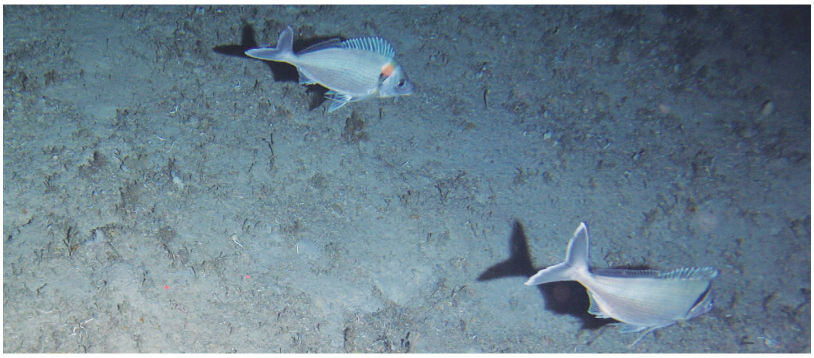
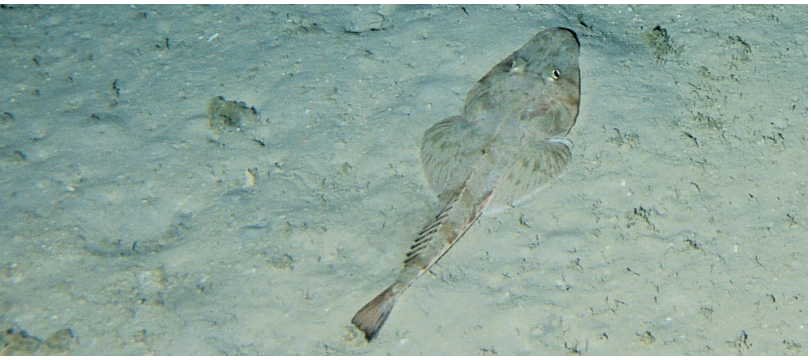
Australian Government
Australian Fisheries Management Authority

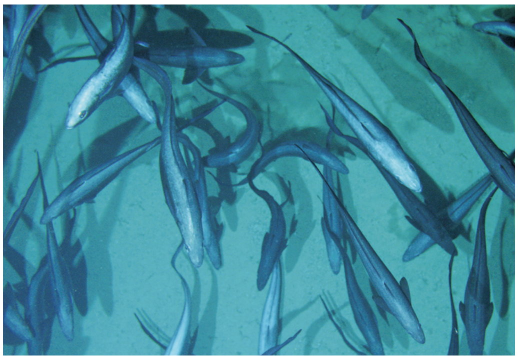
2014/0818 June 2016

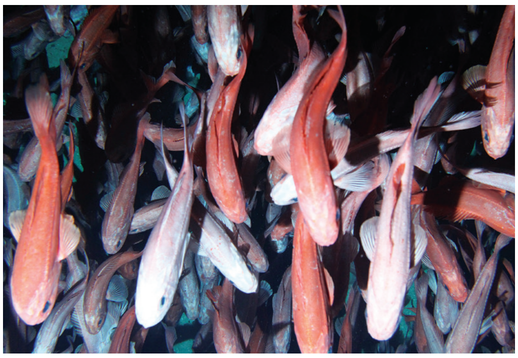
Stock Assessment for the Southern and Eastern Scalefish and Shark Fishery: 2015

PART 2









Principal investigator **G.N. Tuck**

CSIRO

www.afma.gov.au

Protecting our fishing future

Box 7051, Canberra Business Centre, ACT 2610 Tel **(02) 6225 5555** Fax (02) 6225 5500 **AFMA Direct 1300 723 621**

Tuck, Geoffrey N. (Geoffrey Neil).
Stock assessment for the southern and eastern scalefish and shark fishery: 2015.

ISBN 978-1-4863-0695-4

Preferred way to cite this report

Tuck, G.N. (ed.) 2016. Stock Assessment for the Southern and Eastern Scalefish and Shark Fishery 2015. Part 2. Australian Fisheries Management Authority and CSIRO Oceans and Atmosphere Flagship, Hobart. 493 p.

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). Toni Cracknell 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.

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 2015. 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 2015.

Stock Assessment for the Southern and Eastern Scalefish and Shark Fishery: 2015

Part 2: Tier 3 and Tier 4, catch rate standardisations and other work contributing to the assessment and management of SESSF stocks in 2015

G.N. Tuck

June 2016
Report 2014/0818

Australian Fisheries Management Authority

Stock Assessment for the Southern and Eastern Scalefish and Shark Fishery: 2015 Part 2

TABLE OF CONTENTS

12. SESSF Tier 1 CPUE forecasts for multi-year TAC review triggers

Robin Thomson, Neil Klaer, Miriana Sporcic, Geoff Tuck, Jemery Day, Rich Little

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

12.1 Summary

Annual standardized observed CPUE were compared with forecast abundance from the most recent Tier 1 stock assessment models for tiger flathead, redfish, school whiting, blue grenadier, eastern gemfish and pink ling. The observations lay within the 95% confidence region for the forecasts for redfish (only just), blue grenadier, eastern pink ling and western pink ling in 2014 (in 2013 the observation lay above the upper prediction bound). The most recent observation (i.e. 2014) for eastern gemfish lay below the forecast prediction interval (PI) for both the summer and winter fisheries. Flathead trawl CPUE was close to the lower confidence bound in 2013, but in 2014 was well within the PI. Similarly, although the Danish seine observed CPUE for 2014 lay below the PI, it was closer to inclusion in the PI than it had been in 2013. All recent CPUE points for the Danish seine fishery for school whiting lie within the PI. The observed CPUE dropped substantially between 2009 and 2011 compared to the model prediction. Since then (the most recent 4 years) the indices are flat and relatively closer to (but within) the lower bound.

Observed CPUE does not fall within the forecast PI for flathead (Danish Seine) and eastern gemfish, and is close to the lower bound for redfish. Observed CPUE lies within the forecast CI for school whiting, blue grenadier and, for the most part, pink ling.

12.2 Introduction

A number of Southern and Eastern Scalefish and Shark Fishery (SESSF) quota species on Tier 1 are managed on Multi-Year Total Allowable Catches (MYTACs) so that stock assessments are performed for those species at 3-5 year intervals. The most recently accepted base case stock assessment for each MYTAC stock is used to set future Recommended Biological Catches (RBCs) for the stock during the MYTAC period. Each year, to evaluate the continuing accuracy of the model predictions, actual catches are entered into the model and predicted catch rates are forecast. If recent observed catch rates fall outside of a 95% prediction interval around the forecast catch rates, this suggests that the model no longer accurately reflects observed reality and most likely needs to be updated. When recent standardized CPUE falls outside of the 95% prediction interval for forecast abundance, this triggers management attention for the stock. One of the considerations for management must be whether the recent observed (and standardized) CPUE accurately reflects stock abundance. This may be particularly questionable for stocks that are no longer targeted, such as eastern gemfish.

During 2015 CPUE forecasts were sought for the stocks shown in Table 12.1.

Bight redfish and gummy shark are also on MYTACs during 2015. Bight redfish will be considered by GABRAG once data become available for the full 2014-15 financial year. Similarly, gummy shark will be considered later in the year by sharkRAG once the CPUE standardization for that species have been completed.

Table 12.1 Stocks for which CPUE forecasts were performed, the name of the CSIRO scientist responsible for projecting the assessment, and final year of data available to the original stock assessment model, after this year the model is forecasting.

Stock	Assessment scientist	Final assessment year	Reference
Tiger flathead	Jemery Day	2012	Day & Klaer (2014)
Redfish	Geoff Tuck	2013	Tuck & Day (2014)
School whiting	Jemery Day	2008	Day (2009)
Blue Grenadier	Geoff Tuck	2012	Tuck (2014)
Eastern gemfish	Rich Little	2009	Little & Rowling (2011)
Pink Ling	Geoff Tuck	2012	Whitten & Punt (2014)

12.3 Methods

The process of calculating review triggers involves the following steps:

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

Each of these steps is described in more detail below

12.3.1 Updated CPUE

Reported catch and effort data are standardized to take account of factors affecting catch rates (such as fishing depth, season, vessel and zone). Standardized catch rates for the 9 fleets (6 stocks) considered in this report were obtained from Sporcic (2015).

12.3.2 Recent catch history

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

12.3.3 Stock assessment forecast

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

Edit starter.ss
1 # 0=use init values in control file; 1=use ss3.par
0 # Turn off estimation for parameters entering after this phase

Edit ss3.dat
Change end year on line 3 to the most recently available data e.g. 2014.

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

Add lines to the end of recent abundance indices so that they finish in 2014. Please use values of 1.0 and a CV of 999.0.

Edit ss3.par
Add another 0.0000000000 to the end of recruitment deviations for every extra year of data you have added.

Run ss3 -nohess
Look in report.sso under the heading INDEX_2 and there should be estimates of CPUE for all years to 2014 for recent abundance indices.

12.3.4 Matching two standardized CPUE series

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

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

The final year of the historical time series (y) for each stock is shown in Table 12.1.

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

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

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

For the forecast period, the PI is thus given by

$$PI_y = \exp[\,\ln(E_y)\ \pm 1.96\, s_y]$$

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

12.4 Results

The recent observed CPUE for trawl catches of tiger flathead in the east are close to, but lie above, the lower prediction bound in 2014 and are particularly close in 2013. Those for Danish seine lie well below the lower bound in both years (Figure 12.1).

The recent observed CPUE for school whiting falls within the model PI (Figure 12.2), indicating no need to trigger a review for this species. However, the observations have been relatively close to the lower prediction bound in the most recent 4 years.

The recent observed CPUE for redfish in 2014 lies just within the PI with a rescaled CPUE value of 0.2912 compared with a lower prediction bound of 0.2900 (Figure 12.3). Interestingly, the two earlier CPUE values (for 2012 and 2013) both lie below the lower prediction bound, despite being part of the historical period.

The recent observed CPUE value for blue grenadier in 2014 lies close to the expected values, and well within the 95% PI (Figure 12.4).

The recent observed CPUE for eastern gemfish lies below the lower prediction bound for both the winter and summer periods (Figure 12.5).

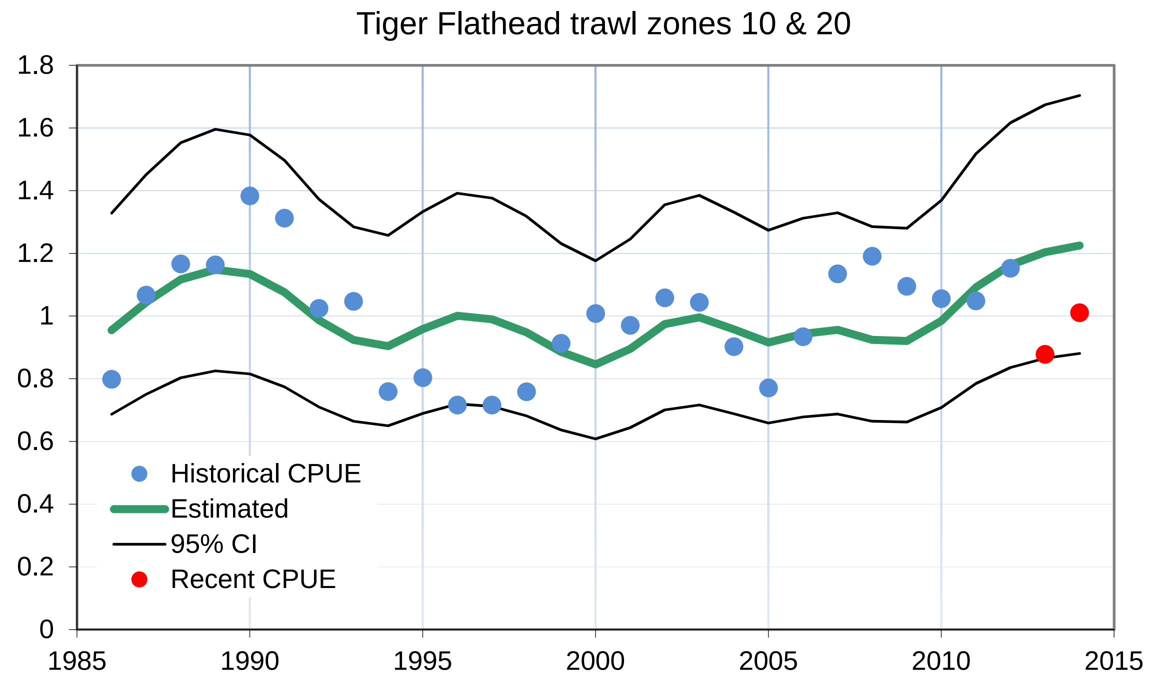
The recent observed CPUE values for pink ling in the east are comfortably within the bounds of the PI, whereas that for the west lies above the PI in 2013 and falls just within it in 2014 (Figure 12.6).

A summary of the results for all fleets and stocks is shown in Table 12.2.

Table 12.2. Summary of comparison between observed and forecast CPUE for all fleets and stocks considered. *Green* shading indicates an observation well within the PI; *orange* indicates within, but close to the lower bound; *red* indicates below the lower bound; and *blue* indicates above the upper bound.

Stock	2009	2010	2011	2012	2013	2014
Flathead TW					orange	green
Flathead DS					red	red
Redfish						orange
School whiting	green	green	green	green	green	green
Blue Grenadier					green	green
E gemfish summer	green	green	green	orange	orange	red
E gemfish winter	green	green	green	green	green	red
Pink Ling East					green	green
Pink Ling West					blue	green

12.4.1 Flathead



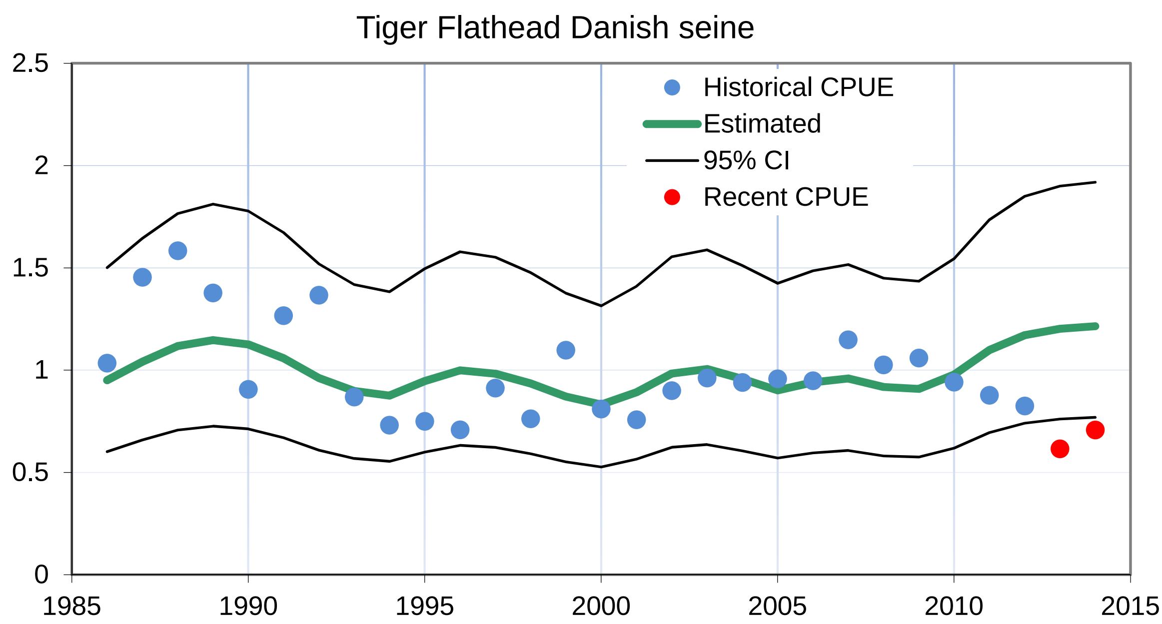


Figure 12.1. Tiger flathead CPUE in zones 10 and 20 caught by trawl (upper plot), and Danish seine in all zones (lower plot). The historical CPUE to which the stock assessment model was tuned is shown as *grey dots* and the recent observed CPUE (scaled to match the older series) as *red dots*. Model estimated catch rates, projected to 2014, are shown as a *green line*, with a 95% prediction interval (*black line*).

12.4.2 Redfish

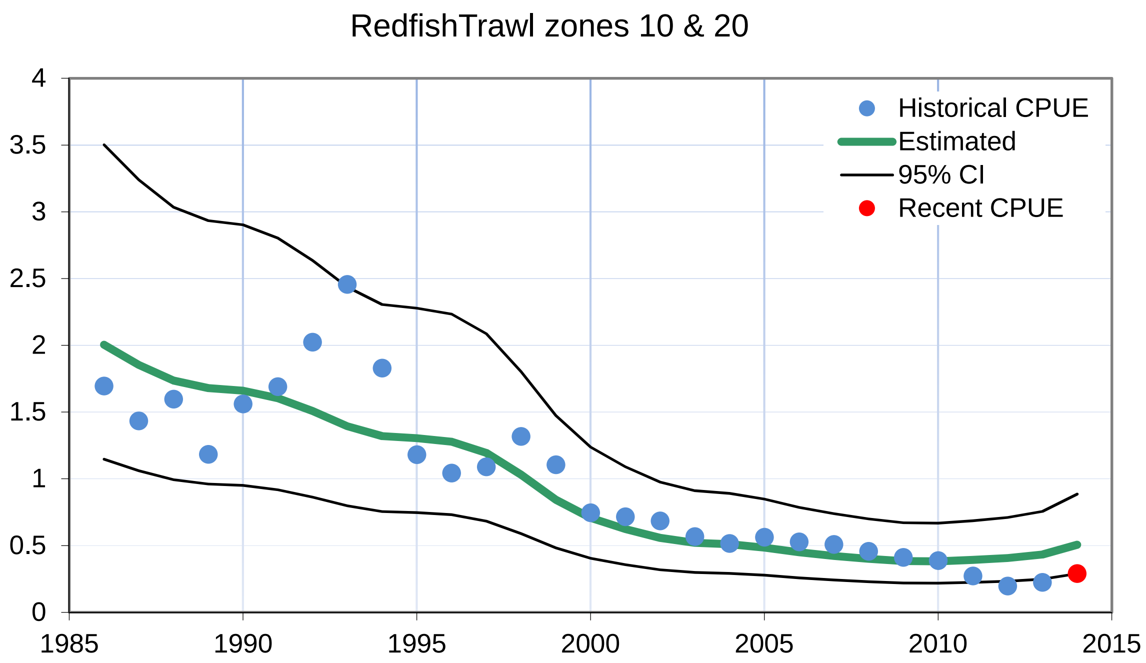


Figure 12.2. Redfish CPUE in zones 10 and 20 caught by trawl. The historical CPUE to which the stock assessment model was tuned is shown as *grey dots* and the recent observed CPUE (scaled to match the older series) as *red dots*. Model estimated catch rates, projected to 2014, are shown as a *green line*, with a corresponding 95% prediction interval (*black line*).

12.4.3 School whiting

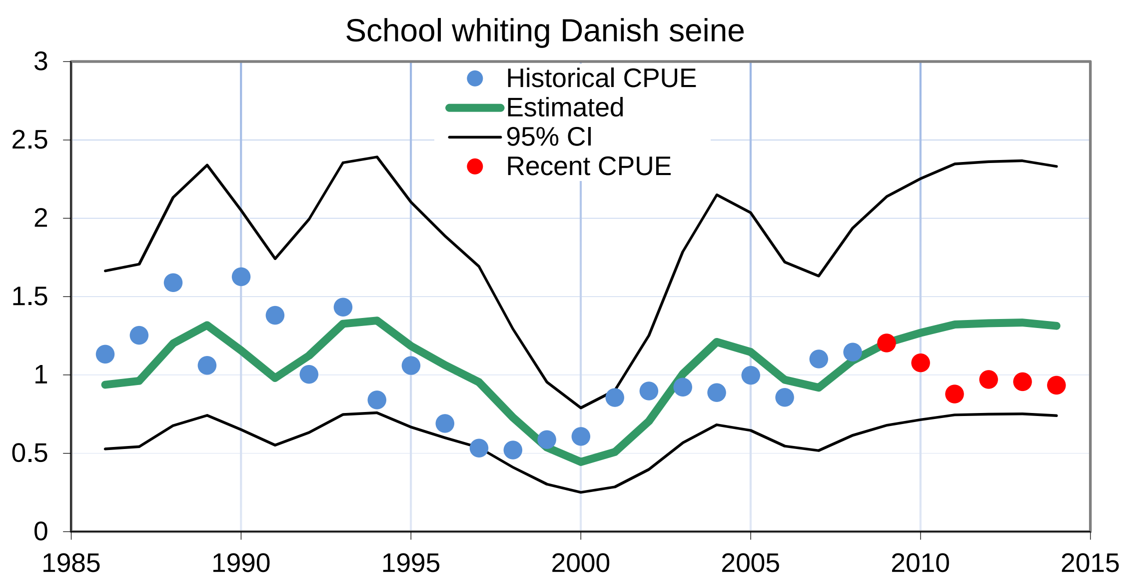


Figure 12.3. School whiting CPUE for Danish seine. The historical CPUE to which the stock assessment model was tuned is shown as *grey dots* and the recent observed CPUE (scaled to match the older series) as *red dots*. Model estimated catch rates, projected to 2014, are shown as a *green line*, with a corresponding 95% prediction interval (*black line*).

12.4.4 Blue grenadier

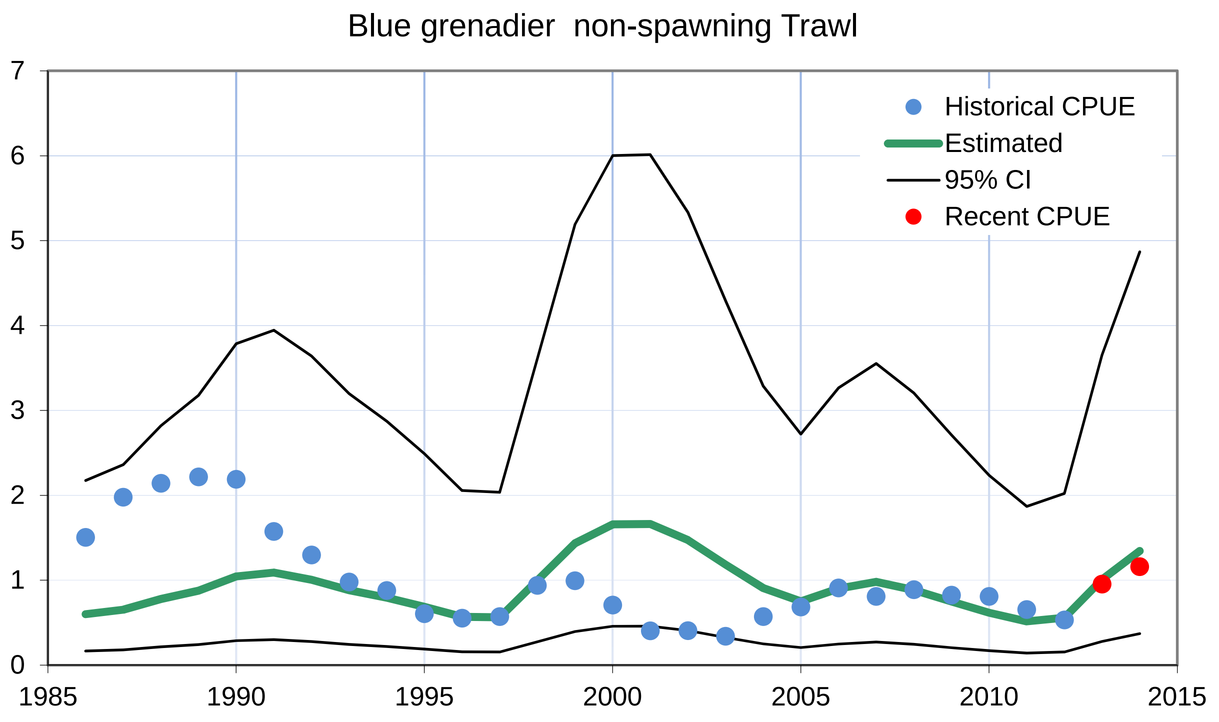
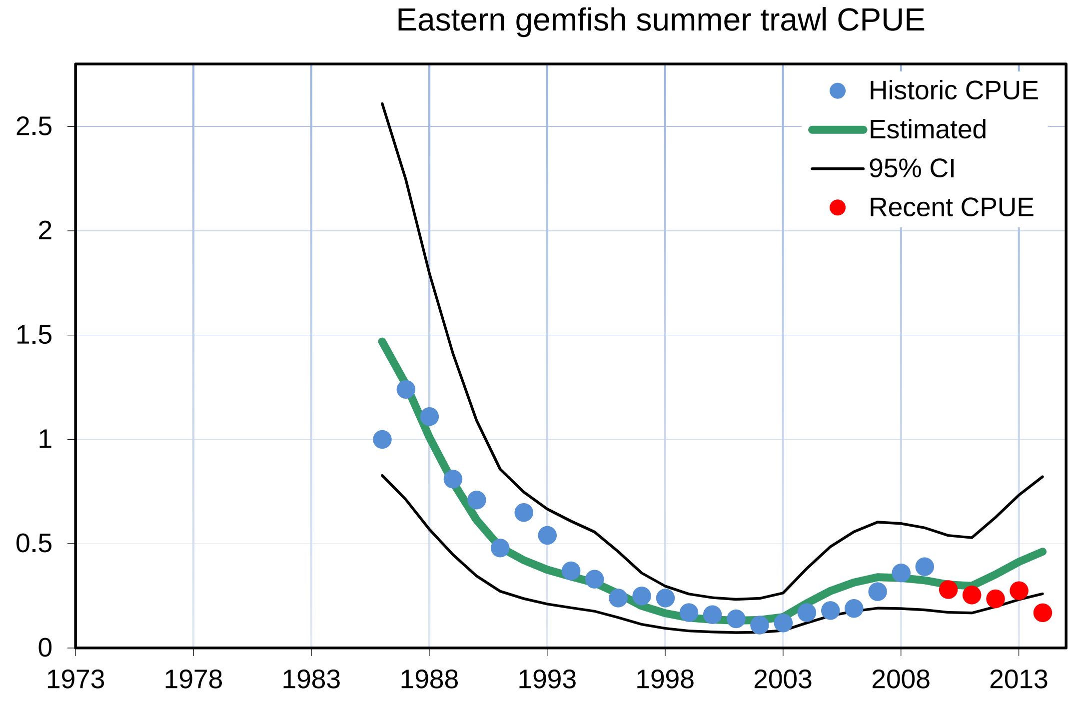


Figure 12.4. Blue grenadier CPUE caught by trawl in the non-spawning fishery (all times and zones except zone 40 during June-Aug). The historical CPUE to which the stock assessment model was tuned is shown as *grey dots* and the recent observed CPUE (scaled to match the older series) as *red dots*. Model estimated catch rates, projected to 2014, are shown as a *green line*, with a corresponding 95% prediction interval (*black line*).

12.4.5 Eastern gemfish



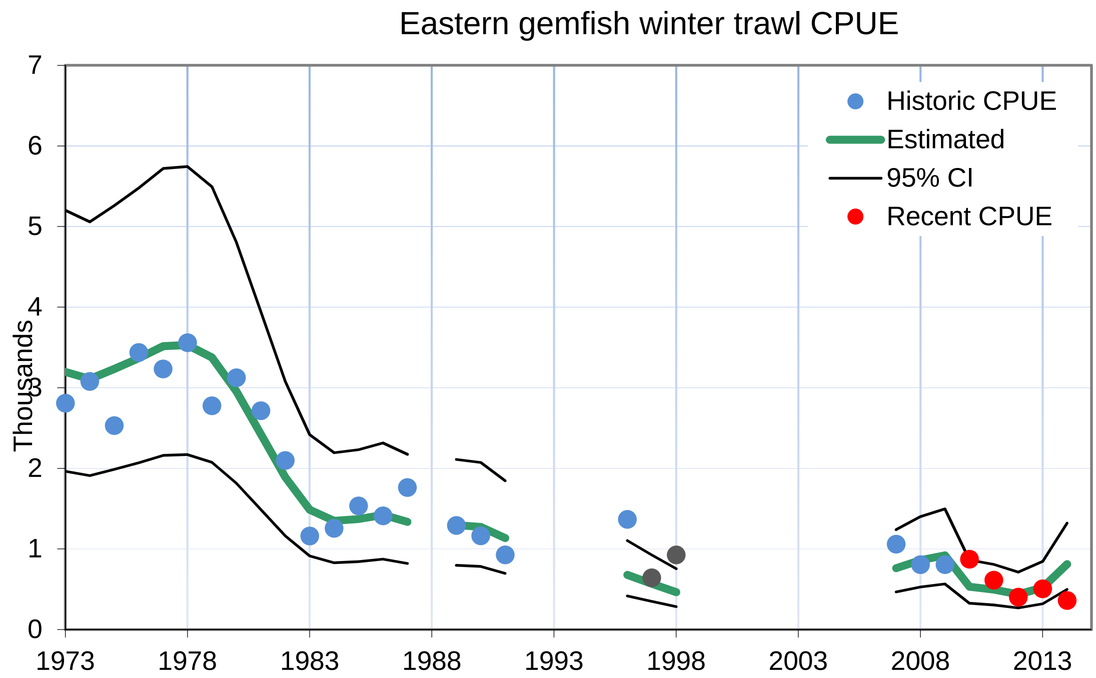


Figure 12.5. Eastern gemfish CPUE in the winter spawning period (June-Aug) (upper plot), and the summer non-spawning period (Sept-May) (lower plot). The historical CPUE to which the stock assessment model was tuned is shown as *grey dots* and the recent observed CPUE (scaled to match the older series) as *red dots*. Model estimated catch rates, projected to 2014, are shown as a *green line*, with a 95% prediction interval (*black line*).

12.4.6 Pink ling

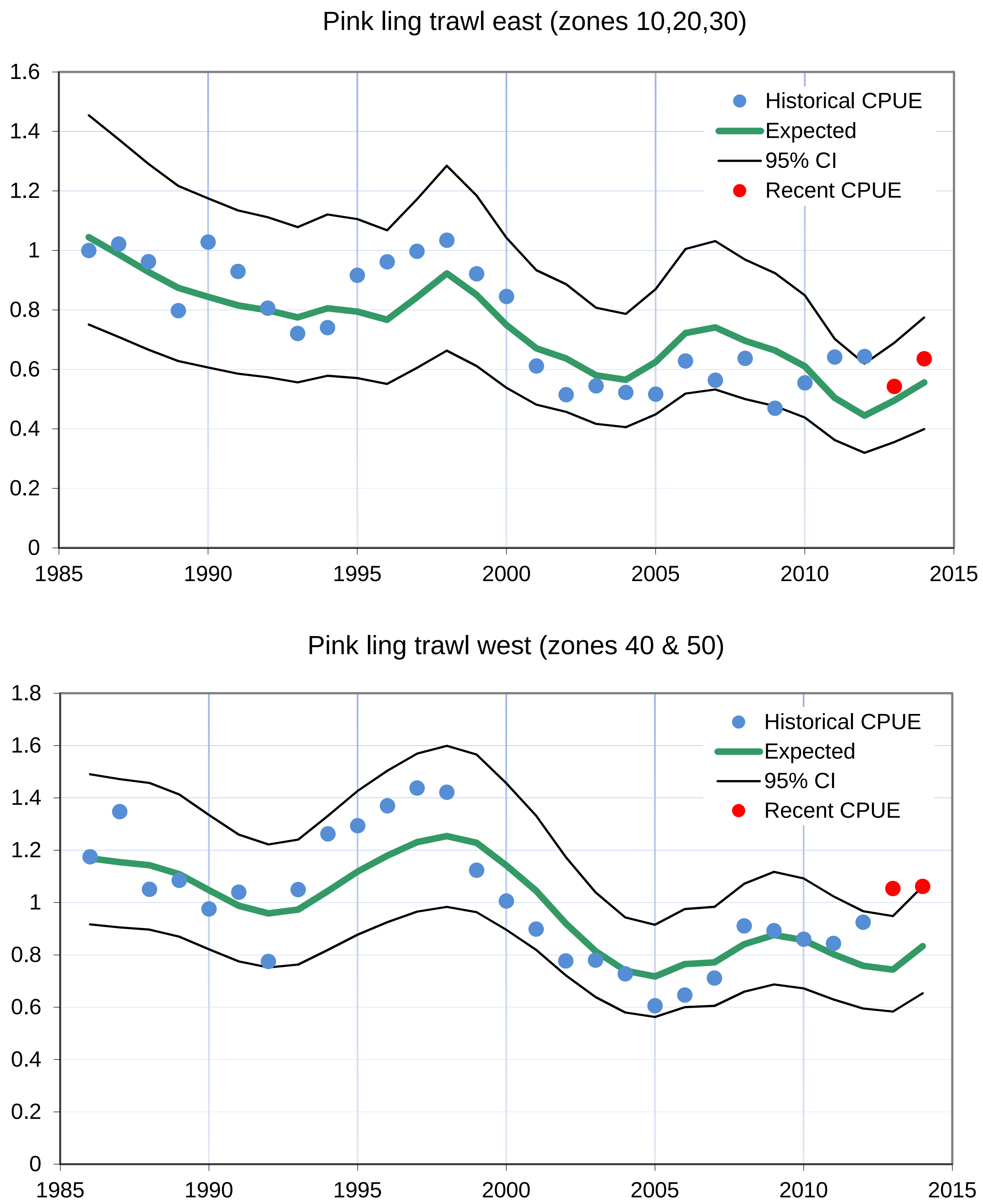


Figure 12.6. Pink ling CPUE for trawl catches in the east (zones 10, 20, 30) (upper plot), and west (zones 40, 50) (lower plot). The historical CPUE to which the stock assessment model was tuned is shown as *grey dots* and the recent observed CPUE (scaled to match the older series) as *red dots*. Model estimated catch rates, projected to 2014, are shown as a *green line*, with a 95% prediction interval (*black line*).

12.5 References

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

Day J & Klaer N (2014) Tiger flathead (*Neoplatycephalus richardsoni*) stock assessment based on data up to 2012. In Tuck, G.N. (ed.) 2014. *Stock Assessment for the Southern and Eastern Scalefish and Shark Fishery 2013*. Part 1. Australian Fisheries Management Authority and CSIRO Marine and Atmospheric Research, Hobart. p 174-232.

Little R & Rowling K (2011) update of the eastern gemfish (*Rexea solandri*) stock assessment 97. In Tuck, G.N. (ed.) 2011. *Stock Assessment for the Southern and Eastern Scalefish and Shark Fishery 2010*. Part 1. Australian Fisheries Management Authority and CSIRO Marine and Atmospheric Research, Hobart. p 97-135.

Sporcic, M. (2015) Catch rate standardizations for selected SESSF species (data to 2014). Draft prepared for the SESSFRAG Data meeting, 4-5 August 2015, Hobart. 268p.

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

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

Whitten AR & Punt AE (2014) Pink Ling (*Genypterus blacodes*) stock assessment based on data up to 2012. In Tuck, G.N. (ed.) 2013. *Stock Assessment for the Southern and Eastern Scalefish and Shark Fishery 2013*. Part 1. Australian Fisheries Management Authority and CSIRO Marine and Atmospheric Research, Hobart. p 116-142.

13. Multi-Year Breakout Analyses for Deepwater Flathead and Western Gemfish in the GAB (2014/15)

Malcolm Haddon

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

13.1 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.

13.2 Introduction

Multi-Year TACs were introduced in 2012 after discussions through 2011 (Tuck *et al*., 2012). In the absence of formal stock assessments within the period of a multi-year TAC, breakout tests are conducted to determine whether the species not assessed had begun to deviate from their expected trajectories through the period of their multi-year TACs. In the Great Australian Bight trawl fishery the quota species not assessed this year are deepwater flathead (*Neoplatycephalus conatus*) and western gemfish (*Rexea solandri*).

Standard methods were used for each species.

Predicted catch-rates for deepwater flathead remain relatively flat for the years 2013/2014 and 2014/2015 while the standardized CPUE declined. However, the 95% confidence intervals around the predicted CPUE easily encompass the standardized CPUE values so no breakout was observed. It should be noted, however, that the predicted CPUE has now been above the observed CPUE for the past four years, with the difference between the two increasing.

Western gemfish in SESSF zones 40 and 50 has exhibited an increase in standardized CPUE in 2014 and discarding continues are at relatively high levels (although less than last year). Combined these observations indicate that the stock status is no worse than previously and may have improved slightly. Once again, it can be concluded that western gemfish has not broken out from its expected trajectory during the period of its multi-year TAC.

13.3 Methods

13.3.1 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. These are identical to those used last year (Haddon, 2015). Both are repeated here for reference.

13.3.1.1 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).

13.3.1.2 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).

13.3.1.3 Western gemfish

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

Western Gemfish will have broken out:

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

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

13.4 Results and Discussion

13.4.1 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 2014/2015 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 13.1 and Table 13.1), although for the last four years the predicted CPUE has been above the standardized CPUE. The standardization has little effect upon the CPUE trend over the last ten years (Sporcic, 2015).

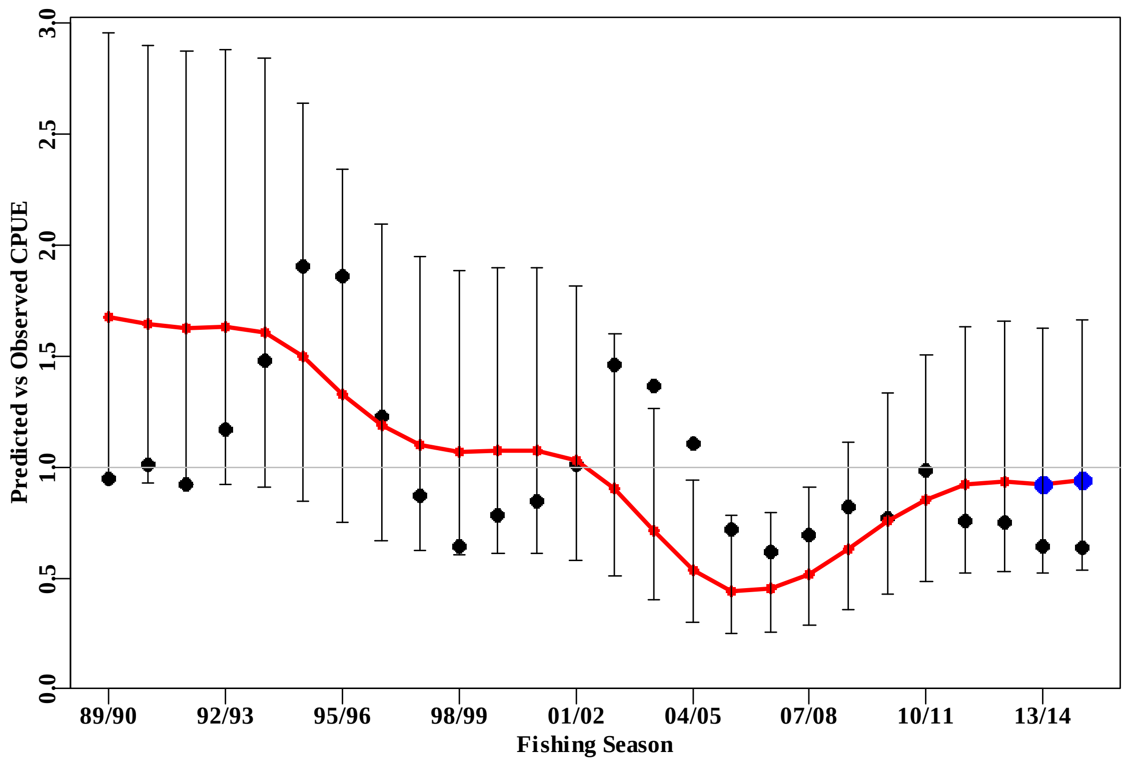


Figure 13.1. The predicted trajectory of deepwater flathead CPUE (red line) obtained from projecting the previous Tier 1 assessment forward through 2013/2014 and 2014/2015 for comparison with the recently observed CPUE data. The black dots represent the mean standardized CPUE while the red line and dots, with their associated 95% confidence intervals represent the expected CPUE from the Tier 1 model. The blue dots are the CPUE projected since the last stock assessment.

13.4.1.1 Catches and catch rates

Discard estimates since 2007/2008 are now included (Table 13.1; Upston and Thomson, 2015), although in some years with very low discard levels the estimates are highly uncertain. In all years they remain a minor component of the catch.

Table 13.1. 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, although a value of 0.29 was used in Figure 13.1.

Year	Standardized	Predicted	Catch	Discards
1989/1990	0.9455	1.6742	402.557	
1990/1991	1.0137	1.6419	430.231	
1991/1992	0.9233	1.6287	621.115	
1992/1993	1.1681	1.6315	524.062	
1993/1994	1.4811	1.6098	593.110	
1994/1995	1.9065	1.4964	1285.933	
1995/1996	1.8572	1.3274	1585.124	
1996/1997	1.2247	1.1857	1499.226	
1997/1998	0.8695	1.1024	1029.988	
1998/1999	0.6440	1.0697	690.389	
1999/2000	0.7824	1.0759	571.050	
2000/2001	0.8478	1.0760	846.620	
2001/2002	1.0106	1.0276	973.9438	
2002/2003	1.4582	0.9063	1711.501	
2003/2004	1.3673	0.7149	2272.717	
2004/2005	1.1054	0.5325	2158.921	
2005/2006	0.7197	0.4427	1433.132	
2006/2007	0.6210	0.4503	1015.479	
2007/2008	0.6918	0.5145	1041.333	9.060
2008/2009	0.8187	0.6298	813.921	0.008
2009/2010	0.7700	0.7563	849.83	0.008
2010/2011	0.9855	0.8537	970.002	2.366
2011/2012	0.7602	0.9244	965.051	2.718
2012/2013	0.7491	0.9371	1017.886	33.133
2013/2014	0.6449	0.9206	882.672	33.531
2014/2015	0.6339	0.9422	456.006	0.482

13.4.2 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.

Table 13.2. A listing of recorded catches and estimated discards for western gemfish (Upston and Thomson, 2015).

Calendar Year	Commonwealth SEF2	SAN2 Non-Trawl	GAB Logbooks	Total inc GAB	Total Catch	Discard
1994	138.266		14.820	153.086	138.266	
1995	124.409		22.531	146.940	124.409	
1996	208.329		20.049	228.378	208.329	
1997	226.983		61.855	288.838	226.983	
1998	185.371		85.476	270.847	185.371	12.000
1999	271.813		146.993	418.806	271.813	5.000
2000	349.236		32.168	381.404	349.236	30.000
2001	253.030	0.363	91.088	344.481	253.393	9.000
2002	138.474	0.441	43.278	182.193	138.915	9.140
2003	173.606	3.918	79.588	257.112	177.524	12.580
2004	146.285	3.655	334.524	484.464	149.940	8.920
2005	156.585	5.732	255.018	417.335	162.317	1.640
2006	135.983	23.656	302.858	462.497	159.639	0.550
2007	90.377	8.854	324.587	423.818	99.231	5.122
2008	75.713	10.682	99.361	185.756	86.395	9.008
2009	77.972	9.516	48.961	136.449	87.488	51.008
2010	106.759	14.468	42.731	163.958	121.227	31.771
2011	64.778	14.926	21.229	100.933	79.704	120.438
2012	55.769	4.265	55.878	115.912	60.034	47.590
2013	39.603	4.165	9.945	53.713	43.768	99.628
2014	66.244	7.186	20.653	94.083	73.430	23.383

The breakout rule for western gemfish relates to CPUE but the estimate of CPUE for this latest year remains uncertain as a result of the relatively high level of discarding occurring. Over the last six years the average proportion of total catches discarded has been about 42.6%. Such high discard levels (Table 13.2) mean that any estimated CPUE is likely to be biased low (unless most discards derive from very low catch rate shots).

The discard rates also apply primarily to the SESSF trawl area in zones 40 and 50 (west Tasmania and western Bass Strait). 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, 2015) indicates a recent improvement over the average from 2003 – 2014 (Figure 13.2).

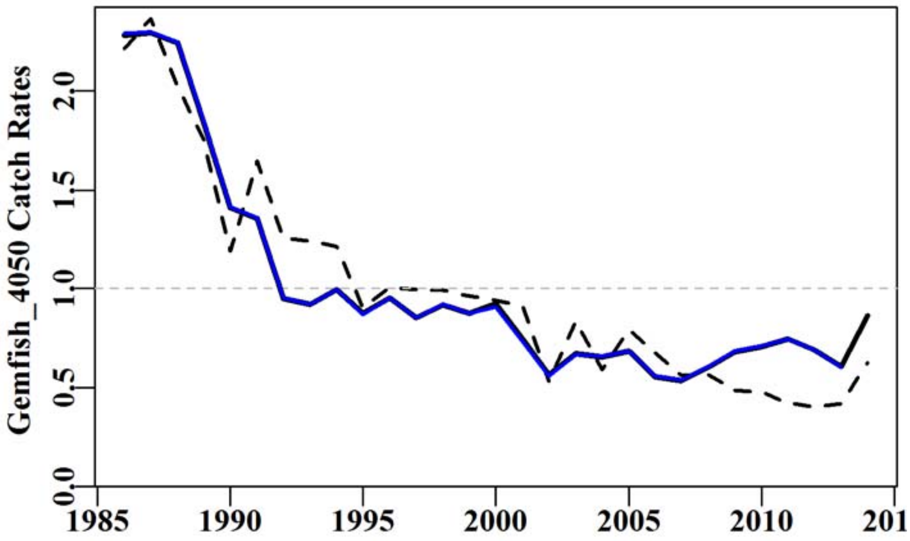


Figure 13.2. Western Gemfish from zones 40 and 50 in depths between 100 – 600 m by Trawl. The dashed black line represents the geometric mean catch rate, solid black line the standardized catch rates and the solid blue line represents the standardized catch rates from last year's analysis. The graph standardizes catch rates relative to the mean of the standardized catch rates (copied from Figure 110 on page 150 in Sporcic [2015]).

In terms of a weight-of-evidence, the standardized CPUE shows a recent increase but could equally be argued to be relatively flat and noisy about the longer term average. At the same time, discards remain relatively high, which suggests that CPUE should be higher than observed (unless only complete shots were completely discards). Hence, there are no negative signs concerning the stock status.

13.5 References

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.

Haddon, M. (2015) Multi-Year Breakout Analyses for Deepwater Flathead and Western Gemfish in the GAB (2014/15). pp 10 – 18 *in* Tuck, G.N. (ed.) *Stock Assessment for the Southern and Eastern Scalefish and Shark Fishery 2014. Part 2.* Australian Fisheries Management Authority and CSIRO Oceans and Atmosphere Flagship, Hobart. 432 p.

Sporcic, M (2015) Catch rate standardizations for selected SESSF species (data to 2014). CSIRO Oceans and Atmosphere Flagship, Hobart. 278p.

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

Upston, J. and R. Thomson (2015) Integrated Scientific Monitoring Program for the Southern and Eastern Scalefish and Shark Fishery – Discard estimation 2014 DRAFT. CSIRO Oceans and Atmosphere, Australian Fisheries Management Authority. 34 p.

13.6 Appendix: SS3 Methods

Extracted from Klaer et al., (2014).

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

0 # Turn off estimation for parameters entering after this phase
```

Edit ss3.dat

Change end year on line 3 to the most recently available data - this year it is 2011.

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

Add lines to the end of recent abundance indices so that they finish in 2011. Please use values of 1.0 and a CV of 999.0 - here are examples used for index 9 for tiger flathead:

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

Edit ss3.par

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

Run ss3 -nohess

Look in report.sso under the heading INDEX_2 and there should be estimates of CPUE for all years to 2011 for recent abundance indices.

14. Gummy shark breakout rules 2015

Robin Thomson

CSIRO, Castray Esplanade, Hobart 7000, Australia

14.1 Summary

The fishery for gummy shark is currently managed using a multi-year TAC (MYTAC), which requires an annual evaluation of a set of breakout rules to ensure that the stock remains in the state forecast when the MYTAC was set. These rules evaluate whether (1) the CPUE for the major component of the fishery (in Bass Strait) has fallen to a low level; (2) catches have fallen to a low level; (3) the new line sector is taking many more large and small sharks than forecast. The length-based breakout rule for gummy shark is designed to ensure that the size selectivity by the growing hook sector does not violate the assumptions on which the current multi-year TAC (MYTAC) is based. *None of the three breakout rules have been triggered during 2015.* Nevertheless, the length-based breakout rule was close to being triggered and it is concerning that the hook fishery does take a much greater proportion of larger sharks than were recorded during the hook trial fishery (Knuckey et al 2013), which is the size range on which the MYTAC is based.

14.2 Introduction

When the fishery for gummy shark was placed on a multi-year TAC (MYTAC), breakout rules, designed to allow rapid evaluation of the status of the fishery, were put into place. These are:

1. "standardized CPUE value for Bass Strait approaches historical low (falls below the 10th percentile of the historical values for Bass Strait)
2. Catches fall below 1200 tonnes
3. Length frenquencies from the line catch change substantially from the model parameters;
   a) More than 15% of gummy shark caught by the line sector are shorter than 76cm in total length; or
   b) More than 20% of the line caught gummy shark are greater than 130cm total length."

The purpose of this report is to evaluate whether any of these rules has been triggered.

14.2.1 Rule 1: CPUE

The first breakout rule evaluates whether the standardized catch rate for gummy shark in Bass Strait has fallen to a low level, specifically, below the tenth percentile of historical values. Because the rule does not specify a year range for "the historical values", the full period excluding the most recent year has been chosen (1997-2013).

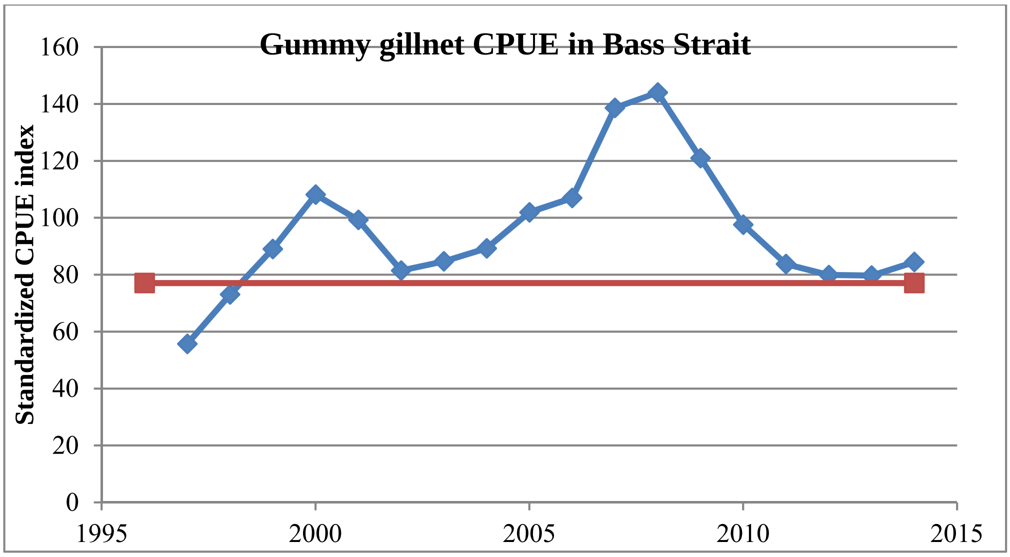


Figure 14.1. Standardized CPUE for gummy shark caught by gillnets in Bass Strait, time series (*blue line*) taken from Table 9 of Sporcic (2015). The tenth percentile of the 1997-2013 values (*red line*) is shown.

14.2.2 Rule 2: Catch

The second breakout rule considers whether catches have fallen to a low level, specifically, below 1200 t. The total gillnet catch for 2014 was 1 381 t (from Sporcic 2015, Table 9). The rule does not specify whether the catch to consider is just the gillnet catch, or all commercial catches, or all catches including state catches and discards, however the gillnet catch alone is sufficient to ensure that the rule is not triggered.

14.2.3 Rule 3: Length frequencies

The third breakout rule evaluates the size of gummy shark captured by the hook sector. The MYTAC currently in place for gummy shark was based on RBC calculations performed using the 2013 stock assessment for gummy shark (Thomson & Sporcic 2013) that assumed that the (soon to commence) shark hook fishery would capture sharks with carcass sizes equivalent to those recorded during a shark hook trial (Knuckey at al 2013). Breakout rule 3 was designed to be triggered if the commercial hook sector captured small, or large, sharks significantly more often than indicated by the hook trial.

14.3 Methods and Results

All length measurements referred to in this report are total lengths, in centimeters (cm). Length measurements for gummy shark collected onboard hook and line vessels were used to calculate the proportion of the catch (by number of sharks) that was less than 76cm total length, or greater than 130cm. Vessels were divided into those fishing in waters shallower than 183m (designated *shark line*) and deeper than 183m (designated *scale line*). This is the legislated depth limit for shark and scalefish hook endorsements. The depth distributions of the observed fishing shots (Figure 14.2) indicate that the two sectors operate in distinct depths with shark vessels concentrated in 0-100m and scalefish vessels in 300-600m with very little few shots observed in depths of 150-300m.

Overall proportions for all hook and line vessels combined (Table 14.1) were calculated by catch weighting and summing the proportions from shark and scale lines. For this purpose, gummy shark catches for waters shallower and deeper than were calculated from logbook data for all years (93% reported by shark hook vessels) and for 2012-2014 (94% reported by shark hook vessels) – the period during which the shark hook sector has operated.

Table 14.1. Proportion (by number of carcasses) of gummy shark of less than 76cm, or more than 130cm, taken in waters shallower (*Shark line*) or deeper (*Scalefish line*) than 183m. Combined figures (*All line)* were calculated by catch weighting.

Length	Trigger	Shark Line (<= 183 m)	Scale Line (> 183 m)	*All line*
<76 cm	>15%	7%	13%	*1% (1%)*
>130 cm	>20%	19%	<1%	*18% (18%)*

The length-based breakout rules for gummy shark were not triggered by the hook and line sector. Nevertheless, the length frequency of gummy shark caught by the hook sector is somewhat different from that recorded during the hook trial (Figure 14.3, Knuckey et al 2013) in that greater numbers of larger sharks, mainly in the 110 to 140 cm range, are captured by the commercial hook fishery. At 18%, the numbers of captured sharks larger than 130 cm come close to breaking the 20% trigger limit. Trawl and gillnet length frequencies are shown for contrast (Figure 14.3).

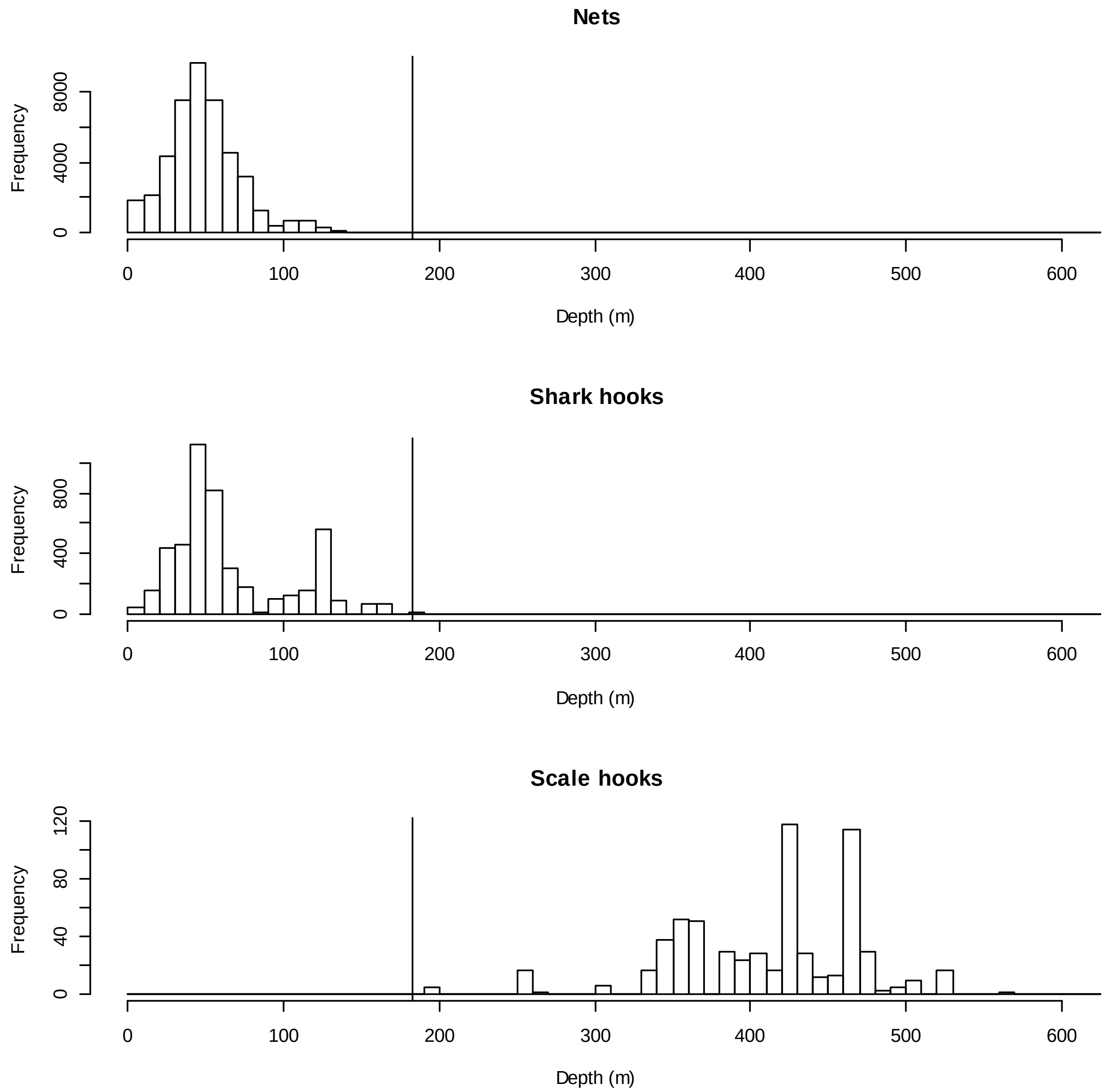


Figure 14.2. Histograms showing the frequency (counts) of observed shots at depths of 10 m intervals by gillnets (*Nets, upper plot*), hooks operating at or shallower than 183 m (*Shark hooks, middle plot*), and deeper hooks (*Scale hooks, lower plot*).

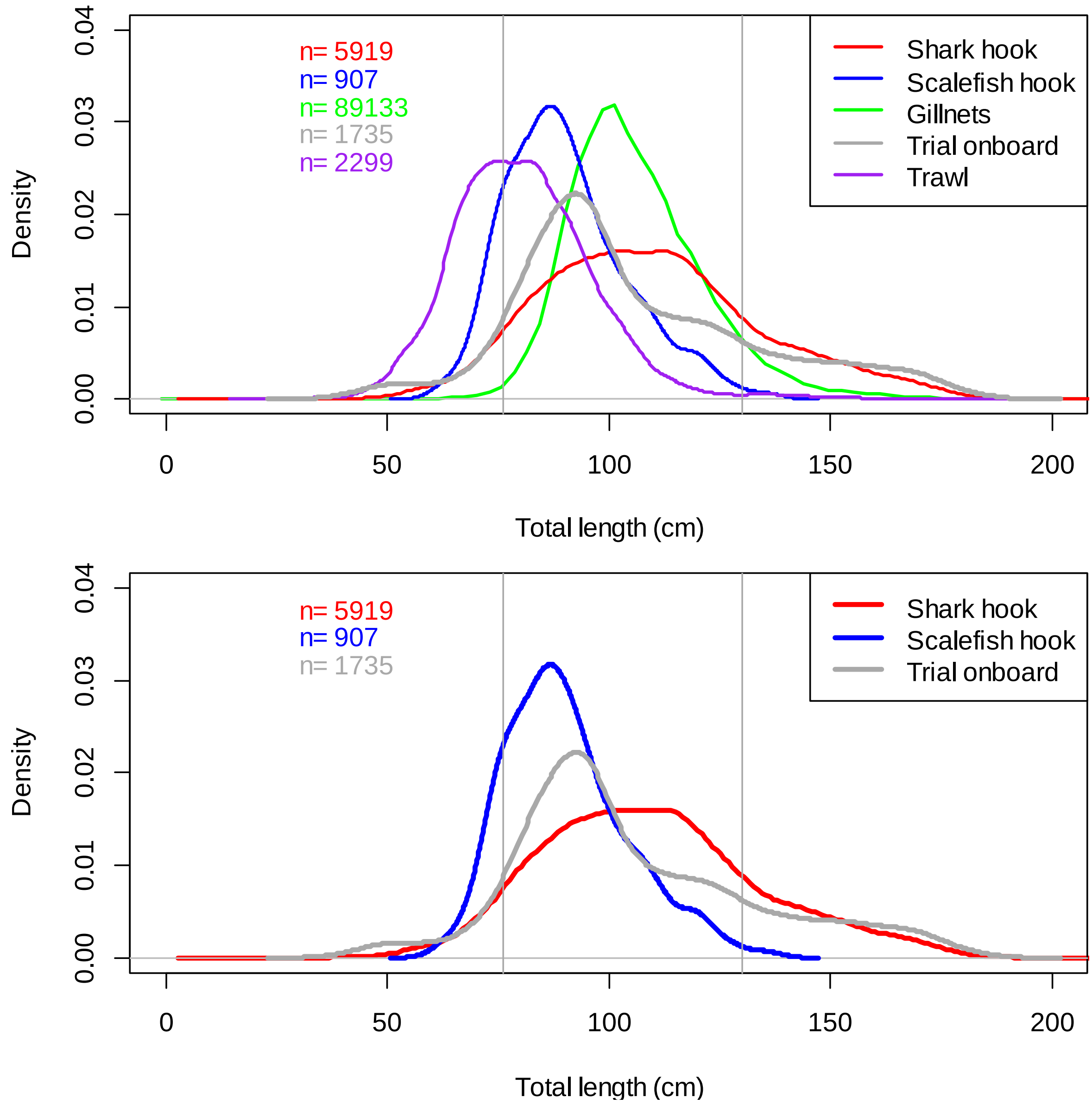


Figure 14.3. Length frequencies, for all years combined, for gummy shark caught using hooks in waters shallower (*Shark hook*) or deeper (*Scalefish hook*) than 183 m; using gillnets (*Gillnets*); by the shark hook trial (*Trial onboard*) or by trawl (*Trawl*). Sample sizes (*n*) are shown. The *upper plot* shows all gear sectors, and the *lower plot* shows a subset, for clarity.

14.4 Acknowledgements

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

14.5 References

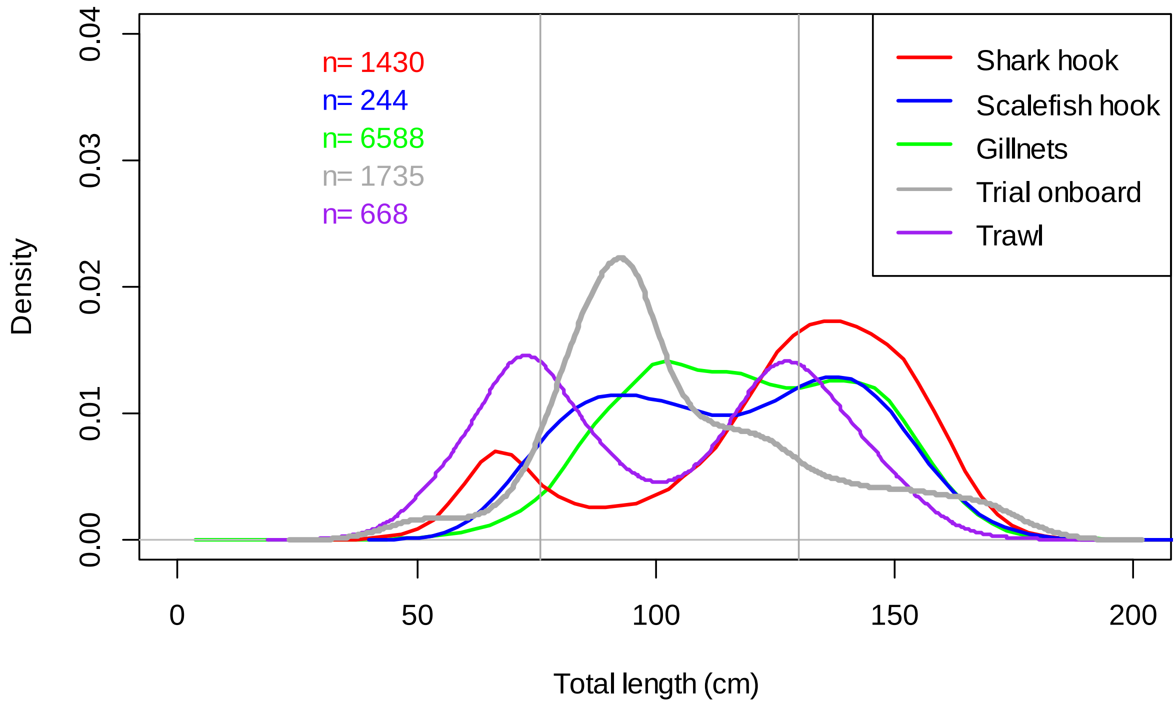
Knuckey I, Ciconte A, Koopman M, Hudson R & Rogers P (2013) Trials of longlines to target gummy shark in SESSF waters off South Australia. FRDC Project 2011/068. Fishwell Consulting 107pp.

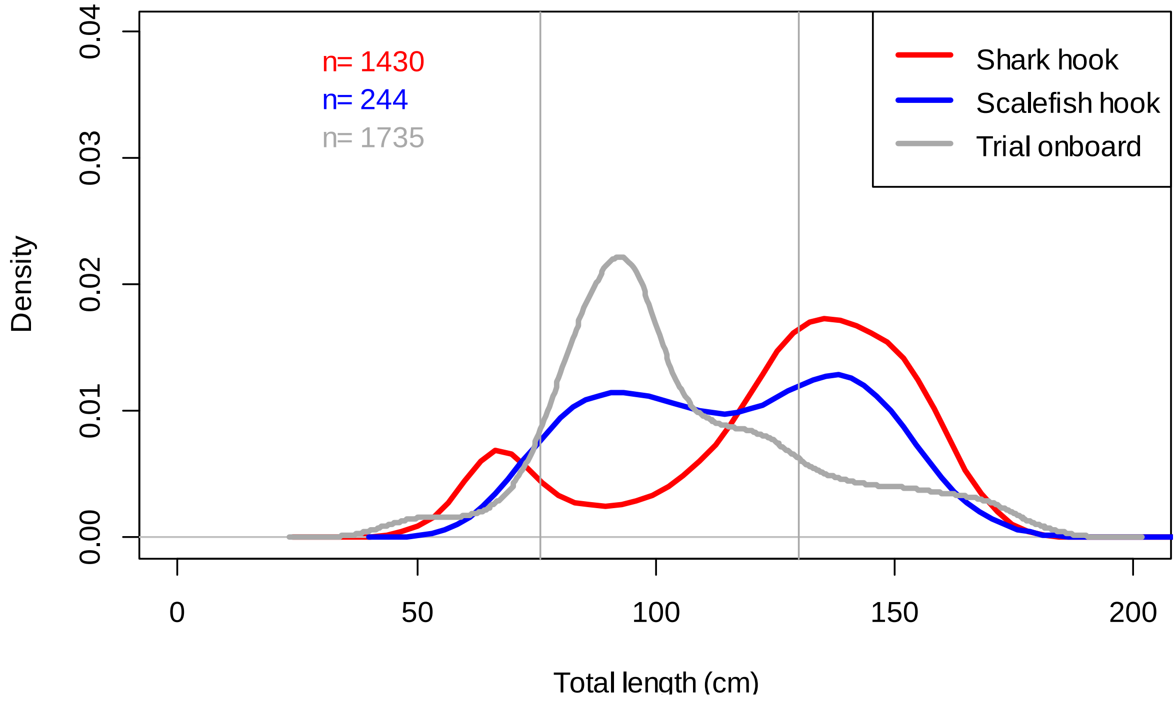
Sporcic, M. (2015). Catch-per-unit effort standardizations for selected shark SESSF Species (data to 2014). Presented to SharkRAG 8 October 2015, Melbourne. CSIRO Oceans and Atmosphere Flagship, Hobart. 68 p.

Thomson RB & Sporcic M (2013) Gummy shark assessment update for 2013, using data to the end of 2012. Presented to SharkRAG, 11-12 December 2013, Melbourne, Victoria.

14.6 Appendix

School shark length frequencies.





15. Fishery and biological data characterization of silver warehou (data to 2014)

Miriana Sporcic, Robin Thomson, Jemery Day, Geoff Tuck, Malcolm Haddon

CSIRO, GPO Box 1538, Hobart, Tasmania

15.1 Introduction

Silver warehou (*Seriolella punctata*) occur throughout the SESSF in depths to approximately 600 m. They are predominantly caught by trawl gear in the South East Trawl (SET) sector, but have also been caught by gillnets. Large catches of silver warehou were first taken in the 1970's (Smith, 1994) and annual catches have decreased since about 2002 (Figure 15.3). Discard tonnage and length frequency are very variable and appear, at times, to be market driven although discarding of smaller fish is also typical. Silver warehou have also been captured off western Tasmania as bycatch of the winter spawning blue grenadier fishery in recent years.

The most recent assessments for silver warehou have been age-structured integrated assessment models using the Stock Synthesis program Version 2 (SS2; Tuck and Fay 2009) and version 3 (SS3; Day et al. 2013). Both assume a single silver warehou stock throughout the SESSF region, and fixed instantaneous natural mortality rate of 0.3. Day et al. (2013) used the same model structure as Tuck and Fay (2009) only updating available data; the inclusion of cohort dependent growth was considered, but not accepted by the RAG for use in the base case model.

Although Tuck and Fay (2009) concluded that silver warehou were at 48% of their unfished levels, subsequent steady declines in both catch and standardized CPUE suggested some concern about stock status. Results from an updated assessment in 2013, (using data to 2011) found the stock to be at 47% of its unfished level (Day et al. 2013). While this model fitted the data well, the most recent CPUE series (for 2011) was well below the corresponding model estimate. The model also indicated an increase in abundance in 2011 compared to 2010, whereas the observed CPUE indicated a decrease. That trend continued and both the 2012 and 2013 observed standardized CPUE values were below the 95% prediction interval forecast using the model (Klaer 2014, Klaer et al. 2015).

A re-examination of the assumptions underlying the model are therefore required, specifically, whether there are differences between east and west regions in terms of fishing practices, selectivity and depletion and whether the factory/freezer trawlers operating in the blue grenadier winter spawning fishery should be treated as a separate fleet. This report examines data trends from the east and west regions, and data availability that may support proposed splits. Examination of other changes to model structure (e.g. to assumed natural mortality rate, or cohort dependent growth) are beyond the scope of this report.

15.2 Methods

15.2.1 Catch rate standardization

Depending on the analysis performed, Commonwealth logbook data were selected from specific SESSF statistical zones (10-50; Figure 15.1) within the SET sector and depth range (0-600 m), by trawl during 1986-2014. This was based on a set of database extracts designed to identify shots containing silver warehou. All statistical standardization analyses were performed in R Version 0.98.1103, following the same statistical technique adopted by Sporcic (2015).

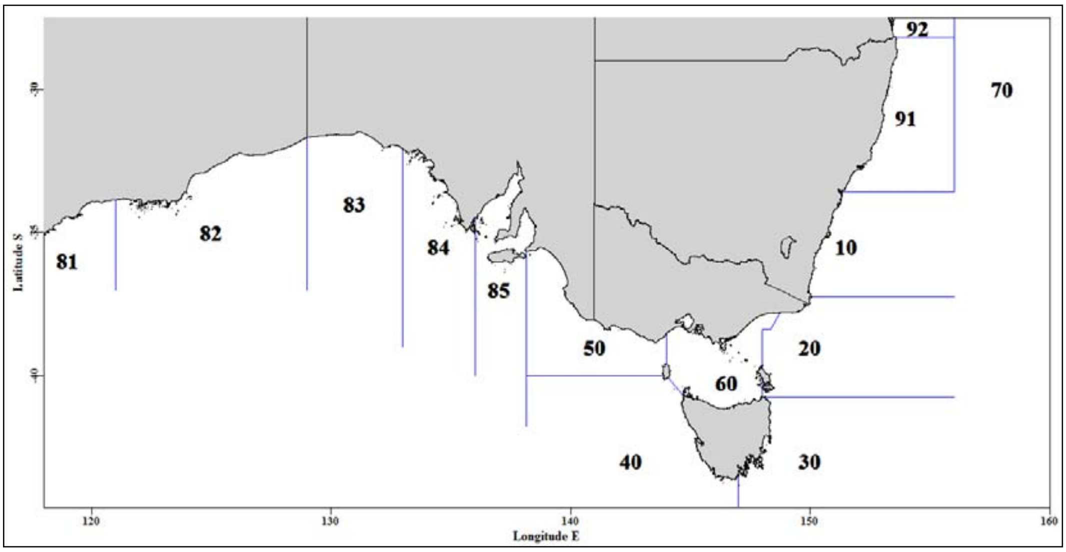


Figure 15.1. A schematic diagram depicting the statistical reporting zones in the SESSF, as used in this document. The Great Australian Bight (GAB) fishery is to the west of zone 50. The main SESSF trawl zones are zones 10 – 50. Each zone extends to the boundary of the EEZ, except for zones 50 and 60, and for zones 91 and 92, which are bounded by zone 70.

15.3 Results

15.3.1 Logbook catch and CPUE summary overview

Approximately 18,266 t and 34,822 t of silver warehou were reported during 1986-2014 at depths 0-600 m in the east and west regions, respectively (Table 15.1).

Table 15.1. Annual total catch (t) of silver warehou from zones 10 to 50 from depths 0 – 600 m by trawl.

Year	10	20	30	40	50	Total
1986	76.82	415.23	1.87	67.93	583.41	1145.26
1987	24.34	229.68	18.78	190.25	313.37	776.42
1988	134.01	748.72	57.23	164.83	536.44	1641.23
1989	9.17	283.90	54.88	365.71	206.53	920.20
1990	189.21	795.05	51.54	120.25	181.37	1337.40
1991	63.94	621.54	72.63	110.15	566.25	1434.49
1992	53.95	386.26	51.47	124.22	83.34	699.24
1993	112.27	761.51	128.81	401.63	368.89	1773.11
1994	268.10	1115.26	162.19	293.71	467.44	2306.69
1995	299.91	805.12	93.24	507.52	277.93	1983.72
1996	123.84	880.60	123.23	556.38	500.55	2184.60
1997	48.25	905.39	257.39	862.57	477.42	2551.02
1998	51.64	660.45	134.83	886.48	380.11	2113.51
1999	20.76	766.39	152.29	1258.84	597.96	2796.23
2000	6.74	634.34	88.60	1859.11	793.31	3382.09
2001	13.37	504.46	123.65	1761.33	559.42	2962.22
2002	35.44	474.86	208.40	2571.78	537.71	3828.18
2003	44.64	448.54	92.77	1766.71	534.86	2887.52
2004	66.87	314.29	123.15	1484.29	1190.99	3179.59
2005	99.60	293.79	62.67	1163.78	992.80	2612.63
2006	49.53	248.95	95.81	884.49	846.52	2125.30
2007	28.10	179.17	71.13	613.53	903.42	1795.36
2008	27.45	288.29	91.29	410.29	557.00	1374.32
2009	55.58	274.20	51.80	589.06	312.17	1282.82
2010	55.07	192.42	40.32	471.55	429.15	1188.51
2011	39.23	168.14	19.04	494.82	383.39	1104.61
2012	52.45	117.63	22.56	482.32	104.76	779.73
2013	31.47	101.20	31.15	296.68	122.56	583.06
2014	16.06	61.32	9.04	121.50	131.40	339.32
Total:	2097.81	13676.68	2491.74	20881.68	13940.47	53088.37
East:	18266.22					
West:	34822.14					

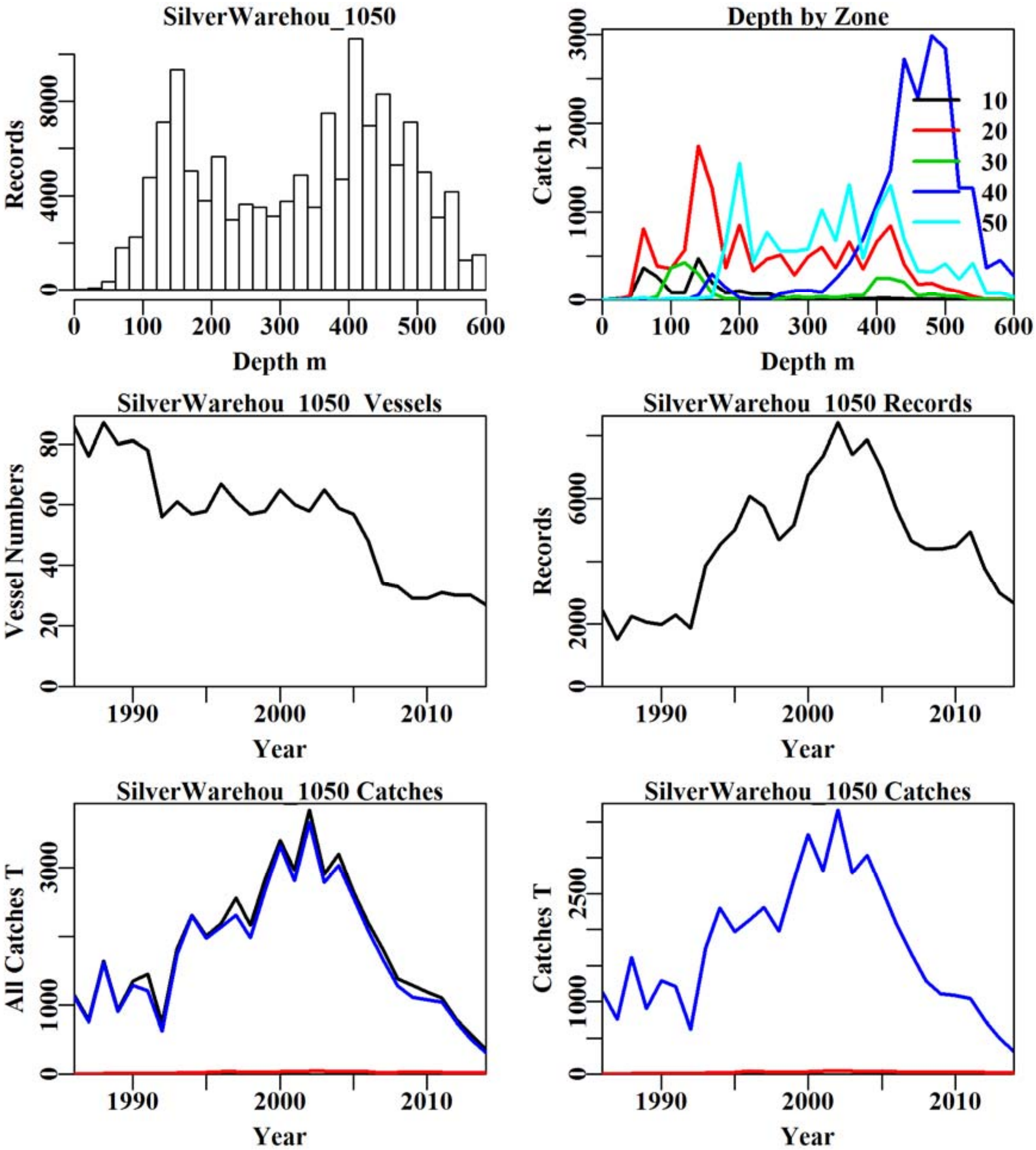


Figure 15.2. Silver warehou from zones 10 to 50 and depths 0 – 600 m caught by trawl. The top left plot depicts the depth distribution of shots containing silver warehou from zones 10 to 50 in depths 0 – 600 m by trawl. The top right plot depicts the catch distribution by depth by zone. The middle left 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 total 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 used in the analysis (blue line: catches used in the analysis; red line: catches < 30 kg).

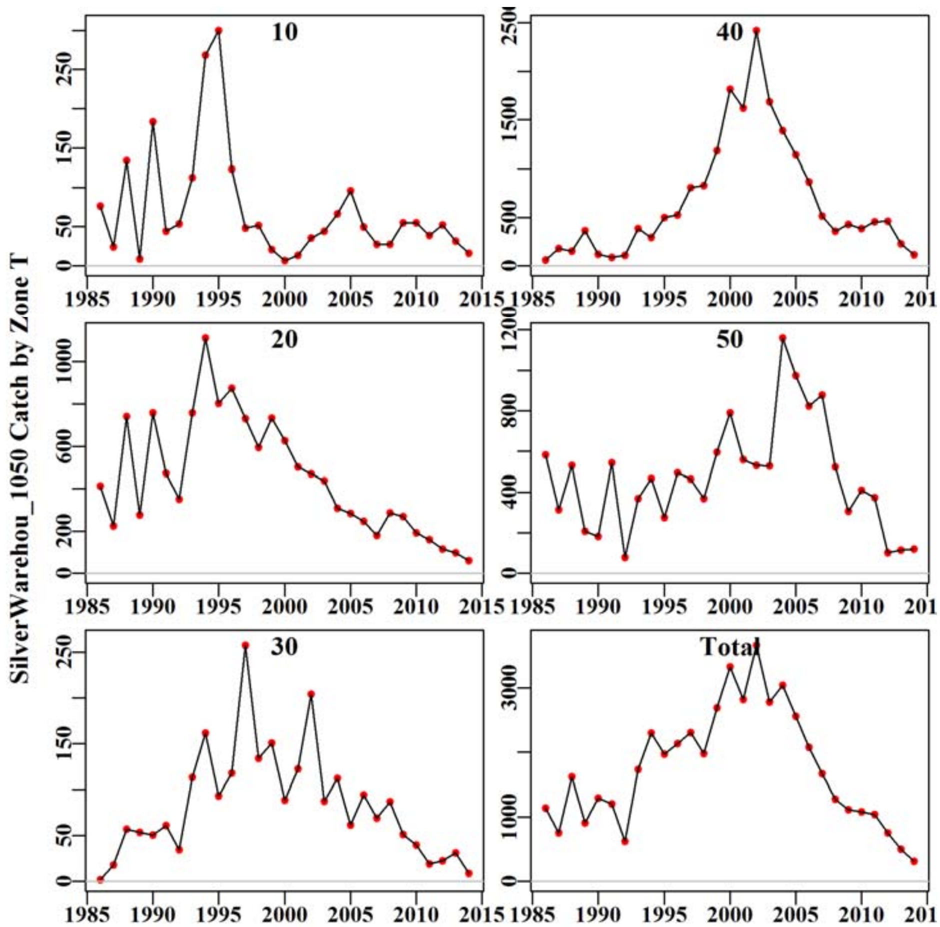


Figure 15.3. Annual silver warehou catches from zones 10 to 50 and depths 0 – 600 m caught by trawl.

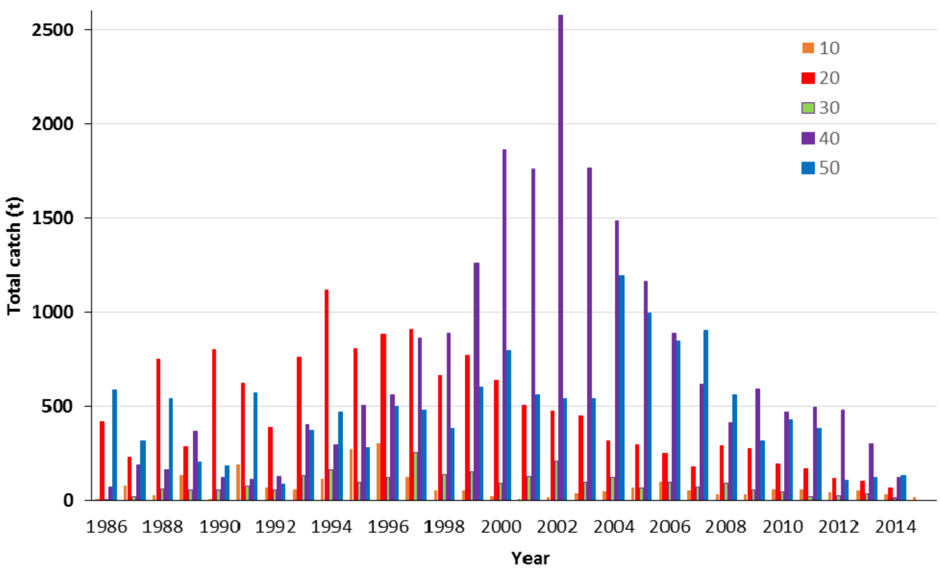


Figure 15.4. Annual silver warehou catch from zones 10 to 50 and depths 0 – 600 m caught by trawl.

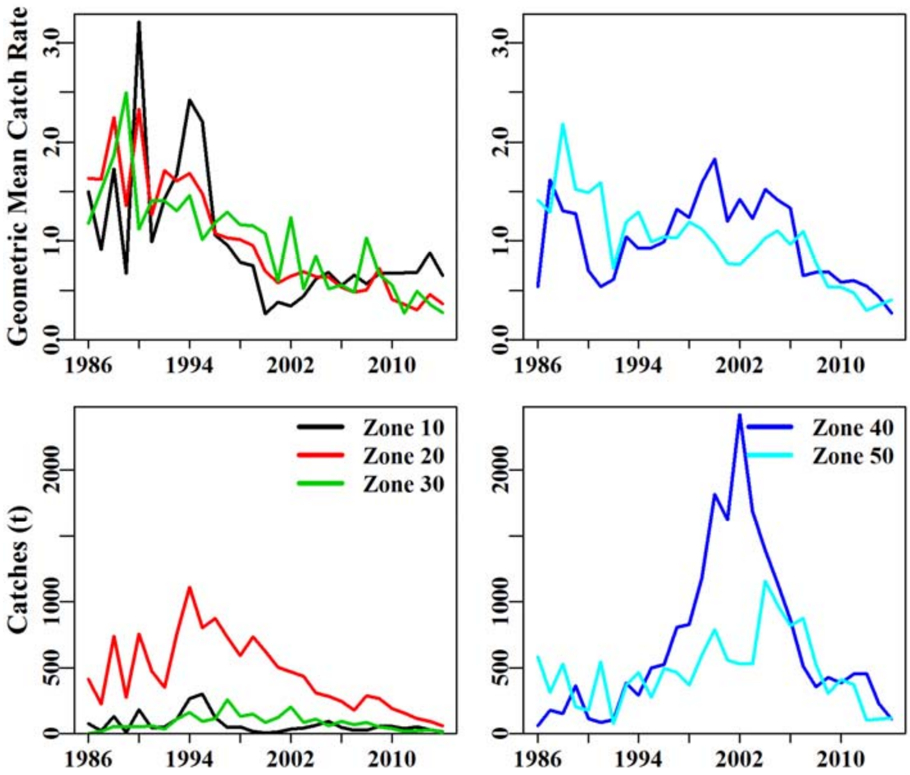


Figure 15.5. Annual catches and catch rates for zones 10 – 50, split east and west.

Unstandardized catch rates in the east all show approximately similar trends, though there are some differences between 2000 and 2003 and a decline from approximately 1994 onwards. In the west, similar patterns are exhibited: noisy but flat from 1992 to 2006 followed by a decline (Figure 15.5). Catches are greater in the west compared to the east, with most catch from zone 40 (Table 15.1, Figure 15.3–Figure 15.5)

15.3.1.1 Vessel characteristics

East – West

Overall, 179 vessels reported silver warehou catches in the east from 1986-2014. Since 2007 (which corresponds to the year after the structural adjustment), the number of vessels reporting silver warehou dropped to 35. Of these 35 vessels, 16 only caught silver warehou in the east (i.e. not in the west). Similarly, there was a drop in the number of vessels reporting silver warehou catches in the west from 98 in the 1986-2014 period to 27 from 2007 to 2014. Eight of these 27 vessels caught silver warehou only in the west. Vessel dynamics have changed through the 1984-2014 period, with (i) vessels harvesting silver warehou both before and after the introduction of ITQs in 1992 and leaving the fishery at about 2007; (ii) new vessels entering the fishery in about 1992 and leaving before 2007 (corresponding to the structural adjustment) or (iii) vessels harvesting silver warehou throughout the 1985-2014 period.

Factory vessels

Overall, factory vessels caught approximately 11.5% of the total reported logbook catch in the west from 1985-2014 inclusive. Since 2007 (corresponding to the year after the structural adjustment and when the Harvest Strategy Policy was introduced), only one factory vessel reported silver warehou catches, comprising 3.8% of the total logbook catches since 2007. Overall, factory vessels only caught a small proportion of the total harvested catch during 1985-2014 period. Therefore, there appears to be little evidence to suggest that the stock assessment model should incorporate a separate factory fleet.

15.3.2 CPUE standardization analyses

15.3.2.1 Silver warehou East + West combined Z10-50

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

Table 15.2. Silver warehou from zones 10 to 50 and depths 0 – 600 m caught 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	1156.533	2438	1135.296	86	32.290	1.533	0.000
1987	782.151	1509	757.298	76	35.504	1.601	0.056
1988	1646.187	2249	1617.240	87	42.935	2.049	0.051
1989	926.257	2049	907.420	80	30.729	1.659	0.054
1990	1346.585	1983	1290.959	81	40.649	1.756	0.054
1991	1453.169	2289	1207.361	78	25.685	1.233	0.053
1992	733.767	1858	625.276	56	27.950	1.088	0.056
1993	1815.801	3866	1735.163	61	33.299	1.234	0.049
1994	2309.510	4519	2300.083	57	34.714	1.315	0.048
1995	2002.881	5016	1969.857	58	29.783	1.193	0.047
1996	2188.244	6080	2137.373	67	22.732	1.117	0.046
1997	2562.016	5765	2305.785	61	25.348	1.147	0.047
1998	2166.021	4702	1976.667	57	26.642	1.104	0.048
1999	2834.052	5148	2685.678	58	31.233	0.947	0.047
2000	3401.563	6745	3325.305	65	26.075	0.863	0.046
2001	2970.407	7352	2816.511	60	21.800	0.727	0.046
2002	3841.439	8423	3659.277	58	23.001	0.785	0.045
2003	2910.095	7405	2782.808	65	20.460	0.788	0.046
2004	3202.084	7861	3036.748	59	23.344	0.874	0.046
2005	2647.967	6920	2558.282	57	20.028	0.860	0.046
2006	2191.197	5663	2076.275	48	18.215	0.757	0.047
2007	1816.517	4657	1665.236	34	20.124	0.715	0.048
2008	1381.159	4400	1279.929	33	16.120	0.647	0.049
2009	1285.306	4387	1109.646	29	15.884	0.668	0.049
2010	1189.434	4484	1082.602	29	13.259	0.554	0.049
2011	1108.751	4940	1042.774	31	12.616	0.515	0.048
2012	781.154	3768	750.557	30	10.408	0.421	0.050
2013	584.073	2979	502.952	30	11.609	0.462	0.052
2014	356.855	2670	316.859	27	9.788	0.387	0.053

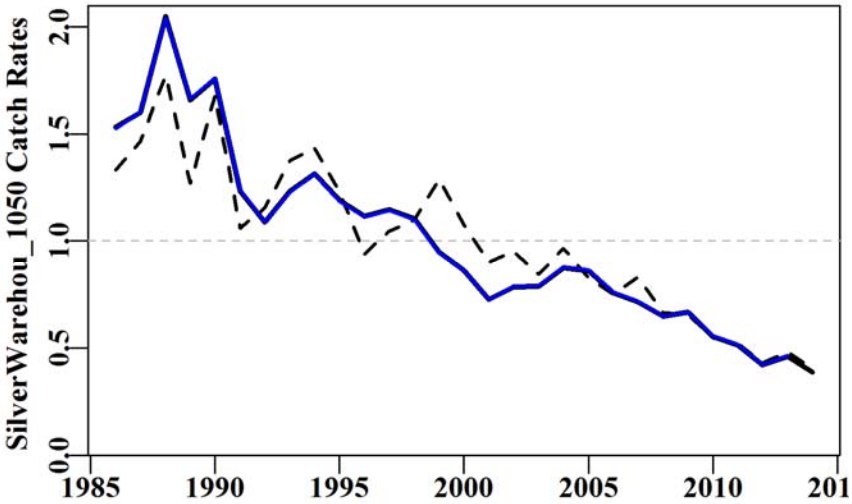


Figure 15.6. Silver warehou from zones 10 to 50 and depths 0 – 600 m caught by trawl. The dashed black line represents the geometric mean catch rate and the solid black line the standardized catch rates (relative to the mean of the standardized catch rates). The blue line corresponds to last year's standardized indices.

Annual standardized catch rates exhibit a declining trend during the period 1986-2014 (Table 15.2, Figure 15.6). Model 7 was the optimum (Table 15.3; Table 15.4).

Table 15.3. Statistical model structures used in analyses. 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 15.4. Silver warehou from zones 10 to 50 and depths 0 – 600 m caught 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	157283	135049	128748	126650	123572	123325	121408	121845
RSS	434292	365925	348825	343310	335104	334459	329388	330103
MSS	15062	83429	100529	106044	114250	114895	119966	119251
Nobs	132125	132125	132125	132125	131240	131240	131240	131240
Npars	29	228	239	243	273	276	320	396
adj_R^2	3.331	18.426	22.232	23.459	25.271	25.413	26.519	26.317
%Change	0.000	15.095	3.806	1.227	1.812	0.142	1.106	-0.202

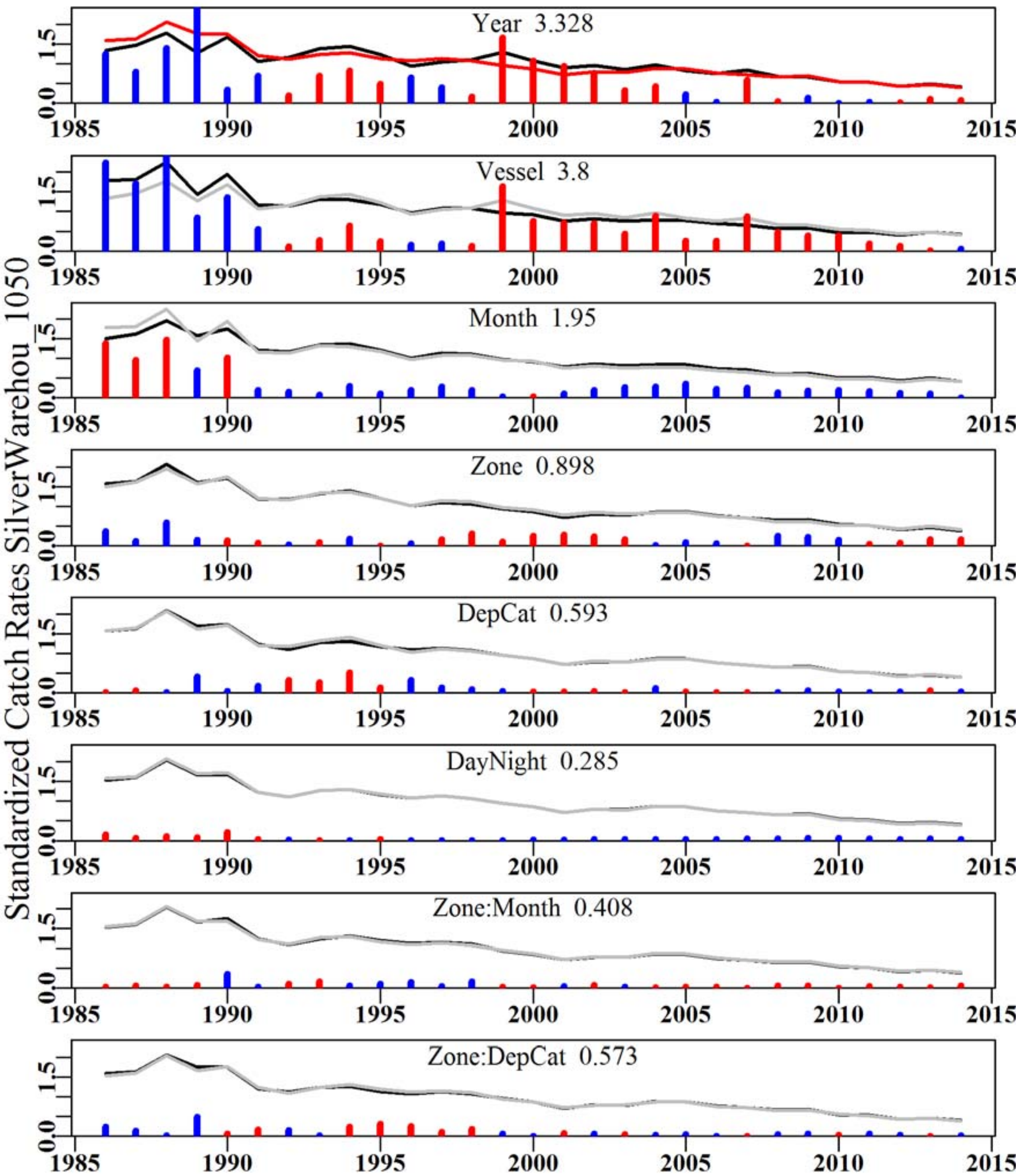


Figure 15.7. The relative influence of each factor used on the final trend in the optimal standardization for silver warehou in zones 10 – 50. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by the vertical bars with blue 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.

15.3.2.2 Silver warehou East Z10-30

Table 15.5. Silver warehou from zones 10 to 30 and depths 0 – 600 m caught 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	1156.5330	1318	491.7080	66	26.2914	1.7230	0.0000
1987	782.1510	784	266.3420	56	24.5689	1.6346	0.0779
1988	1646.1870	1675	932.7990	69	36.4292	2.1414	0.0659
1989	926.2570	1399	337.8800	63	22.5921	1.8205	0.0695
1990	1346.5850	1414	992.2860	59	39.7032	2.2066	0.0707
1991	1453.1690	1583	577.8910	64	21.0325	1.3229	0.0703
1992	733.7670	1274	438.2490	41	28.4491	1.4036	0.0732
1993	1815.8010	2320	982.7060	49	27.6693	1.3843	0.0664
1994	2309.5100	2866	1541.9790	46	30.3557	1.5213	0.0650
1995	2002.8810	3336	1195.7120	45	26.0163	1.3576	0.0635
1996	2188.2440	4514	1116.6110	53	18.6397	1.1338	0.0621
1997	2562.0160	3883	1036.5460	48	19.2212	1.1127	0.0636
1998	2166.0212	2849	779.0660	43	17.8248	0.9391	0.0651
1999	2834.0520	2401	905.8090	43	17.6488	0.8109	0.0668
2000	3401.5633	3172	722.2670	51	12.0298	0.6641	0.0647
2001	2970.4067	3162	637.4020	42	10.0036	0.6209	0.0650
2002	3841.4390	3989	709.3435	43	11.2474	0.7208	0.0638
2003	2910.0946	3986	569.4015	51	10.4670	0.6770	0.0637
2004	3202.0836	3587	488.1205	47	11.0406	0.7761	0.0644
2005	2647.9671	3840	441.7305	43	10.6058	0.7222	0.0640
2006	2191.1968	2968	389.8176	36	9.2292	0.6092	0.0657
2007	1816.5165	1870	275.1950	24	8.8816	0.4841	0.0697
2008	1381.1590	2326	401.1699	25	9.9089	0.5602	0.0678
2009	1285.3059	2330	375.0856	24	11.8427	0.6416	0.0679
2010	1189.4336	2137	286.2760	21	8.2239	0.4674	0.0688
2011	1108.7509	2027	218.1696	23	6.8693	0.4029	0.0694
2012	781.1541	1863	190.1950	21	6.7481	0.3620	0.0701
2013	584.0728	1452	158.9600	22	8.6086	0.4532	0.0728
2014	356.8551	1230	85.8995	23	6.7204	0.3260	0.0747

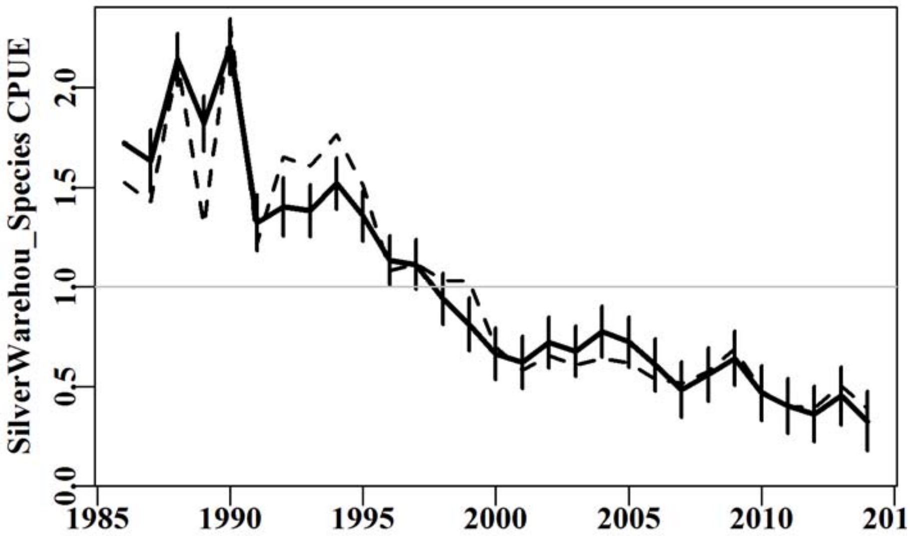


Figure 15.8. Silver warehou from the east (zones 10 to 30) and depths 0 – 600 m caught by trawl. The dashed black line represents the geometric mean catch rate and the solid black line the standardized catch rates (relative to the mean of the standardized catch rates).

There is a downward trend in standardized catch rates from 1994 onwards in the east (Table 15.5, Figure 15.8). Model 8 was the optimum (Table 15.3; Table 15.6).

Table 15.6. Silver warehou from zones 10 to 30 and depths 0 – 600 m caught 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:DepCat (Model 8). Depth Category: DepC.

	Year	Vessel	Month	zone	DepC	DayNight	Zone:Month	Zone:DepC
AIC	79757	73678	70007	68412	68122	68055	67101	67086
RSS	217954	199208	189187	184803	184040	183851	181287	181056
MSS	16476	35222	45243	49627	50390	50579	53144	53374
Nobs	71555	71555	71555	71075	71075	71075	71075	71075
Npars	29	207	218	248	250	253	275	313
adj_R^2	6.992	14.779	19.054	20.894	21.219	21.296	22.370	22.427
%Change	0.000	7.788	4.274	1.841	0.324	0.078	1.074	0.057

15.3.2.3 Silver warehou West Z40-50

Table 15.7. Silver warehou from zones 40 and 50 and depths 0 – 600 m caught by trawl. Total catch (TotCatch; t) is the total reported in the database, number of records used in the analysis (Records), reported catch (CatchT; t) in the area and depth used in the analysis and number of vessels used in the analysis (Vessels). GeoMean is the geometric mean of catch rates (kg/hr). The optimum model is Zone:Month and standard deviation (StDev) relates to the data in the optimum model.

Year	TotCatch	Records	CatchT	Vessels	GeoMean	Zone:Month	StDev
1986	1156.5330	1120	643.5880	23	41.1238	1.3771	0.0000
1987	782.1510	725	490.9560	26	52.8667	1.5718	0.0840
1988	1646.1870	574	684.4410	27	69.3486	1.8137	0.0887
1989	926.2570	650	569.5400	27	59.5779	1.5865	0.0916
1990	1346.5850	569	298.6730	26	43.0973	1.0381	0.0907
1991	1453.1690	706	629.4700	29	40.2037	1.1201	0.0862
1992	733.7670	584	187.0270	21	26.8907	0.8677	0.0899
1993	1815.8010	1546	752.4570	23	43.9668	1.1638	0.0748
1994	2309.5100	1653	758.1040	26	43.8060	1.0742	0.0728
1995	2002.8810	1680	774.1450	24	38.9540	0.8413	0.0728
1996	2188.2440	1566	1020.7620	26	40.2805	0.9624	0.0739
1997	2562.0160	1882	1269.2390	24	44.8612	1.1480	0.0719
1998	2166.0212	1853	1197.6010	22	49.4206	1.3627	0.0724
1999	2834.0520	2747	1779.8690	24	51.4384	1.1308	0.0693
2000	3401.5633	3573	2603.0380	28	51.8176	1.1134	0.0681
2001	2970.4067	4190	2179.1090	29	39.2417	0.8437	0.0673
2002	3841.4390	4434	2949.9330	27	43.7767	0.8979	0.0670
2003	2910.0946	3419	2213.4064	28	44.6963	0.9380	0.0683
2004	3202.0836	4274	2548.6279	25	43.7609	1.0205	0.0674
2005	2647.9671	3080	2116.5510	24	44.2429	1.1156	0.0692
2006	2191.1968	2695	1686.4570	21	38.5112	0.9824	0.0700
2007	1816.5165	2787	1390.0405	16	34.8382	1.0064	0.0697
2008	1381.1590	2074	878.7590	17	27.8222	0.7988	0.0717
2009	1285.3059	2057	734.5600	13	22.1498	0.6928	0.0718
2010	1189.4336	2347	796.3264	14	20.4833	0.6296	0.0708
2011	1108.7509	2913	824.6042	17	19.2600	0.6085	0.0696
2012	781.1541	1905	560.3618	15	15.8987	0.4537	0.0733
2013	584.0728	1527	343.9918	16	15.4259	0.4311	0.0754
2014	356.8551	1440	230.9594	13	13.4958	0.4091	0.0762

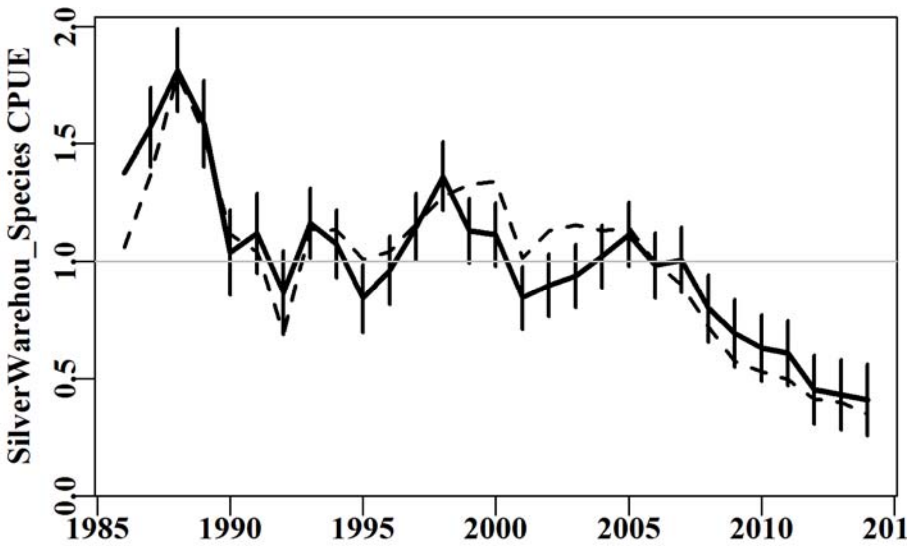


Figure 15.9. Silver warehou from the west (zones 40 and 50) and depths 0 – 600 m caught by trawl. The dashed black line represents the geometric mean catch rate and the solid black line the standardized catch rates (relative to the mean of the standardized catch rates).

There is a downward trend in standardized catch rates from 2007 onwards in the west (Table 15.7, Figure 15.9). Model 7 was the optimum (Table 15.3; Table 15.8).

Table 15.8. Silver warehou from zones 40 and 50 and depths 0 – 600 m caught 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	65523	57882	54998	53513	52716	52346	52076	52188
RSS	178505	156846	149497	145618	143695	142800	142110	142284
MSS	8806	30464	37814	41693	43615	44511	45201	45027
Nobs	60570	60570	60570	60165	60165	60165	60165	60165
Npars	29	126	137	167	168	171	182	201
adj_R^2	4.657	16.091	20.008	22.044	23.072	23.547	23.903	23.785
%Change	0.000	11.434	3.917	2.036	1.028	0.475	0.356	-0.118

15.3.3 ISMP sampling – observer and port based

15.3.3.1 Sample sizes for age and length data for stock assessment purposes

If 500 age and 200 lengths from individual fish are required for adequate sampling (in the absence of any statistical power analysis), there appear to be adequate age samples for only three of the 21 years in both the east (zones 10-30) and west (zones 40, 50) regions respectively (blue shading; Table 15.9). Sufficient length samples are available for most years between 1994 and 2014 although no adequate port samples are available for the west after 2007 (grey shading; Table 15.9).

Table 15.9. Number of silver warehou aged (Age), or measured (Length), between 1994 and 2014 at port (Port), or by on-board (On-board) observers in the east and west. East: zones 10, 20 and 30; west: zones 40, 50 and 60 and Great Australian Bight (GAB). On-board measurements of only the retained component of the population are shown. Age samples > 500: shaded blue; Length samples > 200: shaded grey.

Year	Age east	Age west	Length Port - east	Length On-board east^	Length Port - west	Length On-board west^
1994	186	173	215	172	1802	0
1995	157	294	620	142	4651	0
1996	317	198	1198	293	6023	122
1997	443	123	2831	1585	8875	1883
1998	404	182	6688	3060	9704	2671
1999	220	562	6875	2974	7742	1952
2000	140	267	8573	1642	5424	3698
2001	366	633	8072	1446	6978	4743
2002	327	396	12979	2554	9064	4047
2003	142	303	5547	2052	3359	5174
2004	126	513	4868	2762	2638	3788
2005	250	375	9007	2028	3319	6617
2006	132	263	7994	1923	855	3763
2007	241	69	1042	193	491	42
2008	313	236	1353	524	0	436
2009	494	345	2135	397	163	975
2010	688	135	1274	1418	47	1345
2011	543	309	1349	372	0	1242
2012	792	214	1423	807	0	991
2013	89	386	1836	730	141	1696
2014	184	139	1670	142	152	900

^ Measurements based on the retained at-sea portion of the catch.

Length and age distributions

Port sampling in the west has been poor from 2008 onwards. However, there has been adequate port sampling in the east (Appendix). Length frequency distributions based on port sampling suggest that there are a greater number of smaller fish caught in the east (compared to the west), as shown by the annual bi-modal distributions (Appendix). This is also illustrated by the on-board length frequency distributions. On the whole, there is adequate data sampling from the on-board samples in the west. Further investigation should consider the seasonality of sample coverage to assess the likelihood of observing recruitment pulses. There are observable differences in recruitment patterns between the east and west regions. It is unclear whether these adequately reflect true differences or are due to size selectivity (i.e. availability component of selectivity) differences between these regions.

Sample sizes corresponding to the age distributions are relatively low when split by east and west, and therefore may not reflect the true underlying population. The observed age distributions in both regions fail to show clear cohort progression. However, this may be due to differing selectivity patterns and/or poor sample sizes (Appendix).

Sample coverage shows an inconsistent seasonal spread for port and on-board sampling in the east and west (Appendix). Under-sampling is particularly apparent in the winter samples in both regions. The same is true for age samples in the east, while in the west aged samples appear to be patchy across all months (between years).

Factory vessels

Factory vessels have been used in the blue grenadier winter spawning fishery off north-west Tasmania. Their selectivity function (which is also a function of availability) for silver warehou may differ from that for the rest of the fishery. Adequate length samples are available from on-board measurements on factory vessels for 5 years and from port measurements for only 1 year (Table 15.10). Separate age data from factory vessels may be available, but could not be identified by the authors.

Table 15.10. Number of fish measured by on-board observers on factory vessels (fishing off north-west Tasmania) between 1998 and 2014. Samples > 200 (shaded grey).

Year	On-board length	Port length
1998	498	
1999		715
2000		
2001		
2002		
2003		
2004		
2005		
2006		
2007		
2008		
2009	285	
2010	357	
2011	348	
2012	283	
2013	109	
2014		

15.3.4 Historical data and episodic discards

Silver warehou are closely related to blue warehou and mixed catches occurred historically (Smith and Wayte (2000)). This has led to confusion regarding which species was caught and recorded in Commonwealth logbooks, and was most apparent between logbook catches and verified catches in the late 1980s (Chesson, 1996; Smith and Wayte (2000)). Also, early catches were recorded for all warehou species combined and referred to as Tassie trevally. The currently accepted silver warehou catch history (landings and discards) between 1985 and 2013 is listed in Table 15.11.

The reported estimated discarded weight ranges from approximately 16 t to 1120 t across the 1985-2013 period. This corresponds to approximately 1.25 to 25.25 % discarded relative to the total (landed + discarded) catch (Table 15.11). It has been reported that while size related discarding does occur, discarding of larger fish due to low market prices also occurs at times (Thomson, 2000). The variable nature of the discarding pattern has been accounted for in stock assessments by adding the discarded tonnage to the landed catches, rather than trying to model the inconsistent discarding pattern (Day et al. 2013).

Table 15.11. Accepted catch history of CDR landed and discarded silver warehou catches. Landed catch (t) is the total from Landings database, discard rate (%) is the estimated discard rate based on non-factory vessels; discard weight (t) is the estimated discard weight based on estimated discard weight.

Year	Discard rate (%)	Landed Catch (t)	Discard weight (t)	Total (t)	Percent Discarded (%)
1985	10.851	360.000	43.818	403.818	10.85
1986	10.851	1008.000	122.690	1130.690	10.85
1987	10.851	748.800	91.141	839.941	10.85
1988	10.851	1365.600	166.216	1531.816	10.85
1989	10.851	920.400	112.028	1032.428	10.85
1990	10.851	1125.600	137.004	1262.604	10.85
1991	10.851	1363.200	165.924	1529.124	10.85
1992	10.851	1864.800	226.977	2091.777	10.85
1993	1.334	1969.200	26.618	1995.818	1.33
1994	2.022	2054.296	42.390	2096.686	2.02
1995	23.669	2213.896	686.484	2900.380	23.67
1996	22.186	2735.681	780.008	3515.689	22.19
1997	10.762	2807.462	338.566	3146.027	10.76
1998	9.091	2433.954	243.410	2677.364	9.09
1999	1.214	3255.217	39.989	3295.206	1.21
2000	2.460	3726.592	93.996	3820.588	2.46
2001	14.282	3295.454	549.057	3844.511	14.28
2002	7.834	4101.870	348.664	4450.534	7.83
2003	15.879	3060.003	577.598	3637.600	15.88
2004	25.253	3315.032	1119.958	4434.990	25.25
2005	12.989	2912.725	434.830	3347.555	12.99
2006	3.795	2374.182	93.642	2467.824	3.79
2007	3.944	1987.060	81.595	2068.655	3.94
2008	2.972	1522.999	46.643	1569.643	2.97
2009	2.309	1379.268	32.599	1411.867	2.31
2010	1.248	1288.672	16.286	1304.959	1.25
2011	24.523	1229.277	399.402	1628.680	24.52
2012	13.604	821.618	129.373	950.991	13.60
2013	13.604	645.636	101.663	747.299	13.60
2014		381.117			

15.4 Discussion and Conclusions

This report shows that there are apparent differences in both CPUE and in age and length distributions in the east and west which suggests it may be worth considering implementing separate east and west fleets in a stock assessment, or possibly considering separate populations in the east and west (i.e. separate stock assessments) if sample coverage allows this. The silver warehou catch from factory vessels does not appear to be large enough to warrant consideration of a separate factory vessel fleet in the assessment and age sampling from this fleet has been poor. The poor, and episodic, seasonal sampling, particularly from the winter period, could bias recruitment estimation if fish of particular ages or sizes are more or less available during that time. Length frequencies should be examined by zone, and by month, to look for any such patterns.

15.5 References

Chesson, J. (1996). The South east Fishery 1995, Fishery Assessment Report compiled by the South east Fishery Assessment Group. Australian Fisheries Management Authority, Canberra. 240pp.

Day, J., Klaer, N., Tuck, G. (2012). Silver warehou (*Seriolella punctata*) based on data up to 2011. Report prepared for the Australian Fisheries Management Authority. 33pp.

Day J., Klaer N., Tuck GN., Whitten A (2013). Silver warehou (*Seriolella punctata*) stock assessment based on data up to 2011 – development of a preliminary base case. In Tuck, G.N. (ed.) 2013. Stock Assessment for the Southern and eastern Scalefish and Shark Fishery 2012. Part 1. Australian Fisheries Management Authority and CSIRO Marine and Atmospheric Research, Hobart. 199p. Tuck, G.N. (ed.) 2015. Stock Assessment for the Southern and eastern Scalefish and Shark Fishery 2014. Part 2. Australian Fisheries Management Authority and CSIRO Oceans and Atmosphere Flagship, Hobart. 432 p.

Klaer N. (2014). Tier 1 CPUE forecasts for multi-year TAC breakout. In Tuck, G.N. (ed.) 2014. Stock Assessment for the Southern and eastern Scalefish and Shark Fishery 2013. Part 2. Australian Fisheries Management Authority and CSIRO Marine and Atmospheric Research, Hobart. 487 p.

Klaer N., Day J., Tuck G.N., Little L.R., Wayte S.E. (2015). Tier 1 CPUE forecasts for multi-year TAC breakout. In Tuck, G.N. (ed.) 2015. Stock Assessment for the Southern and eastern Scalefish and Shark Fishery 2014. Part 2. Australian Fisheries Management Authority and CSIRO Oceans and Atmosphere Flagship, Hobart. 432 p.

Tuck, G.N., Fay, G. (2009). Silver warehou (*Seriolella punctata*) stock assessment based on data up to 2008. Unpublished report to Slope RAG. 28 pp.

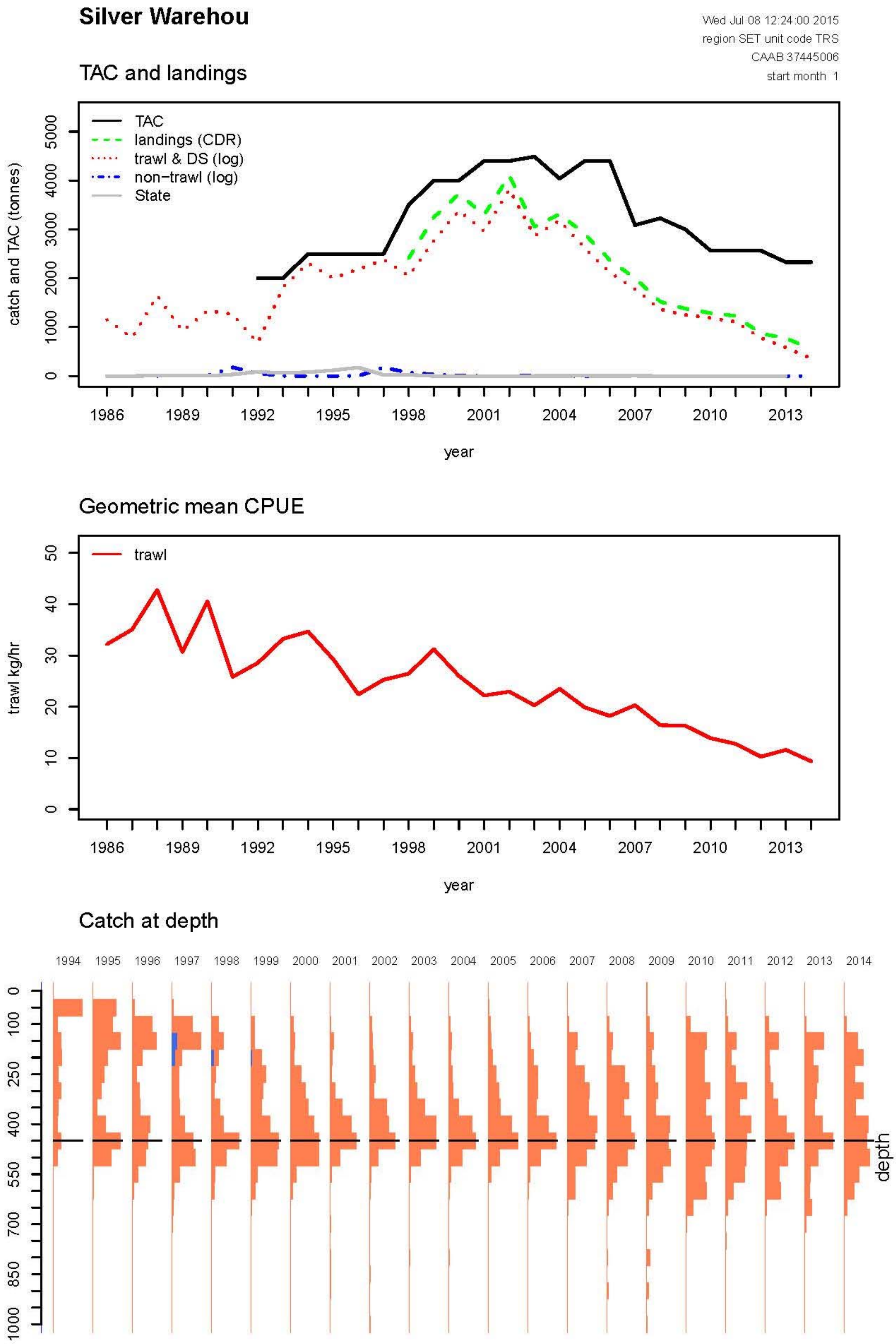
Smith, A.D.M., Wayte, S.E. (eds) (2000). The South east Fishery 1999, Fishery Assessment Report compiled by the South east Fishery Assessment Group. Australian Fisheries Management Authority, Canberra. 246 pp.

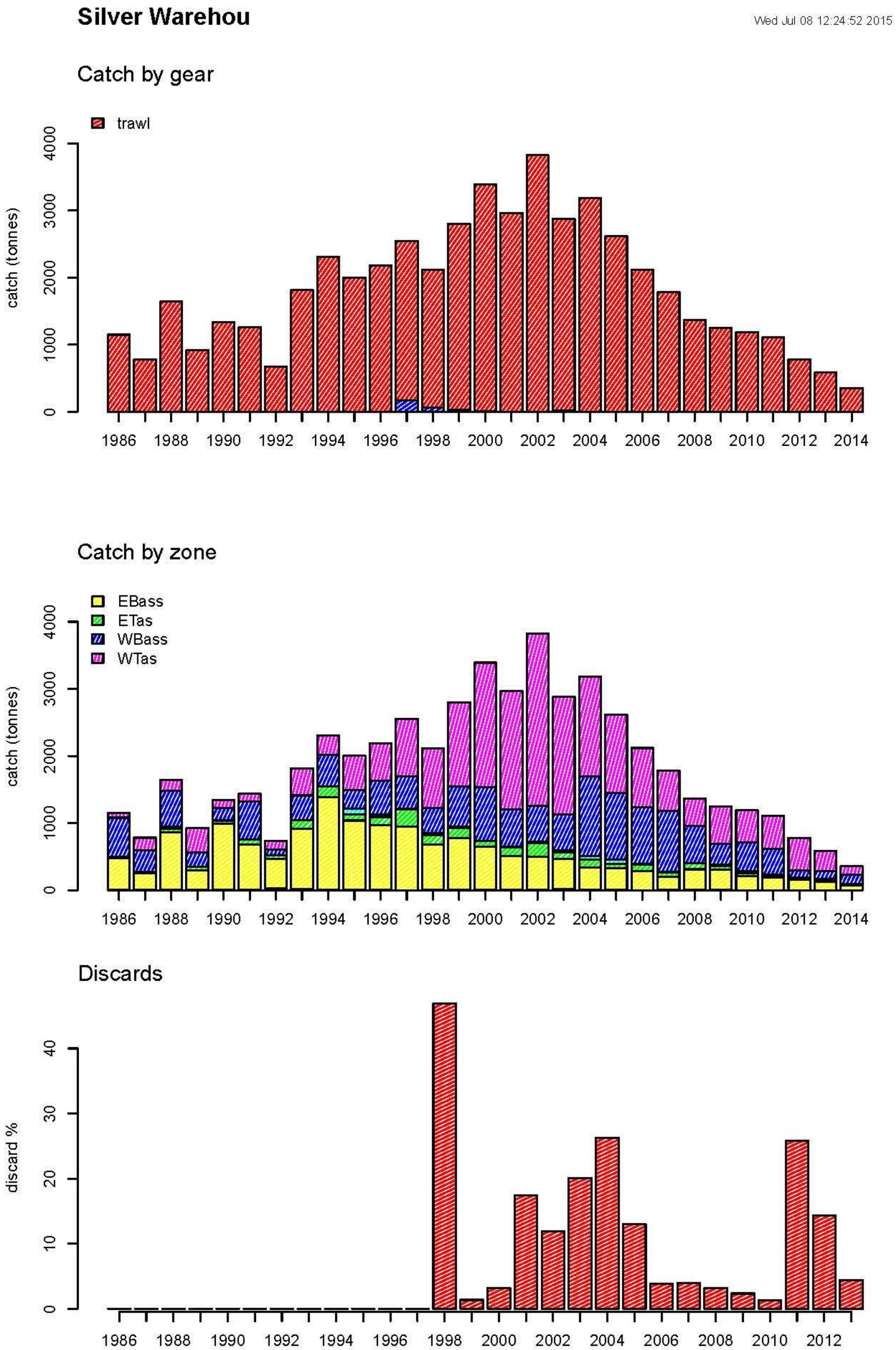
Sporcic, M. (2015). Catch rate standardizations for selected SESSF Species (data to 2014). CSIRO Oceans and Atmosphere Flagship, Hobart. 266 p.

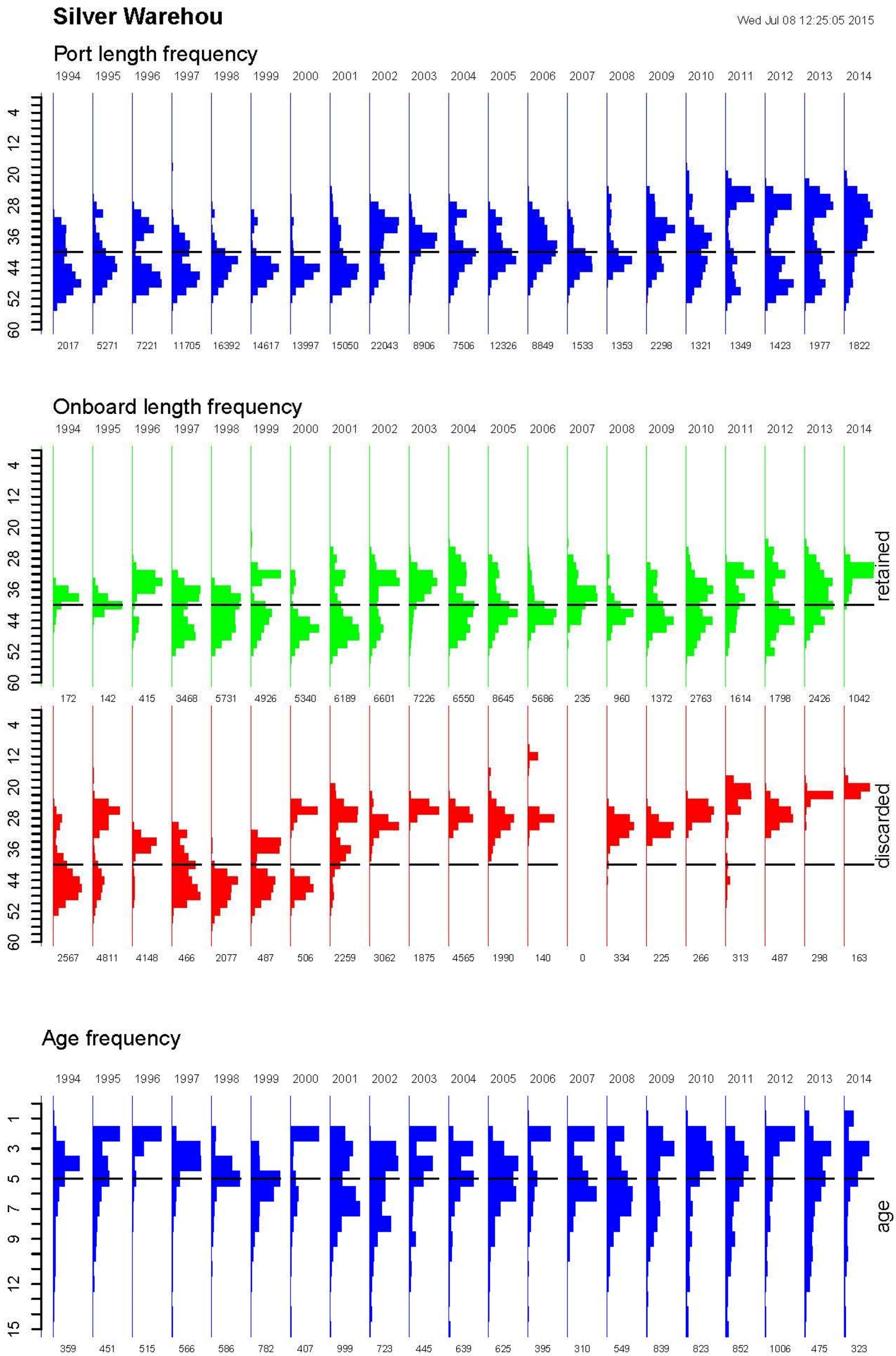
Thomson, R. (2000). Exploratory stock assessment of spotted warehou (*Seriolella punctata*) for the South east Fishery. 21pp.

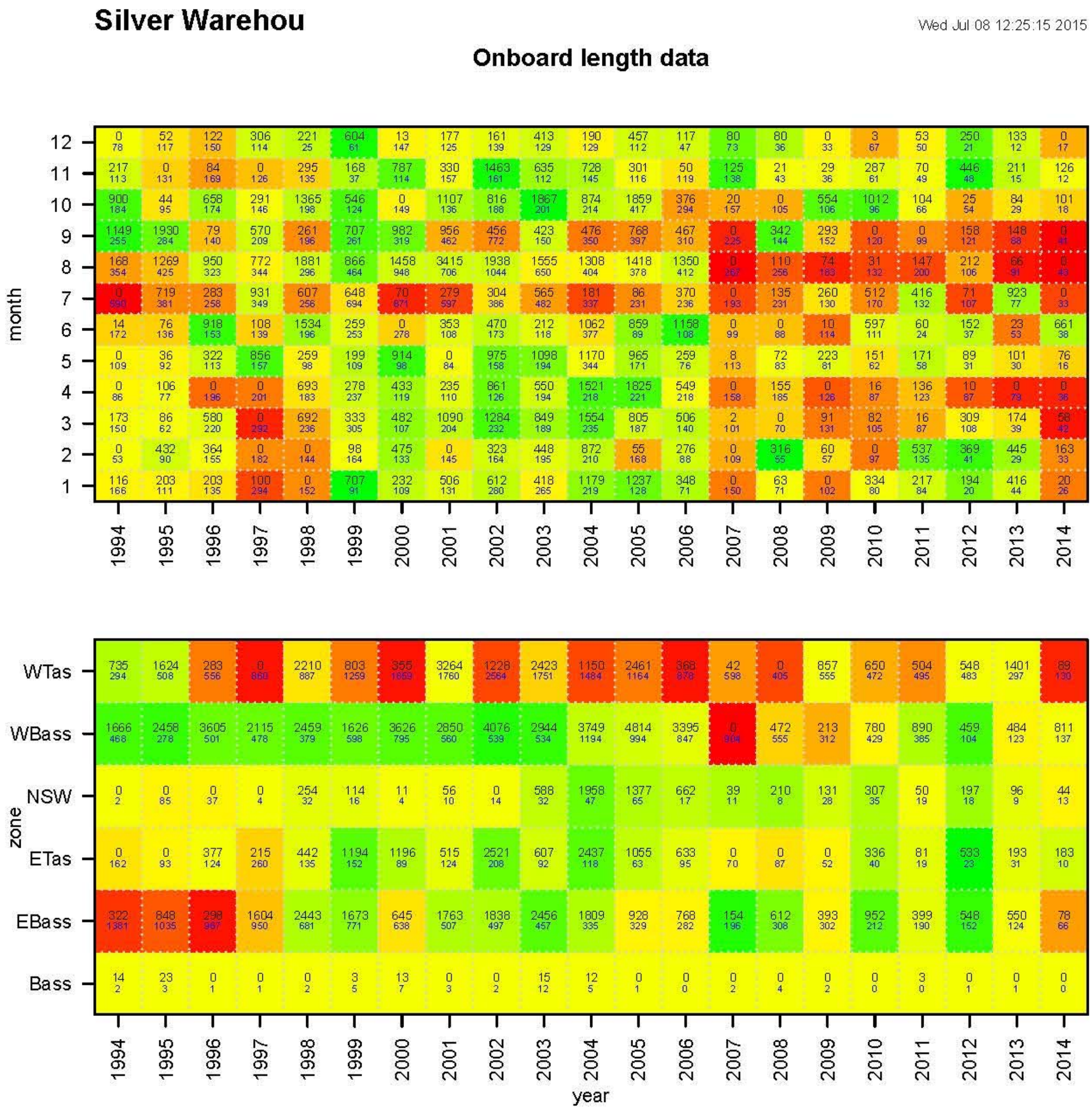
15.6 Appendix

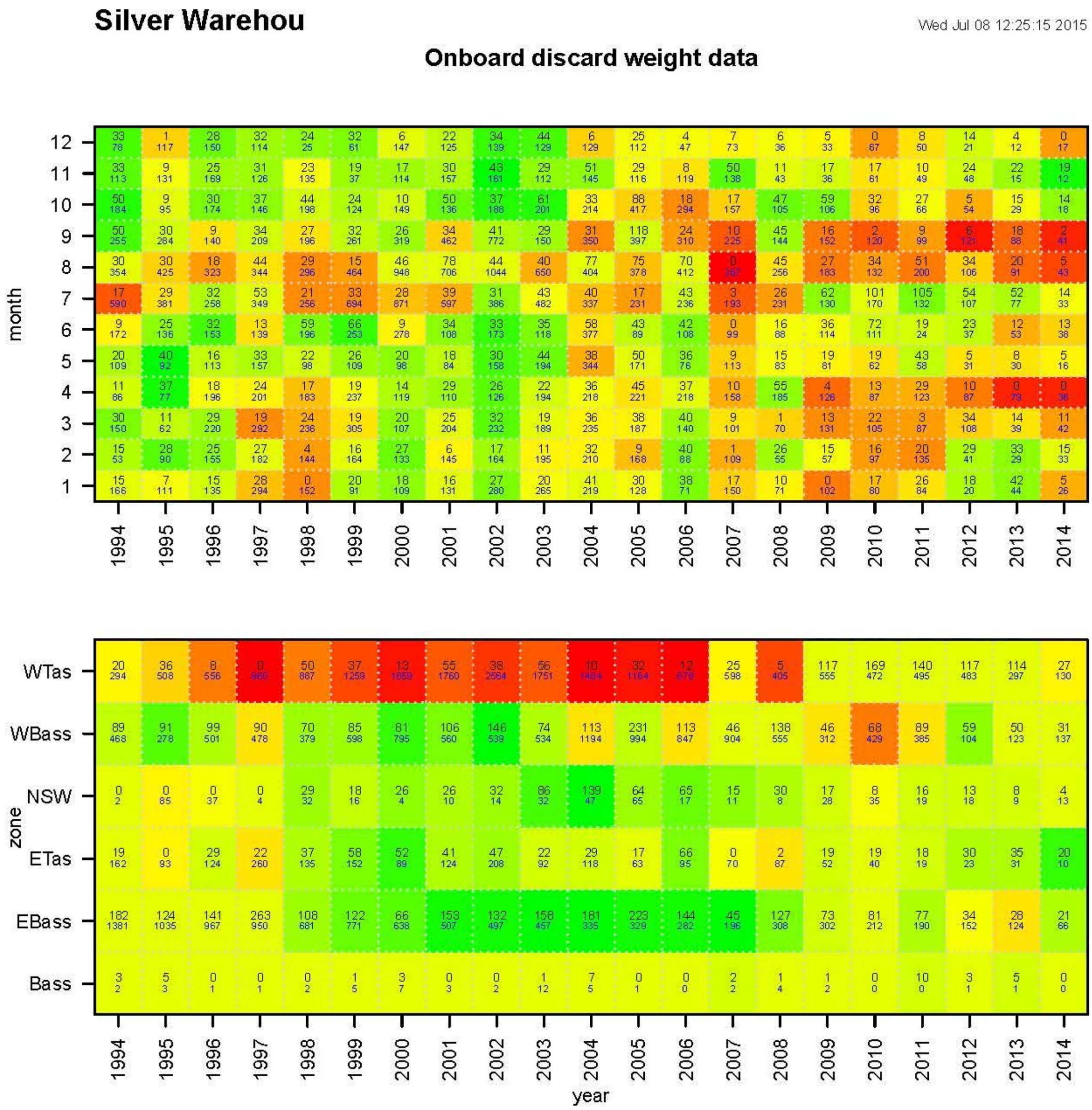
Refer to next 21 pages.

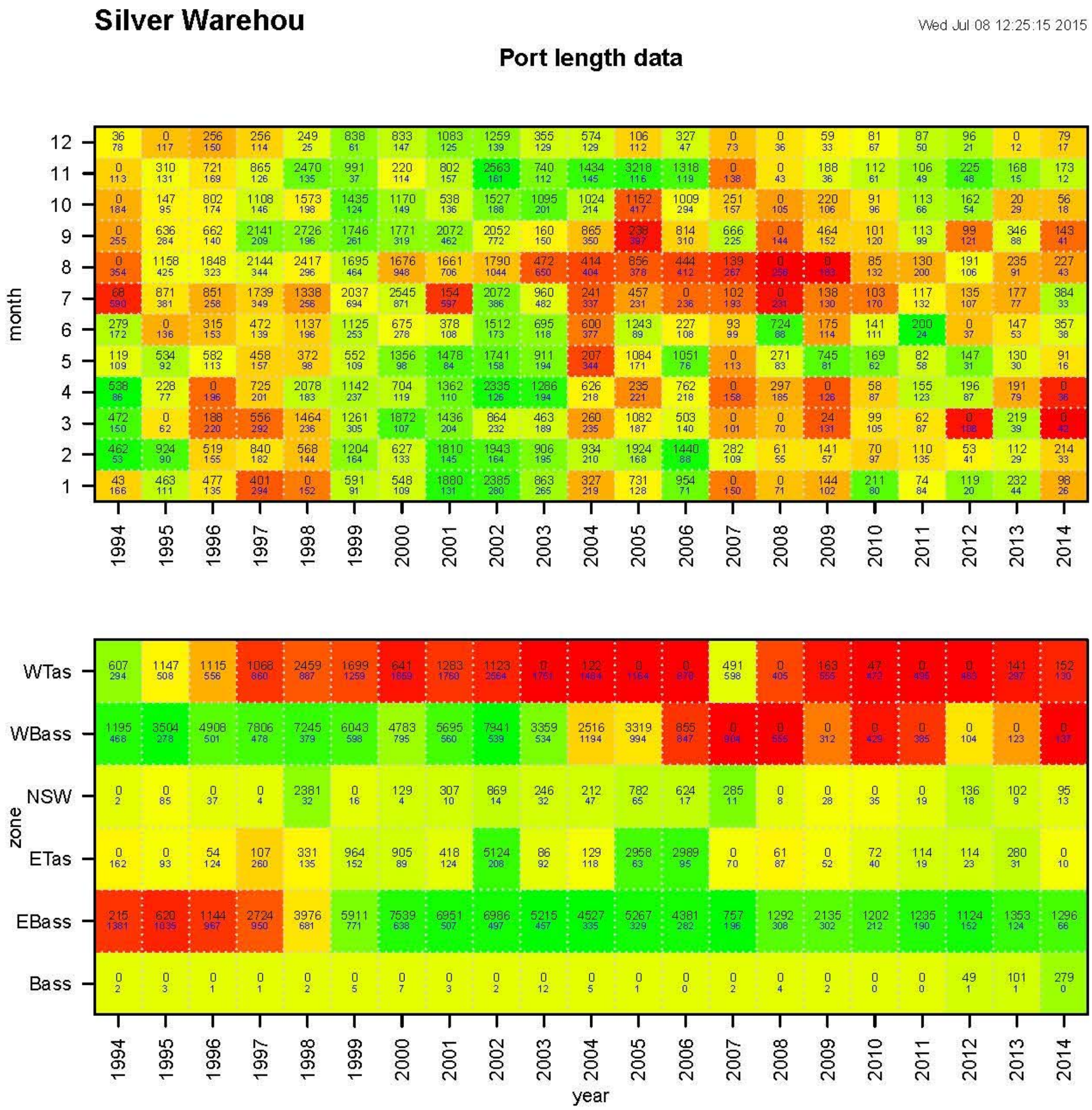

Silver Warehou
Wed Jul 08 12:24:00 2015
region SET unit code TRS
CAAB 37445006
start month 1
TAC and landings
TAC
landings (CDR)
trawl & DS (log)
non−trawl (log)
State
catch and TAC (tonnes)
0
1000
2000
3000
4000
5000
1986
1989
1992
1995
1998
2001
2004
2007
2010
2013
year
Geometric mean CPUE
trawl
trawl kg/hr
0
10
20
30
40
50
1986
1989
1992
1995
1998
2001
2004
2007
2010
2013
year
Catch at depth
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
0
100
250
400
550
700
850
1000
depth

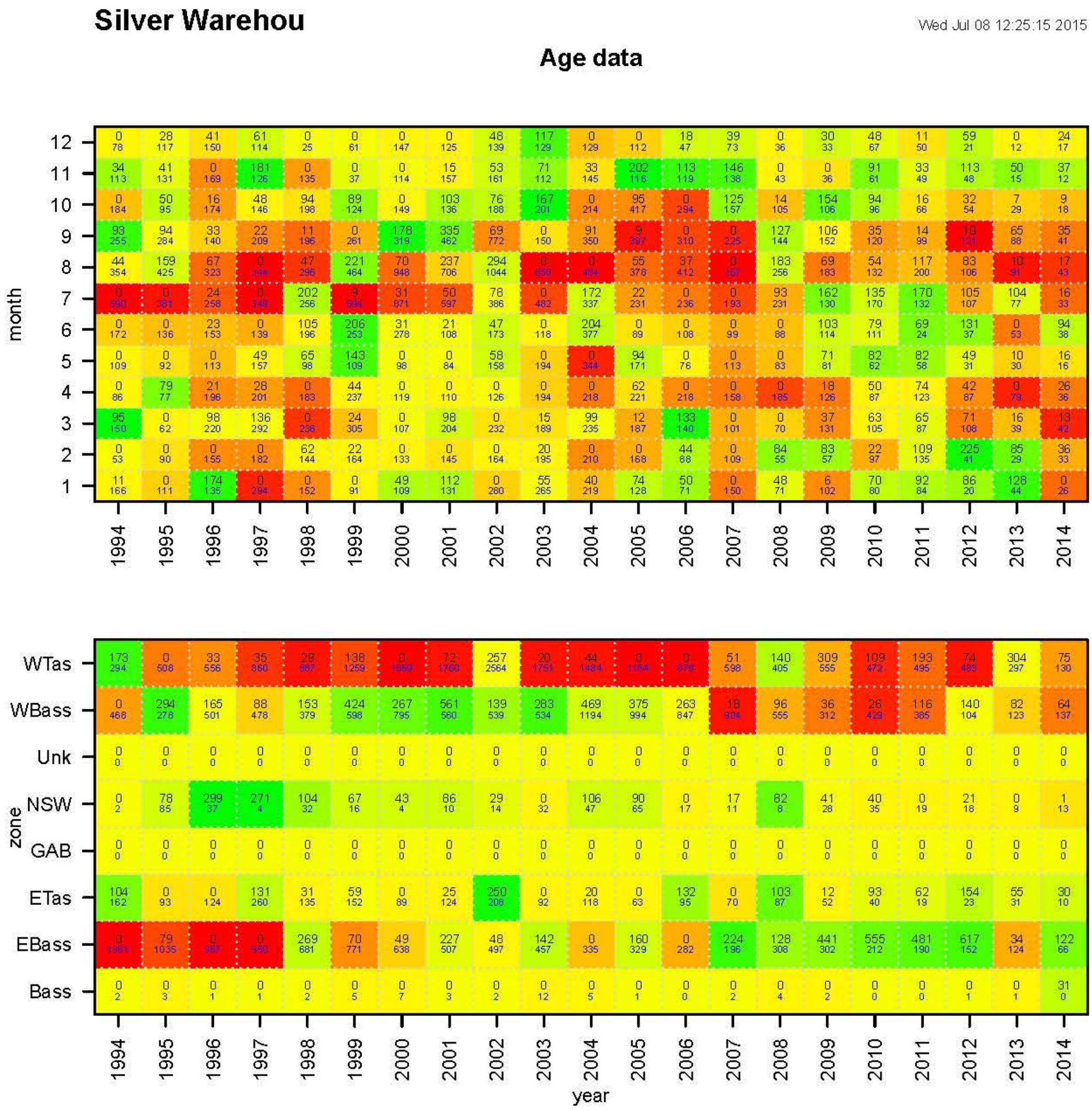

Silver Warehou
Wed Jul 08 12:24:52 2015
Catch by gear
trawl
catch (tonnes)
0
1000
2000
3000
4000
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
Catch by zone
EBass
ETas
WBass
WTas
catch (tonnes)
0
1000
2000
3000
4000
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
Discards
discard %
0
10
20
30
40
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012


Silver Warehou
Wed Jul 08 12:25:05 2015
Port length frequency
1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014
2017 5271 7221 11705 16392 14617 13997 15050 22043 8906 7506 12326 8849 1533 1353 2298 1321 1349 1423 1977 1822
Onboard length frequency
retained
172 142 415 3468 5731 4926 5340 6189 6601 7226 6550 8645 5686 235 960 1372 2763 1614 1798 2426 1042
discarded
2567 4811 4148 466 2077 487 506 2259 3062 1875 4565 1990 140 0 334 225 266 313 487 298 163
Age frequency
age
359 451 515 566 586 782 407 999 723 445 639 625 395 310 549 839 823 852 1006 475 323


Silver Warehou
Wed Jul 08 12:25:15 2015
Onboard length data
month
12
11
10
9
8
7
6
5
4
3
2
1
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
zone
WTas
WBass
NSW
ETas
EBass
Bass
year


Silver Warehou
Wed Jul 08 12:25:15 2015
Onboard discard weight data
month
12
11
10
9
8
7
6
5
4
3
2
1
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
zone
WTas
WBass
NSW
ETas
EBass
Bass
year

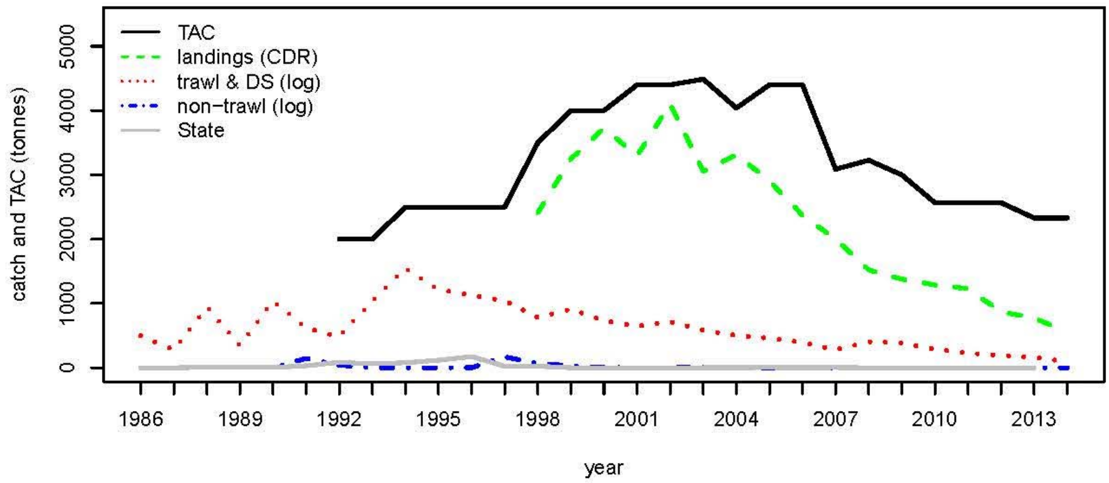

Silver Warehou
Wed Jul 08 12:25:15 2015
Port length data
month
12
11
10
9
8
7
6
5
4
3
2
1
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
zone
WTas
WBass
NSW
ETas
EBass
Bass
year


Silver Warehou
Wed Jul 08 12:25:15 2015
Age data
month
12
11
10
9
8
7
6
5
4
3
2
1
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
zone
WTas
WBass
Unk
NSW
GAB
ETas
EBass
Bass
year

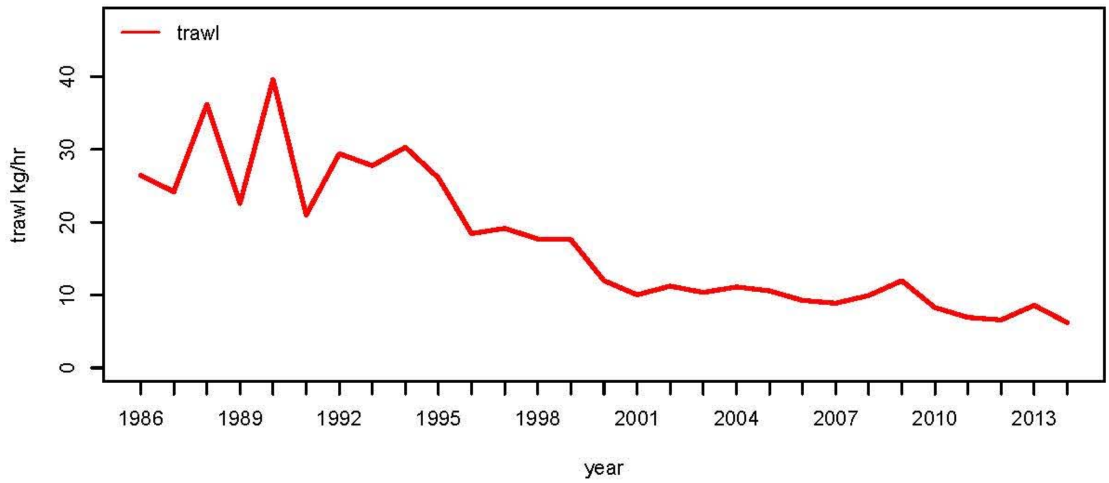
Silver Warehou East

Wed Jul 08 12:25:39 2015
region SEFEAST unit code TRS
CAAB 37445006
start month 1

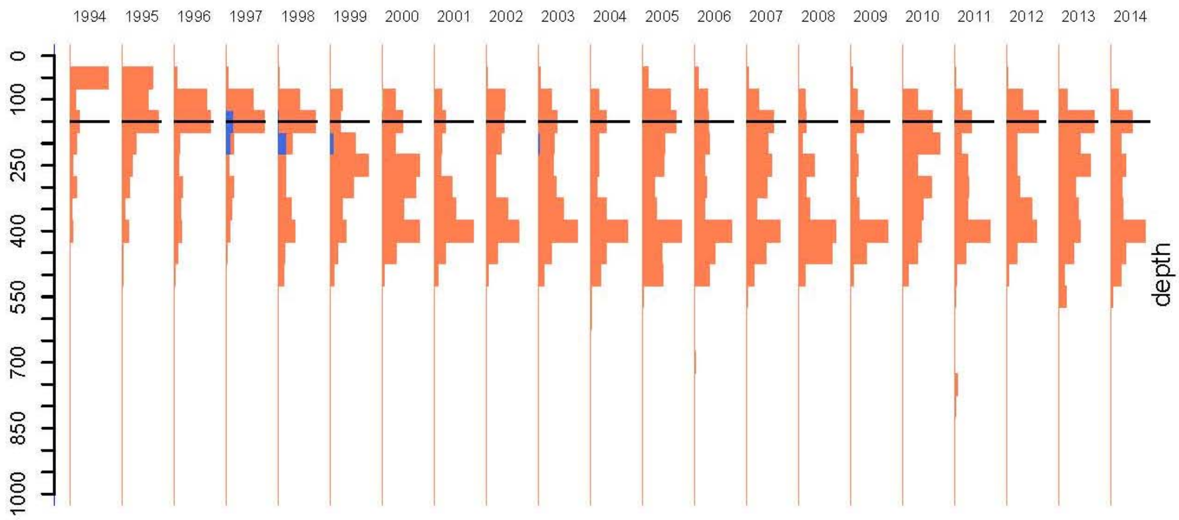
TAC and landings

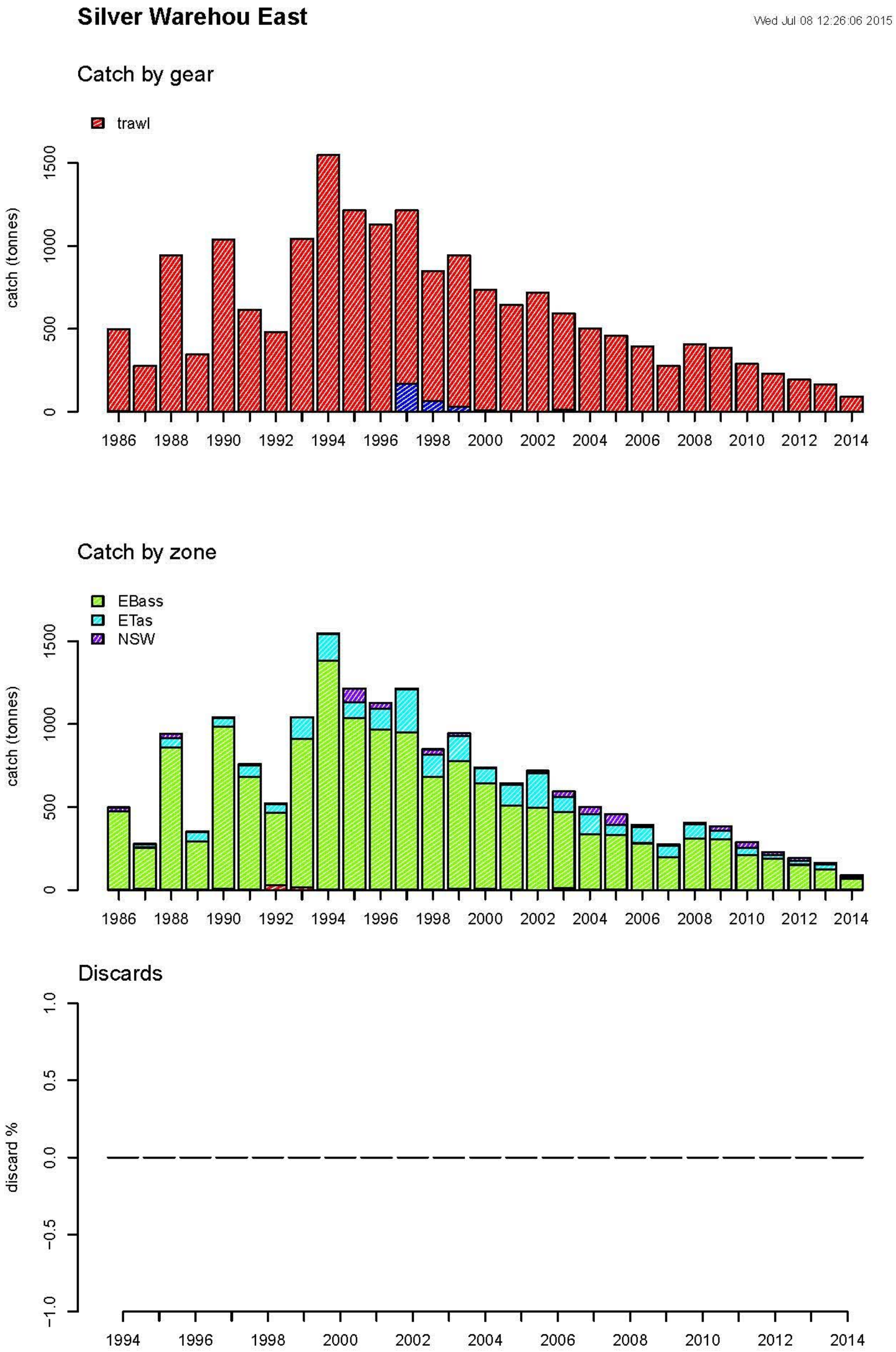


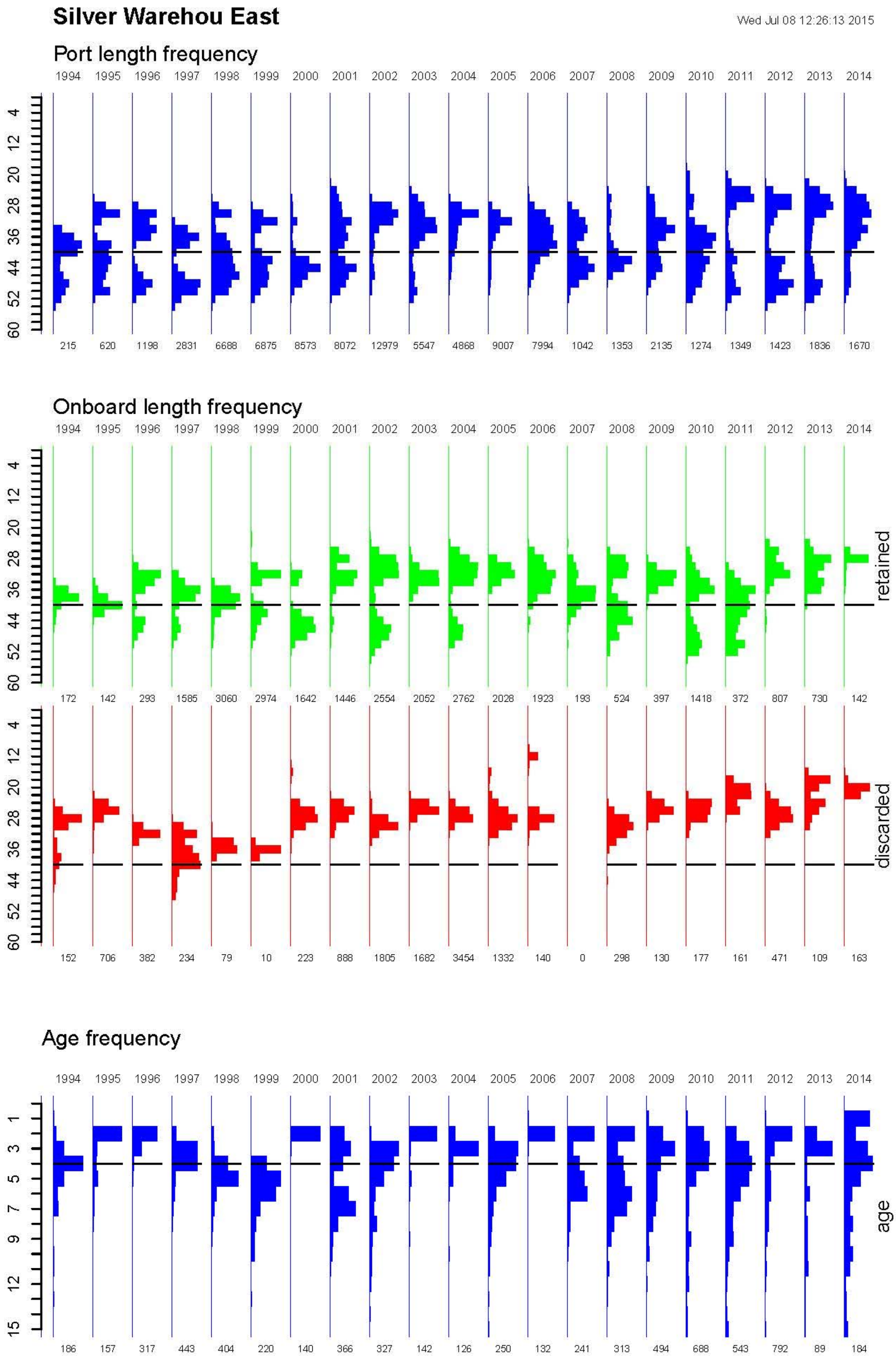
Geometric mean CPUE

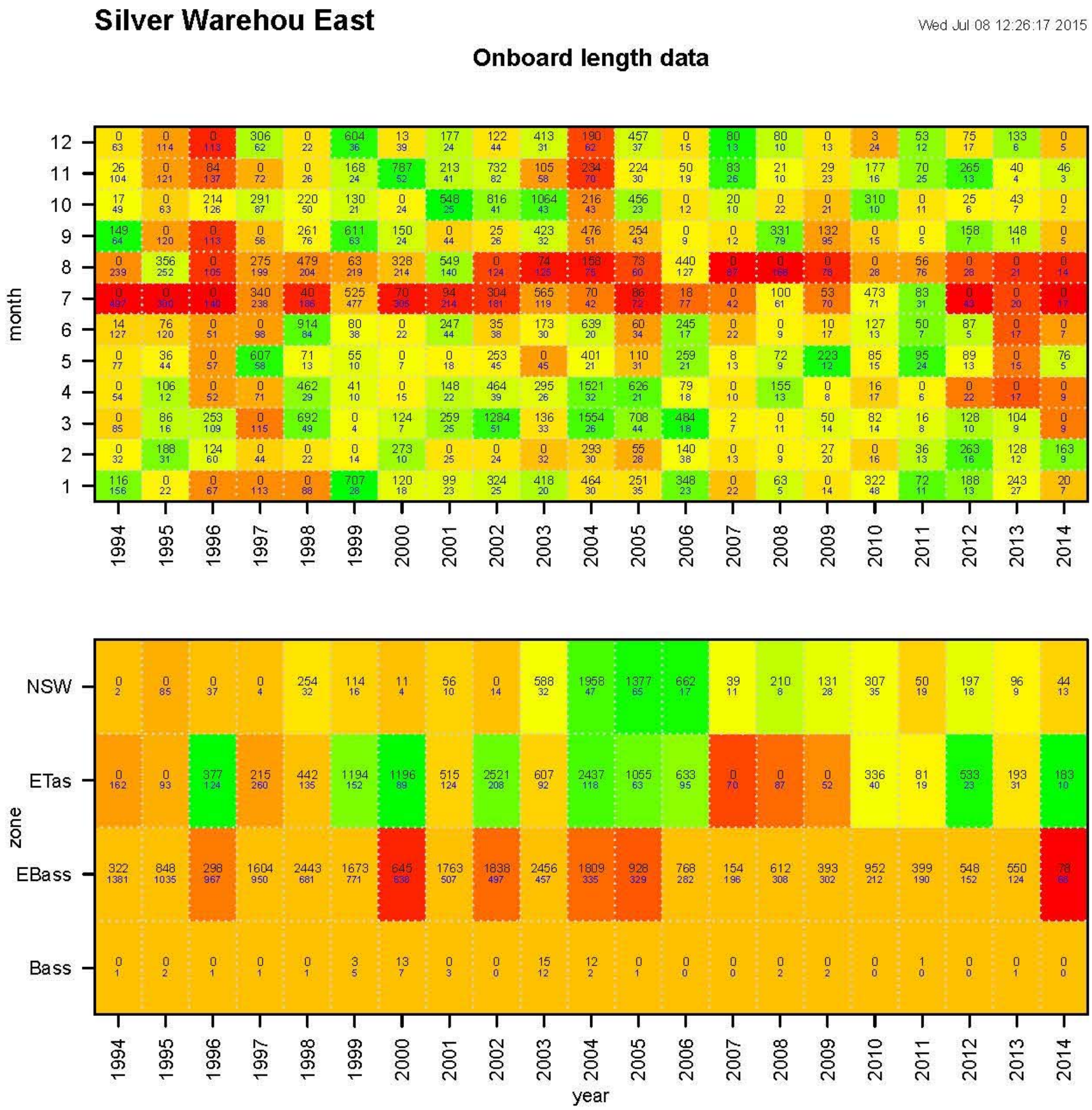


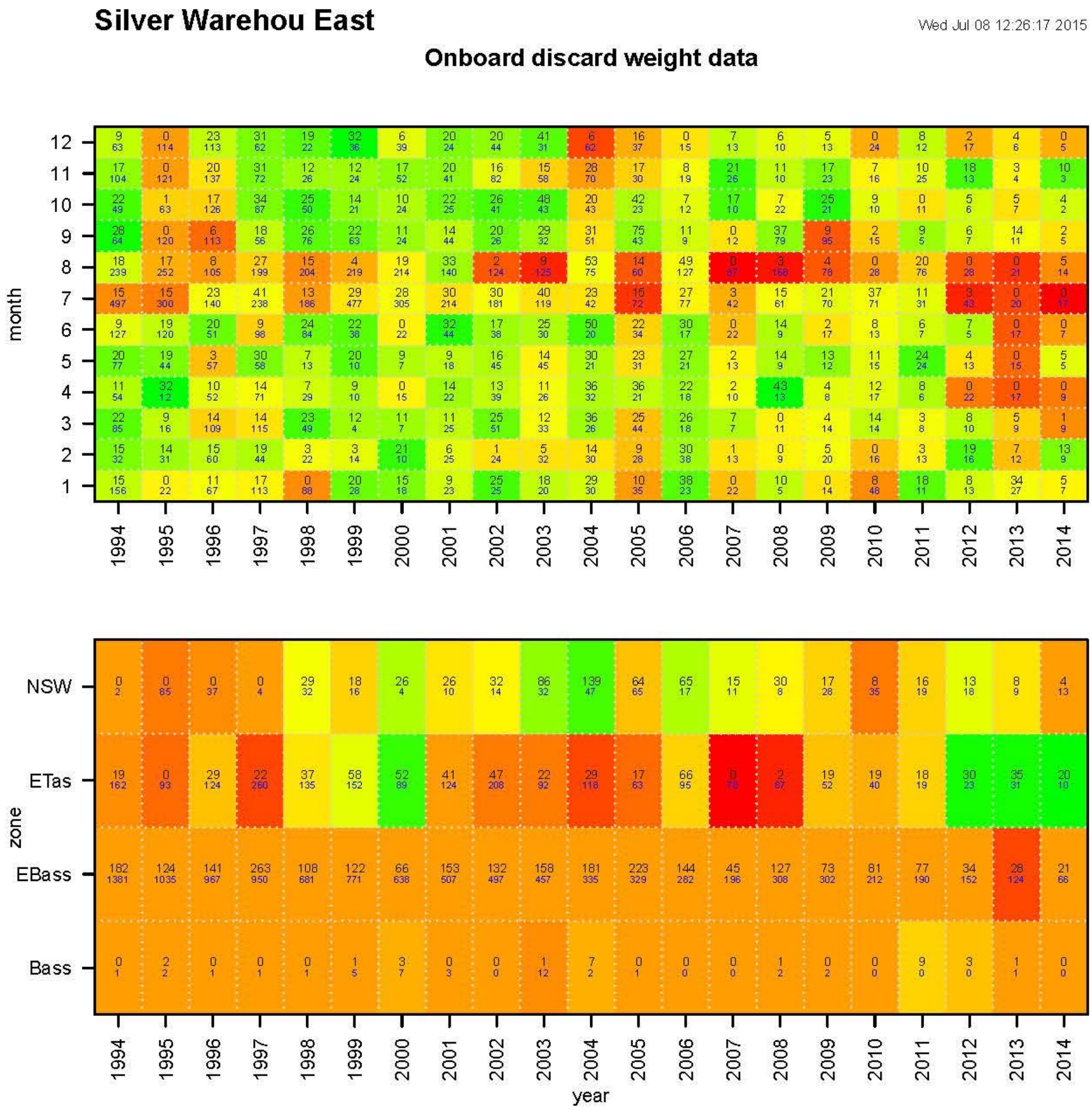
Catch at depth

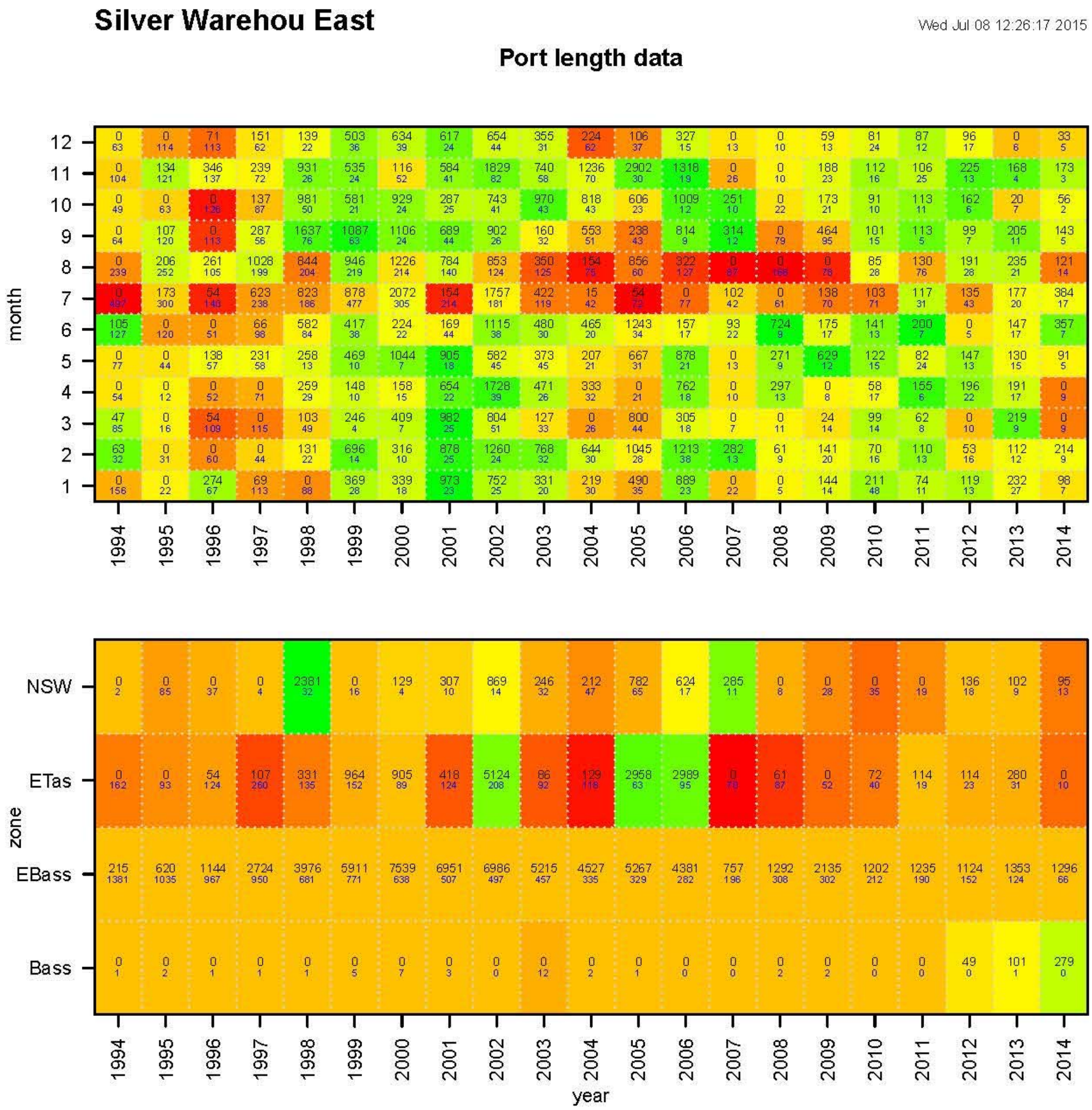


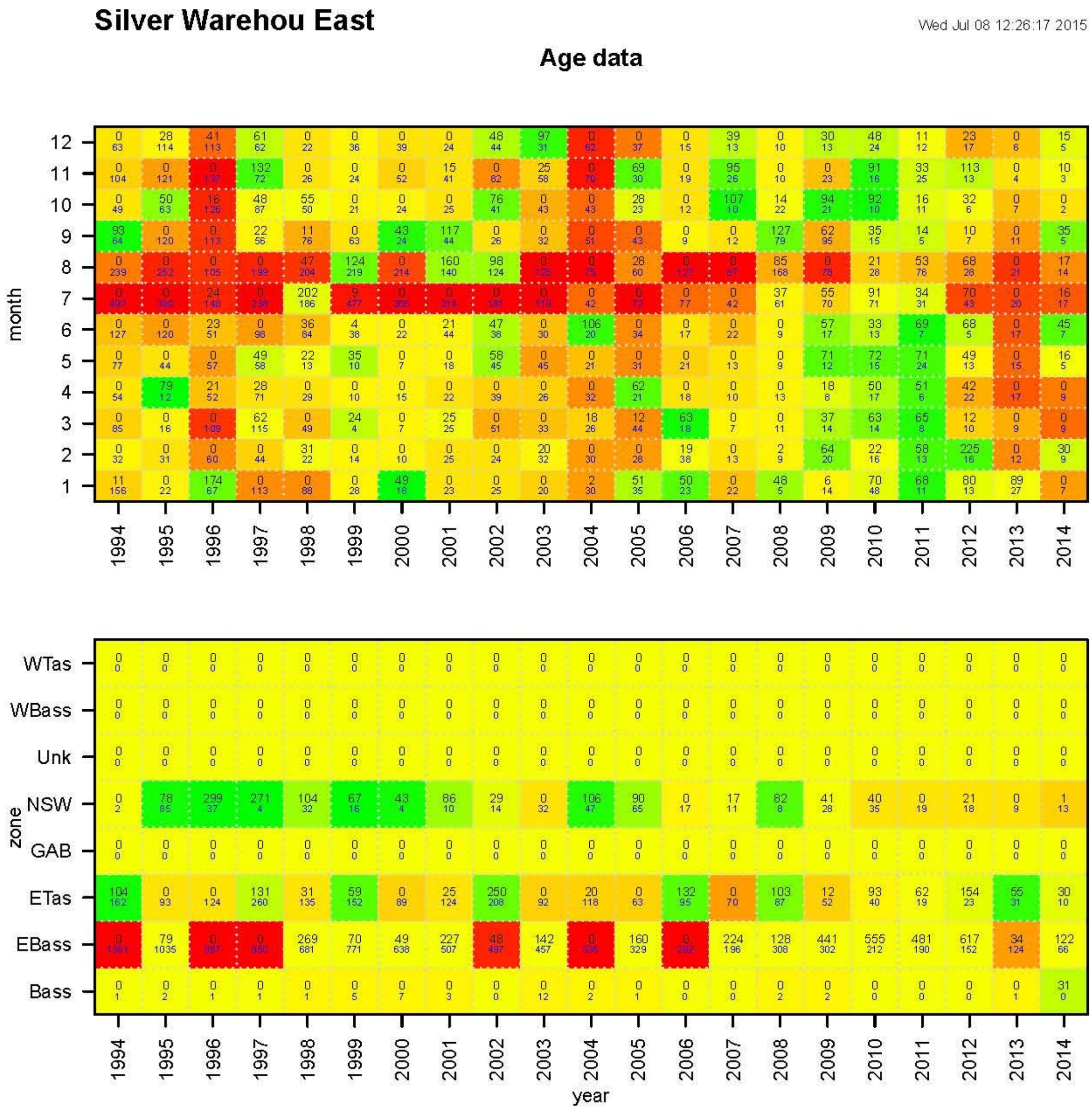

Silver Warehou East
Wed Jul 08 12:26:06 2015
Catch by gear
trawl
catch (tonnes)
0
500
1000
1500
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
Catch by zone
EBass
ETas
NSW
catch (tonnes)
0
500
1000
1500
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
Discards
discard %
−1.0
−0.5
0.0
0.5
1.0
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014


Silver Warehou East
Wed Jul 08 12:26:13 2015
Port length frequency
1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014
4 12 20 28 36 44 52 60
215 620 1198 2831 6688 6875 8573 8072 12979 5547 4868 9007 7994 1042 1353 2135 1274 1349 1423 1836 1670
Onboard length frequency
1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014
4 12 20 28 36 44 52 60
retained
172 142 293 1585 3060 2974 1642 1446 2554 2052 2762 2028 1923 193 524 397 1418 372 807 730 142
4 12 20 28 36 44 52 60
discarded
152 706 382 234 79 10 223 888 1805 1682 3454 1332 140 0 298 130 177 161 471 109 163
Age frequency
1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014
1 3 5 7 9 12 15
age
186 157 317 443 404 220 140 366 327 142 126 250 132 241 313 494 688 543 792 89 184


Silver Warehou East
Wed Jul 08 12:26:17 2015
Onboard length data
month
12
11
10
9
8
7
6
5
4
3
2
1
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
zone
NSW
ETas
EBass
Bass
year


Silver Warehou East
Wed Jul 08 12:26:17 2015
Onboard discard weight data
month
12
11
10
9
8
7
6
5
4
3
2
1
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
zone
NSW
ETas
EBass
Bass
year

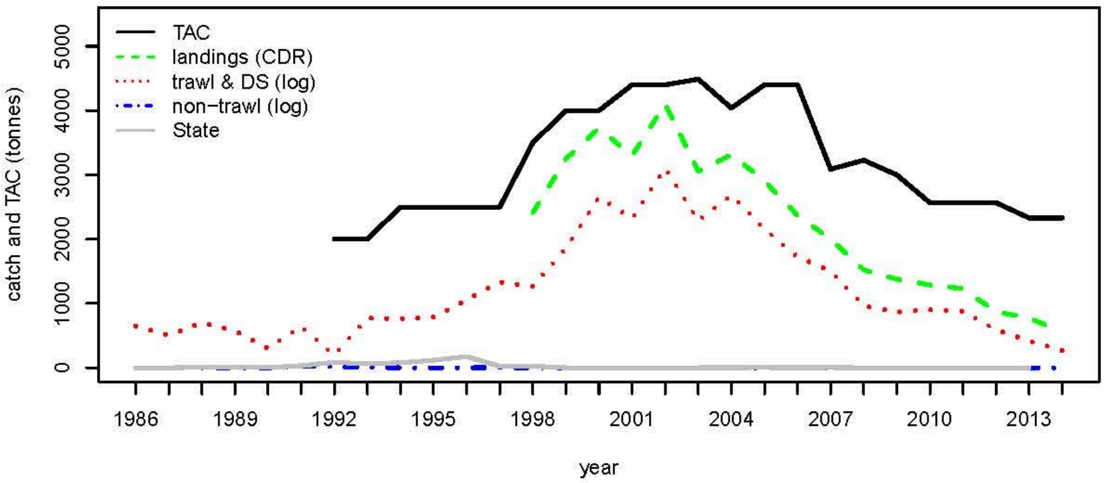

Silver Warehou East
Wed Jul 08 12:26:17 2015
Port length data
month
zone
NSW
ETas
EBass
Bass
year


Silver Warehou East
Wed Jul 08 12:26:17 2015
Age data
month
12
11
10
9
8
7
6
5
4
3
2
1
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
zone
WTas
WBass
Unk
NSW
GAB
ETas
EBass
Bass
year

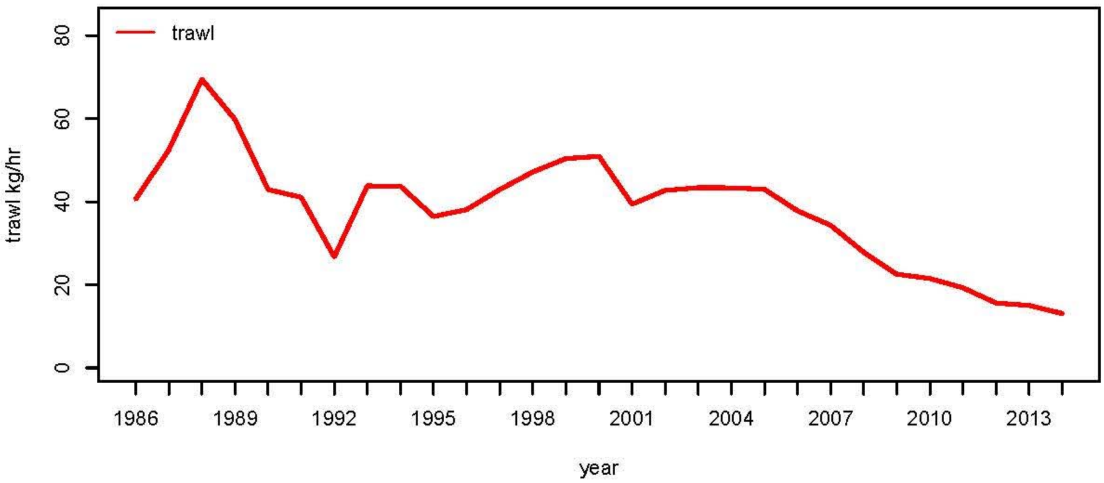
Silver Warehou West

Wed Jul 08 12:26:41 2015
region SEFWEST unit code TRS
CAAB 37445006
start month 1

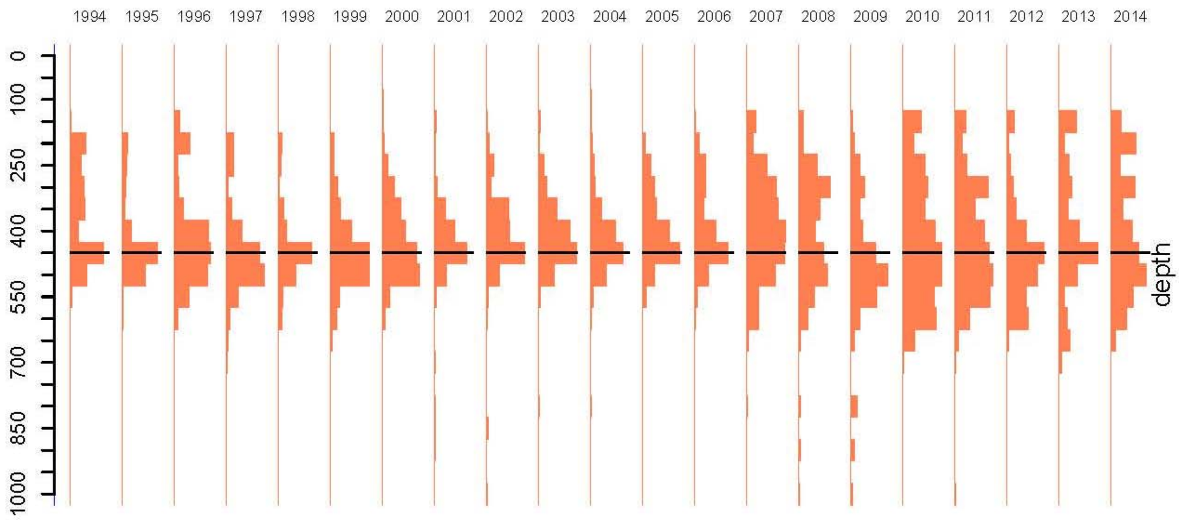
TAC and landings

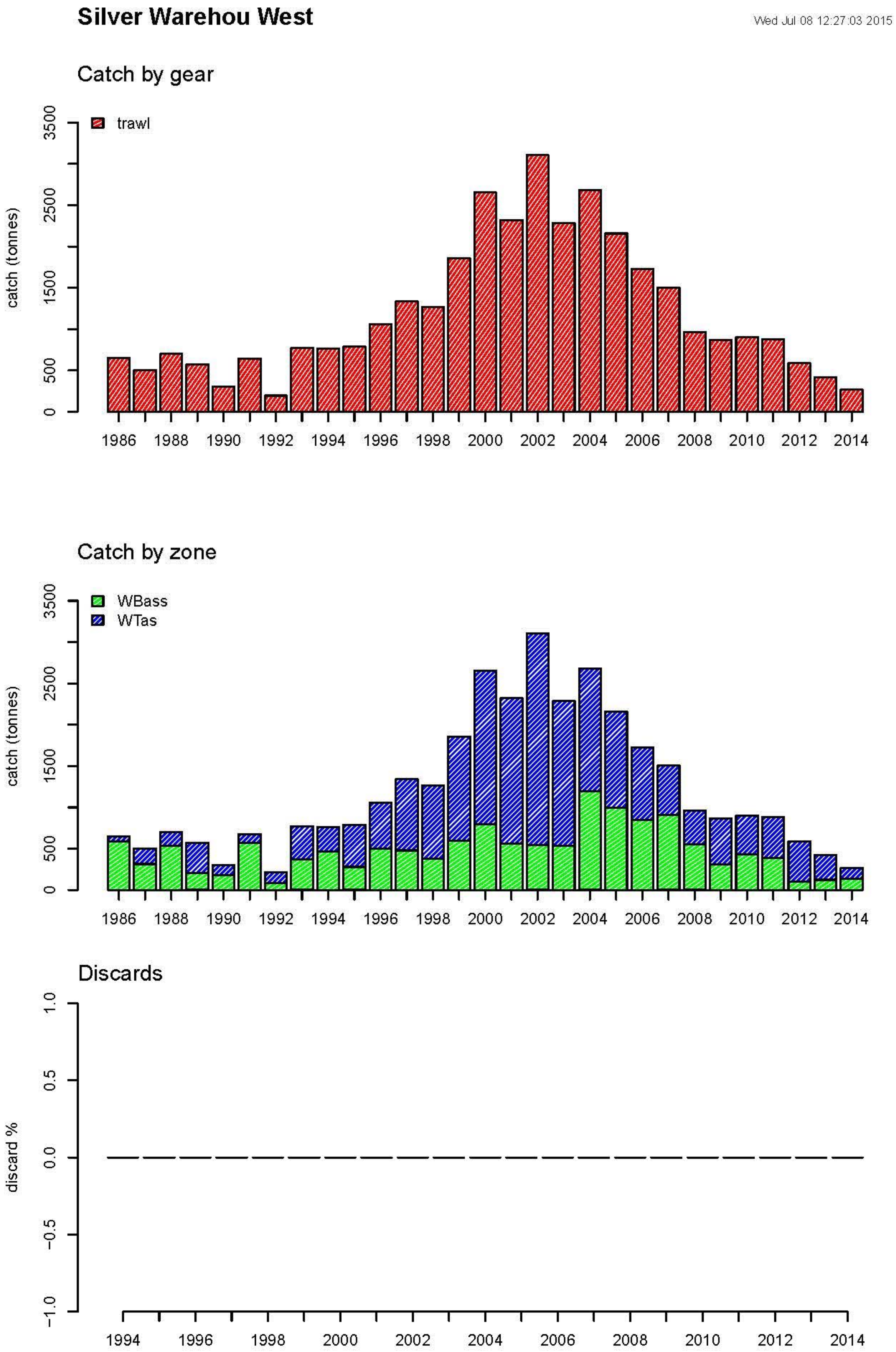


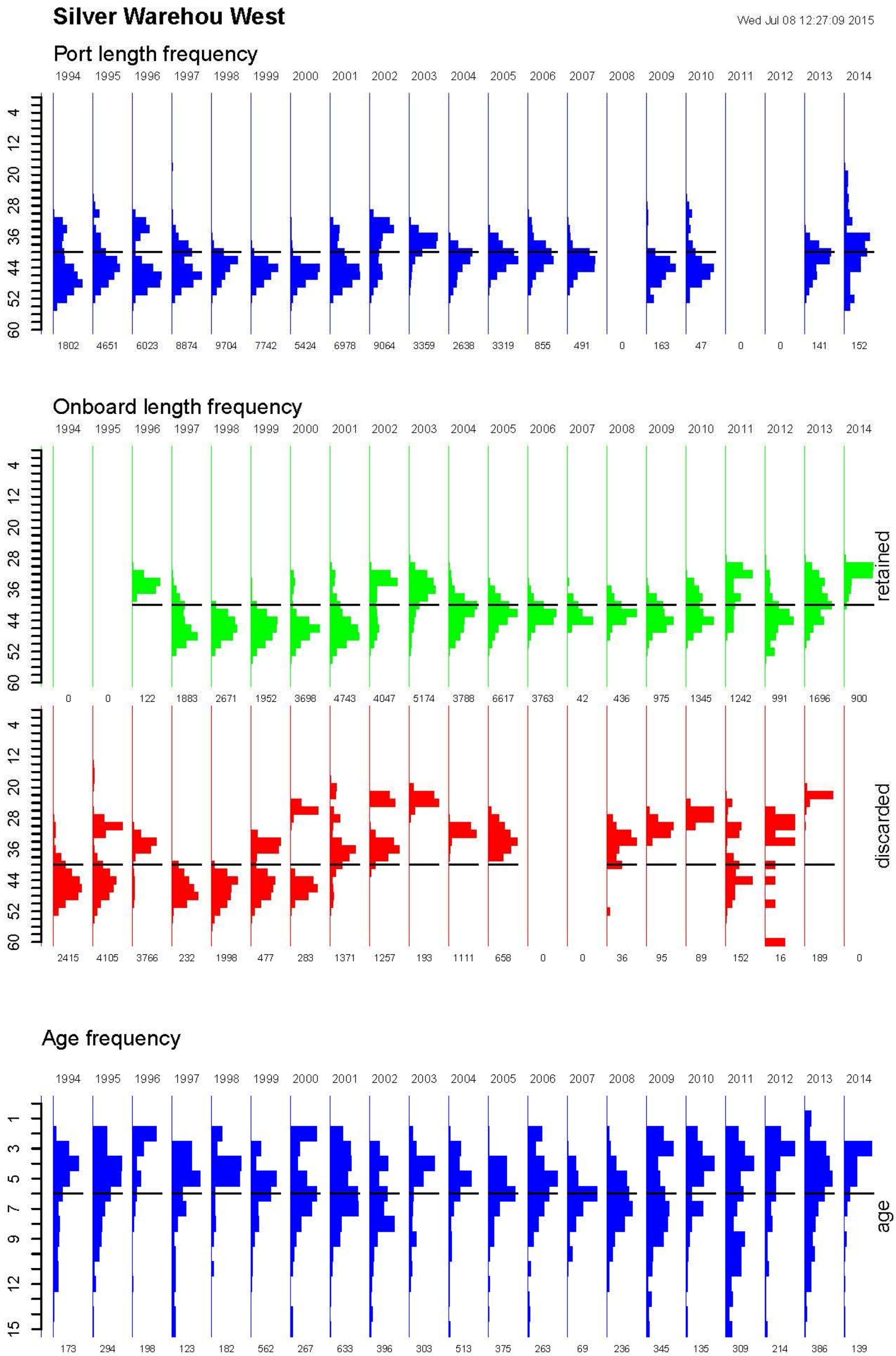
Geometric mean CPUE



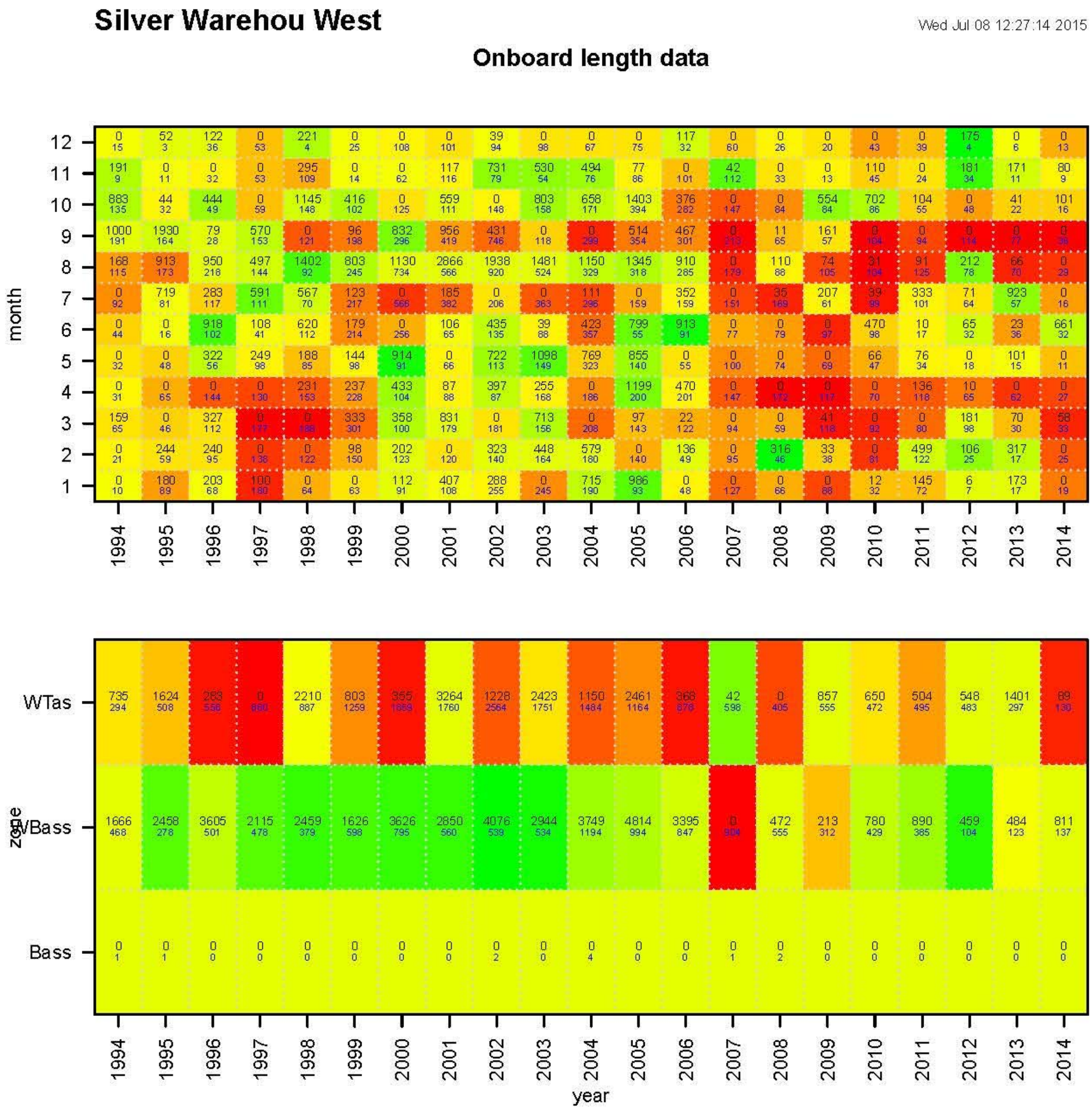
Catch at depth



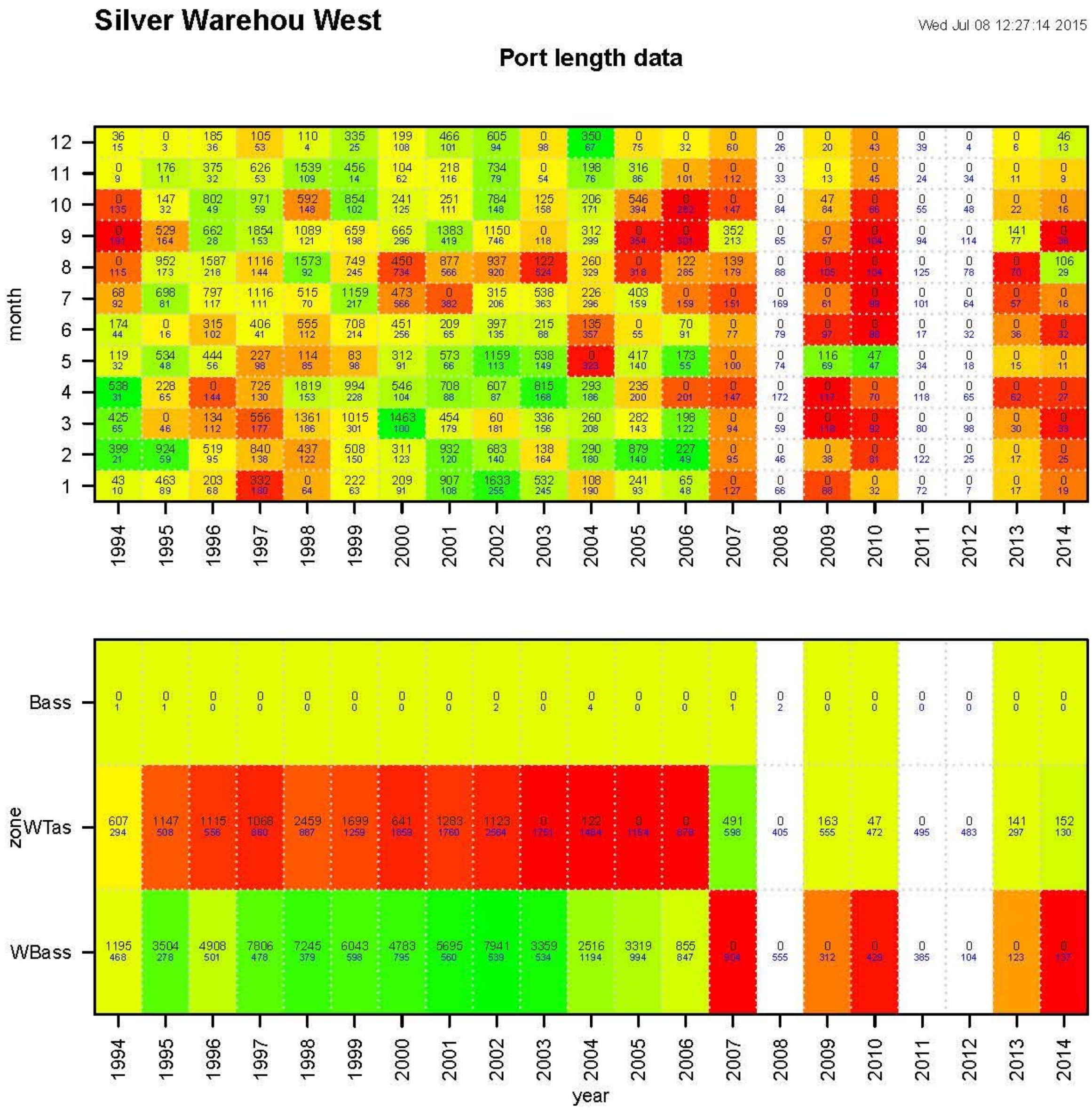

Silver Warehou West
Wed Jul 08 12:27:03 2015
Catch by gear
trawl
catch (tonnes)
Catch by zone
WBass
WTas
catch (tonnes)
Discards
discard %

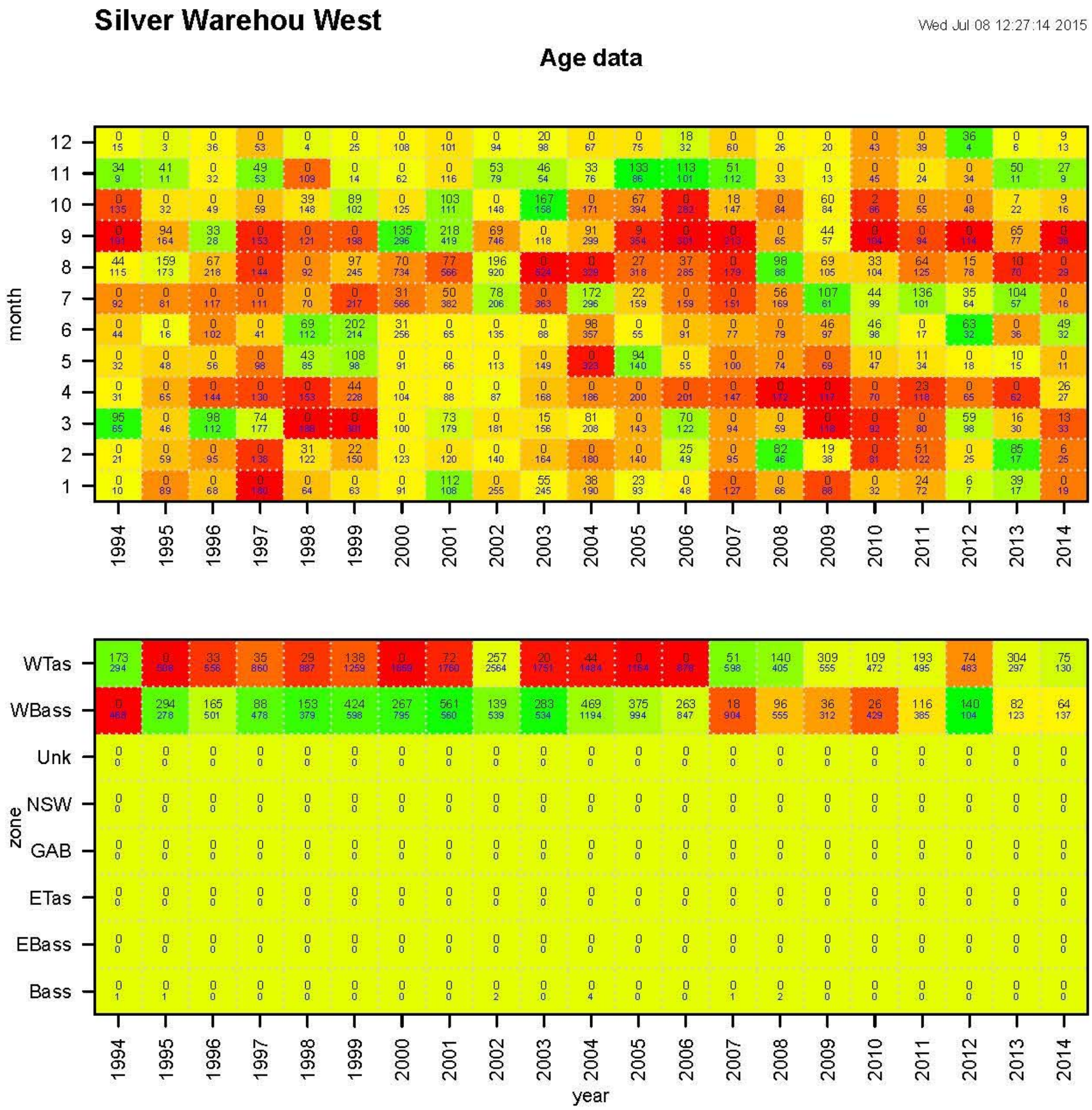


Silver Warehou West
Wed Jul 08 12:27:09 2015
Port length frequency
1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014
4 12 20 28 36 44 52 60
1802 4651 6023 8874 9704 7742 5424 6978 9064 3359 2638 3319 855 491 0 163 47 0 0 141 152
Onboard length frequency
1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014
retained
0 0 122 1883 2671 1952 3698 4743 4047 5174 3788 6617 3763 42 436 975 1345 1242 991 1696 900
discarded
2415 4105 3766 232 1998 477 283 1371 1257 193 1111 658 0 0 36 95 89 152 16 189 0
Age frequency
1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014
1 3 5 7 9 12 15
age
173 294 198 123 182 562 267 633 396 303 513 375 263 69 236 345 135 309 214 386 139


Silver Warehou West
Wed Jul 08 12:27:14 2015
Onboard length data
month
year
zone
WTas
WBass
Bass


Silver Warehou West
Wed Jul 08 12:27:14 2015
Onboard discard weight data
month
12
11
10
9
8
7
6
5
4
3
2
1
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
zone
WTas
WBass
Bass
year


Silver Warehou West
Wed Jul 08 12:27:14 2015
Port length data
month
12
11
10
9
8
7
6
5
4
3
2
1
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
zone
Bass
WTas
WBass
year


Silver Warehou West
Wed Jul 08 12:27:14 2015
Age data
month
zone
WTas
WBass
Unk
NSW
GAB
ETas
EBass
Bass
year

16. Sensitivity of eastern gemfish survey on stock assessment

Rich Little

CSIRO, GPO Box 1538, Hobart, Tasmania

16.1 Introduction

The stock assessment for eastern gemfish is composed of four fleets:

1. A non-trawl fleet
2. A summer trawl fleet
3. A winter fleet that avoids the spawning run
4. A winter fleet that targets the spawning run

An index of abundance was originally developed by Punt et al. (2001) for the winter targeted spawning fleet. This index was continued in 2007 and 2008 for surveys of the spawning run. Discussion has occurred over the potential effect of a spawning run survey. In this report we explored the effect of the spawning survey on the assessment.

16.2 Methods

The most recent version of the eastern gemfish stock assessment was used. It has also been used recently in determining the breakout rules in the CPUE projection (Thomson et al. 2015). The model estimated recruitment to 2015.

The assessment uses a winter targeted spawning run index of abundance that was most recently updated in 2007 and 2008. Age data collected from the survey were also used in the assessment.

Two forms of sensitivity to the survey data were explored:

1. To explore the sensitivity of these survey data, we removed the 2007 and 2008 CPUE index of abundance and age data, and determined what the spawning depletion level would have been estimate at, given these surveys were not conducted (no survey).
2. We added a range of candidate surveys, index of abundance for 2015. The 2015 potential values for targeted spawning run index of abundance were:
    a. an index in 2015 that was at 2008 levels (new med)
    b. an index **10% higher** than in 2008 (new high)
    c. an index **10% lower** than in 2008 (new low)
    d. an index **40% higher** than in 2008 (new v. high)
    e. an index **40% lower** than in 2008 (new v. low)

No age or length data were contrived to correspond with these potential survey values, and so the results should be considered with caution, consequently, the effect of a survey on reducing the CVs of estimated quantities could not be considered. In particular, the inclusion of new age and length data from a 2015 survey would be expected to greatly improve estimates of recent recruitments and hence improve the accuracy and precision model projections into the near future.

16.3 Results and Discussion

16.3.1 The effect of no survey on the previous assessment

The effect of the 2007 and 2008 spawning surveys on the spawning biomass results in higher relative biomass estimates compared to if the survey data were not included (Figure 16.1). The surveys resulted in an uptick in the abundance index.

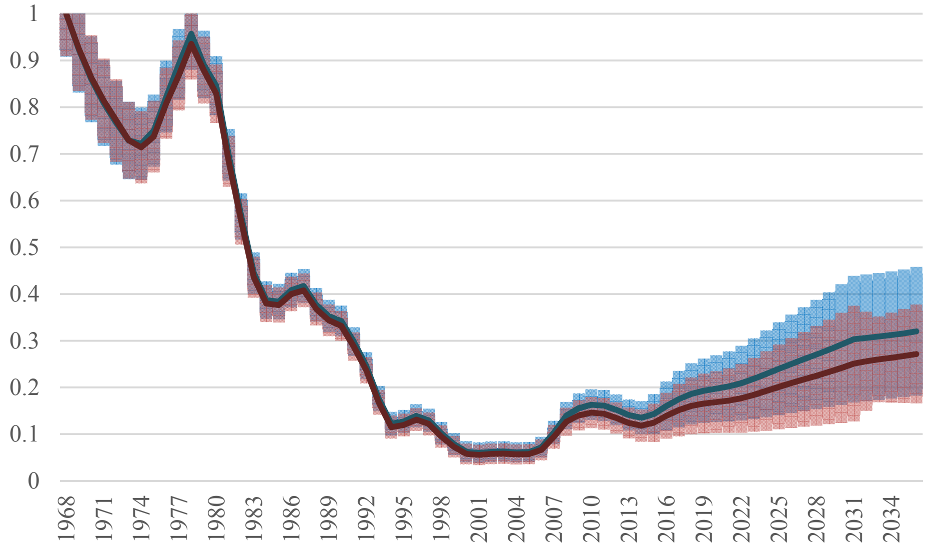


Figure 16.1. Projected relative spawning biomass to 2036 from the assessment model fitted with (blue) and without (orange) the 2007 and 2008 eastern gemfish spawning survey data.

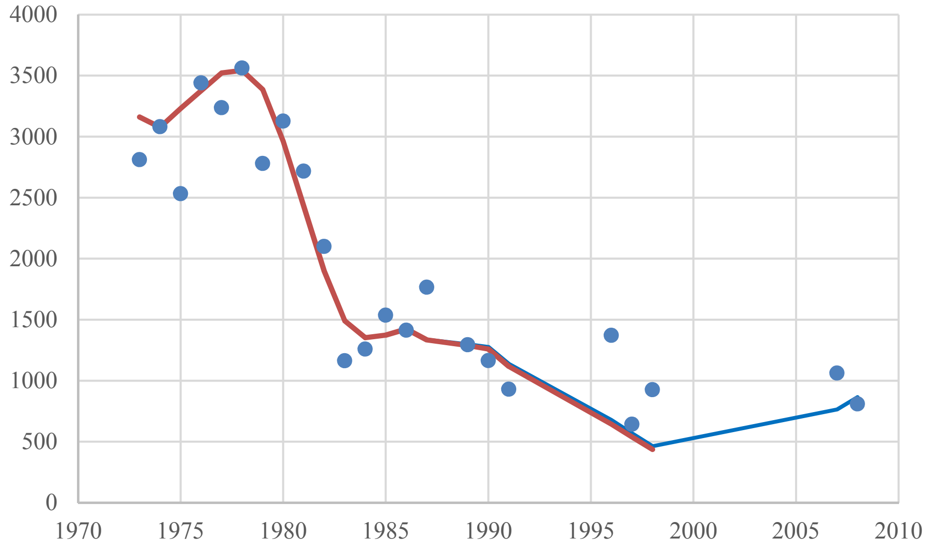


Figure 16.2. Fitted targeted spawning run index of abundance from the assessment model fitted with (blue) and without (orange) the 2007 and 2008 eastern gemfish spawning survey data.

16.3.2 The effect of a survey on a future assessment

Different possible values of a survey index of abundance show that as the index increases, the spawning biomass correspondingly increases as well (Figure 16.3 and Figure 16.4).

The assessment seems to more easily fit a declining catch rate than an increasing one (Figure 16.5), likely because of lack of age data to indicate that a recruitment event has occurred.

This analysis did not include new age or length data, and thus would not be able to indicate any new recruitment events that might have recently occurred. Inclusion of new age and length data from a 2015 survey would be expected to greatly improve estimates of recent recruitments and hence improve the accuracy and precision model projections into the near future.

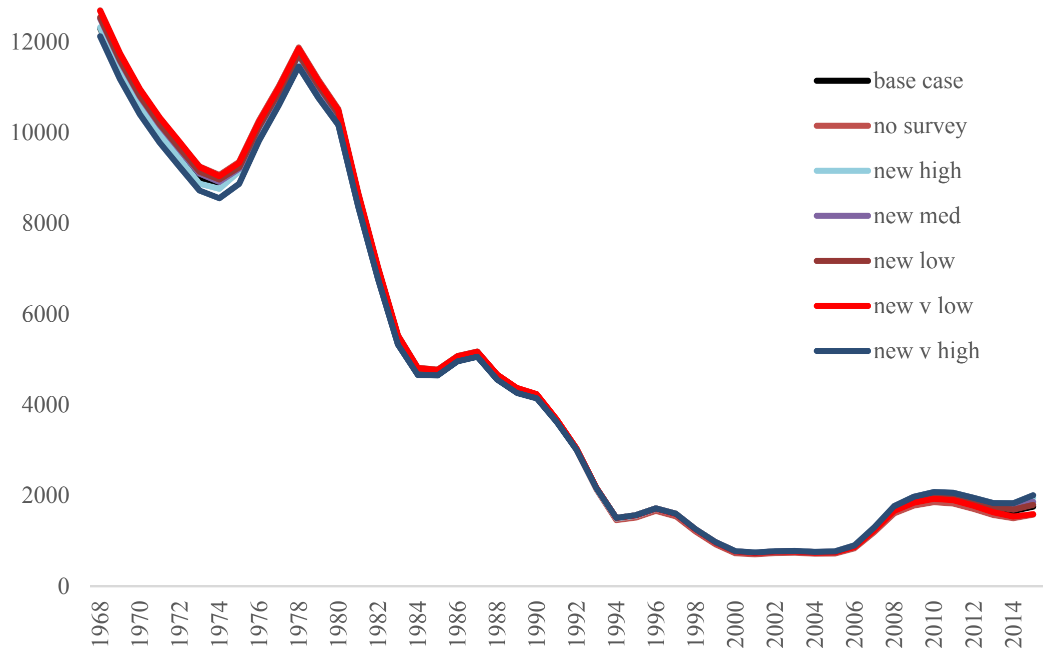


Figure 16.3. Spawning biomass (tonnes) estimated 1968-2015 by the assessment model when different values of a 2015 targeted spawning run index of abundance is used.

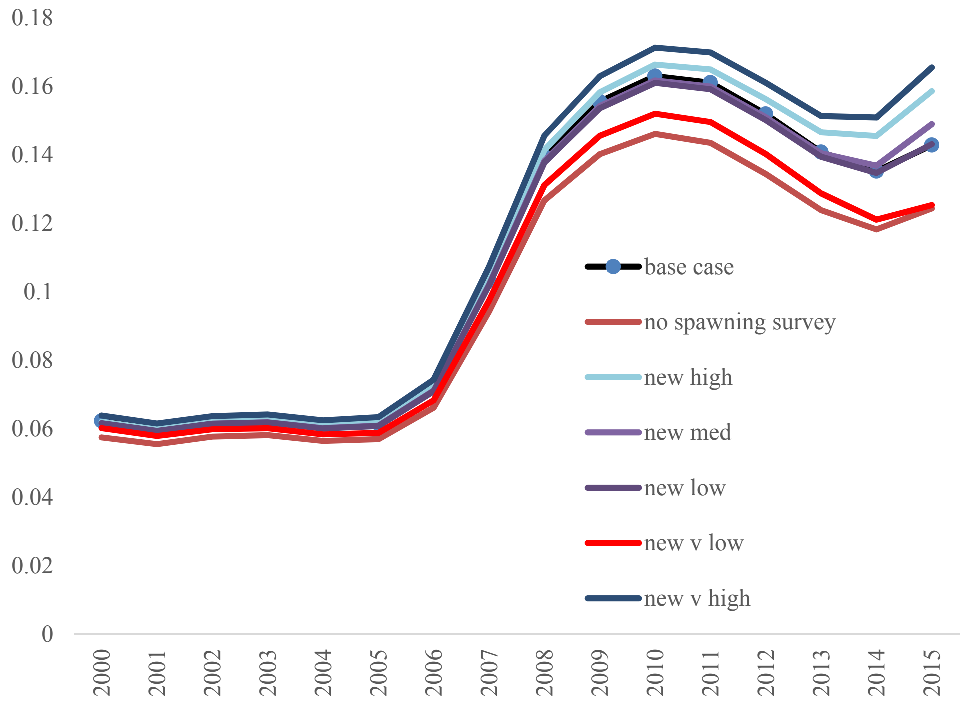


Figure 16.4. Relative spawning biomass estimated for 2000-2015 by the assessment model when different values of a 2015 targeted spawning run index of abundance is used.

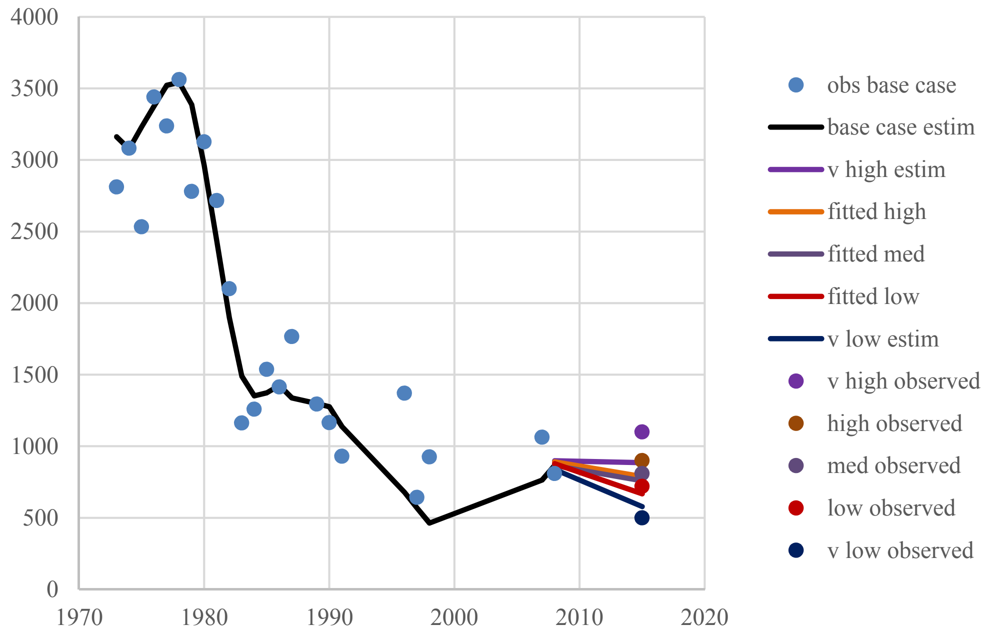


Figure 16.5. Fitted targeted spawning run index of abundance from the assessment model fitted when different values of a 2015 targeted spawning run index of abundance is used.

16.4 References

Punt, A.E., Rowling, K., and Prince, J. 2001. Summary of the Data for Use in the Assessments of the Eastern Stock of Gemfish based on the 2000 Fishing Season, Report to the EGAG.

Thomson, R., Klaer, N. Sporcic, M., Tuck, G., Day, J and Little R. 2015. SESSF Tier 1 CPUE forecasts for multi-year TAC review triggers. Prepared for the Australian Fisheries Management Authority (AFMA) Southern and Eastern Scalefish and Shark Fishery Resource Assessment Group Data Meeting (SESSFRAG Data), 4-5 August 2015, Hobart.

17. Spatial examination of catch ratios of school shark to gummy shark, and school shark discard rates in the SESSF

Robin Thomson

CSIRO, Castray Esplanade, Hobart, 7000, Australia

17.1 Introduction

The shark fishing industry are required to adhere to a catch ratio of 20% school shark : gummy shark by weight, as a means to achieve the management objectives of preventing targeting and minimising discarding (SharkRAG 2014). SharkRAG are in the process reviewing this ratio, to assess whether it is the optimal method for achieving the management objectives. A pertinent issue is whether school to gummy shark catch ratios differ spatially, and this report aims to examine that question. School to gummy shark catch ratios from logbooks are presented by shark management area (essentially 1 degree squares) and by fishing sector (gillnets, hook and line shallower or deeper than 183m). However, because logbook data involve unknown amounts of discarding, AFMA onboard observations of discarding are also presented spatially, for the same gears. Because discard rates could, themselves offer a measure of school shark regional abundance, discard rates are also presented for trawl gear.

17.2 Catch ratio

This brief report uses school and gummy shark catch information from AFMA logbooks. School to gummy shark catch ratios are presented by shark *area* (essentially 1 degree square). Catch ratios were calculated from logbook data as follows:

1. Assign each logbook shot to a shark area.
2. Sum all school shark, and all gummy shark catches for each area.
3. Calculate school to gummy shark catch ratio as:
   Ratio = Total reported school shark catch / Total reported gummy shark catch.

Line gears were divided into shark line (shallower than 183m) and scalefish line (deeper than 183m). Data were pooled across all years for which observations are available. Figure 17.1 shows the school : gummy shark catch ratios by shark area for a range of gear types.

17.3 Discard rate

The Observer program (formerly the ISMP) collects data on the discard rates of school sharks from individual fishing shots. Like the catch ratios above, average discard rates were reported by shark area. Discard rates were calculated as follows:

1. Convert observed catch and discard weights to whole weight.
2. Calculate observed discard rate for each individual fishing shot using:

   Proportion discarded = Whole weight of discards / (Whole weight of discards + Whole weight of retained catch)

3. Assign each fishing shot to a school shark area.
4. Calculate the average discard proportion for each area.

Figure 17.2 shows the average discard rates for each area, and the number of observed shots in each area, by gear type.

Note that the method used to calculate an overall discard rate across fisheries for each SESSF quota species differs from that used here (e.g. Upston & Thomson 2015). That method uses the number of fishing shots recorded in the logbook dataset to scale up estimated discard weights for each of a number of pre-defined strata (according to Bergh et al 2009). The method used in this report is simpler, and is appropriate for the purpose at hand – to seek areas of higher observed discard rates.

Like catch ratios, discards for line gears were divided into shark line (shallower than 183m) and scalefish line (deeper than 183m), and data were pooled across all years.

17.4 References

Bergh M, Knuckey I, Gaylard J, Martens K, & Koopman M (2009) A revised sampling regime for the Southern and Eastern Scalefish and Shark Fishery. AFMA Project F2008/0627. Fishwell Consulting P/L, Victoria. 235 p.

Upston J, & Thomson R (2015) Integrated Scientific Monitoring Program for the Southern and Eastern Scalefish and Shark Fishery – Discard estimation 2014 DRAFT. September 2015.

Figures

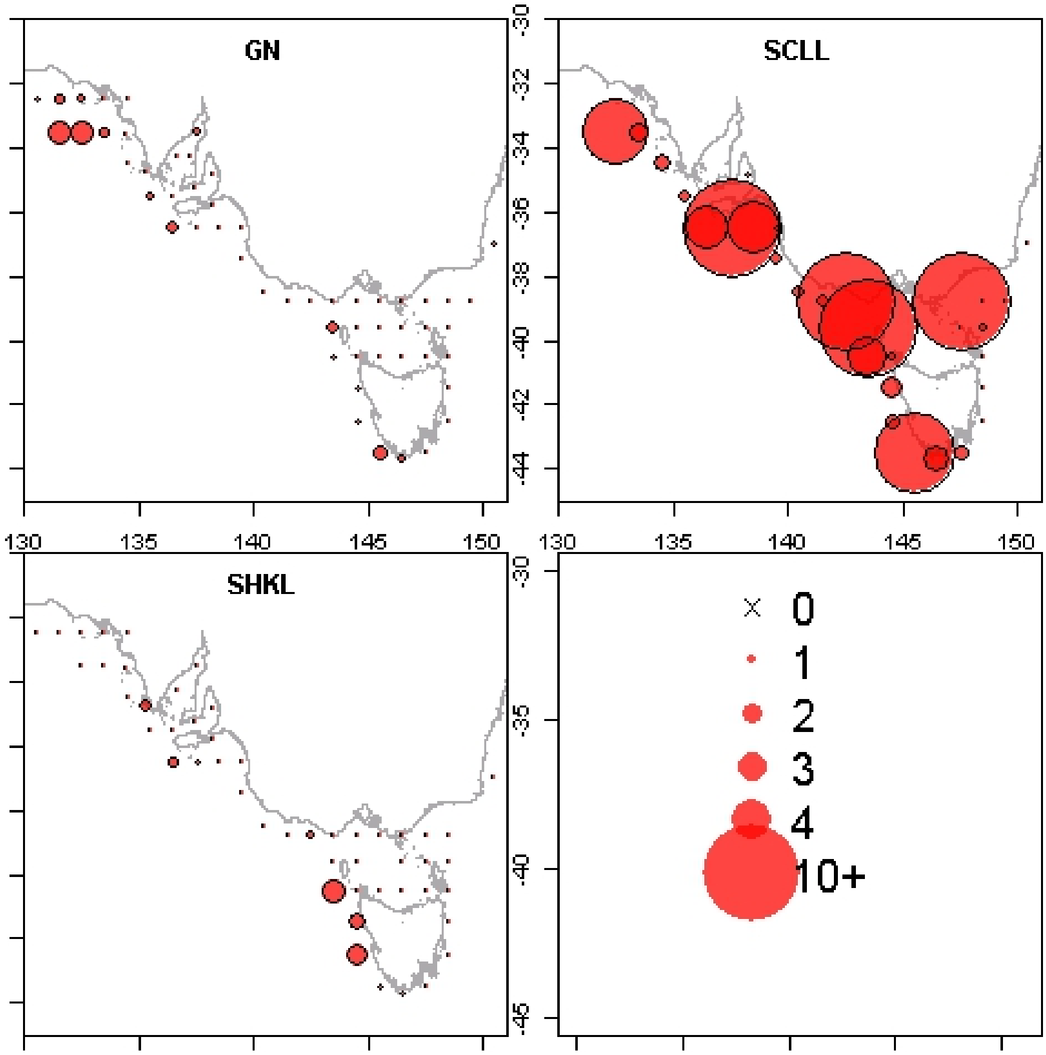


Figure 17.1. School shark : Gummy shark catch ratio for gillnet (GN), scalefish line (deeper than 183m, SCLL) and shark line (shallower than 183m, SHKL). The average ratio in each shark area (square degree) is indicated by the size of the red dot.

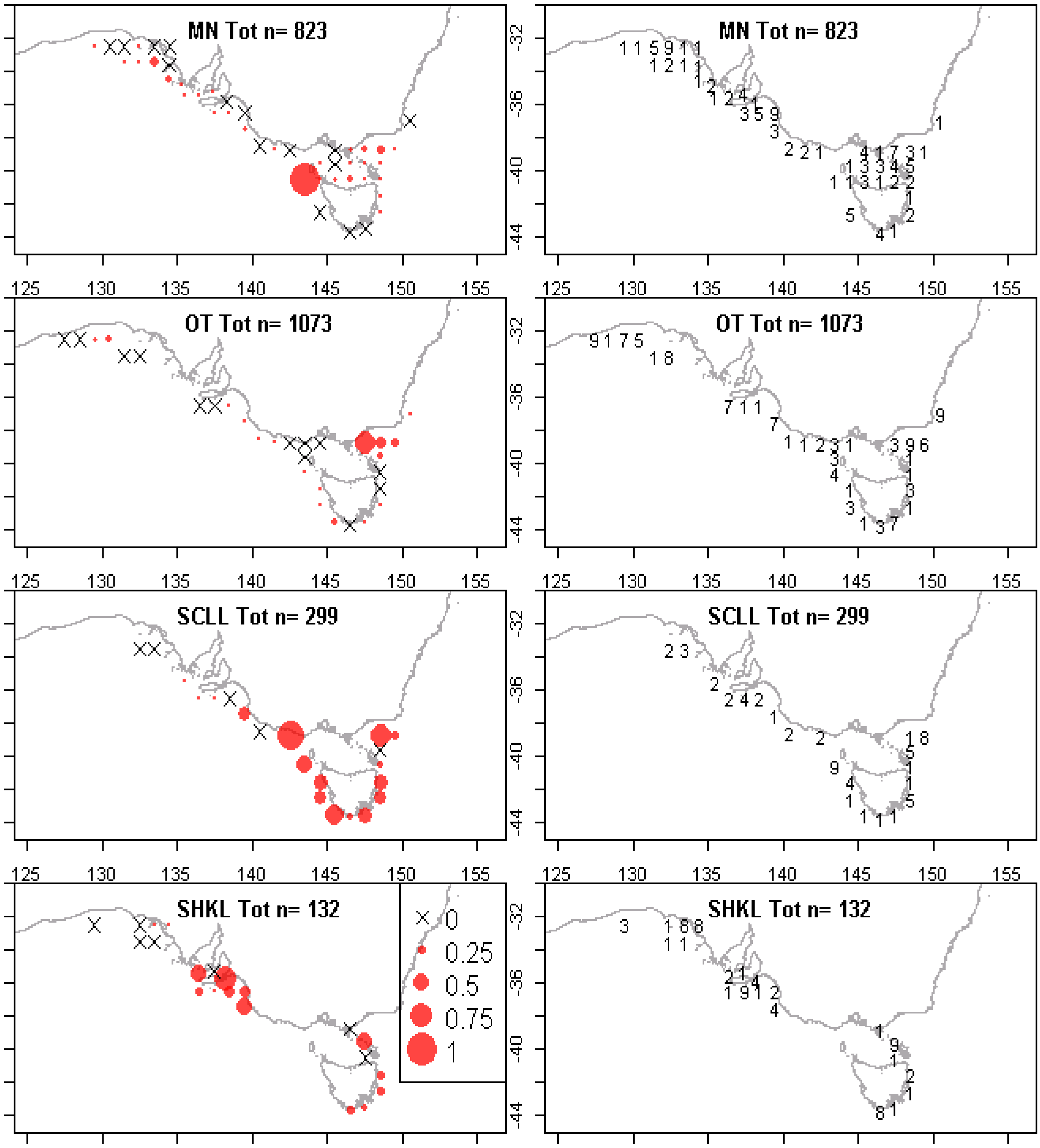


Figure 17.2. Average observed discard rates in each area for mesh nets (MN), trawl (OT), line deeper than 183m (SCLL) and line shallower than 183m (SHKL). The proportion discarded is scaled between 0 and 1 (100%). An “x” indicates 0% discarded, the size of the red spot indicates the rate of discarding. The left-hand plots show the number of shots that were observed in each area.

18. Estimated conversion coefficients for LCF-TOT and PAR-TOT length measurements for gummy shark, school shark, elephant fish and sawshark: a 2015 update

Robin Thomson

CSIRO Marine and Atmospheric Research, Castray Esplanade, Battery Point, Hobart, TAS, 7001

18.1 Summary

Length measurements of the SESSF's four shark quota species (gummy shark, school shark, elephant fish and sawshark) are made by AFMA's Observer program at ports of landing, and onboard vessels at sea. Measurements taken in port are nearly always partial lengths (PAR), and those taken onboard are a mixture, predominantly fork length (LCF) and total length (TOT). However, the biological relationships used in stock assessment relate to TOT, necessitating the conversion of the LCF and PAR measurements to TOT so that the data can be used in stock assessments. Onboard measurements on gillnet and longline vessels, the primary vessels targeting sharks, ceased during 2015 so that future data collections will be exclusively PAR. Duel measurements (LCF-TOT and PAR-TOT) made by the observer program were used to calculate linear relationships that convert LCF and PAR to TOT for each of the four shark quota species. Relatively tight relationships exist for LCF to TOT and PAR to TOT for gummy shark and school shark, and relatively large sets of duel measurements were available. Noisier LCF to TOT relationships exist for elephant fish and sawshark along with smaller data sets, however the estimated relationships are likely to be adequate. A PAR to TOT relationship could not be calculated for elephant fish, for which only three duel measurements have been made. The datasets for for sawshark and elephant fish should ideally be increased to at least 100 duel measurements. During 2015 the decision was made to discontinue collection of any length measurements of sawshark and elephant fish by the Observer program because those lengths are not currently used in stock assessment. Furthermore, observers ceased boarding gillnet and longline vessels during mid 2015 so collection of duel measurements will therefore also cease. However, this report gives advice on data collections that would be needed should the decision be made in future to use the existing length frequency.

18.2 Introduction

The AFMA Observer program and its predecessor the Integrated Scientific Monitoring Program (e.g. Knuckey &Gason 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 sawshark have been collected using a range of measurements, of which total length (TOT), partial length (PAR) and LCF (fork length) predominate (Figure 18.1 and Table 18.1).

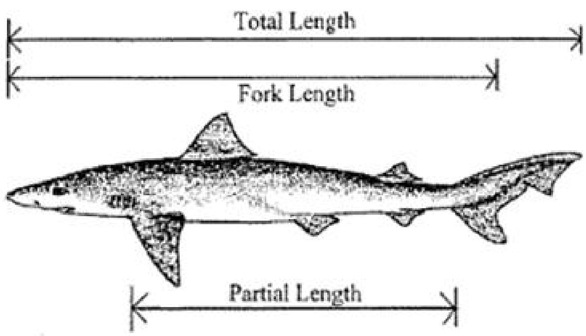


Figure 18.1. Partial length (PAR), fork length (LCF) and total length (TOT) as measured by the AFMA Observer Program (taken from the 'GHATF – Gillnet Observers Manual 2008, AFMA Observer Program'; GHATF, 2008).

Table 18.1. Number of sharks measured by the AFMA Observer Program over all years (1993-2013), regions, gear types and both sexes (including sex unknown). The type of measurement (see Figure 18.1) is shown. Blanks indicate zero samples. Grey shading indicate samples that can be used in stock assessments.

Type	School shark		Gummy shark		Elephant fish		Sawshark	
	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

To use length data in stock assessments, it is necessary to convert all length measurements to a total length (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 18.1). 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 (Thomson 2014). 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.

Sharks are landed in a processed state so that port-based measurements of carcasses are always partial (PAR) lengths (see Figure 18.1). Only onboard observers are able to take TOT measurements. Therefore the process, currently being implemented, of replacing onboard observers with electronic monitoring systems, and onboard length measurements with port measurement makes the calculation of PAR-TOT conversion functions particularly important.

18.3 Data and Methods

Observer data collected by the AFMA Observer Program under the banner "biological samples" were provided by 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 18.1 for the three measurements used. Note that the data shown in Table 18.1 relate to commercially caught sharks, sampled by the Observer Program, for which a single measurement was taken. The data shown in Table 18.2 and Figure 18.3 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 18.2) although the sample is concentrated in the last few months of the year (Table 18.3). 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) or PAR length (cm) to TOT length (cm) for stock assessment purposes using the formulae:

$$\mathrm{TOT}_i = a + b\ \mathrm{LCF}_i, \text{ for shark } i$$

$$\mathrm{PAR}_i = a + b\ \mathrm{LCF}_i, \text{ for shark } i$$

The estimated coefficients (a; b) are shown in Table 18.3.

Table 18.2. 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	Total
Gummy shark								**1245 (670)**
WSA		1 (1)					9 (9)	**10 (10)**
CSA				2		151 (149)	19 (19)	**172 (168)**
ESA						36 (14)		**36 (14)**
WBS					43	103 (165)		**146 (165)**
EBS	1				12	249 (148)	256 (50)	**518 (198)**
WTas					7			**7**
ETas					65	97 (3)	111 (111)	**273 (114)**
SAV						(1)		**(1)**
Unk							83	**83**
School shark								**296 (141)**
WSA			1					**1**
CSA						9 (9)	26 (26)	**35 (35)**
ESA						1		**1**
WBS					24	1 (3)	2 (2)	**27 (5)**
EBS					14	13 (7)	151 (54)	**178 (61)**
WTas					5			**5**
ETas					2	7	40 (40)	**49 (40)**
SAV								
Elephant shark								**98 (3)**
WSA								
CSA				4				**4**
ESA								
WBS					4	28 (3)		**32 (3)**
EBS					16	28	1	**45**
WTas								
ETas					16	1		**17**
SAV								
Unk								**2**
Sawshark								
WSA								
CSA		2						
ESA						(1)		
WBS					25	7 (22)		
EBS					10	28 (24)		
WTas								
ETas					17	1		
SAV								

Table 18.3. Sample sizes for LCF and (PAR) by month and year.

Month	2001	2007	2009	2011	2012	2013	2014	Total
Gummy shark								**1245 (670)**
1		1		2		1	32	**36 (33)**
2	1					96	26 (26)	**123 (26)**
3							12 (12)	**12 (12)**
4								
5							51	**51 (51)**
6								
7								
8							330	**330 (41)**
9						83		**83**
10					127	114 (112)	11	**252 (123))**
11						278 (303)	16	**294 (319**
12						64 (65)		**64 (65)**
School shark								**296**
1							20 (20)	**20 (20)**
2						6	8 (8)	**14 (8)**
3							15 (16)	**15 (16)**
4								
5							21 (21)	**21 (21)**
6								
7								
8							146 (48)	**146 (48)**
9	1					7		**8**
10					41	1	2 (2)	**44 (2)**
11					3	14 (16)	7 (7)	**24 (23)**
12					1	3 (3)		**4 (3)**
Elephant shark								
1				4				**4**
2								
3								
4								
5								
6								
7								
8							3	**3**
9						28		**28**
10					36		(3)	**36 (3)**
11						28		**28**
12						1		**1**
Sawshark								
1								
2		2						
3								
4								
5							1 (1)	**1 (1)**
6								
7								
8							3	**3**
9						7 (6)		**7 (6)**
10					52			**52**
11						27 (39)	6 (6)	**33 (45)**
12						2 (2)		**2 (2)**

18.4 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 18.3; Figure 18.3).

Table 18.4. Estimated coefficients of linear regressions between LCF or PAR and TOT measurements. R^2 statistics and sample sizes are also shown. “na”: indicates insufficient samples.

	Gummy shark		School shark		Elephant fish		Sawshark	
	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	3	90	47

Estimated coefficients 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 sawshark seems to describe two separate lines, each of which is relatively precise. The nine measurements that fall well above the regression line were all made on just three 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.

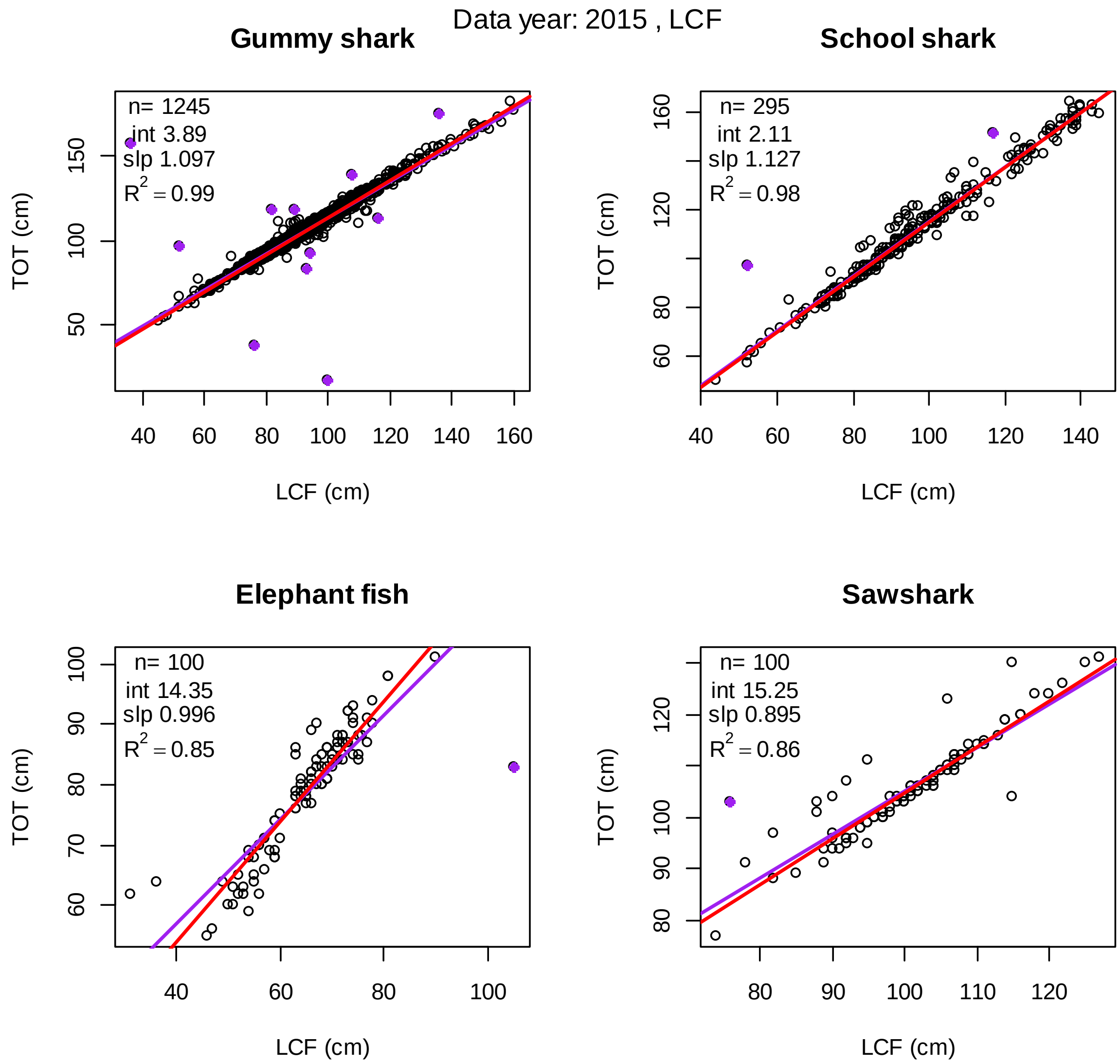


Figure 18.2. Length measurements (cm) of the LCF and TOT type for individual sharks (circles) and an estimated -linear regression (*red line*) for gummy shark, school shark, elephant fish, and sawshark. The sample size "n", fitted values for the intercept "int" and slope "slp", and goodness of fit statistic "R^2" are shown. The *red line* shows the fit to the data when the *purple dots* (outliers) are excluded and the purple line shows the regression line when outliers are included.

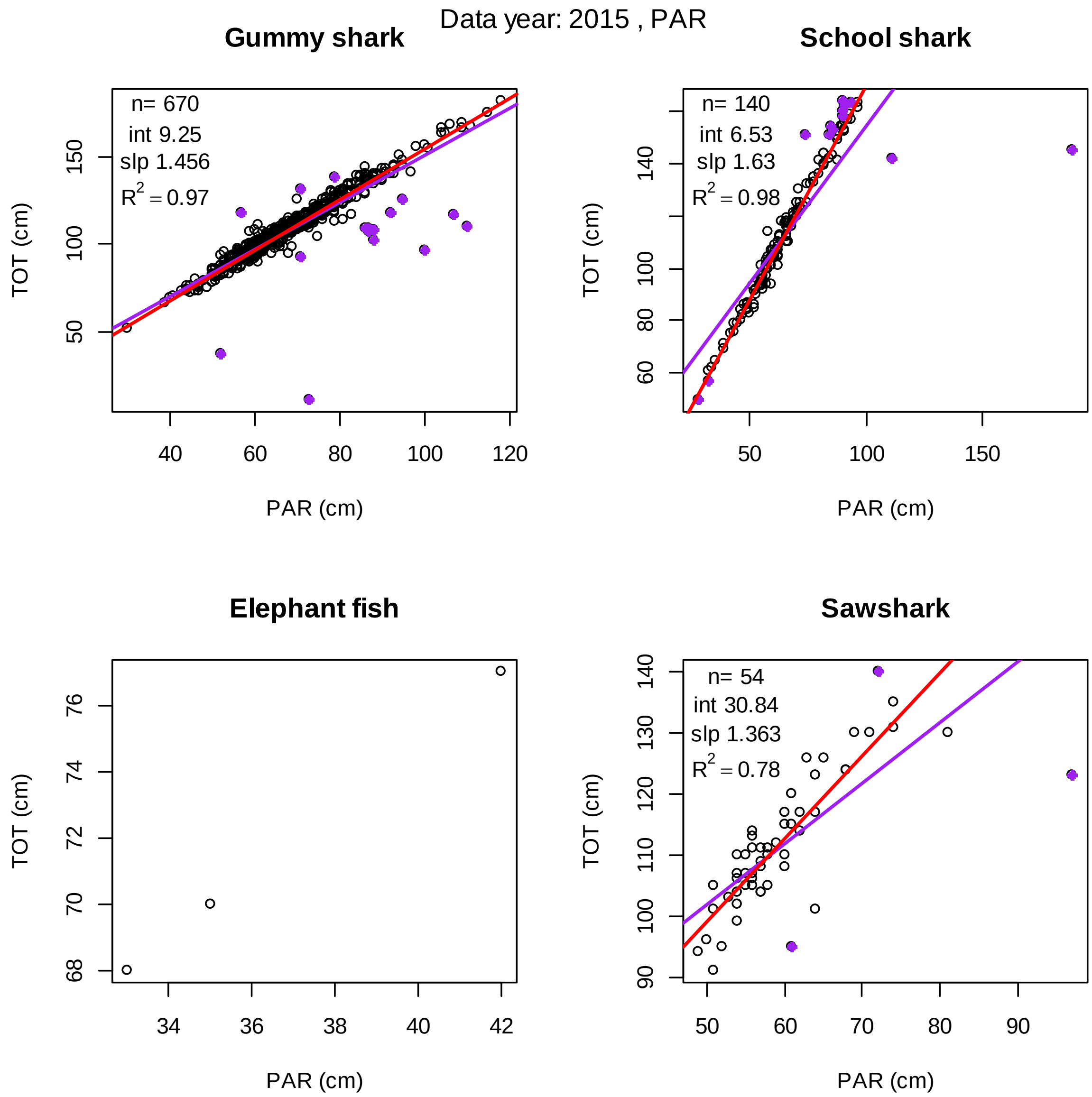


Figure 18.3. Length measurements (cm) of the PAR and TOT type for individual sharks (circles) and an estimated -linear regression (*red line*) for gummy shark, school shark, and sawshark. Only three duel measurements are available for elephant fish so no regression line is shown. The sample size "n", fitted values for the intercept "int" and slope "slp", and goodness of fit statistic "R^2" are shown. The *red line* shows the fit to the data when the *purple dots* (outliers) are excluded and the purple line shows the regression line when outliers are included.

18.5 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 elephant fish would benefit from continuing collection of LCF-TOT and PAR-TOT duel measurements. In particular, the collection of elephant fish 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, as weould removeal (or recoding) of the erroneous measurements.
3. During 2015 the decision was made to discontinue collection of any length measurements of sawshark and elephant fish by the Observer program because those length are not currently used in stock assessment. Further collection of duel measurements will therefore also cease. However, if that decision is ever reversed, collection of futher PAR-TOT duel measurements of elephant fish, building the data set to at least 100 fish, would be necessary.

18.6 Acknowledgements

Thanks to John Garvey and Selvy Coundjidapadam (AFMA) for providing the data on which this work is based, and to the members of sharkRAG who provided useful discussion. Miriana Sporcic and Judy Upston are thanked for helpful comments on an earlier draft.

18.7 References

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

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

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

Thomson, R.B. (2014) Estimated conversion coefficients for LCF-TOT PAR-TOT length measurements for gummy shark, school shark, elephant fish and sawshark. Presented to SharkRAG 20 November 2014, Melbourne. 9pp.

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

19. Capture and post-capture survival rates for school shark taken by gillnets and lines

Robin Thomson

CSIRO Oceans and Atmosphere Flagship, Castray Esplanade, Battery Point, Hobart, 7000

19.1 Introduction

SESSF managers and the fishing industry have made great efforts to reduce mortality of school sharks. To this end, shark fishers have been requested to release discarded school sharks alive. It would be useful to know the post release survival rates for school sharks, and it is expected that these would be better for line caught sharks than for gillnets. In a letter to Richard McLoughlin (Managing Director AFMA) dated 14 August 2006, Jeremy Prince (then SharkRAG chair) wrote:

"School shark are amongst the species that need constant forward motion to pass sufficient oxygenated water over their gills for survival. Most automatic longliners use relatively short snoods ~45cm that do not allow much movement of captured shark. Depending on the soak time many school shark are likely to be dead when brought to the surface. Gummy sharks are more likely to be alive as they are capable of pumping water across their gills when they are not moving. Also school shark are very sensitive to handling practices and do not survive well when brought out of the water. With the sheer number of hooks involved in an automatic longlining operation and no direct financial incentive, SharkRAG is concerned that handling practices will still result in a significant accidental mortality rate. SharkRAG considers that under commercial fishing conditions soak times in excess of 4 hours will cause the survival of released school shark to be very low."

This report summarizes available literature on survival rates for school sharks at the point of release (capture survival), and where possible, some time thereafter (post-capture survival).

19.2 Available Information

Relevant studies known to the author are Walker et al (2005) who recorded the life status of school shark after capture during a large scale shark survey. Braccini et al (2012), using gummy shark captured in the SESSF and acclimated to laboratory conditions, manually inserted sharks into gillnets where they remained for two hours after which they were removed and placed in a fish bin with no water for 15 minutes and then moved to a recovery tank for 10 days. Coelho et al (2012) observed the capture survival of 25 school sharks (*Galeorhinus galeus*), which they call "tope shark" captured by high seas swordfish vessels in the Atlantic Ocean. Griggs & Baird (2013) observed the capture survival of school and gummy shark captured in New Zealand by tuna vessels.

Richard Reiner, Terry Walker & Charlie Huveneers are working on a global meta-analysis and review of species specific mortality rates, especially as affected by gear type and respiratory mode. They've integrated and analyzed all the published data they can find that report numbers of animals landed dead and alive. This includes Terry's data. They are also collecting their own data, but have not been able to find enough school sharks in good condition to study.

Capture and post-capture survival rates from the available literature are shown in Table 19.1 (school shark).

Table 19.1. Capture and post-capture survival for *school shark* from the literature.

Type	Capture survival	Post-Capture	Total	Study
GN (BS)	30% (BS)			Walker et al (2005)
GN (SA)	98% (SA)			Walker et al (2005)
GN	27%	51%	12%	Braccini et al (2012)
Line	74%			Griggs & Baird (2013)
Line	92%			Coelho et al (2012)

19.3 References

Braccini, M., Van Rijn, J., Frick, L. (2012) High Post-Capture Survival for Sharks, Rays and Chimaeras Discarded in the Main Shark Fishery of Australia? *PLoS ONE* **7**, DOI: 10.1371/journal.pone.0032547.

Coelho, R., Fernandez-Carvalho, J., Lino, P.G., Santos, M.N. (2012) An overview of the hooking mortality of elasmobranchs caught in a *swordfish pelagic longline fishery* in the Atlantic Ocean. *Aquatic Living Resources* **25,** 311–319.

Griggs, L.H., Baird, S.J. (2013) Fish bycatch in *New Zealand tuna longline* fisheries 2006–07 to 2009–10. *New Zealand Fisheries Assessment Report 2013/13*, 1–73.

Walker, T.I., Hudson, R.J., Gason, A.S. (2005) Catch evaluation of target, by-product and by-catch species taken by gillnets and longlines in the shark fishery of south-eastern Australia. Journal of Northwest Atlantic Fishery Science 35, 505–530

20. Catch rate standardizations for selected SESSF species (data to 2014)

Miriana Sporcic

CSIRO, GPO Box 1538, Hobart, Tasmania

20.1 Executive Summary

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

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

This document reports the statistical standardization of the commercial catch and effort data for 23 species (including species groups), distributed across 43 different combinations of stocks and fisheries ready for inclusion in the annual round of stock assessments. These include School Whiting, Eastern Gemfish, Jackass Morwong, Flathead, Redfish, Silver Trevally, Royal Red Prawn, Blue Eye,

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

Summary graphs are provided across all species (Figure 20.2 and Figure 20.3), as well as more detailed information for each stock. Out of 43 stocks, there were nine whose catch rates have increased over the last 10 years; 13 stocks where catch rates were stable and 21 stocks whose catch rates have declined over the last 10 years. There were nine stocks whose catch rates have increased since the 2007 corresponding to the structural adjustment and introduction of the Harvest Strategy Policy; six stocks whose catch rates were stable and 28 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).

20.2 Introduction

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

20.2.1 Limits of standardization

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

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

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

20.3 Methods

20.3.1 Catch rate standardization

Preliminary data selection

The methods used when standardizing commercial catch and effort data in the SESSF continue to be discussed in the Commonwealth stock assessment RAGs because the catch rate time series (and associated standardized indices are very influential in many of the assessments. Data were initially selected by fishery (e.g. SET, GHT, GAB, etc), within a specified depth range and method (e.g. trawl, Auto Line, Danish seine etc) in specified statistical zones (e.g. Figure 20.1) within the years specified for the analysis (Table 20.1). This was based on a standard set of database queries, both from ACCESS and ORACLE, designed to identify shots containing the species of interest in each case.

General linear modelling

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

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

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*.).

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.

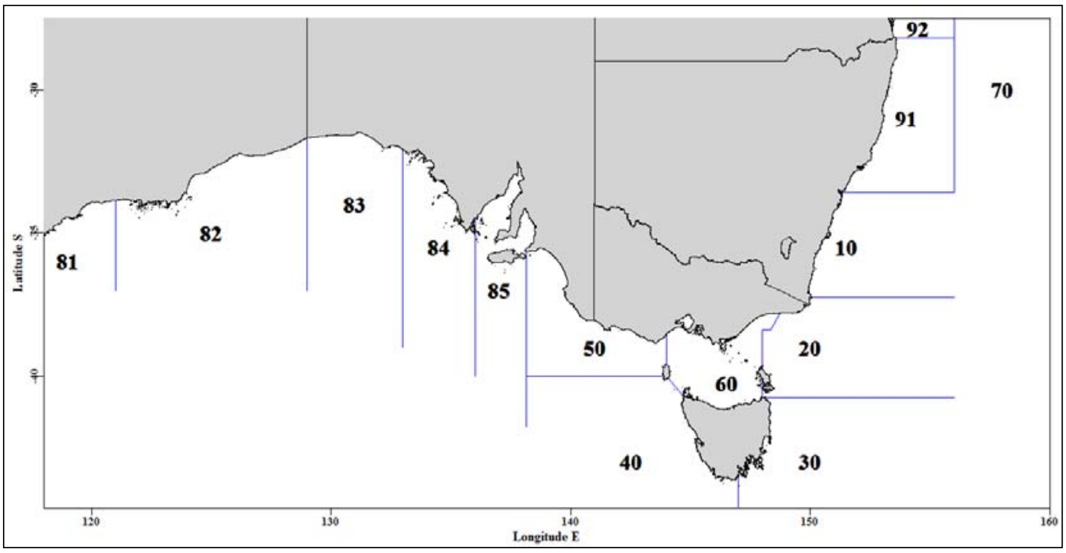


Figure 20.1. A schematic diagram depicting the statistical reporting zones in the SESSF, as used in this document. The GAB fishery is to the west of zone 50. The main SESSF trawl zones are zones 10 – 50. Each zone extends out to the boundary of the EEZ, except for zones 50 and 60, and for zones 92 and 91, which are bounded by zone 70.

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

20.4 Results

Table 20.1. Data characteristics for each analysis. Records show the number of records, depths, zones and other details used in the data analyses.

	Name	Zone(s)	Depth (m)	Comment	Records
1	School Whiting	60	0-100	Danish Seine, catch per shot.	82560
2	Eastern Gemfish	10-30,40/2	300-500	June-Sept 93 onwards, Spawning	14937
3	Eastern Gemfish	10-30,40/2	0-600	Oct-May 86-09 0-600m, Jun-Sep <300m	37587
4	Jackass Morwong	10-50	70-360		150277
5	Jackass Morwong	10,20	70-300		114092
6	Jackass Morwong	30	70-300		19819
7	Jackass Morwong	40,50	70-360		13469
8	Jackass Morwong	40,50	70-250		9641
9	Flathead	10,20	0-400	Trawl	262147
10	Flathead	30	0-400	Trawl	21492
11	Flathead	20,60	0-200	Danish Seine, catch per shot	193734
12	Redfish	10,20	0-400		99408
14	Silver Trevally	10,20	0-200	Remove State waters and MPAs	33960
15	Silver Trevally	10,20	0-200	Including State waters and MPAs	57758
16	Royal Red Prawn	10	200-700		24491
17	Blue Eye Trevalla	20,30	0-1000		12352
18	Blue Eye Trevalla	40,50	0-1000		12921
19	Blue Eye Trevalla	10-50,83-85	200-600	Auto Line	8043
20	Blue Eye Trevalla	10-50,83-85	200-600	Drop Line	6921
21	Blue Eye Trevalla	10-50,83-85	200-600	Auto Line and Drop Line 1997 onwards	14928
22	Blue Grenadier	10-60	0-1000	Except Zone 40 Jun-Aug; non spawning	135216
23	Silver Warehou	10-50	0-600		131240
24	Blue Warehou	10-30	0-400		37070
25	Blue Warehou	40,50	0-600		13143
26	Blue Warehou	10-50	0-600		50718
27	Pink Ling East	10-30	250-600		97818
28	Pink Ling West	40,50	200-800		76427
29	Western Gemfish	40,50,GAB	100-600		42931
30	Western Gemfish	40,50	100-600		32530
31	Western Gemfish	GAB	100-600	Only 1995 onwards	9716
32	Offshore Ocean Perch	10,20	200-700		79460
33	Inshore Ocean Perch	10,20	0-200		16395
34	John Dory	10,20	0-200		138251
35	Mirror Dory	10-50	0-600		124181
36	Mirror Dory East	10-30	0-600		92880
37	Mirror Dory West	40,50	0-600		31267
38	Ribaldo (RBD)	10-50	0-1000		21246
39	Ribaldo	10-50,81-85	0-1000	Auto Line	5167
40	Ocean Jackets	10-50	0-300		84124
41	Ocean Jackets	82-83	80-220		50217
42	Deepwater Flathead	GAB	0-1000		73089
43	Bight Redfish	GAB	0-1000		49209
44	Eastern deepwater sharks	ORZones	600-1250		11022
45	Western deepwater sharks	ORZones	600-1100		20950
46	Mixed oreos	ORZones	500-1200		27073

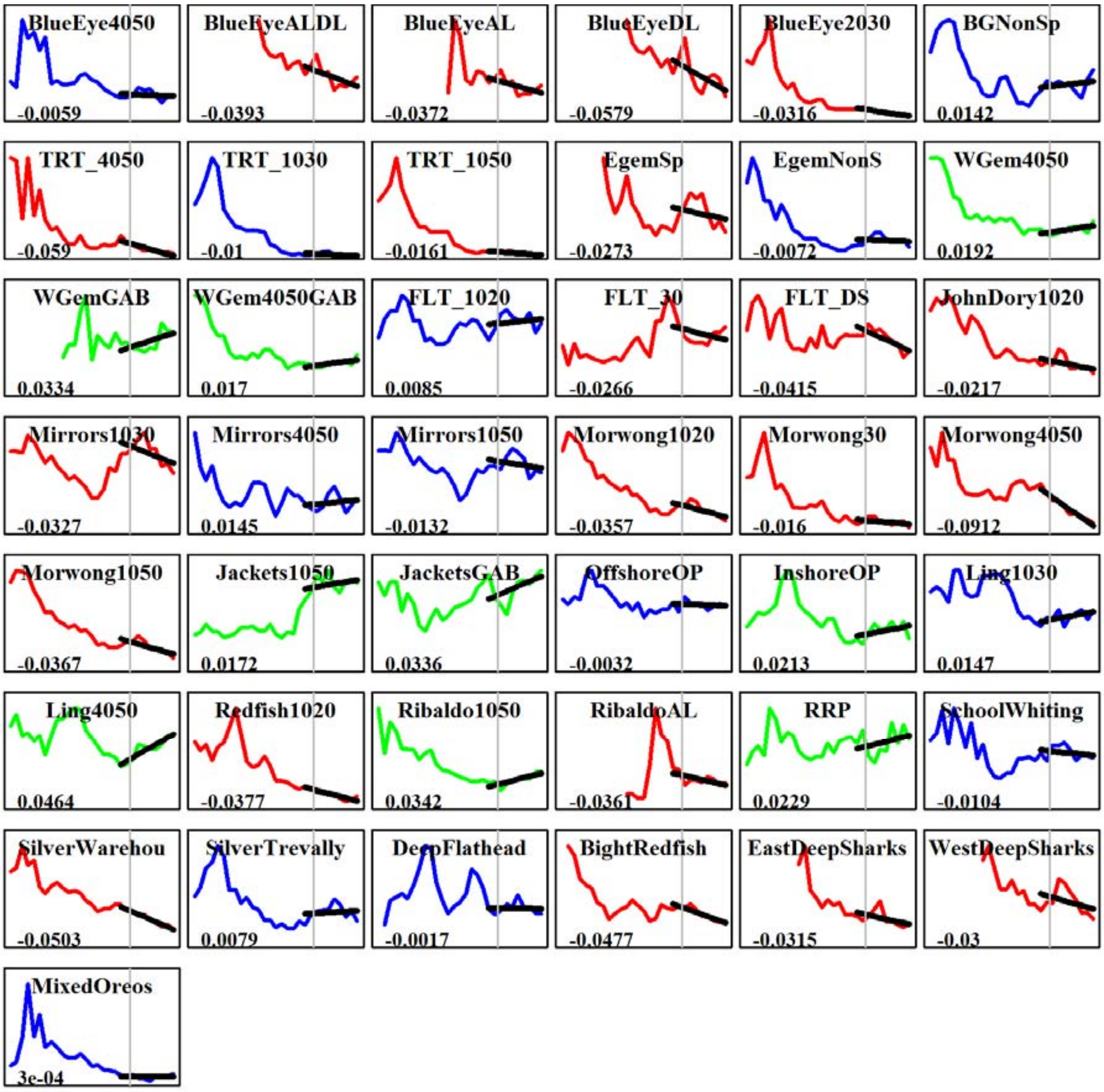


Figure 20.2. Summary graph of the optimum standardizations for 23 species (including grouped species) and 43 different stocks, methods, or fisheries, each with a linear regression across the last ten years (2005-2014). The gradient is at bottom left in each graph and the line colour reflects the gradient: green indicates a positive gradient > 0.015, blue a flat line with a gradient between 0.0149 and – 0.0149, and red indicates a negative gradient < -0.015. There were 9 selections with a positive gradient, 13 selections with a flat gradient, and 21 selections with a negative gradient.

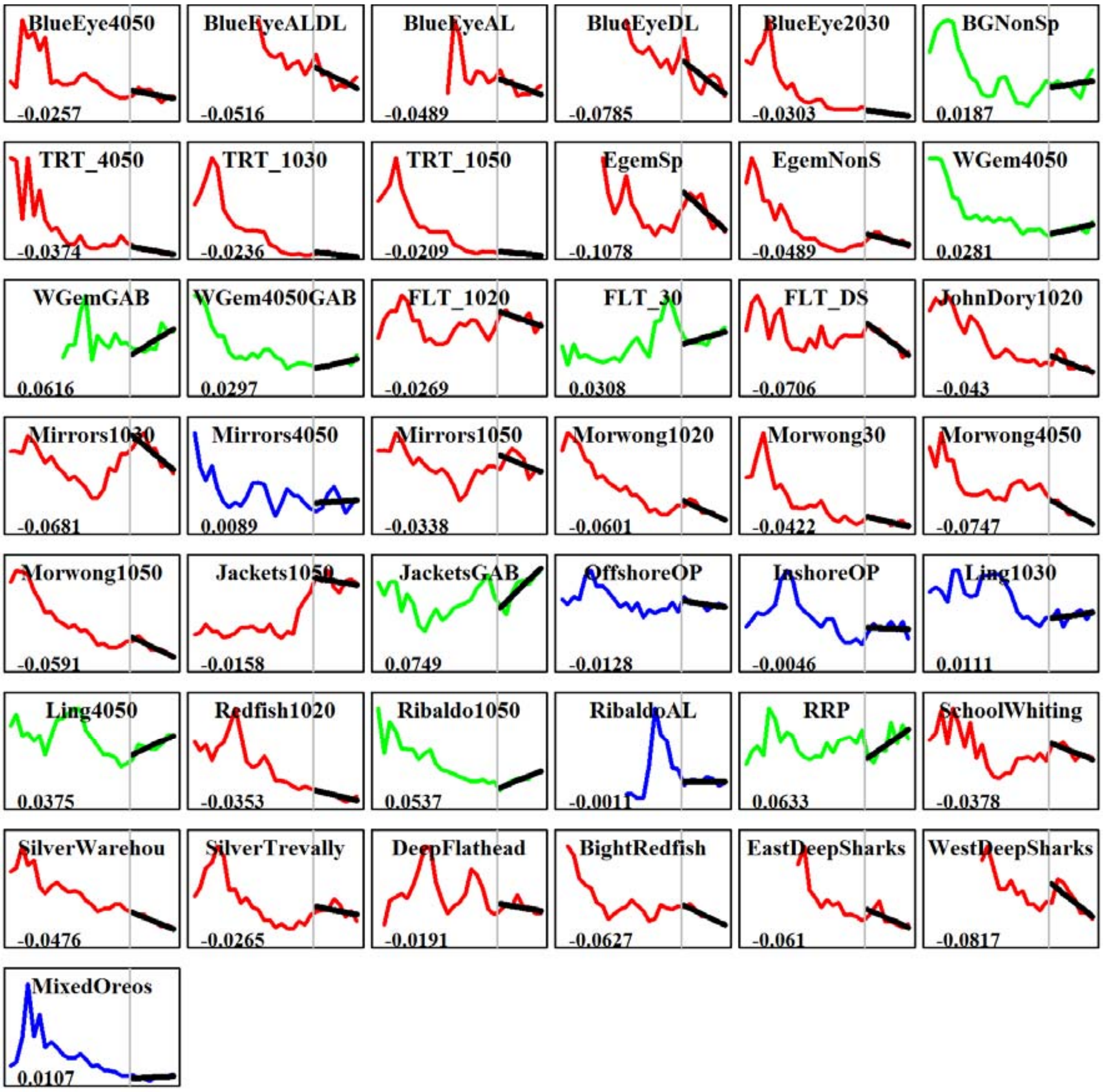


Figure 20.3. Summary graph of the optimum standardizations for 23 species (including grouped species) and 43 different stocks, methods, or fisheries, each with a linear regression across the last eight years (2007-2014). The gradient is at bottom left in each graph and the line colour reflects the gradient: green indicates a positive gradient > 0.015, blue a flat line with a gradient between 0.0149 and – 0.0149, and red indicates a negative gradient < -0.015. There were 9 selections with a positive gradient, 6 selections with a flat gradient, and 28 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 20.2. Summary_of linear regressions (LR) of the annual standardized catch rates corresponding to the (i) last 10 years (Ten Year LR) and (ii) last eight years (Eight Year LR) for 43 stocks. Colour reflects the gradient: a positive gradient > 0.015 (green), a flat line with a gradient between 0.0149 and – 0.0149 (blue), a negative gradient < -0.015 (red). See also Figures 2 and 3. N refers to a change in slope from either a green to blue or blue to red comparing last year's to this year's LRs. Y refers to a change in slope from a red to blue or blue to green comparing last year's to this year's LRs.

Name	**Zone(s)**	**Depth (m)**	**Ten Year LR**	**Eight Year LR**
School Whiting - DS	60	0-100		
Eastern Gemfish SP	10-30,40/2	300-500	N	
Eastern Gemfish - NSpawn	10-30,40/2	0-600	N	
Jackass Morwong	10,20	70-300	N	
Jackass Morwong	30	70-300	N	
Jackass Morwong	40,50	70-360		
Jackass Morwong	10-50	70-360		
Flathead	10,20	0-400	N	
Flathead	30	0-400		
Flathead - DS	20,60	0-200		
Redfish	10	0-400		
Silver Trevally - no MPA	10,20	0-200	N	N
Royal Red Prawn	10	200-700	Y	
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	10-30	0-400		
Blue Warehou	40,50	0-600	N	
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	Y	
Western Gemfish	40,50	100-600	Y	Y
Western Gemfish	GAB	100-600	Y	
Offshore Ocean Perch	10,20	200-700		Y
Inshore Ocean Perch	10,20	0-200		N
John Dory	10,20	0-200	N	
Mirror Dory East	10-30	0-600	N	
Mirror Dory West	40,50	0-600		
Mirror Dory	10-50	0-600		
Ribaldo (RBD)	10-50	0-1000		
Ribaldo - AL	10-50,81-85	0-1000		
Ocean Jackets	10-50	0-300		
Ocean Jackets - GAB	82-83	80-220	Y	
Deepwater Flathead	GAB	0-1000		
Bight Redfish	GAB	0-1000		
Eastern Deepwater Sharks	OR Zones	600-1250		
Western Deepwater Sharks	OR Zones	600-1100		
Mixed oreos	OR Zones	500-1200		

20.4.1 School Whiting Z60 Danish Seine (WHS – 37330014 – Sillago flindersi)

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

Table 20.3. 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	1.1735	0.0000
1987	995.9650	4119	920.4950	23	131.1624	1.2948	0.0293
1988	1255.6880	3815	1177.4560	25	168.5490	1.6820	0.0300
1989	1061.5130	4440	994.4080	27	127.0438	1.1093	0.0289
1990	1930.3680	6263	1859.9230	24	165.2959	1.7188	0.0269
1991	1630.2550	4871	1517.7940	26	164.1905	1.4596	0.0286
1992	854.1060	2980	777.5240	23	124.7066	1.0465	0.0328
1993	1694.8960	4926	1548.6010	24	153.5472	1.4727	0.0287
1994	946.2010	4503	879.1620	24	93.9314	0.8682	0.0291
1995	1212.5610	4270	1065.9340	21	122.4731	1.0935	0.0295
1996	898.2130	4297	718.8140	22	81.4339	0.7178	0.0297
1997	697.3800	3314	481.6600	20	64.5619	0.5557	0.0319
1998	594.1530	2988	464.1540	20	66.0158	0.5348	0.0328
1999	681.2520	2044	452.2150	21	84.3634	0.6111	0.0377
2000	700.8800	1913	335.0750	17	65.1233	0.6168	0.0381
2001	890.9250	1980	425.0945	18	93.2089	0.8598	0.0393
2002	788.3307	2192	429.2183	20	90.8874	0.8715	0.0375
2003	866.2327	2355	463.5434	20	86.7848	0.8890	0.0369
2004	604.8859	1771	334.6310	20	79.7648	0.8349	0.0396
2005	662.6840	1750	311.4275	20	77.2502	0.9424	0.0413
2006	667.5046	1428	270.2720	18	76.2250	0.8174	0.0432
2007	535.3580	1488	347.0490	14	89.2381	1.0847	0.0421
2008	502.2450	1260	317.0575	15	92.3448	1.0784	0.0451
2009	462.5905	1569	350.7230	15	93.6200	1.1330	0.0418
2010	408.9007	1179	272.8700	15	88.6885	1.0137	0.0462
2011	373.9361	1579	260.2995	14	72.0269	0.8265	0.0415
2012	435.7716	1566	302.4675	14	80.0853	0.9137	0.0417
2013	510.6307	1791	339.7765	14	82.5661	0.9002	0.0404
2014	698.5380	1824	422.0845	14	98.6645	0.8797	0.0445

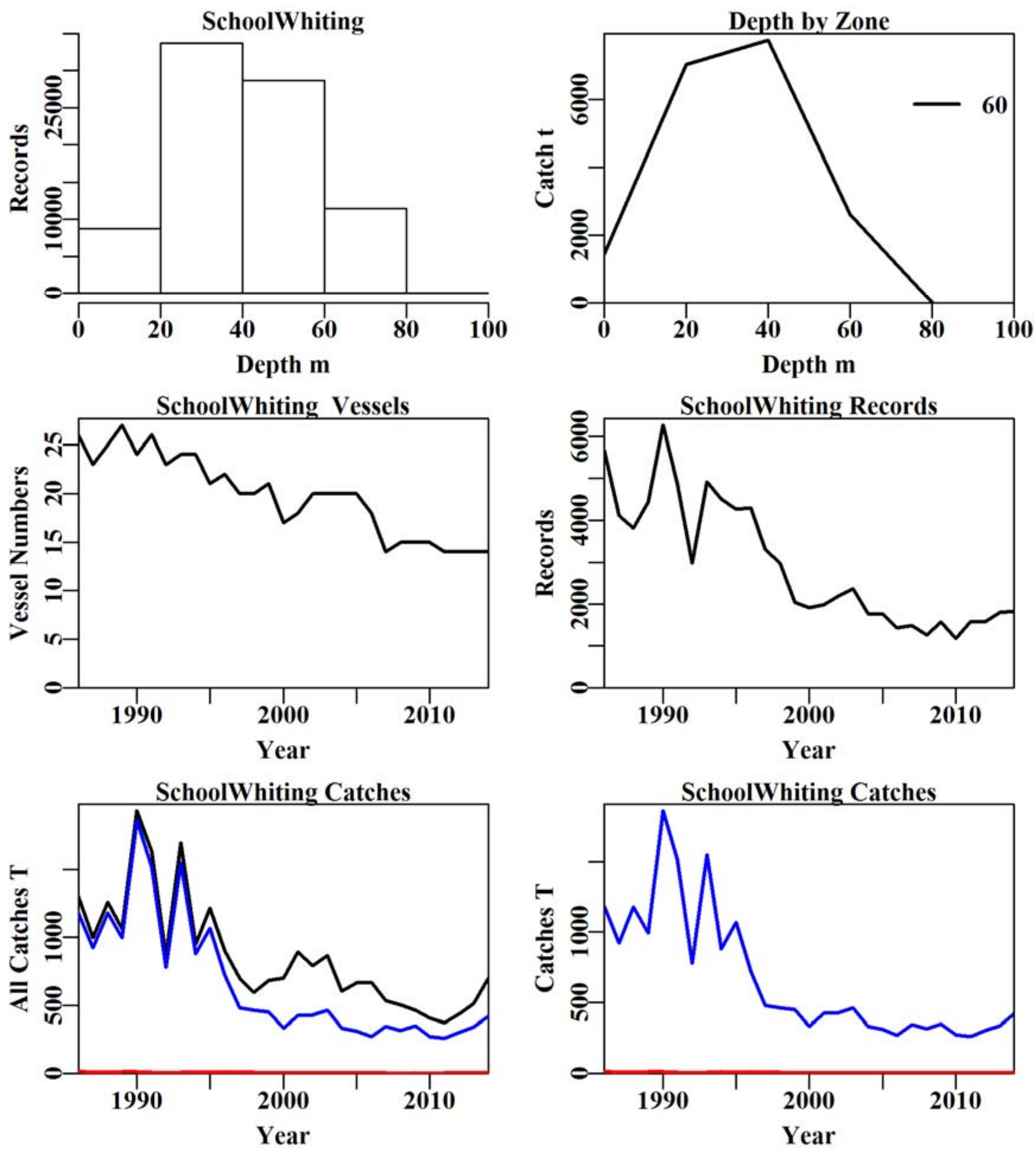


Figure 20.4. School Whiting in zone 60 in depths 0 to 100 m taken by Danish Seine. The top left plot depicts the depth distribution of shots containing School Whiting from zone 60 in depths 0 – 100 m. The top right plot depicts the distribution of catch by depth within zone 60. The middle left plot depicts the number of vessels through time. The middle right plot contains the number of records used in analysis. The bottom left plot contains School Whiting catches (top black line: total catches, middle blue line: catches used in the analysis; bottom red line: catches < 30 kg) and bottom right plot contains School Whiting catches (blue line: catches used in the analysis; red line: catches < 30 kg).

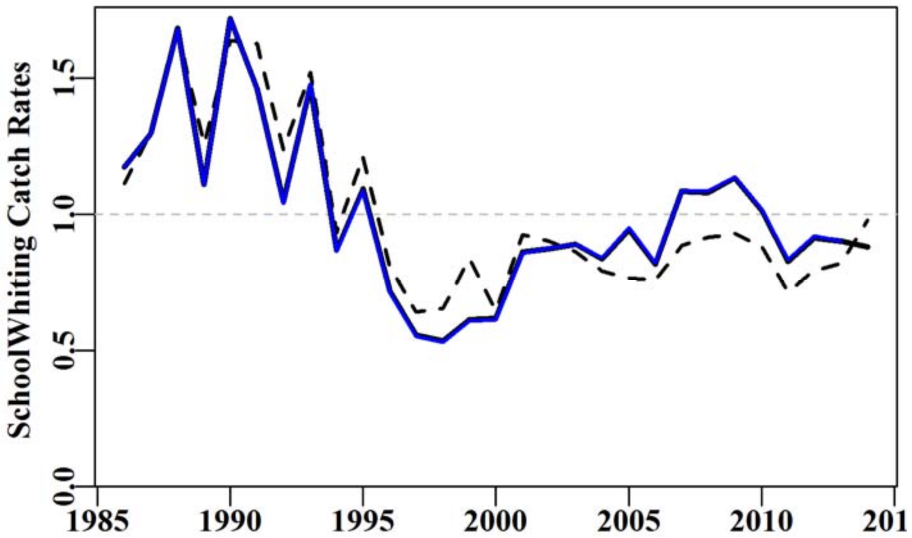


Figure 20.5. School Whiting in zone 60 in depths 0 to 100 m by Danish Seine. The dashed black line represents the geometric mean catch rate, the solid black line the standardized catch rates, and the blue line is standardized catch rates from last year's analysis. The graph standardizes catch rates relative to the mean of the standardized catch rates.

Table 20.4. 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 20.5. 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	59970	57832	55494	53335	51816	51669	51300	51659
RSS	171493	166995	162408	158252	154288	153968	153163	153871
MSS	7855	12353	16940	21096	25060	25380	26185	25477
Nobs	84142	84142	84142	84142	82560	82560	82560	82560
Npars	29	78	81	92	96	108	140	129
adj_R^2	4.348	6.803	9.359	11.667	13.874	14.040	14.456	14.072
%Change	0.000	2.455	2.557	2.308	2.207	0.166	0.416	-0.384

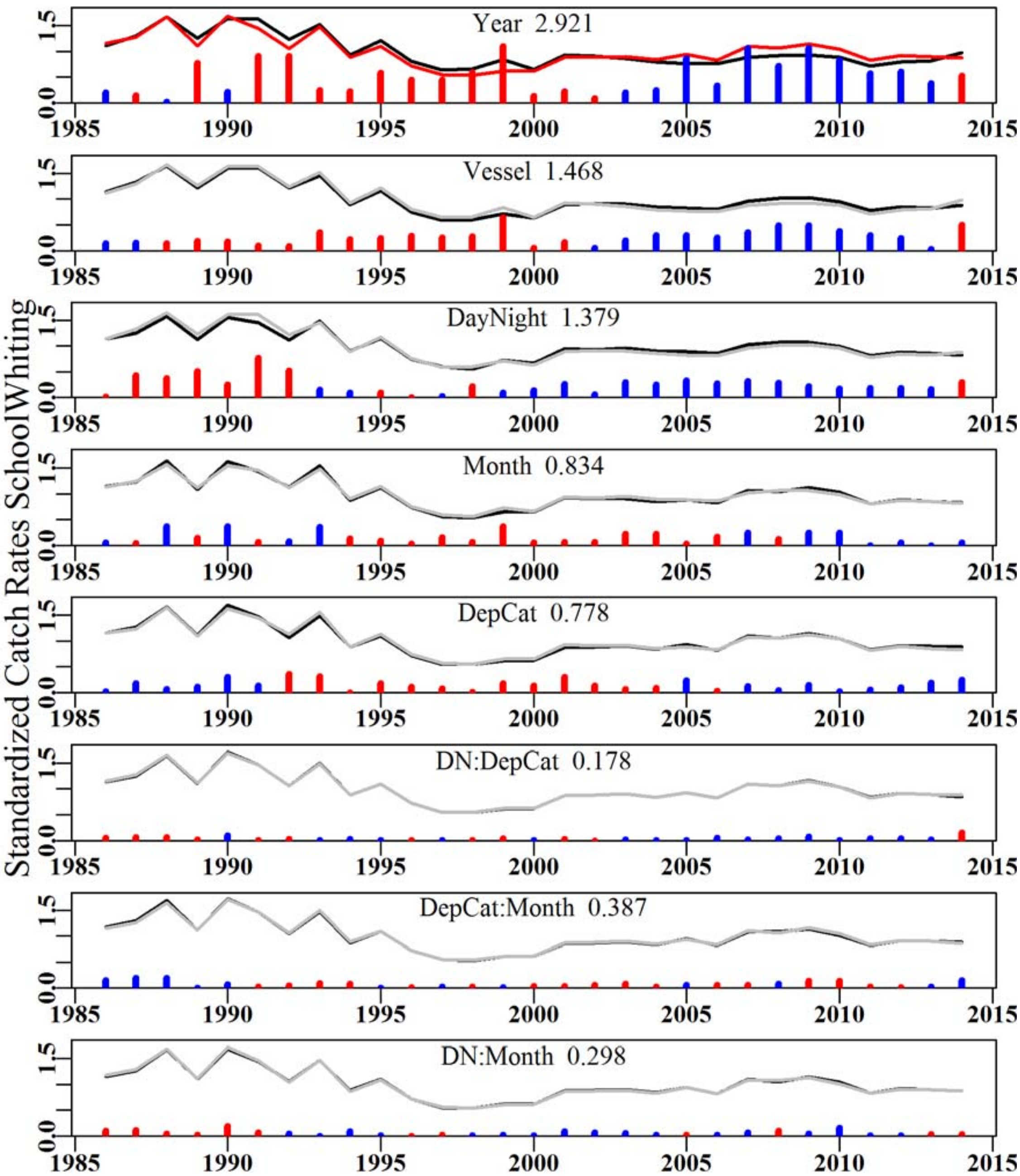


Figure 20.6. The relative influence of each factor used on the final trend in the optimal standardization for School Whiting in zone 60. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by the vertical bars with blue bars 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.

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

Eastern Gemfish are taken by Trawl in the spawning season from June to September in zones 10, 20 and 30, in the bottom half of zone 40 (i.e. below 42°S; west coast of Tasmania) and between depths of 300 to 500 m. There were 15,043 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 20.6. 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	2.0926	0.0000
1994	232.1790	819	49.0380	47	11.8880	1.3453	0.0621
1995	181.7460	657	21.8650	48	7.3973	0.9378	0.0658
1996	382.1960	769	135.1320	49	10.9438	1.1794	0.0634
1997	571.9758	1232	268.5900	48	18.9829	1.7216	0.0587
1998	404.8147	883	144.6760	46	11.5921	1.1465	0.0629
1999	448.6767	1065	87.9210	45	8.4120	0.9621	0.0612
2000	336.4642	1178	37.0190	45	4.8857	0.6581	0.0614
2001	331.4862	855	32.8390	48	4.7369	0.6799	0.0651
2002	195.8983	924	22.4530	43	3.5080	0.4862	0.0645
2003	267.9710	967	31.5869	49	4.5797	0.6816	0.0634
2004	568.8517	631	19.7705	45	4.2927	0.6445	0.0706
2005	511.7585	652	21.6200	41	4.5977	0.5696	0.0694
2006	544.8936	571	34.7529	35	7.7674	0.9012	0.0720
2007	580.6498	308	25.3560	19	8.9499	1.1178	0.0869
2008	257.6855	447	35.2582	24	10.4210	1.3621	0.0793
2009	194.8654	413	37.0383	23	9.3924	1.2463	0.0804
2010	220.6510	390	41.7925	24	10.5969	1.3496	0.0813
2011	147.7397	413	27.4315	21	7.3130	0.9483	0.0796
2012	168.5996	381	28.0095	22	6.0729	0.6250	0.0827
2013	103.8201	296	16.1220	21	7.2972	0.7835	0.0886
2014	130.1963	368	11.2463	20	4.1064	0.5610	0.0824

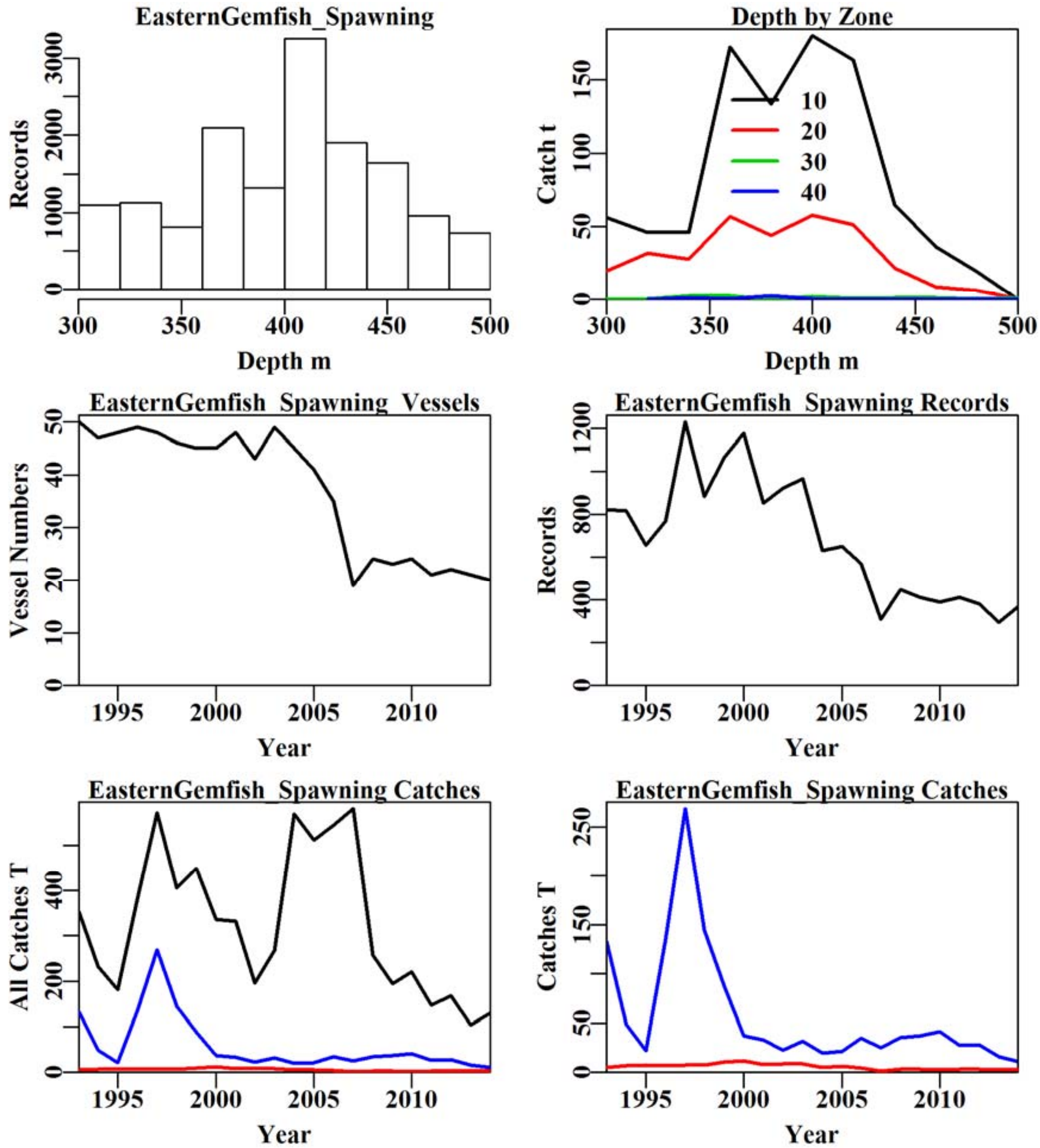


Figure 20.7. Eastern Gemfish, spawning fishery in depths between 300 – 500 m, taken by Trawl. The top left plot depicts the depth distribution of shots containing Eastern Gemfish from zones 10 to 40 in depths 300 – 500 m by Trawl. The top right plot depicts the distribution of catch by depth within zones 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).

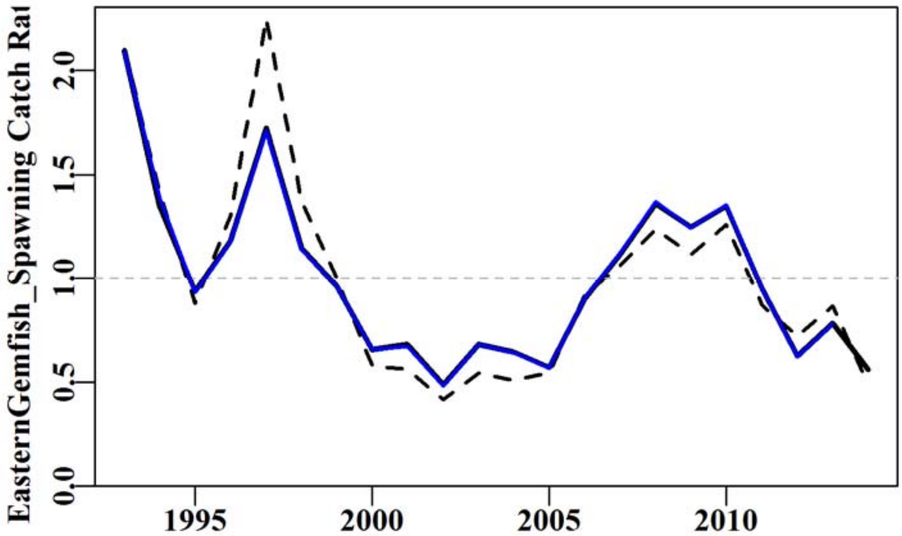


Figure 20.8. Eastern Gemfish, spawning fishery in depths between 300 – 500 m, taken by Trawl. The dashed black line represents the geometric mean catch rate and the solid black line the standardized catch rates (relative to the mean of the standardized catch rates). The blue line is last year's optimum standardization.

Table 20.7. 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 20.8. Eastern Gemfish, spawning fishery in depths between 300 – 500 m, taken by Trawl. Model selection criteria include the Akaike Information Criterion (AIC), residual sum of squares (RSS), model sum of squares (MSS), number of usable observations (Nobs), number of parameters (Npars), adjusted R^2 (adj_R^2) and the change in adjusted R^2 (%Change). The optimum model is Model 7 (Zone:Month). Depth category: DepC.

	Year	Vessel	Month	DepC	DayNight	Zone	Zone:Month	Zone:DepC
AIC	8765	7108	6285	5891	5852	5844	5558	5824
RSS	26861	23738	22465	21759	21694	21673	21236	21558
MSS	3925	7048	8321	9027	9092	9112	9550	9228
Nobs	15043	15043	15043	14937	14937	14937	14937	14937
Npars	22	123	126	136	139	142	151	172
adj_R^2	12.626	22.263	26.417	28.677	28.875	28.929	30.320	29.165
%Change	0.000	9.637	4.154	2.261	0.198	0.053	1.391	-1.156

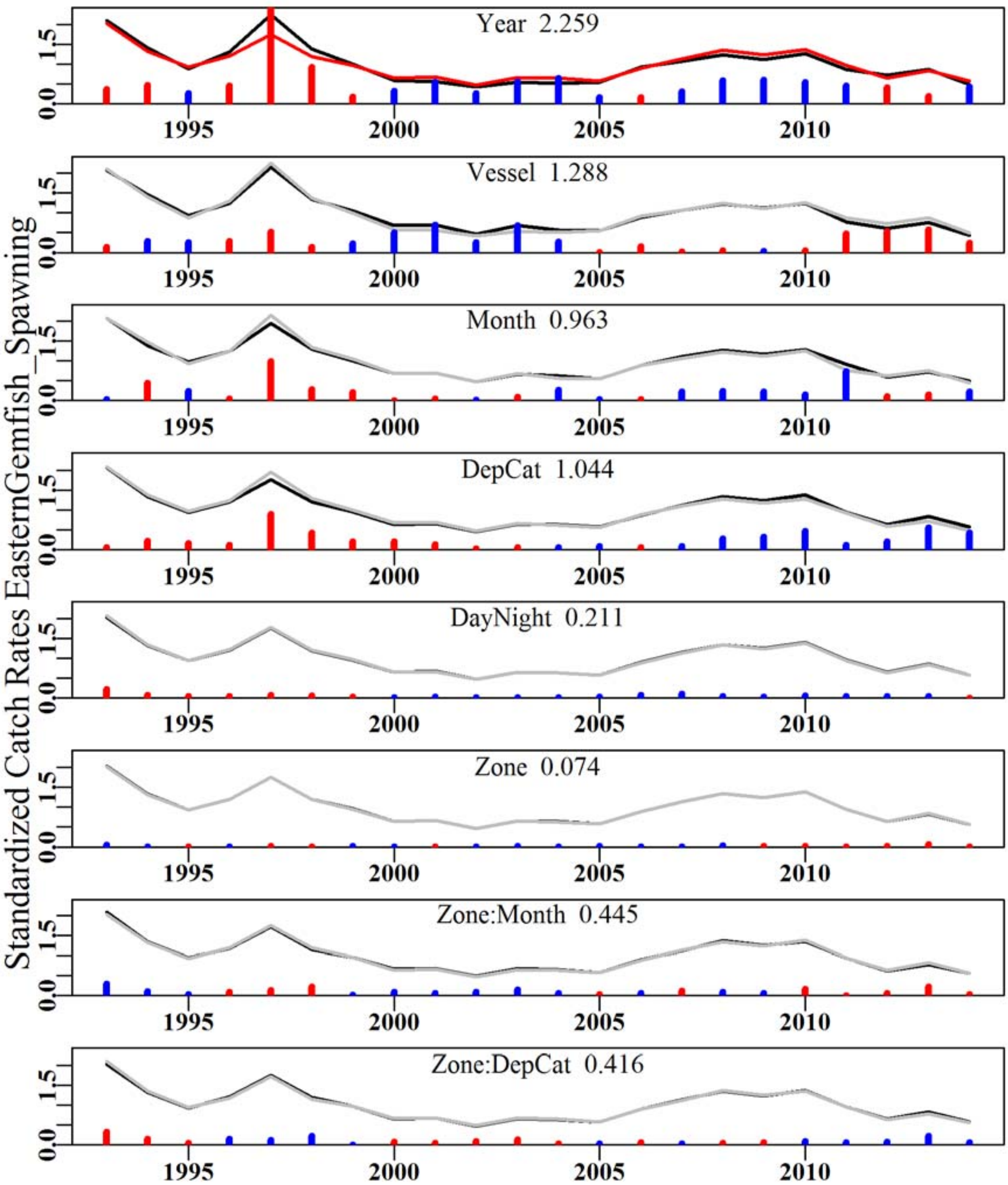


Figure 20.9. The relative influence of each factor used on the final trend in the optimal standardization for the Eastern Gemfish spawning fishery. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by the vertical bars with 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.

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

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

Table 20.9. 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	2.4605	0.0000
1987	4660.4470	1894	770.1410	74	25.6322	3.3006	0.0429
1988	3515.8190	2203	509.5870	77	20.2775	2.8425	0.0429
1989	1778.3250	1434	148.4000	69	11.5170	1.9004	0.0475
1990	1206.8970	758	104.1350	69	12.7467	1.8845	0.0573
1991	580.3220	731	65.9950	71	8.7585	1.2933	0.0585
1992	494.4410	694	135.1540	50	11.2924	1.7860	0.0592
1993	353.4100	1536	94.3200	58	8.9703	1.3851	0.0478
1994	232.1790	1832	63.8120	55	6.3021	0.9544	0.0460
1995	181.7460	1685	49.9770	54	5.5810	0.8647	0.0467
1996	382.1960	1947	55.7080	61	4.1794	0.6557	0.0459
1997	571.9758	1786	66.0200	58	4.3644	0.6886	0.0483
1998	404.8147	1246	45.6350	50	4.3330	0.6505	0.0508
1999	448.6767	1344	30.3190	53	2.9242	0.4754	0.0503
2000	336.4642	1718	32.3180	58	2.7962	0.4283	0.0480
2001	331.4862	1644	32.2480	52	2.0613	0.3487	0.0489
2002	195.8983	1617	19.0340	51	1.5969	0.2684	0.0493
2003	267.9710	1583	20.0334	49	1.7225	0.2961	0.0496
2004	568.8517	1771	38.5647	55	2.6317	0.4213	0.0489
2005	511.7585	1745	40.9667	49	2.8254	0.4511	0.0485
2006	544.8936	1325	32.1506	44	2.9593	0.4783	0.0517
2007	580.6498	788	28.1400	23	4.2429	0.6435	0.0589
2008	257.6855	840	35.4670	27	5.7070	0.8636	0.0581
2009	194.8654	514	27.2266	27	6.6449	0.8892	0.0682
2010	220.6510	704	22.8883	23	4.1931	0.6398	0.0613
2011	147.7397	800	22.8895	23	3.8396	0.5789	0.0602
2012	168.5996	709	21.9958	24	3.5107	0.5384	0.0621
2013	103.8201	596	23.4630	24	4.5974	0.6261	0.0658
2014	130.1963	432	7.6900	23	2.4592	0.3858	0.0715

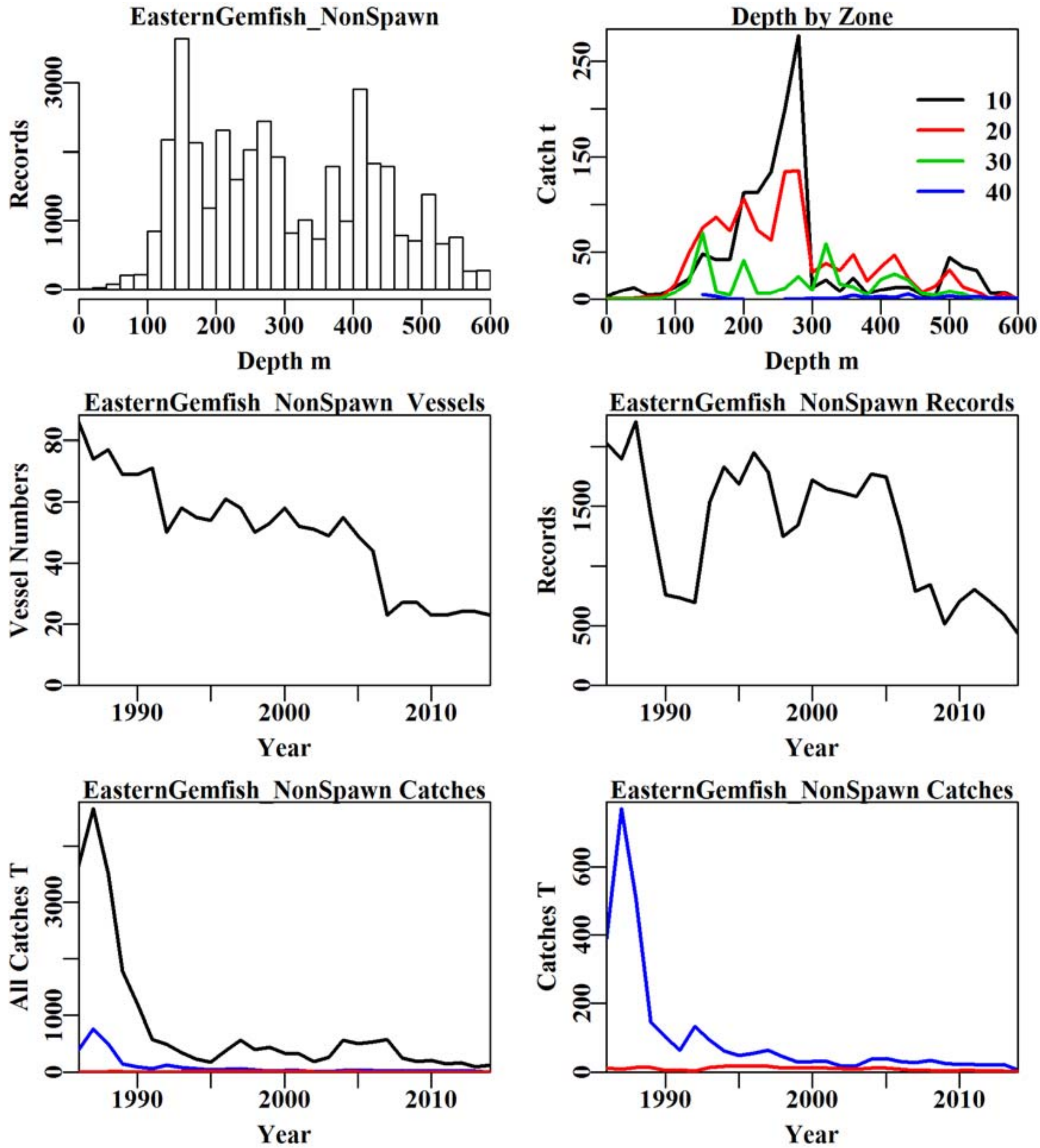


Figure 20.10. Non-spawning Eastern Gemfish from the SET in depths between 0 – 600 m, taken by Trawl. The top left plot depicts the depth distribution of shots containing non-spawning Eastern Gemfish from zones 10 to 40 in depths 0 – 600 m by Trawl. The top right plot depicts the distribution of catch 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).

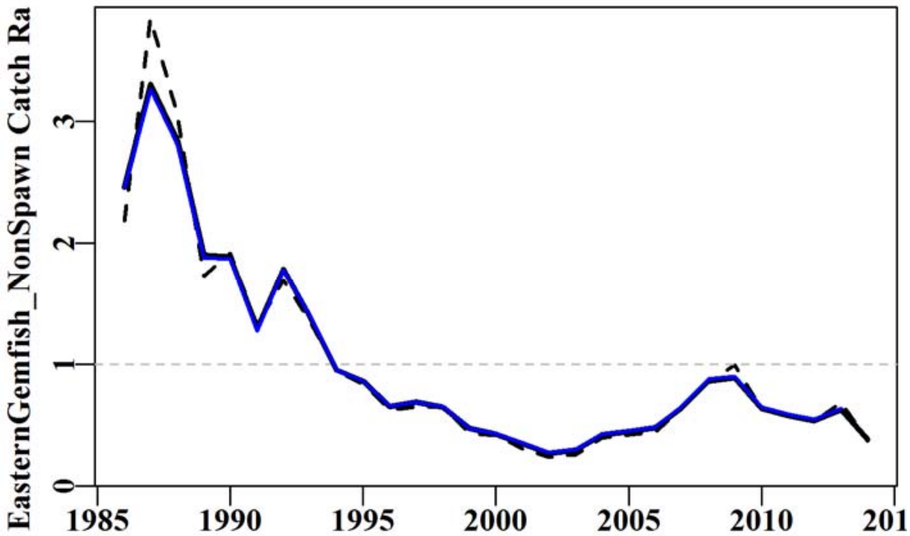


Figure 20.11. Non-spawning Eastern Gemfish from the SET in depths between 0 – 600 m, taken by Trawl. The dashed black line represents the geometric mean catch rate and the solid black line the standardized catch rates (relative to the mean of the standardized catch rates). The blue line is last year's optimum standardization.

Table 20.10. 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 20.11. Non-spawning Eastern Gemfish from the SET in depths between 0 – 600 m, taken by Trawl. Model selection criteria include the Akaike Information Criterion (AIC), residual sum of squares (RSS), model sum of squares (MSS), number of usable observations (Nobs), number of parameters (Npars), adjusted R^2 (adj_R^2) and the change in adjusted R^2 (%Change). The optimum model is Model 8 (Zone:DepCat). Depth category: DepC.

	Year	Vessel	DepC	Month	DayNight	Zone	Zone:Month	Zone:DepC
AIC	23949	18731	16578	16117	15818	15555	15273	15117
RSS	71192	61434	57670	56933	56473	56071	55554	55157
MSS	23042	32799	36564	37300	37761	38162	38680	39077
Nobs	37906	37906	37587	37587	37587	37587	37587	37587
Npars	29	214	244	255	258	261	294	351
adj_R^2	24.396	34.438	38.403	39.172	39.659	40.083	40.584	40.918
%Change	0.000	10.042	3.965	0.768	0.487	0.424	0.500	0.334

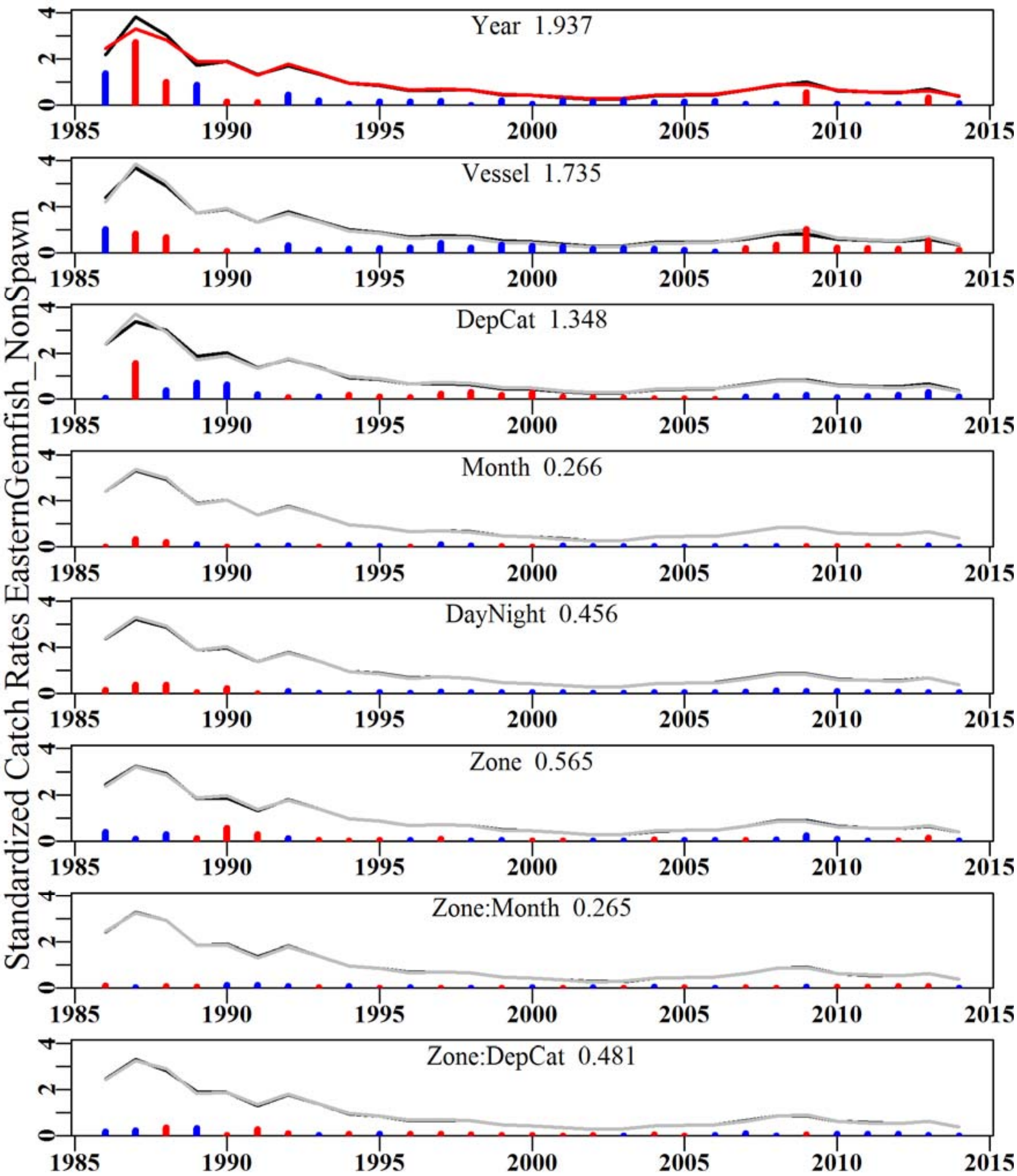


Figure 20.12. The relative influence of each factor used on the final trend in the optimal standardization for Non-spawning Eastern Gemfish. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by the vertical bars with blue 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.

20.4.4 Jackass Morwong Z10-50 (MOR – 37377003 Nemadactylus macropterus)

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

Table 20.12. 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	1.9502	0.0000
1987	1087.6900	4948	1000.0540	104	26.1917	2.2154	0.0267
1988	1483.5120	5984	1314.3970	102	29.1554	2.1850	0.0260
1989	1667.3730	5434	1500.6040	89	33.9001	2.1187	0.0268
1990	1001.4140	5022	837.3570	86	24.2137	1.7584	0.0278
1991	1138.0700	5233	899.6850	85	21.1181	1.5611	0.0276
1992	758.2540	3512	525.2990	64	19.0586	1.3003	0.0308
1993	1014.9853	4732	821.8810	73	21.3530	1.3188	0.0289
1994	818.4180	5660	684.8000	71	18.0744	1.1253	0.0276
1995	789.5280	5852	705.4090	63	16.3623	1.0526	0.0273
1996	827.1910	7535	749.5740	70	13.8607	0.9637	0.0262
1997	1063.3630	7561	934.0010	70	16.1581	1.0317	0.0267
1998	876.4044	5941	688.7050	65	13.4363	0.8876	0.0276
1999	961.2618	5801	779.7030	66	14.1587	0.9159	0.0278
2000	945.0978	6908	732.4510	79	10.1998	0.7717	0.0270
2001	790.1902	6841	651.9350	72	8.3548	0.5864	0.0273
2002	811.1362	7777	692.3930	66	8.3261	0.6150	0.0269
2003	774.5778	6537	600.9390	65	7.9043	0.5326	0.0275
2004	765.5049	6483	604.4761	71	8.6153	0.5317	0.0278
2005	784.1607	6376	597.4155	59	8.9785	0.5733	0.0278
2006	811.2979	5446	616.1015	50	11.5427	0.6599	0.0287
2007	607.8702	3812	443.3657	31	12.2504	0.6691	0.0312
2008	700.4393	4491	546.6400	34	13.7889	0.7807	0.0301
2009	454.3668	3384	344.4442	28	11.4694	0.6888	0.0321
2010	380.0247	3432	291.8870	31	8.5531	0.5071	0.0322
2011	427.9796	3524	303.3383	29	8.5407	0.4828	0.0320
2012	395.5938	3145	305.2530	30	8.9426	0.4863	0.0328
2013	323.9461	2518	238.6190	27	8.7138	0.4263	0.0347
2014	216.4660	2002	136.3130	26	5.8235	0.3036	0.0369

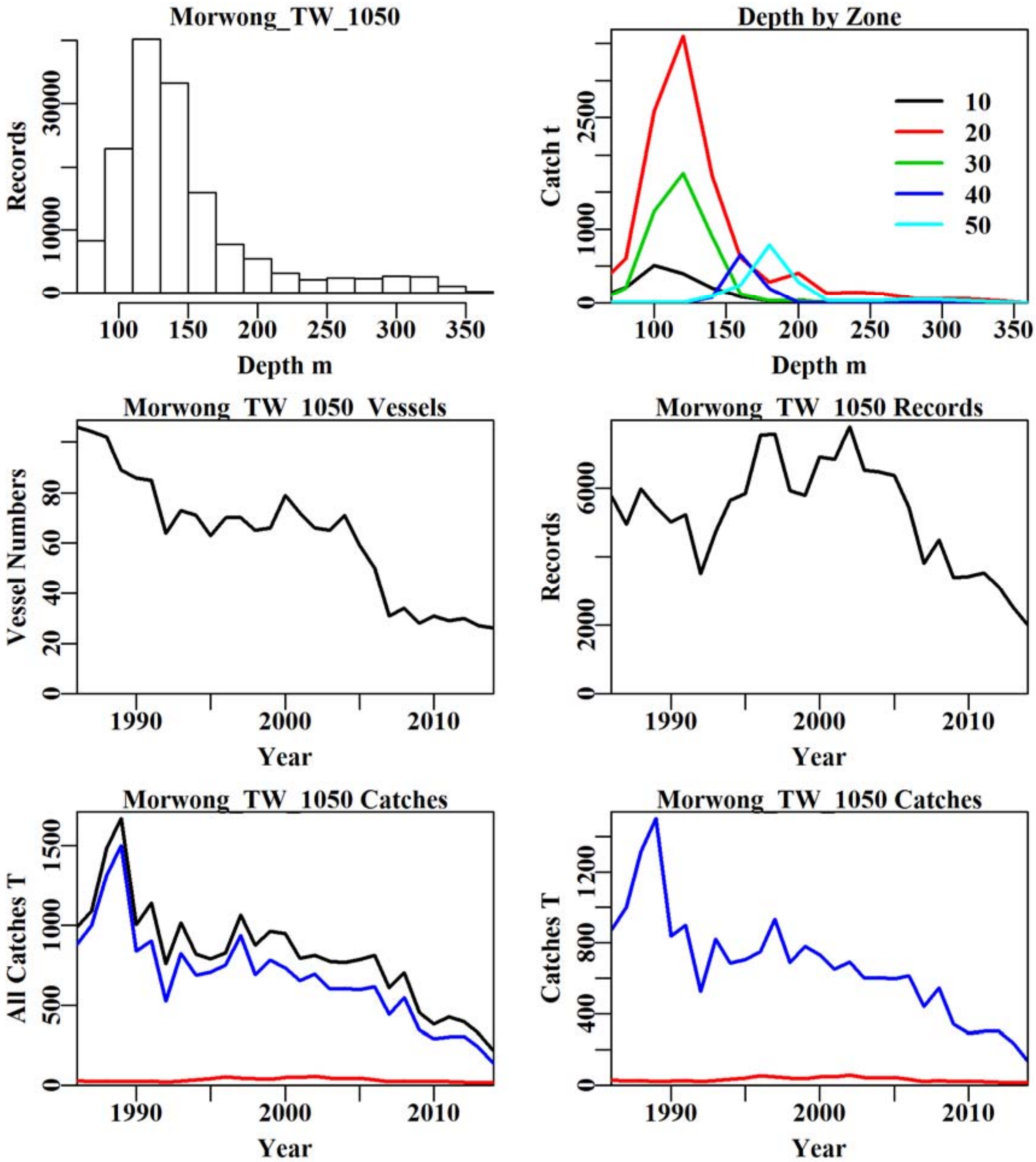


Figure 20.13. Jackass Morwong from zones 10 to 50 in depths 70 – 360 m by Trawl. The top left plot depicts the depth distribution of shots containing Jackass Morwong from zones 10 to 50 in depths 70 – 360 m by Trawl. The top right plot depicts the distribution of catch by depth within zones 10 to 50. 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).

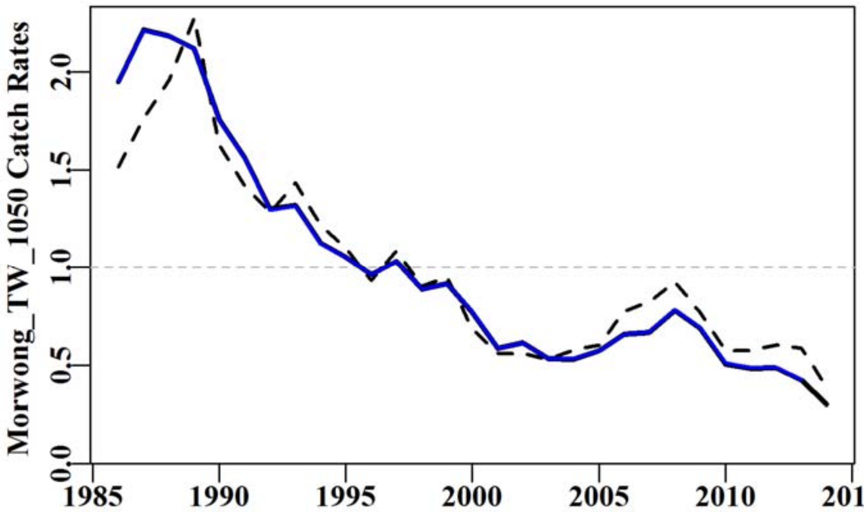


Figure 20.14. Jackass Morwong from zones 10 to 50 in depths 70 – 360 m by Trawl. The dashed black line represents the geometric mean catch rate and the solid black line the standardized catch rates. The graph standardizes catch rates relative to the mean of the standardized catch rates. The blue line is last year's optimum standardization.

Table 20.13. 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 20.14. 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	116977	94985	88208	83815	78886	77494	75409	76016
RSS	327856	282787	270389	261539	253087	250742	247144	248090
MSS	29276	74345	86743	95593	104045	106390	109988	109042
Nobs	151663	151663	151663	150277	150277	150277	150277	150277
Npars	29	247	258	273	277	280	324	340
adj_R^2	8.181	20.689	24.160	26.634	29.003	29.659	30.649	30.376
%Change	0.000	12.508	3.472	2.474	2.369	0.656	0.989	-0.273

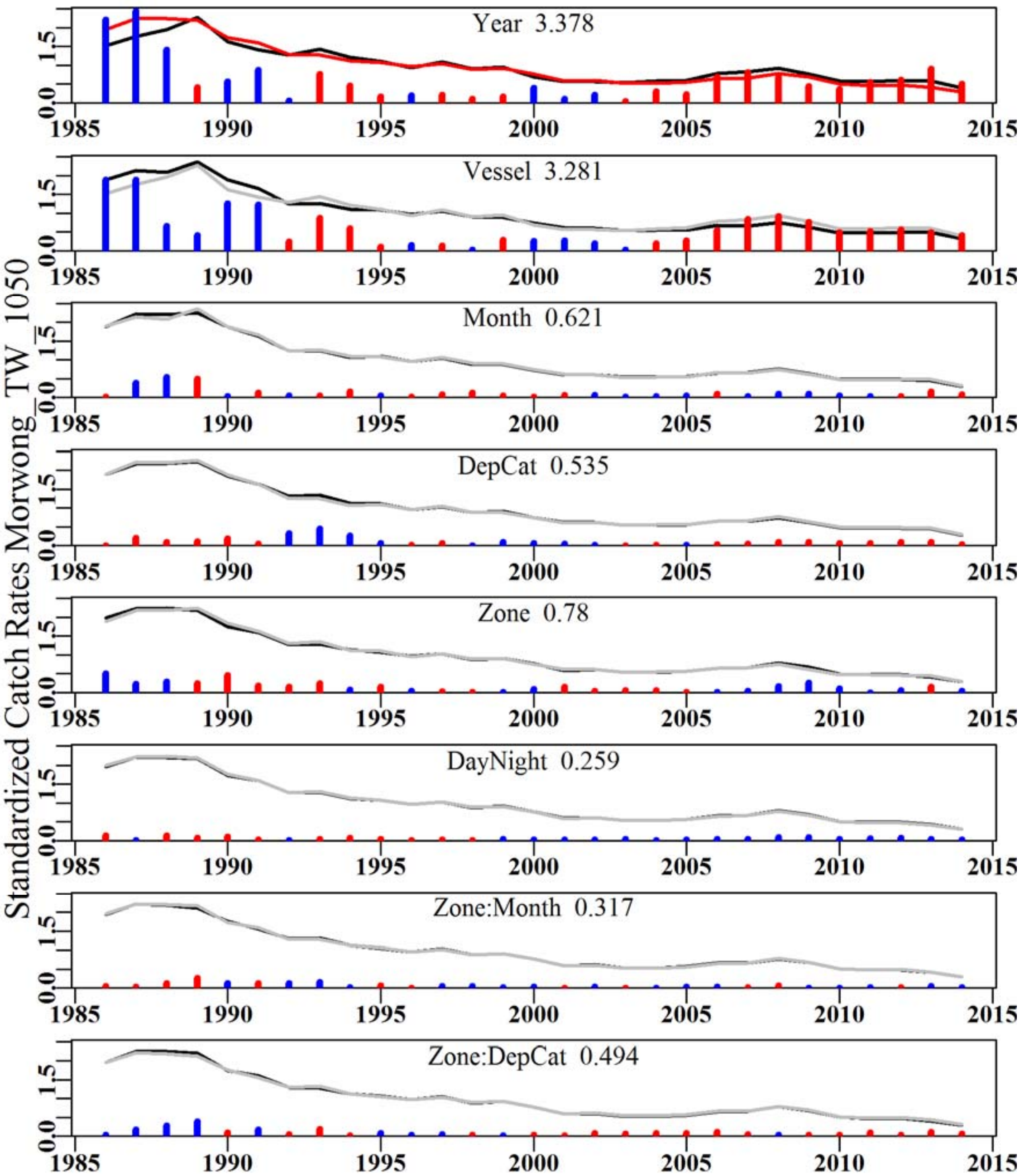


Figure 20.15. The relative influence of each factor used on the final trend in the optimal standardization for Jackass Morwong in zones 10 – 50. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by the vertical bars with 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.

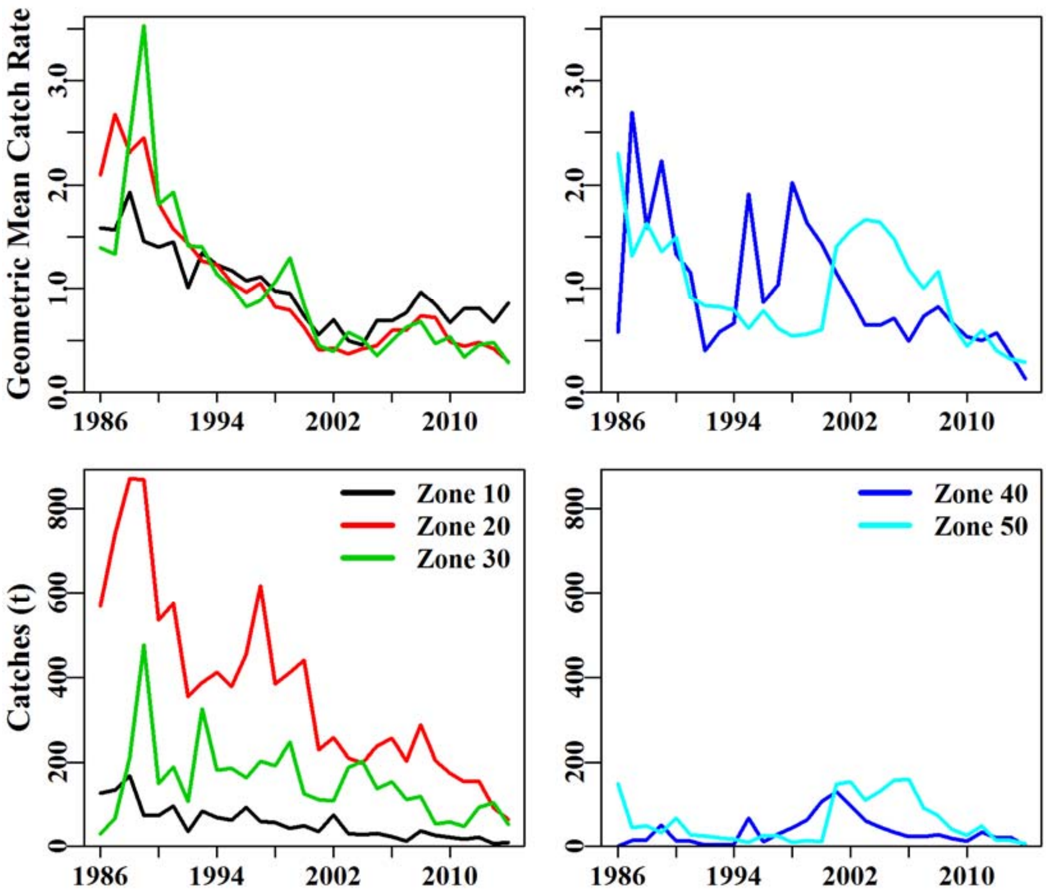


Figure 20.16. The trends in catch and geometric mean catch rates for Jackass Morwong taken by Trawl across SESSF zones 10 – 50. The catch rate trends across zones 10 – 30 are very similar, whilst those for zones 40 to 50 are noisy due to low catches until after 1996.

Table 20.15. 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	12.820
1988	177.971	922.634	213.955	16.700	51.072	56.980	41.430
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	45.693
1991	107.642	690.990	225.715	14.382	33.105	22.191	32.921
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	46.811
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	72.571
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	4.139	26.905
2013	7.630	103.087	105.968	21.596	16.065	4.128	25.447
2014	10.086	72.264	53.583	1.962	8.236	1.705	33.464

20.4.5 Jackas 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 20.16. Jackass Morwong from zones 10 and 20 in depths 70 – 300 m by Trawl. Total catch (TotCatch; t) is the total reported in the database, number of records used in the analysis (Records), reported catch (CatchT; t) in the area and depth used in the analysis and number of vessels used in the analysis (Vessels). GeoMean is the geometric mean of catch rates (kg/hr). The optimum model is Zone:Month and standard deviation (StDev) relates to the data in the optimum model.

Year	TotCatch	Records	CatchT	Vessels	GeoMean	Zone:Month	StDev
1986	982.8110	5045	686.2250	87	21.2677	1.9135	0.0000
1987	1087.6900	4266	858.4750	79	26.2295	2.3263	0.0293
1988	1483.5120	5147	1025.2560	79	27.6740	2.1897	0.0285
1989	1667.3730	4325	929.4090	65	27.9306	2.0564	0.0296
1990	1001.4140	4127	600.5530	59	21.9897	1.7121	0.0305
1991	1138.0700	4436	661.7960	55	19.4037	1.6236	0.0303
1992	758.2540	2871	380.1120	47	17.2369	1.2877	0.0340
1993	1014.9853	3363	464.9550	49	17.0123	1.3526	0.0327
1994	818.4180	4470	473.4230	49	16.1919	1.1855	0.0307
1995	789.5280	4600	435.2090	47	14.0323	1.0998	0.0303
1996	827.1910	6218	544.8280	51	12.3880	0.9947	0.0289
1997	1063.3630	6031	672.1420	53	14.8970	1.0968	0.0296
1998	876.4044	4790	435.7790	46	11.3605	0.8870	0.0306
1999	961.2618	4429	447.8470	50	11.3334	0.8916	0.0312
2000	945.0978	5724	479.7880	56	8.7646	0.7442	0.0298
2001	790.1902	4963	260.7660	49	5.8822	0.5232	0.0307
2002	811.1362	5718	329.1130	45	6.3693	0.5781	0.0302
2003	774.5778	4584	237.0400	48	5.3333	0.4593	0.0312
2004	765.5049	4196	220.2786	53	5.4124	0.4539	0.0321
2005	784.1607	4378	262.6155	40	6.8948	0.5535	0.0318
2006	811.2979	3417	275.5010	37	8.8173	0.6670	0.0334
2007	607.8702	2437	212.3727	21	9.2385	0.6336	0.0369
2008	700.4393	3167	321.5780	26	11.2739	0.8080	0.0348
2009	454.3668	2448	228.4745	20	10.4038	0.7410	0.0370
2010	380.0247	2589	193.6210	20	7.6365	0.5155	0.0367
2011	427.9796	2400	170.9440	19	7.4002	0.4977	0.0377
2012	395.5938	2166	175.1280	20	7.6279	0.4932	0.0383
2013	323.9461	1409	97.4370	16	6.8983	0.4081	0.0434
2014	216.4660	1417	73.4850	18	5.2286	0.3064	0.0431

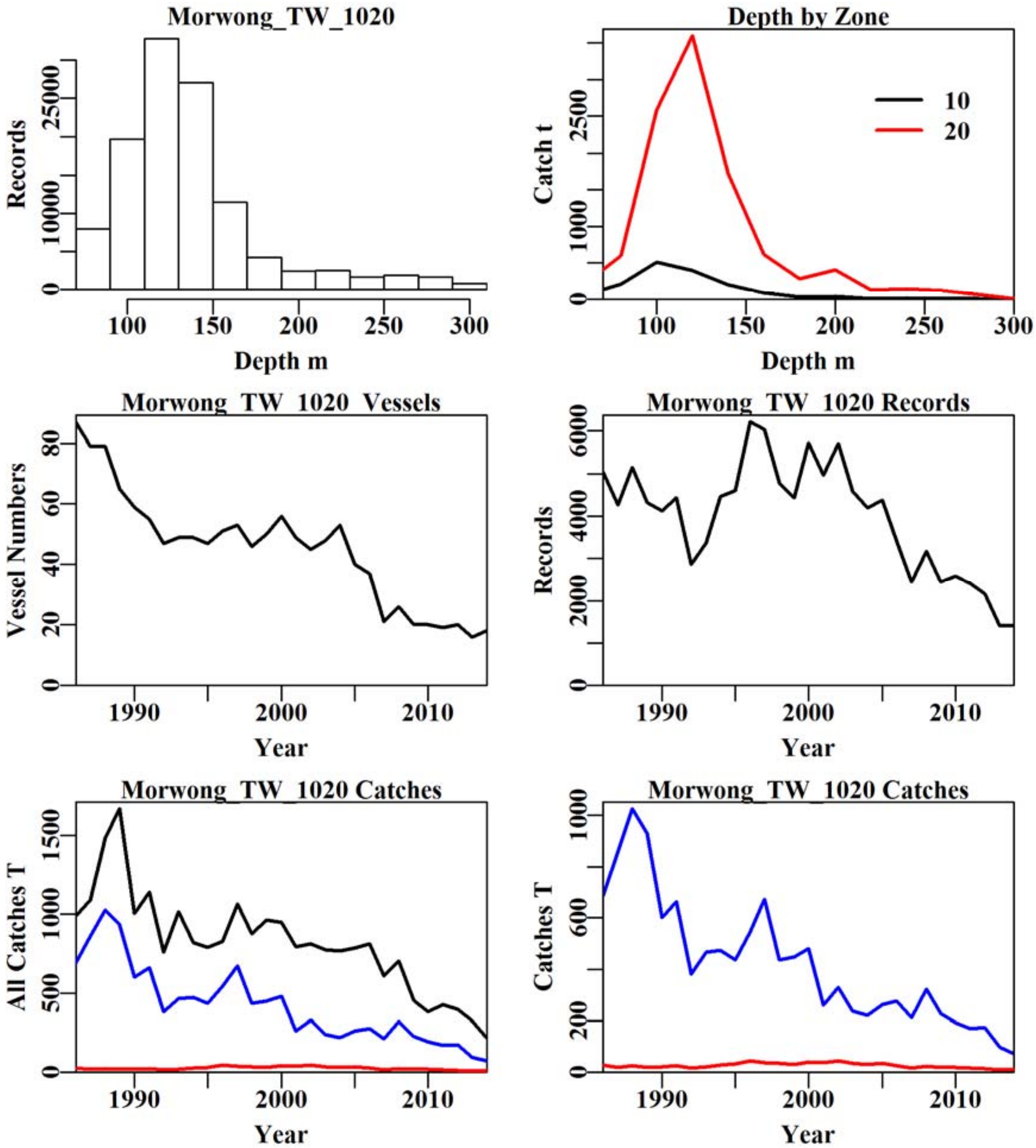


Figure 20.17. Jackass Morwong from zones 10 and 20 in depths 70 – 300 m by Trawl. The top left plot depicts the depth distribution of shots containing Jackass Morwong from zones 10 and 20 in depths 70 – 300 m by Trawl. The top right plot depicts the distribution of catch by depth within zones 10 and 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).

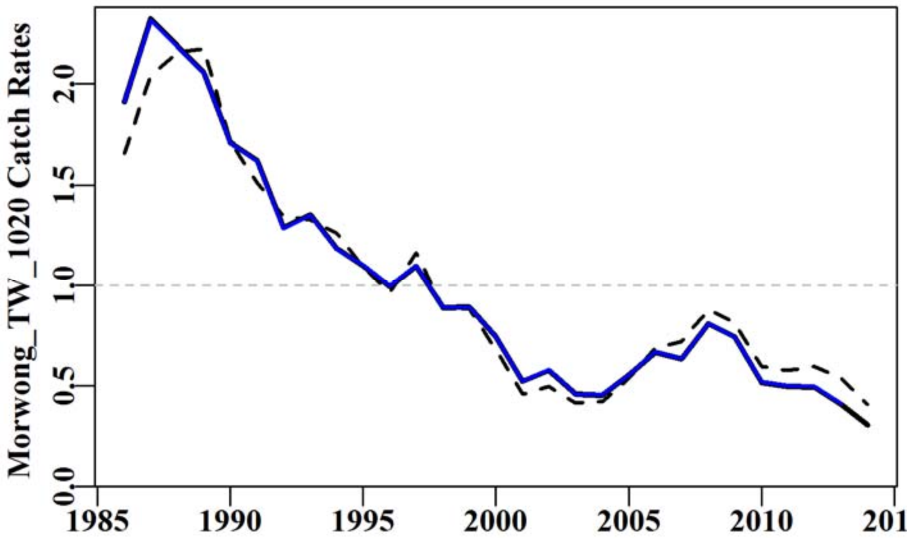


Figure 20.18. Jackass Morwong from zones 10 and 20 in depths 70 – 300 m by Trawl. The dashed black line represents the geometric mean catch rate and the solid black line the standardized catch rates. The graph standardizes catch rates relative to the mean of the standardized catch rates. The blue line is last year's optimum standardization.

Table 20.17. 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 20.18. 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	83077	68720	65780	63554	61680	60376	59503	60047
RSS	236784	208394	203100	198360	195126	192898	191390	192302
MSS	30965	59356	64649	69389	72624	74851	76359	75447
Nobs	115131	115131	115131	114092	114092	114092	114092	114092
Npars	29	203	214	226	227	230	241	242
adj_R^2	11.543	22.032	24.005	25.769	26.979	27.811	28.368	28.026
%Change	0.000	10.488	1.973	1.765	1.210	0.832	0.557	-0.342

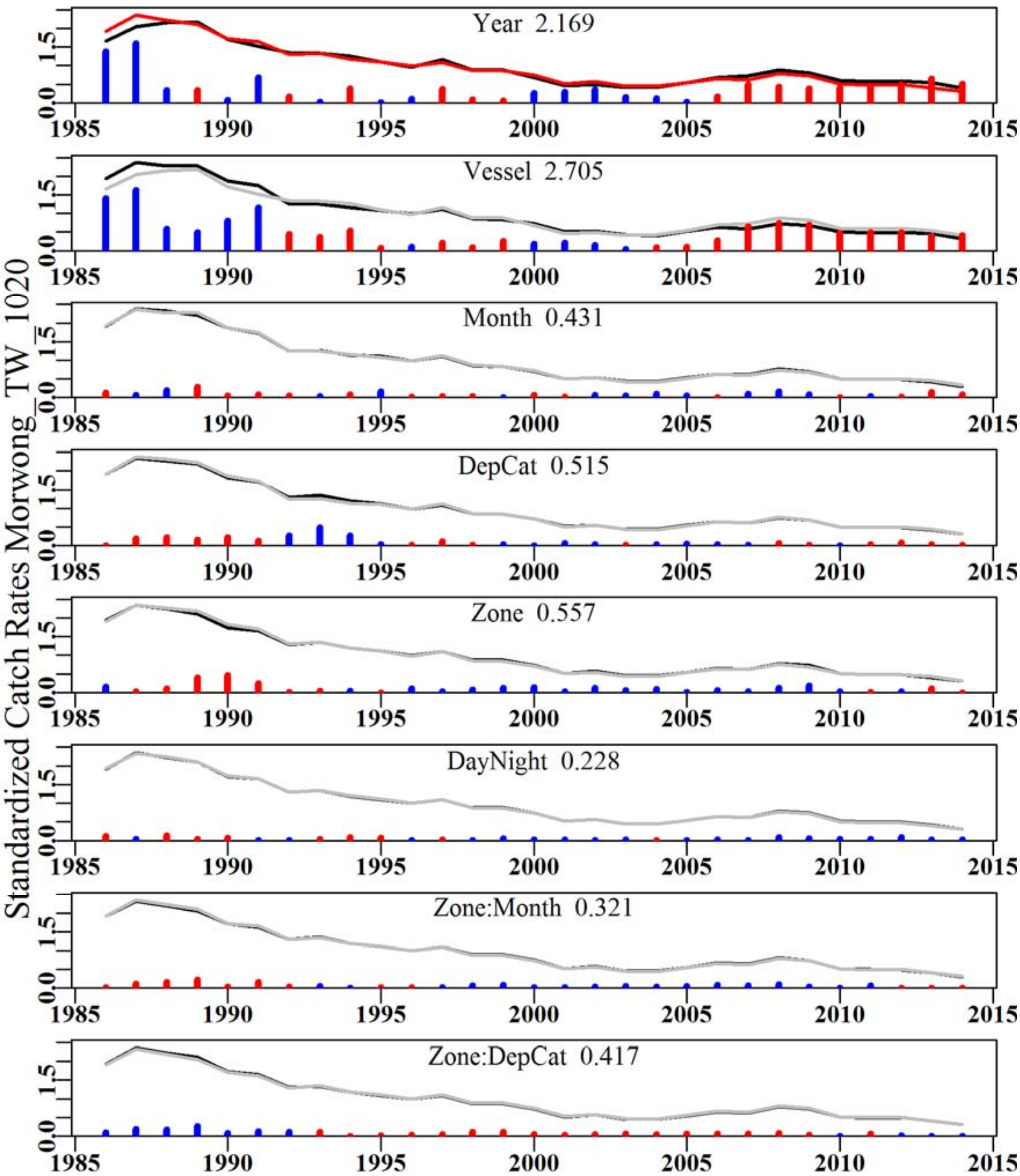


Figure 20.19. The relative influence of each factor used on the final trend in the optimal standardization for Jackass Morwong in Zones 10 – 20. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by the vertical bars with 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.

20.4.6 Jackass Morwong Z30 (MOR – 37377003 – *Nemadactylus macropterus*)

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

Table 20.19. 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	1.8797	0.0000
1987	1087.6900	210	57.4760	13	45.8807	1.9201	0.1797
1988	1483.5120	283	207.9350	13	90.9064	2.6523	0.1744
1989	1667.3730	687	475.0390	19	125.0173	3.3567	0.1675
1990	1001.4140	386	148.8570	26	64.6762	2.3584	0.1683
1991	1138.0700	427	189.5340	29	68.3860	1.5026	0.1666
1992	758.2540	335	106.8190	18	50.3448	1.6388	0.1713
1993	1014.9853	1042	325.8730	27	49.6567	1.2944	0.1612
1994	818.4180	762	180.1850	22	40.3412	0.8837	0.1623
1995	789.5280	826	185.2820	19	36.4017	0.8653	0.1632
1996	827.1910	890	161.4020	19	29.4500	0.8458	0.1623
1997	1063.3630	940	202.3890	15	32.4284	0.9564	0.1617
1998	876.4044	772	191.7330	15	38.4649	0.9266	0.1624
1999	961.2618	855	246.9130	17	46.7614	1.1004	0.1628
2000	945.0978	552	123.7850	23	30.7755	0.7353	0.1647
2001	790.1902	812	110.7990	19	16.3003	0.4903	0.1616
2002	811.1362	1044	108.9440	15	13.9509	0.4301	0.1612
2003	774.5778	1126	187.0530	19	20.4814	0.5930	0.1603
2004	765.5049	1500	201.2780	15	18.1516	0.4493	0.1595
2005	784.1607	1159	137.7100	17	12.3142	0.3295	0.1608
2006	811.2979	1127	154.4820	14	17.6164	0.4134	0.1614
2007	607.8702	714	111.6250	8	22.5650	0.5738	0.1637
2008	700.4393	768	119.0200	9	24.1797	0.5908	0.1635
2009	454.3668	463	54.3427	10	16.5669	0.4293	0.1670
2010	380.0247	372	58.1890	9	19.1085	0.4444	0.1700
2011	427.9796	451	48.2553	8	12.0083	0.2971	0.1676
2012	395.5938	561	92.4940	7	16.4181	0.3919	0.1661
2013	323.9461	599	103.4190	10	17.1228	0.4344	0.1649
2014	216.4660	335	53.0290	9	10.1019	0.2163	0.1704

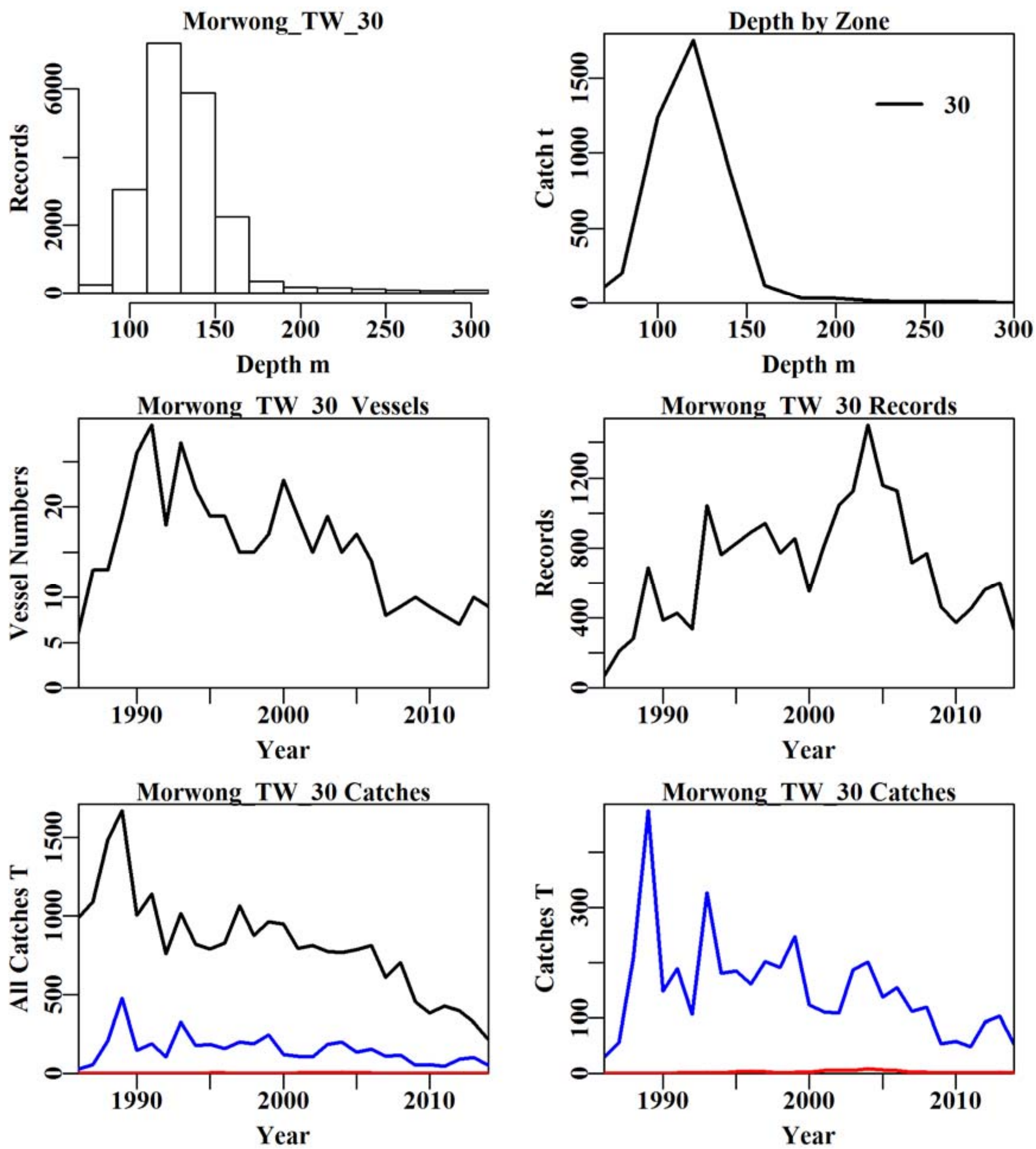


Figure 20.20. Jackass Morwong from zone 30 in depths 70 – 300 m by Trawl. The top left plot depicts the depth distribution of shots containing Jackass Morwong from zone 30 in depths 70 – 300 m by Trawl. The top right plot depicts the catch distribution by depth within zone 30. The middle left plot depicts 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).

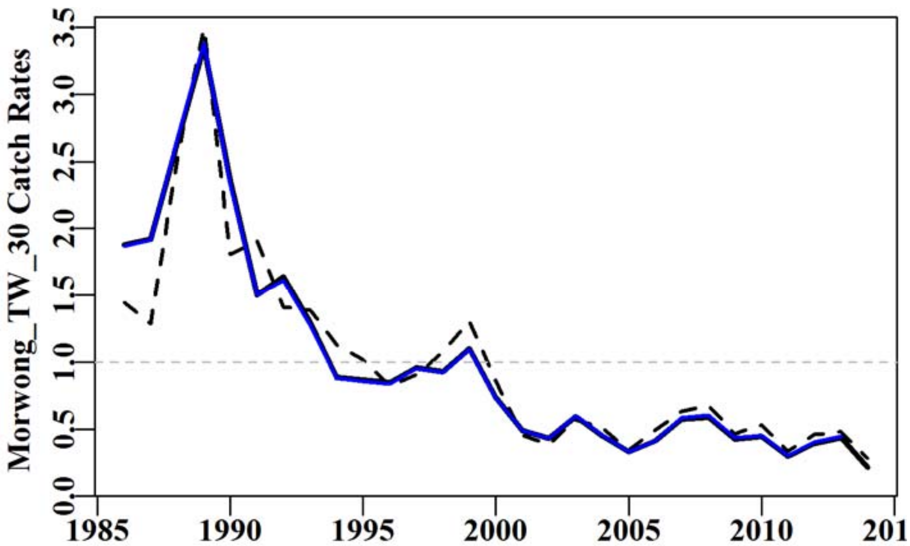


Figure 20.21. Jackass Morwong from zone 30 in depths 70 – 300 m by Trawl. The dashed black line represents the geometric mean catch rate and the solid black line the standardized catch rates (relative to the mean of the standardized catch rates). The blue line is last year's optimum standardization.

Table 20.20. 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 20.21. 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	10586	8738	7559	6889	6725	6681	6653	6778
RSS	33911	30893	28864	27653	27416	27264	26955	27390
MSS	6863	9881	11910	13121	13358	13509	13819	13384
Nobs	20067	20067	20067	19819	19819	19819	19819	19819
Npars	29	40	132	144	147	180	279	183
adj_R^2	16.716	24.086	28.745	31.687	32.263	32.523	32.951	32.202
%Change	0.000	7.370	4.659	2.942	0.575	0.261	0.428	-0.749

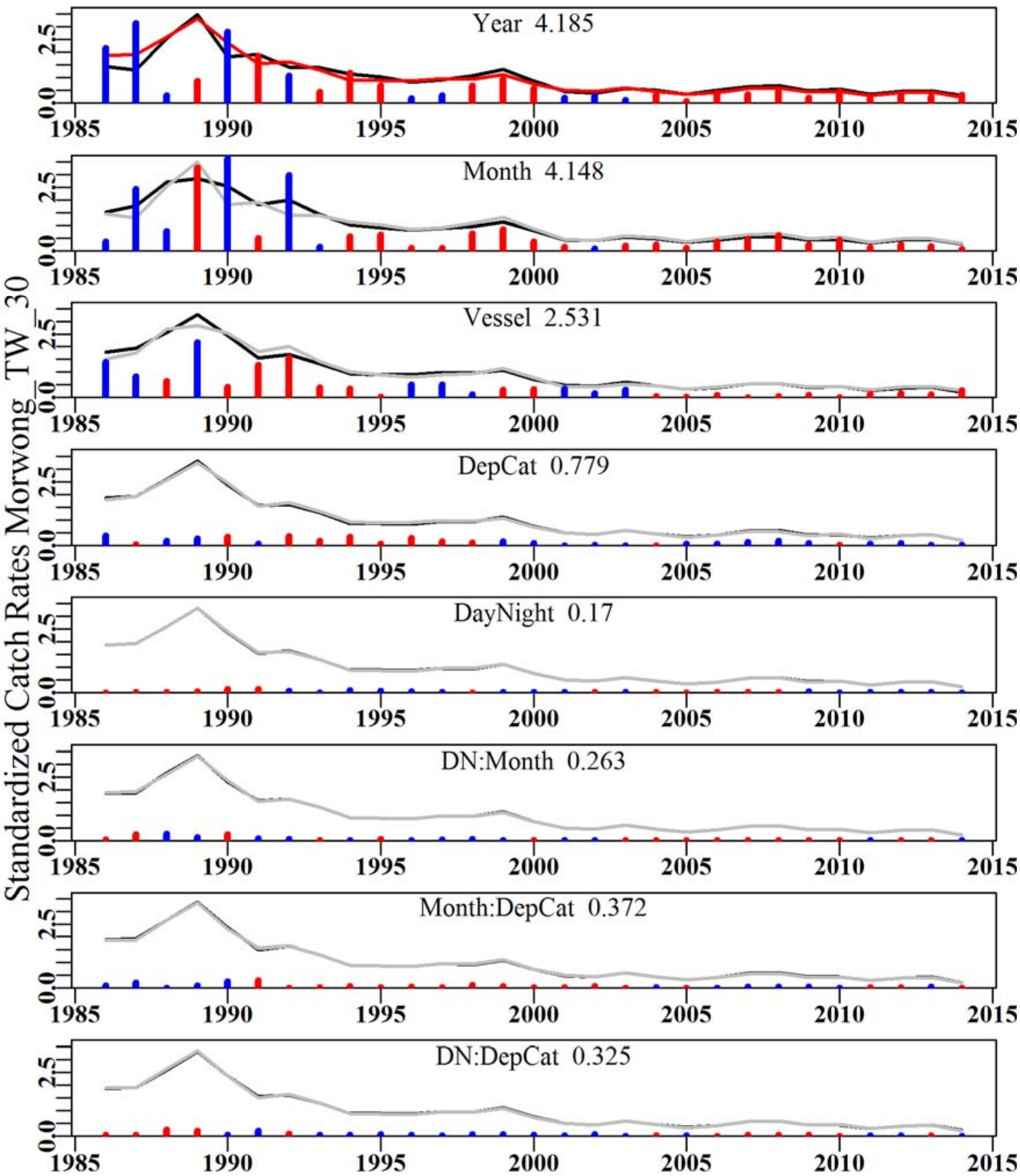


Figure 20.22. The relative influence of each factor used on the final trend in the optimal standardization for Jackass Morwong in zone 30. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by the vertical bars with blue 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.

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

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

Table 20.22. 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	1.9674	0.0000
1987	1087.6900	350	58.4640	21	24.4475	1.5426	0.0871
1988	1483.5120	402	65.4440	19	32.2567	2.3047	0.0872
1989	1667.3730	346	83.2030	21	32.2213	1.6706	0.0921
1990	1001.4140	412	80.6570	22	28.9610	1.6835	0.0935
1991	1138.0700	281	40.3800	26	18.6097	1.1453	0.0977
1992	758.2540	252	28.8780	14	15.3915	0.9301	0.1006
1993	1014.9853	248	24.9710	17	15.5454	0.9039	0.1017
1994	818.4180	312	22.6790	16	14.6606	0.8740	0.0950
1995	789.5280	295	77.6150	17	21.5262	0.9230	0.0960
1996	827.1910	346	37.0710	17	15.3414	1.0060	0.0933
1997	1063.3630	489	53.8510	20	12.8372	0.7958	0.0866
1998	876.4044	267	54.6300	19	14.8359	0.8398	0.0986
1999	961.2618	383	77.2350	17	15.5951	0.7663	0.0914
2000	945.0978	430	118.9080	26	22.5459	1.1093	0.0915
2001	790.1902	920	276.7930	25	34.4490	1.1991	0.0806
2002	811.1362	860	251.7490	22	33.1596	1.1974	0.0808
2003	774.5778	655	171.7260	24	30.9832	1.0062	0.0842
2004	765.5049	681	176.6765	25	30.6678	1.0681	0.0833
2005	784.1607	722	190.7030	21	28.0502	1.1496	0.0827
2006	811.2979	818	183.2035	19	21.6176	0.9186	0.0817
2007	607.8702	594	115.4050	15	19.7196	0.7519	0.0846
2008	700.4393	473	101.9450	16	24.9533	0.7644	0.0878
2009	454.3668	413	59.1540	13	14.8023	0.6098	0.0907
2010	380.0247	410	38.3110	13	10.0420	0.4439	0.0904
2011	427.9796	622	82.8770	14	12.6506	0.4698	0.0851
2012	395.5938	345	34.7220	14	10.2040	0.3539	0.0939
2013	323.9461	466	36.1660	13	8.0357	0.3414	0.0896
2014	216.4660	225	9.2010	12	5.3615	0.2636	0.1047

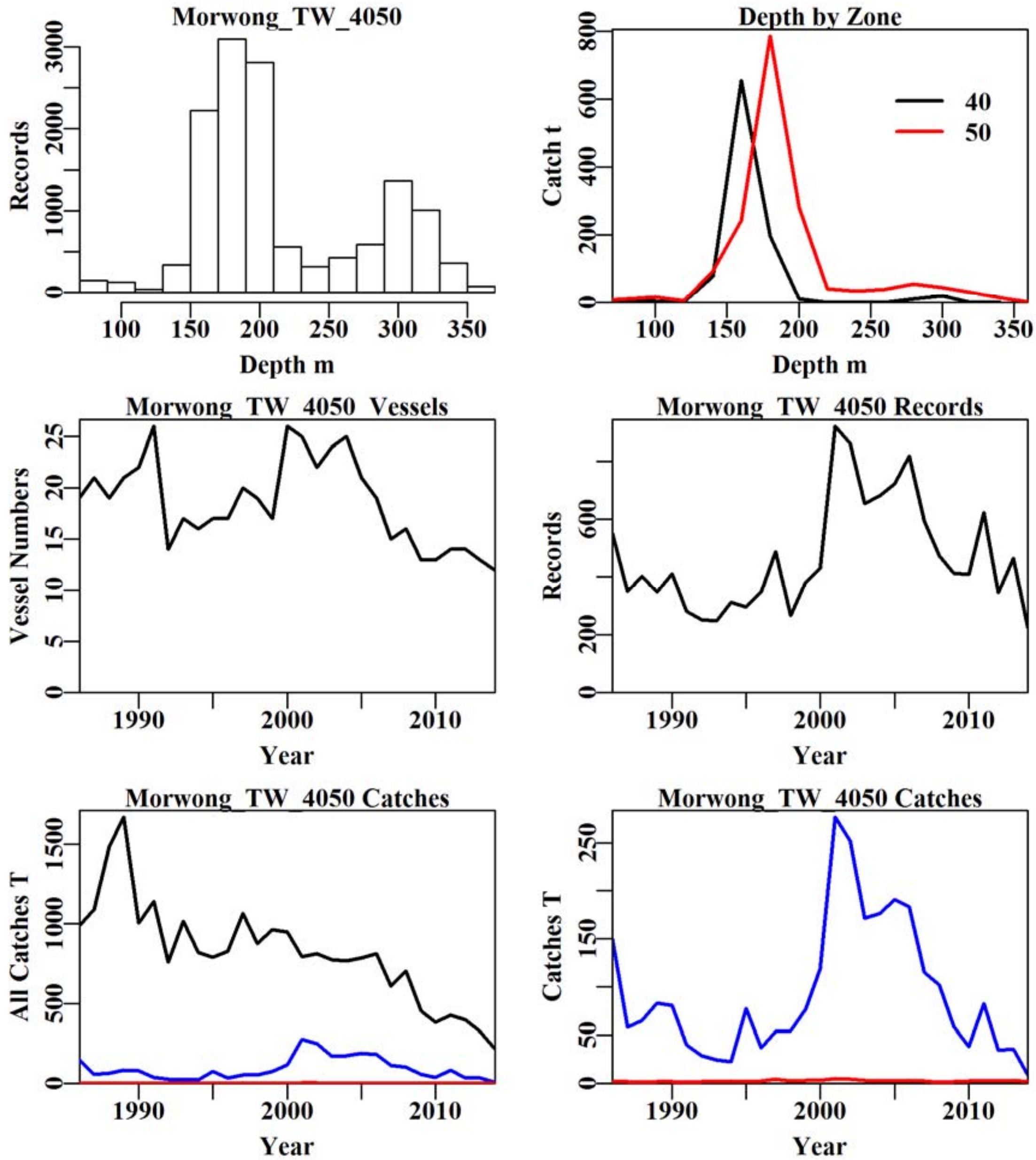


Figure 20.23. Jackass Morwong from zones 40 and 50 in depths 70 – 360 m by Trawl. The top left plot depicts the depth distribution of shots containing Jackass Morwong from zones 40 and 50 in depths 70 – 360 m by Trawl. The top right plot depicts the catch distribution by depth within zones 40 and 50. 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).

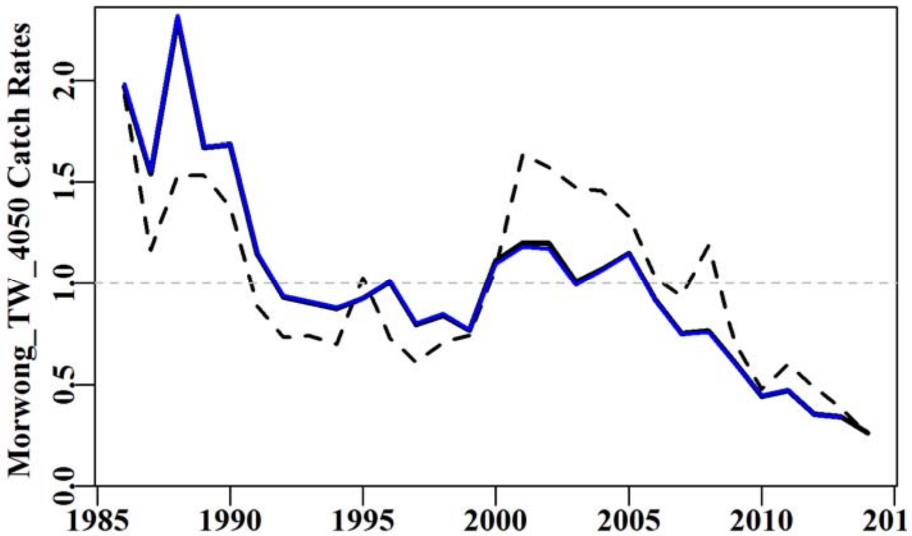


Figure 20.24. Jackass Morwong from zones 40 and 50 in depths 70 – 360 m by Trawl. The dashed black line represents the geometric mean catch rate and the solid black line the standardized catch rates. The graph standardizes catch rates relative to the mean of the standardized catch rates. The blue line is last year's optimum standardization.

Table 20.23. 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 20.24. 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	8013	5659	4468	3859	3762	3622	3467	3534
RSS	24387	20369	18615	17566	17432	17249	17024	17099
MSS	2884	6901	8655	9705	9838	10021	10247	10172
Nobs	13568	13469	13469	13469	13469	13469	13469	13469
Npars	29	44	55	141	144	145	156	160
adj_R^2	10.391	25.068	31.464	34.910	35.390	36.063	36.848	36.551
%Change	0.000	14.678	6.396	3.446	0.480	0.673	0.784	-0.297

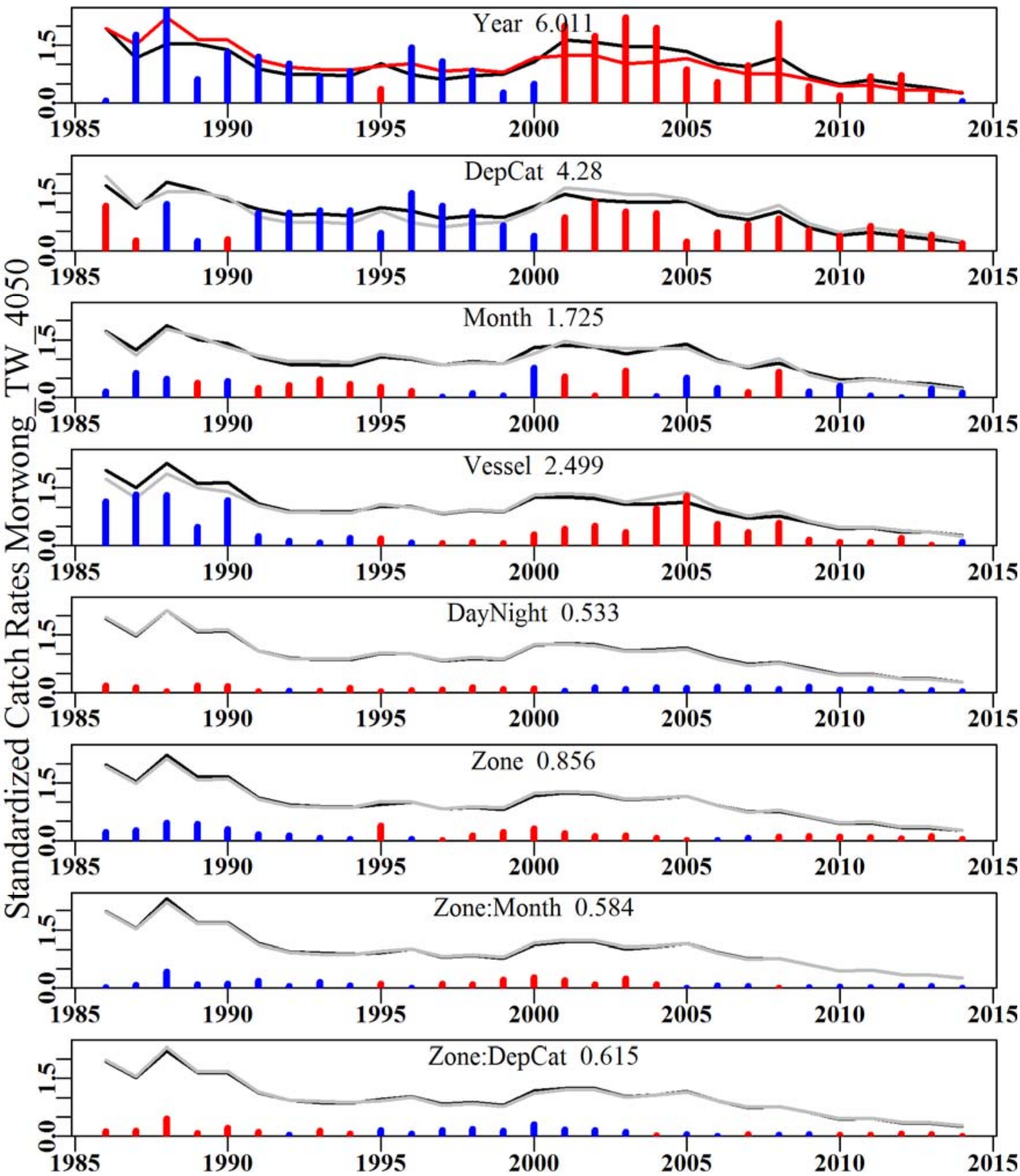


Figure 20.25. The relative influence of each factor used on the final trend in the optimal standardization for Jackass Morwong in zones 40 and 50. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by the vertical bars with 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.

20.4.8 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 3828 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 20.25. 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	1.9228	0.0000
1987	1087.6900	257	52.1400	20	32.6410	1.5514	0.1017
1988	1483.5120	215	48.1230	17	40.4386	1.6269	0.1110
1989	1667.3730	214	76.5180	21	51.8712	1.8158	0.1148
1990	1001.4140	300	75.8570	22	43.5691	1.9109	0.1112
1991	1138.0700	141	29.8920	23	32.8280	1.0211	0.1296
1992	758.2540	116	21.8810	14	23.0810	0.7133	0.1368
1993	1014.9853	124	19.1390	15	25.8778	0.8092	0.1333
1994	818.4180	159	15.7610	15	21.7099	0.8381	0.1222
1995	789.5280	176	72.9900	17	42.3529	1.1403	0.1181
1996	827.1910	144	28.9150	16	27.3737	0.9820	0.1257
1997	1063.3630	206	45.2960	18	24.6520	0.8932	0.1125
1998	876.4044	130	50.2450	16	30.3815	0.9823	0.1285
1999	961.2618	209	57.6800	15	25.6370	0.9859	0.1125
2000	945.0978	264	113.2420	23	38.0129	1.3090	0.1106
2001	790.1902	725	263.6650	23	46.5442	1.2796	0.0913
2002	811.1362	685	244.3640	22	46.0736	1.2187	0.0910
2003	774.5778	507	163.4740	24	42.9567	1.0099	0.0958
2004	765.5049	536	157.2480	23	35.0950	1.0244	0.0941
2005	784.1607	540	174.7060	21	35.8926	1.1929	0.0934
2006	811.2979	663	170.2380	19	25.6084	0.9288	0.0913
2007	607.8702	497	107.1750	15	22.1800	0.7557	0.0941
2008	700.4393	393	95.4710	16	29.4112	0.7481	0.0978
2009	454.3668	356	56.7370	13	17.3238	0.6230	0.1007
2010	380.0247	337	34.8260	13	10.4950	0.4230	0.1015
2011	427.9796	541	78.3450	14	13.8741	0.4487	0.0946
2012	395.5938	284	32.3010	14	11.6905	0.3145	0.1050
2013	323.9461	397	33.9460	13	8.7739	0.3220	0.1001
2014	216.4660	183	7.9680	12	5.3284	0.2084	0.1181

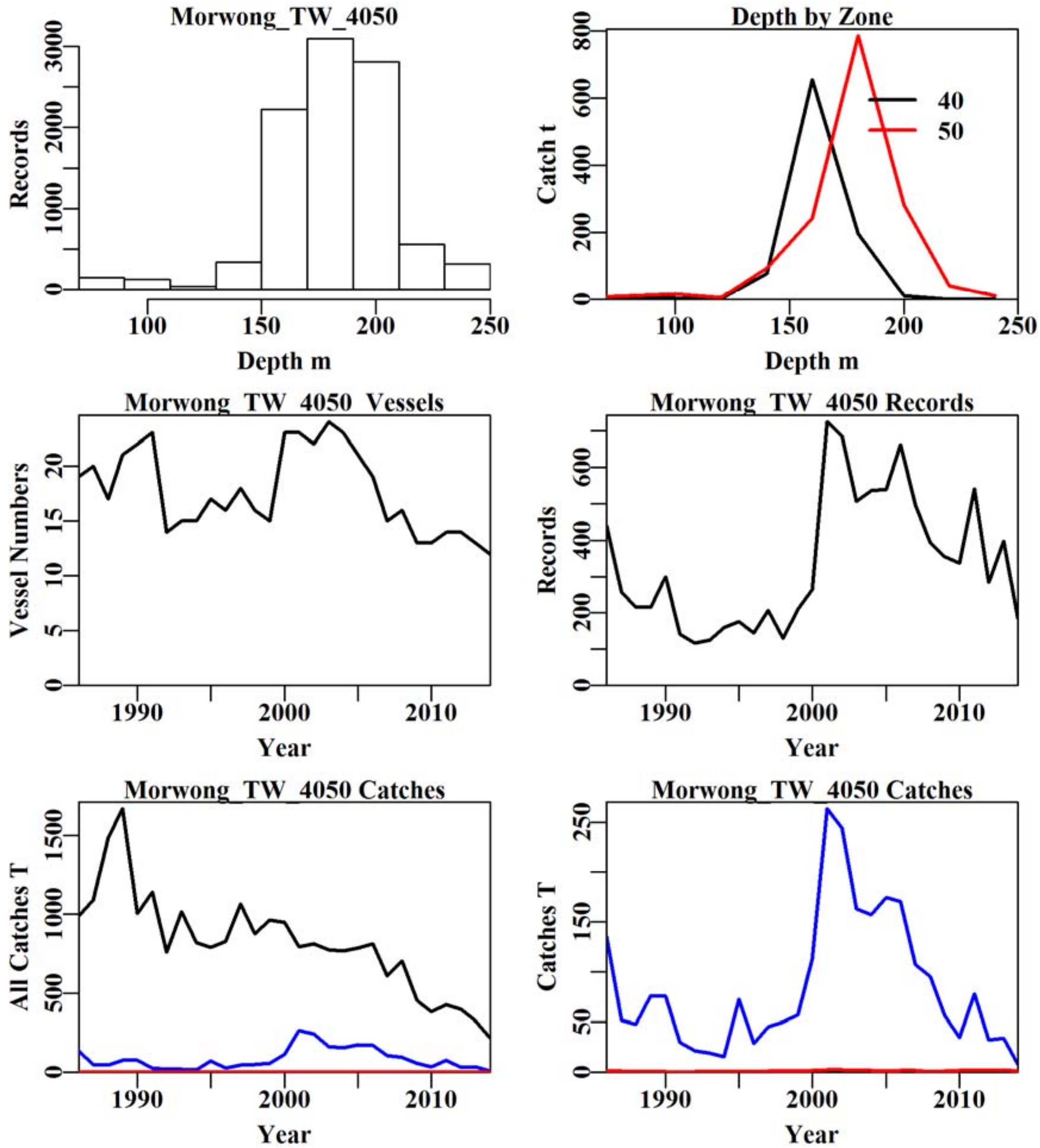
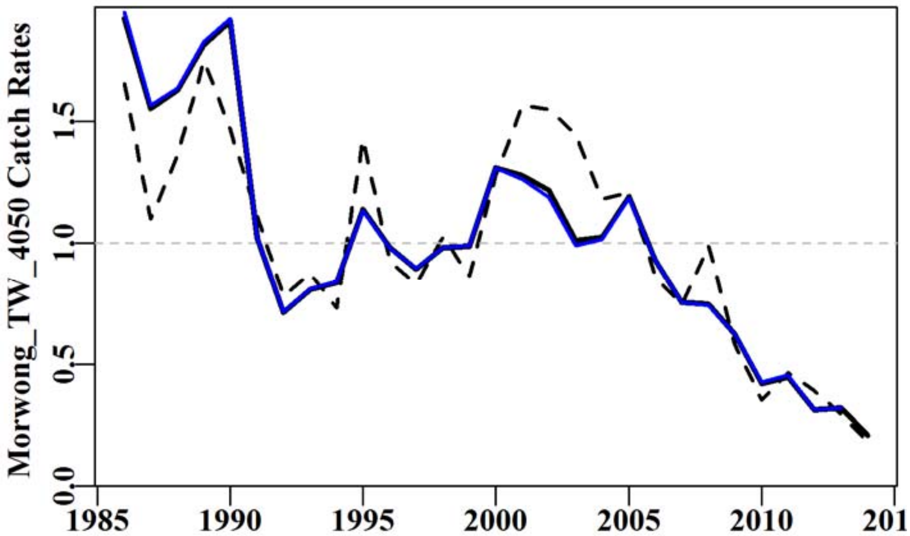


Figure 20.26. Jackass Morwong from zones 40 and 50 in depths 70 – 250 m by Trawl. The top left plot depicts the depth distribution of shots containing Jackass Morwong from zones 40 and 50 in depths 70 – 250 m by Trawl. The top right plot depicts the catch distribution by depth within zones 40 and 50. 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).



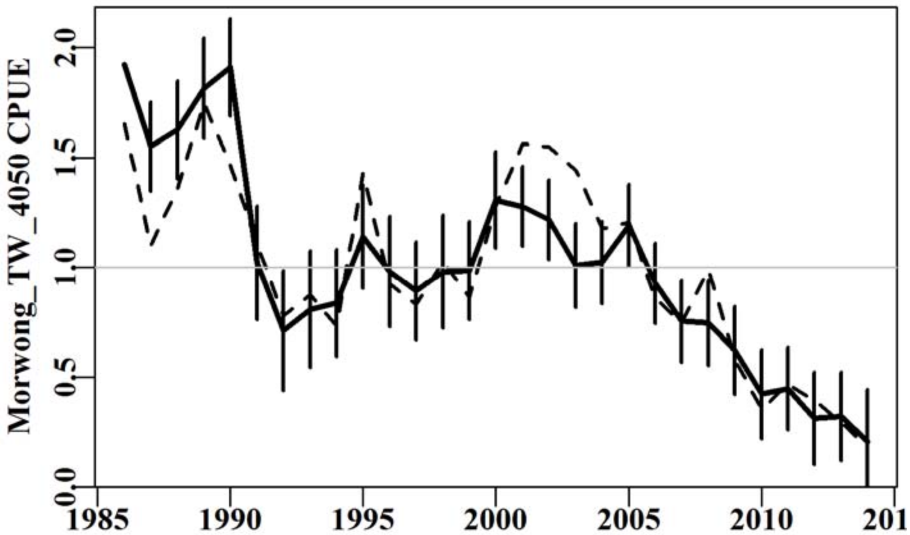


Figure 20.27. Jackass Morwong from zones 40 and 50 in depths 70 – 250 m by Trawl. Upper plot: The dashed black line represents the geometric mean catch rate and the solid black line the standardized catch rates (relative to the mean of the standardized catch rates). The blue line corresponds to last 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.

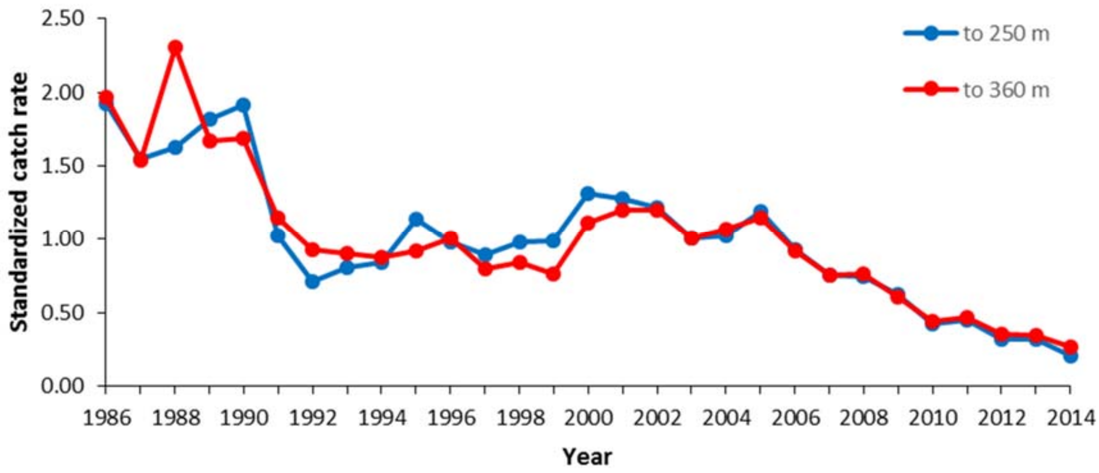


Figure 20.28. A comparison of the two standardizations, one excluding data deeper than 250 m (blue line; to 250 m) the other including data to 360 m (red line; to 360 m).

Table 20.26. 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 20.27. 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	5671	5012	3569	3039	2887	2857	2589	2819
RSS	17331	16087	13819	12854	12645	12602	12230	12530
MSS	2866	4110	6378	7342	7551	7594	7967	7667
Nobs	9740	9641	9641	9641	9641	9641	9641	9641
Npars	29	38	49	133	136	137	148	146
adj_R^2	13.943	20.042	31.238	35.470	36.499	36.709	38.510	37.013
%Change	0.000	6.099	11.196	4.232	1.029	0.209	1.801	-1.497

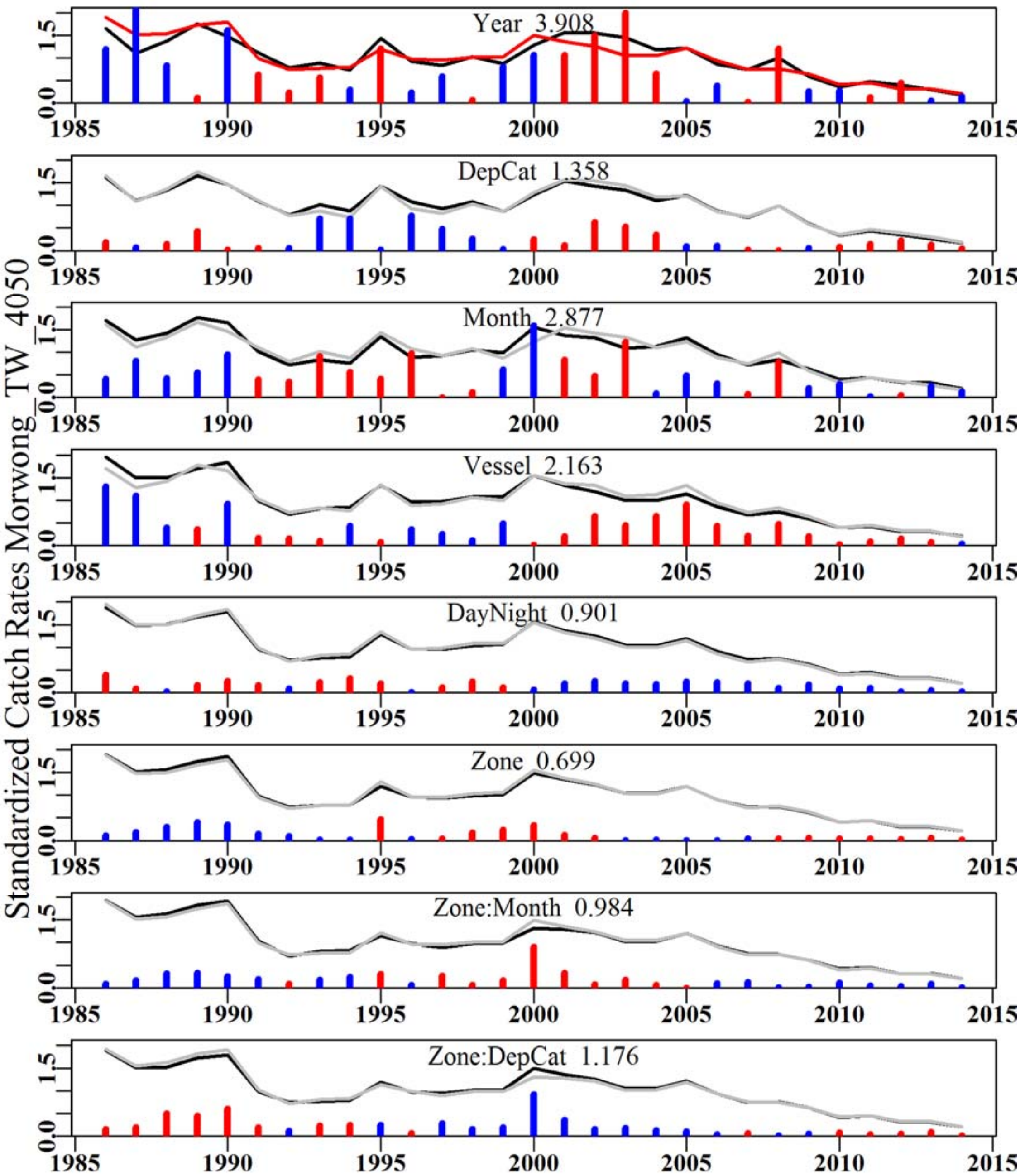


Figure 20.29. The relative influence of each factor used on the final trend in the optimal standardization for Jackass Morwong in zones 40 and 50. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by the vertical bars with 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.

20.4.9 Flathead Trawl (FLT – 37296001 – *Neoplatycephalus richardsoni*)

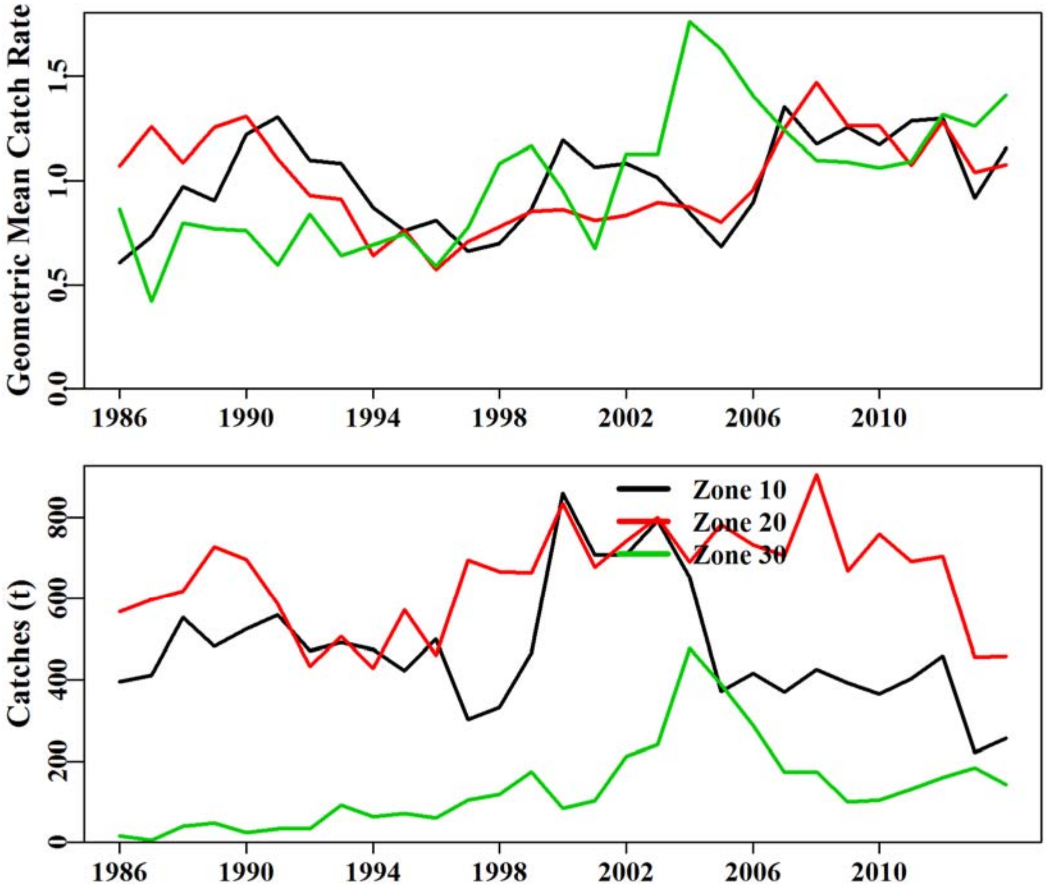


Figure 20.30. The trends in catches and geometric mean catch rates for flathead taken by Trawl in zones 10 to 30. The catch rate trends in 10 and 20 are similar to each other but are different from that expressed in zone 30. For this reason, zones 10 and 20 are standardized separately from Zone 30.

20.4.10 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 20.28. 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	0.8042	0.0000
1987	2461.3370	8104	1008.3320	86	20.4621	1.0749	0.0160
1988	2469.5260	9175	1171.6990	86	23.7988	1.1753	0.0157
1989	2599.0630	8841	1210.4720	74	23.9908	1.1719	0.0159
1990	2032.3230	7765	1221.4590	64	30.1854	1.3944	0.0167
1991	2230.1850	7797	1145.6520	57	28.7154	1.3242	0.0168
1992	2375.3660	6939	903.9830	54	24.0381	1.0405	0.0174
1993	1879.1400	8767	996.4960	57	23.7596	1.0524	0.0166
1994	1710.4040	10280	902.9060	56	17.9798	0.7666	0.0159
1995	1800.6160	10305	994.1340	54	18.0790	0.8057	0.0159
1996	1879.8720	11089	958.7790	59	16.4549	0.7185	0.0157
1997	2355.9870	10395	997.1370	60	16.8264	0.7186	0.0161
1998	2306.4070	9986	999.5350	52	17.7430	0.7611	0.0161
1999	3117.6750	10377	1129.3560	57	20.4344	0.9171	0.0160
2000	2945.5930	13116	1697.1510	61	24.4170	1.0112	0.0154
2001	2599.5120	12040	1385.0040	54	22.3246	0.9730	0.0157
2002	2876.2540	12394	1451.3920	50	22.8489	1.0586	0.0156
2003	3229.8810	12879	1593.8350	53	22.5521	1.0445	0.0155
2004	3222.7810	12218	1342.8575	53	19.7872	0.9057	0.0157
2005	2844.0450	10703	1154.9860	50	17.7159	0.7744	0.0161
2006	2585.8230	9137	1148.7790	47	22.2550	0.9371	0.0166
2007	2648.2110	6336	1076.4633	26	31.3557	1.1360	0.0183
2008	2912.3110	7292	1330.5590	28	31.6602	1.1941	0.0177
2009	2460.4100	6311	1060.7127	27	30.0219	1.0990	0.0183
2010	2502.2850	6873	1124.3120	26	29.4591	1.0603	0.0180
2011	2465.8550	6766	1096.1495	25	28.4046	1.0491	0.0181
2012	2780.5710	6884	1162.3542	25	30.4796	1.1561	0.0179
2013	1844.3710	5560	676.7076	25	23.4042	0.8863	0.0188
2014	1782.1760	5069	714.5456	25	26.7221	0.9891	0.0194

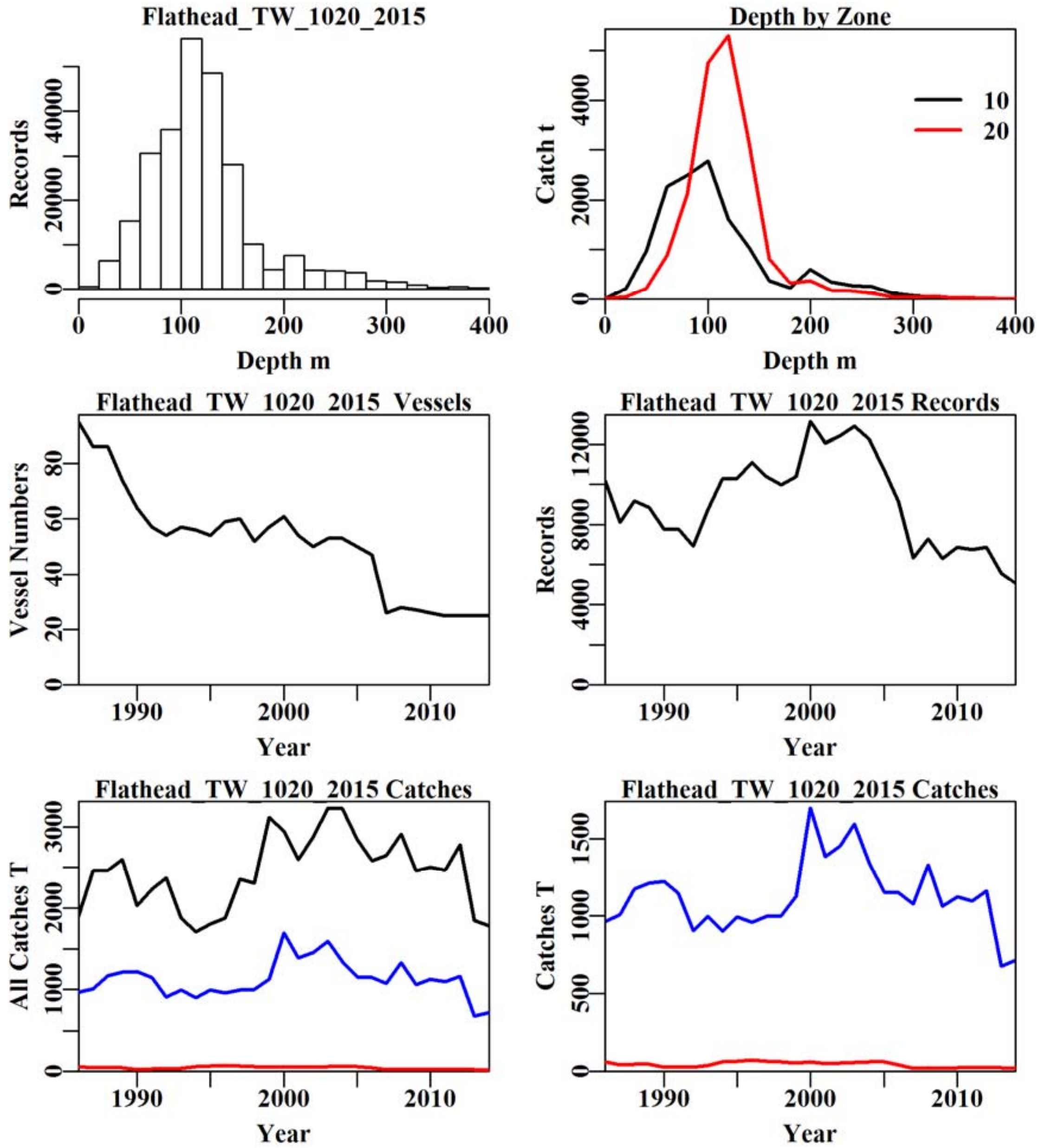


Figure 20.31. Flathead from zones 10 and 20 in depths 0 – 400 m by Trawl. The top left plot depicts the depth distribution of shots containing Flathead from zones 10 and 20 in depths 0 – 400 m by Trawl. The top right plot depicts the catch distribution by depth from zones 10 and 20 (top red line: zone 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).

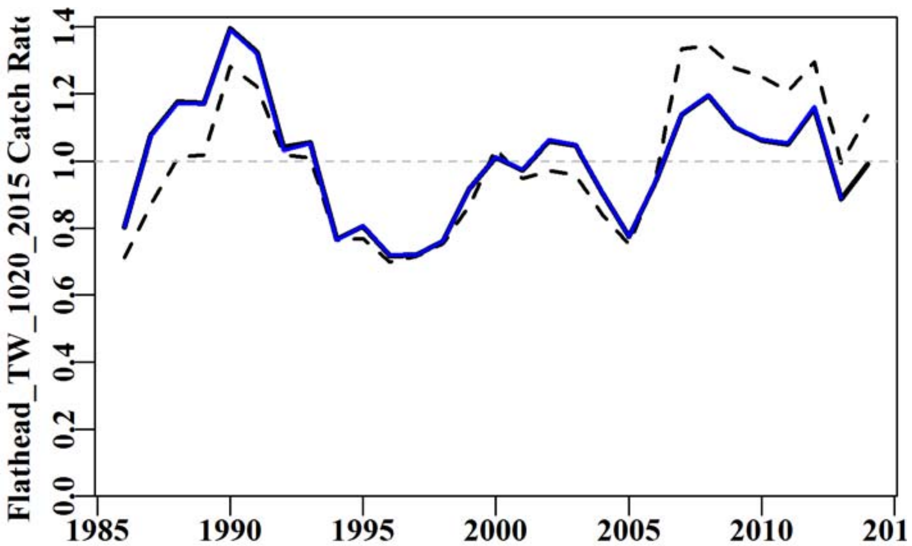


Figure 20.32. Flathead from zones 10 and 20 in depths 0 – 400m by Trawl. The dashed black line represents the geometric mean catch rate and the solid black line the standardized catch rates (relative to the mean of the standardized catch rates). The blue line is last year's optimum standardization.

Table 20.29. 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 20.30. 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	45666	16037	7679	6785	6606	6554	4498	3604
RSS	313385	279683	268800	267859	267670	267615	265497	264572
MSS	10479	44181	55064	56005	56194	56249	58367	59291
Nobs	263594	263594	261480	261480	261480	261480	261480	261480
Npars	29	210	230	241	244	245	256	265
adj_R^2	3.225	13.573	16.930	17.217	17.274	17.291	17.942	18.225
%Change	0.000	10.348	3.356	0.287	0.058	0.017	0.651	0.283

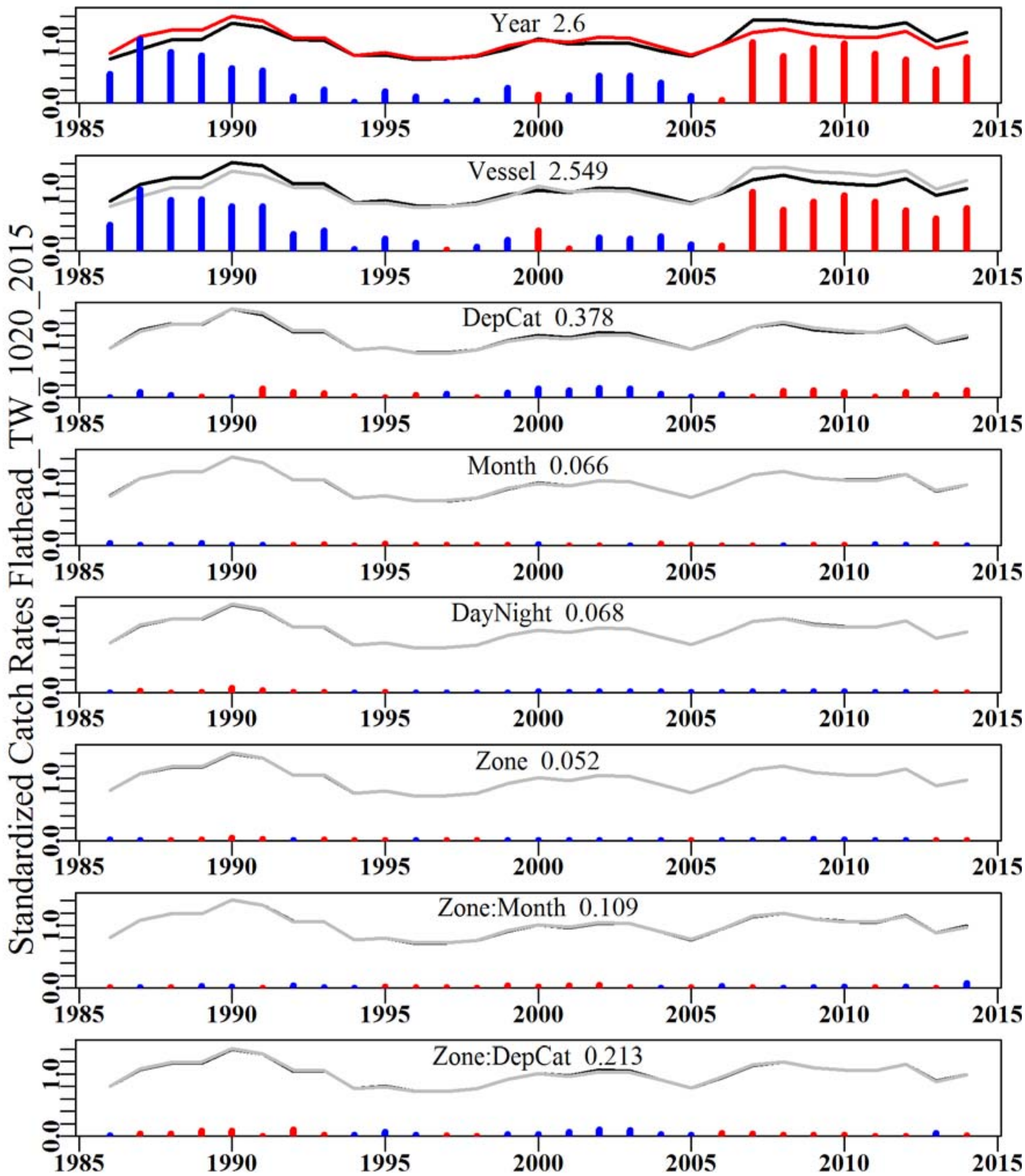


Figure 20.33. The relative influence of each factor used on the final trend in the optimal standardization for Flathead in zones 10 and 20. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by the vertical bars with blue 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.

20.4.11 Flathead Trawl (FLT – 37296001 and 37296000 – Neoplatycephalus richardsoni and Platycephalidae)

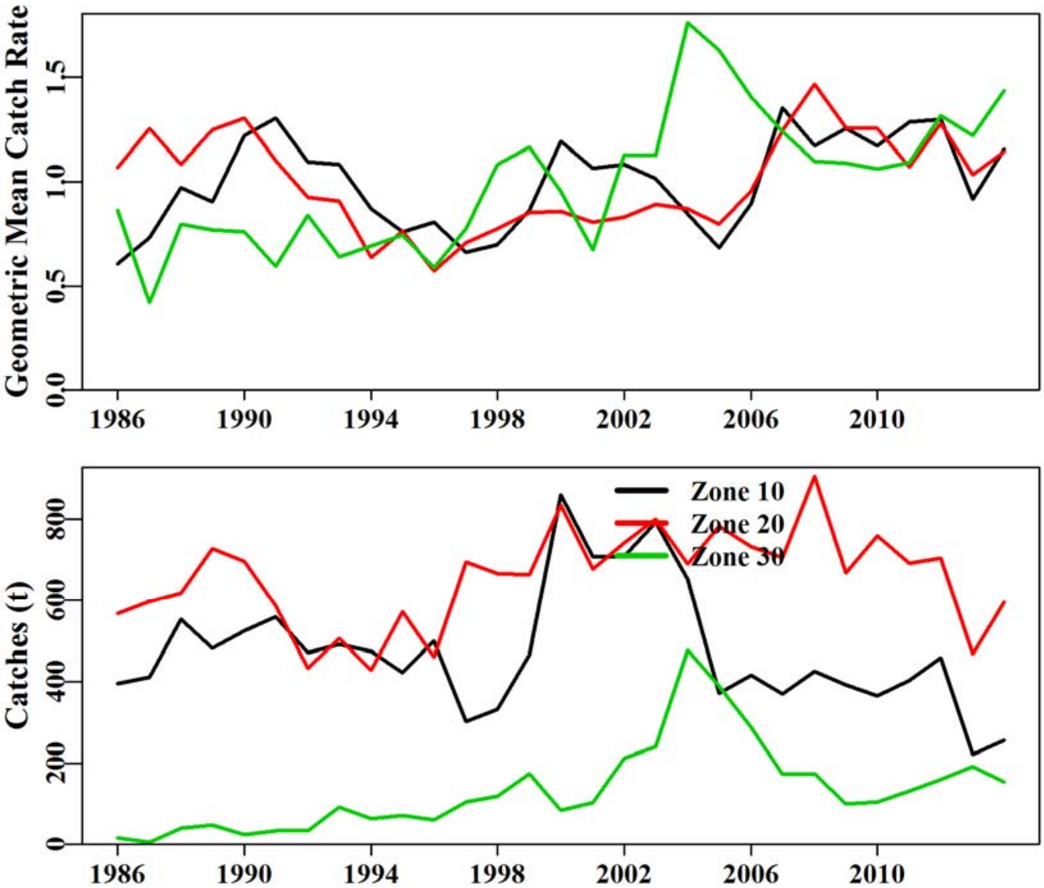


Figure 20.34. The trends in catches and geometric mean catch rates for flathead taken by Trawl in zones 10 to 30. The catch rate trends in 10 and 20 are similar to each other but are different from that expressed in zone 30. For this reason, zones 10 and 20 are standardized separately from Zone 30.

20.4.12 Flathead Trawl Z1020 (FLT – 37296001 and 37296000 – Neoplatycephalus richardsoni and Platycephalidae)

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

Table 20.31. 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	0.8034	0.0000
1987	2461.3370	8104	1008.3320	86	20.4621	1.0738	0.0160
1988	2469.5260	9175	1171.6990	86	23.7988	1.1743	0.0157
1989	2599.0630	8841	1210.4720	74	23.9908	1.1708	0.0159
1990	2032.3230	7765	1221.4590	64	30.1854	1.3936	0.0167
1991	2230.1850	7797	1145.6520	57	28.7154	1.3235	0.0168
1992	2375.3660	6939	903.9830	54	24.0381	1.0397	0.0174
1993	1879.1400	8767	996.4960	57	23.7596	1.0513	0.0166
1994	1710.4040	10280	902.9060	56	17.9798	0.7658	0.0159
1995	1800.6160	10305	994.1340	54	18.0790	0.8050	0.0159
1996	1879.8720	11089	958.7790	59	16.4549	0.7180	0.0157
1997	2356.0020	10395	997.1370	60	16.8264	0.7180	0.0161
1998	2306.4070	9986	999.5350	52	17.7430	0.7604	0.0161
1999	3117.6750	10377	1129.3560	57	20.4344	0.9162	0.0160
2000	2945.5930	13116	1697.1510	61	24.4170	1.0101	0.0154
2001	2599.5220	12040	1385.0040	54	22.3246	0.9721	0.0156
2002	2876.3130	12394	1451.3920	50	22.8489	1.0574	0.0156
2003	3229.9320	12879	1593.8350	53	22.5521	1.0437	0.0155
2004	3222.7810	12218	1342.8575	53	19.7872	0.9049	0.0157
2005	2844.0790	10703	1154.9860	50	17.7159	0.7737	0.0161
2006	2585.8230	9137	1148.7790	47	22.2550	0.9365	0.0166
2007	2648.2540	6336	1076.4633	26	31.3557	1.1355	0.0183
2008	2912.3110	7292	1330.5590	28	31.6602	1.1941	0.0177
2009	2460.4820	6311	1060.7127	27	30.0219	1.0990	0.0183
2010	2502.2850	6873	1124.3120	26	29.4591	1.0603	0.0180
2011	2465.8550	6766	1096.1494	25	28.4045	1.0489	0.0181
2012	2780.5700	6884	1162.3542	25	30.4796	1.1560	0.0179
2013	1940.9480	5640	689.2806	25	23.4473	0.8804	0.0188
2014	2369.7560	5656	851.7746	25	27.9947	1.0136	0.0188

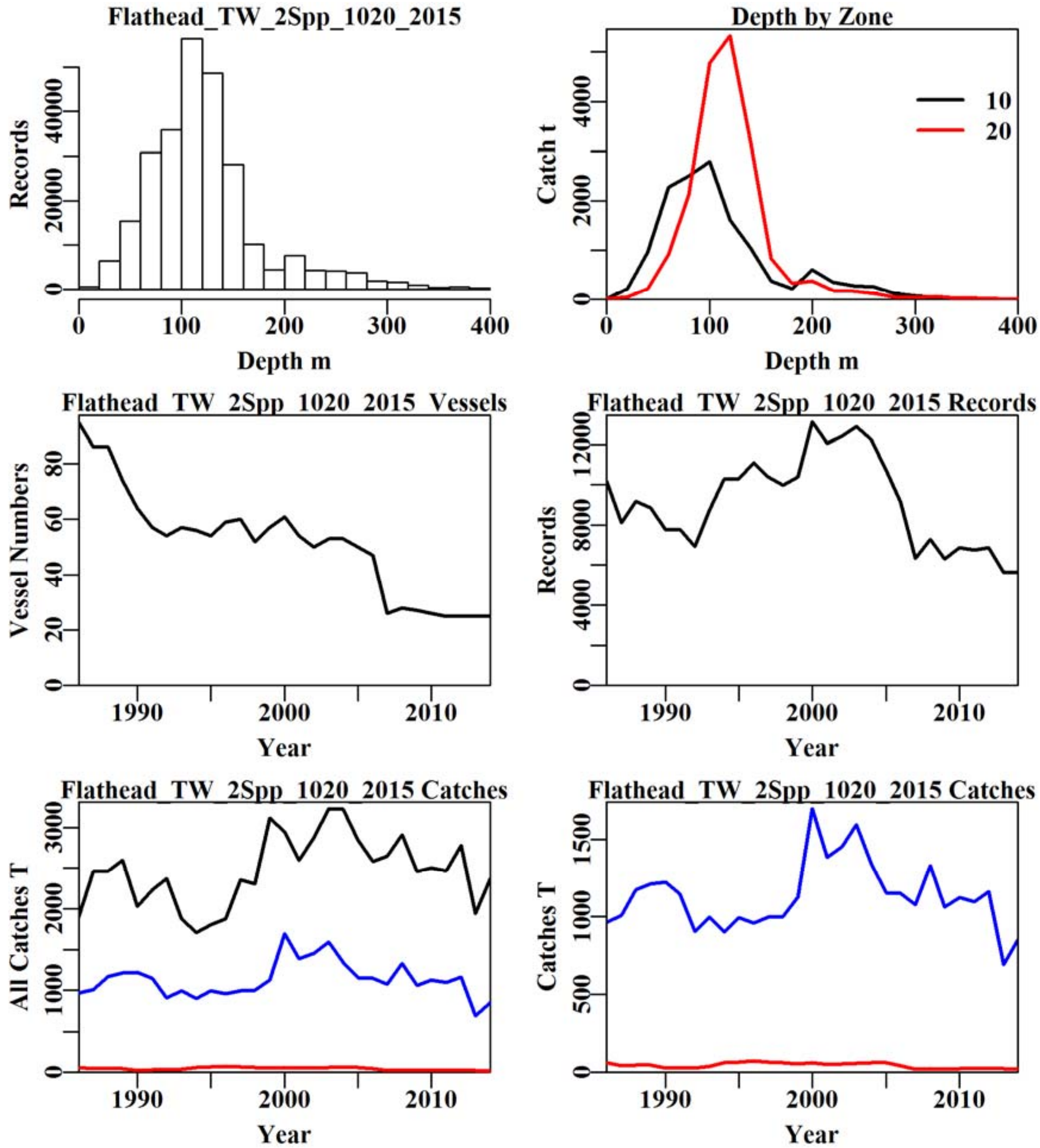


Figure 20.35. Flathead from zones 10 and 20 in depths 0 – 400 m by Trawl. The top left plot depicts the depth distribution of shots containing Flathead from zones 10 and 20 in depths 0 – 400 m by Trawl. The top right plot depicts the catch distribution by depth from zones 10 and 20 (top red line: zone 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).

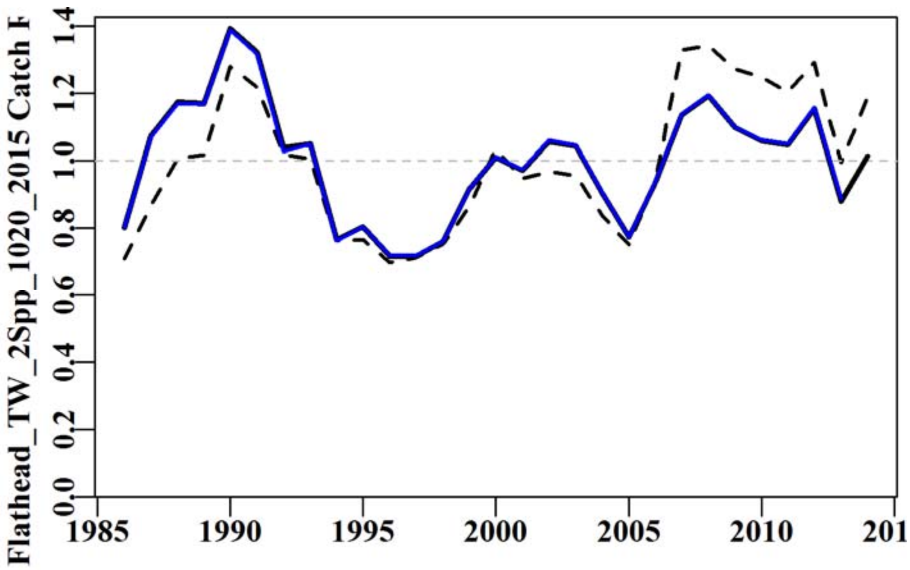


Figure 20.36. Flathead from zones 10 and 20 in depths 0 – 400m by Trawl. The dashed black line represents the geometric mean catch rate and the solid black line the standardized catch rates (relative to the mean of the standardized catch rates). The blue line is last year's optimum standardization.

Table 20.32. 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 20.33. 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	45644	15925	7590	6700	6520	6468	4417	3526
RSS	314015	280230	269374	268439	268249	268194	266081	265161
MSS	10605	44390	55245	56180	56370	56426	58539	59459
Nobs	264261	264261	262147	262147	262147	262147	262147	262147
Npars	29	210	230	241	244	245	256	265
adj_R^2	3.257	13.606	16.946	17.231	17.288	17.305	17.953	18.234
%Change	0.000	10.350	3.340	0.285	0.058	0.017	0.648	0.281

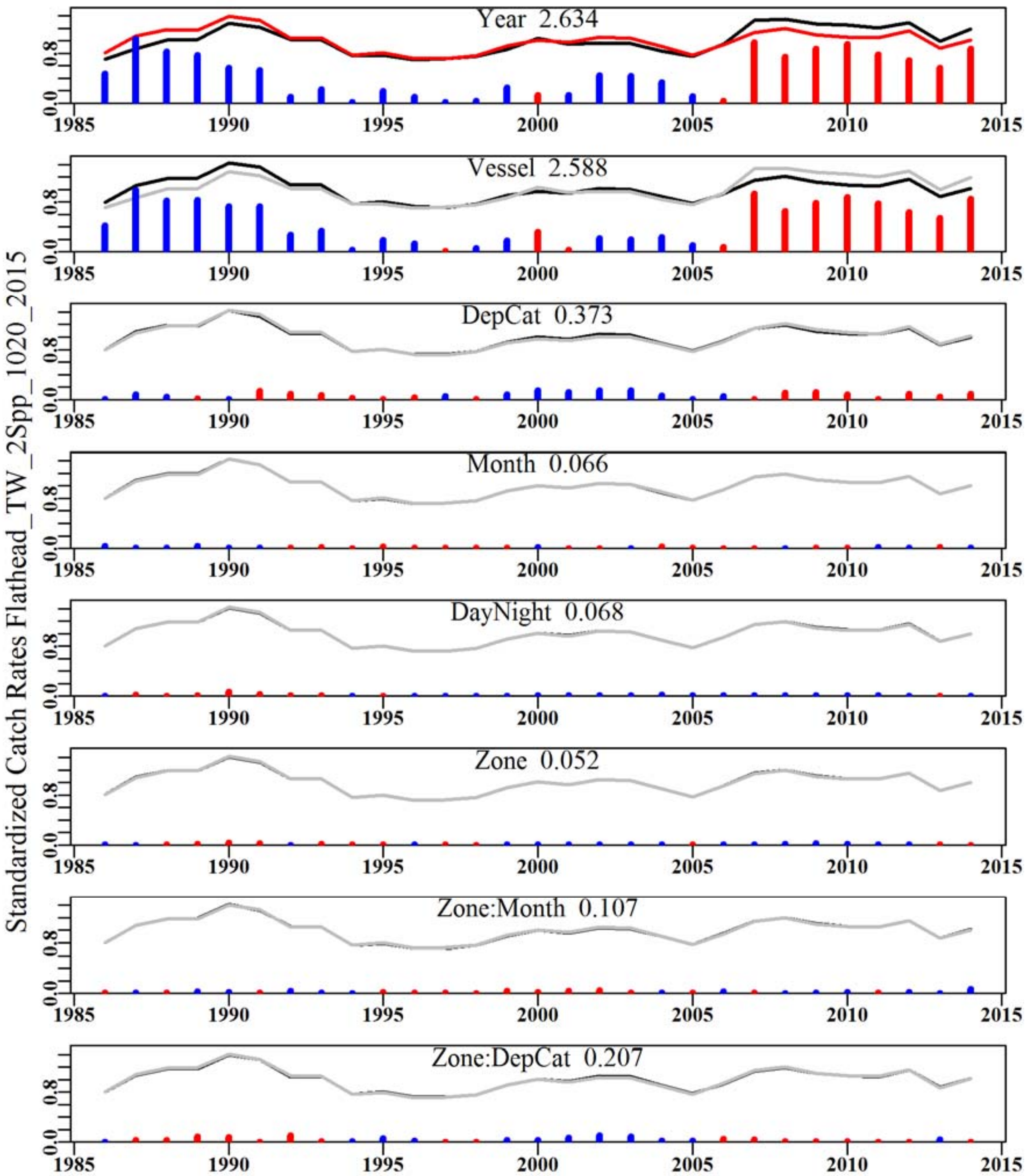


Figure 20.37. The relative influence of each factor used on the final trend in the optimal standardization for Flathead in zones 10 and 20. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by the vertical bars with blue 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.

20.4.13 Flathead Trawl Z30 (FLT – 37296001 – *Neoplatycephalus richardsoni*)

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

Table 20.34. 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	0.9407	0.0000
1987	2461.3370	90	5.1550	9	11.1912	0.5865	0.1902
1988	2469.5260	193	39.9760	9	21.2587	0.9734	0.1710
1989	2599.0630	516	48.4430	19	20.5177	0.7317	0.1635
1990	2032.3230	253	24.6190	27	20.3187	0.7725	0.1656
1991	2230.1850	314	33.3530	29	15.9189	0.7123	0.1617
1992	2375.3660	272	33.8970	15	22.4408	0.6742	0.1658
1993	1879.1400	902	92.0790	24	17.1065	0.6357	0.1572
1994	1710.4040	612	64.4870	17	18.5289	0.6736	0.1582
1995	1800.6160	694	71.3490	17	19.8905	0.7257	0.1585
1996	1879.8720	714	61.4250	17	15.7596	0.6668	0.1582
1997	2355.9870	885	104.8750	14	20.7052	0.8340	0.1571
1998	2306.4070	707	118.5520	14	28.8666	0.9892	0.1577
1999	3117.6750	770	175.0520	17	31.0992	1.0943	0.1579
2000	2945.5930	520	83.6640	21	25.4446	0.8752	0.1592
2001	2599.5120	934	102.7490	17	18.0428	0.7372	0.1561
2002	2876.2540	1367	212.1580	15	30.1174	1.3774	0.1553
2003	3229.8810	1454	240.1100	21	30.0485	1.4116	0.1547
2004	3222.7810	1923	477.4160	15	47.0053	1.8642	0.1543
2005	2844.0450	1540	388.3250	18	43.4956	1.6666	0.1548
2006	2585.8230	1315	287.9680	13	37.5195	1.3376	0.1557
2007	2648.2110	823	173.1554	8	33.0381	1.0983	0.1572
2008	2912.3110	874	173.7390	11	29.3148	1.0203	0.1570
2009	2460.4100	600	100.2251	10	29.0939	0.9918	0.1586
2010	2502.2850	537	104.1860	10	28.3260	1.0084	0.1595
2011	2465.8550	623	131.2742	9	29.1229	0.9544	0.1586
2012	2780.5710	756	160.7460	8	35.1418	1.1811	0.1579
2013	1844.3710	767	184.1795	11	33.6185	1.2049	0.1575
2014	1782.1760	641	143.5375	11	37.5544	1.2604	0.1586

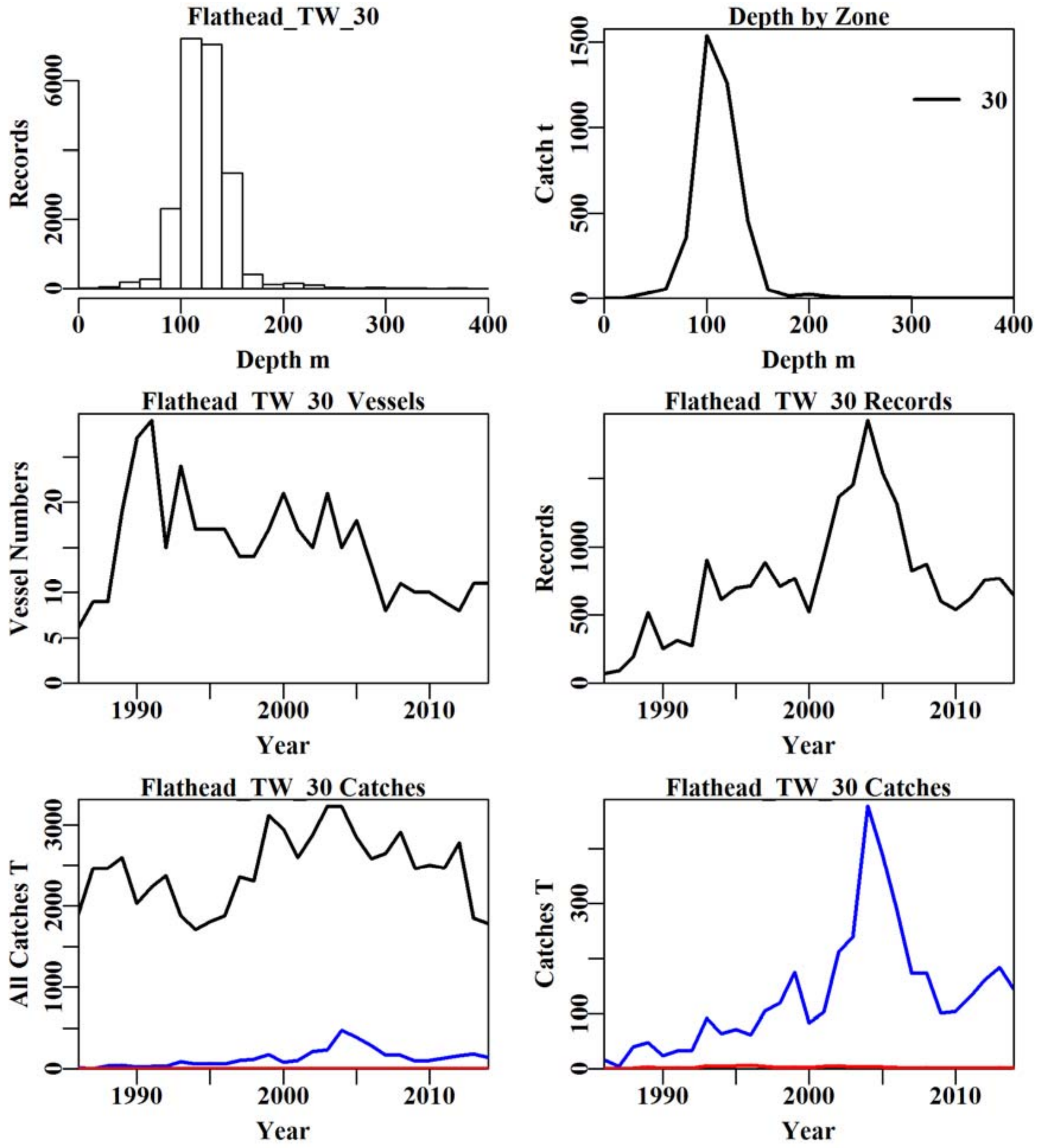


Figure 20.38. Flathead from zone 30 in depths 0 – 400m by Trawl. The top left plot depicts the depth distribution of shots containing Flathead from zones 10 and 20 in depths 0 – 400 m by Trawl. The top right plot depicts the catch distribution by depth from zone 30. The middle left plot depicts the number 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).

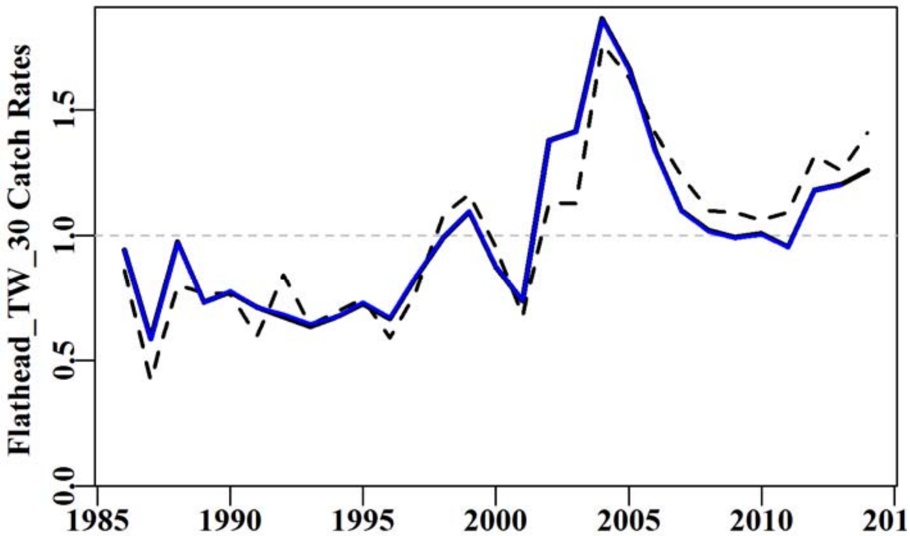


Figure 20.39. Flathead from zone 30 in depths 0 – 400 m by Trawl. The dashed black line represents the geometric mean catch rate and the solid black line the standardized catch rates (relative to the mean of the standardized catch rates). The blue line is last year's optimum standardization.

Table 20.35. 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 20.36. 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	3137	1464	197	-135	-430	-480	-876	-545
RSS	24976	22928	21311	20977	20669	20557	19830	20443
MSS	2279	4326	5944	6277	6586	6697	7424	6812
Nobs	21667	21667	21392	21392	21392	21392	21392	21392
Npars	29	119	139	142	153	186	373	213
adj_R^2	8.242	15.413	21.300	22.521	23.621	23.915	25.952	24.242
%Change	0.000	7.171	5.888	1.221	1.100	0.294	2.037	-1.710

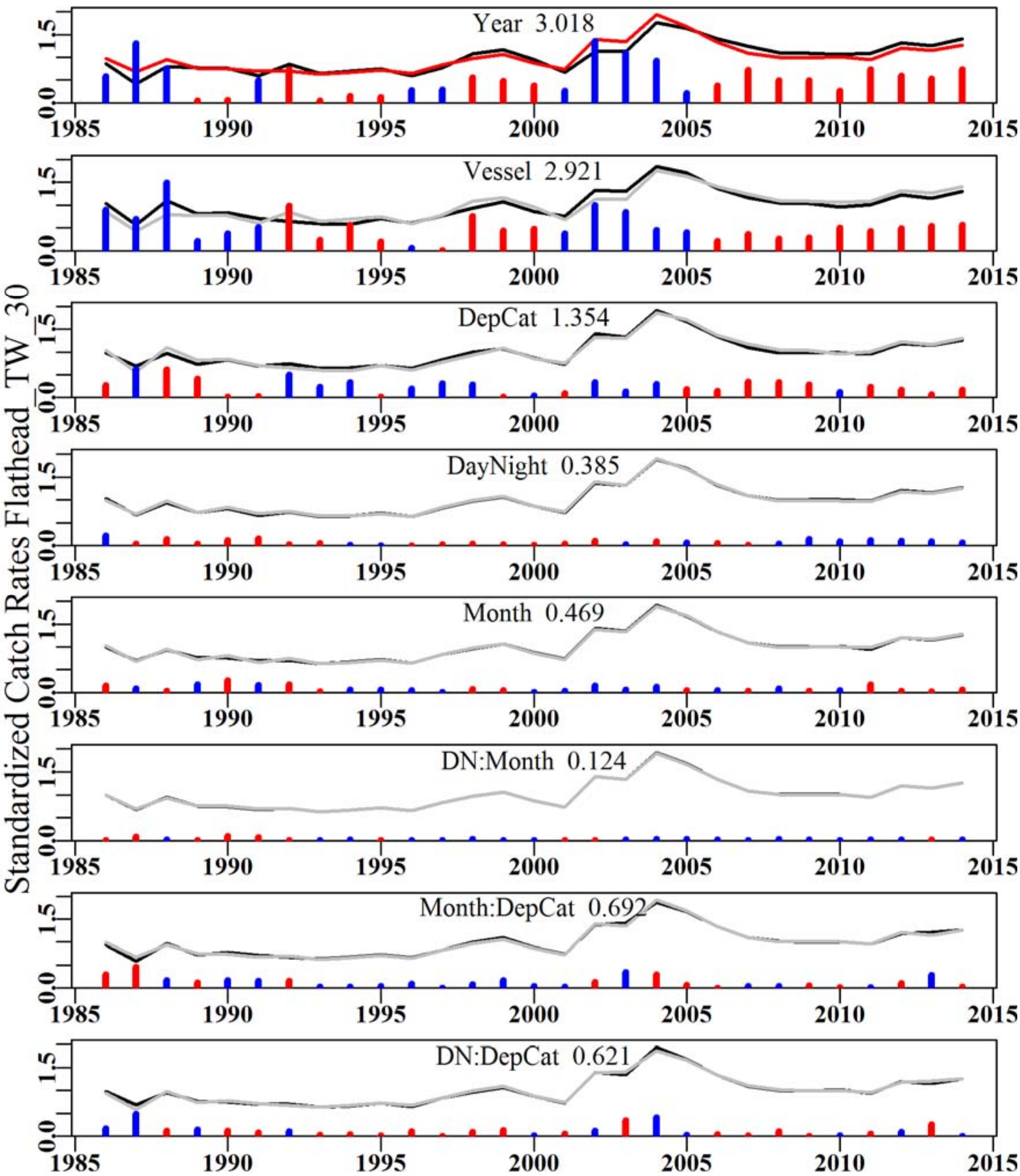


Figure 20.40. The relative influence of each factor used on the final trend in the optimal standardization for Flathead from zone 30. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by the vertical bars with blue bars 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.

20.4.14 Flathead Trawl Z30 (FLT – 37296001 and 37296000 – Neoplatycephalus richardsoni and Platycephalidae)

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

Table 20.37. 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	0.9393	0.0000
1987	2461.3370	90	5.1550	9	11.1912	0.5875	0.1900
1988	2469.5260	193	39.9760	9	21.2587	0.9731	0.1709
1989	2599.0630	516	48.4430	19	20.5177	0.7308	0.1633
1990	2032.3230	253	24.6190	27	20.3187	0.7725	0.1655
1991	2230.1850	314	33.3530	29	15.9189	0.7117	0.1616
1992	2375.3660	272	33.8970	15	22.4408	0.6757	0.1657
1993	1879.1400	902	92.0790	24	17.1065	0.6362	0.1571
1994	1710.4040	612	64.4870	17	18.5289	0.6733	0.1581
1995	1800.6160	694	71.3490	17	19.8905	0.7251	0.1584
1996	1879.8720	714	61.4250	17	15.7596	0.6674	0.1581
1997	2356.0020	885	104.8750	14	20.7052	0.8345	0.1570
1998	2306.4070	707	118.5520	14	28.8666	0.9892	0.1576
1999	3117.6750	770	175.0520	17	31.0992	1.0948	0.1577
2000	2945.5930	520	83.6640	21	25.4446	0.8760	0.1590
2001	2599.5220	934	102.7490	17	18.0428	0.7373	0.1560
2002	2876.3130	1367	212.1580	15	30.1174	1.3785	0.1552
2003	3229.9320	1454	240.1100	21	30.0485	1.4113	0.1546
2004	3222.7810	1923	477.4160	15	47.0053	1.8659	0.1542
2005	2844.0790	1540	388.3250	18	43.4956	1.6697	0.1547
2006	2585.8230	1315	287.9680	13	37.5195	1.3383	0.1556
2007	2648.2540	823	173.1554	8	33.0381	1.0977	0.1571
2008	2912.3110	874	173.7390	11	29.3148	1.0204	0.1569
2009	2460.4820	600	100.2251	10	29.0939	0.9928	0.1585
2010	2502.2850	537	104.1860	10	28.3260	1.0073	0.1594
2011	2465.8550	623	131.2742	9	29.1229	0.9527	0.1585
2012	2780.5700	756	160.7460	8	35.1418	1.1808	0.1577
2013	1940.9480	833	191.3445	11	32.5673	1.1784	0.1571
2014	2369.7560	675	154.1225	11	38.3135	1.2817	0.1582

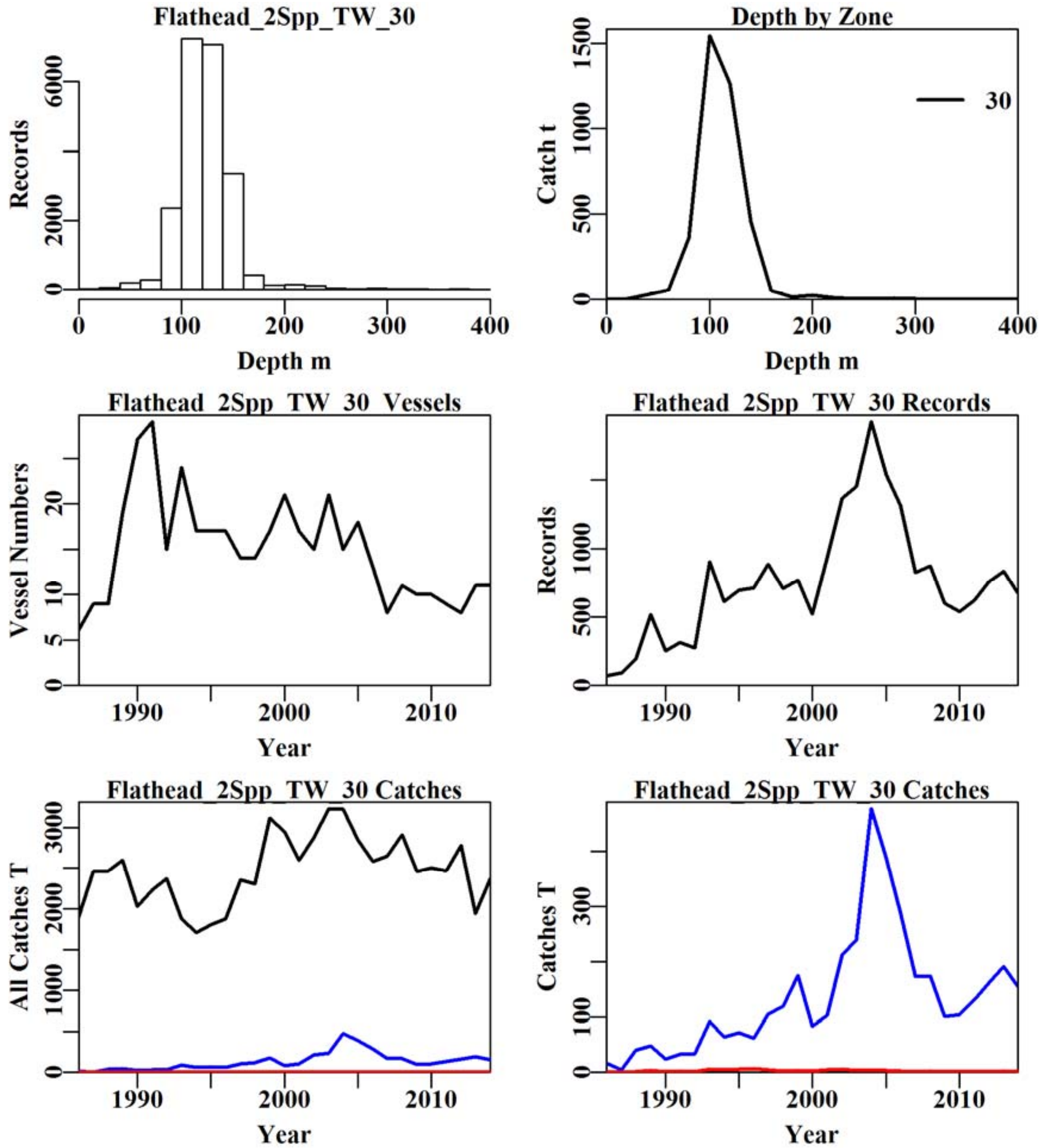


Figure 20.41. Flathead from zone 30 in depths 0 – 400m by Trawl. The top left plot depicts the depth distribution of shots containing Flathead from zones 10 and 20 in depths 0 – 400 m by Trawl. The top right plot depicts the catch distribution by depth from zone 30. The middle left plot depicts the number 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).

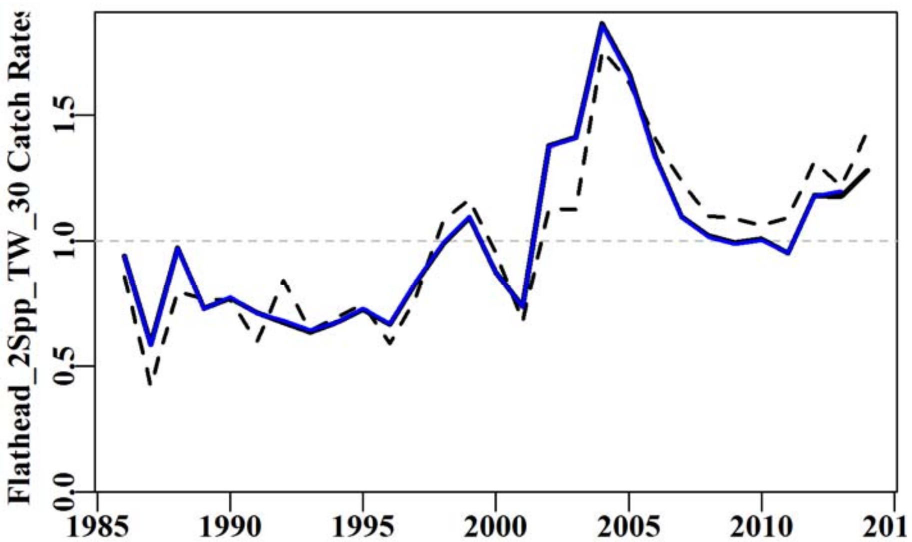


Figure 20.42. Flathead from zone 30 in depths 0 – 400 m by Trawl. The dashed black line represents the geometric mean catch rate and the solid black line the standardized catch rates (relative to the mean of the standardized catch rates). The blue line is last year's optimum standardization.

Table 20.38. 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 20.39. 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	3120	1439	164	-169	-467	-518	-916	-583
RSS	25055	23001	21378	21044	20733	20620	19893	20506
MSS	2283	4337	5960	6294	6605	6718	7445	6832
Nobs	21767	21767	21492	21492	21492	21492	21492	21492
Npars	29	119	139	142	153	186	373	213
adj_R^2	8.232	15.404	21.296	22.515	23.622	23.918	25.952	24.243
%Change	0.000	7.172	5.892	1.219	1.107	0.296	2.033	-1.708

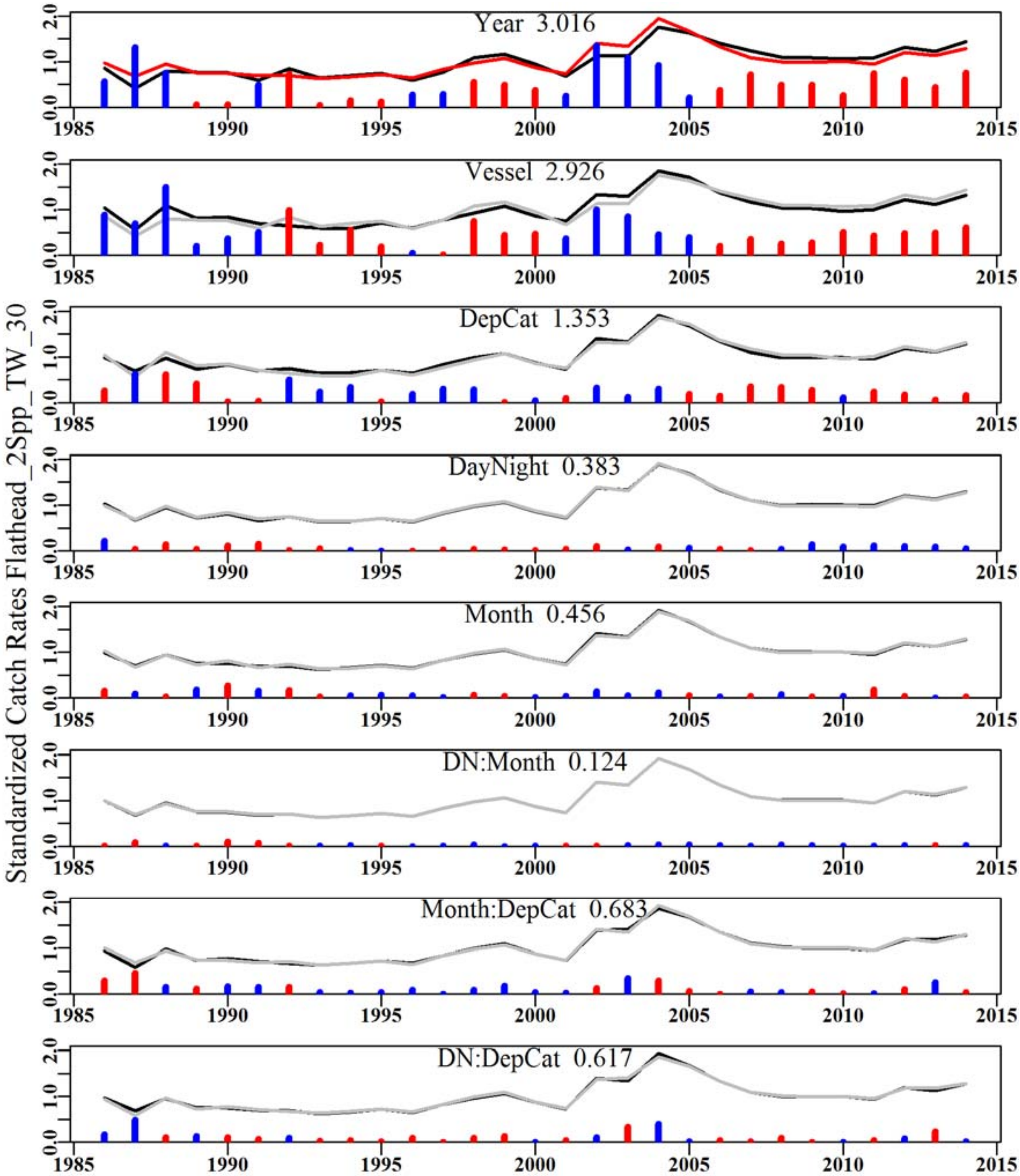


Figure 20.43. The relative influence of each factor used on the final trend in the optimal standardization for Flathead from zone 30. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by the vertical bars with blue bars 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.

20.4.15 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 20.40. 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	1.0690	0.0000
1987	2461.3370	5651	1366.9440	23	88.6187	1.5023	0.0229
1988	2469.5260	5823	1097.5410	25	88.9194	1.6326	0.0227
1989	2599.0630	5412	1142.7080	27	78.4955	1.4164	0.0230
1990	2032.3230	4653	586.0180	25	48.3882	0.9347	0.0243
1991	2230.1850	4670	775.7680	28	69.8580	1.3050	0.0244
1992	2375.3660	6642	1217.9510	23	85.5971	1.4142	0.0224
1993	1879.1400	6163	557.3510	25	38.2511	0.9036	0.0229
1994	1710.4040	7332	649.4810	25	37.6721	0.7605	0.0220
1995	1800.6160	5505	656.6650	21	36.2337	0.7775	0.0234
1996	1879.8720	7679	755.6700	22	33.6052	0.7337	0.0219
1997	2355.9870	8480	1150.4360	21	60.3446	0.9391	0.0216
1998	2306.4070	9904	1134.7320	21	60.5323	0.7861	0.0211
1999	3117.6750	8818	1702.6050	23	98.4160	1.1362	0.0215
2000	2945.5930	7092	1037.6890	19	64.0436	0.8365	0.0226
2001	2599.5120	7457	1004.5070	18	62.0182	0.7806	0.0227
2002	2876.2540	8218	1144.0750	22	75.2709	0.9244	0.0223
2003	3229.8810	9005	1210.2270	23	80.7088	0.9841	0.0220
2004	3222.7810	7784	1253.0260	22	83.7818	0.9583	0.0225
2005	2844.0450	7212	1125.7530	22	87.7421	0.9756	0.0230
2006	2585.8230	5563	968.0510	21	89.1577	0.9649	0.0240
2007	2648.2110	5551	1182.0670	15	104.4620	1.1621	0.0240
2008	2912.3110	6214	1283.4890	15	103.2936	1.0367	0.0235
2009	2460.4100	5499	1168.9280	15	91.4234	1.0743	0.0240
2010	2502.2850	6050	1167.4060	15	101.4792	0.9587	0.0236
2011	2465.8550	6889	1122.3150	14	85.7924	0.8906	0.0231
2012	2780.5710	7214	1382.3340	14	89.5939	0.8382	0.0230
2013	1844.3710	6822	876.5270	14	59.8539	0.6014	0.0232
2014	1782.1760	4227	624.7010	13	66.2292	0.7028	0.0274

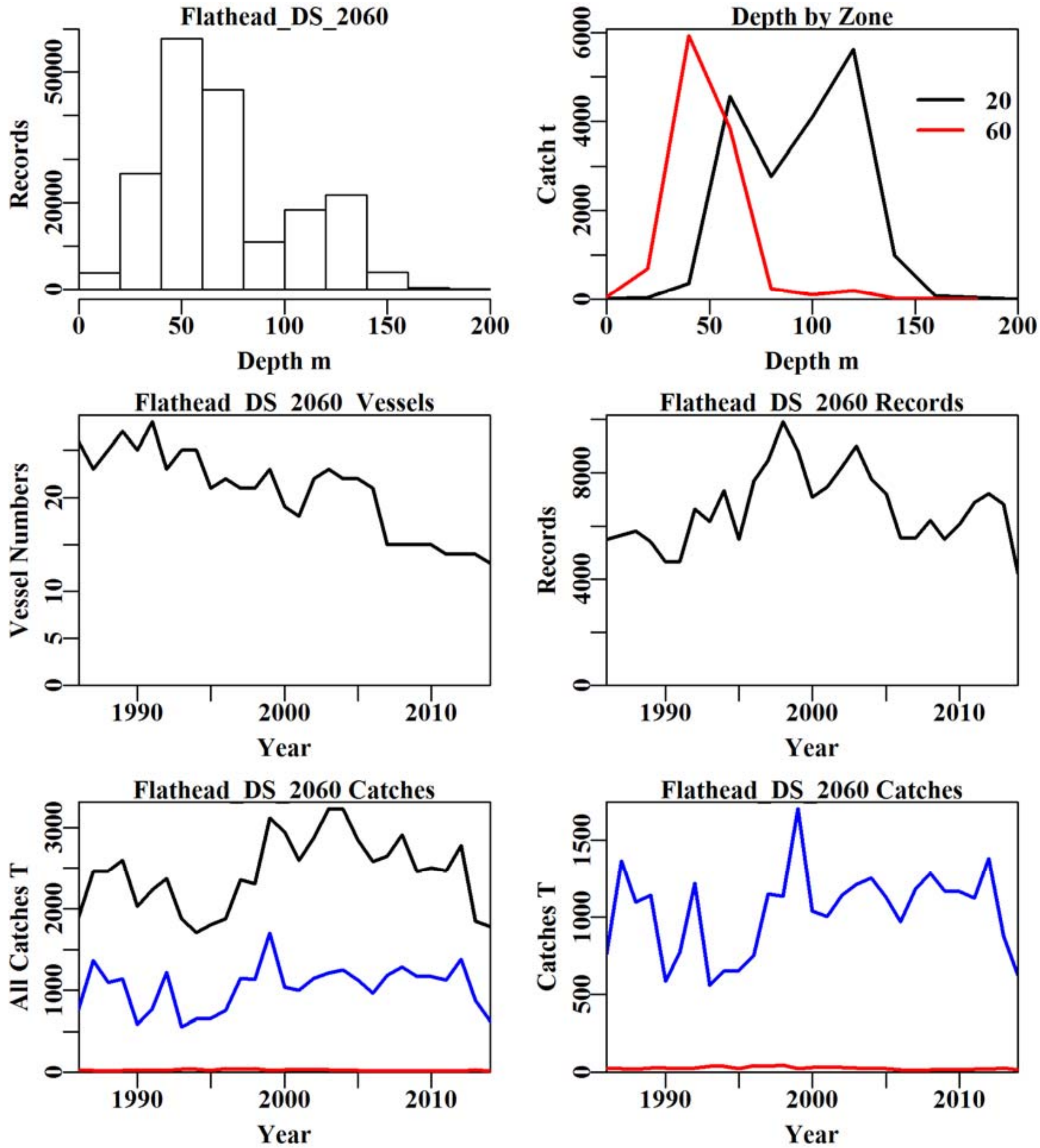


Figure 20.44. Flathead from zones 20 and 60 in depths 0 – 200 m by Danish Seine. The top left plot depicts the depth distribution of shots containing Flathead from zones 20 and 60 in depths 0 – 200 m by Danish Seine. The top right plot depicts the catch distribution by depth from zones 20 and 60. The 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).

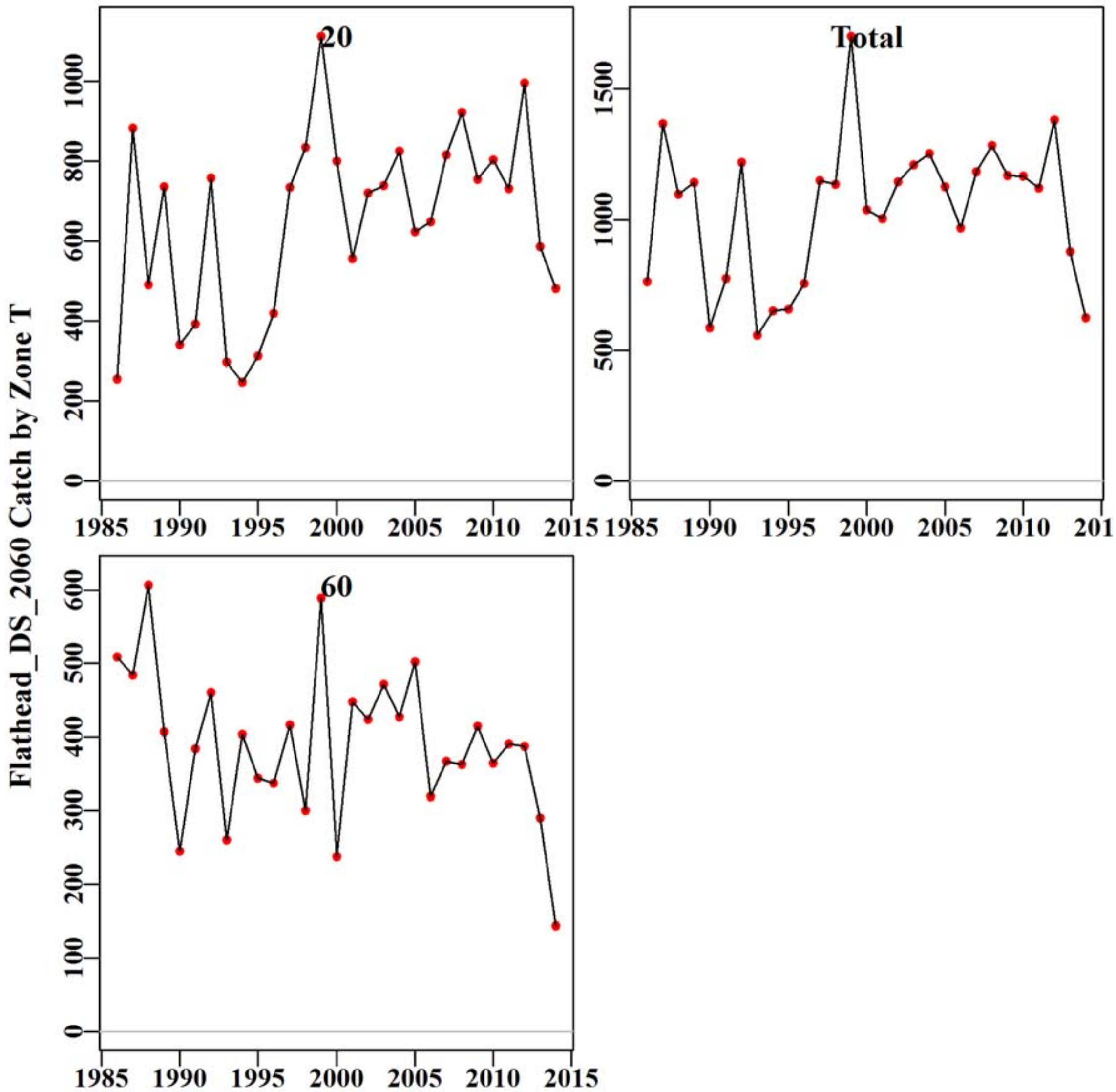


Figure 20.45. Annual flathead catches among the reporting zones 20, 60 and combined (20 & 60).

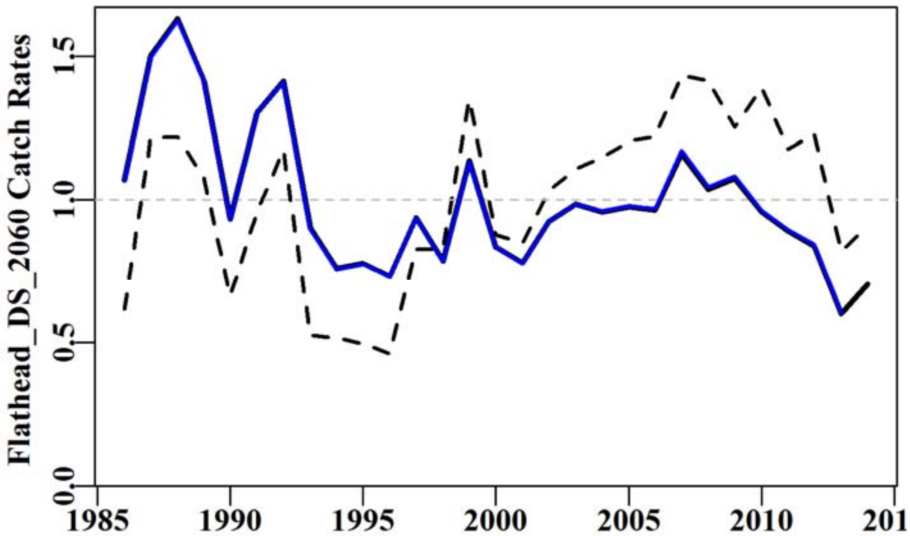


Figure 20.46. Flathead from zones 20 and 60 in depths 0 – 200 m by Danish Seine. The dashed black line represents the geometric mean catch rate and the solid black line the standardized catch rates (relative to the mean of the standardized catch rates). The blue line is last year's optimum standardization.

Table 20.41. 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 20.42. 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	149766	113806	80627	72774	60877	57820	53129	57505
RSS	419228	347968	290296	278384	261455	257274	250970	256821
MSS	20979	92239	149911	161823	178752	182933	189237	183386
Nobs	193030	193030	189983	189983	189983	189983	189983	189983
Npars	29	30	40	94	105	108	119	118
adj_R^2	4.752	20.942	34.041	36.730	40.574	41.523	42.953	41.623
%Change	0.000	16.190	13.099	2.689	3.844	0.949	1.430	-1.330

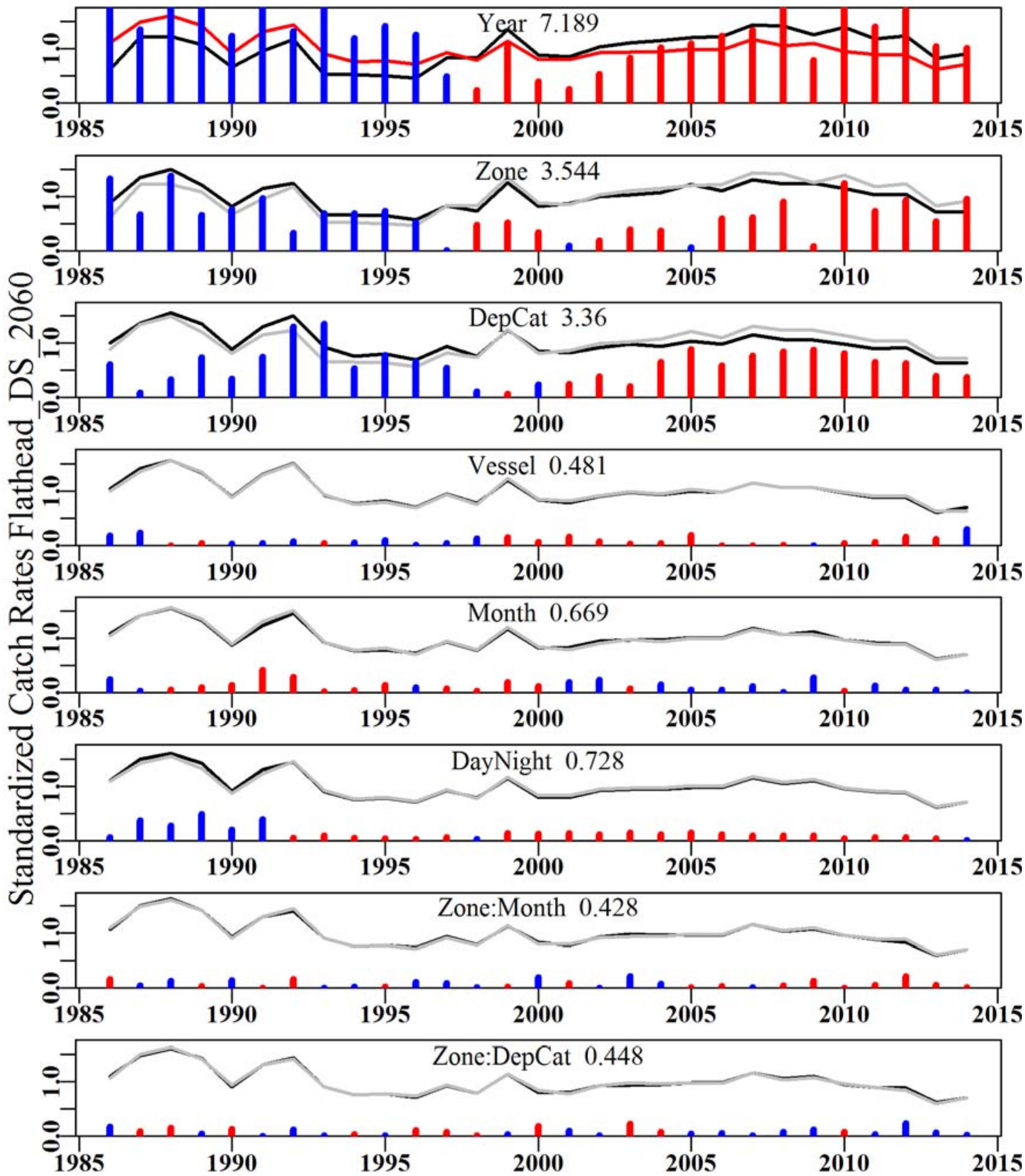


Figure 20.47. The relative influence of each factor used on the final trend in the optimal standardization for Flathead by Danish Seine in zones 20 and 60. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by the vertical 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.

20.4.16 Flathead Danish Seine (FLT – 37296001 and 37296000 – Neoplatycephalus richardsoni and Platycephalidae)

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

Table 20.43. 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	1892.183	5501	763.945	26	45.054	1.058	0.000
1987	2461.337	5651	1366.944	23	88.619	1.490	0.023
1988	2469.526	5823	1097.541	25	88.919	1.616	0.023
1989	2599.063	5412	1142.708	27	78.495	1.404	0.023
1990	2032.323	4653	586.018	25	48.388	0.923	0.024
1991	2230.185	4670	775.768	28	69.858	1.291	0.024
1992	2375.366	6642	1217.951	23	85.597	1.407	0.022
1993	1879.140	6163	557.351	25	38.251	0.898	0.023
1994	1710.404	7332	649.481	25	37.672	0.756	0.022
1995	1800.616	5505	656.665	21	36.234	0.772	0.023
1996	1879.872	7679	755.670	22	33.605	0.730	0.022
1997	2356.002	8480	1150.436	21	60.345	0.937	0.022
1998	2306.407	9904	1134.732	21	60.532	0.785	0.021
1999	3117.675	8818	1702.605	23	98.416	1.136	0.022
2000	2945.593	7092	1037.689	19	64.044	0.838	0.023
2001	2599.522	7457	1004.507	18	62.018	0.785	0.023
2002	2876.313	8218	1144.075	22	75.271	0.929	0.022
2003	3229.932	9005	1210.227	23	80.709	0.987	0.022
2004	3222.781	7784	1253.026	22	83.782	0.963	0.023
2005	2844.079	7212	1125.753	22	87.742	0.981	0.023
2006	2585.823	5563	968.051	21	89.158	0.968	0.024
2007	2648.254	5551	1182.067	15	104.462	1.166	0.024
2008	2912.311	6214	1283.489	15	103.294	1.043	0.024
2009	2460.482	5499	1168.928	15	91.423	1.079	0.024
2010	2502.285	6050	1167.406	15	101.479	0.963	0.024
2011	2465.855	6889	1122.315	14	85.792	0.895	0.023
2012	2780.570	7214	1382.334	14	89.594	0.844	0.023
2013	1940.948	7264	937.017	14	61.465	0.630	0.023
2014	2369.756	7536	1058.609	14	68.715	0.724	0.024

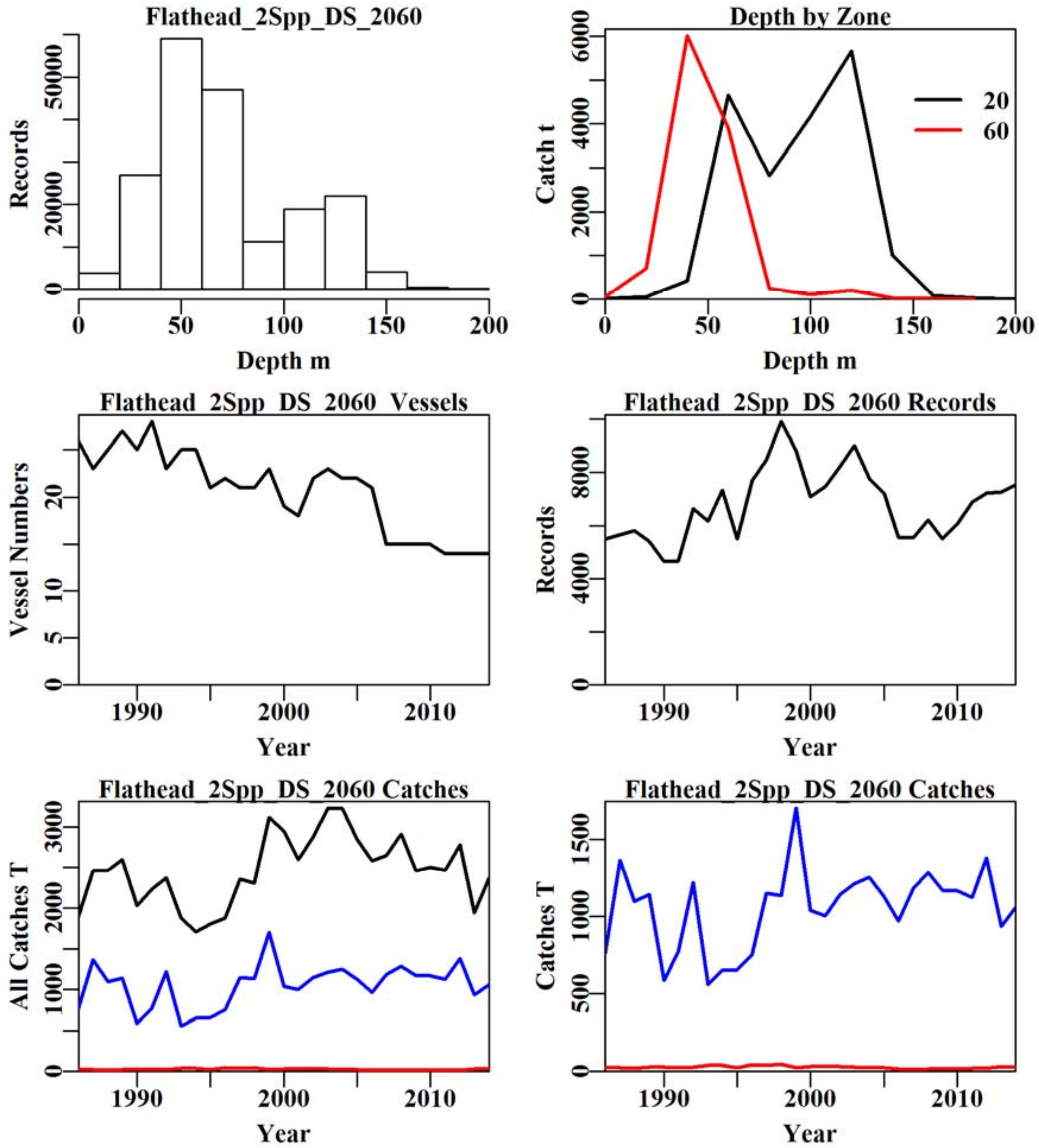


Figure 20.48. Flathead from zones 20 and 60 in depths 0 – 200 m by Danish Seine. The top left plot depicts the depth distribution of shots containing Flathead from zones 20 and 60 in depths 0 – 200 m by Danish Seine. The top right plot depicts the catch distribution by depth from zones 20 and 60. The 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).

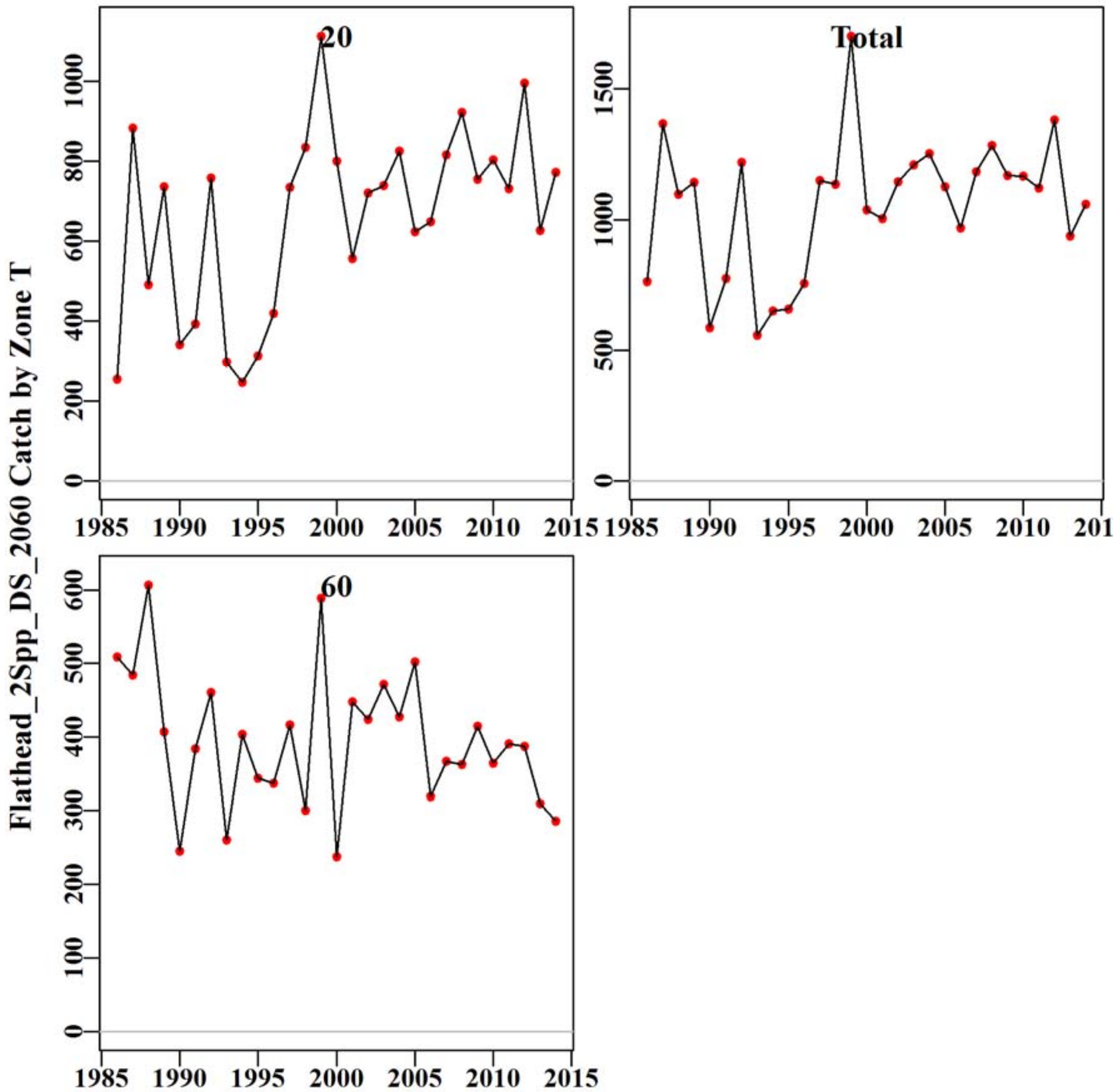


Figure 20.49. Annual flathead catches among the reporting zones 20, 60 and combined (20 & 60).

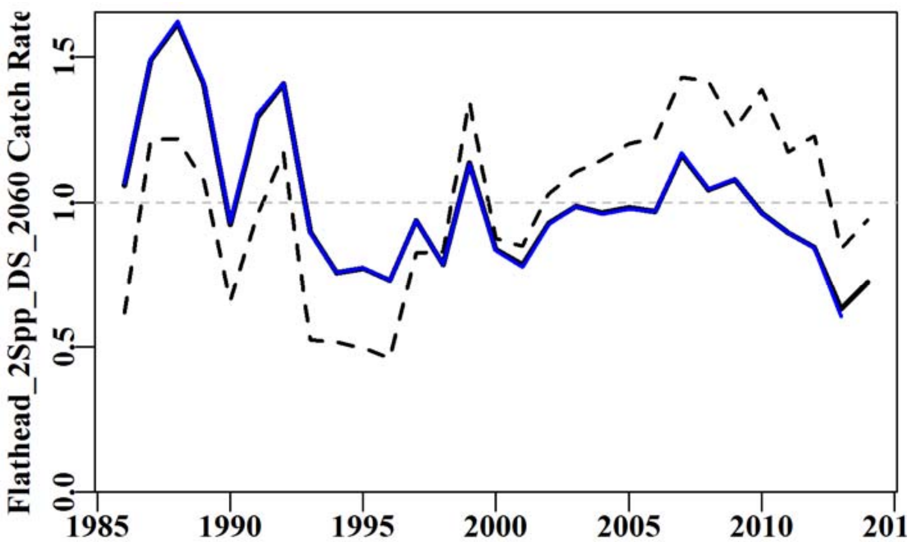


Figure 20.50. Flathead from zones 20 and 60 in depths 0 – 200 m by Danish Seine. The dashed black line represents the geometric mean catch rate and the solid black line the standardized catch rates (relative to the mean of the standardized catch rates). The blue line is last year's optimum standardization.

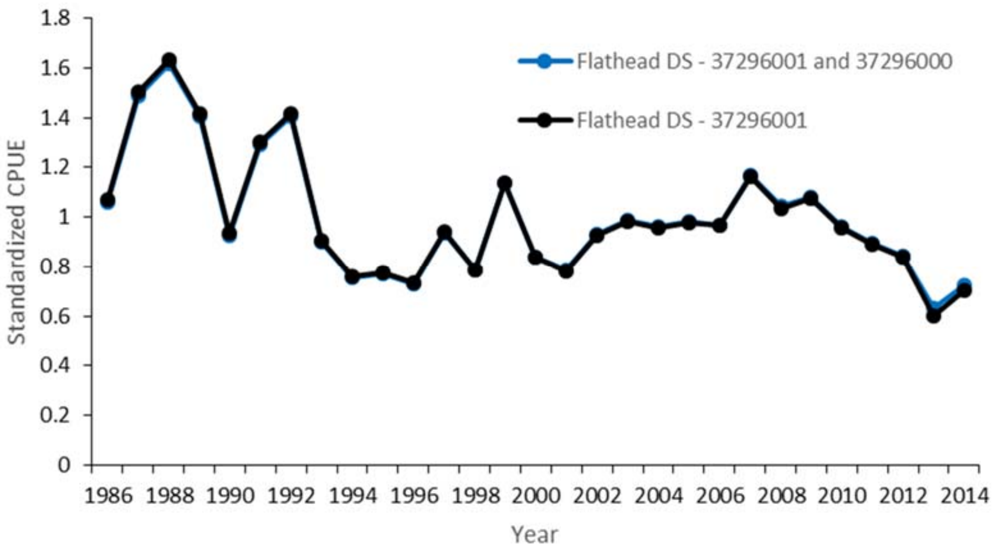


Figure 20.51. Flathead from zones 20 and 60 in depths 0 – 200 m by Danish Seine. The solid blue line represents the standardized catch rates (relative to the mean of the standardized catch rates) for Tiger flathead (37296001) and group code (37296000) and the solid black line the standardized catch rates (relative to the mean of the standardized catch rates) for Tiger flathead (37296001) only.

Table 20.44. Flathead from zones 20 and 60 in depths 0 – 200 m by Danish Seine. Statistical model structures used in this analysis. DepCat is a series of 20 metre depth categories.

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

Table 20.45. Flathead from zones 20 and 60 in depths 0 – 200 m by Danish Seine. Model selection criteria include the Akaike Information Criterion (AIC), residual sum of squares (RSS), model sum of squares (MSS), number of usable observations (Nobs), number of parameters (Npars), adjusted R^2 (adj_R^2) and the change in adjusted R^2 (%Change). The optimum was Model 7 (Zone:Month). Depth category: DepC.

	Year	Zone	DepC	Month	Vessel	DayNight	Zone:Month	Zone:DepC
AIC	151763	115510	82304	70829	62249	59199	54531	58789
RSS	425398	353818	296162	279098	266857	262681	256398	262098
MSS	20928	92508	150164	167229	179469	183645	189928	184228
Nobs	196781	196781	193734	193734	193734	193734	193734	193734
Npars	29.000	30.000	40.000	51.000	105.000	108.000	119.000	118.000
adj_R^2	4.675	20.715	33.631	37.452	40.178	41.113	42.519	41.241
%Change	0.000	16.040	12.916	3.820	2.727	0.935	1.405	-1.278

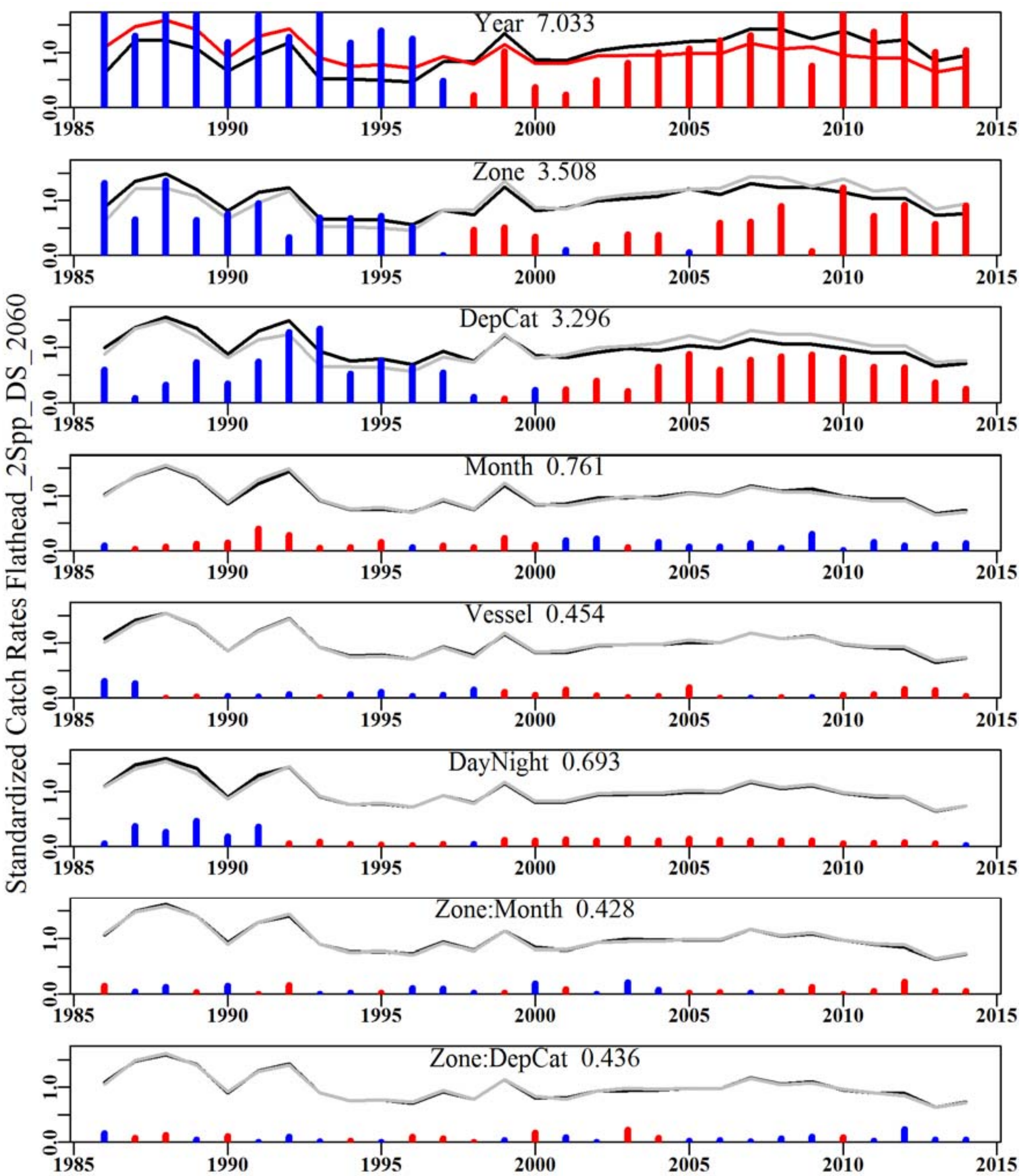


Figure 20.52. The relative influence of each factor used on the final trend in the optimal standardization for Flathead by Danish Seine in zones 20 and 60. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by the vertical 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.

20.4.17 Redfish Z1020 (RED – 37258003 – *Centroberyx affinis*)

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

Table 20.46. Redfish from zones 10 and 20 in depths 0 – 400 m by Trawl. Total catch (TotCatch; t) is the total reported in the database, number of records used in the analysis (Records), reported catch (CatchT; t) in the area and depth used in the analysis and number of vessels used in the analysis (Vessels). GeoMean is the geometric mean of catch rates (kg/hr). The optimum model is Month:DepC and standard deviation (StDev) relates to the data in the optimum model.

Year	TotCatch	Records	CatchT	Vessels	GeoMean	Month:DepC	StDev
1986	1687.4710	5341	1598.5740	87	32.2477	1.7170	0.0000
1987	1252.6580	3931	1185.3720	79	32.2363	1.4850	0.0339
1988	1125.4920	3974	1079.0320	75	32.8464	1.6484	0.0343
1989	714.3160	2723	644.4320	72	25.1327	1.2415	0.0383
1990	931.3700	2593	794.8440	58	29.8742	1.5824	0.0394
1991	1570.6070	3353	1238.3930	52	33.6661	1.7068	0.0368
1992	1636.6870	3201	1520.8800	48	39.9527	2.0857	0.0379
1993	1921.3470	3796	1787.2810	53	46.4398	2.5798	0.0363
1994	1487.7170	5499	1353.7390	53	32.0522	1.9054	0.0337
1995	1240.6170	5713	1196.6550	52	24.0776	1.2230	0.0328
1996	1344.0490	5814	1305.9120	56	20.6506	1.0705	0.0330
1997	1397.3280	4408	1354.0750	58	23.1283	1.1225	0.0351
1998	1553.7182	4309	1528.0460	49	29.8220	1.3474	0.0350
1999	1116.4030	3945	1091.8570	53	24.3308	1.1033	0.0356
2000	758.2751	4668	737.1360	53	14.6627	0.7355	0.0349
2001	742.2683	4587	725.5110	49	12.9727	0.7240	0.0348
2002	807.1325	5215	774.5375	50	12.2185	0.6850	0.0344
2003	615.5584	4119	555.8542	52	10.7368	0.5840	0.0359
2004	475.2044	3965	449.3740	51	10.2028	0.5234	0.0364
2005	483.5160	3796	453.1700	47	11.0542	0.5773	0.0368
2006	325.4821	2589	302.6810	43	10.7454	0.5287	0.0405
2007	216.2794	1880	208.9890	24	10.7721	0.5162	0.0453
2008	183.7567	1932	179.7953	26	10.0057	0.4531	0.0451
2009	160.5248	1619	154.3370	24	9.0193	0.3984	0.0476
2010	152.8285	1871	147.4586	25	7.8240	0.3859	0.0455
2011	87.3052	1408	84.1147	22	5.4792	0.2811	0.0497
2012	66.4453	1354	62.3310	21	4.6073	0.1984	0.0502
2013	62.6740	1137	60.4391	20	5.5586	0.2573	0.0532
2014	86.7989	1218	70.0554	22	7.2835	0.3330	0.0520

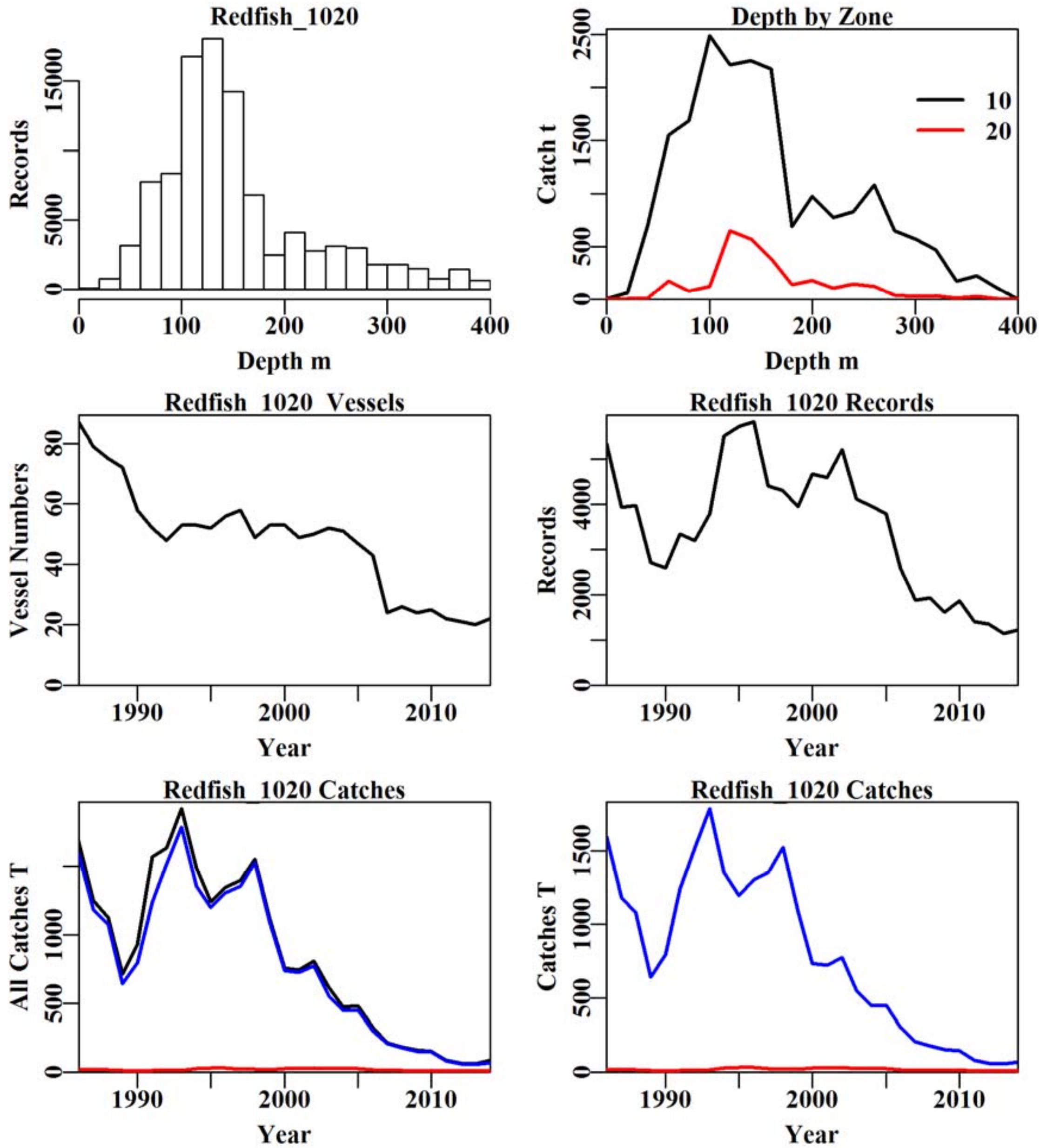


Figure 20.53. Redfish from zones 10 and 20 in depths 0 – 400 m by Trawl. The top left plot depicts the depth distribution of shots containing Redfish from zones 10 and 20 in depths 0 – 400 m by Trawl. The top right plot depicts the catch distribution by depth from zones 10 and 20. The middle left plot depicts the number of vessels through time and middle right plot contains the number of records used in analysis. The bottom left plot contains Redfish catches (top black line: total catches, middle blue line: catches used in the analysis; bottom red line: catches < 30 kg) and bottom right plot contains Redfish catches (blue line: catches used in the analysis; red line: catches < 30 kg).

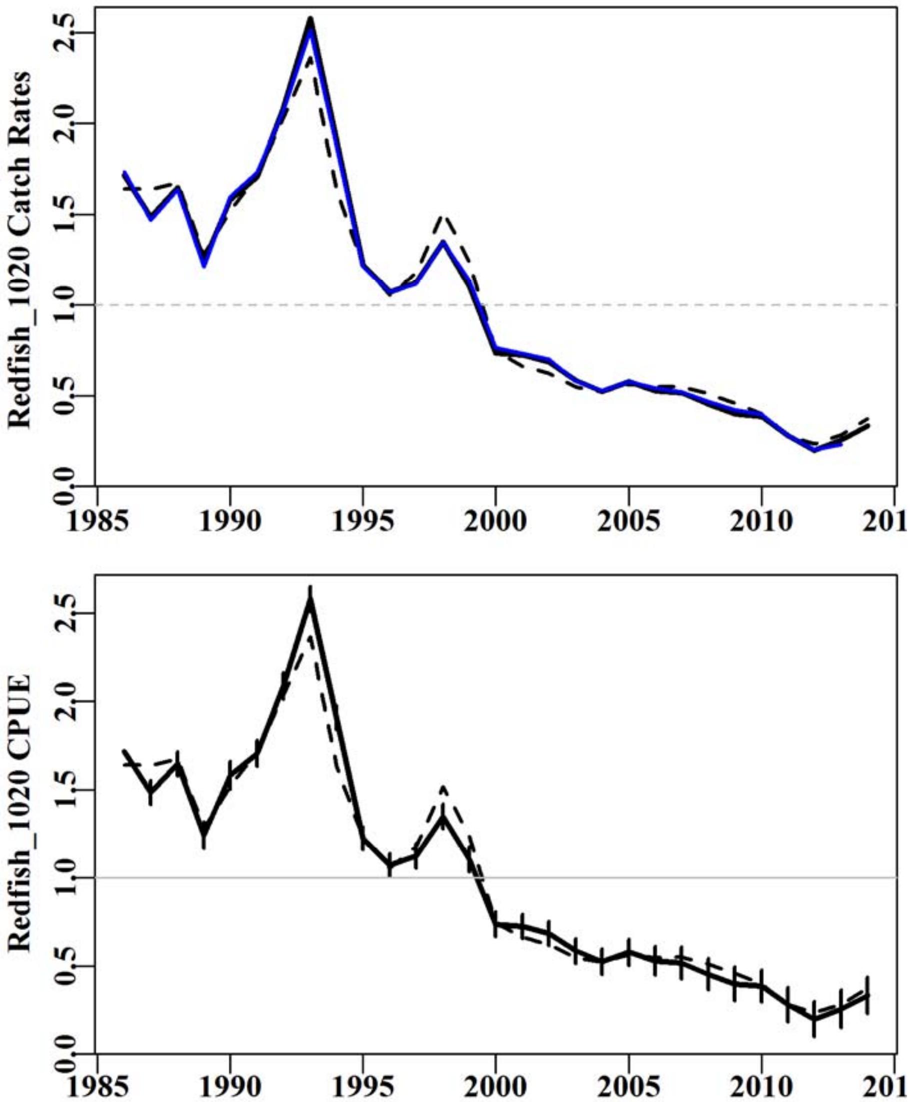


Figure 20.54. Redfish from zones 10 and 20 in depths 0 – 400 m by Trawl. Top plot: The dashed black line represents the geometric mean catch rate and the solid black line the standardized catch rates (relative to the mean of the standardized catch rates). The blue line corresponds to last year's standardized catch rates. Lower plot: Standardized catch rates (solid black line), 95% CI (vertical lines) and geometric mean (dashed black line).

Table 20.47. Redfish from zone 10 in depths 0 – 400m by Trawl. Statistical model structures used in this analysis. DepCat is a series of 20 metre depth categories.

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

Table 20.48. Redfish from zone 10 in depths 0 – 400 m by Trawl. Model selection criteria include the Akaike Information Criterion (AIC), residual sum of squares (RSS), model sum of squares (MSS), number of usable observations (Nobs), number of parameters (Npars), adjusted R^2 (adj_R^2) and the change in adjusted R^2 (%Change). The optimum model was Model 8 (Month:DepCat). Depth category: DepC; DayNight: DN.

	Year	Vessel	DepC	Zone	Month	DN:Month	Month:DepC	DN:DepC	DN:DepC
AIC	108930	92040	85918	84683	84208	83798	83592	82313	82726
RSS	297059	250100	234962	232056	230900	229935	229306	225526	227195
MSS	31909	78868	94006	96911	98068	99033	99661	103441	101773
Nobs	99958	99958	99408	99408	99408	99408	99408	99408	99408
Npars	29	184	204	205	216	219	252	439	279
adj_R^2	9.674	23.835	28.430	29.314	29.659	29.951	30.119	31.141	30.743
%Change	0.000	14.161	4.595	0.884	0.344	0.292	0.168	1.022	-0.397

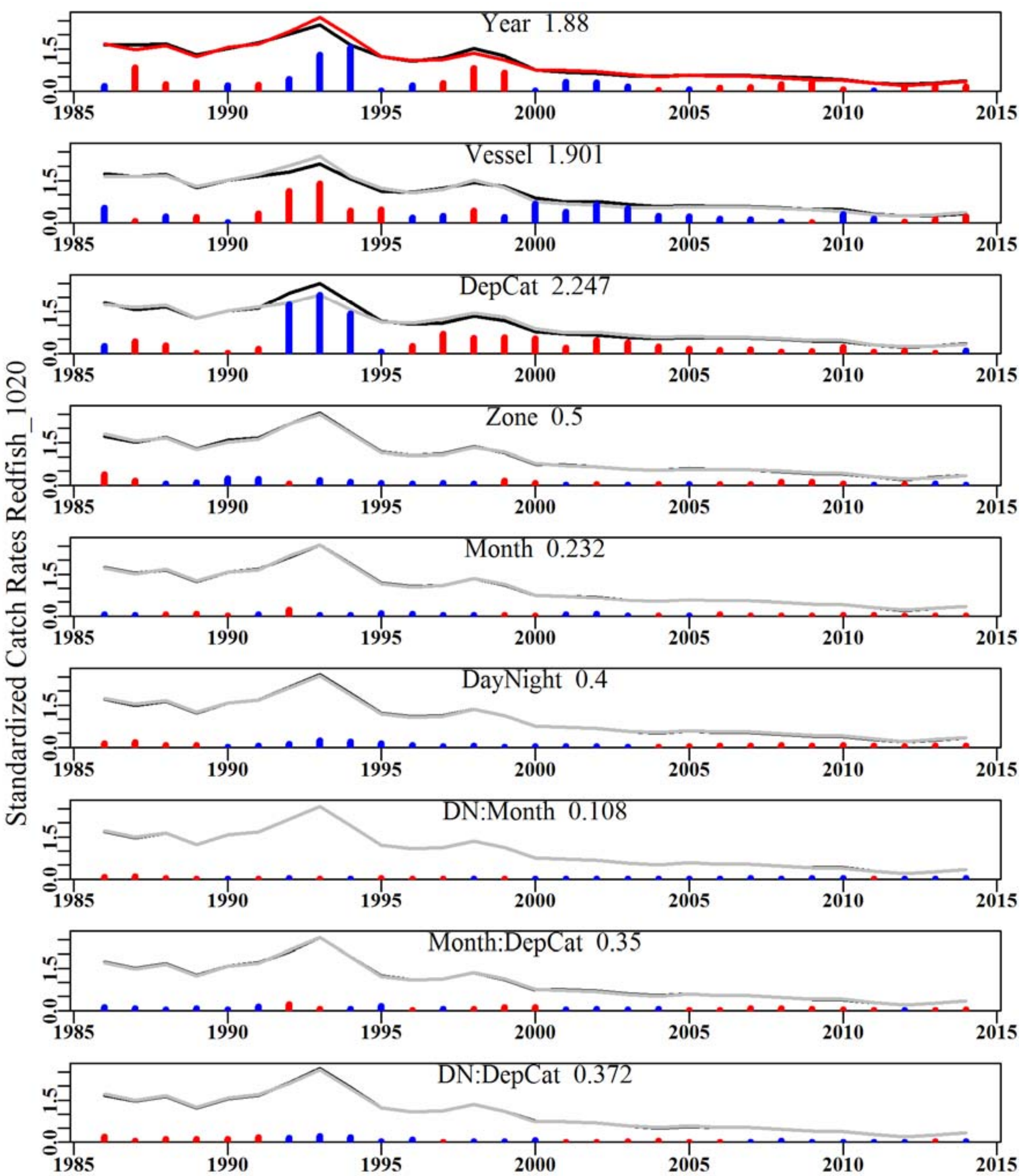


Figure 20.55. The relative influence of each factor used on the final trend in the optimal standardization for Redfish in zones 10 and 20. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by the vertical bars with blue bars indicating the optimum model is higher than the geometric mean and red bars indicating it is lower. The top graph bars are the sum of all the bars in the graphs below. The graphs for individual factors are cumulative. Thus the second graph has the geometric mean (grey line) and the effect of adding Year + factor2 (Model 2). In the third graph, the grey line represents Model 2 and the black line the effect of adding factor3 to the model. The remaining graphs continue in the same cumulative manner except for the interaction terms which are added singularly to the final single factor model.

20.4.18 Silver Trevally Z1020 (TRE – 37337062 – *Pseudocaranx dentex*)

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

Table 20.49. 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	1.1604	0.0000
1987	198.4900	1090	116.3170	63	17.5072	1.3715	0.0598
1988	278.5410	1299	226.6200	52	23.7642	1.8086	0.0551
1989	376.1960	1838	278.0370	62	23.0657	1.9341	0.0505
1990	450.3910	1841	288.8090	52	23.2975	2.3160	0.0522
1991	340.6830	1909	213.9030	49	18.1137	2.0770	0.0525
1992	296.4930	1282	167.7280	45	13.4222	1.3026	0.0576
1993	377.6730	1262	132.8610	47	13.4863	1.3195	0.0579
1994	392.8280	1839	139.1540	46	9.4912	1.0107	0.0533
1995	413.4390	1570	136.6370	43	10.2789	1.1428	0.0555
1996	340.6160	1883	129.5360	47	7.5806	0.9215	0.0540
1997	328.8385	1450	88.4990	48	6.2012	0.8674	0.0576
1998	210.1360	1023	48.9720	40	5.2414	0.6245	0.0614
1999	166.0182	882	41.5680	39	4.9696	0.6299	0.0647
2000	154.7527	1021	43.6240	44	3.6777	0.4627	0.0619
2001	270.1751	1545	82.5005	44	4.1310	0.5417	0.0557
2002	232.7870	1479	68.3950	41	3.1021	0.4394	0.0574
2003	337.8967	1123	57.7278	46	3.3780	0.4310	0.0598
2004	458.0749	1344	84.3135	43	4.5318	0.5987	0.0582
2005	290.9402	673	59.5595	41	4.7971	0.5300	0.0696
2006	247.2843	493	48.8240	32	5.7178	0.7465	0.0770
2007	172.7180	462	47.1000	20	7.4420	0.8299	0.0798
2008	128.3861	818	69.6650	23	8.0833	0.8463	0.0663
2009	164.0519	836	94.1810	24	9.1902	0.8601	0.0655
2010	240.2269	966	135.4903	25	11.7046	1.0984	0.0636
2011	193.4736	862	139.3343	21	11.0895	0.9896	0.0655
2012	139.6903	665	88.0700	21	7.6670	0.6987	0.0706
2013	122.7757	508	72.1860	20	13.3759	0.8366	0.0761
2014	106.1545	478	45.9460	21	10.2871	0.6039	0.0782

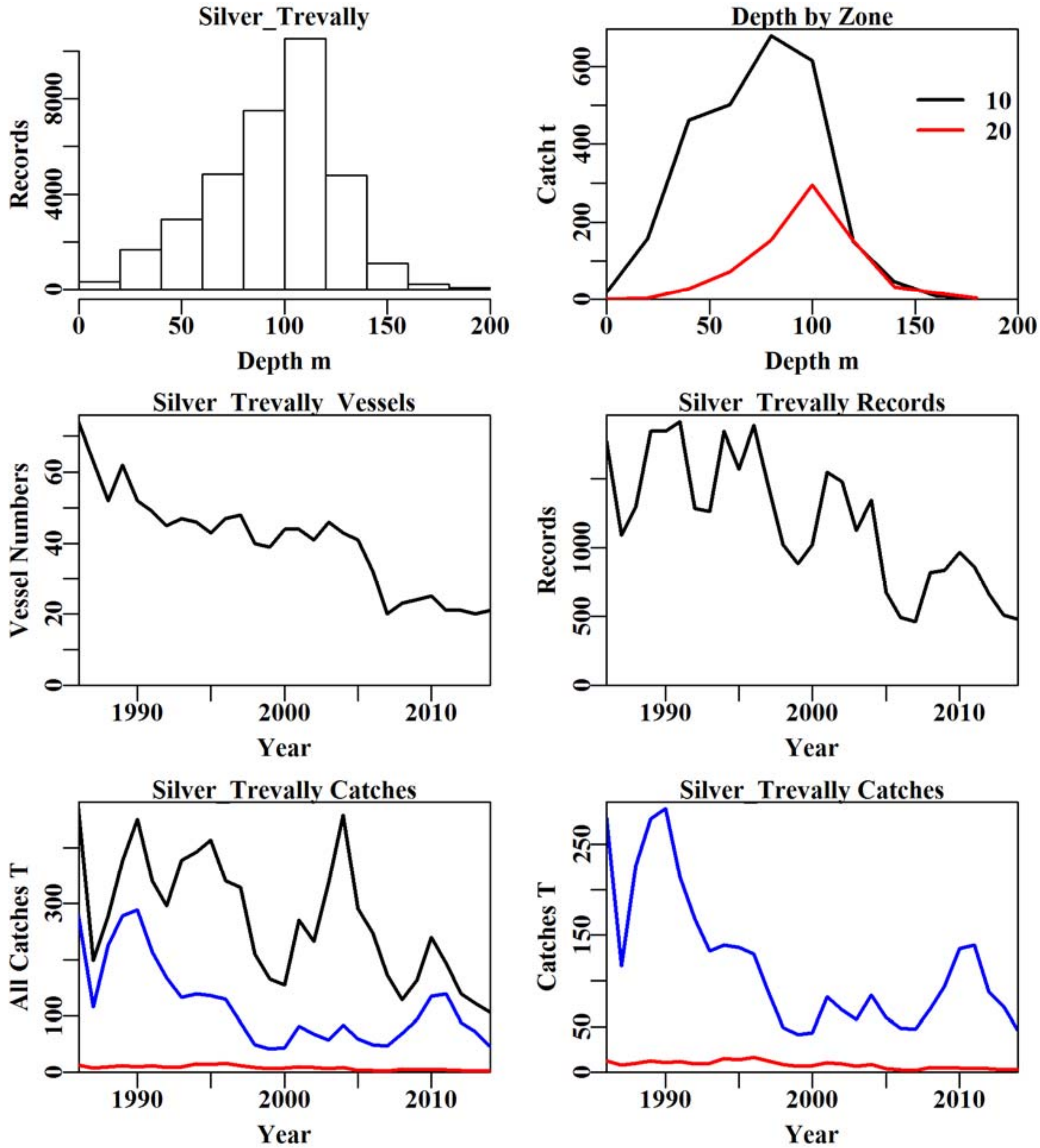


Figure 20.56. Silver Trevally from Zones 10 and 20 in depths 0 to 200 m, excluding data from State waters (Bateman's Bay MPA). The top left plot depicts the depth distribution of shots containing Silver Trevally from zones 10 and 20 in depths 0 to 200 m by Trawl, excluding data from State waters (Bateman's 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).

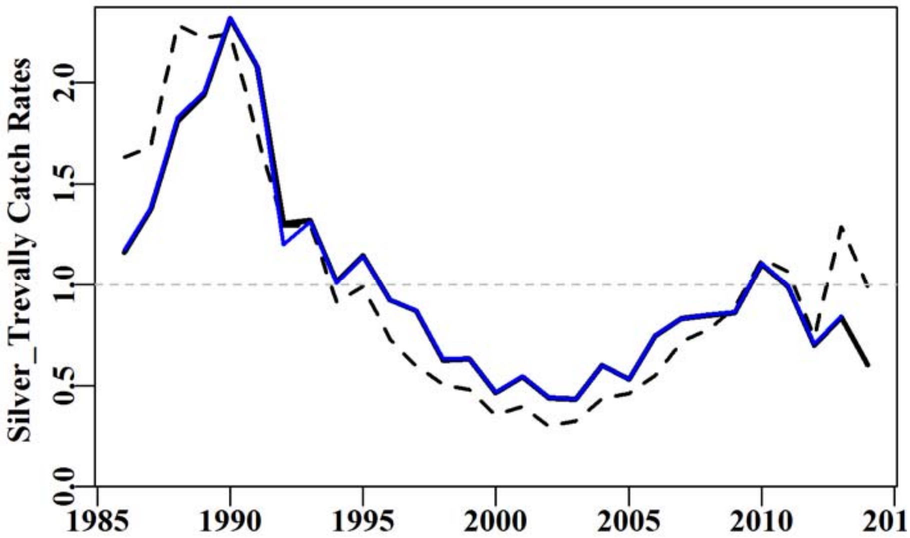


Figure 20.57. Silver Trevally from zones 10 and 20 in depths 0 to 200 m, excluding data taken in State waters (Bateman's Bay MPA). The dashed black line represents the geometric mean catch rate and the solid black line the standardized catch rates (relative to the mean of the standardized catch rates). The blue line corresponds to last year's standardized indices.

Table 20.50. 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 20.51. 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	32139	25088	24061	23346	22951	22892	22809	22869
RSS	87380	70487	68216	66752	65969	65850	65647	65771
MSS	13652	30545	32816	34280	35063	35181	35385	35261
Nobs	34206	34206	33960	33960	33960	33960	33960	33960
Npars	29	178	187	198	201	202	213	211
adj_R^2	13.442	29.870	32.109	33.544	34.318	34.434	34.615	34.495
%Change	0.000	16.428	2.239	1.436	0.773	0.116	0.181	-0.120

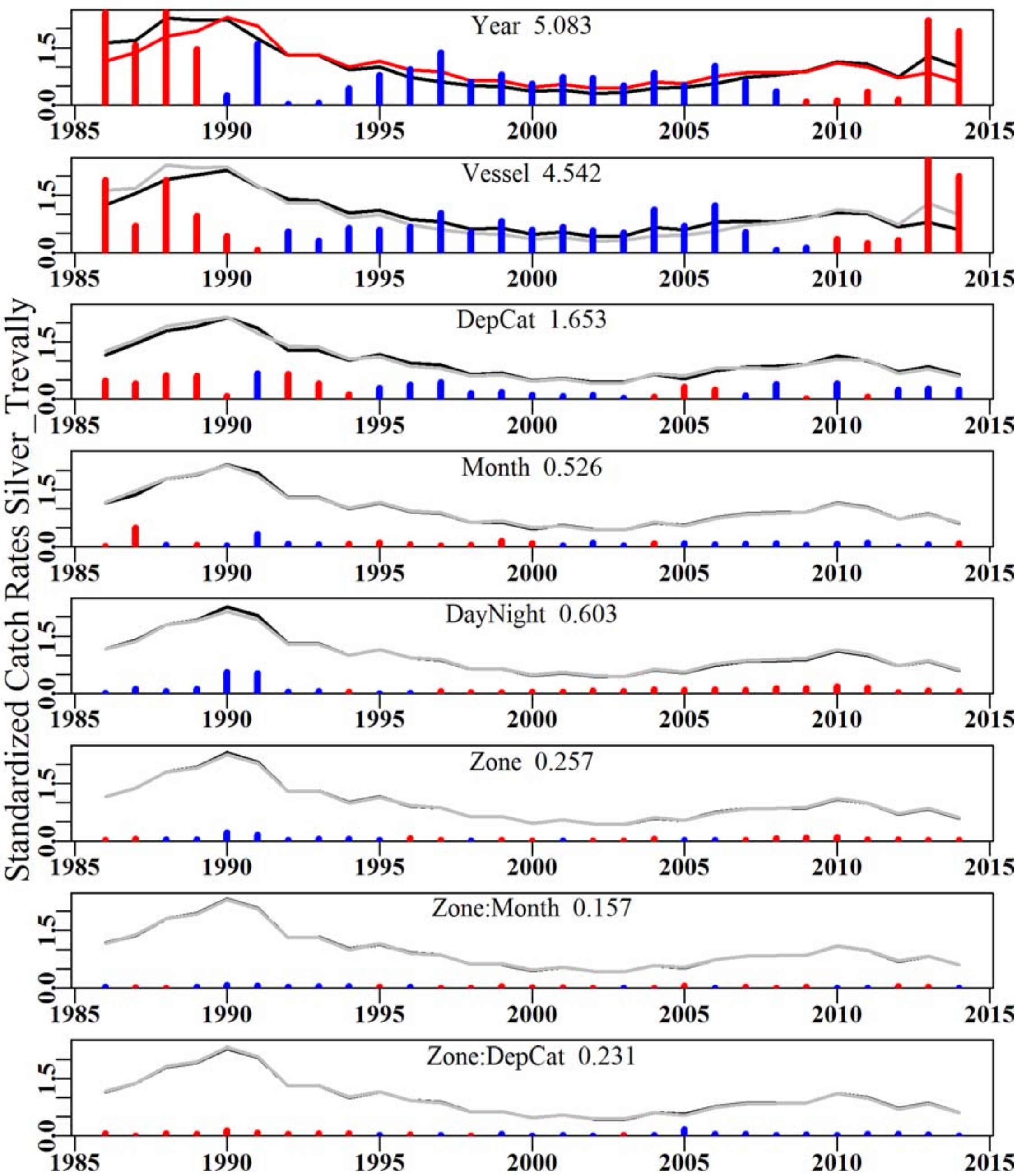


Figure 20.58. The relative influence of each factor used on the final trend in the optimal standardization for Silver Trevally in zones 10 and 20. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by the vertical bars with 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.

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 20.52. 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	1.0515	0.0000
1987	198.4900	1260	135.0590	64	17.4271	1.2438	0.0573
1988	278.5410	1581	243.9060	56	20.1929	1.4299	0.0522
1989	376.1960	2194	332.4520	62	24.2894	1.7955	0.0483
1990	450.3910	2101	349.0320	53	24.1445	2.0609	0.0500
1991	340.6830	2221	251.1220	50	18.0221	1.8466	0.0501
1992	296.4930	1708	255.1340	45	14.4648	1.1310	0.0528
1993	377.6730	2280	282.0380	49	15.1230	1.1375	0.0498
1994	392.8280	3307	361.9670	48	13.0062	0.9695	0.0466
1995	413.4390	3352	380.1920	49	14.3268	1.1023	0.0463
1996	340.6160	3237	315.1980	54	10.8969	0.9952	0.0468
1997	328.8385	2869	298.1160	55	11.5325	0.9776	0.0480
1998	210.1360	2281	177.0570	46	9.4314	0.7434	0.0495
1999	166.0182	1859	115.3820	45	8.3770	0.7278	0.0518
2000	154.7527	2012	122.6510	50	6.0264	0.5601	0.0509
2001	270.1751	3240	227.9255	47	7.6180	0.6743	0.0465
2002	232.7870	2777	209.1290	45	5.9953	0.6353	0.0482
2003	337.8967	2761	281.9697	50	8.0171	0.6781	0.0479
2004	458.0749	3338	367.6270	46	10.6787	0.8303	0.0467
2005	290.9402	2324	242.1420	44	11.1271	0.7255	0.0500
2006	247.2843	1687	209.1645	40	13.2846	0.7888	0.0531
2007	172.7180	835	115.5430	22	11.8089	0.7761	0.0644
2008	128.3861	1065	95.8960	24	9.1077	0.8823	0.0603
2009	164.0519	1152	136.0260	24	10.5189	0.8777	0.0588
2010	240.2269	1264	191.9942	25	13.7770	1.1400	0.0578
2011	193.4736	1125	179.4593	21	12.5672	0.9834	0.0595
2012	139.6903	966	131.5530	21	11.0919	0.7731	0.0618
2013	122.7757	723	112.8740	20	16.1023	0.8264	0.0670
2014	106.1545	710	78.7110	21	11.9182	0.6360	0.0676

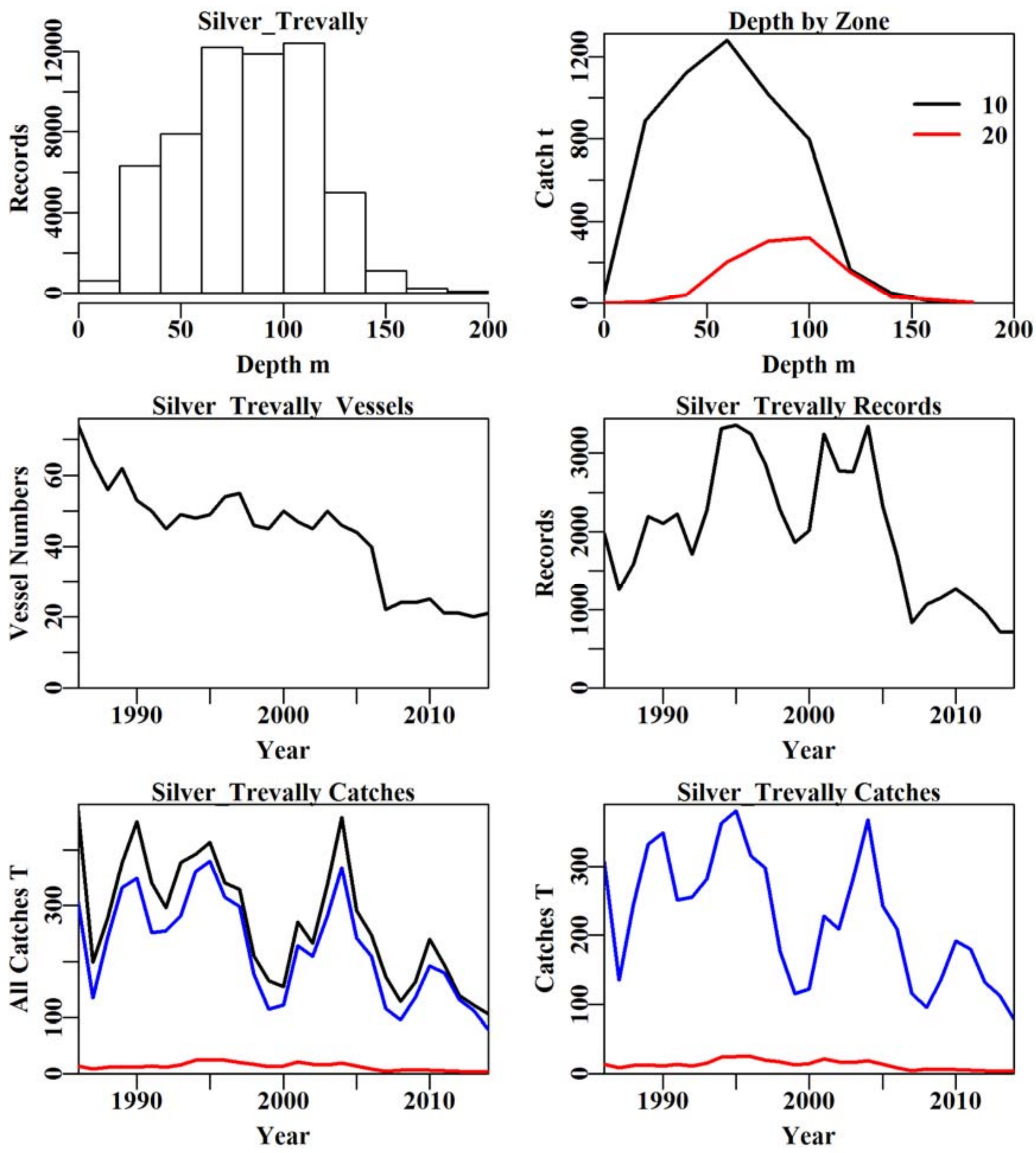


Figure 20.59. Silver Trevally from Zones 10 and 20 in depths 0 to 200 m, including all from State waters (Bateman's Bay MPA). The top left plot depicts the depth distribution of shots containing Silver Trevally from zones 10 and 20 in depths 0 to 200 m by Trawl, including data from State waters (Bateman's 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).

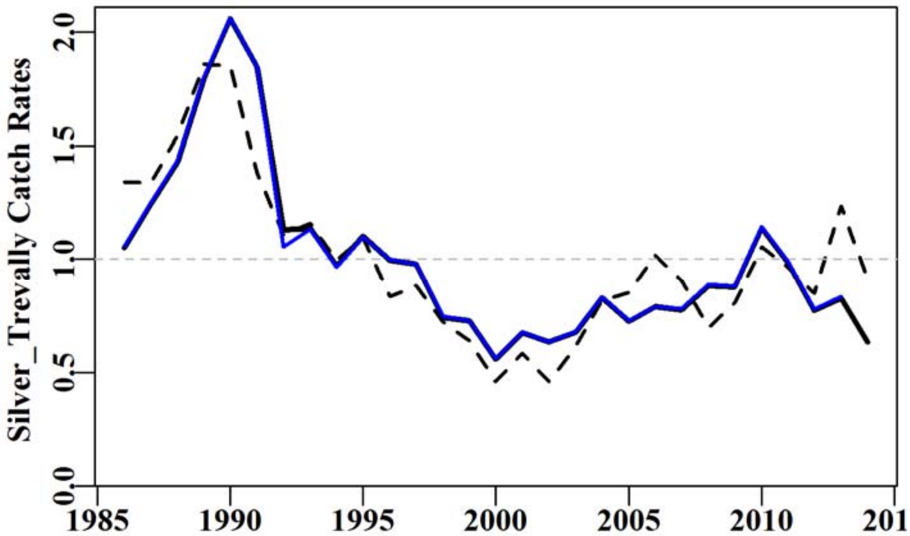


Figure 20.60. Silver Trevally from zones 10 and 20 in depths 0 to 200 m, including data from State waters (Bateman's Bay MPA). The dashed black line represents the geometric mean catch rate and the solid black line the standardized catch rates (relative to the mean of the standardized catch rates). The blue line corresponds to last year's standardized indices.

Table 20.53. 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 20.54. 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	61063	47396	43851	43150	42506	42484	42361	42455
RSS	166014	130594	122602	121076	119720	119671	119370	119574
MSS	7770	43190	51182	52708	54064	54113	54414	54210
Nobs	58207	58207	57758	57758	57758	57758	57758	57758
Npars	29	180	189	200	203	204	215	213
adj_R^2	4.425	24.621	29.221	30.089	30.868	30.895	31.056	30.940
%Change	0.000	20.196	4.600	0.868	0.779	0.027	0.161	-0.115

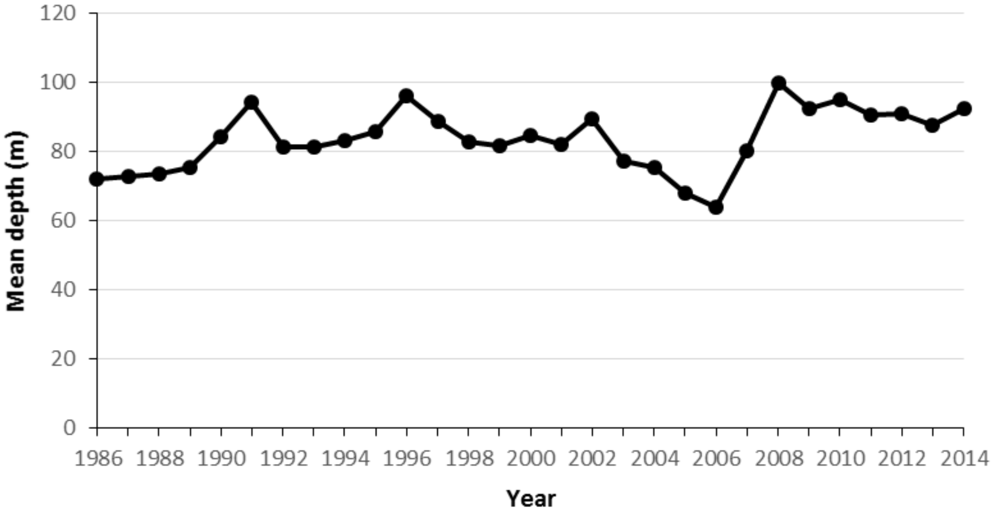


Figure 20.61. Average reported depth of trawling for Silver Trevally from Zones 10 and 20 in depths 0 to 200 m, including data from State waters (Bateman's Bay MPA). The effect of the introduction of the Bateman's Bay MPA in increasing the average depth fished is apparent from 2008 onwards.

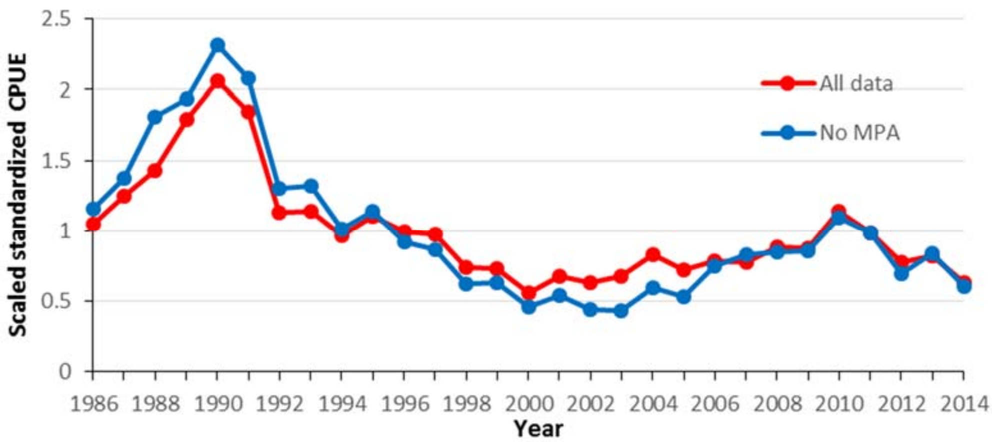


Figure 20.62. Comparison of the CPUE series with and without the data from inside the MPA. The All data series is less variable than the series that excludes data from the MPA.

20.4.19 *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 20.55. 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	0.6845	0.0000
1987	351.2940	1764	324.7160	47	41.9857	0.8715	0.0379
1988	362.5050	1395	344.4570	41	49.1496	0.9669	0.0409
1989	329.2540	1143	310.7600	39	45.8268	0.8234	0.0428
1990	337.1340	727	311.1180	25	95.1525	1.5470	0.0491
1991	334.1340	734	299.3700	29	79.4866	1.3759	0.0495
1992	166.8600	434	146.0810	19	70.3817	1.0286	0.0579
1993	298.7970	673	232.7740	21	68.5216	1.1804	0.0493
1994	359.8303	661	240.3630	26	77.7193	1.1201	0.0496
1995	335.5920	1070	252.9050	25	58.4998	0.8929	0.0436
1996	360.7760	1216	272.6750	25	60.5827	0.8013	0.0420
1997	252.6930	855	166.7030	21	51.9861	0.7553	0.0463
1998	233.2980	1234	190.7320	23	39.1713	0.8091	0.0427
1999	367.0420	1607	348.8040	25	49.7799	0.8045	0.0405
2000	434.9308	1540	398.6840	27	49.5341	1.0126	0.0408
2001	276.7855	1314	229.5490	22	35.9779	0.8610	0.0430
2002	484.2085	1740	417.3700	23	47.9208	1.0393	0.0401
2003	230.8050	801	163.1840	26	39.7063	1.0795	0.0491
2004	193.8510	579	170.6810	22	50.4687	1.1039	0.0535
2005	173.8960	601	159.8050	21	47.1225	1.0098	0.0535
2006	192.2620	455	178.5790	17	55.0038	1.2124	0.0580
2007	121.5453	324	116.4300	9	48.8072	0.8255	0.0660
2008	75.7990	252	70.6050	8	39.0864	0.7096	0.0745
2009	68.7850	250	67.6070	9	59.2670	0.9183	0.0783
2010	96.7650	343	82.8210	9	40.3732	0.8819	0.0659
2011	110.9230	291	108.9600	8	82.0762	1.3191	0.0704
2012	126.5190	363	122.7770	9	57.3988	1.0062	0.0649
2013	212.1670	428	208.2470	9	97.7949	1.2881	0.0688
2014	121.6570	257	82.8700	9	81.6081	1.0713	0.0740

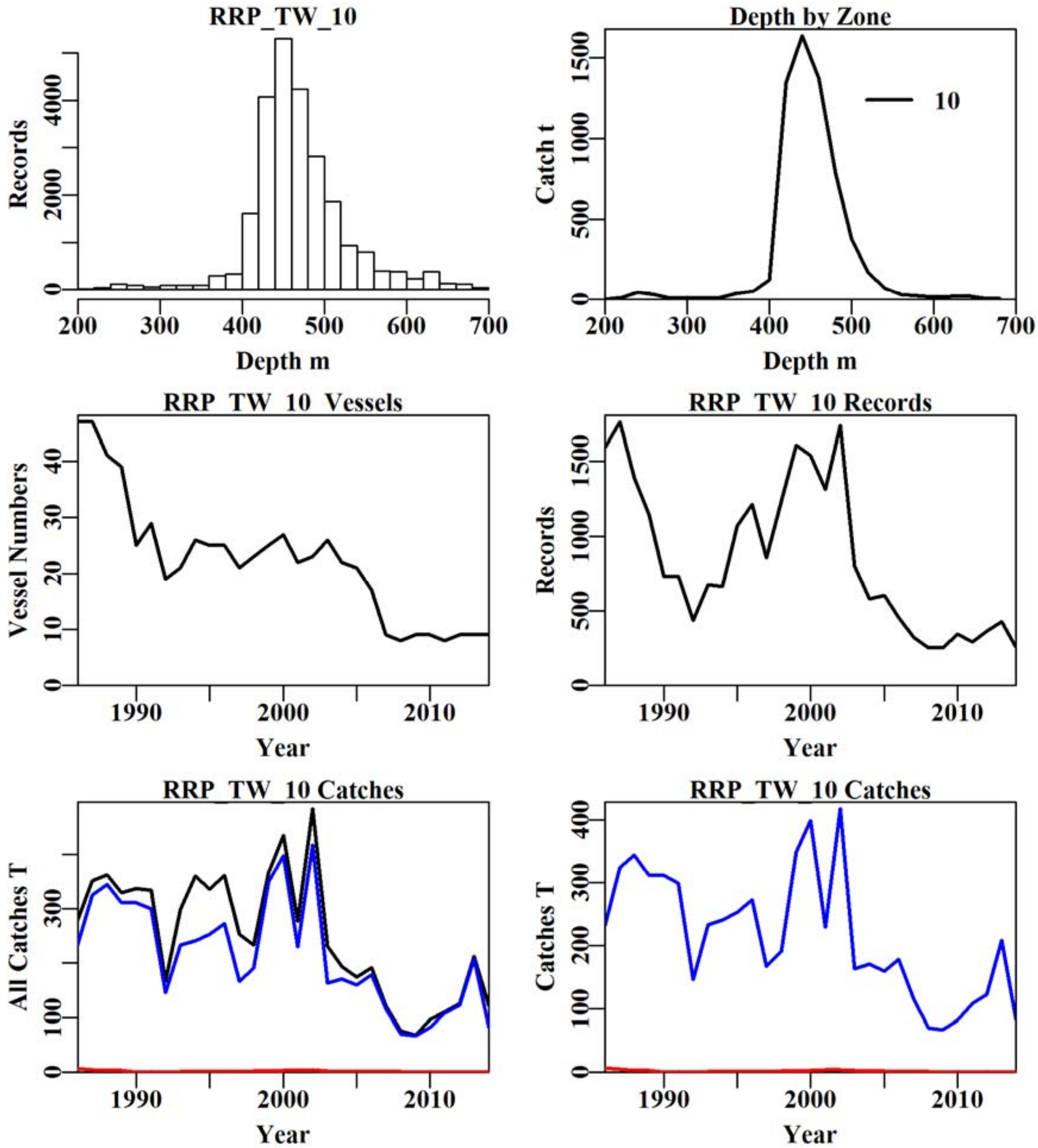


Figure 20.63. Royal Red Prawn from zone 10 in depths 200 – 700m by Trawl. The top left plot depicts the depth distribution of shots containing Royal red Prawn from zone 10 in depths 200 to 700 m by Trawl. The top right plot depicts the catch distribution by depth within zone 10. The middle left plot 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).

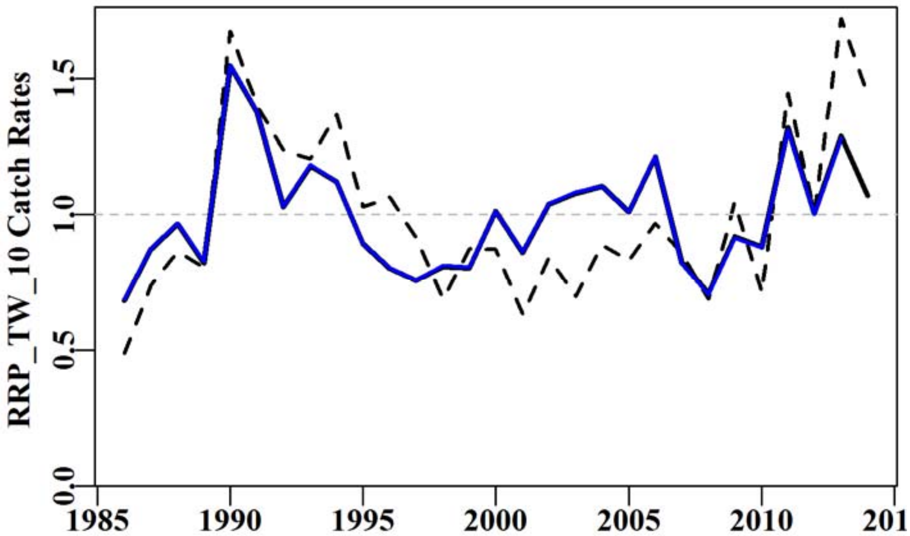


Figure 20.64. Royal Red Prawn from zone 10 in depths 200 – 700 m by Trawl. The dashed black line represents the geometric mean catch rate and the solid black line the standardized catch rates (relative to the mean of the standardized catch rates). The blue line corresponds to last year's standardized indices.

Table 20.56. 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 20.57. 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	13729	8526	3109	1445	1352	1317	839	1308
RSS	42916	34539	27497	25668	25564	25459	24500	25368
MSS	2030	10407	17449	19278	19382	19487	20446	19578
Nobs	24643	24491	24491	24491	24491	24491	24491	24491
Npars	29	53	137	148	151	184	415	223
adj_R^2	4.409	22.991	38.481	42.547	42.772	42.931	44.553	43.043
%Change	0.000	18.582	15.490	4.066	0.225	0.159	1.622	-1.510

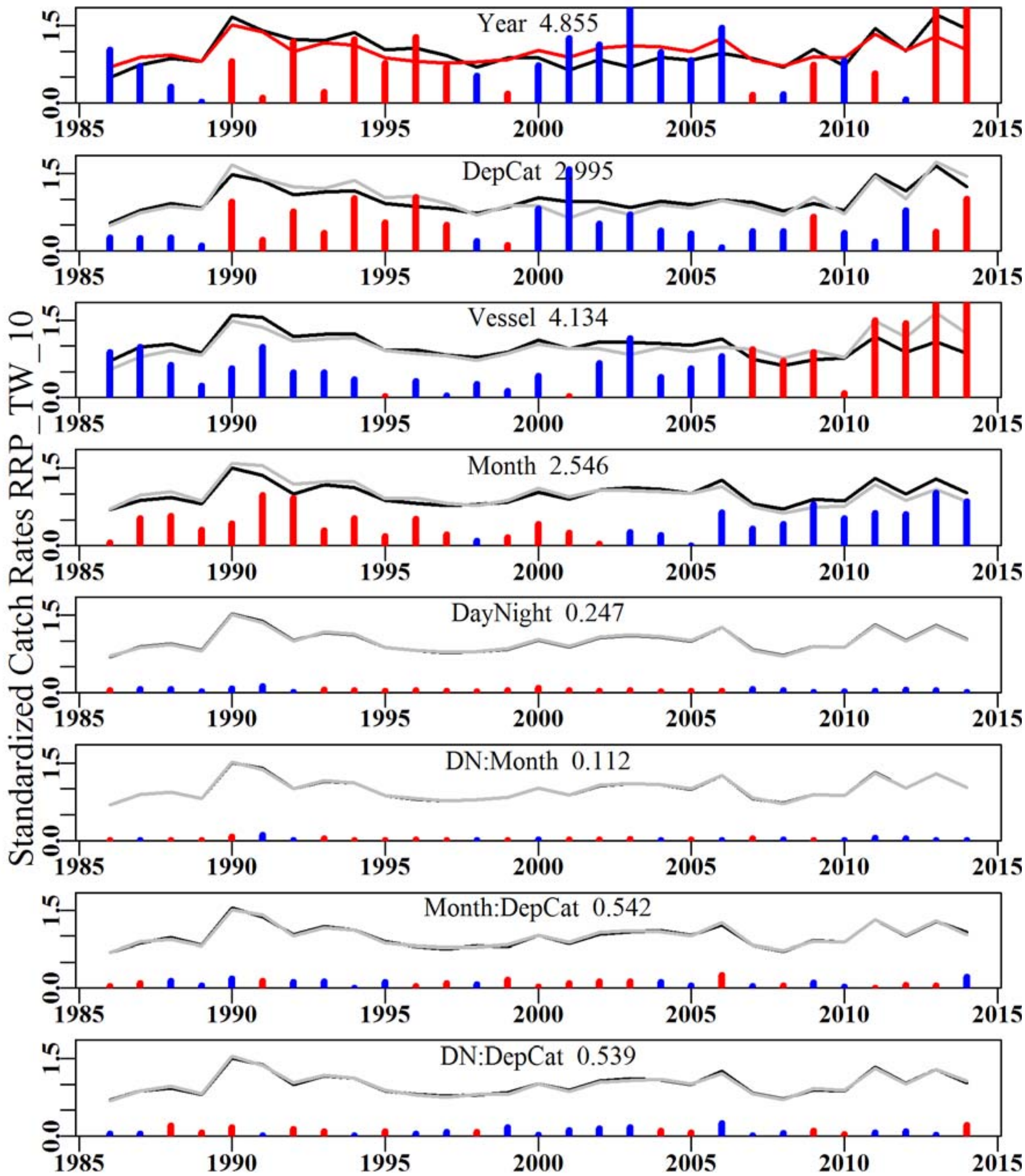


Figure 20.65. The relative influence of each factor used on the final trend in the optimal standardization for Royal Red Prawn in zone 10. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by the vertical bars with blue 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.

20.4.20 Blue Eye Trevalla Z2030 (TBE – 37445001 – Hyperglyphe antarctica)

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

Table 20.58. 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	2.1964	0.0000
1987	15.4950	190	10.0260	14	9.8390	2.0622	0.1365
1988	105.1770	307	19.4330	21	14.4132	2.5668	0.1291
1989	88.0660	315	33.3710	32	14.6333	2.8878	0.1315
1990	79.2980	264	39.8450	36	24.1892	3.6684	0.1341
1991	76.0240	474	29.1890	37	9.3594	1.9688	0.1261
1992	49.3050	313	14.2320	23	8.3976	1.4696	0.1332
1993	59.6540	736	37.7890	31	7.9893	1.1837	0.1233
1994	109.9750	855	89.0330	33	10.7324	1.3672	0.1226
1995	58.5720	489	28.3350	29	5.8281	0.9123	0.1272
1996	71.6840	648	35.5180	29	5.7645	0.7359	0.1250
1997	470.7164	604	19.9210	31	4.6731	0.6749	0.1270
1998	475.9652	475	18.7040	24	4.1103	0.7715	0.1292
1999	574.4838	633	41.7330	27	3.5948	0.8017	0.1260
2000	667.0558	657	37.6610	35	2.7104	0.5093	0.1238
2001	647.5307	700	25.1710	25	2.2528	0.4469	0.1241
2002	843.8591	700	33.7320	29	3.0245	0.4466	0.1260
2003	605.3020	722	14.0635	25	2.2528	0.4452	0.1255
2004	606.2500	623	15.1709	29	2.7224	0.4379	0.1270
2005	755.1858	502	17.9194	26	2.6091	0.4338	0.1302
2006	573.7189	327	36.7820	17	3.9462	0.5333	0.1344
2007	937.1424	247	10.6065	11	3.1151	0.4221	0.1402
2008	398.9433	434	13.6537	15	5.6341	0.4000	0.1339
2009	520.8777	246	22.8489	15	5.4891	0.3951	0.1414
2010	437.3987	197	11.5432	13	3.3742	0.2697	0.1468
2011	554.2188	227	7.8041	12	2.1952	0.2796	0.1436
2012	463.8349	150	1.3334	11	1.6617	0.2414	0.1531
2013	398.3268	147	4.1109	12	3.6020	0.2200	0.1548
2014	459.9604	79	2.3907	12	2.7842	0.2521	0.1779

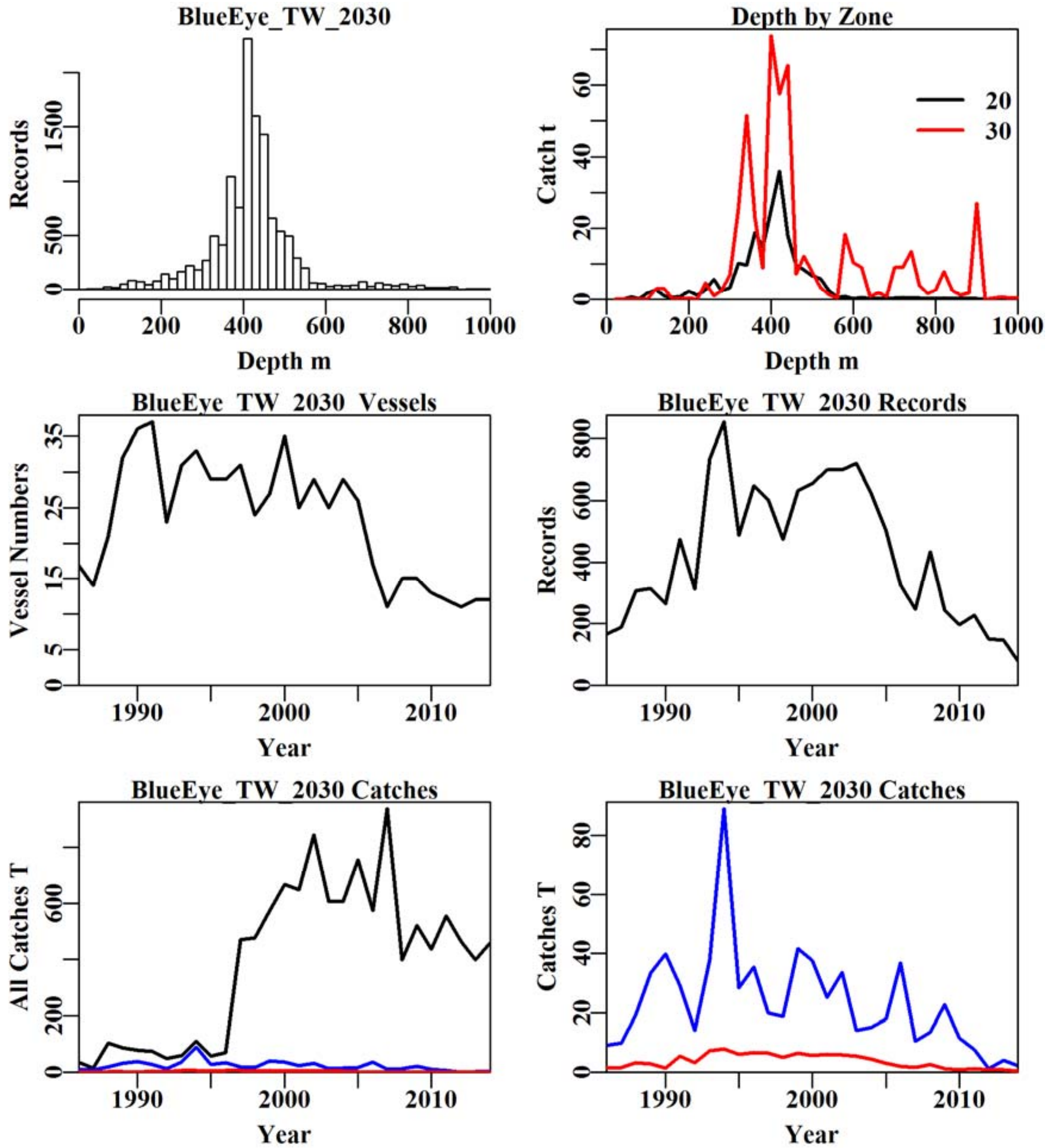


Figure 20.66. Blue Eye Trevalla from zones 20 and 30 in depths 0 – 1000 m by Trawl. The top left plot depicts the depth distribution of shots containing Blue Eye Trevalla from zones 20 and 30 in depths 0 to 1000 m by Trawl. The top right plot depicts the catch distribution by depth within zones 20 and 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).

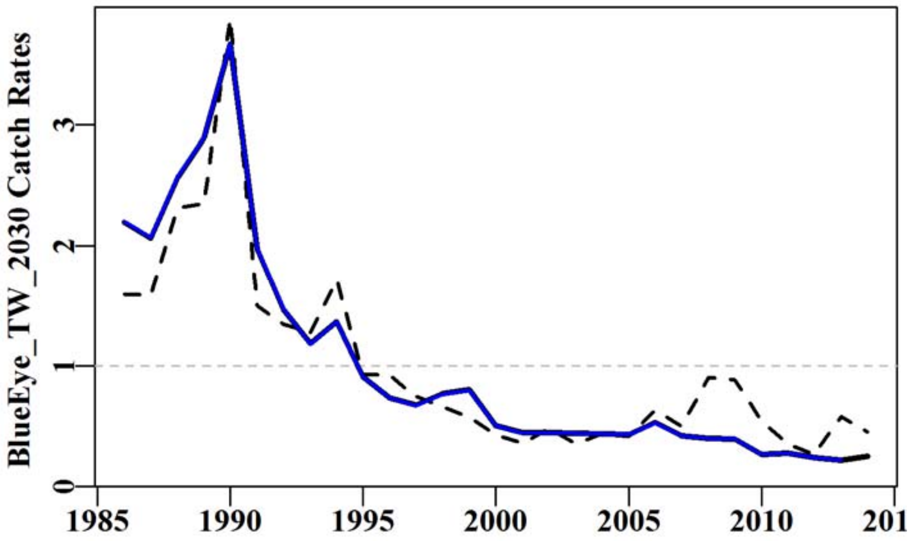


Figure 20.67. Blue Eye Trevalla from zones 20 and 30 in depths 0 – 1000 m by Trawl. The dashed black line represents the geometric mean catch rate and the solid black line the standardized catch rates (relative to the mean of the standardized catch rates). The blue line corresponds to last year's standardized indices.

Table 20.59. 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 20.60. 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	10946	4631	4224	4105	3989	3976	3952	3765
RSS	29845	17611	17042	16678	16514	16468	16407	16063
MSS	4806	17040	17609	17973	18137	18183	18244	18588
Nobs	12427	12427	12427	12352	12352	12352	12352	12352
Npars	29	149	150	198	201	212	223	260
adj_R^2	13.675	48.563	50.222	51.087	51.556	51.649	51.785	52.651
%Change	0.000	34.888	1.659	0.865	0.469	0.093	0.135	0.866

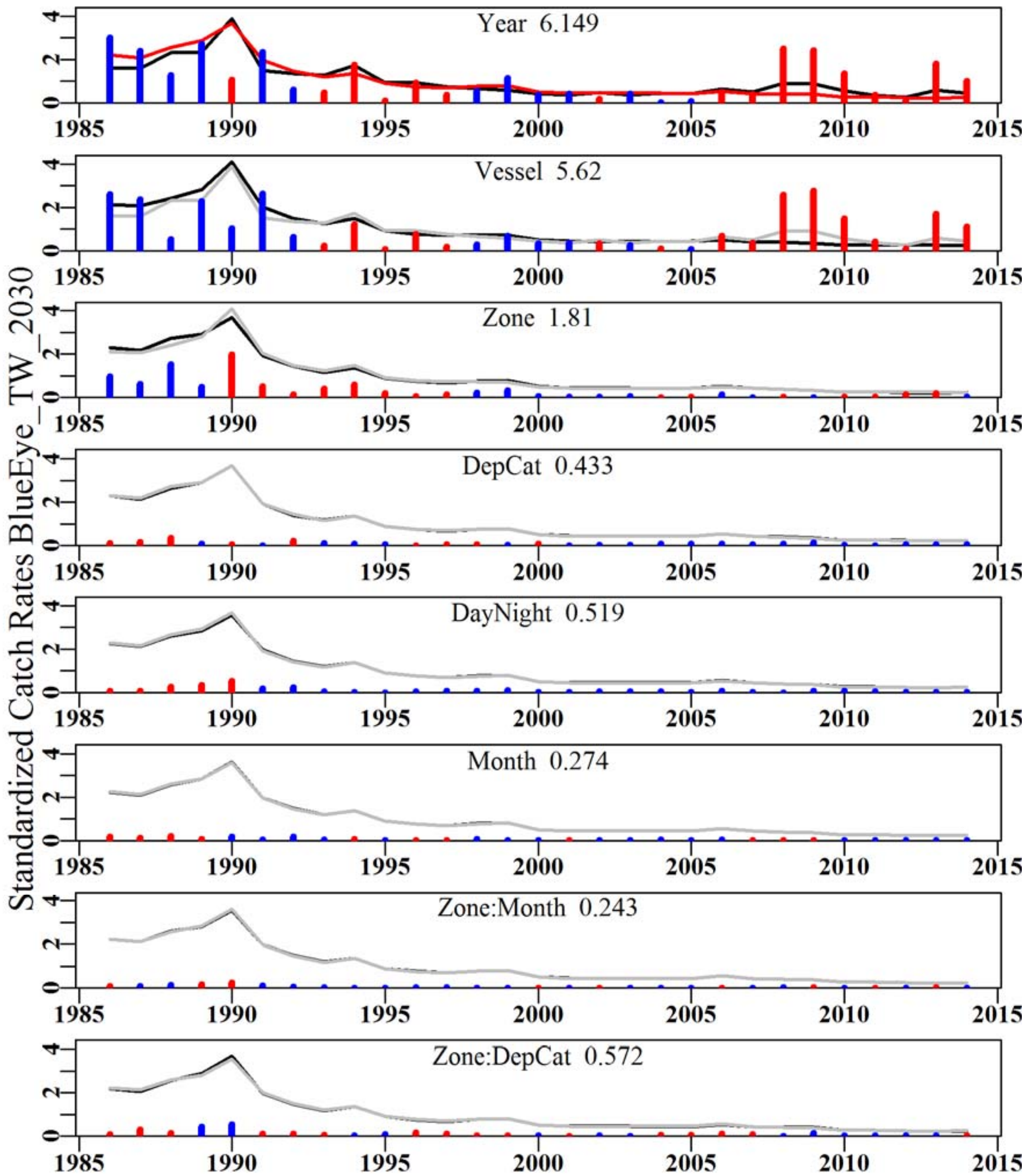


Figure 20.68. The relative influence of each factor used on the final trend in the optimal standardization for Blue Eye Trevalla in zones 20 – 30. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by the vertical bars with 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.

20.4.21 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 20.61. 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	0.9501	0.0000
1987	15.4950	56	3.1450	14	11.6895	0.8035	0.1771
1988	105.1770	142	76.4100	15	41.5696	2.4040	0.1573
1989	88.0660	238	43.9850	24	25.5841	1.9768	0.1389
1990	79.2980	157	30.9100	16	13.0702	2.0981	0.1594
1991	76.0240	129	18.9540	18	17.4424	1.6911	0.1578
1992	49.3050	129	28.6430	15	21.8842	1.9900	0.1576
1993	59.6540	289	18.1090	19	8.5334	0.9090	0.1412
1994	109.9750	348	16.2820	19	8.8991	0.9710	0.1377
1995	58.5720	500	26.3810	21	6.4723	0.8700	0.1339
1996	71.6840	523	30.1840	24	8.0361	0.8938	0.1345
1997	470.7164	788	82.3710	18	6.5139	0.9156	0.1312
1998	475.9652	780	58.9460	19	5.3540	1.0953	0.1326
1999	574.4838	877	46.3030	19	6.4046	1.1233	0.1314
2000	667.0558	1109	44.7290	23	5.2927	0.9856	0.1307
2001	647.5307	969	43.5380	26	5.8514	0.9331	0.1322
2002	843.8591	803	32.2975	26	5.0569	0.7747	0.1323
2003	605.3020	391	11.0128	25	3.1904	0.6991	0.1389
2004	606.2500	852	31.2657	24	4.2140	0.6116	0.1325
2005	755.1858	508	12.7502	22	3.6280	0.5670	0.1358
2006	573.7189	533	16.2790	17	3.6218	0.5762	0.1354
2007	937.1424	538	26.1883	16	4.4303	0.6095	0.1353
2008	398.9433	324	16.3714	14	4.9605	0.8031	0.1405
2009	520.8777	343	15.7939	13	4.0546	0.7377	0.1401
2010	437.3987	427	31.0104	14	5.4788	0.7720	0.1374
2011	554.2188	381	14.7083	14	2.8223	0.6021	0.1385
2012	463.8349	261	9.0066	11	1.8380	0.4464	0.1468
2013	398.3268	203	18.6619	15	3.2601	0.5830	0.1488
2014	459.9604	194	8.4029	12	3.2191	0.6071	0.1505

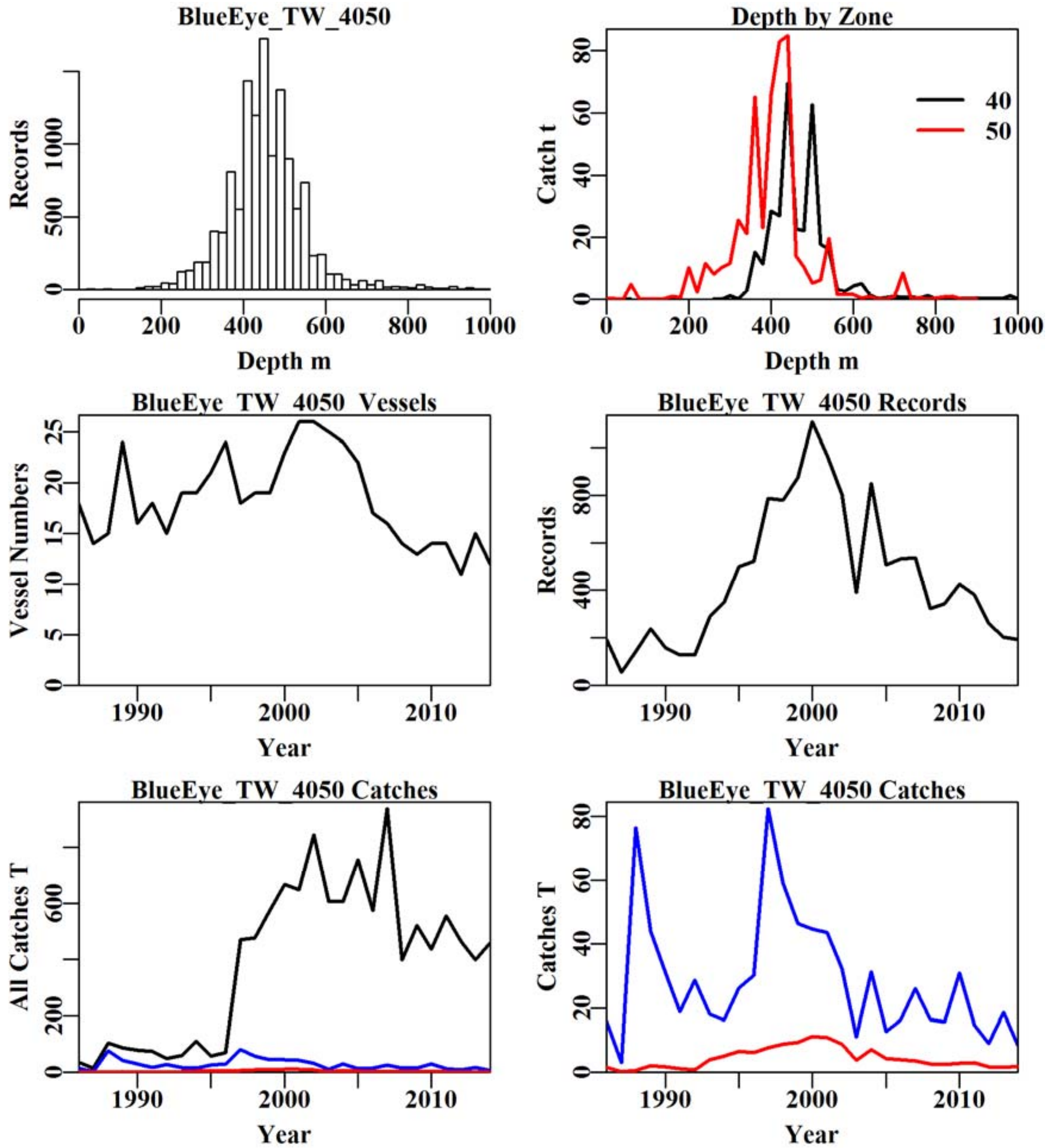


Figure 20.69. Blue Eye Trevalla from Zones 40 and 50 in depths 0 to 1000 m by Trawl. The top left plot depicts the depth distribution of shots containing Blue Eye Trevalla from zones 40 and 50 in depths 0 to 1000 m by Trawl. The top right plot depicts the catch distribution by depth within zones 40 and 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).

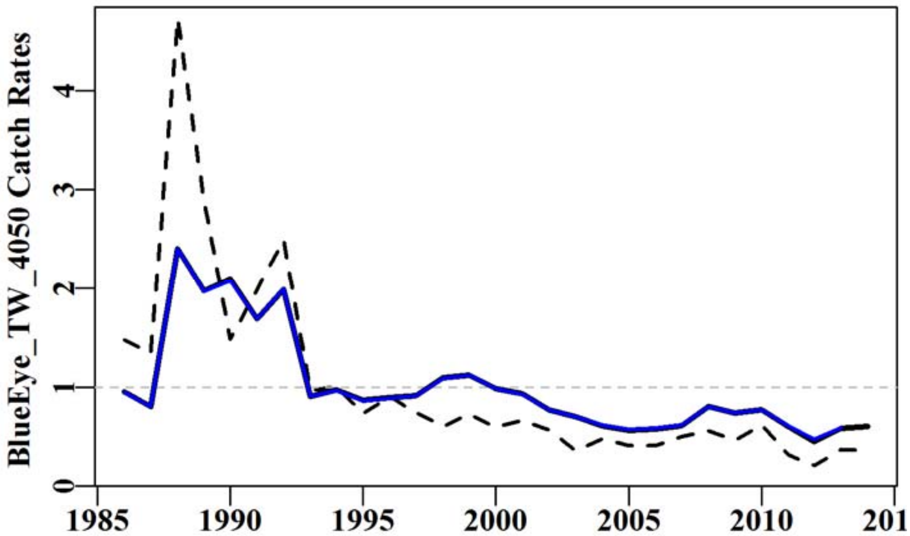


Figure 20.70. Blue Eye Trevalla from Zones 40 and 50 in depths 0 to 1000 m by Trawl. The dashed black line represents the geometric mean catch rate and the solid black line the standardized catch rates (relative to the mean of the standardized catch rates). The blue line corresponds to last year's standardized indices.

Table 20.62. 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 20.63. 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	8476	3158	2707	2446	2405	2357	2358	2337
RSS	24832	16279	15540	15223	15148	15090	15066	14953
MSS	3145	11699	12438	12754	12829	12888	12912	13025
Nobs	12986	12986	12921	12921	12921	12921	12921	12921
Npars	29	112	161	164	175	176	187	225
adj_R^2	11.051	41.314	43.759	44.893	45.117	45.324	45.364	45.611
%Change	0.000	30.263	2.446	1.134	0.224	0.207	0.041	0.247

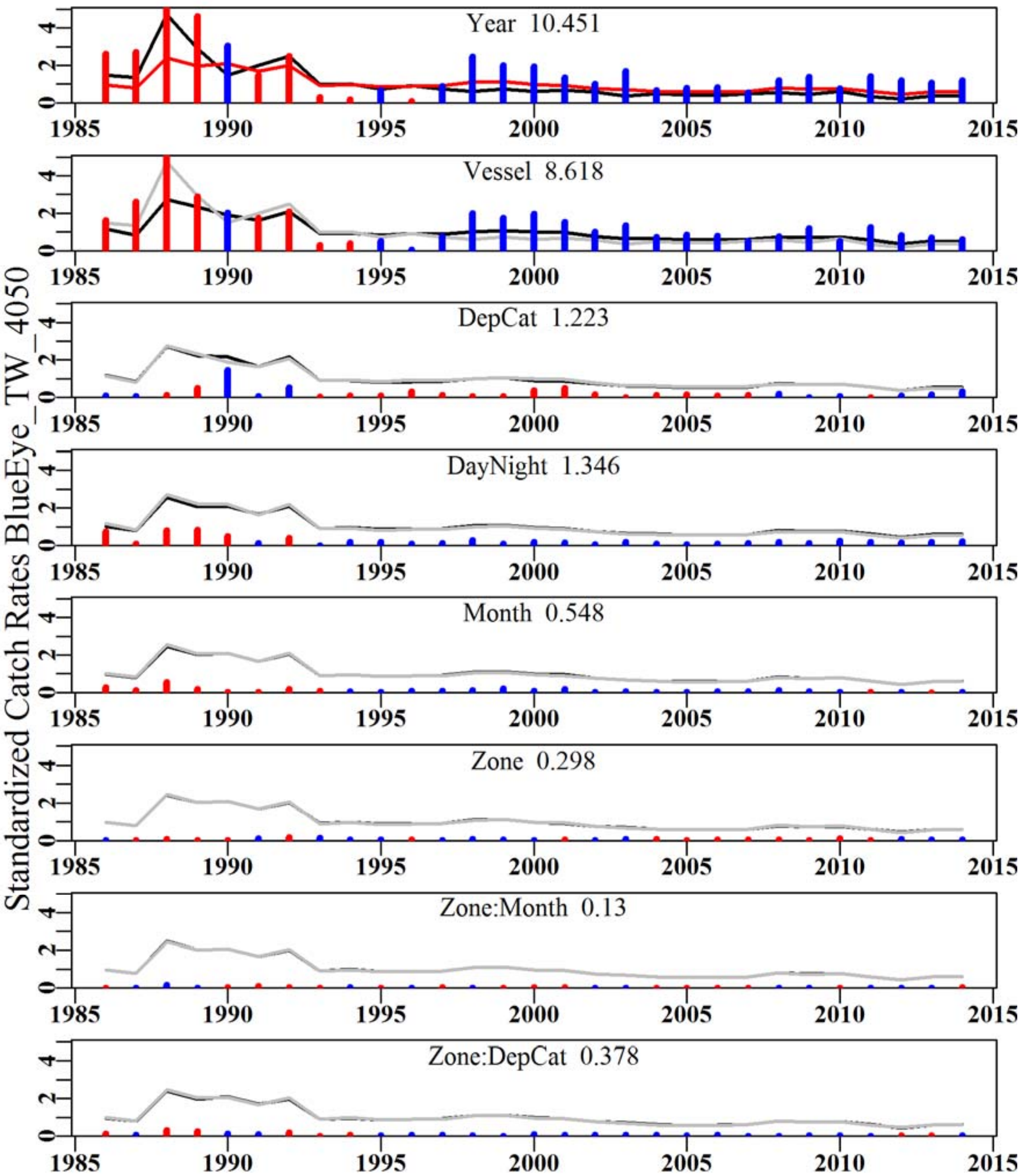


Figure 20.71. The relative influence of each factor used on the final trend in the optimal standardization for Blue Eye Trevalla in Zones 40 – 50. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by the vertical bars with 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.

20.4.22 Blue Eye Trevalla Z1050 (TBE – 37445001 – Hyperoglyphe antarctica)

Trawl data selected for analysis corresponded to zones 10 to 50 from depths less than 1000 m.

Table 20.64. Blue Eye Trevalla from zones 10 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:DepC and standard deviation (StDev) relates to the data in the optimum model.

Year	TotCatch	Records	CatchT	Vessels	GeoMean	Zone:DepC	StDev
1986	37.962	644	37.724	71	8.6205	1.6710	0.0000
1987	15.495	345	15.048	54	7.5310	1.3561	0.0844
1988	105.177	579	98.919	64	13.7507	2.1359	0.0764
1989	88.066	777	86.368	75	13.3187	2.2340	0.0730
1990	79.298	509	74.821	65	15.8450	2.8248	0.0803
1991	76.024	729	59.449	66	10.4911	2.0334	0.0745
1992	49.305	542	45.283	53	9.1718	1.6305	0.0788
1993	59.654	1131	58.152	63	7.5774	1.1946	0.0702
1994	109.975	1345	108.176	60	9.3353	1.3600	0.0690
1995	58.572	1112	57.437	55	6.0120	0.9869	0.0708
1996	71.684	1326	70.503	62	6.1787	0.8496	0.0699
1997	470.716	1456	103.264	58	5.4834	0.8093	0.0699
1998	475.965	1341	79.201	53	4.6467	0.9468	0.0707
1999	574.484	1593	89.917	51	4.9026	0.9609	0.0695
2000	667.056	1843	83.375	60	4.0343	0.7269	0.0686
2001	647.531	1699	68.973	53	3.8686	0.6599	0.0695
2002	843.859	1534	66.509	53	3.9138	0.5837	0.0701
2003	605.302	1161	26.364	57	2.5455	0.5519	0.0723
2004	606.250	1497	46.659	52	3.4737	0.5095	0.0708
2005	755.186	1042	31.151	48	3.0741	0.4917	0.0734
2006	573.719	882	53.253	37	3.6806	0.5458	0.0747
2007	937.142	798	37.066	24	3.9194	0.5200	0.0762
2008	398.943	772	30.142	24	5.2101	0.5950	0.0765
2009	520.878	605	38.735	24	4.4448	0.5604	0.0795
2010	437.399	640	42.662	23	4.5690	0.5177	0.0790
2011	554.219	618	22.707	23	2.5726	0.4610	0.0794
2012	463.835	418	10.528	21	1.7968	0.3826	0.0870
2013	398.327	352	22.788	25	3.3885	0.4282	0.0893
2014	459.960	274	10.799	21	3.0797	0.4718	0.0956

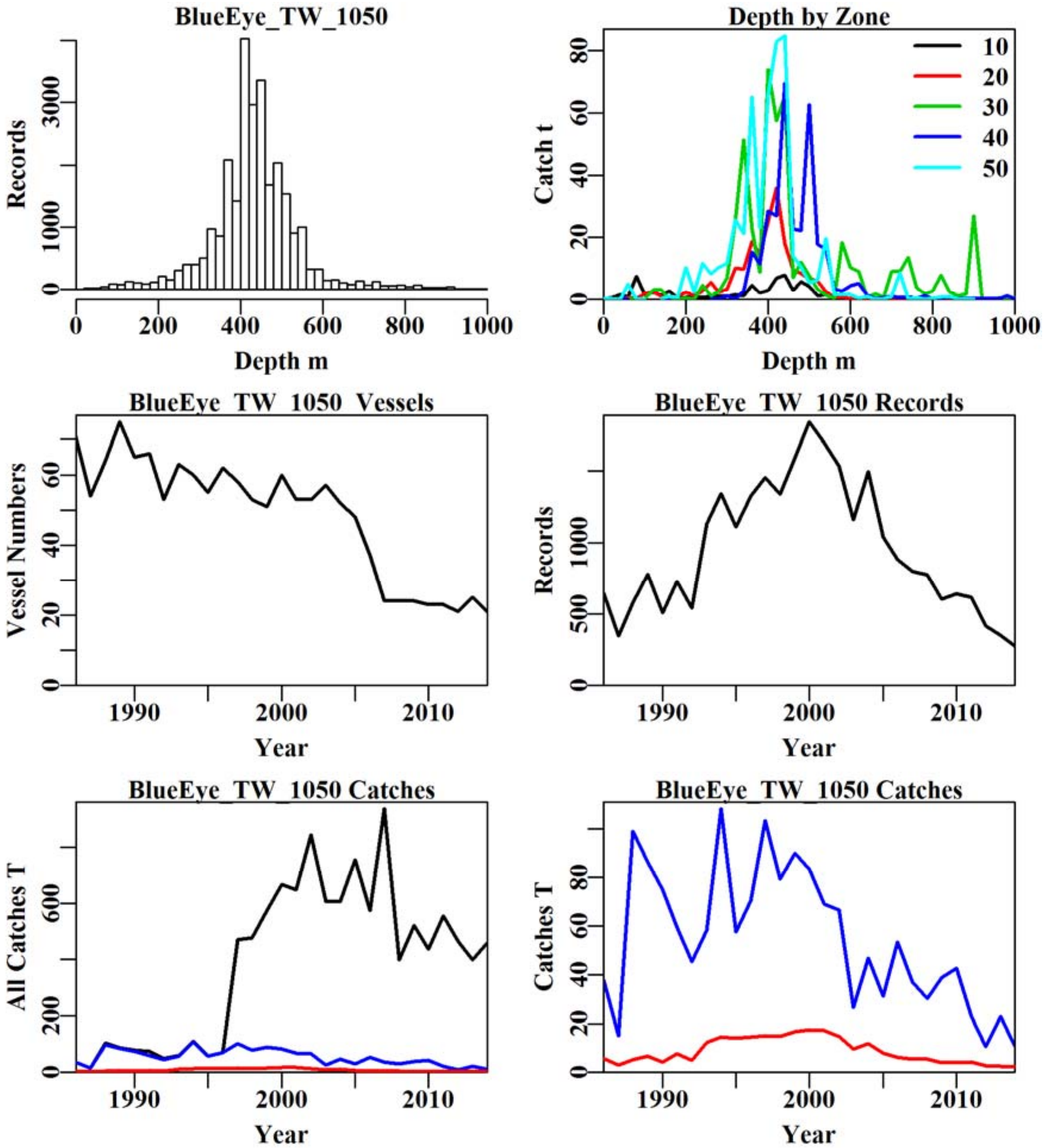


Figure 20.72. Blue Eye Trevalla from Zones 10 to 50 in depths 0 to 1000 m by Trawl. The top left plot depicts the depth distribution of shots containing Blue Eye Trevalla from zones 10 to 50 in depths 0 to 1000 m by Trawl. The top right plot depicts the catch distribution by depth within zones 40 and 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).

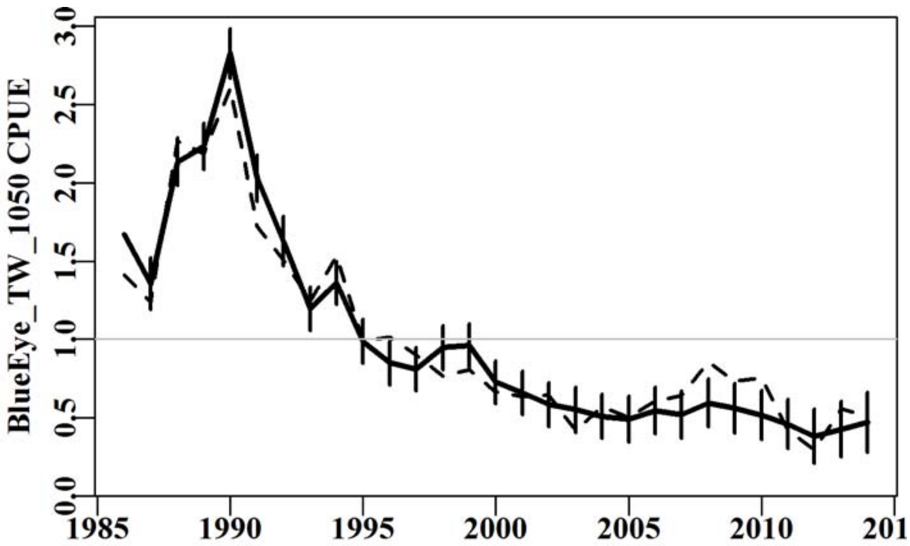


Figure 20.73. Blue Eye Trevalla from Zones 10 to 50 in depths 0 to 1000 m by Trawl. The dashed black line represents the geometric mean catch rate and the solid black line the standardized catch rates (relative to the mean of the standardized catch rates). The vertical bars correspond 95% CI.

Table 20.65. Blue Eye Trevalla 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 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 20.66. Blue Eye Trevalla from zones 10 to 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:DepC. Depth category: DepC.

	Year	Vessel	DepC	DayNight	Month	Zone	Zone:Month	Zone:DepC
AIC	21611	10469	9790	9377	9302	8085	8029	7531
RSS	60246	39667	38424	37842	37707	36060	35871	34827
MSS	5933	26512	27755	28337	28471	30119	30308	31352
Nobs	27564	27564	27417	27417	27417	27417	27417	27417
Npars	29	218	268	271	282	286	330	486
adj_R^2	8.872	39.586	41.368	42.250	42.432	44.939	45.138	46.426
%Change	0.000	30.714	1.782	0.882	0.182	2.507	0.199	1.288

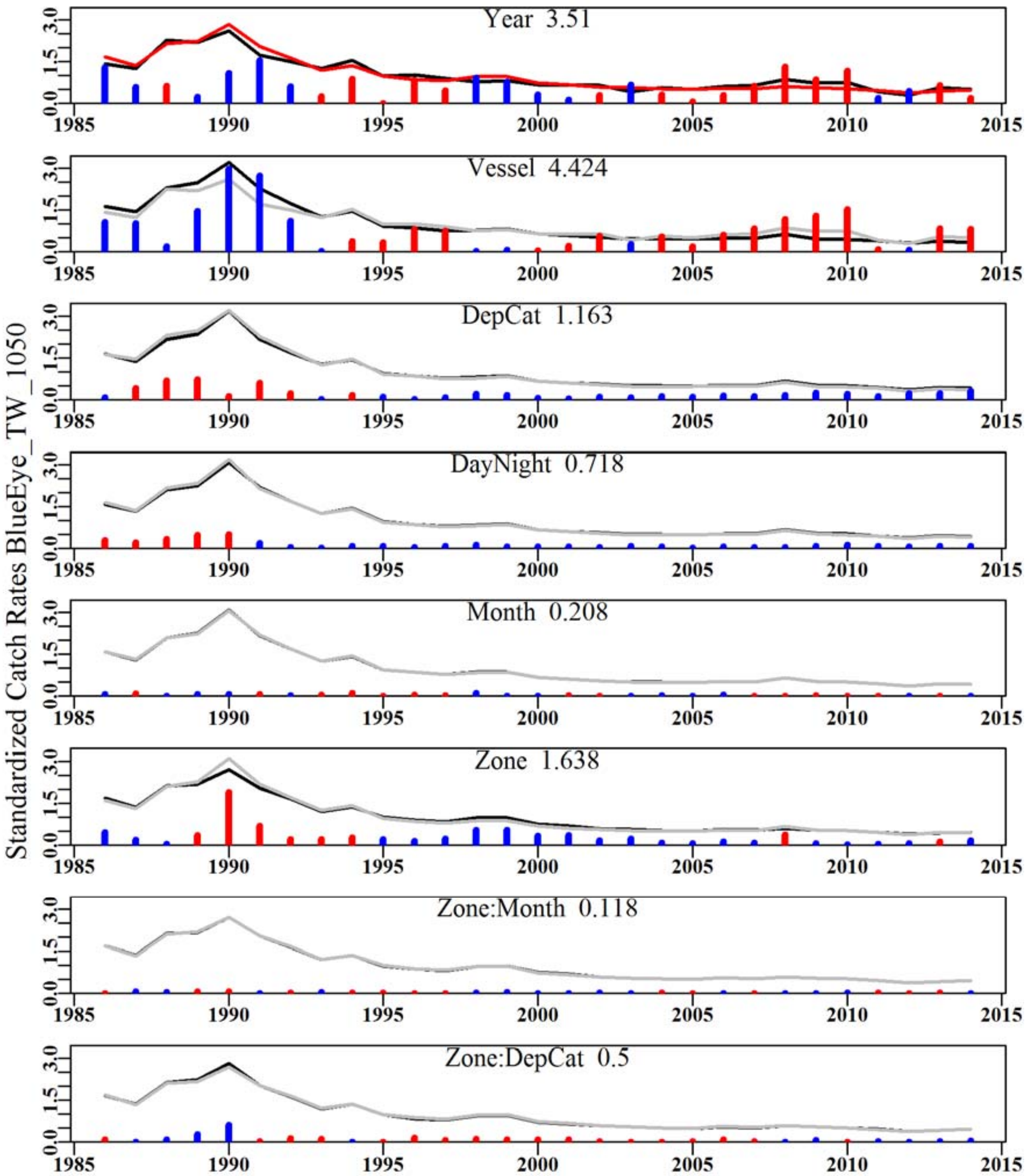


Figure 20.74. The relative influence of each factor used on the final trend in the optimal standardization for Blue Eye Trevalla in Zones 10 – 50. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by the vertical bars with 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.

20.4.23 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. The DayNight factor was not employed in the standardization analysis.

Table 20.67. 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	0.6494	0.0000
1999	574.4838	50	47.6696	2	536.1933	2.2867	0.3290
2000	667.0558	29	28.2990	2	608.0267	1.9413	0.3610
2001	612.3537	65	40.2324	2	246.5002	0.9313	0.3130
2002	758.1031	228	131.6856	4	162.2961	0.8388	0.2860
2003	592.2549	434	157.0156	7	133.4303	1.1308	0.2814
2004	598.0883	1147	269.1203	11	72.0019	1.0904	0.2763
2005	455.3868	1137	300.4620	7	77.8010	0.8664	0.2765
2006	573.7189	1067	345.4813	9	102.2372	0.9727	0.2759
2007	631.1379	658	453.8194	6	364.8943	1.1748	0.2774
2008	337.3348	604	277.9166	6	232.1695	0.8486	0.2775
2009	442.3577	550	313.2070	6	289.4275	0.9223	0.2771
2010	384.8837	483	230.0416	5	184.8051	0.5812	0.2783
2011	517.8688	526	225.7162	5	209.8939	0.6336	0.2777
2012	349.3049	427	180.7403	6	170.2138	0.6045	0.2784
2013	309.4457	352	186.3061	5	233.7214	0.7157	0.2798
2014	325.6904	290	219.1496	5	355.9907	0.8115	0.2814

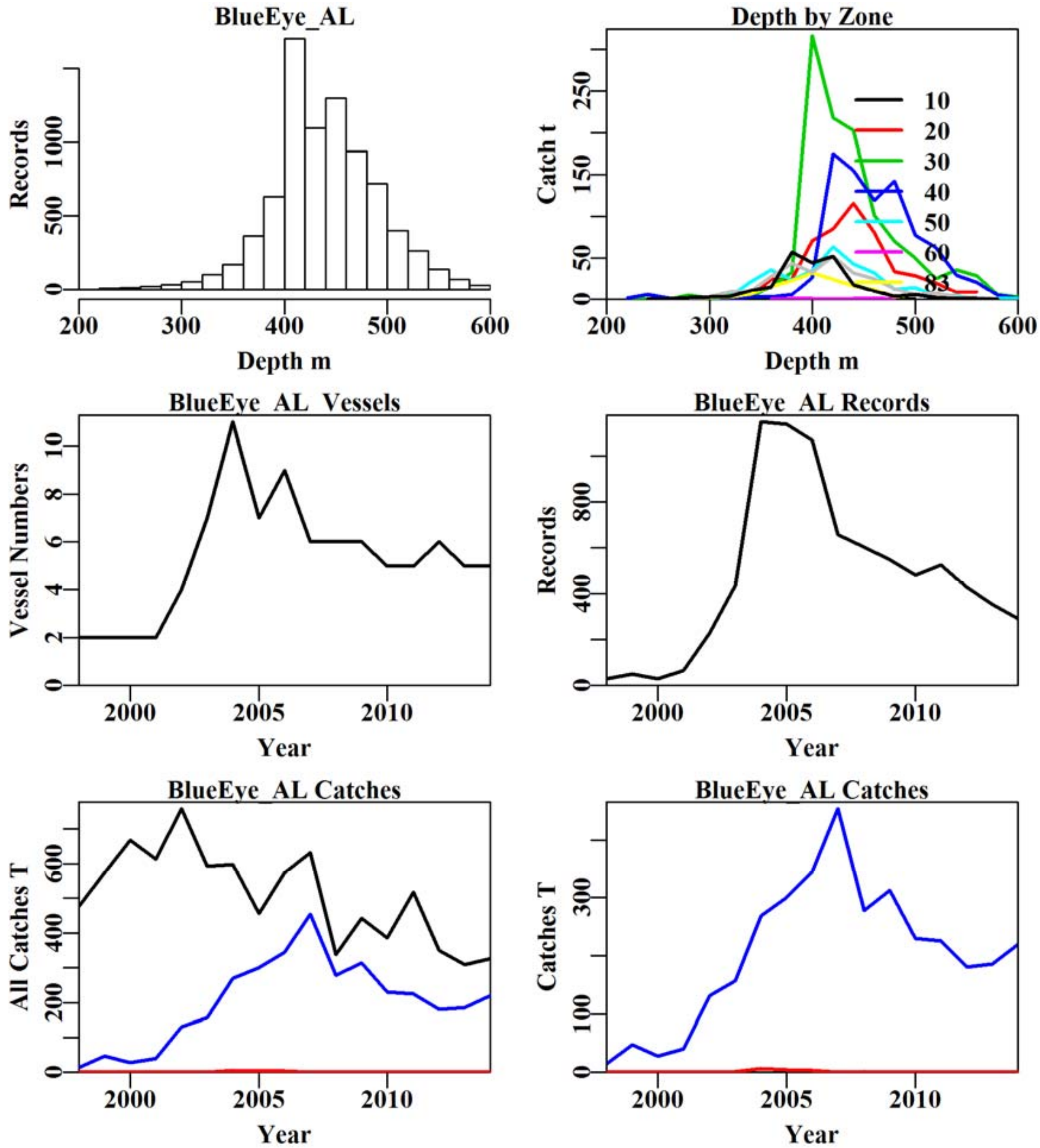


Figure 20.75. Blue Eye Trevalla from the SESSF in depths 200 – 600 m by Auto-Longline. The top left plot depicts the depth distribution of shots containing Blue Eye Trevalla from SESSF in depths 200 to 600 m by Auto-Longline. The top right plot depicts the catch distribution by depth by SESSF zone. The 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).

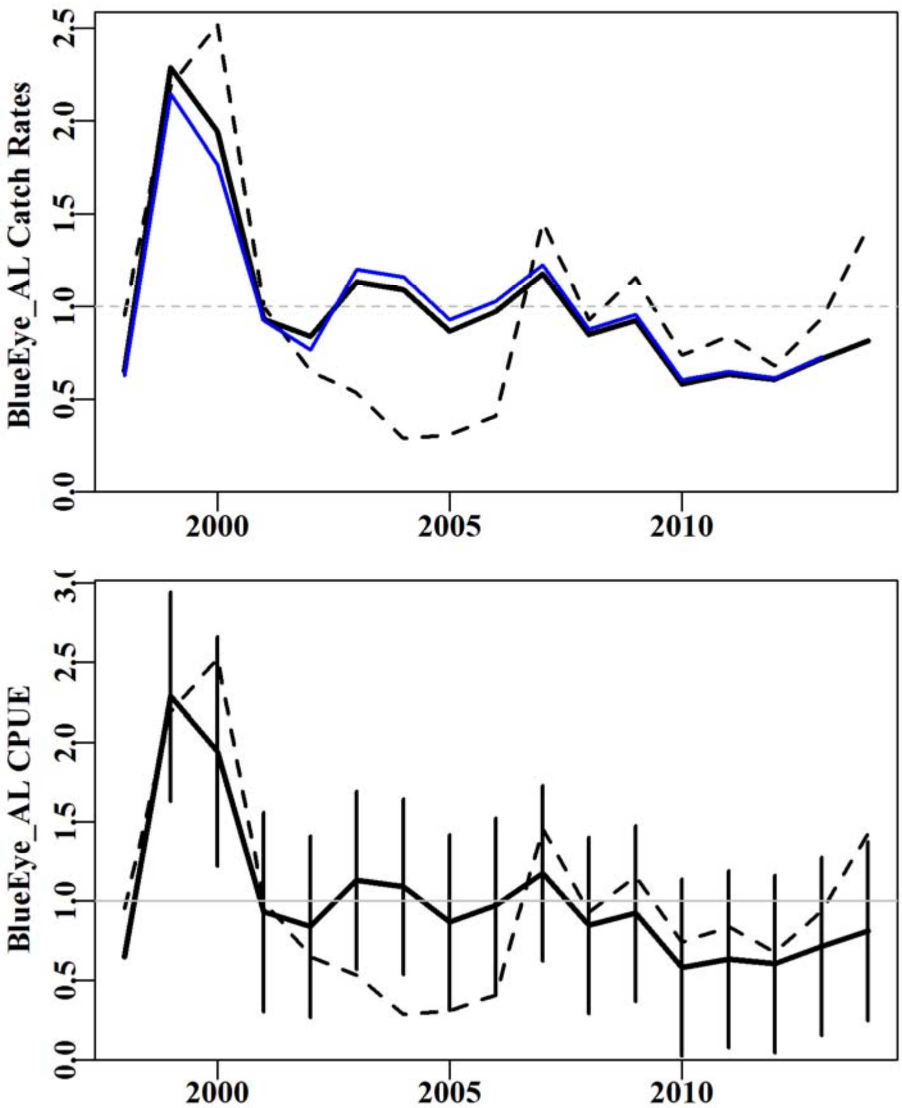


Figure 20.76. Blue Eye Trevalla from the SESSF in depths 200 – 600 m by Auto-Longline. Upper graph: The dashed black line represents the geometric mean catch rate and the solid black line the standardized catch rates (relative to the mean of the standardized catch rates). The blue line corresponds to 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 20.68. 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 + DepCat
Model 5	LnCE ~ Year + Vessel + Month + DepCat + Zone
Model 6	LnCE ~ Year + Vessel + Month + DepCat + Zone + Zone:Month
Model 7	LnCE ~ Year + Vessel + Month + DepCat + Zone +Zone:DepCat

Table 20.69. 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	Zone:Month	Zone:DepC
AIC	7365	5304	4577	4329	4290	4034	4054
RSS	20018	15464	14093	13634	13481	12776	12309
MSS	2679	7234	8604	9063	9216	9921	10389
Nobs	8075	8075	8075	8069	8043	8043	8043
Npars	17	29	40	48	68	156	316
adj_R^2	11.626	31.633	37.608	39.577	40.106	42.604	43.559
%Change	0.000	20.006	5.975	1.969	0.530	2.498	0.955

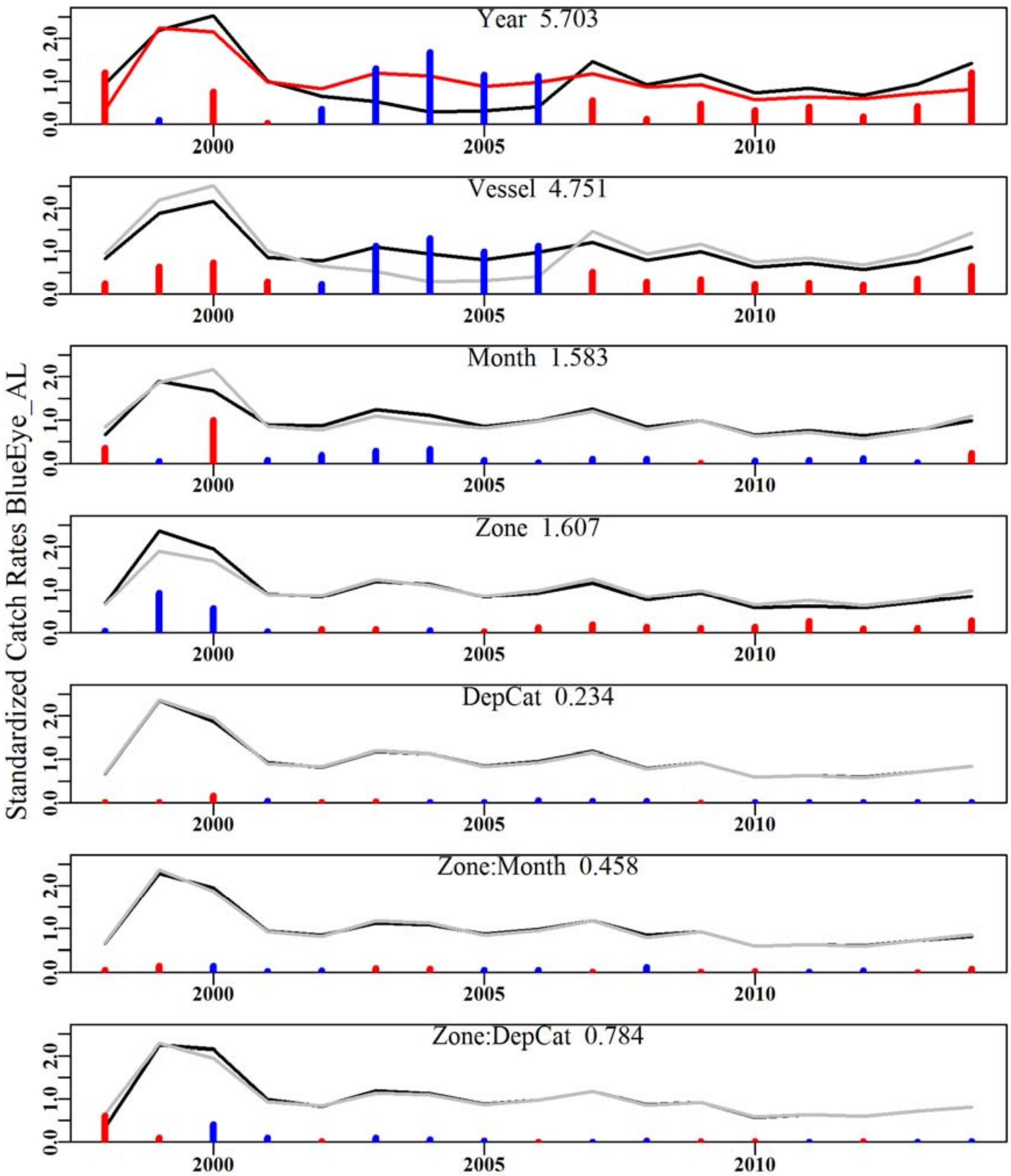


Figure 20.77. The relative influence of each factor used on the final trend in the optimal standardization for Blue Eye Trevalla in by Auto-longline. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by the vertical bars 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.

20.4.24 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. The DayNight factor was not employed in the standardization analysis.

Table 20.70. 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	1.7605	0.0000
1998	475.9652	708	322.9646	28	234.0509	1.3656	0.0762
1999	574.4838	865	337.8070	28	180.6539	1.2210	0.0788
2000	667.0558	1054	377.5383	33	172.3247	1.1900	0.0827
2001	612.3537	742	318.6780	26	199.5629	1.2923	0.0867
2002	758.1031	571	180.5241	22	164.4656	1.1063	0.0917
2003	592.2549	535	167.9685	22	162.1292	0.9510	0.0961
2004	598.0883	490	149.1658	22	160.9540	1.0733	0.0989
2005	455.3868	340	80.2544	16	133.9349	0.8418	0.1079
2006	573.7189	301	101.6487	13	222.2480	1.0870	0.1155
2007	631.1379	125	45.1233	10	208.7957	1.4503	0.1412
2008	337.3348	75	15.3994	6	137.5370	0.8522	0.1616
2009	442.3577	81	17.8185	9	124.4663	0.5681	0.1719
2010	384.8837	197	28.9643	9	76.1903	0.4798	0.1450
2011	517.8688	166	32.3677	9	104.8614	0.7575	0.1557
2012	349.3049	93	17.9277	8	105.1590	0.8203	0.1965
2013	309.4457	44	7.2282	5	86.5165	0.7498	0.2514
2014	325.6904	61	9.1374	6	60.1983	0.4333	0.2465

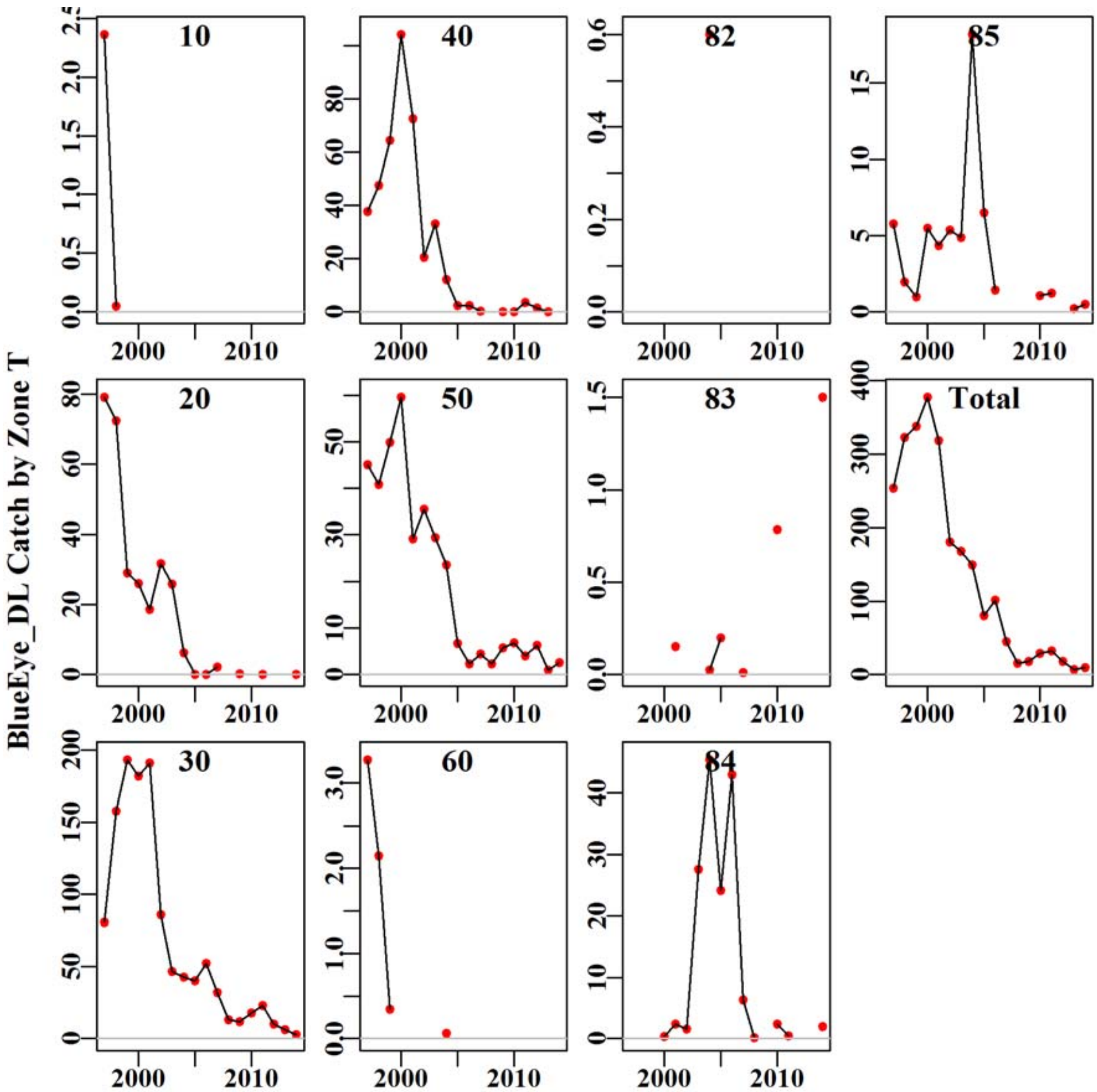


Figure 20.78. Blue Eye Trevalla catches by zone from the SESSF in depths 200 – 600 m by Drop Line.

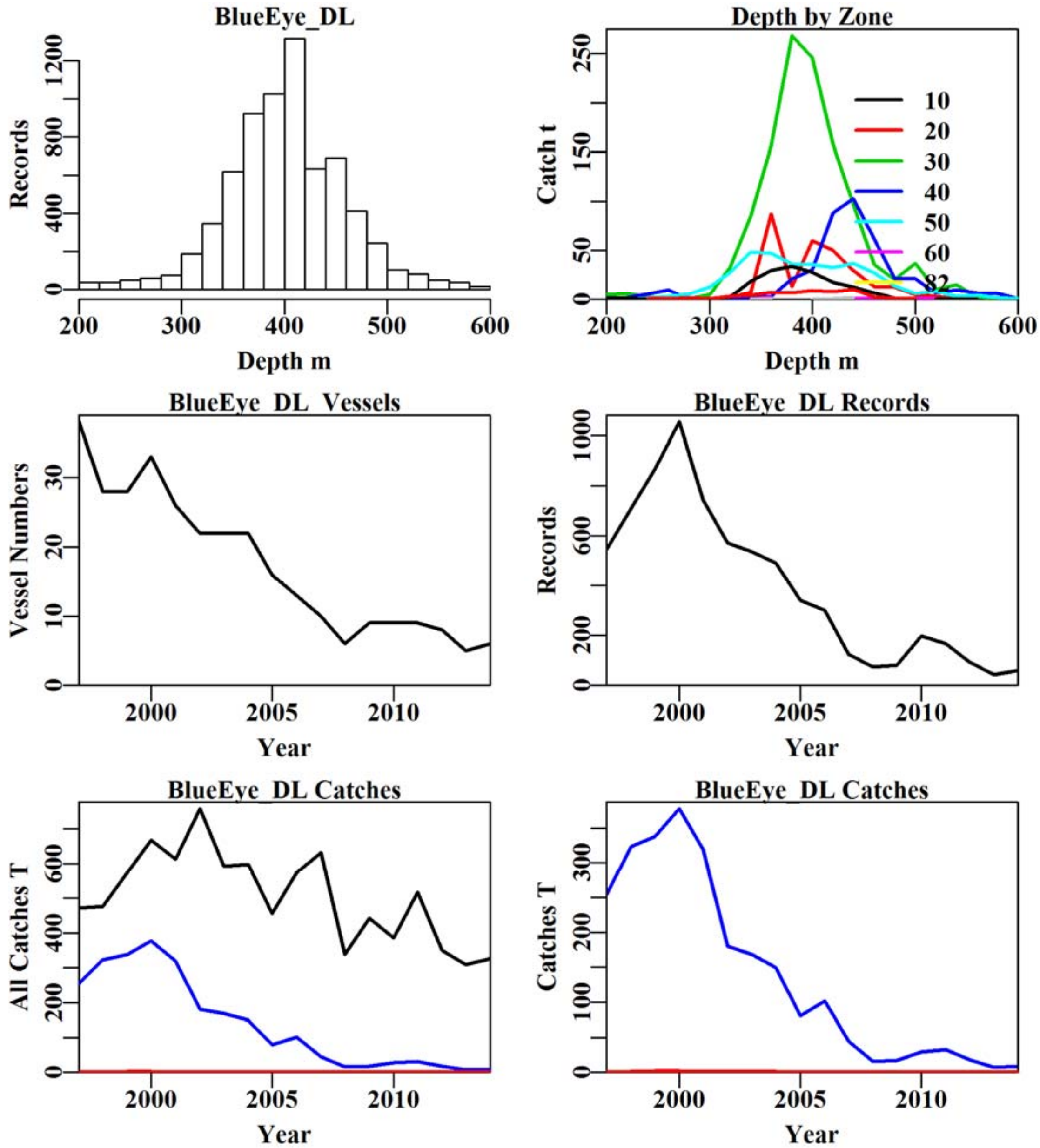


Figure 20.79. Blue Eye Trevalla from the SET and GHT fishery in depths between 200 – 600 m, taken by Drop line. The top left plot depicts the depth distribution of shots containing Blue Eye Trevalla from the SEN and GHT fishery in depths between 200 – 600 m, taken by Drop Line. The top right plot depicts 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).

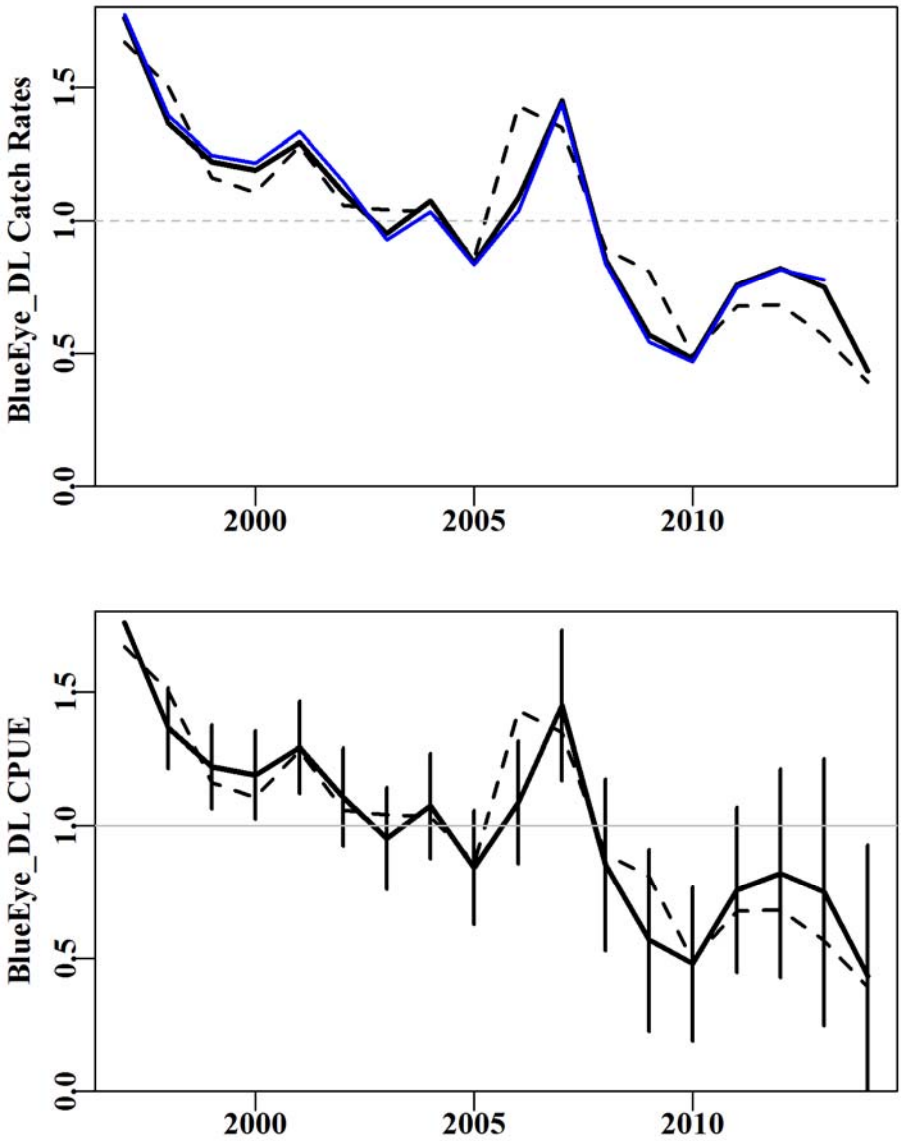


Figure 20.80. Blue Eye Trevalla from the SEN and GHT fishery in depths between 200 – 600 m, taken by Drop line. Upper plot: The dashed black line represents the geometric mean catch rate and the solid black line the standardized catch rates (relative to the mean of the standardized catch rates). The 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 20.71. 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 + Zone:Month
Model 7	LnCE ~ Year + Vessel + Month + DepCat + Zone +Zone:DepCat

Table 20.72. 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:Month). Depth category: DepC.

	Year	Vessel	Month	DepC	Zone	Zone:Month	Zone:DepC
AIC	4118	3021	2652	2590	2564	2469	2532
RSS	12536	10432	9864	9667	9593	9196	8809
MSS	523	2627	3195	3392	3466	3863	4250
Nobs	6992	6992	6992	6935	6921	6921	6921
Npars	18	112	123	143	152	251	431
adj_R^2	3.775	18.831	23.127	24.423	24.902	26.938	28.072
%Change	0.000	15.056	4.296	1.296	0.479	2.036	1.134

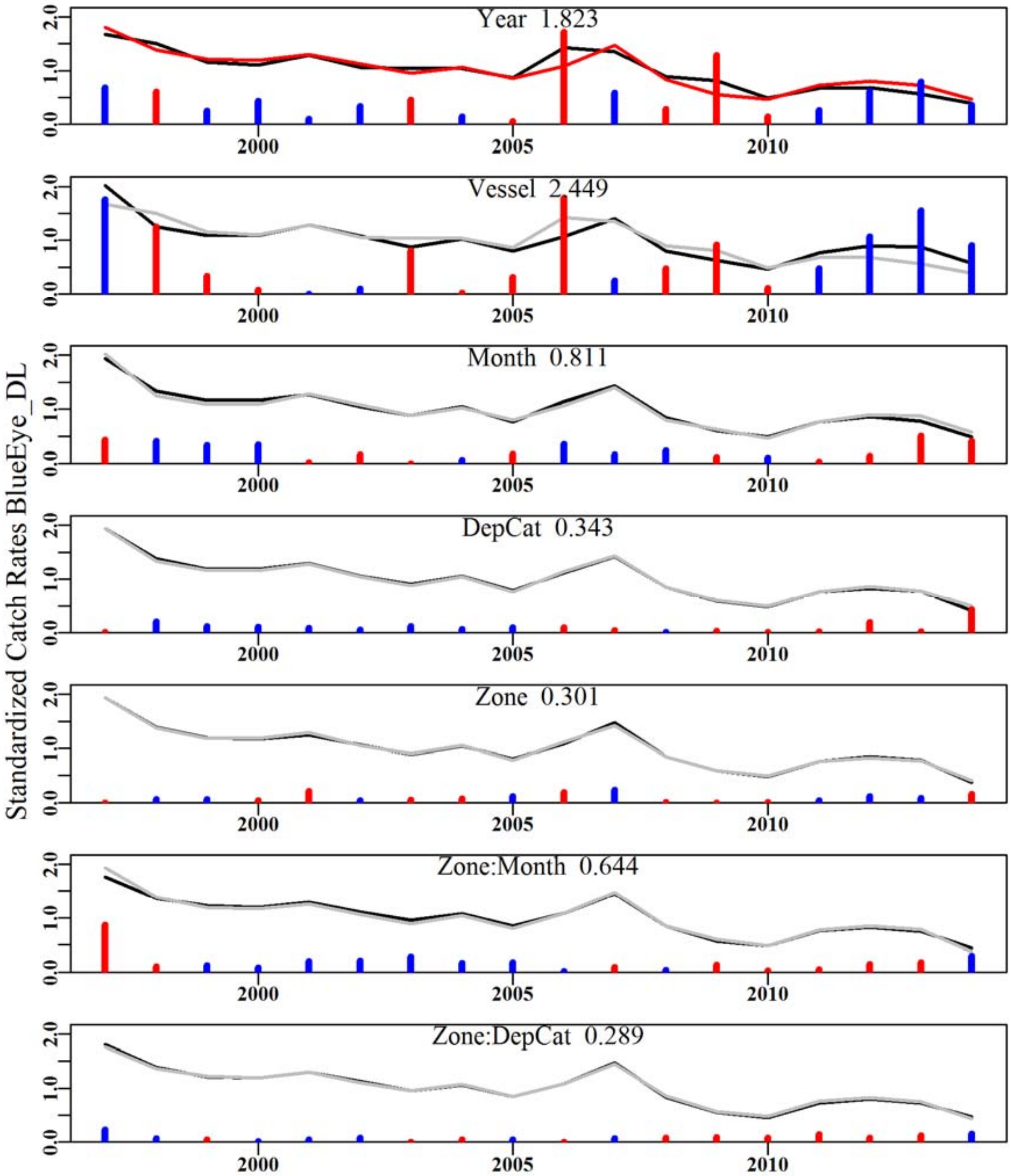


Figure 20.81. The relative influence of each factor used on the final trend in the optimal standardization for Blue Eye Trevalla in by Drop-line. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by the vertical bars with 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.

20.4.25 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 20-50; 83-85 (GAB) were analysed. The DayNight factor was not employed in the standardization analysis.

Table 20.73. 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	518	248.7303	39	266.7144	1.8323	0.0000
1998	475.9652	728	335.6381	29	235.3248	1.3405	0.0795
1999	574.4838	909	384.1146	28	193.9261	1.2005	0.0817
2000	667.0558	1082	405.8123	34	178.5660	1.1572	0.0843
2001	612.3537	805	358.5024	27	203.6327	1.2175	0.0873
2002	758.1031	798	312.1397	24	164.0183	0.9539	0.0889
2003	592.2549	966	324.6241	25	148.7976	1.0437	0.0889
2004	598.0883	1624	415.8251	28	91.6929	1.0904	0.0875
2005	455.3868	1472	378.7224	23	87.7858	0.8510	0.0899
2006	573.7189	1365	445.9060	19	120.9858	1.0134	0.0903
2007	631.1379	782	498.3927	15	333.5686	1.2111	0.0961
2008	337.3348	678	293.2995	12	219.9609	0.8410	0.0976
2009	442.3577	626	330.9558	15	266.1497	0.9010	0.0978
2010	384.8837	679	258.9058	14	143.0407	0.5656	0.0977
2011	517.8688	692	258.0839	14	177.7061	0.6614	0.0975
2012	349.3049	520	198.6680	14	156.1670	0.6225	0.1016
2013	309.4457	393	193.2131	10	210.7895	0.6977	0.1068
2014	325.6904	351	228.2870	11	261.3958	0.7994	0.1106

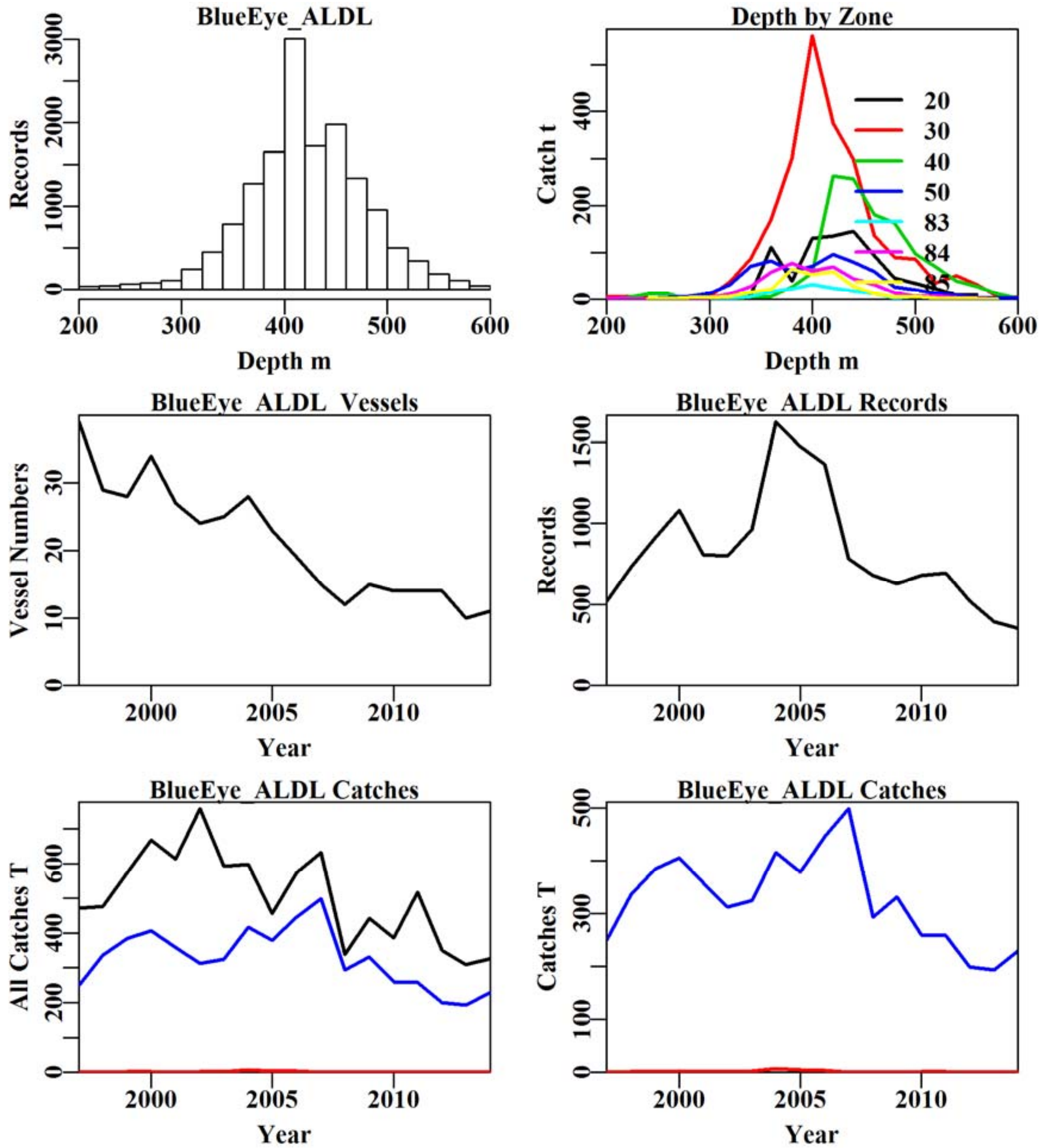


Figure 20.82. Blue Eye Trevalla from the SEN and GHT in depths 200 – 600 m by Auto Line and Drop Line. The top left plot depicts the depth distribution of shots containing Blue Eye Trevalla from the SEN and GHT in depths 200 – 600 m by Auto Long Line and Drop Line. The top right plot depicts the catch 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).

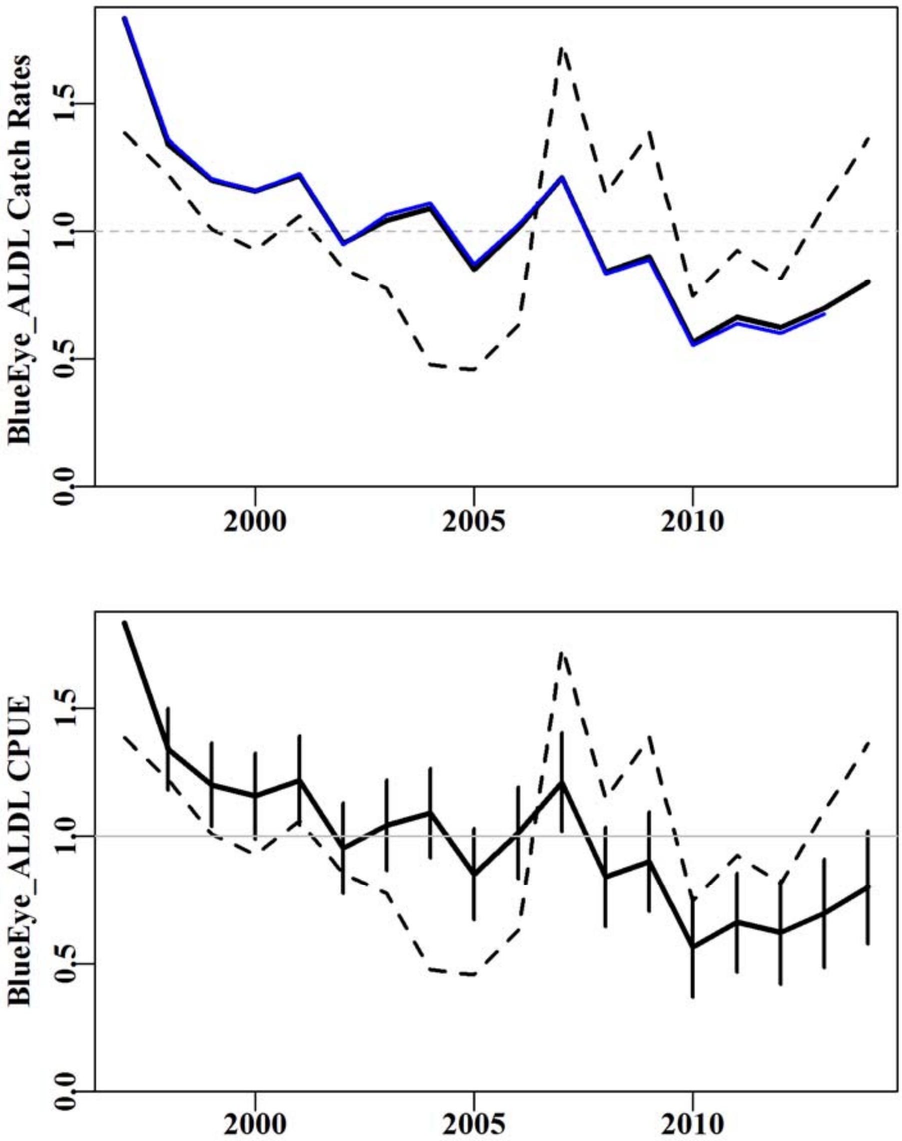


Figure 20.83. Blue Eye Trevalla from the SEN and GHT in depths 200 – 600 m by Auto Line and Drop line. Upper graph: The dashed black line represents the geometric mean catch rate and the solid black line the standardized catch rates (relative to the mean of the standardized catch rates). The blue line 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 20.74. 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+Method
Model 6	LnCE~Year+Vessel+Month+Zone+Method+ DepCat
Model 7	LnCE~Year+Vessel+Month+Zone+Method+ DepCat+Zone:Month
Model 8	LnCE~Year+Vessel+Month+Zone+Method+ DepCat+Zone:DepCat

Table 20.75. 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:Month is very close. Depth Category: DepC.

	Year	Vessel	Month	Zone	Method	DepC	Zone:Month	Zone:DepC
AIC	12068	8528	7581	7330	7213	7188	6880	7199
RSS	33459	26086	24456	24027	23708	23620	22892	23190
MSS	2242	9614	11245	11673	11993	12080	12809	12511
Nobs	15010	15010	15010	15010	14928	14928	14928	14928
Npars	18	116	127	134	154	169	249	312
adj_R^2	6.173	26.366	30.917	32.097	32.905	33.084	34.795	33.662
%Change	0.000	20.193	4.551	1.179	0.809	0.179	1.677	-1.132

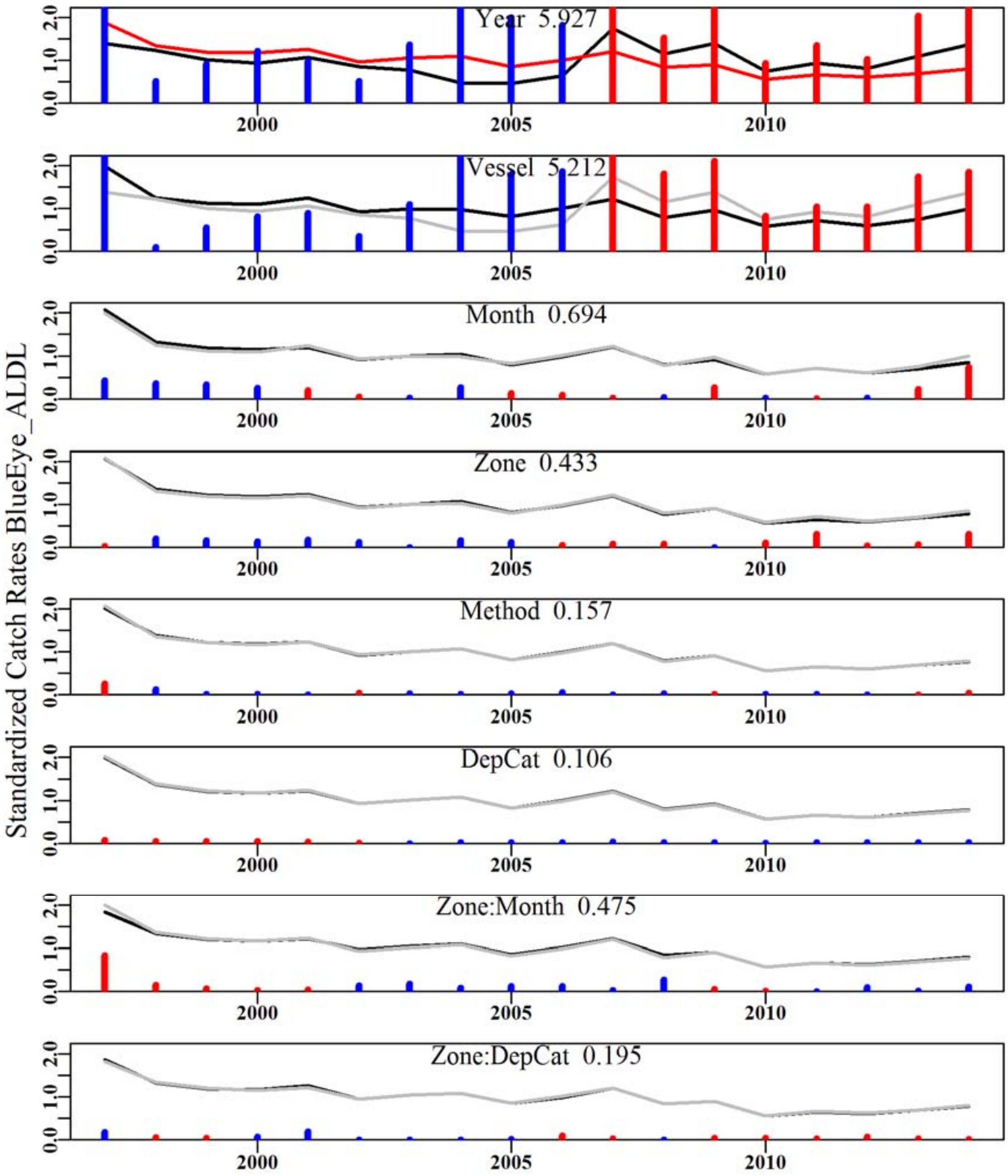


Figure 20.84. The relative influence of each factor used on the final trend in the optimal standardization for Blue Eye Trevalla by AL and DL. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by the vertical bars with blue 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.

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

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

Table 20.76. 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	1.5071	0.0000
1987	2244.8280	3569	1437.4340	91	37.3307	1.9915	0.0337
1988	1849.1470	3961	1470.1960	102	36.6778	2.1557	0.0338
1989	1890.8550	4309	1813.5010	99	45.3866	2.2252	0.0338
1990	2280.4710	3577	1625.1460	92	47.9497	2.1788	0.0357
1991	3669.0360	4308	2392.6870	86	48.2874	1.5815	0.0343
1992	2474.5460	3234	1505.8710	62	40.3590	1.3082	0.0366
1993	2482.2700	4203	1619.0490	63	33.2638	0.9781	0.0350
1994	2315.4900	4491	1309.5630	66	29.5414	0.8859	0.0346
1995	1931.0460	5076	1015.2610	61	19.4025	0.6066	0.0338
1996	2304.2340	5370	1055.3400	73	15.8910	0.5521	0.0337
1997	3654.6590	6194	994.6040	73	13.3293	0.5721	0.0332
1998	4226.1770	6599	1452.5520	65	18.8682	0.9344	0.0330
1999	7573.0180	8045	2051.9460	65	22.7820	0.9874	0.0323
2000	7503.1400	7680	1751.2315	71	16.8678	0.6998	0.0326
2001	8370.7990	7344	1023.0800	61	11.5159	0.3991	0.0330
2002	7976.8590	6347	1124.6527	58	13.3274	0.4007	0.0336
2003	7947.1150	5676	669.6359	57	10.1061	0.3355	0.0339
2004	6091.1790	6393	1204.7328	57	16.9606	0.5649	0.0337
2005	4506.6460	5346	1174.7071	55	19.8329	0.6771	0.0343
2006	3544.3540	4362	1308.8400	43	26.9839	0.8956	0.0355
2007	3127.3930	3659	1203.7072	28	25.1827	0.8023	0.0365
2008	4150.1920	3406	1274.3986	27	28.7998	0.8839	0.0370
2009	3874.2100	3443	1128.4378	24	25.9116	0.8217	0.0369
2010	4551.2510	3314	1136.1358	26	25.9266	0.8071	0.0373
2011	4476.9130	3969	897.7095	27	19.2986	0.6472	0.0362
2012	4465.2920	3210	613.6124	30	15.0034	0.5236	0.0377
2013	4209.4210	3051	741.7840	27	23.1500	0.9380	0.0382
2014	1263.9670	2742	832.4024	28	28.2408	1.1391	0.0388

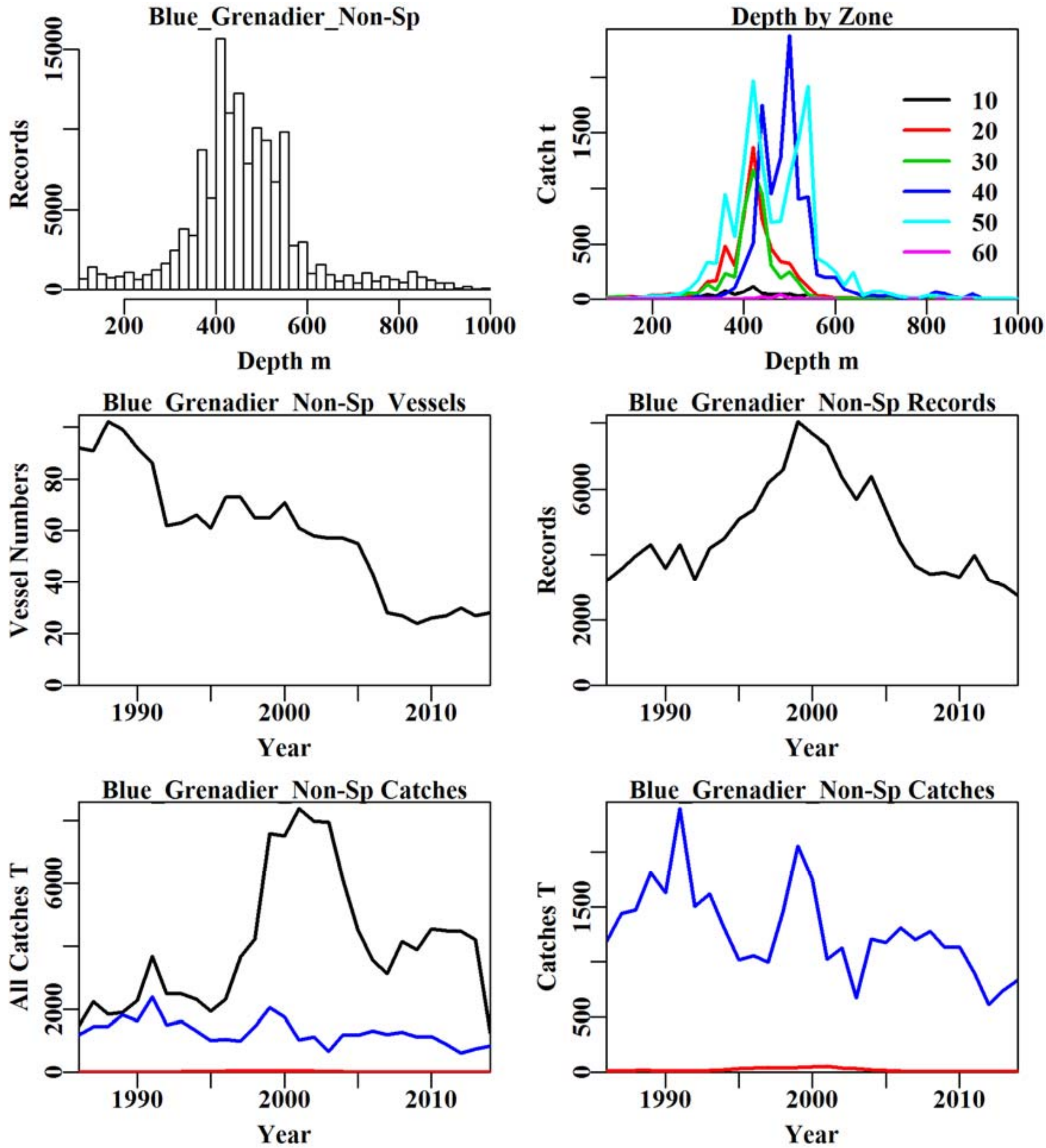


Figure 20.85. Blue Grenadier from the SET in depths between 0 – 1000 m, taken by Trawl, omitting the Spawning fishery (zone 40 between June and August). The top left plot depicts the depth distribution of shots containing Blue Grenadier from the SET omitting the Spawning fishery (zone 40 between June 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).

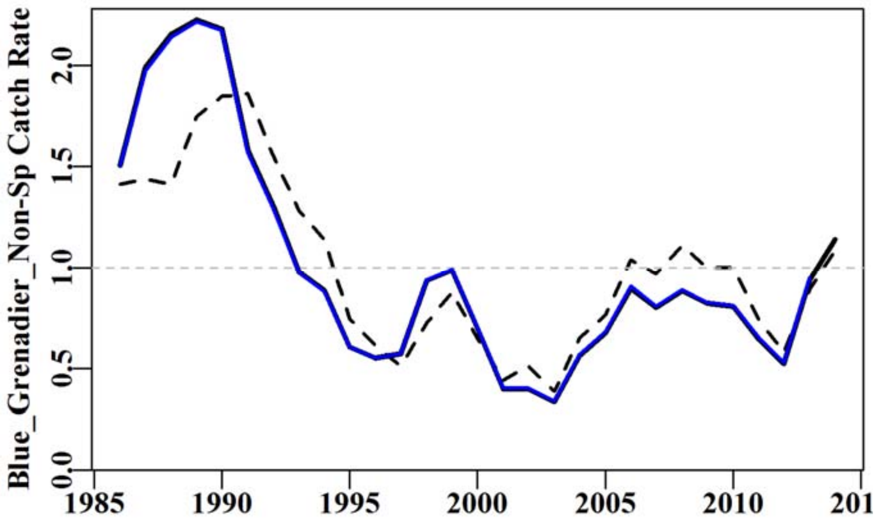


Figure 20.86. Blue Grenadier from the SET in depths between 0 – 1000 m, taken by Trawl, omitting the Spawning fishery (zone 40 between June and August). The dashed black line represents the geometric mean catch rate and the solid black line the standardized catch rates (relative to the mean of the standardized catch rates). The blue line corresponds to last year's standardized indices.

Table 20.77. 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 20.78. 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	124794	100557	85937	80748	77793	75147	71889	73717
RSS	340315	283968	254279	244666	239359	234711	228937	231469
MSS	25164	81511	111201	120814	126120	130769	136543	134010
Nobs	136067	136067	135216	135216	135216	135216	135216	135216
Npars	29	225	270	281	286	289	344	514
adj_R^2	6.866	22.174	30.287	32.917	34.370	35.643	37.201	36.426
%Change	0.000	15.308	8.113	2.630	1.453	1.273	1.558	-0.775

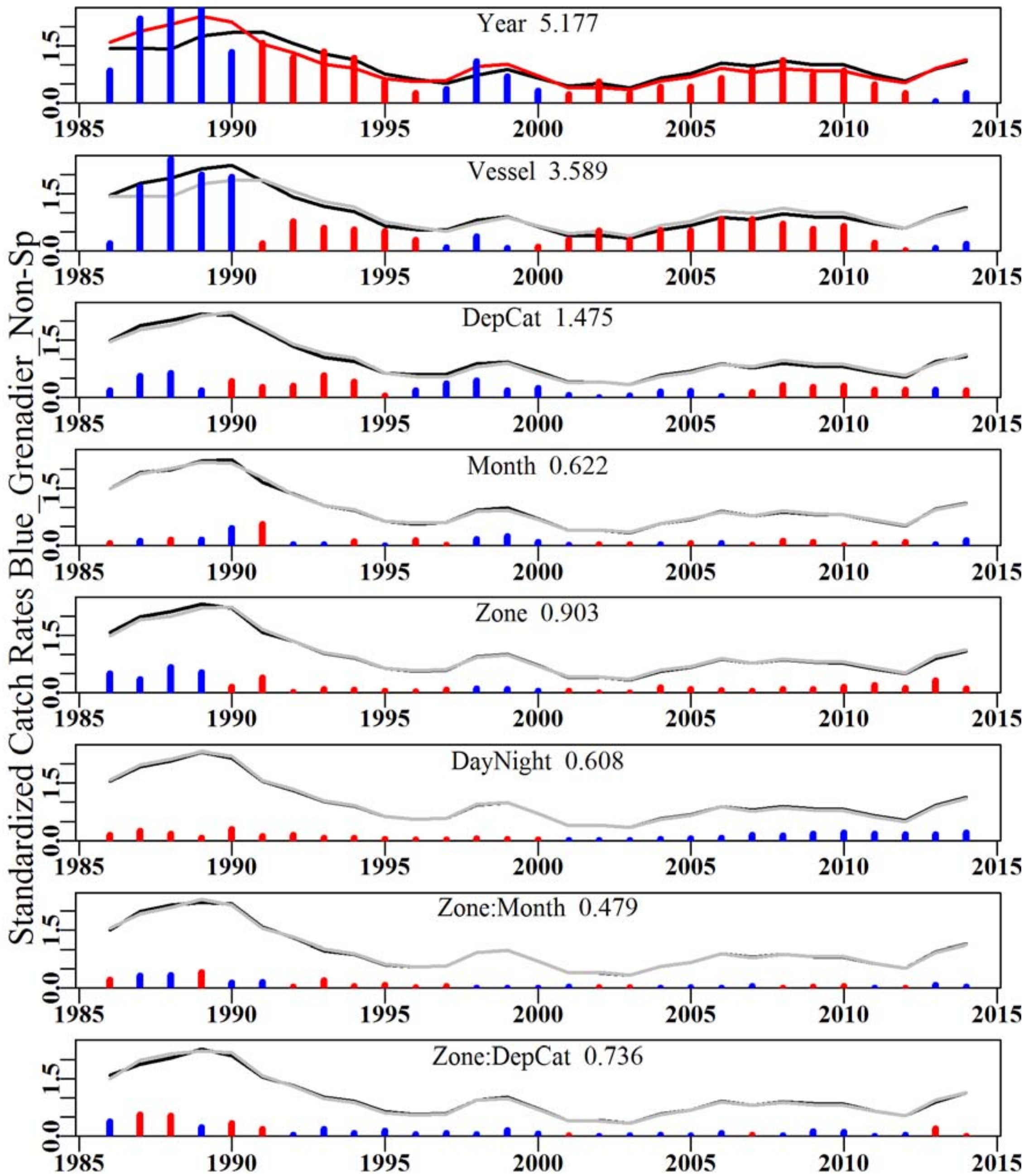


Figure 20.87. The relative influence of each factor used on the final trend in the optimal standardization for Blue Grenadier non-spawning fishery. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by the vertical bars with 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.

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

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

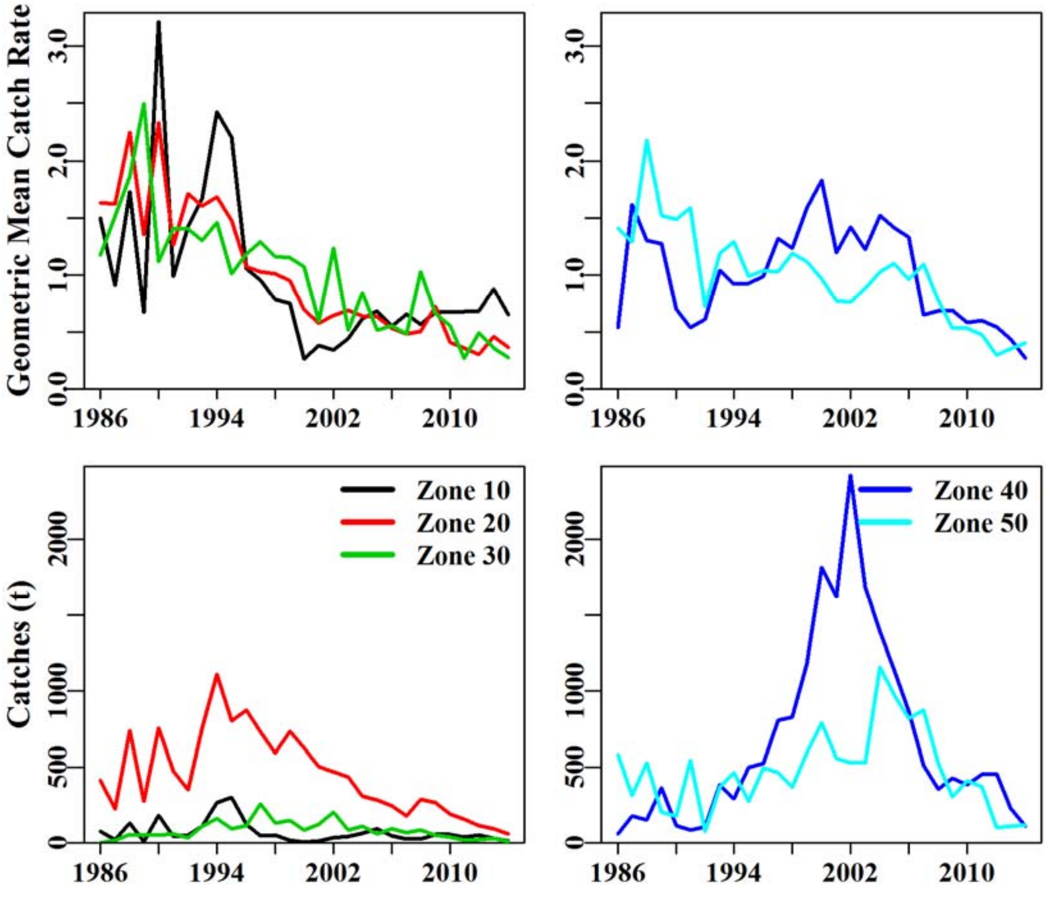


Figure 20.88. The trends in catches and catch rates for zones 10 – 50, split east and west.

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. Trends are different between the east and west.

Table 20.79. 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	1156.533	2438	1135.296	86	32.290	1.533	0.000
1987	782.151	1509	757.298	76	35.504	1.601	0.056
1988	1646.187	2249	1617.240	87	42.935	2.049	0.051
1989	926.257	2049	907.420	80	30.729	1.659	0.054
1990	1346.585	1983	1290.959	81	40.649	1.756	0.054
1991	1453.169	2289	1207.361	78	25.685	1.233	0.053
1992	733.767	1858	625.276	56	27.950	1.088	0.056
1993	1815.801	3866	1735.163	61	33.299	1.234	0.049
1994	2309.510	4519	2300.083	57	34.714	1.315	0.048
1995	2002.881	5016	1969.857	58	29.783	1.193	0.047
1996	2188.244	6080	2137.373	67	22.732	1.117	0.046
1997	2562.016	5765	2305.785	61	25.348	1.147	0.047
1998	2166.021	4702	1976.667	57	26.642	1.104	0.048
1999	2834.052	5148	2685.678	58	31.233	0.947	0.047
2000	3401.563	6745	3325.305	65	26.075	0.863	0.046
2001	2970.407	7352	2816.511	60	21.800	0.727	0.046
2002	3841.439	8423	3659.277	58	23.001	0.785	0.045
2003	2910.095	7405	2782.808	65	20.460	0.788	0.046
2004	3202.084	7861	3036.748	59	23.344	0.874	0.046
2005	2647.967	6920	2558.282	57	20.028	0.860	0.046
2006	2191.197	5663	2076.275	48	18.215	0.757	0.047
2007	1816.517	4657	1665.236	34	20.124	0.715	0.048
2008	1381.159	4400	1279.929	33	16.120	0.647	0.049
2009	1285.306	4387	1109.646	29	15.884	0.668	0.049
2010	1189.434	4484	1082.602	29	13.259	0.554	0.049
2011	1108.751	4940	1042.774	31	12.616	0.515	0.048
2012	781.154	3768	750.557	30	10.408	0.421	0.050
2013	584.073	2979	502.952	30	11.609	0.462	0.052
2014	356.855	2670	316.859	27	9.788	0.387	0.053

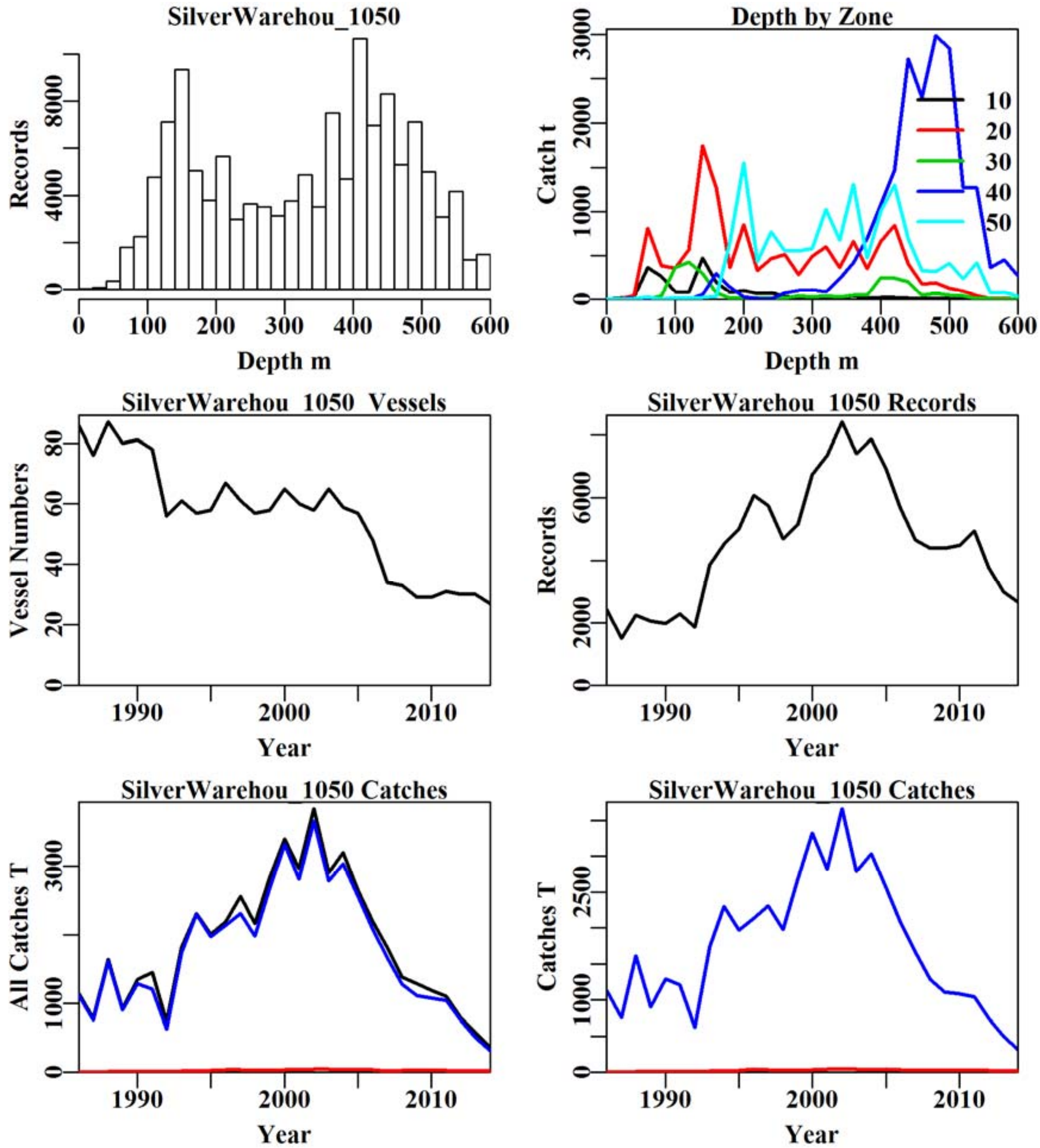


Figure 20.89. Silver Warehou from zones 10 to 50 and depths 0 – 600 m by Trawl. The top left plot depicts the depth distribution of shots containing Silver Warehou from zones 10 to 50 in depths 0 – 600 m by Trawl. The top right plot depicts the catch distribution by depth by zone. The middle left plot 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).

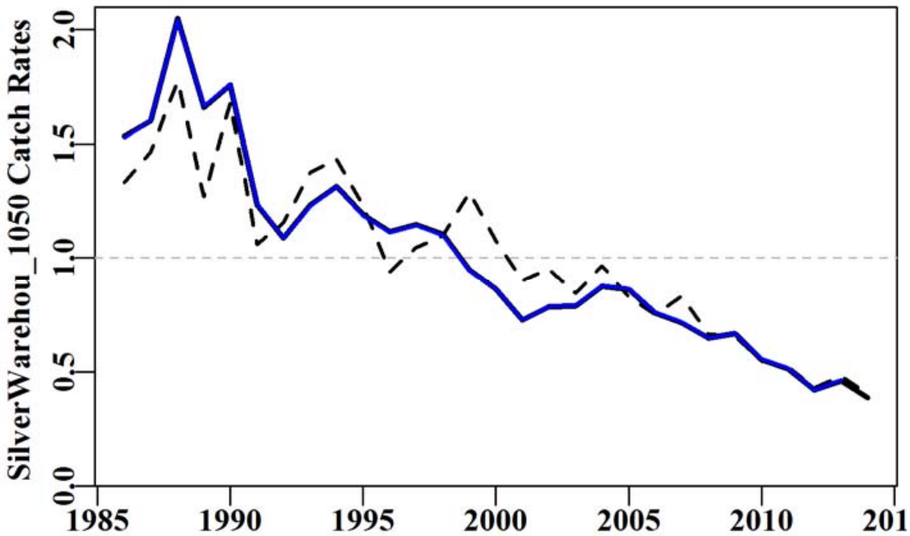


Figure 20.90. Silver Warehou from Zones 10 to 50 and depths 0 – 600 m by Trawl. The dashed black line represents the geometric mean catch rate and the solid black line the standardized catch rates (relative to the mean of the standardized catch rates). The blue line corresponds to last year's standardized indices.

Table 20.80. 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 20.81. 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	157283	135049	128748	126650	123572	123325	121408	121845
RSS	434292	365925	348825	343310	335104	334459	329388	330103
MSS	15062	83429	100529	106044	114250	114895	119966	119251
Nobs	132125	132125	132125	132125	131240	131240	131240	131240
Npars	29	228	239	243	273	276	320	396
adj_R^2	3.331	18.426	22.232	23.459	25.271	25.413	26.519	26.317
%Change	0.000	15.095	3.806	1.227	1.812	0.142	1.106	-0.202

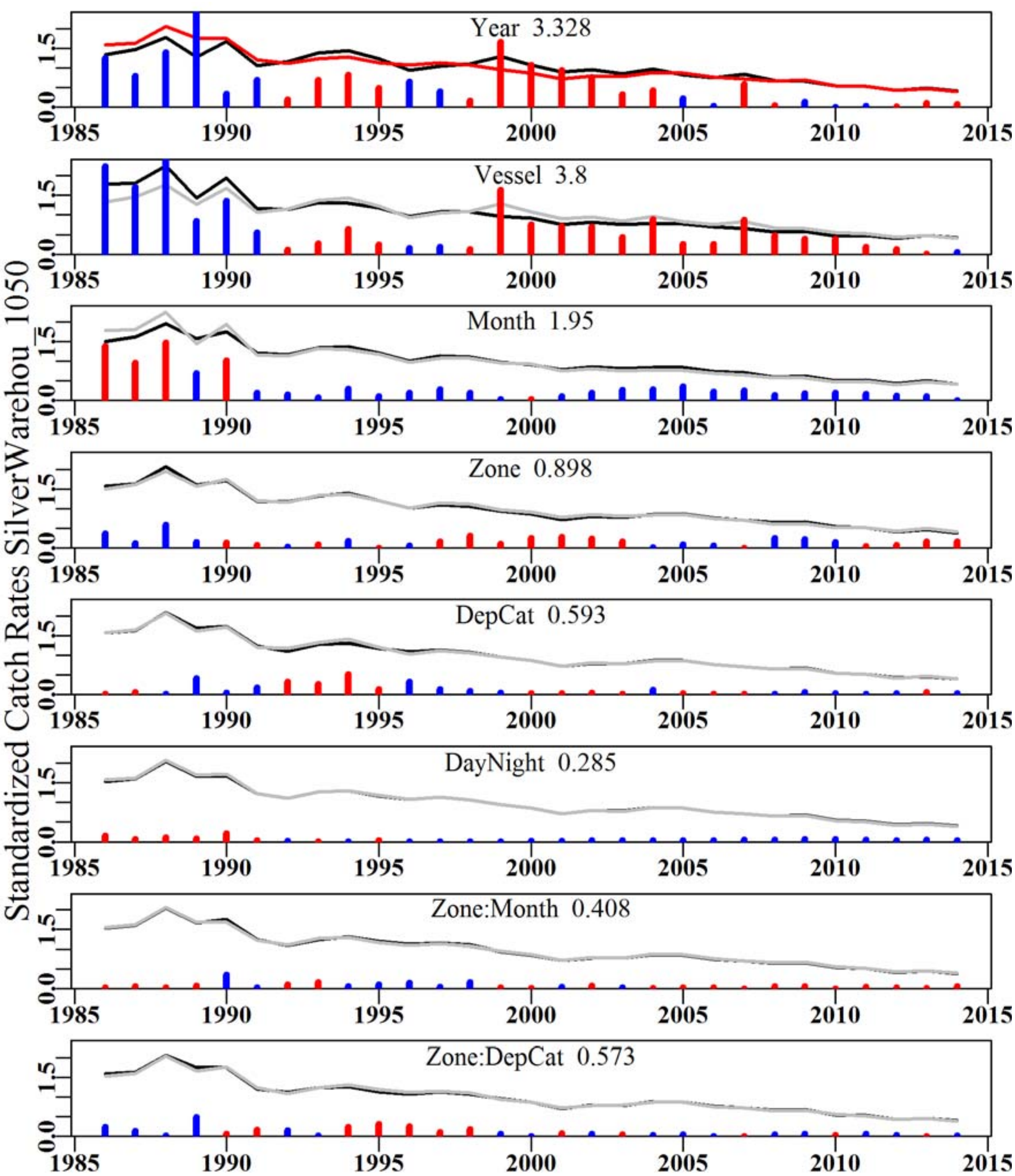


Figure 20.91. The relative influence of each factor used on the final trend in the optimal standardization for Silver Warehou in zones 10 – 50. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by the vertical bars with 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.

20.4.28 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 20.82. 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	2.0722	0.0000
1987	405.8510	457	168.1520	40	23.2716	2.5079	0.1048
1988	543.9760	775	334.0470	33	34.8726	3.0754	0.0953
1989	776.0410	1178	664.7090	41	52.6588	3.8698	0.0926
1990	881.3530	826	508.2700	42	46.5510	3.5330	0.0977
1991	1284.1940	1567	465.1580	54	23.0208	1.8971	0.0920
1992	934.4050	1350	406.8870	40	24.1250	1.5587	0.0925
1993	829.5730	2195	431.7350	45	20.7054	1.2327	0.0892
1994	944.8050	2449	473.8990	44	17.5997	1.1868	0.0882
1995	815.3840	2646	467.8250	44	15.3567	1.0888	0.0880
1996	724.4080	3551	531.2230	49	14.6415	1.1252	0.0872
1997	935.1594	2481	404.2810	42	11.8760	1.0978	0.0895
1998	903.2421	2556	457.2470	39	13.8592	1.0265	0.0890
1999	590.9751	1643	131.6410	39	5.7097	0.5691	0.0920
2000	470.2475	2221	185.5790	42	5.0089	0.4736	0.0901
2001	285.4641	1479	57.3610	35	2.7867	0.2814	0.0936
2002	290.4765	1858	62.9810	37	2.2078	0.2146	0.0921
2003	233.9681	1324	42.0775	39	1.8331	0.1666	0.0951
2004	232.4455	1249	52.0505	39	2.7248	0.2253	0.0969
2005	289.0633	830	21.2863	33	1.8011	0.1503	0.1013
2006	379.5272	776	25.7195	29	2.2327	0.1791	0.1024
2007	177.7756	584	16.7583	14	1.8647	0.1883	0.1073
2008	163.2600	738	27.4410	19	2.6539	0.2636	0.1031
2009	135.2235	447	36.8840	16	3.5956	0.3117	0.1121
2010	129.3300	372	12.0425	15	2.0876	0.1953	0.1176
2011	103.2946	435	9.8117	14	1.7081	0.1640	0.1134
2012	52.2722	356	9.9005	15	1.6727	0.1362	0.1187
2013	67.9643	166	3.6740	18	1.6984	0.1238	0.1475
2014	15.3153	83	1.7550	12	1.0627	0.0852	0.1885

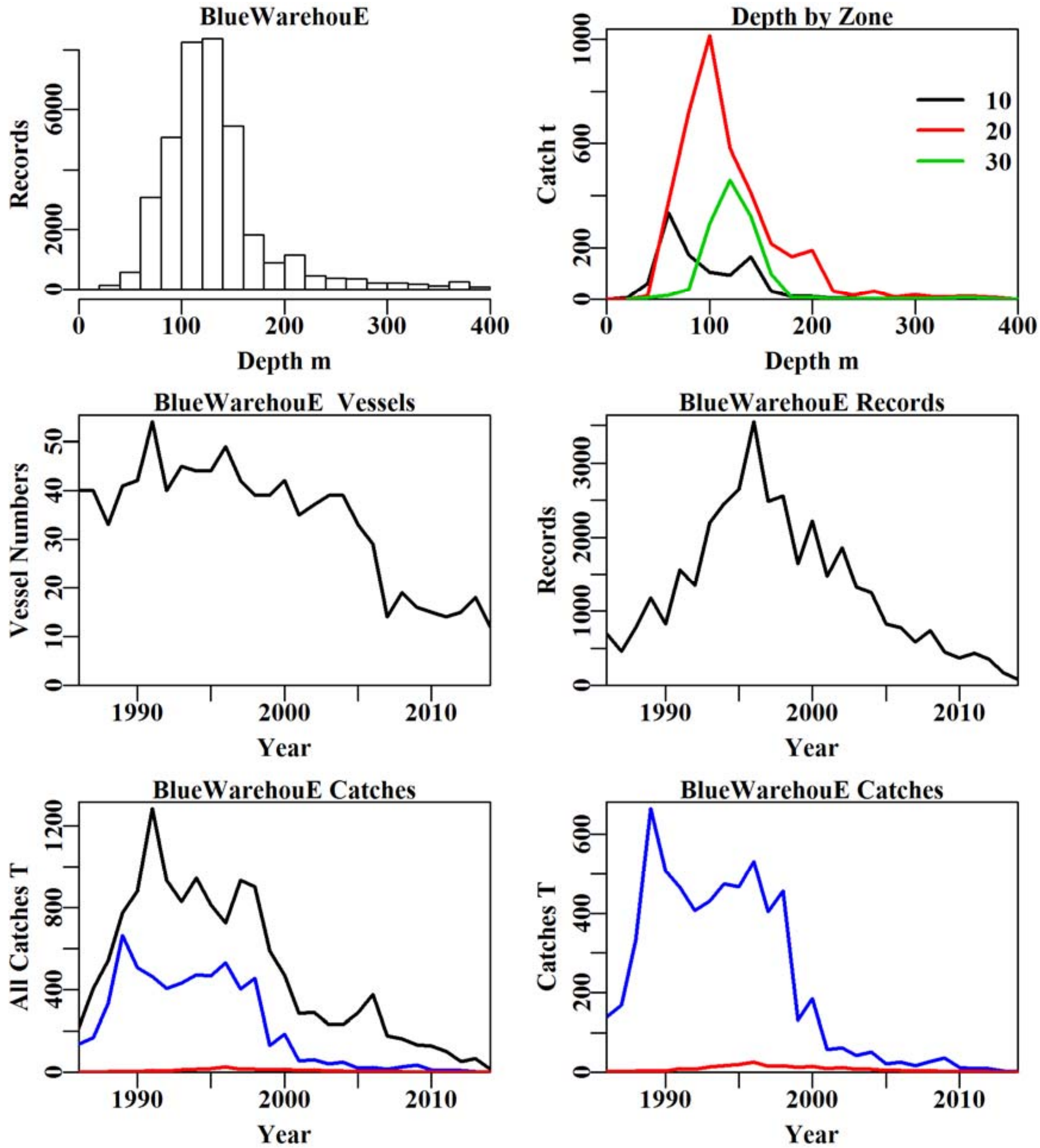


Figure 20.92. Blue Warehou from zones 10 to 30 in depths 0 – 400 m by Trawl. The top left plot depicts the depth distribution of shots containing Blue Warehou from zones 10 to 30 in depths 0 – 400 m by Trawl. The top right plot depicts the catch distribution by depth by zone. The middle left plot depicts 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).

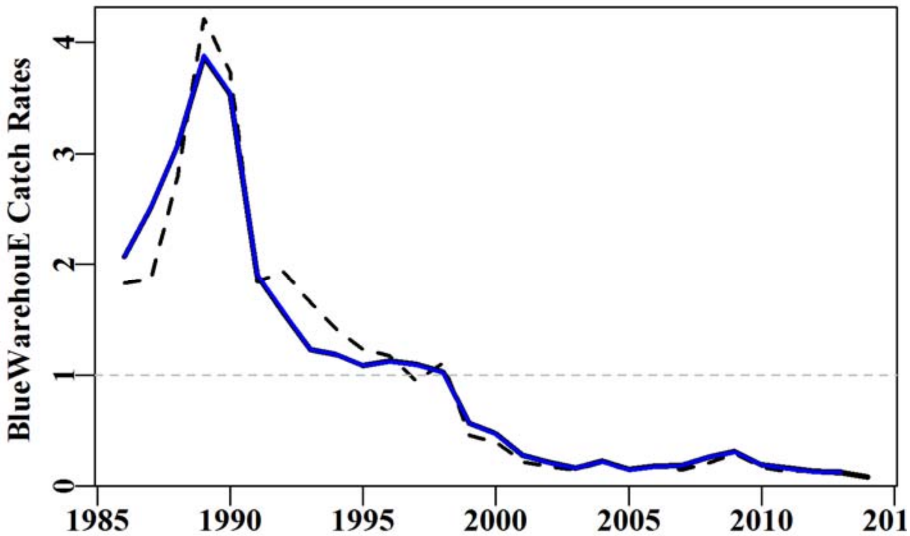


Figure 20.93. Blue Warehou from zones 10 to 30 in depths 0 – 400 m by Trawl. The dashed black line represents the geometric mean catch rate and the solid black line the standardized catch rates (relative to the mean of the standardized catch rates). The blue line corresponds to last year's standardized indices.

Table 20.83. 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 20.84. 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	37337	32627	31980	31709	31319	31316	31066	31025
RSS	101334	88536	86839	86198	85244	85225	84552	84375
MSS	38302	51101	52797	53438	54392	54411	55084	55261
Nobs	37294	37294	37070	37070	37070	37070	37070	37070
Npars	29	192	212	214	225	228	250	268
adj_R^2	27.375	36.269	37.454	37.913	38.581	38.590	39.039	39.137
%Change	0.000	8.894	1.185	0.458	0.669	0.009	0.449	0.098

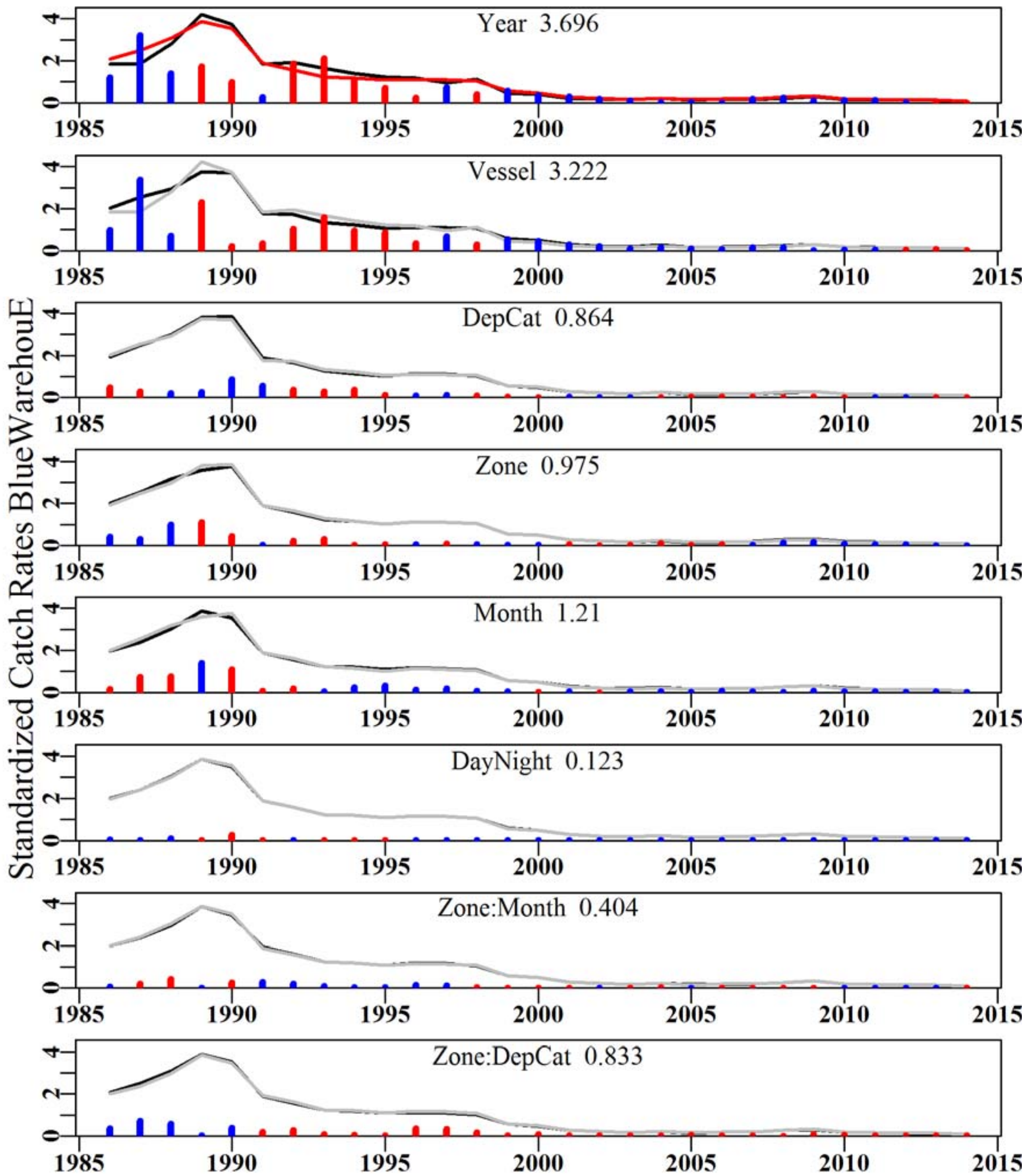


Figure 20.94. The relative influence of each factor used on the final trend in the optimal standardization for Blue Warehou in zone 10 – 30. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by the vertical bars with blue 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.

20.4.29 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 20.85. 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	3.5793	0.0000
1987	405.8510	183	215.6450	10	153.6342	3.4801	0.2436
1988	543.9760	180	197.9890	12	104.5294	1.4277	0.2531
1989	776.0410	56	81.3430	13	91.5270	3.5928	0.3135
1990	881.3530	444	298.2960	14	55.8069	1.5535	0.2388
1991	1284.1940	597	647.5370	18	159.6429	2.4452	0.2368
1992	934.4050	538	430.1330	17	88.9759	1.4064	0.2388
1993	829.5730	495	362.8540	21	92.3447	1.0447	0.2402
1994	944.8050	824	449.9010	21	67.3117	1.1373	0.2358
1995	815.3840	825	325.1500	22	45.1964	0.7646	0.2335
1996	724.4080	700	183.5500	24	26.4215	0.5205	0.2349
1997	935.1594	431	243.5470	23	35.6095	0.5485	0.2404
1998	903.2421	582	354.4830	19	58.9967	0.8348	0.2388
1999	590.9751	688	174.3760	19	32.5226	0.4643	0.2382
2000	470.2475	652	203.6200	24	28.2022	0.3740	0.2384
2001	285.4641	686	194.1760	23	27.6016	0.4024	0.2373
2002	290.4765	531	218.1070	23	35.4283	0.5279	0.2397
2003	233.9681	362	175.4480	19	28.2126	0.4765	0.2455
2004	232.4455	437	159.2550	21	28.4995	0.5203	0.2422
2005	289.0633	461	257.8010	18	53.5991	0.8297	0.2427
2006	379.5272	695	337.4725	16	31.8482	0.5849	0.2391
2007	177.7756	466	148.6395	16	22.9820	0.4910	0.2428
2008	163.2600	353	117.7735	12	20.3955	0.3989	0.2451
2009	135.2235	308	89.0030	11	18.4388	0.3010	0.2474
2010	129.3300	407	105.2905	12	17.5511	0.3479	0.2428
2011	103.2946	519	77.9065	14	14.3950	0.3077	0.2412
2012	52.2722	262	32.7576	14	8.1485	0.1810	0.2520
2013	67.9643	305	57.9275	13	12.4453	0.2546	0.2486
2014	15.3153	60	11.6460	9	9.3873	0.2024	0.3087

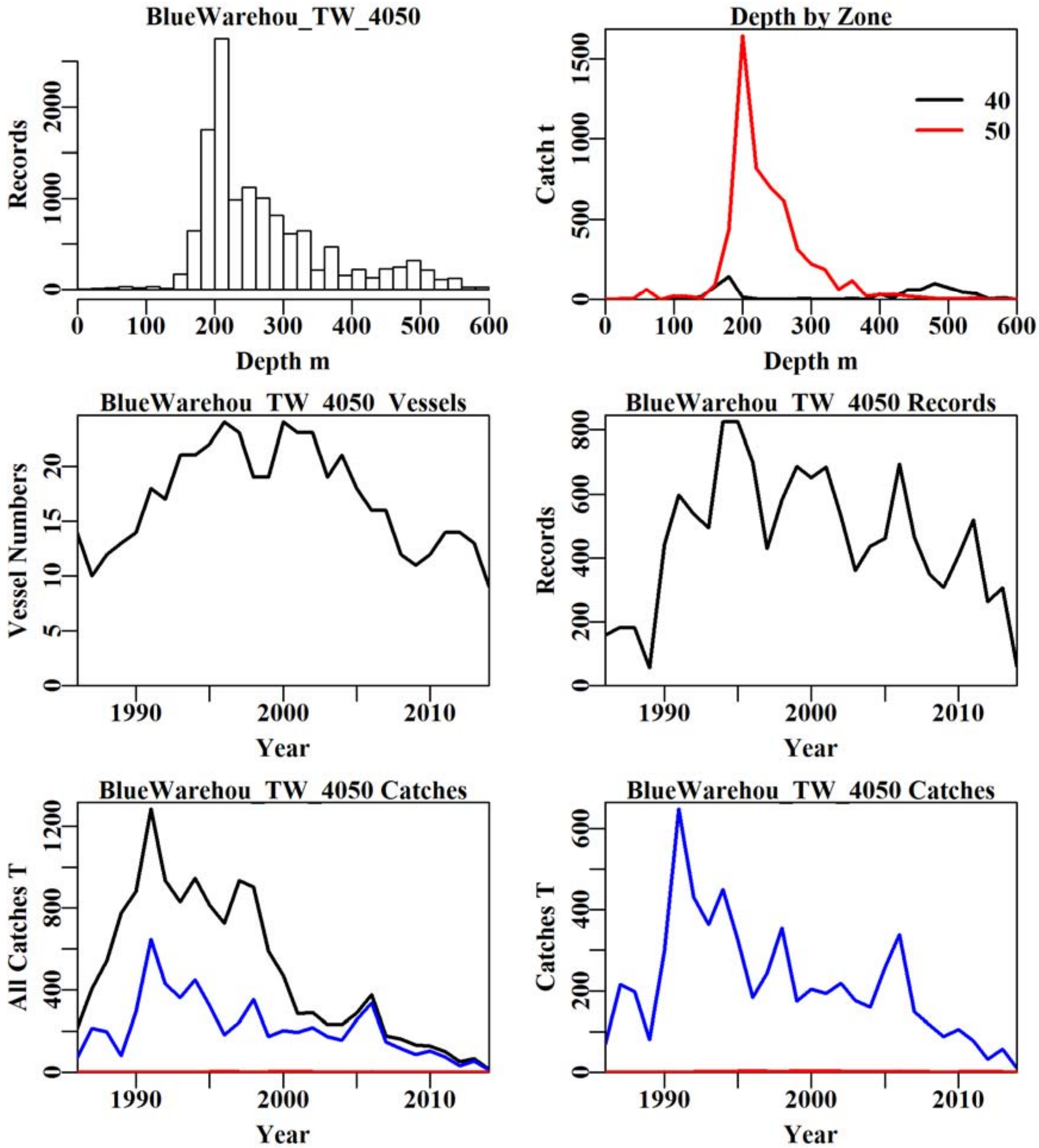


Figure 20.95. Blue Warehou from zones 40 and 50 in depths 0 – 600 m by Trawl. The top left plot depicts the depth distribution of shots containing Blue Warehou from zones 40 and 50 in depths 0 – 600 m by Trawl. The top right plot depicts the catch distribution by depth by zone. The middle left plot depicts 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).

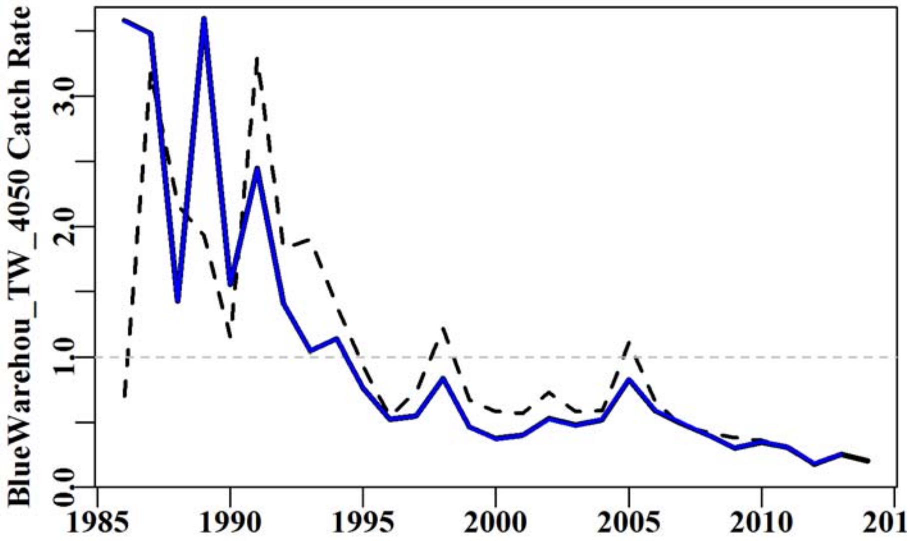


Figure 20.96. Blue Warehou from zones 40 and 50 in depths 0 – 600 m by Trawl. The dashed black line represents the geometric mean catch rate and the solid black line the standardized catch rates (relative to the mean of the standardized catch rates). The blue line corresponds to last year's standardized indices.

Table 20.86. 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 20.87. 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	14690	13537	12512	11714	11553	11551	11510	11526
RSS	39990	36201	33441	31319	30923	30913	30766	30713
MSS	5720	9509	12269	14391	14787	14796	14944	14997
Nobs	13206	13206	13206	13143	13143	13143	13143	13143
Npars	29	110	121	151	154	155	166	185
adj_R^2	12.327	20.144	26.169	30.692	31.552	31.568	31.837	31.855
%Change	0.000	7.816	6.026	4.522	0.861	0.015	0.269	0.018

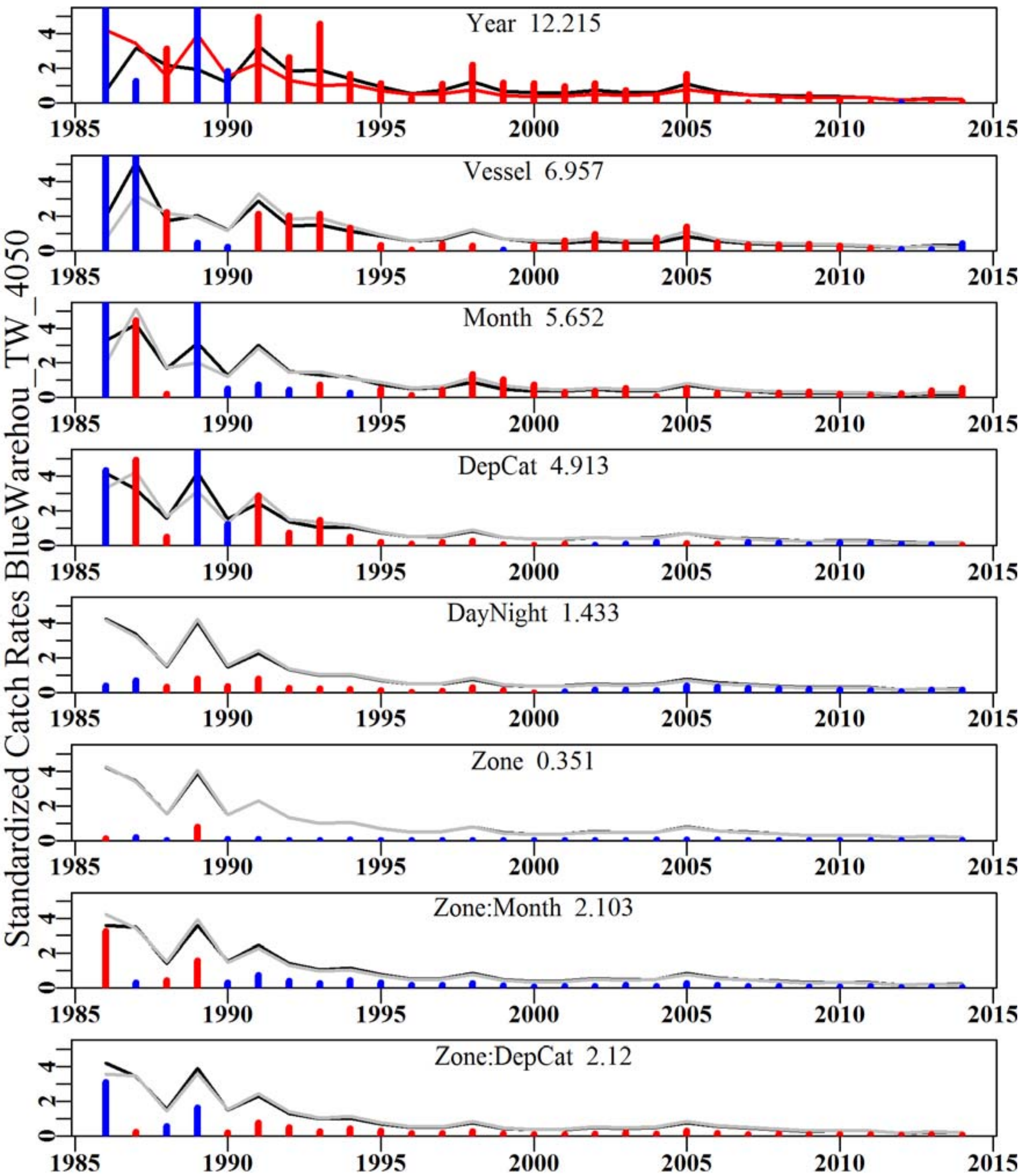


Figure 20.97. The relative influence of each factor used on the final trend in the optimal standardization for Blue Warehou in zone 40 – 50. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by the vertical bars with blue 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.

20.4.30 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.

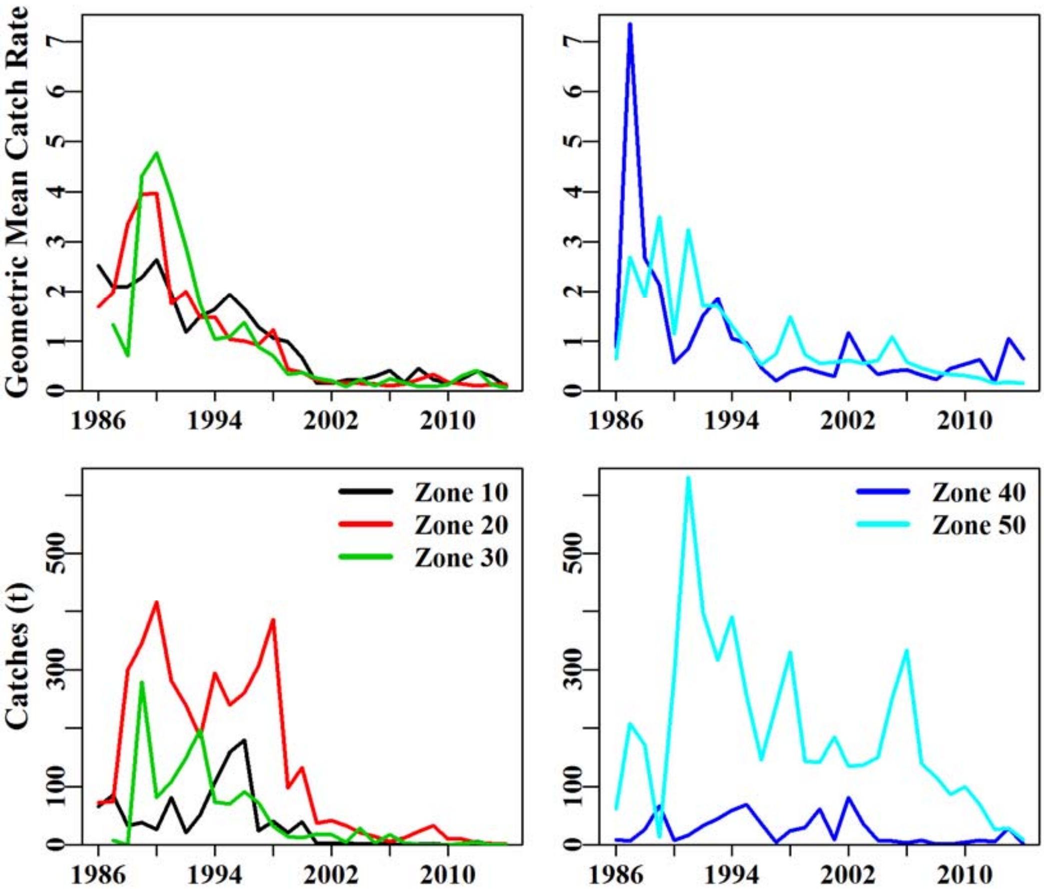


Figure 20.98. Trends in the catches and geometric mean catch rates for Blue Warehou across each of the zones 10 – 50, split east and west. The extreme catch rates in zone 40 reflect very small catches.

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 20.88. 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	2.2034	0.0000
1987	405.8510	655	384.5560	51	38.9818	2.5233	0.0922
1988	543.9760	963	532.3580	45	42.2791	2.8300	0.0893
1989	776.0410	1239	746.1520	50	53.5132	3.8686	0.0877
1990	881.3530	1284	822.4190	56	49.3618	2.7186	0.0890
1991	1284.1940	2193	1119.7880	66	38.9026	2.1607	0.0846
1992	934.4050	1909	840.4420	57	34.6465	1.5910	0.0854
1993	829.5730	2717	797.3080	58	27.0143	1.2545	0.0833
1994	944.8050	3300	927.2280	58	24.5388	1.2067	0.0821
1995	815.3840	3497	794.6970	58	19.7435	1.0225	0.0818
1996	724.4080	4278	715.7540	66	16.0446	1.0400	0.0814
1997	935.1594	2925	648.1390	57	13.9027	1.0376	0.0836
1998	903.2421	3152	813.7270	50	18.0335	1.0308	0.0830
1999	590.9751	2372	309.6960	57	9.5323	0.5559	0.0849
2000	470.2475	2905	390.3170	60	7.3031	0.4795	0.0837
2001	285.4641	2219	253.4480	54	5.6223	0.3225	0.0857
2002	290.4765	2411	281.2400	54	4.0510	0.2730	0.0854
2003	233.9681	1708	218.3395	52	3.2829	0.2207	0.0880
2004	232.4455	1700	211.5094	52	4.9660	0.3004	0.0887
2005	289.0633	1297	279.4293	45	6.0446	0.2799	0.0910
2006	379.5272	1474	363.2420	37	7.8259	0.2831	0.0900
2007	177.7756	1052	165.4073	25	5.6675	0.2591	0.0936
2008	163.2600	1100	145.3175	28	5.0903	0.2943	0.0927
2009	135.2235	766	126.2322	25	6.9116	0.2946	0.0976
2010	129.3300	783	117.5180	22	6.3064	0.2351	0.0976
2011	103.2946	966	91.4787	24	5.5254	0.2225	0.0948
2012	52.2722	633	46.4206	26	3.2664	0.1600	0.1018
2013	67.9643	492	62.5255	27	6.0283	0.1896	0.1074
2014	15.3153	152	13.9680	19	2.8750	0.1422	0.1500

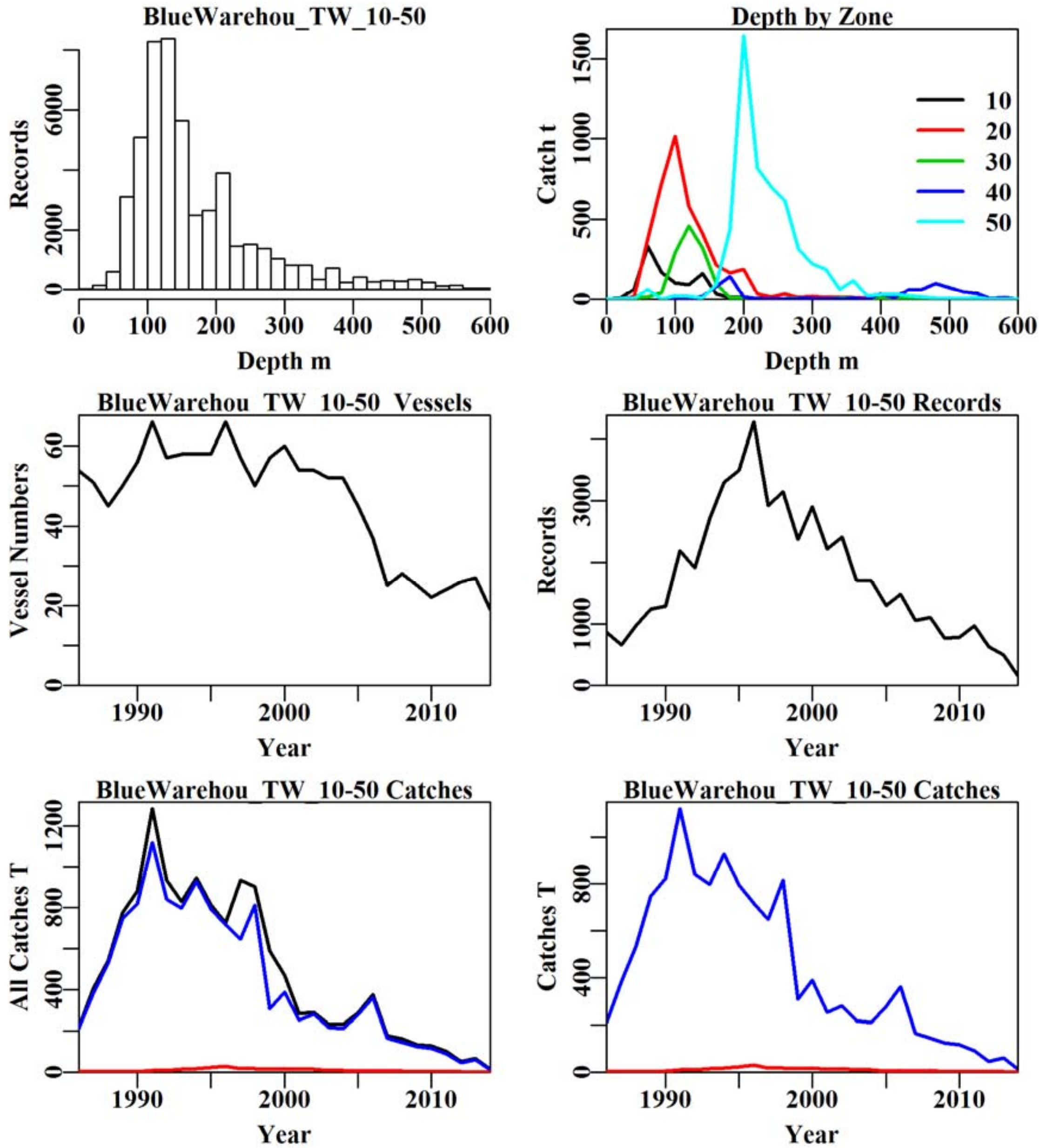


Figure 20.99. Blue Warehou from zones 10 to 50 in depths 0 – 600 m by Trawl. The top left plot depicts the depth distribution of shots containing Blue Warehou from zones 10 to 50 in depths 0 – 600 m by Trawl. The top right plot depicts the catch distribution by depth by zone. The middle left plot depicts 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).

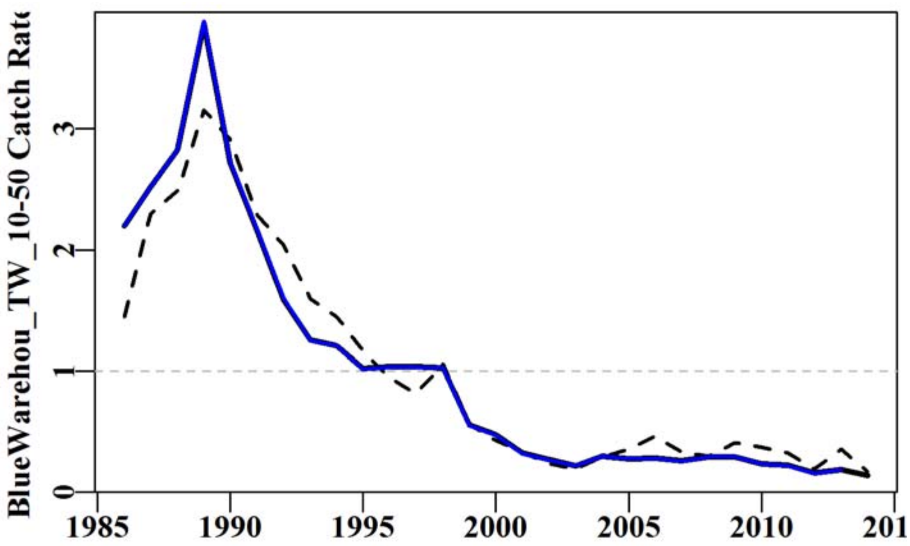


Figure 20.100. Blue Warehou from zones 10 to 50 in depths 0 – 600 m by Trawl. The dashed black line represents the geometric mean catch rate and the solid black line the standardized catch rates (relative to the mean of the standardized catch rates). The blue line corresponds to last year's standardized indices.

Table 20.89. 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 20.90. 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	62917	48967	47656	46452	45735	45667	44670	44919
RSS	174919	132061	128505	125471	123656	123474	120863	121094
MSS	32593	75451	79007	82041	83855	84037	86648	86417
Nobs	51005	51005	50718	50718	50718	50718	50718	50718
Npars	29	222	252	256	267	270	314	390
adj_R^2	15.660	36.083	37.766	39.230	40.096	40.180	41.394	41.193
%Change	0.000	20.423	1.683	1.465	0.866	0.084	1.214	-0.201

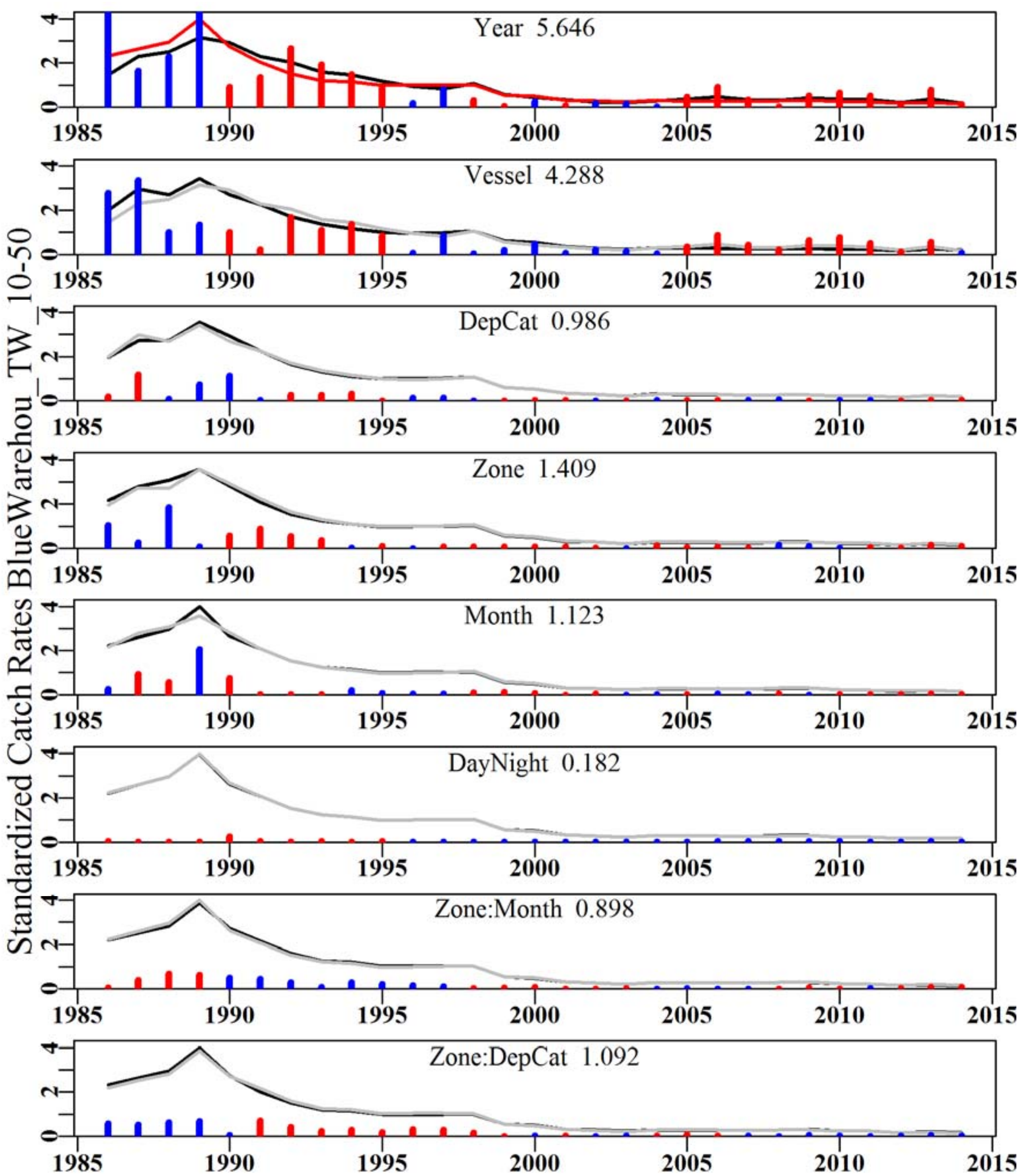


Figure 20.101. The relative influence of each factor used on the final trend in the optimal standardization for Blue Warehou in zone 10 – 50. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by the vertical bars with blue 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.

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

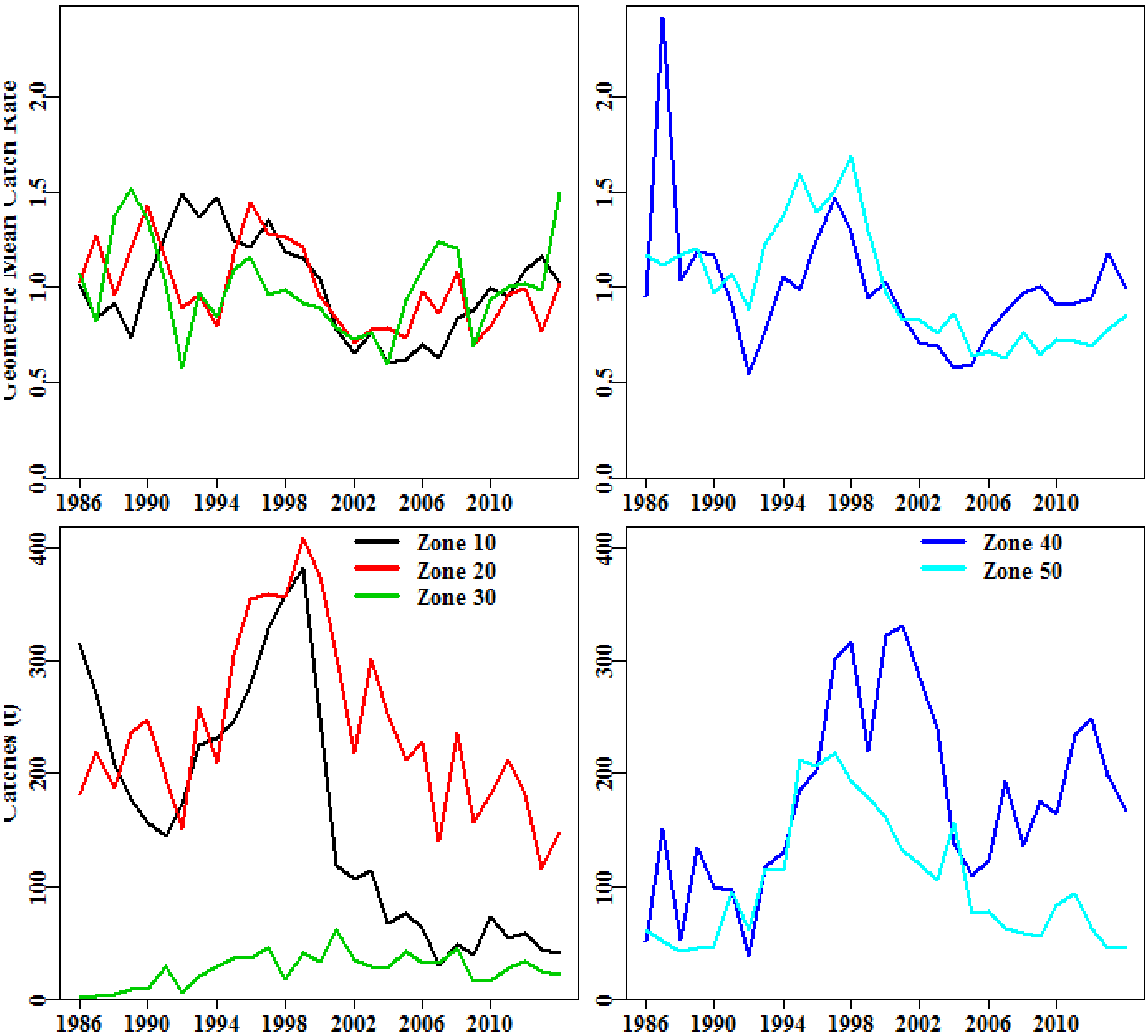


Figure 20.102. Trends in the catches and geometric mean catch rates for Pink Ling taken by Trawler across zones 10 – 50 split between east and west.

The trends in the geometric mean catch rates in the east all follow approximately the same trajectory, albeit with some noise (Figure 20.102). 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.

20.4.32 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 20.91. 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	1.1200	0.0000
1987	765.0660	4260	492.3140	77	19.4237	1.1856	0.0223
1988	583.0770	3613	400.0770	77	20.2595	1.1291	0.0234
1989	678.8960	3879	422.0770	77	19.1575	0.9728	0.0232
1990	674.4790	2794	413.0820	68	26.8201	1.4191	0.0255
1991	736.8030	2938	370.2970	72	26.3050	1.4126	0.0254
1992	568.3080	2434	329.9850	58	25.0221	1.1017	0.0267
1993	892.7960	3525	504.4740	59	25.3075	1.0483	0.0244
1994	895.4310	4066	470.2650	63	23.5158	1.0665	0.0235
1995	1208.8930	4361	586.6860	57	25.8106	1.3523	0.0230
1996	1233.2650	4268	667.5830	63	27.6570	1.3430	0.0232
1997	1696.8475	4808	732.6540	62	27.9375	1.3722	0.0228
1998	1591.9879	4909	730.4580	57	26.0156	1.3602	0.0226
1999	1651.5715	5964	832.6550	59	25.2286	1.2442	0.0221
2000	1507.3786	5114	660.3500	64	22.4055	1.0980	0.0230
2001	1392.8101	4569	485.6305	54	19.0505	0.8487	0.0238
2002	1330.1940	3902	360.5923	53	15.8480	0.7511	0.0246
2003	1353.1029	4310	445.7625	58	18.2826	0.7697	0.0242
2004	1495.1340	3359	347.2374	55	16.7949	0.6904	0.0257
2005	1203.1954	3454	329.9497	52	16.3326	0.6407	0.0254
2006	1069.2001	2593	323.1010	39	21.3189	0.7655	0.0273
2007	875.9218	1652	204.3070	24	20.5015	0.7435	0.0313
2008	980.2672	2382	329.0357	25	25.1511	0.8719	0.0284
2009	775.0457	1947	212.3617	28	18.2953	0.6293	0.0301
2010	906.2231	1991	271.1322	24	20.7020	0.7728	0.0297
2011	1081.9062	2201	294.8960	23	23.4304	0.8189	0.0291
2012	1030.9058	1972	273.3230	25	24.3541	0.8728	0.0300
2013	735.6758	1561	183.9784	23	21.3669	0.7364	0.0320
2014	849.5756	1446	209.5905	23	25.4590	0.8630	0.0326

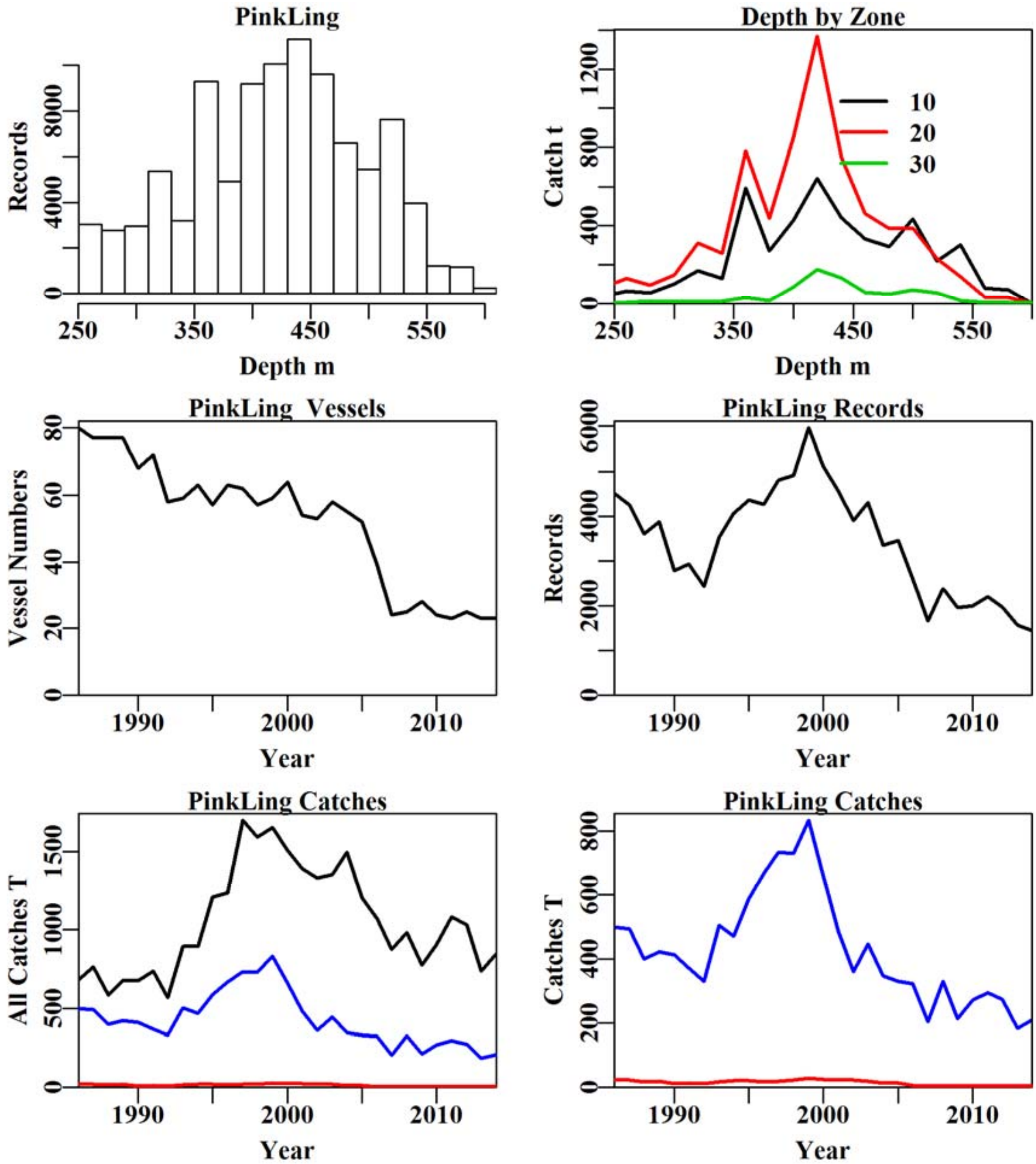


Figure 20.103. Pink Ling from zones 10 to 30 in depths between 250 – 600 m by Trawl. The top left plot depicts the depth distribution of shots containing Pink Ling from zones 10 to 30 in depths 250 – 600 m by Trawl. The top right plot depicts the catch distribution by depth by zone. The middle left plot 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).

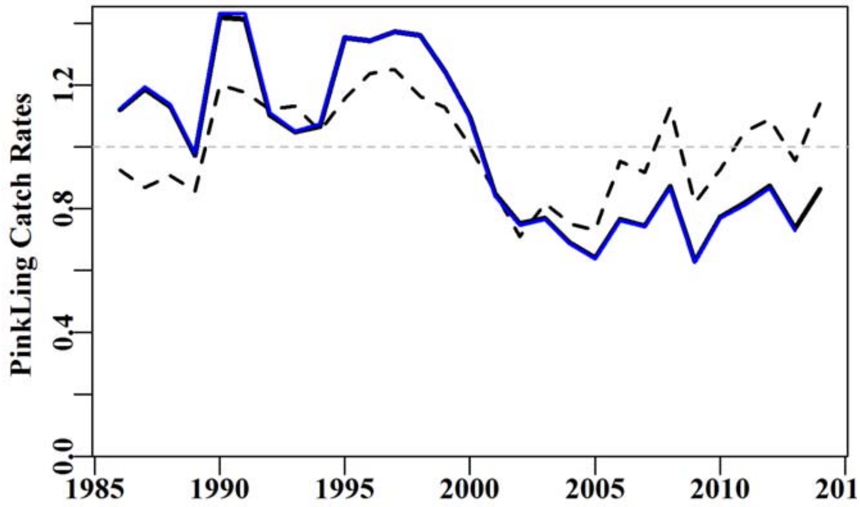


Figure 20.104. Pink Ling from zones 10 to 30 in depths between 250 – 600 m by Trawl. The dashed black line represents the geometric mean catch rate and the solid black line the standardized catch rates (relative to the mean of the standardized catch rates). The blue line corresponds to last year's standardized indices.

Table 20.92. Pink Ling from zones 10 to 30 in depths between 250 – 600 m by Trawl. Statistical model structures used in this analysis. DepCat is a series of 20 metre depth categories.

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

Table 20.93. 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	33306	16439	3293	3293	-20	-56	-1162	-2161
RSS	138312	116170	100768	100768	97394	97351	96215	95168
MSS	2773	24915	40317	40317	43692	43734	44870	45917
Nobs	98784	98784	97898	97898	97898	97898	97898	97898
Npars	29	212	232	232	243	246	268	304
adj_R^2	1.938	17.483	28.408	28.408	30.797	30.825	31.617	32.336
%Change	0.000	15.545	10.924	0.000	2.390	0.028	0.792	0.719

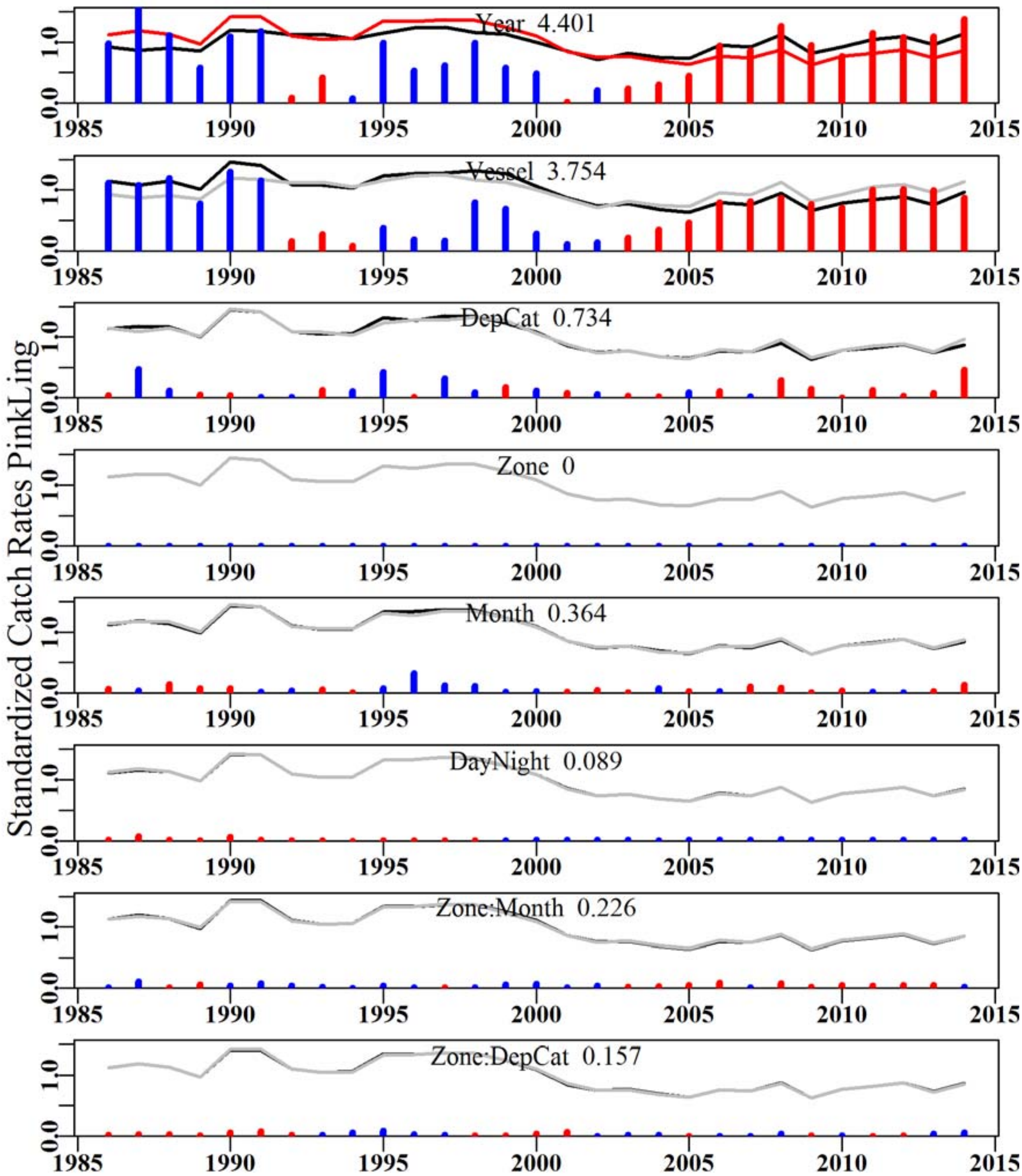


Figure 20.105. The relative influence of each factor used on the final trend in the optimal standardization for Pink Ling from zones 10 to 30. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by the vertical bars with blue 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.

20.4.33 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 20.94. 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	1.1753	0.0000
1987	765.0660	1310	206.3410	28	24.0155	1.3448	0.0375
1988	583.0770	1026	95.7030	32	17.6676	1.0467	0.0406
1989	678.8960	1469	183.1210	34	21.9840	1.0804	0.0387
1990	674.4790	1524	147.4120	32	16.9021	0.9689	0.0392
1991	736.8030	1897	198.9450	37	16.3936	1.0388	0.0374
1992	568.3080	1633	102.1640	24	11.9963	0.7715	0.0384
1993	892.7960	2253	235.4850	24	17.1332	1.0466	0.0372
1994	895.4310	2110	247.7930	24	20.5621	1.2603	0.0371
1995	1208.8930	3516	426.9070	25	20.0613	1.2883	0.0349
1996	1233.2650	3403	448.0440	26	19.9984	1.3651	0.0353
1997	1696.8475	3732	577.4340	24	21.1891	1.4329	0.0349
1998	1591.9879	3710	558.6410	21	22.4111	1.4127	0.0352
1999	1651.5715	3794	427.9200	24	18.0495	1.1190	0.0350
2000	1507.3786	4656	509.3340	28	16.3658	1.0006	0.0346
2001	1392.8101	5100	502.3720	28	14.7225	0.8924	0.0345
2002	1330.1940	4633	429.5610	27	13.4055	0.7722	0.0346
2003	1353.1029	3822	360.2349	27	12.6257	0.7748	0.0350
2004	1495.1340	3901	306.2357	25	11.7174	0.7271	0.0352
2005	1203.1954	2663	195.7375	23	9.9452	0.6064	0.0364
2006	1069.2001	2322	209.9851	21	10.6509	0.6433	0.0372
2007	875.9218	2532	287.3451	16	12.6778	0.7058	0.0367
2008	980.2672	1795	214.2319	17	14.6108	0.9113	0.0382
2009	775.0457	1976	260.6090	13	14.0039	0.8894	0.0377
2010	906.2231	2337	272.1558	14	13.1460	0.8623	0.0370
2011	1081.9062	2792	356.8662	16	13.2635	0.8512	0.0364
2012	1030.9058	2342	344.9726	14	14.5232	0.9161	0.0374
2013	735.6758	1720	272.2423	17	15.6514	1.0439	0.0390
2014	849.5756	1682	250.3459	14	16.2671	1.0518	0.0391

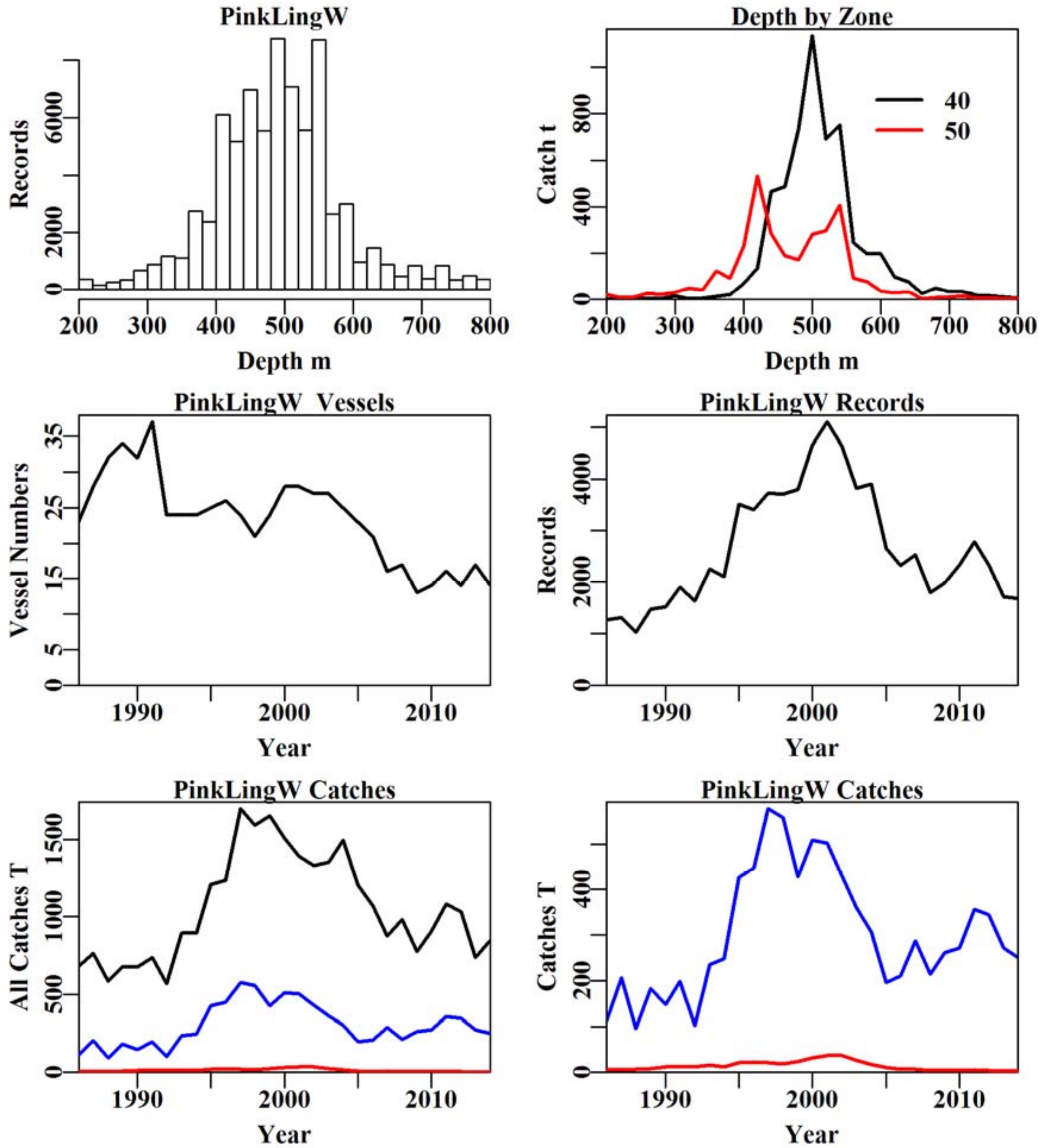


Figure 20.106. Pink Ling from zones 40 and 50 in depths between 200 – 800 m by Trawl. The top left plot depicts the depth distribution of shots containing Pink Ling from zones 40 and 50 in depths 200 – 800 m by Trawl. The top right plot depicts the catch distribution by depth by zone. The middle left 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).

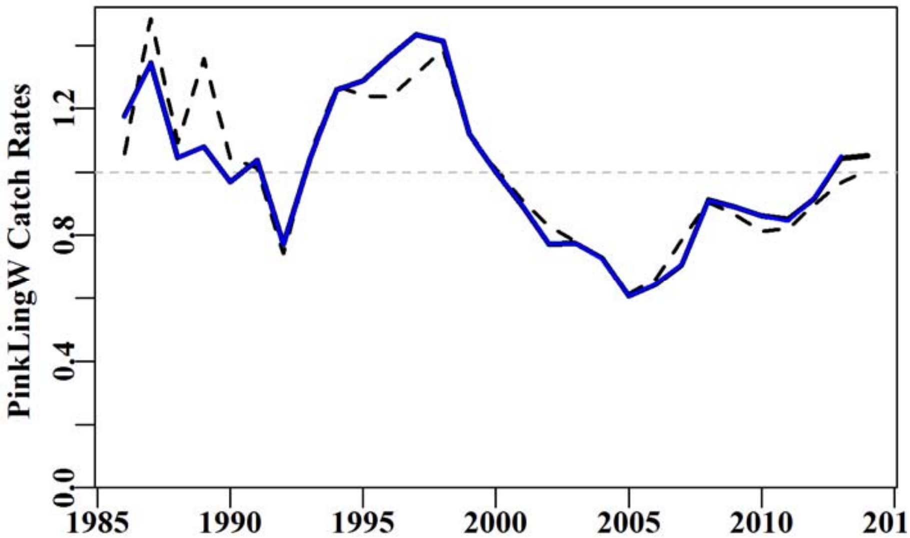


Figure 20.107. Pink Ling from zones 40 and 50 in depths between 200 – 800 m by Trawl. The dashed black line represents the geometric mean catch rate and the solid black line the standardized catch rates (relative to the mean of the standardized catch rates). The blue line corresponds to last year's standardized catch rates.

Table 20.95. 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 20.96. 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	230	-10569	-16965	-19517	-20488	-20516	-21953	-21307
RSS	77087	66454	60967	58948	58202	58176	57076	57532
MSS	3901	14534	20021	22040	22786	22811	23912	23456
Nobs	76915	76427	76427	76427	76427	76427	76427	76427
Npars	29	59	154	165	166	169	180	199
adj_R^2	4.782	17.884	24.570	27.057	27.979	28.008	29.359	28.778
%Change	0.000	13.102	6.686	2.488	0.922	0.029	1.351	-0.582

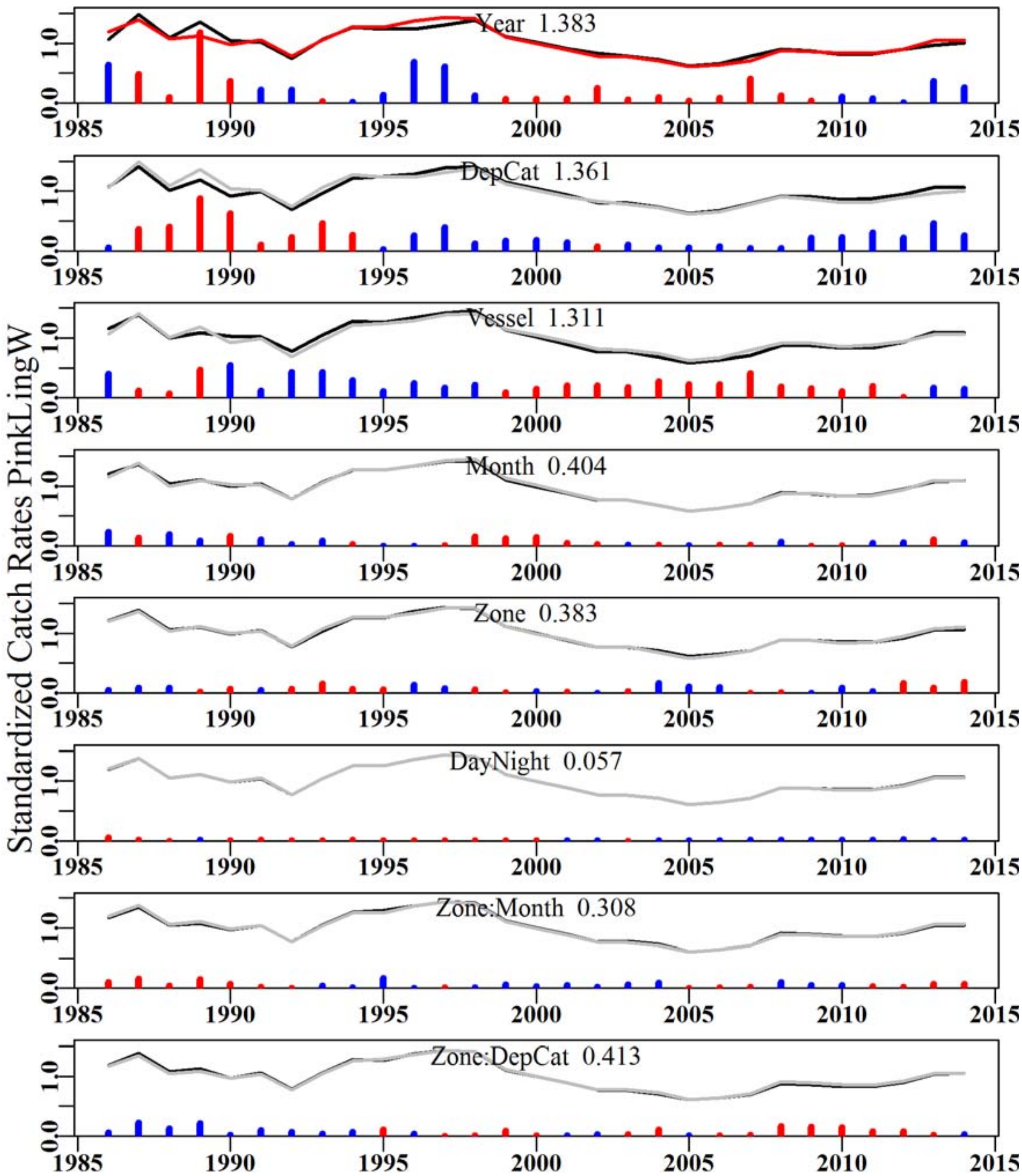


Figure 20.108. The relative influence of each factor used on the final trend in the optimal standardization for Pink Ling from zones 40 and 50. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by the vertical bars with 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.

20.4.34 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 20.97. 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	2.2129	0.0000
1987	4660.4470	1280	261.6060	29	30.7446	2.1725	0.0461
1988	3515.8190	1399	255.4090	36	25.3713	1.9874	0.0483
1989	1778.3250	1396	184.4330	37	19.1431	1.5344	0.0492
1990	1206.8970	1241	145.5200	35	14.4402	1.3463	0.0531
1991	580.3220	1568	279.2890	32	19.1549	1.3248	0.0497
1992	494.4410	799	96.8810	21	15.1631	0.9839	0.0569
1993	353.4100	896	108.2890	21	11.5326	0.8453	0.0559
1994	232.1790	1041	109.8960	24	11.4211	0.8717	0.0535
1995	181.7460	1285	106.8040	26	9.1790	0.8231	0.0512
1996	382.1960	1573	161.7360	32	9.5346	0.9546	0.0493
1997	571.9758	2088	214.0380	28	8.9720	0.8539	0.0473
1998	404.8147	1958	206.7570	26	10.2560	1.0340	0.0481
1999	448.6767	2337	322.9730	24	12.0677	1.0322	0.0470
2000	336.4642	2325	260.6825	30	9.7749	0.8701	0.0475
2001	331.4862	2326	258.4500	30	10.0470	0.8116	0.0475
2002	195.8983	1746	128.4288	28	6.4820	0.6205	0.0493
2003	267.9710	1612	201.0612	33	8.8661	0.6896	0.0501
2004	568.8517	1931	478.0203	30	10.6711	0.7442	0.0500
2005	511.7585	1796	368.5067	27	12.7461	0.7322	0.0507
2006	544.8936	1591	434.7029	26	11.9765	0.6903	0.0517
2007	599.1098	1380	415.0929	21	11.0165	0.6369	0.0526
2008	294.8605	1225	155.5205	19	6.7358	0.6458	0.0533
2009	194.8654	1255	104.8607	16	5.8844	0.6952	0.0529
2010	220.6510	1663	127.5651	18	6.1259	0.7406	0.0504
2011	147.7397	1258	73.2852	16	5.7047	0.7386	0.0531
2012	168.5996	1028	99.0475	18	6.4842	0.8006	0.0564
2013	103.8201	684	47.0844	20	6.4821	0.6889	0.0615
2014	130.1963	737	75.7350	15	9.6721	0.9181	0.0606

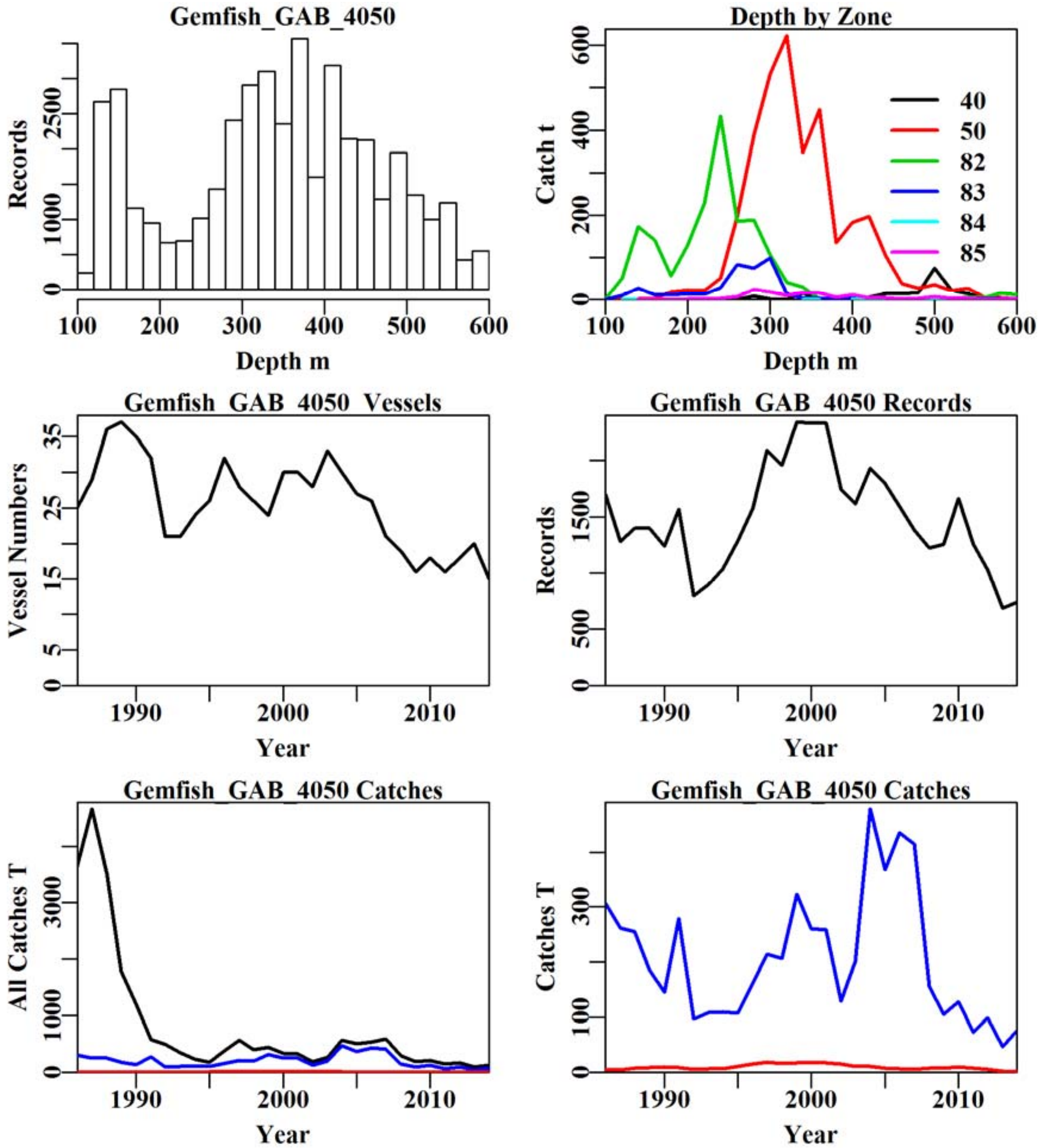


Figure 20.109. Western Gemfish from zones 40 and 50, and the GAB (zones 82, 83, 84, and 85) in depths between 100 – 600 m by Trawl. The top left plot depicts the depth distribution of shots containing Western Gemfish from zones 40 and 50, and the GAB (zones 82, 83, 84, and 85) in depths 100 – 600 m by 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).

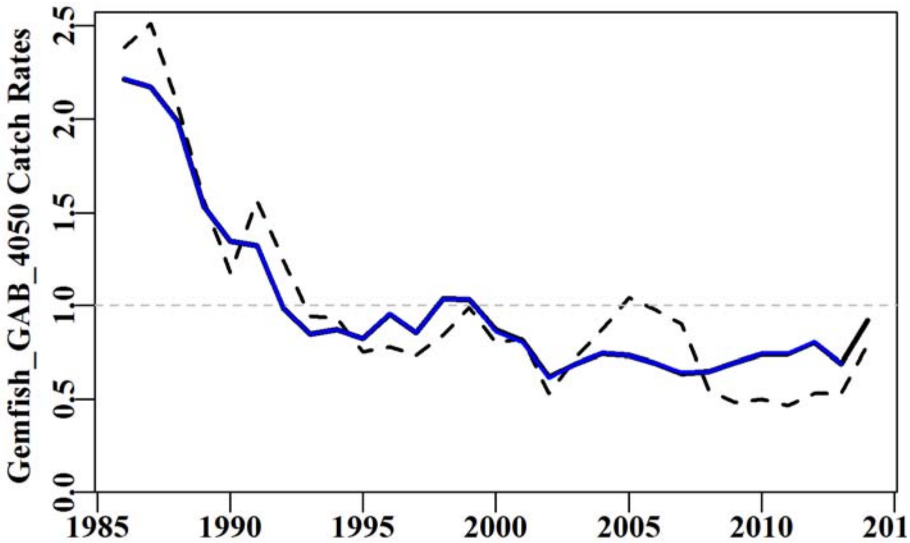


Figure 20.110. Western Gemfish from zones 40 and 50, and the GAB (zones 82, 83, 84, and 85) in depths between 100 – 600 m by Trawl. The dashed black line represents the geometric mean catch rate, solid black line the standardized catch rates and solid blue line the standardized catch rates from last year's analysis. The graph standardizes catch rates relative to the mean of the standardized catch rates.

Table 20.98. 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 20.99. 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	36705	23052	15597	14779	14039	13609	12527	12980
RSS	100873	73261	61273	60103	59067	58449	56849	57265
MSS	8287	35900	47887	49058	50093	50712	52311	51896
Nobs	43116	42931	42931	42931	42931	42931	42931	42931
Npars	29	54	162	167	170	181	236	306
adj_R^2	7.532	32.804	43.657	44.727	45.676	46.231	47.635	47.165
%Change	0.000	25.272	10.853	1.070	0.948	0.555	1.404	-0.470

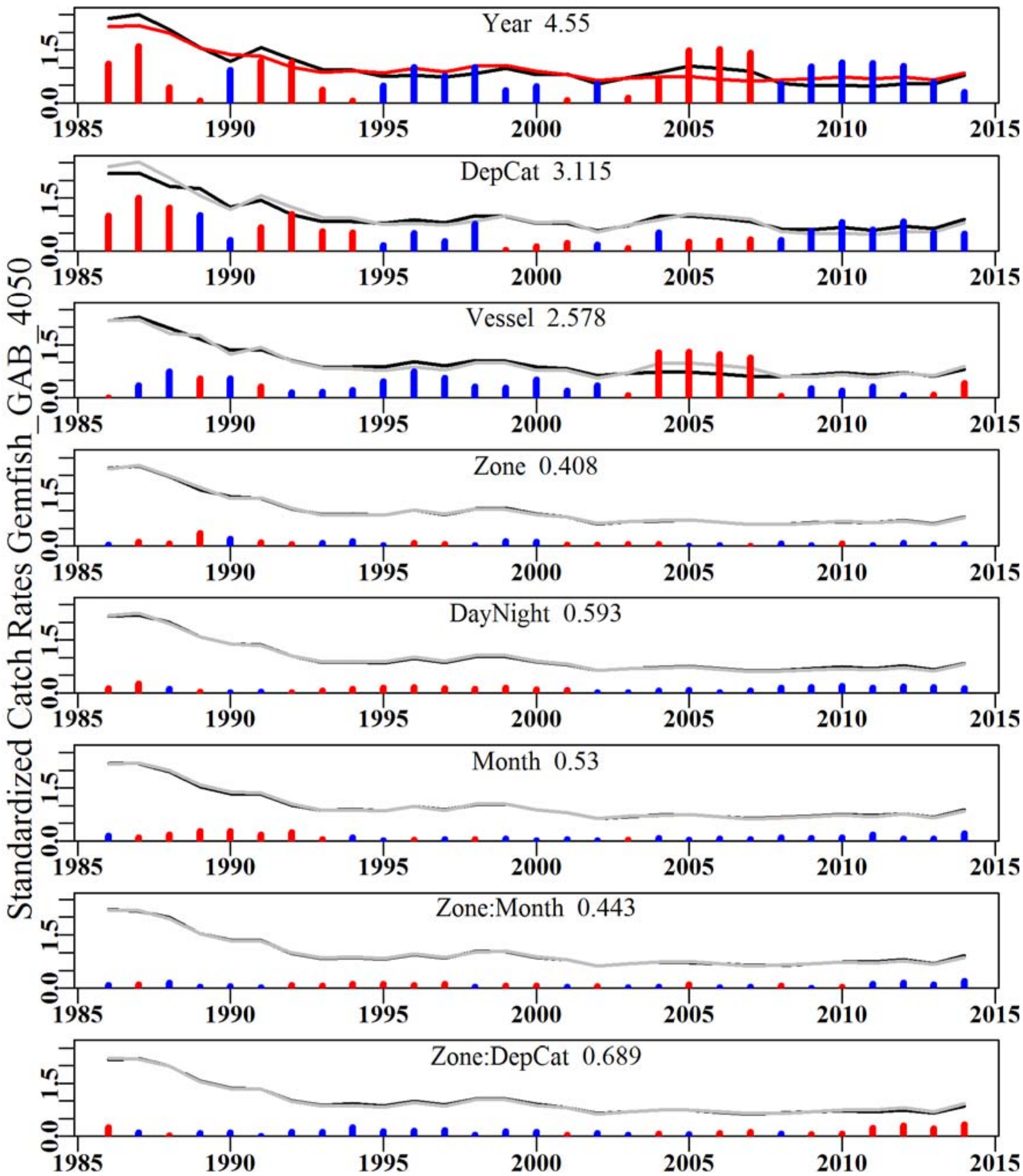


Figure 20.111. The relative influence of each factor used on the final trend in the optimal standardization for Western Gemfish from zones 40 and 50 and the GAB. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by the vertical 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.

20.4.35 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 20.100. 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	2.2831	0
1987	4660.4470	1209	248.8790	26	31.5896	2.2967	0.0452
1988	3515.8190	1235	226.9560	27	26.9924	2.2443	0.0474
1989	1778.3250	1082	156.5780	29	23.3363	1.8366	0.0497
1990	1206.8970	1057	136.0850	29	15.9031	1.4122	0.0529
1991	580.3220	1384	249.4150	28	22.0062	1.3583	0.0494
1992	494.4410	665	80.9300	15	16.7792	0.9510	0.0577
1993	353.4100	718	102.4890	17	16.5820	0.9218	0.0571
1994	232.1790	839	95.3780	20	16.2263	0.9945	0.0544
1995	181.7460	990	84.6880	21	12.0017	0.8744	0.0520
1996	382.1960	1182	145.5880	26	13.4563	0.9517	0.0500
1997	571.9758	1389	153.5890	21	13.2702	0.8521	0.0485
1998	404.8147	1259	121.6610	20	13.2167	0.9181	0.0499
1999	448.6767	1694	176.3230	19	12.8407	0.8753	0.0475
2000	336.4642	1933	228.9645	28	12.5253	0.9223	0.0475
2001	331.4862	1711	170.7050	27	12.1527	0.7450	0.0484
2002	195.8983	1418	85.6338	24	7.1142	0.5656	0.0496
2003	267.9710	1076	122.4803	24	11.1647	0.6716	0.0522
2004	568.8517	1232	105.5549	24	7.9006	0.6554	0.0522
2005	511.7585	1073	117.6765	18	10.5982	0.6852	0.0533
2006	544.8936	889	101.4170	18	8.9869	0.5554	0.0560
2007	599.1098	715	61.0609	16	7.4736	0.5340	0.0583
2008	294.8605	770	53.0883	16	7.5204	0.6046	0.0572
2009	194.8654	925	56.8320	12	6.4884	0.6818	0.0546
2010	220.6510	1364	86.8772	14	6.3620	0.7075	0.0507
2011	147.7397	1158	57.9422	13	5.6504	0.7441	0.0526
2012	168.5996	820	50.6973	14	5.3756	0.6902	0.0581
2013	103.8201	582	38.7114	15	5.5759	0.6056	0.0625
2014	130.1963	614	57.8020	13	8.3346	0.8619	0.0618

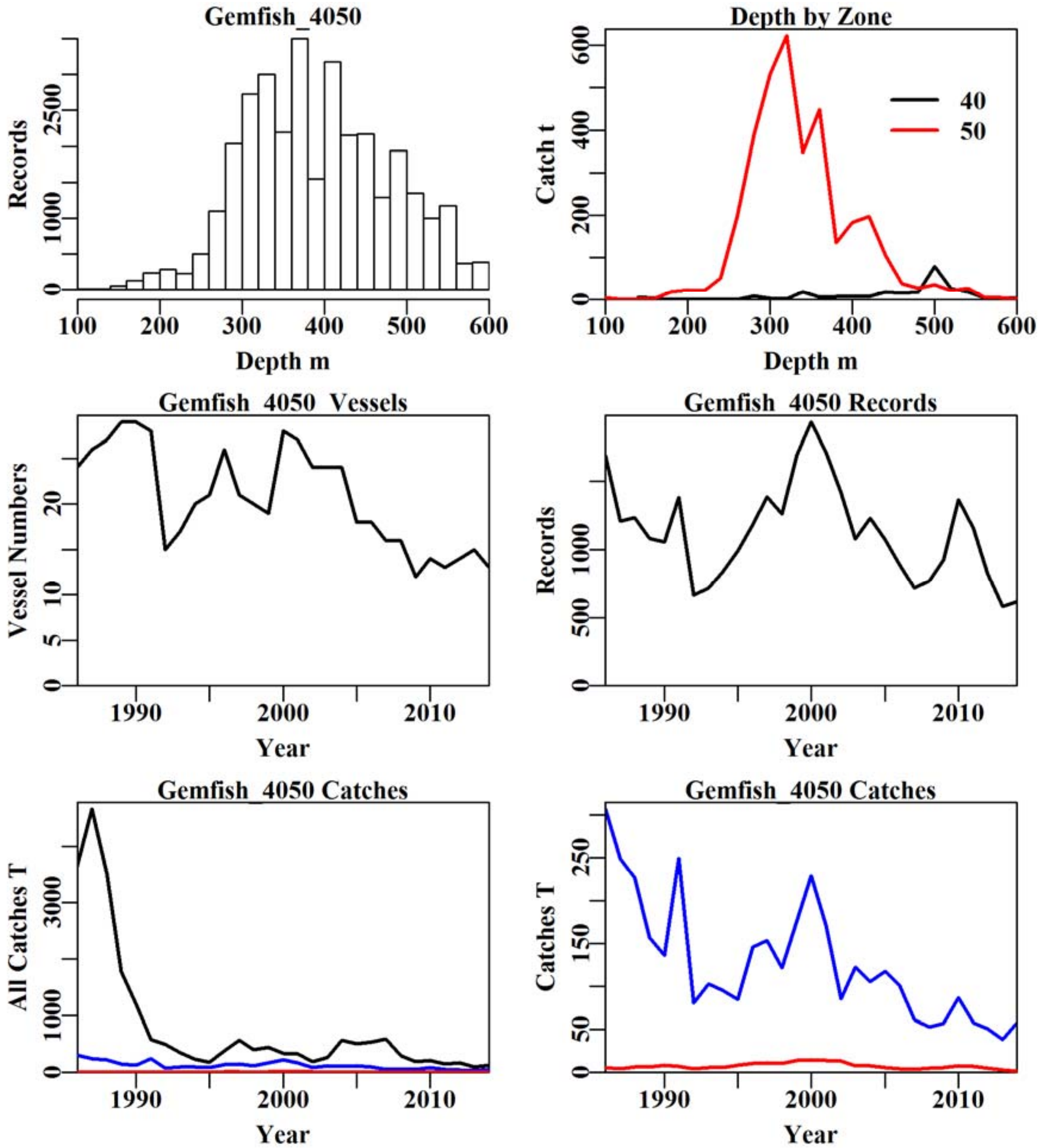


Figure 20.112. Western Gemfish from zones 40 and 50 in depths between 100 – 600 m by Trawl. The top left plot depicts the depth distribution of shots containing Western Gemfish from zones 40 and 50 in depths 100 – 600 m by Trawl. The top right plot depicts the catch distribution by depth by zone. The 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).

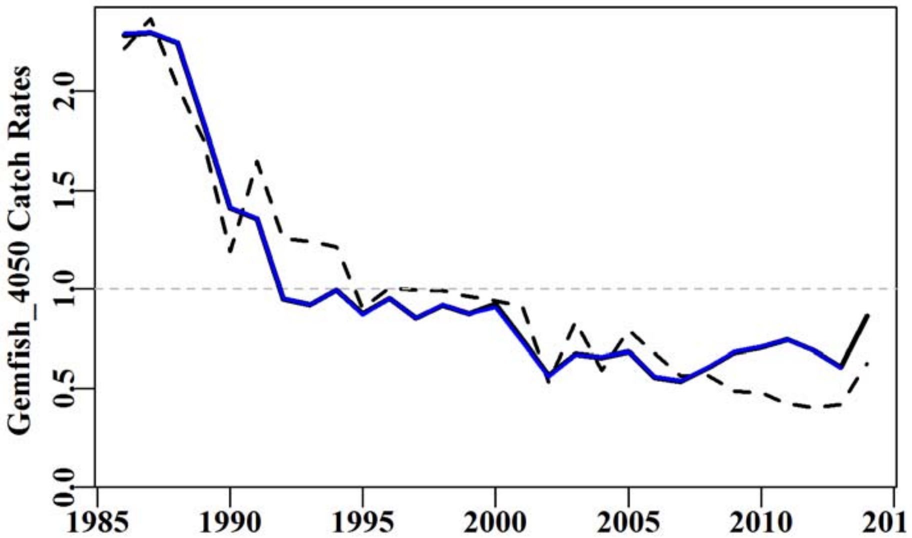


Figure 20.113. Western Gemfish from zones 40 and 50 in depths between 100 – 600 m by Trawl. The dashed black line represents the geometric mean catch rate, solid black line the standardized catch rates and solid blue line standardized catch rates from last year's analysis. The graph standardizes catch rates relative to the mean of the standardized catch rates.

Table 20.101. 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 20.102. 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	22116	14549	8058	7488	7208	7207	6874	6985
RSS	64175	50622	41302	40577	40202	40198	39761	39863
MSS	8184	21737	31057	31782	32157	32161	32598	32496
Nobs	32670	32670	32530	32530	32530	32530	32530	32530
Npars	29	121	146	149	160	161	172	186
adj_R^2	11.234	29.783	42.665	43.667	44.168	44.172	44.760	44.594
%Change	0.000	18.549	12.882	1.001	0.501	0.004	0.588	-0.165

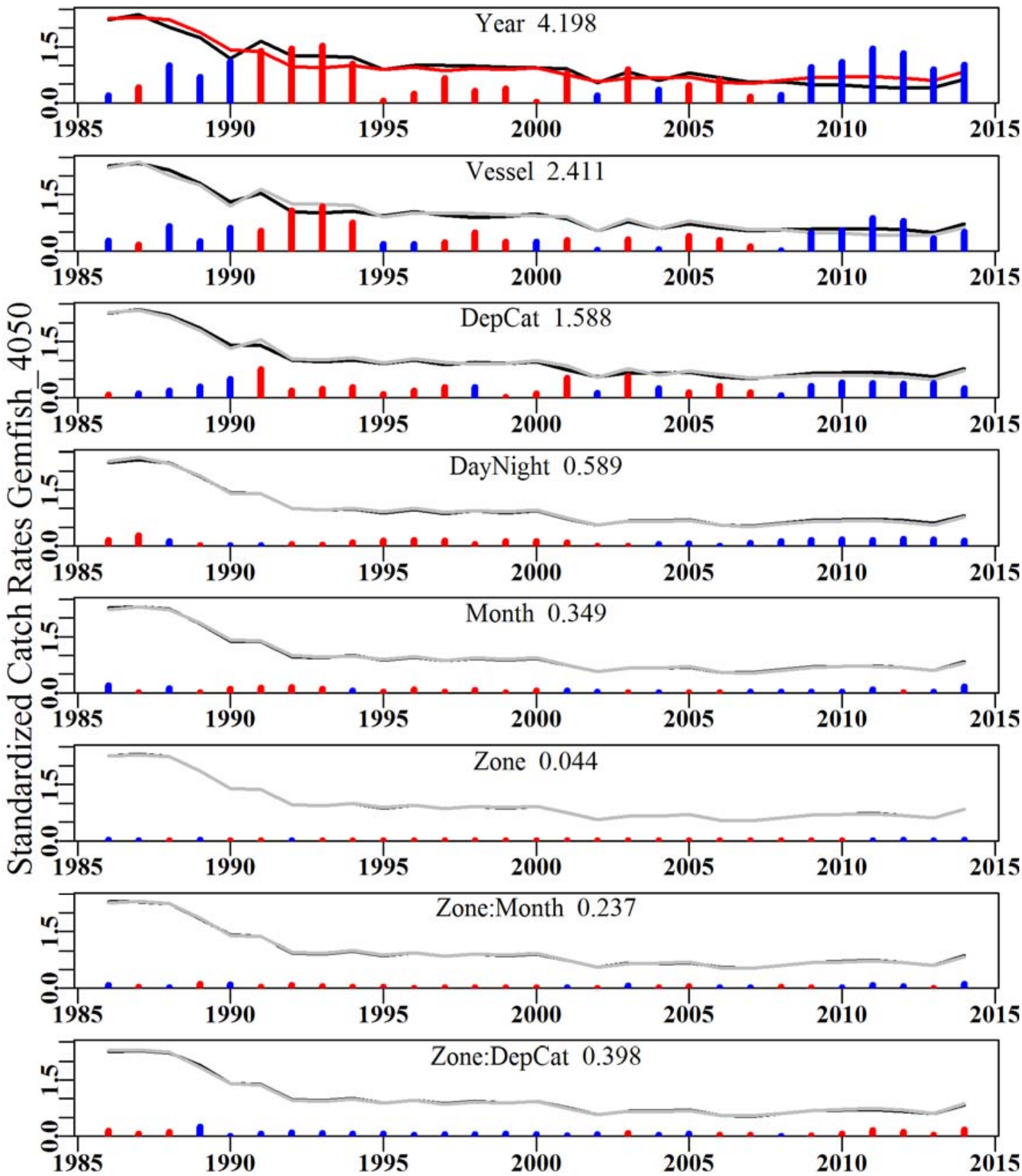


Figure 20.114. The relative influence of each factor used on the final trend in the optimal standardization for Western Gemfish from zones 40 and 50. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by the vertical bars 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.

20.4.36 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 20.103. 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	0.6953	0.0000
1996	382.1960	449	19.2390	7	3.8858	0.9097	0.0932
1997	571.9758	717	61.7730	9	4.2096	0.9131	0.0885
1998	404.8147	708	85.2200	8	6.3801	1.4763	0.0904
1999	448.6767	653	146.9330	7	10.0539	1.7725	0.0931
2000	336.4642	427	32.1620	6	2.8433	0.6429	0.0988
2001	331.4862	669	90.2810	8	5.7470	1.0753	0.0928
2002	195.8983	353	43.3413	8	4.3575	0.9299	0.1018
2003	267.9710	565	79.3545	11	5.4980	0.8539	0.0973
2004	568.8517	720	372.9160	10	17.0005	1.1103	0.0974
2005	511.7585	743	253.8402	10	16.0998	0.9336	0.0988
2006	544.8936	709	333.2422	11	16.7217	0.9582	0.0976
2007	599.1098	697	358.0045	10	15.2782	0.8431	0.0960
2008	294.8605	495	104.3260	7	5.4956	0.8335	0.0980
2009	194.8654	350	48.9613	4	4.5291	0.7808	0.1044
2010	220.6510	339	42.6375	4	4.9524	0.8576	0.1049
2011	147.7397	218	20.2225	4	5.2479	0.8314	0.1174
2012	168.5996	305	52.2863	5	9.0568	1.2877	0.1089
2013	103.8201	148	9.6908	6	8.7733	1.1591	0.1322
2014	130.1963	167	19.1975	5	12.5092	1.1357	0.1363

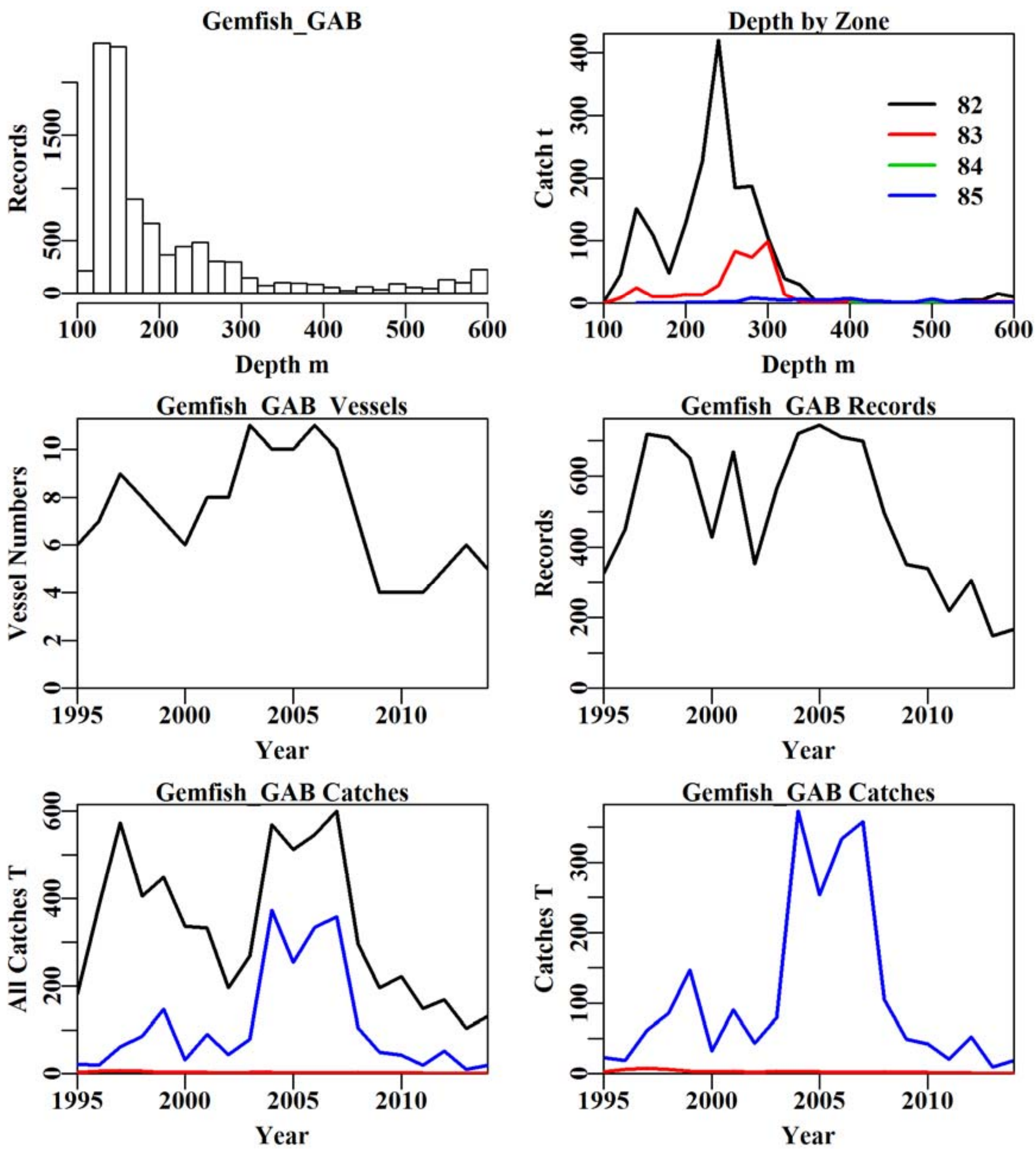


Figure 20.115. Western Gemfish in the GAB (zones 82, 83, 84, and 85) in depths between 100 and 600 m by Trawl. The top left plot depicts the depth distribution of shots containing Western Gemfish from zones in the GAB (zones 82, 83, 84, and 85) in depths 100 – 600 m by Trawl. The top right plot depicts 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).

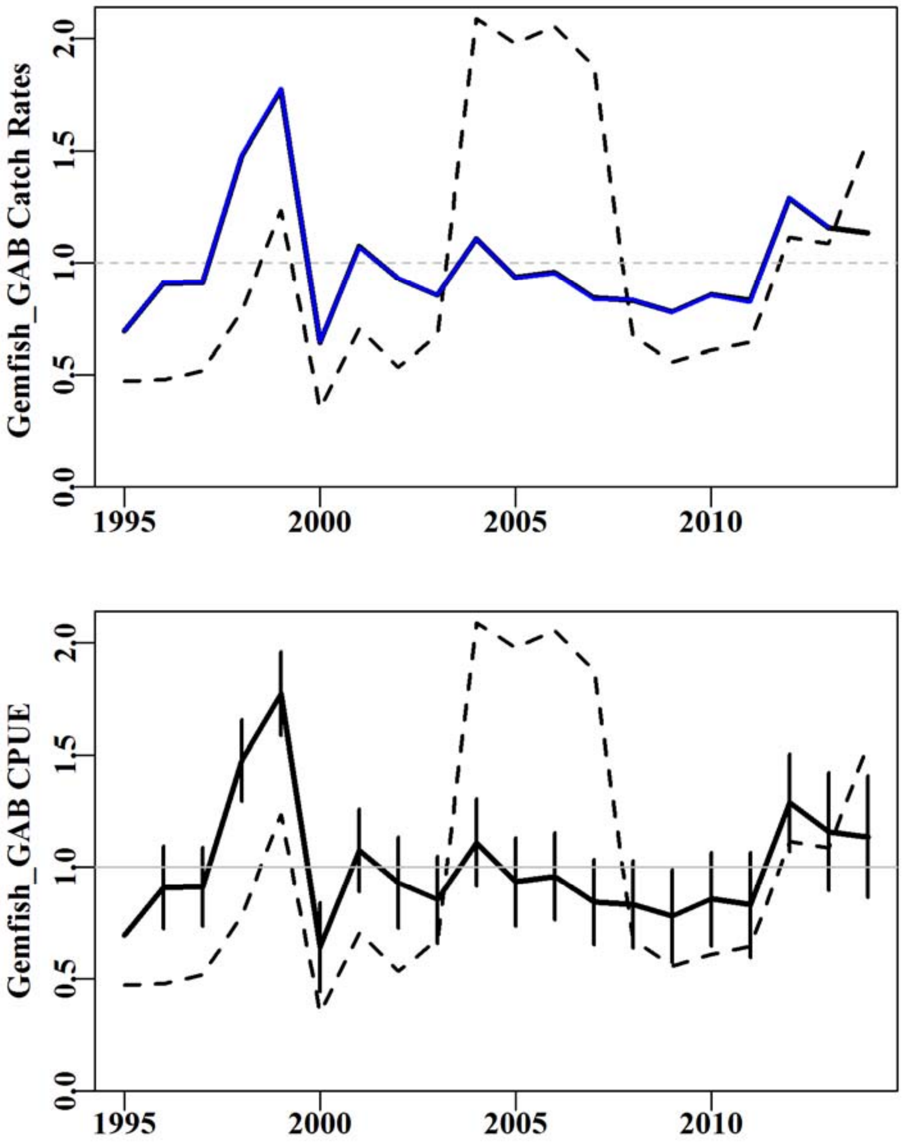


Figure 20.116. Western Gemfish in the GAB (zones 82, 83, 84, and 85) in depths between 100 and 600 m by Trawl. Upper graph: The dashed black line represents the geometric mean catch rate and the solid black line the standardized catch rates (relative to the mean of the standardized catch rates). The blue line corresponds to last year's standardized indices. Lower graph: Standardized indices (solid black line), 95% CI (vertical lines) and geometric mean (dashed black line). The graph standardizes catch rates relative to the mean of the standardized catch rates.

Table 20.104. 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 20.105. 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	11001	7120	5707	5035	4762	4531	4244	4478
RSS	30004	20031	17224	16037	15583	15208	14664	14893
MSS	3263	13236	16043	17230	17684	18059	18603	18374
Nobs	9758	9716	9716	9716	9716	9716	9716	9716
Npars	20	45	72	83	86	89	122	164
adj_R^2	9.633	39.514	47.844	51.384	52.745	53.867	55.364	54.468
%Change	0.000	29.881	8.330	3.540	1.361	1.123	1.496	-0.896

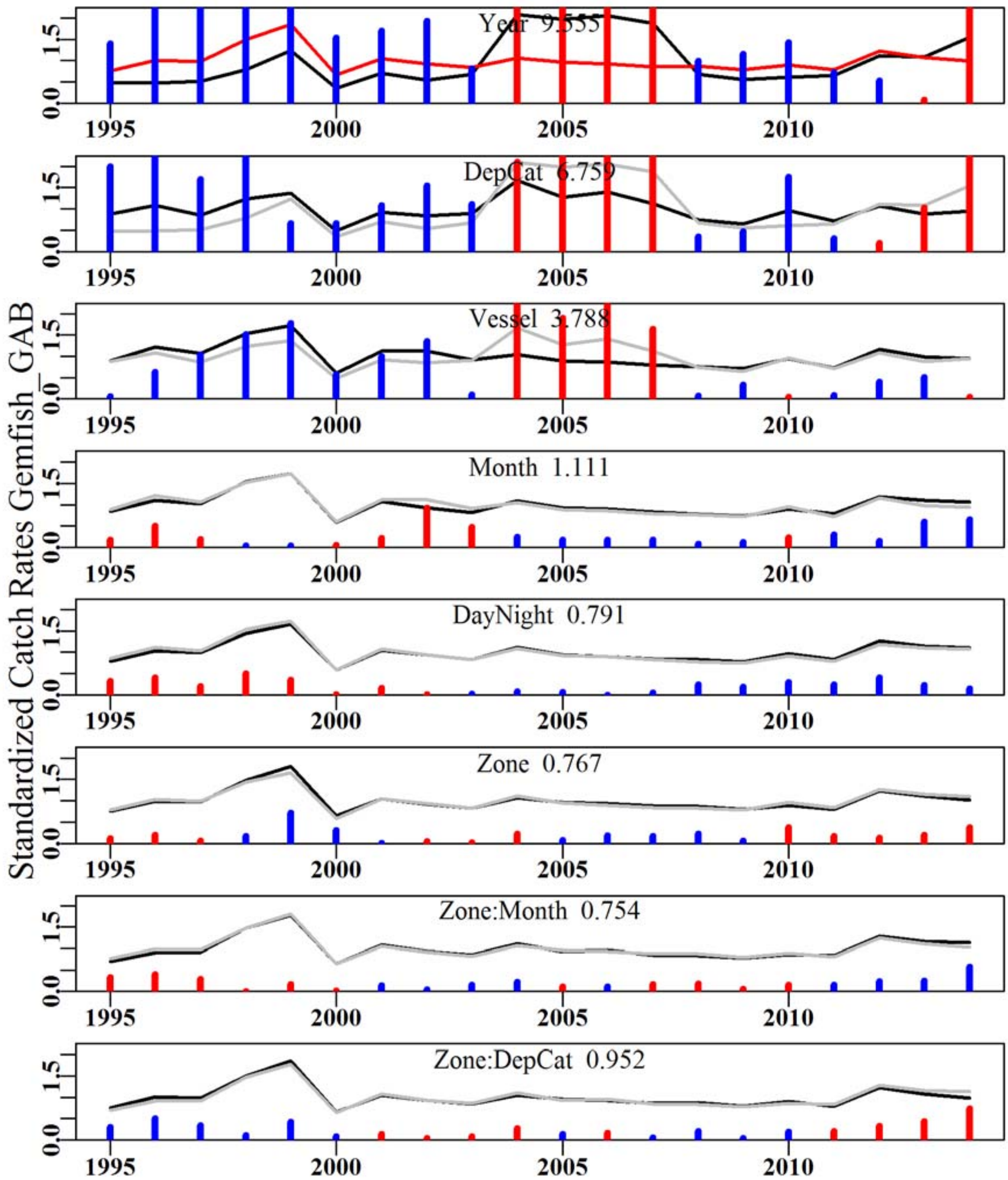


Figure 20.117. The relative influence of each factor used on the final trend in the optimal standardization for Western Gemfish in the GAB (zones 82, 83, 84, and 85). The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by 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.

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

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

Table 20.106. 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	1.0291	0.0000
1987	198.3470	3140	132.7970	70	8.9237	0.9543	0.0256
1988	186.7120	2808	150.7650	73	10.5074	1.0669	0.0266
1989	206.2580	3036	160.0040	67	10.6494	1.0227	0.0265
1990	180.5600	1970	115.9430	57	12.0207	1.3619	0.0298
1991	223.1880	2093	138.9910	53	13.4339	1.4377	0.0294
1992	169.6690	1852	114.2990	48	11.9053	1.2151	0.0303
1993	259.3100	2924	199.1860	53	12.9555	1.2175	0.0270
1994	257.2410	3014	180.9550	49	11.8001	1.1366	0.0267
1995	239.9510	3146	150.3410	50	10.4874	1.0293	0.0265
1996	263.2350	3411	176.8080	53	9.8364	0.9225	0.0260
1997	296.3336	3725	193.7730	54	9.7119	0.9797	0.0258
1998	292.0978	3850	194.6290	49	9.4285	0.8673	0.0255
1999	290.6426	4406	219.0650	52	9.7566	0.9741	0.0253
2000	269.8270	4180	180.9002	54	7.5503	0.7764	0.0257
2001	281.5414	4063	184.8160	44	8.3993	0.8755	0.0259
2002	255.3073	3648	150.6642	46	7.3691	0.8300	0.0266
2003	322.7355	3960	185.0060	54	7.6242	0.8836	0.0263
2004	316.1390	3129	150.4585	47	8.0648	0.8823	0.0277
2005	316.7690	3089	170.0795	47	9.3641	0.9897	0.0276
2006	237.6008	2326	113.1680	40	7.8433	0.8481	0.0295
2007	180.5792	1528	94.9000	23	9.9183	1.0614	0.0332
2008	184.2667	1843	101.8360	24	9.1917	0.9746	0.0318
2009	173.8793	1694	99.6075	24	9.0355	0.9706	0.0327
2010	195.5993	1759	118.1070	22	9.8647	0.9797	0.0322
2011	186.7935	1874	116.6955	23	9.0998	0.8682	0.0317
2012	180.5639	1693	114.1412	23	9.9671	0.9323	0.0325
2013	166.4426	1232	100.1720	21	12.0121	0.9701	0.0357
2014	141.1829	1011	85.1520	18	11.7901	0.9429	0.0380

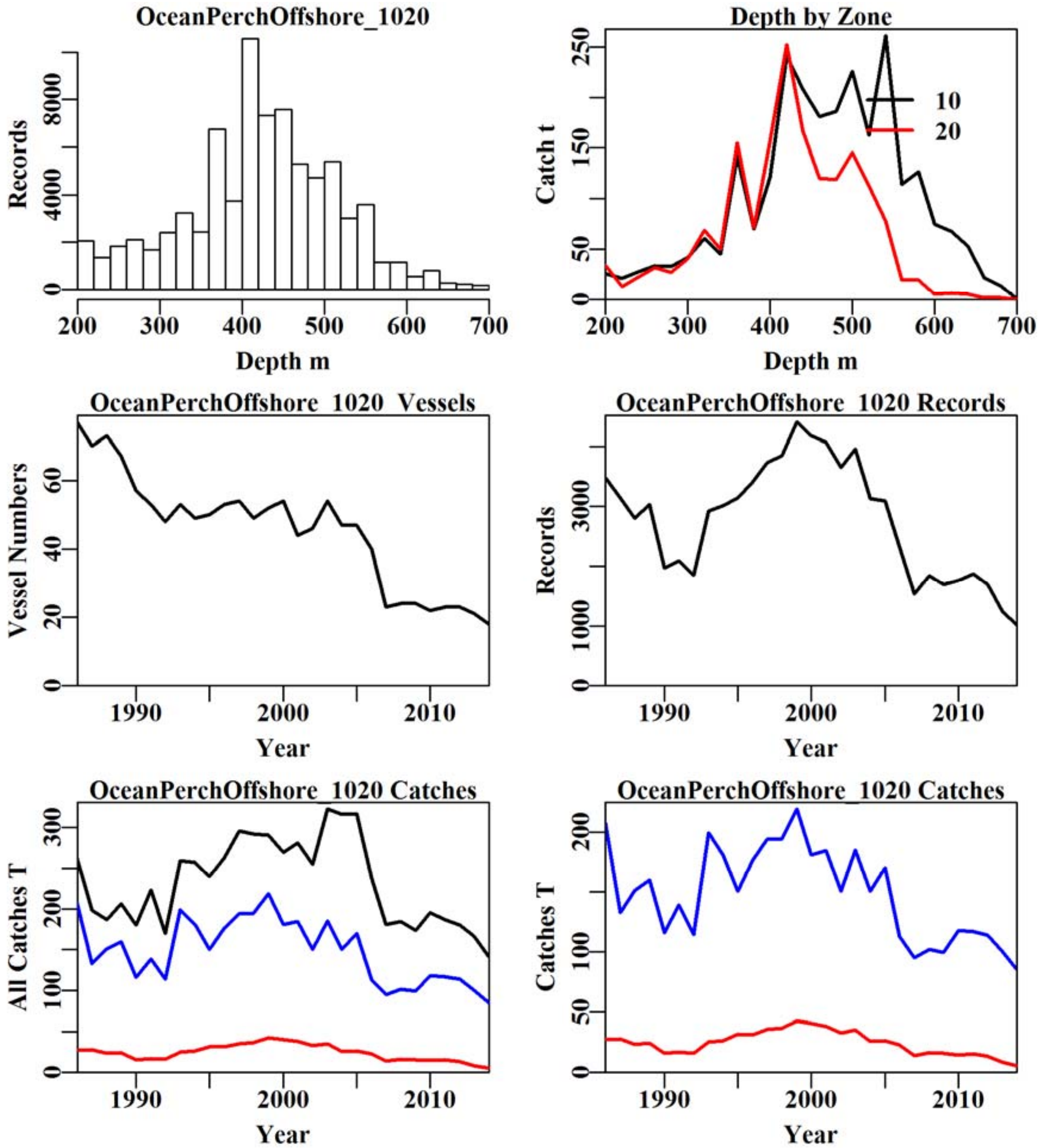


Figure 20.118. Offshore Ocean Perch from zones 10 and 20 in depths 200 – 700 m by Trawl. The top left plot depicts the depth distribution of shots containing Offshore Ocean Perch from zones 10 and 20 in depths 200 – 700m by Trawl. The top right plot depicts the catch distribution by depth by zone. The 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).

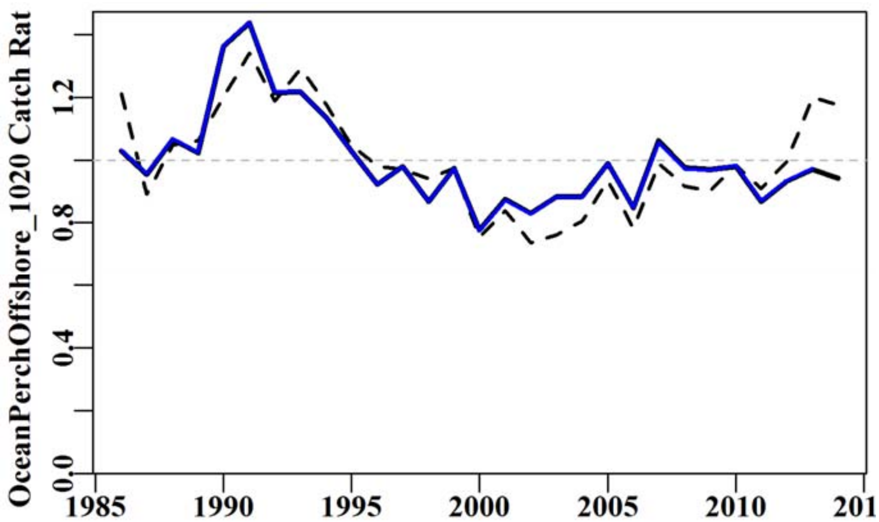


Figure 20.119. Offshore Ocean Perch from zones 10 and 20 in depths 200 – 700 m by Trawl. The dashed black line represents the geometric mean catch rate, solid black line the standardized catch rates and solid blue line standardized catch rates from last year's analysis. The graph standardizes catch rates relative to the mean of the standardized catch rates.

Table 20.107. 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 20.108. 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	23258	11020	2222	-27	-252	-289	-2360	-655
RSS	106804	91157	81280	78990	78762	78723	76676	78311
MSS	2200	17847	27724	30013	30242	30281	32327	30693
Nobs	79883	79460	79460	79460	79460	79460	79460	79460
Npars	29	54	211	222	225	226	237	251
adj_R^2	1.984	16.317	25.236	27.332	27.540	27.575	29.448	27.931
%Change	0.000	14.333	8.919	2.096	0.208	0.035	1.873	-1.517

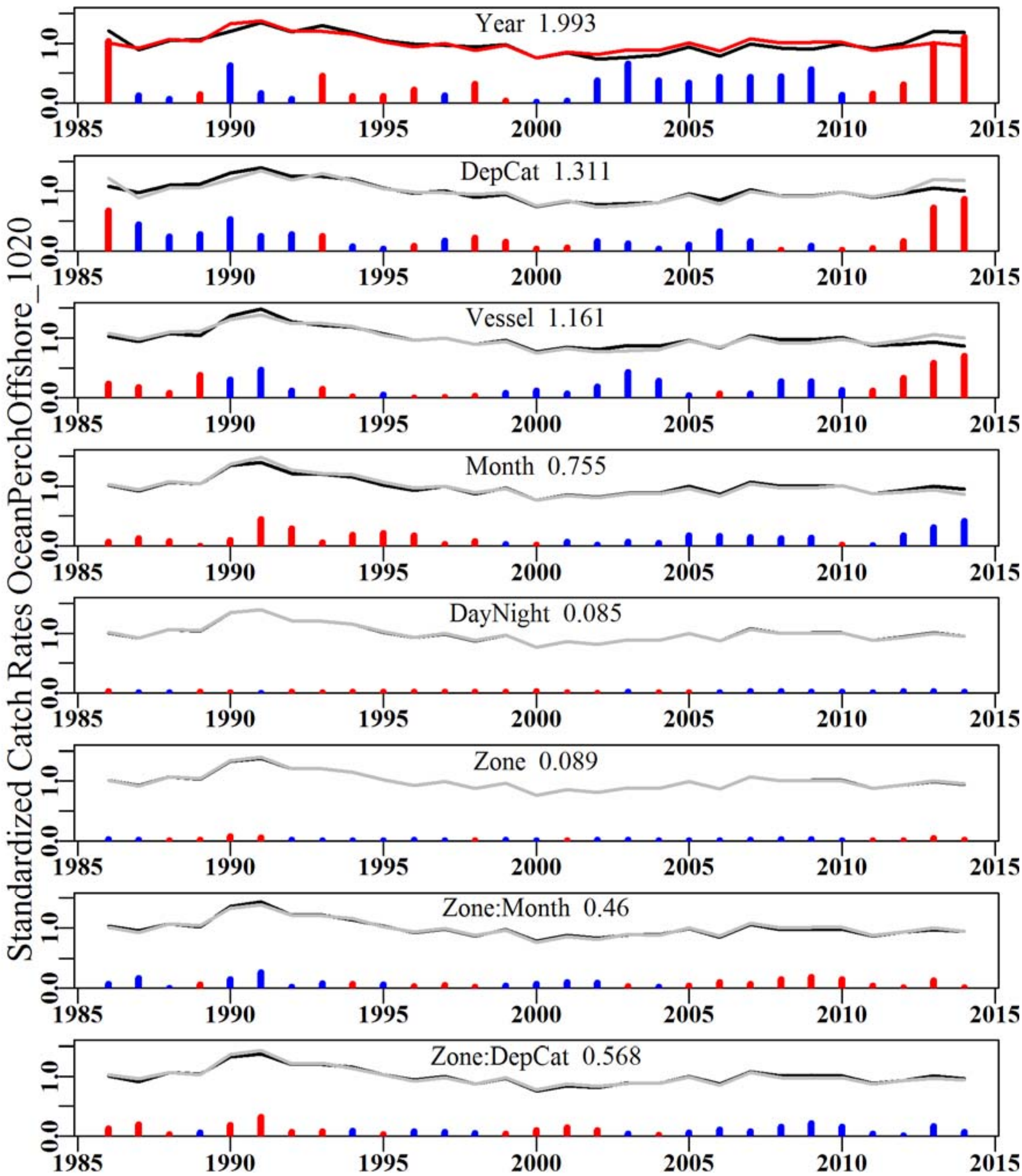
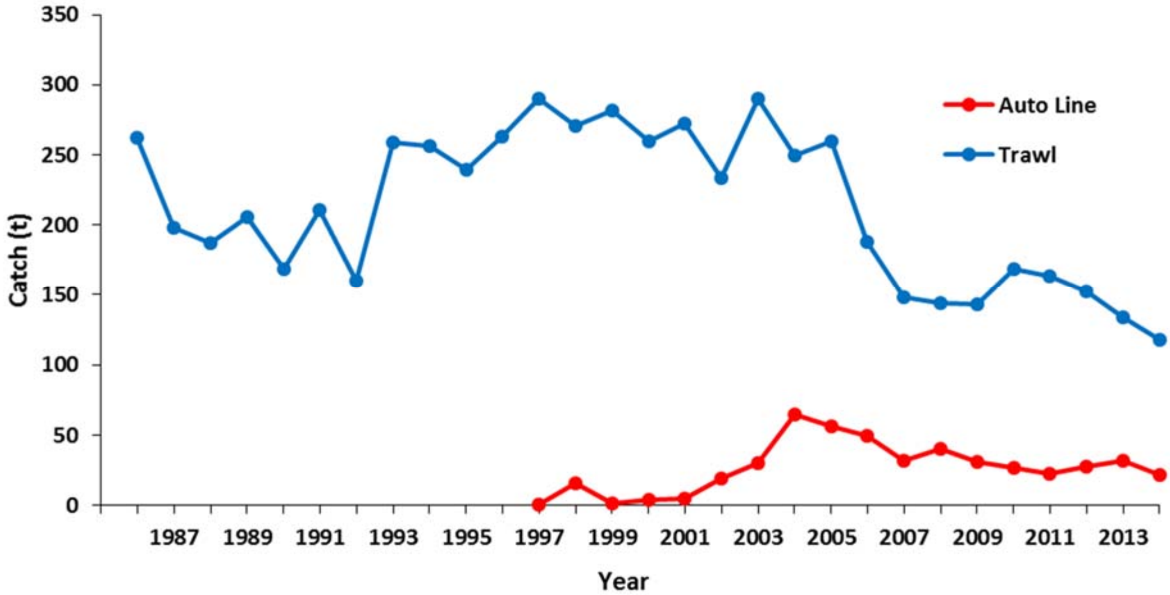


Figure 20.120. The relative influence of each factor used on the final trend in the optimal standardization for Offshore Ocean Perch from zones 10 and 20. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by the vertical 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.



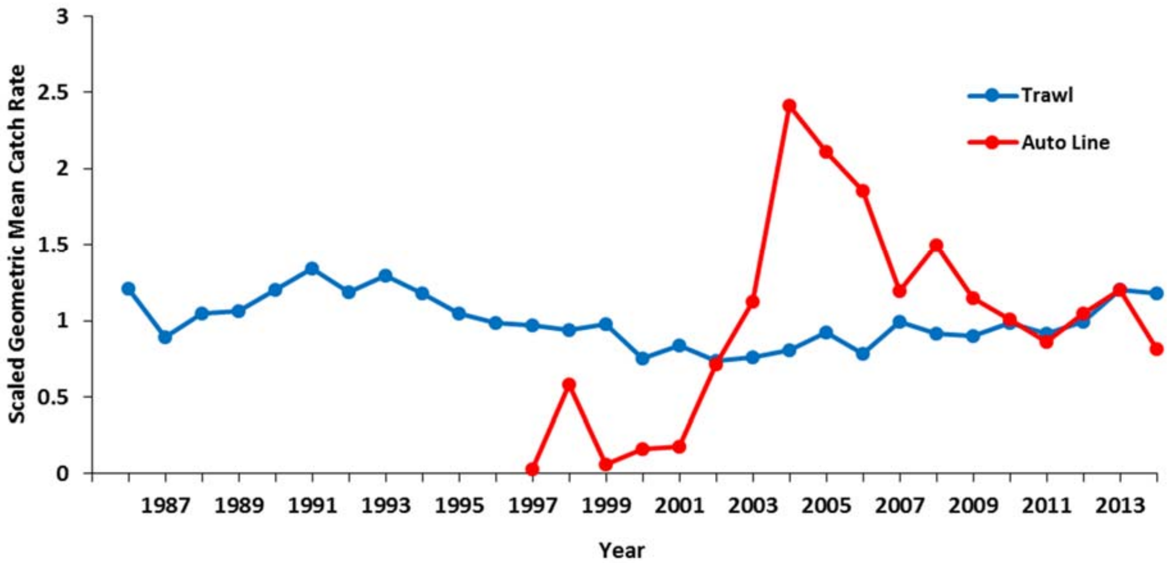


Figure 20.121. Offshore Ocean Perch, depths > 200 m for Trawl and Auto Line, in zones 10 and 20 between 1986 and 2013. Upper plot: Catches through time taken by Trawl and by Auto Line. Some of the decline in trawl catches in recent years have been made up by the Auto Long Lining. Lower plot: Geometric 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.

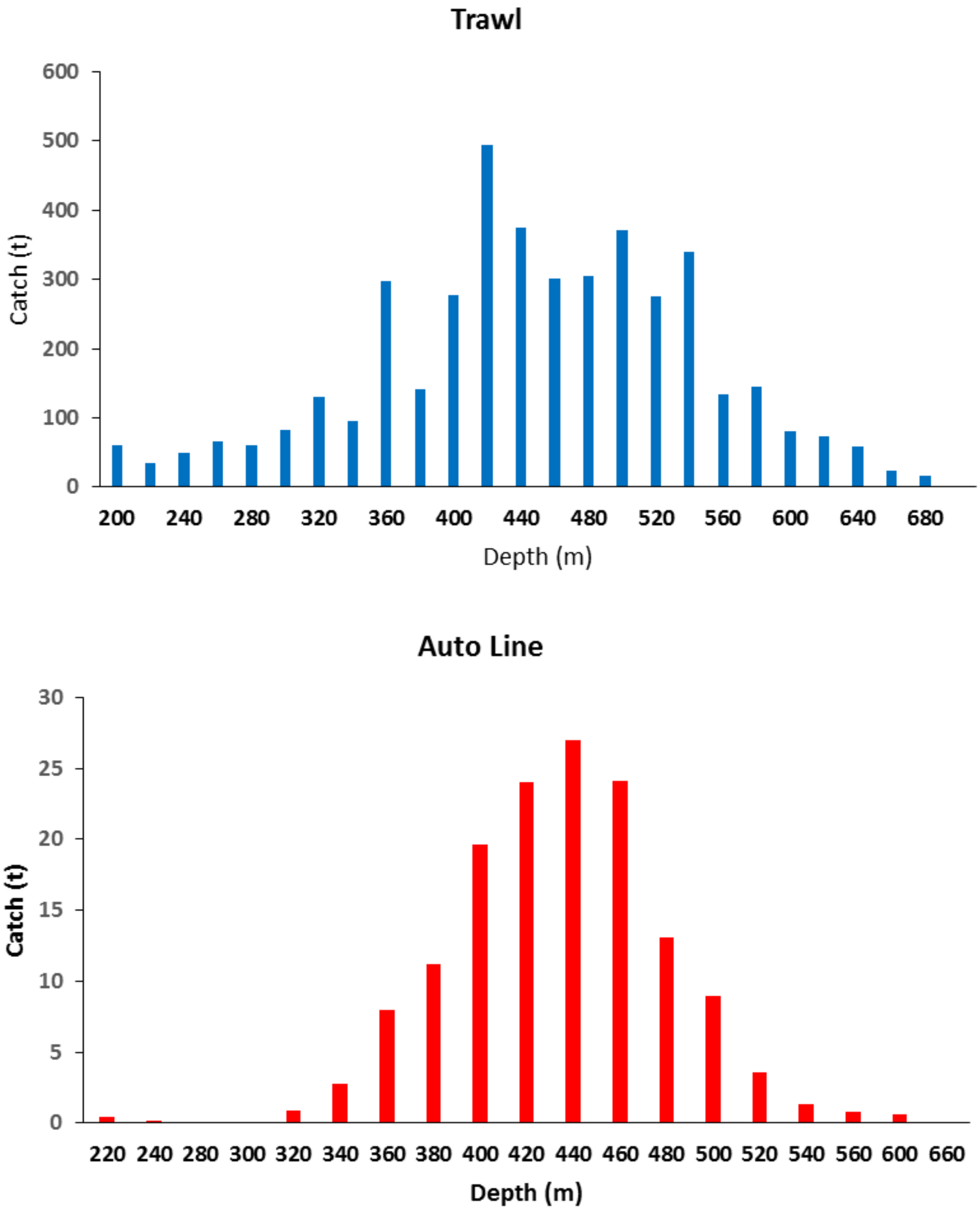


Figure 20.122. Depth distribution of catches of Offshore Ocean Perch, depths 200 – 700 m for Trawl and Auto Line between 1986 and 2014. Most catches by Auto Line are taken in the same depths as trawl catches.

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

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 20.109. 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	0.8516	0.0000
1987	198.3470	406	11.9710	58	5.9511	0.9946	0.0920
1988	186.7120	518	16.5480	59	7.2891	1.1370	0.0885
1989	206.2580	443	15.3920	52	8.0367	1.0928	0.0925
1990	180.5600	450	15.6140	45	7.7738	1.1649	0.0937
1991	223.1880	498	20.3640	43	8.1374	1.2790	0.0926
1992	169.6690	266	14.1700	29	9.5074	1.7456	0.1037
1993	259.3100	467	25.0800	38	10.1873	1.9356	0.0957
1994	257.2410	558	23.3400	35	9.4326	1.7823	0.0926
1995	239.9510	600	21.2000	35	8.7548	1.3088	0.0902
1996	263.2350	688	21.3070	39	7.0539	1.1607	0.0898
1997	296.3336	572	16.3650	40	5.9056	1.0811	0.0925
1998	292.0978	646	15.6280	41	5.7524	0.9471	0.0911
1999	290.6426	675	15.9780	40	4.9974	0.8543	0.0903
2000	269.8270	1328	30.5851	39	4.5758	1.0111	0.0862
2001	281.5414	1047	23.5030	35	4.2030	0.9960	0.0878
2002	255.3073	1423	25.1900	37	2.6158	0.7140	0.0867
2003	322.7355	1086	17.5878	41	2.3189	0.5621	0.0875
2004	316.1390	962	15.4615	42	2.2440	0.5626	0.0892
2005	316.7690	898	19.8485	41	2.9880	0.6352	0.0898
2006	237.6008	602	9.3385	35	2.2501	0.5271	0.0930
2007	180.5792	395	8.7450	21	3.5455	0.7409	0.0995
2008	184.2667	330	7.9690	21	4.2486	0.9186	0.1031
2009	173.8793	289	6.6710	22	4.1335	0.7998	0.1066
2010	195.5993	308	7.1410	21	3.8309	0.8357	0.1051
2011	186.7935	275	6.4305	19	3.6642	0.9657	0.1078
2012	180.5639	392	8.0761	20	3.5117	0.7986	0.1001
2013	166.4426	218	4.8494	14	4.4457	0.9586	0.1098
2014	141.1829	139	2.8575	15	3.8026	0.6388	0.1230

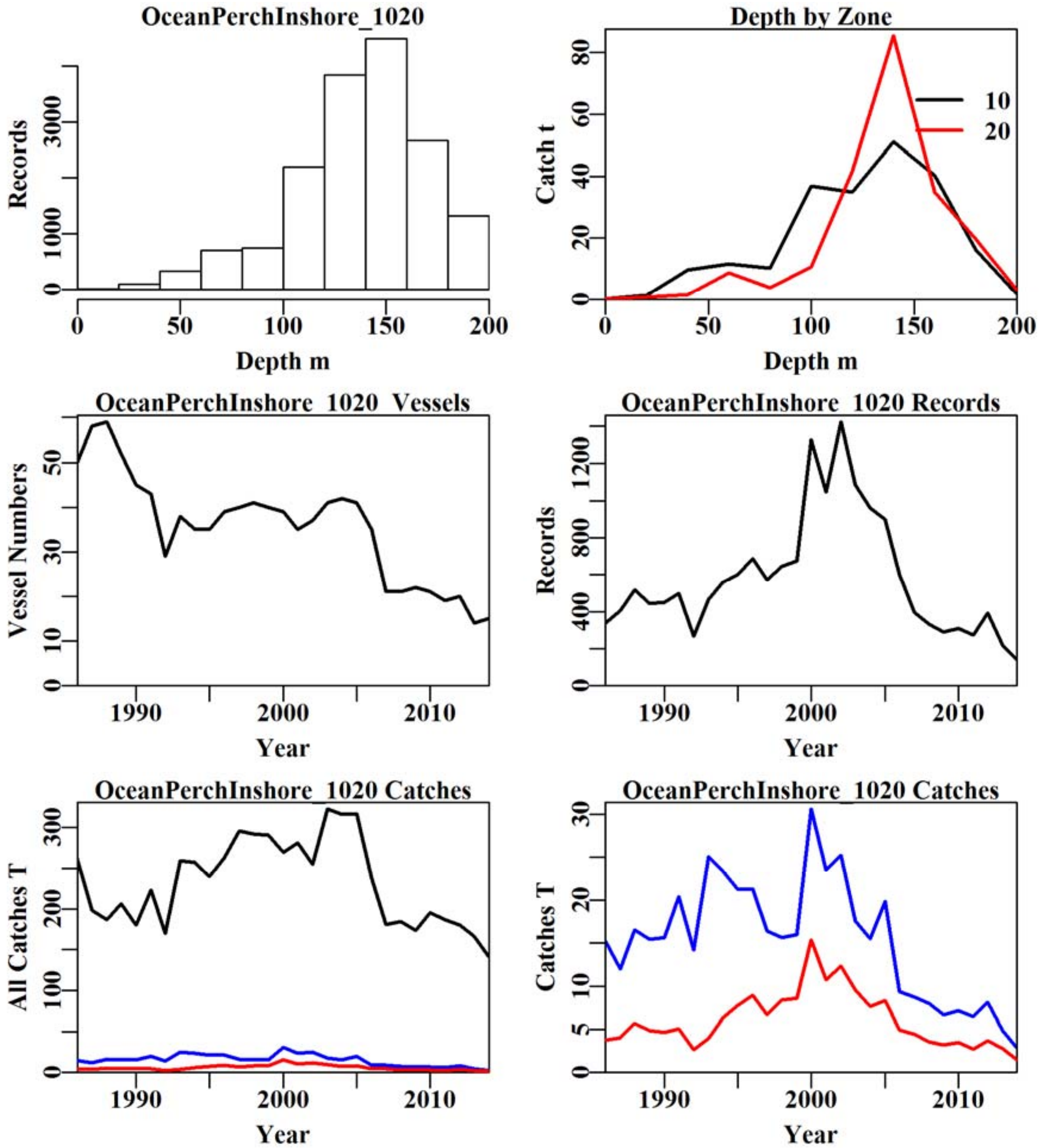


Figure 20.123. Inshore Ocean Perch from zones 10 and 20 in depths 0 – 200 m by Trawl. The top left plot depicts the depth distribution of shots containing Offshore Ocean Perch from zones 10 and 20 in depths 0 – 200 m by Trawl. The top right plot depicts the catch distribution by depth by zone. The middle 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).

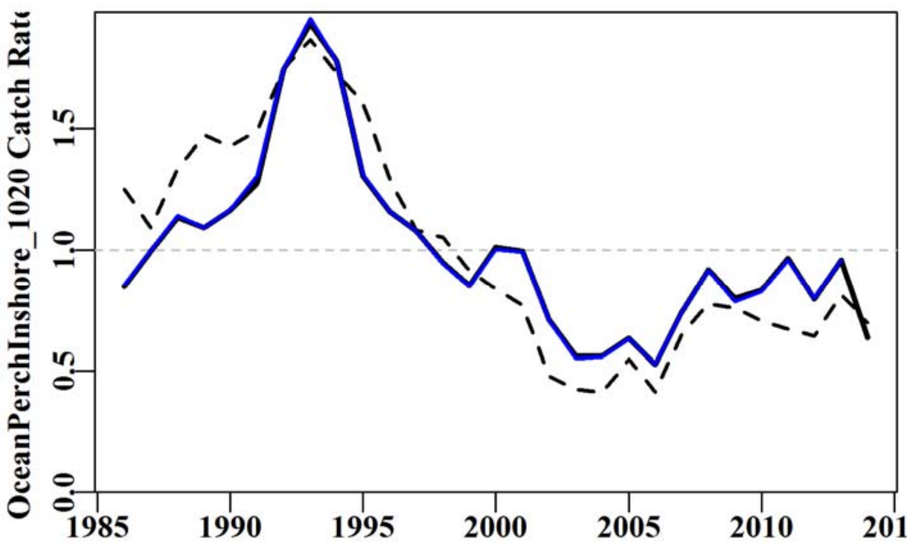


Figure 20.124. Inshore Ocean Perch from zones 10 and 20 in depths 0 – 200 m by Trawl. The dashed black line represents the geometric mean catch rate, solid black line the standardized catch rates and solid blue line standardized catch rates from last year's analysis. The graph standardizes catch rates relative to the mean of the standardized catch rates.

Table 20.110. 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 20.111. 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	5907	2421	1462	1386	1331	1247	1247	1158
RSS	23813	19024	17527	17422	17357	17267	17244	17152
MSS	3810	8600	10097	10202	10266	10357	10380	10472
Nobs	16818	16818	16395	16395	16395	16395	16395	16395
Npars	29	174	184	195	198	199	210	209
adj_R^2	13.650	30.415	35.836	36.176	36.401	36.729	36.770	37.110
%Change	0.000	16.766	5.420	0.341	0.225	0.328	0.042	0.340

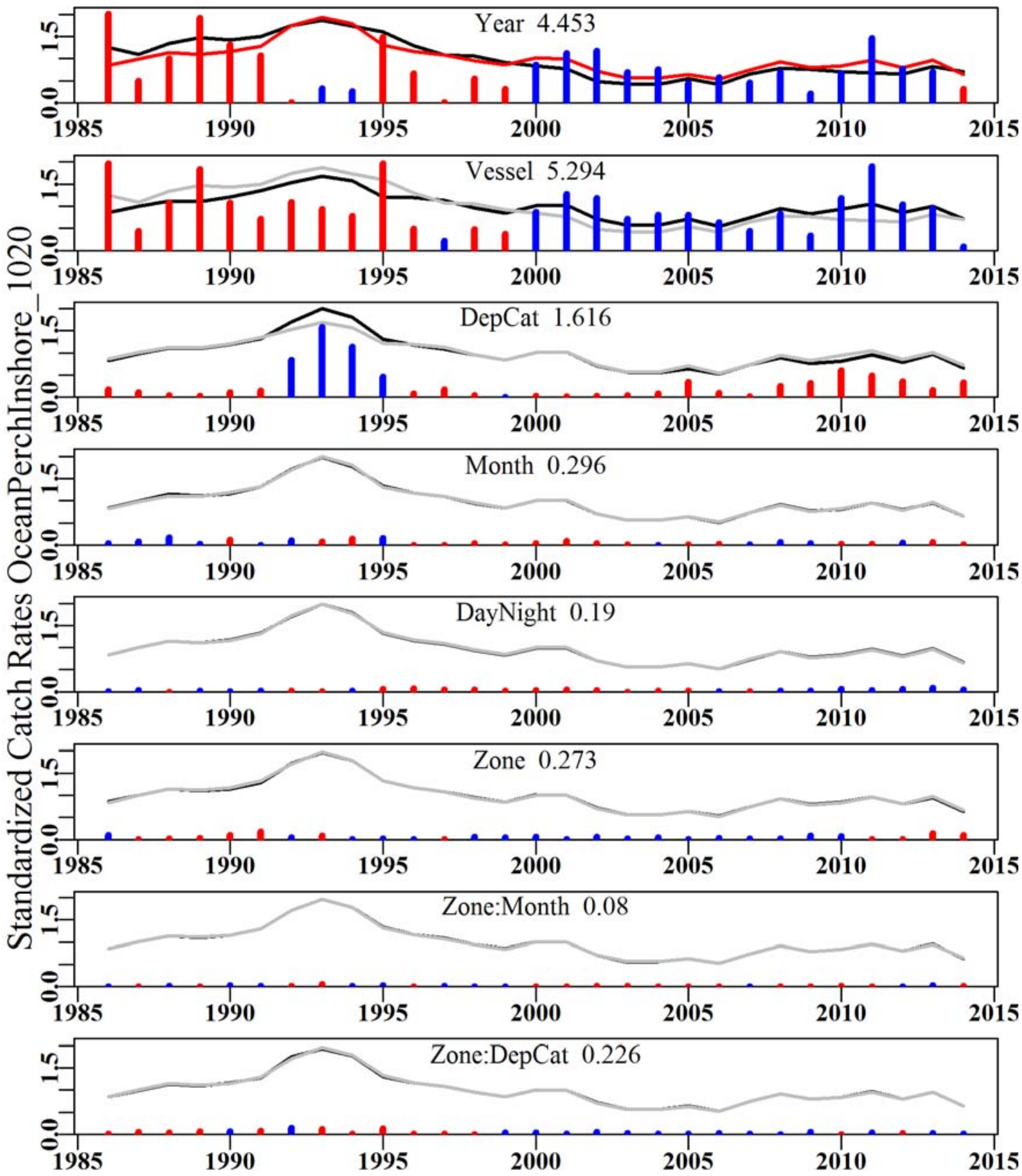


Figure 20.125. The relative influence of each factor used on the final trend in the optimal standardization for Inshore Ocean Perch from zones 10 and 20. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by the vertical 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.

20.4.39 John Dory Z1020 (DOJ – 37264004 – Zeus faber)

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

Table 20.112. 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	1.6332	0.0000
1987	206.0900	4663	181.5910	78	8.5155	1.8717	0.0209
1988	181.9840	4538	161.5630	73	8.3856	1.7578	0.0211
1989	217.9240	4813	188.4430	70	9.5319	1.9274	0.0211
1990	167.8530	3700	136.7640	60	8.7451	1.7414	0.0231
1991	172.2910	4041	126.6960	53	7.1954	1.4232	0.0227
1992	130.8493	3934	108.9353	49	5.7443	1.2049	0.0229
1993	240.4380	5441	181.6090	55	7.1064	1.5264	0.0214
1994	267.8680	6573	209.8970	55	6.7516	1.4317	0.0204
1995	185.6720	6070	168.5310	52	5.9610	1.2285	0.0205
1996	160.7530	6411	146.7690	59	4.5279	0.9604	0.0204
1997	87.7655	4473	79.2240	60	3.3776	0.7445	0.0224
1998	109.0292	5091	98.4790	53	3.6350	0.7709	0.0216
1999	132.8421	5553	121.0210	56	3.9411	0.9049	0.0212
2000	164.0530	7099	147.9365	60	3.5714	0.8382	0.0203
2001	129.2998	6847	117.0680	52	2.9475	0.7032	0.0205
2002	150.9738	6688	136.4103	50	3.1493	0.6927	0.0208
2003	156.9439	6558	137.3210	52	3.1537	0.6720	0.0207
2004	166.0275	7094	147.6960	52	3.4203	0.7126	0.0204
2005	107.3895	4934	88.6397	49	2.6772	0.5898	0.0222
2006	85.4007	3727	71.6251	44	2.8463	0.6646	0.0238
2007	62.4793	2844	51.6850	24	2.8023	0.6023	0.0259
2008	116.7894	3852	102.9915	27	4.3014	0.9004	0.0239
2009	91.7065	3148	79.7460	24	4.1921	0.8365	0.0252
2010	61.9744	3078	52.4480	25	2.6471	0.5375	0.0255
2011	74.8052	3428	57.4000	23	2.7461	0.5605	0.0247
2012	67.1140	3387	56.5785	23	2.8174	0.5490	0.0246
2013	63.4930	2685	48.9130	24	2.8665	0.5764	0.0261
2014	46.1621	2336	30.7370	24	2.0814	0.4373	0.0273

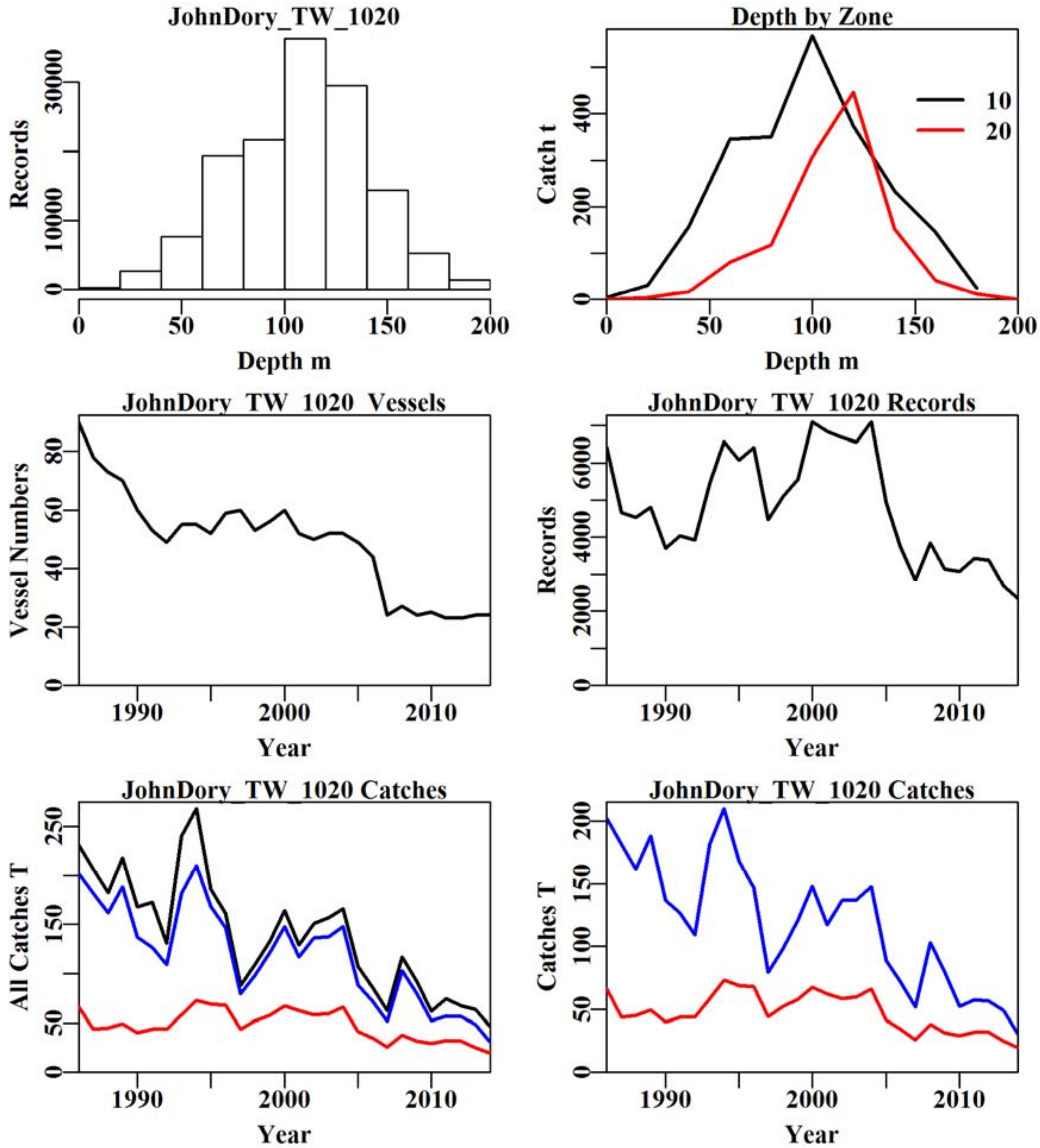


Figure 20.126. John Dory from Zones 10 and 20 in depths 0 to 200 m by Trawl. The top left plot depicts the depth distribution of shots containing John Dory zones 10 and 20 in depths 0 to 200 m by Trawl. The top right plot depicts the catch distribution by depth by zone. The middle left plot depicts the 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).

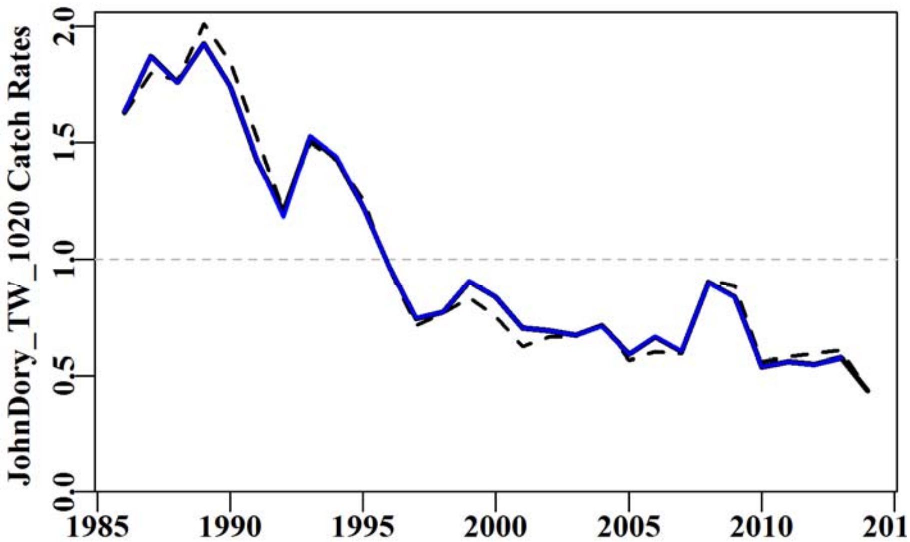


Figure 20.127. John Dory from Zones 10 and 20 in depths 0 to 200 m by Trawl. The dashed black line represents the geometric mean catch rate, solid black line the standardized catch rates and solid blue line the standardized catch rates from last year's analysis. The graph standardizes catch rates relative to the mean of the standardized catch rates.

Table 20.113. 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 20.114. 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	28194	12359	10712	8837	8144	8125	7323	6901
RSS	170600	151930	148956	146943	146184	146162	145293	144853
MSS	25269	43939	46913	48926	49685	49707	50576	51016
Nobs	139424	139424	138251	138251	138251	138251	138251	138251
Npars	29	191	201	204	215	216	227	226
adj_R^2	12.884	22.327	23.841	24.869	25.251	25.261	25.700	25.925
%Change	0.000	9.443	1.514	1.027	0.382	0.011	0.438	0.226

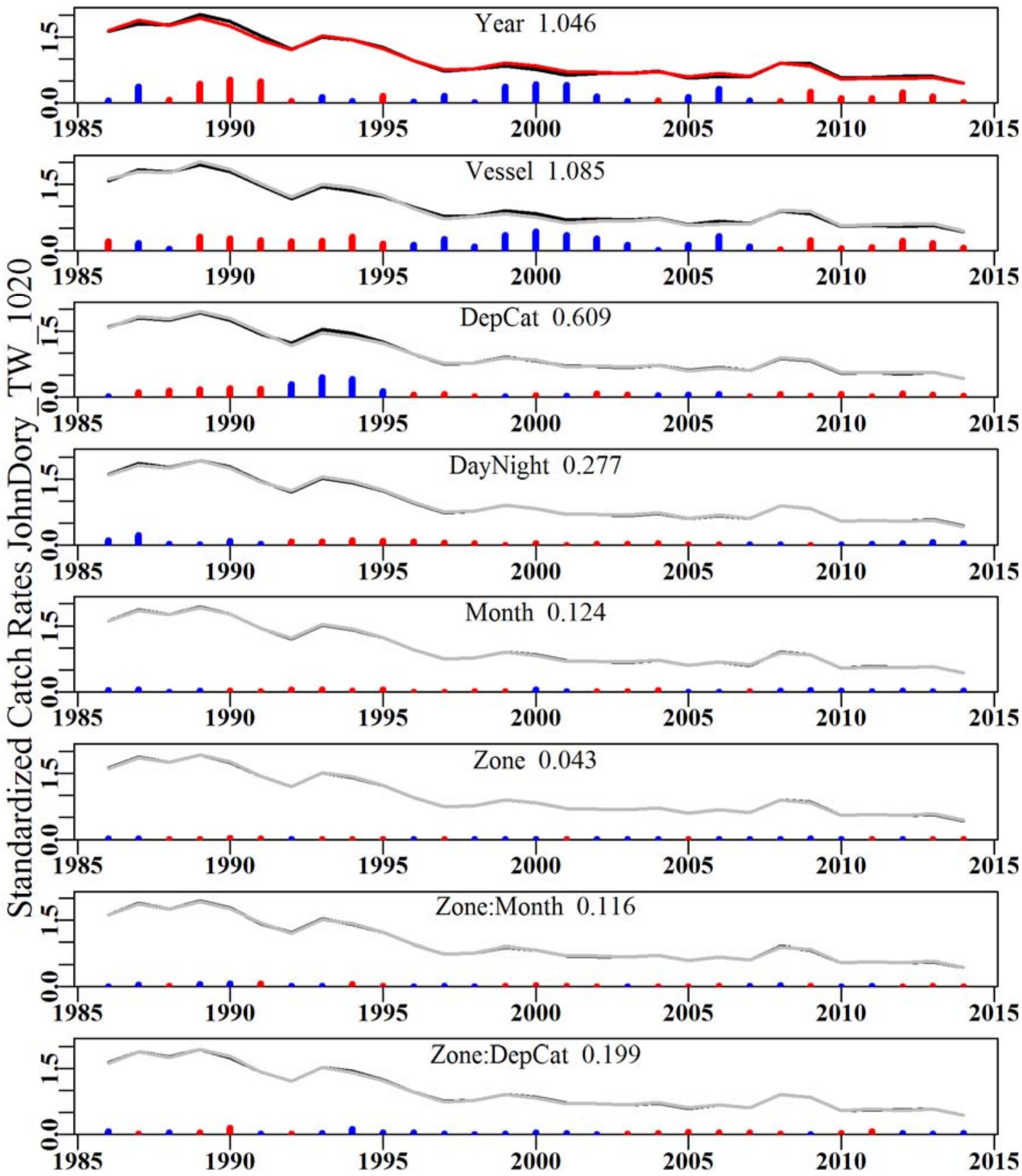


Figure 20.128. The relative influence of each factor used on the final trend in the optimal standardization for John Dory from zones 10 and 20. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by the vertical bars with 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.

20.4.40 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.

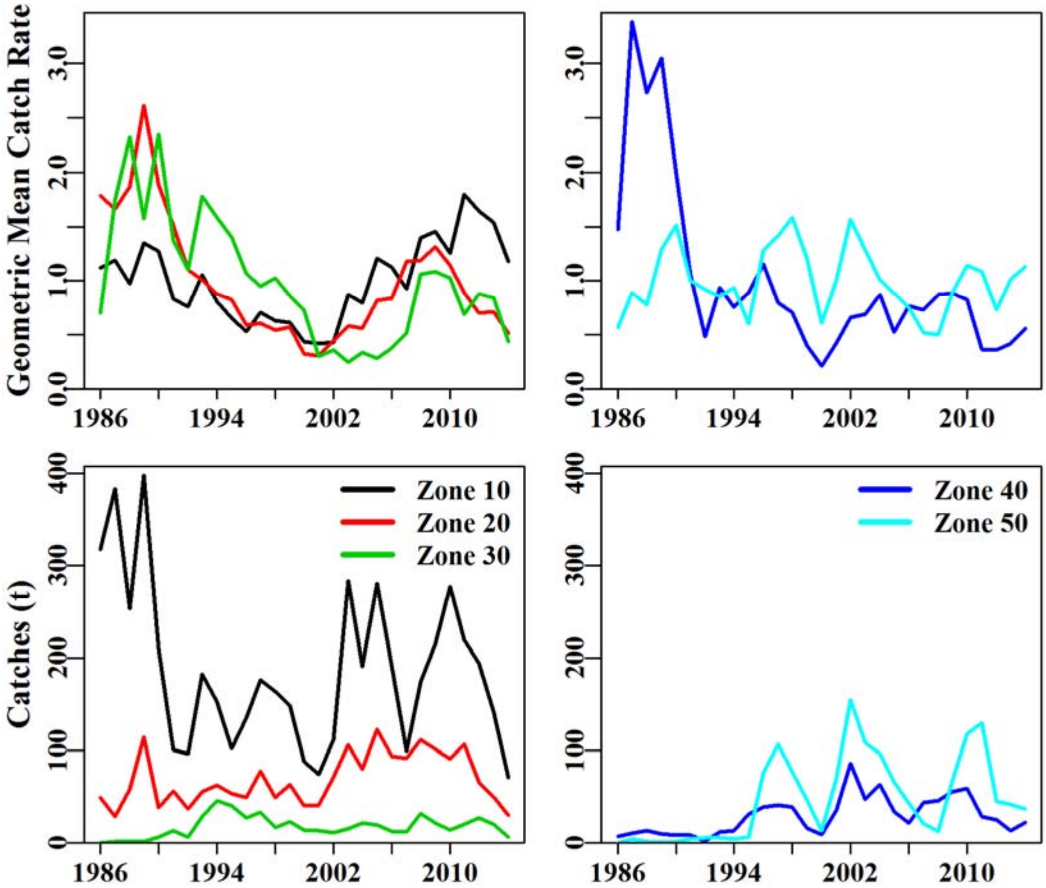


Figure 20.129. The catches and geometric mean catch rates from 1986 – 2012 for Mirror Dory split between east (zones 10 -30) and west (zones 40 and 50). The general trends in catch rates, in periods of significant catches, are similar across zones within the east and west. This implies that the assumption that there are no Year x Zone interactions is valid.

Table 20.115. 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	1.2184	0.0000
1987	450.7660	3103	429.0900	92	19.7476	1.2218	0.0312
1988	346.0140	3189	328.2200	88	16.9455	1.1999	0.0309
1989	591.6310	3068	524.8630	84	23.1957	1.4768	0.0315
1990	295.7640	1906	264.3460	73	20.6077	1.3618	0.0361
1991	240.3130	2230	183.7370	77	13.9567	1.1705	0.0346
1992	166.9803	2242	148.7400	72	11.4026	1.0181	0.0347
1993	306.2200	3290	285.2210	72	13.7999	1.1145	0.0317
1994	297.2680	3828	280.1950	70	11.4667	1.0019	0.0309
1995	244.9240	4209	234.4330	70	10.0782	0.9303	0.0304
1996	352.7220	5835	327.5140	84	8.9039	0.8935	0.0290
1997	459.6263	6681	436.4460	80	9.6820	0.9497	0.0288
1998	355.7935	5572	346.7060	68	9.0983	0.8604	0.0293
1999	309.4810	5543	298.1670	74	8.0995	0.7042	0.0295
2000	171.0664	5615	165.2405	81	4.6512	0.4927	0.0297
2001	243.3623	7073	235.2720	76	5.1016	0.5772	0.0291
2002	449.5550	8204	435.3746	70	7.1674	0.7717	0.0286
2003	613.8621	7797	560.9170	72	8.6659	0.9321	0.0286
2004	507.3770	6484	452.6005	70	8.2047	0.8964	0.0294
2005	579.8856	6190	523.8135	67	9.3924	0.9937	0.0295
2006	419.5564	4293	363.0748	55	9.7517	0.9803	0.0311
2007	289.6026	3400	268.1030	34	9.5152	0.9439	0.0328
2008	396.2424	3377	376.3640	35	12.2034	1.1303	0.0329
2009	476.5154	3567	461.7812	33	13.1797	1.2465	0.0326
2010	579.9761	3702	561.2296	33	12.8612	1.1939	0.0324
2011	514.5297	3921	506.2050	34	10.8184	1.1057	0.0321
2012	365.4882	2757	357.9945	34	8.9809	0.8015	0.0344
2013	279.8848	2289	267.3913	33	10.6434	0.9198	0.0357
2014	189.9213	2296	166.4263	31	7.9715	0.8925	0.0356

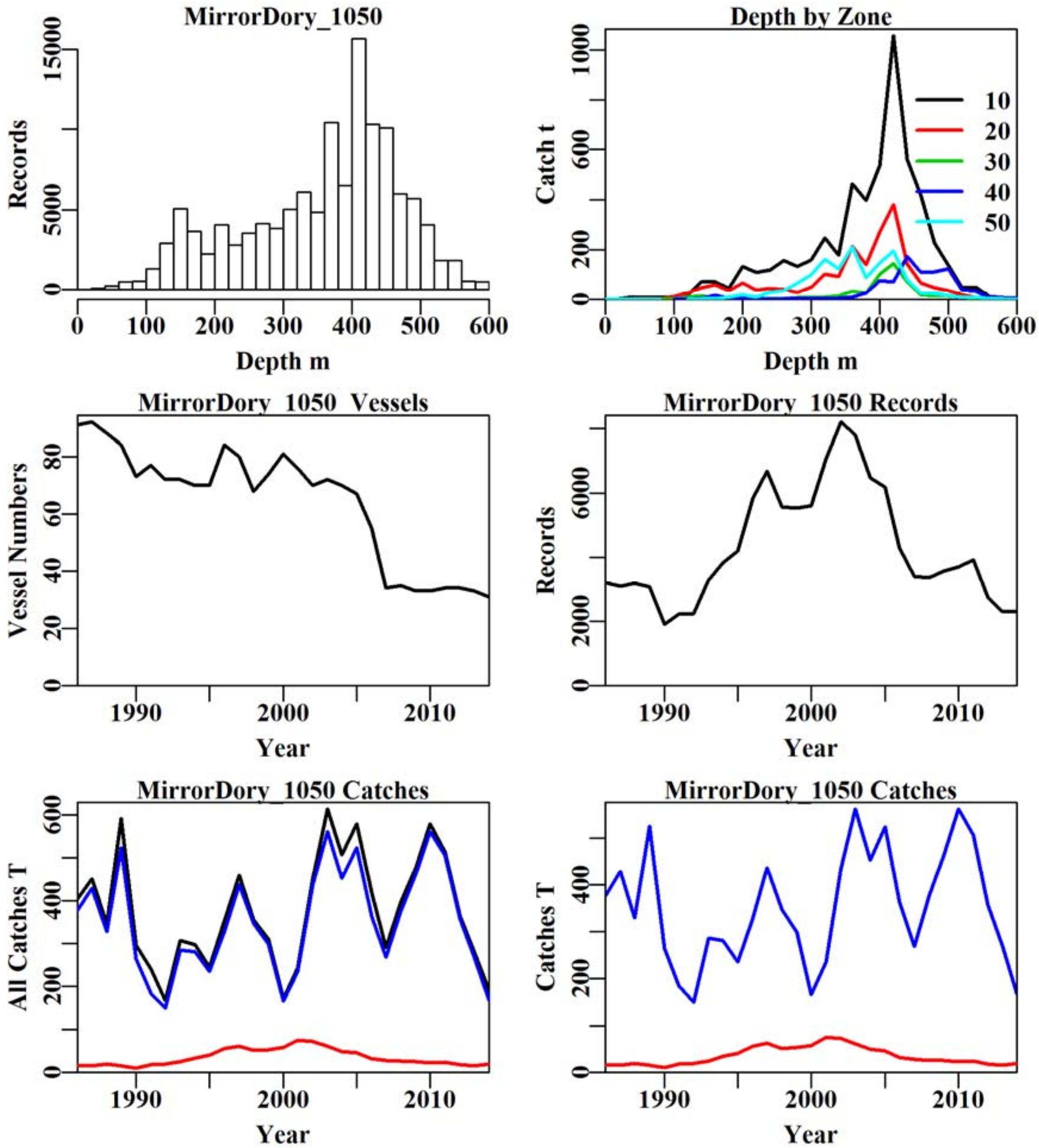


Figure 20.130. Mirror Dory from zones 10 to 50 in depths 0 to 600 m by Trawl. The top left plot depicts the depth distribution of shots containing Mirror Dory zones 10 to 50 in depths 0 to 600 m by Trawl. The top right plot depicts the catch distribution by depth by zone. The middle left plot depicts 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).

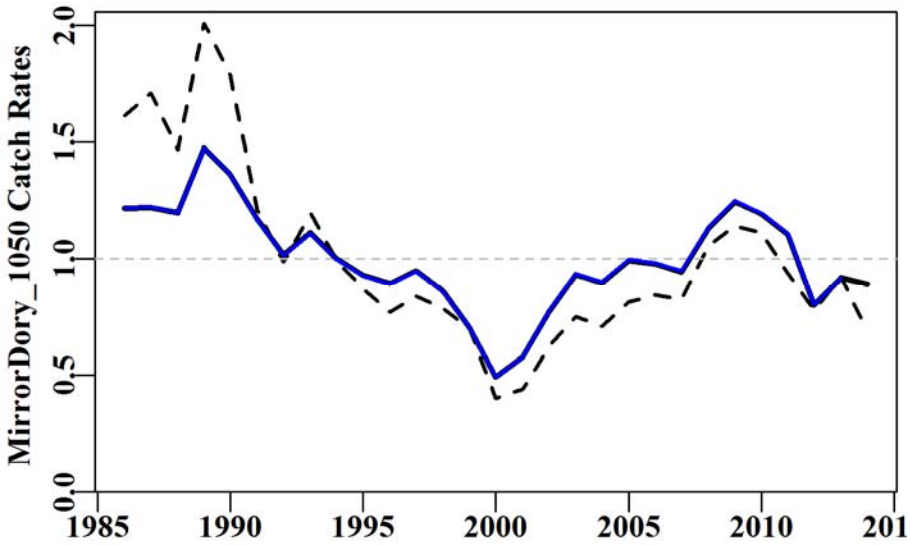


Figure 20.131. Mirror Dory from Zones 10 to 50 in depths 0 to 600 m by Trawl. The dashed black line represents the geometric mean catch rate, solid black line the standardized catch rates and solid blue line the standardized catch rates from last year's analysis. The graph standardizes catch rates relative to the mean of the standardized catch rates.

Table 20.116. 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 20.117. 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	79548	57500	55667	44249	42870	42059	37387	41049
RSS	235998	197159	194251	176565	174606	173458	166936	171722
MSS	16427	55266	58174	75861	77819	78967	85489	80704
Nobs	124860	124860	124860	124181	124181	124181	124181	124181
Npars	29	231	242	272	275	279	323	399
adj_R^2	6.487	21.750	22.897	29.900	30.676	31.129	33.695	31.753
%Change	0.000	15.263	1.147	7.002	0.776	0.453	2.566	-1.943

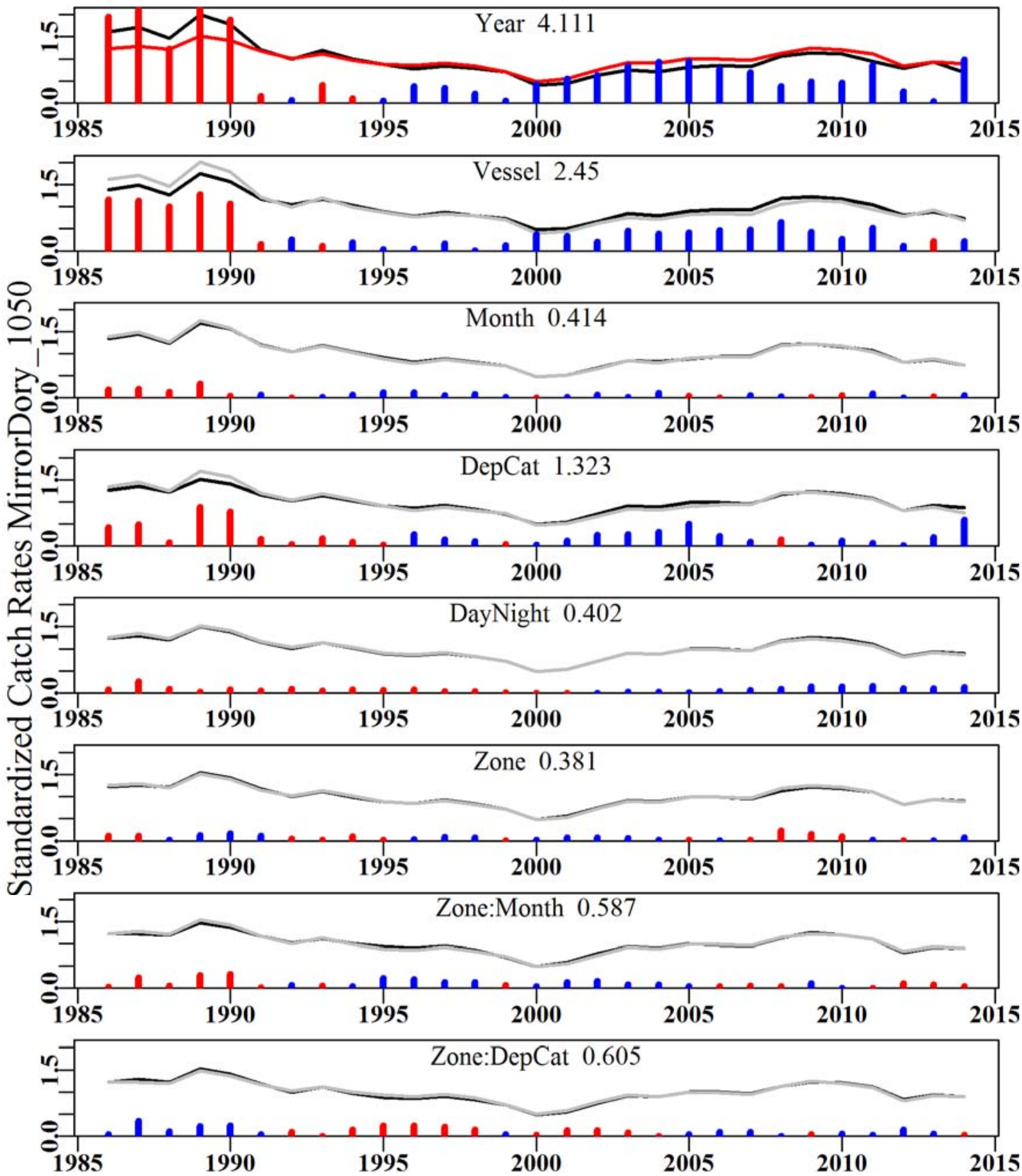


Figure 20.132. The relative influence of each factor used on the final trend in the optimal standardization for Mirror Dory from zones 10 to 50. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by the vertical bars with 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.

20.4.41 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 20.118. 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	1.1606	0.0000
1987	450.7660	2961	413.5710	70	19.9429	1.1595	0.0326
1988	346.0140	3067	313.2370	77	16.8882	1.1408	0.0322
1989	591.6310	2997	513.7360	70	23.1617	1.3766	0.0327
1990	295.7640	1811	254.3800	61	20.5538	1.2925	0.0377
1991	240.3130	2021	170.9540	68	14.2052	1.1431	0.0369
1992	166.9803	2036	140.4410	57	11.7899	0.9968	0.0369
1993	306.2200	3013	267.0910	62	14.1976	1.0881	0.0336
1994	297.2680	3498	262.0330	62	11.6924	0.9578	0.0326
1995	244.9240	3500	196.2900	59	10.2913	0.8724	0.0325
1996	352.7220	4397	212.3690	69	7.7998	0.7637	0.0313
1997	459.6263	4775	288.1360	65	8.6425	0.8100	0.0313
1998	355.7935	4103	230.4950	55	8.0944	0.7324	0.0318
1999	309.4810	4225	234.8730	59	7.8713	0.6511	0.0320
2000	171.0664	4635	142.7795	65	4.7876	0.5042	0.0318
2001	243.3623	4604	129.0870	56	4.0205	0.5066	0.0321
2002	449.5550	5041	194.5926	54	5.2611	0.6340	0.0316
2003	613.8621	5363	405.7085	59	7.7687	0.9251	0.0312
2004	507.3770	4274	292.6610	58	7.2637	0.8808	0.0324
2005	579.8856	4417	423.6310	56	9.9946	1.1229	0.0322
2006	419.5564	3230	297.5593	45	10.3893	1.1258	0.0341
2007	289.6026	2223	203.1620	23	11.4463	1.2105	0.0374
2008	396.2424	2495	317.7050	27	14.4563	1.3466	0.0367
2009	476.5154	2232	338.4877	28	15.8458	1.4223	0.0377
2010	579.9761	2105	383.4800	26	14.3976	1.1928	0.0381
2011	514.5297	2254	347.0670	27	12.7502	1.1976	0.0376
2012	365.4882	1739	287.7780	25	11.2957	0.9465	0.0402
2013	279.8848	1646	212.2493	25	11.8284	0.9835	0.0406
2014	189.9213	1571	107.2383	26	7.4550	0.8554	0.0409

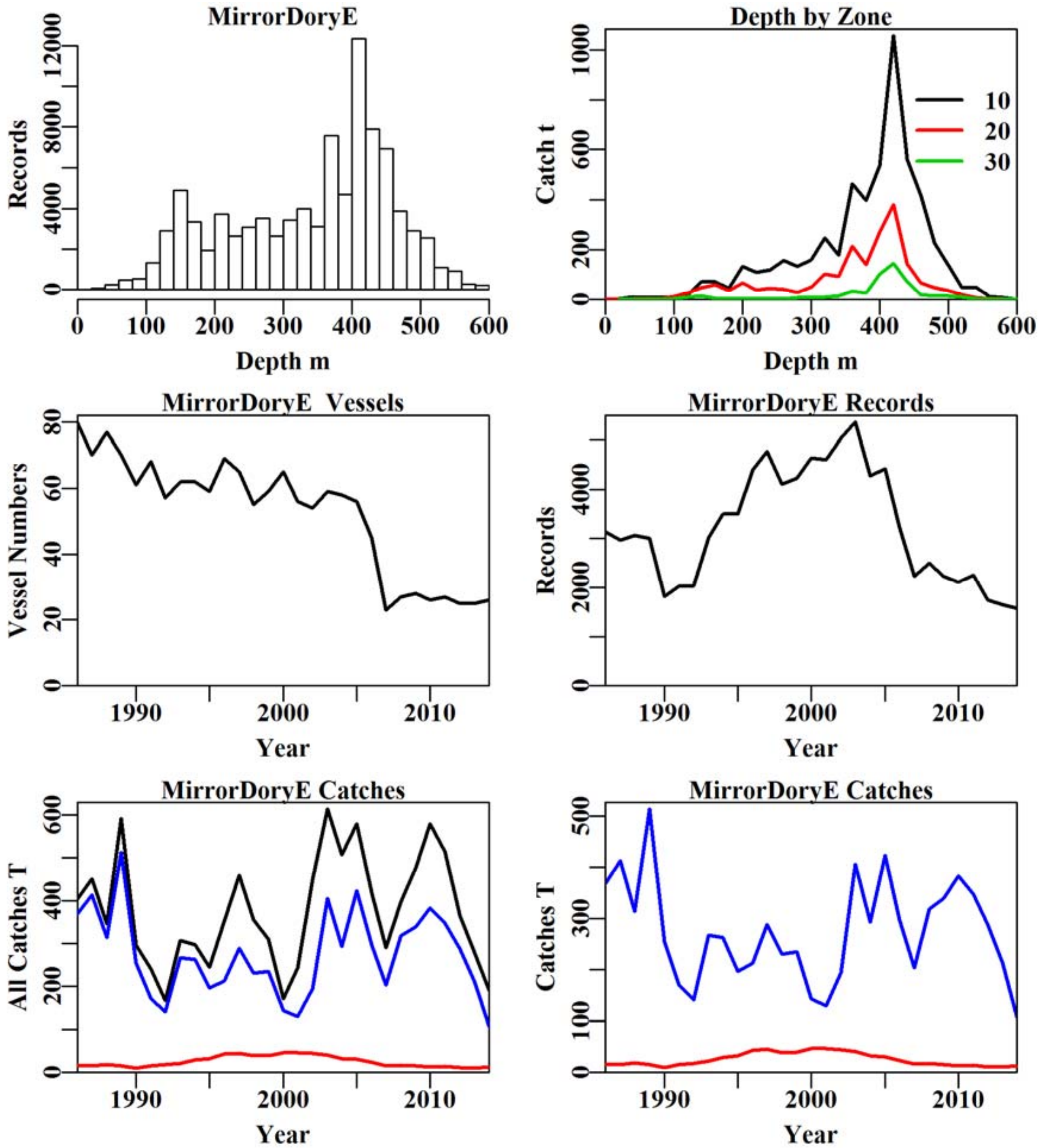


Figure 20.133. Mirror Dory from zones 10 to 30 in depths 0 to 600 m by Trawl. The top left plot depicts the depth distribution of shots containing Mirror Dory zones 10 to 30 in depths 0 to 600 m by Trawl. The top right plot depicts the catch distribution by depth by zone. The middle left plot depicts 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).

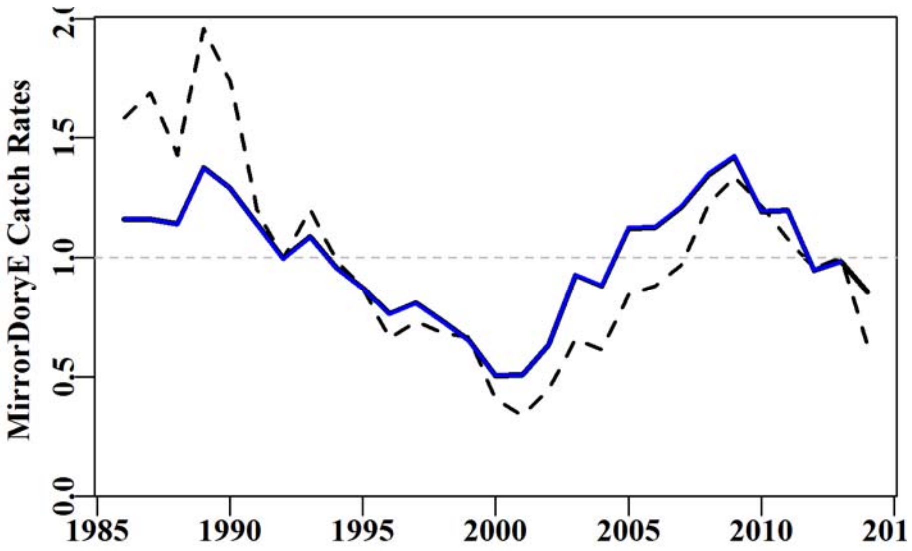


Figure 20.134. Mirror Dory from Zones 10 to 30 in depths 0 to 600 m by Trawl. The dashed black line represents the geometric mean catch rate, solid black line the standardized catch rates and solid blue line the standardized catch rates from last year's analysis. The graph standardizes catch rates relative to the mean of the standardized catch rates.

Table 20.119. 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 20.120. 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	64877	48573	38013	36143	35425	34676	33069	34375
RSS	186942	156404	139148	136342	135284	134191	131828	133585
MSS	18763	49301	66557	69363	70421	71514	73878	72120
Nobs	93374	93374	92880	92880	92880	92880	92880	92880
Npars	29	204	234	245	248	250	272	310
adj_R^2	9.094	23.801	32.185	33.545	34.058	34.590	35.727	34.843
%Change	0.000	14.707	8.384	1.360	0.513	0.531	1.137	-0.884

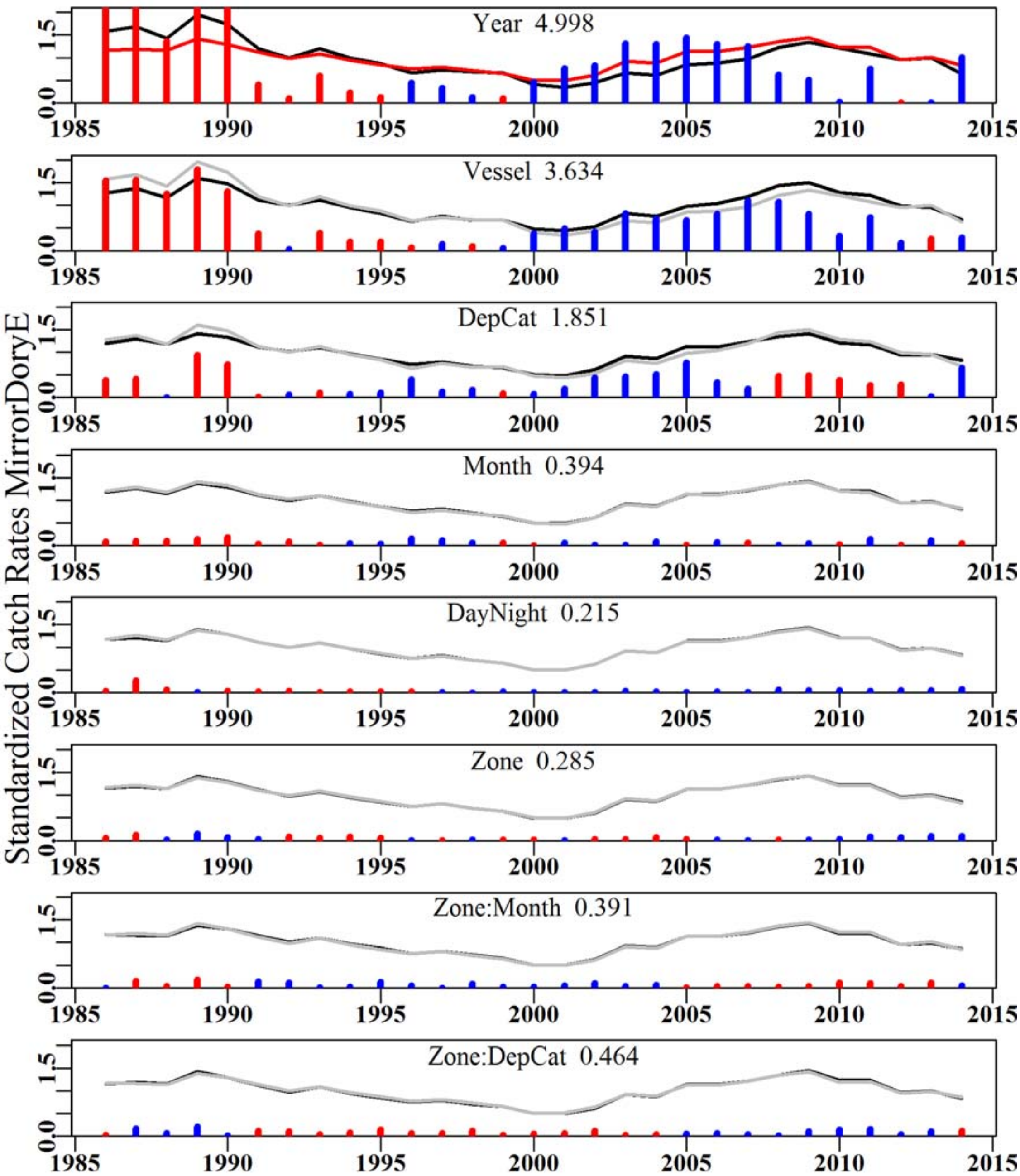


Figure 20.135. The relative influence of each factor used on the final trend in the optimal standardization for Mirror Dory from zones 10 to 30. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by the vertical bars with 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.

20.4.42 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 20.121. 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	2.5269	0.0000
1987	450.7660	142	15.5190	23	16.0832	1.6602	0.2013
1988	346.0140	122	14.9830	17	18.4525	1.3453	0.2101
1989	591.6310	71	11.1270	15	24.6757	1.7029	0.2217
1990	295.7640	95	9.9660	14	21.6631	1.1401	0.2253
1991	240.3130	209	12.7830	17	11.7670	0.8019	0.1986
1992	166.9803	205	8.2890	20	8.1608	0.6683	0.2002
1993	306.2200	276	18.0100	18	10.1017	0.7901	0.1954
1994	297.2680	330	18.1620	20	9.3264	0.7049	0.1938
1995	244.9240	709	38.1430	23	9.0896	0.9111	0.1908
1996	352.7220	1438	115.1450	26	13.3473	1.2695	0.1907
1997	459.6263	1906	148.3100	24	12.8686	1.2853	0.1903
1998	355.7935	1469	116.2110	20	12.6121	1.2429	0.1907
1999	309.4810	1318	63.2940	23	8.8763	0.8155	0.1909
2000	171.0664	980	22.4610	28	4.0569	0.4493	0.1918
2001	243.3623	2469	106.1850	29	7.9539	0.7724	0.1901
2002	449.5550	3158	240.4320	28	11.7235	1.1324	0.1898
2003	613.8621	2429	154.8985	27	11.0165	0.9607	0.1901
2004	507.3770	2208	159.8094	25	10.3786	0.9563	0.1903
2005	579.8856	1769	100.0055	23	8.0456	0.7596	0.1906
2006	419.5564	1061	65.3505	19	8.0395	0.6366	0.1917
2007	289.6026	1177	64.9410	16	6.7120	0.5749	0.1914
2008	396.2424	879	58.5330	17	7.5767	0.6546	0.1920
2009	476.5154	1333	123.2455	14	9.7010	1.0000	0.1909
2010	579.9761	1596	177.5496	14	11.0745	1.1916	0.1907
2011	514.5297	1662	157.8060	16	8.6510	0.9157	0.1906
2012	365.4882	1018	70.2165	15	6.0700	0.5347	0.1918
2013	279.8848	642	54.8860	15	8.0998	0.7313	0.1932
2014	189.9213	724	59.0680	13	9.2029	0.8653	0.1927

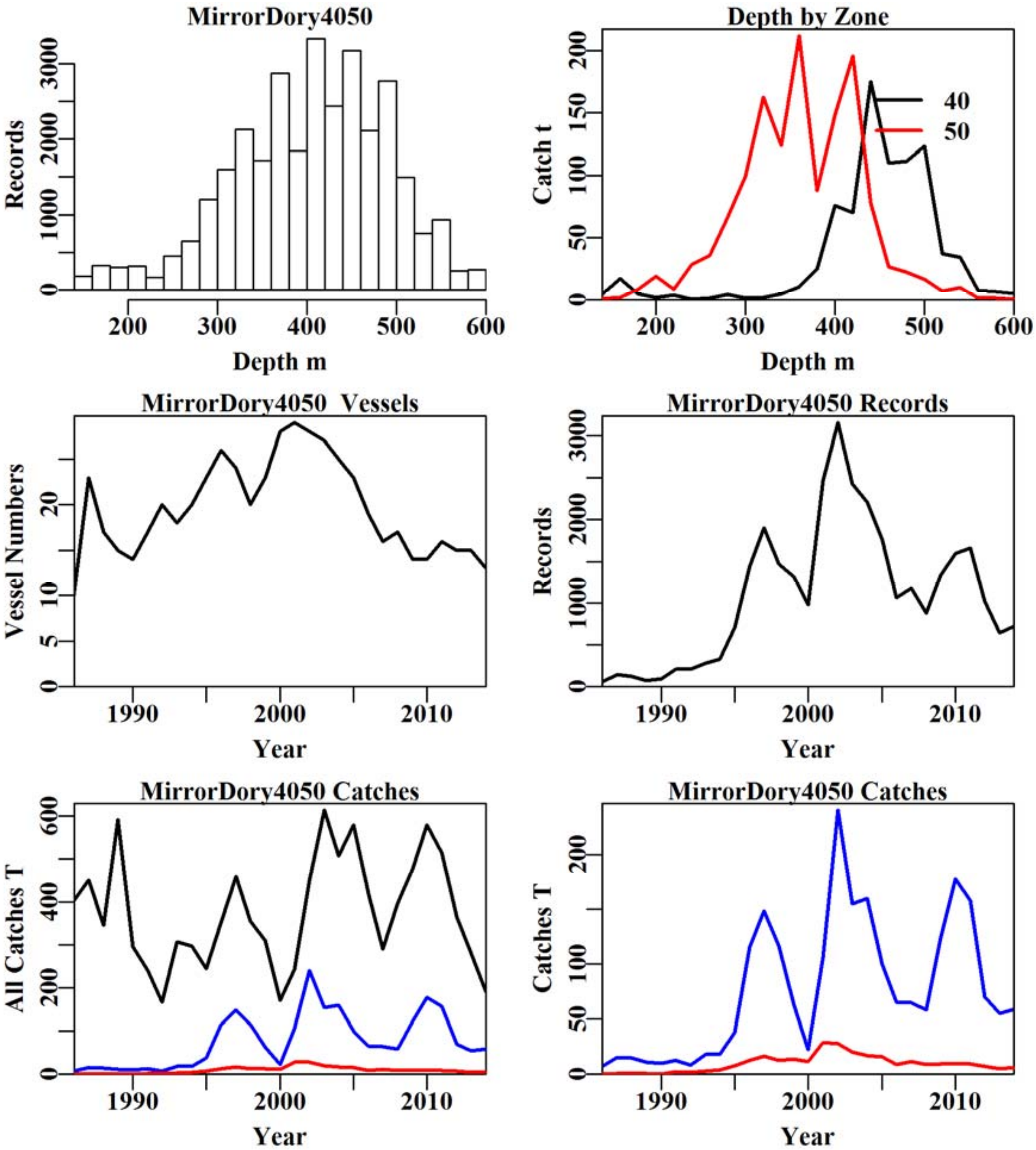


Figure 20.136. Mirror Dory from zones 40 to 50 in depths 0 to 600 m by Trawl. The top left plot depicts the depth distribution of shots containing Mirror Dory zones 40 to 50 in depths 0 to 600 m by Trawl. The top right plot depicts the catch distribution by depth by zone. The middle left plot depicts 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).

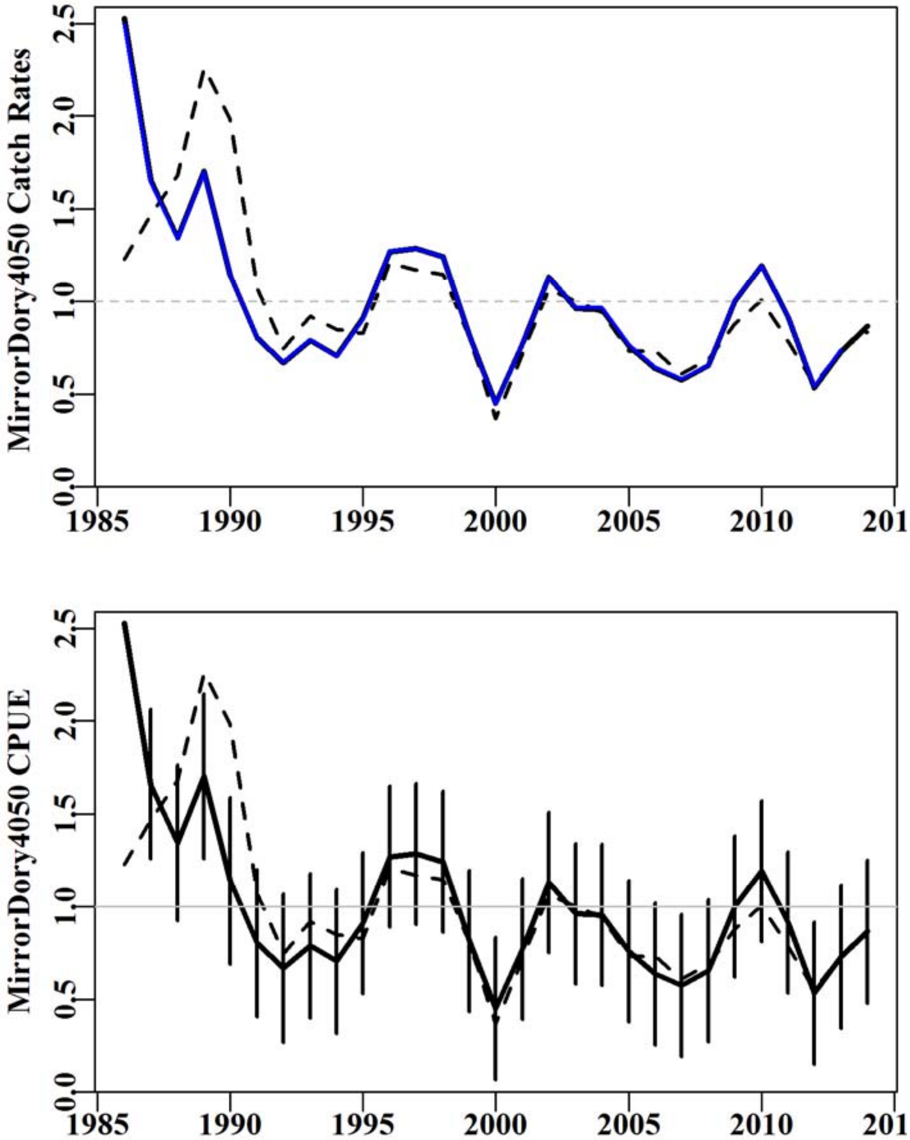


Figure 20.137. Mirror Dory from zones 40 to 50 in depths 0 to 600 m by Trawl. Upper graph: The dashed black line represents the geometric mean catch rate and the solid black line the standardized catch rates (relative to the mean of the standardized catch rates). The blue line corresponds to last year's 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 20.122. 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 20.123. 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	10891	4079	2510	992	241	-132	-520	-182
RSS	44384	35537	33784	31960	31196	30824	30422	30729
MSS	2249	11097	12850	14673	15438	15810	16212	15905
Nobs	31452	31452	31452	31267	31267	31267	31267	31267
Npars	29	119	130	153	156	157	168	180
adj_R^2	4.739	23.509	27.256	31.130	32.772	33.571	34.413	33.726
%Change	0.000	18.770	3.747	3.874	1.641	0.799	0.842	-0.688

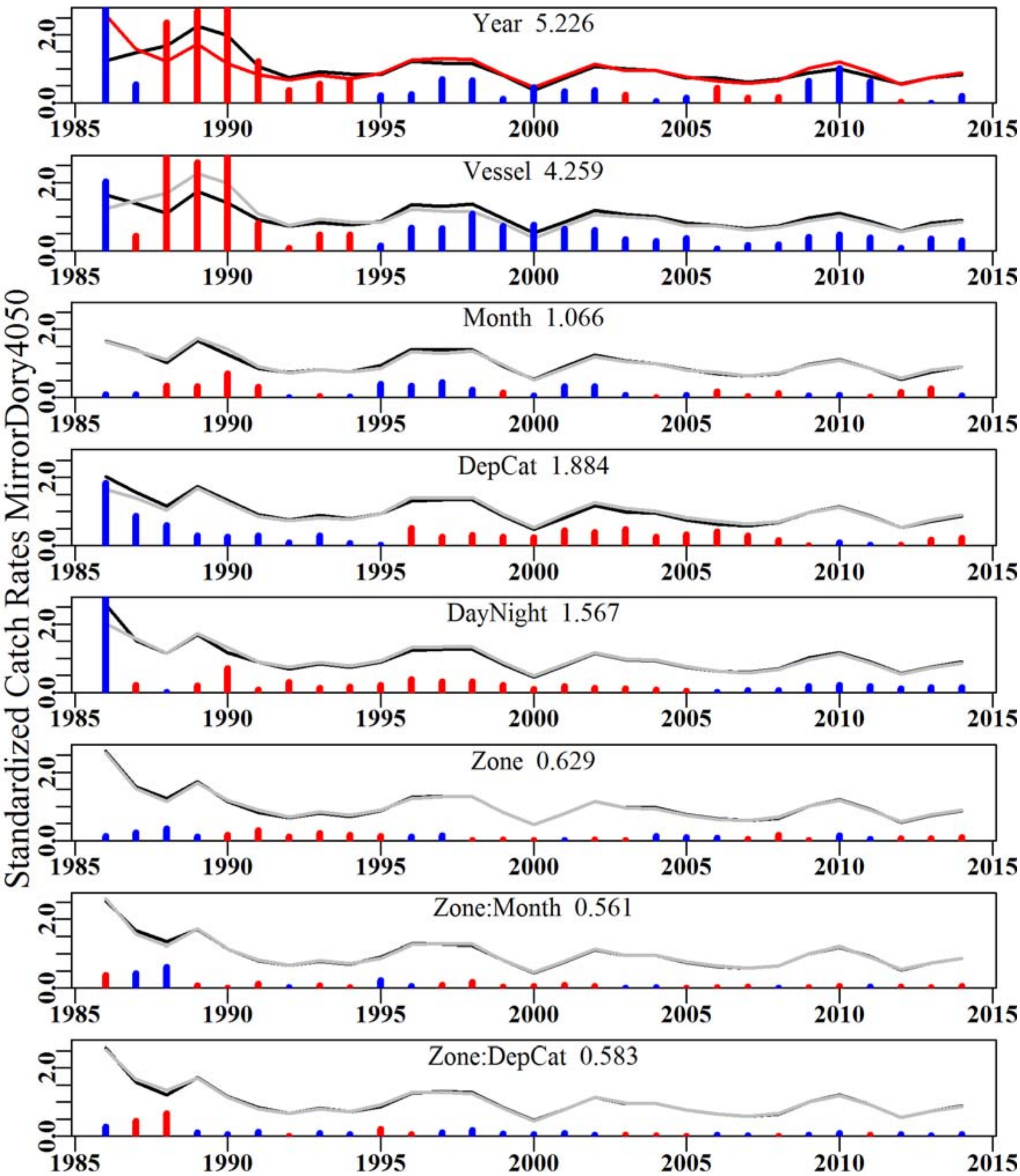


Figure 20.138. The relative influence of each factor used on the final trend in the optimal standardization for Mirror Dory from zones 40 – 50. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by the vertical bars with 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.

20.4.43 Ribaldo Z10-50 (RBD – 37224002 – Mora moro)

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

Table 20.124. 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	2.3165	0.0000
1987	7.9410	158	7.2920	14	10.2593	1.2834	0.1391
1988	10.8980	123	8.0490	22	16.5570	1.9930	0.1554
1989	11.3420	136	7.7110	14	18.2556	1.7859	0.1537
1990	3.6680	58	2.2590	11	8.9113	1.3921	0.1742
1991	7.8080	145	5.1620	22	7.9930	1.3755	0.1534
1992	13.3330	226	11.6890	26	9.7616	1.3484	0.1450
1993	22.7770	330	19.7620	37	11.2449	1.1395	0.1449
1994	41.9380	423	23.6220	30	11.8156	1.2841	0.1425
1995	90.3230	1147	86.2990	26	12.3128	1.3633	0.1391
1996	82.2780	1492	77.0120	32	10.1757	1.0303	0.1388
1997	103.1154	1714	96.5670	30	9.8023	0.9001	0.1385
1998	99.9134	1667	92.0150	33	9.6696	0.8696	0.1386
1999	72.1498	1133	59.6680	32	8.7093	0.8005	0.1395
2000	66.7914	1174	53.8450	39	7.4217	0.7424	0.1394
2001	82.4788	1129	52.6190	38	6.7580	0.6945	0.1393
2002	157.8426	1142	57.2360	31	6.7896	0.6401	0.1395
2003	180.8106	1307	65.9550	36	6.6903	0.6275	0.1393
2004	180.9607	1257	66.4169	34	7.2233	0.6882	0.1395
2005	90.3599	671	30.0311	33	6.3449	0.6033	0.1413
2006	122.5935	637	32.0832	35	6.3304	0.6312	0.1413
2007	78.3142	404	15.5712	25	3.2493	0.4301	0.1441
2008	78.4750	367	17.6183	25	4.7326	0.5925	0.1447
2009	104.9600	572	33.4102	20	5.6978	0.6574	0.1419
2010	91.9240	681	37.1429	23	5.5961	0.6912	0.1410
2011	93.9468	863	44.4726	20	5.8293	0.6968	0.1401
2012	107.2292	759	42.4445	20	6.1631	0.7005	0.1409
2013	122.3639	928	68.9605	24	8.5813	0.8510	0.1402
2014	133.9878	735	52.5006	22	8.1967	0.8709	0.1409

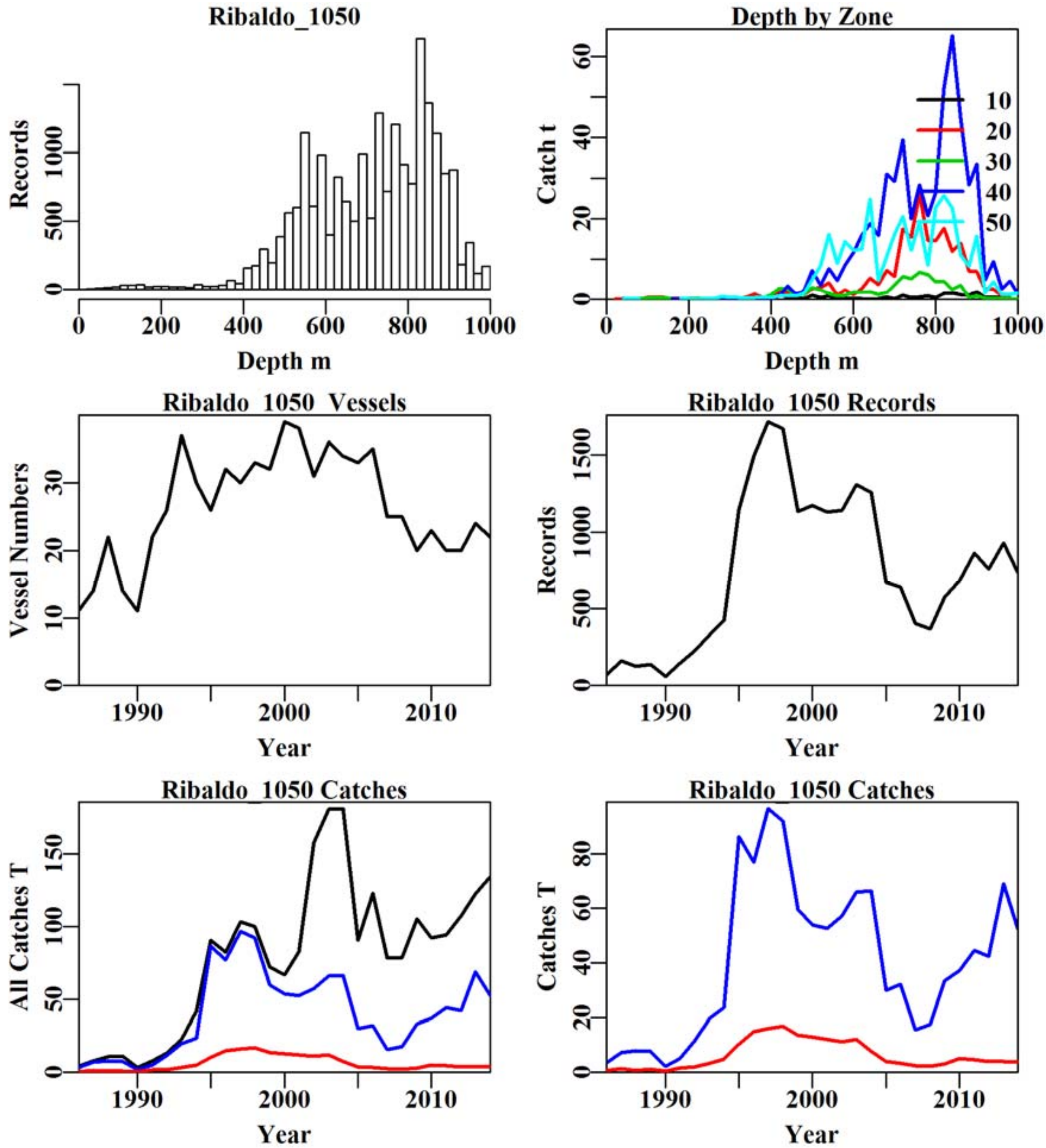


Figure 20.139. Ribaldo from zones 10 to 50 in depths 0 to 1000 m by Trawl. The top left plot depicts the depth distribution of shots containing Ribaldo from zones 10 to 50 in depths 0 to 1000 m by Trawl. The top right plot depicts the catch distribution by depth by zone. The middle left plot depicts 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).

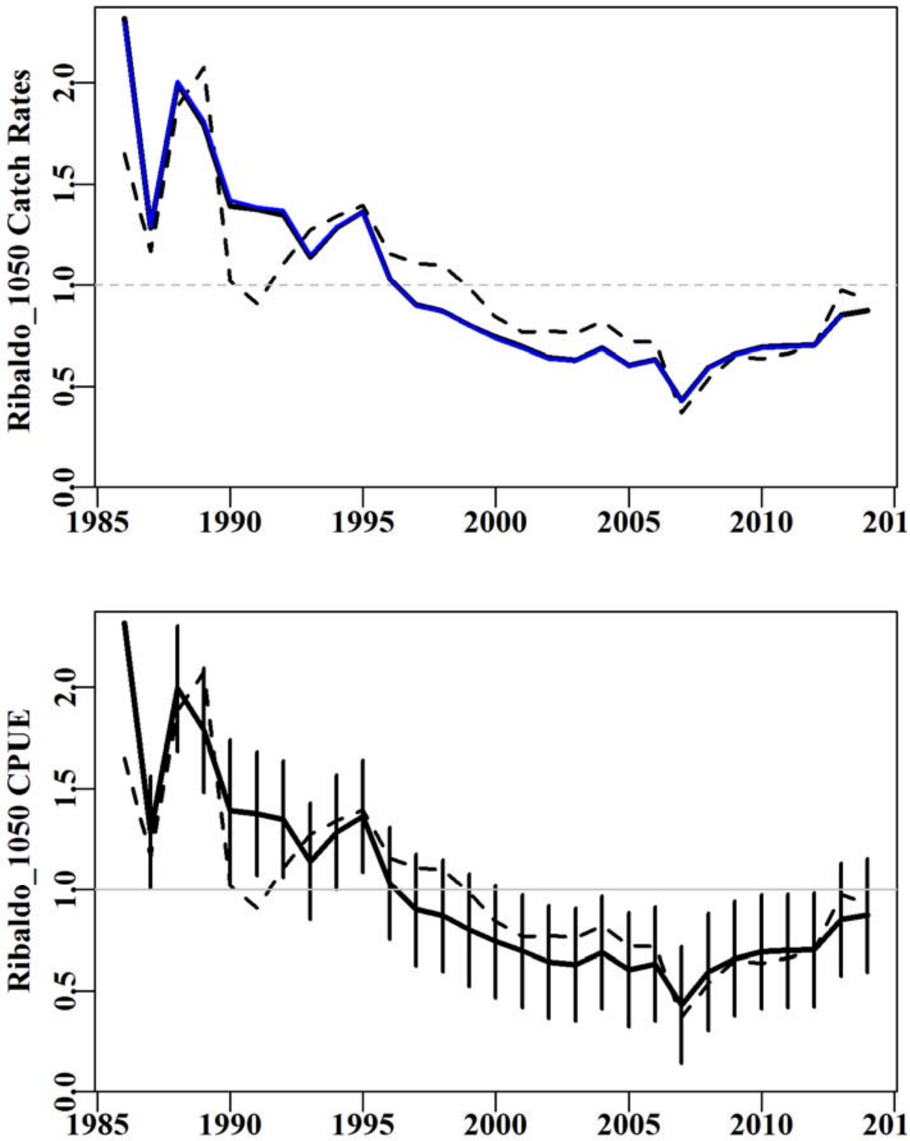


Figure 20.140. Ribaldo from zones 10 to 50 in depths 0 to 1000 m by Trawl. Upper graph: The dashed black line represents the geometric mean catch rate and the solid black line the standardized catch rates (relative to the mean of the standardized catch rates). The blue line corresponds to last year's 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 20.125. 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 20.126. 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	-1911	-3733	-6678	-7370	-7478	-7521	-8083	-7837
RSS	19569	17772	15225	14732	14653	14608	14168	14124
MSS	1661	3458	6005	6498	6577	6622	7062	7106
Nobs	21450	21450	21246	21246	21246	21246	21246	21246
Npars	29	151	201	205	208	219	263	419
adj_R^2	7.704	15.699	27.604	29.936	30.301	30.480	32.431	32.136
%Change	0.000	7.996	11.905	2.332	0.365	0.179	1.952	-0.295

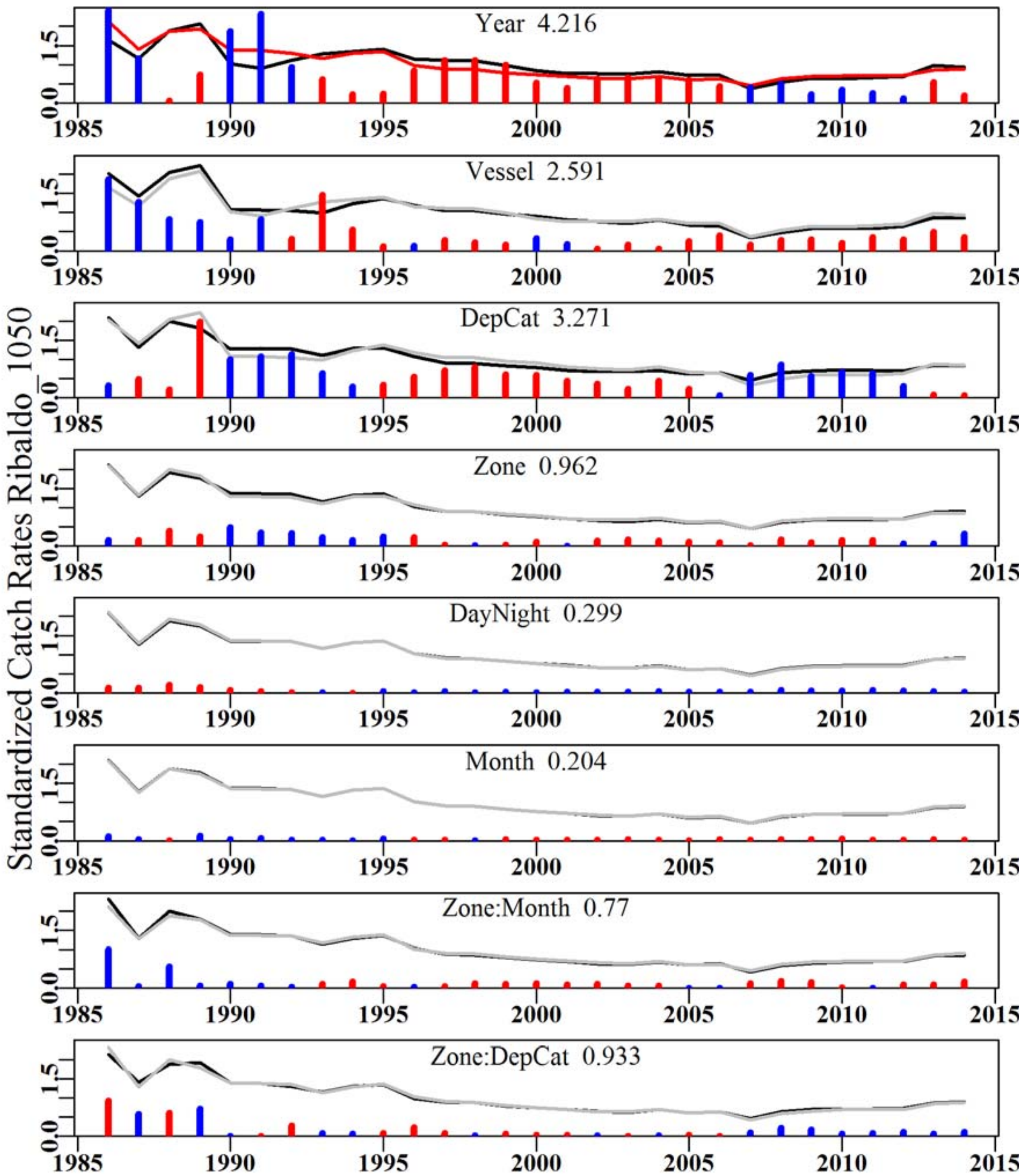


Figure 20.141. The relative influence of each factor used on the final trend in the optimal standardization for Ribaldo from zones 10 to 50. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by the vertical bars with blue 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.

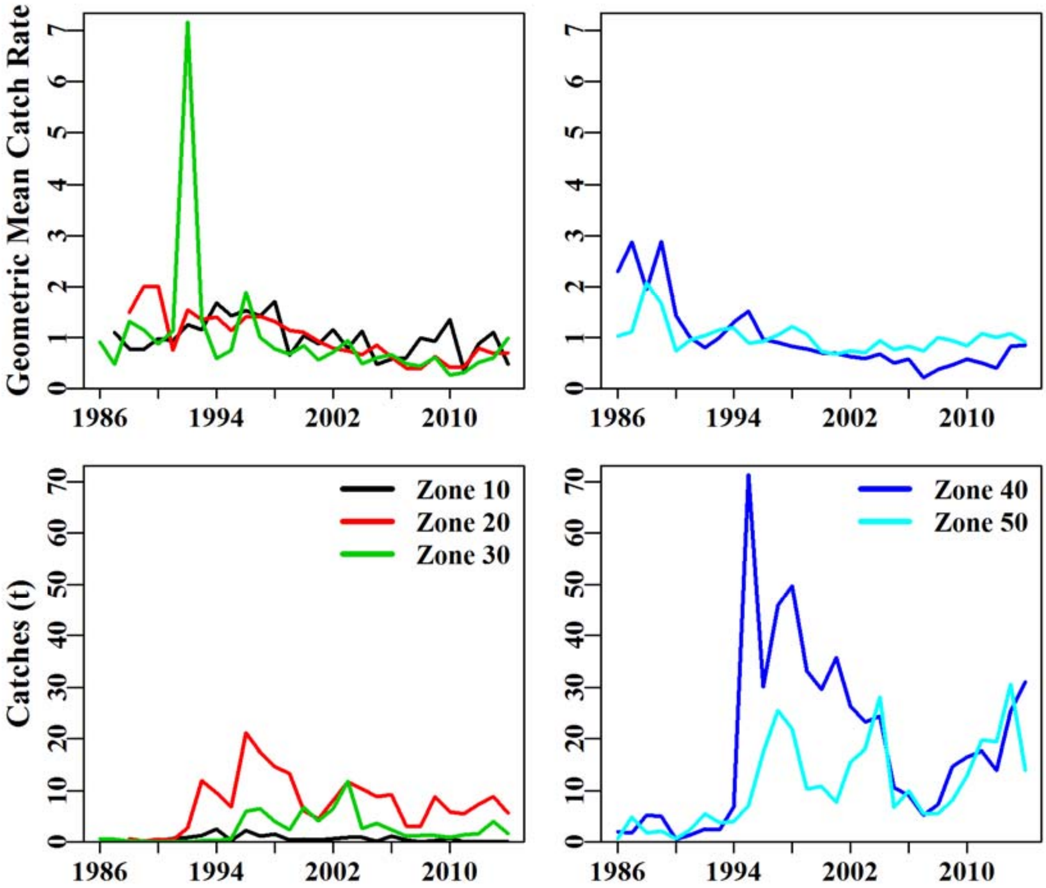


Figure 20.142. Ribaldo from zones 10 to 50 in depths 0 to 1000 m by Trawl. Geometric mean catch rate and catch (t) by zones 10-30 (left plots) and zone 40, 50 (right plots).

20.4.44 Ribaldo AL Z10-50 (RBD – 37224002 – Mora moro)

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

Table 20.127. 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	0.4304	0.0000
1998	99.9134	13	1.7530	2	88.6126	0.4331	0.4453
1999	72.1498	24	1.9470	1	40.6973	0.3213	0.3770
2000	66.7914	43	9.0390	1	96.6841	0.3368	0.3360
2001	82.4788	63	15.7200	2	157.4316	1.2161	0.3129
2002	157.8426	259	95.4965	4	135.9460	2.8184	0.2842
2003	180.8106	337	102.8823	7	75.0323	2.0948	0.2816
2004	180.9607	714	96.5886	11	51.6307	1.8695	0.2788
2005	90.3599	308	37.1892	7	44.5029	1.1563	0.2838
2006	122.5935	605	65.3525	8	39.5723	1.1223	0.2791
2007	78.3142	393	28.1252	6	25.0254	0.6799	0.2808
2008	78.4750	401	56.7722	6	39.2440	0.8082	0.2796
2009	104.9600	433	68.2730	6	49.5683	0.8009	0.2786
2010	91.9240	381	51.6696	5	47.4481	0.7596	0.2799
2011	93.9468	356	46.4764	5	45.6603	0.9106	0.2799
2012	107.2292	295	58.8469	6	60.9351	0.8503	0.2807
2013	122.3639	275	49.8231	5	48.7494	0.6669	0.2819
2014	133.9878	262	64.0475	5	56.3840	0.7245	0.2825

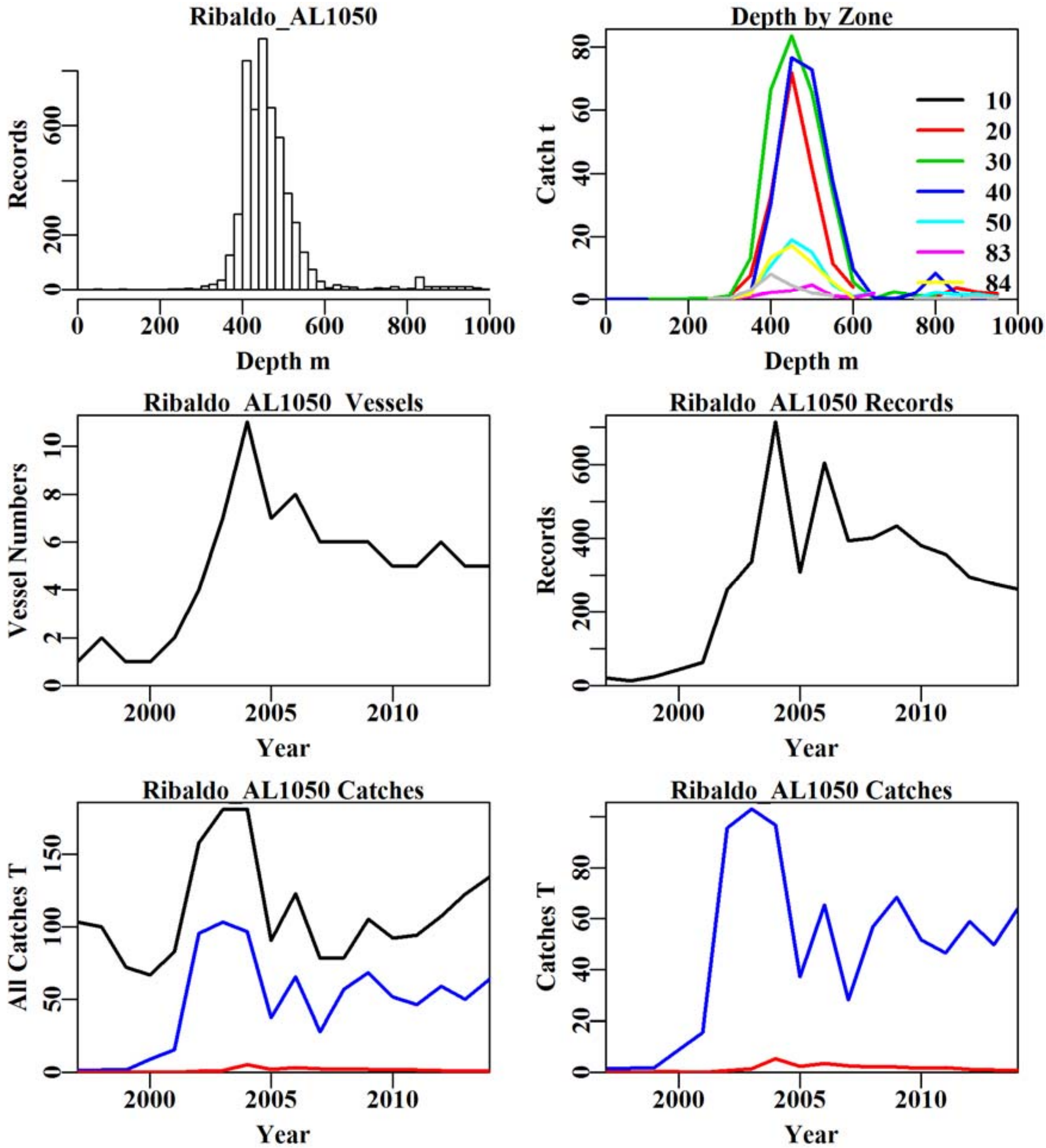


Figure 20.143. Ribaldo by Auto Line. The top left plot depicts the depth distribution of shots containing Ribaldo from zones 10 to 50 and the GAB in depths 0 to 1000 m by Auto Line employed in the standardization analysis. The top right plot depicts the catch distribution by depth by zone. The middle 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).

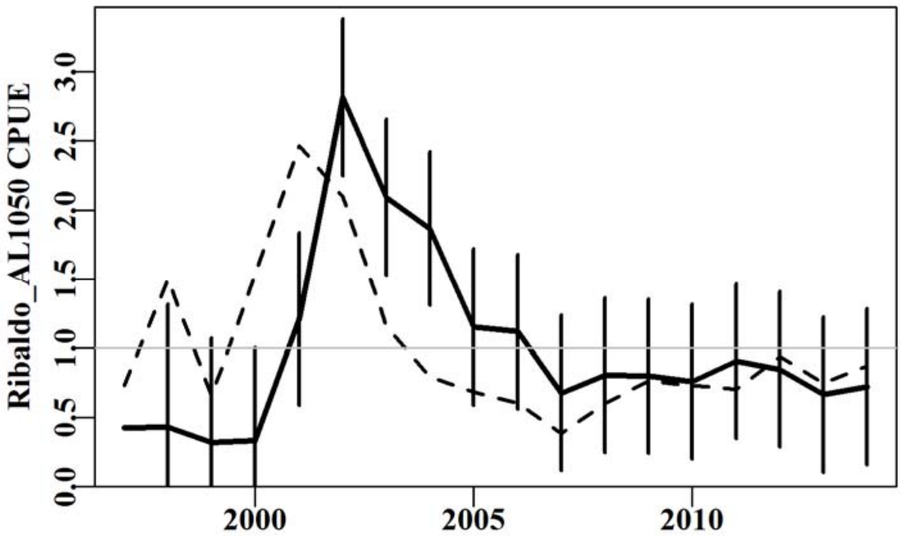


Figure 20.144. Standardized catch rates for Ribaldo by Auto Line. The dashed black line represents the geometric mean catch rate and the solid black line the standardized catch rates. The graph standardizes catch rates relative to the mean of the standardized catch rates. The vertical black lines represent 1.96 times the standard errors. The same statistical models that were used for the trawl analysis were also used here (Table 20.128).

Table 20.128. Ribaldo from zones 10 to 50 in depths 0 to 1000 m by Auto Line. Statistical model structures used in this analysis. DepCat is a series of 20 metre depth categories.

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

Table 20.129. Ribaldo taken by Auto Line. Model selection criteria include the Akaike Information Criterion (AIC), residual sum of squares (RSS), model sum of squares (MSS), number of usable observations (Nobs), number of parameters (Npars), adjusted R^2 (adj_R^2) and the change in adjusted R^2 (%Change). The optimum is Zone:Month (Model 7). Depth category: DepC.

	Year	Vessel	DepC	Zone	Month	Zone:Month	Zone:DepC
AIC	4932	2991	2606	2522	2480	2317	2333
RSS	13331	9124	8402	8244	8142	7658	7336
MSS	691	4897	5620	5778	5880	6364	6686
Nobs	5184	5184	5167	5167	5167	5167	5167
Npars	18	30	47	54	65	142	261
adj_R^2	4.614	34.560	39.540	40.599	41.206	43.853	44.909
%Change	0.000	29.946	4.980	1.059	0.607	2.647	1.056

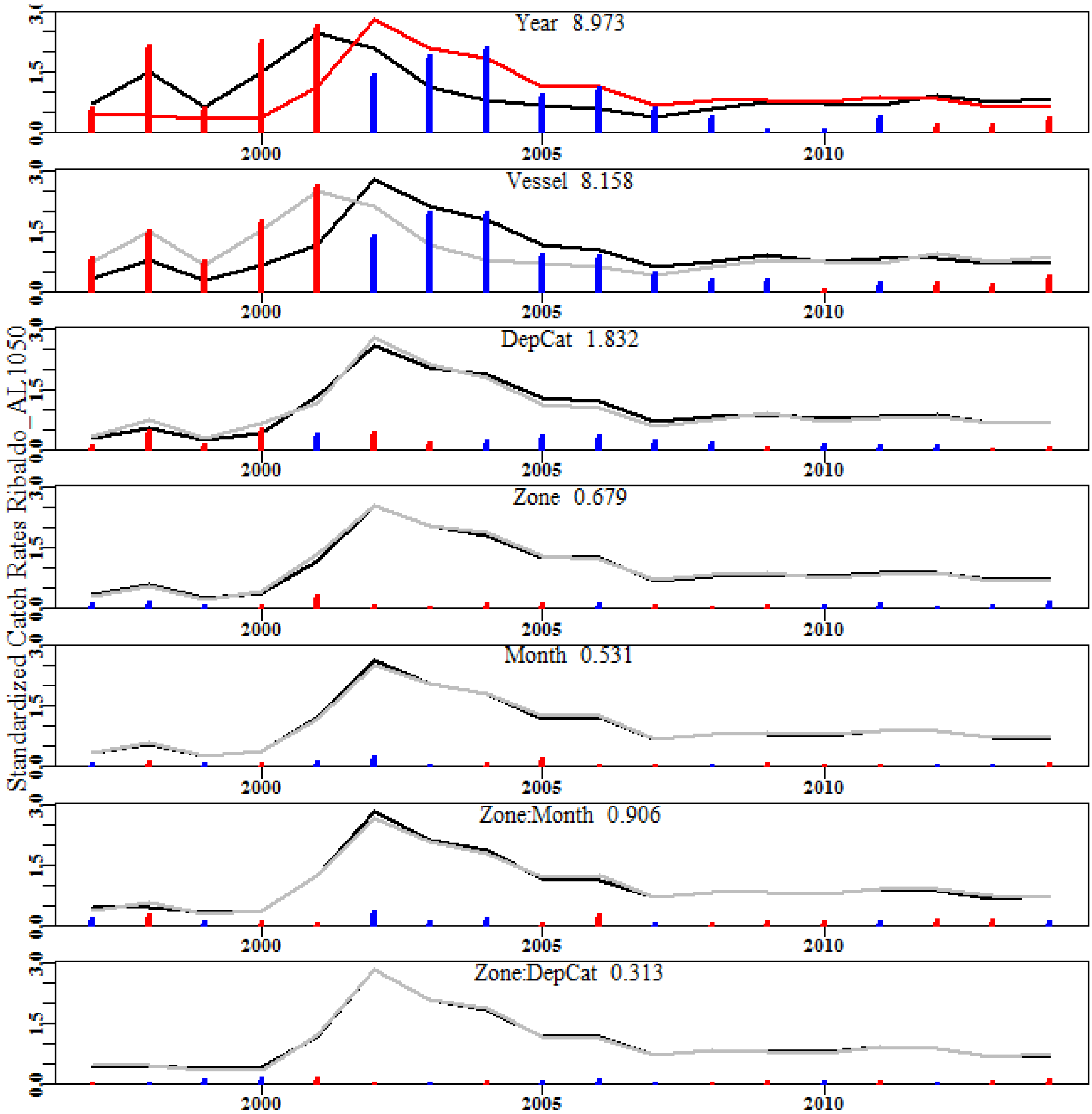


Figure 20.145. The relative influence of each factor used on the final trend in the optimal standardization for Ribaldo from zones 10 to 50 and the GAB. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by the vertical bars 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.

20.4.45 Ocean Jacketrs 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 20.130. 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	0.6470	0.0000
1987	53.3540	1445	28.1510	61	5.1085	0.6819	0.0365
1988	66.3040	1911	45.7250	66	6.2067	0.8248	0.0340
1989	71.6660	1808	32.7780	65	4.8860	0.7109	0.0346
1990	90.9690	1548	33.1570	46	4.9715	0.6954	0.0365
1991	170.4810	1329	24.7880	46	4.4265	0.6085	0.0384
1992	88.8840	1209	24.9530	41	4.8175	0.6297	0.0393
1993	71.8970	1342	29.2450	42	5.0852	0.6812	0.0389
1994	74.4380	1455	35.0440	45	5.9717	0.7679	0.0374
1995	140.1790	2237	59.3160	42	5.9904	0.7686	0.0339
1996	199.5710	2576	72.3070	54	6.3230	0.7900	0.0331
1997	177.4190	2009	52.4920	51	5.4540	0.7176	0.0349
1998	189.8986	2488	68.0170	44	5.2603	0.7105	0.0334
1999	202.8050	2691	88.4150	52	7.0029	0.8314	0.0329
2000	198.8111	2984	73.1960	53	5.1846	0.6642	0.0326
2001	222.5697	3190	64.2490	56	4.1918	0.5895	0.0324
2002	378.4963	4875	199.4070	62	5.4889	0.7013	0.0305
2003	482.3066	5504	187.3785	59	5.0841	0.6676	0.0300
2004	692.5927	6213	313.1105	61	8.3073	1.0898	0.0296
2005	890.6138	5162	342.8585	55	9.8912	1.2552	0.0304
2006	741.5297	4636	301.7370	51	10.2758	1.3867	0.0309
2007	564.8329	3092	285.3964	28	14.0314	1.6627	0.0332
2008	490.3988	3554	318.3140	30	13.7134	1.5747	0.0327
2009	609.9797	3260	376.1120	29	16.0145	1.7669	0.0331
2010	483.8922	3259	300.1655	30	13.2397	1.4656	0.0332
2011	487.4438	3224	277.1800	30	12.3456	1.3766	0.0331
2012	519.6479	3443	343.8395	31	14.4818	1.5879	0.0329
2013	488.2250	2835	264.7285	29	13.7441	1.6032	0.0338
2014	511.8626	2950	253.6885	28	12.5862	1.5427	0.0337

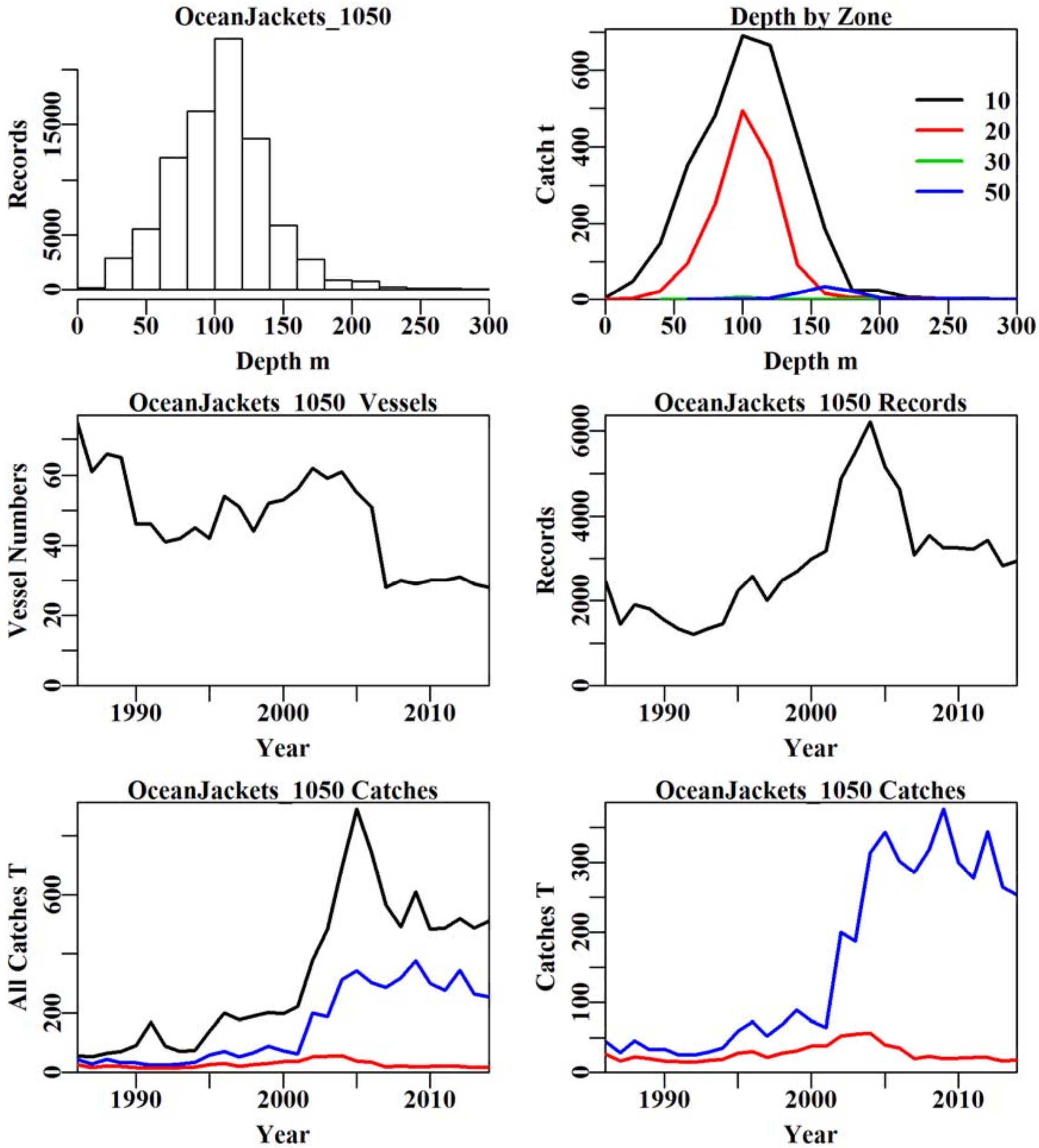


Figure 20.146. Ocean Jackets from zones 10 to 50 in depths 0 to 300 m by Trawl. The top left plot depicts the depth distribution of shots containing Ocean Jackets from zones 10 to 50 in depths 0 to 300 m by Trawl employed in the analysis. The top right plot depicts the catch distribution by depth by 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).

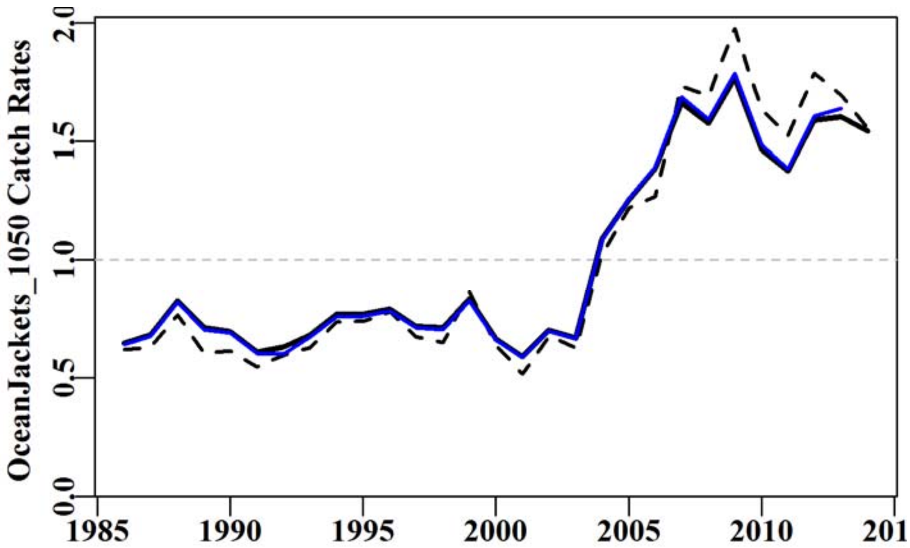


Figure 20.147. Ocean Jackets from zones 10 to 50 in depths 0 to 300 m by Trawl. The dashed black line represents the geometric mean catch rate, solid black line the standardized catch rates and solid blue line the standardized catch rates from last year's analysis. The graph standardizes catch rates relative to the mean of the standardized catch rates.

Table 20.131. 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 20.132. 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	18078	4926	4422	3751	3120	3096	2902	2144
RSS	104782	89356	88217	87492	86833	86802	86534	85734
MSS	15916	31343	32481	33206	33865	33896	34164	34965
Nobs	84702	84702	84124	84124	84124	84124	84124	84124
Npars	29	198	213	224	227	230	263	275
adj_R^2	13.158	25.795	26.727	27.319	27.864	27.887	28.082	28.737
%Change	0.000	12.637	0.931	0.592	0.545	0.023	0.195	0.655

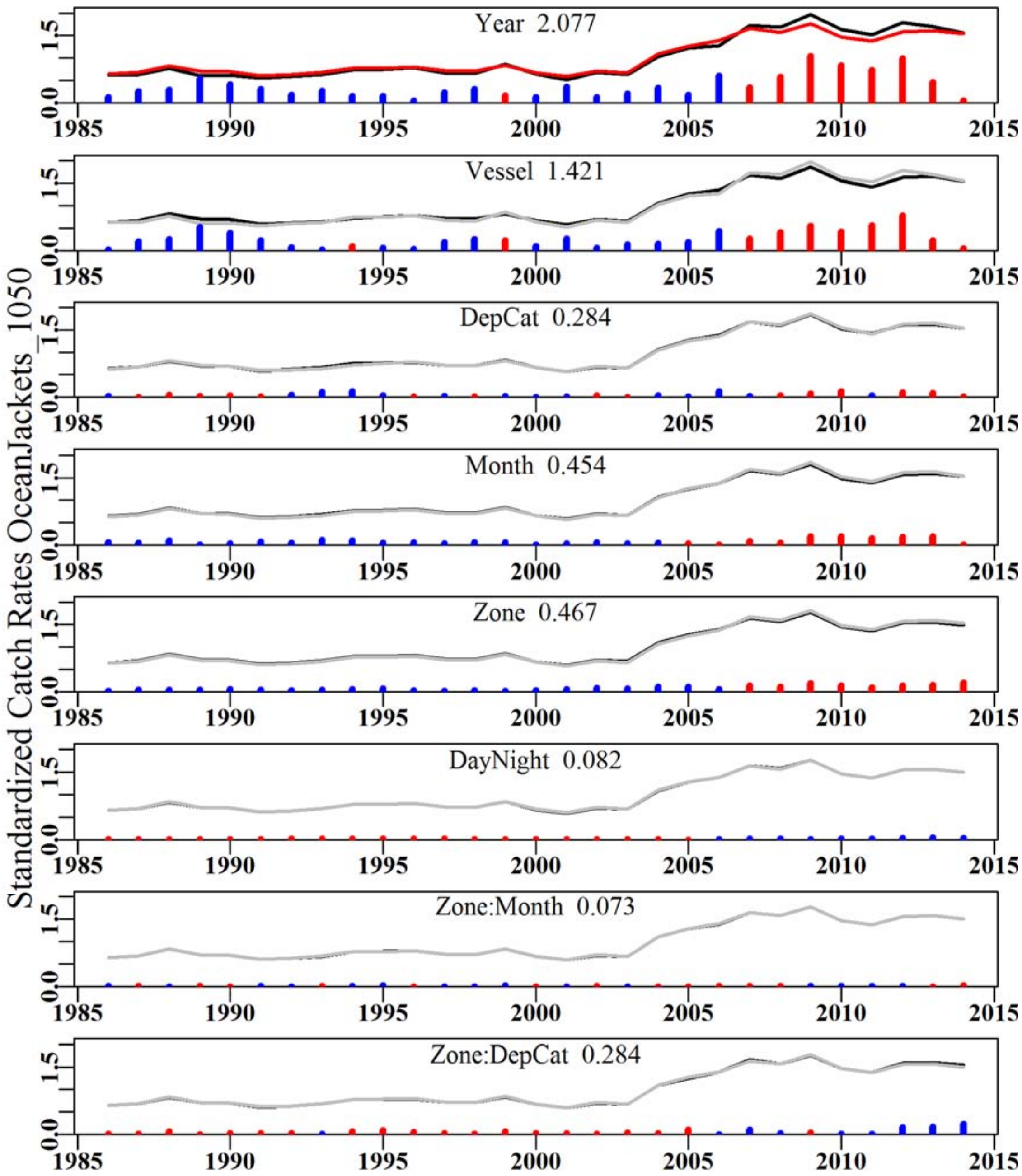


Figure 20.148. The relative influence of each factor used on the final trend in the optimal standardization for Ocean Jackets from Zones 10 to 50. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by the vertical bars with 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.

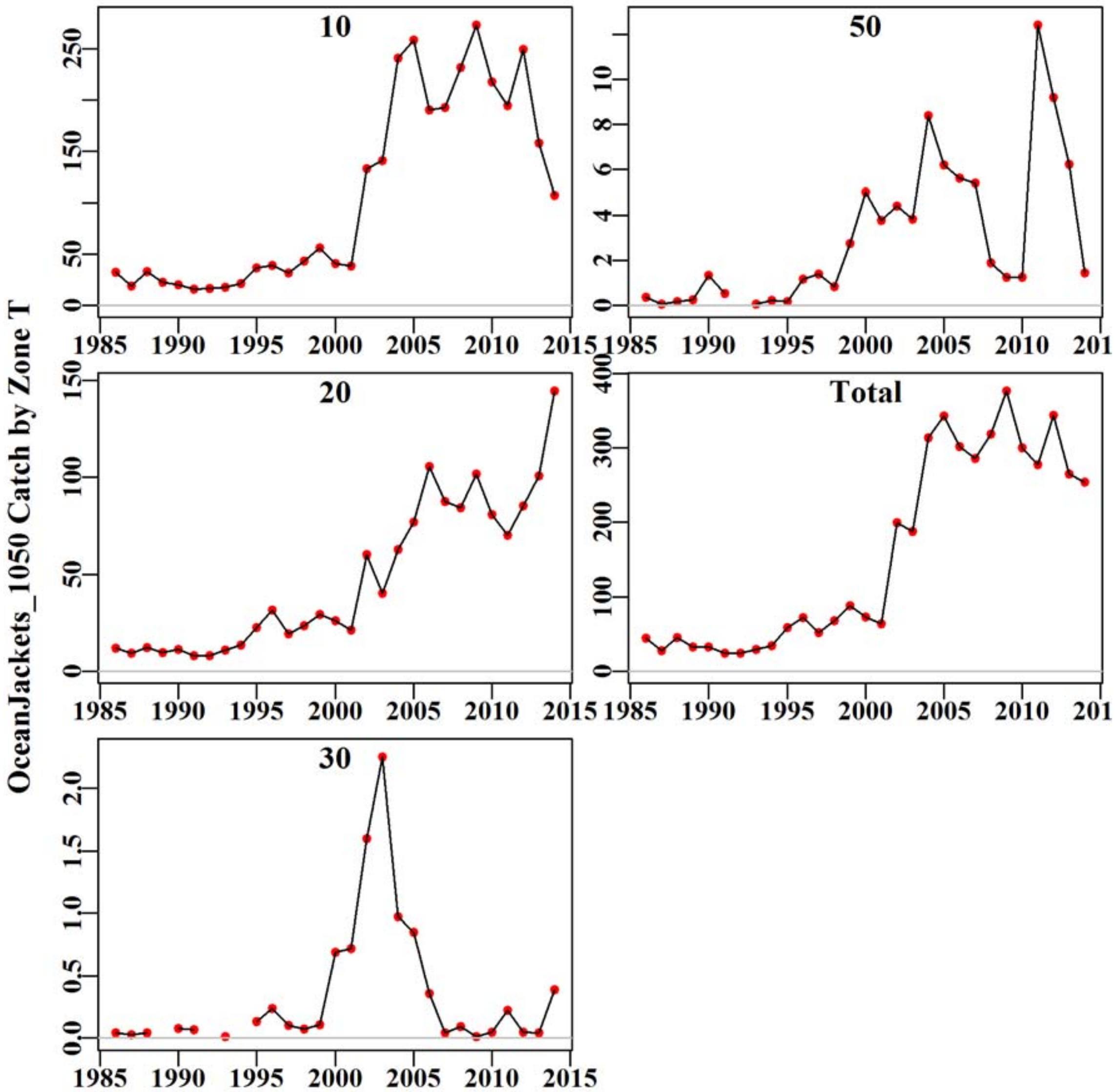


Figure 20.149. Ocean Jackets from Zones 10 to 50 in depths 0 to 300 m by Trawl. The catches taken in each of the four main SESSF zones is depicted with the total catch across these zones. The scales on the y-axis changes between graphs.

20.4.46 Ocean Jackets GAB (LTC – 37465006 – Nelusetta ayraudi)

Alternate: Leatherjackets (LTH – 37465000)

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

Table 20.133. 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	1.2075	0.0000
1987	53.3540	212	22.6320	3	13.7002	1.0285	0.1080
1988	66.3040	245	15.5900	7	14.0350	1.2073	0.1890
1989	71.6660	576	34.7140	7	11.9652	1.2117	0.1873
1990	90.9690	920	51.3800	11	11.1086	0.8226	0.1849
1991	170.4810	1252	139.7970	8	15.0694	1.0521	0.1843
1992	88.8840	954	59.5340	7	9.0287	0.9246	0.1842
1993	71.8970	819	38.7640	4	6.3105	0.6296	0.1841
1994	74.4380	745	36.6600	5	5.7741	0.5514	0.1849
1995	140.1790	1316	78.8320	5	6.2242	0.7197	0.1835
1996	199.5710	1725	123.4690	6	7.8262	0.8429	0.1832
1997	177.4190	2135	121.0640	9	6.4622	0.6977	0.1831
1998	189.8986	1799	116.4370	9	7.1373	0.7532	0.1832
1999	202.8050	1585	108.9700	7	7.8084	0.8664	0.1835
2000	198.8111	1552	122.3260	5	7.8146	0.8911	0.1837
2001	222.5697	1993	146.1530	6	8.6637	0.9278	0.1835
2002	378.4963	1798	148.3705	6	9.0807	0.9772	0.1836
2003	482.3066	2837	279.6050	9	10.8621	1.1235	0.1833
2004	692.5927	3433	364.4399	9	12.7575	1.2141	0.1832
2005	890.6138	4317	522.9095	10	13.9012	1.3070	0.1831
2006	741.5297	3609	408.4483	11	12.0564	1.0085	0.1832
2007	564.8329	2647	254.8505	8	10.2989	0.9012	0.1834
2008	490.3988	2351	146.3620	6	7.4758	0.7728	0.1836
2009	609.9797	2160	219.9650	4	10.4196	1.0640	0.1836
2010	483.8922	1792	168.2025	4	12.6091	1.2107	0.1839
2011	487.4438	1856	190.9830	4	13.1289	1.2343	0.1838
2012	519.6479	1712	154.6335	5	12.9054	1.1827	0.1840
2013	488.2250	2209	203.8610	6	13.9408	1.3014	0.1837
2014	511.8626	2006	206.0260	6	14.5396	1.3683	0.1838

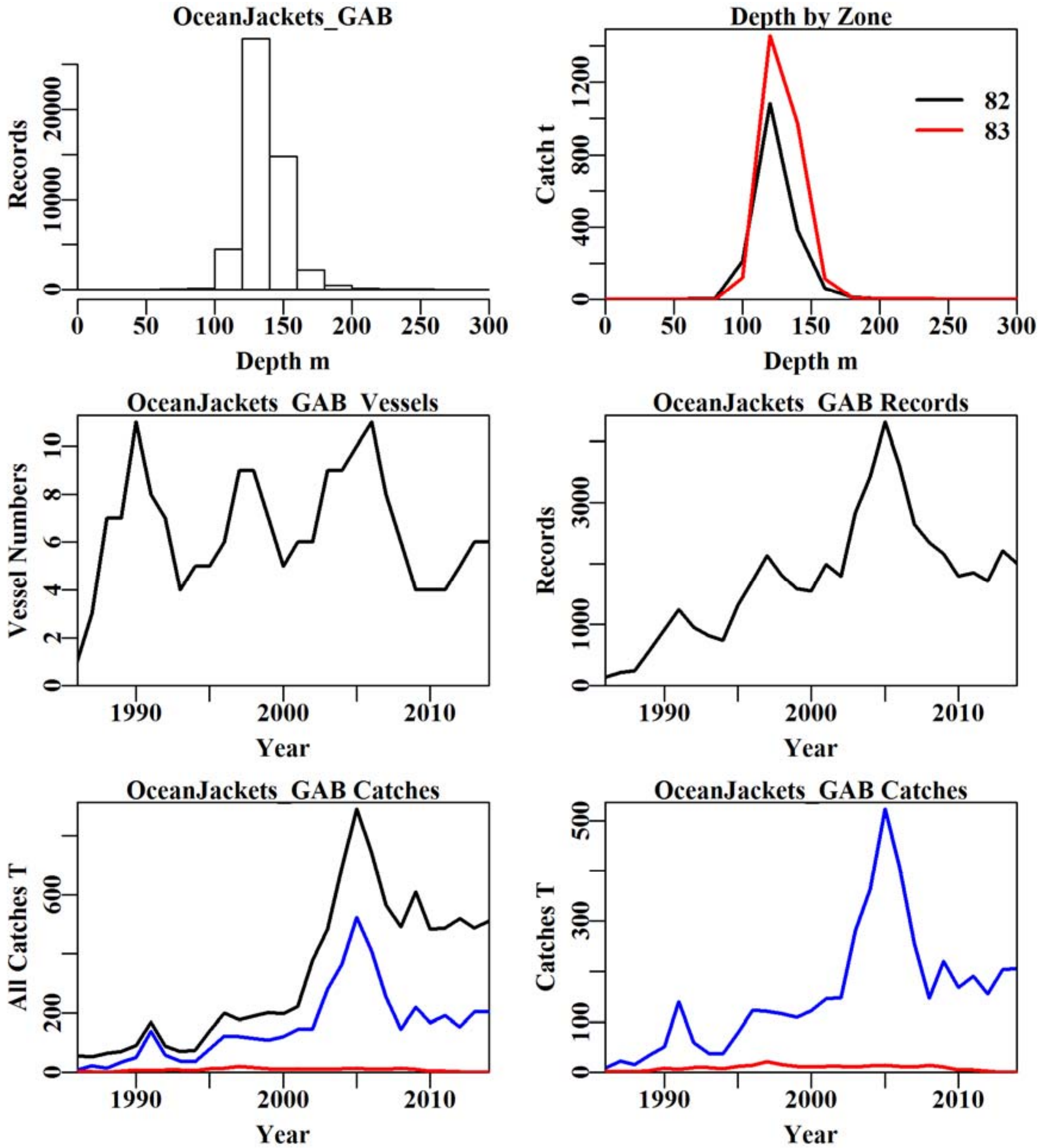


Figure 20.150. Ocean Jackets from zones 82 and 83 in depths 80 to 220 m by Trawl. The top left plot depicts the depth distribution of shots containing Ocean Jackets from Zones 82 and 83 in depths 80 to 220 m by Trawl. The top right plot depicts the catch distribution by depth by zone. The middle left 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).

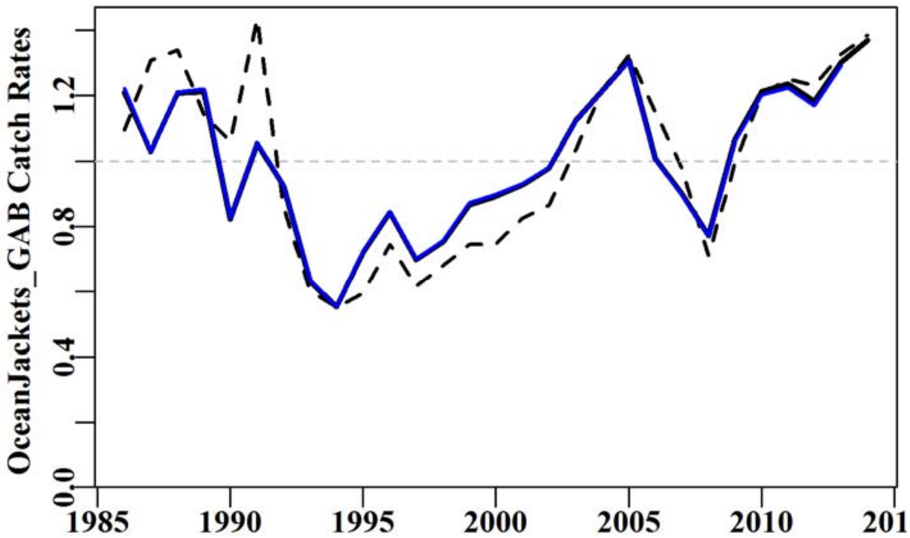


Figure 20.151. Ocean Jackets from zones 82 and 83 in depths 80 to 220 m by Trawl. The dashed black line represents the geometric mean catch rate, solid black line the standardized catch rates and blue line the standardized catch rates based on last year's analysis. The graph standardizes catch rates relative to the mean of the standardized catch rates.

Table 20.134. 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 20.135. 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	3208	-2316	-4636	-7112	-8199	-8218	-8433	-8217
RSS	53946	48371	45756	43494	42544	42527	42327	42502
MSS	3797	9372	11987	14249	15199	15217	15417	15241
Nobs	50696	50696	50271	50271	50271	50271	50271	50271
Npars	29	32	47	84	95	96	107	111
adj_R^2	6.524	16.180	20.686	24.553	26.184	26.213	26.544	26.234
%Change	0.000	9.655	4.507	3.866	1.631	0.029	0.331	-0.310

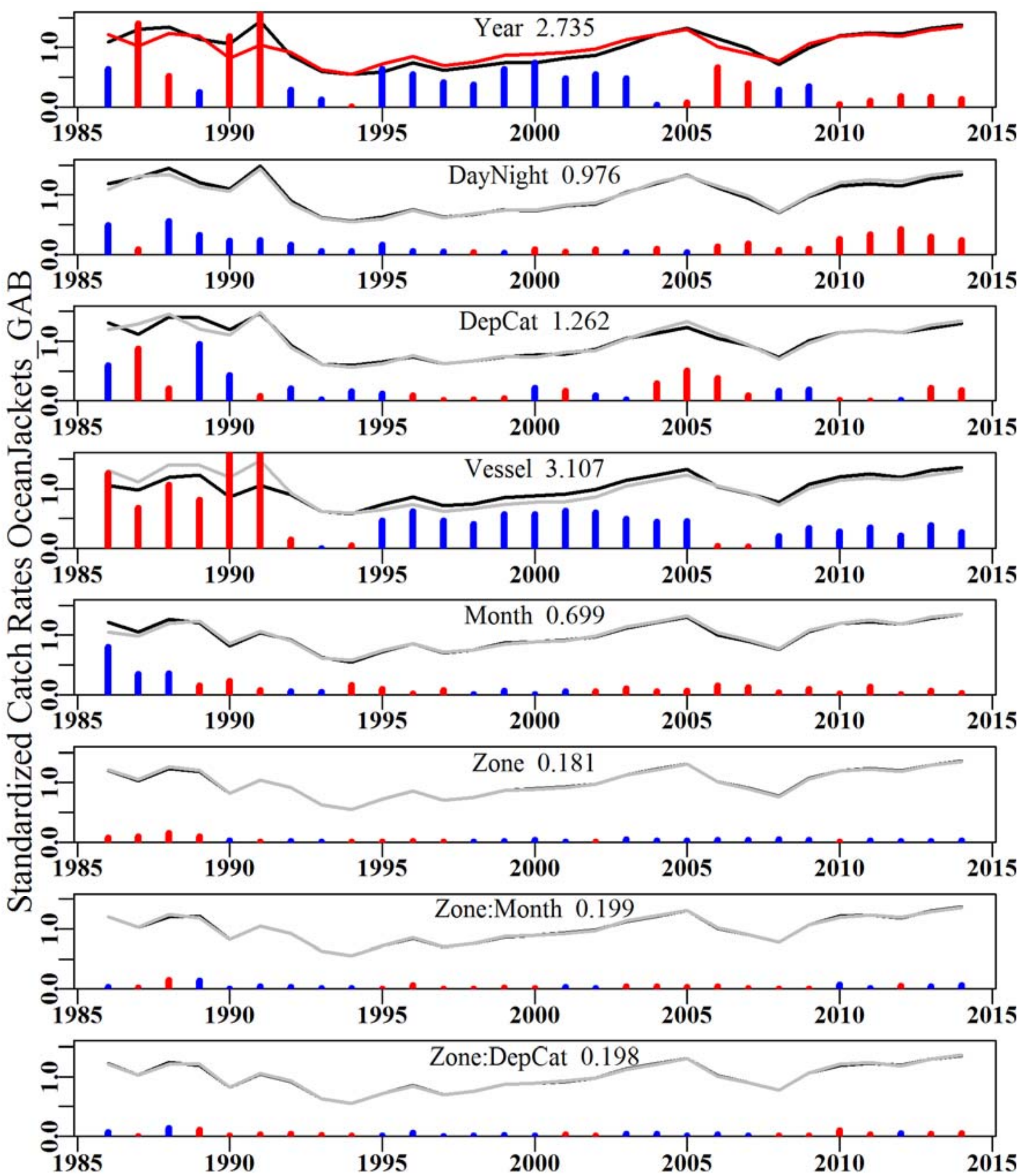
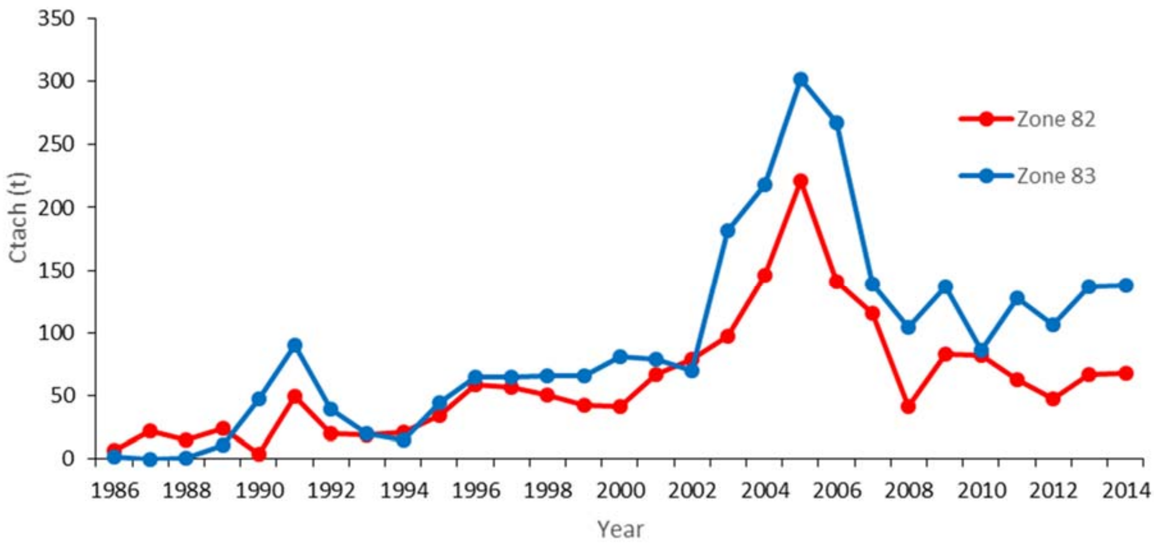


Figure 20.152. The relative influence of each factor used on the final trend in the optimal standardization for Ocean Jackets from zones 82 and 83. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by the vertical bars with 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.



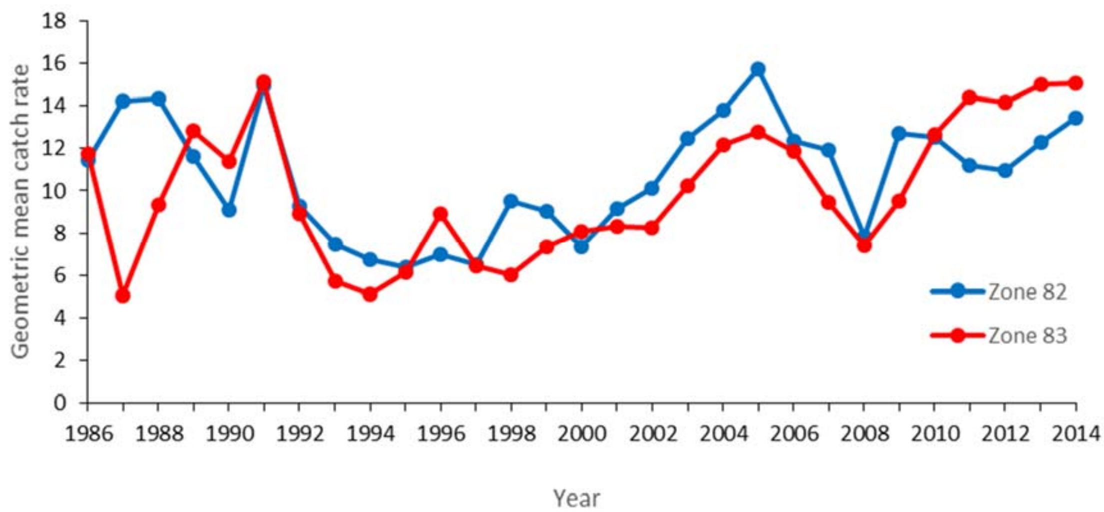


Figure 20.153. Trends in catches and geometric mean catch rates for Ocean Jackets in zones 82 and 83 in the GAB. The catches in the other zones remains too low to be informative about catch rates.

20.4.47 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 analysis.

Table 20.136. 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	0.4440	0.0000
1988/1989	317.2490	815	314.0740	9	56.0806	0.9049	0.0505
1989/1990	402.5570	1126	397.4970	7	53.0361	0.9692	0.0508
1990/1991	430.2310	1501	423.2260	11	49.0776	1.0391	0.0499
1991/1992	621.1150	1781	611.2140	13	54.5388	0.9464	0.0483
1992/1993	524.0620	984	509.2170	4	76.9248	1.1973	0.0502
1993/1994	593.1100	900	585.6450	7	91.4997	1.5182	0.0507
1994/1995	1285.9330	1745	1258.8930	6	106.3058	1.9542	0.0480
1995/1996	1585.1240	1862	1559.4390	5	125.2137	1.9037	0.0479
1996/1997	1499.2260	2784	1466.6360	8	79.3934	1.2554	0.0471
1997/1998	1029.9880	2908	1012.4710	10	50.9703	0.8913	0.0470
1998/1999	690.3890	2558	682.1710	7	34.6696	0.6601	0.0473
1999/2000	571.0500	2102	545.8370	7	39.1315	0.8020	0.0485
2000/2001	846.6200	2413	775.5200	6	43.0405	0.8690	0.0480
2001/2002	973.9438	2448	912.9710	6	51.5431	1.0359	0.0480
2002/2003	1711.5006	3144	1632.1305	8	73.4099	1.4947	0.0474
2003/2004	2272.7170	4536	2188.2269	10	68.4174	1.4015	0.0472
2004/2005	2158.9205	5551	2100.1866	10	55.0520	1.1331	0.0470
2005/2006	1433.1321	5349	1358.4065	11	37.5227	0.7377	0.0470
2006/2007	1015.4786	4254	969.1785	11	32.9286	0.6365	0.0470
2007/2008	1041.3325	4003	971.1735	7	35.9047	0.7091	0.0474
2008/2009	813.9210	3118	775.7370	5	40.6974	0.8392	0.0477
2009/2010	849.8300	3205	829.7290	4	39.1349	0.7893	0.0477
2010/2011	970.0015	2805	930.2880	4	50.8878	1.0102	0.0479
2011/2012	965.0510	3270	788.7420	4	38.5634	0.7792	0.0477
2012/2013	1017.8855	3611	876.1815	5	37.9557	0.7679	0.0476
2013/2014	882.6720	3304	672.6200	7	32.0053	0.6610	0.0477
2014/2015	456.0060	1263	264.2420	4	32.5847	0.6498	0.0506

Table 20.137. Reported catch of Deepwater Flathead by method across all methods and years.

Year	AL	BL	DL	DS	GN	OTT	PTB	TDO	TW
1987/1988									80.334
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									570.91
2000/2001					0.001				846.619
2001/2002					0.0033				973.9405
2002/2003					0.0091				1711.492
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				83.771		5.37	11.09	542.938	239.503
2014/2015				12.312				410.432	33.262

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 20.154 and Figure 20.156; All vessels and 0 – 1000 m).

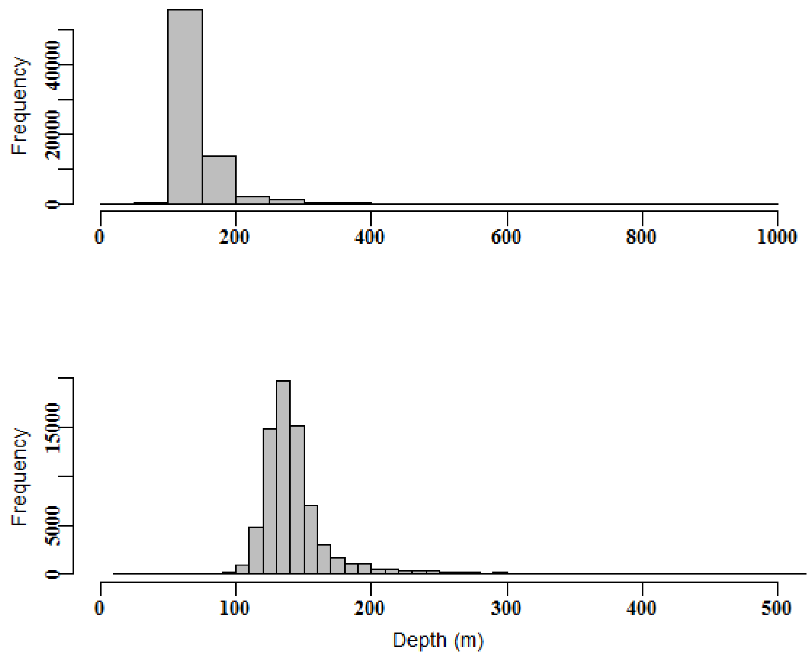


Figure 20.154. The depth distribution of records for the Deepwater Flathead fishery taken by Trawl in the GAB.

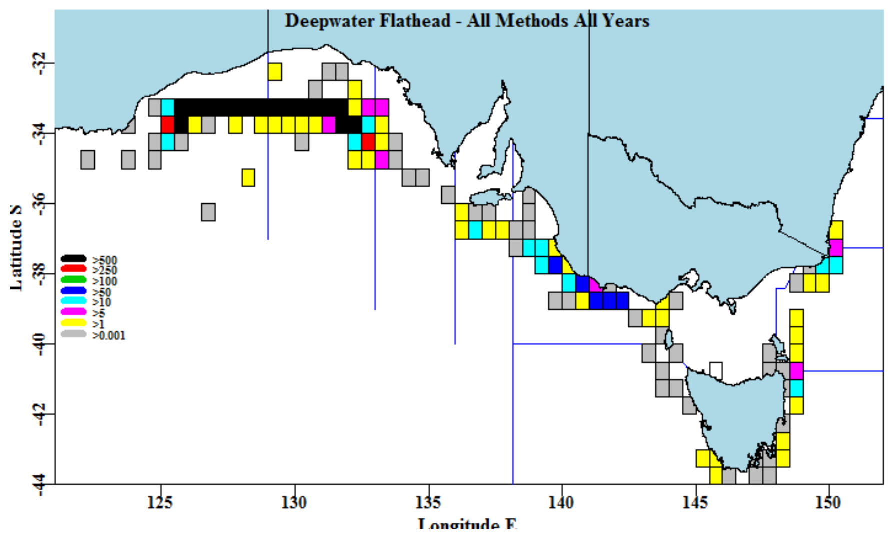


Figure 20.155. Schematic map of the distribution of catches of Deepwater Flathead from 1987/1988 to 2011/2012 taken by all methods (Table 20.137). Whether the catches reported around the south of Tasmania are correctly reported is questionable.

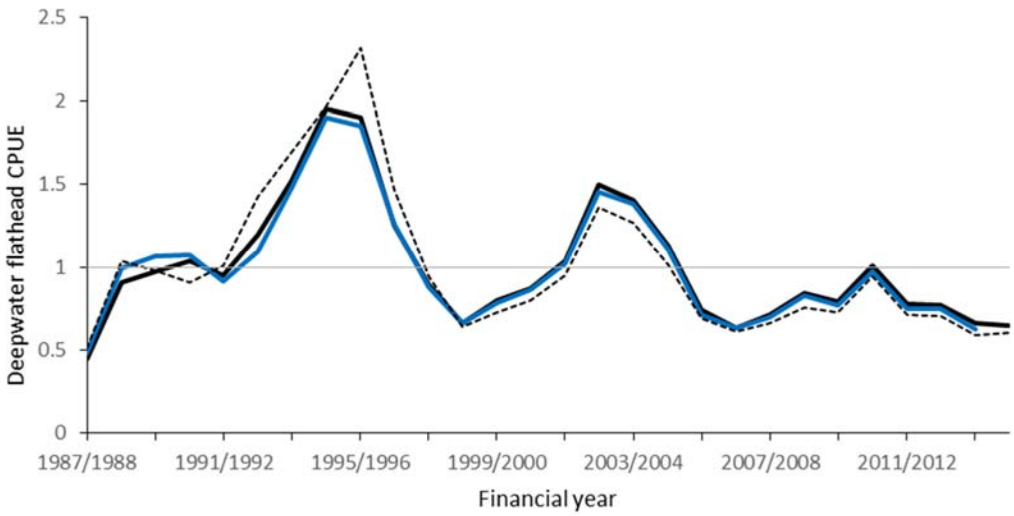


Figure 20.156. The standardized CPUE for Deepwater Flathead from the trawl fishery in the GAB. The dashed black line represents the geometric mean catch rate, solid black line the standardized catch rates and blue line the standardized catch rates based on last year's analysis. The graph standardizes catch rates relative to the mean of the standardized catch rates.

Table 20.138. 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 20.139. 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	-29697	-35523	-40270	-43681	-45104	-46750	-47684	-48575	-47353
RSS	49307	45512	42636	40697	39317	38437	37881	37232	37997
MSS	8545	12340	15216	17155	18535	19415	19971	20620	19855
Nobs	73793	73793	73755	73755	73089	73089	73089	73089	73089
Npars	28	70	75	87	107	110	176	362	230
adj_R^2	14.739	21.257	26.228	29.571	31.941	33.460	34.363	35.323	34.114
%Change	0.000	6.518	4.971	3.343	2.369	1.519	0.904	0.960	-1.209

20.4.48 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 20.157; 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 20.140. 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:Month and standard deviation (StDev) relates to the data in the optimum model.

Year	TotCatch	Records	CatchT	Vessels	GeoMean	Zone:Month	StDev
1987/1988	47.4340	194	33.5640	5	27.0147	2.3348	0.0000
1988/1989	87.9610	500	86.1350	6	32.3190	2.1028	0.1049
1989/1990	173.5590	833	171.8440	7	31.6051	1.5808	0.1024
1990/1991	290.1385	1023	250.2255	8	36.6457	1.4319	0.1005
1991/1992	274.0490	1104	240.5030	8	27.3180	1.3657	0.0981
1992/1993	132.0980	718	120.1880	3	18.3377	1.0363	0.1006
1993/1994	108.6860	696	107.6380	5	16.2401	0.9481	0.1011
1994/1995	163.5980	1290	159.9390	6	11.7236	0.6560	0.0965
1995/1996	176.9320	1395	175.2770	5	11.8016	0.7791	0.0966
1996/1997	334.0670	2037	329.7870	6	15.3350	0.8786	0.0951
1997/1998	375.8710	1930	365.9310	7	16.0229	0.9414	0.0952
1998/1999	442.2460	1813	440.3010	7	20.2060	1.0909	0.0952
1999/2000	328.3430	1478	324.4210	7	17.1853	0.9761	0.0975
2000/2001	398.7389	1697	387.5310	5	15.6494	0.8381	0.0967
2001/2002	232.9888	1637	225.6420	5	10.8567	0.6116	0.0969
2002/2003	378.0266	2118	364.3121	8	13.4661	0.6724	0.0956
2003/2004	862.0778	3154	841.7250	10	20.1099	0.9848	0.0953
2004/2005	889.9464	3809	758.1195	9	18.3680	0.9153	0.0949
2005/2006	802.9481	3556	722.8982	10	17.4060	0.8812	0.0949
2006/2007	961.6332	3294	873.7596	10	21.7641	0.9579	0.0946
2007/2008	759.0168	2743	683.5350	6	20.0988	0.9212	0.0954
2008/2009	665.4162	2443	648.7860	4	21.9054	0.9974	0.0959
2009/2010	463.7251	2298	445.7170	4	17.3788	0.8695	0.0960
2010/2011	286.5087	1851	277.8890	4	14.2669	0.7219	0.0968
2011/2012	330.9570	2188	322.8650	4	14.4261	0.7265	0.0964
2012/2013	266.9629	1873	255.7050	4	15.2702	0.6285	0.0971
2013/2014	199.6347	1494	187.5580	4	14.6134	0.5851	0.0980
2014/2015	214.2191	535	48.3470	4	10.4618	0.5662	0.1068

Table 20.141. Reported catch of Bight Redfish by method and years.

Year	Line	GN	PS	DS	Trawl
1987/1988					47.4340
1988/1989					87.9610
1989/1990					173.5590
1990/1991					290.1385
1991/1992					274.0490
1992/1993					131.4380
1993/1994					108.6860
1994/1995					162.3110
1995/1996					176.9020
1996/1997					334.0470
1997/1998					375.8110
1998/1999					442.2160
1999/2000					328.3430
2000/2001		1.0369			397.7020
2001/2002	0.6440	3.1238			229.2210
2002/2003	0.0055	3.3255			374.6956
2003/2004	0.0200	4.9658			857.0920
2004/2005	0.0040	5.2114		0.0040	884.7160
2005/2006	0.2452	6.4947	30.0000		766.2082
2006/2007	0.1821	7.9965			953.4546
2007/2008	0.1512	7.7796			751.0860
2008/2009	0.0550	8.1033			657.2580
2009/2010	0.0880	5.3801			458.2570
2010/2011	0.0360	2.3296		1.2690	282.8741
2011/2012	0.1698	2.0143		3.1980	325.5750
2012/2013	0.3125	0.3240		0.9050	265.4215
2013/2014	0.7406	0.3991		1.1640	197.3310
2014/2015	1.1527	0.5544		0.1340	212.3780

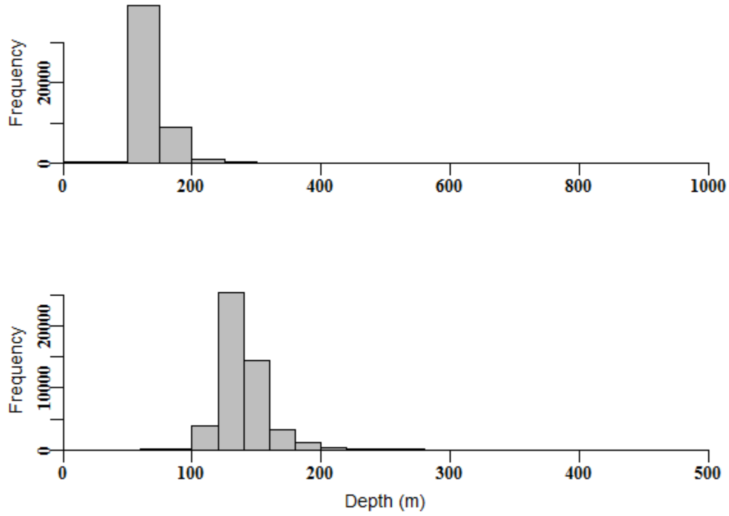


Figure 20.157. The depth distribution of records for the Bight Redfish fishery taken by Trawl in the GAB.

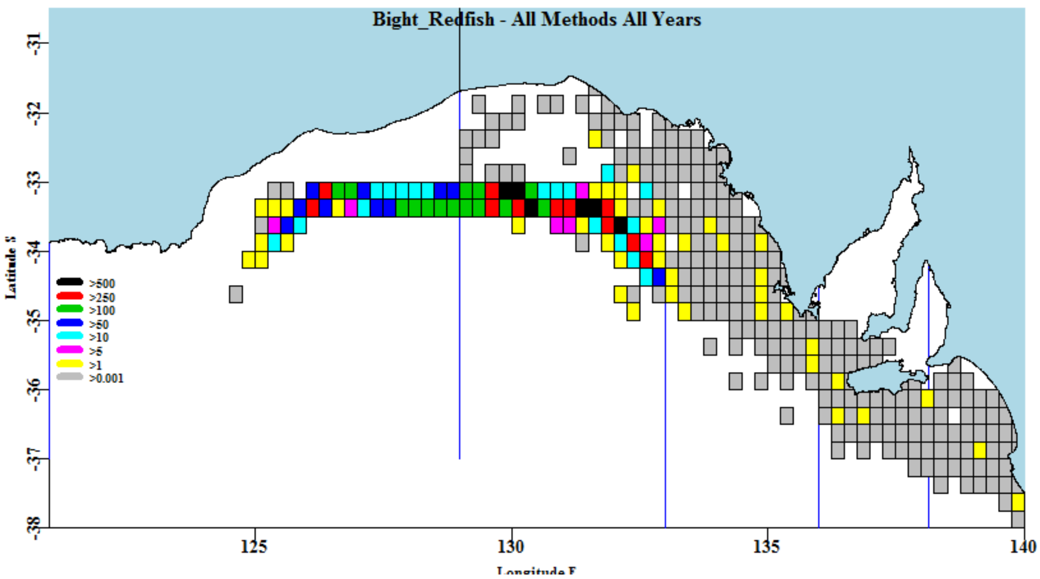


Figure 20.158. Schematic map of the distribution of catches of Bight Redfish from 1987/1988 to 2014/2015 taken by all methods (Table 20.141). Catches are higher in the east of the GAB.

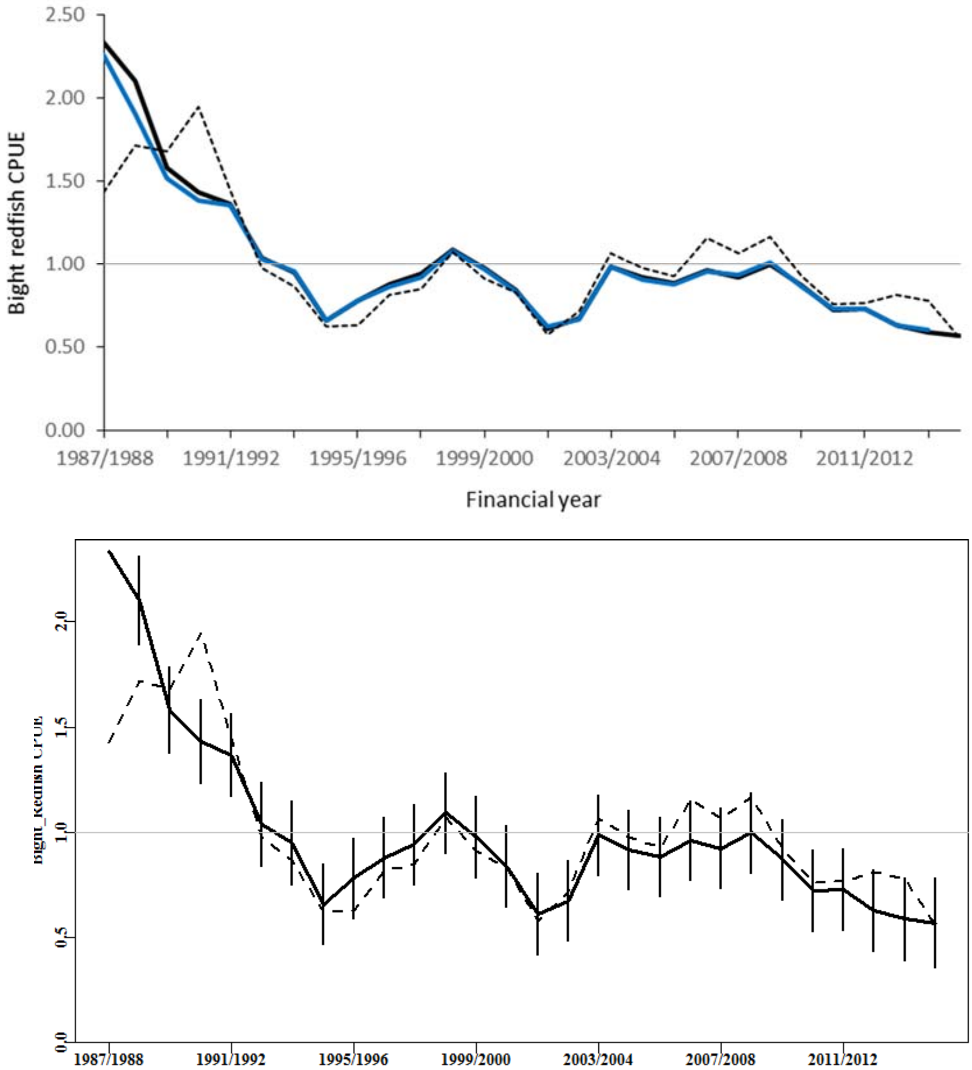


Figure 20.159. The standardized CPUE for Bight Redfish from the trawl fishery in the GAB. Upper graph: solid black line the standardized catch rates (relative to the mean of the standardized catch rates). The blue line corresponds to last year's standardized catch rates. Lower graph: Standardized indices (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 20.142. 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 20.143. 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	31217	25790	21272	18186	17054	16355	16014	16097	16065
RSS	93036	83403	76134	71519	69852	68321	67637	67577	67246
MSS	3137	12771	20039	24654	26321	27852	28537	28596	28927
Nobs	49701	49701	49701	49701	49701	49209	49209	49209	49209
adj_R^2	3.209	13.226	20.777	25.564	27.269	28.812	29.414	29.385	29.580
%Change	0.000	10.017	7.551	4.786	1.706	1.542	0.602	-0.029	0.195

20.5 Deepwater species

Only catch rates for deepwater sharks and oreos are considered here. Both mixed oreos (a basket of oreo species), as well as smooth oreos requires attention however (Table 20.144).

Table 20.144. 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 (t)	TAC with over & under-catch (t)	Catch (t)	% TAC Caught	% Agreed TAC
Deepwater Sharks East	47	50.762	2.675	5.27	5.69
Deepwater Sharks West	215	231.059	5.831	2.52	2.71
Orange Roughy (Albany-Esperance)	50	50.000	0.000	0.00	0.00
Orange Roughy (Cascade Plateau)	500	500.000	0.000	0.00	0.00
Orange Roughy (Eastern)	465	465.000	61.061	13.13	13.13
Orange Roughy (Southern)	66	66.000	23.281	35.27	35.27
Orange Roughy (Western)	60	60.000	1.065	1.78	1.78
Oreos	128	140.296	10.968	7.82	8.57
Smooth Oreos (Cascade Plateau)	150	165.000	0.000	0.00	0.00
Smooth Oreos (other)	23	25.117	11.618	46.26	50.51

20.5.1 Eastern Deepwater Sharks

Table 20.145. 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). Most recent discard rates were not estimnated due to small sample sizes (Upston, 2014).

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 20.146. 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 20.147. 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	80.398	14.518	0.008	31.506	20.583	171.741	183.127	201.516
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	87.409
2003	15.139		15.781	46.218	30.777	158.323	98.648	25.855
2004	13.069		14.591	50.639	22.834	168.265	103.623	21.116
2005	16.526		6.730	30.602	7.843	82.795	34.019	24.614
2006	12.730		4.976	21.827	16.844	83.916	39.181	14.682
2007	17.693		0.001	1.125	6.589	25.756	6.107	5.684
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	27.481	1.874
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
2014	3.416	7.326	3.701	22.905	3.615	47.013	11.115	2.321

Table 20.148. 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	3645	2002	1119	1108	963	964	926	1860
RSS	15532	13245	11961	11925	11761	11759	11626	10939
MSS	2465	4752	6037	6073	6237	6239	6371	7059
Nobs	11285	11285	11022	11022	11022	11022	11022	11022
Npars	20	97	109	120	124	125	169	972
adj_R^2	13.553	25.774	32.884	33.019	33.918	33.920	34.401	33.349
ΔR^2	0.000	12.221	7.110	0.136	0.899	0.002	0.481	-1.052

Table 20.149. Number of records where Eastern Deepwater Sharks are reported from trawling in OR Zones 10, 20, 21, and 50, in depths 600 to 1250 m. Vessel represents the count of vessels reporting eastern deepwater sharks. Yield is the total reported catch in tonnes. The geometric mean CE is the raw unstandardized catch rate in kg/hour. The left hand five columns represent all data, the right hand five columns represent the areas left open following the 700m closure.

Year	Yield	Records	Effort	Vessels	Geom	YieldO	RecordsO	EffortO	VesselsO	GeomO
1986	28.926	254	1051.900	25	11.827	19.987	193	769.490	24	11.734
1987	5.792	97	326.630	26	8.745	3.888	79	262.230	21	8.231
1988	5.246	38	137.000	18	14.679	2.895	25	93.600	11	12.810
1989	5.432	77	243.130	17	13.464	4.811	67	211.630	14	13.246
1990	5.352	42	124.600	17	16.157	2.348	19	60.100	13	7.902
1991	18.828	111	337.360	20	23.288	3.338	34	113.500	13	13.384
1992	62.977	103	467.380	18	36.871	4.465	39	210.030	13	12.201
1993	93.604	258	967.800	19	47.054	8.774	69	262.580	14	13.816
1994	111.139	424	1616.940	25	37.808	13.602	83	354.310	21	22.206
1995	114.605	361	1496.710	17	49.650	19.562	64	266.020	15	43.332
1996	326.351	952	3712.390	26	52.295	48.551	178	695.890	20	32.456
1997	194.116	903	4091.140	24	30.823	29.155	185	806.340	21	21.938
1998	206.236	1104	4996.310	24	27.625	46.182	255	1107.250	18	23.209
1999	156.797	1009	4670.600	25	22.170	26.910	175	817.690	17	18.689
2000	187.075	889	4252.450	30	27.855	30.854	167	768.620	22	19.900
2001	140.686	892	4119.220	28	19.961	28.697	208	873.870	25	14.624
2002	160.781	892	4233.080	29	23.377	30.786	196	901.390	27	16.570
2003	128.789	963	4744.890	25	16.848	17.750	140	687.660	20	15.579
2004	103.248	716	3459.050	30	17.959	17.483	128	605.190	25	15.469
2005	61.376	477	2470.230	17	15.739	10.247	67	306.890	13	22.276
2006	43.227	408	1959.920	22	11.414	7.958	52	229.240	13	14.816
2007	8.418	106	493.530	18	10.127	5.457	76	336.410	15	9.125
2008	12.904	100	658.310	10	10.800	6.788	62	379.010	10	9.723
2009	38.892	230	1226.840	15	16.957	12.240	63	322.670	12	13.675
2010	24.806	244	1264.020	13	10.087	5.257	67	365.750	11	6.458
2011	25.211	243	1356.790	15	10.962	5.901	78	404.510	12	6.611
2012	25.926	278	1544.690	16	8.911	6.442	81	441.360	13	5.443
2013	20.775	252	1362.060	15	8.595	5.536	68	331.290	12	6.440
2014	28.520	266	1734.710	13	11.172	3.308	43	240.340	10	8.225

Table 20.150. 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	2.4546	2.1507	1.9811	1.9978	2.0378	2.0342	2.0070	0.0000
1996	2.5921	2.8454	2.8354	2.8452	2.4782	2.4764	2.4620	0.0726
1997	1.5279	1.5748	1.4247	1.4291	1.3686	1.3676	1.3860	0.0706
1998	1.3692	1.2883	1.1585	1.1658	1.1838	1.1850	1.1937	0.0697
1999	1.0989	1.1002	0.9641	0.9660	0.9891	0.9888	0.9748	0.0698
2000	1.3808	1.3431	1.1756	1.1669	1.1808	1.1811	1.1630	0.0712
2001	0.9895	1.0491	0.9619	0.9556	1.0082	1.0092	1.0174	0.0721
2002	1.1588	1.1372	1.0579	1.0656	1.1070	1.1075	1.0979	0.0720
2003	0.8351	0.8514	0.7669	0.7652	0.7833	0.7833	0.7917	0.0719
2004	0.8904	0.8324	0.7668	0.7612	0.7948	0.7955	0.7998	0.0741
2005	0.7807	0.7760	0.7431	0.7434	0.7613	0.7607	0.7556	0.0798
2006	0.5663	0.5497	0.6624	0.6578	0.6590	0.6579	0.6641	0.0825
2007	0.5049	0.4841	0.7362	0.7327	0.7471	0.7484	0.7429	0.1285
2008	0.5386	0.5935	0.9225	0.9234	0.9447	0.9451	0.9411	0.1273
2009	0.8424	0.9110	1.1208	1.1172	1.1182	1.1193	1.1300	0.0969
2010	0.5010	0.5574	0.6003	0.5964	0.6160	0.6162	0.6178	0.0941
2011	0.5445	0.5332	0.5923	0.5928	0.6237	0.6249	0.6337	0.0958
2012	0.4425	0.4546	0.5127	0.5143	0.5441	0.5446	0.5520	0.0915
2013	0.4269	0.4210	0.4757	0.4758	0.4828	0.4827	0.4951	0.0927
2014	0.5548	0.5469	0.5411	0.5278	0.5715	0.5715	0.5744	0.0898

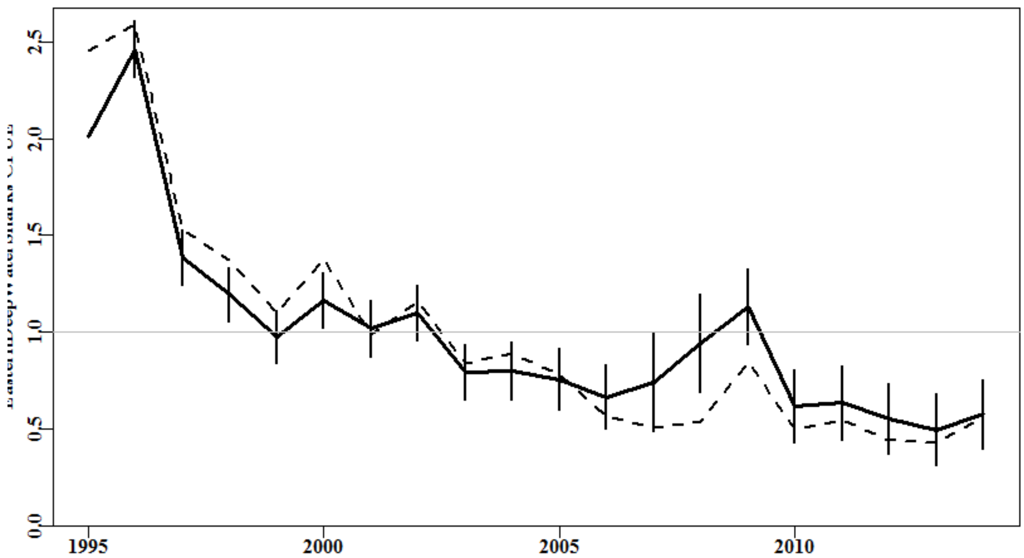


Figure 20.160. Eastern Deepwater Sharks reported from trawling in OR Zones 10, 20, 21, and 50, in depths 600 to 1250 m. The black dashed line from 86-14 represents the geometric mean catch rate and the solid black line the optimum standardized catch rates (Model 7). The graph scales the catch rates relative to the mean of the standardized catch rates (depicted by the horizontal grey line at 1.0).

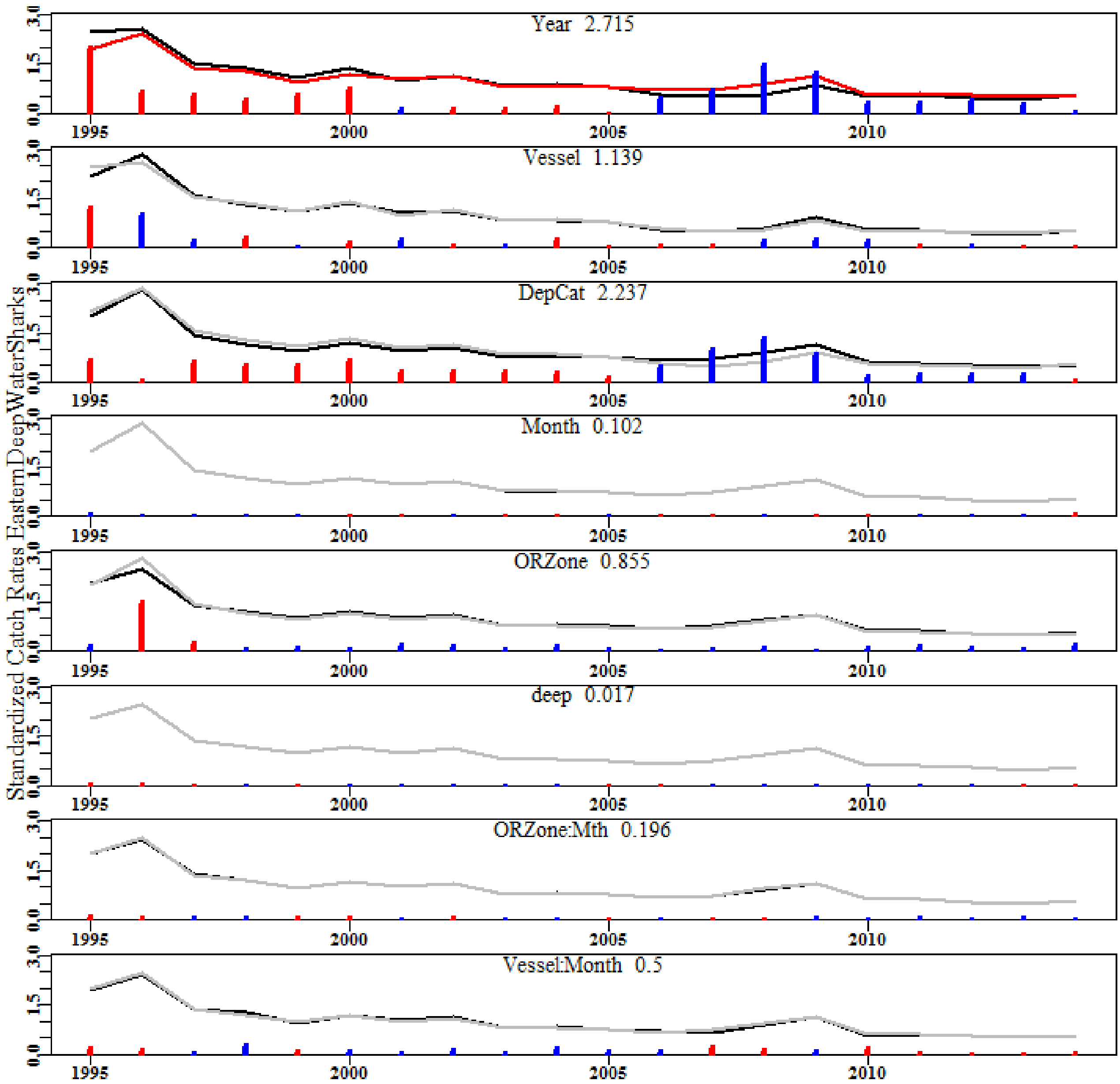


Figure 20.161. The relative impact of the different factors on the changes in the standardized trend. The major effects of both the structural adjustment that occurred across Nov 2005 – Nov 2006, with its change of vessels, and the deepwater closures is clear.

20.5.2 Western Deepwater Sharks

There are numerous species grouped together into the Western Deepwater Sharks (Table 20.151) but only some have data and even fewer have significant catches reported.

Table 20.151. 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). Most recent were not estimated due to small sample sizes (Upston, 2014).

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 20.152. 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 20.153. 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/hour. 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	56.40	3	13.861	0.430	5	18.30	2	14.670
1987	0.558	19	61.50	4	7.496	0.391	12	38.70	3	7.786
1988	0.525	4	11.00	2	46.530					
1989	1.200	13	40.00	2	28.124	0.490	6	19.50	2	23.730
1990	0.250	4	13.00	3	9.554	0.250	4	13.00	3	9.554
1991	0.315	5	17.60	3	12.628	0.015	1	2.00	1	7.500
1992	3.580	20	94.16	3	32.371	2.080	11	46.91	3	34.864
1993	1.785	17	60.75	3	21.610	0.515	3	10.25	1	36.719
1994	1.512	22	127.81	3	9.830	0.120	1	3.50	1	34.286
1995	95.106	593	2928.98	10	19.783	17.586	137	635.90	8	15.837
1996	185.802	955	4490.82	23	23.831	26.576	178	820.51	16	18.611
1997	325.955	1975	10101.85	19	19.686	43.124	336	1664.58	18	15.714
1998	396.302	2901	16201.93	18	16.498	55.336	432	2425.79	16	13.652
1999	312.960	2212	12543.90	19	16.628	35.362	351	1929.83	14	11.954
2000	311.079	1869	10462.51	18	20.998	38.964	287	1477.37	16	18.136
2001	241.687	1833	10406.49	19	15.555	33.968	296	1715.10	16	13.213
2002	251.380	1622	10168.04	17	16.598	32.394	254	1577.64	15	13.450
2003	163.455	1417	8995.89	16	12.107	21.645	223	1363.46	15	11.046
2004	207.534	1717	10870.22	15	13.032	30.394	267	1661.49	13	12.863
2005	81.425	805	4815.85	13	10.785	11.248	131	753.54	11	8.263
2006	70.907	607	3806.42	12	11.730	13.417	122	718.46	11	12.330
2007	8.362	109	681.82	9	6.326	3.439	50	309.96	8	5.468
2008	15.245	117	784.10	8	12.183	7.277	57	371.65	6	13.115
2009	32.803	221	1486.74	10	12.503	11.742	85	563.75	8	10.694
2010	35.050	263	1625.08	10	11.682	9.361	89	519.43	8	8.194
2011	37.547	303	2080.31	11	10.482	7.664	85	572.97	9	6.226
2012	36.848	391	2580.97	10	8.870	9.117	90	641.04	8	7.197
2013	65.370	629	4442.37	12	9.689	11.206	117	810.29	10	8.271
2014	52.028	504	3987.11	8	8.671	5.600	64	490.83	7	6.554

Table 20.154. 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 (Δ R^2). Model 6 was optimal (Deep). The effect of being in the open or closed areas (Deep) was minor. Depth category: DepC.

	Year	DepC	Vessel	Month	DayNight	Deep	Vessel:Month
AIC	857	-1683	-2644	-2839	-2843	-2847	-2558
RSS	21876	19250	18310	18121	18112	18107	17529
MSS	1418	4044	4984	5173	5182	5187	5765
Nobs	21043	20950	20950	20950	20950	20950	20950
Npars	20	45	89	100	103	104	588
adj_ R^2	6.003	17.188	21.066	21.838	21.865	21.885	22.579
ΔR^2	0.000	11.184	3.878	0.772	0.027	0.020	0.694

Table 20.155. 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	1.4227	1.4066	1.4886	1.5450	1.5479	1.5486	1.5692	0.0000
1996	1.7162	1.6778	1.7710	1.7457	1.7451	1.7420	1.8333	0.0507
1997	1.4173	1.3183	1.3641	1.3596	1.3627	1.3607	1.4232	0.0460
1998	1.1877	1.0218	1.0914	1.0664	1.0686	1.0679	1.0583	0.0448
1999	1.1971	0.9950	1.0729	1.0630	1.0647	1.0650	1.0423	0.0459
2000	1.5118	1.2235	1.2481	1.2278	1.2275	1.2284	1.2103	0.0467
2001	1.1199	0.9456	0.9517	0.9495	0.9497	0.9504	0.9585	0.0470
2002	1.1950	1.0515	1.0232	1.0222	1.0214	1.0227	1.0242	0.0473
2003	0.8718	0.7752	0.7578	0.7580	0.7576	0.7578	0.7715	0.0479
2004	0.9382	0.7842	0.7788	0.7725	0.7737	0.7746	0.7807	0.0473
2005	0.7767	0.7219	0.6923	0.6704	0.6701	0.6705	0.6668	0.0528
2006	0.8450	0.8190	0.8517	0.8330	0.8315	0.8321	0.8221	0.0571
2007	0.4575	0.7803	0.8095	0.8072	0.8038	0.8023	0.8001	0.1015
2008	0.8808	1.4492	1.2865	1.3279	1.3298	1.3298	1.2370	0.0983
2009	0.9020	1.2484	1.2030	1.1969	1.1961	1.1961	1.1768	0.0764
2010	0.8425	1.0219	0.9839	1.0050	1.0004	1.0021	1.0053	0.0723
2011	0.7557	0.9131	0.8507	0.8554	0.8544	0.8534	0.8585	0.0679
2012	0.6393	0.6234	0.6042	0.6237	0.6229	0.6230	0.6238	0.0680
2013	0.6979	0.6520	0.6190	0.6210	0.6224	0.6234	0.6212	0.0595
2014	0.6248	0.5712	0.5514	0.5500	0.5497	0.5492	0.5170	0.0622

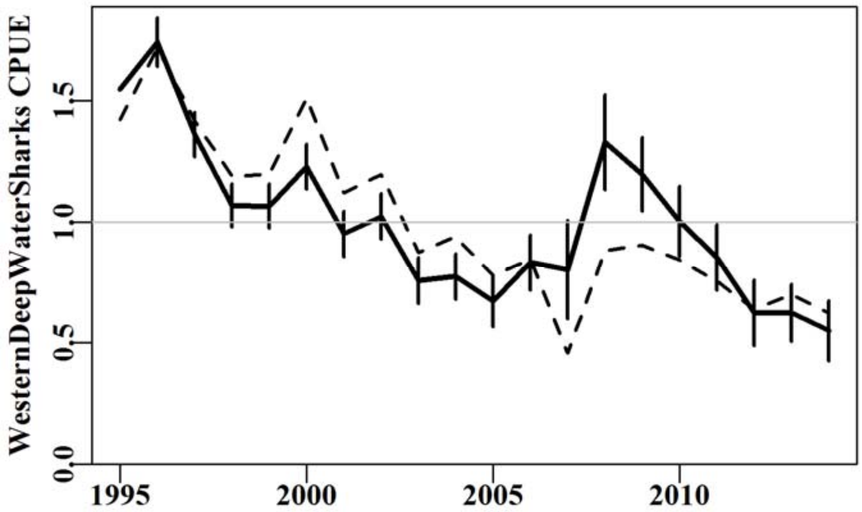


Figure 20.162. Western Deepwater Sharks reported from trawling in OR Zone 30, in depths 600 to 1100 m. The black dashed line from 95-14 represents the geometric mean catch rate and the solid black line the optimum standardized catch rates (Model 5). The graph standardizes catch rates relative to the mean of the standardized catch rates, represented by the horizontal fine grey line.

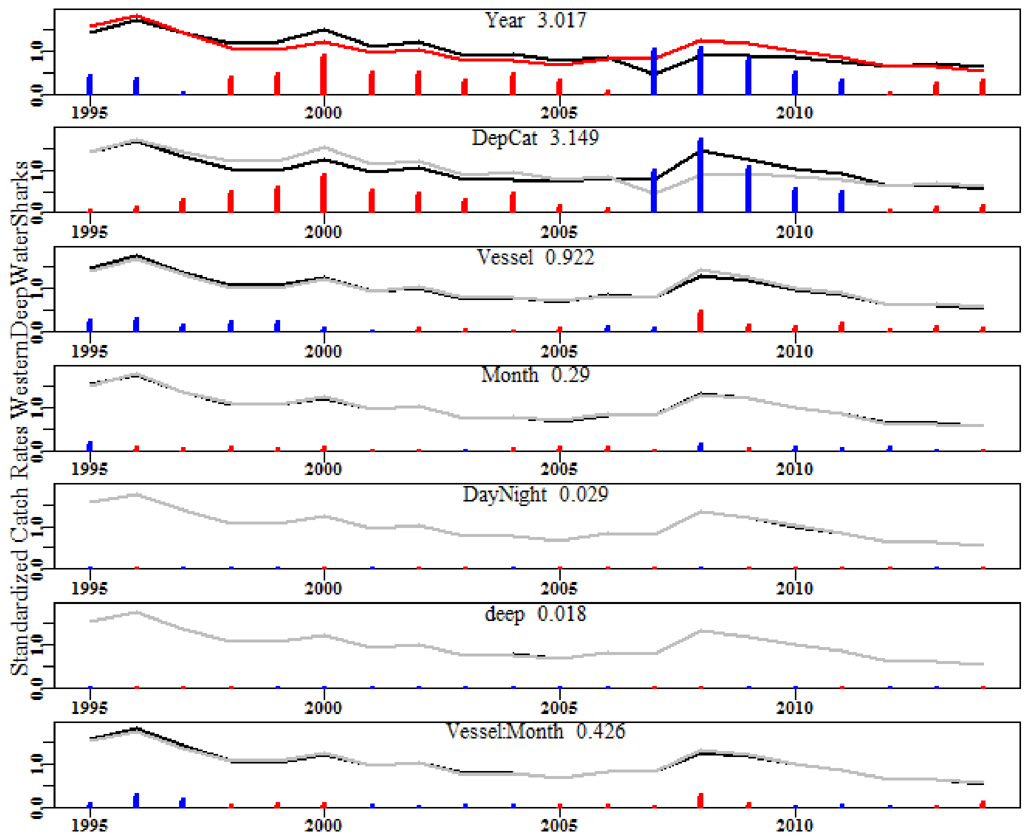


Figure 20.163. The relative impact of the different factors on the changes in the standardized trend. The major effects of both the structural adjustment, with its change of vessels, and the deepwater closures is clear.

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

Spikey (*Neocyttus rhomboidalis*), Oxeye (*Oreosoma atlanticum*) warty (*Allocyttus verrucosus*), rough (*Neocyttus psilorhynchus*) and black (*Allocyttus niger*) and grouped oreo dories (i.e. group of oreo species) were considered for analysis. CAAB codes were 37266001, 37266002, 37266004, 37266005, 37266006 and 37266902 (group code). Only spikey, warty and grouped oreo dories were used in the analysis since the other species were seldom caught in very low catches. The 2007, 2012 and 2013 estimated discard rates were 66.9 %, 9.7% (CV = 2.6%) and 18.5% (CV = 6.5%) respectively (Upston and Klaer 2013; Upston 2014). Approximately, 88.7% of the reported catch is given as spikey oreo (*Neocyttus rhomboidalis*), 2.6% as warty oreo (*Allocyttus verrucosus*), and 6.5% as oreo dories (37266902).

Table 20.156. 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	166	9	366.590	50.9660	44.5349	94	8	258.690	33.4560	30.7362
1987	145	16	353.000	59.9090	61.4753	60	10	155.400	13.0500	76.4337
1988	149	12	338.200	30.9040	131.2311	21	5	64.700	6.5800	145.5362
1989	311	18	422.400	176.1530	201.5261	60	7	150.800	12.5200	139.1462
1990	233	22	165.900	190.1580	205.4341	14	9	38.500	4.6450	125.9071
1991	200	22	479.850	83.9150	152.7337	75	13	276.950	14.6320	83.2764
1992	554	30	817.420	575.0540	149.7096	116	16	355.560	62.3700	160.0638
1993	786	37	1573.040	263.5320	135.9348	147	22	513.820	45.6370	101.6804
1994	1074	33	2482.320	283.8490	138.2444	175	22	668.880	58.1860	111.0419
1995	1709	30	5847.740	468.1250	132.5273	540	21	2141.410	187.1440	130.4097
1996	2080	33	6832.790	417.1090	120.3205	579	29	2139.500	121.5180	151.2315
1997	2263	34	9563.780	571.8770	121.1937	660	27	2939.380	143.7640	124.6610
1998	2346	33	9868.990	666.7560	130.2926	514	25	2289.290	143.4120	141.1691
1999	1904	32	7872.300	439.7870	119.2218	367	26	1624.540	97.7970	112.0439
2000	1723	38	7723.520	376.3140	94.7232	381	32	1710.990	104.8210	105.4104
2001	1943	38	8684.350	402.0390	103.4364	538	34	2395.450	105.1420	103.4581
2002	1457	37	7177.880	213.2560	78.4595	408	32	2021.670	67.0280	83.4248
2003	1460	31	7401.700	228.5240	80.2519	353	23	1725.170	52.1730	77.6378
2004	1445	31	7501.770	181.2726	70.1186	346	27	1747.030	46.9042	78.8507
2005	739	22	3945.560	92.8520	58.1204	196	20	965.070	29.2150	59.9867
2006	628	23	3169.880	78.9260	50.4311	172	19	868.430	19.6710	52.8505
2007	388	17	2026.240	58.7544	55.6257	233	16	1268.860	26.5244	53.2932
2008	288	15	1635.380	45.3140	40.5767	187	14	1008.200	21.4160	36.0851
2009	499	17	2737.410	73.5190	39.7698	235	16	1308.800	25.9010	42.8422
2010	505	15	2881.770	75.9470	27.8049	231	14	1319.810	24.6515	27.2739
2011	571	17	3514.480	78.2621	53.5570	241	15	1437.350	25.0091	62.7757
2012	494	15	2993.590	58.8495	49.7144	175	13	1101.480	17.4338	46.2581
2013	702	16	4234.320	135.7746	50.3941	226	15	1343.970	46.6275	51.1004
2014	527	15	3752.760	102.5260	68.6596	136	12	860.060	25.6870	70.6061

Table 20.157. The catch in tonnes of Mixed Oreos by Orange Roughy (OR) Zone, and, across OR Zones in the current open and closed areas. All data included in the OR Zones.

Year	Total	10	20	21	30	50	Open	Closed
1986	50.966	0.160	30.520		20.278	0.008	33.456	17.510
1987	59.909	0.130	6.470		53.309		13.050	46.859
1988	30.904	0.020			30.794	0.090	6.580	24.324
1989	176.153	0.030	98.650	31.870	45.543	0.060	12.520	163.633
1990	190.158	4.340	120.823	58.165	6.700	0.130	4.645	185.513
1991	83.915	3.191	47.260	16.551	16.528	0.385	14.632	69.283
1992	575.054	31.646	344.104	166.864	30.977	1.463	62.370	512.684
1993	263.532	1.392	99.722	32.651	100.479	29.288	45.637	217.895
1994	283.849	0.882	90.447	34.734	135.927	21.859	58.186	225.663
1995	468.125	1.388	64.172	8.076	388.242	6.247	187.144	280.981
1996	417.109	8.539	92.953	3.451	275.141	37.025	121.518	295.591
1997	571.877	43.955	129.864	1.390	376.367	20.301	143.764	428.113
1998	666.756	33.724	130.832	1.492	379.551	121.157	143.412	523.344
1999	439.787	13.860	126.159	1.295	241.314	57.159	97.797	341.990
2000	376.314	26.075	111.417	0.775	213.445	24.602	104.821	271.493
2001	402.039	19.250	135.819	6.885	220.042	20.043	105.142	296.897
2002	213.256	36.018	59.214	1.025	106.242	10.757	67.028	146.228
2003	228.524	33.272	56.705	7.550	117.764	13.233	52.173	176.351
2004	181.273	12.011	40.705	1.820	115.125	11.612	46.904	134.368
2005	92.852	5.885	18.332	1.500	58.273	8.862	29.215	63.637
2006	78.926	8.579	12.259	0.270	55.623	2.195	19.671	59.255
2007	58.754	2.340	18.565	1.194	35.345	1.310	26.524	32.230
2008	45.314	2.262	16.724		23.672	2.656	21.416	23.898
2009	73.519	4.105	17.271	0.058	47.907	4.178	73.519	
2010	75.947	5.344	25.186	5.860	37.271	2.286	75.947	
2011	78.262	3.643	20.661	1.990	48.064	3.904	78.262	
2012	58.850	2.286	19.305	0.022	33.710	3.527	58.850	
2013	135.775	6.514	47.587	0.180	79.319	2.175	135.775	
2014	102.526	0.668	46.008	0.375	54.503	0.972	102.526	
Total	6480.224	311.508	2027.733	386.043	3347.456	407.484	6480.224	4537.740

In the last five years, 67% of the catch has been reported as Oreo Dory, 19% as spikey dory, 11% as oxeye dory and the remainder smooth and warty oreos. Only data from OR Zones 10, 20, 21, 30, 50, in depths 500 – 1200 m were used in the analysis. All vessels recording mixed oreos were included in the analysis. Orange Roughy zones 40, 60, 70 and unknown were removed.

Table 20.158. 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

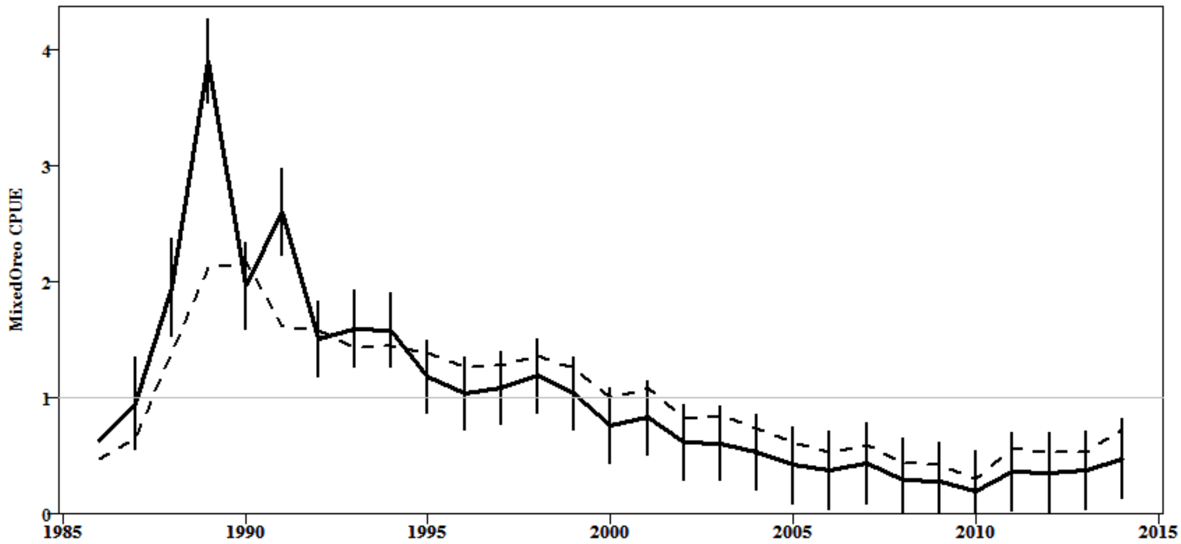


Figure 20.164. The standardized catch rates showing the optimum model (solid black line) and the geometric mean catch rate (dashed line) each scaled to the mean of each time series. The error bars are two times the standard errors.

Table 20.159. 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 (Δ R^2). Model 7 (Closure) was optimal. The effect of being in the open or closed areas (Closure) was minor (Figure 20.165). Depth category: DepC; Month: Mth.

	Year	Vessel	DepC	Month	ORZone	DayNight	Closure	Vessel:Month	DepC:Mth
AIC	24047	22480	22223	22025	22015	22014	22002	22591	22064
RSS	65730	61563	60831	60339	60299	60283	60251	56310	59707
MSS	4500	8666	9398	9891	9931	9946	9979	13919	10522
Nobs	27289	27289	27073	27073	27073	27073	27073	27073	27073
Npars	29	139	153	164	168	171	172	1382	326
adj_R^2	6.311	11.894	12.893	13.563	13.607	13.620	13.664	15.510	13.950
ΔR^2	0.000	5.584	0.999	0.670	0.044	0.013	0.043	1.846	-1.560

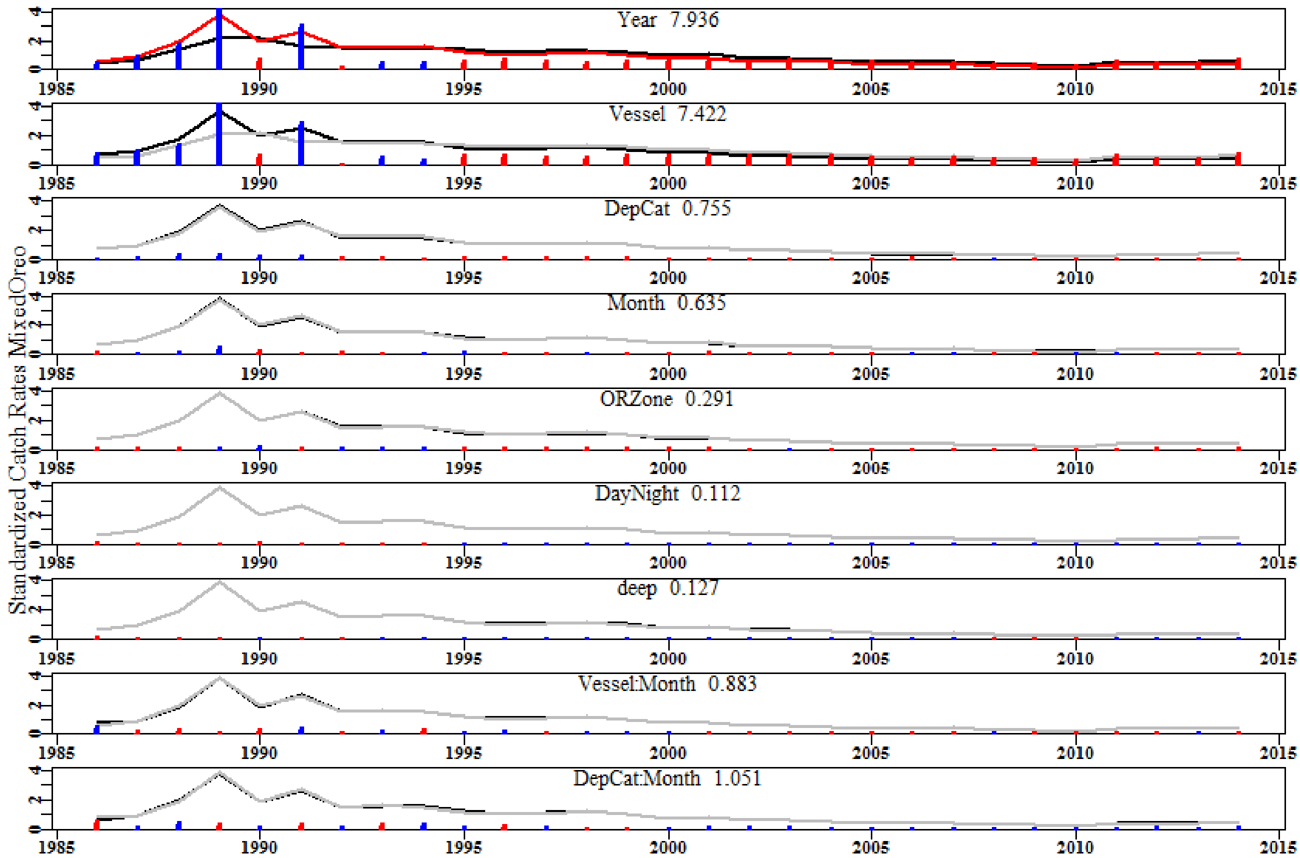


Figure 20.165. Relative impact of each factor on the final trend. Blue bars indicate the standardization is above the previous model, red bars indicate it is below. Closures appear to have only a very small effect.

Table 20.160. Reported catches (t) by CAAB code for the data analysed. Up until 2011 the group code Oreo Dory (37266902) had been omitted from the analysis because of confusion with Black Oreo (37266901). The 37266902 reporting code (grouped Oreo dories) appears only to have been introduced in 2005 when quotas were first applied to Mixed Oreos.

	37266001	37266002	37266004	37266902	
Year	Spikey	Oxeye	Warty	Oreo Dory	Total
1986	20.565	3.608	32.463		56.636
1987	45.771	18.706	19.200		83.677
1988	46.171	10.830	23.234		80.235
1989	372.465	33.817	17.420		423.702
1990	273.956	4.080	2.257		280.293
1991	117.576	2.722	0.528		120.826
1992	737.452	12.285	1.050		750.787
1993	299.459	4.110	3.031		306.600
1994	345.251	3.103	18.900		367.254
1995	485.304	17.195	14.750		517.249
1996	430.944	0.900	15.956		447.800
1997	1078.217	4.927	21.000		1104.144
1998	1297.107	0.340	24.806		1322.253
1999	552.113	0.080	11.275		563.468
2000	450.361	0.030	30.987		481.378
2001	512.394	0.400	6.090		518.884
2002	296.376	0.095	1.595		298.066
2003	454.332		0.800		455.132
2004	233.597	0.120	1.570		235.287
2005	159.654	3.549		7.573	170.776
2006	67.233	10.490		48.496	126.219
2007	20.211	11.983		56.832	89.026
2007	8.558	1.182		54.874	64.614
2009	8.714	2.145		75.238	86.097
2010	10.727	1.282		74.136	86.145
2011	11.237	7.951		77.348	96.536
2012	8.534	13.821		58.085	80.441
2013	18.453	15.497		124.503	158.453
2014	58.459	21.934	2.895	44.044	127.332
Total	8421.190	207.182	249.807	621.130	9499.308

Table 20.161. 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 Closure. St Err is the estimate of standard error for the optimum model. Values are relative to the mean of the standardized catch rates. The Month and closure factors column was omitted for clarity; their relative effect can be seen in Figure 20.165.

Year	Year	Vessel	DepCat	Month	ORZone	DayNight	Closure	Vessel:Month	StErr
1986	0.46244	0.69816	0.71211	0.68206	0.67332	0.65111	0.62431	0.78449	0.0000
1987	0.64837	0.94603	0.96665	0.97931	0.96776	0.96677	0.94421	0.90205	0.1986
1988	1.38376	1.82214	1.91597	1.97999	1.94991	1.94966	1.94566	1.84019	0.2122
1989	2.11604	3.63781	3.72770	3.87851	3.91148	3.90489	3.90213	3.87936	0.1813
1990	2.15988	1.93911	2.01369	1.91998	1.96813	1.95230	1.95742	1.88589	0.1870
1991	1.60717	2.55623	2.63835	2.61851	2.60463	2.60198	2.59801	2.71091	0.1893
1992	1.56929	1.56920	1.53511	1.48475	1.50715	1.50526	1.50344	1.48898	0.1633
1993	1.42399	1.58601	1.56467	1.56301	1.58614	1.58275	1.59197	1.66181	0.1636
1994	1.44759	1.55420	1.53684	1.55544	1.57372	1.57146	1.57877	1.48789	0.1613
1995	1.38714	1.17589	1.13461	1.17859	1.17259	1.17618	1.17916	1.18941	0.1584
1996	1.25922	1.07296	1.03967	1.03090	1.02331	1.02642	1.03110	1.07492	0.1588
1997	1.26830	1.10624	1.07949	1.07919	1.06842	1.07310	1.07927	1.05952	0.1589
1998	1.36349	1.19956	1.17284	1.18290	1.17627	1.17895	1.18572	1.21090	0.1588
1999	1.24779	1.06030	1.03897	1.02464	1.02030	1.02477	1.03217	1.04252	0.1594
2000	0.99145	0.78461	0.76781	0.75490	0.75029	0.75296	0.75469	0.75783	0.1599
2001	1.08256	0.87390	0.85823	0.82795	0.81959	0.82373	0.82554	0.81002	0.1597
2002	0.82132	0.62069	0.61080	0.60566	0.60537	0.60881	0.61015	0.60787	0.1608
2003	0.84008	0.62268	0.61004	0.59908	0.59952	0.60270	0.60459	0.59714	0.1610
2004	0.73402	0.53694	0.52912	0.52541	0.52371	0.52687	0.52764	0.52750	0.1612
2005	0.60890	0.42429	0.42150	0.41145	0.41125	0.41322	0.41402	0.40666	0.1655
2006	0.52850	0.38977	0.36649	0.37112	0.36980	0.37177	0.37289	0.37116	0.1676
2007	0.58363	0.43302	0.42373	0.43067	0.42651	0.42841	0.42940	0.42773	0.1745
2008	0.42619	0.29156	0.29430	0.28904	0.28727	0.28989	0.28917	0.29355	0.1806
2009	0.41698	0.28352	0.27870	0.27521	0.27407	0.27586	0.27568	0.27449	0.1705
2010	0.29152	0.19763	0.19098	0.19446	0.19275	0.19367	0.19315	0.19052	0.1697
2011	0.56136	0.36726	0.35651	0.35869	0.35569	0.35849	0.35958	0.35932	0.1683
2012	0.52126	0.37120	0.35398	0.35337	0.34786	0.35032	0.35036	0.33622	0.1718
2013	0.52800	0.38751	0.38112	0.36952	0.36643	0.36776	0.36817	0.36944	0.1676
2014	0.71979	0.49159	0.48001	0.47570	0.46673	0.46992	0.47164	0.45172	0.1712

20.6 Acknowledgements

Thanks goes to Mike Fuller and Neil Klaer of CSIRO Hobart, for their preliminary processing of the catch and effort data as received from the Australian Fisheries management Authority. Thanks also goes to Malcolm Haddon for helpful discussions.

20.7 References

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

Aitchison, J. (1955). On the distribution of a positive random variable having a discrete probability mass at the origin. *Journal of the American Statistical Association* **50**: 901-908.

Barry, S. C. and A. H. Welsh (2002). Generalized additive modelling and zero inflated count data. *Ecological Modelling* **157**: 179-188.

Bishop, J., Die, D. and Y-G Wang (2000). A generalized estimating equations approach for analysis of the impact of new technology on a trawl fishery. *Australian and New Zealand Journal of Statistics* **42**(2): 159-177.

Bishop, J., Venables, W.N. and Y-G Wang (2004). Analysing commercial catch and effort data from a Penaeid trawl fishery. A comparison of linear models, mixed models, and generalized estimating equations approaches. *Fisheries Research* **70**: 179-193.

Brooks, E. N., Ortiz, M. and L.K. Beerkircher (2005). Standardized catch rates for blue shark and shortfin mako shark from the U.S. pelagic logbook and U.S. pelagic observer program, and U.S. weighout landings. *Collected Volume of Scientific Papers ICCAT* **58**(3): 1054-1072.

Brynjarsdottir, J. and G. Stefansson (2004). Analysis of cod catch data from Icelandic groundfish surveys using generalized linear models. *Fisheries Research* **70**: 195-208.

Dick, E. J. (2004). Beyond "lognormal versus gamma": discrimination among error distributions for generalized linear models. *Fisheries Research* **70**: 351-366.

Haddon, M. (2014a) *Eastern Deepwater Sharks.* Pp 405 - 415 *in* Tuck, G.N. *(ed.)* 2014. *Stock Assessment for the Southern and Eastern Scalefish and Shark Fishery 2013. Part 2. Project No. 2011/0814* Australian Fisheries Management Authority and CSIRO Marine and Atmospheric Research, Hobart. 486 p.

Haddon, M. (2014b) *Western Deepwater Sharks.* Pp 415 - 425 *in* Tuck, G.N. *(ed.)* 2014. *Stock Assessment for the Southern and Eastern Scalefish and Shark Fishery 2013. Part 2. Project No. 2011/0814* Australian Fisheries Management Authority and CSIRO Marine and Atmospheric Research, Hobart. 486 p.

Helser, T. E., Punt, A. E. and R.D. Methot (2004). A generalized linear mixed model analysis of a multi-vessel fishery resource survey. *Fisheries Research* **70**: 251-264.

Hoyle, S. D. and M. N. Maunder (2006). Standardization of yellowfin and bigeye CPUE data from Japanese longliners, 1976-2004. *Inter-American Tropical Tuna Commission Document SAR-7-07*: 19p.

Kawaguchi, S., Candy, S. G. and S. Nicol (2005). Analysis of trends in Japanese krill fishery CPUE data, and its possible use as a krill abundance index. *CCAMLR Science* **12**: 1-28.

Kimura, D.K. (1981) Standardized measures of relative abundance based on modelling log(c.p.u.e.), and their application to pacific ocean perch (*Sebastes alutus*). *Journal du Conseil International pour l'Exploration de la Mer*. 39: 211-218.

Martin, T. G., Wintle, B.A., Rhodes, J.R., Kuhnert, P.M., Field, S.A., Low-Choy, S.J., Tyre, A.J. and H.P. Possingham (2005). Zero tolerance ecology: improving ecological inference by modelling the source of zero observations. *Ecology Letters* **8**: 1235-1246.

Maunder, M. N. and A. E. Punt (2004). Standardizing catch and effort data: a review of recent approaches. *Fisheries Research* **70**: 141-159.

Myers, R. A. and P. Pepin (1990). The robustness of Lognormal-based estimators of abundance. *Biometrics* **46**: 1185-1192.

Neter, J., Kutner, M.H., Nachtsheim, C.J, and W. Wasserman (1996) Applied Linear Statistical Models. Richard D. Irwin, Chicago. 1407p.

Pennington, M. (1983). "Efficient estimators of abundance, for fish and plankton surveys." Biometrics **39**: 281-286.

Punt, A. E., Walker, T.I., Taylor, B.L. and F. Pribac (2000). Standardization of catch and effort data in a spatially-structured shark fishery. *Fisheries Research* **45**: 129-145.

R Development Core Team (2009). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. ISBN 3-900051-07-0, URL http://www.R-project.org.

Rodriguez-Marin, E., Arrizabalaga, H., Ortiz, M., Rodriguez-Cabello, C., Moreno, G. and L.T. Kell (2003). Standardization of bluefin tuna, *Thunnes thynnus*, catch per unit effort in the baitboat fishery of the Bay of Biscay (Eastern Atlantic). *ICES Journal of Marine Science* **60**: 1216-1231.

Stefánsson, G. (1996) Analysis of groundfish survey abundance data: combining the GLM and delta approaches. *ICES Journal of Marine Sciences* **53**: 577-588.

Stephens, A. and A. MacCall (2004). A multispecies approach to subsetting logbook data for purposes of estimating CPUE. *Fisheries Research* **70**: 299-310.

Syrjala, S. E. (2000). Critique on the use of the delta distribution for the analysis of trawl survey data. *ICES Journal of Marine Science* **57**: 831-842.

Venables, W. and C. M. Dichmont (2004). GLMs, GAMs and GLMMs: an overview of theory for applications in fisheries research. *Fisheries Research* **70**: 319-337.

Upston, J., and N. Klaer (2013). Integrated Scientific Monitoring Program for the Southern and Eastern Scalefish and Shark Fishery – Discard estimation 2012. CSIRO Marine and Atmospheric Research Report. 40pp.

Upston, J. (2014). Integrated Scientific Monitoring Program for the Southern and Eastern Scalefish and Shark Fishery – Discard estimation 2013. CSIRO Marine and Atmospheric Research Report. 40pp.

Ye, Y., Al-Husaini, M., and A. Al-Baz (2001). Use of generalized linear models to analyze catch rates having zero values: the Kuwait driftnet fishery. *Fisheries Research* **53**: 151-168.

21. Tier 4 Analyses of Selected Species in the SESSF (Data from 1986 – 2014)

Malcolm Haddon

CSIRO Oceans and Atmosphere, GHPO Box 1538, Hobart, Tas 7001, Australia

21.1 Executive Summary

Seven fisheries are assessed using Tier 4 methodology: BlueEye Trevalla, Jackass Morwong in the west, and Mirror Dory.

Jackass Morwong West generated a zero RBC, which reflects the recent strong reduction in CPUE in the western zones (40 and 50).

The blue-eye trevalla analyses used two new time-series of standardized CPUE derived from Haddon (2015), which were based upon catch-per-hook rather than catch-per-record. These new CPUE analyses have flattened the time series in recent years and have produced a larger RBC than has been produced previously. In addition, a sensitivity analysis was conducted with the blue-eye analysis in which estimates of whale depredation on the auto-line fishery when it was developing are included to illustrate their potential impact. That analysis demonstrates that whale depredations would act to bias the actual kill and the CPUE low, and consequently would bias the RBC low. However, the estimate relate to a single vessel and extrapolating to the fleet adds a great deal of uncertainty. The analysis remains useful in demonstrating the potential bias, but the uncertainty means that care would be required if considering to use the whale depredation sensitivity to modify any catch recommendation.

The analyses for Mirror Dory have been conducted for the whole of the Mirror Dory stock, treating the west and east as separate stocks, and also including the high levels of discards that occur in the east.

The TIER 4 analyses conducted this year used the analytical method developed and tested in 2008 and 2009. This has the capacity to provide advice that will manage a fishery in such a manner that it should achieve the target catch rate derived from the chosen reference period. However, the TIER 4 control rule can only succeed if catch rates do in fact reflect stock size. Many factors could contribute to make this assumption fail so care needs to be taken when applying this control rule. It should be made clear that the control rule works to achieve the selected target but there is no guarantee that this truly corresponds to the HSP proxy target for MEY of 48% B_0.

The inclusion of discards into the CPUE makes the assumption that there were no complete shots discarded; in other words only part of some or all hauls were discarded and no shots were completely discarded. The analyses depend on adjusted the total catch in each instance while not adjusting the effort. However, if complete shots are discarded then the total effort will be under-estimated biasing the CPUE high. Given that some shots may be completely discarded the analysis with discards is thus expected to be biased high, whereas if discards have been variable through time, but are not included in an analysis, then that analysis would be expected to be biased low. Both need to be considered when setting the TAC.

21.2 Introduction

21.2.1 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).

21.3 Methods

21.3.1 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.

$$\text{Scaling Factor } = SF_t = \max\left(0, \frac{\overline{CPUE} - CPUE_{\text{lim}}}{CPUE_{\text{targ}} - CPUE_{\text{lim}}}\right) \tag{4}$$

$$RBC = C_{\text{targ}} \times SF_t \tag{5}$$

If new data becomes available, for example, more State data has become available this year, or other large changes occur in the catch rates then the RBC could undergo large changes. Such changes are constrained by the following limits:

$$\begin{array}{l|l} RBC_y = 1.5RBC_{y-1} & RBC_y > 1.5RBC_{y-1} \\ RBC_y = 0.5RBC_{y-1} & RBC_y < 0.5RBC_{y-1} \end{array} \tag{6}$$

where

RBC_y is the RBC in year y
$CPUE_{targ}$ is the target CPUE for the species; Eq. (8)
$CPUE_{lim}$ is the limit CPUE for the species = either
(0.2/0.48) * $\text{CPUE}_{\text{targ}}$ or
(0.2/0.40) * $\text{CPUE}_{\text{targ}}$ depending on the selected target for the species
$\overline{CPUE}$ the average CPUE over the past *m* years; *m* tends to be the most recent four years.
C_{targ} is a catch target derived from a period of historical catch that has been identified as a desirable target in terms of CPUE, catches and status of the fishery, e.g. 1986 – 1995 (Table 21.1). This is an average of the total removals for the selected reference period, including any discards; Eq. (7).

$$C_{\text{targ}} = \frac{\sum_{y=yr1}^{yr2} L_y}{(yr2 - yr1 + 1)} \tag{7}$$

where L_y represents the landings in year y.

$$CPUE_{\text{targ}} = \frac{\sum_{y=yr1}^{yr2} CPUE_y}{(yr2 - yr1 + 1)} \tag{8}$$

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

$$D_y = \frac{C_y \bar{D}_{98-06}}{\left(1 - \bar{D}_{98-06}\right)} \tag{9}$$

Discard proportions for the projected year for which the RBC is being calculated are taken as a weighted mean of the previous four years:

$$D_{CUR} = (1.0D_{y-1} + 0.5D_{y-2} + 0.25D_{y-3} + 0.125D_{y-4})/1.875 \tag{10}$$

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%):

$$D_y = \frac{Discard_y}{\left(Catches_y + Discard_y\right)} \tag{11}$$

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 21.1). 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.

21.3.2 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 21.1.

21.3.3 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).

21.3.4 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

$$\hat{I}_{R,t} = \frac{\sum C_t}{\sum E_t} \qquad (12)$$

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

$$\hat{I}_{D,t} = \frac{\sum C_t + \sum D_t}{\sum E_t} \qquad (13)$$

The same values of $\hat{I}_{D,t}$ can also be obtained using the following multiplier

$$\hat{I}_{D,t} = \left[\left(\sum D_t / \sum C_t\right) + 1\right] \times I_t \qquad (14)$$

where I_t is the catch rate estimate to be modified by the inclusion of discards. If this is the ratio mean from Equ (12) then the augmented catch rates would be identical to those produced by Equ (13). 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 21.1. 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.**	**Target CPUE**
Blue Eye Trevalla ALDL	1997-2006	1	1997	0.48
Jackass Morwong	1986-1995	1	1986	0.48
Mirror Dory	1986-1995	1	1986	0.48
Mirror Dory East	1986-1995	1	1986	0.48
Mirror Dory West	1996-2005	1	1996	0.48

Table 21.2. Data characteristics for each deep water fishery analysis. Non-Cas indicates the Non-Cascade fishery. Catch and CPUE are the multipliers relating to whether the fishery was considered to be fully developed before the reference years. All catch rates, except Eastern Deepwater Sharks, were halved to form the target but only three of the catches were also halved. Lg is longitude and Lt is latitude.

Species	Zone	Depths	Comment	Catch	CPUE
Smooth Oreo Cascade	40	650-1250	OR Zones	1.0	0.5
Smooth Oreo non-Cas	10-30,50	600-1200	OR Zones 10,20,21,30,50	0.5	0.5

21.3.5 Selection of reference periods

The Tier 4 requires a reference period to be selected in order to establish target and limit levels of catch rates and associated target levels of catch that are deemed by the RAG to act as a proxy for the desired state for the fishery. These act as a proxy for the Harvest Strategy Policy reference points of 48% and 20% unfished spawning biomass. The original Tier 4 rule that used a linear regression of the last four year's catch rates to determine whether catches increase or decrease was not able to rebuild a resource towards a desired target level and the current approach was developed so as to be able to manage a fishery towards a target and away from a limit.

The essence of the Tier 4 control rule is that it sets a RAG agreed target catch rate, which has an associated target catch. An estimate of current catch rates (usually the average of the last four years) is compared with the target and a multiplier is estimated which is to be applied to the target catch to generate the recommended biological catch.

To select a reference period requires a time series of comparable catch rates. For this reason the use of standardized catch rates should be an improvement over using, for example, the observed arithmetic or geometric mean catch rates. Catch rate data is available in the SESSF for all targeted species from 1986 - 2011, although it needs to be noted that the character of the fishery has changed markedly during that period. Little *et al.* (2009) provide a discussion on how reference periods might be selected. They proposed a default ten year period of 1986 – 1995, stating: "We have assumed that the average CPUE from 1986 to 1995 corresponds to that which would be attained if the stock were at the level that provides the maximum economic yield, B_{MEY}. The limit CPUE is 40% of this CPUE." (Little *et al.*, 2009, p 234).

For each species, reference years were selected by the RAGs to generate estimates of target catches and target catch rates. In addition, a decision was required as to whether the fishery could be considered as fully developed or otherwise during the reference period or not. Where a fishery was not considered to be fully developed the target catch rate, $CPUE_{targ}$, was divided by two as a proxy for expected changes to catch rates as the fishery develops and the resource stock size declines towards the assumed proxy target for 48% unfished biomass.

Little *et al.* (2009) proposed three rules used to estimate the CPUE target:

1. The CPUE target for stocks fully exploited at or prior to 1986 is based on the average CPUE from 1986-1995.
2. Where fishing exploitation up to 1986 is thought to be minimal, the CPUE determined in step 1 is halved (to provide a catch rate proxy for B_{MEY}).
3. Where fishing exploitation after 1986 is low, the first year in which catches are above 100t signifies the start of the 10 year period for which CPUE targeted is calculated.

Once the average CPUE for the reference period has been selected as the target CPUE then the limit CPUE is defined as 40% of the target. All of these rules make the assumption that the target catch rates have achieved an equilibrium with the target catches. In other words, if the target catch was maintained long enough the target catch rate would be the result.

In addition, if a fishery begins with a stock in an unfished state the RAGs decided that the initial catch rates would be distorted high and so the target CPUE would be estimated by halving the initial catch rates in the fishery. In some cases the catches would also be halved if the species (Table 21.2).

21.3.6 Treatment of non-target species

In 2012, the SESSF RAG determined that the assessments of those species which do not constitute the economic drivers for a fishery might use the proxy for B_{MSY} as the target instead of B_{MEY}. In practice this means that the target is assumed to be a proxy for B_{40} rather than B_{48}. For the Tier 4, this means modifying the control rule used to estimate the RBC by multiplying the target catch rate by 5/6. If the original target was a proxy for 48% B_0, then 5/6th or 0.83333 of this target would be a proxy for $B_{40\%}$. This option was not pursued this year.

21.3.7 The assumption underlying the Tier 4

For the Tier 4 analyses to be valid a number of assumptions need to be met:

- There is a linear relationship between catch rates and exploitable biomass; *if there is hyper-stability (catch rates remain stable while stock size changes) or hyper-depletion (catch rates decline much faster than stock size changes) then the standard Tier 4 analysis would provide biased results.*
- The character of the estimated catch rates has not changed in significant ways through the period from the start of the reference period to the end of the most recent year; *If there has been significant effort creep altering the catchability, or there have been changes to the fleet that have altered the relative efficiency of the vessels fishing, or the catchability of the species by the fleet has been altered by other changes then the comparability of recent catch rates with the target period may be compromised. Such changes would obviously reduce the responsiveness of the Tier 4 method to change and may generate completely inappropriate management advice. Included in this clause are the effects of targeting or not targeting of deep water or aggregated species. When catch rates are extremely variable through time, such that mean estimates become unreliable measures of stock status, then the Tier 4 approach cannot be validly applied.*
- The reference period provides a good estimate of the stock when at a depletion level of 48% unfished spawning biomass; *the Tier 4 method is based on catch rates and thus relates to exploitable biomass and not spawning biomass. As a minimum the reference period will refer to a period when the stock was in an acceptable, productive and sustainable state. But there can be no guarantees that the target aimed for is really* $B_{48\%}$.

21.4 Results for Tier 4 species

21.4.1 Blue Eye (TBE – 37445001 – Hyperoglyphe antarctica)

The RBC calculation for BlueEye is based on a combination of auto-line and drop-line CPUE each with a revised CPUE time-series using catch-per-hook rather than catch per shot (Haddon, 2015).

This does not take into account the potential effects of whale depredation of fish off the line while the gear is being hauled back to the vessel nor the effects of closures, some of which have been over some of the better blue-eye fishing grounds.

A separate analysis is made of the potential effect of whale depredation by treating them as discards (see below).

Table 21.3 Blue eye Trevalla data for the TIER 4 calculations. Total is the sum of Discards, State, Non Trawl, SEF2, and ECDW catches. All values in Tonnes. CE is the standardized catch rate for all Zones 10 to 50 in depths 0 – 1000m (Haddon, 2013). TAC is a mixture of annual and fishing year so care is required with its interpretation. Discards are estimates from 1998 to present. The ratio of discards to catch over the 1998 – 2006 period was used to estimate the discards between 1986 and 1997, the proportion of which is the PDiscard. The grey hatched rows identify the selected reference period.

Year	Catch	Discards	Total	State	Non-T	PDiscard	CE	TAC
1997	736.984	0.000	736.984	623.141	0.000	0.000	1.6108	125
1998	608.674	0.000	608.674	130.012	380.439	0.000	1.3460	630
1999	718.465	0.000	718.465	139.608	464.658	0.000	1.2985	630
2000	764.386	37.000	801.386	99.563	565.410	4.617	1.0872	630
2001	704.798	33.000	737.798	96.613	478.397	4.473	1.0875	630
2002	631.529	0.100	631.629	117.362	427.969	0.016	0.7917	630
2003	659.762	0.160	659.922	58.623	556.565	0.024	0.8115	690
2004	729.965	1.400	731.365	77.457	566.917	0.191	0.9367	621
2005	573.613	0.000	573.613	71.557	450.678	0.000	0.8192	621
2006	632.913	0.060	632.973	57.095	496.743	0.009	0.9897	560
2007	654.371	2.813	657.184	68.102	536.267	0.428	1.1937	785
2008	415.174	0.993	416.167	41.980	338.852	0.239	0.9920	560
2009	481.452	0.000	481.452	38.090	404.049	0.000	0.9454	560
2010	450.183	0.142	450.325	50.287	358.785	0.031	0.6610	428
2011	504.001	7.436	511.437	45.465	430.038	1.454	0.7440	326
2012	323.144	4.327	327.471	35.317	268.064	1.321	0.6688	388
2013	306.908	2.326	309.234	22.335	268.064	0.752	0.8283	388
2014	292.950	1.138	294.088	23.620	268.064	0.387	1.1880	335

Discards make up approximately 1.2 % of the catch over the 1998-2006 period.

Table 21.4 RBC calculations for Blue Eye. C_{targ} and $CPUE_{targ}$ relate to the period 1997-2006, $CPUE_{Lim}$ is 20% of the B_0 proxy, and $\overline{CPUE}$ is the average catch rate over the last four years. The RBC calculation does not account for predicted discards of predicted State catches. Wt_Discard is the weighted average discards from the last four years, as with Equ (10).

Ref_Year	1997-2006
CE_Targ	1.0779
CE_Lim	0.4491
CE_Recent	0.8573
Wt_Discard	2.3
Scaling	0.6492
Last Year's TAC	335
C_{targ}	683.281
RBC	**443.567**

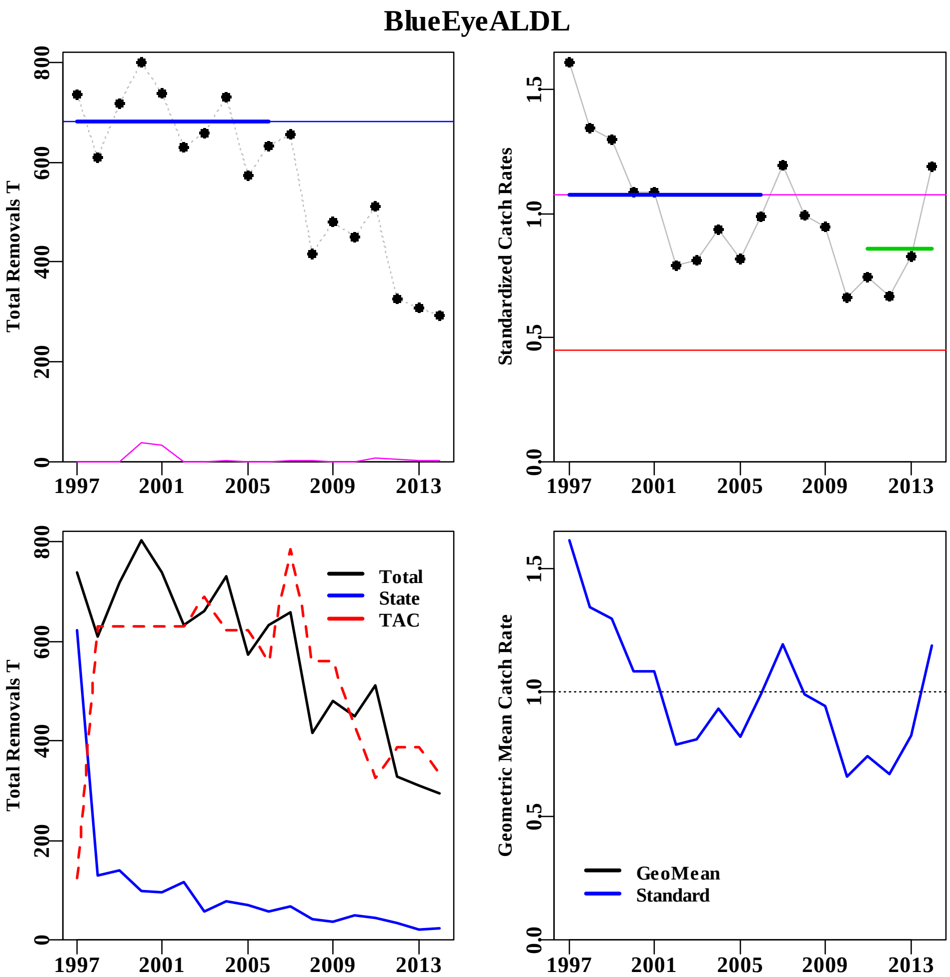


Figure 21.1 Blue Eye Trevalla. Top left is the total removals with the fine line illustrating the target catch. Top right represents the standardized catch rates with the upper fine line representing the target catch rate and the lower line the limit catch rate. Thickened lines represents the reference period for catches, catch rates, and the recent average catch rate.

21.4.2 Blue Eye Whale Discards (H. antarctica)

Whale depredations were estimated to lead to approximately 60% loss of catch when killer whales were present during a haul (Pease, 2012, p55). However, killer whales are not always present during a haul so some means of allowing for their presence or absence was required. Pease (2012, p56) also documents variation in the rate of killer whale sightings between years, which may have been related to different seasonal patterns of fishing as well as location changes. Across the years the relative sighting frequency has also varied but the statement is also made that killer whales were observed across about 25% of days. When the average relative frequency of sighting is scaled to 0.25 and then multiplied by the 60% this enables an approximate estimate of killer whale depredations for 2008 – 2012. Depredations are assumed to fall away strongly after that assuming the fleet have adapted to their presence, either through avoidance or other methods.

The final estimate of the RBC is sensitive to the method used to estimate the proportion of days in which killer whales would have influenced catches. The importance of this analysis is to demonstrate that whale depredations can have significant, albeit short-term, effects on catch rates over and above the impact on the choice of fishing locations. The approach used here only accounts for the direct effect of whales removing fish from the auto-lines, the other impacts such as changing times and location of fishing to avoid whale interactions are more difficult to quantify. What this alternative analysis demonstrates is that whale depredations could be leading to bias if they are left unaccounted.

Table 21.5 Blue eye Trevalla data for the TIER 4 calculations. Total is the sum of Discards, State, Non Trawl, SEF2, and ECDW catches. All values in Tonnes. StandCE is the standardized catch rate for auto-line and drop-line using catch-per-hook (Haddon, 2015). (D/C) +1 is the multiplier used with StandCE to generate DiscCE (see the Methods).

Year	Catch	Discards	Total	(D/C)+1	StandCE	DiscCE	GeoMean	TAC
1997	736.984	0.000	736.984	1.000	1.6108	1.5476		125
1998	608.674	0.000	608.674	1.000	1.3460	1.2932		630
1999	718.465	0.000	718.465	1.000	1.2985	1.2475		630
2000	764.386	37.000	801.386	1.048	1.0872	1.0950		630
2001	704.798	33.000	737.798	1.047	1.0875	1.0937		630
2002	631.529	0.100	631.629	1.000	0.7917	0.7607		630
2003	659.762	0.160	659.922	1.000	0.8115	0.7798		690
2004	729.965	1.400	731.365	1.002	0.9367	0.9017		621
2005	573.613	0.000	573.613	1.000	0.8192	0.7870		621
2006	632.913	0.060	632.973	1.000	0.9897	0.9509		560
2007	654.371	2.813	657.184	1.004	1.1937	1.1518		785
2008	415.174	21.023	436.198	1.051	0.9920	1.0013		560
2009	481.452	44.344	525.796	1.092	0.9454	0.9919		560
2010	450.183	116.637	566.820	1.259	0.6610	0.7995		428
2011	504.001	113.541	617.542	1.225	0.7440	0.8758		326
2012	323.144	49.681	372.824	1.154	0.6688	0.7413		388
2013	306.908	12.251	319.159	1.040	0.8283	0.8276		388
2014	292.950	3.130	296.080	1.011	1.1880	1.1535		335

Estimated whale depredations are added to discards (Table 21.7), which are then used to adjust the standardized CPUE. Obtaining a comparable geometric mean CPUE across both fishing methods is difficult now that catch-per-hook is being used in both auto-line and drop-line.

Table 21.6 RBC calculations for Blue Eye. C_{targ} and $CPUE_{targ}$ relate to the period 1997-2006, $CPUE_{Lim}$ is 20% of the B_0 proxy, and $\overline{CPUE}$ is the average catch rate over the last four years. The RBC calculation does not account for predicted discards of predicted State catches. Wt_Discard is the weighted average discards from the last four years, as with Equ (10).

Ref_Year	1997-2006
CE_Targ	1.0457
CE_Lim	0.4357
CE_Recent	0.8996
Wt_Discard	19.13
Scaling	0.7604
Last Year's TAC	335
C_{targ}	683.281
RBC	**519.584**

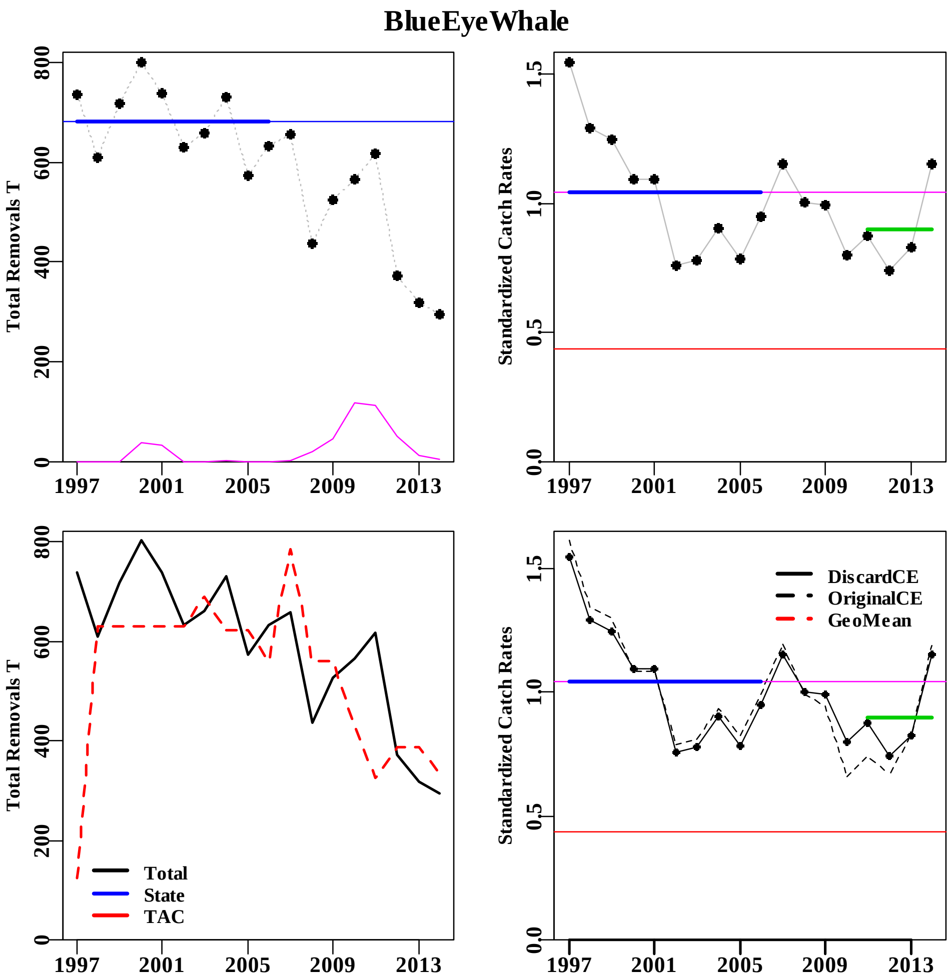


Figure 21.2. Blue Eye Trevalla. Top left is the total removals with the fine line illustrating the target catch. Top right represents the standardized catch rates with the upper fine line representing the target catch rate and the lower line the limit catch rate. Thickened lines represents the reference period for catches, catch rates, and the recent average catch rate. The bottom right compares the original optimal CPUE series (without discards) and the final estimate of the Discard CPUE.

Table 21.7. Estimate of approximate whale depredation based on figures from Pease (2012); proportional depredation in 2013 and 2014 reflect an invented exponential decline. The mean of the proportion of shots affected was 0.342 and the ScaledP was the Proportion divided by 0.342/0.25. The 0.6 relates to 60% reduction in catch. The depredation = Landings x (ScP x 0.6). Columns 2 – 4 are proportions, columns 5 – 8 are in tonnes.

Year	Proportion	ScaledP	ScP x 0.6	Landings	Depredation	Discards	Total
2008	0.110	0.0804	0.0482	415.174	20.030	0.993	436.198
2009	0.210	0.1535	0.0921	481.452	44.344	0.000	525.796
2010	0.590	0.4313	0.2588	450.183	116.495	0.142	566.820
2011	0.480	0.3509	0.2105	504.001	106.105	7.436	617.542
2012	0.320	0.2339	0.1404	323.144	45.354	4.327	372.824
2013	0.074	0.0539	0.0323	306.908	9.925	2.326	319.159
2014	0.016	0.0113	0.0068	292.950	1.992	1.138	296.080

21.4.3 Jackass Morwong West (MOR – 37377003 – *Nemadactylus macropterus*)

Table 21.8 Jackass Morwong data for the TIER 4 calculations. Total is the sum of Discards, State, Non Trawl and SEF2 catches. All values in Tonnes. CE is the standardized catch rate for Zones 10 to 50 in depths 70 – 360m (Sporcic, 2015). GeoMean is the geometric mean catch rates. Discards are assumed to be trivial in the west.

Year	Catch	Discards	Total	State	Non-T	PDiscard	CE	GeoMean
1986	153		153				1.9674	40.7569
1987	60		60				1.5426	24.4475
1988	67		67				2.3047	32.2567
1989	85		85				1.6706	32.2213
1990	83		83				1.6835	28.9610
1991	47		47				1.1453	18.6097
1992	72		72				0.9301	15.3915
1993	27		27				0.9039	15.5454
1994	27		27				0.8740	14.6606
1995	91		91				0.9230	21.5262
1996	44		44				1.0060	15.3414
1997	62		62				0.7958	12.8372
1998	65		65				0.8398	14.8359
1999	89		89				0.7663	15.5951
2000	134		134				1.1093	22.5459
2001	316		316				1.1991	34.4490
2002	289		289				1.1974	33.1596
2003	199		199				1.0062	30.9832
2004	216		216				1.0681	30.6678
2005	230		230				1.1496	28.0502
2006	217		217				0.9186	21.6176
2007	140		140				0.7519	19.7196
2008	124		124				0.7644	24.9533
2009	77		77				0.6098	14.8023
2010	47		47				0.4439	10.0420
2011	99		99				0.4698	12.6506
2012	41		41				0.3539	10.2040
2013	42		42				0.3414	8.0357
2014	13		13				0.2636	5.3615

Table 21.9. RBC calculations for Jackass Morwong West. C_{targ} and $CPUE_{targ}$ relate to the period 2000 – 2009, $CPUE_{Lim}$ is 20% of the B_0 proxy, and $\overline{CPUE}$ is the average catch rate over the last four years. Discarding is assumed to be trivial in the west. Catches only persisted for a number of years above 100t from 2000 onwards

Ref_Year	2000-2009
CE_Targ	0.9774
CE_Lim	0.4073
CE_Recent	0.3572
Wt_Discard	NA
Scaling	0
Last Year's TAC	568
C_{targ}	194.200
RBC	**0**

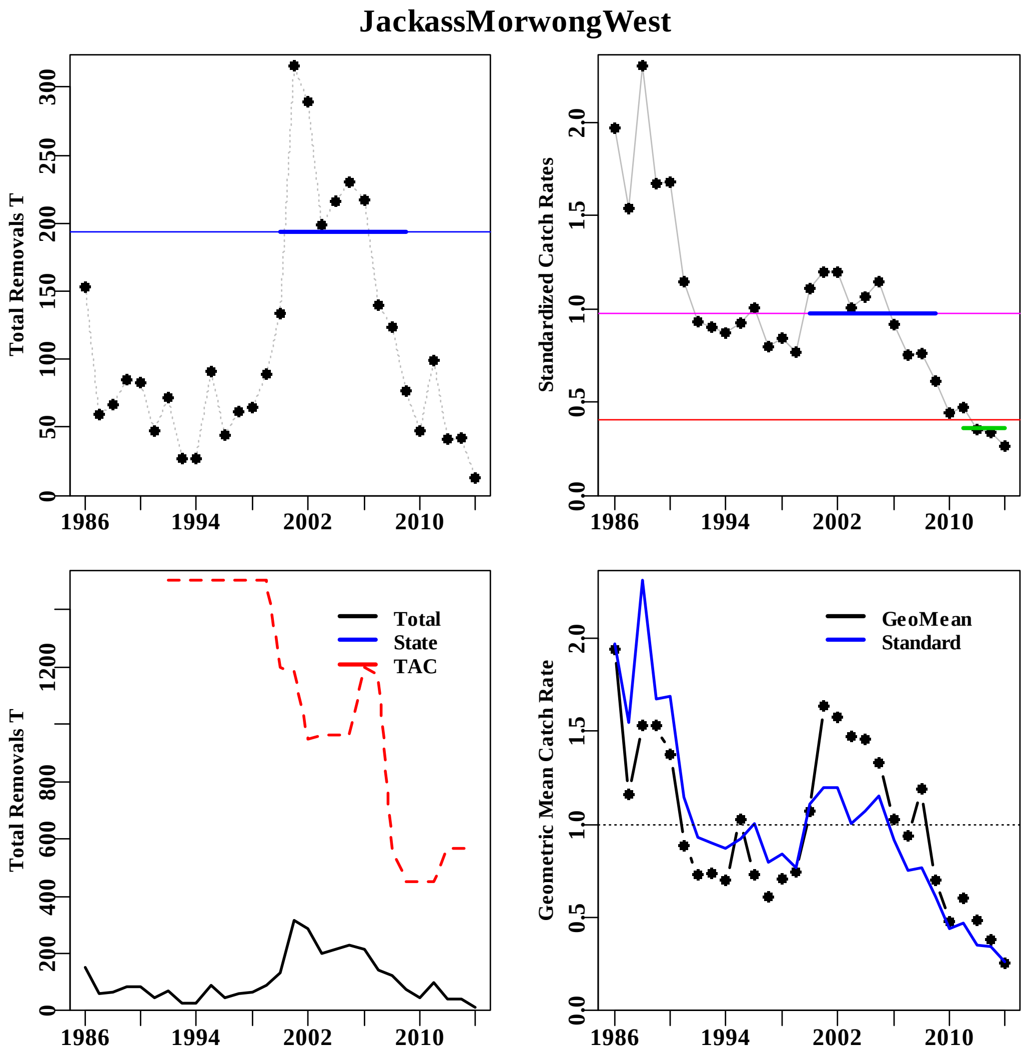


Figure 21.3 Jackass Morwong West (zones 40 – 50). Top left is the total removals with the line illustrating the target catch. Top right represents the standardized catch rates with the upper line representing the target catch rate and the lower line the limit catch rate. Thickened lines represents the reference period for catches, catch rates, and the recent average catch rate.

21.4.4 Mirror Dory (DOM – 37264003 – *Zenopsis nebulosus*)

Table 21.10 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 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	106.588	442.588			24.0829	1.2184	18.6423
1987	340.800	108.111	448.911			24.0829	1.2218	19.7476
1988	373.200	118.389	491.589			24.0829	1.1999	16.9455
1989	542.400	172.064	714.464			24.0829	1.4768	23.1957
1990	267.600	84.890	352.490			24.0829	1.3618	20.6077
1991	277.200	87.935	365.135			24.0829	1.1705	13.9567
1992	357.600	113.440	471.040			24.0829	1.0181	11.4026
1993	537.600	170.541	708.141			24.0829	1.1145	13.7999
1994	246.475	78.189	324.664	21.816		19.4087	1.0019	11.4667
1995	220.124	69.829	289.953	22.320		19.4087	0.9303	10.0782
1996	307.255	97.470	404.725	21.715		19.4087	0.8935	8.9039
1997	415.582	131.834	547.416	21.673		19.4087	0.9497	9.6820
1998	324.374	115.000	439.374	26.988		20.7441	0.8604	9.0983
1999	330.139	52.000	382.139	36.911		11.9777	0.7042	8.0995
2000	124.405	93.000	217.405	11.121		29.9608	0.4927	4.6512
2001	14.752	292.000	306.752	10.343	0.096	48.7681	0.5772	5.1016
2002	448.236	96.920	545.156	21.650	0.029	15.0948	0.7717	7.1674
2003	574.784	163.710	738.494	68.468		18.1456	0.9321	8.6659
2004	457.585	170.310	627.895	106.386	0.505	21.3366	0.8964	8.2047
2005	611.217	52.720	663.937	73.442	0.008	7.3564	0.9937	9.3924
2006	463.974	26.880	490.854	85.434	0.058	5.1919	0.9803	9.7517
2007	271.183	64.522	335.705	28.721	0.060	16.1213	0.9439	9.5152
2008	373.827	89.595	463.422	22.103	0.002	16.2011	1.1303	12.2034
2009	191.868	369.419	561.287	35.112		39.6923	1.2465	13.1797
2010	357.081	275.697	632.778	12.028	0.037	30.3472	1.1939	12.8612
2011	320.662	247.578	568.241	6.093	3.492	30.3472	1.1057	10.8184
2012	237.746	183.560	421.306	5.631	0.013	30.3472	0.8015	8.9809
2013	177.196	136.810	314.006	5.632		30.3472	0.9198	10.6434
2014	153.918	60.633	214.551	1.787		22.0336	0.8925	7.9715

Table 21.11 RBC calculations for Mirror Dory. C_{targ} and $CPUE_{targ}$ relate to the period 1986-1995, $CPUE_{Lim}$ is 20% of the B_0 proxy, and $\overline{CPUE}$ is the average catch rate over the last four years. The RBC calculation does not account for predicted discards of predicted State catches. Wt_Discard is the weighted average discards from the last four years, as with Equ (10).

Ref_Year	1992-1997&2003-2006
CE_Targ	0.971
CE_Lim	0.4046
CE_Recent	0.9299
Wt_Discard	109.8
Scaling	0.9273
Last Year's TAC	808
C_{targ}	526.712
RBC	**488.425**

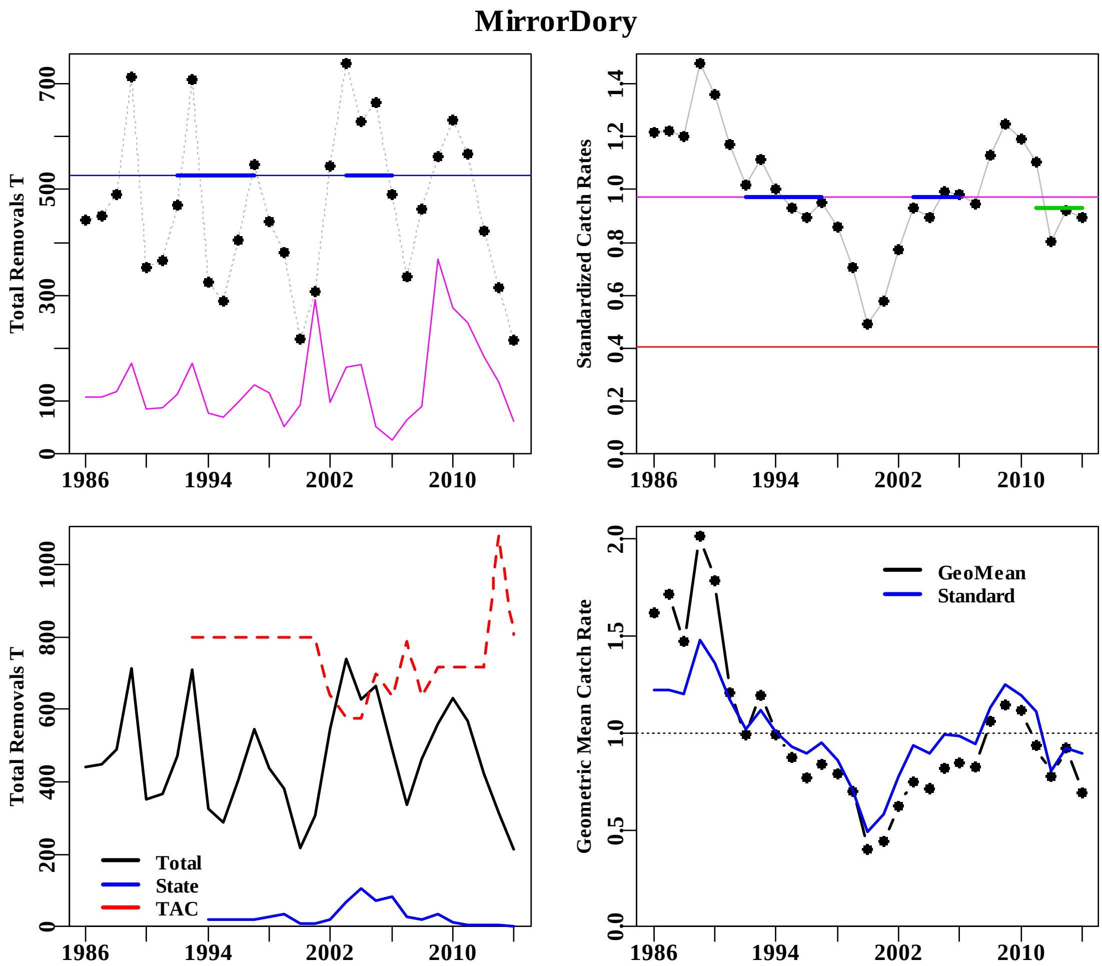


Figure 21.4 Mirror Dory. Top left is the total removals with the fine line illustrating the target catch. Top right represents the standardized catch rates with the upper fine line representing the target catch rate and the lower line the limit catch rate. Thickened lines represents the reference period for catches, catch rates, and the recent average catch rate.

21.4.5 Mirro Dory East – Discards

Following instructions from the RAG an alternative Tier 4 analysis for the eastern Mirror Dory was performed to determine the impact of the recent increase in the discard rate on the catch rates. In this case there was a marked effect, especially in three of the last four years, which are used in the estimate of current CPUE. The effect of this is to alter the estimate of the RBC from about 465 t to 497 t. This enables the reduction to the RBC due to the increased discard levels to be accounted for in the calculation of the TAC.

Table 21.12 Mirror Dory data for the TIER 4 calculations. Total is the sum of Discards, State, Non Trawl, SEF2, and ECDW catches. All values in Tonnes. StandCE is the standardized catch rate for all Zones 10 to 50 in depths 0 – 1000m (Haddon, 2013). GeoMean is the geometric mean catch rates. (D/C) +1 is the multiplier used with StandCE to generate DiscCE (see the Methods).

Year	Catch	Discards	Total	(D/C)+1	StandCE	DiscCE	GeoMean	TAC
1986	367.985	79.329	447.314	1.2156	1.1606	1.0990	18.7487	
1987	413.571	79.106	492.677	1.1913	1.1595	1.0760	19.9429	
1988	313.237	85.775	399.012	1.2738	1.1408	1.1320	16.8882	
1989	513.736	127.857	641.593	1.2489	1.3766	1.3392	23.1617	
1990	254.380	62.016	316.396	1.2438	1.2925	1.2523	20.5538	
1991	170.954	62.113	233.067	1.3633	1.1431	1.2140	14.2052	
1992	140.441	81.270	221.711	1.5787	0.9968	1.2258	11.7899	
1993	267.091	121.291	388.382	1.4541	1.0881	1.2325	14.1976	800
1994	303.620	55.999	303.620	1.1844	0.9578	0.7461	11.6924	800
1995	242.777	44.778	242.777	1.1844	0.8724	0.6796	10.2913	800
1996	262.435	48.403	262.435	1.1844	0.7637	0.5949	7.7998	800
1997	361.397	66.656	361.397	1.1844	0.8100	0.6310	8.6425	800
1998	292.102	76.454	368.556	1.2617	0.7324	0.7198	8.0944	800
1999	301.020	40.962	341.981	1.1361	0.6511	0.5762	7.8713	800
2000	187.853	80.358	268.211	1.4278	0.5042	0.5608	4.7876	800
2001	168.306	160.582	328.888	1.9541	0.5066	0.7711	4.0205	800
2002	243.856	43.352	287.208	1.1778	0.6340	0.5817	5.2611	640
2003	534.444	118.476	652.921	1.2217	0.9251	0.8804	7.7687	576
2004	406.127	110.158	516.285	1.2712	0.8808	0.8722	7.2637	576
2005	537.137	42.651	579.788	1.0794	1.1229	0.9442	9.9946	700
2006	402.464	22.040	424.504	1.0548	1.1258	0.9250	10.3893	634
2007	254.389	48.893	303.282	1.1922	1.2105	1.1242	11.4463	788
2008	391.325	75.656	466.981	1.1933	1.3466	1.2517	14.4563	634
2009	411.469	270.814	682.282	1.6582	1.4223	1.8371	15.8458	718
2010	432.522	188.447	620.969	1.4357	1.1928	1.3340	14.3976	718
2011	390.628	170.194	560.822	1.4357	1.1976	1.3393	12.7502	718
2012	338.672	143.251	481.923	1.4230	0.9465	1.0491	11.2957	718
2013	249.490	108.954	358.444	1.4367	0.9835	1.1007	11.8284	1077
2014	138.348	50.700	189.048	1.3665	0.8554	0.9105	7.4550	808

Discards make up approximately 19.41 % of the catch over the 1998-2006 period, but this is an estimate for the combined east and west. According to an earlier RAG decision this value multiplied by proportion of catch taken in the east, was used to estimate the discards for the years 1986 – 1997.

Table 21.13 RBC calculations for Mirror Dory East. C_{targ} and $CPUE_{targ}$ relate to the period 1986-1995, $CPUE_{Lim}$ is 20% of the B_0 proxy, and $\overline{CPUE}$ 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 (10).

Ref_Year	1986-1995
CE_Targ	1.1095
CE_Lim	0.4623
CE_Recent	1.0762
Wt_Discard	86.541
Scaling	0.9485
Last Year's TAC	808
C_{targ}	381.814
RBC	**362.163**

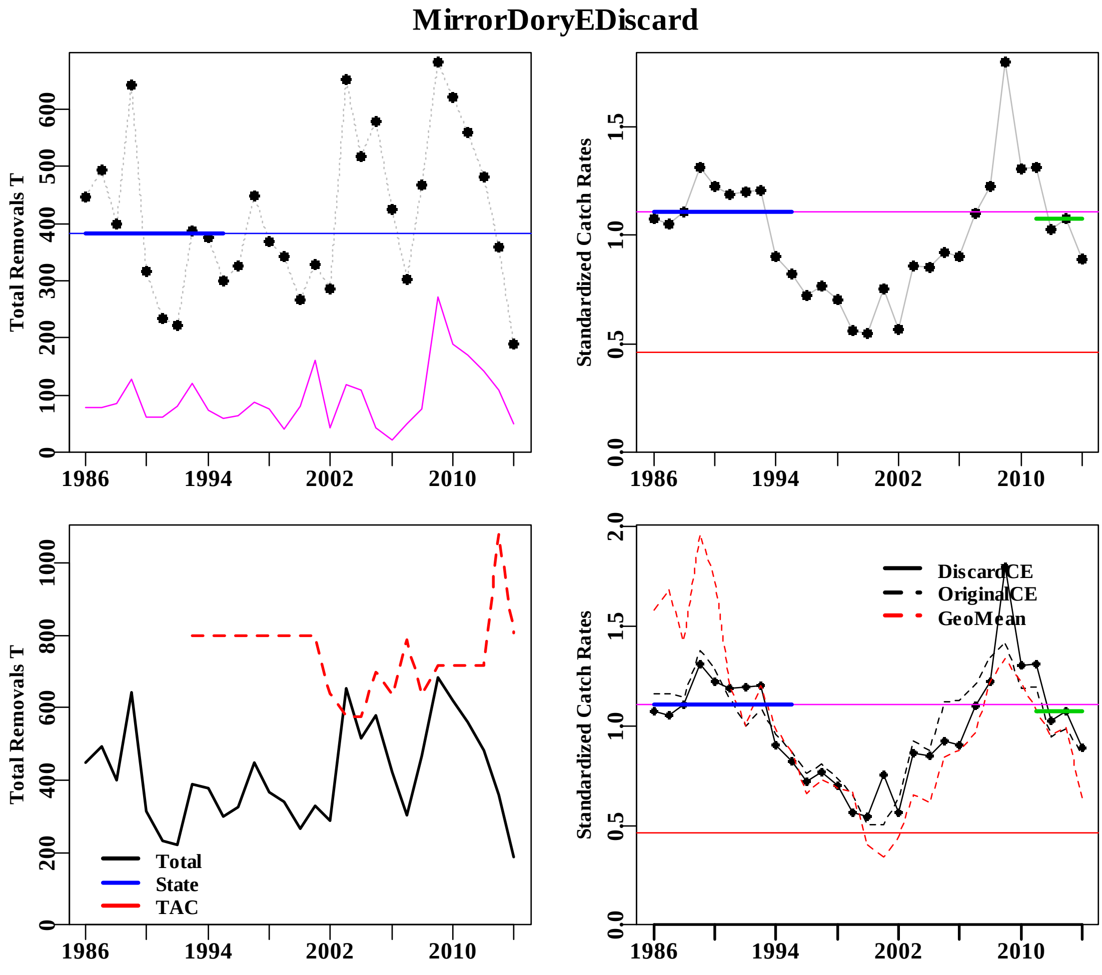


Figure 21.5. Mirror Dory. Top left is the total removals with the fine line illustrating the target catch. Top right represents the standardized catch rates with the upper fine line representing the target catch rate and the lower line the limit catch rate. Thickened lines represents the reference period for catches, catch rates, and the recent average catch rate.

21.4.6 Mirror Dory West (DOM – 37264003 – Z. nebulosus)

Table 21.14. 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	7.374	1.590	8.964			17.7345	2.5269	13.7130
1987	15.519	2.968	18.487			16.0564	1.6602	16.0832
1988	14.983	4.103	19.086			21.4968	1.3453	18.4525
1989	11.127	2.769	13.896			19.9280	1.7029	24.6757
1990	9.966	2.430	12.396			19.6008	1.1401	21.6631
1991	12.783	4.644	17.427			26.6504	0.8019	11.7670
1992	8.289	4.851	13.140			36.9172	0.6683	8.1608
1993	18.010	8.179	26.189			31.2298	0.7901	10.1017
1994	21.044	5.068	26.113	1.414		19.4090	0.7049	9.3264
1995	47.176	11.362	58.538	3.632		19.4090	0.9111	9.0896
1996	142.290	34.268	176.559	7.634		19.4090	1.2695	13.3473
1997	186.019	44.800	230.819	7.365		19.4090	1.2853	12.8686
1998	147.272	38.546	185.818	9.046		20.7441	1.2429	12.6121
1999	81.119	11.038	92.158	7.835		11.9777	0.8155	8.8763
2000	29.552	12.642	42.194	1.512		29.9624	0.4493	4.0569
2001	138.446	131.418	269.864	4.655	0.043	48.6978	0.7724	7.9539
2002	301.300	53.568	354.868	11.966	0.016	15.0952	1.1324	11.7235
2003	204.050	45.234	249.283	18.918	0.000	18.1456	0.9607	11.0165
2004	221.768	60.152	281.920	37.575	0.178	21.3366	0.9563	10.3786
2005	126.800	10.069	136.869	14.026	0.002	7.3564	0.7596	8.0456
2006	88.390	4.840	93.230	15.384	0.010	5.1919	0.6366	8.0395
2007	81.316	15.629	96.945	6.957	0.015	16.1213	0.5749	6.7120
2008	72.097	13.939	86.035	3.439		16.2011	0.6546	7.5767
2009	149.818	98.605	248.423	9.372		39.6923	1.0000	9.7010
2010	200.256	87.250	287.506	3.807	0.012	30.3472	1.1916	11.0745
2011	177.613	42.130	219.743	1.904	1.092	19.1726	0.9157	8.6510
2012	82.634	19.029	101.664	1.195	0.003	18.7179	0.5347	6.0700
2013	64.516	19.029	83.546	1.251		22.7772	0.7313	8.0998
2014	76.204	2.500	78.704	0.050		3.1765	0.8653	9.2029

Discards make up approximately 19.41 % of the catch over the 1998-2006 period, used for estimating discard rates for 1986 – 1997 and 19.17% over the 1998 – 2008 period used for estimating discard rates for 2011 – 2012.

Table 21.15. RBC calculations for Mirror Dory. C_{targ} and $CPUE_{targ}$ relate to the period 1996-2005, $CPUE_{Lim}$ is 20% of the B_0 proxy, and $\overline{CPUE}$ is the average catch rate over the last four years. The RBC calculation does not account for predicted discards of predicted State catches. Wt_Discard is the weighted average discards from the last four years, as with Equ (10).

Ref_Year	1996-2005
CE_Targ	0.9644
CE_Lim	0.4018
CE_Recent	0.7617
Wt_Discard	11.754
Scaling	0.6398
Last Year's TAC	808
C_{targ}	202.035
RBC	**129.260**

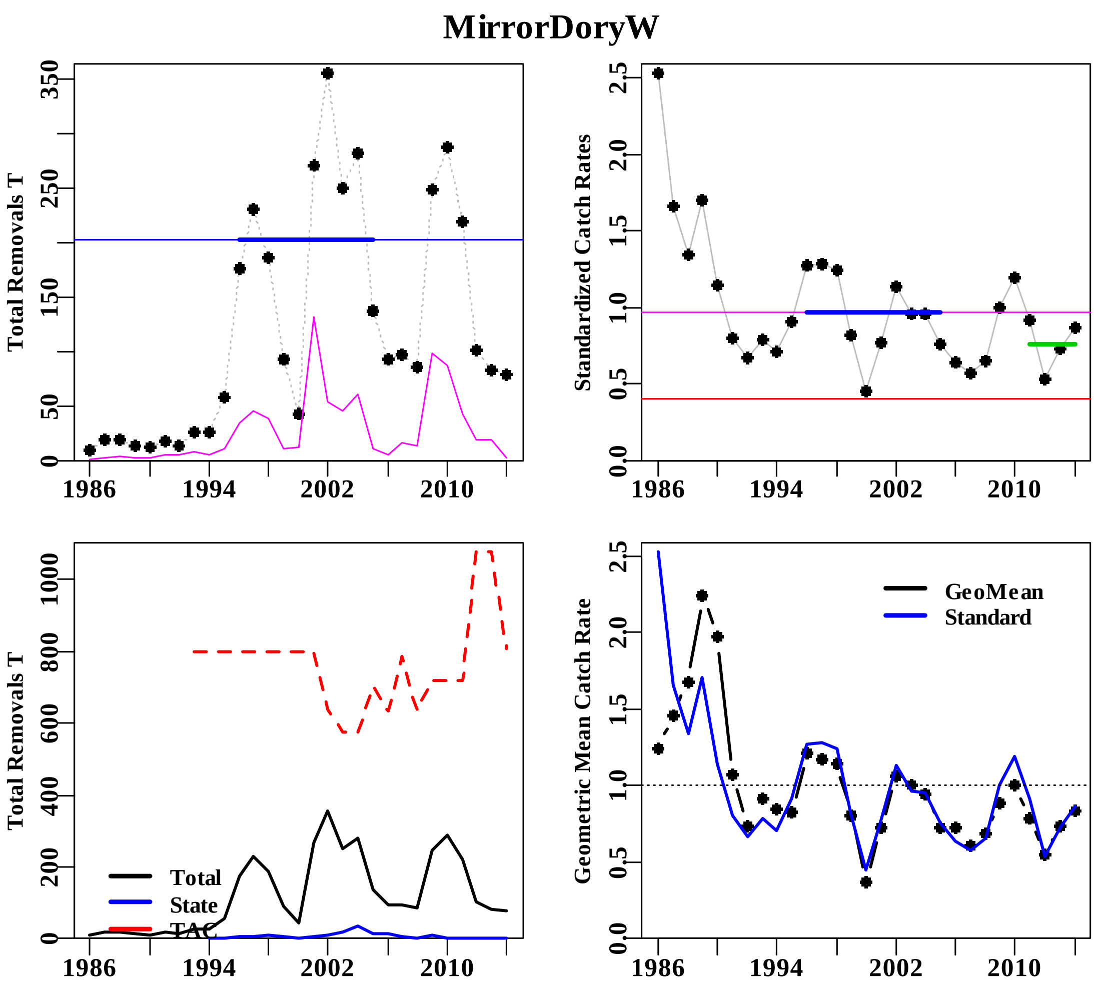


Figure 21.6. Mirror Dory. Top left is the total removals with the fine line illustrating the target catch. Top right represents the standardized catch rates with the upper fine line representing the target catch rate and the lower line the limit catch rate. Thickened lines represents the reference period for catches, catch rates, and the recent average catch rate.

21.5 Acknowledgements

Thanks go to Robin Thomson, Miriana Sporcic, and Judy Upston for the pre-analytical data preparation required maintaining the SESSF data set.

21.6 References

AFMA (2009) SESSF Stock Assessment Methods and TAC Setting Process Version 1.5. 8p.

Haddon, M. (2010) Tier 4 Analyses (data from 1986 – 2008. Pp 319 – 369 *in* Tuck, G.N. (*ed*) *Stock Assessment for the Southern and Eastern Scalefish and Shark Fishery 2009 Part 2.* Australian Fisheries Management Authority and CSIRO Marine and Atmospheric Research, Hobart. 428 pp.

Haddon, M. (2013) Catch Rate Standardizations for Selected Species from the SESSF (data 1986-2012). CSIRO Marine and Atmospheric Research, Hobart. 221 pp. RAG Paper.

Haddon, M. (2012b) Deep water catch rate standardizations and Tier 4 Analyses 2010 (data from 1986 – 2010) Pp 361-413 *Stock Assessment for the Southern and Eastern Scalefish and Shark Fishery:2011. Part 2.* (ed) G.N. Tuck. CSIRO Marine and Atmospheric Research, Hobart. 419 pp.

Haddon, M. (2011b) Tier 4 Analyses (data from 1986 – 2009. Pp 308 – 360 *in* Tuck, G.N. (*ed*) *Stock Assessment for the Southern and Eastern Scalefish and Shark Fishery 2010 Part 2.* Australian Fisheries Management Authority and CSIRO Marine and Atmospheric Research, Hobart. 419 pp.

Haddon, M. (2011c) Assorted Catch and Catch Rate Analyses for the SESSF 2010 pp 10 - 43 *in* Tuck, G.N. *(ed.)* 2011. *Stock Assessment for the Southern and Eastern Scalefish and Shark Fishery 2010. Part 2.* Australian Fisheries Management Authority and CSIRO Marine and Atmospheric Research, Hobart. 419 p.

Little, R., Tuck, G.N., Haddon, M., Day, J., Klaer, N., Smith, A.D.M., Thomson, R., and S. Wayte (2009) Developing CPUE targets for the Tier 4 harvest strategy of the SESSF. Pp 233-254 *in* Tuck, G.N. (*ed*) *Stock Assessment for the Southern and Eastern Scalefish and Shark Fishery: 2008 Part 2.* Australian Fisheries Management Authority and CSIRO Marine and Atmospheric Research, Hobart. 331 pp.

Little, L.R., Wayte, S.E., Tuck, G.N., Smith, A.D.M., Klaer, N., Haddon, M., Punt, A.E., Thomson, R., Day, J. and M. Fuller (2011a) Development and evaluation of a cpue-based harvest control rule for the southern and eastern scalefish and shark fishery of Australia. *ICES Journal of Marine Science*. **68(8)**: 1699-1705.

Little, L.R., Wayte, S.E. and Tuck, G.N. The effects of Cmax on the Tier 4 Harvest Control Rule. Pp 3-9 in Tuck, G.N. (*ed*) *Stock Assessment for the Southern and Eastern Scalefish and Shark Fishery: 2010 Part 2.* Australian Fisheries Management Authority and CSIRO Marine and Atmospheric Research, Hobart. 419 pp.

R Development Core Team (2009). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. ISBN 3-900051-07-0, URL http://www.R-project.org.

Sporcic, M (2015) Catch rate standardizations for selected SESSF species (data to 2014). CSIRO Oceans and Atmosphere Flagship, Hobart. 278p.

Wayte, S.E. and Fuller , M. (2008) Tier 4 Harvest Control Rule applied to deepwater species 2008. Report to DeepRAG, December 2008. 23p.

Wayte, S.E. (ed.) 2009. Evaluation of new harvest strategies for SESSF species. CSIRO Marine and Atmospheric Research, Hobart and Australian Fisheries Management Authority, Canberra. 137 p.

22. Catch-per-unit effort standardizations for selected shark SESSF species (data to 2014)

Miriana Sporcic

CSIRO, GPO Box 1538, Hobart, Tasmania

22.1 Executive Summary

This report focuses on data from years 1997 – 2014 available in the SESSF logbook database, following on from (Haddon 2014). The logbook database contains records relating to all methods and areas and allow for a detailed 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.

Reported catches of school shark are low and those by trawler do not appear to be targeted, as evidenced by the large proportion of < 30 kg shots present in the logbook data. Nevertheless, the areas in which they are caught has not changed greatly and yet the standardized catch-per-unit effort (CPUE) has begun to increase significantly, with the exception of 2014 (although above the long-term average and associated with a 40% reduction in catch). 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.

There has been an increase in reported gillnet catches of gummy shark and standardized CPUE in South Australia and Bass Strait during 2014. By contrast, standardized CPUE of gillnet caught gummy shark around Tasmania remained flat in 2014. Reported catches by bottom line remained at 228 t for both 2013 and 2014, while there was a drop of ~7 t reported (i.e. 18 t to 11 t) in 2014 relative to 2013 for trawl. CPUE standardizations for bottom line remained flat relative to the previous year, while those for trawl declined, but remain above the long-term average.

Elephant fish also constitute a non-targeted species, again with a large proportion of small shots (i.e. <30 kg). Gillnet standardized CPUE is also flat and noisy, however this analysis ignores discarding and uses number of shots instead of net length as a unit of effort. In the last few years discard rates for elephant fish have been very high, which may imply that their CPUE are in fact increasing.

Catches of saws sharks are considered to be a bycatch and this is supported by the high proportion of reported < 30 kg catches reported in both gillnet and trawl caught fish. The standardized CPUE for gillnets exhibits a steady decline since about 2001. However, a detailed analysis should be considered towards using net length as an effort unit instead of shot. Trawl caught saw shark standardized indices exhibit a noisy but flat trend, with an increase in 2014 reaching the long term average. By contrast, saw shark standardized CPUE by Danish seine (which has the highest proportion of shots < 30 kg among methods) has been flat since 2006.

22.2 Introduction

Commercial catch-per-unit effort (CPUE) data are used in very many fishery stock assessments in Australia as an index of relative abundance. This is based on the assumption that there is a direct relationship between CPUE and exploitable biomass. However, many other factors can influence CPUE, including vessel, gear, depth, season, area, and time of fishing (e.g. day or night). The use of CPUE as an index of relative abundance requires the removal of the effects of variation due to changes in these factors on the assumption that what remains will provide a better estimate of the underlying biomass. This process of adjusting the time series for the effects of other factors is known as standardization and the accepted way of doing this is to use a statistical modelling procedure that focuses attention onto the annual average CPUE adjusted for the (average) variation brought about by all the other measureable factors identified. The diversity of species and methods in the SESSF fishery means that each fishery/stock for which standardized CPUE are required requires its own set of conditions and selection of data. This report updates and extends standardized indices (based on data to 2014 inclusive) for 10 different stocks.

22.2.1 Limits of standardization

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

22.3 Methods

The southern shark fishery extends from New South Wales, around Tasmania, and across to Western Australia (Table 22.1, Figure 22.1).

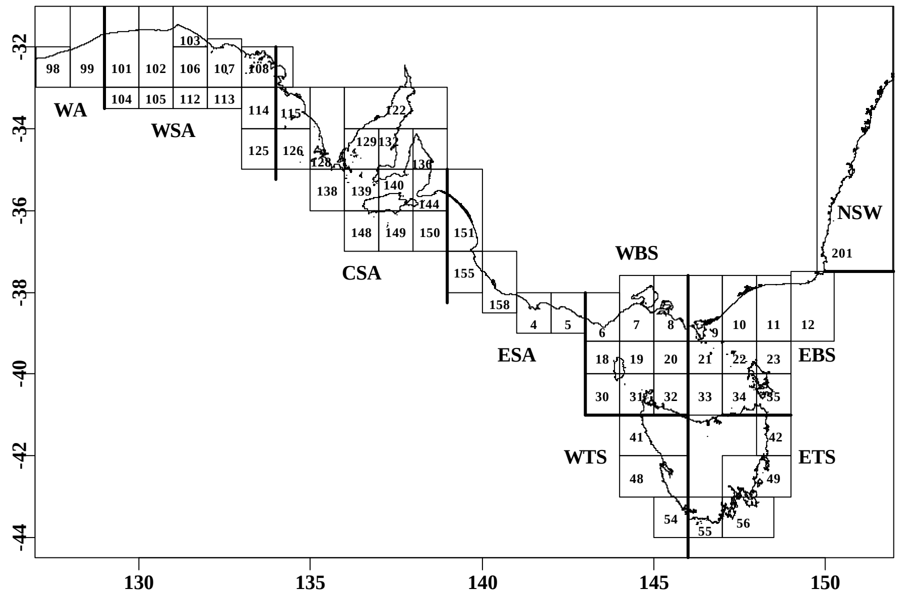


Figure 22.1. Shark statistical reporting areas and statistical regions. WA is Western Australia, WSA is Western South Australia, CSA is Central South Australia, ESA is Eastern South Australia (sometimes known as SAV – South Australia Victoria), WBS is Western Bass Strait, EBS is Eastern Bass Strait, NSW is New South Wales, ETS is Eastern Tasmania and WTS is Western Tasmania.

Table 22.1. Shark regions and corresponding shark zones used in the analysis.

Shark region	Shark region name	Shark zone
WA	Western Australia	10
WSA	Western South Australia	1
CSA	Central South Australia	2
SAV-E	Southern Australia-Victoria East	3
WBS	Western Bass Strait	4
WT	Western Tasmania	6
ET	Eastern Tasmania	7
EBS	Eastern Bass Strait	5
NSW	New South Wales	8
SAV-W	Southern Australia-Victoria West	9

22.3.1 Catch-per-unit effort Standardization

Followiong on from Haddon (2014), the data used in the following analyses applies to only the SESSF logbook data. Data from 1997 – 2014 inclusive is used for most species. Catch-per-unit effort (CPUE) was calculated, where there were positive non-zero catches and associated positive non-zero effort levels. These were also log transformed in preparation for the log-linear modelling. Depth of fishing was sub-divided into 20 metre depth categories for inclusion in statistical standardizations (the size of the depth classes varied with fishing method (e.g. 25 m depth classes (out to 600 m) for trawl caught school sharks).

22.3.1.1 The overall year effect

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

$$CPUE_t = e^{\left(\gamma_t + \sigma_t^2/2\right)} \quad (15)$$

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 CPUE changes:

$$CE_t = \frac{CPUE_t}{\left(\sum CPUE_t\right)/n} \quad (16)$$

$CPUE_t$ is the yearly coefficient 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 yielding the yearly index of relative abundance.

Analyses were performed in the statistical software *R* (R Development Core Team, 2009), using the library 'biglm', which is able to analyse the large size datasets available for many of the species considered in this report. It incorporates classical statistical linear model techniques (e.g. GLMs; McCullagh and Nelder, 1989).

The optimum model chosen was the model which contained the lowest estimated AIC statistic (Burnham and Anderson 2002).

22.3.1.2 Factors considered

Factors considered in the analyses (i.e. categorical variables) were:

Year	standard calendar year
Vessel	each vessel is uniquely and confidentially identified
Month	standard calendar months
Shark Zone	standard shark statistical reporting blocks (see Table 22.1)
SharkArea	an alternative to shark zone, essential 1 degree squares (see Table 22.1)
Gear	gillnets, trawl, bottom line, or Danish seine as appropriate
DepCat	20 m categories (or variants depending on species)

DayNight	day, night, mixed, unknown categories
DayNight:DepCat	an interaction term including depth changes through the day
DepCat:Month	an interaction term used to include any seasonal changes across areas
DayNight:Month	an interaction term used to include any seasonal changes across when fishing occurred during each day

The DayNight term is availavle for trawl gear, but was not available for non-trawl gears.

22.3.1.3 Presentation of time series

Plots of the unstandardized geometric mean CPUE along with the optimum statistical model representing the standardized time series are depicted for each species and/or species groups. This provides a visual indication of whether the standardization alters the trend away from the nominal CPUE. The time series have all been scaled relative to the average of each time series of yearly indices, which means that the overall average in each case equates to one; this centres the vertical location of each series but does not change the relative trends through time.

22.3.2 Data selection for different shark species

Following on from Haddon (2014), shark records corresponding to 1997 – 2014 were analysed, except for gummy shark - bottom line (from 1998), gummy shark – trawl (from 1996) and school shark – trawl (1996-2014). The selection of data by fishery, gear type, depth and shark zones for each species is listed in Table 22.2 through to Table 22.5. The small number of records for which no effort data were available (effort = -1 or 0 could not be included in the standardization.

22.3.2.1 Gummy Sharks (Mustelus antarcticus)

Table 22.2. Data selection criteria for gummy shark standardization caught by gillnets, trawl and bottom line.

Criteria	Values
CSIRO CODE	37017001
Gillnet:	
Gear Types	6", 6.5", and 7" mesh gillnet (GN)
Depth	20 m depth classes 1 – 160 m
Shark zones	SA: 1,2,3,9; TAS: 4,5; BS: 6,7
Years	1996 – 2014
Trawl:	
Gear type	TW, TDO, OTT*
Depth	20 m depth classes 0 – 500 m
Shark zones	SA: 1,2,3,9; TAS: 4,5; BS: 6,7 NSW: 8; WA: 10
Years	1996 – 2014
Bottom line:	
Gear type	BL
Depth	20 m depth classes 0 – 200 m
Shark zones	1–10 inclusive
Years	1998 – 2014

* "TW" otter trawl; "TDO" otter trawl reported by elog; "OTT" bottom otter twin trawls

22.3.2.2 School Shark (Galeorhinus galeus)

Given the change from targeting, to increasingly active avoidance of school sharks by gillnet fishers during the available time series, an analysis of gillnet CPUE would be invalid and misleading. However, the trawl fishery is unlikely to have targeted school shark at any time, providing a consistent time series of catch and effort data. These were standardized using classical statistical methods (Haddon, 2014c). There were various data selections made with respect to gear types, depths, and years prior to data analysis (Table 22.3).

Table 22.3. Data selection criteria for trawl caught school shark standardization.

Criteria	Values
Gear Type(s)	Trawl (TW, TDO, OTT); but catches by other methods summarized.
Depth	25 m depth classes 0 – 600 m
Shark zones	1 – 7: WSA, CSA, ESA, WBS, EBS, WTS, ETS
Years	1997 - 2014

22.3.2.3 Saw Sharks

Saw sharks are considered to be primarily a bycatch species and are taken mostly by gillnets, trawl and Danish seine. The amounts landed by each of these methods are sufficient to allow a standardization for each method with comparison of outcomes. In each case, the same set of years was used but usually a different set of gears, depths, and shark zones were selected on the basis of the number of fishing operations available (Table 22.4).

Table 22.4. Data selection criteria for saw shark standardizations for gillnet, trawl and Danish seine fisheries.

Criteria	Values
CSIRO CODE(S)	37023000, 37023001, 37023002, 37023900
Years	1997 - 2014
Gillnet:	
Gear Type	GN
Depth	0 – 150 m
Shark zones	1 – 7: WSA, CSA, ESA, WBS, EBS, WTS, ETS
Trawl:	
Gear Type(s)	TW and TDO; OTT but catches for all methods summarized.
Depth	20 m depth classes 0 – 500 m
Shark zones	1, 3 – 8: WSA, ESA, WBS, EBS, WTS, ETS, NSW
Danish seine:	
Gear Type	DS
Depth	0 – 240 m
Shark zones	4 – 5: WBS, EBS

22.3.2.4 Elephant Fish (Callorhinchus milii)

While there are reported catches of elephant fish in the trawl and Danish seine fisheries most catches are reported by the gillnet fishery so a standardization for that that only fishery is undertaken. There are relatively high levels of discarding of elephant fish so an analysis that generates a CPUE series that attempts to include the influence of discard levels as well as reported catches is produced.

The data selection criteria for elephant fish (Table 22.5), attempt to eliminate deeper water chimaerid species that are sometimes grouped under the codes used for elephant fish.

Table 22.5. Criteria for selecting which records to include in the standardization of elephant fish.

Criteria	Values
CSIRO CODE(S)	37043001, 37043000, 37043002, 37043900, 37043901
Gear Types	Gillnet (GN); but catches for all methods are summarized.
Depth	20 m depth classes 0 – 160 m
Shark zones	2 – 7: CSA, ESA, WBS, EBS, WTS, ETS
Years	1997 - 2014

22.4 Results

22.4.1 South Australian gummy shark: Gillnet

Positive non-zero records of catch per shot were employed in the statistical standardization analyses for gummy shark caught by gillnets. Further investigation should be considered to determine whether total net length could be used as an alternative effort unit in standardization analyses.

Table 22.6. Gummy shark taken by gillnet across shark zones from South Australia between depths of 0 to 160 m in the period 1997 - 2014. Total catch (TotCatch; t) is the total reported in the database across all gears, TotCat (t) is the total catch reported in the SESSF across all gears, number of records used in the analysis (Records), reported catch (CatchT; t) in the area and depth used in the analysis and number of vessels used in the analysis (Vessels). GeoMean is the geometric mean of CPUE (kg/shot). The optimum model is Model 7 (Table 22.8). SharkZone:DepC and standard deviation (StDev) are the coefficients from the optimum model.

Year	TotCatch	TotCat	Records	CatchT	Vessels	GeoMean	SharkZone:DepC	StDev
1997	1012.197	998.717	4776	458.866	56	50.4779	1.2103	0.0000
1998	1527.171	1493.332	7224	548.339	53	36.9280	0.9551	0.0221
1999	1956.680	1921.228	6225	611.612	47	49.4890	1.0226	0.0242
2000	2349.499	2299.635	5005	787.995	37	82.9671	1.3065	0.0350
2001	1662.581	1613.894	4869	361.593	36	41.8944	0.6366	0.0356
2002	1494.823	1451.966	5007	387.239	32	46.3078	0.6830	0.0355
2003	1618.274	1585.997	5234	457.217	37	50.2395	1.1047	0.0256
2004	1656.377	1611.925	5303	466.305	40	50.5370	1.1590	0.0260
2005	1570.520	1536.342	4890	472.635	29	53.3159	1.1736	0.0264
2006	1577.133	1570.540	5942	549.266	28	53.1761	1.1470	0.0255
2007	1574.951	1573.289	4540	438.229	29	56.3259	1.1983	0.0265
2008	1727.745	1725.819	4868	543.113	23	64.3570	1.4122	0.0264
2009	1500.901	1498.958	5152	418.247	23	47.5308	1.0570	0.0265
2010	1404.788	1402.195	5254	389.416	29	41.5273	0.9338	0.0267
2011	1364.705	1364.060	3276	229.024	19	38.6808	0.8218	0.0298
2012	1301.400	1298.865	1366	82.435	14	31.3386	0.6277	0.0380
2013	1307.510	1305.717	799	60.447	18	35.9082	0.6488	0.0468
2014	1381.489	1363.895	1419	122.670	20	50.5793	0.9020	0.0396

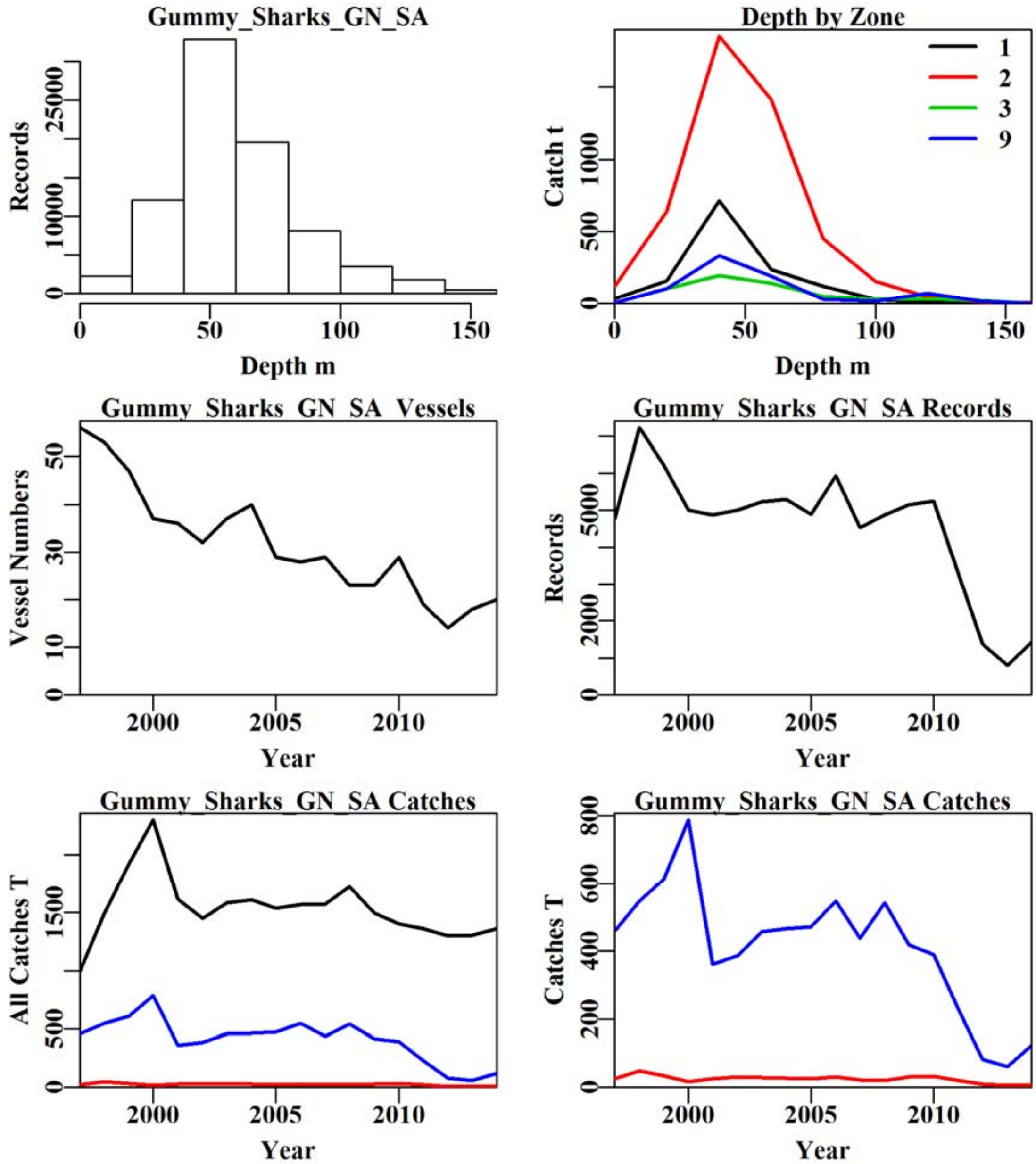


Figure 22.2. Gummy shark in South Australia in depths 0 to 160 m taken by gillnet. The top left plot depicts the depth distribution of shots containing gummy shark from shark zone 1, 2, 3 and 9 in depths 0 – 160 m. The top right plot depicts the distribution of catch by depth within shark zones 1, 2, 3 and 9. The middle left plot depicts the number of vessels through time. The middle right plot contains the number of records used in analysis. The bottom left plot contains gummy shark catches (top black line: total catches, middle blue line: catches used in the analysis; bottom red line: catches < 30 kg) and bottom right plot contains School Whiting catches (blue line: catches used in the analysis; red line: catches < 30 kg).

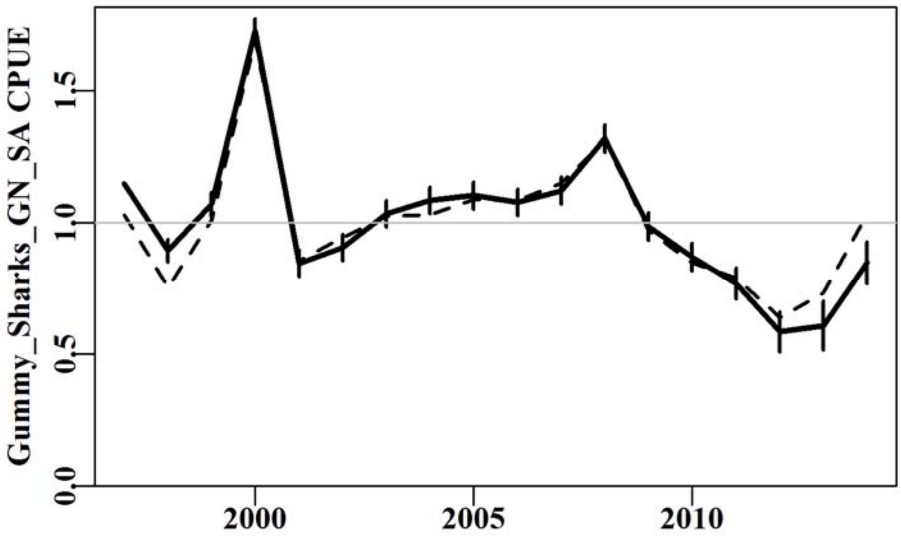


Figure 22.3. The standardized CPUE for gummy sharks taken by gillnet in South Australia showing the optimum model (solid black line) and the geometric mean CPUE (dashed line) each scaled to the mean of each time series. The vertical bars are two times the standard error.

Table 22.7. Gummy shark from across shark zones in depths 0 to 160 m by gillnet. Statistical model structures used in this analysis. DepCat is a series of 20 metre depth categories.

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

Table 22.8. Gummy shark taken by gillnet across shark zones from South Australia between depths of 0 to 160 m and in the period 1997 - 2014. Model selection criteria, include the AIC, the adjusted R^2 (adj_ R^2) and the change in adjusted R^2 (%Change). The optimum model is Model 7 (SharkZone:DepC). Depth category: DepC.

	Year	Vessel	DepCat	SharkZone	Month	SharkZone:Month	SharkZone:DepC
AIC	23364	19079	17878	16818	16302	15515	14963
RSS	108176	102277	100194	98858	98219	97178	96537
MSS	3322	9220	11303	12639	13278	14319	14961
Nobs	81149	81149	80574	80574	80574	80574	80574
Npars	18	151	159	170	173	209	200
adj_R^2	2.959	8.100	9.961	11.150	11.720	12.617	13.204
%Change	0.000	5.141	1.861	1.189	0.570	0.526	0.586

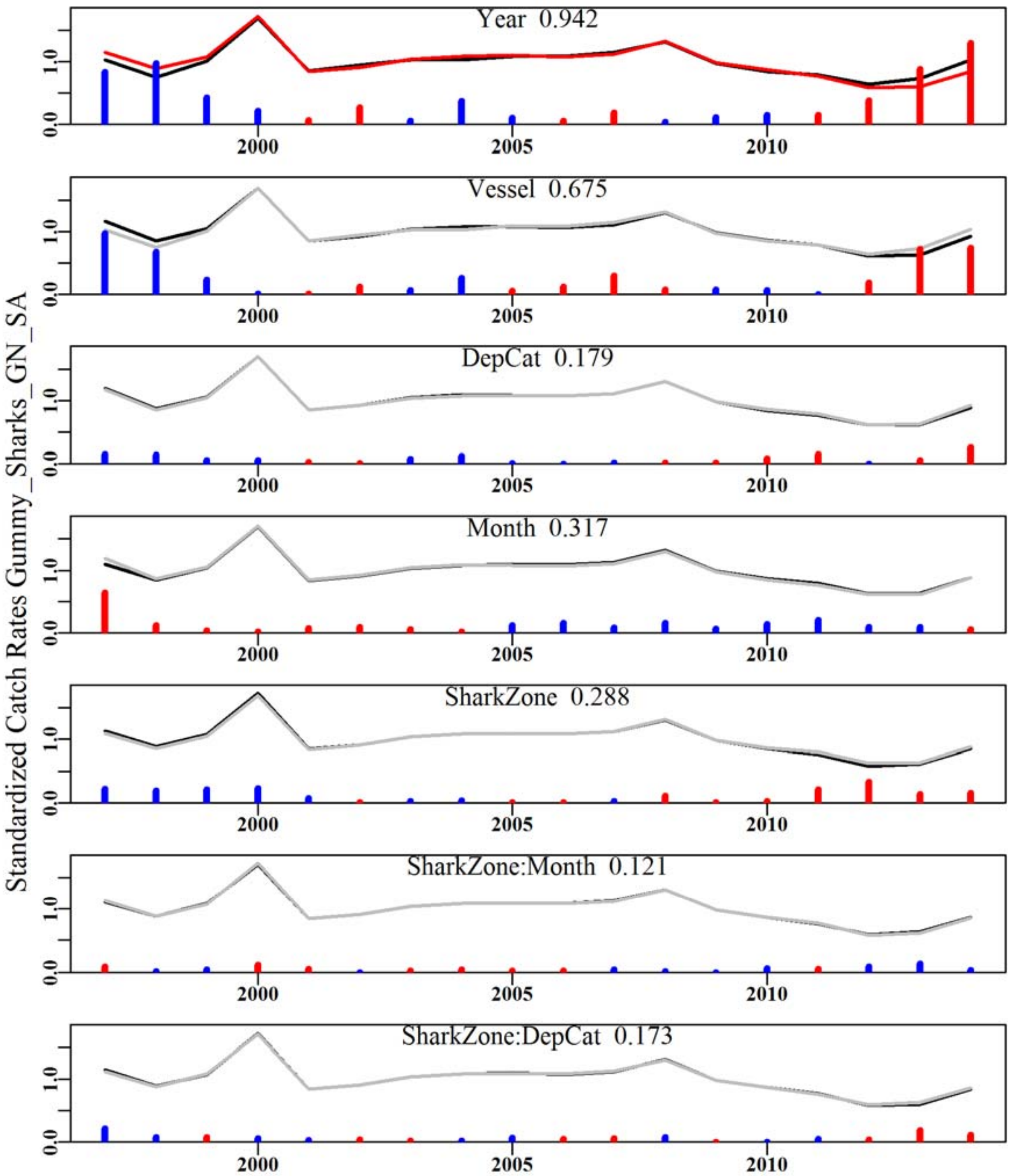


Figure 22.4. The relative influence of each factor on the final trend in the optimal standardization for the South Australian gummy shark gillnet fishery. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by the vertical bars with blue bars indicating the optimum model is higher than the geometric mean and red bars indicating it is lower. The top graph's bars are the sum of all the bars in the graphs below. The graphs for individual factors are cumulative. Thus the second graph has the geometric mean (grey line) and the effect of adding Year + factor2 (Model 2, black line). In the third graph, the grey line represents Model 2 and the black line the effect of adding factor3 to the model. The remaining graphs continue in the same cumulative manner except for the interaction terms which are added singularly to the final single factor model.

22.4.2 Bass Strait gummy shark: Gillnet

Positive non-zero records of catch per shot were employed in the statistical standardization analyses for gummy shark caught by gillnets. Further investigation should be considered to determine whether total net length could be used as an alternative effort unit in standardization analyses.

Table 22.9. Gummy shark taken by gillnet across shark zones in Bass Strait between depths of 0 to 160 m in the period 1997 - 2014. Total catch (TotCatch; t) is the total reported in the database across all gears, TotCat (t) is the total catch reported in the SESSF across all gears, number of records used in the analysis (Records), reported catch (CatchT; t) in the area and depth used in the analysis and number of vessels used in the analysis (Vessels). GeoMean is the geometric mean of CPUE (kg/shot). The optimum model is model 6 (Table 22.11). SharkZone:Month and standard deviation (StDev) are the coefficients from the optimum model.

Year	TotCatch	TotCat	Records	CatchT	Vessels	GeoMean	SharkZone:Month	StDev
1997	1012.197	998.717	4334	440.438	50	55.7055	0.6269	0.0000
1998	1527.171	1493.332	5833	778.117	51	73.0763	0.7925	0.0237
1999	1956.680	1921.228	6422	1086.161	54	89.0885	1.0239	0.0236
2000	2349.499	2299.635	6274	1260.990	49	108.1596	1.1856	0.0236
2001	1662.581	1613.894	5818	1053.308	48	99.2906	1.0525	0.0241
2002	1494.823	1451.966	5781	823.079	46	81.4819	0.8602	0.0242
2003	1618.274	1585.997	5953	873.417	44	84.7081	0.8755	0.0242
2004	1656.377	1611.925	5713	851.865	41	89.2974	0.9269	0.0244
2005	1570.520	1536.342	4945	799.609	39	101.9532	1.0400	0.0253
2006	1577.133	1570.540	4085	735.460	33	106.9983	1.0905	0.0264
2007	1574.951	1573.289	3483	874.844	25	138.6660	1.3284	0.0275
2008	1727.745	1725.819	3671	954.553	26	144.0312	1.4355	0.0273
2009	1500.901	1498.958	4088	833.206	27	121.0018	1.2526	0.0267
2010	1404.788	1402.195	4423	744.051	31	97.6047	0.9976	0.0263
2011	1364.705	1364.060	5170	797.664	32	83.7659	0.9046	0.0258
2012	1301.400	1298.865	5438	780.260	37	79.8965	0.8786	0.0257
2013	1307.510	1305.717	5338	758.408	36	79.7147	0.8372	0.0256
2014	1381.489	1363.895	5230	809.749	36	84.4859	0.8910	0.0258

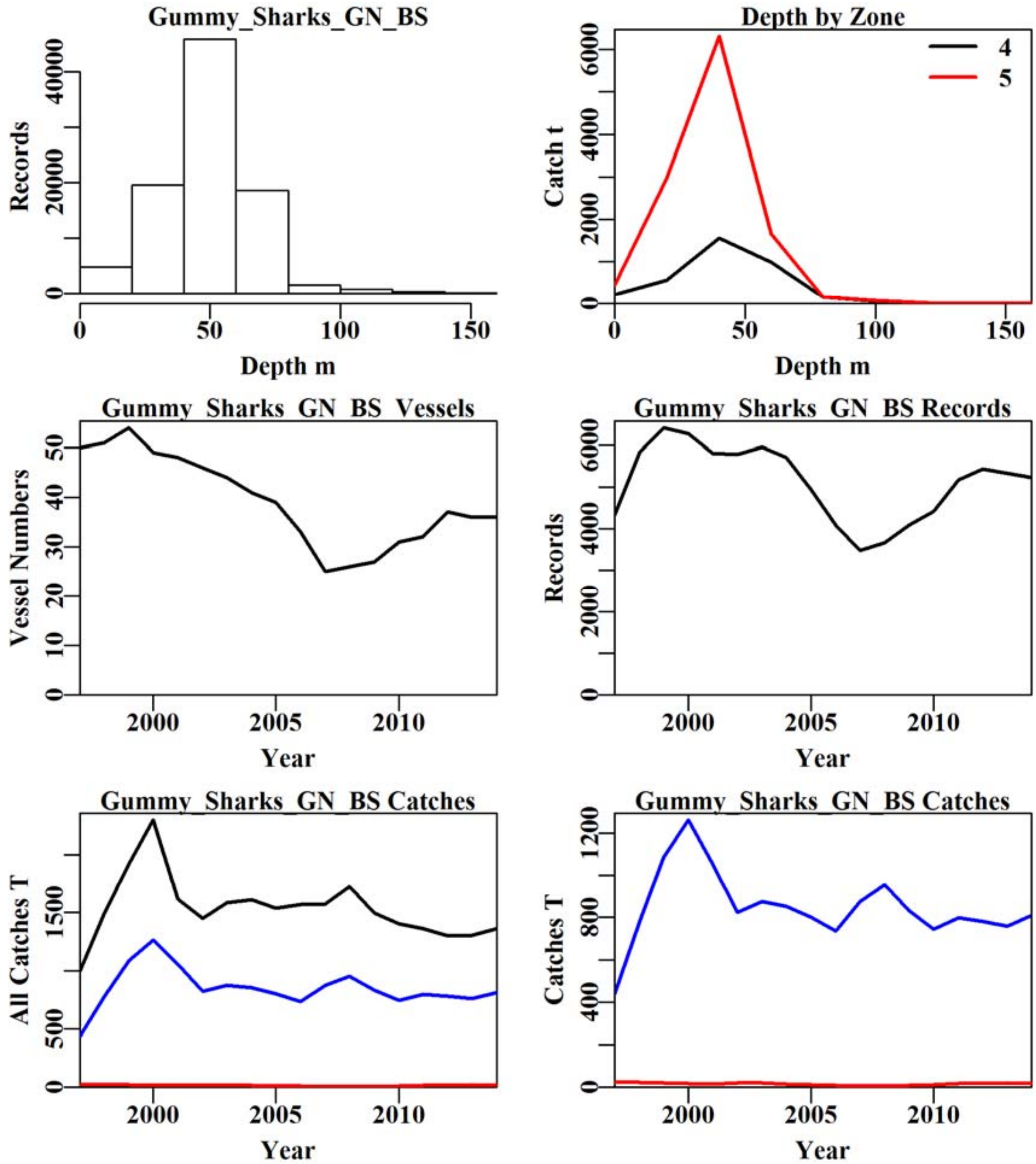


Figure 22.5. Gummy shark in Bass Strait in depths 0 to 160 m taken by gillnet. The top left plot depicts the depth distribution of shots containing gummy shark from zone 4 and 5 in depths 0 – 160 m. The top right plot depicts the distribution of catch by depth within shark zones 4 and 5. The middle left plot depicts the number of vessels through time. The middle right plot contains the number of records used in analysis. The bottom left plot contains gummy shark catches (top black line: total catches, middle blue line: catches used in the analysis; bottom red line: catches < 30 kg) and bottom right plot contains School Whiting catches (blue line: catches used in the analysis; red line: catches < 30 kg).

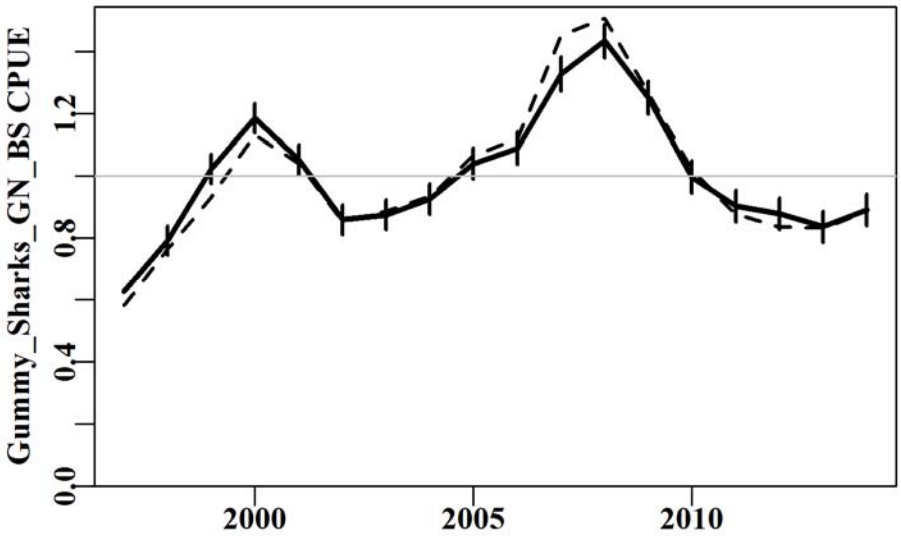


Figure 22.6. The standardized CPUE for gummy sharks taken by gillnet in Bass Strait showing the optimum model (solid black line) and the geometric mean CPUE (dashed line) each scaled to the mean of each time series. The vertical bars are two times the standard error.

Table 22.10. Gummy shark from across shark zones in Bass Strait in depths 0 to 160 m by gillnet. Statistical model structures used in this analysis. DepCat is a series of 20 metre depth categories.

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

Table 22.11. Gummy shark taken by gillnet across shark zones from Bass Strait between depths of 0 to 160 m and during 1997 - 2014. Model selection criteria, include the AIC, the adjusted R^2 (adj_ R^2) and the change in adjusted R^2 (%Change). The optimum model is Model 6 (SharkZone:Month). Depth category: DepC.

	Year	Vessel	DepCat	SharkZone	Month	SharkZone:Month	SharkZone:DepC
AIC	29922	23026	21925	21327	21326	21071	21247
RSS	127310	117824	115869	115086	115083	114735	114963
MSS	3826	13313	15268	16051	16054	16401	16174
Nobs	91999	91999	91448	91448	91448	91448	91448
Npars	18	132	140	151	152	163	160
adj_R^2	2.900	10.024	11.508	12.095	12.097	12.352	12.181
%Change	0.000	7.124	1.484	0.587	0.001	0.255	-0.171

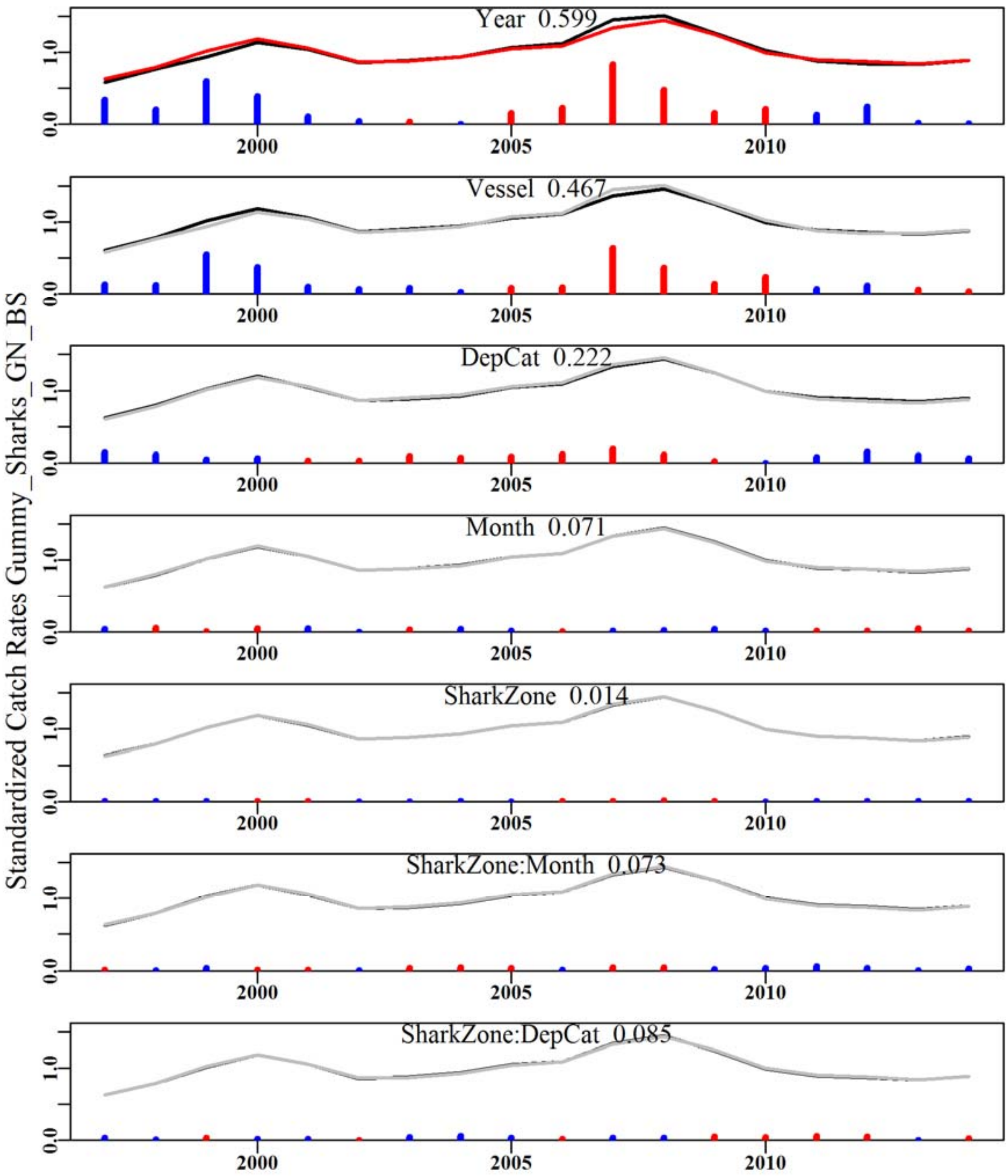


Figure 22.7. The relative influence of each factor on the final trend in the optimal standardization for the Bass Strait gummy shark gillnet fishery. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by the vertical bars with blue bars indicating the optimum model is higher than the geometric mean and red bars indicating it is lower. The top graph bars are the sum of all the bars in the graphs below. The graphs for individual factors are cumulative. Thus the second graph has the geometric mean (grey line) and the effect of adding Year + factor2 (Model 2, black line). In the third graph, the grey line represents Model 2 and the black line the effect of adding factor3 to the model. The remaining graphs continue in the same cumulative manner except for the interaction terms which are added singularly to the final single factor model.

22.4.3 Tasmanian gummy shark: Gillnet

Positive non-zero records of catch per shot were employed in the statistical standardization analyses for gummy shark caught by gillnets. Further investigation should be considered to determine whether total net length could be used as an alternative effort unit in standardization analyses.

Table 22.12. Gummy shark taken by gillnet across shark zones in Tasmania between depths of 0 to 160 m in the period 1997 - 2014. Total catch (TotCatch; t) is the total reported in the database across all gears, TotCat (t) is the total catch reported in the SESSF across all gears, number of records used in the analysis (Records), reported catch (CatchT; t) in the area and depth used in the analysis and number of vessels used in the analysis (Vessels). GeoMean is the geometric mean of CPUE (kg/shot). The optimum model is Model 6 (Table 22.14). SharkZone:Month and standard deviation (StDev) are the coefficients from the optimum model.

Year	TotCatch	TotCat	Records	CatchT	Vessels	GeoMean	SharkZone:Month	StDev
1997	1012.197	998.717	203	18.024	14	46.7535	0.7319	0.0000
1998	1527.171	1493.332	547	63.791	14	52.8692	0.7214	0.1069
1999	1956.680	1921.228	797	100.645	18	65.9742	0.9098	0.1061
2000	2349.499	2299.635	507	81.514	18	86.2155	1.1148	0.1134
2001	1662.581	1613.894	565	66.242	21	66.0826	1.1537	0.1168
2002	1494.823	1451.966	778	103.753	26	61.7342	1.1428	0.1159
2003	1618.274	1585.997	799	90.915	23	58.5075	1.2697	0.1172
2004	1656.377	1611.925	881	122.050	25	64.5900	1.2182	0.1160
2005	1570.520	1536.342	660	86.106	15	69.0883	1.0586	0.1189
2006	1577.133	1570.540	700	117.163	15	92.2733	1.1926	0.1188
2007	1574.951	1573.289	835	95.345	14	57.5239	1.0252	0.1177
2008	1727.745	1725.819	634	61.503	14	52.7297	0.8901	0.1197
2009	1500.901	1498.958	533	68.633	14	66.1554	1.0820	0.1248
2010	1404.788	1402.195	534	75.512	14	75.8358	1.0833	0.1245
2011	1364.705	1364.060	686	102.725	13	87.1495	0.8984	0.1274
2012	1301.400	1298.865	1121	130.062	18	49.5438	0.9393	0.1236
2013	1307.510	1305.717	910	96.581	15	55.4671	0.7824	0.1268
2014	1381.489	1363.895	481	61.056	13	68.1559	0.7857	0.1421

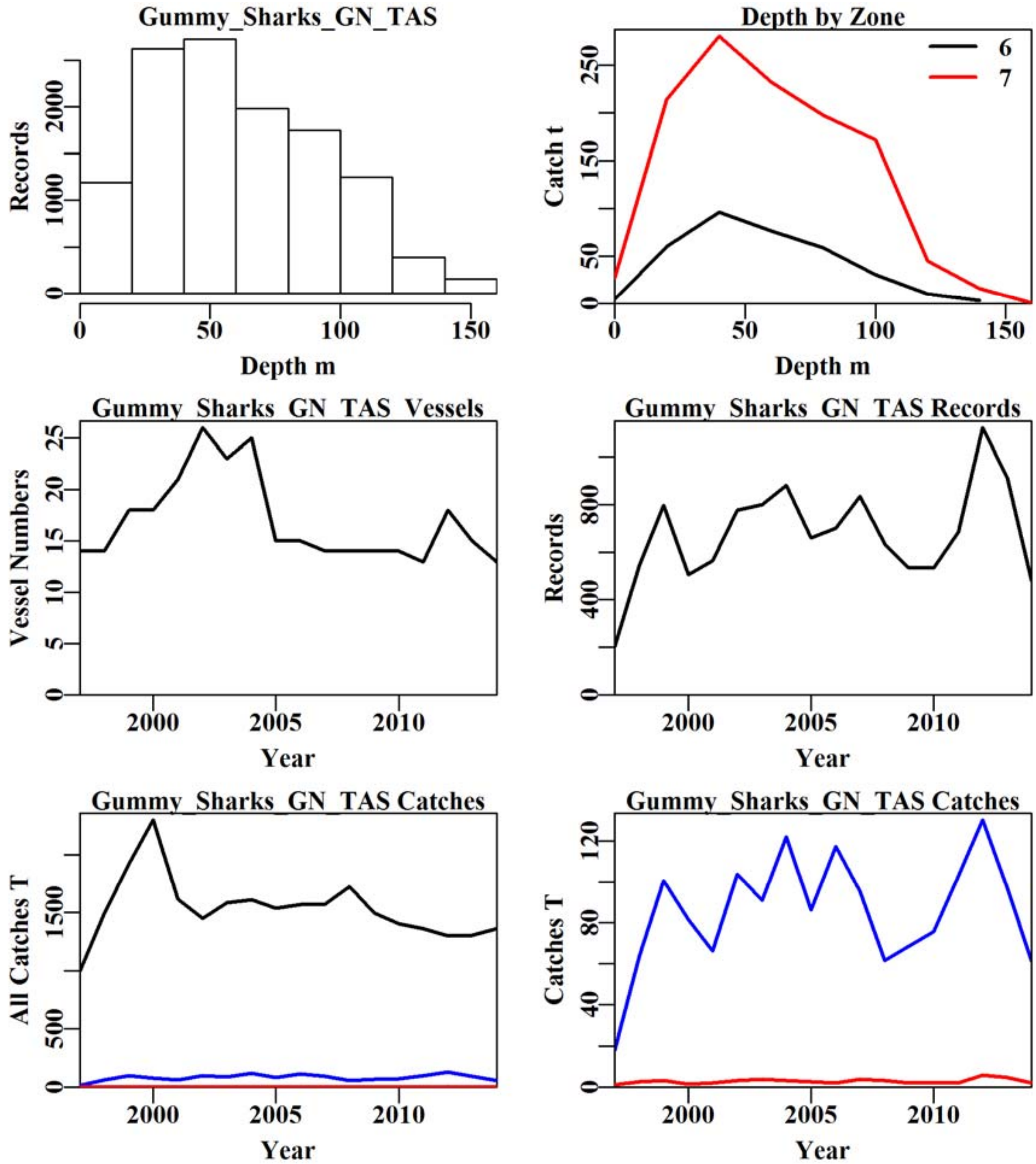


Figure 22.8. Gummy shark in Tasmania in depths 0 to 160 m taken by gillnet. The top left plot depicts the depth distribution of shots containing gummy shark from shark zones 6 and 7 in depths 0 – 160 m. The top right plot depicts the distribution of catch by depth within shark zones 6 and 7. The middle left plot depicts the number of vessels through time. The middle right plot contains the number of records used in analysis. The bottom left plot contains gummy shark catches (top black line: total catches, middle blue line: catches used in the analysis; bottom red line: catches < 30 kg) and bottom right plot contains gummy shark catches (blue line: catches used in the analysis; red line: catches < 30 kg).

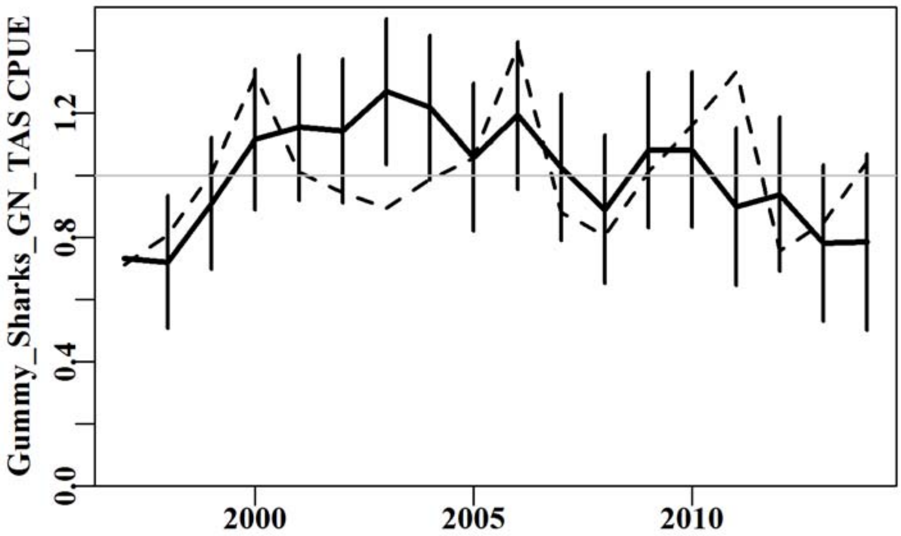


Figure 22.9. The standardized CPUE for gummy sharks taken by gillnet surrounding Tasmania showing the optimum model (solid black line) and the geometric mean CPUE (dashed line) each scaled to the mean of each time series. The vertical bars are two times the standard error.

Table 22.13. Gummy shark from across shark zones surrounding Tasmania in depths 0 to 160 m by gillnet. Statistical model structures used in this analysis. DepCat is a series of 20 metre depth categories.

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

Table 22.14. Gummy shark taken by gillnet across shark zones surrounding Tasmania between depths of 0 to 160 m and during 1997 - 2014. Model selection criteria, include the AIC, the adjusted R^2 (adj_R^2) and the change in adjusted R^2 (%Change). The optimum model is Model 6 (SharkZone:Month). Depth category: DepC.

	Year	Vessel	DepCat	SharkZone	Month	SharkZone:Month	SharkZone:DepC
AIC	6075	818	834	577	572	494	526
RSS	19990	12818	12701	12410	12403	12300	12339
MSS	400	7572	7689	7980	7987	8090	8051
Nobs	12171	12171	12054	12054	12054	12054	12054
Npars	18	94	102	113	114	125	122
adj_R^2	1.824	36.652	37.183	38.564	38.596	39.049	38.870
%Change	0.000	34.828	0.531	1.381	0.032	0.453	-0.179

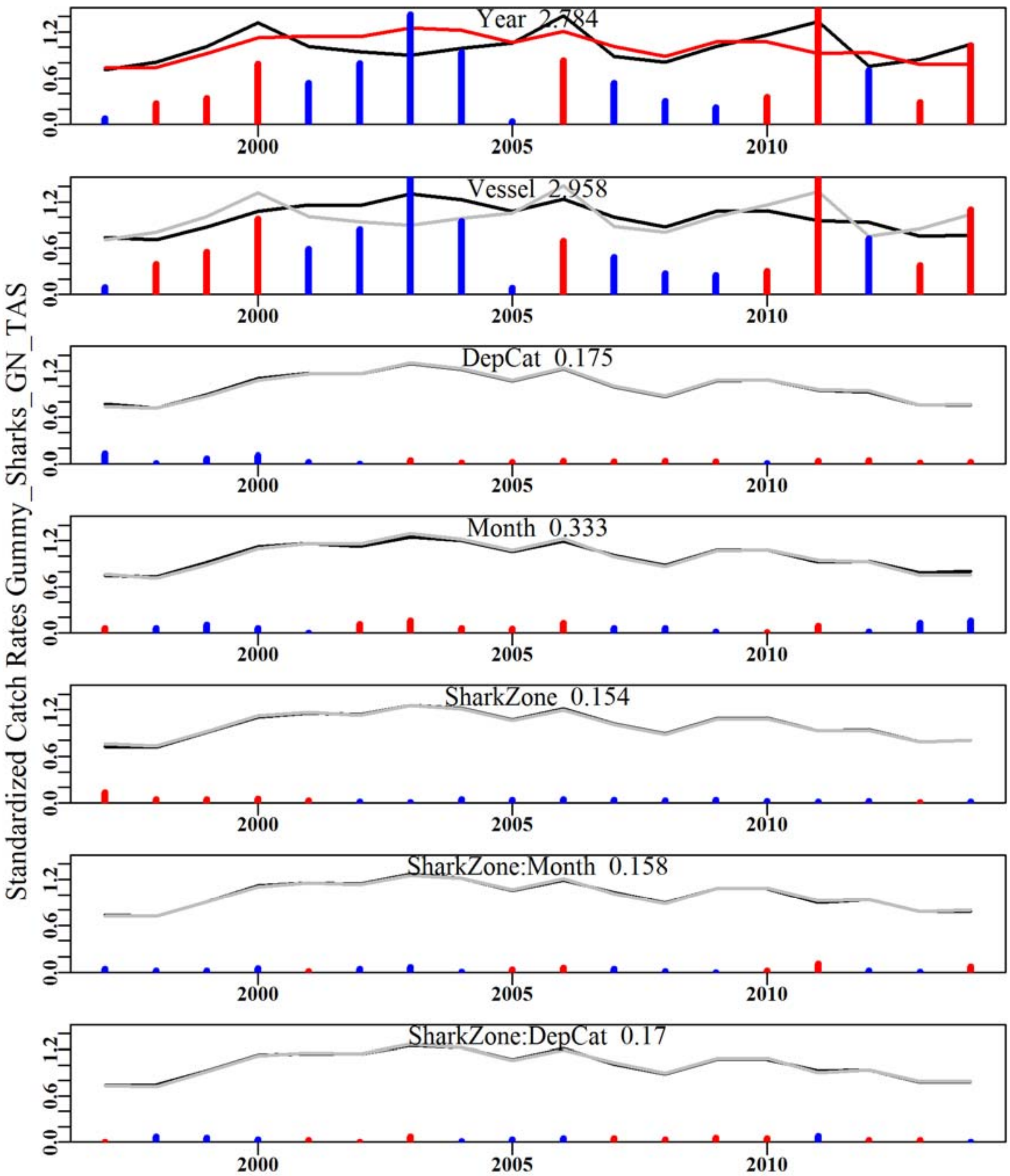


Figure 22.10. The relative influence of each factor on the final trend in the optimal standardization for the Tasmanian gummy shark gillnet fishery. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by the vertical bars with blue bars indicating the optimum model is higher than the geometric mean and red bars indicating it is lower. The top graph bars are the sum of all the bars in the graphs below. The graphs for individual factors are cumulative. Thus the second graph has the geometric mean (grey line) and the effect of adding Year + factor2 (Model 2, black line). In the third graph, the grey line represents Model 2 and the black line the effect of adding factor3 to the model. The remaining graphs continue in the same cumulative manner except for the interaction terms which are added singularly to the final single factor model.

22.4.4 Gummy shark: Trawl

The analysis used shots that reported catches of gummy shark (non zero shots), and included a factor for shark zones, more consistent with gillnet and line standardizations than the SESSF trawl zones previously considered (Haddon, 2014). The proportion of zero gummy shark catches reported by trawl (based on all records) is about 67%. Since gummy shark are not targeted by trawl vessels, it is inappropriate to include zero catches in the analysis.

Table 22.15. Gummy shark taken by trawl across shark zones between depths of 0 to 500 m in the period 1996 - 2014. Total catch (TotCatch; t) is the total reported in the database across all gears, TotCat (t) is the total catch reported in the SESSF across all gears, number of records used in the analysis (Records), reported catch (CatchT; t) in the area and depth used in the analysis and number of vessels used in the analysis (Vessels). GeoMean is the geometric mean of CPUE (kg/hr). The optimum model is Model 8 (Table 22.17). SharkZone:DepC and standard deviation (StDev) are the coefficients from the optimum model.

Year	TotCatch	TotCat	Records	CatchT	Vessels	GeoMean	SharkZone:DepC	StDev
1996	49.354	49.358	2254	41.072	74	3.1006	1.0583	0.0000
1997	1012.197	920.108	2795	43.965	77	2.5780	0.9274	0.0276
1998	1527.171	1524.416	2465	39.209	62	2.6347	0.9228	0.0286
1999	1956.680	1956.285	2399	38.253	69	2.6006	0.9558	0.0292
2000	2349.499	2349.499	3172	50.622	76	2.5578	0.8421	0.0280
2001	1662.581	1662.603	3480	56.933	66	2.4824	0.8265	0.0275
2002	1494.823	1494.968	4015	61.400	68	2.3216	0.7858	0.0268
2003	1618.274	1618.274	4612	81.346	74	2.4624	0.8436	0.0264
2004	1656.377	1656.349	4834	90.328	74	2.5926	0.8586	0.0264
2005	1570.520	1570.520	5101	96.886	71	2.7457	0.8745	0.0262
2006	1577.133	1577.133	4951	103.105	63	2.8071	0.9008	0.0264
2007	1574.951	1574.936	3655	86.473	38	2.9373	0.9235	0.0279
2008	1727.745	1727.745	3819	87.808	37	3.0002	1.0927	0.0275
2009	1500.901	1500.812	3549	88.739	32	3.4595	1.1934	0.0278
2010	1404.788	1404.722	3755	92.517	34	3.2692	1.1728	0.0276
2011	1364.705	1364.705	4380	101.822	33	3.1343	1.0637	0.0270
2012	1301.400	1301.400	3785	99.723	32	3.4501	1.1641	0.0277
2013	1307.510	1306.051	3520	96.910	35	4.0328	1.3133	0.0280
2014	1381.489	1381.004	3165	91.341	35	4.1041	1.2802	0.0284

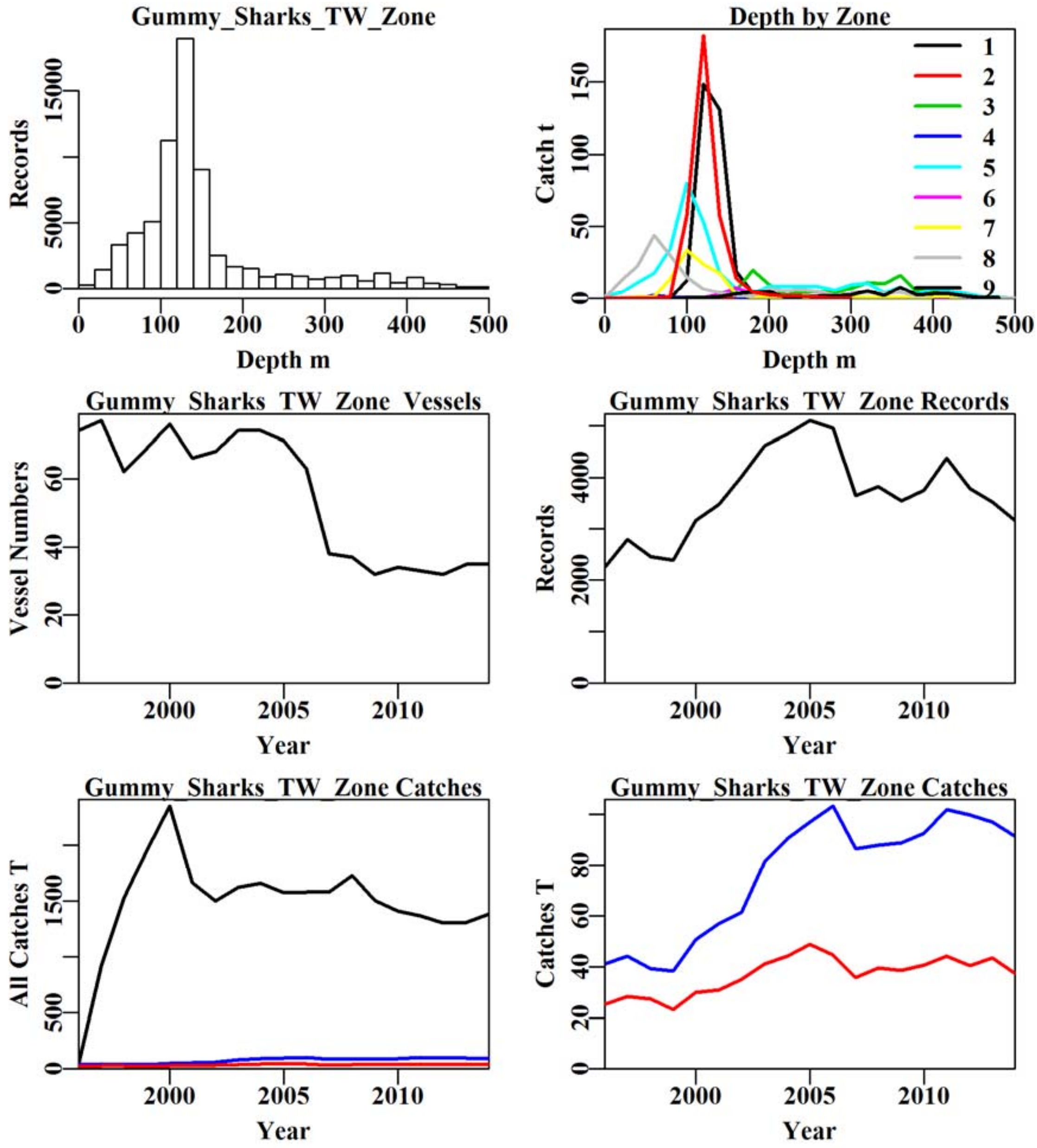


Figure 22.11. Gummy shark in depths 0 to 160 m taken by trawl. The top left plot depicts the depth distribution of shots containing gummy shark from shark zone 6 and 7 in depths 0 – 160 m. The top right plot depicts the distribution of catch by depth within shark zones 6 and 7. The middle left plot depicts the number of vessels through time. The middle right plot contains the number of records used in analysis. The bottom left plot contains gummy shark catches (top black line: total catches, middle blue line: catches used in the analysis; bottom red line: catches < 30 kg) and bottom right plot contains gummy shark catches (blue line: catches used in the analysis; red line: catches < 30 kg).

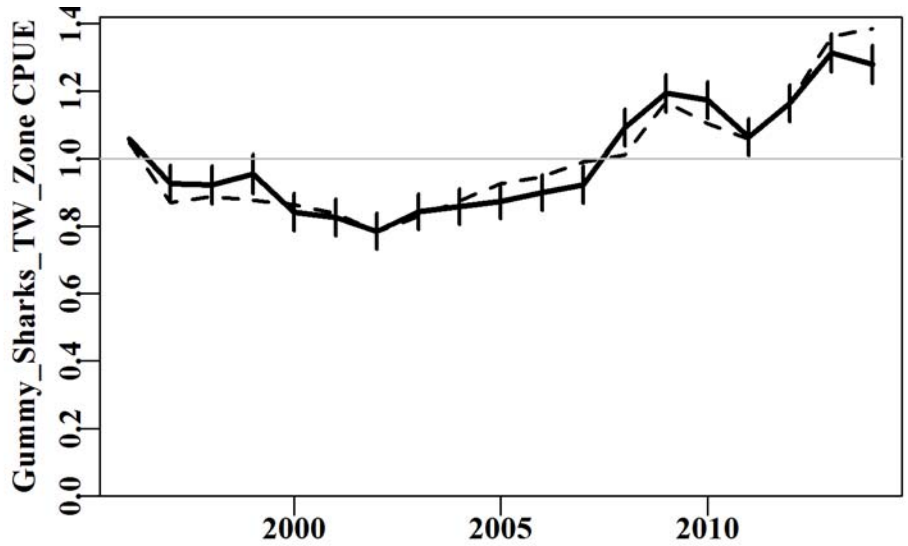


Figure 22.12. The standardized CPUE for gummy sharks taken by trawl showing the optimum model (solid black line) and the geometric mean CPUE (dashed line) each scaled to the mean of each time series. The vertical bars are two times the standard error.

Table 22.16. Gummy shark from across shark zones in depths 0 to 160 m by Trawl. Statistical model structures used in this analysis. DepCat is a series of 20 metre depth categories.

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

Table 22.17. Gummy shark taken by trawl across shark zones between depths of 0 to 160 m and in the period 1997 - 2014. Model selection criteria, include the AIC, the adjusted R^2 (adj_R^2) and the change in adjusted R^2 (%Change). The optimum model is Model 8 (SharkZone:DepC). Depth category: DepC.

	Year	Vessel	DepCat	SharkZone	Month	DayNight	SharkZone:Month	SharkZone:DepC
AIC	8465	-3163	-4403	-5793	-6942	-7890	-8423	-9238
RSS	78664	66334	64390	63085	62026	61174	60529	59600
MSS	1711	14041	15985	17289	18348	19200	19845	20774
Nobs	69706	69706	68977	68977	68977	68977	68977	68977
Npars	19	147	172	183	192	195	294	420
adj_R^2	2.103	17.296	19.689	21.303	22.614	23.674	24.370	25.394
%Change	0.000	15.193	2.393	1.614	1.311	1.060	0.696	1.024

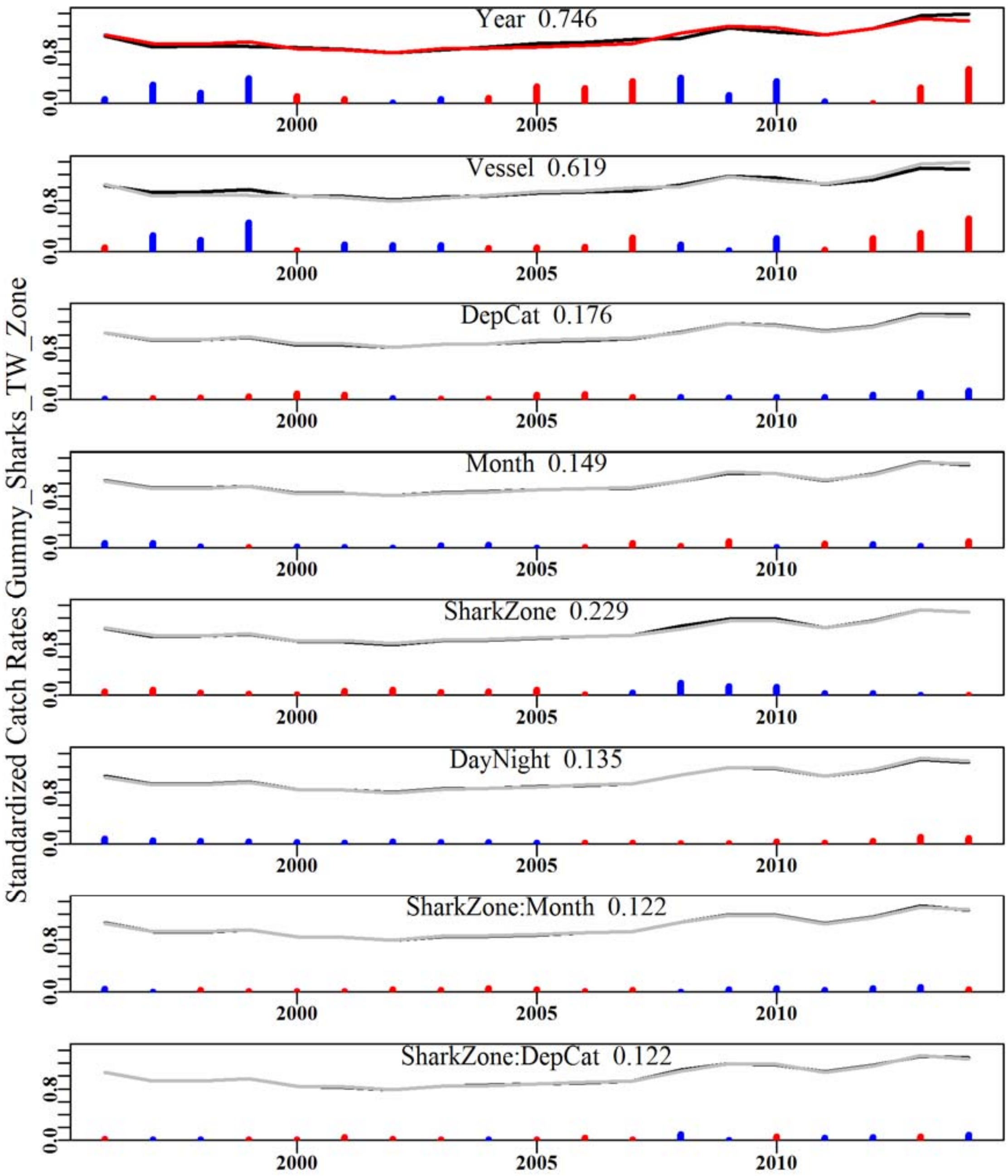


Figure 22.13. The relative influence of each factor on the final trend in the optimal standardization for the Tasmanian gummy shark trawl fishery. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by the vertical bars with blue bars indicating the optimum model is higher than the geometric mean and red bars indicating it is lower. The top graph bars are the sum of all the bars in the graphs below. The graphs for individual factors are cumulative. Thus the second graph has the geometric mean (grey line) and the effect of adding Year + factor2 (Model 2, black line). In the third graph, the grey line represents Model 2 and the black line the effect of adding factor3 to the model. The remaining graphs continue in the same cumulative manner except for the interaction terms which are added singularly to the final single factor model.

22.4.5 Gummy shark: Bottom Line

Records pertaining to shark zones 8 and 10 were omitted from analysis since they contributed very little to the overall catch (8: 0.01 %; 10: 0.09 %). Furthermore, non-zero catches per shot were employed in the statistical standardization analyses for gummy shark caught by bottom line.

Currently, effort units are recorded inconsistently in the logbook database for bottom line caught gummy shark. Any of three alternative pairs of units can be recorded for a shot:

(i) THS (total hooks per set) and TLM (total length of mainline used); (ii) NLP (number of lines per shot) and THS (total number of hooks per set); and (iii) NLS (total number lines per shot) and THS (total number of hooks per shot) and/or HRS (hours). No clear method was apparent for including these inconsistent effort units in a single standardization. However the alternative is to assume that every fishing operation has the same probability of catching sharks, regardless of the number of hooks used, length of line, or soak time. A detailed analysis of these effort units should be investigated to determine whether (i) through to (iii) or some combination could be used as an altenative effort unit in the standardization analyses.

Table 22.18. Gummy shark taken by bottom line across shark zones between depths of 0 to 200 m in the period 1996 - 2014. TotCat (t) is the total catch reported in the SESSF across all gears, number of records used in the analysis (Records), reported catch (CatchT; t) in the area and depth used in the analysis and number of vessels used in the analysis (Vessels). GeoMean is the geometric mean of CPUE (kg/shot). The optimum model is Model 6 (Table 22.20). SharkZone:DepcC and standard deviation (StDev) are the coefficients from the optimum model.

Year	TotCat	Records	CatchT	Vessels	GeoMean	SharkZone:DepC	StDev
1998	1524.416	72	8.928	3	93.0601	0.9384	0.0000
1999	1956.285	335	48.136	13	97.4648	1.1180	0.1550
2000	2349.499	483	112.577	14	142.8284	1.3030	0.1868
2001	1662.603	543	59.052	23	55.1142	0.8028	0.1898
2002	1494.968	507	59.891	22	61.1717	0.8851	0.1904
2003	1618.274	629	66.152	27	61.3844	0.7573	0.1899
2004	1656.349	593	59.226	24	56.8428	0.8142	0.1901
2005	1570.520	585	61.148	25	57.8756	0.9466	0.1912
2006	1577.133	494	48.860	19	50.4682	1.0377	0.1918
2007	1574.936	627	54.519	19	40.7575	0.9550	0.1911
2008	1727.745	599	50.082	16	36.0171	0.7334	0.1932
2009	1500.812	822	67.123	15	37.5970	0.8364	0.1921
2010	1404.722	684	71.961	19	48.2002	0.9767	0.1925
2011	1364.705	1051	87.934	28	46.2099	1.1334	0.1921
2012	1301.400	1407	124.184	24	52.7575	1.1570	0.1919
2013	1306.051	2519	228.789	26	50.3615	1.4222	0.1920
2014	1381.004	2778	228.397	28	40.9891	1.1829	0.1923

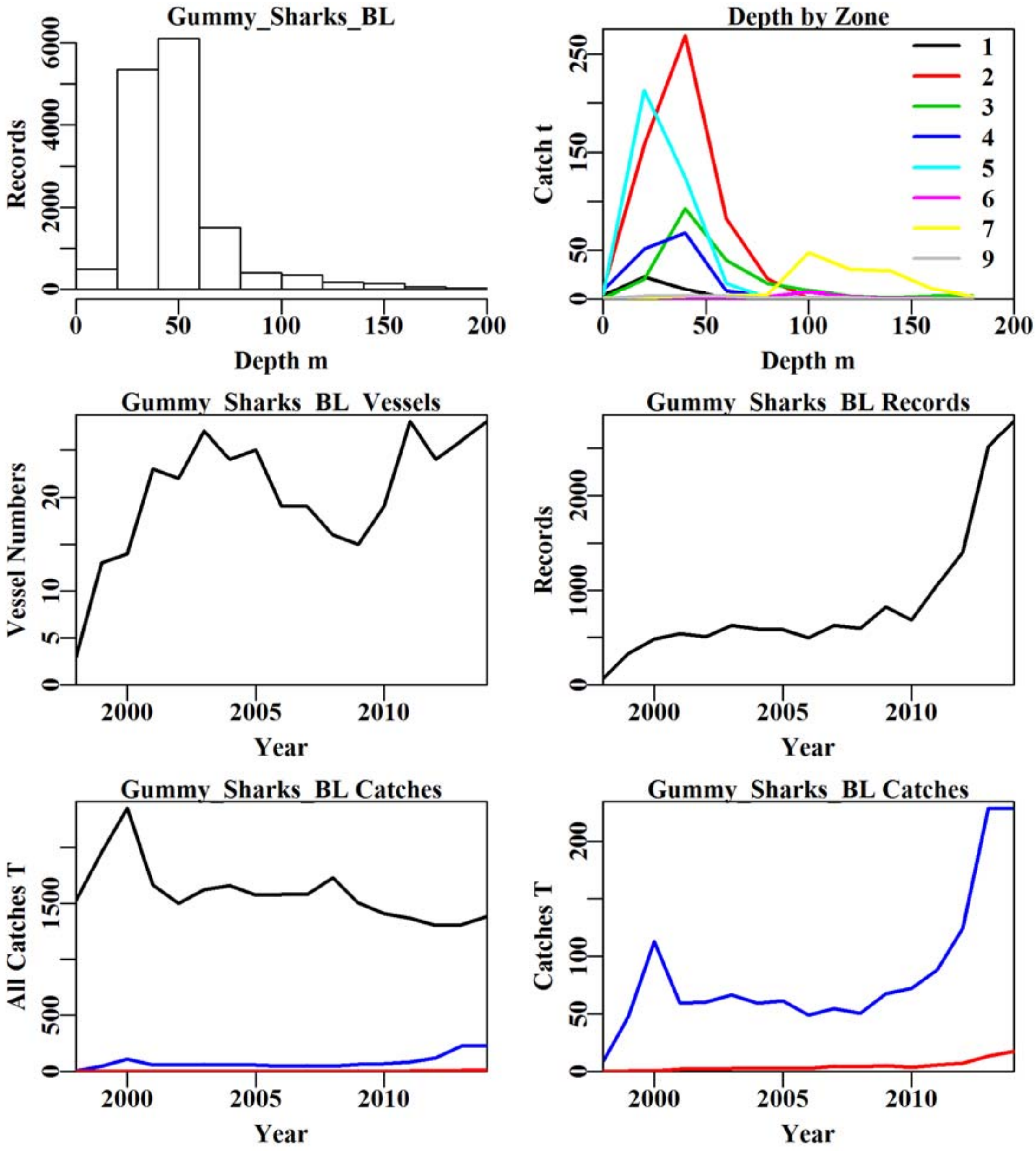


Figure 22.14. Gummy shark in depths 0 to 200 m taken by bottom line. The top left plot depicts the depth distribution of shots containing gummy shark from shark zone 1-7, 9 in depths 0 – 200 m. The top right plot depicts the distribution of catch by depth within shark zones 1-7 and 9. The middle left plot depicts the number of vessels through time. The middle right plot contains the number of records used in analysis. The bottom left plot contains gummy shark catches (top black line: total catches, middle blue line: catches used in the analysis; bottom red line: catches < 30 kg) and bottom right plot contains gummy shark catches (blue line: catches used in the analysis; red line: catches < 30 kg).

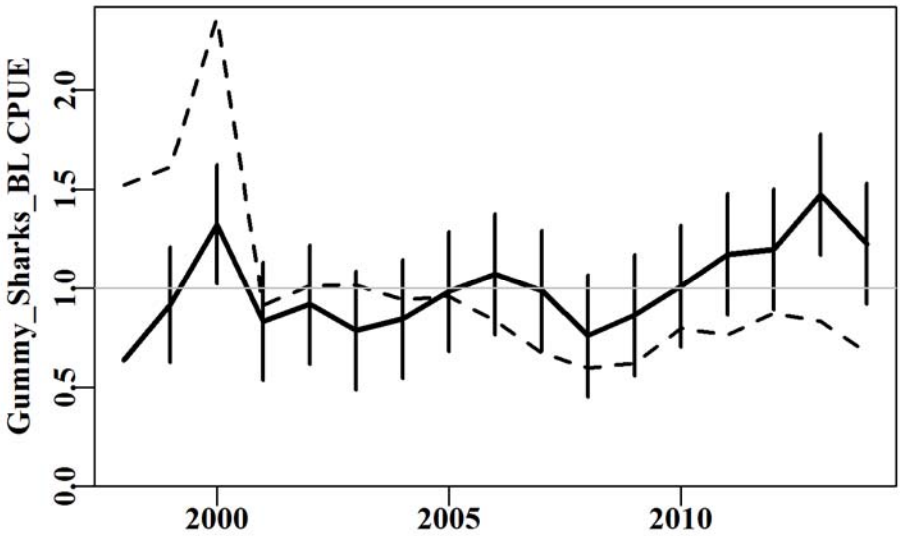


Figure 22.15. The standardized CPUE for gummy sharks taken by bottom line showing the optimum model (solid black line) and the geometric mean CPUE (dashed line) each scaled to the mean of each time series. The vertical bars are two times the standard error.

Table 22.19. Gummy shark from across shark zones in depths 0 to 160 m by bottom line. Statistical model structures used in this analysis. DepCat is a series of 20 metre depth categories.

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

Table 22.20. Gummy shark taken by bottom line across shark zones between depths of 0 to 200 m and in the period 1998 - 2014. Model selection criteria, include the AIC, the adjusted R^2 (adj_ R^2) and the change in adjusted R^2 (%Change). The optimum model is Model 6 (SharkZone:Month). Depth category: DepC.

	Year	Vessel	DepCat	SharkZone	Month	SharkZone:Month	SharkZone:DepC
AIC	5788	-614	-663	-694	-719	-827	-710
RSS	21768	13876	13702	13660	13616	13374	13507
MSS	1062	8954	9128	9170	9214	9456	9322
Nobs	14728	14728	14617	14617	14617	14617	14617
Npars	17	132	141	148	159	236	222
adj_R^2	4.547	38.675	39.400	39.558	39.707	40.460	39.927
%Change	0.000	34.127	0.726	0.157	0.149	0.754	-0.534

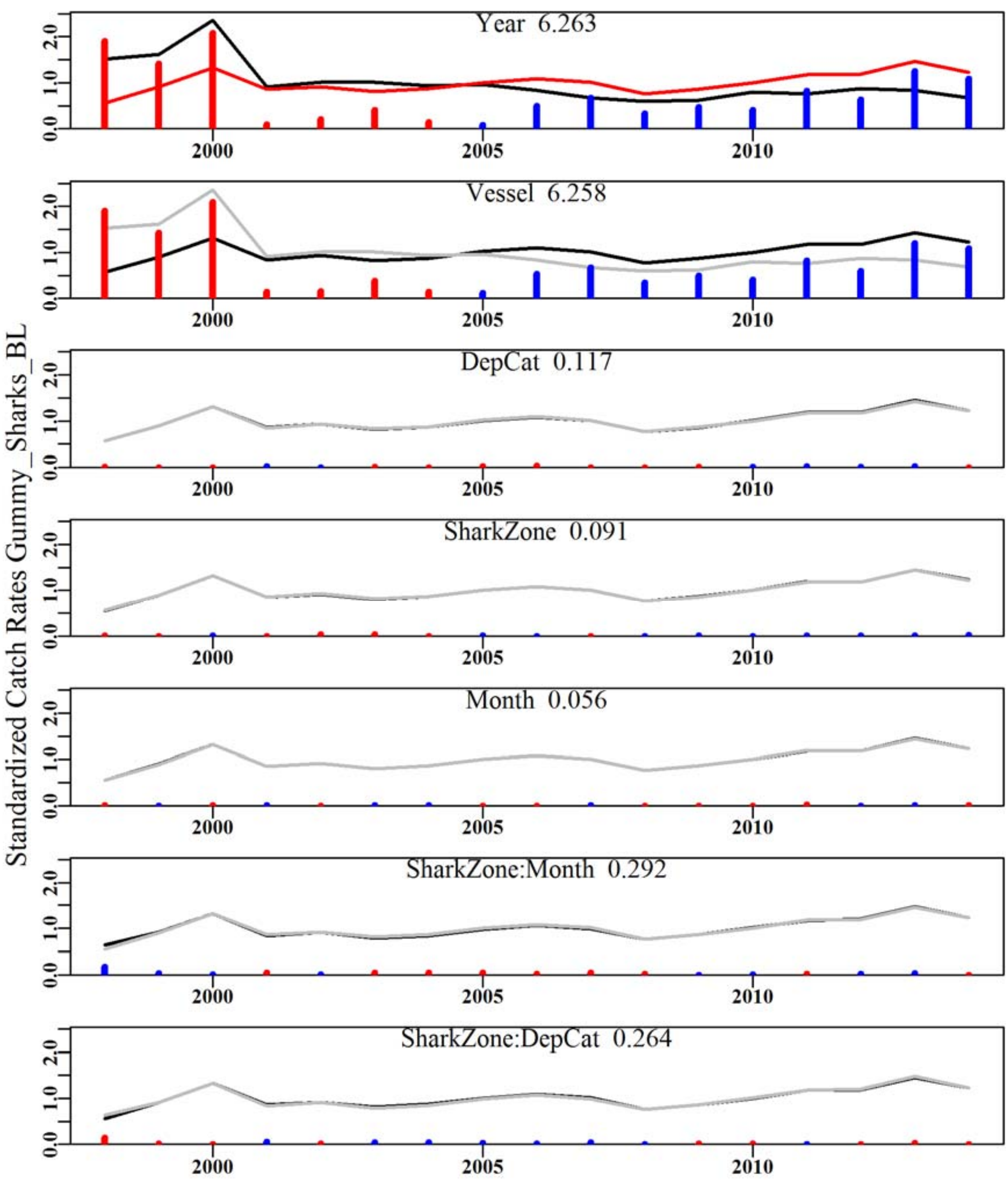


Figure 22.16. The relative influence of each factor on the final trend in the optimal standardization for the gummy shark bottom line fishery. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by the vertical bars with blue bars indicating the optimum model is higher than the geometric mean and red bars indicating it is lower. The top graph bars are the sum of all the bars in the graphs below. The graphs for individual factors are cumulative. Thus the second graph has the geometric mean (grey line) and the effect of adding Year + factor2 (Model 2, black line). In the third graph, the grey line represents Model 2 and the black line the effect of adding factor3 to the model. The remaining graphs continue in the same cumulative manner except for the interaction terms which are added singularly to the final single factor model.

22.4.6 School shark: Trawl

Positive non-zero records of catch per hour were employed in the statistical standardization analyses for reported school shark caught by trawl. Shark zones used in the analysis were 1-8 and 10. This analysis excludes State catches (Table 22.24; Figure 22.20).

Table 22.21. School shark taken by trawl across shark zones between depths of 0 to 200 m during 1996 - 2014. Total catch (TotCatch; t) is the total reported in the database across all gears, number of records used in the analysis (Records), reported catch (CatchT; t) in the area and depth used in the analysis and number of vessels used in the analysis (Vessels). GeoMean is the geometric mean of CPUE (kg/hr). The optimum model is Model 7 (Table 22.23). SharkZone:Month and standard deviation (StDev) are the coefficients from the optimum model.

Year	TotCatch	Records	CatchT	Vessels	GeoMean	SharkZone:Month	StDev
1996	29.141	922	24.441	67	4.2798	1.2374	0.0000
1997	387.990	1193	23.693	60	3.5138	1.0751	0.0432
1998	603.096	962	19.899	51	3.3436	1.0648	0.0457
1999	500.081	765	14.243	51	3.4118	0.9820	0.0501
2000	451.109	921	16.670	69	2.6861	0.8329	0.0483
2001	182.408	860	15.724	48	2.8884	0.8537	0.0490
2002	205.149	948	17.035	58	3.0584	0.8816	0.0482
2003	208.244	773	13.241	60	2.7186	0.8162	0.0514
2004	197.701	700	13.358	54	2.6616	0.8153	0.0530
2005	208.855	521	8.350	45	2.4624	0.8700	0.0569
2006	212.040	573	10.954	47	2.6022	0.8553	0.0558
2007	197.797	350	7.356	32	2.7737	0.8683	0.0647
2008	234.353	406	8.995	31	2.9491	0.9523	0.0606
2009	253.073	444	13.697	28	3.2235	1.0582	0.0588
2010	180.143	437	12.864	26	3.2832	0.9926	0.0603
2011	182.422	453	13.832	29	3.2958	1.1059	0.0593
2012	136.045	346	11.000	27	3.7007	1.1522	0.0647
2013	150.023	375	18.326	34	5.0017	1.3417	0.0642
2014	199.609	395	11.251	27	3.8295	1.2445	0.0629

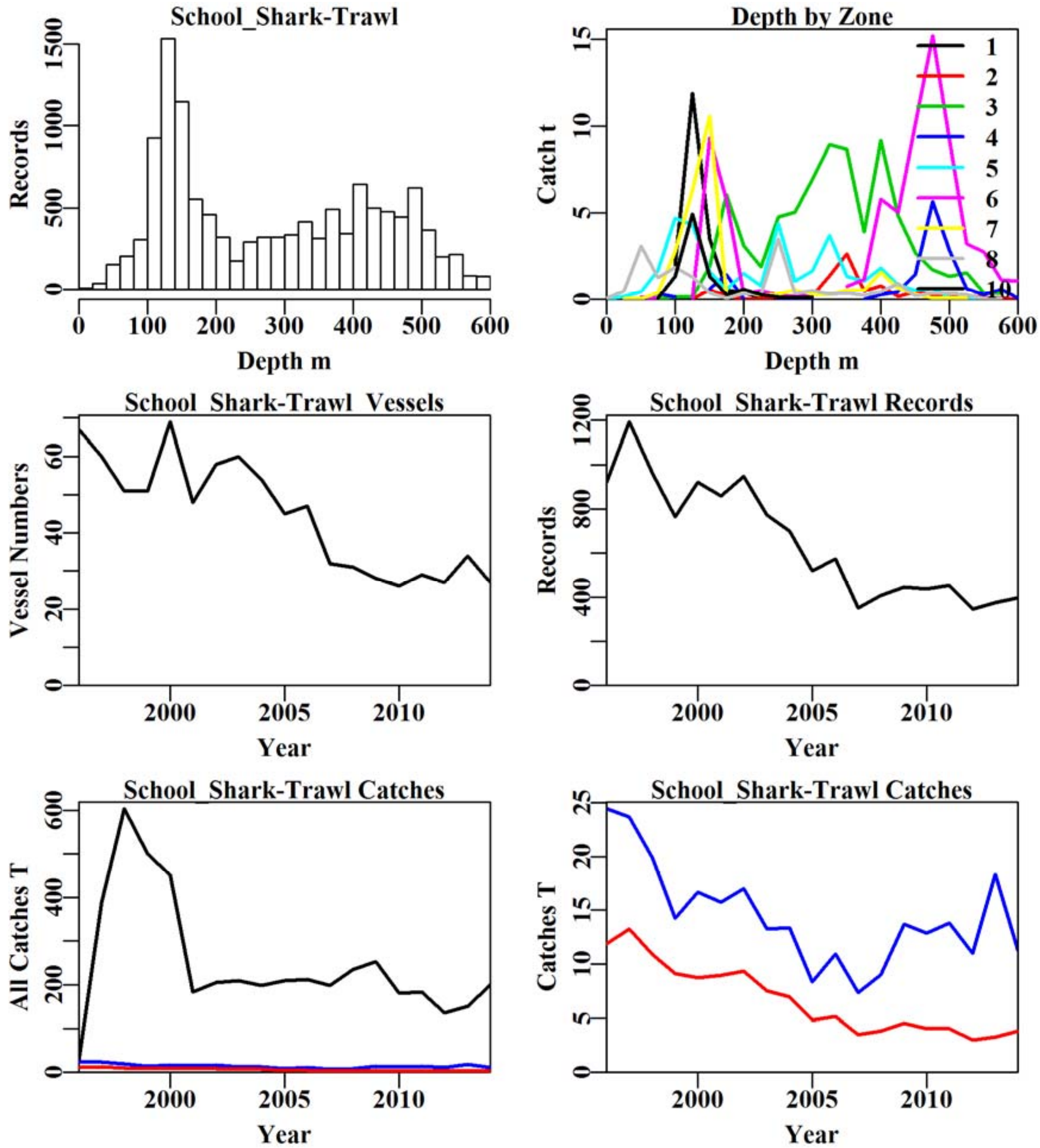


Figure 22.17. School shark in depths 0 to 600 m taken by trawl. The top left plot depicts the depth distribution of shots containing school shark from shark zones 1-8, 10 in depths 0 – 600 m. The top right plot depicts the distribution of catch by depth within shark zones 1-8 and 10. The middle left plot depicts the number of vessels through time. The middle right plot contains the number of records used in analysis. The bottom left plot contains school shark catches (top black line: total catches, middle blue line: catches used in the analysis; bottom red line: catches < 30 kg) and bottom right plot contains school shark catches (blue line: catches used in the analysis; red line: catches < 30 kg).

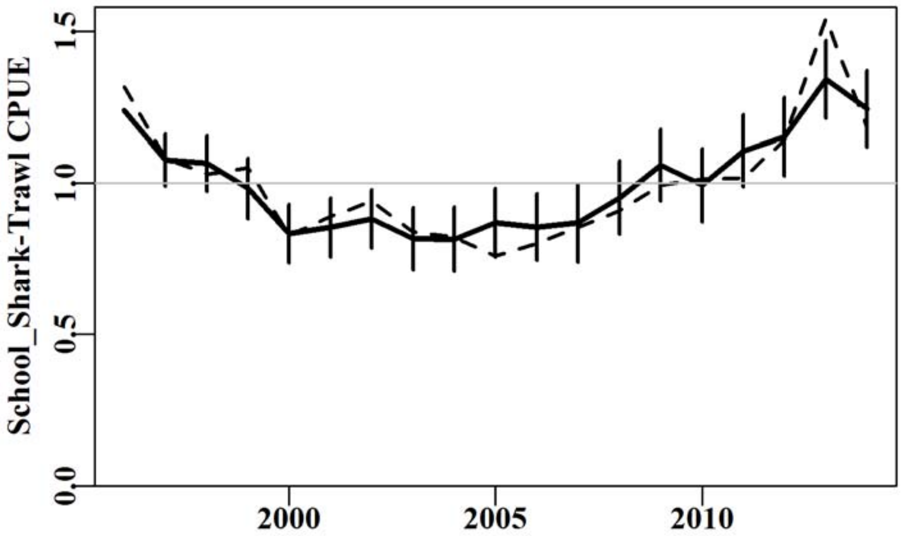


Figure 22.18. The standardized CPUE for school sharks taken by trawl showing the optimum model (solid black line) and the geometric mean CPUE (dashed line) each scaled to the mean of each time series. The vertical bars are two times the standard error.

Table 22.22. School shark from across shark zones in depths 0 to 600 m by trawl. Statistical model structures used in this analysis. DepCat is a series of 25 metre depth categories.

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

Table 22.23. School shark taken by trawl across shark zones between depths of 0 to 600 m and in the period 1996 - 2014. Model selection criteria, include the AIC, the adjusted R^2 (adj_R^2) and the change in adjusted R^2 (%Change). The optimum model is Model 7 (SharkZone:Month). Depth category: DepC.

	Year	Vessel	DepCat	SharkZone	Month	DayNight	SharkZone:Month	SharkZone:DepC
AIC	2557	-755	-1335	-1407	-1468	-1473	-1533	-1487
RSS	15139	11331	10699	10618	10560	10512	10441	10459
MSS	342	4149	4781	4863	4921	4969	5039	5022
Nobs	12344	12344	12274	12274	12274	12231	12231	12231
Npars	19	151	175	186	189	190	201	214
adj_R^2	2.065	25.902	29.891	30.362	30.725	31.032	31.432	31.242
%Change	0.000	23.837	3.989	0.471	0.363	0.306	0.400	-0.189

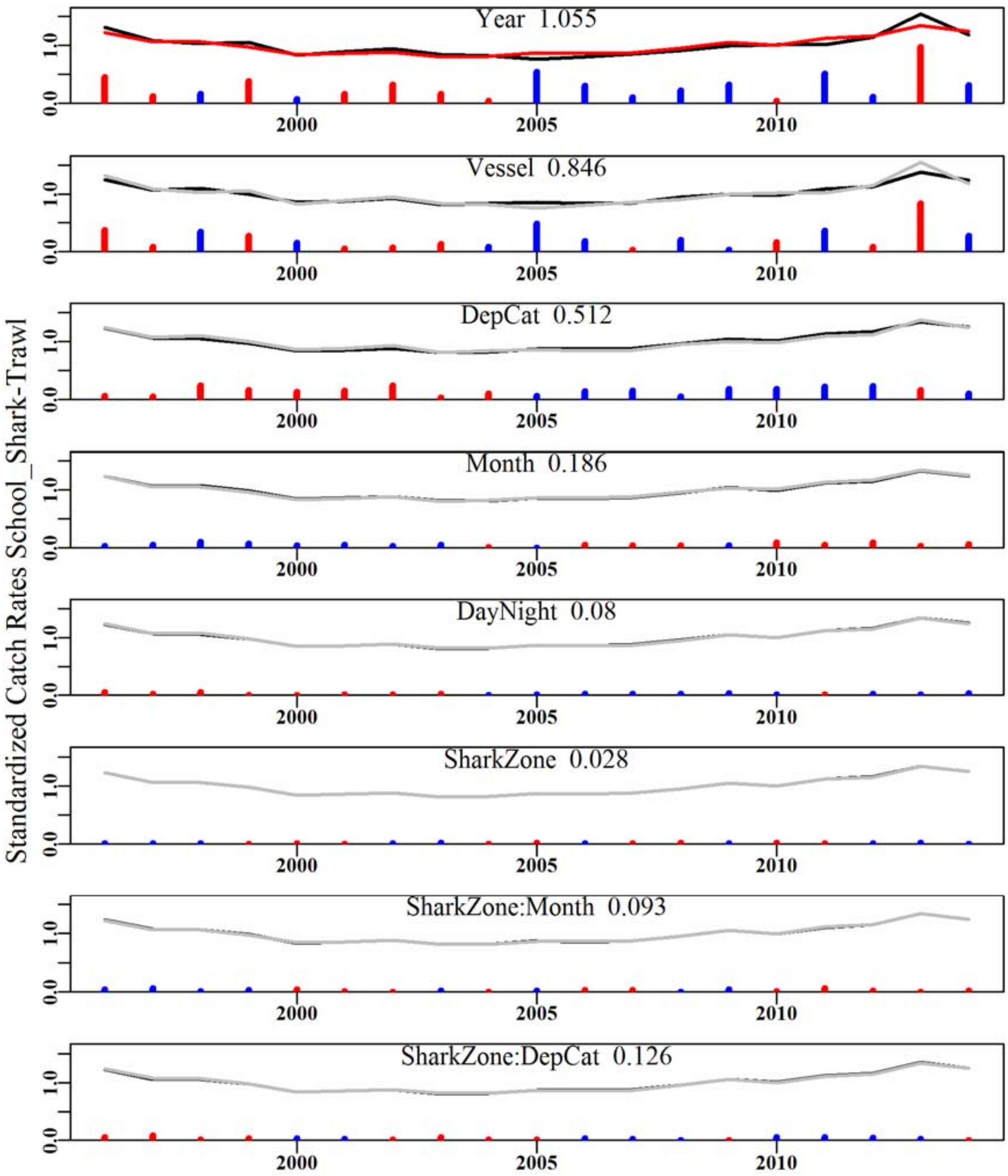


Figure 22.19. The relative influence of each factor on the final trend in the optimal standardization for the school shark trawl fishery. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by the vertical bars with blue bars indicating the optimum model is higher than the geometric mean and red bars indicating it is lower. The top graph bars are the sum of all the bars in the graphs below. The graphs for individual factors are cumulative. Thus the second graph has the geometric mean (grey line) and the effect of adding Year + factor2 (Model 2, black line). In the third graph, the grey line represents Model 2 and the black line the effect of adding factor3 to the model. The remaining graphs continue in the same cumulative manner except for the interaction terms which are added singularly to the final single factor model.

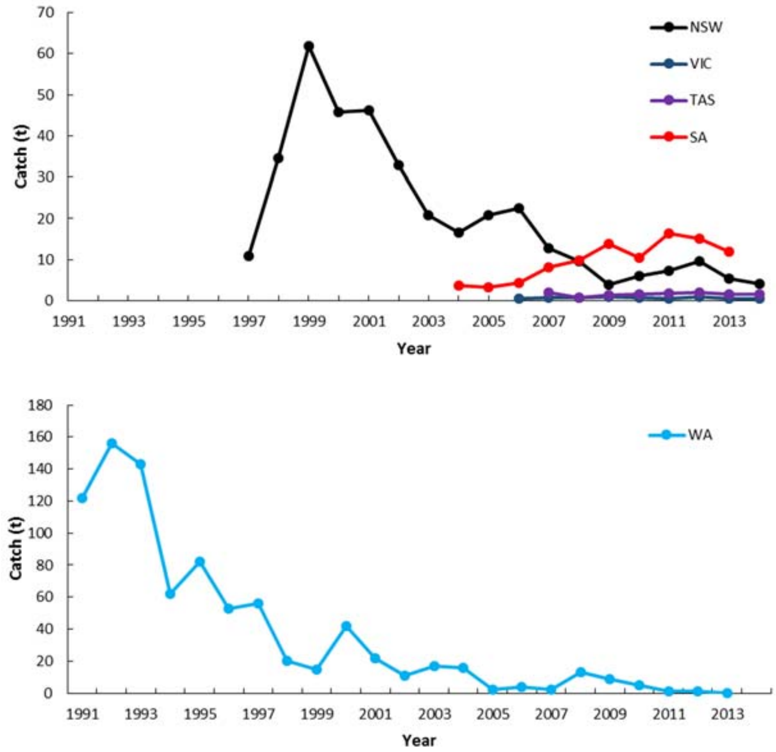


Figure 22.20. Reported State catches of school sharks. Western Australia is on a separate graph due to the different y-axis scale. State catches from SA and WA for 2014 are pending.

Table 22.24. Reported total State catches of School sharks. Estimates from SA and WA for 2014 are pending.

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	7.221	0.489	1.903	16.358	1.000
2012	9.666	0.877	1.935	15.179	1.000
2013	5.298	0.627	1.577	12.020	0.100
2014	4.1194	0.605	1.527		

22.4.7 Elephant fish: Gillnet

The proportion of catches recording < 30 kg is relatively high in elephant fish reports, indicating that elephant fish are not a primary target species and tend to be caught in small numbers and weights in each shot (Figure 22.23). The preliminary estimate of the proportion discarded for 2014 is 0.574 (CV = 12.9%) (Upston and Thomson 2015). Given the high proportion of discards, it is questionable as to whether an analysis including zero catches would be valid. Therefore, only non-zero shots were analysed. The use of effort in units of net length should be investigated for furture analyses. Exploratory analyses shows inconsistency in the recording of gillnet effort units in the logbook database, particularly in 1997 and 1998 compared to later years. A detailed effort analysis is required towards utilizing this in subsequent standardizations (see discussion in Section 22.4.5).

Table 22.25. Elephant fish taken by gillnet across shark zones from Central South Australia to Eastern Bass Strait between depths of 0 to 160 m and during 1997 - 2014. Total catch (TotCatch; t) is the total reported in the database across all gears, number of records used in the analysis (Records), reported catch (CatchT; t) in the area and depth used in the analysis and number of vessels used in the analysis (Vessels). GeoMean is the geometric mean of CPUE (kg/shot). The optimum model is Model 6 (Table 22.27). SharkZone:Month and standard deviation (StDev) are the coefficients from the optimum model.

Year	TotCatch	Records	CatchT	Vessels	GeoMean	SharkZone:Month	StDev
1997	33.507	1481	27.438	56	6.6167	0.9636	0.0000
1998	56.991	2234	48.014	57	6.6317	0.9044	0.0466
1999	70.123	2940	61.393	63	7.0956	1.0271	0.0456
2000	77.497	2867	67.542	57	8.3170	1.2555	0.0455
2001	87.693	2913	76.976	63	9.3138	1.2922	0.0461
2002	59.278	2251	39.666	64	6.1646	0.9213	0.0478
2003	70.592	2219	45.714	61	5.9048	0.9024	0.0484
2004	64.765	1869	32.910	52	5.8738	0.8595	0.0501
2005	66.370	1977	34.201	40	6.2019	0.8941	0.0496
2006	53.259	1708	31.676	43	6.1036	0.9656	0.0516
2007	51.693	1808	34.048	38	6.6645	1.0429	0.0512
2008	61.444	2066	39.995	34	7.0127	1.1239	0.0498
2009	65.313	2138	44.066	35	8.2736	1.2538	0.0498
2010	56.740	2287	34.886	36	6.1679	0.9741	0.0500
2011	50.497	2693	33.848	35	5.3919	0.8631	0.0496
2012	65.930	2730	44.728	38	6.5543	1.0039	0.0491
2013	61.940	2494	38.260	34	6.7187	0.9203	0.0494
2014	47.253	2250	30.538	32	5.9065	0.8322	0.0498

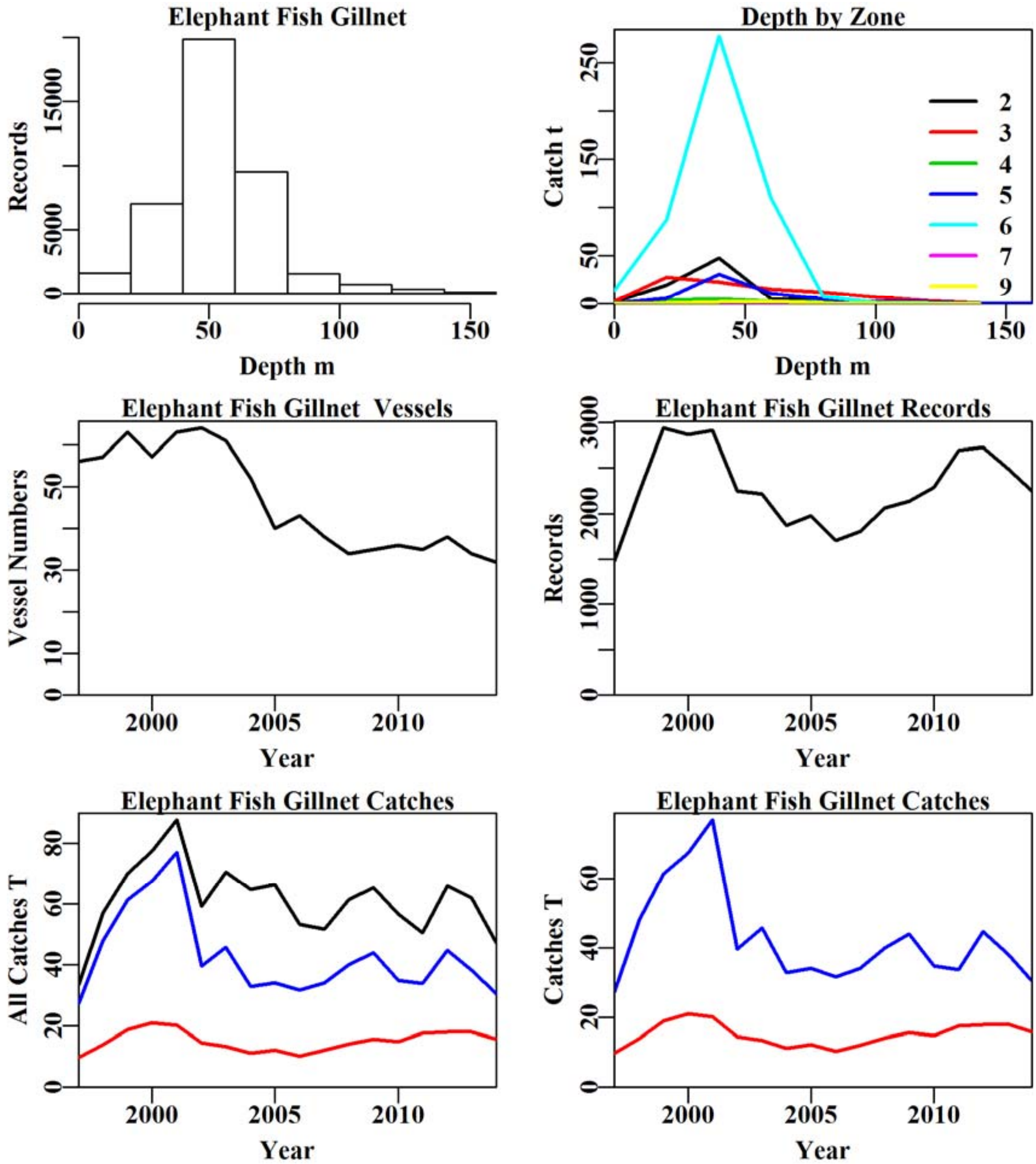


Figure 22.21. Elephant fish in zone 60 in depths 0 to 100 m taken by gillnet. The top left plot depicts the depth distribution of shots containing elephant fish from shark zones 2-7 and 9 in depths 0 – 160 m. The top right plot depicts the distribution of catch by depth within zone 60. The middle left plot depicts the number of vessels through time. The middle right plot contains the number of records used in analysis. The bottom left plot contains elephant fish catches (top black line: total catches, middle blue line: catches used in the analysis; bottom red line: catches < 30 kg) and bottom right plot contains elephant fish catches (blue line: catches used in the analysis; red line: catches < 30 kg).

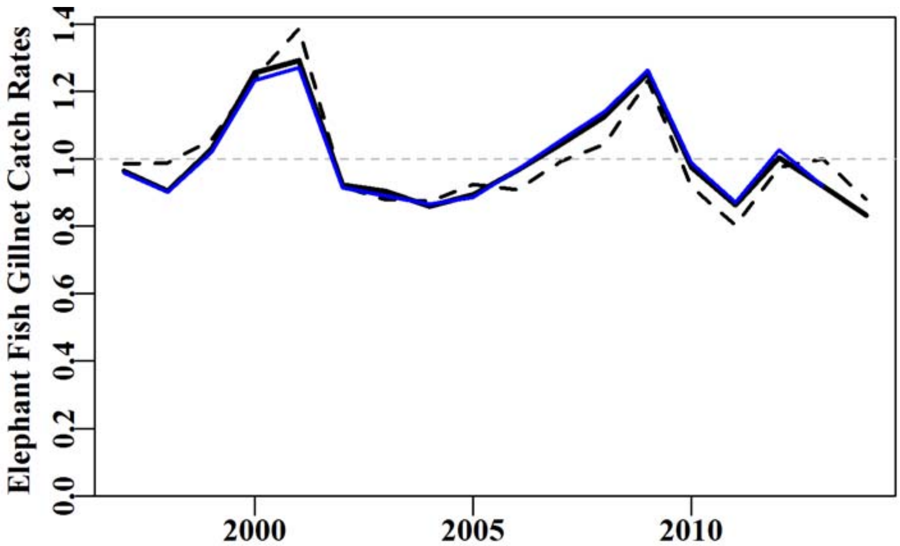


Figure 22.22. Elephant fish from shark zones 2-7 and 9 in depths 0 to 160 m by gillnet. The dashed black line represents the geometric mean CPUE, the solid black line the standardized CPUE, and the blue line is standardized CPUE from last year's analysis. The graph standardizes CPUE relative to the mean of the standardized CPUE.

Table 22.26. Elephant fish from shark zones 2-7 and 9 in depths 0 to 160 m by gillnet. Statistical model structures used in this analysis. DepCat is a series of 20 metre depth categories.

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

Table 22.27. Elephant fish taken by gillnet across shark regions from Central South Australia to Eastern Bass Strait in depths of 0 to 160 m and during 1997 - 2014. Model selection criteria, include the AIC, the adjusted R^2 (adj_R^2) and the change in adjusted R^2 (%Change). The optimum model is Model 7 (SharkZone:Month). Depth category: DepC.

	Year	Vessel	Month	DepC	SharkZone	SharkZone:Month	SharkZone:DepC
AIC	24061	20860	20601	20507	20366	19974	20203
RSS	73611	67573	67109	66753	66503	65652	66080
MSS	849	6888	7351	7708	7958	8808	8381
Nobs	40925	40925	40925	40712	40712	40712	40712
Npars	18	169	180	188	194	260	242
adj_R^2	1.099	8.876	9.477	9.938	10.262	11.265	10.727
%Change	0.000	7.777	0.600	0.461	0.324	1.003	-0.539

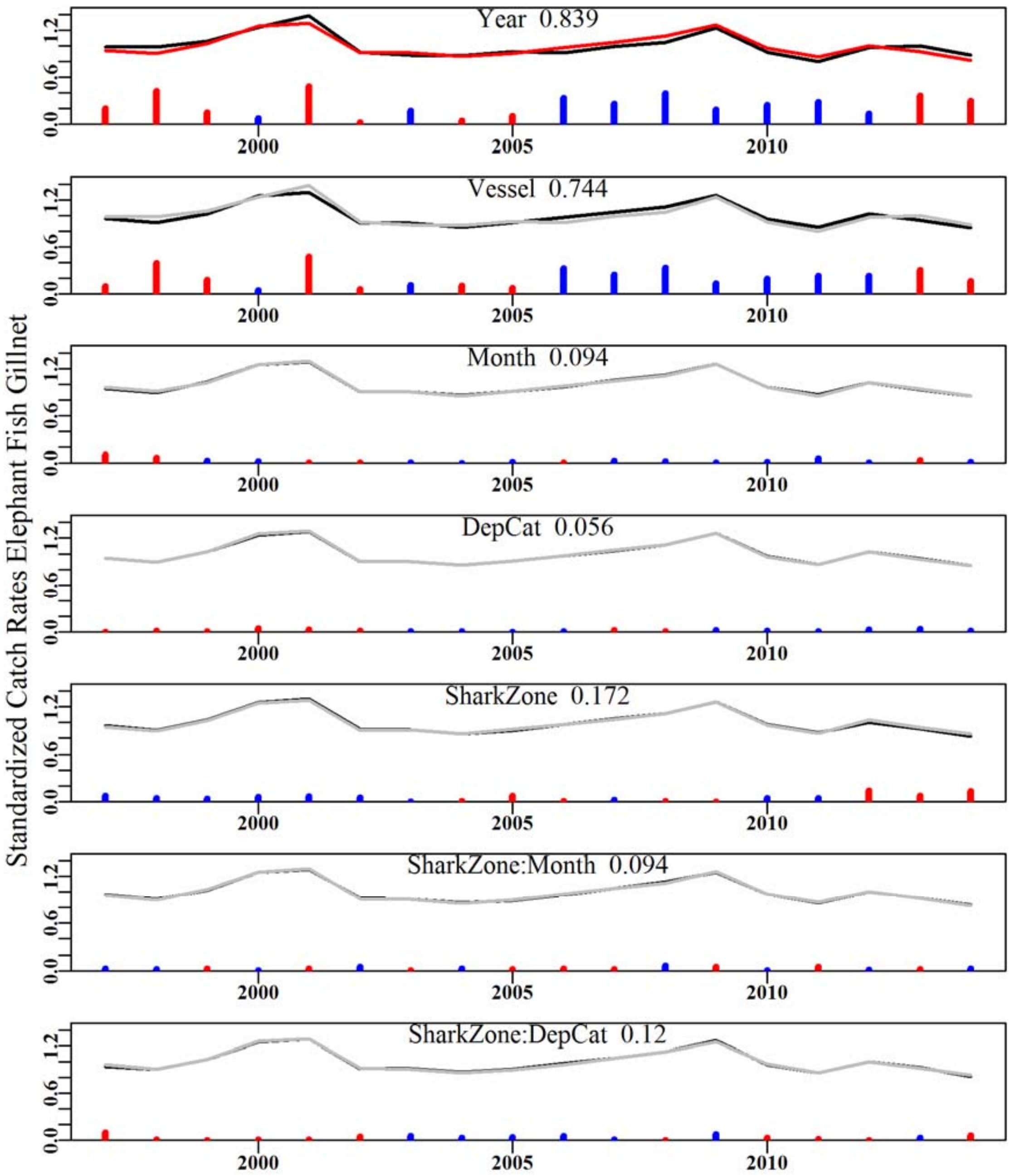


Figure 22.23. The relative influence of each factor on the final trend in the optimal standardization for the elephant fish gillnet fishery. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by the vertical bars with blue bars indicating the optimum model is higher than the geometric mean and red bars indicating it is lower. The top graph bars are the sum of all the bars in the graphs below. The graphs for individual factors are cumulative. Thus the second graph has the geometric mean (grey line) and the effect of adding Year + factor2 (Model 2, black line). In the third graph, the grey line represents Model 2 and the black line the effect of adding factor3 to the model. The remaining graphs continue in the same cumulative manner except for the interaction terms which are added singularly to the final single factor model.

Table 22.28. Reported elephant fish catches by method in the GENLOG database across all regions and methods from 1997. Total is the total catch from 1997 – 2014 (across method). Total_gear is the total catch by gear across the years. Discards are not included.

Year	AL	BL	DL	DS	GA	GN	TDO	TW	Total
1997		0.005	0.014	4.963		27.536		0.790	33.307
1998		0.101		7.141		48.095		1.654	56.991
1999		0.021	0.033	5.625		61.644		2.800	70.123
2000	0.045	0.047	0.046	6.715	0.026	68.028		2.590	77.497
2001	0.035	0.120	0.073	6.456		77.369		3.640	87.693
2002	0.004	0.123	0.006	11.689		39.666		7.792	59.278
2003	0.647	0.088	0.026	12.302		45.752		11.777	70.592
2004	1.888	0.525		15.157		33.172		14.023	64.765
2005	2.065			12.839		34.229		17.238	66.370
2006	0.762	0.003		5.396		32.528		14.571	53.259
2007	0.271	0.037		7.399		34.460		9.526	51.693
2008		0.007		10.325		40.464		10.649	61.444
2009		0.002		8.502		44.134		12.675	65.313
2010		0.004		10.156		35.020		11.560	56.740
2011	0.000	0.025		7.629		33.881		8.963	50.497
2012	0.000	0.046		10.126		44.841		10.917	65.930
2013	0.052	0.024		12.983		38.295	1.169	9.417	61.940
2014	0.003			6.581		30.632	3.955	6.083	47.253
Total_gear	5.772	1.177	0.198	184.213	0.026	769.744	5.124	178.315	1144.569

Table 22.29. Catch of elephant fish by shark reporting zones taken by gillnets. Discards are not included.

Year	WestSA	CentSA	EastSA	WestBS	EastBS	WestTas	EastTas	NSW	WestTas	Total
1997		1.129	1.859	12.072	11.101	0.264	0.138		0.960	27.521
1998	0.012	2.273	0.313	16.128	21.847	1.747	5.546		0.229	48.095
1999	0.038	5.010	1.278	14.784	32.793	0.760	6.363		0.522	61.548
2000	0.285	6.200	0.761	11.357	38.893	1.012	9.264	0.028	0.176	67.976
2001	0.107	9.713	0.889	6.008	46.194	2.402	11.434		0.399	77.145
2002		2.167	0.203	6.308	23.656	0.082	6.946		0.305	39.666
2003	0.038	4.273	0.325	5.287	29.122	1.188	5.196		0.323	45.752
2004	0.152	1.542	0.695	4.567	19.903	0.123	6.047	0.020	0.124	33.172
2005	0.010	1.994	0.053	6.855	20.218	0.215	4.808		0.066	34.219
2006	0.829	1.426	0.011	3.196	21.404	1.010	4.596		0.058	32.528
2007	0.332	2.412	0.075	2.534	20.270	0.354	8.398	0.040	0.046	34.460
2008	0.184	2.597	0.131	3.493	27.290	0.210	6.272	0.020	0.268	40.464
2009	0.035	2.930	0.171	6.088	29.718	0.105	4.992		0.063	44.101
2010	0.058	3.166	0.085	5.103	22.771	0.055	3.582	0.038	0.163	35.020
2011	0.014	4.324	0.035	4.668	20.805	0.334	3.230		0.471	33.881
2012	0.003	0.057	0.097	8.908	29.604	0.880	5.186		0.102	44.836
2013	0.005	0.052	0.021	10.505	23.318	0.608	3.714	0.027	0.044	38.293
2014	0.002	0.084	0.069	8.590	18.526	0.155	3.102	0.017	0.029	30.574
Total	2.102	51.348	7.071	136.448	457.428	11.503	98.812	0.190	4.347	769.248

22.4.8 Saw shark: Gillnet

Positive non-zero records of catch per shot were employed in the statistical standardization analyses for saw shark caught by gillnets. Further investigation should be considered to determine whether total net length could be used as an alternative effort unit in standardization analyses.

Table 22.30. Saw shark taken by gillnet across shark regions from Central South Australia to Eastern Bass Strait between depths of 0 to 150 m and during 1997 - 2014. Total catch (TotCatch; t) is the total reported in the database across all gears, number of records used in the analysis (Records), reported catch (CatchT; t) in the area and depth used in the analysis and number of vessels used in the analysis (Vessels). GeoMean is the geometric mean of CPUE (kg/shot). The optimum model is model 6 (Table 22.32). SharkZone:Month and standard deviation (StDev) are the coefficients from the optimum model.

Year	TotCatch	Records	CatchT	Vessels	GeoMean	SharkZone:Month	StDev
1997	222.227	4648	153.017	81	14.7221	1.1639	0.0000
1998	304.641	6749	242.797	81	13.6959	1.2135	0.0229
1999	300.467	7123	230.070	81	13.7614	1.2692	0.0230
2000	352.384	6385	264.093	76	17.9504	1.6168	0.0236
2001	338.146	5951	250.992	79	17.4523	1.7092	0.0241
2002	255.757	5716	148.722	76	10.9212	0.9908	0.0243
2003	318.812	6422	181.266	81	10.7738	1.0282	0.0240
2004	314.615	6010	176.134	71	11.5115	1.0684	0.0244
2005	296.667	5381	161.855	62	10.8639	0.9749	0.0251
2006	317.698	5169	156.479	58	10.1294	0.9829	0.0255
2007	214.535	4610	106.045	44	7.7355	0.8250	0.0262
2008	211.690	4546	114.231	44	9.2730	0.9632	0.0263
2009	191.453	4830	88.518	44	7.4203	0.8033	0.0261
2010	192.502	5043	91.852	48	7.6490	0.7868	0.0260
2011	196.827	5247	102.342	46	7.9130	0.7680	0.0260
2012	157.827	4500	73.538	42	7.0364	0.6283	0.0271
2013	165.396	4201	70.510	39	8.0360	0.5733	0.0271
2014	163.918	4019	80.085	38	8.7489	0.6344	0.0274

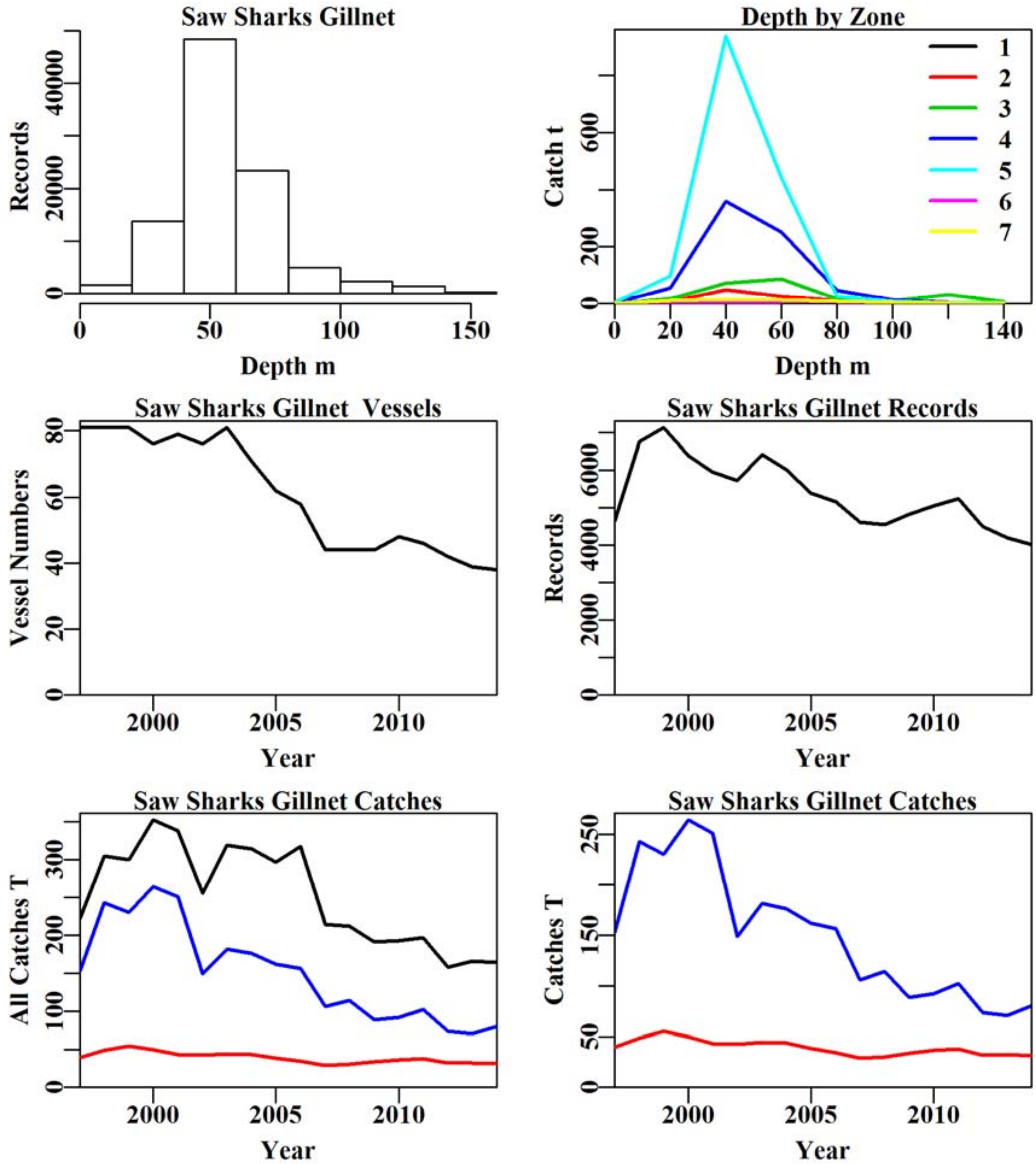


Figure 22.24. Saw shark in shark zones 1-7 in depths 0 to 150 m taken by gillnet. The top left plot depicts the depth distribution of shots containing saw shark from shark zones 1-7 in depths 0 – 150 m. The top right plot depicts the distribution of catch by depth within shark zones 1-7. The middle left plot depicts the number of vessels through time. The middle right plot contains the number of records used in analysis. The bottom left plot contains 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).

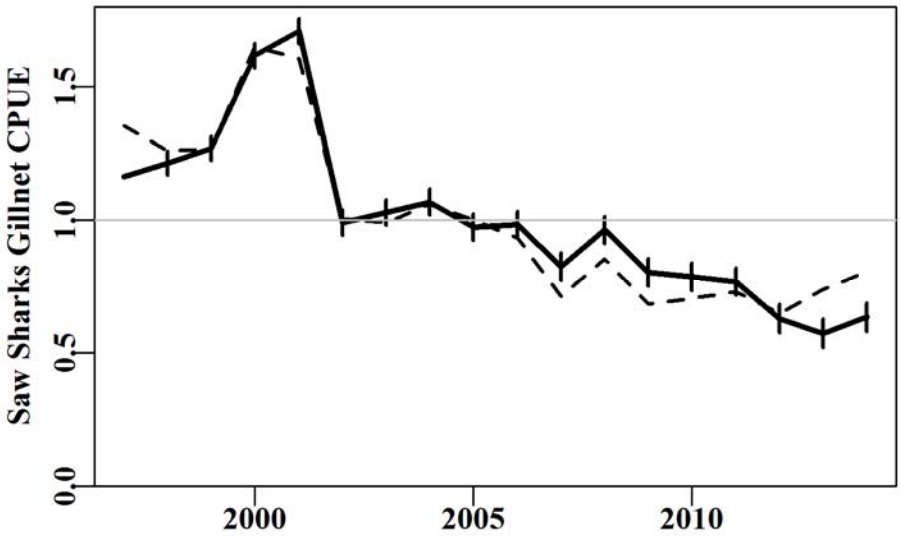


Figure 22.25. The standardized CPUE for saw sharks taken by gillnet showing the optimum model (solid black line) and the geometric mean CPUE (dashed line) each scaled to the mean of each time series. The vertical bars are two times the standard error.

Table 22.31. Saw shark from shark zones 1-7 in depths 0 to 150 m by gillnet. Statistical model structures used in this analysis. DepCat is a series of 20 metre depth categories.

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

Table 22.32. Saw shark taken by gillnet across shark zones 1-7 in depths of 0 to 150 m and during 1997 - 2014. Model selection criteria, include the AIC, the adjusted R^2 (adj_R^2) and the change in adjusted R^2 (%Change). The optimum model is Model 6 (SharkZone:Month). Depth category: DepC.

	Year	Vessel	Month	DepC	SharkZone	SharkZone:Month	SharkZone:DepC
AIC	62079	38951	33501	29961	28195	24260	26408
RSS	183582	143936	135502	130581	128171	122854	125696
MSS	8087	47734	56168	61089	63499	68816	65974
Nobs	96550	96550	95995	95995	95995	95995	95995
Npars	18	199	206	212	223	289	265
adj_R^2	4.203	24.750	29.153	31.722	32.974	35.710	34.240
%Change	0.000	20.547	4.403	2.569	1.252	2.736	-1.471

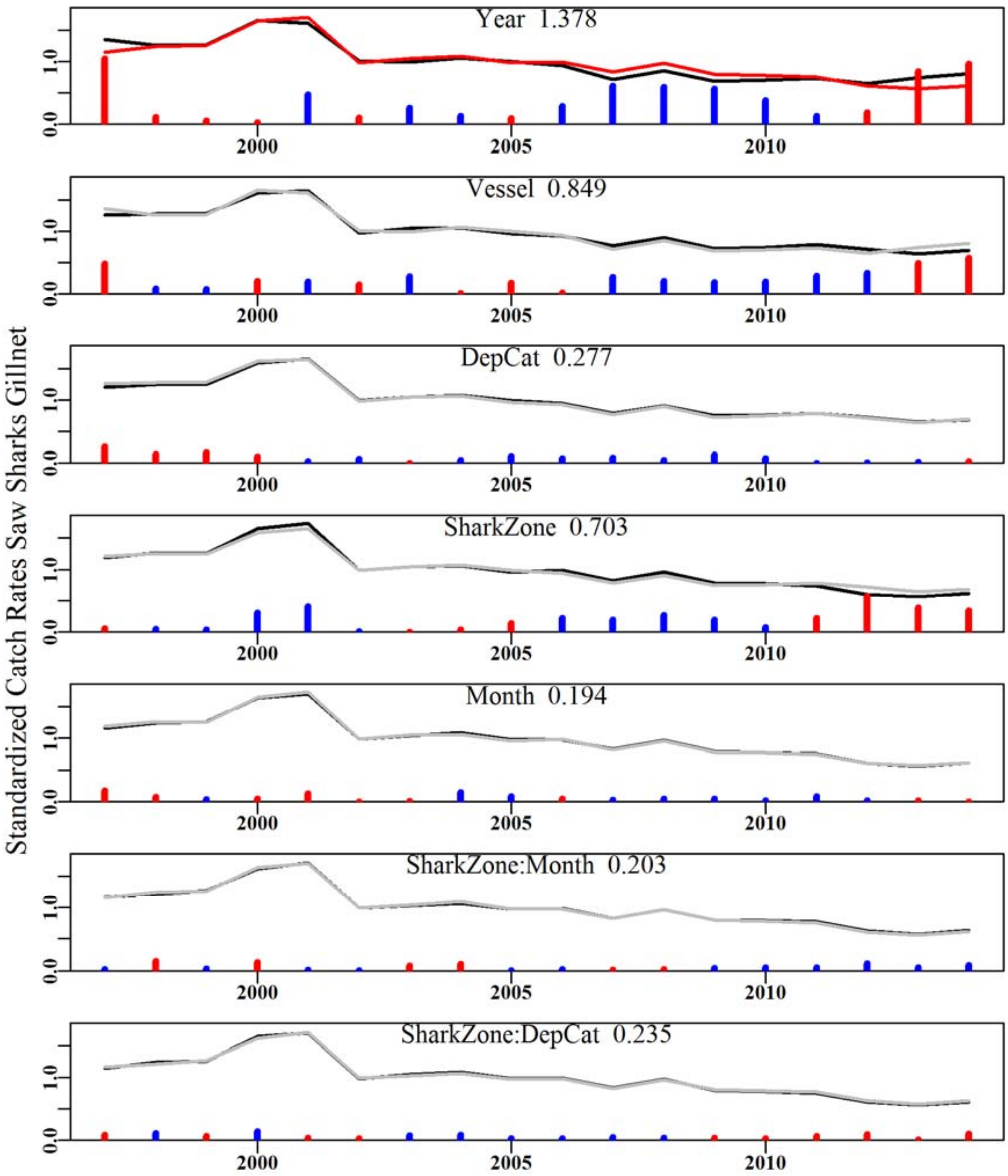


Figure 22.26. The relative influence of each factor on the final trend in the optimal standardization for the saw shark gillnet fishery. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by the vertical bars with blue bars 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, black line). In the third graph, the grey line represents Model 2 and the black line the effect of adding factor3 to the model. The remaining graphs continue in the same cumulative manner except for the interaction terms which are added singularly to the final single factor model.

22.4.9 Saw shark: Trawl (using Shark Zone)

Positive non-zero records of catch per hour were employed in the statistical standardization analyses for saw shark caught by trawl.

Table 22.33. Saw shark taken by trawl across shark regions from Central South Australia to Eastern Bass Strait between depths of 0 to 500 m and during 1997 - 2014. Total catch (TotCatch; t) is the total reported in the database across all gears, number of records used in the analysis (Records), reported catch (CatchT; t) in the area and depth used in the analysis and number of vessels used in the analysis (Vessels). GeoMean is the geometric mean of CPUE (kg/hr). The optimum model is Model 7 (Table 22.35). SharkZone:Month and standard deviation (StDev) are the coefficients from the optimum model.

Year	TotCatch	Records	CatchT	Vessels	GeoMean	SharkZone:Month	StDev
1997	222.227	2025	45.935	59	3.0297	1.1375	0.0000
1998	304.641	1485	34.200	54	2.8938	1.0728	0.0361
1999	300.467	1561	38.452	50	3.7791	1.2872	0.0359
2000	352.384	2094	55.671	65	4.1146	1.1689	0.0353
2001	338.146	2070	49.066	58	3.0880	1.1295	0.0353
2002	255.757	3096	62.262	76	2.7652	0.9922	0.0327
2003	318.812	3957	80.182	77	2.3522	0.8643	0.0314
2004	314.615	3906	80.431	78	2.5885	0.8654	0.0316
2005	296.667	4428	90.920	73	2.5786	0.8730	0.0308
2006	317.698	4073	111.304	65	2.8887	0.9871	0.0313
2007	214.535	2205	63.620	39	2.7224	0.8525	0.0354
2008	211.690	2562	58.346	41	2.5111	0.9124	0.0347
2009	191.453	2545	69.243	35	3.3781	1.1453	0.0345
2010	192.502	2654	59.116	37	2.7260	0.9737	0.0346
2011	196.827	2672	58.192	37	2.5961	0.9073	0.0344
2012	157.827	2316	56.423	36	2.8453	0.8810	0.0357
2013	165.396	2302	58.964	37	3.1305	0.9965	0.0356
2014	163.918	2003	52.618	37	3.1830	0.9535	0.0365

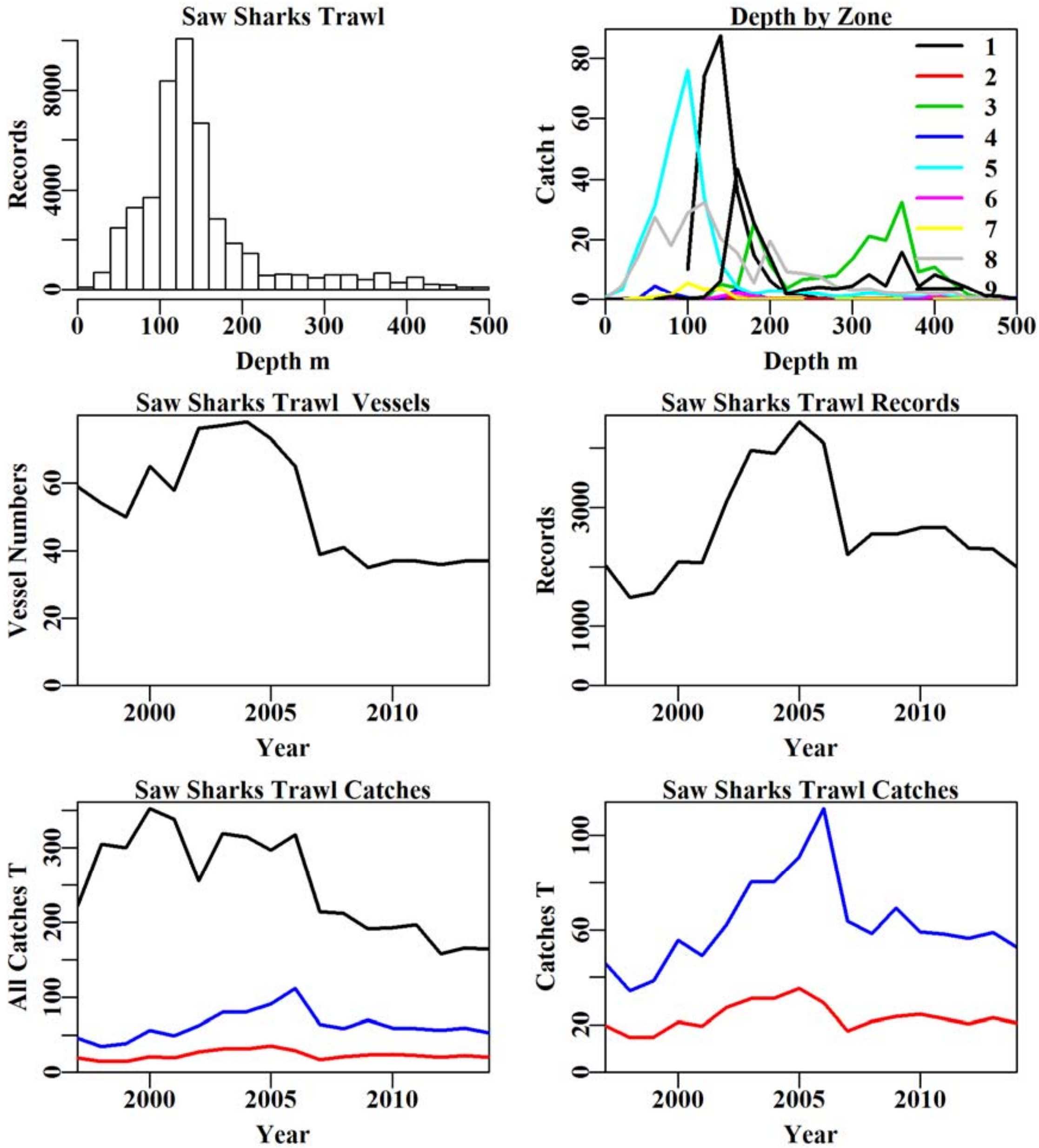


Figure 22.27. Saw shark taken by Trawl. The top left plot depicts the depth distribution of shots containing saw shark from shark zones 1-9 in depths 0 – 500 m. The top right plot depicts the distribution of catch by depth within zone 60. The middle left plot depicts the number of vessels through time. The middle right plot contains the number of records used in analysis. The bottom left plot contains 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).

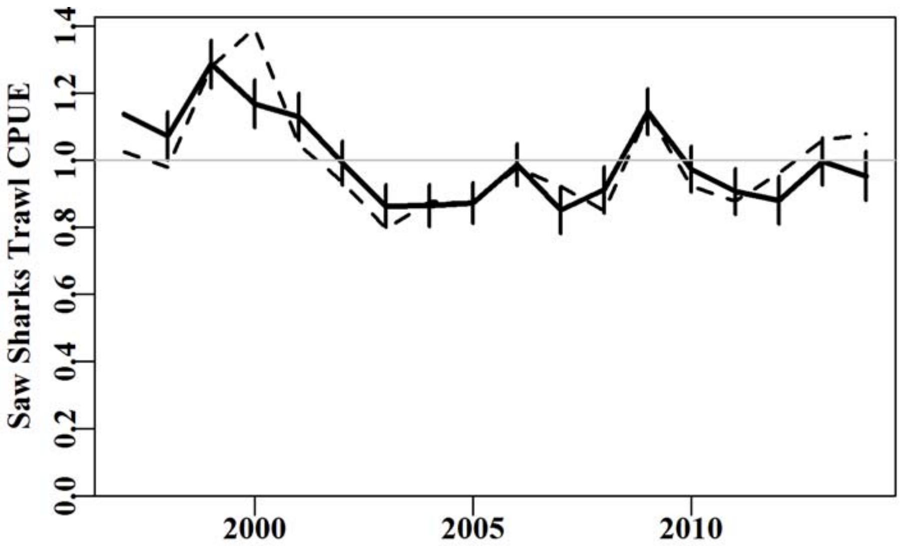


Figure 22.28. The standardized CPUE for saw sharks taken by trawl showing the optimum model (solid black line) and the geometric mean CPUE (dashed line) each scaled to the mean of each time series. The vertical bars are two times the standard error.

Table 22.34. Saw shark from across shark zones in depths 0 to 500 m by Trawl. Statistical model structures used in this analysis. DepCat is a series of 20 metre depth categories.

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

Table 22.35. Saw shark taken by trawl across shark zones from Western South Australia to Eastern Bass Strait between depths of 0 to 500 m and during 1997 - 2014. Model selection criteria, include the AIC, the adjusted R^2 (adj_R^2) and the change in adjusted R^2 (%Change). The optimum model is Model 7 (SharkZone:Month). Depth category: DepC.

	Year	Vessel	DepCat	SharkZone	Month	DayNight	SharkZone:Month	SharkZone:DepC
AIC	22115	7042	5378	4059	3145	3095	2026	2184
RSS	75995	55193	52788	51324	50322	50263	48963	48894
MSS	850	21652	24057	25521	26523	26582	27882	27951
Nobs	47954	47954	47484	47484	47484	47484	47484	47484
Npars	18	150	175	183	194	197	285	397
adj_R^2	1.071	27.952	31.053	32.954	34.247	34.321	35.900	35.838
%Change	0.000	26.881	3.101	1.901	1.293	0.073	1.580	1.517

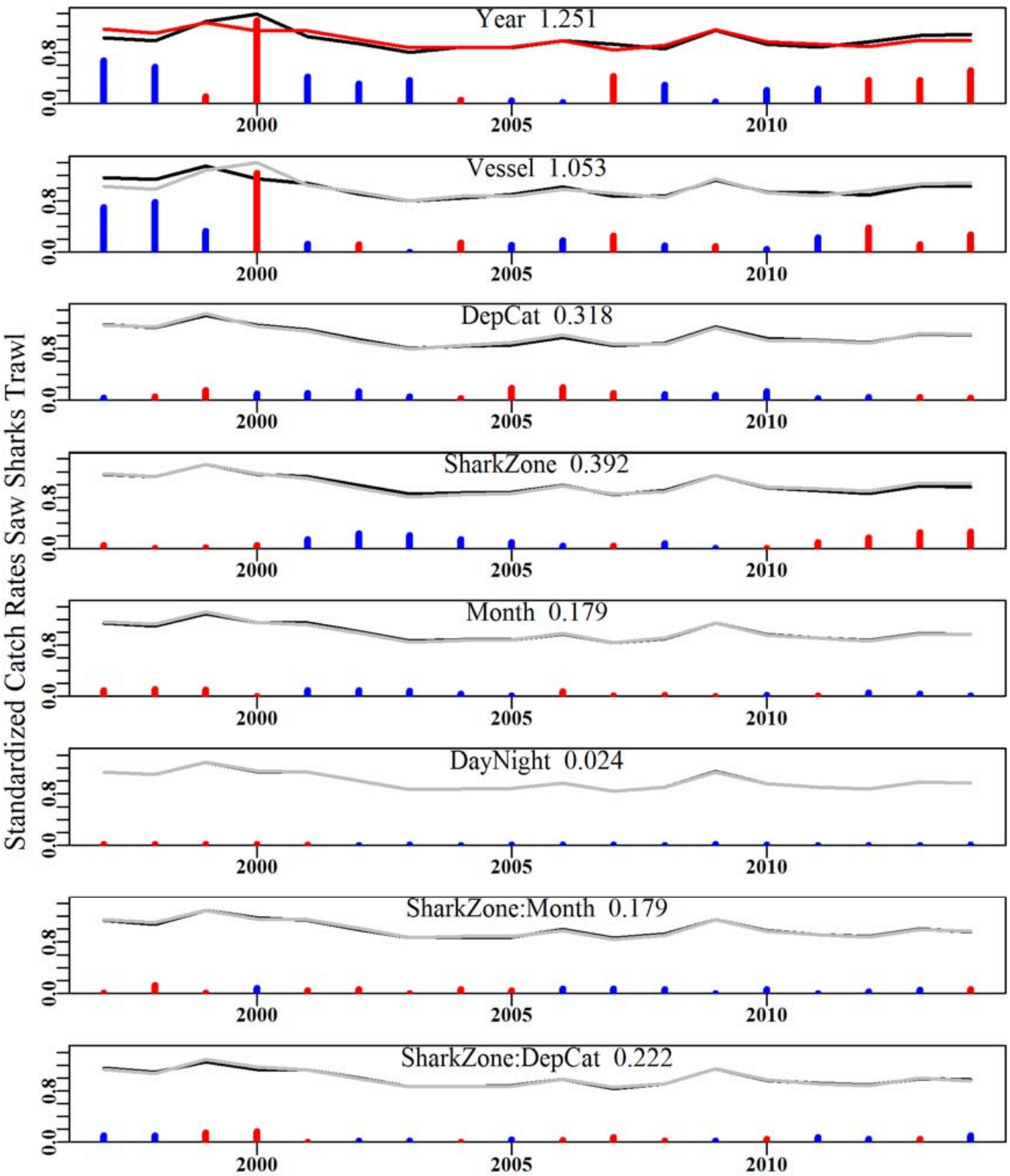


Figure 22.29. The relative influence of each factor on the final trend in the optimal standardization for the saw shark trawl fishery. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by the vertical bars with blue bars 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, black line). In the third graph, the grey line represents Model 2 and the black line the effect of adding factor3 to the model. The remaining graphs continue in the same cumulative manner except for the interaction terms which are added singularly to the final single factor model.

22.4.10 Saw shark: Trawl (using Shark Area)

Positive non-zero records of catch per shot were employed in the statistical standardization analyses for saw shark caught by trawl. This analysis considers the factor SharkArea instead of SharkZone.

Table 22.36. Saw shark taken by trawl across shark areas from Western South Australia to Eastern Bass Strait between depths of 0 to 500 m and during 1997 - 2014. Total catch (TotCatch; t) is the total reported in the database across all gears, number of records used in the analysis (Records), reported catch (CatchT; t) in the area and depth used in the analysis and number of vessels used in the analysis (Vessels). GeoMean is the geometric mean of CPUE (kg/hr). The optimum model is Model 7 (Table 22.38). SharkArea:Month and standard deviation (StDev) are the coefficients from the optimum model.

Year	TotCatch	Records	CatchT	Vessels	GeoMean	SharkArea:Month	StDev
1997	222.227	2025	45.935	59	3.0297	1.1742	0.0000
1998	304.641	1485	34.200	54	2.8938	1.0316	0.0366
1999	300.467	1561	38.452	50	3.7791	1.2387	0.0365
2000	352.384	2094	55.671	65	4.1146	1.1841	0.0357
2001	338.146	2070	49.066	58	3.0880	1.1415	0.0358
2002	255.757	3096	62.262	76	2.7652	1.0332	0.0330
2003	318.812	3957	80.182	77	2.3522	0.8869	0.0317
2004	314.615	3906	80.431	78	2.5885	0.8559	0.0320
2005	296.667	4428	90.920	73	2.5786	0.8698	0.0312
2006	317.698	4073	111.304	65	2.8887	1.0049	0.0319
2007	214.535	2205	63.620	39	2.7224	0.8646	0.0356
2008	211.690	2562	58.346	41	2.5111	0.9013	0.0350
2009	191.453	2545	69.243	35	3.3781	1.1272	0.0348
2010	192.502	2654	59.116	37	2.7260	0.9684	0.0349
2011	196.827	2672	58.192	37	2.5961	0.9039	0.0347
2012	157.827	2316	56.423	36	2.8453	0.8659	0.0359
2013	165.396	2302	58.964	37	3.1305	0.9634	0.0358
2014	163.918	2003	52.618	37	3.1830	0.9846	0.0373

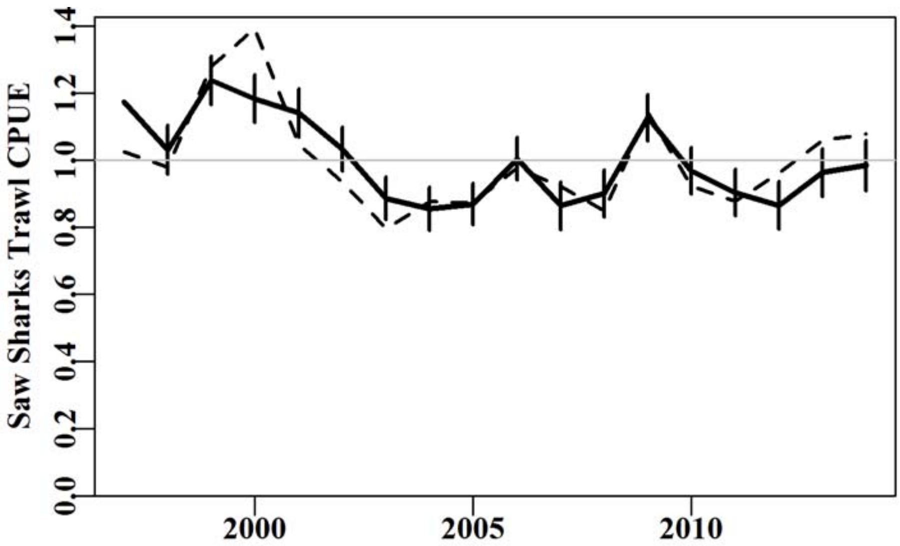


Figure 22.30. The standardized CPUE for saw sharks taken by trawl showing the optimum model (solid black line) and the geometric mean CPUE (dashed line) each scaled to the mean of each time series. The vertical bars are two times the standard error.

Table 22.37. Saw shark from across shark zones in depths 0 to 500 m by Trawl. Statistical model structures used in this analysis. DepCat is a series of 20 metre depth categories.

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

Table 22.38. Saw shark taken by trawl across shark zones from Western South Australia to Eastern Bass Strait between depths of 0 to 500 m and during 1997 - 2014. Model selection criteria, include the AIC, the adjusted R^2 (adj_R^2) and the change in adjusted R^2 (%Change). The optimum model is Model 7 (SharkArea:Month). Depth category: DepC.

	Year	Vessel	DepCat	SharkArea	Month	DayNight	SharkArea:Month	SharkArea:DepC
AIC	22115	7042	5378	3090	2202	2152	1046	2355
RSS	75995	55193	52788	49895	48940	48883	46823	46955
MSS	850	21652	24057	26951	27905	27962	30022	29890
Nobs	47954	47954	47484	47162	47162	47162	47162	47162
Npars	18	150	175	217	228	231	693	1281
adj_R^2	1.071	27.952	31.053	34.772	36.005	36.076	38.161	37.191
%Change	0	26.881	3.101	3.719	1.233	0.071	2.085	-0.97

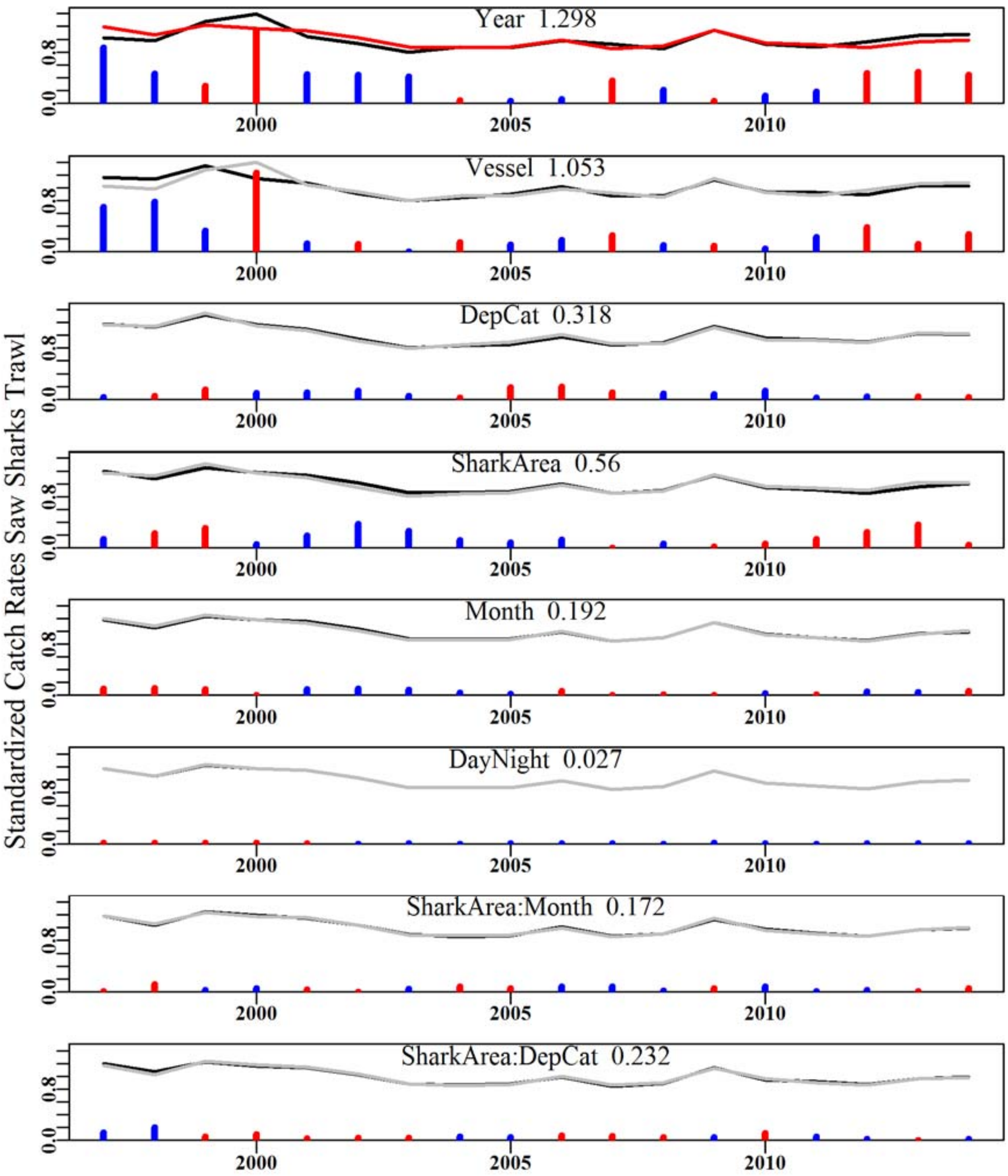


Figure 22.31. The relative influence of each factor on the final trend in the optimal standardization for the saw shark trawl fishery. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by the vertical bars with blue bars 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, black line). In the third graph, the grey line represents Model 2 and the black line the effect of adding factor3 to the model. The remaining graphs continue in the same cumulative manner except for the interaction terms which are added singularly to the final single factor model.

22.4.11 Saw shark: Danish seine (using Shark Zone)

A large proportion of records contain missing effort entries, so CPUE used in the analyses was kg/shot. Data pertaining to Shark Zones 4 and 5 (Western and Eastern Bass Strait respectively).

Table 22.39. Saw shark taken by danish seine across shark regions from Western Bass Strait to Eastern Bass Strait between depths of 0 to 240 m and during 1997 - 2014. Total catch (TotCatch; t) is the total reported in the database across all gears, number of records used in the analysis (Records), reported catch (CatchT; t) in the area and depth used in the analysis and number of vessels used in the analysis (Vessels). GeoMean is the geometric mean of CPUE (kg/shot). The optimum model is Model 7 (Table 22.41). SharkZone:Month and standard deviation (StDev) are the coefficients from the optimum model.

Year	TotCatch	Records	CatchT	Vessels	GeoMean	SharkZone:Month	StDev
1997	222.227	436	4.018	13	6.6325	1.4636	0.0000
1998	304.641	485	6.750	12	8.3699	1.6429	0.0681
1999	300.467	613	6.464	13	6.7292	1.3007	0.0649
2000	352.384	398	7.165	11	10.3938	1.9034	0.0728
2001	338.146	508	7.029	12	8.6081	1.0905	0.0717
2002	255.757	2705	24.403	22	4.5931	0.8960	0.0579
2003	318.812	3057	22.180	22	3.8527	0.8008	0.0579
2004	314.615	3228	24.319	22	3.7264	0.7367	0.0577
2005	296.667	2666	17.348	22	3.2825	0.6631	0.0583
2006	317.698	2253	17.935	20	3.9428	0.7671	0.0591
2007	214.535	2298	21.544	16	4.3890	0.8518	0.0591
2008	211.690	2482	22.547	15	4.6071	0.8981	0.0589
2009	191.453	2844	21.127	15	3.9010	0.8522	0.0586
2010	192.502	2405	17.038	15	3.9924	0.8754	0.0591
2011	196.827	2881	25.348	14	4.4683	0.8605	0.0584
2012	157.827	2196	20.249	14	4.5630	0.8377	0.0594
2013	165.396	2531	20.795	14	4.3873	0.8560	0.0590
2014	163.918	1720	13.125	14	4.1013	0.7035	0.0634

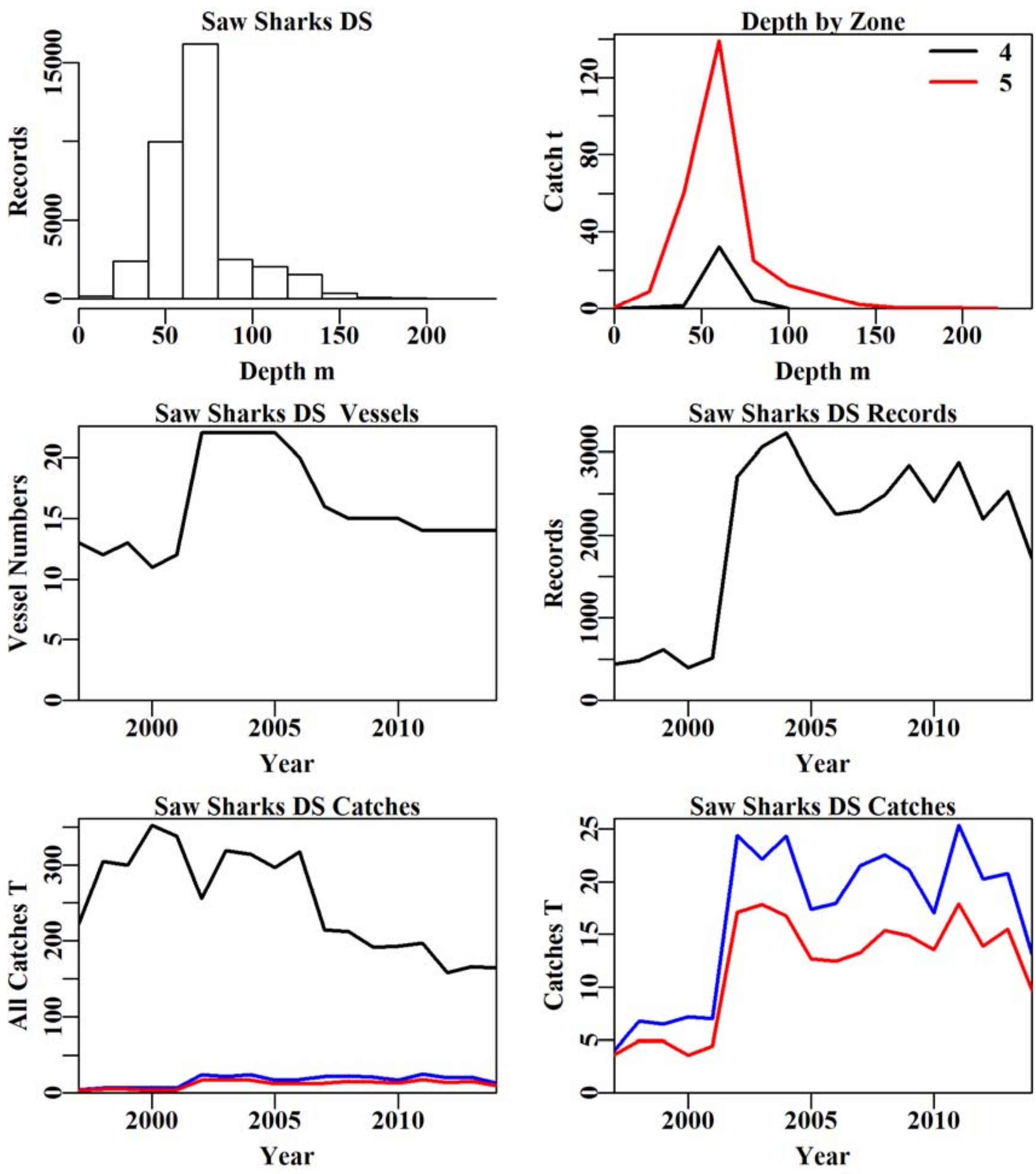


Figure 22.32. Saw shark taken by Danish seine. The top left plot depicts the depth distribution of shots containing saw shark from shark zones 4, 5 in depths 0 – 240 m. The top right plot depicts the distribution of catch by depth within zone 4 and 5. The middle left plot depicts the number of vessels through time. The middle right plot contains the number of records used in analysis. The bottom left plot contains 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).

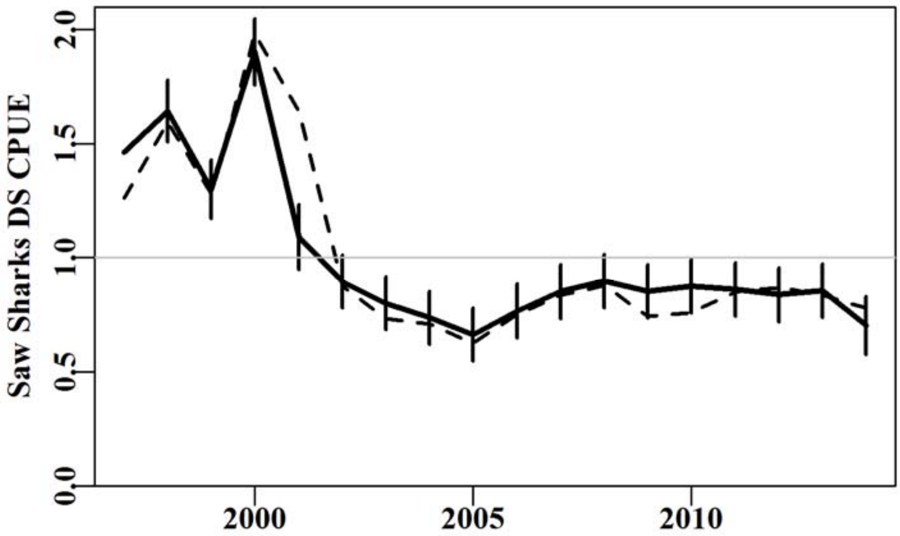


Figure 22.33. The standardized CPUE for saw sharks taken by Danish seine showing the optimum model (solid black line) and the geometric mean CPUE (dashed line) each scaled to the mean of each time series. The vertical bars are two times the standard error.

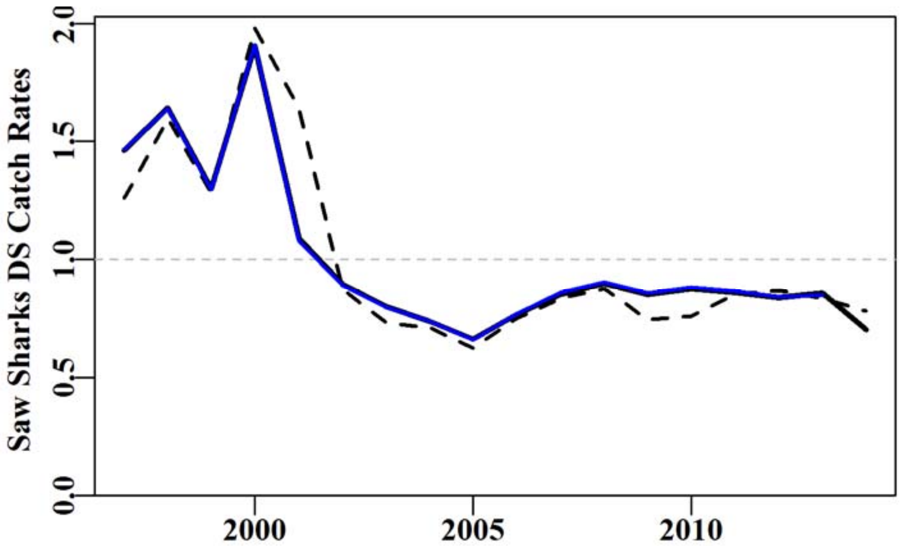


Figure 22.34. Sawshark in shark zones 4, 5 by Danish Seine. The dashed black line represents the geometric mean CPUE, the solid black line the standardized CPUE, and the blue line is standardized CPUE from last year's analysis. The graph standardizes CPUE relative to the mean of the standardized CPUE.

Table 22.40. Sawshark from across shark zones in depths 0 to 240 m by Danish seine. Statistical model structures used in this analysis. DepCat is a series of 20 metre depth categories.

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

Table 22.41. Sawshark taken by Danish seine across shark zones from Western Bass Strait to Eastern Bass Strait between depths of 0 to 240 m and during 1997 - 2014. Model selection criteria, include the AIC, the adjusted R^2 (adj_R^2) and the change in adjusted R^2 (%Change). The optimum model is Model 7 (SharkZone:Month). Depth category: DepCat.

	Year	DepCat	Vessel	Month	SharkZone	DayNight	SharkZone:Month	SharkZone:DepC
AIC	4480	2144	1001	455	372	367	140	201
RSS	40438	37361	36098	35521	35435	35424	35174	35235
MSS	1371	4447	5710	6288	6374	6384	6635	6573
Nobs	35706	35212	35212	35212	35212	35212	35212	35212
Npars	18	29	63	74	75	78	89	89
adj_R^2	3.232	10.566	13.506	14.862	15.067	15.085	15.658	15.511
%Change	0.000	7.333	2.941	1.356	0.204	0.018	0.573	-0.147

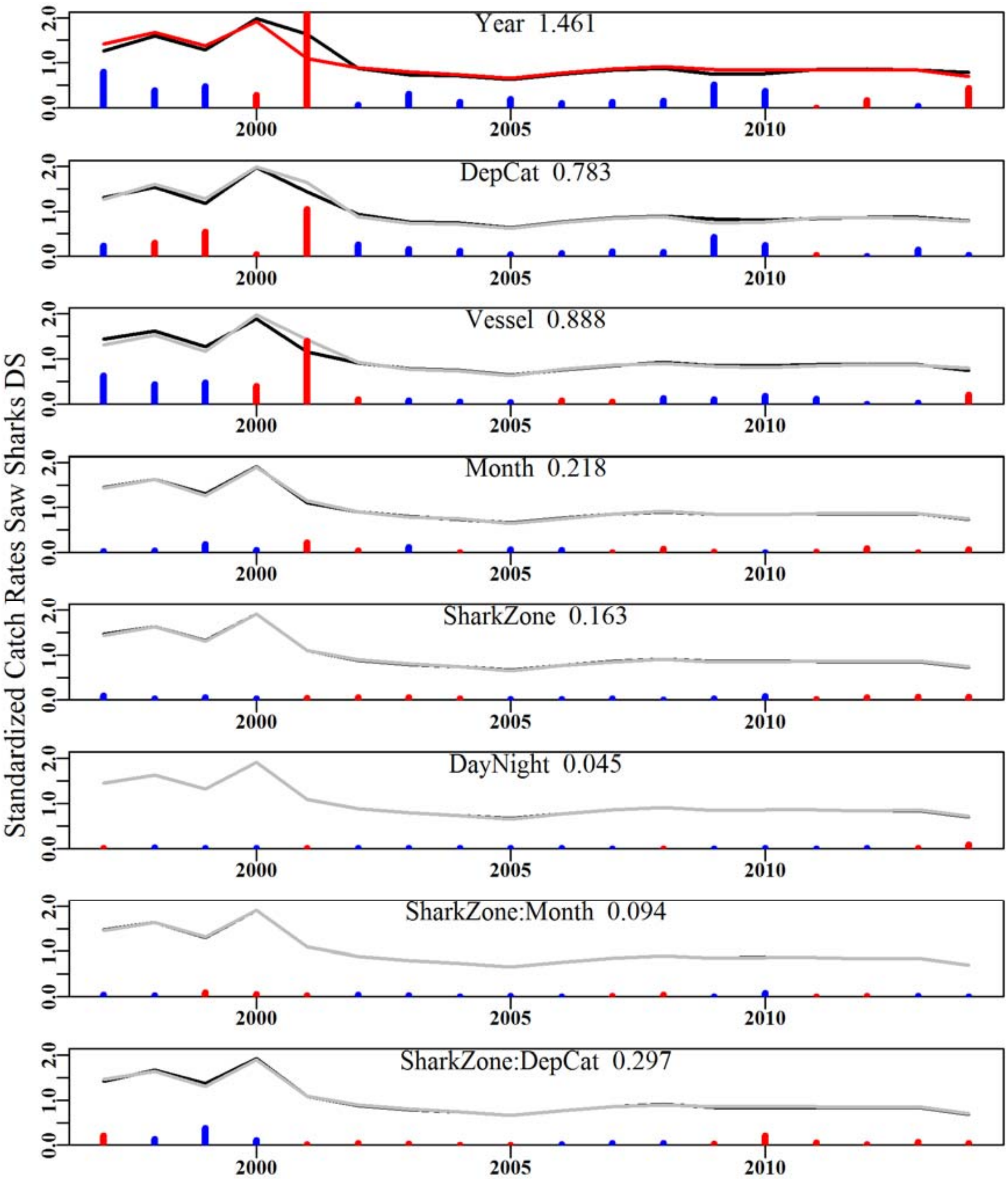


Figure 22.35. The relative influence of each factor on the final trend in the optimal standardization for the saw shark Danish seine fishery. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by the vertical bars with blue 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, black line). In the third graph, the grey line represents Model 2 and the black line the effect of adding factor3 to the model. The remaining graphs continue in the same cumulative manner except for the interaction terms which are added singularly to the final single factor model.

22.4.12 Saw shark: Danish seine (using Shark Area)

This analysis in this section is similar to that of the previous section, except that Shark Area was used instead of Shark Zone.

Table 22.42. Saw shark taken by Danish seine across shark areas from Western Western Bass Strait to Eastern Bass Strait between depths of 0 to 240 m and during 1997 - 2014. Total catch (TotCatch; t) is the total reported in the database across all gears, number of records used in the analysis (Records), reported catch (CatchT; t) in the area and depth used in the analysis and number of vessels used in the analysis (Vessels). GeoMean is the geometric mean of CPUE (kg/shot). The optimum model is Model 7 (Table 22.44). SharkArea:Month and standard deviation (StDev) are the coefficients from the optimum model.

Year	TotCatch	Records	CatchT	Vessels	GeoMean	SharkArea:Month	StDev
1997	222.227	435	4.013	13	6.6369	1.4654	0.0000
1998	304.641	483	6.730	12	8.3637	1.6121	0.0683
1999	300.467	612	6.461	13	6.7381	1.2429	0.0652
2000	352.384	397	7.160	11	10.4130	1.7872	0.0729
2001	338.146	508	7.029	12	8.6081	1.0925	0.0719
2002	255.757	2693	24.167	22	4.5827	0.8931	0.0583
2003	318.812	3027	21.834	22	3.8597	0.8008	0.0582
2004	314.615	3221	24.296	22	3.7301	0.7479	0.0580
2005	296.667	2658	17.302	22	3.2812	0.6773	0.0585
2006	317.698	2243	17.887	20	3.9535	0.7952	0.0593
2007	214.535	2295	21.539	16	4.3949	0.8753	0.0593
2008	211.690	2481	22.541	15	4.6066	0.9116	0.0591
2009	191.453	2843	21.122	15	3.9007	0.8555	0.0589
2010	192.502	2397	17.006	15	3.9936	0.9054	0.0594
2011	196.827	2875	25.326	14	4.4730	0.8869	0.0589
2012	157.827	2196	20.249	14	4.5630	0.8449	0.0597
2013	165.396	2530	20.785	14	4.3859	0.8744	0.0593
2014	163.918	1512	11.905	14	4.1898	0.7315	0.0647

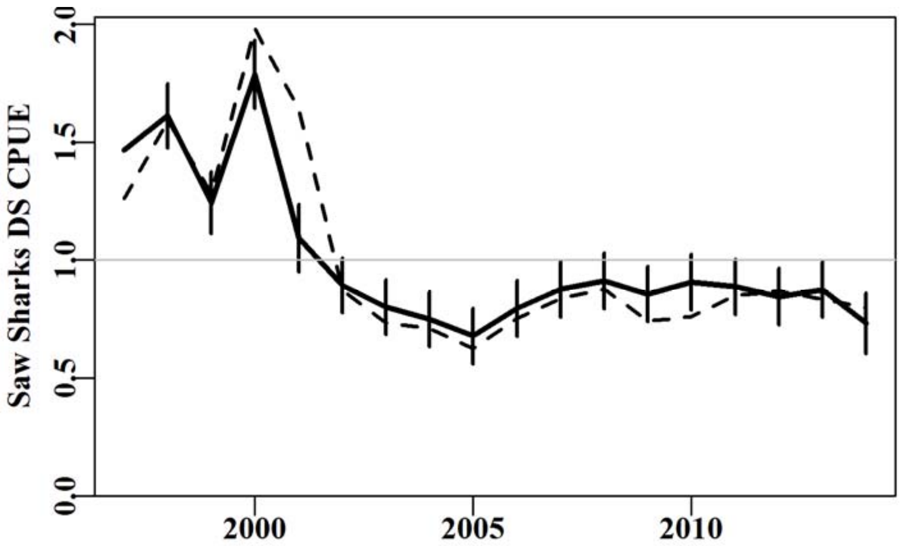


Figure 22.36. The standardized CPUE for saw sharks taken by Danish seine showing the optimum model (solid black line) and the geometric mean CPUE (dashed line) each scaled to the mean of each time series. The vertical bars are two times the standard error.

Table 22.43. Saw shark from across shark zones in depths 0 to 240 m by Danish seine. Statistical model structures used in this analysis. DepCat is a series of 20 metre depth categories.

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

Table 22.44. Saw shark taken by Danish seine across shark areas from Western Bass Strait to Eastern Bass Strait between depths of 0 to 240 m and during 1997 - 2014. Model selection criteria, include the AIC, the adjusted R^2 (adj_R^2) and the change in adjusted R^2 (%Change). The optimum model is Model 7 (SharkArea:Month). Depth category: DepCat.

	Year	Vessel	DepCat	SharkArea	Month	DayNight	SharkArea:Month	SharkArea:DepC
AIC	4449	2107	993	456	99	98	-435	-85
RSS	40106	37025	35793	35224	34836	34829	33978	34321
MSS	1363	4444	5676	6245	6632	6640	7491	7148
Nobs	35406	34915	34915	34915	34915	34915	34915	34915
Npars	18	29	63	74	89	92	257	257
adj_R^2	3.241	10.645	13.534	14.881	15.781	15.792	17.458	16.626
%Change	0.000	7.404	2.889	1.347	0.900	0.011	1.666	-0.832

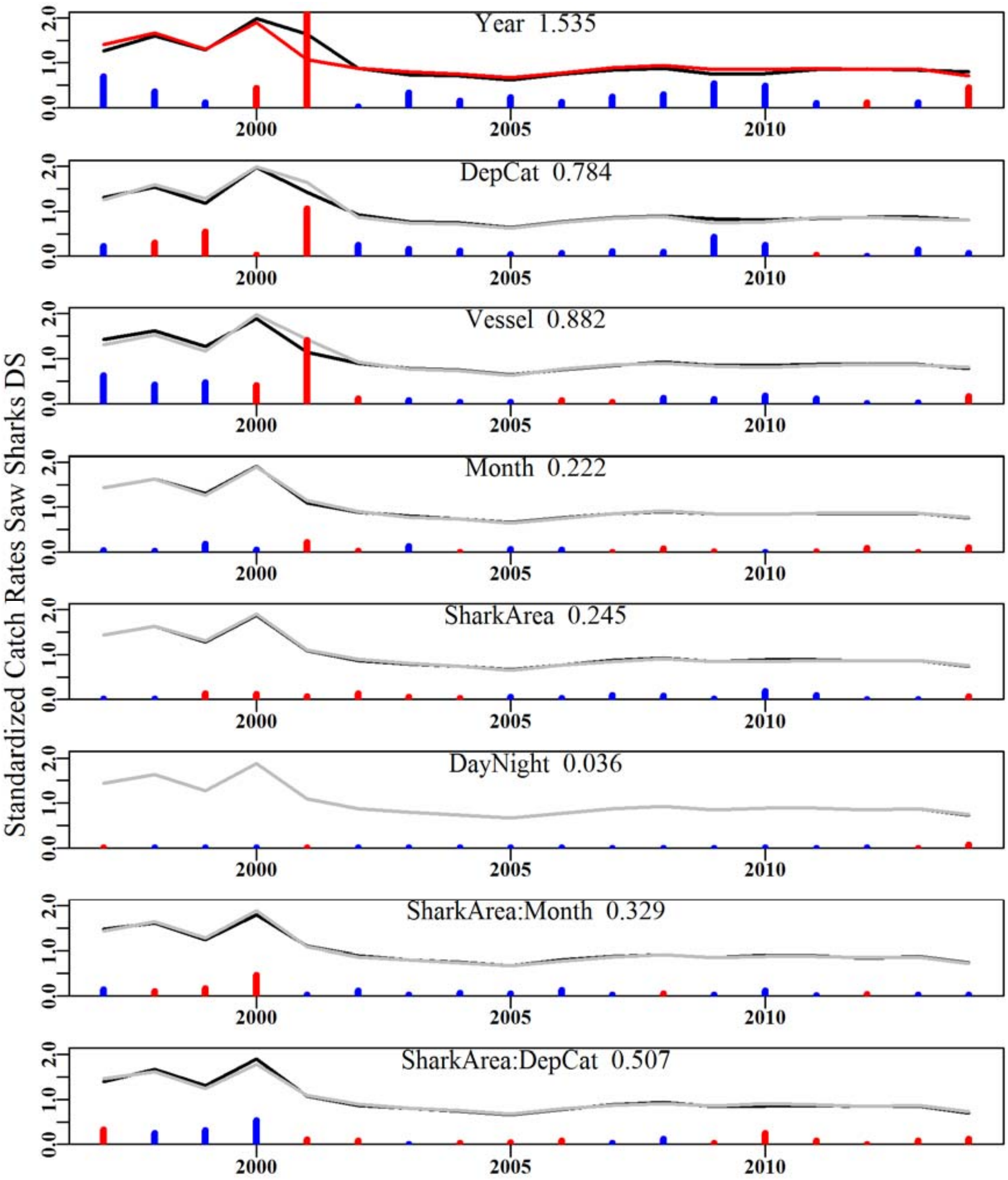


Figure 22.37. The relative influence of each factor on the final trend in the optimal standardization for the saw shark Danish seine fishery. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by the vertical bars with blue 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, black line). In the third graph, the grey line represents Model 2 and the black line the effect of adding factor3 to the model. The remaining graphs continue in the same cumulative manner except for the interaction terms which are added singularly to the final single factor model.

22.5 Discussion and conclusions

22.5.1 Gummy shark – Gillnet

Most gummy shark catches are taken by gillnets (24,300 t; 1997-2014), followed by trawl (1,428 t; 1997-2014) and bottom line (1,519 t; 1997-2014). For consistency with the stock assessment model for gummy shark, the gillnet analysis considered Bass Strait, South Australia and Tasmania separately. Catches are greatest in Bass Strait and least in Tasmania.

Reported gillnet catches in South Australia have dropped to approximately one third of the 2010 levels (CatchT; Table 22.6) but this is balanced by corresponding increases in bottom line (Table 22.18). The shift is a response to the large scale closures to gillnet gear imposed to reduce the risk of interactions with marine mammals. This avoidance of gummy shark in areas of historical high CPUE has led to apparent changes in the CPUE for gillnets in South Australia. The impact on catches and numbers of records is obvious (Figure 22.2). However, there was an increase in catch in reported gillnet catch 2014 (122 t) relative to 2013 (~60 t). Such changes may cast a shadow as to whether this series can be considered as a reliable indicator of the stock's status in South Australia. The recent increase in standardized CPUE (Figure 22.3) may reflect a real change in abundance, or may reflect learning as the industry adapt to fishing in areas previously unfamiliar to them.

Gillnet catches of gummy shark in Bass Strait have been relatively stable (~800 t) in recent years. Standardized indices increased in 2014 compared to the previous year (Figure 22.6). Standardized CPUE have been fairly stable over the last four years (but below the overall long-term average; Figure 22.6). There has been an overall decline since 2008. How much of this decline is due to the avoidance of school shark areas would be difficult to determine.

Tasmania has a relatively minor gummy shark catch (Table 22.12) and the standardized CPUE has been noisy but relatively flat since 1997, with the most recent years possibly indicating a slight decline (Figure 22.9). However, the relatively few fishing operations performed in this region result in wide confidence intervals for the standardized CPUE indices.

22.5.2 Gummy shark – Trawl

Reported gummy shark catches by trawl containing shots less than 30 kg has been consistently more frequent than catches in the gillnet fishery (Figure 22.11), indicating that they are not targeted . Most trawl catches are taken from shark zones ESB, WA and WSA. Standardized trawl CPUE has increased at least 38% since 2007 (Figure 22.12) and presents a strong contrast to all of the gill net CPUE trends (Figure 22.3, Figure 22.6, Figure 22.9)

22.5.3 Gummy shark – Bottom Line

Associated with the drop in gillnet catches in South Australia there has been a marked increase in hook caught catches. Catches in the last two years have remained very similar at ~ 228 t (Table 22.18). The point estimate of the standardized CPUE increased markedly in 2013 but declined in 2014. However, taking into account the the wide and overlapping confidence bands, there is no difference in their standardized CPUE indices for these two years (Figure 22.15).

A CPUE standardization on the bottom line catches (using catch per shot) exhibits much broader confidence intervals owing to the smaller numbers of records relative to gillnet records. Nevertheless, the standardization has a large effect upon the geometric mean CPUE, primarily due to the vessel effect (Figure 22.16). Since about 2010, it has been rising above the long term average (with a possible decline in 2014).

22.5.4 School shark

Industry avoidance of school sharks is reasonably successful, although there are reports that a scarcity of quota for leasing at economic prices is making it difficult for operators to land school shark, consequently unmeasured discarding may be occurring. Recent reports of high school shark catches (SharkRAG No. 1, Meeting Minutes 2014) may also have made it difficult for industry to keep the bycatch ratio of school shark to gummy shark catches below 20%.

There has been a shift in fishing methods to lining methods with a greater catch by bottom long-line than by Auto-line (e.g. during 2014, 15.4 t Auto-line in 2014 compared to 64.4 t Bottom line). Reportd trawl catches in 2014 have decreased by ~ 7 t (but note that this excludes discards) relative to 2013, despite a similar number of records (Table 22.21).

Due to the change in behaviour of the gillnet industry, moving from targeting school sharks to increasing avoidance, their CPUE cannot be taken to be indicative of the stock status in any way. By contrast, although trawl catches are low, fishers do not appear to have changed their behaviour during 1996-2014. The trend in school shark standardized CPUE taken by trawl is gradually increasing (except for 2014); not as rapidly as in gummy sharks, but it has a similar trend (Figure 22.18). However, inspection of the on-board sampling for length frequencies suggests that there has been an increased proportion of smaller school sharks being measured in 2012 and 2014, although not evident from the 2013, despite the large sample size (across all methods; Thomson et al. 2015, page 258).

22.5.5 Elephant fish

Elephant fish are predominately taken by gillnet (Table 22.28). Catches are predominately in about 50 m of water, with most of the records and catch from this depth (Figure 22.21). The number of vessels reporting gillnet catches of elephant fish dropped strongly just before the structural adjustment from about 56 vessels down to about 32, and has stayed roughly stable since. A high proportion of reported catches are less than 30 kg, which is suggests that these are rarely if ever targeted (Figure 22.21). There is no trend through time in the proportion of these small catches. Much of the reported catch is from Eastern Bass Strait (Table 22.29). Industry members have indicated that catches made far from markets are seldom landed due to the cost of transport relative to the low market value of this fish (David Stone, pers comm.).

Reported catches by trawl have remained stable at ~ 10 t in recent years (Table 22.28), providing insufficient information for a useable standardization. Similarly, Danish seine catches have been consistent but low across the years and therefore not currently suitable for a useful standardization (Table 22.28).

Standardized CPUE (not adjusted for discards) of gillnet caught elephant fish show occasional rises and falls about the longer term average (Figure 22.22). There is no evidence of an overall rise or fall apparent in the data. The factor having the greatest influence on the CPUE appears to be which vessel is fishing with a major change in the patterns indicated following the structural adjustment (Figure 22.23).

22.5.6 Saw sharks

Saw shark catches have been split primarily between gillnets and trawls, with a lesser quantity taken by Danish seine. Discarding, which has only really been examined in the context of CPUE in recent years, was relatively high (15 – ~26%) from 2011 to 2013 (Thomson et al. 2015; page 270). The structural adjustment certainly affected vessel numbers reporting catches of saw sharks with number of gillnet vessels dropping from approximately 80 in 2003 down to about 44 in 2007 (Table 22.30). The number of trawl vessels reporting saw sharks also approximately halved from about 65 in 2000 (i.e. pre-2007) to about 39 post-2006 (Table 22.31). Danish Seine vessels reporting saw sharks dropped from about 22 vessels a year down to about 16 vessels each year (Table 22.39).

For all methods, the proportion of the catch reported to be in shots of < 30kg is also relatively high (Danish seine (>70%) greater than gillnet or trawl). 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 (except for 2014), although it do not account for the level of discarding that occurs. If discarding has been increasing over time, the inclusion of discarding may lead to an increase in the CPUE exhibited by the fishery. The effect of the South Australian closures can be seen from the impact of the shark zone factors (Figure 22.26).

Trawl catches are taken in a much wider depth range (0-500 m) than gillnet catches (0-150 m). The standardized CPUE varies around an average of 1.0, ranging between 0.8 and 1.2 since 1997; it is flat and noisy (Figure 22.28). The impact of the introduction of closures to gillnetting in 2010 is evidenced by the influence of the shark zone factor (Figure 22.29). The use of shark area rather than shark zone for both trawl and Danish seine caught saw shark caused no differences in standardized CPUE.

Danish seine catches tend to be more focussed in the shallower depths less than 100 m. Following an initial high standardized CPUE during 1997-2001, a period when reported catches were consistently < 8 tonnes, the standardized Danish seine CPUE is essentially flat from 2001 to 2013 apart from a small decrease in 2014 (Figure 22.33).

Over the period 2001 – 2013 Danish seine and trawl based saw shark CPUE follow essentially the same trajectory when placed on the same scale. If these CPUEs are indexing stock status, there is no indication of a change in the relative abundance, despite the downward trend exhibited by gillnet-CPUE.

22.6 Acknowledgements

Thanks goes to Mike Fuller (CSIRO Hobart), for preliminary processing of the catch and effort data as received from the Australian Fisheries management Authority. Thanks also goes to Malcolm Haddon and Robin Thomson for helpful discussions and editorial commenst to this report.

22.7 References

Burnham, K.P., Anderson, D.R. (2002). Model selection and multimodel inference: A practical information-theoretic approach (2nd Edn). Springer-Verlag.

Haddon, M. (2014) CPUE Standardization and Characterization of the SESSF Shark Fishery. Data from 1997 – 2013. CSIRO. Hobart. 63 p.

McCullagh, P., Nelder, J. (1989). Generalized Linear Models, Second Edition. Boca Raton: Chapman and Hall/CRC.

Thomson R.B., Sporcic M., Klaer N., Fuller M., Krucic-Golub K. and Upston J. (2015). Data summary for the Southern and Eastern Scalefish and Shark Fishery: Logbook, Landings and Observer Data to 2014 (DRAFT). CSIRO, Australia and AFMA. 282 p.

Upston, J., Thomson, R. (2015). Integrated Scientific Monitoring Program for the Southern and Eastern Scalefish and Shark Fishery – Discard estimation 2014. Technical document provided to AFMA October 2015. Draft provided to RAGs 22-25 September 2015. 34 pp.

23. Tier 4 analyses for elephant fish and sawshark in the SESSF (data to 2014)

Miriana Sporcic and Robin Thomson

CSIRO, GPO Box 1538, Hobart, Tasmania

23.1 Executive summary

Tier 4 analyses were conducted to calculate Recommended Biological Catches (RBCs) for sawshark and elephant fish within the SESSF. Standardized CPUE for both species were estimated using the Commonwealth logbook database only (instead of including earlier data into the same time series). This reflects the fact that the reference periods selected by SharkRAG derive from periods that are covered using the Commonwealth logbook data. Tier 4 analyses assume the target CPUE is a proxy for 48% of unfished biomass for both species (groups). However, neither species is reported as being targeted in the fishery (when using any method), so the calculated RBCs are inherently conservative. Alternative estimates based on a proxy target of 40% were therefore calculated.

Elephant fish data used to standardize CPUE were also extracted from the Commonwealth logbook database. In 2014, standardized gillnet-CPUE fell below the long-term mean of the entire time series. However, these annual standardized-CPUE indices do not include discards, which since 2007, and particularly since 2011 have been found to be large. Including discards in the calculation of CPUE, total catch and updated recreational catch in a Tier 4 analysis increased CPUE, and increased the estimated RBC (scenario D3; 305.61 t). When discards are relatively high, as is the case with elephant fish then including discards more closely reflects the fishery dynamics. The Tier 4 method used to adjust CPUE to account for discarding assumes that a portion of each shot of elephant fish catch is discarded. If a significant portion of shots of elephant fish catch are entirely discarded then this assumption is violated and the adjustment will be biased high because catches that were entirely discarded, contributed to, and inflated, the estimated discard rate, but did not contribute to the standardized CPUE.

Given that annual reported sawshark trawl catch is approaching the level of gillnet catch (accounting for inter-annual variation), two Tier 4 analyses were conducted, i.e., using standardized trawl-CPUE and gillnet-CPUE respectively. In 2014, standardized sawshark gillnet-CPUE was slighter higher compared to 2013, and the Tier 4 analysis (assuming no discards), which considers the most recent four-year mean CPUE was about 80% of the target CPUE, while the estimated RBC was 226.36 t. This mean CPUE was approximately 90% of the target CPUE when including discards and the estimated RBC was 296.06 t. Whether the overall apparent decline in standardized gillnet-CPUE constitutes 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 sawshark market value). By contrast, standardized trawl-CPUE exhibited an overall flat trend. In 2000, trawl catches contributed approximately 20% of the total catch, whereas gillnet catches accounted for 78%. By contrast, in 2013 both trawl and gillnet catches each accounted 43% of the total catch, with the remaining catch mostly attributed to Danish seine. In 2014, trawl caught sawshark contributed 41% of the total catch while gillnet-catch contributed 49% of the total catch. In 2014, standardized trawl-CPUE was slighter lower compared to 2013. The most recent four-year mean CPUE (based on the Tier 4

analysis, assuming no discards), was greater than the target CPUE, and the estimated RBC was 534.99 t. The four-year mean CPUE was also greater the target CPUE when including discards and the estimated RBC was 650.28 t.

In summary, the scenarios for elephant fish and sawshark and corresponding Tier 4 RBC estimates are:

Common	Method	Target (%)	Discard	RBC (t)
Elephant fish	Gillnet	40	No	127.203
Elephant fish	Gillnet	40	Yes	423.292
Elephant fish	Gillnet	40	Yes (D1)	429.637
Elephant fish	Gillnet	40	Yes (D2)	429.637
Elephant fish^	Gillnet	40	Yes (D3)	305.614
Sawshark	Gillnet	40	No	226.358
Sawshark	Gillnet	40	Yes	296.062
Sawshark^^	Trawl	40	No	534.990
Sawshark	Trawl	40	Yes	650.277

^ Tier 4 analyses recommended by SharkRAG (Meeting No. 2 Minutes, November 2015);
^^Tier 4 analyses recommended by SharkRAG (Meeting No. 1 Minutes, October 2015)

23.2 Introduction

The assessment of Australia's Southern and Eastern Scalefish and Shark Fishery (SESSF) is based on a multi- tiered system, defined by the amount of available information, whose outcomes are used to inform management decisions. The Tier levels range from integrated stock assessments, containing the most information (Tier 1) to rules based on catch and CPUE only (Tier 4). Specifically, the Tier 4 method is applied to species for which only limited age and length information is available, i.e., a minimum of annual time series of total catch and standardized CPUE yielding no reliable information on current biomass levels or exploitation rates. If available, and if necessary, other inputs corresponding to total removals, such as State and/or recreational catch as well as discards can also be used to adjust the CPUE. These removals are also used to adjust the resulting RBC to calculate the TAC. The outcomes of Tier 4 analyses, i.e., Recommended Biological Catch (RBC) should be more conservative compared to those of higher (i.e., lower numbered) Tiers, since this method is considered to be more precautionary in the absence of information.

The Tier 4 method requires the definition of a reference period for catch and CPUE which is used as the effective target for the fishery and 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 (MEY). In practice, this target is also taken as a proxy for B_{MEY}. SharkRAG considers this reference period to correspond to when the fishery was in a desirable state both biologically and economically. The chosen periods are 1996 to 2007 for elephant fish and 2002 to 2008 for sawshark.

The Harvest Strategy Policy (HSP; DAFF, 2007) does not require that all species in a multi-species fishery aim to achieve MEY, and this is especially the case for bycatch species. However, the objective of avoiding the limit reference point remains. Currently, the limit reference point (within a Tier 4 method) is defined as 48% of the target CPUE. If the mean CPUE over the last four years drops below this limit the RBC is automatically zero.

In addition, the HSP 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 risk have been considered in full.*
>
> (DAFF, 2007, p 25)

This report determines RBCs for elephant fish and sawshark based on updated available data (to 2014).

23.3 Methods

The Tier 4 method has been most recently described by Haddon (2014) and an excerpt is provided in the Appendix. This method used annual SESSF catches and standardized CPUE (Sporcic 2015). Total catches (including catches from State waters, landings, any discards, and/or recreational catches) were also used.

23.3.1 Discard rates, discards, CPUE, landings, State and recreational catch

Discard rates and CPUE

Updated discard rate estimates (Upston and Klaer 2011, 2012, 2013; Upton 2014; Upston and Thomson 2015) have been included in the Tier 4 analyses for both elephant fish and sawshark. The most recent estimated discard rate for elephant fish (0.5743) is similar to the previous three years. By contrast, the estimated discard rate for 2010 is much lower (0.2441) but contained adequate sample coverage (Upston and Klaer, 2011) although adequate sampling of non-trawl gears only occurred for later in the year. This difference calls into question previous discard estimates, so three different Tier 4 analyses were conducted for elephant fish including discards (i) using the 2010 estimate for years 2007-2009 inclusive (Section 23.4.1), (ii) applying the mean discard rate from 2011 to 2014 to the period 2007 to 2009 and 0.2441 for 2010 (D1; Section 23.4.2) and (iii) applying the mean discard rate from 2011 to 2014 to the period 2007 to 2010 (D2; Section 23.4.3). The latter was recommended by SharkRAG (see SharkRAG Meeting No. 1 Minutes, October 2015).

Sawshark standardized trawl-CPUE shows a relatively flat trend in recent years in contrast to gillnet-CPUE, which appears to be declining (except for 2014; Figure 23.1). This is despite larger gillnet catches in recent years (Figure 23.2). This could reflect fishery dynamics, as opposed to stock abundance, given that fishers do not target sawshark and in particular there is some level of avoidance using gillnets (see SharkRAG Meeting No. 1 Minutes, October 2015). Given that annual reported sawshark trawl catch appears to be approaching gillnet catch levels (accounting for inter-annual variation; Figure 23.2), four Tier 4 analyses were conducted with and without discards, i.e., using standardized gillnet-CPUE and trawl-CPUE respectively (Section 23.4.4). Emphasis was placed on trawl-CPUE without adjusting CPUE for discarding following SharkRAG's recommendation (see SharkRAG Meeting No. 1 Minutes, October 2015).

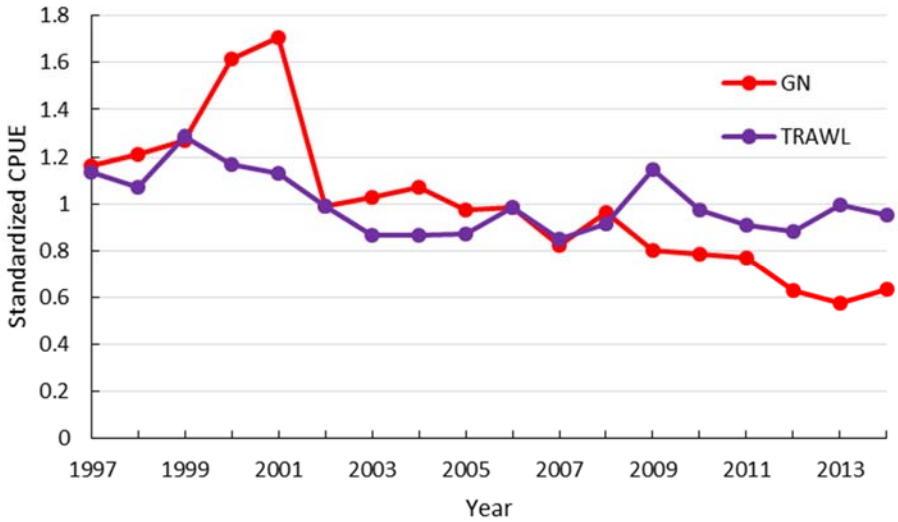


Figure 23.1. Sawshark standardized CPUE by gillnet (GN) and trawl (TRAWL) from Sporcic (2015).

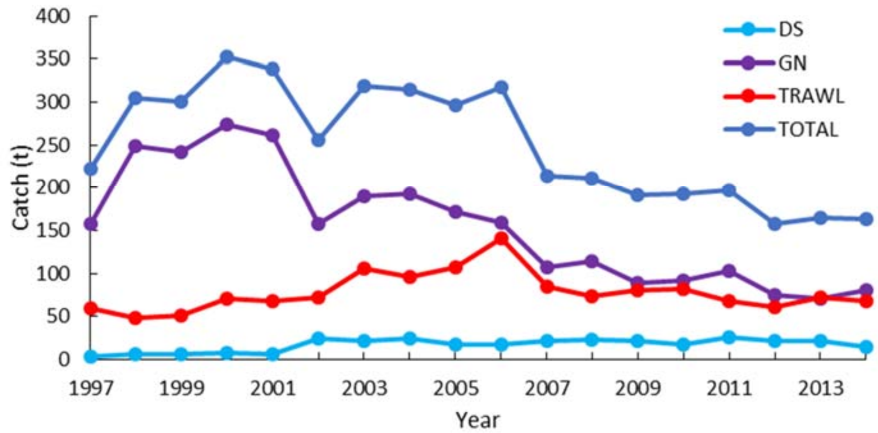


Figure 23.2. Annual sawshark (t) catch by Danish seine (DS), gillnet (GN), trawl (TRAWL) and overall catch (TOTAL).

Discards – ISMP

The AFMA Observer Program (previously ISMP) collects information on discarded and retained portion of the catch of fishing shots, for quota species. This data (i.e., to 2014 inclusive) were used for elephant fish and sawshark to investigate whether or not each fishery typically discards (i) entire catches, or (ii) parts or (iii) just a certain proportion of each catch. Percent retained and discard estimates for both elephant fish and sawshark gillnet fisheries, and for the sawshark trawl fishery are shown (Figure 23.3; Table 23.1). In particular, a large percentage (i.e., 39%) of shots of elephant fish catch were completely discarded (Figure 23.3; Table 23.1), so the discard adjustment made to CPUE (see Appendix) is biased high. This could be corrected by re-calculating the annual discard rates, ignoring shots that were entirely discarded, however, the number of observed shots is relatively low and the corresponding coefficient of variation (CV) for the reduced dataset likely to be high. The relatively large proportion of shots that were completely retained is also high, particularly for sawshark caught by both gillnet and trawl (Figure 23.3; Table 23.1). In principle, this does not seriously violate the assumption of the CPUE adjustment method, that all shots discard some (fixed) proportion of fish, however it would add to the unexplained variation between the observed and expected CPUE.

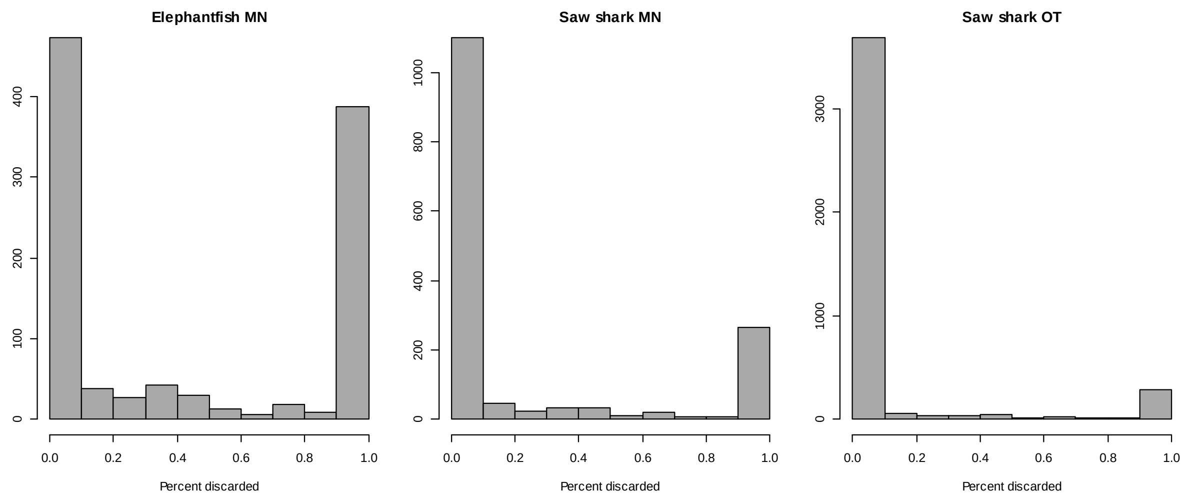


Figure 23.3. Frequency of the observed shots where between 0 and 100% of all elephant fish (gillnet –MN) or sawshark (gillnet: MN or trawl: OT) were discarded.

Table 23.1. Percent of all observed shots (up to 2014 inclusive) of elephant fish and sawshark catch that were entirely discarded (All discarded), entirely retained (All retained), or partly discarded (Some discarded). Gillnet (GN); Trawl (TRW).

Common name	Gear	All discarded (%)	All retained (%)	Some discarded (%)
Elephant fish	GN	39	27	34
Sawshark	GN	12	54	34
Sawshark	TRW	5	69	26

Note that shots where 100% of the catch were discarded are not included in standardized CPUE estimates because this information does not appear in the Commonwealth logbook database from which it is calculated. Corrected standardized CPUE series using annual estimates of overall discard rates assume that every shot is partially discarded and that every shot in the year has the same percentage discarded. Therefore, the average discard rates that apply to those shots are the average, not of all observed shots, but only of those shots that were at least partially retained.

Landings, State and recreational catch

Commonwealth landings were derived from the Quota landings database. The species code in the landings database for elephant fish was SHE (*Callorhinchus milii* or elephant fish) and for sawshark were (i) SAW (*Pristiophorus cirratus* or common sawshark), (ii) SHN (*Pristiophorus nudipinnis* or southern sawshark), and (iii) SHW (*Pristiophoridae* or sawsharks).

Most recent updates to State and/or recreational catches have been included in the analyses for both species groups where applicable. Following previous analyses for elephant fish, a constant recreational catch of 29 t from 2002 was considered (Section 23.4.1). An updated recreational catch survey estimate for 2008 (45 t) from Braccini et al. (2008) was also incorporated into the Tier 4 analyses by interpolating 29 t in 2002 to 45 t in 2008 and remaining constant thereafter (Section 23.4.2; 23.4.3).

The reference period selected by SharkRAG was 1996 – 2007 for elephant fish and 2002 – 2008 for sawshark, and was subsequently employed in all Tier 4 analyses.

23.4 Results

23.4.1 Elephant fish – Gillnet

The following two Tier 4 analyses assume a recreational catch of 29 t from 2002 and either excludes (Section 23.4.1.1) or includes discards (Section 23.4.1.2).

Table 23.2. Elephant Fish. Data used in the Tier 4 analysis. Grey cells relate to the reference period. Total is the catch. From 2002, it comprises reported catches from the CDRs including 29 t of recreational fishing, State catches and discards Recreational catch (RecCatch); Discard rate (DisRate); standardized CPUE (StandCE); standardized CPUE including discards (DiscCE); Geometric mean (GeoMean). All analyses use subsets of this data

Year	Catch (t)	Discard (t)	Total (t)	(D/C)+1	RecCatch (t)	Disrate	StandCE	DiscCE	GeoMean
1986	70.522	6.537	77.059	1.093					
1987	65.209	6.336	71.545	1.097					
1988	79.400	6.710	86.110	1.085					
1989	65.460	6.211	71.671	1.095					
1990	57.729	5.579	63.308	1.097					
1991	74.617	6.920	81.537	1.093					
1992	76.829	7.107	83.936	1.093					
1993	57.060	5.434	62.494	1.095					
1994	64.199	5.950	70.149	1.093					
1995	54.694	5.184	59.878	1.095					
1996	111.796	12.524	124.320	1.112					
1997	94.550	9.573	104.123	1.101			0.9636	0.7426	6.6167
1998	89.802	8.539	98.341	1.095			0.9044	0.6930	6.6317
1999	111.624	9.448	121.072	1.085			1.0271	0.7796	7.0956
2000	95.801	8.189	103.990	1.085			1.2555	0.9537	8.3170
2001	87.880	7.533	95.413	1.086			1.2922	0.9817	9.3138
2002	88.744	5.266	94.010	1.059	29		0.9213	0.6829	6.1646
2003	105.582	7.679	113.261	1.073	29		0.9024	0.6774	5.9048
2004	109.548	6.323	115.871	1.058	29		0.8595	0.6362	5.8738
2005	114.461	6.852	121.313	1.060	29		0.8941	0.6631	6.2019
2006	104.498	6.814	111.312	1.065	29		0.9656	0.7198	6.1036
2007	96.642	31.210	127.852	1.323	29	0.2441	1.0429	0.9655	6.6645
2008	100.291	32.389	132.680	1.323	29	0.2441	1.1239	1.0404	7.0127
2009	114.555	36.995	151.551	1.323	29	0.2441	1.2538	1.1607	8.2736
2010	100.052	32.312	132.364	1.323	29	0.2441	0.9741	0.9018	6.1679
2011	95.868	194.588	290.455	3.030	29	0.6699	0.8631	1.8299	5.3919
2012	108.847	149.928	258.775	2.377	29	0.5794	1.0039	1.6701	6.5543
2013	107.624	148.705	256.329	2.382	29	0.5801	0.9203	1.5338	6.7187
2014	92.497	124.776	217.273	2.349	29	0.5743	0.8322	1.3679	5.9065

23.4.1.1 Elephant fish – Gillnet. Proxy target 40% - No Discards

This analysis uses 29 t of recreational catch from 2002 onwards and excludes discards.

Table 23.3. Elephant Fish – gillnet RBC calculations. C* and $CPUE_{targ}$ relate to the period 1996 – 2007, $CPUE_{Lim}$ is 40% of the original target, and $\overline{CPUE}$ is the mean CPUE 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 = 40% B_0.

1st Reference Year	1996
2nd Reference Year	2007
C*	109.687
$CPUE_{targ}$	0.835
$CPUE_{Lim}$	0.401
$\overline{CPUE}$	0.9049
Scaling Factor	1.1597
Wt_Discard	139.165
RBC	**127.203**

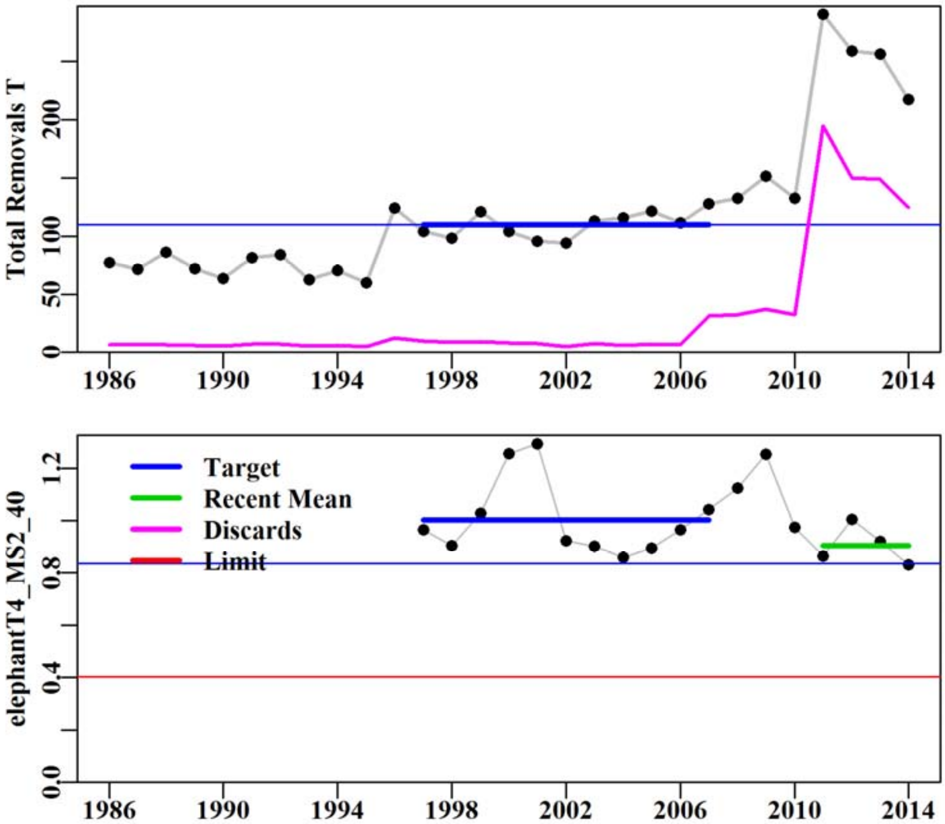


Figure 23.4. Elephant Fish – gillnet. Top panel: total removals (black), target catch (fine blue line, C*). Bottom panel: standardized CPUE (black), target CPUE (lower blue line) and limit reference CPUE (lower red line). Thick lines represent the reference period for catches (1997-2007; top panel, blue), CPUE (1997-2007; bottom panel, blue), and recent mean CPUE (last four years; bottom panel; green). The fine blue line below the target CPUE is the revised target based on a 40% B_0 proxy target for non-target species in a mixed fishery.

23.4.1.2 Elephant fish – Gillnet. Proxy target 40% - Including Discards

This analysis uses 29 t of recreational catch from 2002 onwards and includes discards.

Table 23.4. Elephant Fish – gillnet RBC calculations. C* and $CPUE_{targ}$ relate to the period 1996 – 2007, $CPUE_{Lim}$ is 40% of the original target, and $\overline{CPUE}$ is the mean CPUE 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 = 40% B_0.

1st Reference Year	1997
2nd Reference Year	2007
C*	109.687
$CPUE_{targ}$	0.6436
$CPUE_{Lim}$	0.3089
$\overline{CPUE}$	1.6004
Scaling Factor	3.8591
Wt_Discard	139.165
RBC	**423.292**

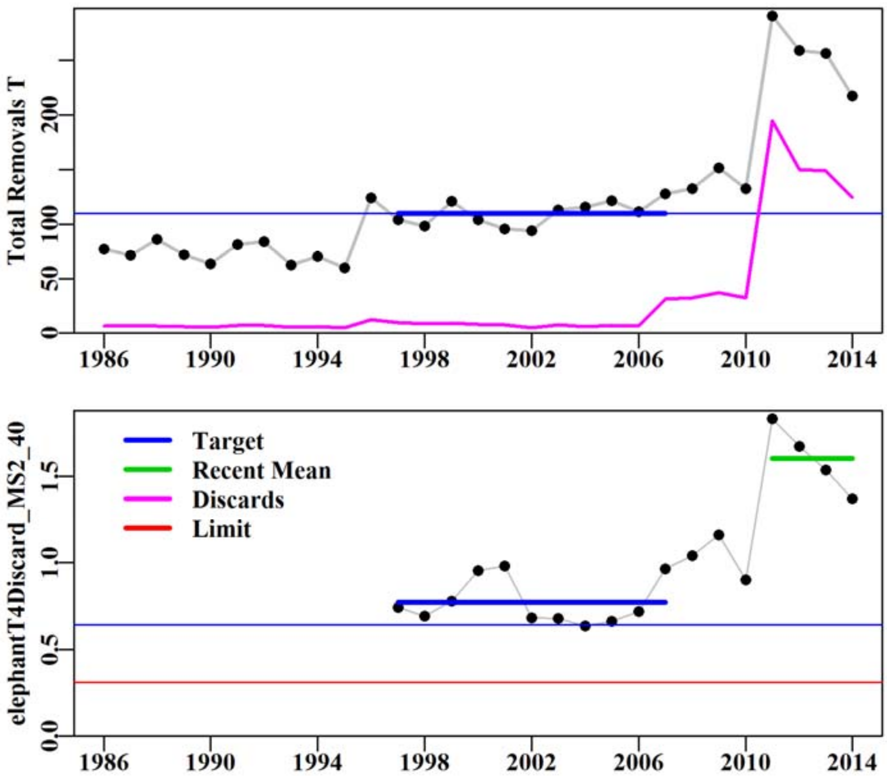


Figure 23.5. Elephant Fish – gillnet. Top panel: total removals (black), target catch (fine blue line, C*). Bottom panel: standardized CPUE (black), target CPUE (lower blue line) and limit reference CPUE (lower red line). Thick lines represent the reference period for catches (1997-2007; top panel, blue), CPUE (1997-2007; bottom panel, blue), and recent mean CPUE (last four years; bottom panel; green). The fine blue line below the target CPUE is the revised target based on a 40% B_0 proxy target for non-target species in a mixed fishery. In this case the discard catches have been included in the CPUE estimates, thereby increasing them markedly.

23.4.2 Elephant fish – gillnet including discards (D1) and updated recreational catch

The following analysis includes changes to annual recreational catch from 29 t in 2002 interpolated to 45 t in 2008 and 45 t thereafter. The discard rate of 0.6009 during 2007 to 2009 corresponds to the mean discard rate during 2011 to 2014. The estimated discard rate of 0.2441 in 2010 is low relative to subsequent years but contains adequate sample size.

Table 23.5. Elephant Fish. Data used in the Tier 4 analysis. Grey cells relate to the reference period. Total is the catch. From 2002 it comprises reported catches from the CDRs including recreational fishing (29 t in 2002, interpolated to 45 t (2008) and constant thereafter), State catches and discards. Recreational catch (RecCatch); Discard rate (DisRate); standardized CPUE (StandCE); standardized CPUE including discards (DiscCE); Geometric mean (GeoMean). All analyses use subsets of this data.

Year	Catch (t)	Discard (t)	Total (t)	(D/C)+1	RecCatch (t)	DisRate	StandCE	DiscCE	GeoMean
1986	70.522	6.537	77.059	1.093					
1987	65.209	6.336	71.545	1.097					
1988	79.400	6.710	86.110	1.085					
1989	65.460	6.211	71.671	1.095					
1990	57.729	5.579	63.308	1.097					
1991	74.617	6.920	81.537	1.093					
1992	76.829	7.107	83.936	1.093					
1993	57.060	5.434	62.494	1.095					
1994	64.199	5.950	70.149	1.093					
1995	54.694	5.184	59.878	1.095					
1996	111.796	12.524	124.320	1.112					
1997	94.550	9.573	104.123	1.101			0.9636	0.7426	6.6167
1998	89.802	8.539	98.341	1.095			0.9044	0.6930	6.6317
1999	111.624	9.448	121.072	1.085			1.0271	0.7796	7.0956
2000	95.801	8.189	103.990	1.085			1.2555	0.9537	8.3170
2001	87.880	7.533	95.413	1.086			1.2922	0.9817	9.3138
2002	88.744	5.266	94.010	1.059	29		0.9213	0.6829	6.1646
2003	108.249	7.679	115.928	1.071	31.667		0.9024	0.6774	5.9048
2004	114.881	6.323	121.204	1.055	34.333		0.8595	0.6362	5.8738
2005	122.461	6.852	129.313	1.056	37.000		0.8941	0.6631	6.2019
2006	115.164	6.814	121.978	1.059	39.667		0.9656	0.7198	6.1036
2007	109.975	165.605	275.580	2.506	42.333	0.6009	1.0429	0.9655	6.6645
2008	116.291	175.117	291.408	2.506	45	0.6009	1.1239	1.0404	7.0127
2009	130.555	196.596	327.151	2.506	45	0.6009	1.2538	1.1607	8.2736
2010	116.052	37.479	153.531	1.323	45	0.2441	0.9741	0.9018	6.1679
2011	111.868	227.064	338.931	3.030	45	0.6699	0.8631	1.8299	5.3919
2012	124.847	171.967	296.814	2.377	45	0.5794	1.0039	1.6701	6.5543
2013	123.624	170.812	294.436	2.382	45	0.5801	0.9203	1.5338	6.7187
2014	108.497	146.359	254.857	2.349	45	0.5743	0.8322	1.3679	5.9065

Table 23.6. Elephant Fish – gillnet RBC calculations. C* and $CPUE_{targ}$ relate to the period 1996 – 2007, $CPUE_{Lim}$ is 40% of the original target, and $\overline{CPUE}$ is the mean CPUE 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 = 40% B_0.

1st Reference Year	1997
2nd Reference Year	2007
C*	125.541
$CPUE_{targ}$	0.6123
$CPUE_{Lim}$	0.2939
$\overline{CPUE}$	1.3835
Scaling Factor	3.4223
Wt_Discard	161.675
RBC	**429.637**

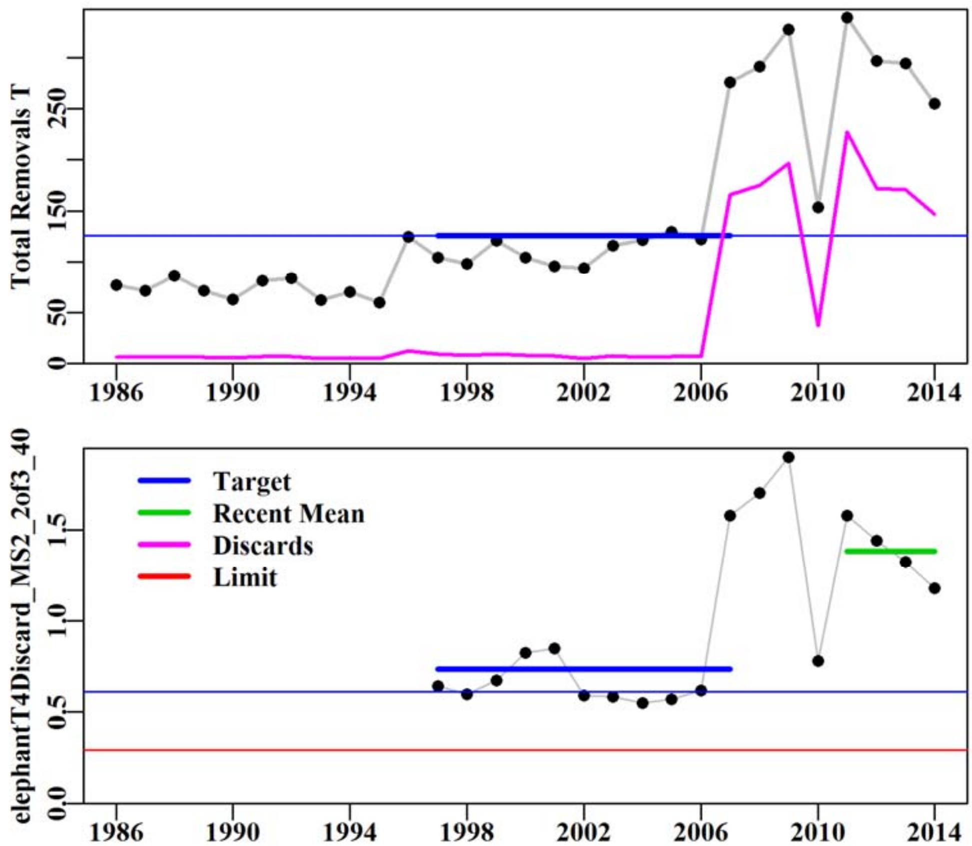


Figure 23.6. Elephant Fish – gillnet. Top panel: total removals (black), target catch (fine blue line, C*). Bottom panel: standardized CPUE (black), target CPUE (lower blue line) and limit reference CPUE (lower red line). Thick lines represent the reference period for catches (1997-2007; top panel, blue), CPUE (1997-2007; bottom panel, blue), and recent mean CPUE (last four years; bottom panel; green). The fine blue line below the target CPUE is the revised target based on a 40% B_0 proxy target for non-target species in a mixed fishery. In this case the discard catches have been included in the CPUE estimates, thereby increasing them markedly.

23.4.3 Elephant fish – gillnet including discards (D2) and updated recreational catch

The following analysis includes changes to annual recreational catch from 29 t in 2002 interpolated to 45 t in 2008 and 45 t thereafter. The discard rate of 0.6009 during 2007 to 2010 corresponds to the mean discard rate during 2011 to 2014 requested by SharkRAG to incorporate in the analysis.

Table 23.7. Elephant Fish. Data used in the Tier 4 analysis. Grey cells relate to the reference period. Total is the catch. From 2002, it comprises reported catches from the CDRs including recreational fishing (29 t in 2002, interpolated to 45 t (2008) and constant thereafter), State catches and discards. Recreational catch (RecCatch); Discard rate (DisRate); standardized CPUE (StandCE); standardized CPUE including discards (DiscCE); Geometric mean (GeoMean). All analyses use subsets of this data.

Year	Catch (t)	Discard (t)	Total (t)	(D/C)+1	RecCatch	DisRate	StandCE	DiscCE	GeoMean
1986	70.522	6.537	77.059	1.093					
1987	65.209	6.336	71.545	1.097					
1988	79.400	6.710	86.110	1.085					
1989	65.460	6.211	71.671	1.095					
1990	57.729	5.579	63.308	1.097					
1991	74.617	6.920	81.537	1.093					
1992	76.829	7.107	83.936	1.093					
1993	57.060	5.434	62.494	1.095					
1994	64.199	5.950	70.149	1.093					
1995	54.694	5.184	59.878	1.095					
1996	111.796	12.524	124.320	1.112					
1997	94.550	9.573	104.123	1.101			0.9636	0.7426	6.6167
1998	89.802	8.539	98.341	1.095			0.9044	0.6930	6.6317
1999	111.624	9.448	121.072	1.085			1.0271	0.7796	7.0956
2000	95.801	8.189	103.990	1.085			1.2555	0.9537	8.3170
2001	87.880	7.533	95.413	1.086			1.2922	0.9817	9.3138
2002	88.744	5.266	94.010	1.059	29		0.9213	0.6829	6.1646
2003	108.249	7.679	115.928	1.071	31.667		0.9024	0.6774	5.9048
2004	114.881	6.323	121.204	1.055	34.333		0.8595	0.6362	5.8738
2005	122.461	6.852	129.313	1.056	37.000		0.8941	0.6631	6.2019
2006	115.164	6.814	121.978	1.059	39.667		0.9656	0.7198	6.1036
2007	109.975	165.605	275.580	2.506	42.333	0.6009	1.0429	0.9655	6.6645
2008	116.291	175.117	291.408	2.506	45	0.6009	1.1239	1.0404	7.0127
2009	130.555	196.596	327.151	2.506	45	0.6009	1.2538	1.1607	8.2736
2010	116.052	174.756	290.809	2.506	45	0.6009	0.9741	0.9018	6.1679
2011	111.868	227.064	338.931	3.030	45	0.6699	0.8631	1.8299	5.3919
2012	124.847	171.967	296.814	2.377	45	0.5794	1.0039	1.6701	6.5543
2013	123.624	170.812	294.436	2.382	45	0.5801	0.9203	1.5338	6.7187
2014	108.497	146.359	254.857	2.349	45	0.5743	0.8322	1.3679	5.9065

Table 23.8. Elephant Fish – gillnet RBC calculations. C* and $CPUE_{targ}$ relate to the period 1996 – 2007, $CPUE_{Lim}$ is 40% of the original target, and $\overline{CPUE}$ is the mean CPUE 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 = 40% B_0.

1st Reference Year	1997
2nd Reference Year	2007
C*	125.541
$CPUE_{targ}$	0.5895
$CPUE_{Lim}$	0.2829
$\overline{CPUE}$	1.3319
Scaling Factor	3.4223
Wt_Discard	161.675
RBC	**429.637**

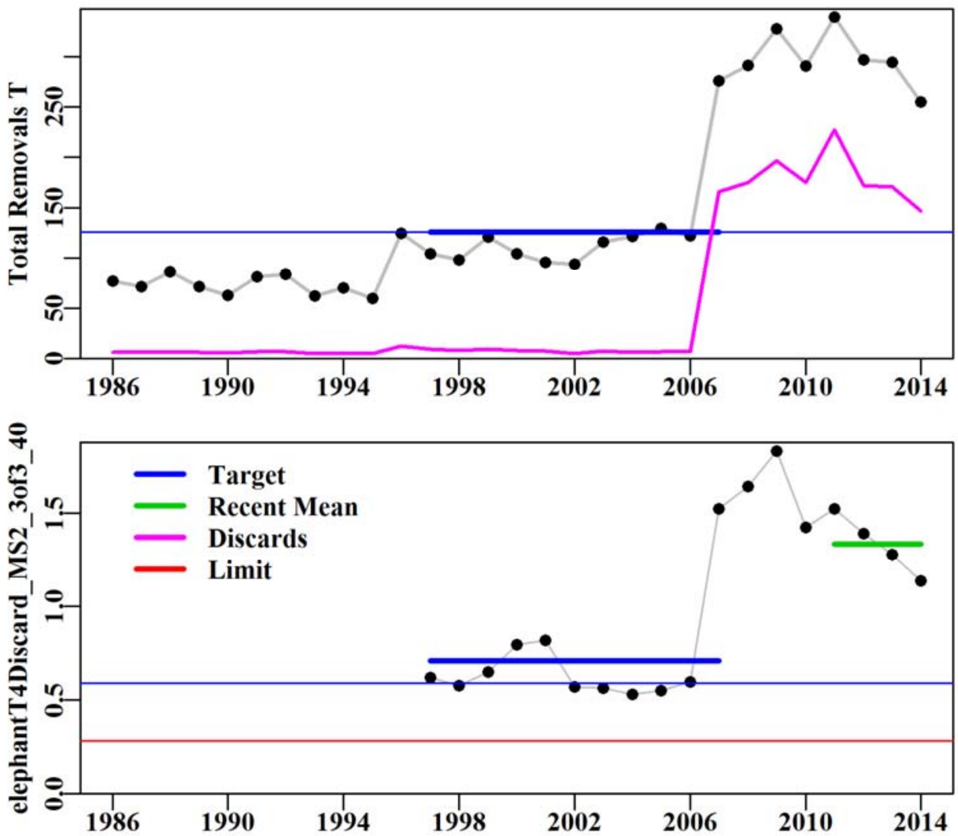


Figure 23.7. Elephant Fish – gillnet. Top panel: total removals (black), target catch (fine blue line, C*). Bottom panel: standardized CPUE (black), target CPUE (lower blue line) and limit reference CPUE (lower red line). Thick lines represent the reference period for catches (1997-2007; top panel, blue), CPUE (1997-2007; bottom panel, blue), and recent mean CPUE (last four years; bottom panel; green). The fine blue line below the target CPUE is the revised target based on a 40% B_0 proxy target for non-target species in a mixed fishery. In this case the discard catches have been included in the CPUE estimates, thereby increasing them markedly.

23.4.4 Elephant fish – gillnet including discards (D3) and updated recreational catch

This analysis uses the mean discard rates corresponding to 2011-2014 extrapolated back to 1986.

Table 23.9. Elephant Fish. Data used in the Tier 4 analysis. Grey cells relate to the reference period. Total is the catch. From 2002, it comprises reported catches from the CDRs including recreational fishing (29 t in 2002, interpolated to 45 t (2008) and constant thereafter), State catches and discards. Recreational catch (RecCatch); Discard rate (DisRate); standardized CPUE (StandCE); standardized CPUE including discards (DiscCE); Geometric mean (GeoMean). All analyses use subsets of this data.

Year	Catch (t)	Discard (t)	Total (t)	(D/C)+1	RecCatch	DisRate	StandCE	DiscCE	GeoMean
1986	70.522	106.195	176.717	2.506		0.6009			
1987	65.209	98.194	163.403	2.506		0.6009			
1988	79.400	119.564	198.964	2.506		0.6009			
1989	65.460	98.572	164.032	2.506		0.6009			
1990	57.729	86.931	144.660	2.506		0.6009			
1991	74.617	112.361	186.978	2.506		0.6009			
1992	76.829	115.692	192.521	2.506		0.6009			
1993	57.060	85.923	142.983	2.506		0.6009			
1994	64.199	96.674	160.873	2.506		0.6009			
1995	54.694	82.361	137.055	2.506		0.6009			
1996	111.796	168.347	280.143	2.506		0.6009			
1997	94.550	142.377	236.927	2.506		0.6009	0.9636	0.9619	6.6167
1998	89.802	135.228	225.030	2.506		0.6009	0.9044	0.9028	6.6317
1999	111.624	168.088	279.712	2.506		0.6009	1.0271	1.0253	7.0956
2000	95.801	144.261	240.062	2.506		0.6009	1.2555	1.2533	8.3170
2001	87.880	132.333	220.213	2.506		0.6009	1.2922	1.2900	9.3138
2002	88.744	133.635	222.379	2.506	29	0.6009	0.9213	0.9197	6.1646
2003	108.249	163.005	271.254	2.506	31.667	0.6009	0.9024	0.9008	5.9048
2004	114.881	172.993	287.874	2.506	34.333	0.6009	0.8595	0.8580	5.8738
2005	122.461	184.407	306.868	2.506	37.000	0.6009	0.8941	0.8926	6.2019
2006	115.164	173.419	288.584	2.506	39.667	0.6009	0.9656	0.9639	6.1036
2007	109.975	165.605	275.580	2.506	42.333	0.6009	1.0429	1.0411	6.6645
2008	116.291	175.117	291.408	2.506	45	0.6009	1.1239	1.1220	7.0127
2009	130.555	196.596	327.151	2.506	45	0.6009	1.2538	1.2516	8.2736
2010	116.052	174.756	290.809	2.506	45	0.6009	0.9741	0.9724	6.1679
2011	111.868	227.064	338.931	3.030	45	0.6699	0.8631	1.0417	5.3919
2012	124.847	171.967	296.814	2.377	45	0.5794	1.0039	0.9508	6.5543
2013	123.624	170.812	294.436	2.382	45	0.5801	0.9203	0.8732	6.7187
2014	108.497	146.359	254.857	2.349	45	0.5743	0.8322	0.7788	5.9065

Table 23.10. Elephant Fish – gillnet RBC calculations. C* and $CPUE_{targ}$ relate to the period 1996 – 2007, $CPUE_{Lim}$ is 40% of the original target, and $\overline{CPUE}$ is the mean CPUE 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 = 40% B_0.

1st Reference Year	1997
2nd Reference Year	2007
C*	259.499
$CPUE_{targ}$	0.8341
$CPUE_{Lim}$	0.4003
$\overline{CPUE}$	0.9111
Scaling Factor	1.1777
Wt_Discard	161.675
RBC	**305.614**

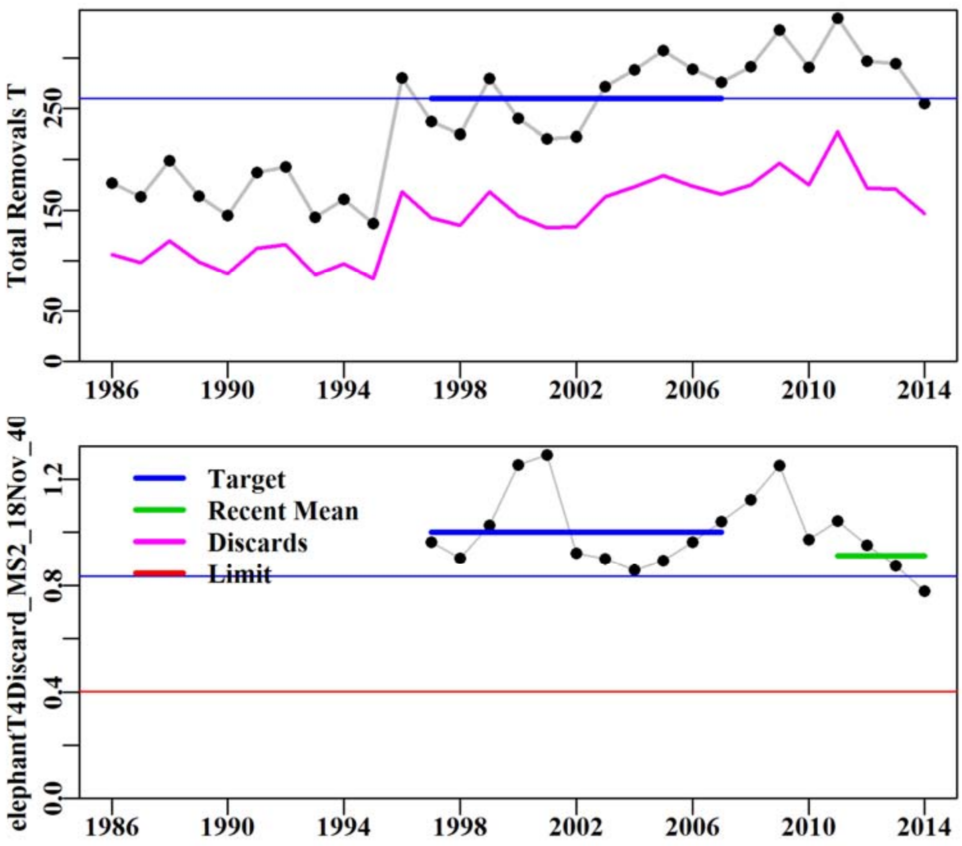


Figure 23.8. Elephant Fish – gillnet. Top panel: total removals (black), target catch (fine blue line, C*). Bottom panel: standardized CPUE (black), target CPUE (lower blue line) and limit reference CPUE (lower red line). Thick lines represent the reference period for catches (1997-2007; top panel, blue), CPUE (1997-2007; bottom panel, blue), and recent mean CPUE (last four years; bottom panel; green). The fine blue line below the target CPUE is the revised target based on a 40% B_0 proxy target for non-target species in a mixed fishery. In this case the discard catches have been included in the CPUE estimates, thereby increasing them markedly.

23.4.5 Sawshark

The most recent (i.e. 2014) estimate of the Western Australian State catch (i.e. 4.1 t) was included in subsequent analyses.

Table 23.11. Sawshark data used for Tier 4 analysis. Standardized CPUE for gillnet (CE-GN) and trawl (CE-TW). Geometric means for gillnet (GeoM_GN) and trawl (GeoM-TW). Greyed cells reflect the reference period (2002 – 2008).

Year	Catch	Discards	Total	CE – GN	GeoM-GN	CE – TW	GeoM-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	259.680	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	296.930	38.773	335.703	1.1639	14.7221	1.1375	3.0297
1998	278.413	39.659	318.072	1.2135	13.6959	1.0728	2.8938
1999	223.661	34.922	258.583	1.2692	13.7614	1.2872	3.7791
2000	195.973	32.211	228.184	1.6168	17.9504	1.1689	4.1146
2001	264.441	30.699	295.140	1.7092	17.4523	1.1295	3.0880
2002	315.372	30.592	345.964	0.9908	10.9212	0.9922	2.7652
2003	367.676	32.486	400.162	1.0282	10.7738	0.8643	2.3522
2004	376.150	32.981	409.131	1.0684	11.5115	0.8654	2.5885
2005	353.911	31.671	385.582	0.9749	10.8639	0.8730	2.5786
2006	373.515	30.656	404.171	0.9829	10.1294	0.9871	2.8887
2007	269.940	41.977	311.917	0.8250	7.7355	0.8525	2.7224
2008	273.382	42.512	315.894	0.9632	9.2730	0.9124	2.5111
2009	259.743	40.392	300.135	0.8033	7.4203	1.1453	3.3781
2010	245.482	38.173	283.655	0.7868	7.6490	0.9737	2.7260
2011	253.639	39.442	293.081	0.7680	7.9130	0.9073	2.5961
2012	203.805	54.795	258.601	0.6283	7.0364	0.8810	2.8453
2013	216.372	85.615	301.987	0.5733	8.0360	0.9965	3.1305
2014	177.106	32.584	209.690	0.6344	8.7489	0.9535	3.1830

23.4.5.1 Sawshark – gillnet. Proxy target 40% - No Discards

This analysis uses standardized gillnet-CPUE and excludes discards.

Table 23.12. Sawshark – gillnet (no discards) RBC calculations. C* and $CPUE_{targ}$ relate to the period 2002 – 2008, $CPUE_{Lim}$ is 40% of the target, and $\overline{CPUE}$ is the mean CPUE over the last four years. The RBC calculation does not account for predicted discards of predicted State catches. The Wt_Discard is the expected weight of discards (t). Implied proxy target is 40% B_0.

1^{st} Reference Year	2002
2^{nd} Reference Year	2008
C*	367.546
$CPUE_{targ}$	0.813
$CPUE_{Lim}$	0.3905
$\overline{CPUE}$	0.651
Scaling Factor	0.6159
Wt_Discard	50.144
RBC	**226.358**

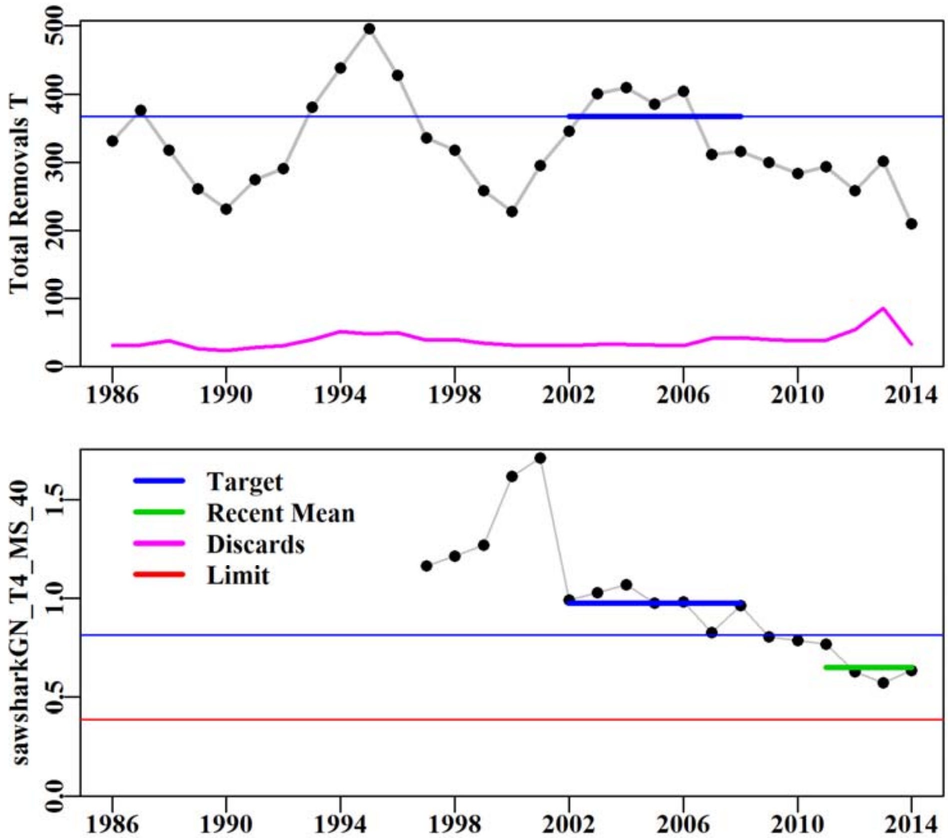


Figure 23.9. Sawshark – gillnet, excluding discards. Top panel: total removals (black), target catch (fine blue line, C*). Bottom panel: standardized CPUE (black), target CPUE (lower blue line) and limit CPUE (lower red line). Thick lines represent the reference period for catches (2002-2008; top panel, blue), CPUE (2002-2008; bottom panel, blue), and recent mean CPUE (bottom panel; green). The fine blue line below the target CPUE is the revised target based on a 40% B_0 proxy target for non-target species in a mixed fishery. The limit reference CPUE is represented by the red line.

23.4.5.2 Sawshark – gillnet. Proxy target 40% - Including Discards

This analysis uses standardized gillnet-CPUE and includes discards.

Table 23.13. Sawshark – gillnet (including discards) RBC calculations. C* and $CPUE_{targ}$ relate to the period 2002 – 2008, $CPUE_{Lim}$ is 40% of the target, and $\overline{CPUE}$ is the mean CPUE over the last four years. The RBC calculation does not account for predicted discards of predicted State catches. The Wt_Discard is the expected weight of discards. Implied proxy target is 40% B_0.

1st Reference Year	2002
2nd Reference Year	2008
C*	367.546
$CPUE_{targ}$	0.7867
$CPUE_{Lim}$	0.3776
$\overline{CPUE}$	0.7071
Scaling Factor	0.8055
Wt_Discard	50.144
RBC	**296.062**

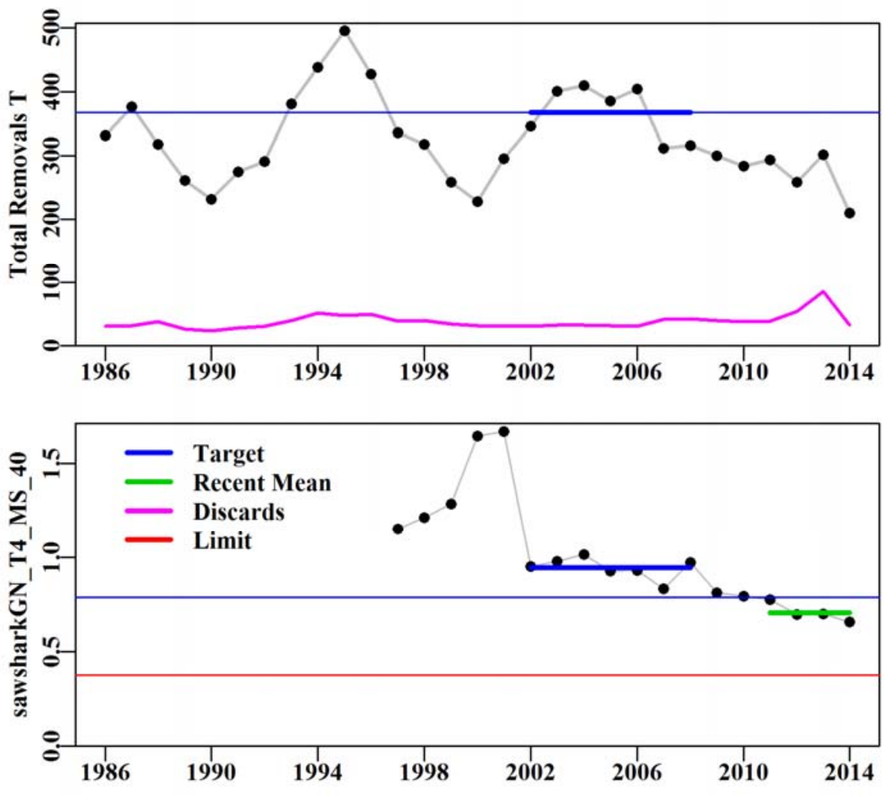


Figure 23.10. Sawshark – gillnet, including discards. Top panel: total removals (black), target catch (fine blue line, C*). Bottom panel: standardized CPUE (black), target CPUE (lower blue line) and limit CPUE (lower red line). Thick lines represent the reference period for catches (top panel, blue), CPUE (bottom panel, blue), and recent mean CPUE (bottom panel; green). The fine blue line below the target CPUE is the revised target based on a 40% B_0 proxy target for non-target species in a mixed fishery. The limit reference CPUE is represented by the red line.

23.4.5.3 *Sawshark – trawl. Proxy target 40% - No Discards*

This analysis uses standardized trawl-CPUE and excludes discards.

Table 23.14. Sawshark – trawl (no discards) RBC calculations. C* and $CPUE_{targ}$ relate to the period 2002 – 2008, $CPUE_{Lim}$ is 40% of the target, and $\overline{CPUE}$ is the mean CPUE over the last four years. The RBC calculation does not account for predicted discards of predicted State catches. The Wt_Discard is the expected weight of discards. Implied proxy target is 40% B_0.

1st Reference Year	2002
2nd Reference Year	2008
C*	367.546
$CPUE_{targ}$	0.756
$CPUE_{Lim}$	0.3627
$\overline{CPUE}$	0.9346
Scaling Factor	1.4556
Wt_Discard	50.144
RBC	**534.99**

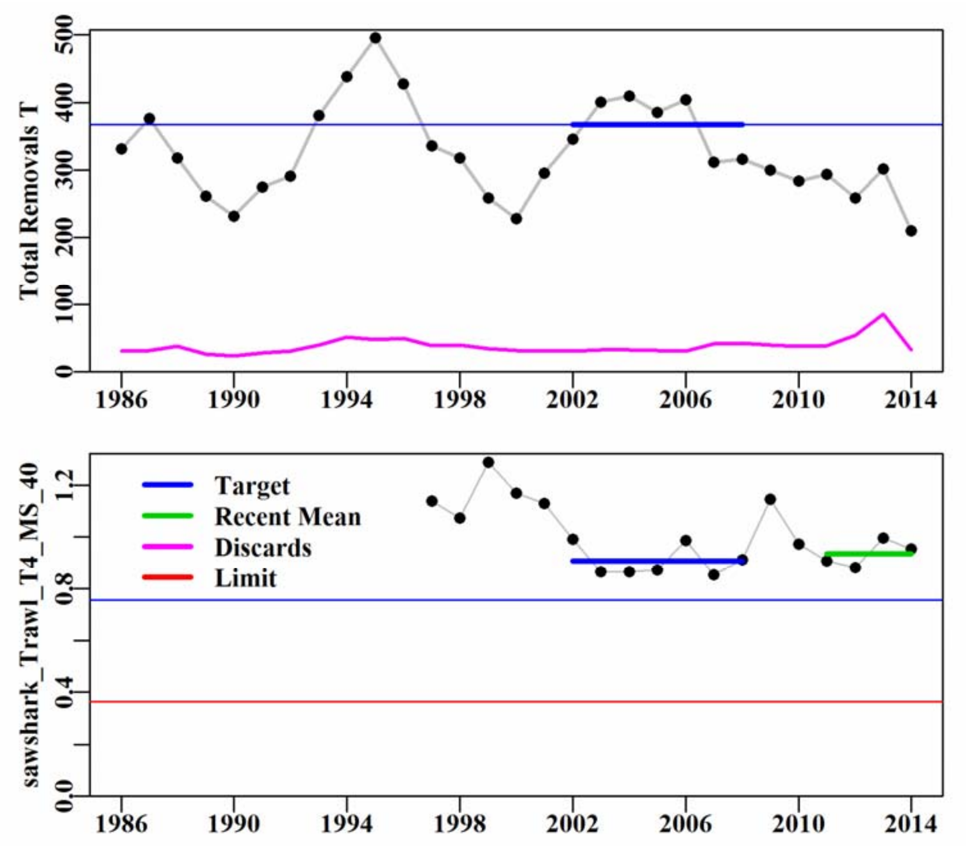


Figure 23.11. Sawshark – trawl, excluding discards. Top panel: total removals (black), target catch (fine blue line, C*). Bottom panel: standardized CPUE (black), target CPUE (lower blue line) and limit CPUE (lower red line). Thick lines represent the reference period for catches (top panel, blue), CPUE (bottom panel, blue), and recent mean CPUE (bottom panel; green). The fine blue line below the target CPUE is the revised target based on a 40% B_0 proxy target for non-target species in a mixed fishery. The limit reference CPUE is represented by the red line

23.4.5.4 Sawshark – trawl. Proxy target 40% - Including Discards

This analysis uses standardized trawl-CPUE and includes discards.

Table 23.15. Sawshark – trawl RBC calculations. C* and $CPUE_{targ}$ relate to the period 2002 – 2008, $CPUE_{Lim}$ is 40% of the target, and $\overline{CPUE}$ is the mean CPUE over the last four years. The RBC calculation does not account for predicted discards of predicted State catches. The Wt_Discard is the expected weight of discards. Implied proxy target is 40% B_0.

1st Reference Year	2002
2nd Reference Year	2008
C*	367.546
$CPUE_{targ}$	0.725
$CPUE_{Lim}$	0.3478
$\overline{CPUE}$	1.1045
Scaling Factor	1.7692
Wt_Discard	50.144
RBC	**650.277**

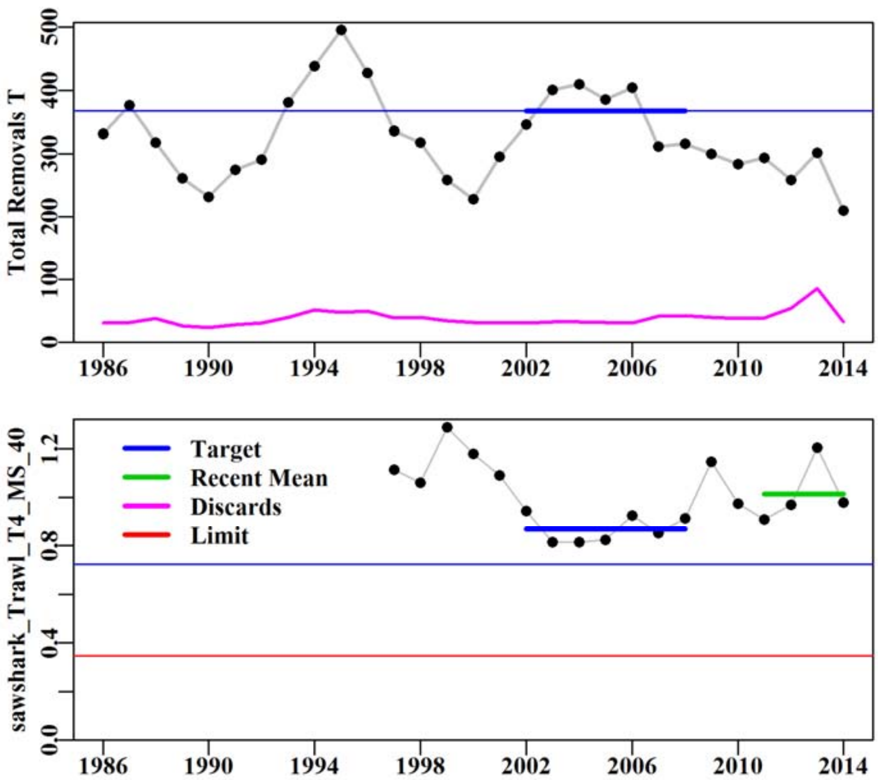


Figure 23.12. Sawshark – trawl including discards. Top panel: total removals (black), target catch (fine blue line, C*). Bottom panel: standardized CPUE (black), target CPUE (lower blue line) and limit CPUE (lower red line). Thick lines represent the reference period for catches (top panel, blue), CPUE (bottom panel, blue), and recent mean CPUE (bottom panel; green). The fine blue line below the target CPUE is the revised target based on a 40% B_0 proxy target for non-target species in a mixed fishery. The limit reference CPUE is represented by the red line.

A summary of the eight estimated RBCs for elephant fish and sawshark is listed in Table 23.16.

Table 23.16. Estimated RBCs for elephant fish (gillnet) and sawshark (gillnet and trawl) based on a proxy target of 40% across the different discard scenarios. Grey cells relate to the two scenarios recommended by SharkRAG (see SharkRAG Meeting No. 1 Minutes, October 2015). Gillnet (GN); Trawl (TRW).

No.	Common name	Method	Target (%)	Discard	RBC (t)	Page
1	Elephant fish	GN	40	No	127.203	9
2	Elephant fish	GN	40	Yes	423.292	10
3	Elephant fish	GN	40	Yes (D1)	429.637	11-12
4	Elephant fish	GN	40	Yes (D2)	429.637	13-14
5	Elephant fish	GN	40	Yes (D3)	305.614	15-16
6	Sawshark	GN	40	No	226.358	18
7	Sawshark	GN	40	Yes	296.062	19
8	Sawshark	TRW	40	No	534.990	20
9	Sawshark	TRW	40	Yes	650.277	21

23.5 Discussion and conclusions

23.5.1 Elephant fish

Elephant fish caught by recreational fishers is not insignificant and estimates of catch are uncertain. Analyses in this report incorporate such catches (i) held constant at 29 t from 2002 and (ii) including the 2008 estimate of 45 t (corresponding to 13,931 fish) inside Western Port (Braccini et al. 2008), by interpolating 29 t (2002) to 45 t (2008) and remaining constant (45 t) thereafter. The latter suggests that recreational catches are much higher than previously employed in Tier 4 analyses.

Following on from previous years analyses, i.e. assuming a recreational catch of 29 t from 2002, led to an approximate increase of 200 t in the 2015 RBC estimate (i.e., 127.20 t versus 423.29 t; Table 23.3, Table 23.4, Table 23.16) when discards were included.

There was no difference in the RBC estimate when including discard (D1) or (D2) scenarios (429.64 t; Table 23.6, Table 23.8, Table 23.16), i.e. whether using (i) mean discard rate of the last four years for each year for period 2007-2009 and a discard rate of 0.2441 in 2010 (D1; see Section 23.4.2) or (ii) mean discard rate of the last four years for each year for the 2007-2010 period (D2; see Section 23.4.3). This is due to the fact that the corresponding 2010 discard estimate is excluded in the recent four year period for mean CPUE. However, including the mean discard rate for the 2011-2014 period extrapolated back to 1986, led to an overall 2015 RBC estimate of 305.61 t (scenario D3; Table 23.10). SharkRAG recommended using this latter RBC estimate in setting a multi-year TAC.

23.5.2 Sawshark

Sawshark catches have been split primarily between gillnets and trawls (with a lesser quantity taken by Danish seine). The standardized gillnet-CPUE has been declining since 2004, although it does not account for the level of discarding that occurs. By contrast, the standardized trawl-CPUE has been relatively flat. Catches by trawl are now almost as high as those taken by gillnets, illustrating the uncertainty in this analysis and providing some evidence that there may be an element of avoidance by gillnet fishers. This avoidance could, in turn, lead to a reduction in gillnet-CPUE. The estimated RBCs by gillnet are much lower compared to those by trawl (Table 23.12 and Table 23.13 versus Table 23.14 and Table 23.15; Table 23.16). The potential avoidance of this species by gillnets suggests that the corresponding standardized CPUE may not adequately reflect stock abundance. Therefore, SharkRAG recommended using standardized trawl-CPUE (see SharkRAG Meeting No. 1 Minutes, October 2015). Also, annual discards have varied between 15- ~26% from 2011 to 2013 (Thomson et al. 2015). The estimated RBCs with and without discards were approximately 650.3 t (Table 23.15, Table 23.16) and 535 t (Table 23.14, Table 23.16) respectively.

23.6 Acknowledgements

Data relating to landings and discards were provided by John Garvey (AFMA), while State catches were provided by Judy Upston (CSIRO). Thanks to Neil Klaer (formally CISRO) for compiling the Observer data to 2014 inclusive. Thanks also to Malcolm Haddon (CSIRO) for his helpful discussions and editorial comments to this report.

23.7 References

Braccini, J. M., Walker, T. I., Conron, S. D. (2008). Evaluation of effects of targeting breeding elephant fish by recreational fishers in Western Port. Draft Final report to Fisheries Revenue Allocation Committee. (December 2008) 59 + ii pp. (Fisheries Research Brand: Queenscliff, Victoria, Australia).

DAFF. (2007) *Commonwealth Fisheries Harvest Strategy Policy Guidelines*. Australian Government Department of Agriculture, Fisheries and Forestry, Canberra, Australia. http://www.agriculture.gov.au/fisheries/domestic/harvest_strategy_policy

Haddon, M. (2014). SESSF saw shark and elephant fish Tier 4 analyses (Data from 1986-2013). CSIRO Hobart. 23 p.

Sporcic, M. (2015). Catch-per-unit effort standardizations for selected shark SESSF species (data to 2014). CSIRO Oceans and Atmosphere Flagship, Hobart. 68 pp.

Thomson R.B., Sporcic M., Klaer N., Fuller M., Krucic□Golub K., Upston J. (2015). Data summary for the

Southern and Eastern Scalefish and Shark Fishery: Logbook, Landings and Observer Data to 2014 (DRAFT).

CSIRO, Australia and AFMA. 282 p.

Upston, J., Klaer, N. (2011). Integrated Scientific Monitoring Program for the Southern and Eastern Scalefish and Shark Fishery – Update on discards: 2010. Technical document provided to AFMA 24 January 2012. Draft provided to RAGs 7-11 November 2011. 28 pp.

Upston, J., Klaer, N. (2012). Integrated Scientific Monitoring Program for the Southern and Eastern Scalefish and Shark Fishery – Update on discards: 2011. Technical document provided to AFMA 24 January 2012. Draft provided to RAGs 7-11 November 2011. 32 pp.

Upston, J., Klaer, N. (2013). Integrated Scientific Monitoring Program for the Southern and Eastern Scalefish and Shark Fishery – Discard estimation 2012. Technical document provided to AFMA November 2013. Draft provided to RAGs 4-8 November 2013. 34 pp.

Upston, J. (2014). Integrated Scientific Monitoring Program for the Southern and Eastern Scalefish and Shark Fishery – Discard estimation 2013. Technical document provided to AFMA November 2014. Draft provided to RAGs 28-30 October 2014. 34 pp.

Upston, J., Thomson, R. (2015). Integrated Scientific Monitoring Program for the Southern and Eastern Scalefish and Shark Fishery – Discard Estimation 2014. Draft. 40 pp.

23.8 Appendix

The following methodology is an excerpt described in Haddon (2014).

Tier 4

Standard analyses were set up in the statistical software, R, which provide tables and graphs required for the Tier 4 analyses. Data and results were presented for clarity for each analysis (see Results Section). The Tier 4 harvest control rule formulation essentially uses a ratio of current CPUE with respect to the selected limit and target reference points to calculate a scaling factor (*SF*). This *SF* is applied to the target catch to generate an RBC:

$$\text{Scaling Factor } = SF = \max\left(0, \frac{\overline{CPUE} - CPUE_{\lim}}{CPUE_{t\arg} - CPUE_{\lim}}\right) \tag{17}$$

$$RBC = C^{*} \times SF \tag{18}$$

where

$CPUE_{targ}$ target CPUE for the species (half the mean CPUE for the reference period).
$CPUE_{lim}$ limit CPUE for the species; which is 40% $CPUE_{targ}$
$\overline{CPUE}$ mean CPUE over the past *m* years
C^* 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. This is a mean of the total removals for a selected reference period (e.g. 1996 – 2007, for elephant fish), including any discards.

$$CPUE_{\text{targ}} = \frac{\sum_{y=yr1}^{yr2} CPUE_y}{\left(yr2 - yr1 + 1\right)} \tag{19}$$

where $CPUE_y$ is the catch-per-unit effort 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.

$$C^{*} = \frac{\sum_{y=yr1}^{yr2} L_y}{\left(yr2 - yr1 + 1\right)} \tag{20}$$

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. CPUE target for stocks fully exploited at or prior to 1986 is based on the mean CPUE from 1986-1995.

2. CPUE determined (step 1 above) is halved (to provide a CPUE proxy for B_{MEY}) where fishing exploitation up to 1986 is thought to be minimal.
3. Where fishing exploitation after 1986 is low, the first year in which catches are above 100 t signifies the start of the 10 year period from which the target CPUE and catch targeted are calculated.

These rules are not always applicable for bycatch shark species (e.g. total catch of elephant fish rarely reaches 100 t annually). 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 shark the reference period chosen was 2002 – 2008.

Once the mean CPUE for the reference period has been selected as the target CPUE (assumed a proxy for $B_{40\%}$ which is assumed to be a proxy for B_{MEY}) then the limit CPUE is defined as 40% of 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.

Annual landings and standardized CPUE was tabulated for each species. The former included all catches (Commonwealth landings, non-trawl catches, combined State catches, discards and/or recreational catches). State catches are available back to 1999 (elephant fish) and 1997 (saw shark). Catches prior to 1994 are either taken from an historical catch database or, if no data are available for the species, are taken from the AFMA GenLog Catch and Effort database. CPUE are standardized, usually from 1986, although from only 1997 for non-trawl fishing methods, using statistical methods described in Sporcic (2015).

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 mean 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. The calculation of the earlier discards is done so that the total catches can be estimated even though only the landed catches are available. To calculate the discards for a given year we used

$$D_y = \frac{C_y \bar{D}_{98-06}}{\left(1 - \bar{D}_{98-06}\right)} \qquad (21)$$

To estimate the expected discards in the coming year a weighted mean 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 CPUE are illustrated with the target CPUE and the limit CPUE.

There are a number of meta-rules that are used when translating the RBCs into TACs. Two that relate to all species are:

1. No TAC will change by more than 50% (either increase or decrease)
2. Only changes greater than 10% (up or down) will be implemented

Analyses including discards

Discard rates cannot simply be added to known catches on the way to calculating CPUE. Standardized CPUE 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 CPUE has been developed, it should be noted that this ignores all complications relating to unknown aspects of discarding behaviour (i.e., are discard rates constant across all catch sizes, across all vessels, across all areas etc.?). This means that including discarded catches into the annual CPUE 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 CPUE and apply that to the standardized CPUE (e.g. Haddon 2014, Sporcic 2015). The ratio mean CPUE 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 CPUE can then be developed and applied to the standardized CPUE.

The ratio mean is simply the sum of all catches divided by the sum of effort

$$\hat{I}_{R,t} = \frac{\sum C_t}{\sum E_t} \tag{22}$$

where $\hat{I}_{R,t}$ is the ratio mean CPUE 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 CPUE would be

$$\hat{I}_{D,t} = \frac{\sum C_t + \sum D_t}{\sum E_t} \tag{23}$$

The same values of $\hat{I}_{D,t}$ can also be obtained using the following multiplier

$$\hat{I}_{D,t} = \left[\left(\sum D_t / \sum C_t \right) + 1 \right] \times I_t \tag{24}$$

where I_t is the CPUE estimate to be modified by the inclusion of discards. If this is the ratio mean from Equation (12) then the augmented CPUE would be identical to those produced by Equation (13) . In practice, CPUE used with the multiplier are the standardized CPUE from Sporcic (2015). This assumes that the total discards are made up from amounts from each recorded shot. If a significant proportion of catch of shots were all discarded then applying this adjustment method to the CPUE would become biased high.

24. Blue-Eye Auto-Line and Drop-Line CPUE Characterization (data from 1986 to 2014)

Malcolm Haddon

CSIRO Oceans & Atmosphere, GPO Box 1538, Hobart, Tas 7001, Australia

24.1 Executive summary

In 2013 the stock status for Blue-Eye (*Hyperoglyphe antarctica*) was assessed using a standardized catch-per-unit-effort (CPUE) time series for the auto-line and drop-line fisheries, which are combined for the purpose (SESSF zone 10 – 50 with 83 – 85) so as to extend the length of the time-series available (Haddon, 2010); to enable this combination, CPUE was estimated as catch-per-record rather than catch-per-hook. 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 was given to 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 the current CPUE analyses as an indicator of Blue-Eye relative abundance.

There are many factors that could potentially change fishing behaviour and hence affect CPUE that could not be included in any standardization. For example, the structural adjustment that occurred between November 2005 and November 2006 may have had such an unaccounted for influence. Given the extensive spatial heterogeneity of both the Blue-Eye fishery and of the biological properties of the Blue-Eye populations across its spatial distribution, the CPUE analyses conducted were in need of a complete review and possible revision.

Catch-per-record has been used for the CPUE since 2009 (Haddon, 2010). In 2009, the recording of effort in the two methods was a mixture of total number of hooks, number of lines with number of hooks per line, and other combinations (the main reason for moving to catch-per-record). Since then the data entry has been more consistent leading the way for an attempt at generating CPUE as catch-per-hook. This may end with two time-series, an early one for drop-line with an over-lapping one for auto-line, but the time-series are now of sufficient length that the general trends should be apparent.

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 first became available (although only starting in November 1997). Catches in what is now the GHT were significant prior to 1997 but there are multiple estimates of total catches and none are available with any reliable spatial 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 a larger proportion of the total catch away from the east coast of

Tasmania, the use of alternative line methods (rod-reel, hand-line, and others) has increased, although, possibly in response to reductions in the available quota, catches by these methods have now declined again.

There are some important assumptions in the earlier analyses. The first is that 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 fact, all of these factors are likely to have had some effect.

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 (Haddon, 2014c; Haddon, 2014d).

The repeated Industry statements implying that whale depredations have significant effects on both observed CPUE and 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 it been stable from the inception of 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.

One of the foundations 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 (Haddon, 2010). The combination was required because, in 2009, on their own each only had a rather short time-series of usable CPUE (sufficient catches, records and representative coverage of the fishery) that could be used for assessment purposes. Catch-per-day was used because early use of the log-books had often mixed up the reporting of lines and hooks-per-line making their direct use invalid. However, by detailed examination of records, often record by record, it was possible to clean the drop-line 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, 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 of the auto-line data 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.

24.2 Introduction

Blue-eye trevalla (*Hyperoglyphe antarctica*) is managed as a single stock but its stock status is difficult to assess because, as a species, its adults are widely but patchily distributed, although its juveniles stages are widely dispersed. Not only is it patchily distributed but the fishery differs markedly by area through the application of different methods and histories of exploitation. The differences in exploitation history along with sampling different areas in sequential years may be sufficient to have led to the appearance of heterogeneity in the biological characteristics of different populations; there is little consistency between consecutive years in the age structure and length structure of samples (Figure 24.1). This lack of consistency has thwarted previous attempts at applying a Tier 1 integrated assessment to blue-eye and has made the application of the Tier 3 catch-curve approach equally problematical (Fay, 2007a, b).

The blue-eye fishery has a relatively long history and while it is taken by trawl the majority of the catch has always been taken by line-methods (generally less than 10% of catches are taken by trawl since 2003; Table 24.1). Unfortunately, fisheries data from such methods, in the GHT fishery, only began to be collected comprehensively from 1997 onwards (Table 24.1). In addition, in 1997 Auto-Line fishing was introduced as an accepted method in the SESSF although only very little fishing was conducted in 1997 and only in the last two months (Table 24.1, Figure 24.2). Auto-line related effort and catches increased from 2002 – 2003 onwards at the same time that drop-line records and catches began to decline (Figure 24.2; Table 24.1).

Table 24.1. The number of records and catches per year for auto-line and drop-line vessels reporting catches of blue-eye trevalla from 1997 – 2014. Trawl catches are included

	Auto-Line		Drop-Line		Trawl
Year	Records	Catches	Records	Catches	Catches
1997	3	0.267	565	265.137	103.264
1998	31	15.189	745	330.802	79.201
1999	64	59.902	931	356.962	89.917
2000	63	85.201	1081	384.504	83.375
2001	76	47.884	771	327.050	68.973
2002	243	145.717	623	227.654	66.509
2003	498	219.937	590	224.749	26.364
2004	1355	334.738	529	161.921	46.659
2005	1148	300.819	372	94.399	31.151
2006	1100	356.716	330	115.059	53.253
2007	668	455.105	136	49.016	37.066
2008	621	281.384	99	24.155	30.142
2009	592	326.553	138	43.378	38.735
2010	495	236.620	257	42.713	42.662
2011	583	282.785	244	59.381	22.707
2012	483	220.734	140	34.107	10.528
2013	392	203.554	54	7.762	22.788
2014	325	244.139	65	10.062	10.799

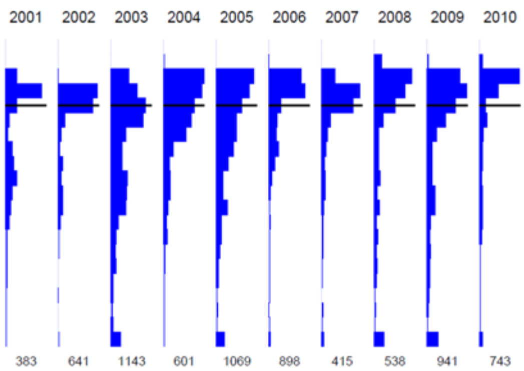


Figure 24.1. Age distributions sampled from the catches of Blue-Eye (*Hyperoglyphe antarctica*;) for the years 2001 – 2010 (Klaer *et al*, 2014), illustrating the variation between years. The sample sizes that should be sufficient to provide a good representation if the stock were homogeneous in its properties. Blue-Eye shows inconsistencies every year with annual progressions of year classes being vague and ephemeral at best.

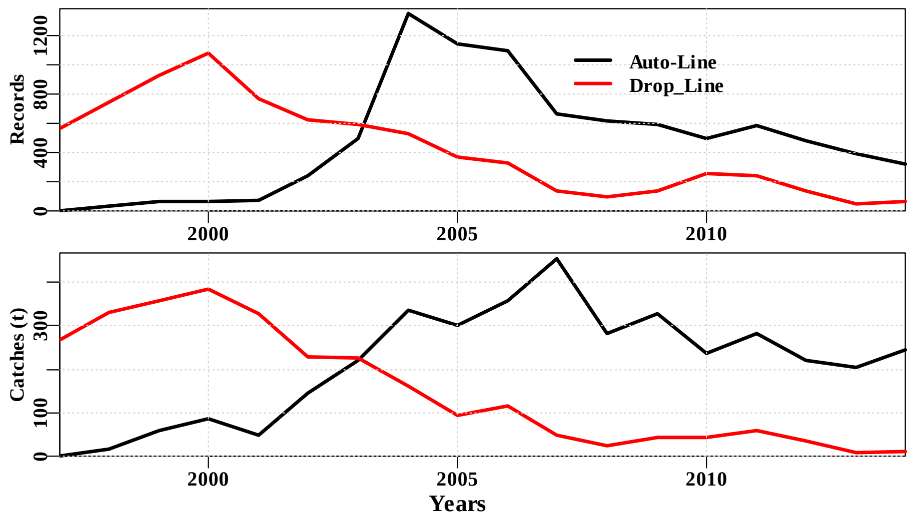


Figure 24.2. The trends in the number of records and the catches of blue-eye from 1997 – 2014 by the two main line methods (Table 24.1); most catches are now taken by auto-line.

In the last two years, 2013 – 2014, the drop-line catches have dropped to 10 t or less while auto-line catches continue to dominate the fishery even though catches are dropping slowly (Table 24.1; Figure 24.2)

24.2.1 Current management

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

By 2007 the auto-line fishery was already dominating the blue-eye fishery but the time series of significant catches by that method was relatively short (only six years from 2002 – 2007; Figure 24.2). At that time some way of extending the time series was required to allow for the application of the Tier 4 methodology. Unfortunately, in the log-book records there was often confusion in how to record effort (in terms of number of lines and number of hooks per line, or number of line drops) so it was not feasible at that time to estimate CPUE as a catch-per-hook. Instead CPUE was based on catch-per-record, which was equivalent to catch-per-day. The CPUE standardization conducted in 2008 on data from 1997 – 2007 (Haddon, 2009) was the first time that the catch-per-day data from drop-line was combined with auto-line catch-per-day data, with a justification presented to the RAGs. This was followed in 2009 by a summary of the separate auto-line and drop-line CPUE and a more detailed defence for their combination (Haddon, 2010). While it was appreciated that the two methods are very different, the intent of combining their data was always to extent the time series of line-caught blue-eye back to 1997 rather than 2002. Despite this extension of time, the early Tier 4 blue-eye analyses had overlap between the reference period (1997 – 2006) and the CPUE grad over the final four years (2004 – 2007); it took three more years for the overlap to cease.

In 2013 the stock status for Blue-Eye (*Hyperoglyphe antarctica*) was assessed using a standardized CPUE time series from the combined auto-line and drop-line fisheries, which combined data from the two methods from 8 zones (SESSF zone 10 – 50 with 83 – 85; Figure 24.3). In addition, the time series of CPUE for trawls, relating to SESSF zones 20 – 30 (eastern Bass Strait and eastern Tasmania) and 40 – 50 (western Tasmania and western Bass Strait) were examined, although these trawl fisheries only relate to a small fraction of the total fishery so less attention is given them (Haddon, 2014 a, b). This was repeated in 2014 (Sporcic and Haddon, 2014), however, because of the unaccounted influences of factors such as the introduction of closures (both all methods and solely for auto-line), depredations by whales, and having to ignore significant catches taken with other new methods, these standardizations, and the Tier 4 analyses dependent upon them, were no longer considered to provide an adequate representation of trends within, and hence the status of, the Blue-Eye fishery.

One outcome of this was the determination to re-examine the available data to determine whether it would be possible to generate a CPUE series based upon some measure of catch-per-hook rather than catch-per-day. The use of catch-per-hook would allow more fine detail to be discerned and might provide a more informative time-series, although the two methods were no longer likely to be able to be combined. However, the length of time-series for auto-line is now sufficiently long that such a combination is now no longer a requirement.

24.2.2 Fishery changes

The fishery as a whole has included a number of large-scale changes in fishing methods and the area of focus for the fishery. Catches in what is now the GHT were significant prior to 1997 but detailed data for that earlier period are not readily available. Catch estimates, have been derived from combining State with Commonwealth estimates, taken from earlier assessment summaries (Tilzey, 1999; Smith and Wayte, 2002; Table 24.2; Figure 24.4) and have the status of being an agreed catch history. While trawl catches have continued at a low (< 10%) but steady level since 2003 there has been a switch from drop-line (alternatively demersal-line) to auto-line. Also, related to the move of a proportion of the total catch away from the east coast up to the north-east seamount region, in the last three to four years the use of alternative line methods (rod-reel, hand-line, etc) has increased, although perhaps now that the TAC is decreasing the proportion of the total catch being taken by these 'minor line' methods is declining again (Figure 24.5; Table 24.3).

Multiple issues have combined to cast doubt on the use of the combined auto-line and drop-line CPUE data; the issues included reported whale depredations, the effects of closures, and the advent of a number of new line fishing methods north of -35° S, all of which have, or have been reported to have, increased since the increase in use of the auto-line method. In amongst a detailed consideration of the CPUE for all areas and methods (Haddon, 2015) a preliminary examination of the auto-line data was made to determine whether it would be possible to go through the data-base records for the drop-line fishery and identify those where the number of lines or drops had been placed in the number of hooks per line field. The aim was to generate a catch-per-hook index to see if the use of the rather crude catch-per-day index was affecting the outcome of the standardization. This proved possible for drop-line so that work has been expanded to include a consideration of the auto-line data in the data-base.

24.2.3 Objectives

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

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

24.2.4 Report Structure

There will be four main sections to the results:

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

The implications of these analyses will be examined in the discussion.

24.3 Methods

24.3.1 Catch rate standardization

24.3.1.1 Data selection

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

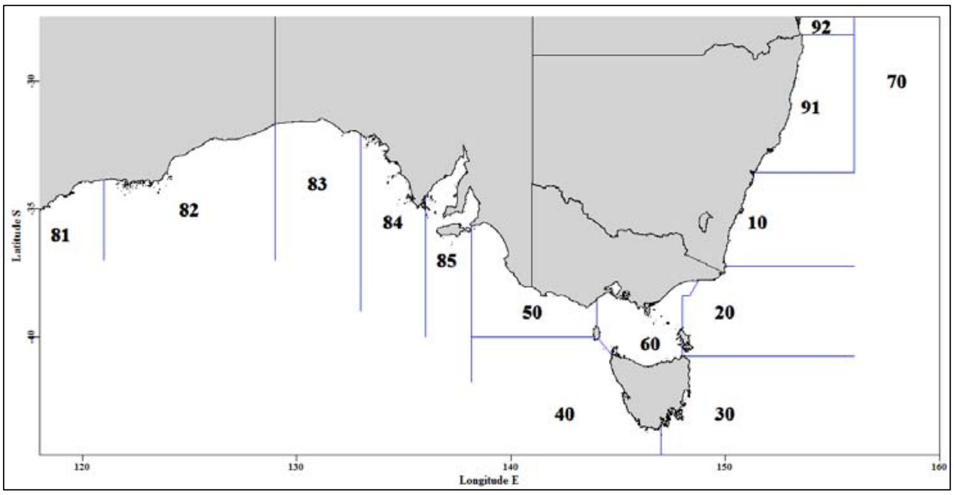


Figure 24.3. A schematic diagram depicting the statistical reporting zones in the SESSF, as used in this document. The GAB fishery is to the west of Zone 50. The main SESSF trawl zones are zones 10 – 50. Each zone extends out to the boundary of the EEZ, except for zones 50 and 60, and for zones 92 and 91, which are bounded by zone 70.

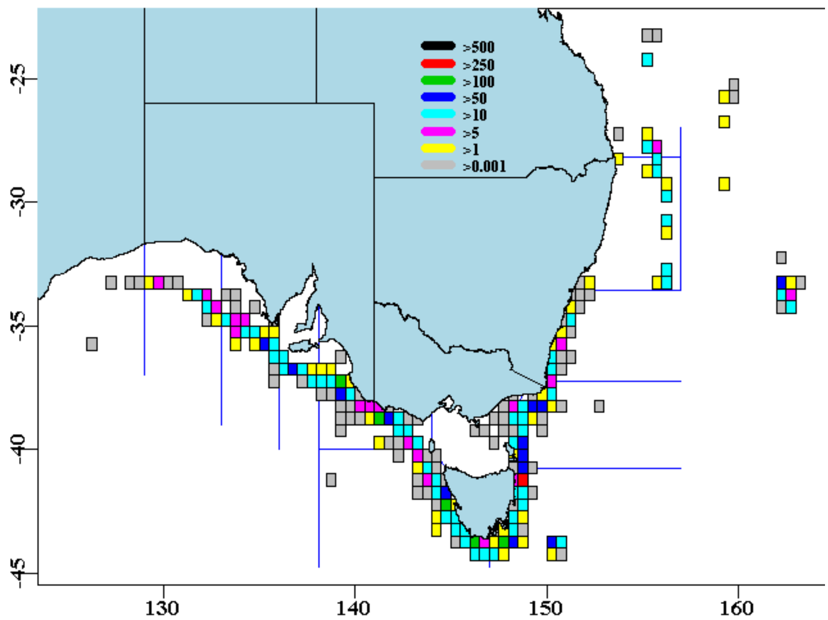


Figure 24.4. All reported catches of blue-eye by all methods from 1986 – 2014 in 0.5 degree squares. At least two records per square were required for inclusion. The legend units are in tonnes summed across all years.

24.3.1.2 General Linear Modelling

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

$$\text{Ln}\left(CPUE_i\right) = \alpha_0 + \alpha_1 x_{i,1} + \alpha_2 x_{i,2} + \sum_{j=3}^{N} \alpha_j x_{ij} + \varepsilon_i \qquad (25)$$

where Ln($CPUE_i$) is the natural logarithm of the catch rate (either kg/h, kg/shot, or kg/hook) for the i-th shot, x_{ij} are the values of the explanatory variables j for the i-th shot and the 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*.).

24.3.1.3 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:

$$CPUE_t = e^{\left(\gamma_t + \sigma_t^2/2\right)} \qquad (26)$$

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:

$$CE_t = \frac{CPUE_t}{\left(\sum CPUE_t\right)/n} \qquad (27)$$

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.

24.4 Results

24.4.1 Reported Catches

Blue-Eye have been a target species before the formation of the SESSF, with large catches reported from eastern Tasmania taken primarily by drop-line. The estimates of total catch through time vary in their completeness and quality and earlier reviews have generated different values (Table 24.2). In particular, prior to 1997, non-trawl catches were only poorly recorded. At very least these early estimates indicate the significant scale of fishing mainly by drop-line, prior to the introduction of auto-line vessels.

Table 24.2. Early estimates of total Blue-Eye Trevalla catches, tonnes, across all methods within the SET area. The North Barenjoey is included as being extra South-East Trawl area catches. Tilzey (1998) is only for catches north of Barenjoey. Recent catches from 1998 are derived from Catch Documentation Records (CDR).

Year	Recent	Tilzey (1998)	Tilzey (1999)	Smith & Wayte (2002)
1980			207	207
1981			257	257
1982			276	276
1983			236	236
1984		7	388	350
1985		9	510	525
1986		38	285	341
1987		105	345	468
1988		210	505	725
1989		174	531	717
1990		243	647	819
1991		181	599	717
1992		60	633	643
1993		38	634	628
1994	801.327	27	729	730
1995	740.046	19	716	725
1996	893.428	16	868	890
1997	733.985		1040	989
1998	472.287			566
1999	572.689			651
2000	656.847			710
2001	586.572			648
2002	512.111			
2003	588.064			
2004	633.794			
2005	492.885			
2006	563.850			
2007	585.310			
2008	373.047			
2009	443.362			
2010	399.896			
2011	458.535			
2012	332.297			
2013	284.574			
2014	269.331			

24.4.2 Catch by Method

In the catch and effort log book database there are 15 fishing methods listed that report catches of Blue-Eye, although six of those, combined with the unknown category only account for about 0.2% of total catches from 1986 to 2014 (Table 24.3), although in 1991 and 1992 they constitute up to 8% of catches (all of which was in 'unknown' method and so was likely by trawl, which was the only method reported in detail at the time). Only six methods have each accounted for more than 1% of total reported catches through that period; data have only been collected for methods other than trawl since 1998, with incomplete data collection in 1997 (Figure 24.5).

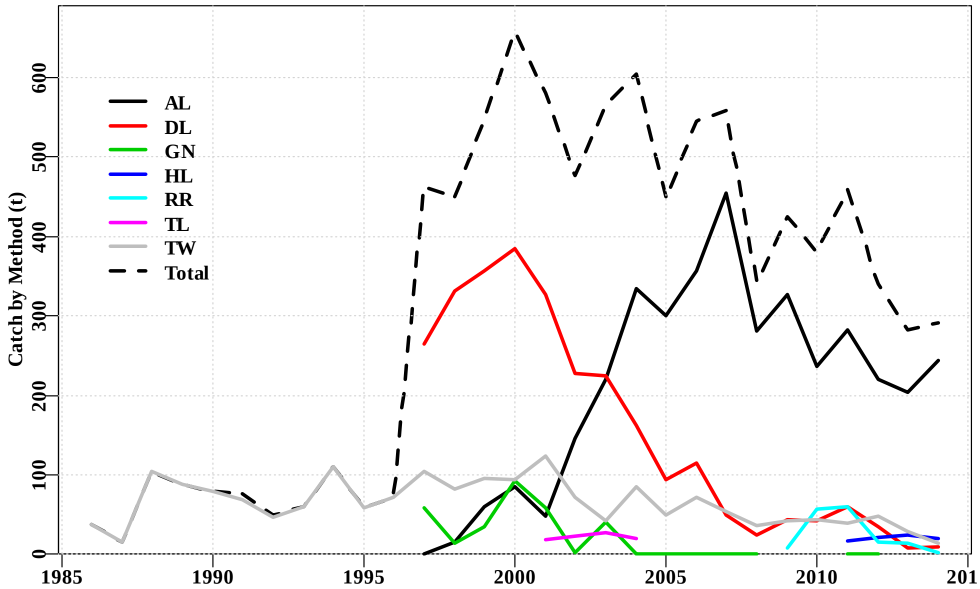


Figure 24.5. Catches of seven methods that together account for about 98.6% of all reported catches of Blue-Eye (Table 24.3) from 1996 – 2013. The codes are AL – auto-line, DL – drop-line, TW – trawl, GN – gill net, TL – trot line, RR – Rod and Reel, and HL – Hand Line. The dominance of drop-line and then auto-line is apparent.

Recently, on the northern sea mounts off the east coast the use of hydraulic reels and hand lines (RR and HL) have expanded (Figure 24.4, Figure 24.5), although these have now declined while auto-line catches have increased in the latest year.

The trawl fishery averaged about 75t from 1986 to 2002 and about 51t from 2003 to 2012 and averaged about 16% of the total fishery from 1998 to 2002, and about 7.8% of the fishery from 2003 - 2014; in 2011 catches by trawl reduced by ~20 t but estimated discard rates remained low (Upston, 2014), the 2014 catches are the lowest recorded at only about 11 t. The non-trawl fishery has always taken the largest proportion of the total catch but useful data have only become available since 1997, with more complete data only being available from 1998 (see Table 24.2 for a previously agreed upon catch history back to 1980). In 1997 auto-lining was introduced as an accepted method in the SESSF and its catches grew to take over from drop-lining, which had been the dominant method used up until then (Figure 24.5, Figure 24.11). The time series for auto-line is truncated to start in 2001 or 2002 as catches only started to be taken over a wider area and in appreciable total amounts after that time (Table 24.3; Figure 24.10); before that time catches were very patchy and varied by location from year to year.

Table 24.3. Reported annual catches of Blue-Eye from 1986 – 2014 by method, Auto Line, Drop Line, Trawl, Gill Net, Rod and Reel, Trot Line, Bottom Line, and Hand Line. Other includes unknown, pole and line, fish trap, Danish seine, pelagic longline, and trolling. The landings relate to annual formal landings against quota but differ from those reported in AFMA's Catch-Watch which relate to fishing seasons (May – April). TAC is the Agreed TAC; from 1992 – 1997 the TAC in trawl only, a non-trawl allocation of 530 t was included in 1998.

Year	AL	DL	TW	GN	RR	TL	BL	HL	Other	Total	Landing	TAC
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	46.030						2.835	49.280		125
1993			59.588						0.056	59.644		125
1994			109.959						0.016	109.975		125
1995			58.533						0.039	58.572		125
1996			71.175						0.509	71.684		125
1997	0.267	265.137	104.567	58.382		6.148	28.262		0.557	463.319		125
1998	15.189	330.802	82.074	14.282			4.526	0.100	1.174	448.146	472.287	630
1999	59.902	356.962	95.309	34.711			0.889		0.294	548.067	572.689	630
2000	85.201	384.504	93.543	92.406			1.739		0.678	658.071	656.847	630
2001	47.884	327.050	124.292	58.872		19.255	3.126		0.037	580.516	586.572	630
2002	145.717	227.654	71.509	1.951		23.415	6.493		0.001	476.739	512.111	630
2003	219.937	224.749	42.271	41.476		28.080	8.589		0.062	565.163	588.064	690
2004	334.738	161.921	85.508	0.171		20.116	2.318		0.009	604.780	633.794	621
2005	300.819	94.399	49.472	0.016			1.941		0.406	447.053	492.885	621
2006	356.716	115.059	71.863	0.002			1.187		0.016	544.842	563.850	560
2007	455.105	49.016	53.828	0.003			0.632	0.400	0.000	558.985	585.310	785
2008	281.384	24.155	36.046	0.016			0.724		0.072	342.397	373.047	560
2009	326.553	43.378	41.556		7.550		1.740		3.482	424.259	443.362	560
2010	236.620	42.713	43.480		56.788		0.022		0.000	379.622	399.896	428
2011	282.785	59.381	39.149	0.111	59.998		0.049	17.118	0.000	458.592	458.535	326
2012	220.734	34.107	48.443	0.003	14.946		1.377	21.171	0.000	340.782	332.297	388
2013	203.554	7.762	28.951		14.125		3.311	24.083	0.002	281.788	284.574	388
2014	244.139	10.062	13.757		2.280		0.377	20.233	0.000	290.848	269.331	335

24.4.3 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 24.4).

Table 24.4. Reported catches by fishery and the landings against quota. Total is all fisheries combined, SET is the south east trawl, GHT is the gillnet, hook and trap fishery (combined with the southeast non-trawl, the southern shark fishery, southern shark gillnet fishery, and the southern shark hook fishery). ECD & HS is the combined catches of the east coast deep-water fishery and the high seas trawl and high seas non-trawl. Other combines 8 other fisheries, which only account for about 0.28% of total catches from 1994 to 2014.

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		3.225
1999	572.689	548.067	90.552	452.585	4.822		0.108
2000	656.847	658.071	83.454	564.421	4.050	5.408	0.738
2001	586.572	580.516	69.255	456.189	19.390	34.934	0.748
2002	512.111	476.739	66.819	386.930	1.150	10.541	11.300
2003	588.064	565.163	27.069	518.839	1.810	17.162	0.283
2004	633.794	604.780	46.912	509.634	2.723	45.166	0.346
2005	492.885	447.053	34.497	396.955	8.698	6.850	0.054
2006	563.850	544.842	54.136	469.860	11.968	8.862	0.016
2007	585.310	558.985	37.287	503.743	0.960	16.590	0.405
2008	373.047	342.397	35.969	303.573	0.147	2.400	0.308
2009	443.362	424.259	39.410	381.699		2.831	0.320
2010	399.896	379.622	43.480	335.502		0.550	0.090
2011	458.535	458.592	23.268	403.940		29.043	2.341
2012	332.297	340.782	10.781	289.268	0.011	39.400	1.322
2013	284.574	281.788	22.845	239.639		18.527	0.778
2014	269.331	290.848	10.843	258.607	0.011	19.954	1.433

24.4.4 Catch by Zone

The fishery has been focussed largely around the south-east for many years, especially off the east and west coasts of Tasmania. In the last four years zones 70, 91, and 92 have increased in their importance to the fishery, although the reduction in TAC has seen a drop in the absolute catches from the area. The limited number of years in the north-east with available data restricts the possibilities for analysis, and this is further restricted by a proliferation of different fishing methods associated with this shift off effort and catch (Table 24.5; Figure 24.6)

Table 24.5. Catches in tonnes of Blue-Eye taken by all methods by zone (Figure 24.3). 80 includes all the GAB catches. The zones are arranged approximately from north-east to south-west.

	70	91	92	10	20	30	40	50	60	80
1986		0.020		12.712	5.771	3.346	4.927	11.058	0.128	1.000
1987				1.882	6.881	3.269	0.214	2.931	0.250	0.068
1988		0.585		3.076	18.841	1.460	23.834	53.101	1.020	3.250
1989		0.101		9.391	10.203	23.654	24.905	19.080	0.031	0.375
1990				4.201	11.622	29.411	14.880	16.030	0.139	2.925
1991				14.119	20.771	18.256	7.871	14.236	0.120	0.308
1992				2.498	13.663	3.408	7.739	21.679	0.063	0.030
1993		0.015		2.270	14.672	24.092	5.892	12.567	0.001	0.135
1994	0.115	0.030		2.861	14.919	74.892	8.140	8.842	0.046	0.125
1995		0.080		2.721	8.776	19.763	12.605	13.791	0.201	0.635
1996		0.075		4.832	9.937	25.660	9.134	21.450	0.192	0.347
1997		10.835	0.140	5.964	149.201	92.819	83.333	100.036	4.149	16.843
1998		1.590		1.774	93.416	171.130	97.903	66.989	4.211	7.967
1999		21.590	0.050	1.881	106.178	225.832	91.602	86.854	5.109	7.044
2000	5.408	1.100	0.750	0.985	129.528	275.937	129.247	95.971	8.559	9.923
2001	34.930	3.186	4.740	0.264	86.447	239.668	100.831	60.290	0.708	48.991
2002	7.469	33.664	7.850	0.489	41.624	180.660	75.524	77.538	0.012	37.437
2003	14.668	57.910	2.400	1.288	91.447	153.646	124.815	43.761	1.567	70.485
2004	36.796	10.045	0.180	0.222	73.957	148.512	113.269	64.437	0.745	152.432
2005	2.607	7.451	4.700	1.601	88.198	119.790	64.249	51.935	0.267	100.616
2006	2.540	10.375	2.516	0.192	69.824	157.401	83.899	41.217	0.932	165.364
2007	16.174			0.271	53.777	235.939	48.581	47.631	0.552	152.539
2008	8.100			0.170	46.583	130.524	55.478	26.535	0.110	74.574
2009	7.631	12.615	22.758	0.133	54.023	159.609	86.619	47.601	0.195	32.416
2010	1.797	34.124	34.027	0.109	26.136	98.273	54.924	97.572	0.100	32.010
2011	14.271	79.995	52.926	0.195	31.830	99.656	45.235	30.612	0.012	75.426
2012	15.079	74.673	13.189	0.188	21.728	67.578	77.448	22.012		22.196
2013	5.546	37.203	1.138	0.015	13.389	58.686	98.770	19.005	0.164	29.874
2014		24.379	0.918	2.908	6.323	84.353	94.245	25.878	0.000	49.042
Total	173.130	421.640	148.282	79.211	1319.664	2927.223	1646.114	1200.638	29.582	1094.377

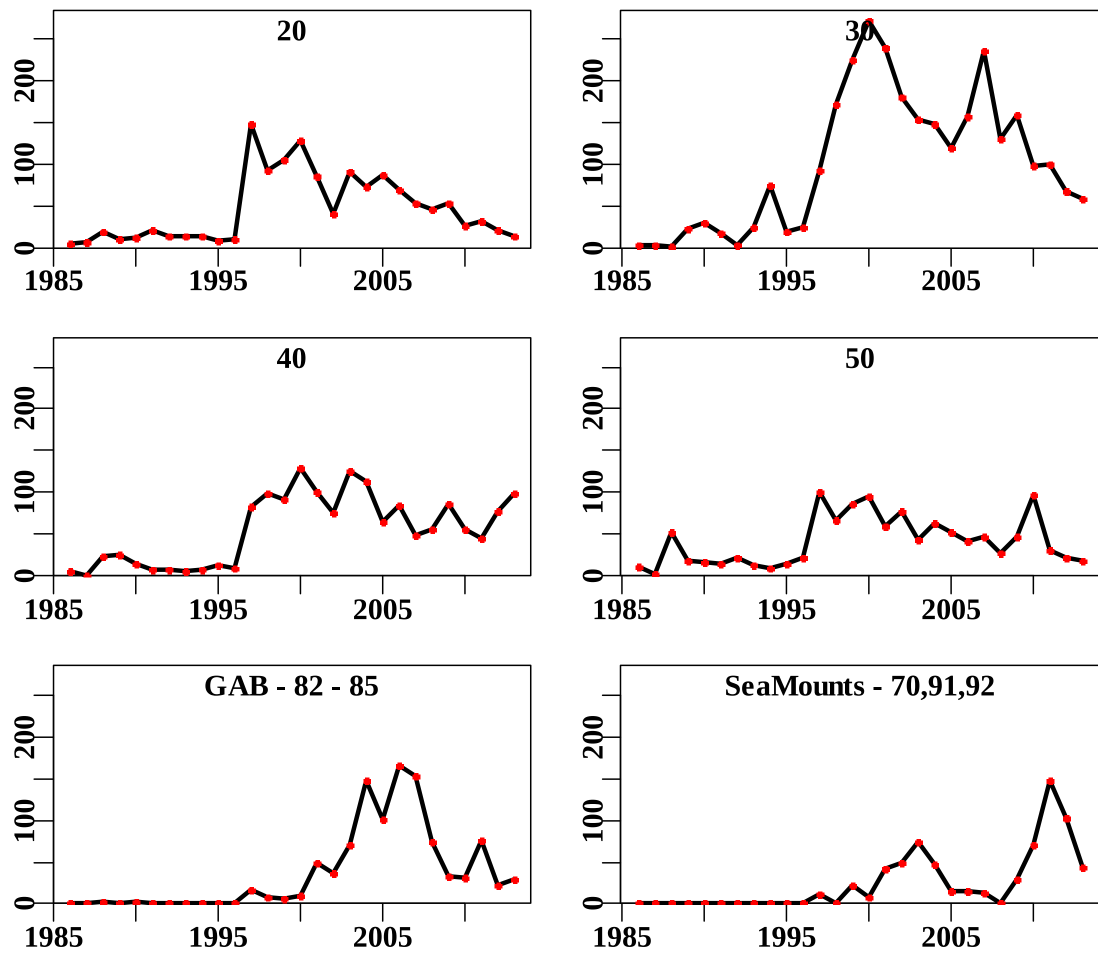


Figure 24.6. Annual catch in Blue-Eye in the four zones 20, 30, 40, and 50, the GAB (zones 82 – 85) and the Seamounts (zones 91, 92, and 70) from 1986 – 2013.

In 1998 one global TAC of 630 t was introduced to cover both the trawl and the GHT fisheries; this was divided 100t for trawl and 530 t for GHT. An increase in effort and catch, particularly in the drop-line fishery on the east coast of Tasmania is reported to be a response in anticipation of that management change, with fishers believing that increasing their catch history would lead to an increase in their allocation of quota. Since 1997 total catches have declined to just over one third of the agreed catches in 1997 (Figure 24.7). The distribution of catches in different regions indicate the changes in the intensity of fishing (Figure 24.8) 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 24.10)

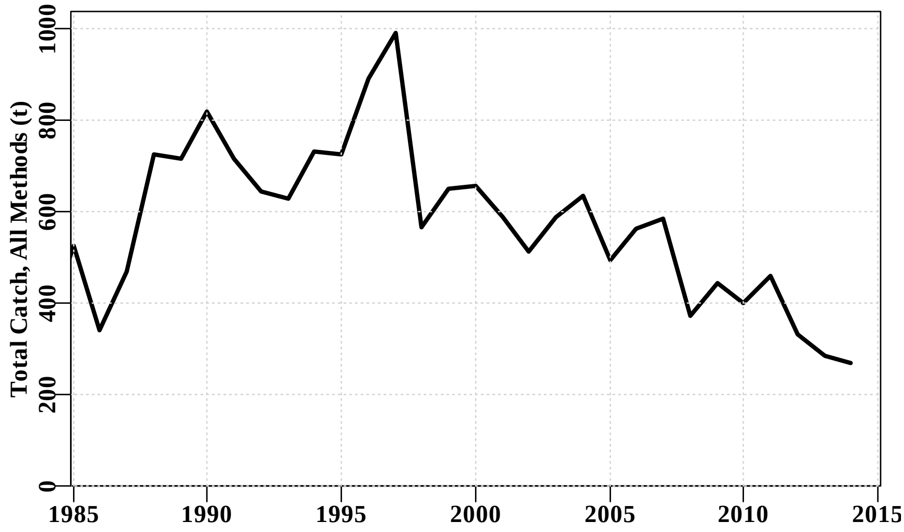


Figure 24.7. Total historical catches of Blue-Eye, with estimates from 1985 – 1999 from Smith and Wayte (2002); see Table 24.2.

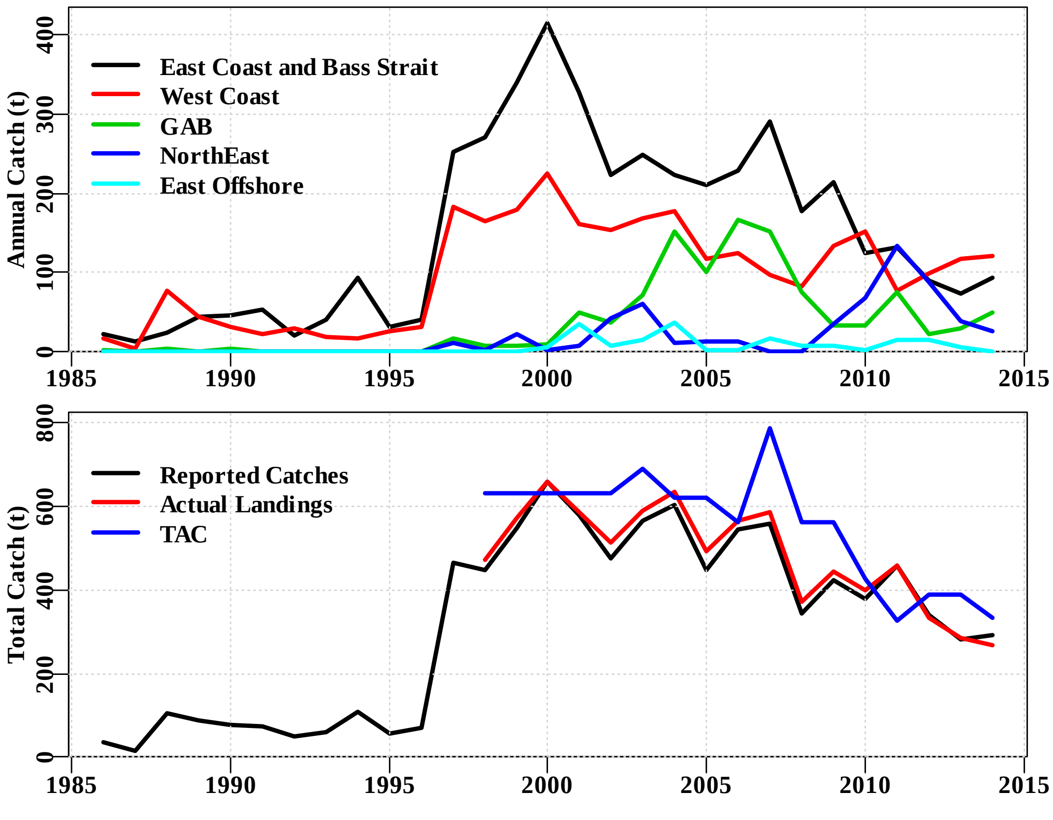


Figure 24.8. Total catches for different regions around the south east of Australia. East coast and Bass Strait includes zones 10, 20 , 30 , and 60; west coast is zones 40 and 50; GAB is zones 82, 83, 84, and 85; North East is zones 91 and 92, an East Offshore is zone 70 (Figure 24.3). The TAC is the 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.

24.4.5 Auto-Line and Drop-Line Catches

Blue-Eye catches taken with Auto-Line and Drop-Line are patchily distributed and the distribution of those catches has changed through time (Figure 24.9). Only the catches from the north-east region near and around the off-shore sea-mounts are included in the assessment of blue-eye. The catches and effort have been so variable and patchily distributed across the different sea-mounts and sub-regions that obtaining a valid CPUE index for the areas is currently not plausible (Haddon, 2015). As a result only zones 20, 30, 40, 50, and 83, 84, and 85 are used. The zones 83, 84, and 85 are in the GAB (see Figure 24.3).

Table 24.6. 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

The focus of this work is the auto-line and drop-line fisheries and there have been large changes in both of these in terms of both catches and location of those catches (Figure 24.10).

The catch rate time series for both methods are now relatively long but catches were relatively low and the number of records was below 70 each year for auto-line before 2001. Drop-line catches have been <= 10 t and with 54 and 65 records in the past two years (Table 24.1; Figure 24.11). By excluding those years of minimum data from the auto-line and drop-line data, when it is combined, not surprisingly, the current standardization, based on catch-per-day shows greater similarities to the drop-line trajectory early on and the auto-line trajectory later on (Figure 24.11). Based on catch-per-day, the auto-line CPUE by itself is now indicating a return to the longer term average CPUE, having completely recovered the decline that appeared to have occurred in 2010. This by itself needs discussion for its management implications but the notion of pursuing CPUE as catch-per-hook remains more intuitively plausible and more likely to reflect changes in the fishery if they have occurred.

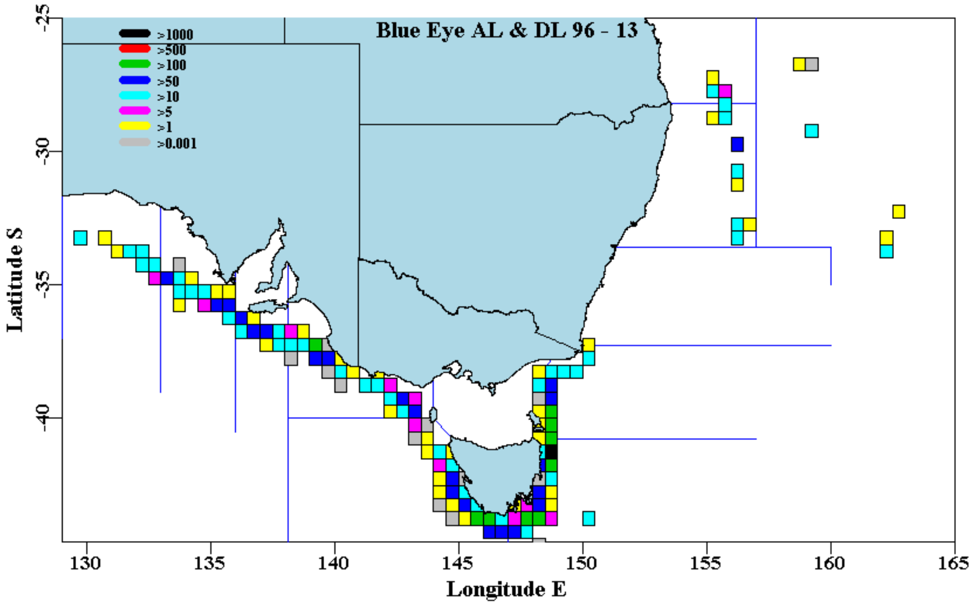


Figure 24.9. Schematic map of the distribution of Blue-Eye catches taken by AL and DL between 1997 – 2014. The zones (Figure 24.3) are used to discern the distribution of catches. A comparison with Figure 24.4 illustrate the different areas fished by different methods.

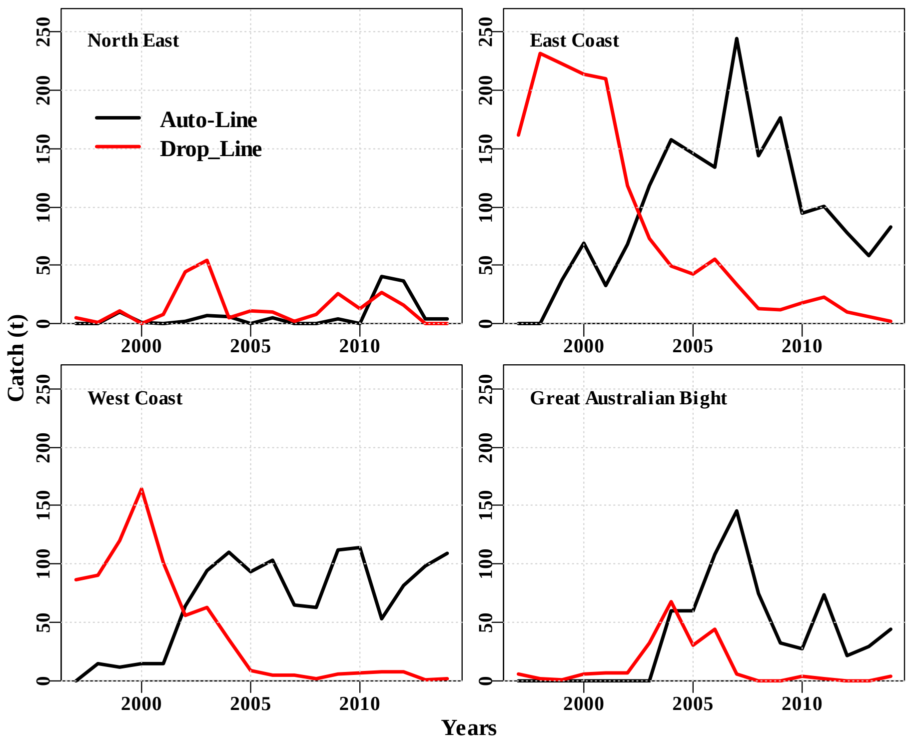


Figure 24.10. Distribution of each year's catch across regions. All graphs are on the same vertical scale. Fishery changes occurred in 2007 (the introduction of the HSP) and 2010 (beginning of TAC reduction).

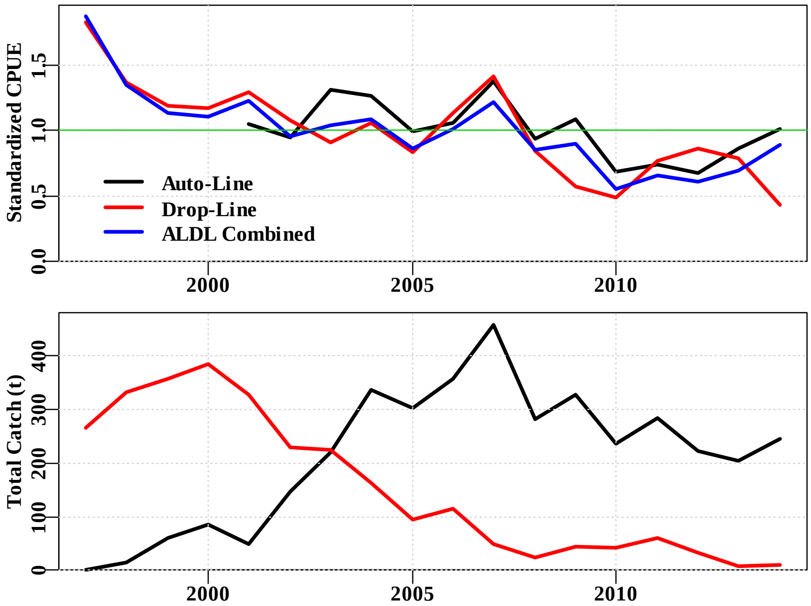


Figure 24.11. A comparison of the standardization for Blue-Eye across zones 20 – 50 and 83 – 85 combined and conducted separately for auto-line from 2001 – 2014 and drop-line from 1997 - 2014. The respective catches across those zones at the same time show the changeover from one method to the other.

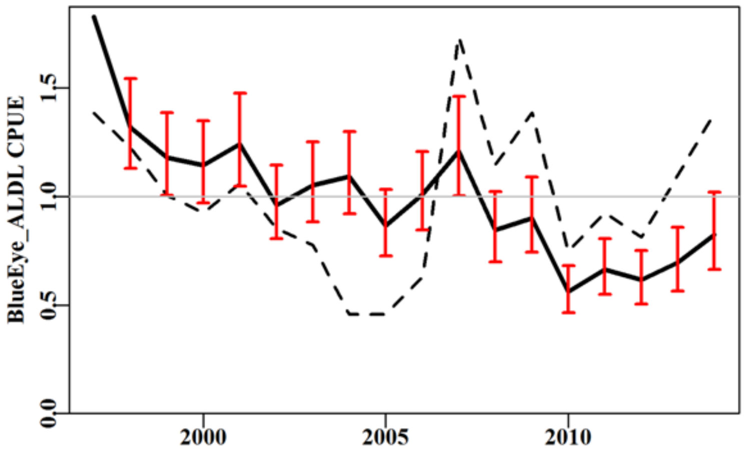


Figure 24.12. Standardized CPUE for the auto-line and drop-line fisheries combined using catch-per-record as the unit of catch rate. The dashed line is the unstandardized geometric mean CPUE. The red bars are the 95% confidence intervals around the mean estimates (their asymmetry reflects the log-normal distribution of the CPUE data. Each time series is called to its own mean value so both series now have a mean of 1.0 for ease of visual comparison of trends. Data filtered to include only drop-line and auto-line from between 200 – 600 m depth and zones 20 – 50 and 83 – 85.

24.4.6 CPUE from the Drop-Line Fishery

The current stock status analysis (Tier 4 harvest strategy) uses the combined CPUE of the drop-line and the auto-line fisheries to provide a time series for use in the Tier 4 analysis. The most recent CPUE analysis indicates that after a relatively strong decline between 2009 – 2010 the CPUE is rising, with the error bounds now once again encompassing the longer term rescaled average of 1.0 (Figure 24.12; see Sporcic, 2015).

While the overall distribution of CPUE from the two methods (as catch-per-record) were sufficiently similar in 2007 and 2008 to allow combination (Haddon, 2010) it is clear that the proportional distribution of each method has changed through time, with catches by drop-line being replaced by auto-line catches following 2001 (Figure 24.5, Figure 24.11; Table 24.1). Given the large area over which fishing could occur, most of the catches tend to be focused in zones 20 – 50 with an occasionally significant fishery developing in the GAB and a couple of years of auto-line effort in the northeast. There were two years of auto-line fishing on the Cascade Plateau but that is currently closed to auto-line fishing. Both auto-line and drop-line catches and effort move between zones a good deal (Figure 24.10 and Table 24.6), although zone 30 (east Tasmania) has often been a favoured fishing area, with reports that this was especially the case before 1997.

The early period from 1997 onwards is especially important to the CPUE analysis as the initial relatively high level of CPUE in 1997 is influential on the perceived changes in catch rate since then. Of course, in 1997 the catches were essentially all from drop-line as only 0.27t were taken by Autoline, and that was only in a very restricted area on the west coast of Tasmania in the months of November and December. The reason the CPUE is estimated as catch-per-record is because with the drop-line vessels, for example, the fields in the logbook for recording the number of lines and the number of hooks were mixed up in a large number of instances. To determine whether the very high CPUE in the drop-line fishery in 1997 was being affected by the use of catch-per-day all drop-line data for zones 20 – 50 were extracted and the 'lines' and 'hooks' fields examined (in fact labelled effort_unit_value and effort_unit_sub_code_value). It was possible to discover the records which had most likely been mixed across each other (for example, 2000 lines of 5 hooks was deemed an error as were 80 drops of 5 hooks) and these were reversed so that more plausible effort estimates in terms of number of lines and number of hooks per line, were available.

After review of data combinations some data selection was still required. There were extreme values in some of the fields (Figure 24.13), which entailed searching for the most reasonable values above which to eliminate data as implausible. Initially an upper limit of 100 line drops and 300 hooks per line were considered (Figure 24.14), however, the resulting data cloud suggested a final range of 1 – 40 for the number of line drops and 1 – 200 for the number of hooks (Figure 24.15; Table 24.7).

Prior to the adjustment and data selection the frequency distribution of the number of lines used was extremely skewed (Figure 24.13), while after the data processing peaks were observed at 1, 10, 15, and 20 line drops a day and 50, 75, 100, 120, and 150 hooks per line (Figure 24.16). These rounding effects when recording the data are the reason it typically takes on a grid like appearance when catches are plotted against effort (Figure 24.14, Figure 24.15). This grid like property of the CPUE data can influence the stability of the standardization. The number or records and total catch omitted remains minor with those up at 40 NLD and 200 AHL also being minor (Figure 24.16; Table 24.7).

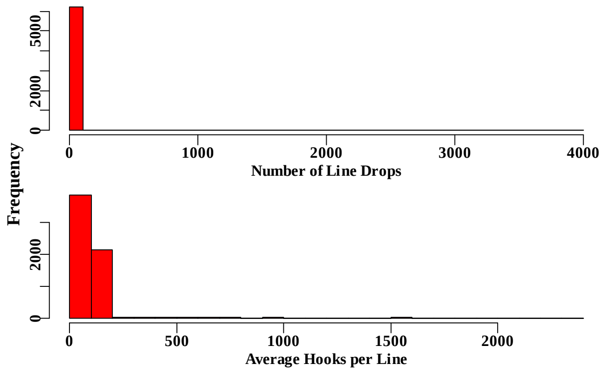


Figure 24.13. The number of line-drops and the average number of hooks per line reported by each vessel in individual records before editing implausible combinations.

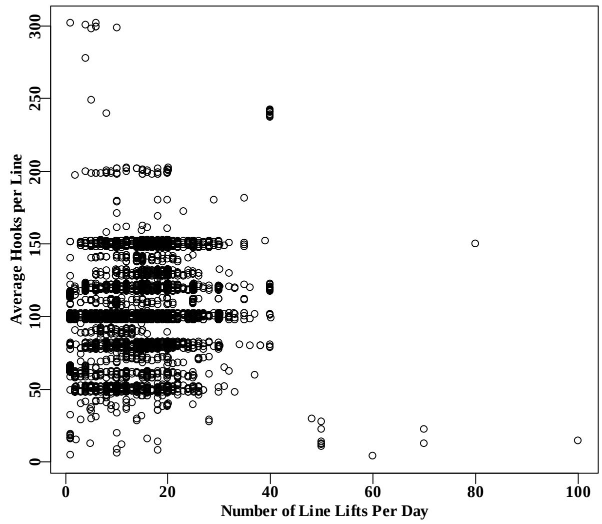


Figure 24.14. Number of hooks per line (generally there is an inverse relationship between number of lines and number of hooks). Limits used were 100 drops/lines and 300 hooks.

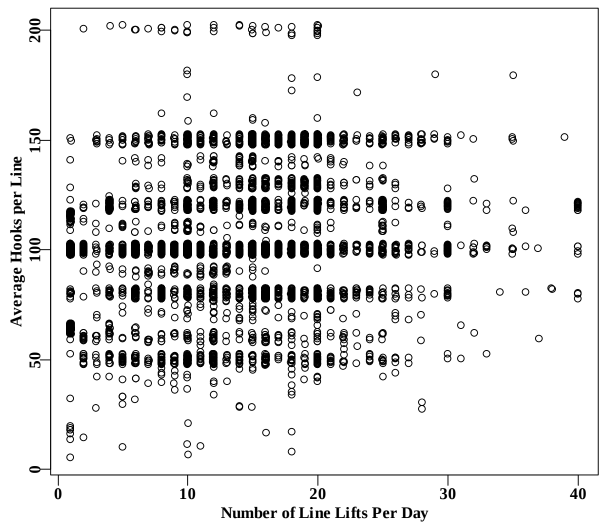


Figure 24.15. The final selection criteria for the number of line drops (or lifts) per day and the average number of hooks per line. Final limits used were 1 – 40 drops/lines and 1 – 200 hooks.

Table 24.7. The effect of data selection in terms of number of line drops and average number of hooks per line. The removal of records with missing data removed ~1.3% of catch, and with the removal of records with > 40 line drops a day and >200 hooks per line there was a total loss of 2.9% of all catches by drop-line.

	No Effort Data	<100; < 300	<40; < 200
Total	2260.430	2260.430	2260.430
Selection	2231.194	2199.134	2193.964
Data Retained	0.987	0.973	0.971
Data Rejected	0.013	0.027	0.029
Catch Difference	29.236	61.297	66.467

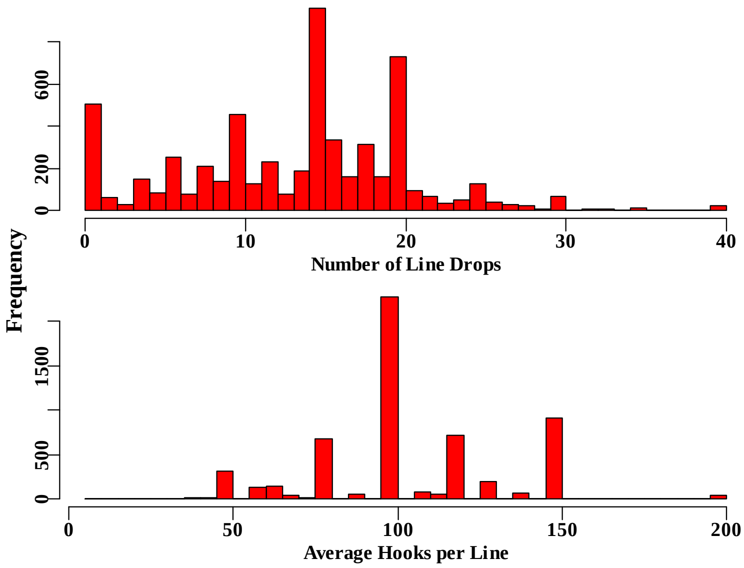


Figure 24.16. The distributions of the number of line drops (NLD) and the average number of hooks per line (AHL) after cleaning and removal of data with NLD values > 40 and AHL values > 200.

24.4.6.1 Single Line Drops

The relatively high frequency of single line drops (Figure 24.16) was unexpected so this was explored further. When the number of records per zone is compared to the number of records per zone where only single line drops were reported it is clear that large changes in reporting practices occurred but only in some zones and only in some years (Table 24.8).

The effect of the records reporting only one line drop can be quite marked. They only make up a small proportion of the total catches up to 2005 and so are less influential but from 2006 onwards, except for 2014, makes up more than 27% and up to 62% (Table 24.9). When all CPUE data are plotted, post-2006 reveals a bimodal distribution relative to the pre-2007 distribution, which is a direct reflection of this increased percentage of single line reports (Figure 24.17; the bimodality disappears when the single line drop records are removed, and the data from the two periods become more comparable).

Even if the catch-per-hook analysis is not accepted to replace the catch-per-shot analysis the impact of these single shots is enough to make the distributions of the catch-per-shot differ between the auto-line and drop-line and so would need to be removed or the combination no longer used (Figure 24.18).

Table 24.8. The total number of records for the selected drop-line records compared with the number of records reporting only single line drops in zones 20 to 50.

	All Selected drop-line records				Records reporting single line drops			
Year	20	30	40	50	20	30	40	50
1997	152	111	53	106				
1998	143	289	74	146				
1999	75	361	108	228	1	0	0	21
2000	94	413	176	248	0	0	0	50
2001	38	338	138	157	0	0	0	45
2002	76	207	56	201	0	0	0	20
2003	72	166	77	135	0	1	0	1
2004	26	150	23	111	0	1	0	0
2005	2	151	7	55				
2006	2	148	11	11	0	65	2	0
2007	13	70	1	18	0	37	1	0
2008	0	64	0	7	0	50	0	0
2009	3	61	1	16	0	50	0	1
2010	0	119	1	43	0	62	0	0
2011	1	108	20	23	0	53	4	0
2012	0	62	6	25	0	20	2	0
2013	0	34	1	6	0	15	1	0
2014	1	22	0	9	0	0	0	1

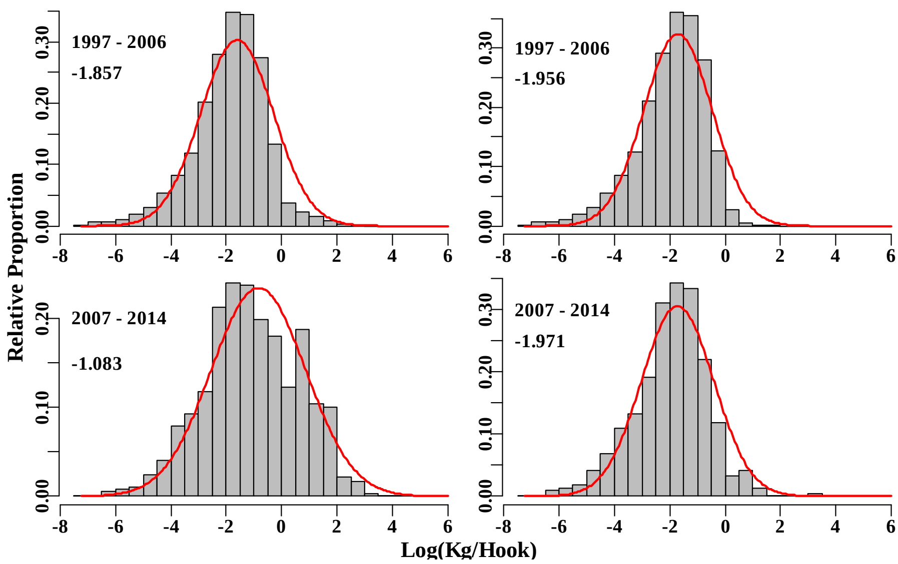


Figure 24.17. The log-transformed CPUE (catch/[linedrops x hooks]) from 1997 – 2006 and 2007 – 2014, both with (left columns) and without single drops (right column). The mode of relatively high log(catch-per-hook) results from single line drops. The negative value is the estimated mean of the fitted normal distribution.

Table 24.9. 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	231.220	422	0.000	0	0.00	33
1998	316.788	652	0.000	0	0.00	26
1999	324.140	750	2.925	22	0.89	27
2000	351.257	881	7.610	50	2.12	28
2001	295.742	626	9.174	45	3.01	24
2002	171.471	520	3.178	20	1.82	20
2003	135.201	448	0.066	2	0.05	20
2004	79.945	309	0.030	1	0.04	16
2005	51.436	215	0.000	0	0.00	14
2006	42.054	105	18.065	67	30.05	10
2007	16.844	64	21.841	38	56.46	9
2008	5.327	21	8.803	50	62.30	6
2009	7.827	30	9.991	51	56.07	9
2010	15.468	101	9.280	62	37.50	9
2011	16.907	95	13.017	57	43.50	9
2012	13.029	71	4.898	22	27.32	8
2013	4.613	25	2.303	16	33.30	5
2014	3.257	31	0.260	1	7.39	4

The records reporting single lines pre-2007 have a major impact on the perceived CPUE. Post-2006 (following the structural adjustment), the proportion of single lines increases to > 50% and catches from > 1 lines reduce to no more than 17t and generally no more than 64 records per year at most (although there were 101 records in 2010; Table 24.9). A comparison of the standardized CPUE for drop-line catches from 1997 – 2006, with and without the single line records illustrates the very large effect these single lines have on records following 2005 (compare Figure 24.19, Figure 24.20, and Figure 24.21). The inclusion of records reporting single lines leads to a similarly noisy but flat time-series after the transition in effort reporting through 2006, however, as evidenced by the wider confidence intervals the later observations are based on far fewer record numbers (Table 24.9). It is apparent that the structural adjustment and associated changes in fishing behaviour (and reporting behaviour) have broken the drop-line CPUE time-series. Of most importance to this is the almost complete changeover in the vessels doing the drop-line fishing. Only one of the significant fishers remained after the structural adjustment and an array of new vessels entered the fishery. It is recommended that the post-2006 drop-line data not be used in future in conjunction with the earlier data as it is too sparse, and has a completely different character. If used alone it is also clear that it is effectively flat but is so noisy (sparse data) that it would be uninformative to any stock assessment that tried to use it.

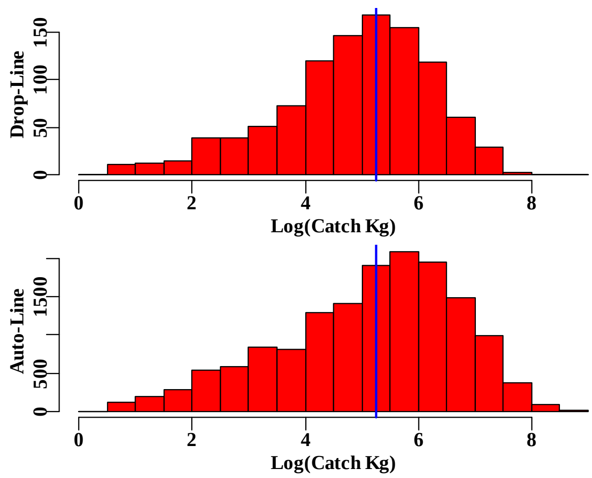


Figure 24.18. The relative frequencies of different log(catch) for auto-line and drop-line from 2007 - 2014. The vertical blue line is the modal group for drop-line.

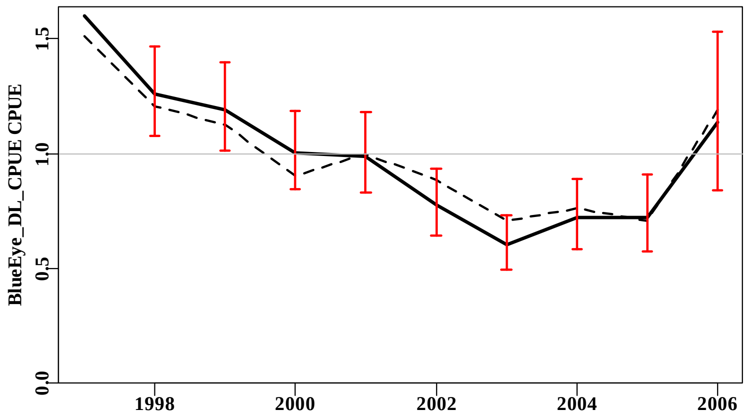


Figure 24.19. The standardized drop-line CPUE from which all records reporting a single line are removed. The low catches and number of records following 2006 (Table 24.9) would make an extension out to 2014 unreliable.

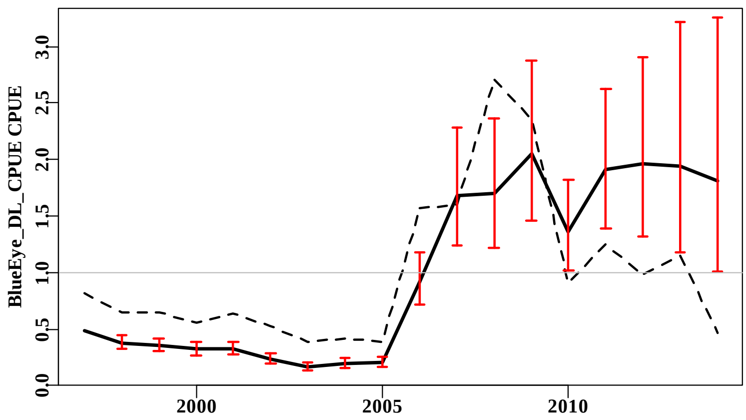


Figure 24.20. The standardized drop-line CPUE from which all records reporting a single line are retained. This time series is extended to 2014 to illustrate the expanded impact of the increased proportion of single lines post-2005; although the small number of records and very low catches in the last two years makes this even less reliable.

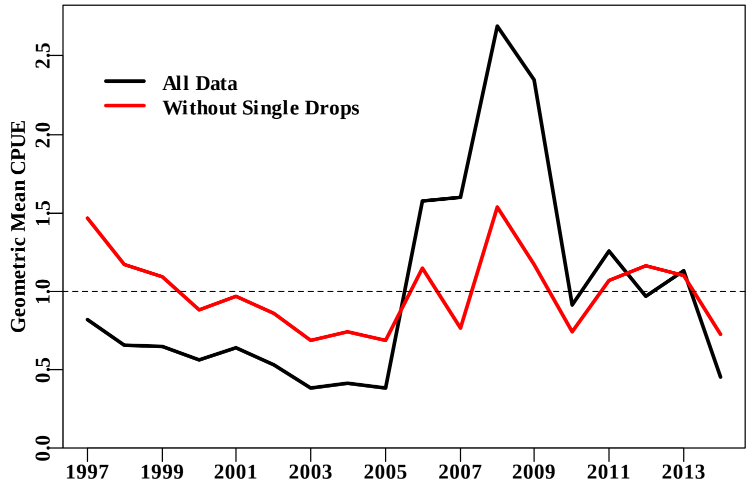


Figure 24.21. The geometric mean CPUE (catch-per-hook) with and without single drops. The numbers of records in the later years become relatively few but the distortion in the general trend brought about by single drops is apparent. Standardization fails because of an almost complete change-over of vessels doing the fishing after 2006/2007.

The catch rate trajectory described when effort is taken to be the corrected hooks by lines differs from that obtained when using catch-per-day (Figure 24.22; see Sporcic and Haddon, 2014 for standard methods). When using all hook x line data (ignoring the single line drop problem) the increase in single line records would lead to a lower total catch-per-day but a higher catch-per-hook-line. Once the impact of the rise in single lines being reported is identified this difference becomes significant.

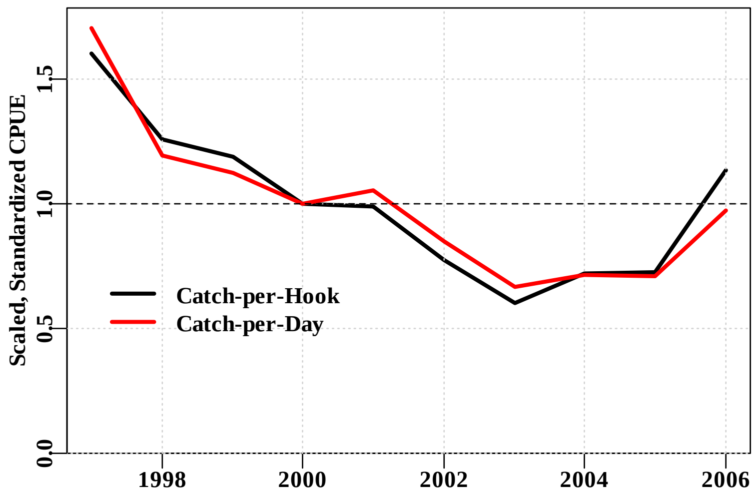


Figure 24.22. A comparison of drop-line CPUE using catch-per-hook (from Figure 24.19) with drop-line CPUE using catch-per-day from the four zones 20 – 50 (Table 24.13 and Table 24.14).

The catch-per-hook trend line begins at a lower level and ends at a higher level than the catch-per-day series (Figure 24.22). However, both have wide uncertainty bars (e.g Figure 24.19). Both time series can be considered to be noisy and uncertain even while oscillating around the mean of 1.0.

24.4.7 CPUE from the Auto-Line Fishery

Auto-line vessels only gained licenses to operate in the SESSF from 1997 although they only began operations in November 1997 on the west coast of Tasmania. Catches in the North East by auto-line only increased since the TAC within the SESSF has declined in recent years (Figure 24.23), although auto-line is now excluded from the area.

Table 24.10. Catches of Blue-Eye (tonnes) reported as being taken by Auto-line since 1997 for those zones where catches are continuous and potentially amenable to a CPUE analysis. See Figure 24.3 for the block descriptions; zone 0 includes catches from zones 10, 60, 70, 91, and 92, as well as outside the SESSF and includes the High Seas Non-Trawl fishery.

Year	0	20	30	40	50	83	84	85
1997				0.267				
1998			0.233	14.956				
1999	11.120	35.575	1.725	11.482				
2000	1.330	12.243	56.804	14.824				
2001	0.242	2.000	31.044	14.598				
2002	2.100	2.640	65.351	42.576	21.400			
2003	7.260	20.634	97.288	84.594	9.900			
2004	1.257	63.236	94.791	82.677	27.149	12.584	15.316	31.689
2005	1.331	84.998	60.426	57.265	36.482	19.278	5.145	35.895
2006	8.019	67.075	67.257	77.940	25.822	31.405	0.330	76.184
2007	0.550	48.019	196.324	41.074	23.907	29.791	100.094	15.337
2008	0.017	44.786	99.013	51.837	11.408	28.943	32.167	13.214
2009	4.795	50.874	125.545	79.909	32.355	1.633	15.369	15.415
2010	0.100	25.642	69.142	50.841	63.093	5.764	7.153	14.884
2011	40.196	30.835	69.512	38.809	14.160	20.576	40.292	12.939
2012	36.777	21.176	56.348	70.428	11.183	8.417	9.736	3.752
2013	4.017	13.151	45.406	84.451	13.684	0.465	16.158	13.025
2014	4.505	3.135	68.561	87.235	19.442	0.607	31.290	11.089

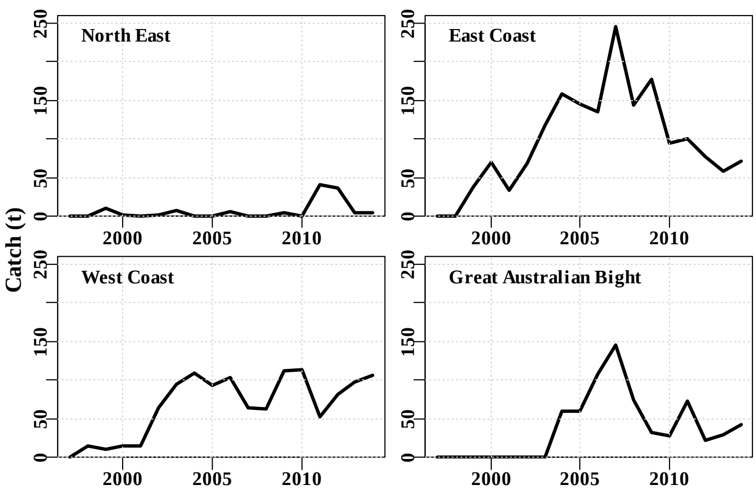


Figure 24.23. Total reported catches of Blue-Eye by auto-line by region. The North East includes zones 70, 91, and 92, the east coast is zones 20 – 30, the west coast is 40 – 50, and the GAB is 83 – 85.

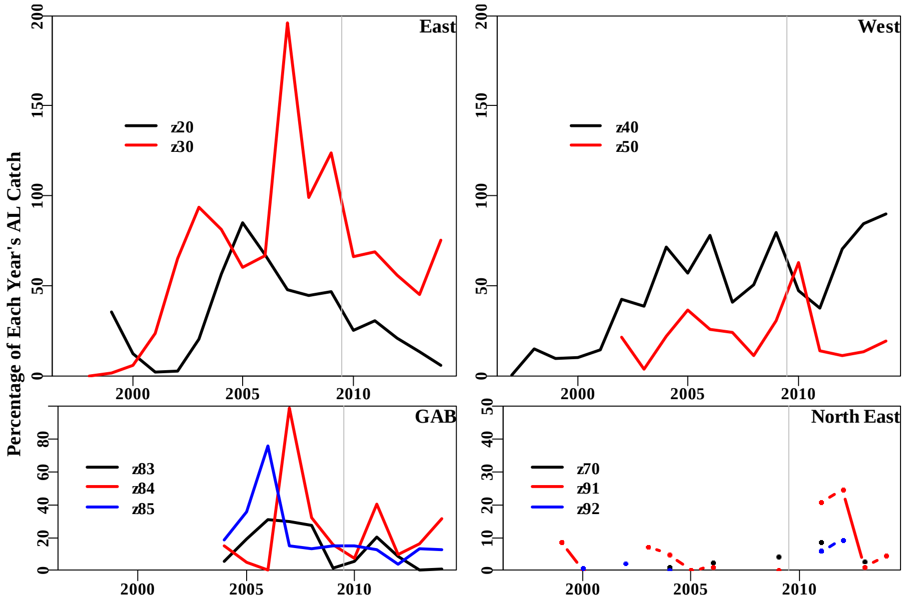


Figure 24.24. A change in catches by auto-line by specific zone within regions. Note the vertical scales are different in each case. Dots are included in the North-East as some zones are not necessarily fished every year.

The east coast of Tasmania and eastern Bass Strait (Horseshoe and Flinders Island) have dominated catches, although since about 2002 catches off western Tasmania have been approximately 100 t per annum and since 2004 catches from the GAB have featured, although these have declined since 2009 (Figure 24.23).

The auto-line fishery for Blue-Eye exhibits some clear seasonal trends around Tasmania but with no clear trend in the GAB (Figure 24.25 and Figure 24.26), which may be related to the recently reduced catches.

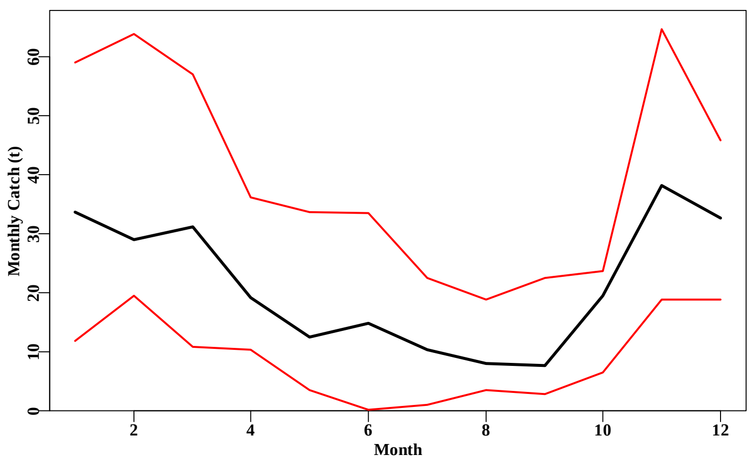


Figure 24.25. The catch per month across years 2002 – 2014 for all areas combined. The black line is the 50th percentile and the red lines are the 5th and 95th percentiles. The lower catches from May to October are apparent.

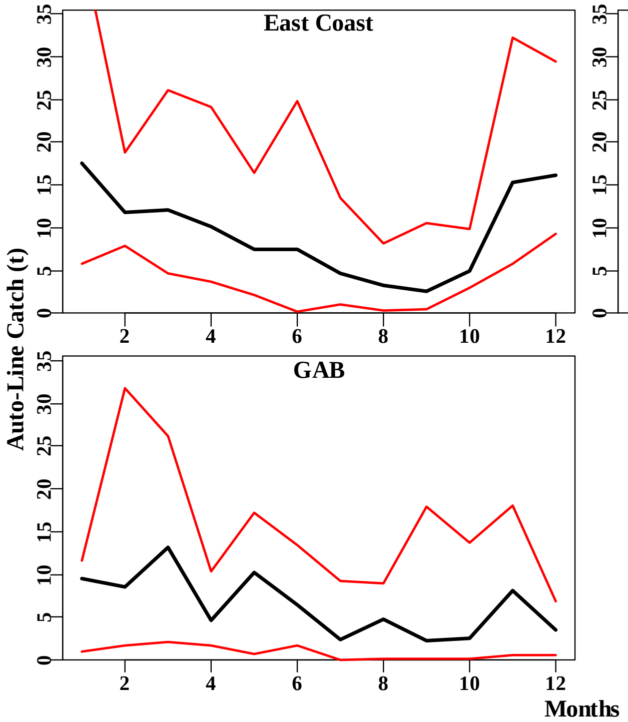


Figure 24.26. The catch per month across years 2002 – 2013 for three identified regions. The black line is the 50th percentile and the red lines are the 5th and 95th percentiles. Seasonality is less apparent in the GAB. In the North East catches are scattered through the years and there is insufficient data to describe any seasonality.

A total of 13 auto-line vessels have reported catches of Blue-Eye since 1997, although there was a maximum of only 11 reporting from any single year (Figure 24.27). The active fleet expanded between 2002 – 2004. The structural adjustment occurred from November 2005 to Nov 2006 and that (along with TAC changes) appears to have stabilized numbers at about six vessels, with only four contributing in recent years.

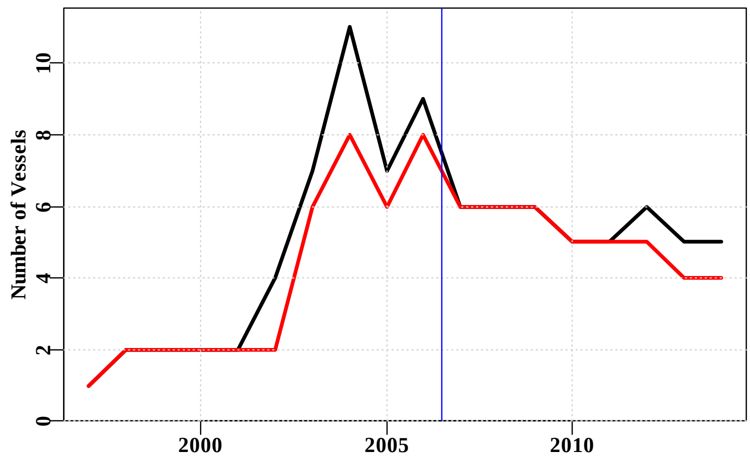


Figure 24.27. The number of auto-line vessels reporting Blue-Eye catches per year of the fishery compared with the number of vessels that caught more than a total of 10 tonnes over the 18 years from 1999 – 2014. Vertical blue line is 2006.5, identifying the structural adjustment.

24.4.7.1 Auto-Line Catch-per-Hook

As with the drop-line analysis the consideration of catch-per-hook will focus on zones 20 – 50. There were numerous confusions in the database, especially in the early years. There was an early change in the database which mixed up a large number of the unit-code-values and sub-unit-code-values so that the 'total-hooks-set' (THS) field might contain '15000' or perhaps just '2'. Other errors occurred but the most important were such transposition errors. The main field used is 'total-hooks-set', so the focus was on making the values in that field plausible for as many records as possible (Figure 24.28).

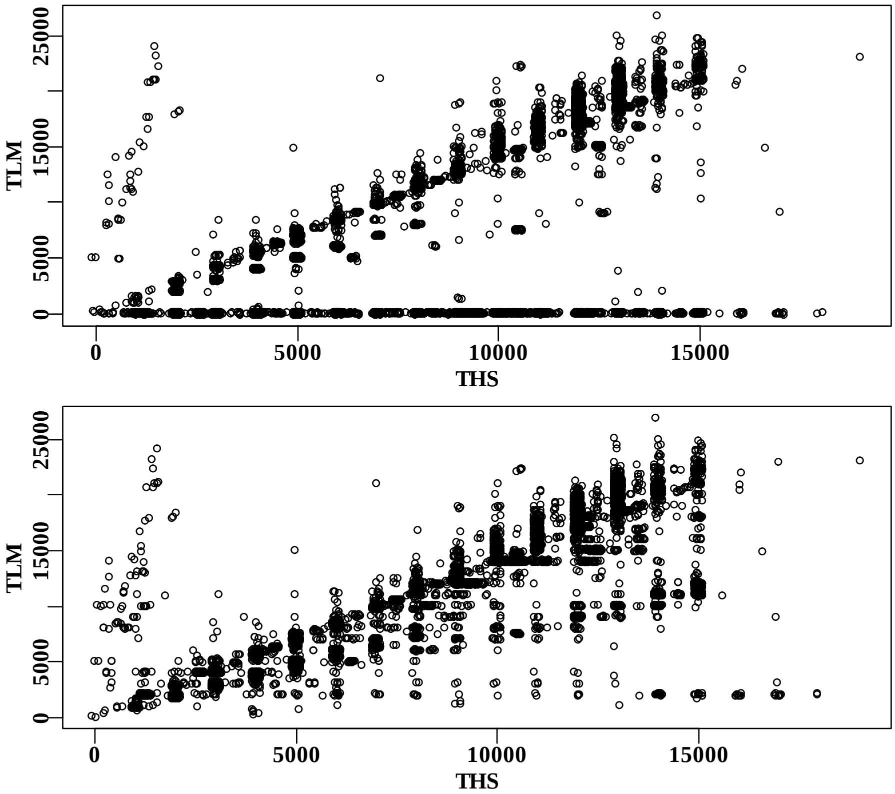


Figure 24.28. Total hooks set reported (THS) against the length of the main line (TLM). The top plot includes a large number of observations with a reported main line length less than 50 meters ranging from 1 – 34. If these are treated as if they are recorded as kilometres rather than metres then the lower plot eventuates.

There were some records which appeared to be more representative of drop-line fishing than auto-line (a unit-value = 20, and subunit-value = 100), such potential errors might need clarification by examination of the original data-sheets.

However, even once the uncertainty generated in the analyses of catch-per-hook by flawed data are managed through data editing or exclusion, it became evident that there have been other sources of change that could influence fishing behaviour and hence CPUE (Figure 24.29). For example, in 1999 – 2000 it is clear that operators reported setting more than 15,000 hooks. However, from 2001 – 2009 it would appear that something stopped them using more than 15,000 hooks, and then from 2010 onwards that maximum appears to have decreased to 13,000 hooks (Figure 24.29). Numerous other changes have occurred in the auto-line fishery with catches only being more evenly distributed among multiple fishers from 2005 onwards. The structural adjustment had the effect, or removing primarily those who had been catching the least, and with so few vessels in the fishery this too can influence CPUE of the remaining vessels, which thus cannot be captured by a standardization.

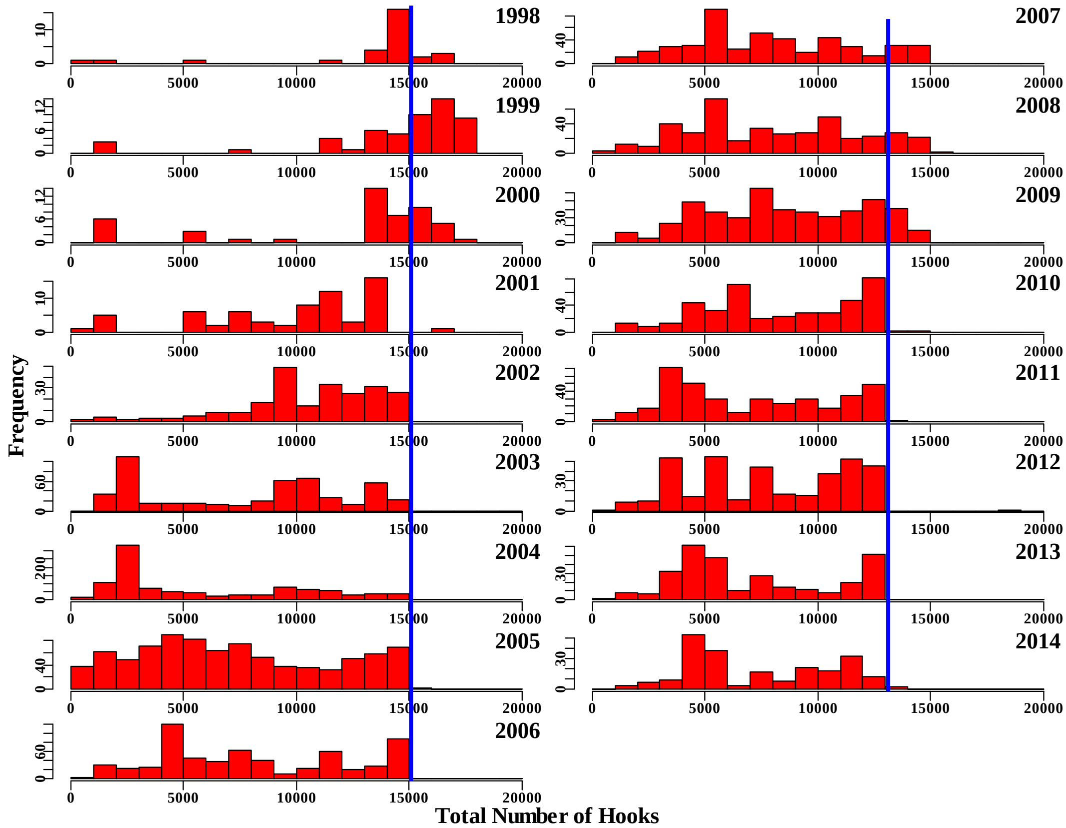


Figure 24.29. The frequency distribution of total number of hooks set each year from 1998 – 2014, after correction of obvious errors.

Once catch-per-hook CPUE data were available these could then be standardized usual standard methods and the two approaches compared (Figure 24.30).

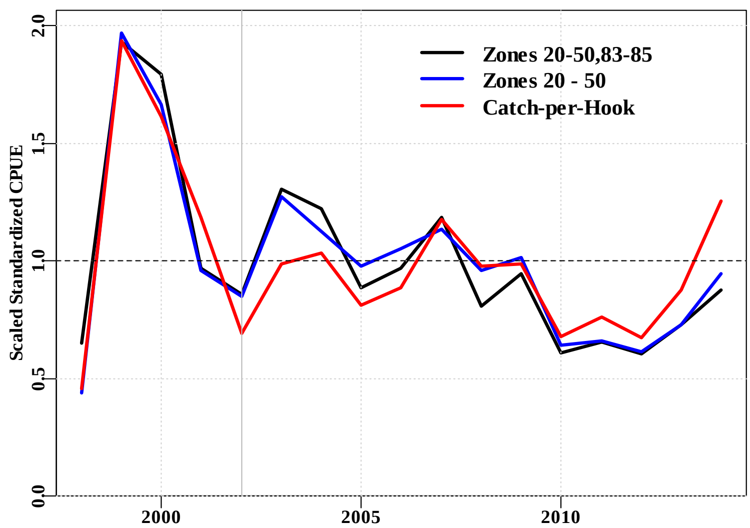


Figure 24.30. A comparison of the standardized catch rates for auto-line vessels using catch-per-record (black and blue lines), and catch-per-hook (red line). All three lines have high levels of uncertainty (see Figure 24.31), but the flattening of the catch-per-hook trajectory is clear.

Finally, once a drop-line CPUE index was available (from 1997 – 2006) and an auto-line index (from 2002 – 2014) the two could also be compared (Figure 24.31). Whether they can be combined to permit a standard Tier 4 analysis to continue (using the overlap period 2002 – 2006 as a reference period) still needs to be decided. However, the standardized time series in each case are both scaled to have a mean of 1.0 over the years 2002 - 2006, and both series (using catch-per-hook CPUE) exhibit similar variation around the longer term average of 1.0. For the provision of management advice it would be possible to use a catch-weighted average of the two lines over the period of overlap (Figure 24.31; Table 24.11).

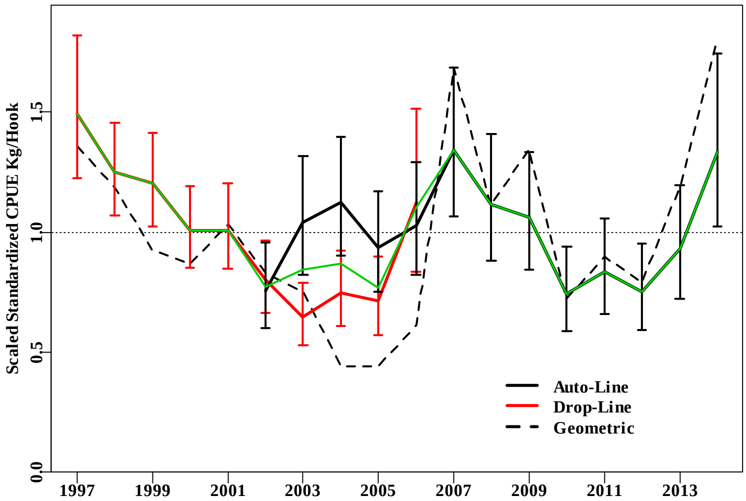


Figure 24.31. A comparison of blue-eye standardized catch-per-hook estimates with the 95% confidence intervals for drop-line (red lines) and auto-line (black lines). A catch-weighted average of the lines from the two methods leads to a compromise in the years 2002 – 2006. If the 2001 auto-line estimates had been included this would have raised the average in 2001 slightly.

24.4.7.2 Catch-per-Record vs Catch-per-Hook

The combined standardized catch-per-hook time-series is flatter than the catch-per-record time series, although just as noisy (Figure 24.32), with large degrees of overlap in their confidence intervals.

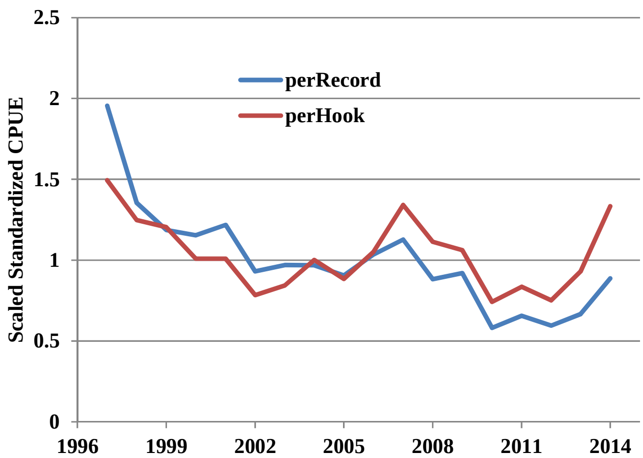


Figure 24.32. Comparison of the standardized catch-per-record with the combined catch-per-hook analyses for drop-line and auto-line.

Table 24.11. The optimum standardized CPUE (scaled to a mean of 1.0 over the years 2002 - 2006) for both drop-line and auto-line. The combined time series weights the relative CPUE by the relative catch by method (Table 24.1), which of course only leads to differences over the years 2002 – 2006 when the two methods overlap. These data are plotted for comparison in Figure 24.33.

Year	Drop-Line	Auto-Line	Combined
1997	1.8507		1.8507
1998	1.5464		1.5464
1999	1.4918		1.4918
2000	1.2490		1.2490
2001	1.2494		1.2494
2002	0.9911	0.7752	0.9068
2003	0.8006	1.0651	0.9314
2004	0.9273	1.1479	1.0760
2005	0.8861	0.9584	0.9411
2006	1.3949	1.0535	1.1367
2007		1.3715	1.3715
2008		1.1397	1.1397
2009		1.0861	1.0861
2010		0.7594	0.7594
2011		0.8547	0.8547
2012		0.7683	0.7683
2013		0.9517	0.9517
2014		1.3648	1.3648

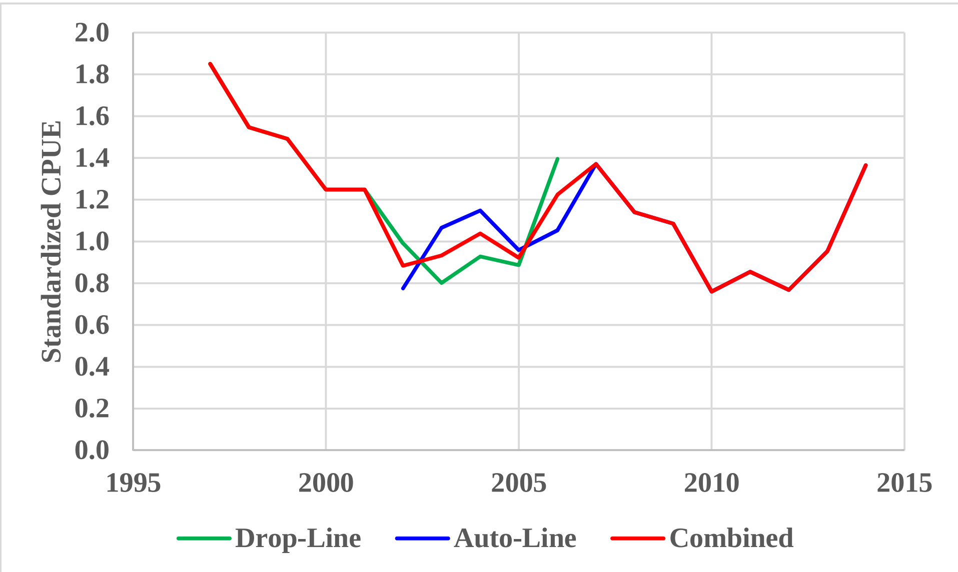


Figure 24.33. The two time series of catch-per-hook combined into one series (see Table 24.11).

24.5 Discussion

24.5.1 Assumptions about CPUE

There are some important assumptions in the analyses previously conducted on Blue-Eye Trevalla and those conducted in this document. These assumptions apply to all species whose stock status assessments rely on CPUE. The first is that changes in CPUE directly reflect changes in the relative stock abundance rather than the influence of other factors such as the structural adjustment, or reduced catch rates through whale depredations or from whale avoidance behaviour from shifting into less optimal CPUE areas. In addition, the various closures in the south-east are assumed to have little or only minor effects on catch rates as are the recent reductions in TAC, which mostly coincide with the introduction of important Blue-Eye closures on the east coast of Tasmania. In addition there would appear to have been changes concerning the maximum number of hooks that could be set by the auto-line vessels in 2001 and 2010. CPUE reflects fishing behaviour and, potentially, any factor that may lead to a change in fishing behaviour may affect CPUE. Such things are confounded with stock size changes, that is a change in the CPUE brought about by a management change, can easily be confused for a change in the stock. Catch rate standardization is a method of using statistical methods in an attempt to take account of such external factors, with common examples of important potentially influential factors being which vessel is fishing, where they are fishing, at what depth they are fishing, and what month they are fishing. The process of standardization is completely dependent upon the availability of quality data concerning the factors being considered.

24.5.2 Other factors affecting CPUE

There are some influential factors whose potential effects upon CPUE would be difficult to identify and isolate as a confounding effect with stock size. Any influence that occurs as 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, or a change in almost all the vessels fishing following the structural adjustment, or a limitation placed on maximum effort or catch per day) is very difficult to correct for, if at all.

In the case of a closure, if the closure is on favoured fishing grounds then there will undoubtedly be a change in fishing behaviour (which, in the case of Blue-Eye is confounded with reductions in TAC). While it is known where the vessels would not be operating it is not known where effort that would have been expended in the now closed region will be transferred to.

The structural adjustment between Nov 2005 – Nov 2006 led to a reduction in the number of vessels operating in the blue-eye fishery and this is very apparent in the trawl fleet and the drop-line fleet, both of which decline significantly in numbers from 2005 - 2007 onwards. Such a reduction in vessel numbers, and which vessels are actually fishing, may have altered fishing behaviour in ways that are not characterized in the standardization. In the case of Blue-Eye drop-line vessels a major change did occur in how effort was being reported with the number of records reporting single lines instead of multiple lines increased dramatically. This is mixed up with the big change in the vessels actually fishing with most significant fishers leaving the fishery after the structural adjustment (one remained). Such transitions invalidate application of the statistical standardization and almost the only thing that can be done is to treat the different periods separately.

One large issue with the analysis of any of the line and hook methods is uncertainty over the representativeness of any single year's data for the fishery. The minor-line methods are still patchily distributed over different sea-mounts and off-shore areas and even auto-line and drop-line have widely varying coverage across the different important statistical reporting zones within the SESSF. This is especially the case with auto-line following its adoption in 1997; for example, there were 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 have remained at low and declining levels (< 20t) throughout that period.

24.5.3 Catch-per-Record vs Catch-per-Hook

The use of catch-per-day or record stemmed from early records of effort data being confused so that for example, with drop-lines the number of separate lines used and the number of hooks per line were sometime placed in each other's fields on the log-books and thereby in the database. For a single and particular species in particular areas it was, however, possible to examine what appeared to be atypical data and reverse obvious errors (for example cases of 200 lines each of 10 hooks, should obviously be reversed). This use of a different measure of effort gives a very different time-series of CPUE than when catch-per-day or record is used. The use of catch-per-day avoids the issue of the remarkable change in effort reporting that appears to have followed the structural adjustment. Intuitively, however, catch-per-hook-line appears more realistic. It is certainly an area that requires further analysis and consideration.

Using catch-per-record means that when significant changes occur in fishing behaviour these would be missed. By missing such major changes, inappropriate data can continue to be used as still representing the fishery. Thus, if catch-per-record data is to continue being used for the provision of management advice then some extra data selection will need to be made to focus on those fishing events that are more typical of the fishery.

One very influential change in how effort was reported occurred with the proportion of single drops (in the drop-line fishery) increasing dramatically following 2006; this is directly related to the advent of an array of new vessels entering the fishery. In terms of catch-per-hook these greatly distort the CPUE although if they are removed from consideration the geometric mean CPUE flattens remarkably and is very different from when all data are considered together (Figure 24.21). This, plus the almost complete change in the fleet of vessels doing the drop-lining fishing, along with the major reduction in the number of drop-line records available post-2006, justify only using the drop-line CPUE from 1997 – 2006 when examining catch-per-hook, and similar arguments apply to the use of catch-per-record.

The auto-line fleet only began to expand and distribute catches from about 2002 onwards, other changes include the first gear limitation (to 15,000 hooks maximum) in 2001 and the rapid expansion of the auto-line fleet from 2002 onwards. The data up to 2000/2001 are not widely distributed spatially each year and are not distributed among many vessels. For this reason it is difficult to justify using the auto-line data before 2002.

24.5.4 The effects of whale depredation

The effects of whale depredation was ignored for the drop-line fishery as this was assumed to have reached an equilibrium years before the collection of detailed fishery data from the non-trawl sector.

Previous work presented estimates of whale depredation on auto-line fishing by treating them in the same way as discards (Pease, 2012).

Table 24.12. Estimates of whale depredation presented to the RAG in 2014.

Year	Whale Depredations (t)	% of Total taken by Whales
2008	19.6	4.6
2009	48.5	9.2
2010	154.4	25.8
2011	123.7	19.6
2012	45.5	12.7

24.6 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.

24.7 Acknowledgements

Thanks go to Robin Thomson and Miriana Sporcic for all the pre-analytical data preparation.

24.8 References

AFMA (2005) Mammal depredation on demersal longlines: A review prepared by AFMA for the Gillnet, Hook and Trap Fishery. 24p.

AFMA (2013) SESSF Total Allowable Catch recommendations for the 2014 – 15 season. Australian Fisheries Management Authority. 33p.

Burnham, K.P. & D.R. Anderson (1998) *Model Selection and Inference. A practical Information-Theoretic approach.* Springer-Verlag, New York Ltd. 353p.

DAFF (2007) Commonwealth Fisheries Harvest Strategy. Policy and Guidelines. Department of Agriculture, Fisheries and Forestry. 55p.

Fay, G. (2007a) Tier 3 Calculations for Blue-Eye Trevalla (*Hyperoglyphe antarctica*) using data up to and including 2005. Pp 520 – 527 *in* Tuck, G.N. (ed.) (2007) Stock Assessment for the Southern and Eastern Scalefish and Shark Fishery 2006-2007. Volume 1: 2006. AFMA Project 2006/813. CSIRO Marine and Atmospheric Research, Hobart. 570p.

Fay, G. (2007b) Data appraisal and progress on Harvest Strategy Evaluation for Blue-Eye Trevalla: update fro July 2007 SlopeRAG meeting. Pp 474 – 497 *in* Tuck, G.N. (ed.) (2007) Stock Assessment for the Southern and Eastern Scalefish and Shark Fishery 2006-2007. Volume 2: 2007. AFMA and CSIRO Marine and Atmospheric Research, Hobart. 584p.

Gomon, M., Bray, D., and R. Kuiter (*eds*) (2008) *Fishes of Australia's Southern Coast.* Museum Victoria. 928p.

Kimura, D.K. (1981) Standardized measures of relative abundance based on modelling log(c.p.u.e.), and their application to pacific ocean perch (*Sebastes alutus*). *Journal du Conseil International pour l'Exploration de la Mer. 39*: 211-218.

Haddon, M. (2009) Catch rate standardizations 2008 (for ata 1986 – 2007) pp 30 - 168 *in* Tuck, G.N. (ed.) 2009. Stock Assessment for the Southern and Eastern Scalefish and Shark Fishery 2008. Australian Fisheries Management Authority and CSIRO Marine and Atmospheric Research, Hobart. 645 p.

Haddon, M. (2010) Blue-Eye Summary (TBE – 37445001 – *H. antarctica*. Pp 99 – 104 *in* Tuck, G.N. (*ed*) (2010) *Stock Assessment for the Southern and Eastern Scalefish and Shark Fishery: 2009.* CSIRO Marine and Atmospheric Research, Hobart. 428p.

Haddon, M. (2014a) Standardized Catch Rates for Selected Species from the SESSF. (Data 1986 – 2012). Pp 57 – 275 *in* Tuck, G.N. (*ed*) (2014) *Stock Assessment for the Southern and Eastern Scalefish and Shark Fishery: 2013. Part 2.* AFMA Project 2011/0814. CSIRO Wealth from Oceans, Hobart. 486p.

Haddon, M. (2014b) Tier 4 Analyses in the SESSF, including Deep Water species. Data from 1986 – 2012. Pp 352 – 461 *in* Tuck, G.N. (*ed*) (2014) *Stock Assessment for the Southern and Eastern Scalefish and Shark Fishery: 2013. Part 2.* AFMA Project 2011/0814. CSIRO Wealth from Oceans, Hobart. 486p.

Haddon, M. (2014c) Blue-Eye Fishery Characterization. Pp 329 – 351 *in* Tuck, G.N. (*ed*) (2014) *Stock Assessment for the Southern and Eastern Scalefish and Shark Fishery: 2013. Part 2.* Australian Fisheries Management Authority and CSIRO Wealth from Oceans, Hobart. 486p.

Haddon, M. (2015) Blue-Eye Fishery Characterization 1986 – 2013. Pp 277 – 327 *in* Tuck, G.N. (*ed*) (2014) *Stock Assessment for the Southern and Eastern Scalefish and Shark Fishery: 2014. Part 2.* Australian Fisheries Management Authority and CSIRO Wealth from Oceans, Hobart. 432p.

Little, L.R., Wayte, S.E., Tuck, G.N., Smith, A.D.M., Klaer, N., Haddon, M., Punt, A.E., Thomson, R., Day, J. and M. Fuller (2011) Development and evaluation of a cpue-based harvest control rule for the southern and eastern scalefish and shark fishery of Australia. ICES Journal of Marine Science. 68(8): 1699-1705.

Neter, J., Kutner, M.H., Nachtsheim, C.J, and W. Wasserman (1996) *Applied Linear Statistical Models*. Richard D. Irwin, Chicago. 1408p.

Pease, D.S. (2012) Acoustic techniques to mitigate killer whale (*Orcinus orca*) and Demersal Longline fishing interactions in Australia. Honours Thesis, Australian Maritime College Tasmania. 112 p.

Peterson, M.J., Mueter, F., Criddle, K. and A.C. Haynie (2014) Killer whale depredation and associated costs to Alaskan Sablefish, Pacific Halibut and Greenland Turbot longliners. *PLOS One* **9**: e88906. doi:10.1371/journal.pone.0088906

Punt, A.E., Walker, T.I., Taylor, B.L., and F. Pribac (2000) Standardization of catch and effort data in a spatially structured shark fishery. *Fisheries Research* **45**: 129-145.

Punt, A.E., Walker, T.I., and A. Gason (2004) Initial assessments of Sawshark (*Pristiophorus cirratus* and *P. nudipinnis*) and Elephant Fish (*Callorhinchus milii*) pp335 – 369 *in* Tuck, G.N. and A.D.M. Smith *Stock Assessment fo South East and Southern Shark Fishery Species*. FRDC Project 2001/005 CSIRO Marine Research, Hobart. 412p.

Punt, A.E. and A. Gason (2006) Revised Standardized Catch-Rate Series for School and Gummy Shark based on Data up to 2005. CSIRO Martine and Atmospheric Research, Hobart.

R Development Core Team (2009). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. ISBN 3-900051-07-0, URL http://www.R-project.org.

Smith, A.D.M. and S.E. Wayte (*eds*) (2002) The South East Fishery 2002. Compiled by the South East Fishery Assessment Group. Australian Fisheries Management Authority, Canberra. 271p.

Sporcic M. and M. Haddon (2014) *Catch rate standardization for selected SESSF species (data to 2013)*. Report to SLOPE and SHELF RAGs 2014. CSIRO Oceans and Atmosphere. Hobart, 228p.

Sporcic, M. (2015) Catch rate standardization for selected SESSF species (data to 2014). Draft document presented to SESSF RAG Aug, 2015. 231 p.

Tilzey, R. (*ed*) (1998) *The South East Fishery 1997*. Fishery Assessment Report. Compiled by the South East Fishery Assessment Group, Australian Fisheries Management Authority, Canberra. 214p.

Tilzey, R. (*ed*) (1999) *The South East Fishery 1998*. Fishery Assessment Report. Compiled by the South East Fishery Assessment Group, Australian Fisheries Management Authority, Canberra. 199p.

Upston, J. (2014) Integrated Scientific Monitoring Program for the Southern and Eastern Scalefish and Shark Fishery – Discard estimation 2013 (draft) AFMA and CSIRO Oceans and Atmosphere. Hobart, 34p.

Venables, W. and C. M. Dichmont (2004). GLMs, GAMs and GLMMs: an overview of theory for applications in fisheries research. *Fisheries Research* **70**: 319-337.

24.9 Appendix – extra tables and figures

Table 24.13. Standardization of drop-line blue-eye catches using catch-per-day and all records. The optimum model included all factors. Standard methods were used.

	Year	Vessel	Month	DepCat	Zone
1997	1.6108	1.9078	1.7394	1.6993	**1.7022**
1998	1.2585	1.1326	1.1823	1.1829	**1.1944**
1999	1.0460	1.0264	1.1040	1.1067	**1.1236**
2000	0.9351	0.9427	1.0066	1.0037	**1.0023**
2001	1.0708	1.0957	1.0938	1.0907	**1.0557**
2002	0.8434	0.8607	0.8369	0.8441	**0.8517**
2003	0.7291	0.6700	0.6608	0.6674	**0.6666**
2004	0.6426	0.6655	0.6960	0.7134	**0.7176**
2005	0.6562	0.6751	0.6823	0.7065	**0.7094**
2006	1.2075	1.0235	0.9978	0.9853	**0.9765**
	Year	Vessel	Month	DepCat	Zone
AIC	2938	2235	1932	1904	1887
RSS	8910	7495	7018	6906	6874
MSS	302	1716	2194	2306	2338
Nobs	4928	4928	4928	4905	4905
Npars	10	84	95	113	116
adj_r2	3.104	17.239	22.335	23.280	23.585
%Change	0.000	14.135	5.096	0.945	0.306

Table 24.14. Standardization of drop-line blue-eye catches using catch-per-hook and only records with > 1 drop per day. The optimum model included all factors.

	Year	Vessel	Month	DepCat	Zone
1997	1.5094	1.7498	1.6333	1.6102	**1.6016**
1998	1.2069	1.1890	1.2352	1.2439	**1.2586**
1999	1.1278	1.0994	1.1692	1.1827	**1.1895**
2000	0.9032	0.9449	1.0006	1.0018	**1.0021**
2001	0.9970	1.0070	0.9995	1.0007	**0.9889**
2002	0.8858	0.7774	0.7564	0.7659	**0.7767**
2003	0.7062	0.6072	0.5989	0.6018	**0.6027**
2004	0.7628	0.6959	0.7190	0.7242	**0.7209**
2005	0.7095	0.7128	0.7121	0.7265	**0.7246**
2006	1.1913	1.2165	1.1759	1.1423	**1.1345**
	Year	Vessel	Month	DepCat	Zone
AIC	1941	1598	1339	1326	1312
RSS	7276	6586	6222	6138	6113
MSS	228	918	1282	1367	1392
Nobs	4928	4928	4928	4905	4905
Npars	10	84	95	113	116
adj_r2	2.864	10.732	15.475	16.297	16.587
%Change	0.000	7.868	4.743	0.822	0.290

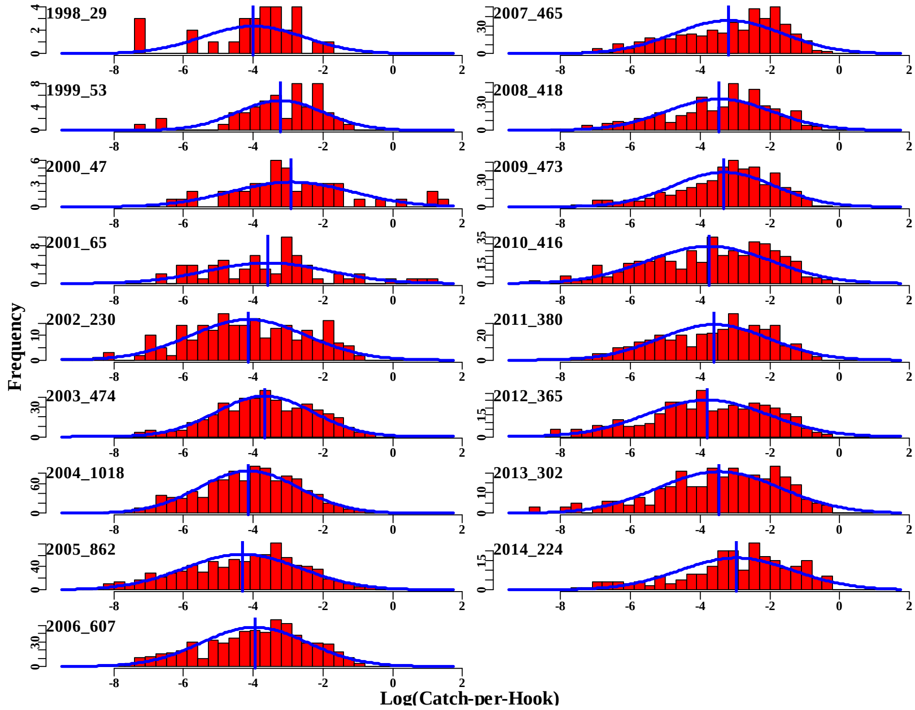


Figure 24.34. Frequency distributions for each year of data relating to the log or the catch-per-hook, with normal distributions fitted on top.

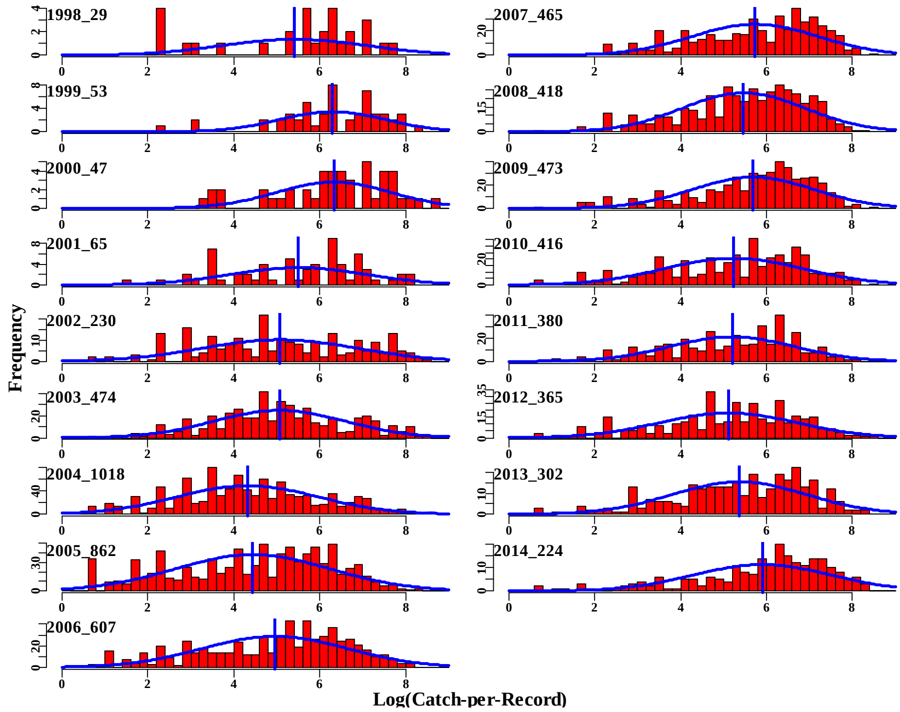


Figure 24.35. Frequency distributions for each year of data relating to the log of the catch-per-record, with normal distributions fitted on top.

Table 24.15. The estimated standard error of each annual cpue estimate when starting the series in different years, with the number of observations available in each year (N). Not surprisingly the most precise estimates are obtained in those years with the most observations.

Year	1999	2000	2001	2002	N
1999	0.217				53
2000	0.284	0.231			47
2001	0.260	0.274	0.189		65
2002	0.217	0.234	0.198	0.120	230
2003	0.209	0.226	0.189	0.119	474
2004	0.203	0.222	0.184	0.112	1018
2005	0.203	0.224	0.185	0.113	862
2006	0.204	0.224	0.186	0.115	607
2007	0.206	0.225	0.186	0.118	465
2008	0.207	0.227	0.188	0.120	418
2009	0.205	0.225	0.186	0.117	473
2010	0.207	0.226	0.188	0.120	416
2011	0.209	0.228	0.189	0.121	380
2012	0.208	0.227	0.189	0.122	365
2013	0.212	0.230	0.193	0.128	302
2014	0.217	0.235	0.198	0.137	224

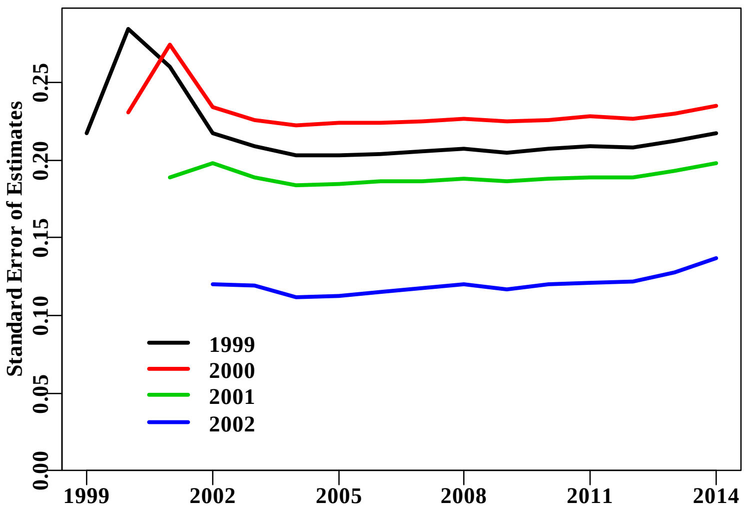


Figure 24.36. The precision of the year parameter estimates is dependent on the number of observations available in each year as well as the full range of the available data.

25. Data-Poor Options for Deep-Water Species

Malcolm Haddon

CSIRO Oceans and Atmosphere, GPO Box 1538, Hobart, Tas 7001, Australia

25.1 Executive Summary

An array of data-poor methods have been proposed as fitting into a new Tier 5 category of harvest strategy within the SESSF. These include four measures of central tendency of the catch history, which could be applied to species for which very little catch information was available. Their application would need to be defended in each separate case so that, for example, with smooth oreos it would not be valid to apply methods which used either the third highest catch or the average catch because the variation in catches through time has been extreme with smooth oreo. Median catches, however, would be easier to justify.

When applied to smooth oreos (non-Cascade) the three catch central-tendency methods gave rise to sustainable catch levels of between 175 – 190 t.

A model-assisted data-poor method called Depletion-Based Stock Reduction Analysis was also used to estimate what would be a sustainable catch level. There are an array of assumptions and required parameters for this method but values for these parameters are selected from distributions which are given wide bounds in an attempt to avoid constraining the outcomes by the inputs. A critical input is the final expected median depletion level. This makes sense in the USA where the search is for a fishing mortality rate that will eventually achieve the maximum yield. Here in Australia where literal catch limits are set selecting a median depletion level could easily bias the outcome. Nevertheless, by using the method to search for the yields that should keep the spawning biomass above 20%B_0 for more than 90% of time, should provide defensible yield values. Testing this approach with flathead and comparing it with the most recent assessment showed this can be a conservative approach,

With smooth oreo (non-Cascade) using the DB-SRA in this manner led to an estimate of sustainable yield of 72 t. The wide bounds used in the DB-SRA method led to relatively high levels of uncertainty around the yield estimate. The 72 t was the median DB-SRA estimate, but the 95th percentile encompassed 237 t, so the estimates from the central tendency methods remain viable options. The results are 72 t (DB-SRA) or 175 – 190t (median catch estimates).

Application of these uncertain methods means that all available information should be used explicitly when defending the choices made and the final decisions from the analyses. The presence of the 700m deep-water closure still means that areas where most historical catches were taken remain closed. This means the risks involved in applying one of the estimated RBCs/TACs would be low.

25.2 Introduction

The SESSF has had a tiered set of harvest strategies in place since 2007, and the assessment methods and harvest control rules specific to each tier have since been formally management strategy evaluation (MSE) tested to ensure that they meet the Commonwealth harvest strategy policy objectives (Little *et al*., 2011; Wayte, 2009: AFMA Project 2006/815, Haddon, 2012: FRRF Project RUSS). This testing highlighted some problems with existing strategies and provided solutions which were implemented (Wayte and Klaer, 2010). There are two major issues remaining with the current tiered system: (i) to answer when it is most appropriate to move species from one tier to another (when is a given tier inappropriate), and (ii) how to assess particularly data-poor species that have CPUE indices that do not appear to reflect abundance or may only have a relatively short time-series of representative catch data. Generally, the Tiered harvest strategy approach implemented in the SESSF appears to be performing well (Smith *et al*, 2014). However, as with all systems, continued improvement and accounting for exceptions as they arise is required.

At present, the most data-poor tier level in the SESSF is the Tier 4 harvest strategy that uses current and target CPUE and catch levels to determine an RBC. One of the assumptions required for the Tier 4 approach to be valid is that CPUE provides a reliable index of relative abundance for the species (Haddon, 2014). It is becoming increasingly clear that CPUE is not a reliable index of abundance for a number of current Tier 4 species, so there is a need for an alternative harvest strategy and tier for such species; a Tier 5 approach, which could contain an array of methods designed for data-poor species. Many deep-water species, such as smooth oreos (*Pseudocyttus maculates*), have been recognized by the resource assessment group as not appropriately fitting within any of the existing tiers and yet, because there is no current alternative, a Tier 4 analysis continues to be used (Haddon, 2014). Similarly with the Tier 3 approach, the management advice for some species has been highly variable from year to year (e.g. Mirror Dory) and its reliability with some species has been questioned (another failure of the underlying assumptions; Klaer, 2014) so alternatives are required.

Various procedures for assessing the status of data poor species that do not have a reliable index of abundance or snapshots of age information have been examined for Australian Commonwealth fisheries (Haddon, 2012; Zhou et al., 2013: FRDC 2010/044), providing a list of candidate data-poor Tier 5 methods that could be recommended for use in the SESSF. In comparison to tiered assessment approaches implemented by other nations, Australia is unusual in that the SESSF does not having a procedure, for example, that uses catch history alone to arrive at TAC recommendations (e.g. New Zealand uses a Constant Annual Yield and the USA now often uses the Depletion-Based Stock Reduction Analysis approaches; Dick and MacCall, 2011). Globally, there are on-going efforts to develop workable stock assessment methods and related harvest strategies for such data-poor stocks; with, for example, a Wakefield Symposium on Data-Poor Approaches being held in May 2015. There is good reason to conclude that there are many options that could be used to bridge the gap between the currently available tiers in the SESSF and the Ecological Risk Assessment (ERA), which, of course, does not provide the RBC required for by-product and minor species.

25.3 Methods

The Tier 5 methods considered can either be fixed, where a single catch level is set and not updated for long periods, or dynamic, where there is feedback from any response of the stock and the analyses are updated regularly using new data from the fishery (Table 25.1).

The methods being considered and used here are described in a draft Final Report currently with the Fisheries Research Development Corporation (Haddon et al., 2015: FRDC 2013/202); that document should become freely available in a few months.

Table 25.1. Some alternative catch-only methods for setting an RBC. $C_{0..-x}$ implies the catch from the current year to –x years before hand; 0..-9 is the previous ten years, and 0..-2 is the previous three years. The top four methods are literally catch-only methods while the bottom three are model-assisted catch-only methods. More information concerning the fishery and biology is needed to implement the bottom three than the top four.

Brief Description	RBC
Third highest landings over the last 10 years - Carruthers et al, 2014	third highest($C_{0..-9}$)
Median catch from the last 10 years - Carruthers et al, 2014	median($C_{0..-9}$)
Median catch from the last 3 years - Carruthers et al, 2014	median($C_{0..-2}$)
Scaled average catch from a reference period - MCY - MPI, 2014	$c\overline{Y}$
DB-SRA – depletion based – stock reduction analysis – Dick & MacCall, 2011	median(DB-SRA)
DCAC – depletion corrected average catch - MacCall, 2009	Median(DCAC)
DACS – depletion adjusted catch scalar – – Dick & MacCall, 2010	median(DACS)

The assessment methods considered here do not include all possible methods and new approaches continue to be developed (e.g. Martell and Froese, 2013; Haddon, 2014b). The Tier 5 harvest strategy being explored is unlike the other SESSF Tiers in that it will contain an array of possible assessment methods each of which may be able to generate an estimate of sustainable catch. However, the notion of a species being data-poor covers a wide range with some species literally only having catch data while others may have catch and an array of biological information relating to growth, mortality, productivity, and in some cases a range of possible initial and final depletion levels (Table 25.2). To reflect this range the proposed Tier 5 can be any one of a range of assessment methods with the final selection being a reflection of exactly what information is available and should be decided or at least confirmed by the RAG involved.

The Management Strategy Evaluation testing conducted in Haddon et al. (2015: FRDC 2013/202) as well as recently published work which pre-empted the FRDC report (Carruthers et al., 2014) both recommend the use of Depletion Based Stock Reduction Analysis if sufficient information is available.

Table 25.2. Origins of different data-poor fisheries and other criteria.

	Description
1	New or developing: short time-series of data
2	Low-value species: no incentive to collect data
3	Bycatch species: data collected on target species
4	Spatially structured: assumption of homogeneity
5	A valid quantitative stock assessment cannot be made
6	Unable to estimate performance measures to compare with reference points.

25.3.1 Requirements of DB-SRA

Some of the requirements of the DB-SRA appear relatively stringent but in reality broad ranges are provided and a Monte Carlo simulation approach is used to randomly select values for some of the constants from relatively non-informative distributions. The requirements are:

1. Catch time series; ideally from the start of the fishery.

2. A simple model of the dynamics of the fishery. Dick and MacCall, (2011) devise a novel delay difference model but a simple surplus production model can also be used.

Plausible values are also required for:

3. The natural Mortality Rate: M
4. The ratio of F_{MSY} to the Natural Mortality: F_{MSY}/M
5. The most productive stock depletion level: B_{MSY}/B_0
6. The age at maturity: A_{mat}

The final depletion level

A large number of random draws are made from the distributions used to describe each of these parameters and the median values of the resulting estimates of MSY, $B_{0,}$

The full methodological approach is described in Dick and MacCall (2011). R-code, originally supplied by Dick and MacCall, has been modified and simplified, to make it suit the Australian management system more closely than the requirements of the system in the USA.

Because of the need to specify a plausible range for the final depletion, instead of simply selecting the median value to aim for, the DB-SRA method was used to search for whatever median target value would ensure that the probability of the spawning biomass falling below 20%B_0 was always > 90%. This would then imply a stock productivity or yield that should ensure that the stock would stay above the Commonwealth Limit Reference Point.

The DB-SRA requires two sets of inputs, the total catches (Table 25.4) and a set of plausible values bracketing the various required parameters for the method (Table 25.3).

Table 25.3. The input file used by the BD-SRA method. age.mat is age at maturity, M is natural mortality, value beginning with SD are the standard deviations of the normal distributions used to describe each parameter, Delta is (1 – target depletion), with the depletion value leading to >90% chance of staying above 20%B_0 being 0.325. Note the bounds placed on the allowable ranges for the target depletion and the B_{MSY}/B_0 ratio are wide; note also that the standard deviation given to the F_{MSY}/M ratio is also relatively large.

Variable	Flathead	MixedOreo	SmoothOreo
sciname	*Neoplatycephalus*	*Allocyttus niger*	*Neocyttus*
spscode	FLT	ORM	ORO
age.mat	3	15	15
start.yr	1915	1986	1987
end.yr	2012	2014	2014
estimation.yr	2012	2014	2014
M.est	0.27	0.05	0.05
SD.lnM	0.3	0.1	0.1
FMSYtoMratio	0.8	0.8	0.8
SD.FMSYtoMratio	0.1	0.8	0.8
Delta	0.52	0.67	0.675
SD.Delta	0.1	0.1	0.1
DeltaLowerBound	0.01	0.01	0.01
DeltaUpperBound	0.99	0.99	0.99
BMSYtoB0ratio	0.4	0.4	0.4
SD.BMSYtoB0ratio	0.05	0.05	0.05
BMSYtoB0LowerBound	0.05	0.05	0.05
BMSYtoB0UpperBound	0.95	0.95	0.95

25.4 Results

25.4.1 Smooth Oreos (non-Cascade)

The catch history of smooth oreos (non-Cascade) exhibit some extreme catches in the early 1990s (Table 25.4; Figure 25.1). It is assumed that none of the fish reported as Oreo Dory (CAAB code 37266902) is, in fact smooth oreos (non-Cascade).

Table 25.4. Reported catches of smooth oreos (non-Cascade). Inside and outside refer to whether the catches were taken in areas in or out of the > 700m deepwater MPA. Total is simply the total catch and %Open is the proportion of the catch taken outside the MPA through time.

Year	Outside	Inside	Total	%Open
1987	2.544	3.990	6.534	0.389
1988	22.876	39.993	62.869	0.364
1989	13.629	182.724	196.353	0.069
1990	39.760	687.761	727.521	0.055
1991	42.627	964.975	1007.602	0.042
1992	285.215	2295.161	2580.376	0.111
1993	89.427	586.647	676.074	0.132
1994	68.869	573.409	642.278	0.107
1995	10.802	484.497	495.299	0.022
1996	12.999	169.432	182.431	0.071
1997	36.658	147.489	184.147	0.199
1998	12.497	133.617	146.114	0.086
1999	5.841	60.695	66.536	0.088
2000	37.978	86.647	124.625	0.305
2001	23.004	269.736	292.740	0.079
2002	12.546	231.237	243.783	0.051
2003	7.197	167.803	175.000	0.041
2004	13.851	107.544	121.395	0.114
2005	7.131	50.988	58.119	0.123
2006	0.283	14.958	15.241	0.019
2007	1.010		1.010	1.000
2008	1.340		1.340	1.000
2009	3.572		3.572	1.000
2010	2.115		2.115	1.000
2011	5.920		5.920	1.000
2012	1.889		1.889	1.000
2013	2.089		2.089	1.000
2014	0.780		0.780	1.000

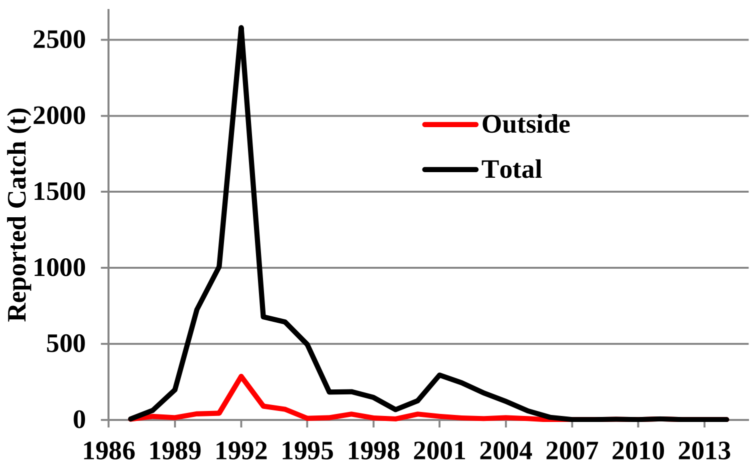


Figure 25.1. Reported Catches of smooth oreo (non-Cascade). Catches outside the deepwater closure make up an average of 12% of yearly catches.

25.4.2 Central Tendency Tier 5 Methods

The central tendency Tier 5 methods are the first four methods in Table 25.2. The exceptionally large catches in the early 1990s illustrate the fact then when Oreos are targeted it is possible to catch very large amounts. That does not imply that such large amounts are sustainable as, like orange roughy, oreos generally aggregate in large easily targeted plumes. Whether the fishers concerned were actually targeting orange roughy when these very large catches were taken is not known but whatever the case they do imply that the method that uses the third highest catch would be inappropriate here. Instead the remaining three methods were applied with the years being used changing with the method (Table 25.5).

Table 25.5. Tier 5 methods that use a measure of the central tendency of the available catch data. Mean % is the average proportion of catches taken from outside the current closure.

Statistic	Value	Years
MedianC	190.250	1987 - 2004
Median10	178.716	1995 - 2004
Median3	175.000	2002 - 2004
Mean C	400.252	1978 - 2004
Mean %	12.90	1987 - 2004

The presence of the very large closure in the deepwater below 700m in the SESSF (Figure 25.2) makes smooth oreos (and the other deep-water species) difficult species to which any Tier 5 assessment method can be applied. The methods can be applied very easily the difficult part is then in deciding what catch level to select. For example, using the $MCY = cY_{AV}$ method should only be applied to the catches when the fishery was open (i.e no major closure) and, in fact, given the rapid decline in catches in the two years prior to the introduction of the closures in 2007, the methods reliant on an estimate of central tendency of the observed catches should only use catches from 1987 - 2004 (Table 25.1). The question arises, however, what value of the precautionary 'c' to use. St Helen's Hill is now open and smooth oreos can potentially be taken (from 1987 – 2006 there were 267.7 t of smooth oreos taken from within the St Helen's closed area, but through that time that only makes up ~3.3% of the total smooth oreo catch). Most earlier smooth oreo catching sites remain within the closed area and as long as large part of that closed area are not re-opened then the precautionary variable 'c' can be set to 1.0.

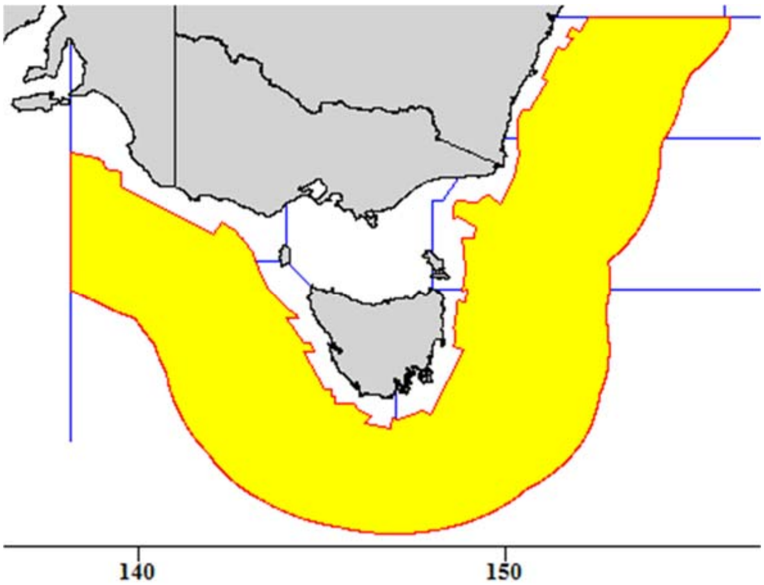


Figure 25.2. Schematic diagram of the latest version of the 700 m deepwater closure, although this does not indicate the recent openings to allow for the 500 t eastern orange roughy fishery.

25.4.3 Depletion-Based Stock Reduction Analysis

25.4.3.1 Flathead (Neoplatycephalus richardsoni)

As a test of the methodology the outcome of applying the Tier 5 DB-SRA methodology to flathead was compared with the outcome from its Tier 1 assessment. The most recent assessment (Day and Klaer, 2014) for tiger flathead estimates the depletion level at the end of 2012 as being 50%B_0, with an RBC of 3,428t, a long term yield (assuming average recruitment) of 2,753 t, and an average RBC over the five years 2014 – 2018 of 3,252 t. The current TAC is 2,878 t.

Using the DB-SRA routines to search for the target depletion giving rise to the required probability of remaining above the limit reference point led to an estimate of the required median depletion of 33%B_0, which implied a 90% chance of remaining above 20.34%B_0 and this implied a target catch (MSY) of 2,426 t (Figure 25.3).

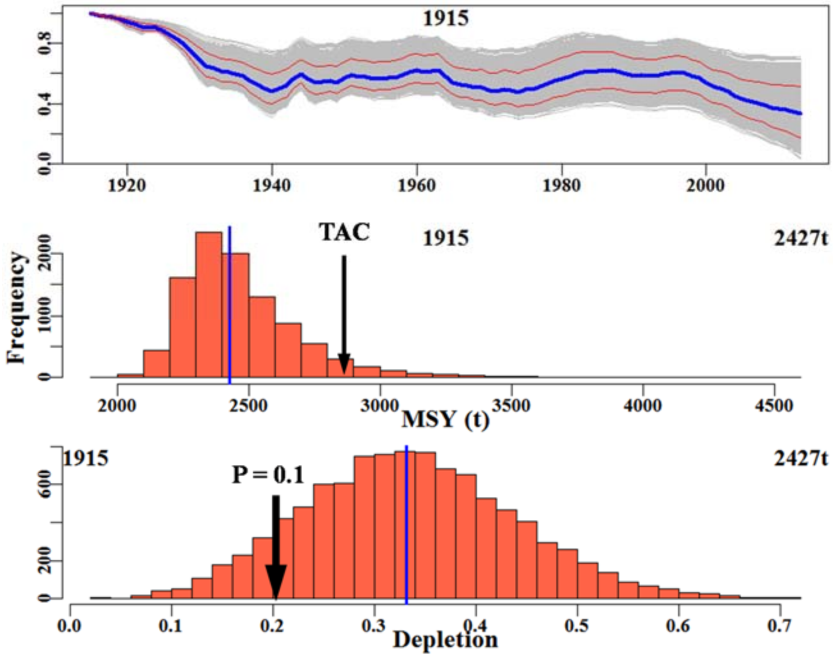


Figure 25.3. An example run of 10000 replicate runs the DB-SRA on Flathead from 1915 – 2012 with the final depletion set at 35%B_0 instead of 50%B_0. The median MSY is 2426 t, and median depletion is 0.331. The 10th percentile is at 0.2034, so the method meets the Limit Reference Point requirement.

25.4.3.2 Smooth Oreos (Neocyttus rhomboidalis)

The yield predicted to be sustainable is at least partly dependent upon the median value selected for the expected state of depletion in the final year of the analysis. As this is unknown the analysis is used to search for the level that would lead to the probability of the spawning biomass remaining above 20%B_0 being > 0.9.

With smooth oreos, potential median values of target depletion from 0.6 down to 0.3 were examined and this allowed the worst case threshold to be determined (Table 25.6). A depletion of 0.48 led to the prediction that at a catch of 90t a year the stock would stay above 35%B_0 > 90% of the time, while a depletion of 0.3 failed to keep the stock above the LRP. The optimum yield of 90 t was determined assuming the target depletion level (Table 25.6).

Table 25.6. The target depletion is that input to the DB-SRA, the median depletion is the actual estimate from the simulations. The RBC is the estimate of MSY from the analysis, and the P <= 0.1 identifies the depletion level the RBC should keep the stock above > 90% of the time.

Target Depletion	Median Depletion	RBC	P <= 0.1
0.6	0.619	118.135	0.481
0.5	0.514	95.363	0.382
0.48	0.479	90.241	0.352
0.4	0.397	82.375	0.274
0.325	0.324	72.375	0.201
0.3	0.290	71.405	0.177

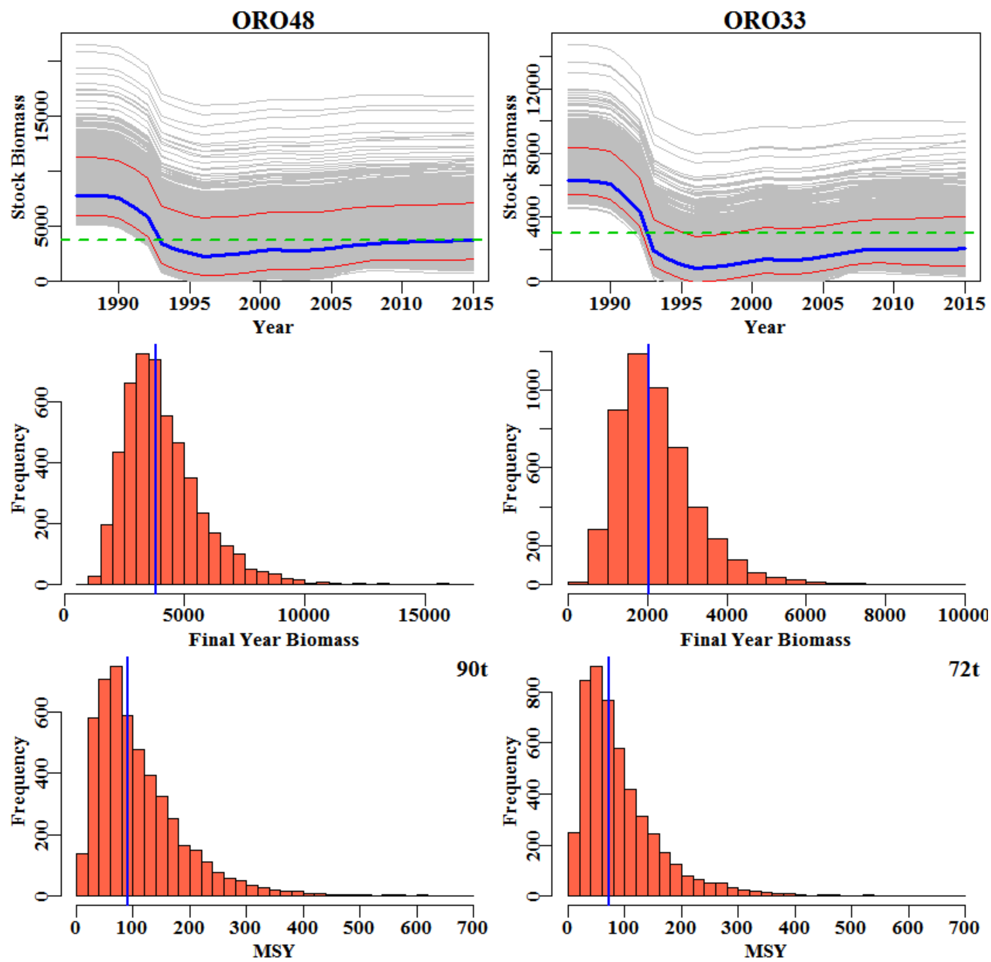


Figure 25.4. 5000 replicate runs of the DB-SRA on smooth oreo (non-Cascade) from 1987 – 2014 with the final depletion set at 48%B_0 (left column) and 32.5%B_0 (right column). The median MSY is 90 t and 72 t, and median depletion was 0.479 and 0.324 respectively. The 10th percentile of depletion was is at 35.2% and 20.1%, so the method meets the Limit Reference Point requirement.

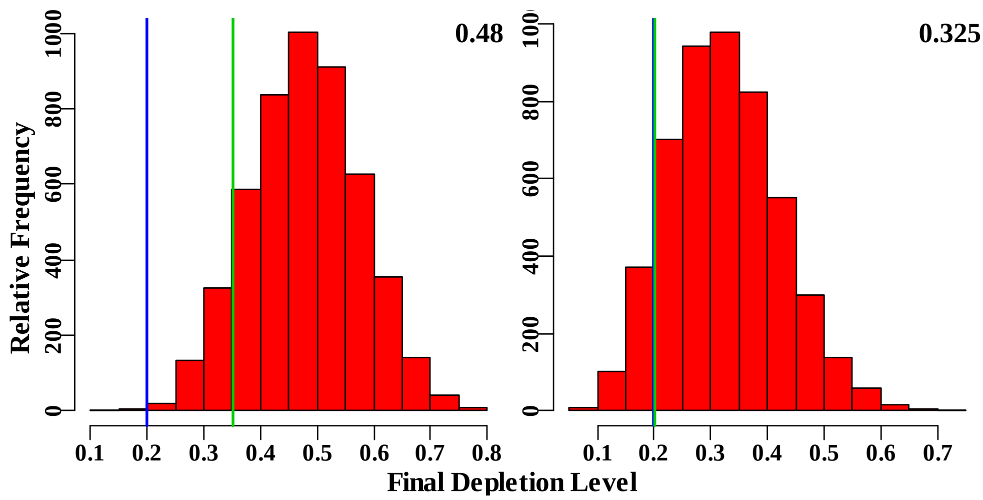


Figure 25.5. Spread of the final predicted depletion level for targets of 48% and 32.5%B_0. Blue lines are 20%, the limit reference point, and green lines are the 10th percentile (Table 25.6).

The distribution of MSY/constant yield estimates is skewed to the right with the 95th percentile (237t) easily encompassing the central tendency estimates that used median estimates, although not the estimate from the average catch method (Table 25.5).

25.5 Discussions

25.5.1 Flathead

The outcome from applying the DB-SRA to flathead from zones 10 – 20 in the SESSF was a conservative estimate of the long-term catch (2,426 t relative to the TAC of 2878 t) that should keep the stock above the Limit Reference Point (LRP) more than 90% of the time. However, this is to be expected as the objective of using a Tier 1 is to attempt to estimate the current state of depletion and act accordingly (via the harvest control rule/decision rule) to set a catch level that should lead the stock to achieve the target reference point. The DB-SRA is not capable of doing that simply because it needs to be given a median depletion level. So by using the method to search for the yield that should keep the stock above the LRP that would achieve the intent of the Harvest Strategy Policy (DAFF, 2007), at least for data-poor species that didn't constitute the primary economic drivers of the fishery.

If flathead were only a bycatch then the imperative to achieve the target of Maximum Economic Yield would not necessarily apply and emphasis would instead be on determining a catch level that wouldn't constrain the actual target fisheries but which would keep the bycatch species above its limit reference point.

25.5.2 Smooth Oreos (non-Cascade)

Given the few years of extreme catches of smooth oreos the use of the third-highest catch or even the average catch as a measure of the central tendency of the catches would be inappropriate because they would include such exceptional and unsustainable catch levels. One advantage of using a median is that extreme values have less effect on the outcome. The range of potential yields from the methods that used median estimates of catch from different ranges of years varied from 175 – 190 t, whereas the estimate from the DB-SRA was 90t. Selection of which value to use is more of a policy decision than a scientific decision but should ideally be influenced by all information available.

In the case of smooth oreos the fact of the 700m deep-water closure will continue to greatly influence the ability of the fishing industry to be able to catch smooth oreos. The crude average catch rate (catch per shot) of smooth oreos in the St Helens area was relatively low and they never appeared to be a particular target in that area. Given the existence of the closure and the fact that smooth oreos are not a primary target it is not expected that catches of smooth oreos from the St Helens region (plus Pedra Branca) will constitute a threat to the viability of the smooth oreo (non-cascade) stock. The peak catch locations remains closed and there are many other areas where substantial smooth oreo catches were taken which also remain closed. There would appear to be no reason to be overly concerned about localized catches, especially in the St Helens region.

25.5.2.1 Should the Estimates have used only Catches from the Open Areas?

It is possible that a question could be raised about whether the total catches should have been used rather than just those catches from the areas that currently remain open. There are a number of problems associated with the notion of restricting the analysis to this artificial sub-set. From 1987 –

2006, before the 700 m closure began fishers were adapting to conditions as they stood then, they attempted to optimize their catches under the conditions of the day and did not explore of fish what are now the open areas with any degree of special attention. In fact, because catches of orange roughy are optimal in depths greater than 700m the currently open areas were relatively neglected. So the catches from those areas are not necessarily representative of what catches could have come from the area had they always been the only open areas. In addition, if only the catches from the currently open areas were used in the analyses this would be treating the open and closed areas as containing two separate stocks that didn't mix. If smooth oreo are very slow moving fish it may be the case that their numbers may decline in small areas for relatively short periods of time, but in terms of risk to the biological stock this closure, which encompasses the bulk of the stock provides so much protection from fishing mortality that any risks will be minor.

25.5.3 Harvest Strategy Implementation

There could be more than one approach used to implement an assessment and harvest control rule using the DB-SRA methodology. The method conducts a stock reduction analysis, which essentially removes the known catches from a stock whose dynamics is modelled using a relatively simple model. Of course, the modelled stock has to start at some level of depletion and must end at some level of depletion, hence the assumption that it starts in an unfished state and that it end near or around some selected median final depletion level. This, along with the age at maturity and natural mortality, is then used to define the productivity of the stock which in turn defines what constant yield (MSY) should be obtainable from the stock. It would therefore be possible to set the desired final depletion at 48% as the proxy for MEY and determine the potential yield that should lead to the target. In the case of smooth oreos, aiming for a median depletion of 48% suggested a yield of 90 t might be possible (Table 25.6). However, the uncertainty around these estimates is, in all cases, very large, which is to be expected given the large coefficient of variations (CVs) and wide bounds on parameters that are used.

In fact, the state of depletion in the most recent year of assessment will be unknown, especially for data-poor species. Smooth oreos form an extreme example because of the variation in catches that have occurred through the fisheries history. The projected biomass trajectory (top panel, Figure 25.4) illustrates the major impact expected from the large catches in the early 1990s, which drop the stock to a third its starting size. Even when the target median depletion was set to 60% (a Delta of 40%) those early catches more than halved the stock size. The potential yield estimate (MSY) from the simulations is distributed with a strong skew out to larger values but with the main mass of possible values centered on 90 t (Figure 25.4).

With the degree of uncertainty around such estimates, which is large for smooth oreos, application of such methods and the subsequent recommendation of an Recommended Biological Catch limit (RBC) is made especially difficult. In such cases, whatever other information is available should be taken explicitly into account. In this case, the remaining presence of the very large and encompassing 700 m closure will ensure that the smooth oreo stock will not be at risk from over-fishing.

25.6 References

Carruthers, T.R., Punt, A.E., Walters, C.J., MacCall, A., McAllister, M.K., Dick, E.J. and Cope, J. (2014) Evaluating methods for setting catch limits in data-limited fisheries. *Fisheries Research* **153**:48-68.

DAFF (2007) Commonwealth Fisheries Harvest Strategy. Policy and Guidelines. Department of Agriculture, Fisheries and Forestry. 55p.

Day, J. and N. Klaer (2014) Tiger flathead (*Neoplatycephalus richardsoni*) stock assessment based on data up to 2012. Pp 174 - 232 *in* Tuck, G.N. (*ed*) (2014) *Stock Assessment for the Southern and Eastern Scalefish and Shark Fishery 2013. Part 1.* Australian Fisheries Management Authority and CSIRO Marine and Atmospheric Research, Hobart. 313p.

Dick, E.J. & MacCall, A.D. (2010) Estimates of sustainable yield for 50 data-poor stocks in the Pacific Coast groundfish fishery management plan. Technical memorandum. Southwest fisheries Science Centre, Santa Cruz, CA. National Marine Fisheries Service, National Oceanic and Atmospheric Administration of the U.S. Department of Commerce, NOAA-TM-NMFS-SWFSC-460.

Dick, E.J. & MacCall, A.D. (2011) Depletion-based stock reduction analysis: a catch-based method for determining sustainable yields for data-poor fish stocks. *Fisheries Research*, **110** (2): 331–341.

Haddon, M. (*ed)* (2012) *Reducing Uncertainty in Stock Status: Harvest Strategy Testing, Evaluation, and Development. General Discussion and Summary.* CSIRO Marine and Atmospheric Research. 42 p.

Haddon, M. (2014) Tier 4 analyses in the SESSF, including deep water species. Data from 1986 – 2012. Pp 352 – 461 *in* Tuck, G.N. (*ed*) (2014) *Stock Assessment for the Southern and Eastern Scalefish and Shark Fishery 2013. Part 1.* Australian Fisheries Management Authority and CSIRO Marine and Atmospheric Research, Hobart. 313p.

Haddon, M. (2014b) Review of the Biomass-Augmented Catch-MSY Model for Pacific Island Coral Reef Ecosystem Resources. A review for the Center for Independent Experts, NOAA and NMFS, USA. 28p.

Haddon, M., Klaer, N., Wayte, S., and G. Tuck (2015) Options for Tier 5 approaches in the SESSF and identification of when data support for harvest strategies are inappropriate. FRDC Project 2013/202. Fisheries Research Development Corporation and CSIRO Oceans and Atmosphere. Hobart. 115 p.

Klaer, N. (2014) Yield, Total Mortality values and Tier 3 estimates for selected Shelf and Slope species in the SESSF 2013. Pp 7 – 56 *in* Tuck, G.N. (*ed*) (2014) *Stock Assessment for the Southern and Eastern Scalefish and Shark Fishery 2013. Part 1.* Australian Fisheries Management Authority and CSIRO Marine and Atmospheric Research, Hobart. 313p.

Little, L.R., Wayte, S.E., Tuck, G.N., Smith, A.D.M., Klaer, N., Haddon, M., Punt, A.E., Thomson, R., Day, J. & Fuller, M. (2011) Development and evaluation of a cpue-based harvest control rule for the southern and eastern scalefish and shark fishery of Australia. *ICES Journal of Marine Science,* **68,** 1699-1705.

MacCall, A.D. 2009 Depletion-corrected average catch: a simple formula for estimating sustainable yields in data-poor situations. *ICES Journal of Marine Science*, **66**:2267-2271.

Martell, S. and Froese, R. (2013) A simple method for estimating MSY from catch and resilience. *Fish and Fisheries* **14**:504-514.

Ministry for Primary Industries (2014). Fisheries Assessment Plenary, May 2014: stock assessments and stock status. Compiled by the Fisheries Science Group, Ministry for Primary Industries, Wellington, New Zealand. 1381 p.

Smith, A.D.M., Smith, D.C., Haddon, M., Knuckey, I., Sainsbury, K.J., Sloan, S. (2014) Implementing harvest strategies in Australia: five years on. *ICES Journal of Marine Science* **71:** 195-203.

Wayte,S.E.(ed) (2009) *Evaluation of new harvest strategies for SESSF species.* CSIRO and AFMA. 137 p.

Wayte, S.E. and N.L. Klaer (2010) An effective harvest strategy using improved catch-curves. *Fisheries Research* **106**: 310 – 320

Zhou, S., Pascoe, S., Dowling, N., Haddon, M., Klaer, N., Larcombe, J., Smith, T., Thebaud, O., Viera, S. and Wayte, S. (2013) *Quantitatively defining biological and economic reference points in data poor fisheries.* Fisheries Research and Development Corporation Project No. 2010/044.

26. 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.

27. 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 2015 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 (silver warehou, eastern and western stocks of jackass morwong and Bight redfish), as well as cpue standardisations for shelf, slope, deepwater and shark species and Tier 4 analyses. Typical assessment outputs provided indications of current stock status and an application of the Commonwealth Harvest Strategy framework. This framework is based on a set of assessment methods and 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 2015 assessment for silver warehou (*Seriolella punctata*) shows reasonably good fits to the catch rate data. However, when comparing the observed and expected catch rate data points for the last 2 years in the series, the model may be overly optimistic and the stock could break out again in a relatively short time period. This assessment estimates that the projected 2016 spawning stock biomass will be 40% of virgin stock biomass. The RBC from the base case model for 2016 is 1,958t for the 20:35:48 harvest control rule, with a long-term yield of 2,281t. However, these scenarios assume recruitment will return to average levels. If future recruitment continues at a similar level to recruitment since 2003, then depletion could fall to around 30% before 2020.

The 2015 assessment of jackass morwong (*Nemadactylus macropterus*) included annual landings, catch rates, discard rates, and length/age compositions data up to the 2014 calendar year. The final assessment of the eastern stock of jackass morwong estimates the 2016 spawning biomass to be 36.5% of the 1988 equilibrium stock biomass. The female equilibrium spawning biomass in 1988 is estimated to be 3,977 t and in 2016 the female spawning biomass is estimated to be 1,451 t. The 2016 recommended biological catch (RBC) under the 20:35:48 harvest control rule for the base-case model is 314 t for the eastern stock of jackass morwong. The long-term RBC is 407 t. Limited data were available for western morwong. The 2015 base case assessment of the western stock of jackass morwong estimates the 2016 spawning biomass to be 69% of unexploited biomass. The female equilibrium spawning biomass in 1986 is estimated to be 1,349 t and in 2016 the female spawning biomass is estimated to be 936 t. The RBC for the base case assessment for the western stock of jackass morwong under the 20:35:48 harvest control rule is 249 t. The long-term RBC is 159 t.

The 2015 base-case assessment of Bight redfish (*Centroberyx gerrardi*) estimates that the female spawning stock biomass at the start of 2015/2016 was 63% of unexploited female spawning stock biomass (SSB0). The 2016/2017 recommended biological catch (RBC) under the agreed 20:35:41 harvest control rule is 862 t and the long-term yield (assuming average recruitment in the future) is

537 t. The unexploited female spawning biomass was estimated as 5,451 t, with a total unfished equilibrium exploitable biomass of 16,042 t. This major reduction in the estimate from that made in 2012 reflects the fact that the data now available are more informative about the unfished biomass and stock status.

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 2015 Seven Tier 4 analyses were conducted and applied to Blue eye, western Jackass morwong and Mirror Dory. Jackass Morwong West generated a zero RBC, which reflects the recent strong reduction in CPUE in the western zones (40 and 50). The Blue eye trevalla analyses used two new time-series of standardized CPUE, which were based upon catch-per-hook rather than catch-per-record. These new CPUE analyses have flattened the time series in recent years and have produced a larger RBC (443t) than has been produced previously. In addition, a sensitivity analysis was conducted with the Blue eye analysis in which estimates of whale depredation on the auto-line fishery when it was developing are included to illustrate their potential impact. That analysis demonstrates that whale depredations would act to bias the actual kill and the CPUE low, and consequently would bias the RBC low. However, the estimate relates to a single vessel and extrapolating to the fleet adds a great deal of uncertainty. The analysis remains useful in demonstrating the potential bias, but the uncertainty means that care would be required if considering to use the whale depredation sensitivity to modify any catch recommendation. The analyses for Mirror Dory have been conducted for the whole of the Mirror Dory stock, treating the west and east as separate stocks, and also including the high levels of discards that occur in the east. The Mirror Dory RBCs were 488t (all areas), 129t (West only), and 362t (east only).

Tier 4 analyses for both sawshark and elephantfish assume the target CPUE is a proxy for 48% of unfished biomass for both species (groups). However, neither species are reported as being targeted in the fishery (when using any method), so the calculated RBCs are inherently conservative. Alternative estimates based on a proxy target of 40% were therefore calculated, with RBCs varying between 127t and 429t for elephantfish and 226t (gillnet) and 650t (trawl) for sawshark.

28. Appendix: Intellectual Property

No intellectual property has arisen from the project that is likely to lead to significant commercial benefits, patents or licenses.

29. Appendix: Project Staff

Jemery Day	CSIRO Oceans and Atmosphere, Hobart, Tasmania
Mike Fuller	CSIRO Oceans and Atmosphere, Hobart, Tasmania
Malcolm Haddon	CSIRO Oceans and Atmosphere, Hobart, Tasmania
André Punt	CSIRO Oceans and Atmosphere, Hobart, Tasmania
Miriana Sporcic	CSIRO Oceans and Atmosphere, Hobart, Tasmania
Robin Thomson	CSIRO Oceans and Atmosphere, Hobart, Tasmania
Geoff Tuck	CSIRO Oceans and Atmosphere, Hobart, Tasmania
Judy Upston	CSIRO Oceans and Atmosphere, Hobart, Tasmania
Sally Wayte	CSIRO Oceans and Atmosphere, Hobart, Tasmania
Athol Whitten	Mezo Research