 80 to 220 m by trawl. The dashed black line represents the geometric mean catch rate and the solid black line the standardized catch rates. The graph standardizes catch rates relative to the mean of the standardized catch rates. The fine vertical lines are the 95% confidence intervals. The horizontal blue line is at one, which is the average of the time series. This is the first time this analysis has been conducted.

Table 18.140. 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+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 18 141. Ocean Jackets from Zones 82 and 83 in depths 80 to 220 m by trawl. Model selection criteria, including the AIC, the adjusted $r^2$ and the change in adjusted $r^2$. The optimum is Zone:Month (model 8).

| | Year | Vessel | DepCat | Zone | DayNight | Month | **Zone:Mth** | Zone:DepC |
|---|---|---|---|---|---|---|---|---|
| AIC | 5647 | 884 | -1361 | -3626 | -4807 | -4836 | **-5077** | -4855 |
| RSS | 51200 | 46078 | 43403 | 41198 | 40108 | 40080 | **39846** | 40036 |
| MSS | 3238 | 8360 | 11035 | 13240 | 14330 | 14357 | **14592** | 14402 |
| Nobs | 45247 | 45247 | 44831 | 44831 | 44831 | 44831 | **44831** | 44831 |
| Npars | 27 | 30 | 45 | 81 | 92 | 93 | **104** | 108 |
| adj_r2 | 5.894 | 15.302 | 20.192 | 24.185 | 26.174 | 26.223 | **26.637** | 26.279 |
| %Change | 0.000 | 9.409 | 4.890 | 3.993 | 1.988 | 0.049 | **0.414** | 0.057 |

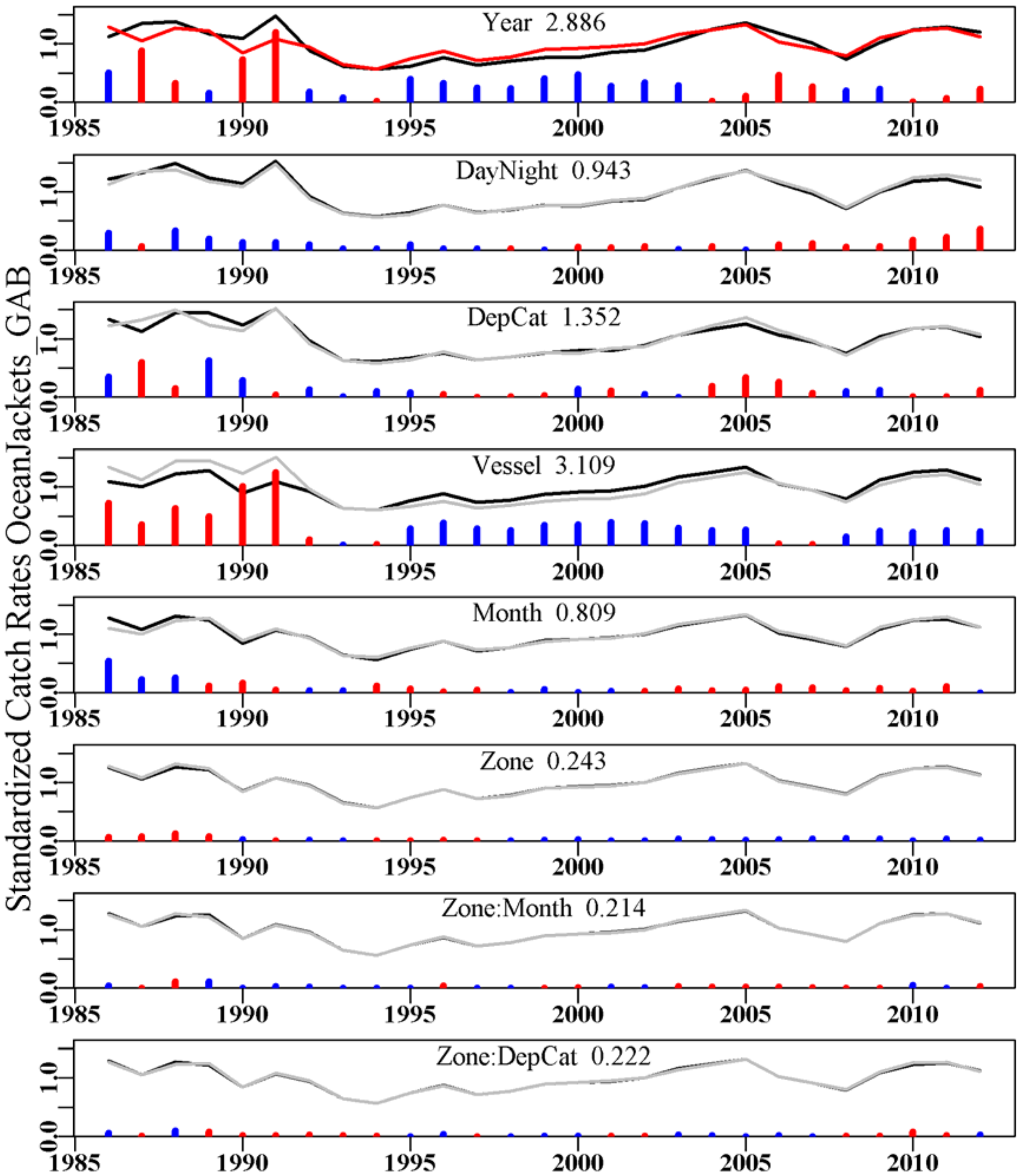



Figure 18.160. The relative influence of each factor used on the final trend in the optimal standardization for Ocean Jackets from Zones 82 and 83. The top graph depicts the geometric mean (the black line) and the optimum model (the red line). The difference between them is illustrated by the vertical 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.

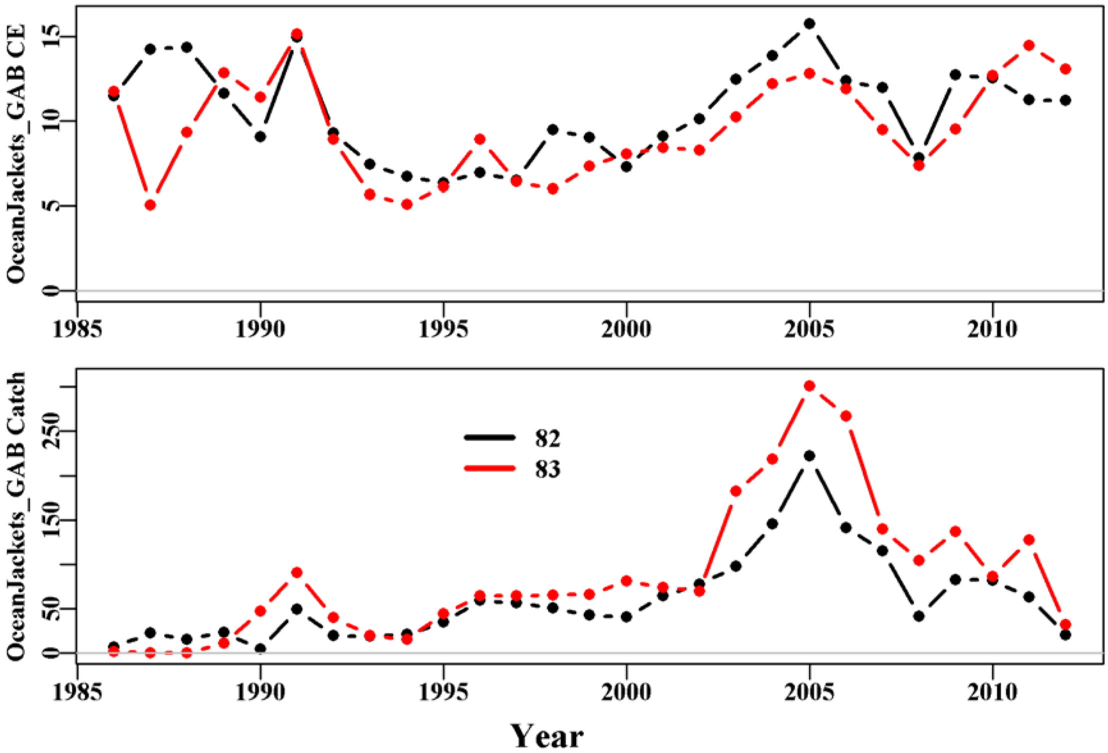



Figure 18.161. Trends in catches and geometric mean catch rates for Ocean Jackets in zones 82 and 83 in the GAB. The catches in the other zones remains too low to be informative about catch rates.

### *18.4.48 DeepWater Flathead (FLD – 37296002 – Platycephalus conatus)*

Data from the GAB fishery, depths between 0 – 1000m, taken by trawl. Previous analyses have restricted analyses to vessels present for more than 2 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 and so now all trawl data between 0 – 1000m are used in the analysis.

Table 18.142. Deepwater Flathead taken by trawl in the GAB in depths between 0 – 1000m. Total Catch is the total Deepwater Flathead catch from all zones and methods reported in the database, Records is the number of records used in the analysis, CatchT is the reported catch in the area and depth used in this analysis, and Vessels relates to all vessels used in the analysis. Geomean is the unstandardized geometric mean of catch rates (kg/hr). Zone:Vessel is the optimum model and StDev is the standard deviation relating to the data in the optimum model.

| | TotCatch | Records | CatchT | Vessels | GeoMean | Optimum | StDev |
|---|---|---|---|---|---|---|---|
| 1987/1988 | 80.334 | 453 | 76.840 | 9 | 27.6907 | 0.4820 | 0.0874 |
| 1988/1989 | 317.249 | 815 | 314.074 | 9 | 56.0806 | 0.9951 | 0.1011 |
| 1989/1990 | 402.557 | 1126 | 397.497 | 7 | 53.0361 | 1.0168 | 0.1013 |
| 1990/1991 | 430.231 | 1501 | 423.226 | 11 | 49.0776 | 1.0348 | 0.1006 |
| 1991/1992 | 621.115 | 1780 | 611.014 | 13 | 54.4990 | 0.8915 | 0.0997 |
| 1992/1993 | 524.062 | 984 | 509.217 | 4 | 76.9248 | 1.0654 | 0.1005 |
| 1993/1994 | 593.110 | 899 | 585.635 | 6 | 91.8668 | 1.4614 | 0.1007 |
| 1994/1995 | 1285.933 | 1744 | 1255.393 | 6 | 106.1909 | 1.8239 | 0.0993 |
| 1995/1996 | 1585.124 | 1862 | 1559.439 | 5 | 125.2137 | 1.7726 | 0.0993 |
| 1996/1997 | 1499.226 | 2784 | 1466.636 | 8 | 79.3934 | 1.2271 | 0.0989 |
| 1997/1998 | 1029.988 | 2908 | 1012.471 | 10 | 50.9703 | 0.8615 | 0.0989 |
| 1998/1999 | 690.389 | 2558 | 682.171 | 7 | 34.6696 | 0.6520 | 0.0990 |
| 1999/2000 | 571.050 | 2089 | 542.529 | 7 | 39.1053 | 0.7726 | 0.0996 |
| 2000/2001 | 846.620 | 2315 | 748.818 | 6 | 43.0243 | 0.8562 | 0.0994 |
| 2001/2002 | 973.944 | 2408 | 901.784 | 6 | 51.8098 | 1.0113 | 0.0994 |
| 2002/2003 | 1711.533 | 3136 | 1628.631 | 8 | 73.4512 | 1.4302 | 0.0990 |
| 2003/2004 | 2272.762 | 4535 | 2186.227 | 10 | 68.3726 | 1.3748 | 0.0989 |
| 2004/2005 | 2159.306 | 5552 | 2100.483 | 10 | 55.0485 | 1.0985 | 0.0988 |
| 2005/2006 | 1433.132 | 5348 | 1358.167 | 11 | 37.5207 | 0.7087 | 0.0988 |
| 2006/2007 | 1015.479 | 4253 | 969.049 | 11 | 32.9304 | 0.6263 | 0.0988 |
| 2007/2008 | 1041.333 | 4003 | 971.174 | 7 | 35.9047 | 0.6944 | 0.0991 |
| 2008/2009 | 813.921 | 3118 | 775.737 | 5 | 40.6974 | 0.8168 | 0.0992 |
| 2009/2010 | 849.830 | 3205 | 829.729 | 4 | 39.1349 | 0.7532 | 0.0992 |
| 2010/2011 | 970.039 | 2805 | 930.288 | 4 | 50.8878 | 0.9495 | 0.0993 |
| 2011/2012 | 965.051 | 3268 | 788.402 | 4 | 38.5737 | 0.7432 | 0.0996 |
| 2012/2013 | 776.465 | 2661 | 665.138 | 5 | 39.1414 | 0.8632 | 0.1022 |

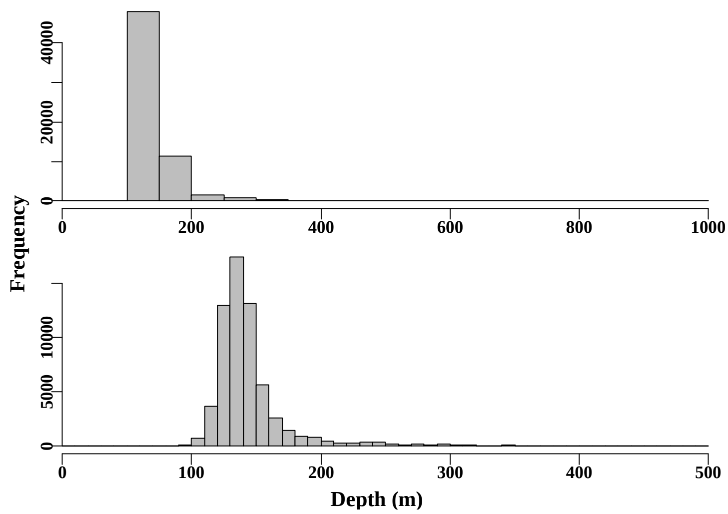



Figure 18.162. The depth distribution of records from the Deepwater flathead fishery taken by trawl in the GAB.

Table 18.143. LogBook catch of Deepwater Flathead by method across all methods and years.

| Year | Unknown | AL | BL | DL | GN | DS | OTT | TDO | TW |
|---|---|---|---|---|---|---|---|---|---|
| 1987/1988 | | | | | | | | | 80.334 |
| 1988/1989 | | | | | | | | | 317.249 |
| 1989/1990 | | | | | | | | | 402.557 |
| 1990/1991 | 0.375 | | | | | | | | 429.856 |
| 1991/1992 | 0.832 | | | | | | | | 620.283 |
| 1992/1993 | 0.400 | | | | | | | | 523.662 |
| 1993/1994 | | | | | | | | | 593.110 |
| 1994/1995 | 7.120 | | | | | | | | 1278.813 |
| 1995/1996 | 2.750 | | | | | | | | 1582.374 |
| 1996/1997 | 1.410 | | | | | | | | 1497.816 |
| 1997/1998 | 0.090 | | | | | | | | 1029.898 |
| 1998/1999 | 0.300 | | | 0.010 | | | | | 690.079 |
| 1999/2000 | 11.539 | | | | | | | | 559.511 |
| 2000/2001 | 26.772 | | | | 0.001 | | | | 819.847 |
| 2001/2002 | 11.247 | | | | 0.003 | | | | 962.694 |
| 2002/2003 | 3.560 | | | | 0.009 | | | | 1707.964 |
| 2003/2004 | | | | | 0.009 | | | | 2272.753 |
| 2004/2005 | | 0.001 | 0.021 | | 0.112 | | | | 2159.172 |
| 2005/2006 | | | | | 0.002 | | | | 1433.130 |
| 2006/2007 | | | | | 0.001 | | | | 1015.478 |
| 2007/2008 | | | | | | | | | 1041.333 |
| 2008/2009 | | | | | | | | | 813.921 |
| 2009/2010 | | | | | | | | | 849.830 |
| 2010/2011 | | | | | | 5.303 | | 24.529 | 940.207 |
| 2011/2012 | | | | | | 136.677 | 13.505 | 606.967 | 207.902 |
| 2012/2013 | | | | | | 83.980 | 0.426 | 414.184 | 277.875 |

An examination of the depth distribution of catches suggests that this could be modified to become 100 – 300m with essentially no loss of information and the outcomes do not differ from the base case adopted here (Figure 18.162 and Figure 18.164; All Vessels and 0 – 1000m).

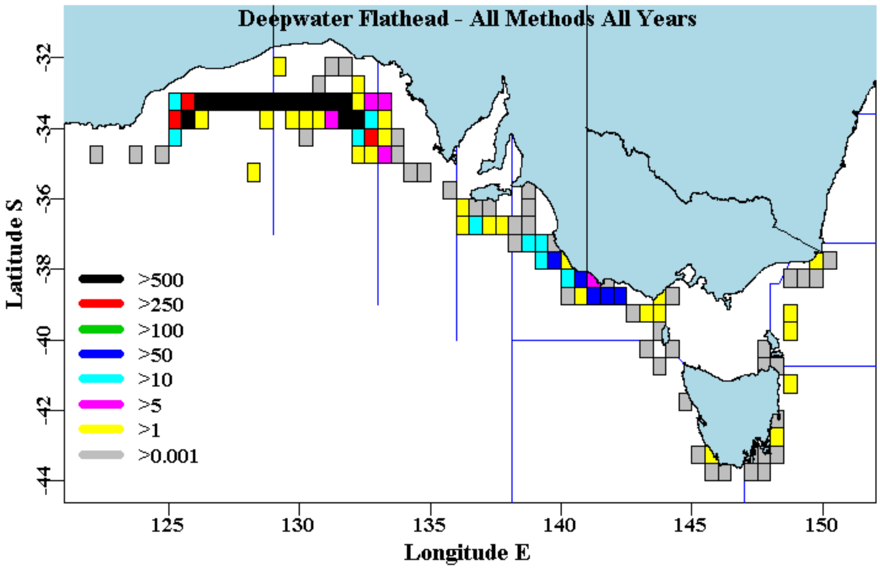



Figure 18.163. Schematic map of the distribution of catches of deepwater flathead from 1987/1988 to 2011/2012 taken by all methods (Table 18.143). Whether the catches reported around the south of Tasmania are correctly reported is questionable.

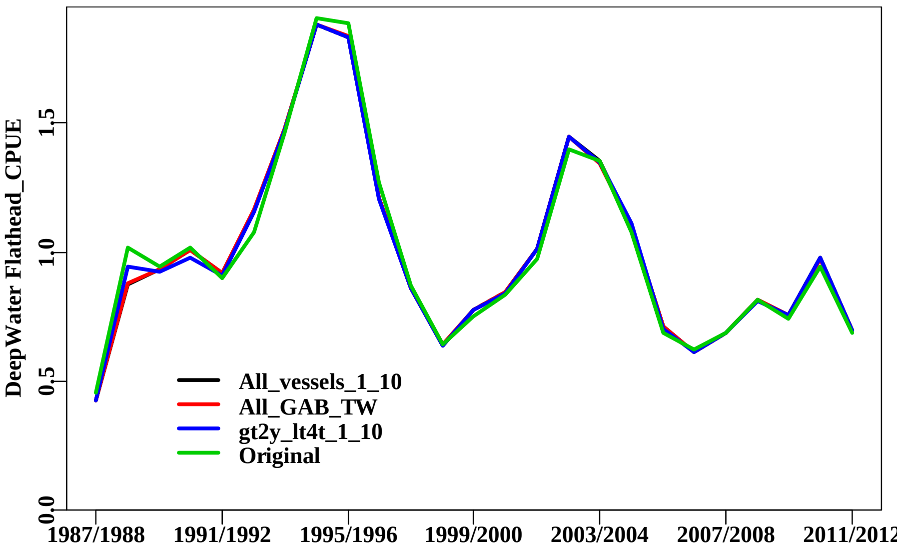



Figure 18.164. Deepwater Flathead taken by trawl in the GAB in depths between 0 – 1000m. All_vessels_1_10 puts no restrictions on which vessels are included, except that effort hours < 1 and > 10 are excluded, no restrictions at all are used in All_GAB_TW, and the red line sits on top of the black. The gt2y_lt4t_1_10 has the effort restriction and also excludes vessels in the fishery for less than 3 years and those with an average annual catch < 4 t; the only difference occurs in 1988/1989. The 'Original' is the standardized CPUE trend taken from Klaer (2013).

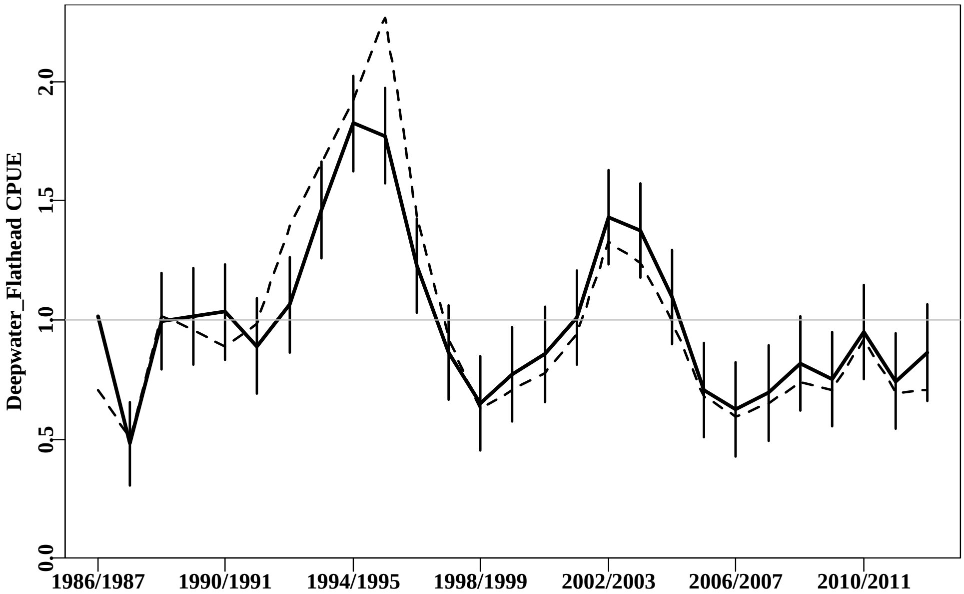



Figure 18.165. The standardized CPUE for Deepwater Flathead from the trawl fishery in the GAB. The dashed line depicts the geometric mean catchrate and the solid line is the optimum model. The vertical bars are the approximate 95% confidence intervals around the mean year parameter estimates.

Table 18.144. Deepwater Flathead from the trawl fishery in the GAB by trawl from 0 – 1000m. 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 + DepCat |
| Model 5 | LnCE~Year+Vessel + Zone + DepCat +Month |
| Model 6 | LnCE~Year+Vessel + Zone + DepCat +Month +DayNight |
| Model 7 | LnCE~Year+Vessel + Zone + DepCat +Month +DayNight + Zone:Month |
| Model 8 | LnCE~Year+Vessel + Zone + DepCat +Month +DayNight + Zone:Vessel |
| Model 9 | LnCE~Year+Vessel + Zone + DepCat +Month +DayNight + Zone:DepCat |

Table 18.145. Deepwater Flathead from the trawl fishery in the GAB by trawl from 0 – 1000m. Model selection criteria, including the AIC, the adjusted $r^2$ and the change in adjusted $r^2$. The optimum is Zone:Vessel (model 8).

| | Year | Vessel | Zone | DepCat | Month | DayNight | Zone:Mth | Zone:Vess | Zone:DepCat |
|---|---|---|---|---|---|---|---|---|---|
| AIC | -24644 | -29035 | -32751 | -33513 | -36266 | -37611 | -38520 | -39603 | -37846 |
| RSS | 41333 | 38466 | 36211 | 35193 | 33629 | 32894 | 32337 | 31706 | 32741 |
| MSS | 7373 | 10240 | 12496 | 13513 | 15077 | 15813 | 16369 | 17000 | 15965 |
| Nobs | 61684 | 61684 | 61684 | 61049 | 61049 | 61049 | 61049 | 61049 | 61049 |
| Npars | 26 | 47 | 53 | 57 | 68 | 71 | 137 | 197 | 95 |
| adj_r2 | 15.104 | 20.965 | 25.593 | 27.678 | 30.879 | 32.388 | 33.459 | 34.694 | 32.675 |
| %Change | 0.000 | 5.861 | 4.628 | 2.085 | 3.202 | 1.509 | 1.071 | 2.306 | 0.287 |

### *18.4.49 Bight Redfish (FLD – 37258004 – Platycephalus conatus)*

Data from the GAB fishery, depths between 0 – 1000m, taken by trawl. Analyses were restricted to vessels present for more than 2 years and which caught an average annual catch > 4 t, and that trawled for more than 1 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 – 250m with essentially no loss of information and the outcomes do not differ from the base case adopted here (Figure 18.162 and Figure 18.164; All Vessels and 0 – 1000m). Catches in 1986/1987 were relatively low and only taken by a single vessel and so are omitted from the analysis.

Table 18.146. Bight Redfish taken by trawl in the GAB in depths between 0 – 1000m. Total Catch is the total Bight Redfish catch from all zones and methods reported in the database, Records is the number of records used in the analysis, CatchT is the reported catch in the area and depth used in this analysis, and Vessels relates to all vessels used in the analysis. Geomean is the unstandardized geometric mean of catch rates (kg/hr). Zone:Vessel is the optimum model and StDev is the standard deviation relating to the data in the optimum model.

| | TotCatch | Records | CatchT | Vessels | GeoMean | Optimum | StDev |
|---|---|---|---|---|---|---|---|
| 1987/1988 | 45.269 | 277 | 41.917 | 6 | 21.8563 | 2.2185 | 0.0000 |
| 1988/1989 | 87.151 | 495 | 85.953 | 8 | 32.6898 | 2.0368 | 0.1063 |
| 1989/1990 | 172.544 | 827 | 171.577 | 7 | 31.8857 | 1.4693 | 0.1043 |
| 1990/1991 | 285.010 | 1170 | 281.389 | 12 | 36.4443 | 1.3668 | 0.1021 |
| 1991/1992 | 266.799 | 1242 | 266.351 | 10 | 27.7067 | 1.3278 | 0.0997 |
| 1992/1993 | 121.338 | 718 | 120.188 | 3 | 18.3377 | 0.9769 | 0.1025 |
| 1993/1994 | 107.978 | 695 | 107.418 | 5 | 16.2182 | 0.9113 | 0.1030 |
| 1994/1995 | 160.099 | 1282 | 159.907 | 6 | 11.9237 | 0.6362 | 0.0983 |
| 1995/1996 | 175.302 | 1395 | 175.277 | 5 | 11.8016 | 0.7490 | 0.0985 |
| 1996/1997 | 331.957 | 2039 | 330.077 | 7 | 15.3484 | 0.8403 | 0.0968 |
| 1997/1998 | 373.604 | 2000 | 372.269 | 9 | 15.7012 | 0.8944 | 0.0970 |
| 1998/1999 | 441.461 | 1812 | 440.296 | 7 | 20.2349 | 1.0491 | 0.0970 |
| 1999/2000 | 325.221 | 1475 | 324.211 | 7 | 17.2082 | 0.9472 | 0.0994 |
| 2000/2001 | 398.739 | 1623 | 370.068 | 5 | 15.4846 | 0.8065 | 0.0986 |
| 2001/2002 | 232.204 | 1610 | 223.570 | 6 | 10.9135 | 0.6086 | 0.0987 |
| 2002/2003 | 377.966 | 2113 | 363.642 | 8 | 13.4561 | 0.6598 | 0.0974 |
| 2003/2004 | 862.194 | 3155 | 841.995 | 10 | 20.1184 | 0.9742 | 0.0970 |
| 2004/2005 | 889.540 | 3964 | 874.520 | 10 | 19.5259 | 0.9009 | 0.0965 |
| 2005/2006 | 803.259 | 3688 | 746.434 | 11 | 17.4128 | 0.8367 | 0.0965 |
| 2006/2007 | 961.509 | 3294 | 873.760 | 10 | 21.7641 | 0.9230 | 0.0962 |
| 2007/2008 | 758.751 | 3026 | 734.810 | 7 | 19.2748 | 0.9241 | 0.0972 |
| 2008/2009 | 665.394 | 2443 | 648.786 | 4 | 21.9054 | 0.9812 | 0.0978 |
| 2009/2010 | 463.725 | 2298 | 445.717 | 4 | 17.3788 | 0.8482 | 0.0980 |
| 2010/2011 | 275.709 | 1785 | 267.936 | 4 | 14.1527 | 0.7119 | 0.0987 |
| 2011/2012 | 66.019 | 512 | 60.305 | 3 | 10.8753 | 0.7544 | 0.1092 |
| 2012/2013 | 38.739 | 435 | 37.524 | 4 | 11.9492 | 0.6470 | 0.1142 |

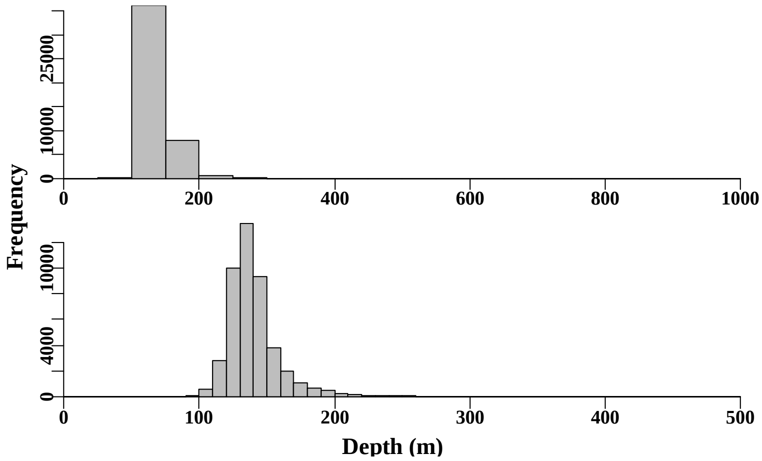



Figure 18.166. The depth distribution of records from the Bight Redfish fishery taken by trawl in the GAB.

Table 18.147. Reported catch of Bight Redfish by method across all methods and years.

| Year | Unknown | Line | GN | PS | DS | TW |
|---|---|---|---|---|---|---|
| 1987/1988 | | | | | | 45.269 |
| 1988/1989 | | | | | | 87.151 |
| 1989/1990 | | | | | | 172.544 |
| 1990/1991 | | | | | | 285.010 |
| 1991/1992 | | | | | | 266.799 |
| 1992/1993 | | | | | 0.010 | 121.328 |
| 1993/1994 | | | | | | 107.978 |
| 1994/1995 | | | | | | 160.099 |
| 1995/1996 | | | | | | 175.302 |
| 1996/1997 | | | | | | 331.957 |
| 1997/1998 | | | | | | 373.604 |
| 1998/1999 | | | | | | 441.461 |
| 1999/2000 | 0.210 | | | | | 325.011 |
| 2000/2001 | 17.463 | | 1.037 | | | 380.239 |
| 2001/2002 | 2.105 | 0.004 | 2.979 | | | 227.116 |
| 2002/2003 | 0.670 | 0.006 | 3.265 | | | 374.026 |
| 2003/2004 | | 0.017 | 5.135 | | | 857.042 |
| 2004/2005 | 0.011 | 0.004 | 5.225 | | 0.004 | 884.296 |
| 2005/2006 | | 0.245 | 6.506 | 30.000 | | 766.508 |
| 2006/2007 | | 0.178 | 7.997 | | | 953.335 |
| 2007/2008 | | 0.055 | 7.780 | | | 750.916 |
| 2008/2009 | | 0.039 | 8.097 | | | 657.258 |
| 2009/2010 | | 0.088 | 5.380 | | | 458.257 |
| 2010/2011 | | 0.036 | 2.330 | | 1.269 | 272.074 |
| 2011/2012 | | 0.087 | 2.014 | | 3.198 | 60.720 |
| 2012/2013 | | 0.130 | 0.095 | | 0.456 | 38.059 |

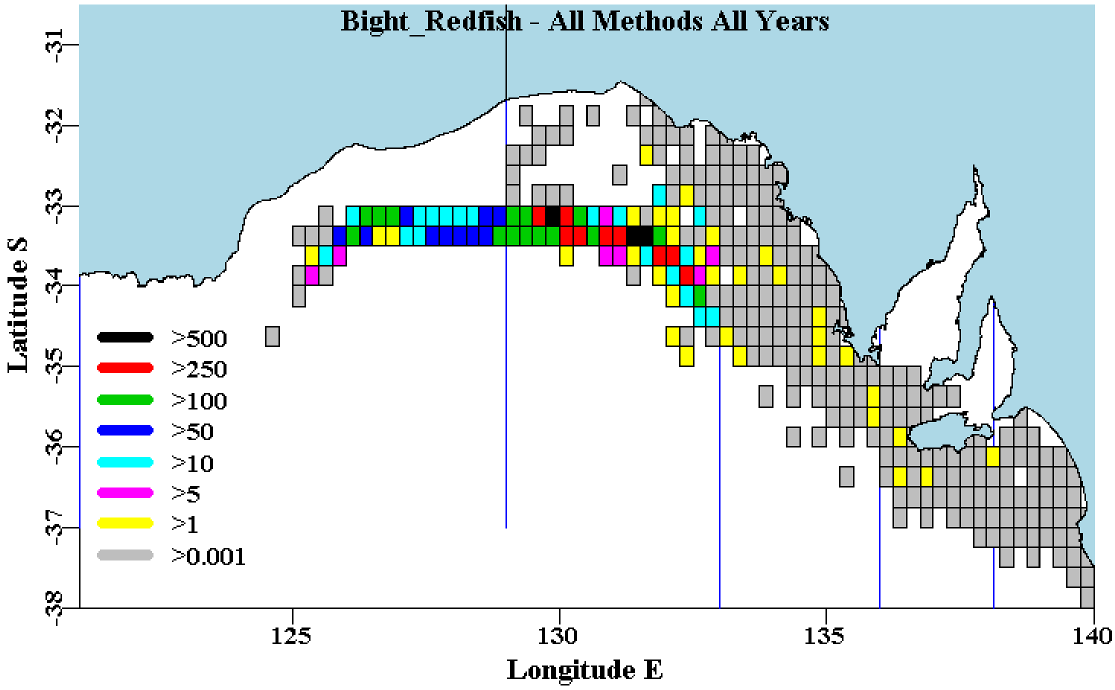



Figure 18.167. Schematic map of the distribution of catches of Bight Redfish from 1987/1988 to 2011/2012 taken by all methods (Table 18.143). Catches and catchrates are higher in the east of the GAB.

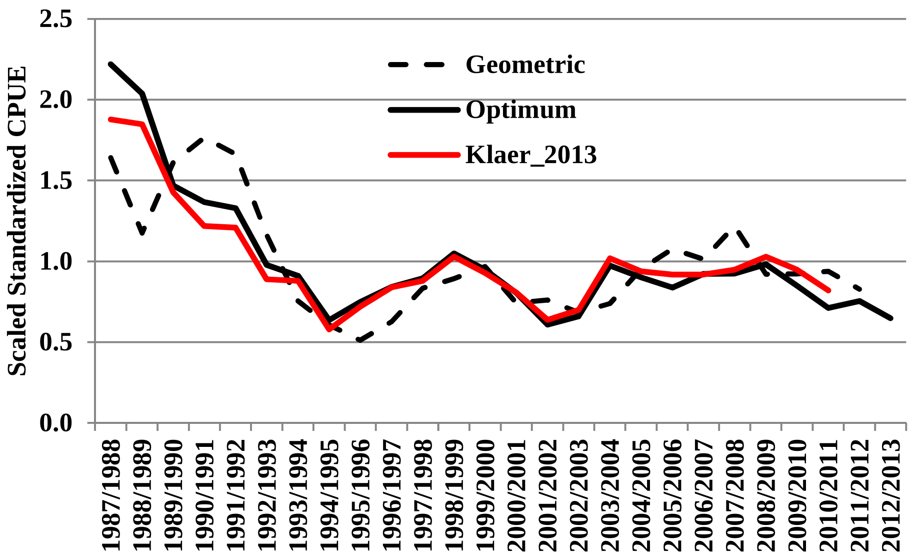



Figure 18.168. Bight Redfish taken by trawl in the GAB in depths between 0 – 1000m. The 'Original' is the standardized CPUE trend taken from Klaer (2013). The other three only show differences in the first three years. Klaer (2013) did not include DayNight or interaction terms in his analysis, the two trends remain approximately similar, especially once the uncertainty of the mean estimates is included (Figure 18.169).

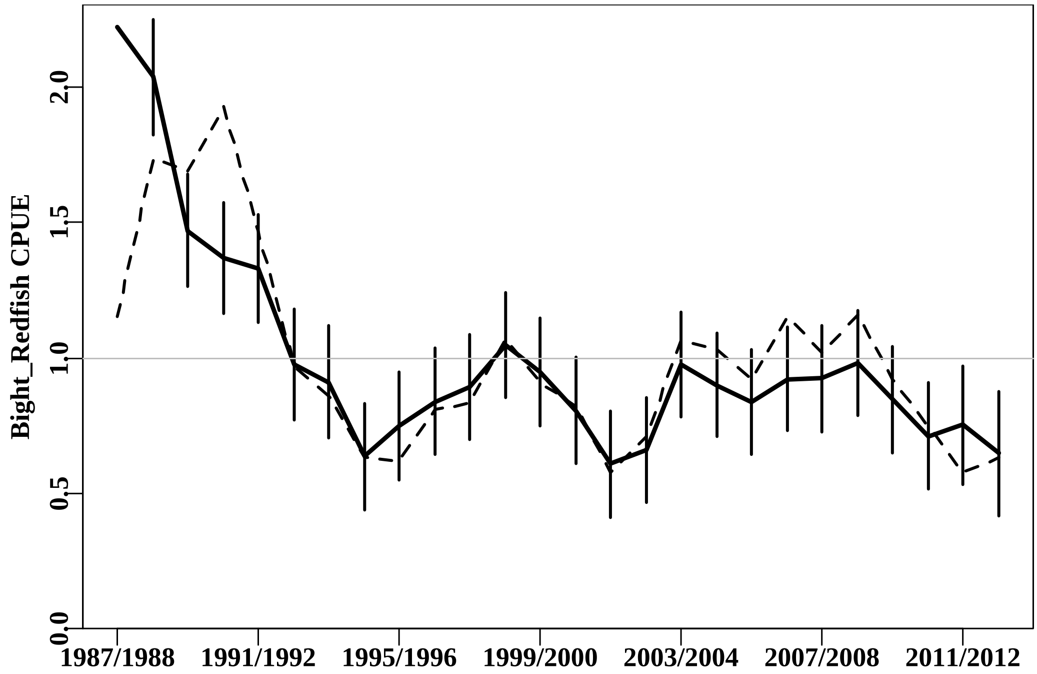



Figure 18.169. The standardized CPUE for Bight Redfish from the trawl fishery in the GAB. The dashed line depicts the geometric mean catchrate and the solid line is the optimum model. The vertical bars are the approximate 95% confidence intervals around the mean year parameter estimates.

Table 18.148. Bight Redfish from the trawl fishery in the GAB by trawl from 0 – 1000m. 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 18.149. Bight Redfish from the trawl fishery in the GAB by trawl from 0 – 1000m. Model selection criteria, including the AIC, the adjusted $r^2$ and the change in adjusted $r^2$. The optimum is Zone:Vessel (model 8). Zone was four 2.5 degree slices through the GAB.

| | Year | DayNight | Zone | Month | Vessel | DepCat | Zone:Month | Zone:Vessel | Zone:DepCat |
|---|---|---|---|---|---|---|---|---|---|
| AIC | 30462 | 25349 | 21723 | 18772 | 17614 | 16955 | 16766 | 16757 | 16728 |
| RSS | 88689 | 79228 | 73139 | 68500 | 66669 | 65130 | 64824 | 64739 | 64699 |
| MSS | 3085 | 12546 | 18634 | 23274 | 25105 | 26643 | 26949 | 27034 | 27074 |
| Nobs | 45373 | 45373 | 45373 | 45373 | 45373 | 44851 | 44851 | 44851 | 44851 |
| Npars | 26 | 29 | 30 | 41 | 77 | 112 | 123 | 148 | 147 |
| adj_r2 | 3.308 | 13.617 | 20.254 | 25.294 | 27.233 | 28.856 | 29.172 | 29.226 | 29.271 |
| %Change | 0.000 | 10.309 | 6.637 | 5.040 | 1.939 | 1.622 | 0.317 | 0.370 | 0.415 |

## 18.5 Acknowledgements

Thanks are due to Mike Fuller and Neil Klaer of CSIRO Hobart, for their preliminary processing of the catch and effort data as received from the Australian Fisheries management Authority. Thanks also to Ian Knuckey for providing reports from the Eastern Gemfish surveys that allowed the individual shots to be removed from consideration to be identified.

## 18.6 Bibliography

A collection of publications relating to the analysis of catch rates, only some of which are referred to explicitly here but the rest are included as a resource for anyone interested in pursuing this subject further.

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# 19. Standardization of Bight Redfish in the GAB 2000/2001 – Feb 2012/2013. Catch rate Update.

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## 19.1 Summary

The change in catch rates between 2011/2012 and July-Feb 2012/2013 is less than 20% (-13.29) (Figure 19.3; Table 19.7), therefore the control rule suggests no change should be made to the default TAC.

## 19.2 Methods

Data was provided from July 2000 to February 2013 for catches of bight redfish from the GAB (Table 19.1, Table 19.2, Table 19.3).

Records were only included in the analysis that adhered to the following selection criteria:

Depths were between 50 – 500 metres (Table 19.2; Figure 19.1),
Non-zero catches of bight redfish,
Shot length > 1.0 and < 10 hours,
Only from Zone 80 (GAB),
The DayNight factor only used Day, Night, and Mixed (Unknown was omitted).

The analysis conducted included all vessels which had reported catches of bight redfish as well as adhering to the conditions listed above (Table 19.3).

Seven statistical models (Table 19.4) were examined using six different factors:

Fishing Year (July – June),
Vessel,
Depth Category (50 metre categories),
Month,
SubZone (5 degree of longitude subdivisions),
DayNight (Day, Night, Mixed – a small number of Unknown were omitted).

All statistical models were plotted after dividing each series by the average of each series. This means that the average of each series becomes one, and this ensures they are all on the same scale and hence directly comparable.

The percent difference of the catch rates between years is calculated as:

$$\%D = 100 \times (CE_{10/11} - CE_{09/10})/CE_{09/10}$$

### 19.3 Results

Catch rates exhibited a highly skewed distribution which was approximately log-normally distribution but a log transformation approximately normalizes the data prior to analysis (Figure 19.2). There are numerous records grouped around catch rates of 1, 2, 5, 10, 15, and 30 kg/hr, which appear as spikes in the observed log of catch rates; this seems likely to be due to rounding to nearest convenient weight of catch.

The optimum statistical model was the most complex having the most parameters (Table 19.5; Table 19.6; Figure 19.3).

Catch rates for bight redfish from the GAB initially increased to a peak in 2003/2004 after which catch rates have remained relatively stable varying slightly up and down until 2009/2010 when they started to decline. In the latest year, 2012/2013, catch rates decreased by about -13% (Figure 19.3; Table 19.7) and, importantly, the estimates from last year reversed direction from being slightly positive to being slightly negative.

The standardization analysis with this year's data follows essentially the same trajectory as that produced by last year's analysis (Figure 19.4). However, the analysis for 2011/2012 indicated that instead of a small positive increase in catchrates the outcome was actually a small decrease.

The GABTF Harvest Strategy decision rules, applied to both deepwater flathead and bight redfish are:

The FIS and the collection of age and length frequency data as well as the monitoring of catch and effort information will be ongoing regardless of whether an assessment is to take place in that year. The information obtained from these sources will be analysed and presented to the RAG each year well prior to the date at which a decision on the TAC for the next year is made.

- Any adjustment to the TAC limit through the application of the decision rules would apply to the default TAC
- When the Fishery Independent Survey (FIS) has been conducted in two consecutive years, the catch rates from the first leg of the survey will be the indicator of abundance used to make any adjustment to the default TAC.
- In a year when the Fishery Independent Survey (FIS) is not conducted, the standardised commercial catch rate for the period July-February inclusive is the indicator of abundance used to make any adjustment to the default TAC, comparing the current year to the immediately preceding year.
- If there is a change of ≥20% to the indicator of abundance, a 10% (increase or decrease) to the default TAC will occur.
- If the RAG is concerned with any indicators over the period between stock assessments (length frequency distributions, standardised commercial catch rates, age distributions etc), then it can decide to undertake a full assessment in that year

### 19.4 Conclusion

The change in catch rates between 2011/2012 and July-Feb 2012/2013 is less than 20% (-13.29) (Figure 19.3; Table 19.7), therefore the control rule suggests no change should be made to the default TAC. Questions need to be asked again about the use of the abbreviated data now that more years are available and they illustrate that use of part-year data can be misleading more often than previously thought.

### 19.5 Acknowledgements

John Garvey of AFMA is thanked for providing the original data extract. Dr Neil Klaer of CSIRO is especially thanked for pre-processing the catch and effort data so rapidly.

Table 19.1. The frequency of catch rate observations in each month and fishing year (financial year – July/June) for Bight Redfish from the GAB following data selection.

| | 7 | 8 | 9 | 10 | 11 | 12 | 1 | 2 | 3 | 4 | 5 | 6 | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 00/01 | 41 | 39 | 143 | 181 | 161 | 99 | 124 | 159 | 176 | 211 | 210 | 71 | 1615 |
| 01/02 | 33 | 89 | 156 | 219 | 216 | 89 | 114 | 159 | 180 | 134 | 133 | 93 | 1615 |
| 02/03 | 77 | 63 | 147 | 136 | 201 | 103 | 235 | 259 | 225 | 218 | 204 | 169 | 2037 |
| 03/04 | 188 | 211 | 181 | 337 | 338 | 192 | 304 | 276 | 289 | 272 | 242 | 118 | 2948 |
| 04/05 | 152 | 185 | 305 | 317 | 346 | 241 | 485 | 492 | 521 | 290 | 234 | 230 | 3798 |
| 05/06 | 178 | 222 | 253 | 294 | 287 | 224 | 437 | 371 | 363 | 313 | 248 | 343 | 3533 |
| 06/07 | 187 | 231 | 335 | 316 | 321 | 198 | 219 | 235 | 332 | 325 | 169 | 215 | 3083 |
| 07/08 | 142 | 204 | 280 | 281 | 307 | 244 | 334 | 229 | 223 | 230 | 208 | 171 | 2853 |
| 08/09 | 159 | 108 | 196 | 268 | 229 | 164 | 206 | 192 | 197 | 189 | 227 | 181 | 2316 |
| 09/10 | 145 | 152 | 196 | 211 | 200 | 163 | 184 | 207 | 248 | 261 | 153 | 125 | 2245 |
| 10/11 | 68 | 67 | 186 | 177 | 180 | 155 | 181 | 144 | 202 | 157 | 195 | 133 | 1845 |
| 11/12 | 121 | 213 | 208 | 182 | 200 | 182 | 228 | 211 | 172 | 167 | 174 | 99 | 2157 |
| 12/13 | 90 | 76 | 80 | 168 | 172 | 183 | 166 | 185 | 80 | 0 | 0 | 0 | 1200 |

Table 19.2. The relative frequency of depths records for Bight Redfish from the GAB see (Figure 19.1).

| Depth M | Count |
|---|---|
| 0 | 0 |
| 50 | 10 |
| 100 | 7500 |
| 150 | 21834 |
| 200 | 1700 |
| 250 | 184 |
| 300 | 9 |
| 350 | 0 |
| 400 | 1 |
| 450 | 4 |
| 500 | 3 |

Table 19.3. Summary statistics characterizing the data included in the standardization.

| | Records | Catches | Effort | GeomCE | Vessels |
|---|---|---|---|---|---|
| 2000/2001 | 1615 | 261.868 | 8422 | 13.448 | 5 |
| 2001/2002 | 1615 | 200.533 | 8459 | 10.426 | 5 |
| 2002/2003 | 2037 | 294.920 | 11034 | 12.630 | 8 |
| 2003/2004 | 2948 | 541.632 | 16041 | 17.453 | 10 |
| 2004/2005 | 3798 | 712.731 | 20591 | 18.617 | 10 |
| 2005/2006 | 3533 | 586.826 | 18928 | 16.236 | 11 |
| 2006/2007 | 3083 | 599.814 | 16194 | 19.014 | 9 |
| 2007/2008 | 2853 | 532.261 | 14876 | 17.290 | 7 |
| 2008/2009 | 2316 | 470.236 | 11975 | 19.573 | 4 |
| 2009/2010 | 2245 | 396.187 | 11644 | 16.682 | 4 |
| 2010/2011 | 1845 | 277.004 | 9463 | 14.269 | 4 |
| 2011/2012 | 2157 | 300.460 | 11527 | 14.154 | 4 |
| 2012/2013 | 1200 | 143.870 | 6317 | 13.940 | 4 |

Table 19.4. The seven statistical models examined for Bight Redfish from the GAB.

| | |
|---|---|
| Model 1 | Fyear |
| Model 2 | Fyear + Vessel |
| Model 3 | Fyear + Vessel + DepCat |
| Model 4 | Fyear + Vessel + DepCat + Month |
| Model 5 | Fyear + Vessel + DepCat + Month + SubZone |
| Model 6 | Fyear + Vessel + DepCat + Month + SubZone + DN |
| Model 7 | Fyear + Vessel + DepCat + Month + SubZone + DN + DepCat:Month |

Table 19.5. The standardized catch rates for the alternative statistical models for Bight Redfish from the GAB in depths 50 to 500 m. Values are relative to the mean of the standardized catch rates so that the average of the series remains 1.0. Fishing Years were from July/June, DepCat were 50 m categories, Subzones were 5° of Longitude, and DN relates to DayNight categories.

| | FYear | DN | Month | Subzone | Vessel | DepCat | DepCat:Mth | StErr |
|---|---|---|---|---|---|---|---|---|
| 00/01 | 0.8612 | 0.8696 | 0.8535 | 0.8247 | 0.9264 | 0.9269 | **0.9180** | 0.0000 |
| 01/02 | 0.6684 | 0.6599 | 0.6630 | 0.6777 | 0.7625 | 0.7694 | **0.7702** | 0.0401 |
| 02/03 | 0.8096 | 0.8083 | 0.7756 | 0.7874 | 0.8603 | 0.8601 | **0.8603** | 0.0387 |
| 03/04 | 1.1187 | 1.1426 | 1.1464 | 1.1200 | 1.1856 | 1.1910 | **1.1872** | 0.0379 |
| 04/05 | 1.1932 | 1.2246 | 1.1445 | 1.2128 | 1.2047 | 1.2075 | **1.2061** | 0.0370 |
| 05/06 | 1.0406 | 1.0336 | 1.0212 | 1.0938 | 1.1079 | 1.1024 | **1.0994** | 0.0372 |
| 06/07 | 1.2187 | 1.2575 | 1.2820 | 1.2170 | 1.1159 | 1.1122 | **1.1130** | 0.0377 |
| 07/08 | 1.1082 | 1.1485 | 1.1796 | 1.1654 | 1.1114 | 1.1198 | **1.1498** | 0.0390 |
| 08/09 | 1.2546 | 1.3001 | 1.3612 | 1.2314 | 1.1968 | 1.2105 | **1.2047** | 0.0400 |
| 09/10 | 1.0693 | 1.0388 | 1.0258 | 1.0616 | 1.0341 | 1.0430 | **1.0415** | 0.0404 |
| 10/11 | 0.9147 | 0.8670 | 0.8704 | 0.9137 | 0.8909 | 0.8753 | **0.8663** | 0.0427 |
| 11/12 | 0.9073 | 0.8492 | 0.8618 | 0.9065 | 0.8677 | 0.8568 | **0.8482** | 0.0417 |
| 12/13 | 0.8354 | 0.8004 | 0.8150 | 0.7881 | 0.7357 | 0.7250 | **0.7354** | 0.0493 |

Table 19.6. Model selection criteria, including the AIC, the adjusted $r^2$, and the proportional change in adj $R^2$. Optimal model was model 7: FYear + Vessel + DepCat + Month + SubZone + DayNight + DepCat:Month. The Daynight factor is clearly the most influential with Bight Redfish.

| | Year | DN | Month | Subzone | Vessel | DepCat | DepCat:Month |
|---|---|---|---|---|---|---|---|
| AIC | 18235 | 13453 | 10455 | 8792 | 7822 | 7740 | 7582 |
| RSS | 55900 | 47942 | 43515 | 41251 | 39951 | 39825 | 39507 |
| MSS | 880 | 8838 | 13265 | 15529 | 16829 | 16955 | 17273 |
| Nobs | 31165 | 31165 | 31165 | 31165 | 31165 | 31165 | 31165 |
| Npars | 13 | 15 | 26 | 27 | 41 | 49 | 95 |
| Adj_r2 | 1.512 | 15.527 | 23.300 | 27.288 | 29.548 | 29.753 | 30.211 |
| %Change | | 14.015 | 7.773 | 3.988 | 2.260 | 0.205 | 0.458 |

Table 19.7. The optimum standardized catch rate model relative to the unstandardized geometric mean catch rates (Fyear) with the percent difference between years for each. The value of interest is at the bottom right showing the difference between 10/11 and 11/12.

| | Fyear | Diff | Optimum | Diff |
|---|---|---|---|---|
| 00/01 | 0.8612 | | **0.9180** | |
| 01/02 | 0.6684 | -22.38 | **0.7702** | -16.10 |
| 02/03 | 0.8096 | 21.12 | **0.8603** | 11.70 |
| 03/04 | 1.1187 | 38.18 | **1.1872** | 38.00 |
| 04/05 | 1.1932 | 6.66 | **1.2061** | 1.60 |
| 05/06 | 1.0406 | -12.79 | **1.0994** | -8.85 |
| 06/07 | 1.2187 | 17.11 | **1.1130** | 1.24 |
| 07/08 | 1.1082 | -9.06 | **1.1498** | 3.30 |
| 08/09 | 1.2546 | 13.21 | **1.2047** | 4.77 |
| 09/10 | 1.0693 | -14.77 | **1.0415** | -13.54 |
| 10/11 | 0.9147 | -14.46 | **0.8663** | -16.83 |
| 11/12 | 0.9073 | -0.81 | **0.8482** | -2.09 |
| 12/13 | 0.8354 | -7.92 | **0.7354** | -13.29 |

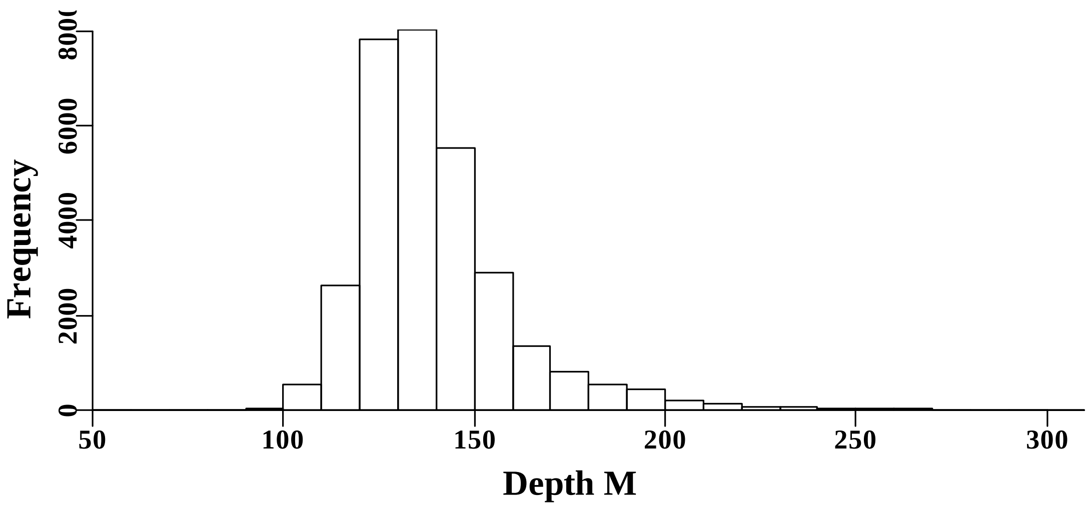


Figure 19.1. The relative frequency of depth records from Bight Redfish from the GAB. The lower graph is a repeat of the upper graph except with more detail. Data is from 2000/2001 – Feb 2012/2013; after data selection.

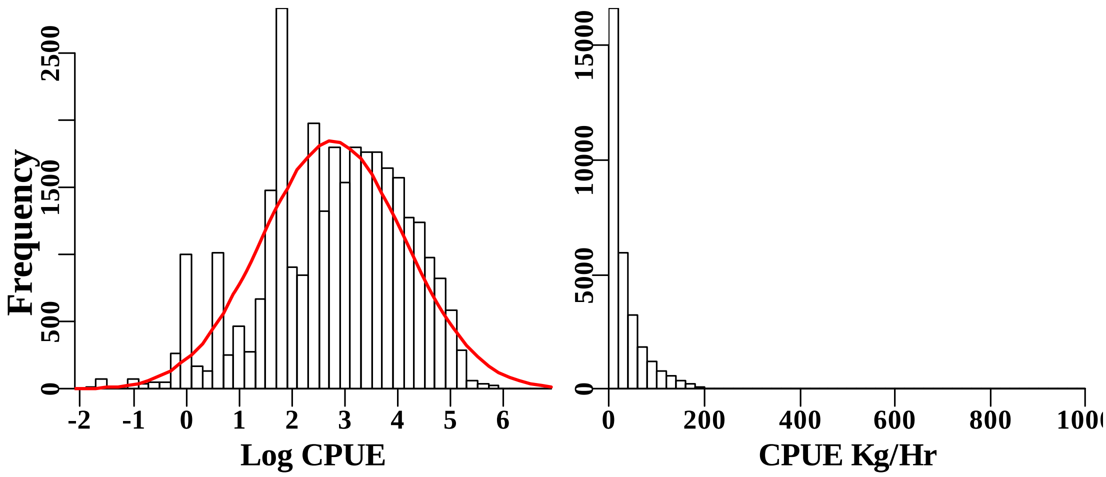


Figure 19.2. The catch rates for Bight Redfish are normalized by a natural log transformation. Data is from 2000/2001 – Feb 2012/2013. The spikes in the distribution, which distort the distribution away from a strict log-normal, relate to catch rates of 1, 2, 5, 10, 15, and 30 kg/hr. There are a very few very large catch rates, but they are so few they do not influence the standardized catch rate trend.

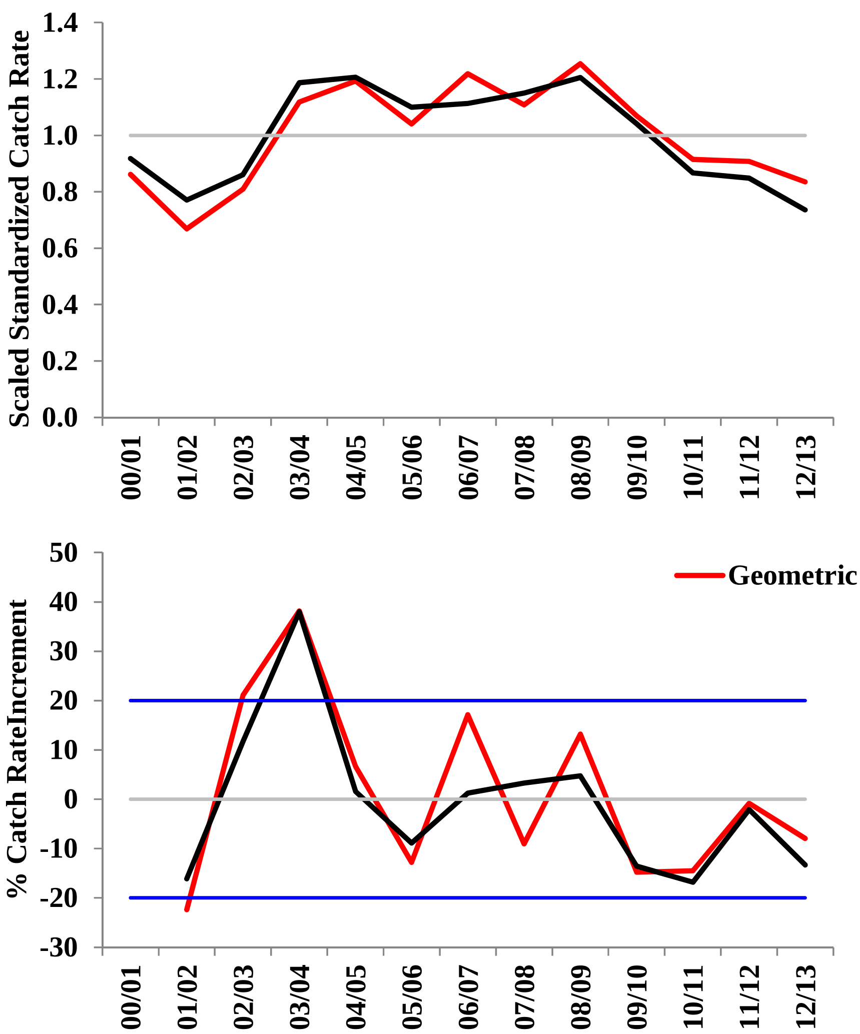


Figure 19.3. The standardized catch rates for Bight Redfish from the GAB. The dashed line is the unstandardized geometric mean catch rates see Table 19.7. The lower graph depicts the percent difference between consecutive fishing years (see Table 19.7).

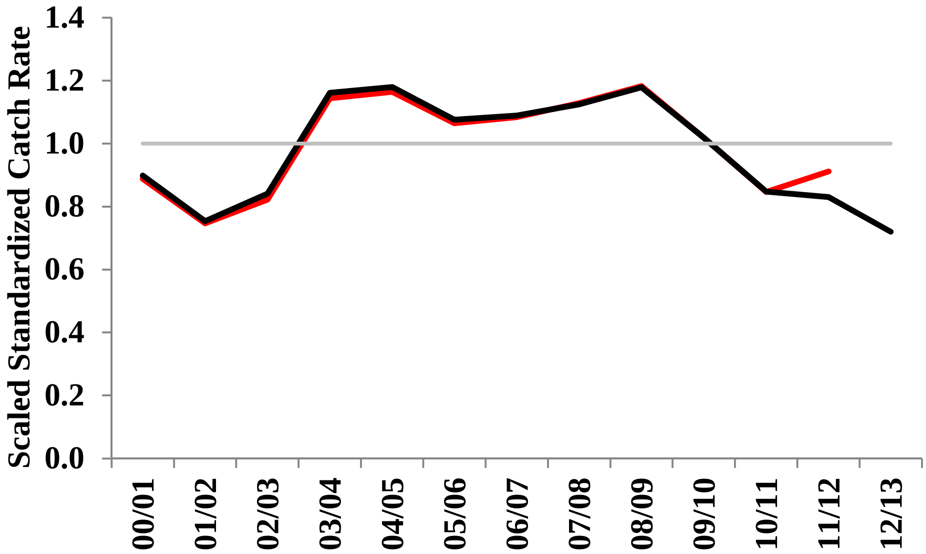


Figure 19.4. Comparison of this year's analysis (black line) with last year's (red line - scaling this year's analysis to the mean of 00/01 – 11/12 to make it comparable with last year's analysis).

# 20. Standardization of Deepwater Flathead in the GAB 2000/2001 – Feb 2012/2013. Catch rate Update.

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## 20.1 Summary

The change in catch rates between 2011/2012 and July-Feb 2012/2013 is relatively slight at -1.45% (Figure 20.3; Table 20.8). However, importantly, it can also be seen that last year's estimate was biased larger than it eventually became. Last year the decrease in catch rates appeared to be about -25% whereas this year, with all available data it appears to be about -17.5%, which would not have triggered a change. If a decrease in TAC occurred last year then this analysis suggests that should be reversed.

## 20.2 Methods

Data was provided from July 2000 to February 2013 for catches of deepwater flathead from the GAB (Table 20.1, Table 20.2, Table 20.3).

Records were only included in the analysis that adhered to the following selection criteria (Table 20.4):

Depths were between 50 – 500 metres (Table 20.3; Figure 20.1),
Non-zero catches of deepwater flathead,
Shot length > 0.5 and < 10 hours,
Only from Zone 80 (GAB),
The DayNight factor only used Day, Night, and Mixed (Unknown was omitted).
Only Vessels in the fishery for more than 2 years were included.

Seven statistical models (Table 20.5) were examined using six different factors:

Fishing Year (July – June),
Vessel,
Depth Category (50 metre categories),
Month,
SubZone (5 degree of longitude subdivisions),
DayNight (Day, Night, Mixed – a small number of Unknown were omitted).

Catch rates are log-normally distributed but a log transformation successfully normalizes the data prior to analysis (Figure 20.2).

The percent difference between years is calculated as:

$$\%D = 100 \times (CE_{11/12} - CE_{10/11})/CE_{10/11}$$

## 20.3 Results

The optimum statistical model was the most complex having the most parameters (Table 20.6; Table 20.7; Figure 20.3).

Catch rates for Deepwater Flathead from the GAB initially increased to a peak in 2002/2003 and 2003/2004 and then declined to half the maximum levels in 2005/2006 after which catch rates have exhibited a slow increase. In the most recent year catch rates have remained stable exhibiting almost no change between 2001/2012 and 2012/2013 (Figure 20.3; Table 20.8).

The standardization analysis with this year's data follows essentially the same trajectory as that produced by last year's analysis (Figure 20.4), however, there is a large difference between this year's estimate of the catch rate in 2011/2012 and last year's estimate. This is contrary to previous findings that data up until February are generally sufficient to predict the eventual complete difference.

The GABTF Harvest Strategy decision rules, applied to both deepwater flathead and bight redfish are:

The FIS and the collection of age and length frequency data as well as the monitoring of catch and effort information will be ongoing regardless of whether an assessment is to take place in that year. The information obtained from these sources will be analysed and presented to the RAG each year well prior to the date at which a decision on the TAC for the next year is made.

- Any adjustment to the TAC limit through the application of the decision rules would apply to the default TAC
- When the Fishery Independent Survey (FIS) has been conducted in two consecutive years, the catch rates from the first leg of the survey will be the indicator of abundance used to make any adjustment to the default TAC.
- In a year when the Fishery Independent Survey (FIS) is not conducted, the standardised commercial catch rate for the period July-February inclusive is the indicator of abundance used to make any adjustment to the default TAC, comparing the current year to the immediately preceding year.
- If there is a change of ≥20% to the indicator of abundance, a 10% (increase or decrease) to the default TAC will occur.
- If the RAG is concerned with any indicators over the period between stock assessments (length frequency distributions, standardised commercial catch rates, age distributions etc), then it can decide to undertake a full assessment in that year

## 20.4 Conclusion

As the change in catch rates between 2011/2012 and July-Feb 2012/2013 is very small at only -1.45% (Figure 20.3; Table 20.8) the control rule suggests no changes should be made to the default TAC. However, because the estimate of catch rates from 2011/2012 have changed significantly so that they are no longer greater than -20%, if the TAC was reduced last year then consideration should be given to reversing that conclusion this year. Questions need to be asked again about the use of the abbreviated data now that more years are available and they illustrate that use of part-year data can be misleading more often than previously thought.

## 20.5 Acknowledgements

John Garvey of AFMA is thanked for providing the original data extract. Dr Neil Klaer of CSIRO is especially thanked for pre-processing the catch and effort data so rapidly.

Table 20.1. The frequency of catch rate observations in each month and fishing year (financial year – July/June) for deepwater flathead from the GAB following data selection.

| | 7 | 8 | 9 | 10 | 11 | 12 | 1 | 2 | 3 | 4 | 5 | 6 | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 00/01 | 60 | 57 | 206 | 250 | 268 | 186 | 213 | 189 | 255 | 268 | 298 | 112 | 2362 |
| 01/02 | 53 | 136 | 211 | 296 | 331 | 161 | 184 | 246 | 259 | 184 | 194 | 147 | 2402 |
| 02/03 | 111 | 106 | 208 | 240 | 316 | 154 | 319 | 380 | 354 | 353 | 322 | 250 | 3113 |
| 03/04 | 237 | 288 | 295 | 450 | 469 | 275 | 429 | 412 | 491 | 493 | 394 | 242 | 4475 |
| 04/05 | 287 | 301 | 423 | 473 | 484 | 367 | 648 | 595 | 624 | 414 | 467 | 418 | 5501 |
| 05/06 | 282 | 335 | 380 | 402 | 471 | 358 | 624 | 550 | 480 | 460 | 436 | 497 | 5275 |
| 06/07 | 270 | 312 | 421 | 391 | 419 | 275 | 304 | 317 | 401 | 432 | 310 | 314 | 4166 |
| 07/08 | 184 | 261 | 277 | 337 | 403 | 284 | 392 | 284 | 301 | 368 | 345 | 222 | 3658 |
| 08/09 | 185 | 129 | 226 | 337 | 315 | 224 | 287 | 263 | 280 | 285 | 312 | 234 | 3077 |
| 09/10 | 205 | 198 | 248 | 298 | 320 | 249 | 278 | 304 | 315 | 332 | 221 | 207 | 3175 |
| 10/11 | 131 | 106 | 293 | 269 | 275 | 251 | 236 | 177 | 267 | 310 | 287 | 221 | 2823 |
| 11/12 | 189 | 316 | 288 | 291 | 327 | 281 | 329 | 278 | 272 | 262 | 280 | 170 | 3283 |
| 12/13 | 179 | 201 | 204 | 338 | 310 | 310 | 308 | 322 | 0 | 0 | 0 | 0 | 2172 |

Table 20.2. The frequency of observations in each depth category (down to 600 m) and fishing year (financial year – July/June) for deepwater flathead from the GAB following data selection.

| | 0 | 50 | 100 | 150 | 200 | 250 | 300 | 350 | 400 | 450 | 500 | 550 | 600 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 00/01 | 3 | 0 | 261 | 1901 | 226 | 14 | 4 | 2 | 20 | 6 | 1 | 0 | 0 |
| 01/02 | 4 | 2 | 244 | 2048 | 126 | 15 | 5 | 11 | 13 | 1 | 0 | 0 | 0 |
| 02/03 | 37 | 0 | 148 | 2738 | 232 | 26 | 12 | 0 | 0 | 1 | 0 | 0 | 0 |
| 03/04 | 70 | 1 | 452 | 3581 | 361 | 108 | 44 | 5 | 2 | 0 | 1 | 1 | 1 |
| 04/05 | 55 | 1 | 830 | 4158 | 267 | 192 | 77 | 6 | 2 | 1 | 4 | 0 | 2 |
| 05/06 | 81 | 2 | 1145 | 3701 | 284 | 162 | 52 | 3 | 0 | 0 | 0 | 1 | 5 |
| 06/07 | 91 | 1 | 675 | 3175 | 204 | 108 | 66 | 6 | 2 | 1 | 0 | 0 | 0 |
| 07/08 | 98 | 7 | 557 | 2771 | 454 | 118 | 65 | 2 | 0 | 0 | 0 | 0 | 0 |
| 08/09 | 51 | 0 | 273 | 2503 | 302 | 32 | 9 | 1 | 0 | 0 | 0 | 0 | 0 |
| 09/10 | 40 | 0 | 550 | 2356 | 261 | 54 | 12 | 0 | 0 | 0 | 0 | 0 | 0 |
| 10/11 | 0 | 0 | 1858 | 832 | 116 | 28 | 2 | 1 | 0 | 0 | 0 | 1 | 0 |
| 11/12 | 1 | 7 | 2329 | 789 | 134 | 49 | 5 | 0 | 0 | 0 | 0 | 0 | 1 |
| 12/13 | 0 | 3 | 1604 | 583 | 71 | 23 | 4 | 0 | 0 | 1 | 0 | 0 | 0 |

Table 20.3. The relative frequency of depths records for Deepwater Flathead from the GAB see (Figure 20.1). Data from 2000/2001 to Feb 2012/2013.

| Depth M | Count |
|---:|---:|
| 0 | 531 |
| 50 | 24 |
| 100 | 10926 |
| 150 | 31136 |
| 200 | 3038 |
| 250 | 929 |
| 300 | 357 |
| 350 | 37 |
| 400 | 39 |
| 450 | 11 |
| 500 | 6 |
| 550 | 3 |
| 600 | 9 |
| 650 | 2 |
| 750 | 2 |
| 800 | 3 |
| 850 | 3 |
| 900 | 1 |
| 950 | 3 |
| 1000 | 1 |
| 1100 | 1 |
| 1250 | 1 |
| 1350 | 1 |
| 1500 | 1 |

Table 20.4. Summary statistics characterizing the data included in the standardization.

| | Records | Catches | Effort | GeomCE | Vessels |
|---|---|---|---|---|---|
| 2000/2001 | 2362 | 769.847 | 12145.79 | 45.17164 | 5 |
| 2001/2002 | 2402 | 905.885 | 12411.32 | 53.99376 | 5 |
| 2002/2003 | 3113 | 1613.01 | 16750.27 | 73.61459 | 8 |
| 2003/2004 | 4475 | 2157.485 | 24114.9 | 68.52785 | 10 |
| 2004/2005 | 5501 | 2086.372 | 29691.95 | 55.28965 | 10 |
| 2005/2006 | 5275 | 1340.978 | 28017.44 | 37.64308 | 11 |
| 2006/2007 | 4166 | 950.308 | 21768.83 | 33.05358 | 10 |
| 2007/2008 | 3658 | 908.836 | 18420.31 | 37.57405 | 6 |
| 2008/2009 | 3077 | 775.535 | 15763.12 | 41.03474 | 4 |
| 2009/2010 | 3175 | 805.6285 | 16332.58 | 38.67861 | 4 |
| 2010/2011 | 2823 | 932.788 | 14351.13 | 50.70244 | 4 |
| 2011/2012 | 3283 | 838.817 | 17281.38 | 41.345 | 5 |
| 2012/2013 | 2172 | 568.733 | 11332.63 | 41.0382 | 5 |

Table 20.5. The seven statistical models examined for Deepwater Flathead from the GAB.

| | |
|---|---|
| Model 1 | Fyear |
| Model 2 | Fyear + Vessel |
| Model 3 | Fyear + Vessel + DepCat |
| Model 4 | Fyear + Vessel + DepCat + Month |
| Model 5 | Fyear + Vessel + DepCat + Month + SubZone |
| Model 6 | Fyear + Vessel + DepCat + Month + SubZone + DN |
| Model 7 | Fyear + Vessel + DepCat + Month + SubZone + DN + DepCat:Month |

Table 20.6. The standardized catch rates for the alternative statistical models for Deepwater Flathead from the GAB in depths 50 to 500 m. Values are relative to the mean of the standardized catch rates so that the average of the series remains 1.0. Fishing Years were from July/June, DepCat were 50 m categories, Subzones were 5° of Longitude, and DN relates to DayNight categories.

| | FYear | Vessel | DepCat | Month | Subzone | DN | **DepCat:Mth** | StErr |
|---|---|---|---|---|---|---|---|---|
| 00/01 | 0.9505 | 0.9339 | 0.9496 | 0.9371 | 0.9465 | 0.9461 | **0.9705** | 0.0000 |
| 01/02 | 1.1365 | 1.1332 | 1.1476 | 1.1449 | 1.1174 | 1.1189 | **1.1379** | 0.0196 |
| 02/03 | 1.5494 | 1.5717 | 1.6019 | 1.5898 | 1.5539 | 1.5515 | **1.5581** | 0.0189 |
| 03/04 | 1.4423 | 1.5081 | 1.5391 | 1.5341 | 1.5484 | 1.5485 | **1.5366** | 0.0187 |
| 04/05 | 1.1637 | 1.2145 | 1.2428 | 1.2515 | 1.2282 | 1.2294 | **1.1877** | 0.0183 |
| 05/06 | 0.7923 | 0.8025 | 0.8014 | 0.8050 | 0.7877 | 0.7886 | **0.7752** | 0.0184 |
| 06/07 | 0.6957 | 0.6643 | 0.6677 | 0.6784 | 0.7078 | 0.7076 | **0.6975** | 0.0189 |
| 07/08 | 0.7908 | 0.7266 | 0.7414 | 0.7403 | 0.7659 | 0.7661 | **0.7640** | 0.0195 |
| 08/09 | 0.8637 | 0.8438 | 0.8678 | 0.8684 | 0.9223 | 0.9223 | **0.9242** | 0.0201 |
| 09/10 | 0.8141 | 0.8141 | 0.8289 | 0.8376 | 0.8195 | 0.8180 | **0.8232** | 0.0201 |
| 10/11 | 1.0672 | 1.0487 | 0.9860 | 0.9888 | 0.9797 | 0.9819 | **0.9948** | 0.0210 |
| 11/12 | 0.8702 | 0.8665 | 0.8108 | 0.8188 | 0.8100 | 0.8085 | **0.8211** | 0.0207 |
| 12/13 | 0.8638 | 0.8721 | 0.8149 | 0.8053 | 0.8127 | 0.8125 | **0.8092** | 0.0226 |

Table 20.7. Model selection criteria, including the AIC, the adjusted $r^2$, and the proportional change in adj $R^2$. Optimal model was model 7: FYear + Vessel + DepCat + Month + SubZone + DayNight + DepCat:Month.

| | FYear | Vessel | DepCat | Month | subzone | DN | **DepCat:Month** |
|---|---|---|---|---|---|---|---|
| AIC | -23845 | -27903 | -29390 | -30951 | -32534 | -33032 | **-36043** |
| RSS | 26909 | 24597 | 23797 | 22983 | 22195 | 21952 | **20487** |
| MSS | 2692 | 5004 | 5804 | 6618 | 7406 | 7649 | **9114** |
| Nobs | 45482 | 45482 | 45482 | 45482 | 45482 | 45482 | **45482** |
| Npars | 13 | 27 | 36 | 47 | 48 | 50 | **115** |
| Adj_r2 | 9.069 | 16.856 | 19.547 | 22.280 | 24.941 | 25.761 | **30.616** |
| %Change | | 7.787 | 2.691 | 2.733 | 2.661 | 0.820 | **4.855** |

Table 20.8. The optimum standardized catch rate model relative to the unstandardized geometric mean catch rates (Fyear) with the percent difference between years for each. The value of interest is at the bottom right showing the difference between 10/12 and 11/13. Importantly, with the updated information it can be seen that the predicted decline of ~25% last year was an over-estimate.

| | Fyear | Diff | **Optimum** | Diff |
|---|---|---|---|---|
| 00/01 | 0.9505 | | **0.9705** | |
| 01/02 | 1.1365 | 19.56 | **1.1379** | 17.25 |
| 02/03 | 1.5494 | 36.34 | **1.5581** | 36.92 |
| 03/04 | 1.4423 | -6.91 | **1.5366** | -1.38 |
| 04/05 | 1.1637 | -19.32 | **1.1877** | -22.70 |
| 05/06 | 0.7923 | -31.92 | **0.7752** | -34.73 |
| 06/07 | 0.6957 | -12.19 | **0.6975** | -10.02 |
| 07/08 | 0.7908 | 13.68 | **0.7640** | 9.54 |
| 08/09 | 0.8637 | 9.21 | **0.9242** | 20.97 |
| 09/10 | 0.8141 | -5.74 | **0.8232** | -10.93 |
| 10/11 | 1.0672 | 31.09 | **0.9948** | 20.84 |
| 11/12 | 0.8702 | -18.46 | **0.8211** | -17.46 |
| 12/13 | 0.8638 | -0.74 | **0.8092** | -1.45 |

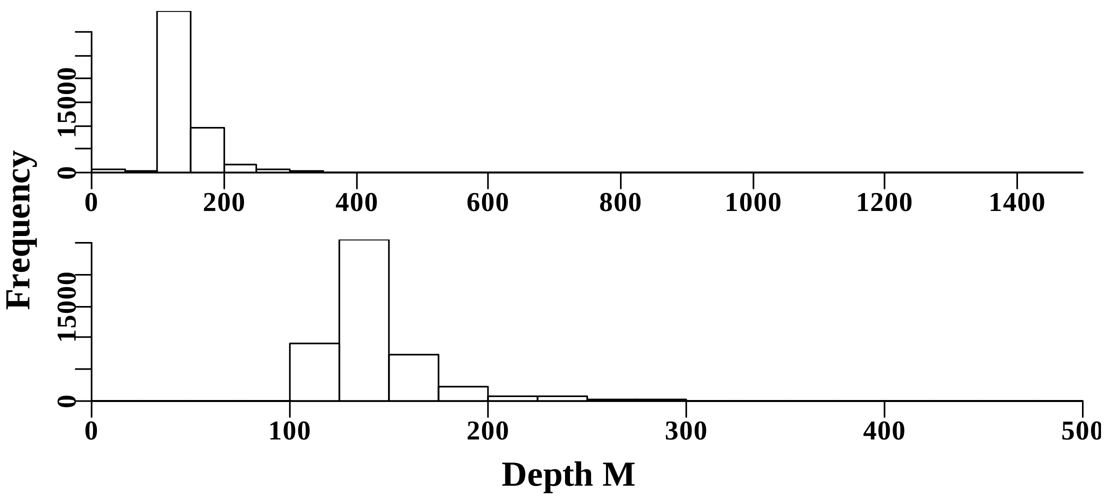


Figure 20.1. The relative frequency of depth records from Deepwater Flathead from the GAB. The lower graph is a repeat of the upper graph except with more detail. Data is from 2000/2001 – Feb 2012/2013.

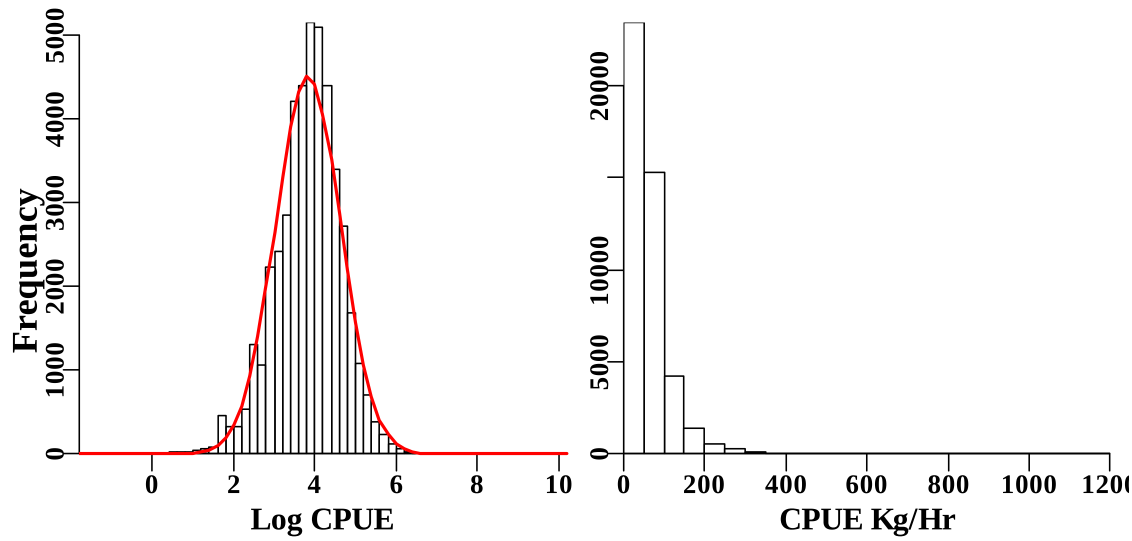


Figure 20.2. The catch rates for Deepwater Flathead are normalized by a natural log transformation. Data is from 2000/2001 – Feb 2012/2013.

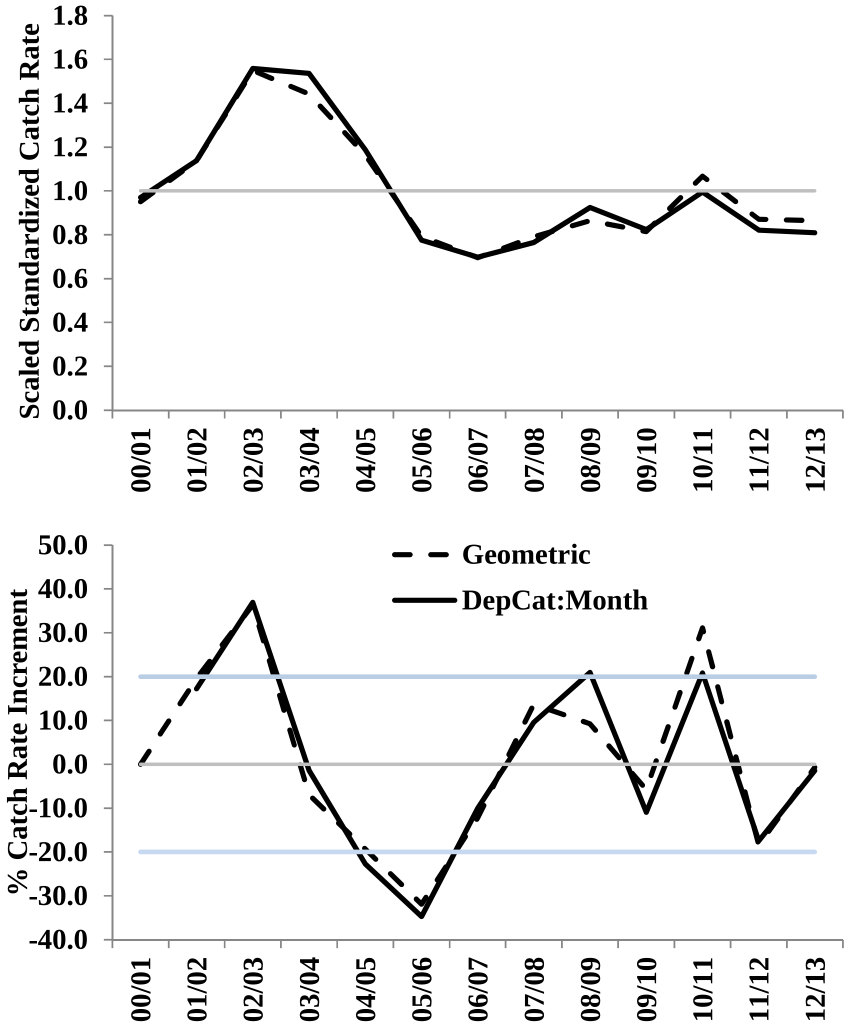


Figure 20.3. The standardized catch rates for Deepwater Flathead from the GAB. The dashed line is the unstandardized geometric mean catch rates see Table 20.8. The lower graph depicts the percent difference between consecutive fishing years (see Table 20.8).

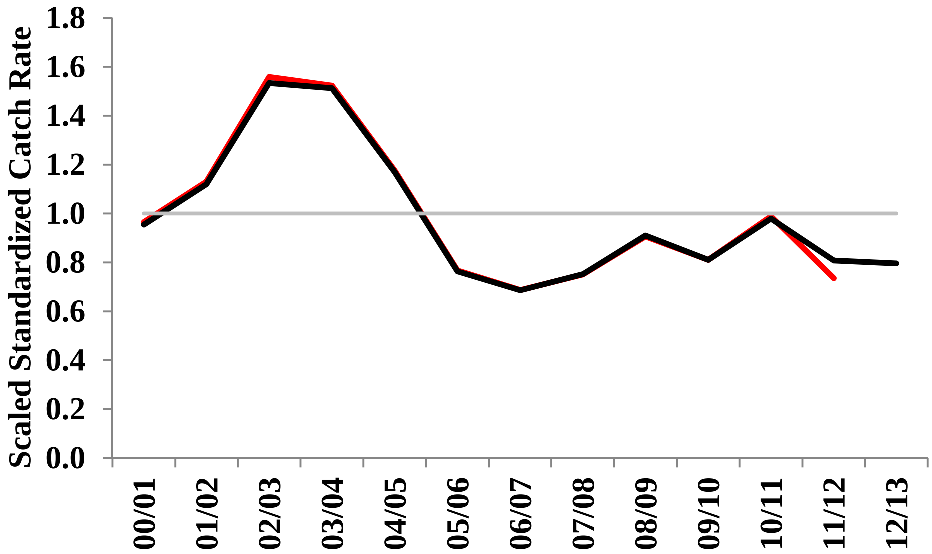


Figure 20.4. Comparison of this year's analysis (black line) with last year's (red line - scaling this year's analysis to the mean of 00/01 – 11/12 to make it comparable with last year's analysis).

# 21. Standardized Catch Rates for the SESSF Gummy Shark Fishery: Data from 1976 - 2012

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## *21.1 Summary*

Reported catches of gummy sharks have declined from a high in 2008, although interpreting this is made more complex because of the 16 month TAC put in place for the 2007/2008 season. Nevertheless, the recent decline in catches is real and is related to the decline in catches from South Australia being greater than the increase in catches in Tasmania and the now relatively stable catches in Bass Strait. Catches from South Australia started to decline seriously in 2011 and continued to decrease further in 2012 until they are now of the same order as in the early 1980s and are only about 50% the catches in 2009. These changes are related to the introduction of gillnet fishery closures to protect Australian Sea Lions and dolphins in South Australian waters. The proportion of catches taken by gillnets in 2012 remained the same as in 2011, despite catches being down overall.

Standardized catch rates in South Australia have also exhibited a decline since 2008, however, the general trend since 1984 remains flat but noisy. The most recent mean estimate is below the long term average, which again is thought to be related to the influence of the marine closures in South Australia rather than any change in the resource status. However, the recent large reduction in catch and the large changes in the spatial distribution of catches means that accurate knowledge of the status of the South Australian gummy shark stock is currently compromised. How best to include this data in any stock assessment is not immediately obvious and may require further data exploration. There is a difference between the standardized CPUE for positive shots from the CANDE12 data set and the standard extracts from the SESSF database. The confluence of the two trends from 2005 reflects the fact that the CANDE12 data set is updated directly from the SESSF database each year.

In Bass Strait, standardized catch rates have also declined since 2008 but they are now still above or at the long term average depending on how the standardization for positive shots is combined with the standardization of the probability of obtaining a positive shot. Catches in the gummy shark fishery continue to be greatest in Bass Strait. In Bass Strait there are also differences between the standardized CPUE for positive shots from the CANDE12 data set and the standard extracts from the SESSF database from 1997 to 2004. Again the confluence of the two trends from 2005 reflects the fact that the CANDE12 data set is updated directly from the SESSF database each year.

Standardized catch rates in Tasmania also remain noisy but flat. There is some indication of a very slow decline since about 2000 but given the variation surrounding the mean estimates the apparent decline is not yet statistically significant; for example,

the trend in 2012, the latest year, exhibits a very slight upturn. Given the noise in the outcome of the analysis, the differences between the CANDE12 analysis and that based on the SESSF database are not significant.

The assumption that it is simple to identify targeted shots in the shark fishery is used to include the proportion of zero shots in the standardization. However, there is an array of factors that call this assumption into doubt. The first factor is that up until 2000 there were amounts of catches reported as 'comb' when no catches were reported in either school or gummy sharks and this was mostly a problem within South Australia; from 2000 onwards, however, the amounts are greatly reduced. This adds greatly to the uncertainty over whether a zero recorded in the gummy column is only seemingly a zero. A second factor is that many changes in effort and fisher behaviour occurred in the fishery sometime between 1991 and 1995. These changes are so marked and would have greatly influenced how the fishery was conducted, and yet the standardization assumes that it is valid to estimate mean parameters across the complete time series. It raises the question of whether there are two time series of catches and catch rates, one up to about 1994 and the other from 1995 onwards, or whether the current assumption of a single time series is valid. The standardization of the positive catches is not greatly affected by separating the time series into 1976 – 1994 and 1995 – 2012, which reflects the fact that these time series are generally noisy but flat about the long term average. However, given the transition that occurs around about 1995 it would influence the analysis of the presence or absence of positive shots more significantly. It is unknown whether these two factors would alter the trend expressed in the analysis of presence or absence and so it remains questionable whether or not to include the analysis of zero shots in the overall analysis of catch rate trends.

The early data, meaning that before about 1997, is difficult to combine with the later data. Details regarding how it has been collated appear to have been lost but there are clearly individual shots together with monthly aggregate data records. The large and sudden change in the proportion of positive shots remains an anomaly which is possible related to the advent of universal reporting of individual shots. Unless some way of transitioning between these two periods is determined it could be recommended that the early data not be used in CPUE standardizations. However, there is the possibility of using data in time blocks as long as means of linking those time blocks can be found. Unfortunately the character of the fishery appears to have changed so much that this may not be possible but it will be explored further as an option.

## 21.2 Introduction

The shark fishery off southern Australia has a long history starting with a long-line fishery which began in the 1920s which switched to gillnets in the 1960s and 1970s when the primary target also switched to gummy sharks (*Mustelus antarcticus*; Punt *et al.,* 2000; Punt & Gason, 2006; Thomson & Punt, 2010). This gillnet fishery now mainly targets gummy sharks although used to target relatively large quantities of School sharks (*Galeorhinus galeus*) but this is now a bycatch only species. In this shark fishery there are significant amounts of the common saw shark (*Pristiophorus cirratus*) and southern saw shark (*P. nudipinnis*; not distinguished from each other in the catch effort records) as well as elephant fish (*Callorhinchus milii*) taken as bycatch.

### 21.2.1 Major Management Changes

In 1990 – 1995 some major management changes were introduced. These included the amalgamation of endorsements and a reduction in the net unit from 6000m to 4,200m (by 1993 in Bass Strait and by 1995 in South Australia and Tasmania). With respect to gummy sharks the next big change came in 2001 when Individual Transferable Quotas (based on catch histories from 1994 – 1997) were introduced for both gummy and school sharks. The structural adjustment package which started in Nov 2005 and finished in Nov 2006 led to 26 gillnet vessel SFRs and 17 shark hook vessel SFRs leaving the fishery. In 2012 the option of increasing the length of gillnets set to 6000m was introduced (Figure 21.2).

Previous attempts to standardize commercial catch rates for sharks in Australia began with Punt *et al.* (2000) who used the Delta method, which analyses any trend in the probability of obtaining a positive shot and, separately, any trends in catch rates in the positive shots and then combining these two trends to obtain a single standardized catch rate for the fishery. Punt *et al.* (2000) focused on school sharks but their method was revised and extended when it was later applied to Gummy sharks (Punt & Gason, 2006; Thomson & Punt, 2010).

As Kimura (1981, p211) says: "Since the 1950s it has been recognized that fishing power generally differs among vessels, and if c.p.u.e. is to be proportional to abundance, effort measurements must be standardized." The most commonly used method of standardization is to include the various factors thought to effect catch rates into a generalized linear model and to include Year as a factor, in this way the parameters derived for each year become the indices of relative abundance (Venables & Dichmont, 2004).

After standardization we are left with a set of yearly coefficients that represent the catch rate relative to some reference year (usually with reference to the mean of the time series, which simplifies visual comparisons with other times series). Unfortunately, even if the standardization accounts for a large proportion of the variability in the data there are no guarantees that catch effort, even standardized catch effort, can act as a good proxy for stock size. Instead of the statistical success of the standardization, one should be able to argue from the nature of the fishery and the species concerned whether or not there is likely to be even an approximate relationship between catch rates and the exploitable biomass.

In this present work we focus on the catch rates for gummy shark, treating South Australia, Bass Strait, and Tasmania separately, because this reflects the assumed stock structure.

## 21.3 Methods

### 21.3.1 Catch Rate Standardization

The original data was provided by Dr Robin Thomson of CSIRO, in a text file named CANDE12.dat. This contained 478,513 records each with 23 fields (Table 18.17). The data provided received some pre-treatment in order to add the catch rate variables of interest and identify those records for inclusion in the analyses. Catch rates were calculated where there were positive catches of gummy sharks associated with positive effort levels. Where catch rates could be calculated they were also log transformed in preparation for the log-linear modelling of positive catches. Depth information, where present, was sub-divided into 10 metre depth categories for inclusion in the standardization. A field was added that identified which records contained positive catches of gummy sharks. This latter was necessary as a separate analysis is conducted to characterize the occurrence of zero shots (the complement of positive shots) and whether their incidence has altered through time (see below). Finally, a field was added that generated net length categories in steps of 500m to simplify some of the comparisons of effort types through time.

In previous standardizations (Punt & Gason, 2006; Thomson & Punt, 2010) a wide array of criteria were used to select records for analysis. An important aspect of any standardization where the trend in the probability of zero shots is included is how to identify zero shots, which relate to targeted effort that fails to catch the species of interest. In the SESSF trawl fishery identifying those shots that might have captured a species but didn't is extremely difficult because targeting is so difficult to establish. Fortunately, in the shark gillnet fishery this is less of a problem because gillnet shark fishers are targeting sharks, especially gummy sharks. The problem thus becomes one of focusing attention on those vessels and areas where the fishery is a main focus of effort. The primary data selection criteria are to select the years where the fishery was operating normally (as defined by the SharkRAG), to use records only where gillnets with mesh sizes of 6", 6.5" and 7" were used, to select only those vessels catching a defined minimum total catch per year and a defined number of years in the fishery, to include only those areas which were the main focus of the fishery, and to exclude those records with effort less than 1000m. In addition, records used were limited to particular gears and finally, those vessels that only caught small amounts of gummy shark across the years of the study were also excluded. The sensitivity of the analyses to the specific values selected as being a minimum reported catch for each area and vessel was tested by comparing an array of different combinations. In addition, the minimum number of years for a vessel to be active in the fishery was also considered.

It has previously been considered that the identification of zero shots could be made easily in the gummy shark fishery. However, there is a field in the database in which gummy shark and school shark catches are reported when combined. There are 9,665 records where there are no data for gummy sharks or for school sharks and yet there is catch data in the 'comb' field (Table 21.1). This is unfortunate because it remains unknown whether the reported catches were gummy or school sharks. What this means is that there may be a significant proportion of catches of gummy sharks which appear to be zero shots but were not in fact zero, they only appear that way. The unattributed catches are greatest in Bass Strait, although South Australia exhibits a few years of increased unattributed catches from 1990 through to 1995 (Table 21.1).

This adds a good deal of uncertainty to the zero shots as previously analysed. An alternative to attempting to identify zero shorts might be to consider the relatively small shots (< 10 kg), which is an option examined by Bradford (2001). In this way those small shots represented in the gummy shark catch field may be a representative sample of all small gummy shark shots. However, it is possible that small shots of both gummy and school sharks were differentially included in the 'comb' field so the outcome of this analysis will remain uncertain.

Table 21.1. The catch in tonnes reported in the separate gummy shark field, and the combined gummy and school shark catches field when there were no data in either the gummy or the school shark fields. It remains unknown whether these catches reported in 'comb' are school or gummy sharks.

| | Bass Strait | | South Australia | | |
|---|---|---|---|---|---|
| Year | Gummy | Comb | Gummy | Comb | Tasmania |
| 1976 | 660.697 | 192.790 | 168.679 | 74.494 | 0.250 |
| 1977 | 812.060 | 170.102 | 223.378 | 65.130 | 8.165 |
| 1978 | 745.308 | 110.671 | 223.522 | 14.868 | |
| 1979 | 639.389 | 92.882 | 241.416 | 1.926 | |
| 1980 | 734.394 | 123.888 | 332.315 | | |
| 1981 | 823.858 | 123.052 | 321.379 | 9.756 | |
| 1982 | 953.134 | 132.193 | 295.701 | 34.104 | 0.054 |
| 1983 | 998.303 | 126.334 | 262.410 | 15.244 | |
| 1984 | 962.745 | 60.208 | 428.028 | 24.856 | |
| 1985 | 921.939 | 98.617 | 436.553 | 1.324 | 7.004 |
| 1986 | 992.087 | 105.184 | 483.357 | 0.606 | 2.170 |
| 1987 | 877.866 | 107.214 | 543.542 | 24.662 | |
| 1988 | 777.049 | 108.477 | 609.177 | 18.789 | 14.993 |
| 1989 | 963.005 | 155.063 | 670.768 | 2.873 | |
| 1990 | 835.802 | 57.606 | 543.310 | 97.907 | 7.355 |
| 1991 | 908.738 | 21.708 | 496.037 | 132.421 | |
| 1992 | 1033.879 | 28.198 | 438.799 | 180.499 | 0.329 |
| 1993 | 1199.372 | 112.922 | 428.101 | 158.216 | 0.637 |
| 1994 | 846.529 | 113.598 | 457.405 | 81.042 | |
| 1995 | 1007.847 | 86.788 | 466.245 | 107.501 | 2.100 |
| 1996 | 790.020 | 57.135 | 553.914 | 59.086 | 0.116 |
| 1997 | 689.712 | 5.736 | 700.073 | 30.942 | 0.152 |
| 1998 | 794.510 | | 531.081 | 24.614 | |
| 1999 | 1026.668 | | 598.994 | 6.162 | |
| 2000 | 1042.436 | | 525.847 | 0.256 | |

### 21.3.2 The Delta Distribution

Including zero shots has two parts: 1) First, determine the relative probability of obtaining a positive catch. 2) Secondly, conduct a log-linear standardization on those records containing positive catches. These two analyses are then combined to provide the overall estimate of the yearly changes in catch rates required for inclusion in stock assessments.

### 21.3.3 Caveat to the Identification of Zero Shots

The assumption that it is simple to identify targeted shots in the shark fishery is used to include the proportion of zero shots in the standardization. However, there is an array of factors that call this assumption into doubt. The first factor is that up until 2000 there were amounts of catches reported as 'comb' when no catches were reported in either school or gummy sharks and this was mostly a problem within South Australia; from 2000 onwards, however, the amounts are greatly reduced. This adds greatly to the uncertainty over whether a zero recorded in the gummy column is only seemingly a zero. A second factor is that many changes in effort and fisher behaviour occurred in the fishery sometime between 1991 and 1995. These changes are so marked and would have greatly influenced how the fishery was conducted, and yet the standardization assumes that it is valid to estimate mean parameters across the complete time series. It raises the question of whether there are two time series of catches and catch rates, one up to about 1994 and the other from 1995 onwards, or whether the current assumption of a single time series is valid. The standardization of the positive catches is not greatly affected by separating the time series into 1976 – 1994 and 1995 – 2012, which reflects the fact that these time series are generally noisy but flat about the long term average. However, given the transition that occurs around about 1995 it would influence the analysis of the presence or absence of positive shots more significantly. It is unknown whether these two factors would alter the trend expressed in the analysis of presence or absence and so it remains questionable whether or not to include the analysis of zero shots in the overall analysis of catch rate trends.

### 21.3.4 Zero Catches

To estimate the probability of a positive observation (i.e. the species of interest is present in a shot) a binomial GLM (using a logit link function) is used to determine the effect of an array of factors on the probability $p_i$, which is the probability that the species of interest is present in the $i^{\text{th}}$ shot:

$$\ln\left(\frac{p_i}{1-p_i}\right) = \beta_0 + \beta_1 x_{i,1} + \beta_2 x_{i,2} + \sum_{j=3}^{N} \beta_j x_{ij} \quad (4)$$

where $p_i$ is the probability that the species of interest was present in the $i^{th}$ shot, and $x_{ij}$ are the values of the explanatory variables, $j$, for the $i^{th}$ shot and the $\beta_j$ are the coefficients for the $N$ factors $j$, to be estimated ($\beta_0$ is the intercept, $\beta_1$ the coefficient for the first factor, *etc*.).

The catch rate standardizations all used individual records from the database, which in a number of cases appeared to be aggregated data, potentially aggregated within months, although there were also many individual shots recorded. This is apparent because the reported effort as net length is sometimes in the 100's of thousands of metres for a single record. The catch rate data for positive catches were normalized by using a natural-log transformation. General Linear Models were used with this transformed data rather than using Generalized Linear Models on the untransformed data with a log-link; the approach used 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).

Up to eight different log-linear models were fitted and compared in an effort to account for the effects of year, area, month of fishing, vessel, which depth category was used, which gear was used, and any interactions between area and month, and area and gear (see Haddon, 2011). All variables were treated as categorical variables (alternatively termed factors). The optimum statistical model was selected on the basis of the Akaike's Information Criterion (Burnham & Anderson, 1998), and the adjusted $r^2$ (Neter *et al.,*1996). The resulting optimal model was plotted in comparison with the geometric mean catch rate, both being scaled to the mean of each series for ease of visual comparison. The standardized catch rates for the year factor can be used in assessment models as the index of relative abundance through time.

Standard analyses were conducted in each case and all were coded in the statistical software R (R development Core Team, 2009). In each case, catch rates, as kilograms per metre of gillnet fished, were natural log-transformed to normalize the data and stabilize the variance. The General Linear Models all had the same form:

$$\mathrm{Ln}\left(CPUE_i\right) = \alpha_0 + \alpha_1 x_{i,1} + \alpha_2 x_{i,2} + \sum_{j=3}^{N} \alpha_j x_{ij} + \varepsilon_{ij} \tag{5}$$

where Ln($CPUE_i$) is the natural logarithm of the catch rate (kg/m) for the *i*-th record, $x_{ij}$ are the values of the explanatory variables *j* for the *i*-th shot (i.e. Year, Disting, Month, etc), 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*.), and $\varepsilon_{ij}$ are the normal random residual errors.

### *21.3.5 The Year Effect*

The standardised overall year effect for the fishery is calculated as the product of the Year coefficients from the binomial and log-linear GLMs (Eqs (4) and 1) transformed back onto their original scales. For back-transformation all other predictor variables were set to zero, indicating the reference level of each categorical factor. The expected probability (back-transformed from logit) of a non-zero catch in year *t* is therefore

$$\hat{p}_t = \frac{\exp\left(\beta_0 + \lambda_t\right)}{1 + \exp\left(\beta_0 + \lambda_t\right)} \tag{6}$$

where $p_t$ is the probability of a non-zero catch in year *t*, $\beta_0$ is the intercept and the $\lambda_t$ is the Year coefficient for year *t*. As a test of the procedure the back transformation of the simple PA = Year model should deliver the annual proportion of positive shots.

For the log-normal model the expected back-transformed year effect involves a bias-correction for log-normality; the back transformation without the correction estimates the median of the distribution rather than the mean, adding $\sigma^2/2$ before back-transformation improves the approximation to the mean of the distribution:

$$CPUE_t = e^{\left(\gamma_t + \sigma_t^2/2\right)} \tag{7}$$

where $\gamma_t$ is the Year coefficient for year *t* and $\sigma_t$ is its standard error. Total standardised catch rates for year *t* are calculated as the product of Eqs (6) and (7), stated relative to the average of all values:

$$\bar{Y} = \frac{\sum_{t=1}^{n} p_t CPUE_t}{n} \tag{8}$$

where *n* is the number of years of data. So the standardized catch rates are given relative to the mean of the series. This implies that the average of the time series of standardized catch rates will always be one, and hence each series is directly comparable with all the others:

$$Y_t = \frac{p_t CPUE_t}{\bar{Y}} \tag{9}$$

The factors considered in the analyses were all taken as categorical variables and were:

Year the standard calendar year,
Disting each vessel is uniquely and confidentially identified,
Month standard calendar months,
Area Standard shark statistical reporting blocks (Figure 21.1).
Gear 6.0”, 6.5”, or 7.0” mesh nets.
DepCat 10m categories (novel this year)
Area:Month An interaction term used to include any seasonal changes across areas.

### *21.3.6 Data Selection Gummy Sharks*

Data selection occurred with the years of data used by zone, the gear used, the depths, used, and with areas only being included if total catches exceeded a given limit, vessels were only included if their average annual catches exceeded a given limit, and they were reporting catches for more than a given number of years in the fishery (Table 21.2).

Table 21.2. Criteria for selecting which records to include in the standardization of gummy sharks.

| Criteria | Values |
|---|---|
| South Australia: years | 1984 – 2010 |
| Bass Strait: years | 1976 – 2010 |
| Tasmania: years | 1990 – 2010 |
| Gear Types | 6”, 6.5”, and 7” mesh gillnet |
| Depth | 10 m depth classes 1 – 240 m |
| Areas | Reporting > 10 t over years. |
| Vessels | Average annual catch > 2 t |
| Vessels | In fishery for > 2 years |
| Effort | >= 1000 m |

Useful depth data was not provided from South Australia until after 1997 so depth cannot be included in the South Australia standardization, although from 2000 onwards it would be useful.

There are a large number of vessels contributing to the final analysis, even with the restricted number of years and areas used. To remove noise generated by those vessels reporting very small amounts of gummy sharks those vessels reporting less than an average of 2 tonne per year (for the years in which they reported sharks) were removed from the analysis. In addition, if they reported for less than 3 years they were excluded.

### *21.3.7 Disjunction around 1995*

Major changes appear to have occurred in the data from the fishery during the early 1990s. To illustrate this disjunction the catch per vessel per year (as identified by their distinguishing marks) can be tabulated. From this table it is possible to sum the catches per vessel from 1976 – 1993 and, separately, the catches by vessel from 1994 – 2010. These data can then be used to estimate the proportional representation of the catches by vessel across these two periods. In addition to the vessel changes there were changes in how fishing occurred with a major alteration in the net length used in the fishery (Figure 21.2). These changes in net length occurred at about the same time as the vessel changes although there were differences between zones.

Such large changes bring into doubt whether or not the time series of catch rates through the decades remain comparable and raise the question whether or not to treat the data as two time series in which the fishery operated sufficiently differently as to require separate treatment. In fact, separate treatment does not appear to have much impact on the analysis of positive catches but there remains a marked difference in the proportion of zero shots.

## 21.4 Results

### 21.4.1 The Shark Fishery

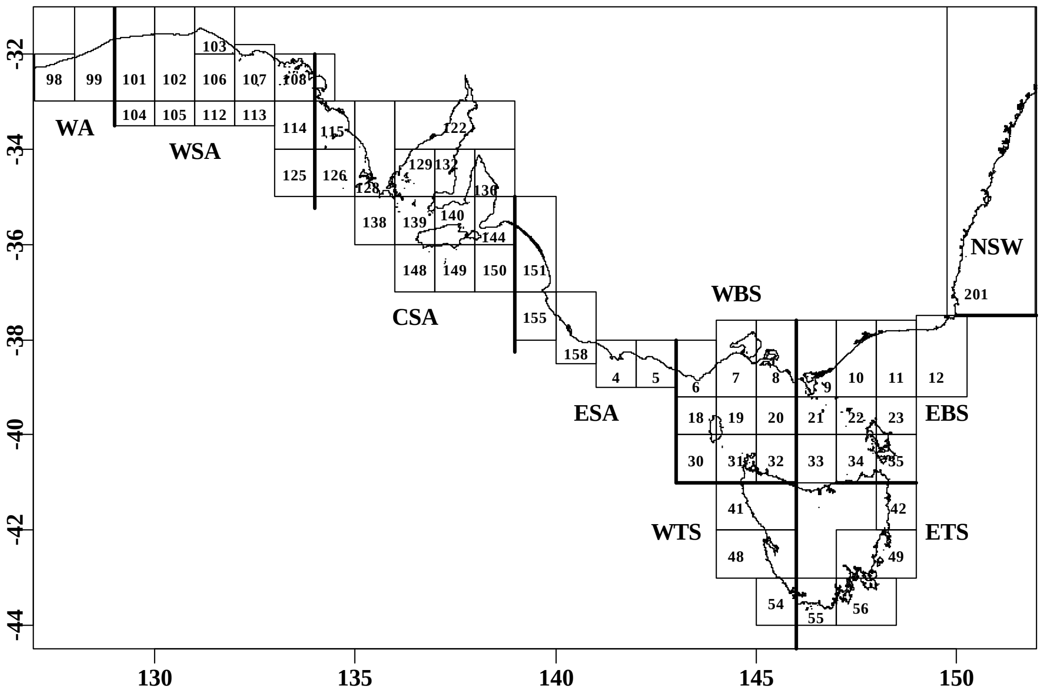


Figure 21.1. Map of shark statistical reporting areas along with the statistical regions. WA is Western Australia, WSA is Western South Australia, CSA is Central South Australia, ESA is Eastern South Australia (sometimes known as SAV – South Australia Victoria), WBS is Western Bass Strait, EBS is Eastern Bass Strait, NSW is New South Wales, ETS is Eastern Tasmania and WTS is Western Tasmania.

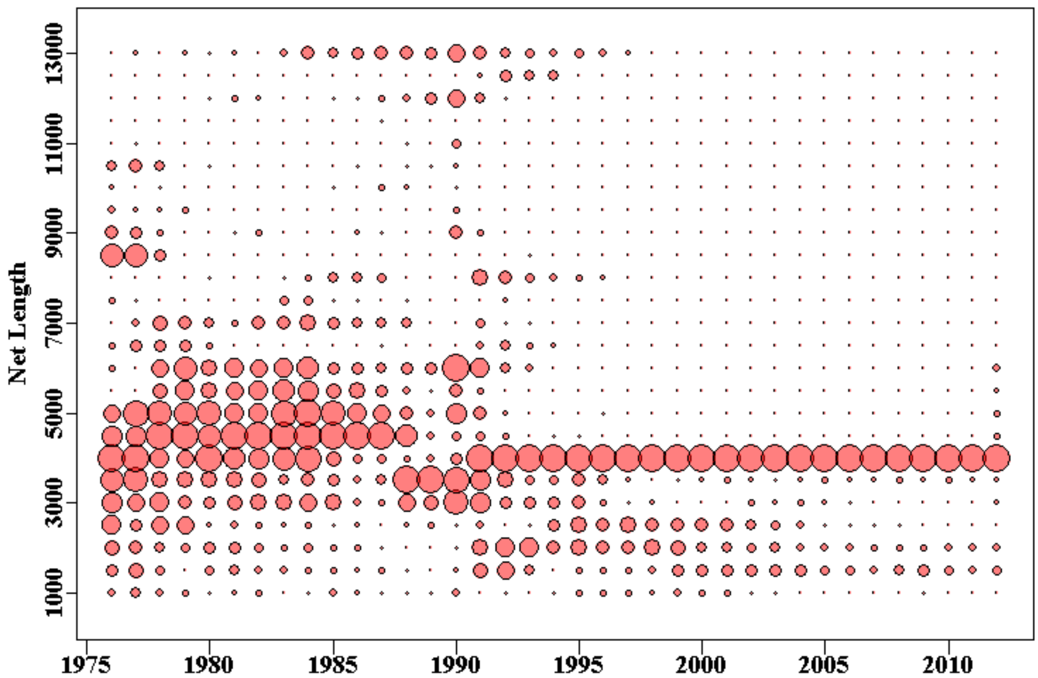


Figure 21.2. The relative number of records in the shark fishery in each year reporting different net lengths of effort. The radical change just before 1995 is clear. The 13000 line is >= 13000m.

### *21.4.2 The Gummy Shark Fishery*

Following the decline in the school shark fishery, the non-trawl shark fishery is now dominated by the gummy shark fishery (Figure 21.3, Figure 21.4; Table 21.18).

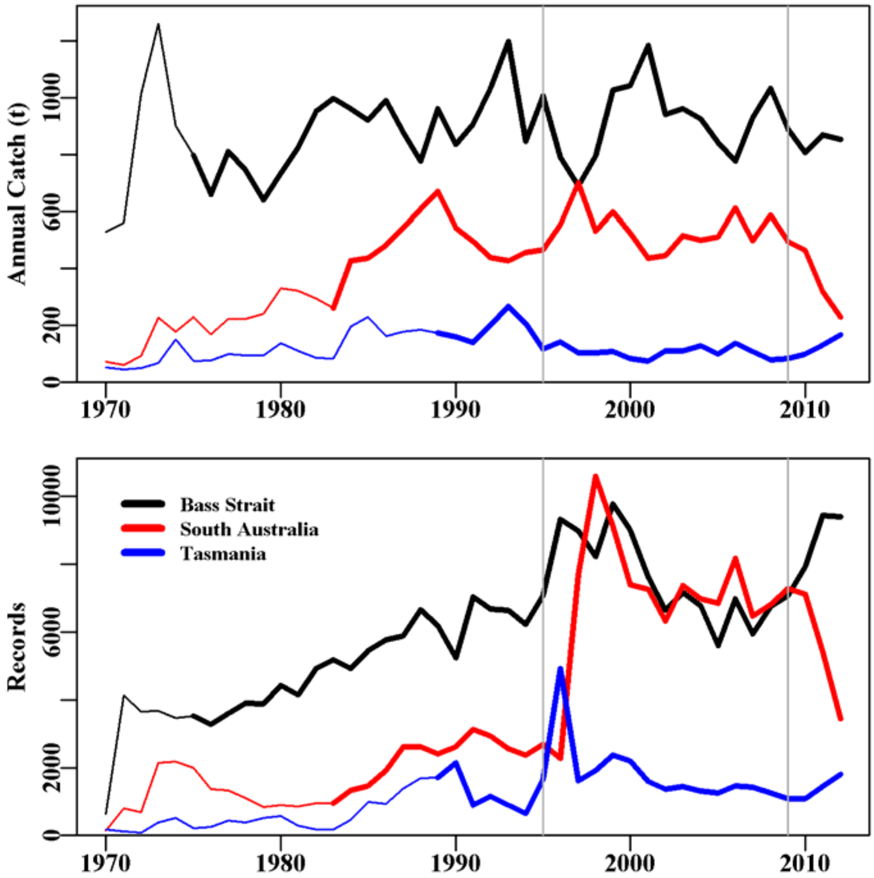


Figure 21.3. The total annual catch and number of records for the three main regions in the Gummy shark fishery for all gears. The thick lines represent the range of years chosen by the SharkRAG to represent the fishery, while the fine lines represent the available data in the CANDE12 log book data base. The grey vertical lines relate to 1995 and 2009.

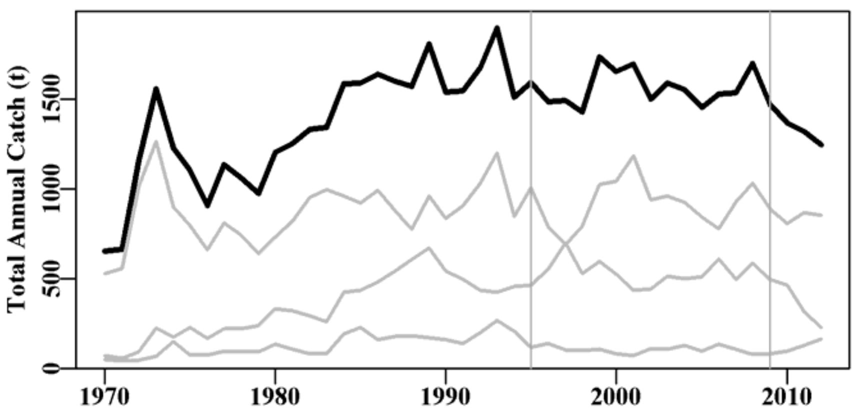


Figure 21.4. Total reported catches of gummy sharks, 1970 – 2012 from the log-books. The grey lines relate to the individual regions. These data relate to all gillnet catches by all mesh sizes. The vertical grey lines relate to 1995 and 2009

There is a clear disjunction between the available data across the period 1995 - 1997, with changes first becoming apparent depending on location (Figure 21.3, Figure 21.4, and Figure 21.5). The impact on the number of records is more strongly marked than with the reporting of catches, which indicates that the earlier period contains many amalgamated days or trips; this is especially the case in South Australia and in Bass Strait. Such a transition also becomes apparent in the standardized catch rates with a transition in character sometime between 1995 and 1997. Total catches have been relatively stable since 1995 although have been declining since 2009, primarily in South Australia, where the Australian Sea Lion closures began to impact the gummy shark fishery.

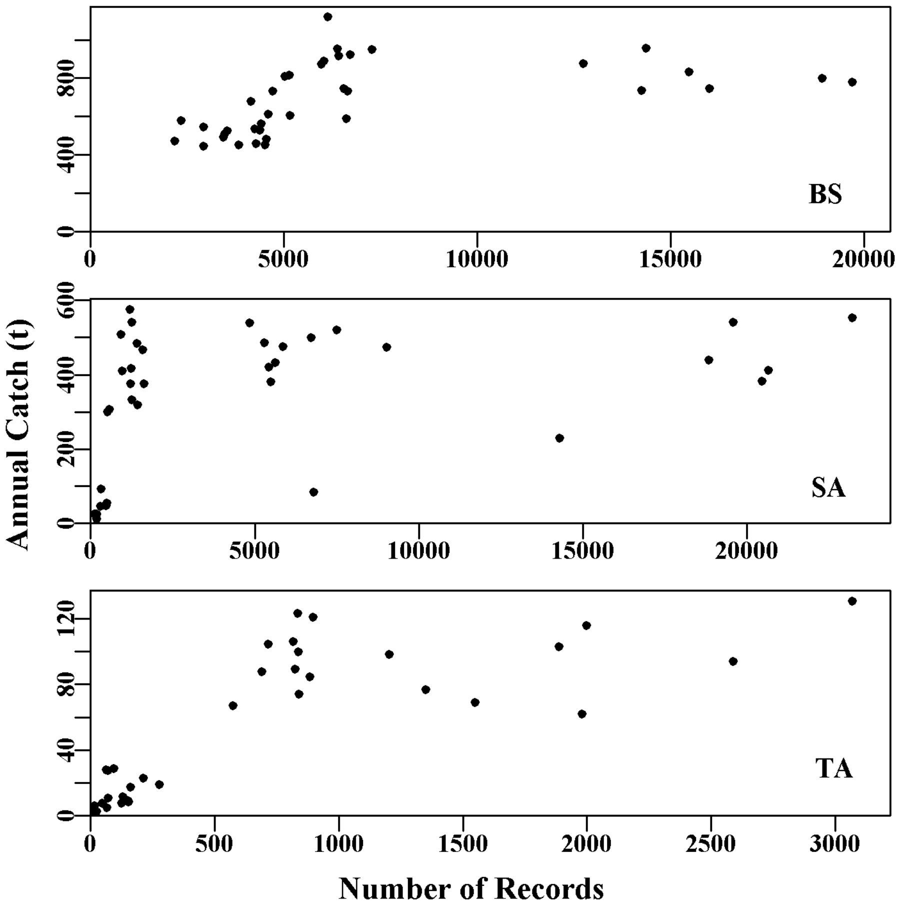


Figure 21.5. The relationship between the number of records and the resulting catch each year in each of the three regions. This data relate only to catches taken with 6", 6.5" and 7" nets are include data from all years 1970 to 2012. Note the different x and Y axes for the different regions.

Reported catches of gummy sharks has declined from a relative high in 2008, although interpreting this is made more complex because of the 16 month TAC put in place for the 2007/2008 season (Table 21.3; Figure 21.8). Nevertheless, the recent decline is real and is related to parallel declines of catches in South Australia and Bass Strait. Catches from South Australia decreased further in 2012 but recovered slightly in Bass Strait. Catches by Drop Line and AutoLine are beginning to rise in the last two years. These various recent changes are attributed to the introduction of gillnet closures to protect Australian Sea Lions and dolphins in South Australian waters.

At the same time the proportion of catches taken by gillnets declined over the period 2001 – 2012 (Table 21.3).

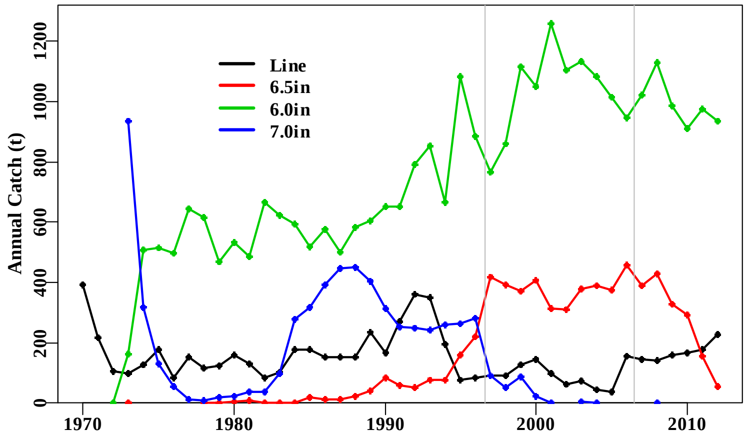


Figure 21.6. The total catches of gummy sharks across years and areas by the three main mesh sizes and Line methods.

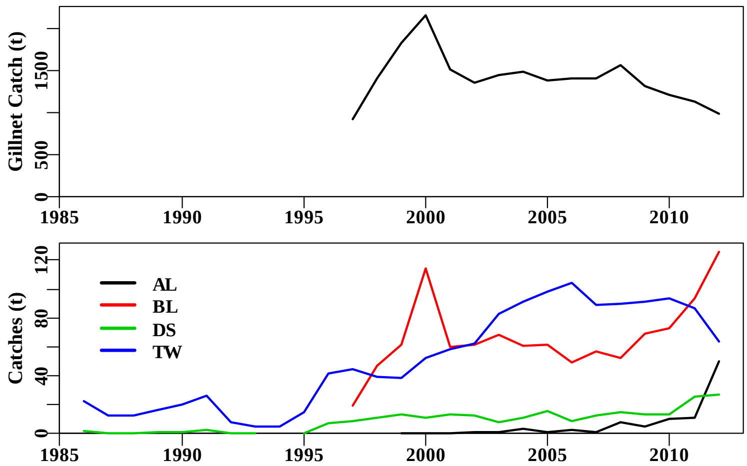


Figure 21.7. The total catch of gummy sharks across years and areas by the five main methods reported in the AFMA logbook database (all gillnet mesh sizes in the top panel).

Table 21.3. A comparison of reported weights with landed weights from the CDR database. Quotas were only introduced in 2001, which was when this data began to be reported in the CDRs. LogBook relate to all methods, GillNets relates to GillNet catches reported in the logbooks.

| Year | Total Landed | Log-Books | GillNets | %LogBook | %GillNet | TAC |
|---|---|---|---|---|---|---|
| 2001 | 1726.384 | 1655.552 | 1521.001 | 95.90 | 91.9 | 1717 |
| 2002 | 1604.916 | 1491.241 | 1352.829 | 92.92 | 90.7 | 1717 |
| 2003 | 1676.143 | 1616.064 | 1454.115 | 96.42 | 90.0 | 1717 |
| 2004 | 1738.575 | 1651.195 | 1484.008 | 94.97 | 89.9 | 1717 |
| 2005 | 1644.973 | 1566.541 | 1388.905 | 95.23 | 88.7 | 1717 |
| 2006 | 1646.440 | 1572.912 | 1405.758 | 95.53 | 89.4 | 1717 |
| 2007 | 1678.090 | 1574.136 | 1413.702 | 93.81 | 89.8 | 2467 |
| 2008 | 1892.140 | 1727.565 | 1561.977 | 91.30 | 90.4 | 1717 |
| 2009 | 1645.739 | 1499.297 | 1320.881 | 91.10 | 88.1 | 1717 |
| 2010 | 1537.398 | 1403.149 | 1212.363 | 91.27 | 86.4 | 1717 |
| 2011 | 1514.216 | 1364.609 | 1130.857 | 90.12 | 82.9 | 1717 |
| 2012 | 1328.018 | 1269.284 | 991.932 | 95.58 | 78.1 | 1717 |

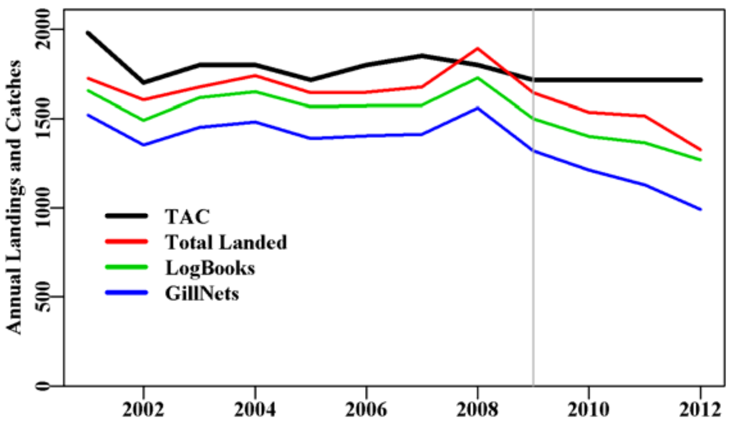


Figure 21.8. A comparison of the annual landings reported against quota in the CDRs and catches reported in the log-books, both across all methods and for Gill Nets only. The TAC in 2008 appears less than the catch but this is a reflection of a 16 month season at that time.

The reduction in catches, especially in gillnets is clearly due to reductions in central South Australia. Catches in Tasmania have risen on both the east and west coasts but only by relatively small amounts (Figure 21.8 and Figure 21.9).

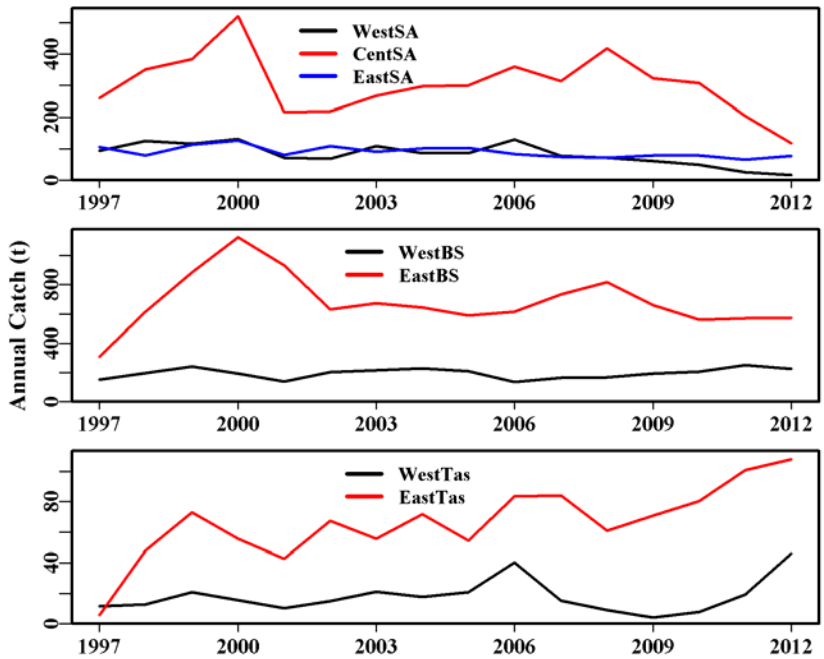


Figure 21.9. The catches reported in the main fishery regions in the logbooks taken in the gillnet, hook, and trap fishery (and its historical antecedents).

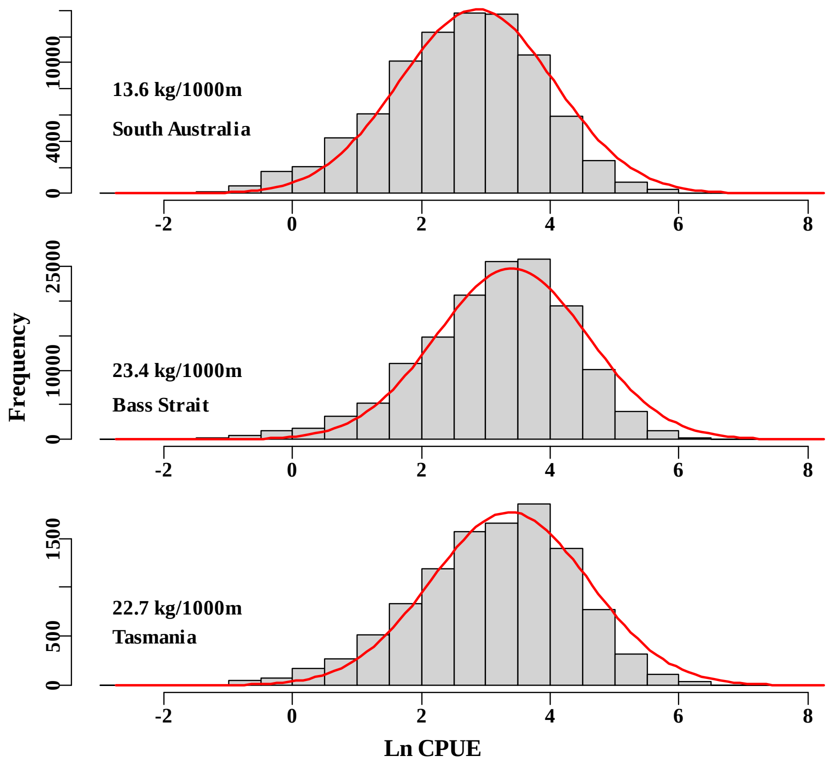


Figure 21.10. Comparisons of all catch rate data for each zone across years with their respective normal distribution. A natural log-transformation is used to normalize the data in each case. There is slight over-representativeness of smaller catch rates and under-representation of larger catch rates but the normal distribution appear to be a reasonable approximation.

#### *21.4.3 South Australia*

The standardization of the South Australian gummy shark catch-rates reduces the variation exhibited by the trend through time, with the geometric mean catch rates having a CV of 8.6% while the optimum model has a CV of 9.5% (Figure 21.11; Table 21.4); although these values are overly small through having so many data records. Nevertheless, each mean estimate is relatively uncertain, as indicated by the 95% confidence intervals on the graphs) and only a few years could be considered statistically significant. It should be noted that the width of these confidence intervals are likely to be under-estimates owing to the various influential factors that have not been able to be included in the analysis. The uncertainty in the analysis of positive shots is even greater (Figure 21.11).

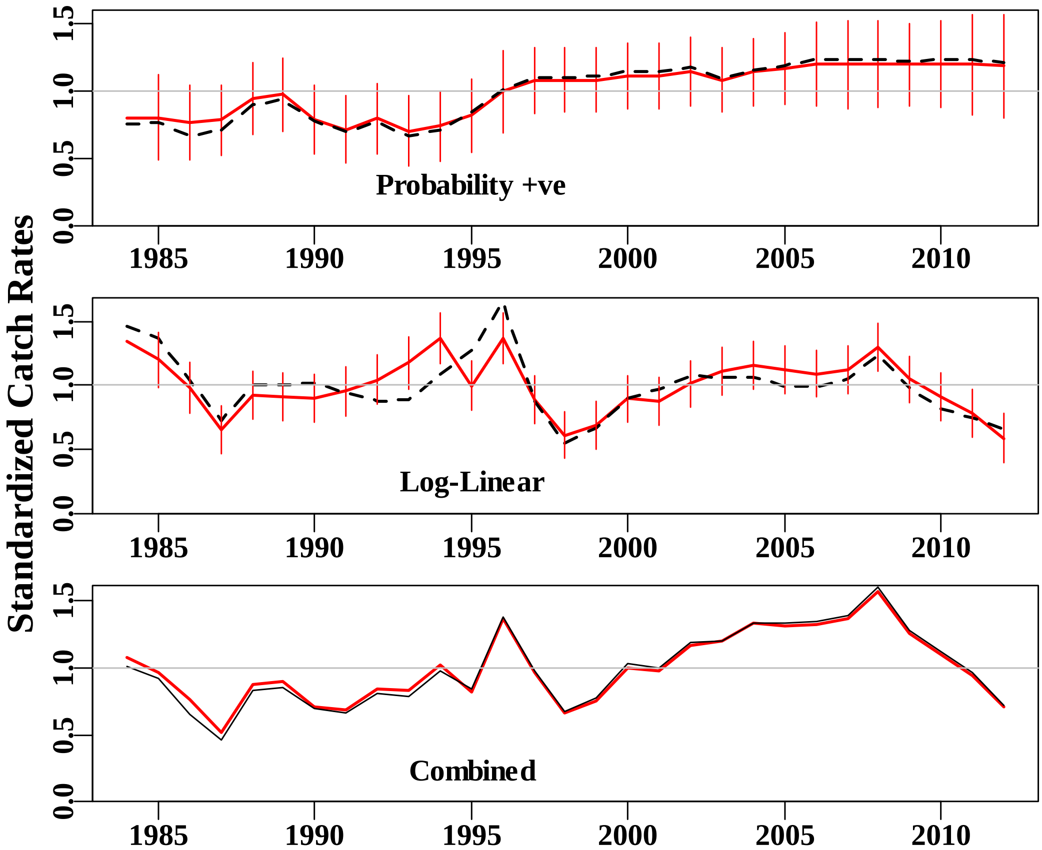


Figure 21.11. Standardized catch rates for South Australia gummy sharks using data relating to 6.0”, 6.5”, and 7.0” mesh gear, from areas that reported more than 10 tonnes across the 28 years considered (1984 – 2011), and from vessels with average catches greater than 2 tonnes per annum which had been present in the fishery for at least 3 years. At top is the probability of obtaining a positive catch, the dashed line being the proportion of positive catches in the raw data and the solid line being the statistical optimum model (with 95% error bars surrounding the trend). The central panel represents the log-linear modelling of positive catches. The dashed line is the geometric mean while the solid line is the optimal model, again with 95% confidence limits on the mean estimates. The bottom panel represents the final standardized catch rates, combining the results from the log-linear modelling and the binomial modelling of the probability of a positive catch. The fine black line is the combination of the standardized catch rates and the probability of a positive catch in the raw data, which in this case makes little difference. All trends have been scaled to the mean of each series to ease visual comparison.

When the analysis of positive catches is combined with the analysis of the relative incidence of positive shots then there does not appear to have been the overall trend through time. Perhaps catch rates were lower pre-1995 and generally higher after 1995.

The decline from the high in 2008 is associated with a reduction in the catch landed in South Australia and with a reduction of greater than 50% in the number of records in 2012, relative to 2009, brought about by the Australian sea lion closures. These closures appear likely to lead to a decline in observed catch rates.

The overall conclusion is that the catch rates for gummy shark in South Australia were effectively flat and noisy about the long term average, but that they are now declining for reasons other than stock status.

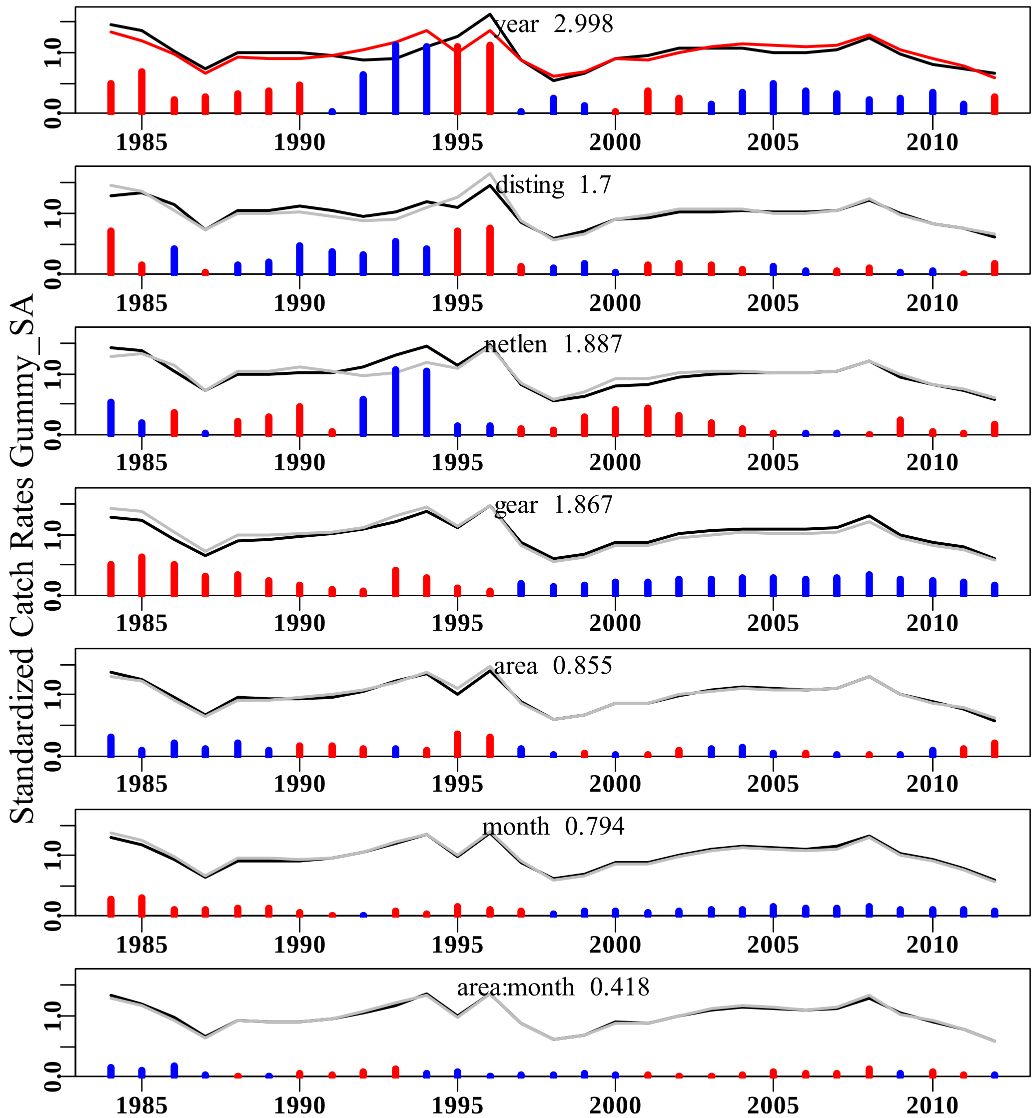


Figure 21.12. South Australian Gummy shark: The relative influence of each factor used on the final trend in the optimal standardization. The top graph depicts the geometric mean (the black line) and the optimum model (the red line). The difference between them is illustrated by the vertical bars with 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 21.4. The different standardization models fitted to the South Australian gummy shark data. The models are cumulative across the table with the optimum being the Area:Month model.

| Year | GeoMean | Vessel | NetLen | Gear | Area | Month | Area:Month |
|---|---|---|---|---|---|---|---|
| 1984 | 1.4643 | 1.2866 | 1.4215 | 1.2927 | 1.3670 | 1.3004 | **1.3393** |
| 1985 | 1.3701 | 1.3320 | 1.3812 | 1.2258 | 1.2469 | 1.1742 | **1.1978** |
| 1986 | 1.0359 | 1.1390 | 1.0459 | 0.9194 | 0.9692 | 0.9403 | **0.9823** |
| 1987 | 0.7288 | 0.7195 | 0.7228 | 0.6423 | 0.6725 | 0.6484 | **0.6573** |
| 1988 | 1.0027 | 1.0378 | 0.9844 | 0.9012 | 0.9564 | 0.9203 | **0.9193** |
| 1989 | 1.0059 | 1.0537 | 0.9838 | 0.9242 | 0.9473 | 0.9131 | **0.9158** |
| 1990 | 1.0127 | 1.1262 | 1.0112 | 0.9697 | 0.9284 | 0.9131 | **0.8984** |
| 1991 | 0.9457 | 1.0388 | 1.0289 | 1.0055 | 0.9631 | 0.9595 | **0.9541** |
| 1992 | 0.8800 | 0.9607 | 1.1060 | 1.0891 | 1.0588 | 1.0640 | **1.0418** |
| 1993 | 0.8937 | 1.0290 | 1.2985 | 1.1984 | 1.2277 | 1.2091 | **1.1746** |
| 1994 | 1.0883 | 1.1895 | 1.4491 | 1.3755 | 1.3541 | 1.3451 | **1.3618** |
| 1995 | 1.2718 | 1.0926 | 1.1301 | 1.1014 | 1.0153 | 0.9762 | **0.9955** |
| 1996 | 1.6424 | 1.4510 | 1.4851 | 1.4700 | 1.3908 | 1.3615 | **1.3632** |
| 1997 | 0.8775 | 0.8451 | 0.8181 | 0.8671 | 0.8974 | 0.8777 | **0.8858** |
| 1998 | 0.5525 | 0.5780 | 0.5596 | 0.5939 | 0.5967 | 0.6076 | **0.6138** |
| 1999 | 0.6617 | 0.7049 | 0.6326 | 0.6711 | 0.6613 | 0.6803 | **0.6934** |
| 2000 | 0.9051 | 0.9119 | 0.8115 | 0.8620 | 0.8643 | 0.8872 | **0.8950** |
| 2001 | 0.9659 | 0.9275 | 0.8193 | 0.8735 | 0.8672 | 0.8831 | **0.8732** |
| 2002 | 1.0756 | 1.0293 | 0.9497 | 1.0139 | 0.9897 | 1.0132 | **1.0113** |
| 2003 | 1.0689 | 1.0324 | 0.9859 | 1.0526 | 1.0831 | 1.1108 | **1.1076** |
| 2004 | 1.0682 | 1.0505 | 1.0269 | 1.0958 | 1.1325 | 1.1617 | **1.1552** |
| 2005 | 0.9922 | 1.0235 | 1.0196 | 1.0892 | 1.0990 | 1.1362 | **1.1177** |
| 2006 | 0.9980 | 1.0104 | 1.0155 | 1.0825 | 1.0730 | 1.1055 | **1.0920** |
| 2007 | 1.0463 | 1.0356 | 1.0405 | 1.1093 | 1.1112 | 1.1422 | **1.1265** |
| 2008 | 1.2403 | 1.2145 | 1.2121 | 1.2946 | 1.2933 | 1.3325 | **1.2994** |
| 2009 | 0.9859 | 0.9952 | 0.9344 | 0.9988 | 1.0039 | 1.0339 | **1.0459** |
| 2010 | 0.8183 | 0.8304 | 0.8168 | 0.8741 | 0.8989 | 0.9261 | **0.9069** |
| 2011 | 0.7446 | 0.7440 | 0.7390 | 0.7927 | 0.7669 | 0.7941 | **0.7845** |
| 2012 | 0.6567 | 0.6104 | 0.5701 | 0.6137 | 0.5639 | 0.5826 | **0.5906** |
| CV | 0.0865 | 0.0887 | 0.0961 | 0.0976 | 0.0960 | 0.0956 | 0.0949 |

Table 21.5. The statistical diagnostics for the South Australian gummy shark standardization. The smallest AIC and largest adjusted $r^2$ indicates the optimum statistical model.

| | GeoMean | Vessel | NetLen | Gear | Area | Month | Area:Month |
|---|---|---|---|---|---|---|---|
| AIC | 28941 | 24135 | 22209 | 22151 | 19179 | 18459 | **16561** |
| RSS | 119468 | 112659 | 109456 | 109377 | 105553 | 104636 | **101589** |
| MSS | 4323 | 11131 | 14334 | 14413 | 18238 | 19154 | **22202** |
| Nobs | 85077 | 85077 | 85077 | 85077 | 85077 | 85077 | **85077** |
| Npars | 29 | 122 | 386 | 388 | 416 | 427 | **735** |
| adj_r2 | 3.460 | 8.862 | 11.178 | 11.240 | 14.315 | 15.048 | **17.221** |
| %Change | 0.000 | 5.402 | 2.315 | 0.062 | 3.075 | 0.733 | **2.906** |

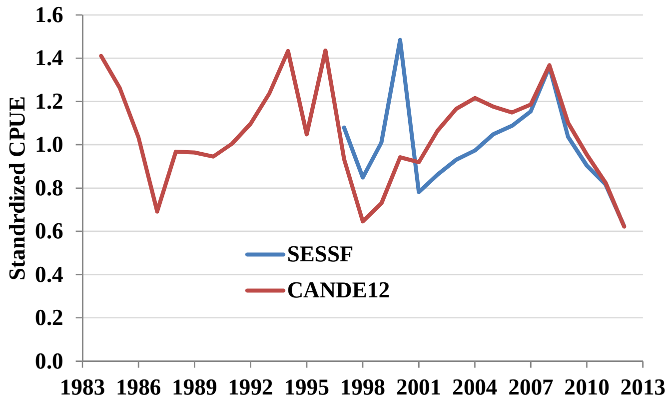


Figure 21.13. A comparison of the standardization obtained for South Australia obtained from positive catches from the CANDE12 database and the SESSF GenLog log book database. The overlap since the structural adjustment is extremely close but that reflects the fact that the CANDE database is updated from 2005 onwards using the GenLog database.

Table 21.6. Standardization of positive shots using data from the SESSF logbooks (Figure 21.13).

| | Year | Vessel | DepCat | Area | Month | DayNight | Area:Month | Area:DepCat |
|---|---|---|---|---|---|---|---|---|
| 1997 | 1.0424 | 1.1517 | 1.1782 | 1.1790 | 1.0895 | 1.0633 | 1.0665 | 1.0795 |
| 1998 | 0.7665 | 0.8499 | 0.8757 | 0.8751 | 0.8597 | 0.8447 | 0.8447 | 0.8485 |
| 1999 | 0.9999 | 1.0161 | 1.0250 | 1.0241 | 1.0189 | 1.0066 | 1.0077 | 1.0107 |
| 2000 | 1.5288 | 1.4883 | 1.4888 | 1.4884 | 1.4858 | 1.4847 | 1.4819 | 1.4841 |
| 2001 | 0.8156 | 0.7965 | 0.7892 | 0.7885 | 0.7804 | 0.7817 | 0.7827 | 0.7811 |
| 2002 | 0.9177 | 0.8776 | 0.8739 | 0.8737 | 0.8643 | 0.8652 | 0.8647 | 0.8621 |
| 2003 | 0.9438 | 0.9305 | 0.9390 | 0.9374 | 0.9294 | 0.9327 | 0.9333 | 0.9309 |
| 2004 | 0.9596 | 0.9569 | 0.9741 | 0.9739 | 0.9734 | 0.9775 | 0.9771 | 0.9738 |
| 2005 | 1.0715 | 1.0278 | 1.0260 | 1.0255 | 1.0409 | 1.0446 | 1.0464 | 1.0479 |
| 2006 | 1.1049 | 1.0687 | 1.0677 | 1.0687 | 1.0891 | 1.0944 | 1.0941 | 1.0878 |
| 2007 | 1.1738 | 1.1344 | 1.1346 | 1.1369 | 1.1482 | 1.1541 | 1.1579 | 1.1543 |
| 2008 | 1.3369 | 1.3417 | 1.3314 | 1.3339 | 1.3546 | 1.3623 | 1.3609 | 1.3603 |
| 2009 | 0.9960 | 1.0319 | 1.0209 | 1.0223 | 1.0300 | 1.0367 | 1.0366 | 1.0355 |
| 2010 | 0.8728 | 0.8966 | 0.8773 | 0.8781 | 0.8959 | 0.9027 | 0.9019 | 0.9031 |
| 2011 | 0.8114 | 0.8174 | 0.7875 | 0.7867 | 0.8160 | 0.8211 | 0.8194 | 0.8169 |
| 2012 | 0.6584 | 0.6139 | 0.6109 | 0.6079 | 0.6238 | 0.6277 | 0.6243 | 0.6234 |
| StErr | 0.0246 | 0.0273 | 0.0273 | 0.0273 | 0.0274 | 0.0293 | 0.0293 | 0.0293 |

### *21.4.4 Bass Strait*

The transition in the character of the gillnet commercial catch and effort data before and after 1995 or 1996 is clearly apparent in the catch rate standardization, although in the case of Bass Strait this is only apparent in the standardization of the probability of obtaining a positive shot. Zero shots for gummy sharks became far less likely following 1995 (Figure 21.14), which corresponds to changes in allowable net length and other related management changes. This transition is very apparent in the plot of the influence of each factor on the trend in the standardized catch rates (Figure 21.15); although see Haddon (2012) for data on net length and other changes in the fishery at that time.

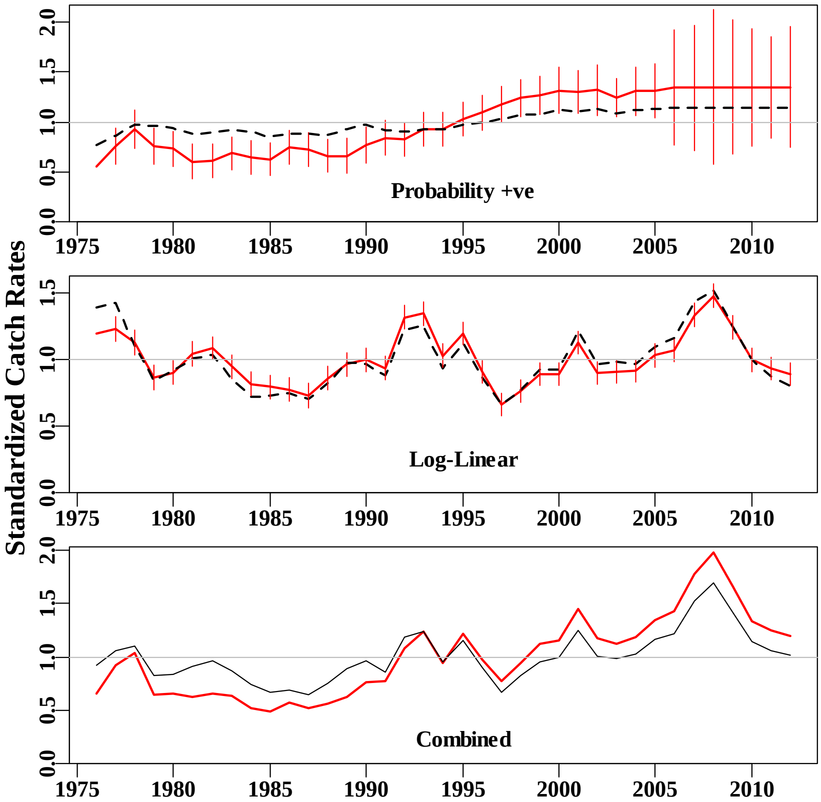


Figure 21.14. Standardized catch rates for Bass Strait gummy sharks using data relating to 6.0”, 6.5”, and 7.0” mesh gear, from areas that reported more than 10 tonnes across the 37 years considered (1976 – 2012), and from vessels with average catches greater than 2 tonnes per annum which had been present in the fishery for at least 3 years. The top panel represents the probability of obtaining a positive catch, the dashed line being the proportion of positive catches in the raw data and the solid line being the statistical optimum model (with the 95% error bars surrounding the trend). The central panel represents the log-linear modelling of positive catches. The dashed line is the geometric mean while the solid line is the optimal model, and again the bars are the 95% confidence limits on the mean estimates. The bottom panel represents the final standardized catch rates, combining the results from the log-linear modelling and the binomial modelling of the probability of a positive catch. The fine black line is the combination of the standardized catch rates and the probability of a positive catch in the raw data. All trends have been scaled to the mean of each series to ease visual comparison.

As with the positive catches in South Australia, the gummy shark catch rates in Bass Strait are noisy and flat relative to the long term catch rate. The probability of a positive catch, however, undergoes a significant change between 1993 – 1997. Thus, when the two series are combined the net result is stable catch rates from 1976 to about 1990 followed by a gradual increase up until 2008, followed by a decline to the present day. There is no simple mitigation for the uncertainty over the estimation of zero catches brought about by the presence of combined school shark and gummy shark records when there are no data for school or gummy sharks (Table 21.19). Despite the decline the catch rates since 2008 the catch rates are still above the long term average. This is even the case if the simple proportion of positive shots is used instead of the standardized time series. The catch rates (for the positive catches only) for both South Australia and Bass Strait (Figure 21.14) follow approximately the same trajectory through time (Figure 21.17).

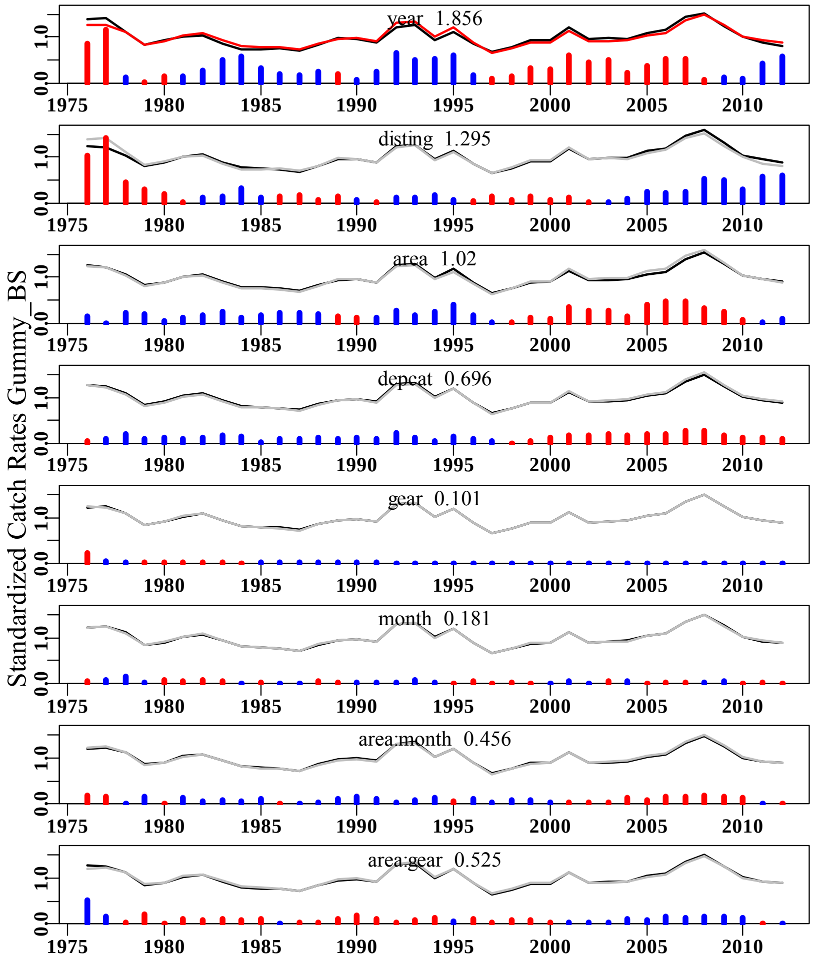


Figure 21.15. The relative influence of each factor used on the final trend in the optimal standardization for Bass Strait Gummy shark. The top graph depicts the geometric mean (the black line) and the optimum model (the red line). The difference between them is illustrated by the vertical bars with 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.

Despite the large change in the fishery between about 1994 and 1995 when the available data are analysed separately pre and post 1995, while there are more deviations from the original single time series trend in the pre-1995 data than post-1994, no important differences in the trends are apparent (Figure 21.16).

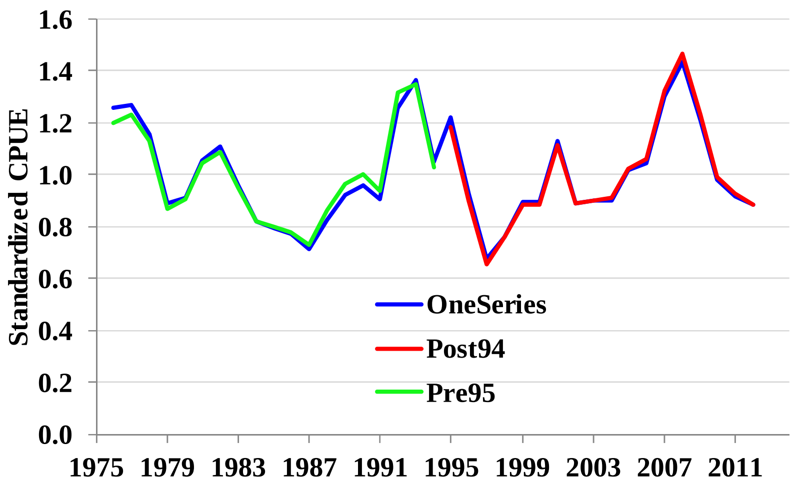


Figure 21.16. A comparison of the standardization when all Bass Strait data are analysed at once with an analysis of only those data from 1976 – 1994, and those data from 1995 – 2012.

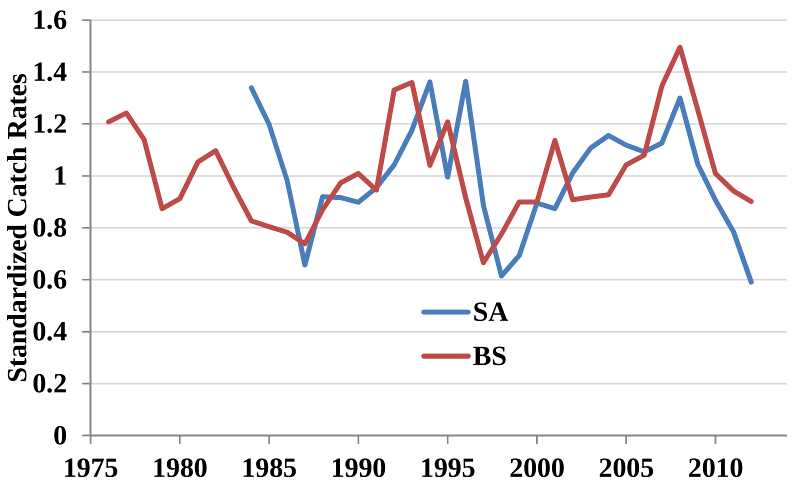


Figure 21.17. A comparison of the optimum standardized catch rates for positive catches for South Australia (SA) and Bass Strait (BS), both scaled to a mean of 1.0 over the years 1984 – 2012.

Table 21.7. The statistical diagnostics for the Bass Strait gummy shark standardization. The smallest AIC and largest adjusted $r^2$ indicates the optimum statistical model.

| | GeoMean | Vessel | Area | Depth | Gear | Month | Area:Month |
|---|---|---|---|---|---|---|---|
| AIC | 43836 | 38302 | 33226 | 31945 | 31932 | 31185 | 28587 |
| RSS | 196698 | 189061 | 182540 | 180882 | 180862 | 179909 | 176249 |
| MSS | 5539 | 13176 | 19697 | 21355 | 21375 | 22328 | 25988 |
| Nobs | 145651 | 145651 | 145651 | 145651 | 145651 | 145651 | 145651 |
| Npars | 37 | 154 | 172 | 196 | 198 | 209 | 407 |
| adj_r2 | 2.715 | 6.417 | 9.633 | 10.439 | 10.448 | 10.913 | 12.607 |
| %Change | 0.000 | 3.702 | 3.216 | 0.806 | 0.009 | 0.465 | 2.159 |

Table 21.8. The different standardization models fitted to the Bass Strait gummy shark data. The models are cumulative across the table with the optimum being the Area:Month model. The CVs reflect the relative variability of each time series. The CVs for each series are again very small, which is a reflection of the large number of observations available.

| Year | GeoMean | Vessel | Area | Depth | Gear | Month | Area:Month |
|---|---|---|---|---|---|---|---|
| 1976 | 1.3899 | 1.2408 | 1.2628 | 1.2576 | 1.2255 | 1.2189 | 1.1917 |
| 1977 | 1.4174 | 1.2151 | 1.2160 | 1.2308 | 1.2390 | 1.2498 | 1.2260 |
| 1978 | 1.1011 | 1.0371 | 1.0690 | 1.0983 | 1.1020 | 1.1228 | 1.1248 |
| 1979 | 0.8370 | 0.7957 | 0.8226 | 0.8360 | 0.8333 | 0.8379 | 0.8622 |
| 1980 | 0.9176 | 0.8911 | 0.8969 | 0.9147 | 0.9123 | 0.9004 | 0.9004 |
| 1981 | 1.0031 | 1.0014 | 1.0175 | 1.0316 | 1.0263 | 1.0204 | 1.0398 |
| 1982 | 1.0321 | 1.0478 | 1.0714 | 1.0891 | 1.0845 | 1.0750 | 1.0824 |
| 1983 | 0.8582 | 0.8804 | 0.9150 | 0.9415 | 0.9388 | 0.9329 | 0.9442 |
| 1984 | 0.7215 | 0.7681 | 0.7870 | 0.8099 | 0.8089 | 0.8094 | 0.8164 |
| 1985 | 0.7311 | 0.7493 | 0.7736 | 0.7780 | 0.7817 | 0.7790 | 0.7941 |
| 1986 | 0.7474 | 0.7280 | 0.7591 | 0.7717 | 0.7752 | 0.7758 | 0.7733 |
| 1987 | 0.7020 | 0.6779 | 0.7081 | 0.7227 | 0.7259 | 0.7262 | 0.7286 |
| 1988 | 0.8183 | 0.8093 | 0.8381 | 0.8558 | 0.8589 | 0.8525 | 0.8581 |
| 1989 | 0.9744 | 0.9540 | 0.9346 | 0.9475 | 0.9511 | 0.9454 | 0.9607 |
| 1990 | 0.9605 | 0.9688 | 0.9512 | 0.9675 | 0.9697 | 0.9723 | 0.9958 |
| 1991 | 0.8815 | 0.8790 | 0.8965 | 0.9102 | 0.9120 | 0.9169 | 0.9331 |
| 1992 | 1.2166 | 1.2336 | 1.2728 | 1.3036 | 1.3039 | 1.3088 | 1.3130 |
| 1993 | 1.2553 | 1.2712 | 1.2970 | 1.3162 | 1.3176 | 1.3289 | 1.3415 |
| 1994 | 0.9350 | 0.9607 | 0.9953 | 1.0039 | 1.0049 | 1.0096 | 1.0267 |
| 1995 | 1.1157 | 1.1239 | 1.1798 | 1.1995 | 1.2008 | 1.2007 | 1.1919 |
| 1996 | 0.8655 | 0.8584 | 0.8820 | 0.8945 | 0.8955 | 0.8894 | 0.9030 |
| 1997 | 0.6635 | 0.6411 | 0.6441 | 0.6524 | 0.6530 | 0.6510 | 0.6569 |
| 1998 | 0.7731 | 0.7633 | 0.7599 | 0.7595 | 0.7602 | 0.7558 | 0.7657 |
| 1999 | 0.9232 | 0.9033 | 0.8843 | 0.8791 | 0.8798 | 0.8780 | 0.8880 |
| 2000 | 0.9250 | 0.9148 | 0.8992 | 0.8820 | 0.8829 | 0.8832 | 0.8879 |
| 2001 | 1.2109 | 1.1955 | 1.1446 | 1.1199 | 1.1209 | 1.1270 | 1.1218 |
| 2002 | 0.9636 | 0.9613 | 0.9238 | 0.8999 | 0.9007 | 0.9011 | 0.8956 |
| 2003 | 0.9837 | 0.9848 | 0.9472 | 0.9174 | 0.9181 | 0.9123 | 0.9062 |
| 2004 | 0.9638 | 0.9755 | 0.9531 | 0.9276 | 0.9280 | 0.9355 | 0.9155 |
| 2005 | 1.0935 | 1.1283 | 1.0702 | 1.0412 | 1.0420 | 1.0417 | 1.0286 |
| 2006 | 1.1622 | 1.1924 | 1.1237 | 1.0933 | 1.0941 | 1.0897 | 1.0660 |
| 2007 | 1.4271 | 1.4637 | 1.3949 | 1.3536 | 1.3545 | 1.3523 | 1.3295 |
| 2008 | 1.5098 | 1.5855 | 1.5375 | 1.4989 | 1.4999 | 1.5023 | 1.4755 |
| 2009 | 1.2435 | 1.3142 | 1.2801 | 1.2546 | 1.2556 | 1.2635 | 1.2399 |
| 2010 | 1.0010 | 1.0426 | 1.0337 | 1.0142 | 1.0150 | 1.0136 | 0.9960 |
| 2011 | 0.8678 | 0.9503 | 0.9536 | 0.9343 | 0.9352 | 0.9295 | 0.9300 |
| 2012 | 0.8070 | 0.8918 | 0.9039 | 0.8915 | 0.8923 | 0.8906 | 0.8895 |
| CV | 0.0423 | 0.0442 | 0.0436 | 0.0438 | 0.0443 | 0.0442 | 0.0439 |

Table 21.9. The statistical diagnostics for the Bass Strait gummy shark standardization using the CANDE12 dataset. The smallest AIC and largest adjusted $r^2$ indicates the optimum statistical model. DN is daynight and DepCat is a series of 20 m depth categories.

| | Year | Disting | Area | DepCat | Gear | Month | Area:Month | Area:Gear |
|---|---|---|---|---|---|---|---|---|
| AIC | 43836 | 38302 | 33226 | 31945 | 31932 | 31185 | 28587 | 31028 |
| RSS | 196698 | 189061 | 182540 | 180882 | 180862 | 179909 | 176249 | 179626 |
| MSS | 5539 | 13176 | 19697 | 21355 | 21375 | 22328 | 25988 | 22611 |
| Nobs | 145651 | 145651 | 145651 | 145651 | 145651 | 145651 | 145651 | 145651 |
| Npars | 37 | 154 | 172 | 196 | 198 | 209 | 407 | 245 |
| adj_r2 | 2.715 | 6.417 | 9.633 | 10.439 | 10.448 | 10.913 | 12.607 | 11.031 |
| %Change | 0.000 | 3.702 | 3.216 | 0.806 | 0.009 | 0.465 | 2.159 | 0.118 |

Table 21.10. Standardization of positive shots using data from the SESSF logbooks (Figure 21.18).

| | Year | Vessel | SArea | DepCat | Month | DN | SArea:Mth | SArea:DepCat |
|---|---|---|---|---|---|---|---|---|
| 1997 | 0.5862 | 0.6389 | 0.6314 | 0.6594 | 0.6624 | 0.6736 | 0.6763 | 0.6731 |
| 1998 | 0.7649 | 0.8227 | 0.8235 | 0.8426 | 0.8405 | 0.8583 | 0.8594 | 0.8589 |
| 1999 | 0.9092 | 1.0379 | 1.0318 | 1.0485 | 1.0499 | 1.0623 | 1.0651 | 1.0610 |
| 2000 | 0.9770 | 1.1035 | 1.1016 | 1.1132 | 1.1047 | 1.1016 | 1.1010 | 1.0985 |
| 2001 | 0.9177 | 0.9936 | 0.9815 | 0.9812 | 0.9864 | 0.9838 | 0.9863 | 0.9883 |
| 2002 | 0.7632 | 0.8056 | 0.7990 | 0.7968 | 0.7959 | 0.7936 | 0.7912 | 0.7915 |
| 2003 | 0.7699 | 0.8198 | 0.8200 | 0.8083 | 0.8045 | 0.8028 | 0.8057 | 0.8109 |
| 2004 | 0.8577 | 0.8725 | 0.8727 | 0.8632 | 0.8669 | 0.8648 | 0.8643 | 0.8635 |
| 2005 | 1.0116 | 0.9783 | 0.9703 | 0.9594 | 0.9637 | 0.9603 | 0.9616 | 0.9545 |
| 2006 | 1.1738 | 1.1095 | 1.0936 | 1.0811 | 1.0762 | 1.0729 | 1.0670 | 1.0616 |
| 2007 | 1.5152 | 1.3667 | 1.3659 | 1.3434 | 1.3392 | 1.3345 | 1.3328 | 1.3371 |
| 2008 | 1.5757 | 1.4603 | 1.4634 | 1.4458 | 1.4466 | 1.4426 | 1.4353 | 1.4368 |
| 2009 | 1.3233 | 1.2513 | 1.2565 | 1.2529 | 1.2617 | 1.2575 | 1.2556 | 1.2575 |
| 2010 | 1.0658 | 0.9911 | 1.0001 | 0.9971 | 0.9978 | 0.9944 | 0.9949 | 1.0031 |
| 2011 | 0.9157 | 0.8852 | 0.9077 | 0.9116 | 0.9068 | 0.9037 | 0.9055 | 0.9060 |
| 2012 | 0.8729 | 0.8631 | 0.8810 | 0.8956 | 0.8969 | 0.8934 | 0.8980 | 0.8977 |
| StErr | 0.0254 | 0.0264 | 0.0262 | 0.0262 | 0.0262 | 0.0292 | 0.0292 | 0.0292 |

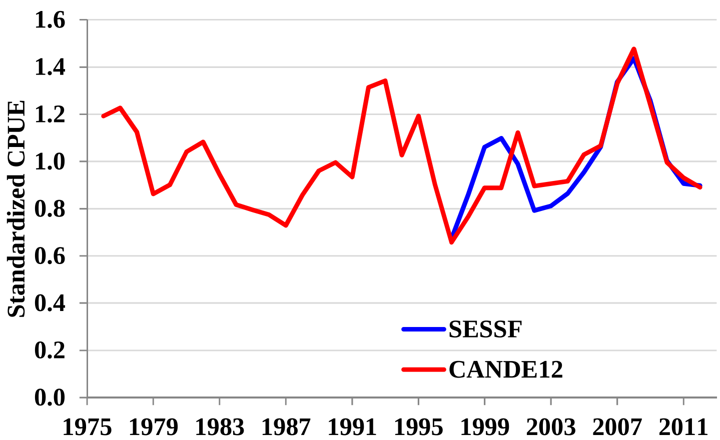


Figure 21.18. A comparison of the standardization obtained for positive catches from the CANDE12 database and the SESSF GenLog log book database for Bass Strait. The overlap since the structural adjustment is extremely close but that reflects the fact that the CANDE database is updated from 2005 onwards using the GenLog database.

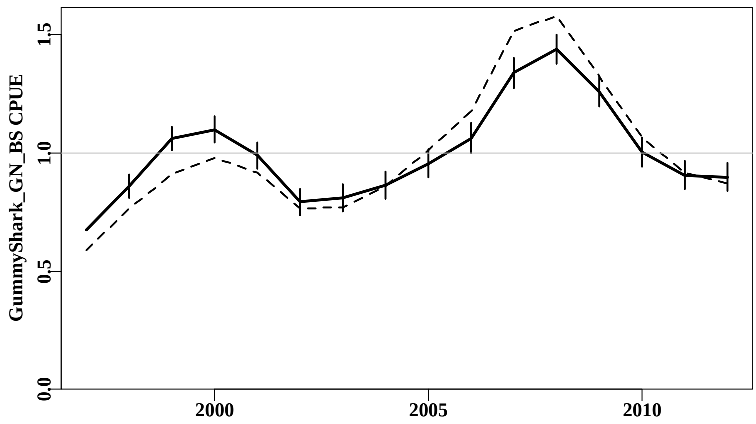


Figure 21.19. Comparison of the standardized CPUE (solid line) from the SESSF logbooks with the geometric mean CPUE (dashed line). The bars are 95% error bars about the mean estimates.

Table 21.11. The statistical diagnostics for the Bass Strait gummy shark standardization using the SESSF database. The smallest AIC and largest adjusted $r^2$ indicates the optimum statistical model. DN is daynight and DepCat is a series of 20 m depth categories.

| | Year | Vessel | Zone | DepCat | Month | DayNight | Zone:Month | Zone:DepCat |
|---|---|---|---|---|---|---|---|---|
| AIC | 34744 | 27483 | 26661 | 25379 | 24999 | 24969 | 24866 | 24588 |
| RSS | 126218 | 115365 | 114226 | 111916 | 111374 | 111325 | 111157 | 110750 |
| MSS | 4385 | 15237 | 16377 | 18686 | 19229 | 19277 | 19446 | 19852 |
| Nobs | 83136 | 83136 | 83135 | 82575 | 82575 | 82575 | 82575 | 82575 |
| Npars | 16 | 123 | 124 | 136 | 147 | 150 | 161 | 173 |
| adj_r2 | 3.340 | 11.537 | 12.410 | 14.167 | 14.572 | 14.606 | 14.724 | 15.024 |
| %Change | 0.000 | 8.197 | 0.873 | 1.757 | 0.405 | 0.034 | 0.118 | 0.418 |

### 21.4.5 Tasmania

Even though the RAG decided to use the years 1990 onwards there are major changes prior to 1995. The catches in the standardized data are all < 20t from 1979 – 1994, and the number of records jumps from <200 to >350 in 1995 (Table 21.18). Nevertheless, as a result of the great variation in the data the trend in the probability of a positive catch is effectively flat throughout the time series and so is the standardized catch rates for positive shots, at least since 1996 (Figure 21.20)

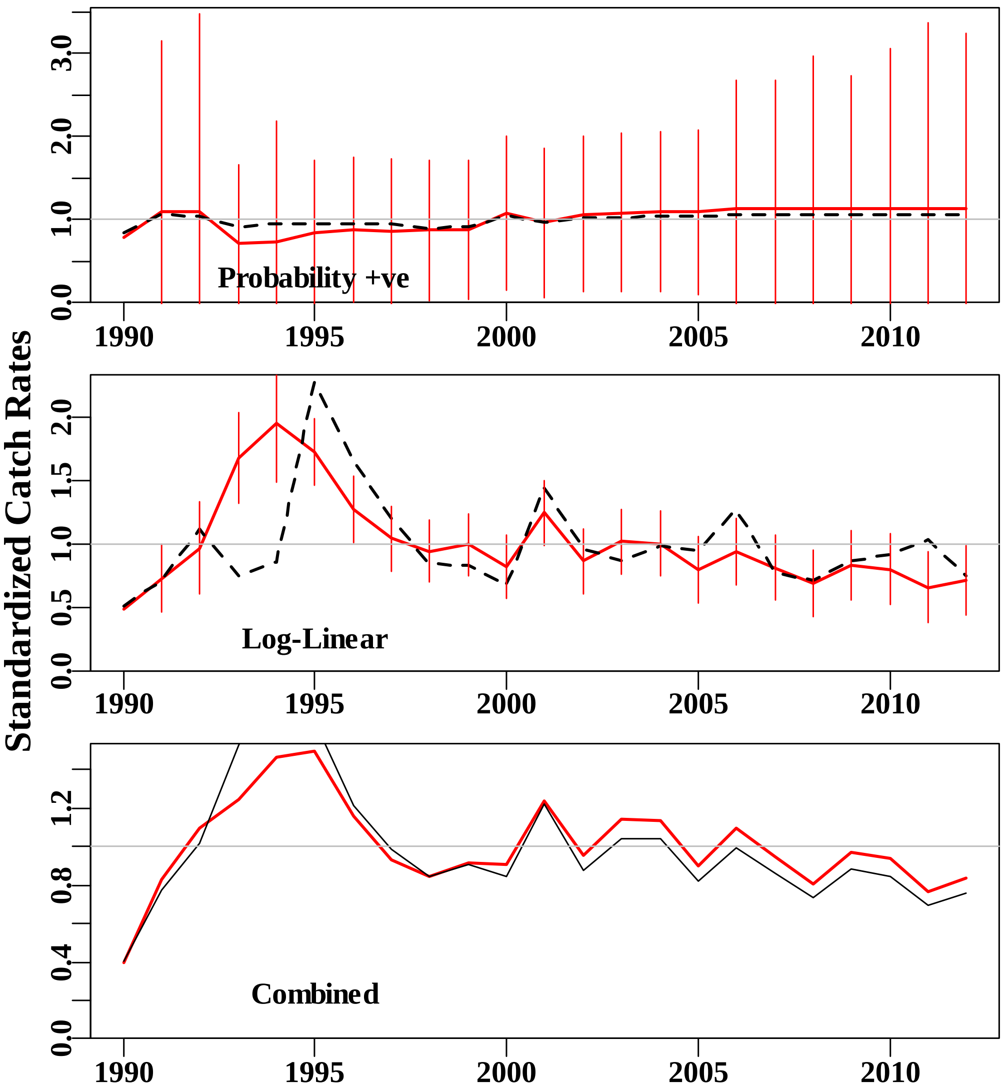


Figure 21.20. Standardized catch rates for Tasmanian gummy sharks using data relating to 6.0”, 6.5”, and 7.0” mesh gear, from areas that reported more than 10 tonnes across the 23 years considered (1990 – 2012), and from vessels with average catches greater than 2 tonnes per annum which had been present in the fishery for at least 3 years. The top panel represents the probability of obtaining a positive catch, the dashed line being the proportion of positive catches in the raw data and the solid line being the statistical optimum model (with the 95% error bars surrounding the trend). The central panel represents the log-linear modelling of positive catches. The dashed line is the geometric mean while the solid line is the optimal model, and again the bars are the 95% confidence limits on the mean estimates. The bottom panel represents the final standardized catch rates, combining the results from the log-linear modelling and the binomial modelling of the probability of a positive catch. The fine black line is the combination of the standardized catch rates and the probability of a positive catch in the raw data. All trends have been scaled to the mean of each series to ease visual comparison.

In Tasmania, the standardization of positive shots has reduced the variation apparent in the overall trend (Figure 21.20). It is perhaps a coincidence that there are almost no data in the combined data field where catches of gummy and school sharks are confused (Table 21.19).

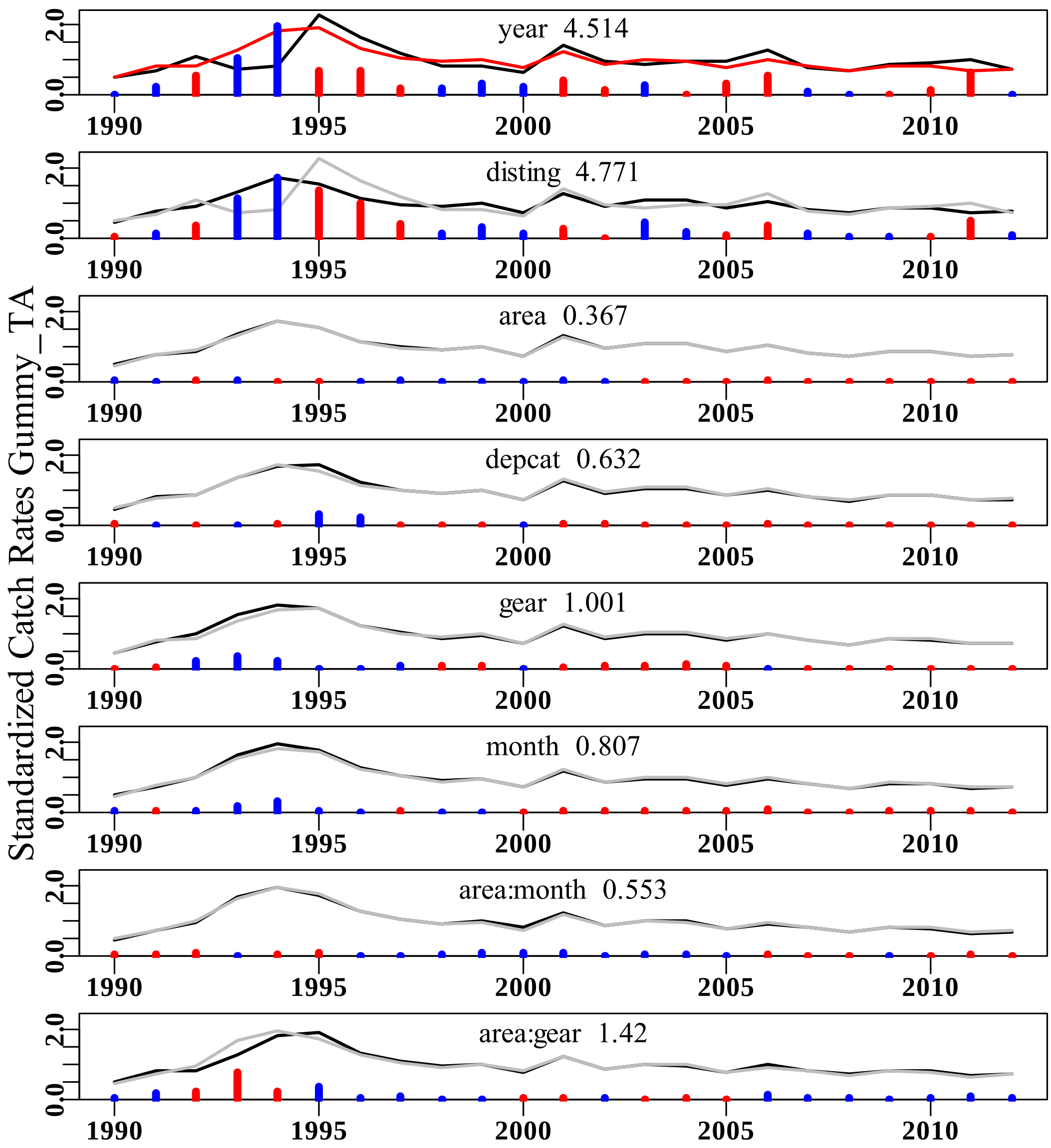


Figure 21.21. The relative influence of each factor used on the final trend in the optimal standardization for Tasmanian Gummy shark. The top graph depicts the geometric mean (the black line) and the optimum model (the red line). The difference between them is illustrated by the vertical bars with blue 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.

Some large changes occurred in the Tasmanian fishery prior to 1997 with respect to both the vessels doing the fishing and the gear that was used (6”, 6.5”, or 7”; Haddon, 2012). Otherwise there were few differences between the geometric mean catch rates and the optimum model, so other factors only contributed very little to changes in the observed trend.

Table 21.12. The different standardization models fitted to the Tasmanian gummy shark data. The models are cumulative across the table with the optimum being the Area:Month model. The CVs reflect the relative variability of each time series.

| Year | GeoMean | Vessel | Area | Depth | Gear | Month | Area:Month |
|---|---|---|---|---|---|---|---|
| 1990 | 0.5131 | 0.4770 | 0.5154 | 0.4880 | 0.4768 | 0.5119 | 0.4893 |
| 1991 | 0.7149 | 0.7921 | 0.8104 | 0.8266 | 0.7841 | 0.7486 | 0.7287 |
| 1992 | 1.1225 | 0.9200 | 0.8900 | 0.8779 | 0.9942 | 1.0261 | 0.9691 |
| 1993 | 0.7481 | 1.3306 | 1.3574 | 1.3653 | 1.5606 | 1.6685 | 1.6740 |
| 1994 | 0.8542 | 1.7311 | 1.7221 | 1.6943 | 1.8103 | 1.9811 | 1.9584 |
| 1995 | 2.2756 | 1.5808 | 1.5733 | 1.7494 | 1.7566 | 1.7830 | 1.7261 |
| 1996 | 1.6577 | 1.1378 | 1.1419 | 1.2571 | 1.2624 | 1.2685 | 1.2772 |
| 1997 | 1.1966 | 0.9890 | 1.0112 | 1.0060 | 1.0589 | 1.0365 | 1.0440 |
| 1998 | 0.8445 | 0.9303 | 0.9416 | 0.9391 | 0.8884 | 0.9055 | 0.9411 |
| 1999 | 0.8379 | 0.9959 | 1.0046 | 0.9992 | 0.9469 | 0.9550 | 0.9966 |
| 2000 | 0.6753 | 0.7481 | 0.7602 | 0.7610 | 0.7638 | 0.7600 | 0.8182 |
| 2001 | 1.4429 | 1.2886 | 1.3152 | 1.2720 | 1.2316 | 1.2033 | 1.2467 |
| 2002 | 0.9652 | 0.9492 | 0.9640 | 0.9408 | 0.8924 | 0.8613 | 0.8629 |
| 2003 | 0.8681 | 1.0962 | 1.0936 | 1.0776 | 1.0243 | 0.9903 | 1.0204 |
| 2004 | 0.9880 | 1.0995 | 1.0951 | 1.0755 | 1.0030 | 0.9715 | 1.0037 |
| 2005 | 0.9576 | 0.8969 | 0.8893 | 0.8746 | 0.8187 | 0.7871 | 0.7947 |
| 2006 | 1.2758 | 1.0812 | 1.0414 | 1.0168 | 1.0213 | 0.9667 | 0.9382 |
| 2007 | 0.7755 | 0.8561 | 0.8442 | 0.8259 | 0.8236 | 0.8150 | 0.8121 |
| 2008 | 0.7164 | 0.7482 | 0.7340 | 0.7173 | 0.7112 | 0.6991 | 0.6877 |
| 2009 | 0.8684 | 0.9013 | 0.8907 | 0.8734 | 0.8567 | 0.8310 | 0.8353 |
| 2010 | 0.9209 | 0.8913 | 0.8764 | 0.8673 | 0.8487 | 0.8172 | 0.8023 |
| 2011 | 1.0330 | 0.7635 | 0.7526 | 0.7363 | 0.7211 | 0.6848 | 0.6561 |
| 2012 | 0.7476 | 0.7951 | 0.7753 | 0.7587 | 0.7445 | 0.7280 | 0.7169 |
| CV | 0.1235 | 0.1344 | 0.1351 | 0.1378 | 0.1398 | 0.1388 | 0.1396 |

Table 21.13. The statistical diagnostics for the Tasmanian gummy shark standardization. The smallest AIC and largest adjusted $r^2$ indicates the optimum statistical model.

| | GeoMean | Vessel | Area | Depth | Gear | Month | Area:Month |
|---|---|---|---|---|---|---|---|
| AIC | 3833 | 524 | 482 | 458 | 437 | 207 | -10 |
| RSS | 15352 | 11243 | 11187 | 11114 | 11089 | 10833 | 10489 |
| MSS | 839 | 4949 | 5004 | 5077 | 5102 | 5358 | 5702 |
| Nobs | 10818 | 10818 | 10818 | 10818 | 10818 | 10818 | 10818 |
| Npars | 23 | 54 | 60 | 83 | 85 | 96 | 162 |
| adj_r2 | 4.989 | 30.221 | 30.530 | 30.834 | 30.978 | 32.499 | 34.236 |
| %Change | 0.000 | 25.232 | 0.309 | 0.304 | 0.143 | 1.521 | 1.737 |

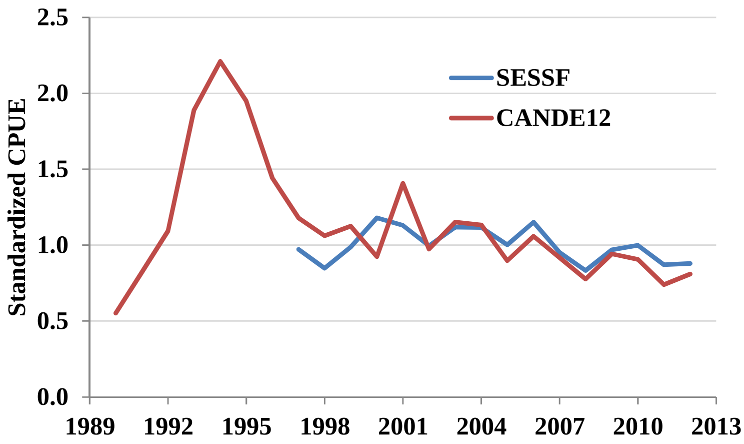


Figure 21.22. A comparison of the standardization obtained for Tasmania from positive catches from the CANDE12 database and the SESSF GenLog log book database. The overlap since the structural adjustment is extremely close but that reflects the fact that the CANDE database is updated from 2005 onwards using the GenLog database.

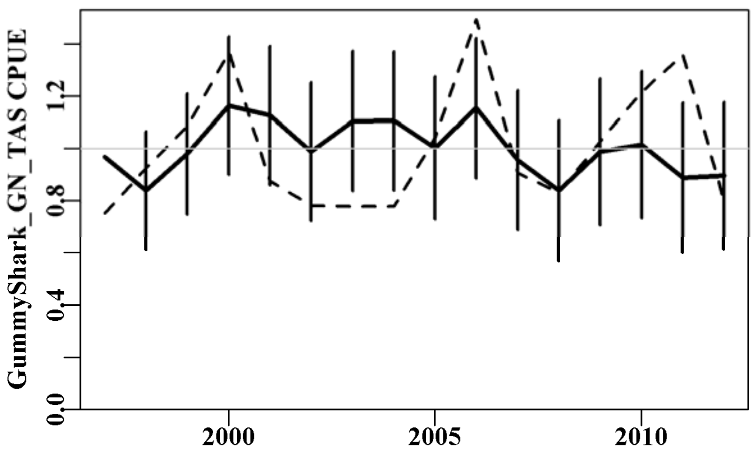


Figure 21.23. Comparison of the standardized CPUE (solid line) from the SESSF logbooks with the geometric mean CPUE (dashed line) for Tasmania. The bars are 95% error bars about the mean estimates.

Table 21.14. Standardization of positive shots using data from the SESSF logbooks (Figure 21.23).

| | Year | Vessel | Month | DepCat | DN | Area | Area:Mth | Area:DepCat |
|---|---|---|---|---|---|---|---|---|
| 1997 | 0.7500 | 0.8168 | 0.7968 | 0.8290 | 0.9107 | 0.9134 | 0.9670 | 0.9714 |
| 1998 | 0.9239 | 0.7367 | 0.7480 | 0.7678 | 0.8314 | 0.8334 | 0.8374 | 0.8478 |
| 1999 | 1.0831 | 0.8710 | 0.8946 | 0.9244 | 0.9584 | 0.9668 | 0.9788 | 0.9870 |
| 2000 | 1.3685 | 1.0831 | 1.1038 | 1.1677 | 1.1468 | 1.1517 | 1.1636 | 1.1795 |
| 2001 | 0.8741 | 1.1780 | 1.1566 | 1.1682 | 1.1425 | 1.1460 | 1.1254 | 1.1290 |
| 2002 | 0.7818 | 1.0286 | 1.0066 | 1.0103 | 0.9946 | 0.9975 | 0.9877 | 0.9951 |
| 2003 | 0.7770 | 1.1772 | 1.1402 | 1.1314 | 1.1145 | 1.1215 | 1.1047 | 1.1173 |
| 2004 | 0.7764 | 1.1168 | 1.1116 | 1.1114 | 1.0986 | 1.1046 | 1.1053 | 1.1170 |
| 2005 | 1.0399 | 1.0222 | 1.0045 | 0.9943 | 0.9862 | 0.9880 | 1.0021 | 1.0015 |
| 2006 | 1.4941 | 1.2338 | 1.2065 | 1.1818 | 1.1695 | 1.1635 | 1.1544 | 1.1520 |
| 2007 | 0.9048 | 0.9817 | 1.0069 | 0.9840 | 0.9722 | 0.9702 | 0.9549 | 0.9521 |
| 2008 | 0.8293 | 0.8511 | 0.8745 | 0.8578 | 0.8462 | 0.8436 | 0.8372 | 0.8324 |
| 2009 | 1.0268 | 1.0146 | 1.0280 | 1.0017 | 0.9901 | 0.9846 | 0.9866 | 0.9686 |
| 2010 | 1.2161 | 1.0344 | 1.0492 | 1.0337 | 1.0241 | 1.0164 | 1.0135 | 0.9988 |
| 2011 | 1.3571 | 0.9394 | 0.9311 | 0.9117 | 0.9002 | 0.8933 | 0.8870 | 0.8707 |
| 2012 | 0.7970 | 0.9145 | 0.9409 | 0.9250 | 0.9142 | 0.9055 | 0.8946 | 0.8797 |
| StErr | 0.1099 | 0.1241 | 0.1234 | 0.1246 | 0.1324 | 0.1325 | 0.1335 | 0.1338 |

Table 21.15. The statistical diagnostics for the Tasmanian gummy shark standardization. The smallest AIC and largest adjusted $r^2$ indicates the optimum statistical model. DN is daynight and DepCat is a series of 20 m depth categories.

| | Year | Vessel | Month | DepCat | DN | Area | Area:Mth | Area:DepCat |
|---|---|---|---|---|---|---|---|---|
| AIC | 5235 | 621 | 396 | 365 | 351 | 354 | 325 | 330 |
| RSS | 16560 | 10132 | 9876 | 9711 | 9691 | 9678 | 9627 | 9610 |
| MSS | 467 | 6895 | 7151 | 7316 | 7336 | 7349 | 7400 | 7417 |
| Nobs | 9668 | 9668 | 9668 | 9557 | 9557 | 9543 | 9543 | 9543 |
| Npars | 16 | 84 | 95 | 106 | 109 | 110 | 121 | 132 |
| adj_r2 | 2.591 | 39.977 | 41.429 | 42.334 | 42.433 | 42.506 | 42.741 | 42.776 |
| %Change | 0.000 | 37.386 | 1.452 | 0.905 | 0.099 | 0.073 | 0.236 | 0.034 |

## 21.5 Extra Tables

Table 21.16. The final combined analyses for each zone. These should be used if the probability of a positive catch is to be included in the assessment.

| Year | BS | SA | TAS |
|---|---|---|---|
| 1976 | 0.657816 | | |
| 1977 | 0.919666 | | |
| 1978 | 1.033815 | | |
| 1979 | 0.65019 | | |
| 1980 | 0.654582 | | |
| 1981 | 0.621516 | | |
| 1982 | 0.65994 | | |
| 1983 | 0.641005 | | |
| 1984 | 0.524362 | 1.075058 | |
| 1985 | 0.494253 | 0.967725 | |
| 1986 | 0.573726 | 0.759408 | |
| 1987 | 0.520346 | 0.519877 | |
| 1988 | 0.561601 | 0.873703 | |
| 1989 | 0.629708 | 0.896784 | |
| 1990 | 0.760013 | 0.711507 | 0.395995 |
| 1991 | 0.77771 | 0.687006 | 0.826789 |
| 1992 | 1.075849 | 0.837051 | 1.09718 |
| 1993 | 1.233562 | 0.833322 | 1.241404 |
| 1994 | 0.942944 | 1.017533 | 1.465948 |
| 1995 | 1.217083 | 0.821202 | 1.499091 |
| 1996 | 0.978781 | 1.366473 | 1.155247 |
| 1997 | 0.769438 | 0.961287 | 0.928108 |
| 1998 | 0.943452 | 0.668498 | 0.846442 |
| 1999 | 1.120007 | 0.756255 | 0.911791 |
| 2000 | 1.157581 | 1.003006 | 0.910573 |
| 2001 | 1.447686 | 0.977275 | 1.236792 |
| 2002 | 1.173542 | 1.165447 | 0.952764 |
| 2003 | 1.119147 | 1.203587 | 1.142914 |
| 2004 | 1.189954 | 1.330072 | 1.136708 |
| 2005 | 1.339402 | 1.313557 | 0.898011 |
| 2006 | 1.424885 | 1.31988 | 1.092003 |
| 2007 | 1.776393 | 1.360139 | 0.94658 |
| 2008 | 1.976022 | 1.569446 | 0.802073 |
| 2009 | 1.662934 | 1.259269 | 0.973146 |
| 2010 | 1.334452 | 1.095339 | 0.936212 |
| 2011 | 1.244737 | 0.945783 | 0.766698 |
| 2012 | 1.191899 | 0.704511 | 0.837532 |

Table 21.17. Data fields contained in the original file, CANDE12.dat, used in the analyses. The fields from CE down (24 – 29) were added prior to analysis.

| Field | Column | Contents |
|---|---|---|
| 1 | Year | Calendar Year |
| 2 | Month | Calendar Month |
| 3 | Vessel | Vessel Name – only available consistently in two years |
| 4 | Disting | Vessel Distinguishing mark – across all years |
| 5 | orig | Presumably region of original port |
| 6 | op | Operation within the month |
| 7 | Gear | Type of fishing gear mesh size, hooks, or unknown |
| 8 | Region | Fishery Region |
| 9 | Zone | Fishery zone name : BS, SA, TS, or UN |
| 10 | Gummy | Gummy shark catches |
| 11 | School | School shark catches |
| 12 | Comb | Combined School and Gummy shark catches |
| 13 | Saw | Saw shark catches |
| 14 | Eleph | Elephant fish/shark catches |
| 15 | other | Other sharks - seven gill, etc. |
| 16 | Scale | Scalefish catches |
| 17 | Effort | Fishing effort: -1 = no data |
| 18 | sh | Number of shots per records (0 = 1 !). |
| 19 | Area | Statistical reporting area |
| 20 | dmin | minimum depth |
| 21 | dmax | maximum depth |
| 22 | gear2 | Second type of gear when used |
| 23 | effort2 | Effort in second type of gear where used. |
| 24 | dav | Average depth – the average of dmin and dmax |
| 25 | depcat | 10 metre depth categories 0–9 = 0, 10–19 = 10, 20-29 = 20, etc |
| 26 | PA | Positive gummy shark catches vs zero gummy shark catch |
| 27 | netlen | 500 m net length categories 1000, 1500, 2000, 2500, etc. |
| 28 | LnCE | Log of CE, where CE is valid |
| 29 | CE | Catch rate where catches>0 and effort>0 |

Table 21.18. The annual catches and reported number of records for each of the three main regions. The greyed cells illustrate the years used in the analyses for each region.

| | Bass Strait | | South Australia | | Tasmania | | Unknown | |
|---|---|---|---|---|---|---|---|---|
| Year | Catch | Records | Catch | Records | Catch | Records | Catch | Records |
| 1976 | 660.697 | 3273 | 168.679 | 1367 | 77.043 | 247 | | |
| 1977 | 812.060 | 3595 | 223.378 | 1323 | 99.252 | 443 | | |
| 1978 | 745.308 | 3903 | 223.522 | 1112 | 94.017 | 382 | | |
| 1979 | 639.389 | 3885 | 241.416 | 837 | 93.939 | 512 | | |
| 1980 | 734.394 | 4418 | 332.315 | 898 | 137.005 | 577 | | |
| 1981 | 823.858 | 4145 | 321.379 | 868 | 109.678 | 298 | | |
| 1982 | 953.134 | 4925 | 295.701 | 953 | 84.599 | 188 | | |
| 1983 | 998.303 | 5184 | 262.410 | 954 | 82.986 | 176 | | |
| 1984 | 962.745 | 4915 | 428.028 | 1327 | 195.025 | 463 | | |
| 1985 | 921.939 | 5445 | 436.553 | 1455 | 230.356 | 983 | | |
| 1986 | 992.087 | 5761 | 483.357 | 1910 | 162.412 | 942 | | |
| 1987 | 877.866 | 5875 | 543.542 | 2620 | 178.763 | 1384 | | |
| 1988 | 777.049 | 6659 | 609.177 | 2615 | 185.300 | 1683 | | |
| 1989 | 963.005 | 6183 | 670.768 | 2406 | 173.237 | 1714 | | |
| 1990 | 835.802 | 5238 | 543.310 | 2609 | 161.099 | 2143 | | |
| 1991 | 908.738 | 7025 | 496.037 | 3121 | 140.333 | 903 | | |
| 1992 | 1033.879 | 6677 | 438.799 | 2942 | 200.993 | 1168 | | |
| 1993 | 1199.372 | 6643 | 428.101 | 2562 | 268.476 | 902 | | |
| 1994 | 846.529 | 6215 | 457.405 | 2362 | 208.221 | 650 | | |
| 1995 | 1007.847 | 7066 | 466.245 | 2699 | 118.041 | 1645 | | |
| 1996 | 790.020 | 9308 | 553.914 | 2280 | 142.581 | 4915 | | |
| 1997 | 689.712 | 8979 | 700.073 | 7697 | 104.189 | 1606 | | |
| 1998 | 794.510 | 8221 | 531.081 | 10579 | 103.123 | 1923 | | |
| 1999 | 1026.668 | 9773 | 598.994 | 9103 | 109.187 | 2368 | | |
| 2000 | 1042.436 | 9000 | 525.847 | 7397 | 83.574 | 2193 | | |
| 2001 | 1185.790 | 7625 | 437.488 | 7265 | 73.784 | 1586 | | |
| 2002 | 941.709 | 6631 | 445.909 | 6312 | 111.375 | 1376 | | |
| 2003 | 963.146 | 7167 | 517.162 | 7374 | 110.403 | 1448 | | |
| 2004 | 925.161 | 6767 | 499.861 | 6973 | 129.520 | 1316 | 1.253 | 33 |
| 2005 | 842.555 | 5597 | 511.215 | 6835 | 98.833 | 1262 | 2.026 | 76 |
| 2006 | 778.575 | 6972 | 612.635 | 8168 | 137.053 | 1466 | 46.302 | 1816 |
| 2007 | 930.965 | 5942 | 497.020 | 6466 | 108.761 | 1427 | 38.168 | 1247 |
| 2008 | 1034.396 | 6754 | 588.393 | 6809 | 78.652 | 1263 | 25.354 | 1069 |
| 2009 | 890.071 | 7063 | 496.803 | 7279 | 83.002 | 1087 | 29.458 | 1116 |
| 2010 | 807.203 | 7909 | 464.079 | 7113 | 98.401 | 1092 | 33.989 | 1315 |
| 2011 | 870.488 | 9424 | 318.885 | 5436 | 131.001 | 1440 | 27.613 | 1249 |
| 2012 | 853.235 | 9382 | 228.910 | 3453 | 165.641 | 1810 | 11.864 | 694 |

Table 21.19. The catch and number of records for the 9665 records which had no gummy or school shark catches but had data in the combined field.

| | Bass Strait | | South Australia | | Tasmania | |
|---|---|---|---|---|---|---|
| Year | Catch | Records | Catch | Records | Catch | Records |
| 1976 | 192.790 | 449 | 74.494 | 177 | 0.250 | 1 |
| 1977 | 170.102 | 447 | 65.130 | 142 | 8.165 | 6 |
| 1978 | 110.671 | 277 | 14.868 | 36 | | |
| 1979 | 92.882 | 257 | 1.926 | 9 | | |
| 1980 | 123.888 | 381 | | | | |
| 1981 | 123.052 | 461 | 9.756 | 24 | | |
| 1982 | 132.193 | 567 | 34.104 | 57 | 0.054 | 1 |
| 1983 | 126.334 | 490 | 15.244 | 43 | | |
| 1984 | 60.208 | 375 | 24.856 | 48 | | |
| 1985 | 98.617 | 452 | 1.324 | 7 | 7.004 | 17 |
| 1986 | 105.184 | 317 | 0.606 | 3 | 2.170 | 2 |
| 1987 | 107.214 | 367 | 24.662 | 127 | | |
| 1988 | 108.477 | 359 | 18.789 | 127 | 14.993 | 22 |
| 1989 | 155.063 | 400 | 2.873 | 19 | | |
| 1990 | 57.606 | 260 | 97.907 | 132 | 7.355 | 5 |
| 1991 | 21.708 | 200 | 132.421 | 249 | | |
| 1992 | 28.198 | 135 | 180.499 | 189 | 0.329 | 2 |
| 1993 | 112.922 | 304 | 158.216 | 213 | 0.637 | 2 |
| 1994 | 113.598 | 234 | 81.042 | 129 | | |
| 1995 | 86.788 | 360 | 107.501 | 185 | 2.100 | 10 |
| 1996 | 57.135 | 306 | 59.086 | 103 | 0.116 | 4 |
| 1997 | 5.736 | 62 | 30.942 | 79 | 0.152 | 1 |
| 1998 | | | 24.614 | 22 | | |
| 1999 | | | 6.162 | 8 | | |
| 2000 | | | 0.256 | 4 | | |

## 21.6 Acknowledgements

Thanks go to Robin Thomson and Miriana Sporcic for all the pre-analytical data preparation required maintaining the Shark data set.

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# 22. Blue Eye Fishery Characterization

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## *22.1 Summary*

The Blue Eye CPUE standardization for trawls and for the combination of auto-line and bottom-line were not considered to provide an adequate representation of trends within the Blue Eye fishery. The expansion of whale depredations in association with the changed behaviour of the fishing vessels in the presence of whales, along with the restriction of fishing location options due to an increase in the number of marine closures that were impacting on the availability of fishing grounds and the movement of fishing effort in recent years much further north off the north east coast of New South Wales and Queensland has altered the reliability of CPUE as an indicator of relative abundance. The key issue of the reliability of simple CPUE analyses for relating to stock abundance reflects the spatial heterogeneity of both the Blue Eye fishery and of the biological properties of the Blue Eye populations across its spatial distribution.

The fishery itself has included a number of large scale changes in fishing methods and the area of focus for the fishery from around 1997, when improved records from the GHT fishery became available. While trawl catches have continued at a low but steady level since 1986 there has been a switch from Drop-line (alternatively Demersal Line) to Auto-line. In the last three to four years, related to the move of a proportion of the total catch off the east coast, the use of alternative line methods (rod-reel, and hand-line) has increased.

The catch rate trends east and west differ, with the east exhibiting depletion in the last five years while the west appears to remain noisy but relatively flat. When this spatial heterogeneity is included in the Tier 4 analysis it suggests that catches in the east should be reduced while those in the west could be larger.

There are some important assumptions in this analysis. The first is that the CPUE is reflecting changes in the relative stock abundance rather than 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, the various closures in the south-east are assumed to have little or only minor effects on catch rates.

In reality, the relatively large shift in effort to the north-astern sea-mounts and repeated Industry statements imply that whale depredations do indeed have significant effects on both observed CPUE but also on fisher behaviour, which would be more difficult to identify and isolate as a depressing effect. Closures have undoubtedly shut off some previously popular fishing grounds for Blue Eye, so these extraneous factors, which are

not included in the standardizations, can certainly be concluded to have had some negative effects upon CPUE; however, estimating the extent of any such effects remains an intractable problem currently. What it does suggest is that the recommended RBCs from these analyses are inherently conservative because any depressing effects of whales, closures, or even the structural adjustment, are currently being ignored.

## 22.2 Introduction

The Blue Eye CPUE standardization for trawls and for the combination of auto-line and bottom-line were not considered to provide an adequate representation of trends within the Blue Eye fishery. The expansion of whale depredations in association with the changed behaviour of the fishing vessels in the presence of whales, along with the restriction of fishing location options due to an increase in the number of marine closures that were impacting on the availability of fishing grounds and the movement of fishing effort in recent years much further north off the north east coast of New South Wales and Queensland has altered the reliability of CPUE as an indicator of relative abundance. The key issue of the reliability of simple CPUE analyses for relating to stock abundance reflects the spatial heterogeneity of both the Blue Eye fishery and of the biological properties of the Blue Eye populations across its spatial distribution.

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## 22.3 Methods

### 22.3.1 Catch Rate Standardization

#### *22.3.1.1 Data Selection*

Blue eye catches were selected by method and area for CPUE analyses. The SESSF zones proved too coarse and so finer regions were identified by the use of schematic maps and, where sufficient data were available, CPUE from these smaller areas were standardized using the usual methods.

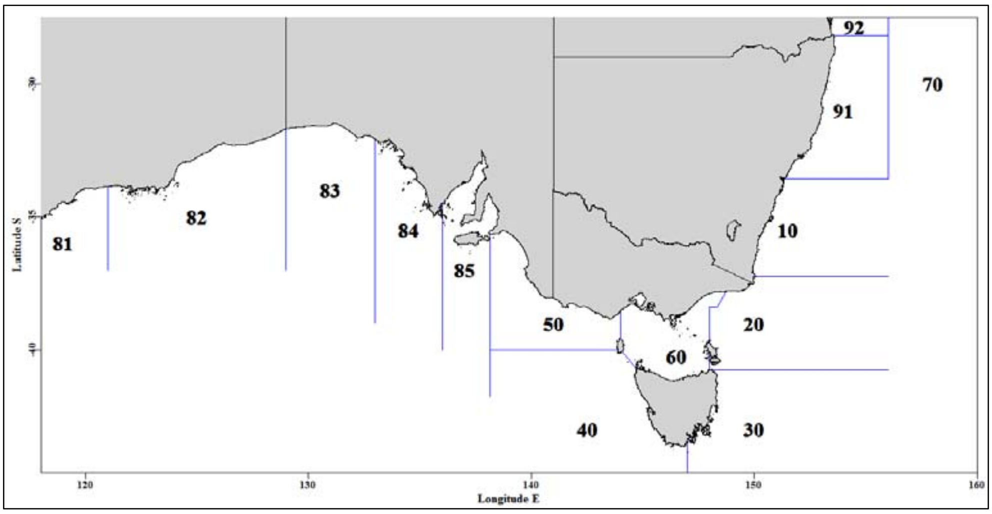


Figure 22.1. A schematic diagram depicting the statistical reporting zones in the SESSF, as used in this document. The GAB fishery is to the west of Zone 50. The main SESSF trawl zones are zones 10 – 50. Each zone extends out to the boundary of the EEZ, except for zones 50 and 60, and for zones 92 and 91, which are bounded by zone 70.

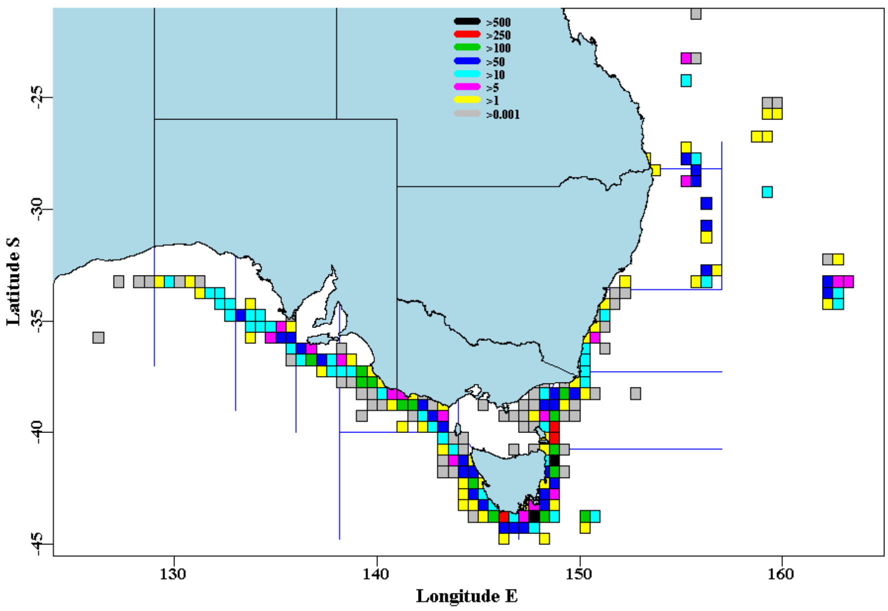


Figure 22.2. Schematic map of all reported catches of blue eye by all methods from 1986 – 2012 in 0.5 x 0.5 degree squares.

### *22.3.1.2 General Linear Modelling*

Where trawling was the method used, catch rates were kilograms per hour fished; 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, the length of net, the number of nets, etc; there is greater consistency in more recent years but still sufficient heterogeneity to make the use of catch per hook unreliable). 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:

$$\mathrm{Ln}\left(CPUE_i\right) = \alpha_0 + \alpha_1 x_{i,1} + \alpha_2 x_{i,2} + \sum_{j=3}^{N} \alpha_j x_{ij} + \varepsilon_i \qquad (10)$$

where Ln($CPUE_i$) is the natural logarithm of the catch rate (usually kg/h, 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*.).

### 22.3.2 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:

$$CPUE_t = e^{\left(\gamma_t + \sigma_t^2/2\right)} \qquad (11)$$

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:

$$CE_t = \frac{CPUE_t}{\left(\sum CPUE_t\right)/n} \qquad (12)$$

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.

## 22.4 Results

#### *22.4.1.1 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, combined with the unknown category only account for about 0.21% of total catches from 1986 to 2012 (Table 22.1). 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 22.3).

The trawl fishery averaged about 75t from 1986 to 2002 and about 51t from 2003 to 2012 and averaged about 13% of the total fishery from 1998 to 2012. 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. In 1997 auto-lining was introduced as a formal method in the SESSF and its catches grew to take over from drop-lining, which had been the dominant method used up until then.

Recently, on the northern sea mounts off the east coast the use of hydraulic reels and hand lines (RR and HL) have expanded (Figure 22.3).

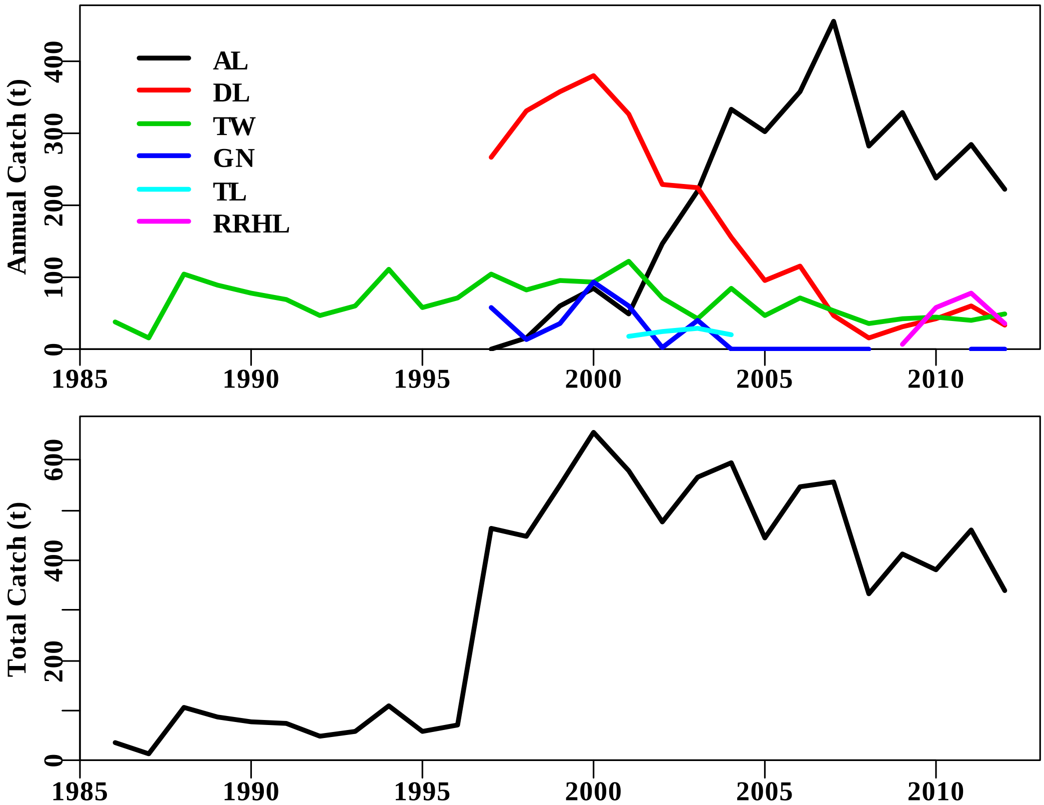


Figure 22.3. Catches of six methods that together account for about 98.6% of all reported catches of Blue Eye (Table 22.1). The codes are AL – auto-line, DL – drop-line, TW – trawl, GN – gill net, TL – trot line, and RRHL relates to the catches of Rod and Reel and Hand Line combined.

Table 22.1. Annual catches of Blue Eye by different methods, 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 formal landings against quota.

| Year | AL | DL | TW | GN | RR | TL | BL | HL | Other | Total | Landing |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1986 | | | 37.774 | | | | | | 0.188 | 37.962 | |
| 1987 | | | 15.495 | | | | | | 0.000 | 15.495 | |
| 1988 | | 0.160 | 103.969 | | | | | | 1.048 | 105.177 | |
| 1989 | | | 87.740 | | | | | | 0.000 | 87.740 | |
| 1990 | | | 78.596 | | | | | | 0.612 | 79.208 | |
| 1991 | | | 69.233 | | | | | | 6.448 | 75.681 | |
| 1992 | | 0.415 | 45.771 | | | | | | 3.094 | 49.280 | |
| 1993 | | | 59.588 | | | | | | 0.056 | 59.644 | |
| 1994 | | | 109.959 | | | | | | 0.016 | 109.975 | |
| 1995 | | | 58.533 | | | | | | 0.039 | 58.572 | |
| 1996 | | | 71.175 | | | | | | 0.468 | 71.643 | |
| 1997 | 0.267 | 265.137 | 104.567 | 58.382 | | 6.148 | 28.262 | | 0.265 | 463.027 | |
| 1998 | 15.189 | 330.802 | 82.074 | 14.282 | | | 4.526 | 0.100 | 1.001 | 447.973 | 472.287 |
| 1999 | 59.902 | 356.962 | 95.309 | 34.711 | | | 0.889 | | 0.294 | 548.067 | 572.689 |
| 2000 | 85.201 | 380.208 | 93.453 | 92.406 | | | 1.739 | | 0.678 | 653.685 | 656.847 |
| 2001 | 47.884 | 326.750 | 122.422 | 58.872 | | 18.805 | 3.086 | | 0.037 | 577.856 | 586.572 |
| 2002 | 145.717 | 227.654 | 71.479 | 1.951 | | 23.415 | 6.493 | | 0.001 | 476.709 | 512.111 |
| 2003 | 219.937 | 224.749 | 42.311 | 40.966 | | 28.080 | 8.589 | | 0.062 | 564.693 | 588.064 |
| 2004 | 331.788 | 155.341 | 84.547 | 0.171 | | 20.116 | 2.318 | | 0.009 | 594.289 | 633.794 |
| 2005 | 300.819 | 94.420 | 46.512 | 0.016 | | | 1.941 | | 0.006 | 443.714 | 492.885 |
| 2006 | 356.716 | 115.059 | 71.863 | 0.002 | | | 1.187 | | 0.008 | 544.834 | 563.850 |
| 2007 | 455.105 | 47.016 | 53.862 | 0.003 | | | 0.632 | | 0.000 | 556.619 | 585.310 |
| 2008 | 281.384 | 16.055 | 36.046 | 0.016 | | | 0.724 | | 0.072 | 334.297 | 373.047 |
| 2009 | 327.333 | 30.158 | 41.513 | | 7.550 | | 1.740 | | 3.322 | 411.616 | 443.362 |
| 2010 | 236.620 | 42.663 | 44.302 | | 56.788 | | 0.022 | | 0.000 | 380.394 | 399.896 |
| 2011 | 282.785 | 59.381 | 39.199 | 0.111 | 59.998 | | 0.049 | 17.118 | 0.000 | 458.642 | 458.535 |
| 2012 | 220.732 | 34.107 | 48.616 | 0.003 | 14.776 | | 1.377 | 21.021 | 0.000 | 340.633 | 287.816 |

#### *22.4.1.2 Catch 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 22.2).

Table 22.2. 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 0.27% of total catches from 1994 to 2012.

| Year | Landings | Total | SET | GHT | GAB | ECD & HS | Other |
|---|---|---|---|---|---|---|---|
| 1986 | | 37.962 | 37.962 | | | | |
| 1987 | | 15.495 | 15.467 | | 0.028 | | |
| 1988 | | 105.177 | 101.767 | 0.160 | 3.250 | | |
| 1989 | | 87.740 | 87.365 | | 0.375 | | |
| 1990 | | 79.208 | 76.283 | | 2.925 | | |
| 1991 | | 75.681 | 75.373 | | 0.308 | | |
| 1992 | | 49.280 | 49.250 | | 0.030 | | |
| 1993 | | 59.644 | 59.509 | | 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 | | 463.319 | 103.464 | 358.380 | 1.199 | | 0.276 |
| 1998 | 472.287 | 448.146 | 79.878 | 362.782 | 2.261 | | 3.225 |
| 1999 | 572.689 | 548.059 | 90.552 | 452.585 | 4.822 | | 0.100 |
| 2000 | 656.847 | 653.775 | 83.454 | 560.125 | 4.050 | 5.408 | 0.738 |
| 2001 | 586.572 | 579.726 | 69.255 | 455.399 | 19.390 | 34.934 | 0.748 |
| 2002 | 512.111 | 476.739 | 66.819 | 386.930 | 1.150 | 10.541 | 11.300 |
| 2003 | 588.064 | 564.693 | 27.109 | 518.839 | 1.810 | 16.652 | 0.283 |
| 2004 | 633.794 | 594.289 | 46.943 | 503.624 | 1.831 | 41.646 | 0.246 |
| 2005 | 492.885 | 444.114 | 34.497 | 396.976 | 8.473 | 4.115 | 0.054 |
| 2006 | 563.850 | 544.834 | 54.136 | 469.860 | 11.968 | 8.862 | 0.008 |
| 2007 | 585.310 | 556.619 | 37.321 | 501.743 | 0.960 | 16.590 | 0.005 |
| 2008 | 373.047 | 334.297 | 35.969 | 297.673 | 0.147 | 0.200 | 0.308 |
| 2009 | 443.362 | 411.616 | 39.366 | 369.259 | | 2.831 | 0.160 |
| 2010 | 399.896 | 380.394 | 44.302 | 335.452 | | 0.550 | 0.090 |
| 2011 | 458.535 | 458.642 | 23.322 | 403.940 | | 29.039 | 2.341 |
| 2012 | 287.816 | 340.633 | 10.781 | 288.946 | 0.011 | 39.573 | 1.322 |

#### *22.4.1.3 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. 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 22.3. Catches in tonnes of Blue Eye by zone (Figure 22.1).

| | 10 | 20 | 30 | 40 | 50 | 91 | 92 | 70 |
|---|---|---|---|---|---|---|---|---|
| 1986 | 12.712 | 5.771 | 3.346 | 4.927 | 11.058 | 0.020 | | |
| 1987 | 1.882 | 6.881 | 3.269 | 0.214 | 2.931 | | | |
| 1988 | 3.076 | 18.841 | 1.460 | 23.834 | 53.101 | 0.585 | | |
| 1989 | 9.391 | 10.203 | 23.654 | 24.905 | 19.080 | 0.101 | | |
| 1990 | 4.201 | 11.622 | 29.411 | 14.880 | 16.030 | | | |
| 1991 | 14.119 | 20.771 | 18.256 | 7.871 | 14.236 | | | |
| 1992 | 2.498 | 13.663 | 3.408 | 7.739 | 21.679 | | | |
| 1993 | 2.270 | 14.672 | 24.092 | 5.892 | 12.567 | 0.015 | | |
| 1994 | 2.861 | 14.919 | 74.892 | 8.140 | 8.842 | 0.030 | | 0.115 |
| 1995 | 2.721 | 8.776 | 19.763 | 12.605 | 13.791 | 0.080 | | |
| 1996 | 4.832 | 9.937 | 25.660 | 9.134 | 21.450 | 0.075 | | |
| 1997 | 5.964 | 149.201 | 92.819 | 83.333 | 100.036 | 10.835 | 0.140 | |
| 1998 | 1.774 | 93.416 | 171.130 | 97.903 | 66.989 | 1.590 | | |
| 1999 | 1.881 | 106.178 | 225.832 | 91.602 | 86.854 | 21.590 | 0.050 | |
| 2000 | 0.985 | 129.422 | 271.747 | 129.247 | 95.971 | 1.100 | 0.750 | 5.408 |
| 2001 | 0.264 | 86.447 | 239.368 | 100.831 | 60.290 | 3.186 | 4.740 | 34.930 |
| 2002 | 0.489 | 41.624 | 180.660 | 75.524 | 77.538 | 33.664 | 7.850 | 7.469 |
| 2003 | 1.288 | 91.477 | 153.646 | 124.815 | 43.771 | 57.910 | 2.400 | 14.668 |
| 2004 | 0.222 | 73.957 | 148.512 | 112.297 | 63.714 | 10.045 | 0.180 | 36.796 |
| 2005 | 1.601 | 88.198 | 119.790 | 64.249 | 51.935 | 7.451 | 4.700 | 2.607 |
| 2006 | 0.192 | 69.824 | 157.401 | 83.899 | 41.217 | 10.375 | 2.508 | 2.540 |
| 2007 | 0.271 | 53.777 | 235.961 | 48.581 | 47.631 | | | 16.174 |
| 2008 | 0.170 | 46.583 | 130.524 | 55.478 | 26.535 | | | 8.100 |
| 2009 | 0.133 | 53.863 | 159.609 | 86.619 | 47.601 | 12.615 | 22.758 | 7.631 |
| 2010 | 0.109 | 26.136 | 98.669 | 54.969 | 98.067 | 34.124 | 34.027 | 1.797 |
| 2011 | 0.195 | 31.830 | 99.722 | 45.235 | 30.612 | 79.995 | 52.926 | 14.271 |
| 2012 | 0.188 | 21.728 | 67.578 | 77.448 | 22.012 | 74.673 | 13.189 | 15.079 |

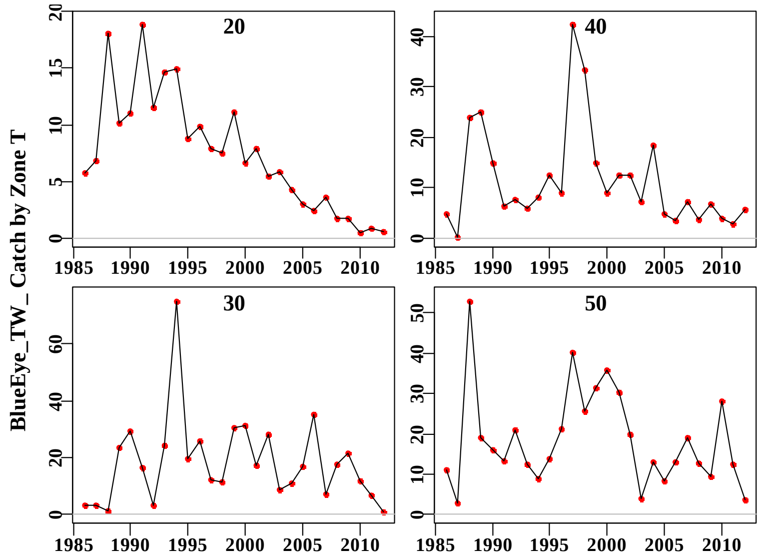


Figure 22.4. Annual catch in Trawl Caught Blue Eye in the four zones 20, 30, 40, and 50.

Table 22.4. Catches in tonnes of Blue Eye in Bass Strait and the GAB (Figure 22.1).

| | 60 | 82 | 83 | 84 | 85 |
|---|---|---|---|---|---|
| 1986 | 0.128 | | | | |
| 1987 | 0.250 | 0.020 | | 0.008 | 0.040 |
| 1988 | 1.020 | | | | 3.250 |
| 1989 | 0.031 | | 0.060 | | 0.315 |
| 1990 | 0.139 | | | 0.300 | 2.625 |
| 1991 | 0.120 | | | | 0.308 |
| 1992 | 0.063 | | | | 0.030 |
| 1993 | 0.001 | | 0.005 | | 0.130 |
| 1994 | 0.046 | | | 0.005 | 0.120 |
| 1995 | 0.201 | | | | 0.635 |
| 1996 | 0.192 | | | | 0.347 |
| 1997 | 4.149 | | 0.030 | 0.450 | 16.363 |
| 1998 | 4.211 | | 0.100 | 0.380 | 7.487 |
| 1999 | 5.109 | | | 0.766 | 6.278 |
| 2000 | 8.559 | | | 0.357 | 9.566 |
| 2001 | 0.708 | | 0.850 | 19.453 | 28.198 |
| 2002 | 0.012 | | 3.973 | 22.991 | 10.473 |
| 2003 | 1.567 | | | 52.812 | 17.673 |
| 2004 | 0.745 | 0.983 | 12.787 | 75.739 | 58.608 |
| 2005 | 0.267 | 0.632 | 19.552 | 29.273 | 51.158 |
| 2006 | 0.932 | 0.169 | 31.511 | 44.495 | 89.189 |
| 2007 | 0.552 | | 29.876 | 107.069 | 15.594 |
| 2008 | 0.110 | 0.015 | 28.943 | 32.267 | 13.350 |
| 2009 | 0.195 | | 1.633 | 15.369 | 15.415 |
| 2010 | 0.100 | | 6.549 | 9.532 | 15.929 |
| 2011 | 0.012 | | 20.576 | 40.692 | 14.159 |
| 2012 | | | 8.428 | 10.016 | 3.752 |

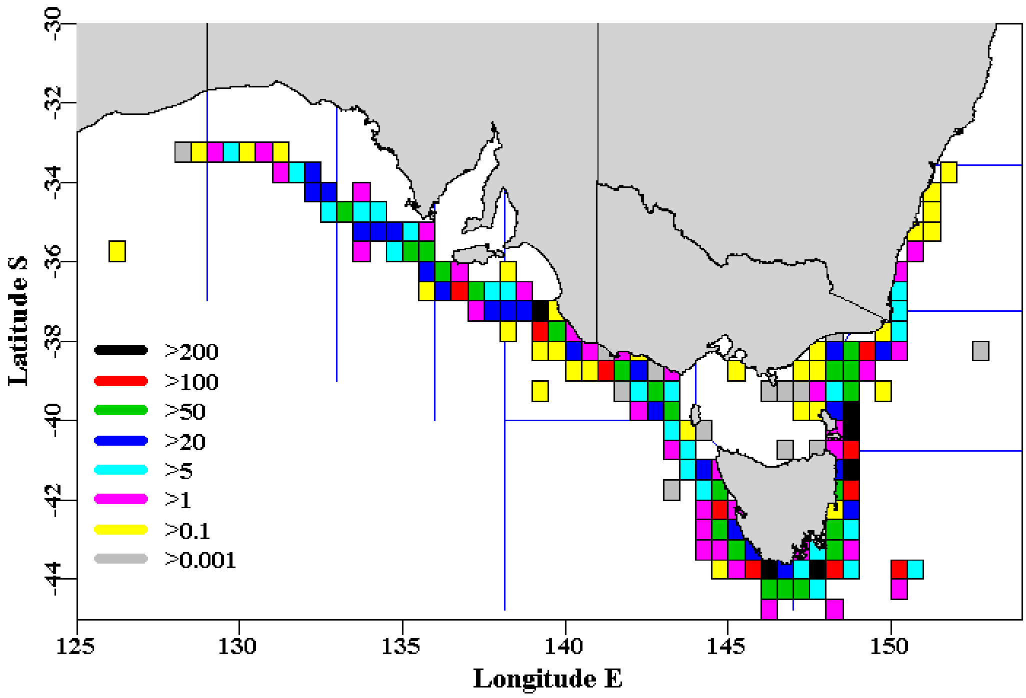


Figure 22.5. Schematic map of the distribution of all Blue Eye catches around the southern zones since 1997 onwards. The gird scale is 0.5 degree and the catch scale is in tonnes.

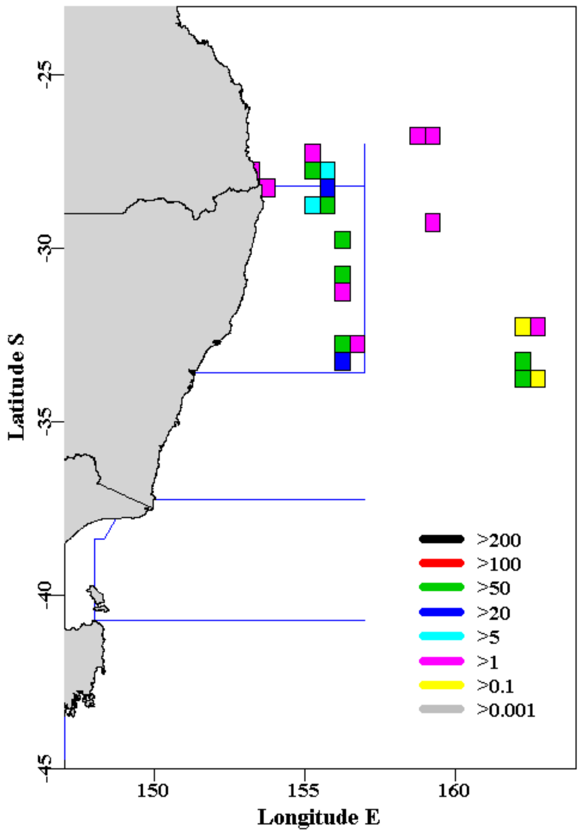


Figure 22.6. Schematic map of all Blue Eye catches since 1997 off the east coast. The gird scale is 0.5 degree and the catch scale is in tonnes. The offshore catches are high seas fisheries.

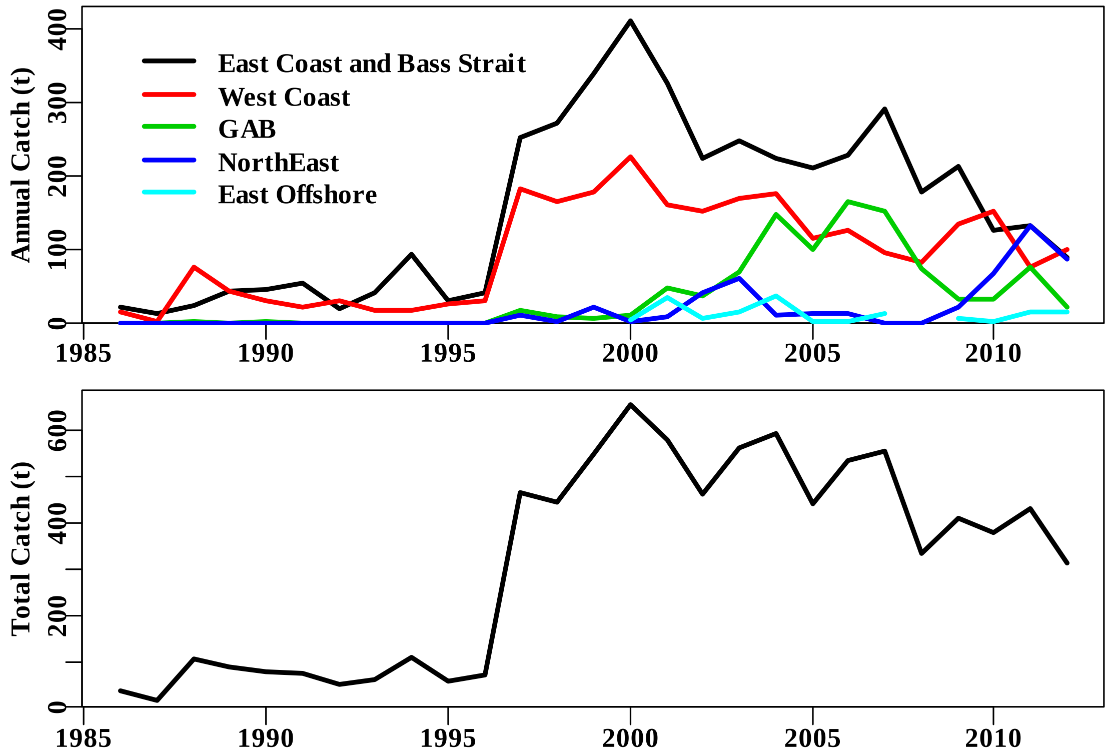


Figure 22.7. Total catches for different regions around the south east of Australia. East coast and Bass Strait includes zones 10, 20 , 30 , and 60; west coast is zones 40 and 50; GAB is zones 82, 83, 84, and 85; North East is zones 91 and 92, an East Offshore is zone 70 (Figure 22.1).


Figure 22.8. Relative catches by trawl vessels within each year across all fisheries for those vessels reporting the catch of more than 1 t summed across the years 1986 - 2012. The array of vessels is sorted by those remaining after 2006, then from 1997 onwards, and then from 1986.

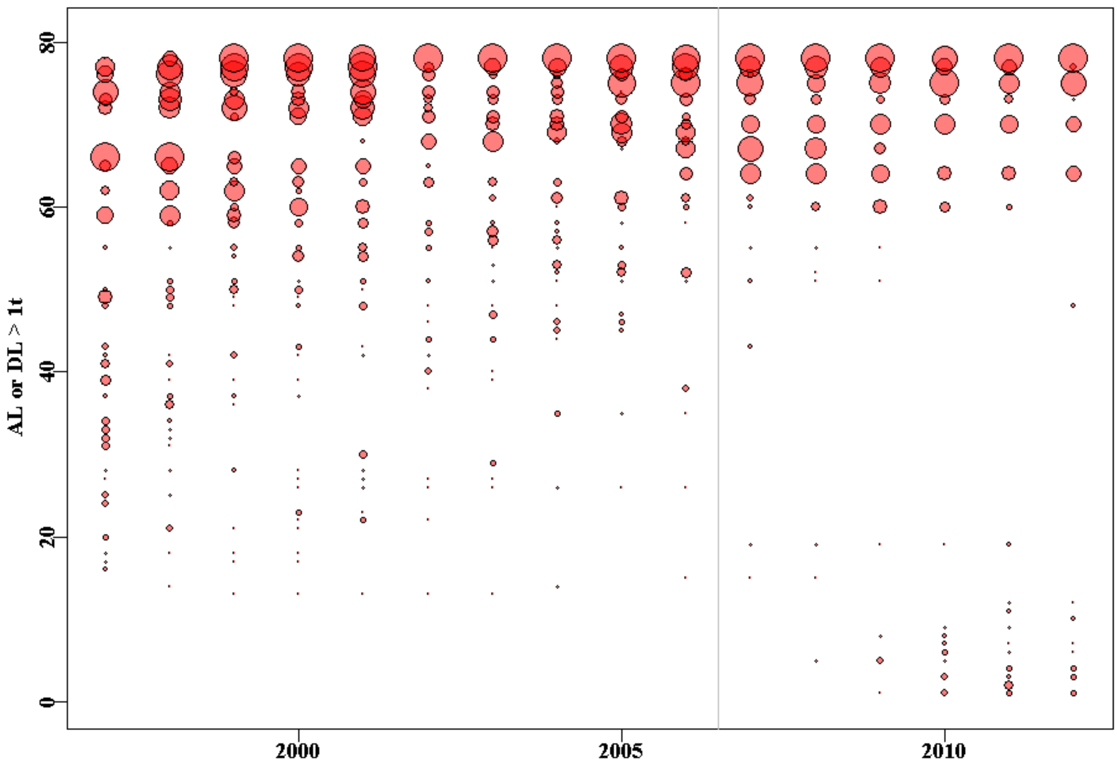


Figure 22.9. Relative catches by line vessels within each year across all fisheries for those vessels reporting the catch of more than 1 t summed across the years 1986 - 2012. The array of vessels is sorted by those remaining after 2006, then from 1997 onwards. The grey vertical line separates 2006 and 2007 to designate the structural adjustment.

#### *22.4.1.4 Time Series Suitable for CPUE Analyses*

Despite the recent shift of a significant proportion of the fishery to the north-east, no single area or method in that region has a time-series of sufficient duration or intensity to allow for a valid CPUE analysis. None of the seamounts have catches taken consistently through time (for example the Cascade fishery only last for two years). The seamounts just to the east of 155° have had catches taken in many of the years from 1997 – 2012. However, even if they are all combined, which would be a questionable assumption of homogeneity to impose, some years were unfished and others barely fished so that the number of records and amount of catch were too few to include in a valid analysis (Table 22.5).

Table 22.5. The combined data from the seamount chain just east of 155°.

| Year | Catch | Records | Year | Catch | Records |
|---|---|---|---|---|---|
| 1997 | 4.658 | 11 | 2005 | 7.581 | 17 |
| 1998 | 7.640 | 6 | 2006 | 12.679 | 28 |
| 1999 | | | 2007 | | |
| 2000 | 1.100 | 4 | 2008 | | |
| 2001 | 5.300 | 9 | 2009 | 3.288 | 5 |
| 2002 | 12.114 | 24 | 2010 | 8.990 | 22 |
| 2003 | 25.560 | 30 | 2011 | 34.715 | 54 |
| 2004 | 8.600 | 20 | 2012 | 18.591 | 28 |

The only data with sufficient data to permit a valid analysis derives from the trawl fishery or the auto-line and drop-line fisheries around the south-east and across the GAB.

*22.4.1.5 CPUE from the GAB AL and DL Vessels*

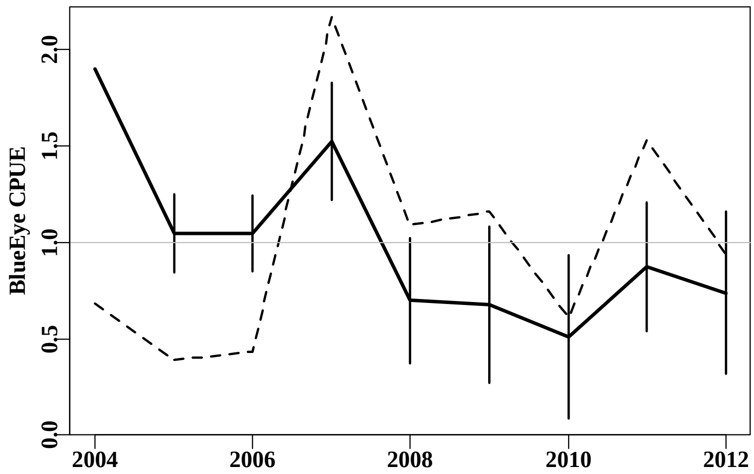


Figure 22.10. The standardized CPUE for AL and DL vessels from the GAB (zones 83, 84, and 85 (see Figure 22.1). Note the transition that occurs between 2007 and 2008, which may be related to the structural adjustment. Overall, the trend is noisy with a possible shift downwards in the last five years.

*22.4.1.6 CPUE from AL and DL Vessels from Zones 40 – 50*

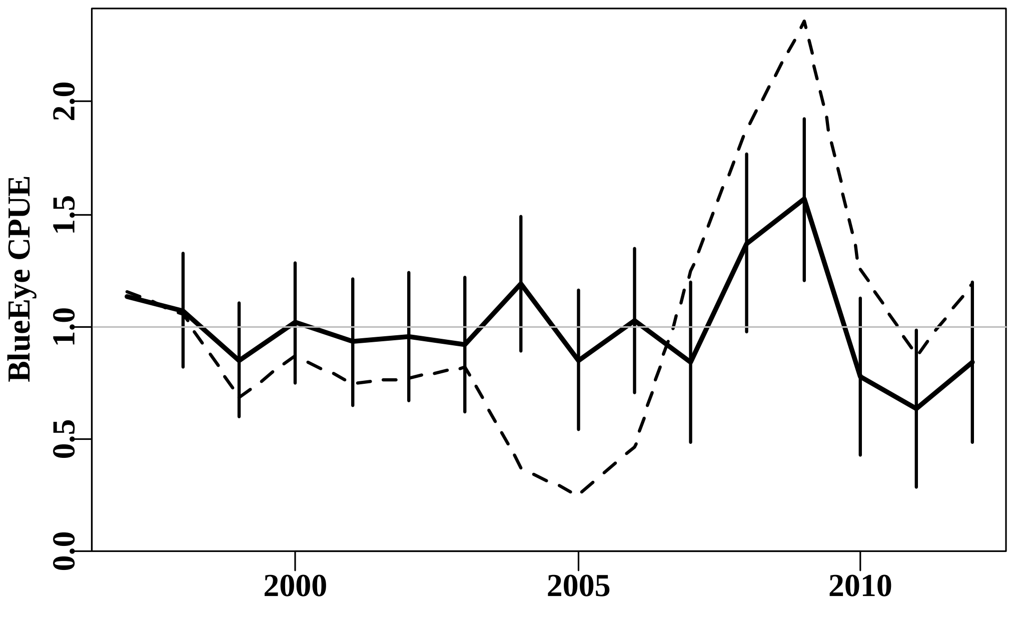


Figure 22.11. Standardized CPUE from the AL and DL fishery on the west coast (zones 40 and 50 combined) from 1997 – 2012.

The western fishery appears relatively flat although with relatively large variations in recent years (Figure 22.11). There appears to be a large change in the dynamics from

2006 to 2007, which suggests that the structural adjustment may have had some influences in the western fishery (Figure 22.12).

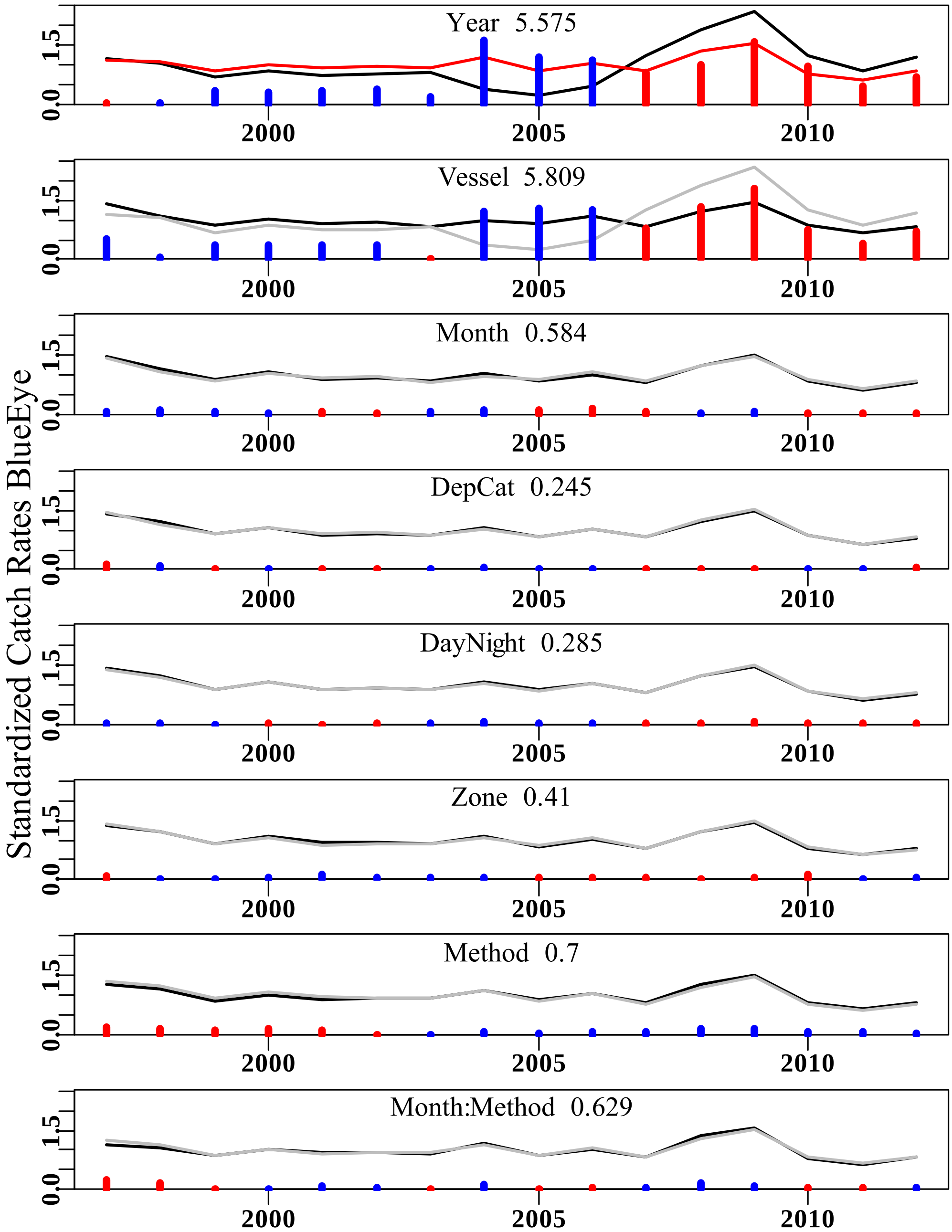


Figure 22.12. The relative influence of each factor used on the final trend in the optimal standardization for BlueEye by AL and DL in zones 40 and 50. The top graph is the geometric mean (the black line) and the optimum model (the red line). The difference between them is reflected by the vertical bars 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 22.6. BlueEye by AL and DL from zones 40 and 50 in depths 200 – 700m. Model selection criteria, including the AIC, the adjusted $r^2$ and the change in adjusted $r^2$. The optimum is model Month:Method. DepC is Depth Category, Mth is Month, DN is DayNight (omitted for space), Meth is Method.

| | Year | Vessel | Month | DepCat | Zone | Method | Mth:Meth |
|---|---|---|---|---|---|---|---|
| AIC | 4058.74 | 2663.032 | 2529.811 | 2481.596 | 2410.478 | 2401.275 | 2359.952 |
| RSS | 11141.68 | 8169.325 | 7914.133 | 7737.784 | 7622.359 | 7595.453 | 7497.23 |
| MSS | 1506.339 | 4478.688 | 4733.88 | 4910.23 | 5025.654 | 5052.56 | 5150.783 |
| Nobs | 4891 | 4891 | 4891 | 4865 | 4865 | 4865 | 4865 |
| Npars | 16 | 76 | 88 | 112 | 113 | 117 | 128 |
| adj_r2 | 11.639 | 34.404 | 36.294 | 37.393 | 38.314 | 38.48 | 39.135 |
| %Change | 0 | 22.766 | 1.89 | 1.099 | 0.921 | 0.057 | 0.655 |

#### *22.4.1.7 CPUE from AL and DL Vessels from Zones 20 and 30*

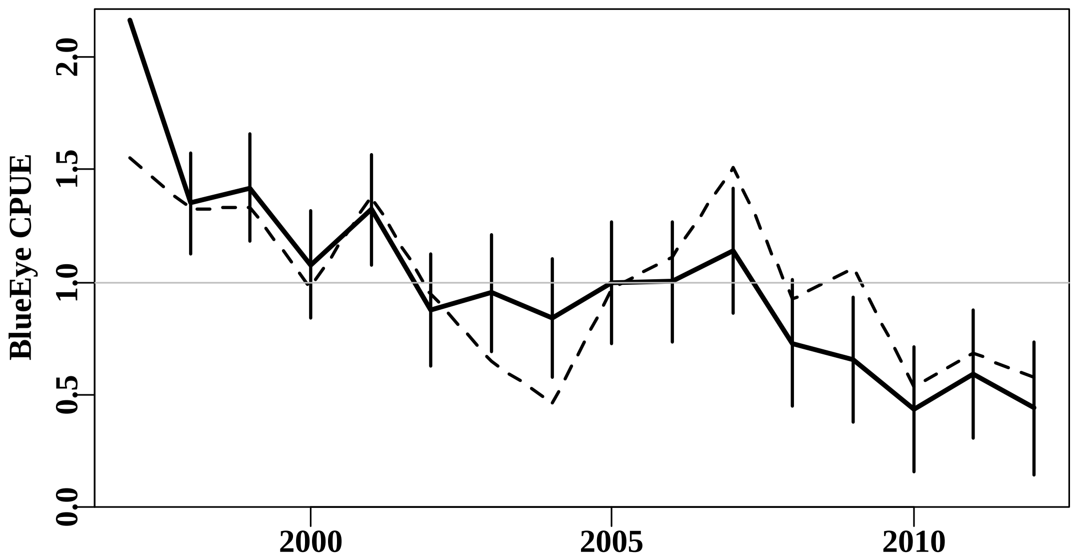


Figure 22.13. Standardized CPUE from the AL and DL fishery on the east coast (zones 20 and 30 combined) from 1997 – 2012.

The eastern fishery falls initially from a relative high and remains flat from about 2000 – 2007, with a reduction to lower noisy but flat level from 2008 onwards (Figure 22.13). The vessel fishing is clearly important but the effects of vessel are more confused on the east coast than in the west. Changes occurred around the structural adjustment in the east but they are more confused than those in the west (Figure 22.14).

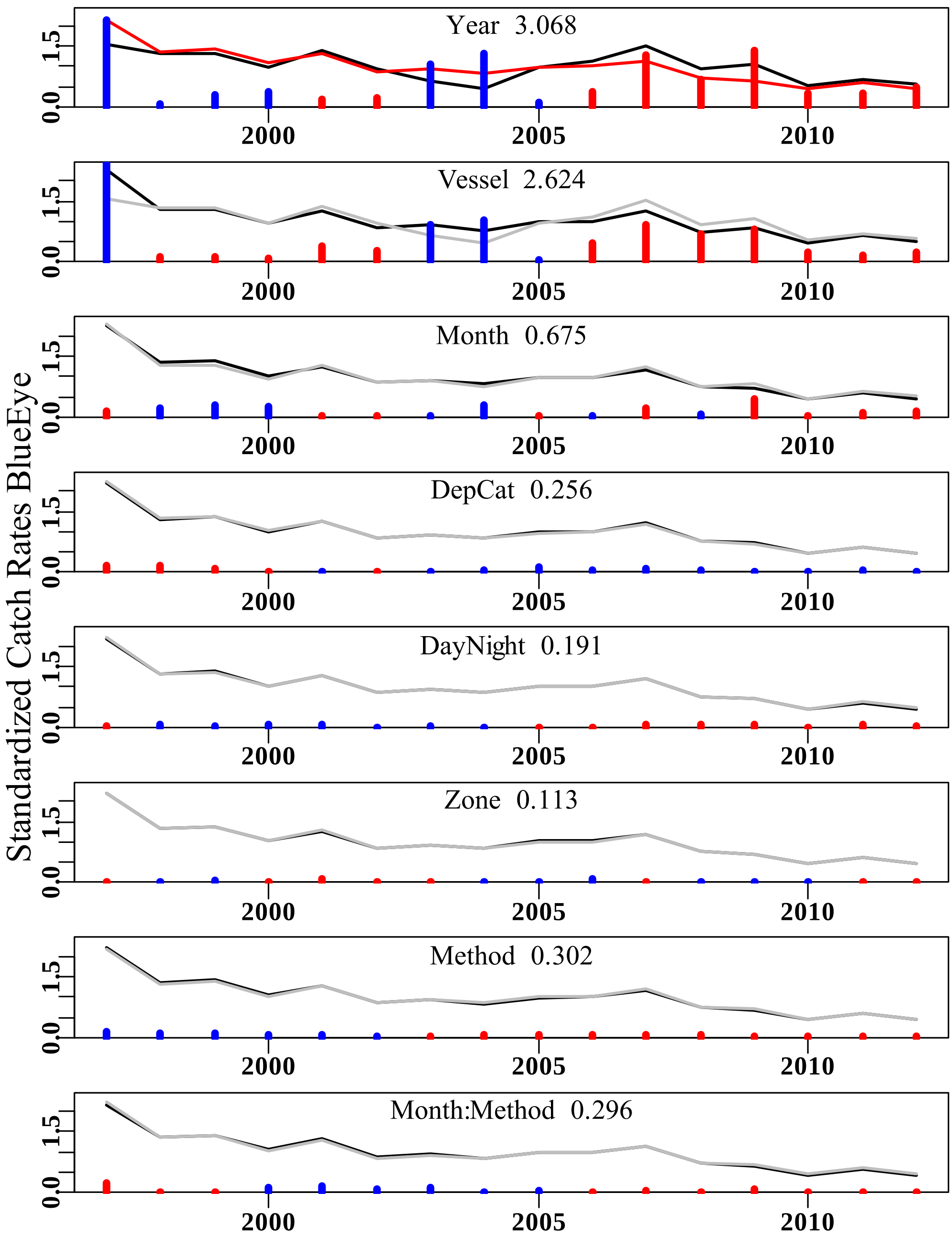


Figure 22.14. The relative influence of each factor used on the final trend in the optimal standardization for BlueEye by AL and DL. The top graph depicts the geometric mean (the black line) and the optimum model (the red line). The difference between them is illustrated by the vertical bars with blue 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 22.7. BlueEye by AL and DL from zones 20 and 30 in depths 200 – 700m. Model selection criteria, including the AIC, the adjusted $r^2$ and the change in adjusted $r^2$. The optimum is model Month:Method. DepC is Depth Category, Mth is Month, DN is DayNight (omitted for space), Meth is Method.

| | Year | Vessel | Month | DepCat | Zone | Method | Mth:Meth |
|---|---|---|---|---|---|---|---|
| AIC | 4649.469 | 3709.81 | 3038.653 | 3019.638 | 2990.014 | 2988.945 | 2933.339 |
| RSS | 13431.08 | 11522.14 | 10410.79 | 10280.43 | 10223.75 | 10219.14 | 10103.26 |
| MSS | 965.315 | 2874.254 | 3985.605 | 4115.963 | 4172.646 | 4177.255 | 4293.135 |
| Nobs | 6834 | 6834 | 6834 | 6805 | 6805 | 6805 | 6805 |
| Npars | 16 | 70 | 81 | 106 | 110 | 111 | 122 |
| adj_r2 | 6.5 | 19.149 | 26.828 | 27.471 | 27.828 | 27.85 | 28.55 |
| %Change | 0 | 12.649 | 7.679 | 0.643 | 0.142 | 0.022 | 0.701 |

Table 22.8. Catches, geometric mean CPUE and optimal standardized CPUE for the east (zones 20 and 30) and west (zones 40 and 50) coasts.

| | | East | | | West | |
|---|---|---|---|---|---|---|
| Year | Catches | Geomean | Optimum | Catches | Geomean | Optimum |
| 1997 | 242.020 | 1.5511 | 2.1605 | 183.369 | 1.1567 | 1.1365 |
| 1998 | 264.546 | 1.3260 | 1.3491 | 164.892 | 1.0569 | 1.0739 |
| 1999 | 332.010 | 1.3321 | 1.4187 | 178.456 | 0.6829 | 0.8534 |
| 2000 | 401.169 | 0.9737 | 1.0781 | 225.218 | 0.8684 | 1.0184 |
| 2001 | 325.815 | 1.3772 | 1.3206 | 161.121 | 0.7485 | 0.9319 |
| 2002 | 222.284 | 0.9452 | 0.8792 | 153.062 | 0.7690 | 0.9567 |
| 2003 | 245.123 | 0.6481 | 0.9527 | 168.586 | 0.8197 | 0.9192 |
| 2004 | 222.469 | 0.4627 | 0.8418 | 176.011 | 0.3750 | 1.1910 |
| 2005 | 207.988 | 0.9705 | 0.9974 | 116.184 | 0.2508 | 0.8534 |
| 2006 | 227.225 | 1.1139 | 1.0019 | 125.116 | 0.4692 | 1.0304 |
| 2007 | 289.738 | 1.5068 | 1.1413 | 96.212 | 1.2453 | 0.8435 |
| 2008 | 177.107 | 0.9282 | 0.7309 | 82.013 | 1.8840 | 1.3717 |
| 2009 | 213.472 | 1.0612 | 0.6580 | 134.220 | 2.3592 | 1.5650 |
| 2010 | 124.805 | 0.5348 | 0.4382 | 153.036 | 1.2535 | 0.7786 |
| 2011 | 131.552 | 0.6884 | 0.5904 | 75.847 | 0.8703 | 0.6344 |
| 2012 | 89.306 | 0.5800 | 0.4409 | 99.460 | 1.1904 | 0.8420 |

### *22.4.2 Tier 4 Analyses – Split East and West*

#### *22.4.2.1 East*

Table 22.9 Blue eye Trevalla data from AL and DL in zones 20 and 30. Total is the sum of Discards, State, Non Trawl, SEF2, and ECDW catches apportioned by logbook split between east and west. All values in Tonnes. CE is the standardized catch rate. 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 | Non-T | PDiscard | CE | GeoMean |
|---|---|---|---|---|---|---|---|---|
| 1997 | 417.592 | - | 417.592 | 620.142 | - | - | 2.1605 | 1.5511 |
| 1998 | 370.648 | - | 370.648 | 123.012 | 380.439 | - | 1.3491 | 1.3260 |
| 1999 | 462.741 | - | 462.741 | 132.608 | 464.658 | - | 1.4187 | 1.3321 |
| 2000 | 483.081 | 23.697 | 506.778 | 89.462 | 565.410 | 4.676 | 1.0781 | 0.9737 |
| 2001 | 458.876 | 22.081 | 480.957 | 77.613 | 478.397 | 4.591 | 1.3206 | 1.3772 |
| 2002 | 365.115 | 0.059 | 365.175 | 102.362 | 427.969 | 0.016 | 0.8792 | 0.9452 |
| 2003 | 386.762 | 0.095 | 386.857 | 51.623 | 556.565 | 0.025 | 0.9527 | 0.6481 |
| 2004 | 400.277 | 0.782 | 401.059 | 64.457 | 566.917 | 0.195 | 0.8418 | 0.4627 |
| 2005 | 357.763 | - | 357.763 | 55.557 | 450.678 | - | 0.9974 | 0.9705 |
| 2006 | 399.783 | 0.039 | 399.821 | 44.095 | 496.743 | 0.010 | 1.0019 | 1.1139 |
| 2007 | 479.985 | 2.112 | 482.097 | 53.102 | 536.267 | 0.438 | 1.1413 | 1.5068 |
| 2008 | 278.985 | 0.679 | 279.664 | 34.980 | 338.852 | 0.243 | 0.7309 | 0.9282 |
| 2009 | 293.755 | - | 293.755 | 35.090 | 404.049 | - | 0.6580 | 1.0612 |
| 2010 | 198.959 | 0.064 | 199.023 | 43.027 | 358.785 | 0.032 | 0.4382 | 0.5348 |
| 2011 | 316.407 | 4.717 | 321.123 | 40.297 | 430.038 | 1.469 | 0.5904 | 0.6884 |
| 2012 | 146.092 | 2.047 | 148.139 | 20.967 | 268.064 | 1.382 | 0.4409 | 0.5800 |

Discards make up approximately 1.2 % of the catch over the 1998-2006 period.
The catch rate time series used came from the combined autolongline and drop line fishery.

Table 22.10 RBC calculations for Blue Eye. Ctarg and CPUEtarg relate to the period 1997-2006, CPUELim is 40% of the target, 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.

| | |
|---|---|
| Ref_Year | 1997-2006 |
| CE_Targ | 1.200 |
| CE_Lim | 0.480 |
| CE_Recent | 0.5319 |
| Wt_Discard | 2.358 |
| Scaling | 0.0721 |
| Last Year’s TAC | 326 |
| $C_{targ}$ | 414.939 |
| **RBC** | **29.908** |

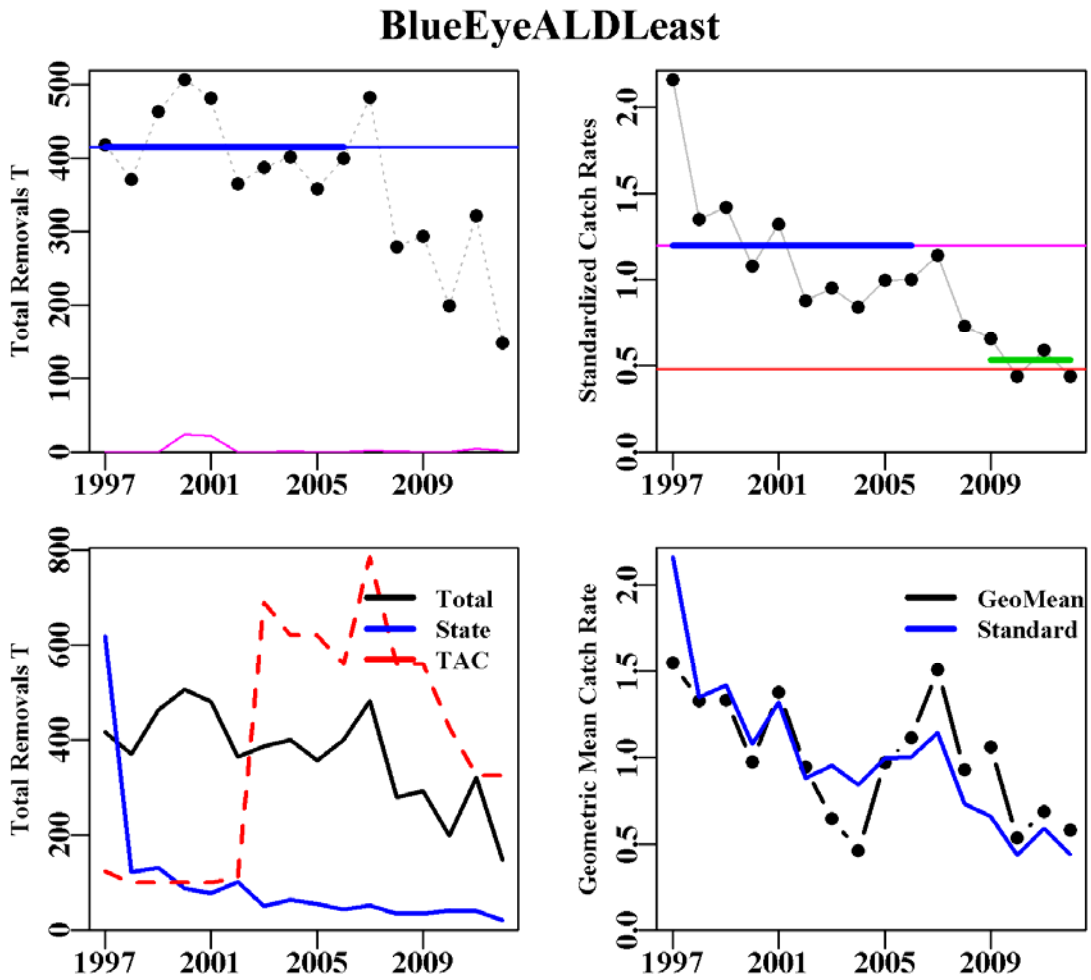


Figure 22.15 Blue Eye Trevalla taken by AL and DL in the Eastern zones 20 and 30. Top left is the total removals with the fine line illustrating the target catch. Top right represents the standardized catch rates with the upper fine line representing the target catch rate and the lower line the limit catch rate. Thickened lines represents the reference period for catches, catch rates, and the recent average catch rate.

### *22.4.2.2 West*

Table 22.11 Blue eye Trevalla data from AL and DL in zones 20 and 30. Total is the sum of Discards, State, Non Trawl, SEF2, and ECDW catches apportioned by logbook split between east and west. All values in Tonnes. CE is the standardized catch rate. 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 | Non-T | PDiscard | CE | GeoMean |
|---|---|---|---|---|---|---|---|---|
| 1997 | 316.393 | - | 316.393 | 620.142 | - | - | 1.1365 | 1.1567 |
| 1998 | 231.026 | - | 231.026 | 123.012 | 380.439 | - | 1.0739 | 1.0569 |
| 1999 | 248.724 | - | 248.724 | 132.608 | 464.658 | - | 0.8534 | 0.6829 |
| 2000 | 271.204 | 13.303 | 284.507 | 89.462 | 565.410 | 4.676 | 1.0184 | 0.8684 |
| 2001 | 226.922 | 10.919 | 237.841 | 77.613 | 478.397 | 4.591 | 0.9319 | 0.7485 |
| 2002 | 251.414 | 0.041 | 251.455 | 102.362 | 427.969 | 0.016 | 0.9567 | 0.7690 |
| 2003 | 266.000 | 0.065 | 266.065 | 51.623 | 556.565 | 0.025 | 0.9192 | 0.8197 |
| 2004 | 316.688 | 0.618 | 317.306 | 64.457 | 566.917 | 0.195 | 1.1910 | 0.3750 |
| 2005 | 199.850 | - | 199.850 | 55.557 | 450.678 | - | 0.8534 | 0.2508 |
| 2006 | 220.131 | 0.021 | 220.152 | 44.095 | 496.743 | 0.010 | 1.0304 | 0.4692 |
| 2007 | 159.387 | 0.701 | 160.088 | 53.102 | 536.267 | 0.438 | 0.8435 | 1.2453 |
| 2008 | 129.190 | 0.314 | 129.504 | 34.980 | 338.852 | 0.243 | 1.3717 | 1.8840 |
| 2009 | 184.698 | - | 184.698 | 35.090 | 404.049 | - | 1.5650 | 2.3592 |
| 2010 | 243.964 | 0.078 | 244.042 | 43.027 | 358.785 | 0.032 | 0.7786 | 1.2535 |
| 2011 | 182.426 | 2.719 | 185.145 | 40.297 | 430.038 | 1.469 | 0.6344 | 0.8703 |
| 2012 | 162.702 | 2.280 | 164.982 | 20.967 | 268.064 | 1.382 | 0.8420 | 1.1904 |

Discards make up approximately 1.2 % of the catch over the 1998-2006 period.
The catch rate time series used came from the combined autolongline and drop line fishery.

Table 22.12 RBC calculations for Blue Eye. Ctarg and CPUEtarg relate to the period 1997-2006, CPUELim is 40% of the target, 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.

| | |
|---|---|
| Ref_Year | 1997-2006 |
| CE_Targ | 0.9965 |
| CE_Lim | 0.3986 |
| CE_Recent | 0.955 |
| Wt_Discard | 1.951 |
| Scaling | 0.9307 |
| Last Year's TAC | 326 |
| $C_{targ}$ | 257.332 |
| **RBC** | **239.486** |

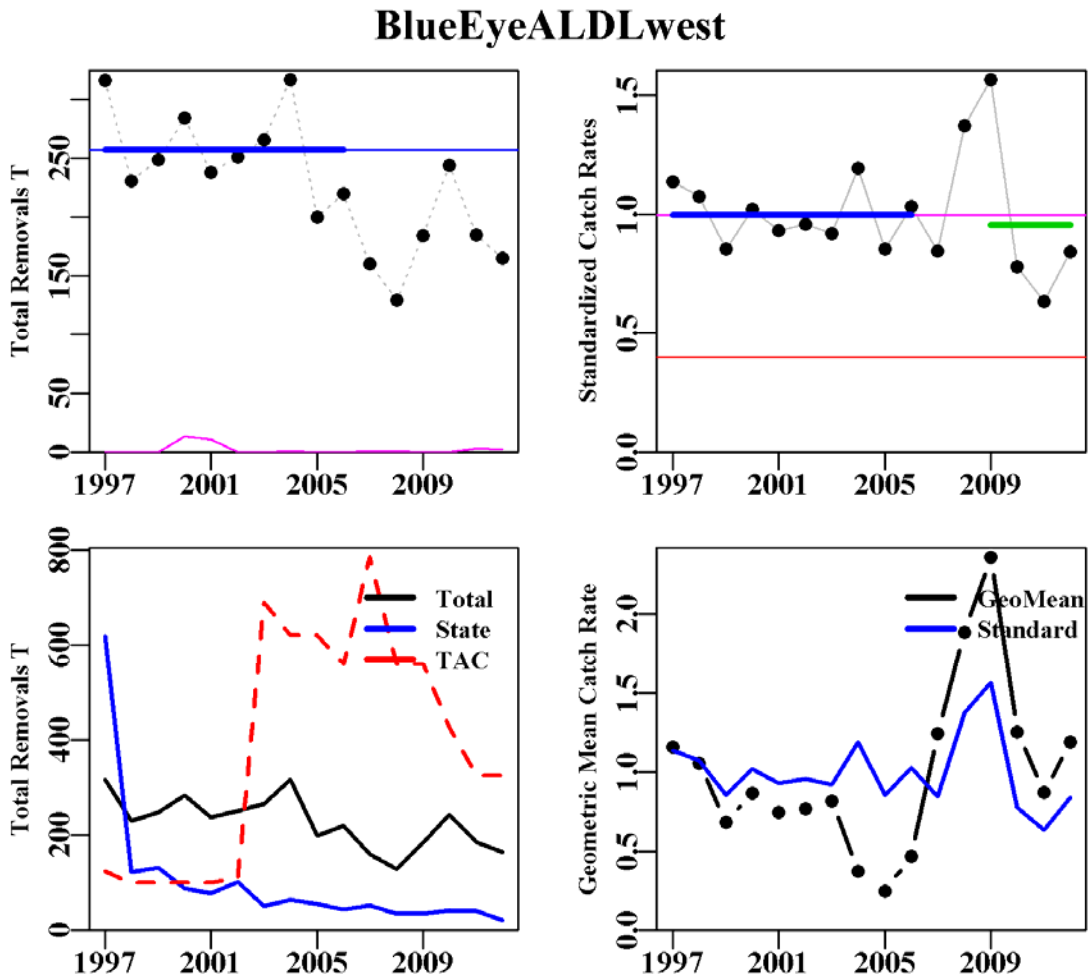


Figure 22.16 Blue Eye Trevalla taken by AL and DL in the Eastern zones 20 and 30. Top left is the total removals with the fine line illustrating the target catch. Top right represents the standardized catch rates with the upper fine line representing the target catch rate and the lower line the limit catch rate. Thickened lines represents the reference period for catches, catch rates, and the recent average catch rate.

Table 22.13. Summary of Tier 4 calculations for Blue Eye using standardized catch rates for AL and DL separated east and west. The total catches were divided in proportion to the relative catches taken east and west from 1997 – 2012. Thus the total target catch remains the same as for the combined analysis but the different states of the stock east and west influence the outcome of the analysis.

| | East | West | Total |
|---|---|---|---|
| Ref_Year | 1997-2006 | 1997-2006 | |
| CE_Targ | 1.200 | 0.9965 | |
| CE_Lim | 0.480 | 0.3986 | |
| CE_Recent | 0.5319 | 0.955 | |
| Wt_Discard | 2.358 | 1.951 | 4.409 |
| Scaling | 0.0721 | 0.9307 | |
| TAC | 326 | 326 | |
| C*(target) | 414.939 | 257.332 | 672.271 |
| RBC | **29.908** | **239.486** | **269.394** |

### 22.5 Discussion

The catch rate trends east and west differ, with the east exhibiting depletion in the last five years while the west appears to remain noisy but relatively flat. When this spatial heterogeneity is included in the Tier 4 analysis it suggests that catches in the east should be reduced while those in the west could be larger.

There are some important assumptions in this analysis. The first is that the CPUE is reflecting changes in the relative stock abundance rather than 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, the various closures in the south-east are assumed to have little or only minor effects on catch rates.

In reality, the relatively large shift in effort to the north-astern sea-mounts and repeated Industry statements imply that whale depredations do indeed have significant effects on both observed CPUE but also on fisher behaviour, which would be more difficult to identify and isolate as a depressing effect. Closures have undoubtedly shut off some previously popular fishing grounds for Blue Eye, so these extraneous factors, which are not included in the standardizations, can certainly be concluded to have had some negative effects upon CPUE; however, estimating the extent of any such effects remains an intractable problem currently. What it does suggest is that the recommended RBCs from these analyses are inherently conservative because any depressing effects of whales, closures, or even the structural adjustment, are currently being ignored.

### 22.1 Acknowledgements

Thanks also go to Mike Fuller and Neil Klaer for all the pre-analytical data preparation required maintaining the SESSF data set.

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# 23. Tier 4 Analyses in the SESSF, including Deep Water Species. Data from 1986 – 2012

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## *23.1 Summary*

Thirty four Tier 4 analyses are documented here which included a number of species where spatial information was available (Blue Warehou and Mirror Dory) leading to analyses for the east and west presumed stock regions. There are also Tier 4 analyses for some species where discard estimates were included in the analysis of catch rates. In addition, some non-key commercial species were assessed at the RAG's request, at a target assuming a proxy of 40%$B_0$ as well as a proxy target assuming 48%$B_0$.

Seven fisheries are assessed using Tier 4 methodology: BlueEye Trevalla, Blue Warehou (split east and west), Inshore Ocean Perch and Offshore Ocean Perch, Redfish, Royal Red Prawns, and Silver Trevally. Three of these fisheries generated zero RBCs and these were Blue Warehou, Jackass Morwong and Redfish.

Alternative analyses were provided for Redfish and Inshore Ocean Perch in which discards were included in the estimation of the catch rate trends. The inclusion of discards in estimating catch rates adds a great deal of noise to the CPUE trends so the uncertainty in these analyses expands. At the same time it is not clear whether to remove the discards from the RBC to generate a TAC or not. The use of this approach for setting RBCs needs further discussion and examination.

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.

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% $B_0$.

To ensure consistency and provide for efficient operation once data becomes available, standard analyses were set up in the statistical software, R, which provided the results as the tables and graphs required for the TIER4 analyses. Both the data and results for each analysis are presented for transparency. The TIER 4 harvest control rule formulation essentially uses a ratio of current catch rates with respect to selected limit and target reference points to calculate a scaling factor. This scaling factor is applied to the target catch to generate an RBC. In all cases where individual attention was required by a particular analysis it was more difficult to automate analyses and these therefore took a disproportionate amount of time.

### 23.1.1 Summary of RBCs and Discards

The Recommended Biological Catch from this year's analyses are compared (Table 23.1) with those from the previous three years (Haddon, 2010, 2011b). Blue Warehou and Mirror Dory are sub-divided spatially as east and west. Those species where the Tier 4 rule is not used to set a TAC have the RBC, given in the specific sections throughout the document, replaced with NA.

The upper group of species are those whose TAC is determined using the Tier 4 and the lower group the remainder.

Table 23.1. TIER 4 outcomes by species. The RBC in tonnes, while the weighted discards are a percentage. RBC09 are the 2009 estimates and RBC10 are this year's estimates. For those species where the total catches have been sub-divided (Blue Warehou, Silver Trevally, Ocean Perch, and Mirror Dory) the sub-division of catches and discards was done using the ratio of catches, by the respective areas, observed in the catch effort database. Discards t is the weighted estimate of the discards in 2013, see Equ (19).

| Species | RBC09 | RBC10 | RBC11 | RBC12 | RBC13 | Discard t |
|---|---|---|---|---|---|---|
| Blue Eye Trevalla AL | 536 | 521 | 415 | 288 | 179.044 | 4.310 |
| Blue Eye Whale Depredation | | | | | 301.213 | 86.214 |
| Blue Warehou | 0 | 0 | 0 | 0 | 0 | 23.484 |
| Blue Warehou East | 0 | 0 | 0 | 0 | 0 | 3.741 |
| Blue Warehou West | 0 | 0 | 0 | 0 | 0 | 18.514 |
| Ocean Perch Inshore D 48%T | NA | NA | 95 | 126 | 135.406 | 181.845 |
| Ocean Perch Inshore D 40%T | NA | NA | 95 | 126 | 187.487 | 181.845 |
| Ocean Perch Offshore 48%T | 219 | 193 | 215 | 196 | 191.562 | 30.262 |
| Ocean Perch Offshore D 40%T | 219 | 193 | 215 | 196 | 276.105 | 30.262 |
| Royal Red Prawn | 336 | 351 | 276 | 352 | 392.622 | 3.797 |
| Silver Trevally | 649 | 754 | 863 | 980 | 857.524 | 4.395 |
| Silver Trevally MPA | | | | | 866.708 | 4.395 |
| Ribaldo 48% T | 160 | 202 | 197 | 232 | 256.219 | 4.226 |
| Ribaldo 40% T | 160 | 202 | 197 | 232 | 354.768 | 4.226 |
| Deep Water Taxa | | | | | | |
| Cascade Smooth Oreo | | | 710 | <10t | < 10t | 12.3% |
| Non-Cascade Smooth Oreo | | | 20 | <10t | < 10t | 12.3% |
| Mixed Oreos | | | 120 | 132 | 128.246 | 16.2% |
| Eastern Deepwater Sharks | | | 89 | NA | 77.662 | 2.8% |
| Western Deepwater Sharks | | | 374 | NA | 299.823 | 2.8% |
| Alfonsino | | | 189 | NA | NA | NA |
| Cascade Smooth Oreo | | | | | catch < 10t | 12.3% |
| Non-Cascade Smooth Oreo | | | | | catch < 10t | 12.3% |
| Mixed Oreos | | | | | 124.885 | 16.2% |
| Eastern Deepwater Sharks | | | | | 77.662 | 2.8% |
| Western Deepwater Sharks | | | | | 299.823 | 2.8% |
| Alfonsino | | | | | NA | NA |

## 23.2 Introduction

### 23.2.1 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).

## 23.3 Methods

### 23.3.1 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 2010 data relating to catches and discards, from both State waters and SEF2 data sets, were provided by AFMA, with initial processing by Dr Neil Klaer 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 Mike Fuller of CSIRO Hobart.

Standard analyses were set up in the statistical software, R (2009), which provided the tables and graphs required for the TIER4 analyses. The data and results for each analysis are presented for 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.

$$\text{Scaling Factor } = SF_t = \max\left(0, \frac{\overline{CPUE} - CPUE_{\text{lim}}}{CPUE_{\text{targ}} - CPUE_{\text{lim}}}\right) \quad (13)$$

$$RBC = C_{\text{targ}} \times SF_t \quad (14)$$

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:

$$\begin{array}{l|l} RBC_y = 1.5RBC_{y-1} & RBC_y > 1.5RBC_{y-1} \\ RBC_y = 0.5RBC_{y-1} & RBC_y < 0.5RBC_{y-1} \end{array} \tag{15}$$

where

$RBC_y$ is the RBC in year $y$
$CPUE_{targ}$ is the target CPUE for the species; Eq. (17)
$CPUE_{lim}$ is the limit CPUE for the species = 0.4 * $CPUE_{targ}$
$\overline{CPUE}$ 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 23.2). This is an average of the total removals for the selected reference period, including any discards; Eq. (16).

$$C_{\text{targ}} = \frac{\sum_{y=yr1}^{yr2} L_y}{\left(yr2 - yr1 + 1\right)} \tag{16}$$

where $L_y$ represents the landings in year *y*.

$$CPUE_{\text{targ}} = \frac{\sum_{y=yr1}^{yr2} CPUE_y}{\left(yr2 - yr1 + 1\right)} \tag{17}$$

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. The catch rates are standardized, usually from 1986, using methods described in Haddon (2012).

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

$$D_y = \frac{C_y \bar{D}_{98-06}}{\left(1 - \bar{D}_{98-06}\right)} \tag{18}$$

Discard proportions for the projected year for which the RBC is being calculated are taken as a weighted mean of the previous four years:

$$D_{CUR} = (1.0D_{y-1} + 0.5D_{y-2} + 0.25D_{y-3} + 0.125D_{y-4})/1.875 \tag{19}$$

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%):

$$D_y = \frac{Discard_y}{\left(Catches_y + Discard_y\right)} \tag{20}$$

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 (Table 23.2). 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 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.

### *23.3.2 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 23.2.

### *23.3.3 The Inclusion of Discards*

Some species, especially redfish (*Centroberyx affinis*) and inshore Ocean Perch (*Helicolenus percoides*), 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, 2010a, b); 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).

### 23.3.4 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

$$\hat{I}_{R,t} = \frac{\sum C_t}{\sum E_t} \tag{21}$$

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

$$\hat{I}_{D,t} = \frac{\sum C_t + \sum D_t}{\sum E_t} \tag{22}$$

The same values of $\hat{I}_{D,t}$ can also be obtained using the following multiplier

$$\hat{I}_{D,t} = \left[\left(\sum D_t / \sum C_t\right) + 1\right] \times I_t \tag{23}$$

where $I_t$ is the catch rate estimate to be modified by the inclusion of discards. If this is the ratio mean from Equ (29) then the augmented catch rates would be identical to those produced by Equ (30). In practice, the catch rates used with the multiplier are the standardized catch rates from Haddon (2010a).

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).

Table 23.2. 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. |
|---|---|---|---|
| Blue Eye Trevalla ALDL | 1997-2006 | 1 | 1997 |
| Blue Warehou | 1986-1995 | 1 | 1986 |
| Blue Warehou East | 1986-1996 | 1 | 1986 |
| Blue Warehou West | 1986-1997 | 1 | 1986 |
| Ocean Perch Inshore | 1986-1995 | 1 | 1986 |
| Ocean Perch Inshore Discards | 1986-1996 | 1 | 1986 |
| Ocean Perch Offshore | 1986-1997 | 1 | 1986 |
| Royal Red Prawn | 1986-1995 | 1 | 1986 |
| Silver Trevally | 1992-2001 | 1 | 1986 |
| | | | |
| Blue Grenadier | 1986-1995 | 1 | 1986 |
| Flathead | 1986-1995 | 1 | 1986 |
| Eastern Gemfish | 1993-2002 | 1 | 1986 |
| Western Gemfish | 1992-2001 | 1 | 1992 |
| Jackass Morwong | 1986-1995 | 1 | 1986 |
| John Dory | 1986-1995 | 1 | 1986 |
| Mirror Dory | 1986-1995 | 1 | 1986 |
| Mirror Dory East | 1986-1995 | 1 | 1986 |
| Mirror Dory West | 1996-2005 | 1 | 1996 |
| Pink Ling | 1986-1995 | 1 | 1986 |
| Redfish | 86-90;99-03 | 1 | 1986 |
| Redfish Discards | 86-90;99-04 | 1 | 1986 |
| Ribaldo | 1995-2004 | 0.5 | 1995 |
| School Whiting | 1986-1995 | 1 | 1986 |
| Spotted/Silver Warehou | 1986-1995 | 0.5 | 1986 |

Table 23.3. Data characteristics for each deep water fishery analysis. Non-Cas indicates the Non-Cascade fishery. Catch and CPUE are the multipliers relating to whether the fishery was considered to be fully developed before the reference years. All catch rates, except Eastern Deepwater Sharks, were halved to form the target but only three of the catches were also halved. Lg is longitude and Lt is latitude.

| Species | Zone | Depths | Comment | Catch | CPUE |
|---|---|---|---|---|---|
| Smooth Oreo Cascade | 40 | 650-1250 | OR Zones | 1.0 | 0.5 |
| Smooth Oreo non-Cas | 10-30,50 | 600-1200 | OR Zones 10,20,21,30,50 | 0.5 | 0.5 |
| Mixed Oreo | 10-30,50 | 500-1200 | OR Zones 10,20,21,30,50 | 0.5 | 0.5 |
| West Deepwater Sharks | 30 | 600-1100 | OR Zone 30 | 1.0 | 0.5 |
| East Deepwater Sharks | 10-21,50 | 600-1250 | OR Zones 10,20,21,50 | 1.0 | 1.0 |
| Alfonsino | EDW | | > 157 & < 165 Lg; > -36 & < -30 Lt | 0.5 | 0.5 |

### *23.3.5 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.

In addition, if a fishery begins with a stock in an unfished state the RAGs decided that the initial catch rates would be distorted high and so the target CPUE would be estimated by halving the initial catch rates in the fishery. In some cases the catches would also be halved if the species (Table 18.1).

### *23.3.6 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 was not pursued this year.

### *23.3.7 The Assumption underlying the Tier 4*

For the Tier 4 analyses to be valid a number of assumptions need to be met:

- 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.*
- 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.*
- 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* $B_{48\%}$.

## 23.4 Results for Tier 4 species

### 23.4.1 Blue Eye (TBE – 37445001 – *Hyperoglyphe antarctica*)

Table 23.4. Blue eye Trevalla data for the TIER 4 calculations. Total is the sum of Discards, State, Non Trawl, SEF2, and ECDW catches. All values in Tonnes. CE is the standardized catch rate for all Zones 10 to 50 in depths 0 – 1000m (Haddon, 2013). 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 | Non-T | PDiscard | CE | GeoMean |
|---|---|---|---|---|---|---|---|---|
| 1997 | 733.985 | 0.000 | 733.985 | 620.142 | 0.000 | 0.000 | 1.9604 | 258.9752 |
| 1998 | 601.674 | 0.000 | 601.674 | 123.012 | 380.439 | 0.000 | 1.3375 | 226.1524 |
| 1999 | 711.465 | 0.000 | 711.465 | 132.608 | 464.658 | 0.000 | 1.1768 | 189.6587 |
| 2000 | 754.285 | 37.000 | 791.285 | 89.462 | 565.410 | 4.676 | 1.1240 | 177.6127 |
| 2001 | 685.798 | 33.000 | 718.798 | 77.613 | 478.397 | 4.591 | 1.1817 | 203.6327 |
| 2002 | 616.529 | 0.100 | 616.629 | 102.362 | 427.969 | 0.016 | 0.8899 | 164.0183 |
| 2003 | 652.762 | 0.160 | 652.922 | 51.623 | 556.565 | 0.025 | 0.9941 | 148.5823 |
| 2004 | 716.965 | 1.400 | 718.365 | 64.457 | 566.917 | 0.195 | 1.0449 | 91.3225 |
| 2005 | 557.613 | 0.000 | 557.613 | 55.557 | 450.678 | 0.000 | 0.8302 | 88.1440 |
| 2006 | 619.913 | 0.060 | 619.973 | 44.095 | 496.743 | 0.010 | 0.9562 | 121.2856 |
| 2007 | 639.371 | 2.813 | 642.184 | 53.102 | 536.267 | 0.438 | 1.1731 | 333.7817 |
| 2008 | 408.174 | 0.993 | 409.167 | 34.980 | 338.852 | 0.243 | 0.7572 | 214.3734 |
| 2009 | 478.452 | 0.000 | 478.452 | 35.090 | 404.049 | 0.000 | 0.8553 | 259.8521 |
| 2010 | 442.923 | 0.142 | 443.065 | 43.027 | 358.785 | 0.032 | 0.5414 | 142.9654 |
| 2011 | 498.833 | 7.436 | 506.269 | 40.297 | 430.038 | 1.469 | 0.6190 | 177.7306 |
| 2012 | 308.794 | 4.327 | 313.121 | 20.967 | 268.064 | 1.382 | 0.5584 | 156.1670 |

Discards make up approximately 1.2 % of the catch over the 1998-2006 period.
The catch rate time series used came from the combined autolongline and drop line fishery.

Table 23.5. RBC calculations for Blue Eye. Ctarg and CPUEtarg relate to the period 1997-2006, CPUELim is 40% of the target, 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 (19).

| | |
|---|---|
| Ref_Year | 1997-2006 |
| CE_Targ | 1.1496 |
| CE_Lim | 0.4598 |
| CE_Recent | 0.6435 |
| Wt_Discard | 4.310 |
| Scaling | 0.2663 |
| Last Year’s TAC | 326 |
| $C_{targ}$ | 672.271 |
| **RBC** | **179.044** |

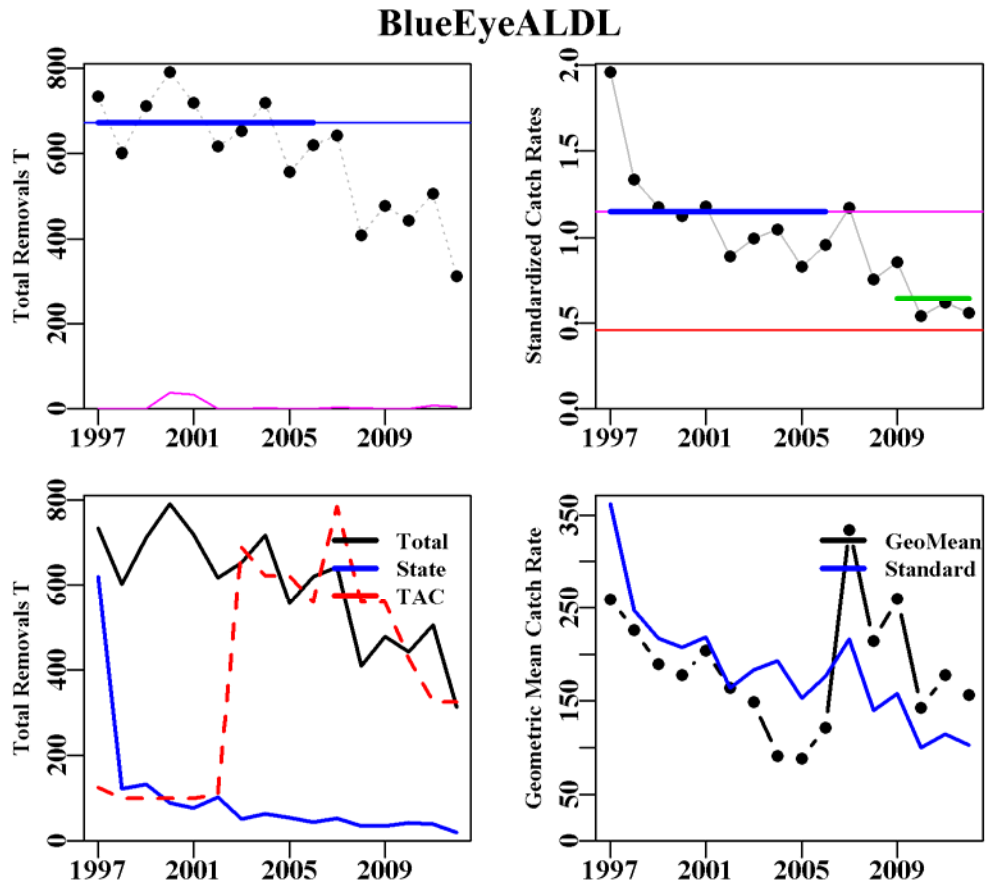


Figure 23.1. Blue Eye Trevalla. Top left is the total removals with the fine line illustrating the target catch. Top right represents the standardized catch rates with the upper fine line representing the target catch rate and the lower line the limit catch rate. Thickened lines represents the reference period for catches, catch rates, and the recent average catch rate.

The RBC calculation for BlueEye based on the Autoline CPUE series has been called in to question because od the advent of whale depredation of fish off the line while the gear is being hauled back to the vessel. An attempt was made to use observations made (Pease, 2012) of such depredations to make estimates of the rate of depredation and whether that rate has changed through time. This leads to a larger RBC as seen below, however, some depletion is still apparent.

### *23.4.2 Blue Eye Whale Discards (H. antarctica)*

Table 23.6. Blue eye Trevalla 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 |
|---|---|---|---|---|---|---|---|---|
| 1997 | 733.985 | 0.000 | 733.985 | 1.000 | 1.9604 | 1.8793 | 258.9752 | 125 |
| 1998 | 601.674 | 0.000 | 601.674 | 1.000 | 1.3375 | 1.2822 | 226.1524 | 100 |
| 1999 | 711.465 | 0.000 | 711.465 | 1.000 | 1.1768 | 1.1281 | 189.6587 | 100 |
| 2000 | 754.285 | 37.000 | 791.285 | 1.049 | 1.1240 | 1.1304 | 177.6127 | 100 |
| 2001 | 685.798 | 33.000 | 718.798 | 1.048 | 1.1817 | 1.1873 | 203.6327 | 100 |
| 2002 | 616.529 | 0.100 | 616.629 | 1.000 | 0.8899 | 0.8532 | 164.0183 | 109 |
| 2003 | 652.762 | 0.160 | 652.922 | 1.000 | 0.9941 | 0.9532 | 148.5823 | 690 |
| 2004 | 716.965 | 1.400 | 718.365 | 1.002 | 1.0449 | 1.0036 | 91.3225 | 621 |
| 2005 | 557.613 | 0.000 | 557.613 | 1.000 | 0.8302 | 0.7959 | 88.1440 | 621 |
| 2006 | 619.913 | 0.060 | 619.973 | 1.000 | 0.9562 | 0.9167 | 121.2856 | 560 |
| 2007 | 639.371 | 2.813 | 642.184 | 1.004 | 1.1731 | 1.1295 | 333.7817 | 785 |
| 2008 | 408.174 | 20.691 | 428.865 | 1.051 | 0.7572 | 0.7627 | 214.3734 | 560 |
| 2009 | 478.452 | 48.539 | 526.991 | 1.101 | 0.8553 | 0.9031 | 259.8521 | 560 |
| 2010 | 442.923 | 154.630 | 597.553 | 1.349 | 0.5414 | 0.7002 | 142.9654 | 428 |
| 2011 | 498.833 | 133.022 | 631.855 | 1.267 | 0.6190 | 0.7516 | 177.7306 | 326 |
| 2012 | 308.794 | 50.415 | 359.209 | 1.163 | 0.5584 | 0.6227 | 156.1670 | 326 |

Discards make up approximately 1.2 % of the catch over the 1998-2006 period.
The catch rate time series used came from the combined autolongline and drop line fishery.

Table 23.7. RBC calculations for Blue Eye. Ctarg and CPUEtarg relate to the period 1997-2006, CPUELim is 40% of the target, 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 (19).

| | |
|---|---|
| Ref_Year | 1997-2006 |
| CE_Targ | 1.113 |
| CE_Lim | 0.4452 |
| CE_Recent | 0.7444 |
| Wt_Discard | 86.214 |
| Scaling | 0.4481 |
| Last Year’s TAC | 326 |
| $C_{targ}$ | 672.271 |
| **RBC** | **301.213** |

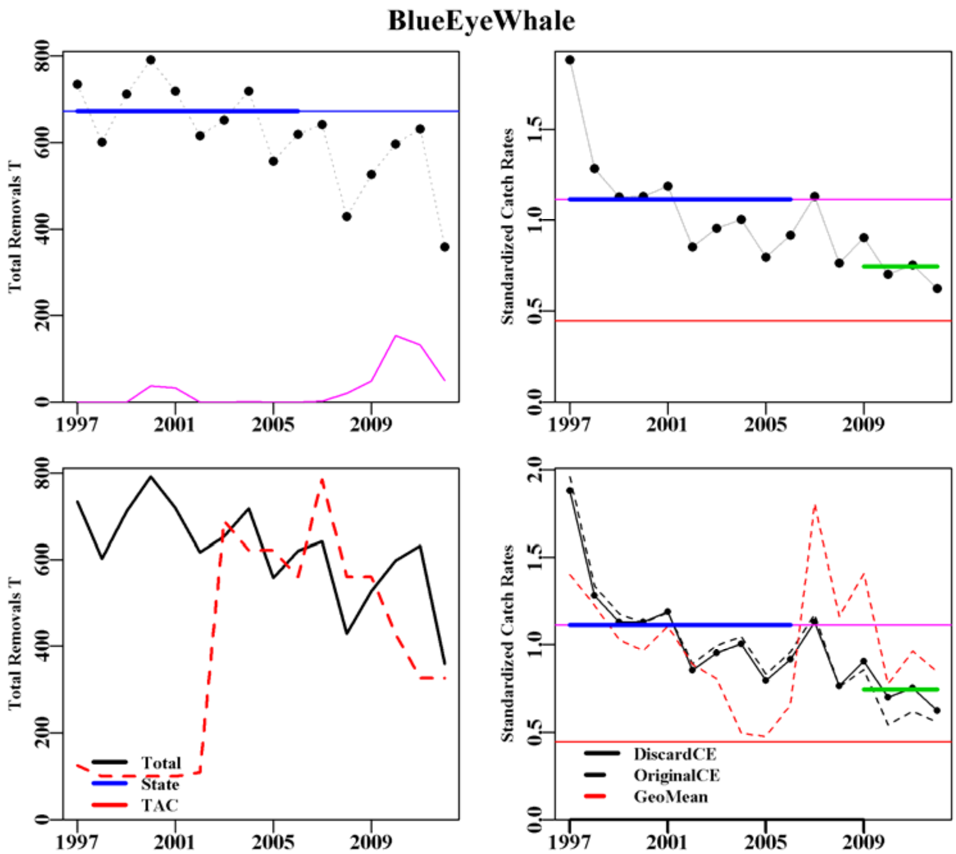


Figure 23.2. Blue Eye Trevalla. Top left is the total removals with the fine line illustrating the target catch. Top right represents the standardized catch rates with the upper fine line representing the target catch rate and the lower line the limit catch rate. Thickened lines represents the reference period for catches, catch rates, and the recent average catch rate. The bottom right compares the geometric mean CPUE with the original optimal CPUE series (without discards) and the final estimate of the Discard CPUE.

Whale depredations were estimated to lead to approximately 60% loss of catch when killer whales were present during a haul (Pease, 2012, p55). However, killer whales are not always present during a haul so some means of allowing for their presence or absence was required. Pease (2012, p56) also documents variation in the rate of killer whale sightings between years, which may have been related to different seasonal patterns of fishing as well as location changes. Across the years the relative sighting frequency has also varied but the statement is also made that killer whales were observed across about 25% of days. When the average relative frequency of sighting is scaled to 0.25 and then multiplied by the 60% this enables an approximate estimate of killer whale depredations for 2008 – 2012.

The final estimate of the RBC is sensitive to the method used to estimate the proportion of days in which killer whales would have influenced catches. If the relative frequency of sightings through the years 2008 – 2012 are used without rescaling to 25% then the RBC is estimated at about 371 t. The importance of this analysis is to demonstrate that whale depredations can have significant effects on catch rates over and above the impact on the choice of fishing locations. The approach used here only accounts for the direct effect of whales removing fish from the auto-lines, the other impacts such as times and location of fishing are more difficult to quantify. What this alternative analysis demonstrates is that whale depredations could be leading to a great deal of bias if they are left unaccounted.

Table 23.8. Estimate of approximate whale depredation based on figures from Pease (2012). The mean of the Relative Frequency (RF) was 0.342 and the ScaledRF was the RF divided by 0.342/0.25. The 0.6 relates to 60% reduction in catch. The depredation = Landings x (RF x 0.6).

| Relative Frequency | ScaledRF | RF x 0.6 | Landings | Depredation | Total |
|---|---|---|---|---|---|
| 0.11 | 0.0804 | 0.0482 | 408.174 | 20.691 | 428.865 |
| 0.21 | 0.1535 | 0.0921 | 478.452 | 48.539 | 526.991 |
| 0.59 | 0.4313 | 0.2588 | 442.923 | 154.630 | 597.553 |
| 0.48 | 0.3509 | 0.2105 | 498.832 | 133.022 | 631.854 |
| 0.32 | 0.2339 | 0.1404 | 308.794 | 50.415 | 359.209 |

### *23.4.3 Blue Warehou (TRT – 37445005 – Seriolella brama) Zones 10 - 50*

Table 23.9. Blue Warehou 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 50 in depths 0 – 400m (Haddon, 2013). 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 | Non-T | PDiscard | CE | GeoMean |
|---|---|---|---|---|---|---|---|---|
| 1986 | 277.200 | 53.638 | 330.838 | | | 16.2128 | 2.0703 | 24.6419 |
| 1987 | 1010.400 | 195.512 | 1205.912 | | | 16.2128 | 2.3727 | 38.9818 |
| 1988 | 999.600 | 193.422 | 1193.022 | | | 16.2128 | 2.6488 | 42.2791 |
| 1989 | 1598.400 | 309.290 | 1907.690 | | | 16.2128 | 3.6574 | 53.5132 |
| 1990 | 2272.800 | 439.786 | 2712.586 | | | 16.2128 | 2.5841 | 49.3618 |
| 1991 | 2478.000 | 479.492 | 2957.492 | | | 16.2128 | 2.0552 | 38.9026 |
| 1992 | 1869.600 | 361.767 | 2231.367 | | | 16.2128 | 1.5133 | 34.9011 |
| 1993 | 1440.000 | 278.639 | 1718.639 | | | 16.2128 | 1.1760 | 27.0143 |
| 1994 | 1308.081 | 253.113 | 1561.194 | 453.110 | 0.000 | 16.2128 | 1.1348 | 24.5388 |
| 1995 | 1086.315 | 210.201 | 1296.516 | 326.364 | 0.000 | 16.2128 | 0.9631 | 19.7435 |
| 1996 | 1223.451 | 236.737 | 1460.189 | 373.121 | 0.000 | 16.2128 | 0.9765 | 16.0446 |
| 1997 | 981.513 | 189.922 | 1171.436 | 190.547 | 0.000 | 16.2128 | 0.9728 | 13.9027 |
| 1998 | 1271.881 | 86.000 | 1357.881 | 266.850 | 80.448 | 6.3334 | 0.9660 | 18.0335 |
| 1999 | 925.892 | 16.000 | 941.892 | 283.003 | 287.791 | 1.6987 | 0.5210 | 9.5323 |
| 2000 | 628.918 | 16.000 | 644.918 | 113.480 | 82.121 | 2.4809 | 0.4484 | 7.2891 |
| 2001 | 354.866 | 39.000 | 393.866 | 25.980 | 30.742 | 9.9019 | 0.3021 | 5.6327 |
| 2002 | 389.328 | 7.370 | 396.698 | 71.886 | 3.720 | 1.8578 | 0.2549 | 4.0433 |
| 2003 | 296.069 | 19.490 | 315.559 | 42.301 | 2.077 | 6.1763 | 0.2065 | 3.2843 |
| 2004 | 293.191 | 381.440 | 674.631 | 31.148 | 1.719 | 56.5405 | 0.2822 | 4.966 |
| 2005 | 329.935 | 273.920 | 603.855 | 17.249 | 1.318 | 45.3619 | 0.2635 | 6.0446 |
| 2006 | 412.776 | 109.480 | 522.256 | 26.282 | 0.732 | 20.9629 | 0.2645 | 7.8259 |
| 2007 | 224.990 | 24.929 | 249.919 | 29.271 | 0.780 | 9.9749 | 0.2444 | 5.6784 |
| 2008 | 194.125 | 265.391 | 459.516 | 36.859 | 0.976 | 57.7545 | 0.2754 | 5.0903 |
| 2009 | 171.807 | 16.561 | 188.368 | 33.663 | 1.704 | 8.7918 | 0.2752 | 6.9116 |
| 2010 | 157.283 | 15.161 | 172.444 | 25.554 | 4.584 | 8.7918 | 0.2207 | 6.3388 |
| 2011 | 119.504 | 40.116 | 159.620 | 9.047 | 11.805 | 25.1324 | 0.2025 | 5.5254 |
| 2012 | 53.962 | 18.115 | 72.077 | 3.895 | 5.776 | 25.1324 | 0.1477 | 3.2664 |

Discards make up approximately 16.2 % of the catch over the 1998-2006 period.

Table 23.10. RBC calculations for Blue Warehou1050. Ctarg and CPUEtarg relate to the period 1986-1995, CPUELim is 40% of the target, 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 (19).

| | |
|---|---|
| Ref_Year | 1986-1995 |
| CE_Targ | 2.0176 |
| CE_Lim | 0.807 |
| CE_Recent | 0.2115 |
| Wt_Discard | 23.484 |
| Scaling | 0 |
| Last Year's TAC | 133 |
| $C_{targ}$ | 1711.526 |
| **RBC** | **0** |

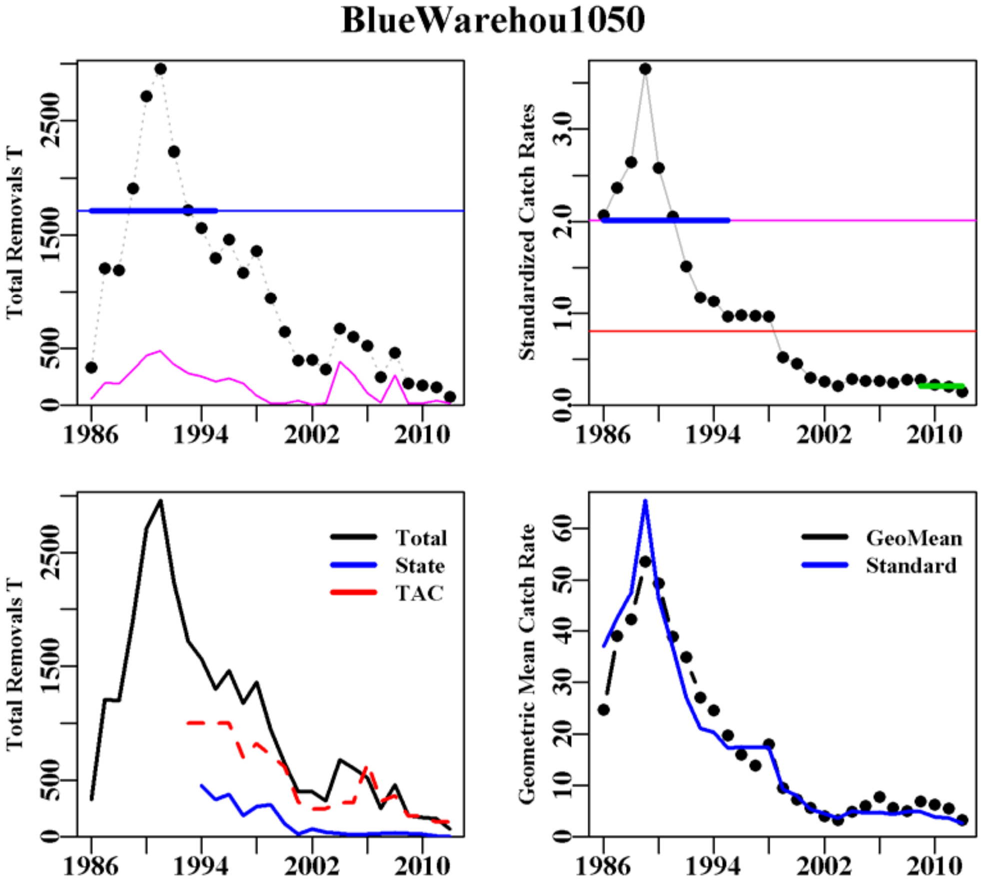


Figure 23.3. Blue Warehou. Top left is the total removals with the fine line illustrating the target catch. Top right represents the standardized catch rates with the upper fine line representing the target catch rate and the lower line the limit catch rate. Thickened lines represents the reference period for catches, catch rates, and the recent average catch rate.

### *23.4.4 Blue Warehou (TRT – 37445005 – Seriolella brama) Zones 10, 20 & 30*

To provide an analysis more relevant to the two stocks of Blue Warehou (east and west) the landed catches, which are reported in total across zones 10 – 50, were subdivided in the same ratio as the reported catches from the catch effort log books, the discards were treated in the same fashion. Thus the catches and discards in Table 23.11 and Table 23.13 should sum in each year to the catches and discards in Table 23.9. The separate columns for the State and Non-Trawl catches were not adjusted and so, for these analyses are not meaningful.

Table 23.11. Blue Warehou 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 – 400m (Haddon, 2013). 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. Prop is the proportion of the Commonwealth catch taken in zones 10 – 30 estimated from logbook data.

| Year | Catch | Discards | Total | State | Non-T | PDiscard | CE | GeoMean | Prop |
|---|---|---|---|---|---|---|---|---|---|
| 1986 | 182.965 | 35.404 | 218.369 | | | 16.2128 | 1.9418 | 22.9216 | 0.660 |
| 1987 | 441.810 | 85.490 | 527.300 | | | 16.2128 | 2.3584 | 23.2716 | 0.437 |
| 1988 | 627.235 | 121.370 | 748.604 | | | 16.2128 | 2.8779 | 34.8726 | 0.627 |
| 1989 | 1423.934 | 275.530 | 1699.464 | | | 16.2128 | 3.6492 | 52.6588 | 0.891 |
| 1990 | 1404.632 | 271.796 | 1676.428 | | | 16.2128 | 3.3387 | 46.551 | 0.618 |
| 1991 | 1029.357 | 199.180 | 1228.537 | | | 16.2128 | 1.7949 | 23.0208 | 0.415 |
| 1992 | 904.980 | 175.113 | 1080.093 | | | 16.2128 | 1.4771 | 24.3304 | 0.484 |
| 1993 | 779.747 | 150.881 | 930.627 | | | 16.2128 | 1.1518 | 20.7054 | 0.541 |
| 1994 | 668.550 | 129.364 | 797.914 | 231.581 | | 16.2128 | 1.1110 | 17.5997 | 0.511 |
| 1995 | 639.496 | 123.742 | 763.238 | 192.125 | | 16.2128 | 1.0166 | 15.3567 | 0.589 |
| 1996 | 908.029 | 175.703 | 1083.732 | 276.926 | | 16.2128 | 1.0478 | 14.6415 | 0.742 |
| 1997 | 612.225 | 118.465 | 730.691 | 118.855 | | 16.2128 | 1.0217 | 11.876 | 0.624 |
| 1998 | 714.692 | 48.325 | 763.016 | 149.948 | 45.205 | 6.3334 | 0.9546 | 13.8592 | 0.562 |
| 1999 | 393.565 | 6.801 | 400.366 | 120.295 | 122.330 | 1.6987 | 0.5292 | 5.7097 | 0.425 |
| 2000 | 298.780 | 7.601 | 306.381 | 53.911 | 39.013 | 2.4809 | 0.4393 | 5.0072 | 0.475 |
| 2001 | 80.201 | 8.814 | 89.015 | 5.872 | 6.948 | 9.9019 | 0.2615 | 2.7867 | 0.226 |
| 2002 | 87.092 | 1.649 | 88.740 | 16.081 | 0.832 | 1.8578 | 0.1982 | 2.2036 | 0.224 |
| 2003 | 57.050 | 3.756 | 60.806 | 8.151 | 0.400 | 6.1763 | 0.1538 | 1.8331 | 0.193 |
| 2004 | 72.152 | 93.870 | 166.022 | 7.665 | 0.423 | 56.5405 | 0.2087 | 2.7248 | 0.246 |
| 2005 | 25.133 | 20.866 | 46.000 | 1.314 | 0.100 | 45.3619 | 0.1395 | 1.8011 | 0.076 |
| 2006 | 29.227 | 7.752 | 36.979 | 1.861 | 0.052 | 20.9629 | 0.1656 | 2.2327 | 0.071 |
| 2007 | 22.793 | 2.526 | 25.319 | 2.965 | 0.079 | 9.9749 | 0.1745 | 1.8677 | 0.101 |
| 2008 | 36.657 | 50.115 | 86.772 | 6.960 | 0.184 | 57.7545 | 0.2439 | 2.6539 | 0.189 |
| 2009 | 50.201 | 4.839 | 55.040 | 9.836 | 0.498 | 8.7918 | 0.2875 | 3.5956 | 0.292 |
| 2010 | 16.385 | 1.579 | 17.965 | 2.662 | 0.478 | 8.7918 | 0.1840 | 2.1227 | 0.104 |
| 2011 | 12.818 | 4.303 | 17.121 | 0.970 | 1.266 | 25.1324 | 0.1490 | 1.7081 | 0.107 |
| 2012 | 11.509 | 3.864 | 15.373 | 0.831 | 1.232 | 25.1324 | 0.1238 | 1.6727 | 0.213 |

Discards make up approximately 16.2% for the period 1998 – 2006.

Table 23.12. RBC calculations for Blue Warehou East. Ctarg and CPUEtarg relate to the period 1986-1995, CPUELim is 40% of the target, 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 (19).

| | |
|---|---|
| Ref_Year | 1986-1995 |
| CE_Targ | 2.0717 |
| CE_Lim | 0.8287 |
| CE_Recent | 0.1861 |
| Wt_Discard | 3.741 |
| Scaling | 0 |
| Last Year's TAC | 133 |
| $C_{targ}$ | 967.057 |
| **RBC** | **0** |

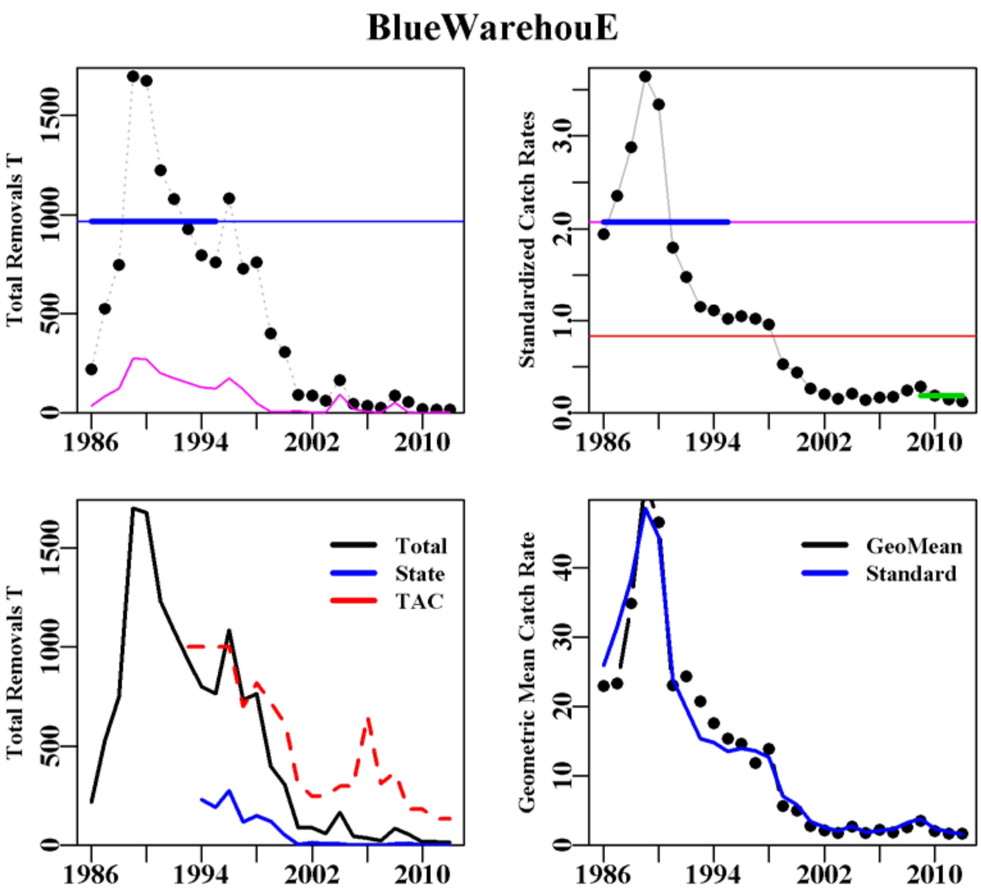


Figure 23.4. Blue Warehou zones 10 - 30. Top left is the total removals with the fine line illustrating the target catch. Top right represents the standardized catch rates with the upper fine line representing the target catch rate and the lower line the limit catch rate. Thickened lines represents the reference period for catches, catch rates, and the recent average catch rate.

### 23.4.5 Blue Warehou (TRT – 37445005 – *Seriolella brama*) Zones 40 & 50

To provide an analysis more relevant to the two stocks of Blue Warehou (east and west) the landed catches, which are reported in total across zones 10 – 50, were subdivided in the same ratio as the reported catches from the catch effort log books, the discards were treated in the same fashion. Thus the catches and discards in Table 23.11 and Table 23.13 should sum in each year to the catches and discards in Table 23.9. The separate columns for the State and Non-Trawl catches were not adjusted and so, for these analyses are not meaningful.

Table 23.13. Blue Warehou 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 – 400m (Haddon, 2013). 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. Prop is the proportion of the Commonwealth catch taken in zones 40 – 50 estimated from logbook data.

| Year | Catch | Discards | Total | State | Non-T | PDiscard | CE | GeoMean | Prop |
|---|---|---|---|---|---|---|---|---|---|
| 1986 | 94.090 | 18.206 | 112.296 | | | 16.2128 | 3.3898 | 34.3927 | 0.339 |
| 1987 | 566.596 | 109.636 | 676.231 | | | 16.2128 | 3.2398 | 153.6342 | 0.561 |
| 1988 | 371.761 | 71.936 | 443.696 | | | 16.2128 | 1.3376 | 104.5294 | 0.372 |
| 1989 | 174.252 | 33.718 | 207.970 | | | 16.2128 | 3.3688 | 91.527 | 0.109 |
| 1990 | 824.357 | 159.513 | 983.870 | | | 16.2128 | 1.4738 | 55.8069 | 0.363 |
| 1991 | 1432.947 | 277.274 | 1710.221 | | | 16.2128 | 2.3199 | 159.6429 | 0.578 |
| 1992 | 957.007 | 185.180 | 1142.187 | | | 16.2128 | 1.3324 | 88.9759 | 0.512 |
| 1993 | 655.342 | 126.808 | 782.151 | | | 16.2128 | 0.9834 | 92.3447 | 0.455 |
| 1994 | 634.695 | 122.813 | 757.508 | 219.854 | | 16.2128 | 1.0772 | 67.3117 | 0.485 |
| 1995 | 444.465 | 86.004 | 530.469 | 133.532 | | 16.2128 | 0.7260 | 45.1964 | 0.409 |
| 1996 | 313.745 | 60.710 | 374.455 | 95.684 | | 16.2128 | 0.4958 | 26.4215 | 0.256 |
| 1997 | 368.817 | 71.366 | 440.183 | 71.601 | | 16.2128 | 0.5195 | 35.6095 | 0.376 |
| 1998 | 554.068 | 37.464 | 591.532 | 116.248 | 35.045 | 6.3334 | 0.7874 | 58.9967 | 0.436 |
| 1999 | 521.329 | 9.009 | 530.338 | 159.347 | 162.042 | 1.6987 | 0.4387 | 32.5226 | 0.563 |
| 2000 | 328.333 | 8.353 | 336.686 | 59.243 | 42.872 | 2.4809 | 0.3523 | 28.0473 | 0.522 |
| 2001 | 272.029 | 29.896 | 301.925 | 19.915 | 23.566 | 9.9019 | 0.3768 | 27.5825 | 0.767 |
| 2002 | 302.026 | 5.717 | 307.743 | 55.766 | 2.886 | 1.8578 | 0.4992 | 35.4216 | 0.776 |
| 2003 | 237.916 | 15.662 | 253.577 | 33.992 | 1.669 | 6.1763 | 0.4553 | 28.1023 | 0.804 |
| 2004 | 220.757 | 287.204 | 507.961 | 23.453 | 1.294 | 56.5405 | 0.5094 | 28.4995 | 0.753 |
| 2005 | 304.398 | 252.718 | 557.116 | 15.914 | 1.216 | 45.3619 | 0.8063 | 53.5991 | 0.923 |
| 2006 | 383.493 | 101.713 | 485.206 | 24.417 | 0.680 | 20.9629 | 0.5689 | 31.8482 | 0.929 |
| 2007 | 202.184 | 22.402 | 224.586 | 26.304 | 0.701 | 9.9749 | 0.4872 | 22.982 | 0.899 |
| 2008 | 157.330 | 215.088 | 372.418 | 29.873 | 0.791 | 57.7545 | 0.3823 | 20.3955 | 0.810 |
| 2009 | 121.137 | 11.677 | 132.813 | 23.735 | 1.202 | 8.7918 | 0.2859 | 18.4388 | 0.705 |
| 2010 | 140.652 | 13.558 | 154.209 | 22.852 | 4.100 | 8.7918 | 0.3290 | 17.5511 | 0.894 |
| 2011 | 101.774 | 34.165 | 135.938 | 7.705 | 10.053 | 25.1324 | 0.2809 | 14.395 | 0.852 |
| 2012 | 38.079 | 12.783 | 50.862 | 2.749 | 4.076 | 25.1324 | 0.1766 | 8.1485 | 0.706 |

Discards make up approximately 16.2 % of the catch over the 1998-2006 period.

Table 23.14. RBC calculations for Blue Warehou West (Zones 40-50). Ctarg and CPUEtarg relate to the period 1986-1995, CPUELim is 40% of the target, 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 (19).

| | |
|---|---|
| Ref_Year | 1986-1995 |
| CE_Targ | 1.9249 |
| CE_Lim | 0.7699 |
| CE_Recent | 0.2681 |
| Wt_Discard | 18.514 |
| Scaling | 0 |
| Last Year's TAC | 133 |
| $C_{targ}$ | 734.66 |
| **RBC** | **0** |

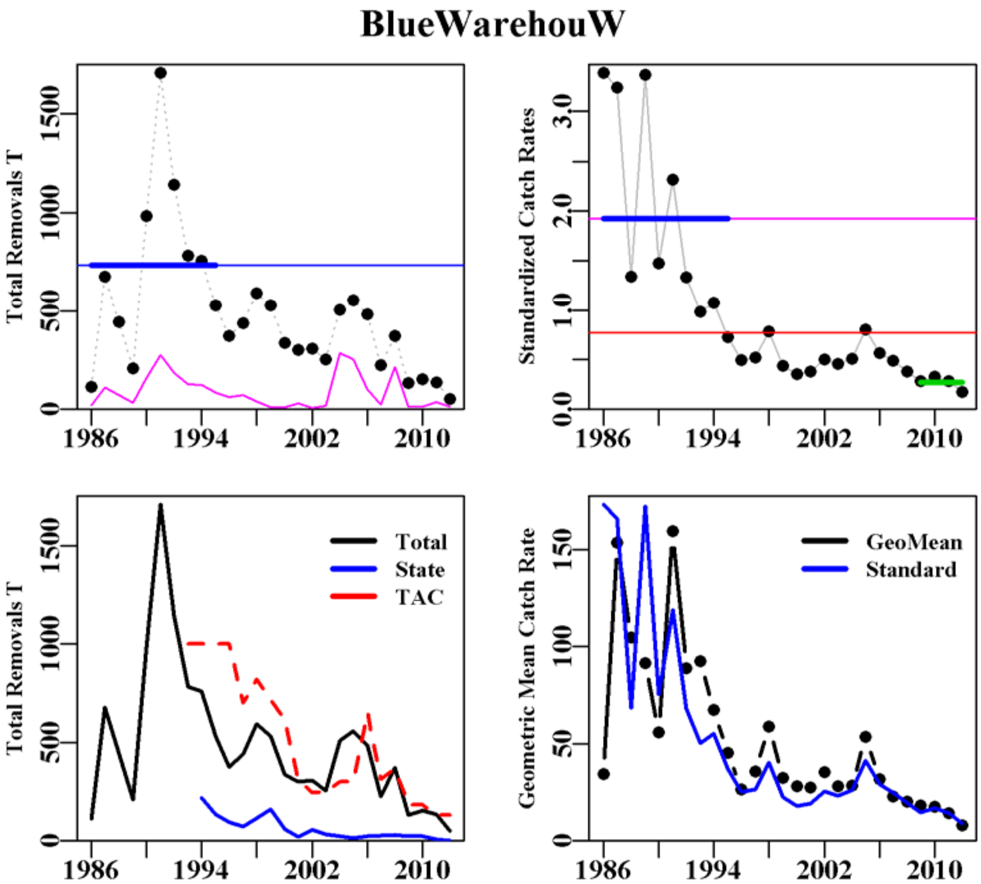


Figure 23.5. Blue Warehou zones 40 - 50. Top left is the total removals with the fine line illustrating the target catch. Top right represents the standardized catch rates with the upper fine line representing the target catch rate and the lower line the limit catch rate. Thickened lines represents the reference period for catches, catch rates, and the recent average catch rate.

### 23.4.6 *Inshore Ocean Perch Including Discards (REG – 37287001 – Helicolenus barathri)*

Inshore Ocean Perch are subject to relatively high levels of discarding, which was likely to have large effects on the perceived catch rates. By including the estimated discards in with the reported catches revised catch rates were possible. No standardization was possible using the simple ratio means but a method was devised that uses the standardized catch rates with a multiplier devised from the ratio discards to total catches; see equation (28). The reference period includes periods of catches less than 100t because this is a well-developed fishery and 100t constitutes a large proportion of the maximum catch.

Table 23.15. Inshore Ocean Perch data for the Alternative TIER 4 calculations using ratio mean catch rates that include discards in the catch rate calculations. Total is the sum of Discards, and other catches. All values in Tonnes. StandCE is the standardized catch rate for Inshore Ocean perch from Zones 10 and 20 in depths 0 – 200m (Haddon, 2013). GeoMean is the geometric mean catch rates (without discards). Discards are estimates from 1998 to present. DiscCE is the standardized catch rates multiplied by [(Discard/Catch)+1], see Haddon (2011c) and Methods.

| Year | Catch | Discards | Total | (D/C)+1 | StandCE | DiscCE | GeoMean |
|---|---|---|---|---|---|---|---|
| 1986 | 15.239 | 49.930 | 65.169 | 4.2765 | 0.8440 | 0.7345 | 6.8543 |
| 1987 | 12.441 | 34.842 | 47.283 | 3.8006 | 0.9873 | 0.7636 | 5.9511 |
| 1988 | 16.643 | 49.027 | 65.670 | 3.9458 | 1.1256 | 0.9038 | 7.2891 |
| 1989 | 16.758 | 50.257 | 67.015 | 3.9990 | 1.0802 | 0.8790 | 8.0367 |
| 1990 | 17.076 | 88.665 | 105.741 | 6.1924 | 1.1551 | 1.4555 | 7.7738 |
| 1991 | 26.084 | 106.551 | 132.635 | 5.0849 | 1.2906 | 1.3354 | 8.1374 |
| 1992 | 16.106 | 106.112 | 122.218 | 7.5884 | 1.7155 | 2.6490 | 9.5229 |
| 1993 | 29.267 | 100.307 | 129.574 | 4.4273 | 1.9258 | 1.7350 | 10.1873 |
| 1994 | 38.765 | 99.192 | 137.957 | 3.5588 | 1.7529 | 1.2694 | 9.4326 |
| 1995 | 40.881 | 104.606 | 145.487 | 3.5588 | 1.2956 | 0.9383 | 8.7548 |
| 1996 | 51.250 | 131.139 | 182.389 | 3.5588 | 1.1461 | 0.8300 | 7.0539 |
| 1997 | 34.279 | 87.713 | 121.992 | 3.5588 | 1.0647 | 0.7710 | 5.9056 |
| 1998 | 39.085 | 124.000 | 163.085 | 4.1726 | 0.9289 | 0.7887 | 5.7524 |
| 1999 | 25.438 | 78.000 | 103.438 | 4.0663 | 0.8336 | 0.6898 | 4.9974 |
| 2000 | 47.846 | 100.000 | 147.846 | 3.0901 | 0.9928 | 0.6243 | 4.5708 |
| 2001 | 37.815 | 89.000 | 126.815 | 3.3536 | 0.9850 | 0.6722 | 4.2075 |
| 2002 | 48.363 | 145.110 | 193.473 | 4.0004 | 0.7049 | 0.5738 | 2.6164 |
| 2003 | 30.865 | 61.320 | 92.185 | 2.9867 | 0.5446 | 0.3310 | 2.3132 |
| 2004 | 25.887 | 194.450 | 220.337 | 8.5116 | 0.5539 | 0.9594 | 2.244 |
| 2005 | 23.829 | 41.680 | 65.509 | 2.7491 | 0.6252 | 0.3497 | 2.988 |
| 2006 | 50.439 | 9.760 | 60.199 | 1.1935 | 0.5197 | 0.1262 | 2.2501 |
| 2007 | 35.923 | 17.195 | 53.117 | 1.4787 | 0.7315 | 0.2201 | 3.5455 |
| 2008 | 29.746 | 23.433 | 53.180 | 1.7878 | 0.8917 | 0.3244 | 4.2486 |
| 2009 | 19.480 | 91.350 | 110.830 | 5.6894 | 0.7600 | 0.8799 | 4.1335 |
| 2010 | 21.952 | 132.847 | 154.798 | 7.0518 | 0.8047 | 1.1547 | 3.8363 |
| 2011 | 19.797 | 325.480 | 345.277 | 17.4409 | 0.9396 | 3.3347 | 3.6642 |
| 2012 | 14.098 | 133.590 | 147.688 | 10.4755 | 0.8006 | 1.7066 | 3.5117 |

Discards are calculated now according to the latest ISMP design and this has led to a re-assessment of the levels of discards from 2008 onwards; hence the difference between this year's analysis and last year's.

### *23.4.6.1 40% Target*

Table 23.16. RBC calculations for Inshore Ocean Perch. Ctarg and CPUEtarg relate to the period 1986-1995, CPUELim is 40% of the target, 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 (19).

| | |
|---|---|
| Ref_Year | 1986-1995 |
| CE_Targ | 1.0553 |
| CE_Lim | 0.5065 |
| CE_Recent | 1.769 |
| Wt_Discard | 181.845 |
| Scaling | 2.3006 |
| Last Year's TAC | 300 |
| $C_{targ}$ | 101.875 |
| **RBC** | **234.373** |

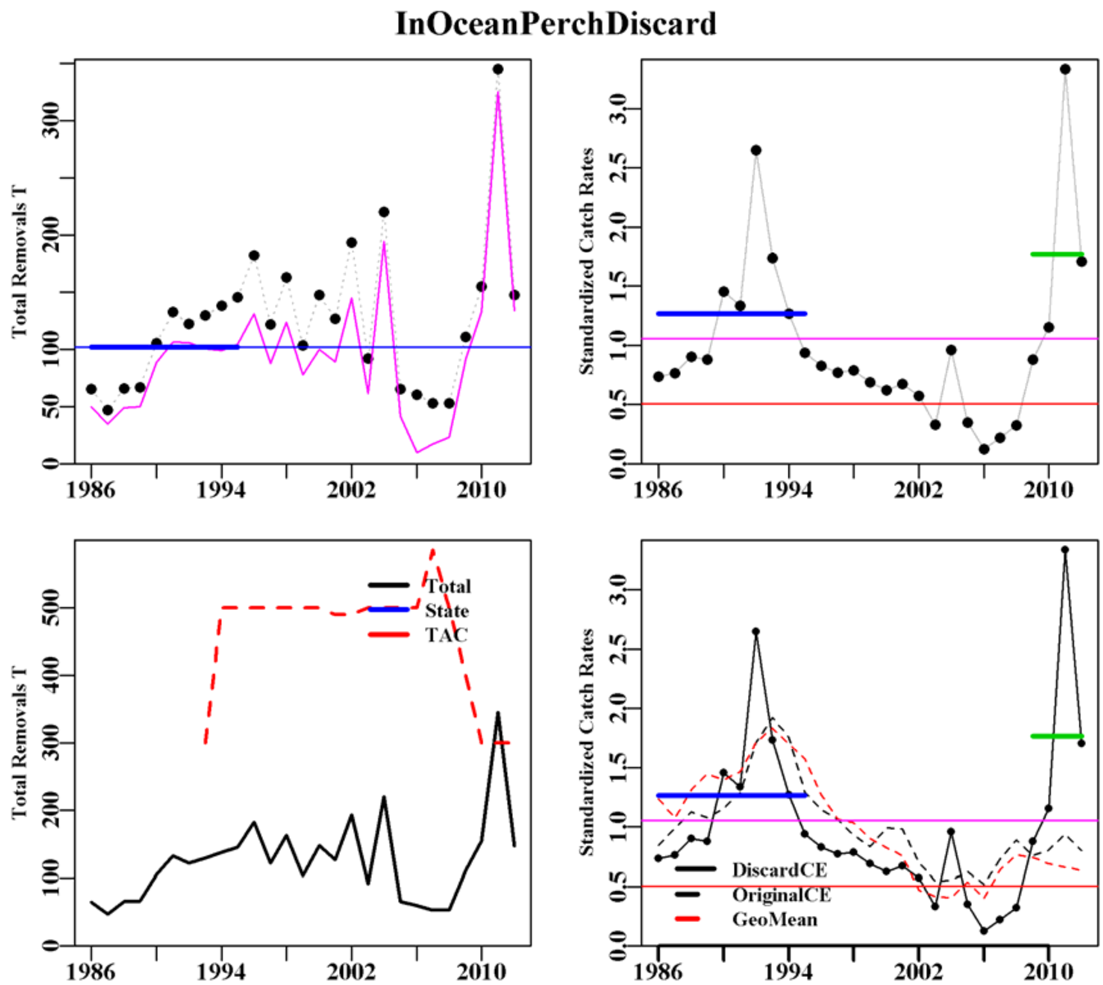


Figure 23.6. Alternative InShore Ocean Perch (where catch rates include discards). Top left is the total removals with the fine line illustrating the target catch. Top right represents the standardized catch rates with the upper fine line representing the target catch rate and the lower line the limit catch rate. Thickened lines represents the reference period for catches, catch rates, and the recent average catch rate.

### *23.4.7 Offshore Ocean Perch (REG – 37287001 – H percoides)*

Offshore Ocean Perch were defined as those records that were reported as being from 200 – 700 metres depth; Inshore Ocean Perch were defined as those records from depths of 0 – 200 metres (A decision of the RAG in 2010, reversing a different decision made in 2009). In addition, the data series of reported catches differ from those previously used as they have been recently reviewed and revised, splitting the landings between Offshore and Inshore Ocean Perch relative to the Commonwealth log book catches for the two depth ranges. This increased the total catches reported, but these data are now the best available information on Ocean Perch catches.

Table 23.17. Offshore Ocean Perch 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 Offshore Ocean perch from Zones 10 and 20 in depths 200 – 700m (Haddon, 2013). 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. Landings before 1994 were subdivided according to the ratio of inshore to offshore in the Commonwealth logbook data.

| Year | Catch | Discards | Total | State | Non-T | Pdiscard | CE | GeoMean |
|---|---|---|---|---|---|---|---|---|
| 1986 | 218.366 | 31.876 | 250.242 | | | 12.7381 | 1.0273 | 12.1440 |
| 1987 | 179.087 | 26.142 | 205.230 | | | 12.7381 | 0.9524 | 8.9237 |
| 1988 | 178.089 | 25.997 | 204.086 | | | 12.7381 | 1.0646 | 10.5074 |
| 1989 | 207.462 | 30.284 | 237.746 | | | 12.7381 | 1.0226 | 10.6494 |
| 1990 | 176.918 | 25.826 | 202.744 | | | 12.7381 | 1.3618 | 12.0207 |
| 1991 | 234.031 | 34.163 | 268.193 | | | 12.7381 | 1.4388 | 13.4339 |
| 1992 | 349.336 | 50.994 | 400.330 | | | 12.7381 | 1.2143 | 11.9264 |
| 1993 | 314.476 | 45.906 | 360.382 | | | 12.7381 | 1.2142 | 12.9555 |
| 1994 | 294.313 | 42.962 | 337.276 | 35.478 | | 12.7381 | 1.1338 | 11.8001 |
| 1995 | 320.654 | 46.807 | 367.461 | 35.712 | | 12.7381 | 1.0258 | 10.4874 |
| 1996 | 363.621 | 53.080 | 416.701 | 35.992 | | 12.7381 | 0.9196 | 9.8364 |
| 1997 | 440.479 | 64.299 | 504.777 | 37.041 | 5.312 | 12.7381 | 0.9729 | 9.7119 |
| 1998 | 372.254 | 174.000 | 546.254 | 35.974 | 6.250 | 31.8533 | 0.8631 | 9.4285 |
| 1999 | 395.062 | 64.000 | 459.062 | 39.250 | 7.018 | 13.9415 | 0.9696 | 9.7566 |
| 2000 | 344.156 | 34.000 | 378.156 | 36.369 | 9.086 | 8.9910 | 0.7723 | 7.5464 |
| 2001 | 356.183 | 46.000 | 402.183 | 29.725 | 8.597 | 11.4376 | 0.8676 | 8.3956 |
| 2002 | 322.376 | 22.470 | 344.846 | 36.660 | 18.885 | 6.5160 | 0.8247 | 7.3709 |
| 2003 | 373.003 | 27.800 | 400.803 | 28.965 | 30.940 | 6.9361 | 0.8799 | 7.6242 |
| 2004 | 362.370 | 42.440 | 404.810 | 19.579 | 66.129 | 10.4839 | 0.8767 | 8.0648 |
| 2005 | 322.617 | 17.100 | 339.717 | 15.404 | 34.518 | 5.0336 | 0.9852 | 9.3641 |
| 2006 | 226.413 | 20.980 | 247.393 | 15.835 | 46.229 | 8.4804 | 0.8429 | 7.8433 |
| 2007 | 186.607 | 100.727 | 287.334 | 13.362 | 28.638 | 35.0559 | 1.0503 | 9.9183 |
| 2008 | 208.930 | 22.187 | 231.117 | 13.489 | 37.801 | 9.6000 | 0.9672 | 9.1917 |
| 2009 | 218.732 | 28.233 | 246.965 | 18.551 | 32.967 | 11.4319 | 0.9630 | 9.0355 |
| 2010 | 238.512 | 81.596 | 320.108 | 27.782 | 28.977 | 25.4902 | 0.9863 | 9.8647 |
| 2011 | 223.762 | 18.550 | 242.312 | 10.619 | 24.104 | 7.6555 | 0.8673 | 9.0998 |
| 2012 | 211.337 | 23.539 | 234.876 | 13.403 | 27.049 | 10.0218 | 0.9357 | 9.9671 |

Discards make up approximately 12.68% % of the catch over the 1998-2006 period. The catch rates used were for Offshore Ocean Perch from 200 to 700 metres depth. State catches from 1994 to 1997 were compromised through including some Commonwealth catches. As an agreed upon better estimates, the State catches in these years were replaced with the average State catch from the years 1998 to 2003.

#### *23.4.7.1 48% Target No Discards*

Table 23.18. RBC calculations for Offshore Ocean Perch. Ctarg and CPUEtarg relate to the period 1986-1995, CPUELim is 40% of the target, 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 (19).

| | |
|---|---|
| Ref_Year | 1986-1995 |
| CE_Targ | 1.1456 |
| CE_Lim | 0.4582 |
| CE_Recent | 0.9381 |
| Wt_Discard | 30.262 |
| Scaling | 0.6981 |
| Last Year's TAC | 300 |
| $C_{targ}$ | 283.369 |
| **RBC** | **197.829** |

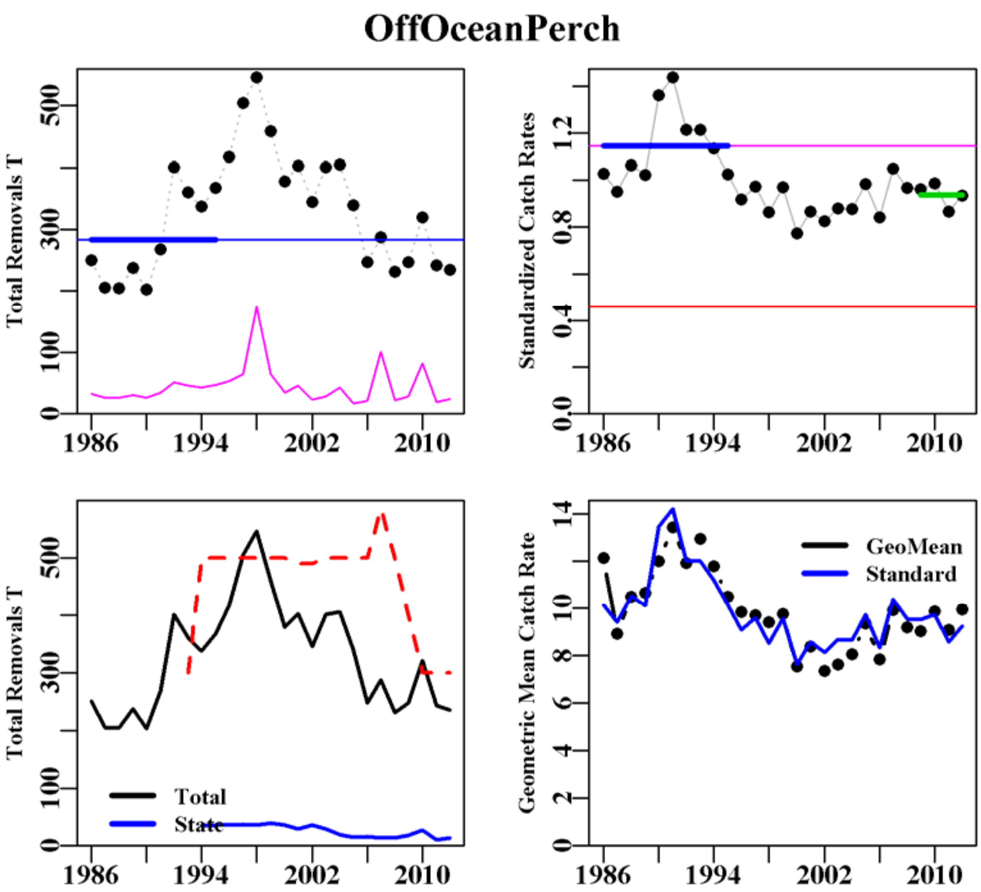


Figure 23.7. OffShore Ocean Perch. Top left is the total removals with the fine line illustrating the target catch. Top right represents the standardized catch rates with the upper fine line representing the target catch rate and the lower line the limit catch rate. Thickened lines represents the reference period for catches, catch rates, and the recent average catch rate.

### *23.4.8 Offshore Ocean Perch (REG – 37287001 – H percoides) Including Discards*

A request has been made to estimate the Tier 4 for Offshore Ocean Perch by including discards and setting a target at a proxy of 40% instead of 48%.

Table 23.19. Offshore Ocean Perch 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 Offshore Ocean perch from Zones 10 and 20 in depths 200 – 700m (Haddon, 2013). 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. Landings before 1994 were subdivided according to the ratio of inshore to offshore in the Commonwealth logbook data.

| Year | Catch | Discards | Total | (D/C)+1 | StandCE | DiscCE | GeoMean | TAC |
|---|---|---|---|---|---|---|---|---|
| 1986 | 218.366 | 31.876 | 250.242 | 1.1460 | 1.0273 | 1.0136 | 12.1440 | |
| 1987 | 179.087 | 26.142 | 205.230 | 1.1460 | 0.9524 | 0.9397 | 8.9237 | |
| 1988 | 178.089 | 25.997 | 204.086 | 1.1460 | 1.0646 | 1.0504 | 10.5074 | |
| 1989 | 207.462 | 30.284 | 237.746 | 1.1460 | 1.0226 | 1.0089 | 10.6494 | |
| 1990 | 176.918 | 25.826 | 202.744 | 1.1460 | 1.3618 | 1.3436 | 12.0207 | |
| 1991 | 234.031 | 34.163 | 268.193 | 1.1460 | 1.4388 | 1.4196 | 13.4339 | |
| 1992 | 349.336 | 50.994 | 400.330 | 1.1460 | 1.2143 | 1.1981 | 11.9264 | |
| 1993 | 314.476 | 45.906 | 360.382 | 1.1460 | 1.2142 | 1.1980 | 12.9555 | 300 |
| 1994 | 294.313 | 42.962 | 337.276 | 1.1460 | 1.1338 | 1.1186 | 11.8001 | 500 |
| 1995 | 320.654 | 46.807 | 367.461 | 1.1460 | 1.0258 | 1.0121 | 10.4874 | 500 |
| 1996 | 363.621 | 53.080 | 416.701 | 1.1460 | 0.9196 | 0.9073 | 9.8364 | 500 |
| 1997 | 440.479 | 64.299 | 504.777 | 1.1460 | 0.9729 | 0.9599 | 9.7119 | 500 |
| 1998 | 372.254 | 174.000 | 546.254 | 1.4674 | 0.8631 | 1.0904 | 9.4285 | 500 |
| 1999 | 395.062 | 64.000 | 459.062 | 1.1620 | 0.9696 | 0.9700 | 9.7566 | 500 |
| 2000 | 344.156 | 34.000 | 378.156 | 1.0988 | 0.7723 | 0.7306 | 7.5464 | 500 |
| 2001 | 356.183 | 46.000 | 402.183 | 1.1291 | 0.8676 | 0.8434 | 8.3956 | 490 |
| 2002 | 322.376 | 22.470 | 344.846 | 1.0697 | 0.8247 | 0.7595 | 7.3709 | 490 |
| 2003 | 373.003 | 27.800 | 400.803 | 1.0745 | 0.8799 | 0.8140 | 7.6242 | 500 |
| 2004 | 362.370 | 42.440 | 404.810 | 1.1171 | 0.8767 | 0.8432 | 8.0648 | 500 |
| 2005 | 322.617 | 17.100 | 339.717 | 1.0530 | 0.9852 | 0.8932 | 9.3641 | 500 |
| 2006 | 226.413 | 20.980 | 247.393 | 1.0927 | 0.8429 | 0.7929 | 7.8433 | 500 |
| 2007 | 186.607 | 100.727 | 287.334 | 1.5398 | 1.0503 | 1.3924 | 9.9183 | 585 |
| 2008 | 208.930 | 22.187 | 231.117 | 1.1062 | 0.9672 | 0.9211 | 9.1917 | 500 |
| 2009 | 218.732 | 28.233 | 246.965 | 1.1291 | 0.9630 | 0.9361 | 9.0355 | 400 |
| 2010 | 238.512 | 81.596 | 320.108 | 1.3421 | 0.9863 | 1.1397 | 9.8647 | 300 |
| 2011 | 223.762 | 18.550 | 242.312 | 1.0829 | 0.8673 | 0.8086 | 9.0998 | 300 |
| 2012 | 211.337 | 23.539 | 234.876 | 1.1114 | 0.9357 | 0.8953 | 9.9671 | 300 |

### *23.4.8.1 40% Target Including Discards*

Table 23.20. RBC calculations for Offshore Ocean Perch. Ctarg and CPUEtarg relate to the period 1986-1995, CPUELim is 40% of the target, 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 (19).

| | |
|---|---|
| Ref_Year | 1986-1995 |
| CE_Targ | 0.9419 |
| CE_Lim | 0.4521 |
| CE_Recent | 0.9449 |
| Wt_Discard | 30.262 |
| Scaling | 1.0062 |
| Last Year's TAC | 300 |
| $C_{targ}$ | 283.369 |
| **RBC** | **285.139** |

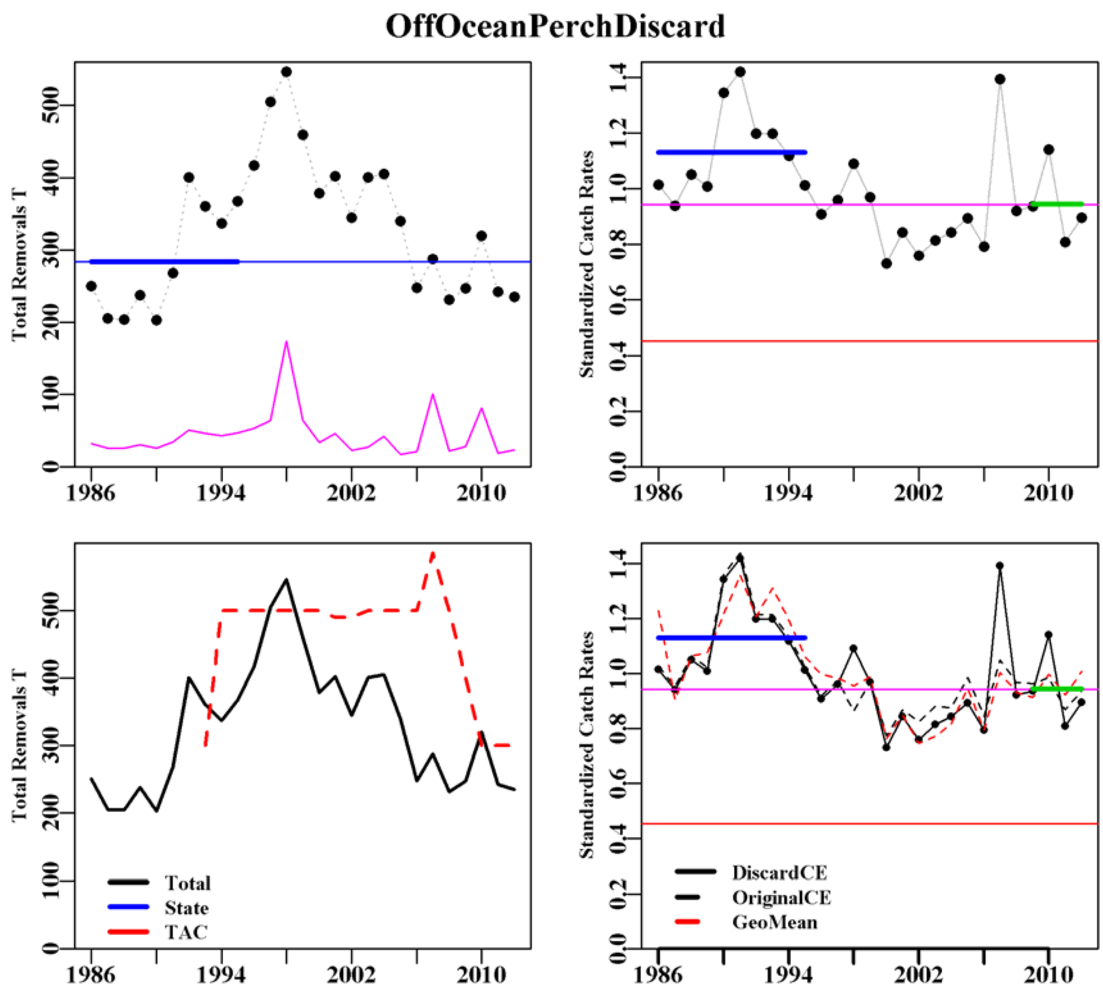


Figure 23.8. OffShore Ocean Perch. Top left is the total removals with the fine line illustrating the target catch. Top right represents the standardized catch rates with the upper fine line representing the target catch rate and the lower line the limit catch rate. Thickened lines represents the reference period for catches, catch rates, and the recent average catch rate.

### 23.4.9 Royal Red Prawn (PRR – 28714005 – Haliporoides sibogae)

Table 23.21. Royal Red Prawn 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 Zone 10 in depths 0 – 400m (Haddon, 2013). 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 | Non-T | PDiscard | CE | GeoMean |
|---|---|---|---|---|---|---|---|---|
| 1986 | 271.200 | 12.234 | 283.434 | | | 4.3164 | 0.6918 | 27.7627 |
| 1987 | 177.600 | 8.012 | 185.612 | | | 4.3164 | 0.8829 | 41.9857 |
| 1988 | 273.600 | 12.342 | 285.942 | | | 4.3164 | 0.9778 | 49.1496 |
| 1989 | 224.400 | 10.123 | 234.523 | | | 4.3164 | 0.8333 | 45.8268 |
| 1990 | 315.600 | 14.237 | 329.837 | | | 4.3164 | 1.5634 | 95.1525 |
| 1991 | 441.600 | 19.921 | 461.521 | | | 4.3164 | 1.3943 | 79.4866 |
| 1992 | 639.600 | 28.853 | 668.453 | | | 4.3164 | 1.0408 | 70.3817 |
| 1993 | 549.600 | 24.793 | 574.393 | | | 4.3164 | 1.1942 | 68.5216 |
| 1994 | 482.073 | 0.000 | 482.073 | 334.299 | 0 | 0.0000 | 1.1348 | 77.7193 |
| 1995 | 529.336 | 0.000 | 529.336 | 335.820 | 0 | 0.0000 | 0.9016 | 58.4998 |
| 1996 | 424.963 | 0.000 | 424.963 | 157.685 | 0 | 0.0000 | 0.8127 | 60.5827 |
| 1997 | 473.406 | 0.000 | 473.406 | 285.669 | 0 | 0.0000 | 0.7652 | 51.9861 |
| 1998 | 438.916 | 12.000 | 450.916 | 228.345 | 0 | 2.6612 | 0.8236 | 39.1713 |
| 1999 | 581.324 | 2.000 | 583.324 | 205.320 | 0 | 0.3429 | 0.8162 | 49.7799 |
| 2000 | 623.637 | 3.000 | 626.637 | 206.945 | 0 | 0.4787 | 1.0253 | 49.6136 |
| 2001 | 470.039 | 11.000 | 481.039 | 227.810 | 0 | 2.2867 | 0.8726 | 35.9685 |
| 2002 | 674.384 | 15.580 | 689.964 | 240.645 | 0 | 2.2581 | 1.0496 | 47.9208 |
| 2003 | 323.442 | 17.370 | 340.812 | 135.277 | 0 | 5.0966 | 1.0933 | 39.7063 |
| 2004 | 247.193 | 43.460 | 290.653 | 74.965 | 0 | 14.9526 | 1.1214 | 50.4687 |
| 2005 | 212.742 | 40.290 | 253.032 | 46.255 | 0 | 15.9229 | 1.0284 | 47.1225 |
| 2006 | 224.276 | 26.540 | 250.816 | 31.868 | 0 | 10.5815 | 1.2332 | 55.0038 |
| 2007 | 154.746 | 18.312 | 173.058 | 20.207 | 0 | 10.5815 | 0.8421 | 48.8072 |
| 2008 | 112.198 | 13.277 | 125.475 | 24.592 | 0 | 10.5815 | 0.7242 | 39.0864 |
| 2009 | 91.320 | 10.806 | 102.126 | 12.646 | 0 | 10.5815 | 0.9315 | 59.2670 |
| 2010 | 113.736 | 13.459 | 127.196 | 5.409 | 0 | 10.5815 | 0.8879 | 40.3732 |
| 2011 | 132.613 | 1.419 | 134.032 | 5.409 | 0 | 1.0584 | 1.3371 | 82.0762 |
| 2012 | 158.335 | 1.694 | 160.029 | 5.409 | 0 | 1.0584 | 1.0207 | 57.3988 |

Discards make up approximately 4.3 % of the catch over the 1998-2006 period.

Table 23.22. RBC calculations for Royal Red Prawn. Ctarg and CPUEtarg relate to the period 1986-1995, CPUELim is 40% of the target, and $\overline{CPUE}$ is the average catch rate, from all fishing gear, 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 (19).

| | |
|---|---|
| Ref_Year | 1986-1995 |
| CE_Targ | 1.0615 |
| CE_Lim | 0.4246 |
| CE_Recent | 1.0443 |
| Wt_Discard | 3.797 |
| Scaling | 0.973 |
| Last Year's TAC | 303 |
| $C_{targ}$ | 403.512 |
| **RBC** | **392.622** |

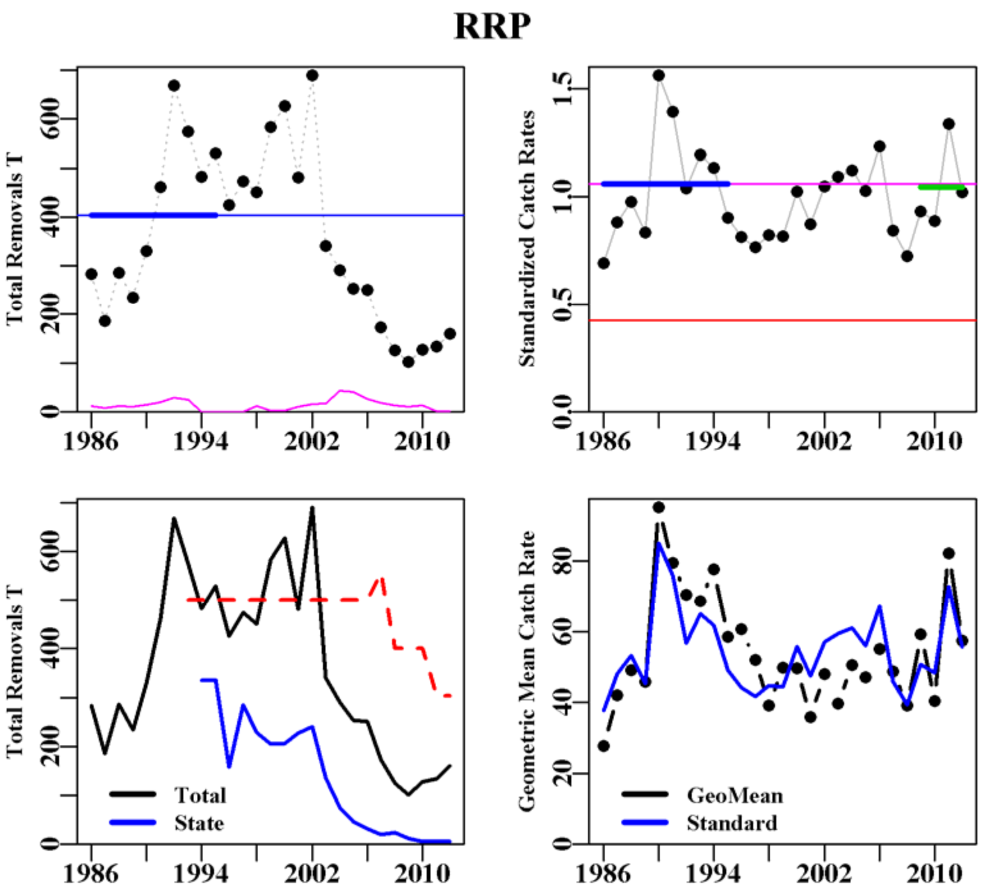


Figure 23.9. Royal Red Prawn. Top left is the total removals with the fine line illustrating the target catch. Top right represents the standardized catch rates with the upper fine line representing the target catch rate and the lower line the limit catch rate. Thickened lines represents the reference period for catches, catch rates, and the recent average catch rate.

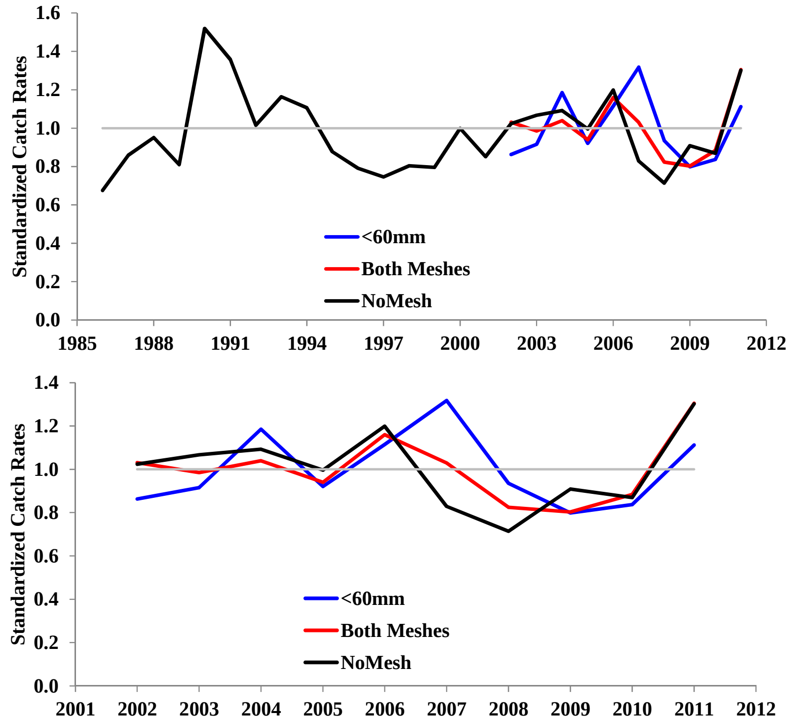


Figure 23.10. a comparison of the standardization based on all data with the standardizations that relate to the data where mesh size information was available for both large and small meshes, and also for a separate analysis where only the small mesh data were standardized.

#### *23.4.9.1 The Effect of the Endeavour Dogfish Closure*

Catches in the final version of the Endeavour Dogfish closure reached between 15 – 21% between 1998 – 2001 but have always been less than that in other years (Table 23.23).

Table 23.23. Catches of Royal Red Prawn in the Endeavour dogfish closure and elsewhere.

| Year | Open | Endeavour | Year | Open | Endeavour |
|---|---|---|---|---|---|
| 1986 | 228.150 | 3.694 | 1999 | 283.239 | 65.565 |
| 1987 | 320.209 | 4.507 | 2000 | 340.739 | 57.735 |
| 1988 | 340.567 | 3.890 | 2001 | 180.289 | 48.410 |
| 1989 | 303.417 | 7.343 | 2002 | 406.385 | 10.985 |
| 1990 | 311.118 | | 2003 | 156.969 | 6.215 |
| 1991 | 299.370 | | 2004 | 167.451 | 3.230 |
| 1992 | 145.291 | 0.790 | 2005 | 159.605 | 0.200 |
| 1993 | 232.774 | | 2006 | 177.629 | 0.950 |
| 1994 | 240.363 | | 2007 | 116.430 | |
| 1995 | 237.595 | 15.310 | 2008 | 70.605 | |
| 1996 | 258.345 | 14.330 | 2009 | 67.587 | 0.020 |
| 1997 | 152.173 | 14.530 | 2010 | 82.221 | 0.600 |
| 1998 | 152.960 | 37.772 | 2011 | 108.960 | |

Catches within what has become the Endeavour dogfish closure have been less than 4 tonnes since 2004. Once all data from this area are removed from the Royal Red Prawn data a standardization demonstrated no appreciable difference from the trend exhibited by using all data.

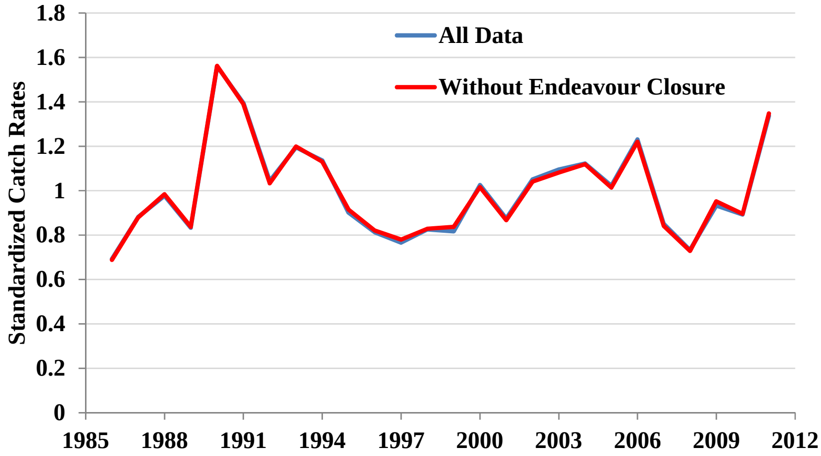

Figure 23.11. The standardization of all Royal Red Prawn

### *23.4.10 Silver Trevally (TRE – 37337062 – Pseudocaranx dentex)*

Table 23.24. Silver Trevally data for the TIER 4 calculations. Total is the sum of Discards, State (not SA or WA), Non Trawl and SEF2 catches. All values in Tonnes. CE is the standardized catch rate for Zones 10 and 20 from depths 0 to 200 m (Haddon, 2013) with records from the Bateman's Bay MPA removed. GeoMean is the geometric mean catch rates. Discards are estimates from the ISMP 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 | Non-T | PDiscard | CE | GeoM |
|---|---|---|---|---|---|---|---|---|
| 1986 | 1166.400 | 5.489 | 1171.889 | | | 0.4684 | 1.1540 | 17.0086 |
| 1987 | 1142.400 | 5.376 | 1147.776 | | | 0.4684 | 1.3641 | 17.5072 |
| 1988 | 1226.400 | 5.771 | 1232.171 | | | 0.4684 | 1.8041 | 23.7642 |
| 1989 | 1394.400 | 6.562 | 1400.962 | | | 0.4684 | 1.9185 | 23.0657 |
| 1990 | 1587.600 | 7.471 | 1595.071 | | | 0.4684 | 2.2806 | 23.2975 |
| 1991 | 990.000 | 4.659 | 994.659 | | | 0.4684 | 2.0451 | 18.1137 |
| 1992 | 949.200 | 4.467 | 953.667 | | | 0.4684 | 1.1704 | 12.0774 |
| 1993 | 1030.800 | 4.851 | 1035.651 | | | 0.4684 | 1.2771 | 13.4863 |
| 1994 | 835.815 | 3.933 | 839.748 | 704.273 | 0.000 | 0.4684 | 0.9802 | 9.4912 |
| 1995 | 995.628 | 4.685 | 1000.313 | 799.656 | 0.000 | 0.4684 | 1.1131 | 10.2789 |
| 1996 | 1018.880 | 4.795 | 1023.674 | 810.543 | 0.000 | 0.4684 | 0.9028 | 7.5806 |
| 1997 | 785.220 | 3.695 | 788.915 | 626.604 | 0.526 | 0.4684 | 0.8527 | 6.2012 |
| 1998 | 628.496 | 0.000 | 628.496 | 536.569 | 12.215 | 0.0000 | 0.6199 | 5.2414 |
| 1999 | 488.585 | 2.000 | 490.585 | 412.778 | 7.275 | 0.4077 | 0.6205 | 4.9696 |
| 2000 | 493.293 | 0.000 | 493.293 | 405.277 | 2.707 | 0.0000 | 0.4567 | 3.6777 |
| 2001 | 649.441 | 9.000 | 658.441 | 490.553 | 2.170 | 1.3669 | 0.5340 | 4.1345 |
| 2002 | 517.873 | 1.100 | 518.973 | 361.505 | 2.444 | 0.2120 | 0.4323 | 3.0864 |
| 2003 | 524.148 | 1.510 | 525.658 | 402.604 | 2.435 | 0.2873 | 0.4233 | 3.3755 |
| 2004 | 654.880 | 7.400 | 662.280 | 519.086 | 1.977 | 1.1174 | 0.5859 | 4.5401 |
| 2005 | 502.335 | 0.100 | 502.435 | 416.717 | 0.607 | 0.0199 | 0.5181 | 4.7971 |
| 2006 | 413.782 | 1.820 | 415.602 | 358.778 | 2.046 | 0.4379 | 0.7261 | 5.7178 |
| 2007 | 355.694 | 3.065 | 358.760 | 303.373 | 2.070 | 0.8544 | 0.8055 | 7.4274 |
| 2008 | 279.914 | 2.460 | 282.374 | 185.746 | 0.319 | 0.8711 | 0.8328 | 8.0833 |
| 2009 | 310.694 | 0.000 | 310.694 | 167.808 | 0.740 | 0.0000 | 0.8479 | 9.2632 |
| 2010 | 376.736 | 0.165 | 376.902 | 176.787 | 0.302 | 0.0438 | 1.0767 | 11.7000 |
| 2011 | 387.650 | 14.290 | 401.940 | 190.537 | 0.104 | 3.5553 | 0.9727 | 11.0895 |
| 2012 | 261.387 | 1.055 | 262.442 | 152.240 | 0.113 | 0.4020 | 0.6850 | 7.6670 |

Discards make up approximately 0.16% of the catch over the 1998-2006 period.

Silver Trevally exhibited a period of high catch rates during 1989-1991 which were the result of a set of highly efficient vessels entering the fishery. These catch rates were considered not to represent a sustainable fishery and are not expected to be repeated. Therefore 1992-2001 was selected by the RAG as being a more representative reference period. In addition, the coastal waters within the Bateman's Bay MPA were removed from consideration during the catch rate standardization; the catches were deemed possible as fish could move from the MPA, but catch rates are not expected to be so high outside the MPA.

Table 23.25. RBC calculations for Silver Trevally. Ctarg and CPUEtarg relate to the period 1992-2001, CPUELim is 40% of the target, 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 (19).

| | |
|---|---|
| Ref_Year | 1992-2001 |
| CE_Targ | 0.8527 |
| CE_Lim | 0.3411 |
| CE_Recent | 0.8956 |
| Wt_Discard (t) | 4.395 |
| Scaling | 1.0837 |
| Last Year's TAC | 540 |
| $C_{targ}$ | 791.278 |
| **RBC** | **857.524** |

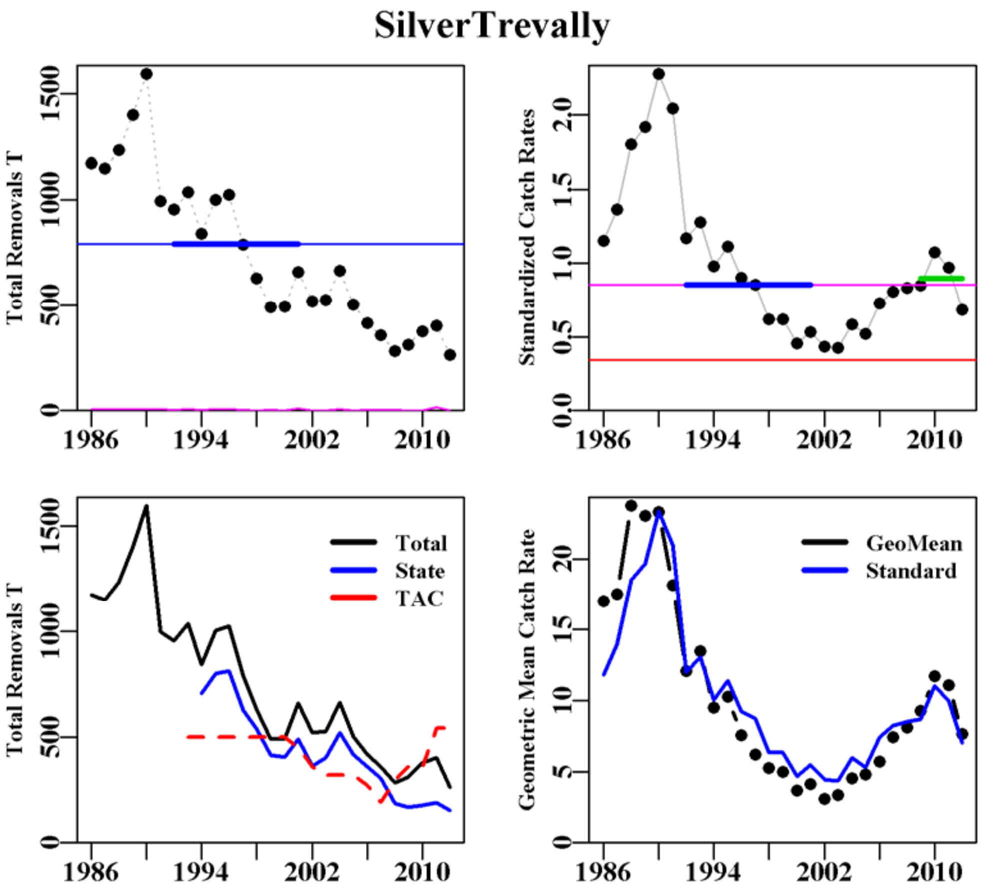


Figure 23.12. Silver Trevally. Top left is the total removals with the fine line illustrating the target catch. Top right represents the standardized catch rates (with records within the Bateman's Bay MPA removed; Haddon, 2013) with the upper fine line representing the target catch rate and the lower line the limit catch rate. Thickened lines represents the reference period for catches, catch rates, and the recent average catch rate.

### *23.4.11 Silver TrevallyMPA (TRE – 37337062 – P. dentex)*

An alternative analysis was requested that used all data to estimate the standardized CPUE series rather than just the data from outside the Bateman's Bay MPA. This differs from the analysis without the MPA in terms of the optimum standardized catch rates. Because the target and recent catch rate series are similar between the two analyses the outcomes are very similar.

Conducting the analysis such that only records from outside the MPA are used for the catches and the CPUE is not a simple exercise because a large proportion of catches were taken from State waters and their precise location is unknown.

Table 23.26. Silver Trevally data for the TIER 4 calculations. Total is the sum of Discards, State (not SA or WA), Non Trawl and SEF2 catches. All values in Tonnes. CE is the standardized catch rate for Zones 10 and 20 from depths 0 to 200 m (Haddon, 2013) with records from the Bateman's Bay MPA removed. GeoMean is the geometric mean catch rates. Discards are estimates from the ISMP 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 | Non-T | PDiscard | CE | GeoM |
|---|---|---|---|---|---|---|---|---|
| 1986 | 1166.400 | 1.838 | 1168.238 | | | 0.157 | 1.0402 | 17.0086 |
| 1987 | 1142.400 | 1.800 | 1144.200 | | | 0.157 | 1.2330 | 17.5072 |
| 1988 | 1226.400 | 1.933 | 1228.333 | | | 0.157 | 1.4170 | 23.7642 |
| 1989 | 1394.400 | 2.198 | 1396.598 | | | 0.157 | 1.7729 | 23.0657 |
| 1990 | 1587.600 | 2.502 | 1590.102 | | | 0.157 | 2.0276 | 23.2975 |
| 1991 | 990.000 | 1.560 | 991.560 | | | 0.157 | 1.8146 | 18.1137 |
| 1992 | 949.200 | 1.496 | 950.696 | | | 0.157 | 1.0322 | 12.0774 |
| 1993 | 1030.800 | 1.625 | 1032.425 | | | 0.157 | 1.1101 | 13.4863 |
| 1994 | 835.815 | 1.317 | 839.748 | 704.273 | 0.000 | 0.157 | 0.9447 | 9.4912 |
| 1995 | 995.628 | 1.569 | 1000.313 | 799.656 | 0.000 | 0.157 | 1.0790 | 10.2789 |
| 1996 | 1018.880 | 1.606 | 1023.674 | 810.543 | 0.000 | 0.157 | 0.9774 | 7.5806 |
| 1997 | 785.220 | 1.237 | 788.915 | 626.604 | 0.526 | 0.157 | 0.9615 | 6.2012 |
| 1998 | 628.496 | 0.000 | 628.496 | 536.569 | 12.215 | 0.000 | 0.7327 | 5.2414 |
| 1999 | 488.585 | 2.000 | 490.585 | 412.778 | 7.275 | 0.408 | 0.7143 | 4.9696 |
| 2000 | 493.293 | 0.000 | 493.293 | 405.277 | 2.707 | 0.000 | 0.5512 | 3.6777 |
| 2001 | 649.441 | 9.000 | 658.441 | 490.553 | 2.170 | 1.367 | 0.6656 | 4.1345 |
| 2002 | 517.873 | 1.100 | 518.973 | 361.505 | 2.444 | 0.212 | 0.6240 | 3.0864 |
| 2003 | 524.148 | 1.510 | 525.658 | 402.604 | 2.435 | 0.287 | 0.6650 | 3.3755 |
| 2004 | 654.880 | 7.400 | 662.280 | 519.086 | 1.977 | 1.117 | 0.8146 | 4.5401 |
| 2005 | 502.335 | 0.100 | 502.435 | 416.717 | 0.607 | 0.020 | 0.7116 | 4.7971 |
| 2006 | 413.782 | 1.820 | 415.602 | 358.778 | 2.046 | 0.438 | 0.7714 | 5.7178 |
| 2007 | 355.694 | 3.065 | 358.760 | 303.373 | 2.070 | 0.854 | 0.7619 | 7.4274 |
| 2008 | 279.914 | 2.460 | 282.374 | 185.746 | 0.319 | 0.871 | 0.8675 | 8.0833 |
| 2009 | 310.694 | 0.000 | 310.694 | 167.808 | 0.740 | 0.000 | 0.8627 | 9.2632 |
| 2010 | 376.736 | 0.165 | 376.902 | 176.787 | 0.302 | 0.044 | 1.1179 | 11.7000 |
| 2011 | 387.650 | 14.290 | 401.940 | 190.537 | 0.104 | 3.555 | 0.9676 | 11.0895 |
| 2012 | 261.387 | 1.055 | 262.442 | 152.240 | 0.113 | 0.402 | 0.7617 | 7.6670 |

Discards make up approximately 0.16% of the catch over the 1998-2006 period.

Table 23.27. RBC calculations for Silver Trevally. Ctarg and CPUEtarg relate to the period 1992-2001, CPUELim is 40% of the target, 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 (19).

| | |
|---|---|
| Ref_Year | 1992-2001 |
| CE_Targ | 0.8769 |
| CE_Lim | 0.3507 |
| CE_Recent | 0.9275 |
| Wt_Discard (t) | 4.395 |
| Scaling | 1.0962 |
| Last Year's TAC | 540 |
| $C_{targ}$ | 790.659 |
| **RBC** | **866.708** |

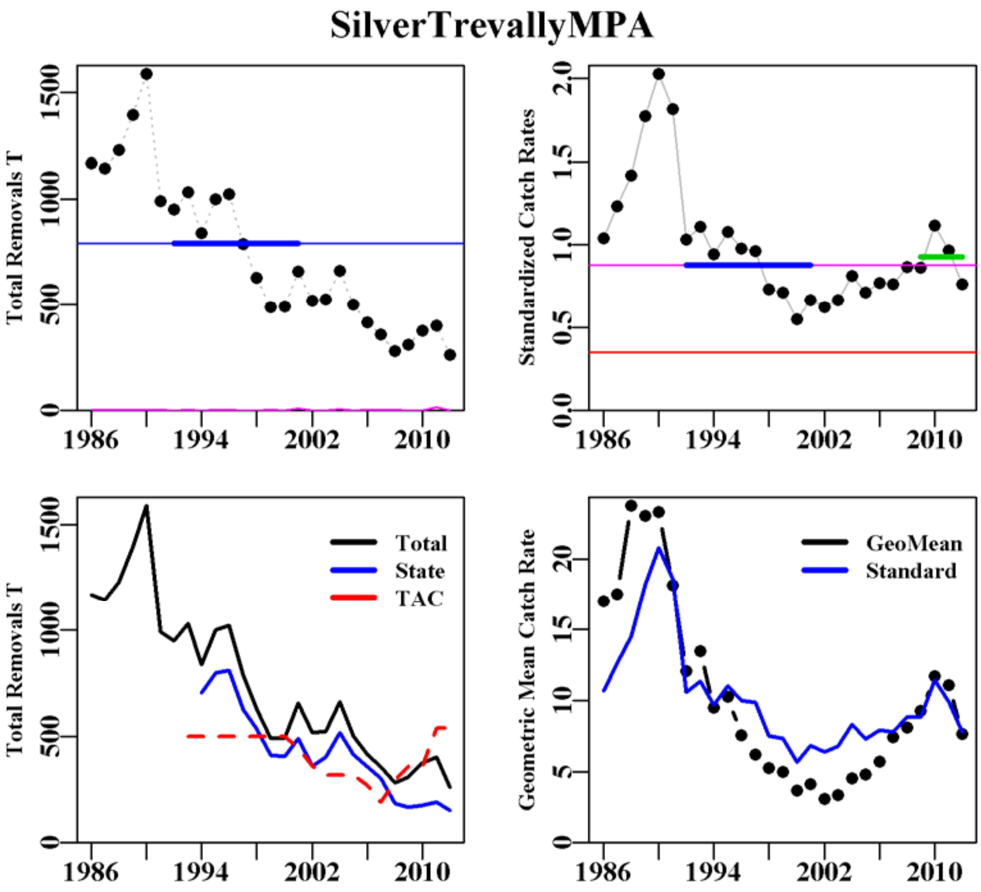


Figure 23.13. Silver TrevallyMPS. Top left is the total removals with the fine line illustrating the target catch. Top right represents the standardized catch rates (with records within the Bateman's Bay MPA included; Haddon, 2013) with the upper fine line representing the target catch rate and the lower line the limit catch rate. Thickened lines represents the reference period for catches, catch rates, and the recent average catch rate.

The two catch rate time series are very similar from about 2006 onwards but prior to then, before there was discussion of an MPA the data from outside the closure is more variable than that which used all data. This reflects the focus of the main fishery in the area that is now enclosed by the MPA (Figure 23.14).

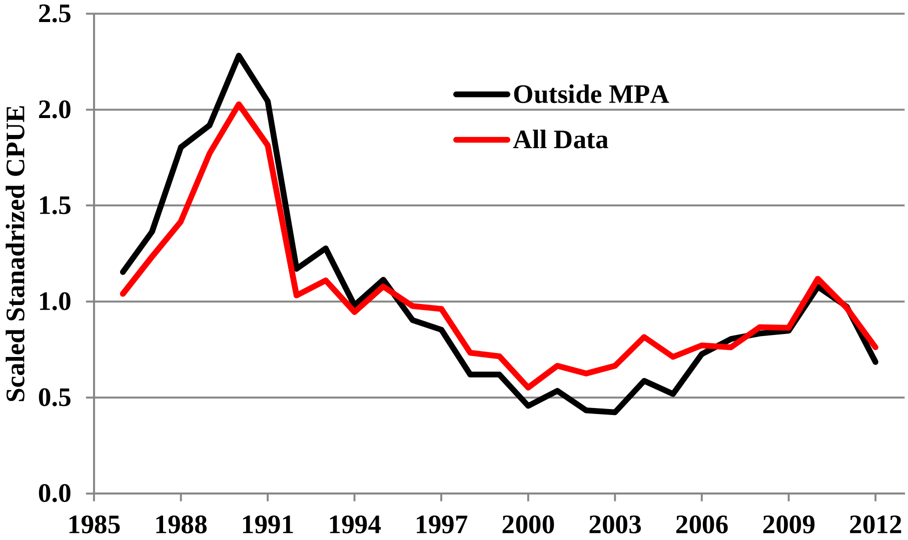


Figure 23.14. A comparison of the different catch rate time series for Silver Trevally with one series including all available data and the other only using records from outside the Batemans Bay MPA.

### *23.4.12 Ribaldo (RBD – 37224002 – Mora moro)*

Table 23.28. Ribaldo 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 50 in depths 0 – 1000m (Haddon, 2013). 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 | Non-T | PDiscard | CE | GeoMean |
|---|---|---|---|---|---|---|---|---|
| 1986 | 4.800 | 0.723 | 5.523 | | | 13.0907 | 2.2751 | 14.6630 |
| 1987 | 8.400 | 1.265 | 9.665 | | | 13.0885 | 1.2766 | 10.2593 |
| 1988 | 8.400 | 1.265 | 9.665 | | | 13.0885 | 1.9946 | 16.5570 |
| 1989 | 8.400 | 1.265 | 9.665 | | | 13.0885 | 1.8008 | 18.2556 |
| 1990 | 2.400 | 0.362 | 2.762 | | | 13.1064 | 1.4191 | 8.9113 |
| 1991 | 7.200 | 1.085 | 8.285 | | | 13.0960 | 1.3807 | 7.9930 |
| 1992 | 15.600 | 2.350 | 17.950 | | | 13.0919 | 1.3643 | 9.7616 |
| 1993 | 36.000 | 5.423 | 41.423 | | | 13.0918 | 1.1334 | 11.2449 |
| 1994 | 28.021 | 0.063 | 28.021 | 0.418 | 0.000 | 0.2248 | 1.2752 | 11.8156 |
| 1995 | 95.719 | 0.814 | 95.719 | 5.401 | 0.000 | 0.8504 | 1.3346 | 12.3128 |
| 1996 | 85.154 | 0.529 | 85.154 | 3.510 | 0.000 | 0.6212 | 1.0110 | 10.1757 |
| 1997 | 103.704 | 0.907 | 103.704 | 4.057 | 1.962 | 0.8746 | 0.8805 | 9.8023 |
| 1998 | 95.427 | 23.766 | 119.193 | 0.102 | 2.431 | 19.9391 | 0.8523 | 9.6696 |
| 1999 | 64.076 | 6.555 | 70.631 | 0.031 | 3.335 | 9.2806 | 0.7859 | 8.7093 |
| 2000 | 63.117 | 8.284 | 71.401 | 0.022 | 8.736 | 11.6021 | 0.7236 | 7.4217 |
| 2001 | 75.565 | 4.468 | 80.033 | 0.303 | 21.161 | 5.5827 | 0.6772 | 6.7639 |
| 2002 | 171.727 | 7.305 | 179.033 | 0.000 | 95.820 | 4.0803 | 0.6324 | 6.7944 |
| 2003 | 205.908 | 26.457 | 232.365 | 0.037 | 103.460 | 11.3860 | 0.6250 | 6.7153 |
| 2004 | 199.188 | 16.087 | 215.275 | 0.061 | 102.509 | 7.4728 | 0.6759 | 7.2233 |
| 2005 | 105.471 | 21.800 | 127.271 | 0.118 | 52.297 | 17.1288 | 0.5916 | 6.3488 |
| 2006 | 116.822 | 3.100 | 119.921 | 0.000 | 73.324 | 2.5848 | 0.6254 | 6.3304 |
| 2007 | 61.126 | 0.451 | 61.577 | 0.000 | 36.371 | 0.7330 | 0.4183 | 3.2493 |
| 2008 | 97.215 | 2.629 | 99.843 | 0.000 | 70.985 | 2.6328 | 0.5781 | 4.7326 |
| 2009 | 134.086 | 3.626 | 137.712 | 0.000 | 86.624 | 2.6328 | 0.6424 | 5.6978 |
| 2010 | 111.395 | 1.955 | 113.350 | 0.000 | 65.348 | 1.7244 | 0.6603 | 5.5851 |
| 2011 | 116.704 | 7.076 | 123.780 | 0.030 | 56.922 | 5.7165 | 0.6703 | 5.8331 |
| 2012 | 107.028 | 3.445 | 110.473 | 0.003 | 62.545 | 3.1182 | 0.6954 | 6.1631 |

Discards make up approximately 13.1 % of the catch over the 1998-2006 period.

There was no significant effect on the catch rate standardization of whether a shot was within or outside of one of the current closures (Haddon, 2011). As the standardized catch rate trend was indistinguishable from the series without the spatial factor it was not included.

*23.4.12.1 40% Target*

Table 23.29. RBC calculations for Ribaldo. Ctarg and CPUEtarg relate to the period 1995-2004, CPUELim is 40% of the target, 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 (19).

| | |
|---|---|
| Ref_Year | 1995-2004 |
| CE_Targ | 0.3416 |
| CE_Lim | 0.164 |
| CE_Recent | 0.6671 |
| Wt_Discard | 4.226 |
| Scaling | 2.8325 |
| Last Year's TAC | |
| $C_{targ}$ | 125.251 |
| **RBC** | **354.768** |

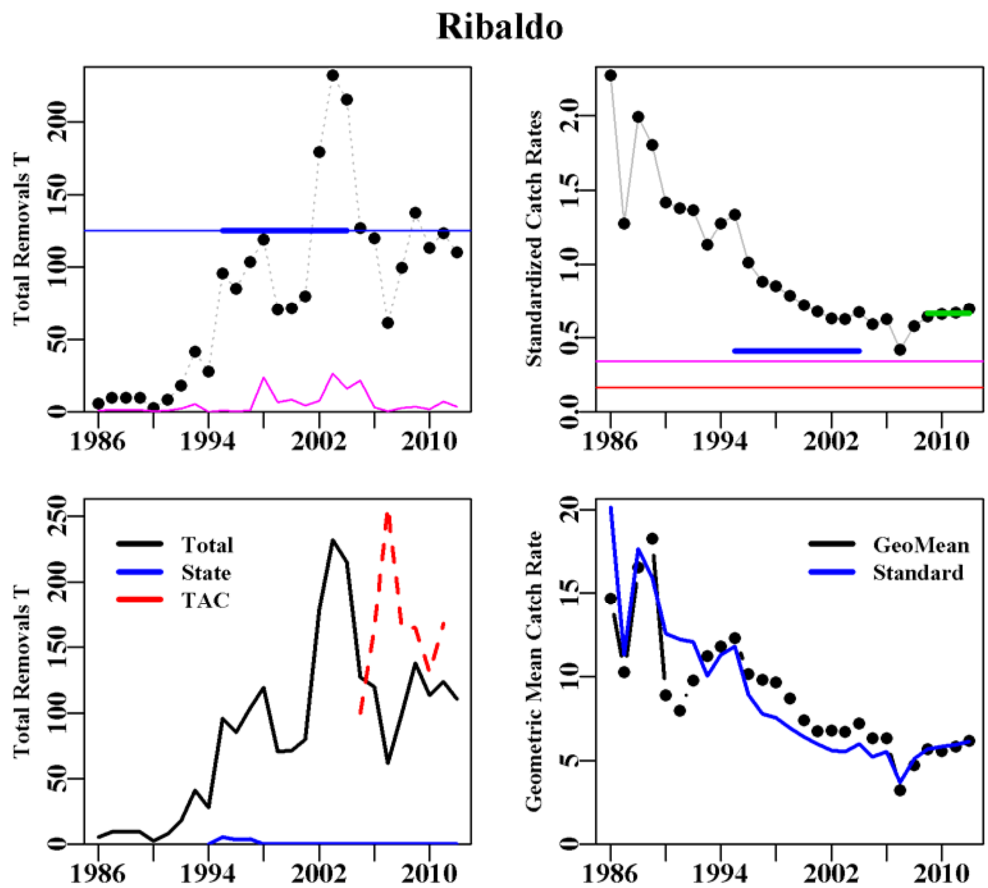


Figure 23.15. Ribaldo. Top left is the total removals with the fine line illustrating the target catch. Top right represents the standardized catch rates with the upper fine line representing the target catch rate and the lower line the limit catch rate. Thickened lines represents the reference period for catches, catch rates, and the recent average catch rate. The purple line is below the original target because the target has been ,moved to a proxy of 40%.

## 23.5 Deep-Water Tier 4 Results

### 23.5.1 Oreos General

Table 23.30. The catch of all species of Oreos in tonnes reported in each fishery. GAB is the Great Australian Bight, SET is the South East Fishery, and HST is High Seas Trawl STR is South Tasman Rise fishery and the WDW is the Western Deep Water Trawl fishery.

| Year | GAB | GHT | HSN | HST | SEN | SET | SPF | SSF | STR | VIT | WDW |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1986 | | | | | | 56.636 | | | | | |
| 1987 | 0.581 | | | | | 89.630 | | | | | |
| 1988 | 67.935 | | | | | 89.242 | | | | | |
| 1989 | 215.481 | | | | | 533.720 | | | | | |
| 1990 | 10.178 | | | | | 1090.260 | | | | | |
| 1991 | 6.982 | | | | | 1129.201 | | | | | |
| 1992 | 94.219 | | | | | 3201.806 | | | | | 58.000 |
| 1993 | 2.800 | | | | | 1036.616 | | | | | 58.030 |
| 1994 | 48.184 | | | | | 1043.359 | | | | | 20.795 |
| 1995 | 0.730 | | | | | 1025.771 | | | | | 1.186 |
| 1996 | 5.264 | | | | | 771.783 | | | | | 8.268 |
| 1997 | 39.757 | | | | | 2050.730 | | | | | 0.635 |
| 1998 | 20.916 | | | | 0.009 | 2021.332 | | | | | |
| 1999 | 20.437 | | | 2.896 | 0.019 | 882.455 | | | | | |
| 2000 | 49.187 | | | | 0.001 | 1010.255 | | 0.100 | | | 0.111 |
| 2001 | 12.647 | | | | 0.007 | 1097.623 | | | 25.450 | | 4.314 |
| 2002 | 0.580 | | 0.007 | 24.389 | 0.137 | 829.622 | | | 2.500 | | |
| 2003 | 5.678 | 0.527 | | 129.630 | | 750.909 | | | | 0.070 | |
| 2004 | 8.782 | 0.702 | | 168.647 | | 432.483 | | | 32.683 | | 0.633 |
| 2005 | 24.215 | 0.807 | | 92.576 | | 233.887 | | | 151.600 | | |
| 2006 | 16.621 | 1.168 | | 0.246 | | 173.732 | 0.034 | | 22.520 | | |
| 2007 | 3.447 | 0.823 | | 1.224 | | 129.664 | | | | | |
| 2008 | 0.275 | 0.685 | | | | 77.386 | | | | | 0.020 |
| 2009 | 1.796 | 1.958 | | 101.491 | | 85.975 | | | | | |
| 2010 | 1.180 | 1.047 | | | | 89.314 | | | | | |
| 2011 | 0.080 | 0.400 | | | | 101.980 | | | | | |
| 2012 | | 0.303 | | | | 82.057 | | | | | |

Table 23.31. The catch of each recognized species of Oreos in tonnes reported in the GenLog (SEF1) database. Smooth and Spiky Oreos are the most commonly reported.

| | Oreo | Spiky | Oxeye | Smooth | Warty | Black | Oreo Dory |
|---|---|---|---|---|---|---|---|
| Year | 37266000 | 37266001 | 37266002 | 37266003 | 37266004 | 37266005 | 37266902 |
| 1986 | | 20.565 | 3.608 | | 32.463 | | |
| 1987 | | 45.771 | 18.706 | 6.534 | 19.200 | | |
| 1988 | 13.451 | 46.386 | 10.830 | 62.969 | 23.541 | | |
| 1989 | 0.970 | 372.495 | 33.817 | 324.499 | 17.420 | | |
| 1990 | 0.430 | 274.056 | 4.080 | 819.615 | 2.257 | | |
| 1991 | | 117.596 | 2.722 | 1015.337 | 0.528 | | |
| 1992 | | 743.462 | 12.285 | 2597.228 | 1.050 | | |
| 1993 | 0.580 | 409.953 | 4.110 | 679.732 | 3.071 | | |
| 1994 | | 351.801 | 3.103 | 738.534 | 18.900 | | |
| 1995 | | 486.155 | 17.195 | 509.587 | 14.750 | | |
| 1996 | | 431.104 | 0.900 | 337.355 | 15.956 | | |
| 1997 | | 1080.351 | 4.927 | 984.844 | 21.000 | | |
| 1998 | | 1297.604 | 0.940 | 718.907 | 24.806 | | |
| 1999 | 0.400 | 554.449 | 0.080 | 339.483 | 11.275 | 0.120 | |
| 2000 | | 474.784 | 0.030 | 553.853 | 30.987 | | |
| 2001 | | 525.634 | 0.400 | 607.917 | 6.090 | | |
| 2002 | | 305.405 | 0.095 | 534.331 | 1.595 | 15.809 | |
| 2003 | | 457.110 | | 367.077 | 0.800 | 61.827 | |
| 2004 | | 366.919 | 0.120 | 263.296 | 1.570 | 12.025 | |
| 2005 | | 183.308 | 3.549 | 296.377 | | 12.278 | 7.573 |
| 2006 | | 67.263 | 10.490 | 87.811 | | 0.261 | 48.496 |
| 2007 | | 21.435 | 11.983 | 44.908 | | | 56.832 |
| 2008 | | 8.558 | 1.182 | 13.745 | | 0.007 | 54.874 |
| 2009 | | 110.205 | 2.145 | 3.632 | | | 75.238 |
| 2010 | | 10.727 | 1.282 | 5.326 | | | 74.206 |
| 2011 | | 11.237 | 7.951 | 5.920 | | | 77.348 |
| 2012 | | 8.534 | 13.821 | 1.919 | | | 58.085 |
| Total | 15.831 | 8782.866 | 170.351 | 11920.737 | 247.259 | 102.327 | 452.653 |

### *23.5.2 Smooth Oreo (Cascade) (DOO – 37266003 – Smooth Oreo Pseudocyttus maculatus and DOE 37266902 – Oreo Dory)*

After examination of the depth distribution of records, only data from OR Zone 40 in depths 650 – 1250m were used. All vessels recording smooth oreos in orange roughy zone 40 were included in the analysis. The discard rate estimated in 2007 was 12.3 %. Catch rates as Kg/Tow.

Table 23.32. Number of records where Smooth Oreos or Oreos (CAAB codes 37266003, and 37266902 = Smooth Oreo, and Oreo Dory) on the Cascade are reported by trawling in OR Zone 40, in depths 650 to 1250 m. Used are the number of records excluding those reported as being in the 700 m closure. Vessels represent the count of vessels reporting oreos. Effort H and CatchT are the reported effort and catch of Smooth Oreos from the used records. The geometric mean CE is the raw unstandardized catch rate in Kg/tow. Catches and numbers of records for Smooth Oreo (37266003) and for the recent new category Oreo Dory (37266902).

| Year | Records | Vessels | EffortH | CatchT | GeoMean | 37266003 | Records | 37266902 | Records |
|---|---|---|---|---|---|---|---|---|---|
| 1989 | 211 | 5 | 120.8 | 127.768 | 267.387 | 127.768 | 211 | | |
| 1990 | 296 | 7 | 126.3 | 91.494 | 146.934 | 91.494 | 296 | | |
| 1991 | 7 | 1 | 2.7 | 1.060 | 86.926 | 1.060 | 7 | | |
| 1992 | 13 | 4 | 7.6 | 11.320 | 426.816 | 11.320 | 13 | | |
| 1993 | 19 | 1 | 8.0 | 2.098 | 50.017 | 2.098 | 19 | | |
| 1994 | 241 | 4 | 140.0 | 94.474 | 142.348 | 94.474 | 241 | | |
| 1995 | 94 | 6 | 88.4 | 14.288 | 49.713 | 14.288 | 94 | | |
| 1996 | 457 | 8 | 311.2 | 142.244 | 64.177 | 142.244 | 457 | | |
| 1997 | 305 | 7 | 185.9 | 281.722 | 99.386 | 281.722 | 305 | | |
| 1998 | 166 | 8 | 126.7 | 103.366 | 128.204 | 103.366 | 166 | | |
| 1999 | 94 | 9 | 52.8 | 98.568 | 191.733 | 98.568 | 94 | | |
| 2000 | 358 | 10 | 240.1 | 295.843 | 195.144 | 295.843 | 358 | | |
| 2001 | 216 | 9 | 109.4 | 276.287 | 234.844 | 276.287 | 216 | | |
| 2002 | 354 | 9 | 118.4 | 284.595 | 110.842 | 284.595 | 354 | | |
| 2003 | 161 | 7 | 63.8 | 104.069 | 139.562 | 104.069 | 161 | | |
| 2004 | 116 | 5 | 27.7 | 100.785 | 375.609 | 100.785 | 116 | | |
| 2005 | 88 | 5 | 35.2 | 60.033 | 149.794 | 60.033 | 88 | | |
| 2006 | 46 | 3 | 10.9 | 61.300 | 288.216 | 60.910 | 38 | 0.390 | 8 |
| 2007 | 53 | 2 | 28.5 | 45.408 | 168.150 | 43.698 | 37 | 1.710 | 16 |
| 2008 | 85 | 3 | 50.7 | 16.245 | 44.721 | 12.365 | 14 | 3.880 | 71 |
| 2009 | 35 | 2 | 18.9 | 2.485 | 41.907 | 0.060 | 3 | 2.425 | 32 |
| 2010 | 29 | 2 | 27.1 | 7.315 | 144.194 | 3.200 | 5 | 4.115 | 24 |
| 2011 | 10 | 2 | 8.0 | 1.320 | 73.602 | | | 1.320 | 10 |
| 2012 | 23 | 1 | 21.2 | 4.120 | 119.124 | 0.030 | 1 | 4.090 | 22 |

#### *23.5.2.1 Catch Rates and TIER 4 Smooth Oreo (Cascade)*

Catches of smooth oreos are now so low on the Cascade Plateau that neither catch rate nor Tier 4 analyses are likely to have validity. There are only 35 or fewer data points in each year from 2009 onwards, and these are not necessarily in the same months across years.

Because the catches were so small it would not have been valid to update the TIER 4 analysis, which is in-line with a RAG decision to only update the Tier 4 assessment if there were more than 10 t of catch taken. The reasons for a lack of fishing are reported as being related solely to the economics of fishing for relatively small amounts of oreo quota in such deep water fisheries.

### *23.5.3 Smooth Oreo (non-Cascade) (DOO – 37266003 – Pseudocyttus maculates)*

After examination of the depth distribution of records, only data from OR Zones 10, 20, 21, 30, and 50, taken by trawl in the SET fishery in depths 400 – 1200m were used. All vessels recording smooth oreos were included in the analysis. The Cascade, GAB and zone 70 Smooth Oreos were excluded. The discard rate estimated in 2007 was 12.3 % and this was assumed for other years. The ratio of catches inside relative to outside the current closures is 84.9% versus 15.7 % out of a total of 7236 t considered in the analysis.

Table 23.33. Number of records where Smooth Oreos not on the Cascade are reported from trawling in OR Zones 10, 20, 21, 30, 50, in depths 400 to 1200 m. Vessels represents the count of vessels reporting smooth oreos. CatchT is the reported catch of Smooth Oreos. The geometric mean CE is the raw unstandardized catch rate in Kg/tow. The left hand five columns represent data, in both the closed and currently open areas the right hand five columns (post-fixed O) represent the areas left open following the 700m closure.

| Year | Records | Vessels | Effort | Yield | Geom | RecordsO | VesselsO | EffortO | YieldO | GeomO |
|---|---|---|---|---|---|---|---|---|---|---|
| 1987 | 33 | 3 | 74 | 6.250 | 118.343 | 27 | 2 | 62 | 4.660 | 112.932 |
| 1988 | 41 | 9 | 72 | 39.363 | 232.252 | 15 | 6 | 21 | 5.218 | 144.408 |
| 1989 | 247 | 22 | 152 | 177.234 | 209.771 | 25 | 8 | 33 | 8.855 | 136.437 |
| 1990 | 648 | 38 | 479 | 715.045 | 302.562 | 54 | 12 | 36 | 62.269 | 382.833 |
| 1991 | 667 | 34 | 689 | 904.830 | 242.766 | 134 | 20 | 236 | 119.733 | 129.486 |
| 1992 | 1327 | 30 | 1063 | 2216.456 | 396.338 | 231 | 21 | 289 | 384.811 | 206.685 |
| 1993 | 999 | 31 | 691 | 605.649 | 136.366 | 95 | 19 | 140 | 68.926 | 97.532 |
| 1994 | 1068 | 26 | 744 | 574.904 | 93.488 | 109 | 18 | 172 | 43.981 | 91.736 |
| 1995 | 667 | 21 | 1175 | 493.353 | 114.545 | 76 | 11 | 261 | 34.425 | 105.413 |
| 1996 | 498 | 18 | 810 | 171.377 | 72.869 | 77 | 15 | 178 | 13.503 | 54.227 |
| 1997 | 407 | 20 | 775 | 153.412 | 108.713 | 77 | 16 | 224 | 21.482 | 107.409 |
| 1998 | 342 | 19 | 901 | 134.877 | 114.236 | 59 | 16 | 200 | 28.092 | 116.670 |
| 1999 | 278 | 21 | 1044 | 61.895 | 101.167 | 51 | 13 | 253 | 5.444 | 60.900 |
| 2000 | 314 | 23 | 1133 | 91.490 | 94.029 | 80 | 16 | 375 | 19.153 | 71.681 |
| 2001 | 520 | 23 | 2017 | 282.152 | 175.312 | 194 | 22 | 844 | 86.807 | 159.792 |
| 2002 | 516 | 22 | 2539 | 222.806 | 132.965 | 163 | 19 | 876 | 56.186 | 109.442 |
| 2003 | 444 | 17 | 2009 | 166.908 | 114.728 | 141 | 14 | 788 | 40.513 | 90.968 |
| 2004 | 404 | 18 | 1988 | 110.666 | 95.065 | 126 | 16 | 656 | 32.213 | 101.907 |
| 2005 | 191 | 10 | 763 | 53.557 | 89.466 | 60 | 9 | 296 | 12.648 | 69.210 |
| 2006 | 26 | 7 | 50 | 15.019 | 113.430 | 11 | 4 | 44 | 0.589 | 13.588 |
| 2007 | 8 | 2 | 3 | 0.886 | 73.216 | 3 | 2 | 3 | 0.156 | 49.716 |
| 2008 | 3 | 2 | 19 | 0.910 | 125.992 | 3 | 2 | 19 | 0.910 | 125.992 |
| 2009 | 15 | 8 | 49 | 1.295 | 47.042 | 14 | 7 | 43 | 1.265 | 48.579 |
| 2010 | 11 | 4 | 49 | 0.579 | 32.832 | 11 | 4 | 49 | 0.579 | 32.832 |
| 2011 | 17 | 7 | 105 | 4.727 | 92.224 | 17 | 7 | 105 | 4.727 | 92.224 |
| 2012 | 14 | 6 | 49 | 0.765 | 22.096 | 14 | 6 | 49 | 0.765 | 22.096 |

#### *23.5.3.1 Catch Rates and TIER 4 Smooth Oreo (Non-Cascade)*

Catches of smooth oreos are now so low even away from the Cascade Plateau that neither catch rate nor Tier 4 analyses are likely to have validity. There have been less than 20 data points since the year 2005, and these are not necessarily in the same months across years.

Because the catches were so small it would not have been valid to update the TIER 4 analysis, which is in-line with a RAG decision to only update the Tier 4 assessment if there were more than 10 t of catch taken. The reasons for a lack of fishing are reported as being related solely to the economics of fishing for relatively small amounts of oreo quota in such deep water fisheries.

The analysis described in Haddon (2013) remains the latest analysis of available data, although the catch rate analysis in that is also suspect due to the very low number of available data points.

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

*Allocyttus verrucosus* (warty), *Neocyttus rhomboidalis* (spiky), *Neocyttus psilorhynchus* (rough), *Allocyttus niger* (black). CAAB codes : 37266004, 37266001, 37266006, 37266005, 37266901, 37266902 (group code). Estimated discard rate in 2007 was 16.2 % and recent estiamtes have been highly variable (Klaer et al, 2013). 97.01% of the reported catch is given as spikey oreo (*Neocyttus rhomboidalis*), 2.98% as warty oreo (*Allocyttus verrucosus*), and 0.01% as black oreo (*Allocyttus niger*) (Table 23.31).

Table 23.34. 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 of mixed Oreos. The geometric mean CE is the raw unstandardized catch rate in Kg/tow. The left hand five columns represent all data, 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 | 367 | 50.966 | 114.224 | 138 | 9 | 329 | 47.586 | 128.028 |
| 1987 | 145 | 16 | 353 | 59.909 | 133.794 | 84 | 12 | 217 | 17.390 | 108.044 |
| 1988 | 161 | 12 | 372 | 33.809 | 82.647 | 68 | 7 | 192 | 12.228 | 77.821 |
| 1989 | 352 | 18 | 497 | 189.239 | 137.647 | 114 | 10 | 263 | 25.771 | 103.141 |
| 1990 | 257 | 22 | 172 | 257.178 | 292.016 | 23 | 11 | 61 | 7.335 | 107.273 |
| 1991 | 215 | 22 | 532 | 86.887 | 85.155 | 113 | 16 | 389 | 18.421 | 72.479 |
| 1992 | 577 | 31 | 848 | 607.582 | 227.389 | 174 | 22 | 499 | 76.258 | 111.068 |
| 1993 | 832 | 38 | 1621 | 281.255 | 94.969 | 337 | 29 | 1144 | 80.648 | 111.752 |
| 1994 | 1077 | 34 | 2494 | 284.569 | 75.354 | 419 | 32 | 1543 | 97.882 | 86.332 |
| 1995 | 1766 | 30 | 6060 | 482.242 | 92.167 | 953 | 23 | 3835 | 311.961 | 128.068 |
| 1996 | 2107 | 33 | 6898 | 420.967 | 69.658 | 1237 | 32 | 4824 | 284.955 | 91.185 |
| 1997 | 2274 | 34 | 9607 | 572.827 | 103.523 | 1502 | 31 | 6813 | 387.711 | 115.469 |
| 1998 | 2348 | 33 | 9873 | 666.856 | 121.631 | 1455 | 30 | 6170 | 448.279 | 132.626 |
| 1999 | 1912 | 33 | 7905 | 441.017 | 105.804 | 1191 | 31 | 4968 | 313.340 | 120.753 |
| 2000 | 1726 | 38 | 7739 | 376.494 | 97.319 | 1033 | 36 | 4541 | 253.999 | 114.544 |
| 2001 | 1926 | 37 | 8622 | 399.034 | 98.900 | 1262 | 36 | 5714 | 247.178 | 101.183 |
| 2002 | 1457 | 36 | 7174 | 212.546 | 70.372 | 931 | 33 | 4597 | 145.658 | 75.006 |
| 2003 | 1462 | 30 | 7411 | 229.224 | 75.450 | 915 | 28 | 4685 | 145.208 | 77.220 |
| 2004 | 1445 | 30 | 7502 | 181.402 | 66.947 | 912 | 28 | 4802 | 121.256 | 72.045 |
| 2005 | 813 | 22 | 4271 | 101.266 | 64.123 | 553 | 20 | 2882 | 72.176 | 67.852 |
| 2006 | 643 | 23 | 3230 | 80.260 | 50.683 | 422 | 22 | 2168 | 53.096 | 53.582 |
| 2007 | 388 | 17 | 2026 | 58.754 | 55.456 | 340 | 17 | 1831 | 52.028 | 54.586 |
| 2008 | 305 | 16 | 1751 | 48.564 | 72.522 | 280 | 16 | 1602 | 42.937 | 70.213 |
| 2009 | 500 | 17 | 2743 | 73.639 | 65.057 | 455 | 17 | 2482 | 73.639 | 62.511 |
| 2010 | 508 | 15 | 2900 | 76.137 | 65.407 | 508 | 15 | 2900 | 76.137 | 65.407 |
| 2011 | 571 | 17 | 3514 | 78.262 | 76.354 | 571 | 17 | 3514 | 78.262 | 76.354 |
| 2012 | 499 | 14 | 3021 | 59.514 | 61.119 | 499 | 14 | 3021 | 59.514 | 61.119 |

Table 23.35. The catch in tonnes of mixed oreos by Orange Roughy Zone, and, across ORzones in the current open and closed areas.

| Year | Total | 10 | 20 | 21 | 30 | 50 | Open | Closed |
|---|---|---|---|---|---|---|---|---|
| 1986 | 50.966 | 0.160 | 30.520 | | 20.278 | 0.008 | 47.586 | 3.38 |
| 1987 | 59.909 | 0.130 | 6.470 | | 53.309 | | 17.39 | 42.519 |
| 1988 | 33.809 | 0.020 | 0.150 | | 33.549 | 0.090 | 12.228 | 21.581 |
| 1989 | 189.239 | 0.030 | 98.650 | 37.090 | 53.409 | 0.060 | 25.771 | 163.468 |
| 1990 | 257.178 | 4.340 | 183.043 | 62.965 | 6.700 | 0.130 | 7.335 | 249.843 |
| 1991 | 86.887 | 3.191 | 47.720 | 17.251 | 18.340 | 0.385 | 18.421 | 68.466 |
| 1992 | 607.582 | 31.646 | 352.204 | 190.614 | 31.622 | 1.496 | 76.258 | 531.324 |
| 1993 | 281.255 | 1.392 | 106.148 | 36.651 | 107.769 | 29.295 | 80.648 | 200.607 |
| 1994 | 284.569 | 0.882 | 90.447 | 34.734 | 136.647 | 21.859 | 97.882 | 186.687 |
| 1995 | 482.242 | 1.388 | 64.172 | 8.076 | 402.359 | 6.247 | 311.961 | 170.281 |
| 1996 | 420.967 | 8.539 | 92.953 | 3.451 | 278.999 | 37.025 | 284.955 | 136.012 |
| 1997 | 572.827 | 43.955 | 129.864 | 1.390 | 377.317 | 20.301 | 387.711 | 185.116 |
| 1998 | 666.856 | 33.724 | 130.862 | 1.492 | 379.621 | 121.157 | 448.279 | 218.577 |
| 1999 | 441.017 | 13.860 | 126.159 | 1.295 | 241.554 | 58.149 | 313.34 | 127.677 |
| 2000 | 376.494 | 26.075 | 111.417 | 0.775 | 213.565 | 24.662 | 253.999 | 122.495 |
| 2001 | 399.034 | 17.880 | 134.639 | 7.785 | 218.687 | 20.043 | 247.178 | 151.856 |
| 2002 | 212.546 | 36.018 | 59.214 | 1.025 | 105.532 | 10.757 | 145.658 | 66.888 |
| 2003 | 229.224 | 33.272 | 57.005 | 7.550 | 118.164 | 13.233 | 145.208 | 84.016 |
| 2004 | 181.402 | 12.011 | 40.705 | 1.820 | 115.255 | 11.612 | 121.256 | 60.145 |
| 2005 | 101.266 | 5.967 | 22.182 | 1.500 | 62.499 | 9.118 | 72.176 | 29.09 |
| 2006 | 80.260 | 8.581 | 12.259 | 0.270 | 56.955 | 2.195 | 53.096 | 27.164 |
| 2007 | 58.754 | 2.340 | 18.565 | 1.194 | 35.345 | 1.310 | 52.028 | 6.726 |
| 2008 | 48.564 | 2.262 | 17.114 | | 26.527 | 2.661 | 42.937 | 5.627 |
| 2009 | 73.639 | 4.105 | 17.271 | 0.058 | 48.027 | 4.178 | 73.639 | |
| 2010 | 76.137 | 5.344 | 25.346 | 5.860 | 37.301 | 2.286 | 76.137 | |
| 2011 | 78.262 | 3.643 | 20.661 | 1.990 | 48.064 | 3.904 | 78.262 | |
| 2012 | 59.514 | 2.286 | 19.455 | 0.022 | 34.064 | 3.687 | 59.514 | |
| Total | 6410.399 | 303.040 | 2015.195 | 424.858 | 3261.458 | 405.848 | 3550.853 | 2859.545 |

In the last five years 80 – 91% has been reported as Oreo Dory and the remainder as Spiky oreos. Only data from OR Zones 10, 20, 21, 30, 50, in depths 500 – 1200m were used, in particular only the data from outside the closures are used. All vessels recording mixed oreos were included in the analysis. Orange Roughy zones 40, 60, 70 and unknown were removed.

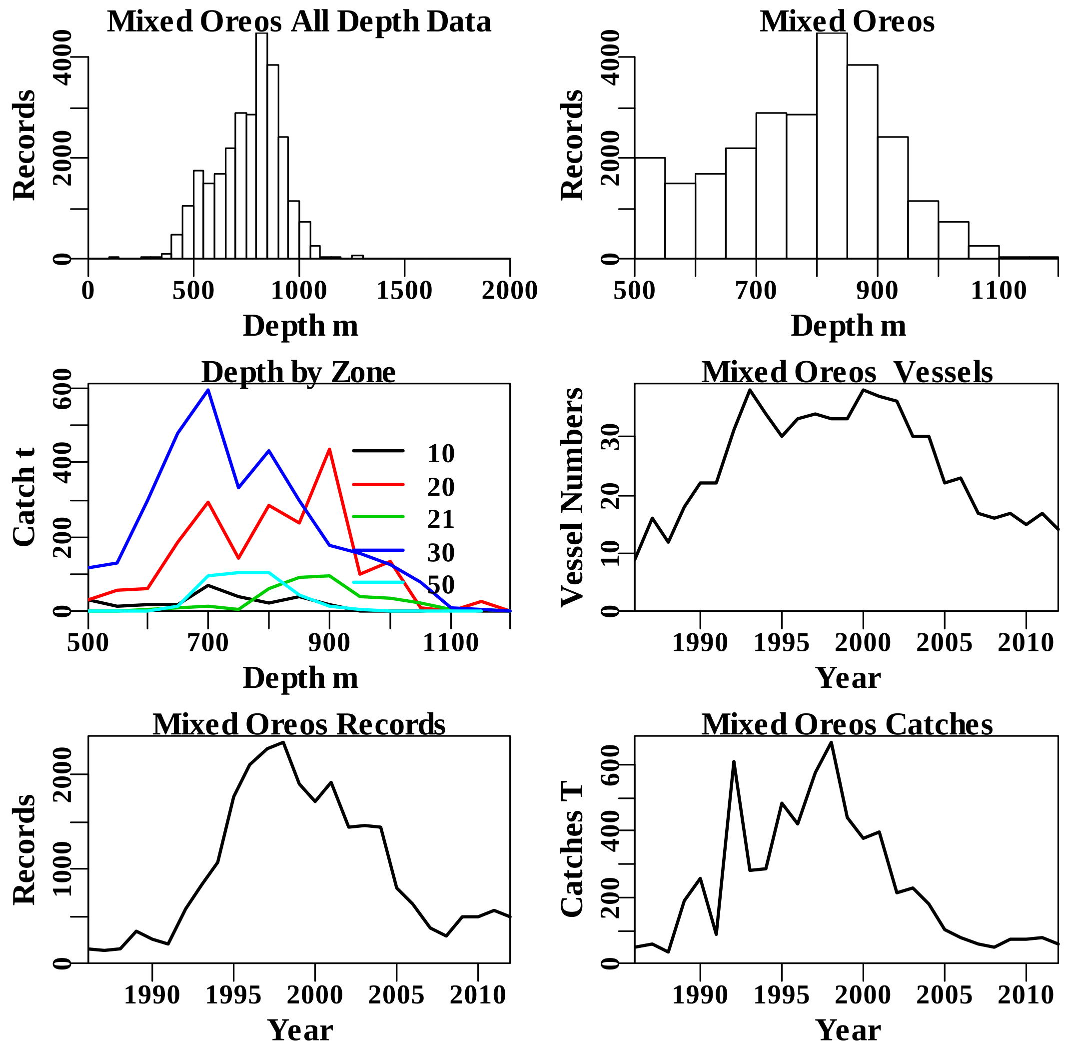


Figure 23.16. Mixed Oreo are reported from trawling in OR Zones 10, 20, 21, 30, and 50, in depths 500 to 1200 m. The top left is the depth distribution of all records reporting Mixed Oreo, the top right graph depicts the depth distribution of shots containing Mixed Oreo in OR Zones 10, 20, 21, 30, 50, in depths 500 to 1200 m. The middle left diagram depicts the distribution of catch across all years by depth within separate OR zones, the right hand middle graph depicts the number of vessels reporting mixed oreos through time. The bottom left reflects the number of records for mixed oreos, and bottom right are the Mixed Oreo catches used in the analysis.

Table 23.36. 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 | Year |
| Model 2 | Year + Vessel |
| Model 3 | Year + Vessel + DepCat |
| Model 4 | Year + Vessel + DepCat + Month |
| Model 5 | Year + Vessel + DepCat + Month + ORZone |
| Model 6 | Year + Vessel + DepCat + Month + ORZone + DayNight |
| Model 7 | Year + Vessel + DepCat + Month + ORZone + DayNight + Closure |
| Model 8 | Year + Vessel + DepCat + Month + ORZone + DayNight + Closure + Vessel:Month |
| Model 9 | Year + Vessel + DepCat + Month + ORZone + DayNight + Closure + DepCat:Month |

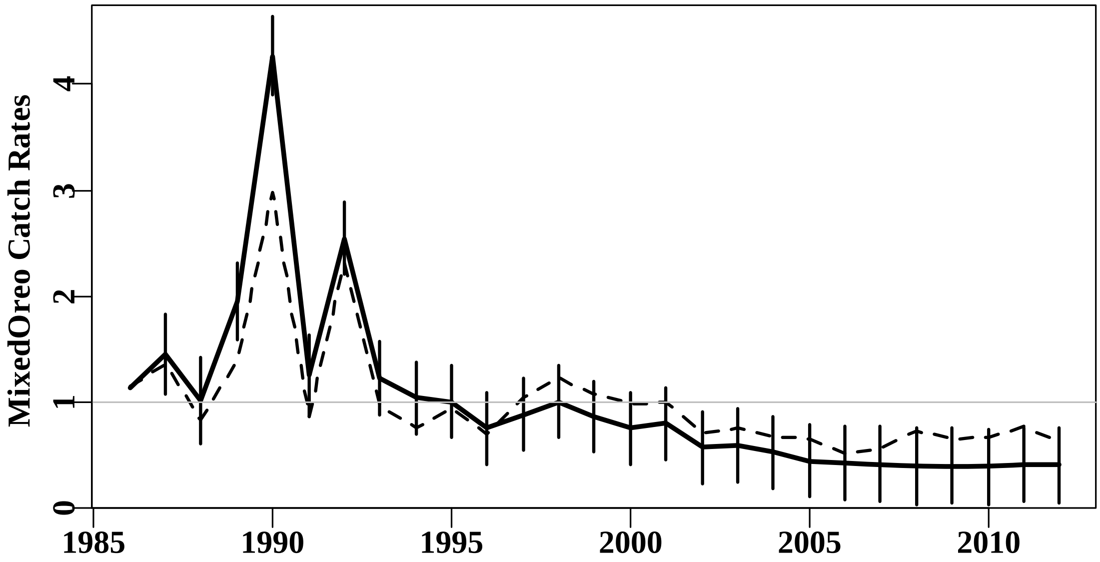


Figure 23.17. The standardized catch rates showing the optimum model (solid black line) and the geometric mean catch rate (dashed line) each scaled to the mean of each time series. The error bars are two times the standard errors.

Table 23.37. Model selection criteria, including the AIC, the residual sum of squares, the Model sum of squares, the number of usable observations, the number of parameters, the adjusted $r^2$ and the increment in adjusted $r^2$. The Vessel:Month model (model89) was optimal. The effect of being in the open or closed areas (Closed) was minor (Figure 23.18).

| | Year | Vessel | DepCat | Month | ORZone | DayNight | Closed | **Vess:Mth** | Dep:Mth |
|---|---|---|---|---|---|---|---|---|---|
| AIC | 16680 | 12017 | 10228 | 9301 | 8712 | 8522 | 8472 | **7959** | 8192.818 |
| RSS | 49580 | 41219 | 38289 | 36929 | 36096 | 35828 | 35757 | **32026** | 34964.88 |
| MSS | 2317 | 10677 | 13608 | 14968 | 15800 | 16069 | 16139 | **19870** | 16931.53 |
| Nobs | 26432 | 26427 | 26217 | 26217 | 26217 | 26217 | 26217 | **26217** | 26217 |
| Npars | 27 | 135 | 149 | 160 | 164 | 167 | 168 | **1356** | 322 |
| adj_$r^2$ | 4.370 | 20.170 | 25.802 | 28.407 | 30.011 | 30.523 | 30.657 | **34.925** | 31.79 |
| $\Delta r^2$ | 0.000 | 15.800 | 5.633 | 2.605 | 1.603 | 0.513 | 0.133 | **4.268** | 1.133 |

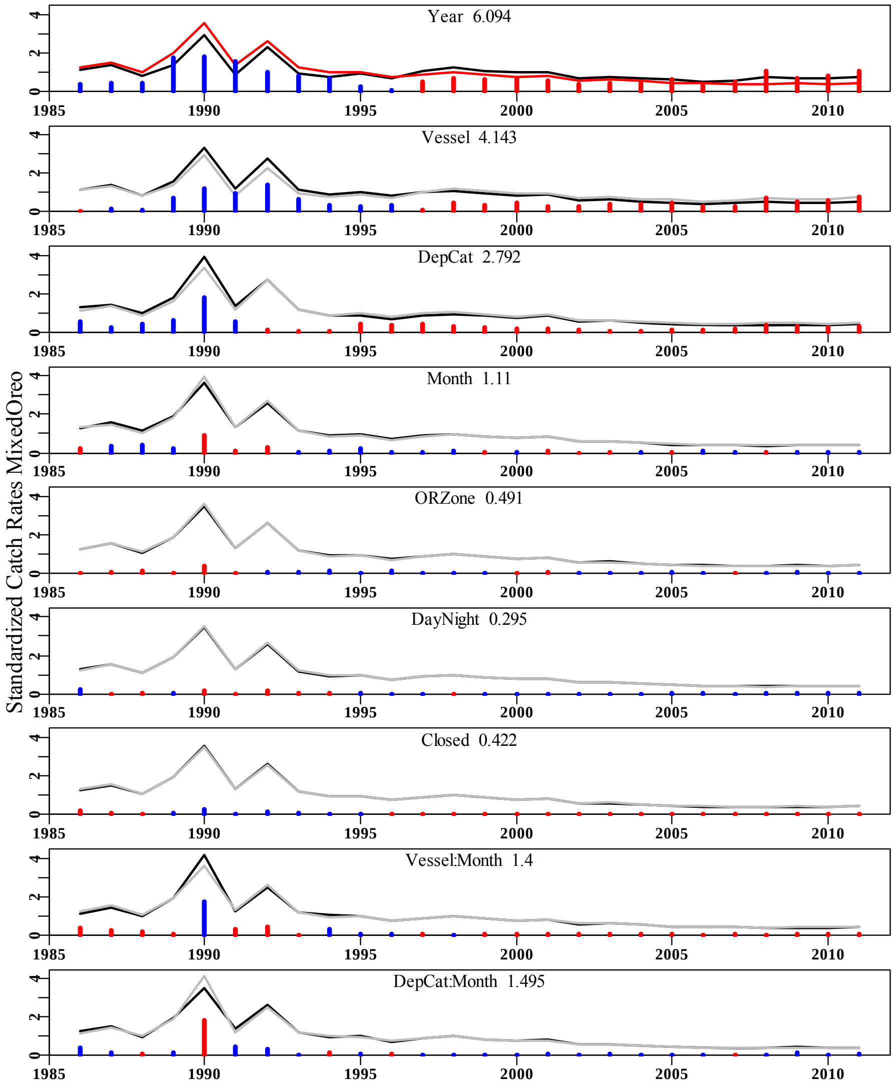


Figure 23.18. Relative impact of each factor on the final trend. Blue bars indicate the standardization is above the previous model, red bars indicate it is below. Closures appear to have only a very small effect.

Table 23.38. Reported catches 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 (Oreo Dories) appears only to have been introduced in 2005 when quotas were first applied to Mixed Oreos.

| Year | Spiky 37266001 | Warty 37266004 | OreoDory 37266902 | Year | Spiky 37266001 | Warty 37266004 | OreoDory 37266902 |
|---|---|---|---|---|---|---|---|
| 1986 | 19.269 | 31.697 | | 1999 | 429.802 | 11.215 | |
| 1987 | 40.834 | 19.075 | | 2000 | 345.507 | 30.987 | |
| 1988 | 13.860 | 19.949 | | 2001 | 392.974 | 6.060 | |
| 1989 | 175.798 | 13.441 | | 2002 | 210.951 | 1.595 | |
| 1990 | 254.921 | 2.257 | | 2003 | 228.924 | 0.300 | |
| 1991 | 86.359 | 0.528 | | 2004 | 179.862 | 1.540 | |
| 1992 | 606.532 | 1.050 | | 2005 | 93.756 | | 7.510 |
| 1993 | 278.224 | 3.031 | | 2006 | 38.109 | | 42.151 |
| 1994 | 265.949 | 18.620 | | 2007 | 11.771 | | 46.983 |
| 1995 | 468.212 | 14.030 | | 2008 | 6.983 | | 41.581 |
| 1996 | 405.361 | 15.606 | | 2009 | 6.851 | | 66.788 |
| 1997 | 552.637 | 20.190 | | 2010 | 8.061 | | 68.076 |
| 1998 | 642.050 | 24.806 | | 2011 | 6.802 | | 71.460 |
| | | | | 2012 | 8.235 | | 51.278 |

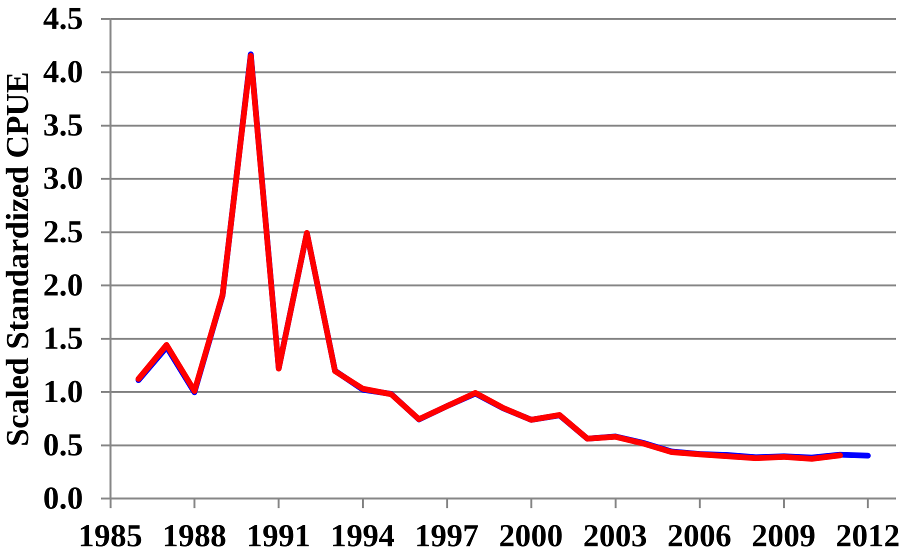


Figure 23.19. A comparison of last year’s standardization with this year’s.

Table 23.39. 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 DepCat:Month. St Err is the estimate of standard error for the optimum model. Values are relative to the mean of the standardized catch rates. The Month and closure factors column was omitted for clarity; their relative effect can be seen in Figure 23.18.

| Year | Year | Vessel | DepCat | ORZone | DayNight | deep | Vessel:Month | StErr |
|---|---|---|---|---|---|---|---|---|
| 1986 | 1.1528 | 1.1469 | 1.3417 | 1.2630 | 1.3439 | 1.2556 | **1.1356** | 0.0000 |
| 1987 | 1.3668 | 1.4029 | 1.4726 | 1.5577 | 1.5566 | 1.5228 | **1.4516** | 0.1900 |
| 1988 | 0.8437 | 0.8780 | 1.0115 | 1.1005 | 1.0931 | 1.0811 | **1.0195** | 0.2039 |
| 1989 | 1.4008 | 1.6371 | 1.8475 | 1.9329 | 1.9478 | 1.9767 | **1.9530** | 0.1834 |
| 1990 | 2.9747 | 3.3745 | 4.0003 | 3.5930 | 3.5450 | 3.6652 | **4.2617** | 0.1857 |
| 1991 | 0.8681 | 1.1977 | 1.3860 | 1.3417 | 1.3413 | 1.3576 | **1.2514** | 0.1890 |
| 1992 | 2.3117 | 2.7661 | 2.7407 | 2.6684 | 2.6131 | 2.6677 | **2.5472** | 0.1712 |
| 1993 | 0.9650 | 1.1916 | 1.1867 | 1.2185 | 1.1935 | 1.2261 | **1.2255** | 0.1730 |
| 1994 | 0.7655 | 0.8869 | 0.8783 | 0.9586 | 0.9453 | 0.9583 | **1.0448** | 0.1707 |
| 1995 | 0.9360 | 1.0406 | 0.8997 | 0.9823 | 0.9905 | 0.9921 | **1.0045** | 0.1688 |
| 1996 | 0.7073 | 0.8258 | 0.7024 | 0.7476 | 0.7490 | 0.7470 | **0.7597** | 0.1692 |
| 1997 | 1.0512 | 1.0262 | 0.8913 | 0.9114 | 0.9114 | 0.9071 | **0.8888** | 0.1687 |
| 1998 | 1.2350 | 1.0777 | 0.9768 | 1.0118 | 1.0104 | 1.0074 | **1.0068** | 0.1687 |
| 1999 | 1.0744 | 0.9579 | 0.8797 | 0.8793 | 0.8792 | 0.8753 | **0.8675** | 0.1690 |
| 2000 | 0.9883 | 0.8415 | 0.7842 | 0.7768 | 0.7780 | 0.7722 | **0.7555** | 0.1691 |
| 2001 | 1.0043 | 0.9229 | 0.8647 | 0.8204 | 0.8212 | 0.8128 | **0.7993** | 0.1691 |
| 2002 | 0.7147 | 0.6179 | 0.5861 | 0.5932 | 0.5959 | 0.5913 | **0.5751** | 0.1699 |
| 2003 | 0.7663 | 0.6386 | 0.6131 | 0.6206 | 0.6230 | 0.6190 | **0.5953** | 0.1699 |
| 2004 | 0.6799 | 0.5543 | 0.5351 | 0.5446 | 0.5466 | 0.5408 | **0.5336** | 0.1700 |
| 2005 | 0.6516 | 0.5002 | 0.4635 | 0.4628 | 0.4661 | 0.4613 | **0.4518** | 0.1720 |
| 2006 | 0.5152 | 0.4385 | 0.3976 | 0.4299 | 0.4341 | 0.4287 | **0.4269** | 0.1734 |
| 2007 | 0.5642 | 0.4733 | 0.4083 | 0.4252 | 0.4279 | 0.4221 | **0.4173** | 0.1775 |
| 2008 | 0.7383 | 0.5136 | 0.4007 | 0.3999 | 0.4036 | 0.3981 | **0.3971** | 0.1808 |
| 2009 | 0.6615 | 0.4990 | 0.4051 | 0.4347 | 0.4412 | 0.4293 | **0.4061** | 0.1751 |
| 2010 | 0.6651 | 0.4859 | 0.4051 | 0.4212 | 0.4264 | 0.4088 | **0.3924** | 0.1749 |
| 2011 | 0.7762 | 0.5399 | 0.4327 | 0.4398 | 0.4494 | 0.4318 | **0.4199** | 0.1739 |
| 2012 | 0.6215 | 0.5643 | 0.4887 | 0.4643 | 0.4665 | 0.4438 | **0.4121** | 0.1774 |

#### *23.5.4.1 TIER 4 Mixed Oreo Target Proxy 48%*

Using the standardized catch rates and the updated catches for 2010, which now include the Oreo Dory (CAAB code 37266902) previously omitted, the TIER 4 analysis shows the recent catch rates to be not far from the target ( ~82% of the target) so the RBC calculation is restrained.

The RAG, in Oct 2011, recommended the reference period be moved from 1992-2001 to become 1993-2001. The reasoning behind this move was that 1992 was the last year of the Orange Roughy fishery in which mixed oreos were a significant discard component, while from 1993 onwards Oreos were landed much more often.

Table 23.40. CE are the standardized catch rates. GeoCE is the geometric mean catch rate from the raw data. Total is the total catch in the open areas, including discards (estimated at 16.2%). The target catch rate and target catch are both halved to allow for an assumed lack of exploitation prior to the reference period.

| Year | Catch | Discard | Total | CE | GeoCE | | |
|---|---|---|---|---|---|---|---|
| 1986 | 47.586 | 9.199 | 56.785 | 1.1356 | 128.0280 | Ref_Year | 1993 |
| 1987 | 17.390 | 3.362 | 20.752 | 1.4516 | 108.0437 | Ref_Year | 2001 |
| 1988 | 12.228 | 2.364 | 14.592 | 1.0195 | 77.8207 | Except Yr | |
| 1989 | 25.771 | 4.982 | 30.753 | 1.9530 | 103.1413 | CE_Targ | 0.464 |
| 1990 | 7.335 | 1.418 | 8.753 | 4.2617 | 107.2726 | CE_Lim | 0.1856 |
| 1991 | 18.421 | 3.561 | 21.982 | 1.2514 | 72.4795 | CE_Recent | 0.4076 |
| 1992 | 76.258 | 14.742 | 91.000 | 2.5472 | 111.0680 | Wt_Discard | |
| 1993 | 80.648 | 15.591 | 96.239 | 1.2255 | 111.7519 | Scaling | 0.7974 |
| 1994 | 97.882 | 18.922 | 116.804 | 1.0448 | 86.3323 | TAC | |
| 1995 | 311.961 | 60.308 | 372.269 | 1.0045 | 128.0685 | C*(target) | 160.830 |
| 1996 | 284.955 | 55.087 | 340.042 | 0.7597 | 91.1849 | **RBC** | **128.246** |
| 1997 | 387.711 | 74.952 | 462.663 | 0.8888 | 115.4691 | | |
| 1998 | 448.279 | 86.661 | 534.940 | 1.0068 | 132.6256 | | |
| 1999 | 313.340 | 60.575 | 373.915 | 0.8675 | 120.7534 | | |
| 2000 | 253.999 | 49.103 | 303.102 | 0.7555 | 114.5441 | | |
| 2001 | 247.178 | 47.784 | 294.962 | 0.7993 | 101.1833 | | |
| 2002 | 145.658 | 28.159 | 173.817 | 0.5751 | 75.0058 | | |
| 2003 | 145.208 | 28.072 | 173.280 | 0.5953 | 77.2203 | Years | TAC |
| 2004 | 121.256 | 23.441 | 144.697 | 0.5336 | 72.0455 | 2005 | 200 |
| 2005 | 72.176 | 13.953 | 86.129 | 0.4518 | 67.8523 | 2006 | 200 |
| 2006 | 53.096 | 10.264 | 63.360 | 0.4269 | 53.5816 | 2007/08 | 190 |
| 2007 | 52.028 | 10.058 | 62.086 | 0.4173 | 54.5861 | 2008/09 | 150 |
| 2008 | 42.937 | 8.301 | 51.238 | 0.3971 | 70.2134 | 2009/10 | 188 |
| 2009 | 73.639 | 14.236 | 87.875 | 0.4061 | 62.5112 | 2010/11 | 188 |
| 2010 | 76.137 | 14.719 | 90.856 | 0.3924 | 65.4074 | 2011/12 | 113 |
| 2011 | 78.262 | 15.130 | 93.392 | 0.4199 | 76.3535 | 2012/13 | 111 |
| 2012 | 59.514 | 11.505 | 71.019 | 0.4121 | 61.1189 | | |

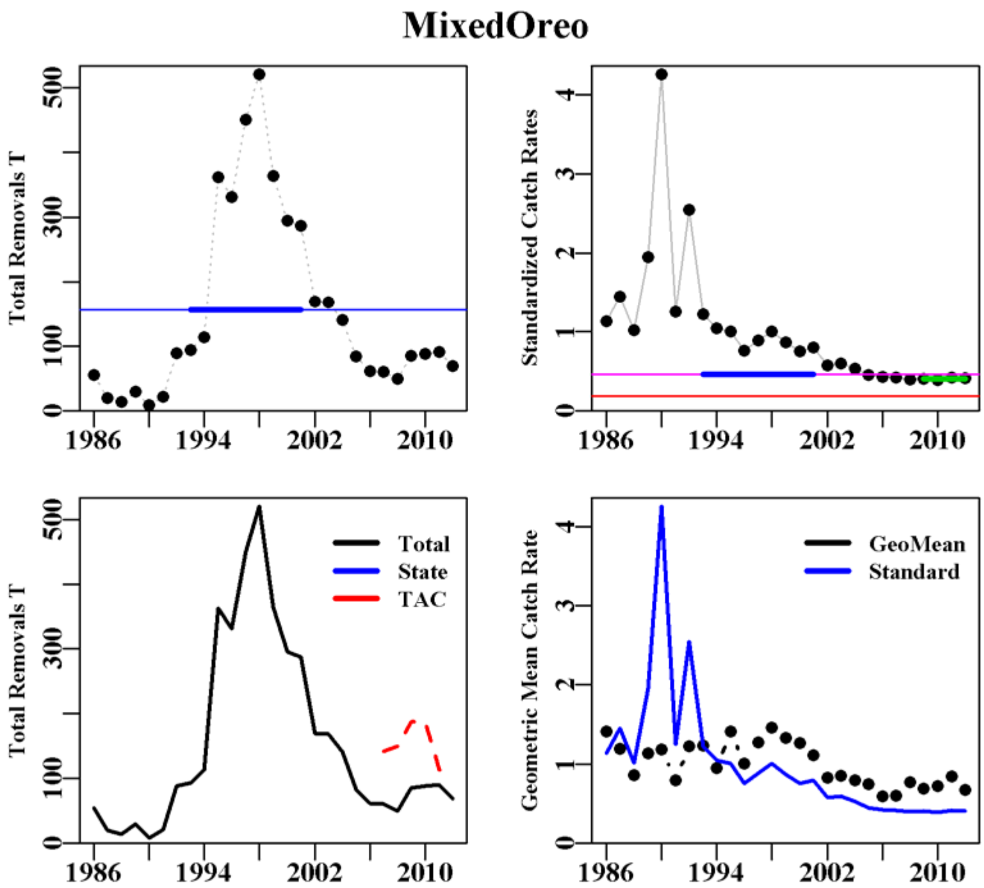


Figure 23.20. Tier 4 analysis for mixed oreos. Top left is the total catch in the open areas with the target catch indicated by the horizontal line. The target period is indicated by the thickened section of the line. Top right, illustrates the standardized catch rates plus both the target and limit catch rates, as well as the recent average catch rate, again with the target period identified with a thickened line. The distance of the mean of the last four points from the target indicates the potential scaling used to produce the RBC. Bottom left is total removals. Bottom left is the geometric mean catch rate compared to the standardized catch rates, scaled to the mean of the unstandardized rates.

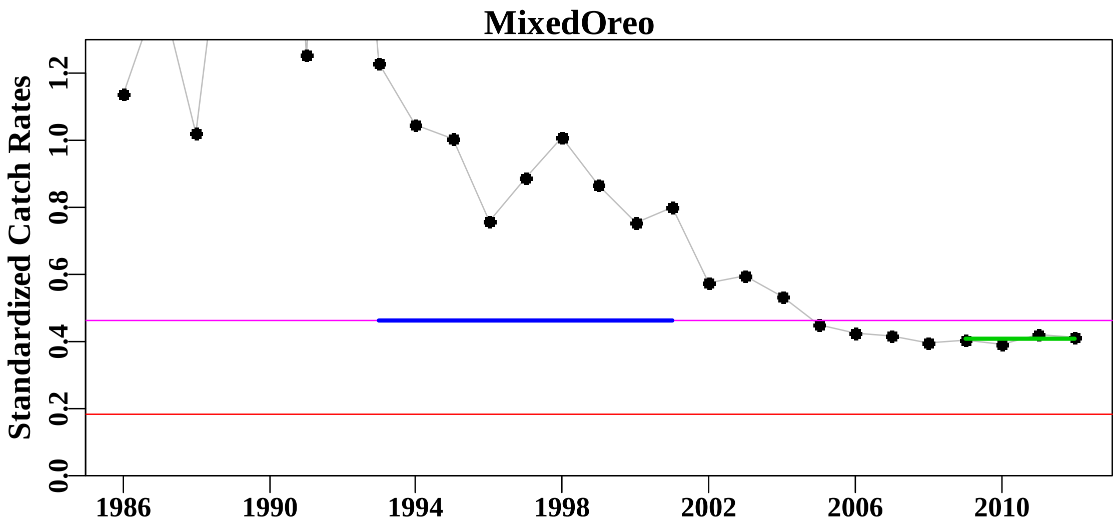


Figure 23.21. An expanded version of the Tier 4 analysis of catch rates to improve the illustration of the reference period and the recent mean catch rates.\

### 23.5.5 Eastern Deepwater Sharks

Table 23.41. 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 |

Discards make up approximately 2.8% of the catch over the 1998-2006 period (Wayte and Fuller, 2008), but recent estimates are highly uncertain (Klaer et al, 2013).

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.

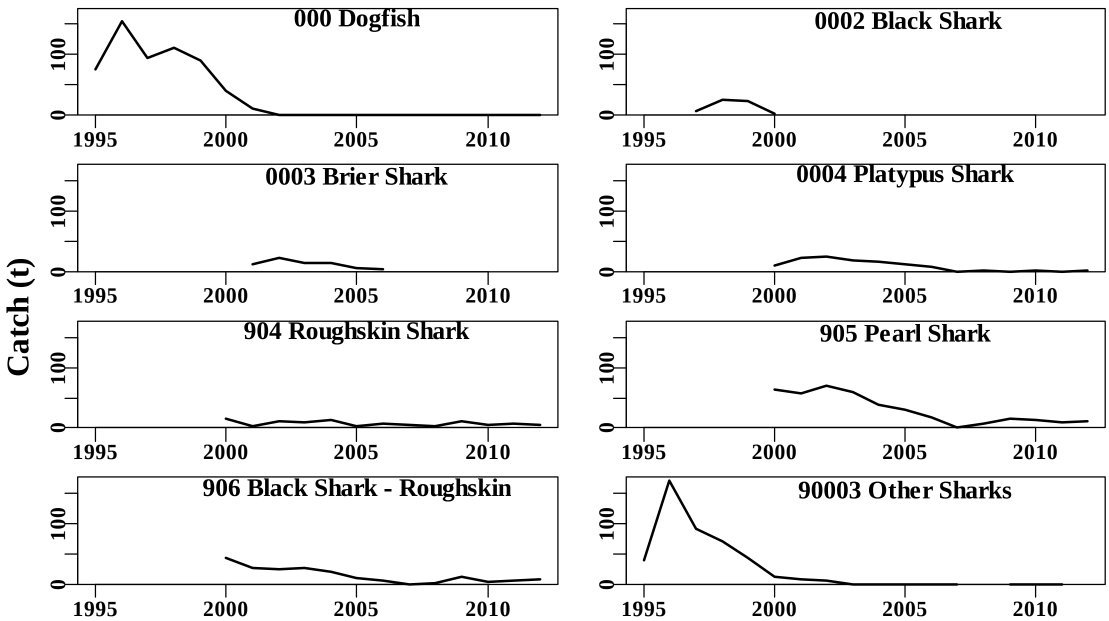


Figure 23.22. Eastern Deepwater Sharks catches broken down by species taken by trawling in OR Zones 10, 20, and 50 (catches in 21 and 40 were trivial), in depths 600 to 1250 m.

Table 23.42. 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. Recs is the number of records used. Vess represents the count of vessels reporting Deepwater Sharks. Yield is the total reported catch in tonnes. The geometric mean CE is the raw unstandardized catch rate in Kg/tow. 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 | 1052 | 25 | 45.111 | 25.898 | 209 | 874 | 24 | 46.096 |
| 1987 | 6.061 | 105 | 327 | 28 | 26.456 | 4.821 | 89 | 272 | 24 | 26.085 |
| 1988 | 5.746 | 47 | 137 | 22 | 45.312 | 4.919 | 37 | 107 | 17 | 45.225 |
| 1989 | 5.561 | 85 | 220 | 21 | 37.910 | 5.080 | 76 | 191 | 19 | 37.505 |
| 1990 | 7.228 | 69 | 125 | 23 | 42.032 | 3.189 | 42 | 67 | 19 | 23.441 |
| 1991 | 20.213 | 129 | 316 | 24 | 62.171 | 10.119 | 87 | 208 | 21 | 54.265 |
| 1992 | 64.054 | 115 | 463 | 25 | 120.583 | 5.527 | 49 | 206 | 20 | 48.652 |
| 1993 | 95.237 | 295 | 968 | 26 | 132.886 | 17.922 | 118 | 322 | 22 | 48.635 |
| 1994 | 112.086 | 434 | 1605 | 30 | 130.137 | 38.050 | 215 | 780 | 27 | 96.916 |
| 1995 | 115.605 | 368 | 1453 | 22 | 179.615 | 61.899 | 220 | 804 | 22 | 163.944 |
| 1996 | 327.383 | 966 | 3712 | 30 | 191.197 | 260.404 | 777 | 2949 | 26 | 183.367 |
| 1997 | 194.243 | 907 | 4091 | 26 | 131.258 | 135.947 | 684 | 3062 | 24 | 122.844 |
| 1998 | 206.076 | 1105 | 4989 | 24 | 117.628 | 170.931 | 927 | 4093 | 23 | 114.465 |
| 1999 | 156.977 | 1013 | 4667 | 28 | 95.560 | 128.817 | 842 | 3829 | 26 | 91.905 |
| 2000 | 187.075 | 889 | 4252 | 28 | 124.127 | 150.371 | 707 | 3326 | 24 | 121.916 |
| 2001 | 140.954 | 893 | 4097 | 28 | 86.377 | 113.107 | 724 | 3224 | 26 | 90.318 |
| 2002 | 161.446 | 898 | 4230 | 29 | 102.917 | 130.026 | 752 | 3450 | 28 | 97.882 |
| 2003 | 130.839 | 974 | 4769 | 25 | 76.461 | 93.895 | 749 | 3534 | 22 | 73.496 |
| 2004 | 104.208 | 724 | 3459 | 29 | 79.814 | 78.429 | 587 | 2773 | 27 | 79.701 |
| 2005 | 61.426 | 480 | 2470 | 17 | 74.410 | 48.427 | 377 | 1949 | 15 | 75.336 |
| 2006 | 43.617 | 410 | 1960 | 21 | 51.361 | 33.066 | 279 | 1274 | 20 | 63.563 |
| 2007 | 8.418 | 106 | 494 | 17 | 43.938 | 8.378 | 104 | 484 | 17 | 44.636 |
| 2008 | 12.904 | 100 | 658 | 10 | 65.755 | 11.859 | 96 | 628 | 10 | 62.155 |
| 2009 | 39.137 | 232 | 1227 | 14 | 81.789 | 38.692 | 229 | 1208 | 14 | 81.183 |
| 2010 | 25.529 | 251 | 1264 | 13 | 48.906 | 25.529 | 251 | 1264 | 13 | 48.906 |
| 2011 | 25.471 | 246 | 1352 | 15 | 56.150 | 25.471 | 246 | 1352 | 15 | 56.150 |
| 2012 | 26.498 | 283 | 1545 | 16 | 46.199 | 26.498 | 283 | 1545 | 16 | 46.199 |

Table 23.43. 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 | Year |
| Model 2 | Year + Vessel |
| Model 3 | Year + Vessel + DepCat |
| Model 4 | Year + Vessel + DepCat + Month |
| Model 5 | Year + Vessel + DepCat + Month + ORZone |
| Model 6 | Year + Vessel + DepCat + Month + ORZone + Deep |
| Model 7 | Year + Vessel + DepCat + Month + ORZone + Deep + ORZone:Month |
| Model 8 | Year + Vessel + DepCat + Month + ORZone + Deep + Vessel:Month |

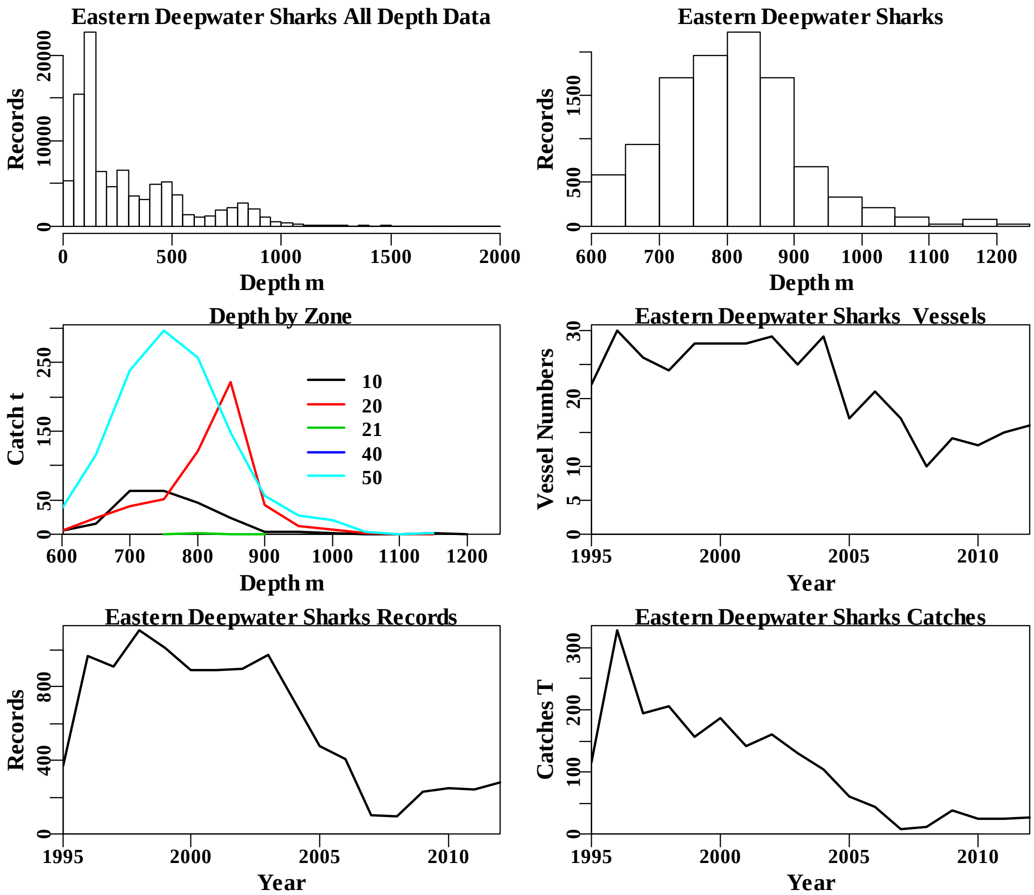


Figure 23.23. Eastern Deepwater Sharks reported from trawling in OR Zones 10, 20, 21, 50, in depths 600 to 1250 m. The top left is the depth distribution of all records reporting Deepwater Sharks, the top right graph depicts the depth distribution of shots containing Deepwater Sharks in OR Zones 10, 20, 21, 50, in depths 600 to 1250 m. The middle left diagram depicts the distribution of catch across all years by depth within separate OR zones (most catch is in zones 10, 20, and 50), the right hand middle graph depicts the number of vessels reporting Eastern Deepwater Sharks through time. The bottom left reflects the number of records for Deepwater Sharks, and bottom right are the Deepwater Shark catches used in the analysis.

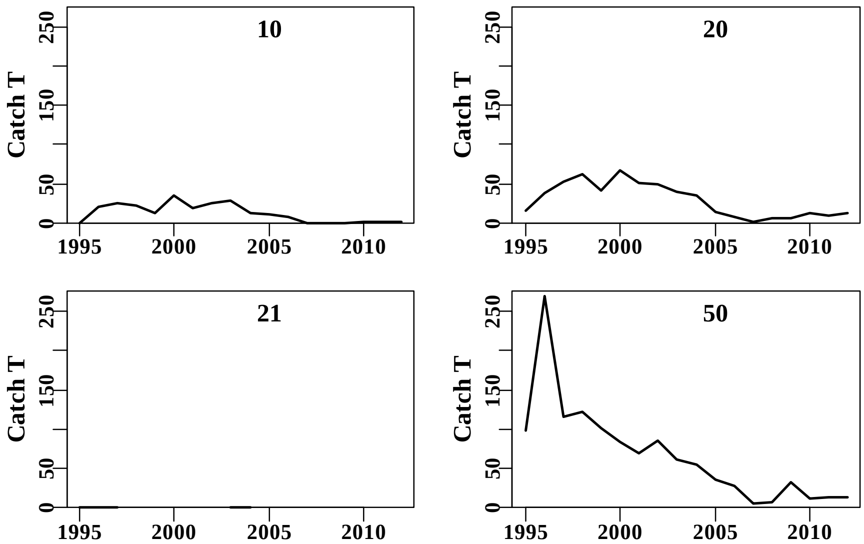


Figure 23.24. Eastern Deepwater Sharks catches taken by trawling in OR Zones 10, 20, 21, and 50, in depths 600 to 1250 m. Less than 7.0 t was reported in OR Zone 70 across all years.

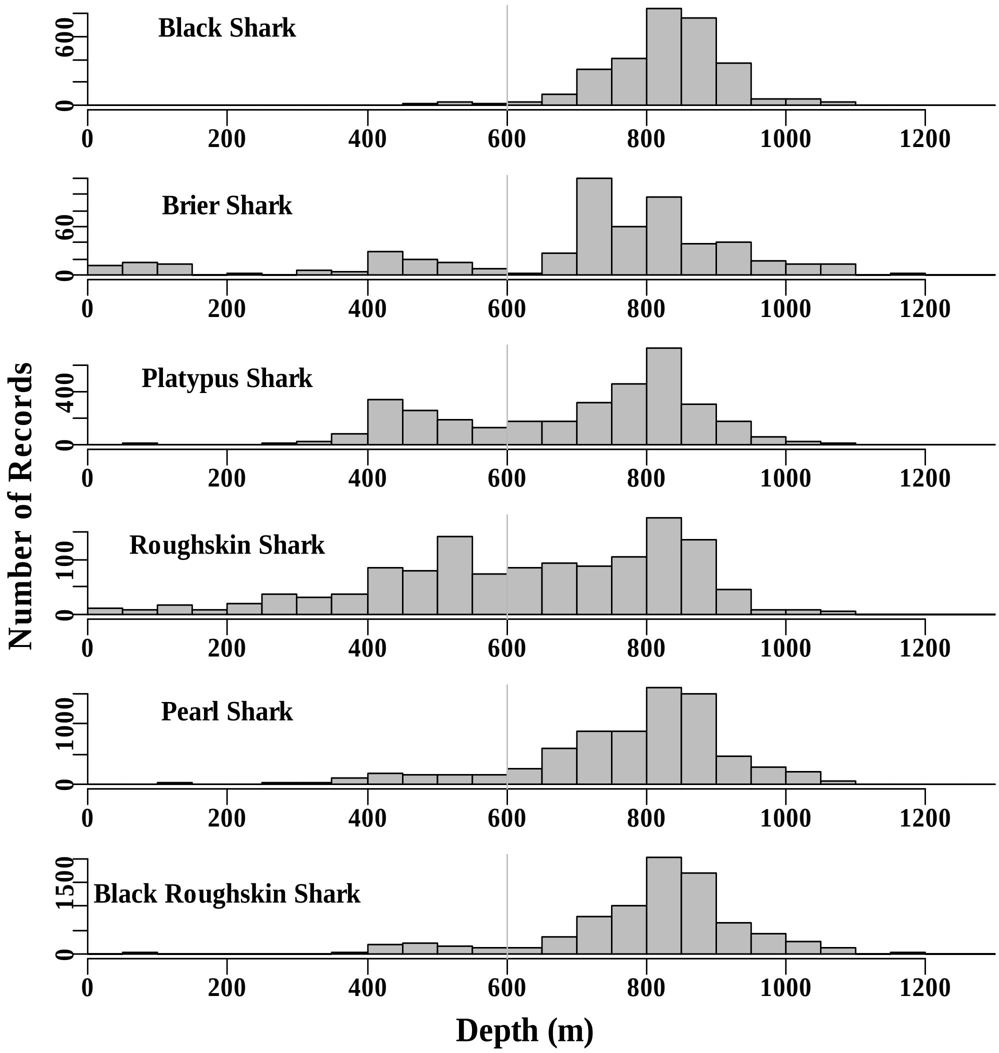


Figure 23.25. Depth distribution of the six main species of Eastern Deepwater Sharks catches taken by trawl in OR Zones 10, 20, 21,and 50, in depths 600 to 1250 m. 37020002: Black Shark, 37020003: Brier Shark, 37020004: Platypus Shark, 37020904:Roughskin Shark, 37020905: Pearl Shark, and 37020906: Black Shark – Roughskin category, Data updated to 2012.

Table 23.44. Model selection criteria, including the AIC, the residual sum of squares, the Model sum of squares, the number of usable observations, the number of parameters, the adjusted $r^2$ and the increment in adjusted $r^2$. The model including the ORZone:Month 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.

| | Year | Vessel | DepCat | Month | ORzone | deep | **ORzone:Mth** | Vessel:Month |
|---|---|---|---|---|---|---|---|---|
| AIC | 3336 | 1836 | 950 | 939 | 934 | 934 | **896** | 1969 |
| RSS | 14703 | 12618 | 11322 | 11287 | 11272 | 11271 | **11137** | 10545 |
| MSS | 1495 | 3579 | 4876 | 4910 | 4925 | 4927 | **5061** | 5652 |
| Nobs | 10845 | 10845 | 10564 | 10564 | 10564 | 10564 | **10564** | 10564 |
| Npars | 18 | 97 | 109 | 120 | 124 | 125 | **169** | 994 |
| adj_$r^2$ | 9.086 | 21.403 | 29.379 | 29.521 | 29.586 | 29.591 | **30.134** | 28.142 |
| $\Delta r^2$ | 0.000 | 12.317 | 7.975 | 0.143 | 0.065 | 0.005 | **0.543** | -1.449 |

Table 23.45. 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. 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 | Month | ORzone | Deep | **ORzone:Mth** | StErr |
|---|---|---|---|---|---|---|---|---|
| 1995 | 1.9494 | 1.8788 | 1.7336 | 1.7537 | 1.7624 | 1.7494 | **1.7150** | 0.0000 |
| 1996 | 2.0804 | 2.1388 | 2.1230 | 2.1257 | 2.0457 | 2.0409 | **2.0384** | 0.0728 |
| 1997 | 1.4283 | 1.4188 | 1.2895 | 1.2889 | 1.2685 | 1.2646 | **1.2825** | 0.0706 |
| 1998 | 1.2798 | 1.1801 | 1.0645 | 1.0668 | 1.0671 | 1.0675 | **1.0772** | 0.0697 |
| 1999 | 1.0398 | 1.0441 | 0.9163 | 0.9164 | 0.9198 | 0.9200 | **0.9067** | 0.0699 |
| 2000 | 1.3507 | 1.3308 | 1.1533 | 1.1446 | 1.1446 | 1.1460 | **1.1290** | 0.0716 |
| 2001 | 0.9399 | 1.0590 | 0.9525 | 0.9489 | 0.9604 | 0.9622 | **0.9648** | 0.0722 |
| 2002 | 1.1199 | 1.1558 | 1.0694 | 1.0788 | 1.0879 | 1.0892 | **1.0839** | 0.0720 |
| 2003 | 0.8320 | 0.8593 | 0.7648 | 0.7633 | 0.7674 | 0.7664 | **0.7714** | 0.0718 |
| 2004 | 0.8687 | 0.8430 | 0.7732 | 0.7649 | 0.7738 | 0.7742 | **0.7792** | 0.0740 |
| 2005 | 0.8102 | 0.7972 | 0.7533 | 0.7512 | 0.7565 | 0.7559 | **0.7565** | 0.0799 |
| 2006 | 0.5594 | 0.5552 | 0.6603 | 0.6538 | 0.6536 | 0.6524 | **0.6593** | 0.0825 |
| 2007 | 0.4808 | 0.4925 | 0.7267 | 0.7225 | 0.7264 | 0.7293 | **0.7251** | 0.1288 |
| 2008 | 0.7199 | 0.6858 | 1.0599 | 1.0592 | 1.0677 | 1.0703 | **1.0649** | 0.1277 |
| 2009 | 0.8919 | 0.9710 | 1.1693 | 1.1687 | 1.1748 | 1.1776 | **1.1942** | 0.0966 |
| 2010 | 0.5332 | 0.5411 | 0.5977 | 0.5971 | 0.6055 | 0.6088 | **0.6099** | 0.0973 |
| 2011 | 0.6122 | 0.5674 | 0.6426 | 0.6431 | 0.6552 | 0.6591 | **0.6697** | 0.0964 |
| 2012 | 0.5035 | 0.4813 | 0.5502 | 0.5526 | 0.5627 | 0.5662 | **0.5724** | 0.0936 |

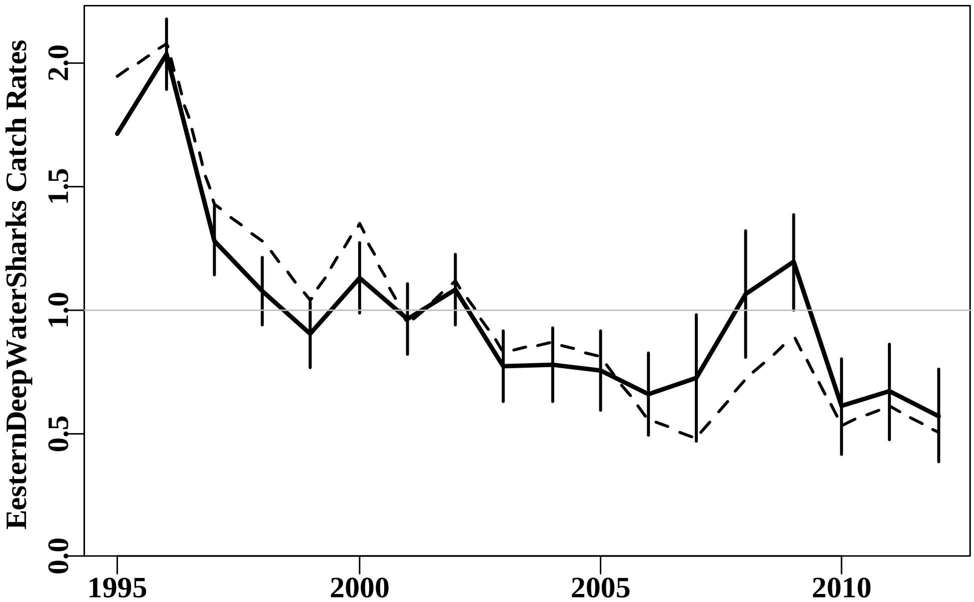


Figure 23.26. Eastern Deepwater Sharks reported from trawling in OR Zones 10, 20, 21, and 50, in depths 600 to 1250 m. The black dashed line from 86-12 represents the geometric mean catch rate and the solid black line the optimum standardized catch rates (Model 7). The graph scales the catch rates relative to the mean of the standardized catch rates (depicted by the horizontal grey line at 1.0).

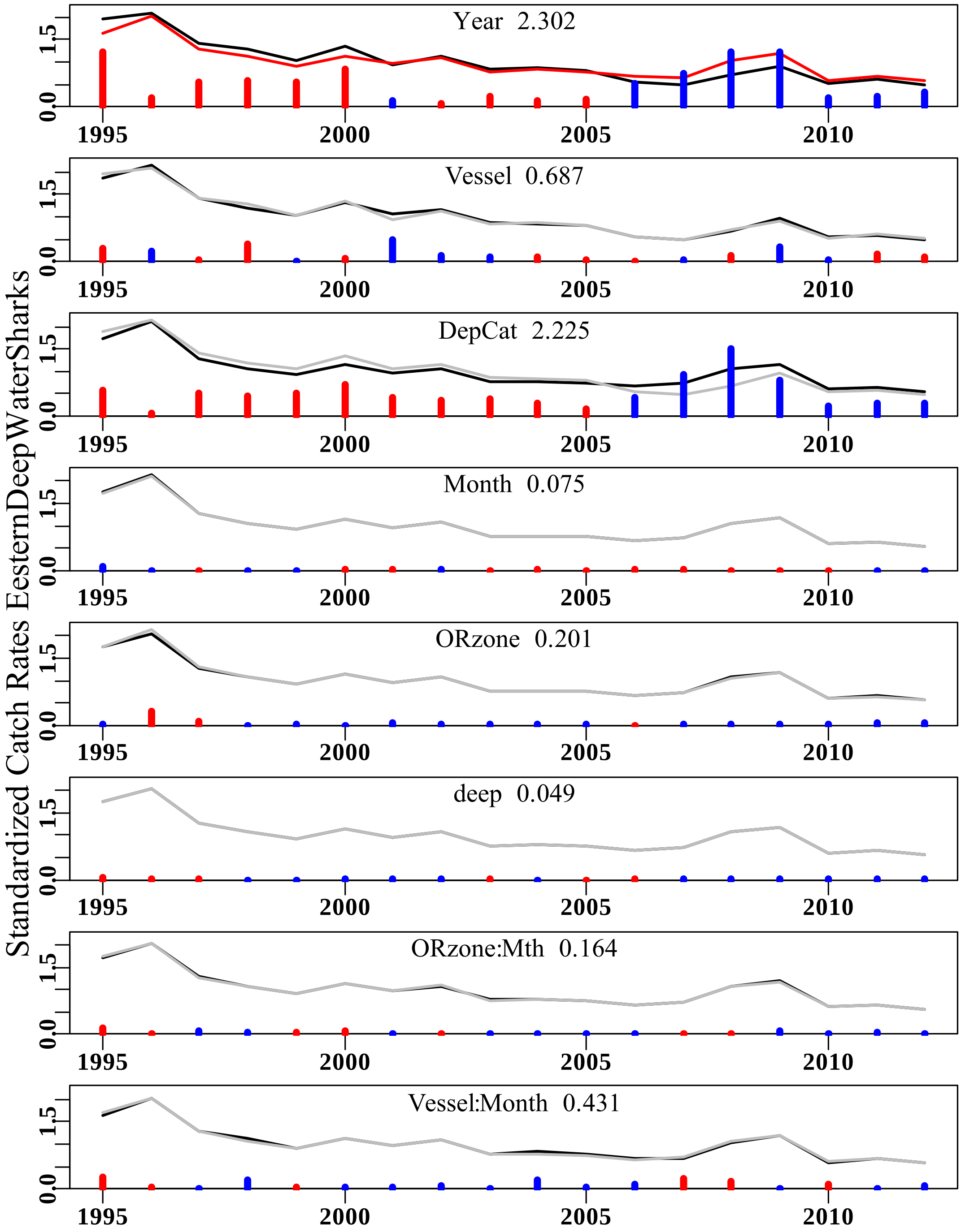


Figure 23.27. The relative impact of the different factors on the changes in the standardized trend. The major effects of both the structural adjustment that occurred across Nov 2005 – Nov 2006, with its change of vessels, and the deepwater closures is clear.

The catch rates used in the analysis are based upon log-transformed catches rather than log-transformed catch/effort. This was a RAG decision relating to how the sharks are fished. However, by comparing the statistical distributions of both types of catch rate data it is clear that the use of kg/hr for individual records as a catch rate leads to information with better statistical properties. The use of log catch per tow to represent catch rates appears to be influenced more by the use of rounding to the nearest half hour of effort and similar rounding issues with the catch recorded. Generally it would be recommended that the data giving rise to the cleaner statistical distribution should be used but there appear to be other changes in how fishers are operating, possibly due to the advent of the structural adjustment (Nov 2005 – Nov 2006), followed by the deepwater closures in 2007, followed by their modification in 2009. Before any changes to the analyses are made this would require a more thorough analytical investigation of the available data. Nevertheless, this issue should be noted by the RAG for future reference.

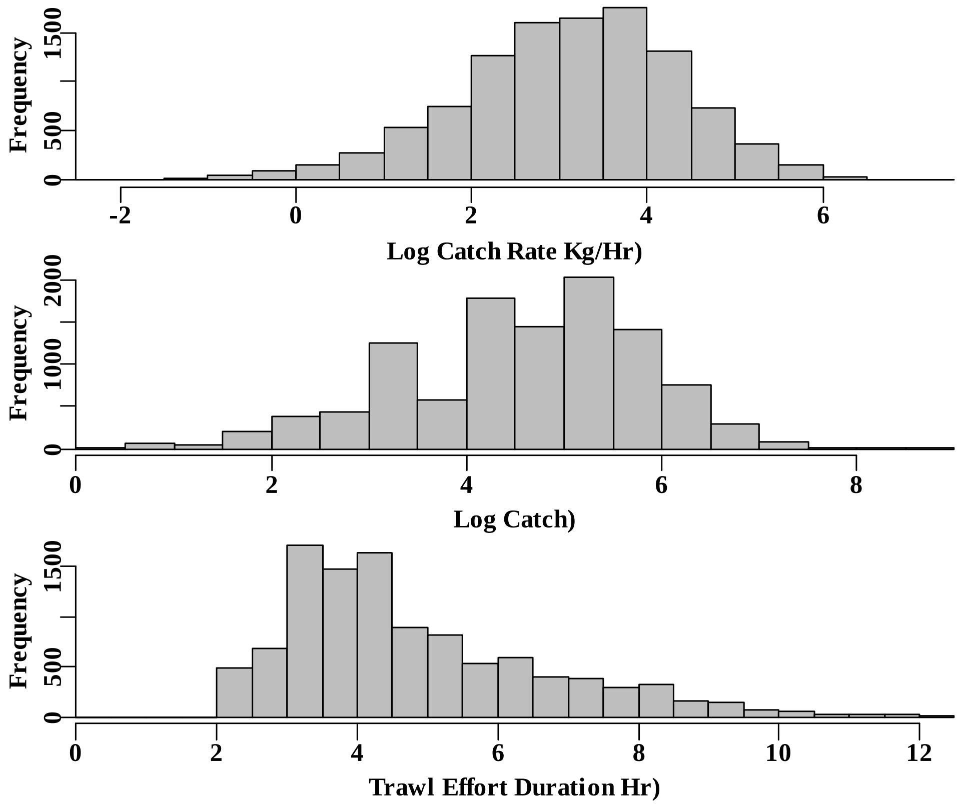


Figure 23.28. The frequency distribution of log-transformed catch rates when based on catches compared with those based on catch/effort, and the frequency distribution of effort. Effort is truncated at 2 hours as the RAG recommended that shorter tows would not be targeting deep water sharks. There were 17 records with trawl durations > 12.5 hours.

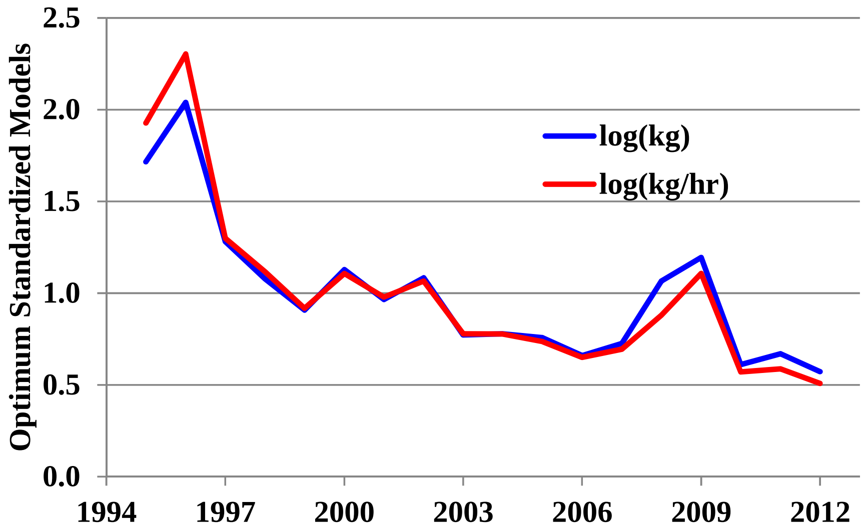


Figure 23.29. Comparison of the standardized catch rate series when based on log-transformed catches, log(kg), as used previously on RAG instructions, and those based on log-transformed catch/effort, log(kg.hr).

### *23.5.5.1 TIER 4 Eastern Deepwater Sharks*

The reference period relates to a relatively stable series of catches omitting the peak of catches in 1995 and 1996. Catches and catchrates are not halved as the fishery is considered to be well developed.

Table 23.46. CE are the catch rates (log(catch per tow) standardized to the mean of the series of catch rates GeoCE is the geometric mean catch rates from the raw data. Total is the total catch in the open areas. The discard estimate of 2.8% was used.

| Year | Catch | Total | CE | GeoCE | | |
|---|---|---|---|---|---|---|
| 1986 | 25.898 | 26.623 | | 45.111 | | |
| 1987 | 4.821 | 4.956 | | 26.456 | | |
| 1988 | 4.919 | 5.057 | | 45.312 | | |
| 1989 | 5.080 | 5.222 | | 37.910 | | |
| 1990 | 3.189 | 3.278 | | 42.032 | | |
| 1991 | 10.119 | 10.402 | | 62.171 | | |
| 1992 | 5.527 | 5.682 | | 120.583 | | |
| 1993 | 17.922 | 18.424 | | 132.886 | Ref_Year | 1997 |
| 1994 | 38.050 | 39.115 | | 130.137 | Ref_Year | 2004 |
| 1995 | 61.899 | 63.632 | 1.7150 | 179.615 | Except Yr | |
| 1996 | 260.404 | 267.695 | 2.0384 | 191.197 | CE_Targ | 0.9993 |
| 1997 | 135.947 | 139.754 | 1.2825 | 131.258 | CE_Lim | 0.3997 |
| 1998 | 170.931 | 175.717 | 1.0772 | 117.628 | CE_Recent | 0.7616 |
| 1999 | 128.817 | 132.424 | 0.9067 | 95.560 | Wt_Discard | NA |
| 2000 | 150.371 | 154.581 | 1.1290 | 124.127 | Scaling | 0.6035 |
| 2001 | 113.107 | 116.274 | 0.9648 | 86.377 | TAC | 70 |
| 2002 | 130.026 | 133.667 | 1.0839 | 102.917 | C*(target) | 128.696 |
| 2003 | 93.895 | 96.524 | 0.7714 | 76.461 | **RBC** | **77.662** |
| 2004 | 78.429 | 80.625 | 0.7792 | 79.814 | | |
| 2005 | 48.427 | 49.783 | 0.7565 | 74.410 | | |
| 2006 | 33.066 | 33.992 | 0.6593 | 51.361 | | |
| 2007 | 8.378 | 8.613 | 0.7251 | 43.938 | | |
| 2008 | 11.859 | 12.191 | 1.0649 | 65.755 | | |
| 2009 | 38.692 | 39.775 | 1.1942 | 81.789 | | |
| 2010 | 25.529 | 26.244 | 0.6099 | 48.906 | | |
| 2011 | 25.471 | 26.184 | 0.6697 | 56.150 | | |
| 2012 | 26.498 | 27.240 | 0.5724 | 46.199 | | |

Discards make up approximately 2.8% of the catch over the 1998-2006 period (Wayte and Fuller, 2008), but recent estimates are highly uncertain (Klaer et al, 2013).

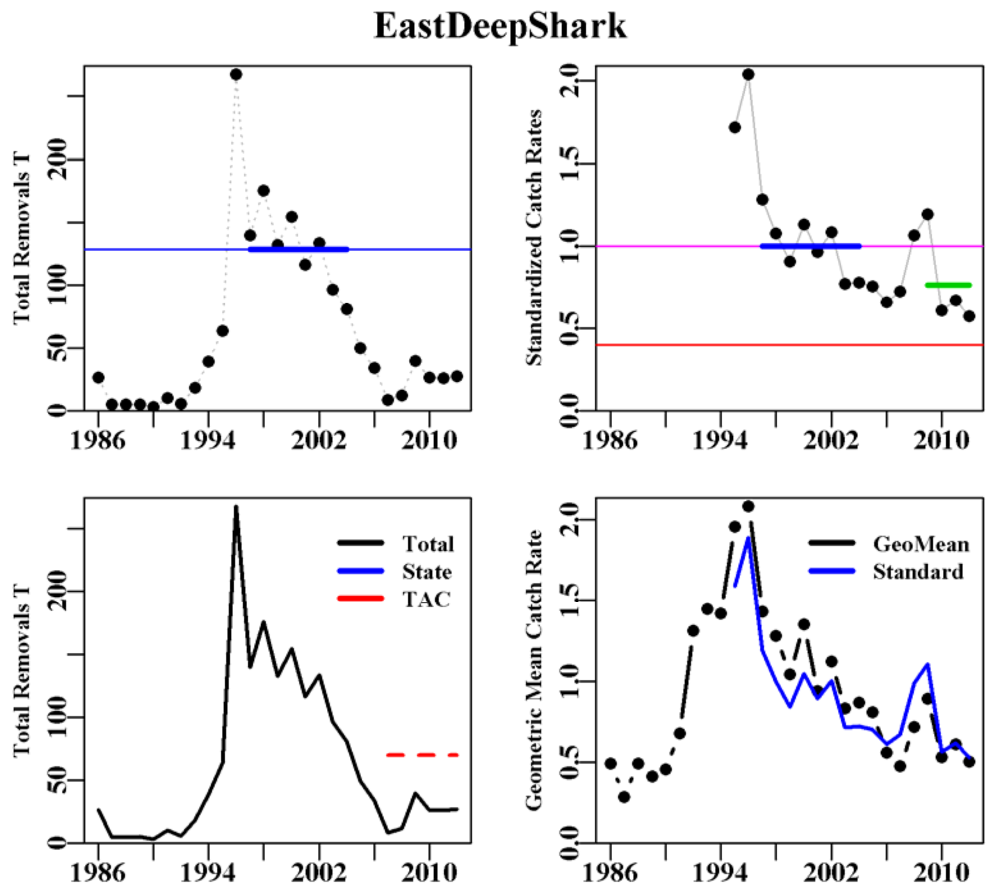


Figure 23.30. Eastern Deepwater Sharks. Top left is the total removals with the fine line illustrating the target catch. Top right represents the standardized catch rates with the upper fine line representing the target catch rate and the lower line the limit catch rate. Thickened lines represents the reference period for catches, catch rates, and the recent average catch rate. The geometric mean has been graphed on the same scale as the standardized catch rates to illustrate the effect of the standardization.

### *2.1.1 A Three Year RBC for Eastern Deepwater Sharks*

The SLOPE RAG in its November 2013 meeting decided that a three-year RBC was needed as well as the one-year RBC, which is the usual output from the Tier4 analysis. Given the apparently unusual catch rates from the east in 2008 and 2009 on both the east and west coasts it was decided to leave those out of the estimation of a three-year RBC and use, instead, the last three years of standardized CPUE and put that average through the usual Tier4 control rule.

Table 23.47. Application of average of last 3 years to produce RBC

| | |
|---|---|
| WestDeepShark | 1986-2012 |
| Ref_Year | 1997-2004 |
| CE_Targ | 0.9993 |
| CE_Lim | 0.3997 |
| CE_Recent | 0.6173 |
| Scaling | 0.3629 |
| TAC | 70 |
| C*(target) | 128.696 |
| 3-year RBC | 46.705 |

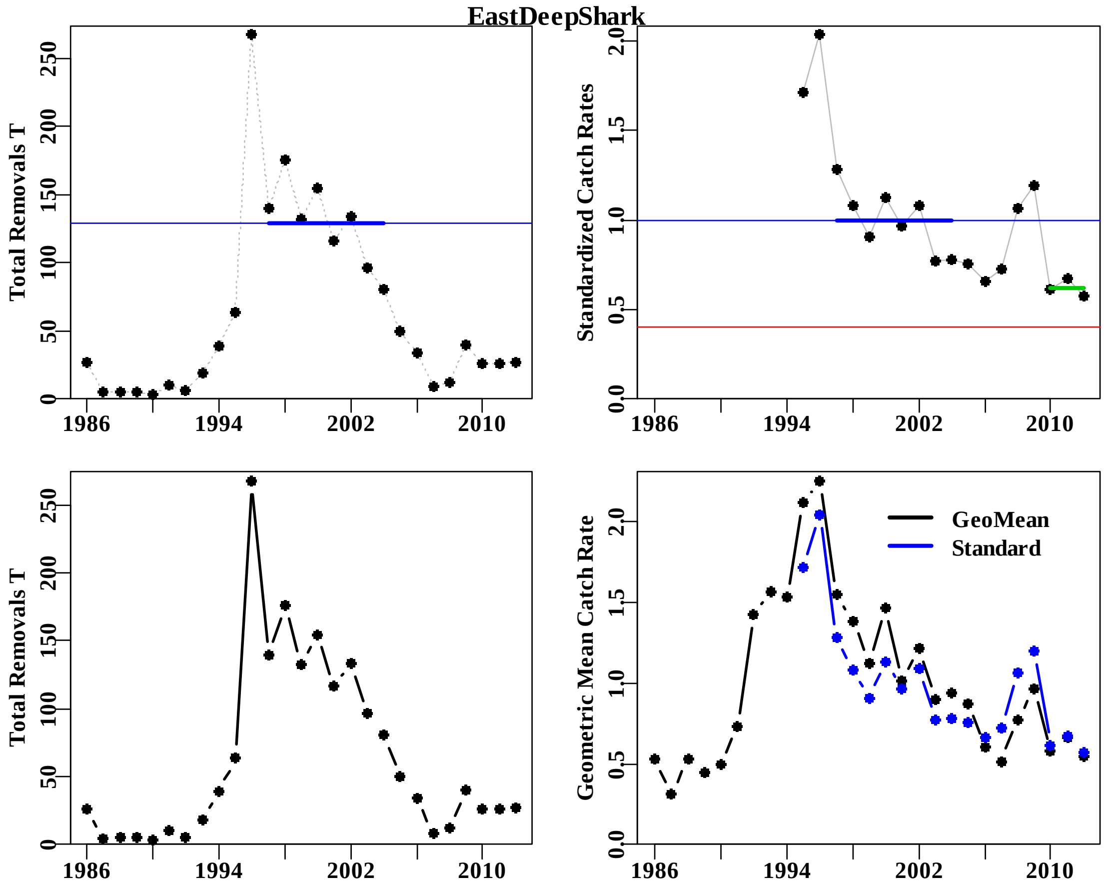


Figure 23.31. Eastern Deepwater Sharks. Top left is the total removals with the fine line illustrating the target catch. Top right represents the standardized catch rates with the upper fine line representing the target catch rate and the lower line the limit catch rate. Thickened lines represents the reference period for catches, catch rates, and the recent three year average catch rate (compare with the previous figure). The geometric mean has been graphed on the same scale as the standardized catch rates to illustrate the effect of the standardization.

### *23.5.6 Western Deepwater Sharks*

There are numerous species grouped together into the Deepwater Sharks (Table 23.48) but only some have data and even fewer have significant catches reported.

Table 23.48. 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 |

Discards make up approximately 2.8% of the catch over the 1998-2006 period (Wayte and Fuller, 2008), but recent estimates are highly uncertain (Klaer et al, 2013).

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.

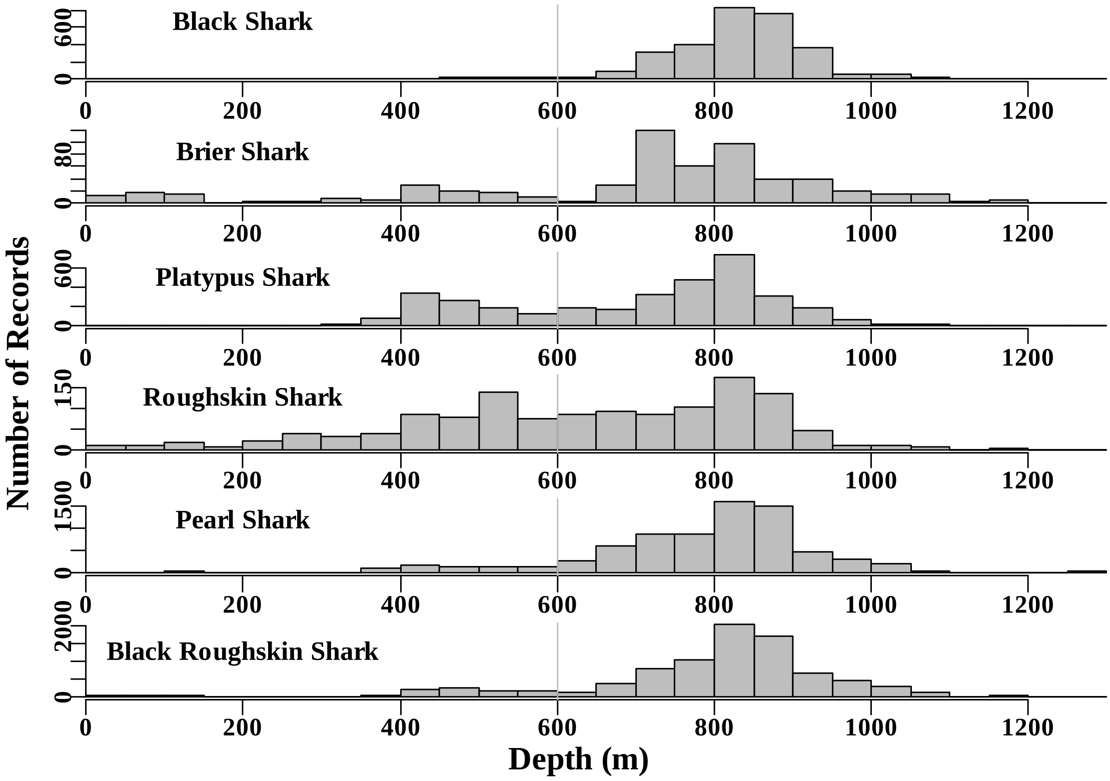


Figure 23.32. The depth distribution of the six main species with catches reported in the western deepwater shark fishery. The vertical line at 600 m illustrates the cut-off used in data selection.

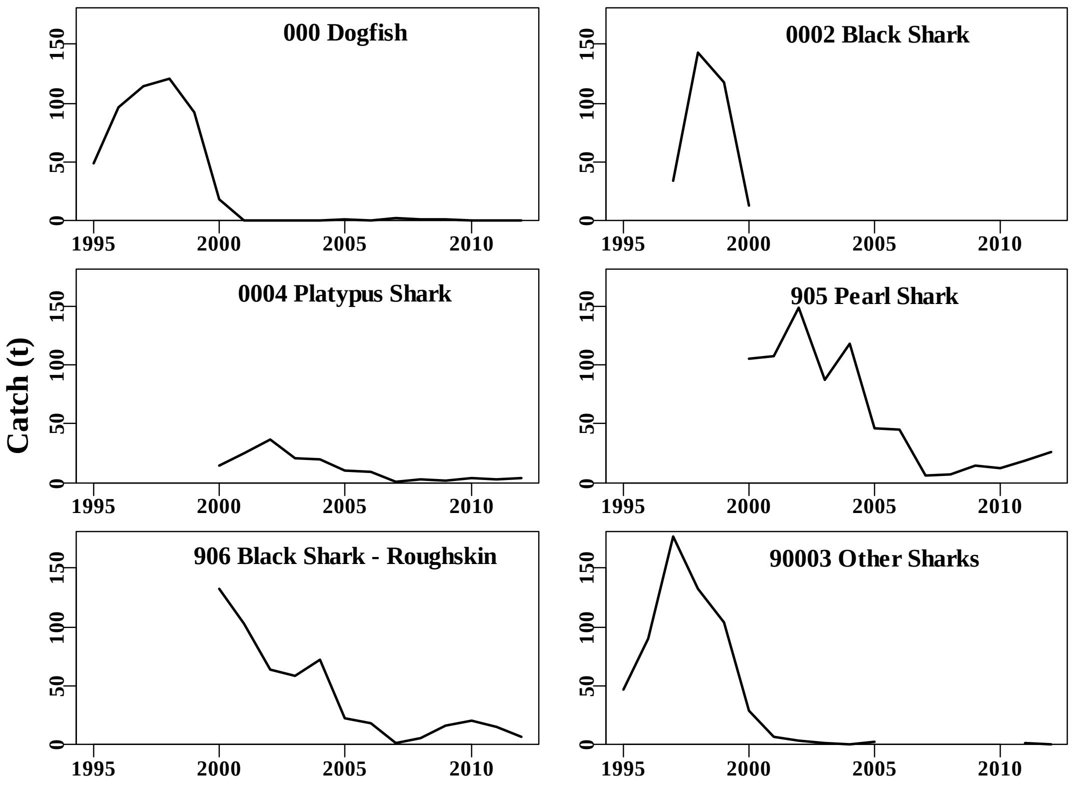


Figure 23.33. Western Deepwater Sharks catches broken down by species taken by trawling in OR Zone 30, in depths 600 to 1100 m for the years 1995 – 2012.

Table 23.49. 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.

| | |
|---|---|
| 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 23.50. Number of records where Western Deepwater Sharks are reported from trawling in OR Zone 30, in depths 600 to 1100 m. Vess represents the count of vessels reporting Deepwater Sharks. Yield is the total reported catch. The geometric mean CE is the raw unstandardized catch rate in Kg/tow. The left hand five columns represent all data, the right hand five columns represent the areas left open following the 700m closure. There appear to be captures in the closed areas because many vessels track the edge of the closures and the software is making category errors.

| Year | Yield | Records | Effort | Vessels | Geom | YieldO | RecordsO | EffortO | VesselsO | GeomO |
|---|---|---|---|---|---|---|---|---|---|---|
| 1986 | 1.030 | 14 | 56 | 3 | 54.016 | 0.600 | 8 | 31 | 3 | 50.148 |
| 1987 | 0.603 | 21 | 62 | 5 | 22.509 | 0.498 | 17 | 48 | 4 | 22.239 |
| 1988 | 0.525 | 4 | 11 | 2 | 122.474 | 0.100 | 1 | 2 | 1 | 100.000 |
| 1989 | 1.238 | 15 | 40 | 3 | 65.597 | 0.528 | 8 | 20 | 3 | 49.240 |
| 1990 | 0.314 | 5 | 13 | 4 | 34.822 | 0.250 | 4 | 13 | 3 | 29.907 |
| 1991 | 0.315 | 5 | 18 | 3 | 42.929 | 0.195 | 2 | 5 | 2 | 51.962 |
| 1992 | 3.600 | 21 | 94 | 4 | 128.049 | 3.460 | 19 | 86 | 4 | 137.919 |
| 1993 | 2.025 | 18 | 61 | 3 | 79.840 | 1.815 | 14 | 47 | 2 | 91.027 |
| 1994 | 1.612 | 23 | 128 | 4 | 55.626 | 0.572 | 9 | 43 | 3 | 57.241 |
| 1995 | 95.106 | 593 | 2929 | 10 | 93.596 | 52.021 | 314 | 1524 | 9 | 94.563 |
| 1996 | 186.252 | 956 | 4491 | 23 | 105.541 | 107.189 | 590 | 2702 | 18 | 105.814 |
| 1997 | 325.955 | 1975 | 10102 | 19 | 95.986 | 172.838 | 1161 | 5758 | 19 | 91.063 |
| 1998 | 396.667 | 2905 | 16202 | 18 | 88.170 | 176.847 | 1389 | 7402 | 18 | 82.178 |
| 1999 | 312.960 | 2212 | 12544 | 19 | 89.926 | 132.354 | 1102 | 6030 | 18 | 77.864 |
| 2000 | 311.679 | 1872 | 10454 | 17 | 111.018 | 134.953 | 887 | 4629 | 17 | 102.849 |
| 2001 | 242.052 | 1832 | 10384 | 19 | 84.155 | 112.239 | 951 | 5284 | 19 | 77.448 |
| 2002 | 251.392 | 1625 | 10161 | 17 | 98.832 | 126.044 | 835 | 5076 | 17 | 93.777 |
| 2003 | 166.630 | 1431 | 9008 | 16 | 73.359 | 83.051 | 745 | 4575 | 16 | 72.296 |
| 2004 | 209.774 | 1733 | 10870 | 15 | 78.244 | 110.708 | 894 | 5454 | 14 | 79.743 |
| 2005 | 82.725 | 818 | 4816 | 13 | 61.230 | 43.012 | 441 | 2540 | 12 | 57.434 |
| 2006 | 72.064 | 617 | 3806 | 12 | 70.529 | 42.429 | 360 | 2165 | 12 | 72.058 |
| 2007 | 8.612 | 112 | 682 | 9 | 38.108 | 6.987 | 94 | 553 | 9 | 38.533 |
| 2008 | 15.625 | 121 | 784 | 8 | 76.979 | 12.590 | 102 | 636 | 8 | 72.536 |
| 2009 | 34.072 | 233 | 1487 | 10 | 79.505 | 29.940 | 206 | 1313 | 9 | 76.737 |
| 2010 | 35.955 | 269 | 1625 | 10 | 69.046 | 35.955 | 269 | 1625 | 10 | 69.046 |
| 2011 | 37.807 | 305 | 2080 | 11 | 68.774 | 37.807 | 305 | 2080 | 11 | 68.774 |
| 2012 | 36.988 | 395 | 2581 | 10 | 55.495 | 36.988 | 395 | 2581 | 10 | 55.495 |

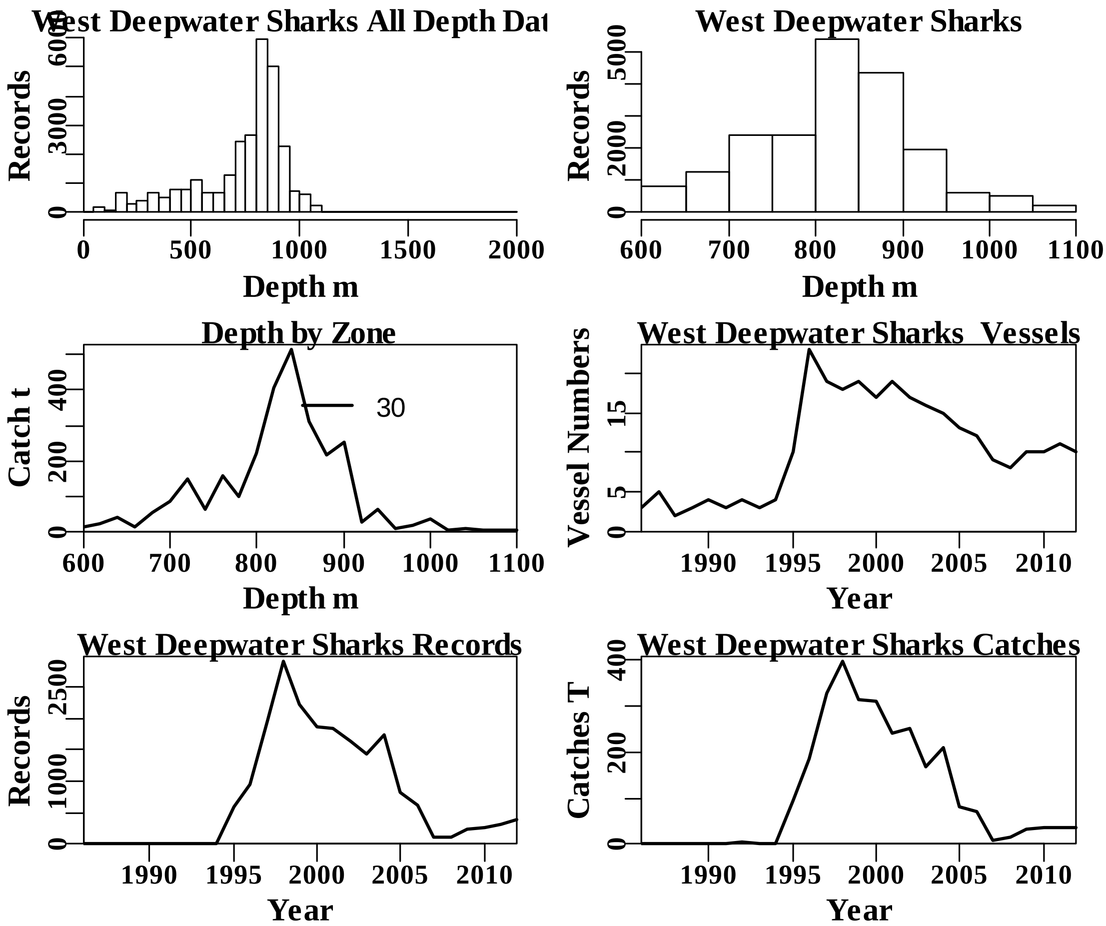


Figure 23.34. Western Deepwater Sharks reported from trawling in OR Zone 30, in depths 600 to 1100 m. The top left is the depth distribution of all records reporting Deepwater Sharks, the top right graph depicts the depth distribution of shots containing Deepwater Sharks in OR Zone 30, in depths 600 to 1100 m. The middle left diagram depicts the distribution of catch across all years by depth within separate OR zones (only catch from zone 30), the right hand middle graph depicts the number of vessels reporting Western Deepwater Sharks through time. The bottom left reflects the number of records for Deepwater Sharks, and bottom right are the Deepwater Shark catches used in the analysis.

Table 23.51. Model selection criteria, including the AIC, the residual sum of squares, the Model sum of squares, the number of usable observations, the number of parameters, the adjusted $r^2$ and the increment in adjusted $r^2$. Model 6 was optimal. The effect of being in the open or closed areas (Deep) was minor.

| | Year | DepCat | Vessel | Month | DayNight | deep | Vessel:Month |
|---|---|---|---|---|---|---|---|
| AIC | 1546 | -1044 | -2418 | -2594 | **-2609** | -2607 | -2350.51 |
| RSS | 21573 | 18812 | 17483 | 17310 | **17292** | 17291 | 16721.77 |
| MSS | 580 | 3341 | 4669 | 4842 | **4861** | 4861 | 5430.713 |
| Nobs | 20004 | 19910 | 19910 | 19910 | **19910** | 19910 | 19910 |
| Npars | 18 | 43 | 85 | 96 | **99** | 100 | 562 |
| adj_$r^2$ | 2.535 | 14.900 | 20.743 | 21.485 | **21.557** | 21.553 | 22.326 |
| $\Delta r^2$ | 0.000 | 12.366 | 5.843 | 0.741 | **0.072** | -0.003 | 0.773 |

Table 23.52. 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 5. 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 | 1.1690 | 1.1358 | 1.1434 | 1.1793 | **1.1799** | 1.1792 | 1.1811 | 0.0000 |
| 1996 | 1.3202 | 1.2681 | 1.4530 | 1.4310 | **1.4309** | 1.4300 | 1.4832 | 0.0508 |
| 1997 | 1.2003 | 1.0973 | 1.1591 | 1.1564 | **1.1567** | 1.1560 | 1.1563 | 0.0461 |
| 1998 | 1.1025 | 0.9214 | 0.9377 | 0.9213 | **0.9235** | 0.9227 | 0.9002 | 0.0448 |
| 1999 | 1.1245 | 0.8978 | 0.9498 | 0.9472 | **0.9473** | 0.9466 | 0.9239 | 0.0460 |
| 2000 | 1.3883 | 1.0769 | 1.1657 | 1.1488 | **1.1487** | 1.1478 | 1.1315 | 0.0468 |
| 2001 | 1.0524 | 0.8552 | 0.9132 | 0.9150 | **0.9153** | 0.9148 | 0.9102 | 0.0470 |
| 2002 | 1.2360 | 1.0403 | 1.0516 | 1.0531 | **1.0539** | 1.0536 | 1.0419 | 0.0474 |
| 2003 | 0.9174 | 0.7839 | 0.7788 | 0.7823 | **0.7835** | 0.7830 | 0.7865 | 0.0480 |
| 2004 | 0.9785 | 0.7812 | 0.8024 | 0.8003 | **0.7988** | 0.7985 | 0.7960 | 0.0474 |
| 2005 | 0.7660 | 0.6825 | 0.6728 | 0.6554 | **0.6552** | 0.6550 | 0.6571 | 0.0528 |
| 2006 | 0.8825 | 0.8292 | 0.9011 | 0.8888 | **0.8900** | 0.8898 | 0.8756 | 0.0573 |
| 2007 | 0.4787 | 0.8505 | 0.8745 | 0.8731 | **0.8793** | 0.8793 | 0.9074 | 0.1008 |
| 2008 | 0.9667 | 1.6474 | 1.3892 | 1.4126 | **1.4153** | 1.4154 | 1.3869 | 0.0973 |
| 2009 | 0.9962 | 1.3917 | 1.2411 | 1.2384 | **1.2315** | 1.2327 | 1.2319 | 0.0753 |
| 2010 | 0.8649 | 1.0418 | 0.9354 | 0.9521 | **0.9515** | 0.9534 | 0.9525 | 0.0721 |
| 2011 | 0.8613 | 1.0333 | 0.9024 | 0.9060 | **0.9015** | 0.9034 | 0.9089 | 0.0684 |
| 2012 | 0.6947 | 0.6658 | 0.7288 | 0.7391 | **0.7373** | 0.7389 | 0.7691 | 0.0726 |

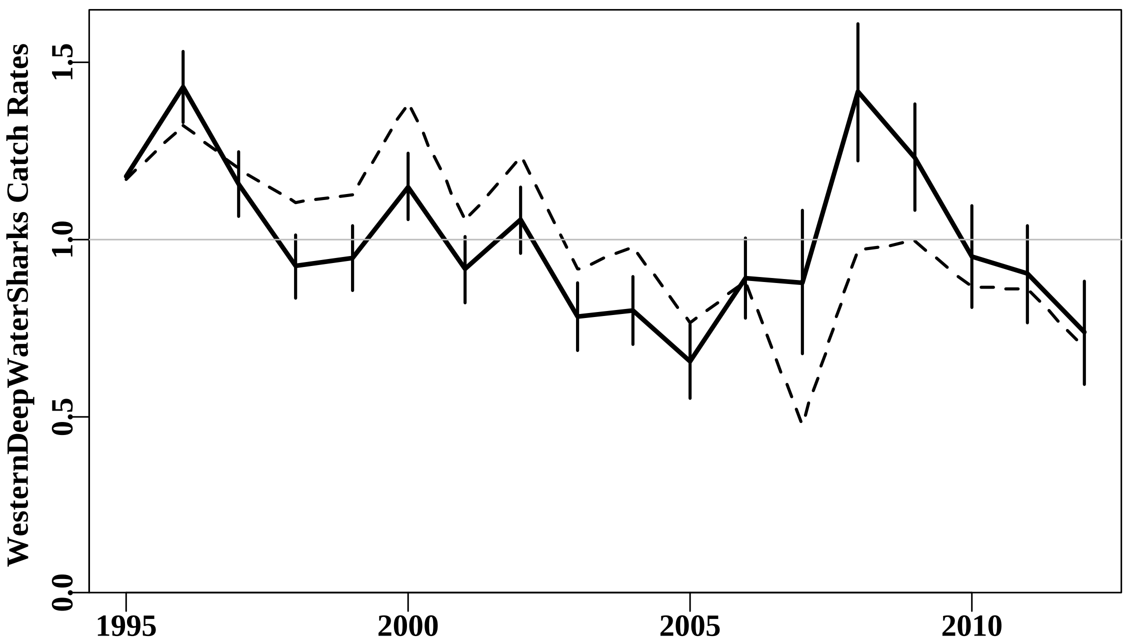


Figure 23.35. Western Deepwater Sharks reported from trawling in OR Zone 30, in depths 600 to 1100 m. The black dashed line from 95-12 represents the geometric mean catch rate and the solid black line the optimum standardized catch rates (Model 5). The graph standardizes catch rates relative to the mean of the standardized catch rates, represented by the horizontal fine grey line.

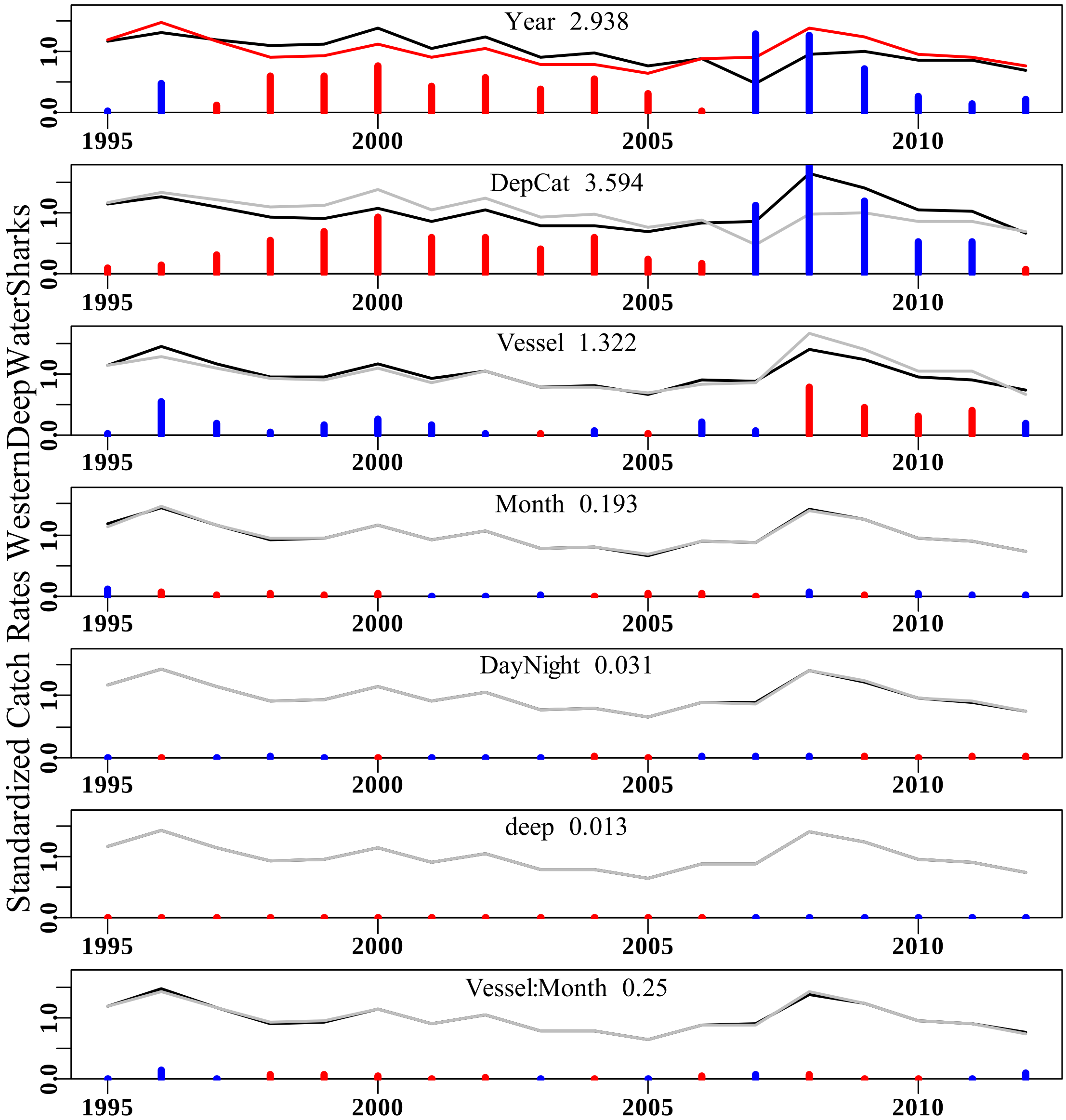


Figure 23.36. The relative impact of the different factors on the changes in the standardized trend. The major effects of both the structural adjustment, with its change of vessels, and the deepwater closures is clear.

### *23.5.6.1 TIER 4 Western Deepwater Sharks*

The reference period relates to a relatively stable series of catches omitting the peak of catches in 1995 and 1996. Catch rates are halved as the fishery is considered only to have begun in 1995.

Table 23.53. CE are the catch rates (log(catch per tow) standardized to the mean of the series of catch rates GeoCE is the geometric mean catch rates from the raw data. Total is the total catch in the open areas. The discard estimate is 0.0%.

| Year | Catch | Total | CE | GeoCE | | |
|---|---|---|---|---|---|---|
| 1986 | 0.600 | 0.600 | | 50.148 | | |
| 1987 | 0.498 | 0.498 | | 22.239 | | |
| 1988 | 0.100 | 0.100 | | 100.000 | | |
| 1989 | 0.528 | 0.528 | | 49.240 | | |
| 1990 | 0.250 | 0.250 | | 29.907 | | |
| 1991 | 0.195 | 0.195 | | 51.962 | | |
| 1992 | 3.460 | 3.460 | | 137.919 | | |
| 1993 | 1.815 | 1.815 | | 91.027 | Ref_Year | 1997 |
| 1994 | 0.572 | 0.572 | | 57.241 | Ref_Year | 2004 |
| 1995 | 52.021 | 52.021 | 1.1799 | 94.563 | Except Yr | |
| 1996 | 107.189 | 107.189 | 1.4309 | 105.814 | CE_Targ | 0.5169 |
| 1997 | 172.838 | 172.838 | 1.1567 | 91.063 | CE_Lim | 0.2068 |
| 1998 | 176.847 | 176.847 | 0.9235 | 82.178 | CE_Recent | 0.9554 |
| 1999 | 132.354 | 132.354 | 0.9473 | 77.864 | Wt_Discard | |
| 2000 | 134.953 | 134.953 | 1.1487 | 102.849 | Scaling | 2.4139 |
| 2001 | 112.239 | 112.239 | 0.9153 | 77.448 | TAC | 215 |
| 2002 | 126.044 | 126.044 | 1.0539 | 93.777 | C*(target) | 124.207 |
| 2003 | 83.051 | 83.051 | 0.7835 | 72.296 | **RBC** | **299.823** |
| 2004 | 110.708 | 110.708 | 0.7988 | 79.743 | | |
| 2005 | 43.012 | 43.012 | 0.6552 | 57.434 | | |
| 2006 | 42.429 | 42.429 | 0.8900 | 72.058 | | |
| 2007 | 6.987 | 6.987 | 0.8793 | 38.533 | | |
| 2008 | 12.590 | 12.590 | 1.4153 | 72.536 | | |
| 2009 | 29.940 | 29.940 | 1.2315 | 76.737 | | |
| 2010 | 35.955 | 35.955 | 0.9515 | 69.046 | | |
| 2011 | 37.807 | 37.807 | 0.9015 | 68.774 | | |
| 2012 | 36.988 | 36.988 | 0.7373 | 55.495 | | |

Discards make up approximately 2.8% of the catch over the 1998-2006 period (Wayte and Fuller, 2008), but recent estimates are highly uncertain (Klaer et al, 2013).

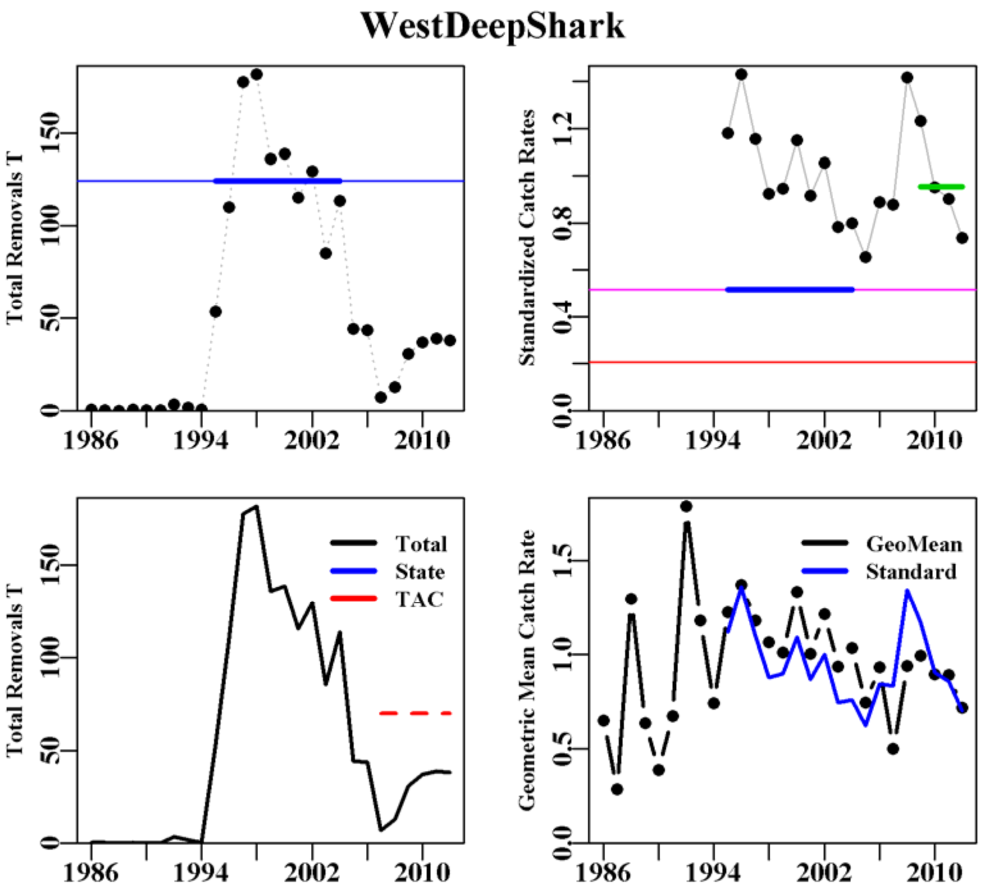


Figure 23.37. Western Deepwater Sharks. Top left is the total removals with the fine line illustrating the target catch. Top right represents the standardized catch rates with the upper fine line representing the target catch rate and the lower line the limit catch rate. Thickened lines represents the reference period for catches, catch rates, and the recent average catch rate. The geometric mean has been graphed on the same scale as the standardized catch rates to illustrate the effect of the standardization.

### *23.5.6.2 A Three Year RBC for Western Deepwater Sharks*

The SLOPE RAG in its November 2013 meeting decided that a three-year RBC was needed as well as the one-year RBC, which is the usual output from the Tier4 analysis. Given the apparently unusual catch rates from the east in 2008 and 2009 on both the east and west coasts it was decided to leave those out of the estimation of a three-year RBC and use, instead, the last three years of standardized CPUE and put that average through the usual Tier4 control rule.

Table 23.54. Application of average of last 3 years to produce RBC

| | |
|---:|---:|
| WestDeepShark | 1986-2012 |
| Ref_Year | 1995-2004 |
| CE_Targ | 0.5169 |
| CE_Lim | 0.2068 |
| CE_Recent | 0.8634 |
| Scaling | 2.1172 |
| TAC | 70 |
| C*(target) | 124.207 |
| 3-year RBC | 262.973 |

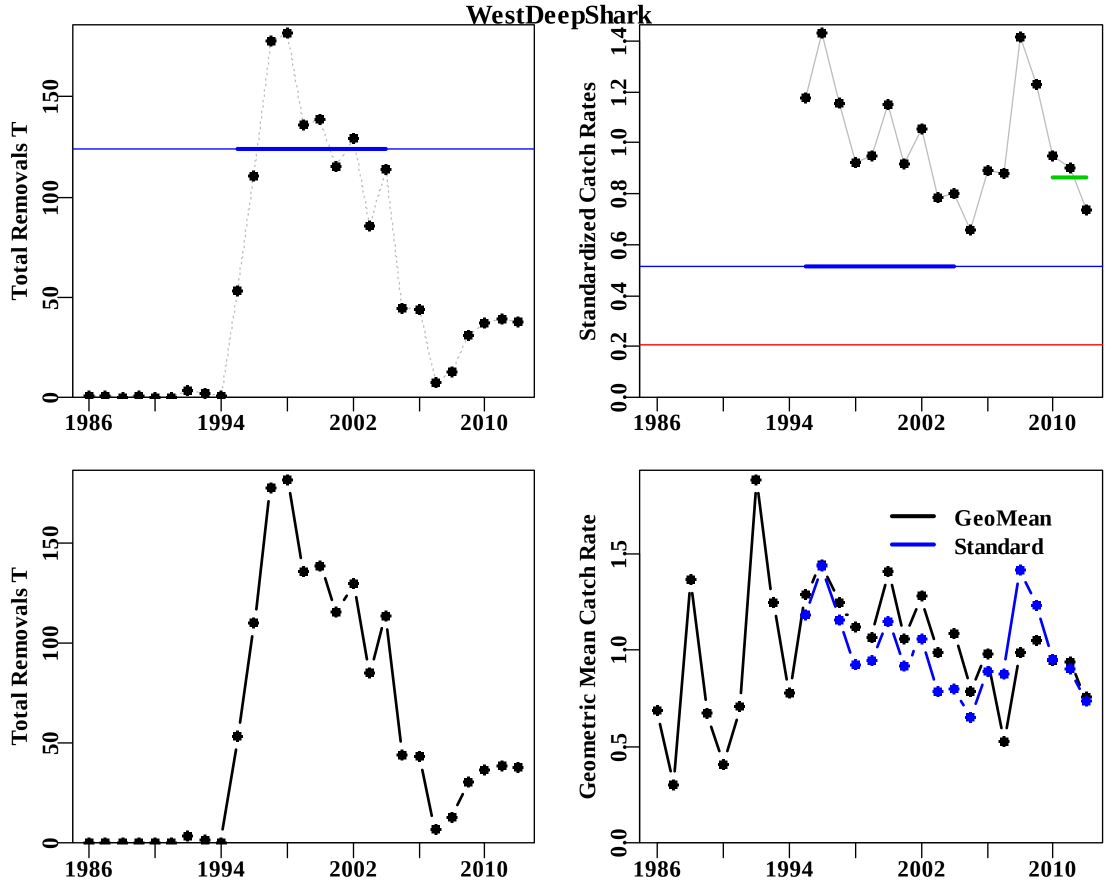


Figure 23.38. Western Deepwater Sharks. Top left is the total removals with the fine line illustrating the target catch. Top right represents the standardized catch rates with the upper fine line representing the target catch rate and the lower line the limit catch rate. Thickened lines represents the reference period for catches, catch rates, and the recent three year average catch rate (compare with the previous figure). The geometric mean has been graphed on the same scale as the standardized catch rates to illustrate the effect of the standardization.

### *23.5.7 Alfonsino (ALF – 37258002)*

There were no reported catches of Alfonsino in the East Coast Deepwater fishery in 2006, 2008, and 2010, but there were catches reported in 2011 and 2012 so the analysis conducted in 2011 (Haddon, 2012b) was updated. However, there was only a single vessel active and the information remained sparse so the resulting catchrates are highly uncertain and still cannot be used to conduct a Tier 4 analysis (Figure 23.39). Once again summary information is provided instead to allow discussion.

The SESSF is made up of the Commonwealth trawl sector, the Great Australian Bight Sector, the East Coast Deepwater Trawl sector, and the Gillnet, Hook and Trap sector. Currently the Tier 4 analysis focuses on the East Coast Deepwater trawl fishery but it should include the South east Trawl fishery and the GAB. Currently there are only intermittent reported catches of Alfonsino in the ECD, so no Tier 4 analysis can proceed, but the TAC set (via a Tier 3 analysis) is applicable to the SET and the ECD. If a Tier 4 analysis were to be used, strictly it should include catches taken in each of these jurisdictions. However, with the gaps in catches and the variation in this fishery the application of a Tier 4 analysis would be difficult.

Table 23.55. Reported catches of Alfonsino by method. AL – autoline, BL – Bottom Line, DL – Drop Line, DS – Danish Seine, FP - , GN – Gill net, LL – Long Line, RR - , TL – Trot Line, and TW – trawl.

| Year | Unknown | AL | BL | DL | DS | FP | GN | HL | RR | TL | TW |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1988 | | | | | | | | | | | 0.538 |
| 1989 | | | | | | | | | | | 2.578 |
| 1990 | | | | | | | | | | | 3.644 |
| 1991 | 0.050 | | | | | | | | | | 5.652 |
| 1992 | 0.497 | | | | 0.350 | | | | | | 17.787 |
| 1993 | | | | | | | | | | | 5.071 |
| 1994 | | | | | | | | | | | 15.172 |
| 1995 | | | | | | | | | | | 8.589 |
| 1996 | | | | | | | | | | | 12.427 |
| 1997 | | | 0.034 | 0.728 | | 0.030 | 2.431 | | | 0.200 | 7.546 |
| 1998 | | | | 1.063 | | | 0.955 | | | | 3.427 |
| 1999 | 0.060 | | | 1.665 | | 0.010 | 1.549 | | | | 13.300 |
| 2000 | 0.030 | | | 1.291 | | 0.006 | 2.792 | | | | 105.968 |
| 2001 | 6.300 | 0.190 | | 0.741 | | | 2.324 | | | | 313.277 |
| 2002 | | 0.984 | | 0.954 | | | 0.116 | | | | 135.040 |
| 2003 | | 1.603 | | 0.522 | | | 0.096 | | | | 205.845 |
| 2004 | | 2.959 | 0.290 | 0.358 | | | | | | | 539.723 |
| 2005 | | 3.300 | | 0.266 | | | | | | | 224.738 |
| 2006 | | 2.835 | | 0.226 | | | | | | | 227.046 |
| 2007 | | 3.026 | | 0.042 | 0.004 | | 0.001 | | | | 341.359 |
| 2008 | | 3.039 | | 0.091 | | | 0.001 | | | | 118.735 |
| 2009 | | 4.990 | | 0.104 | 0.002 | | | | 0.001 | | 110.193 |
| 2010 | | 1.866 | | 0.151 | | | | | 0.009 | | 88.292 |
| 2011 | | 2.183 | | 0.386 | 0.008 | | 0.010 | | 0.044 | | 297.758 |
| 2012 | | 2.771 | 0.005 | 0.174 | | | 0.005 | 0.003 | 0.068 | | 390.789 |

While the obvious hotspots are in the ECD, there are catches taken in the SET. There are very low catches spread widely although there do appear to be relative hot spots, the same order of magnitude as in the ECD) one off Eddystone point on the East Coast of Tasmania and one south of the Tasman Peninsula. There is another, somewhat smaller spot, off Macquarie Harbour on the west coast of Tasmania and another spot off Robe or Cape Jaffa in western Victoria.

Table 23.56. Catch of Alfonsino taken by trawl in the different fisheries. CSF – Coral Sea Fishery, ECD – East Coast Deepwater, GAB – Great Australian Bight, GHT – Gillnet, Hook, and Trap (include the Southeast Non-Trawl, and Southern Shark Fishery), HST – High Seas Trawl, SET – South East Trawl, and WDW – Western Deepwater. Currently no attention is paid to the catches other than in the ECD.

| | CSF | ECD | GAB | GHT | HST | SET | WDW |
|---|---|---|---|---|---|---|---|
| 1988 | | | | | | 0.538 | |
| 1989 | | | 0.276 | | | 2.302 | |
| 1990 | | | 0.010 | | | 3.634 | |
| 1991 | | | | | | 5.702 | |
| 1992 | | | | | | 18.634 | |
| 1993 | | | | | | 5.071 | |
| 1994 | | | | | | 7.792 | 7.380 |
| 1995 | | | | | | 8.423 | 0.166 |
| 1996 | | | | | | 12.427 | |
| 1997 | | | | 3.423 | | 7.530 | 0.016 |
| 1998 | 0.010 | | | 2.008 | | 3.427 | |
| 1999 | | | | 3.224 | | 13.360 | |
| 2000 | | 66.950 | | 4.089 | | 36.338 | 2.710 |
| 2001 | | 313.171 | 0.827 | 3.255 | | 5.579 | |
| 2002 | 63.820 | 42.036 | 0.270 | 1.794 | 3.993 | 25.181 | |
| 2003 | 58.666 | 140.771 | 0.025 | 2.195 | 0.236 | 6.173 | |
| 2004 | 14.803 | 509.466 | 0.032 | 2.968 | | 16.062 | |
| 2005 | | 136.050 | 0.039 | 3.566 | 80.124 | 8.525 | |
| 2006 | 14.091 | | 0.320 | 3.039 | 201.397 | 11.239 | |
| 2007 | 55.582 | 85.397 | 1.609 | 3.069 | 86.264 | 112.512 | |
| 2008 | | | 0.170 | 3.131 | | 118.545 | 0.020 |
| 2009 | | 14.156 | 1.657 | 5.085 | | 94.382 | |
| 2010 | | | 1.073 | 2.025 | | 87.219 | |
| 2011 | 0.650 | 147.500 | 0.038 | 1.731 | 62.863 | 87.365 | |
| 2012 | 0.904 | 143.871 | | 2.057 | 184.976 | 61.941 | |

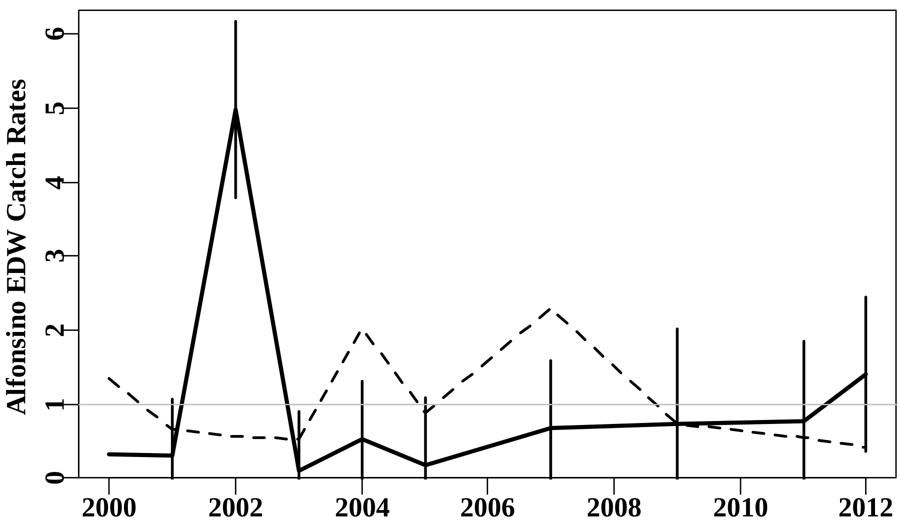


Figure 23.39. The scaled, standardized catch rate time series for Alfonsino from the East Coast Deep Water Trawl fishery. There were no reported catches in 2006, 2008, or 2010, hence the missing confidence bounds.

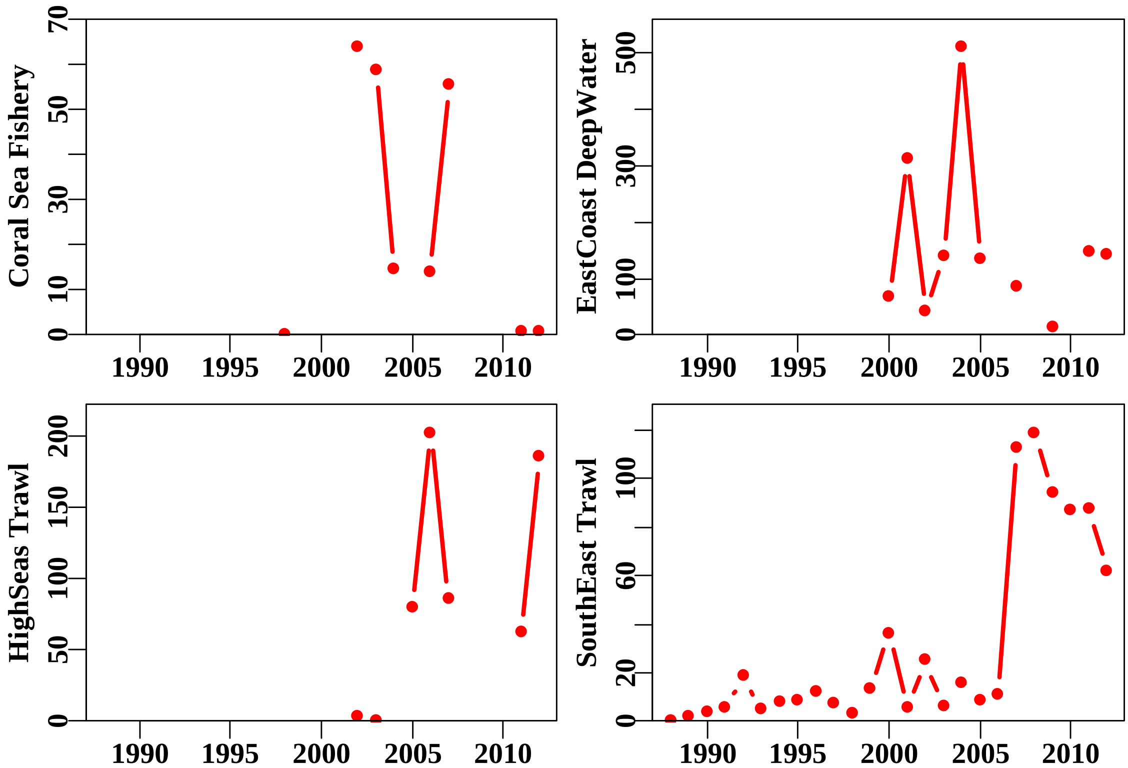

Figure 23.40. The relative catch in four of the fisheries listed in Table 23.56. Note the different scales in the different fisheries. To indicate isolated years of reported catches points are added to the graphs.

## 23.6 Non-Tier 4 Species

### 23.6.1 Blue Grenadier (GRE – 37227001 – *Macruronus novaezelandiae*)

Table 23.57. Blue Grenadier 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 the non-spawning fishery (Haddon, 2013). 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 | Non-T | PDiscard | CE | GeoMean |
|---|---|---|---|---|---|---|---|---|
| 1986 | 1408.800 | 86.672 | 1495.472 | | | 5.7956 | 1.5053 | 36.7375 |
| 1987 | 2197.200 | 135.176 | 2332.376 | | | 5.7956 | 1.9781 | 37.3307 |
| 1988 | 1760.400 | 108.303 | 1868.703 | | | 5.7956 | 2.1430 | 36.6778 |
| 1989 | 1798.800 | 110.665 | 1909.465 | | | 5.7956 | 2.2189 | 45.3866 |
| 1990 | 2433.600 | 149.719 | 2583.319 | | | 5.7956 | 2.1902 | 47.9497 |
| 1991 | 3812.400 | 234.546 | 4046.946 | | | 5.7956 | 1.5761 | 48.2874 |
| 1992 | 3338.400 | 205.384 | 3543.784 | | | 5.7956 | 1.2980 | 40.5408 |
| 1993 | 3412.800 | 209.961 | 3622.761 | | | 5.7956 | 0.9795 | 33.2638 |
| 1994 | 3282.698 | 0.000 | 3282.698 | 126.682 | 0.000 | 0.0000 | 0.8805 | 29.5414 |
| 1995 | 2814.169 | 0.000 | 2814.169 | 51.541 | 0.000 | 0.0000 | 0.6073 | 19.4025 |
| 1996 | 3104.762 | 0.000 | 3104.762 | 40.338 | 0.000 | 0.0000 | 0.5537 | 15.8910 |
| 1997 | 4571.003 | 0.000 | 4571.003 | 17.700 | 0.000 | 0.0000 | 0.5734 | 13.3293 |
| 1998 | 5772.808 | 2959.000 | 8731.808 | 11.941 | 0.000 | 33.8876 | 0.9410 | 18.8682 |
| 1999 | 9378.626 | 140.000 | 9518.626 | 8.359 | 0.000 | 1.4708 | 0.9948 | 22.7820 |
| 2000 | 8661.650 | 129.000 | 8790.650 | 0.599 | 0.000 | 1.4675 | 0.7095 | 16.8751 |
| 2001 | 9156.253 | 1.000 | 9157.253 | 0.469 | 3.684 | 0.0109 | 0.4060 | 11.4735 |
| 2002 | 9164.857 | 5.270 | 9170.127 | 0.011 | 3.808 | 0.0575 | 0.4074 | 13.3454 |
| 2003 | 8503.752 | 9.810 | 8513.562 | 0.057 | 8.925 | 0.1152 | 0.3407 | 10.1345 |
| 2004 | 6619.154 | 27.190 | 6646.344 | 0.042 | 9.878 | 0.4091 | 0.5734 | 16.9690 |
| 2005 | 4714.040 | 526.640 | 5240.680 | 0.075 | 10.222 | 10.0491 | 0.6857 | 19.8341 |
| 2006 | 3769.512 | 246.570 | 4016.082 | 0.076 | 11.436 | 6.1396 | 0.9109 | 26.9839 |
| 2007 | 3258.143 | 64.615 | 3322.758 | 0.149 | 8.015 | 1.9446 | 0.8113 | 25.1832 |
| 2008 | 3940.598 | 42.020 | 3982.618 | 0.033 | 6.285 | 1.0551 | 0.8895 | 28.8353 |
| 2009 | 3269.116 | 66.608 | 3335.723 | 0.075 | 9.655 | 1.9968 | 0.8260 | 25.9256 |
| 2010 | 4200.531 | 20.037 | 4220.568 | 0.147 | 9.545 | 0.4747 | 0.8097 | 25.9279 |
| 2011 | 2820.365 | 1022.369 | 3842.734 | 0.147 | 5.924 | 26.6053 | 0.6567 | 19.3008 |
| 2012 | 2821.365 | 298.550 | 3119.915 | 0.147 | 3.586 | 9.5692 | 0.5333 | 15.0049 |

Discards make up approximately 5.9 % of the catch over the 1998-2006 period. NOTE: Actual landings in 2011 were in fact 4201.400 t rather than 2820 t, the source of this error is still being investigated. However, had this been used in a full Tier 4 it would not have influenced the result because the RBC depends on catch rates and the target catch not the current catch.

Table 23.58. RBC calculations for Blue Grenadier. Ctarg and CPUEtarg relate to the period 1986-1995, CPUELim is 40% of the target, 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 (19).

| | |
|---|---|
| Ref_Year | 1986-1995 |
| CE_Targ | 1.5377 |
| CE_Lim | 0.6151 |
| CE_Recent | 0.7064 |
| Wt_Discard | 438.971 |
| Scaling | 0.099 |
| Last Year's TAC | 4700 |
| $C_{targ}$ | 2749.969 |

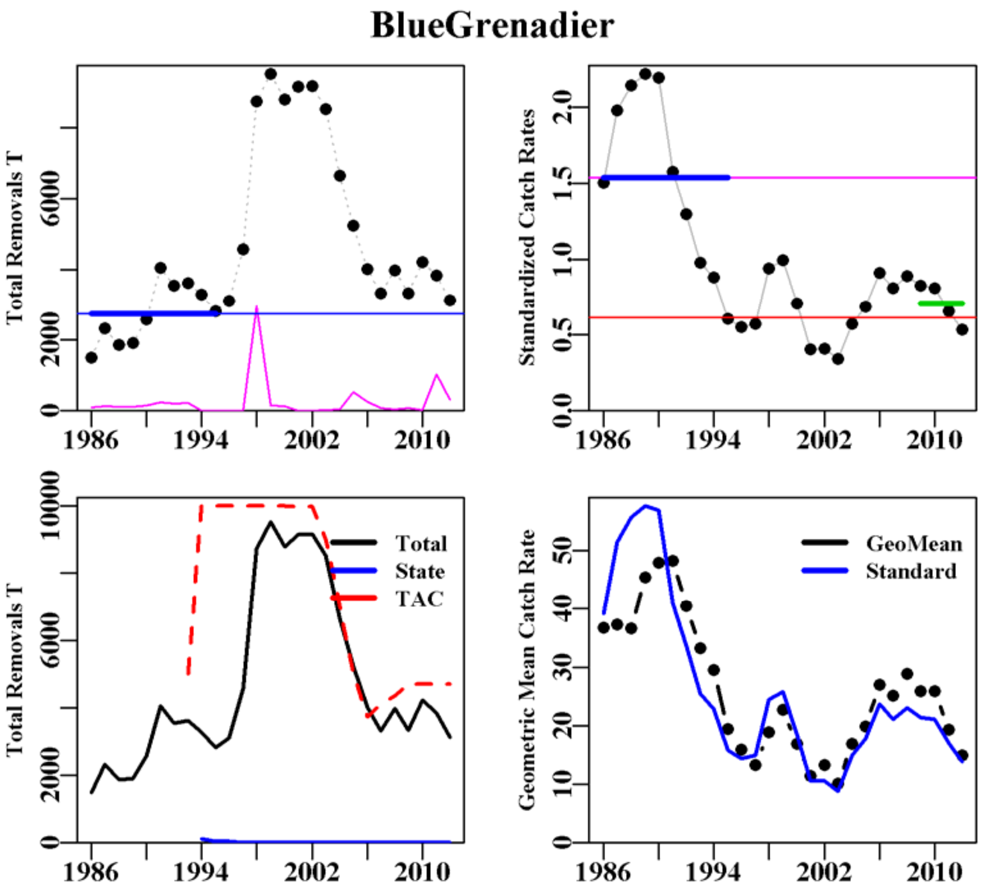


Figure 23.41. Blue Grenadier. Top left is the total removals with the fine line illustrating the target catch. Top right represents the standardized catch rates with the upper fine line representing the target catch rate and the lower line the limit catch rate. Thickened lines represents the reference period for catches, catch rates, and the recent average catch rate.

### *23.6.2 Flathead (FLT – 37296001 – Neoplatycephalus richardsoni)*

Table 23.59. Tiger Flathead 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 otter trawl for Zones 10 and 20 in depths 0 – 400m (Haddon, 2013).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 | Non-T | PDiscard | CE | GeoMean |
|---|---|---|---|---|---|---|---|---|
| 1986 | 2133.600 | 158.670 | 2292.270 | | | 6.9219 | 0.7988 | 16.7357 |
| 1987 | 2496.000 | 185.620 | 2681.620 | | | 6.9219 | 1.0669 | 20.4621 |
| 1988 | 2444.400 | 181.783 | 2626.183 | | | 6.9219 | 1.1668 | 23.7988 |
| 1989 | 2623.200 | 195.080 | 2818.280 | | | 6.9219 | 1.1636 | 23.9908 |
| 1990 | 2188.800 | 162.775 | 2351.575 | | | 6.9219 | 1.3835 | 30.1854 |
| 1991 | 2620.800 | 194.901 | 2815.701 | | | 6.9219 | 1.3128 | 28.7154 |
| 1992 | 3564.000 | 265.045 | 3829.044 | | | 6.9219 | 1.0246 | 23.8898 |
| 1993 | 3132.000 | 232.918 | 3364.918 | | | 6.9219 | 1.0470 | 23.8001 |
| 1994 | 2786.959 | 0.000 | 2786.959 | 836.206 | 0.000 | 0.0000 | 0.7592 | 17.9798 |
| 1995 | 2735.929 | 0.000 | 2735.929 | 697.065 | 0.000 | 0.0000 | 0.8038 | 18.0790 |
| 1996 | 2725.609 | 0.000 | 2725.609 | 610.327 | 0.000 | 0.0000 | 0.7163 | 16.4549 |
| 1997 | 3093.299 | 0.000 | 3093.299 | 419.555 | 0.000 | 0.0000 | 0.7162 | 16.8264 |
| 1998 | 2933.991 | 291.000 | 3224.991 | 229.097 | 0.000 | 9.0233 | 0.7588 | 17.7430 |
| 1999 | 3729.333 | 267.000 | 3996.333 | 218.125 | 0.000 | 6.6811 | 0.9137 | 20.4344 |
| 2000 | 3427.408 | 511.000 | 3938.408 | 191.666 | 0.000 | 12.9748 | 1.0085 | 24.4338 |
| 2001 | 2992.436 | 160.000 | 3152.436 | 130.592 | 0.281 | 5.0754 | 0.9704 | 22.3118 |
| 2002 | 3272.572 | 193.970 | 3466.542 | 116.084 | 0.337 | 5.5955 | 1.0586 | 22.8273 |
| 2003 | 3670.170 | 178.030 | 3848.200 | 174.049 | 0.809 | 4.6263 | 1.0439 | 22.5536 |
| 2004 | 3596.871 | 228.380 | 3825.251 | 207.723 | 0.858 | 5.9703 | 0.9029 | 19.7879 |
| 2005 | 3295.823 | 195.140 | 3490.963 | 291.601 | 1.145 | 5.5899 | 0.7712 | 17.7159 |
| 2006 | 3017.332 | 201.730 | 3219.062 | 318.879 | 0.607 | 6.2667 | 0.9342 | 22.2550 |
| 2007 | 3052.284 | 278.562 | 3330.847 | 179.821 | 0.486 | 8.3631 | 1.1350 | 31.3544 |
| 2008 | 3446.847 | 43.736 | 3490.582 | 248.606 | 0.362 | 1.2530 | 1.1909 | 31.6602 |
| 2009 | 2925.235 | 155.881 | 3081.116 | 242.782 | 0.403 | 5.0592 | 1.0952 | 30.0219 |
| 2010 | 2989.871 | 250.874 | 3240.744 | 262.513 | 0.297 | 7.7412 | 1.0558 | 29.4565 |
| 2011 | 2946.378 | 504.081 | 3450.459 | 274.324 | 0.686 | 14.6091 | 1.0487 | 28.4013 |
| 2012 | 3064.948 | 205.877 | 3270.825 | 204.087 | 0.996 | 6.2943 | 1.1529 | 30.4796 |

Discards make up approximately 6.9 % of the catch over the 1998-2006 period.

The catch rate trend used was from trawl caught flathead in zones 10 and 20. The fishery was well developed before 1986, the start of our data series.

Table 23.60. RBC for Flathead. Ctarg and CPUEtarg relate to the period 1986-1995, CPUELim is 40% of the target, 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 (19).

| | |
|---|---|
| Ref_Year | 1986-1995 |
| CE_Targ | 1.0527 |
| CE_Lim | 0.4211 |
| CE_Recent | 1.0881 |
| Wt_Discard | 288.064 |
| Scaling | 1.0561 |
| Last Year's TAC | 2750 |
| $C_{targ}$ | 2830.248 |

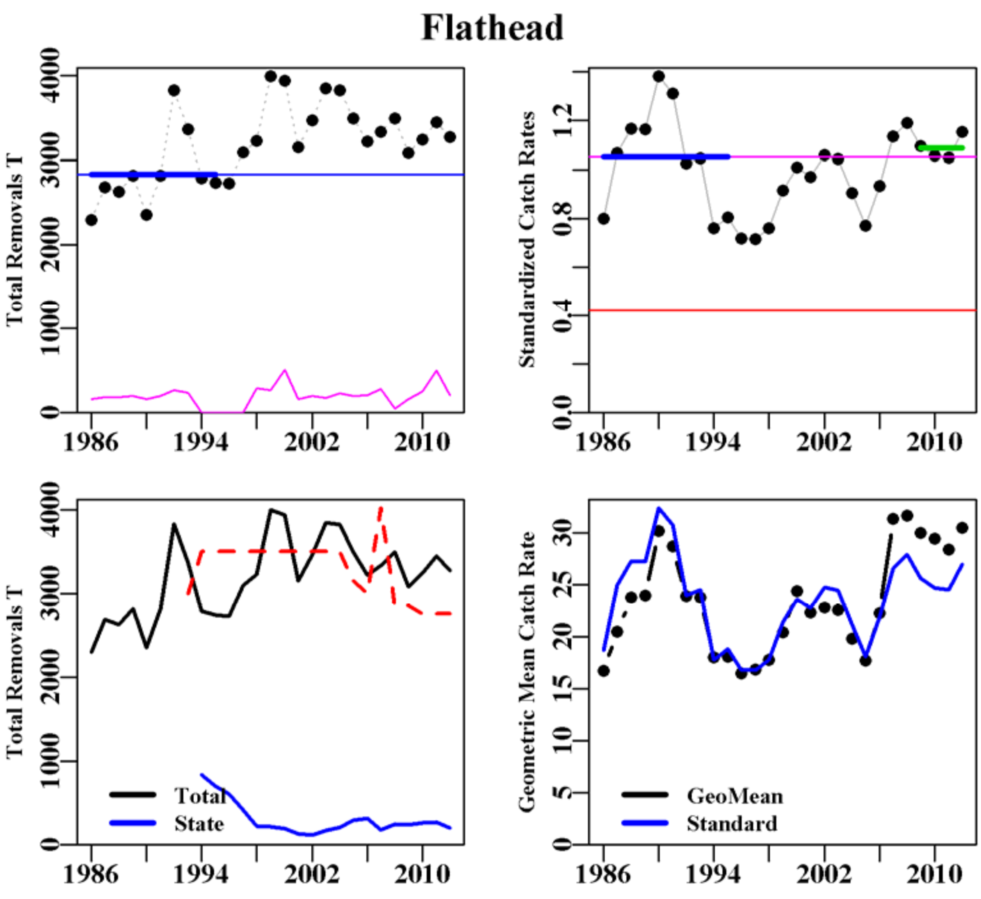


Figure 23.42. Tiger Flathead. Top left is the total removals with the fine line illustrating the target catch. Top right represents the standardized catch rates with the upper fine line representing the target catch rate and the lower line the limit catch rate. Thickened lines represents the reference period for catches, catch rates, and the recent average catch rate.

### 23.6.3 Eastern Gemfish (GEM – 37439002 – Rexea solandri)

Table 23.61. Eastern Gemfish 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, 20, and 30 in depths 300 – 500m from June to September (Haddon, 2013). GeoMean is the geometric mean catch rate. 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 | Non-T | PDiscard | CE | GeoMean |
|---|---|---|---|---|---|---|---|---|
| 1986 | 1945.200 | 218.268 | 2163.468 | | | 10.0888 | 2.3736 | 14.5833 |
| 1987 | 2208.000 | 247.757 | 2455.757 | | | 10.0888 | 3.1365 | 25.6322 |
| 1988 | 1148.400 | 128.860 | 1277.261 | | | 10.0888 | 2.7031 | 20.2775 |
| 1989 | 980.400 | 110.009 | 1090.409 | | | 10.0888 | 1.8111 | 11.5170 |
| 1990 | 979.200 | 109.875 | 1089.075 | | | 10.0888 | 1.8021 | 12.7467 |
| 1991 | 301.200 | 33.797 | 334.997 | | | 10.0888 | 1.2263 | 8.7585 |
| 1992 | 1028.400 | 115.395 | 1143.795 | | | 10.0888 | 1.7144 | 11.2867 |
| 1993 | 457.200 | 51.302 | 508.502 | | | 10.0888 | 1.3372 | 8.9703 |
| 1994 | 266.110 | 0.000 | 266.110 | 131.931 | 0.000 | 0.0000 | 0.9164 | 6.3021 |
| 1995 | 251.022 | 0.000 | 251.022 | 157.756 | 0.000 | 0.0000 | 0.8339 | 5.5810 |
| 1996 | 315.471 | 0.000 | 315.471 | 204.700 | 0.000 | 0.0000 | 0.6333 | 4.1794 |
| 1997 | 529.152 | 0.000 | 529.152 | 136.395 | 0.000 | 0.0000 | 0.6651 | 4.3644 |
| 1998 | 373.133 | 23.000 | 396.133 | 127.144 | 0.000 | 5.8061 | 0.6289 | 4.3330 |
| 1999 | 247.201 | 31.000 | 278.201 | 88.664 | 0.000 | 11.1430 | 0.4601 | 2.9242 |
| 2000 | 123.746 | 29.000 | 152.746 | 30.747 | 0.000 | 18.9858 | 0.4177 | 2.7970 |
| 2001 | 110.245 | 8.000 | 118.245 | 23.859 | 2.702 | 6.7656 | 0.3438 | 2.0726 |
| 2002 | 77.867 | 13.600 | 91.467 | 16.174 | 3.564 | 14.8688 | 0.2644 | 1.5969 |
| 2003 | 82.841 | 115.170 | 198.011 | 7.781 | 2.697 | 58.1633 | 0.2907 | 1.7227 |
| 2004 | 97.542 | 83.210 | 180.752 | 17.731 | 2.683 | 46.0355 | 0.4134 | 2.6319 |
| 2005 | 112.493 | 77.650 | 190.143 | 15.751 | 8.598 | 40.8376 | 0.4417 | 2.8266 |
| 2006 | 101.951 | 46.350 | 148.301 | 15.153 | 6.564 | 31.2540 | 0.4689 | 2.9593 |
| 2007 | 93.213 | 128.758 | 221.971 | 14.091 | 10.096 | 58.0066 | 0.6383 | 4.2429 |
| 2008 | 118.957 | 164.319 | 283.276 | 11.607 | 20.277 | 58.0066 | 0.8546 | 5.7070 |
| 2009 | 101.999 | 171.228 | 273.228 | 16.294 | 11.688 | 62.6687 | 0.8814 | 6.6449 |
| 2010 | 112.668 | 191.005 | 303.673 | 20.152 | 16.264 | 62.8983 | 0.6351 | 4.1887 |
| 2011 | 85.915 | 107.690 | 193.605 | 15.460 | 10.492 | 55.6234 | 0.5807 | 3.8210 |
| 2012 | 78.284 | 28.018 | 106.302 | 9.249 | 7.822 | 26.3571 | 0.5270 | 3.5107 |

Discards make up approximately 10.08 % of the catch over the 1998-2002 period. The reduced period, relative to other species, reflects the bycatch nature of the fishery in recent years.

Table 23.62. RBC calculations for Eastern Gemfish. Ctarg and CPUEtarg relate to the period 1993-2002, CPUELim is 40% of the target, 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 (19).

| | |
|---|---|
| Ref_Year | 1993-2002 |
| CE_Targ | 0.6501 |
| CE_Lim | 0.26 |
| CE_Recent | 0.656 |
| Wt_Discard | 80.543 |
| Scaling | 1.0153 |
| Last Year's TAC | 100 |
| $C_{targ}$ | 290.705 |

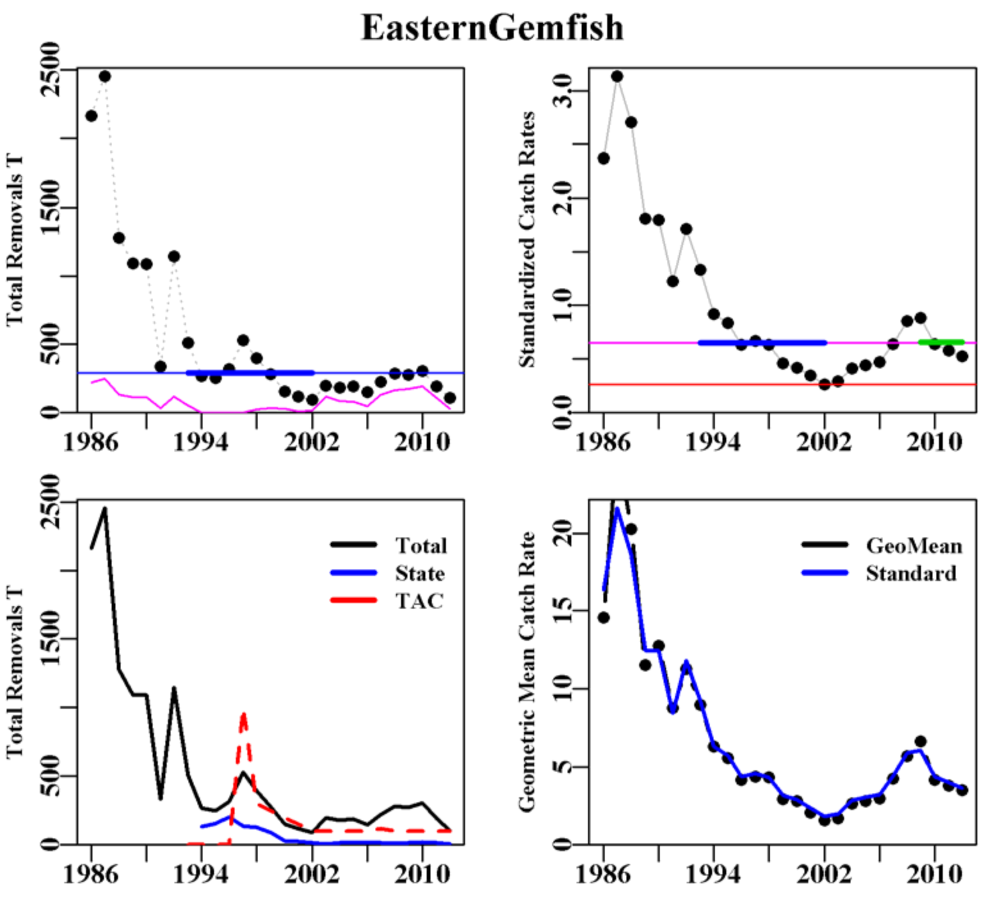


Figure 23.43. Eastern Gemfish. Top left is the total removals with the fine line illustrating the target catch. Top right represents the standardized catch rates with the upper fine line representing the target catch rate and the lower line the limit catch rate. Thickened lines represents the reference period for catches, catch rates, and the recent average catch rate.

#### *23.6.4 Western Gemfish (GEM – 37439002 – Rexea solandri)*

This relates solely to the SESSF zones 40 and 50; specifically it does not include the GAB, either in the catch rate standardization or the catches.

Table 23.63. Western Gemfish 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 & 50 in depths 0 – 600m, GAB not included (Haddon, 2013). 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 | Non-T | PDiscard | CE | GeoMean |
|---|---|---|---|---|---|---|---|---|
| 1986 | 1986 | 256.262 | 7.072 | 263.334 | | 2.6854 | 2.2547 | 29.5835 |
| 1987 | 1987 | 228.792 | 6.314 | 235.106 | | 2.6854 | 2.2580 | 31.5896 |
| 1988 | 1988 | 226.320 | 6.245 | 232.565 | | 2.6854 | 2.2045 | 26.9924 |
| 1989 | 1989 | 156.496 | 4.319 | 160.815 | | 2.6854 | 1.8127 | 23.3363 |
| 1990 | 1990 | 132.675 | 3.661 | 136.336 | | 2.6854 | 1.3844 | 15.9031 |
| 1991 | 1991 | 251.158 | 6.931 | 258.089 | | 2.6854 | 1.3339 | 22.0062 |
| 1992 | 1992 | 84.384 | 2.329 | 86.713 | | 2.6854 | 0.9334 | 16.7792 |
| 1993 | 1993 | 90.489 | 2.497 | 92.986 | | 2.6854 | 0.9003 | 16.5820 |
| 1994 | 1994 | 153.086 | 0.000 | 153.086 | 0 | 0.0000 | 0.9698 | 16.2263 |
| 1995 | 1995 | 146.940 | 0.000 | 146.940 | 0 | 0.0000 | 0.8493 | 12.0017 |
| 1996 | 1996 | 228.378 | 0.000 | 228.378 | 0 | 0.0000 | 0.9350 | 13.4563 |
| 1997 | 1997 | 288.838 | 0.000 | 288.838 | 0 | 0.0000 | 0.8366 | 13.2702 |
| 1998 | 1998 | 270.847 | 12.000 | 282.847 | 0 | 4.2426 | 0.9026 | 13.2167 |
| 1999 | 1999 | 418.806 | 5.000 | 423.806 | 0 | 1.1798 | 0.8569 | 12.8407 |
| 2000 | 2000 | 381.404 | 30.000 | 411.404 | 0 | 7.2921 | 0.8804 | 12.4996 |
| 2001 | 2001 | 344.481 | 9.000 | 353.481 | 0 | 2.5461 | 0.7110 | 12.1589 |
| 2002 | 2002 | 182.193 | 9.140 | 191.333 | 0 | 4.7770 | 0.5418 | 7.1243 |
| 2003 | 2003 | 257.112 | 12.580 | 269.692 | 0 | 4.6646 | 0.6601 | 11.3050 |
| 2004 | 2004 | 484.364 | 8.920 | 493.284 | 0 | 1.8083 | 0.6457 | 7.9049 |
| 2005 | 2005 | 417.335 | 1.640 | 418.975 | 0 | 0.3914 | 0.6721 | 10.6004 |
| 2006 | 2006 | 462.497 | 0.550 | 463.047 | 0 | 0.1188 | 0.5481 | 8.9869 |
| 2007 | 2007 | 423.946 | 5.122 | 429.068 | 0 | 1.1937 | 0.5320 | 7.4717 |
| 2008 | 2008 | 185.757 | 9.008 | 194.765 | 0 | 4.6253 | 0.5927 | 7.5220 |
| 2009 | 2009 | 136.450 | 51.008 | 187.458 | 0 | 27.2104 | 0.6726 | 6.4871 |
| 2010 | 2010 | 163.958 | 31.771 | 195.729 | 0 | 16.2323 | 0.6984 | 6.3681 |
| 2011 | 2011 | 100.933 | 120.438 | 221.372 | 0 | 54.4054 | 0.7323 | 5.6449 |
| 2012 | 2012 | 78.860 | 46.386 | 125.245 | 0 | 37.0360 | 0.6807 | 5.3756 |

Discards make up approximately 4.6 % of the catch over the 1998-2006 period.

Table 23.64. RBC calculations for Western Gemfish. Ctarg and CPUEtarg relate to the period 1992-2001, CPUELim is 40% of the target, 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. Only catches from zones 40 and 50 included. Wt_Discard is the weighted average discards from the last four years, as with Equ (19).

| | |
|---|---|
| Ref_Year | 1992-2001 |
| CE_Targ | 0.8775 |
| CE_Lim | 0.351 |
| CE_Recent | 0.696 |
| Wt_Discard | 64.493 |
| Scaling | 0.6552 |
| Last Year's TAC | 94 |
| $C_{targ}$ | 246.848 |

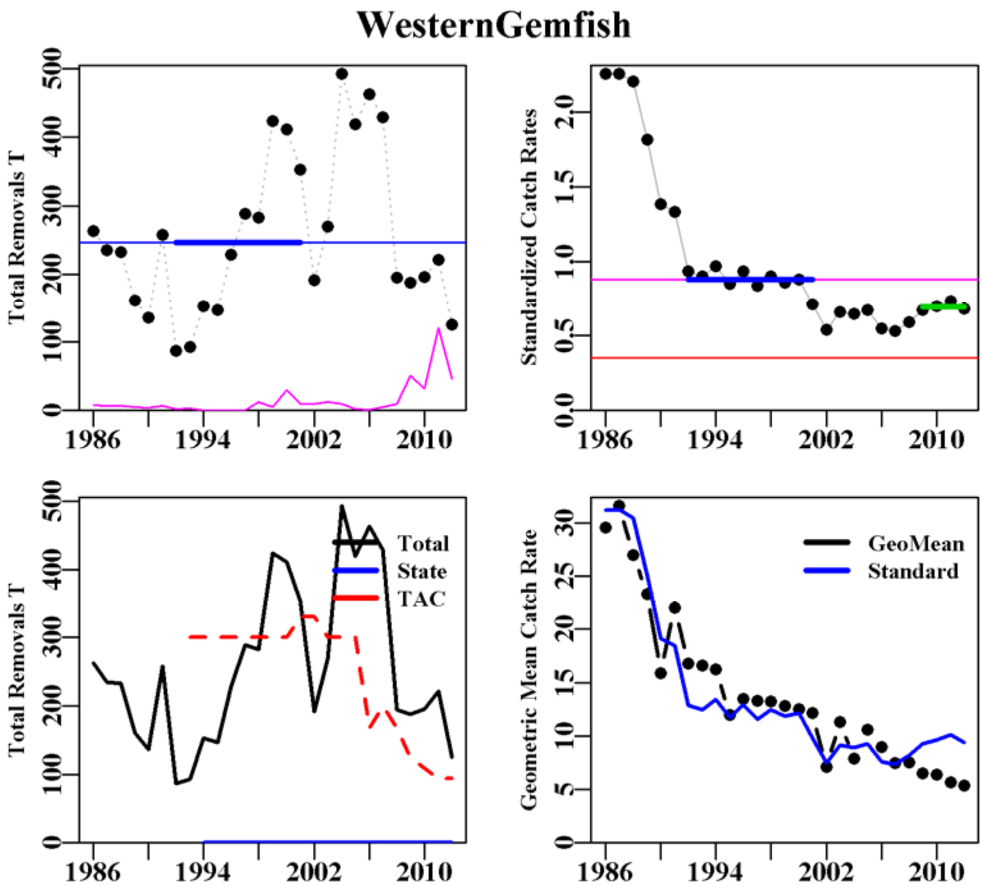


Figure 23.44. Western Gemfish. Top left is the total removals with the fine line illustrating the target catch. Top right represents the standardized catch rates with the upper fine line representing the target catch rate and the lower line the limit catch rate. Thickened lines represents the reference period for catches, catch rates, and the recent average catch rate.

### *23.6.5 Western Gemfish Discard (GEM – 37439002 – R solandri)*

This relates solely to the SESSF zones 40 and 50; specifically it does not include the GAB, either in the catch rate standardization, the catches, or the discards. As the discards in recent years have increased markedly this analysis includes their effects in the CPUE analysis.

Table 23.65. Western Gemfish 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 & 50 in depths 0 – 600m, GAB not included (Haddon, 2013). 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 | (D/C)+1 | StandCE | DiscCE | GeoMean |
|---|---|---|---|---|---|---|---|
| 1986 | 256.262 | 7.072 | 263.334 | 1.0276 | 2.2547 | 2.1372 | 29.5835 |
| 1987 | 228.792 | 6.314 | 235.106 | 1.0276 | 2.2580 | 2.1404 | 31.5896 |
| 1988 | 226.320 | 6.245 | 232.565 | 1.0276 | 2.2045 | 2.0897 | 26.9924 |
| 1989 | 156.496 | 4.319 | 160.815 | 1.0276 | 1.8127 | 1.7183 | 23.3363 |
| 1990 | 132.675 | 3.661 | 136.336 | 1.0276 | 1.3844 | 1.3123 | 15.9031 |
| 1991 | 251.158 | 6.931 | 258.089 | 1.0276 | 1.3339 | 1.2644 | 22.0062 |
| 1992 | 84.384 | 2.329 | 86.713 | 1.0276 | 0.9334 | 0.8848 | 16.7792 |
| 1993 | 90.489 | 2.497 | 92.986 | 1.0276 | 0.9003 | 0.8534 | 16.5820 |
| 1994 | 153.086 | 0.000 | 153.086 | 1.0000 | 0.9698 | 0.8946 | 16.2263 |
| 1995 | 146.940 | 0.000 | 146.940 | 1.0000 | 0.8493 | 0.7834 | 12.0017 |
| 1996 | 228.378 | 0.000 | 228.378 | 1.0000 | 0.9350 | 0.8625 | 13.4563 |
| 1997 | 288.838 | 0.000 | 288.838 | 1.0000 | 0.8366 | 0.7717 | 13.2702 |
| 1998 | 270.847 | 12.000 | 282.847 | 1.0443 | 0.9026 | 0.8695 | 13.2167 |
| 1999 | 418.806 | 5.000 | 423.806 | 1.0119 | 0.8569 | 0.7999 | 12.8407 |
| 2000 | 381.404 | 30.000 | 411.404 | 1.0787 | 0.8804 | 0.8760 | 12.4996 |
| 2001 | 344.481 | 9.000 | 353.481 | 1.0261 | 0.7110 | 0.6730 | 12.1589 |
| 2002 | 182.193 | 9.140 | 191.333 | 1.0502 | 0.5418 | 0.5249 | 7.1243 |
| 2003 | 257.112 | 12.580 | 269.692 | 1.0489 | 0.6601 | 0.6387 | 11.3050 |
| 2004 | 484.364 | 8.920 | 493.284 | 1.0184 | 0.6457 | 0.6066 | 7.9049 |
| 2005 | 417.335 | 1.640 | 418.975 | 1.0039 | 0.6721 | 0.6224 | 10.6004 |
| 2006 | 462.497 | 0.550 | 463.047 | 1.0012 | 0.5481 | 0.5062 | 8.9869 |
| 2007 | 423.946 | 5.122 | 429.068 | 1.0121 | 0.5320 | 0.4967 | 7.4717 |
| 2008 | 185.757 | 9.008 | 194.765 | 1.0485 | 0.5927 | 0.5733 | 7.5220 |
| 2009 | 136.450 | 51.008 | 187.458 | 1.3738 | 0.6726 | 0.8524 | 6.4871 |
| 2010 | 163.958 | 31.771 | 195.729 | 1.1938 | 0.6984 | 0.7691 | 6.3681 |
| 2011 | 100.933 | 120.438 | 221.372 | 2.1932 | 0.7323 | 1.4816 | 5.6449 |
| 2012 | 78.860 | 46.386 | 125.245 | 1.5882 | 0.6807 | 0.9973 | 5.3756 |

Discards make up approximately 4.6 % of the catch over the 1998-2006 period.

Table 23.66. RBC calculations for Western Gemfish. Ctarg and CPUEtarg relate to the period 1992-2001, CPUELim is 40% of the target, 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. Only catches from zones 40 and 50 included. Wt_Discard is the weighted average discards from the last four years, as with Equ (19).

| | |
|---|---|
| Ref_Year | 1992-2001 |
| CE_Targ | 0.8269 |
| CE_Lim | 0.3308 |
| CE_Recent | 1.0251 |
| Wt_Discard | 64.493 |
| Scaling | 1.3995 |
| Last Year's TAC | 94 |
| $C_{targ}$ | 246.848 |

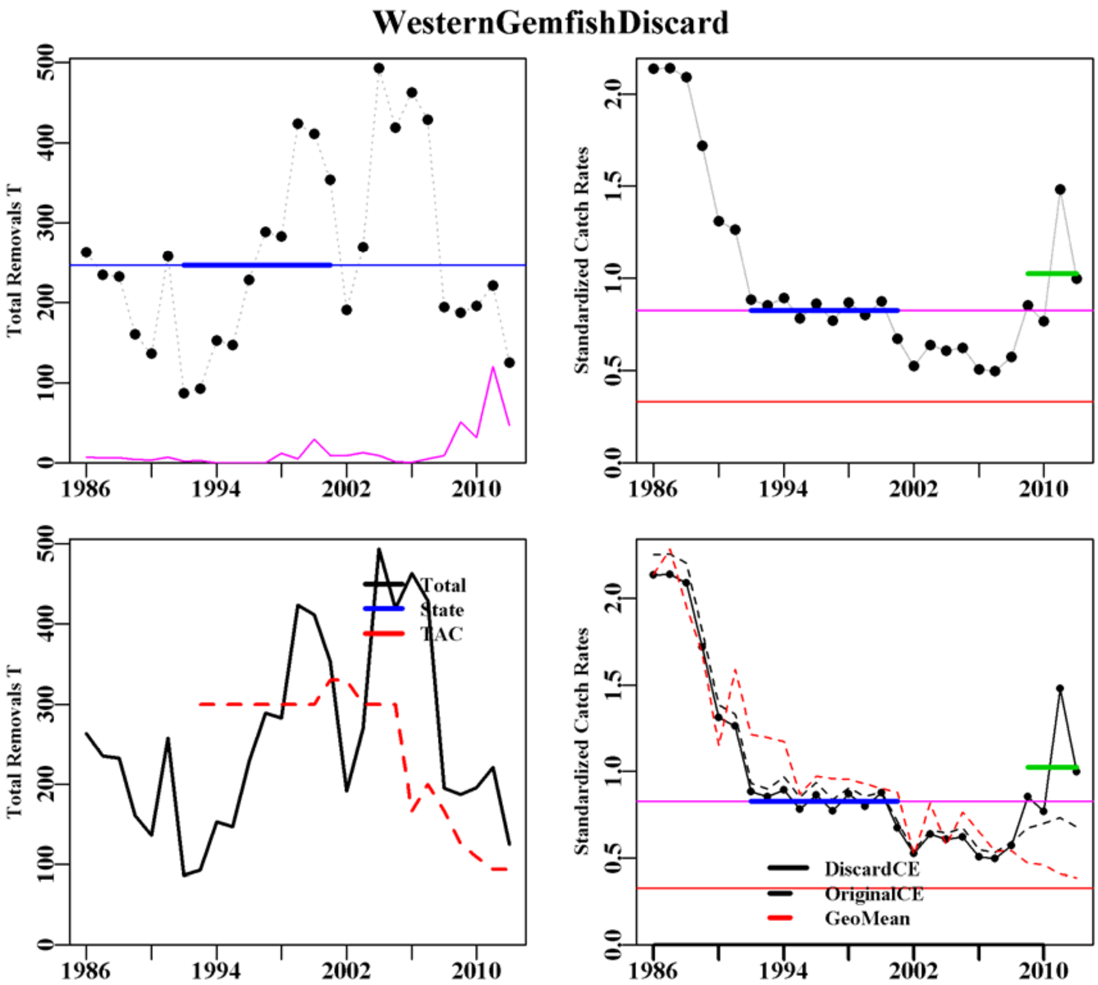


Figure 23.45. Western Gemfish. Top left is the total removals with the fine line illustrating the target catch. Top right represents the standardized catch rates with the upper fine line representing the target catch rate and the lower line the limit catch rate. Thickened lines represents the reference period for catches, catch rates, and the recent average catch rate.

### 23.6.6 Jackass Morwong (MOR – 37377003 –Nemadactylus macropterus)

Table 23.67. Jackass Morwong 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 50 in depths 70 – 360m (Haddon, 2013). 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 | Non-T | PDiscard | CE | GeoMean |
|---|---|---|---|---|---|---|---|---|
| 1986 | 1390.800 | 67.274 | 1458.074 | | | 4.6139 | 1.8636 | 22.5592 |
| 1987 | 1459.200 | 70.582 | 1529.782 | | | 4.6139 | 2.1150 | 26.1917 |
| 1988 | 1742.400 | 84.281 | 1826.681 | | | 4.6139 | 2.0887 | 29.1554 |
| 1989 | 1971.600 | 95.367 | 2066.967 | | | 4.6139 | 2.0266 | 33.9001 |
| 1990 | 1129.200 | 54.620 | 1183.820 | | | 4.6139 | 1.6782 | 24.2137 |
| 1991 | 1406.400 | 68.028 | 1474.428 | | | 4.6139 | 1.4883 | 21.1181 |
| 1992 | 888.000 | 42.953 | 930.953 | | | 4.6139 | 1.2362 | 19.1937 |
| 1993 | 1132.800 | 54.794 | 1187.594 | | | 4.6139 | 1.2543 | 21.3530 |
| 1994 | 1034.932 | 0.000 | 1034.932 | 225.635 | 0.000 | 0.0000 | 1.0712 | 18.0744 |
| 1995 | 981.801 | 0.000 | 981.801 | 160.930 | 0.000 | 0.0000 | 1.0034 | 16.3623 |
| 1996 | 972.505 | 0.000 | 972.505 | 89.062 | 0.211 | 0.0000 | 0.9215 | 13.8607 |
| 1997 | 1213.726 | 0.000 | 1213.726 | 82.173 | 3.192 | 0.0000 | 0.9853 | 16.1581 |
| 1998 | 939.914 | 34.000 | 973.914 | 56.807 | 4.519 | 3.4911 | 0.8471 | 13.4363 |
| 1999 | 994.363 | 45.000 | 1039.363 | 41.159 | 17.667 | 4.3296 | 0.8733 | 14.1587 |
| 2000 | 950.201 | 27.000 | 977.201 | 41.029 | 29.294 | 2.7630 | 0.7379 | 10.1983 |
| 2001 | 865.808 | 12.000 | 877.808 | 50.298 | 2.177 | 1.3670 | 0.5590 | 8.3295 |
| 2002 | 879.009 | 25.440 | 904.449 | 29.376 | 1.819 | 2.8128 | 0.5880 | 8.3275 |
| 2003 | 772.015 | 71.850 | 843.865 | 28.583 | 3.299 | 8.5144 | 0.5102 | 7.9077 |
| 2004 | 793.832 | 47.380 | 841.212 | 37.380 | 4.258 | 5.6323 | 0.5097 | 8.6153 |
| 2005 | 844.641 | 38.610 | 883.251 | 42.118 | 5.435 | 4.3713 | 0.5486 | 8.9785 |
| 2006 | 812.736 | 78.550 | 891.286 | 34.415 | 5.306 | 8.8131 | 0.6298 | 11.5427 |
| 2007 | 586.950 | 70.811 | 657.760 | 18.299 | 4.507 | 10.7654 | 0.6369 | 12.2504 |
| 2008 | 715.142 | 86.276 | 801.418 | 12.108 | 5.740 | 10.7654 | 0.7480 | 13.7889 |
| 2009 | 465.638 | 56.176 | 521.814 | 11.506 | 2.812 | 10.7654 | 0.6605 | 11.4713 |
| 2010 | 376.410 | 21.122 | 397.533 | 8.452 | 3.007 | 5.3134 | 0.4886 | 8.5497 |
| 2011 | 411.811 | 46.601 | 458.412 | 5.820 | 2.384 | 10.1658 | 0.4623 | 8.5284 |
| 2012 | 342.927 | 38.806 | 381.733 | 10.478 | 1.457 | 10.1658 | 0.4679 | 8.9426 |

Discards make up approximately 4.6 % of the catch over the 1998-2006 period.

Table 23.68. RBC calculations for Jackass Morwong. Ctarg and CPUEtarg relate to the period 1986-1995, CPUELim is 40% of the target, 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. The Wt_Discard is the weighted discards from 2008 – 2011, as in Equ (19) .

| | |
|---|---|
| Ref_Year | 1986-1995 |
| CE_Targ | 1.5825 |
| CE_Lim | 0.633 |
| CE_Recent | 0.5198 |
| Wt_Discard | 39.685 |
| Scaling | 0 |
| Last Year's TAC | 450 |
| $C_{targ}$ | 1367.503 |

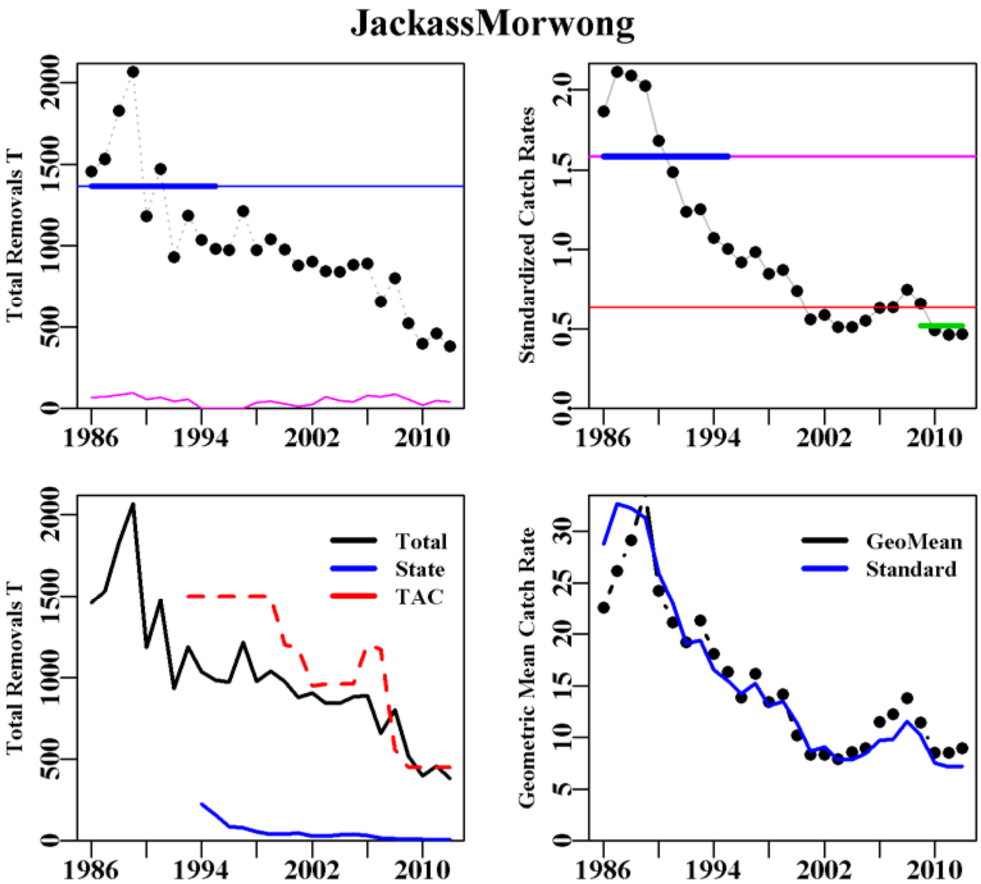


Figure 23.46. Jackass Morwong. Top left is the total removals with the line illustrating the target catch. Top right represents the standardized catch rates with the upper line representing the target catch rate and the lower line the limit catch rate. Thickened lines represents the reference period for catches, catch rates, and the recent average catch rate.

### *23.6.7 John Dory (DOJ – 37264004 – Zeus faber)*

It was decided that this year the option of treating John Dory as a non-target species would be examined. This entailed changing the implied target reference point from 48% of the unfished state to 40% of the unfished state. Because the target catch rate is taken as a proxy for 48% unfished biomass, to make it equivalent to 40% means the average catch rate over the reference period should be multiplied by 0.8333 (thus 0.83334 × 48 = 40).

Table 23.69. John 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 and 20 in depths 0 – 200m (Haddon, 2013). 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 | Non-T | PDiscard | CE | GeoMean |
|---|---|---|---|---|---|---|---|---|
| 1986 | 301.200 | 7.987 | 309.187 | | | 2.5833 | 1.5766 | 7.6948 |
| 1987 | 240.000 | 6.364 | 246.364 | | | 2.5833 | 1.8050 | 8.5155 |
| 1988 | 226.800 | 6.014 | 232.814 | | | 2.5833 | 1.6952 | 8.3856 |
| 1989 | 252.000 | 6.683 | 258.683 | | | 2.5833 | 1.8594 | 9.5319 |
| 1990 | 212.400 | 5.633 | 218.033 | | | 2.5833 | 1.6799 | 8.7451 |
| 1991 | 236.400 | 6.269 | 242.669 | | | 2.5833 | 1.3793 | 7.1954 |
| 1992 | 240.000 | 6.364 | 246.364 | | | 2.5833 | 1.1422 | 5.6282 |
| 1993 | 400.800 | 10.629 | 411.429 | | | 2.5833 | 1.4786 | 7.0963 |
| 1994 | 289.728 | 0.000 | 289.728 | 172.902 | 0.000 | 0.0000 | 1.3946 | 6.7516 |
| 1995 | 243.673 | 0.000 | 243.673 | 129.005 | 0.000 | 0.0000 | 1.1844 | 5.9610 |
| 1996 | 137.004 | 0.000 | 137.004 | 1.568 | 0.000 | 0.0000 | 0.9272 | 4.5279 |
| 1997 | 178.118 | 0.000 | 178.118 | 87.931 | 0.000 | 0.0000 | 0.7205 | 3.3776 |
| 1998 | 138.811 | 3.000 | 141.811 | 23.440 | 0.000 | 2.1155 | 0.7458 | 3.6350 |
| 1999 | 178.334 | 3.000 | 181.334 | 40.742 | 0.000 | 1.6544 | 0.8748 | 3.9411 |
| 2000 | 209.229 | 17.000 | 226.229 | 39.499 | 0.000 | 7.5145 | 0.8088 | 3.5716 |
| 2001 | 164.643 | 6.000 | 170.643 | 29.768 | 0.000 | 3.5161 | 0.6769 | 2.9450 |
| 2002 | 182.316 | 1.660 | 183.976 | 19.629 | 0.000 | 0.9023 | 0.6678 | 3.1506 |
| 2003 | 193.130 | 3.190 | 196.320 | 28.253 | 0.000 | 1.6249 | 0.6480 | 3.1538 |
| 2004 | 193.824 | 1.740 | 195.564 | 27.514 | 0.000 | 0.8897 | 0.6859 | 3.4191 |
| 2005 | 132.030 | 3.530 | 135.560 | 29.296 | 0.000 | 2.6040 | 0.5702 | 2.6772 |
| 2006 | 107.020 | 0.640 | 107.660 | 23.481 | 0.000 | 0.5945 | 0.6420 | 2.8463 |
| 2007 | 82.383 | 1.355 | 83.738 | 13.819 | 0.000 | 1.6181 | 0.5811 | 2.8023 |
| 2008 | 177.122 | 0.596 | 177.718 | 41.012 | 0.000 | 0.3356 | 0.8665 | 4.3014 |
| 2009 | 127.476 | 4.332 | 131.808 | 19.660 | 0.000 | 3.2867 | 0.8057 | 4.1921 |
| 2010 | 86.586 | 2.934 | 89.520 | 14.280 | 0.000 | 3.2777 | 0.5191 | 2.6414 |
| 2011 | 125.032 | 8.423 | 133.455 | 32.986 | 0.000 | 6.3112 | 0.5402 | 2.7461 |
| 2012 | 88.106 | 1.141 | 89.248 | 15.719 | 0.000 | 1.2788 | 0.5241 | 2.8174 |

Discards make up approximately 2.6% of the catch over the 1998-2006 period.

Table 23.70. RBC calculations for John Dory. Ctarg and CPUEtarg relate to the period 1986-1995, CPUELim is 40% of the target, 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 (19).

| | |
|---|---|
| Ref_Year | 1986-1995 |
| CE_Targ | 1.5195 |
| CE_Lim | 0.6078 |
| CE_Recent | 0.5973 |
| Wt_Discard | 3.535 |
| Scaling | 0 |
| Last Year's TAC | 221 |
| $C_{targ}$ | 269.894 |

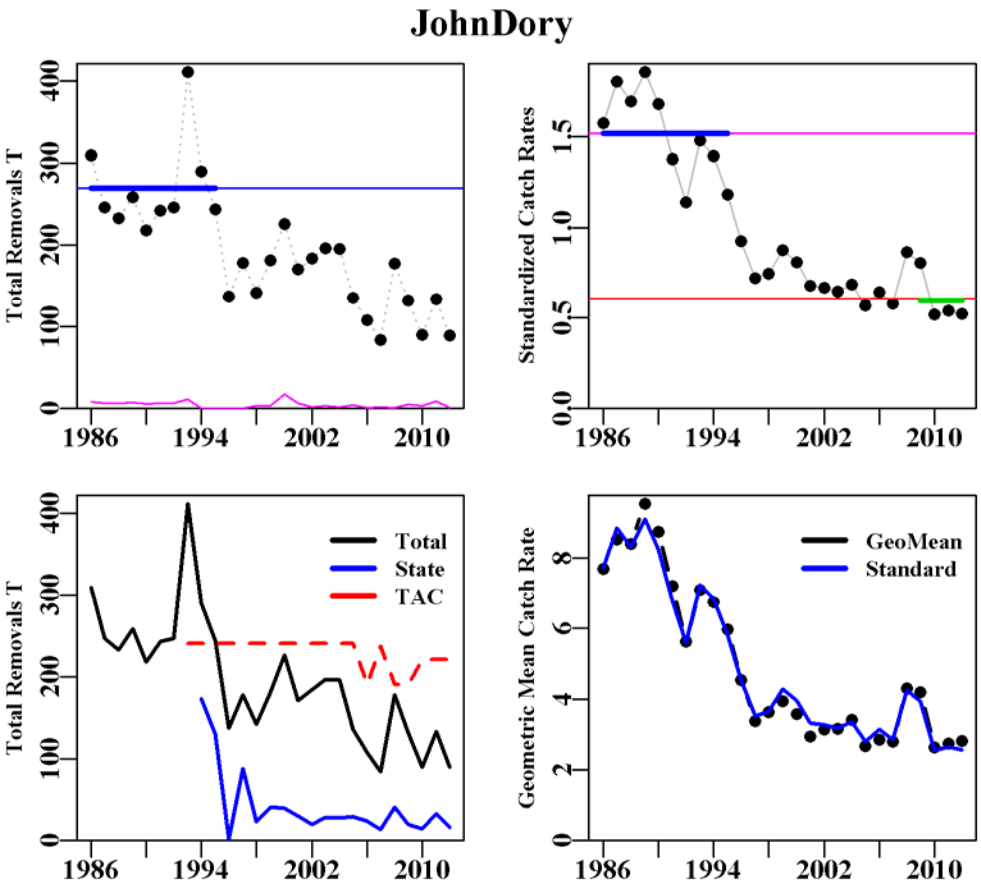


Figure 23.47. Jackass MOrwong. Top left is the total removals with the fine line illustrating the target catch. Top right represents the standardized catch rates with the upper fine line representing the target catch rate and the lower line the limit catch rate. Thickened lines represents the reference period for catches, catch rates, and the recent average catch rate.

## 2.2 Mirror Dory (DOM – 37264003 – *Zenopsis nebulosus*)

Table 23.71. 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 50 in depths 0 – 600m (Haddon, 2013). 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 | Non-T | PDiscard | CE | GeoMean |
|---|---|---|---|---|---|---|---|---|
| 1986 | 336.000 | 80.919 | 416.919 | | | 19.4087 | 1.2143 | 18.6423 |
| 1987 | 340.800 | 82.075 | 422.875 | | | 19.4087 | 1.2174 | 19.7476 |
| 1988 | 373.200 | 89.877 | 463.078 | | | 19.4087 | 1.1918 | 16.9455 |
| 1989 | 542.400 | 130.626 | 673.026 | | | 19.4087 | 1.4711 | 23.1957 |
| 1990 | 267.600 | 64.446 | 332.046 | | | 19.4087 | 1.3573 | 20.6077 |
| 1991 | 277.200 | 66.758 | 343.958 | | | 19.4087 | 1.1606 | 13.9567 |
| 1992 | 357.600 | 86.121 | 443.721 | | | 19.4087 | 1.0060 | 11.3487 |
| 1993 | 537.600 | 129.470 | 667.070 | | | 19.4087 | 1.1016 | 13.7999 |
| 1994 | 324.664 | 0.000 | 324.664 | 21.816 | 0.000 | 0.0000 | 0.9869 | 11.4667 |
| 1995 | 289.953 | 0.000 | 289.953 | 22.320 | 0.000 | 0.0000 | 0.9147 | 10.0782 |
| 1996 | 404.725 | 0.000 | 404.725 | 21.715 | 0.000 | 0.0000 | 0.8809 | 8.9039 |
| 1997 | 547.416 | 0.000 | 547.416 | 21.673 | 0.000 | 0.0000 | 0.9361 | 9.6820 |
| 1998 | 439.374 | 115.000 | 554.374 | 26.988 | 0.000 | 20.7441 | 0.8501 | 9.0983 |
| 1999 | 382.139 | 52.000 | 434.139 | 36.911 | 0.000 | 11.9777 | 0.6989 | 8.0995 |
| 2000 | 217.405 | 93.000 | 310.405 | 11.121 | 0.000 | 29.9608 | 0.4882 | 4.6519 |
| 2001 | 306.752 | 292.000 | 598.752 | 10.343 | 0.096 | 48.7681 | 0.5725 | 5.1157 |
| 2002 | 545.156 | 96.920 | 642.076 | 21.650 | 0.029 | 15.0948 | 0.7646 | 7.1647 |
| 2003 | 738.494 | 163.710 | 902.204 | 68.468 | 0.000 | 18.1456 | 0.9308 | 8.6661 |
| 2004 | 627.895 | 170.310 | 798.205 | 106.386 | 0.505 | 21.3366 | 0.8942 | 8.2044 |
| 2005 | 663.937 | 52.720 | 716.657 | 73.442 | 0.008 | 7.3564 | 0.9902 | 9.3924 |
| 2006 | 490.854 | 26.880 | 517.734 | 85.434 | 0.058 | 5.1919 | 0.9763 | 9.7517 |
| 2007 | 335.705 | 64.522 | 400.226 | 28.721 | 0.060 | 16.1213 | 0.9435 | 9.5152 |
| 2008 | 463.422 | 89.595 | 553.017 | 22.103 | 0.002 | 16.2011 | 1.1278 | 12.2034 |
| 2009 | 561.287 | 369.419 | 930.706 | 35.112 | 0.000 | 39.6923 | 1.2442 | 13.1797 |
| 2010 | 632.778 | 275.697 | 908.475 | 12.028 | 0.037 | 30.3472 | 1.1866 | 12.8612 |
| 2011 | 568.241 | 247.578 | 815.819 | 6.093 | 3.492 | 30.3472 | 1.0983 | 10.8184 |
| 2012 | 409.013 | 178.204 | 587.217 | 6.090 | 0.013 | 30.3472 | 0.7952 | 8.9809 |

Discards make up approximately 19.41 % of the catch over the 1998-2006 years.

Table 23.72. RBC calculations for Mirror Dory. Ctarg and CPUEtarg relate to the period 1986-1995, CPUELim is 40% of the target, 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 (19).

| | |
|---:|---:|
| Ref_Year | 1992-1997&2003-2006 |
| CE_Targ | 0.9618 |
| CE_Lim | 0.3847 |
| CE_Recent | 1.0811 |
| Wt_Discard | 222.45 |
| Scaling | 1.2067 |
| Last Year's TAC | 718 |
| $C_{targ}$ | 561.235 |

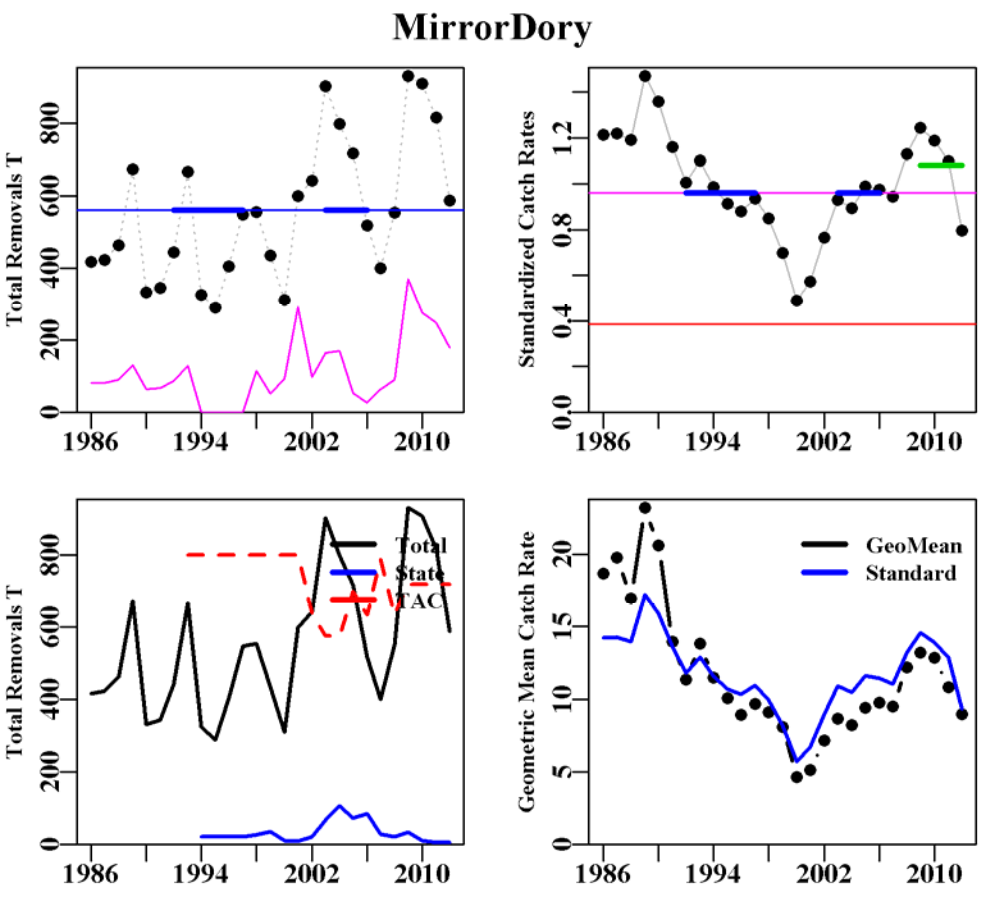


Figure 23.48. Mirror Dory. Top left is the total removals with the fine line illustrating the target catch. Top right represents the standardized catch rates with the upper fine line representing the target catch rate and the lower line the limit catch rate. Thickened lines represents the reference period for catches, catch rates, and the recent average catch rate.

### 23.6.8 Mirror Dory East (DOM – 37264003 – Z. nebulosus)

Table 23.73. 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 (Haddon, 2013). 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 | Non-T | PDiscard | CE | GeoMean |
|---|---|---|---|---|---|---|---|---|
| 1986 | 329.399 | 79.329 | 408.728 | | | 19.4087 | 1.1544 | 18.7487 |
| 1987 | 328.474 | 79.106 | 407.580 | | | 19.4087 | 1.1514 | 19.9429 |
| 1988 | 356.164 | 85.775 | 441.938 | | | 19.4087 | 1.1314 | 16.8882 |
| 1989 | 530.901 | 127.857 | 658.758 | | | 19.4087 | 1.3706 | 23.1617 |
| 1990 | 257.511 | 62.016 | 319.528 | | | 19.4087 | 1.2855 | 20.5538 |
| 1991 | 257.915 | 62.113 | 320.028 | | | 19.4087 | 1.1310 | 14.2052 |
| 1992 | 337.458 | 81.270 | 418.727 | | | 19.4087 | 0.9827 | 11.7312 |
| 1993 | 503.640 | 121.291 | 624.931 | | | 19.4087 | 1.0769 | 14.1976 |
| 1994 | 303.620 | 0.000 | 303.620 | 20.402 | 0.000 | 0.0000 | 0.9440 | 11.6924 |
| 1995 | 242.777 | 0.000 | 242.777 | 18.688 | 0.000 | 0.0000 | 0.8593 | 10.2913 |
| 1996 | 262.435 | 0.000 | 262.435 | 14.081 | 0.000 | 0.0000 | 0.7517 | 7.7998 |
| 1997 | 361.397 | 0.000 | 361.397 | 14.308 | 0.000 | 0.0000 | 0.7960 | 8.6425 |
| 1998 | 292.102 | 76.454 | 368.556 | 17.942 | 0.000 | 20.7441 | 0.7223 | 8.0944 |
| 1999 | 301.020 | 40.962 | 341.981 | 29.076 | 0.000 | 11.9777 | 0.6464 | 7.8713 |
| 2000 | 187.852 | 80.358 | 268.209 | 9.610 | 0.000 | 29.9608 | 0.4998 | 4.7885 |
| 2001 | 168.695 | 160.582 | 329.277 | 5.688 | 0.053 | 48.7681 | 0.5029 | 4.0443 |
| 2002 | 243.846 | 43.352 | 287.198 | 9.684 | 0.013 | 15.0948 | 0.6270 | 5.2594 |
| 2003 | 534.433 | 118.474 | 652.907 | 49.549 | 0.000 | 18.1456 | 0.9220 | 7.7688 |
| 2004 | 406.135 | 110.160 | 516.294 | 68.813 | 0.327 | 21.3366 | 0.8749 | 7.2635 |
| 2005 | 537.136 | 42.651 | 579.787 | 59.416 | 0.006 | 7.3564 | 1.1179 | 9.9946 |
| 2006 | 402.464 | 22.040 | 424.504 | 70.049 | 0.048 | 5.1919 | 1.1214 | 10.3893 |
| 2007 | 254.389 | 48.893 | 303.282 | 21.764 | 0.046 | 16.1213 | 1.2150 | 11.4463 |
| 2008 | 391.325 | 75.656 | 466.981 | 18.664 | 0.002 | 16.2011 | 1.3541 | 14.4563 |
| 2009 | 411.469 | 270.813 | 682.282 | 25.740 | 0.000 | 39.6923 | 1.4297 | 15.8458 |
| 2010 | 432.522 | 188.446 | 620.968 | 8.221 | 0.025 | 30.3472 | 1.1956 | 14.3976 |
| 2011 | 390.628 | 170.194 | 560.822 | 4.188 | 2.401 | 30.3472 | 1.1932 | 12.7502 |
| 2012 | 328.789 | 143.251 | 472.040 | 4.896 | 0.010 | 30.3472 | 0.9430 | 11.2957 |

Discards make up approximately 19.41 % of the catch over the 1998-2006 period.

Table 23.74. RBC calculations for Mirror Dory East. Ctarg and CPUEtarg relate to the period 1986-1995, CPUELim is 40% of the target, 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 (19).

| | |
|---|---|
| Ref_Year | 1986-1995 |
| CE_Targ | 1.1087 |
| CE_Lim | 0.4435 |
| CE_Recent | 1.1904 |
| Wt_Discard | 164.966 |
| Scaling | 1.1227 |
| Last Year's TAC | 1616 |
| $C_{targ}$ | 414.661 |
| **RBC** | **465.560** |

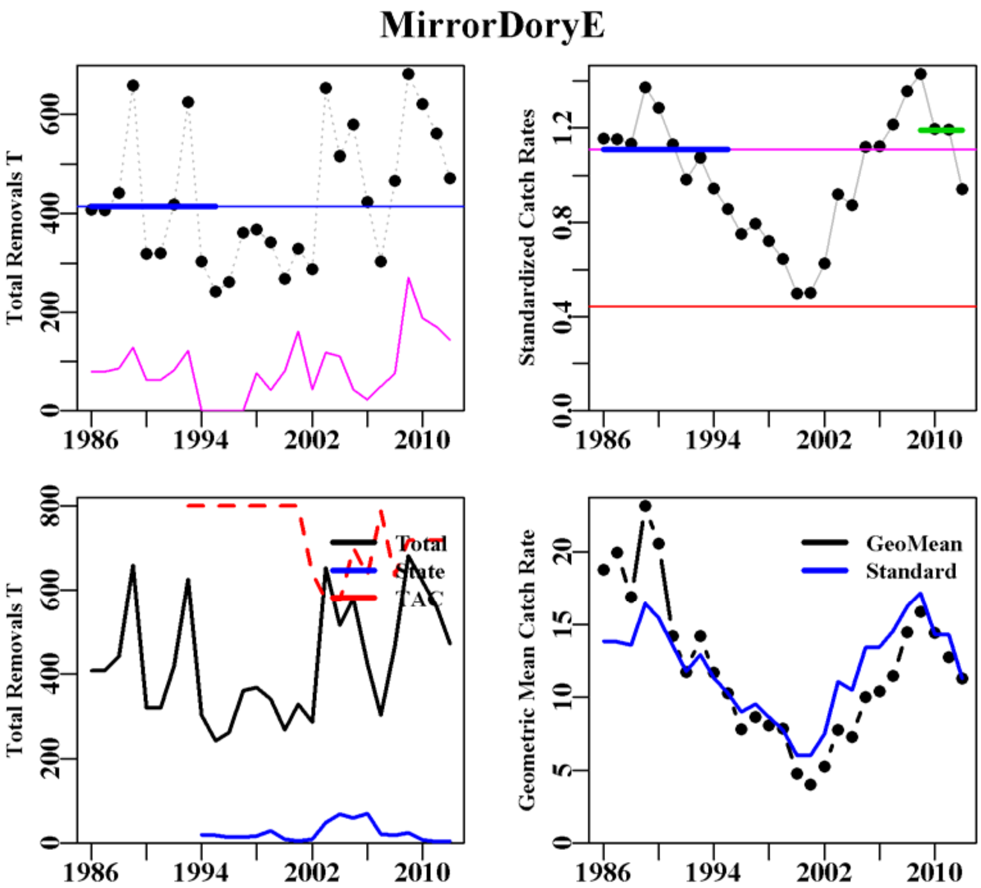


Figure 23.49. Mirror Dory. Top left is the total removals with the fine line illustrating the target catch. Top right represents the standardized catch rates with the upper fine line representing the target catch rate and the lower line the limit catch rate. Thickened lines represents the reference period for catches, catch rates, and the recent average catch rate.

### *23.6.9 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 the recent increase in the discard rate on the catch rates. In this case there was a marked effect, especially in three of the last four years, which 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 23.75. 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 | 336.000 | 80.919 | 416.919 | 1.2408 | 1.2143 | 1.1892 | 18.6423 | NA |
| 1987 | 340.800 | 82.075 | 422.875 | 1.2408 | 1.2174 | 1.1922 | 19.7476 | NA |
| 1988 | 373.200 | 89.877 | 463.078 | 1.2408 | 1.1918 | 1.1672 | 16.9455 | NA |
| 1989 | 542.400 | 130.626 | 673.026 | 1.2408 | 1.4711 | 1.4407 | 23.1957 | NA |
| 1990 | 267.600 | 64.446 | 332.046 | 1.2408 | 1.3573 | 1.3293 | 20.6077 | NA |
| 1991 | 277.200 | 66.758 | 343.958 | 1.2408 | 1.1606 | 1.1366 | 13.9567 | NA |
| 1992 | 357.600 | 86.121 | 443.721 | 1.2408 | 1.0060 | 0.9852 | 11.3487 | NA |
| 1993 | 537.600 | 129.470 | 667.070 | 1.2408 | 1.1016 | 1.0788 | 13.7999 | 800 |
| 1994 | 324.664 | 78.189 | 402.853 | 1.2408 | 0.9869 | 0.9665 | 11.4667 | 800 |
| 1995 | 289.953 | 69.829 | 359.782 | 1.2408 | 0.9147 | 0.8958 | 10.0782 | 800 |
| 1996 | 404.725 | 97.470 | 502.195 | 1.2408 | 0.8809 | 0.8627 | 8.9039 | 800 |
| 1997 | 547.416 | 131.834 | 679.250 | 1.2408 | 0.9361 | 0.9168 | 9.6820 | 800 |
| 1998 | 439.374 | 115.000 | 554.374 | 1.2617 | 0.8501 | 0.8466 | 9.0983 | 800 |
| 1999 | 382.139 | 52.000 | 434.139 | 1.1361 | 0.6989 | 0.6267 | 8.0995 | 800 |
| 2000 | 217.405 | 93.000 | 310.405 | 1.4278 | 0.4882 | 0.5501 | 4.6519 | 800 |
| 2001 | 306.752 | 292.000 | 598.752 | 1.9519 | 0.5725 | 0.8820 | 5.1157 | 800 |
| 2002 | 545.156 | 96.920 | 642.076 | 1.1778 | 0.7646 | 0.7108 | 7.1647 | 640 |
| 2003 | 738.494 | 163.710 | 902.204 | 1.2217 | 0.9308 | 0.8975 | 8.6661 | 576 |
| 2004 | 627.895 | 170.310 | 798.205 | 1.2712 | 0.8942 | 0.8972 | 8.2044 | 576 |
| 2005 | 663.937 | 52.720 | 716.657 | 1.0794 | 0.9902 | 0.8436 | 9.3924 | 700 |
| 2006 | 490.854 | 26.880 | 517.734 | 1.0548 | 0.9763 | 0.8128 | 9.7517 | 634 |
| 2007 | 335.705 | 64.522 | 400.226 | 1.1922 | 0.9435 | 0.8878 | 9.5152 | 788 |
| 2008 | 463.422 | 89.595 | 553.017 | 1.1933 | 1.1278 | 1.0622 | 12.2034 | 634 |
| 2009 | 561.287 | 369.419 | 930.706 | 1.6582 | 1.2442 | 1.6283 | 13.1797 | 718 |
| 2010 | 632.778 | 275.697 | 908.475 | 1.4357 | 1.1866 | 1.3446 | 12.8612 | 718 |
| 2011 | 568.241 | 134.789 | 703.030 | 1.2372 | 1.0983 | 1.0725 | 10.8184 | 718 |
| 2012 | 409.013 | 97.019 | 506.033 | 1.2372 | 0.7952 | 0.7765 | 8.9809 | 718 |

Discards make up approximately 19.41 % of the catch over the 1998-2006 period, and according to an earlier RAG decision this value was used to estimate the discards for the years 1986 – 1997. The average discard rate from 1998 – 2008, 19.17%, was used to estimate the more recent discard rates in 2011 and 2012.

Table 23.76. RBC calculations for Mirror Dory East. Ctarg and CPUEtarg relate to the period 1986-1995, CPUELim is 40% of the target, 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 (19).

| | |
|---:|---:|
| Ref_Year | 1986-1995 |
| CE_Targ | 1.1382 |
| CE_Lim | 0.4553 |
| CE_Recent | 1.2055 |
| Wt_Discard | 149.075 |
| Scaling | 1.0986 |
| Last Year's TAC | 1616 |
| $C_{targ}$ | 452.533 |
| **RBC** | **497.134** |

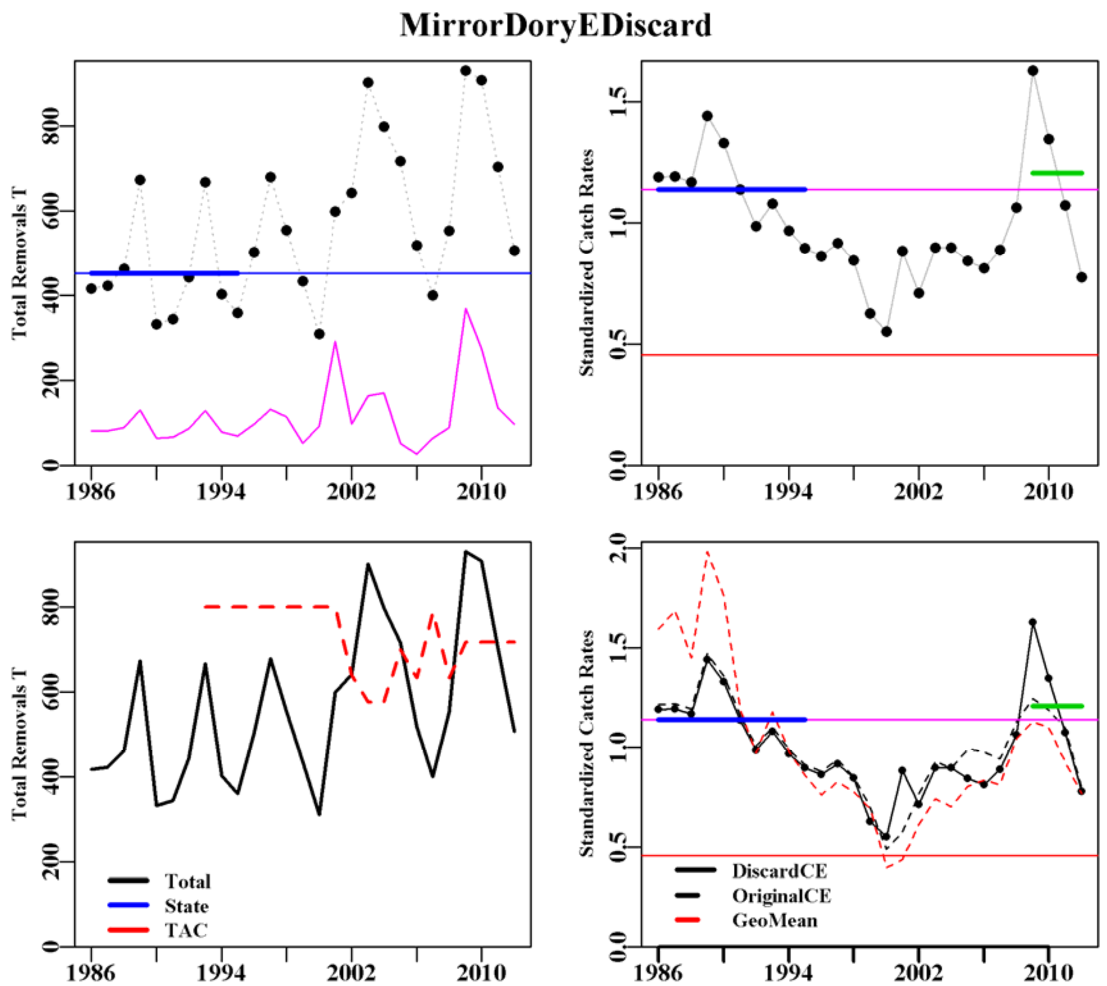


Figure 23.50 Mirror Dory. Top left is the total removals with the fine line illustrating the target catch. Top right represents the standardized catch rates with the upper fine line representing the target catch rate and the lower line the limit catch rate. Thickened lines represents the reference period for catches, catch rates, and the recent average catch rate.

### 23.6.10 Mirror Dory West (DOM – 37264003 – Z. nebulosus)

Table 23.77. 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 40 to 50 in depths 0 – 600m (Haddon, 2013). 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 | Non-T | PDiscard | CE | GeoMean |
|---|---|---|---|---|---|---|---|---|
| 1986 | 6.601 | 1.590 | 8.190 | | | 19.4087 | 2.4486 | 13.7130 |
| 1987 | 12.326 | 2.968 | 15.294 | | | 19.4087 | 1.6108 | 16.0832 |
| 1988 | 17.036 | 4.103 | 21.139 | | | 19.4087 | 1.3227 | 18.4525 |
| 1989 | 11.499 | 2.769 | 14.268 | | | 19.4087 | 1.6770 | 24.6757 |
| 1990 | 10.089 | 2.430 | 12.518 | | | 19.4087 | 1.1269 | 21.6631 |
| 1991 | 19.285 | 4.644 | 23.930 | | | 19.4087 | 0.8009 | 11.7670 |
| 1992 | 20.142 | 4.851 | 24.993 | | | 19.4087 | 0.6650 | 8.1608 |
| 1993 | 33.961 | 8.179 | 42.139 | | | 19.4087 | 0.7842 | 10.1017 |
| 1994 | 21.044 | 5.068 | 26.113 | 1.414 | 0 | 19.4090 | 0.6901 | 9.3264 |
| 1995 | 47.176 | 11.362 | 58.538 | 3.632 | 0 | 19.4090 | 0.8794 | 9.0896 |
| 1996 | 142.290 | 34.268 | 176.559 | 7.634 | 0 | 19.4090 | 1.2517 | 13.3473 |
| 1997 | 186.019 | 44.800 | 230.819 | 7.365 | 0 | 19.4090 | 1.2660 | 12.8686 |
| 1998 | 147.272 | 38.546 | 185.818 | 9.046 | 0 | 20.7441 | 1.2261 | 12.6121 |
| 1999 | 81.119 | 11.038 | 92.158 | 7.835 | 0 | 11.9777 | 0.8060 | 8.8763 |
| 2000 | 29.554 | 12.642 | 42.196 | 1.512 | 0 | 29.9608 | 0.4399 | 4.0569 |
| 2001 | 138.057 | 131.418 | 269.475 | 4.655 | 0.043 | 48.7681 | 0.7588 | 7.9361 |
| 2002 | 301.310 | 53.568 | 354.878 | 11.966 | 0.016 | 15.0948 | 1.1130 | 11.7181 |
| 2003 | 204.061 | 45.236 | 249.297 | 18.919 | 0.000 | 18.1456 | 0.9545 | 11.0165 |
| 2004 | 221.760 | 60.150 | 281.911 | 37.573 | 0.178 | 21.3366 | 0.9571 | 10.3786 |
| 2005 | 126.801 | 10.069 | 136.870 | 14.026 | 0.002 | 7.3564 | 0.7563 | 8.0456 |
| 2006 | 88.391 | 4.840 | 93.231 | 15.385 | 0.010 | 5.1919 | 0.6419 | 8.0395 |
| 2007 | 81.316 | 15.629 | 96.944 | 6.957 | 0.015 | 16.1213 | 0.5779 | 6.7120 |
| 2008 | 72.097 | 13.939 | 86.035 | 3.439 | 0.000 | 16.2011 | 0.6475 | 7.5767 |
| 2009 | 149.819 | 98.605 | 248.424 | 9.372 | 0.000 | 39.6923 | 0.9881 | 9.7010 |
| 2010 | 200.256 | 87.250 | 287.506 | 3.807 | 0.012 | 30.3472 | 1.1728 | 11.0745 |
| 2011 | 177.613 | 42.130 | 219.743 | 1.904 | 1.092 | 19.1726 | 0.8995 | 8.6510 |
| 2012 | 80.224 | 19.029 | 99.253 | 1.195 | 0.003 | 19.1726 | 0.5376 | 6.0700 |

Discards make up approximately 19.41 % of the catch over the 1998-2006 period, used for estimating discard rates for 1986 – 1997 and 19.17% over the 1998 – 2008 period used for estimating discard rates for 2011 – 2012.

Table 23.78. RBC calculations for Mirror Dory. Ctarg and CPUEtarg relate to the period 1996-2005, CPUELim is 40% of the target, 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 (19).

| | |
|---|---|
| Ref_Year | 1996-2005 |
| CE_Targ | 0.9529 |
| CE_Lim | 0.3812 |
| CE_Recent | 0.8995 |
| Wt_Discard | 39.591 |
| Scaling | 0.9065 |
| Last Year's TAC | 1616 |
| $C_{targ}$ | 201.998 |
| **RBC** | **183.118** |

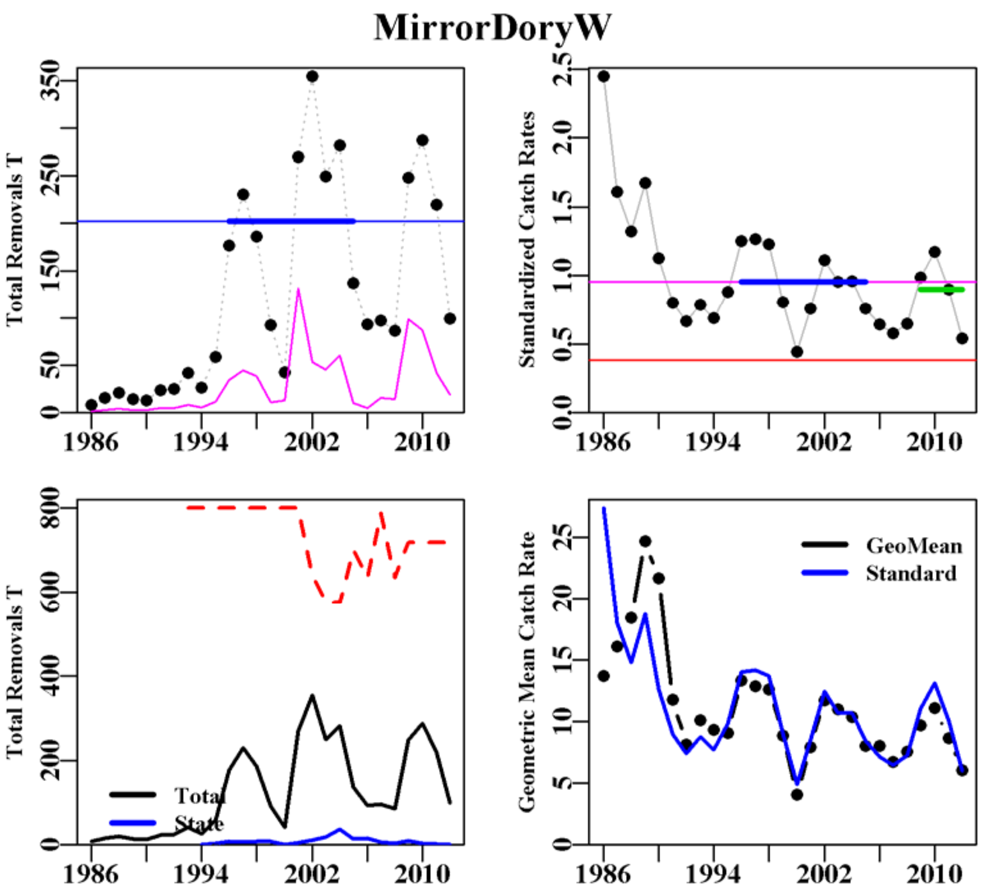


Figure 23.51. Mirror Dory. Top left is the total removals with the fine line illustrating the target catch. Top right represents the standardized catch rates with the upper fine line representing the target catch rate and the lower line the limit catch rate. Thickened lines represents the reference period for catches, catch rates, and the recent average catch rate.

### 23.6.11 Pink Ling (LIG – 37228002 – Genypterus blacodes)

Table 23.79. Pink Ling 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, 20 and 30 in depths 0 – 1000m (Haddon, 2013). 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 | Non-T | PDiscard | CE | LnCE |
|---|---|---|---|---|---|---|---|---|
| 1986 | 650.400 | 3.598 | 653.998 | | | 0.5501 | 1.1112 | 20.6651 |
| 1987 | 802.800 | 4.440 | 807.241 | | | 0.5501 | 1.1786 | 19.4237 |
| 1988 | 621.600 | 3.438 | 625.038 | | | 0.5501 | 1.1234 | 20.2595 |
| 1989 | 744.000 | 4.115 | 748.115 | | | 0.5501 | 0.9652 | 19.1575 |
| 1990 | 776.400 | 4.294 | 780.695 | | | 0.5501 | 1.4198 | 26.8201 |
| 1991 | 910.800 | 5.038 | 915.838 | | | 0.5501 | 1.4201 | 26.3050 |
| 1992 | 1081.200 | 5.980 | 1087.180 | | | 0.5501 | 1.0966 | 24.8497 |
| 1993 | 1657.200 | 9.166 | 1666.366 | | | 0.5501 | 1.0313 | 25.3075 |
| 1994 | 1463.814 | 0.000 | 1463.814 | 522.744 | 0.000 | 0.0000 | 1.0448 | 23.5158 |
| 1995 | 1944.832 | 0.000 | 1944.832 | 672.139 | 0.000 | 0.0000 | 1.3164 | 25.8106 |
| 1996 | 2246.616 | 0.000 | 2246.616 | 810.611 | 0.000 | 0.0000 | 1.3170 | 27.6570 |
| 1997 | 2136.689 | 0.000 | 2136.689 | 391.286 | 0.000 | 0.0000 | 1.3472 | 27.9375 |
| 1998 | 1941.212 | 41.000 | 1982.212 | 50.861 | 202.203 | 2.0684 | 1.3413 | 26.0156 |
| 1999 | 2027.018 | 12.000 | 2039.018 | 50.738 | 270.473 | 0.5885 | 1.2284 | 25.2286 |
| 2000 | 1854.579 | 11.000 | 1865.579 | 18.943 | 246.839 | 0.5896 | 1.0837 | 22.4049 |
| 2001 | 1741.307 | 5.000 | 1746.307 | 9.879 | 376.527 | 0.2863 | 0.8413 | 19.0624 |
| 2002 | 1609.255 | 6.640 | 1615.895 | 15.616 | 522.075 | 0.4109 | 0.7343 | 15.8660 |
| 2003 | 1625.789 | 1.390 | 1627.179 | 8.277 | 477.396 | 0.0854 | 0.7492 | 18.2929 |
| 2004 | 1797.662 | 1.390 | 1799.052 | 12.195 | 850.358 | 0.0773 | 0.6719 | 16.7984 |
| 2005 | 1466.180 | 3.330 | 1469.510 | 20.890 | 643.671 | 0.2266 | 0.6280 | 16.3335 |
| 2006 | 1230.147 | 2.840 | 1232.987 | 15.646 | 455.183 | 0.2303 | 0.7491 | 21.3189 |
| 2007 | 1026.187 | 21.882 | 1048.069 | 23.317 | 339.055 | 2.0879 | 0.7292 | 20.5015 |
| 2008 | 1183.839 | 16.566 | 1200.405 | 32.212 | 443.663 | 1.3800 | 0.8466 | 25.1511 |
| 2009 | 901.081 | 50.095 | 951.175 | 16.474 | 298.114 | 5.2666 | 0.6172 | 18.2953 |
| 2010 | 1103.679 | 57.895 | 1161.574 | 54.977 | 388.518 | 4.9842 | 0.7541 | 20.7211 |
| 2011 | 1258.643 | 14.613 | 1273.256 | 36.108 | 429.517 | 1.1477 | 0.7997 | 23.4304 |
| 2012 | 1058.538 | 16.400 | 1074.938 | 37.944 | 339.483 | 1.5257 | 0.8544 | 24.3541 |

Discards make up approximately 0.54 % of the catch over the 1998-2006 period. The standardized catch rate series used was from Zones 10, 20 and 30 as taken by trawl.

Table 23.80. RBC calculations for Pink Ling. Ctarg and CPUEtarg relate to the period 1986-1995, CPUELim is 40% of the target, 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 (19).

| | |
|---|---|
| Ref_Year | 1986-1995 |
| CE_Targ | 1.1707 |
| CE_Lim | 0.4683 |
| CE_Recent | 0.7564 |
| Wt_Discard | 23.703 |
| Scaling | 0.4101 |
| Last Year's TAC | 1200 |
| $C_{targ}$ | 1069.312 |

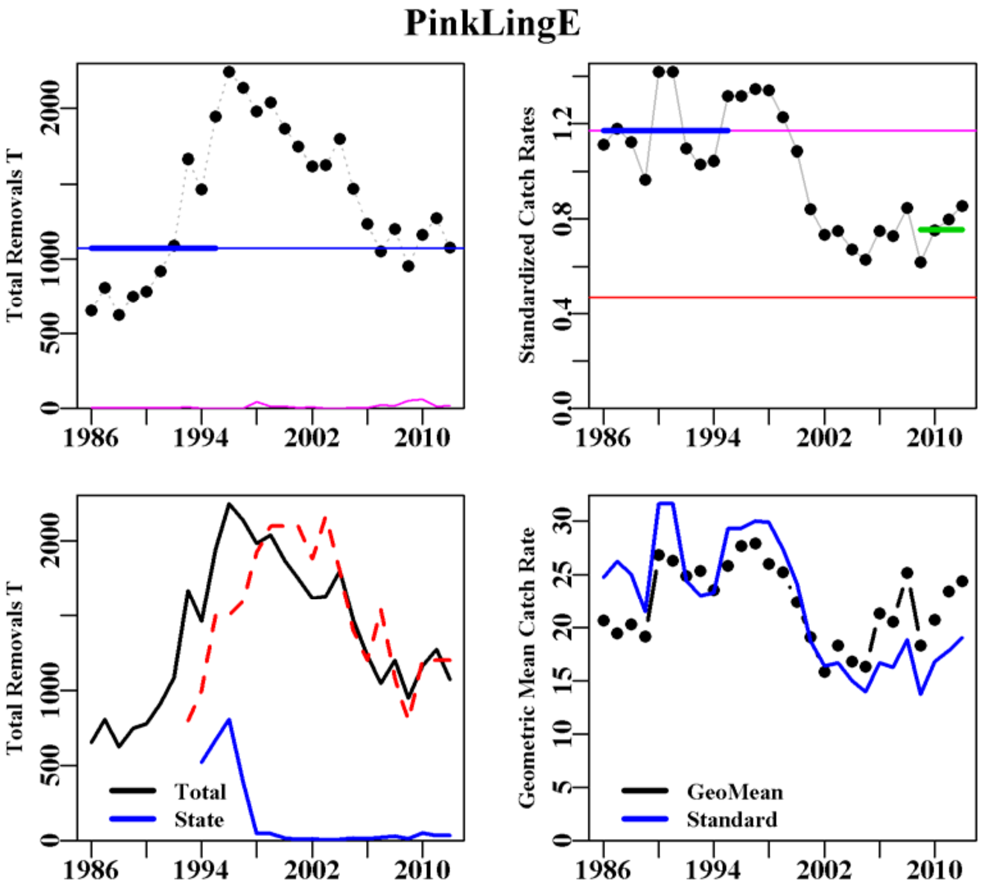


Figure 23.52. Top left is the total removals with the fine line illustrating the target catch. Top right represents the standardized catch rates with the upper fine line representing the target catch rate and the lower line the limit catch rate. Thickened lines represents the reference period for catches, catch rates, and the recent average catch rate.

### 23.6.12 RedFish (RED – 37258003 – *Centroberyx affinis*)

The period of the redfish fishery between 1991 to 1998 appears to have been during an era of heightened availability for redfish. This period is no longer considered to be representative of the fishery as it normally runs and has been running for the last few years.

Table 23.81. Redfish 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 Zone 10 in depths 0 – 400m (Haddon, 2013) relative to the catch rate in 1986. 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 | Non-T | PDiscard | CE | GeoMean |
|---|---|---|---|---|---|---|---|---|
| 1986 | 1426.800 | 904.992 | 2331.792 | | | 38.8110 | 1.6365 | 38.3044 |
| 1987 | 986.400 | 625.655 | 1612.055 | | | 38.8110 | 1.3134 | 35.9993 |
| 1988 | 961.200 | 609.671 | 1570.871 | | | 38.8110 | 1.3632 | 37.3114 |
| 1989 | 649.200 | 411.775 | 1060.975 | | | 38.8110 | 1.1309 | 29.4122 |
| 1990 | 792.000 | 502.350 | 1294.350 | | | 38.8110 | 1.5351 | 37.2522 |
| 1991 | 1737.600 | 1102.126 | 2839.726 | | | 38.8110 | 1.5924 | 39.9367 |
| 1992 | 2443.200 | 1549.675 | 3992.875 | | | 38.8110 | 2.0517 | 50.0990 |
| 1993 | 2114.400 | 1341.123 | 3455.523 | | | 38.8110 | 2.5963 | 56.0385 |
| 1994 | 1957.210 | 0.000 | 1957.210 | 1343.683 | 0.000 | 0.0000 | 1.8208 | 35.8972 |
| 1995 | 1999.572 | 0.000 | 1999.572 | 789.203 | 0.000 | 0.0000 | 1.1812 | 27.8589 |
| 1996 | 2219.833 | 0.000 | 2219.833 | 784.081 | 0.000 | 0.0000 | 0.9638 | 26.2588 |
| 1997 | 1840.798 | 0.000 | 1840.798 | 303.982 | 0.000 | 0.0000 | 1.1307 | 33.5183 |
| 1998 | 1835.469 | 2324.000 | 4159.469 | 83.346 | 0.000 | 55.8725 | 1.4172 | 43.1196 |
| 1999 | 1346.976 | 69.000 | 1415.976 | 94.939 | 0.000 | 4.8730 | 1.1127 | 32.7876 |
| 2000 | 859.909 | 233.000 | 1092.909 | 27.446 | 0.000 | 21.3193 | 0.7499 | 22.7760 |
| 2001 | 846.662 | 738.000 | 1584.662 | 52.093 | 0.545 | 46.5714 | 0.7333 | 17.8301 |
| 2002 | 926.928 | 894.850 | 1821.778 | 46.951 | 0.155 | 49.1196 | 0.6250 | 16.4201 |
| 2003 | 726.661 | 347.500 | 1074.161 | 48.604 | 0.828 | 32.3508 | 0.5978 | 17.0122 |
| 2004 | 557.603 | 377.440 | 935.043 | 58.124 | 1.005 | 40.3661 | 0.5076 | 15.2541 |
| 2005 | 579.526 | 126.180 | 705.706 | 46.690 | 0.568 | 17.8800 | 0.5194 | 16.1484 |
| 2006 | 397.194 | 13.070 | 410.264 | 75.690 | 0.541 | 3.1858 | 0.4873 | 15.6812 |
| 2007 | 283.332 | 2.681 | 286.013 | 53.689 | 0.089 | 0.9374 | 0.4341 | 15.4678 |
| 2008 | 230.566 | 2.182 | 232.748 | 29.369 | 0.163 | 0.9374 | 0.4057 | 13.9780 |
| 2009 | 207.440 | 231.285 | 438.726 | 25.489 | 0.076 | 52.7175 | 0.3285 | 11.3207 |
| 2010 | 187.992 | 27.086 | 215.079 | 22.340 | 0.019 | 12.5936 | 0.3115 | 10.4815 |
| 2011 | 114.991 | 26.770 | 141.761 | 16.473 | 0.247 | 18.8840 | 0.2479 | 8.5118 |
| 2012 | 84.888 | 4.064 | 88.951 | 13.611 | 0.009 | 4.5684 | 0.2061 | 7.0022 |

Discards make up approximately 38.8% of the catch over the 1998-2006 period. The standardized catch rate series is from Zone 10.

Table 23.82. RBC calculations for Redfish. Ctarg and CPUEtarg relate to the period 1986-1990 and 1999-2003 (omitting a period of enhanced availability during the 1990s). CPUELim is 40% of the target, 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 (19).

| | |
|---|---|
| Ref_Year | 1986-1990&1999-2003 |
| CE_Targ | 1.0798 |
| CE_Lim | 0.4319 |
| CE_Recent | 0.2735 |
| Wt_Discard | 28.337 |
| Scaling | 0 |
| Last Year's TAC | 276 |
| $C_{targ}$ | 1485.953 |

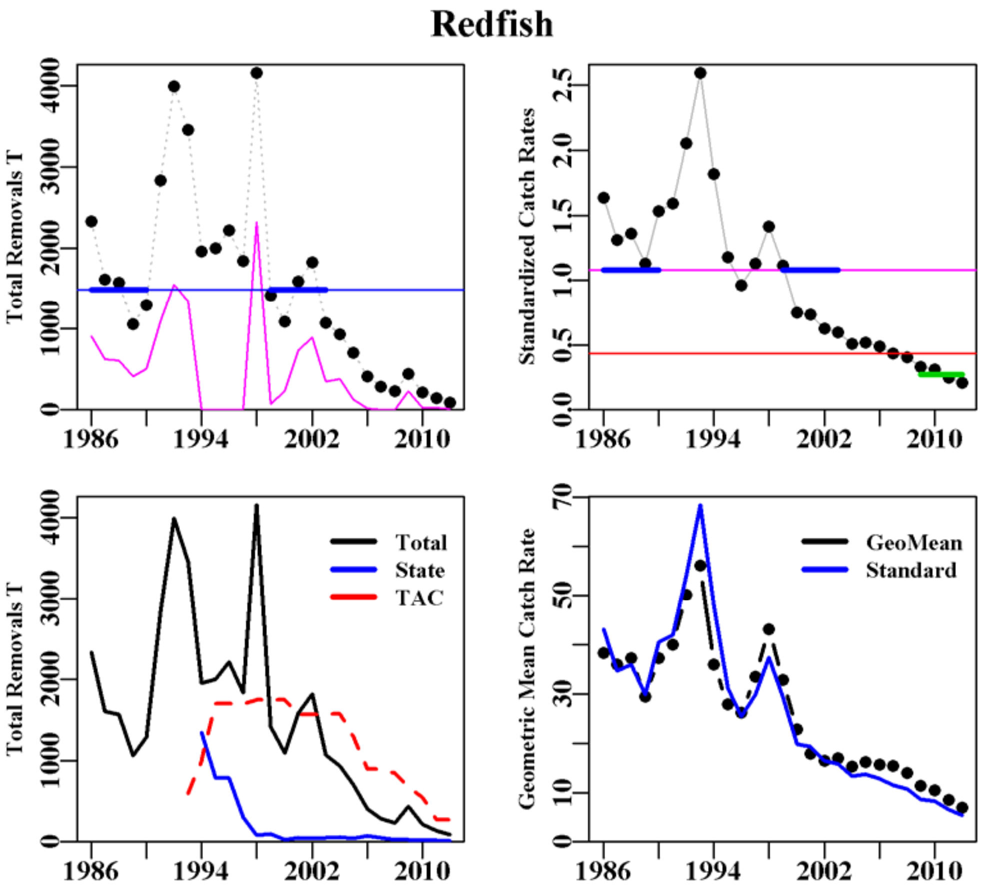


Figure 23.53. Redfish. Left is the total removals with the fine line illustrating the target catch. Right represents the standardized catch rates with the upper fine line representing the target catch rate and the lower line the limit catch rate. Thickened lines represents the reference period for catches, catch rates, and the recent average catch rate.

### *23.6.13 RedFish plus Discards (RED – 37258003 – C. affinis)*

The period of the redfish fishery between 1991 to 1998 appears to have been during an era of heightened availability for redfish. This period is no longer considered to be representative of the fishery as it normally runs and has been running for the last few years.

Table 23.83. Redfish data for the Alternative TIER 4 calculations using ratio mean catch rates that include discards in the catch rate calculations. Total is the sum of Discards, and other catches. All values in Tonnes. StandCE is the standardized catch rate for redfish from Zone 10 in depths 0 – 400m (Haddon, 2013). GeoMean is the geometric mean catch rates (without discards). Discards are estimates from 1998 to present. DiscCE is the standardized catch rates multiplied by [ (Discard/Catch)+1], see Haddon (2011c) for methods.

| Year | Catch | Discards | Total | Effort | (D/C)+1 | StandCE | DiscCE | GeoMean |
|---|---|---|---|---|---|---|---|---|
| 1986 | 1426.800 | 904.992 | 2331.792 | | | 38.8110 | 1.6365 | 38.3044 |
| 1987 | 986.400 | 625.655 | 1612.055 | | | 38.8110 | 1.3134 | 35.9993 |
| 1988 | 961.200 | 609.671 | 1570.871 | | | 38.8110 | 1.3632 | 37.3114 |
| 1989 | 649.200 | 411.775 | 1060.975 | | | 38.8110 | 1.1309 | 29.4122 |
| 1990 | 792.000 | 502.350 | 1294.350 | | | 38.8110 | 1.5351 | 37.2522 |
| 1991 | 1737.600 | 1102.126 | 2839.726 | | | 38.8110 | 1.5924 | 39.9367 |
| 1992 | 2443.200 | 1549.675 | 3992.875 | | | 38.8110 | 2.0517 | 50.0990 |
| 1993 | 2114.400 | 1341.123 | 3455.523 | | | 38.8110 | 2.5963 | 56.0385 |
| 1994 | 1957.210 | 0.000 | 1957.210 | 1343.683 | 0.000 | 0.0000 | 1.8208 | 35.8972 |
| 1995 | 1999.572 | 0.000 | 1999.572 | 789.203 | 0.000 | 0.0000 | 1.1812 | 27.8589 |
| 1996 | 2219.833 | 0.000 | 2219.833 | 784.081 | 0.000 | 0.0000 | 0.9638 | 26.2588 |
| 1997 | 1840.798 | 0.000 | 1840.798 | 303.982 | 0.000 | 0.0000 | 1.1307 | 33.5183 |
| 1998 | 1835.469 | 2324.000 | 4159.469 | 83.346 | 0.000 | 55.8725 | 1.4172 | 43.1196 |
| 1999 | 1346.976 | 69.000 | 1415.976 | 94.939 | 0.000 | 4.8730 | 1.1127 | 32.7876 |
| 2000 | 859.909 | 233.000 | 1092.909 | 27.446 | 0.000 | 21.3193 | 0.7499 | 22.7760 |
| 2001 | 846.662 | 738.000 | 1584.662 | 52.093 | 0.545 | 46.5714 | 0.7333 | 17.8301 |
| 2002 | 926.928 | 894.850 | 1821.778 | 46.951 | 0.155 | 49.1196 | 0.6250 | 16.4201 |
| 2003 | 726.661 | 347.500 | 1074.161 | 48.604 | 0.828 | 32.3508 | 0.5978 | 17.0122 |
| 2004 | 557.603 | 377.440 | 935.043 | 58.124 | 1.005 | 40.3661 | 0.5076 | 15.2541 |
| 2005 | 579.526 | 126.180 | 705.706 | 46.690 | 0.568 | 17.8800 | 0.5194 | 16.1484 |
| 2006 | 397.194 | 13.070 | 410.264 | 75.690 | 0.541 | 3.1858 | 0.4873 | 15.6812 |
| 2007 | 283.332 | 2.681 | 286.013 | 53.689 | 0.089 | 0.9374 | 0.4341 | 15.4678 |
| 2008 | 230.566 | 2.182 | 232.748 | 29.369 | 0.163 | 0.9374 | 0.4057 | 13.9780 |
| 2009 | 207.440 | 231.285 | 438.726 | 25.489 | 0.076 | 52.7175 | 0.3285 | 11.3207 |
| 2010 | 187.992 | 27.086 | 215.079 | 22.340 | 0.019 | 12.5936 | 0.3115 | 10.4815 |
| 2011 | 114.991 | 26.770 | 141.761 | 16.473 | 0.247 | 18.8840 | 0.2479 | 8.5118 |
| 2012 | 84.888 | 4.064 | 88.951 | 13.611 | 0.009 | 4.5684 | 0.2061 | 7.0022 |

Discards make up approximately 38.8% of the catch over the 1998-2006 period. The standardized catch rate series is from Zone 10.

Table 23.84. RBC calculations for Redfish. Ctarg and CPUEtarg relate to the period 1986-1990 and 1999-2003 (omitting a period of enhanced availability during the 1990s). CPUELim is 40% of the target, 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 (19).

| | |
|---|---|
| Ref_Year | 1986-1990&1999-2003 |
| CE_Targ | 1.0798 |
| CE_Lim | 0.4319 |
| CE_Recent | 0.2735 |
| Wt_Discard | 28.337 |
| Scaling | 0 |
| Last Year's TAC | 276 |
| $C_{targ}$ | **1485.953** |

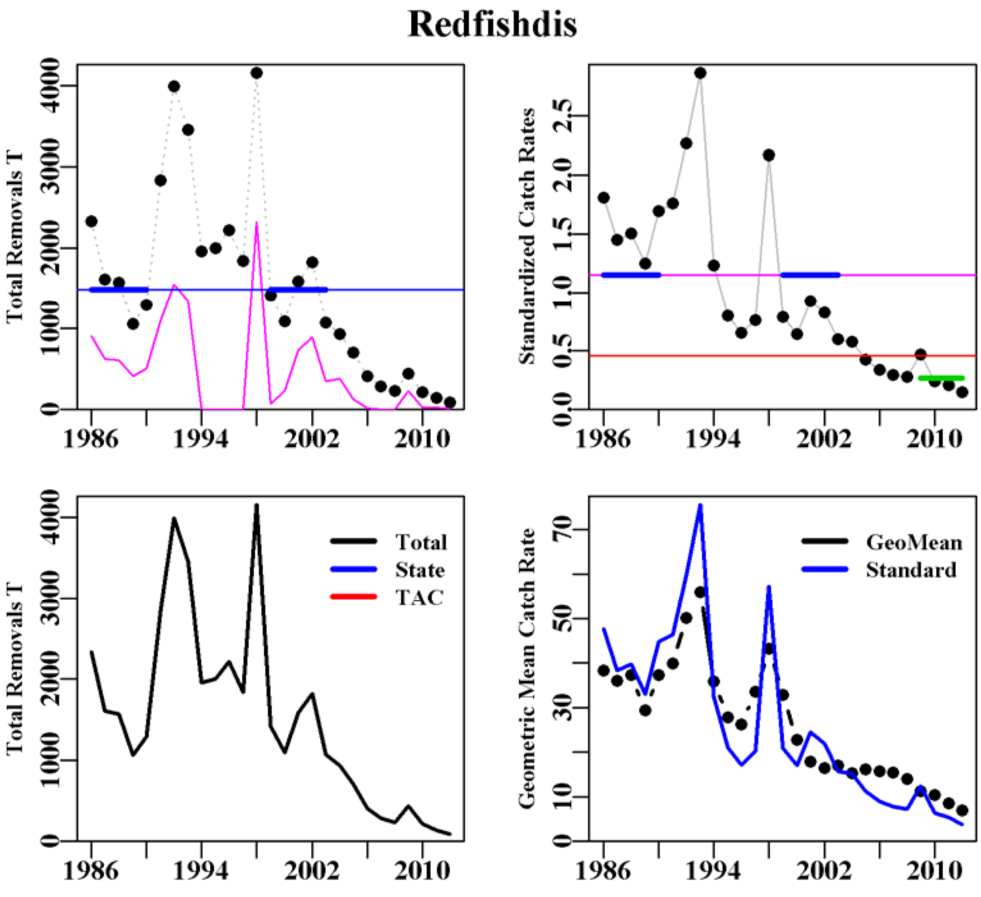


Figure 23.54. Redfish. Left is the total removals with the fine line illustrating the target catch. Right represents the standardized catch rates with the upper fine line representing the target catch rate and the lower line the limit catch rate. Thickened lines represents the reference period for catches, catch rates, and the recent average catch rate.

### 23.6.14 School Whiting (WHS – 37330014 – *Sillago flindersi*)

Table 23.85. School Whiting 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 Zone 60 from depths 0 to 100 m (Haddon, 2013). 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 | Non-T | PDiscard | CE | GeoMean |
|---|---|---|---|---|---|---|---|---|
| 1986 | 1903.200 | 29.416 | 1932.616 | | | 1.5221 | 1.1634 | 112.3054 |
| 1987 | 1320.000 | 20.402 | 1340.402 | | | 1.5221 | 1.2824 | 131.1624 |
| 1988 | 1549.200 | 23.945 | 1573.145 | | | 1.5221 | 1.6623 | 168.5490 |
| 1989 | 1220.400 | 18.863 | 1239.263 | | | 1.5221 | 1.0976 | 127.0438 |
| 1990 | 2007.600 | 31.030 | 2038.630 | | | 1.5221 | 1.7010 | 165.2959 |
| 1991 | 1866.000 | 28.841 | 1894.841 | | | 1.5221 | 1.4401 | 164.1905 |
| 1992 | 1219.200 | 18.844 | 1238.044 | | | 1.5221 | 1.0249 | 124.7066 |
| 1993 | 2007.600 | 31.030 | 2038.630 | | | 1.5221 | 1.4595 | 152.4819 |
| 1994 | 1647.018 | 0.000 | 1647.018 | 656.797 | 0.000 | 0.0000 | 0.8526 | 93.9314 |
| 1995 | 1990.790 | 0.000 | 1990.790 | 742.580 | 0.000 | 0.0000 | 1.0721 | 122.4731 |
| 1996 | 1695.105 | 0.000 | 1695.105 | 829.202 | 0.000 | 0.0000 | 0.7020 | 81.4339 |
| 1997 | 1556.380 | 0.000 | 1556.380 | 917.387 | 0.000 | 0.0000 | 0.5436 | 64.5619 |
| 1998 | 1813.848 | 48.000 | 1861.848 | 1169.056 | 48.000 | 2.5781 | 0.5241 | 66.0158 |
| 1999 | 1448.810 | 5.000 | 1453.810 | 824.832 | 5.000 | 0.3439 | 0.5996 | 84.3634 |
| 2000 | 1289.460 | 9.000 | 1298.460 | 687.243 | 9.000 | 0.6931 | 0.6039 | 65.1233 |
| 2001 | 1719.372 | 28.000 | 1747.372 | 1044.883 | 28.000 | 1.6024 | 0.8466 | 93.2089 |
| 2002 | 1577.598 | 9.760 | 1587.358 | 898.782 | 9.760 | 0.6149 | 0.8685 | 90.8874 |
| 2003 | 1509.107 | 46.340 | 1555.447 | 898.545 | 46.340 | 2.9792 | 0.8882 | 87.1013 |
| 2004 | 1412.951 | 26.360 | 1439.311 | 1001.215 | 26.360 | 1.8314 | 0.8380 | 79.7648 |
| 2005 | 1461.710 | 37.500 | 1499.210 | 1008.226 | 37.500 | 2.5013 | 0.9476 | 77.2502 |
| 2006 | 1551.224 | 3.090 | 1554.314 | 1080.014 | 3.090 | 0.1988 | 0.8179 | 76.2250 |
| 2007 | 1636.456 | 3.260 | 1639.716 | 1125.459 | 3.260 | 0.1988 | 1.0781 | 89.2381 |
| 2008 | 1369.947 | 2.729 | 1372.676 | 916.794 | 2.729 | 0.1988 | 1.0854 | 92.3448 |
| 2009 | 1227.521 | 2.445 | 1229.966 | 755.575 | 2.445 | 0.1988 | 1.1373 | 93.6200 |
| 2010 | 1226.626 | 18.316 | 1244.942 | 802.888 | 18.316 | 1.4713 | 1.0153 | 88.7190 |
| 2011 | 1240.111 | 58.467 | 1298.578 | 863.421 | 58.467 | 4.5024 | 0.8322 | 72.0269 |
| 2012 | 1269.130 | 19.429 | 1288.559 | 859.546 | 19.429 | 1.5078 | 0.9157 | 80.0853 |

Discards make up approximately 1.5% of the catch over the 1998-2006 period.

Table 23.86. RBC calculations for School Whiting. Ctarg and CPUEtarg relate to the period 1986-1995, CPUELim is 40% of the target, 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 (19).

| | |
|---|---|
| Ref_Year | 1986-1995 |
| CE_Targ | 1.2756 |
| CE_Lim | 0.5102 |
| CE_Recent | 0.9751 |
| Wt_Discard | 28.558 |
| Scaling | 0.6074 |
| Last Year's TAC | 641 |
| $C_{targ}$ | 1693.338 |

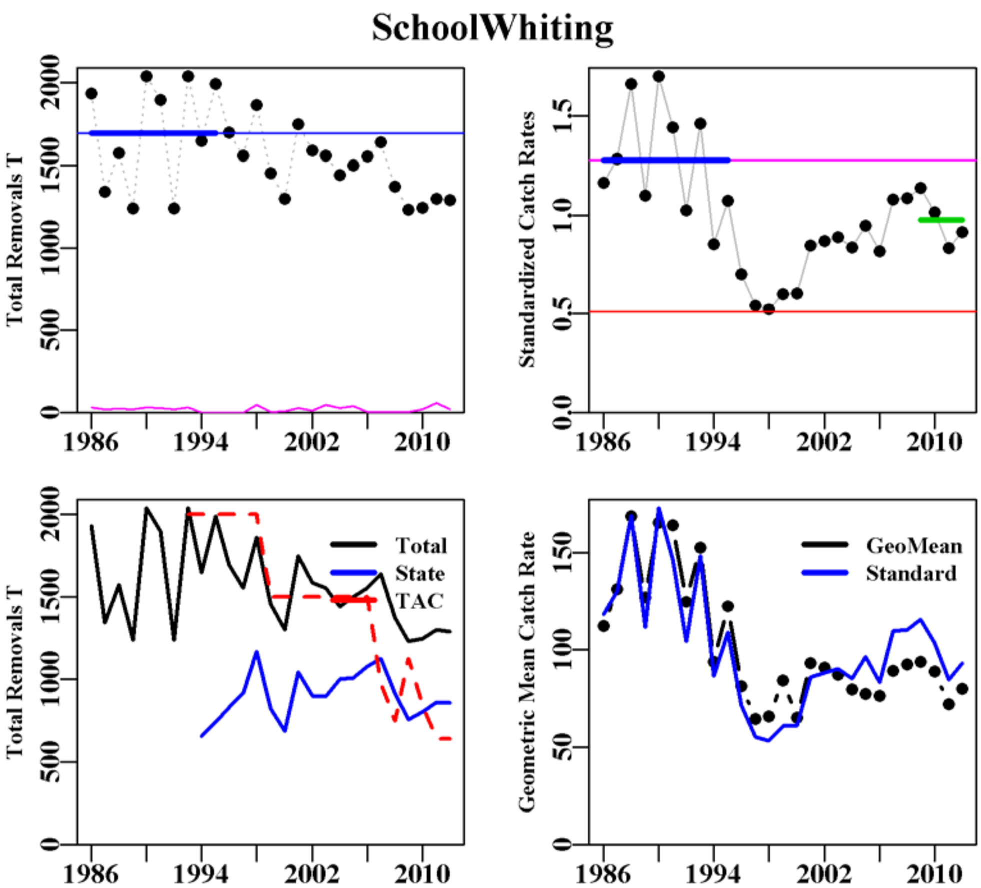


Figure 23.55. School Whiting. Top left is the total removals with the fine line illustrating the target catch. Top right represents the standardized catch rates with the upper fine line representing the target catch rate and the lower line the limit catch rate. Thickened lines represents the reference period for catches, catch rates, and the recent average catch rate.

## 2.3 Silver Warehou (TRS – 37445006 – *Seriolella punctata*)

Table 23.87. Spotted/Silver Warehou 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 50 in depths 0 – 1000m (Haddon, 2013). 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 | Non-T | PDiscard | CE | GeoMean |
|---|---|---|---|---|---|---|---|---|
| 1986 | 1142.927 | 242.793 | 1385.720 | | | 17.5211 | 1.4578 | 32.2897 |
| 1987 | 779.270 | 165.541 | 944.811 | | | 17.5211 | 1.5375 | 35.5040 |
| 1988 | 1637.312 | 347.815 | 1985.127 | | | 17.5211 | 1.9596 | 42.9346 |
| 1989 | 916.714 | 194.738 | 1111.452 | | | 17.5211 | 1.5983 | 30.7291 |
| 1990 | 1319.413 | 280.284 | 1599.697 | | | 17.5211 | 1.6895 | 40.6488 |
| 1991 | 1421.943 | 302.064 | 1724.007 | | | 17.5211 | 1.1874 | 25.6848 |
| 1992 | 709.181 | 150.652 | 859.833 | | | 17.5211 | 1.0405 | 27.9469 |
| 1993 | 1775.414 | 377.152 | 2152.566 | | | 17.5211 | 1.1751 | 33.2988 |
| 1994 | 2054.296 | 0 | 2054.296 | 78.956 | | 0 | 1.2561 | 34.7142 |
| 1995 | 2213.896 | 0 | 2213.896 | 117.062 | | 0 | 1.1350 | 29.7825 |
| 1996 | 2735.681 | 0 | 2735.681 | 174.562 | | 0 | 1.0664 | 22.7319 |
| 1997 | 2807.462 | 0 | 2807.462 | 23.013 | | 0 | 1.0937 | 25.3481 |
| 1998 | 2433.954 | 2150.000 | 4583.954 | 23.220 | | 46.9027 | 1.0527 | 26.6416 |
| 1999 | 3255.217 | 45.000 | 3300.217 | 1.732 | | 1.3635 | 0.9059 | 31.2330 |
| 2000 | 3726.592 | 123.000 | 3849.592 | 0.464 | | 3.1951 | 0.8281 | 26.0708 |
| 2001 | 3295.454 | 695.000 | 3990.454 | 0.324 | 0.923 | 17.4166 | 0.6968 | 21.7853 |
| 2002 | 4101.870 | 552.470 | 4654.340 | 0.487 | 0.701 | 11.8700 | 0.7532 | 22.9919 |
| 2003 | 3060.003 | 769.760 | 3829.763 | 1.007 | 12.642 | 20.0994 | 0.7615 | 20.4815 |
| 2004 | 3315.032 | 1183.280 | 4498.312 | 3.767 | 0.251 | 26.3050 | 0.8452 | 23.3323 |
| 2005 | 2912.725 | 434.830 | 3347.555 | 4.996 | 0.139 | 12.9895 | 0.8309 | 20.0277 |
| 2006 | 2374.182 | 95.630 | 2469.812 | 2.494 | 0.086 | 3.8720 | 0.7316 | 18.2160 |
| 2007 | 1987.060 | 82.453 | 2069.513 | 4.373 | 0.056 | 3.9842 | 0.6931 | 20.1239 |
| 2008 | 1522.999 | 49.718 | 1572.717 | 0.541 | 0.063 | 3.1613 | 0.6233 | 16.1202 |
| 2009 | 1379.268 | 33.280 | 1412.548 | 1.240 | 0.002 | 2.3560 | 0.6437 | 15.8837 |
| 2010 | 1288.673 | 17.155 | 1305.827 | 0.561 | 1.285 | 1.3137 | 0.5328 | 13.2653 |
| 2011 | 1229.279 | 428.738 | 1658.017 | 0.548 | 0.112 | 25.8585 | 0.4973 | 12.6164 |
| 2012 | 821.618 | 137.265 | 958.883 | 0.527 | 0.044 | 14.3151 | 0.4068 | 10.4075 |

Discards make up approximately 17.52 % of the catch over the 1998-2006 period. The standardization is an annual analysis conducted for the TIER 4 analysis.

Table 23.88. RBC calculations for Silver Warehou. Ctarg and CPUEtarg relate to the period 1986-1995, CPUELim is 40% of the target, 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 (19).

| | |
|---|---|
| Ref_Year | 1986-1995 |
| CE_Targ | 0.7018 |
| CE_Lim | 0.2807 |
| CE_Recent | 0.5202 |
| Wt_Discard | 192.044 |
| Scaling | 0.5685 |
| Last Year's TAC | 2566 |
| $C_{targ}$ | 1603.141 |

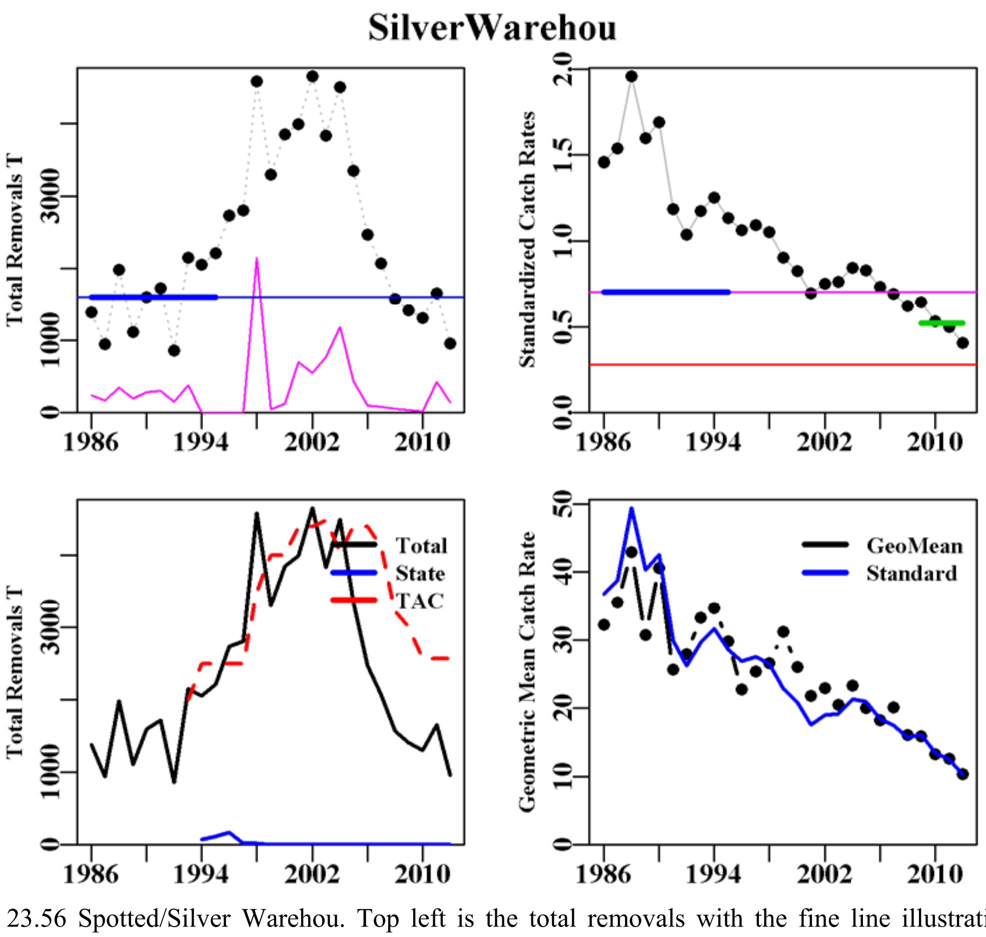


Figure 23.56 Spotted/Silver Warehou. Top left is the total removals with the fine line illustrating the target catch. Top right represents the standardized catch rates with the upper fine line representing the target catch rate and the lower line the limit catch rate. Thickened lines represents the reference period for catches, catch rates, and the recent average catch rate.

## 23.1 Acknowledgements

Thanks also go to Mike Fuller and Neil Klaer for all the pre-analytical data preparation required maintaining the SESSF data set.

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# 24. Saw Shark and Elephant Fish TIER 4 Analyses (Data from 1980 – 2012)

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## 24.1 Summary

The stock assessments that feed into the management control rules that reflect the harvest strategy adopted in the SESSF are arranged in a tiered system ranging from fully quantified modelled stock assessments (Tier 1) down to empirical rules based only on catch and catch rates (Tier 4). For those species where biological and fisheries data are limited an examination of trends in catch rates is used to modify allowable catches with the objective of managing the particular fishery towards a target that represents a desirable state for the fishery that also acts as a proxy for the general Harvest Strategy Policy target of 48% $B_0$.

The Tier 4 control rule is used to calculate Recommended Biological Catches (RBCs) for saw sharks and elephant fish from the southern shark fishery. Standardized catch rates for both species were estimated using the SESSF logbook data only rather than the earlier data, along with total catches of the respective species in a standard analysis. For saw sharks the reported catches by trawl are now approaching the level of gill net catches so an additional analysis was conducted where the standardized catch rate for trawl saw shark catches was used instead of the gillnet catch rates.

The gillnet catch rates for saw sharks in 2012 were slightly lower than those in 2011 but owing to the initial drop in catch rates in 2010 the tier 4 analysis, which considers the average catch rate over the last four years, generates a RBC for saw sharks at the 48% target that has now declined to about 59% of the target catch (down from 64% last year). Whether the decline in the gillnet catch rates constitute a reasonable reflection of the stock status remains questionable due to the level of avoidance that occurs in the fishery (due to low and reducing value of saw sharks in the market). Importantly, when the trawl catch rates for saw sharks are standardized a different trend is apparent. In 2000 the catches by trawl were only 20% of all catches by gillnet plus trawl but now make up 40%.

The catch rate data used for Elephant fish now relates to the SESSF database, which means the probability of obtaining a positive shot cannot be well identified. The decline in catch rates in elephant fish seen in 2010 continued in 2011 but then recovered its 2011 losses in 2012 (Figure 24.6). However, these values do not include discards in their calculations and since 2007 and especially since 2011 the importance of discards has become particularly influential in Elephant fish. When discards are included in the calculation of CPUE as well as total catches then the CPUE increased in both 2011 and 2012, implying a rise in RBC (Figure 24.7). When discards are not stable, as is the case with Elephant fish then this latter analysis more closely reflects the fishery dynamics.

In both the saw shark and elephant fish these analyses relate to the target catch rate being a proxy for 48% of unfished biomass. However, neither species are reported as being targeted in the fishery (when using any method) so these calculated RBC are inherently conservative.

Table 24.1. TIER 4 outcomes by species. The RBC in tonnes; this has not had discards, State catches, or recreational catches removed. The 2010, 2011, and 2012 values came from Haddon (2010; 2011; 2012) and the 2009 values came from Rodriguez and McLoughlin (2009a, b).

| Species | RBC09 | RBC10 | RBC11 | RBC12 | **RBC13** |
|---|---|---|---|---|---|
| SawSharks @ 48% | 370 | 340 | 268 | 234 | **216.218** |
| Saw Sharks Trawl @ 48% | Zones 20,60,50 | | | 514 | **467.933** |
| Saw Sharks Trawl @ 48% | Zones 20,60,50,83,82 | | | 477 | **459.086** |
| | | | | | |
| Elephant Fish @ 48% | 123 | 135 | 208 | 186 | **115.812** |
| Elephant Fish @ 48% + Discards | | | | | **232.300** |

## *24.2 Introduction*

The TIER 4 harvest control rule is the default procedure applied to species for which only limited information is available; specifically, if no reliable information is available relating to 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. In essence TIER 4 analyses require as a minimum, knowledge of the time series of total catches and of standardized catch rates.

Initially a control rule was implemented that was based around using any trend in recent catch rates to scale average recent catches. However, in 2008, an alternative was proposed that would not be prone to a declining ratchet effect on catches, and, in line with the Harvest Strategy Policy, could manage each fishery towards a target catch rate and away from a limit catch rate (Little, *et al*., 2008) The current TIER 4 analysis and control rule underwent Management Strategy Evaluation (Wayte, 2009; Little *et al,* 2011), which demonstrated its advantages over the original implementation.

The Tier 4 assessment requires the definition of a reference period for catches and catch rates which are to constitute the effective target for the fishery. This reference period is intended to act as a proxy for the fishery in a desirable state; ideally close to the stock size that leads to the maximum economic yield, and so in practice this target is also taken as a proxy for $B_{MEY}$. In practice, in TIER 4 analyses, all that is really known about the reference period is that the RAG considers this period to be when the fishery was in a desirable state both biologically and economically. The Harvest Strategy Policy does not require that all species in a multi-species fishery aim to achieve the maximum economic yield, and this is especially the case with bycatch species. Nevertheless, the objective of avoiding the limit reference point remains. Within the current Tier 4 methodology the limit reference point is defined as 40 % of the target catch rate. In addition, the Harvest Strategy Policy also states that:

Consideration should also be given to:

- Demonstrating that economic modelling and other advice clearly supports such action;

- No cost effective, alternative management options (e.g. gear modifications or spatial management) are available; and
- The associated ecosystem risks have been considered in full.

(DAFF, 2007, p 25)

If the average catch rate over the last four years drops below this limit the RBC is automatically zero.

## 24.3 Methods

### 24.3.1 TIER 4 Methods

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, any discards, and any recreational catches (for elephant fish). Despite the fishery now operating from May through to April each year, the fishery data was collated in calendar years for consistency with the earlier fishery.

The fishery for both saw sharks and elephant fish was established before the catch rate standardization period selected by the RAG (i.e. significant catches were taken in the 1970s). Thus, although the Shark RAG did not consider the stocks of saw sharks and elephant fish to be seriously depleted by 1980, the stock was not pristine. In previous TIER 4 analyses (Rodriguez & McLoughlin, 2009a, b) two reference periods were examined for saw sharks, 1986-2001 and 2002-2008, and two for elephant fish, 1980 – 1992 and 1998 – 2004. The earlier period had an extra source of uncertainty because the estimates of trawl bycatch and discards were likely under-estimated. To avoid these uncertainties and focus on a period when the total catches are known with most certainty the Shark RAG has selected 2002 – 2008 as the reference period for saw sharks and 1996 – 2007 for elephant fish.

All data to the end of 2010 relating to catches and discards, from both State waters and SEF2 data sets were provided by John Garvey of AFMA, with initial processing by Dr Neil Klaer and Mike Fuller of CSIRO. For saw sharks the species codes used in the landings database were SAW (*Pristiophorus cirratus or Common Saw Shark*), SHN (*Pristiophorus nudipinnis* or Southern Saw Shark), and SHW (*Pristiophoridae* or saw sharks). For elephant fish the species code in the landings database was SHE (*Callorhinchus milii* or Elephantfish). All catch rate data from the GHT fishery for both species were derived from the CANDE11.csv data files and analysed in Haddon (2012). All analyses of trawl caught fish used data straight from the AFMA Log Book database following pre-processing by Mike Fuller and Neil Klaer of CSIRO.

Standard analyses were set up in the statistical software, R, which provided the tables and graphs required for the TIER 4 analyses. The data and results for each analysis are presented for clarity. 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. This scaling factor is applied to the target catch to generate an RBC:

$$\text{Scaling Factor } = SF = \max\left(0, \frac{\overline{CPUE} - CPUE_{\lim}}{CPUE_{t\arg} - CPUE_{\lim}}\right) \quad (24)$$

$$RBC = C^{*} \times SF \quad (25)$$

where

$CPUE_{targ}$ is the target CPUE for the species (half the average CPUE for the reference period).
$CPUE_{lim}$ is the limit CPUE for the species; which is 40% CPUE $_{\text{targ}}$
$\overline{CPUE}$ the average CPUE over the past *m* years
$C^*$ 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. 1996 – 2007, as for Elephant fish). This is an average of the total removals for the selected reference period, including any discards.

$$CPUE_{\text{targ}} = \frac{\sum_{y=yr1}^{yr2} CPUE_y}{(yr2 - yr1 + 1)} \qquad (26)$$

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. The catch target is the mean of the total catch across the reference years.

$$C^* = \frac{\sum_{y=yr1}^{yr2} L_y}{(yr2 - yr1 + 1)} \qquad (27)$$

where $L_y$ represents the total catch (landings plus discards) in year *y*.

Usually there are three rules used to select/estimate the CPUE/catch 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 from which the target CPUE and catch targeted are calculated.

With bycatch shark species these rules are not always applicable (for example, with elephant fish the total catch rarely reaches 100 tonnes. Instead periods were chosen during which the fishery was considered to be well developed but in a good and relatively stable condition. For elephant fish the reference period chosen was 1996 – 2007 and for saw sharks the reference period chosen was 2002 – 2008.

Once the average CPUE for the reference period has been selected as the target CPUE (assumed a proxy for $B_{48\%}$ which is assumed to be a proxy for $B_{MEY}$) then the limit CPUE is defined as 40% of the that target. The maximum of the terms in the brackets, that is either zero or the ratio of CPUE values, is a scaling factor which is multiplied by the catch target (C*) to determine the expected total catch. If the $\overline{CPUE}$ is less than the $\text{CPUE}_{\text{lim}}$ this will automatically set the scaling factor to be negative, which means that the scaling factor will be set to zero and the consequent RBC will be zero.

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. The catch rates are standardized, usually from 1986, using methods described in Haddon (2012).

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

$$D_y = \frac{C_y \bar{D}_{98-06}}{\left(1 - \bar{D}_{98-06}\right)} \qquad (28)$$

To estimate the expected discards in the coming year a weighted average is used:

$$D_{CUR} = (1.0D_{i-1} + 0.5D_{i-2} + 0.25D_{i-3} + 0.125D_{i-4})/1.875$$

where $D_i$ is the discards rate in year $i$, the discard rate in year $i$ is the ratio of discards to the sum of landed catches plus discards:

$$D_i = \frac{Discard_i}{\left(Catches_i + Discard_i\right)}$$

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.

There are a number of meta-rules that are used when translating the RBCs into TACs. Two that relate to all species are:

- No TAC will change by more than 50% (either increase or decrease)
- Only changes greater than 10% (up or down) will be implemented.

### 24.3.2 Catches

The discard data for both saw sharks and elephant fish have been included in the most recent SESSF data summaries (Klaer and Upston, 2012) and this has led to some changes in the histories. Fortunately, the changes to the tier4 targets have barely changed as a result so this aspect of the change should have little effect. On the other hand the discard rate for elephant fish appears to have increased dramatically in 2011 from a base level of about 30 t up to about 132 t. This change calls into question the previous discard estimates. There have been no updates of information concerning State or recreational catches and these have been assumed to be equal to the last available estimates. This is unfortunate because there are anecdotal reports that recreational catches of elephant fish has been larger recently. Commonwealth landings were derived from the Quota landings database.

#### *24.3.3 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

$$\hat{I}_{R,t} = \frac{\sum C_t}{\sum E_t} \tag{29}$$

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

$$\hat{I}_{D,t} = \frac{\sum C_t + \sum D_t}{\sum E_t} \tag{30}$$

The same values of $\hat{I}_{D,t}$ can also be obtained using the following multiplier

$$\hat{I}_{D,t} = \left[\left(\sum D_t / \sum C_t\right) + 1\right] \times I_t \tag{31}$$

where $I_t$ is the catch rate estimate to be modified by the inclusion of discards. If this is the ratio mean from Equ (29) then the augmented catch rates would be identical to those produced by Equ (30). In practice, the catch rates used with the multiplier are the standardized catch rates from Haddon (2010a).

## 24.4 Results

### 24.4.1 Saw Sharks

Table 24.2. Saw Sharks. Data used in the Tier 4 analysis of saw sharks (full details of the available data are given in the Tables appendix (see Table 24.10)). See the methods for a description of how the discards are calculated. The standardized catch rates for gillnet and trawl are in columns pre-fixed with CE. The greyed cells reflect the reference period.

| Year | Catch | Discards | Total | CE – GN | CE – TW |
|---|---|---|---|---|---|
| 1986 | 300.007 | 31.407 | 331.414 | | |
| 1987 | 343.811 | 31.937 | 375.748 | | |
| 1988 | 279.727 | 37.755 | 317.482 | | |
| 1989 | 234.846 | 26.428 | 261.274 | | |
| 1990 | 207.187 | 23.874 | 231.061 | | |
| 1991 | 246.785 | 28.213 | 274.998 | | |
| 1992 | 259.68 | 31.399 | 291.079 | | |
| 1993 | 340.195 | 40.162 | 380.357 | | |
| 1994 | 387.141 | 51.517 | 438.658 | | |
| 1995 | 447.775 | 47.723 | 495.498 | | |
| 1996 | 378.107 | 49.728 | 427.835 | | |
| 1997 | 296.93 | 38.773 | 335.703 | 1.1280 | 1.2230 |
| 1998 | 278.413 | 39.659 | 318.072 | 1.2260 | 1.1440 |
| 1999 | 223.661 | 34.922 | 258.583 | 1.2208 | 1.2714 |
| 2000 | 195.973 | 32.211 | 228.184 | 1.5120 | 1.1419 |
| 2001 | 264.441 | 30.699 | 295.140 | 1.5328 | 1.0795 |
| 2002 | 315.372 | 30.592 | 345.964 | 0.9603 | 0.9857 |
| 2003 | 367.676 | 32.486 | 400.162 | 1.0181 | 0.8469 |
| 2004 | 376.150 | 32.981 | 409.131 | 1.0709 | 0.8032 |
| 2005 | 353.910 | 31.671 | 385.581 | 0.9551 | 0.8177 |
| 2006 | 373.515 | 30.656 | 404.171 | 0.9139 | 0.9154 |
| 2007 | 269.940 | 41.977 | 311.917 | 0.7715 | 0.8214 |
| 2008 | 273.382 | 42.512 | 315.894 | 0.8687 | 0.9299 |
| 2009 | 259.743 | 40.392 | 300.135 | 0.7606 | 1.1705 |
| 2010 | 245.482 | 38.173 | 283.655 | 0.7159 | 1.0757 |
| 2011 | 253.639 | 39.442 | 293.081 | 0.7174 | 0.9151 |
| 2012 | 188.148 | 50.586 | 238.734 | 0.6280 | 0.8586 |

#### *24.4.1.1 Comparison of GN amd TW cPUE Series*

The CPUE series by trawl across the years 1997 – 2012 varies above and below the long term average, with the most recent two years falling below. This contrasts with the CPUE series for saw sharks from gillnets, which began the period at a relatively high level but has declined over the last 9 years since 2004 (Figure 24.1). This fall has been despite the catches being relatively stable by gill net during that time (Figure 24.2).

The difference in catch rates reflects the different distribution of effort for the two methods. The trawl fishers are not known to ever target the saw sharks but the gillnet fishers are known to be making efforts to avoid saw sharks. Which CPUE series provides the better stock indicator would depend on whether the saw sharks are sufficiently mobile that the populations in Bass Strait mix freely with those just outside it.

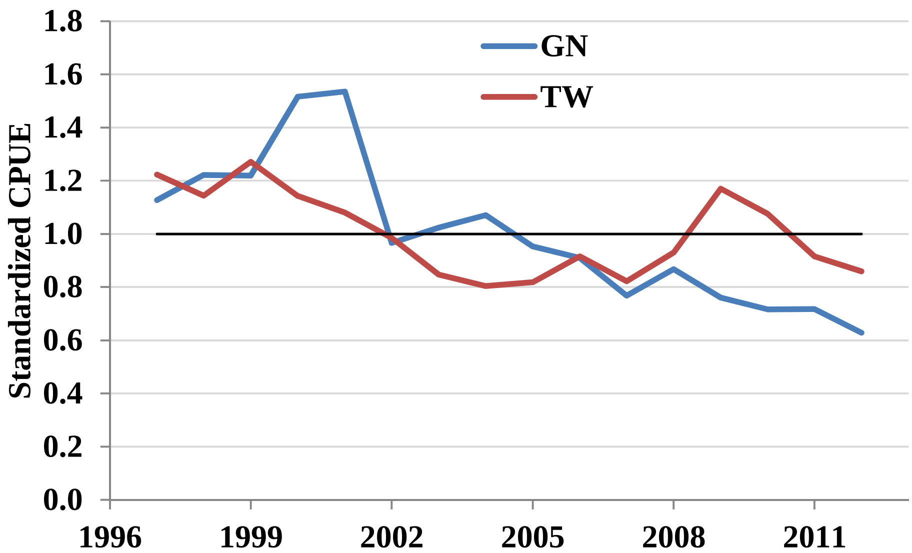


Figure 24.1. A comparison of the standardized CPUE derived from the SESSF logbooks for gillnets and for trawl. The fine black line is along 1.0, the average of each time series.

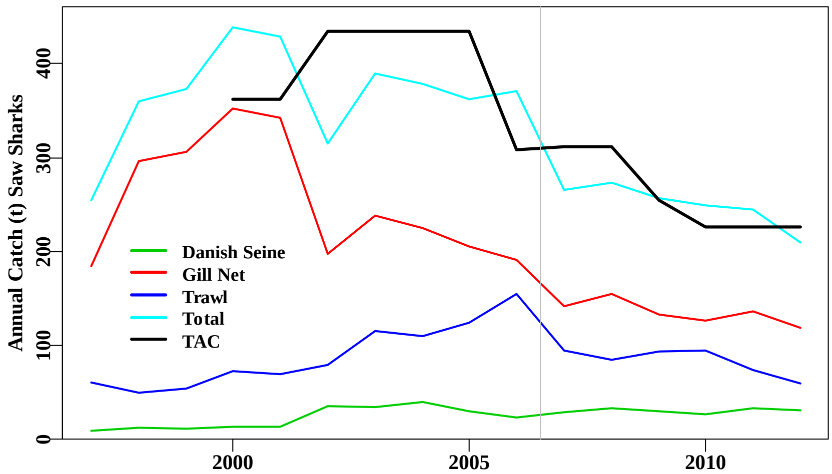


Figure 24.2. The annual catch of saw sharks, as reported in the logbooks by different methods, from 1997 – 2012. The fine black line is indicating the transition before and after the structural adjustment that finished in November 2006.

### *24.4.1.2 Proxy Target 48% Gillnet*

Table 24.3. Saw Sharks RBC calculations. C* and CPUEtarg relate to the period 2002 – 2008, CPUELim is 40% of the target, 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. The Wt_discards is the expected weight of discards. Implied proxy target = 48% B0.

| | |
|---|---|
| 1st Reference Year | 2002 |
| 2nd Reference Year | 2008 |
| C* | 367.546 |
| $CPUE_{targ}$ | 0.9370 |
| $CPUE_{Lim}$ | 0.3748 |
| $\overline{CPUE}$ | 0.7055 |
| Scaling Factor | 0.5883 |
| Wt_Discard | 45.28 |
| TAC 2012 | 226 |
| **RBC** | **216.218** |

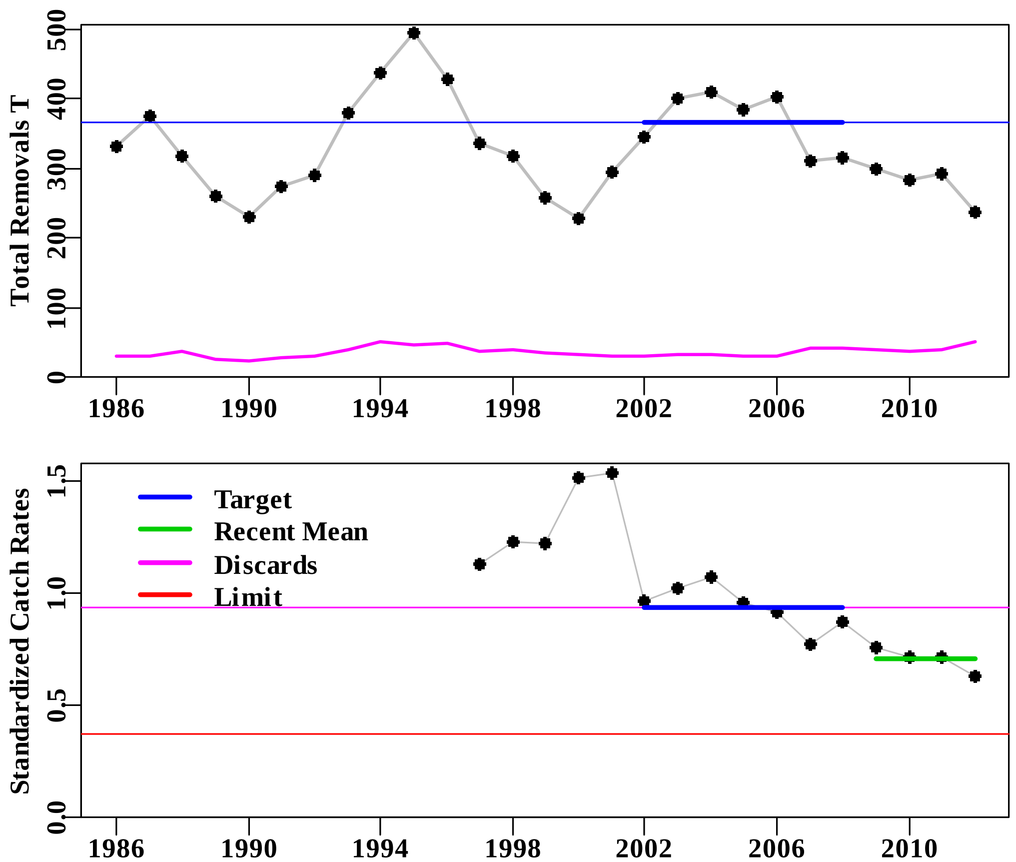


Figure 24.3. Saw Sharks. Top panel is the total removals with the fine line illustrating the target catch. Bottom panel represents the standardized catch rates with the upper fine line representing the target catch rate and the lower line the limit catch rate. Thickened lines represents the reference period for catches, catch rates, and the recent average catch rate.

### *24.4.1.3 Proxy Target 48% Trawl SESSF Zones 20, 60, 50*

Table 24.4. TRAWL: Saw Sharks RBC calculations. C* and CPUEtarg relate to the period 2002 – 2008, CPUELim is 48% of the target, 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. The Wt_discards is the expected weight of discards. Implied proxy target = 48% B0.

| | |
|---|---|
| 1st Reference Year | 2002 |
| 2nd Reference Year | 2008 |
| C* | 367.546 |
| $CPUE_{targ}$ | 0.8140 |
| $CPUE_{Lim}$ | 0.3256 |
| $\overline{CPUE}$ | 0.9474 |
| Scaling Factor | 1.2731 |
| Wt_Discard | 45.280 |
| **RBC** | **467.933** |

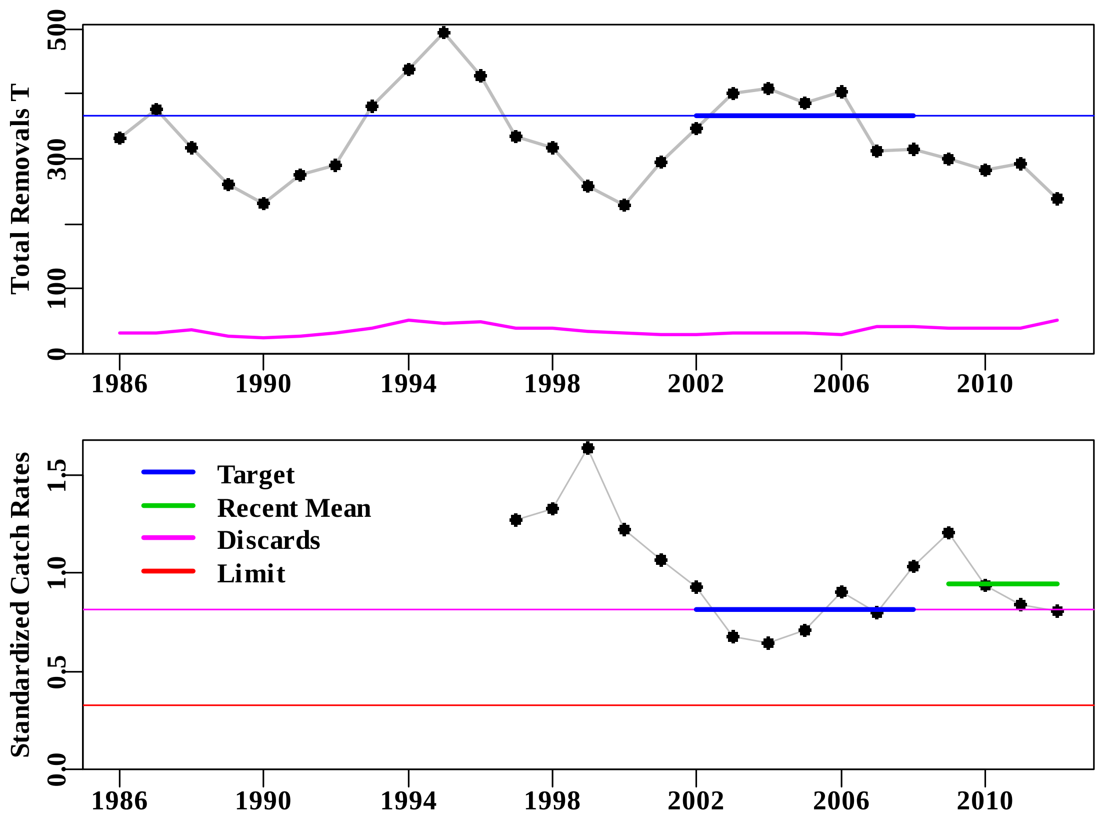


Figure 24.4. Saw Sharks taken by Trawl in Zones 20, 60, and 50. Top panel is the total removals with the fine line illustrating the target catch. Bottom panel represents the standardized catch rates with the upper fine line representing the target catch rate and the lower line the limit catch rate. Thickened lines represents the reference period for catches, catch rates, and the recent average catch rate. The fine purple line below the target CPUE target is the revised target based on a 48% B0 proxy target for non-target species in a mixed fishery. The limit reference point is represented by the red line.

### *24.4.1.4 Proxy Target 48% Trawl SESSF Zones 20, 60, 50, 83 & 82*

Table 24.5. TRAWL (20,60,50,83,82): Saw Sharks RBC calculations. C* and CPUEtarg relate to the period 2002 – 2008, CPUELim is 48% of the target, and $\overline{CPUE}$ is average catch rate over the last four years. The RBC calculation does not account for predicted discards of predicted State catches. The Wt_ discards is the expected weight of discards. Implied proxy target = 48% B0.

| | |
|---|---|
| 1st Reference Year | 2002 |
| 2nd Reference Year | 2008 |
| C* | 367.546 |
| $CPUE_{targ}$ | 0.8740 |
| $CPUE_{Lim}$ | 0.3497 |
| $\overline{CPUE}$ | 1.0050 |
| Scaling Factor | 1.2491 |
| Wt_Discard | 45.280 |
| **RBC** | **459.086** |

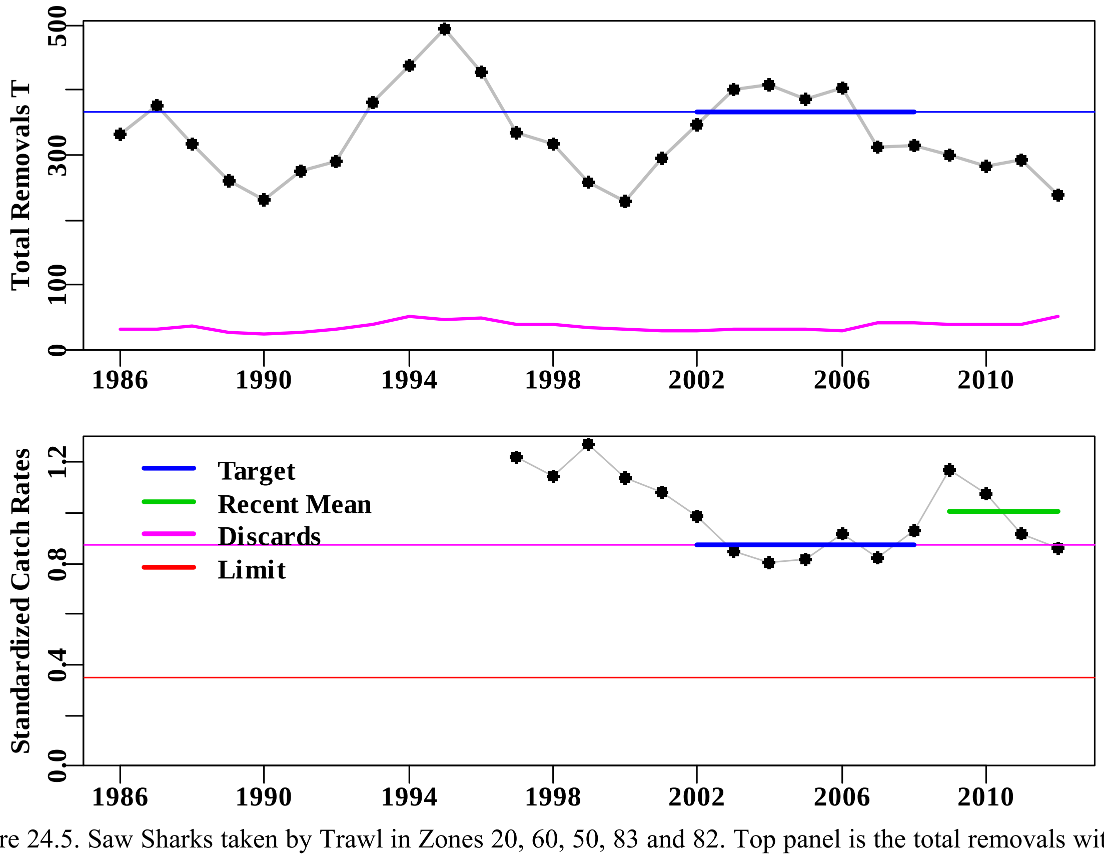


Figure 24.5. Saw Sharks taken by Trawl in Zones 20, 60, 50, 83 and 82. Top panel is the total removals with the fine line illustrating the target catch. Bottom panel represents the standardized catch rates with the upper fine line representing the target catch rate and the lower line the limit catch rate. Thickened lines represents the reference period for catches, catch rates, and the recent average catch rate.

### *24.4.2 Elephant Fish*

Table 24.6. Elephant Fish. Data used in the Tier 4 analysis of Elephant Fish (full details of the available data are given in the Tables appendix (see Table 24.11)). See the methods for a description of how the discards are calculated. The standardized catch rates (CE) are derived from Haddon (2012). The greyed cells relate to the reference period. Catch from 2002 onwards is the reported catches from the CDRs plus 29t of recreational fishing.

| Year | Catch | Discards | Total | CE |
|---|---|---|---|---|
| 1986 | 70.522 | 6.537 | 77.059 | |
| 1987 | 65.209 | 6.336 | 71.545 | |
| 1988 | 79.400 | 6.710 | 86.110 | |
| 1989 | 65.460 | 6.211 | 71.671 | |
| 1990 | 57.729 | 5.579 | 63.308 | |
| 1991 | 74.617 | 6.920 | 81.537 | |
| 1992 | 76.829 | 7.107 | 83.936 | |
| 1993 | 57.060 | 5.434 | 62.494 | |
| 1994 | 64.199 | 5.950 | 70.149 | |
| 1995 | 54.694 | 5.184 | 59.878 | |
| 1996 | 111.796 | 12.524 | 124.320 | |
| 1997 | 94.550 | 9.573 | 104.123 | 0.9629 |
| 1998 | 89.802 | 8.539 | 98.341 | 0.8847 |
| 1999 | 111.624 | 9.448 | 121.072 | 1.0096 |
| 2000 | 95.801 | 8.189 | 103.99 | 1.1759 |
| 2001 | 87.880 | 7.533 | 95.413 | 1.2117 |
| 2002 | 102.259 | 5.266 | 91.05318 | 0.8843 |
| 2003 | 116.403 | 7.679 | 111.9661 | 0.8618 |
| 2004 | 103.401 | 6.323 | 113.4055 | 0.8708 |
| 2005 | 104.907 | 6.852 | 118.6227 | 0.8718 |
| 2006 | 91.176 | 6.814 | 106.102 | 0.9442 |
| 2007 | 89.154 | 21.84463 | 108.8933 | 1.0512 |
| 2008 | 99.194 | 23.02335 | 123.5357 | 1.1681 |
| 2009 | 103.519 | 27.62985 | 141.1379 | 1.3264 |
| 2010 | 94.438 | 22.94613 | 122.2235 | 0.9861 |
| 2011 | 88.5601 | 135.7247 | 222.272 | 0.8104 |
| 2012 | 70.842 | 97.57982 | 195.7599 | 0.9800 |

*24.4.2.1 Proxy Target 48% Gillnet*

Table 24.7. Elephant Fish. RBC calculations. C* and CPUEtarg relate to the period 1996 – 2007, CPUELim is 48% of the original target, 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. The Wt_discards is the expected weight of discards. Implied proxy target = 48% B0.

| | |
|---|---|
| 1st Reference Year | 1996 |
| 2nd Reference Year | 2007 |
| C* | 106.635 |
| $CPUE_{targ}$ | 0.975 |
| $CPUE_{Lim}$ | 0.3901 |
| $\overline{CPUE}$ | 1.0257 |
| Scaling Factor | 1.0861 |
| Wt_Discard | 93.137 |
| TAC 2012 | 89 |
| **RBC** | **115.812** |

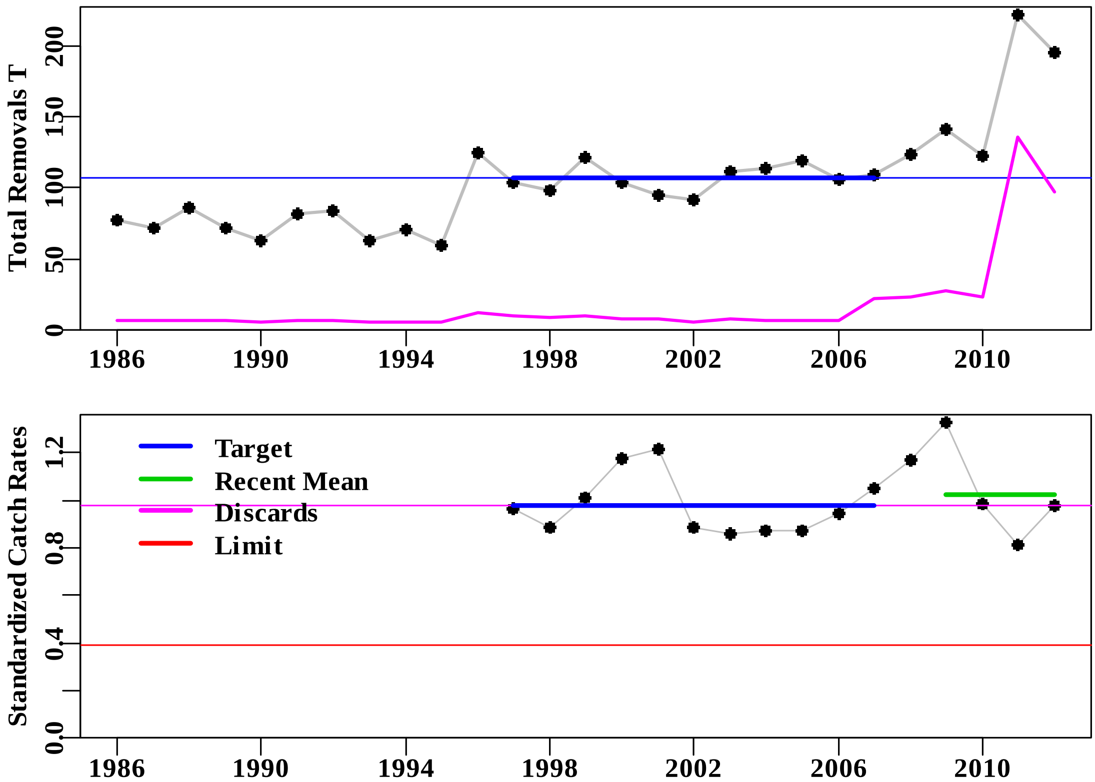


Figure 24.6. Elephant Fish. Top panel is the total removals with the fine line illustrating the target catch. Bottom panel represents the standardized catch rates with the upper fine line representing the target catch rate and the lower line the limit catch rate. Thickened lines represents the reference period for catches, catch rates (1996 – 2007), and the recent average catch rate (last four years).

### *24.4.2.2 Plus Discards in the CPUE: Target 48% Gillnet*

Table 24.8. Elephant Fish. Data used in the Tier 4 analysis of Elephant Fish (full details of the available data are given in the Tables appendix (see Table 24.11)). See the methods for a description of how the discards are calculated. The greyed cells relate to the reference period. Total is the catch from 2002 onwards made up of the reported catches from the CDRs plus 29t of recreational fishing, plus State catches, plus discards.

| Year | Catch | Discards | Total | (D/C)+1 | StandCE | DiscCE | GeoMean | TAC |
|---|---|---|---|---|---|---|---|---|
| 1986 | 70.522 | 6.537 | 77.059 | 1.0927 | | | | |
| 1987 | 65.209 | 6.336 | 71.545 | 1.0972 | | | | |
| 1988 | 79.400 | 6.710 | 86.110 | 1.0845 | | | | |
| 1989 | 65.460 | 6.211 | 71.671 | 1.0949 | | | | |
| 1990 | 57.729 | 5.579 | 63.308 | 1.0966 | | | | |
| 1991 | 74.617 | 6.920 | 81.537 | 1.0927 | | | | |
| 1992 | 76.829 | 7.107 | 83.936 | 1.0925 | | | | |
| 1993 | 57.060 | 5.434 | 62.494 | 1.0952 | | | | |
| 1994 | 64.199 | 5.950 | 70.149 | 1.0927 | | | | |
| 1995 | 54.694 | 5.184 | 59.878 | 1.0948 | | | | |
| 1996 | 111.796 | 12.524 | 124.320 | 1.1120 | | | | |
| 1997 | 94.550 | 9.573 | 104.123 | 1.1012 | 0.9629 | 0.8289 | 6.6363 | |
| 1998 | 89.802 | 8.539 | 98.341 | 1.0951 | 0.8847 | 0.7573 | 6.6255 | |
| 1999 | 111.624 | 9.448 | 121.072 | 1.0846 | 1.0096 | 0.8560 | 7.1170 | |
| 2000 | 95.801 | 8.189 | 103.990 | 1.0855 | 1.1759 | 0.9978 | 8.3421 | |
| 2001 | 87.880 | 7.533 | 95.413 | 1.0857 | 1.2117 | 1.0284 | 9.3968 | |
| 2002 | 102.259 | 5.266 | 91.053 | 1.0515 | 0.8843 | 0.7268 | 6.1690 | 80 |
| 2003 | 116.403 | 7.679 | 111.966 | 1.0660 | 0.8618 | 0.7181 | 5.9089 | 83 |
| 2004 | 103.401 | 6.323 | 113.405 | 1.0612 | 0.8708 | 0.7223 | 5.8752 | 100 |
| 2005 | 104.907 | 6.852 | 118.623 | 1.0653 | 0.8718 | 0.7260 | 6.1762 | 130 |
| 2006 | 91.176 | 6.814 | 106.102 | 1.0747 | 0.9442 | 0.7932 | 5.9030 | 130 |
| 2007 | 89.154 | 21.845 | 108.893 | 1.2450 | 1.0512 | 1.0231 | 6.4174 | 130 |
| 2008 | 99.194 | 23.023 | 123.536 | 1.2321 | 1.1681 | 1.1250 | 6.7380 | 92 |
| 2009 | 103.519 | 27.630 | 141.138 | 1.2669 | 1.3264 | 1.3136 | 8.1596 | 94 |
| 2010 | 94.438 | 22.946 | 122.223 | 1.2430 | 0.9861 | 0.9581 | 6.0921 | 94 |
| 2011 | 88.560 | 135.725 | 222.272 | 2.5326 | 0.8104 | 1.6043 | 5.3679 | 65 |
| 2012 | 70.842 | 97.580 | 195.760 | 2.3774 | 0.9800 | 1.8212 | 6.5355 | 89 |

Table 24.9. Elephant Fish. RBC calculations. C* and CPUEtarg relate to the period 1996 – 2007, CPUELim is 48% of the original target, 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. . The Wt_discards is the expected weight of discards. Implied proxy target = 48% B0.

| | |
|---|---|
| 1st Reference Year | 1997 |
| 2nd Reference Year | 2007 |
| C* | 106.635 |
| $CPUE_{targ}$ | 0.8343 |
| $CPUE_{Lim}$ | 0.3337 |
| $\overline{CPUE}$ | 1.4243 |
| Scaling Factor | 2.1785 |
| Wt_Discard | 93.137 |
| TAC 2012 | 89 |
| **RBC** | **232.300** |

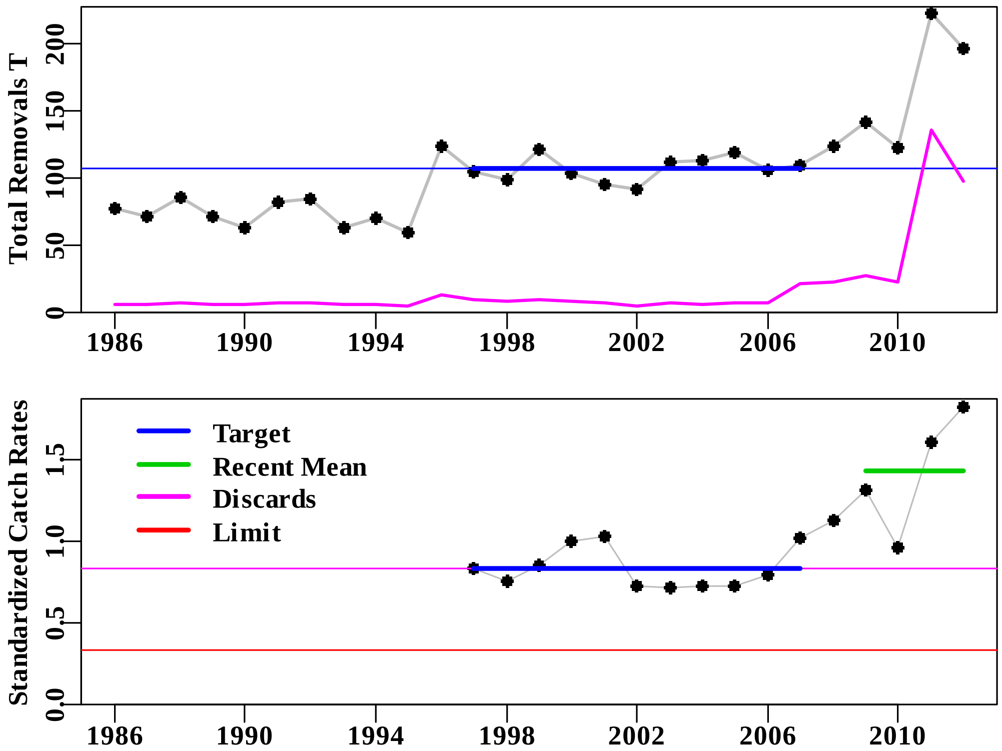


Figure 24.7. Elephant Fish. Top panel is the total removals with the fine line illustrating the target catch. Bottom panel represents the standardized catch rates with the upper fine line representing the target catch rate and the lower line the limit catch rate. Thickened lines represents the reference period for catches, catch rates (1996 – 2007), and the recent average catch rate (last four years). In this case the discard catches have been included in the CPUE estimates, thereby increasing them markedly.

## 24.5 Discussion

In the case of Saw sharks this is the first year when the reference years do not overlap the last four years used to generate an estimate of the recent catch rates, which means the reference estimates and the current rate estimates are now free to diverge. This ceased to be a problem for elephant fish last year.

The capture of Elephant fish by recreational fishers is not insignificant but the estimates of catch are uncertain. In the analysis these have been held constant at 29 t since 1996. Braccini et al (2009) derive an estimated catch of Elephant fish of 13.931 t in 2008 inside Western Port (of which they estimated 70% were females). If this were included rather than the default 29t it would not influence the Tier 4 calculation of the RBC but it might influence the removals taken from the RBC to form the TAC, although that would depend on whether such an adjustment to the total catches were made across the reference period as well as more recently. However, this may not represent all recreational catches of Elephant fish around Victoria and so the analysis retained the default value for recreational catches. Clearly a new estimate of total recreational catch would have value. It does suggest that the catch rate dynamics are likely being influenced by larger catches than believed, which in terms of the commercial fishery implies that the resulting RBC will be relatively conservative, as long as recreational catches are now stable, which is unknown.

The inclusion of discards into the CPUE analysis for elephant fish had a marked effect on CPUE and the analytical outcome, especially in the last two years. This led to a relatively large increase in the RBC over that where the discards are not included.

Not as expected, the standardized catch rates for trawl caught saw sharks behave differently to those from the gill net fishery, so much so that the analysis of trawl caught catch rates recommends a relatively large increase in the RBC (Table 23.1). Catches of saw sharks by trawl are now almost as high as those taken by gill net so this finding illustrates the uncertainty in this analysis, which provides some evidence that there may be an element of avoidance by gill net fishers. This avoidance would, in turn, lead to a reduction in gill net catch rates.

## 24.6 Acknowledgements

Thanks also go to Mike Fuller and Neil Klaer for all the pre-analytical data preparation required maintaining the SESSF data set.

## 24.7 Tables

Table 24.10. Saw Sharks. Total catches and discards by fishery and Standardized catch rates, ready for the TIER 4 analysis (only the total catches and Standardized catch rates are used). Columns starting with Disc relate to discards. Only the Catch T and Std CE columns are used in the Tier 4 analysis, the first four columns derive from log-book data and under-estimate the landings and leave out the discards.

| Year | GHT | SET | GAB | State | Discard | Catch T | Std CE |
|---|---|---|---|---|---|---|---|
| 1976 | 248.65 | | | | | 263.569 | |
| 1977 | 230.377 | | | | | 244.200 | |
| 1978 | 269.2 | | | | | 285.352 | |
| 1979 | 236.76 | | | | | 250.966 | |
| 1980 | 227.969 | | | | | 241.647 | |
| 1981 | 193.592 | | | | | 205.208 | |
| 1982 | 244.047 | | | | | 258.690 | |
| 1983 | 234.673 | | | | | 248.753 | |
| 1984 | 230.465 | | | | | 244.293 | |
| 1985 | 262.913 | 4.11 | | | 3.075 | 285.873 | |
| 1986 | 280.529 | 19.478 | | | 14.575 | 331.414 | |
| 1987 | 327.365 | 16.431 | 0.015 | | 12.295 | 375.748 | |
| 1988 | 248.708 | 30.514 | 0.505 | | 22.833 | 317.482 | |
| 1989 | 212.59 | 18.608 | 3.983 | | 13.673 | 261.274 | |
| 1990 | 180.123 | 17.598 | 9.601 | | 13.067 | 231.061 | |
| 1991 | 211.606 | 23.931 | 14.442 | | 15.517 | 274.998 | |
| 1992 | 209.242 | 25.541 | 25.265 | | 18.844 | 291.079 | |
| 1993 | 289.205 | 31.782 | 20.506 | | 22.810 | 380.357 | |
| 1994 | 327.406 | 43.078 | 17.149 | | 31.873 | 438.658 | |
| 1995 | 390.983 | 32.762 | 24.375 | | 24.264 | 495.498 | |
| 1996 | 310.827 | 37.963 | 29.537 | | 31.078 | 427.835 | |
| 1997 | 158.440 | 36.176 | 27.611 | 17.528 | 24.773 | 335.703 | |
| 1998 | 249.497 | 29.418 | 25.726 | 10.444 | 25.010 | 318.072 | |
| 1999 | 242.185 | 35.155 | 23.123 | 14.33 | 22.156 | 258.583 | |
| 2000 | 274.919 | 53.421 | 23.645 | 15.24 | 20.150 | 228.184 | |
| 2001 | 262.689 | 41.698 | 33.684 | 8.387 | 20.150 | 295.140 | |
| 2002 | 158.250 | 75.473 | 20.355 | 17.106 | 20.150 | 345.964 | |
| 2003 | 190.996 | 78.034 | 47.541 | 26.31 | 20.150 | 400.162 | |
| 2004 | 193.424 | 87.501 | 33.488 | 28.953 | 20.150 | 409.131 | |
| 2005 | 172.616 | 85.607 | 38.071 | 33.949 | 20.150 | 385.581 | |
| 2006 | 158.713 | 112.938 | 45.982 | 36.352 | 20.150 | 404.171 | |
| 2007 | 107.878 | 77.417 | 28.719 | 34.602 | 41.977 | 311.917 | |
| 2008 | 115.421 | 75.926 | 19.648 | 24.718 | 42.512 | 315.894 | |
| 2009 | 89.441 | 79.631 | 22.344 | 33.357 | 40.392 | 300.135 | |
| 2010 | 92.732 | 67.327 | 32.255 | 32.378 | 38.173 | 283.655 | |
| 2011 | 102.973 | 72.874 | 20.502 | 24.756 | 39.442 | 293.081 | |
| 2012 | 74.7939 | 67.556 | 4.731 | 23.000 | 50.586 | 238.734 | |

Table 24.11. Elephant Fish. Total catches and discards by fishery and Standardized catch rates, ready for the TIER 4 analysis (only the total catches and Standardized catch rates are used). Columns starting with Disc relate to discards. Recr is the recreational catch.

| Year | GHT | SET | GAB | State | Recr | DiscGHT | DiscS_G | CatchT | Std CE |
|---|---|---|---|---|---|---|---|---|---|
| 1976 | 42.188 | | | | | 4.219 | | 46.407 | |
| 1977 | 68.334 | | | | | 6.833 | | 75.167 | |
| 1978 | 65.575 | | | | | 6.558 | | 72.133 | |
| 1979 | 100.581 | | | | | 10.058 | | 110.639 | |
| 1980 | 82.283 | | | | | 8.228 | | 90.511 | |
| 1981 | 82.065 | | | | | 8.207 | | 90.272 | |
| 1982 | 58.663 | | | | | 5.866 | | 64.529 | |
| 1983 | 80.478 | | | | | 8.048 | | 88.526 | |
| 1984 | 78.195 | | | | | 7.82 | | 86.015 | |
| 1985 | 108.987 | 0.911 | | | | 10.899 | | 120.797 | |
| 1986 | 65.368 | 5.154 | | | | 6.537 | | 77.059 | |
| 1987 | 63.363 | 1.846 | | | | 6.336 | | 71.545 | |
| 1988 | 67.1 | 12.2 | 0.1 | | | 6.71 | | 86.11 | |
| 1989 | 62.109 | 3.207 | 0.144 | | | 6.211 | | 71.671 | |
| 1990 | 55.792 | 1.892 | 0.045 | | | 5.579 | | 63.308 | |
| 1991 | 69.2 | 5.385 | 0.032 | | | 6.92 | | 81.537 | |
| 1992 | 71.071 | 5.698 | 0.06 | | | 7.107 | | 83.936 | |
| 1993 | 54.335 | 2.725 | 0 | | | 5.434 | | 62.494 | |
| 1994 | 59.502 | 3.987 | 0.71 | | | 5.95 | | 70.149 | |
| 1995 | 51.836 | 2.819 | 0.039 | | | 5.184 | | 59.878 | |
| 1996 | 77.111 | 5.41 | 0.275 | | 29 | 7.711 | 4.813 | 124.32 | |
| 1997 | 59.857 | 5.598 | 0.095 | | 29 | 5.986 | 3.587 | 104.123 | |
| 1998 | 52.832 | 7.9 | 0.07 | | 29 | 5.283 | 3.256 | 98.341 | |
| 1999 | 59.199 | 7.46 | 0.965 | 0.384 | 29 | 5.92 | 3.528 | 121.072 | |
| 2000 | 53.888 | 8.913 | 0 | 0.699 | 29 | 5.389 | 2.8 | 103.99 | |
| 2001 | 47.330 | 8.444 | 0.106 | 0.420 | 29 | 4.733 | 2.8 | 95.413 | |
| 2002 | 24.659 | 17.888 | 0.191 | 0.472 | 29 | 2.466 | 2.8 | 107.526 | |
| 2003 | 42.763 | 20.4088 | 2.032 | 0.439 | 29 | 4.879 | 2.8 | 124.082 | |
| 2004 | 29.088 | 27.2915 | 1.619 | 0.731 | 29 | 3.523 | 2.8 | 109.724 | |
| 2005 | 34.853 | 27.2535 | 1.878 | 0.663 | 29 | 4.052 | 2.8 | 118.611 | |
| 2006 | 36.061 | 17.865 | 1.426 | 3.933 | 29 | 4.014 | 2.8 | 104.804 | |
| 2007 | 36.206 | 14.093 | 1.701 | 11.954 | 29 | 21.845 | 2.8 | 115.270 | |
| 2008 | 40.471 | 19.297 | 0.834 | 2.092 | 29 | 23.023 | 2.8 | 127.814 | |
| 2009 | 44.136 | 20.2703 | 0.520 | 3.848 | 29 | 27.630 | 2.8 | 136.745 | |
| 2010 | 34.754 | 20.7817 | 0.310 | 3.570 | 29 | 22.946 | 2.8 | 122.975 | |
| 2011 | 33.906 | 15.7776 | 0.285 | 8.791 | 29 | 135.725 | 2.8 | 226.552 | |
| 2012 | 44.748 | 20.845 | 0 | 4.463 | 29 | 97.580 | 2.8 | 171.222 | |

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# 25. 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.

# 26. Conclusion

- Provide quantitative and qualitative species assessments in support of the five SESSFRAG assessment groups, including RBC calculations within the SESSF harvest strategy framework.

The 2013 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 several of the key quota species (blue grenadier, pink ling (east and west), tiger flathead, gummy shark and deepwater flathead), as well as catch curve analyses and cpue standardisations for shelf, slope, deepwater and shark species. 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 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 2013 assessment of blue grenadier (*Macruronus novaezelandiae*) concluded that for the base case model the female spawning biomass in 2012 is around 77% of the unexploited spawning stock biomass (*SBo*) and in 2014 will be approximately 94%*SBo*. The marked increase in biomass is due to the estimation of a large cohort in 2010. While a promising sign for the fishery, the existence and magnitude of this recruitment should be treated with some caution until it can be verified by the addition of further data from future years. For the base case model, the 2014 recommended biological catch (RBC) under the 20:35:48 harvest control rule is 8138t, with the predicted retained portion of the RBC being 8065t. Note that this is greater than 150% of the current TAC (5208t). The long-term RBC is 4155t.

The 2013 Tier 1 assessment of pink ling (*Genypterus blacodes*) used a model similar to that developed for the 2012 assessment was used as the base-case model (aggregated zones model). The current base-case model differs from the 2012 base-case model in terms of how selectivity is time-blocked for the eastern trawl CPUE series and the exclusion of the non-trawl CPUE indices (for both the eastern and western stocks). The current base-case model also differs from the 2012 model by excluding data from the Kapala surveys, assuming that growth is time-invariant (rather than time-varying) and in how length frequency data is both initially weighted and re- weighted. In the base-case model, the eastern stock is assessed to be $0.19B_0$ at the start of 2014 and the western stock is assessed to be $0.43B_0$ at this time (under the assumption that the TAC for 2013 of 834t is taken). The RBCs arising from the base-case models are 0 tonnes for the eastern stock and 573 tonnes for the western stock. The long term RBC (for the year 2033) is 647 tonnes for the eastern stock and 645 tonnes for the western stock. Note that the base case model presented in this document was not used for management purposes in 2013.

A full quantitative assessment of jackass morwong (*Nemadactylus macropterus*) was not conducted in 2013. To calculate the 2014 RBC, the 2011 Tier 1 Stock Synthesis assessments for both eastern and western morwong have been projected for two more years, using actual catches from 2011 and 2012, and estimated catches for 2013. No other data were added and no new parameter estimation was performed. The 'recruitment shift' assessment model accepted as the base-case for the eastern stock in 2011, and the base-case model for the western stock from 2011 were used for the projections. Current spawning biomass in the eastern stock is projected to be 40% of 1988 equilibrium spawning stock biomass, and the 2014 RBC under the 20:35:48 harvest control rule is 400 t. For the western stock, current spawning biomass is projected to be 68% of unexploited stock biomass, and the 2014 RBC is 292 t. The 2014 combined RBC is 692 t.

An update of the 2010 assessment of tiger flathead (*Neoplatycephalus richardsoni*) was conducted providing estimates of stock status in the SESSF at the start of 2014. A range of sensitivities were explored, including incorporation of the summer fishery independent survey results for 2008, 2010 and 2012, and estimating recruitment to 2007 instead of 2009. The base-case assessment estimates that current spawning stock biomass is 50% of unexploited stock biomass ($SSB_0$). Under the 20:35:40 harvest control rule, the 2014 RBC is 3,428 t and the long term yield (assuming average recruitment in the future) is 2,753 t.

The most recent gummy shark (*Mustelus antarcticus*) assessment model formulation was updated using data from 2010-2012. The model recognises three separate populations (Bass Strait, South Australia and Tasmania), that share some parameter values. Closures of traditional fishing grounds in South Australia (SA), in order to protect Australian sea lions, began to take effect during 2010 and have caused declines in catches and catch per unit effort (CPUE) in that state. RBCs have been calculated for the base case model assuming a range of splits between hook and gillnet fishing in the future. Future hook fishing in SA alone, or in all states, is considered. RBCs (for the base case) for 2014 range from 2044t (whole catch taken by line gear) to 2232t (whole catch taken by gillnets) with more line fishing resulting in lower RBCs. Present catches of gummy shark have been held at approximately 1800 t in order to limit catches of school shark. If line fishing does not occur outside of South Australia, catches of roughly 1800t would not exceed the RBCs for gummy shark even if the South Australian line sector is dominant. However, if line fishing dominates in all regions of the fishery and takes 50% of the catch, the RBC for gummy shark will be lower than 1800t.

An update of the assessment of deepwater flathead (*Neoplatycephalus conatus*) was conducted in 2013 providing estimates of stock status in the Great Australian Bight at the start of 2014/15. The base-case assessment estimates an unexploited spawning stock biomass ($SSB_0$) of 9,320t and a current depletion at the start of 2014/15 of 45% of $SSB_0$. The 2014/15 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. Exploration of model sensitivity showed a variation in depletion levels of between 32% and 54% of $SSB_0$.

Tier 3 calculations use the estimates of total mortality, natural mortality and average recent catches to determine the RBC for the following year. RBC values for alfonsino, John dory and redfish were greater than reference average catches. The RBC for mirror dory is lower than the reference catch which is a result very different to that presented in 2012. The reason is a considerable shift in the average $Z$ fit for catch curves in the east caused by a change in emphasis in the overall fit from younger to older fish. This highlights the possible catch variability inherent in a data-poor procedure such as the Tier 3. Western gemfish, blue grenadier, pink ling, blue-eye trevalla and silver trevally were unable to be assessed using catch curves due to probable dome-shaped selectivity or high recruitment variability.

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. In 2013 seven fisheries were assessed using the Tier 4 methodology: Blue-eye Trevalla, Blue Warehou (split east and west), Inshore Ocean Perch and Offshore Ocean Perch, Redfish, Royal Red Prawns, and Silver Trevally. Three of these fisheries generated zero RBCs and these were Blue Warehou, Jackass Morwong and Redfish. Alternative analyses were provided for Redfish and Inshore Ocean Perch in which discards were included in the estimation of the catch rate trends. The inclusion of discards in estimating catch rates adds a great deal of noise to the CPUE trends so the uncertainty in these analyses expands.

# 27. Appendix: Intellectual Property

No intellectual property has arisen from the project that is likely to lead to significant commercial benefits, patents or licenses.

# 28. Appendix: Project Staff

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|---|---|
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