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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). Tania Cesile is greatly thanked for her assistance with the production of this report and Tim Ryan and Bruce Barker for the cover photographs of SESSF fish. Neil Klaer and Sally Wayte 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 2014. 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 2014.

Stock Assessment for the Southern and Eastern Scalefish and Shark Fishery: 2014

Part 2: Tier 3 and Tier 4, catch rate standardisations and other work contributing to the assessment and management of SESSF stocks in 2014

G.N. Tuck
June 2015
Report 2013/0010

Australian Fisheries Management Authority

Stock Assessment for the Southern and Eastern Scalefish and Shark Fishery: 2014
Part 2

TABLE OF CONTENTS

9. Tier 1 CPUE forecasts for multi-year TAC breakout

Neil Klaer, Jemery Day, Geoff Tuck, Rich Little, Sally Wayte

CSIRO Oceans and Atmosphere Flagship, GPO Box 1538, Hobart, TAS 7001, Australia

9.1 Summary

This document 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, four showed actual CPUE trends that fell outside of the 95% confidence bounds projected from the stock assessment – tiger flathead, pink ling, jackass morwong and silver warehou. Break out for pink ling and jackass morwong were for only one of the areas/fleets, and were marginal. Silver warehou however, only had one CPUE indicator series, and this had unambiguously broken out for the past two years. This was not unexpected given past RAG deliberations that the assessment shows bad retrospective behaviour. It is of concern that flathead Danish seine CPUE has broken out, but the east coast trawl CPUE for that species has not.

9.2 Methods

To generate forecast CPUE from stock synthesis version 3.x (SS) requires a run of the most recent stock assessment, updated with recent actual catches. Results were sought for SESSF blue grenadier, eastern gemfish, school whiting, morwong, ling, Bight redfish, deepwater flathead and tiger flathead. CPUE was not used for orange roughy, and shark assessments do not use SS, so this procedure does not apply to those. The total landings information for the financial year 2013/14 for Bight redfish and deepwater flathead are not yet available, so calculations will be made for them later this year.

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

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2011.

Add the most recent actual catch estimates for the years to 2011 to the catch
```
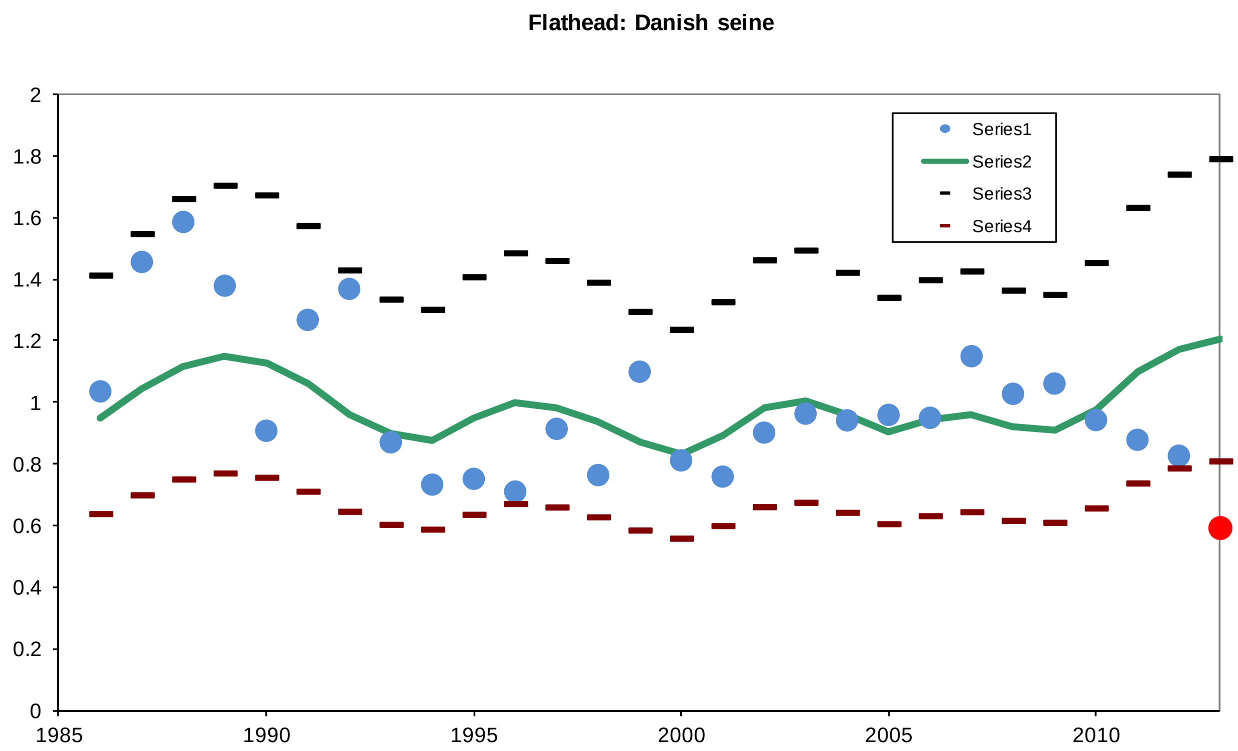

```
series using the attached CDRsum.xlsx file - assume fleet splits as per your last
projections (don't forget to increase the number of lines of catch data.

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.
```

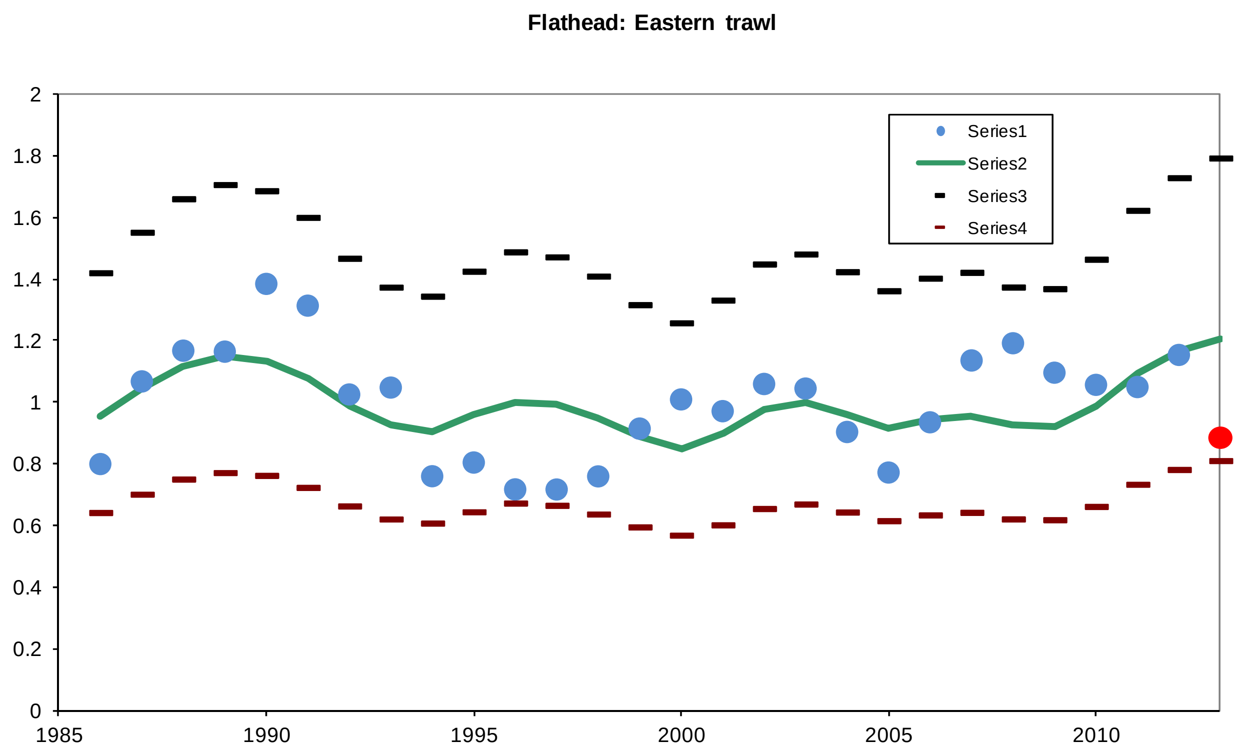
9.3 Results

Observed CPUE values used for the last stock assessment are shown as blue circles. Observed values as calculated in 2014 (Sporcic and Haddon 2014) 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.

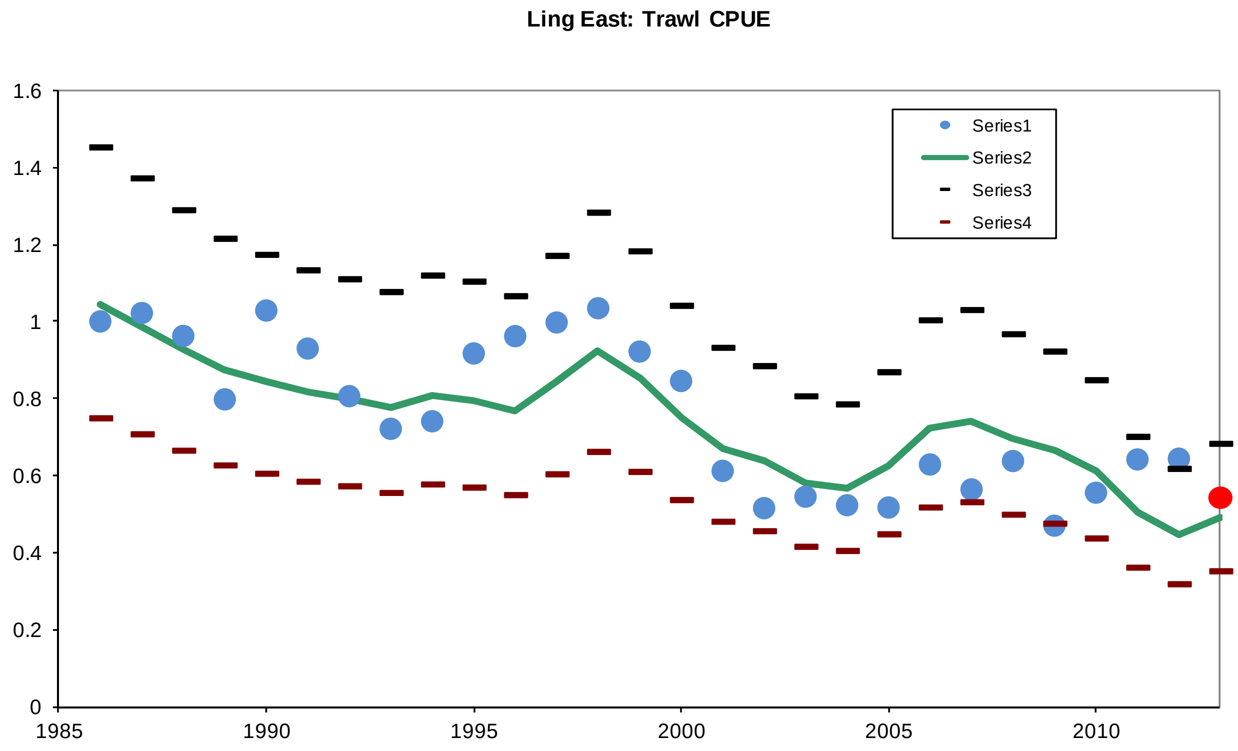
The series that have been examined where recent observed CPUE values have landed outside of the 95% confidence interval of the data as predicted by the last stock assessment are for tiger flathead Danish seine, pink ling west trawl, jackass morwong east trawl, and silver warehou trawl. The break out for jackass morwong and pink ling were marginal. Those for tiger flathead Danish seine and silver warehou were clear and unambiguous. It has been noted by previous RAGs that the silver warehou stock assessment appears to be displaying retrospective problems due to internal inconsistencies among data sources that may not be resolvable with a new stock assessment. For tiger flathead it is a concern that the Danish seine CPUE has broken out. However, the eastern trawl for tiger flathead has not.

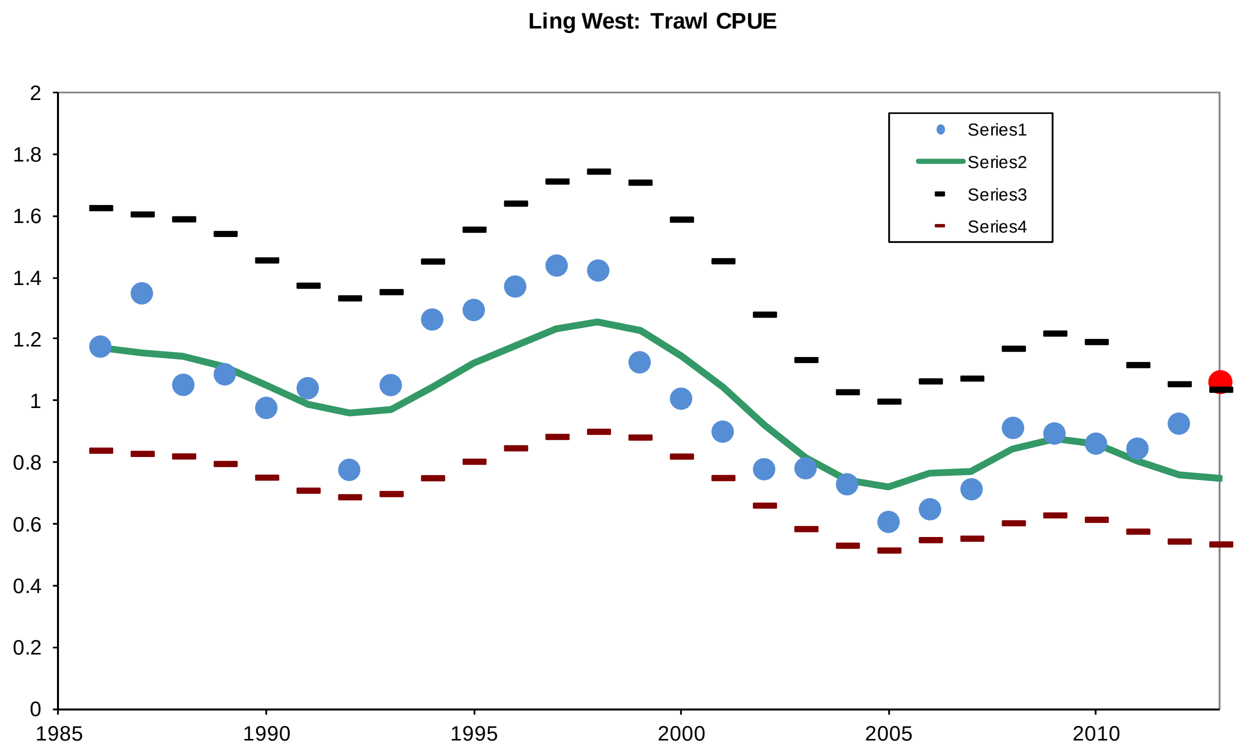
Tiger flathead





Pink Ling


Ling East: Trawl CPUE
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
1985
1990
1995
2000
2005
2010
Series1
Series2
Series3
Series4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2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
1985
1990
1995
2000
2005
2010
Series1
Series2
Series3
Series4

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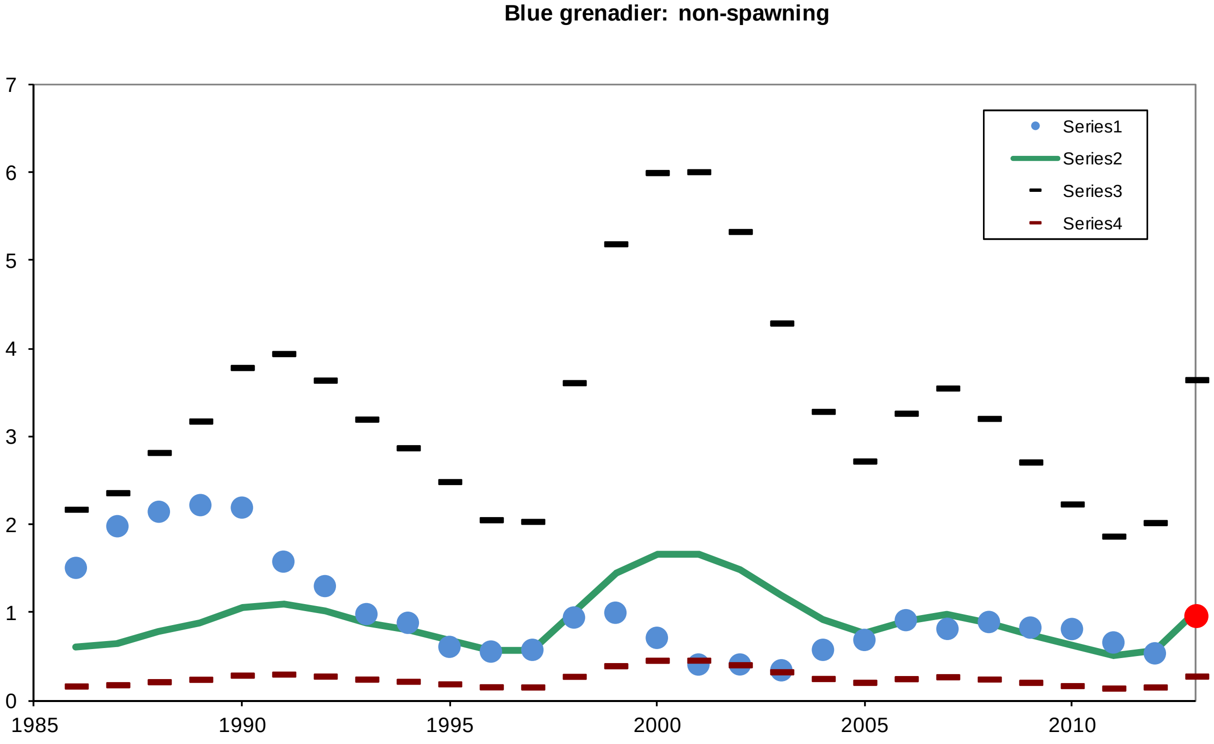

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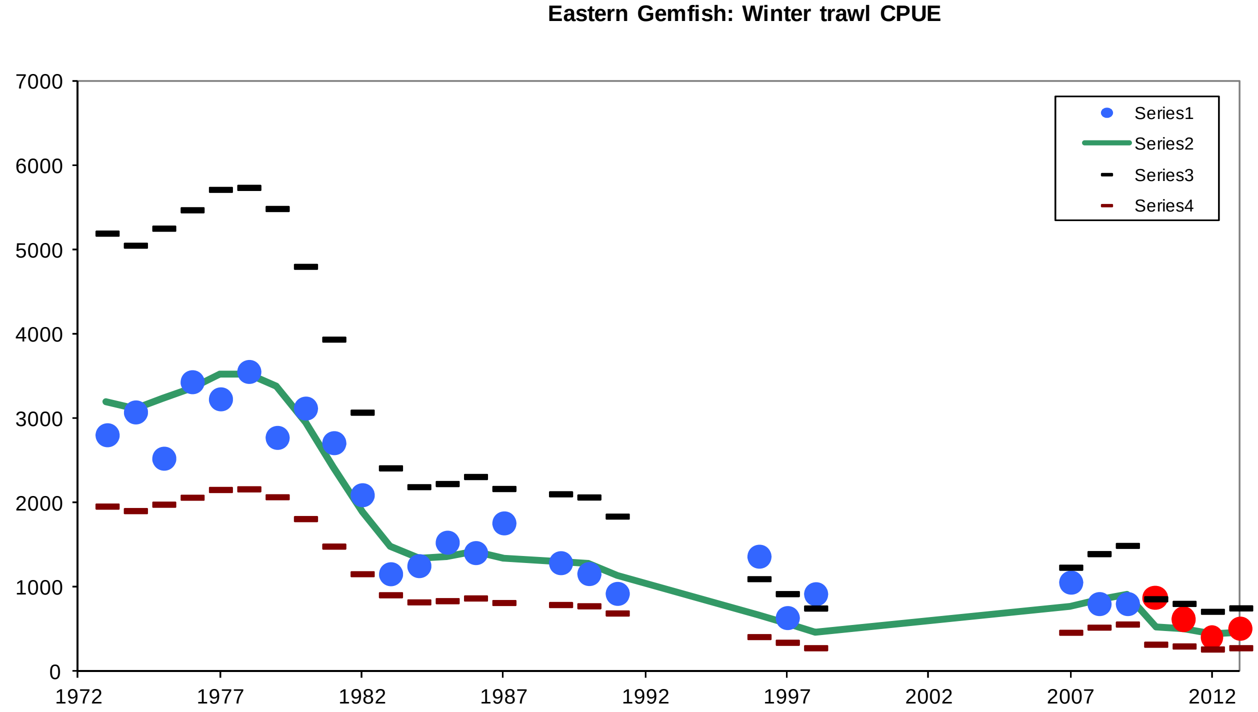
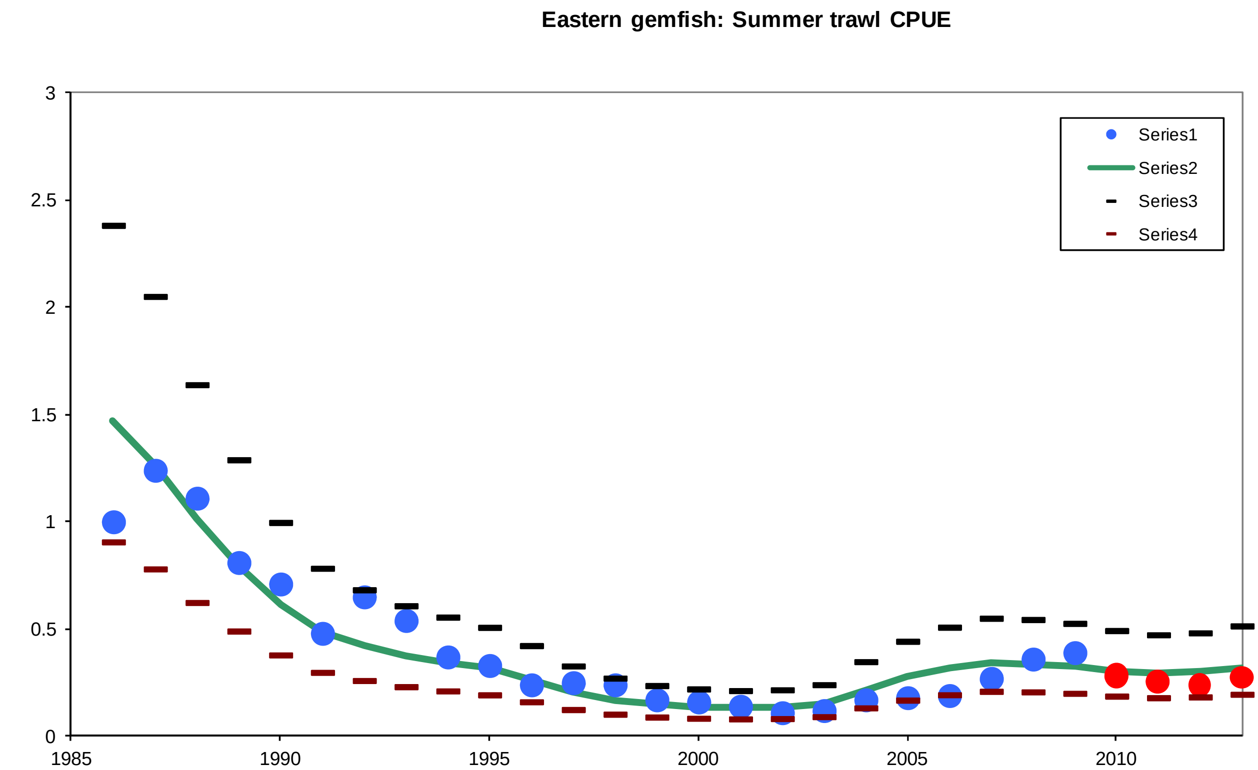
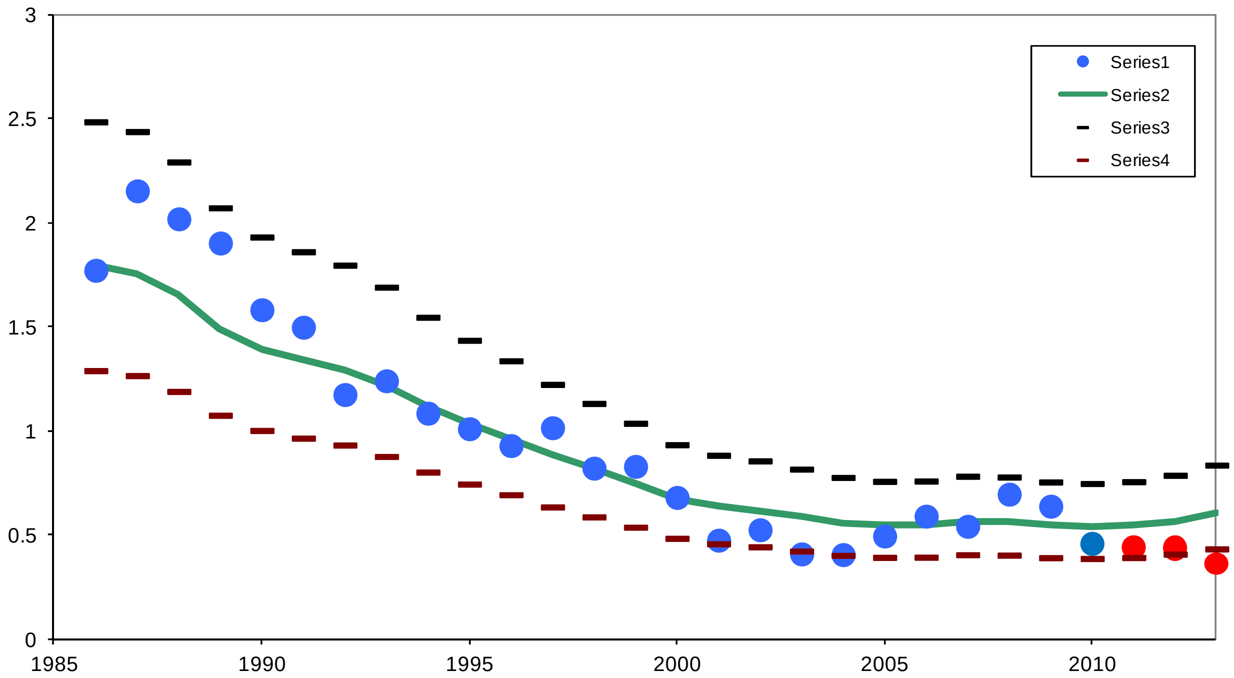


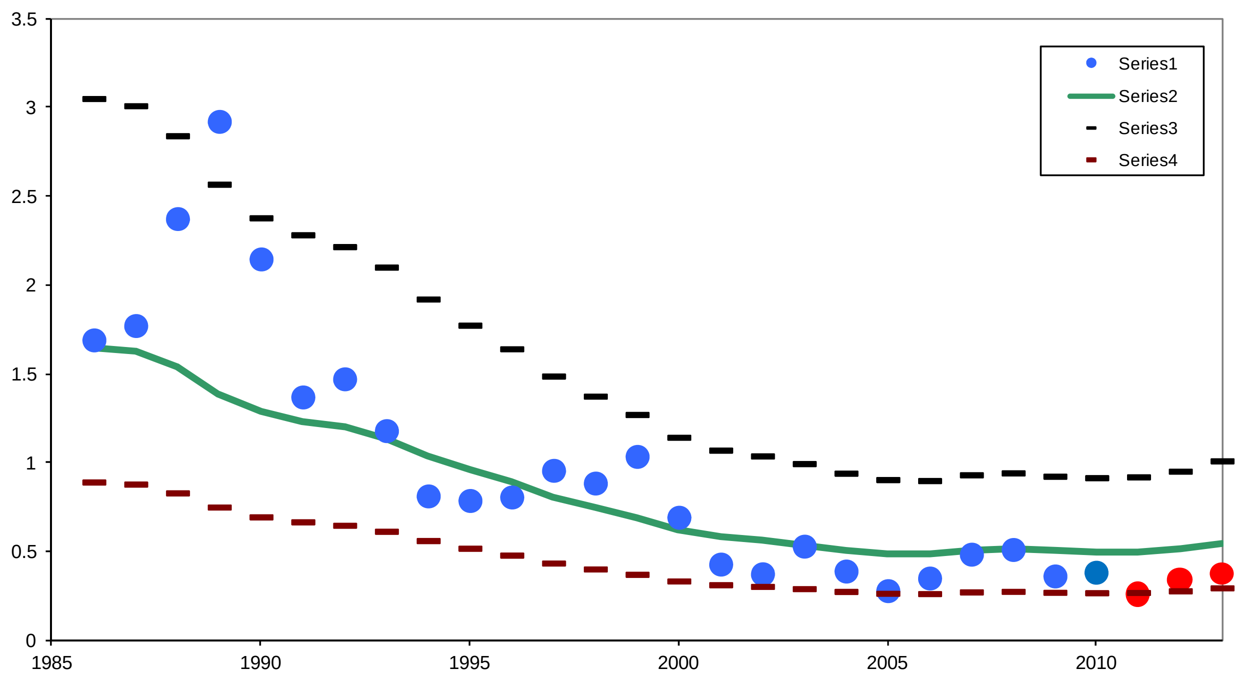


Jackass morwong

Jackass morwong: NSW Vic trawl CPUE



Jackass morwong: Tas trawl CPUE



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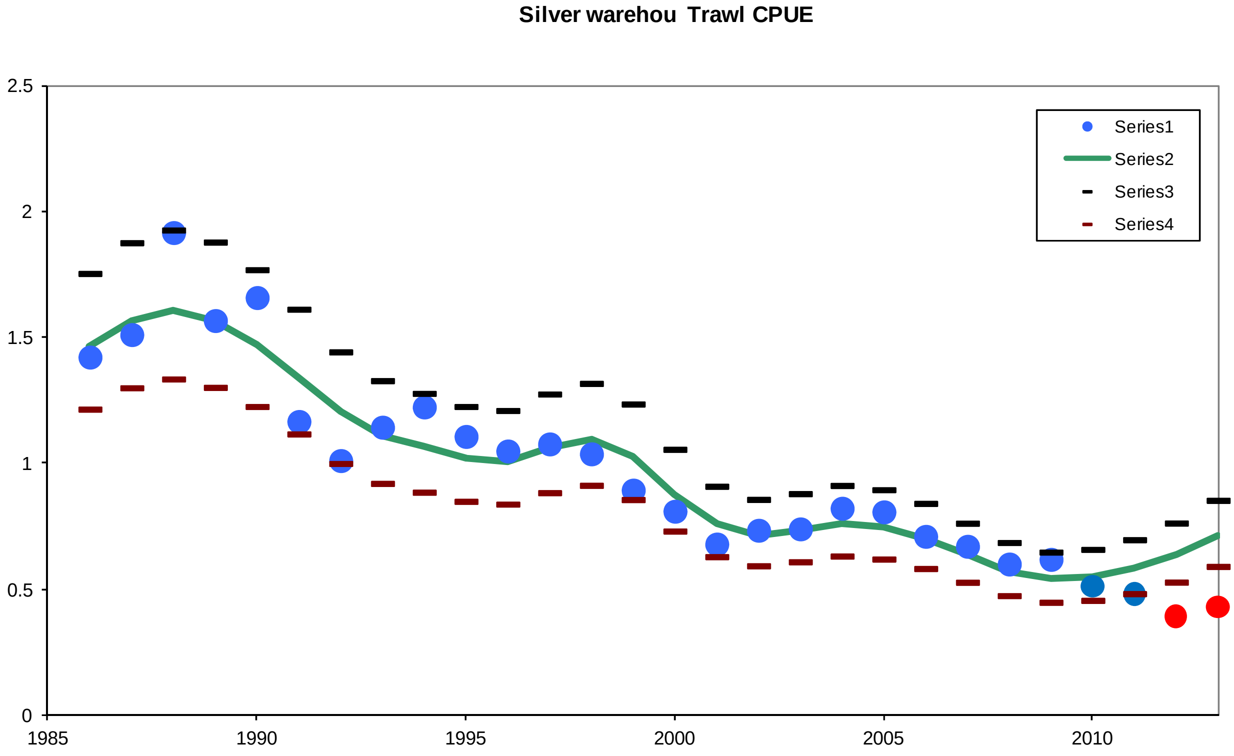
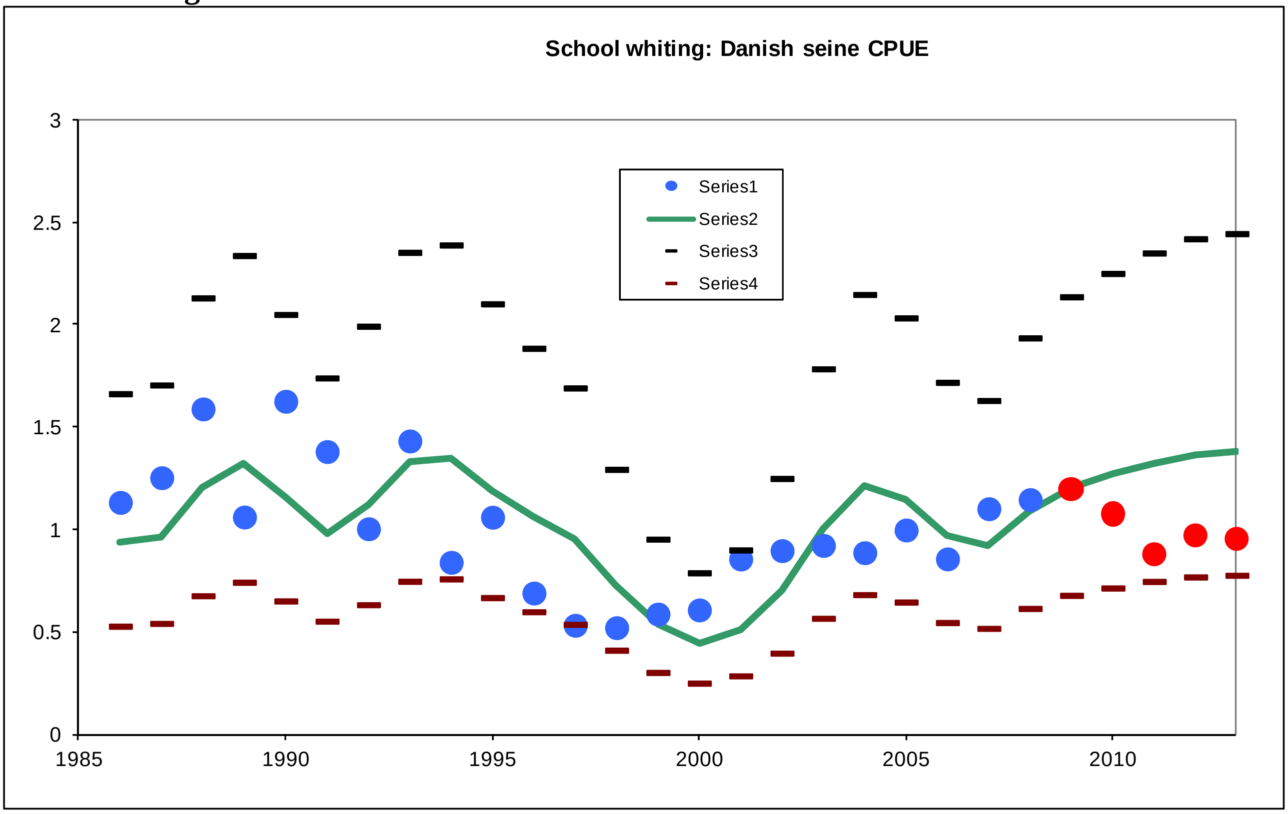


School whiting



9.4 References

Sporcic and Haddon 2014. Catch Rate Standardizations for Selected SESSF Species (data to 2013). Draft report SESSFRAG, July 2014.

10. Multi-Year Breakout Analyses for Deepwater Flathead, Bight Redfish, and Western Gemfish in the GAB (2013/14)

Malcolm Haddon

CSIRO Oceans and Atmosphere Flagship, GPO Box 1538, Hobart, TAS 7001, Australia

10.1 Executive summary

Standard CPUE breakout analyses were conducted for deepwater flathead and Bight redfish in the GAB. Neither species was close to the edge of the projected 95% confidence intervals around the CPUE predicted from the projected Tier 1 assessments from earlier years.

Western gemfish did not exhibit any exceptional deviations in CPUE from the long term average. However, the estimate of high discarding rates for western gemfish in the latest year may imply that the latest CPUE estimate is not a valid representation of current real catch rates. On the other hand, if this is actually the case then it is likely that CPUE should be higher than the records suggest, which again is not a sign of stock decline.

10.2 Introduction

In the absence of formal stock assessments because of the introduction of multi-year TACs breakout tests were conducted to determine whether the three species deepwater flathead, Bight redfish, and western gemfish had begun to deviate from their expected trajectories through the period of their multi-year TACs.

Standard methods were used where appropriate.

10.3 Methods

10.3.1 TIER 1 Breakout Rules

Standard breakout rules for Tier 1 species were adopted in the GAB for Deepwater Flathead and Bight Redfish. These rules, along with multi-year TACs remain untested in terms of the risks they entail.

10.3.1.1 Bight Redfish

The breakout rule is triggered:

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

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

10.3.1.2 Deepwater Flathead

The breakout rule is triggered:

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

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

10.3.1.3 Western Gemfish

A breakout rule for western gemfish was decided in August 2014:

Western Gemfish will have broken out:

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

This rule, is as yet both un-tested and un-tried.

10.4 Results and Discussion

10.4.1 Deepwater Flathead (*Neoplatycephalus conatus*)

The latest Tier1 assessment for deepwater flathead was based on data up to and including the 2012/2013 (Klaer, 2014). The standardized catch rates are now available for the 2013/2014 year and these are used in the breakout rules agreed to by the GAB RAG in August 2014. By including the latest landed catch into the Tier 1 assessment and projecting the dynamics forward the model predicted CPUE can be produced and compared with the standardized value. If the latest year is outside the 95% confidence intervals then the fishery will be said to have broken out of its expected trajectory.

There is no indication that the deepwater flathead fishery has broken out of its expected trajectory (Figure 10.1 and Table 10.1).

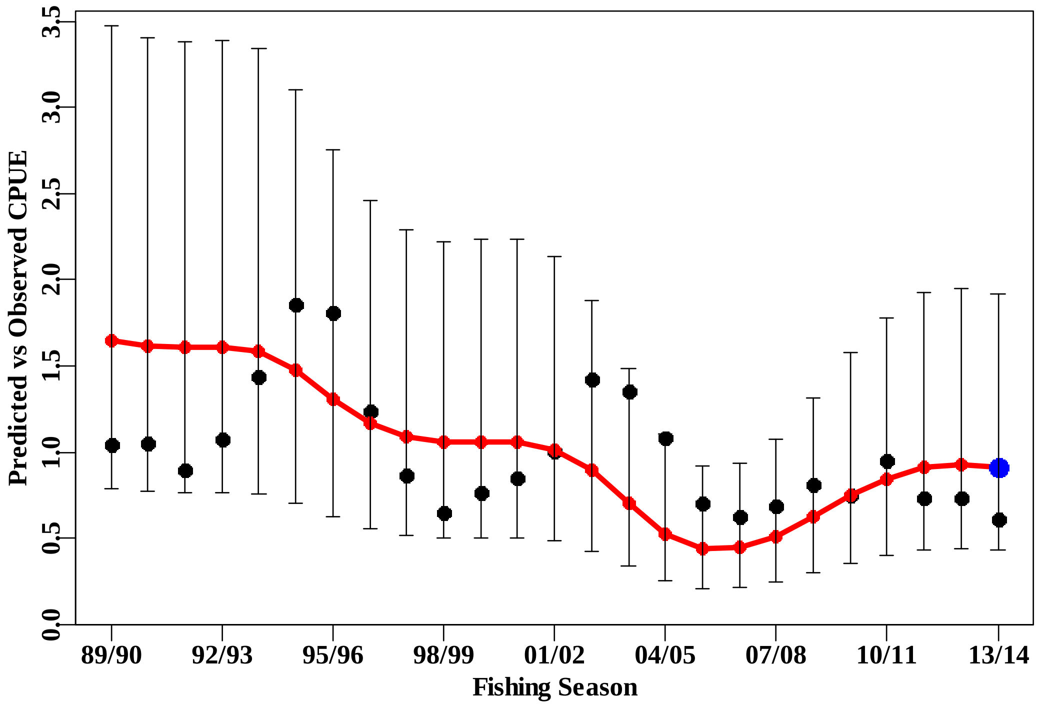


Figure 10.1. The predicted trajectory of deepwater flathead CPUE obtained from projecting the previous Tier 1 assessment forward to the latest year of observed CPUE data. The black dots represent the mean standardized CPUE while the red line and dots, with their associated 95% confidence intervals represent the expected CPUE from the Tier 1 model. The blue dot is the CPUE projected since the last stock assessment.

10.4.1.1 Catches and Catch Rates

No discard estimates are available this last season as there were too few (<= 10) observations to produce a reliable estimate.

Table 10.1**.** A comparison of the standardized observed CPUE for deepwater flathead and that predicted from projecting the previous Tier 1 assessment (Klaer, 2014). The standard error estimate for the CPUE from the Tier 1 model was 0.3797.

Year	Standardized	Predicted	Catch
1989/1990	0.9364	1.6504	394.672
1990/1991	0.9577	1.6190	420.152
1991/1992	0.9282	1.6064	608.128
1992/1993	1.1507	1.6093	508.162
1993/1994	1.5080	1.5879	585.072
1994/1995	1.8654	1.4760	1254.803
1995/1996	1.7455	1.3097	1551.593
1996/1997	1.1722	1.1704	1459.341
1997/1998	0.8308	1.0884	1010.348
1998/1999	0.6415	1.0561	680.659
1999/2000	0.7613	1.0620	544.992
2000/2001	0.8425	1.0618	776.912
2001/2002	1.0169	1.0139	963.613
2002/2003	1.3921	0.8941	1866.026
2003/2004	1.3889	0.7055	2482.093
2004/2005	1.0901	0.5259	2264.119
2005/2006	0.7000	0.4377	1545.604
2006/2007	0.6494	0.4453	1039.690
2007/2008	0.7176	0.5090	1034.709
2008/2009	0.8549	0.6230	812.663
2009/2010	0.7554	0.7480	851.272
2010/2011	0.9536	0.8444	968.028
2011/2012	0.7590	0.9143	973.371
2012/2013	0.7630	0.9271	1027.842
2013/2014	0.6513	0.9111	878.380

10.4.2 Bight Redfish (Centroberyx gerrardi)

The latest Tier1 assessment for Bight redfish was based on data up to and including 2010/2011 (Klaer, 2012). The standardized catch rates are now available for the 2013/2014 year and these are used in the breakout rules agreed to by the GAB RAG in August 2014. By including the latest landed catch into the Tier 1 assessment and projecting the dynamics forward the model predicted CPUE can be produced and compared with the standardized value. If the latest year is outside the 95% confidence intervals then the fishery will be said to have broken out of its expected trajectory.

There is no indication that the Bight redfish fishery has broken out of its expected trajectory (Figure 10.2 and Table 10.2).

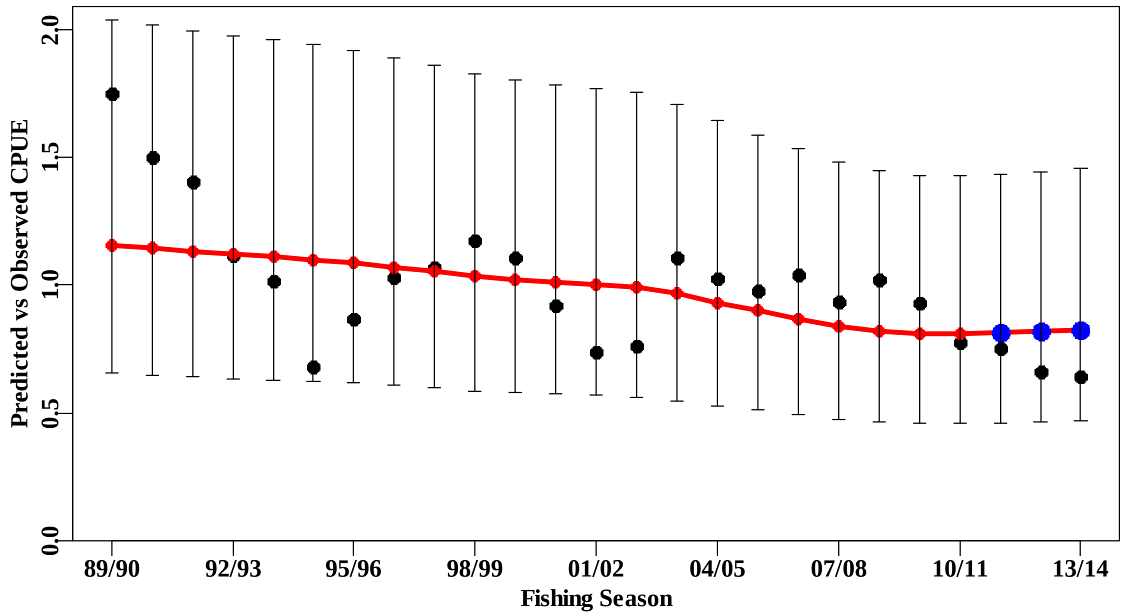


Figure 10.2**.** The predicted trajectory of Bight redfish CPUE obtained from projecting the previous Tier 1 assessment (Klaer, 2012) forward to the latest year of observed CPUE data. The black dots represent the mean standardized CPUE while the red line and dots, with their associated 95% confidence intervals represent the expected CPUE from the Tier 1 model. The blue dots are the CPUE projected from the Tier 1 since the last stock assessment.

10.4.3 Catches and Catch Rates

No discard estimates are available this last season as there were too few (<= 10) observations to produce a reliable estimate.

Table 10.2**.** A comparison of the standardized observed CPUE for Bight redfish and that predicted from projecting the previous Tier 1 assessment (Klaer, 2012). The standard error estimate for the CPUE from the Tier 1 model was 0.290.

Year	Standardized	Predicted	Catch
1989/1990	1.7493	1.1558	170.833
1990/1991	1.4994	1.1449	281.808
1991/1992	1.4055	1.1308	265.612
1992/1993	1.1170	1.1192	120.698
1993/1994	1.0153	1.1101	107.472
1994/1995	0.6804	1.0990	157.803
1995/1996	0.8673	1.0864	173.922
1996/1997	1.0313	1.0707	327.177
1997/1998	1.0701	1.0527	372.617
1998/1999	1.1759	1.0350	437.788
1999/2000	1.1080	1.0213	323.641
2000/2001	0.9207	1.0106	387.879
2001/2002	0.7359	1.0023	262.613
2002/2003	0.7610	0.9929	424.672
2003/2004	1.1053	0.9673	946.477
2004/2005	1.0239	0.9311	937.456
2005/2006	0.9758	0.9002	789.704
2006/2007	1.0385	0.8687	1,023.908
2007/2008	0.9350	0.8393	808.024
2008/2009	1.0195	0.8198	681.885
2009/2010	0.9319	0.8096	469.696
2010/2011	0.7745	0.8094	297.596
2011/2012	0.7533	0.8126	351.758
2012/2013	0.6619	0.8171	267.078
2013/2014	0.6432	0.8254	196.447

10.4.4 Western Gemfish (*Rexea solandri*)

The Tier 1 assessment for western gemfish was not considered stable or able to represent the observed dynamics in the fishery adequately and was therefore rejected and a Tier 4 assessment used in its stead.

The breakout rule for western gemfish relates to CPUE but the estimate of CPUE for this latest year is highly uncertain. The reason for this is that the estimate of the discard rate for western gemfish is very high (Table 10.3).

Table 10.3**.** Estimated discard rates from the ISMP sampling.

Discard Rate	0.6948
Landed Catch	72.783
Discard Rate	165.673

If this discard rate is indicative of the discards within the GAB then the breakout rule would be inapplicable to CPUE calculated only on the estimated landed catch. In fact, the CPUE series in the latest standardization document (Sporcic and Haddon, 2014) doesn't indicate any significant deviation from the long term average (Figure 10.3).

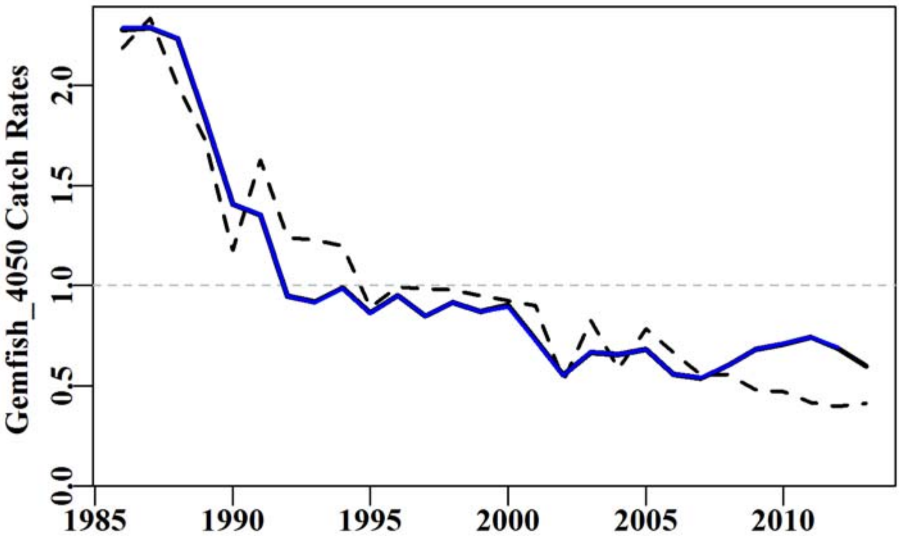


Figure 10.3. Western Gemfish from zones 40 and 50 in depths between 100 – 600 m by Trawl. The dashed black line represents the geometric mean catch rate, solid black line the standardized catch rates and solid blue line standardized catch rates from last year's analysis. The graph standardizes catch rates relative to the mean of the standardized catch rates. . Copied from Sporcic and Haddon (2014)

10.5 Bibliography

Klaer, N. (2012) Bight redfish (*Centroberyx gerrardi*) stock assessment based on data up to 2010/11 – development of a preliminary base case pp 330 – 345 *in* Tuck, G.N. (ed) (2012) *Stock Assessment for the Southern and Eastern Scalefish and Shark Fishery 2011. Part 1.* Australian Fisheries Management Authority and CSIRO Marine and Atmospheric Research, 377p.

Klaer, N. (2014) Deepwater flathead (*Neoplatycephalus conatus*) stock assessment based on data up to 2012/13 – Development of a base case. pp 233 – 248 *in* Tuck, G.N. (ed) (2014) *Stock Assessment for the Southern and Eastern Scalefish and Shark Fishery 2013. Part 1.* Australian Fisheries Management Authority and CSIRO Marine and Atmospheric Research, 313p.

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

Sporcic, M. and M. Haddon (2014) Catch rate standardizations for selected SESSF species (data to 2013). Draft paper presented to SLOPE and SHELF RAGs July 2014. 228p.

10.6 Appendix: SS3 Methods

Extracted from Klaer et al. (2014b).

To generate forecast CPUE from stock synthesis version 3.x (SS) requires a run of the most recent stock assessment, updated with recent actual catches. Results were sought for SESSF blue grenadier, eastern gemfish, school whiting, morwong, ling, Bight redfish, deepwater flathead and tiger flathead. CPUE was not used for orange roughy, and shark assessments do not use SS, so this procedure does not apply to those. The total landings information for the financial year 2013/14 for Bight redfish and deepwater flathead are not yet available, so calculations will be made for them later this year.

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

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```

Edit ss3.dat

```
Change end year on line 3 to the most recently available data - this year it is
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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
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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.
```

11. Estimated conversion coefficients for LCF-TOT PAR-TOT length measurements for gummy shark, school shark, school shark, elephant fish and sawshark

Robin Thomson

CSIRO Oceans and Atmosphere Flagship, GPO Box 1538, Hobart, TAS 7001, Australia

11.1 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 11.1 and Table 11.1).

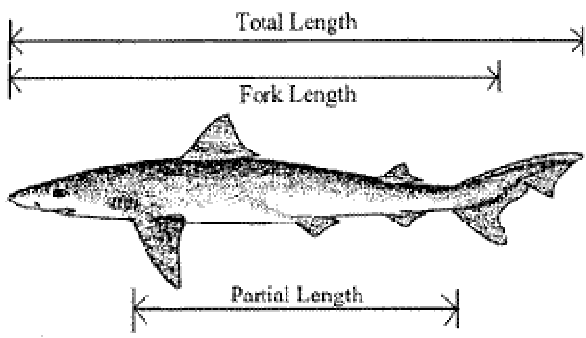

Figure 11.1. Partial length (PAR), fork length (LCF) and total length (TOT) as measured by the AFMA Observer Program (taken from the 'GHATF – Gillnet Observers Manual 2008, AFMA Observer Program'; GHATF, 2008).

Table 11.1. Number of sharks measured by the AFMA Observer Program over all years (1993-2013), regions, gear types and for both sexes (and sex unknown). The type of measurement (seeFigure 11.1) 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		4,248		68,626		10,292		13,059
PAR	19,573	662	58,713	2,640	8,792	6	12,311	465
LCF	1,492	1,545	4,640	10,659		1,867		997
Unknown	2	6	931*	40		1		47
STL			204	36		3		33
Other				4				6

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. Estimated conversion coefficients are required for (i) PAR to TOT and (ii) LCF to TOT for all four shark quota species (Table 11.1). 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 11.2). 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.

With the proposed replacement of onboard observers with electronic monitoring systems, port measurement are likely to become more important, increasing the urgency of calculating conversation factors form the PAR measures taken in port to the TOT measures used in stock assessment models.

11.2 Data and Methods

Observer data collected by the AFMA Observer Program under the banner “biological samples” were provided by John Garvey (AFMA, Canberra) on 3 July 2014. 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. See Figure 11.1for the three measurements used. Note that the data shown in and Figure 11.2 relate to commercially caught sharks, sampled by the Observer Program, for which a single measurement were taken. The data shown in Table 11.2 and Figure 11.3 relate to sharks for which dual or triple 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.

The samples taken in 2013 show a better spread across regions for gummy shark and school shark (Table 11.2) although the sample is concentrated in the last few months of the year (Table 11.3). If measurement practices are the same at all times and places then the spread of the sample should influence the estimated conversion factors.

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: $TOT_i = a + b\ LCF_i$, for shark i (Table 11.3).

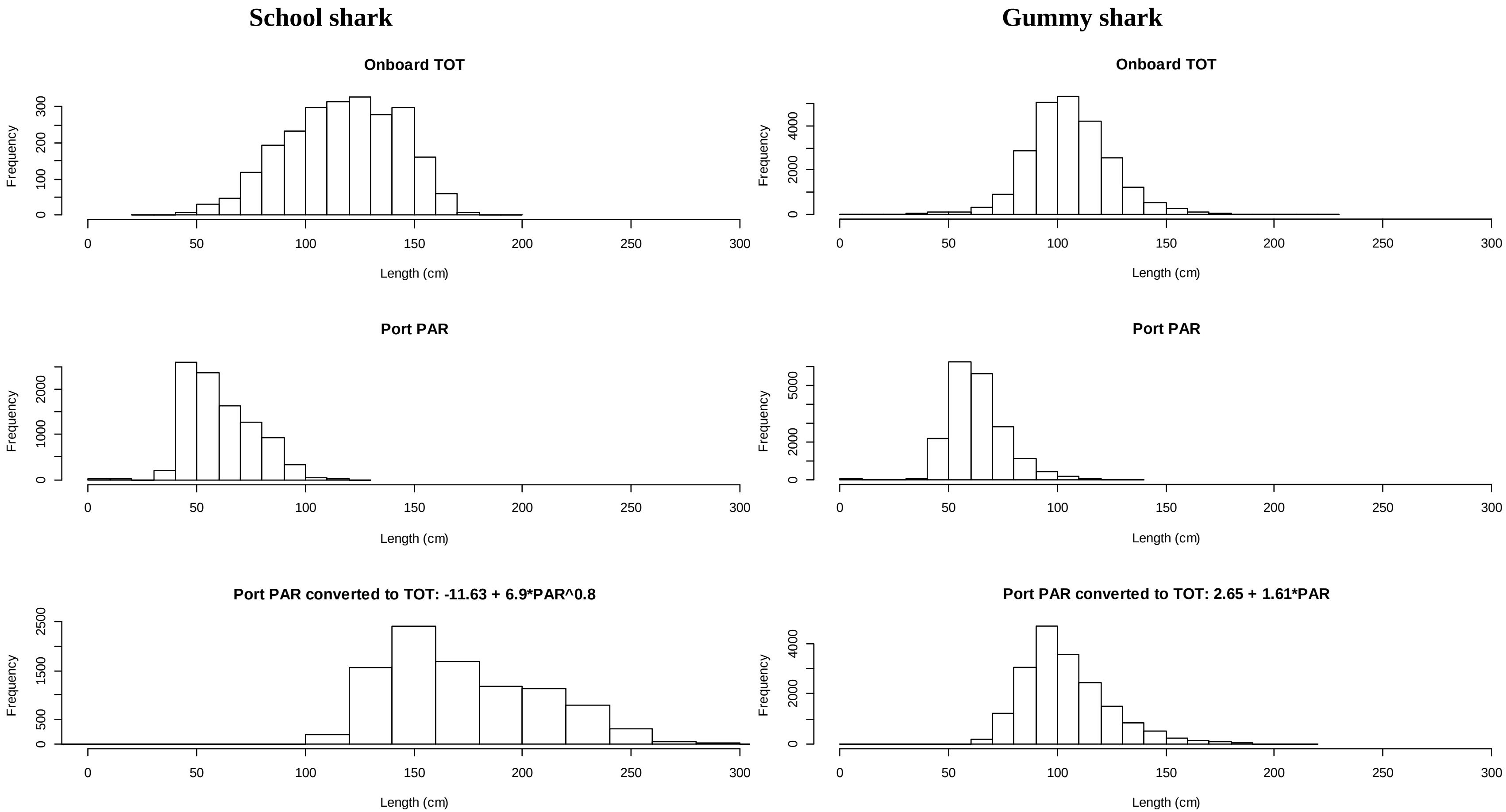

Figure 11.2 Length frequencies for school shark and gummy shark collected by the AFMA Observer program. Top panel: All data collected as total length (TOT);middle panel: All data collected using partial length (PAR), and bottom panel: PAR measurements after conversation to TOT.

Table 11.2 Sample sizes for LCF and (PAR) by shark region of capture and by year. WSA: Western South Australia; CSA: Central South Australia; WBS: Western Bass Strait; EBS: Eastern Bass Strait; WTas: Western Tasmania; ETas: Eastern Tasmania.

	2001	2007	2009	2011	2012	2013	2014
Gummy shark							
WSA		1 (1)					
CSA				2		151 (149)	
ESA						36 (14)	
WBS					43	103 (165)	
EBS	1				12	249 (148)	11 (11)
WTas					7		
ETas					65	97 (3)	59 (59)
SAV						(1)	
School shark							
WSA			1				
CSA						9 (9)	
ESA						1	
WBS					24	1 (3)	
EBS					14	13 (7)	18 (19)
WTas					5		
ETas					2	7	25 (25)
SAV							
Elephant shark							
WSA							
CSA				4			
ESA							
WBS						4	28
EBS						16	28
WTas							
ETas						16	1
SAV							
Saw shark							
WSA							
CSA		2					
ESA						(1)	
WBS					25	7 (22)	
EBS					10	28 (24)	
WTas							
ETas					17	1	
SAV							

Table 11.3. Sample sizes for LCF and (PAR) by month and year.

Month	2001	2007	2009	2011	2012	2013	2014
Gummy shark							
1		1 (1)		2		1	32 (32)
2	1					96	26 (26)
3							12 (12)
4							
5							
6							
7							
8							
9						83	
10					127	114 (112)	
11						278 (303)	
12						64 (65)	
School shark							
1							20 (20)
2						6	8 (8)
3							15 (16)
4							
5							
6							
7							
8							
9	1					7	
10					41	1	
11					3	14 (16)	
12					1	3 (3)	
Elephant shark							
1							
2							
3							
4				4			
5							
6							
7							
8							
9						28	
10					36		
11						28	
12						1	
Saw shark							
1							
2		2					
3							
4							
5							
6							
7							
8							
9						7 (6)	
10					52		
11						27 (39)	
12						2 (2)	

11.3 Results and Conclusions

The estimated conversion coefficients for gummy shark and school shark appear reliable, with R^2statistics close to 1 – these can be used with confidence to convert LCF to TOT lengths for stock assessment purposes (Table 11.3; Figure 11.3).

Table 11.3. Estimated coefficients of linear regressions between LCF or PAR and TOT measurements. R2 statistics and sample sizes are also shown. “na”: indicates insufficient samples.

	Gummy shark		School shark		Elephant fish		Saw shark	
	LCF	PAR	LCF	PAR	LCF	PAR	LCF	PAR
Intercept (*a*)	7.77	17.25	2.65	4.42	13.42	na	13.51	53.95
Slope (*b*)	1.062	1.328	1.116	1.672	1.012	na	0.915	0.965
R^2	0.94	0.88	0.99	0.98	0.84	na	0.87	0.57
Sample size (*n*)	836	550	120	63	97	na	90	47

Estimated coeffcients for elephant fish for PAR-TOT shark could not be obtained because only 10 measurements had been made. The regression for elephant fish for LCF-TOT is surprisingly noisy, as is that for sawshark for PAR-TOT. The LCF-TOT relationship for saw shark seems to describe two separate lines, each of which is relatively precise. The 9 measurements that fall well above the regression line were all made on just 3 trips and none of the other measurements were made on those trips, suggesting that a single observer may be involved. Chris Burns of the Observer Program has been asked to look into this.

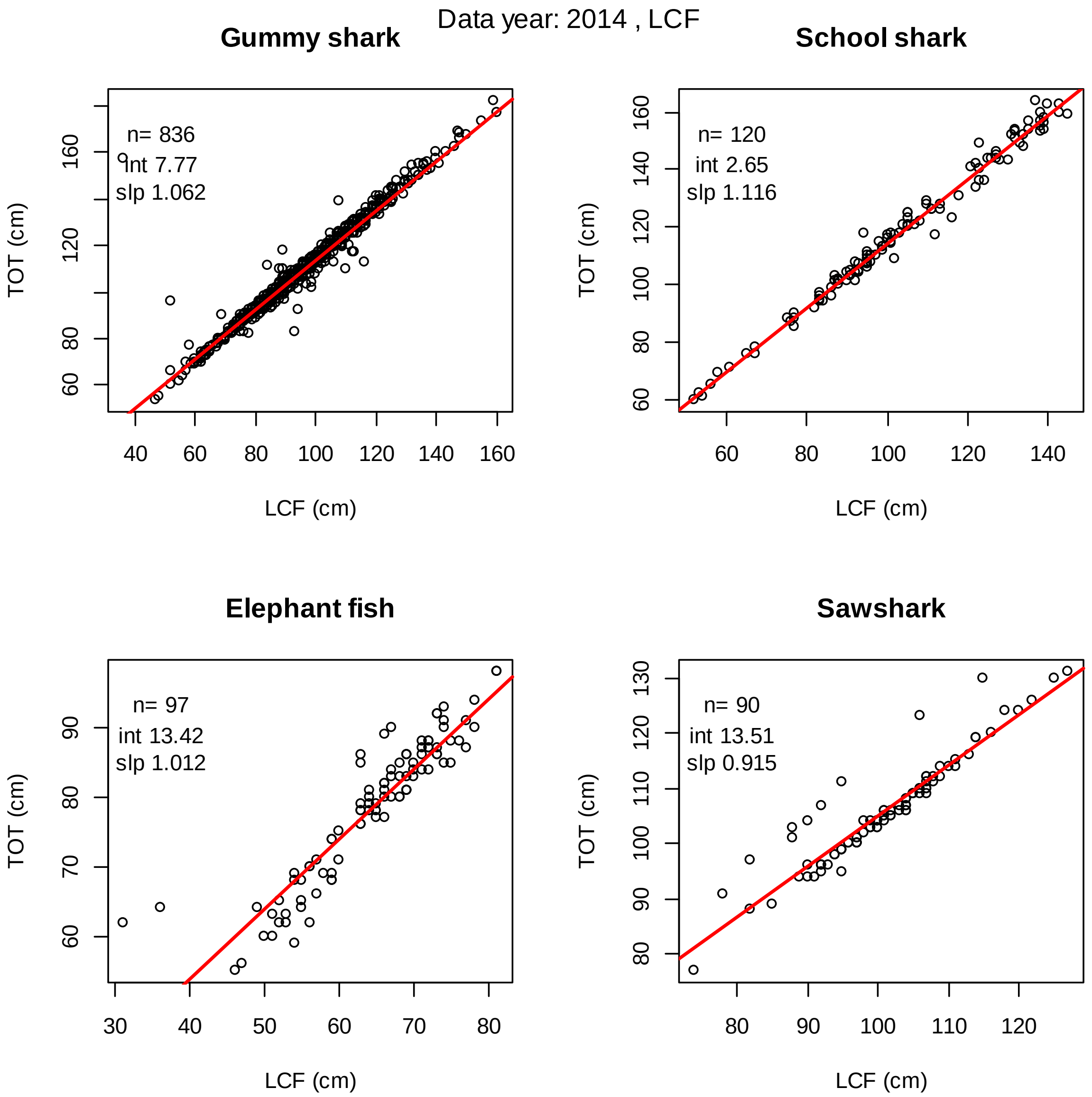

Figure 11.3. Length measurements (cm) of the LCF and TOT type for individual sharks (circles) and an estimated -linear regression (line) for gummy shark, school shark and elephant fish. The sample size “n”, and fitted values for the intercept “int” and slope “slp” are shown.

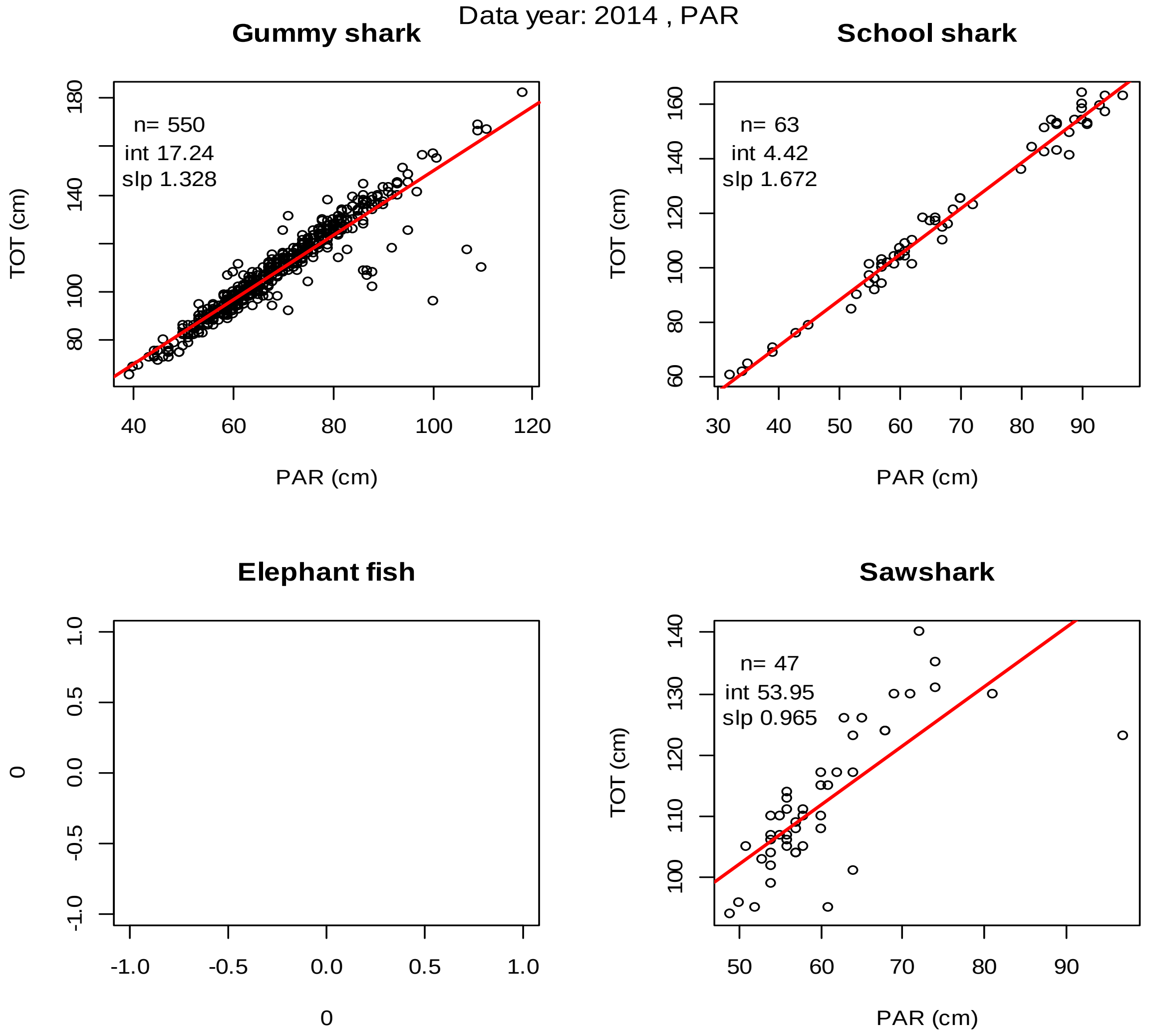

Figure 11.4. Length measurements (cm) of the PAR and TOT type for individual sharks (circles) and an estimated -linear regression (line) for gummy shark, school shark, and sawshark. Insufficuent measurement were available for elephant fish. The sample size "n", and fitted values for the intercept "int" and slope "slp" are shown.

11.3.1 Further Work

1. The datasets for school shark and gummy shark are sufficient for this analysis – no further measurements are required for these species. However, both sawshark and elephantfish would benefit from continuing collection of LCF-TOT and PAR-TOT duel measurements. In particular, the collection of elephantfish PAR-TOT duel measurements, where none are currently available.

2. There is some indication that there are two different, but consistent, measurements made for sawshark, both of which are recorded as LCF. More information on this, and possibly the generation of new codes for these alternative methods, or correction of procedures used by the observer's) who collected those data would be of value

11.4 Acknowledgements

Thanks to both John Garvey (AFMA) for providing the data on which this work is based, and to the members of sharkRAG who provided useful discussion.

11.5 References

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12. Yield, total mortality values and Tier 3 estimates for selected shelf and slope species in the SESSF 2014

Robin Thomson

CSIRO Oceans and Atmosphere Flagship, GPO Box 1538, Hobart, TAS 7001, Australia

12.1 Summary

This document updates yield analyses presented in Klaer (2013) for John dory and Mirror dory 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). During 2014 the data processing work was transferred from Neil Klaer to Robin Thomson. As part of this process some aspects of the automated processing had to be re-created, or done without automation.

Yield and total mortality estimates are provided. 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.

For John dory, age data are available from otoliths collected during a 14 month period from mid 2010 to mid 2011.

For Mirror dory, age data are available from a range of years, most recently 242 otoliths collected during 2013 and 111 from 2014, mainly from the east. Length data are only available to 2013. The 2013 and 2014 samples both show relatively large numbers of young fish. The sample for 2013 is reasonably well spread across the months of 2013, but the 2014 sample came from June and July only. For mirror dory, estimated F current (F_{cur}) values are averaged over the east and west. Fits to the age data for the west are poor, possibly indicating that the theoretical relationship for gear selectivity that is used, is not appropriate for that sector. Estimated F_{cur} is much lower in the west (0.01) than in the east (0.88) giving an overall F_{cur} of 0.44.

The calculated RBCs are lower than those presented by Klaer (2013) at 164t for John dory and zero for Mirror dory (due to an estimate that the fishing mortality rate is above that which leads to a stock size of 20% of pristine).

12.2 Methods

A detailed account of the methodology involved in applying a Tier 3 stock assessment are given in Appendix 1. Briefly, Tier 3 employs age length keys (ALKs) to convert length frequency data into age frequencies, or, if ALKs are unavailable, information from a von Bertalanffy growth curve is used to chop length frequencies into age frequencies. Theoretical gear selectivity relationships (from Bax & Knuckey 2002) are then used to describe the expected age frequency in the catch, for a population that is in equilibrium, with given fishing mortality rate. The fishing mortality rate that gives the best match between the expected and observed age frequencies over the most recent five years, is considered to be the current fishing mortality rate (F_{cur}).

Yield per recruit (YpR) analyses are performed using the assumed biological parameter values shown in Table 1. The YpR analysis gives the fishing mortality rates that would hold the population (at equilibrium) at specified depletions (i.e. 20%, 40% and 48%).

A harvest control rule (See Appendix 1) is used to assign a recommended fishing mortality rate (F_{RBC}). The harvest control rule uses the current fishing mortality rate (F_{cur}) and limit and threshold reference points. The recommended biological catch (RBC) is calculated by multiplying the current average catch by a ratio of the exploitation rate corresponding with F_{RBC}, to the exploitation rate corresponding with F_{cur}. The current average catch is defined over the same years (y_{min} to y_{max}) to which F_{cur} applies.

Table 12.1. Population parameters used for yield analysis: natural mortality (M), steepness (h), growth parameters (L_∞, k, t_0), length-weight relationship (a, b), gear selectivity (l_{25}, l_{50}), length at first maturity (lmat), maximum age for plus group (amax), maximum age for inclusion in catch curve (CCamax). The source for these values is given in Appendix 1.

Species	M	h	L_∞	k	t_0	a	b	l_{25}	l_{50}	l_{mat}	a_{max}	CC_{amax}	S_{25}
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

12.3 Data

The age data that were available for this analysis are shown in Figure 12.1 (John Dory) and Figure 12.2 (Mirror Dory). The length distribution *of the aged sample* is shown for John Dory (Figure 12.1).

Appendix 2 contains an updated data summary for mirror dory, showing the distribution of samples, relative to catches, by month and zone. The 2013 age data for mirror dory shows a better spread over months, especially during winter, than older samples.

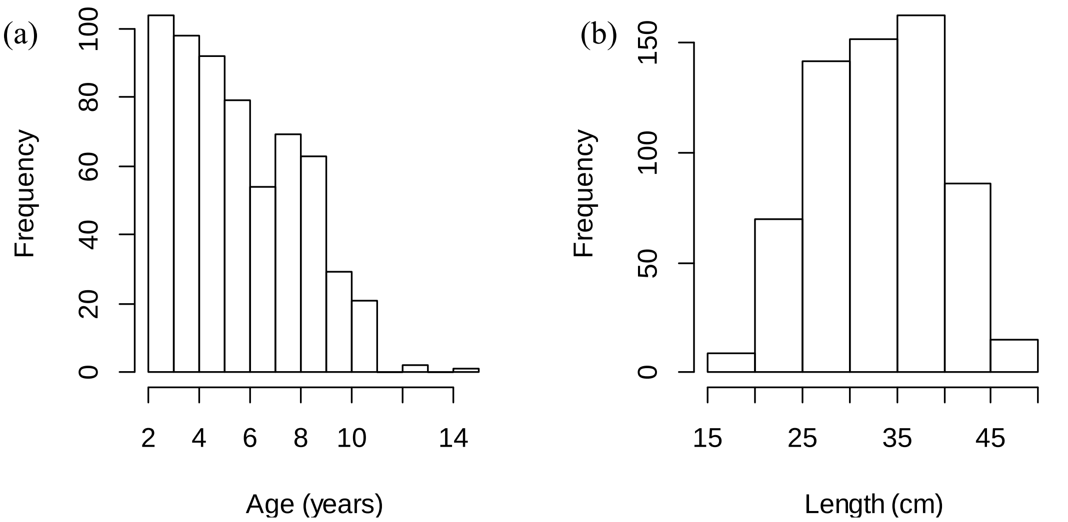


Figure 12.1.(a) Age and (b) length frequencies for aged John Dory samples for the 14 months (mid 2010 to mid 2011) for which data are available.

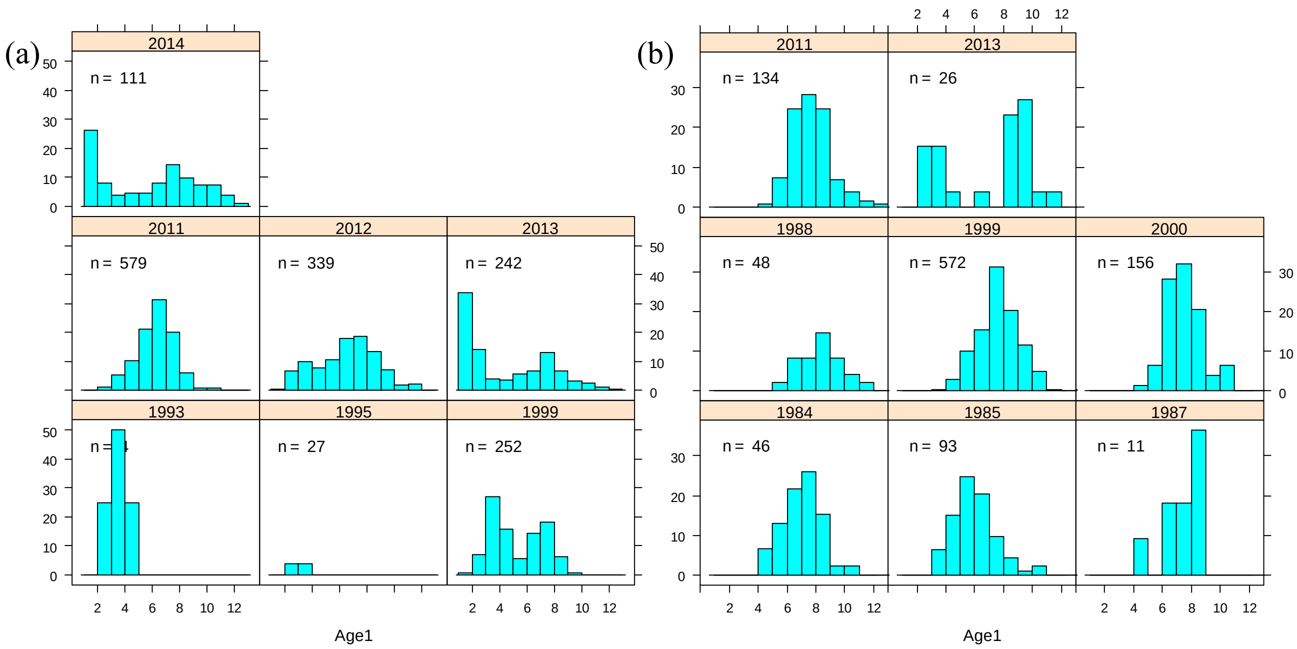


Figure 12.2. Age frequencies for (a) aast and (b) west mirror dory for all years for which data are available.

12.4 Results

12.4.1.1 Yield per recruit

The yield per recruit calculations are unchanged from those presented in Klaer (2013) because the underlying population parameters have not changed (see Figure 12.3 and Figure 12.4).

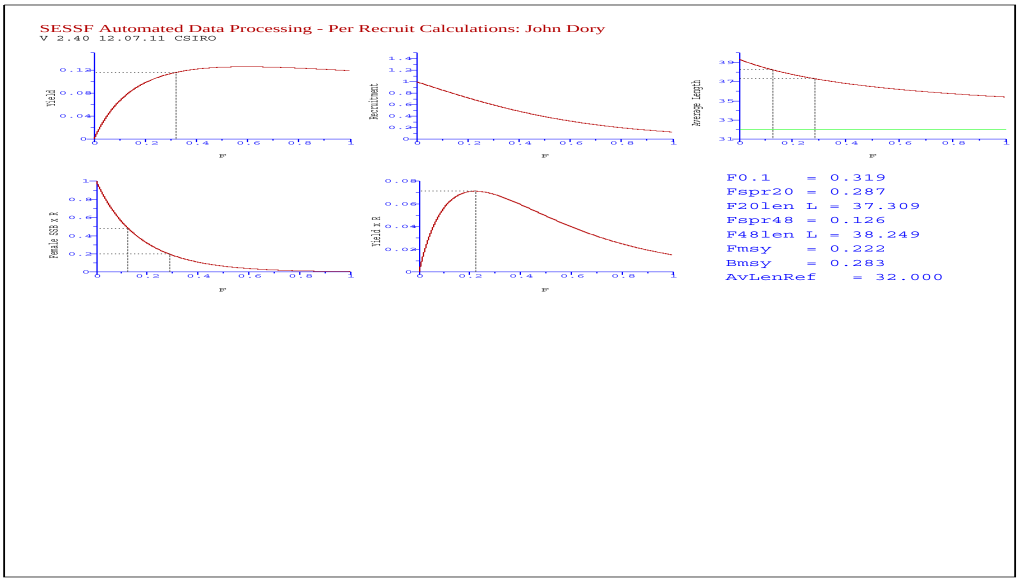


Figure 12.3. John dory yield per recruit reference point calculations.

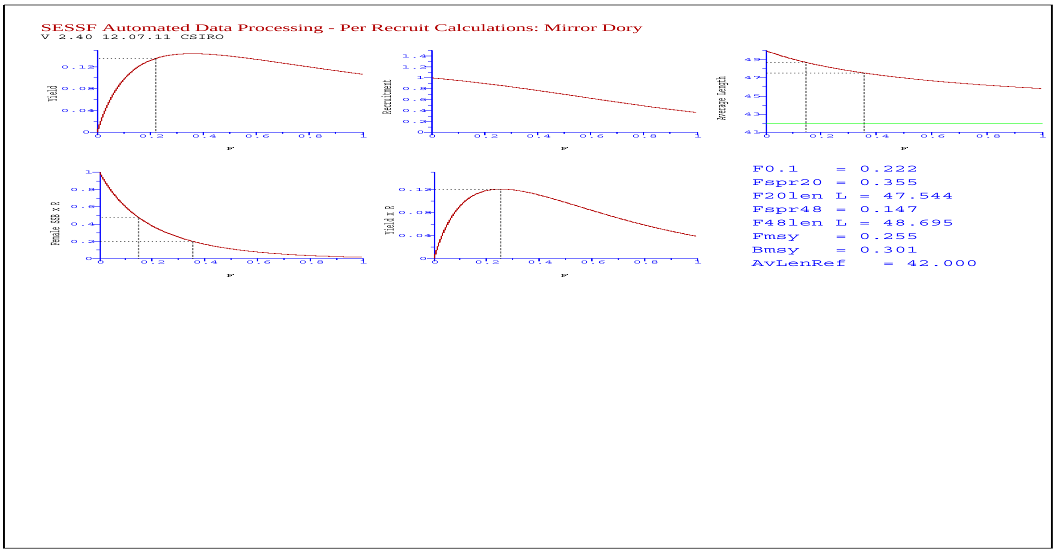
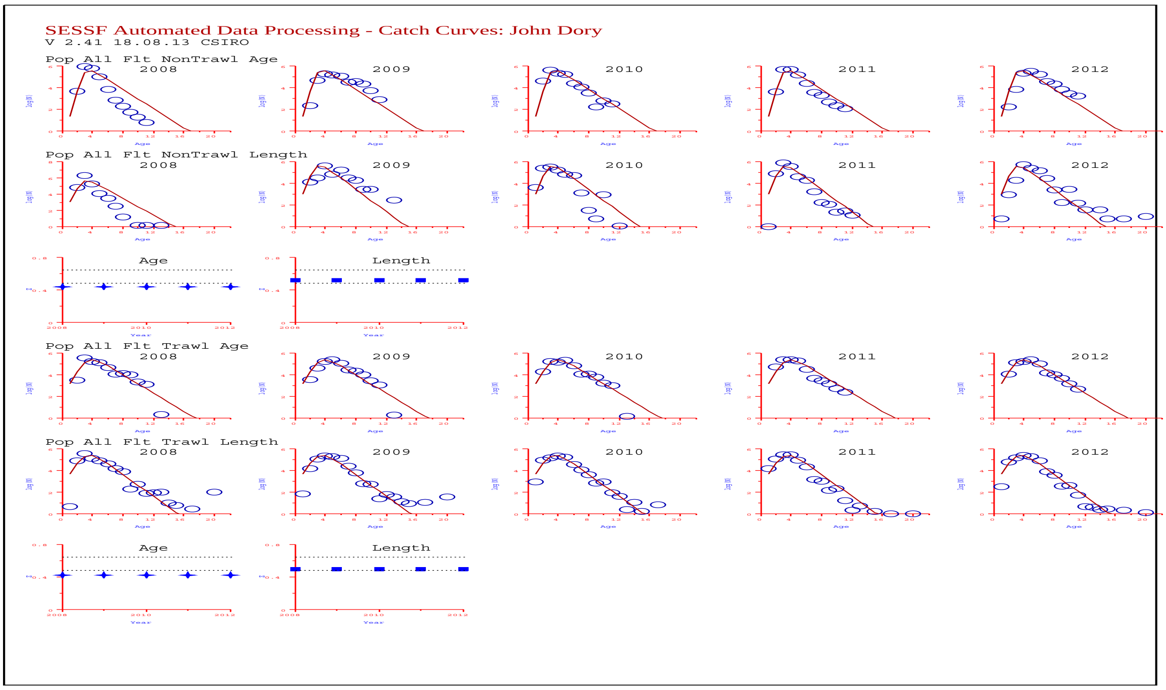


Figure 12.4. Mirror dory yield per recruit reference point calculations.

2013 DOJ



2014 DOJ

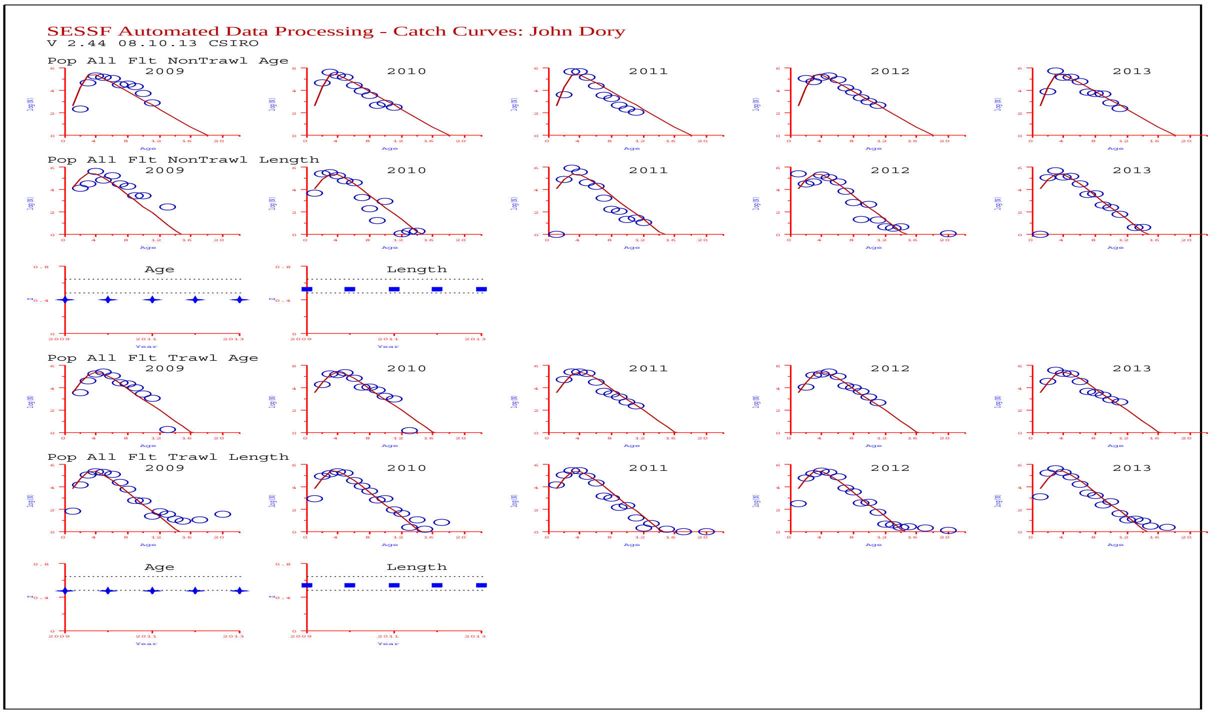


Figure 12.5. John dory catch curve results (only those labelled “age” were used, those labelled “length” relate to the less reliable method of “chopping” length frequencies into age classes).

2013 DOM

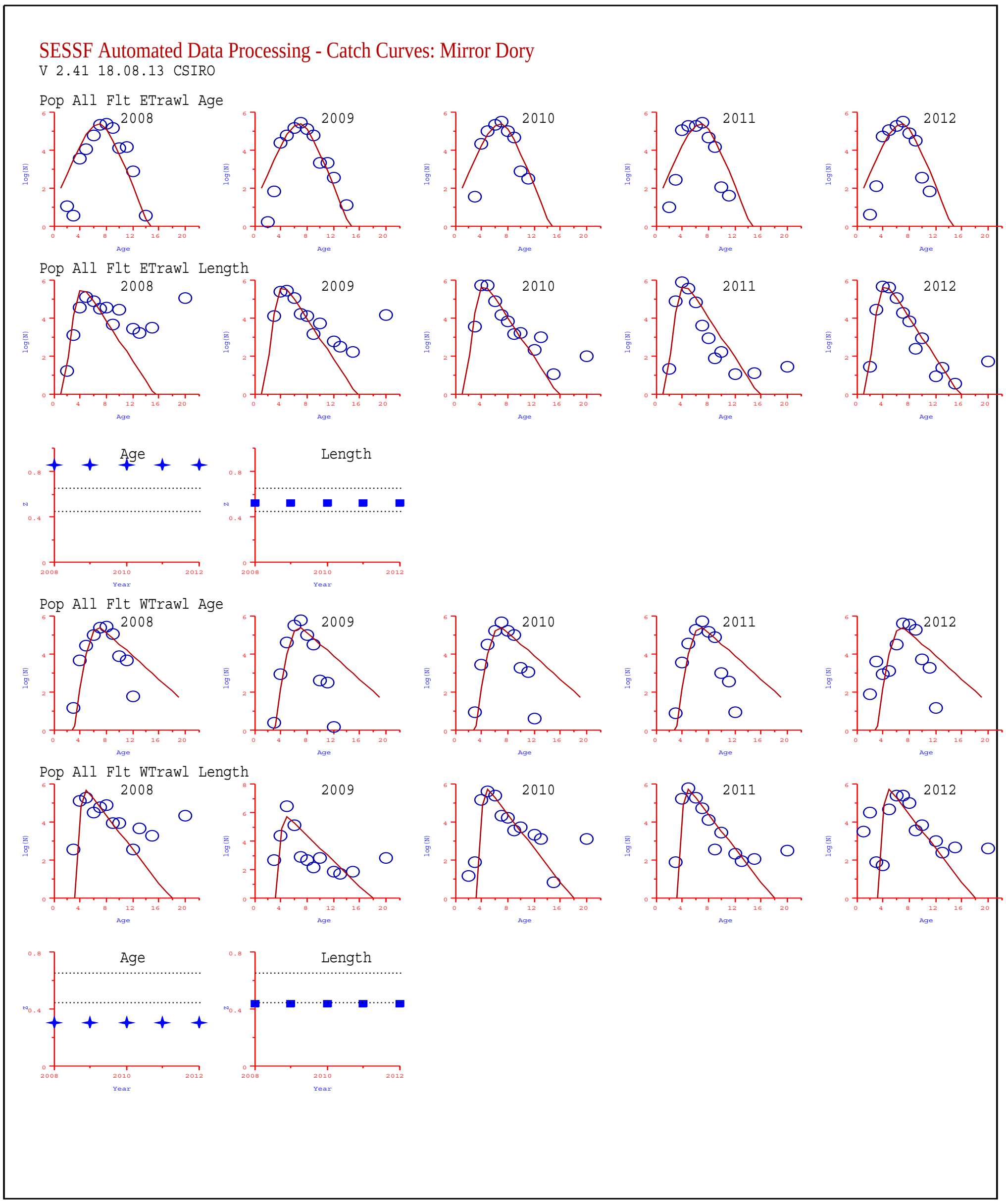


Figure 12.6a. Mirror dory catch curve results for 2013 (data ending 2012): east trawl is shown in the top three rows of plots, and west trawl in the lower three rows. Only those labelled “age” were used, those labelled “length” relate to the less reliable method of “chopping” length frequencies into age classes.

2014 DOM

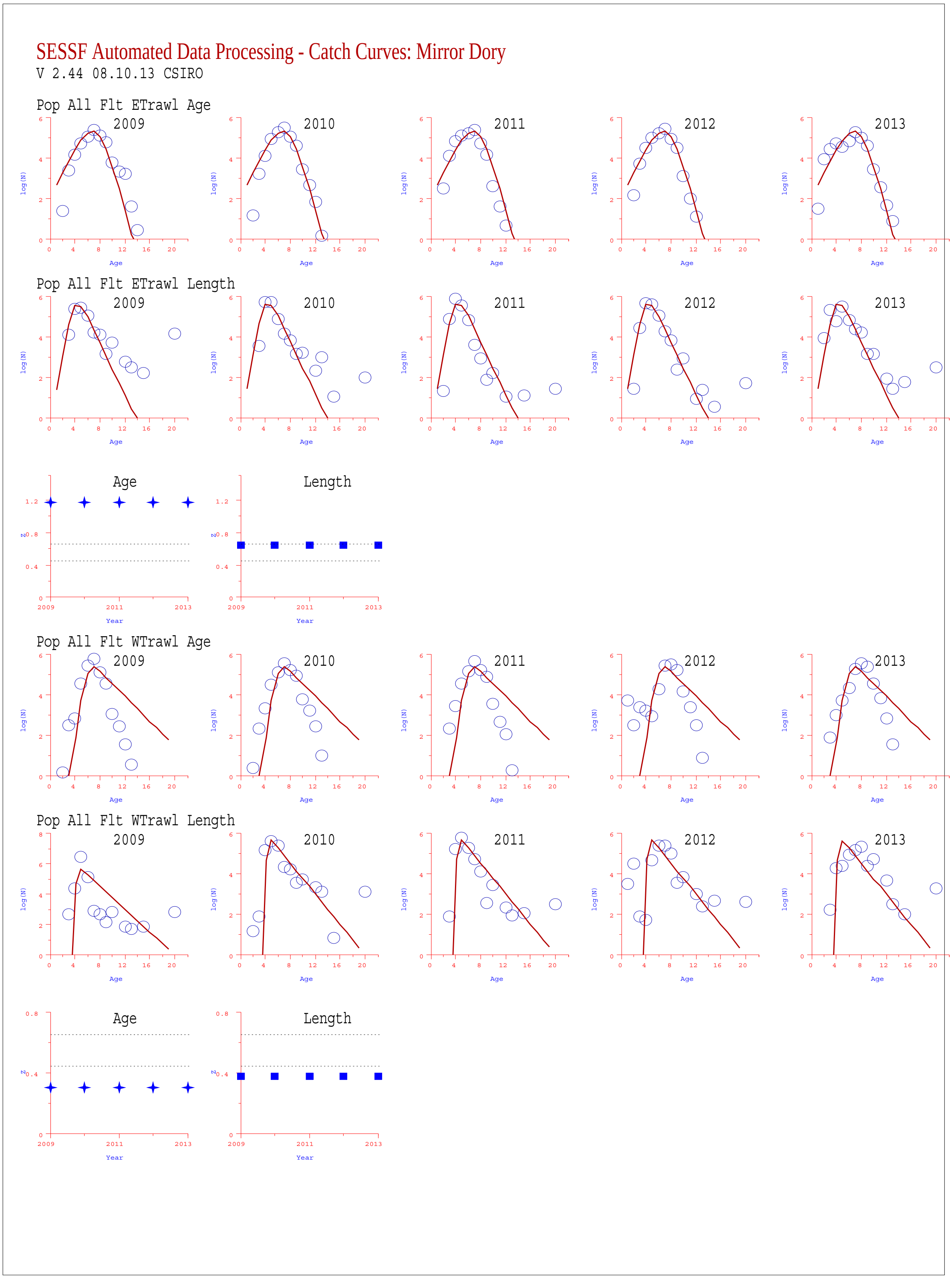


Figure 12.6b. Mirror dory catch curve results for 2014 (data ending 2013): east trawl is shown in the top three rows of plots, and west trawl in the lower three rows. Only those labelled "age" were used, those labelled "length" relate to the less reliable method of "chopping" length frequencies into age classes.

12.4.1.2 Catch curves

The resulting estimates of *Z* are shown in Figures 12.5 and 12.6. 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).

12.4.1.3 RBC Calculations

A summary of *Z* and current *F* estimates from catch curve analysis performed in 2013 on data ending 2012 is shown (Table 12.2) for comparison with the more recent results (Table 12.3). The *F* values resulting in 20% and 48% depletion are also shown. Recent *Z* estimates are taken from the values in Figure 12.8and 9 from age-based estimates from fleets that take the majority of catches. For John dory, the value calculated using trawl data is used, and for mirror dory the east trawl and west trawl values are averaged (an unweighted average). The actual values chosen for averaging are highlighted in Appendix 3.

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} (see Appendix 1 for further explanation). In Table 12.2 the F_{spr} target used for RBC calculations is highlighted in bold, and the target for John dory is now F_{spr40}.

For Mirror dory, age data are available from a range of years, most recently 242 otoliths collected during 2013 and 111 from 2014, mainly from the east. Length data are only available to 2013. The 2013 and 2014 samples both show relatively large numbers of young fish. The sample for 2013 is reasonably well spread across the months of 2013, but the 2014 sample came from June and July only. For mirror dory, estimated F current (F_{cur}) values are averaged over the east and west. Fits to the age data for the west are poor, possibly indicating that the theoretical relationship for gear selectivity that is used, is not appropriate for that sector. Estimated F_{cur} is much lower in the west (0.0.1) than in the east (0.88) giving an over all F_{cur} of 0.44.

The calculated RBCs are lower than those presented by Klaer (2013) at 164t for John dory and zero for Mirror dory (due to an estimate that the fishing mortality rate is above that which leads to a stock size of 20% of pristine).

Table 12.2. *F* reference points, Z_{cur}, C_{cur} and RBC estimates from *2013 calculations applied to data to 2012.*

Species	F_{spr20}	F_{spr40}	F_{spr48}	Z_{cur}	F_{cur}	p	y_{min}	y_{max}	C_{cur}	F_{rbc}	RBC
John Dory	0.287	**0.159**	0.126	0.424	0.064	2.371	1994	2011	168	0.159	398
Mirror Dory	0.355	**0.188**	0.147	0.585	0.285	0.242	1994	2011	613	0.062	148

Table 12.3. *F* reference points, Z_{cur}, C_{cur} and RBC estimates from *2014 calculations applied to data to 2013.*

Species	F_{spr20}	F_{spr40}	F_{spr48}	Z_{cur}	F_{cur}	p	y_{min}	y_{max}	C_{cur}	F_{rbc}	RBC
John Dory	0.287	**0.159**	0.126	0.480	0.120	1.30	1995	2012	157	0.159	203
Mirror Dory	0.355	**0.188**	0.147	0.743	0.443	0.00	1995	2012	623	0	0

12.5 References

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12.6 Appendix 1: Tier 3 Methods

12.6.1 Management zones

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

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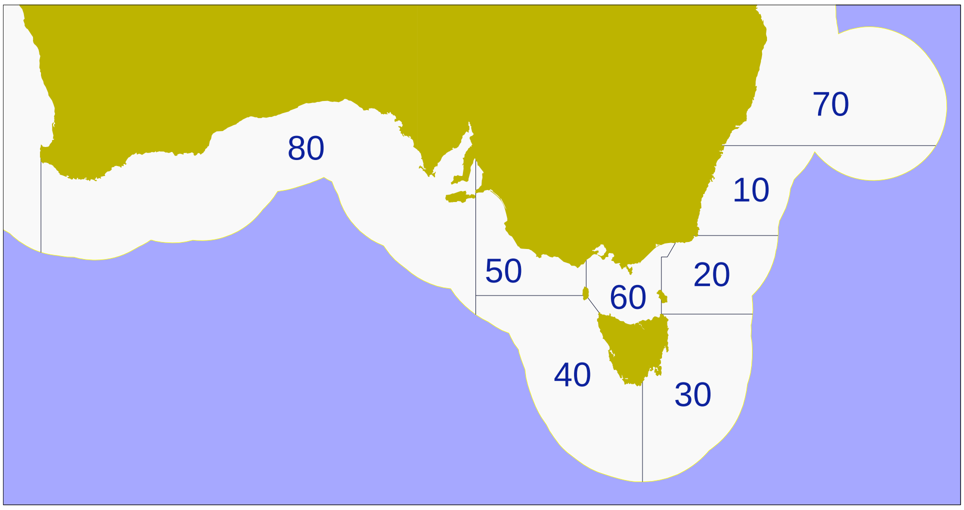


Figure 12.7. Map of the SESSF showing 8 statistical zones used in analyses here.

12.6.2 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 12.1.

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.

12.6.2.1 Length- and weight-at-age

Length-at-age was calculated using the von Bertalanffy growth equation (parameters are l_∞, 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.

12.6.2.2 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.

12.6.2.3 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).

12.6.2.4 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.

12.6.2.5 Maximum age

Maximum observed age (a_{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_{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.

12.6.2.6 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.

12.6.2.7 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_{spr30} (or $F_{30\%SPR}$, Gabriel *et al.* 1989) are reasonably widely known, the method used to calculate F_{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_{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.

Recruitment as a function of F depends on the assumed form of the stock-recruitment relationship, e.g. the Beverton-Holt relationship:

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

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.

12.6.3 Catch curves

12.6.3.1 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.

12.6.3.2 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.

12.6.3.3 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:

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

12.6.3.4 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 12.8). 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 12.8 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 12.8.

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

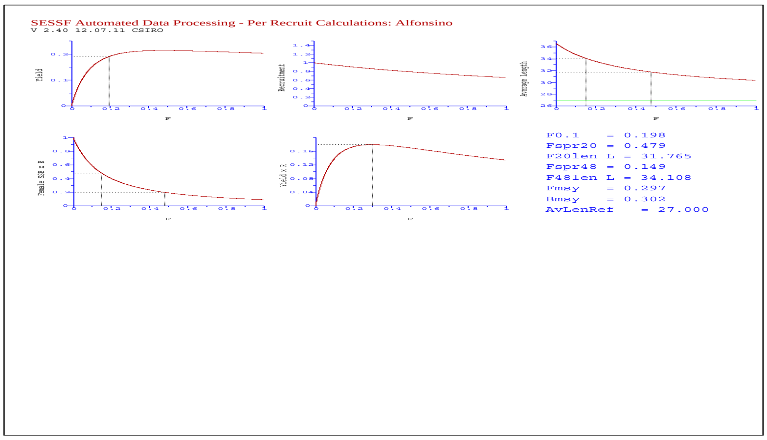


Figure 12.8. Average length reference point calculations.

12.6.4 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),Figure 12.9. 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.

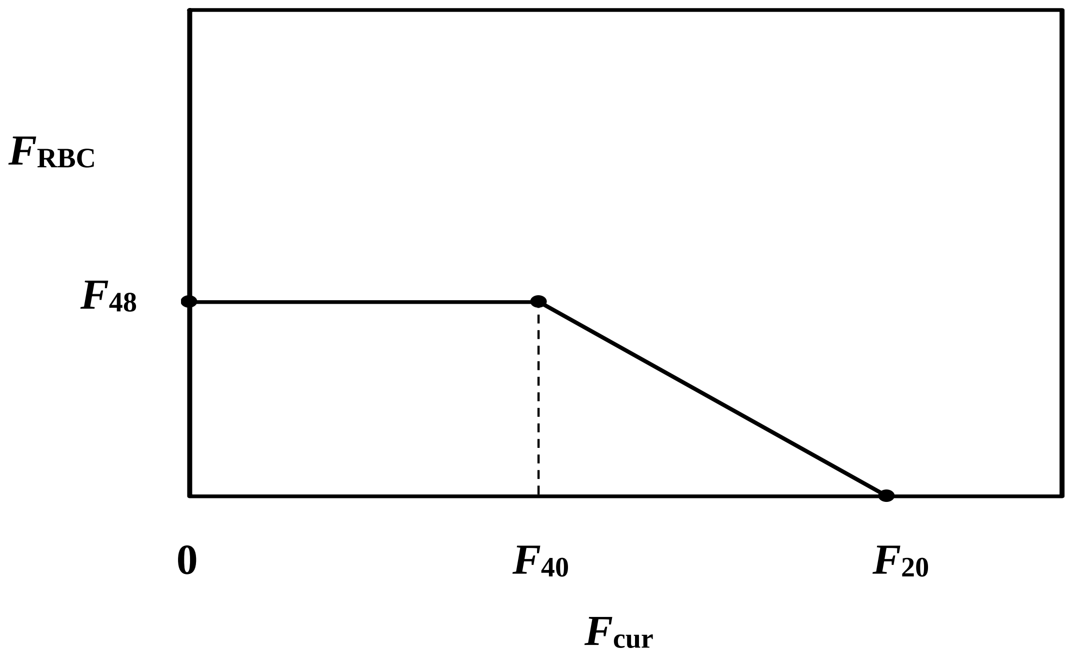


Figure 12.9. Method for selecting F_{RBC} based on estimated F_{cur}.

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 12.1 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.

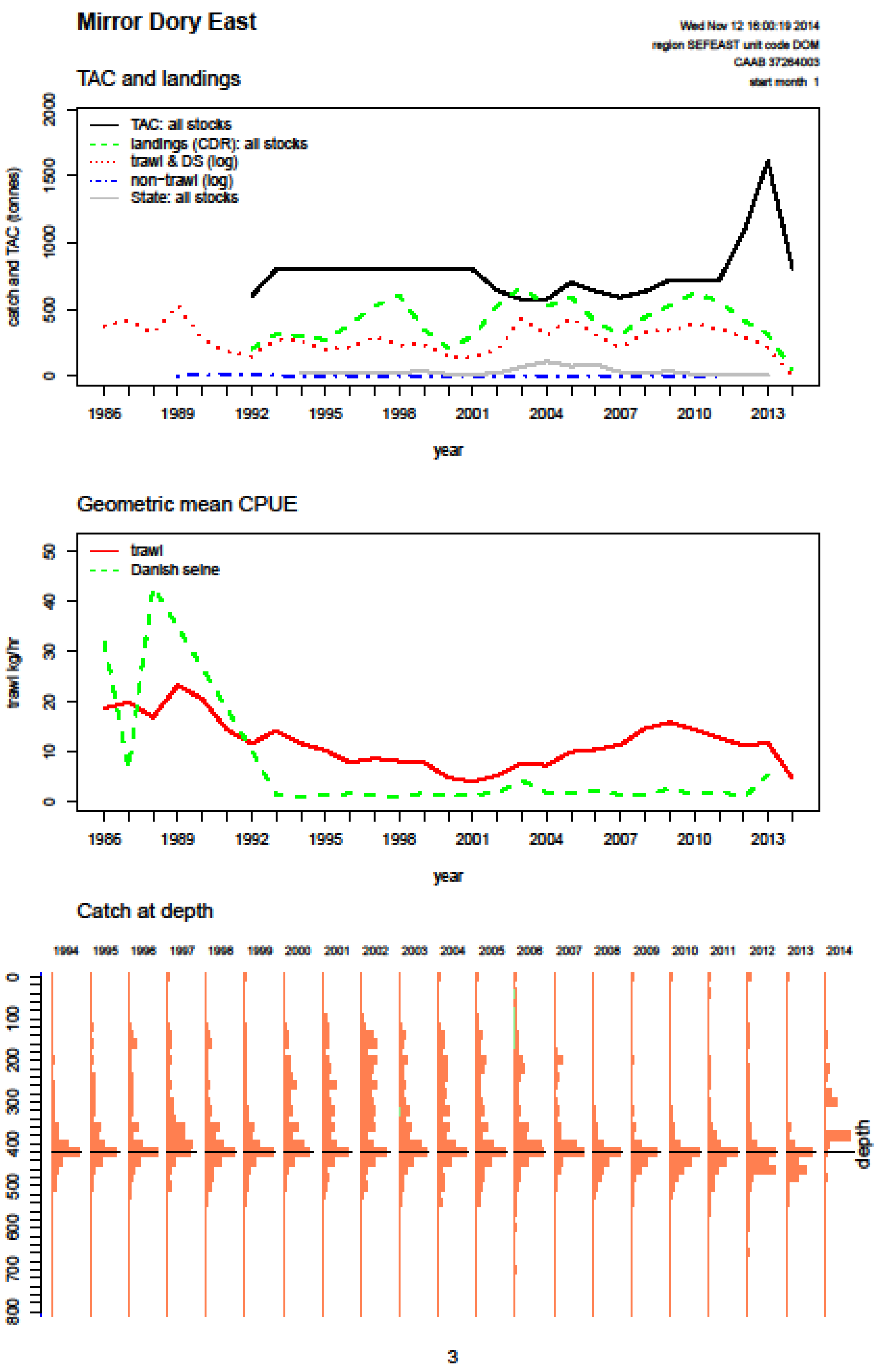
In the past, the actual RBC value generated by the Tier 3 HCR has been criticised if it was well above any of the known historical catch levels. The reason why such values are possible using the current HCR have been described here, and how they are correctly dealt with in the overall TAC setting framework. 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.

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.

12.7 Appendix 2: Data summary for mirror dory

Click on the figure below to open the data summary in Adobe Acrobat.

The plot for eastern mirror dory showing the distribution of aged samples relative to catches (labelled page 9) is blank for 2014 because of the absence of catch data for that year, however 50 samples were taken in June, 61 in July and none in any other months of 2014.


Mirror Dory East
Wed Nov 12 16:00:19 2014
region SEFEAST unit code DOM
CAAB 37264003
start month 1
TAC and landings
TAC: all stocks
landings (CDR): all stocks
trawl & DS (log)
non−trawl (log)
State: all stocks
catch and TAC (tonnes)
year
Geometric mean CPUE
trawl
Danish seine
trawl kg/hr
year
Catch at depth
depth
3

12.8 Appendix 3 – details of values that were used as estimates of total Z

Values that were used as estimates of total Z are highlighted.

DOJCCRes	All	NonTrawl	2009	6.08797	1	-99	-99	0.401059	0.529581	611	64
DOJCCRes	All	NonTrawl	2010	4.816	1	-99	-99	0.401059	0.529581	611	1399
DOJCCRes	All	NonTrawl	2011	11.0446	1	-99	-99	0.401059	0.529581	611	525
DOJCCRes	All	NonTrawl	2012	6.13983	1	-99	-99	0.401059	0.529581	611	730
DOJCCRes	All	NonTrawl	2013	7.6233	1	-99	-99	0.401059	0.529581	611	411
DOJCCRes	All	Trawl	2009	84.48	1	-99	-99	0.480047	0.543427	611	3363
DOJCCRes	All	Trawl	2010	55.4175	1	-99	-99	0.480047	0.543427	611	2603
DOJCCRes	All	Trawl	2011	62.3314	1	-99	-99	0.480047	0.543427	611	1890
DOJCCRes	All	Trawl	2012	59.4406	1	-99	-99	0.480047	0.543427	611	2552
DOJCCRes	All	Trawl	2013	54.6621	1	-99	-99	0.480047	0.543427	611	1918
DOMCCRes	All	ETrawl	2009	344.107	1	-99	-99	1.17687	0.64925	2387	2318
DOMCCRes	All	ETrawl	2010	389.139	1	-99	-99	1.17687	0.64925	2387	2657
DOMCCRes	All	ETrawl	2011	352.347	1	-99	-99	1.17687	0.64925	2387	1757
DOMCCRes	All	ETrawl	2012	292.815	1	-99	-99	1.17687	0.64925	2387	1882
DOMCCRes	All	ETrawl	2013	214.814	1	-99	-99	1.17687	0.64925	2387	1909
DOMCCRes	All	WTrawl	2009	131.066	1	-99	-99	0.31006	0.38133	2387	299
DOMCCRes	All	WTrawl	2010	187.747	1	-99	-99	0.31006	0.38133	2387	628
DOMCCRes	All	WTrawl	2011	161.886	1	-99	-99	0.31006	0.38133	2387	658
DOMCCRes	All	WTrawl	2012	71.9615	1	-99	-99	0.31006	0.38133	2387	423
DOMCCRes	All	WTrawl	2013	57.694	1	-99	-99	0.31006	0.38133	2387	531

13. Catch rate standardizations for selected SESSF species (data to 2013)

Miriana Sporcic and Malcolm Haddon

CSIRO Oceans and Atmosphere Flagship, GPO Box 1538, Hobart, TAS 7001, Australia

13.1 Executive summary

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

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

This document reports the statistical standardization of the commercial catch and effort data for 21 species, distributed across 50 different combinations of stocks and fisheries ready for inclusion in the annual round of stock assessments. These include School Whiting, Eastern Gemfish, Jackass Morwong, Flathead, Redfish, Silver Trevally, Royal Red Prawn, Blue Eye, Blue Grenadier, Spotted/Silver Warehou, Blue Warehou, Pink Ling, Western Gemfish, Ocean Perch, John Dory, Mirror Dory, Ribaldo, Ocean Jackets, Deepwater Flathead and Bight Redfish.

Summary graphs are provided across all species (Figure 13.2 and Figure 12.3), as well as more detailed information for each stock. Out of 36 stocks, there were seven whose catch rates have increased over the last 10 years; 17 stocks where catch rates were stable and 12 stocks whose catch rates have declined over the last 10 years. There were eight stocks whose catch rates have increased since the 2007 corresponding to the structural adjustment and introduction of the Harvest Strategy Policy; five stocks whose catch rates were stable and 23 stocks whose catch rates have declined over last seven year period. Many of the species were also examined for trends in catches and geometric catch rates between zones; this was to provide a check that there were only minor Year x Zone interactions (differences in catch rate trends between zones).

13.2 Introduction

Commercial catch and effort data are used 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.

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

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

13.4 Methods

13.4.1 Catch Rate Standardization

13.4.1.1 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 data relating to a specific fishery (e.g. SET, GHT, GAB, etc), data within a specified depth range and taken with a specified method in specified statistical zones within the years specified for the analysis (Table 13.1). This was based on a standard set of database extracts, designed to identify shots containing the species of interest in each case.

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. These influence plots illustrate the fact that for most species while the best statistical model can involve many factors and possibly interaction terms, the influence of many of the later factors tends to be either minor or possibly relates to noisy data rather than trend changes. In many species the difference between the final full model and one with the first three or four factors is trivial.

13.4.1.2 General Linear Modelling

In each case, catch rates, generally as kilograms per hour fished (though sometimes as catch per shot *e.g.* School Whiting caught by Danish Seine), were natural log-transformed. A General Linear Model was used rather than using a Generalized Linear Model with a log-link; this has advantages in terms of normalizing the data while stabilizing the variance, which the Generalized Linear Model approach does not always achieve appropriately (Venables & Dichmont, 2004). This relatively simple analytical approach means that the exact same methods can be applied to all species in a relatively robust manner. The statistical models were variants on the form: Ln(*CPUE*) = Year + Vessel + Month + Depth Category + Zone + DayNight. Gear type was also included for some fisheries. 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/hr, but sometimes kg/shot) for the *i*-th shot, x_{ij} are the values of the explanatory variables *j* for the *i*-th shot and the α_j are the coefficients for the *N* factors *j* to be estimated (α_0 is the intercept, α_1 is the coefficient for the first factor, *etc*.).

13.4.1.3 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:

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

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

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

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

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

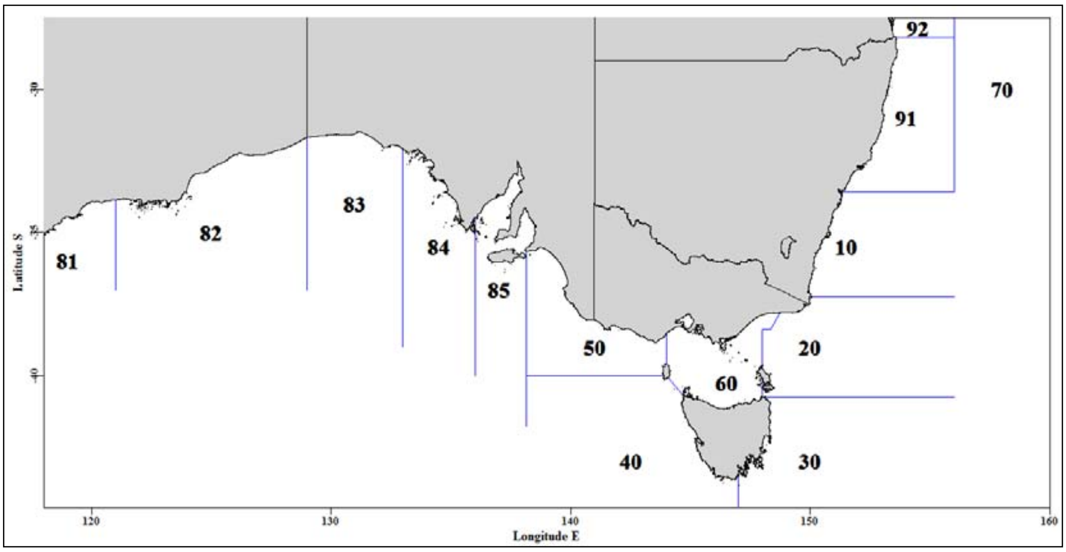


Figure 13.1. A schematic diagram depicting the statistical reporting zones in the SESSF, as used in this document. The GAB fishery is to the west of zone 50. The main SESSF trawl zones are zones 10 – 50. Each zone extends out to the boundary of the EEZ, except for zones 50 and 60, and for zones 92 and 91, which are bounded by zone 70.

13.5 Results

Table 13.1. Data characteristics for each analysis. Records show the number of records, depths, zones and other details used in the data selection for analyses.

	Name	Zone(s)	Depth (m)	Comment	Records
1	School Whiting	60	0-100	Danish Seine, catch per shot.	80538
2	Eastern Gemfish	10-30,40/2	300-500	June-Sept 93 onwards, Spawning	14566
3	Eastern Gemfish	10-30,40/2	0-600	Oct-May 86-09 0-600m, Jun-Sep <300m	37121
4	Jackass Morwong	10-50	70-360		148179
5	Jackass Morwong	10,20	70-300		112597
6	Jackass Morwong	30	70-300		19473
7	Jackass Morwong	40,50	70-360		13237
8	Jackass Morwong	40,50	70-250		9452
9	Flathead	10,20	0-400	Trawl	256183
10	Flathead	30	0-400	Trawl	20745
11	Flathead	20,60	0-200	Danish Seine, catch per shot	185499
12	Redfish	10	0-400		71284
13	Redfish	20	0-400		26786
14	Silver Trevally	10,20	0-200	Remove State waters and MPAs	33388
15	Silver Trevally	10,20	0-200	Including State waters and MPAs	56935
16	Royal Red Prawn	10	200-700		24228
17	Blue Eye Trevalla	20,30	0-1000		12265
18	Blue Eye Trevalla	40,50	0-1000		12712
19	Blue Eye Trevalla	10-50,83-85	200-600	Auto Line	7755
20	Blue Eye Trevalla	10-50,83-85	200-600	Drop Line	6883
21	Blue Eye Trevalla	10-50,83-85	200-600	Auto Line and Drop Line 1997 onwards	14641
22	Blue Grenadier	10-60	0-1000	Except Zone 40 Jun-Aug	132405
23	Silver Warehou	10-50	0-600		128507
24	Blue Warehou	10-30	0-400		36966
25	Blue Warehou	40,50	0-600		13079
26	Blue Warehou	10-50	0-600		50540
27	Pink Ling	10-30	250-600		96410
28	Pink Ling	40,50	200-800		74709
29	Western Gemfish	40,50,GAB	100-600		42151
30	Western Gemfish	40,50	100-600		31907
31	Western Gemfish	GAB	100-600	Only 1995 onwards	9518
32	Offshore Ocean Perch	10,20	200-700		78414
33	Inshore Ocean Perch	10,20	0-200		16234
34	John Dory	10,20	0-200		136885
35	Mirror Dory	10-50	0-600		121811
36	Mirror Dory East	10-30	0-600		91259
37	Mirror Dory West	40,50	0-600		30519
38	Ribaldo (RBD)	10-50	0-1000		20505
39	Ribaldo	10-50,81-85	0-1000	Auto Line	4906
40	Ocean Jackets	10-50	0-300		81057
41	Ocean Jackets	82-83	80-220		48130
42	Deepwater Flathead	GAB	0-1000	Trawl only, new more detailed analysis	69875
43	Bight Redfish	GAB	0-1000	Trawl only, new more detailed analysis	47868

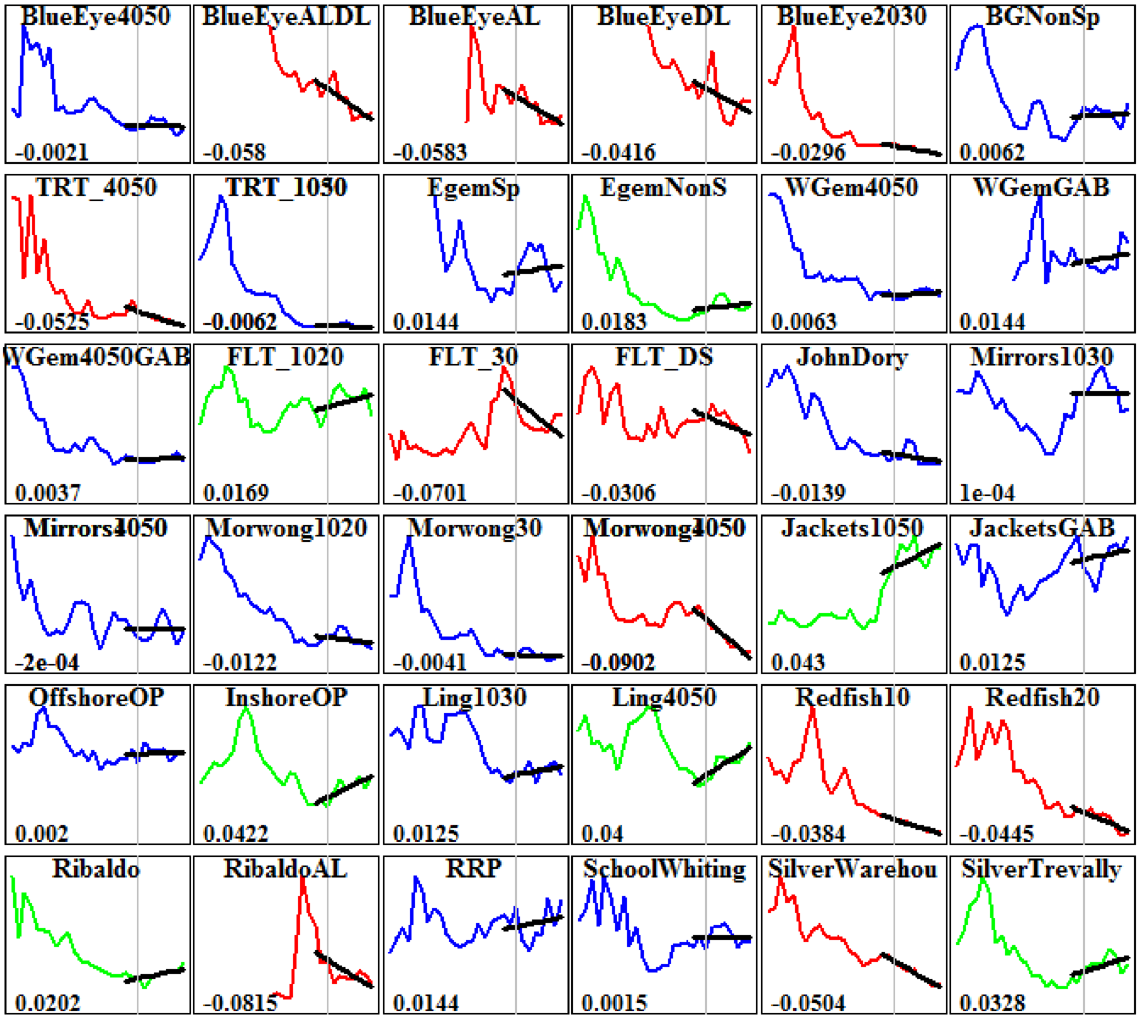


Figure 13.2. Summary graph of the optimum standardizations for 19 species and 36 different stocks, methods, or fisheries, each with a linear regression across the last ten years (2004-2013). The gradient is at bottom left in each graph and the line colour reflects the gradient: green indicates a positive 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 7 selections with a positive gradient, 17 selections with a flat gradient, and 12 selections with a negative gradient. Composite selections, such as Mirror Dory10-50 and Total Ocean Perch are omitted.

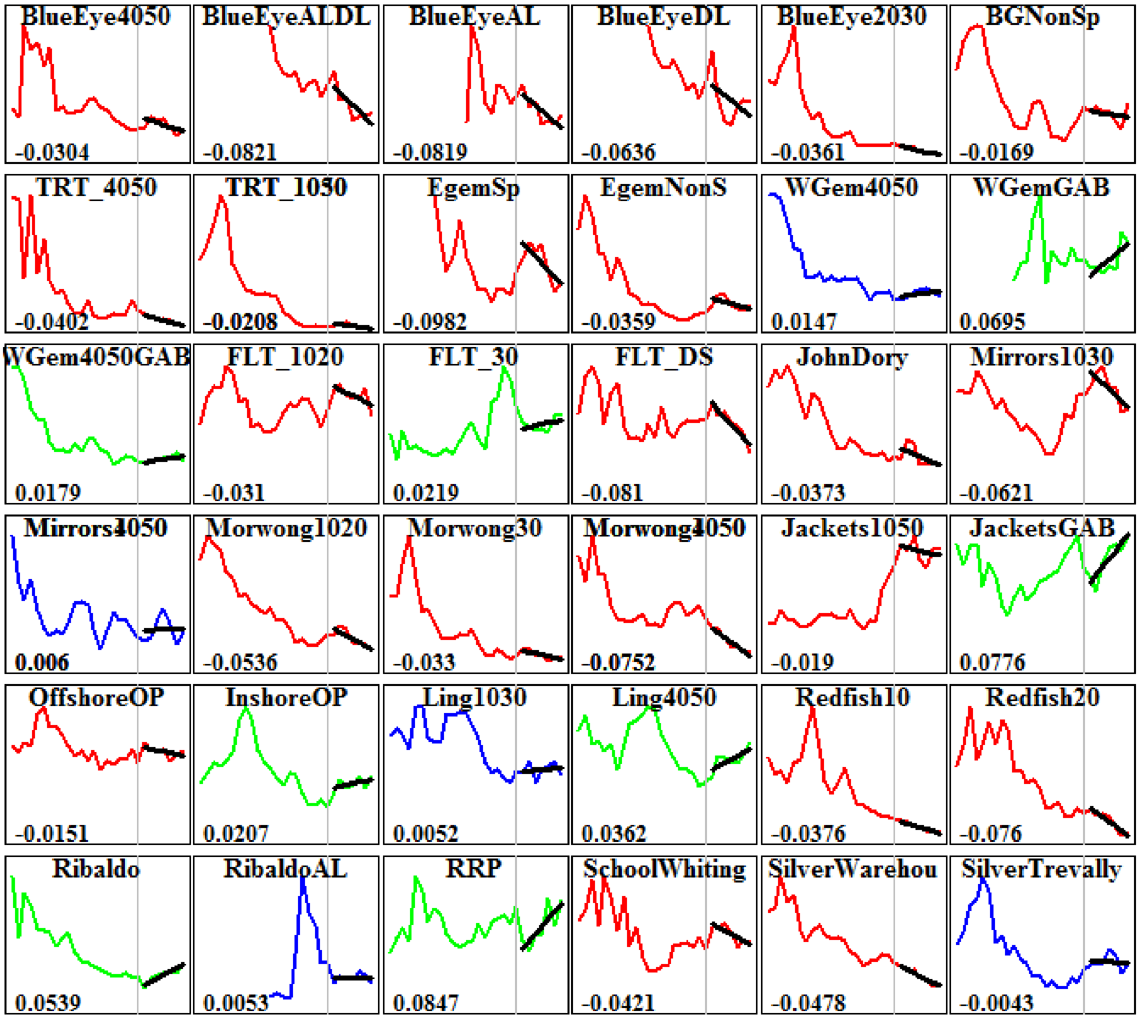


Figure 13.3. Summary graph of the optimum standardizations for 19 species and 36 different stocks, methods, or fisheries, each with a linear regression across the last seven years (2007-2013). The gradient is at bottom left in each graph and the line colour reflects the gradient: green indicates a positive 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 8 selections with a positive gradient, 5 selections with a flat gradient, and 23 selections with a negative gradient. The starting year, 2007 was the year after the structural adjustment and the year of introducing the Harvest Strategy Policy.

Table 13.2. Summary of linear regressions (LR) of the annual standardized catch rates corresponding to the (i) last10 years (Ten Year LR) and (ii) last seven years (Seven Year LR) for 36 stocks. Colour reflects the gradient: a positive gradient > 0.015 (green), a flat line with a gradient between 0.0149 and – 0.0149 (blue), a negative gradient < -0.015 (red). See also Figures 2 and 3.

Name	Zone(s)	Depth (m)	Ten Year LR	Seven Year LR
School Whiting - DS	60	0-100		
Eastern Gemfish SP	10-30,40/2	300-500		
Eastern Gemfish - NSpawn	10-30,40/2	0-600		
Jackass Morwong	10,20	70-300		
Jackass Morwong	30	70-300		
Jackass Morwong	40,50	70-360		
Flathead	10,20	0-400		
Flathead	30	0-400		
Flathead - DS	20,60	0-200		
Redfish	10	0-400		
Redfish	20	0-400		
Silver Trevally - no MPA	10,20	0-200		
Royal Red Prawn	10	200-700		
Blue Eye Trevalla	20,30	0-1000		
Blue Eye Trevalla	40,50	0-1000		
Blue Eye Trevalla AL	10-50,83-85	200-600		
Blue Eye Trevalla DL	10-50,83-85	200-600		
Blue Eye Trevalla (AL+DL)	10-50,83-85	200-600		
Blue Grenadier – NSpawn	10-60	0-1000		
Silver Warehou	10-50	0-600		
Blue Warehou	40,50	0-600		
Blue Warehou	10-50	0-600		
Pink Ling	10-30	250-600		
Pink Ling	40,50	200-800		
Western Gemfish	40,50,GAB	100-600		
Western Gemfish	40,50	100-600		
Western Gemfish	GAB	100-600		
Offshore Ocean Perch	10,20	200-700		
Inshore Ocean Perch	10,20	0-200		
John Dory	10,20	0-200		
Mirror Dory East	10-30	0-600		
Mirror Dory West	40,50	0-600		
Ribaldo (RBD)	10-50	0-1000		
Ribaldo - AL	10-50,81-85	0-1000		
Ocean Jackets	10-50	0-300		
Ocean Jackets - GAB	82-83	80-220		

13.6 School Whiting (WHS – 37330014 – *Sillago flindersi*)

School Whiting are taken primarily by Danish Seine (and within State waters). In Commonwealth waters, catches are primarily in zone 60, and in depths less than or equal to 100 m. All vessels and all records were included in the analysis. Catch rates were expressed as the natural log of catch per shot (catch/shot). There were 82,088 records for analysis.

Table 13.3. School Whiting from zone 60 in depths 0 to 100 m by Danish Seine. Total catch (TotCatch; t) is the total reported in the database, number of records used in the analysis (Records), reported catch (CatchT; t) in zone 60 and depth used in the analysis and number of vessels used in the analysis (Vessels). GeoMean is the geometric mean of catch rates (kg/shot). The optimum model is DepC:Month and standard deviation (StDev) relates to the data in the optimum model.

Year	TotCatch	Records	CatchT	Vessels	GeoMean	DepC:Month	StDev
1986	1302.4100	5667	1181.5830	26	112.3054	1.1695	0.0000
1987	995.9650	4119	920.4950	23	131.1624	1.2900	0.0293
1988	1255.6880	3815	1177.4560	25	168.5490	1.6739	0.0299
1989	1061.5130	4440	994.4080	27	127.0438	1.1032	0.0289
1990	1930.3680	6263	1859.9230	24	165.2959	1.7107	0.0269
1991	1630.2550	4871	1517.7940	26	164.1905	1.4518	0.0286
1992	854.1060	2980	777.5240	23	124.7066	1.0339	0.0328
1993	1694.8960	4696	1471.5590	23	152.4819	1.4716	0.0289
1994	946.2010	4503	879.1620	24	93.9314	0.8592	0.0290
1995	1212.5610	4270	1065.9340	21	122.4731	1.0821	0.0295
1996	898.2130	4297	718.8140	22	81.4339	0.7086	0.0297
1997	697.3800	3314	481.6600	20	64.5619	0.5484	0.0319
1998	594.1530	2988	464.1540	20	66.0158	0.5280	0.0328
1999	681.2520	2044	452.2150	21	84.3634	0.6038	0.0376
2000	700.8800	1913	335.0750	17	65.1233	0.6096	0.0381
2001	890.9250	1980	425.0945	18	93.2089	0.8518	0.0392
2002	788.3307	2192	429.2183	20	90.8874	0.8704	0.0375
2003	866.2327	2355	463.5434	20	86.7848	0.8862	0.0368
2004	604.8859	1771	334.6310	20	79.7648	0.8368	0.0396
2005	662.6840	1750	311.4275	20	77.2502	0.9460	0.0412
2006	667.5046	1428	270.2720	18	76.2250	0.8168	0.0431
2007	535.3580	1488	347.0490	14	89.2381	1.0806	0.0421
2008	502.2450	1260	317.0575	15	92.3448	1.0811	0.0451
2009	462.5905	1569	350.7230	15	93.6200	1.1299	0.0418
2010	408.9007	1179	272.8700	15	88.6885	1.0131	0.0461
2011	373.9361	1579	260.2995	14	72.0269	0.8293	0.0415
2012	435.7716	1566	302.4675	14	80.0853	0.9154	0.0417
2013	510.6307	1791	339.7765	14	82.5661	0.8981	0.0406

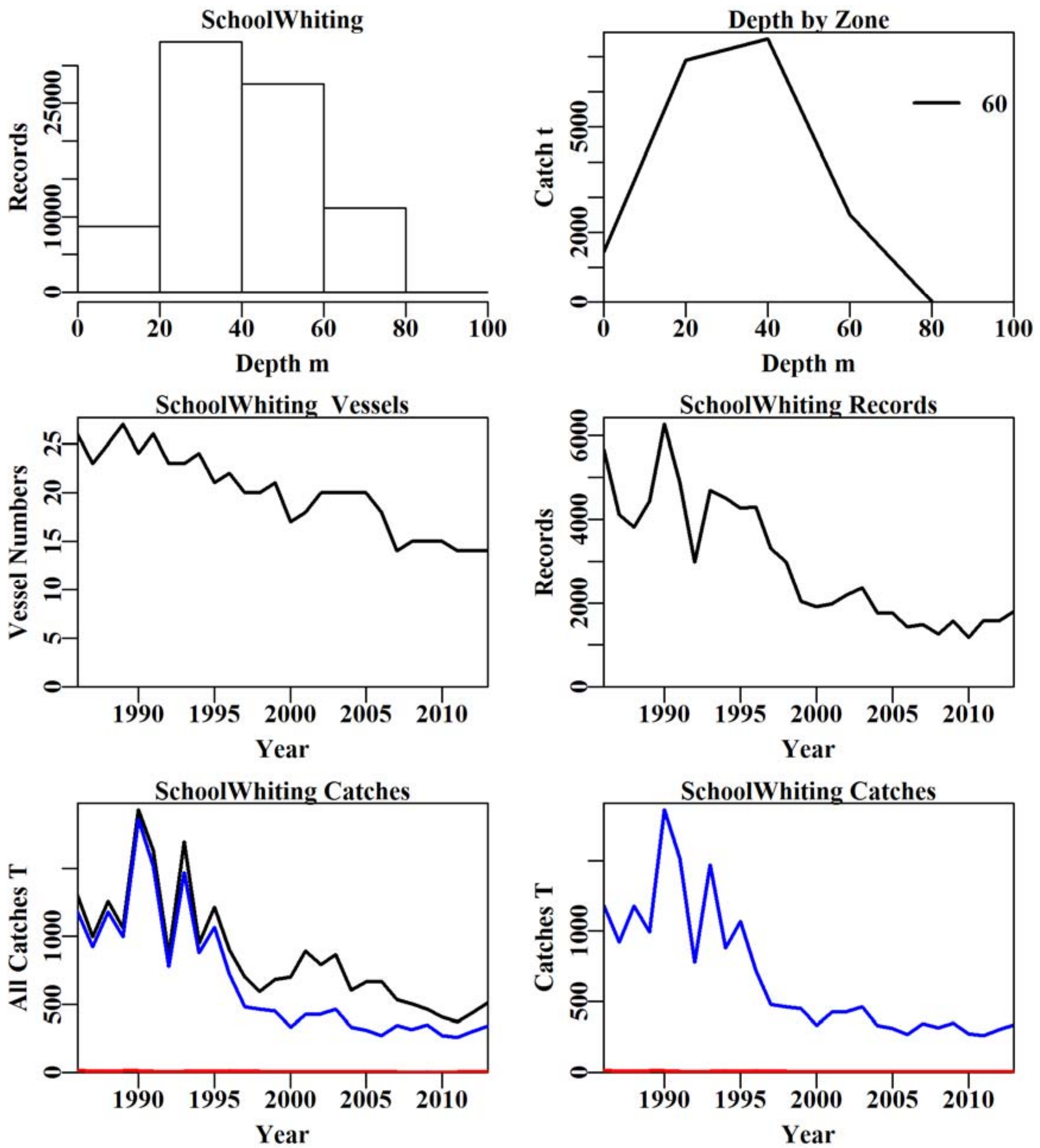


Figure 13.4. School Whiting in zone 60 in depths 0 to 100 m taken by Danish Seine. The top left plot depicts the depth distribution of shots containing School Whiting from zone 60 in depths 0 – 100 m by Trawl. The top right plot depicts the distribution of catch by depth within zone 60. The middle left plot depicts the number of vessels through time. The middle right plot contains the number of records used in analysis. The bottom left plot contains School Whiting catches (top black line: total catches, middle blue line: catches used in the analysis; bottom red line: catches < 30 kg) and bottom right plot contains School Whiting catches (blue line: catches used in the analysis; red line: catches < 30 kg).

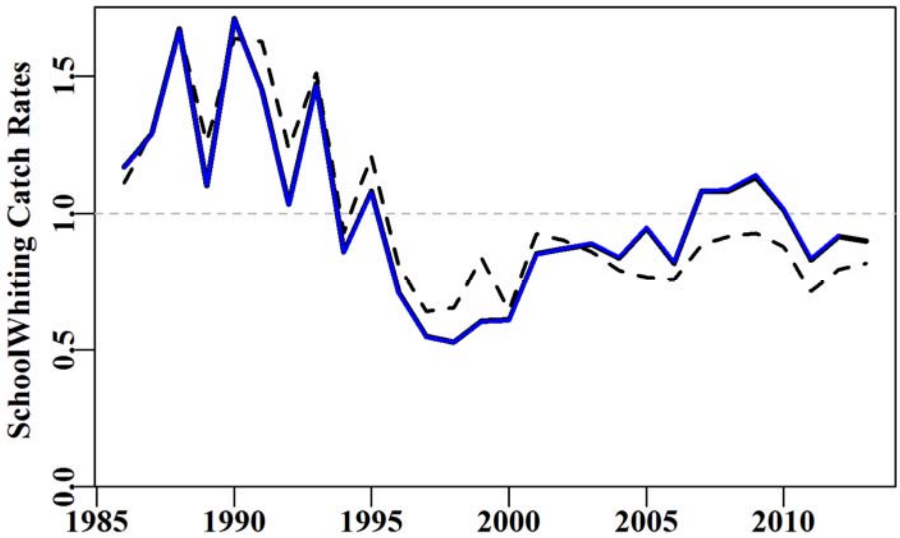


Figure 13.5. School Whiting in zone 60 in depths 0 to 100 m by Danish Seine. The dashed black line represents the geometric mean catch rate, the solid black line the standardized catch rates, and the blue line is standardized catch rates from last year's analysis. The graph standardizes catch rates relative to the mean of the standardized catch rates.

Table 13.4. School Whiting from Zone 60 in depths 0 to 100 m by Danish Seine. Statistical model structures used in this analysis. DepCat is a series of 20 metre depth categories.

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

Table 13.5. School Whiting from Zone 60 in depths 0 to 100 m by Danish Seine. Model selection criteria include the Akaike Information Criterion (AIC), residual sum of squares (RSS), model sum of squares (MSS), number of usable observations (Nobs), number of parameters (Npars), adjusted R^2 (adj_R^2) and the change in adjusted R^2 (%Change). The optimum model was Model 7 (DepC:Month). Depth category: DepC; DayNight:DN.

	Year	Vessel	DN	Month	DepC	DN:DepC	DepC:Month	DN:Month
AIC	58217	56165	53899	51760	50267	50111	49717	50119
RSS	166720	162417	157983	153880	149989	149653	148806	149591
MSS	7790	12092	16526	20630	24520	24856	25704	24919
Nobs	82088	82088	82088	82088	80538	80538	80538	80538
Npars	28	75	78	89	93	105	137	126
adj_R^2	4.432	6.845	9.385	11.727	13.953	14.133	14.585	14.146
%Change	0.000	2.413	2.540	2.342	2.226	0.180	0.452	-0.439

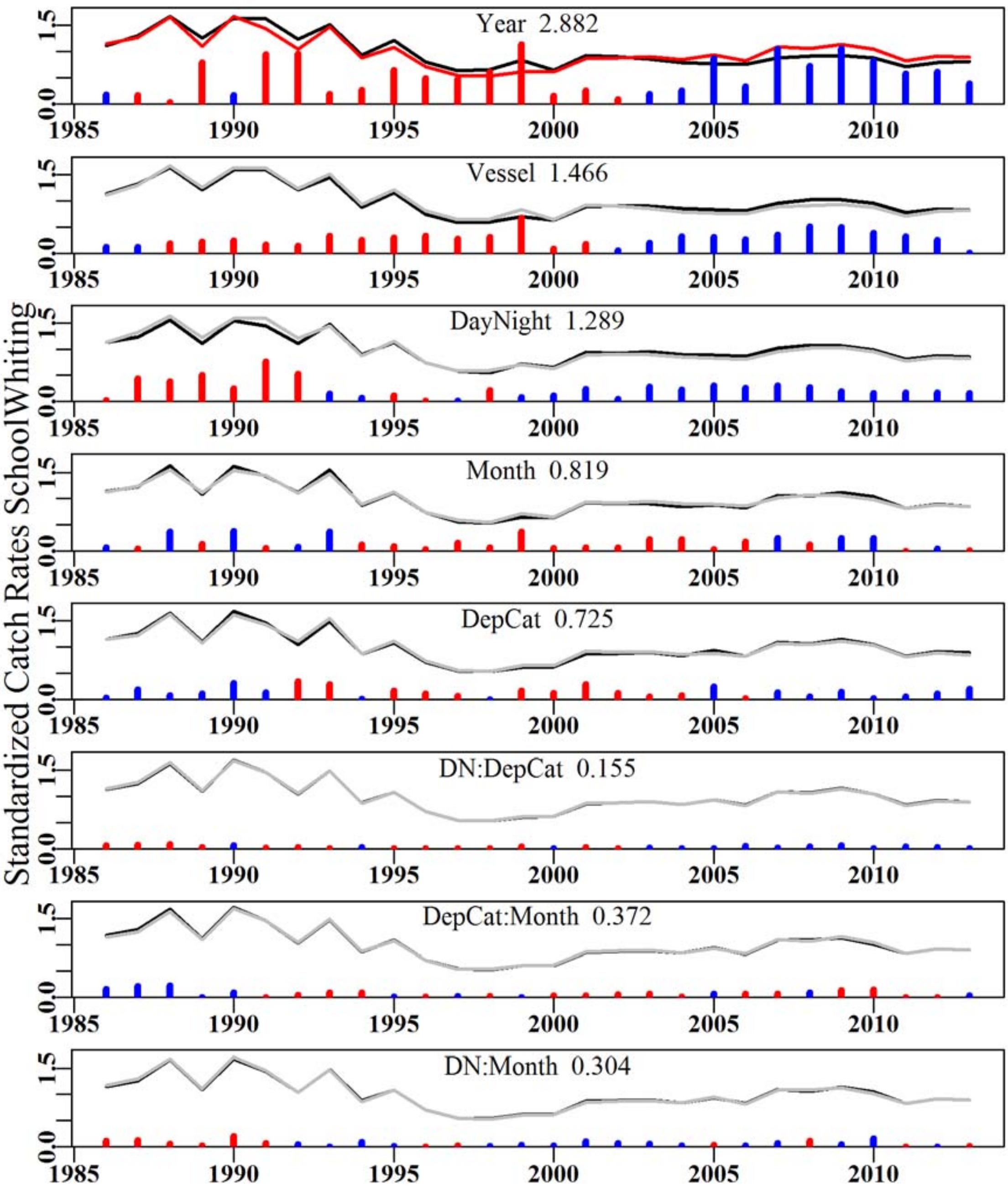


Figure 13.6. The relative influence of each factor used on the final trend in the optimal standardization for School Whiting in zone 60. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by the vertical bars with blue bars indicating the optimum model is higher than the geometric mean and red bars indicating it is lower. The top graph bars are the sum of all the bars in the graphs below. The graphs for individual factors are cumulative. Thus the second graph has the geometric mean (grey line) and the effect of adding Year + factor2 (Model 2). In the third graph, the grey line represents Model 2 and the black line the effect of adding factor3 to the model. The remaining graphs continue in the same cumulative manner except for the interaction terms which are added singularly to the final single factor model.

13.7 Eastern Gemfish Spawning (GEM – 37439002 – Rexea solandri)

Eastern Gemfish are taken by Trawl in the spawning season from June to September in zones 10, 20 and 30, in the bottom half of zone 40 (i.e. below 42°S; west coast of Tasmania) and between depths of 300 to 500 m. There were 14,672 records for analysis. The spawning run of Eastern Gemfish is considered to be a by-catch fishery. Particular records in the database relating to the Eastern Gemfish surveys in 2007 and 2008 were removed from the data set prior to the analysis.

Table 13.6. Eastern Gemfish, spawning fishery in depths between 300 – 500 m, taken by Trawl. Total catch (TotCatch; t) is the total reported in the database, number of records used in the analysis (Records), reported catch (CatchT; t) in the area and depth used in the analysis and number of vessels used in the analysis (Vessels). GeoMean is the geometric mean of catch rates (kg/hr). The optimum model is Zone:Month and standard deviation (StDev) relates to the data in the optimum model.

Year	TotCatch	Records	CatchT	Vessels	GeoMean	Zone:Month	StDev
1993	353.4100	824	133.2310	50	17.7598	2.0481	0.0000
1994	232.1790	819	49.0380	47	11.8880	1.3571	0.0622
1995	181.7460	657	21.8650	48	7.3973	0.9122	0.0657
1996	382.1960	769	135.1320	49	10.9438	1.1508	0.0633
1997	571.9758	1232	268.5900	48	18.9829	1.6735	0.0586
1998	404.8147	883	144.6760	46	11.5921	1.1156	0.0628
1999	448.6767	1065	87.9210	45	8.4120	0.9407	0.0611
2000	336.4642	1178	37.0190	44	4.8857	0.6433	0.0614
2001	331.4862	854	32.8090	47	4.7139	0.6585	0.0651
2002	195.8983	922	22.4380	42	3.5128	0.4729	0.0645
2003	267.9710	967	31.5869	48	4.5797	0.6678	0.0633
2004	568.8517	631	19.7705	44	4.2927	0.6288	0.0706
2005	511.7585	652	21.6200	40	4.5977	0.5570	0.0694
2006	544.8936	571	34.7529	35	7.7674	0.8867	0.0719
2007	580.6498	308	25.3560	19	8.9499	1.0972	0.0868
2008	257.6855	447	35.2582	23	10.4210	1.3413	0.0792
2009	194.8654	413	37.0383	22	9.3924	1.2191	0.0803
2010	220.6510	390	41.7925	24	10.5969	1.3257	0.0813
2011	147.7397	413	27.4315	21	7.3130	0.9284	0.0795
2012	168.5996	381	28.0095	21	6.0729	0.6111	0.0827
2013	103.7326	296	16.1220	20	7.2972	0.7643	0.0886

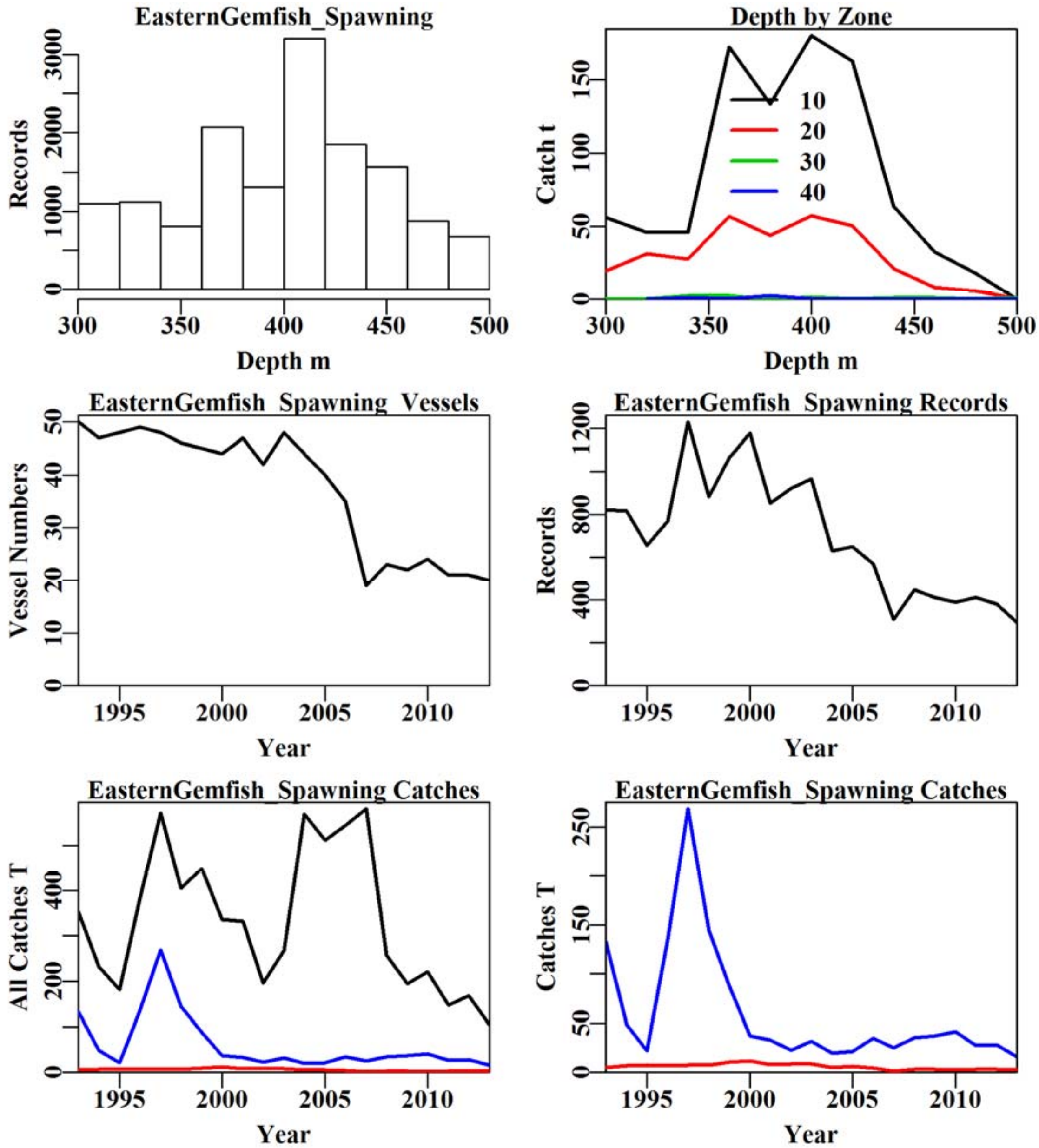


Figure 13.7. Eastern Gemfish, spawning fishery in depths between 300 – 500 m, taken by Trawl. The top left plot depicts the depth distribution of shots containing Eastern Gemfish from zones 10 to 40 in depths 300 – 500 m by Trawl. The top right plot depicts the distribution of catch by depth within zones 10 to 40. The middle left plot depicts the number of vessels through time. The middle right plot contains the number of records used in analysis. The bottom left plot contains Eastern Gemfish catches (top black line: total catches for all gemfish (Eastern and Western), middle blue line: catches used in the analysis; bottom red line: catches < 30 kg) and bottom right plot contains Eastern Gemfish catches (blue line: catches used in the analysis; red line: catches < 30 kg).

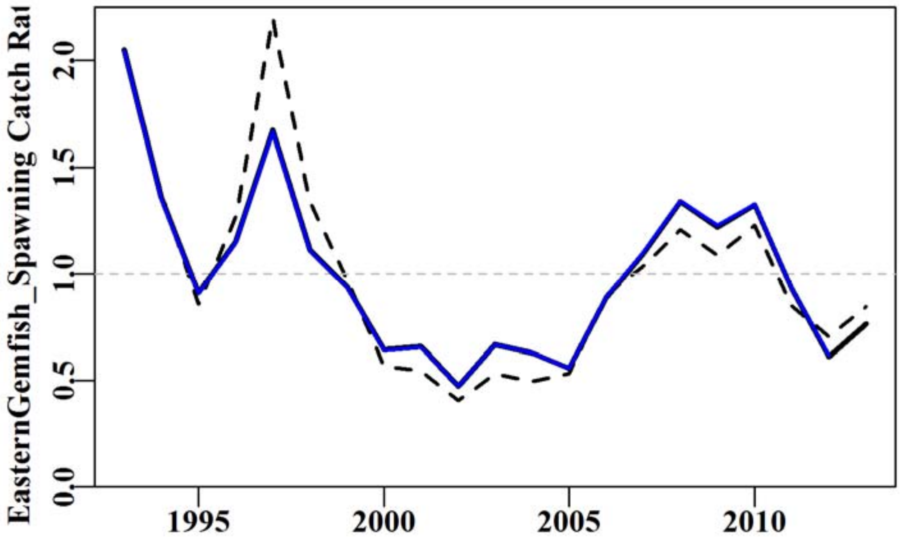


Figure 13.8. Eastern Gemfish, spawning fishery in depths between 300 – 500 m, taken by Trawl. The dashed black line represents the geometric mean catch rate and the solid black line the standardized catch rates (relative to the mean of the standardized catch rates). The blue line is last year's optimum standardization.

Table 13.7. Eastern Gemfish, spawning fishery in depths between 300 – 500 m, taken by Trawl. Statistical model structures used in this analysis. DepCat is a series of 20 metre depth categories.

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

Table 13.8. Eastern Gemfish, spawning fishery in depths between 300 – 500 m, taken by Trawl. Model selection criteria include the Akaike Information Criterion (AIC), residual sum of squares (RSS), model sum of squares (MSS), number of usable observations (Nobs), number of parameters (Npars), adjusted R^2 (adj_R^2) and the change in adjusted R^2 (%Change). The optimum model is Model 7 (Zone:Month). Depth category: DepC.

	Year	Vessel	DepC	Month	DayNight	Zone	Zone:Month	Zone:DepC
AIC	8598	6906	6103	5696	5659	5643	5366	5626
RSS	26288	23107	21868	21143	21081	21049	20627	20939
MSS	3776	6957	8196	8920	8983	9015	9437	9125
Nobs	14672	14672	14672	14566	14566	14566	14566	14566
Npars	21	121	124	134	137	140	149	170
adj_R^2	12.441	22.507	26.646	29.023	29.219	29.311	30.685	29.535
%Change	0.000	10.066	4.139	2.378	0.196	0.092	1.374	-1.150

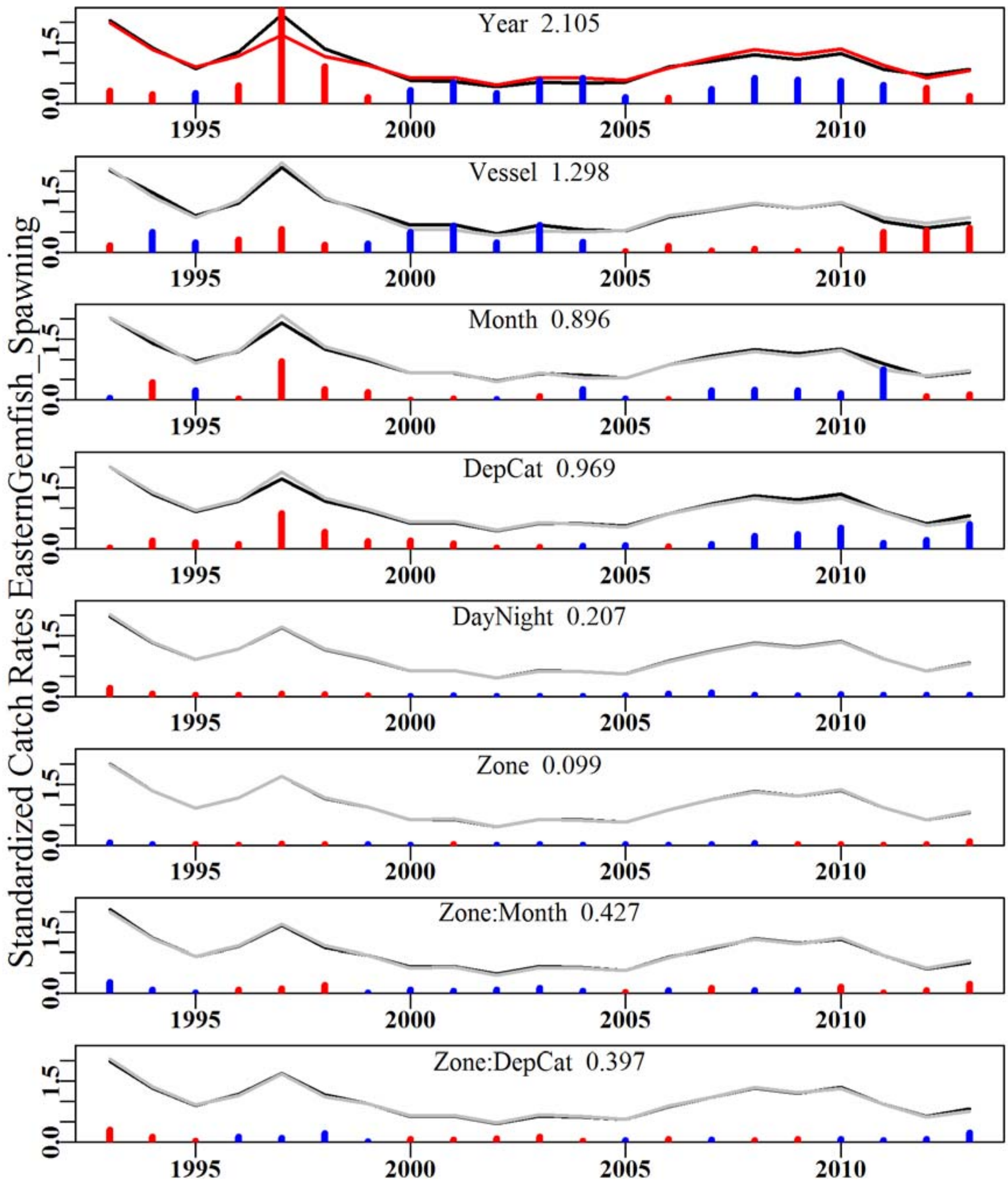


Figure 13.9. The relative influence of each factor used on the final trend in the optimal standardization for the Eastern Gemfish spawning fishery. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by the vertical bars with blue bars indicating the optimum model is higher than the geometric mean and red bars indicating it is lower. The top graph bars are the sum of all the bars in the graphs below. The graphs for individual factors are cumulative. Thus the second graph has the geometric mean (grey line) and the effect of adding Year + factor2 (Model 2). In the third graph, the grey line represents Model 2 and the black line the effect of adding factor3 to the model. The remaining graphs continue in the same cumulative manner except for the interaction terms which are added singularly to the final single factor model.

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

Data selected for analysis were based on records from zones 10-30 from October to May 1986-2012, all depths to 600 m; and from June to September in depths less than 300 m. Also, records below 42°S on the west coast of Tasmania (zone 40) were used. Particular records in the database relating to the Eastern Gemfish surveys in 2007 and 2008 were removed from the data set prior to the analysis.

Table 13.9. Non-spawning Eastern Gemfish from the SET in depths between 0 – 600 m, taken by Trawl. Total catch (TotCatch; t) is the total reported in the database, number of records used in the analysis (Records), reported catch (CatchT; t) in the area and depth used in the analysis and number of vessels used in the analysis (Vessels). GeoMean is the geometric mean of catch rates (kg/hr). The optimum model is Zone:DepCat and standard deviation (StDev) relates to the data in the optimum model.

Year	TotCatch	Records	CatchT	Vessels	GeoMean	Zone:DepCat	StDev
1986	3639.9550	2030	390.3560	86	14.5833	2.4057	0.0000
1987	4660.4470	1894	770.1410	74	25.6322	3.1891	0.0430
1988	3515.8190	2203	509.5870	77	20.2775	2.7434	0.0430
1989	1778.3250	1434	148.4000	69	11.5170	1.8408	0.0475
1990	1206.8970	758	104.1350	69	12.7467	1.8266	0.0573
1991	580.3220	731	65.9950	71	8.7585	1.2455	0.0586
1992	494.4410	693	135.1060	49	11.2867	1.7432	0.0593
1993	353.4100	1536	94.3200	58	8.9703	1.3594	0.0479
1994	232.1790	1832	63.8120	55	6.3021	0.9324	0.0460
1995	181.7460	1685	49.9770	54	5.5810	0.8482	0.0468
1996	382.1960	1947	55.7080	61	4.1794	0.6444	0.0460
1997	571.9758	1786	66.0200	58	4.3644	0.6764	0.0484
1998	404.8147	1246	45.6350	50	4.3330	0.6397	0.0509
1999	448.6767	1344	30.3190	53	2.9242	0.4678	0.0503
2000	336.4642	1716	32.3100	57	2.7970	0.4235	0.0481
2001	331.4862	1621	32.0190	51	2.0726	0.3477	0.0492
2002	195.8983	1617	19.0340	50	1.5969	0.2678	0.0494
2003	267.9710	1583	20.0334	48	1.7225	0.2942	0.0497
2004	568.8517	1771	38.5647	54	2.6317	0.4183	0.0490
2005	511.7585	1745	40.9667	48	2.8254	0.4471	0.0486
2006	544.8936	1325	32.1506	43	2.9593	0.4750	0.0518
2007	580.6498	788	28.1400	22	4.2429	0.6421	0.0590
2008	257.6855	840	35.4670	26	5.7070	0.8606	0.0582
2009	194.8654	514	27.2266	27	6.6449	0.8843	0.0683
2010	220.6510	704	22.8883	23	4.1931	0.6368	0.0614
2011	147.7397	800	22.8895	22	3.8396	0.5783	0.0603
2012	168.5996	709	21.9958	23	3.5107	0.5364	0.0623
2013	103.7326	585	23.0830	23	4.5833	0.6254	0.0666

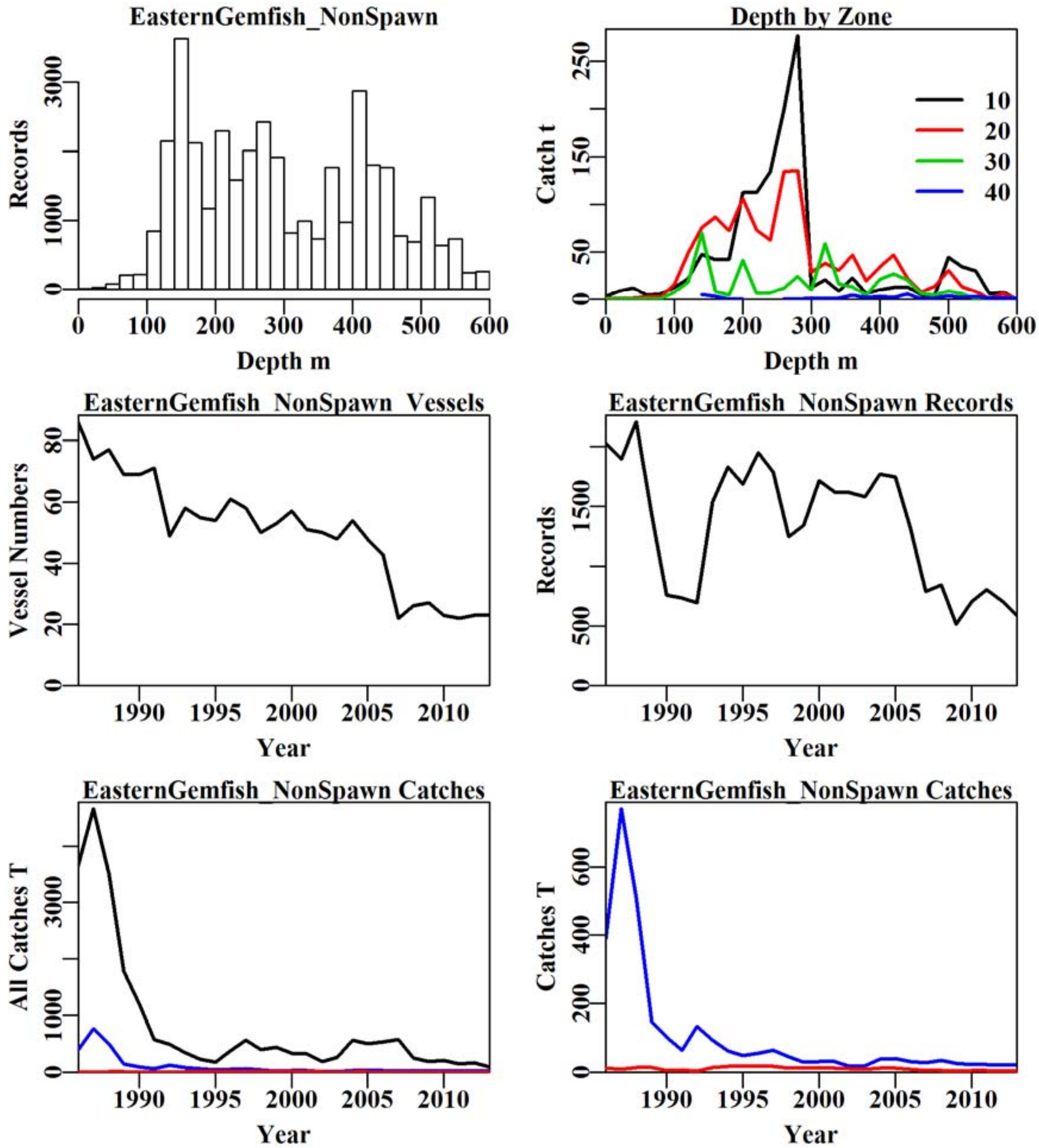


Figure 13.10. Non-spawning Eastern Gemfish from the SET in depths between 0 – 600 m, taken by Trawl. The top left plot depicts the depth distribution of shots containing non-spawning Eastern Gemfish from zones 10 to 40 in depths 0 – 600 m by Trawl. The top right plot depicts the distribution of catch by depth within zones 10 to 40. The middle left plot depicts the number of vessels through time. The middle right plot contains the number of records used in analysis. The bottom left plot contains non-spawning Eastern Gemfish catches (top black line: total catches, middle blue line: catches used in the analysis; bottom red line: catches < 30 kg) and bottom right plot contains non-spawning Eastern Gemfish catches (blue line: catches used in the analysis; red line: catches < 30 kg).

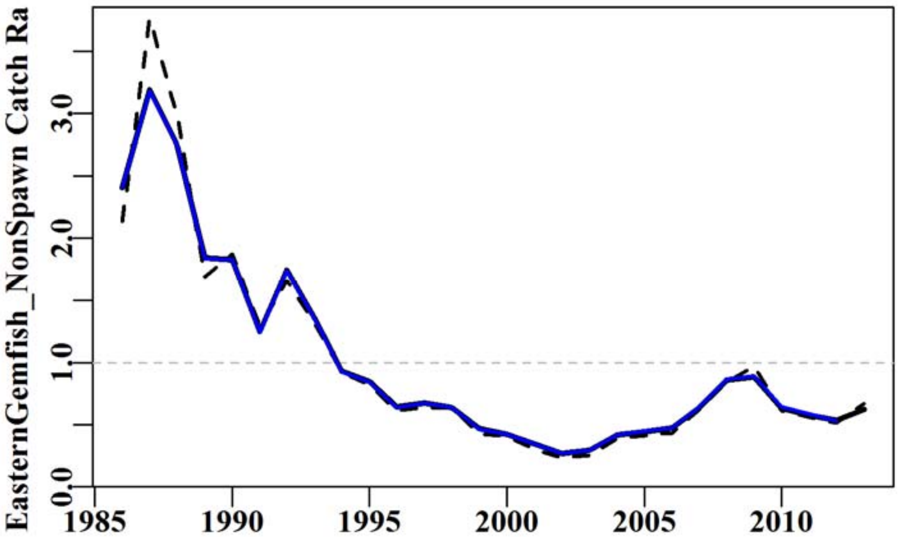


Figure 13.11. Non-spawning Eastern Gemfish from the SET in depths between 0 – 600 m, taken by Trawl. The dashed black line represents the geometric mean catch rate and the solid black line the standardized catch rates (relative to the mean of the standardized catch rates). The blue line is last year's optimum standardization.

Table 13.10. Non-spawning Eastern Gemfish from the SET in depths between 0 – 600 m, taken by Trawl. Statistical model structures used in this analysis. DepCat is a series of 20 metre depth categories.

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

Table 13.11. Non-spawning Eastern Gemfish from the SET in depths between 0 – 600 m, taken by Trawl. Model selection criteria include the Akaike Information Criterion (AIC), residual sum of squares (RSS), model sum of squares (MSS), number of usable observations (Nobs), number of parameters (Npars), adjusted R^2 (adj_R^2) and the change in adjusted R^2 (%Change). The optimum model is Model 8 (Zone:DepCat). Depth category: DepC.

	Year	Vessel	DepC	Month	Zone	DayNight	Zone:Month	Zone:DepC
AIC	23726	18543	16393	15936	15640	15370	15093	14944
RSS	70452	60743	56983	56253	55796	55384	54874	54487
MSS	22755	32464	36224	36954	37411	37824	38333	38720
Nobs	37437	37437	37121	37121	37121	37121	37121	37121
Npars	28	212	242	253	256	259	292	349
adj_R^2	24.359	34.461	38.464	39.235	39.723	40.164	40.662	40.989
%Change	0.000	10.102	4.003	0.771	0.488	0.441	0.498	0.327

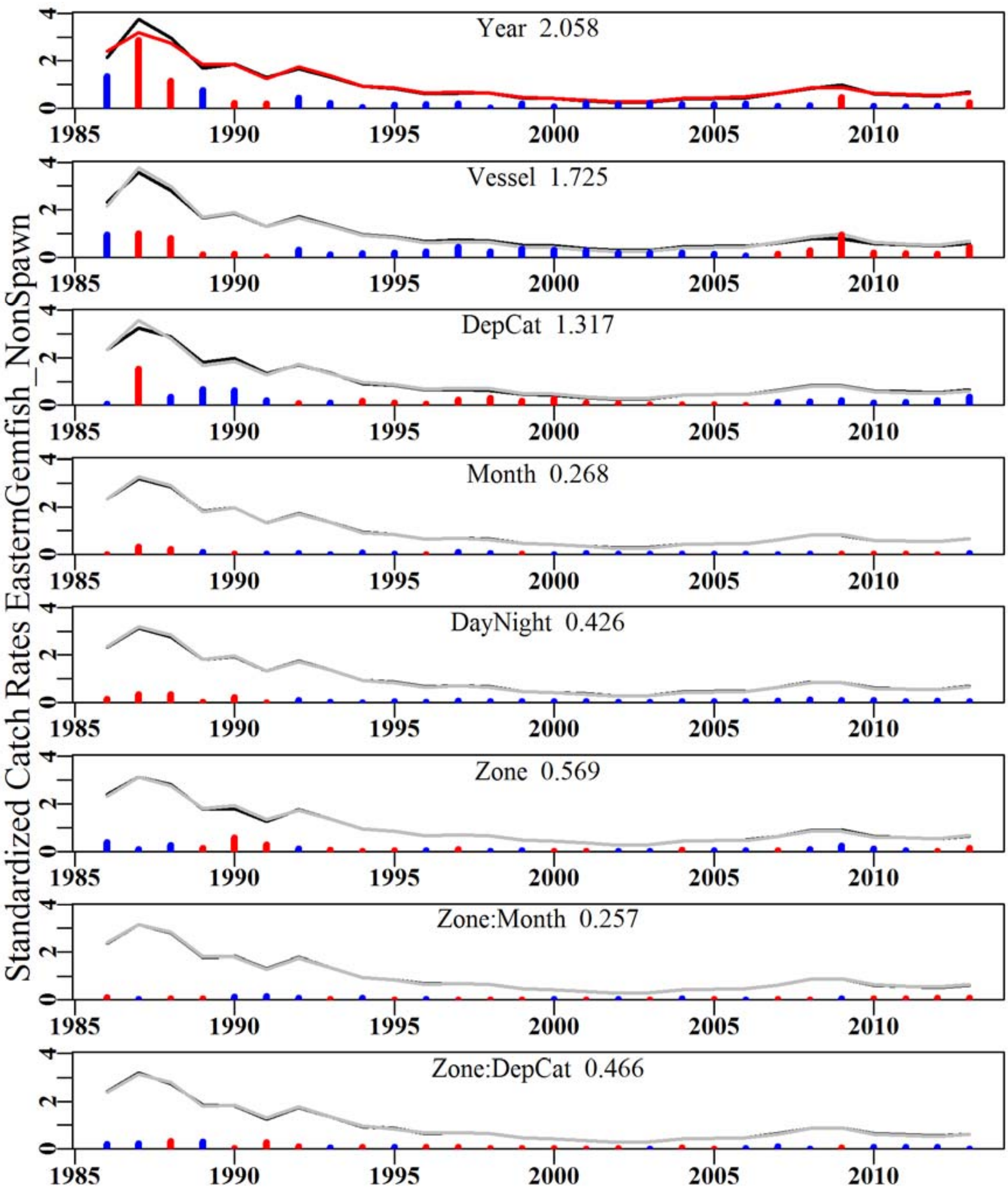


Figure 13.12. The relative influence of each factor used on the final trend in the optimal standardization for Non-spawning Eastern Gemfish. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by the vertical bars with blue bars indicating the optimum model is higher than the geometric mean and red bars indicating it is lower. The top graph bars are the sum of all the bars in the graphs below. The graphs for individual factors are cumulative. Thus the second graph has the geometric mean (grey line) and the effect of adding Year + factor2 (Model 2). In the third graph, the grey line represents Model 2 and the black line the effect of adding factor3 to the model. The remaining graphs continue in the same cumulative manner except for the interaction terms which are added singularly to the final single factor model.

13.9 Jackass Morwong Z10–50 (MOR – 37377003 Nemadactylus macropterus)

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

Table 13.12. Jackass Morwong from zones 10 to 50 in depths 70 – 360 m by Trawl. Total catch (TotCatch; t) is the total reported in the database, number of records used in the analysis (Records), reported catch (CatchT; t) in the area and depth used in the analysis and number of vessels used in the analysis (Vessels). GeoMean is the geometric mean of catch rates (kg/hr). The optimum model is Zone:Month and standard deviation (StDev) relates to the data in the optimum model.

Year	TotCatch	Records	CatchT	Vessels	GeoMean	Zone:Month	StDev
1986	982.8110	5772	873.2110	106	22.5592	1.9045	0.0000
1987	1087.6900	4948	1000.0540	104	26.1917	2.1567	0.0266
1988	1483.5120	5984	1314.3970	102	29.1554	2.1309	0.0260
1989	1667.3730	5434	1500.6040	89	33.9001	2.0679	0.0267
1990	1001.4140	5022	837.3570	86	24.2137	1.7125	0.0277
1991	1138.0700	5233	899.6850	85	21.1181	1.5195	0.0275
1992	758.2540	3483	523.7790	63	19.1937	1.2627	0.0308
1993	1014.9853	4732	821.8810	73	21.3530	1.2823	0.0288
1994	818.4180	5660	684.8000	71	18.0744	1.0959	0.0275
1995	789.5280	5852	705.4090	63	16.3623	1.0270	0.0272
1996	827.1910	7535	749.5740	70	13.8607	0.9411	0.0262
1997	1063.3630	7561	934.0010	70	16.1581	1.0069	0.0266
1998	876.4044	5941	688.7050	65	13.4363	0.8669	0.0276
1999	961.2618	5801	779.7030	66	14.1587	0.8936	0.0278
2000	945.0978	6902	732.1880	78	10.1983	0.7538	0.0270
2001	790.1902	6786	644.1780	71	8.3295	0.5718	0.0273
2002	811.1362	7761	691.2820	65	8.3275	0.6014	0.0268
2003	774.5778	6537	600.9390	64	7.9043	0.5207	0.0275
2004	765.5049	6483	604.4761	70	8.6153	0.5200	0.0277
2005	784.1607	6376	597.4155	58	8.9785	0.5598	0.0278
2006	811.2979	5446	616.1015	49	11.5427	0.6433	0.0287
2007	607.8702	3812	443.3657	30	12.2504	0.6531	0.0311
2008	700.4393	4491	546.6400	33	13.7889	0.7642	0.0301
2009	454.3668	3384	344.4442	27	11.4694	0.6748	0.0320
2010	380.0247	3432	291.8870	30	8.5531	0.4983	0.0321
2011	427.9796	3524	303.3383	28	8.5407	0.4739	0.0320
2012	395.5908	3145	305.2530	29	8.9426	0.4778	0.0328
2013	323.9160	2517	238.5890	26	8.7151	0.4186	0.0347

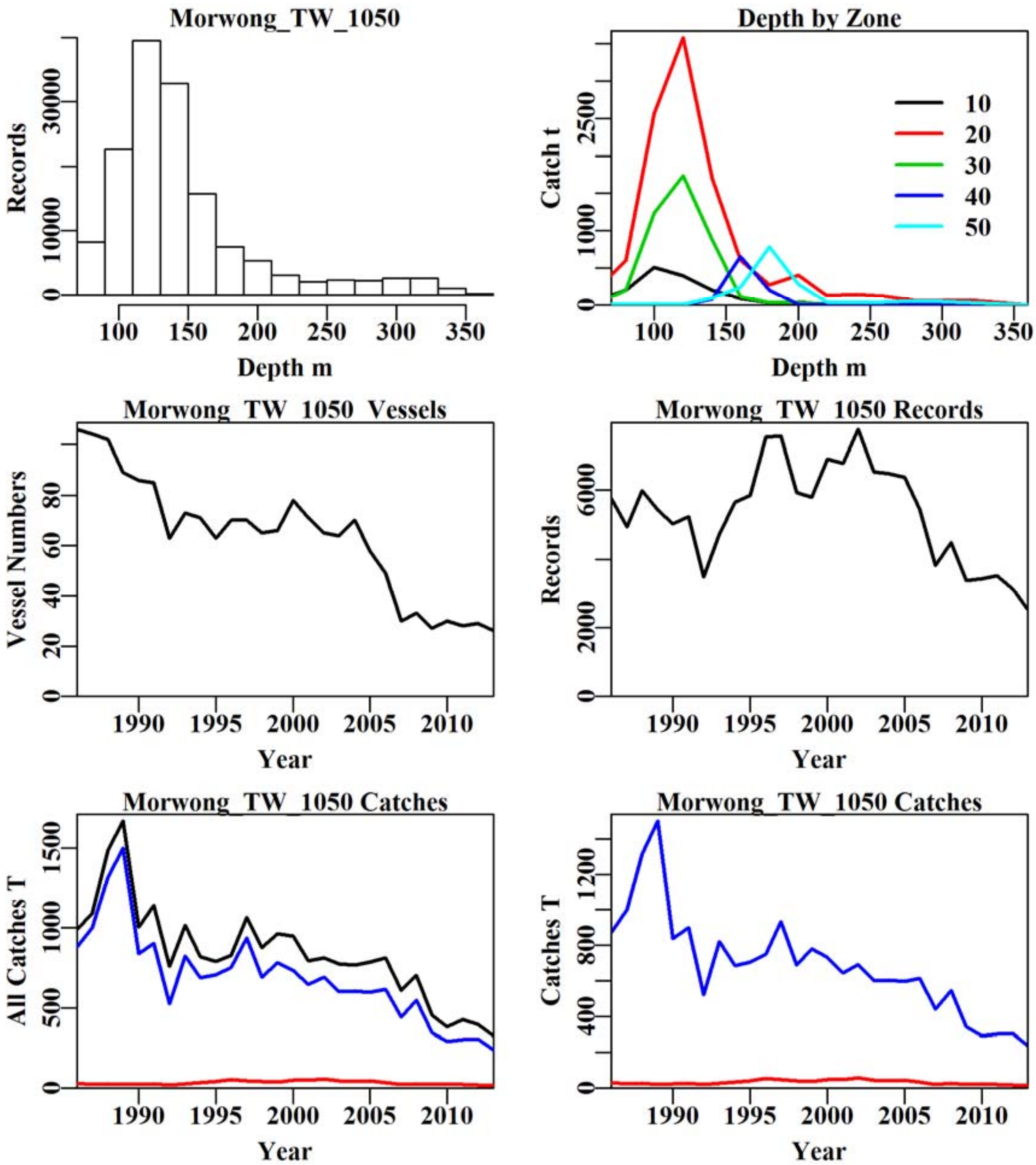


Figure 13.13. Jackass Morwong from zones 10 to 50 in depths 70 – 360 m by Trawl. The top left plot depicts the depth distribution of shots containing Jackass Morwong from zones 10 to 50 in depths 70 – 360 m by Trawl. The top right plot depicts the distribution of catch by depth within zones 10 to 50. The middle left plot depicts the number of vessels through time. The middle right plot contains the number of records used in analysis. The bottom left plot contains Jackass Morwong catches (top black line: total catches, middle blue line: catches used in the analysis; bottom red line: catches < 30 kg) and bottom right plot contains Jackass Morwong catches (blue line: catches used in the analysis; red line: catches < 30 kg).

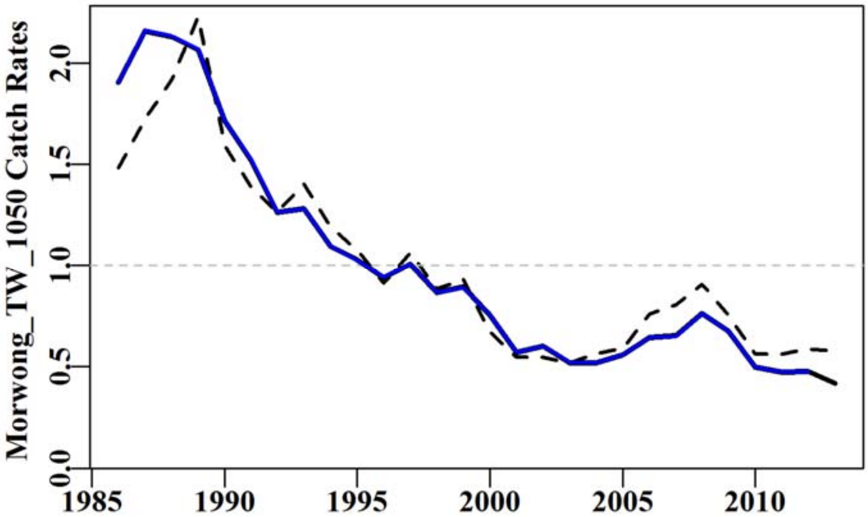


Figure 13.14. Jackass Morwong from zones 10 to 50 in depths 70 – 360 m by Trawl. The dashed black line represents the geometric mean catch rate and the solid black line the standardized catch rates. The graph standardizes catch rates relative to the mean of the standardized catch rates. The blue line is last year's optimum standardization.

Table 13.13. Jackass Morwong from zones 10 to 50 in depths 70 – 360 m by Trawl. Statistical model structures used in this analysis. DepCat is a series of 20 metre depth categories.

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

Table 13.14. Jackass Morwong from zones 10 to 50 in depths 70 – 360 m by Trawl. Model selection criteria include the Akaike Information Criterion (AIC), residual sum of squares (RSS), model sum of squares (MSS), number of usable observations (Nobs), number of parameters (Npars), adjusted R^2 (adj_R^2) and the change in adjusted R^2 (%Change). The optimum model was Model 7 (Zone:Month). Depth category: DepC.

	Year	Vessel	Month	DepC	Zone	DayNight	Zone:Month	Zone:DepC
AIC	115088	93173	86512	82153	77120	75755	73681	74279
RSS	322732	277938	265792	257031	248433	246145	242580	243508
MSS	27807	72600	84746	93507	102105	104393	107958	107030
Nobs	149554	149554	149554	148179	148179	148179	148179	148179
Npars	28	244	255	270	274	277	321	337
adj_R^2	8	21	24	27	29	30	31	30
%Change	0.000	12.666	3.465	2.495	2.455	0.653	0.998	-0.273

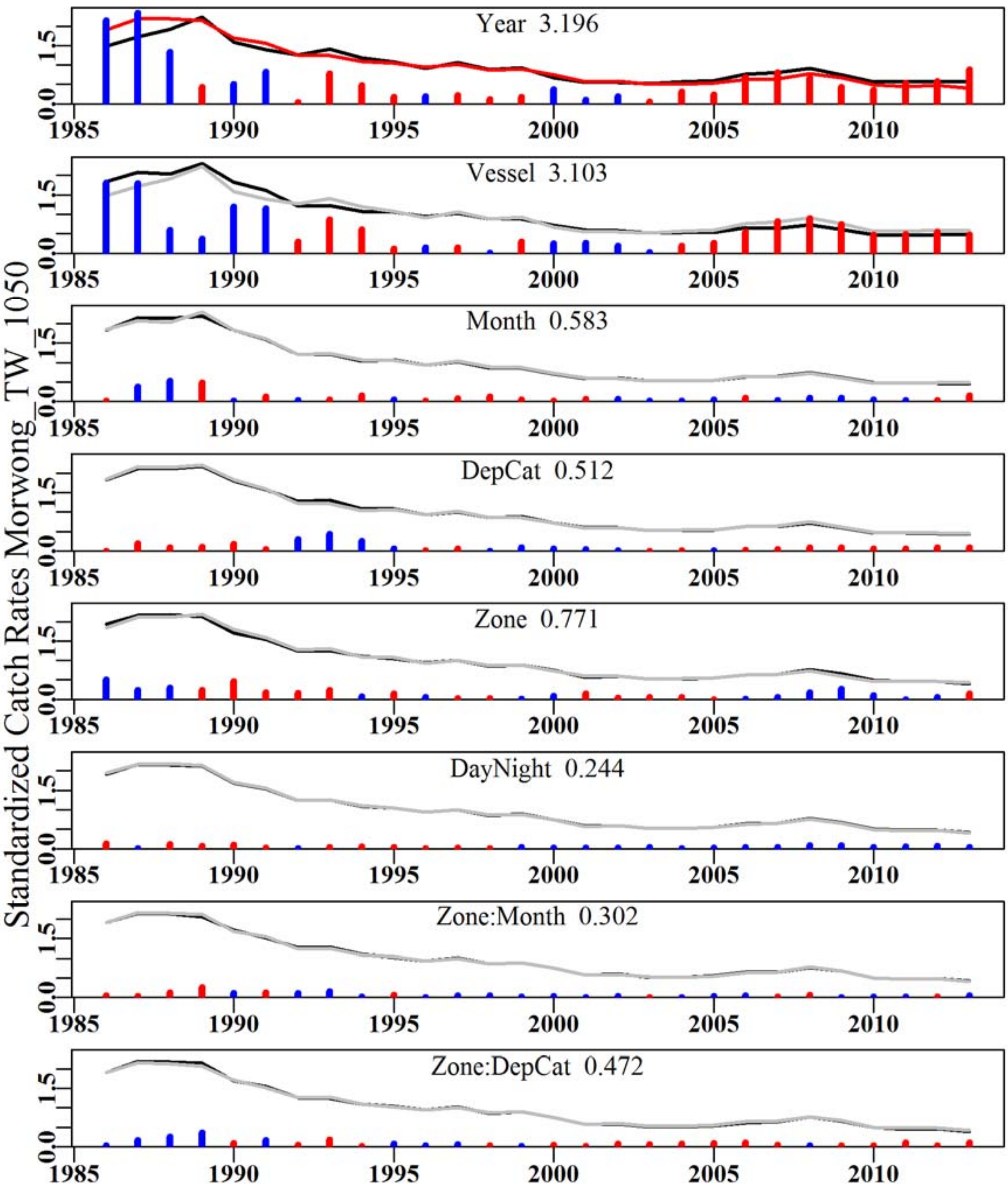


Figure 13.15. The relative influence of each factor used on the final trend in the optimal standardization for Jackass Morwong in zones 10 – 50. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by the vertical bars with blue bars indicating the optimum model is higher than the geometric mean and red bars indicating it is lower. The top graph bars are the sum of all the bars in the graphs below. The graphs for individual factors are cumulative. Thus the second graph has the geometric mean (grey line) and the effect of adding Year + factor2 (Model 2). In the third graph, the grey line represents Model 2 and the black line the effect of adding factor3 to the model. The remaining graphs continue in the same cumulative manner except for the interaction terms which are added singularly to the final single factor model.

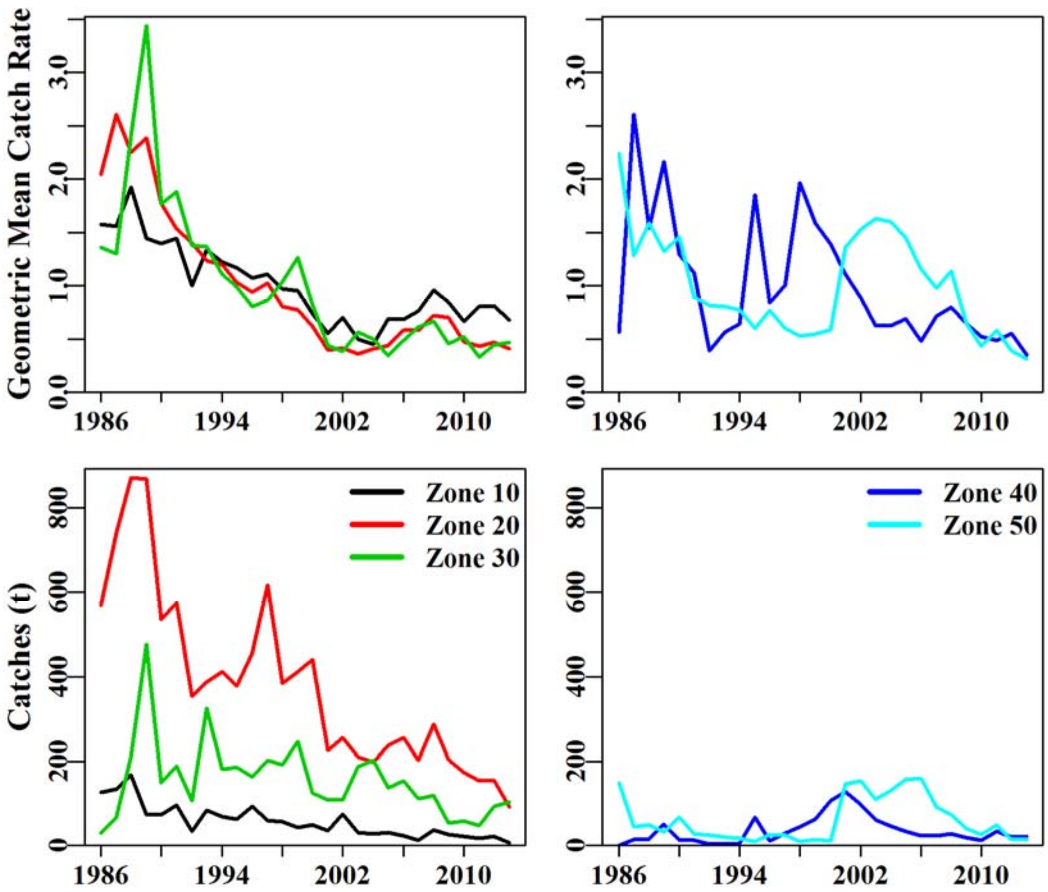


Figure 13.16. The trends in catch and geometric mean catch rates for Jackass Morwong taken by Trawl across SESSF zones 10 – 50. The catch rate trends across zones 10 – 30 are very similar, whilst those for zones 40 to 50 are noisy due to low catches until after 1996.

Table 13.15. The split of reported catches in tonnes by zone as taken by Trawl in the identified depths. GAB includes zones 82, 83, 84, and 85.

Year	**10**	**20**	**30**	**40**	**50**	**60**	**GAB**
1986	153.290	597.906	32.287	0.400	152.246	27.077	16.565
1987	142.674	770.594	80.446	13.775	46.426	19.748	12.960
1988	177.971	922.634	213.955	16.700	51.072	56.980	41.625
1989	80.174	896.639	505.097	50.770	34.226	39.482	51.348
1990	82.706	606.652	158.494	14.701	68.417	22.015	45.800
1991	107.642	690.990	225.715	14.382	33.105	22.191	32.935
1992	56.005	444.369	132.726	27.490	34.501	7.577	45.160
1993	104.483	431.220	344.380	4.474	21.107	20.498	46.599
1994	105.480	436.446	185.204	4.641	18.665	18.064	46.813
1995	77.205	388.259	187.464	67.835	10.855	3.854	52.929
1996	97.641	475.605	162.715	10.917	27.350	6.793	45.263
1997	62.813	652.029	205.295	29.995	27.213	13.946	66.733
1998	58.295	441.898	193.305	45.258	12.960	13.458	72.596
1999	44.685	445.380	249.027	64.502	16.404	8.962	102.751
2000	49.760	475.166	126.249	107.740	13.703	20.428	73.115
2001	37.154	273.619	112.989	137.773	149.603	17.561	52.075
2002	76.130	291.396	110.840	98.844	156.460	15.729	48.200
2003	32.855	239.895	196.687	62.151	114.646	12.053	98.563
2004	31.203	223.494	205.915	48.383	141.840	7.189	104.330
2005	37.108	288.939	151.947	36.915	162.915	8.309	96.863
2006	30.714	289.117	166.045	24.665	167.622	6.735	121.021
2007	14.548	230.969	118.917	25.839	96.708	5.620	109.069
2008	38.791	327.492	122.652	29.875	74.678	6.366	91.719
2009	27.420	230.783	55.928	20.819	45.113	3.843	64.330
2010	21.832	190.898	59.890	13.603	27.351	3.445	39.384
2011	17.680	184.606	51.254	35.147	51.226	11.685	30.838
2102	22.588	170.102	94.482	20.303	16.295	4.136	26.905
2013	7.630	103.057	105.968	21.596	16.065	4.128	25.447

13.10 Jackass Morwong Z1020 (MOR–37377003 – Nemadactylus macropterus)

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

Table 13.16. Jackass Morwong from zones 10 and 20 in depths 70 – 300 m by Trawl. Total catch (TotCatch; t) is the total reported in the database, number of records used in the analysis (Records), reported catch (CatchT; t) in the area and depth used in the analysis and number of vessels used in the analysis (Vessels). GeoMean is the geometric mean of catch rates (kg/hr). The optimum model is Zone:Month and standard deviation (StDev) relates to the data in the optimum model.

Year	TotCatch	Records	CatchT	Vessels	GeoMean	Zone:Month	StDev
1986	982.811	5045	686.225	87	21.2677	1.8675	0.0000
1987	1087.690	4266	858.475	79	26.2295	2.2635	0.0292
1988	1483.512	5147	1025.256	79	27.6740	2.1320	0.0285
1989	1667.373	4325	929.409	65	27.9306	2.0058	0.0295
1990	1001.414	4127	600.553	59	21.9897	1.6686	0.0304
1991	1138.070	4436	661.796	55	19.4037	1.5797	0.0302
1992	758.254	2842	378.592	46	17.3690	1.2513	0.0340
1993	1014.985	3363	464.955	49	17.0123	1.3174	0.0327
1994	818.418	4470	473.423	49	16.1919	1.1540	0.0306
1995	789.528	4600	435.209	47	14.0323	1.0737	0.0303
1996	827.191	6218	544.828	51	12.3880	0.9715	0.0289
1997	1063.363	6031	672.142	53	14.8970	1.0710	0.0296
1998	876.404	4790	435.779	46	11.3605	0.8670	0.0305
1999	961.262	4429	447.847	50	11.3334	0.8700	0.0312
2000	945.098	5719	479.565	55	8.7637	0.7279	0.0298
2001	790.190	4930	258.551	48	5.8826	0.5116	0.0307
2002	811.136	5702	328.002	44	6.3660	0.5665	0.0302
2003	774.578	4584	237.040	47	5.3333	0.4497	0.0312
2004	765.505	4196	220.279	52	5.4124	0.4446	0.0321
2005	784.161	4378	262.616	39	6.8948	0.5418	0.0317
2006	811.298	3417	275.501	36	8.8173	0.6515	0.0334
2007	607.870	2437	212.373	20	9.2385	0.6182	0.0368
2008	700.439	3167	321.578	25	11.2739	0.7899	0.0348
2009	454.367	2448	228.475	19	10.4038	0.7255	0.0370
2010	380.025	2589	193.621	19	7.6365	0.5068	0.0367
2011	427.980	2400	170.944	18	7.4002	0.4881	0.0377
2012	395.591	2166	175.128	19	7.6279	0.4842	0.0383
2013	323.916	1408	97.407	15	6.8990	0.4004	0.0434

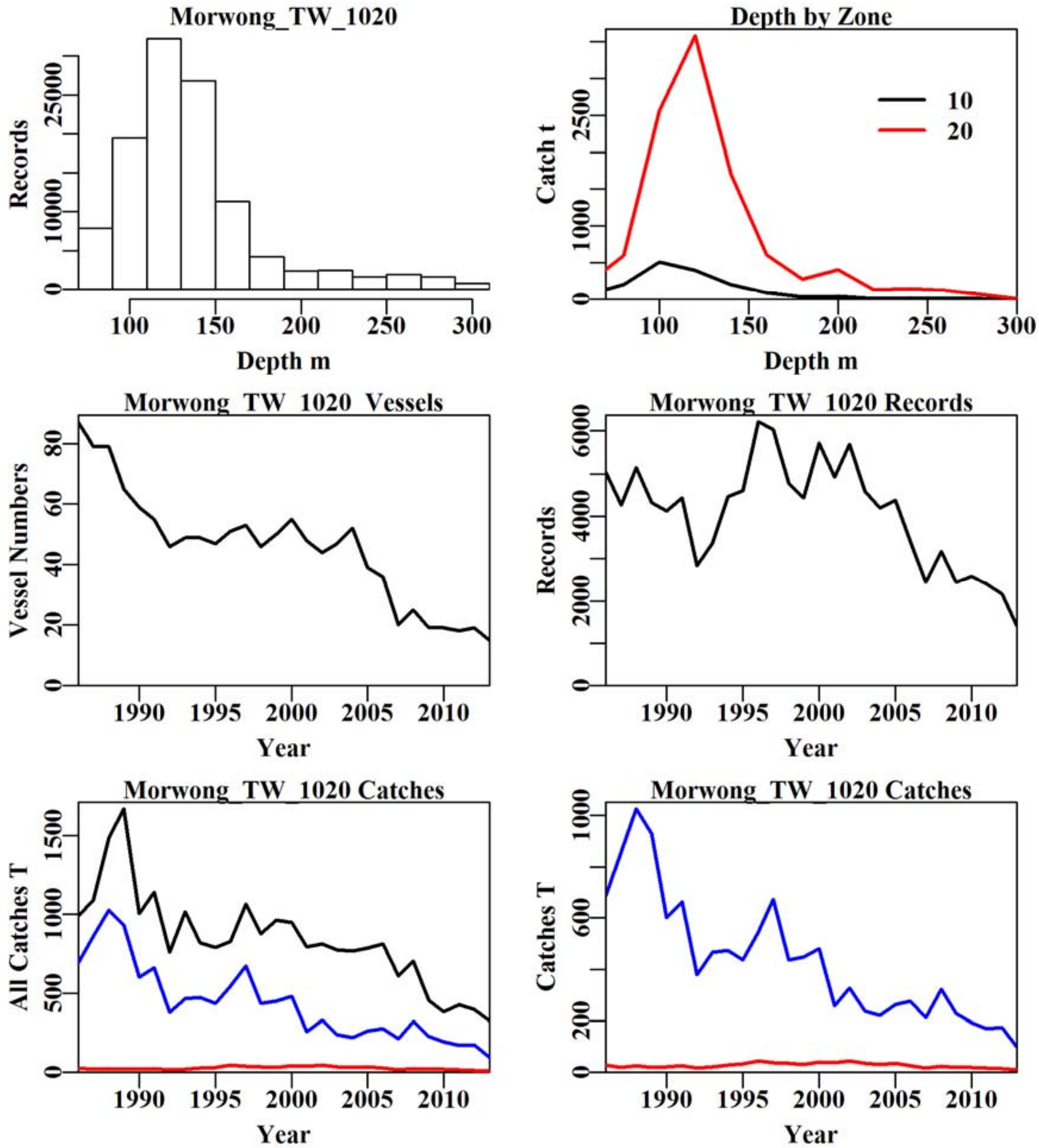


Figure 13.17. Jackass Morwong from zones 10 and 20 in depths 70 – 300 m by Trawl. The top left plot depicts the depth distribution of shots containing Jackass Morwong from zones 10 and 20 in depths 70 – 300 m by Trawl. The top right plot depicts the distribution of catch by depth within zones 10 and 20 (Zone 20 is the top red line). The middle left plot depicts the number of vessels through time. The middle right plot contains the number of records used in analysis. The bottom left plot contains Jackass Morwong catches (top black line: total catches, middle blue line: catches used in the analysis; bottom red line: catches < 30 kg) and bottom right plot contains Jackass Morwong catches (blue line: catches used in the analysis; red line: catches < 30 kg).

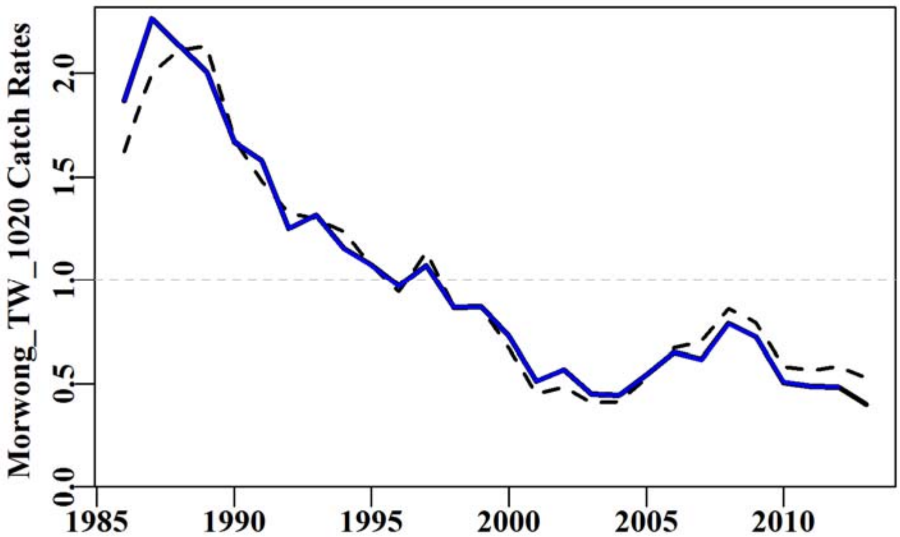


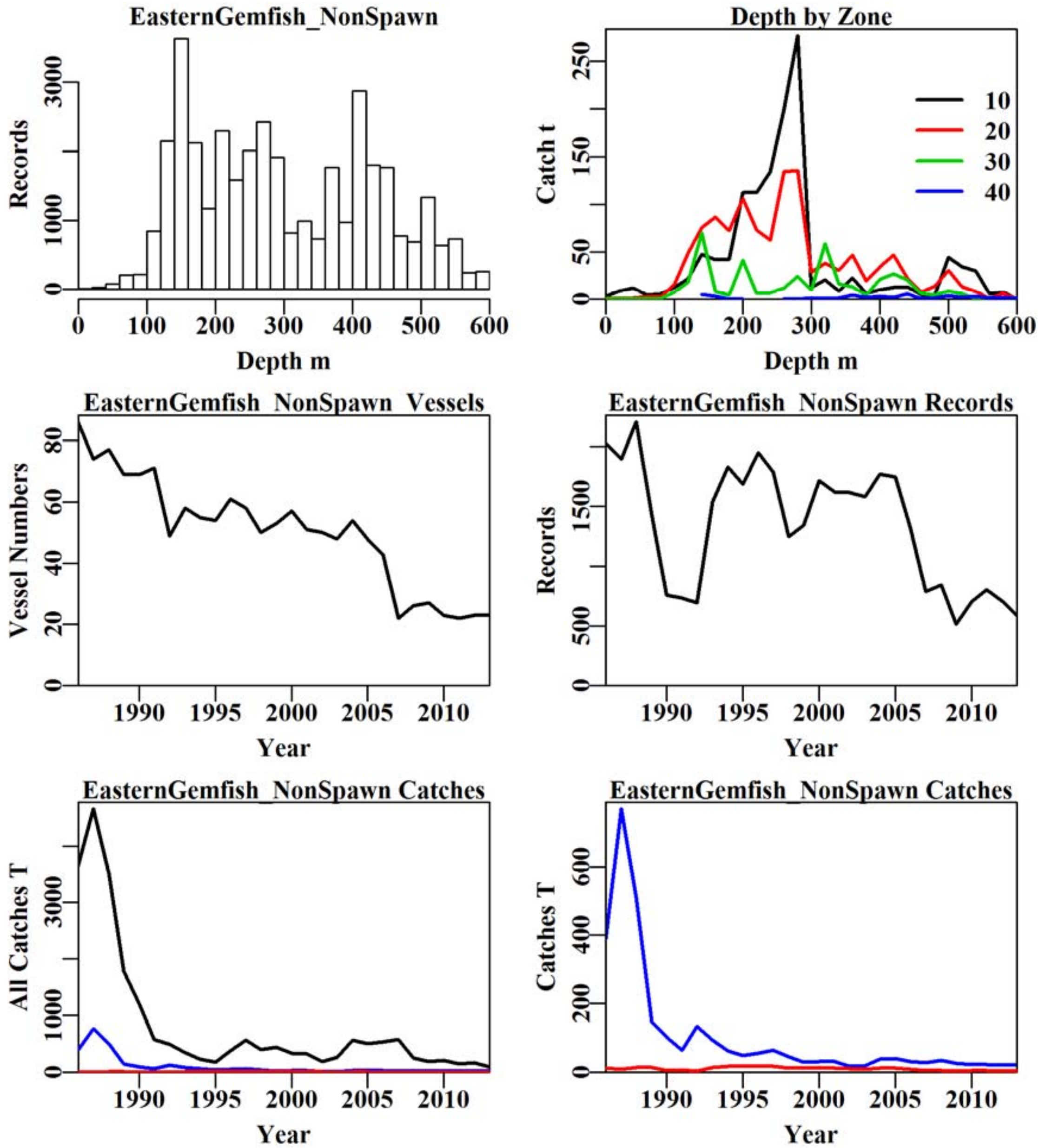
Figure 13.18. Jackass Morwong from zones 10 and 20 in depths 70 – 300 m by Trawl. The dashed black line represents the geometric mean catch rate and the solid black line the standardized catch rates. The graph standardizes catch rates relative to the mean of the standardized catch rates. The blue line is last year's optimum standardization.

Table 13.17. Jackass Morwong from zones 10 and 20 in depths 70 – 300 m by Trawl. Statistical model structures used in this analysis. DepCat is a series of 20 metre depth categories.

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

Table 13.18. Jackass Morwong from zones 10 and 20 in depths 70 – 300 m by Trawl. Model selection criteria include the Akaike Information Criterion (AIC), residual sum of squares (RSS), model sum of squares (MSS), number of usable observations (Nobs), number of parameters (Npars), adjusted R^2 (adj_R^2) and the change in adjusted R^2 (%Change). The optimum model was Model 7 (Zone:Month). Depth category: DepC.

	Year	Vessel	Month	DepC	Zone	DayNight	Zone:Month	Zone:DepC
AIC	81708	67427	64548	62338	60425	59145	58280	58823
RSS	233113	204957	199791	195092	191803	189625	188137	189043
MSS	30005	58162	63328	68027	71316	73494	74982	74076
Nobs	113630	113630	113630	112597	112597	112597	112597	112597
Npars	28	201	212	224	225	228	239	240
adj_R^2	11.383	21.967	23.927	25.707	26.959	27.786	28.346	28.000
%Change	0.000	10.585	1.960	1.780	1.252	0.827	0.560	-0.346


EasternGemfish_NonSpawn
Records
Depth m
Depth by Zone
Catch t
10
20
30
40
Depth m
EasternGemfish_NonSpawn_Vessels
Vessel Numbers
Year
EasternGemfish_NonSpawn Records
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Year
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Year

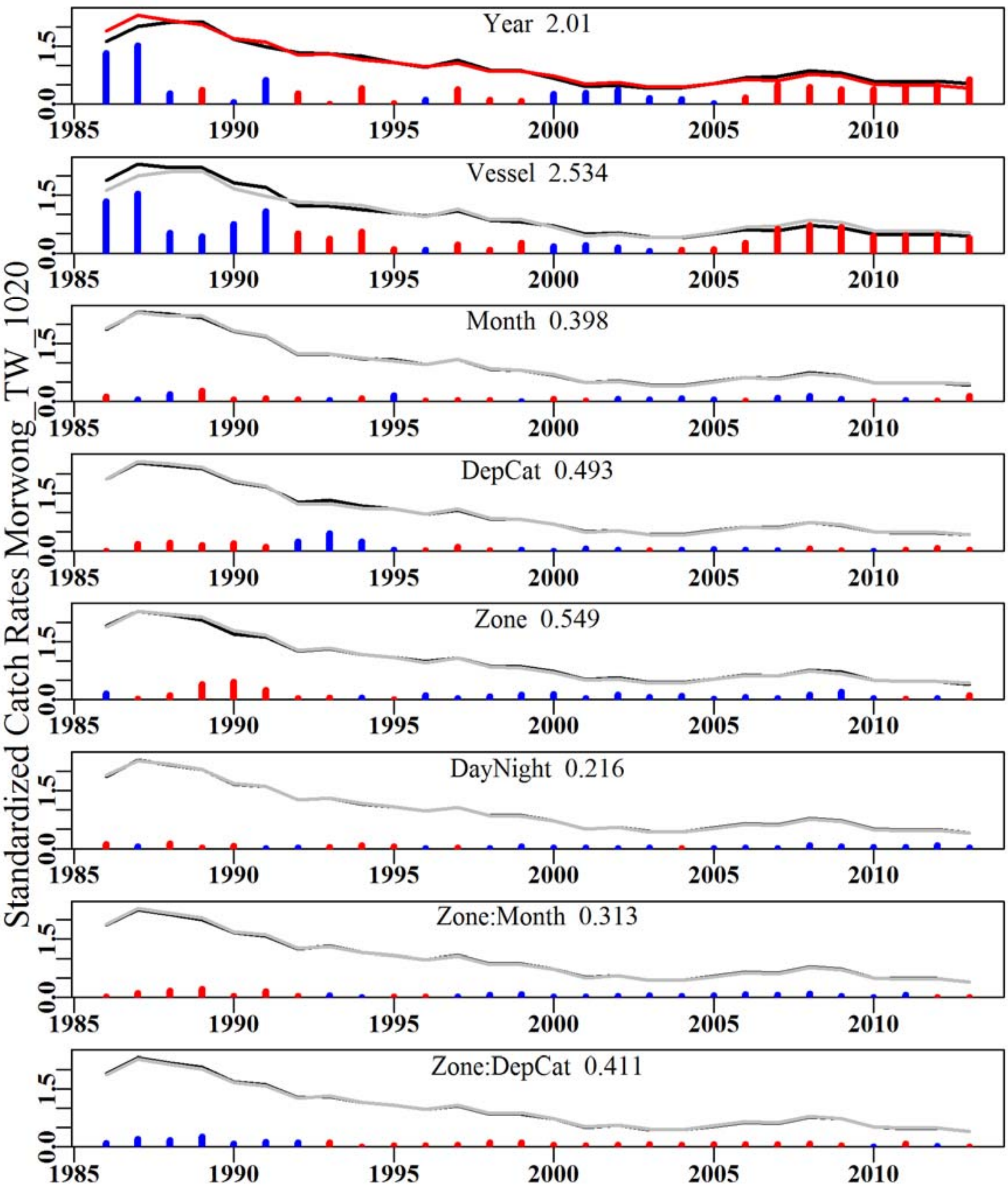


Figure 13.19. The relative influence of each factor used on the final trend in the optimal standardization for Jackass Morwong in Zones 10 – 20. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by the vertical bars with blue bars indicating the optimum model is higher than the geometric mean and red bars indicating it is lower. The top graph bars are the sum of all the bars in the graphs below. The graphs for individual factors are cumulative. Thus the second graph has the geometric mean (grey line) and the effect of adding Year + factor2 (Model 2). In the third graph, the grey line represents Model 2 and the black line the effect of adding factor3 to the model. The remaining graphs continue in the same cumulative manner except for the interaction terms which are added singularly to the final single factor model.

13.11 Jackass Morwong Z30 (MOR – 37377003 – Nemadactylus macropterus)

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

Table 13.19. Jackass Morwong from zone 30 in depths 70 – 300 m by Trawl. Total catch (TotCatch; t) is the total reported in the database, number of records used in the analysis (Records), reported catch (CatchT; t) in the area and depth used in the analysis and number of vessels used in the analysis (Vessels). GeoMean is the geometric mean of catch rates (kg/hr). The optimum model is Month:DepC and standard deviation (StDev) relates to the data in the optimum model.

Year	TotCatch	Records	CatchT	Vessels	GeoMean	Month:DepC	StDev
1986	982.8110	69	29.8870	6	52.3193	1.8192	0.0000
1987	1087.6900	210	57.4760	13	45.8807	1.8646	0.1789
1988	1483.5120	283	207.9350	13	90.9064	2.6007	0.1735
1989	1667.3730	687	475.0390	19	125.0173	3.2863	0.1667
1990	1001.4140	386	148.8570	26	64.6762	2.2680	0.1674
1991	1138.0700	427	189.5340	29	68.3860	1.4603	0.1657
1992	758.2540	335	106.8190	18	50.3448	1.5666	0.1705
1993	1014.9853	1042	325.8730	27	49.6567	1.2392	0.1604
1994	818.4180	762	180.1850	22	40.3412	0.8554	0.1615
1995	789.5280	826	185.2820	19	36.4017	0.8319	0.1624
1996	827.1910	890	161.4020	19	29.4500	0.8168	0.1615
1997	1063.3630	940	202.3890	15	32.4284	0.9241	0.1609
1998	876.4044	772	191.7330	15	38.4649	0.8972	0.1616
1999	961.2618	855	246.9130	17	46.7614	1.0644	0.1619
2000	945.0978	552	123.7850	23	30.7755	0.7140	0.1638
2001	790.1902	796	108.0970	19	16.1559	0.4761	0.1609
2002	811.1362	1044	108.9440	15	13.9509	0.4216	0.1604
2003	774.5778	1126	187.0530	19	20.4814	0.5830	0.1595
2004	765.5049	1500	201.2780	15	18.1516	0.4442	0.1588
2005	784.1607	1159	137.7100	17	12.3142	0.3215	0.1600
2006	811.2979	1127	154.4820	14	17.6164	0.4027	0.1606
2007	607.8702	714	111.6250	8	22.5650	0.5669	0.1629
2008	700.4393	768	119.0200	9	24.1797	0.5884	0.1628
2009	454.3668	463	54.3427	10	16.5669	0.4265	0.1663
2010	380.0247	372	58.1890	9	19.1085	0.4393	0.1691
2011	427.9796	451	48.2553	8	12.0083	0.2959	0.1669
2012	395.5908	561	92.4940	7	16.4181	0.3910	0.1653
2013	323.9160	599	103.4190	10	17.1228	0.4342	0.1641

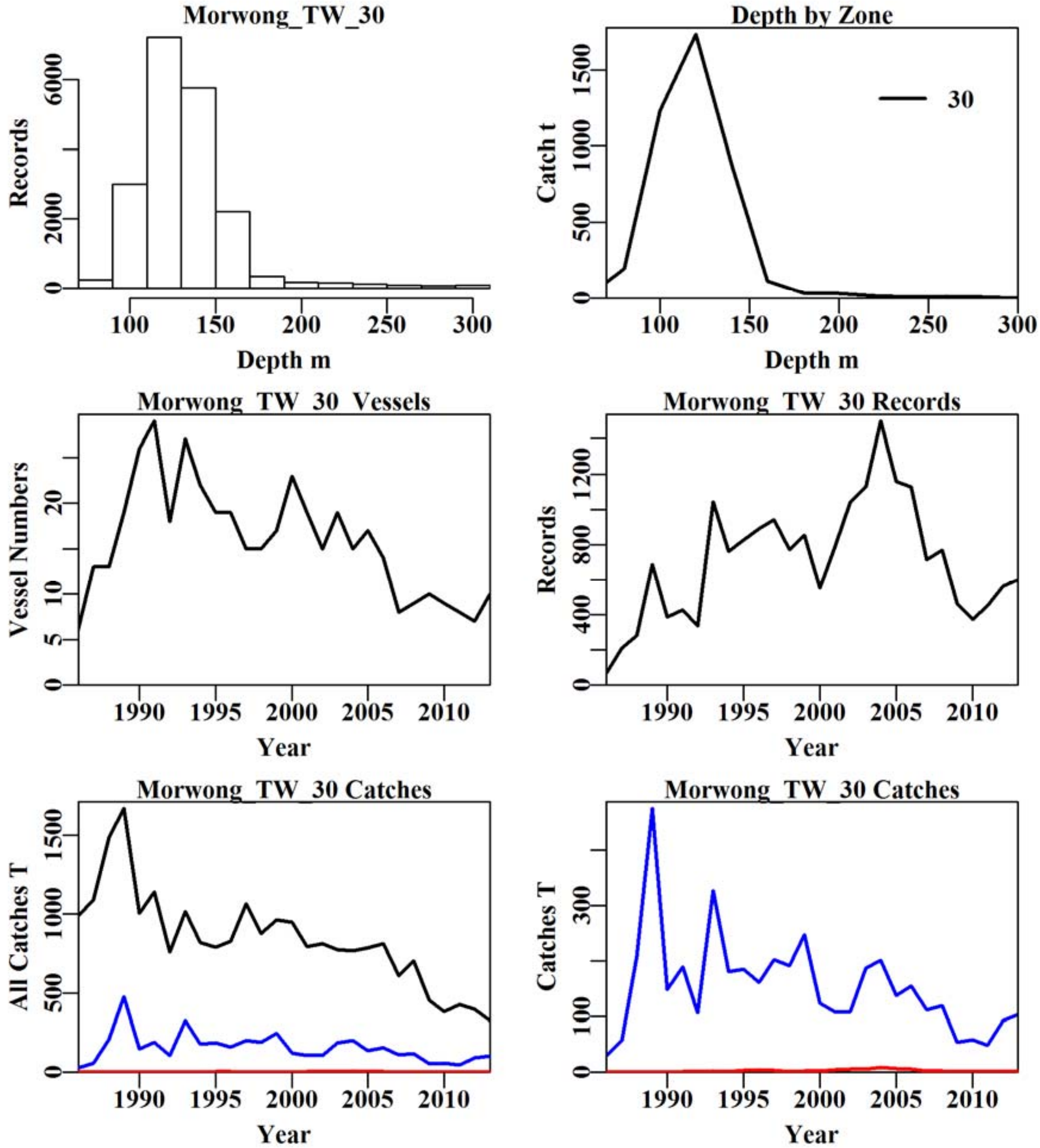


Figure 13.20. Jackass Morwong from zone 30 in depths 70 – 300 m by Trawl. The top left plot depicts the depth distribution of shots containing Jackass Morwong from zone 30 in depths 70 – 300 m by Trawl. The top right plot depicts the catch distribution by depth within zone 30. The middle left plot depicts the number of vessels through time and middle right plot contains the number of records used in analysis. The bottom left plot contains Jackass Morwong catches (top black line: total catches, middle blue line: catches used in the analysis; bottom red line: catches < 30 kg) and bottom right plot contains Jackass Morwong catches (blue line: catches used in the analysis; red line: catches < 30 kg).

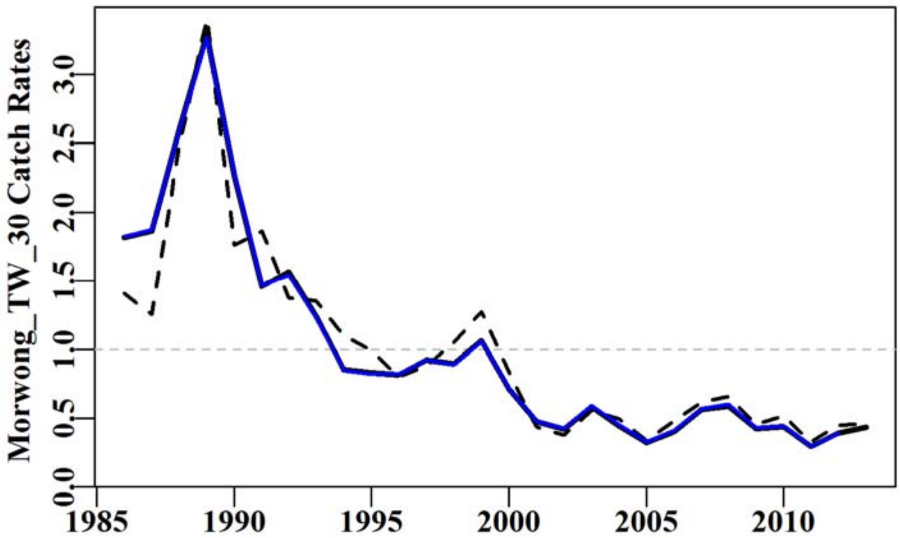


Figure 13.21. Jackass Morwong from zone 30 in depths 70 – 300 m by Trawl. The dashed black line represents the geometric mean catch rate and the solid black line the standardized catch rates (relative to the mean of the standardized catch rates). The blue line is last year's optimum standardization.

Table 13.20. Jackass Morwong from zone 30 in depths 70 – 300 m by Trawl. Statistical model structures used in this analysis. DepCat is a series of 20 metre depth categories.

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

Table 13.21. Jackass Morwong from zone 30 in depths 70 – 300 m by Trawl. Model selection criteria include the Akaike Information Criterion (AIC), residual sum of squares (RSS), model sum of squares (MSS), number of usable observations (Nobs), number of parameters (Npars), adjusted R^2 (adj_R^2) and the change in adjusted R^2 (%Change). The optimum was model was Model 7 (Month:DepC). Depth category: DepC; DayNight: DN.

	Year	Month	Vessel	DepC	DN	DN:Month	Month:DepC	DN:DepC
AIC	10183	8363	7231	6583	6422	6373	6334	6474
RSS	32952	30013	28076	26907	26677	26520	26199	26650
MSS	6552	9491	11429	12597	12827	12984	13305	12854
Nobs	19716	19716	19716	19473	19473	19473	19473	19473
Npars	28	39	131	143	146	179	278	182
adj_R^2	16.471	23.879	28.459	31.387	31.963	32.248	32.723	31.906
%Change	0.000	7.407	4.580	2.928	0.576	0.286	0.475	-0.818

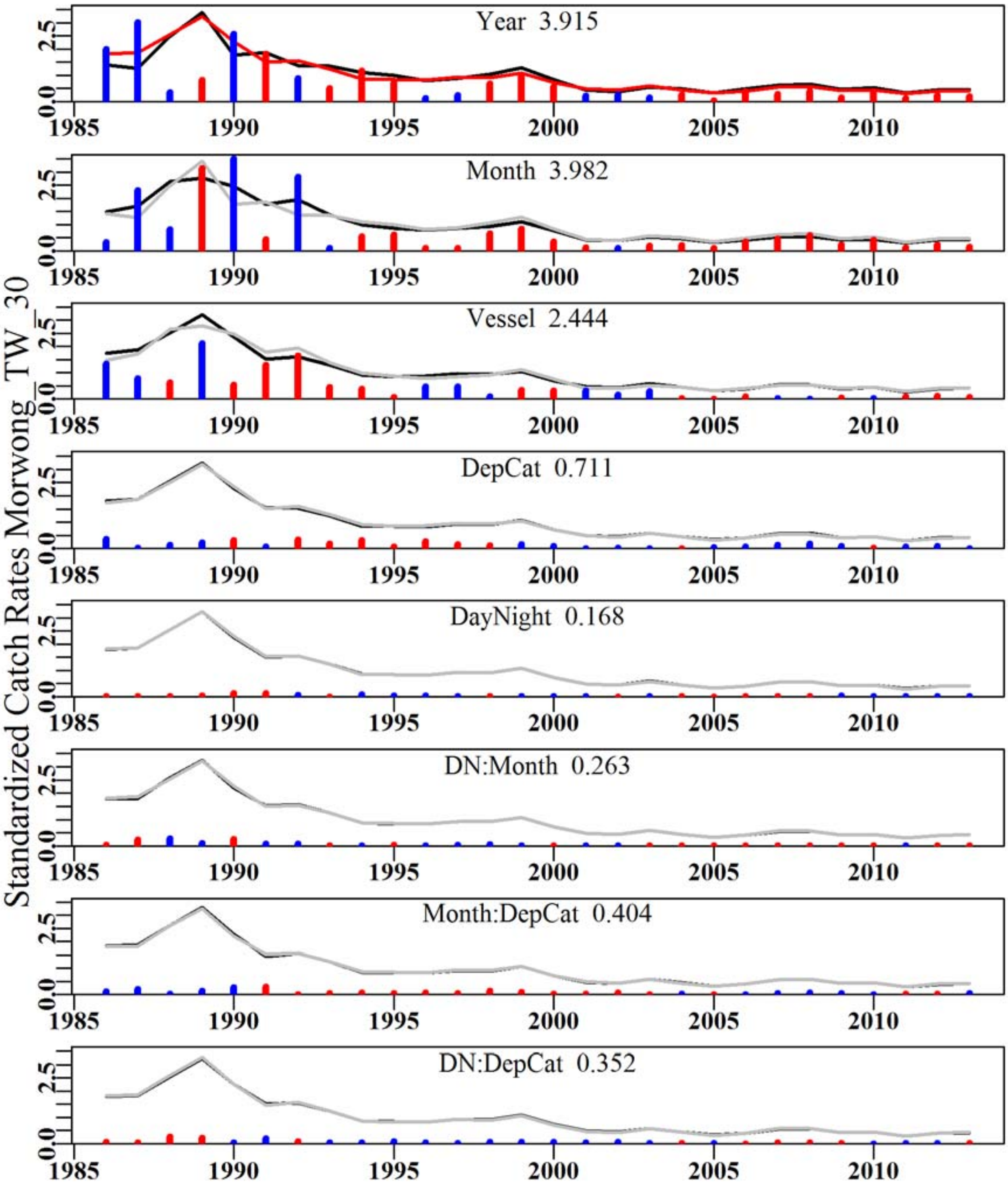


Figure 13.22. The relative influence of each factor used on the final trend in the optimal standardization for Jackass Morwong in zone 30. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by the vertical bars with blue bars indicating the optimum model is higher than the geometric mean and red bars indicating it is lower. The top graph bars are the sum of all the bars in the graphs below. The graphs for individual factors are cumulative. Thus the second graph has the geometric mean (grey line) and the effect of adding Year + factor2 (Model 2). In the third graph, the grey line represents Model 2 and the black line the effect of adding factor3 to the model. The remaining graphs continue in the same cumulative manner except for the interaction terms which are added singularly to the final single factor model.

13.12 Jackass Morwong Z4050 (MOR – 3737700 – N. macropterus 70–360 m)

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

Table 13.22. Jackass Morwong from zones 40 and 50 in depths 70 – 360 m by Trawl. Total catch (TotCatch; t) is the total reported in the database, number of records used in the analysis (Records), reported catch (CatchT; t) in the area and depth used in the analysis and number of vessels used in the analysis (Vessels). GeoMean is the geometric mean of catch rates (kg/hr). The optimum model is Zone:Month and standard deviation (StDev) relates to the data in the optimum model.

Year	TotCatch	Records	CatchT	Vessels	GeoMean	Zone:Month	StDev
1986	982.8110	551	149.2610	19	40.7569	1.9325	0.0000
1987	1087.6900	350	58.4640	21	24.4475	1.5117	0.0870
1988	1483.5120	402	65.4440	19	32.2567	2.2612	0.0872
1989	1667.3730	346	83.2030	21	32.2213	1.6300	0.0921
1990	1001.4140	412	80.6570	22	28.9610	1.6434	0.0934
1991	1138.0700	281	40.3800	26	18.6097	1.1243	0.0976
1992	758.2540	252	28.8780	14	15.3915	0.9125	0.1005
1993	1014.9853	248	24.9710	17	15.5454	0.8850	0.1017
1994	818.4180	312	22.6790	16	14.6606	0.8583	0.0949
1995	789.5280	295	77.6150	17	21.5262	0.8995	0.0959
1996	827.1910	346	37.0710	17	15.3414	0.9866	0.0932
1997	1063.3630	489	53.8510	20	12.8372	0.7825	0.0866
1998	876.4044	267	54.6300	19	14.8359	0.8256	0.0986
1999	961.2618	383	77.2350	17	15.5951	0.7515	0.0913
2000	945.0978	429	118.8680	26	22.5254	1.0668	0.0915
2001	790.1902	914	273.9530	25	34.2135	1.1495	0.0806
2002	811.1362	860	251.7490	22	33.1596	1.1406	0.0809
2003	774.5778	655	171.7260	24	30.9832	0.9638	0.0842
2004	765.5049	681	176.6765	25	30.6678	1.0343	0.0832
2005	784.1607	722	190.7030	21	28.0502	1.1151	0.0827
2006	811.2979	818	183.2035	19	21.6176	0.8908	0.0817
2007	607.8702	594	115.4050	15	19.7196	0.7293	0.0846
2008	700.4393	473	101.9450	16	24.9533	0.7394	0.0878
2009	454.3668	413	59.1540	13	14.8023	0.5917	0.0907
2010	380.0247	410	38.3110	13	10.0420	0.4345	0.0903
2011	427.9796	622	82.8770	14	12.6506	0.4607	0.0852
2012	395.5908	345	34.7220	14	10.2040	0.3454	0.0938
2013	323.9160	466	36.1660	13	8.0357	0.3334	0.0897

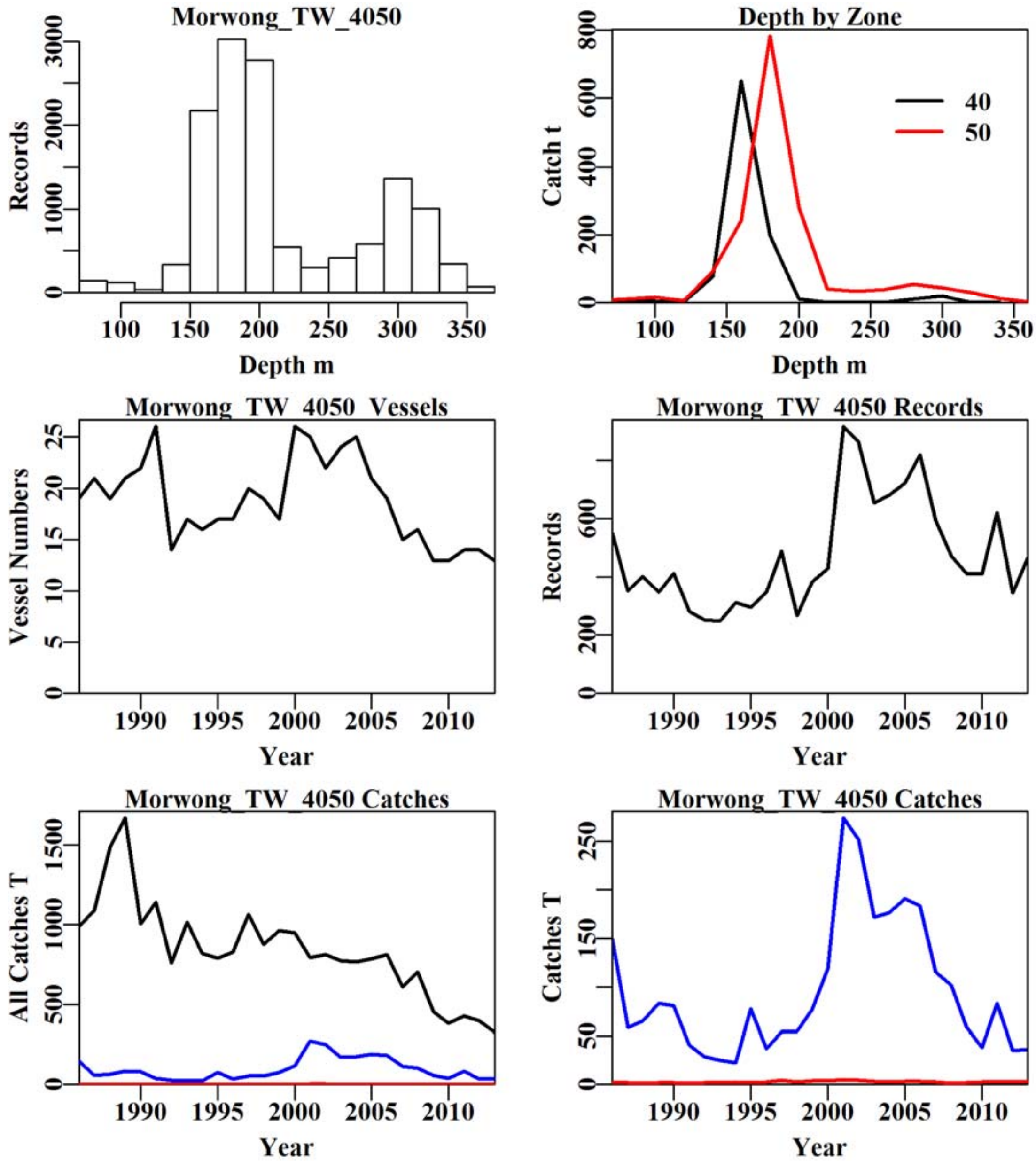


Figure 13.23. Jackass Morwong from zones 40 and 50 in depths 70 – 360 m by Trawl. The top left plot depicts the depth distribution of shots containing Jackass Morwong from zones 40 and 50 in depths 70 – 360 m by Trawl. The top right plot depicts the catch distribution by depth within zones 40 and 50. The middle left plot depicts the number of vessels through time and middle right plot contains the number of records used in analysis. The bottom left plot contains Jackass Morwong catches (top black line: total catches, middle blue line: catches used in the analysis; bottom red line: catches < 30 kg) and bottom right plot contains Jackass Morwong catches (blue line: catches used in the analysis; red line: catches < 30 kg).

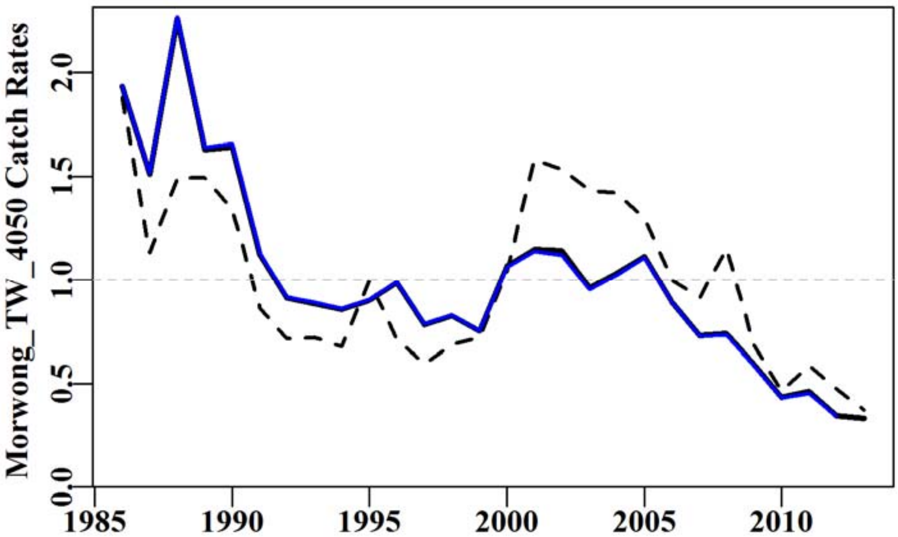


Figure 13.24. Jackass Morwong from zones 40 and 50 in depths 70 – 360 m by Trawl. The dashed black line represents the geometric mean catch rate and the solid black line the standardized catch rates. The graph standardizes catch rates relative to the mean of the standardized catch rates. The blue line is last year's optimum standardization.

Table 13.23. Jackass Morwong from zones 40 and 50 in depths 70 – 360 m by Trawl. Statistical model structures used in this analysis. DepCat is a series of 20 metre depth categories.

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

Table 13.24. Jackass Morwong from zones 40 and 50 in depths 70 – 360 m by Trawl. Model selection criteria include the Akaike Information Criterion (AIC), residual sum of squares (RSS), model sum of squares (MSS), number of usable observations (Nobs), number of parameters (Npars), adjusted R^2 (adj_R^2) and the change in adjusted R^2 (%Change). The optimum was Model 7 (Zone:Month). Depth category: DepC.

	Year	DepC	Month	Vessel	DayNight	Zone	Zone:Month	Zone:DepC
AIC	7969	5586	4370	3748	3657	3519	3374	3422
RSS	24139	20055	18265	17205	17079	16899	16688	16738
MSS	2454	6537	8328	9388	9513	9693	9905	9854
Nobs	13336	13237	13237	13237	13237	13237	13237	13237
Npars	28	43	54	139	142	143	154	158
adj_R^2	9.042	24.343	31.041	34.622	35.083	35.762	36.513	36.301
%Change	0.000	15.301	6.697	3.581	0.461	0.679	0.752	-0.212

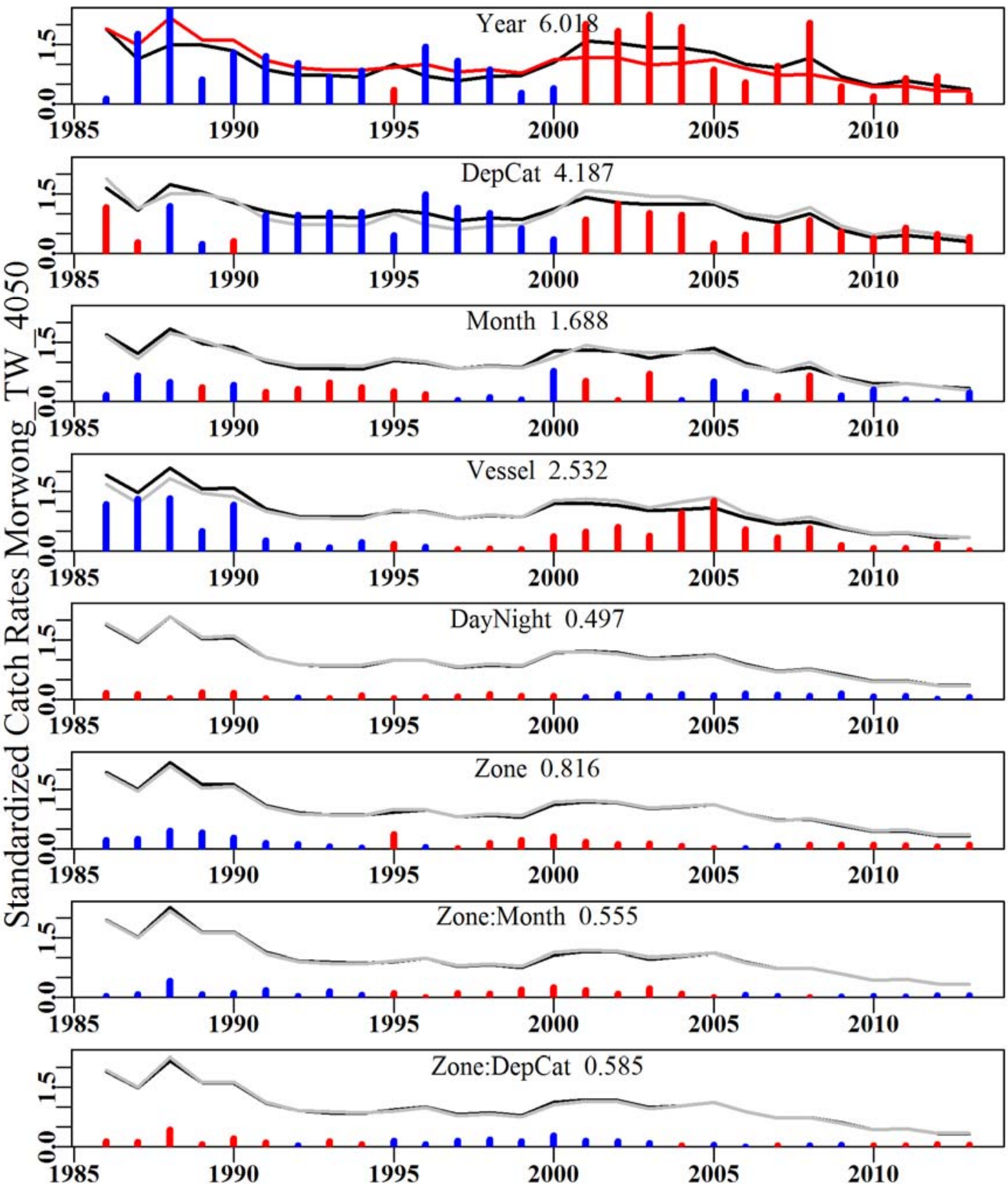


Figure 13.25. The relative influence of each factor used on the final trend in the optimal standardization for Jackass Morwong in zones 40 and 50. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by the vertical bars with blue bars indicating the optimum model is higher than the geometric mean and red bars indicating it is lower. The top graph bars are the sum of all the bars in the graphs below. The graphs for individual factors are cumulative. Thus the second graph has the geometric mean (grey line) and the effect of adding Year + factor2 (Model 2). In the third graph, the grey line represents Model 2 and the black line the effect of adding factor3 to the model. The remaining graphs continue in the same cumulative manner except for the interaction terms which are added singularly to the final single factor model.

13.13 Jackass Morwong Z4050 (MOR – 37377003 – N. macropterus 70–250 m)

Data selected for analysis corresponded to records from zones 40 and 50 in depths between 70 and 250 m. This was a special request to determine the effect of the bimodality of catches between 250 and 360 m. However, this removes about 3785 records for 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 catching Jackass Morwong.

Table 13.25. Jackass Morwong from zones 40 and 50 in depths 70 – 250 m by Trawl. Total catch (TotCatch; t) is the total reported in the database, number of records used in the analysis (Records), reported catch (CatchT; t) in the area and depth used in the analysis and number of vessels used in the analysis (Vessels). GeoMean is the geometric mean of catch rates (kg/hr). The optimum model is Zone:Month and standard deviation (StDev) relates to the data in the optimum model.

Year	TotCatch	Records	CatchT	Vessels	GeoMean	Zone:Month	StDev
1986	982.8110	441	135.5450	19	49.3798	1.8958	0.0000
1987	1087.6900	257	52.1400	20	32.6410	1.5223	0.1016
1988	1483.5120	215	48.1230	17	40.4386	1.5903	0.1109
1989	1667.3730	214	76.5180	21	51.8712	1.7763	0.1147
1990	1001.4140	300	75.8570	22	43.5691	1.8691	0.1111
1991	1138.0700	141	29.8920	23	32.8280	0.9963	0.1295
1992	758.2540	116	21.8810	14	23.0810	0.6969	0.1366
1993	1014.9853	124	19.1390	15	25.8778	0.7884	0.1332
1994	818.4180	159	15.7610	15	21.7099	0.8154	0.1221
1995	789.5280	176	72.9900	17	42.3529	1.1036	0.1181
1996	827.1910	144	28.9150	16	27.3737	0.9524	0.1256
1997	1063.3630	206	45.2960	18	24.6520	0.8699	0.1124
1998	876.4044	130	50.2450	16	30.3815	0.9554	0.1284
1999	961.2618	209	57.6800	15	25.6370	0.9630	0.1124
2000	945.0978	264	113.2420	23	38.0129	1.2730	0.1106
2001	790.1902	719	260.8250	23	46.2560	1.2278	0.0914
2002	811.1362	685	244.3640	22	46.0736	1.1572	0.0911
2003	774.5778	507	163.4740	24	42.9567	0.9624	0.0958
2004	765.5049	536	157.2480	23	35.0950	0.9885	0.0941
2005	784.1607	540	174.7060	21	35.8926	1.1542	0.0934
2006	811.2979	663	170.2380	19	25.6084	0.9022	0.0913
2007	607.8702	497	107.1750	15	22.1800	0.7337	0.0941
2008	700.4393	393	95.4710	16	29.4112	0.7216	0.0978
2009	454.3668	356	56.7370	13	17.3238	0.6060	0.1007
2010	380.0247	337	34.8260	13	10.4950	0.4146	0.1015
2011	427.9796	541	78.3450	14	13.8741	0.4429	0.0947
2012	395.5908	284	32.3010	14	11.6905	0.3065	0.1050
2013	323.9160	397	33.9460	13	8.7739	0.3141	0.1003

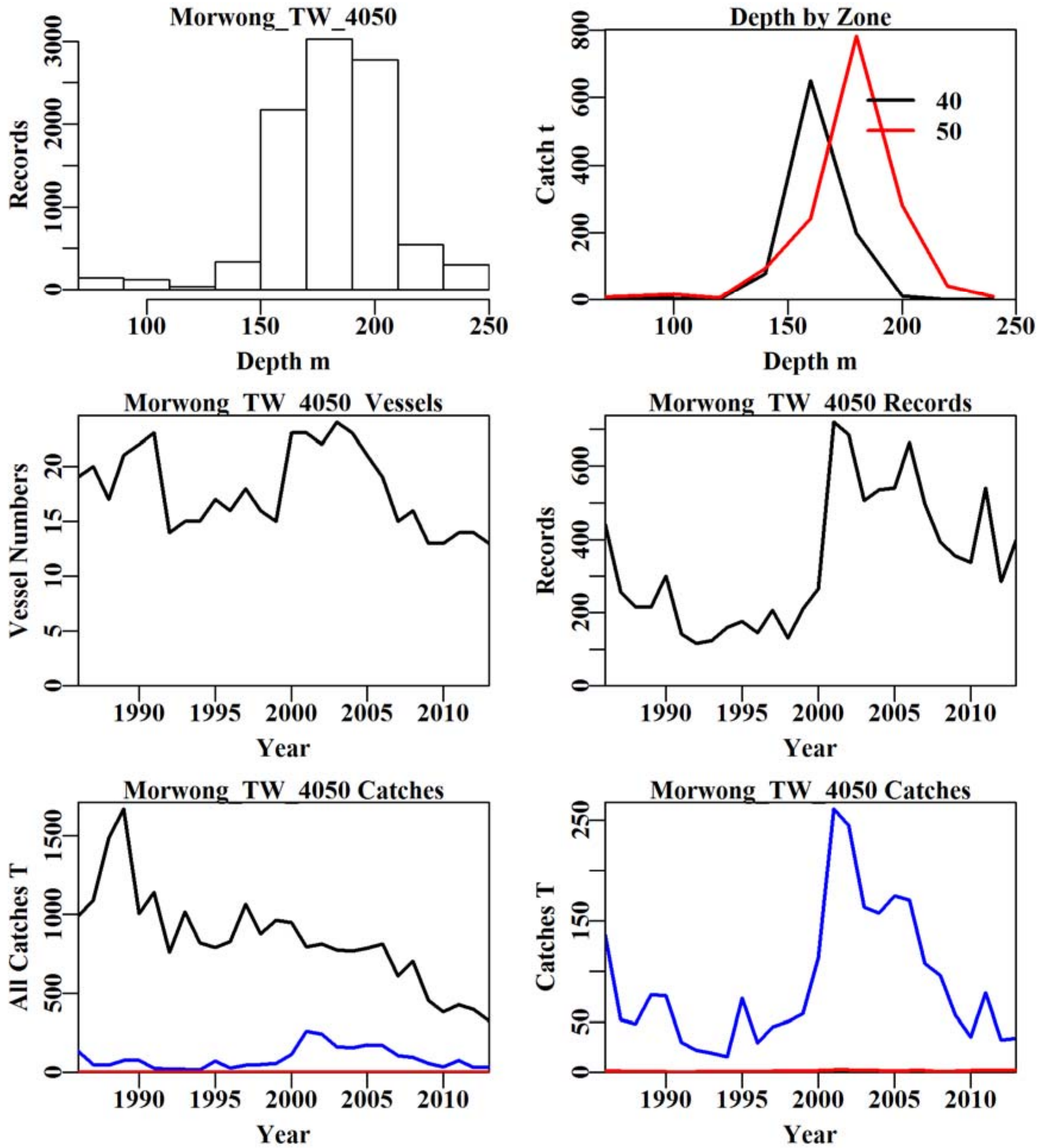


Figure 13.26. Jackass Morwong from zones 40 and 50 in depths 70 – 250 m by Trawl. The top left plot depicts the depth distribution of shots containing Jackass Morwong from zones 40 and 50 in depths 70 – 250 m by Trawl. The top right plot depicts the catch distribution by depth within zones 40 and 50. The middle left plot depicts the number of vessels through time and middle right plot contains the number of records used in analysis. The bottom left plot contains Jackass Morwong catches (top black line: total catches, middle blue line: catches used in the analysis; bottom red line: catches < 30 kg) and bottom right plot contains Jackass Morwong catches (blue line: catches used in the analysis; red line: catches < 30 kg).

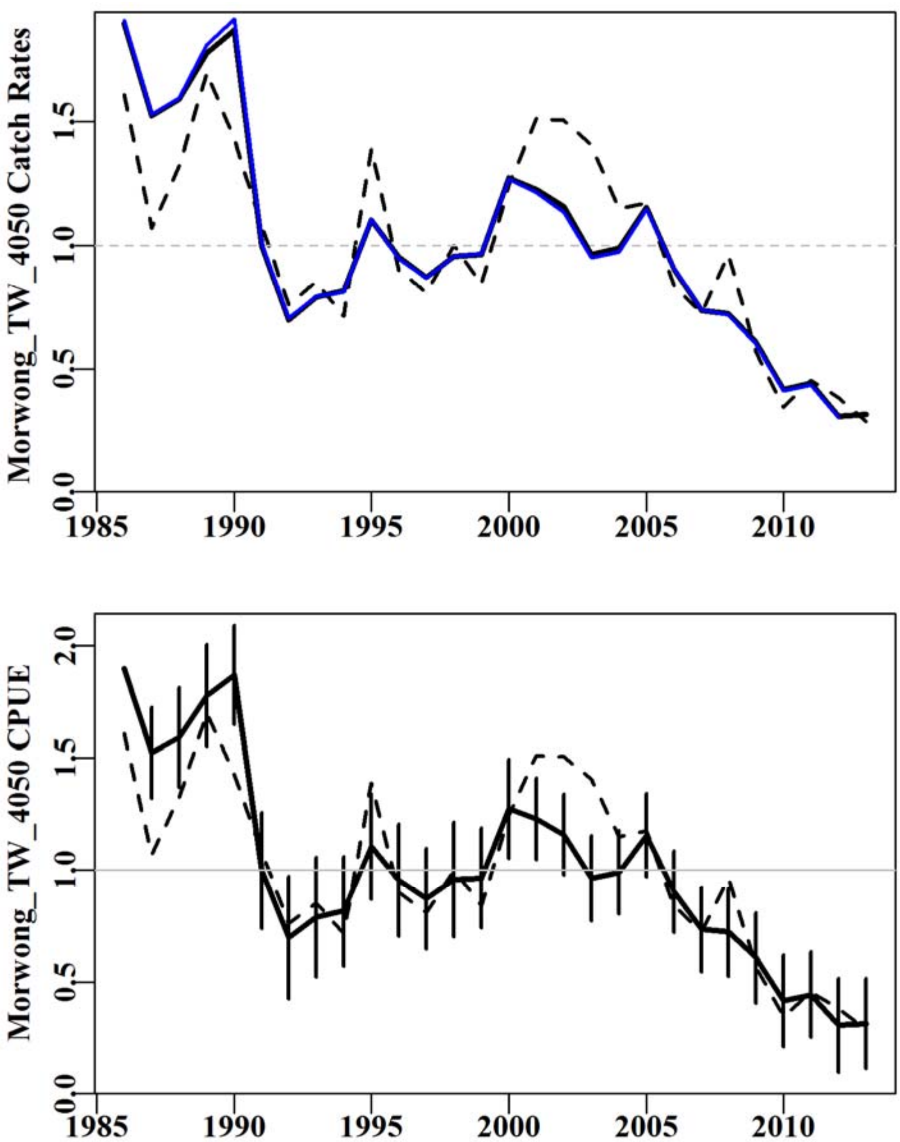


Figure 13.27. Jackass Morwong from zones 40 and 50 in depths 70 – 250 m by Trawl. Upper plot: The dashed black line represents the geometric mean catch rate and the solid black line the standardized catch rates (relative to the mean of the standardized catch rates). The blue line corresponds to last year's standardized catch rates. Lower plot: Standardized catch rates (solid black line), 95% CI (vertical lines) and geometric mean (dashed black line). This illustrates the impact on the relative uncertainty of the relatively small number of records, especially in the early years.

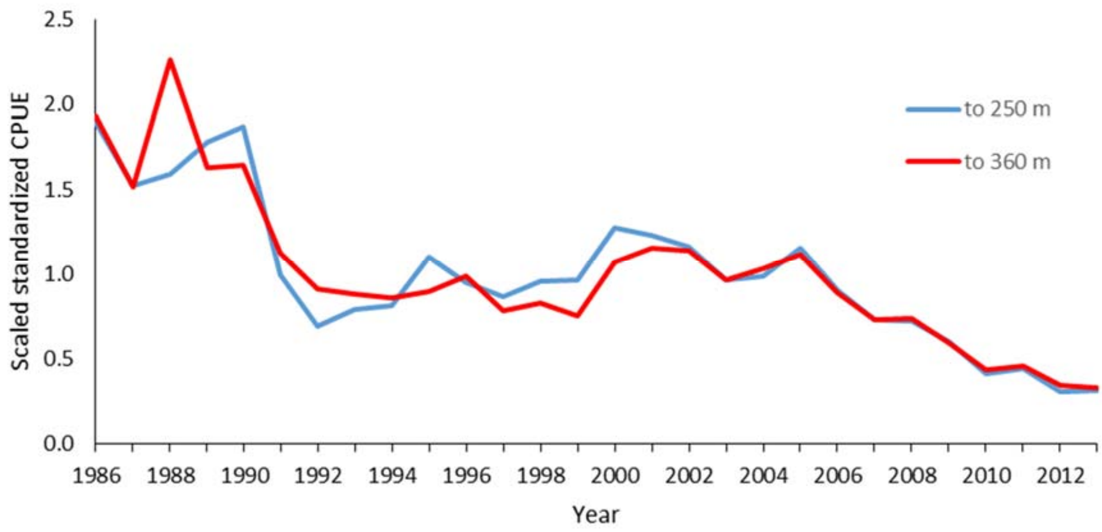


Figure 13.28. A comparison of the two standardizations, one excluding data deeper than 250 m (blue line; to 250 m) the other including data to 360 m (red line; to 360 m).

Table 13.26. Jackass Morwong from zones 40 and 50 in depths 70 – 250 m by Trawl. Statistical model structures used in this analysis. DepCat is a series of 20 metre depth categories.

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

Table 13.27. Jackass Morwong from zones 40 and 50 in depths 70 – 250 m by Trawl. Model selection criteria include the Akaike Information Criterion (AIC), residual sum of squares (RSS), model sum of squares (MSS), number of usable observations (Nobs), number of parameters (Npars), adjusted R^2 (adj_R^2) and the change in adjusted R^2 (%Change). The optimum was Model 7 (Zone:Month). Depth category: DepC.

	Year	DepC	Month	Vessel	DayNight	Zone	Zone:Month	Zone:DepC
AIC	5622	4957	3486	2953	2807	2775	2516	2736
RSS	17105	15844	13529	12565	12365	12321	11960	12246
MSS	2357	3619	5933	6898	7098	7142	7503	7217
Nobs	9551	9452	9452	9452	9452	9452	9452	9452
Npars	28	37	48	131	134	135	146	144
adj_R^2	11.863	18.282	30.139	34.542	35.563	35.786	37.594	36.113
%Change	0.000	6.419	11.857	4.403	1.021	0.222	1.809	-1.482

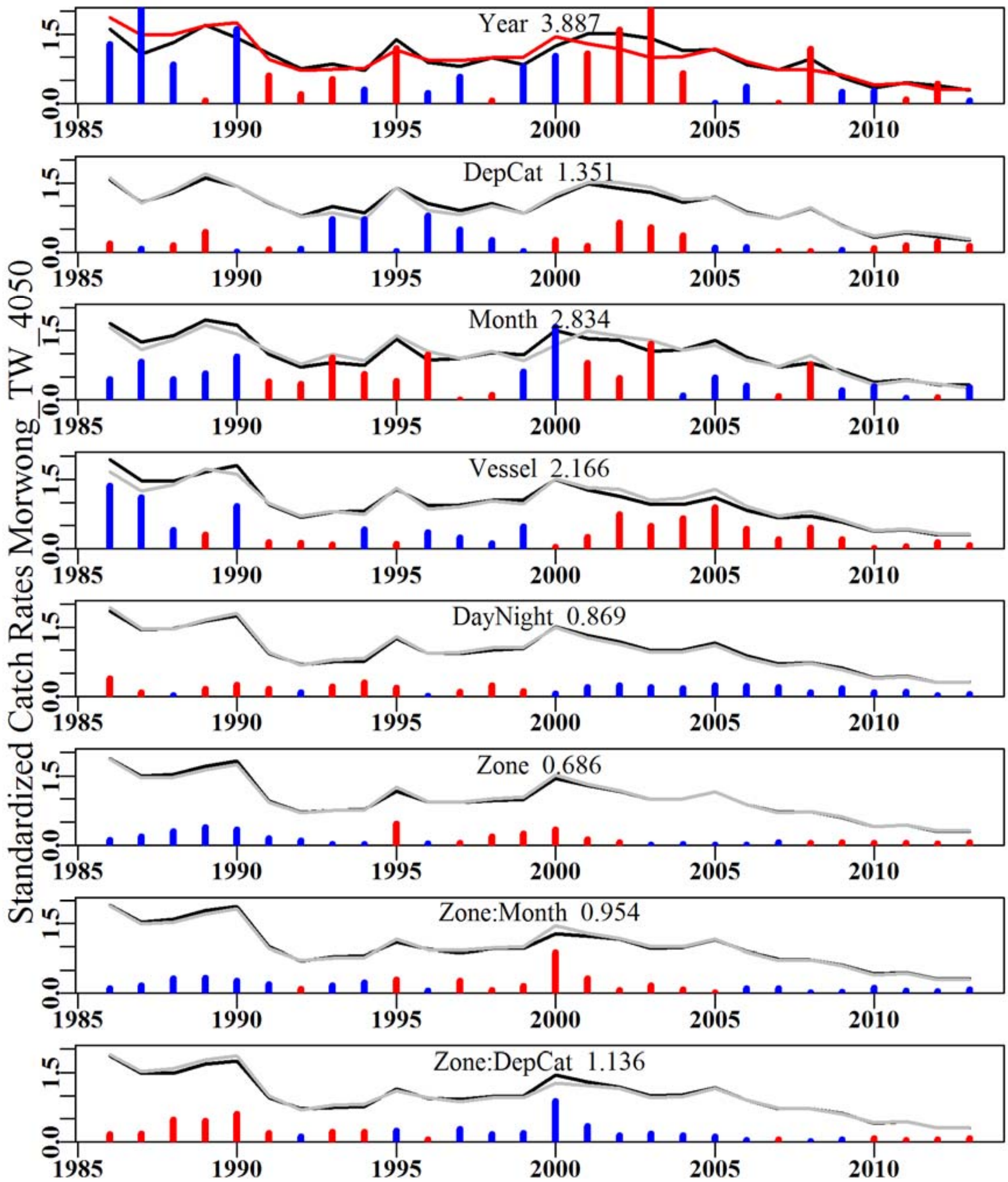


Figure 13.29. The relative influence of each factor used on the final trend in the optimal standardization for Jackass Morwong in zones 40 and 50. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by the vertical bars with blue bars indicating the optimum model is higher than the geometric mean and red bars indicating it is lower. The top graph bars are the sum of all the bars in the graphs below. The graphs for individual factors are cumulative. Thus the second graph has the geometric mean (grey line) and the effect of adding Year + factor2 (Model 2). In the third graph, the grey line represents Model 2 and the black line the effect of adding factor3 to the model. The remaining graphs continue in the same cumulative manner except for the interaction terms which are added singularly to the final single factor model.

13.14 Flathead Trawl (FLT – 37296001 – Neoplatycephalus richardsoni)

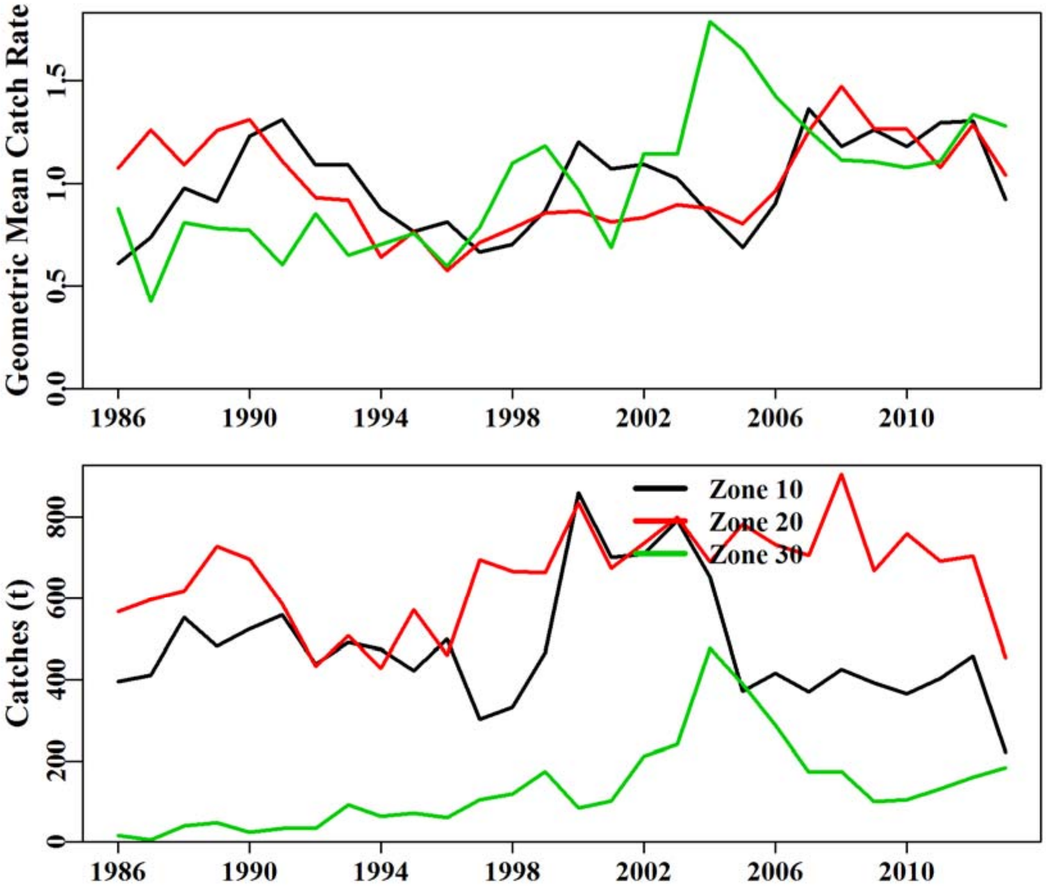


Figure 13.30. The trends in catches and geometric mean catch rates for flathead taken by Trawl in zones 10 to 30. The catch rate trends in 10 and 20 are similar to each other but are different from that expressed in zone 30. For this reason, zones 10 and 20 are standardized separately from Zone 30.

13.15 Flathead Trawl Z1020 (FLT – 37296001 – Neoplatycephalus richardsoni)

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

Table 13.28. Flathead from zones 10 and 20 in depths 0 – 400 m by Trawl. Total catch (TotCatch; t) is the total reported in the database, number of records used in the analysis (Records), reported catch (CatchT; t) in the area and depth used in the analysis and number of vessels used in the analysis (Vessels). GeoMean is the geometric mean of catch rates (kg/hr). The optimum model is Zone:DepC and standard deviation (StDev) relates to the data in the optimum model.

Year	TotCatch	Records	CatchT	Vessels	GeoMean	Zone:DepC	StDev
1986	1892.1830	10196	963.0310	95	16.7357	0.8028	0.0000
1987	2461.3370	8104	1008.3320	86	20.4621	1.0708	0.0160
1988	2469.5260	9175	1171.6990	86	23.7988	1.1711	0.0158
1989	2599.0630	8841	1210.4720	74	23.9908	1.1687	0.0159
1990	2032.3230	7765	1221.4590	64	30.1854	1.3897	0.0167
1991	2230.1850	7797	1145.6520	57	28.7154	1.3182	0.0168
1992	2375.3660	6810	871.9340	53	23.8898	1.0287	0.0175
1993	1879.1400	8782	998.1460	58	23.8001	1.0512	0.0166
1994	1710.4040	10280	902.9060	56	17.9798	0.7622	0.0160
1995	1800.6160	10305	994.1340	54	18.0790	0.8060	0.0159
1996	1879.8720	11089	958.7790	59	16.4549	0.7186	0.0158
1997	2355.9870	10395	997.1370	60	16.8264	0.7188	0.0161
1998	2306.4070	9986	999.5350	52	17.7430	0.7618	0.0162
1999	3117.6750	10377	1129.3560	57	20.4344	0.9175	0.0160
2000	2945.5930	13110	1696.8140	60	24.4338	1.0130	0.0155
2001	2599.5120	11957	1375.3790	53	22.3118	0.9739	0.0157
2002	2876.2540	12357	1444.0490	49	22.8273	1.0619	0.0157
2003	3229.8810	12879	1593.8350	52	22.5521	1.0470	0.0155
2004	3222.7810	12218	1342.8575	52	19.7872	0.9072	0.0157
2005	2844.0450	10703	1154.9860	49	17.7159	0.7746	0.0161
2006	2585.8230	9137	1148.7790	46	22.2550	0.9383	0.0166
2007	2648.2110	6336	1076.4633	25	31.3557	1.1388	0.0183
2008	2912.3110	7292	1330.5590	27	31.6602	1.1957	0.0177
2009	2460.4100	6311	1060.7127	26	30.0219	1.1001	0.0184
2010	2502.2850	6873	1124.3120	25	29.4591	1.0617	0.0181
2011	2465.8550	6766	1096.1494	24	28.4045	1.0518	0.0182
2012	2780.5710	6884	1162.3542	24	30.4796	1.1602	0.0180
2013	1841.6240	5549	674.2176	24	23.3776	0.8895	0.0189

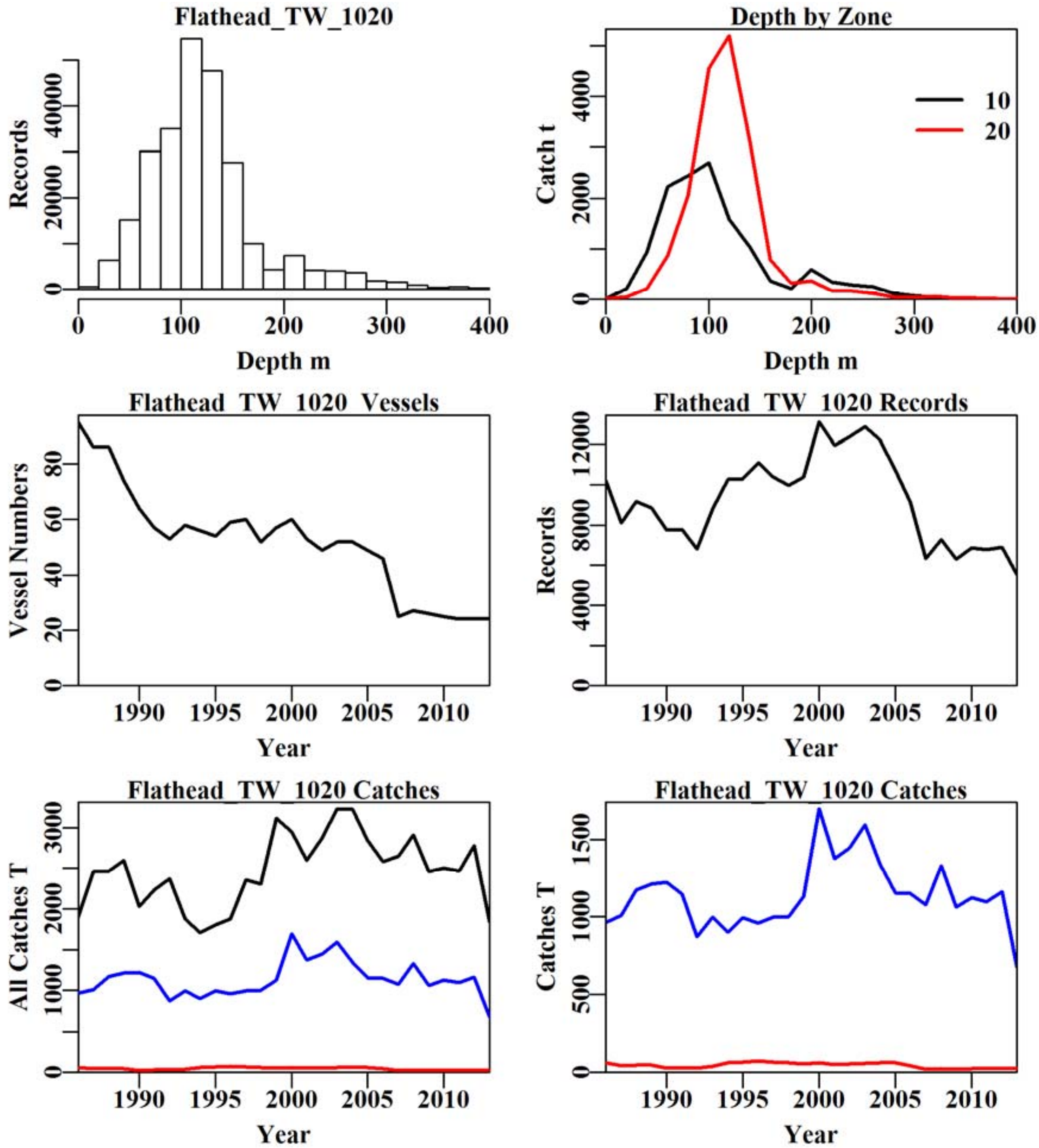


Figure 13.31. Flathead from zones 10 and 20 in depths 0 – 400 m by Trawl. The top left plot depicts the depth distribution of shots containing Flathead from zones 10 and 20 in depths 0 – 400 m by Trawl. The top right plot depicts the catch distribution by depth from zones 10 and 20 (top red line: zone 20). The middle left plot depicts the number of vessels through time and middle right plot contains the number of records used in analysis. The bottom left plot contains Flathead catches (top black line: total catches, middle blue line: catches used in the analysis; bottom red line: catches < 30 kg) and bottom right plot contains Flathead catches (blue line: catches used in the analysis; red line: catches < 30 kg).

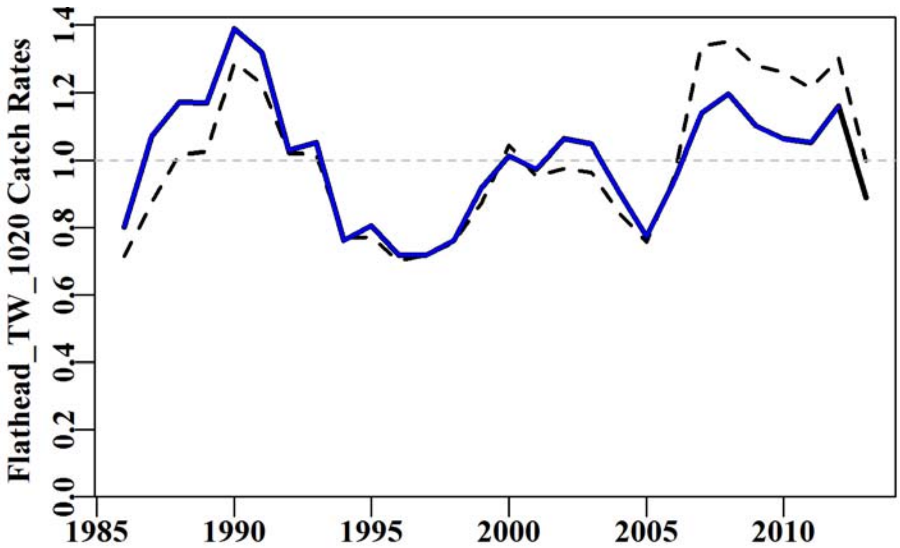


Figure 13.32. Flathead from zones 10 and 20 in depths 0 – 400m by Trawl. The dashed black line represents the geometric mean catch rate and the solid black line the standardized catch rates (relative to the mean of the standardized catch rates). The blue line is last year's optimum standardization.

Table 13.29. Flathead from zones 10 and 20 in depths 0 – 400 m by Trawl. Statistical model structures used in this analysis. DepCat is a series of 20 metre depth categories.

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

Table 13.30. Flathead from zones 10 and 20 in depths 0 – 400 m by Trawl. Model selection criteria include the Akaike Information Criterion (AIC), residual sum of squares (RSS), model sum of squares (MSS), number of usable observations (Nobs), number of parameters (Npars), adjusted R^2 (adj_R^2) and the change in adjusted R^2 (%Change). The optimum model was Model 8 (Zone:DepC) Depth category: DepC.

	Year	Vessel	DepC	Month	DayNight	Zone	Zone:Month	Zone:DepC
AIC	45460	16441	8319	7424	7263	7206	5185	4238
RSS	307913	274804	264166	263222	263050	262990	260901	259920
MSS	10307	43416	54054	54998	55170	55231	57319	58301
Nobs	258274	258274	256183	256183	256183	256183	256183	256183
Npars	28	209	229	240	243	244	255	264
adj_R^2	3.229	13.574	16.913	17.206	17.259	17.278	17.931	18.237
%Change	0.000	10.345	3.339	0.293	0.053	0.019	0.653	0.306

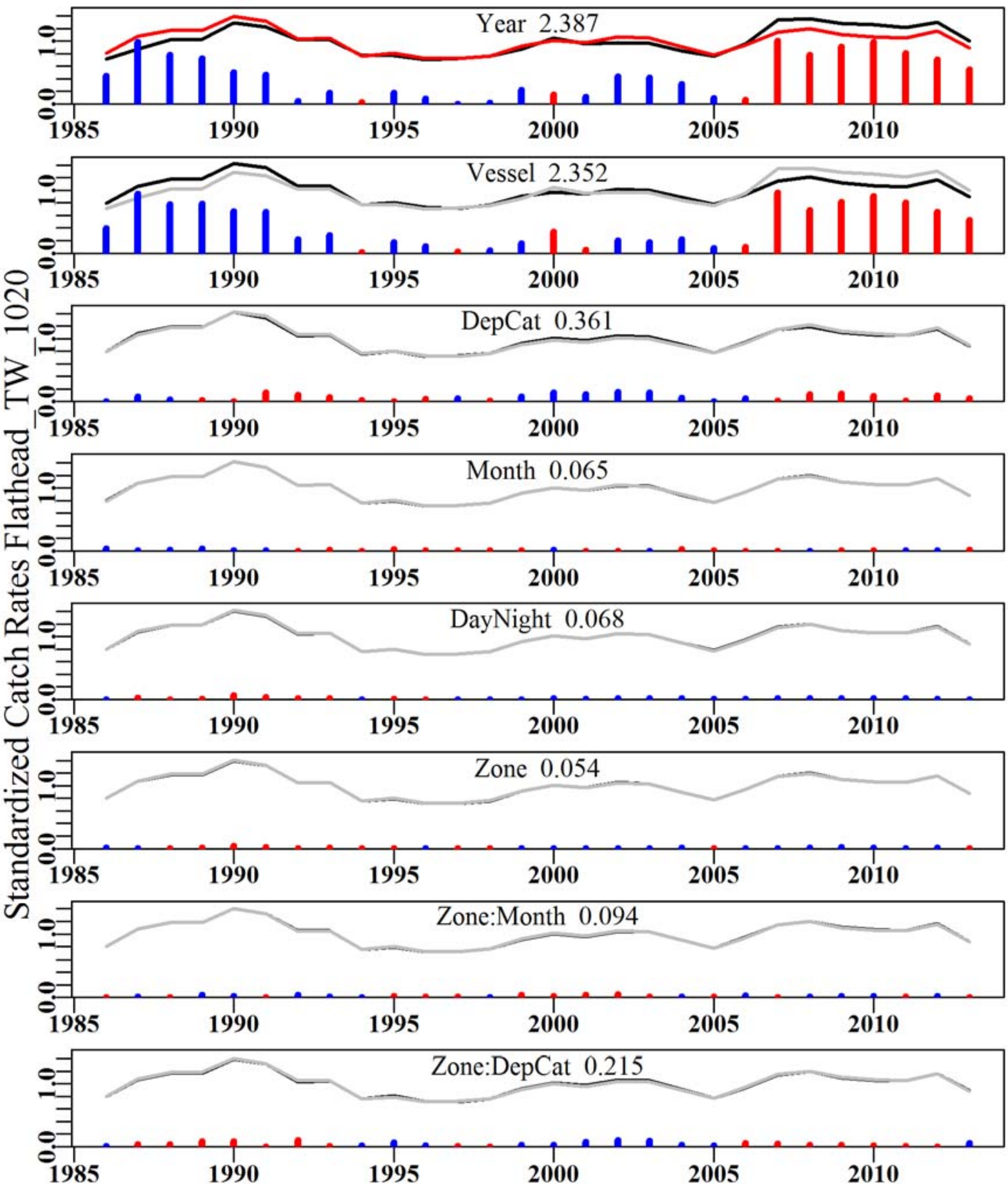


Figure 13.33. The relative influence of each factor used on the final trend in the optimal standardization for Flathead in zones 10 and 20. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by the vertical bars with blue bars indicating the optimum model is higher than the geometric mean and red bars indicating it is lower. The top graph bars are the sum of all the bars in the graphs below. The graphs for individual factors are cumulative. Thus the second graph has the geometric mean (grey line) and the effect of adding Year + factor2 (Model 2). In the third graph, the grey line represents Model 2 and the black line the effect of adding factor3 to the model. The remaining graphs continue in the same cumulative manner except for the interaction terms which are added singularly to the final single factor model.

13.16 Flathead Trawl Z30 (FLT – 37296001 – Neoplatycephalus richardsoni)

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

Table 13.31. Flathead from zone 30 in depths 0 – 400 m by Trawl. Total catch (TotCatch; t) is the total reported in the database, number of records used in the analysis (Records), reported catch (CatchT; t) in the area and depth used in the analysis and number of vessels used in the analysis (Vessels). GeoMean is the geometric mean of catch rates (kg/hr). The optimum model is Month:DepC and standard deviation (StDev) relates to the data in the optimum model.

Year	TotCatch	Records	CatchT	Vessels	GeoMean	Month:DepC	StDev
1986	1892.1830	71	16.7540	6	23.1157	0.9505	0.0000
1987	2461.3370	90	5.1550	9	11.1912	0.5886	0.1905
1988	2469.5260	193	39.9760	9	21.2587	0.9804	0.1711
1989	2599.0630	516	48.4430	19	20.5177	0.7359	0.1635
1990	2032.3230	253	24.6190	27	20.3187	0.7855	0.1657
1991	2230.1850	314	33.3530	29	15.9189	0.7177	0.1617
1992	2375.3660	272	33.8970	15	22.4408	0.6903	0.1659
1993	1879.1400	902	92.0790	24	17.1065	0.6507	0.1573
1994	1710.4040	612	64.4870	17	18.5289	0.6812	0.1583
1995	1800.6160	694	71.3490	17	19.8905	0.7385	0.1586
1996	1879.8720	714	61.4250	17	15.7596	0.6771	0.1583
1997	2355.9870	885	104.8750	14	20.7052	0.8478	0.1572
1998	2306.4070	707	118.5520	14	28.8666	1.0021	0.1577
1999	3117.6750	770	175.0520	17	31.0992	1.1095	0.1579
2000	2945.5930	520	83.6640	21	25.4446	0.8847	0.1592
2001	2599.5120	916	101.3080	17	18.0579	0.7444	0.1562
2002	2876.2540	1367	212.1580	15	30.1174	1.3904	0.1554
2003	3229.8810	1454	240.1100	21	30.0485	1.4244	0.1547
2004	3222.7810	1923	477.4160	15	47.0053	1.8759	0.1544
2005	2844.0450	1540	388.3250	18	43.4956	1.6734	0.1549
2006	2585.8230	1315	287.9680	13	37.5195	1.3426	0.1557
2007	2648.2110	823	173.1554	8	33.0381	1.1066	0.1573
2008	2912.3110	874	173.7390	11	29.3148	1.0258	0.1571
2009	2460.4100	600	100.2251	10	29.0939	0.9979	0.1587
2010	2502.2850	537	104.1860	10	28.3260	1.0125	0.1596
2011	2465.8550	623	131.2742	9	29.1229	0.9616	0.1587
2012	2780.5710	756	160.7460	8	35.1418	1.1920	0.1579
2013	1841.6240	767	184.1795	11	33.6185	1.2120	0.1576

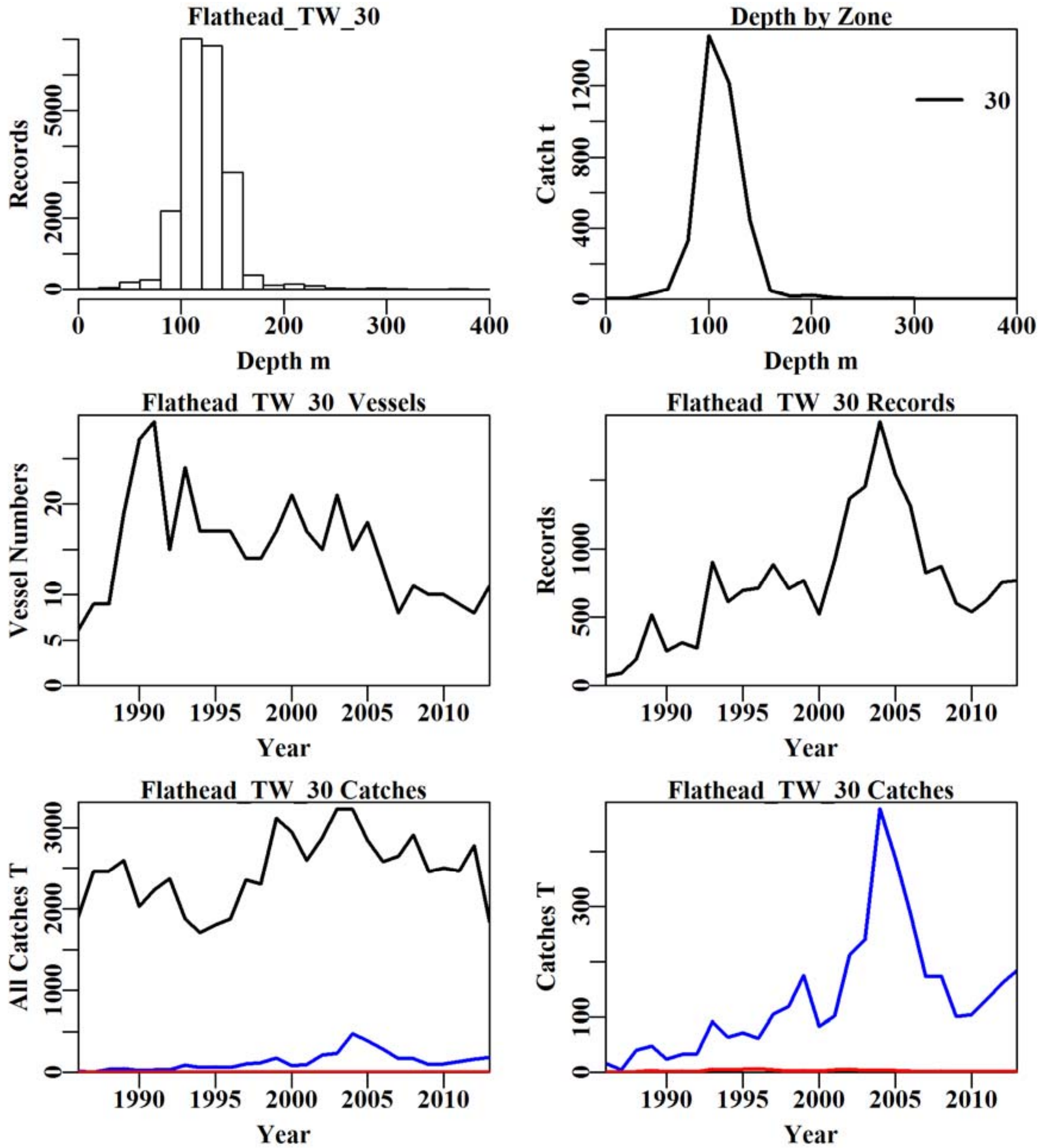


Figure 13.34. Flathead from zone 30 in depths 0 – 400m by Trawl. The top left plot depicts the depth distribution of shots containing Flathead from zones 10 and 20 in depths 0 – 400 m by Trawl. The top right plot depicts the catch distribution by depth from zone 30. The middle left plot depicts the number of vessels through time and middle right plot contains the number of records used in analysis. The bottom left plot contains Flathead catches (top black line: total catches, middle blue line: catches used in the analysis; bottom red line: catches < 30 kg) and bottom right plot contains Flathead catches (blue line: catches used in the analysis; red line: catches < 30 kg).

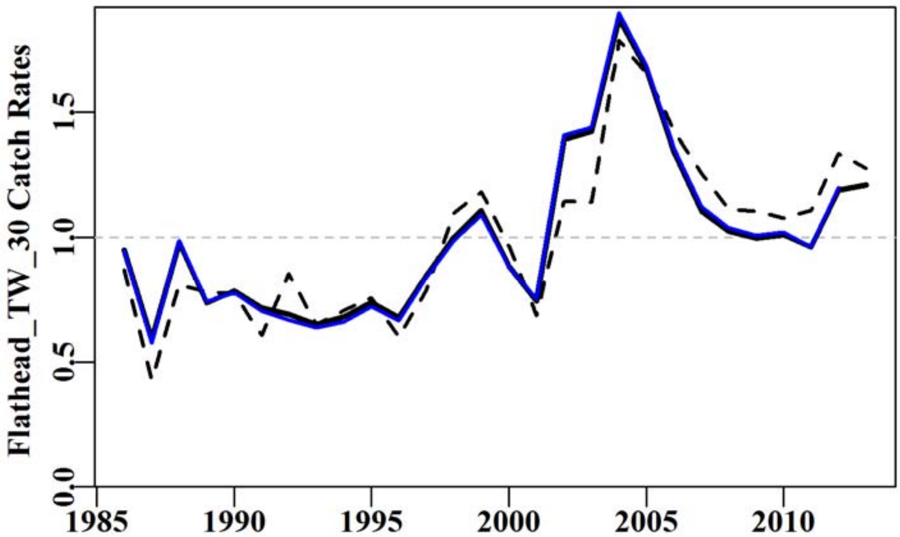


Figure 13.35. Flathead from zone 30 in depths 0 – 400 m by Trawl. The dashed black line represents the geometric mean catch rate and the solid black line the standardized catch rates (relative to the mean of the standardized catch rates). The blue line is last year's optimum standardization.

Table 13.32. Flathead from zone 30 in depths 0 – 400 m by Trawl. Statistical model structures used in this analysis. DepCat is a series of 20 metre depth categories.

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

Table 13.33. Flathead from zone 30 in depths 0 – 400 m by Trawl. Model selection criteria include the Akaike Information Criterion (AIC), residual sum of squares (RSS), model sum of squares (MSS), number of usable observations (Nobs), number of parameters (Npars), adjusted R^2 (adj_R^2) and the change in adjusted R^2 (%Change). The optimum was Model 7 (Mth:DepC). Depth category: DepC; DayNight: DN; Month: Mth.

	Year	Vessel	DepC	DN	Mth	DN:Mth	Mth:DepC	DN:DepC
AIC	3100	1446	220	-126	-403	-453	-906	-496
RSS	24284	22254	20689	20341	20050	19938	19159	19845
MSS	2224	4254	5819	6167	6457	6570	7349	6662
Nobs	21008	21008	20745	20745	20745	20745	20745	20745
Npars	28	118	138	141	152	185	372	212
adj_R^2	8.273	15.579	21.432	22.742	23.806	24.112	26.407	24.365
%Change	0.000	7.306	5.853	1.311	1.064	0.306	2.295	-2.042

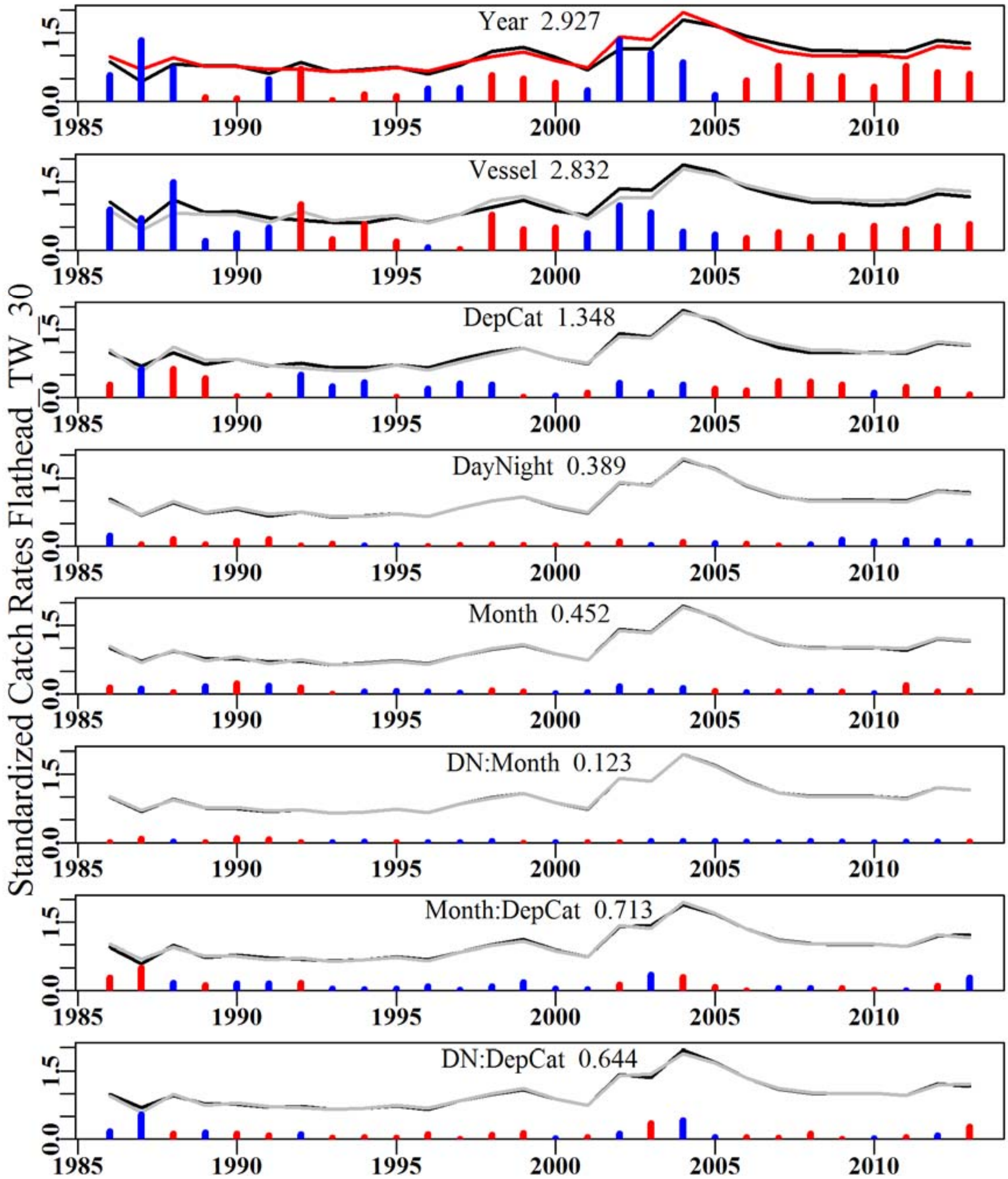


Figure 13.36. The relative influence of each factor used on the final trend in the optimal standardization for Flathead from zone 30. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by the vertical bars with blue bars indicating the optimum model is higher than the geometric mean and red bars indicating it is lower. The top graph bars are the sum of all the bars in the graphs below. The graphs for individual factors are cumulative. Thus the second graph has the geometric mean (grey line) and the effect of adding Year + factor2 (Model 2). In the third graph, the grey line represents Model 2 and the black line the effect of adding factor3 to the model. The remaining graphs continue in the same cumulative manner except for the interaction terms which are added singularly to the final single factor model.

13.17 Flathead Danish Seine (FLT – 37296001 –*Neoplatycephalus richardsoni*)

Data selected for analysis corresponded to records from zones 20 and 60, for Danish Seine vessels only (i.e. excluded Otter Trawl vessels), and depths less than 200 m.

Table 13.34. Flathead from zones 20 and 60 in depths 0 – 200 m by Danish Seine. Total catch (TotCatch; t) is the total reported in the database, number of records used in the analysis (Records), reported catch (CatchT; t) in the area and depth used in the analysis and number of vessels used in the analysis (Vessels). GeoMean is the geometric mean of catch rates (kg/shot). The optimum model is Zone:Month and standard deviation (StDev) relates to the data in the optimum model.

Year	TotCatch	Records	CatchT	Vessels	GeoMean	Zone:Month	StDev
1986	1892.1830	5501	763.9450	26	45.0535	1.0548	0.0000
1987	2461.3370	5651	1366.9440	23	88.6187	1.4801	0.0228
1988	2469.5260	5823	1097.5410	25	88.9194	1.6091	0.0227
1989	2599.0630	5412	1142.7080	27	78.4955	1.3986	0.0230
1990	2032.3230	4653	586.0180	25	48.3882	0.9226	0.0242
1991	2230.1850	4670	775.7680	28	69.8580	1.2895	0.0243
1992	2375.3660	6643	1218.0410	24	85.5977	1.3958	0.0224
1993	1879.1400	5859	539.5880	24	39.0251	0.8856	0.0231
1994	1710.4040	7332	649.4810	25	37.6721	0.7486	0.0219
1995	1800.6160	5505	656.6650	21	36.2337	0.7667	0.0233
1996	1879.8720	7679	755.6700	22	33.6052	0.7233	0.0219
1997	2355.9870	8480	1150.4360	21	60.3446	0.9278	0.0216
1998	2306.4070	9904	1134.7320	21	60.5323	0.7764	0.0211
1999	3117.6750	8818	1702.6050	23	98.4160	1.1200	0.0215
2000	2945.5930	7092	1037.6890	19	64.0436	0.8258	0.0226
2001	2599.5120	7457	1004.5070	18	62.0182	0.7696	0.0226
2002	2876.2540	8218	1144.0750	22	75.2709	0.9145	0.0223
2003	3229.8810	9005	1210.2270	23	80.7088	0.9757	0.0220
2004	3222.7810	7784	1253.0260	22	83.7818	0.9503	0.0225
2005	2844.0450	7212	1125.7530	22	87.7421	0.9680	0.0229
2006	2585.8230	5563	968.0510	21	89.1577	0.9593	0.0240
2007	2648.2110	5551	1182.0670	15	104.4620	1.1593	0.0239
2008	2912.3110	6214	1283.4890	15	103.2936	1.0351	0.0235
2009	2460.4100	5499	1168.9280	15	91.4234	1.0710	0.0239
2010	2502.2850	6050	1167.4060	15	101.4792	0.9530	0.0236
2011	2465.8550	6889	1122.3150	14	85.7924	0.8864	0.0230
2012	2780.5710	7214	1382.3340	14	89.5939	0.8350	0.0229
2013	1841.6240	6822	876.5270	14	59.8539	0.5982	0.0232

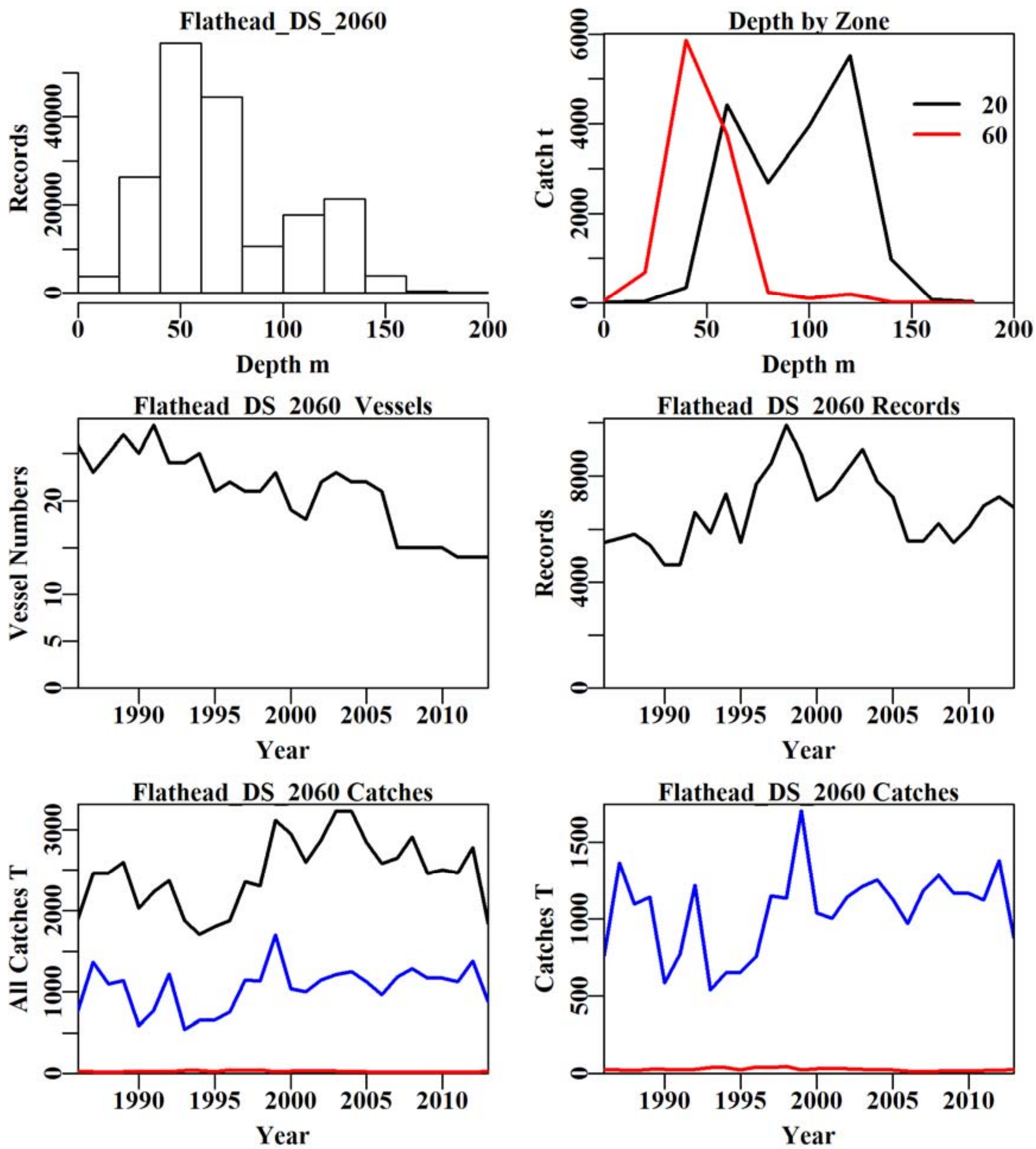


Figure 13.37. Flathead from zones 20 and 60 in depths 0 – 200 m by Danish Seine. The top left plot depicts the depth distribution of shots containing Flathead from zones 20 and 60 in depths 0 – 200 m by Danish Seine. The top right plot depicts the catch distribution by depth from zones 20 and 60. The middle left plot depicts the number of vessels through time and middle right plot contains the number of records used in analysis. The bottom left plot contains Flathead catches (top black line: total catches, middle blue line: catches used in the analysis; bottom red line: catches < 30 kg) and bottom right plot contains Flathead catches (blue line: catches used in the analysis; red line: catches < 30 kg).

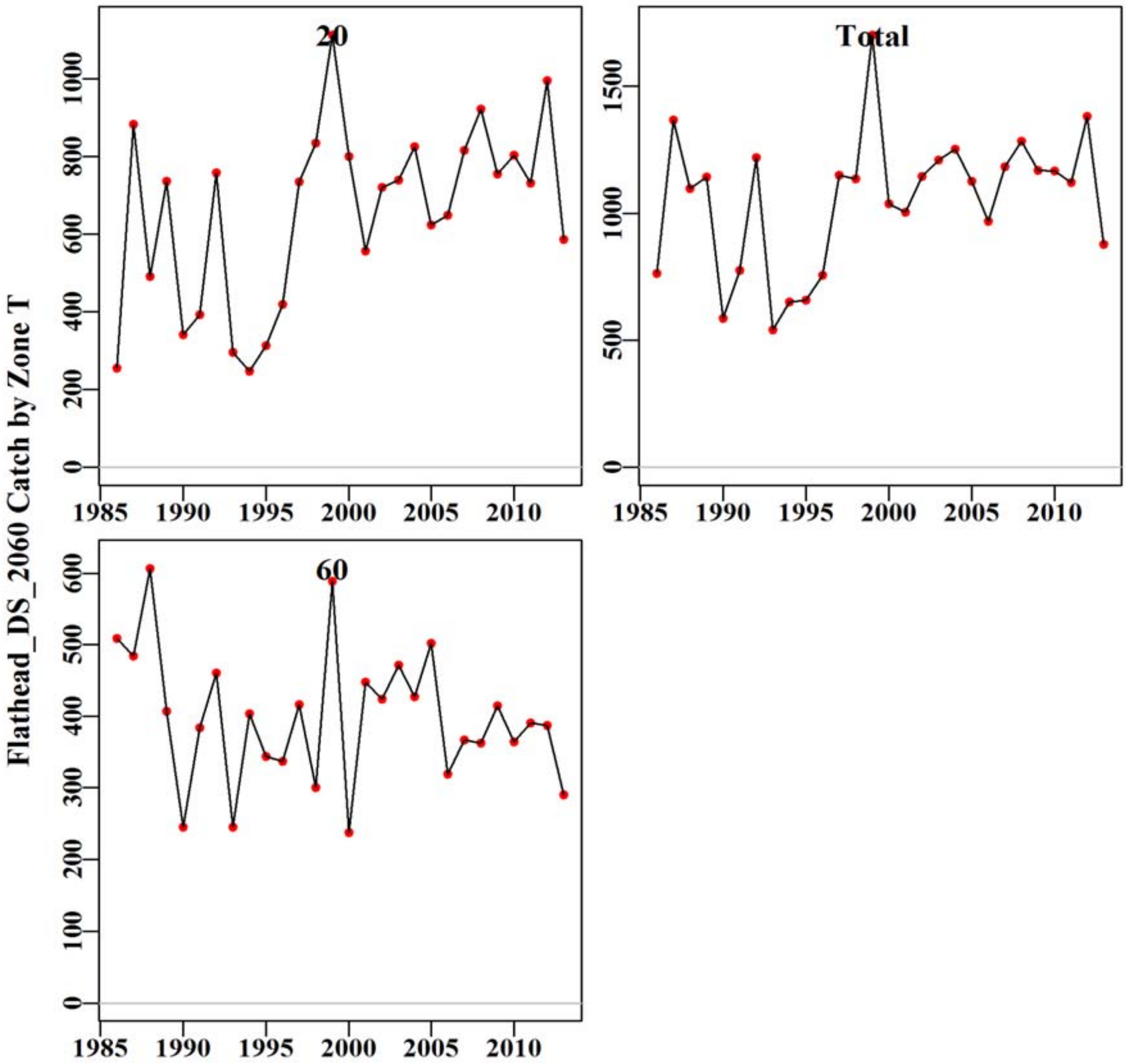


Figure 13.38. Annual flathead catches among the reporting zones 20, 60 and combined (20 & 60).

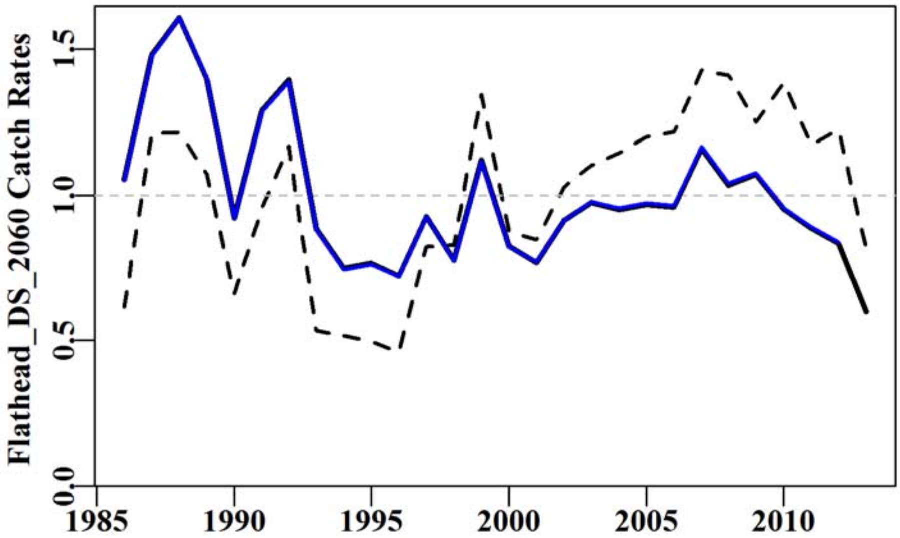


Figure 13.39. Flathead from zones 20 and 60 in depths 0 – 200 m by Danish Seine. The dashed black line represents the geometric mean catch rate and the solid black line the standardized catch rates (relative to the mean of the standardized catch rates). The blue line is last year's optimum standardization.

Table 13.35. Flathead from zones 20 and 60 in depths 0 – 200 m by Danish Seine. Statistical model structures used in this analysis. DepCat is a series of 20 metre depth categories.

Model 1	LnCE~Year
Model 2	LnCE~Year+Zone
Model 3	LnCE~Year+Zone+DepCat
Model 4	LnCE~Year+Zone+DepCat+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 13.36. Flathead from zones 20 and 60 in depths 0 – 200 m by Danish Seine. Model selection criteria include the Akaike Information Criterion (AIC), residual sum of squares (RSS), model sum of squares (MSS), number of usable observations (Nobs), number of parameters (Npars), adjusted R^2 (adj_R^2) and the change in adjusted R^2 (%Change). The optimum was Model 7 (Zone:Month). Depth category: DepC.

	Year	Zone	DepC	Vessel	Month	DayNight	Zone:Month	Zone:DepC
AIC	146195	111000	78057	70382	58722	55727	51054	55405
RSS	409268	339559	282431	270829	254299	250218	243964	249760
MSS	20723	90432	147561	159163	175692	179774	186027	180232
Nobs	188500	188500	185499	185499	185499	185499	185499	185499
Npars	28	29	38	91	102	105	116	114
adj_R^2	4.806	21.019	34.304	36.985	40.827	41.776	43.228	41.880
%Change	0.000	16.214	13.285	2.681	3.843	0.949	1.452	-1.348

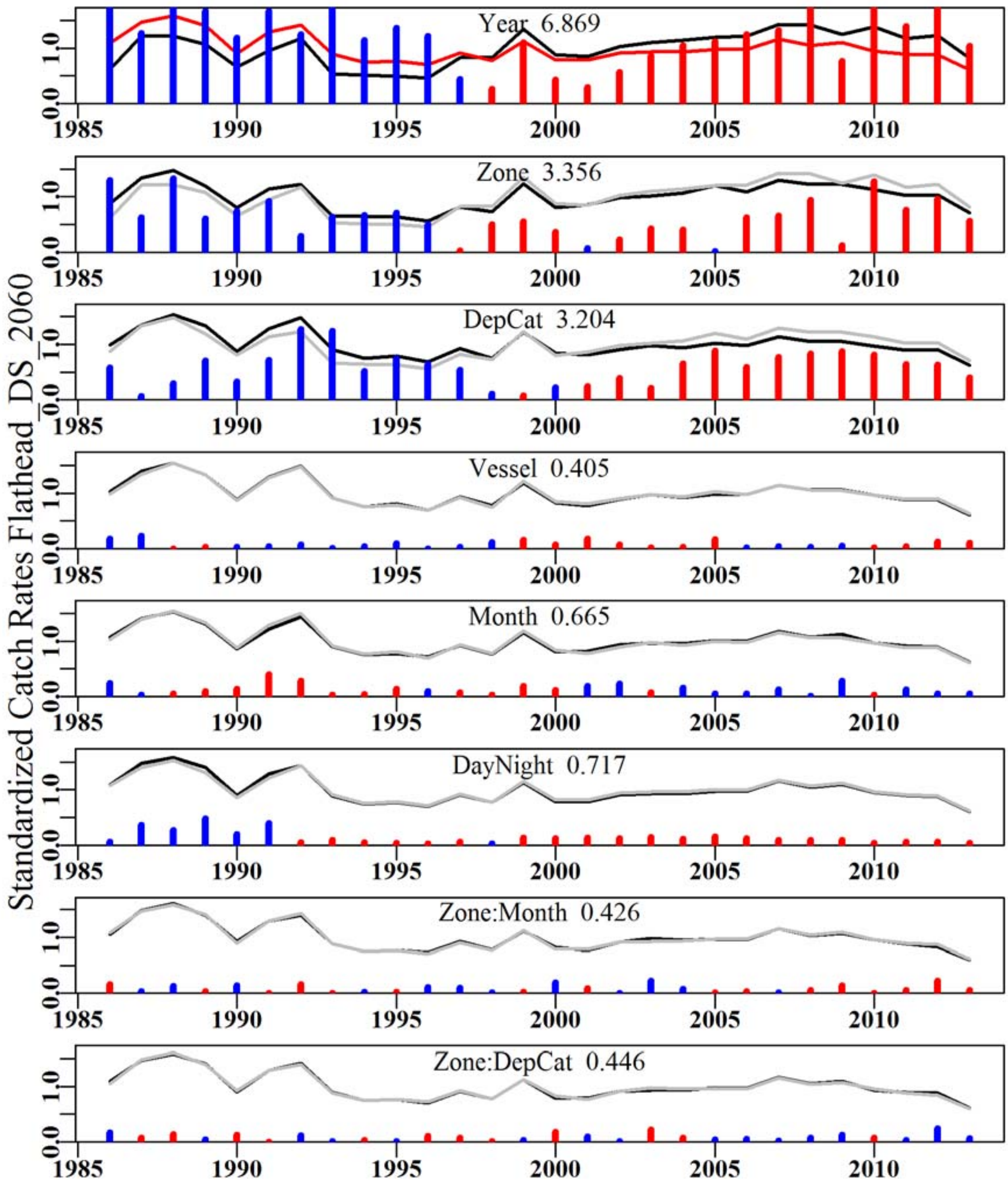


Figure 13.40. The relative influence of each factor used on the final trend in the optimal standardization for Flathead by Danish Seine in zones 20 and 60. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by the vertical bars with blue bars indicating the optimum model is higher than the geometric mean and red bars indicating it is lower. The top graph bars are the sum of all the bars in the graphs below. The graphs for individual factors are cumulative. Thus the second graph has the geometric mean (grey line) and the effect of adding Year + factor2 (Model 2). In the third graph, the grey line represents Model 2 and the black line the effect of adding factor3 to the model. The remaining graphs continue in the same cumulative manner except for the interaction terms which are added singularly to the final single factor model.

13.18 Redfish Z10 (RED – 37258003 – *Centroberyx affinis*)

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

Table 13.37. Redfish from zone 10 in depths 0 – 400 m by Trawl. Total catch (TotCatch; t) is the total reported in the database, number of records used in the analysis (Records), reported catch (CatchT; t) in the area and depth used in the analysis and number of vessels used in the analysis (Vessels). GeoMean is the geometric mean of catch rates (kg/hr). The optimum model is Month:DepC and standard deviation (StDev) relates to the data in the optimum model.

Year	TotCatch	Records	CatchT	Vessels	GeoMean	Month:DepC	StDev
1986	1687.4710	4503	1528.9260	81	38.3044	1.6834	0.0000
1987	1252.6580	3383	1114.8050	73	35.9993	1.3514	0.0370
1988	1125.4920	2966	904.3610	70	37.3114	1.4029	0.0389
1989	714.3160	2156	586.9420	64	29.4122	1.1642	0.0431
1990	931.3700	1894	699.7540	49	37.2522	1.5783	0.0452
1991	1570.6070	2467	1056.9960	44	39.9367	1.6379	0.0421
1992	1636.6870	2428	1393.7250	41	50.0990	2.1097	0.0429
1993	1921.3470	2960	1611.7950	47	56.0385	2.6676	0.0406
1994	1487.7170	4208	1140.8910	49	35.8972	1.8706	0.0377
1995	1240.6170	4397	1027.5760	46	27.8589	1.2138	0.0368
1996	1344.0490	4063	1094.9930	50	26.2588	0.9913	0.0375
1997	1397.3280	2952	1157.7430	50	33.5183	1.1637	0.0405
1998	1553.7182	3072	1363.4040	43	43.1196	1.4567	0.0401
1999	1116.4030	2998	969.4240	44	32.7876	1.1428	0.0402
2000	758.2751	3300	642.1370	48	22.7760	0.7692	0.0398
2001	742.2683	3209	607.2150	41	17.8301	0.7531	0.0398
2002	807.1325	3481	601.8230	44	16.4201	0.6413	0.0395
2003	615.5584	2691	478.8938	43	17.0044	0.6138	0.0416
2004	475.2044	2717	390.1620	44	15.2352	0.5212	0.0416
2005	483.5160	2443	360.9610	41	16.1484	0.5329	0.0428
2006	325.4821	1768	256.2120	34	15.6812	0.5008	0.0471
2007	216.2794	1207	149.2880	18	15.4678	0.4431	0.0545
2008	183.7567	1396	155.2900	22	13.9780	0.4150	0.0523
2009	160.5248	1171	123.8100	20	11.3207	0.3355	0.0556
2010	152.8285	1227	112.7730	19	10.4862	0.3190	0.0545
2011	87.3052	870	63.8060	17	8.5118	0.2541	0.0613
2012	66.4453	973	54.7790	17	7.0022	0.2109	0.0586
2013	62.6620	768	51.5511	18	8.7751	0.2558	0.0637

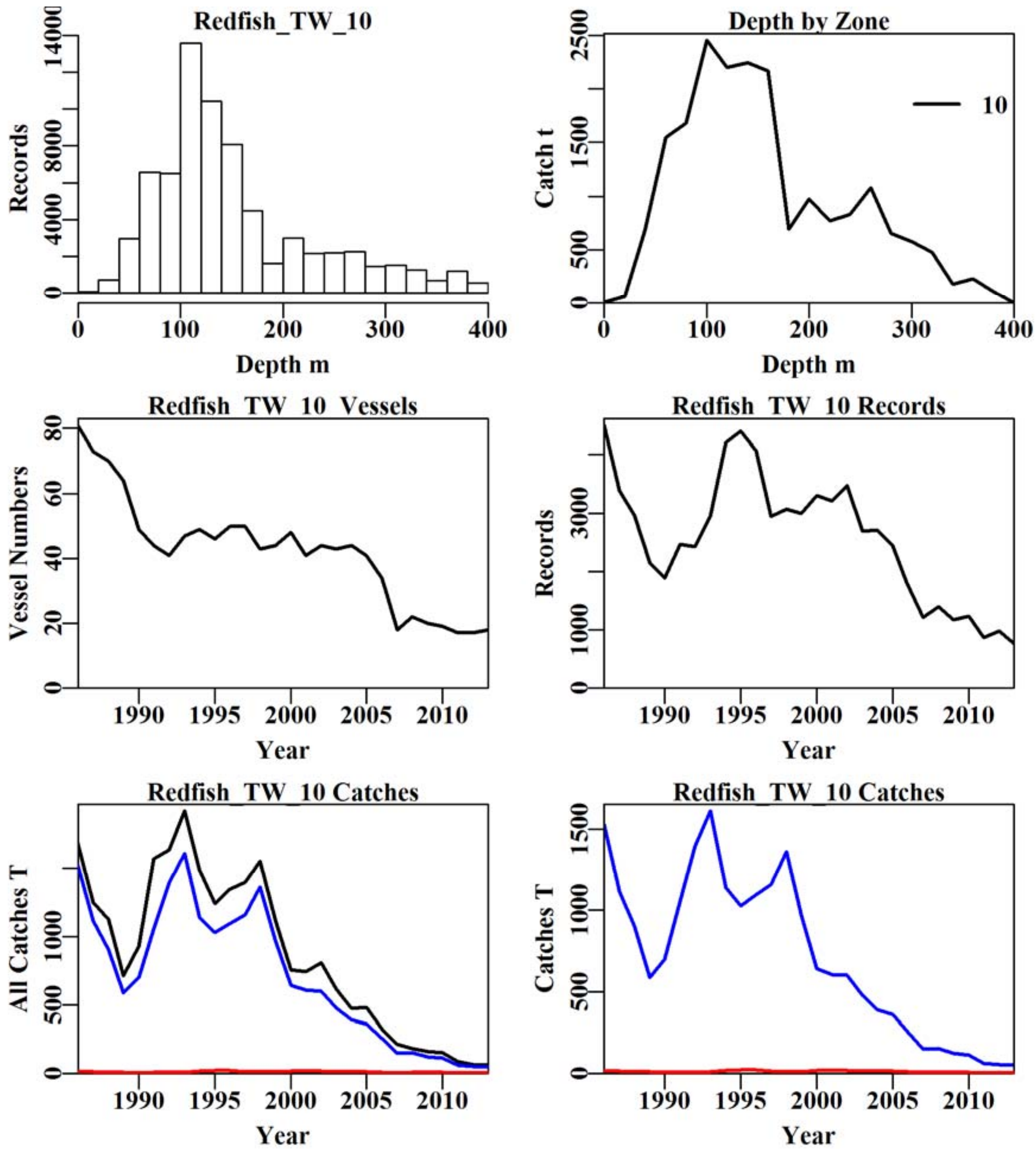


Figure 13.41. Redfish from zone 10 in depths 0 – 400 m by Trawl. The top left plot depicts the depth distribution of shots containing Redfish from zone 10 in depths 0 – 400 m by Trawl. The top right plot depicts the catch distribution by depth from zone 10. The middle left plot depicts the number of vessels through time and middle right plot contains the number of records used in analysis. The bottom left plot contains Redfish catches (top black line: total catches, middle blue line: catches used in the analysis; bottom red line: catches < 30 kg) and bottom right plot contains Redfish catches (blue line: catches used in the analysis; red line: catches < 30 kg).

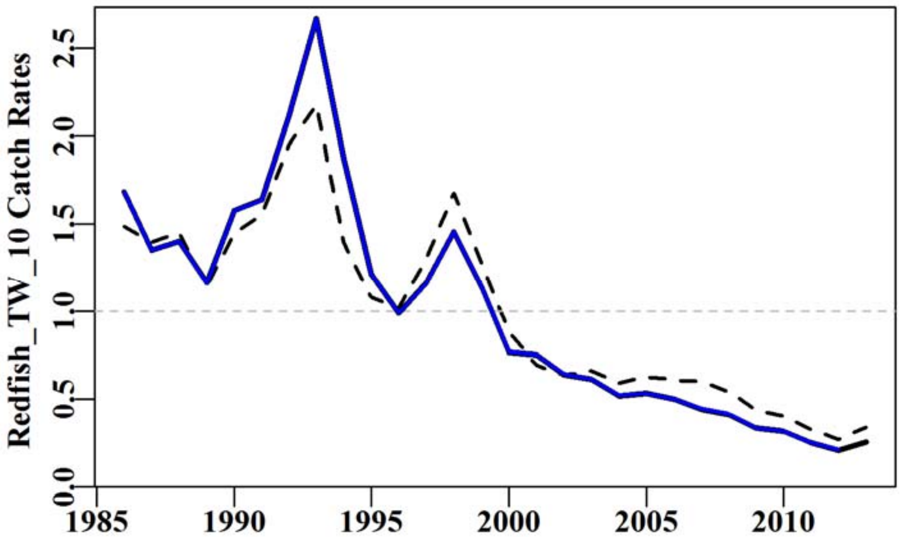


Figure 13.42. Redfish from zone 10 in depths 0 – 400 m by Trawl. The dashed black line represents the geometric mean catch rate and the solid black line the standardized catch rates (relative to the mean of the standardized catch rates). The blue line is last year's optimum standardization.

Table 13.38. 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:Month
Model 7	LnCE~Year+Vessel+DepCat+DayNight+Month+Month:DepCat
Model 8	LnCE~Year+Vessel+DepCat+DayNight+Month+DayNight:DepCat

Table 13.39. Redfish from zone 10 in depths 0 – 400 m by Trawl. Model selection criteria include the Akaike Information Criterion (AIC), residual sum of squares (RSS), model sum of squares (MSS), number of usable observations (Nobs), number of parameters (Npars), adjusted R^2 (adj_R^2) and the change in adjusted R^2 (%Change). The optimum model was Model 7 (Month:DepCat). Depth category: DepC; DayNight: DN.

	Year	Vessel	DepC	DN	Month	DN:Month	Month:DepC	DN:DepC
AIC	75548	67497	62564	61976	61482	61350	60225	60689
RSS	205492	182919	170537	169123	167903	167438	163954	165766
MSS	16408	38980	51363	52776	53997	54462	57946	56133
Nobs	71668	71668	71284	71284	71284	71284	71284	71284
Npars	28	172	192	195	206	239	426	266
adj_R^2	7.359	17.370	22.940	23.576	24.116	24.291	25.671	25.018
%Change	0.000	10.010	5.571	0.636	0.540	0.175	1.380	-0.653

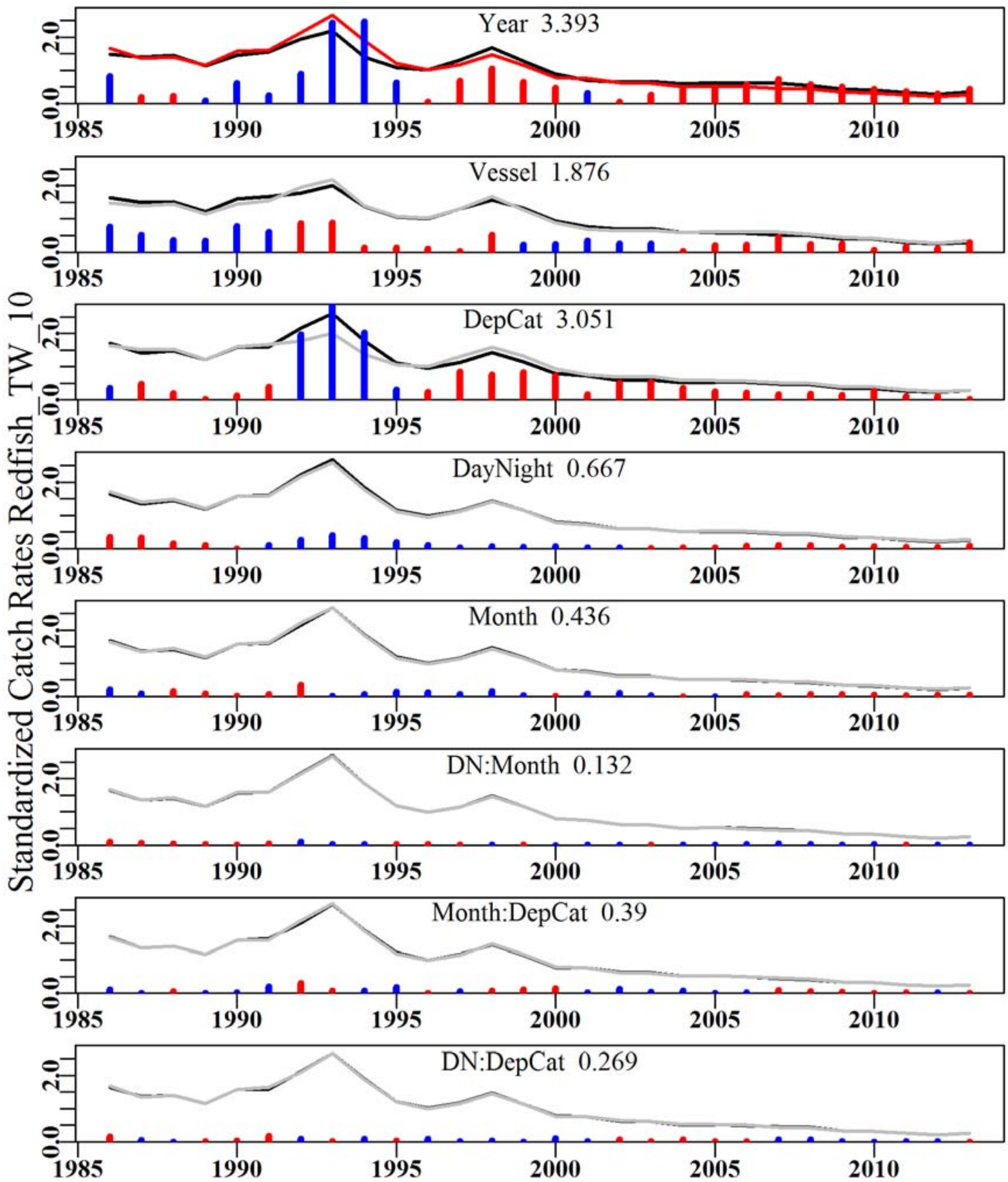


Figure 13.43. The relative influence of each factor used on the final trend in the optimal standardization for Redfish in Zone 10. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by the vertical bars with blue bars indicating the optimum model is higher than the geometric mean and red bars indicating it is lower. The top graph bars are the sum of all the bars in the graphs below. The graphs for individual factors are cumulative. Thus the second graph has the geometric mean (grey line) and the effect of adding Year + factor2 (Model 2). In the third graph, the grey line represents Model 2 and the black line the effect of adding factor3 to the model. The remaining graphs continue in the same cumulative manner except for the interaction terms which are added singularly to the final single factor model.

13.19 Redfish Z20 (RED – 37258003 – *Centroberyx affinis*)

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

Table 13.40. Redfish from zone 20 in depths 0 – 400 m by Trawl. Total catch (TotCatch; t) is the total reported in the database, number of records used in the analysis (Records), reported catch (CatchT; t) in the area and depth used in the analysis and number of vessels used in the analysis (Vessels). GeoMean is the geometric mean of catch rates (kg/hr). The optimum model is Month:DepC and standard deviation (StDev) relates to the data in the optimum model.

Year	TotCatch	Records	CatchT	Vessels	GeoMean	Month:DepC	StDev
1986	1687.4710	838	69.6480	34	12.7888	1.3084	0.0000
1987	1252.6580	548	70.5670	28	16.3056	1.6301	0.0867
1988	1125.4920	1008	174.6710	35	22.5742	2.3040	0.0785
1989	714.3160	567	57.4900	32	13.8221	1.4072	0.0881
1990	931.3700	699	95.0900	34	16.4273	1.6406	0.0864
1991	1570.6070	886	181.3970	27	20.9240	2.0394	0.0852
1992	1636.6870	691	100.1490	25	18.2135	1.6735	0.0902
1993	1921.3470	836	175.4860	25	23.8774	2.0577	0.0871
1994	1487.7170	1291	212.8480	26	22.1556	1.9208	0.0820
1995	1240.6170	1316	169.0790	24	14.7891	1.2063	0.0806
1996	1344.0490	1751	210.9190	26	11.8255	1.2387	0.0789
1997	1397.3280	1456	196.3320	28	10.9003	1.0048	0.0812
1998	1553.7182	1237	164.6420	24	11.9357	1.0601	0.0822
1999	1116.4030	947	122.4330	25	9.4628	0.9228	0.0853
2000	758.2751	1364	92.9880	27	5.0564	0.6041	0.0825
2001	742.2683	1345	113.4560	24	5.9658	0.6162	0.0831
2002	807.1325	1725	172.1645	24	6.7628	0.7098	0.0819
2003	615.5584	1428	76.9605	26	4.5142	0.4566	0.0831
2004	475.2044	1248	59.2120	22	4.2622	0.4670	0.0855
2005	483.5160	1353	92.2090	20	5.5759	0.5928	0.0841
2006	325.4821	821	46.4690	21	4.7612	0.5194	0.0896
2007	216.2794	673	59.7010	11	5.6299	0.5988	0.0936
2008	183.7567	536	24.5053	17	4.1887	0.4785	0.0983
2009	160.5248	448	30.5270	12	4.9795	0.5004	0.1019
2010	152.8285	644	34.6856	15	4.4782	0.4446	0.0966
2011	87.3052	538	20.3087	11	2.6875	0.2639	0.0992
2012	66.4453	381	7.5520	11	1.5820	0.1378	0.1071
2013	62.6620	367	8.8760	10	2.1568	0.1957	0.1100

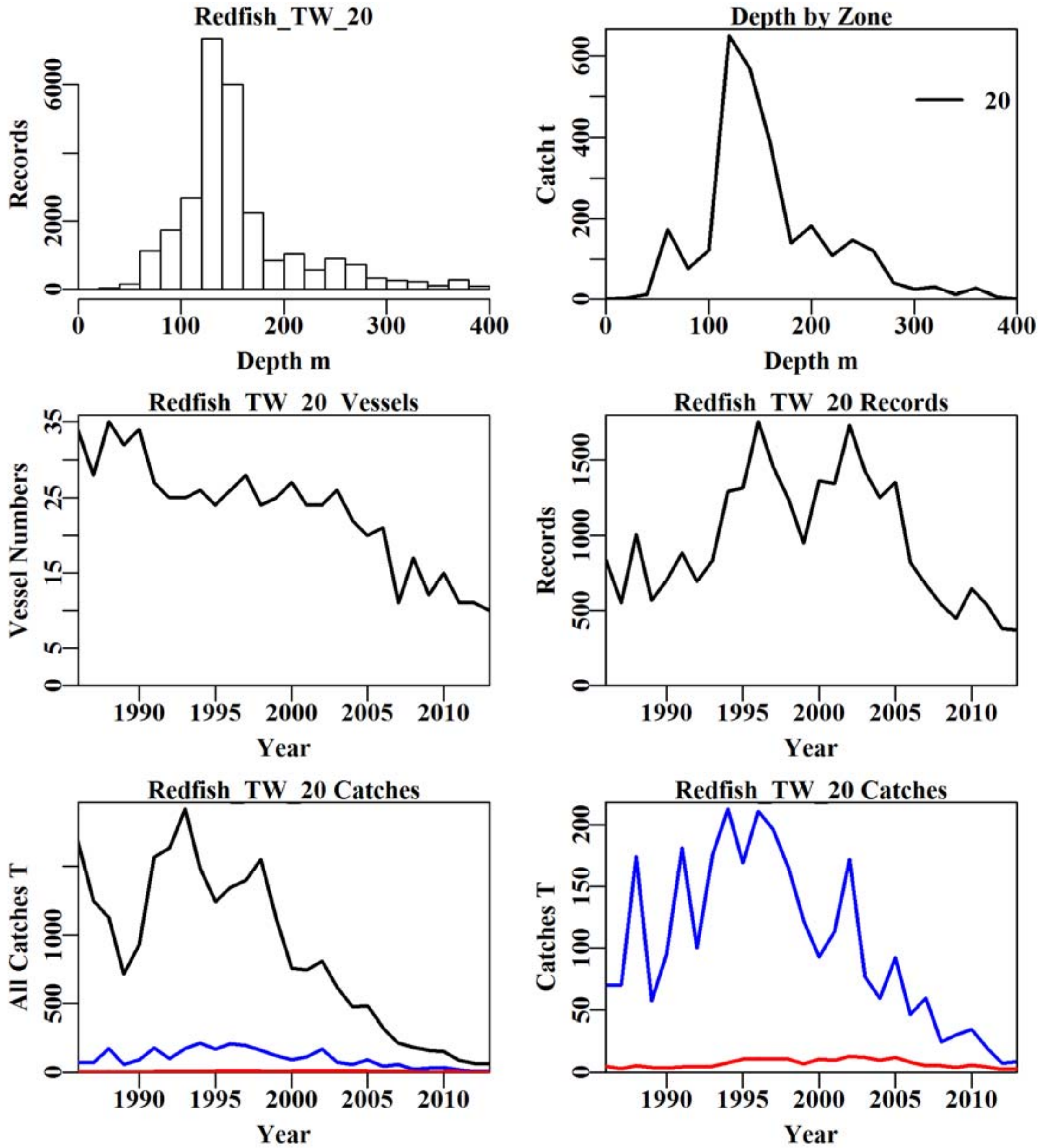


Figure 13.44. Redfish from zone 20 in depths 0 – 400 m by Trawl. The top left plot depicts the depth distribution of shots containing Redfish from zone 20 in depths 0 – 400 m by Trawl. The top right plot depicts the catch distribution by depth from zone 10. The middle left plot depicts the number of vessels through time and middle right plot contains the number of records used in analysis. The bottom left plot contains Redfish catches (top black line: total catches, middle blue line: catches used in the analysis; bottom red line: catches < 30 kg) and bottom right plot contains Redfish catches (blue line: catches used in the analysis; red line: catches < 30 kg).

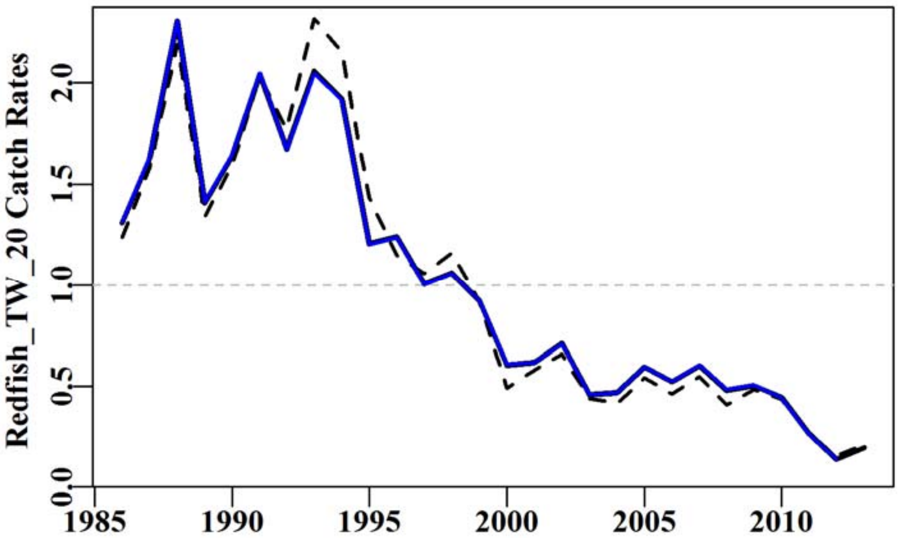


Figure 13.45. Redfish from zone 20 in depths 0 – 400 m by Trawl. The dashed black line represents the geometric mean catch rate and the solid black line the standardized catch rates (relative to the mean of the standardized catch rates). The blue line is last year's optimum standardization.

Table 13.41. Redfish from zone 20 in depths 0 – 400 m by Trawl. Statistical model structures used in this analysis. DepCat is a series of 20 metre depth categories.

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

Table 13.42. Redfish from zone 20 in depths 0 – 400 m by Trawl. Model selection criteria include the Akaike Information Criterion (AIC), residual sum of squares (RSS), model sum of squares (MSS), number of usable observations (Nobs), number of parameters (Npars), adjusted R^2 (adj_R^2) and the change in adjusted R^2 (%Change). The optimum was model Month:DepCat. Depth category: DepC; DayNight: DN.

	Year	Vessel	DepCat	Mth	DayNight	DN:Mth	Mth:DepCat	DN:DepCat
AIC	24841	21451	19723	19291	19258	19221	19018	19140
RSS	67602	59147	55300	54371	54292	54083	52931	53810
MSS	11360	19815	23662	24591	24670	24879	26031	25151
Nobs	26942	26942	26786	26786	26786	26786	26786	26786
Npars	28	133	153	164	167	200	387	227
adj_R^2	14.301	24.726	29.567	30.721	30.814	30.995	31.986	31.273
%Change	0.000	10.425	4.841	1.154	0.093	0.181	0.991	-0.713

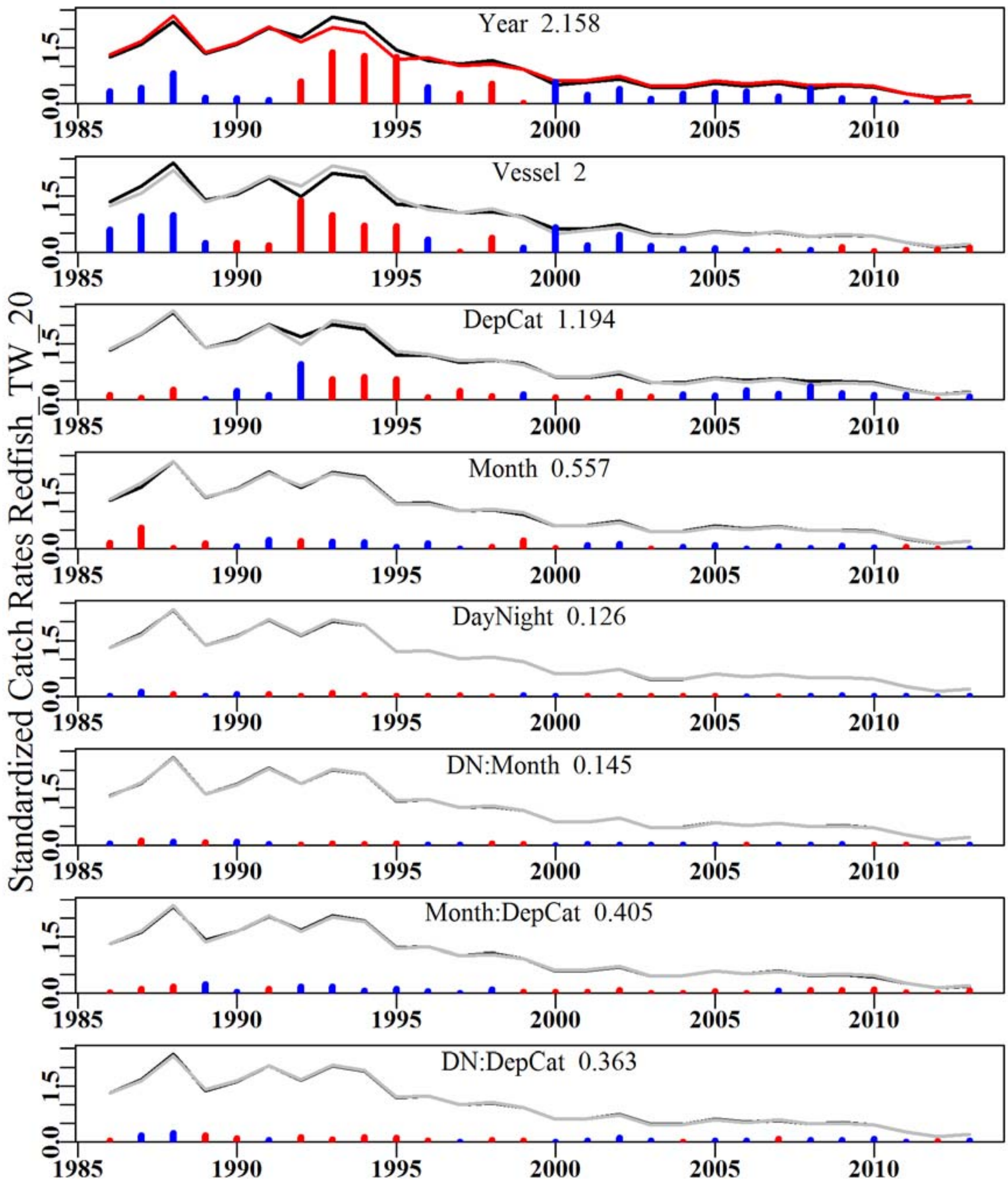


Figure 13.46. The relative influence of each factor used on the final trend in the optimal standardization for Redfish in zone 20. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by the vertical bars with blue bars indicating the optimum model is higher than the geometric mean and red bars indicating it is lower. The top graph bars are the sum of all the bars in the graphs below. The graphs for individual factors are cumulative. Thus the second graph has the geometric mean (grey line) and the effect of adding Year + factor2 (Model 2). In the third graph, the grey line represents Model 2 and the black line the effect of adding factor3 to the model. The remaining graphs continue in the same cumulative manner except for the interaction terms which are added singularly to the final single factor model.

13.20 Redfish Z10 at -36° (RED – 37258003 – C. affinis)

Trawl data selected for analysis corresponded to records from zone 10 from depths less than 400 m. Redfish data split on the -36° line rather than the usual 10:20 boundary.

Table 13.43. Redfish from zone 10 in depths 0 – 400 m by Trawl; data split on the -36° line. Total catch (TotCatch; t) is the total reported in the database, number of records used in the analysis (Records), reported catch (CatchT; t) in the area and depth used in the analysis and number of vessels used in the analysis (Vessels). GeoMean is the geometric mean of catch rates (kg/hr). The optimum model is Month:DepC and standard deviation (StDev) relates to the data in the optimum model.

Year	TotCatch	Records	CatchT	Vessels	GeoMean	Month:DepC	StDev
1986	1687.471	3007	1084.030	53	40.3993	1.4945	0.0000
1987	1247.550	2641	881.694	53	37.6349	1.2929	0.0439
1988	1125.467	1894	618.488	43	35.5572	1.2308	0.0485
1989	694.060	1479	472.353	40	33.4848	1.1858	0.0531
1990	931.360	1045	508.143	32	54.3338	2.1413	0.0596
1991	1414.081	1469	685.629	29	45.4641	1.9211	0.0545
1992	1624.316	1474	1079.021	24	65.0488	1.8457	0.0545
1993	1911.212	2272	1179.243	30	55.4399	2.1773	0.0485
1994	1486.623	2753	814.549	27	34.1313	1.5607	0.0464
1995	1240.437	2722	783.886	29	31.4159	1.1586	0.0464
1996	1342.798	2367	774.742	29	29.2967	0.9944	0.0480
1997	1397.191	1836	864.665	36	34.8464	1.2061	0.0516
1998	1553.528	1782	931.317	28	52.4234	1.5807	0.0517
1999	1116.156	1706	677.918	25	42.4228	1.3299	0.0516
2000	757.894	1691	378.748	27	29.1897	0.7803	0.0521
2001	739.597	1717	398.322	26	26.7522	0.8755	0.0515
2002	802.192	1757	444.747	25	30.2628	0.8694	0.0517
2003	614.471	1513	353.100	23	26.5630	0.7801	0.0539
2004	473.712	1729	302.539	29	22.2318	0.6671	0.0518
2005	483.361	1465	247.921	22	19.9675	0.5543	0.0546
2006	324.367	1198	176.679	19	17.4966	0.5160	0.0580
2007	215.824	765	90.061	11	16.1503	0.3407	0.0694
2008	183.757	868	98.353	14	15.5593	0.3584	0.0665
2009	160.487	652	70.601	13	12.4802	0.2710	0.0729
2010	152.674	650	71.638	13	12.9328	0.2830	0.0726
2011	87.271	445	32.163	13	9.9648	0.2053	0.0847
2012	66.439	573	29.391	13	7.5770	0.1639	0.0768
2013	62.655	538	35.423	12	9.3363	0.2151	0.0781

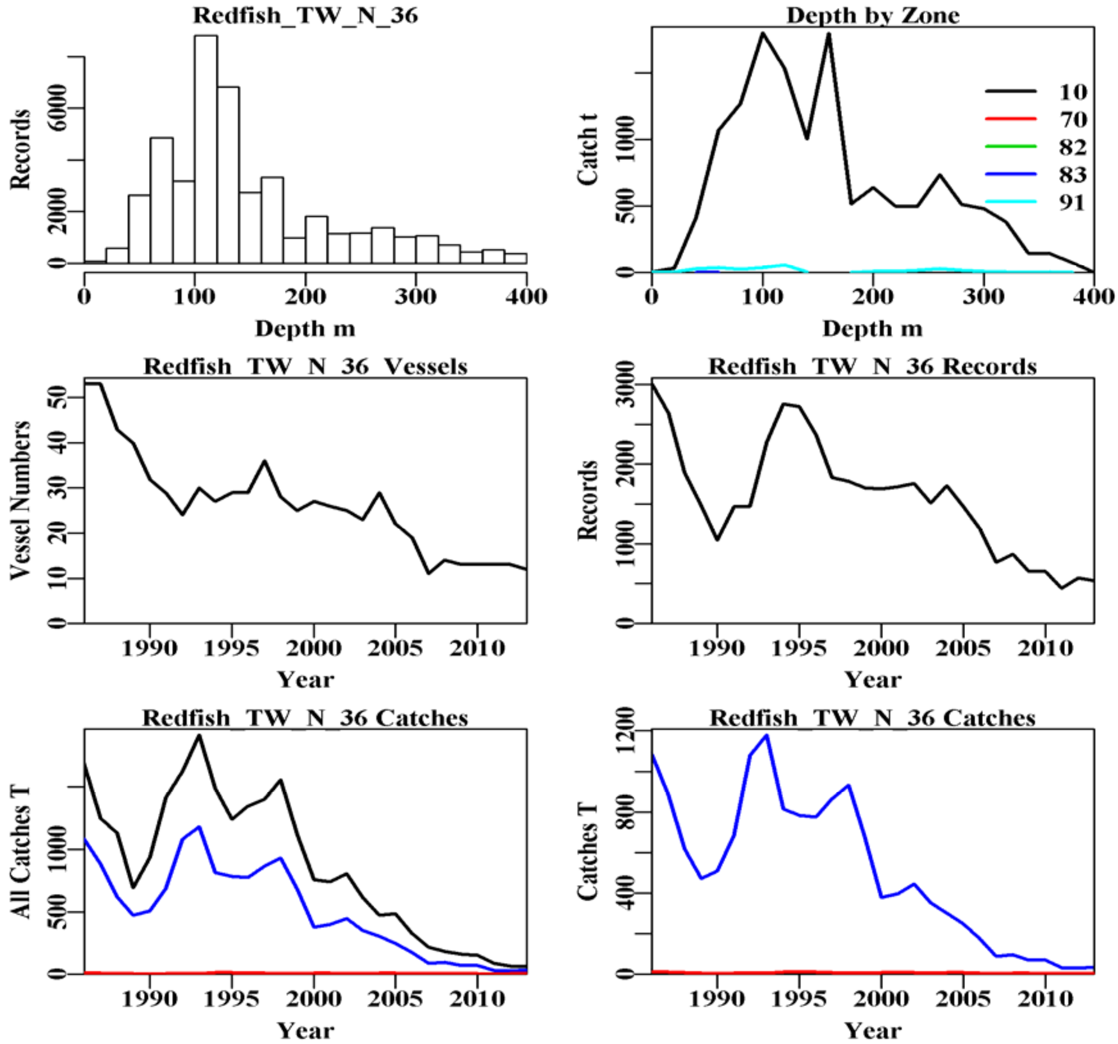


Figure 13.47. Redfish from zone 10 in depths 0 – 400 m by Trawl; data split on the -36° line. The top left plot depicts the depth distribution of shots containing Redfish from zone 10 in depths 0 – 400 m by Trawl. The top right plot depicts the catch distribution by depth from zone 10. The middle left plot depicts the number of vessels through time and middle right plot contains the number of records used in analysis. The bottom left plot contains Redfish catches (top black line: total catches, middle blue line: catches used in the analysis; bottom red line: catches < 30 kg) and bottom right plot contains Redfish catches (blue line: catches used in the analysis; red line: catches < 30 kg).

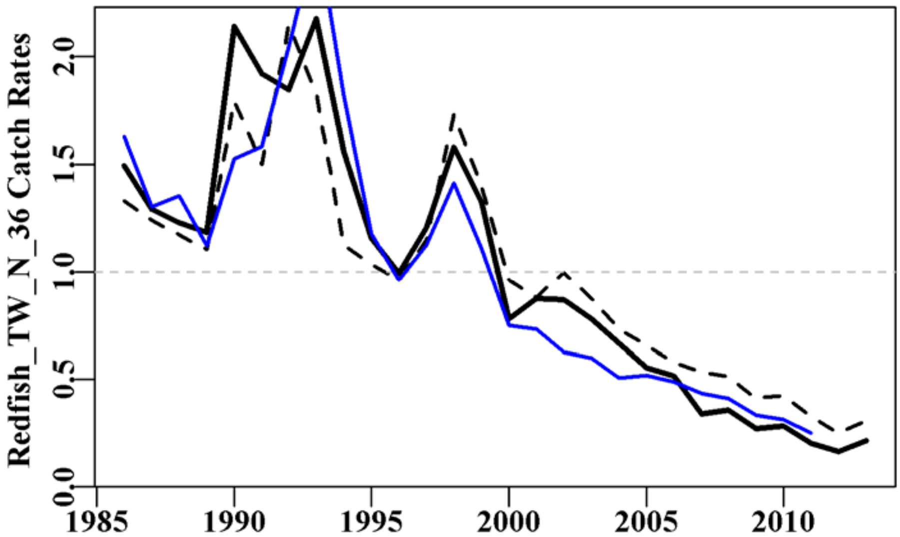


Figure 13.48. Redfish from zone 10 in depths 0 – 400 m by Trawl; data split on the -36° line. The dashed black line represents the geometric mean catch rate and the solid black line the standardized catch rates (relative to the mean of the standardized catch rates). The blue line is last year's standardization, which was for Zone 10 and not the -36° line, illustrating the difference.

Table 13.44. 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:Month
Model 7	LnCE~Year+Vessel+DepCat+DayNight+Month+Month:DepCat
Model 8	LnCE~Year+Vessel+DepCat+DayNight+Month+DayNight:DepCat

Table 13.45. Redfish from zone 10 in depths 0 – 400 m by Trawl. Model selection criteria include the Akaike Information Criterion (AIC), residual sum of squares (RSS), model sum of squares (MSS), number of usable observations (Nobs), number of parameters (Npars), adjusted R^2 (adj_R^2) and the change in adjusted R^2 (%Change). The optimum model was Model 7 (Month:DepC). Depth category: DepC; DayNight: DN.

	Year	Vessel	DepC	DN	Month	DN:Month	Month:DepC	DN:DepC
AIC	48324	42071	39704	39143	38775	38653	37665	38096
RSS	131786	113847	107714	106326	105382	104929	101710	103474
MSS	8399	26337	32471	33859	34802	35255	38474	36711
Nobs	44008	44008	43712	43712	43712	43712	43712	43712
Npars	28	121	141	144	155	188	375	215
adj_R^2	5.934	18.565	22.916	23.904	24.560	24.828	26.819	25.824
%Change	5.934	12.632	4.350	0.988	0.656	0.267	2.259	1.264

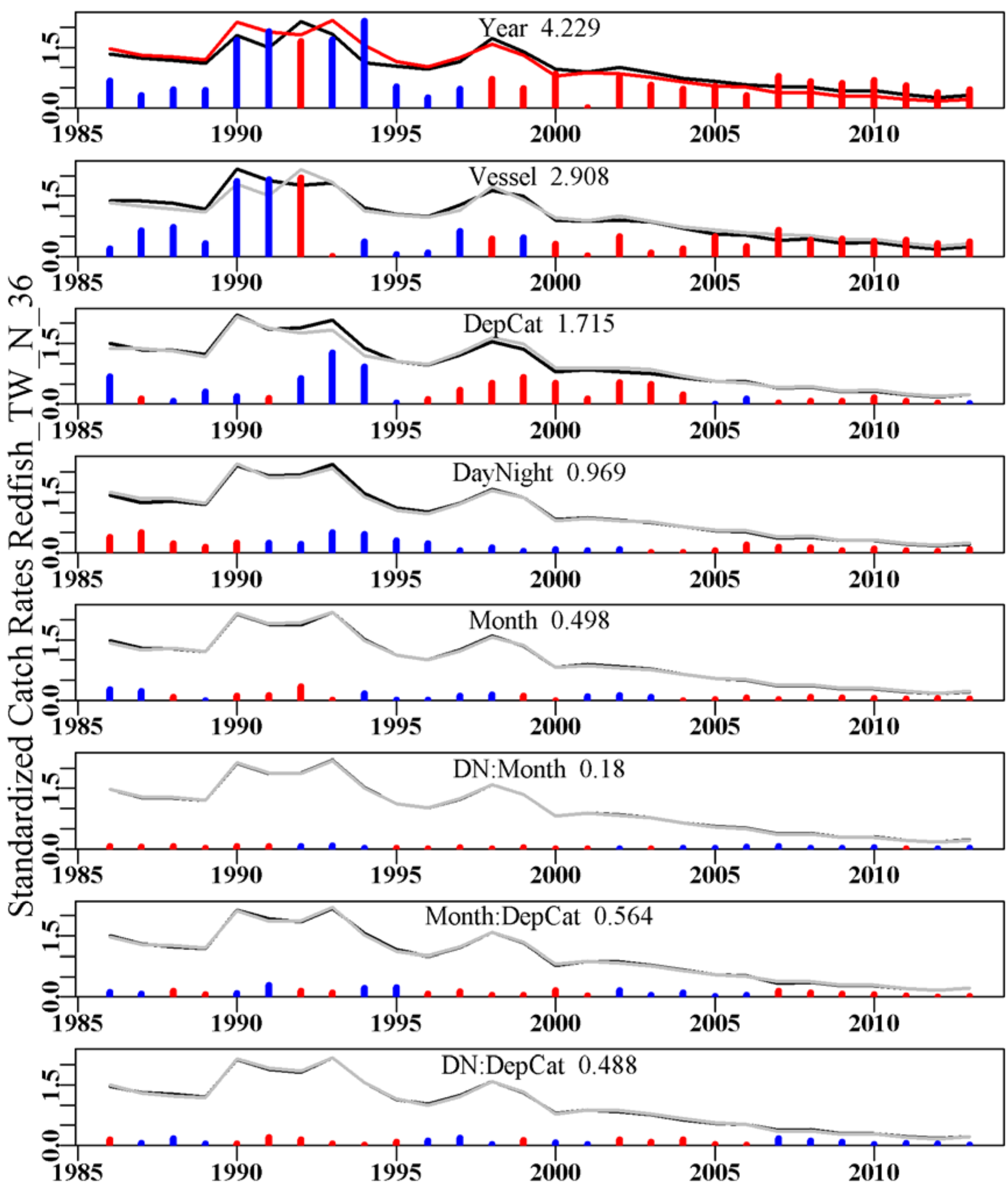


Figure 13.49. The relative influence of each factor used on the final trend in the optimal standardization for Redfish in Zone 10; data split on the -36° line. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by the vertical bars with blue bars indicating the optimum model is higher than the geometric mean and red bars indicating it is lower. The top graph bars are the sum of all the bars in the graphs below. The graphs for individual factors are cumulative. Thus the second graph has the geometric mean (grey line) and the effect of adding Year + factor2 (Model 2). In the third graph, the grey line represents Model 2 and the black line the effect of adding factor3 to the model. The remaining graphs continue in the same cumulative manner except for the interaction terms which are added singularly to the final single factor model.

13.21 Redfish Z20 at -36° (RED – 37258003 – C. affinis)

Trawl data selected for analysis corresponded to records from zone 20 and depths less than 400 m. Redfish data split on the -36° line rather than the usual 10:20 boundary.

Table 13.46. Redfish from zone 20 in depths 0 – 400 m by Trawl; data split on the -36° line. Total catch (TotCatch; t) is the total reported in the database, number of records used in the analysis (Records), reported catch (CatchT; t) in the area and depth used in the analysis and number of vessels used in the analysis (Vessels). GeoMean is the geometric mean of catch rates (kg/hr). The optimum model is Month:DepC and standard deviation (StDev) relates to the data in the optimum model.

Year	TotCatch	Records	CatchT	Vessels	GeoMean	Month:DepC	StDev
1986	1687.471	2673	573.524	66	23.3186	1.6380	0.0000
1987	1247.550	1453	336.935	62	22.8698	1.4071	0.0519
1988	1125.467	2249	480.299	65	29.2183	1.8540	0.0477
1989	694.060	1323	189.450	55	17.7668	1.0787	0.0544
1990	931.360	1619	320.916	48	21.0375	1.3713	0.0533
1991	1414.081	2088	583.783	51	25.5297	1.6561	0.0513
1992	1624.316	1788	446.193	39	25.7346	1.9448	0.0542
1993	1911.212	2007	695.589	42	31.1788	2.2827	0.0527
1994	1486.623	3137	636.588	46	29.1988	2.0803	0.0488
1995	1240.437	3208	433.517	45	18.2176	1.1736	0.0476
1996	1342.798	3620	545.635	46	15.8286	1.1142	0.0471
1997	1397.191	2707	511.144	46	16.7838	1.0908	0.0495
1998	1553.528	2584	601.178	37	19.5996	1.2656	0.0496
1999	1116.156	2272	419.508	38	15.8766	1.0385	0.0508
2000	757.894	3029	360.094	43	9.9087	0.7303	0.0494
2001	739.597	2907	326.853	38	8.2710	0.6676	0.0498
2002	802.192	3513	334.880	37	7.6842	0.5916	0.0490
2003	614.471	2666	210.385	35	6.4281	0.4864	0.0505
2004	473.712	2409	162.313	39	5.8755	0.4590	0.0519
2005	483.361	2526	221.368	37	7.9011	0.5794	0.0511
2006	324.367	1630	142.290	30	7.4909	0.5751	0.0557
2007	215.824	1142	121.217	18	8.2045	0.6577	0.0614
2008	183.757	1096	82.426	20	6.9265	0.5382	0.0624
2009	160.487	989	84.387	16	7.2249	0.5399	0.0640
2010	152.674	1246	77.452	20	5.9922	0.4502	0.0604
2011	87.271	970	52.051	17	4.1437	0.3118	0.0640
2012	66.439	794	33.304	15	3.2081	0.2128	0.0678
2013	62.655	540	22.735	12	3.2682	0.2043	0.0765

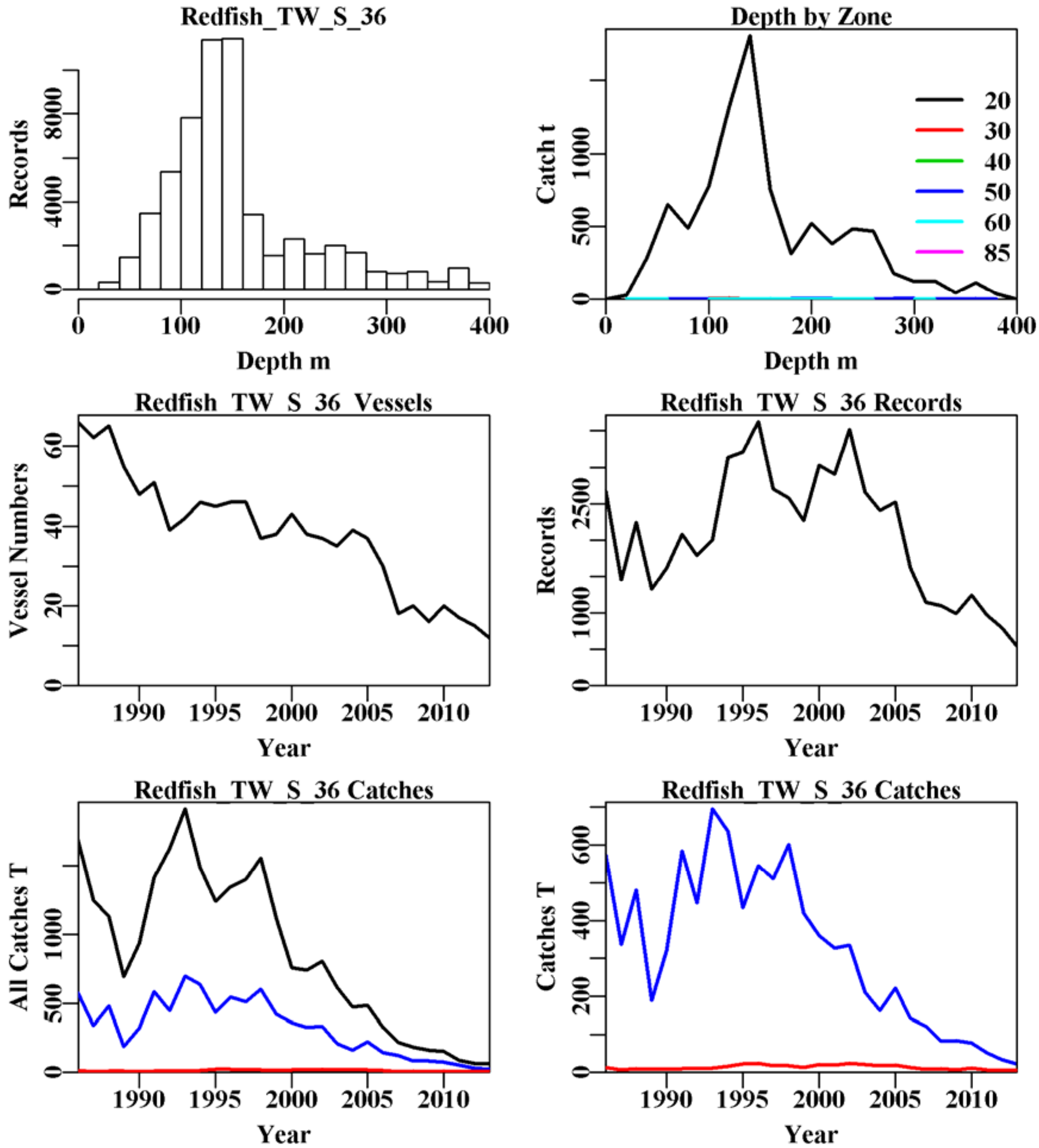


Figure 13.50. Redfish from zone 20 in depths 0 – 400 m by Trawl; data split on the -36° line. The top left plot depicts the depth distribution of shots containing Redfish from zone 20 in depths 0 – 400 m by Trawl. The top right plot depicts the catch distribution by depth from zone 10. The middle left plot depicts the number of vessels through time and middle right plot contains the number of records used in analysis. The bottom left plot contains Redfish catches (top black line: total catches, middle blue line: catches used in the analysis; bottom red line: catches < 30 kg) and bottom right plot contains Redfish catches (blue line: catches used in the analysis; red line: catches < 30 kg).

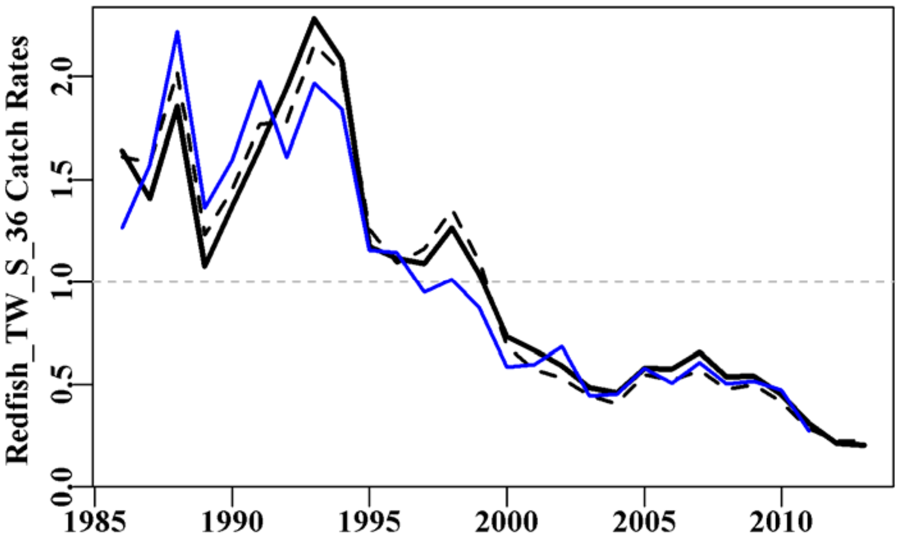


Figure 13.51. Redfish from zone 20 in depths 0 – 400 m by Trawl; data split on the -36° line. The dashed black line represents the geometric mean catch rate and the solid black line the standardized catch rates (relative to the mean of the standardized catch rates). The blue line is last year's standardization, which was for Zone 10 and not the -36° line, illustrating the difference.

Table 13.47. Redfish from zone 20 in depths 0 – 400 m by Trawl. Statistical model structures used in this analysis. DepCat is a series of 20 metre depth categories.

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

Table 13.48. Redfish from zone 20 in depths 0 – 400 m by Trawl. Model selection criteria include the Akaike Information Criterion (AIC), residual sum of squares (RSS), model sum of squares (MSS), number of usable observations (Nobs), number of parameters (Npars), adjusted R^2 (adj_R^2) and the change in adjusted R^2 (%Change). The optimum was model Mth:DepC. Depth category: DepC; DayNight: DN; Month: Mth.

	Year	Vessel	DepC	Mth	DN	DN:Mth	Mth:DepC	DN:DepC
AIC	56476	49979	45115	44608	44614	44521	43862	44190
RSS	153438	136466	125276	124137	124135	123796	121606	122975
MSS	21301	38273	49462	50602	50603	50943	53132	51763
Nobs	58185	58185	57867	57867	57867	57867	57867	57867
Npars	28	190	210	221	224	257	444	284
adj_R^2	12.149	21.649	28.047	28.688	28.685	28.839	29.870	29.277
%Change	12.149	9.499	6.398	0.641	-0.003	0.154	1.185	0.593

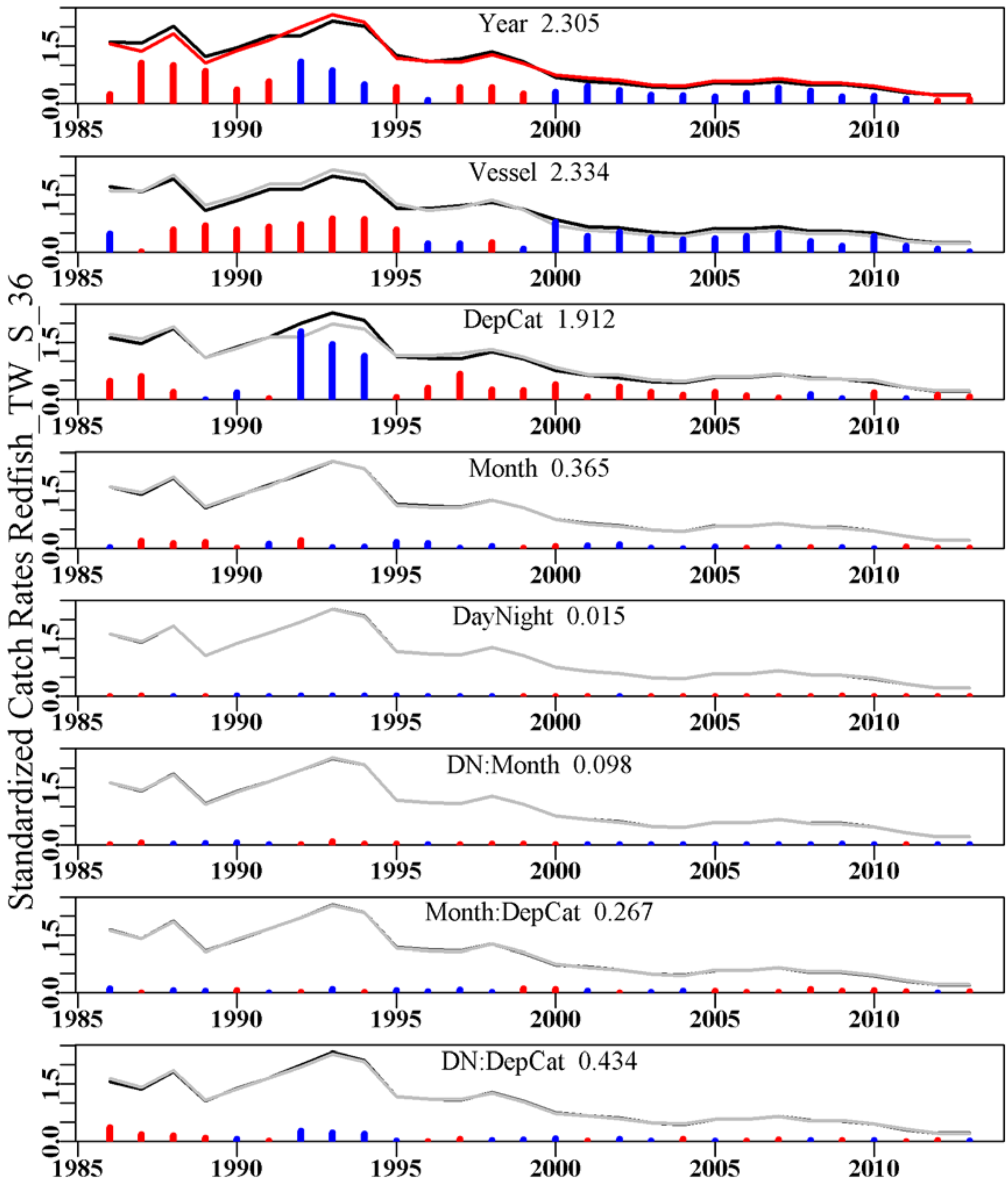


Figure 13.52. The relative influence of each factor used on the final trend in the optimal standardization for Redfish in zone 20. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by the vertical bars with blue bars indicating the optimum model is higher than the geometric mean and red bars indicating it is lower. The top graph bars are the sum of all the bars in the graphs below. The graphs for individual factors are cumulative. Thus the second graph has the geometric mean (grey line) and the effect of adding Year + factor2 (Model 2). In the third graph, the grey line represents Model 2 and the black line the effect of adding factor3 to the model. The remaining graphs continue in the same cumulative manner except for the interaction terms which are added singularly to the final single factor model.

13.22 Silver Trevally (TRE – 37337062 – Pseudocaranx dentex)

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

Table 13.49**.** Silver Trevally from zones 10 and 20 in depths 0 to 200 m, excluding data taken in State waters (Bateman's Bay MPA). Total catch (TotCatch; t) is the total reported in the database, number of records used in the analysis (Records), reported catch (CatchT; t) in the area and depth used in the analysis and number of vessels used in the analysis (Vessels). GeoMean is the geometric mean of catch rates (kg/hr). The optimum model is Zone:Month and standard deviation (StDev) relates to the data in the optimum model.

Year	TotCatch	Records	CatchT	Vessels	GeoMean	Zone:Month	StDev
1986	469.5080	1765	278.6280	74	17.0086	1.1562	0.0000
1987	198.4900	1090	116.3170	63	17.5072	1.3608	0.0597
1988	278.5410	1299	226.6200	52	23.7642	1.8028	0.0550
1989	376.1960	1838	278.0370	62	23.0657	1.9256	0.0504
1990	450.3910	1841	288.8090	52	23.2975	2.2880	0.0521
1991	340.6830	1909	213.9030	49	18.1137	2.0522	0.0525
1992	296.4930	1194	108.3660	44	12.0774	1.1813	0.0589
1993	377.6730	1262	132.8610	47	13.4863	1.2929	0.0579
1994	392.8280	1839	139.1540	46	9.4912	0.9895	0.0534
1995	413.4390	1570	136.6370	43	10.2789	1.1236	0.0554
1996	340.6160	1883	129.5360	47	7.5806	0.9096	0.0539
1997	328.8385	1450	88.4990	48	6.2012	0.8584	0.0576
1998	210.1360	1023	48.9720	40	5.2414	0.6227	0.0613
1999	166.0182	882	41.5680	39	4.9696	0.6242	0.0646
2000	154.7527	1020	43.6200	43	3.6777	0.4592	0.0618
2001	270.1751	1536	82.0845	43	4.1345	0.5372	0.0557
2002	232.7870	1474	67.8520	40	3.0864	0.4341	0.0574
2003	337.8967	1123	57.7278	45	3.3780	0.4271	0.0598
2004	458.0749	1344	84.3135	42	4.5318	0.5913	0.0582
2005	290.9402	673	59.5595	40	4.7971	0.5225	0.0695
2006	247.2843	493	48.8240	32	5.7178	0.7366	0.0769
2007	172.7180	462	47.1000	19	7.4420	0.8179	0.0798
2008	128.3861	818	69.6650	23	8.0833	0.8392	0.0662
2009	164.0519	836	94.1810	23	9.1902	0.8517	0.0655
2010	240.2269	966	135.4903	24	11.7046	1.0898	0.0636
2011	193.4736	862	139.3343	20	11.0895	0.9796	0.0656
2012	139.6903	665	88.0700	21	7.6670	0.6933	0.0706
2013	122.7757	508	72.1860	20	13.3759	0.8325	0.0760

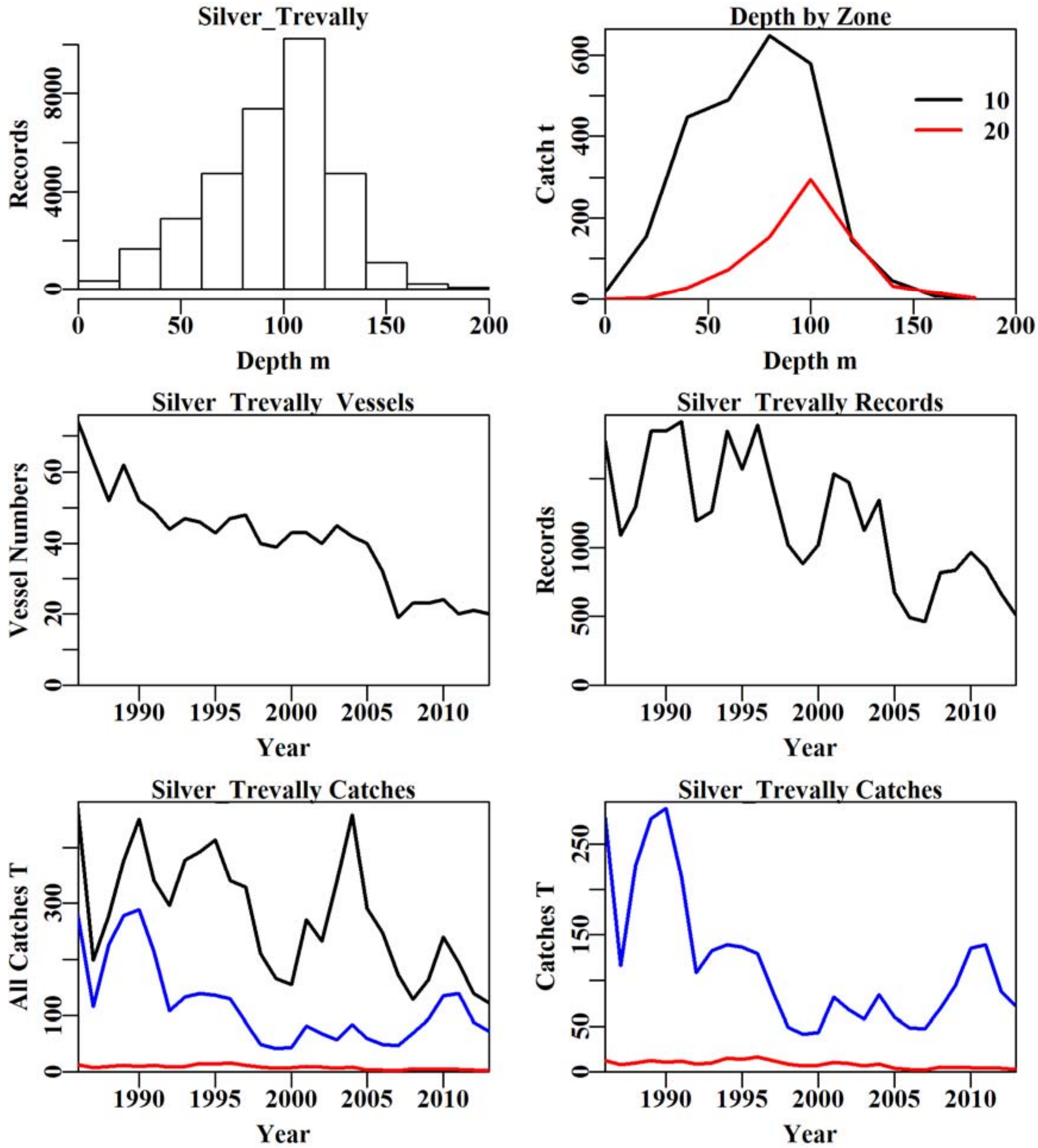


Figure 13.53**.** Silver Trevally from Zones 10 and 20 in depths 0 to 200 m, excluding data from State waters (Bateman's Bay MPA). The top left plot depicts the depth distribution of shots containing Silver Trevally from zones 10 and 20 in depths 0 to 200 m by Trawl, excluding data from State waters (Bateman's Bay MPA). The top right plot depicts the catch distribution by depth within zones 10 and 20 (20 is bottom red line). The middle left plot depicts the number of vessels through time and middle right plot contains the number of records used in analysis. The bottom left plot contains Silver Trevally catches (top black line: total catches, middle blue line: catches used in the analysis; bottom red line: catches < 30 kg) and bottom right plot contains Silver Trevally catches (blue line: catches used in the analysis; red line: catches < 30 kg).

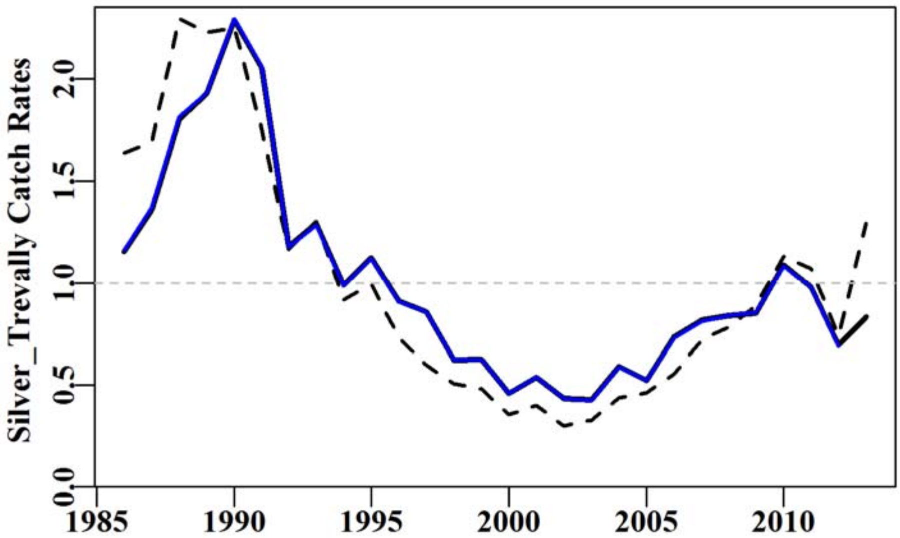


Figure 13.54. Silver Trevally from zones 10 and 20 in depths 0 to 200 m, excluding data taken in State waters (Bateman's Bay MPA). The dashed black line represents the geometric mean catch rate and the solid black line the standardized catch rates (relative to the mean of the standardized catch rates). The blue line corresponds to last year's standardized indices.

Table 13.50. 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 13.51. Silver Trevally from Zones 10 and 20 in depths 0 to 200 m, excluding data taken in State waters (Bateman's Bay MPA). Model selection criteria include the Akaike Information Criterion (AIC), residual sum of squares (RSS), model sum of squares (MSS), number of usable observations (Nobs), number of parameters (Npars), adjusted R^2 (adj_R^2) and the change in adjusted R^2 (%Change). The optimum model is Model 7 (Zone:Month). Depth category: DepC.

	Year	Vessel	DepC	Month	DayNight	Zone	Zone:Month	Zone:DepC
AIC	31387	24518	23504	22799	22419	22364	22286	22338
RSS	85375	68986	66754	65316	64567	64455	64263	64371
MSS	13559	29948	32180	33618	34367	34479	34671	34563
Nobs	33625	33625	33388	33388	33388	33388	33388	33388
Npars	28	177	186	197	200	201	212	210
adj_R^2	13.636	29.904	32.151	33.590	34.346	34.458	34.631	34.525
%Change	0.000	16.267	2.247	1.440	0.756	0.111	0.174	-0.106

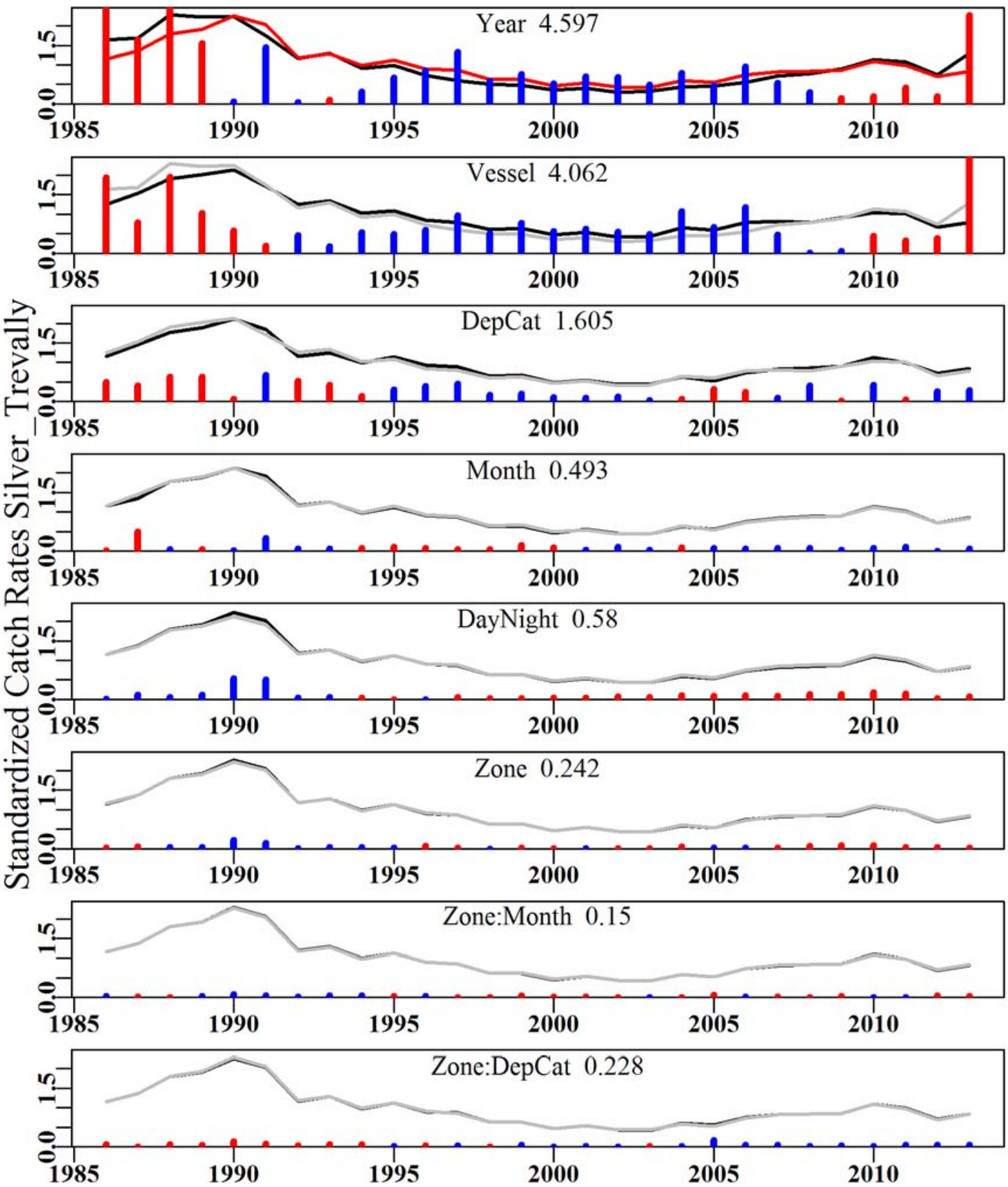


Figure 13.55**.** The relative influence of each factor used on the final trend in the optimal standardization for Silver Trevally in zones 10 and 20. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by the vertical bars with blue bars indicating the optimum model is higher than the geometric mean and red bars indicating it is lower. The top graph bars are the sum of all the bars in the graphs below. The graphs for individual factors are cumulative. Thus the second graph has the geometric mean (grey line) and the effect of adding Year + factor2 (Model 2). In the third graph, the grey line represents Model 2 and the black line the effect of adding factor3 to the model. The remaining graphs continue in the same cumulative manner except for the interaction terms which are added singularly to the final single factor model.

13.22.1 *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 13.52**.** Silver Trevally from Zones 10 and 20 in depths 0 to 200 m, including all data taken in State waters (Bateman's Bay MPA). Total catch (TotCatch; t) is the total reported in the database, number of records used in the analysis (Records), reported catch (CatchT; t) in the area and depth used in the analysis and number of vessels used in the analysis (Vessels). GeoMean is the geometric mean of catch rates (kg/hr). The optimum model is Zone:Month and standard deviation (StDev) relates to the data in the optimum model.

Year	TotCatch	Records	CatchT	Vessels	GeoMean	Zone:Month	StDev
1986	469.5080	1978	306.5040	74	17.5551	1.0451	0.0000
1987	198.4900	1260	135.0590	64	17.4271	1.2318	0.0573
1988	278.5410	1581	243.9060	56	20.1929	1.4180	0.0521
1989	376.1960	2194	332.4520	62	24.2894	1.7810	0.0483
1990	450.3910	2101	349.0320	53	24.1445	2.0366	0.0499
1991	340.6830	2221	251.1220	50	18.0221	1.8229	0.0500
1992	296.4930	1620	195.7720	44	13.4364	1.0399	0.0536
1993	377.6730	2280	282.0380	49	15.1230	1.1192	0.0497
1994	392.8280	3307	361.9670	48	13.0062	0.9518	0.0466
1995	413.4390	3352	380.1920	49	14.3268	1.0868	0.0463
1996	340.6160	3237	315.1980	54	10.8969	0.9843	0.0467
1997	328.8385	2869	298.1160	55	11.5325	0.9674	0.0479
1998	210.1360	2281	177.0570	46	9.4314	0.7371	0.0494
1999	166.0182	1859	115.3820	45	8.3770	0.7196	0.0518
2000	154.7527	2010	122.6370	49	6.0305	0.5552	0.0508
2001	270.1751	3219	226.3485	46	7.6285	0.6693	0.0465
2002	232.7870	2766	207.4740	44	5.9678	0.6273	0.0482
2003	337.8967	2761	281.9697	49	8.0171	0.6712	0.0478
2004	458.0749	3338	367.6270	45	10.6787	0.8211	0.0467
2005	290.9402	2324	242.1420	43	11.1271	0.7177	0.0500
2006	247.2843	1687	209.1645	39	13.2846	0.7795	0.0531
2007	172.7180	835	115.5430	21	11.8089	0.7703	0.0644
2008	128.3861	1065	95.8960	23	9.1077	0.8760	0.0602
2009	164.0519	1152	136.0260	23	10.5189	0.8699	0.0588
2010	240.2269	1264	191.9942	24	13.7770	1.1313	0.0577
2011	193.4736	1125	179.4593	20	12.5672	0.9760	0.0595
2012	139.6903	966	131.5530	21	11.0919	0.7701	0.0617
2013	122.7757	723	112.8740	20	16.1023	0.8236	0.0669

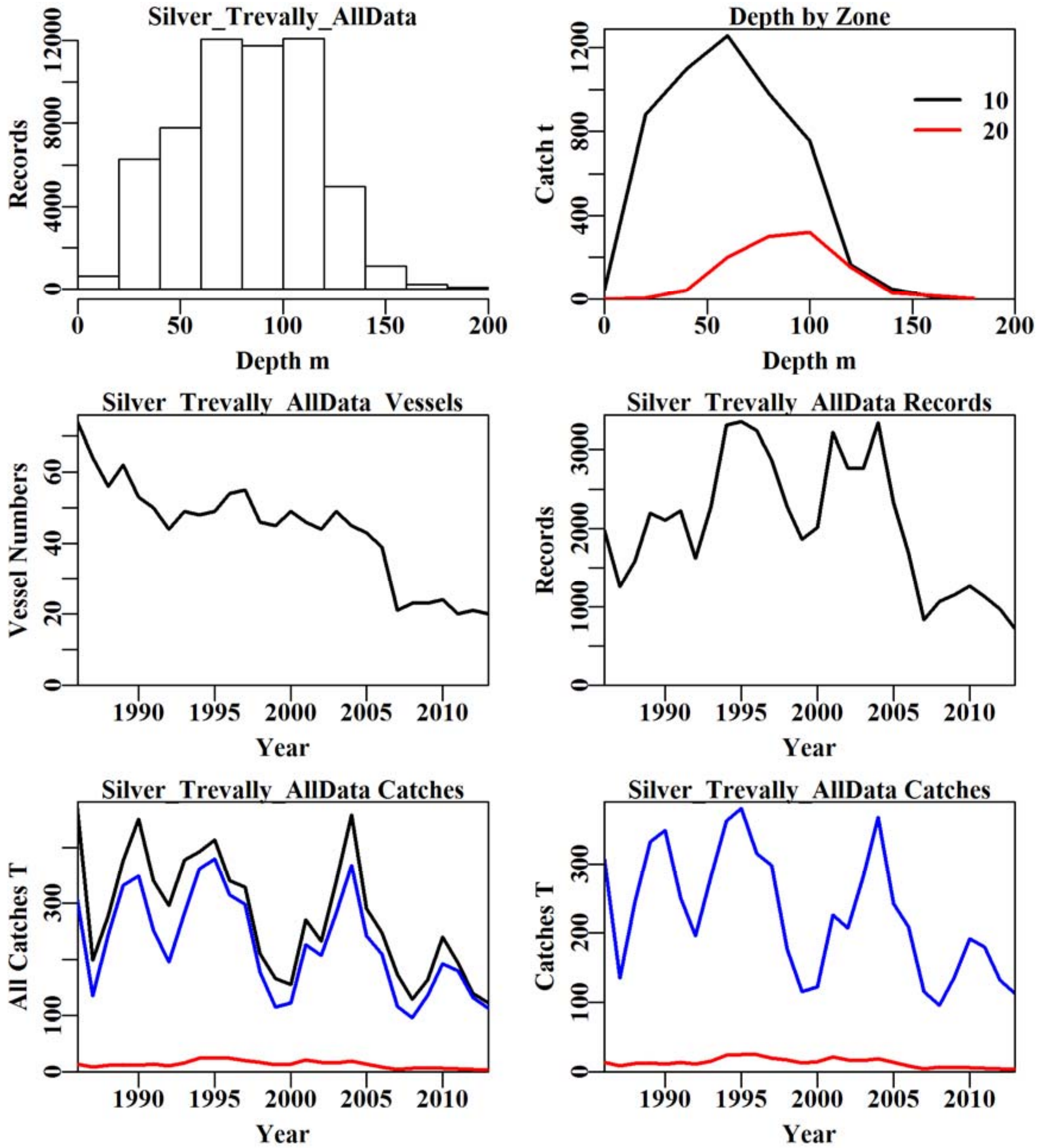


Figure 13.56. Silver Trevally from Zones 10 and 20 in depths 0 to 200 m, including all from State waters (Bateman's Bay MPA). The top left plot depicts the depth distribution of shots containing Silver Trevally from zones 10 and 20 in depths 0 to 200 m by Trawl, including data from State waters (Bateman's Bay MPA). The top right plot depicts the catch distribution by depth within zones 10 and 20 (20 is bottom red line). The middle left plot depicts the number of vessels through time and middle right plot contains the number of records used in analysis. The bottom left plot contains Silver Trevally catches (top black line: total catches, middle blue line: catches used in the analysis; bottom red line: catches < 30 kg) and bottom right plot contains Silver Trevally catches (blue line: catches used in the analysis; red line: catches < 30 kg).

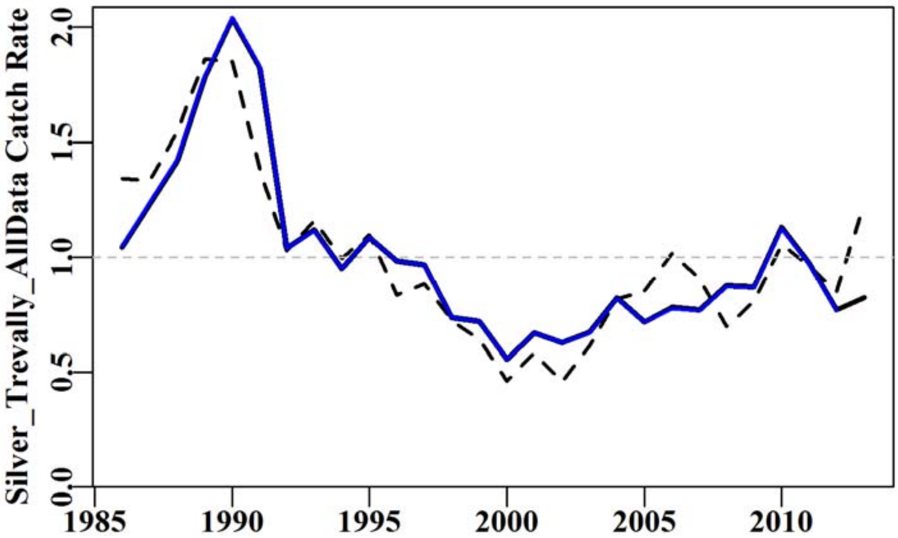


Figure 13.57. Silver Trevally from zones 10 and 20 in depths 0 to 200 m, including data from State waters (Bateman's Bay MPA). The dashed black line represents the geometric mean catch rate and the solid black line the standardized catch rates (relative to the mean of the standardized catch rates). The blue line corresponds to last year's standardized indices.

Table 13.53**.** Silver Trevally from zones 10 and 20 in depths 0 to 200 m, including data from State waters (Bateman's Bay MPA). Statistical model structures used in this analysis. DepCat is a series of 20 metre depth categories.

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

Table 13.54. Silver Trevally from Zones 10 and 20 in depths 0 to 200 m, excluding data taken in State waters (Bateman's Bay MPA). Model selection criteria include the Akaike Information Criterion (AIC), residual sum of squares (RSS), model sum of squares (MSS), number of usable observations (Nobs), number of parameters (Npars), adjusted R^2 (adj_R^2) and the change in adjusted R^2 (%Change). The optimum model is Model 7 (Zone:Month). Depth category: DepC.

	Year	Vessel	DepC	Month	DayNight	Zone	Zone:Mth	Zone:DepC
AIC	59994	46557	43021	42332	41713	41695	41575	41664
RSS	163087	128359	120413	118918	117620	117579	117285	117478
MSS	7731	42459	50405	51900	53198	53239	53533	53340
Nobs	57375	57375	56935	56935	56935	56935	56935	56935
Npars	28	179	188	199	202	203	214	212
adj_R^2	4.481	24.623	29.276	30.140	30.899	30.922	31.082	30.970
%Change	0.000	20.142	4.653	0.864	0.759	0.023	0.160	-0.111

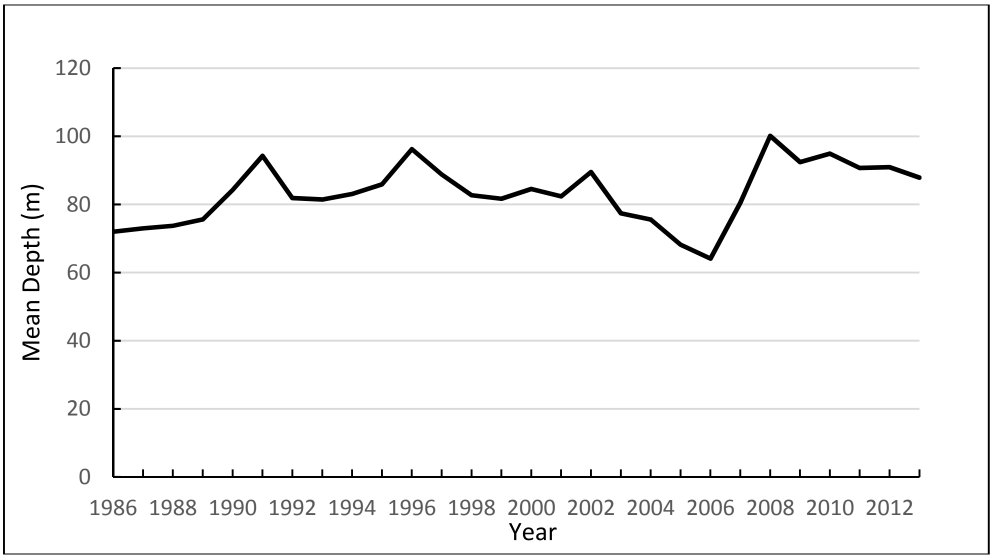


Figure 13.58**.** Average reported depth of trawling for Silver Trevally from Zones 10 and 20 in depths 0 to 200 m, including data from State waters (Bateman's Bay MPA). The effect of the introduction of the Bateman's Bay MPA in increasing the average depth fished is apparent from 2008 onwards.

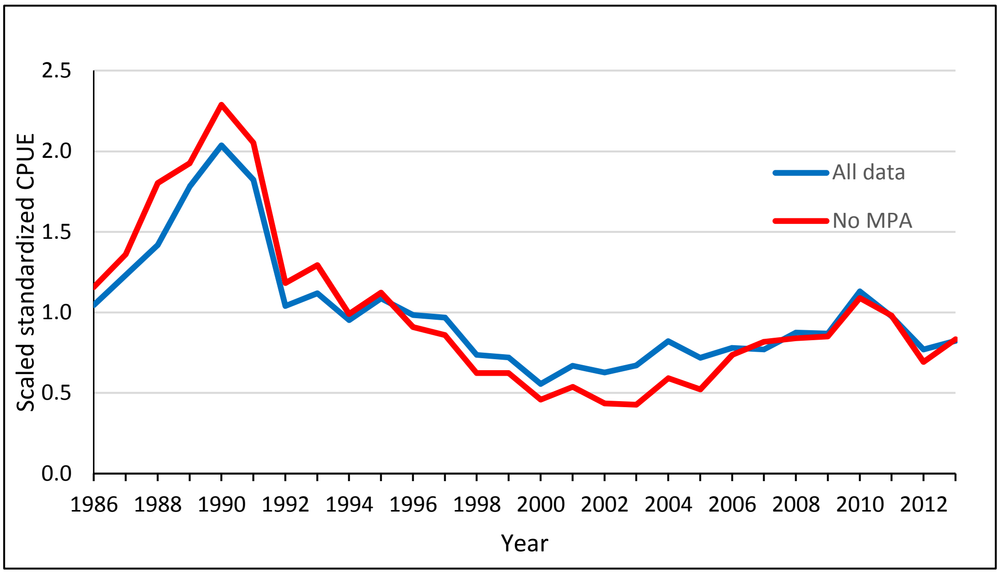


Figure 13.59**.** Comparison of the CPUE series with and without the data from inside the MPA. The All data series is less variable than the series that excludes data from the MPA.

13.23 Royal Red Prawn (PRR – 28714005 – Haliporoides sibogae)

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

Table 13.55**.** Royal Red Prawn from zone 10 in depths 200 – 700 m by Trawl. Total catch (TotCatch; t) is the total reported in the database, number of records used in the analysis (Records), reported catch (CatchT; t) in the area and depth used in the analysis and number of vessels used in the analysis (Vessels). GeoMean is the geometric mean of catch rates (kg/hr). The optimum model is Month:DepC and standard deviation (StDev) relates to the data in the optimum model.

Year	TotCatch	Records	CatchT	Vessels	GeoMean	Month:DepC	StDev
1986	277.7170	1592	231.8440	47	27.7627	0.6874	0.0000
1987	351.2940	1764	324.7160	47	41.9857	0.8754	0.0380
1988	362.5050	1395	344.4570	41	49.1496	0.9710	0.0410
1989	329.2540	1143	310.7600	39	45.8268	0.8281	0.0429
1990	337.1340	727	311.1180	25	95.1525	1.5532	0.0492
1991	334.1340	734	299.3700	29	79.4866	1.3805	0.0496
1992	166.8600	434	146.0810	19	70.3817	1.0322	0.0580
1993	298.7970	673	232.7740	21	68.5216	1.1867	0.0494
1994	359.8303	661	240.3630	26	77.7193	1.1245	0.0497
1995	335.5920	1070	252.9050	25	58.4998	0.8960	0.0436
1996	360.7760	1216	272.6750	25	60.5827	0.8050	0.0421
1997	252.6930	855	166.7030	21	51.9861	0.7592	0.0464
1998	233.2980	1234	190.7320	23	39.1713	0.8147	0.0428
1999	367.0420	1607	348.8040	25	49.7799	0.8082	0.0405
2000	434.9308	1538	398.4740	27	49.6136	1.0149	0.0409
2001	276.7855	1307	228.6990	22	35.9685	0.8649	0.0431
2002	484.2085	1740	417.3700	23	47.9208	1.0426	0.0402
2003	230.8050	801	163.1840	26	39.7063	1.0855	0.0491
2004	193.8510	579	170.6810	22	50.4687	1.1071	0.0536
2005	173.8960	601	159.8050	21	47.1225	1.0129	0.0536
2006	192.2620	455	178.5790	17	55.0038	1.2193	0.0581
2007	121.5453	324	116.4300	9	48.8072	0.8253	0.0662
2008	75.7990	252	70.6050	8	39.0864	0.7060	0.0748
2009	68.7850	250	67.6070	9	59.2670	0.9159	0.0786
2010	96.7650	343	82.8210	9	40.3732	0.8809	0.0661
2011	110.9230	291	108.9600	8	82.0762	1.3151	0.0706
2012	126.5190	363	122.7770	9	57.3988	1.0039	0.0652
2013	212.1670	428	208.2470	9	97.7949	1.2838	0.0691

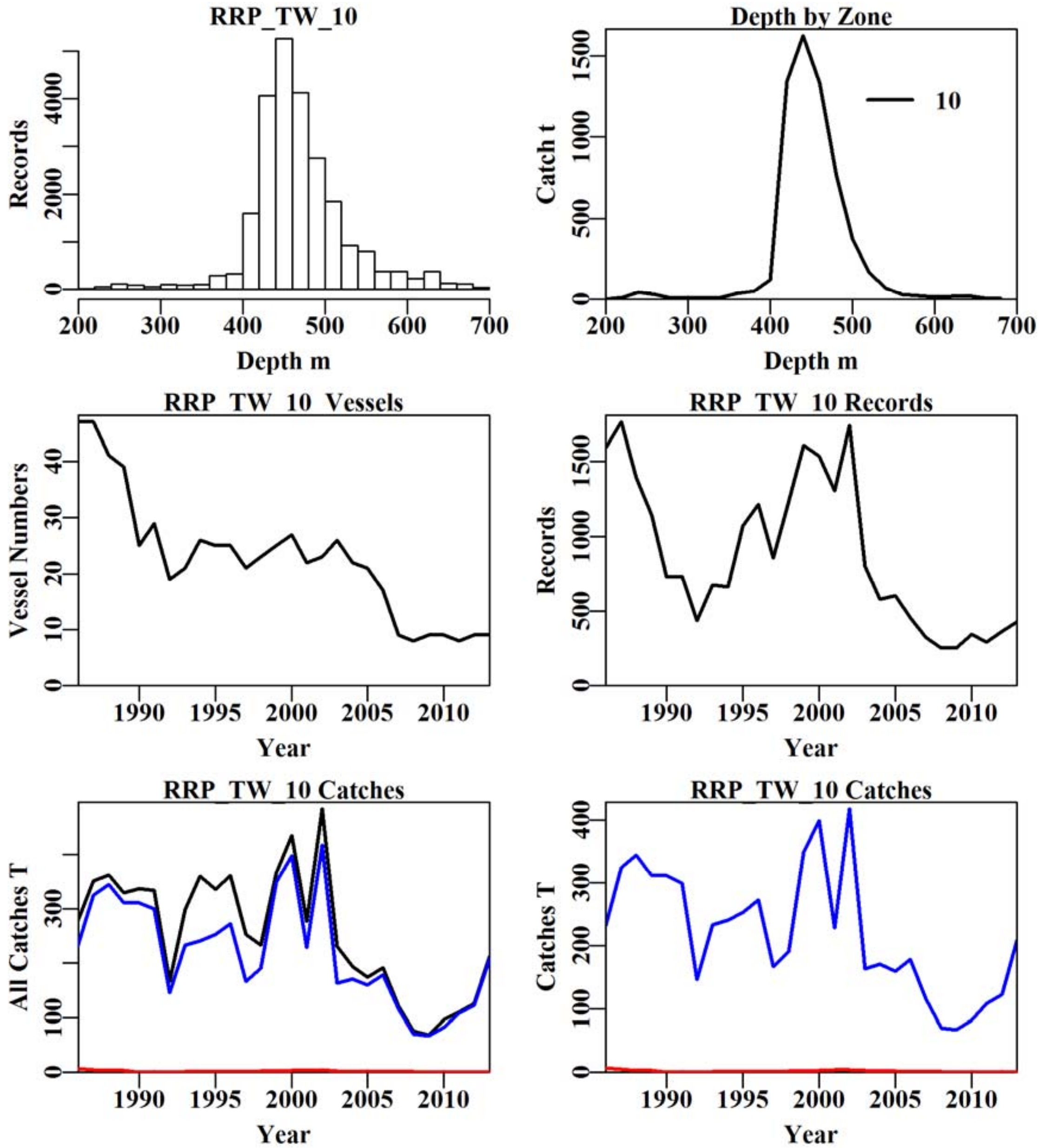


Figure 13.60**.** Royal Red Prawn from zone 10 in depths 200 – 700m by Trawl. The top left plot depicts the depth distribution of shots containing Royal red Prawn from zone 10 in depths 200 to 700 m by Trawl. The top right plot depicts the catch distribution by depth within zone 10. The middle left plot depicts the number of vessels through time and middle right plot contains the number of records used in analysis. The bottom left plot contains Royal Red Prawn catches (top black line: total catches, middle blue line: catches used in the analysis; bottom red line: catches < 30 kg) and bottom right plot contains Royal Red Prawn catches (blue line: catches used in the analysis; red line: catches < 30 kg).

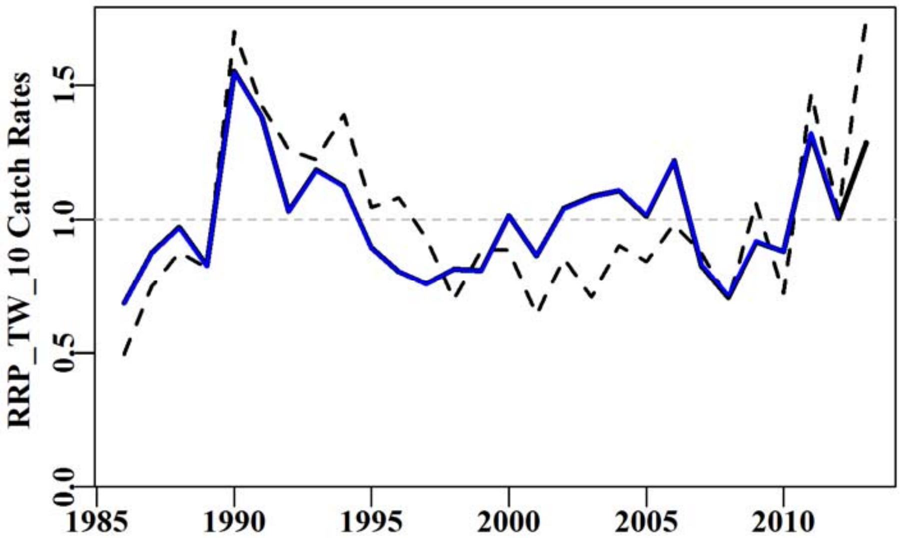


Figure 13.61. Royal Red Prawn from zone 10 in depths 200 – 700 m by Trawl. The dashed black line represents the geometric mean catch rate and the solid black line the standardized catch rates (relative to the mean of the standardized catch rates). The blue line corresponds to last year's standardized indices.

Table 13.56. Royal Red Prawn from zone 10 in depths 200 – 700 m by Trawl. Statistical model structures used in this analysis. DepCat is a series of 20 metre depth categories.

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

Table 13.57. Royal Red Prawn from zone 10 in depths 200 – 700 m by Trawl. Model selection criteria include the Akaike Information Criterion (AIC), residual sum of squares (RSS), model sum of squares (MSS), number of usable observations (Nobs), number of parameters (Npars), adjusted R^2 (adj_R^2) and the change in adjusted R^2 (%Change). The optimum was Model 7: Month:DepC. Depth category: DepC; DayNight: DN.

	Year	DepC	Vessel	Month	DN	DN:Month	Month:DepC	DN:DepC
AIC	13624	8509	3147	1510	1417	1382	888	1370
RSS	42530	34275	27281	25475	25371	25266	24288	25172
MSS	1968	10223	17217	19023	19127	19232	20210	19326
Nobs	24377	24228	24228	24228	24228	24228	24228	24228
Npars	28	52	136	147	150	183	414	222
adj_R^2	4.316	22.812	38.349	42.403	42.632	42.791	44.472	42.911
%Change	0.000	18.495	15.537	4.055	0.228	0.159	1.681	-1.561

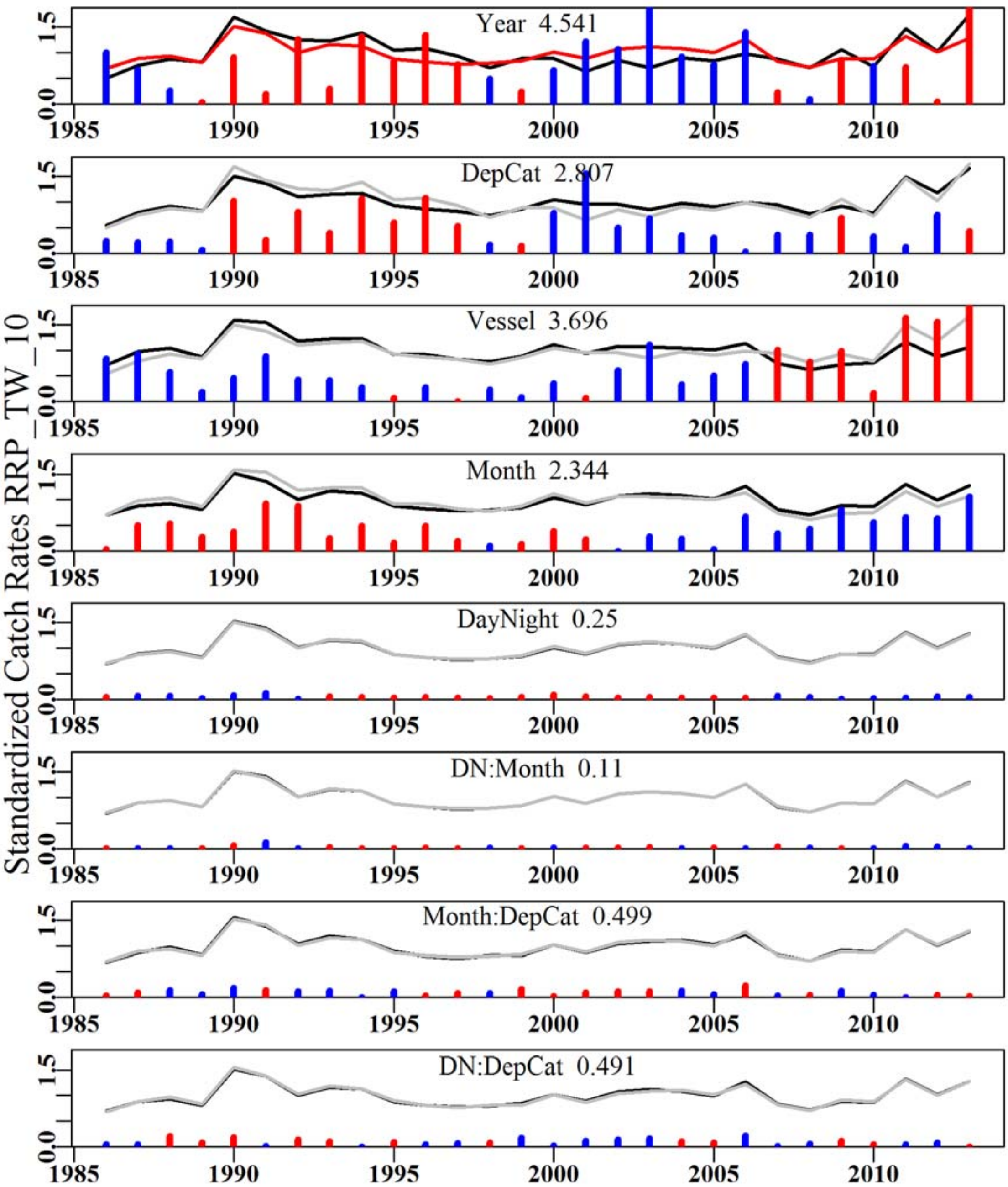


Figure 13.62. The relative influence of each factor used on the final trend in the optimal standardization for Royal Red Prawn in zone 10. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by the vertical bars with blue bars indicating the optimum model is higher than the geometric mean and red bars indicating it is lower. The top graph bars are the sum of all the bars in the graphs below. The graphs for individual factors are cumulative. Thus the second graph has the geometric mean (grey line) and the effect of adding Year + factor2 (Model 2). In the third graph, the grey line represents Model 2 and the black line the effect of adding factor3 to the model. The remaining graphs continue in the same cumulative manner except for the interaction terms which are added singularly to the final single factor model.

13.24 Blue Eye Trevalla Z2030 (TBE – 37445001 – Hyperoglyphe antarctica)

Trawl data from zones 20 and 3 and depths less than 1000 m were analysed.

Table 13.58**.** Blue Eye Trevalla from zones 20 and 30 in depths 0 – 1000 m by Trawl. Total catch (TotCatch; t) is the total reported in the database, number of records used in the analysis (Records), reported catch (CatchT; t) in the area and depth used in the analysis and number of vessels used in the analysis (Vessels). GeoMean is the geometric mean of catch rates (kg/hr). The optimum model is Zone:DepC and standard deviation (StDev) relates to the data in the optimum model.

Year	TotCatch	Records	CatchT	Vessels	GeoMean	Zone:DepC	StDev
1986	37.9620	166	9.1170	17	10.0553	2.1397	0.0000
1987	15.4950	190	10.0260	14	9.8390	2.0131	0.1366
1988	105.1770	307	19.4330	21	14.4132	2.5048	0.1292
1989	88.0660	315	33.3710	32	14.6333	2.8173	0.1316
1990	79.2980	264	39.8450	36	24.1892	3.5811	0.1342
1991	76.0240	474	29.1890	37	9.3594	1.9243	0.1263
1992	49.3050	313	14.2320	23	8.3976	1.4334	0.1334
1993	59.6540	736	37.7890	31	7.9893	1.1499	0.1234
1994	109.9750	855	89.0330	33	10.7324	1.3311	0.1227
1995	58.5720	489	28.3350	29	5.8281	0.8866	0.1274
1996	71.6840	648	35.5180	29	5.7645	0.7158	0.1251
1997	470.7164	604	19.9210	31	4.6731	0.6557	0.1271
1998	475.9652	475	18.7040	24	4.1103	0.7487	0.1293
1999	574.4838	633	41.7330	27	3.5948	0.7782	0.1262
2000	667.0558	657	37.6610	34	2.7104	0.4953	0.1240
2001	647.5307	692	25.0380	24	2.2460	0.4333	0.1244
2002	843.8591	700	33.7320	28	3.0245	0.4342	0.1263
2003	605.3020	722	14.0635	25	2.2528	0.4329	0.1257
2004	606.2500	623	15.1709	28	2.7224	0.4251	0.1273
2005	755.1858	502	17.9194	26	2.6091	0.4214	0.1304
2006	573.7189	327	36.7820	17	3.9462	0.5161	0.1346
2007	937.1424	247	10.6065	11	3.1151	0.4097	0.1404
2008	398.9433	434	13.6537	15	5.6341	0.3893	0.1342
2009	520.8777	246	22.8489	14	5.4891	0.3830	0.1416
2010	437.3987	197	11.5432	13	3.3742	0.2610	0.1471
2011	554.2188	227	7.8041	12	2.1952	0.2709	0.1438
2012	463.8349	150	1.3334	11	1.6617	0.2347	0.1533
2013	398.3268	147	4.1109	11	3.6020	0.2134	0.1552

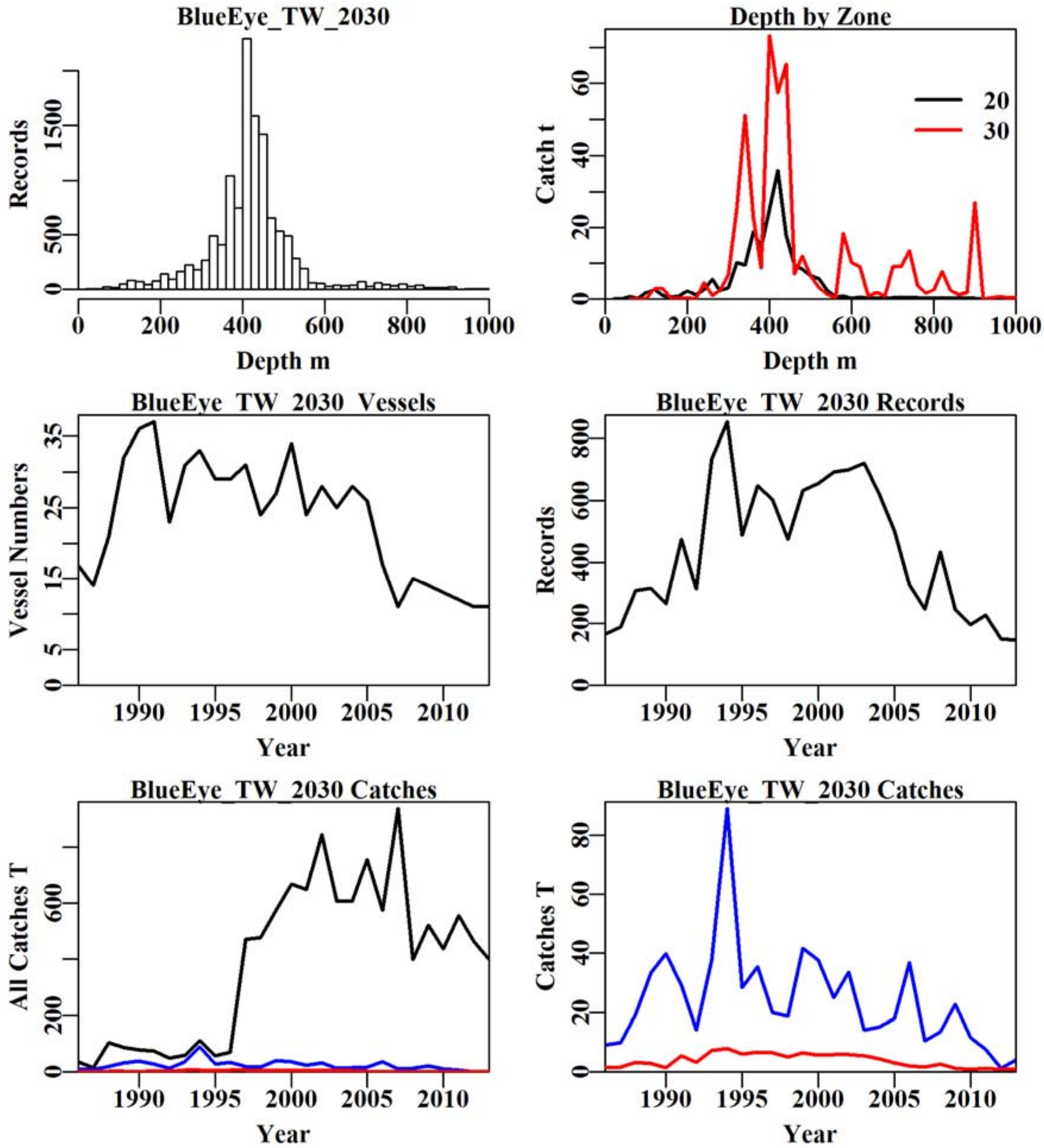


Figure 13.63. Blue Eye Trevalla from zones 20 and 30 in depths 0 – 1000 m by Trawl. The top left plot depicts the depth distribution of shots containing Blue Eye Trevalla from zones 20 and 30 in depths 0 to 1000 m by Trawl. The top right plot depicts the catch distribution by depth within zones 20 and 30. The middle left plot depicts the number of vessels through time and middle right plot contains the number of records used in analysis. The bottom left plot contains Blue Eye Trevalla catches (top black line: total catches, middle blue line: catches used in the analysis; bottom red line: catches < 30 kg) and bottom right plot contains Blue Eye Trevalla catches (blue line: catches used in the analysis; red line: catches < 30 kg).

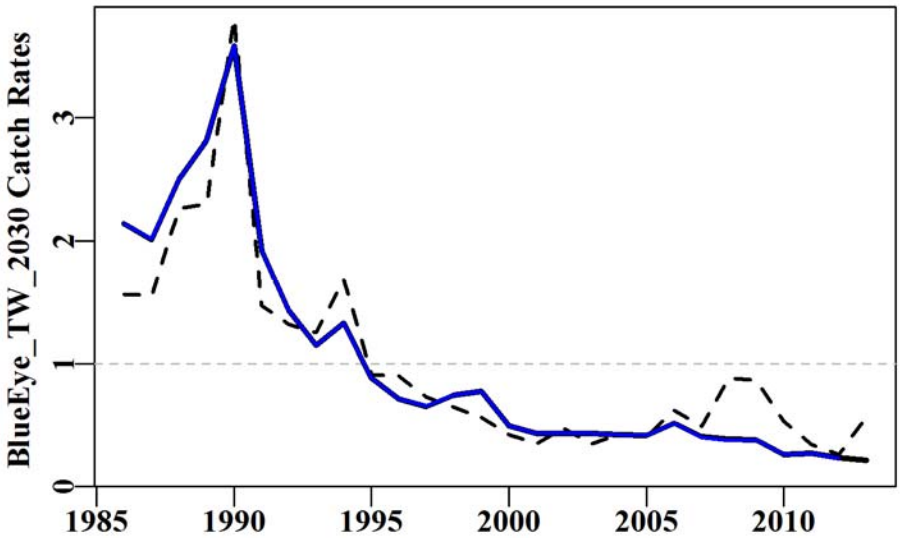


Figure 13.64. Blue Eye Trevalla from zones 20 and 30 in depths 0 – 1000 m by Trawl. The dashed black line represents the geometric mean catch rate and the solid black line the standardized catch rates (relative to the mean of the standardized catch rates). The blue line corresponds to last year's standardized indices.

Table 13.59**.** Blue Eye Trevalla from zones 20 and 30 in depths 0 – 1000 m by Trawl. Statistical model structures used in this analysis. DepCat is a series of 20 metre depth categories.

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

Table 13.60**.** Blue Eye Trevalla from zones 20 and 30 in depths 0 – 1000 m by Trawl. Model selection criteria include the Akaike Information Criterion (AIC), residual sum of squares (RSS), model sum of squares (MSS), number of usable observations (Nobs), number of parameters (Npars), adjusted R^2 (adj_R^2) and the change in adjusted R^2 (%Change). The optimum was Model 8: Zone:DepC. Depth category: DepC.

	Year	Vessel	Zone	DepC	DayNight	Month	Zone:Month	Zone:DepC
AIC	10841	4614	4211	4094	3981	3968	3944	3762
RSS	29573	17512	16947	16587	16426	16379	16319	15980
MSS	4782	16843	17408	17768	17928	17975	18036	18374
Nobs	12340	12340	12340	12265	12265	12265	12265	12265
Npars	28	147	148	196	199	210	221	258
adj_R^2	13.730	48.415	50.076	50.940	51.401	51.496	51.632	52.488
%Change	0.000	34.685	1.661	0.864	0.462	0.095	0.136	0.856

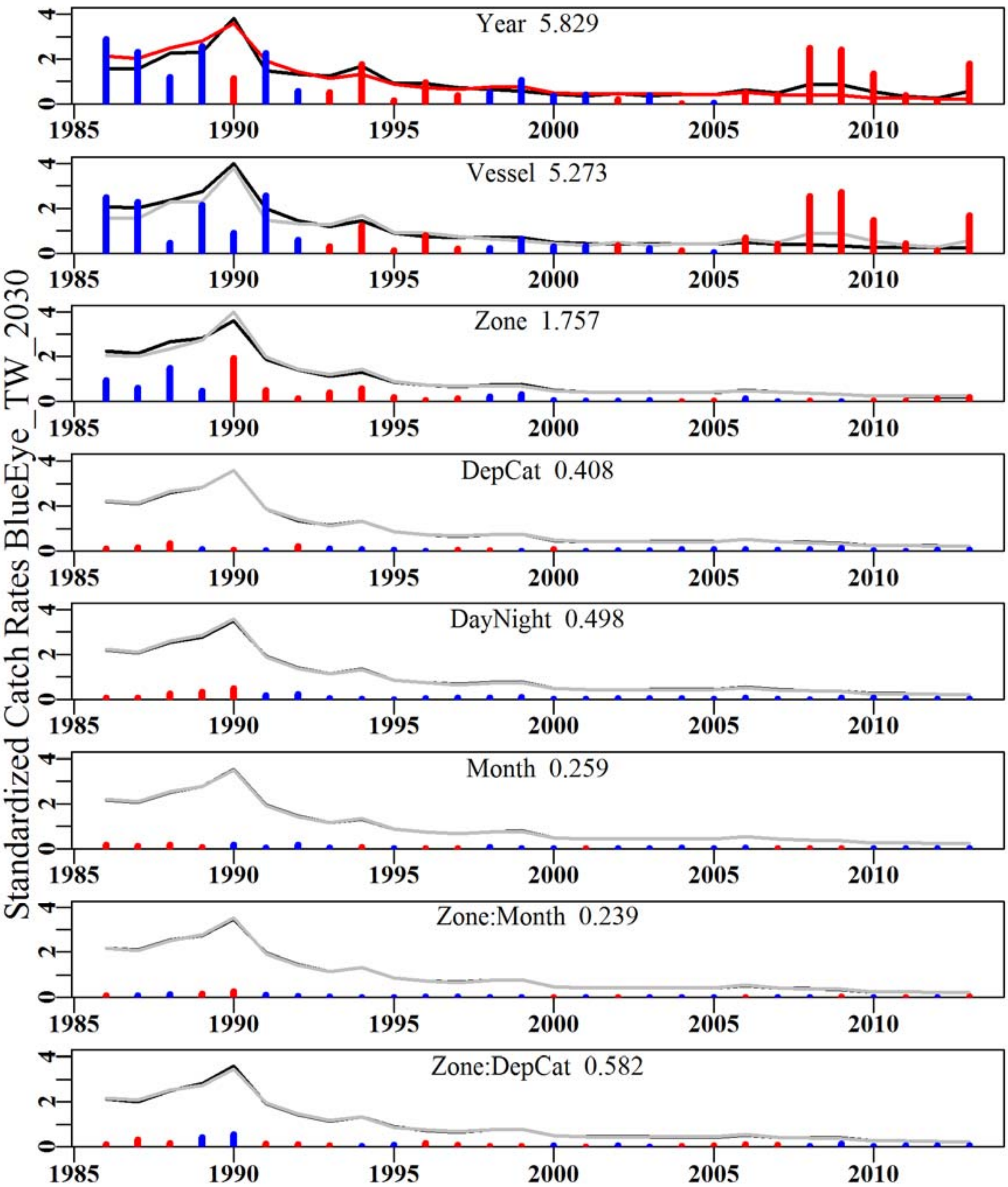


Figure 13.65. The relative influence of each factor used on the final trend in the optimal standardization for Blue Eye Trevalla in zones 20 – 30. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by the vertical bars with blue bars indicating the optimum model is higher than the geometric mean and red bars indicating it is lower. The top graph bars are the sum of all the bars in the graphs below. The graphs for individual factors are cumulative. Thus the second graph has the geometric mean (grey line) and the effect of adding Year + factor2 (Model 2). In the third graph, the grey line represents Model 2 and the black line the effect of adding factor3 to the model. The remaining graphs continue in the same cumulative manner except for the interaction terms which are added singularly to the final single factor model.

13.25 Blue Eye Trevalla Z4050 (TBE – 37445001 – Hyperoglyphe antarctica)

Trawl data selected for analysis corresponded to zones 40 and 50 from depths less than 1000 m.

Table 13.61**.** Blue Eye Trevalla from zones 40 and 50 in depths 0 to 1000 m by Trawl. Total catch (TotCatch; t) is the total reported in the database, number of records used in the analysis (Records), reported catch (CatchT; t) in the area and depth used in the analysis and number of vessels used in the analysis (Vessels). GeoMean is the geometric mean of catch rates (kg/hr). The optimum model is Zone:Month and standard deviation (StDev) relates to the data in the optimum model.

Year	TotCatch	Records	CatchT	Vessels	GeoMean	Zone:Month	StDev
1986	37.9620	194	15.9550	18	13.1296	0.9356	0.0000
1987	15.4950	56	3.1450	14	11.6895	0.7906	0.1766
1988	105.1770	142	76.4100	15	41.5696	2.3670	0.1569
1989	88.0660	238	43.9850	24	25.5841	1.9386	0.1385
1990	79.2980	157	30.9100	16	13.0702	2.0511	0.1590
1991	76.0240	129	18.9540	18	17.4424	1.6639	0.1574
1992	49.3050	129	28.6430	15	21.8842	1.9638	0.1572
1993	59.6540	289	18.1090	19	8.5334	0.8965	0.1408
1994	109.9750	348	16.2820	19	8.8991	0.9541	0.1374
1995	58.5720	500	26.3810	21	6.4723	0.8498	0.1336
1996	71.6840	523	30.1840	24	8.0361	0.8782	0.1342
1997	470.7164	788	82.3710	18	6.5139	0.8991	0.1309
1998	475.9652	780	58.9460	19	5.3540	1.0731	0.1323
1999	574.4838	877	46.3030	19	6.4046	1.1047	0.1311
2000	667.0558	1109	44.7290	23	5.2927	0.9699	0.1304
2001	647.5307	955	42.1880	26	5.7866	0.9128	0.1320
2002	843.8591	802	32.2675	26	5.0532	0.7639	0.1320
2003	605.3020	391	11.0128	25	3.1904	0.6935	0.1386
2004	606.2500	852	31.2657	24	4.2140	0.6084	0.1322
2005	755.1858	508	12.7502	22	3.6280	0.5623	0.1355
2006	573.7189	533	16.2790	17	3.6218	0.5747	0.1351
2007	937.1424	538	26.1883	16	4.4303	0.6099	0.1350
2008	398.9433	324	16.3714	14	4.9605	0.7942	0.1401
2009	520.8777	343	15.7939	13	4.0546	0.7282	0.1399
2010	437.3987	427	31.0104	14	5.4788	0.7614	0.1371
2011	554.2188	381	14.7083	14	2.8223	0.6013	0.1382
2012	463.8349	261	9.0066	11	1.8380	0.4670	0.1470
2013	398.3268	203	18.6619	15	3.2601	0.5863	0.1486

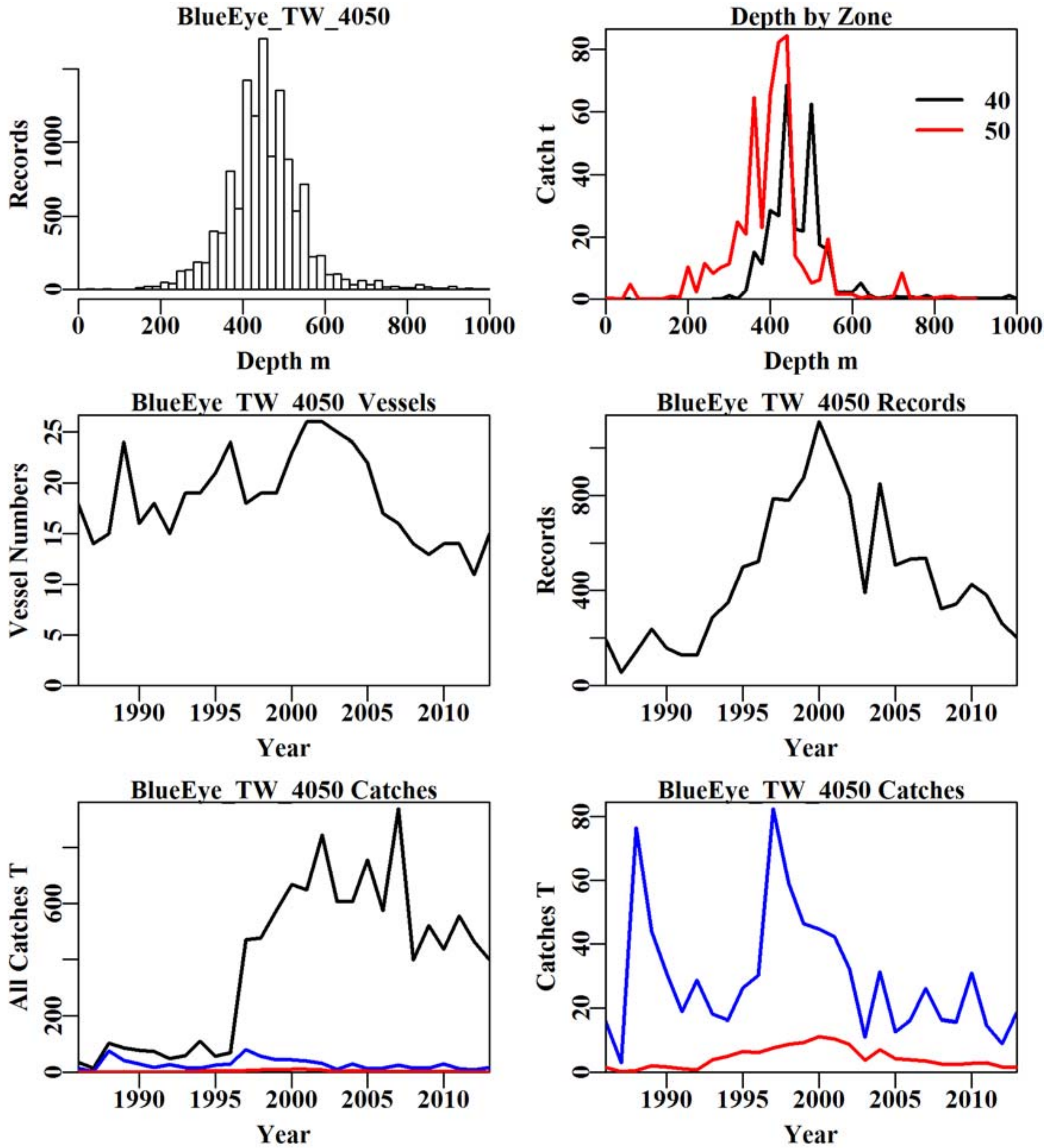


Figure 13.66**.** Blue Eye Trevalla from Zones 40 and 50 in depths 0 to 1000 m by Trawl. The top left plot depicts the depth distribution of shots containing Blue Eye Trevalla from zones 40 and 50 in depths 0 to 1000 m by Trawl. The top right plot depicts the catch distribution by depth within zones 40 and 50. The middle left plot depicts the number of vessels through time and middle right plot contains the number of records used in analysis. The bottom left plot contains Blue Eye Trevalla catches (top black line: total catches, middle blue line: catches used in the analysis; bottom red line: catches < 30 kg) and bottom right plot contains Blue Eye Trevalla catches (blue line: catches used in the analysis; red line: catches < 30 kg).

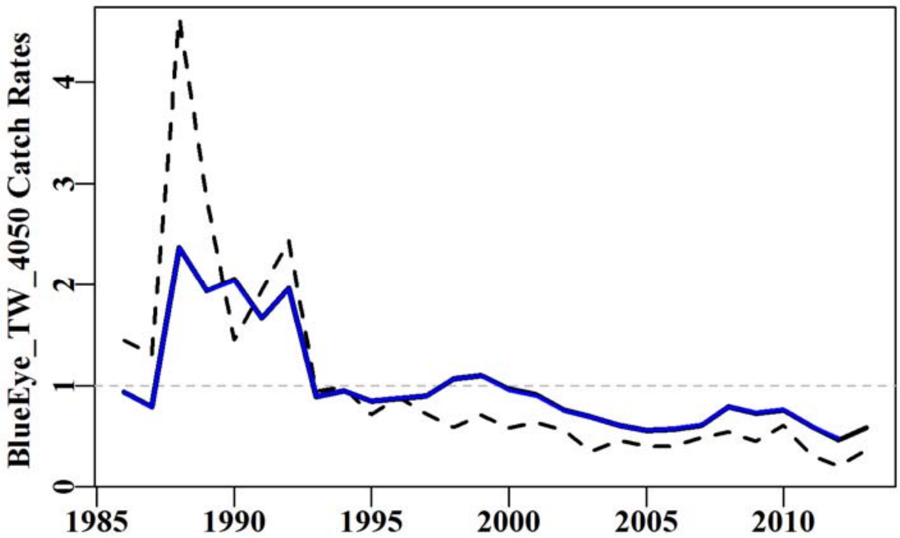


Figure 13.67. Blue Eye Trevalla from Zones 40 and 50 in depths 0 to 1000 m by Trawl. The dashed black line represents the geometric mean catch rate and the solid black line the standardized catch rates (relative to the mean of the standardized catch rates). The blue line corresponds to last year's standardized indices.

Table 13.62. Blue Eye Trevalla 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 13.63. Blue Eye Trevalla from zones 40 and 50 in depths 0 to 1000 m by Trawl. Model selection criteria include the Akaike Information Criterion (AIC), residual sum of squares (RSS), model sum of squares (MSS), number of usable observations (Nobs), number of parameters (Npars), adjusted R^2 (adj_R^2) and the change in adjusted R^2 (%Change). The optimum was model 8: Zone:DepCat. Depth category: DepC.

	Year	Vessel	DepC	DayNight	Month	Zone	Zone:Month	Zone:DepC
AIC	8370	3047	2605	2353	2311	2257	2256	2225
RSS	24491	15941	15218	14912	14837	14772	14745	14621
MSS	3085	11635	12358	12664	12739	12804	12831	12955
Nobs	12777	12777	12712	12712	12712	12712	12712	12712
Npars	28	110	159	162	173	174	185	223
adj_R^2	10.998	41.694	44.120	45.232	45.457	45.692	45.745	46.036
%Change	0.000	30.696	2.426	1.112	0.225	0.235	0.053	0.291

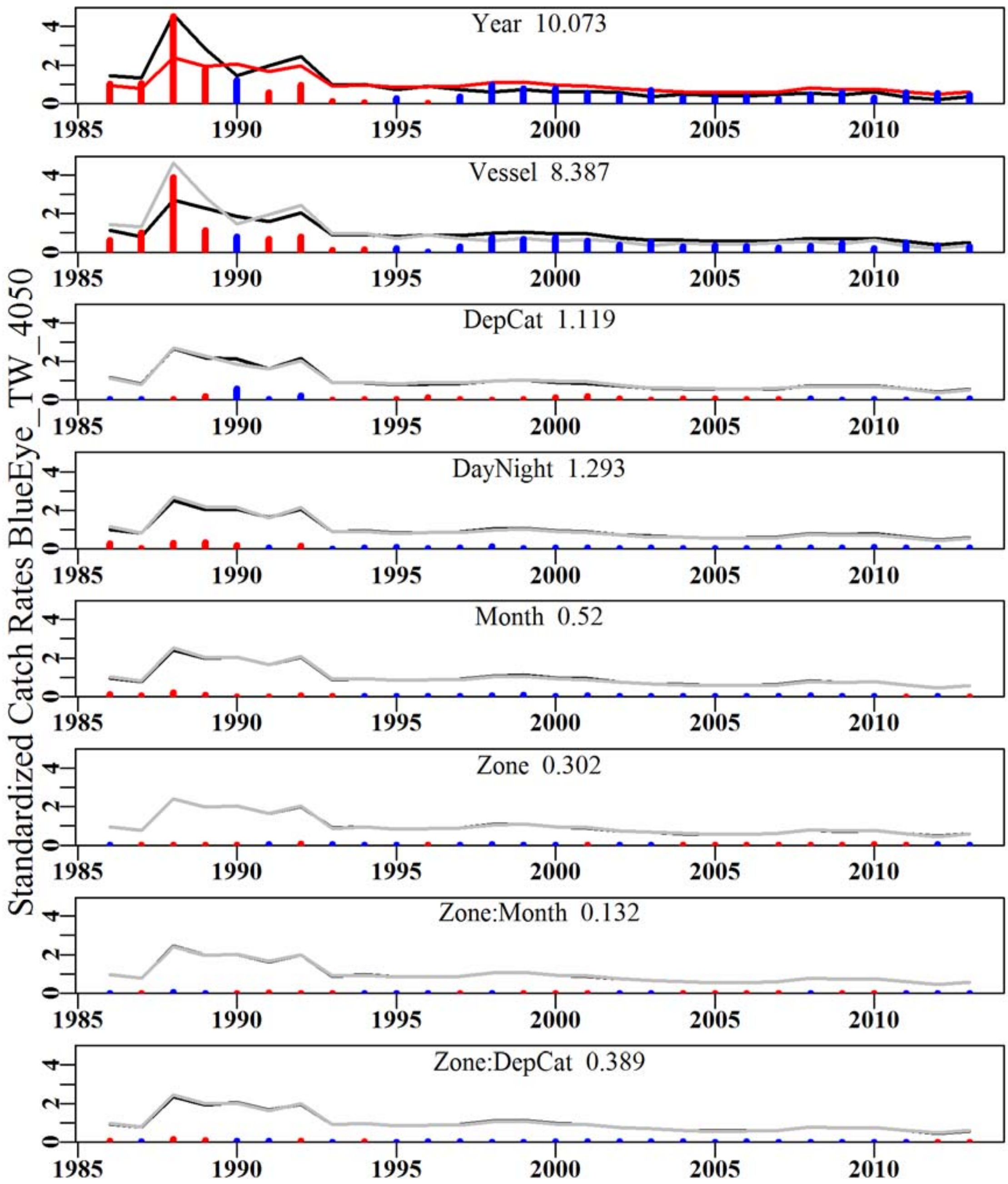


Figure 13.68**.** The relative influence of each factor used on the final trend in the optimal standardization for Blue Eye Trevalla in Zones 40 – 50. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by the vertical bars with blue bars indicating the optimum model is higher than the geometric mean and red bars indicating it is lower. The top graph bars are the sum of all the bars in the graphs below. The graphs for individual factors are cumulative. Thus the second graph has the geometric mean (grey line) and the effect of adding Year + factor2 (Model 2). In the third graph, the grey line represents Model 2 and the black line the effect of adding factor3 to the model. The remaining graphs continue in the same cumulative manner except for the interaction terms which are added singularly to the final single factor model.

13.26 Blue Eye Trevalla AL (TBE – 37445001 – *Hyperoglyphe antarctica*)

Auto-Line data selected for analysis corresponded to records from depths between 200-600 m in the SESSF. All records in 1997 were omitted due to very lower numbers of records.

Table 13.64**.** Blue Eye Trevalla from the SESSF in depths 200 – 600 m by Auto-Line. Total catch (TotCatch; t) is the total reported in the database, number of records used in the analysis (Records), reported catch (CatchT; t) in the area and depth used in the analysis and number of vessels used in the analysis (Vessels). GeoMean is the geometric mean of catch rates (kg/shot). The optimum model is Zone:Month and standard deviation (StDev) relates to the data in the optimum model.

Year	TotCatch	Records	CatchT	Vessels	GeoMean	Zone:Month	StDev
1998	475.9652	28	14.9890	2	249.6862	0.6188	0.0000
1999	574.4838	50	47.6696	2	536.1933	2.1216	0.3290
2000	667.0558	29	28.2990	2	608.0267	1.7470	0.3635
2001	647.5307	65	40.2324	2	246.5002	0.9128	0.3136
2002	843.8591	228	131.6856	4	162.2961	0.7558	0.2863
2003	605.3020	434	157.0156	7	133.4303	1.1868	0.2912
2004	606.2500	1147	269.1203	11	72.0019	1.1440	0.2864
2005	755.1858	1137	300.4620	7	77.8010	0.9149	0.2866
2006	573.7189	1067	345.4814	9	102.2372	1.0159	0.2860
2007	937.1424	658	453.8194	6	364.8943	1.2098	0.2879
2008	398.9433	604	277.9166	6	232.1695	0.8656	0.2879
2009	520.8777	550	313.2070	6	289.4275	0.9442	0.2875
2010	437.3987	483	230.0416	5	184.8051	0.5970	0.2887
2011	554.2188	526	225.7162	5	209.8939	0.6395	0.2881
2012	463.8349	427	180.7403	6	170.2138	0.6066	0.2889
2013	398.3268	352	186.3061	5	233.7214	0.7199	0.2903

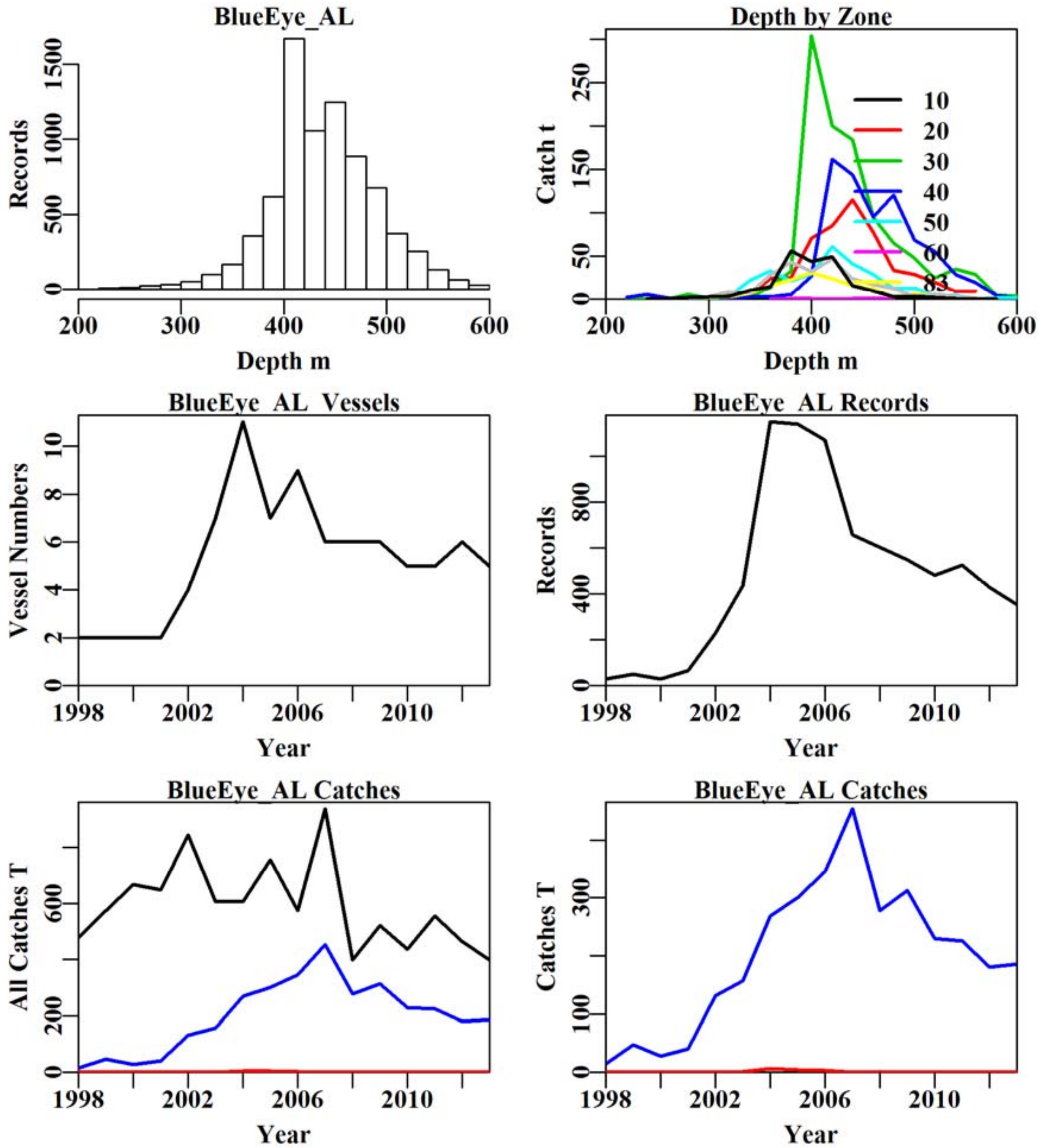


Figure 13.69**.** Blue Eye Trevalla from the SESSF in depths 200 – 600 m by Auto-Longline. The top left plot depicts the depth distribution of shots containing Blue Eye Trevalla from SESSF in depths 200 to 600 m by Auto-Longline. The top right plot depicts the catch distribution by depth by SESSF zone. The middle left plot depicts the number of vessels through time and middle right plot contains the number of records used in analysis. The bottom left plot contains Blue Eye Trevalla catches (top black line: total catches, middle blue line: catches used in the analysis; bottom red line: catches < 30 kg) and bottom right plot contains Blue Eye Trevalla catches (blue line: catches used in the analysis; red line: catches < 30 kg).

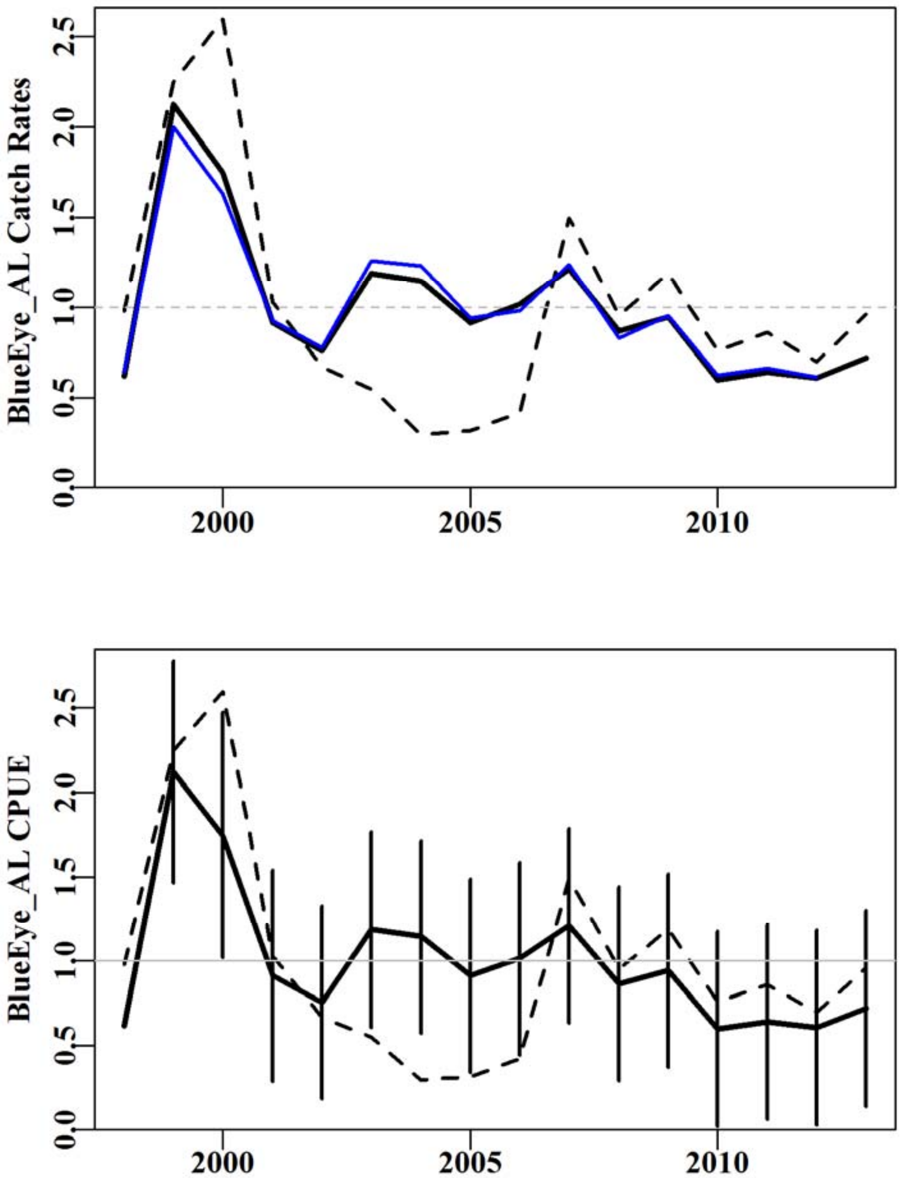


Figure 13.70**.** Blue Eye Trevalla from the SESSF in depths 200 – 600 m by Auto-Longline. Upper graph: The dashed black line represents the geometric mean catch rate and the solid black line the standardized catch rates (relative to the mean of the standardized catch rates). The blue line corresponds to last year's standardized indices. Lower graph: Standardized indices (solid black line), 95% CI (vertical lines) and geometric mean (dashed black line). This illustrates the impact on the relative uncertainty of the relatively small number of records, especially in the early years.

Table 13.65. Blue Eye Trevalla from the SESSF in depths 200 – 600 m 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 + 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 13.66. Blue Eye Trevalla from the SESSF in depths 200 – 600m by Auto-LongLine. Model selection criteria include the Akaike Information Criterion (AIC), residual sum of squares (RSS), model sum of squares (MSS), number of usable observations (Nobs), number of parameters (Npars), adjusted R^2 (adj_R^2) and the change in adjusted R^2 (%Change). The optimum was Model 7 (Zone:Month). Depth category: DepC.

	Year	Vessel	Month	Zone	DepC	DayNight	Zone:Month	Zone:DepC
AIC	7126	5087	4411	4167	4128	4111	3907	4166
RSS	19364	14857	13582	13131	12980	12941	12322	12507
MSS	2458	6965	8241	8691	8843	8881	9500	9316
Nobs	7785	7785	7785	7779	7755	7755	7755	7755
Npars	16	28	39	47	67	70	158	230
adj_R^2	11.094	31.682	37.456	39.470	40.011	40.165	42.367	40.944
%Change	0.000	20.588	5.775	2.013	0.542	0.153	2.202	-1.423

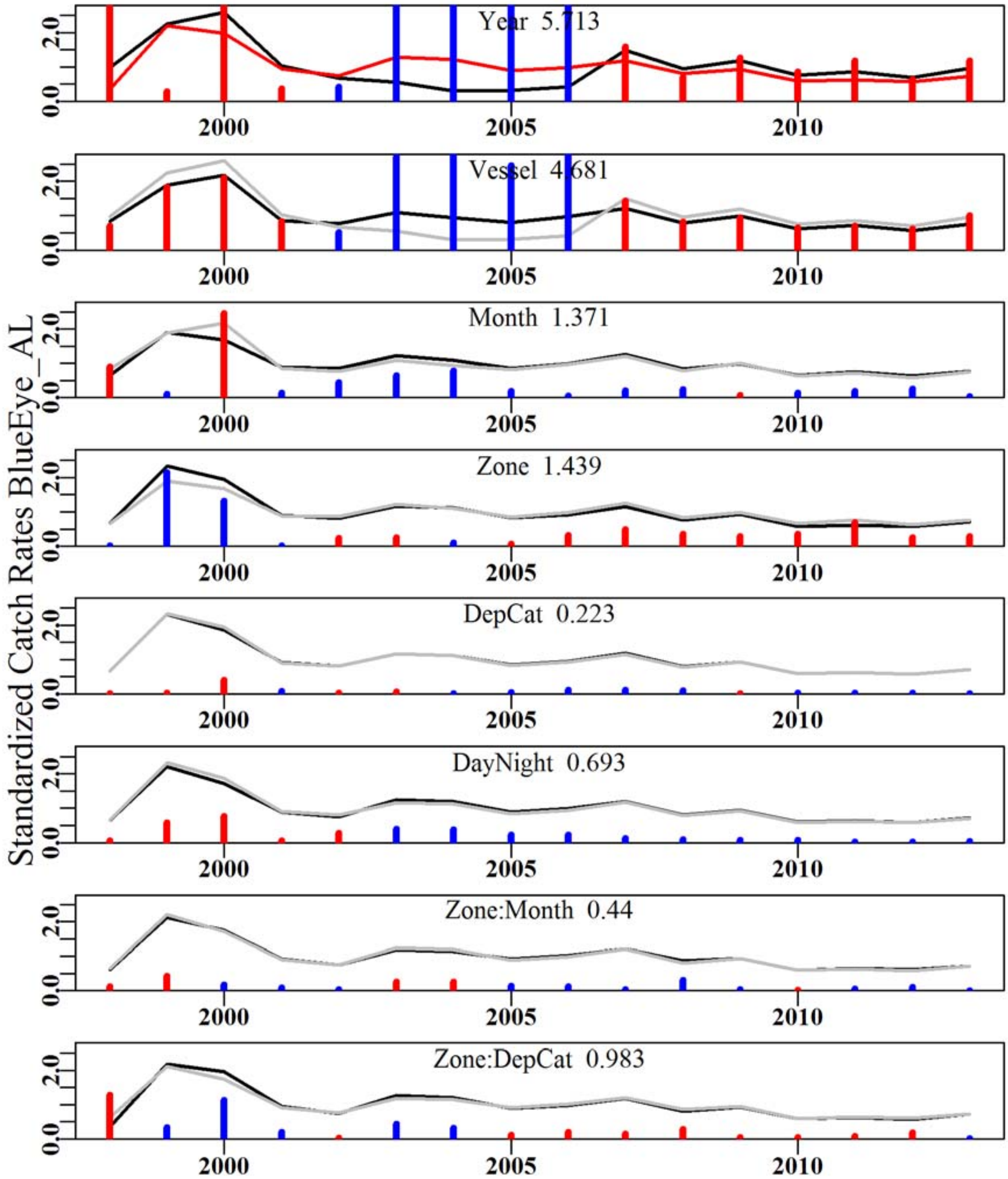


Figure 13.71**.** The relative influence of each factor used on the final trend in the optimal standardization for Blue Eye Trevalla in by Auto-longline. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by the vertical bars with blue bars indicating the optimum model is higher than the geometric mean and red bars indicating it is lower. The top graph bars are the sum of all the bars in the graphs below. The graphs for individual factors are cumulative. Thus the second graph has the geometric mean (grey line) and the effect of adding Year + factor2 (Model 2). In the third graph, the grey line represents Model 2 and the black line the effect of adding factor3 to the model. The remaining graphs continue in the same cumulative manner except for the interaction terms which are added singularly to the final single factor model.

13.27 Blue Eye Trevalla DL (TBE – 37445001 – Hyperoglyphe antarctica)

Data from Drop Lines and depths between 200-600 m in the SESSF were used. All vessels reporting Blue Eye Trevalla by Drop Line were included.

Table 13.67. Blue Eye Trevalla from the SET and GHT fishery in depths between 200 – 600 m, taken by Drop Line. Total catch (TotCatch; t) is the total reported in the database, number of records used in the analysis (Records), reported catch (CatchT; t) in the area and depth used in the analysis and number of vessels used in the analysis (Vessels). GeoMean is the geometric mean of catch rates (kg/shot). The optimum model is Zone:Month and standard deviation (StDev) relates to the data in the optimum model.

Year	TotCatch	Records	CatchT	Vessels	GeoMean	Zone:Month	StDev
1997	470.7164	544	254.5190	38	260.8365	1.7169	0.0000
1998	475.9652	730	325.9071	29	225.2953	1.3486	0.0767
1999	574.4838	877	339.3850	29	178.2172	1.2051	0.0791
2000	667.0558	1057	377.8533	33	171.7160	1.1773	0.0831
2001	647.5307	742	318.6780	26	199.5629	1.2915	0.0872
2002	843.8591	571	180.5241	22	164.4656	1.1104	0.0922
2003	605.3020	535	167.9685	22	162.1292	0.8977	0.1006
2004	606.2500	491	149.1758	23	160.0458	0.9989	0.1032
2005	755.1858	342	80.6044	16	134.1365	0.8057	0.1114
2006	573.7189	301	101.6487	13	222.2480	1.0016	0.1192
2007	937.1424	125	45.1233	10	208.7957	1.3939	0.1438
2008	398.9433	80	15.5799	7	117.4039	0.8121	0.1627
2009	520.8777	81	17.8185	9	124.4663	0.5253	0.1747
2010	437.3987	197	28.9643	9	76.1903	0.4523	0.1468
2011	554.2188	166	32.3677	9	104.8614	0.7246	0.1576
2012	463.8349	93	17.9277	8	105.1590	0.7874	0.1987
2013	398.3268	44	7.2282	5	86.5165	0.7505	0.2534

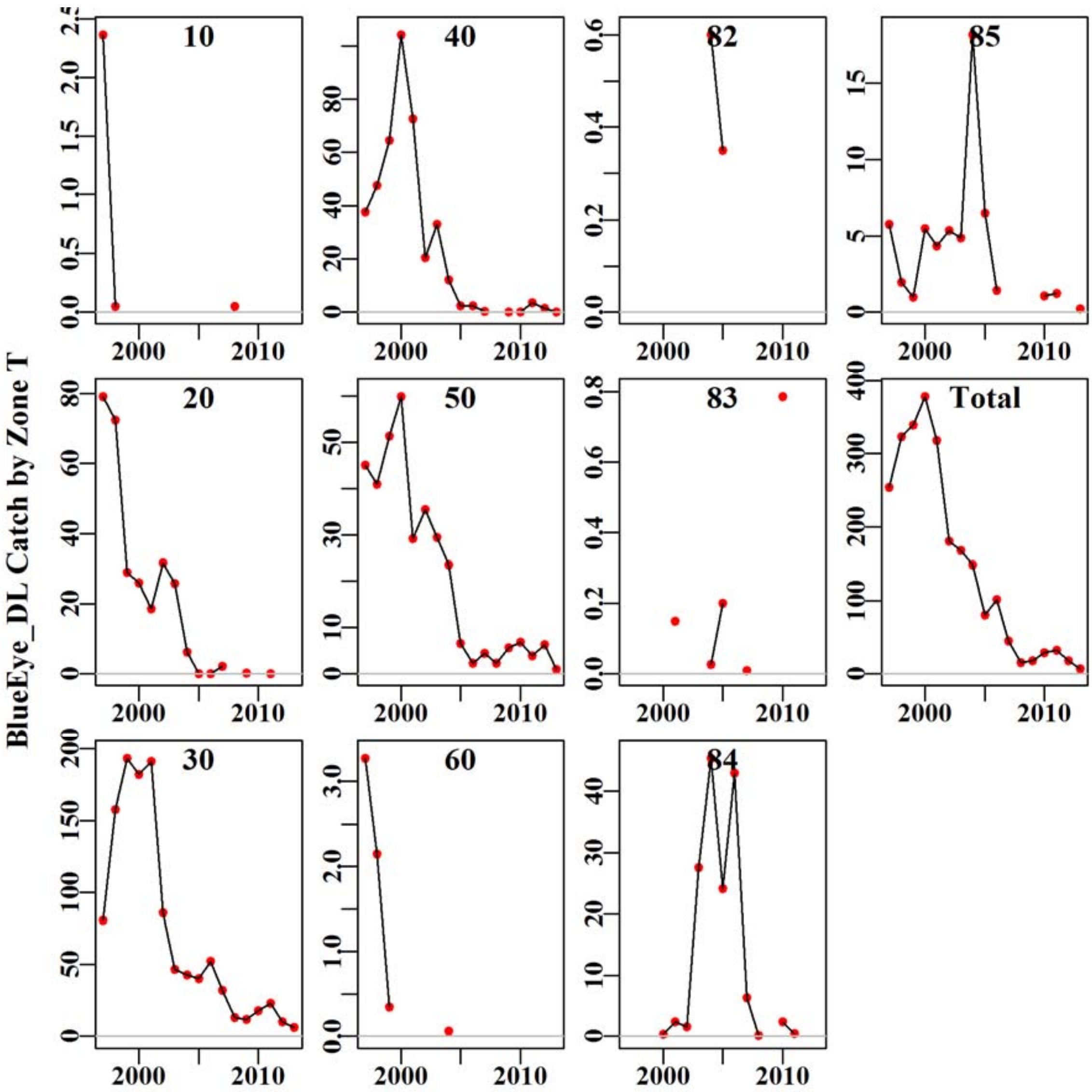


Figure 13.72. Blue Eye Trevalla catches by zone from the SESSF in depths 200 – 600 m by Drop Line.

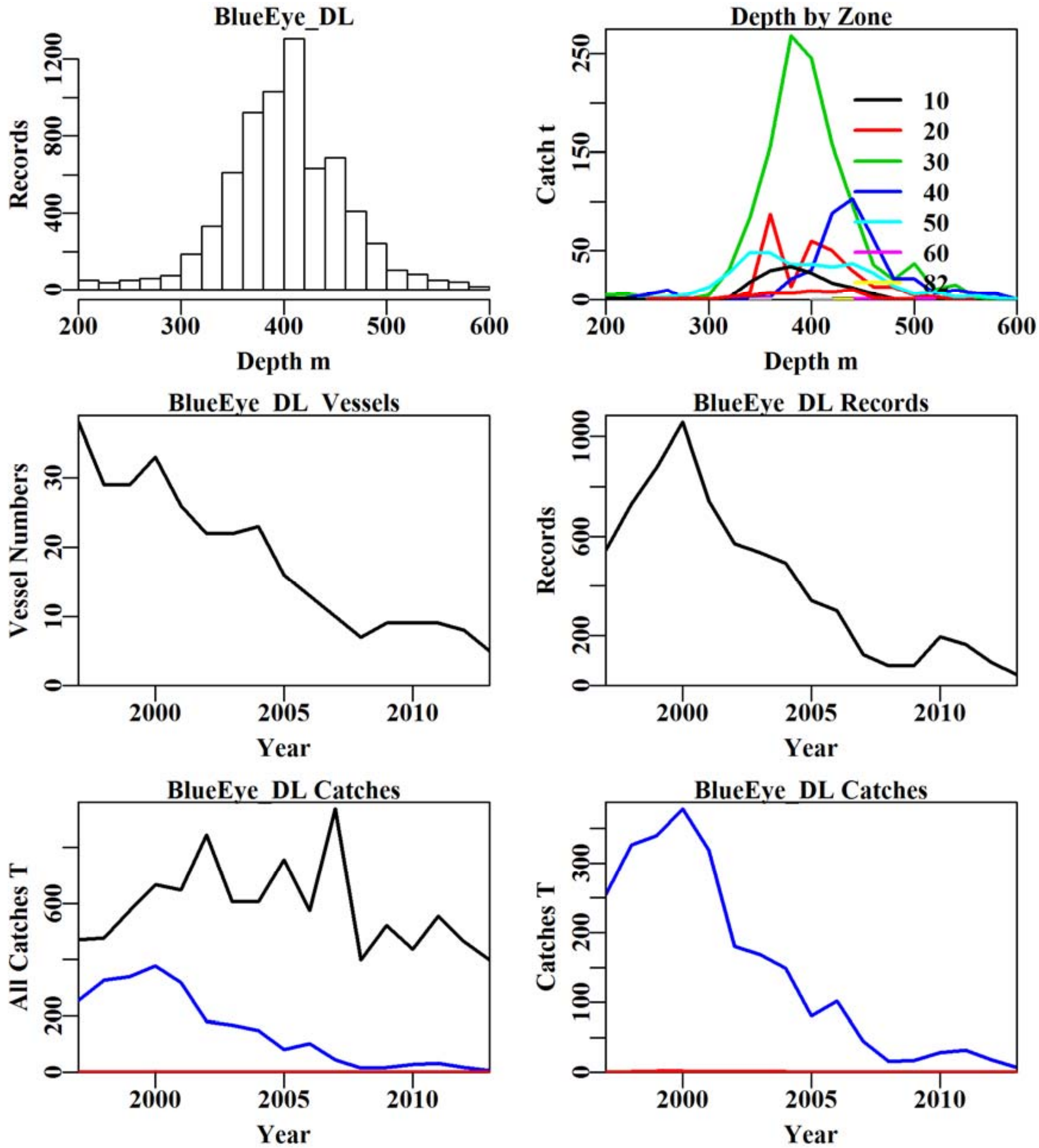
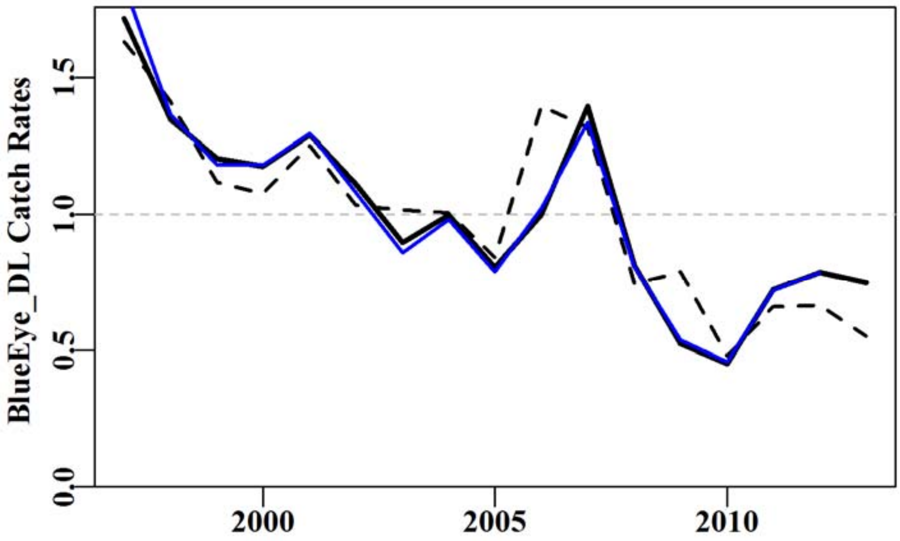


Figure 13.73**.** Blue Eye Trevalla from the SET and GHT fishery in depths between 200 – 600 m, taken by Drop line. The top left plot depicts the depth distribution of shots containing Blue Eye Trevalla from the SEN and GHT fishery in depths between 200 – 600 m, taken by Drop Line. The top right plot depicts the catch distribution by depth by SESSF zone. The middle left plot depicts the number of vessels through time and middle right plot contains the number of records used in analysis. The bottom left plot contains Blue Eye Trevalla catches (top black line: total catches, middle blue line: catches used in the analysis; bottom red line: catches < 30 kg) and bottom right plot contains Blue Eye Trevalla catches (blue line: catches used in the analysis; red line: catches < 30 kg).



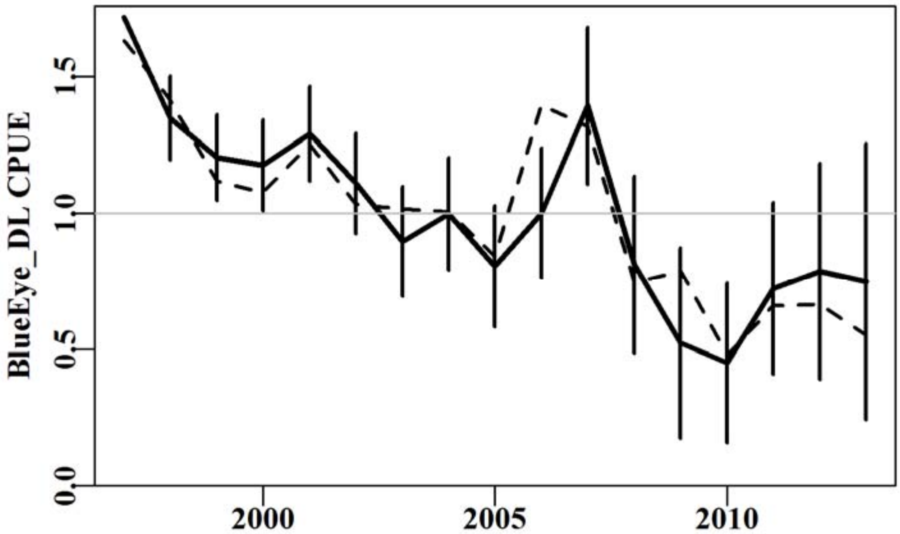


Figure 13.74**.** Blue Eye Trevalla from the SEN and GHT fishery in depths between 200 – 600 m, taken by Drop line. Upper plot: The dashed black line represents the geometric mean catch rate and the solid black line the standardized catch rates (relative to the mean of the standardized catch rates). The blue line corresponds to last year's standardized catch rates. Lower plot: Standardized catch rates (solid black line), 95% CI (vertical lines) and geometric mean (dashed black line). This illustrates the impact on the relative uncertainty of the relatively small number of records, especially in the early years.

Table 13.68**.** Blue Eye Trevalla from the SET and GHT fishery in depths between 200 – 600 m, 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 + DepCat
Model 5	LnCE ~ Year + Vessel + Month + DepCat + Zone
Model 6	LnCE ~ Year + Vessel + Month + DepCat + Zone + DayNight
Model 7	LnCE ~ Year + Vessel + Month + DepCat + Zone + DayNight+ Zone:Month
Model 8	LnCE ~ Year + Vessel + Month + DepCat + Zone + DayNight +Zone:DepCat

Table 13.69**.** Blue Eye Trevalla from the SET and GHT fishery in depths between 200 – 600 m, taken by Drop Line. Model selection criteria include the Akaike Information Criterion (AIC), residual sum of squares (RSS), model sum of squares (MSS), number of usable observations (Nobs), number of parameters (Npars), adjusted R^2 (adj_R^2) and the change in adjusted R^2 (%Change). The optimum is Model 7 (Zone:Mth). Depth category: DepC.

	Year	Vessel	Month	DepC	Zone	DayNight	Zone:Month	Zone:DepC
AIC	4121	2978	2599	2536	2505	2466	2411	2586
RSS	12532	10350	9771	9580	9474	9412	9072	9090
MSS	449	2632	3210	3402	3508	3570	3909	3892
Nobs	6976	6976	6976	6924	6883	6883	6883	6883
Npars	17	113	124	144	153	156	255	336
adj_R^2	3.238	18.973	23.378	24.647	25.372	25.829	27.437	26.396
%Change	0.000	15.736	4.405	1.269	0.725	0.457	1.608	-1.041

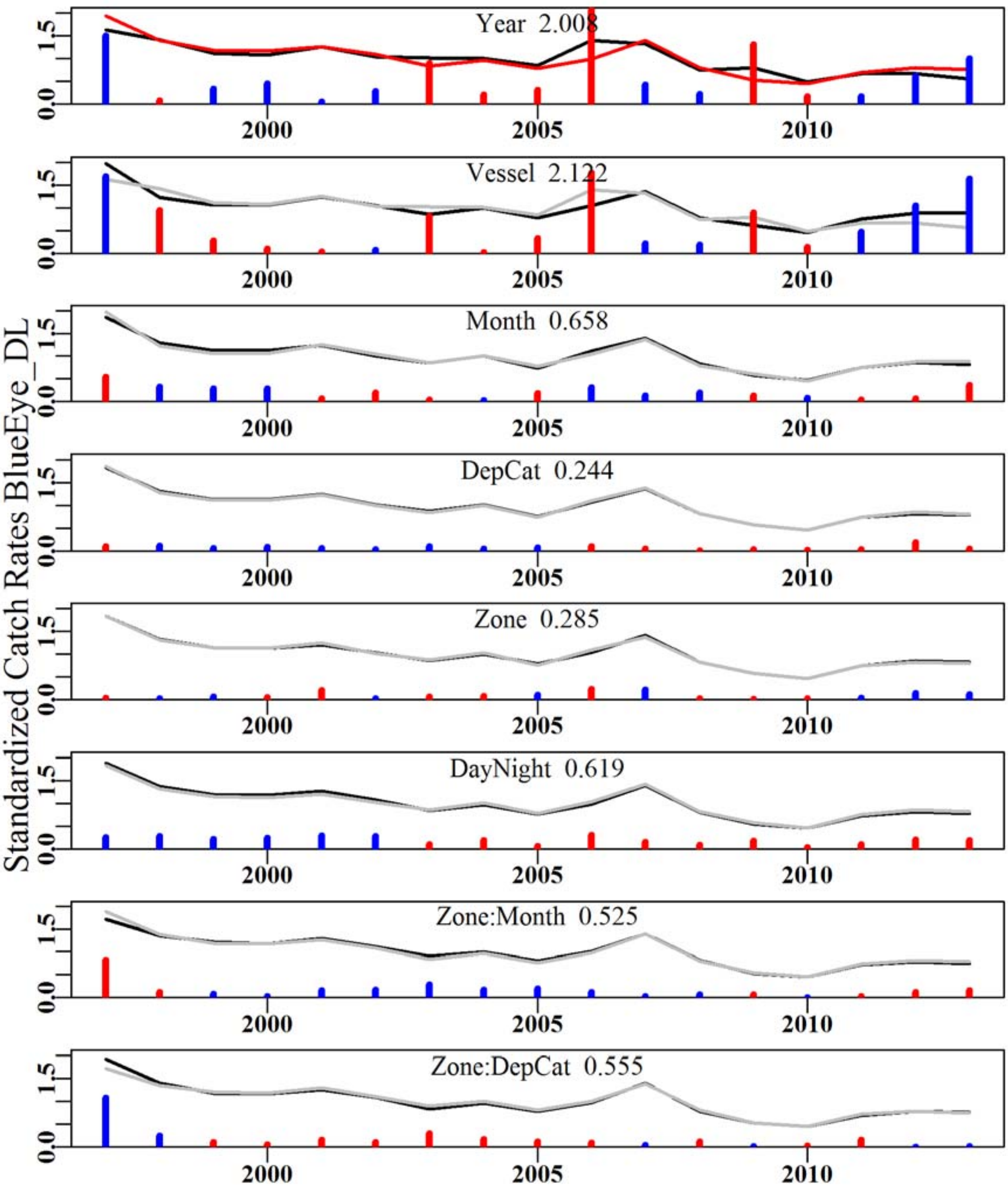


Figure 13.75**.** The relative influence of each factor used on the final trend in the optimal standardization for Blue Eye Trevalla in by Drop-line. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by the vertical bars with blue bars indicating the optimum model is higher than the geometric mean and red bars indicating it is lower. The top graph bars are the sum of all the bars in the graphs below. The graphs for individual factors are cumulative. Thus the second graph has the geometric mean (grey line) and the effect of adding Year + factor2 (Model 2). In the third graph, the grey line represents Model 2 and the black line the effect of adding factor3 to the model. The remaining graphs continue in the same cumulative manner except for the interaction terms which are added singularly to the final single factor model.

13.28 Blue Eye Trevalla AL & DL (TBE – 37445001 –Hyperoglyphe antarctica)

Data from Auto Lines and Drop lines corresponding to depths between 200-600 m and from zones 10-50; 83-85 (GAB) were analysed.

Table 13.70**.** Blue Eye Trevalla from the SEN and GHT in depths 200 – 600 m by Auto Line and Drop Line. Total catch (TotCatch; t) is the total reported in the database, number of records used in the analysis (Records), reported catch (CatchT; t) in the area and depth used in the analysis and number of vessels used in the analysis (Vessels). GeoMean is the geometric mean of catch rates (kg/shot). The optimum model is Zone:Month and standard deviation (StDev) relates to the data in the optimum model.

Year	TotCatch	Records	CatchT	Vessels	GeoMean	Zone:Month	StDev
1997	470.7164	547	254.7863	39	258.2795	1.8145	0.0000
1998	475.9652	758	340.8961	30	226.1524	1.3436	0.0795
1999	574.4838	927	387.0546	30	189.1263	1.1915	0.0817
2000	667.0558	1086	406.1523	34	177.6127	1.1456	0.0844
2001	647.5307	807	358.9104	27	202.9873	1.2115	0.0876
2002	843.8591	799	312.2097	24	163.8436	0.9363	0.0892
2003	605.3020	969	324.9841	25	148.5823	1.0522	0.0922
2004	606.2500	1638	418.2961	29	91.4807	1.0977	0.0906
2005	755.1858	1479	381.0664	23	88.2444	0.8611	0.0931
2006	573.7189	1368	447.1301	19	121.2856	1.0133	0.0936
2007	937.1424	783	498.9427	15	333.7817	1.1969	0.0994
2008	398.9433	684	293.4965	13	214.3734	0.8218	0.1007
2009	520.8777	631	331.0255	15	259.7135	0.8779	0.1013
2010	437.3987	680	259.0059	14	142.9654	0.5468	0.1010
2011	554.2188	692	258.0839	14	177.7061	0.6311	0.1010
2012	463.8349	520	198.6680	14	156.1670	0.5922	0.1050
2013	398.3268	396	193.5343	10	209.2874	0.6659	0.1099

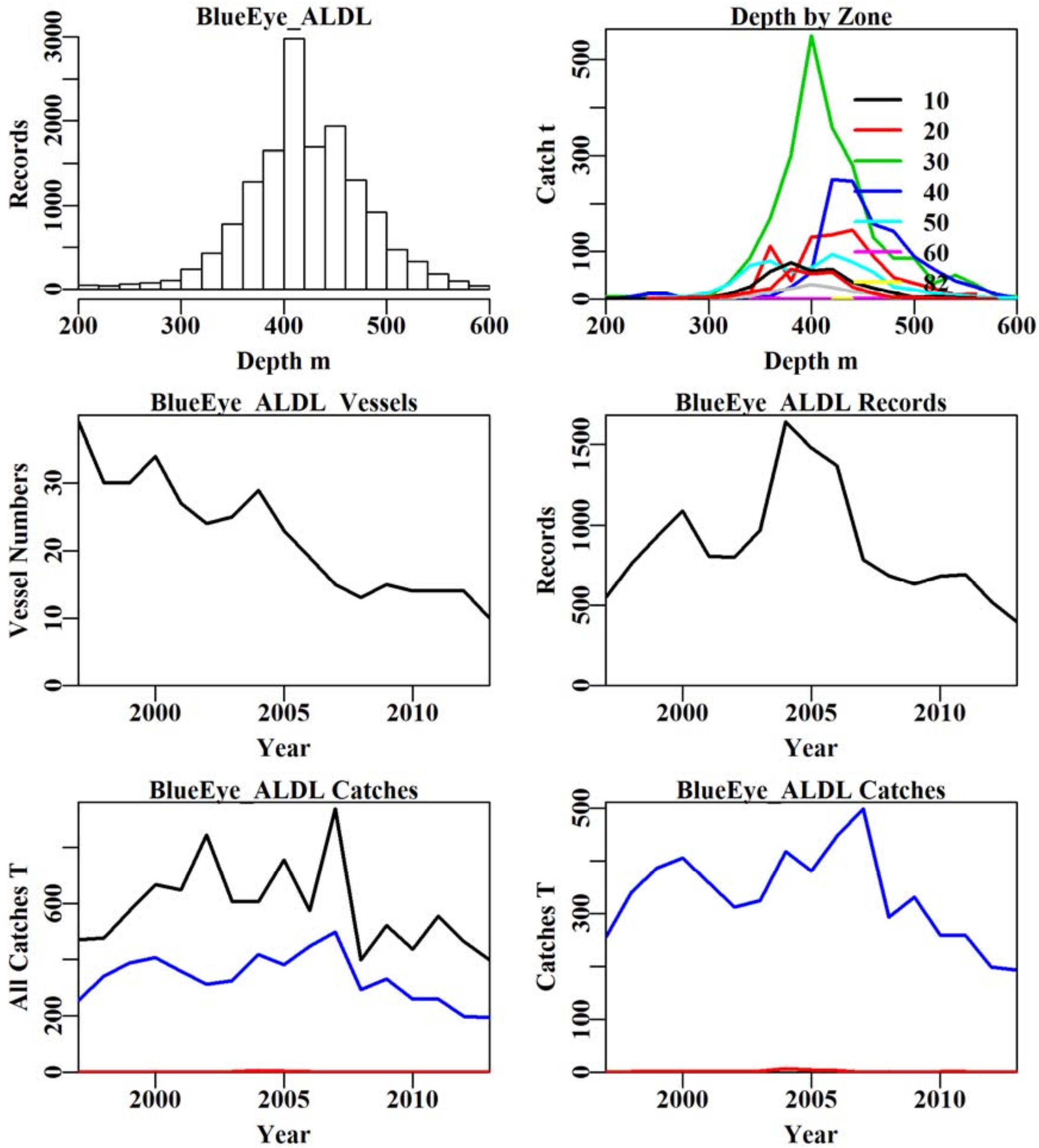
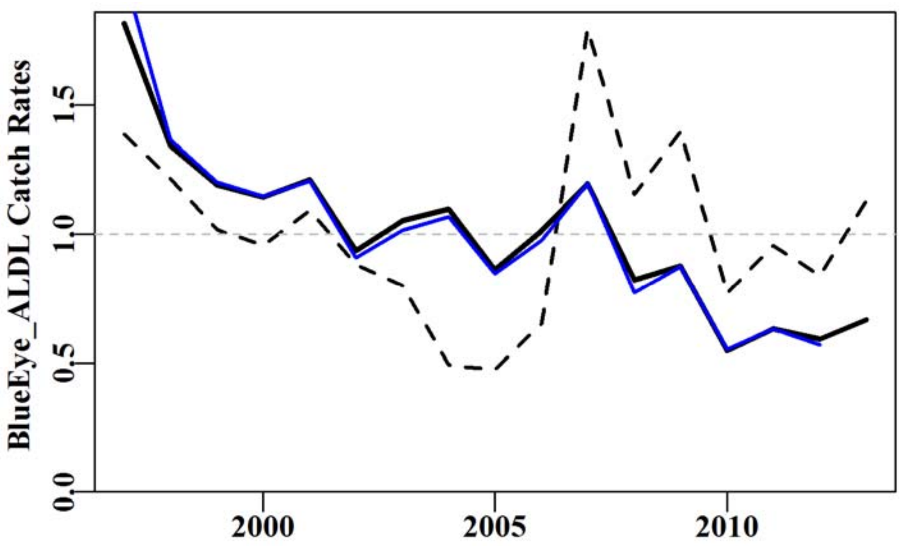


Figure 13.76**.** Blue Eye Trevalla from the SEN and GHT in depths 200 – 600 m by Auto Line and Drop Line. The top left plot depicts the depth distribution of shots containing Blue Eye Trevalla from the SEN and GHT in depths 200 – 600 m by Auto Long Line and Drop Line. The top right plot depicts the catch distribution by depth by zone. The middle left plot depicts the number of vessels through time and middle right plot contains the number of records used in analysis. The bottom left plot contains Blue Eye Trevalla catches (top black line: total catches, middle blue line: catches used in the analysis; bottom red line: catches < 30 kg) and bottom right plot contains Blue Eye Trevalla catches (blue line: catches used in the analysis; red line: catches < 30 kg).



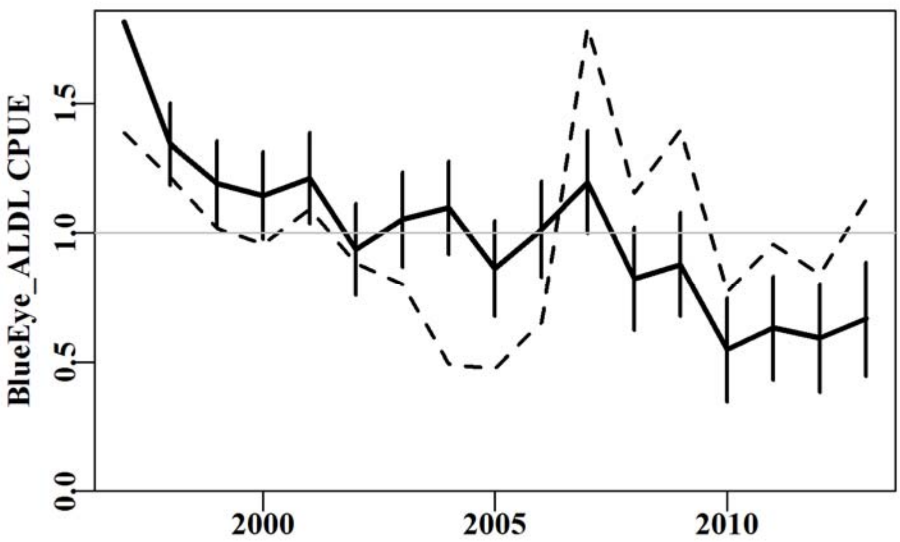


Figure 13.77**.** Blue Eye Trevalla from the SEN and GHT in depths 200 – 600 m by Auto Line and Drop line. Upper graph: The dashed black line represents the geometric mean catch rate and the solid black line the standardized catch rates (relative to the mean of the standardized catch rates). The blue line corresponds to last year's standardized indices. Lower graph: Standardized indices (solid black line), 95% CI (vertical lines) and geometric mean (dashed black line). This illustrates the impact on the relative uncertainty of the relatively small number of records, especially in the early years.

Table 13.71**.** Blue Eye Trevalla from the SEN and GHT in depths 200 – 600 m 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+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+Method
Model 8	LnCE~Year+Vessel+Month+Zone+DepCat+DayNight+Method+Zone:Month
Model 9	LnCE~Year+Vessel+Month+Zone+DepCat+DayNight+Method+Zone:DepCat
Model 10	LnCE~Year+Vessel+Month+Zone+DepCat+DayNight+Method+Zone:Method
Model 11	LnCE~Year+Vessel+Month+Zone+DepCat+DayNIght+Method+Month:Method

Table 13.72. Blue Eye Trevalla from the SEN and GHT in depths 200 – 600 m by Auto Long Line and Drop Line. Model selection criteria include the Akaike Information Criterion (AIC), residual sum of squares (RSS), model sum of squares (MSS), number of usable observations (Nobs), number of parameters (Npars), adjusted R^2 (adj_R^2) and the change in adjusted R^2 (%Change). The optimum is model Zone, though Zon:Mth is very close. Depth Category: DepC; Month: Mth; DayNight: DN; Method: Meth; Zone: Zon.

	Year	Vessel	Month	Zone	DepC	DN	Meth	Zon:Mth	Zon:DepC	Zon:Meth	Mth:Meth
AIC	11822	8292	7388	7134	7013	6959	6987	6753	7017	7171	7109
RSS	32807	25482	23933	23455	23136	23041	23041	22371	22527	22935	22750
MSS	2121	9445	10995	11472	11792	11887	11887	12556	12401	11993	12178
Nobs	14764	14764	14764	14716	14641	14641	14641	14641	14641	14641	14641
Npars	17	117	128	137	157	160	161	273	354	300	328
adj_R^2	5.970	26.464	30.884	32.220	33.048	33.308	33.304	34.737	33.910	32.968	33.377
%Change	0.000	20.495	4.419	1.336	0.829	0.260	-0.004	1.433	-0.827	-0.942	0.409

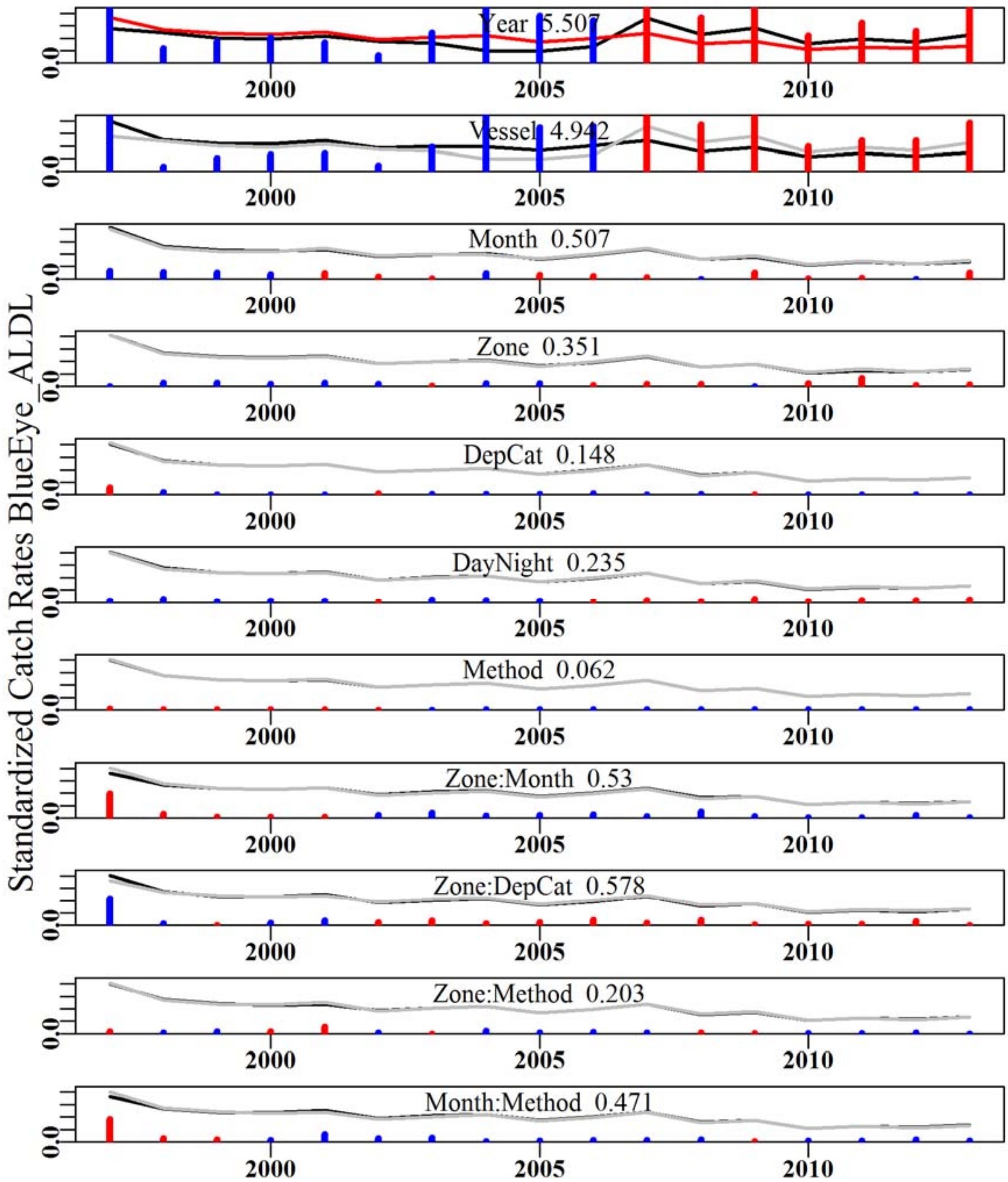


Figure 13.78. The relative influence of each factor used on the final trend in the optimal standardization for Blue Eye Trevalla by AL and DL. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by the vertical bars with blue bars indicating the optimum model is higher than the geometric mean and red bars indicating it is lower. The top graph bars are the sum of all the bars in the graphs below. The graphs for individual factors are cumulative. Thus the second graph has the geometric mean (grey line) and the effect of adding Year + factor2 (Model 2). In the third graph, the grey line represents Model 2 and the black line the effect of adding factor3 to the model. The remaining graphs continue in the same cumulative manner except for the interaction terms which are added singularly to the final single factor model.

13.29 Blue Grenadier Non-Spawning (GRE – 3722700 *Macruronus novaezelandiae*)

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

Table 13.73. Blue Grenadier from the SET in depths between 0 – 1000 m, taken by Trawl, omitting the Spawning fishery (zone 40 between June and August). Total catch (TotCatch; t) is the total reported in the database, number of records used in the analysis (Records), reported catch (CatchT; t) in the area and depth used in the analysis and number of vessels used in the analysis (Vessels). GeoMean is the geometric mean of catch rates (kg/hr). The optimum model is Zone:Month and standard deviation (StDev) relates to the data in the optimum model.

Year	TotCatch	Records	CatchT	Vessels	GeoMean	Zone:Month	StDev
1986	1451.7780	3189	1183.3070	92	36.7375	1.5100	0.0000
1987	2244.8280	3569	1437.4340	91	37.3307	1.9807	0.0337
1988	1849.1470	3961	1470.1960	102	36.6778	2.1512	0.0338
1989	1890.8550	4309	1813.5010	99	45.3866	2.2257	0.0338
1990	2280.4710	3577	1625.1460	92	47.9497	2.1842	0.0357
1991	3669.0360	4308	2392.6870	86	48.2874	1.5754	0.0343
1992	2474.5460	3228	1505.7990	61	40.5408	1.3016	0.0366
1993	2482.2700	4203	1619.0490	63	33.2638	0.9810	0.0350
1994	2315.4900	4491	1309.5630	66	29.5414	0.8859	0.0346
1995	1931.0460	5076	1015.2610	61	19.4025	0.6094	0.0338
1996	2304.2340	5370	1055.3400	73	15.8910	0.5555	0.0337
1997	3654.6590	6194	994.6040	73	13.3293	0.5751	0.0332
1998	4226.1770	6599	1452.5520	65	18.8682	0.9422	0.0330
1999	7573.0180	8045	2051.9460	65	22.7820	0.9963	0.0323
2000	7503.1400	7679	1751.2295	70	16.8751	0.7079	0.0326
2001	8370.7990	7279	1013.7740	60	11.4735	0.4049	0.0331
2002	7976.8590	6344	1124.4927	57	13.3281	0.4064	0.0336
2003	7947.1150	5676	669.6359	56	10.1061	0.3401	0.0339
2004	6091.1790	6393	1204.7328	56	16.9606	0.5734	0.0337
2005	4506.6460	5346	1174.7071	54	19.8329	0.6867	0.0344
2006	3544.3540	4362	1308.8400	42	26.9839	0.9108	0.0355
2007	3127.3930	3659	1203.7072	27	25.1827	0.8122	0.0365
2008	4150.1920	3406	1274.3986	26	28.7998	0.8951	0.0371
2009	3874.2100	3443	1128.4378	23	25.9116	0.8309	0.0370
2010	4551.2510	3314	1136.1358	25	25.9266	0.8139	0.0373
2011	4476.9130	3969	897.7095	26	19.2986	0.6572	0.0363
2012	4465.2920	3210	613.6124	29	15.0034	0.5309	0.0378
2013	4209.4210	3051	741.7840	26	23.1500	0.9555	0.0382

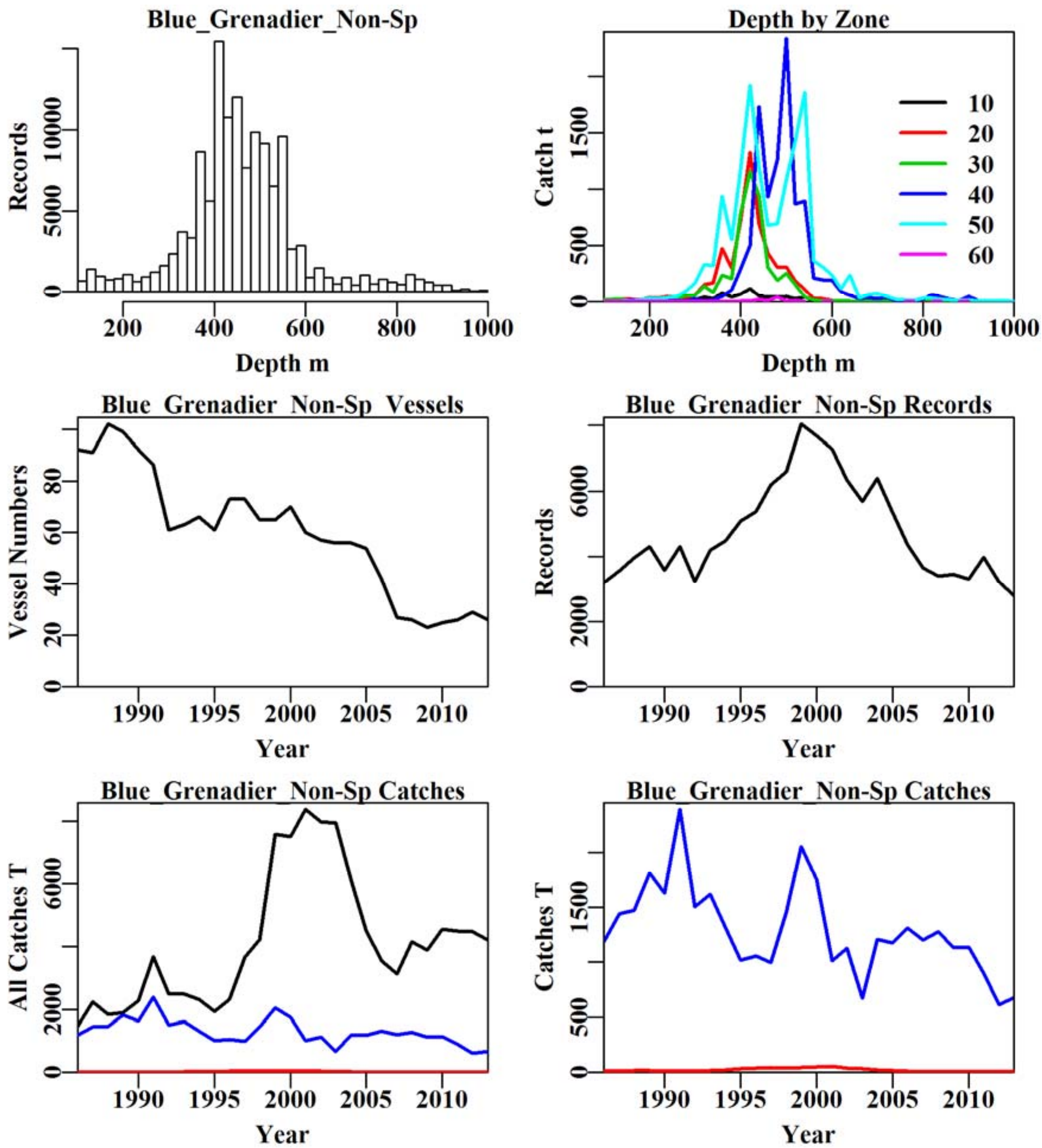


Figure 13.79**.** Blue Grenadier from the SET in depths between 0 – 1000 m, taken by Trawl, omitting the Spawning fishery (zone 40 between June and August). The top left plot depicts the depth distribution of shots containing Blue Grenadier from the SET omitting the Spawning fishery (zone 40 between June and August) in depths 0 – 1000 m by Trawl. The top right plot depicts the catch distribution by depth by zone. The middle left plot depicts the number of vessels through time and middle right plot contains the number of records used in analysis. The bottom left plot contains Blue Grenadier catches (top black line: total catches, middle blue line: catches used in the analysis; bottom red line: catches < 30 kg) and bottom right plot contains Blue Grenadier catches (blue line: catches used in the analysis; red line: catches < 30 kg).

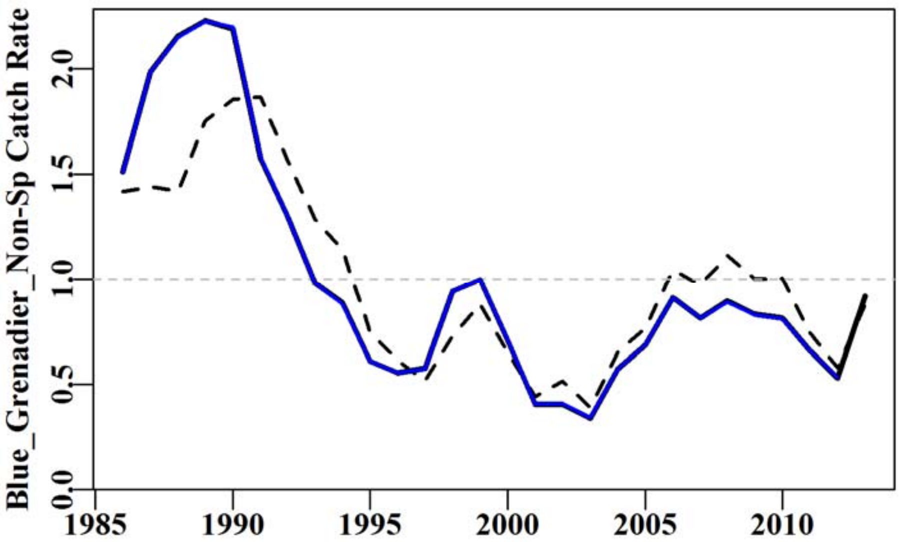


Figure 13.80. Blue Grenadier from the SET in depths between 0 – 1000 m, taken by Trawl, omitting the Spawning fishery (zone 40 between June and August). The dashed black line represents the geometric mean catch rate and the solid black line the standardized catch rates (relative to the mean of the standardized catch rates). The blue line corresponds to last year's standardized indices.

Table 13.74**.** Blue Grenadier from the SET in depths between 0 – 1000 m, taken by Trawl, omitting the Spawning fishery (zone 40 between June and August). Statistical model structures used in this analysis. DepCat is a series of 20 metre depth categories.

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

Table 13.75**.** Blue Grenadier from the SET in depths between 0 – 1000 m, taken by Trawl, omitting the Spawning fishery (zone 40 between June and August). Model selection criteria include the Akaike Information Criterion (AIC), residual sum of squares (RSS), model sum of squares (MSS), number of usable observations (Nobs), number of parameters (Npars), adjusted R^2 (adj_R^2) and the change in adjusted R^2 (%Change). The optimum is Model 7 (Zone:Month). Depth category: DepC.

	Year	Vessel	DepC	Month	Zone	DayNight	Zone:Month	Zone:DepC
AIC	122685	98406	84181	78995	76063	73552	70311	72136
RSS	334460	277939	249042	239435	234174	229764	224023	226548
MSS	25006	81527	110424	120030	125292	129702	135443	132918
Nobs	133250	133250	132405	132405	132405	132405	132405	132405
Npars	28	222	267	278	283	286	341	511
adj_R^2	6.938	22.552	30.579	33.252	34.716	35.944	37.519	36.733
%Change	0.000	15.614	8.028	2.672	1.464	1.228	1.574	-0.786

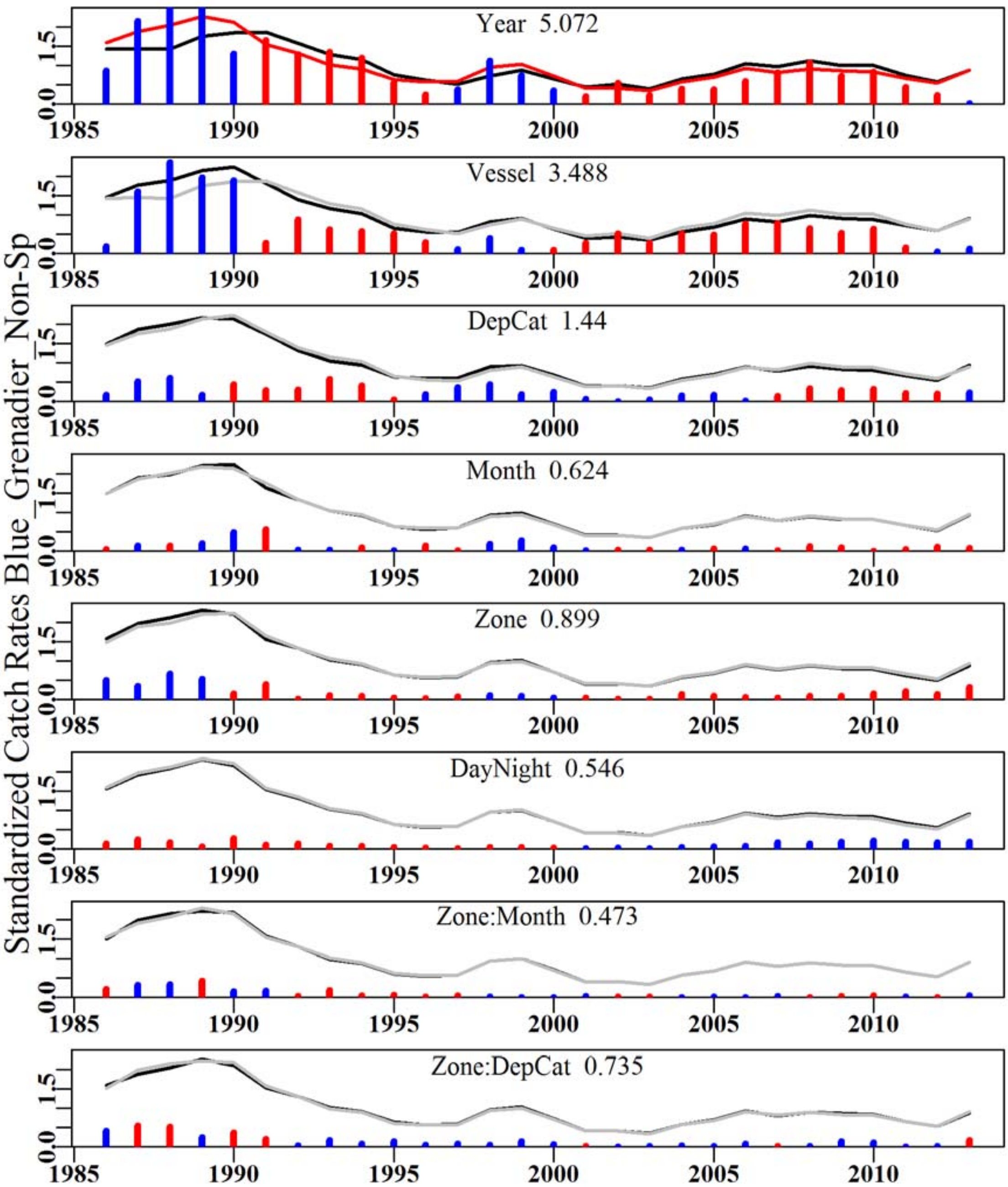


Figure 13.81**.** The relative influence of each factor used on the final trend in the optimal standardization for Blue Grenadier non-spawning fishery. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by the vertical bars with blue bars indicating the optimum model is higher than the geometric mean and red bars indicating it is lower. The top graph bars are the sum of all the bars in the graphs below. The graphs for individual factors are cumulative. Thus the second graph has the geometric mean (grey line) and the effect of adding Year + factor2 (Model 2). In the third graph, the grey line represents Model 2 and the black line the effect of adding factor3 to the model. The remaining graphs continue in the same cumulative manner except for the interaction terms which are added singularly to the final single factor model.

13.30 Silver Warehou (TRS – 37445006 – Seriolella punctata)

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

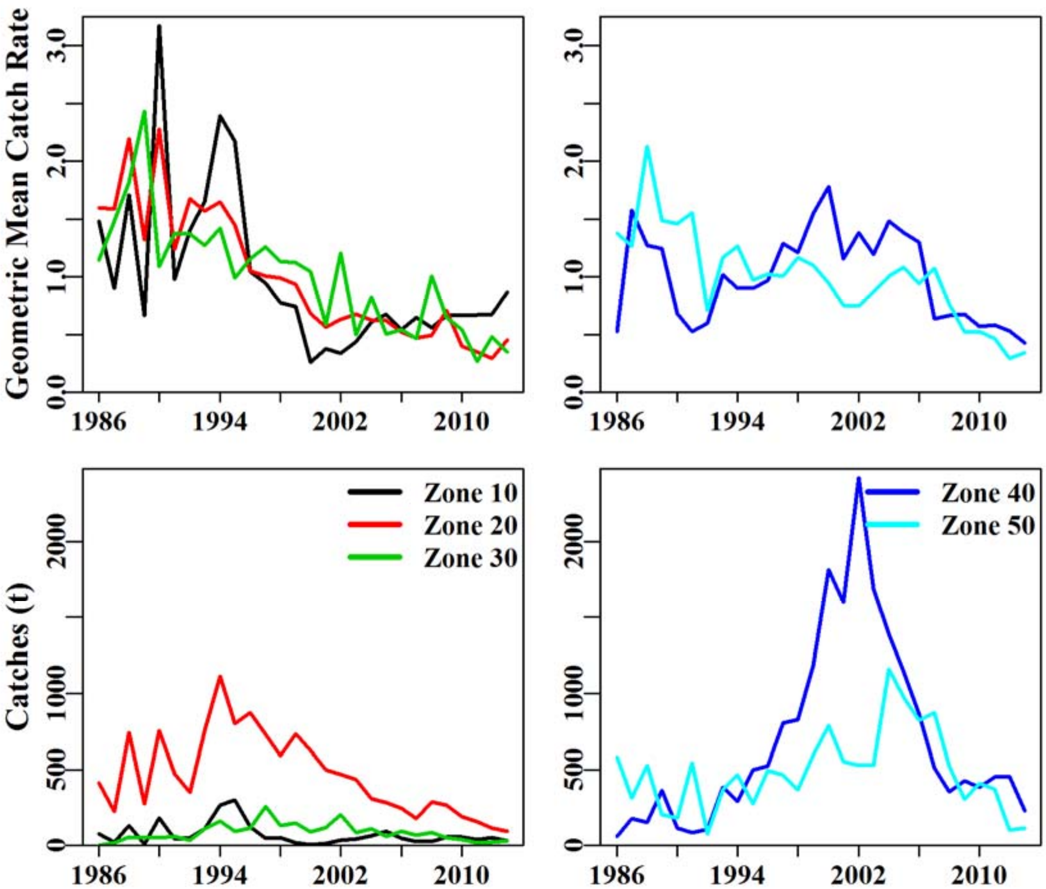


Figure 13.82**.** The trends in catches and catch rates for zones 10 – 50, split east and west.

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

Year	TotCatch	Records	CatchT	Vessels	GeoMean	Zone:Month	StDev
1986	1156.5330	2438	1135.2960	86	32.2897	1.4933	0.0000
1987	782.1510	1509	757.2980	76	35.5040	1.5681	0.0562
1988	1646.1870	2249	1617.2400	87	42.9346	2.0001	0.0510
1989	926.2570	2049	907.4200	80	30.7291	1.6286	0.0538
1990	1346.5850	1983	1290.9590	81	40.6488	1.7213	0.0543
1991	1453.1690	2289	1207.3610	78	25.6848	1.2123	0.0532
1992	733.7670	1857	625.0740	55	27.9469	1.0650	0.0557
1993	1815.8010	3866	1735.1630	61	33.2988	1.2031	0.0486
1994	2309.5100	4519	2300.0830	57	34.7142	1.2857	0.0476
1995	2002.8810	5016	1969.8570	58	29.7825	1.1606	0.0469
1996	2188.2440	6080	2137.3730	67	22.7319	1.0902	0.0462
1997	2562.0160	5765	2305.7850	61	25.3481	1.1189	0.0468
1998	2166.0212	4702	1976.6670	57	26.6416	1.0759	0.0478
1999	2834.0520	5148	2685.6780	58	31.2330	0.9246	0.0474
2000	3401.5633	6738	3324.0090	64	26.0708	0.8447	0.0463
2001	2970.4067	7293	2789.4120	59	21.7853	0.7100	0.0461
2002	3841.4390	8418	3656.5965	57	22.9919	0.7676	0.0455
2003	2910.0946	7405	2782.8079	64	20.4602	0.7735	0.0460
2004	3202.0836	7861	3036.7484	58	23.3439	0.8594	0.0458
2005	2647.9671	6920	2558.2815	56	20.0277	0.8449	0.0463
2006	2191.1968	5663	2076.2746	47	18.2147	0.7437	0.0473
2007	1816.5165	4657	1665.2355	33	20.1239	0.7032	0.0483
2008	1381.1590	4400	1279.9289	32	16.1202	0.6339	0.0487
2009	1285.3059	4387	1109.6456	28	15.8837	0.6549	0.0487
2010	1189.4336	4484	1082.6024	28	13.2592	0.5431	0.0487
2011	1108.7509	4940	1042.7738	30	12.6164	0.5063	0.0482
2012	781.1541	3768	750.5568	29	10.4075	0.4136	0.0500
2013	584.0728	2979	502.9518	29	11.6086	0.4537	0.0518

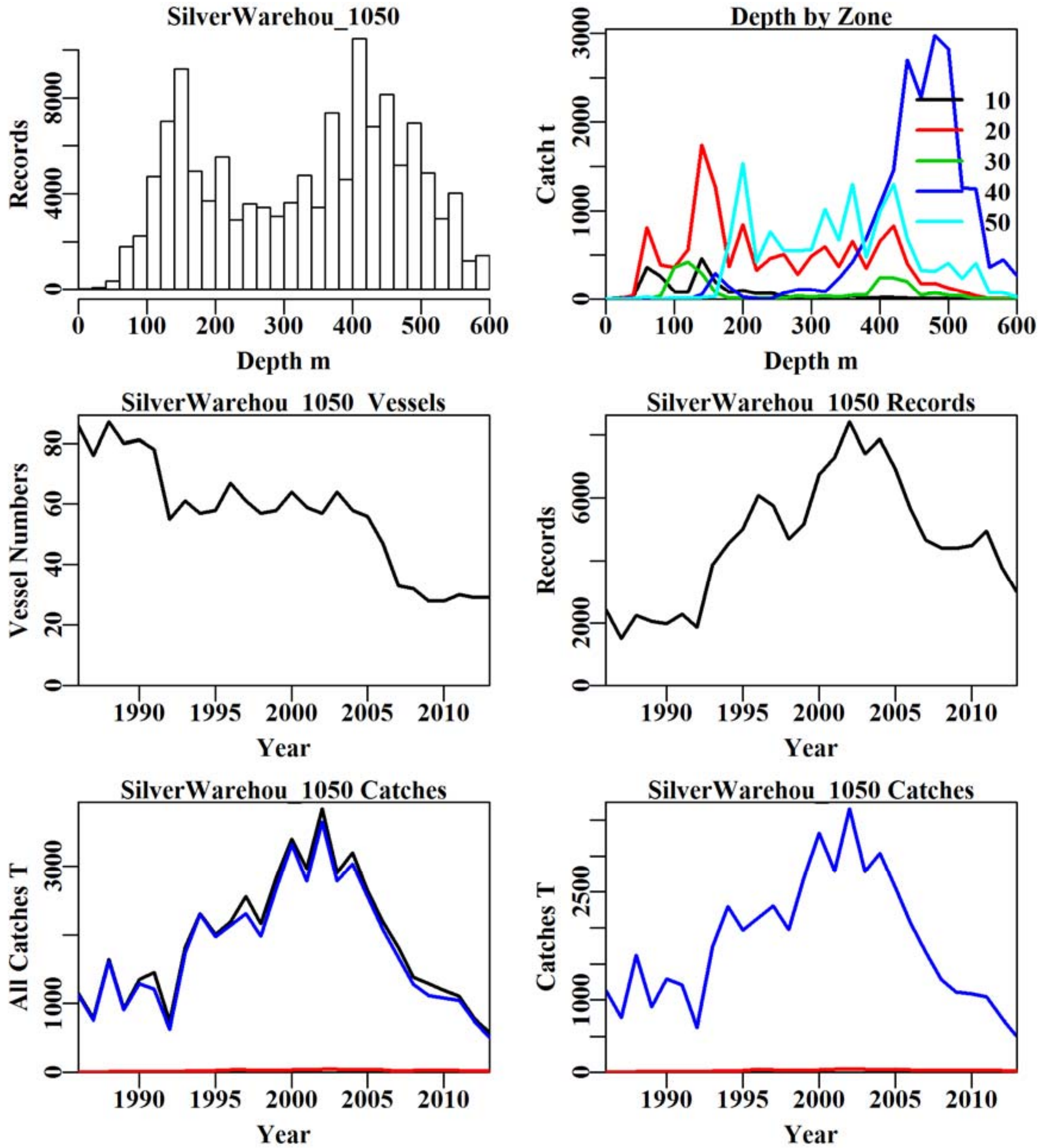


Figure 13.83**.** Silver Warehou from zones 10 to 50 and depths 0 – 600 m by Trawl. The top left plot depicts the depth distribution of shots containing Silver Warehou from zones 10 to 50 in depths 0 – 600 m by Trawl. The top right plot depicts the catch distribution by depth by zone. The middle left plot depicts the number of vessels through time and middle right plot contains the number of records used in analysis. The bottom left plot contains Silver Warehou catches (top black line: total catches, middle blue line: catches used in the analysis; bottom red line: catches < 30 kg) and bottom right plot contains Silver Warehou catches (blue line: catches used in the analysis; red line: catches < 30 kg).

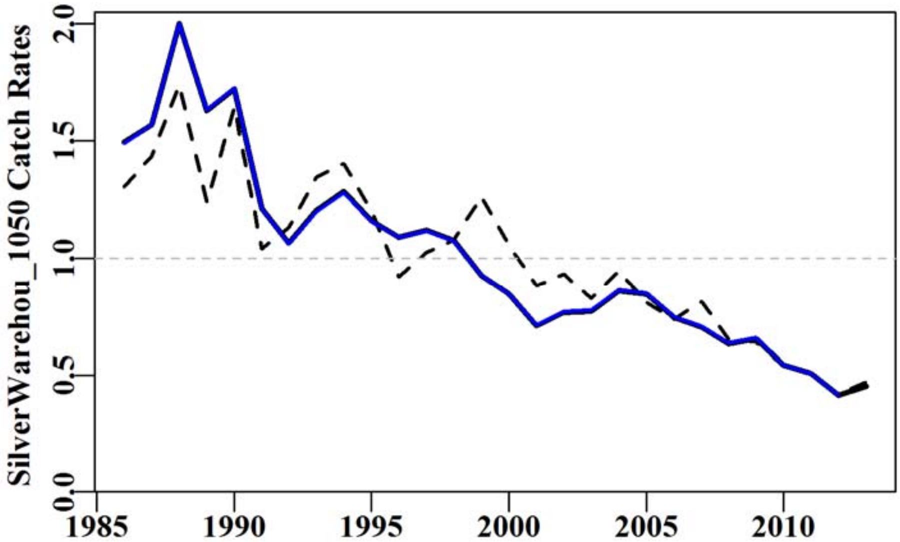


Figure 13.84. Silver Warehou from Zones 10 to 50 and depths 0 – 600 m by Trawl. The dashed black line represents the geometric mean catch rate and the solid black line the standardized catch rates (relative to the mean of the standardized catch rates). The blue line corresponds to last year's standardized indices.

Table 13.77. Silver Warehou from Zones 10 to 50 and depths 0 – 600 m by Trawl. Statistical model structures used in this analysis. DepCat is a series of 20 metre depth categories.

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

Table 13.78. Silver Warehou from Zones 10 to 50 and depths 0 – 600 m by Trawl. Model selection criteria include the Akaike Information Criterion (AIC), residual sum of squares (RSS), model sum of squares (MSS), number of usable observations (Nobs), number of parameters (Npars), adjusted R^2 (adj_R^2) and the change in adjusted R^2 (%Change). The optimum is Zone:Month (Model 7). Depth Category: DepC.

	Year	Vessel	Month	Zone	DepC	DayNight	Zone:Month	Zone:DepC
AIC	154938	132829	126442	124403	121377	121132	119230	119701
RSS	428316	359933	342539	337161	329075	328430	323386	324189
MSS	13297	81679	99073	104451	112538	113182	118227	117423
Nobs	129383	129383	129383	129383	128507	128507	128507	128507
Npars	28	226	237	241	271	274	318	394
adj_R^2	2.991	18.354	22.293	23.510	25.326	25.471	26.591	26.365
%Change	0.000	15.363	3.939	1.218	1.816	0.144	1.120	-0.226

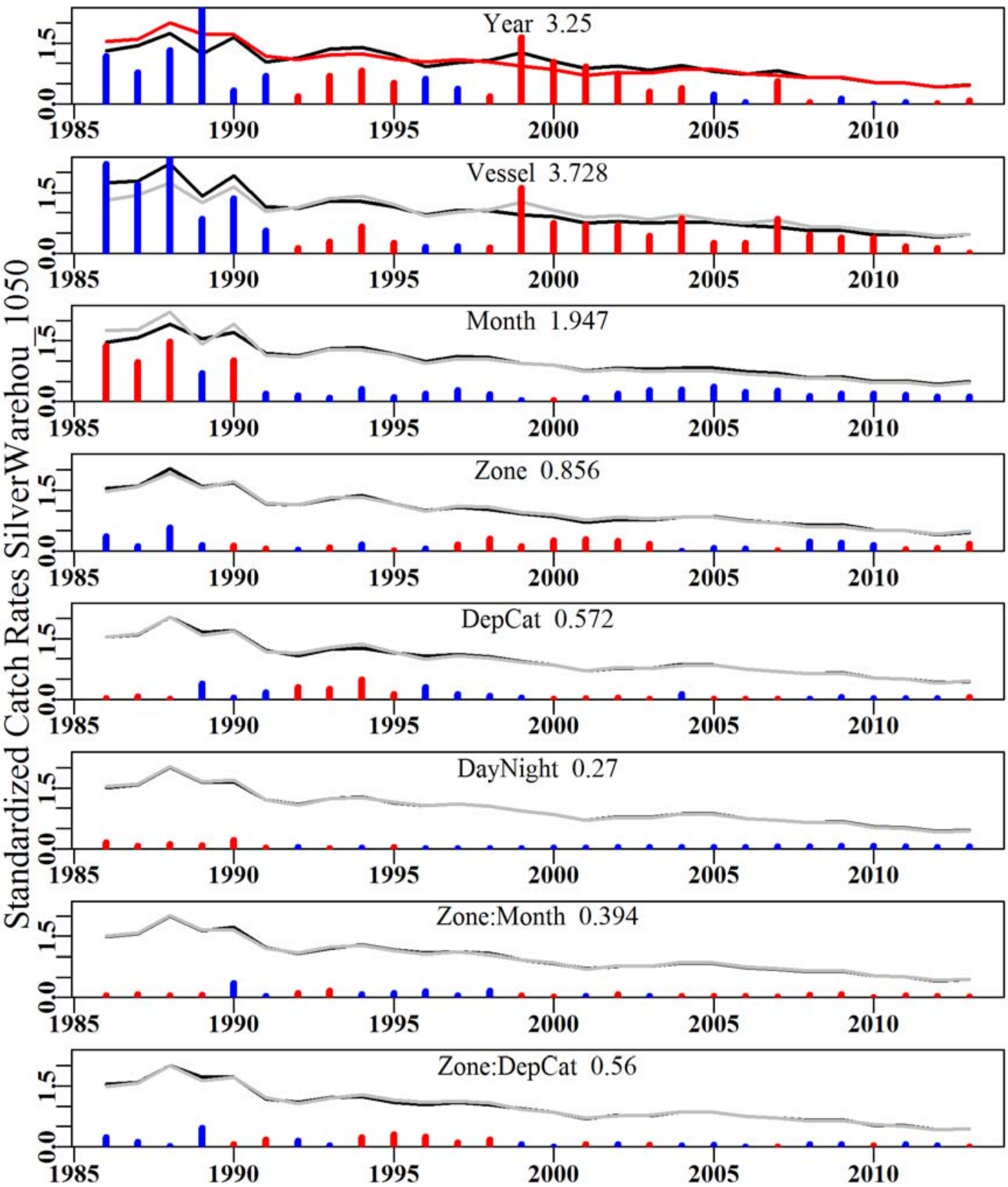


Figure 13.85. The relative influence of each factor used on the final trend in the optimal standardization for Silver Warehou in zones 10 – 50. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by the vertical bars with blue bars indicating the optimum model is higher than the geometric mean and red bars indicating it is lower. The top graph bars are the sum of all the bars in the graphs below. The graphs for individual factors are cumulative. Thus the second graph has the geometric mean (grey line) and the effect of adding Year + factor2 (Model 2). In the third graph, the grey line represents Model 2 and the black line the effect of adding factor3 to the model. The remaining graphs continue in the same cumulative manner except for the interaction terms which are added singularly to the final single factor model.

13.31 Blue Warehou Z10–30 (TRT – 37445005 – Seriolella brama)

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

Table 13.79**.** Blue Warehou from zones 10 to 30 in depths 0 – 400 m by Trawl. Total catch (TotCatch; t) is the total reported in the database, number of records used in the analysis (Records), reported catch (CatchT; t) in the area and depth used in the analysis and number of vessels used in the analysis (Vessels). GeoMean is the geometric mean of catch rates (kg/hr). The optimum model is Zone:DepC and standard deviation (StDev) relates to the data in the optimum model.

Year	TotCatch	Records	CatchT	Vessels	GeoMean	Zone:DepC	StDev
1986	211.8770	702	138.8220	40	22.9216	2.0080	0.0000
1987	405.8510	457	168.1520	40	23.2716	2.4359	0.1047
1988	543.9760	775	334.0470	33	34.8726	2.9762	0.0952
1989	776.0410	1178	664.7090	41	52.6588	3.7641	0.0925
1990	881.3530	826	508.2700	42	46.5510	3.4362	0.0976
1991	1284.1940	1567	465.1580	54	23.0208	1.8493	0.0919
1992	934.4050	1343	406.7490	39	24.3304	1.5263	0.0925
1993	829.5730	2195	431.7350	45	20.7054	1.1903	0.0892
1994	944.8050	2449	473.8990	44	17.5997	1.1484	0.0881
1995	815.3840	2646	467.8250	44	15.3567	1.0501	0.0879
1996	724.4080	3551	531.2230	49	14.6415	1.0833	0.0872
1997	935.1594	2481	404.2810	42	11.8760	1.0569	0.0894
1998	903.2421	2556	457.2470	39	13.8592	0.9881	0.0890
1999	590.9751	1643	131.6410	39	5.7097	0.5481	0.0920
2000	470.2475	2217	185.0830	41	5.0072	0.4545	0.0901
2001	285.4641	1470	57.2420	33	2.7867	0.2706	0.0937
2002	290.4765	1856	62.8670	36	2.2036	0.2049	0.0921
2003	233.9681	1324	42.0775	38	1.8331	0.1592	0.0951
2004	232.4455	1249	52.0505	38	2.7248	0.2163	0.0969
2005	289.0633	830	21.2863	33	1.8011	0.1443	0.1012
2006	379.5272	776	25.7195	28	2.2327	0.1716	0.1024
2007	177.7756	584	16.7583	14	1.8647	0.1806	0.1073
2008	163.2600	738	27.4410	18	2.6539	0.2525	0.1031
2009	135.2235	447	36.8840	15	3.5956	0.2980	0.1120
2010	129.3300	372	12.0425	15	2.0876	0.1866	0.1176
2011	103.2946	435	9.8117	13	1.7081	0.1542	0.1134
2012	52.2722	356	9.9005	14	1.6727	0.1279	0.1187
2013	67.9643	166	3.6740	17	1.6984	0.1177	0.1475

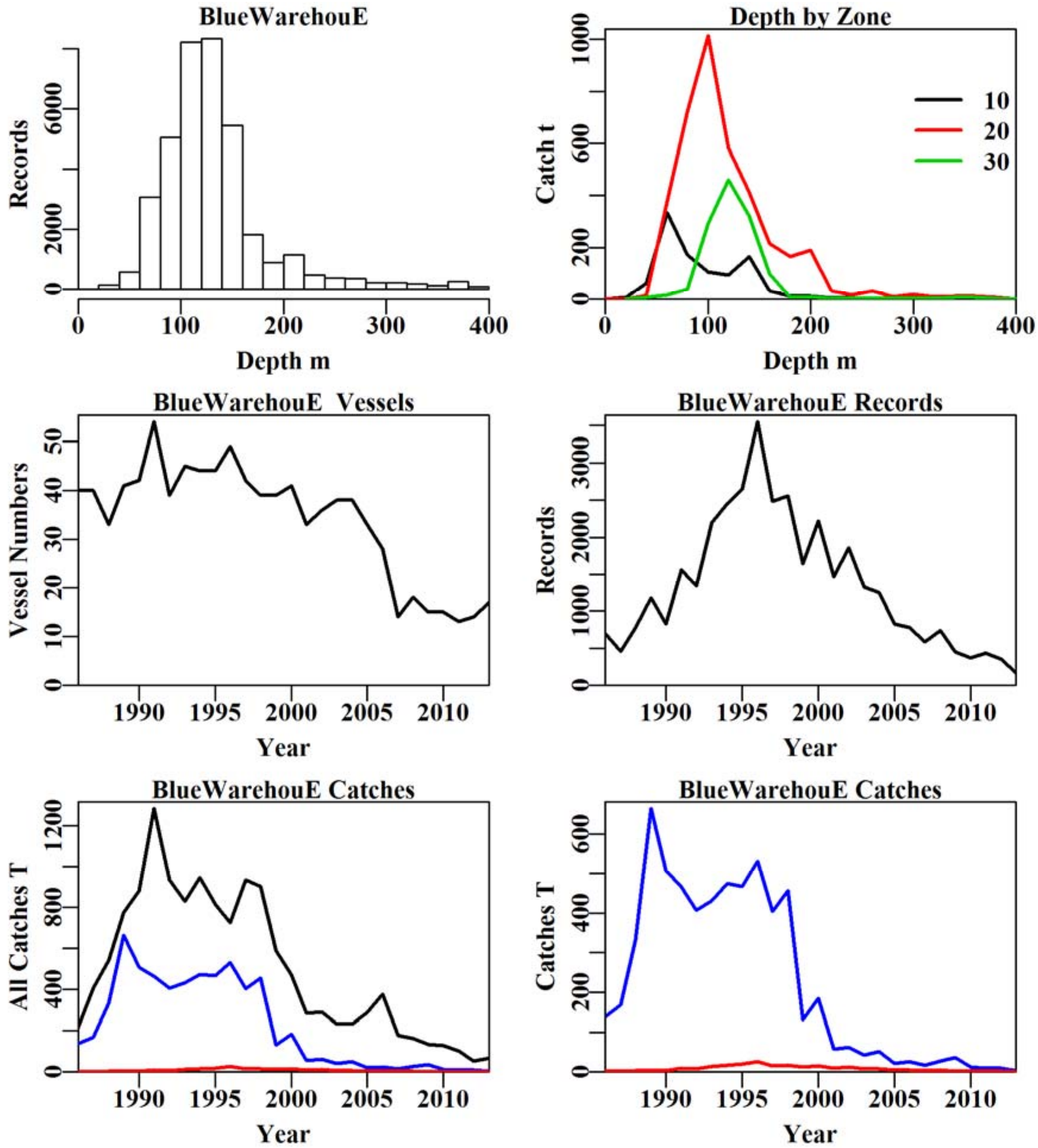


Figure 13.86**.** Blue Warehou from zones 10 to 30 in depths 0 – 400 m by Trawl. The top left plot depicts the depth distribution of shots containing Blue Warehou from zones 10 to 30 in depths 0 – 400 m by Trawl. The top right plot depicts the catch distribution by depth by zone. The middle left plot depicts the number of vessels through time and middle right plot contains the number of records used in analysis. The bottom left plot contains Blue Warehou catches (top black line: total catches, middle blue line: catches used in the analysis; bottom red line: catches < 30 kg) and bottom right plot contains Blue Warehou catches (blue line: catches used in the analysis; red line: catches < 30 kg).

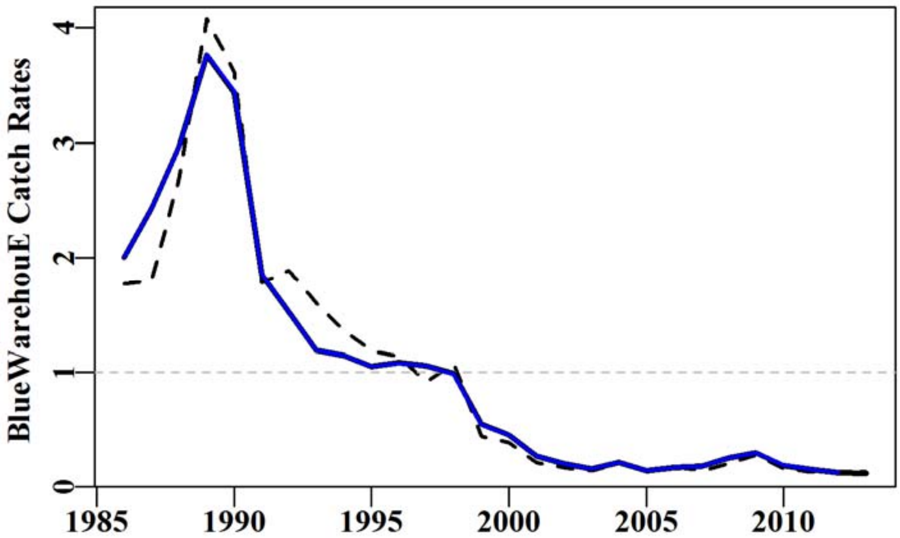


Figure 13.87. Blue Warehou from zones 10 to 30 in depths 0 – 400 m by Trawl. The dashed black line represents the geometric mean catch rate and the solid black line the standardized catch rates (relative to the mean of the standardized catch rates). The blue line corresponds to last year's standardized indices.

Table 13.80. Blue Warehou from zones 10 to 30 in depths 0 – 400 m by Trawl. Statistical model structures used in this analysis. DepCat is a series of 20 metre depth categories.

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

Table 13.81. Blue Warehou from zones 10 to 30 in depths 0 – 400 m by Trawl Model selection criteria include the Akaike Information Criterion (AIC), residual sum of squares (RSS), model sum of squares (MSS), number of usable observations (Nobs), number of parameters (Npars), adjusted R^2 (adj_R^2) and the change in adjusted R^2 (%Change). The optimum is Zone:DepC (Model 8). Depth Category: DepC.

	Year	Vessel	DepC	Month	Zone	DayNight	Zone:Month	Zone:DepC
AIC	37234	32491	31844	31646	31178	31175	30923	30888
RSS	101060	88184	86490	85976	84885	84865	84188	84027
MSS	37933	50809	52503	53017	54108	54128	54805	54967
Nobs	37189	37189	36966	36966	36966	36966	36966	36966
Npars	28	191	211	222	224	227	249	267
adj_R^2	27.238	36.229	37.419	37.772	38.558	38.567	39.021	39.108
%Change	0.000	8.991	1.189	0.353	0.786	0.010	0.453	0.087

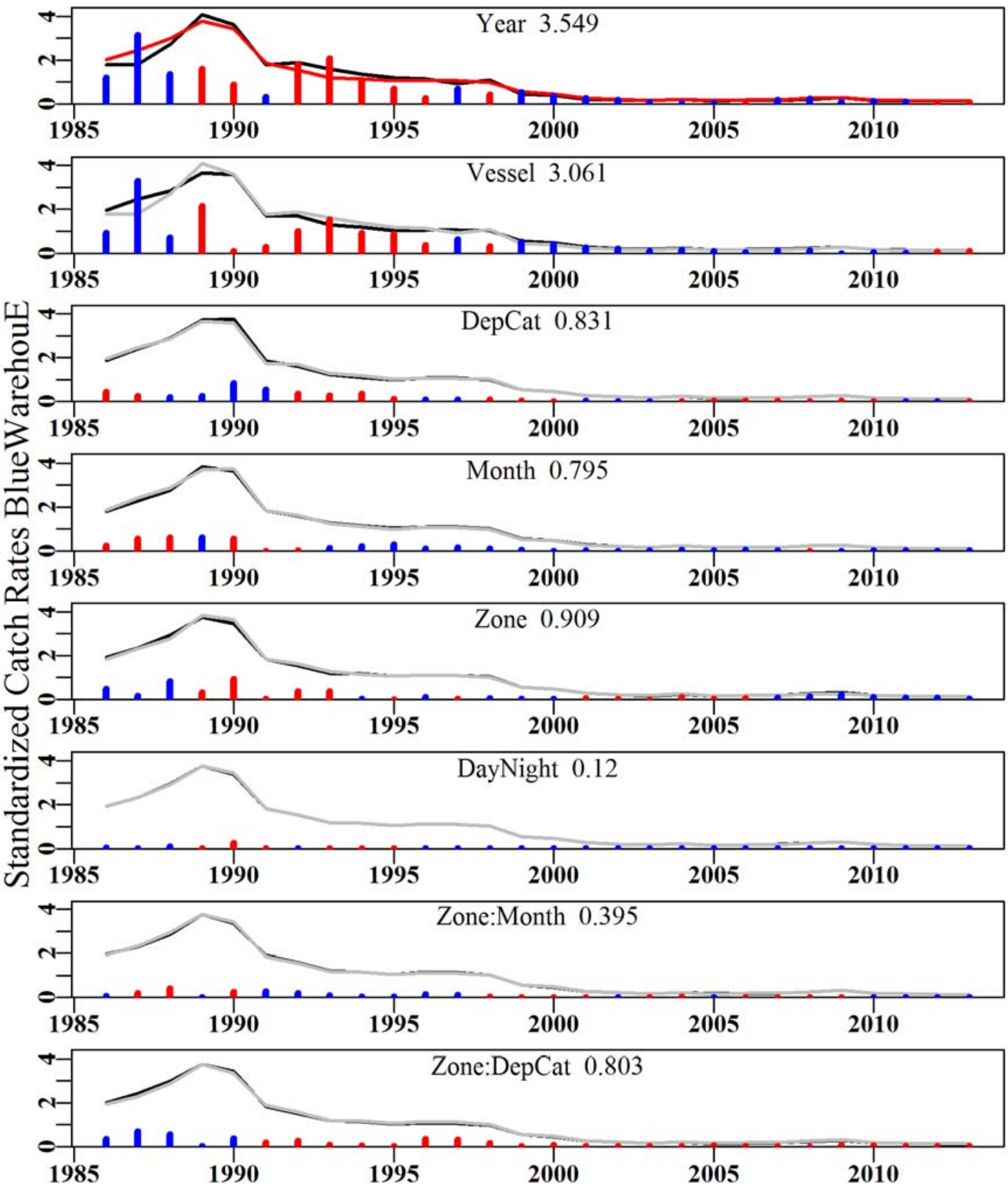


Figure 13.88. The relative influence of each factor used on the final trend in the optimal standardization for Blue Warehou in zone 10 – 30. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by the vertical bars with blue bars indicating the optimum model is higher than the geometric mean and red bars indicating it is lower. The top graph bars are the sum of all the bars in the graphs below. The graphs for individual factors are cumulative. Thus the second graph has the geometric mean (grey line) and the effect of adding Year + factor2 (Model 2). In the third graph, the grey line represents Model 2 and the black line the effect of adding factor3 to the model. The remaining graphs continue in the same cumulative manner except for the interaction terms which are added singularly to the final single factor model.

13.32 Blue Warehou Z4050 (TRT – 37445005 – Seriolella brama)

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

Table 13.82**.** Blue Warehou from zones 40 and 50 in depths 0 – 600 m by Trawl. Total catch (TotCatch; t) is the total reported in the database, number of records used in the analysis (Records), reported catch (CatchT; t) in the area and depth used in the analysis and number of vessels used in the analysis (Vessels). GeoMean is the geometric mean of catch rates (kg/hr). The optimum model is Zone:Month and standard deviation (StDev) relates to the data in the optimum model.

Year	TotCatch	Records	CatchT	Vessels	GeoMean	Zone:Month	StDev
1986	211.8770	159	71.3890	14	34.3927	3.4744	0.0000
1987	405.8510	183	215.6450	10	153.6342	3.3784	0.2436
1988	543.9760	180	197.9890	12	104.5294	1.3863	0.2531
1989	776.0410	56	81.3430	13	91.5270	3.4902	0.3134
1990	881.3530	444	298.2960	14	55.8069	1.5090	0.2387
1991	1284.1940	597	647.5370	18	159.6429	2.3766	0.2368
1992	934.4050	538	430.1330	17	88.9759	1.3664	0.2388
1993	829.5730	495	362.8540	21	92.3447	1.0151	0.2402
1994	944.8050	824	449.9010	21	67.3117	1.1073	0.2358
1995	815.3840	825	325.1500	22	45.1964	0.7443	0.2335
1996	724.4080	700	183.5500	24	26.4215	0.5066	0.2349
1997	935.1594	431	243.5470	23	35.6095	0.5338	0.2404
1998	903.2421	582	354.4830	19	58.9967	0.8117	0.2388
1999	590.9751	688	174.3760	19	32.5226	0.4512	0.2381
2000	470.2475	650	203.3900	24	28.0473	0.3605	0.2384
2001	285.4641	685	194.1560	23	27.5825	0.3883	0.2373
2002	290.4765	530	218.0170	23	35.4216	0.5076	0.2398
2003	233.9681	362	175.4480	19	28.2126	0.4628	0.2455
2004	232.4455	437	159.2550	21	28.4995	0.5076	0.2422
2005	289.0633	461	257.8010	18	53.5991	0.8110	0.2427
2006	379.5272	695	337.4725	16	31.8482	0.5741	0.2391
2007	177.7756	466	148.6395	16	22.9820	0.4834	0.2428
2008	163.2600	353	117.7735	12	20.3955	0.3912	0.2451
2009	135.2235	308	89.0030	11	18.4388	0.2949	0.2474
2010	129.3300	407	105.2905	12	17.5511	0.3402	0.2427
2011	103.2946	519	77.9065	14	14.3950	0.3003	0.2412
2012	52.2722	262	32.7576	14	8.1485	0.1787	0.2521
2013	67.9643	305	57.9275	13	12.4453	0.2480	0.2486

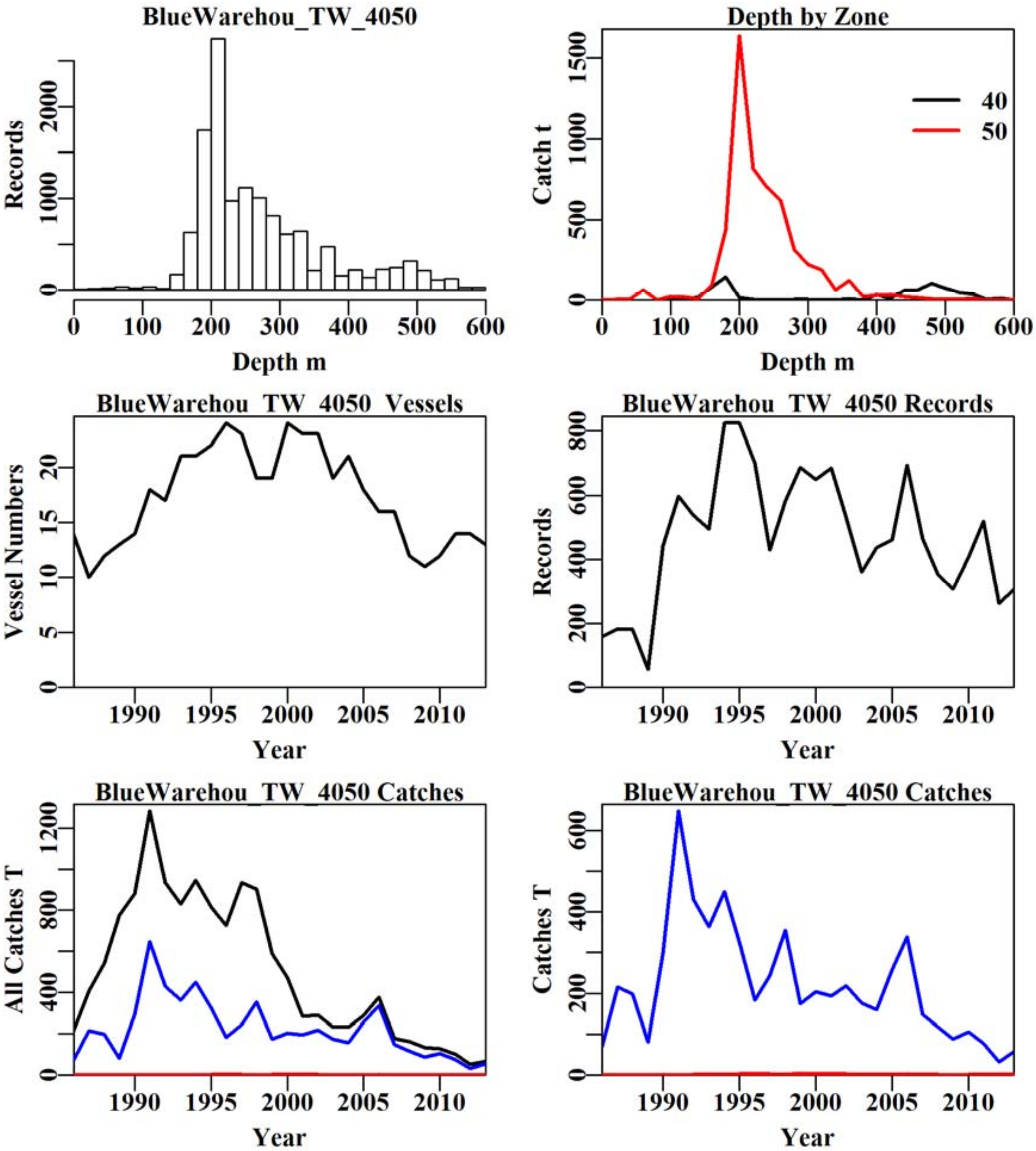


Figure 13.89**.** Blue Warehou from zones 40 and 50 in depths 0 – 600 m by Trawl. The top left plot depicts the depth distribution of shots containing Blue Warehou from zones 40 and 50 in depths 0 – 600 m by Trawl. The top right plot depicts the catch distribution by depth by zone. The middle left plot depicts the number of vessels through time and middle right plot contains the number of records used in analysis. The bottom left plot contains Blue Warehou catches (top black line: total catches, middle blue line: catches used in the analysis; bottom red line: catches < 30 kg) and bottom right plot contains Blue Warehou catches (blue line: catches used in the analysis; red line: catches < 30 kg).

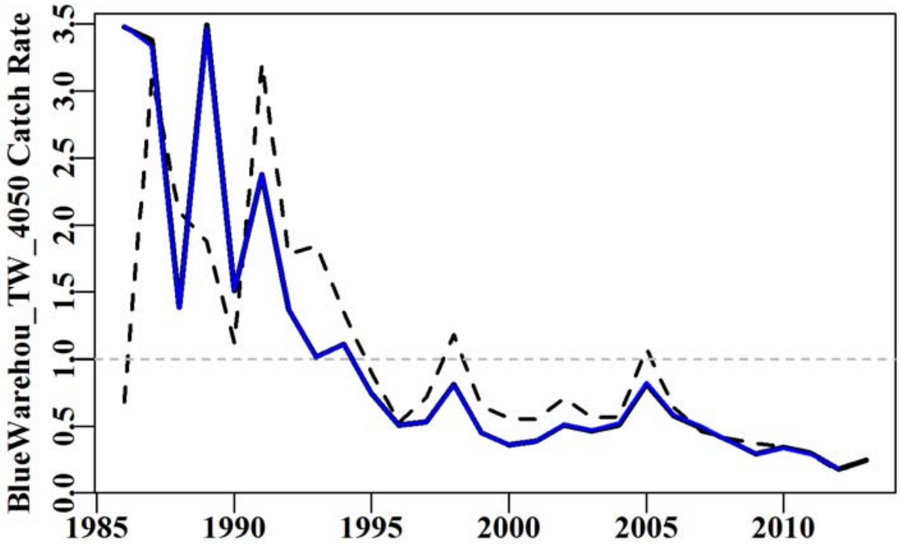


Figure 13.90**.** Blue Warehou from zones 40 and 50 in depths 0 – 600 m by Trawl. The dashed black line represents the geometric mean catch rate and the solid black line the standardized catch rates (relative to the mean of the standardized catch rates). The blue line corresponds to last year's standardized indices.

Table 13.83**.** Blue Warehou from zones 40 and 50 in depths 0 – 600 m by Trawl. Statistical model structures used in this analysis. DepCat is a series of 20 metre depth categories.

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

Table 13.84**.** Blue Warehou from zones 40 and 50 in depths 0 – 600m by Trawl. Model selection criteria include the Akaike Information Criterion (AIC), residual sum of squares (RSS), model sum of squares (MSS), number of usable observations (Nobs), number of parameters (Npars), adjusted R^2 (adj_R^2) and the change in adjusted R^2 (%Change). The optimum is Model 7 (Zone:Month). Depth category: DepC.

	Year	Vessel	Month	DepC	DayNight	Zone	Zone:Month	Zone:DepC
AIC	14614	13473	12450	11655	11492	11490	11450	11476
RSS	39788	36032	33278	31161	30763	30753	30607	30579
MSS	5605	9362	12115	14232	14631	14640	14787	14814
Nobs	13142	13142	13142	13079	13079	13079	13079	13079
Npars	28	109	120	150	153	154	165	184
adj_R^2	12.168	19.966	26.019	30.561	31.434	31.450	31.719	31.680
%Change	0.000	7.798	6.053	4.543	0.872	0.016	0.269	-0.039

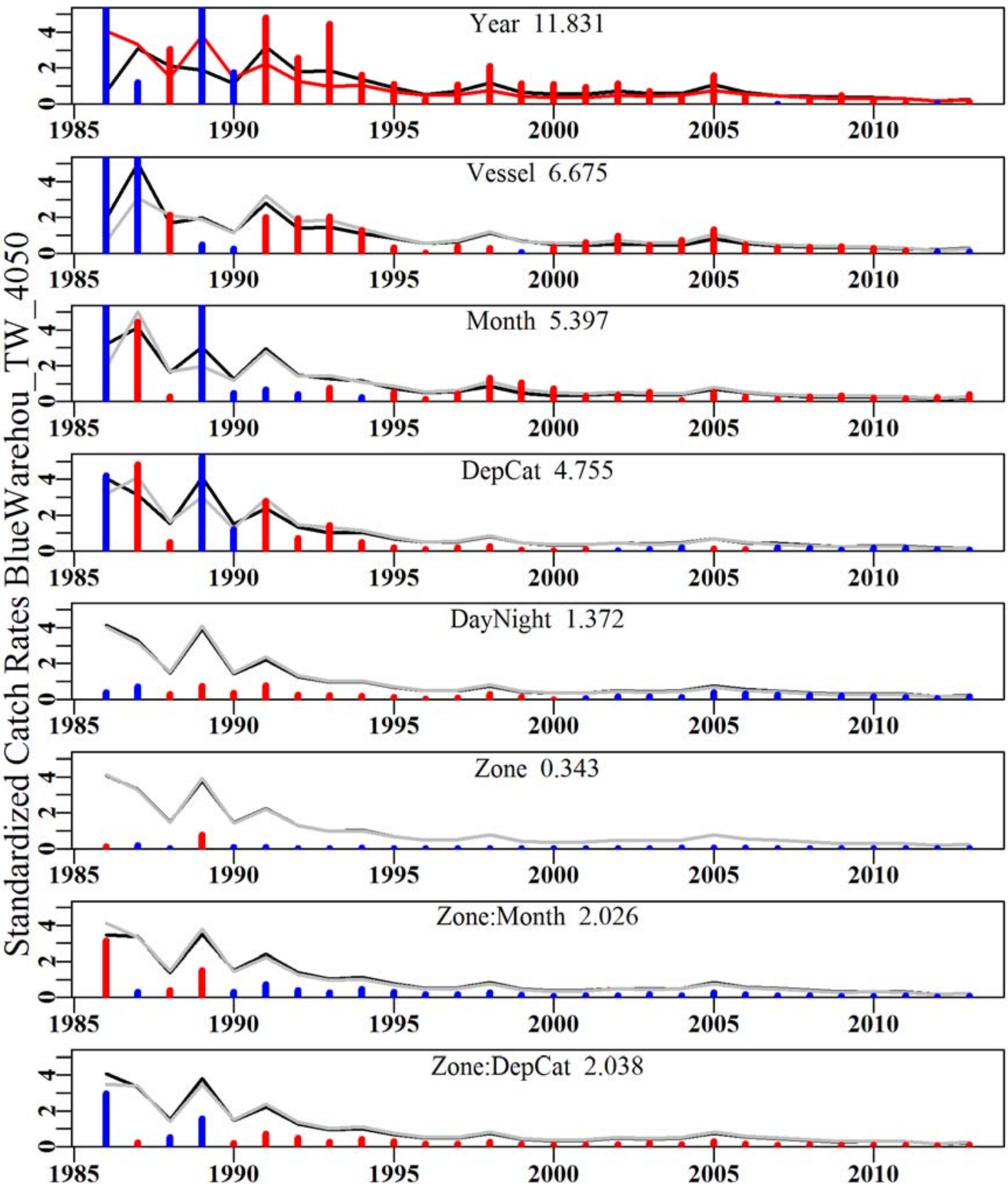


Figure 13.91**.** The relative influence of each factor used on the final trend in the optimal standardization for Blue Warehou in zone 40 – 50. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by the vertical bars with blue bars indicating the optimum model is higher than the geometric mean and red bars indicating it is lower. The top graph bars are the sum of all the bars in the graphs below. The graphs for individual factors are cumulative. Thus the second graph has the geometric mean (grey line) and the effect of adding Year + factor2 (Model 2). In the third graph, the grey line represents Model 2 and the black line the effect of adding factor3 to the model. The remaining graphs continue in the same cumulative manner except for the interaction terms which are added singularly to the final single factor model.

13.33 Blue Warehou Z10–50 (TRT – 37445005 – Seriolella brama)

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

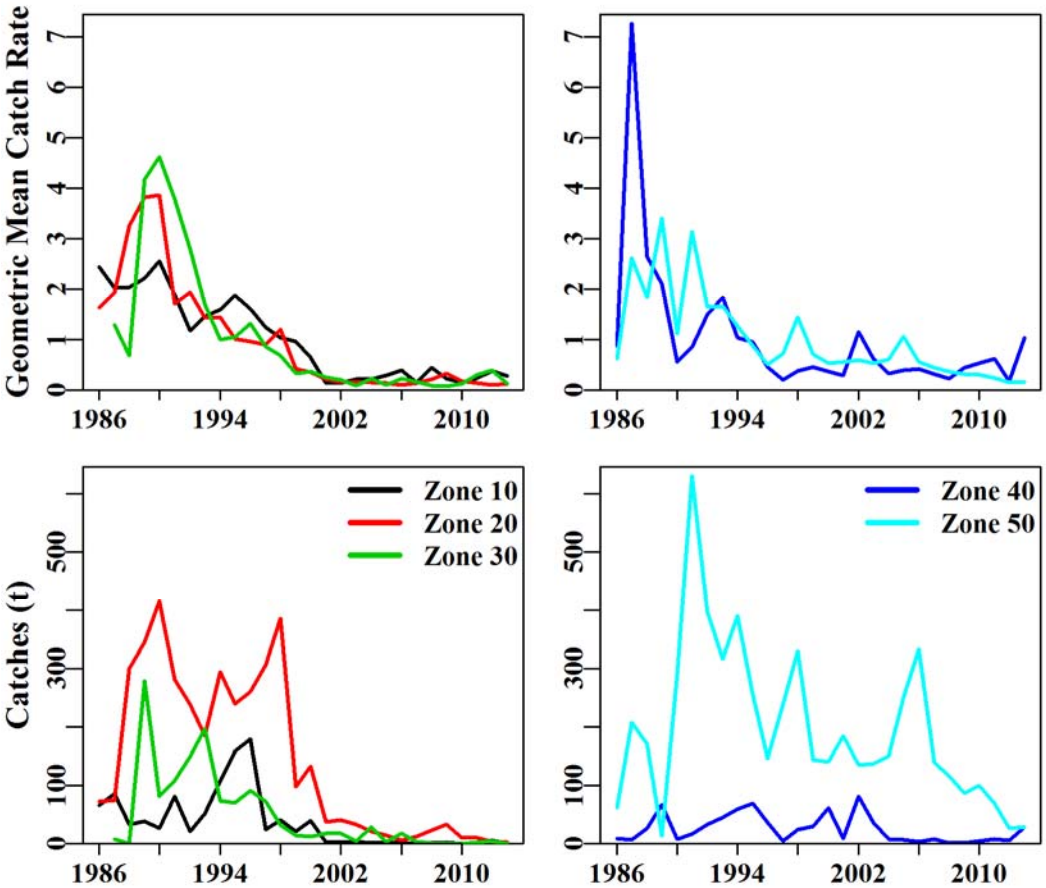


Figure 13.92. Trends in the catches and geometric mean catch rates for Blue Warehou across each of the zones 10 – 50, split east and west. The extreme catch rates in zone 40 reflect very small catches.

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

Year	TotCatch	Records	CatchT	Vessels	GeoMean	Zone:Month	StDev
1986	211.8770	863	210.3210	54	24.6419	2.1373	0.0000
1987	405.8510	655	384.5560	51	38.9818	2.4498	0.0921
1988	543.9760	963	532.3580	45	42.2791	2.7448	0.0892
1989	776.0410	1239	746.1520	50	53.5132	3.7726	0.0876
1990	881.3530	1284	822.4190	56	49.3618	2.6489	0.0889
1991	1284.1940	2193	1119.7880	66	38.9026	2.1072	0.0845
1992	934.4050	1902	840.3040	56	34.9011	1.5559	0.0854
1993	829.5730	2717	797.3080	58	27.0143	1.2137	0.0832
1994	944.8050	3300	927.2280	58	24.5388	1.1705	0.0820
1995	815.3840	3497	794.6970	58	19.7435	0.9897	0.0817
1996	724.4080	4278	715.7540	66	16.0446	1.0049	0.0813
1997	935.1594	2925	648.1390	57	13.9027	1.0028	0.0835
1998	903.2421	3152	813.7270	50	18.0335	0.9963	0.0830
1999	590.9751	2372	309.6960	57	9.5323	0.5375	0.0848
2000	470.2475	2899	389.5910	59	7.2891	0.4616	0.0837
2001	285.4641	2208	253.2790	53	5.6327	0.3108	0.0857
2002	290.4765	2408	281.0360	53	4.0433	0.2616	0.0854
2003	233.9681	1708	218.3395	51	3.2829	0.2119	0.0880
2004	232.4455	1700	211.5094	51	4.9660	0.2890	0.0887
2005	289.0633	1297	279.4293	45	6.0446	0.2696	0.0910
2006	379.5272	1474	363.2420	36	7.8259	0.2722	0.0900
2007	177.7756	1052	165.4073	25	5.6675	0.2502	0.0935
2008	163.2600	1100	145.3175	27	5.0903	0.2838	0.0927
2009	135.2235	766	126.2322	24	6.9116	0.2842	0.0976
2010	129.3300	783	117.5180	22	6.3064	0.2264	0.0975
2011	103.2946	966	91.4787	23	5.5254	0.2127	0.0948
2012	52.2722	633	46.4206	25	3.2664	0.1528	0.1018
2013	67.9643	492	62.5255	26	6.0283	0.1811	0.1074

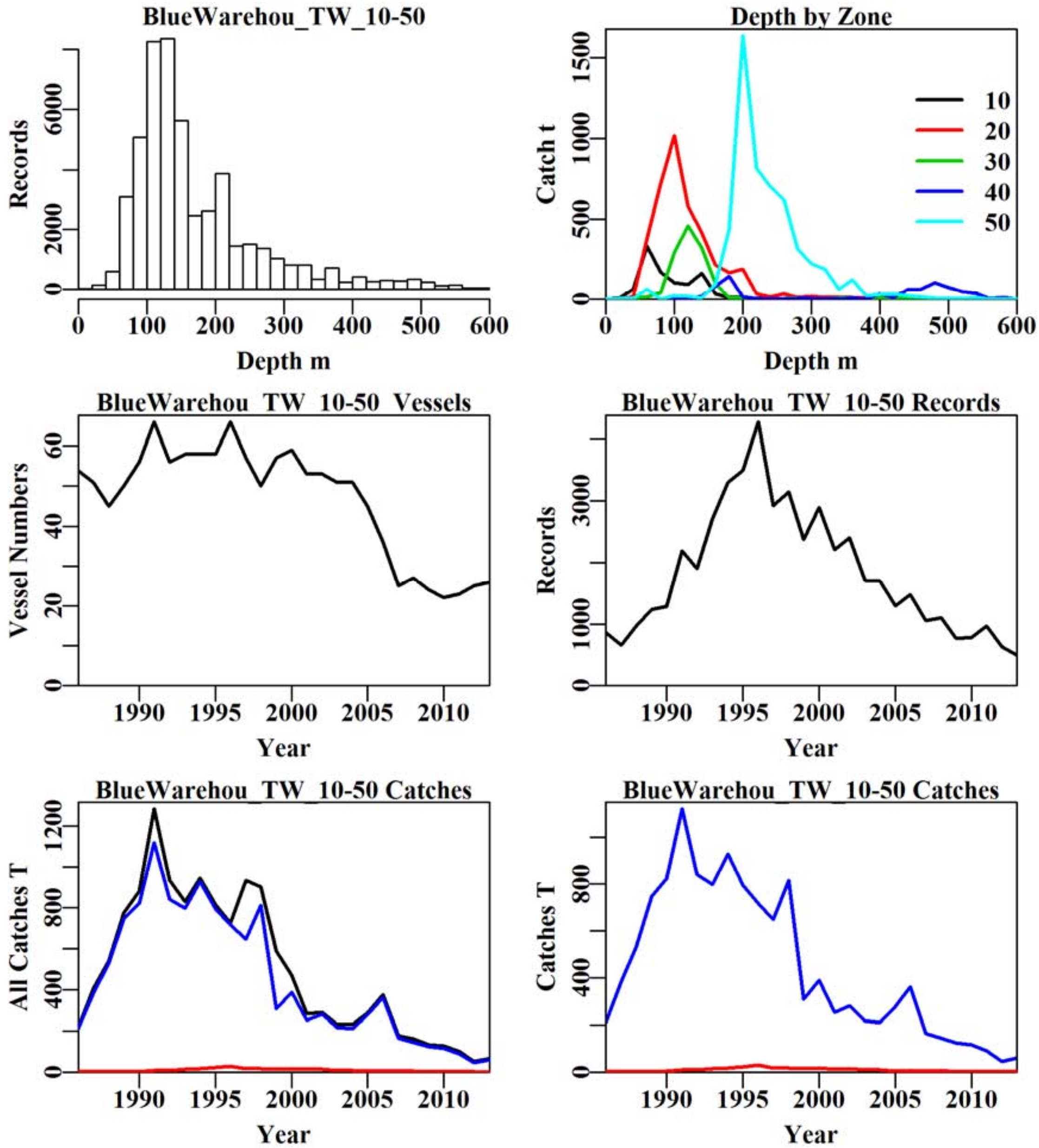


Figure 13.93**.** Blue Warehou from zones 10 to 50 in depths 0 – 600 m by Trawl. The top left plot depicts the depth distribution of shots containing Blue Warehou from zones 10 to 50 in depths 0 – 600 m by Trawl. The top right plot depicts the catch distribution by depth by zone. The middle left plot depicts the number of vessels through time and middle right plot contains the number of records used in analysis. The bottom left plot contains Blue Warehou catches (top black line: total catches, middle blue line: catches used in the analysis; bottom red line: catches < 30 kg) and bottom right plot contains Blue Warehou catches (blue line: catches used in the analysis; red line: catches < 30 kg).

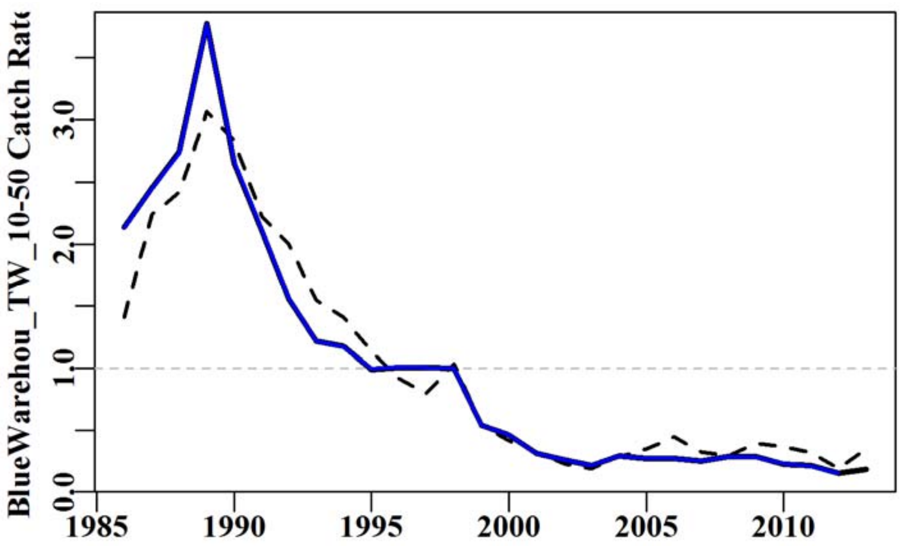


Figure 13.94**.** Blue Warehou from zones 10 to 50 in depths 0 – 600 m by Trawl. The dashed black line represents the geometric mean catch rate and the solid black line the standardized catch rates (relative to the mean of the standardized catch rates). The blue line corresponds to last year's standardized indices.

Table 13.86**.** Blue Warehou from zones 10 to 50 in depths 0 – 600 m by Trawl. Statistical model structures used in this analysis. DepCat is a series of 20 metre depth categories.

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

Table 13.87**.** Blue Warehou from zones 10 to 50 in depths 0 – 600 m by Trawl. Model selection criteria include the Akaike Information Criterion (AIC), residual sum of squares (RSS), model sum of squares (MSS), number of usable observations (Nobs), number of parameters (Npars), adjusted R^2 (adj_R^2) and the change in adjusted R^2 (%Change). The optimum is Zone:Month (Model 7). Depth category: DepC.

	Year	Vessel	DepC	Zone	Month	DayNight	Zone:Month	Zone:DepC
AIC	62668	48733	47417	46217	45494	45424	44428	44687
RSS	174215	131438	127874	124853	123025	122841	120236	120489
MSS	32265	75042	78606	81627	83455	83639	86244	85991
Nobs	50826	50826	50540	50540	50540	50540	50540	50540
Npars	28	221	251	255	266	269	313	389
adj_R^2	15.581	36.067	37.762	39.227	40.104	40.190	41.407	41.195
%Change	0.000	20.485	1.695	1.466	0.877	0.086	1.217	-0.212

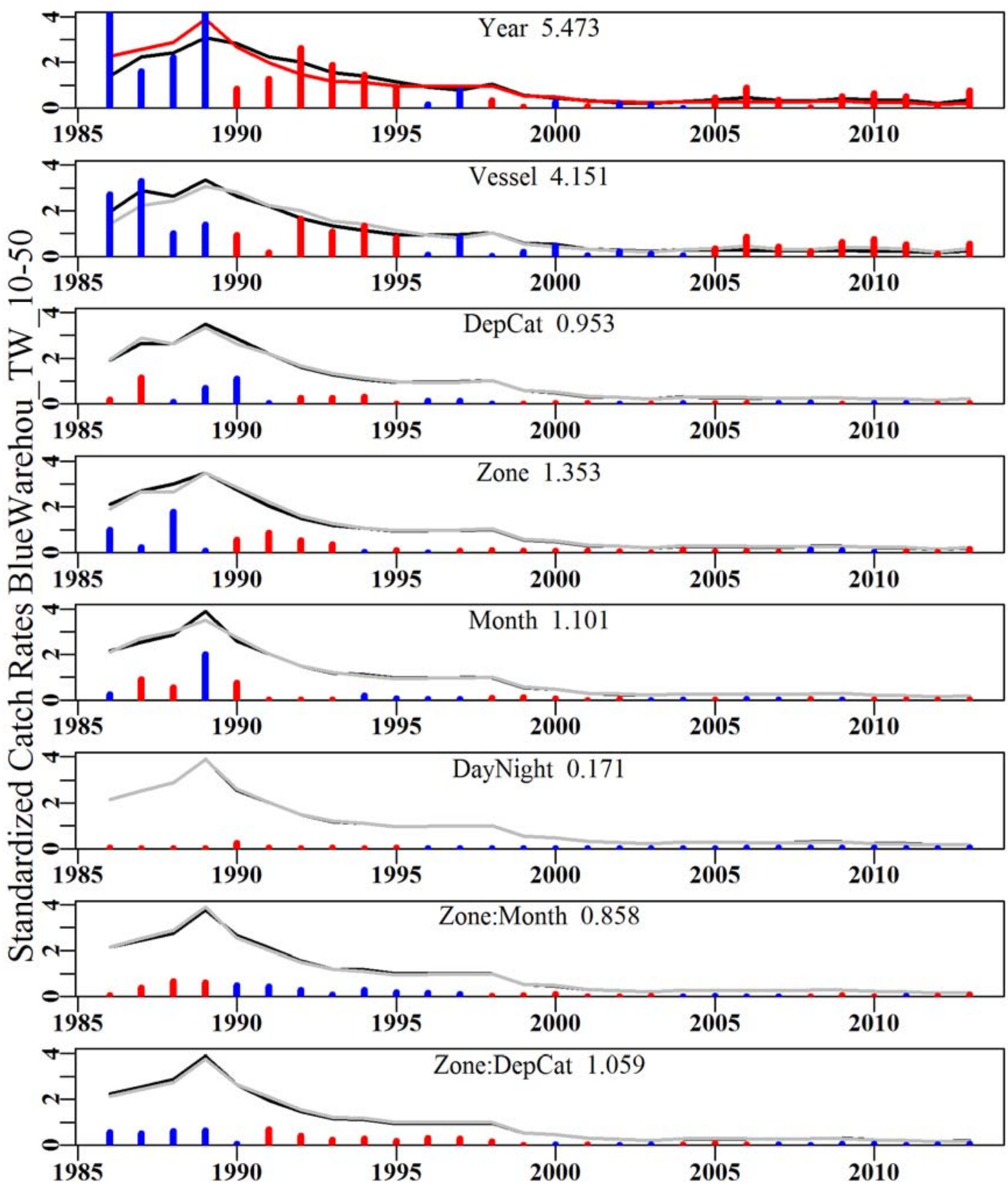


Figure 13.95**.** The relative influence of each factor used on the final trend in the optimal standardization for Blue Warehou in zone 10 – 50. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by the vertical bars with blue bars indicating the optimum model is higher than the geometric mean and red bars indicating it is lower. The top graph bars are the sum of all the bars in the graphs below. The graphs for individual factors are cumulative. Thus the second graph has the geometric mean (grey line) and the effect of adding Year + factor2 (Model 2). In the third graph, the grey line represents Model 2 and the black line the effect of adding factor3 to the model. The remaining graphs continue in the same cumulative manner except for the interaction terms which are added singularly to the final single factor model.

13.34 Pink Ling TW (LIG – 37228002 – Genypterus blacodes)

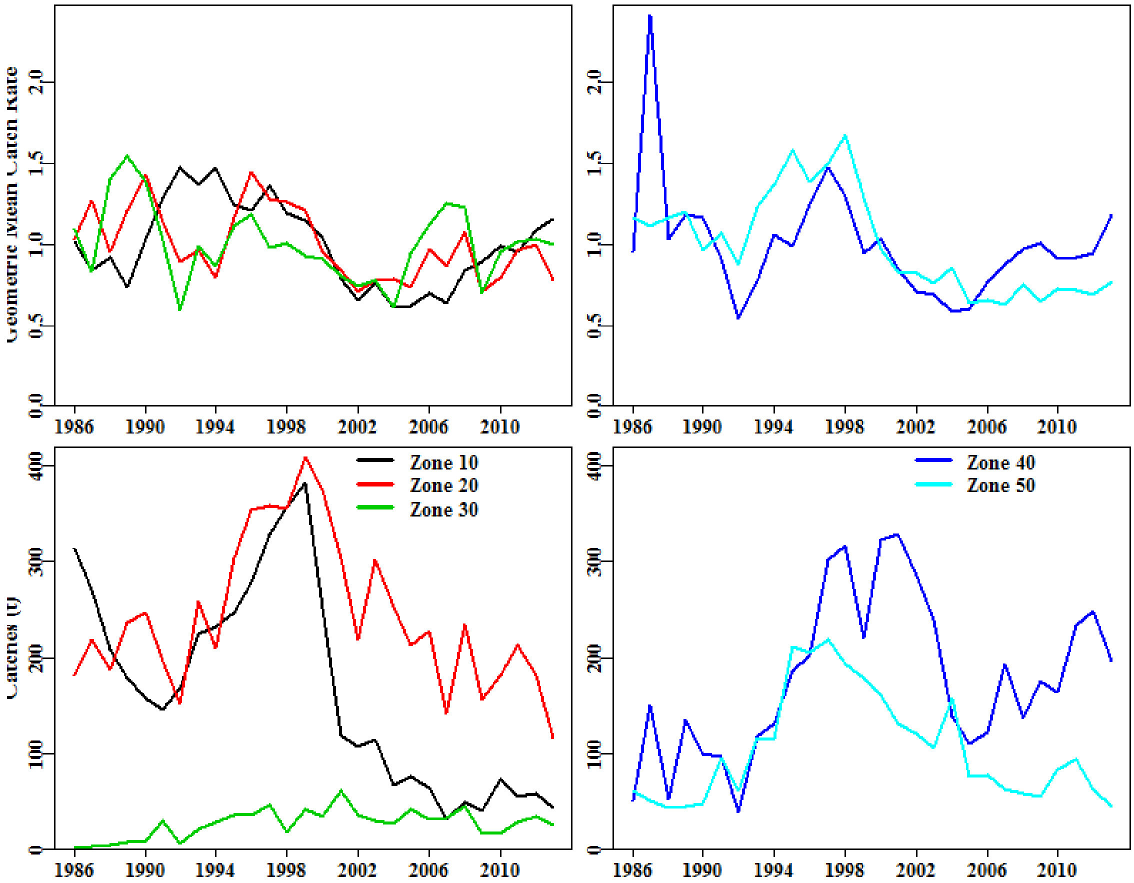


Figure 13.96. Trends in the catches and geometric mean catch rates for Pink Ling taken by Trawler across zones 10 – 50 split between east and west.

The trends in the geometric mean catch rates in the east all follow approximately the same trajectory, albeit with some noise (Figure 13.96). In the west, however, zones 40 and 50 appear to follow rather different trajectories with rates increasing since 2005 in zone 40 while staying flat in zone 50. However, this may simply reflect that catches were increasing in zone 40 and were decreasing in zone 50.

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

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

Table 13.88**.** Pink Ling from zones 10 to 30 in depths between 250 – 600 m by Trawl. Total catch (TotCatch; t) is the total reported in the database, number of records used in the analysis (Records), reported catch (CatchT; t) in the area and depth used in the analysis and number of vessels used in the analysis (Vessels). GeoMean is the geometric mean of catch rates (kg/hr). The optimum model is Zone:Month and standard deviation (StDev) relates to the data in the optimum model.

Year	TotCatch	Records	CatchT	Vessels	GeoMean	Zone:Month	StDev
1986	678.9770	4512	498.2980	80	20.6651	1.1186	0.0000
1987	765.0660	4260	492.3140	77	19.4237	1.1881	0.0223
1988	583.0770	3613	400.0770	77	20.2595	1.1318	0.0234
1989	678.8960	3879	422.0770	77	19.1575	0.9735	0.0232
1990	674.4790	2794	413.0820	68	26.8201	1.4258	0.0255
1991	736.8030	2938	370.2970	72	26.3050	1.4225	0.0254
1992	568.3080	2417	324.3710	57	24.8497	1.1055	0.0267
1993	892.7960	3525	504.4740	59	25.3075	1.0453	0.0244
1994	895.4310	4066	470.2650	63	23.5158	1.0674	0.0235
1995	1208.8930	4361	586.6860	57	25.8106	1.3475	0.0230
1996	1233.2650	4268	667.5830	63	27.6570	1.3360	0.0232
1997	1696.8475	4808	732.6540	62	27.9375	1.3650	0.0228
1998	1591.9879	4909	730.4580	57	26.0156	1.3530	0.0226
1999	1651.5715	5964	832.6550	59	25.2286	1.2375	0.0221
2000	1507.3786	5113	660.2800	63	22.4049	1.0878	0.0230
2001	1392.8101	4544	484.0215	52	19.0624	0.8367	0.0238
2002	1330.1940	3898	360.4653	52	15.8660	0.7425	0.0247
2003	1353.1029	4310	445.7625	57	18.2826	0.7611	0.0242
2004	1495.1340	3359	347.2374	54	16.7949	0.6822	0.0257
2005	1203.1954	3454	329.9497	51	16.3326	0.6343	0.0254
2006	1069.2001	2593	323.1010	38	21.3189	0.7583	0.0273
2007	875.9219	1652	204.3070	23	20.5015	0.7376	0.0314
2008	980.2672	2382	329.0357	24	25.1511	0.8621	0.0285
2009	775.0457	1947	212.3617	27	18.2953	0.6220	0.0301
2010	906.2231	1991	271.1322	23	20.7020	0.7648	0.0298
2011	1081.9062	2201	294.8960	22	23.4304	0.8075	0.0291
2012	1030.9058	1972	273.3230	24	24.3541	0.8616	0.0300
2013	735.6858	1561	183.9784	22	21.3669	0.7242	0.0321

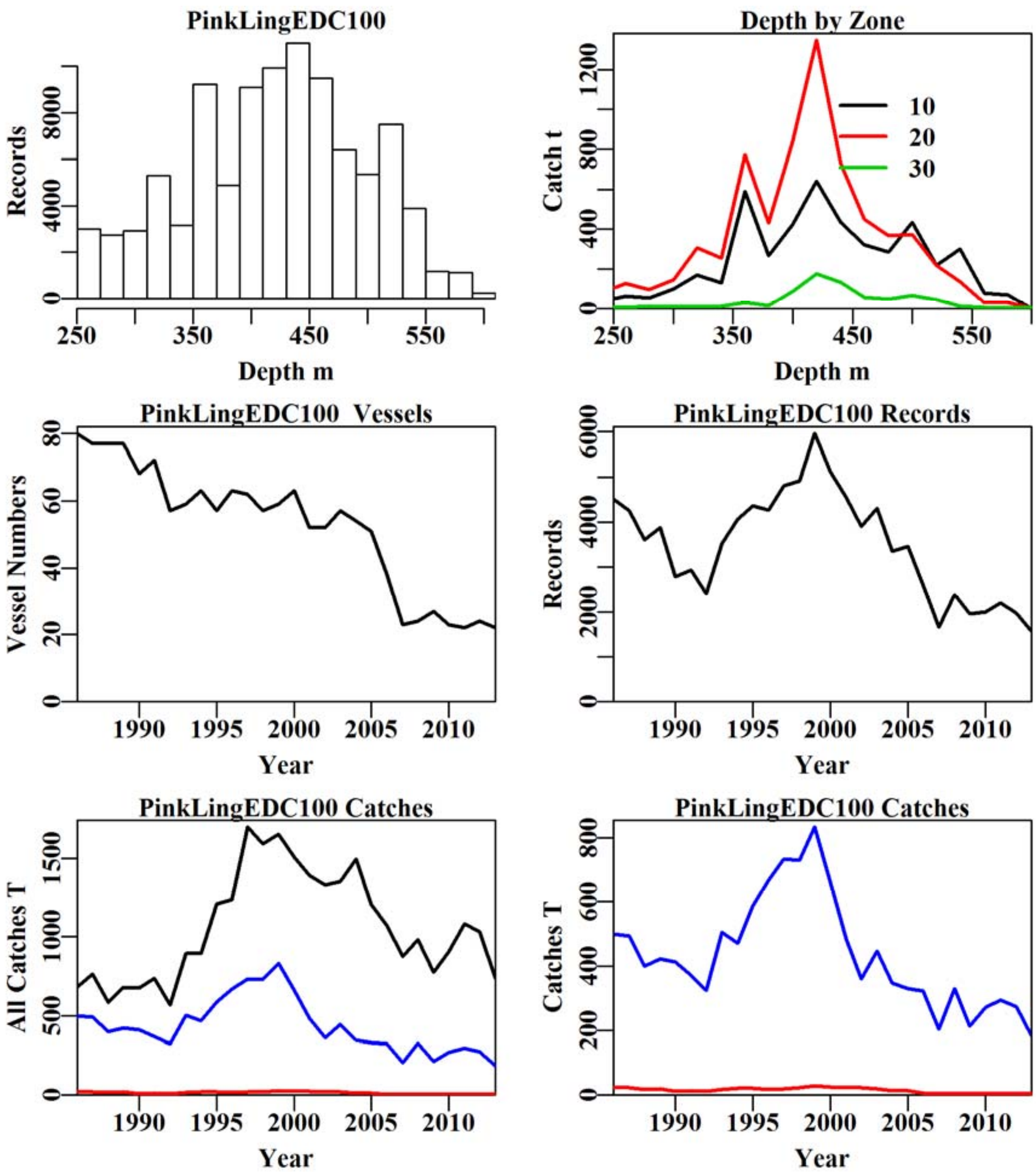


Figure 13.97**.** Pink Ling from zones 10 to 30 in depths between 250 – 600 m by Trawl. The top left plot depicts the depth distribution of shots containing Pink Ling from zones 10 to 30 in depths 250 – 600 m by Trawl. The top right plot depicts the catch distribution by depth by zone. The middle left plot depicts the number of vessels through time and middle right plot contains the number of records used in analysis. The bottom left plot contains Pink Ling catches (top black line: total catches, middle blue line: catches used in the analysis; bottom red line: catches < 30 kg) and bottom right plot contains Pink Ling catches (blue line: catches used in the analysis; red line: catches < 30 kg).

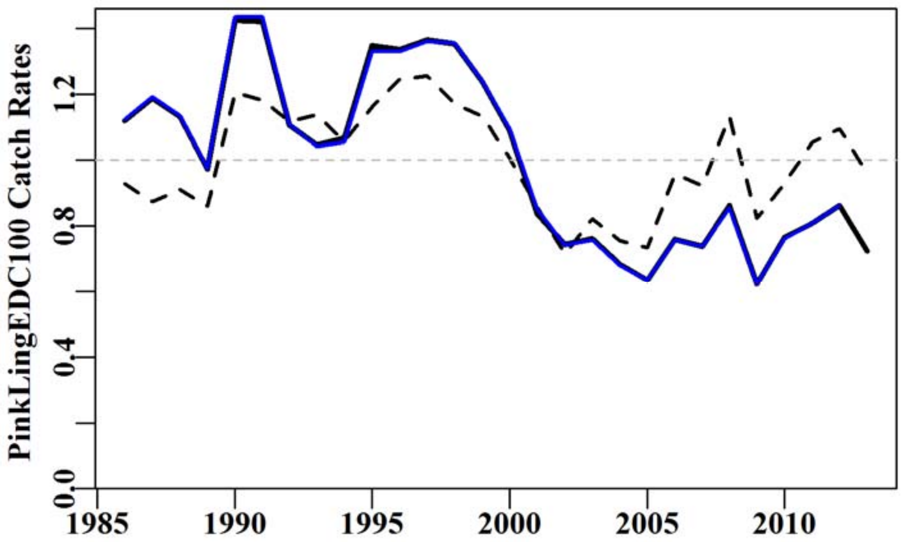


Figure 13.98. Pink Ling from zones 10 to 30 in depths between 250 – 600 m by Trawl. The dashed black line represents the geometric mean catch rate and the solid black line the standardized catch rates (relative to the mean of the standardized catch rates). The blue line corresponds to last year's standardized indices.

Table 13.89**.** Pink Ling from zones 10 to 30 in depths between 250 – 600 m by Trawl. Statistical model structures used in this analysis. DepCat is a series of 20 metre depth categories.

Model 1	LnCE~Year
Model 2	LnCE~Year+DepCat
Model 3	LnCE~Year+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 13.90. Pink Ling from zones 10 to 30 in depths between 250 – 600 m by Trawl. Model selection criteria include the Akaike Information Criterion (AIC), residual sum of squares (RSS), model sum of squares (MSS), number of usable observations (Nobs), number of parameters (Npars), adjusted R^2 (adj_R^2) and the change in adjusted R^2 (%Change). The optimum is Zone:DepC (Model 8). Depth category: DepC.

	Year	DepC	Vessel	Month	Zone	DayNight	Zone:Month	Zone:DepC
AIC	32864	25347	3155	553	-55	-96	-1212	-2200
RSS	136308	125282	99141	96483	95873	95826	94680	93644
MSS	2735	13762	39902	42560	43171	43217	44363	45399
Nobs	97291	96410	96410	96410	96410	96410	96410	96410
Npars	28	46	230	240	242	245	267	303
adj_R^2	1.940	9.855	28.528	30.437	30.875	30.907	31.718	32.439
%Change	0.000	7.915	18.673	1.909	0.439	0.032	0.811	0.722

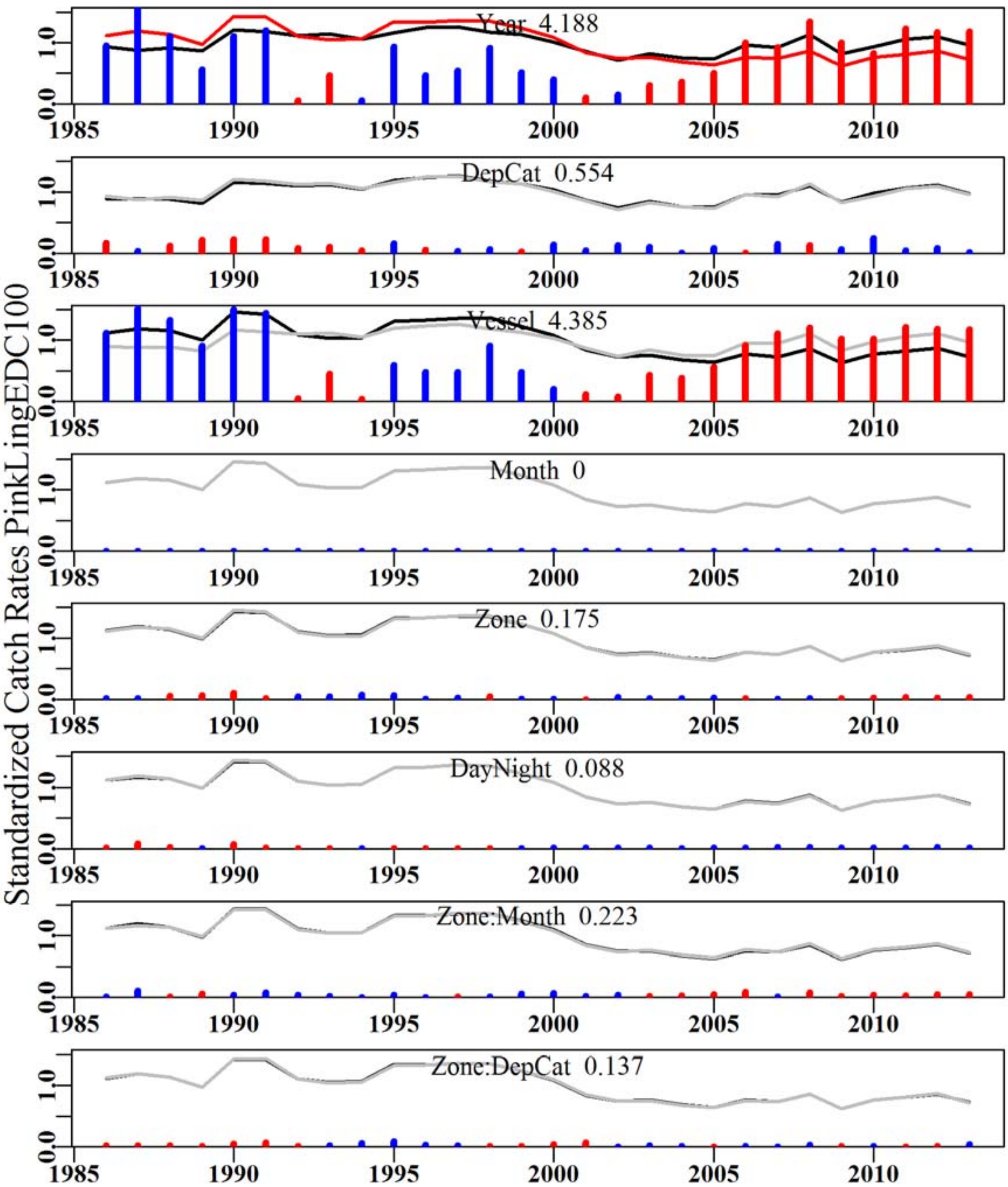


Figure 13.99. The relative influence of each factor used on the final trend in the optimal standardization for Pink Ling from zones 10 to 30. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by the vertical bars with blue bars indicating the optimum model is higher than the geometric mean and red bars indicating it is lower. The top graph bars are the sum of all the bars in the graphs below. The graphs for individual factors are cumulative. Thus the second graph has the geometric mean (grey line) and the effect of adding Year + factor2 (Model 2). In the third graph, the grey line represents Model 2 and the black line the effect of adding factor3 to the model. The remaining graphs continue in the same cumulative manner except for the interaction terms which are added singularly to the final single factor model.

13.36 Pink Ling Z4050 (LIG – 37228002 – Genypterus blacodes)

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

Table 13.91. Pink Ling from zones 40 and 50 in depths between 200 – 800 m by Trawl. Total catch (TotCatch; t) is the total reported in the database, number of records used in the analysis (Records), reported catch (CatchT; t) in the area and depth used in the analysis and number of vessels used in the analysis (Vessels). GeoMean is the geometric mean of catch rates (kg/hr). The optimum model is Zone:Month and standard deviation (StDev) relates to the data in the optimum model.

Year	TotCatch	Records	CatchT	Vessels	GeoMean	Zone:Month	StDev
1986	678.9770	1265	112.9440	23	17.1417	1.1746	0.0000
1987	765.0660	1310	206.3410	28	24.0155	1.3461	0.0376
1988	583.0770	1026	95.7030	32	17.6676	1.0487	0.0406
1989	678.8960	1469	183.1210	34	21.9840	1.0822	0.0388
1990	674.4790	1524	147.4120	32	16.9021	0.9716	0.0393
1991	736.8030	1897	198.9450	37	16.3936	1.0392	0.0374
1992	568.3080	1633	102.1640	24	11.9963	0.7726	0.0385
1993	892.7960	2253	235.4850	24	17.1332	1.0478	0.0373
1994	895.4310	2110	247.7930	24	20.5621	1.2610	0.0371
1995	1208.8930	3516	426.9070	25	20.0613	1.2909	0.0350
1996	1233.2650	3403	448.0440	26	19.9984	1.3675	0.0353
1997	1696.8475	3732	577.4340	24	21.1891	1.4355	0.0349
1998	1591.9879	3710	558.6410	21	22.4111	1.4172	0.0352
1999	1651.5715	3794	427.9200	24	18.0495	1.1216	0.0351
2000	1507.3786	4655	509.3040	28	16.3679	1.0032	0.0347
2001	1392.8101	5061	500.0220	28	14.7513	0.8955	0.0346
2002	1330.1940	4631	429.4710	27	13.4047	0.7736	0.0347
2003	1353.1029	3822	360.2349	27	12.6257	0.7763	0.0351
2004	1495.1340	3901	306.2357	25	11.7174	0.7275	0.0353
2005	1203.1954	2663	195.7375	23	9.9452	0.6060	0.0365
2006	1069.2001	2322	209.9851	21	10.6509	0.6450	0.0373
2007	875.9219	2532	287.3451	16	12.6778	0.7088	0.0368
2008	980.2672	1795	214.2319	17	14.6108	0.9111	0.0383
2009	775.0457	1976	260.6090	13	14.0039	0.8914	0.0378
2010	906.2231	2337	272.1558	14	13.1460	0.8621	0.0370
2011	1081.9062	2792	356.8662	16	13.2635	0.8476	0.0365
2012	1030.9058	2342	344.9726	14	14.5232	0.9205	0.0375
2013	735.6858	1720	272.2423	17	15.6514	1.0551	0.0392

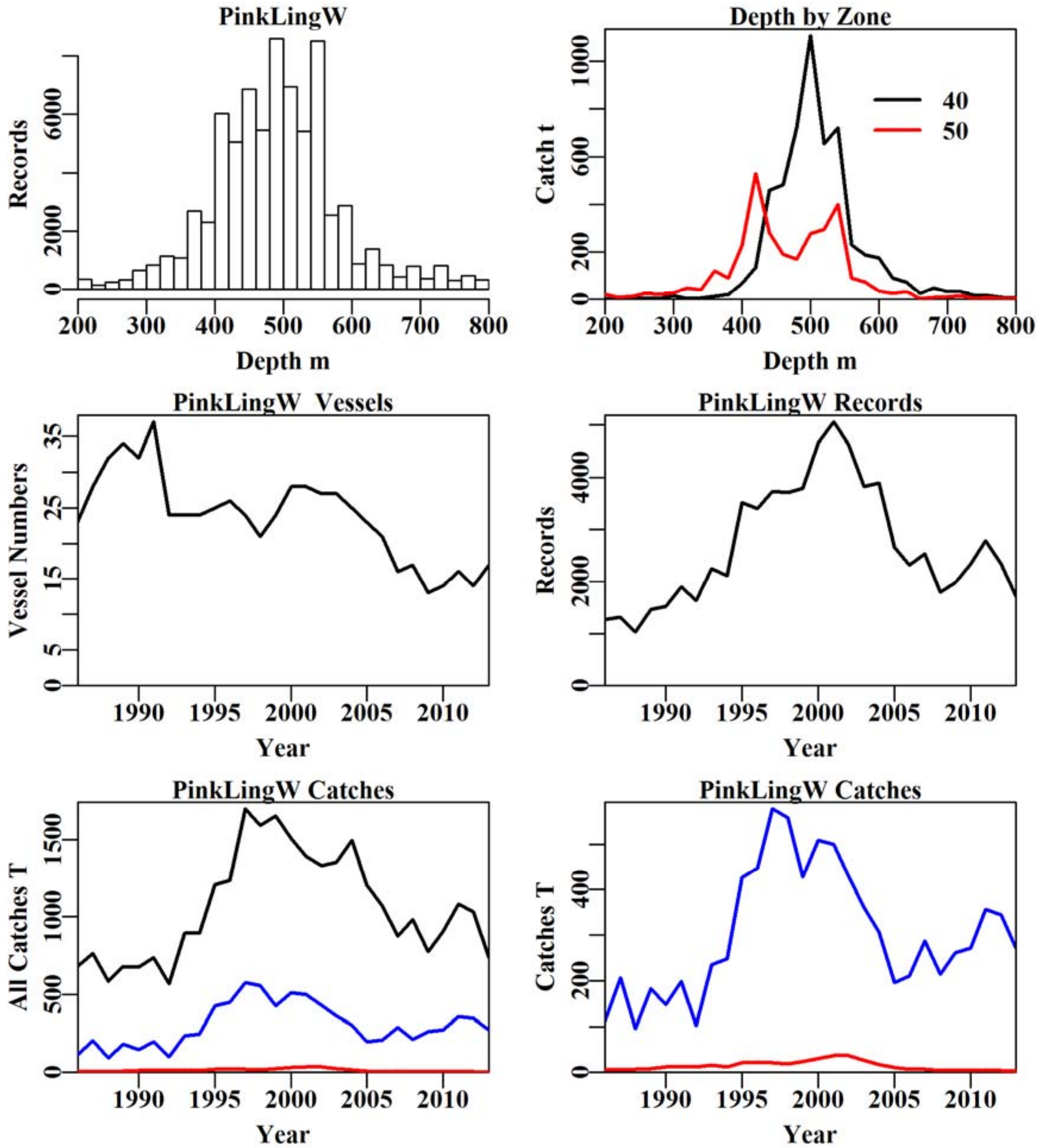


Figure 13.100**.** Pink Ling from zones 40 and 50 in depths between 200 – 800 m by Trawl. The top left plot depicts the depth distribution of shots containing Pink Ling from zones 40 and 50 in depths 200 – 800 m by Trawl. The top right plot depicts the catch distribution by depth by zone. The middle left plot depicts the number of vessels through time and middle right plot contains the number of records used in analysis. The bottom left plot contains Pink Ling catches (top black line: total catches, middle blue line: catches used in the analysis; bottom red line: catches < 30 kg) and bottom right plot contains Pink Ling catches (blue line: catches used in the analysis; red line: catches < 30 kg).

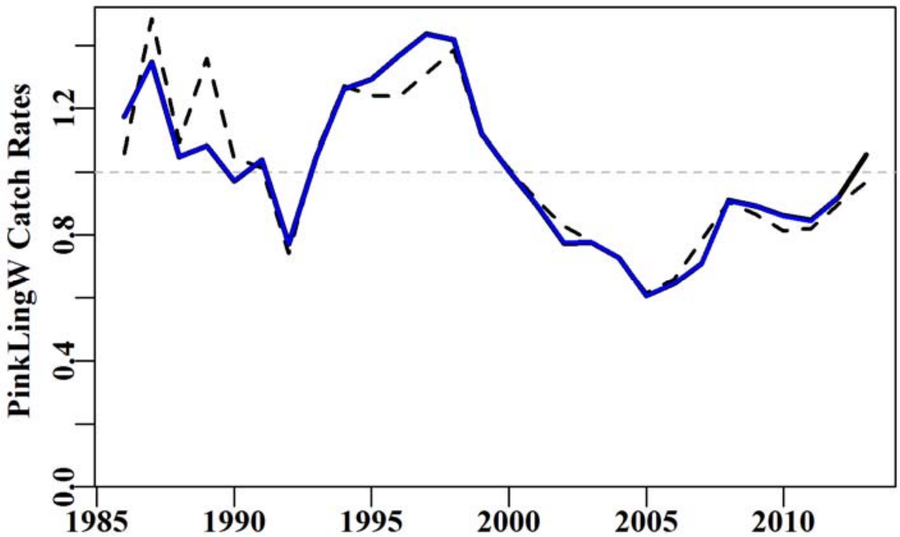


Figure 13.101**.** Pink Ling from zones 40 and 50 in depths between 200 – 800 m by Trawl. The dashed black line represents the geometric mean catch rate and the solid black line the standardized catch rates (relative to the mean of the standardized catch rates). The blue line corresponds to last year's standardized catch rates.

Table 13.92**.** Pink Ling from zones 40 and 50 in depths between 200 – 800 m by Trawl. Statistical model structures used in this analysis. DepCat is a series of 20 metre depth categories.

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

Table 13.93**.** Pink Ling from zones 40 and 50 in depths between 200 – 800 m by Trawl. Model selection criteria include the Akaike Information Criterion (AIC), residual sum of squares (RSS), model sum of squares (MSS), number of usable observations (Nobs), number of parameters (Npars), adjusted R^2 (adj_R^2) and the change in adjusted R^2 (%Change). The optimum is Zone:Month (Model 7). Depth category: DepC.

	Year	DepC	Vessel	Month	Zone	DayNight	Zone:Month	Zone:DepC
AIC	397	-10113	-16414	-18836	-19728	-19752	-21152	-20510
RSS	75532	65149	59729	57807	57119	57097	56020	56475
MSS	3897	14280	19700	21622	22310	22332	23409	22955
Nobs	75191	74709	74709	74709	74709	74709	74709	74709
Npars	28	58	152	163	164	167	178	197
adj_R^2	4.872	17.916	24.650	27.064	27.931	27.956	29.304	28.713
%Change	0.000	13.044	6.734	2.414	0.867	0.025	1.348	-0.592

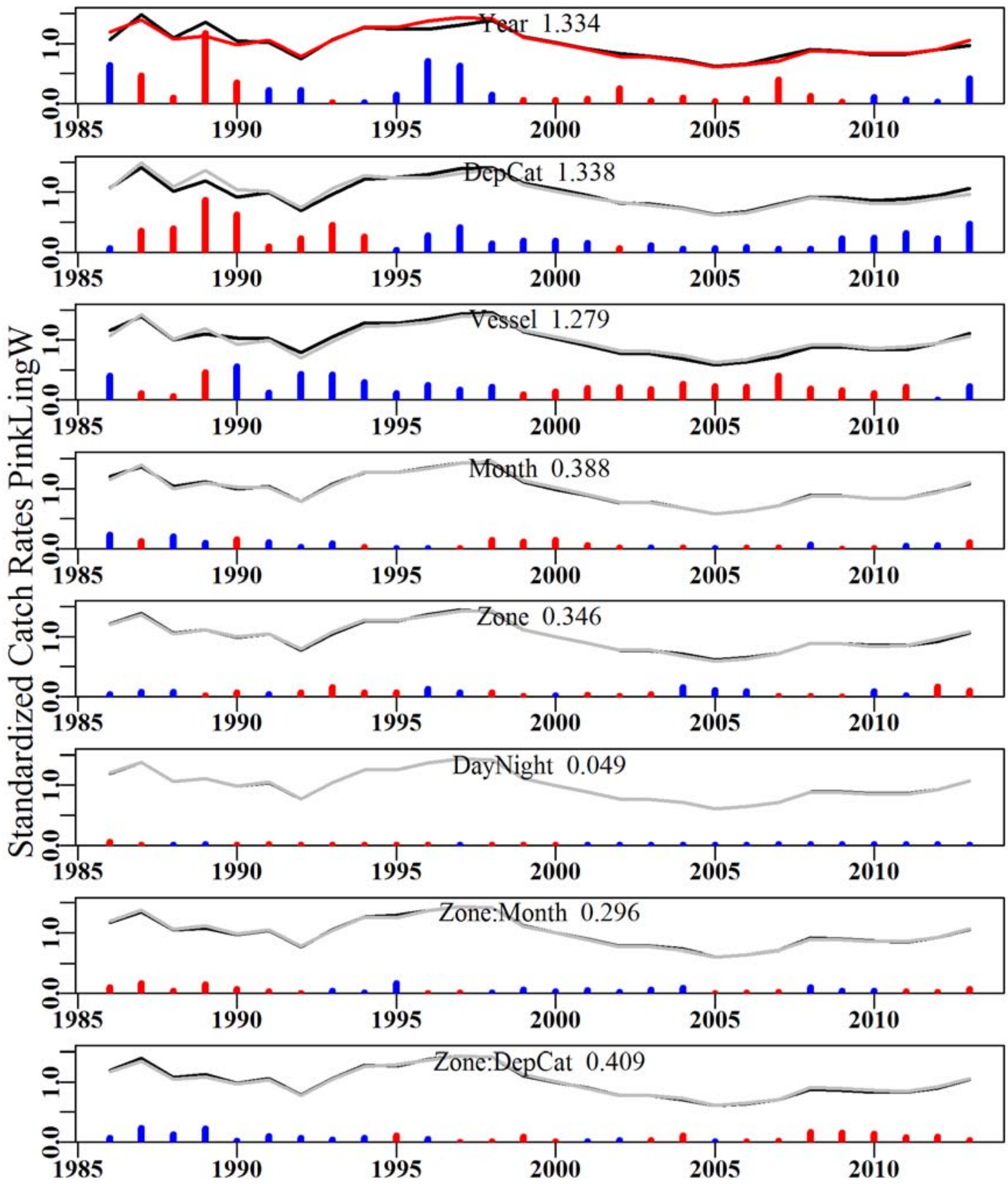


Figure 13.102. The relative influence of each factor used on the final trend in the optimal standardization for Pink Ling from zones 40 and 50. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by the vertical bars with blue bars indicating the optimum model is higher than the geometric mean and red bars indicating it is lower. The top graph bars are the sum of all the bars in the graphs below. The graphs for individual factors are cumulative. Thus the second graph has the geometric mean (grey line) and the effect of adding Year + factor2 (Model 2). In the third graph, the grey line represents Model 2 and the black line the effect of adding factor3 to the model. The remaining graphs continue in the same cumulative manner except for the interaction terms which are added singularly to the final single factor model.

13.37 Western Gemfish and GAB (GEM – 37439002 – Rexea solandri)

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

Table 13.94. Western Gemfish from zones 40 and 50, and the GAB in depths between 100 – 600 m by Trawl (now represented by TW and TDO). Total catch (TotCatch; t) is the total reported in the database, number of records used in the analysis (Records), reported catch (CatchT; t) in the area and depth used in the analysis and number of vessels used in the analysis (Vessels). GeoMean is the geometric mean of catch rates (kg/hr). The optimum model is Zone:Month and standard deviation (StDev) relates to the data in the optimum model.

Year	TotCatch	Records	CatchT	Vessels	GeoMean	Zone:Month	StDev
1986	3639.9550	1698	306.4910	25	29.2406	2.2100	0.0000
1987	4660.4470	1280	261.6060	29	30.7446	2.1645	0.0461
1988	3515.8190	1399	255.4090	36	25.3713	1.9737	0.0482
1989	1778.3250	1396	184.4330	37	19.1431	1.5293	0.0492
1990	1206.8970	1241	145.5200	35	14.4402	1.3445	0.0531
1991	580.3220	1568	279.2890	32	19.1549	1.3210	0.0497
1992	494.4410	799	96.8810	21	15.1631	0.9817	0.0569
1993	353.4100	896	108.2890	21	11.5326	0.8424	0.0559
1994	232.1790	1041	109.8960	24	11.4211	0.8694	0.0535
1995	181.7460	1285	106.8040	26	9.1790	0.8186	0.0511
1996	382.1960	1573	161.7360	32	9.5346	0.9541	0.0493
1997	571.9758	2088	214.0380	28	8.9720	0.8520	0.0473
1998	404.8147	1958	206.7570	26	10.2560	1.0338	0.0481
1999	448.6767	2337	322.9730	24	12.0677	1.0298	0.0470
2000	336.4642	2322	259.8225	30	9.7603	0.8578	0.0475
2001	331.4862	2284	252.7610	30	10.1427	0.8003	0.0476
2002	195.8983	1745	128.4137	28	6.4852	0.6123	0.0493
2003	267.9710	1612	201.0612	33	8.8661	0.6855	0.0501
2004	568.8517	1931	478.0203	30	10.6711	0.7448	0.0500
2005	511.7585	1796	368.5067	27	12.7461	0.7307	0.0507
2006	544.8936	1591	434.7029	26	11.9765	0.6888	0.0517
2007	599.1098	1380	415.0929	21	11.0165	0.6403	0.0527
2008	294.8605	1225	155.5205	19	6.7358	0.6468	0.0533
2009	194.8654	1255	104.8607	16	5.8844	0.6950	0.0528
2010	220.6510	1663	127.5651	18	6.1259	0.7419	0.0504
2011	147.7397	1258	73.2852	16	5.7047	0.7398	0.0532
2012	168.5996	1028	99.0475	18	6.4842	0.8033	0.0566
2013	103.7326	684	47.0844	20	6.4821	0.6879	0.0616

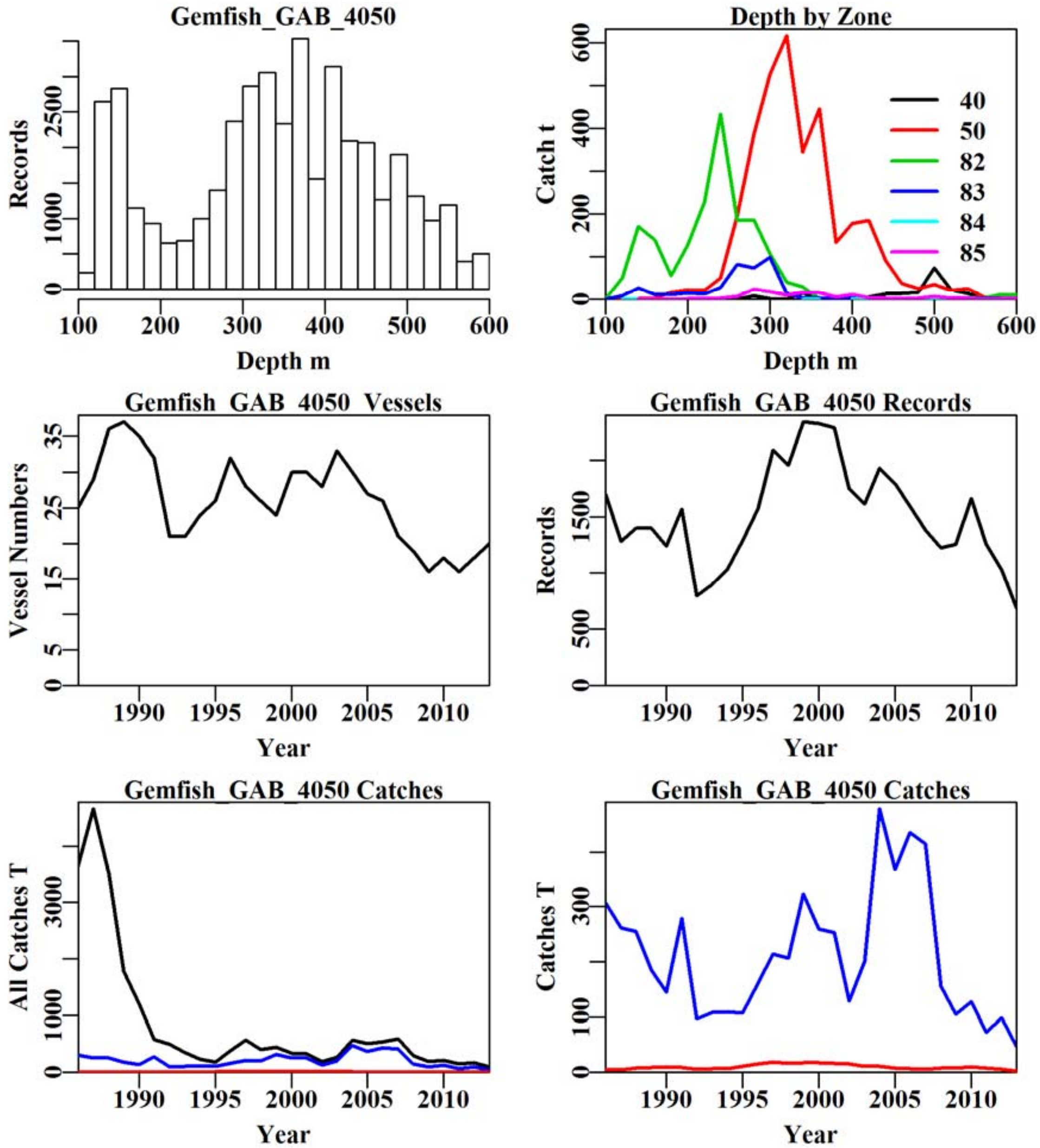


Figure 13.103**.** Western Gemfish from zones 40 and 50, and the GAB (zones 82, 83, 84, and 85) in depths between 100 – 600 m by Trawl. The top left plot depicts the depth distribution of shots containing Western Gemfish from zones 40 and 50, and the GAB (zones 82, 83, 84, and 85) in depths 100 – 600 m by Trawl. The top right plot depicts the catch distribution by depth by zone. The middle left plot depicts the number of vessels through time and middle right plot contains the number of records used in analysis. The bottom left plot contains Gemfish catches across east and west regions (top black line: total catches, middle blue line: catches used in the analysis; bottom red line: catches < 30 kg) and bottom right plot contains Gemfish catches across east and west regions (blue line: catches used in the analysis; red line: catches < 30 kg).

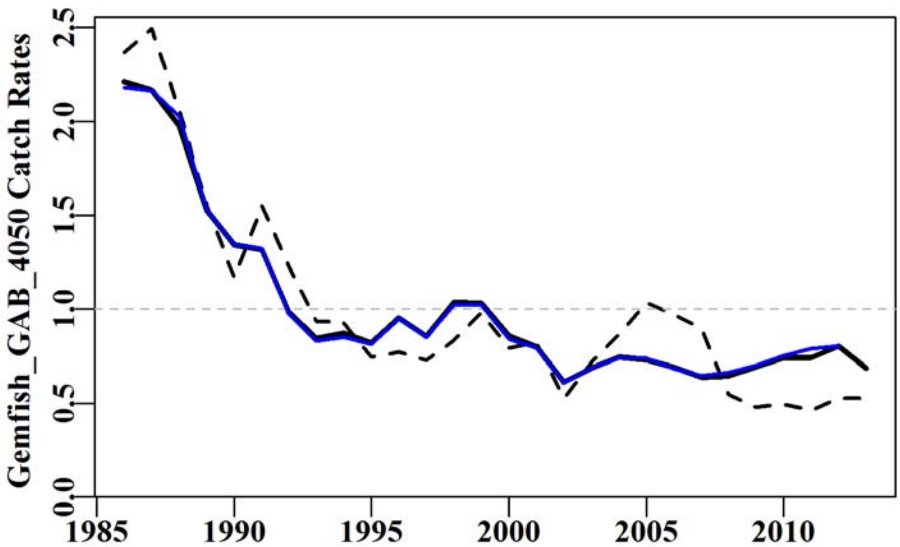


Figure 13.104. Western Gemfish from zones 40 and 50, and the GAB (zones 82, 83, 84, and 85) in depths between 100 – 600 m by Trawl. The dashed black line represents the geometric mean catch rate, solid black line the standardized catch rates and solid blue line the standardized catch rates from last year's analysis. The graph standardizes catch rates relative to the mean of the standardized catch rates.

Table 13.95. Western Gemfish from zones 40 and 50, and the GAB (zones 82, 83, 84, and 85) in depths between 100 – 600 m by Trawl. Statistical model structures used in this analysis. DepCat is a series of 20 metre depth categories.

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

Table 13.96. Western Gemfish from zones 40 and 50, and the GAB (zones 82, 83, 84, and 85) in depths between 100 – 600 m by Trawl. Model selection criteria include the Akaike Information Criterion (AIC), residual sum of squares (RSS), model sum of squares (MSS), number of usable observations (Nobs), number of parameters (Npars), adjusted R^2 (adj_R^2) and the change in adjusted R^2 (%Change). The optimum is Zone:Month (Model 7). Depth category: DepC.

	Year	DepC	Vessel	Zone	DayNight	Month	Zone:Month	Zone:DepC
AIC	36181	22512	15223	14411	13692	13290	12229	12770
RSS	99376	71724	60025	58866	57863	57283	55714	56246
MSS	8270	35922	47621	48780	49783	50363	51931	51400
Nobs	42333	42151	42151	42151	42151	42151	42151	42151
Npars	28	53	161	166	169	180	235	305
adj_R^2	7.624	33.288	44.026	45.100	46.032	46.559	47.954	47.369
%Change	0.000	25.665	10.737	1.075	0.931	0.527	1.395	-0.585

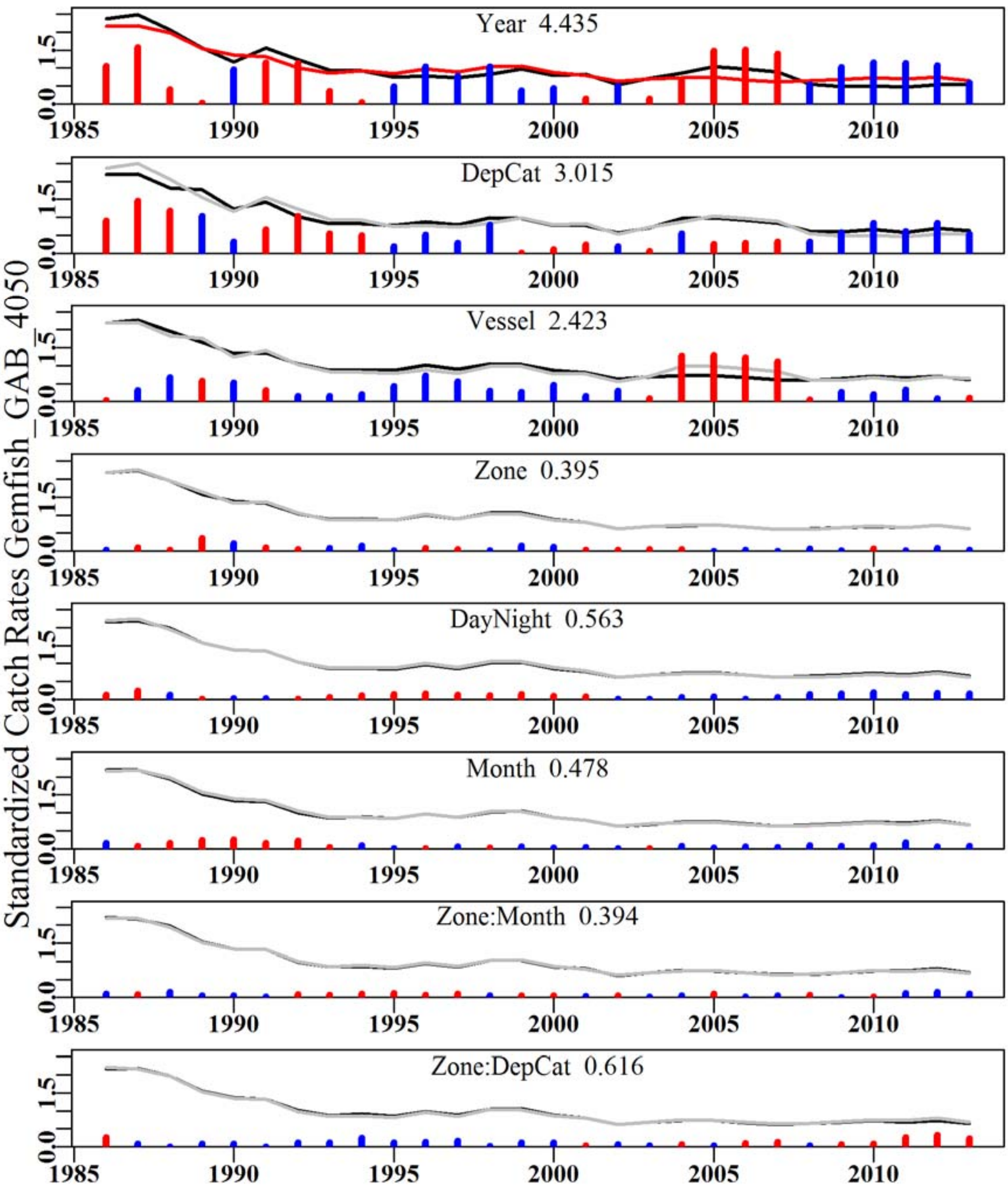


Figure 13.105**.** The relative influence of each factor used on the final trend in the optimal standardization for Western Gemfish from zones 40 and 50 and the GAB. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by the vertical bars with blue bars indicating the optimum model is higher than the geometric mean and red bars indicating it is lower. The top graph bars are the sum of all the bars in the graphs below. The graphs for individual factors are cumulative. Thus the second graph has the geometric mean (grey line) and the effect of adding Year + factor2 (Model 2). In the third graph, the grey line represents Model 2 and the black line the effect of adding factor3 to the model. The remaining graphs continue in the same cumulative manner except for the interaction terms which are added singularly to the final single factor model.

13.38 Western Gemfish Z4050 (GEM – 37439002 – Rexea solandri)

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

Table 13.97**.** Western Gemfish from zones 40 and 50 in depths between 100 – 600m by Trawl. Total catch (TotCatch; t) is the total reported in the database, number of records used in the analysis (Records), reported catch (CatchT; t) in the area and depth used in the analysis and number of vessels used in the analysis (Vessels). GeoMean is the geometric mean of catch rates (kg/hr). The optimum model is Zone:Month and standard deviation (StDev) relates to the data in the optimum model.

Year	TotCatch	Records	CatchT	Vessels	GeoMean	Zone:Month	StDev
1986	3639.9550	1687	306.8610	24	29.5835	2.2794	0.0000
1987	4660.4470	1209	248.8790	26	31.5896	2.2885	0.0452
1988	3515.8190	1235	226.9560	27	26.9924	2.2344	0.0473
1989	1778.3250	1082	156.5780	29	23.3363	1.8334	0.0496
1990	1206.8970	1057	136.0850	29	15.9031	1.4078	0.0528
1991	580.3220	1384	249.4150	28	22.0062	1.3532	0.0493
1992	494.4410	665	80.9300	15	16.7792	0.9475	0.0575
1993	353.4100	718	102.4890	17	16.5820	0.9171	0.0570
1994	232.1790	839	95.3780	20	16.2263	0.9890	0.0543
1995	181.7460	990	84.6880	21	12.0017	0.8645	0.0519
1996	382.1960	1182	145.5880	26	13.4563	0.9489	0.0499
1997	571.9758	1389	153.5890	21	13.2702	0.8488	0.0484
1998	404.8147	1259	121.6610	20	13.2167	0.9158	0.0498
1999	448.6767	1694	176.3230	19	12.8407	0.8705	0.0475
2000	336.4642	1932	228.1645	28	12.4996	0.9022	0.0474
2001	331.4862	1694	169.8900	27	12.1589	0.7289	0.0484
2002	195.8983	1418	85.6338	24	7.1142	0.5542	0.0496
2003	267.9710	1076	122.4803	24	11.1647	0.6647	0.0521
2004	568.8517	1232	105.5549	24	7.9006	0.6555	0.0522
2005	511.7585	1073	117.6765	18	10.5982	0.6824	0.0532
2006	544.8936	889	101.4170	18	8.9869	0.5565	0.0559
2007	599.1098	715	61.0609	16	7.4736	0.5376	0.0583
2008	294.8605	770	53.0883	16	7.5204	0.6025	0.0571
2009	194.8654	925	56.8320	12	6.4884	0.6817	0.0546
2010	220.6510	1364	86.8772	14	6.3620	0.7073	0.0507
2011	147.7397	1158	57.9422	13	5.6504	0.7423	0.0527
2012	168.5996	820	50.6973	14	5.3756	0.6864	0.0583
2013	103.7326	582	38.7114	15	5.5759	0.5989	0.0626

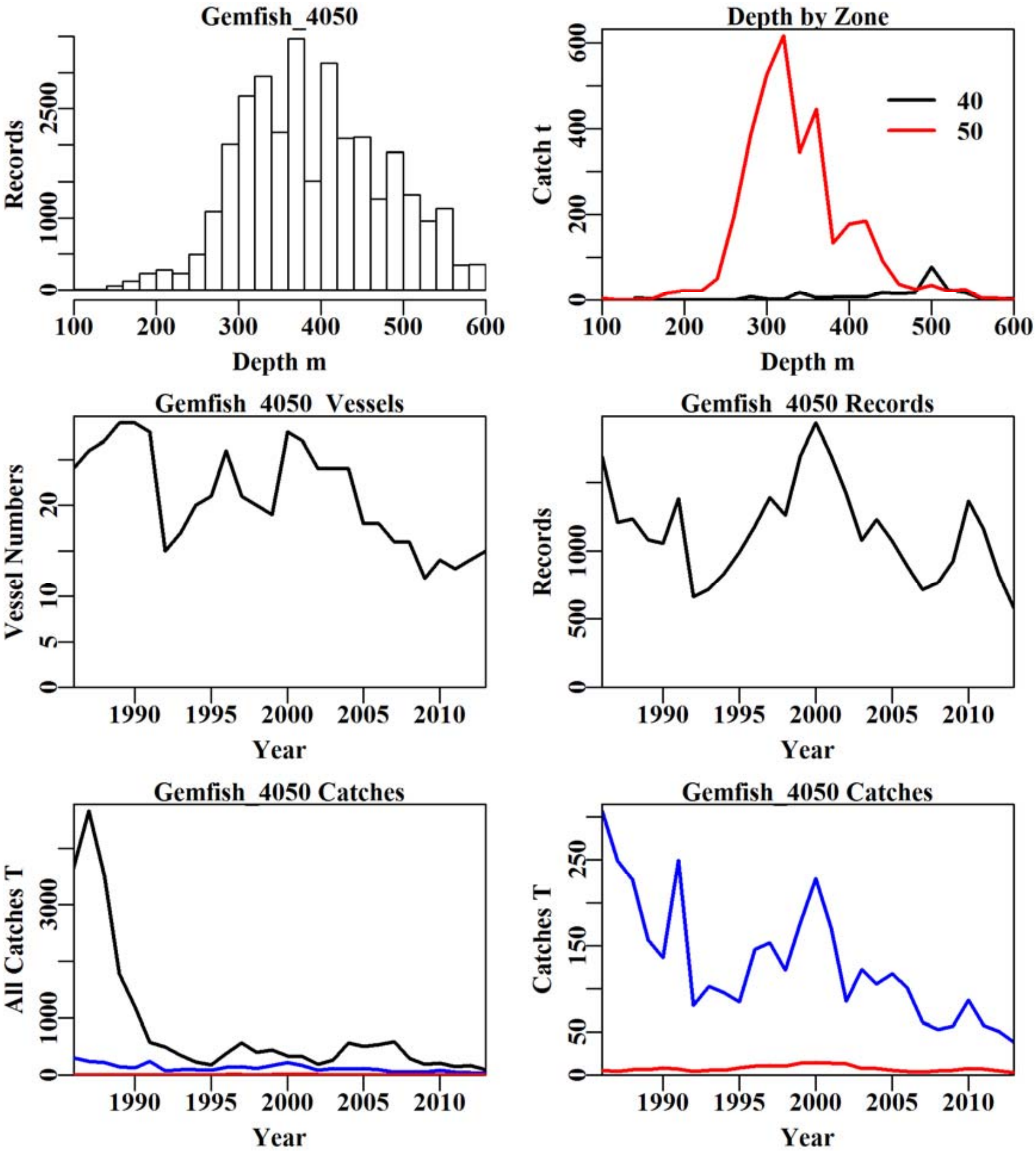


Figure 13.106**.** Western Gemfish from zones 40 and 50 in depths between 100 – 600 m by Trawl. The top left plot depicts the depth distribution of shots containing Western Gemfish from zones 40 and 50 in depths 100 – 600 m by Trawl. The top right plot depicts the catch distribution by depth by zone. The middle left plot depicts the number of vessels through time and middle right plot contains the number of records used in analysis. The bottom left plot contains Western Gemfish catches (top black line: total catches, middle blue line: catches used in the analysis; bottom red line: catches < 30 kg) and bottom right plot contains Western Gemfish catches (blue line: catches used in the analysis; red line: catches < 30 kg).

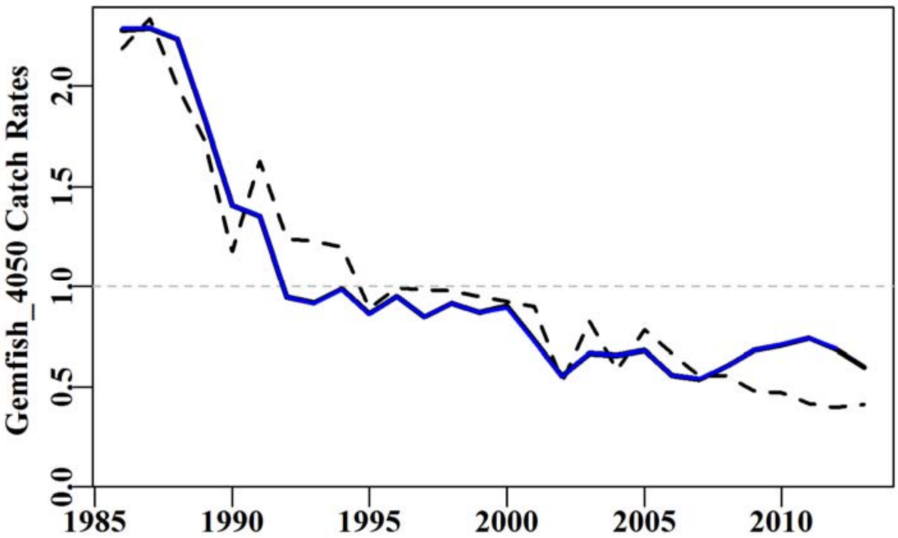


Figure 13.107**.** Western Gemfish from zones 40 and 50 in depths between 100 – 600 m by Trawl. The dashed black line represents the geometric mean catch rate, solid black line the standardized catch rates and solid blue line standardized catch rates from last year's analysis. The graph standardizes catch rates relative to the mean of the standardized catch rates.

Table 13.98**.** Western Gemfish from zones 40 and 50 in depths between 100 – 600 m by Trawl. Statistical model structures used in this analysis. DepCat is a series of 20 metre depth categories.

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

Table 13.99**.** Western Gemfish from zones 40 and 50 in depths between 100 – 600 m by Trawl. Model selection criteria include the Akaike Information Criterion (AIC), residual sum of squares (RSS), model sum of squares (MSS), number of usable observations (Nobs), number of parameters (Npars), adjusted R^2 (adj_R^2) and the change in adjusted R^2 (%Change). The optimum is Zone:Month (Model 7). Depth category: DepC.

	Year	Vessel	DepC	DayNight	Month	Zone	Zone:Month	Zone:DepC
AIC	21660	14281	7753	7206	6935	6935	6615	6773
RSS	62881	49662	40312	39619	39257	39254	38836	38995
MSS	8089	21308	30658	31351	31713	31716	32134	31976
Nobs	32038	32038	31901	31901	31901	31901	31901	31901
Npars	28	119	144	147	158	159	170	184
adj_R^2	11.323	29.766	42.943	43.918	44.411	44.414	44.987	44.738
%Change	0.000	18.443	13.177	0.975	0.493	0.003	0.573	-0.249

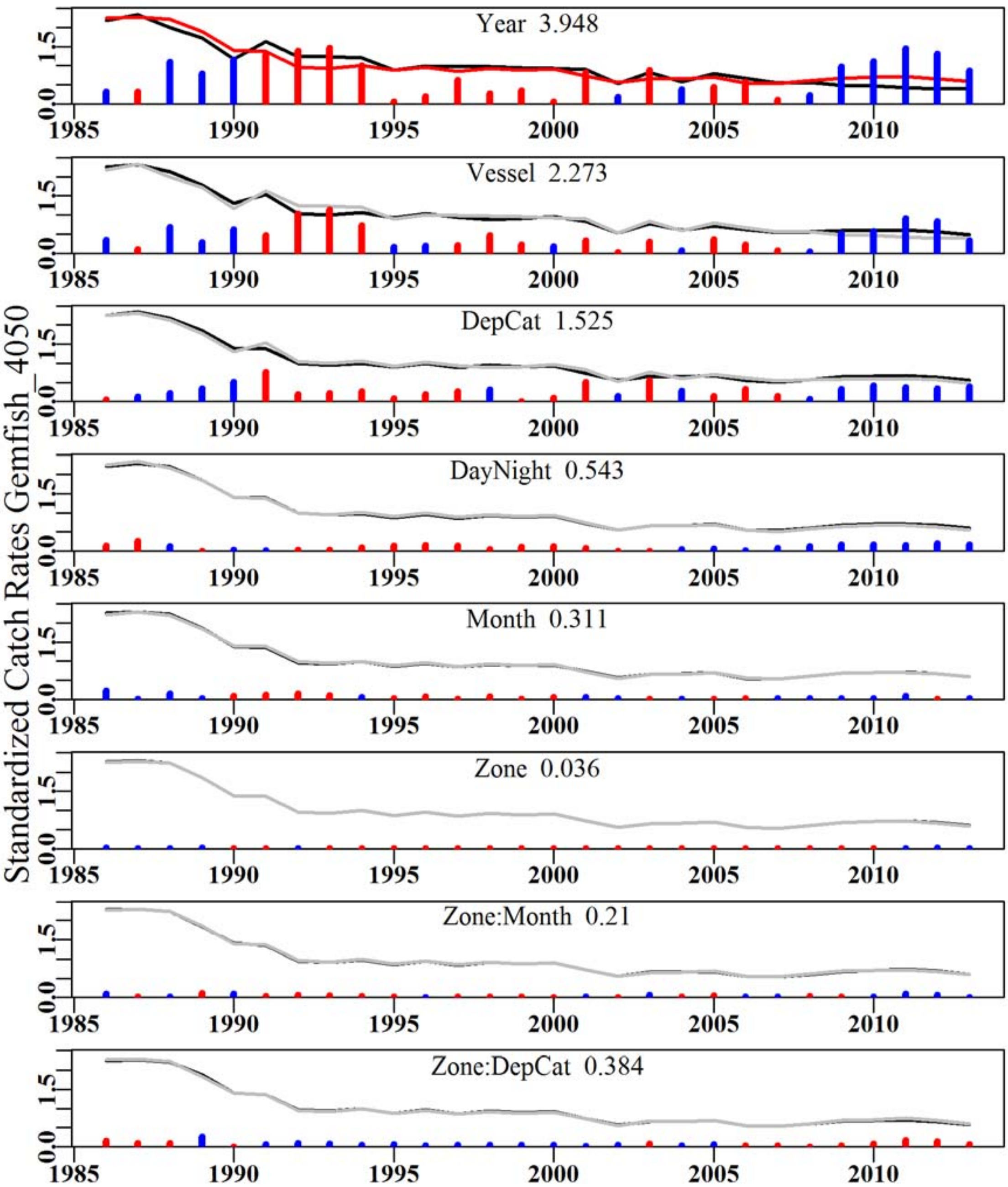


Figure 13.108. The relative influence of each factor used on the final trend in the optimal standardization for Western Gemfish from zones 40 and 50. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by the vertical bars with blue bars indicating the optimum model is higher than the geometric mean and red bars indicating it is lower. The top graph bars are the sum of all the bars in the graphs below. The graphs for individual factors are cumulative. Thus the second graph has the geometric mean (grey line) and the effect of adding Year + factor2 (Model 2). In the third graph, the grey line represents Model 2 and the black line the effect of adding factor3 to the model. The remaining graphs continue in the same cumulative manner except for the interaction terms which are added singularly to the final single factor model.

13.39 Western Gemfish GAB (GEM – 37439002 – *Rexea solandri*)

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

Table 13.100**.** Western Gemfish in the GAB in depths between 100 and 600 m by Trawl. Total catch (TotCatch; t) is the total reported in the database, number of records used in the analysis (Records), reported catch (CatchT; t) in the area and depth used in the analysis and number of vessels used in the analysis (Vessels). GeoMean is the geometric mean of catch rates (kg/hr). The optimum model is Zone:Month and standard deviation (StDev) relates to the data in the optimum model.

Year	TotCatch	Records	CatchT	Vessels	GeoMean	Zone:Month	StDev
1995	181.7460	326	22.8450	6	3.8779	0.7007	0.0000
1996	382.1960	449	19.2390	7	3.8858	0.9194	0.0932
1997	571.9758	717	61.7730	9	4.2096	0.9209	0.0886
1998	404.8147	708	85.2200	8	6.3801	1.4952	0.0905
1999	448.6767	653	146.9330	7	10.0539	1.7899	0.0931
2000	336.4642	425	32.1020	6	2.8318	0.6499	0.0990
2001	331.4862	641	85.3320	8	5.8477	1.0766	0.0935
2002	195.8983	352	43.3263	8	4.3633	0.9382	0.1020
2003	267.9710	565	79.3545	11	5.4980	0.8617	0.0974
2004	568.8517	720	372.9160	10	17.0005	1.1174	0.0976
2005	511.7585	743	253.8402	10	16.0998	0.9376	0.0990
2006	544.8936	709	333.2422	11	16.7217	0.9593	0.0977
2007	599.1098	697	358.0045	10	15.2782	0.8451	0.0961
2008	294.8605	495	104.3260	7	5.4956	0.8400	0.0981
2009	194.8654	350	48.9613	4	4.5291	0.7828	0.1045
2010	220.6510	339	42.6375	4	4.9524	0.8624	0.1050
2011	147.7397	218	20.2225	4	5.2479	0.8310	0.1176
2012	168.5996	305	52.2863	5	9.0568	1.3023	0.1093
2013	103.7326	148	9.6908	6	8.7733	1.1696	0.1325

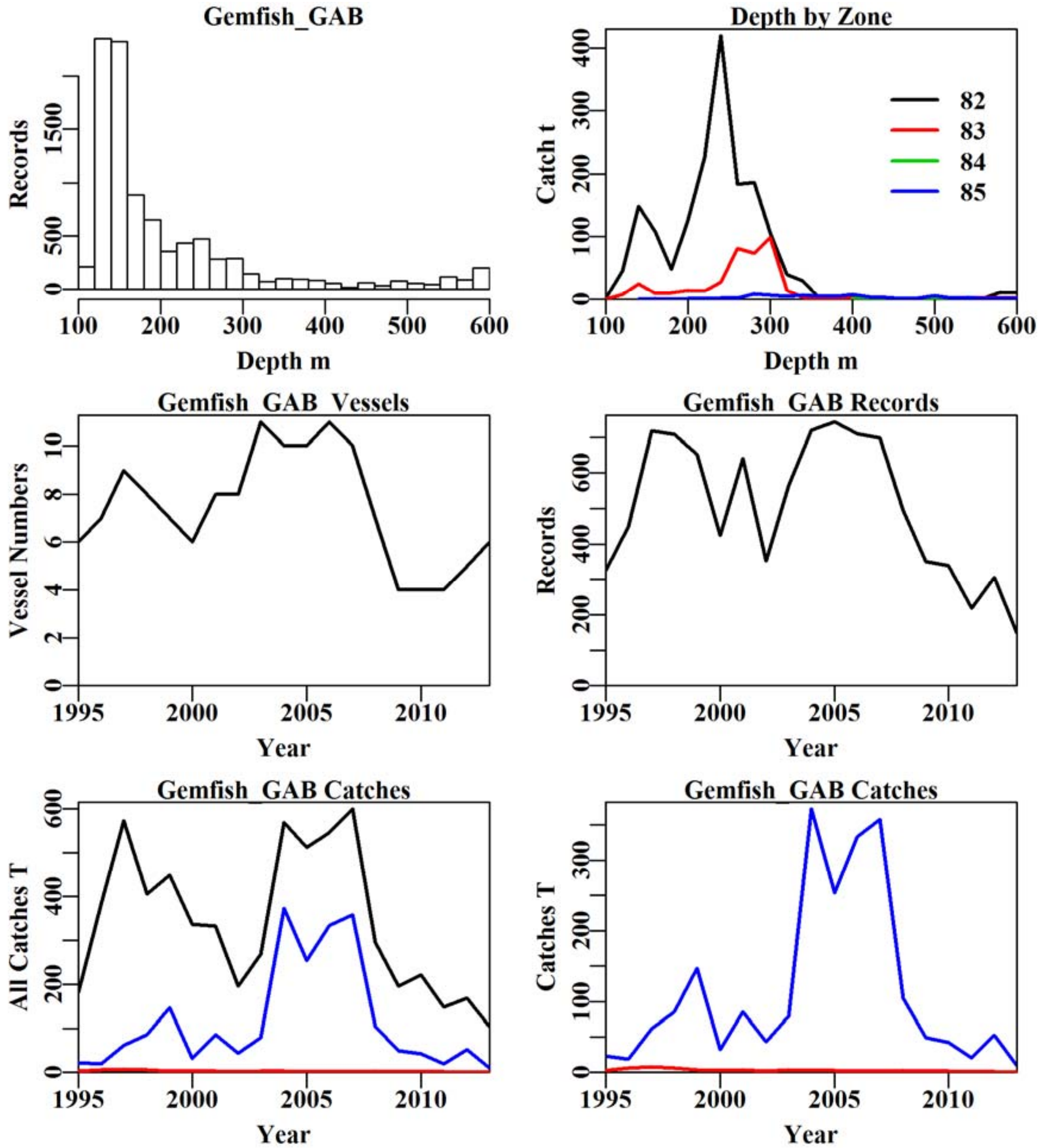


Figure 13.109**.** Western Gemfish in the GAB (zones 82, 83, 84, and 85) in depths between 100 and 600 m by Trawl. The top left plot depicts the depth distribution of shots containing Western Gemfish from zones in the GAB (zones 82, 83, 84, and 85) in depths 100 – 600 m by Trawl. The top right plot depicts the catch distribution by depth by zone. The middle left plot depicts the number of vessels through time and middle right plot contains the number of records used in analysis. The bottom left plot contains Western Gemfish catches (top black line: total catches, middle blue line: catches used in the analysis; bottom red line: catches < 30 kg) and bottom right plot contains Western Gemfish catches (blue line: catches used in the analysis; red line: catches < 30 kg).

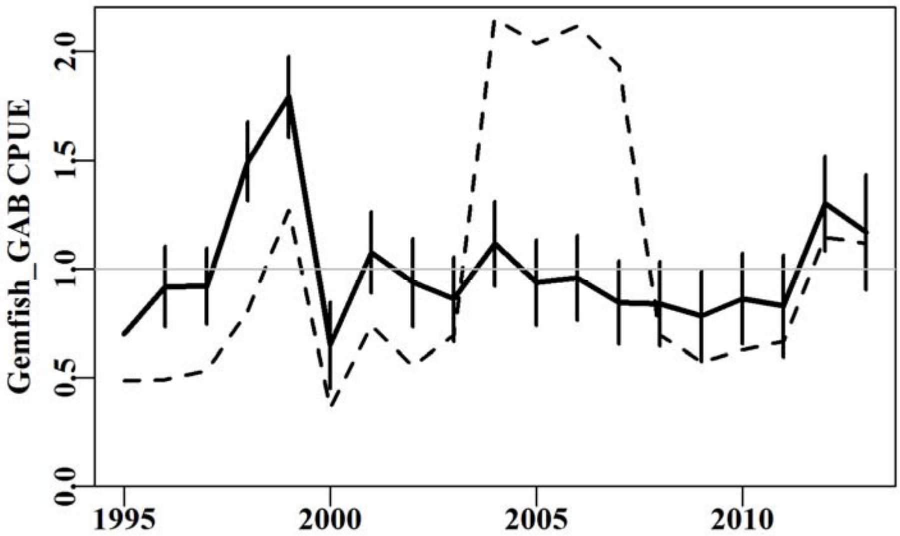


Figure 13.110**.** Western Gemfish in the GAB (zones 82, 83, 84, and 85) in depths between 100 and 600 m by Trawl. The dashed black line represents the geometric mean catch rate and the solid black line the standardized catch rates with associated 95% CI's. The graph standardizes catch rates relative to the mean of the standardized catch rates.

Table 13.101**.** 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 13.102**.** Western Gemfish in the GAB (zones 82, 83, 84, and 85) in depths between 100 and 600 m by Trawl. Model selection criteria include the Akaike Information Criterion (AIC), residual sum of squares (RSS), model sum of squares (MSS), number of usable observations (Nobs), number of parameters (Npars), adjusted R^2 (adj_R^2) and the change in adjusted R^2 (%Change). The optimum is Zone:Month (Model 7). Depth category: DepC.

	Year	DepC	Vessel	Month	DayNight	Zone	Zone:Month	Zone:DepC
AIC	10874	6978	5602	4942	4679	4451	4162	4391
RSS	29698	19630	16895	15728	15289	14918	14372	14591
MSS	3212	13280	16015	17182	17621	17992	18538	18318
Nobs	9560	9518	9518	9518	9518	9518	9518	9518
Npars	19	44	70	81	84	87	120	162
adj_R^2	9.590	40.082	48.289	51.805	53.134	54.257	55.776	54.899
%Change	0.000	30.491	8.207	3.517	1.329	1.123	1.519	-0.877

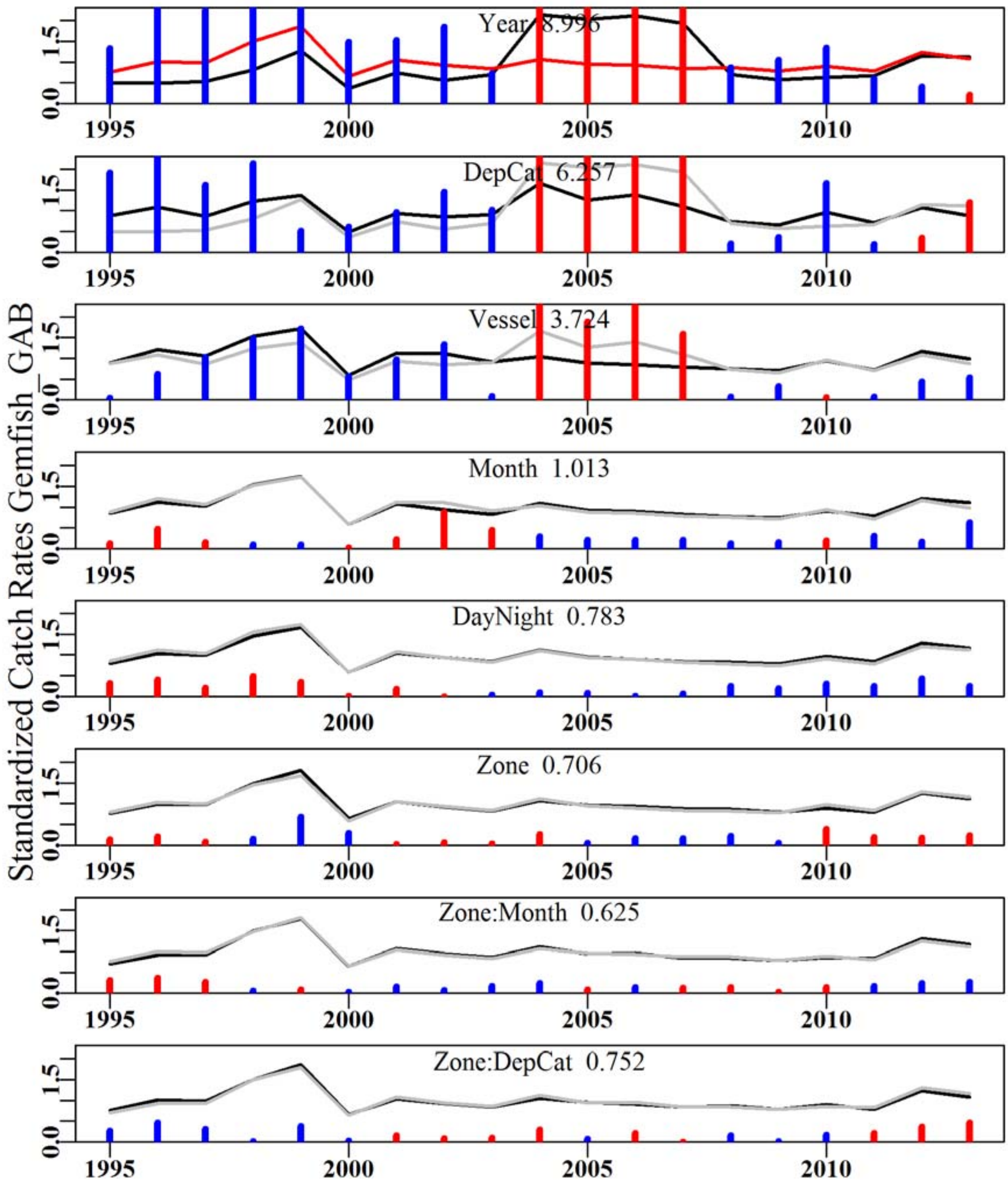


Figure 13.111**.** The relative influence of each factor used on the final trend in the optimal standardization for Western Gemfish in the GAB (zones 82, 83, 84, and 85). The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by the vertical bars with blue bars indicating the optimum model is higher than the geometric mean and red bars indicating it is lower. The top graph bars are the sum of all the bars in the graphs below. The graphs for individual factors are cumulative. Thus the second graph has the geometric mean (grey line) and the effect of adding Year + factor2 (Model 2). In the third graph, the grey line represents Model 2 and the black line the effect of adding factor3 to the model. The remaining graphs continue in the same cumulative manner except for the interaction terms which are added singularly to the final single factor model.

13.40 Offshore Ocean Perch Z1020 (REG – 37287001 Helicolenus percoides; 200m)

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

Table 13.103**.** Offshore Ocean Perch from zones 10 and 20 in depths 200 – 700 m by Trawl. Total catch (TotCatch; t) is the total reported in the database, number of records used in the analysis (Records), reported catch (CatchT; t) in the area and depth used in the analysis and number of vessels used in the analysis (Vessels). GeoMean is the geometric mean of catch rates (kg/hr). The optimum model is Zone:Month and standard deviation (StDev) relates to the data in the optimum model.

Year	TotCatch	Records	CatchT	Vessels	GeoMean	Zone:Month	StDev
1986	262.4460	3479	207.3630	77	12.1440	1.0287	0.0000
1987	198.3470	3140	132.7970	70	8.9237	0.9533	0.0256
1988	186.7120	2808	150.7650	73	10.5074	1.0654	0.0266
1989	206.2580	3036	160.0040	67	10.6494	1.0220	0.0264
1990	180.5600	1970	115.9430	57	12.0207	1.3614	0.0297
1991	223.1880	2093	138.9910	53	13.4339	1.4369	0.0294
1992	169.6690	1845	114.0790	47	11.9264	1.2143	0.0303
1993	259.3100	2924	199.1860	53	12.9555	1.2153	0.0270
1994	257.2410	3014	180.9550	49	11.8001	1.1348	0.0267
1995	239.9510	3146	150.3410	50	10.4874	1.0273	0.0264
1996	263.2350	3411	176.8080	53	9.8364	0.9213	0.0260
1997	296.3336	3725	193.7730	54	9.7119	0.9766	0.0258
1998	292.0978	3850	194.6290	49	9.4285	0.8657	0.0255
1999	290.6426	4406	219.0650	52	9.7566	0.9723	0.0252
2000	269.8270	4178	180.7502	53	7.5464	0.7737	0.0257
2001	281.5414	4038	183.9110	43	8.3956	0.8702	0.0259
2002	255.3073	3646	150.6222	45	7.3709	0.8260	0.0266
2003	322.7355	3960	185.0060	53	7.6242	0.8807	0.0263
2004	316.1390	3129	150.4585	46	8.0648	0.8787	0.0276
2005	316.7690	3089	170.0795	46	9.3641	0.9870	0.0275
2006	237.6008	2326	113.1680	39	7.8433	0.8453	0.0295
2007	180.5792	1528	94.9000	22	9.9183	1.0549	0.0332
2008	184.2667	1843	101.8360	23	9.1917	0.9701	0.0317
2009	173.8793	1694	99.6075	23	9.0355	0.9661	0.0326
2010	195.5993	1759	118.1070	21	9.8647	0.9810	0.0321
2011	186.7935	1874	116.6955	22	9.0998	0.8668	0.0316
2012	180.5639	1693	114.1412	22	9.9671	0.9327	0.0324
2013	166.4316	1232	100.1720	20	12.0121	0.9716	0.0357

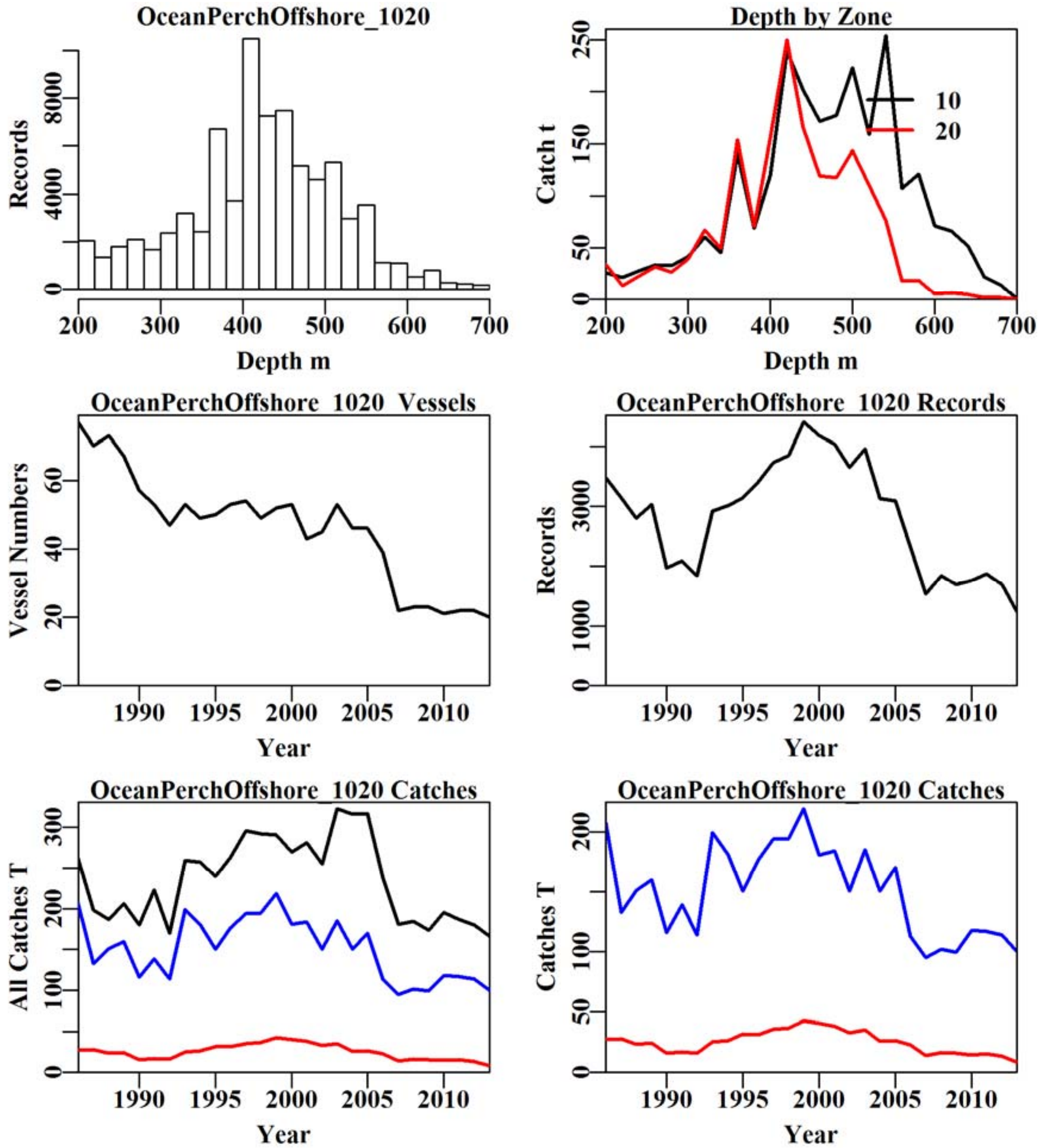


Figure 13.112**.** Offshore Ocean Perch from zones 10 and 20 in depths 200 – 700 m by Trawl. The top left plot depicts the depth distribution of shots containing Offshore Ocean Perch from zones 10 and 20 in depths 200 – 700m by Trawl. The top right plot depicts the catch distribution by depth by zone. The middle left plot depicts the number of vessels through time and middle right plot contains the number of records used in analysis. The bottom left plot contains Offshore Ocean Perch catches (top black line: total catches, middle blue line: catches used in the analysis; bottom red line: catches < 30 kg) and bottom right plot contains Offshore Ocean Perch catches (blue line: catches used in the analysis; red line: catches < 30 kg).

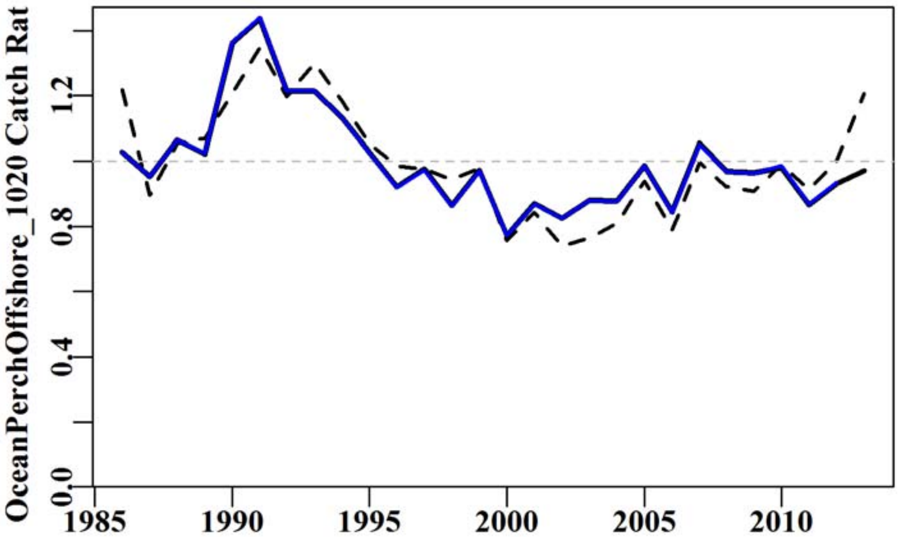


Figure 13.113. Offshore Ocean Perch from zones 10 and 20 in depths 200 – 700 m by Trawl. The dashed black line represents the geometric mean catch rate, solid black line the standardized catch rates and solid blue line standardized catch rates from last year's analysis. The graph standardizes catch rates relative to the mean of the standardized catch rates.

Table 13.104. Offshore Ocean Perch from zones 10 and 20 in depths 200 – 700 m by Trawl. Statistical model structures used in this analysis. DepCat is a series of 20 metre depth categories.

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

Table 13.105. Offshore Ocean Perch from zones 10 and 20 in depths 200 – 700 m by Trawl. Model selection criteria include the Akaike Information Criterion (AIC), residual sum of squares (RSS), model sum of squares (MSS), number of usable observations (Nobs), number of parameters (Npars), adjusted R^2 (adj_R^2) and the change in adjusted R^2 (%Change). The optimum is Zone:Month (Model 7). Depth category: DepC.

	Year	DepC	Vessel	Month	DayNight	Zone	Zone:Month	Zone:DepC
AIC	22253	10257	1706	-458	-688	-726	-2714	-1113
RSS	104473	89252	79711	77519	77286	77247	75292	76817
MSS	2161	17383	26923	29115	29348	29387	31342	29817
Nobs	78836	78414	78414	78414	78414	78414	78414	78414
Npars	28	53	210	221	224	225	236	250
adj_R^2	1.993	16.246	25.049	27.099	27.316	27.352	29.180	27.732
%Change	0.000	14.253	8.803	2.050	0.217	0.036	1.829	-1.448

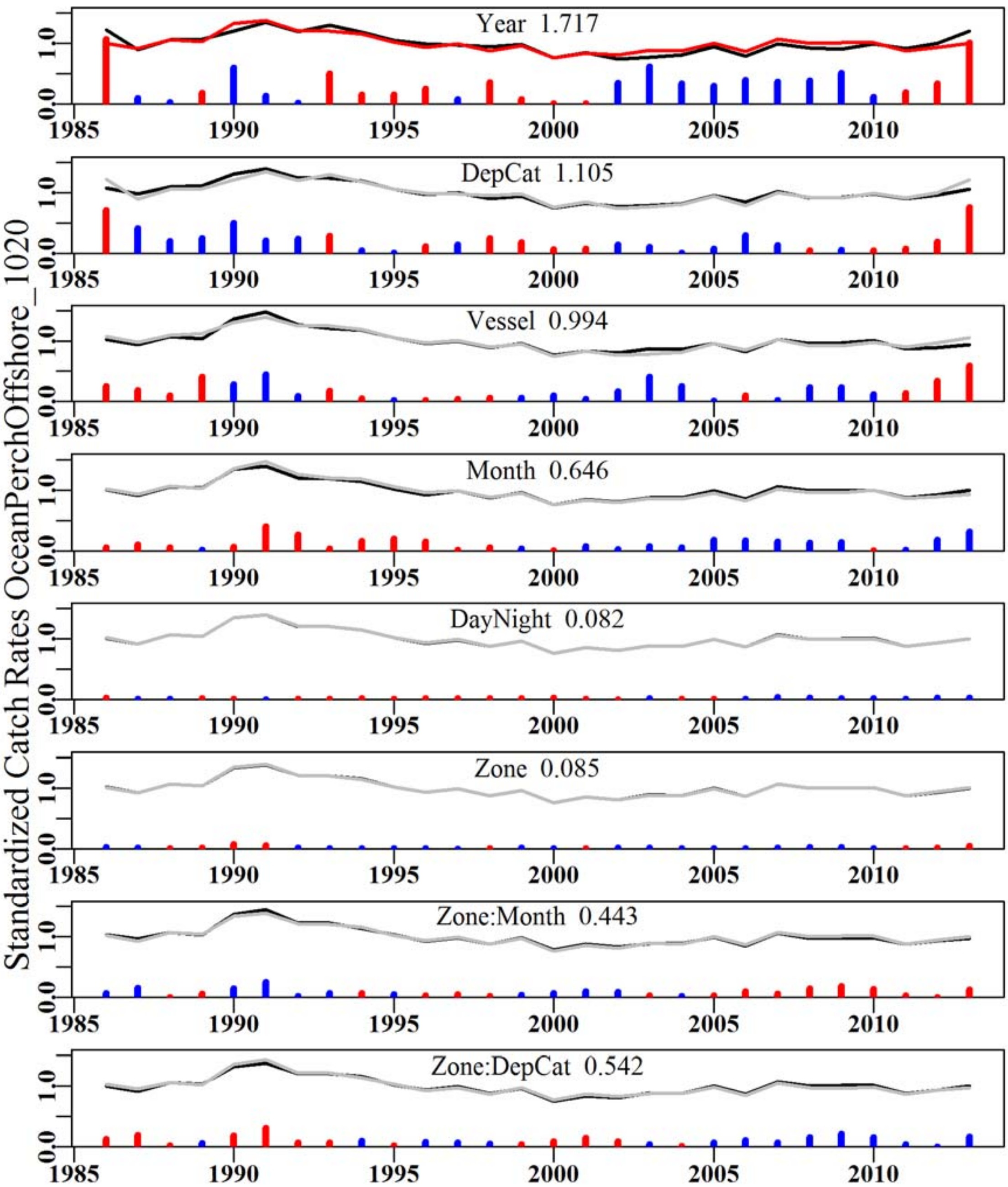
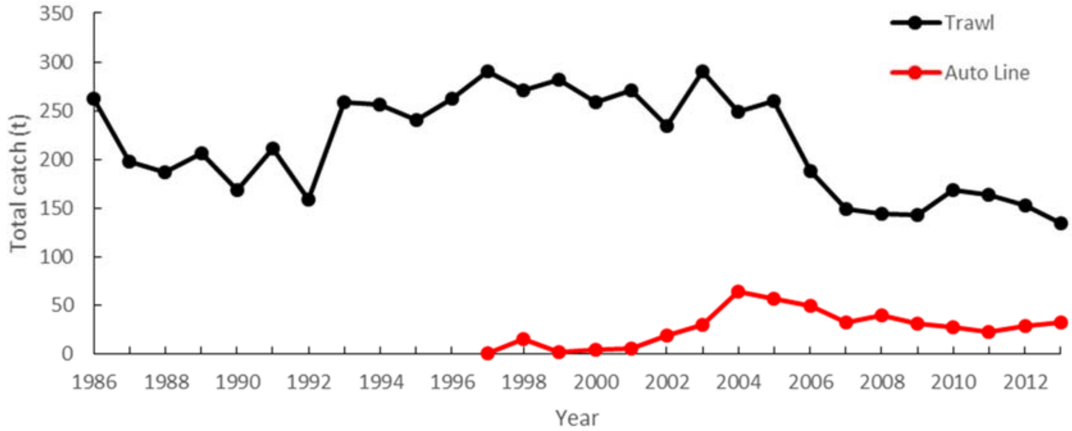


Figure 13.114**.** The relative influence of each factor used on the final trend in the optimal standardization for Offshore Ocean Perch from zones 10 and 20. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by the vertical bars with blue bars indicating the optimum model is higher than the geometric mean and red bars indicating it is lower. The top graph bars are the sum of all the bars in the graphs below. The graphs for individual factors are cumulative. Thus the second graph has the geometric mean (grey line) and the effect of adding Year + factor2 (Model 2). In the third graph, the grey line represents Model 2 and the black line the effect of adding factor3 to the model. The remaining graphs continue in the same cumulative manner except for the interaction terms which are added singularly to the final single factor model.



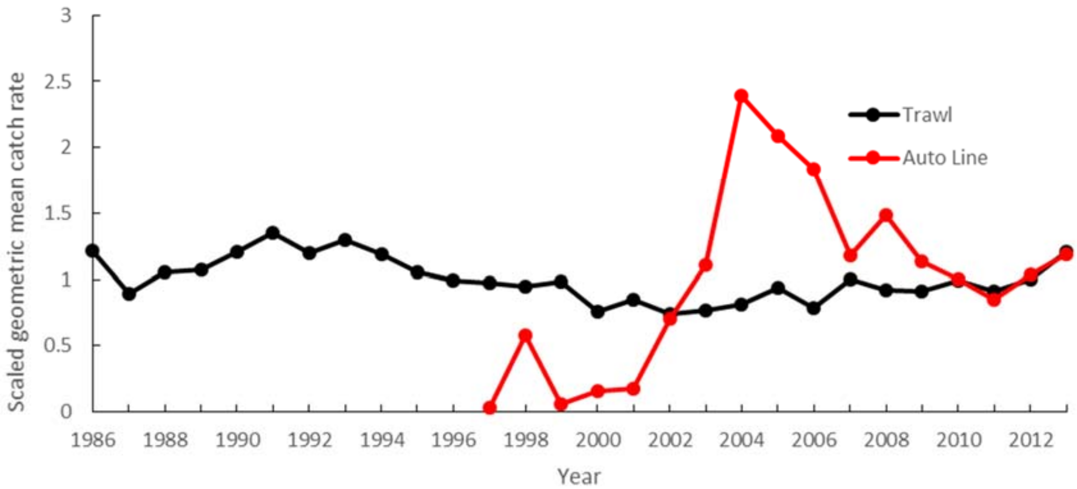
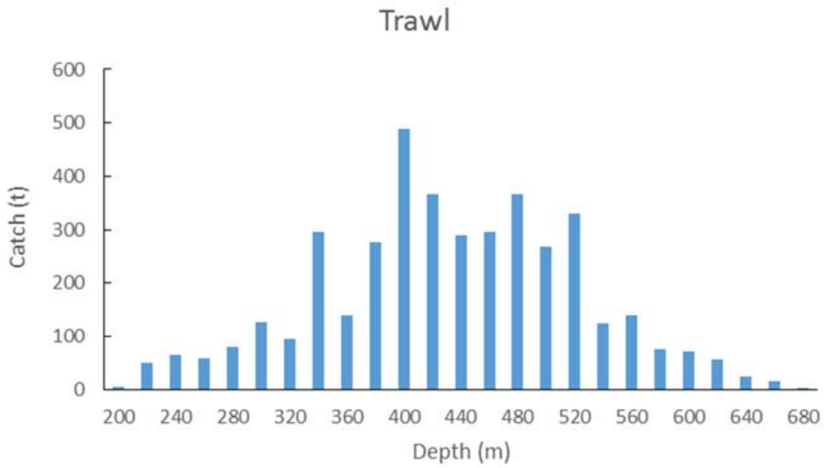


Figure 13.115. Offshore Ocean Perch, depths > 200 m for Trawl and Auto Line, in zones 10 and 20 between 1986 and 2013. Upper plot: Catches through time taken by Trawl and by Auto Line. Some of the decline in trawl catches in recent years have been made up by the Auto Long Lining. Lower plot: Geometric mean catch rates for Offshore Ocean Perch in depth 200 – 700 m for both trawl and Auto Line scaled to the mean of each series for comparison.



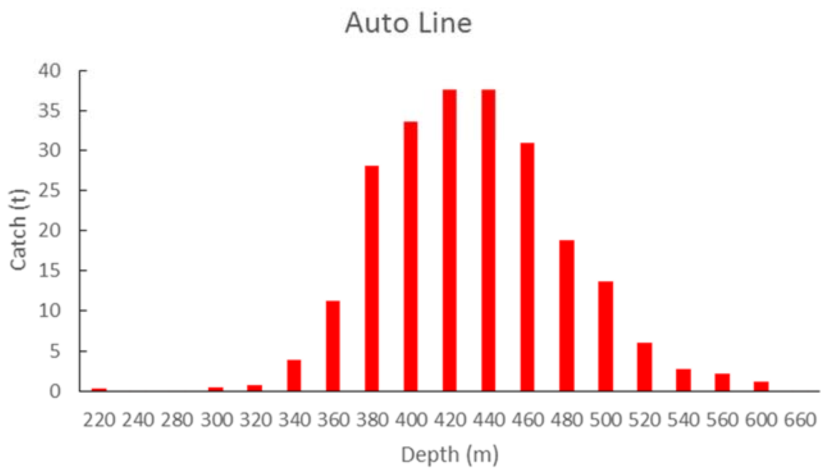


Figure 13.116. Depth distribution of catches of Offshore Ocean Perch, depths 200 – 700 m for Trawl and Auto Line between 1986 and 2013. Most catches by Auto Line are taken in the same depths as trawl catches.

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

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

Table 13.106**.** Inshore Ocean Perch from zones 10 and 20 in depths 0 – 200 m by Trawl. Total catch (TotCatch; t) is the total reported in the database, number of records used in the analysis (Records), reported catch (CatchT; t) in the area and depth used in the analysis and number of vessels used in the analysis (Vessels). GeoMean is the geometric mean of catch rates (kg/hr). The optimum model is Zone:DepC and standard deviation (StDev) relates to the data in the optimum model.

Year	TotCatch	Records	CatchT	Vessels	GeoMean	Zone:DepC	StDev
1986	262.4460	339	15.2390	50	6.8543	0.8444	0.0000
1987	198.3470	406	11.9710	58	5.9511	0.9870	0.0920
1988	186.7120	518	16.5480	59	7.2891	1.1284	0.0885
1989	206.2580	443	15.3920	52	8.0367	1.0810	0.0925
1990	180.5600	450	15.6140	45	7.7738	1.1529	0.0937
1991	223.1880	498	20.3640	43	8.1374	1.2912	0.0928
1992	169.6690	258	13.8300	28	9.5229	1.7226	0.1044
1993	259.3100	467	25.0800	38	10.1873	1.9323	0.0957
1994	257.2410	558	23.3400	35	9.4326	1.7576	0.0926
1995	239.9510	600	21.2000	35	8.7548	1.2957	0.0902
1996	263.2350	688	21.3070	39	7.0539	1.1453	0.0898
1997	296.3336	572	16.3650	40	5.9056	1.0657	0.0925
1998	292.0978	646	15.6280	41	5.7524	0.9321	0.0911
1999	290.6426	675	15.9780	40	4.9974	0.8385	0.0903
2000	269.8270	1326	30.5511	39	4.5708	0.9923	0.0862
2001	281.5414	1035	23.3970	34	4.2075	0.9797	0.0879
2002	255.3073	1422	25.1850	36	2.6164	0.7001	0.0867
2003	322.7355	1086	17.5878	40	2.3189	0.5434	0.0876
2004	316.1390	962	15.4615	41	2.2440	0.5511	0.0892
2005	316.7690	898	19.8485	41	2.9880	0.6250	0.0899
2006	237.6008	602	9.3385	35	2.2501	0.5199	0.0931
2007	180.5792	395	8.7450	21	3.5455	0.7329	0.0994
2008	184.2667	330	7.9690	21	4.2486	0.9039	0.1032
2009	173.8793	289	6.6710	21	4.1335	0.7775	0.1068
2010	195.5993	308	7.1410	21	3.8309	0.8177	0.1052
2011	186.7935	275	6.4305	19	3.6642	0.9459	0.1078
2012	180.5639	392	8.0761	20	3.5117	0.7895	0.1002
2013	166.4316	218	4.8494	14	4.4457	0.9464	0.1100

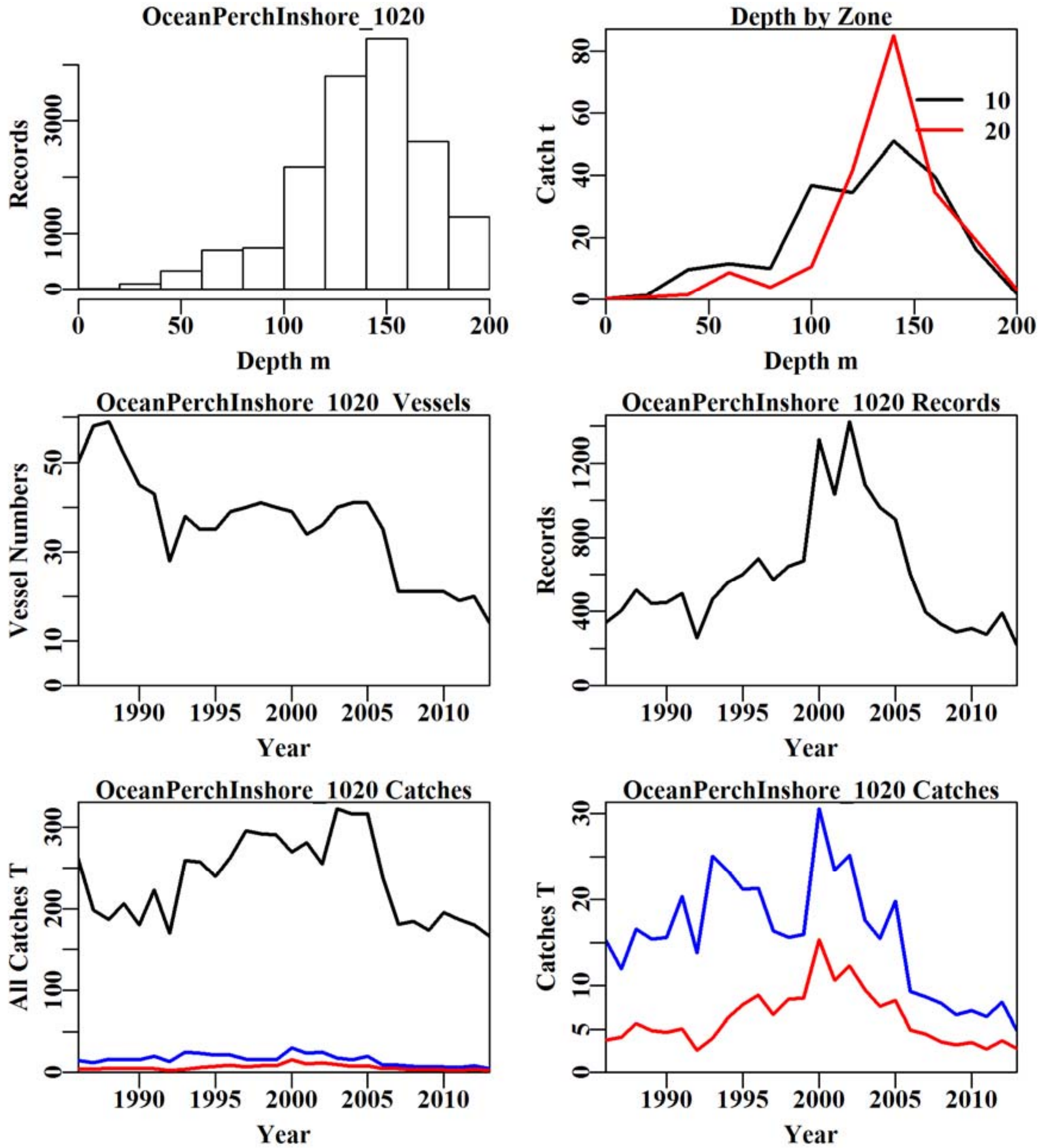


Figure 13.117. Inshore Ocean Perch from zones 10 and 20 in depths 0 – 200 m by Trawl. The top left plot depicts the depth distribution of shots containing Offshore Ocean Perch from zones 10 and 20 in depths 0 – 200 m by Trawl. The top right plot depicts the catch distribution by depth by zone. The middle left plot depicts the number of vessels through time and middle right plot contains the number of records used in analysis. The bottom left plot contains Offshore Ocean Perch catches (top black line: total catches, middle blue line: catches used in the analysis; bottom red line: catches < 30 kg) and bottom right plot contains Offshore Ocean Perch catches (blue line: catches used in the analysis; red line: catches < 30 kg).

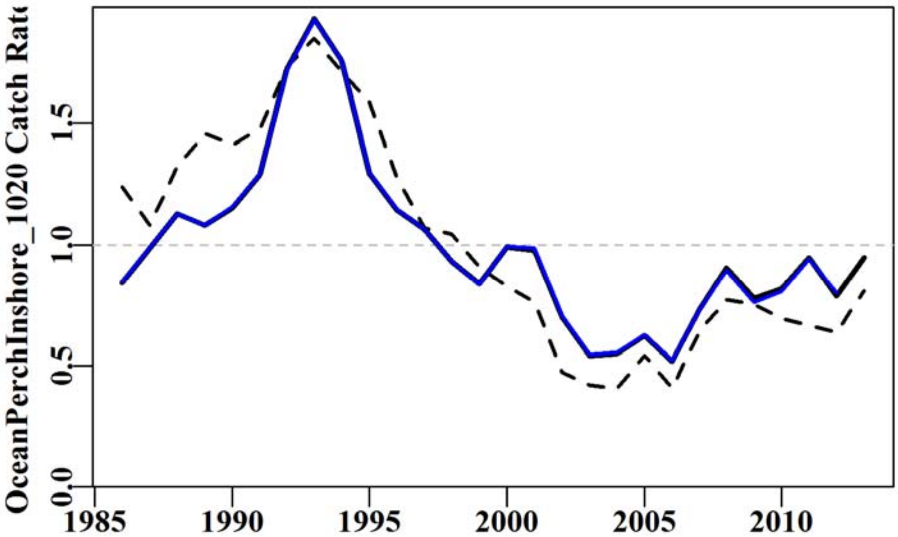


Figure 13.118. Inshore Ocean Perch from zones 10 and 20 in depths 0 – 200 m by Trawl. The dashed black line represents the geometric mean catch rate, solid black line the standardized catch rates and solid blue line standardized catch rates from last year's analysis. The graph standardizes catch rates relative to the mean of the standardized catch rates.

Table 13.107. Inshore Ocean Perch from zones 10 and 20 in depths 0 – 200 m by Trawl. Statistical model structures used in this analysis. DepCat is a series of 20 metre depth categories.

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

Table 13.108. Inshore Ocean Perch from zones 10 and 20 in depths 0 – 200 m by Trawl. Model selection criteria include the Akaike Information Criterion (AIC), residual sum of squares (RSS), model sum of squares (MSS), number of usable observations (Nobs), number of parameters (Npars), adjusted R^2 (adj_R^2) and the change in adjusted R^2 (%Change). The optimum is Zone:DepC (Model 8). Depth category: DepC.

	Year	Vessel	DepC	Month	DayNight	Zone	Zone:Month	Zone:DepC
AIC	5886	2404	1451	1374	1320	1235	1234	1148
RSS	23637	18849	17359	17252	17189	17098	17073	16985
MSS	3802	8590	10080	10186	10250	10341	10366	10454
Nobs	16656	16656	16234	16234	16234	16234	16234	16234
Npars	28	172	182	193	196	197	208	207
adj_R^2	13.715	30.593	36.023	36.370	36.594	36.925	36.974	37.303
%Change	0.000	16.878	5.430	0.347	0.224	0.332	0.049	0.329

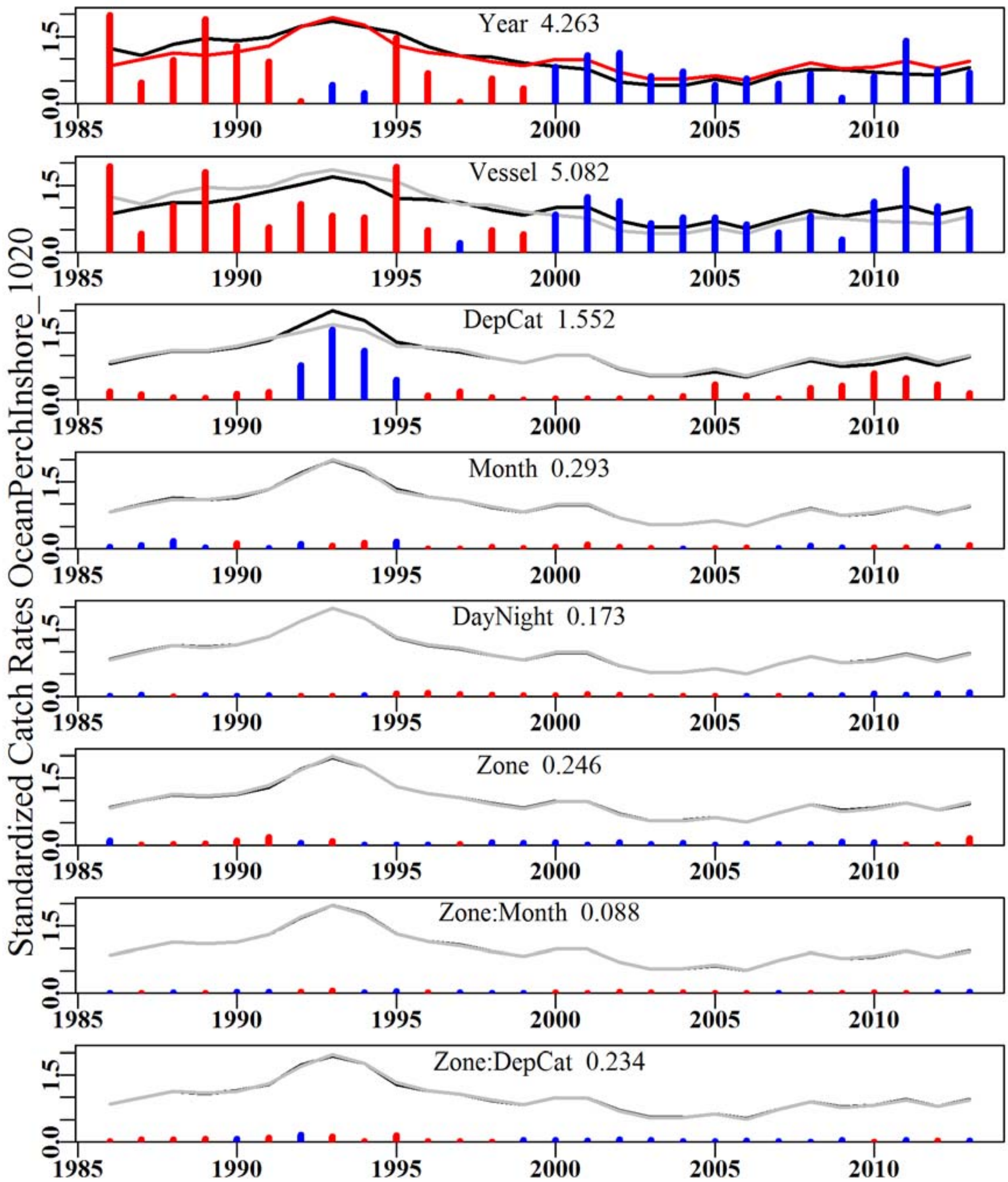


Figure 13.119. The relative influence of each factor used on the final trend in the optimal standardization for Inshore Ocean Perch from zones 10 and 20. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by the vertical bars with blue bars indicating the optimum model is higher than the geometric mean and red bars indicating it is lower. The top graph bars are the sum of all the bars in the graphs below. The graphs for individual factors are cumulative. Thus the second graph has the geometric mean (grey line) and the effect of adding Year + factor2 (Model 2). In the third graph, the grey line represents Model 2 and the black line the effect of adding factor3 to the model. The remaining graphs continue in the same cumulative manner except for the interaction terms which are added singularly to the final single factor model.

13.42 John Dory (DOJ – 37264004 – *Zeus faber*)

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

Table 13.109**.** John Dory from zones 10 and 20 in depths 0 to 200 m by Trawl. Total catch (TotCatch; t) is the total reported in the database, number of records used in the analysis (Records), reported catch (CatchT; t) in the area and depth used in the analysis and number of vessels used in the analysis (Vessels). GeoMean is the geometric mean of catch rates (kg/hr). The optimum model is Zone:DepC and standard deviation (StDev) relates to the data in the optimum model.

Year	TotCatch	Records	CatchT	Vessels	GeoMean	Zone:DepC	StDev
1986	231.7150	6418	202.2350	90	7.6948	1.6025	0.0000
1987	206.0900	4663	181.5910	78	8.5155	1.8351	0.0209
1988	181.9840	4538	161.5630	73	8.3856	1.7229	0.0211
1989	217.9240	4813	188.4430	70	9.5319	1.8903	0.0211
1990	167.8530	3700	136.7640	60	8.7451	1.7082	0.0231
1991	172.2910	4041	126.6960	53	7.1954	1.4022	0.0227
1992	130.8493	3809	100.0263	48	5.6282	1.1578	0.0231
1993	240.4380	5446	181.6220	56	7.0963	1.4990	0.0214
1994	267.8680	6573	209.8970	55	6.7516	1.4137	0.0204
1995	185.6720	6070	168.5310	52	5.9610	1.2049	0.0205
1996	160.7530	6411	146.7690	59	4.5279	0.9423	0.0204
1997	87.7655	4473	79.2240	60	3.3776	0.7308	0.0224
1998	109.0292	5091	98.4790	53	3.6350	0.7565	0.0216
1999	132.8421	5553	121.0210	56	3.9411	0.8874	0.0212
2000	164.0530	7094	147.8755	59	3.5716	0.8213	0.0203
2001	129.2998	6789	116.2240	51	2.9450	0.6881	0.0205
2002	150.9738	6670	136.1303	49	3.1506	0.6786	0.0208
2003	156.9439	6558	137.3210	51	3.1537	0.6586	0.0207
2004	166.0275	7094	147.6960	51	3.4203	0.6979	0.0204
2005	107.3895	4934	88.6397	48	2.6772	0.5795	0.0222
2006	85.4007	3727	71.6251	43	2.8463	0.6534	0.0238
2007	62.4793	2844	51.6850	23	2.8023	0.5914	0.0259
2008	116.7894	3852	102.9915	26	4.3014	0.8813	0.0239
2009	91.7065	3148	79.7460	23	4.1921	0.8190	0.0252
2010	61.9744	3078	52.4480	24	2.6471	0.5282	0.0255
2011	74.8052	3428	57.4000	22	2.7461	0.5495	0.0248
2012	67.1140	3387	56.5785	22	2.8174	0.5355	0.0246
2013	63.4730	2683	48.8930	23	2.8673	0.5638	0.0261

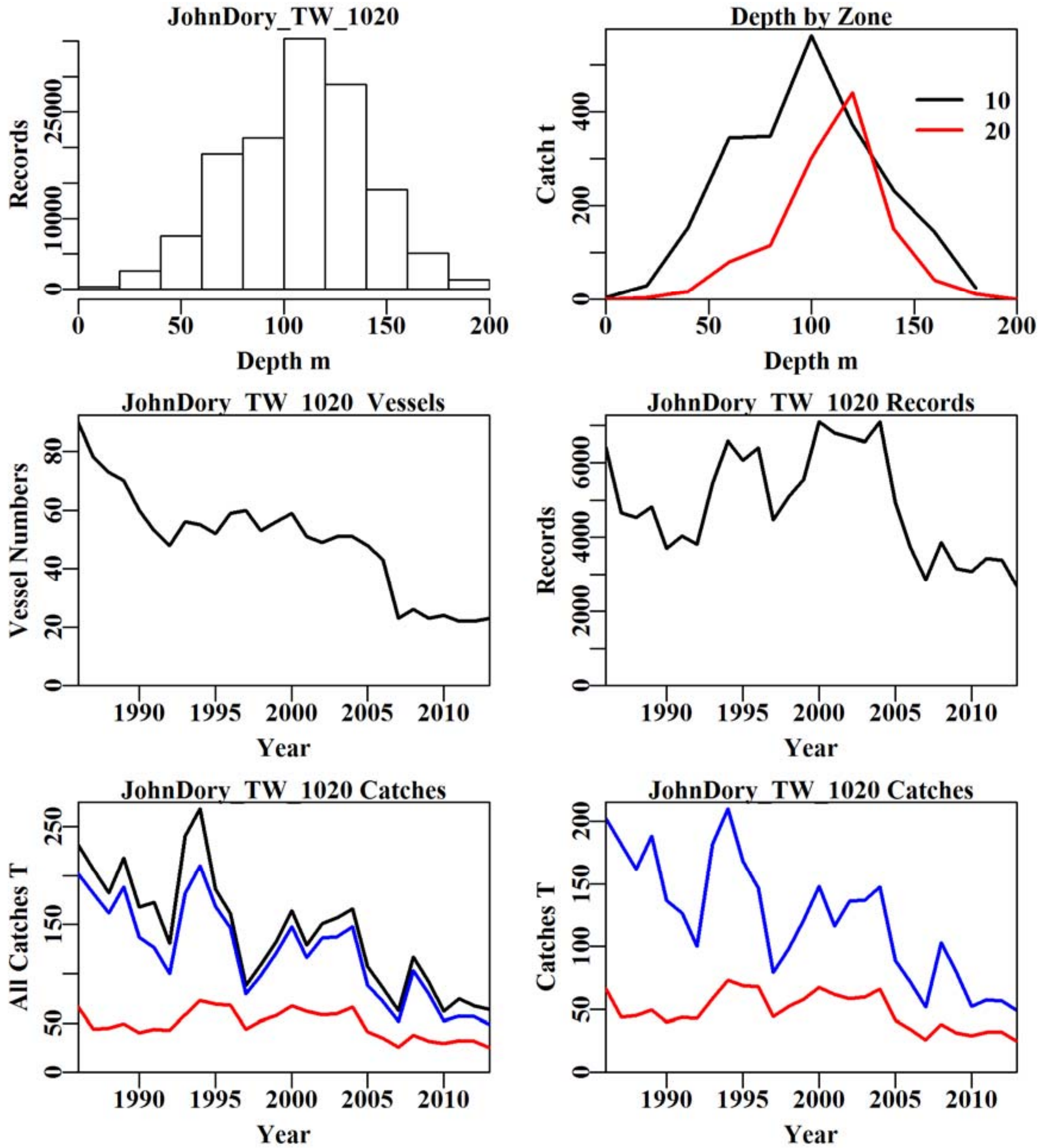


Figure 13.120. John Dory from Zones 10 and 20 in depths 0 to 200 m by Trawl. The top left plot depicts the depth distribution of shots containing John Dory zones 10 and 20 in depths 0 to 200 m by Trawl. The top right plot depicts the catch distribution by depth by zone. The middle left plot depicts the number of vessels through time and middle right plot contains the number of records used in analysis. The bottom left plot contains John Dory catches (top black line: total catches, middle blue line: catches used in the analysis; bottom red line: catches < 30 kg) and bottom right plot contains John Dory catches (blue line: catches used in the analysis; red line: catches < 30 kg).

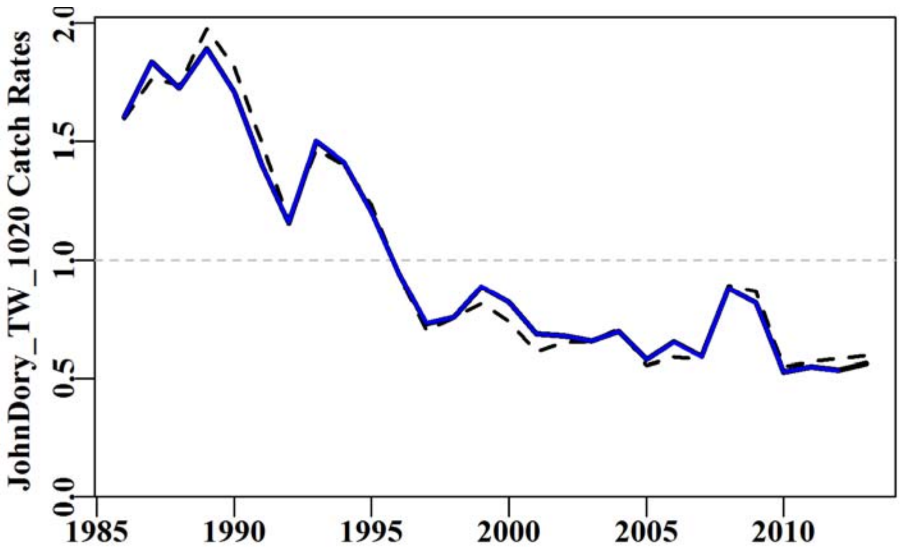


Figure 13.121. John Dory from Zones 10 and 20 in depths 0 to 200 m by Trawl. The dashed black line represents the geometric mean catch rate, solid black line the standardized catch rates and solid blue line the standardized catch rates from last year's analysis. The graph standardizes catch rates relative to the mean of the standardized catch rates.

Table 13.110. 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 13.111. John Dory from Zones 10 and 20 in depths 0 to 200 m by Trawl. Model selection criteria include the Akaike Information Criterion (AIC), residual sum of squares (RSS), model sum of squares (MSS), number of usable observations (Nobs), number of parameters (Npars), adjusted R^2 (adj_R^2) and the change in adjusted R^2 (%Change). The optimum is Zone:DepC (Model 8). Depth category: DepC.

	Year	Vessel	DepC	DayNight	Month	Zone	Zone:Month	Zone:DepC
AIC	27753	11926	10283	8454	7778	7755	6936	27753
RSS	167583	148932	145980	144020	143281	143254	142370	167583
MSS	23876	42527	45479	47439	48178	48204	49089	23876
Nobs	136885	136885	135728	135728	135728	135728	135728	136885
Npars	28	190	200	203	214	215	226	28
adj_R^2	12.453	22.104	23.642	24.666	25.046	25.059	25.516	12.453
%Change	0.000	9.651	1.538	1.024	0.381	0.013	0.457	0.000

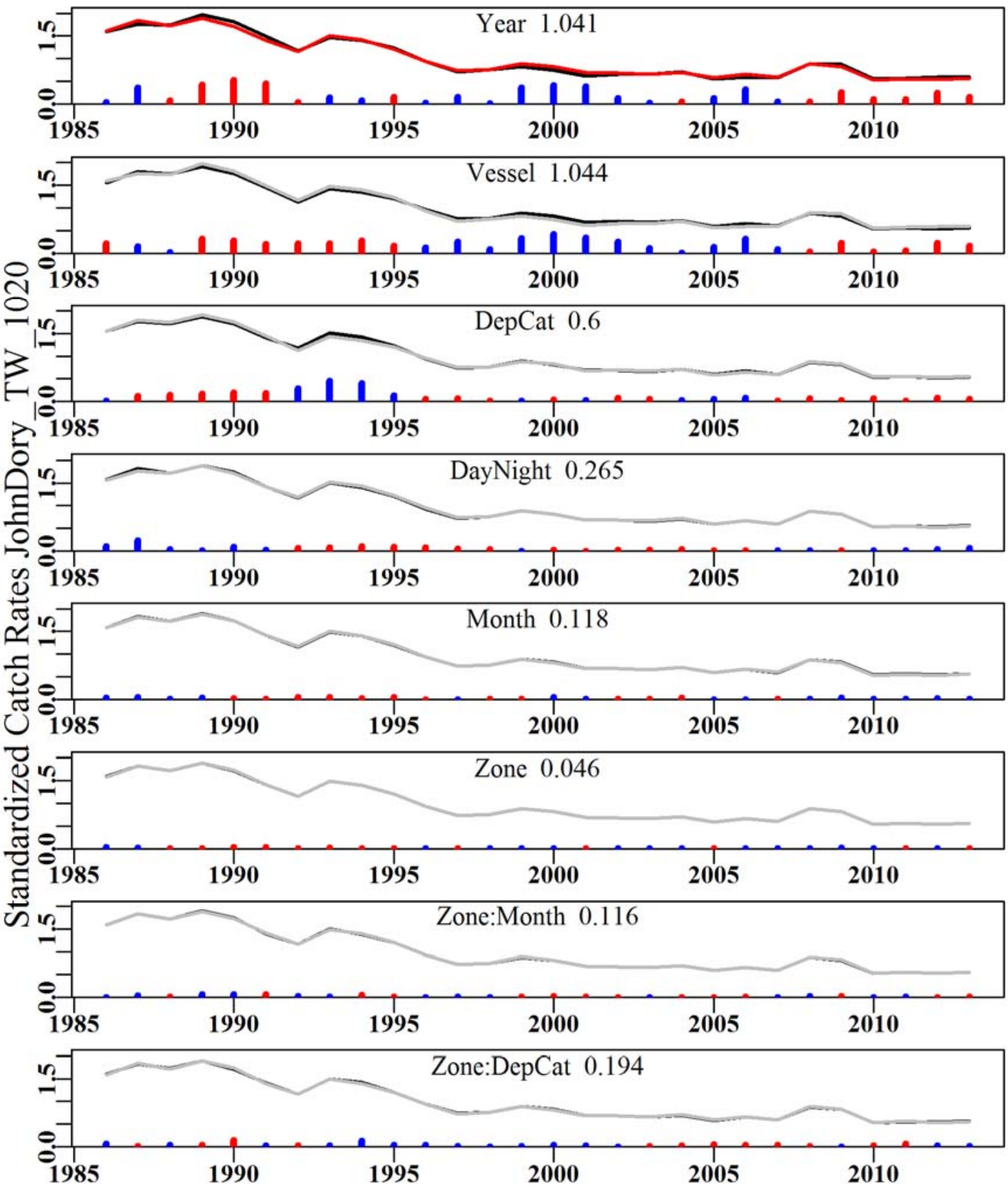


Figure 13.122. The relative influence of each factor used on the final trend in the optimal standardization for John Dory from zones 10 and 20. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by the vertical bars with blue bars indicating the optimum model is higher than the geometric mean and red bars indicating it is lower. The top graph bars are the sum of all the bars in the graphs below. The graphs for individual factors are cumulative. Thus the second graph has the geometric mean (grey line) and the effect of adding Year + factor2 (Model 2). In the third graph, the grey line represents Model 2 and the black line the effect of adding factor3 to the model. The remaining graphs continue in the same cumulative manner except for the interaction terms which are added singularly to the final single factor model.

13.43 Mirror Dory Z10-50 (DOM – 37264003 – Zenopsis nebulosus)

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

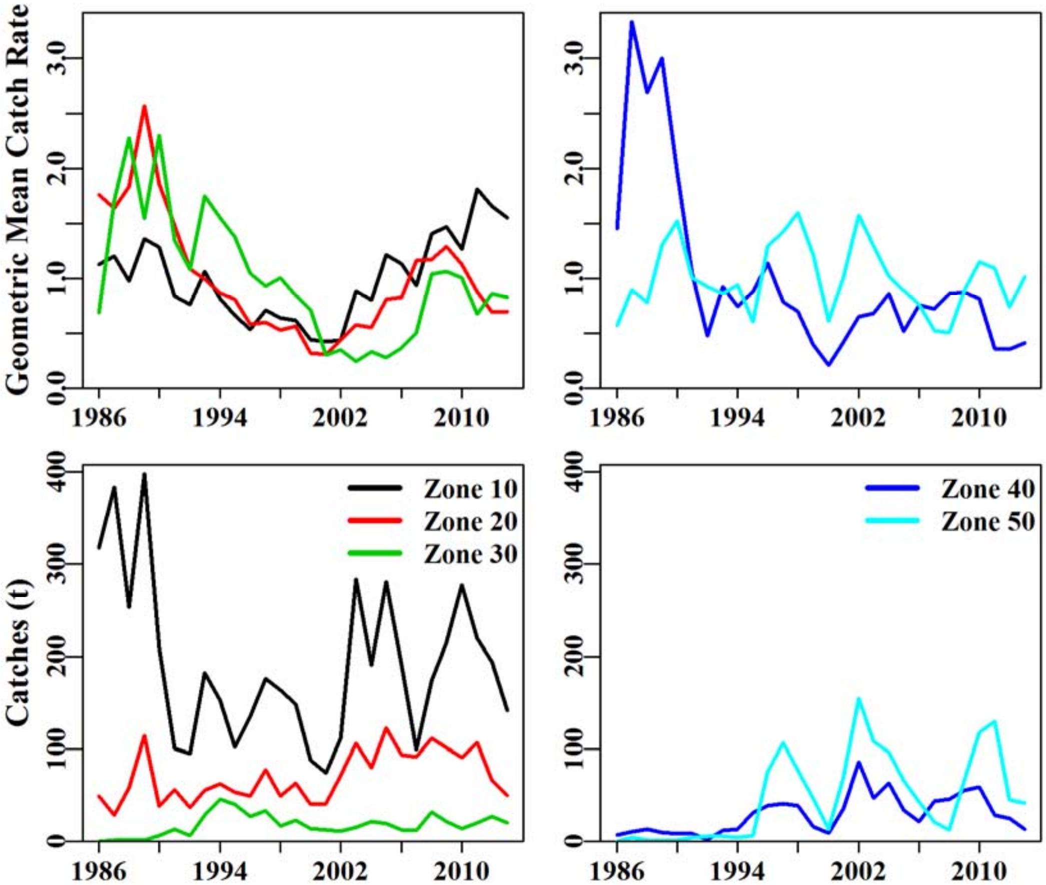


Figure 13.123. The catches and geometric mean catch rates from 1986 – 2012 for Mirror Dory split between east (zones 10 -30) and west (zones 40 and 50). The general trends in catch rates, in periods of significant catches, are similar across zones within the east and west. This implies that the assumption that there are no Year x Zone interactions is valid.

Table 13.112. Mirror Dory from zones 10 to 50 in depths 0 to 600 m by Trawl. Total catch (TotCatch; t) is the total reported in the database, number of records used in the analysis (Records), reported catch (CatchT; t) in the area and depth used in the analysis and number of vessels used in the analysis (Vessels). GeoMean is the geometric mean of catch rates (kg/hr). The optimum model is Zone:Month and standard deviation (StDev) relates to the data in the optimum model.

Year	TotCatch	Records	CatchT	Vessels	GeoMean	Zone:Month	StDev
1986	402.0480	3199	375.3850	91	18.6423	1.2147	0.0000
1987	450.7660	3103	429.0900	92	19.7476	1.2190	0.0311
1988	346.0140	3189	328.2200	88	16.9455	1.1945	0.0309
1989	591.6310	3068	524.8630	84	23.1957	1.4707	0.0314
1990	295.7640	1906	264.3460	73	20.6077	1.3570	0.0360
1991	240.3130	2230	183.7370	77	13.9567	1.1633	0.0347
1992	166.9803	2228	147.1700	71	11.3487	1.0102	0.0348
1993	306.2200	3290	285.2210	72	13.7999	1.1054	0.0317
1994	297.2680	3828	280.1950	70	11.4667	0.9932	0.0309
1995	244.9240	4209	234.4330	70	10.0782	0.9229	0.0303
1996	352.7220	5835	327.5140	84	8.9039	0.8889	0.0290
1997	459.6263	6681	436.4460	80	9.6820	0.9439	0.0287
1998	355.7935	5572	346.7060	68	9.0983	0.8555	0.0293
1999	309.4810	5543	298.1670	74	8.0995	0.7005	0.0295
2000	171.0664	5613	165.2285	80	4.6519	0.4902	0.0297
2001	243.3623	7016	233.9240	75	5.1157	0.5756	0.0291
2002	449.5550	8199	435.0346	69	7.1647	0.7690	0.0286
2003	613.8621	7797	560.9170	71	8.6659	0.9327	0.0286
2004	507.3770	6484	452.6005	69	8.2047	0.8965	0.0294
2005	579.8856	6190	523.8135	66	9.3924	0.9933	0.0295
2006	419.5564	4293	363.0748	54	9.7517	0.9790	0.0311
2007	289.6026	3400	268.1030	33	9.5152	0.9445	0.0328
2008	396.2424	3377	376.3640	34	12.2034	1.1280	0.0328
2009	476.5154	3567	461.7812	32	13.1797	1.2456	0.0326
2010	579.9761	3702	561.2296	32	12.8612	1.1909	0.0324
2011	514.5297	3921	506.2050	33	10.8184	1.1031	0.0320
2012	365.4882	2757	357.9945	33	8.9809	0.7988	0.0344
2013	278.7298	2289	267.3913	32	10.6434	0.9132	0.0357

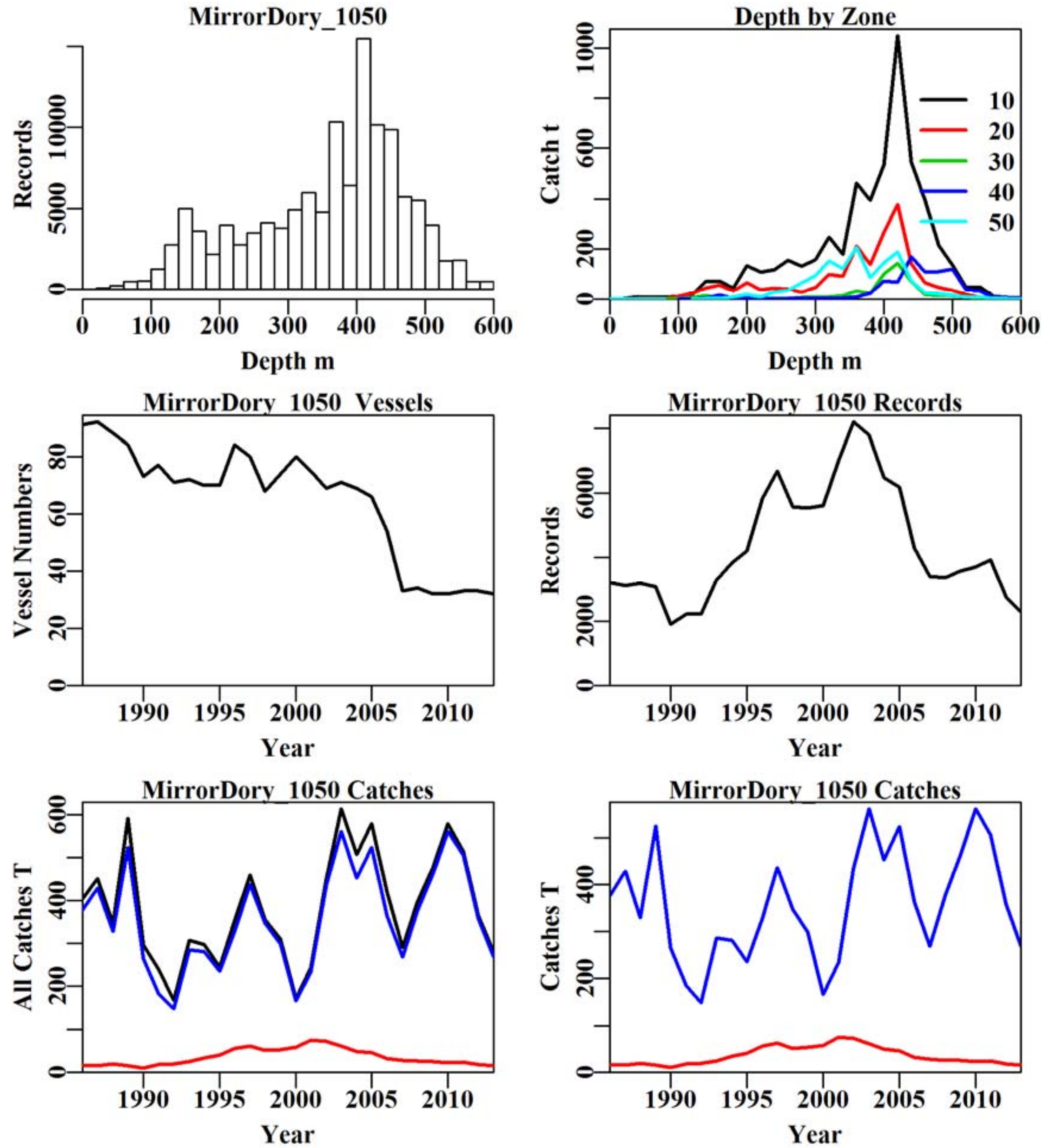


Figure 13.124**.** Mirror Dory from zones 10 to 50 in depths 0 to 600 m by Trawl. The top left plot depicts the depth distribution of shots containing Mirror Dory zones 10 to 50 in depths 0 to 600 m by Trawl. The top right plot depicts the catch distribution by depth by zone. The middle left plot depicts the number of vessels through time and middle right plot contains the number of records used in analysis. The bottom left plot contains Mirror Dory catches (top black line: total catches, middle blue line: catches used in the analysis; bottom red line: catches < 30 kg) and bottom right plot contains Mirror Dory catches (blue line: catches used in the analysis; red line: catches < 30 kg).

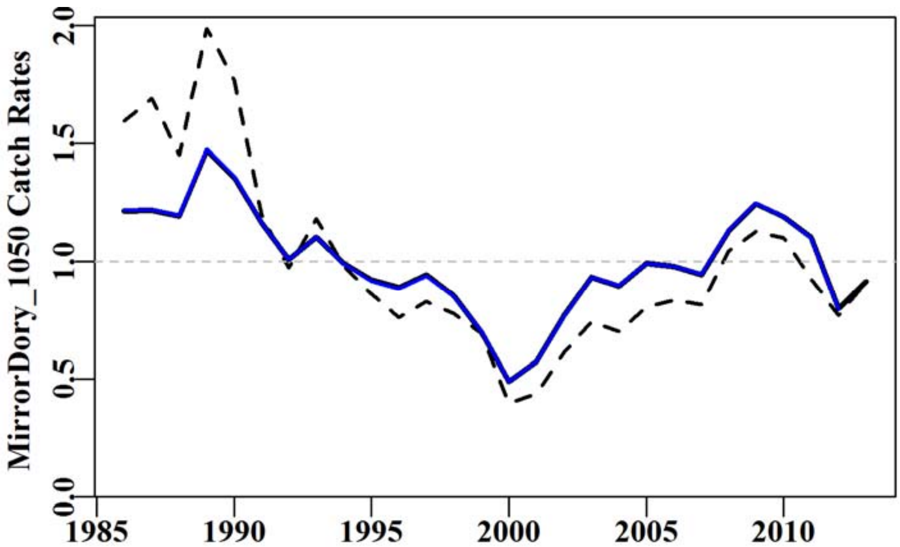


Figure 13.125. Mirror Dory from Zones 10 to 50 in depths 0 to 600 m by Trawl. The dashed black line represents the geometric mean catch rate, solid black line the standardized catch rates and solid blue line the standardized catch rates from last year's analysis. The graph standardizes catch rates relative to the mean of the standardized catch rates.

Table 13.113. 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 13.114. Mirror Dory from zones 10 to 50 in depths 0 to 600 m by Trawl. Model selection criteria include the Akaike Information Criterion (AIC), residual sum of squares (RSS), model sum of squares (MSS), number of usable observations (Nobs), number of parameters (Npars), adjusted R^2 (adj_R^2) and the change in adjusted R^2 (%Change). The optimum is Zone:Month (Model 7). Depth category: DepC.

	Year	Vessel	DepC	Month	DayNight	Zone	Zone:Month	Zone:DepC
AIC	77659	55892	54086	43003	41664	40893	36339	39970
RSS	230802	192589	189736	172614	170718	169629	163287	168018
MSS	16276	54489	57342	74464	76360	77448	83791	79060
Nobs	122486	122486	122486	121811	121811	121811	121811	121811
Npars	28	230	241	271	274	278	322	398
adj_R^2	77659	55892	54086	43003	41664	40893	36339	39970
%Change	230802	192589	189736	172614	170718	169629	163287	168018

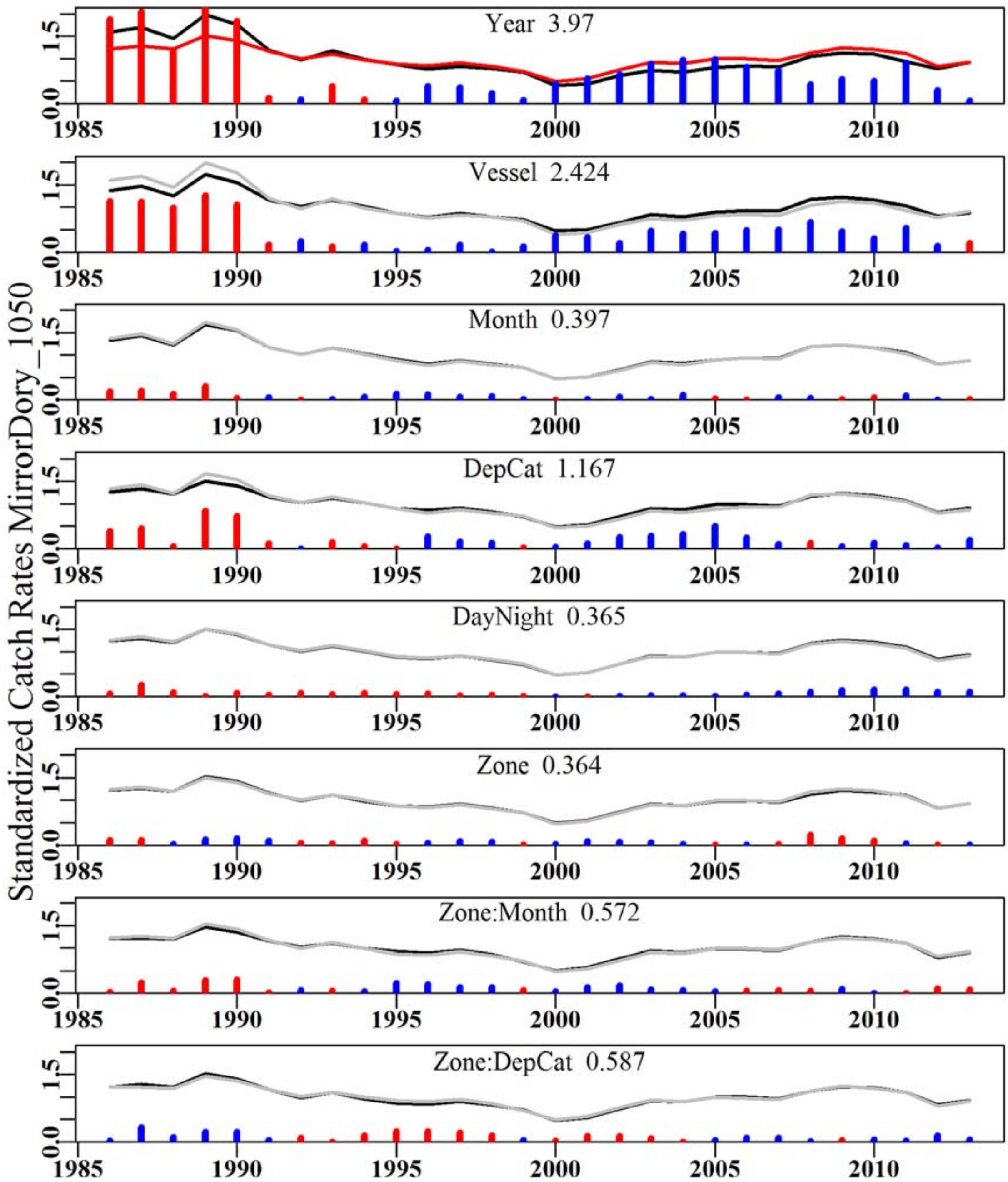


Figure 13.126**.** The relative influence of each factor used on the final trend in the optimal standardization for Mirror Dory from zones 10 to 50. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by the vertical bars with blue bars indicating the optimum model is higher than the geometric mean and red bars indicating it is lower. The top graph bars are the sum of all the bars in the graphs below. The graphs for individual factors are cumulative. Thus the second graph has the geometric mean (grey line) and the effect of adding Year + factor2 (Model 2). In the third graph, the grey line represents Model 2 and the black line the effect of adding factor3 to the model. The remaining graphs continue in the same cumulative manner except for the interaction terms which are added singularly to the final single factor model.

13.44 Mirror Dory East (DOM – 37264003 – *Zenopsis nebulosus*)

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

Table 13.115. Mirror Dory from Zones 10 to 30 in depths 0 to 600 m by Trawl. Total catch (TotCatch; t) is the total reported in the database, number of records used in the analysis (Records), reported catch (CatchT; t) in the area and depth used in the analysis and number of vessels used in the analysis (Vessels). GeoMean is the geometric mean of catch rates (kg/hr). The optimum model is Zone:Month and standard deviation (StDev) relates to the data in the optimum model.

Year	TotCatch	Records	CatchT	Vessels	GeoMean	Zone:Month	StDev
1986	402.0480	3141	367.9850	80	18.7487	1.1548	0.0000
1987	450.7660	2961	413.5710	70	19.9429	1.1538	0.0326
1988	346.0140	3067	313.2370	77	16.8882	1.1336	0.0321
1989	591.6310	2997	513.7360	70	23.1617	1.3691	0.0327
1990	295.7640	1811	254.3800	61	20.5538	1.2850	0.0377
1991	240.3130	2021	170.9540	68	14.2052	1.1339	0.0370
1992	166.9803	2022	138.8710	56	11.7312	0.9861	0.0370
1993	306.2200	3013	267.0910	62	14.1976	1.0790	0.0335
1994	297.2680	3498	262.0330	62	11.6924	0.9486	0.0326
1995	244.9240	3500	196.2900	59	10.2913	0.8644	0.0325
1996	352.7220	4397	212.3690	69	7.7998	0.7576	0.0313
1997	459.6263	4775	288.1360	65	8.6425	0.8025	0.0312
1998	355.7935	4103	230.4950	55	8.0944	0.7264	0.0318
1999	309.4810	4225	234.8730	59	7.8713	0.6466	0.0320
2000	171.0664	4633	142.7675	64	4.7885	0.5010	0.0318
2001	243.3623	4570	128.6440	55	4.0443	0.5047	0.0321
2002	449.5550	5038	194.4326	53	5.2594	0.6302	0.0316
2003	613.8621	5363	405.7085	58	7.7687	0.9230	0.0312
2004	507.3770	4274	292.6610	57	7.2637	0.8777	0.0324
2005	579.8856	4417	423.6310	55	9.9946	1.1194	0.0322
2006	419.5564	3230	297.5593	44	10.3893	1.1227	0.0341
2007	289.6026	2223	203.1620	22	11.4463	1.2110	0.0374
2008	396.2424	2495	317.7050	26	14.4563	1.3456	0.0367
2009	476.5154	2232	338.4877	27	15.8458	1.4212	0.0377
2010	579.9761	2105	383.4800	25	14.3976	1.1906	0.0380
2011	514.5297	2254	347.0670	26	12.7502	1.1928	0.0376
2012	365.4882	1739	287.7780	24	11.2957	0.9416	0.0402
2013	278.7298	1646	212.2493	24	11.8284	0.9771	0.0406

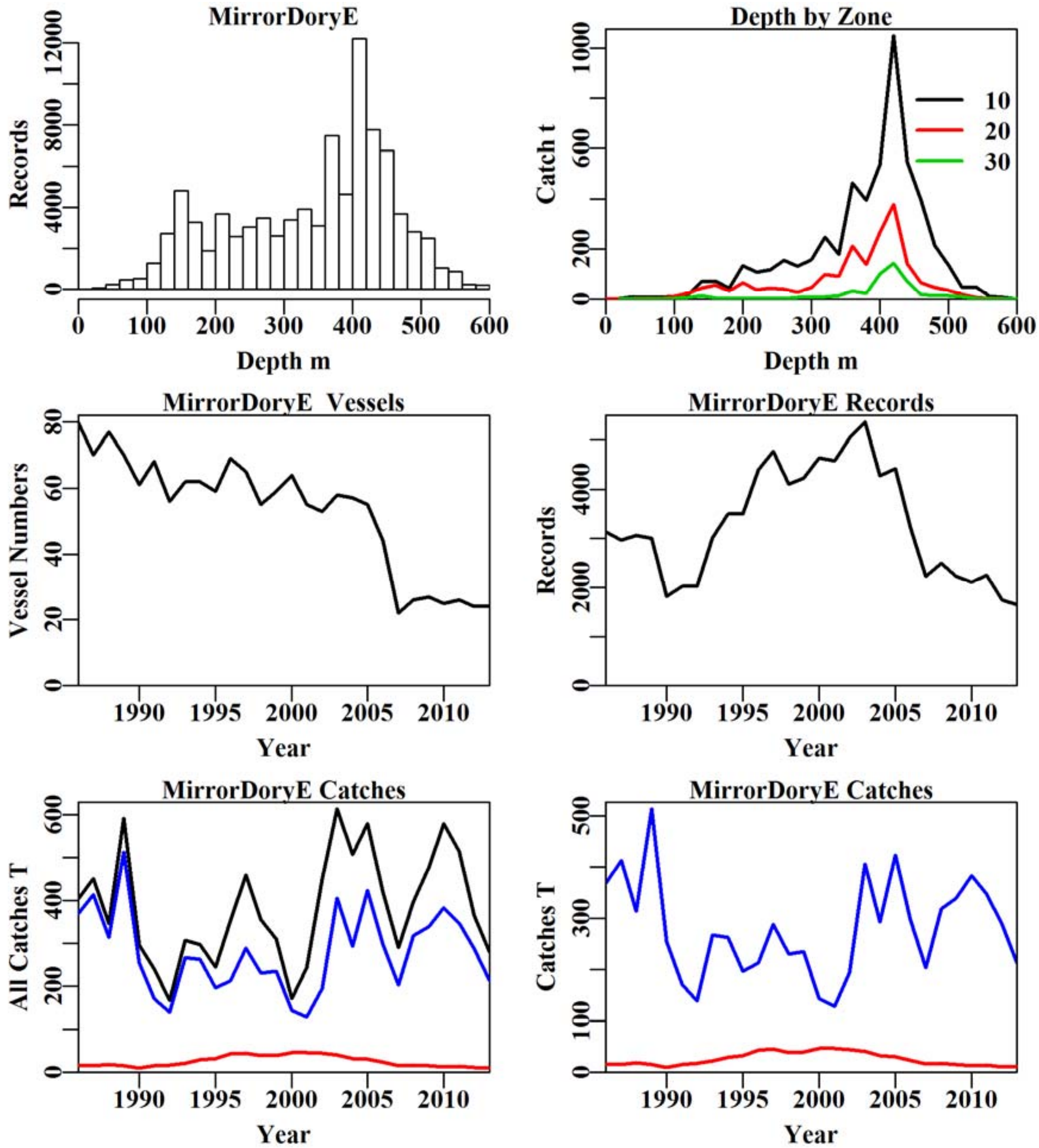


Figure 13.127**.** Mirror Dory from zones 10 to 30 in depths 0 to 600 m by Trawl. The top left plot depicts the depth distribution of shots containing Mirror Dory zones 10 to 30 in depths 0 to 600 m by Trawl. The top right plot depicts the catch distribution by depth by zone. The middle left plot depicts the number of vessels through time and middle right plot contains the number of records used in analysis. The bottom left plot contains Mirror Dory catches (top black line: total catches, middle blue line: catches used in the analysis; bottom red line: catches < 30 kg) and bottom right plot contains Mirror Dory catches (blue line: catches used in the analysis; red line: catches < 30 kg).

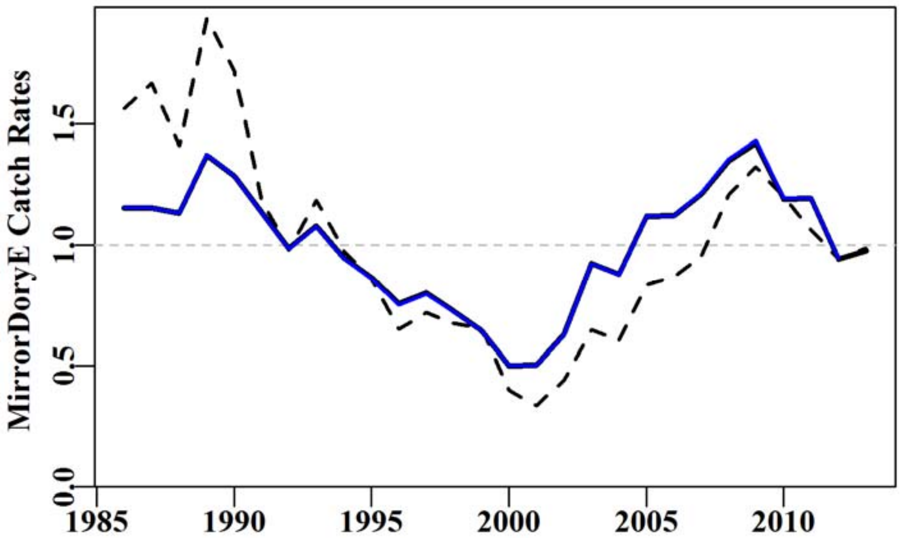


Figure 13.128**.** Mirror Dory from Zones 10 to 30 in depths 0 to 600 m by Trawl. The dashed black line represents the geometric mean catch rate, solid black line the standardized catch rates and solid blue line the standardized catch rates from last year's analysis. The graph standardizes catch rates relative to the mean of the standardized catch rates.

Table 13.116**.** 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 13.117**.** Mirror Dory from zones 10 to 30 in depths 0 to 600 m by Trawl. Model selection criteria include the Akaike Information Criterion (AIC), residual sum of squares (RSS), model sum of squares (MSS), number of usable observations (Nobs), number of parameters (Npars), adjusted R^2 (adj_R^2) and the change in adjusted R^2 (%Change). The optimum is Zone:Month (Model 7). Depth category: DepC.

	Year	Vessel	DepC	Month	DayNight	Zone	Zone:Month	Zone:DepC
AIC	63367	47389	37048	35230	34539	33816	32270	33560
RSS	182931	153108	136259	133540	132524	131472	129201	130931
MSS	18557	48379	65229	67947	68963	70016	72286	70556
Nobs	91750	91750	91259	91259	91259	91259	91259	91259
Npars	28	203	233	244	247	249	271	309
adj_R^2	9.183	23.843	32.201	33.546	34.049	34.572	35.686	34.798
%Change	0.000	14.660	8.358	1.345	0.503	0.522	1.115	-0.888

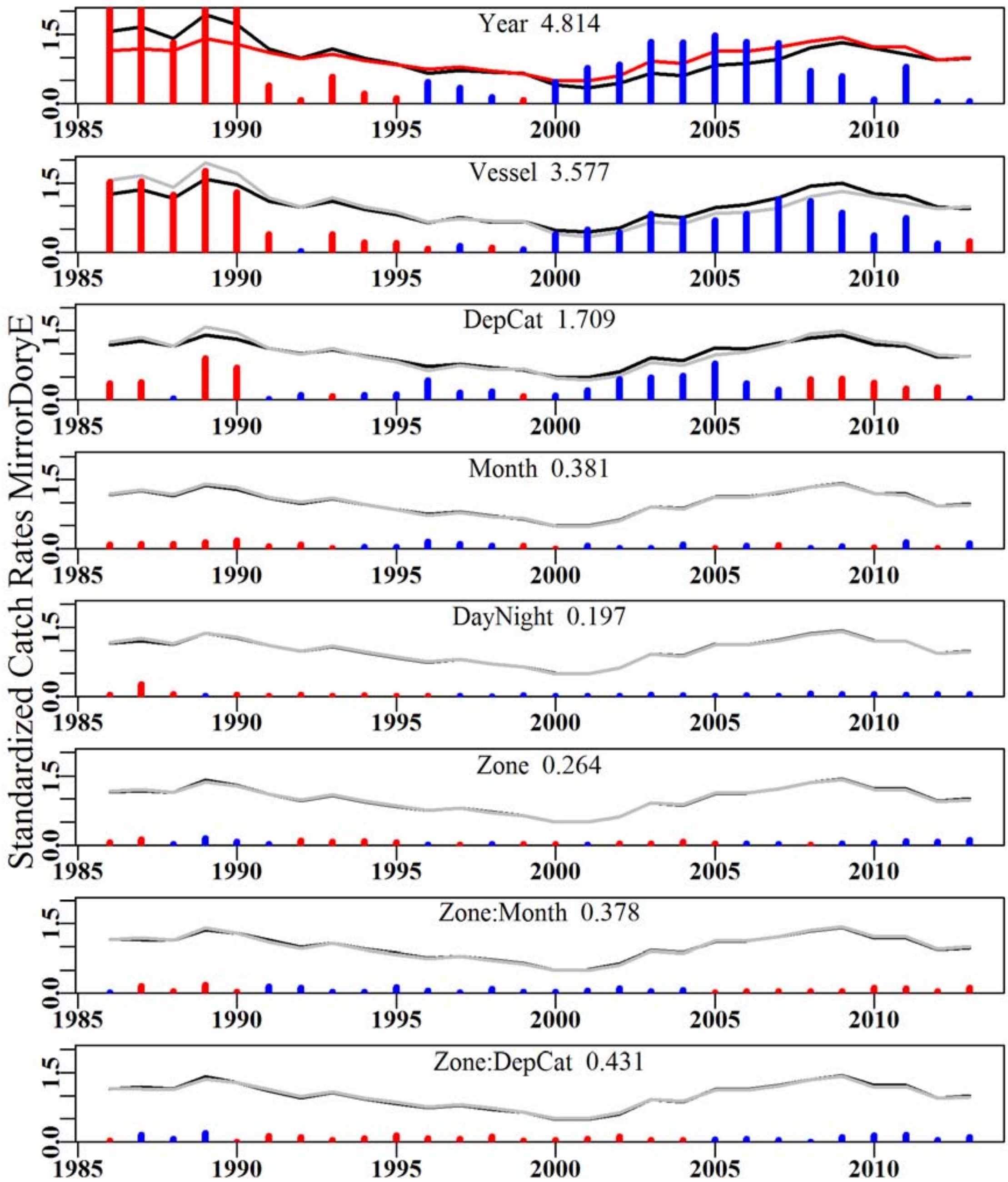


Figure 13.129**.** The relative influence of each factor used on the final trend in the optimal standardization for Mirror Dory from zones 10 to 30. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by the vertical bars with blue bars indicating the optimum model is higher than the geometric mean and red bars indicating it is lower. The top graph bars are the sum of all the bars in the graphs below. The graphs for individual factors are cumulative. Thus the second graph has the geometric mean (grey line) and the effect of adding Year + factor2 (Model 2). In the third graph, the grey line represents Model 2 and the black line the effect of adding factor3 to the model. The remaining graphs continue in the same cumulative manner except for the interaction terms which are added singularly to the final single factor model.

13.45 Mirror Dory West (DOM – 37264003 – Zenopsis nebulosus)

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

Table 13.118**.** Mirror Dory from Zones 40 to 50 in depths 0 to 600 m by Trawl. Total catch (TotCatch; t) is the total reported in the database, number of records used in the analysis (Records), reported catch (CatchT; t) in the area and depth used in the analysis and number of vessels used in the analysis (Vessels). GeoMean is the geometric mean of catch rates (kg/hr). The optimum model is Zone:Month and standard deviation (StDev) relates to the data in the optimum model.

Year	TotCatch	Records	CatchT	Vessels	GeoMean	Zone:Month	StDev
1986	402.0480	57	7.3740	10	13.7130	2.4840	0.0000
1987	450.7660	142	15.5190	23	16.0832	1.6361	0.2006
1988	346.0140	122	14.9830	17	18.4525	1.3323	0.2093
1989	591.6310	71	11.1270	15	24.6757	1.6929	0.2209
1990	295.7640	95	9.9660	14	21.6631	1.1358	0.2245
1991	240.3130	209	12.7830	17	11.7670	0.7994	0.1979
1992	166.9803	205	8.2890	20	8.1608	0.6694	0.1995
1993	306.2200	276	18.0100	18	10.1017	0.7884	0.1947
1994	297.2680	330	18.1620	20	9.3264	0.6993	0.1931
1995	244.9240	709	38.1430	23	9.0896	0.8999	0.1901
1996	352.7220	1438	115.1450	26	13.3473	1.2675	0.1901
1997	459.6263	1906	148.3100	24	12.8686	1.2801	0.1896
1998	355.7935	1469	116.2110	20	12.6121	1.2371	0.1900
1999	309.4810	1318	63.2940	23	8.8763	0.8117	0.1902
2000	171.0664	980	22.4610	28	4.0569	0.4445	0.1911
2001	243.3623	2446	105.2800	29	7.9361	0.7680	0.1895
2002	449.5550	3156	240.2520	28	11.7181	1.1255	0.1891
2003	613.8621	2429	154.8985	27	11.0165	0.9608	0.1895
2004	507.3770	2208	159.8094	25	10.3786	0.9606	0.1896
2005	579.8856	1769	100.0055	23	8.0456	0.7613	0.1899
2006	419.5564	1061	65.3505	19	8.0395	0.6415	0.1910
2007	289.6026	1177	64.9410	16	6.7120	0.5786	0.1908
2008	396.2424	879	58.5330	17	7.5767	0.6516	0.1913
2009	476.5154	1333	123.2455	14	9.7010	0.9974	0.1902
2010	579.9761	1596	177.5496	14	11.0745	1.1872	0.1900
2011	514.5297	1662	157.8060	16	8.6510	0.9114	0.1900
2012	365.4882	1018	70.2165	15	6.0700	0.5395	0.1911
2013	278.7298	642	54.8860	15	8.0998	0.7381	0.1925

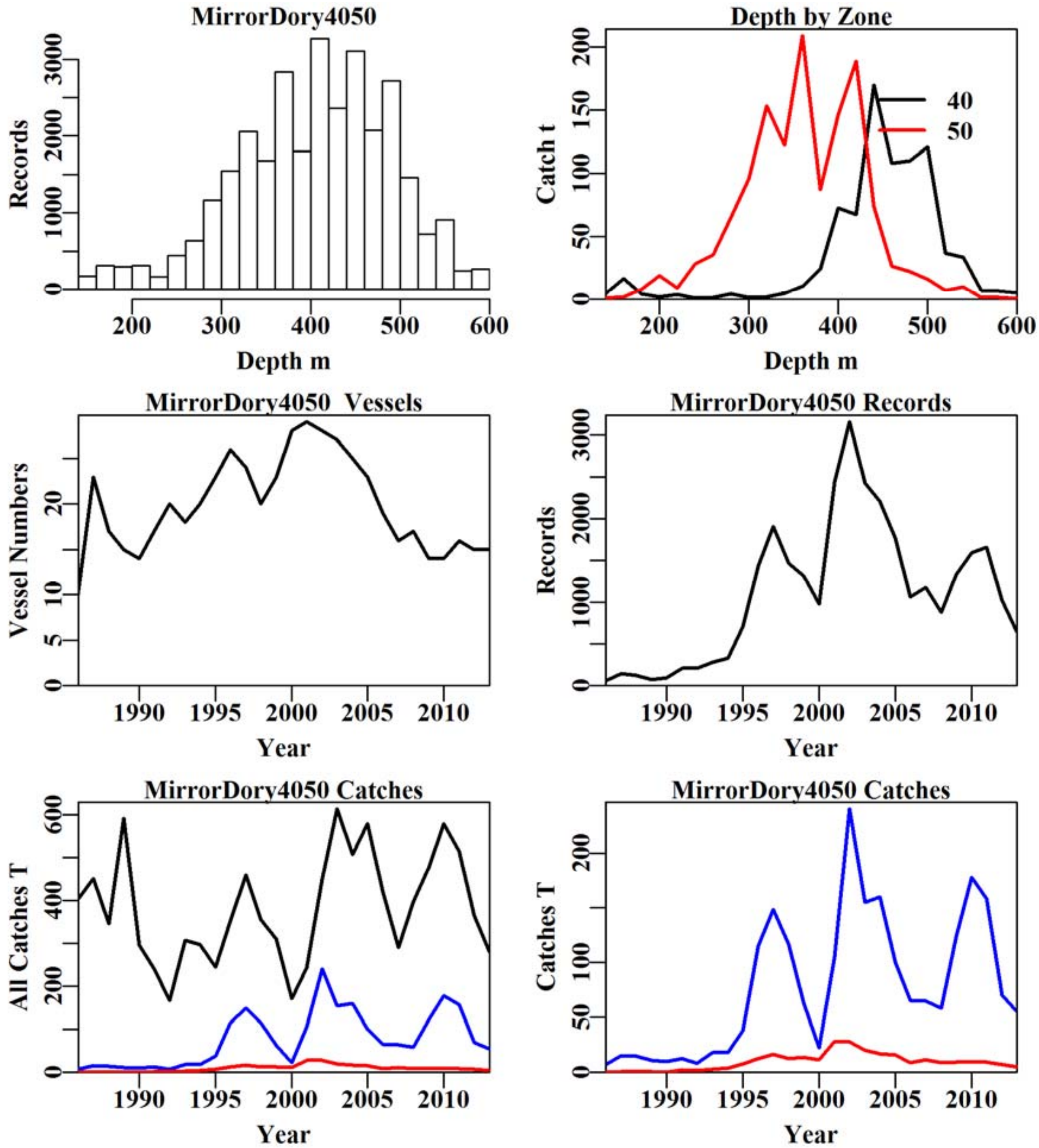
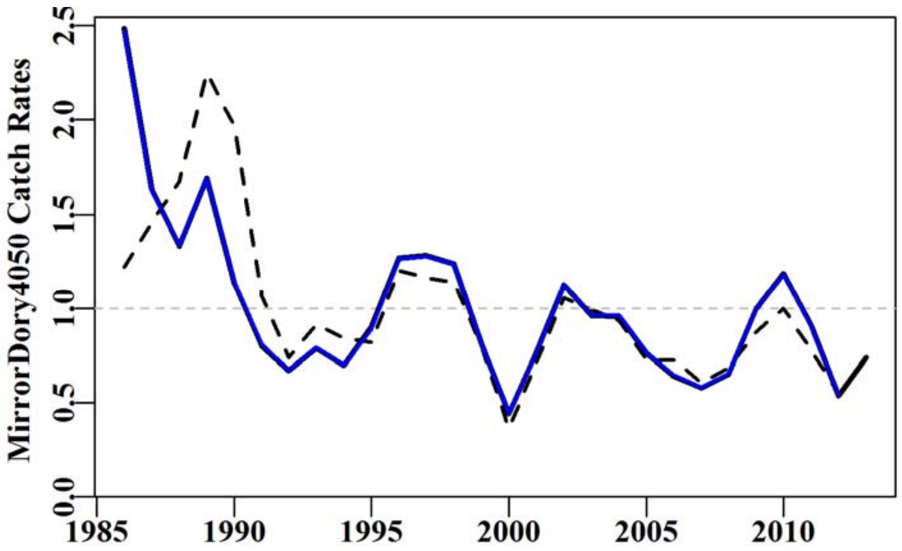


Figure 13.130**.** Mirror Dory from zones 40 to 50 in depths 0 to 600 m by Trawl. The top left plot depicts the depth distribution of shots containing Mirror Dory zones 40 to 50 in depths 0 to 600 m by Trawl. The top right plot depicts the catch distribution by depth by zone. The middle left plot depicts the number of vessels through time and middle right plot contains the number of records used in analysis. The bottom left plot contains Mirror Dory catches (top black line: total catches, middle blue line: catches used in the analysis; bottom red line: catches < 30 kg) and bottom right plot contains Mirror Dory catches (blue line: catches used in the analysis; red line: catches < 30 kg).



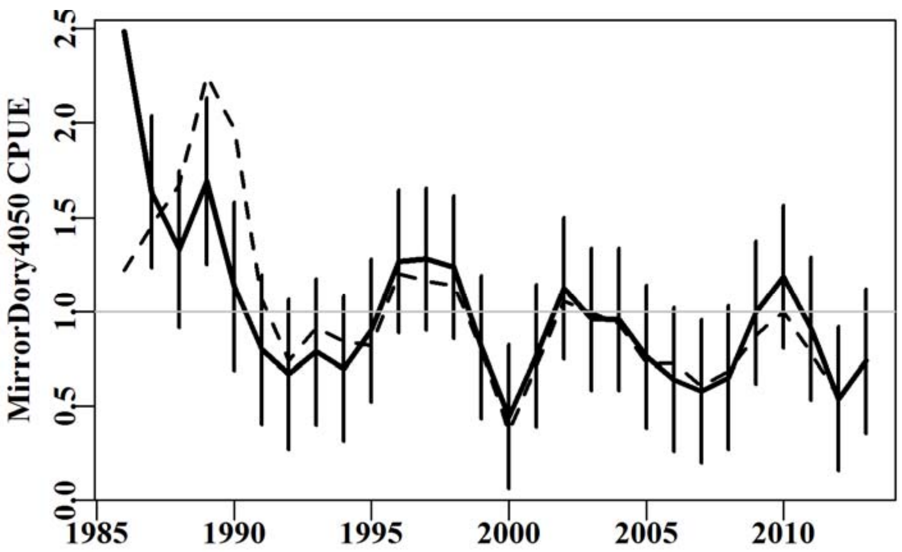


Figure 13.131. Mirror Dory from zones 40 to 50 in depths 0 to 600 m by Trawl. Upper graph: The dashed black line represents the geometric mean catch rate and the solid black line the standardized catch rates (relative to the mean of the standardized catch rates). The blue line corresponds to last year's standardized catch rates. Lower graph: Standardized indices (solid black line), 95% CI (vertical lines) and geometric mean (dashed black line). This illustrates the impact on the relative uncertainty of the relatively small number of records, especially in the early years.

Table 13.119. Mirror Dory from Zones 40 to 50 in depths 0 to 600 m by Trawl. Statistical model structures used in this analysis. DepCat is a series of 20 metre depth categories.

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

Table 13.120. Mirror Dory from zones 40 to 50 in depths 0 to 600 m by Trawl. Model selection criteria include the Akaike Information Criterion (AIC), residual sum of squares (RSS), model sum of squares (MSS), number of usable observations (Nobs), number of parameters (Npars), adjusted R^2 (adj_R^2) and the change in adjusted R^2 (%Change). The optimum is Zone:Month (Model 7). Depth category: DepC.

	Year	Vessel	Month	DepC	DayNight	Zone	Zone:Month	Zone:DepC
AIC	10575	3689	2113	726	9	-350	-732	-391
RSS	43249	34360	32618	30946	30221	29866	29473	29781
MSS	2249	11138	12880	14552	15277	15632	16025	15717
Nobs	30703	30703	30703	30519	30519	30519	30519	30519
adj_R^2	4.859	24.193	28.012	31.647	33.242	34.024	34.869	34.163
%Change	0.000	19.334	3.819	3.635	1.595	0.782	0.845	-0.706

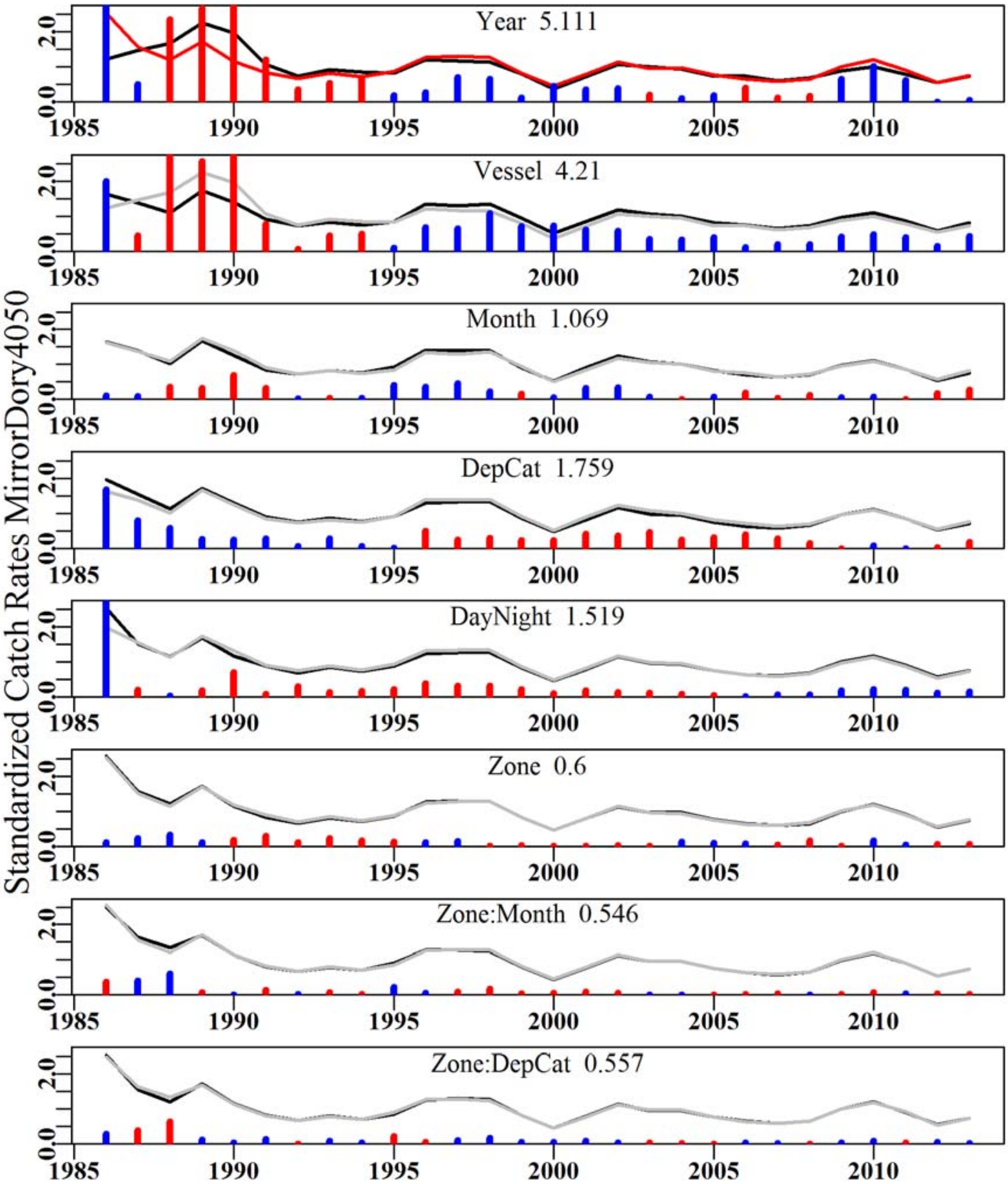


Figure 13.132**.** The relative influence of each factor used on the final trend in the optimal standardization for Mirror Dory from zones 40 – 50. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by the vertical bars with blue bars indicating the optimum model is higher than the geometric mean and red bars indicating it is lower. The top graph bars are the sum of all the bars in the graphs below. The graphs for individual factors are cumulative. Thus the second graph has the geometric mean (grey line) and the effect of adding Year + factor2 (Model 2). In the third graph, the grey line represents Model 2 and the black line the effect of adding factor3 to the model. The remaining graphs continue in the same cumulative manner except for the interaction terms which are added singularly to the final single factor model.

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

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

Table 13.121. Ribaldo from zones 10 to 50 in depths 0 to 1000 m by Trawl. Total catch (TotCatch; t) is the total reported in the database, number of records used in the analysis (Records), reported catch (CatchT; t) in the area and depth used in the analysis and number of vessels used in the analysis (Vessels). GeoMean is the geometric mean of catch rates (kg/hr). The optimum model is Zone:Month and standard deviation (StDev) relates to the data in the optimum model.

Year	TotCatch	Records	CatchT	Vessels	GeoMean	Zone:Month	StDev
1986	4.1040	72	3.5240	11	14.6630	2.2796	0.0000
1987	7.9410	158	7.2920	14	10.2593	1.2825	0.1393
1988	10.8980	123	8.0490	22	16.5570	1.9963	0.1558
1989	11.3420	136	7.7110	14	18.2556	1.8007	0.1541
1990	3.6680	58	2.2590	11	8.9113	1.4128	0.1746
1991	7.8080	145	5.1620	22	7.9930	1.3772	0.1537
1992	13.3330	226	11.6890	26	9.7616	1.3625	0.1455
1993	22.7770	330	19.7620	37	11.2449	1.1409	0.1453
1994	41.9380	423	23.6220	30	11.8156	1.2832	0.1429
1995	90.3230	1147	86.2990	26	12.3128	1.3540	0.1395
1996	82.2780	1492	77.0120	32	10.1757	1.0233	0.1392
1997	103.1154	1714	96.5670	30	9.8023	0.8913	0.1389
1998	99.9134	1667	92.0150	33	9.6696	0.8612	0.1390
1999	72.1498	1133	59.6680	32	8.7093	0.7932	0.1399
2000	66.7914	1174	53.8450	38	7.4217	0.7304	0.1398
2001	82.4788	1122	52.3900	37	6.7639	0.6835	0.1397
2002	157.8426	1142	57.2360	30	6.7896	0.6324	0.1400
2003	180.8106	1307	65.9550	35	6.6903	0.6218	0.1397
2004	180.9607	1257	66.4169	33	7.2233	0.6782	0.1399
2005	90.3599	671	30.0311	32	6.3449	0.5964	0.1417
2006	122.5935	637	32.0832	34	6.3304	0.6247	0.1418
2007	78.3142	404	15.5712	24	3.2493	0.4252	0.1445
2008	78.4750	367	17.6183	24	4.7326	0.5869	0.1451
2009	104.9600	572	33.4102	20	5.6978	0.6512	0.1423
2010	91.9240	681	37.1429	22	5.5961	0.6830	0.1414
2011	93.9468	863	44.4726	20	5.8293	0.6882	0.1405
2012	107.2292	759	42.4445	19	6.1631	0.6967	0.1414
2013	122.3639	928	68.9605	23	8.5813	0.8425	0.1407

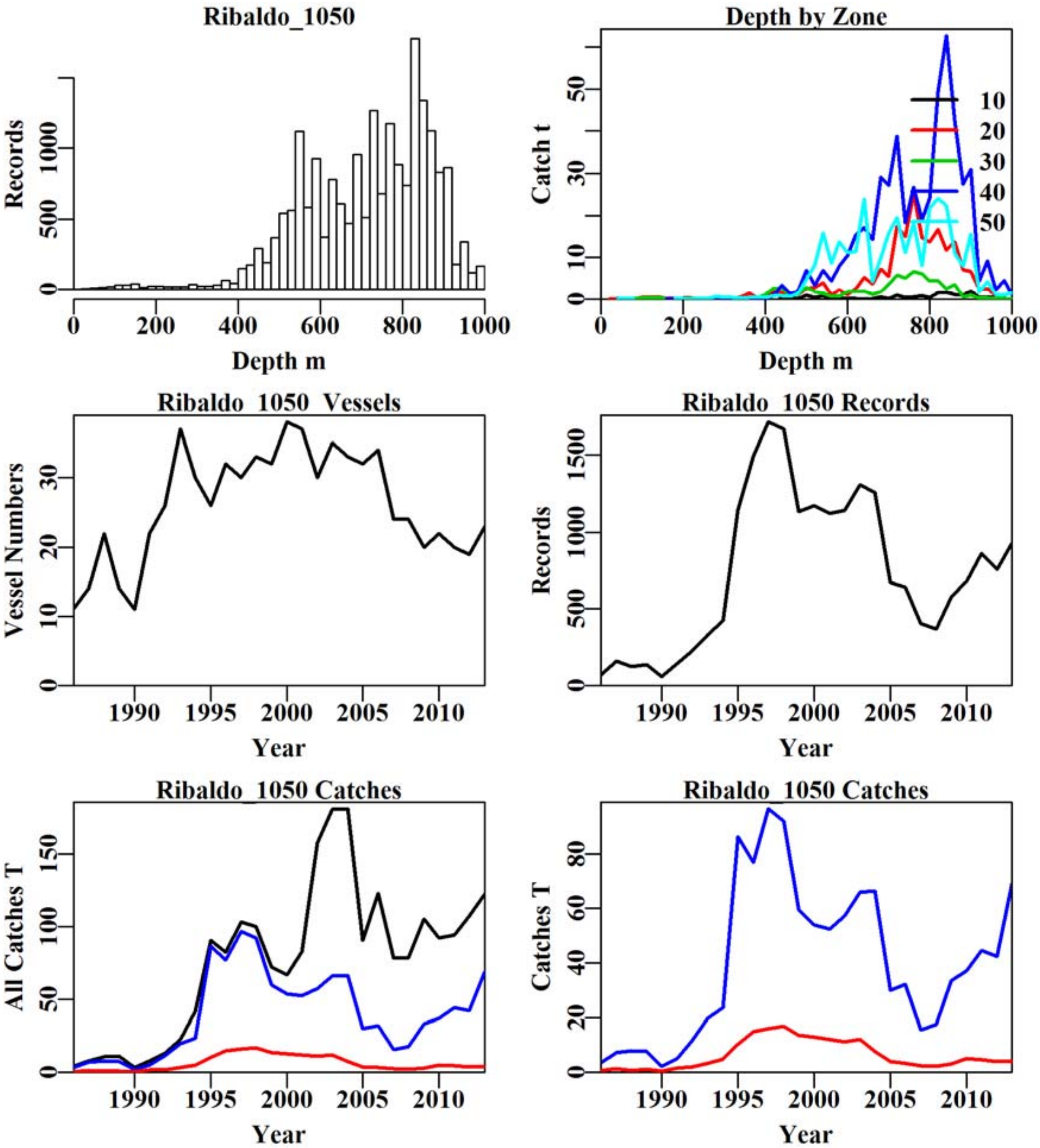


Figure 13.133**.** Ribaldo from zones 10 to 50 in depths 0 to 1000 m by Trawl. The top left plot depicts the depth distribution of shots containing Ribaldo from zones 10 to 50 in depths 0 to 1000 m by Trawl. The top right plot depicts the catch distribution by depth by zone. The middle left plot depicts the number of vessels through time and middle right plot contains the number of records used in analysis. The bottom left plot contains Ribaldo catches (top black line: total catches, middle blue line: catches used in the analysis; bottom red line: catches < 30 kg) and bottom right plot contains Ribaldo catches (blue line: catches used in the analysis; red line: catches < 30 kg).

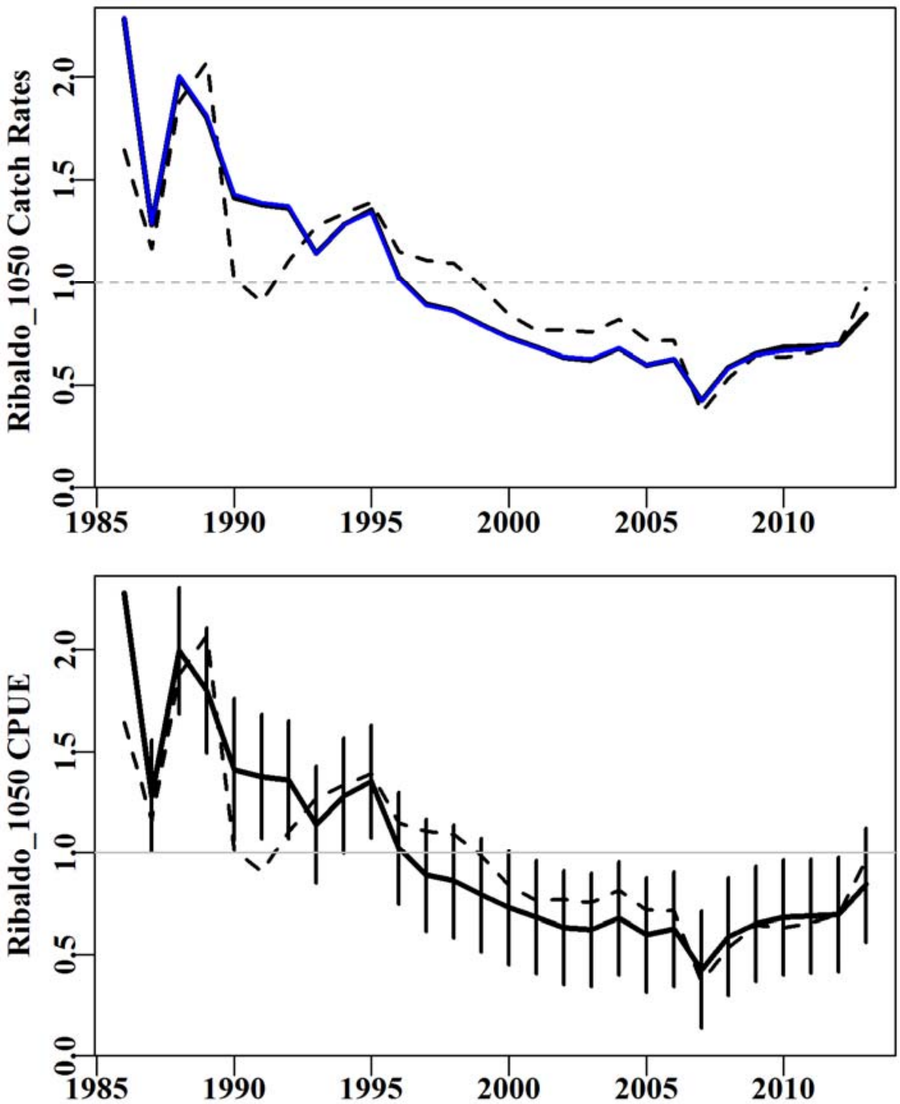


Figure 13.134**.** Ribaldo from zones 10 to 50 in depths 0 to 1000 m by Trawl. Upper graph: The dashed black line represents the geometric mean catch rate and the solid black line the standardized catch rates (relative to the mean of the standardized catch rates). The blue line corresponds to last year's standardized catch rates. Lower graph: Standardized indices (solid black line), 95% CI (vertical lines) and geometric mean (dashed black line). This illustrates the impact on the relative uncertainty of the relatively small number of records, especially in the early years.

Table 13.122. Ribaldo from zones 10 to 50 in depths 0 to 1000 m by Trawl. Statistical model structures used in this analysis. DepCat is a series of 50 metre depth categories.

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

Table 13.123**.** Ribaldo from zones 10 to 50 in depths 0 to 1000 m by Trawl. Model selection criteria include the Akaike Information Criterion (AIC), residual sum of squares (RSS), model sum of squares (MSS), number of usable observations (Nobs), number of parameters (Npars), adjusted R^2 (adj_R^2) and the change in adjusted R^2 (%Change). The optimum is Zone:Month (Model 7). Depth category: DepC.

	Year	Vessel	DepC	Zone	DayNight	Month	Zone:Month	Zone:DepC
AIC	-1832	-3608	-6411	-7086	-7187	-7225	-7753	-7481
RSS	18903	17148	14711	14229	14155	14114	13696	13670
MSS	1659	3415	5852	6333	6408	6449	6867	6893
Nobs	20708	20708	20505	20505	20505	20505	20505	20505
Npars	28	149	199	203	206	217	261	417
adj_R^2	7.950	16.005	27.762	30.112	30.468	30.631	32.537	32.146
%Change	0.000	8.055	11.757	2.350	0.356	0.163	1.906	-0.391

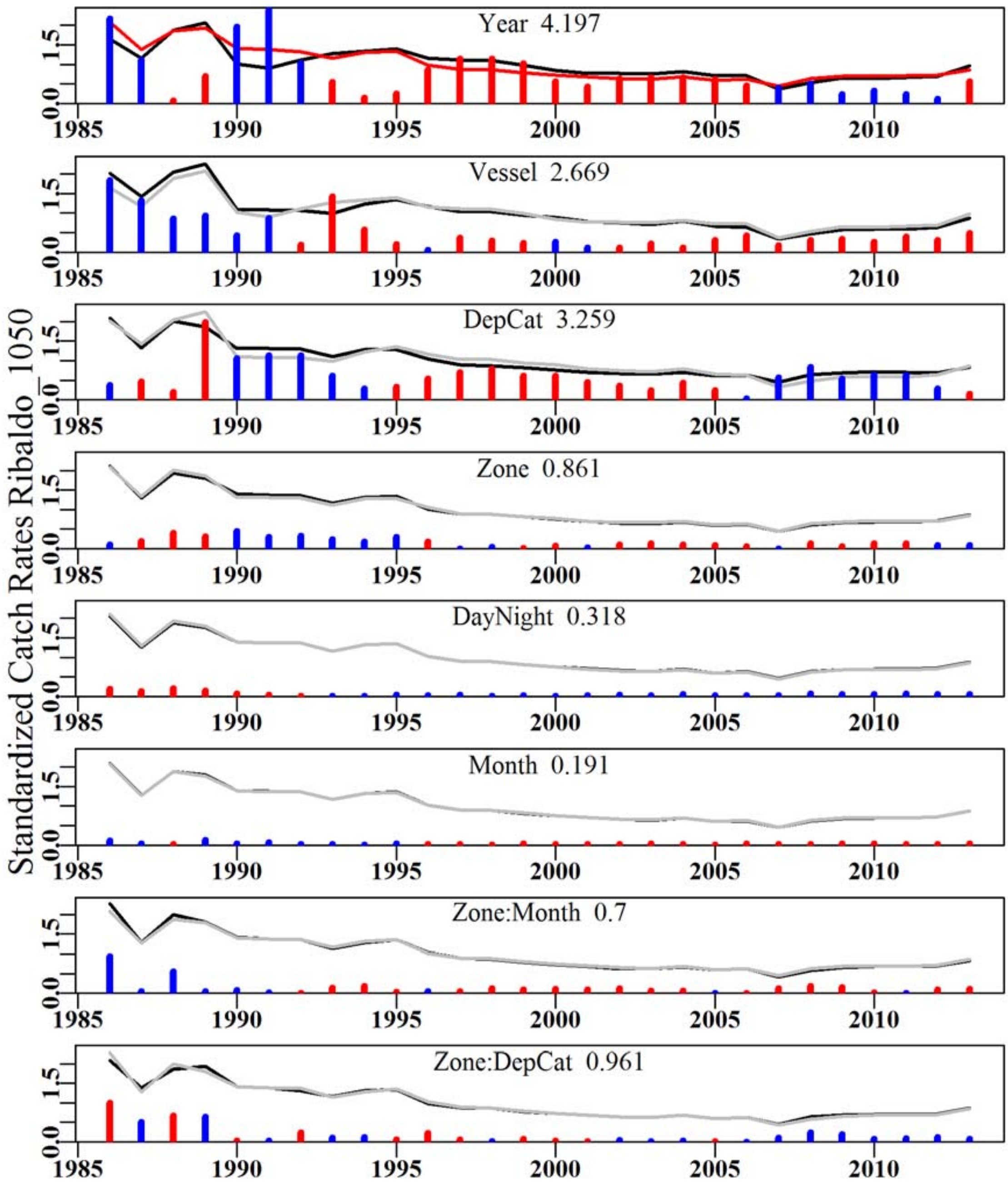


Figure 13.135**.** The relative influence of each factor used on the final trend in the optimal standardization for Ribaldo from zones 10 to 50. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by the vertical bars with blue bars indicating the optimum model is higher than the geometric mean and red bars indicating it is lower. The top graph bars are the sum of all the bars in the graphs below. The graphs for individual factors are cumulative. Thus the second graph has the geometric mean (grey line) and the effect of adding Year + factor2 (Model 2). In the third graph, the grey line represents Model 2 and the black line the effect of adding factor3 to the model. The remaining graphs continue in the same cumulative manner except for the interaction terms which are added singularly to the final single factor model.

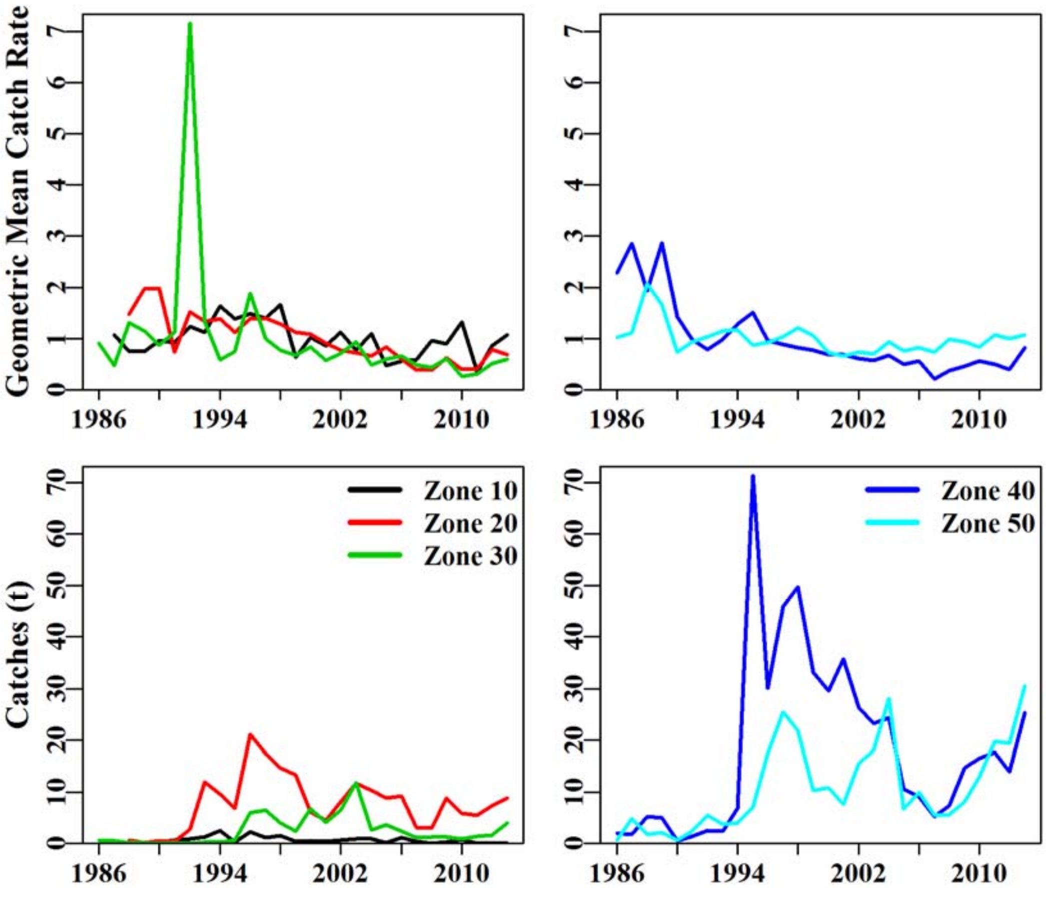


Figure 13.136. Ribaldo from zones 10 to 50 in depths 0 to 1000 m by Trawl. Geometric mean catch rate and catch (t) by zones 10-30 (left plots) and zone 40, 50 (right plots).

13.47 Ribaldo AL (RBD – 37224002 – Mora moro)

Auto Line Ribaldo data selected for analysis corresponded to records from zones 10 – 50 and the GAB in depths 0 to 1000 m.

Table 13.124**.** Ribaldo taken by Auto Line in zones 10, 20, 30 40, 50 and the GAB in depths 0 to 1000 m. Total catch (TotCatch; t) is the total reported in the database, number of records used in the analysis (Records), reported catch (CatchT; t) in the area and depth used in the analysis and number of vessels used in the analysis (Vessels). GeoMean is the geometric mean of catch rates (kg/shot). The optimum model is Zone:Month and standard deviation (StDev) relates to the data in the optimum model.

Year	TotCatch	Records	CatchT	Vessels	GeoMean	Zone:Month	StDev
1997	103.1154	22	1.4050	1	50.5984	0.3544	0.0000
1998	99.9134	13	1.7530	2	88.6126	0.4287	0.5074
1999	72.1498	24	1.9470	1	40.6973	0.3480	0.4495
2000	66.7914	43	9.0390	1	96.6841	0.3355	0.4049
2001	82.4788	63	15.7200	2	157.4316	1.2483	0.3937
2002	157.8426	259	95.4965	4	135.9460	2.8692	0.3712
2003	180.8106	337	102.8823	7	75.0323	2.1364	0.3777
2004	180.9607	714	96.5886	11	51.6307	1.8539	0.3753
2005	90.3599	308	37.1892	7	44.5029	1.0683	0.3794
2006	122.5935	605	65.3525	8	39.5723	1.0815	0.3753
2007	78.3142	393	28.1252	6	25.0254	0.6541	0.3782
2008	78.4750	401	56.7722	6	39.2440	0.7773	0.3753
2009	104.9600	433	68.2730	6	49.5683	0.7672	0.3760
2010	91.9240	381	51.6696	5	47.4481	0.7351	0.3765
2011	93.9468	356	46.4764	5	45.6603	0.8888	0.3763
2012	107.2292	295	58.8469	6	60.9351	0.8172	0.3763
2013	122.3639	275	49.8231	5	48.7494	0.6361	0.3765

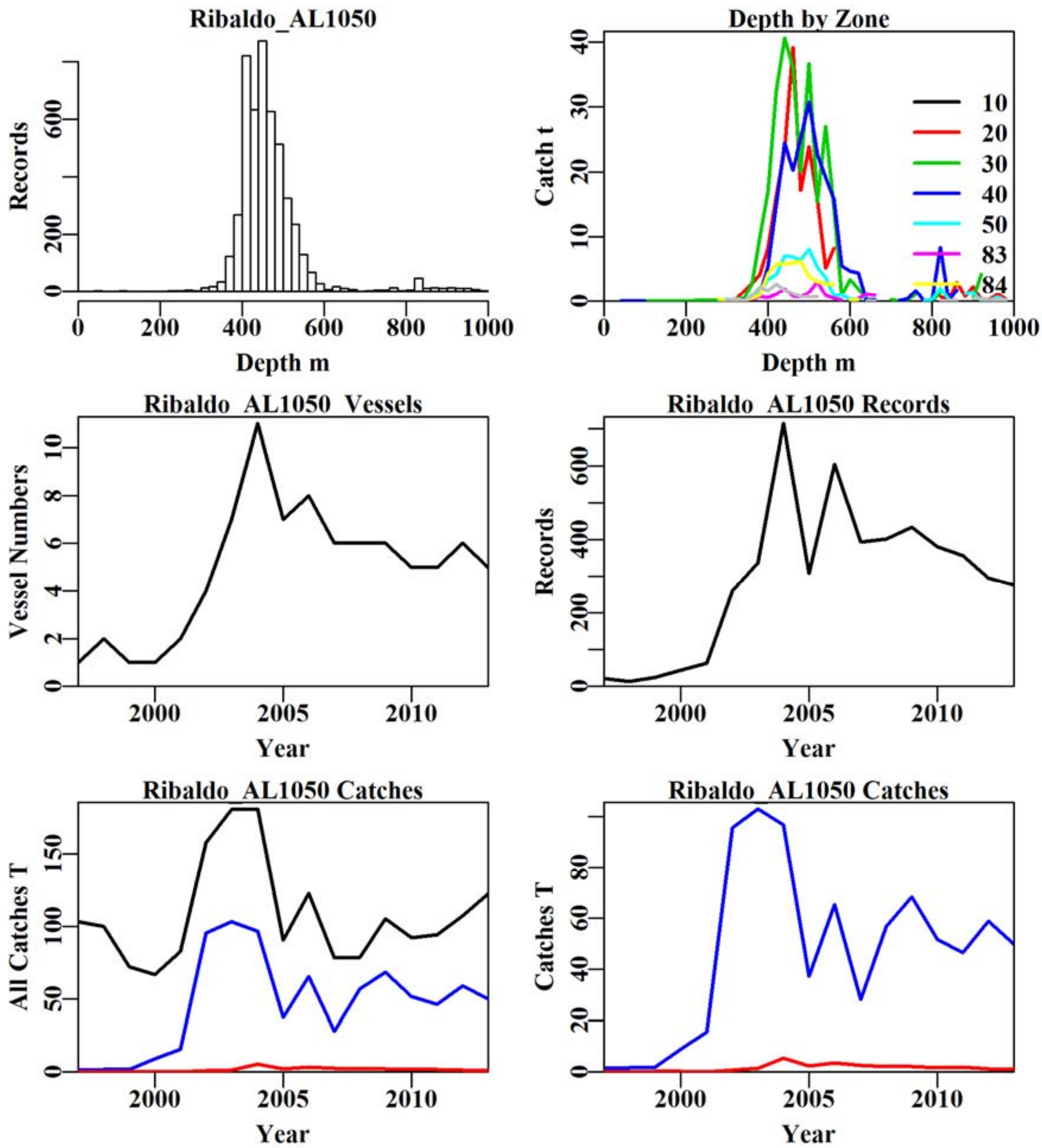


Figure 13.137**.** Ribaldo by Auto Line. The top left plot depicts the depth distribution of shots containing Ribaldo from zones 10 to 50 and the GAB in depths 0 to 1000 m by Auto Line employed in the standardization analysis. The top right plot depicts the catch distribution by depth by zone. The middle left plot depicts the number of vessels through time and middle right plot contains the number of records used in analysis. The bottom left plot contains Ribaldo catches (top black line: total catches, middle blue line: catches used in the analysis; bottom red line: catches < 30 kg) and bottom right plot contains Ribaldo catches (blue line: catches used in the analysis; red line: catches < 30 kg).

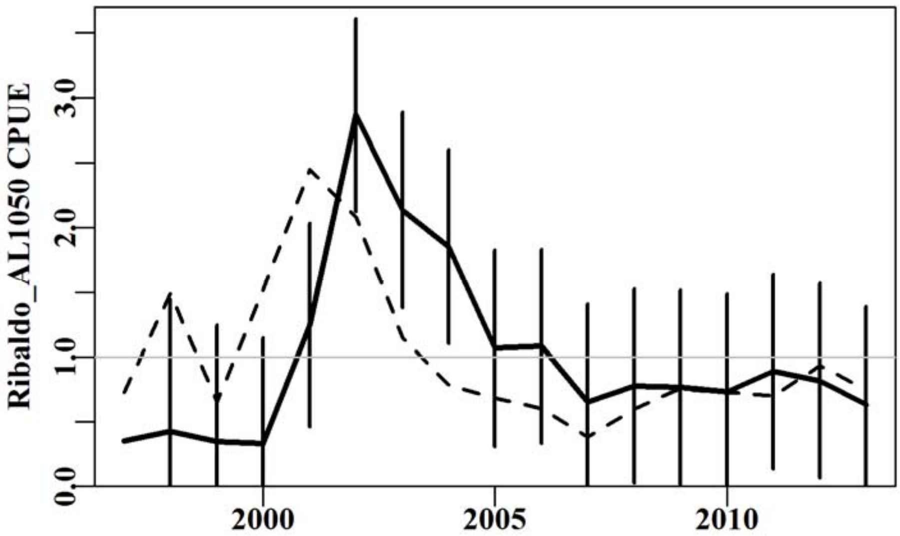


Figure 13.138**.** Standardized catch rates for Ribaldo by Auto Line. The dashed black line represents the geometric mean catch rate and the solid black line the standardized catch rates. The graph standardizes catch rates relative to the mean of the standardized catch rates. The vertical black lines represent 1.96 times the standard errors. The same statistical models that were used for the trawl analysis were also used here (

Table 13.125).

Table 13.125**.** Ribaldo from zones 10 to 50 in depths 0 to 1000 m by Auto Line. Statistical model structures used in this analysis. DepCat is a series of 20 metre depth categories.

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

Table 13.126**.** Ribaldo taken by Auto Line. Model selection criteria include the Akaike Information Criterion (AIC), residual sum of squares (RSS), model sum of squares (MSS), number of usable observations (Nobs), number of parameters (Npars), adjusted R^2 (adj_R^2) and the change in adjusted R^2 (%Change). The optimum is Zone:Month (Model 7). Depth category: DepC.

	Year	Vessel	DepC	Zone	Month	DayNight	Zone:Month	Zone:DepC
AIC	4503	2716	2377	2282	2223	2228	2073	2449
RSS	12202	8446	7744	7573	7449	7447	6994	6951
MSS	687	4443	5145	5315	5440	5441	5895	5938
Nobs	4922	4922	4906	4906	4906	4906	4906	4906
Npars	17	29	69	76	87	90	167	370
adj_R^2	5.020	34.095	39.075	40.328	41.176	41.151	43.837	41.683
%Change	0.000	29.075	4.979	1.254	0.848	-0.025	2.686	-2.154

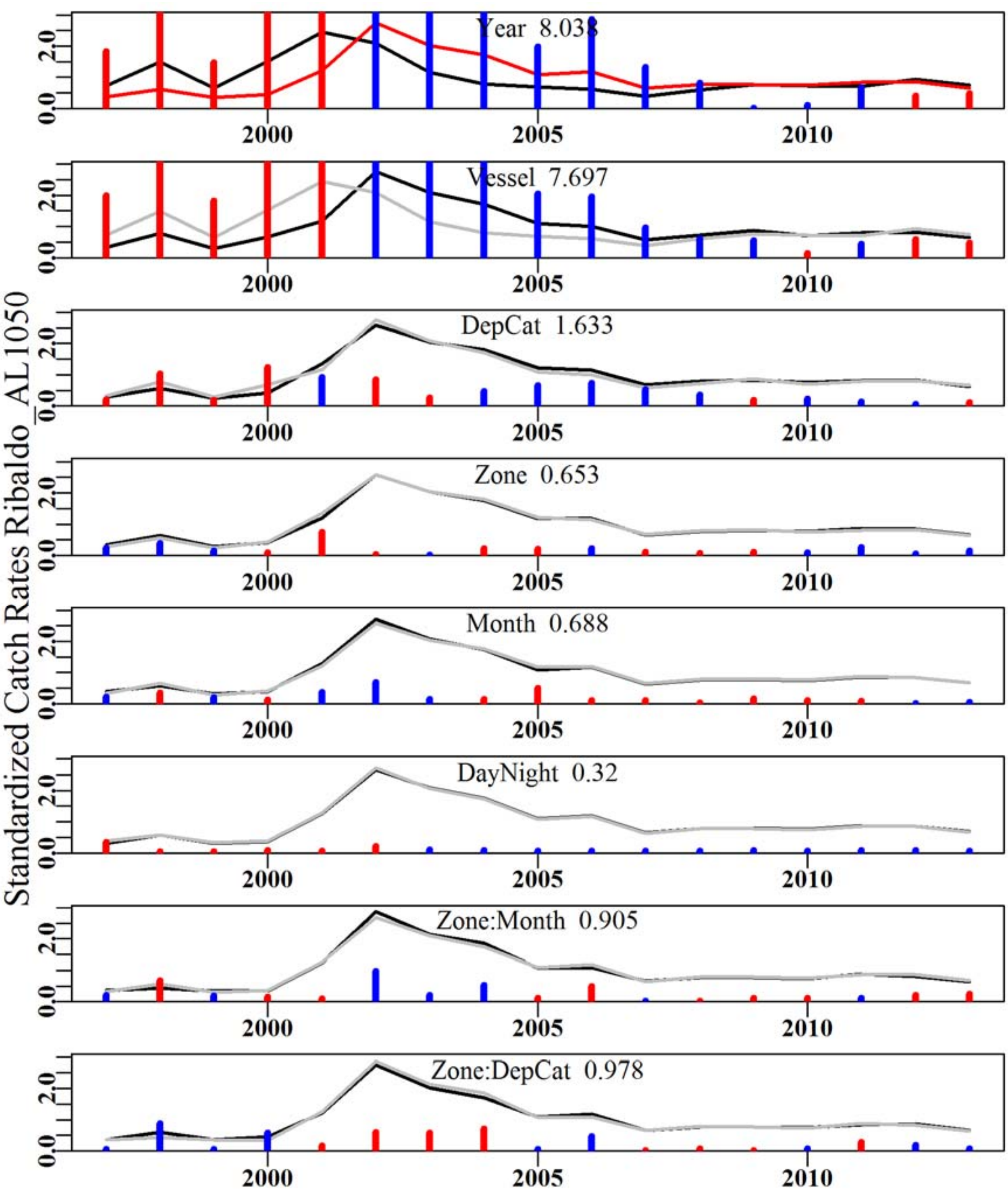


Figure 13.139**.** The relative influence of each factor used on the final trend in the optimal standardization for Ribaldo from zones 10 to 50 and the GAB. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by the vertical bars with blue bars indicating the optimum model is higher than the geometric mean and red bars indicating it is lower. The top graph bars are the sum of all the bars in the graphs below. The graphs for individual factors are cumulative. Thus the second graph has the geometric mean (grey line) and the effect of adding Year + factor2 (Model 2). In the third graph, the grey line represents Model 2 and the black line the effect of adding factor3 to the model. The remaining graphs continue in the same cumulative manner except for the interaction terms which are added singularly to the final single factor model.

13.48 Ocean Jackets Z1050 (LTC – 37465006 – *Nelusetta ayraudi*)

Alternate: Leather Jackets (LTH – 37465000)

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

Table 13.127**.** Ocean Jackets from zones 10 to 50 in depths 0 to 300 m by Trawl. Total catch (TotCatch; t) is the total reported in the database, number of records used in the analysis (Records), reported catch (CatchT; t) in the area and depth used in the analysis and number of vessels used in the analysis (Vessels). GeoMean is the geometric mean of catch rates (kg/hr). The optimum model is Zone:DepCat and standard deviation (StDev) relates to the data in the optimum model.

Year	TotCatch	Records	CatchT	Vessels	GeoMean	Zone:DepCat	StDev
1986	56.4290	2473	44.7150	75	5.0337	0.6543	0.0000
1987	53.3540	1445	28.1510	61	5.1085	0.6893	0.0363
1988	66.3040	1911	45.7250	66	6.2067	0.8343	0.0338
1989	71.6660	1808	32.7780	65	4.8860	0.7181	0.0343
1990	90.9690	1548	33.1570	46	4.9715	0.7029	0.0363
1991	170.4810	1329	24.7880	46	4.4265	0.6144	0.0382
1992	88.8840	1127	22.0740	40	4.7352	0.6130	0.0399
1993	71.8970	1342	29.2450	42	5.0852	0.6856	0.0386
1994	74.4380	1455	35.0440	45	5.9717	0.7710	0.0372
1995	140.1790	2237	59.3160	42	5.9904	0.7754	0.0336
1996	199.5710	2576	72.3070	54	6.3230	0.7982	0.0329
1997	177.4190	2009	52.4920	51	5.4540	0.7260	0.0346
1998	189.8986	2488	68.0170	44	5.2603	0.7179	0.0332
1999	202.8050	2691	88.4150	52	7.0029	0.8415	0.0327
2000	198.8111	2983	73.1760	52	5.1836	0.6729	0.0324
2001	222.5697	3160	63.7940	55	4.2040	0.5977	0.0322
2002	378.4963	4863	199.0680	61	5.4885	0.7119	0.0303
2003	482.3066	5504	187.3785	58	5.0841	0.6779	0.0298
2004	692.5927	6213	313.1105	60	8.3073	1.1059	0.0294
2005	890.6138	5162	342.8585	54	9.8912	1.2812	0.0302
2006	741.5297	4636	301.7370	50	10.2758	1.4195	0.0308
2007	564.8329	3092	285.3964	27	14.0314	1.7185	0.0331
2008	490.3988	3554	318.3140	29	13.7134	1.6222	0.0325
2009	609.9797	3260	376.1120	28	16.0145	1.8221	0.0330
2010	483.8922	3259	300.1655	29	13.2397	1.5127	0.0330
2011	487.4438	3224	277.1800	29	12.3456	1.4095	0.0329
2012	519.6479	3443	343.8395	30	14.4818	1.6374	0.0327
2013	487.0849	2828	263.7385	28	13.7320	1.6689	0.0336

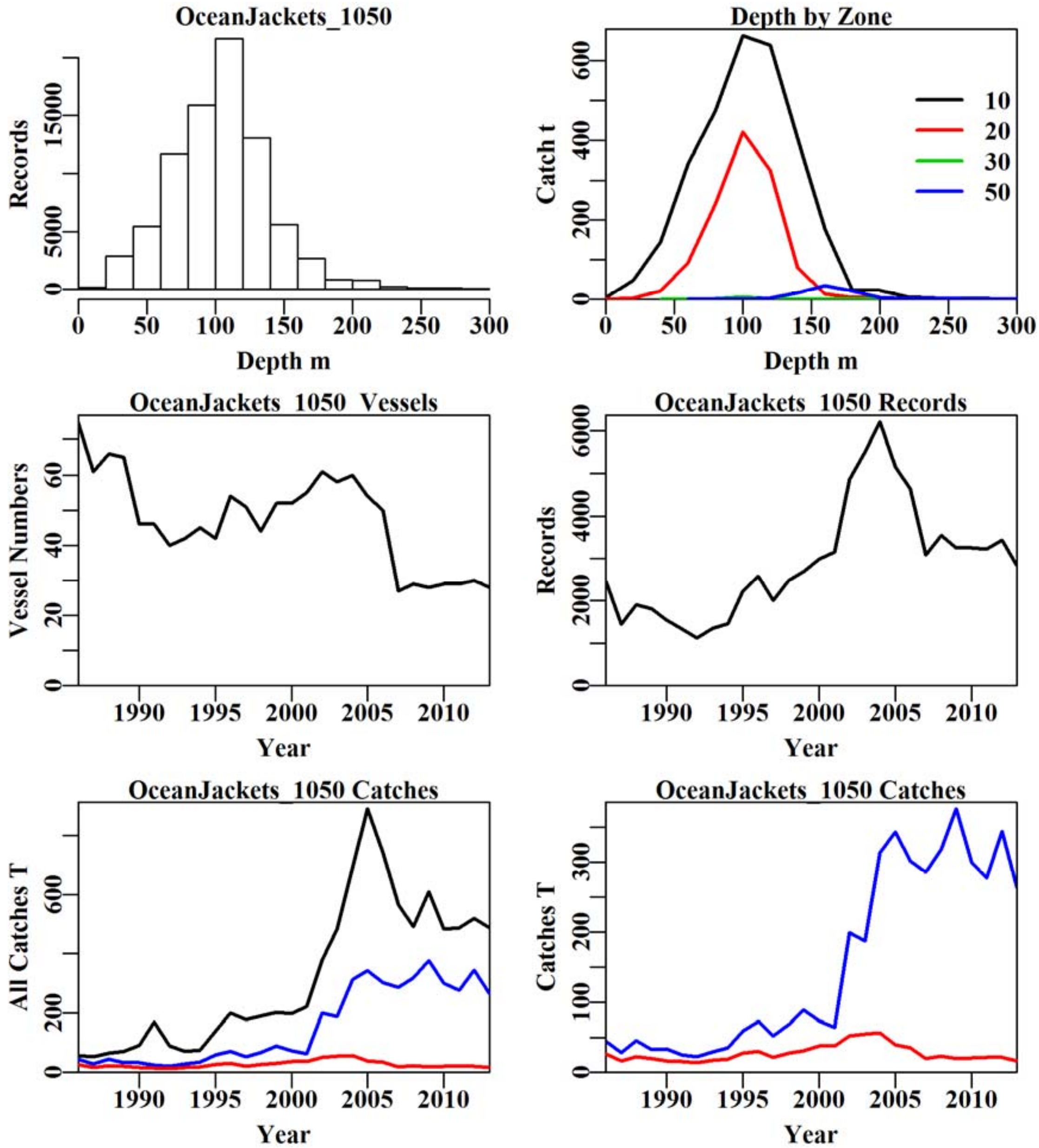


Figure 13.140**.** Ocean Jackets from zones 10 to 50 in depths 0 to 300 m by Trawl. The top left plot depicts the depth distribution of shots containing Ocean Jackets from zones 10 to 50 in depths 0 to 300 m by Trawl employed in the analysis. The top right plot depicts the catch distribution by depth by zone. The middle left plot depicts the number of vessels through time and middle right plot contains the number of records used in analysis. The bottom left plot contains Ocean Jackets catches (top black line: total catches, middle blue line: catches used in the analysis; bottom red line: catches < 30 kg) and bottom right plot contains Ocean Jackets catches (blue line: catches used in the analysis; red line: catches < 30 kg).

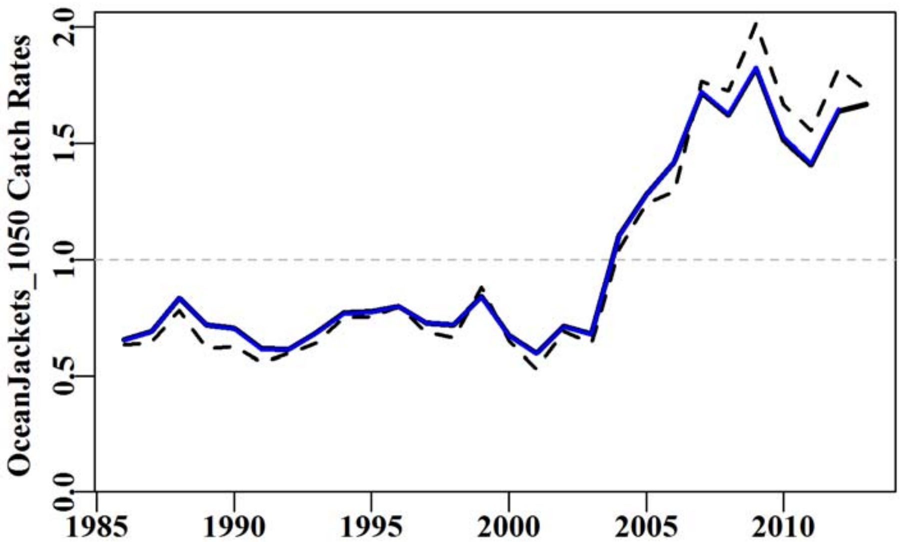


Figure 13.141. Ocean Jackets from zones 10 to 50 in depths 0 to 300 m by Trawl. The dashed black line represents the geometric mean catch rate, solid black line the standardized catch rates and solid blue line the standardized catch rates from last year's analysis. The graph standardizes catch rates relative to the mean of the standardized catch rates.

Table 13.128. 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 13.129. Ocean Jackets from Zones 10 to 50 in depths 0 to 300 m by Trawl. Model selection criteria include the Akaike Information Criterion (AIC), residual sum of squares (RSS), model sum of squares (MSS), number of usable observations (Nobs), number of parameters (Npars), adjusted R^2 (adj_R^2) and the change in adjusted R^2 (%Change). The optimum is Zone:DepC (Model 8). Depth category: DepC.

	Year	Vessel	DepC	Month	Zone	DayNight	Zone:Month	Zone:DepC
AIC	16976	3524	3068	2444	1933	1901	1723	1044
RSS	100421	84813	83746	83082	82554	82515	82267	81557
MSS	15224	30833	31899	32563	33092	33131	33378	34089
Nobs	81620	81620	81057	81057	81057	81057	81057	81057
Npars	28	196	211	222	225	228	261	273
adj_R^2	13.136	26.486	27.395	27.962	28.417	28.448	28.633	29.239
%Change	0.000	13.350	0.910	0.566	0.455	0.031	0.185	0.606

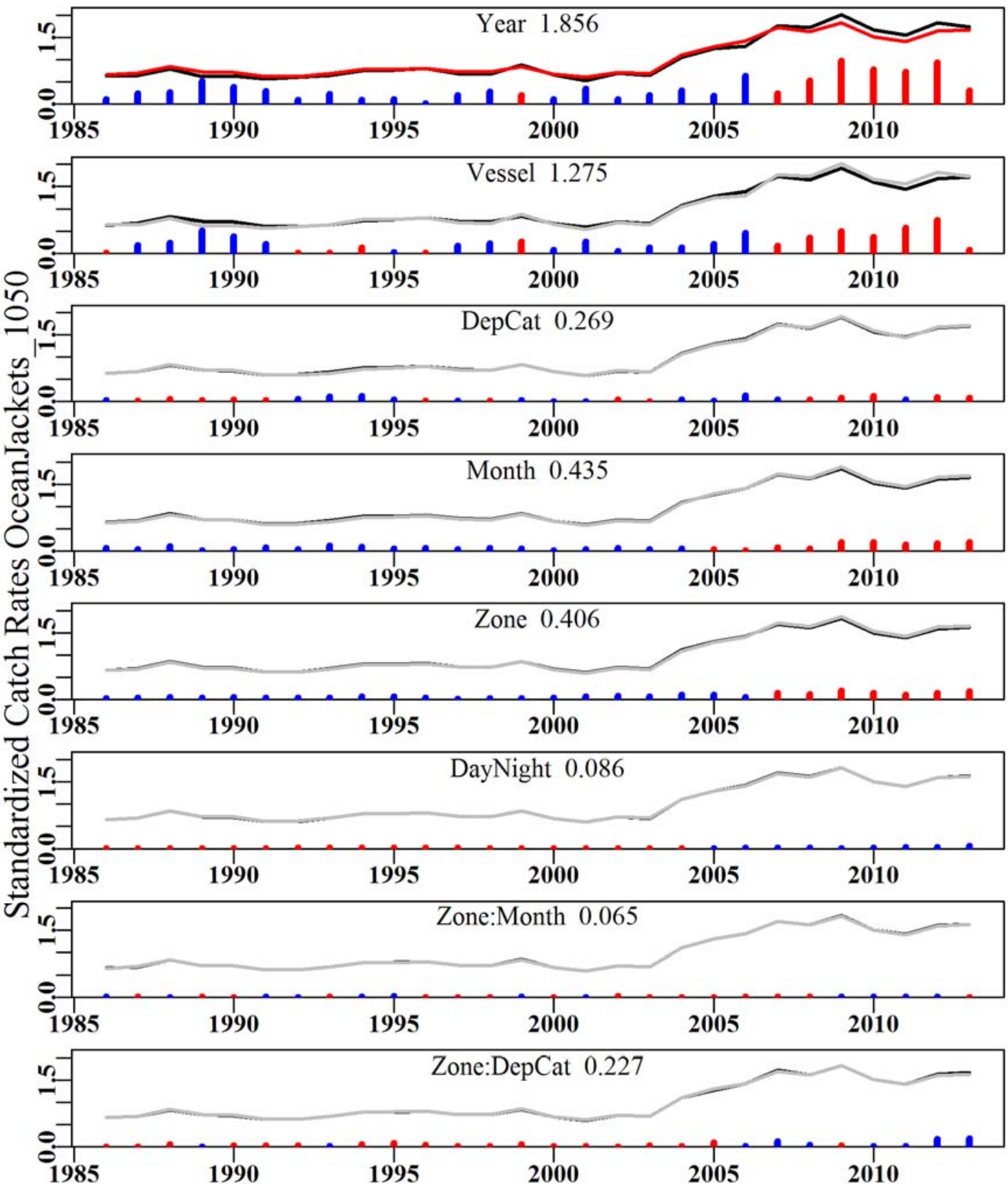


Figure 13.142. The relative influence of each factor used on the final trend in the optimal standardization for Ocean Jackets from Zones 10 to 50. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by the vertical bars with blue bars indicating the optimum model is higher than the geometric mean and red bars indicating it is lower. The top graph bars are the sum of all the bars in the graphs below. The graphs for individual factors are cumulative. Thus the second graph has the geometric mean (grey line) and the effect of adding Year + factor2 (Model 2). In the third graph, the grey line represents Model 2 and the black line the effect of adding factor3 to the model. The remaining graphs continue in the same cumulative manner except for the interaction terms which are added singularly to the final single factor model.

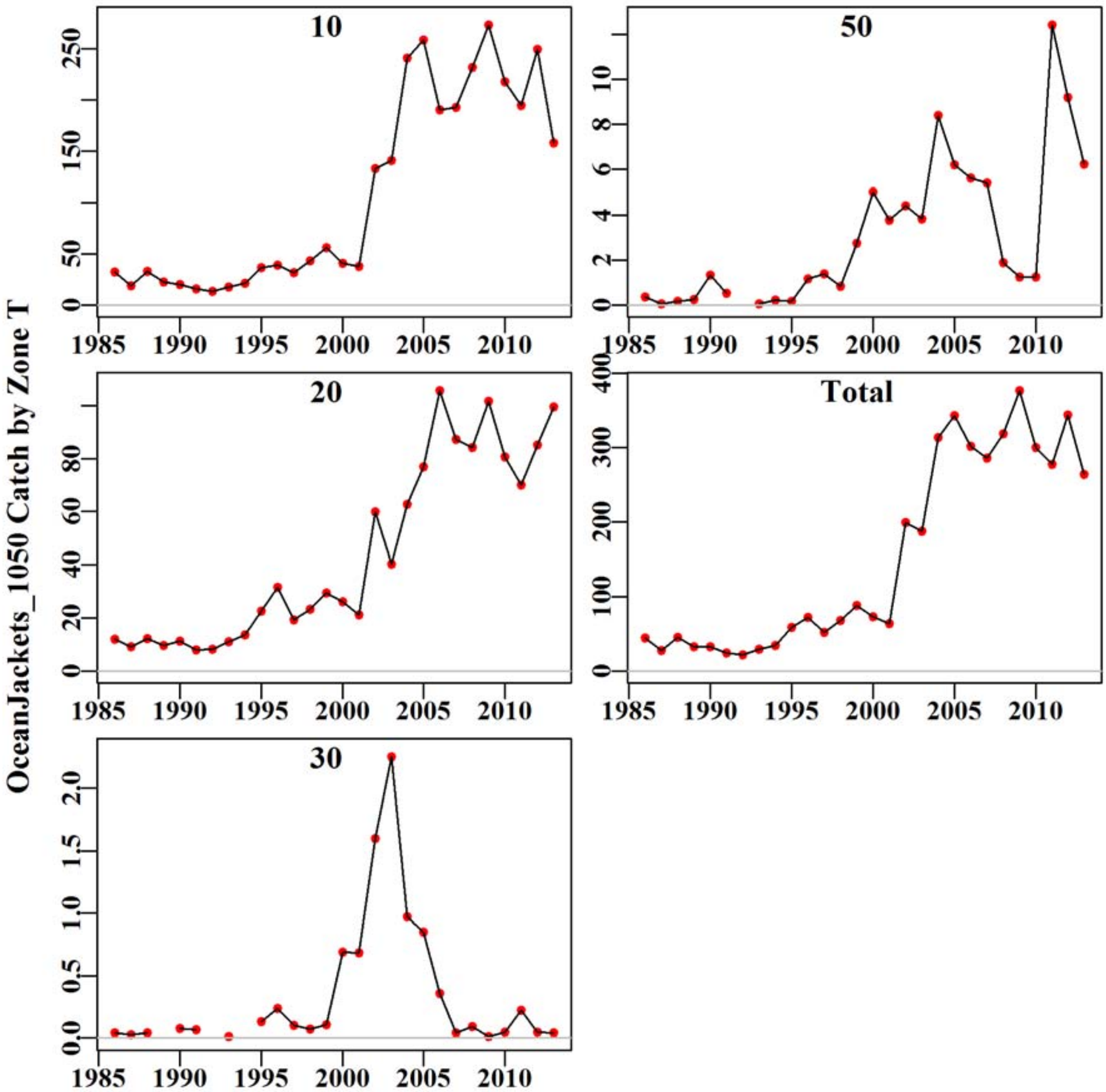


Figure 13.143. Ocean Jackets from Zones 10 to 50 in depths 0 to 300 m by Trawl. The catches taken in each of the four main SESSF zones is depicted with the total catch across these zones. The scales on the y-axis changes between graphs.

13.49 Ocean Jackets (LTC – 37465006 – *Nelusetta ayraudi*)

Alternate: Leatherjackets (LTH – 37465000)

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

Table 13.130**.** Ocean Jackets from zones 82 and 83 in depths 80 to 220 m by Trawl. Total catch (TotCatch; t) is the total reported in the database, number of records used in the analysis (Records), reported catch (CatchT; t) in the area and depth used in the analysis and number of vessels used in the analysis (Vessels). GeoMean is the geometric mean of catch rates (kg/hr). The optimum model is Zone:Month and standard deviation (StDev) relates to the data in the optimum model.

Year	TotCatch	Records	CatchT	Vessels	GeoMean	Zone:Month	StDev
1986	56.4290	141	8.4900	1	11.5206	1.2372	0.0000
1987	53.3540	212	22.6320	3	13.7002	1.0428	0.1091
1988	66.3040	245	15.5900	7	14.0350	1.2250	0.1908
1989	71.6660	576	34.7140	7	11.9652	1.2362	0.1891
1990	90.9690	920	51.3800	11	11.1086	0.8366	0.1866
1991	170.4810	1252	139.7970	8	15.0694	1.0680	0.1860
1992	88.8840	954	59.5340	7	9.0287	0.9379	0.1859
1993	71.8970	819	38.7640	4	6.3105	0.6408	0.1859
1994	74.4380	745	36.6600	5	5.7741	0.5592	0.1866
1995	140.1790	1316	78.8320	5	6.2242	0.7329	0.1852
1996	199.5710	1725	123.4690	6	7.8262	0.8564	0.1849
1997	177.4190	2135	121.0640	9	6.4622	0.7096	0.1849
1998	189.8986	1799	116.4370	9	7.1373	0.7672	0.1849
1999	202.8050	1585	108.9700	7	7.8084	0.8832	0.1853
2000	198.8111	1540	121.6140	5	7.8119	0.9098	0.1854
2001	222.5697	1877	138.4290	6	8.7175	0.9431	0.1853
2002	378.4963	1788	147.5505	6	9.0818	0.9938	0.1853
2003	482.3066	2837	279.6050	9	10.8621	1.1391	0.1850
2004	692.5927	3433	364.4399	9	12.7575	1.2289	0.1849
2005	890.6138	4317	522.9095	10	13.9012	1.3222	0.1849
2006	741.5297	3609	408.4483	11	12.0564	1.0191	0.1850
2007	564.8329	2647	254.8505	8	10.2989	0.9094	0.1852
2008	490.3988	2351	146.3620	6	7.4758	0.7801	0.1853
2009	609.9797	2160	219.9650	4	10.4196	1.0722	0.1853
2010	483.8922	1792	168.2025	4	12.6091	1.2170	0.1857
2011	487.4438	1856	190.9830	4	13.1289	1.2400	0.1856
2012	519.6479	1712	154.6335	5	12.9054	1.1836	0.1858
2013	487.0849	2209	203.8610	6	13.9408	1.3087	0.1855

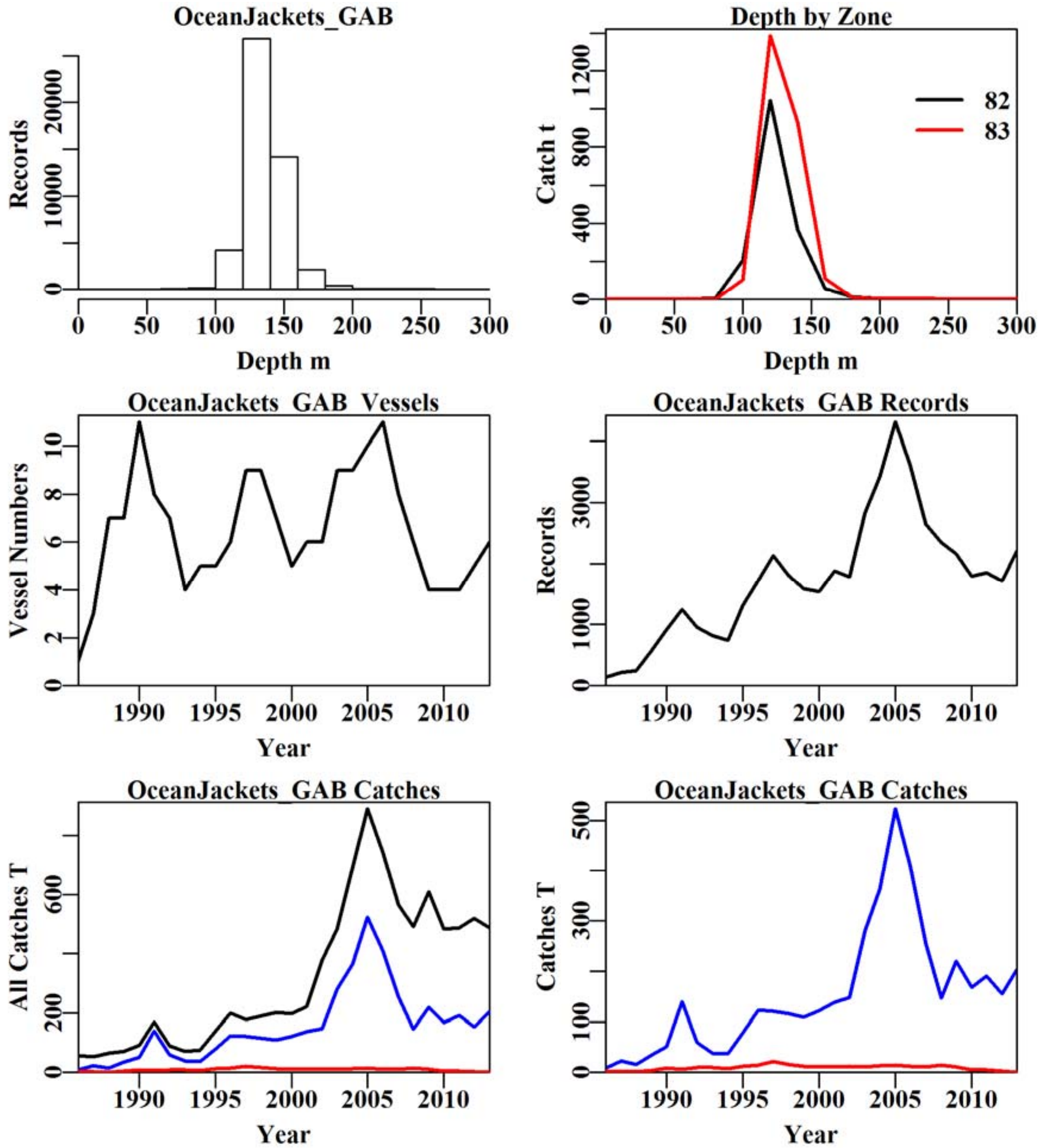


Figure 13.144. Ocean Jackets from zones 82 and 83 in depths 80 to 220 m by Trawl. The top left plot depicts the depth distribution of shots containing Ocean Jackets from Zones 82 and 83 in depths 80 to 220 m by Trawl. The top right plot depicts the catch distribution by depth by zone. The middle left plot depicts the number of vessels through time and middle right plot contains the number of records used in analysis. The bottom left plot contains Ocean Jackets catches (top black line: total catches, middle blue line: catches used in the analysis; bottom red line: catches < 30 kg) and bottom right plot contains Ocean Jackets catches (blue line: catches used in the analysis; red line: catches < 30 kg).

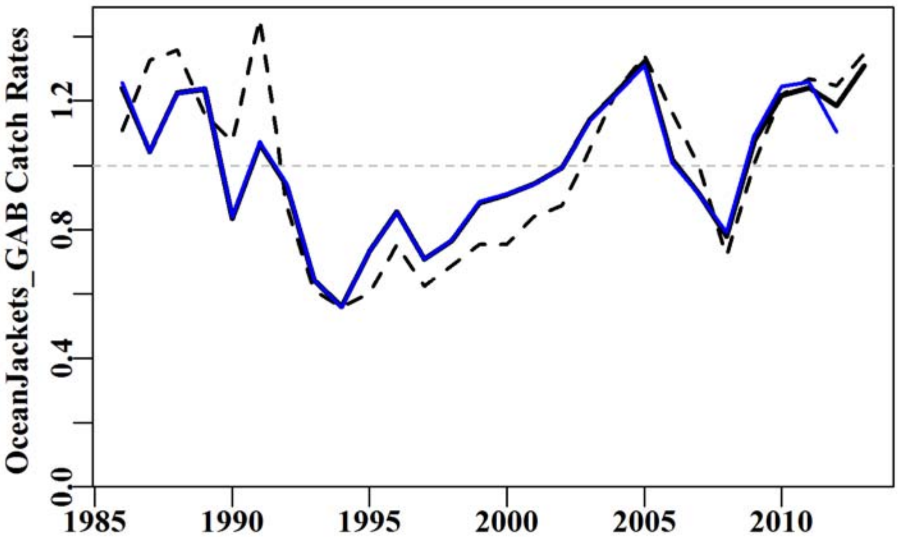


Figure 13.145. Ocean Jackets from zones 82 and 83 in depths 80 to 220 m by Trawl. The dashed black line represents the geometric mean catch rate, solid black line the standardized catch rates and blue line the standardized catch rates based on last year's analysis. The graph standardizes catch rates relative to the mean of the standardized catch rates.

Table 13.131. Ocean Jackets from zones 82 and 83 in depths 80 to 220 m by Trawl. Statistical model structures used in this analysis. DepCat is a series of 20 metre depth categories.

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

Table 13.132. Ocean Jackets from zones 82 and 83 in depths 80 to 220 m by Trawl. Model selection criteria include the Akaike Information Criterion (AIC), residual sum of squares (RSS), model sum of squares (MSS), number of usable observations (Nobs), number of parameters (Npars), adjusted R^2 (adj_R^2) and the change in adjusted R^2 (%Change). The optimum is Zone:Month (Model 8). Depth category: DepC.

	Year	DayNight	DepC	Zone	Vessel	Month	Zone:Month	Zone:DepC
AIC	4167	-1060	-3358	-5804	-6928	-6949	-7189	-6960
RSS	52842	47443	44800	42516	41515	41495	41270	41460
MSS	3546	8945	11588	13872	14873	14893	15118	14928
Nobs	48552	48552	48130	48130	48130	48130	48130	48130
Npars	28	31	46	83	94	95	106	110
adj_R^2	6.237	15.812	20.476	24.473	26.234	26.268	26.651	26.307
%Change	0.000	9.575	4.664	3.997	1.761	0.034	0.383	-0.343

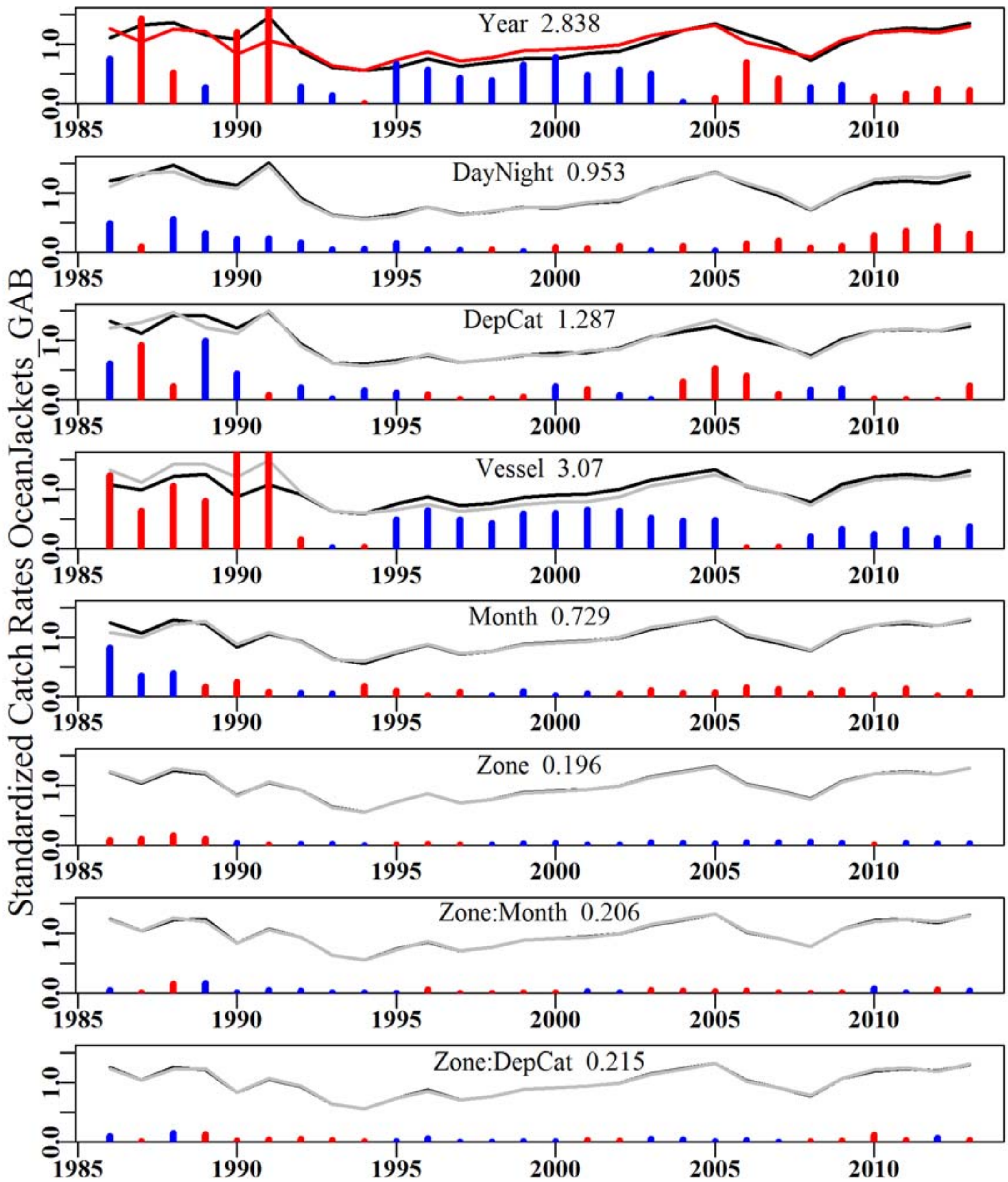


Figure 13.146**.** The relative influence of each factor used on the final trend in the optimal standardization for Ocean Jackets from zones 82 and 83. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by the vertical bars with blue bars indicating the optimum model is higher than the geometric mean and red bars indicating it is lower. The top graph bars are the sum of all the bars in the graphs below. The graphs for individual factors are cumulative. Thus the second graph has the geometric mean (grey line) and the effect of adding Year + factor2 (Model 2). In the third graph, the grey line represents Model 2 and the black line the effect of adding factor3 to the model. The remaining graphs continue in the same cumulative manner except for the interaction terms which are added singularly to the final single factor model.

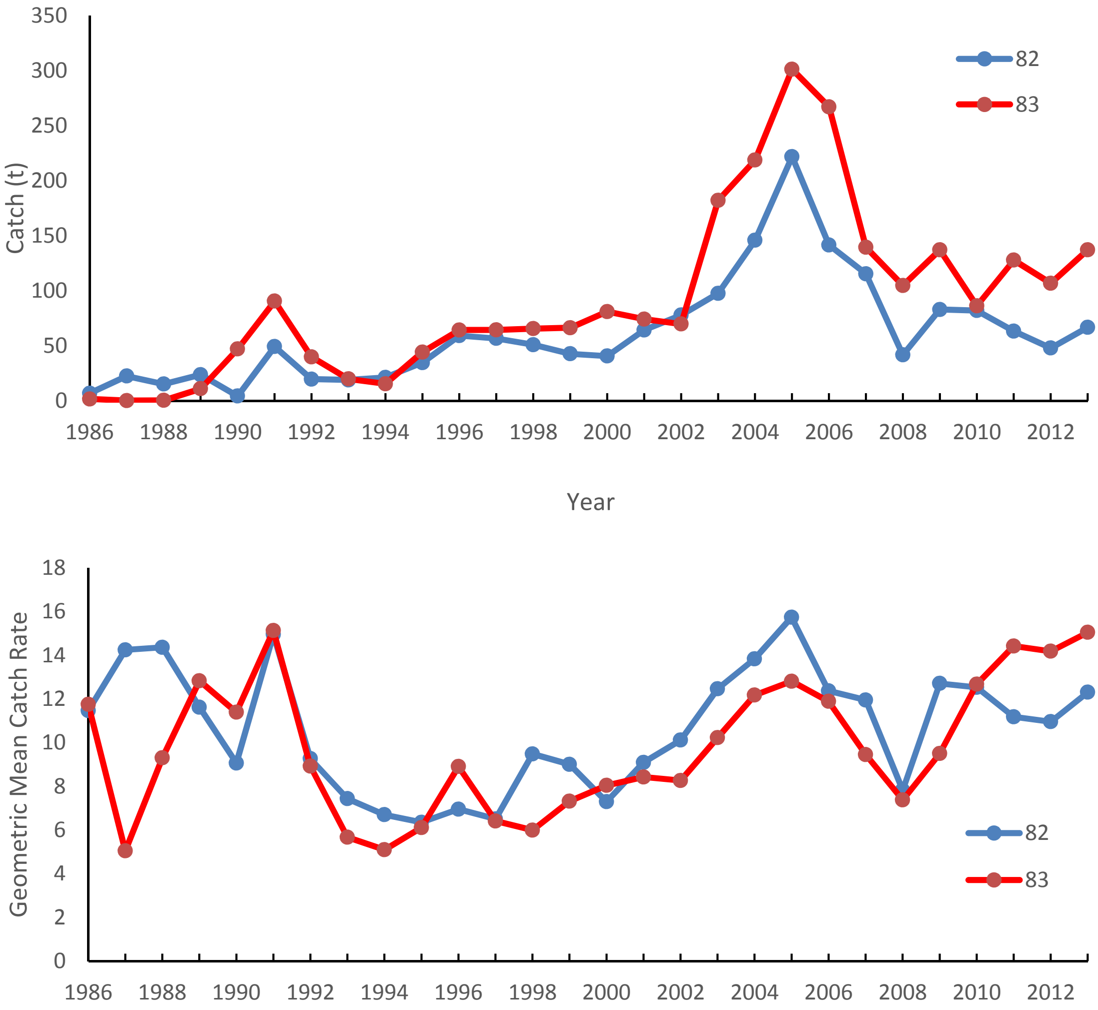


Figure 13.147**.** Trends in catches and geometric mean catch rates for Ocean Jackets in zones 82 and 83 in the GAB. The catches in the other zones remains too low to be informative about catch rates.

13.50 Deepwater Flathead (FLD – 37296002 – Platycephalus conatus)

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

Table 13.133. Deepwater Flathead taken by Trawl in the GAB in depths between 0 – 1000 m. Total catch (TotCatch; t) is the total reported in the database, number of records used in the analysis (Records), reported catch (CatchT; t) in the area and depth used in the analysis and number of vessels used in the analysis (Vessels). GeoMean is the geometric mean of catch rates (kg/hr). The optimum model is Zone:Ves and standard deviation (StDev) relates to the data in the optimum model.

Year	TotCatch	Records	CatchT	Vessels	GeoMean	Zone:Ves	StDev
1987/1988	80.3340	453	76.8400	9	27.6907	0.4785	0.0000
1988/1989	317.2490	815	314.0740	9	56.0806	0.9923	0.0503
1989/1990	402.5570	1126	397.4970	7	53.0361	1.0670	0.0504
1990/1991	430.2310	1501	423.2260	11	49.0776	1.0733	0.0492
1991/1992	621.1150	1781	611.2140	13	54.5388	0.9162	0.0474
1992/1993	524.0620	984	509.2170	4	76.9248	1.0964	0.0490
1993/1994	593.1100	900	585.6450	7	91.4997	1.4720	0.0494
1994/1995	1285.9330	1745	1258.8930	6	106.3058	1.8967	0.0465
1995/1996	1585.1240	1862	1559.4390	5	125.2137	1.8519	0.0465
1996/1997	1499.2260	2784	1466.6360	8	79.3934	1.2600	0.0457
1997/1998	1029.9880	2908	1012.4710	10	50.9703	0.8808	0.0456
1998/1999	690.3890	2558	682.1710	7	34.6696	0.6621	0.0459
1999/2000	571.0500	2089	542.5290	7	39.1053	0.7826	0.0471
2000/2001	846.6200	2315	748.8180	6	43.0243	0.8642	0.0467
2001/2002	973.9438	2408	901.7840	6	51.8098	1.0244	0.0466
2002/2003	1711.5006	3136	1628.6305	8	73.4512	1.4515	0.0460
2003/2004	2272.7170	4536	2188.2269	10	68.4174	1.3816	0.0457
2004/2005	2158.9205	5551	2100.1866	10	55.0520	1.1073	0.0455
2005/2006	1433.1321	5349	1358.4065	11	37.5227	0.7151	0.0455
2006/2007	1015.4786	4254	969.1785	11	32.9286	0.6359	0.0454
2007/2008	1041.3325	4003	971.1735	7	35.9047	0.7004	0.0460
2008/2009	813.9210	3118	775.7370	5	40.6974	0.8299	0.0463
2009/2010	849.8300	3205	829.7290	4	39.1349	0.7680	0.0463
2010/2011	970.0015	2805	930.2880	4	50.8878	0.9680	0.0465
2011/2012	965.0510	3270	788.7420	4	38.5634	0.7492	0.0463
2012/2013	1017.8855	3611	876.1815	5	37.9557	0.7484	0.0462
2013/2014	551.9370	1477	307.0490	5	31.8137	0.6262	0.0488

Table 13.134**.** Reported catch of Deepwater Flathead by method across all methods and years.

Year	AL	BL	DL	GN	DS	OTT	TDO	TW
1987/1988								80.334
1988/1989								317.249
1989/1990								402.557
1990/1991								429.856
1991/1992								620.283
1992/1993								523.662
1993/1994								593.11
1994/1995								1278.813
1995/1996								1582.374
1996/1997								1497.816
1997/1998								1029.898
1998/1999			0.01					690.079
1999/2000								559.511
2000/2001					0.001			819.847
2001/2002					0.0033			962.6935
2002/2003					0.0091			1707.932
2003/2004					0.0091			2272.708
2004/2005	0.001	0.021			0.11197			2158.787
2005/2006					0.0021			1433.13
2006/2007					0.0011			1015.478
2007/2008								1041.333
2008/2009								813.921
2009/2010								849.83
2010/2011				5.303			24.529	940.1695
2011/2012				136.677		13.505	606.967	207.902
2012/2013				103.493		0.65	512.331	401.4115
2013/2014				48.248		5.37	333.863	153.366

An examination of the depth distribution of catches suggests that this could be modified to become 100 – 300 m with essentially no loss of information and the outcomes do not differ from the base case adopted here (Figure 13.149 andFigure 13.150; All vessels and 0 – 1000 m).

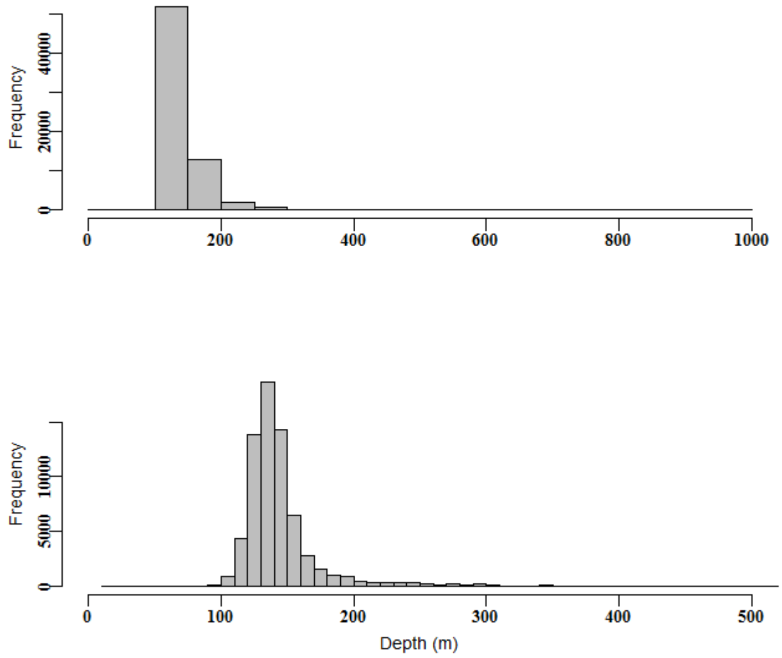


Figure 13.148**.** The depth distribution of records for the Deepwater Flathead fishery taken by Trawl in the GAB.

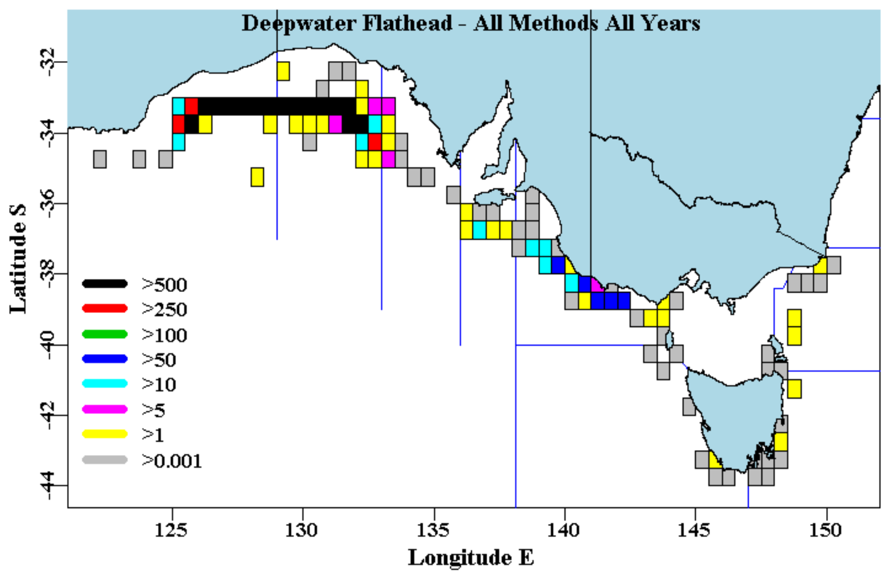


Figure 13.149**.** Schematic map of the distribution of catches of Deepwater Flathead from 1987/1988 to 2011/2012 taken by all methods (**Table 13.134**). Whether the catches reported around the south of Tasmania are correctly reported is questionable.

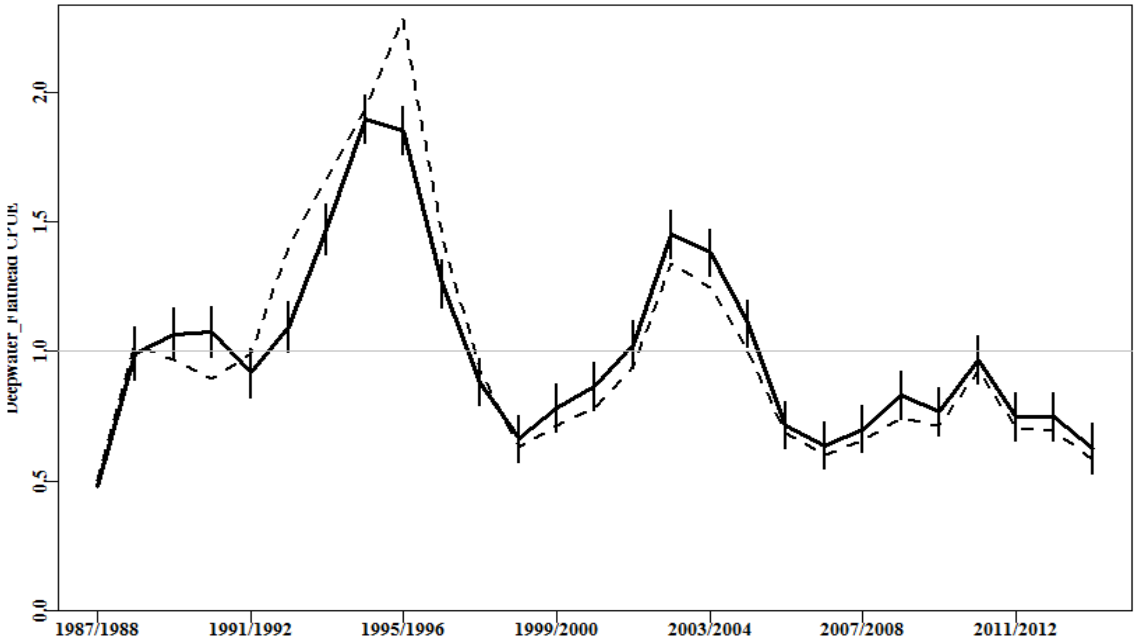


Figure 13.150. The standardized CPUE for Deepwater Flathead from the trawl fishery in the GAB. The dashed line depicts the geometric mean catch rate and the solid line is the optimum model. The vertical bars are the approximate 95% confidence intervals around the mean year parameter estimates.

Table 13.135. Deepwater Flathead from the trawl fishery in the GAB by Trawl from 0 – 1000 m. Statistical model structures used in this analysis. DepCat is a series of 50 metre depth categories.

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

Table 13.136. Deepwater Flathead from the trawl fishery in the GAB by Trawl from 0 – 1000 m. Model selection criteria include the Akaike Information Criterion (AIC), residual sum of squares (RSS), model sum of squares (MSS), number of usable observations (Nobs), number of parameters (Npars), adjusted R^2 (adj_R^2) and the change in adjusted R^2 (%Change). The optimum model is Zone:Ves (Model 8). Depth category: DepC; Vessel: Ves; Month: Mth.

	Year	Ves	Zone	Month	DepC	DayNight	Zone:Mth	Zone:Ves	Zone:DepC
AIC	-27160	-32701	-37743	-41190	-42650	-44151	-44963	-46112	-44294
RSS	47965	44288	41216	39238	37834	37027	36496	35615	36761
MSS	8044	11721	14793	16772	18175	18982	19514	20394	19248
Nobs	70544	70544	70536	70536	69875	69875	69875	69875	69875
adj_R^2	14.331	20.851	26.332	29.857	32.346	33.786	34.643	35.964	34.091
%Change	0.000	6.520	5.481	3.525	2.489	1.440	0.858	1.321	-1.873

13.51 Bight Redfish (FLD – 37258004 – *Centroberyx gerrardi*)

Data from the GAB fishery used in the analysis was based on depths between 0 – 1000 m, taken by Trawl. Also, analyses were restricted to vessels present for more than two years and which caught an average annual catch > 4 t, and that trawled for more than one hour but less than 10 hours. Instead of 5 degree zones across the GAB, 2.5 degree zones were employed to allow better resolution of location based differences in CPUE. An examination of the depth distribution of catches suggests that this could be modified to become 100 – 250 m with essentially no loss of information and the outcomes do not differ from the base case adopted here (Figure 13.151); All vessels and 0 – 1000 m). Catches in 1986/1987 were relatively low and only taken by a single vessel and so were omitted from analysis.

Table 13.137. Bight Redfish taken by Trawl in the GAB in depths between 0 – 1000 m. Total catch (TotCatch; t) is the total reported in the database, number of records used in the analysis (Records), reported catch (CatchT; t) in the area and depth used in the analysis and number of vessels used in the analysis (Vessels). GeoMean is the geometric mean of catch rates (kg/hr). The optimum model is Zone:Ves and standard deviation (StDev) relates to the data in the optimum model.

Year	TotCatch	Records	CatchT	Vessels	GeoMean	Zone:Ves	StDev
1987/1988	47.4340	195	33.6640	5	27.0439	2.2586	0.0000
1988/1989	87.9610	503	86.6850	7	32.3956	1.9076	0.1048
1989/1990	173.5590	833	171.8440	7	31.6051	1.5148	0.1027
1990/1991	290.1385	1032	252.5655	8	36.7512	1.3812	0.1008
1991/1992	274.0490	1105	240.5930	8	27.3132	1.3581	0.0983
1992/1993	132.0980	718	120.1880	3	18.3377	1.0297	0.1009
1993/1994	108.6860	696	107.6380	5	16.2401	0.9534	0.1013
1994/1995	163.5980	1290	159.9390	6	11.7236	0.6599	0.0966
1995/1996	176.9320	1395	175.2770	5	11.8016	0.7744	0.0969
1996/1997	334.0670	2037	329.7870	6	15.3350	0.8603	0.0953
1997/1998	375.8710	1931	366.2610	7	16.0388	0.9196	0.0954
1998/1999	442.2460	1814	440.3360	7	20.1921	1.0838	0.0954
1999/2000	328.3430	1475	324.2110	7	17.2082	0.9685	0.0977
2000/2001	398.7389	1623	370.0680	5	15.4846	0.8304	0.0970
2001/2002	232.9888	1607	223.6570	5	10.9362	0.6200	0.0971
2002/2003	378.0266	2113	363.6421	8	13.4561	0.6651	0.0959
2003/2004	862.0778	3155	842.0450	10	20.1172	0.9829	0.0954
2004/2005	889.9464	3816	759.3895	10	18.3721	0.9040	0.0950
2005/2006	802.9481	3558	722.9882	10	17.3990	0.8789	0.0950
2006/2007	961.6332	3295	873.7796	11	21.7544	0.9514	0.0946
2007/2008	759.0168	3029	735.0800	7	19.2706	0.9333	0.0955
2008/2009	665.4162	2443	648.7860	4	21.9054	1.0092	0.0960
2009/2010	463.7251	2298	445.7170	4	17.3788	0.8650	0.0962
2010/2011	286.5087	1851	277.8890	4	14.2669	0.7268	0.0968
2011/2012	330.9570	2188	322.8650	4	14.4261	0.7310	0.0965
2012/2013	266.9629	1874	255.7950	4	15.2715	0.6312	0.0972
2013/2014	123.0561	512	38.6310	4	10.0521	0.6010	0.1075

Table 13.138.Reported catch of Bight Redfish by method and years.

Year	Unknown	Line	GN	PS	DS	TW
1987/1988						47.434
1988/1989						87.961
1989/1990						173.559
1990/1991						290.139
1991/1992						274.049
1992/1993	0.650	0.010			0.010	131.438
1993/1994						108.686
1994/1995	1.287					162.311
1995/1996	0.030					176.902
1996/1997	0.020					334.047
1997/1998	0.060					375.811
1998/1999	0.030					442.216
1999/2000	2.037					326.306
2000/2001	17.463		1.037			380.239
2001/2002	2.105	0.644	3.124			227.116
2002/2003	0.670	0.006	3.326			374.026
2003/2004		0.017	4.966			857.095
2004/2005	0.011	0.008	5.211		0.004	884.716
2005/2006		0.245	6.495	30		766.208
2006/2007		0.182	7.997			953.455
2007/2008		0.151	7.780			751.086
2008/2009		0.055	8.103			657.258
2009/2010		0.088	5.380			458.257
2010/2011		1.305	2.330		1.269	282.864
2011/2012		3.368	2.014		3.198	325.575
2012/2013		1.217	0.324		0.905	265.422
2013/2014		1.139	0.218		0.723	116.329

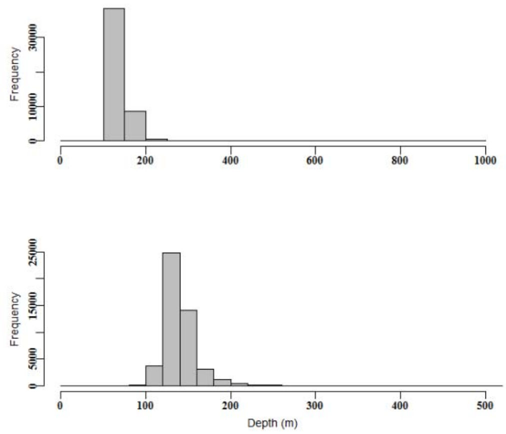


Figure 13.151.The depth distribution of records for the Bight Redfish fishery taken by Trawl in the GAB.

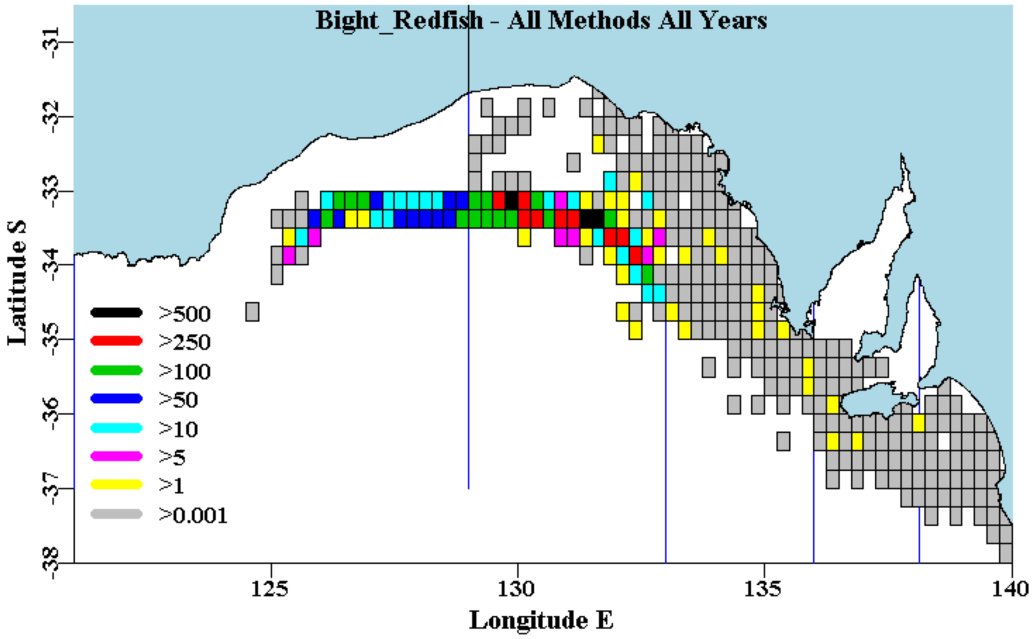
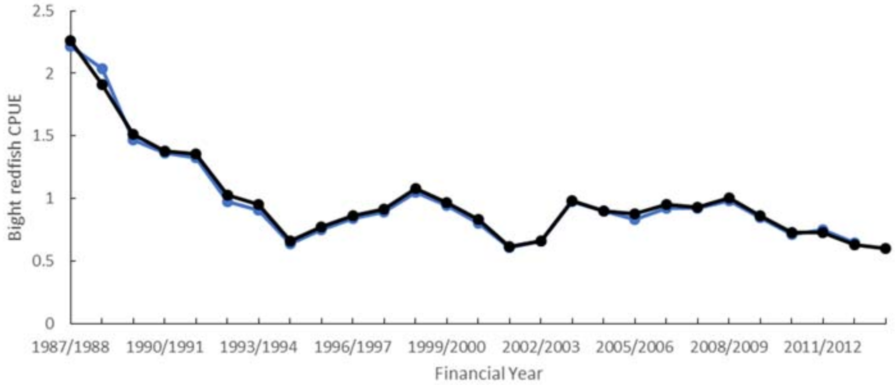


Figure 13.152. Schematic map of the distribution of catches of Bight Redfish from 1987/1988 to 2011/2012 taken by all methods. Catches are higher in the east of the GAB.



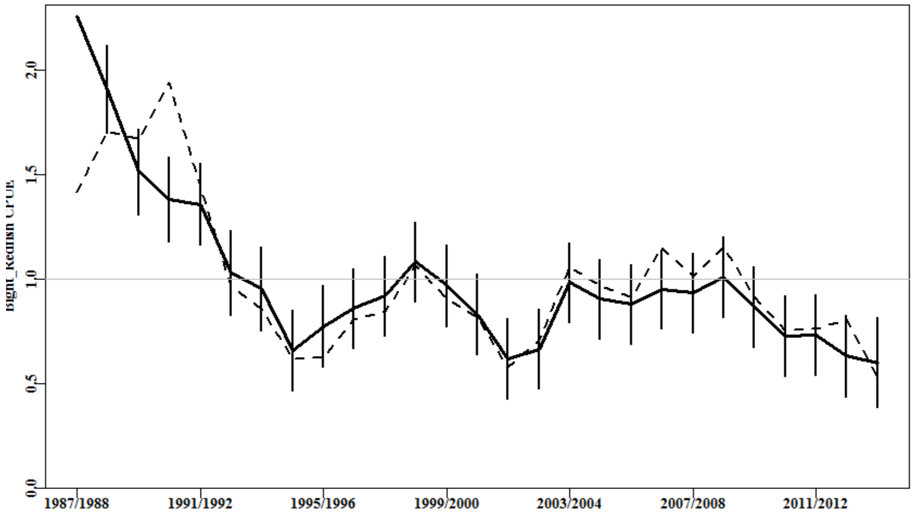


Figure 13.153**.** The standardized CPUE for Bight Redfish from the trawl fishery in the GAB. Upper graph: solid black line the standardized catch rates (relative to the mean of the standardized catch rates). The blue line corresponds to last year's standardized catch rates. Lower graph: Standardized indices (solid black line), 95% CI (vertical lines) and geometric mean (dashed black line). This illustrates the impact on the relative uncertainty of the relatively small number of records, especially in the early years.

Table 13.139**.** Bight Redfish in the GAB by Trawl from 0 – 1000 m. Statistical model structures used in this analysis. DepCat is a series of 20 metre depth categories.

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

Table 13.140. Bight Redfish in the GAB by Trawl from 0 – 1000 m. Model selection criteria include the Akaike Information Criterion (AIC), residual sum of squares (RSS), model sum of squares (MSS), number of usable observations (Nobs), number of parameters (Npars), adjusted R^2 (adj_R^2) and the change in adjusted R^2 (%Change). The optimum model is Zone:Month (Model 7). Zone was four 2.5 degree slices through the GAB. Depth category: DepC; Vessel: Ves.

	Year	DayNight	Zone	Month	Ves	DepC	Zone:Month	Zone:Ves	Zone:DepC
AIC	31060	25656	21560	18498	17381	16666	16317	16464	16742
RSS	91837	82123	75431	70773	69099	67506	66771	66753	66827
MSS	3076	12790	19482	24140	25814	27407	28142	28161	28086
Nobs	48386	48386	48386	48386	48386	47868	47868	47868	47868
adj_R^2	3.189	13.424	20.465	25.359	27.094	28.721	29.367	29.268	29.022
%Change	0.000	10.235	7.041	4.894	1.735	1.627	0.646	-0.100	-0.246

13.52 Deepwater species

Only catch rates for deepwater sharks and oreos are considered here, although this year there was so little smooth oreo caught that no update on their catch rates can be made. Mixed oreos (a basket of oreo species) requires attention however (Table 13.141).

Table 13.141. End of season catches obtained from the summary Catch-Watch data on the AFMA website. These catches are for the May through to April rather than the calendar years of the CPUE analyses.

Quota Available	Agreed TAC	TAC with over & under-catch	Catch (t)	%TAC Caught	%Agreed TAC
Deepwater Sharks East	85	91.841	21.766	24%	25.61
Deepwater Sharks West	215	233.653	76.356	33%	35.51
Orange Roughy (Albany-Esperance)	50	50	0	0%	0.00
Orange Roughy (Cascade Plateau)	500	550	0	0%	0.00
Orange Roughy (Eastern)	25	25	13.562	54%	54.25
Orange Roughy (Southern)	35	35	21.649	62%	61.85
Orange Roughy (Western)	60	60	40.395	67%	67.33
Oreos	132	139.616	120.372	86%	91.19
Smooth Oreos (Cascade Plateau)	150	165	0	0%	0.00
Smooth Oreos (other)	23	24.081	0.076	0%	0.33

13.53 Eastern Deepwater Sharks

Table 13.142. 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.

A number of the fishery characteristics for eastern deepwater sharks have been described in Haddon (2014a).

Table 13.143. 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

Table 13.144. Annual reported catches of deepwater sharks (east and west combined). Earlier years are given in Haddon (2014a).

	Dogfish	Black	Brier	Platypus	Roughskin	Pearl	Black-Roughskin	OtherSharks
	37020000	37020002	37020003	37020004	37020904	37020905	37020906	37990003
2000	80.298	14.488	0.008	31.506	20.583	171.741	183.127	201.070
2001	27.213		11.854	65.172	15.552	173.089	137.094	157.930
2002	10.436		23.658	70.969	31.079	228.767	93.899	87.349
2003	15.139		15.781	46.218	30.777	158.323	98.648	22.790
2004	13.069		14.591	50.639	22.834	168.265	103.623	16.135
2005	16.526		6.730	30.602	7.843	82.795	34.019	16.029
2006	12.730		4.976	21.827	16.844	83.916	39.181	14.416
2007	17.693		0.001	1.125	6.589	25.756	6.107	5.657
2008	12.961		0.107	3.785	4.175	21.200	8.777	4.978
2009	13.360		0.461	2.611	14.192	32.935	31.327	2.350
2010	12.350		0.282	5.216	5.632	30.135	27.471	1.688
2011	12.898		0.085	3.672	9.625	29.642	28.104	4.435
2012	9.990	0.000	0.551	6.660	5.375	39.800	19.230	3.291
2013	8.934	1.478	1.200	27.494	5.157	36.893	22.874	2.881

Table 13.145. Eastern deepwater sharks. Model selection criteria include the Akaike Information Criterion (AIC), residual sum of squares (RSS), model sum of squares (MSS), number of usable observations (Nobs), number of parameters (Npars), adjusted R^2 (adj_R^2) and the increment in adjusted R^2 (ΔR^2). The model including the ORZone:Mth interaction term (Model 7) was optimal. There was a trivial effect of being in the open or closed areas (Deep) on the statistical model fit. Year, Vessel, and DepCat dominated the analysis. The DayNight factor was omitted because it detracted from the fit. Depth category: DepC; Month: Mth.

	Year	Vessel	DepC	Month	ORZone	Deep	ORZone:Mth	Vessel:Month
AIC	3616	2002	1146	1133	989	991	960	1818
RSS	15220	12962	11703	11666	11502	11502	11375	10630
MSS	2364	4622	5880	5918	6082	6082	6208	6953
Nobs	10991	10991	10730	10730	10730	10730	10730	10730
Npars	19	95	107	118	122	123	167	959
adj_R^2	13.300	25.650	32.778	32.923	33.841	33.834	34.291	33.617
ΔR^2	13.300	12.349	7.128	0.145	0.918	-0.006	0.457	-0.217

Table 13.146. Number of records where Eastern Deepwater Sharks are reported from trawling in OR Zones 10, 20, 21, and 50, in depths 600 to 1250 m. Vessel represents the count of vessels reporting eastern deepwater sharks. Yield is the total reported catch in tonnes. The geometric mean CE is the raw unstandardized catch rate in kg/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	11.827	21.487	194	779	24	11.889
1987	5.792	97	327	26	8.745	3.952	80	265	22	8.349
1988	5.246	38	137	18	14.679	2.895	25	94	11	12.810
1989	5.106	69	220	16	13.865	4.625	60	191	14	13.960
1990	5.352	42	125	17	16.157	2.348	19	60	13	7.902
1991	18.644	106	321	19	24.752	3.327	33	111	13	13.919
1992	62.931	102	463	17	37.294	4.419	38	206	12	12.220
1993	93.604	258	968	19	47.054	8.774	69	263	14	13.816
1994	110.394	420	1605	25	37.705	14.502	87	364	21	23.262
1995	114.285	359	1453	17	50.193	22.292	70	279	15	48.892
1996	326.351	952	3712	26	52.295	55.647	196	764	20	34.778
1997	194.116	903	4091	24	30.823	31.563	198	853	21	22.962
1998	205.896	1102	4989	24	27.601	50.332	279	1217	20	23.329
1999	156.517	1005	4652	25	22.211	29.080	187	881	17	19.189
2000	187.075	889	4252	29	27.855	34.577	185	837	21	20.303
2001	140.158	887	4097	27	19.984	30.834	219	919	24	15.097
2002	160.721	891	4230	28	23.381	38.176	226	1037	27	17.721
2003	128.789	963	4745	25	16.848	22.450	174	879	20	15.237
2004	103.248	716	3459	29	17.959	18.913	138	656	24	15.287
2005	61.376	477	2470	16	15.739	13.319	82	377	12	21.799
2006	43.227	408	1960	21	11.414	9.532	61	270	13	15.569
2007	8.418	106	494	17	10.127	6.027	78	358	16	9.296
2008	12.904	100	658	10	10.800	6.918	64	384	10	9.963
2009	38.892	230	1227	14	16.957	38.892	230	1227	14	16.957
2010	24.806	244	1264	13	10.087	24.806	244	1264	13	10.087
2011	25.171	242	1352	15	10.976	25.171	242	1352	15	10.976
2012	25.926	278	1545	16	8.911	25.926	278	1545	16	8.911
2013	19.590	239	1321	15	8.153	19.590	239	1321	15	8.153

Table 13.147. The standardized catch rates for the alternative statistical models for Eastern Deepwater Sharks in OR zones10, 20, 21, and 50, in depths 600 to 1250 m. The optimal model was Model 7 (ORZone:Mth). St Err is the estimate of standard error for the optimum model. Values are relative to the mean of the standardized catch rates. The models for Deep and Vessel:Month were omitted for brevity.

Year	Year	Vessel	DepCat	Month	ORzone	Deep	ORZone:Mth	StErr
1995	2.4236	2.1038	1.9402	1.9570	1.9993	1.9981	1.9691	0.0000
1996	2.5318	2.7708	2.7575	2.7628	2.4103	2.4091	2.3875	0.0729
1997	1.4923	1.5263	1.3817	1.3858	1.3284	1.3278	1.3427	0.0709
1998	1.3361	1.2523	1.1274	1.1331	1.1519	1.1515	1.1586	0.0701
1999	1.0753	1.0730	0.9413	0.9420	0.9660	0.9656	0.9504	0.0702
2000	1.3486	1.3138	1.1510	1.1417	1.1552	1.1548	1.1366	0.0715
2001	0.9675	1.0318	0.9468	0.9390	0.9912	0.9908	0.9970	0.0724
2002	1.1320	1.1178	1.0397	1.0460	1.0892	1.0888	1.0779	0.0723
2003	0.8157	0.8359	0.7523	0.7498	0.7712	0.7708	0.7786	0.0722
2004	0.8697	0.8179	0.7541	0.7483	0.7839	0.7836	0.7865	0.0743
2005	0.7626	0.7609	0.7276	0.7264	0.7483	0.7479	0.7426	0.0802
2006	0.5531	0.5393	0.6484	0.6433	0.6477	0.6473	0.6526	0.0829
2007	0.4931	0.4736	0.7185	0.7164	0.7309	0.7310	0.7255	0.1291
2008	0.5261	0.5770	0.8944	0.8950	0.9178	0.9178	0.9130	0.1279
2009	0.8228	0.8966	1.0994	1.0964	1.1039	1.1061	1.1255	0.1003
2010	0.4894	0.5476	0.5900	0.5869	0.6072	0.6084	0.6151	0.0976
2011	0.5325	0.5224	0.5801	0.5796	0.6110	0.6123	0.6253	0.0997
2012	0.4322	0.4445	0.5027	0.5048	0.5347	0.5357	0.5469	0.0951
2013	0.3956	0.3946	0.4466	0.4458	0.4519	0.4528	0.4687	0.0978

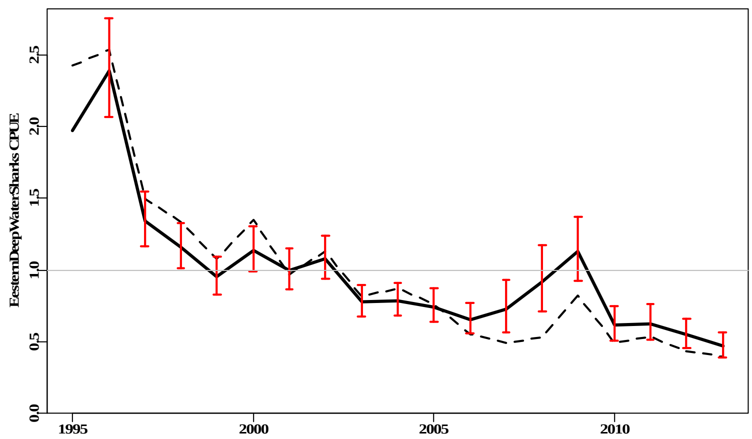


Figure 13.154. Eastern Deepwater Sharks reported from trawling in OR Zones 10, 20, 21, and 50, in depths 600 to 1250 m. The black dashed line from 86-12 represents the geometric mean catch rate and the solid black line the optimum standardized catch rates (Model 7). The graph scales the catch rates relative to the mean of the standardized catch rates (depicted by the horizontal grey line at 1.0).

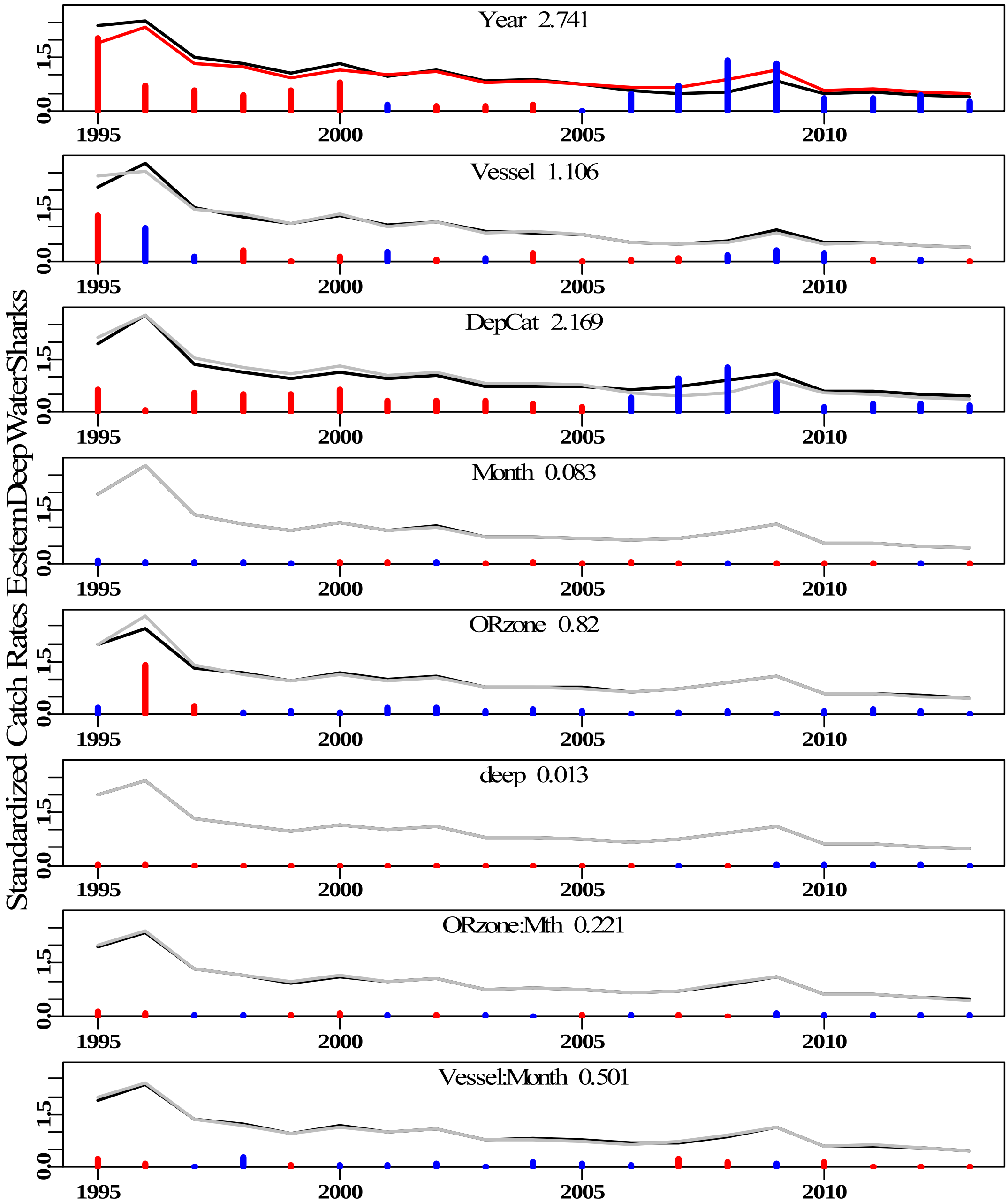


Figure 13.155. The relative impact of the different factors on the changes in the standardized trend. The major effects of both the structural adjustment that occurred across Nov 2005 – Nov 2006, with its change of vessels, and the deepwater closures is clear.

13.54 Western Deepwater Sharks

There are numerous species grouped together into the Western Deepwater Sharks (Table 13.148) but only some have data and even fewer have significant catches reported.

Table 13.148**.** 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.

Table 13.149**.** Statistical model structures used with Western Deepwater Sharks. DepCat is a series of 20 metre depth categories. Deep relates to whether the area is open or closed.

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

Table 13.150**.** Number of records where Western Deepwater Sharks are reported from trawling in ORZone 30, in depths 600 to 1100 m. Vessels represents the count of vessels reporting Western Deepwater Sharks. Yield is the total reported catch. The geometric mean CE is the raw unstandardized catch rate in kg/tow. Columns 2-6 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	1.030	14	56	3	54.016	0.430	5	18	2	52.531
1987	0.558	19	62	4	22.650	0.391	12	39	3	23.450
1988	0.525	4	11	2	122.474					
1989	1.200	13	40	2	83.323	0.490	6	20	2	75.141
1990	0.250	4	13	3	29.907	0.250	4	13	3	29.907
1991	0.315	5	18	3	42.929	0.015	1	2	1	15.000
1992	3.580	20	94	3	140.506	2.080	11	47	3	145.736
1993	1.785	17	61	3	74.835	0.515	3	10	1	125.380
1994	1.512	22	128	3	54.163	0.120	1	4	1	120.000
1995	95.106	593	2929	10	93.596	17.806	140	650	8	69.874
1996	185.802	955	4491	23	105.381	26.703	182	842	16	79.975
1997	325.955	1975	10102	19	95.986	45.134	354	1732	18	74.310
1998	396.302	2901	16202	18	88.286	58.046	451	2512	16	74.437
1999	312.960	2212	12544	19	89.926	36.642	370	2004	15	61.884
2000	311.489	1869	10454	18	111.139	40.094	303	1526	16	84.863
2001	242.052	1832	10384	19	84.155	35.153	305	1747	16	72.420
2002	251.392	1625	10161	17	98.832	33.729	271	1680	15	77.413
2003	166.440	1429	8996	16	73.365	23.640	241	1456	15	65.000
2004	209.774	1733	10870	15	78.244	34.824	304	1851	13	74.428
2005	82.725	818	4816	13	61.230	12.509	141	790	11	47.902
2006	72.064	617	3806	12	70.529	14.641	131	760	11	69.243
2007	8.612	112	682	9	38.108	3.777	55	330	8	33.757
2008	15.625	121	784	8	76.979	7.862	65	400	7	75.612
2009	34.072	233	1487	10	79.505	34.072	233	1487	10	79.505
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
2013	61.947	592	4180	12	64.732	61.947	592	4180	12	64.732

Table 13.151. Western deepwater sharks. Model selection criteria include the Akaike Information Criterion (AIC), residual sum of squares (RSS), model sum of squares (MSS), number of usable observations (Nobs), number of parameters (Npars), adjusted R^2 (adj_R^2) and the increment in adjusted R^2 (ΔR^2). Model 6 was optimal (Deep). The effect of being in the open or closed areas (Deep) was minor. Depth category: DepC.

	Year	DepC	Vessel	Month	DayNight	Deep	Vessel:Month
AIC	1501	-901	-2373	-2532	-2551	-2555	-2283
RSS	22102	19551	18118	17958	17937	17931	17332
MSS	628	3179	4613	4772	4794	4799	5398
Nobs	20586	20488	20488	20488	20488	20488	20488
Npars	19	29	73	84	87	88	572
adj_ R^2	2.677	13.869	20.012	20.674	20.757	20.777	21.561
ΔR^2	2.677	11.191	6.143	0.662	0.083	0.021	0.784

Table 13.152. The standardized catch rates for the alternative statistical models for Western Deepwater Sharks in OR zone 30, in depths 600 to 1100 m. The optimal model was Model 6. St Err is the estimate of standard error for the optimum model. Values are relative to the mean of the standardized catch rates.

Year	Year	DepCat	Vessel	Month	DayNight	Deep	Vessel:Month	StErr
1995	1.1808	1.1298	1.1446	1.1774	1.1779	1.1685	1.1818	0.0000
1996	1.3314	1.2744	1.4955	1.4722	1.4713	1.4553	1.5414	0.0510
1997	1.2124	1.1150	1.2185	1.2133	1.2138	1.2007	1.2526	0.0462
1998	1.1150	0.9394	0.9976	0.9785	0.9804	0.9707	0.9627	0.0449
1999	1.1358	0.9225	1.0068	1.0010	1.0016	0.9927	0.9681	0.0459
2000	1.4038	1.1031	1.1808	1.1638	1.1648	1.1550	1.1474	0.0469
2001	1.0630	0.8739	0.9188	0.9202	0.9215	0.9134	0.9174	0.0471
2002	1.2484	1.0585	1.0536	1.0547	1.0568	1.0482	1.0466	0.0474
2003	0.9267	0.7983	0.7934	0.7961	0.7978	0.7907	0.8048	0.0480
2004	0.9883	0.8015	0.8131	0.8098	0.8088	0.8025	0.8081	0.0473
2005	0.7737	0.6997	0.6820	0.6648	0.6648	0.6592	0.6584	0.0528
2006	0.8914	0.8427	0.8950	0.8810	0.8823	0.8753	0.8696	0.0572
2007	0.4835	0.8373	0.8412	0.8414	0.8477	0.8425	0.8547	0.1005
2008	0.9763	1.6754	1.3953	1.4231	1.4236	1.4170	1.3367	0.0972
2009	1.0062	1.4103	1.2457	1.2429	1.2337	1.2624	1.2449	0.0762
2010	0.8736	1.0415	0.9277	0.9444	0.9430	0.9678	0.9593	0.0733
2011	0.8700	1.0533	0.8978	0.9023	0.8973	0.9204	0.9204	0.0692
2012	0.7017	0.6678	0.6912	0.7091	0.7075	0.7278	0.7290	0.0701
2013	0.8181	0.7556	0.8013	0.8041	0.8053	0.8299	0.7959	0.0629

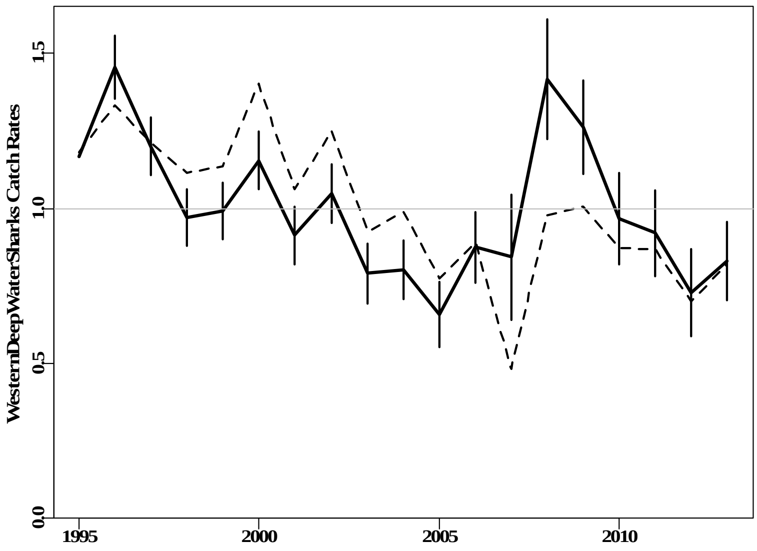


Figure 13.156**.** Western Deepwater Sharks reported from trawling in OR Zone 30, in depths 600 to 1100 m. The black dashed line from 95-12 represents the geometric mean catch rate and the solid black line the optimum standardized catch rates (Model 5). The graph standardizes catch rates relative to the mean of the standardized catch rates, represented by the horizontal fine grey line**.**

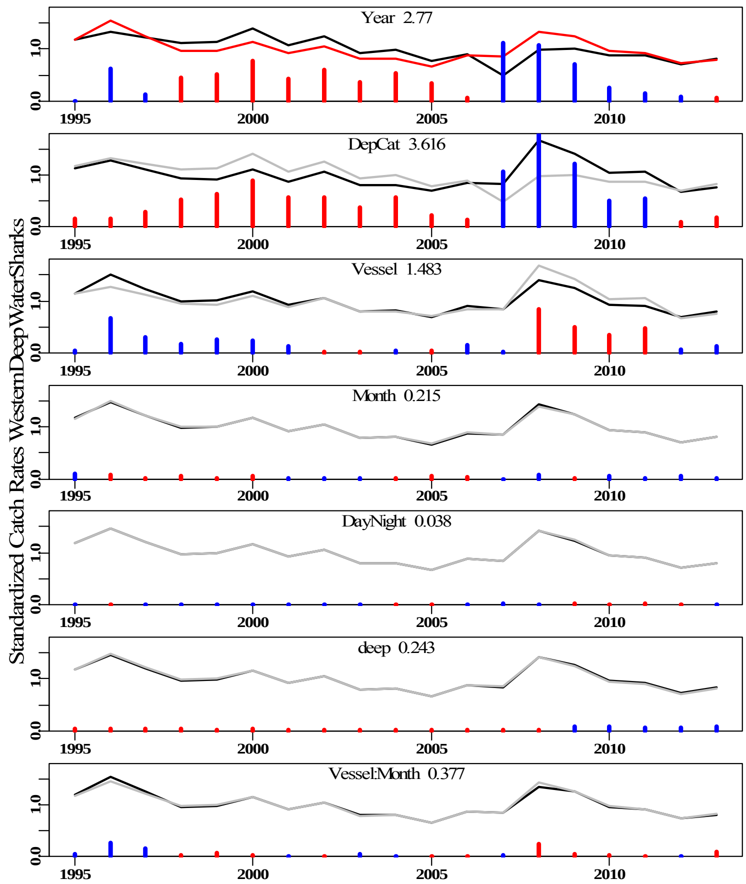


Figure 13.157**.** The relative impact of the different factors on the changes in the standardized trend. The major effects of both the structural adjustment, with its change of vessels, and the deepwater closures is clear.

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

Allocyttus verrucosus (warty), *Neocyttus rhomboidalis* (spiky), *Neocyttus psilorhynchus* (rough), *Allocyttus niger* black) were used in the analysis. CAAB codes were 37266004, 37266001, 37266006, 37266005, 37266901 and 37266902 (group code). Estimated discard rate in 2007 was 16.2 % and recent estimates 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 13.153**.** 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. Columns 2-6 represent all data while the right hand five columns represent the areas left open following the 700m closure.

Year	Records	Vessels	Effort	Yield	Geom	RecordsO	VesselsO	EffortO	YieldO	GeomO
1986	187	11	429	54.174	111.896	104	8	292	35.196	131.502
1987	249	20	681	77.989	109.667	124	13	383	20.936	86.186
1988	274	20	595	80.076	85.603	45	8	140	8.095	74.806
1989	684	31	788	382.798	143.596	97	13	234	19.900	98.826
1990	907	43	708	942.108	288.423	46	14	69	43.734	268.597
1991	875	44	1288	972.138	185.009	121	25	384	49.454	118.344
1992	1919	38	2026	2764.913	322.010	232	27	524	190.053	164.372
1993	1843	43	2426	881.321	115.798	206	26	682	73.254	119.777
1994	2133	36	3272	853.626	84.316	190	23	713	61.291	130.123
1995	2422	30	7256	983.366	98.368	595	23	2340	205.412	139.958
1996	2599	35	7738	589.604	70.088	615	29	2296	131.068	78.715
1997	2695	35	10441	731.324	104.799	732	28	3198	163.084	99.304
1998	2688	35	10830	801.091	120.613	563	26	2504	163.342	124.798
1999	2193	37	8983	502.937	105.041	419	28	1848	106.637	117.811
2000	2037	45	8887	466.591	96.445	441	34	1929	115.886	121.728
2001	2457	38	10693	682.333	111.392	621	34	2726	125.575	103.393
2002	1982	39	9751	435.642	82.673	485	32	2439	81.439	78.110
2003	1912	35	9450	396.194	82.852	422	28	2090	67.040	70.554
2004	1862	33	9551	292.373	71.463	423	29	2127	58.189	73.837
2005	1036	22	5121	156.510	66.732	254	21	1228	36.467	75.672
2006	745	25	3598	104.036	53.333	216	21	1088	24.249	53.660
2007	418	19	2101	70.960	59.521	257	19	1365	37.302	48.127
2008	312	16	1788	50.754	74.052	207	14	1136	24.856	60.463
2009	528	18	2836	76.322	63.395	528	18	2836	76.322	63.395
2010	525	15	2982	77.736	64.648	525	15	2982	77.736	64.648
2011	612	19	3705	91.564	78.054	612	19	3705	91.564	78.054
2012	572	16	3281	74.820	60.849	572	16	3281	74.820	60.849
2013	798	19	4686	155.004	79.637	798	19	4686	155.004	79.637

Table 13.154**.** The catch in tonnes of Mixed Oreos by Orange Roughy Zone, and, across OR Zones in the current open and closed areas. All data included in the OR Zones.

Year	Total	10	20	21	30	50	Open	Closed
1986	54.174	0.160	30.880		23.126	0.008	35.196	18.978
1987	77.989	0.130	10.740		67.119		20.936	57.053
1988	80.076	3.240	3.668		73.048	0.120	8.095	71.981
1989	382.798	0.300	223.037	70.232	89.169	0.060	19.900	362.898
1990	942.108	49.420	499.229	382.560	10.299	0.600	43.734	898.374
1991	972.138	42.790	132.880	765.881	27.214	3.373	49.454	922.684
1992	2764.913	652.343	760.250	1274.829	75.337	2.154	190.053	2574.860
1993	881.321	1.852	279.578	374.461	195.404	30.026	73.254	808.067
1994	853.626	1.785	213.457	468.245	144.127	26.012	61.291	792.335
1995	983.366	6.628	90.778	326.718	552.995	6.247	205.412	777.954
1996	589.604	17.209	113.483	90.035	330.440	38.437	131.068	458.536
1997	731.324	50.988	159.385	48.719	445.601	26.631	163.084	568.240
1998	801.091	38.664	141.880	63.831	424.179	132.537	163.342	637.749
1999	502.937	14.875	129.003	14.805	286.040	58.214	106.637	396.300
2000	466.591	42.391	121.102	18.698	259.548	24.852	115.886	350.705
2001	682.333	31.145	196.224	119.010	315.806	20.148	125.575	556.758
2002	435.642	38.252	79.809	56.770	248.524	12.287	81.439	354.203
2003	396.194	36.972	67.427	54.730	217.764	19.301	67.040	329.154
2004	292.373	13.175	49.340	10.498	202.142	17.219	58.189	234.184
2005	156.510	7.047	37.017	11.780	89.283	11.383	36.467	120.043
2006	104.036	9.862	20.390	3.970	62.408	7.406	24.249	79.787
2007	70.960	13.150	18.657	1.924	35.469	1.760	37.302	33.658
2008	50.754	2.262	17.384		27.487	3.621	24.856	25.898
2009	76.322	4.423	17.431	0.078	48.647	5.743	76.322	
2010	77.736	5.658	25.590	5.860	37.681	2.947	77.736	
2011	91.564	9.773	25.261	1.990	48.584	5.956	91.564	
2012	74.820	5.500	20.535	0.062	34.404	14.319	74.820	
2013	155.004	11.211	49.417	0.180	87.269	6.927	155.004	
Total	13748.304	1111.204	3533.831	4165.866	4459.114	478.288	2317.904	11430.399

In the last five years 68-88% has been reported as Oreo Dory and the remainder as Spiky, Oxeye and Smooth oreos. Only data from OR Zones 10, 20, 21, 30, 50, in depths 500 – 1200 m 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.

Table 13.155. 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

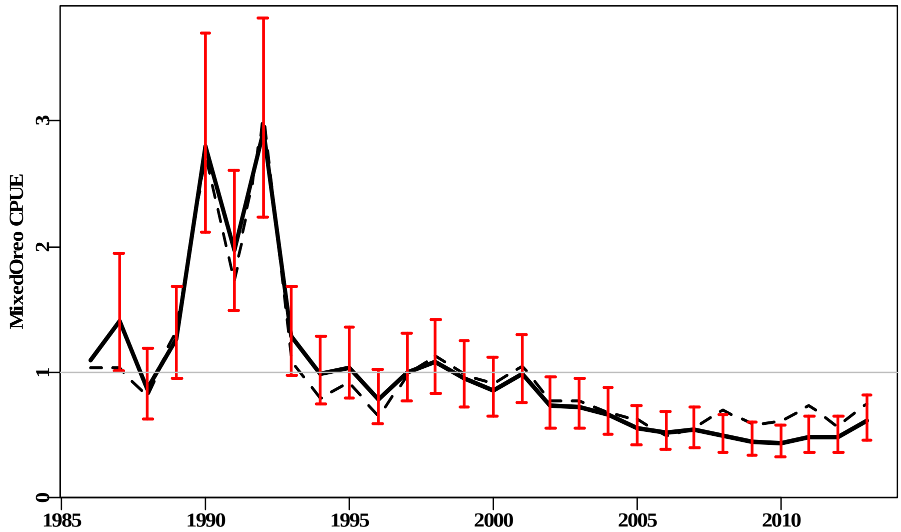


Figure 13.158. The standardized catch rates showing the optimum model (solid black line) and the geometric mean catch rate (dashed line) each scaled to the mean of each time series. The error bars are two times the standard errors.

Table 13.156. Mixed oreos. Model selection criteria include the Akaike Information Criterion (AIC), residual sum of squares (RSS), model sum of squares (MSS), number of usable observations (Nobs), number of parameters (Npars), adjusted R^2 (adj_R^2) and the increment in adjusted R^2 (ΔR^2). Model 8 (Vessel:Month) was optimal. The effect of being in the open or closed areas (Closed) was minor (Figure 13.159). Depth category: DepC; Month: Mth.

	Year	Vessel	DepC	Month	ORZone	DayNight	Closed	Vessel:Month	DepC:Mth
AIC	29172	24319	23002	22270	21877	21811	21760	21345	21416
RSS	81496	71130	68437	67063	66346	66216	66122	60839	64974
MSS	6024	16390	19083	20457	21174	21304	21397	26681	22546
Nobs	37464	37464	37208	37208	37208	37208	37208	37208	37208
Npars	28	150	164	175	179	182	183	1525	337
adj_R^2	6.816	18.403	21.460	23.014	23.829	23.972	24.077	27.516	25.084
ΔR^2	6.816	11.587	3.057	1.554	0.815	0.143	0.105	3.439	1.007

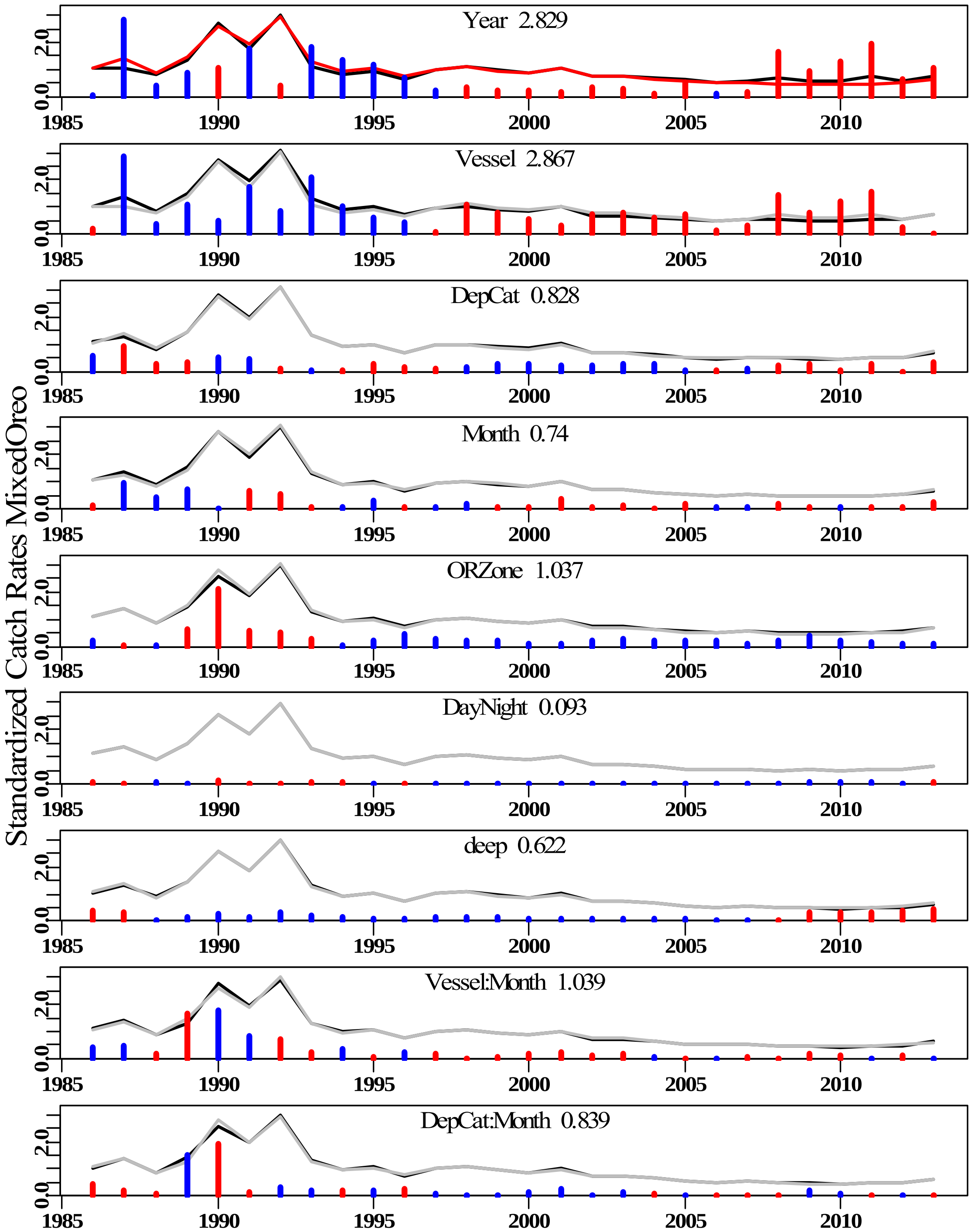


Figure 13.159**.** Relative impact of each factor on the final trend. Blue bars indicate the standardization is above the previous model, red bars indicate it is below. Closures appear to have only a very small effect.

Table 13.157. 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.

	37266001	37266002	37266004		37266001	37266002	37266004	37266902
Year	Spiky	Oxeye	Warty	Year	Spiky	Oxeye	Warty	Oreo Dory
1986	19.27	3.21	31.70	2000	345.437	0.030	30.987	
1987	39.95	13.71	18.08	2001	392.974	0.400	6.060	
1988	13.86	8.50	17.98	2002	210.951	0.095	1.595	
1989	165.77	27.31	13.44	2003	228.224		0.300	
1990	241.81	3.40	2.06	2004	179.733	0.120	1.540	
1991	80.49	2.68	0.53	2005	93.756	1.679		7.510
1992	603.20	11.71	1.05	2006	38.109	8.757		42.151
1993	271.82	3.14	3.02	2007	11.771	11.260		46.983
1994	264.43	3.10	18.62	2008	6.983	0.950		41.581
1995	465.93	17.17	14.03	2009	6.851	1.388		66.788
1996	404.07	0.55	15.55	2010	8.061	0.660		68.006
1997	552.55	4.93	20.19	2011	6.802	7.875		71.460
1998	641.57	0.34	24.81	2012	8.235	13.591		51.278
1999	429.47	0.08	11.22	2013	18.378	14.145		120.456

Table 13.158. 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 Vessel: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 inFigure 13.159.

Year	Year	Vessel	DepCat	ORZone	DayNight	Deep	Vessel:Month	StErr
1986	1.0407	1.0182	1.0883	1.1040	1.0972	1.0467	1.1002	0.0000
1987	1.0304	1.3873	1.2739	1.3890	1.3872	1.3487	1.4087	0.1664
1988	0.8040	0.8489	0.8156	0.8744	0.8808	0.8852	0.8636	0.1655
1989	1.3454	1.4830	1.4397	1.4508	1.4543	1.4725	1.2673	0.1462
1990	2.7013	2.7627	2.8262	2.5648	2.5505	2.5848	2.8045	0.1424
1991	1.7328	1.9487	2.0021	1.8475	1.8464	1.8675	1.9705	0.1432
1992	3.0140	3.1189	3.1082	2.9761	2.9747	3.0135	2.9228	0.1378
1993	1.0839	1.3435	1.3450	1.3001	1.2920	1.3162	1.2858	0.1387
1994	0.7891	0.9150	0.9119	0.9248	0.9194	0.9378	0.9811	0.1374
1995	0.9206	0.9951	0.9570	1.0250	1.0283	1.0413	1.0380	0.1376
1996	0.6559	0.7080	0.6879	0.7377	0.7376	0.7495	0.7787	0.1380
1997	0.9808	0.9708	0.9611	1.0062	1.0063	1.0232	1.0025	0.1376
1998	1.1287	0.9939	1.0153	1.0639	1.0639	1.0841	1.0814	0.1378
1999	0.9831	0.8883	0.9244	0.9379	0.9397	0.9592	0.9531	0.1382
2000	0.9027	0.8308	0.8625	0.8671	0.8693	0.8814	0.8567	0.1383
2001	1.0425	1.0074	1.0332	1.0008	1.0026	1.0162	0.9909	0.1380
2002	0.7738	0.6832	0.7125	0.7299	0.7307	0.7408	0.7304	0.1388
2003	0.7755	0.6782	0.7105	0.7278	0.7300	0.7412	0.7221	0.1389
2004	0.6689	0.5913	0.6245	0.6489	0.6503	0.6588	0.6662	0.1391
2005	0.6249	0.5346	0.5375	0.5452	0.5479	0.5553	0.5541	0.1417
2006	0.4996	0.4833	0.4771	0.5094	0.5117	0.5181	0.5181	0.1445
2007	0.5582	0.5164	0.5290	0.5442	0.5452	0.5461	0.5405	0.1509
2008	0.6951	0.5185	0.4932	0.4946	0.4962	0.4933	0.4919	0.1562
2009	0.5943	0.4996	0.4644	0.5058	0.5104	0.4717	0.4514	0.1478
2010	0.6060	0.4564	0.4509	0.4809	0.4848	0.4470	0.4323	0.1473
2011	0.7315	0.5378	0.5069	0.5189	0.5246	0.4842	0.4862	0.1458
2012	0.5703	0.5388	0.5386	0.5449	0.5462	0.5011	0.4851	0.1490
2013	0.7460	0.7415	0.7025	0.6793	0.6717	0.6148	0.6160	0.1452

13.56 REFERENCES

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14. Blue Eye Fishery Characterization 1986 - 2013

Malcolm Haddon

CSIRO Marine and Atmospheric Research, GPO Box 1538, Hobart, TAS 7001, Australia

14.1 Summary

In 2013 the stock status for Blue Eye (*Hyperoglyphe antarctica*) was assessed using a standardized CPUE time series for the auto-line and bottom-line fisheries, which are combined for the purpose (SESSF zone 10 – 50 with 83 – 85). In addition, the time series of CPUE for trawls, relate to SESSF zones 20 – 30 (eastern Bass Strait and eastern Tasmania) and 40 – 50 (western Tasmania and western Bass Strait) were examined, although these only relate to a small fraction of the total fishery so less attention is given them. However, these 2013 standardizations, and the Tier 4 analyses dependent upon them, were no longer considered to provide an adequate representation of trends within, and hence the status of, the Blue Eye fishery. The reported expansion of whale depredations on long-line catches 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 recent movement of fishing effort much further north off the east coast of New South Wales and Queensland has altered the reliability of CPUE as an indicator of relative abundance. There were many factors that could potentially change fishing behaviour and hence affecting CPUE that could not be included in any standardization. In addition, the structural adjustment that occurred in 2006 may also have had such an influence. The key and difficult question of the reliability of simple CPUE analyses 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. Catches in what is now the GHT were significant prior to 1997 but are not readily available in any detail. While trawl catches have continued at a low but steady level since 1986 there has been a switch or transition from Drop-line (alternatively Demersal Line) to Auto-line. In the last three to four years, related to the move of the total catch away from the east coast of Tasmania, the use of alternative line methods (rod-reel, and hand-line) has increased, although, possibly in response to reductions in the available quota, catches by these methods have now declined again..

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, it is assumed the various closures in the south-east have had little or only minor effects on catch rates.

In reality, the recent relatively large shift in effort to the north-eastern sea-mounts is a change whose impact is difficult to assess. It is the case that examination of the CPUE from the minor line methods (Rod-and-Reel, and Hand-Line) indicates no particular trends in CPUE, but to make those analyses required amalgamation of data across seamounts so the possibility of serial depletion cannot be

excluded. Now that quota is less available these catches seem to have declined again to relatively low levels.

The repeated Industry statements implying that whale depredations do indeed have significant effects on both observed CPUE but also on fisher behaviour, are certainly difficult to identify and isolate as a depressing effect with currently available data. A key question to answer is whether the rate of depredation has increased through time on the auto-line vessels, and if so on what time-table, or has been stable from the inception if auto-line use. This is important because the initial catches by auto-line were relatively minor anyway, it is only from 2002 onwards that auto-line catches and CPUE dominate.

Closures have undoubtedly shut off some previously popular fishing grounds for Blue Eye Trevalla, so these extraneous factors, which cannot be directly included in the standardizations because they are instantaneous transitions (not present then present), can certainly be concluded to have had some negative effects upon CPUE; however, estimating the extent of any such effects remains a difficult problem that can only be approached indirectly. 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.

One of the foundation of the current assessment is that the CPUE for drop-line and auto-line can be combined. This is the case because both have used catch-per-record (or day) as their unit of CPUE and on that basis their CPUE was comparable. The combination was required because on their own each only had a rather shorter time-series of usable CPUE (sufficient catches, records and representative coverage of the fishery) that could be used for assessment purposes. Catch-per-day as used because early use of the log-books had often mixed up the reporting of lines and hooks-per-line making their direct use invalid. However, by detailed examination of records it was possible to clean this data so it could be used as an alternative estimate of effort. When this was done a different, less variable CPUE time-series was obtained for drop-line catches. This was important because the earliest CPUE from the combined data appeared relatively high making more recent trends appear to be a large decline. In addition, by focussing on the auto-line and drop-line data that are representative of the fishery (i.e. catches in all the major Blue Eye SESSF zones, 20 – 50, in the same year) now suggests a relatively flat but noisy CPUE series until a step down in the auto-line CPUE from 2010 onwards. Further examination is required to elucidate the drivers behind this drop down.

Further work is recommended to expand on what is known about the fishery data and how it interacts with management changes (structural adjustment, TAC changes, closures, etc).

The validity of the previous analyses conducted on Blue Eye catch rates should now be questioned. There are undoubted uncertainties that were not previously accounted for the CPUE time-series that were used for earlier advice. The alternatives presented in this document should only be considered as draft analyses but the correctness of any earlier recommendations can certainly be questioned.

14.2 Introduction

In 2013 the stock status for Blue Eye (*Hyperoglyphe antarctica*) was assessed using a standardized CPUE time series for the auto-line and bottom-line fisheries, which combined data from 8 zones for the purpose (SESSF zone 10 – 50 with 83 – 85; (Figure 14.1). In addition, the time series of CPUE for trawls, relating to SESSF zones 20 – 30 (eastern Bass Strait and eastern Tasmania) and 40 – 50 (western

Tasmania and western Bass Strait) were examined, although these only relate to a small fraction of the total fishery so less attention is given them (Haddon, 2014 a, b). However, these standardizations, and the Tier 4 analyses dependent upon them, were no longer considered to provide an adequate representation of trends within and hence the status of the Blue Eye fishery.

The reported expansion of whale depredations on auto-line catches 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 recent movement of fishing effort much further north off the east coast of New South Wales and Queensland has altered the reliability of CPUE as an indicator of relative abundance. This change in reliability reflects that there were changes in the CPUE for particular areas which were not due to inferred changes in fish abundance but rather were due to alterations in fishing behaviour that were not captured in the standardization. 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 (Haddon, 2014,c).

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. Catches in what is now the GHT were significant prior to 1997 but are not readily available. Earlier estimates, constituting combining State with Commonwealth estimates, taken from earlier assessment summaries (Tilzey, 1999; Smith and Wayte, 2002) are given in the Appendix (Table 14.29). 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, although now that the TAC is decreasing the proportion of the total catch being taken by these 'minor line' methods is declining again.

The Tier 4 analysis in 2013 (Haddon, 2014 b) was conducted on all assessed blocks together and on the east and west coast of Tasmania separately. The latter indicated that the east coast was very close to the limit reference point within the Tier 4 analysis whereas the west coast analysis indicated the populations there were close to the target reference point. In the AFMA TAC recommendations for 2014/15 (AFMA, 2013) it was stated that:

> In making recommendations for 2014-15, the RAG noted that last year it did not have sufficient confidence in the Tier 4 assessment to use it for an RBC recommendation. Instead, the 2012-13 RBC was continued through to 2013-14 with recommendations for additional scientific work around the effect of Killer Whales, the New Zealand experience with Blue-eye Trevalla and the effects of closures and fishing on seamounts. Although this additional work was undertaken, some uncertainties with the assessment remain.
>
> In 2013, the Tier 4 assessment treated eastern and western zones separately to better account for spatial differences in stock depletion. The RAG noted that the assessment did not account for the potential influence of Killer Whale depletion of catches or the effect of recent spatial closures, and so was inherently conservative. For this reason, and the additional precaution provided by closures, the RAG recommended that the default Tier 4 discount factor of 15% should not apply to TAC-setting for 2014-15.
>
> The RAG recommended that Blue-eye Trevalla be reassessed in 2014 to allow the effect of spatial closures and Killer Whales to be better dealt with, but noted that there was currently a lack of information available to treat Killer Whale depredation in an evidence-based manner.

> Consistent with the RAG's advice, AFMA Management recommends that the TAC be set at 229 tonnes for one fishing season (2014-15). It also recommends that the percentage for undercatch and overcatch be determined at 10% and that no discount factor be applied. AFMA (2013, p5).

Specific questions that need attention relate to the representativeness of particular regions for the fishery as a whole. CPUE standardization can be very effective but works best when there are large numbers of records, which relates to representativeness again. In some years and with some methods the catches and number of records in particular areas were relatively low. The assumption that these limited data constitute a representative sample of the whole stock is difficult to test but at least is can receive attention.

Whether there is now sufficient information from the fishery to determine whether the planned sequence of declines in TAC should continue needed to be determined. This report attempts to summarize the available information and present in in a manner that should assist with answering this question.

14.3 Objectives

The intent of this report is to characterize the fishery for Blue Eye Trevalla in sufficient detail to determine whether or not the suggested step-down in TAC is still required. The specific objectives were to:

1. Update the CPUE around the different fishing regions. *This is a description of Catch per Unit Effort trends in different identifiable regions of the fishery based on different*

2. Document any shifts between fishing methods. *This is a characterization of how catch and effort – separately – have been distributed among different methods and how this has changed through time.*

3. Document any shifts between fishing regions. *This is a characterization of how catch and effort – separately – have been distributed among different regions and how this has changed through time.*

14.4 Methods

14.4.1 Catch Rate Standardization

14.4.1.1 Data Selection

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

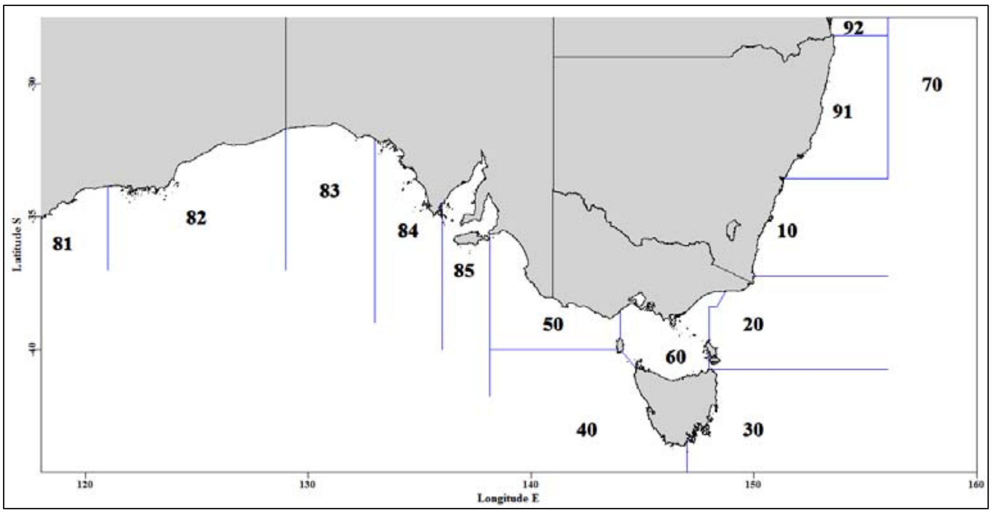

Figure 14.1. A schematic diagram depicting the statistical reporting zones in the SESSF, as used in this document. The GAB fishery is to the west of Zone 50. The main SESSF trawl zones are zones 10 – 50. Each zone extends out to the boundary of the EEZ, except for zones 50 and 60, and for zones 92 and 91, which are bounded by zone 70.

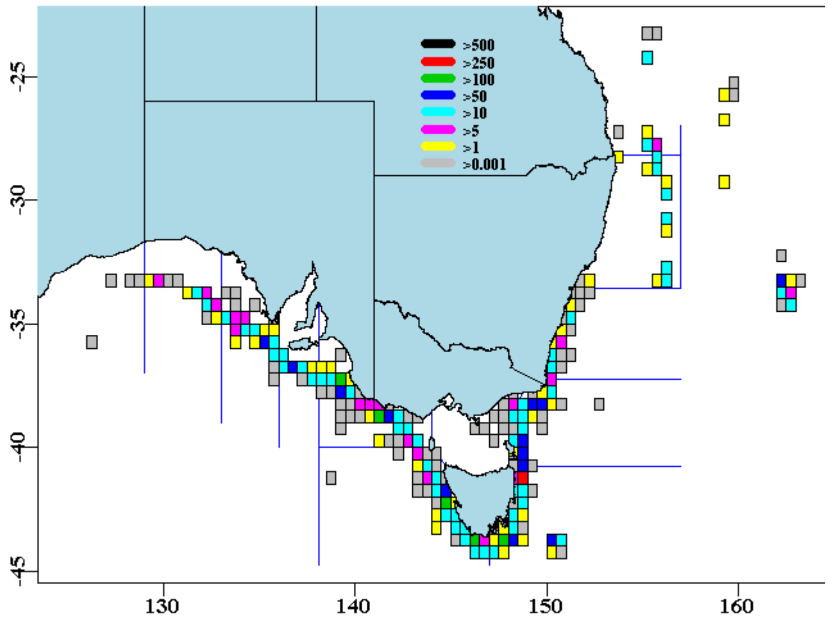

Figure 14.2.Schematic map of all reported catches of blue eye by all methods from 1986 – 2013 in 0.5 x 0.5 degree squares. At least two records per square were required for inclusion.

14.4.1.2 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:

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

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 α_j are the coefficients for the *N* factors *j* to be estimated (α_0 is the intercept, α_1 is the coefficient for the first factor, *etc*.).

14.4.1.3 The Year Effect

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

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

where γ_t is the Year coefficient for year *t* and σ_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:

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

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.

14.5 Results

14.5.1.1 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 0.2% of total catches from 1986 to 2013 (Figure 14.1), although 1991 and 1992 were up to 0.85%. 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 (Table 14.3).

Recently, on the northern sea mounts off the east coast the use of hydraulic reels and hand lines (RR and HL) have expanded (Figure 14.3).

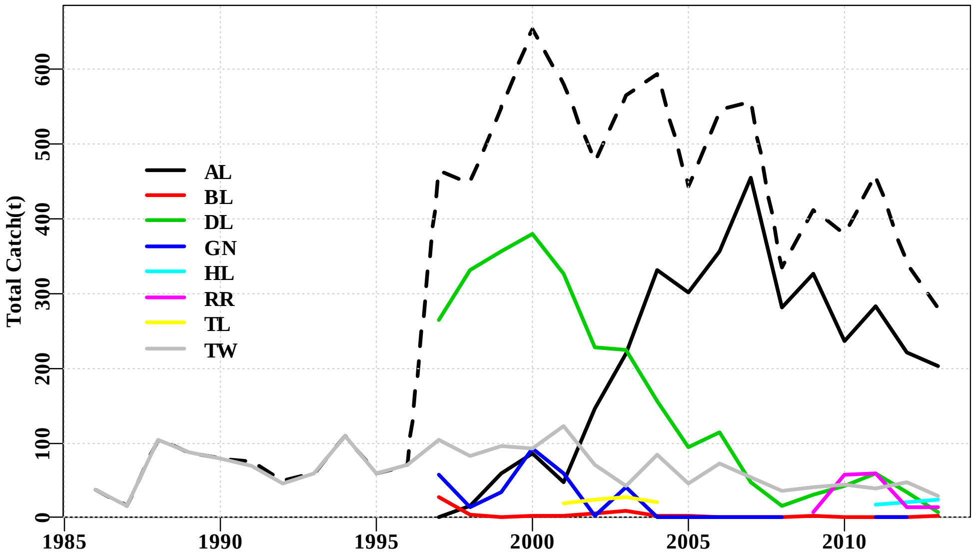

Figure 14.3.Catches of six methods that together account for about 98.6% of all reported catches of Blue Eye (Table 14.1) from 1996 – 2013. The codes are AL – auto-line, DL – drop-line, TW – trawl, GN – gill net, TL – trot line, RR – Rod and Reel, and HL – Hand Line.

The 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; in 2013 catches by trawl reduced by 20 t but estimated discard rates remained low (Upston, 2014). The non-trawl fishery has always taken the largest proportion of the total catch but useful data have only become available since 1997, with more complete data only being available from 1998 (see Table 14.29 for a previously agreed upon catch history back to 1980). 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 (Figure 14.4). This change over in the dominance of the two methods is why they are now combined in a single standardization. The time series for auto-line is truncated to start in 2001 as catches only started to be taken over a wider area and in appreciable total amounts after that time (Appendix) and before that time catches were very patchy and varied by location from year to year.

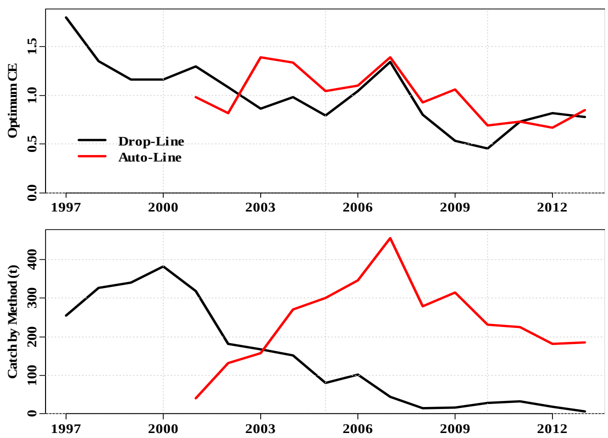

Figure 14.4**.** A comparison of the standardization for Blue Eye across zones 20 – 50 and 83 – 85 conducted separately for auto-line and drop-line. The respective catches across those zones at the same time show the changeover

Table 14.1. Reported annual catches of Blue Eye from 1986 – 2013 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 annual formal landings against quota but differ from those reported in AFMA's Catch-Watch which relate to fishing seasons (May – April).

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						0.509	71.684	
1997	0.267	265.137	104.567	58.382		6.148	28.262		0.557	463.319	
1998	15.189	330.802	82.074	14.282			4.526		1.174	448.146	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		0.768	653.775	656.847
2001	47.884	326.750	122.422	58.872		18.805	3.086		1.907	579.726	586.572
2002	145.717	227.654	71.479	1.951		23.415	6.493		0.031	476.739	512.111
2003	219.937	224.749	42.271	40.966		28.080	8.589		0.062	564.653	588.064
2004	331.788	155.341	84.516	0.171		20.116	2.318		0.009	594.258	633.794
2005	300.819	94.399	46.512	0.016			1.941		0.406	444.093	492.885
2006	356.716	115.059	71.863	0.002			1.187		0.008	544.834	563.850
2007	455.105	47.016	53.828	0.003			0.632		0.000	556.585	585.310
2008	281.384	16.055	36.046	0.016			0.724		0.072	334.297	373.047
2009	326.553	30.158	41.556		7.550		1.740		3.322	410.879	443.362
2010	236.620	42.663	43.480		56.788		0.022		0.000	379.572	399.896
2011	282.785	59.381	39.149	0.111	59.998		0.049	17.118	0.000	458.592	458.535
2012	220.732	34.107	48.432	0.003	14.776		1.377	21.021	0.011	340.460	332.297
2013	203.331	7.762	28.536		14.125		3.311	23.977	0.417	281.459	284.574

14.5.1.2 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 14.2).

Table 14.2**.** 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 2013.

Year	Landings	Total	SET	GHT	GAB	ECD+HST+HSN	Other
1986		37.962	37.962				
1987		15.495	15.467		0.028		
1988		105.177	101.767	0.160	3.250		
1989		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		3.288
1999	572.689	548.067	90.552	452.585	4.822		2.712
2000	656.847	653.775	83.454	560.125	4.050	5.408	6.539
2001	586.572	579.726	69.255	455.399	19.390	34.934	1.447
2002	512.111	476.739	66.819	386.930	1.150	10.541	11.946
2003	588.064	564.653	27.069	518.839	1.810	16.652	0.283
2004	633.794	594.258	46.912	503.624	1.831	41.646	0.246
2005	492.885	444.093	34.497	396.955	8.473	4.115	0.054
2006	563.850	544.834	54.136	469.860	11.968	8.862	0.008
2007	585.310	556.585	37.287	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	410.879	39.410	368.479		2.831	0.160
2010	399.896	379.572	43.480	335.452		0.550	0.090
2011	458.535	458.592	23.268	403.940		29.043	2.341
2012	332.297	340.460	10.781	288.946	0.011	39.400	1.322
2013	354.972	281.459	22.989	239.533		18.160	0.778

14.5.1.3 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, although the reduction in TAC has seen a drop in the absolute catches from the area. The limited number of years in the north-east with available data restricts the possibilities for analysis, and this is further restricted by a proliferation of different fishing methods associated with this shift off effort and catch.

Table 14.3**.** Catches in tonnes of Blue Eye by zone (Figure 14.1).

	70	92	91	10	20	30	40	50	80
1986			0.020	12.712	5.771	3.346	4.927	11.058	
1987				1.882	6.881	3.269	0.214	2.931	0.068
1988			0.585	3.076	18.841	1.460	23.834	53.101	3.250
1989			0.101	9.391	10.203	23.654	24.905	19.080	0.375
1990				4.201	11.622	29.411	14.880	16.030	2.925
1991				14.119	20.771	18.256	7.871	14.236	0.308
1992				2.498	13.663	3.408	7.739	21.679	0.030
1993			0.015	2.270	14.672	24.092	5.892	12.567	0.135
1994	0.115		0.030	2.861	14.919	74.892	8.140	8.842	0.125
1995			0.080	2.721	8.776	19.763	12.605	13.791	0.635
1996			0.075	4.832	9.937	25.660	9.134	21.450	0.347
1997		0.140	10.835	5.964	149.201	92.819	83.333	100.036	16.843
1998			1.590	1.774	93.416	171.130	97.903	66.989	7.967
1999		0.050	21.590	1.881	106.178	225.832	91.602	86.854	7.044
2000	5.408	0.750	1.100	0.985	129.422	271.747	129.247	95.971	9.923
2001	34.930	4.740	3.186	0.264	86.447	239.368	100.831	60.290	48.501
2002	7.469	7.850	33.664	0.489	41.624	180.660	75.524	77.538	37.437
2003	14.668	2.400	57.910	1.288	91.447	153.646	124.815	43.761	70.485
2004	36.796	0.180	10.045	0.222	73.957	148.512	112.297	63.714	147.225
2005	2.607	4.700	7.451	1.601	88.198	119.790	64.249	51.935	100.391
2006	2.540	2.508	10.375	0.192	69.824	157.401	83.899	41.217	165.364
2007	13.774			0.271	53.777	235.939	48.581	47.631	152.539
2008				0.170	46.583	130.524	55.478	26.535	74.574
2009	7.231	12.038	10.515	0.133	53.863	159.609	86.619	47.601	32.416
2010	1.797	33.977	34.124	0.109	26.136	98.273	54.924	97.572	32.010
2011	14.271	52.926	79.995	0.195	31.830	99.656	45.235	30.612	75.426
2012	15.079	13.189	74.351	0.188	21.728	67.578	77.448	22.012	22.196
2013	5.546	1.138	37.097	0.015	13.389	58.686	98.770	19.005	29.874

In 1998 one global TAC of 630 t was introduced to cover both the trawl and the GHT fisheries; this was divided 100t for trawl and 530 t for GHT. An increase in effort, particularly in the drop-line fishery on the east coast of Tasmania is reported to be a response to anticipation of that management change, with fishers believing that increasing their catch history wold lead to an increase their allocation of quota. Since 1997 total catches have declined to just over one third of the catches in 1997 (Figure 14.6). The distribution of catches in different regions indicate the changes in the intensity of fishing (Figure 14.7) with the proportion changes occurring through time showing the dominance of zones 10 – 40 as well as that changes in the location of fishing can occur rapidly from year to year (Figure 14.8).

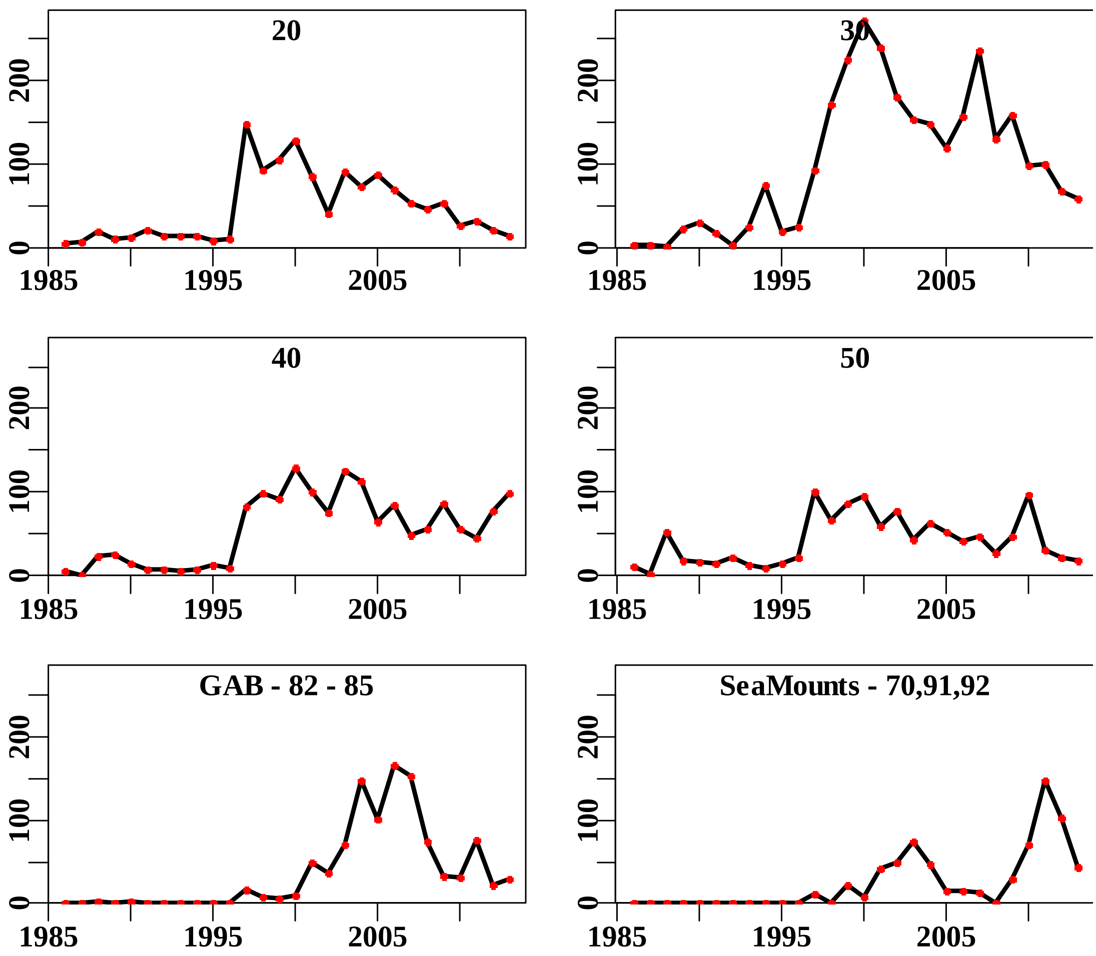

Figure 14.5. Annual catch in Blue Eye in the four zones 20, 30, 40, and 50, the GAB (zones 82 – 85) and the Seamounts (zones 91, 92, and 70) from 1986 – 2013.

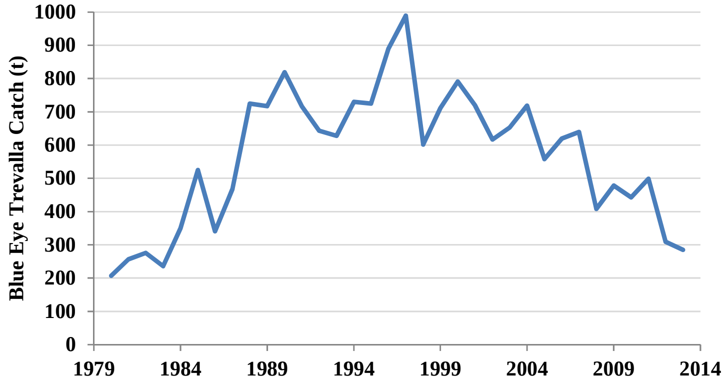

Figure 14.6. Total historical catches of Blue Eye, with estimates from 1980 – 1999 from Smith and Wayte (2002) .

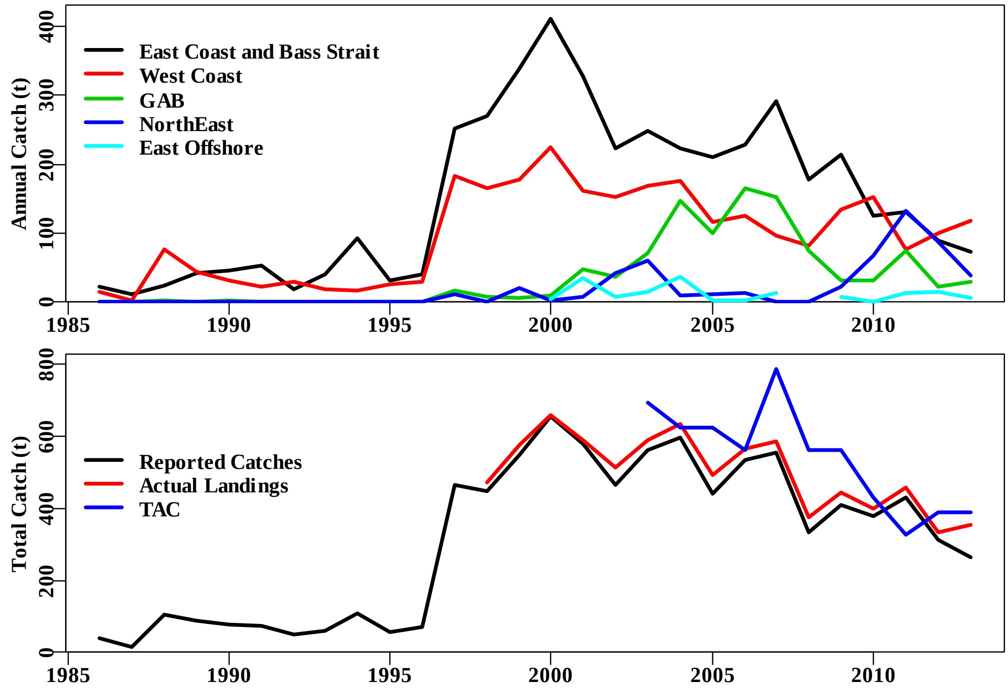

Figure 14.7.Total catches for different regions around the south east of Australia. East coast and Bass Strait includes zones 10, 20 , 30 , and 60; west coast is zones 40 and 50; GAB is zones 82, 83, 84, and 85; North East is zones 91 and 92, an East Offshore is zone 70 (Figure 14.1). The TAC is the agreed TAC, the actual will depend on over- and under-catch from the previous year, also, since 2007 the TAC fishing season has been May – April rather than annual.

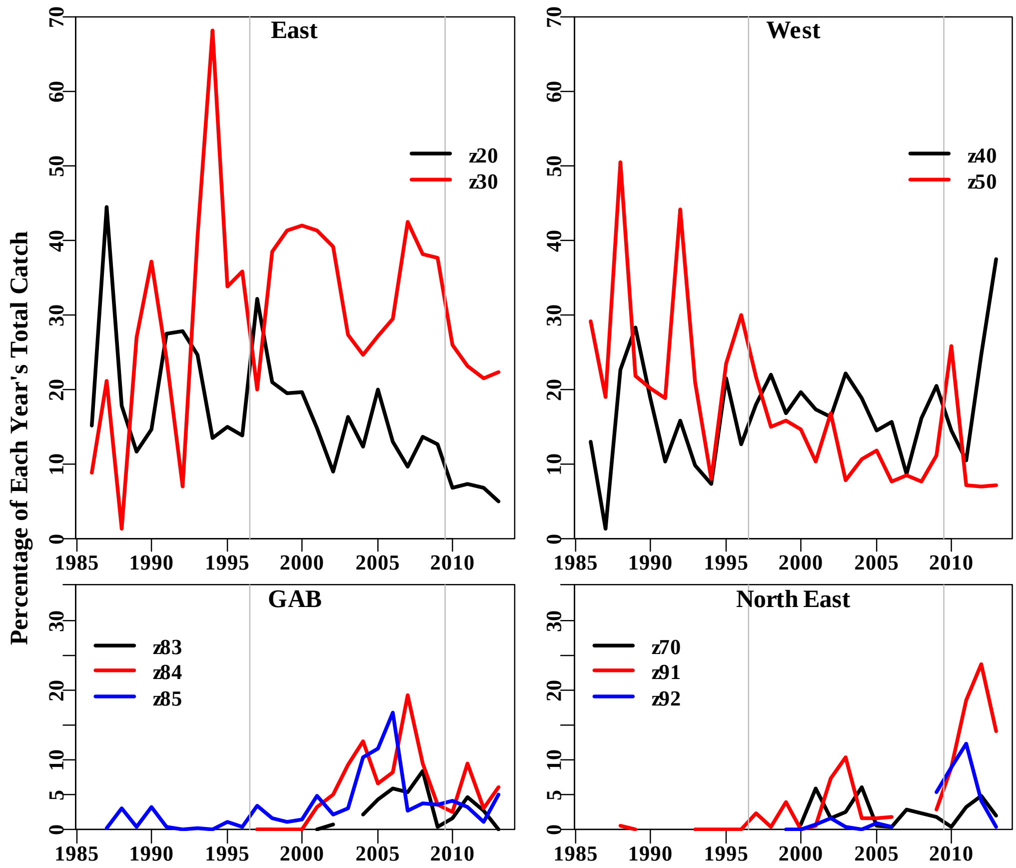

Figure 14.8**.** Percent distribution of each year's catch across regions. All graphs are on the same vertical scale. The vertical lines are to indicate 1997 and 2010, fishery changes occurred.

14.6 Catch by Main methods through Time

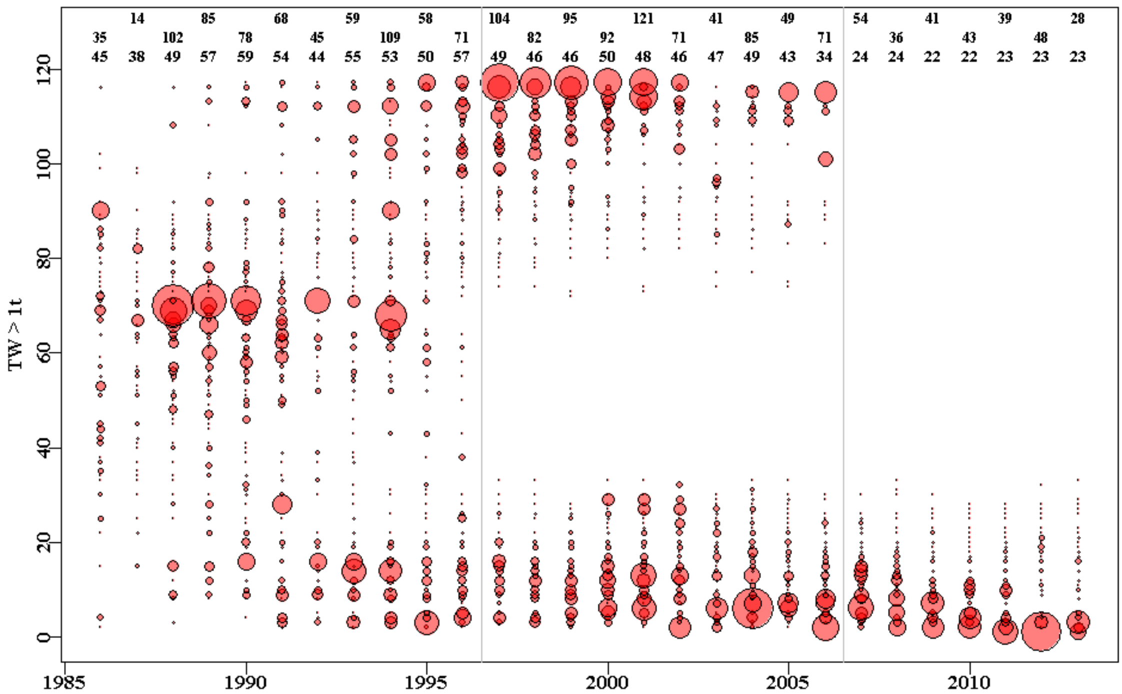

Figure 14.9**.** Relative catches by trawl vessels within each year across all fisheries for those vessels reporting the catch of more than 1 t summed across the years 1986 - 2013. The array of vessels is sorted by those remaining after 2006, then from 1997 onwards, and then from 1986. The upper two lines of text are the catches in each year, while the third line is the number of vessels.

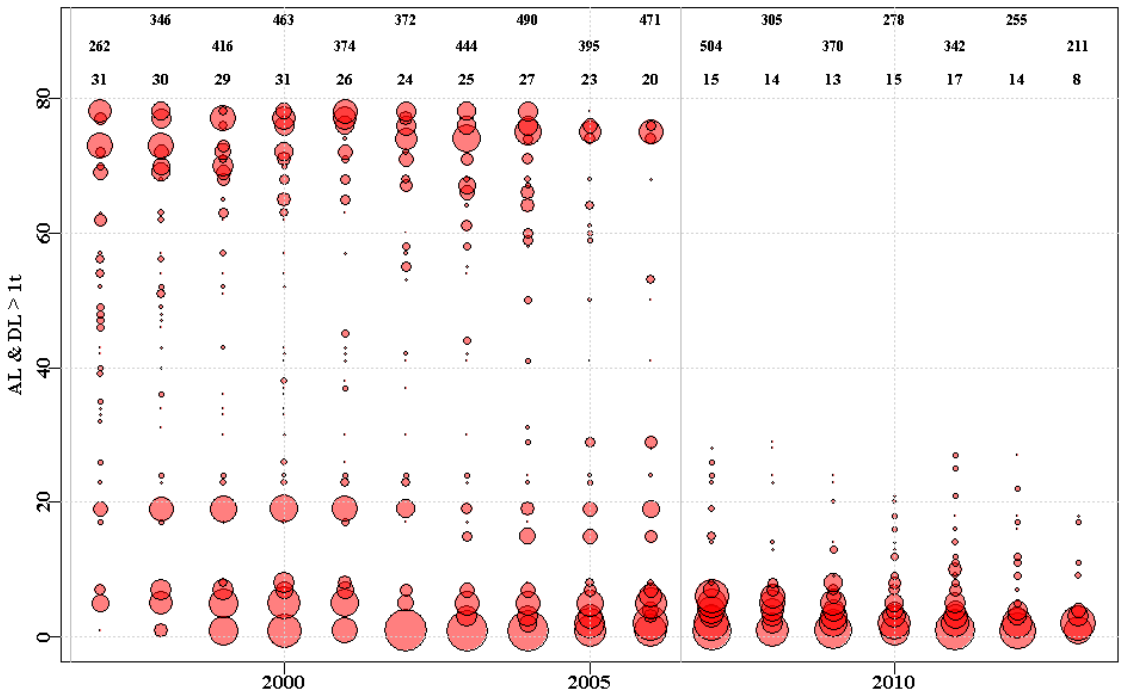

Figure 14.10. Relative catches by line vessels within each year across all fisheries for those vessels reporting the catch of more than 1 t summed across the years 1997 – 2013. The array of vessels is sorted by those remaining after 2006, then from 1997 onwards. The grey vertical line separates 2006 and 2007 to designate the structural adjustment. The upper two lines of text are the catches in each year, while the third line is the number of vessels.

14.7 Catch Distribution across SE Australia

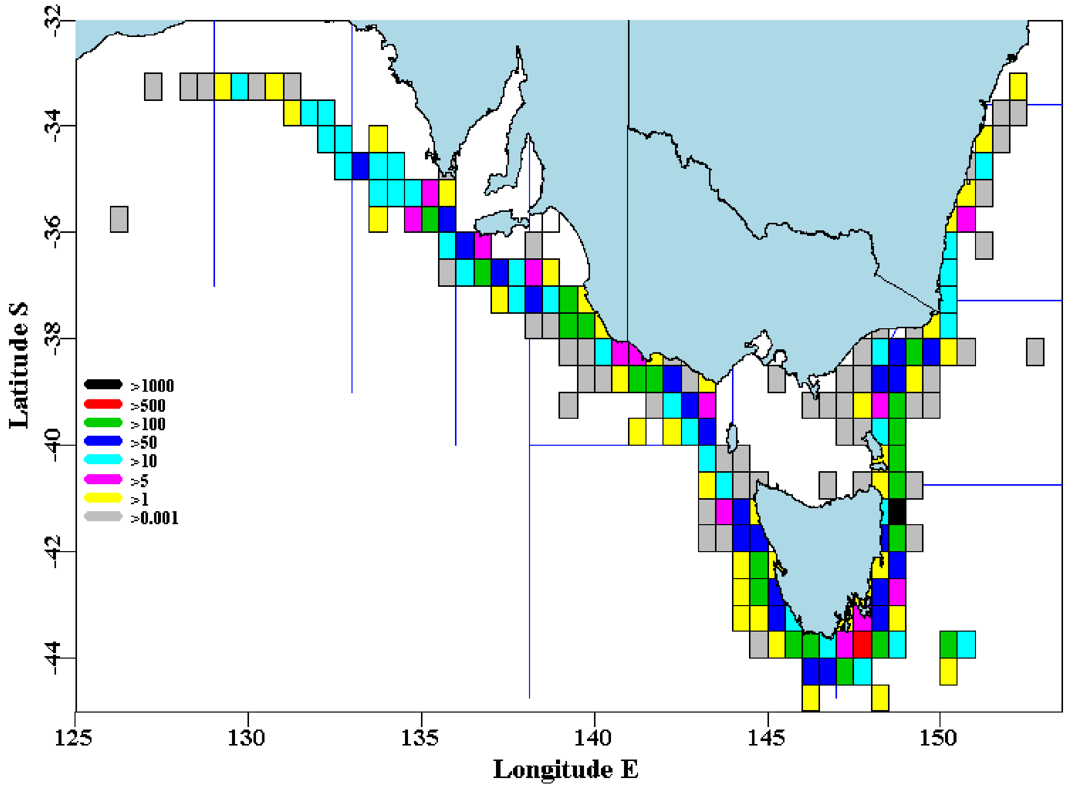

Figure 14.11. Schematic map of the distribution of all Blue Eye catches around the southern zones since 1986 onwards. The gird scale is 0.5 degree and the catch scale is in tonnes.

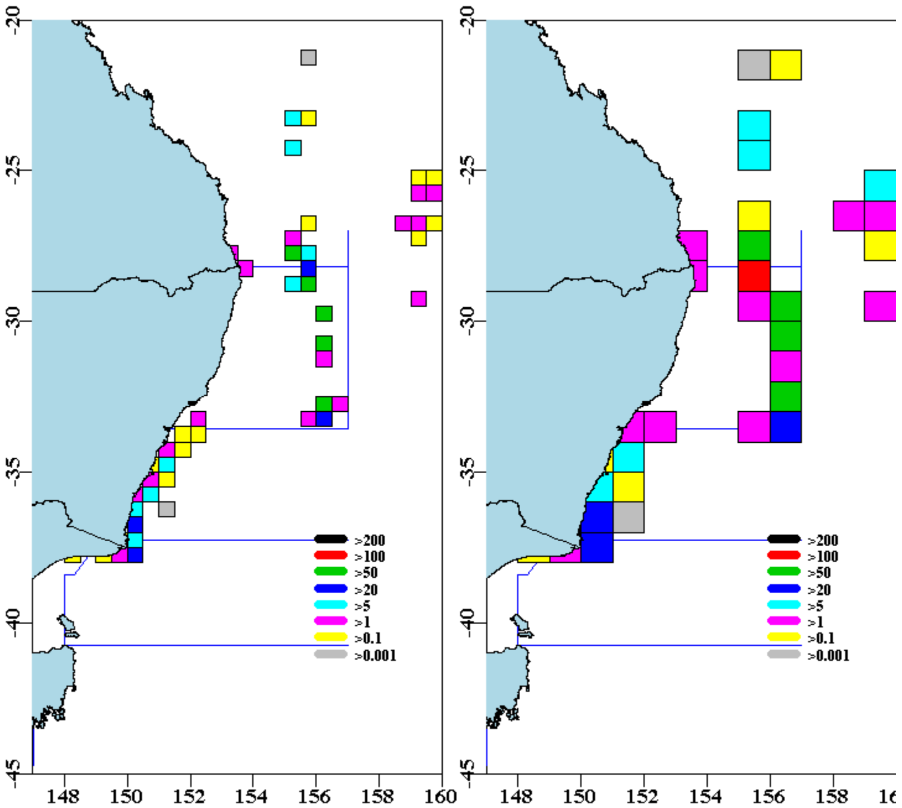

Figure 14.12. Schematic map of all Blue Eye catches since 1997 off the east coast. The grid scale is 0.25 and 0.5 degree and the catch scale is in tonnes.

14.8 Auto-Line and Drop-Line Catches

Blue Eye catches taken with AutoLine and DropLine are patchily distributed and the distribution of those catches has changed through time.

Table 14.4**.** Catch by zone of Blue Eye taken by Auto Line and Drop Line.

Year	20	30	40	50	70	83	84	85	91	92
1997	79.106	80.730	38.059	45.057				5.778	3.745	
1998	72.375	158.012	62.428	40.856				1.968	1.100	
1999	64.544	194.869	73.864	51.344				0.972	16.910	0.050
2000	38.380	192.116	114.245	59.822			0.357	5.504	0.350	0.750
2001	20.659	214.877	87.241	29.127	0.060	0.150	2.404	4.345	2.536	4.740
2002	34.257	151.234	62.851	56.857	4.700		1.561	5.380	30.164	7.850
2003	46.396	140.638	71.804	33.364	1.300		27.547	4.875	57.890	2.400
2004	62.638	123.851	83.746	45.793	1.020	5.444	60.898	39.467	9.945	0.180
2005	84.933	100.196	59.525	43.088	1.550	19.313	29.273	42.395	4.881	4.700
2006	67.115	118.703	80.403	28.130	2.540	31.117	43.306	77.133	8.395	2.500
2007	50.175	227.937	41.324	28.367	2.700	29.801	105.451	15.337		
2008	44.439	111.933	50.407	13.668	8.100	27.543	32.227	13.214		
2009	47.164	136.003	79.743	36.219	5.460	1.633	15.369	14.826	11.505	9.670
2010	25.422	83.893	47.662	69.919	1.153	6.549	9.532	15.929	7.932	3.545
2011	30.838	92.213	41.476	18.131	8.900	20.576	40.692	14.159	27.388	21.330
2012	21.176	66.302	71.830	17.454		8.417	9.736	3.752	40.113	10.017
2013	13.151	51.492	84.457	14.244	3.197	0.465	16.152	13.250	1.131	
Total	802.767	2244.998	1151.064	631.439	40.680	151.008	394.505	278.284	223.984	67.731

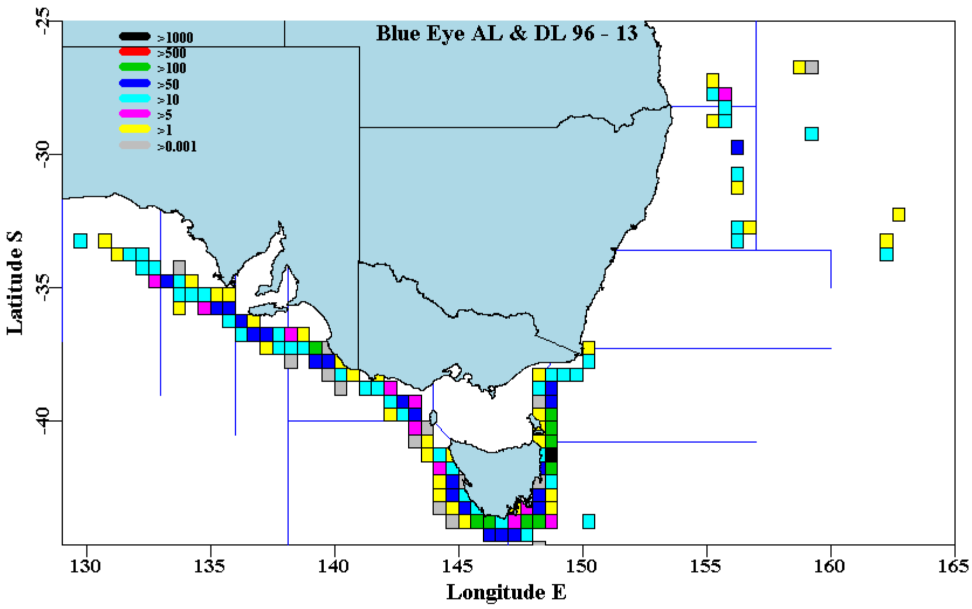

Figure 14.13**.** Schematic map of the distribution of Blue Eye catches taken by Al and DL between 1997 – 2013. The zones (Figure 14.1) are used to discern the distribution of catches

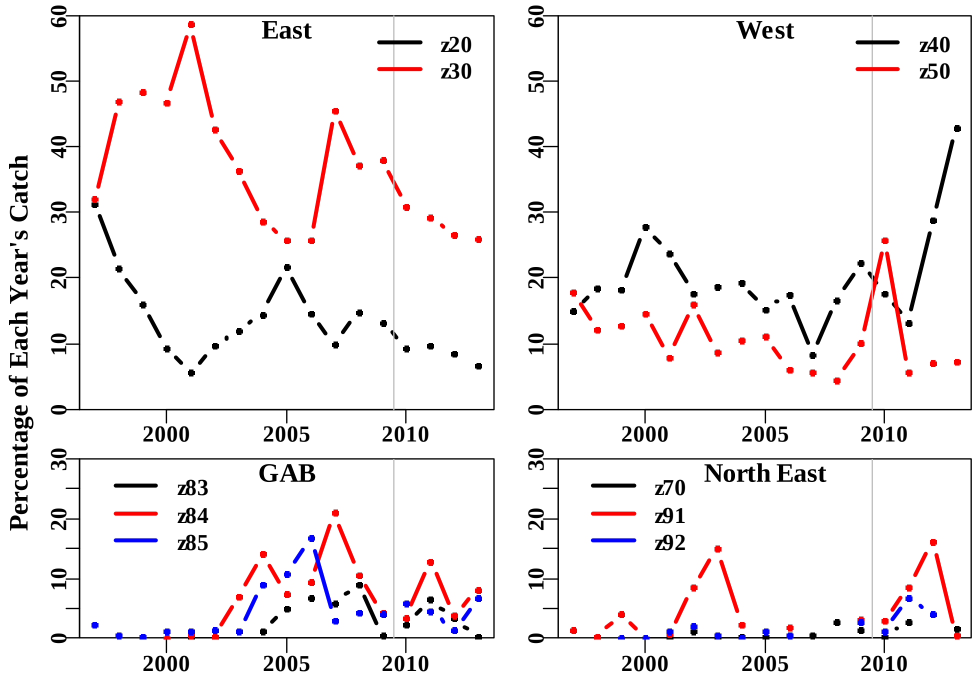

Figure 14.14. The percentage of each year's AL and DL catches taken in each zone, with the zones categorized into four regions. The vertical grey line separates 2009 and 2010.

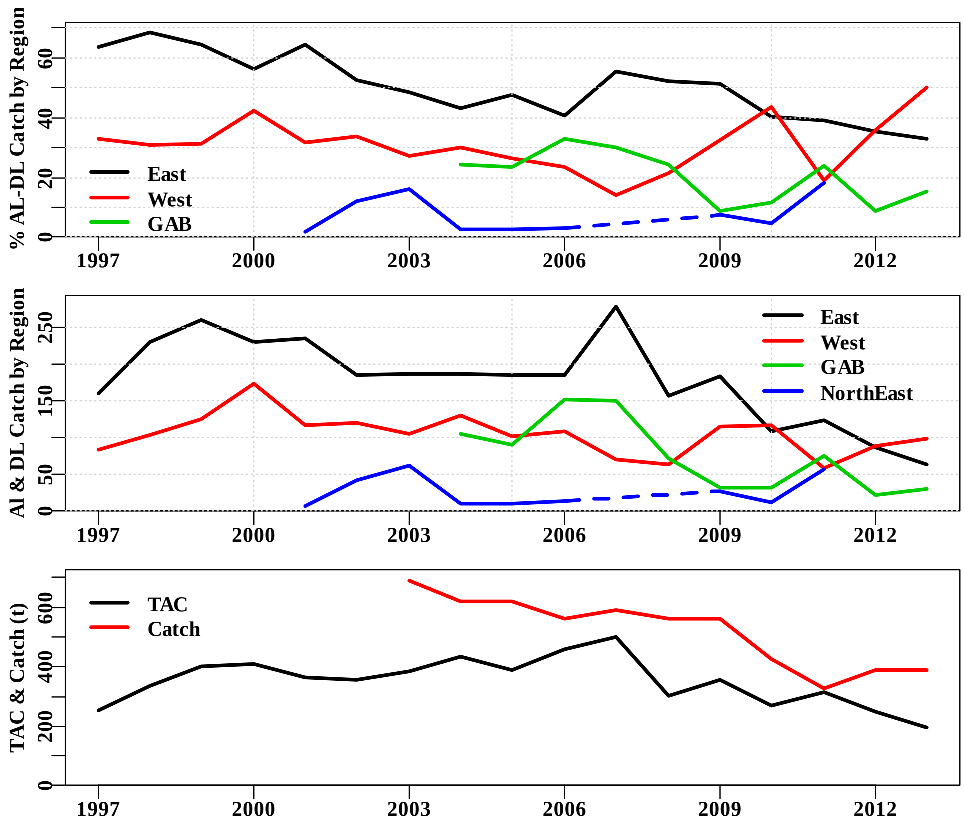

Figure 14.15. Each year's AL and DL catches, the proportion in each region through time, and the total catch with the TAC. Dotted lines bridge years with no data.

14.8.1.1 CPUE from AL and DL Vessels from Zones 20 and 30

Table 14.5. Catch by method by zone on eastern Tasmania and Bass Strait/Horseshoe areas.

Year	Zone 20 AL	Zone 20 DL	Zone 20 Total	Zone 30 AL	Zone 30 DL	Zone 30 Total
1997		80.796	80.796		80.730	80.730
1998		72.375	72.375	0.233	158.954	159.187
1999	35.575	29.061	64.636	1.725	193.339	195.064
2000	12.243	26.170	38.413	56.804	187.555	244.359
2001	2.000	18.659	20.659	31.044	191.312	222.357
2002	2.640	31.617	34.257	65.351	87.014	152.365
2003	20.634	25.822	46.456	97.288	47.450	144.738
2004	63.236	6.332	69.568	94.791	42.729	137.521
2005	84.998	0.140	85.138	60.426	42.590	103.016
2006	67.075	0.290	67.365	67.257	55.118	122.376
2007	48.019	2.174	50.193	196.324	32.071	228.395
2008	44.786		44.786	99.013	13.319	112.333
2009	50.874	0.150	51.024	125.545	11.958	137.503
2010	25.642		25.642	69.142	17.803	86.945
2011	30.835	0.003	30.838	69.512	23.158	92.670
2012	21.176		21.176	56.348	10.254	66.602
2013	13.151		13.151	45.406	6.091	51.497

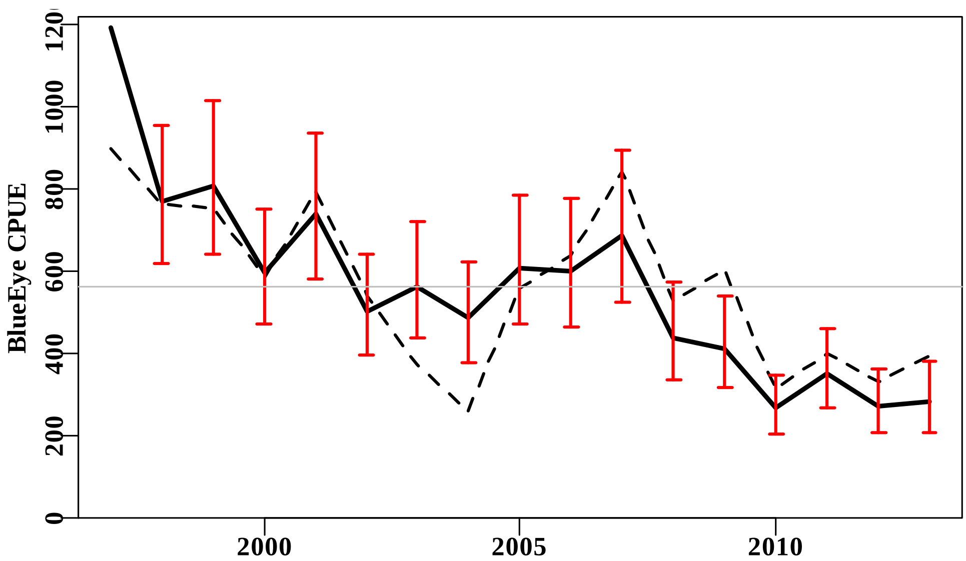

Figure 14.16. Standardized CPUE from the AL and DL fishery on the east coast (zones 20 and 30 combined) from 1997 – 2013.

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 14.16). 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 14.17).

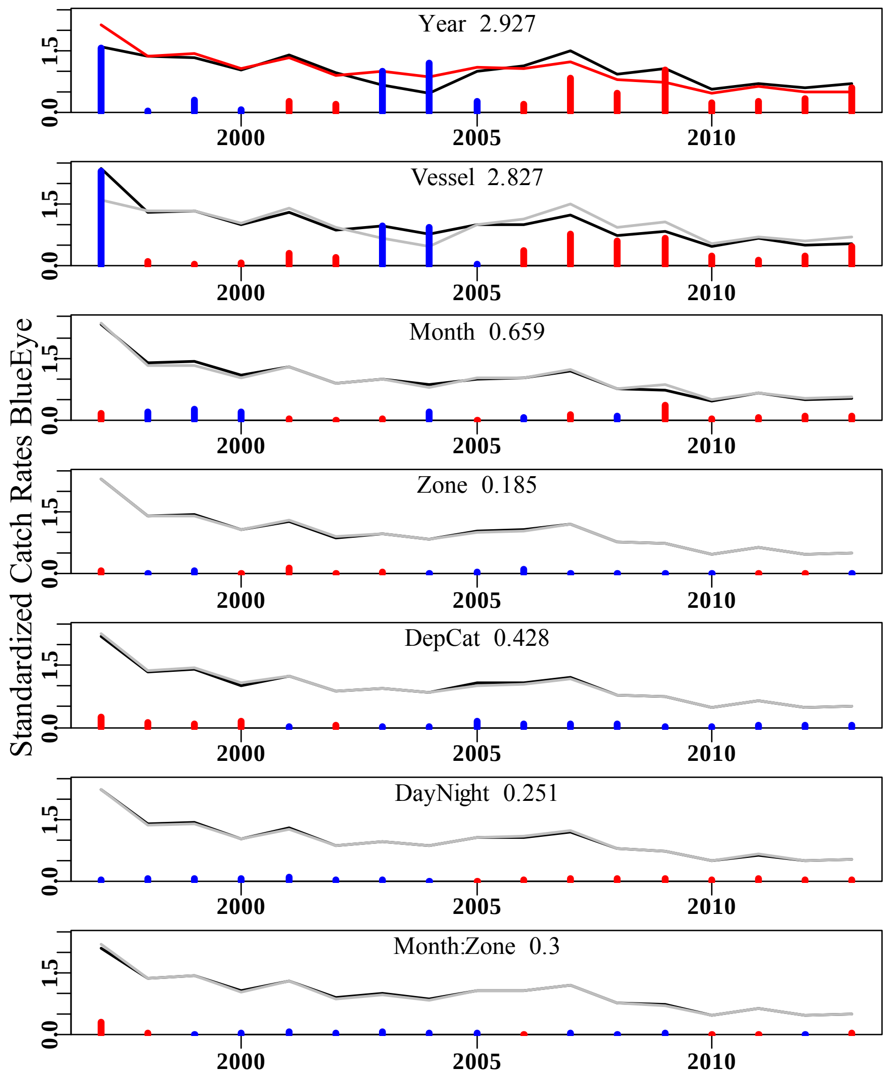

Figure 14.17**.** The relative influence of each factor used on the final trend in the optimal standardization for BlueEye by AL and DL. The top graph depicts the geometric mean (the black line) and the optimum model (the red line). The difference between them is illustrated by the vertical bars with 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 14.6. BlueEye by AL and DL from zones 20 and 30. Model selection criteria, including the AIC, the adjusted r^2 and the change in adjusted r^2. The optimum is model Month:Zone. DepCat is Depth Category.

	Year	Vessel	Month	Zone	DepCat	DayNight	Month:Zone
AIC	5098	4070	3361	3331	3282	3263	3202
RSS	14602	12488	11295	11247	11066	11028	10903
MSS	1027	3141	4334	4382	4563	4601	4726
Nobs	7289	7289	7289	7289	7260	7260	7260
Npars	17	73	84	85	111	114	125
adj_r2	6.364	19.299	26.895	27.198	28.108	28.324	29.028
%Change	6.364	12.934	7.597	0.303	0.910	0.216	0.704

Table 14.7. Blue Eye AL and DL fishery on the east coast of Tasmania and the Horseshoe. Total catch (TotCatch; t) is the total reported in the CPUE database, number of records used in the analysis (Records), reported catch (CatchT; t) using RR in the area and number of vessels used in the analysis (Vessels). GeoMean is the geometric mean of catch rates (kg/hr). The optimum model is Zone:Month and standard deviation (StDev) relates to the data in the optimum model.

Year	TotCatch	Records	CatchT	Vessels	GeoMean	Optimum	StDev
1997	462.762	279	161.526	20	738.759	2.110	0.000
1998	446.972	441	231.562	16	715.734	1.365	0.111
1999	547.773	481	259.700	17	684.099	1.433	0.117
2000	657.303	554	282.772	17	640.982	1.059	0.118
2001	578.609	422	243.015	15	753.188	1.311	0.121
2002	476.708	399	186.622	11	601.256	0.893	0.123
2003	565.101	562	191.194	15	393.266	0.996	0.127
2004	604.771	730	207.088	14	333.471	0.862	0.127
2005	446.647	495	188.153	13	451.876	1.079	0.130
2006	544.826	449	189.741	11	512.403	1.068	0.130
2007	558.985	428	278.587	11	891.332	1.217	0.135
2008	342.325	407	157.119	8	479.055	0.781	0.134
2009	420.777	403	188.527	10	621.950	0.734	0.135
2010	379.622	384	112.587	10	365.983	0.475	0.135
2011	458.592	363	123.509	9	434.048	0.627	0.137
2012	340.782	295	87.778	10	410.826	0.486	0.142
2013	281.786	197	64.648	8	432.759	0.503	0.151

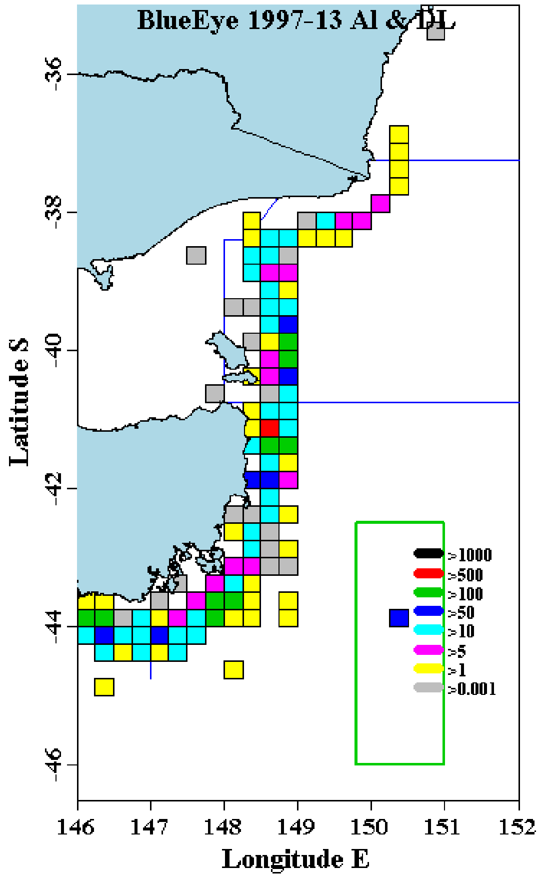

Figure 14.18**.** Schematic map of the distribution of catches form the east coast of Tasmania and Bass Strait from 1997 – 2013 taken by AL and DL. The blue square north of 150.3 is the Cascade and is not included in the east coast.

14.8.1.2 CPUE from AL and DL Vessels from Zones 40 – 50

The western fishery appears relatively flat although with relatively large variations in recent years (Figure 14.19). There appears to be a large change in the dynamics from 2006 to 2007, which suggests that the structural adjustment may had had some influences in the western fishery (Table 14.8;Figure 14.20).

Table 14.8**.**Catch by method by zone on western Tasmania and off Portland.

Year	Zone 40 AL	Zone 40 DL	Zone 40 Total	Zone 50 AL	Zone 50 DL	Zone 50 Total	Total
1997	0.267	40.722	40.989		45.977	45.977	86.966
1998	14.956	49.692	64.648		40.856	40.856	105.504
1999	11.482	65.244	76.726		55.078	55.078	131.804
2000	14.824	104.457	119.280		59.822	59.822	179.102
2001	14.598	72.643	87.241		29.127	29.127	116.368
2002	42.576	20.530	63.106	21.400	35.487	56.887	119.993
2003	84.594	33.081	117.674	9.900	29.464	39.364	157.038
2004	82.677	12.169	94.846	27.149	23.579	50.728	145.573
2005	57.265	2.261	59.525	36.482	6.651	43.133	102.658
2006	77.940	2.463	80.403	25.822	2.308	28.130	108.532
2007	41.074	0.250	41.324	23.907	4.460	28.367	69.692
2008	51.837		51.837	11.408	2.260	13.668	65.505
2009	79.909	0.010	79.919	32.355	5.700	38.055	117.974
2010	50.841	0.165	51.006	63.093	6.826	69.919	120.925
2011	38.809	3.615	42.424	14.160	3.971	18.131	60.555
2012	70.428	1.403	71.830	11.183	6.271	17.454	89.285
2013	84.451	0.007	84.457	13.684	0.910	14.594	99.052

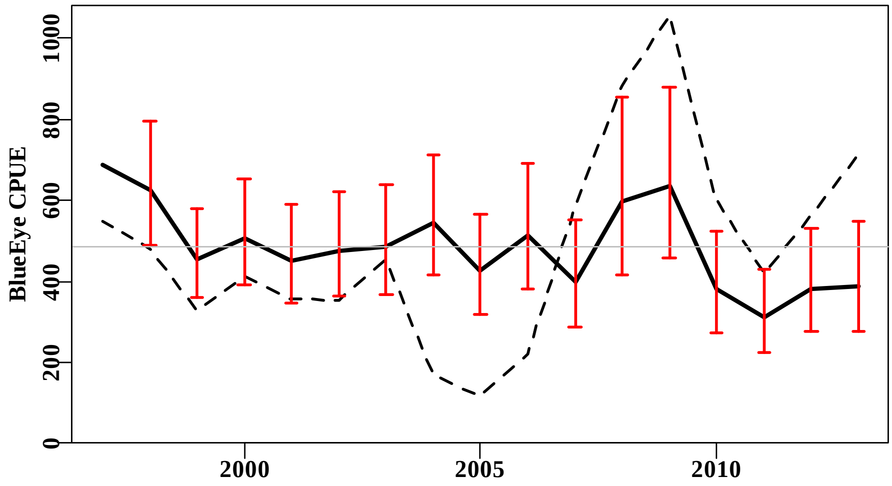

Figure 14.19**.** Standardized CPUE from the AL and DL fishery on the west coast (zones 40 and 50 combined) from 1997 – 2013.

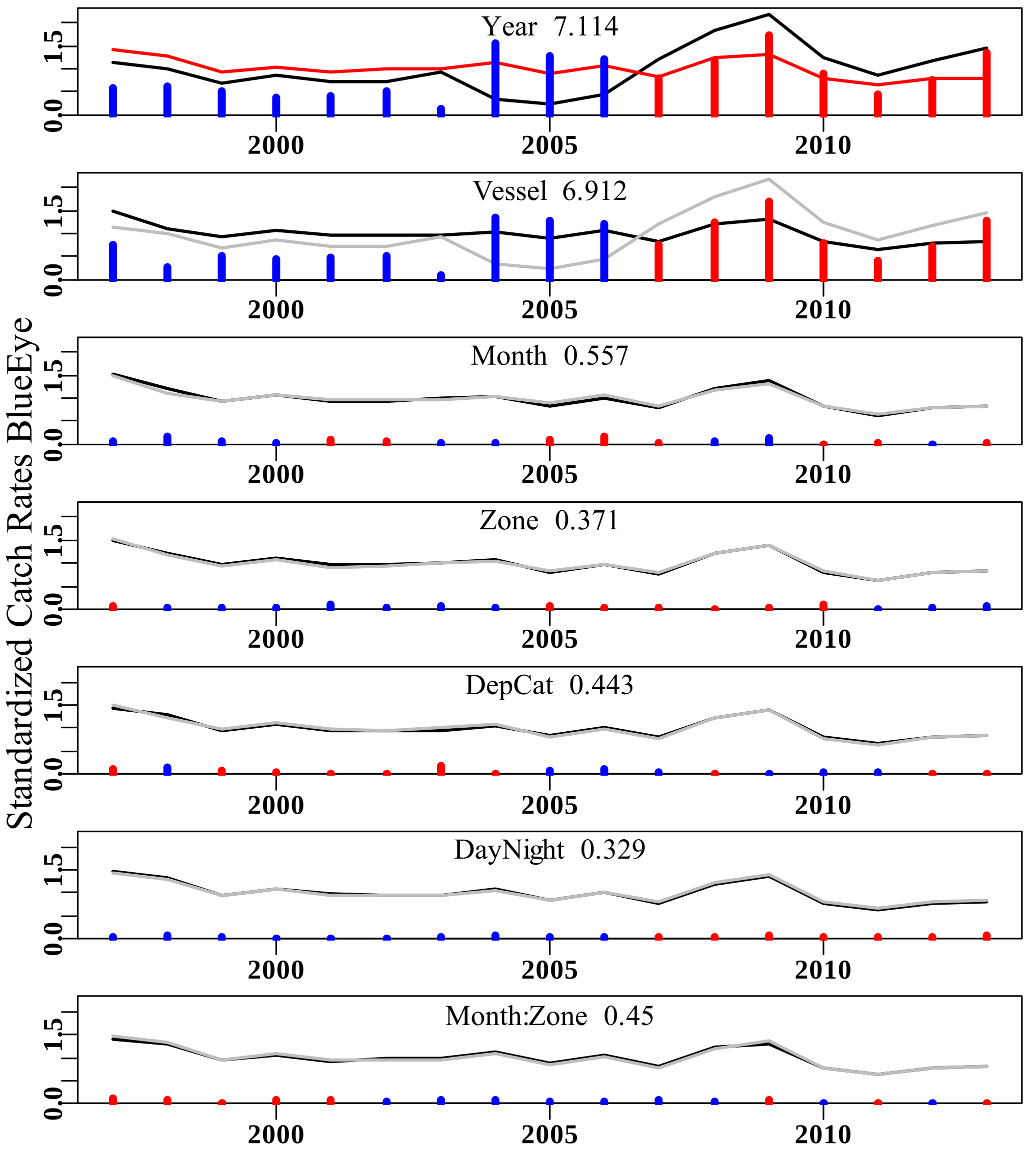

Figure 14.20**.** The relative influence of each factor used on the final trend in the optimal standardization for BlueEye by AL and DL in zones 40 and 50. The top graph is the geometric mean (the black line) and the optimum model (the red line). The difference between them is reflected by the vertical 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 14.9. BlueEye by AL and DL from zones 40 and 50. Model selection criteria, including the AIC, the adjusted r^2 and the change in adjusted r^2. The optimum is model Month:Zone. DepCat is Depth Category.

	Year	Vessel	Month	Zone	DepCat	DayNight	Month:Zone
AIC	4460	2960	2788	2737	2669	2663	2604
RSS	12215	8991	8668	8581	8377	8359	8230
MSS	1714	4938	5262	5348	5553	5571	5700
Nobs	5295	5295	5295	5295	5269	5269	5269
Npars	17	78	89	90	113	116	127
adj_r2	12.040	34.500	36.723	37.343	38.556	38.656	39.470
%Change	12.040	22.459	2.224	0.619	1.213	0.100	0.814

Table 14.10. Blue Eye AL and DL fishery on the west coast of Tasmania and off Portland. Total catch (TotCatch; t) is the total reported in the CPUE database, number of records used in the analysis (Records), reported catch (CatchT; t) using RR in the area and number of vessels used in the analysis (Vessels). GeoMean is the geometric mean of catch rates (kg/hr). The optimum model is Zone:Month and standard deviation (StDev) relates to the data in the optimum model.

Year	TotCatch	Records	CatchT	Vessels	GeoMean	Optimum	StDev
1997	462.762	224	86.966	21	477.169	1.415	0.000
1998	446.972	278	105.504	19	483.335	1.286	0.124
1999	547.773	460	131.804	20	353.726	0.937	0.122
2000	657.303	541	179.102	22	388.679	1.042	0.129
2001	578.609	353	116.368	15	451.361	0.929	0.136
2002	476.708	373	119.993	15	391.955	0.980	0.137
2003	565.101	366	157.038	16	520.790	0.996	0.141
2004	604.771	673	145.573	17	254.601	1.121	0.136
2005	446.647	596	102.658	13	213.114	0.875	0.145
2006	544.826	336	108.532	12	448.323	1.055	0.151
2007	558.985	144	69.692	7	585.500	0.820	0.168
2008	342.325	89	65.505	7	1076.801	1.227	0.185
2009	420.777	164	117.974	8	967.381	1.308	0.166
2010	379.622	201	120.925	9	930.485	0.782	0.165
2011	458.592	184	60.555	11	406.050	0.639	0.165
2012	340.782	166	89.285	9	652.298	0.787	0.167
2013	281.786	147	99.052	6	1040.262	0.801	0.173

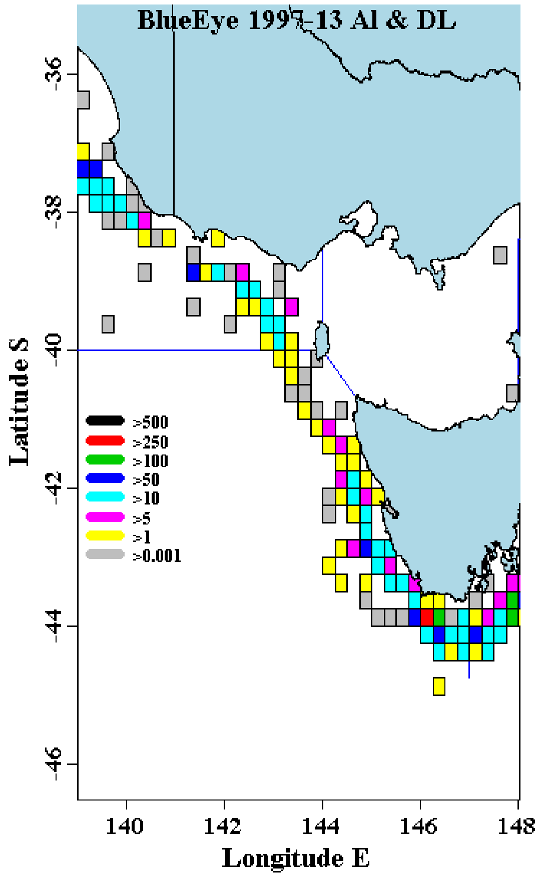

Figure 14.21**.** Schematic map of the distribution of catches form the west coast of Tasmania and off the Portland coast from 1997 – 2013 taken by AL and DL.

14.8.1.3 Comparison East with West AL & Dl fishery

Table 14.11**.** Catches, geometric mean CPUE and optimal standardized CPUE for AL and DL catches from the east (zones 20 and 30) and west (zones 40 and 50) coasts.

	East			West		
Year	Catches	Geomean	Optimum	Catches	Geomean	Optimum
1997	161.526	738.759	2.110	86.966	477.169	1.415
1998	231.562	715.734	1.365	105.504	483.335	1.286
1999	259.700	684.099	1.433	131.804	353.726	0.937
2000	282.772	640.982	1.059	179.102	388.679	1.042
2001	243.015	753.188	1.311	116.368	451.361	0.929
2002	186.622	601.256	0.893	119.993	391.955	0.980
2003	191.194	393.266	0.996	157.038	520.790	0.996
2004	207.088	333.471	0.862	145.573	254.601	1.121
2005	188.153	451.876	1.079	102.658	213.114	0.875
2006	189.741	512.403	1.068	108.532	448.323	1.055
2007	278.587	891.332	1.217	69.692	585.500	0.820
2008	157.119	479.055	0.781	65.505	1076.801	1.227
2009	188.527	621.950	0.734	117.974	967.381	1.308
2010	112.587	365.983	0.475	120.925	930.485	0.782
2011	123.509	434.048	0.627	60.555	406.050	0.639
2012	87.778	410.826	0.486	89.285	652.298	0.787
2013	64.648	432.759	0.503	99.052	1040.262	0.801

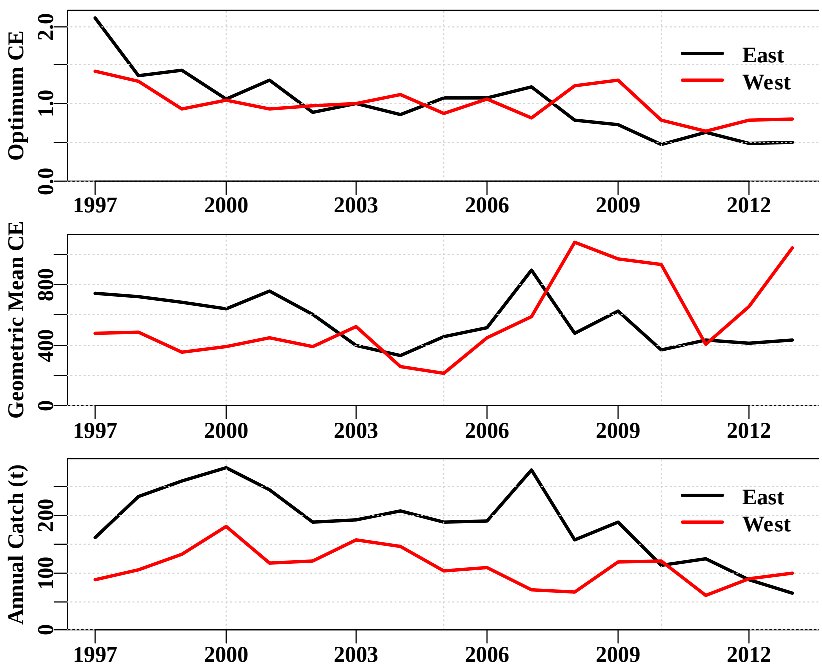

Figure 14.22**.** Comparison of the trends in optimum standardized CPUE, geometric mean CPUE, and catches from 1997 – 2013 between the east and west for the Blue Eye Al and DL fishery.

14.8.1.4 CPUE from the GAB (83 – 85)

Table 14.12**.** Catches by Method in the GAB (zones 83, 84, and 85).

Year	AL	BL	DL	GN	TL	TW
1997		8.416	5.778	1.250	0.200	1.199
1998		2.755	1.968	0.983		2.261
1999		0.484	0.972	0.766		4.822
2000			5.861	0.012		3.960
2001		2.637	7.309	0.360	19.255	19.193
2002		5.924	6.941	0.007	23.415	1.150
2003		8.158	32.422	0.015	28.080	1.810
2004	59.589	1.588	67.513	0.054	20.116	2.590
2005	60.318		30.828	0.002		8.435
2006	107.919	1.057	44.420			11.799
2007	145.222		6.357			0.960
2008	74.323		0.100	0.003		0.132
2009	32.416					
2010	27.801		4.209			
2011	73.806		1.620			
2012	21.905	0.280				0.011
2013	29.649		0.225			

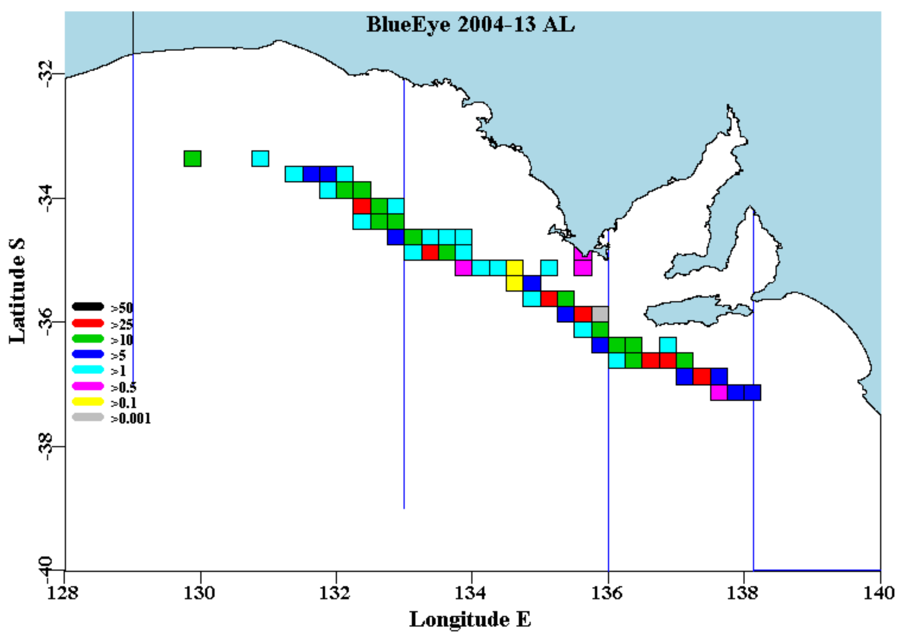

Figure 14.23**.** Schematic map of the distribution of catches form the GAB from 1997 – 2013 taken by AL.

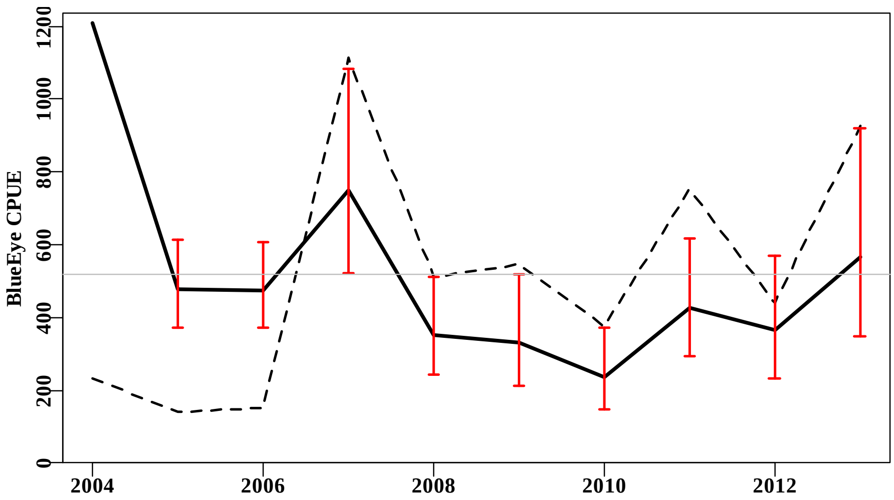

Figure 14.24**.** Standardized CPUE from the AL fishery in the GAB (zones83, 84, and 85) from 2004 – 2013.

Table 14.13**.** BlueEye by AL from zones 83, 84, 85 in the GAB. Model selection criteria, including the AIC, the adjusted r^2 and the change in adjusted r^2. The optimum is model Month:Zone. DepCat is Depth Category.

	Year	Vessel	Month	Zone	DepCat	DayNight	Month:Zone
AIC	1369	907	695	677	646	640	613
RSS	3786	2897	2536	2508	2397	2382	2317
MSS	992	1881	2242	2271	2381	2396	2462
Nobs	1757	1757	1757	1757	1750	1750	1750
Npars	10	14	25	26	48	50	61
adj_r2	20.362	38.909	46.192	46.761	48.453	48.702	49.795
%Change	20.362	18.547	7.283	0.569	1.692	0.250	1.093

Table 14.14**.** Blue Eye Rod and Reel fishery of the north east. Total catch (TotCatch; t) is the total reported in the CPUE database, number of records used in the analysis (Records), reported catch (CatchT; t) using RR in the area and number of vessels used in the analysis (Vessels). GeoMean is the geometric mean of catch rates (kg/hr). The optimum model is Zone:Month and standard deviation (StDev) relates to the data in the optimum model.

Year	TotCatch	Records	CatchT	Vessels	GeoMean	Optimum	StDev
2004	604.771	248	59.589	3	256.978	2.327	0.000
2005	446.647	265	60.318	3	259.737	0.920	0.128
2006	544.826	464	107.919	4	274.690	0.917	0.124
2007	558.985	198	145.222	4	904.405	1.448	0.186
2008	342.325	191	74.323	3	527.257	0.678	0.190
2009	420.777	77	32.416	3	614.680	0.642	0.225
2010	379.622	66	27.801	1	666.259	0.455	0.235
2011	458.592	139	73.806	2	589.229	0.820	0.191
2012	340.782	60	21.905	3	411.100	0.703	0.228
2013	281.786	49	29.649	1	757.026	1.092	0.247

14.8.1.5 Other 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.

Table 14.15**.** Catch by method from all reported shots east of 155°.

Year	DL	TW	AL	RR	HL	TL	PL	BL	GN	DLH
1997	5.503					5.470				
1998	1.680									
1999	12.220	0.527	10.120							
2000	0.615	5.408	1.330							
2001	8.000	34.912	0.242							
2002	44.564	3.641	13.750							
2003	55.880	13.382	7.491						0.630	
2004	8.625	35.776	6.620							0.006
2005	11.390	6.230	0.011					1.550		
2006	10.160	5.758	9.779							
2007	3.705	15.581	0.009		0.400					
2008	8.425									
2009	25.560	2.171	5.148	7.550			3.138			
2010	13.710			55.083						
2011	26.823	15.876	53.463	58.770	16.756					
2012	16.179	37.651	39.694	14.936	21.171					
2013	0.529	6.098	17.050	14.125	24.083					
Total	253.568	183.009	164.706	150.464	62.410	5.470	3.138	1.550	0.630	0.006

Spatially the various methods are distributed about this very large area so, no single fishing method has sufficient data available without aggregation of seamounts and areas. If it is amalgamated then analyses of Rod and Reel, and Hand Line could be attempted. Autoline have been excluded from the north east seamount region for the 20143/2014 season onwards (the table shows 2013, but the data only occurs up to the end of April). Thus there are too few recent data to enable a useable analysis.

The main data with sufficient numbers to permit a valid analysis by sub-area derives from the trawl fishery or the auto-line and drop-line fisheries around the east coast (zones 20 – 30), the west of Tasmania and Bass Strait (zones 40 – 50), and across the GAB (Table 14.3;

Figure 14.5 and Figure 14.7).

14.8.1.6 CPUE from the North East Rod and Reel Vessels

Catches by Rod and Reel (RR) in the north-east are distributed across a range of sea mounts plus some very close to the coast; there may be some seasonality in the fishing but more years of such data are required to adequately characterize such details (Figure 14.25; Table 14.16).

Table 14.16**.** Catches in the north east zones taken by Rod and Reel (RR) for years, and for months (to illustrate any seasonality).

Year	70	91	92	Month	70	91	92
2009			7.550	1	0.030	0.410	1.589
2010	0.644	26.192	29.952	2	0.060	4.585	12.234
2011	0.710	39.029	20.195	3	0.650	7.514	4.924
2012	0.850	13.579	0.353	4		11.852	1.584
2013	0.030	13.507	0.588	5		7.275	5.307
				6	0.644	6.639	3.338
				7		3.680	3.939
				8		7.889	3.712
				9		16.936	4.962
				10		13.863	4.681
				11		8.257	7.774
				12	0.850	3.407	4.594

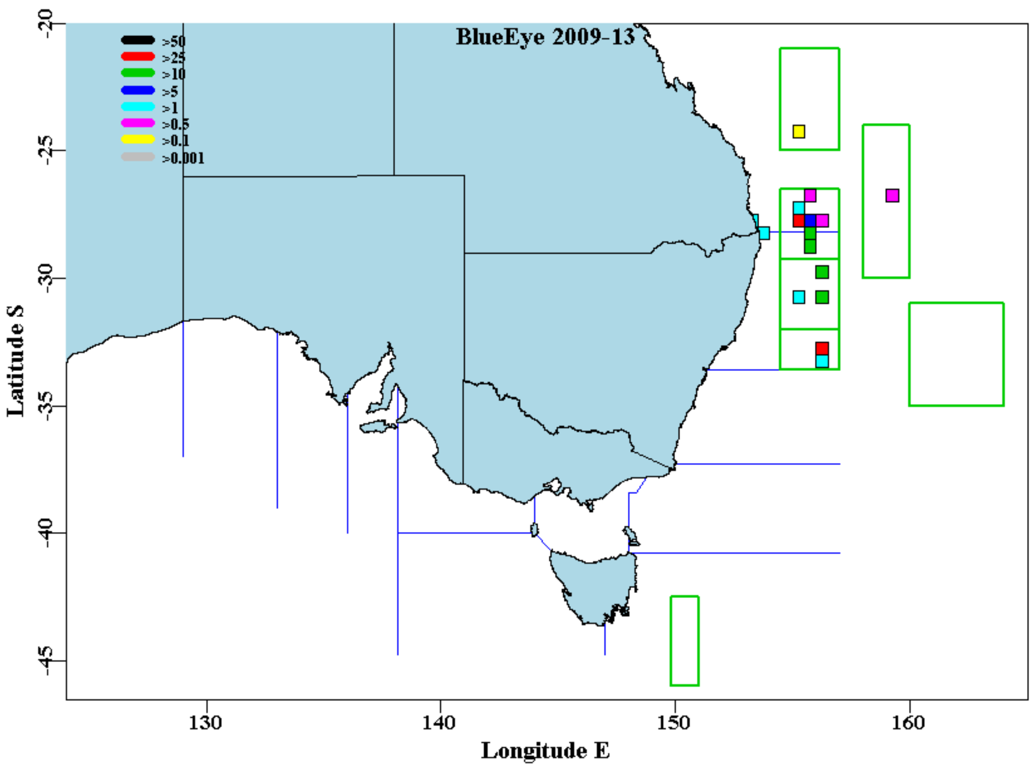

Figure 14.25**.** Schematic map of the distribution of total catches taken by RR between 2009 – 2013 in the northern areas. The green boxes delineate discernible parts of the fishery but these may mean little biologically.

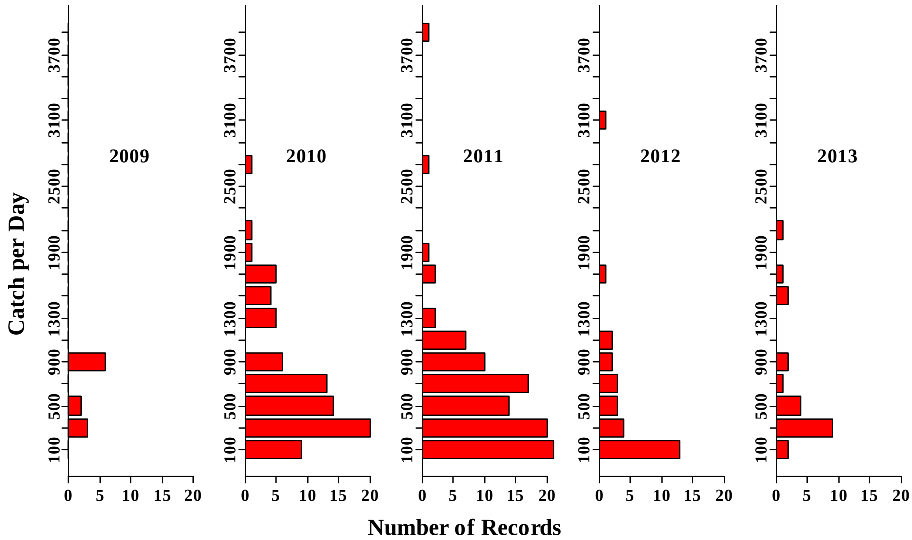

Figure 14.26. The distribution of catch per record/day for Rod and Reel from the north east region.

The Rod and Reel fishery remains very small, which may reflect quota availability rather than an reduced availability of fish) but in 2010 – 2011 this method caught as much as 15% of the total logbook reported catch, this has reduced to ~5% in the last two years (Table 14.17).

Table 14.17. Blue Eye Rod and Reel fishery of the north east. Total catch (TotCatch; t) is the total reported in the CPUE database, number of records used in the analysis (Records), reported catch (CatchT; t) using RR in the area and number of vessels used in the analysis (Vessels). GeoMean is the geometric mean of catch rates (kg/hr). The optimum model is Zone:Month and standard deviation (StDev) relates to the data in the optimum model.

Year	TotCatch	Records	CatchT	Vessels	GeoMean	Mth:Zone	StDev
2009	420.777	11	7.550	1	702.829	1.597	0.000
2010	379.622	79	56.788	2	778.478	1.265	0.397
2011	458.592	96	59.970	2	724.273	0.878	0.410
2012	340.782	29	14.936	2	721.941	0.345	0.445
2013	281.786	22	14.125	1	756.213	0.915	0.442

Table 14.18. Model selection criteria for the standardization of BlueEye by RR from the north east; including the AIC, the adjusted r^2 and the change in adjusted r^2. The optimum is model Month:Zone. DepC is Depth Category.

	Year	Vessel	Month	Zone	DepCat	DayNight	**Month:Zone**
AIC	39.0	41.0	16.0	-2.4	-1.3	-3.7	**-10.4**
RSS	263.9	263.8	215.7	194.7	180.9	177.4	**156.6**
MSS	15.7	15.7	63.8	84.9	98.7	102.2	**123.0**
Nobs	233	233	233	230	230	230	**230**
Npars	5	6	17	18	27	28	**39**
adj_r2	3.963	3.550	17.120	24.781	27.014	28.067	**32.837**
%Change	3.963	-0.413	13.570	7.661	2.233	1.054	**4.770**

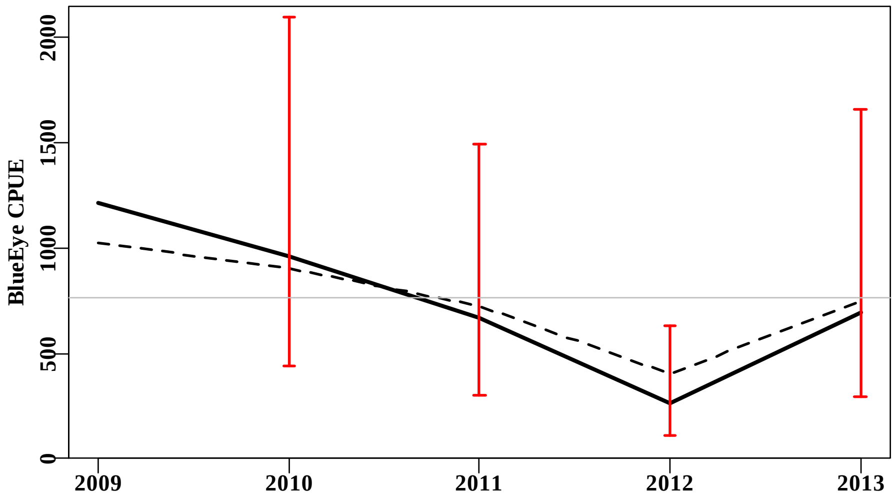

Figure 14.27**.** Standardized CPUE of blue eye taken by rod and reel in the north east rescaled to the mean geometric mean catch rate for the time series. The geometric mean is the dotted line, the solid line is the standardized time series, and the red bars are 95% confidence intervals. The geometric mean through the series is 761.784 kg/record.

14.8.1.7 CPUE from the North East Hand Line Vessels

Catches by Hand Line (HL) in the north-east are distributed across a range of sea mounts plus some very close to the coast; there may be some seasonality in the fishing but more years of such data are required to adequately characterize such details (Figure 16.25;Table 14.16).

Table 14.19**.** Catches in the north east zones taken by Hand Line (HL) for years, and for months (to illustrate any seasonality).

Year	70	91	92	Month	70	91	92
2011	0.164	7.277	9.650	1			0.945
2012	0.198	18.154	2.820	2			0.628
2013	0.968	22.565	0.550	3	0.164	4.980	2.463
				4		1.706	1.204
				5		11.090	3.374
				6		3.507	2.836
				7		1.971	0.425
				8		10.717	0.220
				9		7.037	0.375
				10	0.198	0.990	
				11	0.968	1.532	0.550
				12		4.466	

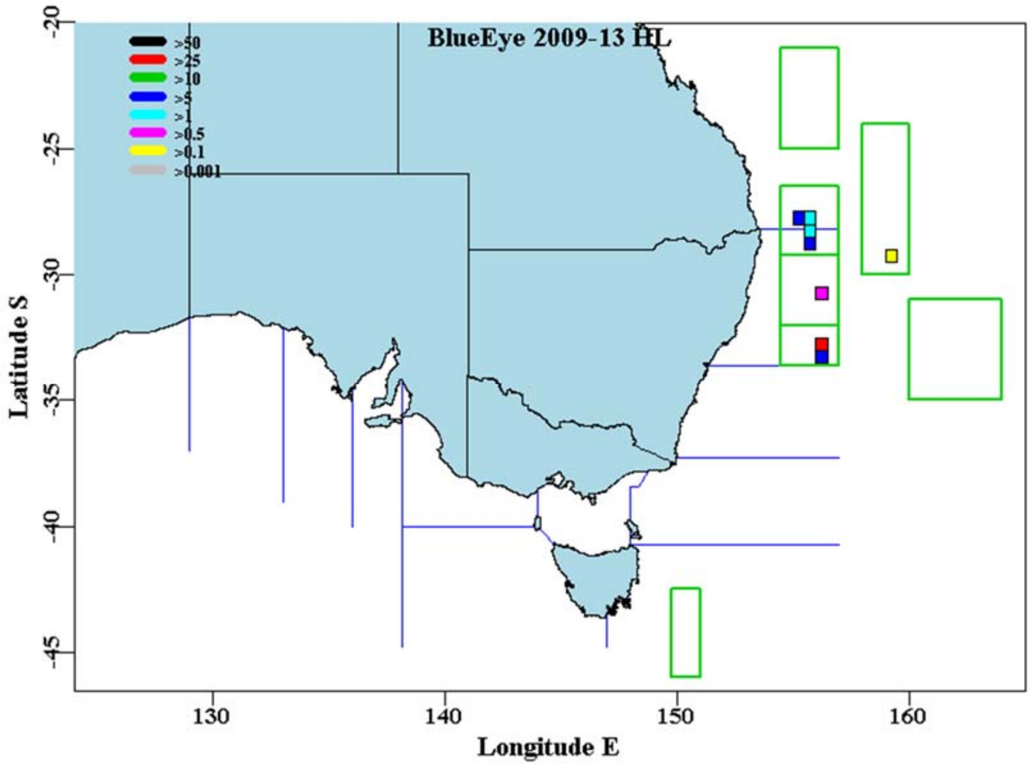

Figure 14.28**.** Schematic map of the distribution of total catches taken by HL between 2011 – 2013 in the northern areas. The green boxes delineate discernible parts of the fishery but these may have little biological meaning.

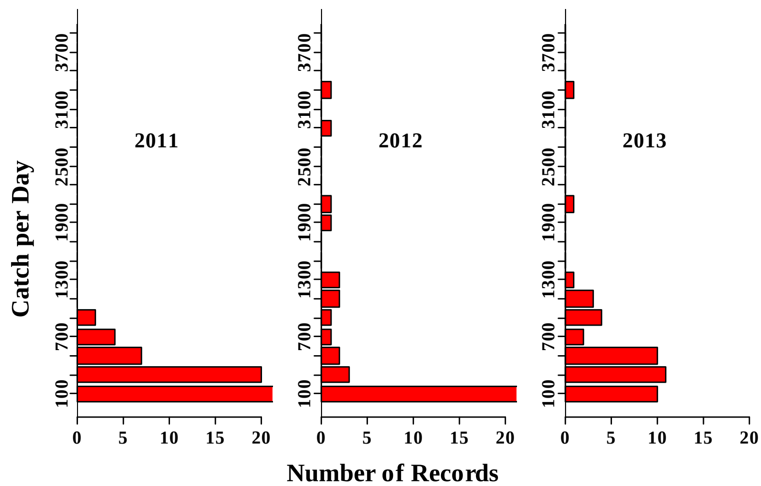

Figure 14.29**.** The distribution of catch per record/day for Hand Line from the north east region.

Table 14.20**.** Blue Eye Hand Line fishery of the north east. Total catch (TotCatch; t) is the total reported in the CPUE database, number of records used in the analysis (Records), reported catch (CatchT; t) using HL in the area, and number of vessels used in the analysis (Vessels). GeoMean is the geometric mean of catch rates (kg/hr). The optimum model is Zone:Month and standard deviation (StDev) relates to the data in the optimum model.

Year	TotCatch	Records	CatchT	Vessels	GeoMean	Optimum	StDev
2011	458.592	58	17.103	2	320.366	1.292	0.000
2012	340.782	43	21.171	3	622.714	0.906	0.438
2013	281.786	43	24.083	1	695.237	0.801	0.467

Table 14.21**.** Model selection criteria for the standardization of BlueEye by HL from the north east; including the AIC, the adjusted r^2 and the change in adjusted r^2. The optimum is model Zone. DepC is Depth Category.

	Year	Vessel	Month	**Zone**	DepCat	DayNight	Month:Zone
AIC	73.1	40.1	39.3	**34.0**	37.4	38.5	48.5
RSS	229.4	177.5	151.5	**143.0**	129.9	127.3	117.0
MSS	12.4	64.3	90.4	**98.9**	111.9	114.5	124.9
Nobs	144	144	144	**143**	142	142	142
Npars	3	5	16	**17**	25	27	38
adj_r2	3.802	24.485	30.024	**33.384**	35.264	35.457	34.429
%Change	3.802	20.683	5.539	**3.360**	1.880	0.193	-1.028

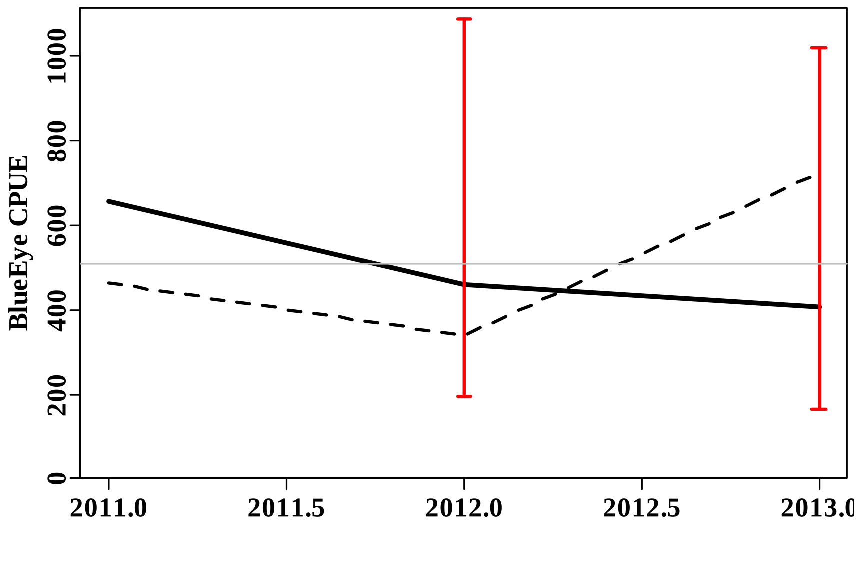

Figure 14.30**.** Standardized CPUE of blue eye taken by hand line in the north east rescaled to the mean geometric mean catch rate for the time series. The geometric mean is the dotted line, the solid line is the standardized time series, and the red bars are 95% confidence intervals. The geometric mean through the series is 507.970 kg/record.

14.8.1.8 Blue Eye CPUE from the Trawl Fishery

Table 14.22**.** Catches of Blue Eye by year and zone taken by trawl. Only zones 30 – 50 had sufficient catches through time for an analysis (see

Table 14.28 for all trawl catches by zone).

Year	30	40	50	Year	30	40	50
1986	3.346	4.927	11.058	2000	31.091	8.927	35.817
1987	3.269	0.214	2.931	2001	17.223	12.530	30.408
1988	1.460	23.834	52.941	2002	28.295	12.415	20.033
1989	23.654	24.905	19.080	2003	8.808	7.141	3.947
1990	29.411	14.880	16.030	2004	10.991	18.423	12.984
1991	16.376	6.344	13.254	2005	16.775	4.724	8.408
1992	3.140	7.706	20.937	2006	35.025	3.497	12.957
1993	24.092	5.892	12.567	2007	7.156	7.190	19.084
1994	74.892	8.140	8.842	2008	17.477	3.641	12.867
1995	19.763	12.605	13.791	2009	21.406	6.700	9.454
1996	25.645	9.104	21.180	2010	11.328	3.918	27.632
1997	12.089	42.266	40.165	2011	6.921	2.783	12.481
1998	11.641	33.225	25.801	2012	0.786	5.617	3.638
1999	30.647	14.875	31.428	2013	3.878	14.313	4.411

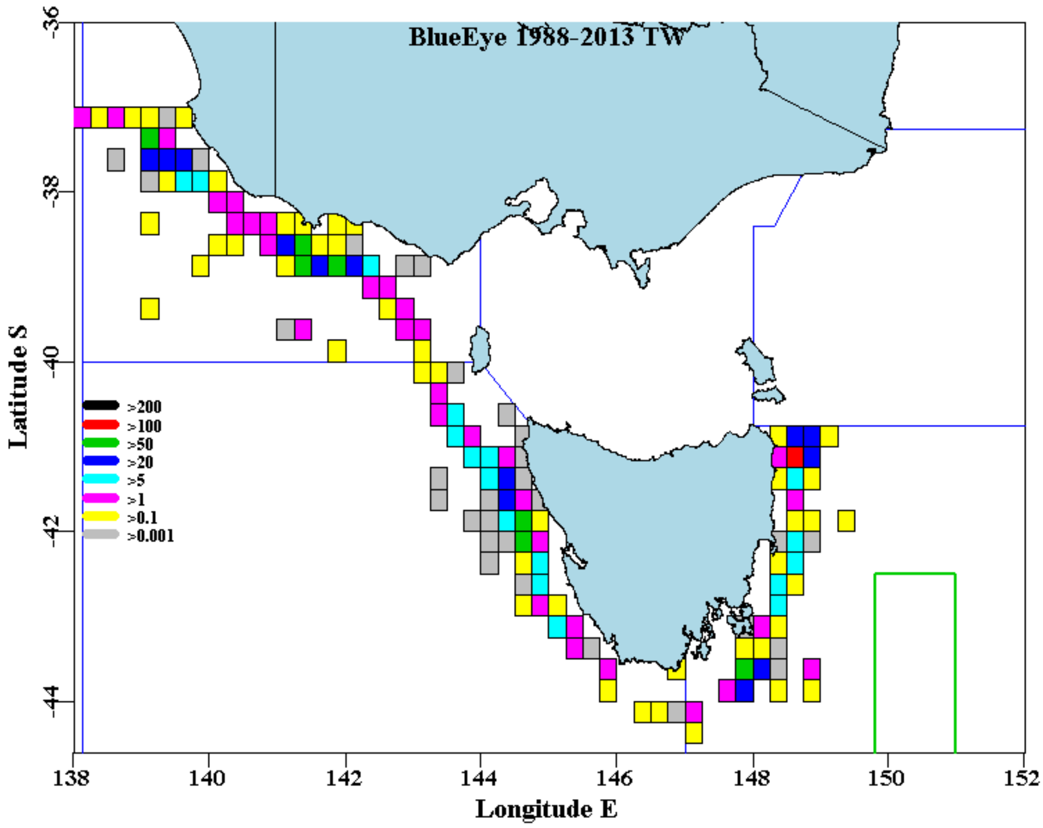

Table 14.23. Schematic map of the distribution of total catches taken by Trawl between 1988 – 2013 in zones 30, 40, and 50.

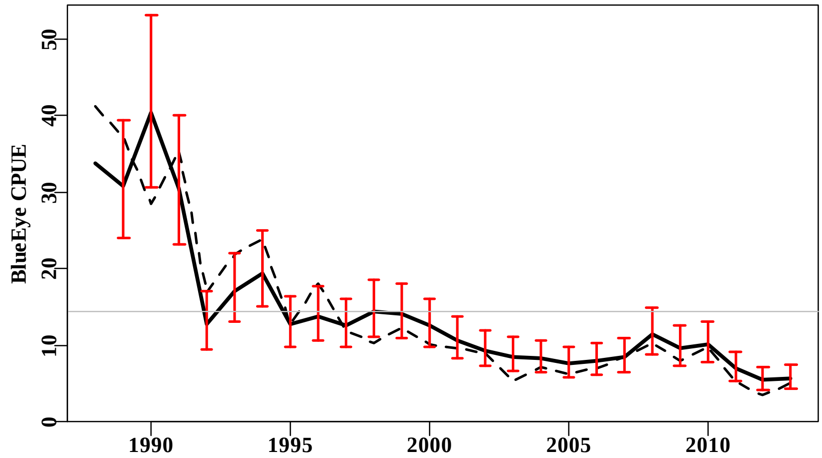

Figure 14.31**.** Standardized CPUE from Trawl fishery in zones 30, 40, and 50 from 1988 – 2013.

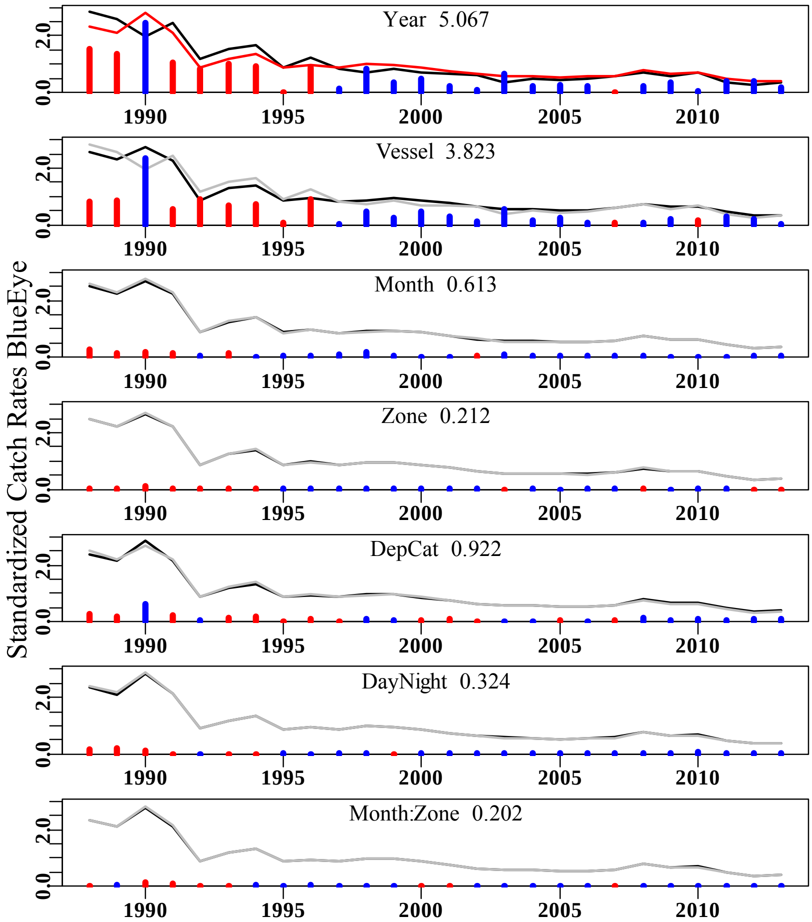

Figure 14.32**.** The relative influence of each factor used on the final trend in the optimal standardization for BlueEye by AL and DL in zones 40 and 50. The top graph is the geometric mean (the black line) and the optimum model (the red line). The difference between them is reflected by the vertical 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 14.24**.** Model selection criteria for the standardization of BlueEye by TW from zones 30, 40, and 50; including the AIC, the adjusted r^2 and the change in adjusted r^2. The optimum is model Month:Zone. DepCat is Depth Category.

	Year	Vessel	Month	Zone	DepCat	DayNight	**Month:Zone**
AIC	8405	2331	2206	2192	1599	1520	**1508**
RSS	26608	17782	17615	17596	16792	16700	**16664**
MSS	3799	12624	12792	12810	13615	13707	**13743**
Nobs	15548	15548	15548	15548	15463	15463	**15463**
Npars	26	122	133	134	162	165	**176**
adj_r2	12.352	41.060	41.574	41.630	44.194	44.490	**44.569**
%Change	12.352	28.708	0.514	0.056	2.564	0.296	**0.079**

Table 14.25**.** Blue Eye Trawl fishery in zones 30, 40, and 50. Total catch (TotCatch; t) is the total reported in the CPUE database, number of records used in the analysis (Records), reported catch (CatchT; t) using HL in the area, and number of vessels used in the analysis (Vessels). GeoMean is the geometric mean of catch rates (kg/hr). The optimum model is Month:Zone and standard deviation (StDev) relates to the data in the optimum model.

Year	TotCatch	Records	CatchT	Vessels	GeoMean	Optimum	StDev
1988	104.129	136	40.091	15	65.693	2.340	0.000
1989	87.740	265	32.298	29	36.764	2.128	0.127
1990	78.596	215	25.375	24	38.954	2.796	0.140
1991	69.233	217	32.396	28	37.481	2.109	0.139
1992	46.186	155	11.318	27	27.193	0.885	0.148
1993	59.588	512	36.954	28	20.078	1.180	0.130
1994	109.959	649	47.124	28	23.281	1.349	0.128
1995	58.533	642	31.736	26	13.213	0.884	0.129
1996	71.175	749	51.631	33	21.157	0.954	0.129
1997	462.762	1016	92.667	27	19.342	0.871	0.128
1998	446.972	861	58.765	27	14.192	0.996	0.129
1999	547.773	960	72.525	24	15.465	0.975	0.128
2000	657.303	1181	48.811	31	12.704	0.871	0.127
2001	578.609	1097	43.266	33	11.845	0.743	0.128
2002	476.708	977	38.145	33	11.262	0.648	0.128
2003	565.101	523	11.643	30	5.822	0.595	0.133
2004	604.771	998	30.292	30	7.681	0.575	0.128
2005	446.647	663	15.925	26	7.006	0.528	0.130
2006	544.826	587	17.354	22	7.123	0.552	0.131
2007	558.985	622	31.324	20	12.282	0.589	0.131
2008	342.325	519	22.894	17	13.730	0.796	0.132
2009	420.777	420	22.288	16	11.750	0.669	0.134
2010	379.622	493	33.991	17	15.277	0.700	0.133
2011	458.592	459	16.088	17	5.879	0.489	0.133
2012	340.782	341	9.761	15	3.966	0.378	0.138
2013	281.786	291	10.405	18	5.968	0.400	0.139

14.8.1.9 Blue Eye CPUE from the Drop Line Fishery

The current stock status analysis uses the combined CPUE of the drop-line and the auto-line fisheries to provide a time series of sufficient length for use in the Tier 4 analysis.

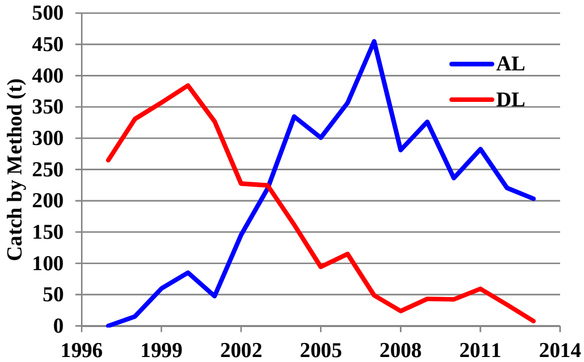

Figure 14.33**.** A comparison of the Blue Eye catches taken across zones 20 – 50. These data relate to the 200 – 600 m depth restriction used in the CPUE standardizations (although there are few data outside those depths. More important, but omitted, are the early catches by drop-line in the north east off New South Wales and Queensland.

While the overall distribution of CPUE from the two methods (as catch per record) were sufficiently similar to allow combination it is clear that the proportional distribution of each method changes through time, with catches by drop-line being replaced by auto-line catches following 2001 (Figure 14.33) all catches by zone and method are given in Table 14.30 andTable 14.31). Given the large area over which fishing could occur most of the catches tend to be focused in zones 20 – 50 with a significant fishery developing in the GAB and a couple of years of auto-line effort in the northeast. Both auto-line and drop-line catches and effort move between zones a good deal (Table 14.30 and Table 14.31), although zone 30 (east Tasmania) always been favoured.

The early period from 1997 onwards is especially important to the CPUE analysis as the initial relatively high level of CPUE in 1997 is influential on the perceived changes in catch rate since then. Of course, in 1997 the catches were essentially all from drop-line as only 0.27t were taken by Autoline, and that was only in a very restricted area on the east coast of Tasmania. The reason the CPUE is estimated as catch per record is because with the drop-line vessels, for example, the fields in the logbook number for recording the number of lines and the number of hooks was mixed up in a number of instances. To determine whether the very high CPUE in the drop-line fishery in 1997 was being affected by the use of catch per day the drop-line data for zones 20 – 50 was extracted and the 'lines' and 'hooks' fields examined. It was possible to discover the records which had most likely been mixed across each other (for example 2000 lines of 5 hooks was deemed an error) and these were reversed so that more proper effort estimates in terms of number of lines and number of hooks per line, were available. For example, prior to the adjustment the frequency distribution of the number of lines used was distorted beyond recognition. By finding that > 100 lines separated off all the extreme values the number of reports containing more than 40 lines per records dropped greatly, with a maximum number of 100 (Figure 14.34A pattern of a peak at about 100 hooks per line and then lower levels at 500 and 1500 hooks occurs (Figure 14.35). By multiplying the number of hooks by the number of lines an estimate of effort is obtained the character of which changes over a period from about 2003 – 2006; in particular the number of single lines reported increases disproportionately.

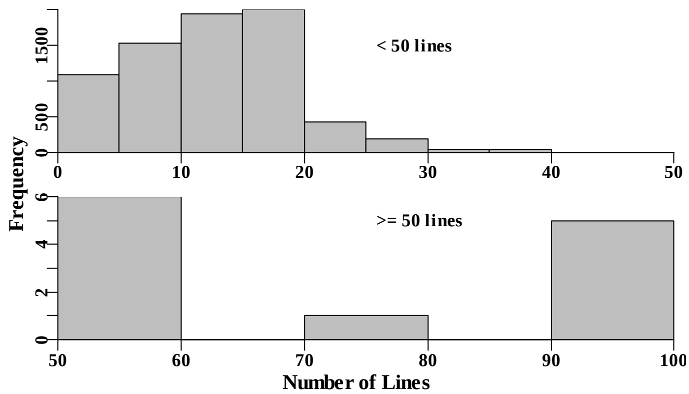

Figure 14.34. The number of drop-lines reported by each vessel in individual records. Prior to adjustment there had been examples reporting more than 4000 lines.

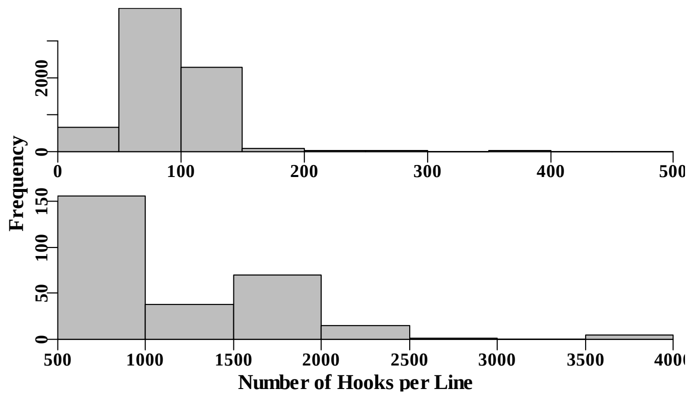

Figure 14.35. Number of hooks per line (generally there is an inverse relationship between number of lines and number of hooks).

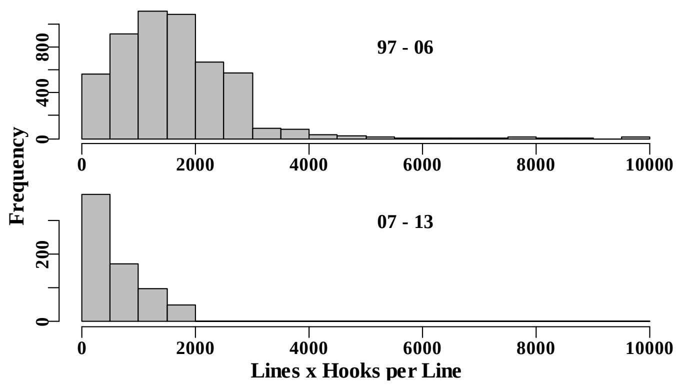

Figure 14.36. An estimate of effort as number of lines multiplied by number of hooks. A major change occurs between 2003 and 2006.

The effect of these records reporting only one line is quite marked. They only make up a small proportion of the total catches prior to 2006 but from 2006 onwards makes up more than 27% and up to 62% (Table 14.26). When all CPUE is plotted post-2006 reveals a bimodal distribution relative to the pre-2007 distribution, which reflects this increased percentage of single line reports (Figure 14.37).

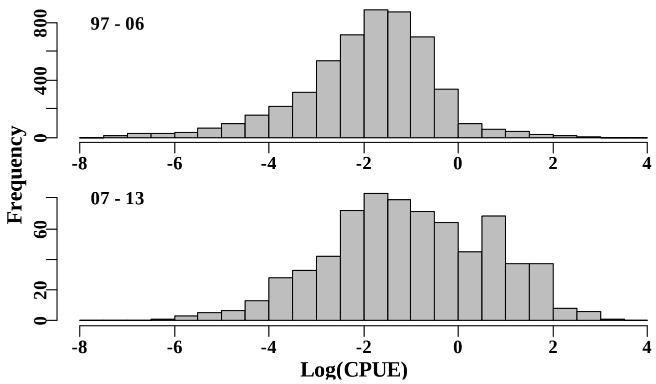

Figure 14.37**.** The log-transformed CPUE (catch/[lines x hooks]) from 1997 – 2006 and 2007 – 2013.

Table 14.26**.** The catches and number of records taken by drop-line in zones 20 - 50 where either 1 line was reported or > 1 line. The sum of the records accounts for all records in the given area, a large reduction occurs after 2006. The percent is of relative catches.

Year	Catch (L > 1)	Records (L > 1)	Catch (L = 1)	Records (L = 1)	Percent (L = 1)	Vessels
1997	232.253	458	0.250	1	0.11	34
1998	316.077	666	0.000	0	0.00	28
1999	329.003	809	4.540	30	1.36	27
2000	363.880	963	7.610	50	2.05	29
2001	299.372	645	9.474	46	3.07	24
2002	170.335	517	3.178	20	1.83	20
2003	135.151	450	0.066	2	0.05	20
2004	83.465	314	0.210	2	0.25	16
2005	49.131	212	0.000	0	0.00	14
2006	38.804	102	18.065	67	31.77	10
2007	16.926	65	21.841	38	56.34	9
2008	5.177	20	8.803	50	62.97	5
2009	7.827	30	9.991	51	56.07	9
2010	15.514	102	9.241	61	37.33	9
2011	16.916	96	13.017	57	43.49	9
2012	13.029	71	4.898	22	27.32	8
2013	4.608	24	2.303	16	33.32	5

The relatively few records reporting single lines pre-2007 have a major impact on the perceived CPUE. Post-2006 the proportion of single lines increases to > 50% and catches from > 1 lines reduce to only 17t and only 65 records through the year. A comparison of the standardized CPUE for drop-line catches from 1997 – 2006, with and without the single line records illustrates the very large effect these single lines have on records following 2005 (Figure 14.38 and Figure 14.39). The inclusion of records reporting single lines leads to a similarly noisy but flat time-series after the transition in effort reporting through 2006, however, as evidenced by the wider confidence intervals the later observations are based on far smaller record numbers.

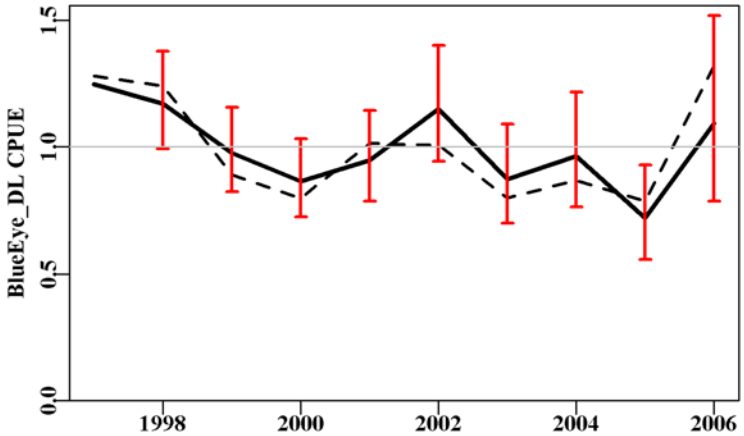

Figure 14.38**.** The standardized drop-line CPUE from which all records reporting a single line are removed.

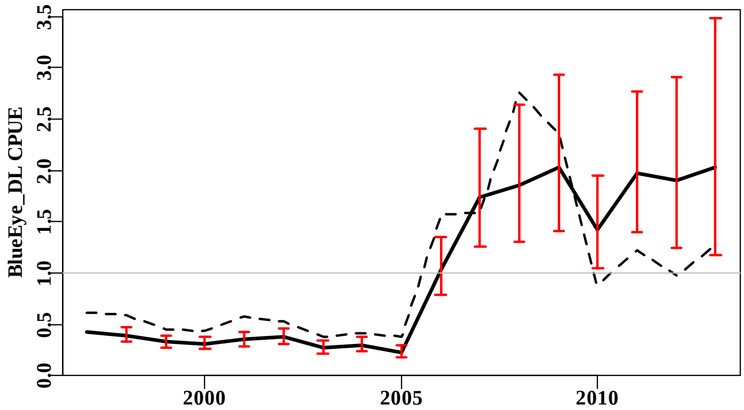

Figure 14.39**.** The standardized drop-line CPUE from which all records reporting a single line are retained. This time series is extended to 2013 to illustrate the expanded impact of the increased proportion of single lines post-2005.

The catch rate trajectory described when effort is taken to be the corrected hooks by lines differs from that obtained when using catch per day (Sporcic and Haddon, 2014). In the reverse of the perception of the full trajectory when using all hook x line data the increase in single line records would lead to a lower total catch per day but a higher catch per hook-line. Once the impact of the rise in single lines being reported is identified this difference becomes significant.

Similarly, auto-line records only become sufficiently numerous to be defensible as representing the fishery from about 2002 onwards. When the trends of auto-line from 2002 onwards are compared with those for drop-line from 1997 – 2006 (excluding records reporting single lines of hooks)

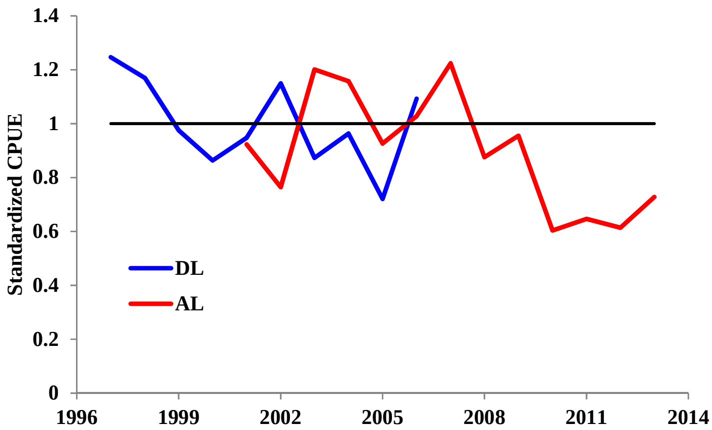

Figure 14.40**.** A comparison of drop-line with auto-line standardized CPUE each series based on those in which significant catches were taken in each of the four zones 20 – 50 (Table 14.30. Catches by auto-line vessel in each year in each zone (seeFigure 14.1).andTable 14.31**.** Catches by zone taken by drop-line.).

Unfortunately, neither of these time-series is sufficiently long to permit the application of the Tier 4 decision rule for determining an RBC. Note, however, that the combined series primarily reflects the series from the respective method retaining the majority of data and where they overlap in relative numbers the combined trend is approximately the average between the two series (Figure 14.41). Correcting for the incidence of single line records reduces the initial spike in drop-line CPUE (Figure 14.40), which suggests that line CPUE in zones 20 – 50 was very noisy but flat on average about the mean of one, from 1997 – 2009. The effect of reductions in the available TAC and the introduction of several closures in important fishing ground on east Tasmania may have led to the observed step down in catch rates in 2010. Elucidating this would take further work.

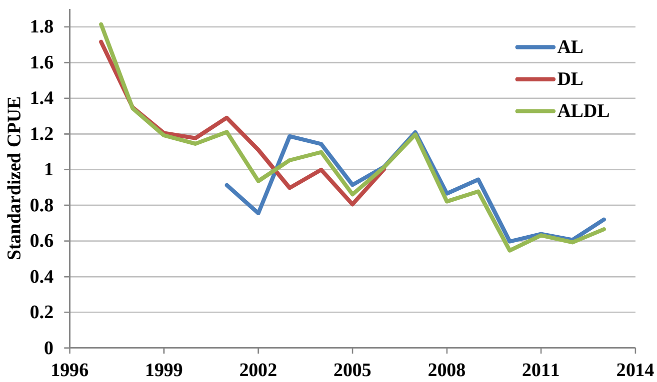

Figure 14.41**.** A comparison of the usual standardizations applied to zones 20 - 50 and 83 – 85, rather than just 20 – 50 (see Sporcic and Haddon, 2014). This illustrates the auto-line, the drop-line, and the combined time series for both methods. Auto-line and drop-line series are truncated where there are not significant catches in at least zones 20 – 50.

14.9 Discussion

There are some important assumptions in the analyses previously conducted on Blue Eye Trevalla and those conducted in this document. These assumptions apply to all species whose stock status assessments rely on CPUE. The first is that changes in CPUE directly reflect changes in the relative stock abundance rather than the influence of other factors such as the structural adjustment, or reduced catch rates through whale depredations or from whale avoidance behaviour from shifting into less optimal CPUE areas. In addition, the various closures in the south-east are assumed to have little or only minor effects on catch rates as are the recent reductions in TAC, which mostly coincide with the introduction of important Blue Eye closures on the east coast of Tasmania. CPUE reflects fishing behaviour and, potentially, any factor that may lead to a change in fishing behaviour may affect CPUE. Such things are confounded with stock size changes. Catch rate standardization is a method of using statistical methods in an attempt to take account of such external factors, with common examples of important potentially influential factors being which vessel is fishing, where they are fishing, at what depth they are fishing, and what month they are fishing. The process of standardization is completely dependent upon the availability of quality data concerning the factors being considered.

There are such influential factors, however, whose potential effects upon CPUE would be difficult to identify and isolate as a confounding effect with stock size. Any influence that occurs as a transition so that for a sequence of years it is not there but after a given date it is present (such as the introduction of a closure) is very difficult to correct for. In the case of a closure, if the closure is on favoured fishing grounds then there will undoubtedly be a change in fishing behaviour (which, in the case of Blue Eye is confounded with reductions in TAC). While it is known where the vessels would not be operating it is not known where effort that would have been expended in the now closed region will be transferred to. The structural adjustment between Nov 2005 – Nov 2006 led to a reduction in the number of vessels operating although with Blue Eye this was only apparent in the trawl fleet and the drop-line fleet, both of which drop away in numbers from 2005 - 2007 onwards. Such a reduction in vessel numbers may have altered fishing behaviour in ways that are difficult to characterize. In the case of Blue Eye drop-line vessels a major change did occur in how effort was being reported with the number of records reporting single lines instead of multiple lines increased dramatically.

One large issue with the analysis of any of the line and hook methods is uncertainty over the representativeness of any single year's data for the fishery. The minor-line methods are still patchily distributed over different sea-mounts and off-shore areas and even auto-line and drop-line have widely varying coverage across the different important statistical reporting zones within the SESSF. This is especially the case with auto-line following its adoption in 1997; for example, there were only significant catches in all four zones 20 – 50 from 2002 onwards with very small catches early on. Similarly, although also inversely, after 2006 dropping catches by drop-lining meant they did not occur consistently every year in all four zones 20 – 50 and remained at low levels (< 20t) throughout that period.

The use of catch-per-day or record stemmed from early records of effort data being relatively mixed so that for example, with drop-lines the number of separate lines used and the number of hooks per line were sometime placed in each other's fields on the log-books and thereby in the database. For a single and particular species in particular areas it was, however, possible to examine what appeared to be atypical data and reverse obvious errors (for example cases of 2000 lines each of 10 hooks, should obviously be reversed). This use of a different measure of effort gives a very different time-series of CPUE than when catch per day or record is used. The use of catch per day avoids the issue of the remarkable change in effort reporting that appears to have followed the structural adjustment. Intuitively, however, catch per hook-line appears more realistic. It is certainly an area that requires further analysis and consideration.

By considering a range of different fishing methods and determining the CPUE series for different areas under different methods the underlying stock trajectory for Blue Eye Trevalla remains difficult to perceive. It is certainly noisy, at least partly because the number of records available for analysis is invariably limited owing to the large number of different methods across which the catches are spread. Currently, most catches are taken using a combination of drop-line and then auto-line. However, under detailed scrutiny there appear to be issues with the interpretation of the CPUE both early in the time series (1997 – 2000) and later in the series (2009 – 2013). Both periods suffer from varying coverage of the two fishing methods. Drop-line catch rates are greatly influenced by the number of records reporting single lines of hooks and auto-line catch rates from 2010 onwards appear negatively influenced by drops in TAC and increasing variation in fishing location.

14.10 Conclusions

This work remains incomplete. The diversity of methods used to fish for Blue Eye and the patchy nature of the fishing grounds mean that there is no simple, catch-all analysis that can be used to summarize the fishery as a whole. Further work is required at least to facilitate:

- Individual cleansing of the data relating to the effort reporting for each major method to allow for alternative, intuitively better measure of CPUE.
- More mapping of the catches and CPUE from the early periods of the fishery to ascertain the degree of representativeness of those data.
- Further exploration of the impact of all closures on Blue Eye catches to try to clarify the 2010 step down in auto-line CPUE apparent in standardizations using both catch per hook-line and catch per day.
- Explore the issue of whale depredation more thoroughly if adequate data becomes available (adequate being the inclusion of location, date, effort, catch, and the presence or not of whales).

There is now sufficient evidence that the validity of the previous analyses conducted on Blue Eye catch rates should now be questioned. There are undoubted uncertainties that were not previously accounted for the CPUE time-series that were used for earlier advice. The alternatives presented in this document should only be considered as draft analyses but the correctness of any earlier recommendations can certainly be questioned.

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14.11.1 Appendix – extra tables

Table 14.27**.**Total catches of Blue Eye across all methods for each reported in the log books.

Year	30	40	20	50	84	85	91	70	83	92	10	60	82	Total
1986	3.346	4.927	5.771	11.058			0.020				12.712	0.128		37.962
1987	3.269	0.214	6.881	2.931	0.008	0.040					1.882	0.250	0.020	15.495
1988	1.460	23.834	18.841	53.101		3.250	0.585				3.076	1.020		105.167
1989	23.654	24.905	10.203	19.080		0.315	0.101		0.060		9.391	0.031		87.740
1990	29.411	14.880	11.622	16.030	0.300	2.625					4.201	0.139		79.208
1991	18.256	7.871	20.771	14.236		0.308					14.119	0.120		75.681
1992	3.408	7.739	13.663	21.679		0.030					2.498	0.063		49.080
1993	24.092	5.892	14.672	12.567		0.130	0.015		0.005		2.270	0.001		59.644
1994	74.892	8.140	14.919	8.842	0.005	0.120	0.030	0.115			2.861	0.046		109.970
1995	19.763	12.605	8.776	13.791		0.635	0.080				2.721	0.201		58.572
1996	25.660	9.134	9.937	21.450		0.347	0.075				4.832	0.192		71.627
1997	92.819	83.333	149.201	100.036	0.450	16.363	10.835		0.030	0.140	5.964	4.149		463.319
1998	171.130	97.903	93.416	66.989	0.380	7.487	1.590		0.100		1.774	4.211		444.979
1999	225.832	91.602	106.178	86.854	0.766	6.278	21.590			0.050	1.881	5.109		546.140
2000	275.937	129.247	129.528	95.971	0.357	9.566	1.100	5.408		0.750	0.985	8.559		657.408
2001	239.668	100.831	86.447	60.290	19.493	28.648	3.186	34.930	0.850	4.740	0.264	0.708		580.054
2002	180.660	75.524	41.624	77.538	22.991	10.473	33.664	7.469	3.973	7.850	0.489	0.012		462.267
2003	153.646	124.815	91.447	43.761	52.812	17.673	57.910	14.668		2.400	1.288	1.567		561.987
2004	148.512	113.269	73.957	64.437	75.979	62.473	10.045	36.796	12.997	0.180	0.222	0.745	0.983	600.595
2005	119.790	64.249	88.198	51.935	29.273	51.158	7.451	2.607	19.552	4.700	1.601	0.267	0.632	441.415
2006	157.401	83.899	69.824	41.217	44.495	89.189	10.375	2.540	31.511	2.516	0.192	0.932	0.169	534.261
2007	235.939	48.581	53.777	47.631	107.069	15.594		16.174	29.876		0.271	0.552		555.464
2008	130.524	55.478	46.583	26.535	32.267	13.350		8.100	28.943		0.170	0.110	0.015	342.072
2009	159.609	86.619	54.023	47.601	15.369	15.415	12.615	7.631	1.633	22.758	0.133	0.195		423.599
2010	98.273	54.924	26.136	97.572	9.532	15.929	34.124	1.797	6.549	34.027	0.109	0.100		379.072
2011	99.656	45.235	31.830	30.612	40.692	14.159	79.995	14.271	20.576	52.926	0.195	0.012		430.158
2012	67.578	77.448	21.728	22.012	10.016	3.752	74.673	15.079	8.428	13.189	0.188			314.091
2013	58.686	98.770	13.389	19.005	16.158	13.250	37.203	5.546	0.465	1.138	0.015	0.164		263.790

Table 14.28**.** Total catches of Blue Eye taken by trawl for each reported in the log books.

Year	10	20	30	40	50	60	70	82	83	84	85	91
1986	12.652	5.771	3.346	4.927	11.058							0.020
1987	1.882	6.881	3.269	0.214	2.931	0.250		0.020		0.008	0.040	
1988	3.076	18.073	1.460	23.834	52.941	0.740					3.250	0.585
1989	9.391	10.203	23.654	24.905	19.080	0.031			0.060		0.315	0.101
1990	4.174	11.037	29.411	14.880	16.030	0.139				0.300	2.625	
1991	13.998	18.833	16.376	6.344	13.254	0.120					0.308	
1992	2.164	11.534	3.140	7.706	20.937	0.060					0.030	
1993	2.270	14.617	24.092	5.892	12.567				0.005		0.130	0.015
1994	2.861	14.915	74.892	8.140	8.842	0.034	0.115			0.005	0.120	0.030
1995	2.721	8.769	19.763	12.605	13.791	0.169					0.635	0.080
1996	4.801	9.903	25.645	9.104	21.180	0.087					0.347	0.051
1997	0.972	7.874	12.089	42.266	40.165				0.030		1.169	0.002
1998	1.551	7.563	11.641	33.225	25.801	0.032			0.100		2.161	
1999	1.881	11.091	30.647	14.875	31.428	0.038					4.822	
2000	0.985	6.677	31.091	8.927	35.817	0.045	5.408				3.960	
2001	0.264	7.870	17.223	12.530	30.408	0.022	34.720			0.040	19.153	
2002	0.489	5.456	28.295	12.415	20.033		2.769				1.150	
2003	1.288	5.807	8.808	7.141	3.947	0.009	13.368			0.117	1.693	
2004	0.222	4.269	10.991	18.423	12.984	0.020	35.776	0.133	0.387	0.205	1.998	
2005	0.531	3.061	16.775	4.724	8.408	0.006	1.057	0.282	0.074		8.362	1.020
2006	0.192	2.459	35.025	3.497	12.957	0.006		0.169	0.106	0.132	11.562	
2007	0.271	3.584	7.156	7.190	19.084	0.002	13.074		0.075	0.628	0.257	
2008	0.117	1.738	17.477	3.641	12.867	0.060		0.015			0.132	
2009	0.092	1.727	21.406	6.700	9.454	0.007	2.171					
2010	0.109	0.494	11.328	3.918	27.632							
2011	0.195	0.891	6.921	2.783	12.481	0.001	2.957					
2012	0.188	0.552	0.786	5.617	3.638		14.031		0.011			
2013	0.015	0.236	3.878	14.313	4.411		1.296					

Table 14.29**.** Early estimates of total Blue Eye Trevalla catches across all methods within the SET area. The North Barenjoey is included as being extra South-East Trawl area catches.

Year	Recent	Tilzey (1999)	Tilzey (1998) N Barrenjoey	Smith & Wayte (2002)
1980		207		207
1981		257		257
1982		276		276
1983		236		236
1984		388	7	350
1985		510	9	525
1986		285	38	341
1987		345	105	468
1988		505	210	725
1989		531	174	717
1990		647	243	819
1991		599	181	717
1992		633	60	643
1993		634	38	628
1994	801.327	729	27	730
1995	740.046	716	19	725
1996	893.428	868	16	890
1997	733.985	1040		989
1998	601.674			566
1999	711.465			651
2000	791.285			710
2001	718.798			648
2002	616.629			
2003	652.922			
2004	718.365			
2005	557.613			
2006	619.973			
2007	639.371			
2008	408.174			
2009	478.452			
2010	442.923			
2011	498.832			
2012	308.794			
2013	284.575			

Table 14.30**.** Catches by auto-line vessel in each year in each zone (seeFigure 14.1).

Year	20	30	40	50	70	83	84	85	91	92
1997			0.267							
1998		0.033	14.956							
1999	35.575	1.725	9.370						8.800	
2000	12.210	6.061	10.028						0.250	0.750
2001	2.000	23.634	14.598							
2002	2.640	65.320	42.326	21.400						2.100
2003	20.574	93.788	38.724	3.900					7.210	
2004	56.336	81.121	71.577	22.214	0.900	5.418	15.316	18.442	5.000	0.180
2005	84.793	59.976	57.265	36.472		19.113	5.145	35.895	0.011	
2006	67.075	66.585	77.940	25.822	2.420	31.117	0.330	75.689	1.155	
2007	48.001	196.055	41.074	23.907		29.791	99.104	15.337		
2008	44.439	98.763	50.407	11.408		27.543	32.127	13.214		
2009	47.014	124.045	79.733	30.519	4.400	1.633	15.369	14.826	0.185	
2010	25.422	66.128	47.497	63.093		5.764	7.153	14.884		
2011	30.835	69.055	37.861	14.160	8.800	20.576	40.292	12.939	20.946	5.995
2012	21.176	56.048	70.428	11.183		8.417	9.736	3.752	24.617	9.334
2013	13.151	45.406	84.451	13.334	2.668	0.465	16.152	13.025	1.131	

Table 14.31**.** Catches by zone taken by drop-line.

Year	20	30	40	50	70	83	84	85	91	92
1997	79.106	80.730	37.792	45.057				5.778	3.745	
1998	72.375	157.979	47.472	40.856				1.968	1.100	
1999	28.969	193.144	64.494	51.344				0.972	8.110	0.050
2000	26.170	186.055	104.217	59.822			0.357	5.504	0.100	
2001	18.659	191.242	72.643	29.127	0.060	0.150	2.404	4.345	2.536	4.740
2002	31.617	85.914	20.525	35.457	4.700		1.561	5.380	30.164	5.750
2003	25.822	46.850	33.081	29.464	1.300		27.547	4.875	50.680	2.400
2004	6.302	42.729	12.169	23.579	0.120	0.026	45.582	21.025	4.945	
2005	0.140	40.220	2.261	6.616	1.550	0.200	24.128	6.500	4.870	4.700
2006	0.040	52.118	2.463	2.308	0.120		42.976	1.444	7.240	2.500
2007	2.174	31.883	0.250	4.460	2.700	0.010	6.347			
2008		13.169		2.260	8.100		0.100			
2009	0.150	11.958	0.010	5.700	1.060				11.320	9.670
2010		17.764	0.165	6.826	1.153	0.785	2.379	1.045	7.932	3.545
2011	0.003	23.158	3.615	3.971	0.100		0.400	1.220	6.442	15.335
2012		10.254	1.403	6.271					15.496	0.683
2013		6.087	0.007	0.910	0.529			0.225		

15. Tier 4 Analyses for Selected Species in the SESSF. Data from 1986 - 2013

Malcolm Haddon

CSIRO Oceans and Atmosphere Flagship, GPO Box 1538, Hobart, TAS 7001, Australia

15.1 Summary

Five Tier 4 analyses are documented here applied only to John Dory and Mirror Dory. There was spatial data available for Mirror Dory, which led to analyses for the east and west presumed stock regions. Recent discard estimates for Mirror Dory have been relatively high so a further Tier 4 analyses was conducted where discard estimates were included in the analysis of catch rates. Neither John Dory nor Mirror Dory are recognized as Tier 4 managed species.

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.

15.2 Introduction

15.2.1 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).

15.3 Methods

15.3.1 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.

$$\text{Scaling Factor } = SF_t = \max\left(0, \frac{\overline{CPUE} - CPUE_{\text{lim}}}{CPUE_{\text{targ}} - CPUE_{\text{lim}}}\right) \quad (1)$$

$$RBC = C_{\text{targ}} \times SF_t \quad (2)$$

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:

$$\begin{array}{l|l} RBC_y = 1.5RBC_{y-1} & RBC_y > 1.5RBC_{y-1} \\ RBC_y = 0.5RBC_{y-1} & RBC_y < 0.5RBC_{y-1} \end{array} \quad (3)$$

where

RBC_y is the RBC in year *y*
$CPUE_{targ}$ is the target CPUE for the species;
$CPUE_{lim}$ 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 15.1). This is an average of the total removals for the selected reference period, including any discards;

$$C_{\text{targ}} = \frac{\sum_{y=yr1}^{yr2} L_y}{(yr2 - yr1 + 1)} \quad (4)$$

where L_y represents the landings in year *y*.

$$CPUE_{\text{targ}} = \frac{\sum_{y=yr1}^{yr2} CPUE_y}{(yr2 - yr1 + 1)} \quad (5)$$

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

$$D_y = \frac{C_y \bar{D}_{98-06}}{\left(1 - \bar{D}_{98-06}\right)} \tag{6}$$

Discard proportions for the projected year for which the RBC is being calculated are taken as a weighted mean of the previous four years:

$$D_{CUR} = (1.0D_{y-1} + 0.5D_{y-2} + 0.25D_{y-3} + 0.125D_{y-4})/1.875 \tag{7}$$

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%):

$$D_y = \frac{Discard_y}{\left(Catches_y + Discard_y\right)} \tag{8}$$

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 15.1). 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.

15.3.2 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 15.1.

15.3.3 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).

15.3.4 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

$$\hat{I}_{R,t} = \frac{\sum C_t}{\sum E_t} \tag{9}$$

where $\hat{I}_{R,t}$ is the ratio mean catch rate for year t, ΣC_t is the sum of landed catches in year t, and ΣE_t is the sum of effort (as hours trawled) in year t. If ΣD_t is the sum of discards in year t then the discard incremented ratio mean catch rate would be

$$\hat{I}_{D,t} = \frac{\sum C_t + \sum D_t}{\sum E_t} \tag{10}$$

The same values of $\hat{I}_{D,t}$ can also be obtained using the following multiplier

$$\hat{I}_{D,t} = \left[\left(\sum D_t / \sum C_t \right) + 1 \right] \times I_t \tag{11}$$

where I_t is the catch rate estimate to be modified by the inclusion of discards. If this is the ratio mean from Equ (9) then the augmented catch rates would be identical to those produced by Equ (10). 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 15.1. 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.**
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

15.3.5 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.

15.3.6 The Assumptions 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 $B_{48\%}$.

15.4 Non-Tier 4 Species

15.4.1 John Dory (DOJ – 37264004 – *Zeus faber*)

Table 15.2 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			2.583	1.6025	7.6948
1987	240.000	6.364	246.364			2.583	1.8351	8.5155
1988	226.800	6.014	232.814			2.583	1.7229	8.3856
1989	252.000	6.683	258.683			2.583	1.8903	9.5319
1990	212.400	5.633	218.033			2.583	1.7082	8.7451
1991	236.400	6.269	242.669			2.583	1.4022	7.1954
1992	240.000	6.364	246.364			2.583	1.1578	5.6282
1993	400.800	10.629	411.429			2.583	1.499	7.0963
1994	289.728	0.000	289.728	172.902	0	0.000	1.4137	6.7516
1995	243.673	0.000	243.673	129.005	0	0.000	1.2049	5.961
1996	137.0035	0.000	137.004	1.568	0	0.000	0.9423	4.5279
1997	178.118	0.000	178.118	87.931	0	0.000	0.7308	3.3776
1998	138.8109	3.000	141.811	23.44	0	2.115	0.7565	3.635
1999	178.3337	3.000	181.334	40.742	0	1.654	0.8874	3.9411
2000	209.2288	17.000	226.229	39.499	0	7.515	0.8213	3.5716
2001	164.6426	6.000	170.643	29.768	0	3.516	0.6881	2.945
2002	182.3163	1.660	183.976	19.629	0	0.902	0.6786	3.1506
2003	193.1297	3.190	196.320	28.253	0	1.625	0.6586	3.1537
2004	193.8235	1.740	195.564	27.514	0	0.890	0.6979	3.4203
2005	132.0296	3.530	135.560	29.296	0	2.604	0.5795	2.6772
2006	107.0199	0.640	107.660	23.481	0	0.594	0.6534	2.8463
2007	82.38318	1.355	83.738	13.819	0	1.618	0.5914	2.8023
2008	177.1218	0.596	177.718	41.012	0	0.336	0.8813	4.3014
2009	127.476	4.332	131.808	19.66	0	3.287	0.819	4.1921
2010	86.5856	2.934	89.520	14.458	0	3.278	0.5282	2.6471
2011	125.032	8.423	133.455	33.406	0	6.311	0.5495	2.7461
2012	88.106	1.141	89.248	17.454	0	1.279	0.5355	2.8174
2013	100.326	1.218	101.544	21.810	0	1.199	0.5638	2.8673

Discards make up approximately 2.6% of the catch over the 1998-2006 period.

Table 15.3. RBC calculations for John Dory. C_{targ} and $CPUE_{targ}$ relate to the period 1986-1995, $CPUE_{Lim}$ 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 (7).

Ref_Year	1986-1995
CE_Targ	1.5437
CE_Lim	0.6175
CE_Recent	0.5442
Wt_Discard	2.272
Scaling	0
Last Year's TAC	118
C_{targ}	269.894
RBC	**0**

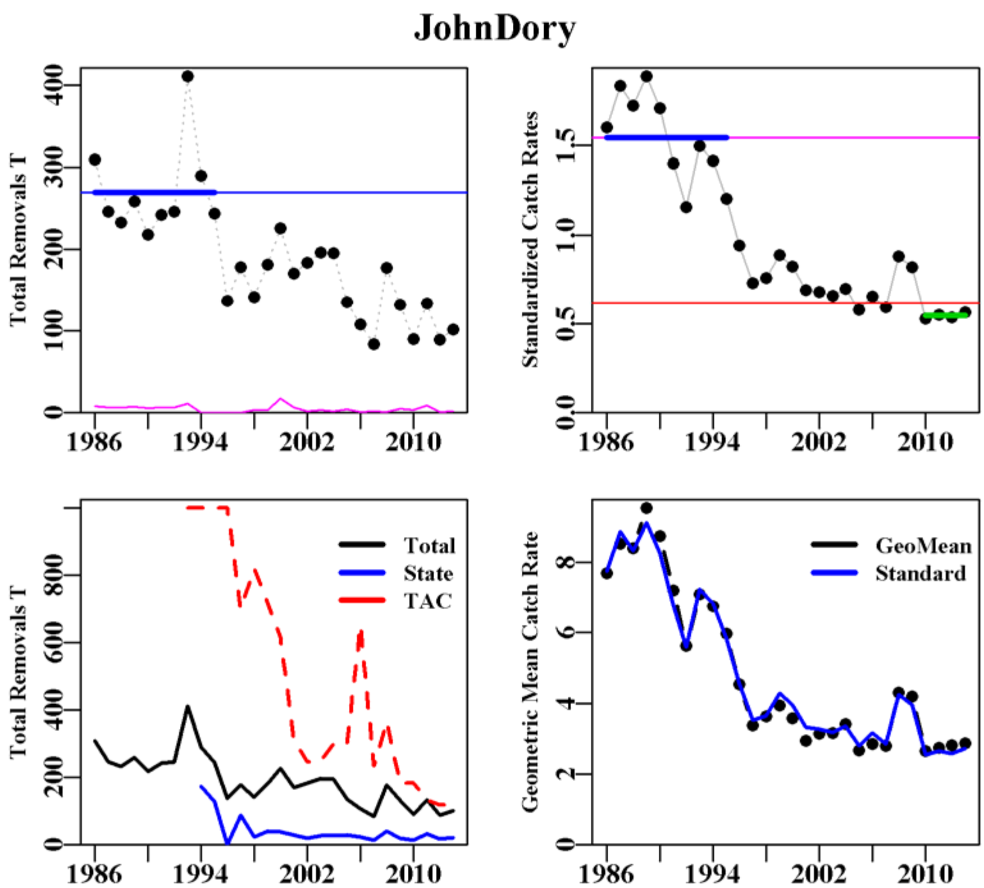

Figure 15.1. John Dory. Top left is the total removals with the fine line illustrating the target catch. Top right represents the standardized catch rates with the upper fine line representing the target catch rate and the lower line the limit catch rate. Thickened lines represents the reference period for catches, catch rates, and the recent average catch rate.

15.4.2 Mirror Dory (DOM – 37264003 – Zenopsis nebulosus)

Table 15.4 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			19.409	1.2147	18.6423
1987	340.800	82.075	422.875			19.409	1.2190	19.7476
1988	373.200	89.877	463.078			19.409	1.1945	16.9455
1989	542.400	130.626	673.026			19.409	1.4707	23.1957
1990	267.600	64.446	332.046			19.409	1.3570	20.6077
1991	277.200	66.758	343.958			19.409	1.1633	13.9567
1992	357.600	86.121	443.721			19.409	1.0102	11.3487
1993	537.600	129.470	667.070			19.409	1.1054	13.7999
1994	324.664	0.000	324.664	21.816	0.000	0.000	0.9932	11.4667
1995	289.953	0.000	289.953	22.320	0.000	0.000	0.9229	10.0782
1996	404.725	0.000	404.725	21.715	0.000	0.000	0.8889	8.9039
1997	547.416	0.000	547.416	21.673	0.000	0.000	0.9439	9.6820
1998	439.374	115.000	554.374	26.988	0.000	20.744	0.8555	9.0983
1999	382.139	52.000	434.139	36.911	0.000	11.978	0.7005	8.0995
2000	217.405	93.000	310.405	11.121	0.000	29.961	0.4902	4.6519
2001	306.752	292.000	598.752	10.343	0.096	48.768	0.5756	5.1157
2002	545.156	96.920	642.076	21.650	0.029	15.095	0.7690	7.1647
2003	738.494	163.710	902.204	68.468	0.000	18.146	0.9327	8.6659
2004	627.895	170.310	798.205	106.386	0.505	21.337	0.8965	8.2047
2005	663.937	52.720	716.657	73.442	0.008	7.356	0.9933	9.3924
2006	490.854	26.880	517.734	85.434	0.058	5.192	0.9790	9.7517
2007	335.705	64.522	400.226	28.721	0.060	16.121	0.9445	9.5152
2008	463.422	89.595	553.017	22.103	0.002	16.201	1.1280	12.2034
2009	561.287	369.419	930.706	35.112	0.000	39.692	1.2456	13.1797
2010	632.778	275.697	908.475	12.028	0.037	30.347	1.1909	12.8612
2011	568.241	247.578	815.819	6.093	3.492	30.347	1.1031	10.8184
2012	409.013	178.204	587.217	6.090	0.013	30.347	0.7988	8.9809
2013	314.740	137.129	451.869	6.090	0.000	30.347	0.9132	10.6434

Discards make up approximately 19.41 % of the catch over the 1998-2006 years.

Table 15.5 RBC calculations for Mirror Dory. C_{targ} and $CPUE_{targ}$ relate to the period 1986-1995, $CPUE_{Lim}$ 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 (7).

Ref_Year	1992-1997&2003-2006
CE_Targ	0.9666
CE_Lim	0.3866
CE_Recent	1.0015
Wt_Discard	172.046
Scaling	1.0602
Last Year's TAC	1077
C_{targ}	561.235
RBC	**595.008**

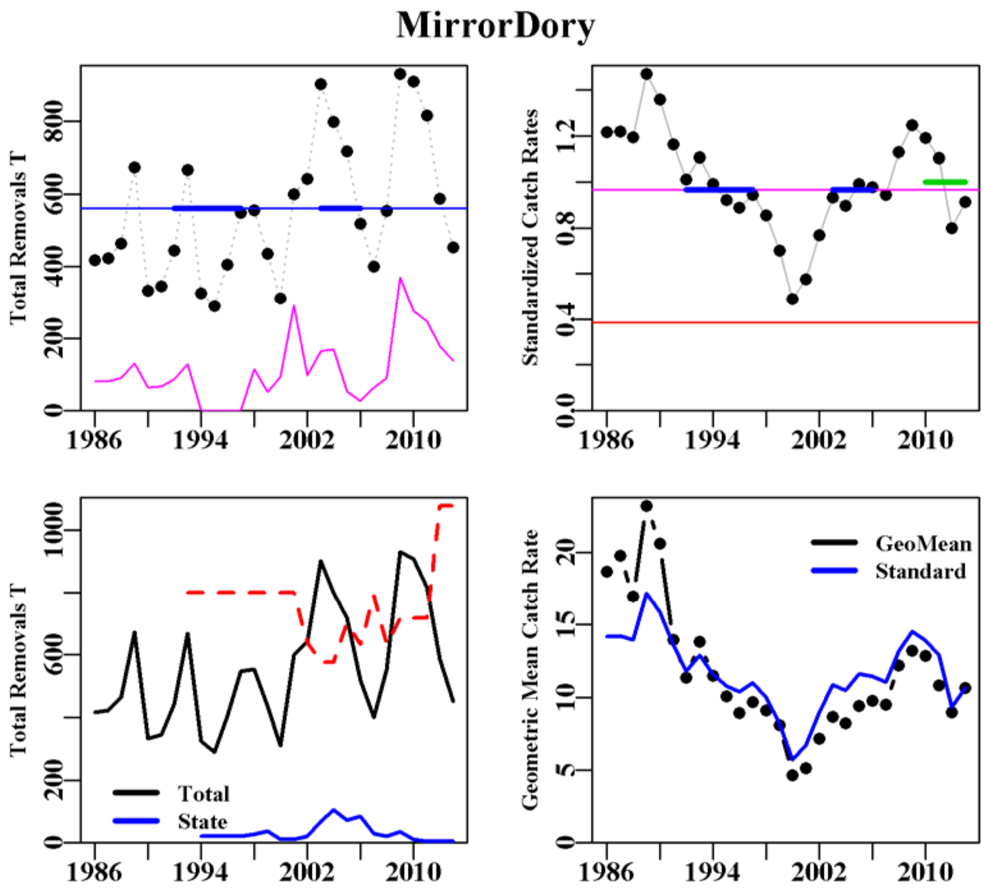

Figure 15.2 Mirror Dory. Top left is the total removals with the fine line illustrating the target catch. Top right represents the standardized catch rates with the upper fine line representing the target catch rate and the lower line the limit catch rate. Thickened lines represents the reference period for catches, catch rates, and the recent average catch rate.

15.4.3 Mirror Dory East (DOM – 37264003 – Z. nebulosus)

Table 15.6 Mirror Dory data for the TIER 4 calculations. Total is the sum of Discards, State, Non Trawl and SEF2 catches. All values in Tonnes. CE is the standardized catch rate for Zones 10 to 30 in depths 0 – 600m (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			19.409	1.1548	18.7487
1987	328.474	79.106	407.580			19.409	1.1538	19.9429
1988	356.164	85.775	441.938			19.409	1.1336	16.8882
1989	530.901	127.857	658.758			19.409	1.3691	23.1617
1990	257.511	62.016	319.528			19.409	1.2850	20.5538
1991	257.915	62.113	320.028			19.409	1.1339	14.2052
1992	337.458	81.270	418.727			19.409	0.9861	11.7312
1993	503.640	121.291	624.931			19.409	1.0790	14.1976
1994	303.620	0.000	303.620	20.402	0.000	0.000	0.9486	11.6924
1995	242.777	0.000	242.777	18.688	0.000	0.000	0.8644	10.2913
1996	262.435	0.000	262.435	14.081	0.000	0.000	0.7576	7.7998
1997	361.397	0.000	361.397	14.308	0.000	0.000	0.8025	8.6425
1998	292.102	76.454	368.556	17.942	0.000	20.744	0.7264	8.0944
1999	301.020	40.962	341.981	29.076	0.000	11.978	0.6466	7.8713
2000	187.852	80.358	268.209	9.610	0.000	29.961	0.5010	4.7885
2001	168.695	160.582	329.277	5.688	0.053	48.768	0.5047	4.0443
2002	243.846	43.352	287.198	9.684	0.013	15.095	0.6302	5.2594
2003	534.444	118.476	652.921	49.550	0.000	18.146	0.9230	7.7687
2004	406.127	110.158	516.285	68.811	0.327	21.337	0.8777	7.2637
2005	537.137	42.651	579.788	59.416	0.006	7.356	1.1194	9.9946
2006	402.465	22.040	424.504	70.050	0.048	5.192	1.1227	10.3893
2007	254.389	48.893	303.282	21.764	0.046	16.121	1.2110	11.4463
2008	391.325	75.656	466.981	18.664	0.002	16.201	1.3456	14.4563
2009	411.469	270.814	682.283	25.740	0.000	39.692	1.4212	15.8458
2010	432.522	188.447	620.969	8.221	0.025	30.347	1.1906	14.3976
2011	390.628	170.194	560.822	4.188	2.401	30.347	1.1928	12.7502
2012	328.790	143.251	472.041	4.896	0.010	30.347	0.9416	11.2957
2013	250.073	108.954	359.027	4.839	0.000	30.347	0.9771	11.8284

Discards make up approximately 19.41 % of the catch over the 1998-2006 period.

Table 15.7 RBC calculations for Mirror Dory East. C_{targ} and $CPUE_{targ}$ relate to the period 1986-1995, $CPUE_{Lim}$ 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 (7).

Ref_Year	1986-1995
CE_Targ	1.1108
CE_Lim	0.4443
CE_Recent	1.0755
Wt_Discard	131.565
Scaling	0.947
Last Year's TAC	1077
C_{targ}	414.661
RBC	**392.696**

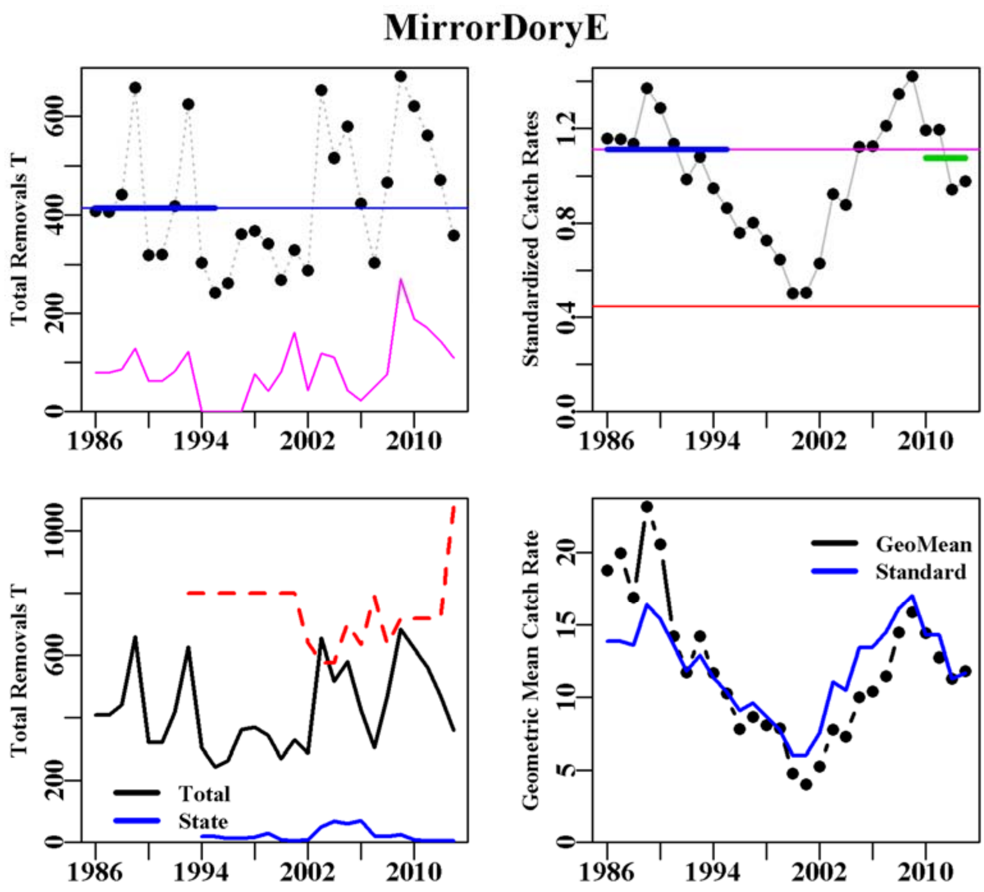

Figure 15.3 Mirror Dory. Top left is the total removals with the fine line illustrating the target catch. Top right represents the standardized catch rates with the upper fine line representing the target catch rate and the lower line the limit catch rate. Thickened lines represents the reference period for catches, catch rates, and the recent average catch rate.

15.4.4 Mirror Dory East – Discards

Following instructions from the RAG last year 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 392 t to523 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 15.8 Mirror Dory data for the TIER 4 calculations. Total is the sum of Discards, State, Non Trawl, SEF2, and ECDW catches. All values in Tonnes. StandCE is the standardized catch rate for all Zones 10 to 50 in depths 0 – 1000m (Haddon, 2013). GeoMean is the geometric mean catch rates. (D/C) +1 is the multiplier used with StandCE to generate DiscCE (see the Methods)

Year	Catch	Discards	Total	(D/C)+1	StandCE	DiscCE	GeoMean	TAC
1986	329.399	79.329	408.728	1.2408	1.1548	1.1392	18.7487	1986
1987	328.474	79.106	407.580	1.2408	1.1538	1.1382	19.9429	1987
1988	356.164	85.775	441.938	1.2408	1.1336	1.1183	16.8882	1988
1989	530.901	127.857	658.758	1.2408	1.3691	1.3506	23.1617	1989
1990	257.511	62.016	319.528	1.2408	1.2850	1.2676	20.5538	1990
1991	257.915	62.113	320.028	1.2408	1.1339	1.1186	14.2052	1991
1992	337.458	81.270	418.727	1.2408	0.9861	0.9728	11.7312	1992
1993	503.640	121.291	624.931	1.2408	1.0790	1.0644	14.1976	1993
1994	303.620	0.000	303.620	1.0000	0.9486	0.7542	11.6924	1994
1995	242.777	0.000	242.777	1.0000	0.8644	0.6872	10.2913	1995
1996	262.435	0.000	262.435	1.0000	0.7576	0.6023	7.7998	1996
1997	361.397	0.000	361.397	1.0000	0.8025	0.6380	8.6425	1997
1998	292.102	76.454	368.556	1.2617	0.7264	0.7287	8.0944	1998
1999	301.020	40.962	341.981	1.1361	0.6466	0.5840	7.8713	1999
2000	187.852	80.358	268.209	1.4278	0.5010	0.5687	4.7885	2000
2001	168.695	160.582	329.277	1.9519	0.5047	0.7832	4.0443	2001
2002	243.846	43.352	287.198	1.1778	0.6302	0.5901	5.2594	2002
2003	534.444	118.476	652.921	1.2217	0.9230	0.8965	7.7687	2003
2004	406.127	110.158	516.285	1.2712	0.8777	0.8871	7.2637	2004
2005	537.137	42.651	579.788	1.0794	1.1194	0.9606	9.9946	2005
2006	402.465	22.040	424.504	1.0548	1.1227	0.9414	10.3893	2006
2007	254.389	48.893	303.282	1.1922	1.2110	1.1478	11.4463	2007
2008	391.325	75.656	466.981	1.1933	1.3456	1.2766	14.4563	2008
2009	411.469	270.814	682.283	1.6582	1.4212	1.8735	15.8458	2009
2010	432.522	188.447	620.969	1.4357	1.1906	1.3590	14.3976	2010
2011	390.628	170.194	560.822	1.4357	1.1928	1.3615	12.7502	2011
2012	328.790	143.251	472.041	1.4357	0.9416	1.0747	11.2957	2012
2013	250.073	108.954	359.027	1.4357	0.9771	1.1153	11.8284	2013

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 15.9 RBC calculations for Mirror Dory East. C_{targ} and $CPUE_{targ}$ relate to the period 1986-1995, $CPUE_{Lim}$ 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 (7).

Ref_Year	1986-1995
CE_Targ	1.0611
CE_Lim	0.4244
CE_Recent	1.2276
Wt_Discard	131.565
Scaling	1.2615
Last Year's TAC	1077
C_{targ}	414.661
RBC	**523.107**

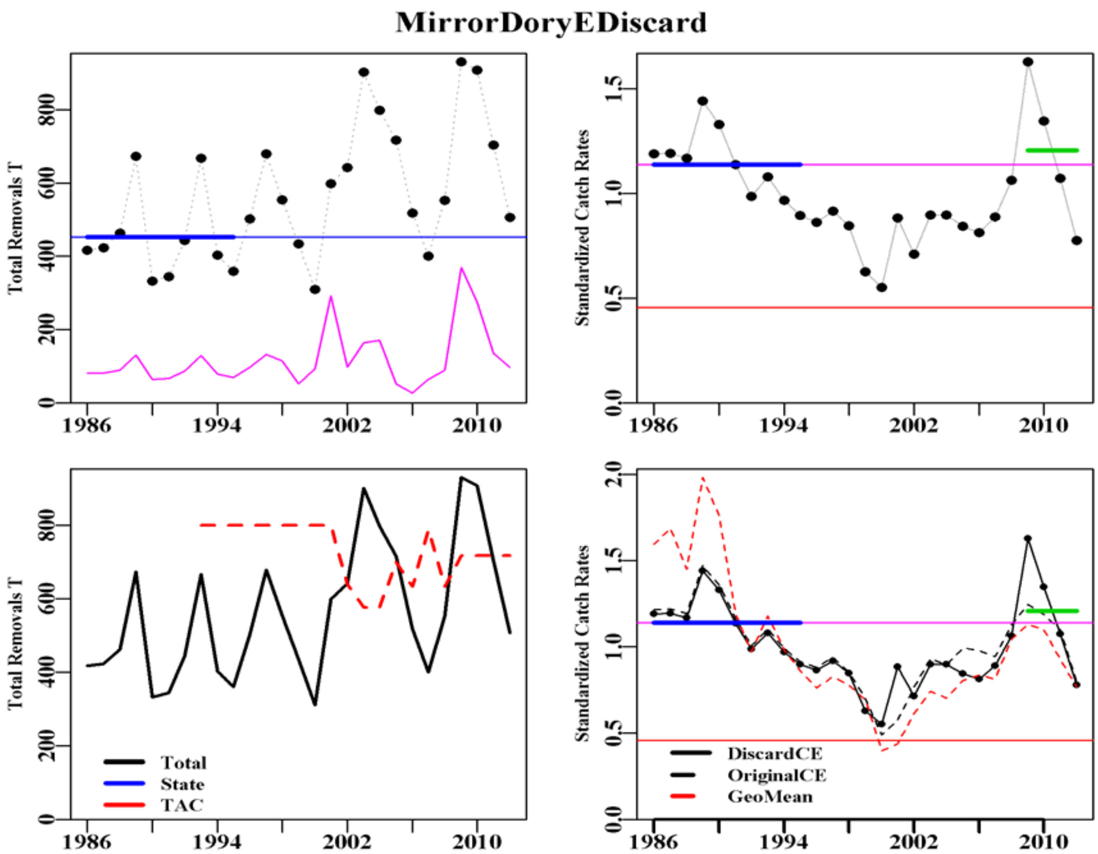

Figure 15.4 Mirror Dory. Top left is the total removals with the fine line illustrating the target catch. Top right represents the standardized catch rates with the upper fine line representing the target catch rate and the lower line the limit catch rate. Thickened lines represents the reference period for catches, catch rates, and the recent average catch rate.

15.4.5 Mirror Dory West (DOM – 37264003 – Z. nebulosus)

Table 15.10 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			19.409	2.4840	13.7130
1987	12.326	2.968	15.294			19.409	1.6361	16.0832
1988	17.036	4.103	21.139			19.409	1.3323	18.4525
1989	11.499	2.769	14.268			19.409	1.6929	24.6757
1990	10.089	2.430	12.518			19.409	1.1358	21.6631
1991	19.285	4.644	23.930			19.409	0.7994	11.7670
1992	20.142	4.851	24.993			19.409	0.6694	8.1608
1993	33.961	8.179	42.139			19.409	0.7884	10.1017
1994	21.044	5.068	26.113	1.414	0.000	19.409	0.6993	9.3264
1995	47.176	11.362	58.538	3.632	0.000	19.409	0.8999	9.0896
1996	142.290	34.268	176.559	7.634	0.000	19.409	1.2675	13.3473
1997	186.019	44.800	230.819	7.365	0.000	19.409	1.2801	12.8686
1998	147.272	38.546	185.818	9.046	0.000	20.744	1.2371	12.6121
1999	81.119	11.038	92.158	7.835	0.000	11.978	0.8117	8.8763
2000	29.554	12.642	42.196	1.512	0.000	29.961	0.4445	4.0569
2001	138.057	131.418	269.475	4.655	0.043	48.768	0.7680	7.9361
2002	301.310	53.568	354.878	11.966	0.016	15.095	1.1255	11.7181
2003	204.050	45.234	249.283	18.918	0.000	18.146	0.9608	11.0165
2004	221.768	60.152	281.920	37.575	0.178	21.337	0.9606	10.3786
2005	126.800	10.069	136.869	14.026	0.002	7.356	0.7613	8.0456
2006	88.390	4.840	93.230	15.384	0.010	5.192	0.6415	8.0395
2007	81.316	15.629	96.944	6.957	0.015	16.121	0.5786	6.7120
2008	72.097	13.939	86.035	3.439	0.000	16.201	0.6516	7.5767
2009	149.818	98.605	248.423	9.372	0.000	39.692	0.9974	9.7010
2010	200.256	87.250	287.506	3.807	0.012	30.347	1.1872	11.0745
2011	177.613	42.130	219.743	1.904	1.092	19.173	0.9114	8.6510
2012	80.223	19.029	99.253	1.195	0.003	19.173	0.5395	6.0700
2013	64.667	19.029	99.253	1.251	0.000	19.173	0.7381	8.0998

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 – 2013.

Table 15.11 RBC calculations for Mirror Dory. C_{targ} and $CPUE_{targ}$ relate to the period 1996-2005, $CPUE_{Lim}$ 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 (7).

Ref_Year	1996-2005
CE_Targ	0.9617
CE_Lim	0.3847
CE_Recent	0.844
Wt_Discard	26.658
Scaling	0.7961
Last Year's TAC	1077
C_{targ}	201.998
RBC	**160.809**

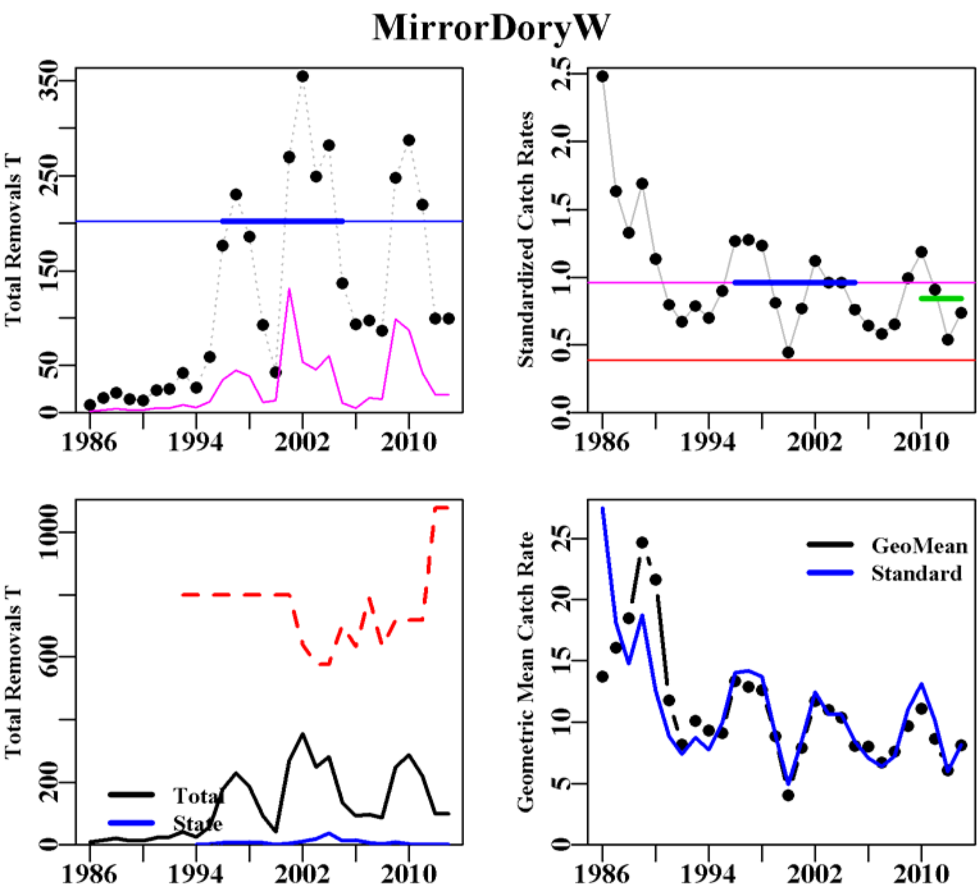

Figure 15.5 Mirror Dory. Top left is the total removals with the fine line illustrating the target catch. Top right represents the standardized catch rates with the upper fine line representing the target catch rate and the lower line the limit catch rate. Thickened lines represents the reference period for catches, catch rates, and the recent average catch rate.

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16. CPUE Standardization and Characterization for the SESSF Shark Fishery. Data from 1997 - 2013

Malcolm Haddon

CSIRO Oceans and Atmosphere Flagship, GPO Box 1538, Hobart, TAS 7001, Australia

16.1 Summary

There are numerous previous documents that summarize earlier shark related data available in the CANDE data sets; these contained data pre-1997 which has been shown to have a different character to that collected together in the SESSF logbooks (Haddon, 2014a). This present document focuses on data from years 1997 – 2013 available in the SESSF database. The SESSF database contains records relating to all methods and areas and allow for a more inclusive analysis, which given the reduction in School shark catches in recent years, for example, is required to provide a complete view of the current state of the fishery.

Catches of School shark are as low as they have ever been, however, CPUE from the gill net fishery can no longer be assumed to constitute an index of relative abundance for the School shark stock. The efforts to avoid School shark appear to be relatively successful, but exactly that is leading to both the gill net catch rate appearing to decline and those catch rates no longer providing a valid index of abundance. Catches by trawler are not targeted, as evidenced by the large proportion of < 30kg shots present in the data. Nevertheless, the areas in which they are caught has not changed greatly and yet the catch rates have begun to increase significantly. This is a positive sign, which when combined with the observation of increased proportions of smaller School sharks in the ISMP sampling are a first clear evidence of School sharks showing some signs of increasing.

The avoidance of School sharks and an array of closures in South Australia have also led to a reduction in gill net catches of gummy sharks as well as an apparent reduction in the catch rates for gill net caught gummy sharks. However, catches by bottom line and trawl are increasing, especially those by bottom line. Catch rate standardizations for both bottom-line and for trawl caught gummy sharks indicate strong and recent increases in catch rates for gummy shark. This counters the appearance of events from the gill net fishery.

Catches of saws sharks are considered to be a bycatch and this is supported by the high proportion of reported catches being < 30 kg in both gill net and trawl caught fish. The CPUE standardization for gill nets exhibits a steady decline since about 2001, however, the trawl caught saw shark standardization exhibits a noisy but flat trend. To complement this finding CPUE of saw sharks by Danish Seine (which has the highest proportion of shots < 30kg among methods) has been flat since 2006 onwards.

Finally, elephant fish also constitute a non-targeted species, again with a large proportion of small shots. The gill net CPUE is also flat and noisy, which is an analysis conducted in the absence of discard data. In the last few years discard rates for elephant fish have been very high, which would imply that their catchrates would in fact be increasing.

16.2 Introduction

The shark fishery off southern Australia has a long history, starting with a long-line fishery which began in the 1920s, primarily targeting School sharks (*Galeorhinus galeus*). This fishery 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 it also used to target relatively large quantities of School sharks but these are now a non-target only species (to be avoided where possible). 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. This document attempts to draw together the catch and CPUE data, as reported in the SESSF logbooks, for each of these species.

16.2.1 Current Issues

School sharks, sawsharks, and elephant fish are not usually targeted and discards can be relatively high in these species. School sharks especially are currently considered to be in a depleted state and the Gillnet, Hook, and Trap fishery (GHT) actively attempts to avoid this species and because some prime gummy shark areas are also prime school shark areas, this avoidance may be having a negative effect upon cpue for the primary target, the gummy shark. Such a negative effect will be difficult or impossible to allow for in the following analyses, which thus need to be considered with caution.

For the last 50 years the GHT shark fishery has primarily been a gill net fishery, however, in South Australian waters there have been incidents of marine mammal mortalities with the Australian sea lion (*Neophoca cinerea*; Goldsworthy et al., 2007) and with dolphins (common dolphin – *Delphinus delphis* and Bottlenose dolphin – *Tursiops aduncus*). These interactions have led to the development of an extensive set of marine areas closed to gill net fishing throughout South Australia (AFMA, 2011). In an attempt to address these bycatch problems a move to return to line methods and to auto-lining for gummy sharks has also occurred (Knuckey et al., 2014). These events and responses have mainly affected the gummy and school shark fisheries rather than those for saw sharks and elephant fish.

The effects of the closures has also led to gill net effort moving into the Bass Strait and the full implications are still to be fully expressed within the fishery as a whole.

16.3 Methods

16.3.1 Catch Rate Standardization

The data used in the following analyses only derives from the SESSF logbook data, which differs in a number of ways from the data used previously. However, there is a disjunction in the complete time series of data that occurred at the same time as the introduction of the use of the SESSF logbooks to the shark fishery (Haddon, 2014a, see especially Figure 21.13 on page 312; Haddon2014b).

Catch rates were calculated where there were positive catches of gummy sharks associated with positive effort levels. Where catch rates could be calculated (positive catches of a species) they were also log transformed in preparation for the log-linear modelling of positive catches. Depth information, where present, was sub-divided into 20 metre depth categories for inclusion in statistical standardizations (the size of the depth classes varied with fishing method (thus with trawl catches of School sharks, out to 800 m, depth classes were 50m).

16.3.2 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 16.2). 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.

16.3.3 The Year Effect

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:

$$CPUE_t = e^{\left(\gamma_t + \sigma_t^2/2\right)} \tag{1}$$

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

Year	the standard calendar year,
Vessel	each vessel is uniquely and confidentially identified,
Month	standard calendar months,
Region	Standard shark statistical reporting blocks (Figure 16.1).
Gear	Gillnets, Trawl, or Danish Seine as appropriate..
DepCat	20m categories
DayNight	Day, Night, Mixed, Unknown categories
DayNight:DepCat	An interaction term including depth changes through the day.
DepCat:Month	An interaction term used to include any seasonal changes across areas.
DayNight:Month	An interaction term used to include any seasonal changes across when fishing occurred during each day.

16.3.4 Data Selection for Different Shark species

Data selection occurred with the years of data used by zone, the gear used, the depths, used. With gummy shark areas were only 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 16.4).

In all cases only data between 1997 – 2013 were used

There were also some records where no effort data were included (effort = -1) and these could not be included in the standardization. In addition, if the reported effort was < 1000m these records were also excluded.

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.

16.3.4.1 School Shark

Given the active avoidance of school sharks by industry an analysis of gillnets CPUE would have been invalid and misleading. Nevertheless there were trawl CPUE available and these were standardized using classical methods (Haddon, 2014c).

There were various data selections made with respect to gear types, depths, and years prior to data analysis (Table 16.1).

Table 16.1. Criteria for selecting which records to include in the standardization of school sharks.

Criteria	Values
Gear Types	Trawl (TW and TDO); but all method catches summarized.
Depth	50 m depth classes 1 – 800 m
Regions	1 – 7: WSA, CSA, ESA, WBS, EBS, WTS, ETS
Years	1997 - 2013

16.3.4.2 Saw Sharks

Saw sharks are considered to be primarily a bycatch species and are taken mostly in the gillnet, the trawl, and the Danish seine fisheries. The amounts landed by each of these methods are such that a standardization was conducted for each method in turn and the outcomes compared. In each case the same set of years was used but usually a different set of gears, depths, and Regions were selected to match the operations within each fishery (Table 16.2).

Table 16.2. Criteria for selecting which records to include in the standardization of saw sharks for the gillnet, trawl, and Danish Seine fisheries.

Criteria	Values
Years	1997 - 2013
Gear Type	Gillnets (GN)
Depth	0 – 150
Regions	1 – 7: WSA, CSA, ESA, WBS, EBS, WTS, ETS
Gear Types	Trawl (TW and TDO); but all method catches summarized.
Depth	20 m depth classes 0 - 500
Regions	1, 3 – 8: WSA, ESA, WBS, EBS, WTS, ETS, NSW
Gear Types	Danish Seine (DS)
Depth	0 – 240
Regions	4 – 5: WBS, EBS

16.3.4.3 Elephant Fish

While there are reported catches of elephant fish (*Callorhinchus milli*) in the trawl and Danish seine fisheries most catches are taken in the gillnet fishery so only a standardization for that fishery is undertaken. There are relatively high levels of discarding of elephant fish so an analysis that generates a CPUE series that attempts to include the influence of discard levels as well as reported catches is produced.

There are data selection criteria for elephant fish (Table 16.3), in particular, in order to eliminate the influence of deeper water chimaerid species that can be included in the code elephant fish.

Table 16.3**.** Criteria for selecting which records to include in the standardization of elephant fish.

Criteria	Values
Gear Types	Gillnet (GN); but all method catches summarized.
Depth	20 m depth classes 1 – 160 m
Regions	2 – 7: CSA, ESA, WBS, EBS, WTS, ETS
Years	1997 - 2013

16.3.4.4 Gummy Sharks (Mustelus antarcticus 37017001)

Table 16.4. Criteria for selecting which records to include in the standardization of gummy sharks.

Criteria	Values
Gear Types	6", 6.5", and 7" mesh gillnet
Depth	25 m depth classes 1 – 250 m
Areas	Reporting > 10 t over years.
Vessels	Average annual catch > 2 t
Vessels	In fishery for > 2 years
Effort	Remove records < 1000 m

16.4 Results

16.4.1 The Shark Fishery

The southern shark fishery extends across from New South Wales, around Tasmania, and across to Western Australia (Figure 16.1).

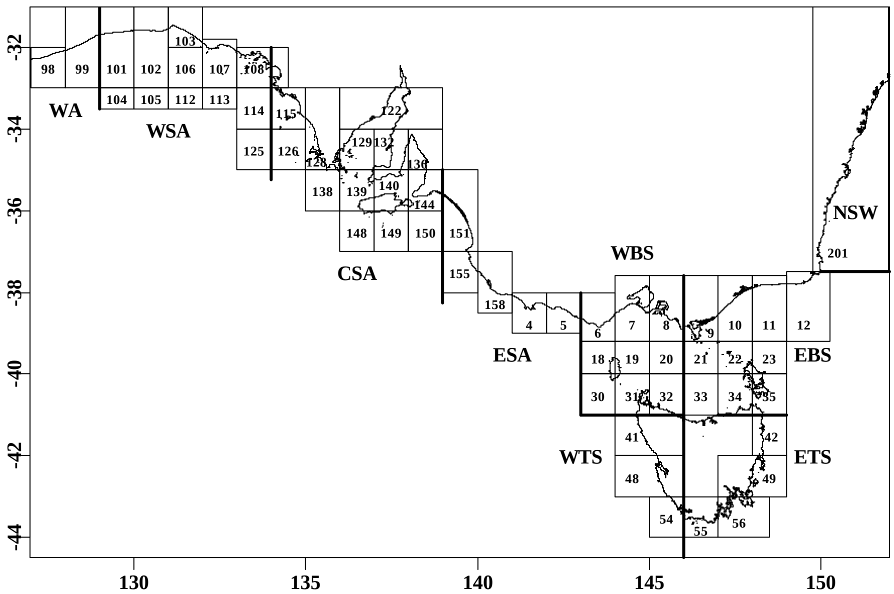

Figure 16.1. Shark statistical reporting areas and statistical regions. WA is Western Australia, WSA is Western South Australia, CSA is Central South Australia, ESA is Eastern South Australia (sometimes known as SAV – South Australia Victoria), WBS is Western Bass Strait, EBS is Eastern Bass Strait, NSW is New South Wales, ETS is Eastern Tasmania and WTS is Western Tasmania.

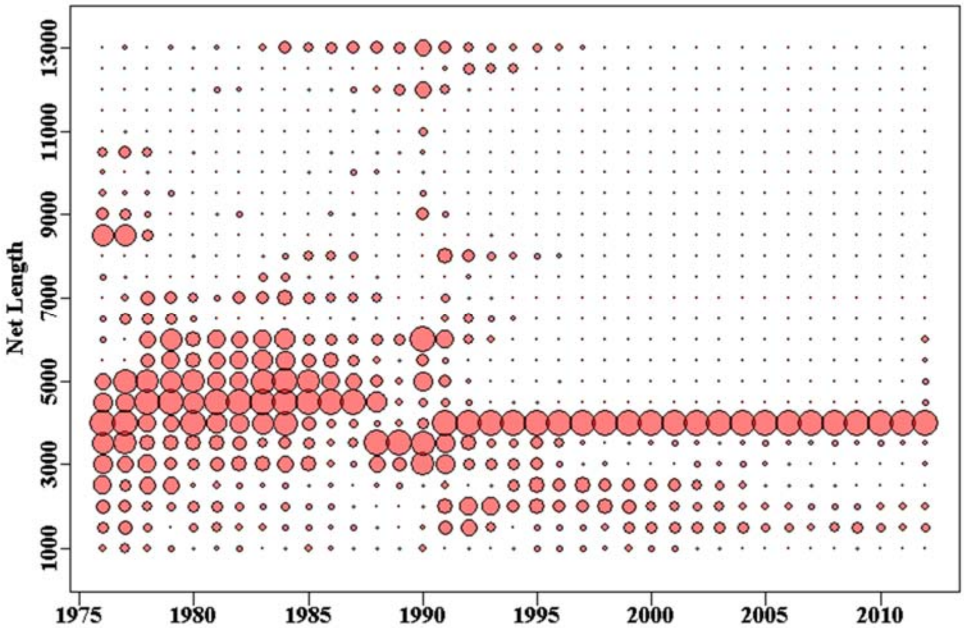

Figure 16.2**.** The relative number of records in the shark fishery in each year reporting different net lengths of effort. The radical change just before 1995 is clear. The 13000m line is >= 13000m (which included many data records that were monthly summaries).

16.4.2 School Shark Catches

16.4.2.1 The Data

The CSIRO version of the GenLog catch and effort database was used to identify catches of School Shark (*Galeorhinus galeus*; CAAB code 37017008; code SHS). Between 1997 and 2013 there were 77,659 records.

A number of fisheries report School Shark either regularly through time, or at high levels, or both (Table 16.5). These include the GAB, the GHT, the SEN (before the GHT was defined), the SET, the SSF, SSG, and SSH, and the WDW (fishery abbreviations in Table 16.6). Not surprisingly the major catches are reported in the Southern Shark fishery (SSF, SSG, and SSH) and the South East Non-Trawl, and then the Gillnet, Hook and Trap fishery.

Table 16.5. The reported catches of School Shark in the different fisheries around Australia. The ordering has been modified to keep all the shark gillnet fisheries together at left.

Year	GHT	SEN	SSF	SSG	SSH	SET	GAB	TUN	WDW	CSF	ECT	VIT	NPF
1986						34.472							
1987						17.767	0.472						
1988		0.035				12.951	9.199						
1989						17.075	4.712						
1990						19.200	9.399						
1991						10.835	6.462						
1992						0.308	2.662						
1993						0.040	0.916		0.384				
1994							1.475		0.546				
1995							2.255		0.228				
1996						18.144	7.126	1.780	1.734				
1997		449.978		0.012		19.398	5.075	2.652	0.288				
1998		475.764		92.413	2.650	18.062	4.000	1.154	0.070	0.250			
1999		148.910	185.383	129.899	12.300	13.485	2.115	1.600		0.665			
2000		3.507	439.427			15.570	1.658	0.940	0.389	0.110			
2001		2.029	169.443			15.596	1.567		0.223		0.105		0.012
2002	0.007	2.822	197.123			17.059	0.496		0.010	0.003			
2003	203.616					12.866	0.830		0.351				
2004	185.811					12.957	1.205		0.066				
2005	201.337					7.187	1.650					0.010	
2006	198.714					9.848	1.339		0.010		0.035		
2007	189.666					7.395	0.715					0.001	
2008	224.362					9.124	0.748		0.027	0.045		0.002	
2009	238.873					13.085	1.072						
2010	166.000					12.838	1.218		0.019			0.010	
2011	167.143					14.841	0.405					0.008	
2012	123.657					11.351	0.616						
2013	128.120					18.274	0.358		0.000		0.010		
Total	2027.305	1083.045	991.376	222.325	14.949	359.727	69.746	8.126	4.345	1.073	0.150	0.031	0.012

Table 16.6. Fishery abbreviations and their full names.

Abbreviation	Full Name of Fishery
CSF	Coral Sea Fishery
ECT	Eastern Tuna & Billfish Fishery
GAB	Great Australian Bight Fishery
GHT	Gillnet, Hook and Trap Fishery
NPF	Northern Prawn Fishery
SEN	South East Non-Trawl Fishery
SET	South East Trawl Fishery
SSF	Southern Shark Fishery
SSG	Southern Shark Gillnet Fishery
SSH	Southern Shark Hook Fishery
TUN	Tuna Fishery
VIT	Victorian Inshore Trawl Fishery
WDW	Western Deep Water Trawl Fishery

The main Fishing methods reporting catches (Table 16.7 and Table 16.8) of School Shark include many of the lining methods, gillnets, trawling, and even Danish Seine. Relatively small amounts were reported with no method, with fish traps, Graball net, Handline, Long Line, or Rod and Reel.

Table 16.7. The main methods reporting School Shark in the SESSF GenLog database. Eight categories of method with catches < 10 t are at the bottom. Under trawl the larger figure in parentheses) is from 1986 – 2013.

Code	Method Name	Total Catch 97 – 13
GN	Gillnet	3984.435
TW	Trawl	248.753 (423.955)
BL	Demersal Longline	274.091
AL	Auto Line	60.502
DL	Drop Line	19.857
LLP	Pelagic Longline	8.241
DS	Danish Seine	5.809
Unknown	Unknown	3.506
TDO	Trawl Demersal Otter = Trawl	1.281
TL	Trotline	0.272
HL	Handline	0.219
FP	Fish Trap	0.025
GA	Graball	0.016

Table 16.8. Catches of School Shark (t) reported by different methods; where catches are > 1 t (method codes given in Table 16.7)..

Method	GN	TW	BL	AL	DL	LLP	DS	Unknown	TDO
1986		34.347					0.125		
1987		18.192					0.047		
1988		22.150			0.035				
1989		21.784					0.003		
1990		28.214					0.044	0.341	
1991		14.879					0.370	2.048	
1992		2.965						0.005	
1993		1.340							
1994		2.021							
1995		2.483							
1996		26.827				1.780	0.177		
1997	415.183	24.345	29.925		3.892	2.652	0.351	0.755	
1998	532.815	22.006	34.524	0.082	3.656	1.154	0.121	0.005	
1999	441.939	15.452	32.375		2.821	1.600	0.118	0.030	
2000	407.568	17.583	33.501		1.939	0.940	0.034		
2001	159.874	17.009	8.862	0.652	2.029	0.105	0.067	0.322	
2002	186.275	17.464	11.143	1.763	0.734		0.101		
2003	183.391	13.943	17.260	1.625	1.333		0.104		
2004	171.324	14.034	8.237	5.441	0.737		0.194		
2005	194.372	8.727	4.539	2.030	0.396		0.121		
2006	190.957	11.118	4.041	3.605	0.146		0.079		
2007	181.949	7.650	5.960	1.589	0.168		0.461		
2008	216.031	9.022	5.534	2.743	0.099		0.879		
2009	227.803	13.908	5.926	4.473	0.671		0.249		
2010	149.771	13.802	9.439	6.457	0.333		0.283		
2011	146.498	14.028	8.346	11.912	0.387		1.136		0.090
2012	100.477	10.875	15.313	7.678	0.189		0.532		0.560
2013	78.210	17.788	39.168	10.452	0.290	0.010	0.213		0.631
Total	3984.435	423.955	274.091	60.502	19.857	8.241	5.809	3.506	1.281

Gillnet fishing dominated across the shark fishery since the late 1970s but the bycatch issues in South Australia are leading to a recent increase in the use of long lining methods, especially bottom line and auto-line fishing (Table 16.8;Figure 16.3). The decline in landing reported from trawl from 1991 – 1995 is only a figment of non-reporting and has been reported as stemming from the belief that non-quota species need not be reported in the logbooks in the lead up and following the introductions of quotas into the South Eastern trawl fishery. Quotas were only introduced to the shark fishery for the 1997 fishing year with other management events occurring in the mid-1990s also having large effects upon the fleet and fishing activities (Figure 16.2).

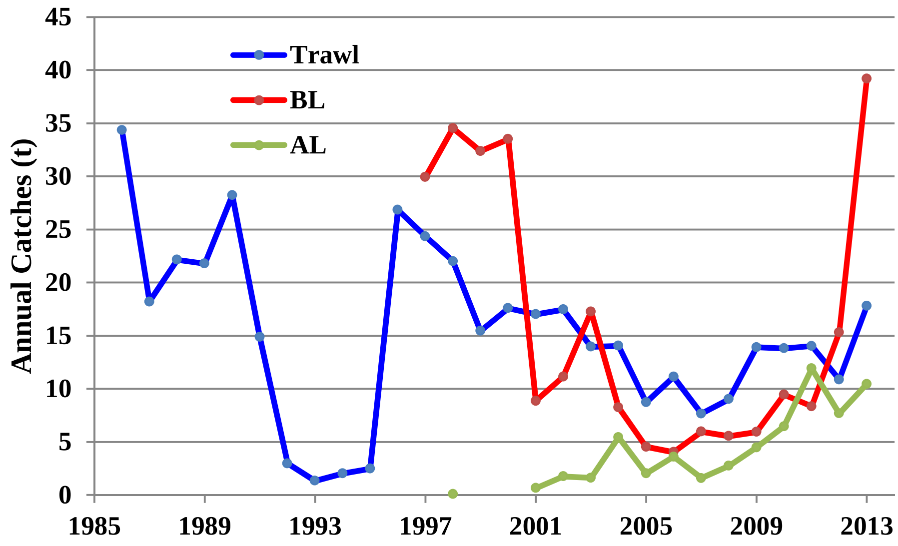

Figure 16.3. The reported catches of School Shark in GenLog from 1986 – 2013 for two line methods (Autoline and Bottom line). The dip in trawl catches in 1992 – 1995 is due to a lack of reporting. The recent increase in line catches is mostly due to changes in South Australia, although partly involves smaller increases in Tasmania.

Table 16.9. Catches of School shark taken by gill net in different regions, reported in the SESSF catch and effort log books. The SA, BS, and TAS columns are the totals for each complete region. SA is South Australia, BS is Bass Strait, and TAS is Tasmania. There were 40kg reported in NSW and 4.003 t in WA.

Year	WestSA	CentSA	EastSA	WestBS	EastBS	WestTas	EastTas	SA	BS	TAS
1997	130.975	139.257	26.434	53.536	29.826	18.200	5.927	296.666	83.361	24.127
1998	131.308	124.004	12.203	124.136	71.070	44.998	17.015	267.516	195.205	62.013
1999	72.847	131.219	13.211	92.808	37.699	43.208	26.090	217.278	130.507	69.299
2000	79.506	96.707	18.993	89.931	25.312	35.138	37.232	195.207	115.243	72.370
2001	35.329	54.819	9.567	24.544	19.417	3.686	2.062	99.714	43.961	5.749
2002	31.534	48.429	9.297	48.838	20.617	15.421	5.188	89.260	69.455	20.609
2003	35.889	63.677	8.173	34.047	20.876	11.692	1.250	107.739	54.923	12.942
2004	24.298	59.983	7.400	43.710	23.289	5.056	1.257	91.681	66.999	6.313
2005	23.652	69.955	8.386	43.533	33.819	9.331	1.217	101.993	77.352	10.548
2006	23.378	77.835	19.719	35.443	19.359	7.157	4.172	120.932	54.802	11.329
2007	37.933	46.747	13.053	30.778	31.766	10.428	6.078	97.733	62.544	16.506
2008	37.696	57.867	12.602	58.119	41.481	2.032	4.262	108.164	99.600	6.294
2009	43.179	62.277	24.816	58.917	29.712	2.065	6.768	130.272	88.629	8.833
2010	21.129	28.509	15.263	43.339	32.037	4.609	4.667	64.901	75.376	9.276
2011	15.122	23.735	14.953	38.849	36.987	3.051	13.718	53.810	75.836	16.769
2012	2.305	16.415	10.920	16.002	40.064	8.185	6.388	29.640	56.065	14.573
2013	1.832	7.940	7.395	29.043	23.538	4.290	4.023	17.167	52.581	8.313
Total	747.913	1109.374	232.385	865.571	536.865	228.548	147.314	2089.672	1402.436	375.861

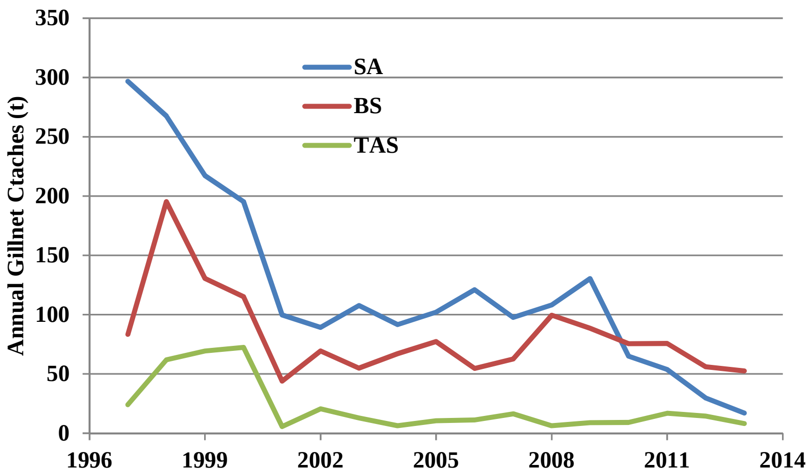

Figure 16.4 The reported catches of School Shark in GenLog by region from 1997 – 2013 for gill nets. SA is South Australia, BS is Bass Strait, and TAS is Tasmania.

South Australia dominated gill net catches of School sharks up until 2010, after which the multiple area closures to gill nets led to a major decline in gill net landings). Now Bass Strait dominates the gill net catches (Figure 16.4;Table 16.9). Gill nets remain the dominant fishing method for School sharks although following the gill net closures in South Australia the proportion of the total taken by other methods has begun to increase (Table 16.9, Table 16.14; Figure 16.5).

With changes in the proportion of the total catch taken by different methods the depth of fishing has also altered to reflect the fishing method changes (Figure 16.6 and Figure 16.7).

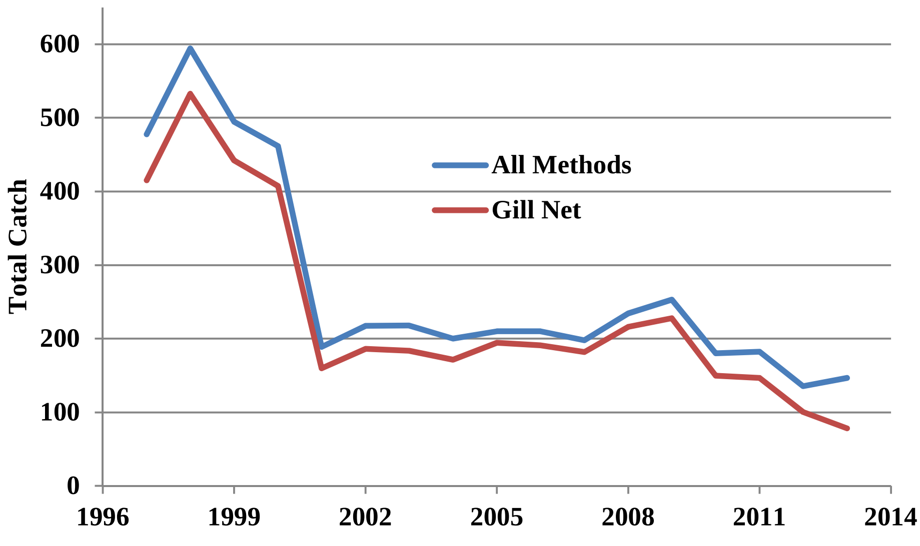

Figure 16.5. The total reported catches of School Shark in GenLog across all regions from 1997 – 2012 for all methods and for gill nets.

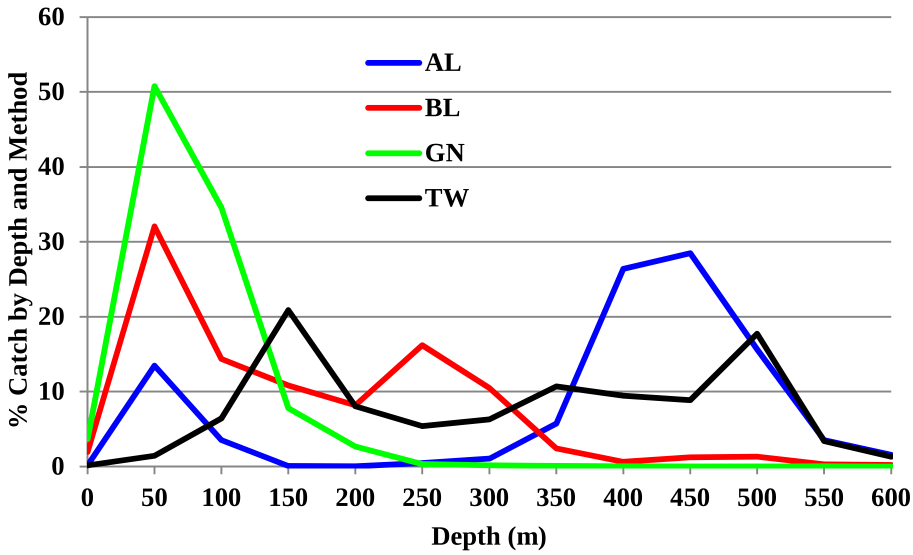

Figure 16.6. The proportional distribution of School Shark catches by depth (m) for four different fishing methods in the SESSF database across all regions from 1997 – 2012 for gill nets. The methods are AL – autoline, BL – bottom line, GN – gill net, and TW – trawl.

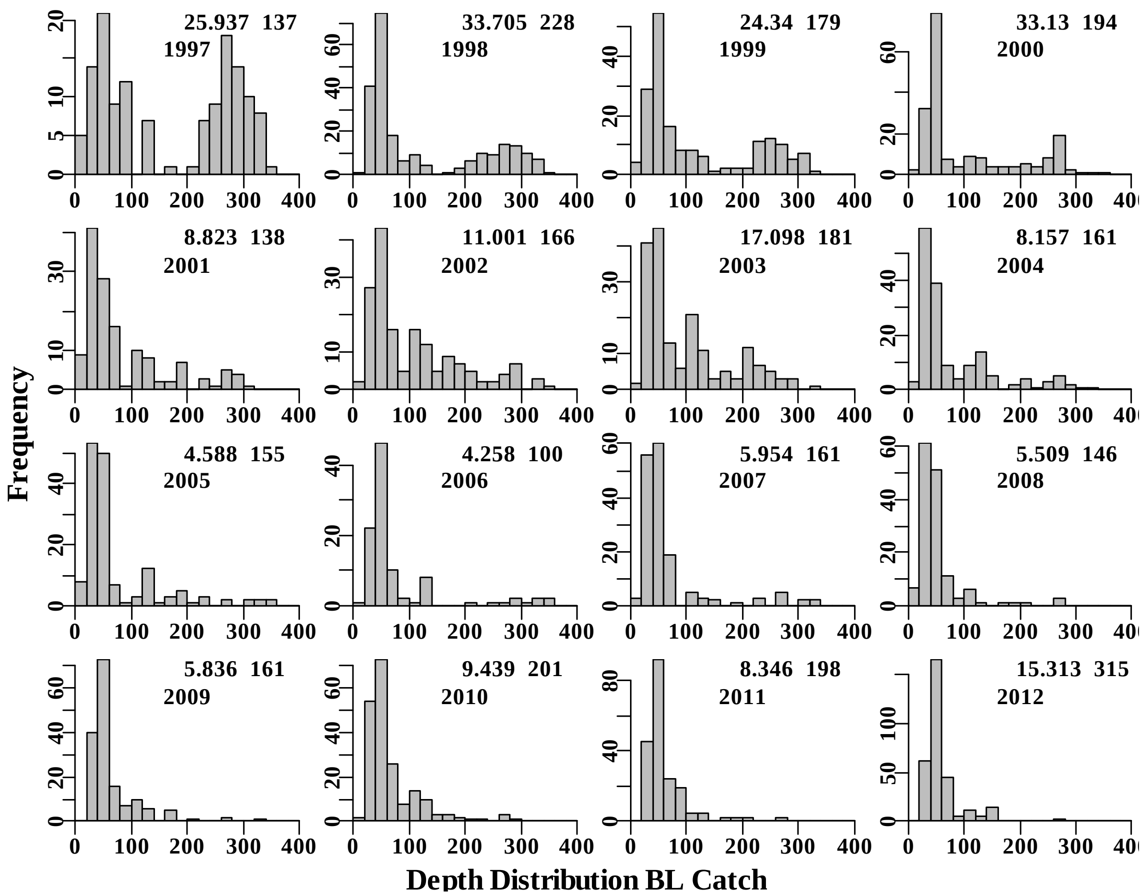

Figure 16.7. The depth distribution of Bottom Line catches from 1997 – 2012. The numbers on each graph are the annual Bottom Line catch and number of records, and the year of the observations.

16.4.3 Standardization of Trawl School Shark Catches

The efforts made by industry to avoid catching school sharks by gillnet imply that an attempt to standardize the gillnet CPUE would be invalid and misleading. However, trawl CPUE would not suffer from this bias, although a reported inability to obtain school shark quota at a viable price means that discarding rates of school sharks from trawls has increased in recent years.

The School shark data used was for catches taken by Trawl across shark regions from Western South Australia to Eastern Tasmania between depths of 0 to 600 m and between 1997 – 2013 (Table 16.10). There were 10153 records for analysis and nine different statistical models were fitted and compared (Table 16.11 andTable 16.12;Figure 16.9).

The standardization only operates from 1997 and indicates that a stock low was reached over the years 2000 – 2004 with the trend indicating a positive rise since 2005. The standardization reduces the large increase in the geometric mean CPUE observed in 2012 and 2013. Nevertheless, the CPUE index still continues to rise (Figure 16.8).

Table 16.10**.** School shark taken by Trawl across shark regions from Western South Australia to Eastern Tasmania between depths of 0 to 600 m and between 1997 - 2013. Total catch (TotCatch; t) is the total reported in the database, number of records used in the analysis (Records), reported catch (CatchT; t) in the area and depth used in the analysis and number of vessels used in the analysis (Vessels). GeoMean is the geometric mean of catch rates (kg/hr). The optimum model is model 6 (Table 16.11), Month and standard deviation (StDev) relates to the data in the optimum model.

Year	TotCatch	Records	CatchT	Vessels	GeoMean	Month	StDev
1997	477.403	980	18.735	53	3.4169	1.0825	0.0000
1998	594.363	768	17.333	45	3.5248	1.0792	0.0477
1999	494.357	636	12.986	45	3.5232	0.9674	0.0526
2000	461.601	870	15.475	66	2.6915	0.8239	0.0496
2001	188.975	761	15.314	44	3.1187	0.8399	0.0516
2002	217.520	911	16.812	50	3.1429	0.9095	0.0495
2003	217.662	716	12.601	52	2.8112	0.8156	0.0532
2004	200.040	619	12.594	45	2.8693	0.8680	0.0553
2005	210.185	417	7.019	39	2.6431	0.8803	0.0613
2006	209.946	480	9.585	38	2.7361	0.9113	0.0597
2007	197.777	288	6.767	25	3.2451	0.9758	0.0694
2008	234.307	363	8.093	25	2.9989	1.0918	0.0641
2009	253.029	377	12.541	24	3.4955	1.1671	0.0628
2010	180.085	454	12.307	23	3.5398	1.0791	0.0639
2011	182.397	591	13.470	25	3.4180	1.1281	0.0612
2012	135.624	503	10.622	24	3.8310	1.1429	0.0675
2013	146.762	419	17.872	28	5.1066	1.2375	0.0659

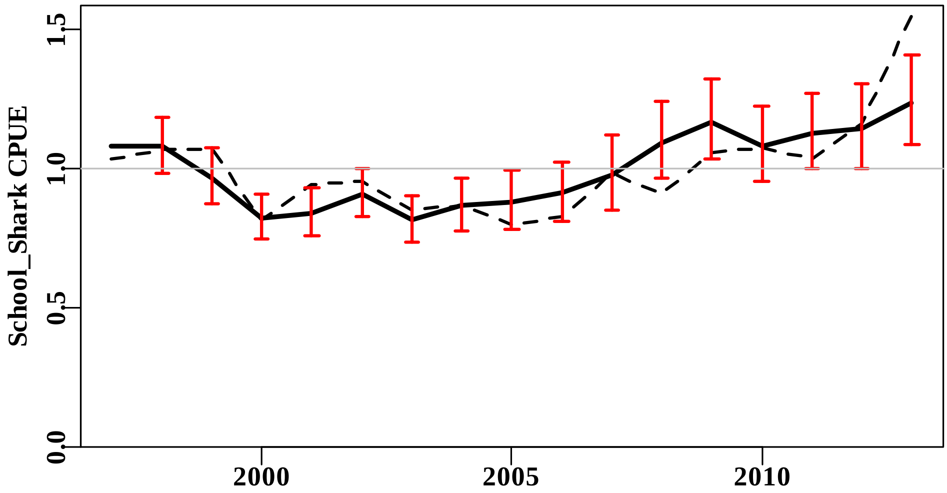

Figure 16.8. School shark taken by Trawl across shark regions from Western South Australia to Eastern Tasmania between depths of 0 to 600 m and between 1997 - 2013. The dashed black line represents the geometric mean catch rate and the solid black line the standardized catch rates (relative to the mean of the standardized catch rates). The red bars are 95% confidence intervals. Given reports of increased discarding of school sharks from trawlers the recent estimates of CPUE are presumably conservative.

Table 16.11. School shark taken by Trawl across shark regions from Western South Australia to Eastern Tasmania between depths of 0 to 250 m and between 1997 - 2013. Statistical model structures used in this analysis. DepCat is a series of 25 metre depth categories.

Model 1	LnCE ~ Year
Model 2	LnCE ~ Year +Vessel
Model 3	LnCE ~ Year +Vessel +Region
Model 4	LnCE ~ Year +Vessel +Region +DepCat
Model 5	LnCE ~ Year +Vessel +Region +DepCat +DayNight
Model 6	LnCE ~ Year +Vessel +Region +DepCat +DayNight +Month
Model 7	LnCE ~ Year +Vessel +Region +DepCat +DayNight +Month +DN:DepCat
Model 8	LnCE ~ Year +Vessel +Region +DepCat +DayNight +Month +DepCat:Month
Model 9	LnCE ~ Year +Vessel +Region +DepCat +DayNight +Month +DN:Month

Table 16.12**.** School shark taken by Trawl across shark regions from Western South Australia to Eastern Tasmania between depths of 0 to 600 m and between 1997 - 2013. Model selection criteria, include the AIC, the adjusted r^2 and the change in adjusted r^2 (%Change). The optimum model is model 6 (Month).

	Year	Vessel	SharkRegion	DepCat	DayNight	**Month**	DN:DepCat	DepCat:Month	DN:Month
AIC	2541	-20	-600	-968	-1016	**-1037**	-958	-947	-1021
RSS	12480	9336	8761	8332	8285	**8247**	8191	7877	8204
MSS	189	3332	3908	4336	4384	**4421**	4477	4791	4464
Nobs	9616	9616	9598	9540	9540	**9540**	9540	9540	9540
Npars	17	132	138	162	165	**176**	248	440	209
adj_r^2	1.324	25.287	29.844	33.099	33.459	**33.682**	33.621	34.821	33.796
Δr^2	1.324	23.963	4.557	3.255	0.361	**0.222**	-0.061	1.139	0.114

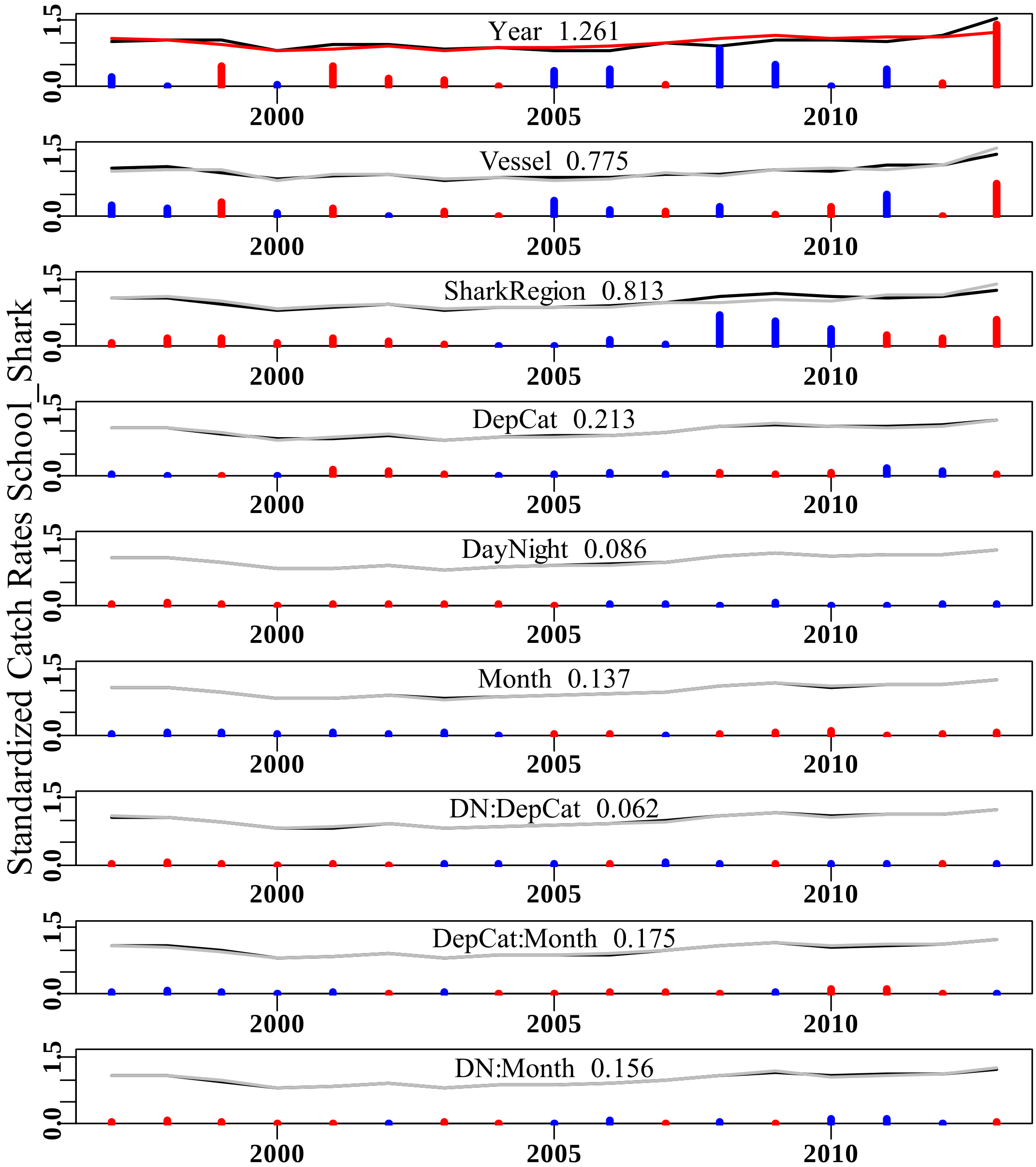

Figure 16.9. The relative influence of each factor used on the final trend in the optimal standardization for the Eastern Gemfish spawning fishery. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by the vertical bars with blue bars indicating the optimum model is higher than the geometric mean and red bars indicating it is lower. The top graph bars are the sum of all the bars in the graphs below. The graphs for individual factors are cumulative. Thus the second graph has the geometric mean (grey line) and the effect of adding Year + factor2 (Model 2). In the third graph, the grey line represents Model 2 and the black line the effect of adding factor3 to the model. The remaining graphs continue in the same cumulative manner except for the interaction terms which are added singularly to the final single factor model.

16.4.4 Extra Tables and Graphs for School Shark

Table 16.13.Catch of School sharks by Bottom Line in different regions. Note the recent increase in central South Australia, with smaller increases in Tasmania.

Year	WestSA	CentSA	EastSA	WestBS	EastBS	WestTas	EastTas
1997		10.076	11.206	5.593	2.090	0.910	
1998		7.701	10.471	11.121	1.718	0.303	0.200
1999		6.304	6.146	5.896	4.370	2.309	7.326
2000		1.453	3.788	4.928	2.976	14.684	5.362
2001		1.451	0.418	1.345	1.663	0.690	3.197
2002	0.135	0.424	2.794	1.323	1.193	1.838	2.719
2003		1.019	8.629	2.251	0.826	0.628	2.974
2004		0.488	1.444	0.600	0.894	2.026	2.219
2005		0.664	0.877	0.368	0.174	0.406	1.138
2006		0.456	1.008	0.556	0.086		1.935
2007		0.718	1.439	0.573	1.140		2.082
2008		0.484	0.430	2.282	0.190	0.024	2.064
2009		0.517	2.399	1.338	0.297	0.165	1.210
2010	0.070	1.368	2.193	2.183	0.086	0.159	3.380
2011		4.222	2.352	0.542		0.080	1.150
2012	0.202	8.223	2.309	0.802	0.052	0.015	3.658
2013	0.930	25.758	2.834	0.364	0.073	3.564	5.568

Table 16.14.Catch of School sharks by Autoline in different regions. Note the recent increase in central South Australia, with smaller increases in Tasmania.

	WestSA	CentSA	EastSA	WestBS	EastBS	WestTas	EastTas
1998				0.045			0.037
1999							
2000							
2001						0.257	0.395
2002			0.060	0.070	0.115	0.847	0.671
2003			0.025	0.050	0.137	0.543	0.870
2004	0.048	3.494	0.354	0.402	0.261	0.368	0.514
2005	0.043	0.350	0.468	0.116	0.236	0.345	0.472
2006	0.491	0.994	0.681	0.271	0.423	0.387	0.358
2007	0.171	0.545	0.063	0.015	0.030	0.352	0.388
2008	0.096	0.950	0.073		0.210	0.373	1.041
2009	0.021	0.562	1.877	0.350	0.336	0.480	0.847
2010	0.252	1.619	0.713	0.110	1.192	2.206	0.365
2011	0.132	4.412	0.525	0.695	0.177	4.443	1.528
2012	0.919	4.418	0.288	0.032	0.179	1.118	0.724
2013	0.004	5.558	0.338	0.097	0.553	2.597	1.305

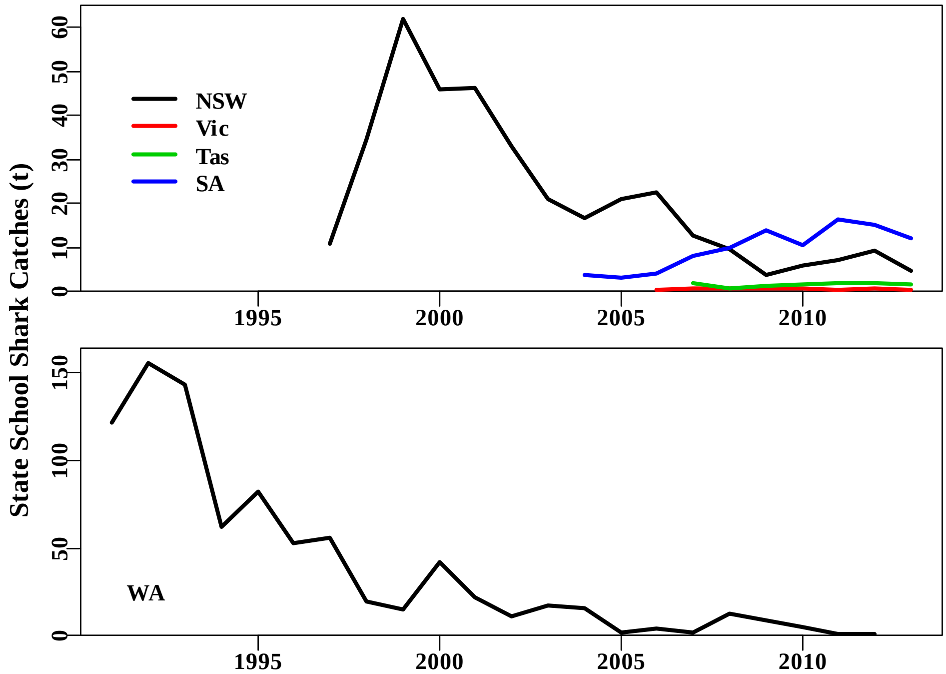

Figure 16.10. Reported State catches of School sharks. Western Australia is on a separate graph due to the different y-axis scale.

Table 16.15. Reported total State catches of School sharks.

Year	NSW	Vic	Tas	SA	WA
1991					122.100
1992					156.100
1993					143.100
1994					62.000
1995					82.000
1996					53.000
1997	10.985				56.000
1998	34.584				20.000
1999	61.947				15.000
2000	45.729				42.000
2001	46.229				22.000
2002	32.880				11.000
2003	20.909				17.100
2004	16.674			3.794	16.000
2005	20.913			3.321	2.000
2006	22.456	0.544		4.275	4.000
2007	12.868	0.836	2.104	8.063	2.000
2008	9.618	0.791	0.728	9.855	13.000
2009	3.961	0.916	1.304	13.813	9.000
2010	6.017	0.836	1.605	10.544	5.000
2011	7.208	0.489	1.903	16.358	1.000
2012	9.454	0.877	1.935	15.179	1.000
2013	4.719	0.607	1.577	12.020	

16.4.5 Saw Shark Catches and CPUE: Gillnet

Most catches are taken by gill nets, which catch twice as much as trawlers and nearly 10 times as much as Danish Seiners, with all other methods catching only minor amounts (Table 16.15). While catches of sawsharks are widespread most catches are taken in Bass Strait (Table 16.16). Primarily gill net catches are taken in < 100m of water, although they extend out to 150m (Figure 16.10).

Table 16.16**.** Reported catches by method in the GenLog database across all fisheries. Method names are given in Table 16.7. The total is the sum of catches from 1997 – 2013. Discards are not included.

Total	2713.971	1306.770	32.743	287.748	5.119	3.802	0.100	0.099	0.060	0.041	0.025	0.014
Year	GN	TW	TDO	DS	BL	AL	TR	DL	TL	GA	PTB	HL
1986		15.900		3.578								
1987		13.812		2.402								
1988		25.922		4.648								
1989		19.565		2.457								
1990		23.019		3.120								
1991		33.060		2.356								
1992		44.297		4.344								
1993		46.917		3.467								
1994		52.544		6.221								
1995		51.958		4.066								
1996		60.341		6.909								
1997	156.638	59.632		3.957	0.157							
1998	248.642	48.279		6.720	0.418							
1999	243.384	51.625		6.386	0.541			0.052				
2000	282.885	69.766		7.158	0.623			0.005		0.041		
2001	264.110	65.804		7.029	0.454			0.003				
2002	158.310	72.092		24.291	0.072	0.119		0.005				
2003	191.510	105.246		22.396	0.188	0.093		0.009	0.060			
2004	192.139	96.553		24.309	0.151	0.897	0.100	0.009				
2005	170.815	106.571		17.404	0.700	0.504						
2006	158.484	140.874		17.977	0.061	0.144						
2007	107.667	85.020		21.623	0.062	0.092						0.014
2008	114.871	73.873		22.596	0.124	0.393						
2009	88.630	80.897		21.127	0.129	0.315						
2010	92.184	82.676		17.028	0.368	0.093		0.016				
2011	102.554	64.990	2.865	25.996	0.187	0.233						
2012	74.526	48.235	13.140	21.118	0.317	0.418		0.001				
2013	66.624	54.639	16.738	20.636	0.569	0.501					0.025	

Table 16.17**.** Catch of sawsharks by shark reporting regions taken by Gillnets. Discards are no included.

Year	WestSA	CentSA	EastSA	WestBS	EastBS	WestTas	EastTas	WA
1997	2.550	4.404	22.062	50.292	71.356	1.102	0.404	0.027
1998	3.216	9.344	15.460	83.539	122.957	1.856	5.113	
1999	2.588	8.946	22.469	63.410	126.102	1.439	4.743	0.004
2000	1.980	13.142	18.884	51.849	174.918	1.104	5.190	
2001	2.665	10.078	13.571	34.205	183.266	1.775	4.155	
2002	1.227	3.919	12.985	39.570	86.222	0.769	3.699	0.064
2003	1.655	4.661	17.257	61.018	92.477	2.032	2.243	0.063
2004	0.396	4.891	13.829	70.017	82.917	0.555	2.693	
2005	1.725	6.515	22.797	64.203	62.887	0.776	2.291	
2006	0.860	5.603	32.945	33.653	72.400	6.265	3.532	0.031
2007	0.533	5.561	11.945	27.800	55.152	1.132	3.578	0.021
2008	0.567	7.029	9.776	22.747	70.982	0.189	3.143	0.020
2009	0.594	4.817	6.717	21.431	52.719	0.337	1.769	0.003
2010	0.704	6.299	7.857	19.765	54.849	0.262	1.572	0.004
2011	0.331	3.717	4.112	23.922	67.249	1.141	1.851	0.007
2012	0.057	0.500	4.327	19.181	47.024	0.375	2.035	
2013	0.041	0.203	3.829	21.289	38.865	0.422	1.591	

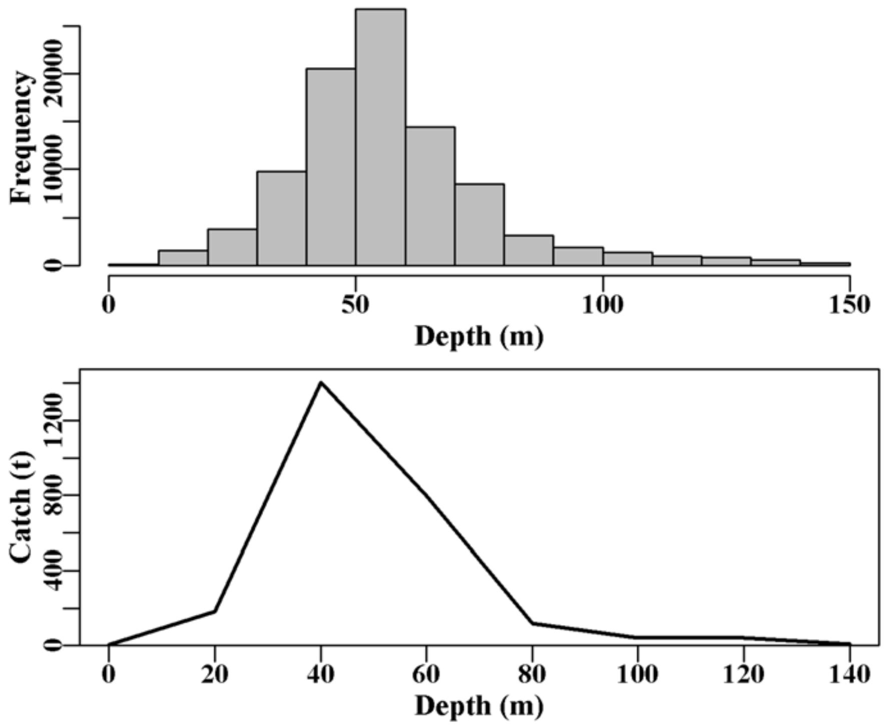

Figure 16.11. The frequency of record of sawsharks taken by gillnet and the catches relative to different 20m depth categories.

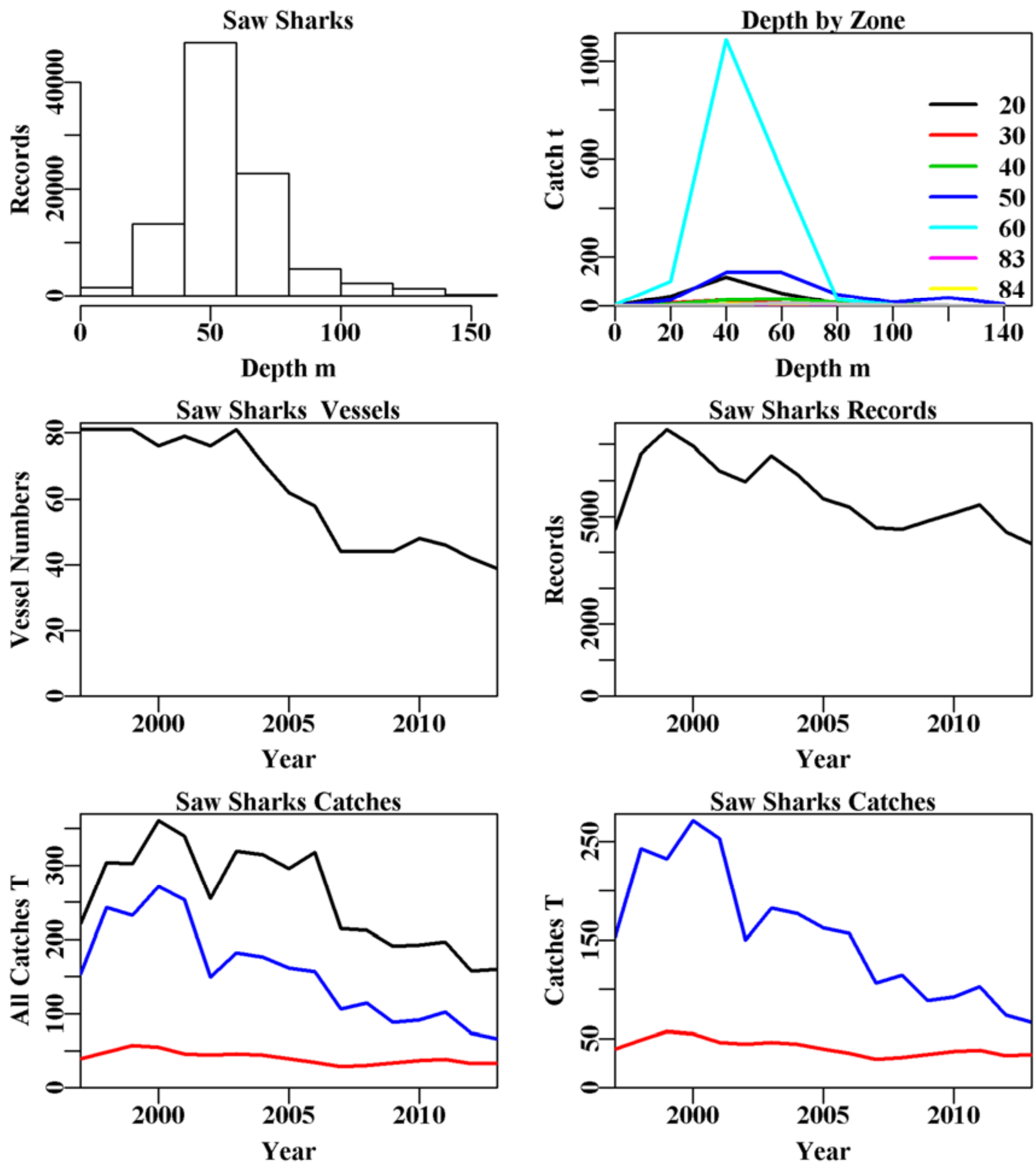

Figure 16.12. Saw sharks taken in the gillnet fishery in depths between 0 – 160 m. The top left plot depicts the depth distribution of shots containing sawsharks in regions 1 – 7 (Western South Australia – Eastern Tasmania). The top right plot depicts the distribution of catch by depth within SESSF zones 10 to 40. The middle left plot depicts the number of vessels through time. The middle right plot contains the number of records used in analysis. The bottom left plot contains saw shark catches (top black line: total catches, middle blue line: catches used in the analysis; bottom red line: catches < 30 kg) and bottom right plot contains saw shark catches (blue line: catches used in the analysis; red line: catches < 30 kg).

The number of vessels reporting saw sharks decreased from about 80 vessels in 2003, stabilizing at about 40 vessels in 2007 onwards (Figure 16.11). Importantly, across all years from 1997 – 2013 the proportion of reported catches that were <= 30kg was always an appreciable proportion of total catches (Figure 16.11). The occurrence of so many relatively small catches is repeated in other methods also, indicating that saw sharks are rarely, if ever, targeted.

The standardized CPUE for gill nets only differs from the geometric mean CPUE in relatively minor ways. Importantly, in the final year the standardized CPUE declines further than the geometric mean (Figure 16.12). This appears to be primarily due to a combination of the effects of the vessels fishing and the region in which they are fishing, which presumably relates to the shift out of Southern Australia by gill nets (Figure 16.13).

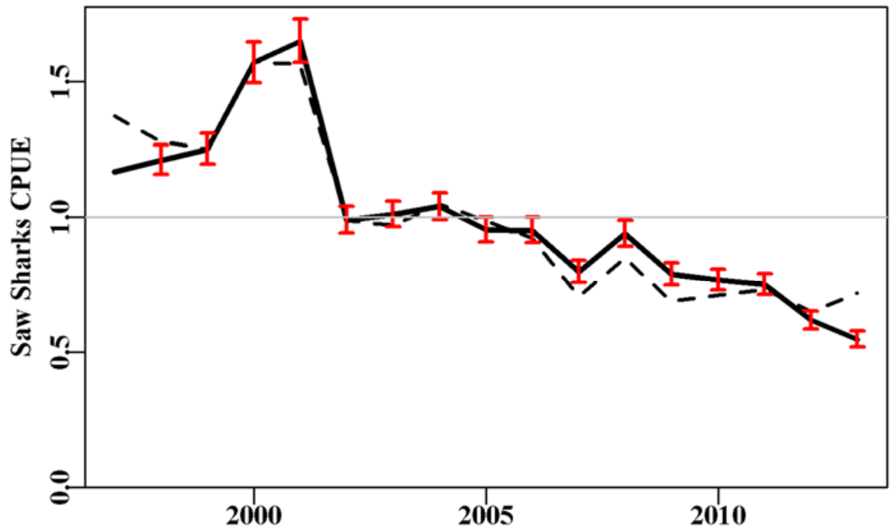

Figure 16.13. The standardized catch rates for saw sharks taken by gillnet showing the optimum model (solid black line) and the geometric mean catch rate (dashed line) each scaled to the mean of each time series. The error bars are two times the standard errors.

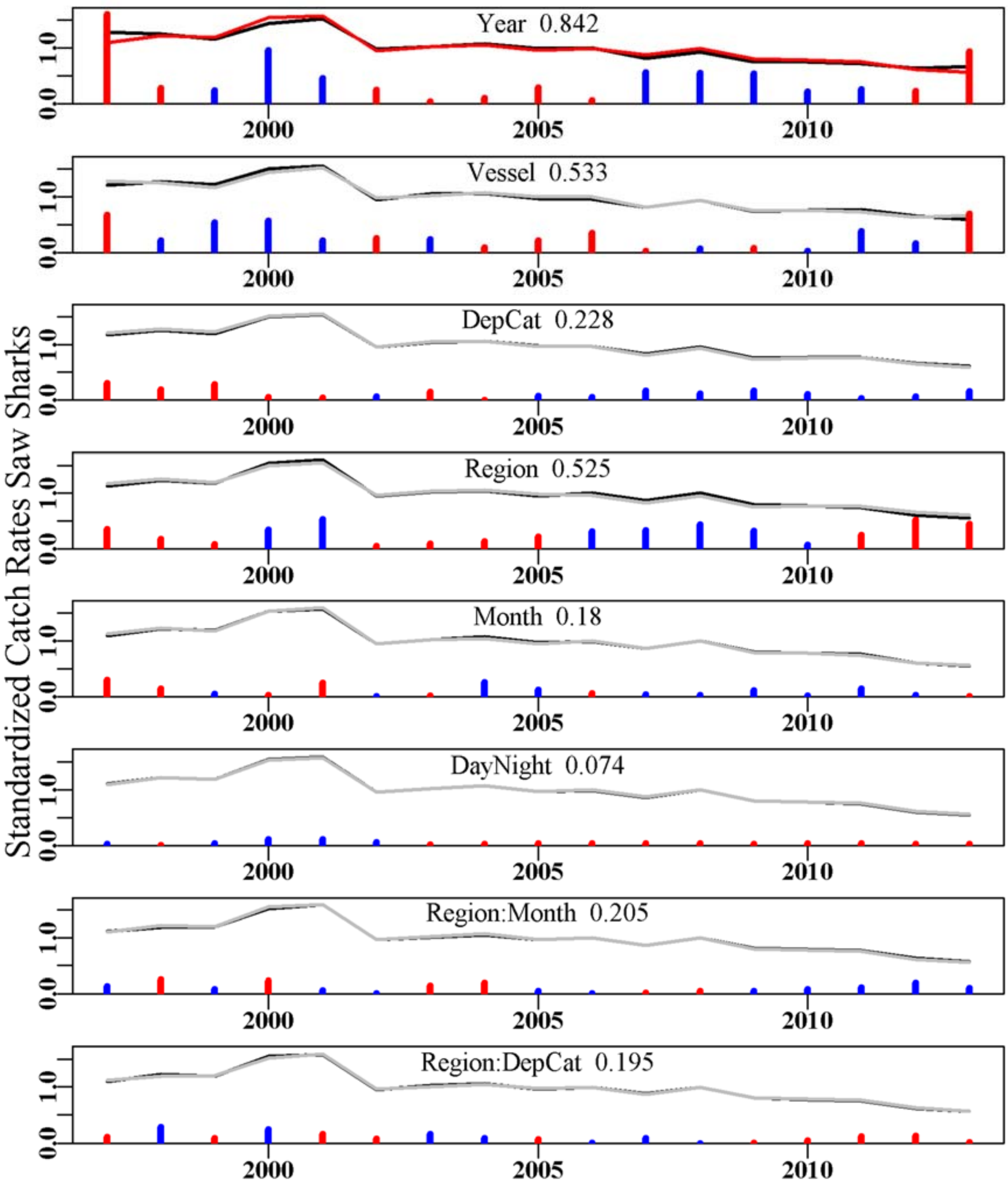

Figure 16.14**.** The relative influence of each factor used on the final trend in the optimal standardization for the saw shark gillnet fishery. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by the vertical bars with blue bars indicating the optimum model is higher than the geometric mean and red bars indicating it is lower. The top graph bars are the sum of all the bars in the graphs below. The graphs for individual factors are cumulative. Thus the second graph has the geometric mean (grey line) and the effect of adding Year + factor2 (Model 2). 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.

16.4.6 Saw Shark Catches and CPUE: Trawl

Catch of saw sharks by trawl occurs mostly in western and eastern South Australia, eastern Bass Strait, and the east coast of Tasmania (Table 16.17) and between 25 – 200 m of water with a further spike in catches out at 350m (Figure 16.14).

Table 16.18**.** Catch of sawsharks by shark reporting regions taken by trawl.

Year	WestSA	EastSA	WestBS	EastBS	WestTas	EastTas	NSW
1997	13.603	14.515		8.912		0.231	8.269
1998	11.812	8.785	0.003	8.204		0.091	4.968
1999	9.677	13.010	0.030	9.536		0.036	5.791
2000	9.364	23.055	2.358	12.796	0.091	0.362	7.126
2001	12.615	14.745	0.162	12.269	0.202	1.292	5.773
2002	11.125	16.558	0.388	17.813	0.284	2.441	13.643
2003	25.098	14.169	0.114	12.514	0.555	2.137	25.428
2004	17.905	17.870	0.615	12.051	0.312	1.414	29.973
2005	22.899	21.977	2.056	16.401	0.253	1.579	25.764
2006	17.455	43.417	1.752	17.920	0.777	1.756	28.083
2007	9.295	27.324	2.801	12.099	0.349	0.732	11.031
2008	5.435	22.299	0.916	19.218	0.176	0.622	9.865
2009	12.546	22.859	0.794	23.311	0.426	0.648	9.374
2010	9.722	16.964	0.524	19.163	0.130	0.611	12.051
2011	10.613	18.326	0.735	16.858	1.691	0.683	9.427
2012	10.163	22.612	0.670	13.075	0.500	0.942	8.926
2013	13.453	22.746	0.905	13.368	0.479	0.765	8.114
Total	222.780	341.231	14.823	245.508	6.225	16.342	223.606

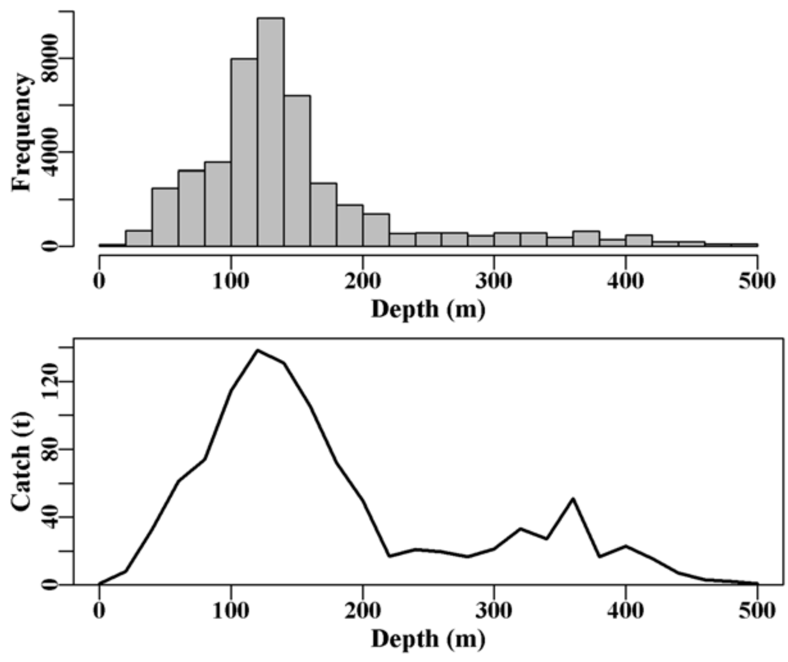

Figure 16.15.The frequency of record of sawsharks taken by gillnet and the catches relative to different 20m depth categories.

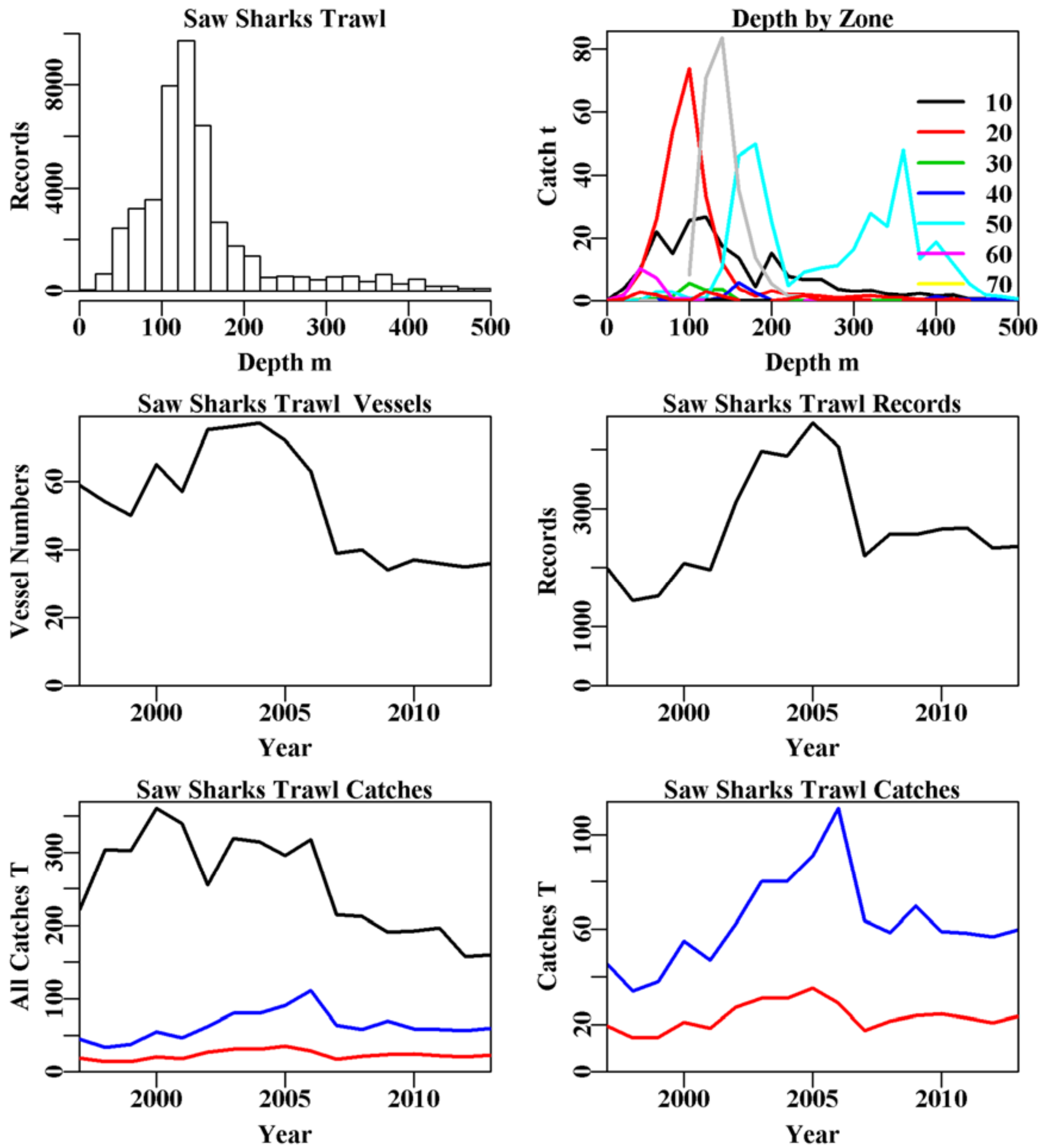

Figure 16.16. Saw sharks taken in the trawl fishery in depths between 0 – 160 m. The top left plot depicts the depth distribution of shots containing sawsharks in regions 1 & 2 – 8 (Western South Australia – New South Wales; not Central South Australia). The top right plot depicts the distribution of catch by depth within SESSF zones 10 to 40. The middle left plot depicts the number of vessels through time. The middle right plot contains the number of records used in analysis. The bottom left plot contains saw shark catches (top black line: total catches, middle blue line: catches used in the analysis; bottom red line: catches < 30 kg) and bottom right plot contains saw shark catches (blue line: catches used in the analysis; red line: catches < 30 kg).

Vessel numbers reported saw shark catches were clearly affected by the structural adjustment in 2006 (Figure 16.15), and, just as with gill net catches, there was a continuous high proportion of catches <=30kg reported in the system (Figure 16.15).

The standardized CPUE only differed in minor ways from the geometric mean CPUE and both exhibited a noisy but flat trajectory ranging from between 0.8 and 1.2 with occasional relatively high years (Figure 16.16). The trawl caught CPUE differs markedly from that taken using gill nets. The factors affecting the CPUE trends do not exhibit any clear trends except for the shark regions (SharkZone;Figure 16.17).

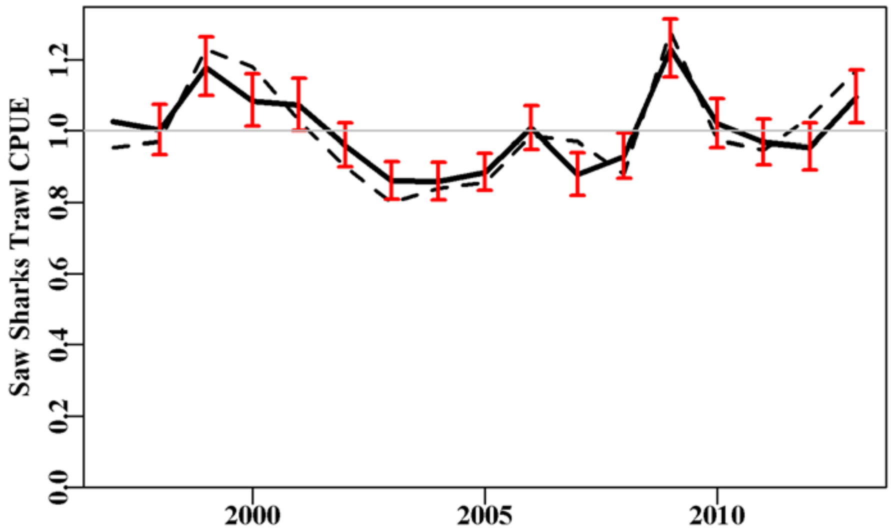

Figure 16.17. The standardized catch rates for saw sharks taken by trawl showing the optimum model (solid black line) and the geometric mean catch rate (dashed line) each scaled to the mean of each time series. The error bars are two times the standard errors.

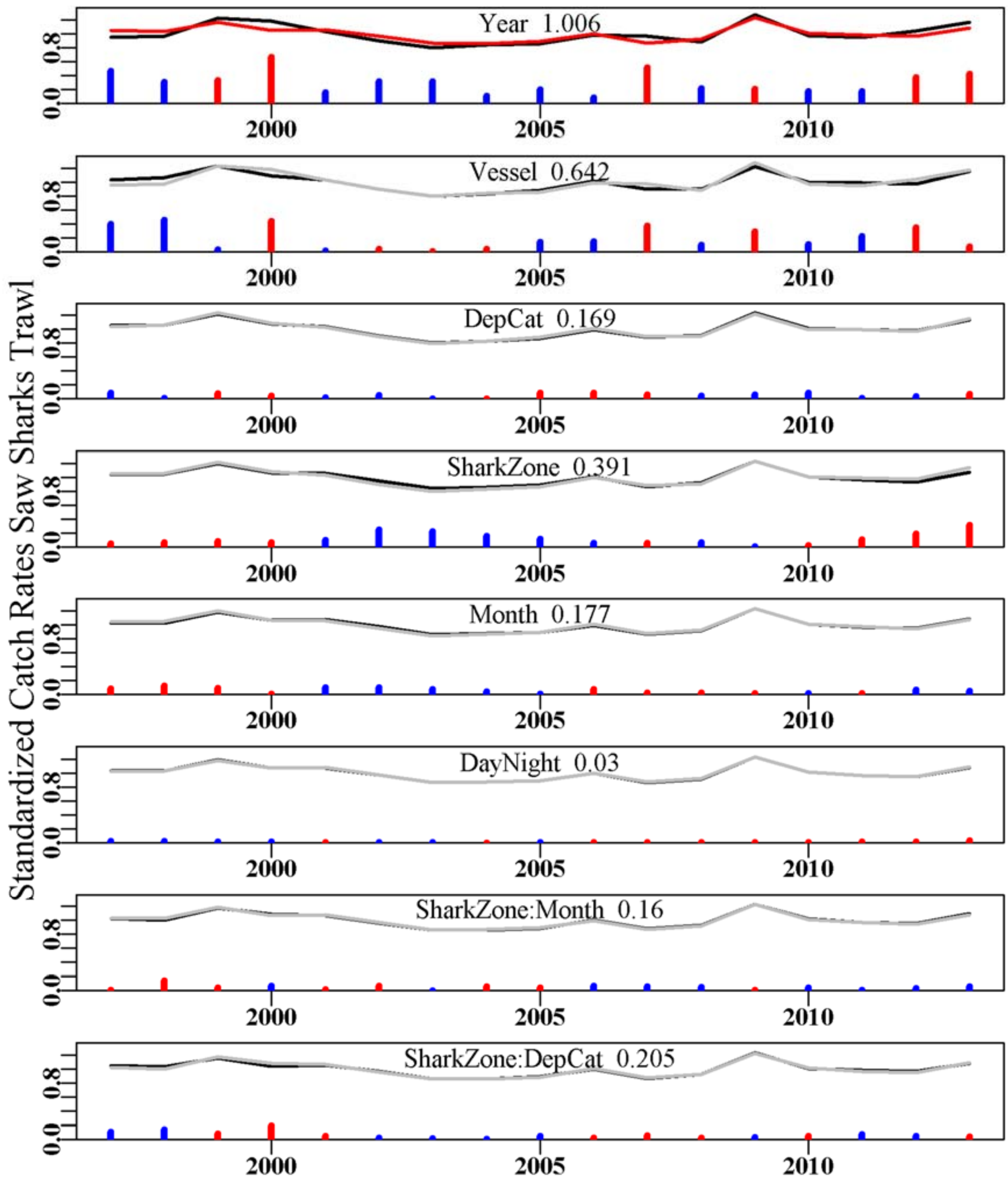

Figure 16.18. The relative influence of each factor used on the final trend in the optimal standardization for the saw shark trawl fishery. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by the vertical bars with blue bars indicating the optimum model is higher than the geometric mean and red bars indicating it is lower. The top graph bars are the sum of all the bars in the graphs below. The graphs for individual factors are cumulative. Thus the second graph has the geometric mean (grey line) and the effect of adding Year + factor2 (Model 2). 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.

16.4.7 Saw Shark Catches and CPUE: Danish Seine

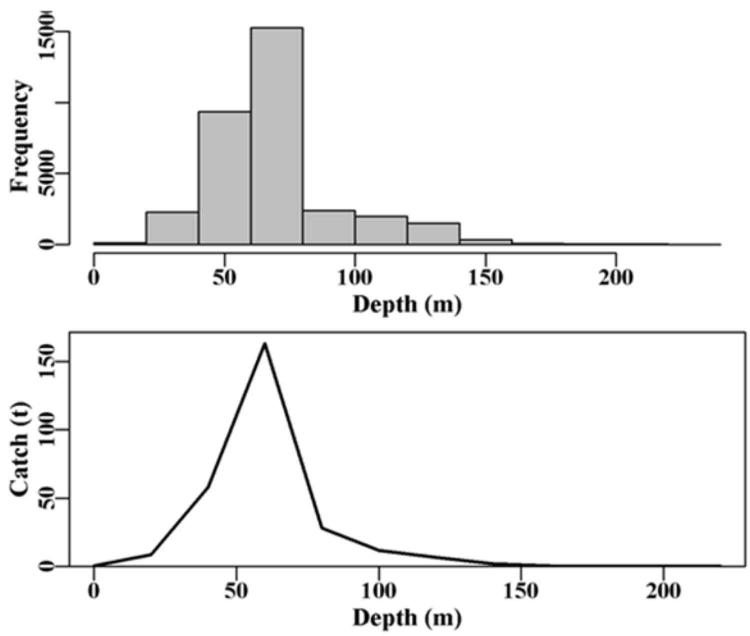

Figure 16.19**.** The frequency of record of sawsharks taken by Danish Seine and the catches relative to different 20m depth categories.

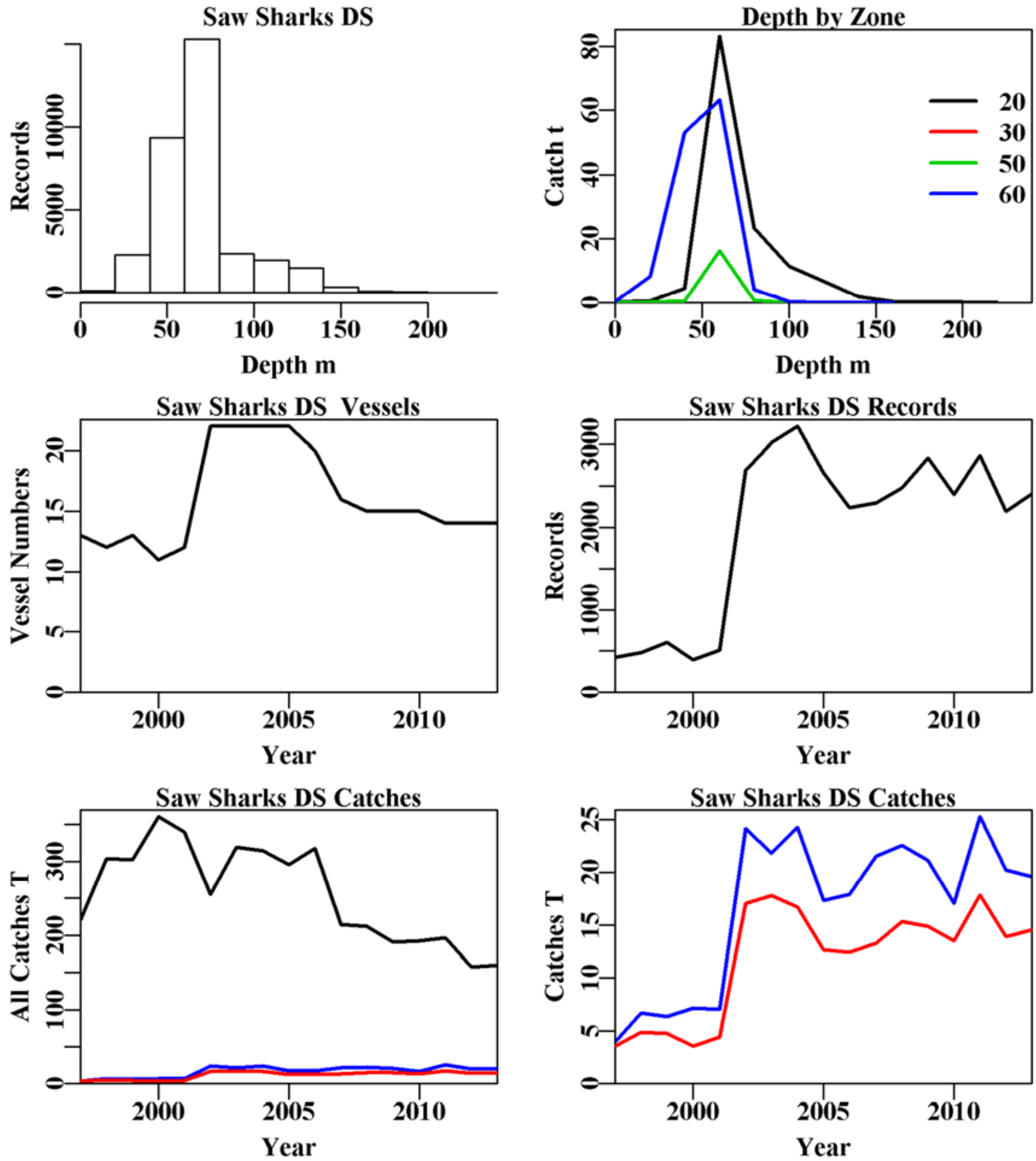

Figure 16.20. Saw sharks taken in the Danish seine fishery in depths between 0 – 240 m. The top left plot depicts the depth distribution of shots containing sawsharks in regions 4 $& 5 (Western Bass Strait and Eastern Bass Strait). The top right plot depicts the distribution of catch by depth within SESSF zones. The middle left plot depicts the number of vessels through time. The middle right plot contains the number of records used in analysis. The bottom left plot contains saw shark catches (top black line: total catches, middle blue line: catches used in the analysis; bottom red line: catches < 30 kg) and bottom right plot contains saw shark catches (blue line: catches used in the analysis; red line: catches < 30 kg).

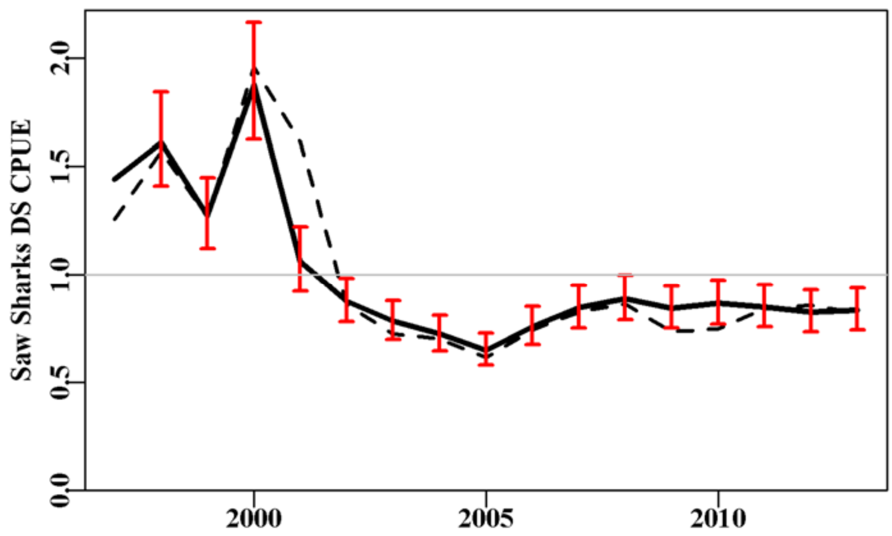

Figure 16.21**.** The standardized catch rates for saw sharks taken by Danish Seine showing the optimum model (solid black line) and the geometric mean catch rate (dashed line) each scaled to the mean of each time series. The error bars are two times the standard errors.

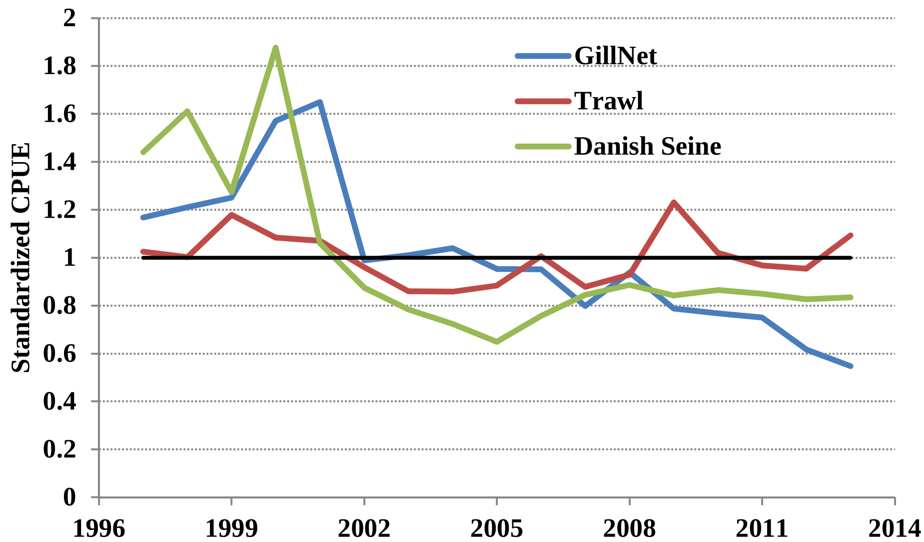

Figure 16.22. The standardized catch rates for saw sharks comparing the optimum models from Gillnets, Trawl, and Danish Seine, each scaled to the mean of each time series.

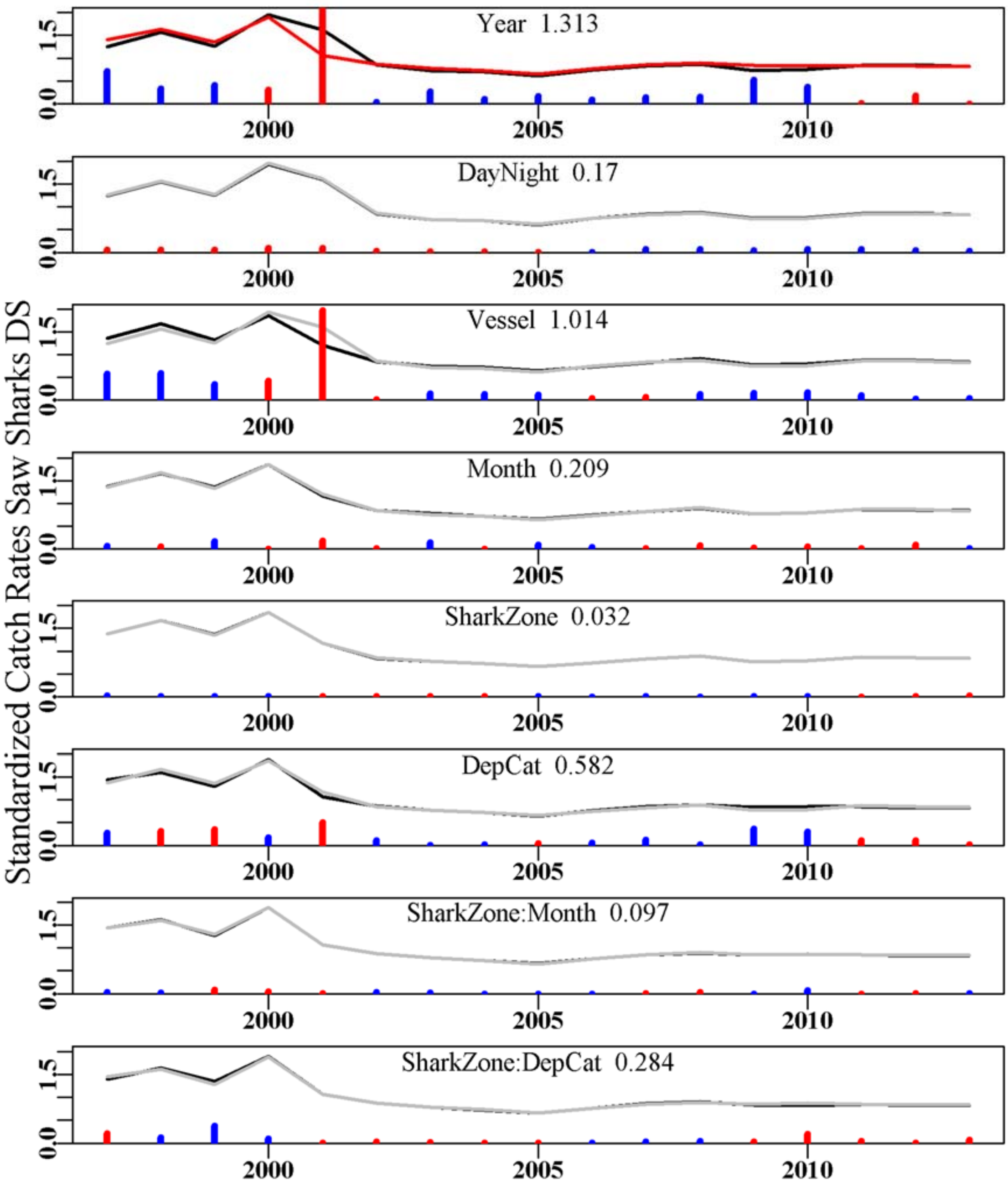

Figure 16.23. The relative influence of each factor used on the final trend in the optimal standardization for the saw shark Danish Seine fishery. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by the vertical bars with blue bars indicating the optimum model is higher than the geometric mean and red bars indicating it is lower. The top graph bars are the sum of all the bars in the graphs below. The graphs for individual factors are cumulative. Thus the second graph has the geometric mean (grey line) and the effect of adding Year + factor2 (Model 2). 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.

16.4.8 Elephant Fish Catches and CPUE: Gillnet

As with saw sharks, importantly the proportion of catches recording < 30kg is relatively high in elephant fish reports, indicating again that elephant fish are not a primary target species and tend to be caught in small numbers and weights in each shot (Figure 16.23).

Table 16.19**.** Elephant fish taken by gillnet across shark regions from Central South Australia to Eastern Bass Strait between depths of 0 to 160 m and between 1997 - 2013. Total catch (TotCatch; t) is the total reported in the database, number of records used in the analysis (Records), reported catch (CatchT; t) in the area and depth used in the analysis and number of vessels used in the analysis (Vessels). GeoMean is the geometric mean of catch rates (kg/hr). The optimum model is model 7 (Table 16.19), Month and standard deviation (StDev) relates to the data in the optimum model.

Year	TotCatch	Records	CatchT	Vessels	GeoMean	Month	StDev
1997	33.332	1451	26.950	56	6.6094	0.9493	0.0000
1998	56.166	2149	46.939	57	6.7151	0.8928	0.0472
1999	71.295	2824	58.060	63	7.0563	1.0094	0.0464
2000	78.516	2748	63.004	57	8.2160	1.2201	0.0484
2001	88.516	2789	72.684	62	9.2270	1.2580	0.0489
2002	59.332	2128	37.346	61	6.1456	0.9050	0.0508
2003	71.103	2181	42.103	60	5.7933	0.8816	0.0490
2004	64.762	1771	30.612	51	5.8542	0.8566	0.0509
2005	66.362	1887	32.832	40	6.1720	0.8777	0.0504
2006	53.212	1688	31.176	43	6.1025	0.9579	0.0521
2007	51.636	1785	33.890	38	6.7289	1.0451	0.0518
2008	61.409	2054	39.869	34	7.0222	1.1277	0.0503
2009	65.278	2133	43.934	35	8.2648	1.2511	0.0504
2010	56.401	2275	34.511	35	6.1660	0.9780	0.0507
2011	50.497	2690	33.811	35	5.3872	0.8627	0.0503
2012	65.914	2701	44.347	38	6.5869	1.0159	0.0497
2013	59.007	2382	36.925	34	6.7222	0.9110	0.0505

Table 16.20.Elephant fish taken by gillnet across shark regions from Central South Australia to Eastern Bass Strait between depths of 0 to 160 m and between 1997 - 2013. Model selection criteria, include the AIC, the adjusted r^2 and the change in adjusted r^2 (%Change). The optimum model is model 7 (SharkZone:Month). DN is a DayNight factor.

	Year	Vessel	DepCat	SZone	Month	DN	SZone:Mth	SZone:DepCat
AIC	22274	19026	18937	18817	18642	18647	18262	18494
RSS	67958	61840	61500	61287	60965	60964	60162	60585
MSS	771	6888	7228	7441	7763	7764	8566	8143
Nobs	37636	37636	37433	37433	37433	37433	37433	37433
Npars	17	168	176	181	192	195	250	235
adj_r2	1.079	9.621	10.097	10.396	10.840	10.835	11.878	11.294
%Change	1.079	8.542	0.476	0.300	0.444	-0.006	1.043	0.459

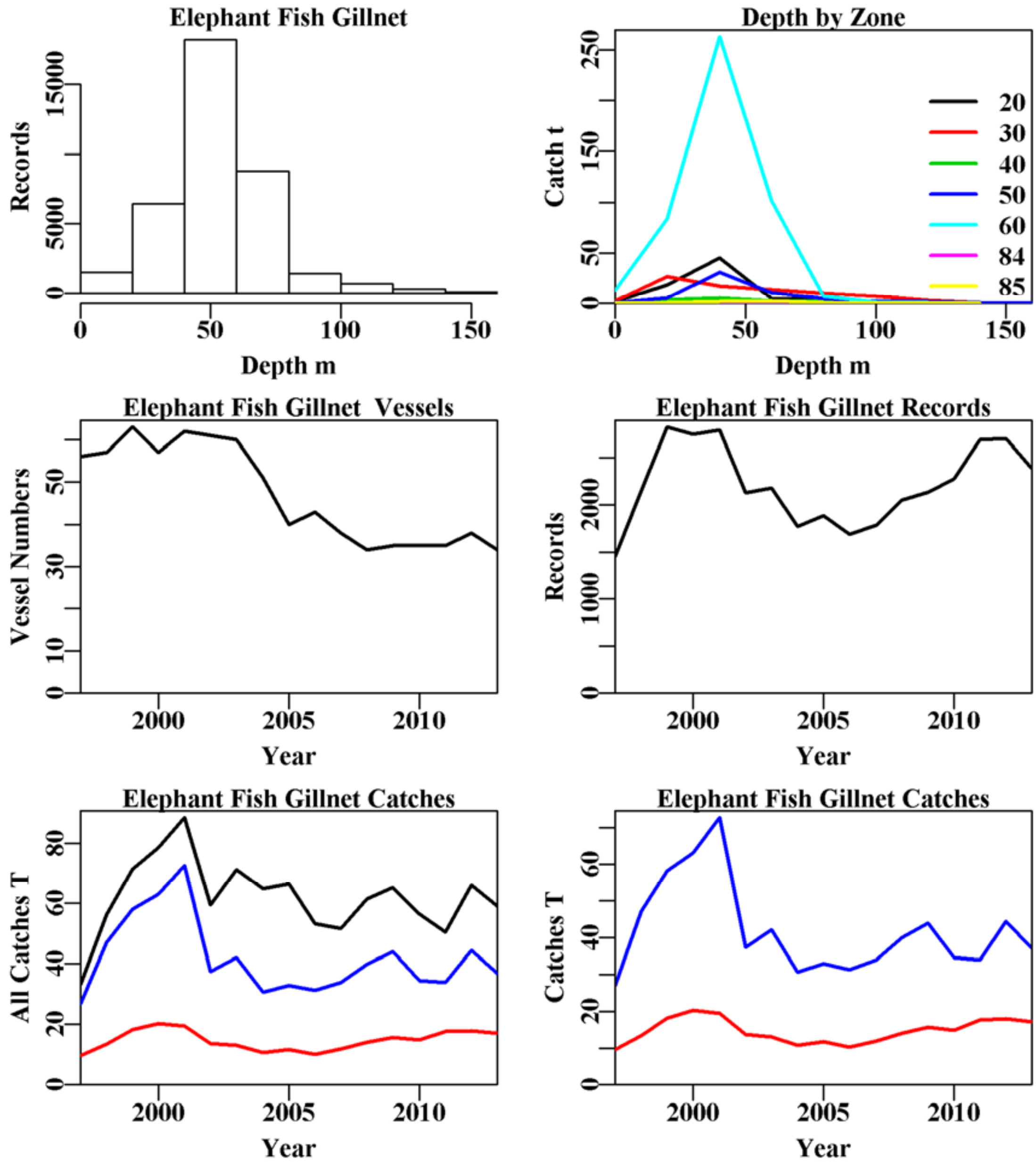

Figure 16.24. Elephant fish taken in the gillnet fishery in depths between 0 – 160 m. The top left plot depicts the depth distribution of shots containing sawsharks in regions 2 – 7 (Central South Australia to Eastern Bass Strait). The top right plot depicts the distribution of catch by depth within SESSF zones. The middle left plot depicts the number of vessels through time. The middle right plot contains the number of records used in analysis. The bottom left plot contains saw shark catches (top black line: total catches, middle blue line: catches used in the analysis; bottom red line: catches < 30 kg) and bottom right plot contains saw shark catches (blue line: catches used in the analysis; red line: catches < 30 kg).

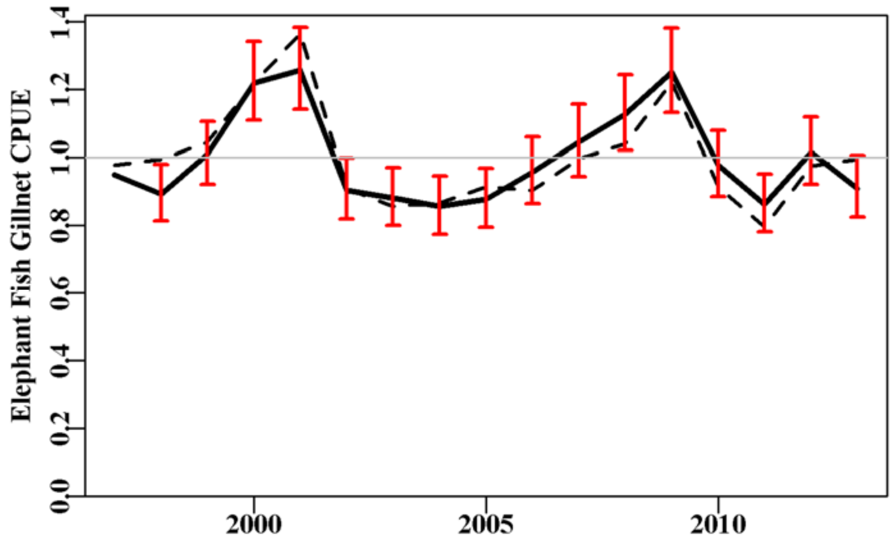

Figure 16.25. The standardized catch rates for elephant fish taken by gillnet showing the optimum model (solid black line) and the geometric mean catch rate (dashed line) each scaled to the mean of each time series. The error bars are two times the standard errors.

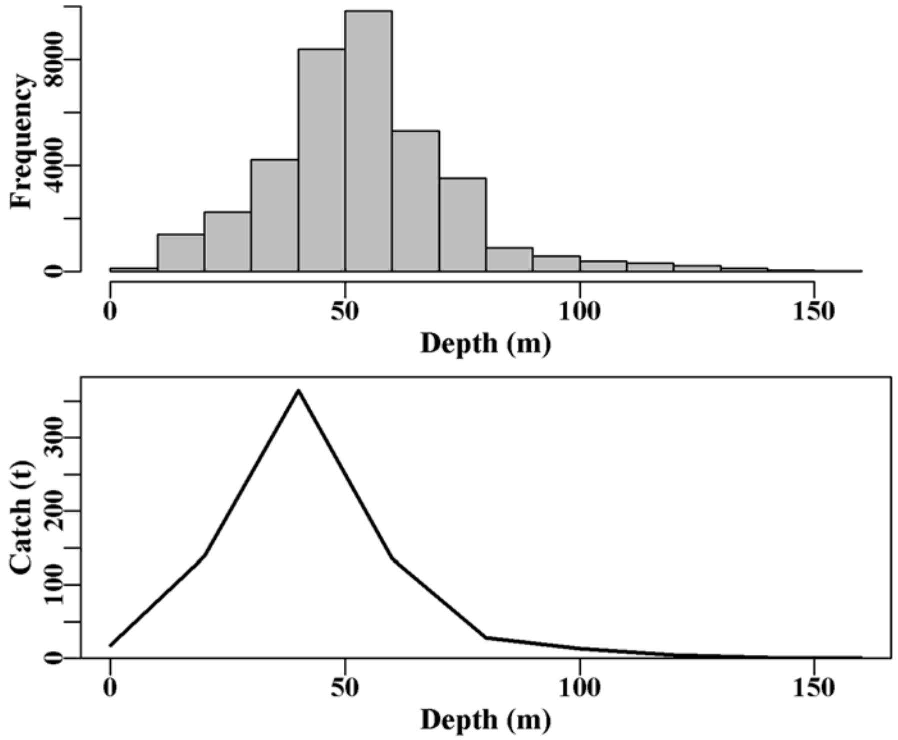

Figure 16.26. The frequency of record of elephant fish taken by gillnet and the catches relative to different 20m depth categories.

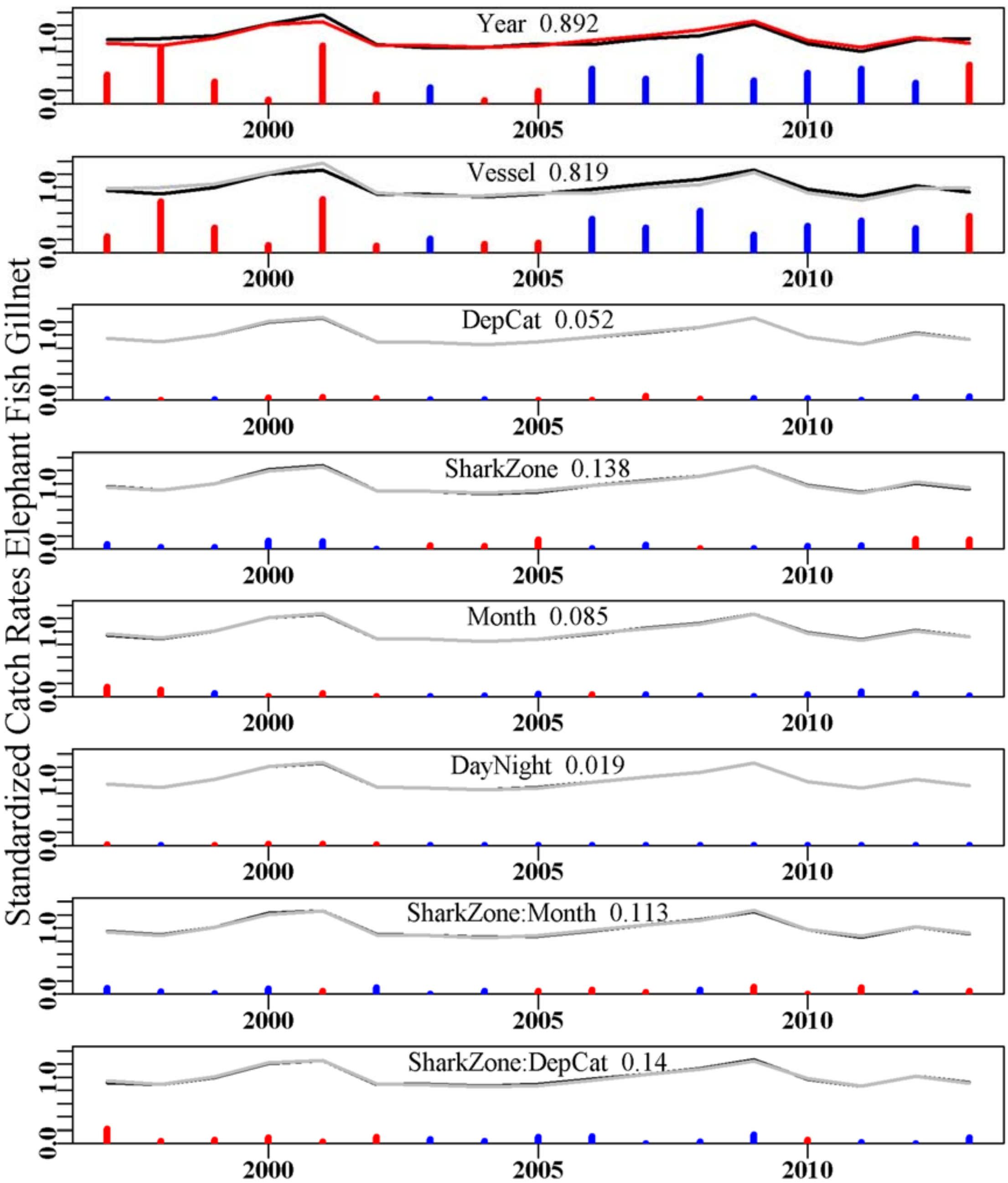

Figure 16.27. The relative influence of each factor used on the final trend in the optimal standardization for the elephant fish gillnet fishery. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by the vertical bars with blue bars indicating the optimum model is higher than the geometric mean and red bars indicating it is lower. The top graph bars are the sum of all the bars in the graphs below. The graphs for individual factors are cumulative. Thus the second graph has the geometric mean (grey line) and the effect of adding Year + factor2 (Model 2). 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 16.21. Reported catches by method in the GenLog database across all regions and methods. Method names are given inTable 16.7. The total is the sum of catches from 1997 – 2013. Discards are not included.

Year	AL	BL	DL	GA	GN	TDO	TW	DS	Total
1997		0.005	0.014		27.450		0.780	4.883	33.132
1998		0.101			48.095		1.654	6.316	56.166
1999		0.021	0.033		62.816		2.800	5.625	71.295
2000	0.045	0.047	0.046	0.026	69.047		2.590	6.715	78.516
2001	0.035	0.120	0.073		78.241		3.591	6.456	88.516
2002	0.004	0.123	0.006		39.768		7.782	11.651	59.332
2003	0.647	0.088	0.026		46.307		11.777	12.258	71.103
2004	1.888	0.530			33.197		14.014	15.133	64.762
2005	2.062				34.226		17.238	12.837	66.362
2006	0.762	0.003			32.528		14.526	5.394	53.212
2007	0.271	0.037			34.405		9.524	7.399	51.636
2008		0.007			40.429		10.649	10.325	61.409
2009		0.002			44.100		12.674	8.502	65.278
2010		0.004			34.712		11.560	10.125	56.401
2011		0.025			33.881		8.963	7.629	50.497
2012		0.046			44.825		10.917	10.126	65.914
2013	0.052	0.024			36.993	1.169	9.357	11.412	59.007
Total	5.766	1.182	0.198	0.026	741.018	1.169	150.395	152.782	1052.536

Table 16.22. Catch of elephant fish by shark reporting regions taken by gillnets. Discards are not included.

Year	WestSA	CentSA	EastSA	WestBS	EastBS	WestTas	EastTas	WA	Total
1997		0.934	2.748	11.988	11.009	0.255	0.101		27.033
1998	0.012	2.271	0.542	16.153	21.191	1.626	5.225		47.020
1999	0.008	5.011	1.711	14.871	31.235	0.705	4.644		58.185
2000	0.285	6.027	0.958	11.302	36.944	0.810	7.084		63.409
2001	0.168	8.915	1.274	5.959	42.753	3.413	10.433		72.914
2002		1.929	0.465	6.322	22.650	0.076	5.905		37.346
2003	0.068	4.160	0.648	5.285	25.728	1.184	5.098		42.171
2004	0.152	1.435	0.819	4.634	18.261	0.008	5.531		30.839
2005	0.010	1.972	0.117	6.861	19.068	0.214	4.608		32.850
2006	0.779	1.417	0.069	3.138	21.282	1.010	4.285	0.050	32.028
2007	0.292	2.397	0.121	2.509	20.411	0.350	8.143	0.055	34.277
2008	0.198	2.581	0.399	3.493	27.321	0.170	6.171		40.332
2009	0.035	2.943	0.221	6.120	29.699	0.093	4.859		43.969
2010	0.058	3.166	0.248	5.055	22.496	0.042	3.543		34.607
2011	0.014	4.324	0.506	4.662	20.806	0.319	3.213		33.844
2012	0.003	0.052	0.199	8.930	29.379	0.881	5.012		44.454
2013	0.009	0.048	0.065	10.320	22.251	0.594	3.649		36.935
Total	2.089	49.581	11.111	127.598	422.479	11.749	87.502	0.105	712.214

16.4.9 Gummy Shark Catches and CPUE

Table 16.23**.** Reported catches (t) of gummy shark in each fishery. See Table 16.6 for abbreviations.

Year	GHT	SSF	SEN	SSG	SSH	SET	GAB
1996						30.363	17.523
1997			950.475	0.100		32.483	19.443
1998			1133.718	315.026	8.995	35.707	13.364
1999		840.019	502.003	570.842	21.645	37.304	11.947
2000		2358.011	7.643			50.059	11.171
2001		1614.260	1.221			49.522	21.583
2002	0.008	1444.280	4.146			55.363	18.996
2003	1559.936					51.522	38.781
2004	1561.634					54.061	47.936
2005	1455.191					56.115	57.382
2006	1459.701					60.145	52.260
2007	1472.921					53.185	47.411
2008	1622.417					72.997	30.748
2009	1394.912					64.806	39.376
2010	1296.032					61.368	45.225
2011	1235.822					76.924	51.110
2012	1172.151					83.283	44.744
2013	1156.748					76.344	47.567
97-2013	15387.473	6256.570	2599.205	885.968	30.640	971.185	599.044

Table 16.24**.** Reported catches (t) of gummy shark by each method. See Table 16.7 for abbreviations.

Year	GN	AL	BL	DL	TW	TDO	OTT	DS
1996					41.377			6.549
1997	927.167	0.030	19.453	0.145	44.320			7.701
1998	1410.348		47.103	0.437	39.398			9.669
1999	1871.463	0.165	61.511	1.369	38.578			10.636
2000	2250.855	0.015	113.856	0.836	52.063			10.337
2001	1554.122	0.155	60.086	1.112	58.511			13.698
2002	1384.950	1.145	61.399	0.980	62.149			12.517
2003	1488.840	1.481	68.694	1.098	82.626			8.047
2004	1488.869	3.496	69.489	0.475	91.161			11.059
2005	1390.945	1.123	62.504	0.435	98.311			15.749
2006	1405.758	2.633	49.452	1.895	104.507			8.650
2007	1413.702	1.471	57.219	0.549	88.839			12.346
2008	1561.977	7.887	52.403	0.142	89.986			15.155
2009	1320.993	4.680	69.025	0.215	91.127			13.370
2010	1212.364	10.229	73.288	0.181	93.309			13.688
2011	1130.857	10.861	93.436	0.668	86.392	16.213	0.490	25.708
2012	994.648	50.645	125.463	1.395	63.580	37.307	0.295	26.978
2013	894.852	34.469	227.674	0.718	66.728	32.482	0.225	24.572
97-2013	23702.709	130.485	1312.055	12.650	1251.583	86.002	1.010	239.878

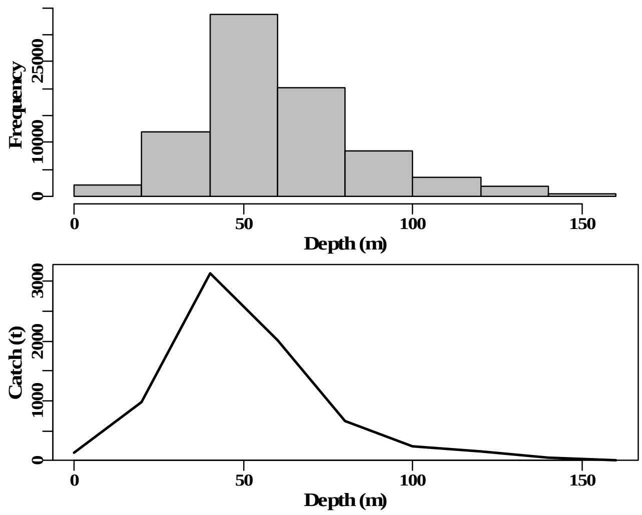

Figure 16.28. South Australian gummy shark records and catches by gillnet and depth. The y-axis scale differs from Bass Strait and Tasmania.

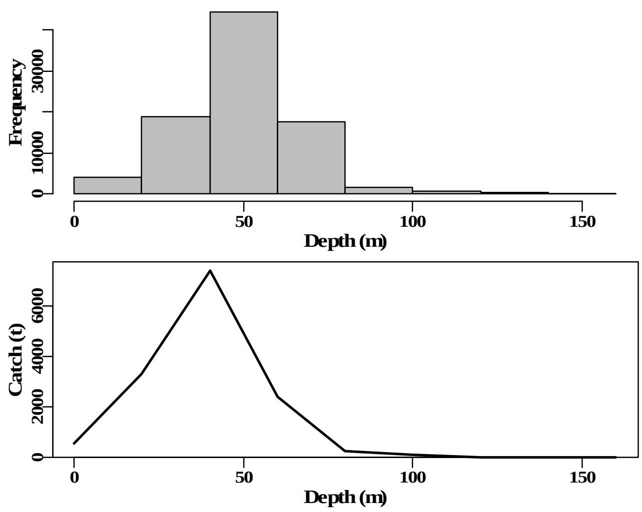

Figure 16.29**.** Bass Strait gummy shark records and catches by gillnet and depth. The y-axis scale differs from Tasmania and South Australia.

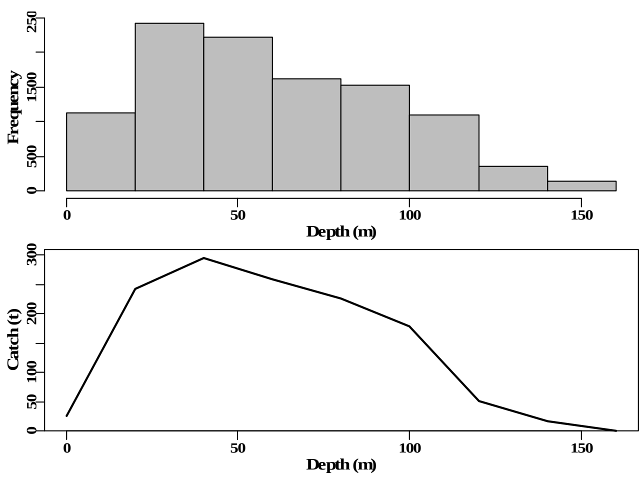

Figure 16.30**.** Tasmanian gummy shark records and catches by gillnet and depth. The y-axis scale differs from Bass Strait and South Australia.

Table 16.25. Reported gummy shark catches taken by all methods by shark region

Year	WestSA	CentSA	EastSA	WestBS	EastBS	WestTas	EastTas	NSW	WA
1997	106.251	255.648	111.397	150.856	322.338	11.647	7.086	10.615	12.423
1998	130.571	351.000	83.396	196.579	633.147	12.786	48.730	9.794	7.162
1999	122.582	412.611	128.962	244.436	906.803	20.981	75.147	7.165	7.916
2000	138.415	580.570	161.323	195.712	1151.078	17.815	57.652	9.012	3.954
2001	92.527	226.412	100.163	139.170	960.983	12.156	46.582	7.758	11.684
2002	91.567	229.750	120.397	205.343	656.592	15.666	77.561	10.864	11.213
2003	148.141	278.970	96.612	215.406	693.665	22.544	67.407	12.799	18.303
2004	109.522	300.132	108.238	231.609	673.929	18.610	81.073	12.462	24.784
2005	110.768	301.389	109.403	210.682	615.404	21.580	64.852	13.212	33.437
2006	151.828	360.074	94.345	137.478	635.793	40.703	93.263	16.588	32.107
2007	96.071	314.313	84.248	165.522	761.416	15.557	90.755	8.347	31.178
2008	87.400	418.928	81.305	168.798	863.023	9.677	66.232	10.925	14.854
2009	81.258	322.789	91.746	195.655	694.446	4.678	76.209	9.902	20.420
2010	69.152	307.474	86.396	210.528	593.822	9.834	85.810	8.829	25.513
2011	51.200	203.551	74.614	253.065	615.103	21.795	108.103	8.983	24.849
2012	42.867	117.433	91.579	226.243	625.665	48.034	114.050	8.583	17.628
2013	41.814	188.874	92.061	263.405	535.170	42.220	86.593	8.385	19.209
97-13	1671.935	5169.917	1716.185	3410.485	11938.376	346.282	1247.104	174.222	316.635

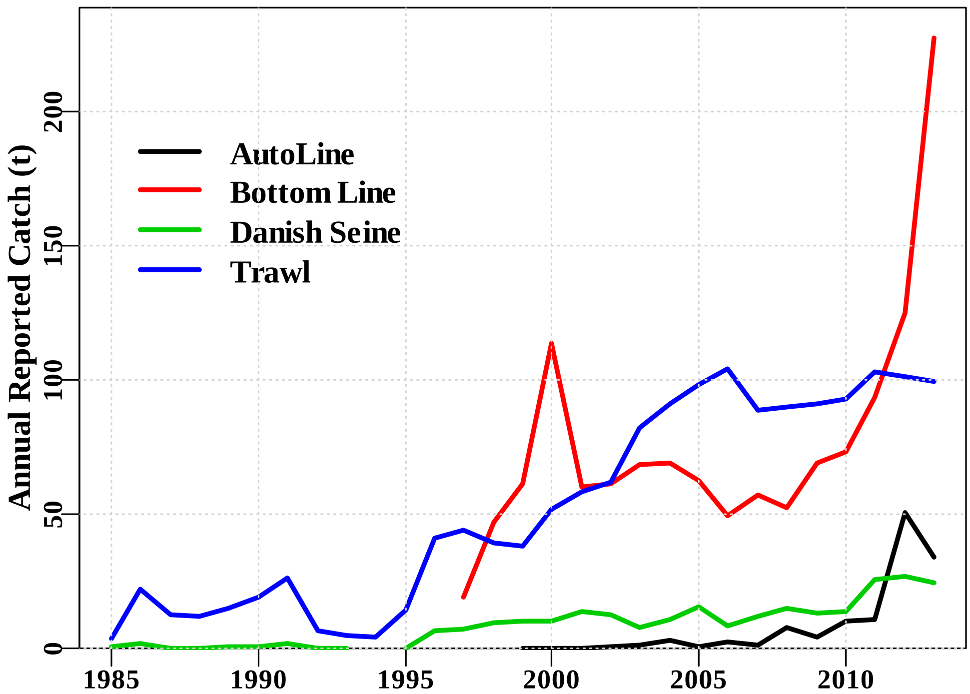

Figure 16.31. Relative catch of gummy sharks, not including discards, by four non-gill net fishing methods.

16.4.10 South Australian Gummy Shark: Gill net

Table 16.26**.** Gill net caught gummy shark from South Australia in depths between 0 – 160 m. Total catch (TotCatch; t) is the total reported in the database, number of records used in the analysis (Records), reported catch (CatchT; t) in the area and depth used in the analysis and number of vessels used in the analysis (Vessels). GeoMean is the geometric mean of catch rates (kg/hr). The optimum model is Region:DepCat and standard deviation (StDev) relates to the data in the optimum model

.

Year	TotCatch	Records	CatchT	Vessels	GeoMean	Optimum	StDev
1997	1002.598	4730	453.648	56	50.308	1.153	0.000
1998	1506.959	7230	548.171	54	36.873	0.917	0.023
1999	1983.759	6614	643.803	47	48.419	1.086	0.024
2000	2428.312	5937	852.718	37	70.689	1.569	0.025
2001	1688.674	5371	386.919	36	39.309	0.844	0.026
2002	1523.362	5492	411.703	32	44.179	0.920	0.026
2003	1650.786	5757	479.150	37	45.610	0.943	0.026
2004	1664.765	5497	465.646	40	45.954	0.985	0.027
2005	1569.251	4917	465.411	30	51.241	1.060	0.027
2006	1572.907	5939	546.571	28	52.934	1.082	0.026
2007	1574.136	4540	436.768	29	56.054	1.151	0.027
2008	1727.565	4892	542.885	23	63.764	1.365	0.027
2009	1499.409	5149	417.537	23	47.486	1.038	0.027
2010	1403.059	5250	389.422	29	41.585	0.913	0.028
2011	1364.624	3272	228.909	19	38.701	0.800	0.031
2012	1300.311	1367	82.593	14	31.390	0.591	0.039
2013	1281.744	796	60.501	18	35.948	0.583	0.050

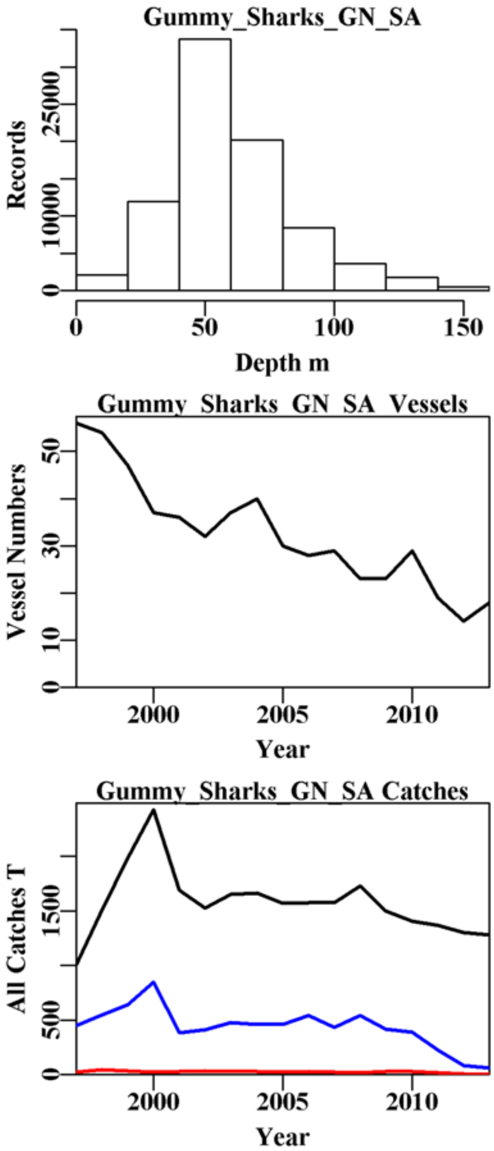

Figure 16.32. Gill net caught gummy shark from South Australia in depths between 0 – 160 m. The top left plot depicts the depth distribution of shots containing gummy sharks. The top right plot depicts the distribution of catch by depth within SESSF zones. The middle left plot depicts the number of vessels through time. The middle right plot contains the number of records used in analysis. The bottom left plot contains Eastern Gemfish catches (top black line: total catches, middle blue line: catches used in the analysis; bottom red line: catches < 30 kg) and bottom right plot contains Eastern Gemfish catches (blue line: catches used in the analysis; red line: catches < 30 kg).

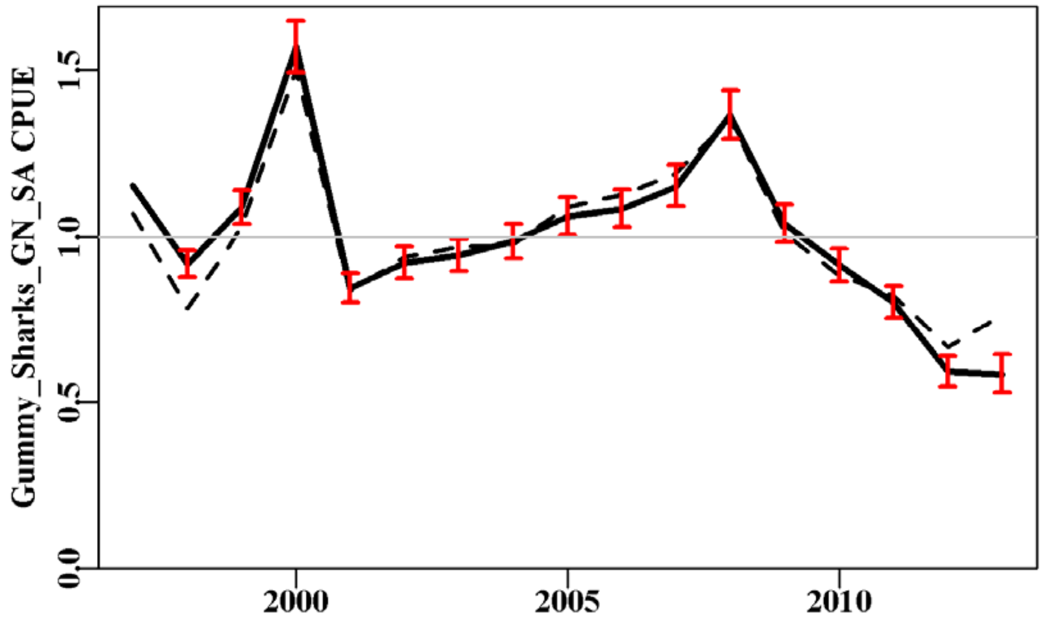

Figure 16.33. Gill net caught gummy shark from South Australia in depths between 0 – 160 m. The dashed black line represents the geometric mean catch rate and the solid black line the standardized catch rates (relative to the mean of the standardized catch rates). The red bars are 95% confidence intervals.

Table 16.27**.** Gill net caught gummy shark from South Australia in depths between 0 – 160 m. Statistical model structures used in this analysis. DepCat is a series of 20 metre depth categories.

Model 1	LnCE ~ Year
Model 2	LnCE ~ Year +Vessel
Model 3	LnCE ~ Year +Vessel +DepCat
Model 4	LnCE ~ Year +Vessel +DepCat +Region
Model 5	LnCE ~ Year +Vessel +DepCat +Region +Month
Model 6	LnCE ~ Year +Vessel +DepCat +Region +Month +DayNight
Model 7	LnCE ~ Year +Vessel +DepCat +Region +Month +DayNight +Region:Month
Model 9	LnCE ~ Year +Vessel +DepCat +Region +Month +DayNight +Region:DepCat

Table 16.28.Gill net caught gummy shark from South Australia in depths between 0 – 160 m. Model selection criteria, include the AIC, the adjusted r^2 and the change in adjusted r^2 (%Change). The optimum model is model 8 (Region:DepCat).

	Year	Vessel	DepCat	Region	Month	DayNight	Region:Month	Region:DepCat
AIC	27574	23639	22475	22099	20992	20806	20438	19967
RSS	115426	109715	107612	107116	105654	105407	104880	104296
MSS	2830	8540	10644	11140	12602	12849	13376	13959
Nobs	82750	82750	82175	82175	82175	82175	82175	82175
Npars	17	149	157	159	170	173	195	189
adj_r^2	2.374	7.056	8.828	9.245	10.472	10.678	11.101	11.602
Δr^2	2.374	4.682	1.772	0.418	1.227	0.206	0.423	0.924

16.4.11 Bass Strait Gummy Shark: Gill net

Table 16.29. Gill net caught gummy shark from Bass Strait in depths between 0 – 160 m. Total catch (TotCatch; t) is the total reported in the database, number of records used in the analysis (Records), reported catch (CatchT; t) in the area and depth used in the analysis and number of vessels used in the analysis (Vessels). GeoMean is the geometric mean of catch rates (kg/hr). The optimum model is Region:DepCat and standard deviation (StDev) relates to the data in the optimum model.

Year	TotCatch	Records	CatchT	Vessels	GeoMean	Optimum	StDev
1997	1002.598	4347	436.947	49	54.845	0.680	0.000
1998	1506.959	5882	769.538	51	70.564	0.847	0.025
1999	1983.759	6583	1075.067	54	83.847	1.091	0.025
2000	2428.312	6693	1223.093	49	89.763	1.154	0.026
2001	1688.674	6085	1029.372	47	84.055	1.036	0.026
2002	1523.362	5997	801.252	46	69.793	0.834	0.027
2003	1650.786	6287	851.163	44	70.383	0.806	0.025
2004	1664.765	5965	835.950	41	78.323	0.862	0.025
2005	1569.251	5009	775.194	38	92.483	0.963	0.026
2006	1572.907	4048	731.098	33	107.315	1.091	0.028
2007	1574.136	3475	871.606	25	138.457	1.327	0.029
2008	1727.565	3663	952.187	26	144.022	1.435	0.029
2009	1499.409	4088	832.917	27	120.943	1.252	0.028
2010	1403.059	4417	742.392	30	97.419	0.995	0.028
2011	1364.624	5164	796.521	32	83.689	0.905	0.027
2012	1300.311	5417	777.171	37	79.841	0.884	0.027
2013	1281.744	5205	735.083	36	78.885	0.839	0.027

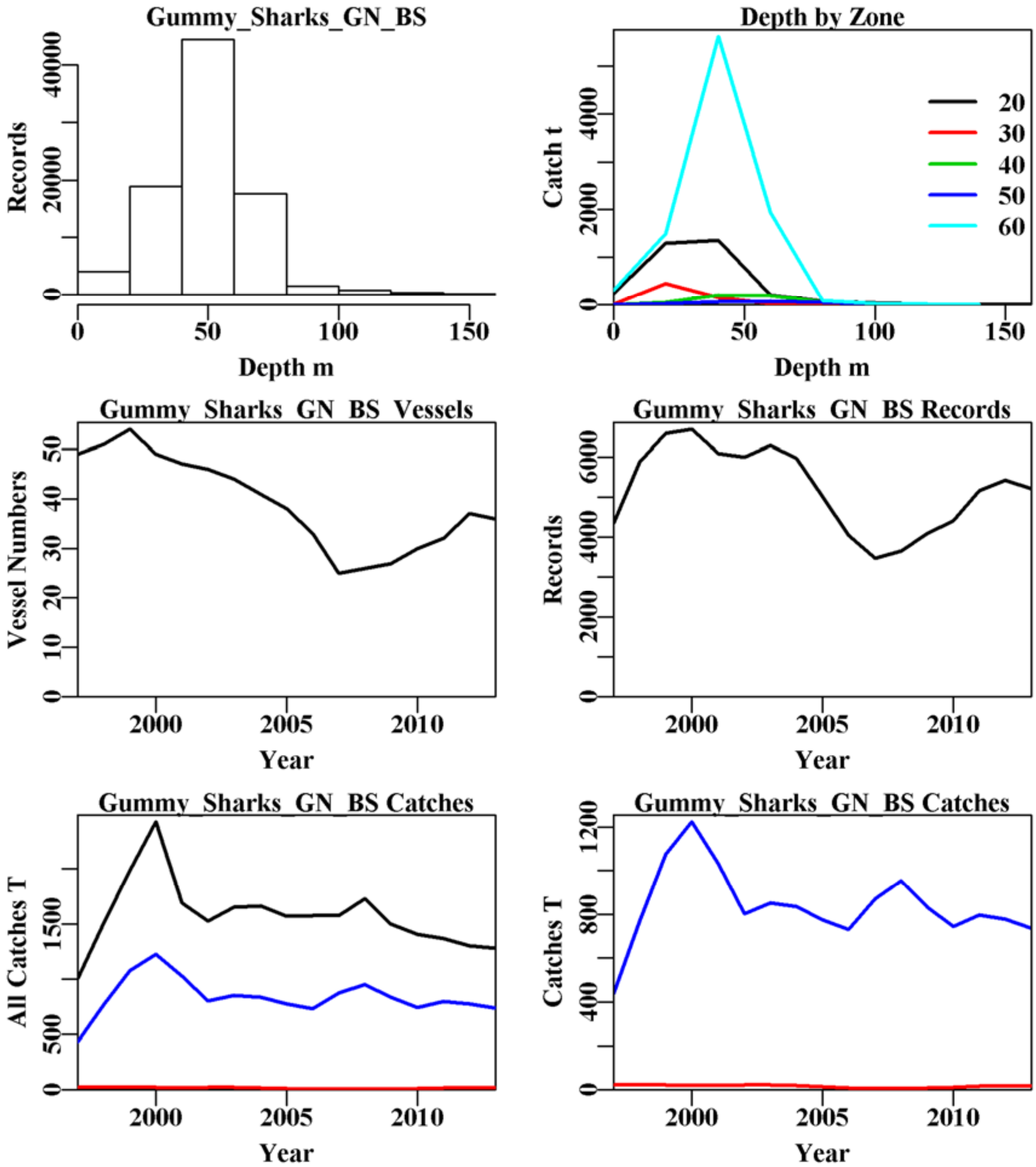

Figure 16.34**.** Gill net caught gummy shark from Bass Strait in depths between 0 – 160 m. The top left plot depicts the depth distribution of shots containing gummy sharks. The top right plot depicts the distribution of catch by depth within SESSF zones. The middle left plot depicts the number of vessels through time. The middle right plot contains the number of records used in analysis. The bottom left plot contains Eastern Gemfish catches (top black line: total catches, middle blue line: catches used in the analysis; bottom red line: catches < 30 kg) and bottom right plot contains Eastern Gemfish catches (blue line: catches used in the analysis; red line: catches < 30 kg).

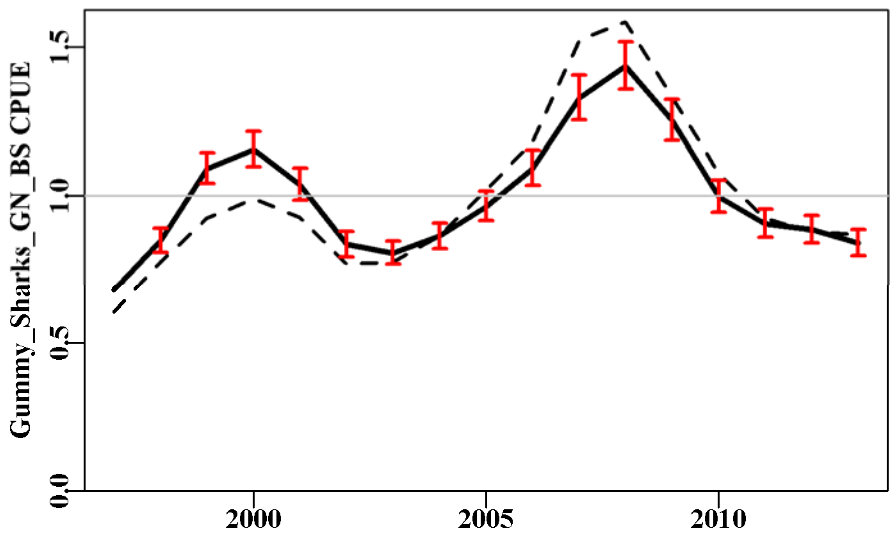

Figure 16.35. Gill net caught gummy shark from Bass Strait in depths between 0 – 160 m. The dashed black line represents the geometric mean catch rate and the solid black line the standardized catch rates (relative to the mean of the standardized catch rates). The red bars are 95% confidence intervals.

Table 16.30**.** Gill net caught gummy shark from Bass Strait in depths between 0 – 160 m. Statistical model structures used in this analysis. DepCat is a series of 20 metre depth categories.

Model 1	LnCE ~ Year
Model 2	LnCE ~ Year +Vessel
Model 3	LnCE ~ Year +Vessel +DepCat
Model 4	LnCE ~ Year +Vessel +DepCat +Region
Model 5	LnCE ~ Year +Vessel +DepCat +Region +Month
Model 6	LnCE ~ Year +Vessel +DepCat +Region +Month +DayNight
Model 7	LnCE ~ Year +Vessel +DepCat +Region +Month +DayNight +Region:Month
Model 9	LnCE ~ Year +Vessel +DepCat +Region +Month +DayNight +Region:DepCat

Table 16.31**.** Gill net caught gummy shark from Bass Strait in depths between 0 – 160 m. Model selection criteria, include the AIC, the adjusted r^2 and the change in adjusted r^2 (%Change). The optimum model is model 7 (Region:Month).

	Year	Vessel	DepCat	Region	Month	DayNight	Region:Month	Region:DepCat
AIC	36045	28499	27452	27453	27026	27020	26779	26952
RSS	132785	121603	119619	119617	119007	118991	118634	118876
MSS	4297	15479	17464	17465	18075	18091	18448	18206
Nobs	88325	88325	87762	87762	87762	87762	87762	87762
Npars	17	129	137	138	149	152	163	160
adj_r^2	3.117	11.163	12.604	12.604	13.039	13.048	13.298	13.124
Δr^2	3.117	8.047	1.441	0.000	0.435	0.009	0.250	0.076

16.4.12 *Tasmanian Gummy Shark: Gill net*

Table 16.32**.** Gill net caught gummy shark from Tasmania in depths between 0 – 160 m. Total catch (TotCatch; t) is the total reported in the database, number of records used in the analysis (Records), reported catch (CatchT; t) in the area and depth used in the analysis and number of vessels used in the analysis (Vessels). GeoMean is the geometric mean of catch rates (kg/hr). The optimum model is Region:Month and standard deviation (StDev) relates to the data in the optimum model.

Year	TotCatch	Records	CatchT	Vessels	GeoMean	Optimum	StDev
1997	1002.598	186	16.945	13	48.090	0.786	0.000
1998	1506.959	477	59.659	14	59.182	0.759	0.117
1999	1983.759	674	88.367	17	68.663	0.912	0.116
2000	2428.312	418	70.883	15	87.662	1.155	0.127
2001	1688.674	492	50.801	17	54.992	1.176	0.127
2002	1523.362	688	76.754	24	50.049	1.043	0.128
2003	1650.786	745	68.542	22	45.667	1.196	0.127
2004	1664.765	675	81.114	20	49.491	1.152	0.127
2005	1569.251	502	64.489	12	66.365	1.019	0.130
2006	1572.907	667	114.141	15	95.243	1.193	0.128
2007	1574.136	807	92.967	14	57.691	1.018	0.127
2008	1727.565	617	60.045	14	52.689	0.882	0.129
2009	1499.409	525	67.348	14	65.433	1.038	0.135
2010	1403.059	516	74.059	14	76.905	1.064	0.135
2011	1364.624	682	101.810	13	86.698	0.917	0.137
2012	1300.311	1080	127.835	18	50.811	0.924	0.134
2013	1281.744	897	95.910	15	55.938	0.765	0.137

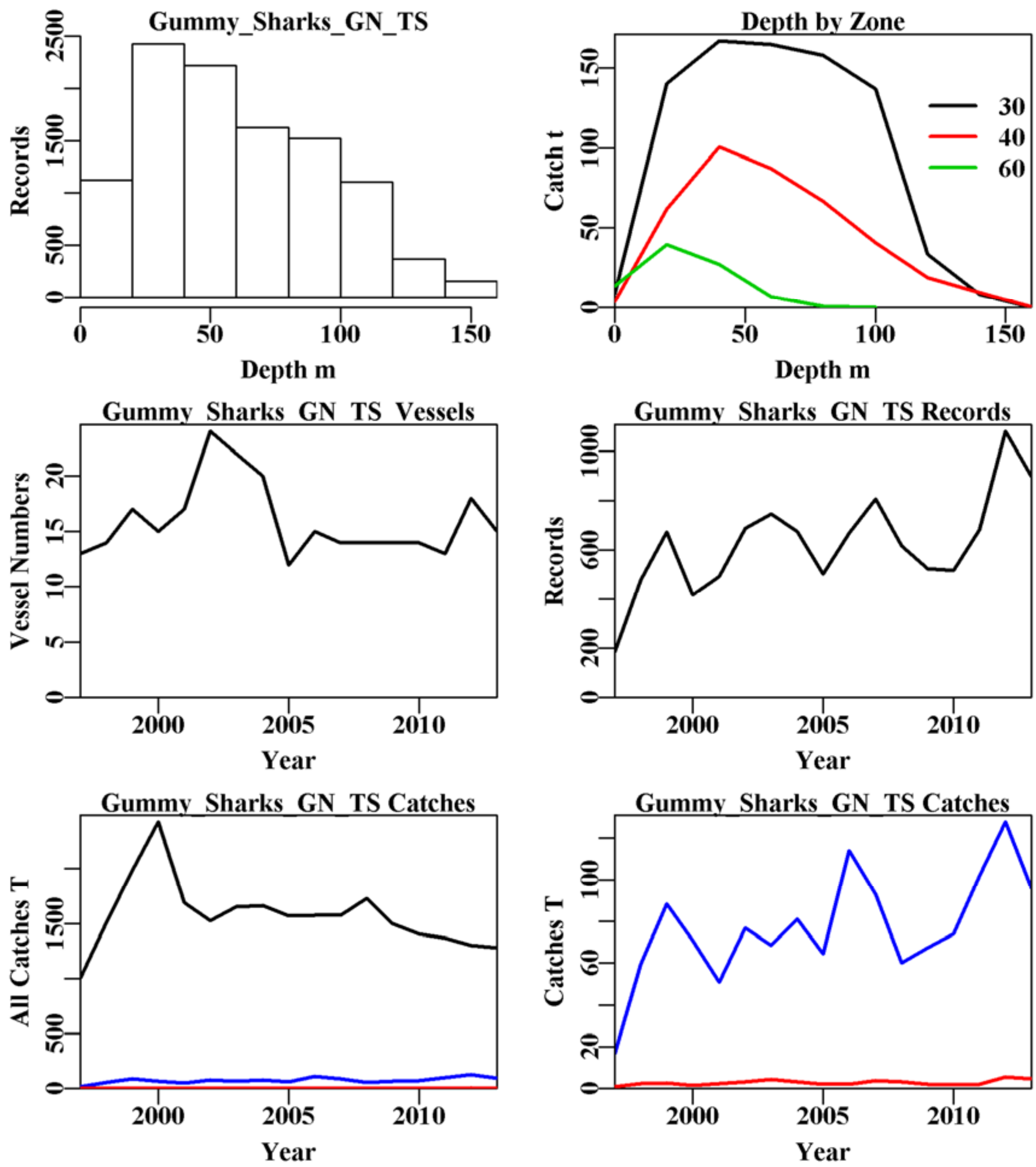

Figure 16.36. Gill net caught gummy shark from Tasmania in depths between 0 – 160 m. The top left plot depicts the depth distribution of shots containing gummy sharks. The top right plot depicts the distribution of catch by depth within SESSF zones. The middle left plot depicts the number of vessels through time. The middle right plot contains the number of records used in analysis. The bottom left plot contains Eastern Gemfish catches (top black line: total catches, middle blue line: catches used in the analysis; bottom red line: catches < 30 kg) and bottom right plot contains Eastern Gemfish catches (blue line: catches used in the analysis; red line: catches < 30 kg).

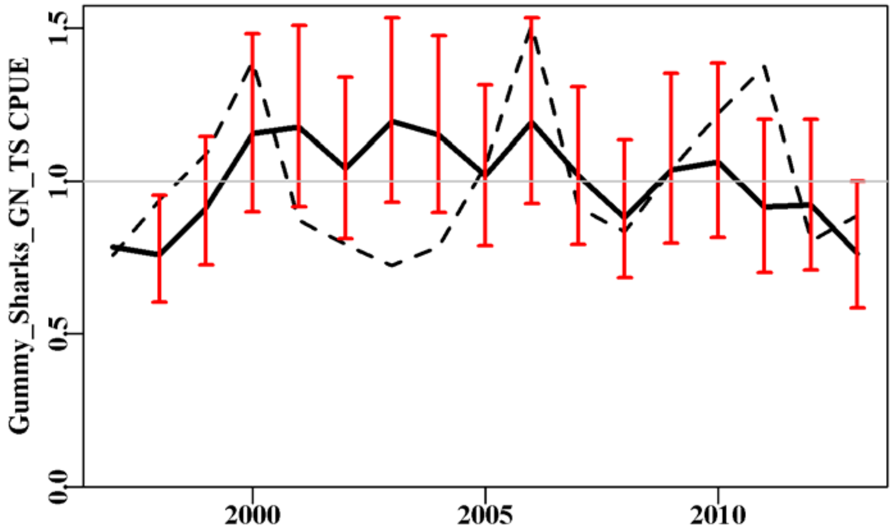

Figure 16.37. Gill net caught gummy shark from Tasmania in depths between 0 – 160 m. The dashed black line represents the geometric mean catch rate and the solid black line the standardized catch rates (relative to the mean of the standardized catch rates). The red bars are 95% confidence intervals.

Table 16.33. Gill net caught gummy shark from Tasmania in depths between 0 – 160 m. Statistical model structures used in this analysis. DepCat is a series of 20 metre depth categories.

Model 1	LnCE ~ Year
Model 2	LnCE ~ Year +Vessel
Model 3	LnCE ~ Year +Vessel +DepCat
Model 4	LnCE ~ Year +Vessel +DepCat +Region
Model 5	LnCE ~ Year +Vessel +DepCat +Region +Month
Model 6	LnCE ~ Year +Vessel +DepCat +Region +Month +DayNight
Model 7	LnCE ~ Year +Vessel +DepCat +Region +Month +DayNight +Region:Month
Model 9	LnCE ~ Year +Vessel +DepCat +Region +Month +DayNight +Region:DepCat

Table 16.34**.** Gill net caught gummy shark from Tasmania in depths between 0 – 160 m. Model selection criteria, include the AIC, the adjusted r^2 and the change in adjusted r^2 (%Change). The optimum model is model 7 (Region:Month).

	Year	Vessel	DepCat	Region	Month	DayNight	Region:Month	Region:DepCat
AIC	5586	718	718	719	459	463	413	431
RSS	17936	11204	11075	11074	10782	10780	10706	10730
MSS	508	7240	7369	7370	7662	7664	7738	7714
Nobs	10648	10648	10536	10536	10536	10536	10536	10536
Npars	17	88	96	97	108	111	122	119
adj_r^2	2.610	38.753	39.408	39.406	40.942	40.937	41.279	41.163
Δr^2	2.610	36.143	0.654	-0.002	1.536	-0.005	0.342	0.226

16.4.13 Gummy Shark: Trawl

Table 16.35**.** Trawl caught gummy shark from depths between 0 – 500 m in SESSF zones. The analysis of CPUE only used those zones where catches from 1996 – 2013 were greater than 20 t.

Year	**10**	**20**	**30**	**40**	**50**	**60**	**82**	**83**	**84**	**85**	**91**
1986	8.179	8.974	0.298		4.077	0.214					0.045
1987	7.031	4.994	0.055		0.230				0.205		0.170
1988	5.877	2.984	0.630	0.030	0.060		1.155			0.151	
1989	5.958	5.819	0.050		0.241		1.362	1.460	0.122	0.045	0.016
1990	3.863	4.242	1.012		0.875		1.510	6.318		0.175	0.535
1991	5.461	2.116	0.202	0.030	0.087		4.764	11.855	0.106	0.064	1.087
1992	0.015	0.110		0.060			2.300	2.496		0.010	
1993	0.019						2.501	2.321		0.040	
1994							2.241	2.228		0.027	
1995							6.416	7.956		0.018	
1996	8.570	6.640	1.306	0.020	4.798	0.576	10.027	7.136		0.035	0.763
1997	8.504	6.108	1.506	0.092	5.188	1.599	11.337	7.975	0.025	0.017	1.047
1998	7.412	10.830	0.892	0.075	4.643	1.411	7.147	6.146		0.016	0.378
1999	5.821	10.058	1.180	0.075	6.495	2.113	5.593	6.076		0.013	0.193
2000	7.098	15.721	1.791	0.507	12.581	1.420	3.774	7.103		0.036	0.456
2001	6.076	13.334	3.591	0.568	9.734	2.389	11.210	9.376	0.048		0.101
2002	7.666	16.454	9.497	0.758	7.772	0.252	10.956	7.823	0.010		0.118
2003	9.302	15.428	10.144	1.597	5.118	0.312	17.311	20.680		0.003	0.902
2004	8.797	14.738	9.284	1.204	6.916	0.839	24.451	22.649	0.015	0.022	0.741
2005	8.501	11.452	9.760	0.805	6.483	2.262	32.728	23.344	0.130	0.032	0.724
2006	9.866	17.885	9.644	0.422	11.195	1.428	29.102	22.293	0.025	0.106	0.612
2007	5.900	17.054	6.213	0.826	9.708	0.128	27.617	18.546	0.045	0.005	0.102
2008	8.015	32.847	5.604	0.455	10.256	0.091	14.017	15.999		0.010	0.049
2009	6.889	23.485	5.433	0.685	13.660	0.056	19.320	19.400			
2010	5.515	24.648	4.993	1.968	7.961	0.368	25.245	19.645			
2011	5.960	27.235	6.962	2.622	9.215	0.272	18.798	13.737			
2012	6.829	29.171	5.634	2.040	13.634	0.545	2.125	2.336			
2013	6.854	20.771	4.706	2.800	11.747	0.307	10.214	8.430			
Total	133.574	313.858	98.140	17.519	157.104	16.368	280.972	238.694	0.298	0.295	6.186

Table 16.36**.** Trawl caught gummy shark from depths between 0 – 500 m in SESSF zones 10, 20, 30, 50, 82, 83. Total catch (TotCatch; t) is the total reported in the database, number of records used in the analysis (Records), reported catch (CatchT; t) in the area and depth used in the analysis and number of vessels used in the analysis (Vessels). GeoMean is the geometric mean of catch rates (kg/hr). The optimum model is Zone:DepCat and standard deviation (StDev) relates to the data in the optimum model.

Year	TotCatch	Records	CatchT	Vessels	GeoMean	Optimum	StDev
1996	47.926	1084	19.555	41	10.728	0.920	0.000
1997	1002.598	1618	21.716	48	7.683	0.789	0.038
1998	1506.959	1455	21.932	39	8.691	0.841	0.039
1999	1983.759	1583	24.847	44	8.327	0.869	0.039
2000	2428.312	2116	36.610	56	8.711	0.747	0.038
2001	1688.674	2196	36.541	45	8.690	0.795	0.038
2002	1523.362	2413	38.813	44	8.764	0.748	0.038
2003	1650.786	2857	49.762	47	9.934	0.844	0.037
2004	1664.765	2870	52.092	50	10.237	0.849	0.037
2005	1569.251	2988	50.302	47	10.027	0.876	0.037
2006	1572.907	3100	56.355	41	10.423	0.883	0.037
2007	1574.136	2394	50.537	28	11.577	0.943	0.038
2008	1727.565	2765	61.876	30	12.073	1.107	0.038
2009	1499.409	2420	59.303	25	14.936	1.330	0.038
2010	1403.059	2416	56.356	23	14.096	1.356	0.038
2011	1364.624	2832	65.592	27	13.845	1.248	0.038
2012	1300.311	2682	73.442	23	15.489	1.370	0.038
2013	1281.744	2553	69.611	28	17.352	1.483	0.038

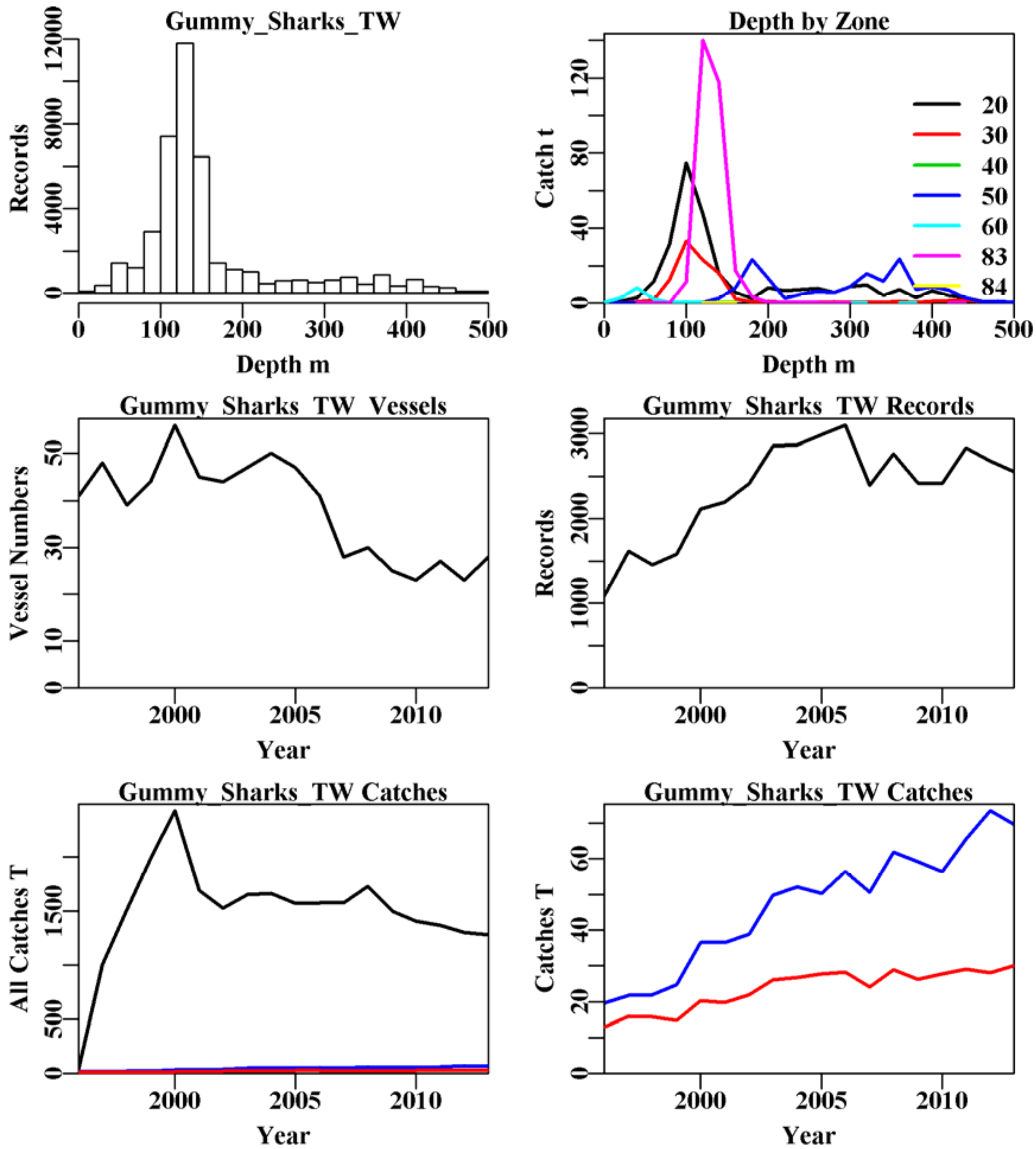

Figure 16.38**.** Trawl caught gummy shark from depths between 0 – 500 m. The top left plot depicts the depth distribution of shots containing gummy sharks. The top right plot depicts the distribution of catch by depth within SESSF zones. The middle left plot depicts the number of vessels through time. The middle right plot contains the number of records used in analysis. The bottom left plot contains Eastern Gemfish catches (top black line: total catches, middle blue line: catches used in the analysis; bottom red line: catches < 30 kg) and bottom right plot contains Eastern Gemfish catches (blue line: catches used in the analysis; red line: catches < 30 kg).

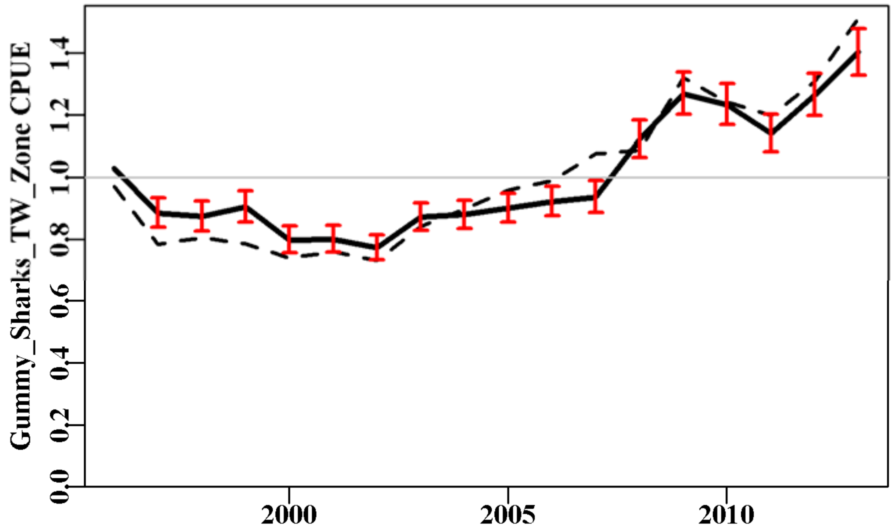

Figure 16.39. Trawl caught gummy shark from depths between 0 – 500 m. The dashed black line represents the geometric mean catch rate and the solid black line the standardized catch rates (relative to the mean of the standardized catch rates). The red bars are 95% confidence intervals.

Table 16.37. Trawl caught gummy shark from depths between 0 – 500 m. Statistical model structures used in this analysis. DepCat is a series of 20 metre depth categories.

Model 1	LnCE ~ Year
Model 2	LnCE ~ Year +Vessel
Model 3	LnCE ~ Year +Vessel +DepCat
Model 4	LnCE ~ Year +Vessel +DepCat +Region
Model 5	LnCE ~ Year +Vessel +DepCat +Region +Month
Model 6	LnCE ~ Year +Vessel +DepCat +Region +Month +DayNight
Model 7	LnCE ~ Year +Vessel +DepCat +Region +Month +DayNight +Region:Month
Model 9	LnCE ~ Year +Vessel +DepCat +Region +Month +DayNight +Region:DepCat

Table 16.38. Trawl caught gummy shark from depths between 0 – 500 m. Model selection criteria, include the AIC, the adjusted r^2 and the change in adjusted r^2 (%Change). The optimum model is model 7 (Region:Month).

	Year	Vessel	DepCat	Region	Month	DayNight	Region:Month	Region:DepCat
AIC	5586	718	718	719	459	463	413	431
RSS	17936	11204	11075	11074	10782	10780	10706	10730
MSS	508	7240	7369	7370	7662	7664	7738	7714
Nobs	10648	10648	10536	10536	10536	10536	10536	10536
Npars	17	88	96	97	108	111	122	119
adj_r^2	2.610	38.753	39.408	39.406	40.942	40.937	41.279	41.163
Δr^2	2.610	36.143	0.654	-0.002	1.536	-0.005	0.342	0.226

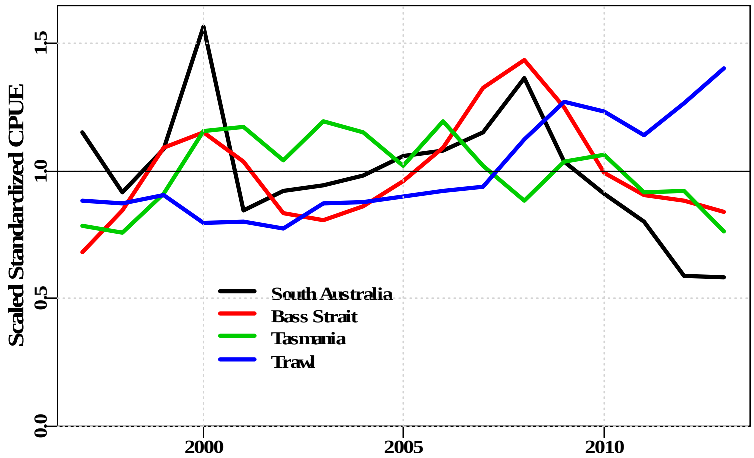

Figure 16.40**.** The optimum standardized CPUE for gummy sharks by gill net from the three main regions and also those taken by trawl, all shown on the same scale.

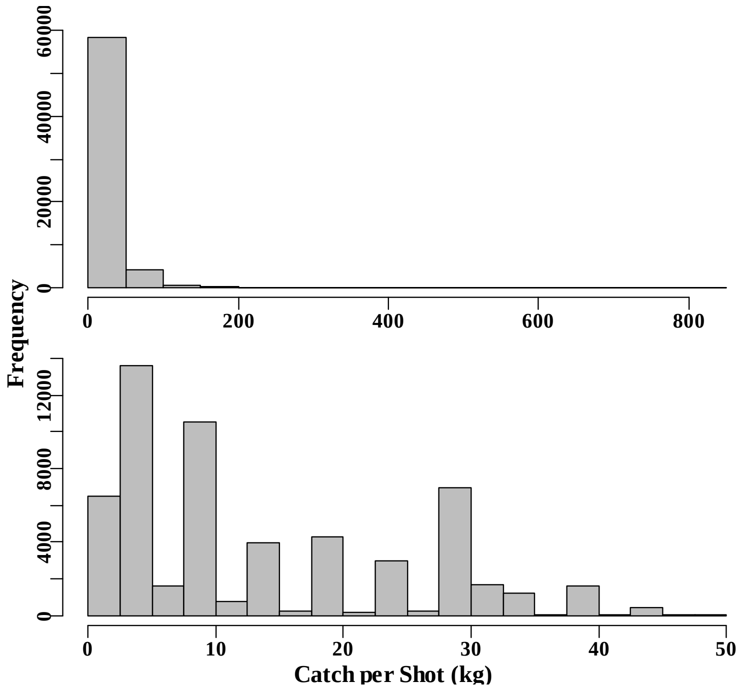

Figure 16.41. The relative frequency of catch per shot from trawler across years 1996 – 2013.

Since 2010, the gillnet gummy shark fisheries in all three regions appear to have exhibited declines. This has been most marked in South Australia where much of the State has effectively been closed to the Commonwealth gillnet fishery. Despite these apparent declines in the gillnet fishery, the CPUE from trawlers has been rising since 2007, and this is despite reports that they are having to discard amounts of gummy and school sharks through being until to access quota.

It is possible that the successful avoidance of catching School sharks has led to a decrease in the effectiveness at catching gummy sharks also. A detailed examination of the spatial distribution of catches may clarify this.

16.4.14 Gummy Shark Bottom Line

Table 16.39**.** Bottom Line caught gummy shark from depths between 0 – 200 m in SESSF zones 10, 20, 30, 40, 50, 60, 82, 83, 84, and 85. Number of records used in the analysis (Records), reported catch (CatchT; t) in the area and depth used in the analysis and number of vessels used in the analysis (Vessels). GeoMean is the geometric mean of catch rates (kg/shot). The optimum model is Zone:DepCat and standard deviation (StDev) relates to the data in the optimum model.

Year	Records	CatchT	Vessels	GeoMean	Optimum	StDev
1998	72	8.928	3	93.0601	0.7074	0.0000
1999	335	48.136	13	97.4648	1.0024	0.1459
2000	482	112.465	14	143.4869	1.3838	0.1613
2001	547	58.989	23	54.6039	0.8483	0.1613
2002	505	59.875	22	61.6949	0.9371	0.1625
2003	627	66.037	27	61.4020	0.8003	0.1613
2004	648	67.909	24	60.4273	0.8664	0.1605
2005	588	61.802	25	58.3962	0.9759	0.1628
2006	494	48.768	19	49.9757	1.0719	0.1637
2007	626	54.489	19	40.7775	1.0170	0.1630
2008	599	50.082	16	36.0171	0.7827	0.1655
2009	822	67.123	15	37.5970	0.9006	0.1642
2010	684	71.961	19	48.2002	1.0139	0.1645
2011	1051	87.934	28	46.2099	1.1802	0.1646
2012	1405	124.161	23	52.9018	1.1543	0.1644
2013	2502	227.038	26	50.2814	1.3579	0.1647

Table 16.40. Bottom line caught gummy shark in depths between 0 – 200 m. Statistical model structures used in this analysis. DepCat is a series of 20 metre depth categories.

Model 1	LnCE ~ Year
Model 2	LnCE ~ Year +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 9	LnCE ~ Year +Vessel +DepCat + Zone +Month +DayNight + Zone:DepCat

Table 16.41. Bottom line caught gummy shark from depths between 0 – 200 m. Model selection criteria, include the AIC, the adjusted r^2 and the change in adjusted r^2 (%Change). The optimum model is model 7 (Zone:Month).

	Year	Vessel	DepCat	Zone	Month	DayNight	Zone:Month	Zone:DepCat
AIC	4547	-1172	-1202	-1276	-1292	-1313	-1345	-1263
RSS	17470	10651	10536	10373	10340	10317	10156	10251
MSS	932	7750	7866	8029	8062	8085	8246	8151
Nobs	11987	11987	11913	11828	11828	11828	11828	11828
Npars	16	122	131	138	149	152	229	215
adj_r^2	4.943	41.527	42.116	42.969	43.099	43.212	43.727	43.269
Δr^2	0.000	36.584	0.589	0.853	0.130	0.113	0.515	0.057

Table 16.42. Bottom line caught gummy shark from depths between 0 – 200 m in SESSF zones.

Year	20	30	40	50	60	83	84	85
1998	0.555	2.495	1.823		4.055			
1999	0.470	12.085	4.020	0.869	30.450			0.091
2000	12.371	19.512	0.897	4.191	65.457			
2001	0.360	17.451	2.420	5.896	26.328		1.775	3.207
2002	1.372	19.224	4.912	9.799	16.366		1.605	5.792
2003		12.473	7.316	11.075	30.883	0.085	1.009	2.905
2004		20.859	4.369	12.105	25.640		1.766	2.670
2005	6.480	11.730	3.482	19.876	15.410	0.140	1.698	2.034
2006	1.404	7.493	4.276	15.758	11.685		2.975	5.175
2007	5.178	4.182	1.689	17.687	18.331		2.148	5.274
2008	5.556	4.068	4.029	13.435	19.750			3.244
2009	4.546	6.381	2.823	32.878	11.743		0.490	8.262
2010	3.744	8.897	6.697	33.372	12.051	0.025		7.175
2011	3.382	6.230	4.827	38.382	12.678		0.734	21.701
2012	4.171	18.020	3.987	67.228	9.986	0.210	3.256	16.893
2013	0.751	11.955	7.846	144.377	6.670	0.856	12.781	41.722

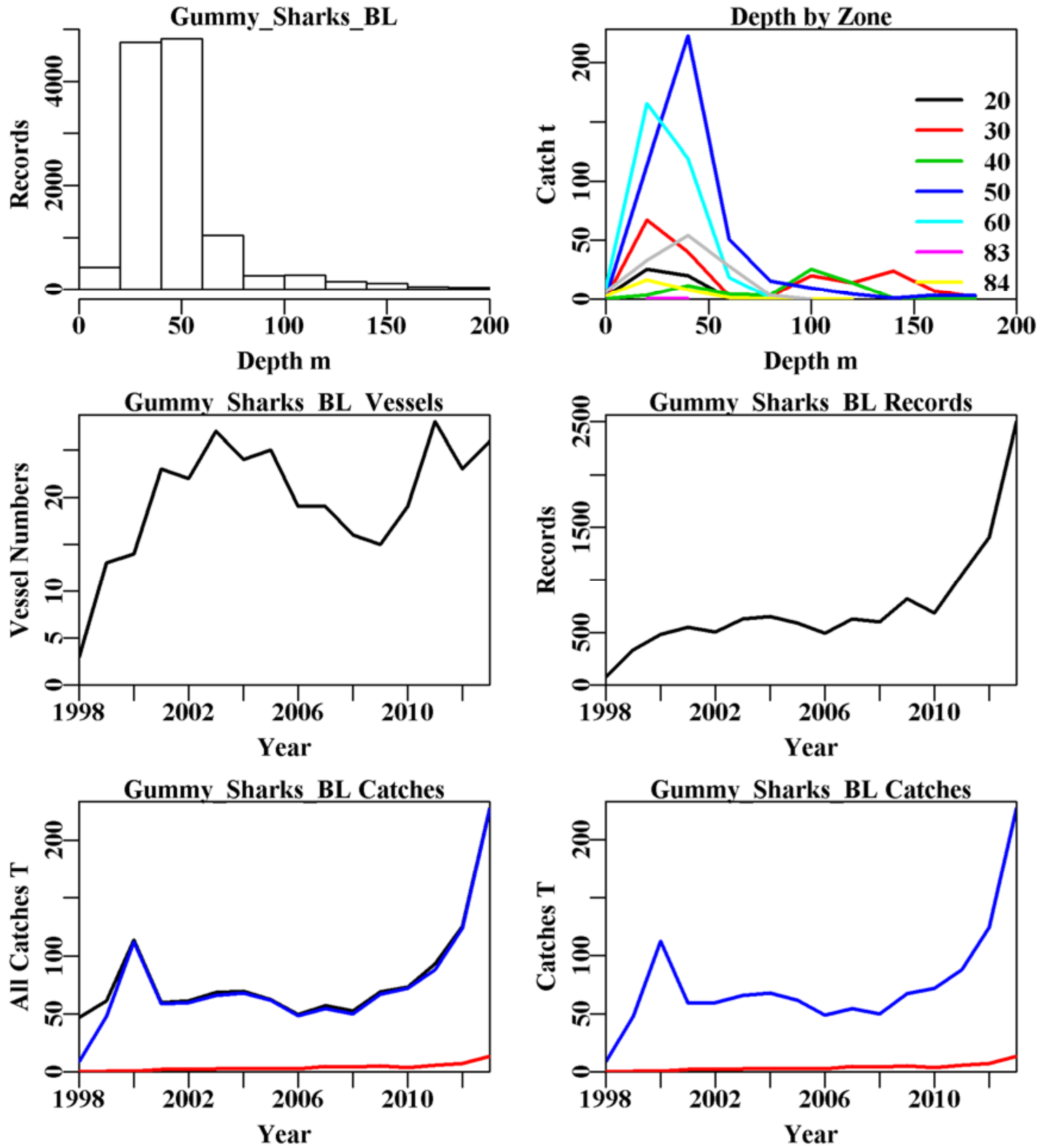

Figure 16.42. Bottom line caught gummy shark from depths between 0 – 200 m. The top left plot depicts the depth distribution of shots containing gummy sharks. The top right plot depicts the distribution of catch by depth within SESSF zones. The middle left plot depicts the number of vessels through time. The middle right plot contains the number of records used in analysis. The bottom left plot contains Eastern Gemfish catches (top black line: total catches, middle blue line: catches used in the analysis; bottom red line: catches < 30 kg) and bottom right plot contains Eastern Gemfish catches (blue line: catches used in the analysis; red line: catches < 30 kg).

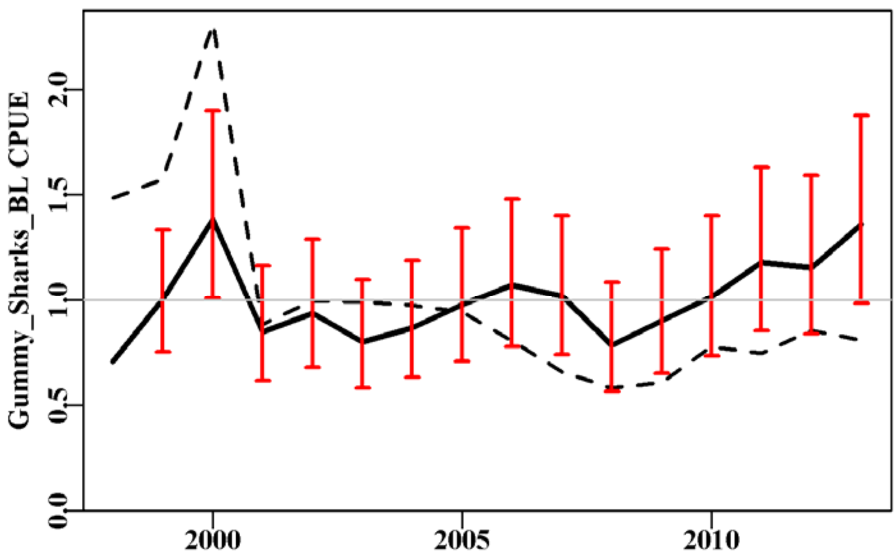

Figure 16.43**.** Bottom line caught gummy shark from depths between 0 – 200 m. The dashed black line represents the geometric mean catch rate and the solid black line the standardized catch rates (relative to the mean of the standardized catch rates). The red bars are 95% confidence intervals.

16.5 Discussion

16.5.1 School Sharks

Catches of School sharks are now greatly reduced relative to catches in 2009. Industry avoidance of School sharks is reasonably successful, although there are reports that a scarcity of quota for leasing at economic prices is making it difficult for operators to keep the proportion of School sharks to Gummy shark catches down to 20%.

The multiple gill net closures in South Australia continue to have the effect of pushing catches outside of South Australia. In addition, there has been a shift in fishing methods to lining methods with a greater catch by Bottom long-lining than by Auto-lining. Trawl catches are also increasing, especially if reported discards are included (Figure 16.3).

Because of the active avoidance of School sharks by the lining methods their CPUE is noisy and low but with the large changes in the fishing practices of industry members the CPUE cannot be taken to be indicative of the stock status in any way. The trawl catches, on the other hand, although low are not making efforts to avoid School sharks. The trend in School shark CPUE taken by trawl is positive and gradually increasing; not as rapidly as in Gummy sharks, but it has a similar trend (Figure 16.8). Whether this is in response to the improved avoidance of School sharks or simply new recruits entering the fishery cannot currently be determined. However, inspection of the on-board sampling for length frequencies (across all methods; Klaer et al, 2014, p245) suggests that for the last four years there have been an increased proportion of smaller School sharks being captured and being discarded.

16.5.2 Gummy Sharks

16.5.2.1 The Gillnet Fishery

Gummy shark catches are clearly greatest in the Gillnet Hook and Trap fishery followed by the South East Trawl, and then the Great Australian Bight, with catches in 2013 being 1157 t, 76 t , and 48 t respectively. The gill net fishery is primarily focussed in Bass Strait with only relatively minor catches coming from around Tasmania.

Gill net catches in South Australia have dropped to one sixth their 2010 levels with increases there by hook methods, especially bottom line (Table 16.23). This is a response to the closures in relation to potential marine mammal interactions. This avoidance of the optimum catching areas has led to apparent changes in the CPUE for gillnets in South Australia, so they can no longer be considered to be reliable indicators of the stock's status there (Figure 16.32). The impact on catches and numbers of records is obvious (Figure 16.31).

Bass Strait gill net catches are relatively stable (Figure 16.33) and the CPUE has shown a recent decline with apparent stabilization occurring over the last three years (Figure 16.34). How much of this decline is due to the avoidance of School shark areas has not been determined, and would be difficult to determine.

Tasmania only has a relatively minor gummy shark catch (Figure 16.35) and the CPUE has been noisy but relatively flat since 1997, with the most recent years possibly indicating a slight decline (Figure 16.36).

16.5.2.2 The Trawl Fishery

Unlike the gill net fishery the catches by trawlers, which do not target gummy sharks, has been increasing. Evidence that they are not targeted can be seen in the number of individual shots containing less than 30kg (Figure 16.37 andFigure 16.40). Most trawl catches are taken in eastern Bass Strait in depths of about 150m, just outside and deeper than the depths of the lowest catches by gill nets (Figure 16.27 -Figure 16.29). Trawl CPUE at least 40% since 2007 (Figure 16.38) and presents a strong contrast to all of the gill net CPUE trends (Figure 16.39).

16.5.2.3 The Hook Fishery

With the drop in gill net catches in South Australia there has been an increase in the hook caught catches. The bottom line method increased markedly in 2013 with 7 times the catch taken by the Autoline method (Figure 16.30 and Table 16.23).

A catch rate standardization on the bottom line catches (using catch per shot) exhibits much broader confidence intervals owing to the smaller numbers of records relative to gill net records. Nevertheless, the standardization has a large effect upon the geometric mean CPUE. Since about 2010 it has been rising above the long term average, which the unstandardized bottom line CPUE does not appear to do.

This outcome is consistent with the findings from the trawl fishery, except this fishery is undoubtedly a targeted fishery.

16.5.3 Saw Sharks

Saw sharks catches have been split primarily between Gill nets, trawls, and a minor third in Danish Seine. Discarding, which has only really been examined in recent years, was relatively high (15 – 20%) in 2011 and 2012 (Klaer et al, 2014, p261). Most catches are taken in Bass Strait, although up to about 2006 there were also catches in Central and Eastern South Australia. it is possible the structural adjustment influenced that outcome, but more detailed analysis would be required to increase certainty. The structural adjustment certainly affected the number of vessels reporting catches of saw sharks with number of gill net vessels dropping from approximately 80 per year in 2003 down to about 42 in 2007. The number of trawl vessels reporting saw sharks also approximately halved from about 65 pre-2007 to about 37 post-2006. Danish Seine vessels reporting saw sharks only dropped from about 22 vessels a year down to about 15 vessels each year.

In all methods the proportion of the catch that is reported to be in shots of < 30kg is also relatively high (gillnet 32.8%, trawl 36.6%, and Danish seine 71.3%). This indicates that saw sharks are not a primary target species and that few individuals are taken in each shot, especially in the Danish Seine fishery.

The standardized CPUE for gillnet caught saw sharks has been declining since 2004, although these catch rates do not take into account the level of discarding that occurs. Invariably the inclusion of discarding leads to an increase in the CPUE exhibited by the fishery unless the level of discarding has been relatively constant through time. In the impact plot the effect of the South Australian closures can be seen in the Region factors influence.

The trawl catches are from a much wider depth range than the gillnet catches. The standardized CPUE varies around the average of 1.0 ranging between 0.8 and 1.2 since 1997; it is flat and noisy. Again in the impact plot region indicates changes since 2010, which correlates with the advent of gill net closures.

The Danish seine catches tend to be more focussed in the shallower depths less than 100m. Following an initial high CPUE up to 2001, a period when reported catches were consistently < 8 tonnes, the standardized Danish seine CPUE is essentially flat out to 2013.

Over the period 2001 – 2013 Danish seine and trawl saw shark CPUE follows essentially the same trajectory if they are placed on the same scale. If CPUE is indexing the stock status there is no indication of a change in the relative abundance, despite the downward trend exhibited by the gill net CPUE.

16.5.4 Elephant Fish

Elephant fish are predominately taken by gillnet, however, the catch by area and method tables (Table 16.18, Table 16.20, andTable 16.21) do not yet include discards and these have been large in recent years so these tables require updating.

The fishery is very focussed in about 50m of water, where most of the records and catch come from. The number of vessels reporting gill net catches of elephant fish dropped strongly just before the structural adjustment from about 55 vessels down to about 32, and has stayed roughly stable since. A high proportion of reported catches are less than 30kg, which is once again suggestive of the fact that these are rarely if ever targeted. There is no trend through time in these small catches. Much of the fishery is concentrated in SESSF zone 60 (Bass Strait) (Figure 16.23).

Reported catches by trawl and Danish seine have remained stable at about 10 t a year each (Table 16.20), but there is insufficient information to provide a useable standardization.

The catch rates (un-adjusted for discards) show occasional rises and falls about the longer term average catch rate (Figure 16.24). There is no evidence of a rise or a fall apparent in the data. The factor having the greatest influence on the CPUE appears to be which vessel is doing the fishing with a major change in the patterns indicated following the structural adjustment (Figure 16.26).

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17. SESSF Saw Shark and Elephant Fish TIER 4 Analyses (Data from 1986 – 2013)

Malcolm Haddon

CSIRO Oceans and Atmosphere Flagship, GPO Box 1538, Hobart, TAS 7001, Australia

17.1 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 17.6). 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 17.7). 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 17.1. 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**

17.2 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.

17.3 Methods

17.3.1 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:

$$\text{Scaling Factor } = SF = \max\left(0, \frac{\overline{CPUE} - CPUE_{\lim}}{CPUE_{t\arg} - CPUE_{\lim}}\right) \quad (1)$$

$$RBC = C^{*} \times SF \quad (2)$$

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.

$$CPUE_{\text{targ}} = \frac{\sum_{y=yr1}^{yr2} CPUE_y}{(yr2 - yr1 + 1)} \qquad (3)$$

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.

$$C^* = \frac{\sum_{y=yr1}^{yr2} L_y}{(yr2 - yr1 + 1)} \qquad (4)$$

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 $CPUE_{lim}$ 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

$$D_y = \frac{C_y \bar{D}_{98-06}}{\left(1 - \bar{D}_{98-06}\right)} \tag{5}$$

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.

17.3.2 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.

17.3.3 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

$$\hat{I}_{R,t} = \frac{\sum C_t}{\sum E_t} \tag{6}$$

where $\hat{I}_{R,t}$ is the ratio mean catch rate for year *t*, ΣC_t is the sum of landed catches in year *t*, and ΣE_t is the sum of effort (as hours trawled) in year *t*. If ΣD_t is the sum of discards in year *t* then the discard incremented ratio mean catch rate would be

$$\hat{I}_{D,t} = \frac{\sum C_t + \sum D_t}{\sum E_t} \tag{7}$$

The same values of $\hat{I}_{D,t}$ can also be obtained using the following multiplier

$$\hat{I}_{D,t} = \left[\left(\sum D_t / \sum C_t\right) + 1\right] \times I_t \tag{8}$$

where I_t is the catch rate estimate to be modified by the inclusion of discards. If this is the ratio mean from Equ (6) then the augmented catch rates would be identical to those produced by Equ (7). In practice, the catch rates used with the multiplier are the standardized catch rates from Haddon (2010a).

17.4 Results

17.4.1 Saw Sharks

Table 17.2. 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 17.10)). 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

17.4.1.1 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 17.1). This fall has been despite the catches being relatively stable by gill net during that time (Figure 17.2Figure 17.2).

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.

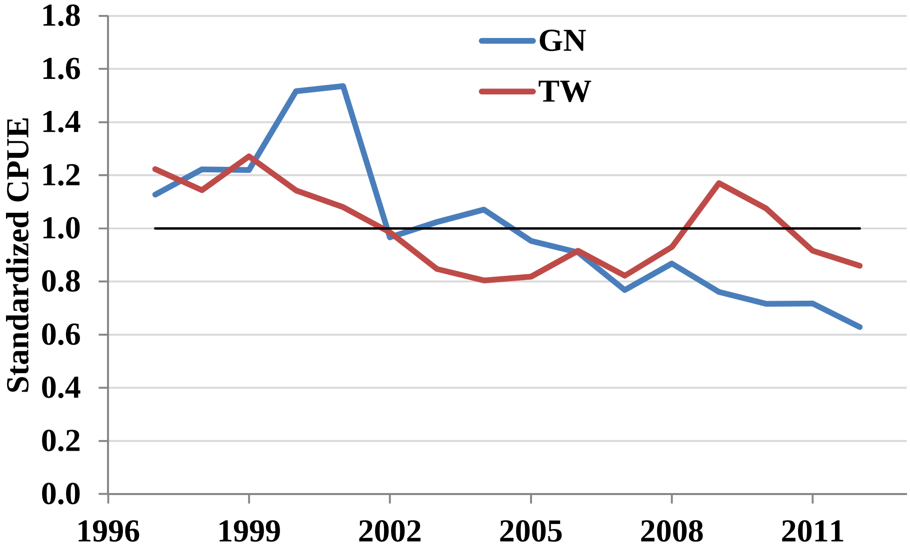

Figure 17.1. A comparison of the standardized CPUE derived from the SESSF logbooks for gillnets and for trawl. The fine black line is along 1.0, the average of each time series.

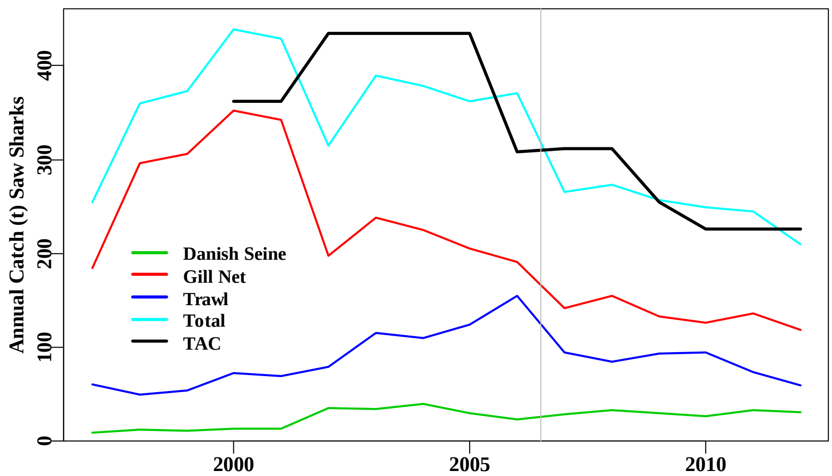

Figure 17.2. The annual catch of saw sharks, as reported in the logbooks by different methods, from 1997 – 2012. The fine black line is indicating the transition before and after the structural adjustment that finished in November 2006.

17.4.1.2 Proxy Target 48% Gillnet

Table 17.3. 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**

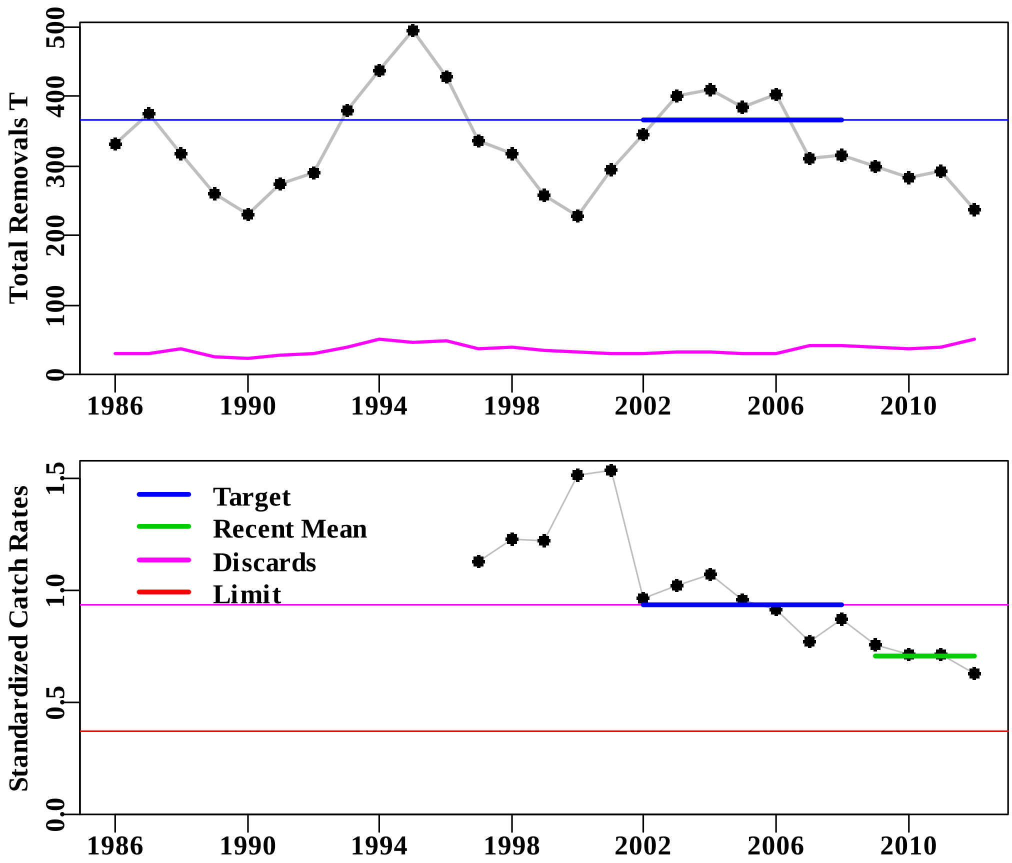

Figure 17.3. Saw Sharks. Top panel is the total removals with the fine line illustrating the target catch. Bottom panel represents the standardized catch rates with the upper fine line representing the target catch rate and the lower line the limit catch rate. Thickened lines represents the reference period for catches, catch rates, and the recent average catch rate.

17.4.1.3 Proxy Target 48% Trawl SESSF Zones 20, 60, 50

Table 17.4. 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**

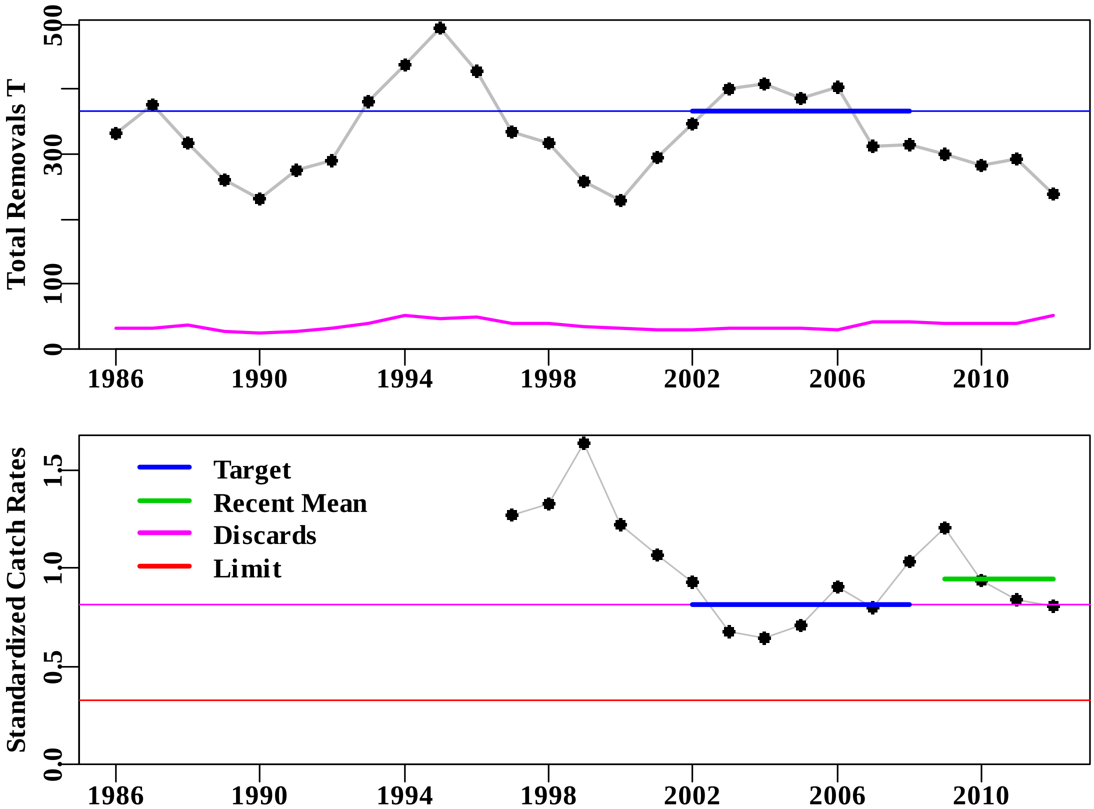

Figure 17.4. Saw Sharks taken by Trawl in Zones 20, 60, and 50. Top panel is the total removals with the fine line illustrating the target catch. Bottom panel represents the standardized catch rates with the upper fine line representing the target catch rate and the lower line the limit catch rate. Thickened 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.

17.4.1.4 Proxy Target 48% Trawl SESSF Zones 20, 60, 50, 83 & 82

Table 17.5. 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**

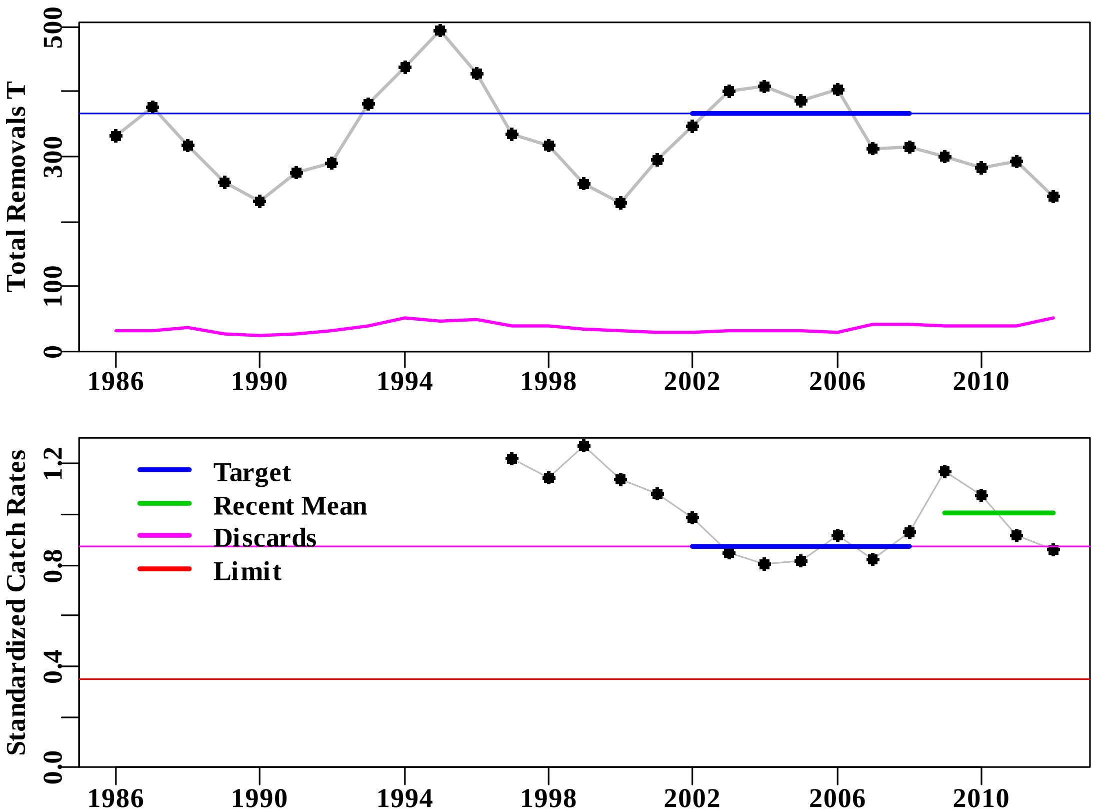

Figure 17.5. Saw Sharks taken by Trawl in Zones 20, 60, 50, 83 and 82. Top panel is the total removals with the fine line illustrating the target catch. Bottom panel represents the standardized catch rates with the upper fine line representing the target catch rate and the lower line the limit catch rate. Thickened lines represents the reference period for catches, catch rates, and the recent average catch rate.

17.4.2 Elephant Fish

Table 17.6. 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 able 17.11)). 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

17.4.2.1 Proxy Target 48% Gillnet

Table 17.7. 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**

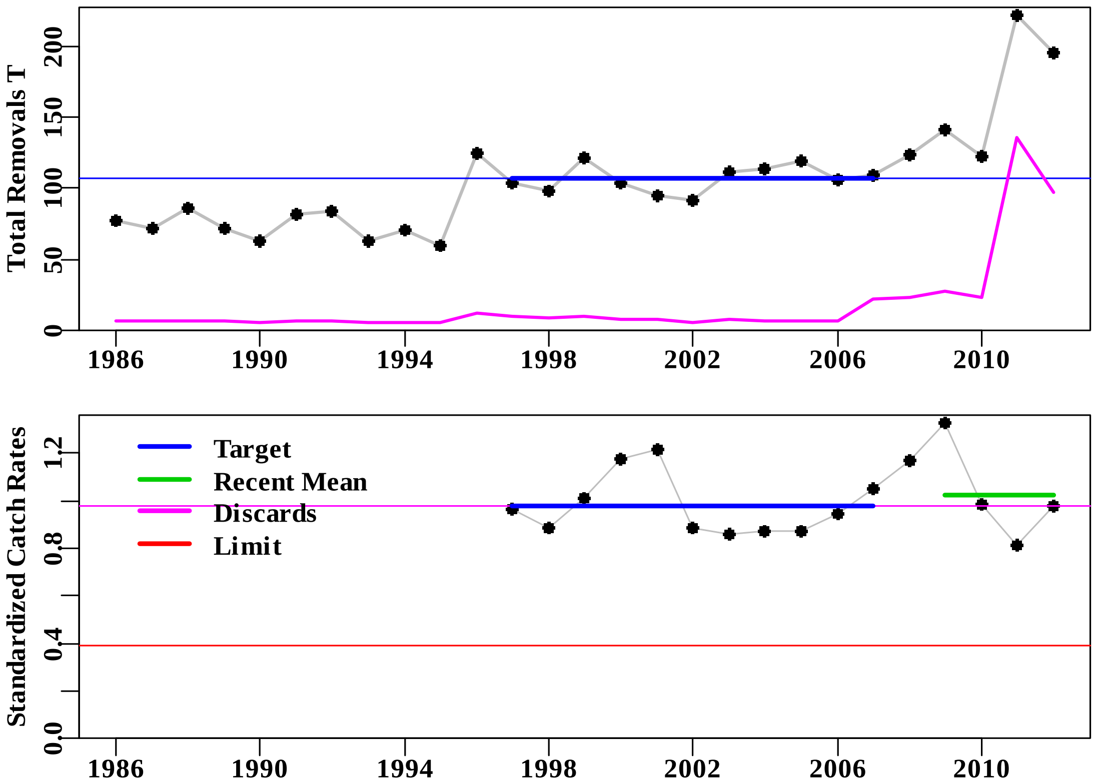

Figure 17.6. Elephant Fish. Top panel is the total removals with the fine line illustrating the target catch. Bottom panel represents the standardized catch rates with the upper fine line representing the target catch rate and the lower line the limit catch rate. Thickened lines represents the reference period for catches, catch rates (1996 – 2007), and the recent average catch rate (last four years).

17.4.2.2 Plus Discards in the CPUE: Target 48% Gillnet

Table 17.8. Elephant Fish. Data used in the Tier 4 analysis of Elephant Fish (full details of the available data are given in the Tables appendix (seeTable 17.11)). 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 17.9. 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**

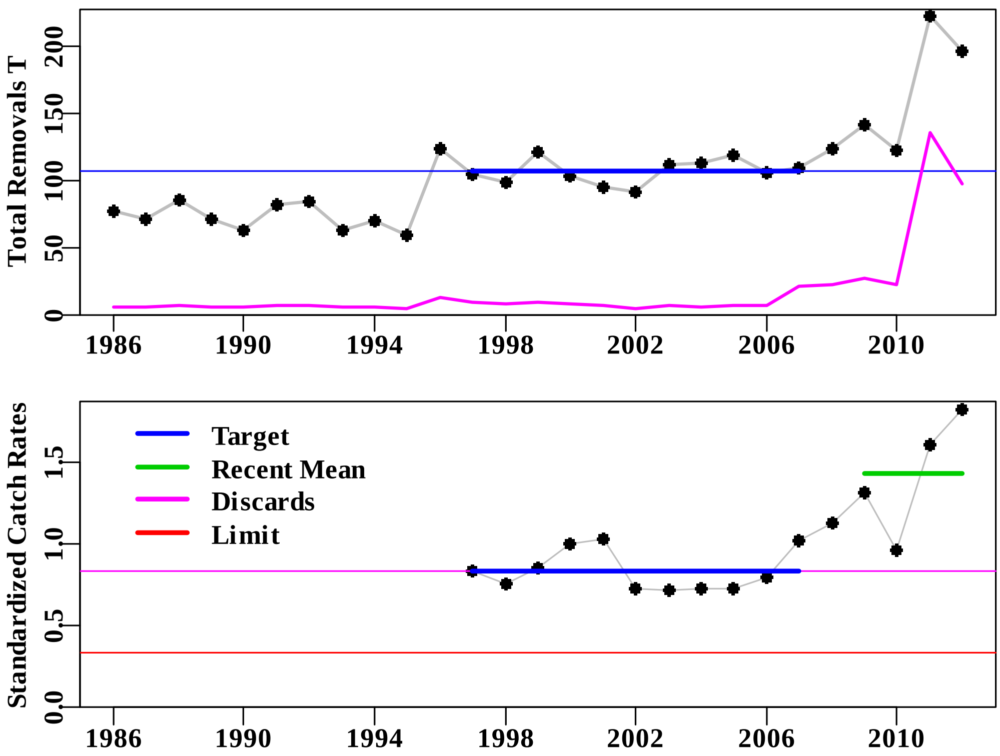

Figure 17.7. Elephant Fish. Top panel is the total removals with the fine line illustrating the target catch. Bottom panel represents the standardized catch rates with the upper fine line representing the target catch rate and the lower line the limit catch rate. Thickened lines represents the reference 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.

17.5 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. 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.

17.6 Acknowledgements

Thanks also go to Mike Fuller and Neil Klaer for all the pre-analytical data preparation required maintaining the SESSF data set.

17.7 Tables

Table 17.10. 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 17.11. 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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18. Benefits

The results of this project have had a direct bearing on the management of the Southern and Eastern Scalefish and Shark Fishery. Direct benefits to the commercial fishing industry in the SESSF have arisen from improvements to, or the development of, assessments under the various Tier Rules of the Commonwealth Harvest Strategy Policy for selected quota and non-quota species. Information from the stock assessments has fed directly into the TAC setting process for SESSF quota species. As specific and agreed harvest strategies are being developed for SESSF species (a process required by and agreed to under EPBC approval for the fishery), improvements in the assessments developed under this project have had direct and immediate impacts on quota levels or other fishery management measures (in the case of non-quota species).

Participation by the project's staff on the SESSF Resource Assessment Groups has enabled the production of critical assessment reports and clear communication of the reports' results to a wide audience (including managers, industry). Project staff's scientific advice on quantitative and qualitative matters is also clearly valued.

The stock assessments presented in this report have provided managers and industry greater confidence when making key commercial and sustainability decisions for species in the SESSF. These assessments have provided the most up-to-date information, in terms of data and methods, to facilitate the management of the Southern and Eastern Scalefish and Shark Fishery.

19. Conclusion

- Provide quantitative and qualitative species assessments in support of the five SESSFRAG assessment groups, including RBC calculations within the SESSF harvest strategy framework.

The 2014 assessment of the stock status of key Southern and Eastern Scalefish and Shark fishery species is based on the methods presented in this report. Documented are the latest quantitative assessments (Tier 1) for key quota species (orange roughy and eastern redfish), 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 2014 assessment for Eastern Zone orange roughy (*Hoplostethus atlanticus*) uses an integrated stock assessment model implemented using the platform Stock Synthesis. It assumes a stock structure hypothesis that the Eastern Zone and Pedra Branca from the Southern Zone (all seasons) constitutes a single homogeneous stock. New data inputs since the 2011 preliminary assessment model include recent research catches; total spawning biomass estimates for 2012 and 2013 from acoustic towed surveys at St Helens Hill and St Patricks Head, and revised indices of spawning biomass from towed and hull surveys since 1990. The base case model estimated female spawning biomass in 2015 to be 26% of the unfished level. The estimated RBC under the 20:35:48 harvest control rule is 381t, with a long-term RBC of approximately 1,534 t. This outcome is consistent with those from the 2006 Eastern Zone orange roughy stock assessment. The posterior median estimates from the MCMC simulation were close to the MPD estimates for most of the parameters of interest. The median estimate of female spawning depletion (SB_{2015}/ SB_0) was 0.25 with a 95% Bayesian CI of 0.23 to 0.28, and is close to the MPD estimate of 0.26.

For the first time, the 2014 assessment of eastern redfish *Centroberyx affinis* in the SESSF uses an age- and size-structured model implemented in the generalized stock assessment software package, Stock Synthesis. The assessment includes data up to the end of the 2013 calendar year. Data include annual landings, catch rates, discard rates, and length/age compositions. Alternative potential base-case models were considered that differed according to assumptions regarding discard and retention practices, as changes occurred in the fishery as it moved from market-based discarding to size-based discarding. For the base-case model, the estimated virgin female biomass is 14,558 t, and the 2015 estimated spawning biomass level is 11% of un-exploited levels. As the estimated stock status is below the limit reference point of 20% assuming the 20:35:48 control rule, the RBCs are consequently zero. Evidence in the aging data suggests that there have been two recent years of improved recruitment (in 2011 and 2012). While a small improvement in catch rates may also have occurred as a consequence of these fish moving into the available biomass, the existence and magnitude of these recruitments should be monitored over the ensuing years to verify what may be a positive sign for the stock.

Tier 3 calculations use the estimates of total mortality, natural mortality and average recent catches to determine the RBC for the following year. The calculated RBCs for John dory and Mirror dory are lower than those of 2013, being 164t for John dory and zero for Mirror dory (due to an estimate that the fishing mortality rate is above that which leads to a stock size of 20% of pristine).

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 2014 five non-shark Tier 4 analyses were applied, and only to John Dory and Mirror Dory in the SESSF. There were spatial data available for Mirror Dory, which led to analyses for the east and west presumed stock regions. Recent discard estimates for Mirror Dory have been relatively high, so a further Tier 4 analyses was conducted where discard estimates were included in the analysis of catch rates. Neither John Dory nor Mirror Dory are recognized as Tier 4 managed species. The estimated RBC for John Dory was zero, while the Mirror Dory RBC varied between 161 t (west) to 392 t (east) and 523 t (east with discards), and 595 t across all zones. Tier 4 analyses were also conducted for the shark stocks, elephant fish and saw shark. In both the saw shark and elephant fish the 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 so these calculated RBC are conservative. Alternative estimates based on a target of 40% were therefore also calculated. RBCs varied between 185 t and 600 t for saw shark and 99 t and 357 t for elephant fish.

20. Appendix: Intellectual Property

No intellectual property has arisen from the project that is likely to lead to significant commercial benefits, patents or licenses.

21. Appendix: Project Staff

Jemery Day	CSIRO Oceans and Atmosphere Flagship, Hobart, Tasmania
Mike Fuller	CSIRO Oceans and Atmosphere Flagship, Hobart, Tasmania
Malcolm Haddon	CSIRO Oceans and Atmosphere Flagship, Hobart, Tasmania
Neil Klaer	CSIRO Oceans and Atmosphere Flagship, Hobart, Tasmania
André Punt	CSIRO Oceans and Atmosphere Flagship, Hobart, Tasmania
Miriana Sporcic	CSIRO Oceans and Atmosphere Flagship, Hobart, Tasmania
Robin Thomson	CSIRO Oceans and Atmosphere Flagship, Hobart, Tasmania
Geoff Tuck	CSIRO Oceans and Atmosphere Flagship, Hobart, Tasmania
Judy Upston	CSIRO Oceans and Atmosphere Flagship, Hobart, Tasmania
Sally Wayte	CSIRO Oceans and Atmosphere Flagship, Hobart, Tasmania