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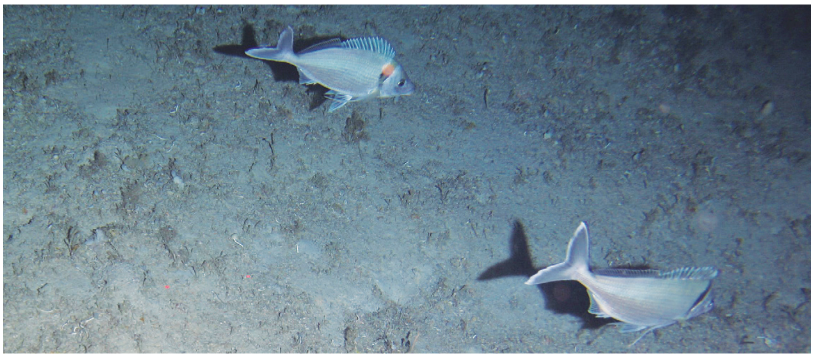
Stock Assessment for the Southern and Eastern Scalefish and Shark Fishery: 2018 and 2019



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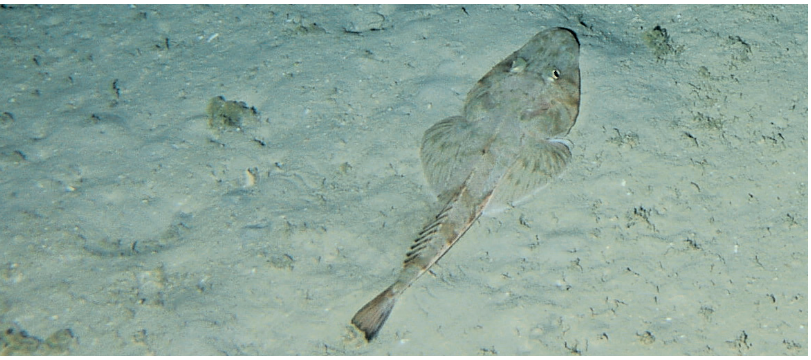

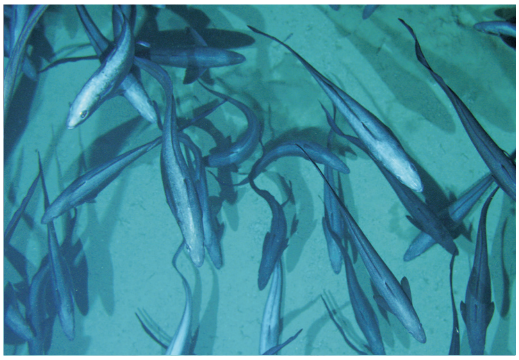

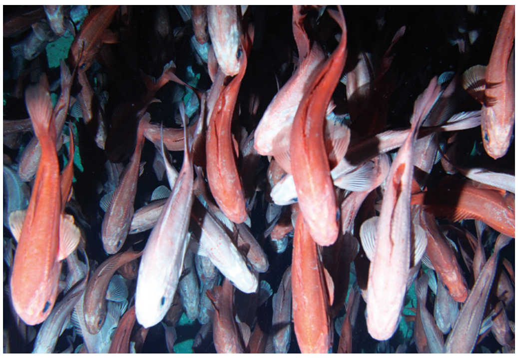

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Cover photographs

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

Report structure

Part 1 of this report describes the Tier 1 assessments of 2019. Part 2 describes the Tier 3 and Tier 4 assessments, catch rate standardisations and other work contributing to the assessment and management of SESSF stocks in 2019.

Stock Assessment for the Southern and Eastern Scalefish and Shark Fishery 2018 and 2019

Part 2: 2019

G.N. Tuck
June 2020
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Stock Assessment for the Southern and Eastern Scalefish and Shark Fishery: 2019

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1. Non-Technical Summary

Stock Assessment for the Southern and Eastern Scalefish and Shark Fishery 2018 and 2019

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OBJECTIVES:

- Provide quantitative and qualitative species assessments in support of the four SESSFRAG assessment groups, including RBC calculations within the SESSF harvest strategy framework
- 2018: Provide Tier 1 assessments for Blue grenadier, Jackass morwong (east and west), School shark, and Silver warehou; Tier 3 assessment for Alfonsino; Tier 4 assessments for Blue eye trevalla and Deepwater shark (east and west); and Tier 5 for Smooth oreo.
- 2019: Provide Tier 1 assessments for Deepwater flathead, Tiger flathead, Western gemfish, and Gummy shark; and Tier 4 for Mirror Dory

Outcomes Achieved - 2019

The 2019 assessments of stock status of the key Southern and Eastern Scalefish and Shark fishery (SESSF) species are based on the methods presented in this report. Documented are the latest quantitative assessments for the SESSF quota species. Typical assessment results provide indications of current stock status, in addition to an application of the recently introduced Commonwealth fishery harvest control rules that determine a Recommended Biological Catch (RBC). These assessment outputs are a critical component of the management and Total Allowable Catch (TAC) setting process for these fisheries. The results from these studies are being used by SESSFRAG, industry and management to help manage the fishery in accordance with agreed sustainability objectives.

1.1 General

Catch rate standardisations

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

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

This chapter summarizes the main findings regarding the standardization for 21 species, distributed across 40 different combinations of stocks and fisheries using statistical models customized to suit each set of circumstances. Visual summaries of all optimum statistical models are presented along with tables of the properties of each dataset and any issues that the standardizations may have raised for each species. These include school whiting, eastern gemfish, jackass morwong, flathead, redfish, silver trevally, royal red prawn, blue eye trevalla, blue grenadier, silver warehou, blue warehou, pink ling, western gemfish, ocean perch, john dory, mirror dory, ribaldo, ocean jackets, deepwater flathead and bight redfish.

Standardized CPUE has generally increased since about 2005 for pink ling west. Other species/stocks have shown shorter term increases over the last two to three years e.g., pink ling east, royal red prawn and inshore ocean perch. Standardized CPUE has increased in the last two years for silver warehou east and silver warehou west, after at least a ten-year general decline. Standardized CPUE has remained near the long-term average over the last six years for blue grenadier (non-spawning) with these indices all higher than those between 2000-2013. By contrast, standardized CPUE has declined for tiger flathead - Danish seine (zone 20-60) since 2016 and more generally since 2007 and fluctuated around the long-term average for both tiger flathead in zone 10, 20 (combined) and zone 30 since 2000. The results from the standardisations are a key input to Tier 4 and Tier 1 assessments.

Blue-eye catch rate standardisation

Separate data selection rules and database manipulations (separate algorithms) developed for Drop-Line and Auto-Line data sets were repeated with updated datasets such that the outcome provided estimates of the total number of hooks set for each record. These data were used to generate catch-per-hook catch rate data which were in turn used in catch rate standardizations for the two methods.

The two time-series of CPUE were combined using catch weighting and scaling the two series to the same mean CPUE of 1.0 for the period of 2002 - 2006, which was the period of overlap. For the catch-per-hook data to be acceptable required there to be sufficient records to provide a reasonable spatial coverage of the fishery as well as reasonably precise estimates of the annual mean values. Drop-Line CPUE were considered acceptable from 1997 - 2006 and Auto-Line data were acceptable from 2002 - 2017.

The analysis using catch-per-hook exhibits a noisy but flat trajectory not seen in the catch-per-record, which appears to be declining. All analyses have limited numbers of observations and hence are relatively uncertain. Given this uncertainty it does not matter greatly whether the analysis of catch-per-hook is restricted to zones 20 - 50, as has been done previously, or extended to include the GAB zones 83, 84, and 85.

Deepwater species catch rate standardisation

For eastern deepwater sharks, this basket quota group is made up of many recognized species but only nine have any records, and only seven of these have any significant catches. Dogfish and Other Sharks dominate catches until about 2000. Catches declined steadily from 1996 to a low in 2007 when the 700m closure was introduced. Since this was modified in 2009 (and 2016) catches have increased again to reach a low of 23t per annum with very few vessels contributing significantly to this fishery. Nevertheless, fishing appears to be consistent and the standardized CPUE trend has been essentially low and flat since 2010. The removal of catch from the 700 m closure, made minimal differences to standardized CPUE compared to CPUE indices which included them in analyses.

For western deepwater sharks, this basket quota group is made up of many recognized species but only nine have any records, and only seven 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. As with the eastern deepwater sharks, catches of western deepwater sharks declined from a high in 1997 and 1998 to a low in 2007 on the introduction of the 700 m closure, picking up again after the modifications in 2009 and 2016, with an average of 57 t over the last five years. Standardized CPUE has exhibited an approximate cycle since about 1998 - 2017 with lows in 2005 and 2012-2014 and highs (corresponding to the long-term average) from 1998-2003, 2008-2010 and has returned to the long-term average in 2018. The removal of catch from the 700 m closure, made minimal differences to standardized CPUE compared to CPUE indices which included them in analyses.

Mixed Oreos is a basket quota species made up of Spiky, Oxeye, Warty, Black, Rough Oreos as well as the catchall category OreoDory, which has only been used in more recent years. Catches have been variable through time with spikes in 1992 and elevated catches from 1995 - 2001 after which catches declined and have remained relatively low since the 700 m closure in 2007 but have increased to a mean of 113 t from 2013 - 2018. The majority of catch occurred in ORzone 30, 20 followed by 50. After an initial period of great volatility between 1986 - 1994 the standardized CPUE has been essentially flat and stable since 2000.

Shark species catch rate standardisation

Reported catch of school shark in 2017 was the largest since 2010 but declined in 2018. Trawl caught school shark do not appear to be targeted, as evidenced by the large proportion of < 30 kg shots present in logbook data. The standardized catch-per-unit effort (CPUE) trend has continued to increase since 2003.

There has been a decrease in reported gillnet catches of gummy shark in 2018 in South Australia and Bass Strait. Standardized CPUE in South Australia has dropped to the long-term average in 2018 and in Bass Strait it has remained at the long-term average in 2017 and 2018. Similarly, standardized CPUE of gillnet caught gummy shark around Tasmania has remained flat since 2014 and at the long-term average since 2016. The 2018 catch of trawl caught gummy shark is the largest in the series (i.e., since 1986). Standardized CPUE for trawl has increased steadily since 2012, remaining significantly above the long-term average. By contrast, standardized CPUE for bottom line has remained flat and noisy since 2012.

Sawshark are a bycatch group which is supported by the high proportion of < 30 kg catches. Catches are reported by both gillnets, trawls and Danish seine. Standardized CPUE for gillnets exhibits a steady decline since about 2001, with small increases in recent years, except in 2017. Trawl caught sawshark standardized indices exhibit a noisy but flat trend, with an increase in 2014 reaching the long-term average and an overall decrease below the long-term average in 2016, followed by a small increase in 2017 and 2018. By contrast, sawshark standardized CPUE by Danish seine has been flat and below the long-term average over the 2002-14 period and increased above the long-term average in 2015, although not significantly so, and has remained at the long-term average since then.

Like school shark, elephant fish are a non-targeted species, as indicated by the large proportion of small shots (i.e. <30 kg). Gillnet standardized CPUE is flat and noisy, but decreased in 2015, increased in 2016, decreased in 2017 and increased in 2018. In recent years discard rates for elephant fish have been very high, which may imply that their CPUE is in fact increasing.

Tier 4 analyses 1986 – 2018

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

In 2019, Tier 4 analyses were performed for the following species and/or species groups: mirror dory east, mirror dory west, and western gemfish (Zone 50). The RBC estimated for mirror dory east declined from 140.4 t in 2018 to 92.7 t in 2019. Such a decline in RBC of approximately 48 t could be attributed to a drop in the most recent standardized CPUE (including discards) and hence the mean of the most recent 4-year average which are used to calculate the RBC. The 2019 RBC is greater than the 2018 reported catch of approximately 79.8 t for this species. The RBC estimated for mirror dory west declined from 94.8 t in 2018 to 76.7 t in 2019. Such a decline in RBC of approximately 18 t could be attributed to a drop in the most recent standardized CPUE and hence the mean of the most recent 4-year average which are used to calculate the RBC. The 2019 RBC is greater than the 2018 reported catch of approximately 37.4 t for this species. In summary, the 2019 RBC estimate for mirror dory east is 92.7 t and for mirror dory west is 76.7 t, with a combined RBC (i.e., east and west) of 169.4 t. The RBC estimated for western gemfish declined from 436.29 t in 2017 to 423.1 t in 2019.

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

2. Background

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

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

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

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

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

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

3. Need

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

4. Objectives

These Objectives include the SESSFRAG agreed changes to the assessment schedule:

- Provide quantitative and qualitative species assessments in support of the four SESSFRAG assessment groups, including RBC calculations within the SESSF harvest strategy framework
- 2018: Provide Tier 1 assessments for Blue grenadier, Jackass morwong (east and west), School shark, and Silver warehou; Tier 3 assessment for Alfonsino (removed); Tier 4 assessments for Blue eye trevalla (addition of T5 for seamounts) and Deepwater shark (east and west); and Tier 5 for Smooth oreo (removed).
- 2019: Provide Tier 1 assessments for Deepwater flathead, Tiger flathead, Western gemfish (moved to T4), Bight redfish (addition) and Gummy shark (delayed); and Tier 4 for Mirror Dory

5. CPUE standardizations for selected SESSF Species (data to 2018)

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5.1 Introduction

Commercial catch and effort (CPUE) data are used in very many fishery stock assessments in Australia as an index of relative abundance. Using CPUE in this way assumes 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 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 dynamics. 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 2018 inclusive) for over 40 different stocks within Australia’s Southern and Eastern Scalefish and Shark Fishery (SESSF).

5.2 The Limits of Standardization

The use of commercial CPUE as an index of the relative abundance of exploitable biomass can be misleading when there are factors that significantly influence CPUE but cannot be accounted for in a generalized linear model (GLM) standardization analysis. Over the last two decades there have been various 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 to avoid having to discard and to stay within the bounds of their own quota holdings. Such influences on catch rates would tend to bias 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.

5.3 Methods

5.3.1 *Catch Rate Standardization*

5.3.1.1 Preliminary Data Selection

The methods used when standardizing commercial catch and effort data in the SESSF continue to be discussed in the Commonwealth stock assessment RAGs because the catch rate time series (and associated standardized indices) are very influential in many of the assessments. Data were initially selected from the ORACLE database by CAAB code to obtain all data relating to a given species. Then selections were made using R (R Core Team, 2017) with respect to 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 5.1) within the years specified for each analysis.

5.3.1.2 General Linear Modelling

In each case, catch rates, generally as kilograms per hour fished (though sometimes as catch per shot e.g. School Whiting caught by Danish Seine, or catch-per-hook for Blue-Eye Trevalla), 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. 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:

$$Ln(CPUE_i) = \alpha_0 + \alpha_1 x_{i,1} + \alpha_2 x_{i,2} + \sum_{j=3}^{N} \alpha_i x_{i,j} + \varepsilon_i$$

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 (where α_0 is the intercept, α_1 is the coefficient for the first factor, etc.).

5.3.1.3 The Mean Year Estimates

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:

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

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

$$CE_t = \frac{CPUE_t}{(\sum CPUE_t)/n}$$

where $CPUE_t$ is the yearly coefficients from the standardization, $(\sum CPUE_t)/n$ 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.

5.3.1.4 Model Development and Selection

In each case an array of statistical models are fitted sequentially to the available data, with the order of the non-interaction terms being determined by the relative contribution of each term to model fit.

This sequential development of the standardization models for each species simplifies the search for the optimum model and requires a consideration of different performance statistics such as the AIC (Akaike's Information Criterion, the smaller the better; Burnham and Anderson, 1992) or adjusted R^2 (the larger the better; Neter et al, 1996). In addition, the examination of the various diagnostic plots and tables allows for an improved interpretation of the observed trends.

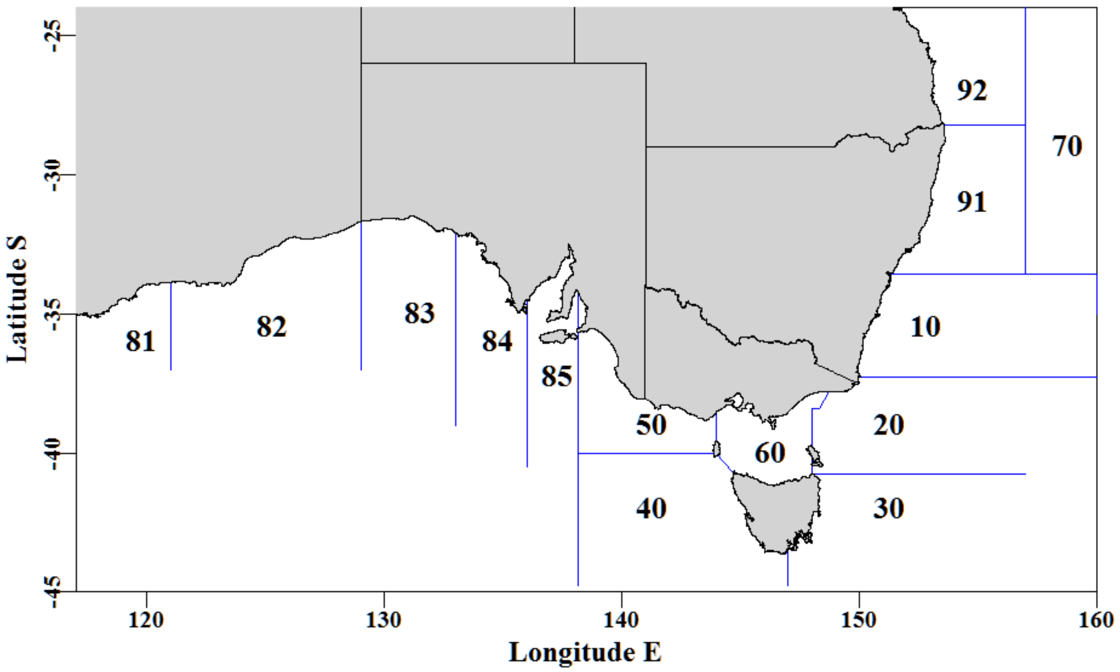

Figure 5.1. The statistical reporting zones in the SESSF.

5.4 John Dory 10 – 20

For John Dory (DOJ– 37264004 – *Zeus faber*) have been primarily caught by trawl in zones 10 and 20 between the years 1986 - 2018. Small catches have also been recorded by gillnet and danish seine. Initial data selection was based on criteria provided in Table 5.1 from the Commonwealth logbook database. A total of 8 statistical models were fitted sequentially to the available data, and the order of the non-interaction terms added based on the relative contribution of each term to model fit.

5.4.1 *Inferences*

A significant proportion of the shots each year were < 30kg, which suggests this is rarely a targeted species, low and even availability, or high levels of small fish (Figure 5.3).

The terms Year, Vessel and DayNight had the greatest contribution to model fit, with the remaining terms each explaining < 1% of the overall variation in CPUE based on the AIC and R^2 statistics (Table 5.5). The qqplot suggests that the assumed Normal distribution is valid, with small deviations at the upper tail of the distribution (Figure 5.5).

Standardized CPUE has been below the long term average since 1997 (Figure 5.2).

5.4.2 *Action Items and Issues*

A potential change in fishing behaviour is suggested to have occurred since about 2014, which is evidenced by changes in the distribution of log-transformed CPUE each year. From 2014, a number of widely spread spikes in the histograms have become apparent, most especially in 2015, 2016 and 2017. The underlying driver for these changes is not immediately apparent.

Table 5.1. JohnDory1020. The data selection criteria used to specify and identify the fishery data to be included in the analysis.

Property	Value
label	JohnDory1020
csirocode	37264004
fishery	SET
depthrange	0 - 200
depthclass	20
zones	10, 20
methods	TW, TDO, TMO, OTT
years	1986 - 2018

Table 5.2. JohnDory1020. Total catch (Total; t) is the total reported in the database, number of records used in the analysis (N), reported catch (Catch; t) in the area and depth used in the analysis and number of vessels used in the analysis (Vess). GeoM is the geometric mean of catch rates (kg/hr), standard deviation (StDev) relates to the optimum model. C<30Kg denotes the amount of catch in shots of <30kg, and %<30Kg is the percent of total. The optimum model was Zone:DepCat.

	Total	N	Catch	Vess	GeoM	Opt	StDev	C<30Kg	P<30Kg
1986	231.7	6414	202.1	90	12.1	1.7837	0.000	66.553	0.329
1987	206.1	4638	180.9	78	14.5	2.0642	0.021	43.254	0.239
1988	182.0	4532	161.2	73	13.5	1.9104	0.021	45.311	0.281
1989	217.9	4786	186.9	70	14.2	2.0868	0.021	49.093	0.263
1990	167.9	3674	135.7	60	13.0	1.9063	0.023	39.868	0.294
1991	172.3	4001	125.2	53	11.9	1.5194	0.023	43.575	0.348
1992	130.8	3886	107.9	49	9.6	1.2762	0.023	42.917	0.398
1993	240.4	5353	179.1	55	11.6	1.6028	0.022	57.555	0.321
1994	267.9	6505	207.7	55	11.1	1.5141	0.021	72.298	0.348
1995	185.7	6033	167.1	52	10.1	1.2855	0.021	68.473	0.410
1996	160.8	6339	145.0	58	8.4	1.0118	0.021	67.184	0.463
1997	87.8	4386	77.9	60	6.2	0.7858	0.023	43.209	0.555
1998	109.0	5079	98.2	53	6.9	0.8159	0.022	52.297	0.533
1999	132.8	5534	120.1	56	7.7	0.9586	0.021	57.792	0.481
2000	164.1	6955	146.6	59	7.2	0.8892	0.021	66.790	0.456
2001	129.3	6611	116.1	50	5.8	0.7480	0.021	61.558	0.530
2002	151.0	6663	135.9	49	6.7	0.7319	0.021	58.195	0.428
2003	156.9	6518	136.7	51	6.7	0.7101	0.021	59.400	0.434
2004	166.0	7051	147.0	51	6.8	0.7488	0.021	65.525	0.446
2005	107.4	4894	88.0	48	5.7	0.6191	0.022	41.054	0.466
2006	85.4	3706	71.0	43	5.8	0.6932	0.024	34.230	0.482
2007	62.5	2822	51.3	23	6.0	0.6291	0.026	25.586	0.498
2008	116.8	3800	102.1	26	8.8	0.9521	0.024	37.392	0.366
2009	91.7	3097	79.0	23	8.4	0.8795	0.025	31.271	0.396
2010	62.0	2952	51.1	24	5.4	0.5590	0.026	27.963	0.548
2011	74.8	3337	56.3	22	5.4	0.5847	0.025	31.341	0.557
2012	67.1	3336	55.9	22	5.4	0.5807	0.025	31.500	0.563
2013	63.5	2659	48.5	22	5.7	0.6074	0.026	24.778	0.511
2014	46.6	2637	35.3	23	3.8	0.4536	0.026	21.683	0.614
2015	73.6	2789	54.6	29	5.7	0.5748	0.026	24.484	0.448
2016	66.9	2227	39.4	24	5.4	0.4806	0.029	18.756	0.476
2017	68.6	1958	39.6	22	6.2	0.5447	0.030	17.717	0.447
2018	57.8	1776	30.5	19	4.8	0.4921	0.032	15.475	0.507

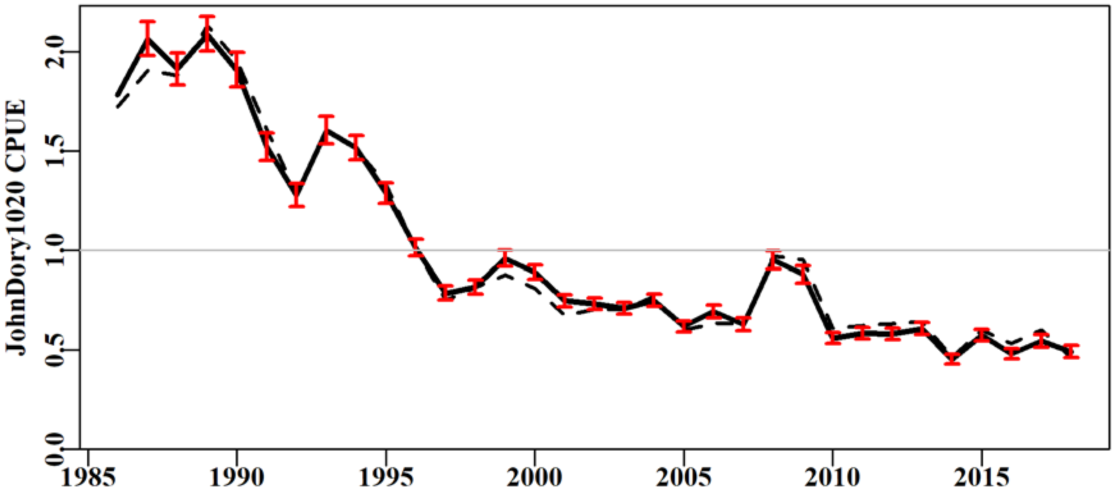

Figure 5.2. JohnDory1020 standardization. The dashed black line represents the geometric mean catch rate, solid black line the standardized catch rates. The red bars are the 95% confidence intervals about the mean estimates. The graph scales both time-series of standardized catch rates relative to the mean of each time-series.

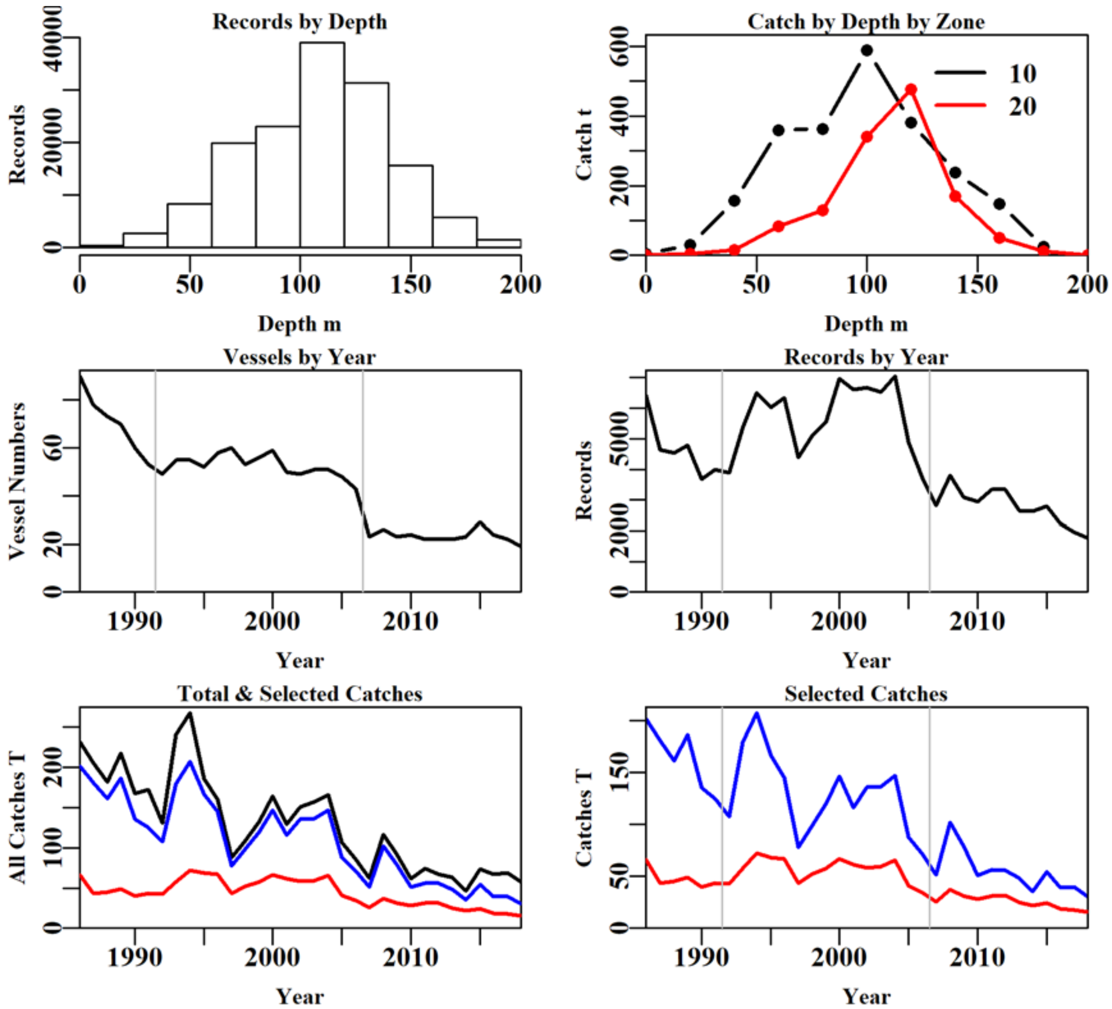

Figure 5.3. JohnDory1020 fishery details. The bottom left plot depicts all known catches (top black line), and all selected catches used in the analysis (middle blue line); the lower red line: selected catches < 30 kg).

Table 5.3. JohnDory1020 data selection effects. Total is the total number of records in the database, NoCE removes those records with either missing catch or effort, and then only those records are kept that meet the criteria for depth, years, zone, method and fishery.

	Total	NoCE	Depth	Years	Zones	Method	Fishery
Records	239548	218317	212124	208758	174770	147069	146948
Difference	0	21231	6193	3366	33988	27701	121
Catch	4369.477	4234.7216	4091.2209	4029.8781	3717.5175	3581.7903	3580.047
Difference	0.000	134.7555	143.5007	61.3428	312.3606	135.7273	1.743

Table 5.4. The models used to analyse data for JohnDory1020.

	Model
Model1	Year
Model2	Year + Vessel
Model3	Year + Vessel + DayNight
Model4	Year + Vessel + DayNight + DepCat
Model5	Year + Vessel + DayNight + DepCat + Month
Model6	Year + Vessel + DayNight + DepCat + Month + Zone
Model7	Year + Vessel + DayNight + DepCat + Month + Zone + Zone:Month
Model8	Year + Vessel + DayNight + DepCat + Month + Zone + Zone:DepCat

Table 5.5. JohnDory1020. The row names are 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_r2) and the change in adjusted R^2 (%Change). The optimum model was Zone:DepCat.

	AIC	RSS	MSS	Nobs	Npars	adj_r2	%Change
Year	32320	183016	27745	146948	33	13.1	0.00
Vessel	16399	163842	46920	146948	204	22.2	9.01
DayNight	13990	161171	49590	146948	207	23.4	1.27
DepCat	12329	159337	51424	146948	217	24.3	0.87
Month	11126	158015	52746	146948	228	24.9	0.62
Zone	11097	157982	52779	146948	229	24.9	0.02
Zone:Month	10480	157297	53465	146948	240	25.2	0.32
Zone:DepCat	9851	156629	54132	146948	238	25.6	0.64

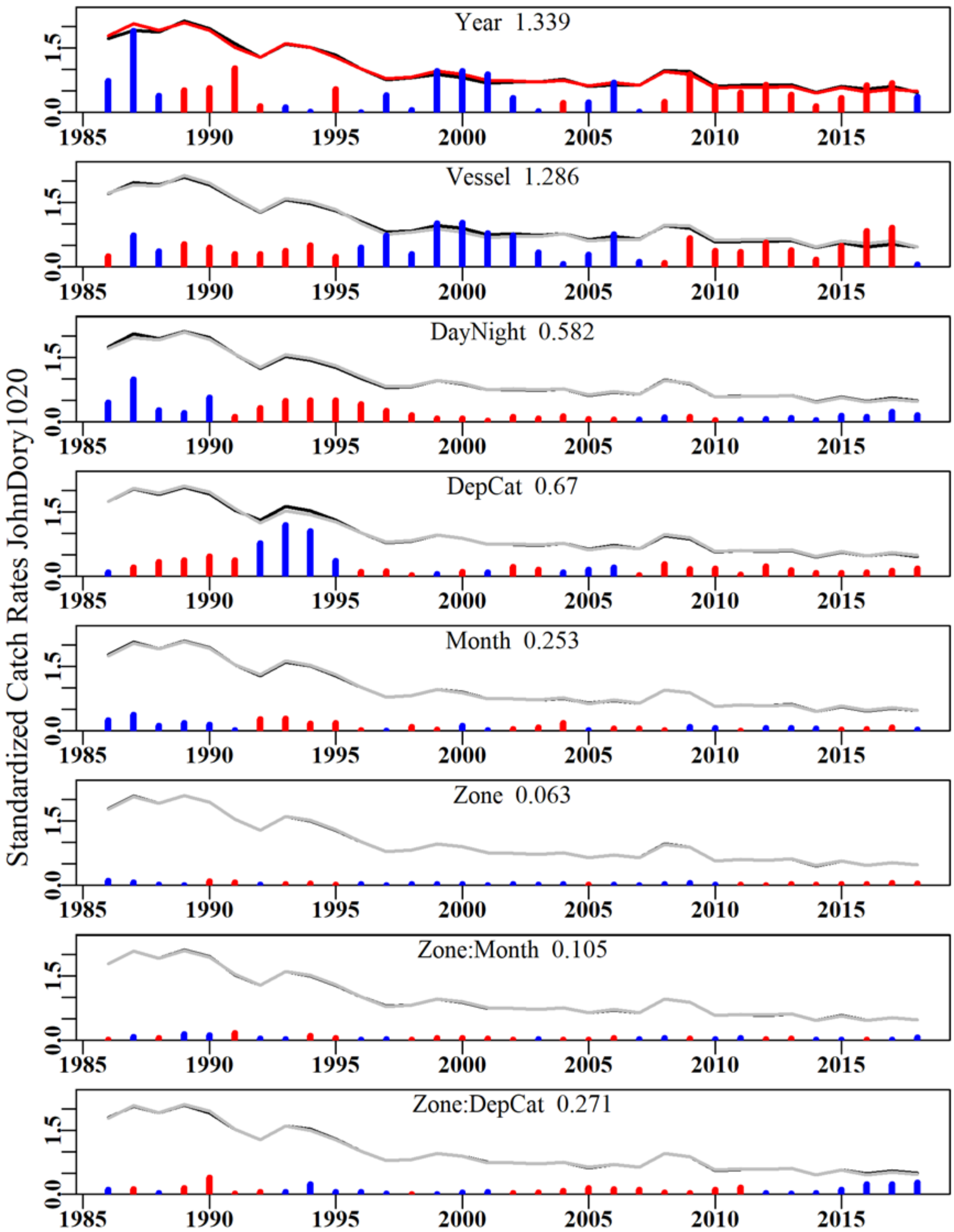

Figure 5.4. JohnDory1020. The influence of each factor on the optimal standardization. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by vertical bars with blue bars indicating the optimum model is higher than the geometric 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.

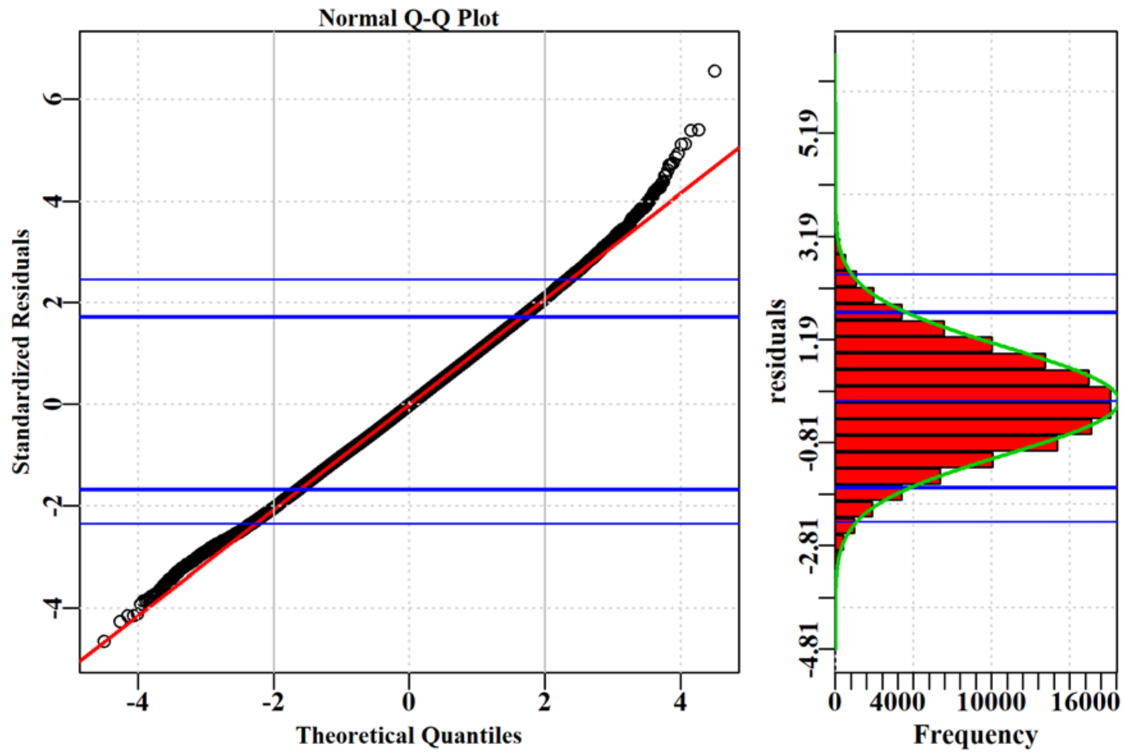

Figure 5.5. JohnDory1020. diagnostic plots. The distribution of residuals from the optimum fit. The qqplot indicates the fit to the expected normality, while the histogram of residuals illustrates the 90% quantiles to indicate the intensity of any lack of fit at the margins of the distribution.

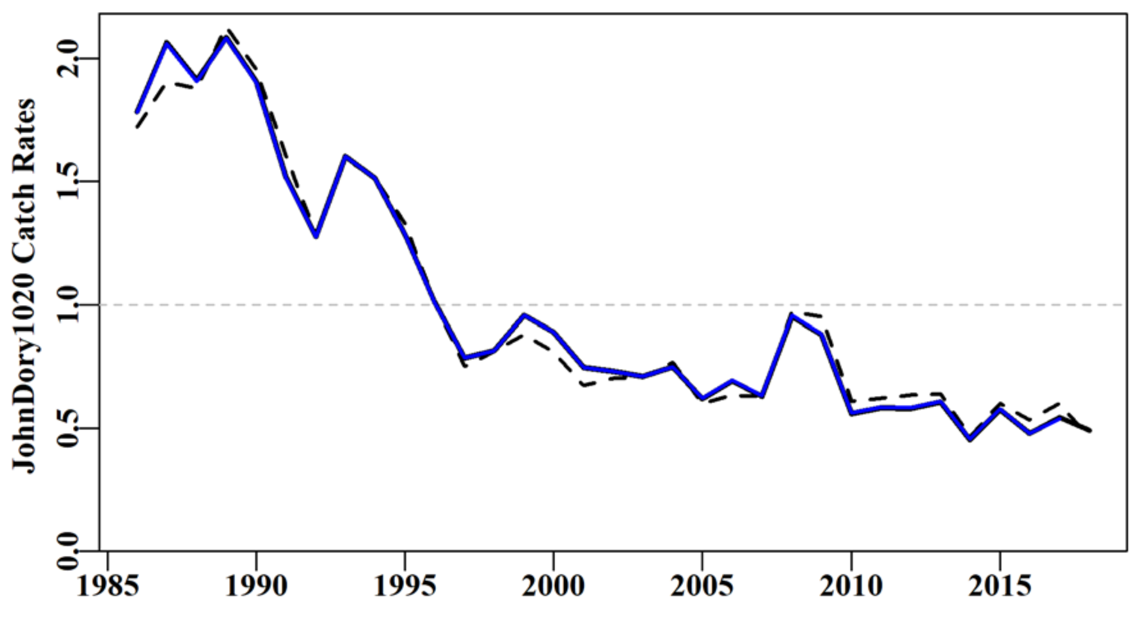

Figure 5.6. JohnDory1020. A comparison of the previous year's standardization (blue line) with this year's. They should lie on top of each other, although small deviations may relate to data adjustments, particularly in very recent years.

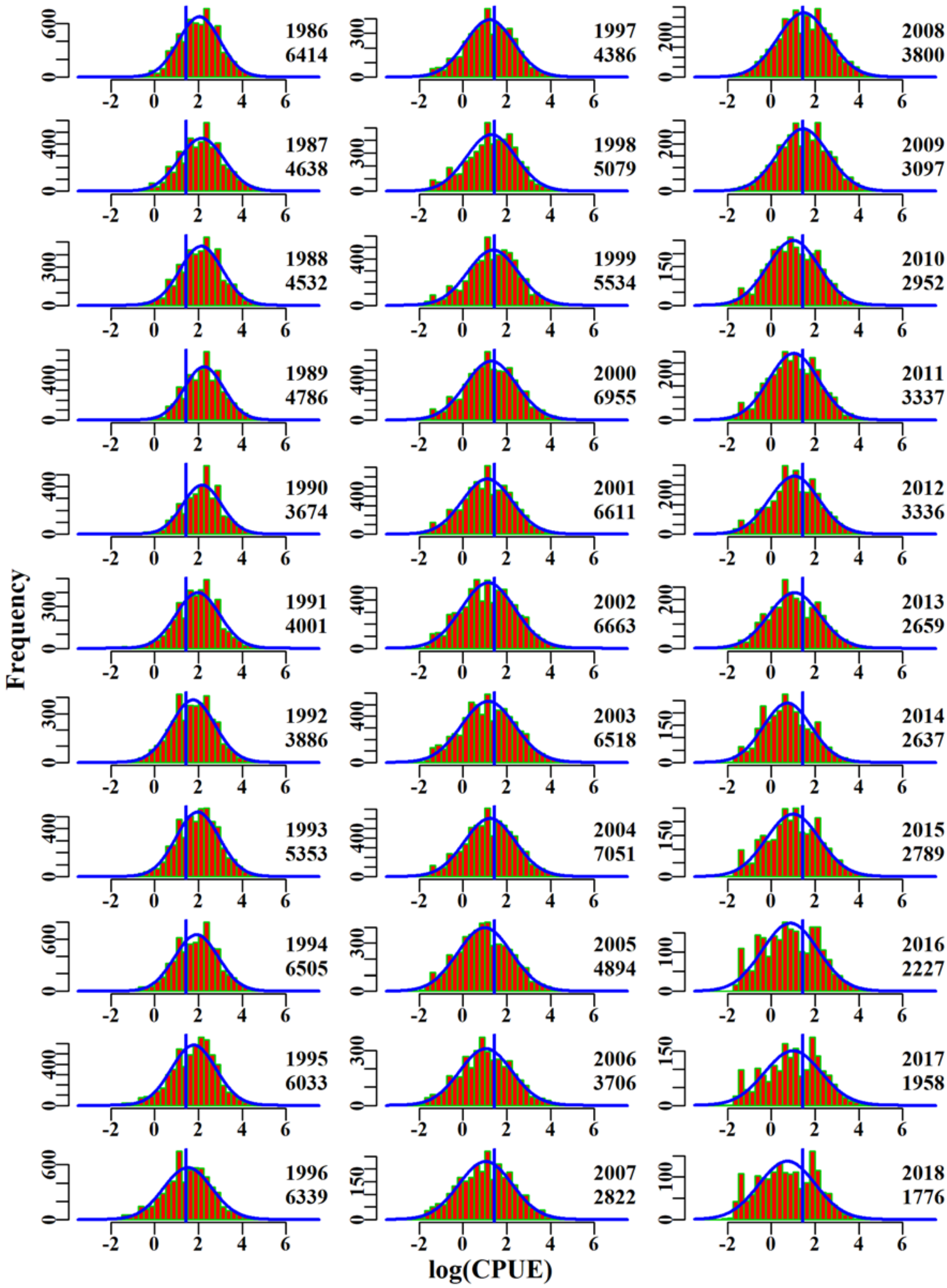

Figure 5.7. JohnDory1020. The natural log(CPUE) for each year of data available the blue lines are normal distributions fitted to the histogram frequencies. The numbers in each plot are the year and number of records.

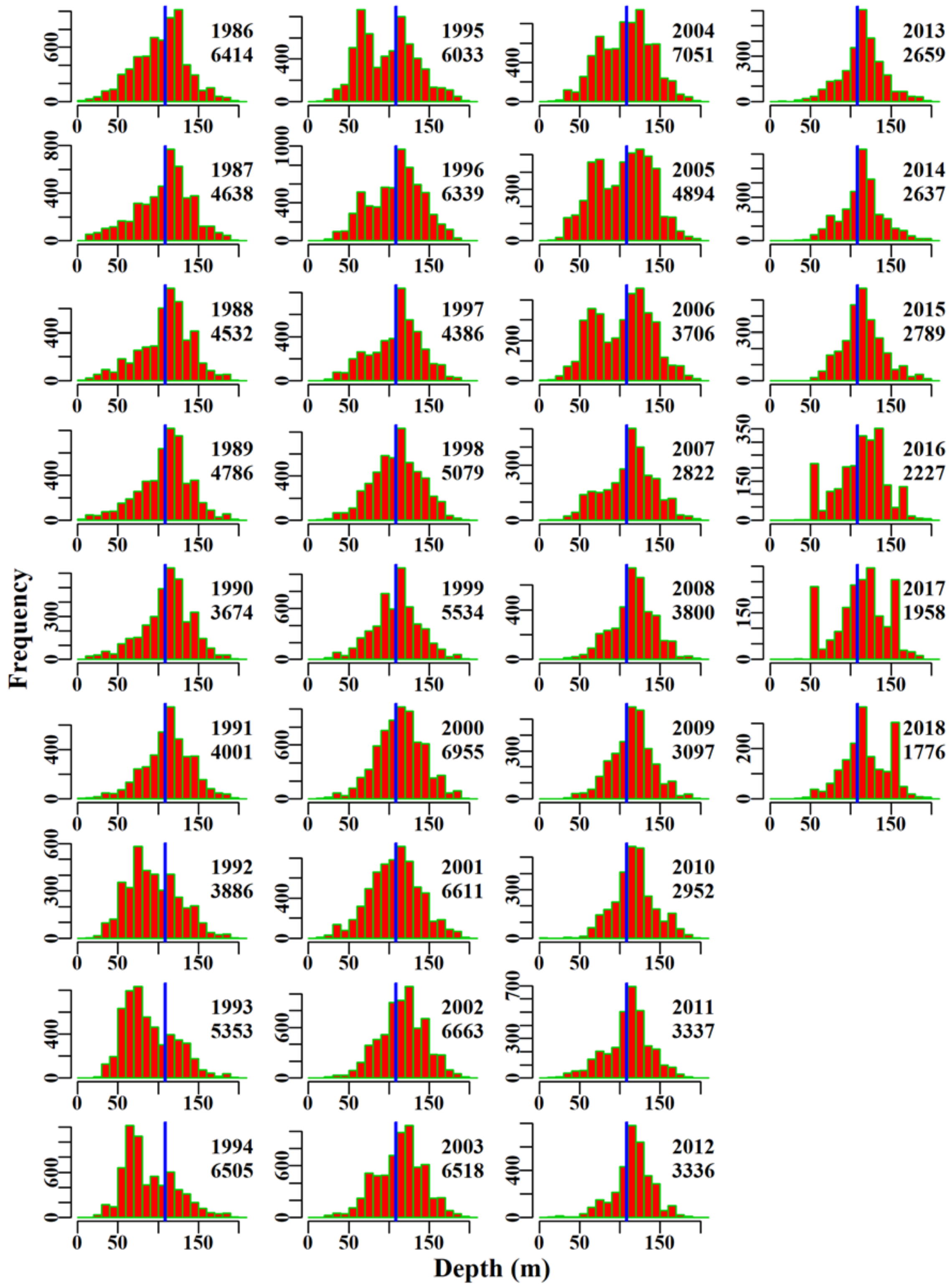

Figure 5.8. JohnDory1020. The average Depth of fishing for each year of data available to illustrate the development of the fishery through time. The numbers in each plot are the year and number of records.

5.5 School Whiting 60

School Whiting (WHS – 37330014 – *Sillago flindersi*) 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). The years used in the analysis were 1986 - 2018. Initial data selection was based on criteria provided in Table 5.6 from the Commonwealth logbook database. A total of 8 statistical models were fitted sequentially to the available data, and the order of the non-interaction terms added based on the relative contribution of each term to model fit.

5.5.1 *Inferences*

The early years of this data exhibit relatively large inter-annual variation, far greater than the stock itself could be under-going. This suggests either flaws in the data or some unknown factor having a sporadic effect upon the fishery. Since a low point in 1997 catch rates have been slowly rising and have been approximately at the long term average over the 2013-2016 period.

The terms Year, Daynight, Vessel and Month had the greatest contribution to model fit, with the remaining terms each explaining < 1% of the overall variation in CPUE based on the AIC and R^2 statistics (Table 5.10).

Since 2013, there has been fewer catches in deeper waters (i.e. greater than 50 m). Standardized CPUE exhibits a flat trend since 2012 with 2017 and 2018 dropping below the long term average based on 95% CIs (Figure 5.11).

5.5.2 *Action Items and Issues*

The qqplot suggests that the assumed Normal distribution of the log-transformed CPUE, in fact log(catch per shot) may be invalid, as relatively high proportions of the tails of the distribution deviate from the expected straight line (Figure 5.12). Further work is required to determine the reason behind the frequent occurrence of spikes of low values of catch-per-shot and how they may best be described or explained.

The influence of the vessels fishing changed in about 2003 onwards, and this was reinforced by the DayNight term. The vessel effect also changed dramatically since 2014, at which time the distribution of catches among the vessels participating became more even than previously.

Table 5.6. SchoolWhiting60. The data selection criteria used to specify and identify the fishery data to be included in the analysis.

Property	Value
label	SchoolWhiting60
csirocode	37330014
fishery	SET
depthrange	0 - 100
depthclass	20
zones	60
methods	DS
years	1986 - 2018

Table 5.7. SchoolWhiting60. Total catch (Total; t) is the total reported in the database, number of records used in the analysis (N), reported catch (Catch; t) in the area and depth used in the analysis and number of vessels used in the analysis (Vess). GeoM is the geometric mean of catch rates (kg/hr), standard deviation (StDev) relates to the optimum model. C<30Kg denotes the amount of catch in shots of <30kg, and %<30Kg is the percent of total. The optimum model was DepCat:Month.

	Total	N	Catch	Vess	GeoM	Opt	StDev	C<30Kg	P<30Kg
1986	1302.4	5616	1167.1	26	262.4	1.1540	0.000	18.476	0.016
1987	996.0	4058	909.2	23	271.6	1.2784	0.029	12.131	0.013
1988	1255.7	3767	1157.7	25	375.6	1.6296	0.030	10.303	0.009
1989	1061.5	4421	989.1	26	260.6	1.0813	0.029	14.045	0.014
1990	1930.4	6082	1803.1	24	351.5	1.6700	0.027	15.136	0.008
1991	1630.3	4645	1456.3	26	407.7	1.4755	0.029	10.954	0.008
1992	854.1	2906	751.3	23	362.0	1.0682	0.033	8.103	0.011
1993	1694.9	4784	1496.0	24	441.7	1.5237	0.029	9.902	0.007
1994	946.2	4406	864.6	23	273.8	0.8915	0.029	12.619	0.015
1995	1212.6	4198	1050.0	21	337.1	1.1312	0.030	9.197	0.009
1996	898.2	4126	692.3	22	223.6	0.7436	0.030	13.981	0.020
1997	697.4	3066	442.1	20	202.5	0.5603	0.032	11.232	0.025
1998	594.2	2913	447.6	20	211.5	0.5409	0.033	10.661	0.024
1999	681.3	1870	411.5	21	345.1	0.6211	0.039	6.013	0.015
2000	700.9	1916	343.9	18	266.9	0.6445	0.038	7.058	0.021
2001	890.9	1990	424.6	19	296.0	0.8924	0.039	6.779	0.016
2002	788.3	2186	428.2	20	258.4	0.8724	0.037	7.753	0.018
2003	866.2	2338	460.0	20	275.4	0.9153	0.037	7.942	0.017
2004	604.9	1751	332.0	20	264.4	0.8344	0.040	6.951	0.021
2005	662.7	1562	296.4	20	255.6	0.9307	0.041	4.883	0.016
2006	667.5	1404	263.4	18	258.3	0.8392	0.043	5.336	0.020
2007	535.4	1469	343.1	14	330.0	1.1119	0.042	4.479	0.013
2008	502.2	1248	313.7	15	370.2	1.1011	0.045	4.280	0.014
2009	462.6	1548	347.6	15	309.7	1.1872	0.042	5.171	0.015
2010	408.9	1167	270.8	15	339.6	1.0406	0.046	4.199	0.016
2011	373.9	1564	257.2	14	198.8	0.8333	0.042	6.430	0.025
2012	435.8	1562	302.3	14	262.7	0.8969	0.042	5.604	0.019
2013	510.6	1765	336.1	14	249.9	0.9184	0.040	6.569	0.020
2014	698.8	2047	480.8	14	336.2	1.0047	0.039	6.106	0.013
2015	741.1	2449	563.7	14	327.5	0.9564	0.037	7.530	0.013
2016	698.7	2326	556.4	15	304.4	0.9357	0.037	7.843	0.014
2017	746.7	2379	633.9	16	380.2	0.8688	0.037	6.235	0.010
2018	589.4	2576	504.2	16	243.6	0.8467	0.044	9.024	0.018

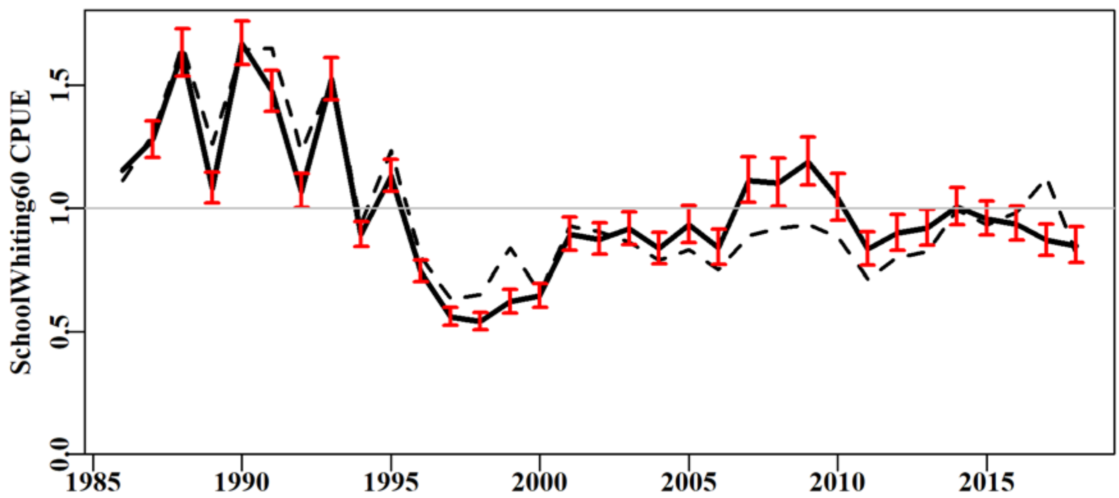

Figure 5.9. SchoolWhiting60 standardization. The dashed black line represents the geometric mean catch rate, solid black line the standardized catch rates. The red bars are the 95% confidence intervals about the mean estimates. The graph scales both time-series of standardized catch rates relative to the mean of each time-series.

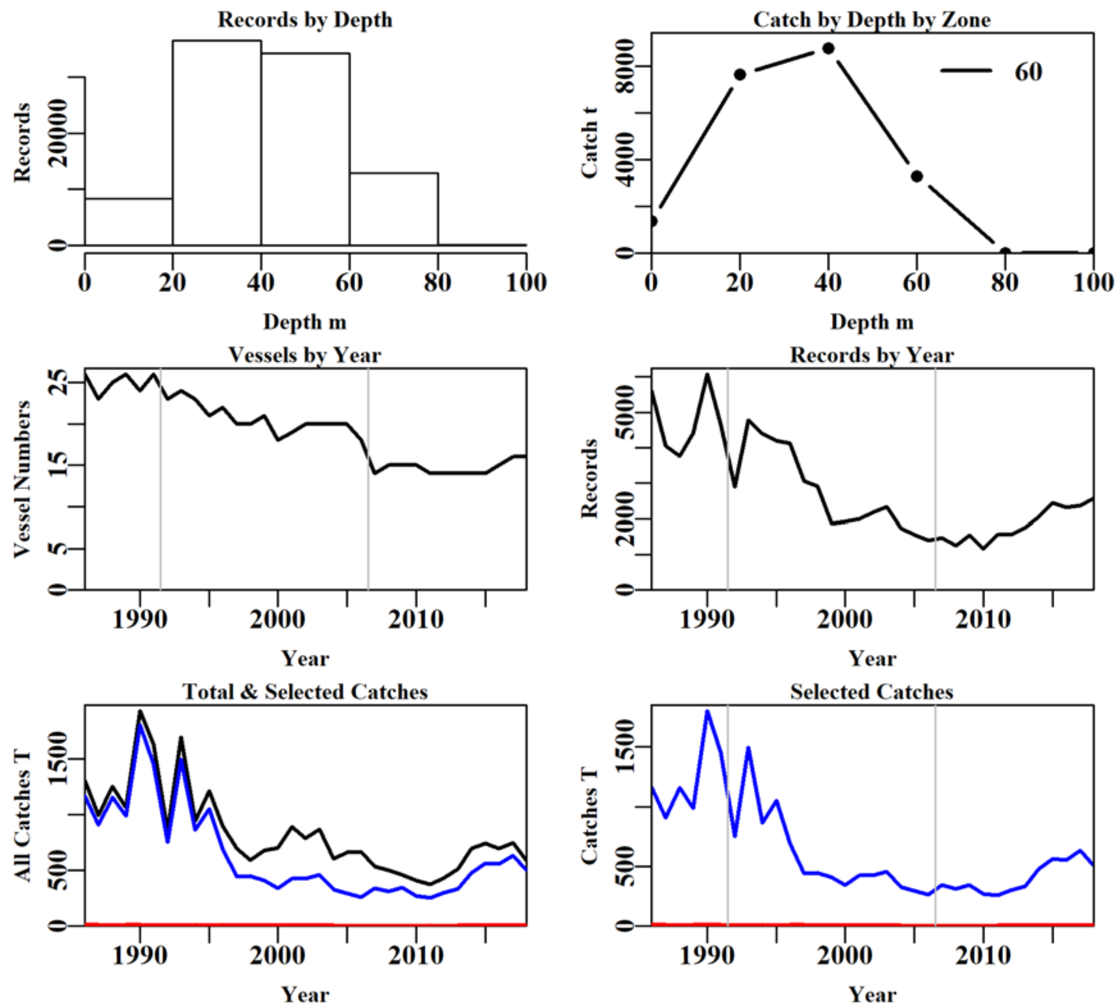

Figure 5.10. SchoolWhiting60 fishery details. The bottom left plot depicts all known catches (top black line), and all selected catches used in the analysis (middle blue line); the lower red line: selected catches < 30 kg).

Table 5.8. SchoolWhiting60 data selection effects. Total is the total number of records in the database, NoCE removes those records with either missing catch or effort, and then only those records are kept that meet the criteria for depth, years, zone, method and fishery.

	Total	NoCE	Depth	Years	Zones	Method	Fishery
Records	145612	136980	131953	129445	97771	95034	92105
Difference	0	8632	5027	2508	31674	2737	2929
Catch	28049.29	28049.29	27305.5879	26905.659	22200.841	21786.0276	21096.344
Difference	0.00	0.00	743.6975	399.929	4704.818	414.8135	689.684

Table 5.9. The models used to analyse data for SchoolWhiting60.

	Model
Model1	Year
Model2	Year + DayNight
Model3	Year + DayNight + Vessel
Model4	Year + DayNight + Vessel + Month
Model5	Year + DayNight + Vessel + Month + DepCat
Model6	Year + DayNight + Vessel + Month + DepCat + DayNight:DepCat
Model7	Year + DayNight + Vessel + Month + DepCat + DepCat:Month
Model8	Year + DayNight + Vessel + Month + DepCat + DayNight:Month

Table 5.10. SchoolWhiting60. The row names are 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_r2) and the change in adjusted R^2 (%Change). The optimum model was DepCat:Month

	AIC	RSS	MSS	Nobs	Npars	adj_r2	%Change
Year	67103	190711	7869	92105	33	3.9	0.00
DayNight	63291	182968	15612	92105	36	7.8	3.90
Vessel	60071	176494	22087	92105	85	11.0	3.21
Month	58894	174211	24370	92105	96	12.2	1.14
DepCat	58394	173248	25332	92105	101	12.7	0.48
DayNight:DepCat	58167	172780	25800	92105	112	12.9	0.23
DepCat:Month	57766	171918	26663	92105	142	13.3	0.63
DayNight:Month	58119	172609	25972	92105	134	13.0	0.29

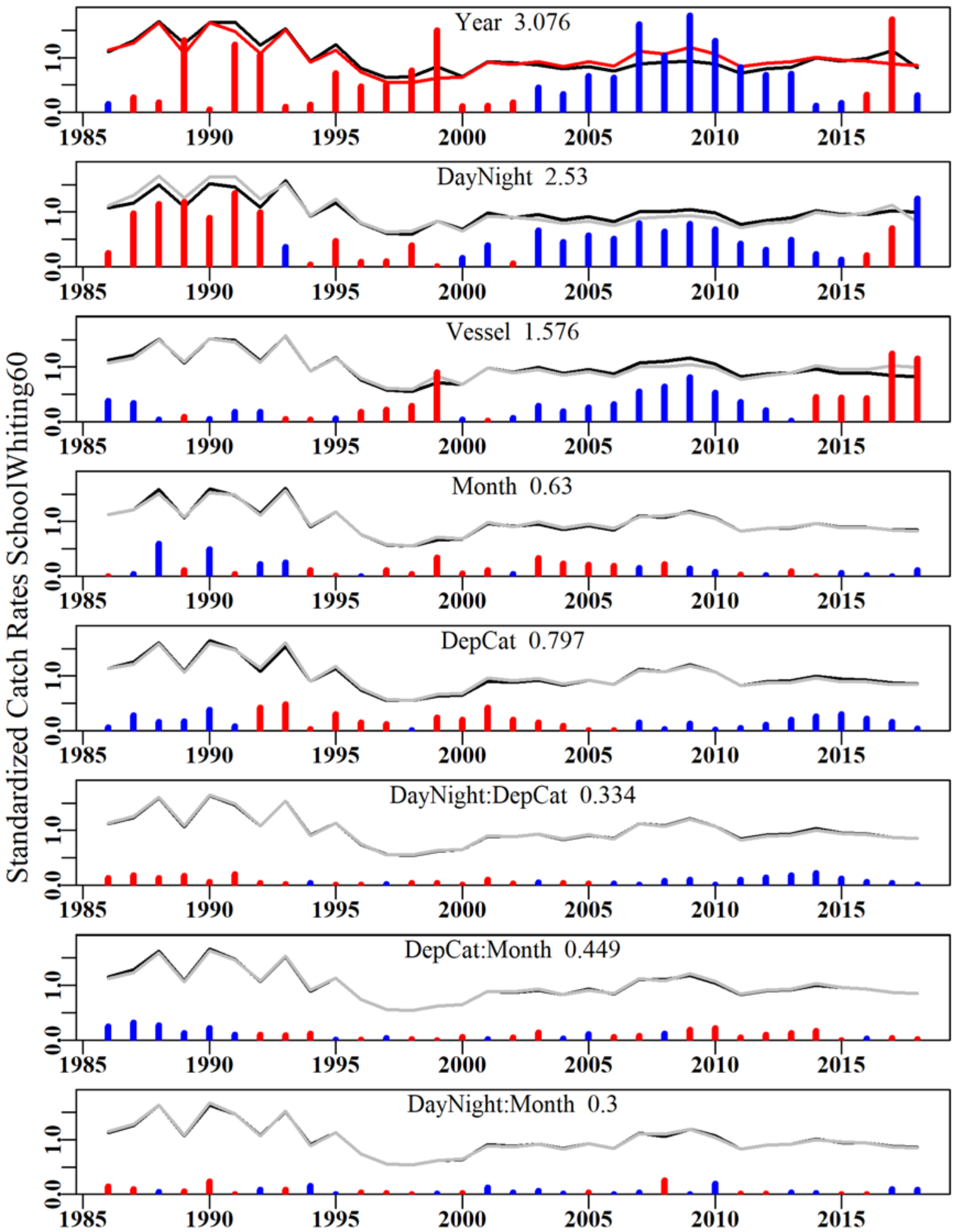

Figure 5.11. SchoolWhiting60. The influence of each factor on the optimal standardization. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by vertical bars with blue bars indicating the optimum model is higher than the 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.

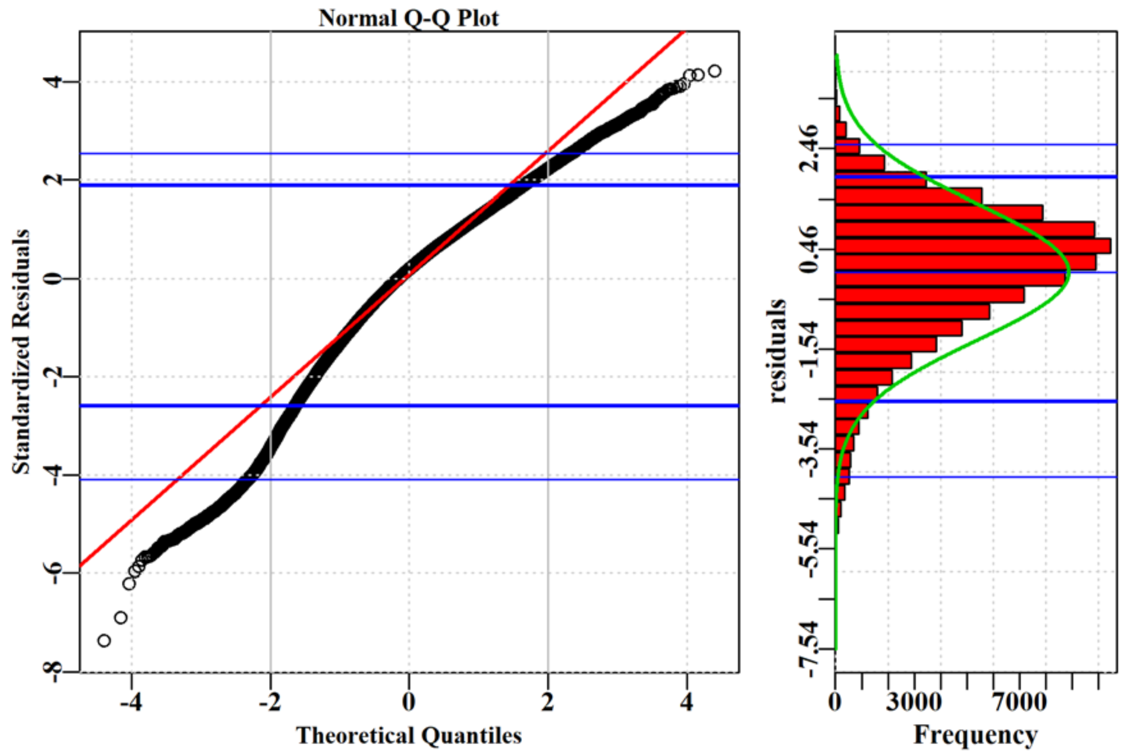

Figure 5.12. SchoolWhiting60. diagnostic plots. The distribution of residuals from the optimum fit. The qqplot indicates the fit to the expected normality, while the histogram of residuals illustrates the 90% quantiles to indicate the intensity of any lack of fit at the margins of the distribution.

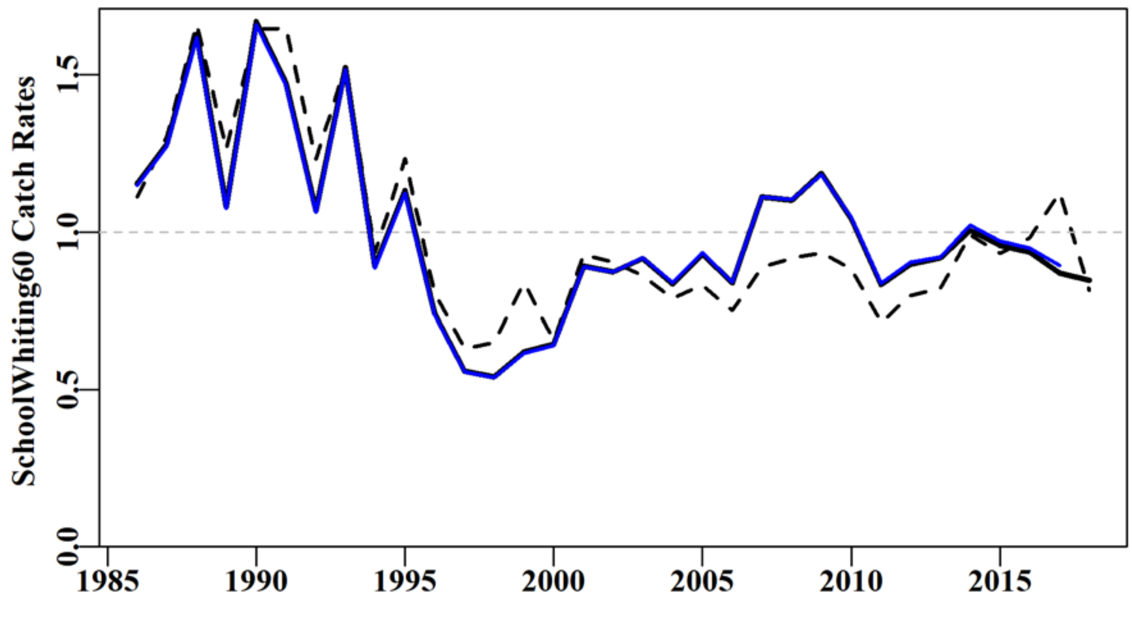

Figure 5.13. SchoolWhiting60. A comparison of the previous year's standardization (blue line) with this year's. They should lie on top of each other, although small deviations may relate to data adjustments, particularly in very recent years.

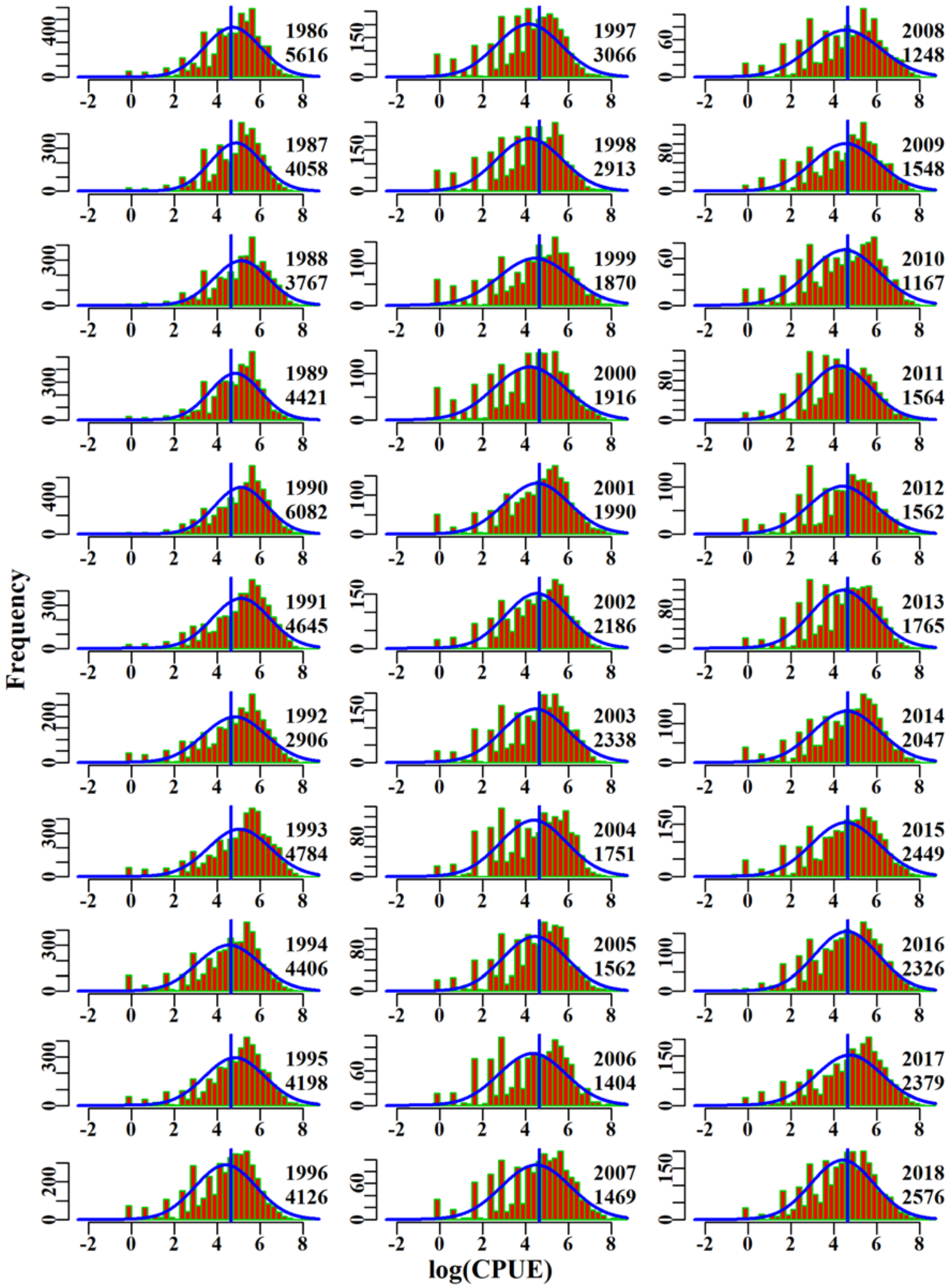

Figure 5.14. SchoolWhiting60. The natural log(CPUE) for each year of data available the blue lines are normal distributions fitted to the histogram frequencies. The numbers in each plot are the year and number of records.

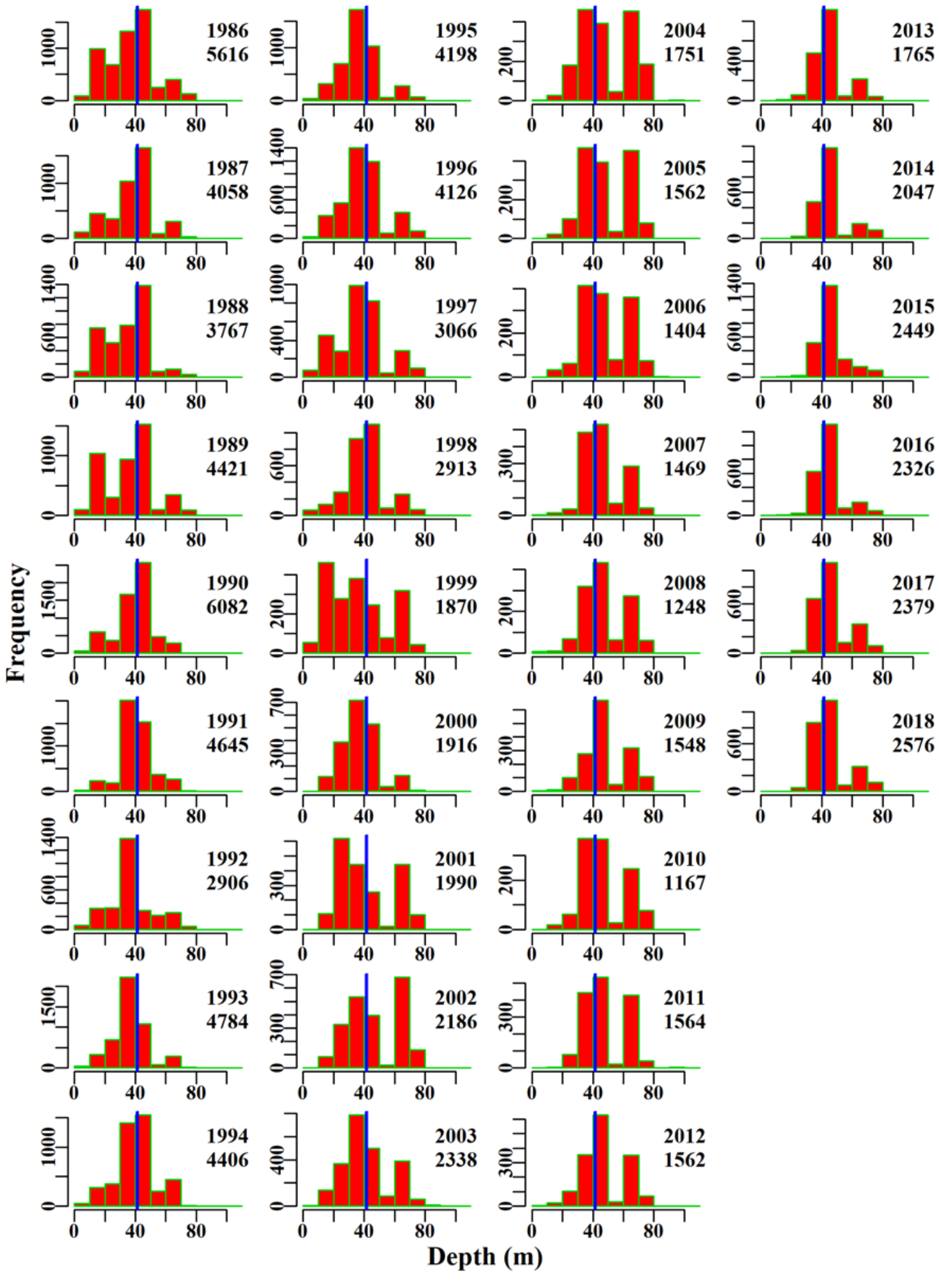

Figure 5.15. SchoolWhiting60. The average Depth of fishing for each year of data available to illustrate the development of the fishery through time. The numbers in each plot are the year and number of records.

5.6 School Whiting TW 10 20 91

School Whiting (WHS - 37330014 - *Sillago flindersi*) are taken by trawl in zones 10, 20 and 91. All vessels and all records were employed in the analysis for the years 1995 - 2018. Catch rates were expressed as the natural log of catch per hour (catch/hr). A total of 8 statistical models were fitted sequentially to the available data. Only minor catches are taken in zone 20 but maximum catches by depth category illustrate that catches in zones 10 and 91 are of the same order. Zone 91 catches are strictly State catches and while included here are excluded in the next analysis for comparison.

A total of 8 statistical models were fitted sequentially to the available data, and the order of the non-interaction terms added based on the relative contribution of each term to model fit.

5.6.1 *Inferences*

Most trawl caught school whiting occur between ~ 40 - 60 m, extending out to 150 m. Since 2014, catches have also been reported in deeper waters. Annual catches since 2009 have been smaller compared to previous years.

The terms Year, Vessel, DayNight, and DepCat had the greatest contribution to model fit, with the remaining terms each explaining < 1% of the overall variation in CPUE based on the AIC and R^2 statistics (Table 5.15). The qqplot suggests that the assumed Normal distribution is valid, with small deviations at the tails (Figure 5.19).

Standardized CPUE has exceeded the long term average in 2016 based on the 95% CI, the first time since 2008 (Figure 5.16).

5.6.2 *Action Items and Issues*

Again, the last three years 2014 - 2016 appear to have exhibited an alteration in fishing behaviour as evidenced by the changing distributions of records of catch at depth, why this has occurred in the last three years remains unknown.

Table 5.11. SchoolWhitingTW. The data selection criteria used to specify and identify the fishery data to be included in the analysis.

Property	Value
label	SchoolWhitingTW
csirocode	37330014
fishery	SET
depthrange	0 - 150
depthclass	10
zones	10, 20, 91
methods	TW, TDO
years	1995 - 2018

Table 5.12. SchoolWhitingTW. Total catch (Total; t) is the total reported in the database, number of records used in the analysis (N), reported catch (Catch; t) in the area and depth used in the analysis and number of vessels used in the analysis (Vess). GeoM is the geometric mean of catch rates (kg/hr), standard deviation (StDev) relates to the optimum model. C<30Kg denotes the amount of catch in shots of <30kg, and %<30Kg is the percent of total. The optimum model was DepCat:Month.

	Total	N	Catch	Vess	GeoM	Opt	StDev	C<30Kg	P<30Kg
1995	1212.6	277	40.7	16	64.8	1.2149	0.000	1.046	0.026
1996	898.2	437	75.1	21	83.2	1.3647	0.095	0.806	0.011
1997	697.4	824	97.0	23	68.0	0.9456	0.086	2.771	0.029
1998	594.2	710	81.1	25	54.6	0.9546	0.087	2.844	0.035
1999	681.3	886	107.1	27	63.2	1.1572	0.085	2.809	0.026
2000	700.9	1229	154.4	30	69.6	1.1584	0.082	3.735	0.024
2001	890.9	2101	309.2	34	92.7	1.2701	0.080	7.896	0.026
2002	788.3	1662	172.1	36	73.2	1.0505	0.081	6.024	0.035
2003	866.2	2426	291.3	40	68.7	1.0011	0.079	9.290	0.032
2004	604.9	2037	186.2	39	48.0	0.7740	0.080	9.837	0.053
2005	662.7	1953	250.4	37	71.4	1.0908	0.080	7.556	0.030
2006	667.5	1437	225.6	28	75.4	1.5043	0.082	5.825	0.026
2007	535.4	495	86.7	15	105.5	1.4814	0.094	2.110	0.024
2008	502.2	841	107.4	15	68.1	0.9496	0.087	3.724	0.035
2009	462.6	444	36.8	17	46.7	0.8229	0.096	2.629	0.071
2010	408.9	463	47.6	17	60.4	0.9888	0.096	2.282	0.048
2011	373.9	494	64.5	15	83.4	0.8433	0.095	2.313	0.036
2012	435.8	509	45.3	16	49.7	0.6211	0.094	3.115	0.069
2013	510.6	663	57.0	14	44.4	0.5541	0.090	4.006	0.070
2014	698.8	815	71.4	18	52.2	0.7539	0.088	4.168	0.058
2015	741.1	767	55.2	18	36.7	0.6898	0.089	4.944	0.090
2016	698.7	618	66.6	14	64.9	0.9264	0.092	3.387	0.051
2017	746.7	390	45.7	12	65.6	1.0682	0.100	2.252	0.049
2018	589.4	276	22.9	14	38.1	0.8143	0.111	1.311	0.057

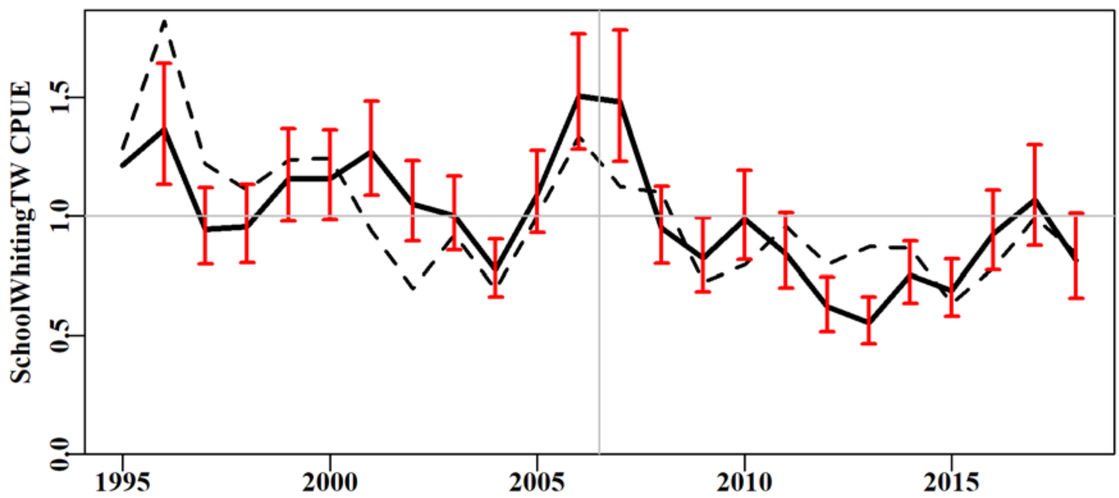

Figure 5.16. SchoolWhitingTW standardization. The dashed black line represents the geometric mean catch rate, solid black line the standardized catch rates. The red bars are the 95% confidence intervals about the mean estimates. The graph scales both time-series of standardized catch rates relative to the mean of each time-series.

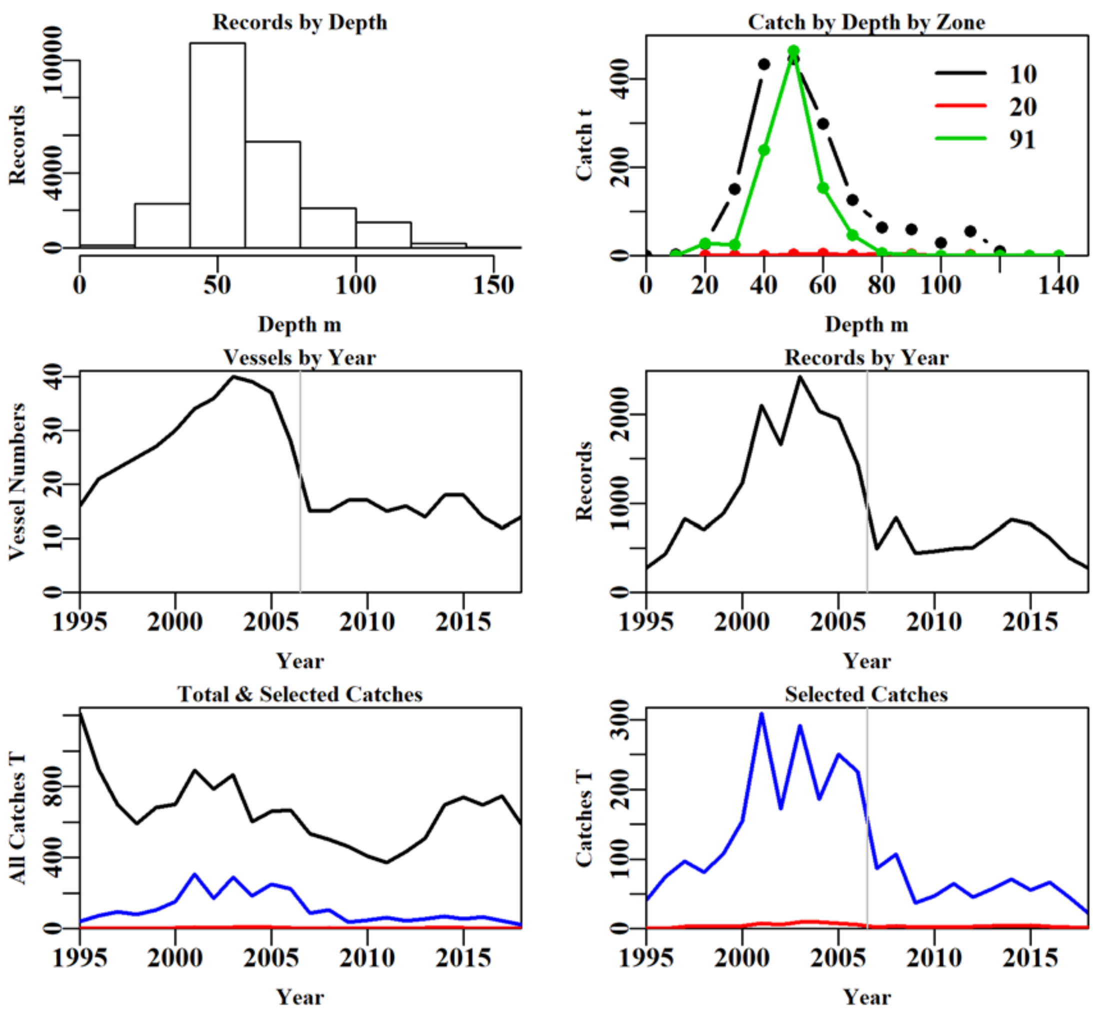

Figure 5.17. SchoolWhitingTW fishery details. The bottom left plot depicts all known catches (top black line), and all selected catches used in the analysis (middle blue line); the lower red line: selected catches < 30 kg).

Table 5.13. SchoolWhitingTW data selection effects. Total is the total number of records in the database, NoCE removes those records with either missing catch or effort, and then only those records are kept that meet the criteria for depth, years, zone, method and fishery.

	Total	NoCE	Depth	Years	Zones	Method	Fishery
Records	145612	111986	109912	66030	24002	22781	22754
Difference	0	33626	2074	43882	42028	1221	27
Catch	28049.29	23094.33	22682.314	11800.28	2896.09	2699.60	2697.43
Difference	0.00	4954.96	412.011	10882.04	8904.19	196.484	2.173

Table 5.14. The models used to analyse data for SchoolWhitingTW.

	Model
Model1	Year
Model2	Year + Vessel
Model3	Year + Vessel + DayNight
Model4	Year + Vessel + DayNight + DepCat
Model5	Year + Vessel + DayNight + DepCat + Month
Model6	Year + Vessel + DayNight + DepCat + Month + DayNight:DepCat
Model7	Year + Vessel + DayNight + DepCat + Month + DepCat:Month
Model8	Year + Vessel + DayNight + DepCat + Month + DayNight:Month

Table 5.15. SchoolWhitingTW. The row names are 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_r2) and the change in adjusted R^2 (%Change). The optimum model was DepCat:Month.

	AIC	RSS	MSS	Nobs	Npars	adj_r2	%Change
Year	20197	55160	1228	22754	24	2.1	0.00
Vessel	12283	38721	17667	22754	93	31.1	28.97
DayNight	10147	35242	21145	22754	96	37.2	6.19
DepCat	9307	33923	22465	22754	110	39.6	2.31
Month	9244	33797	22591	22754	121	39.7	0.20
DayNight:DepCat	8956	33293	23095	22754	148	40.6	0.83
DepCat:Month	9006	33039	23349	22754	260	40.7	0.99
DayNight:Month	9170	33616	22771	22754	145	40.0	0.26

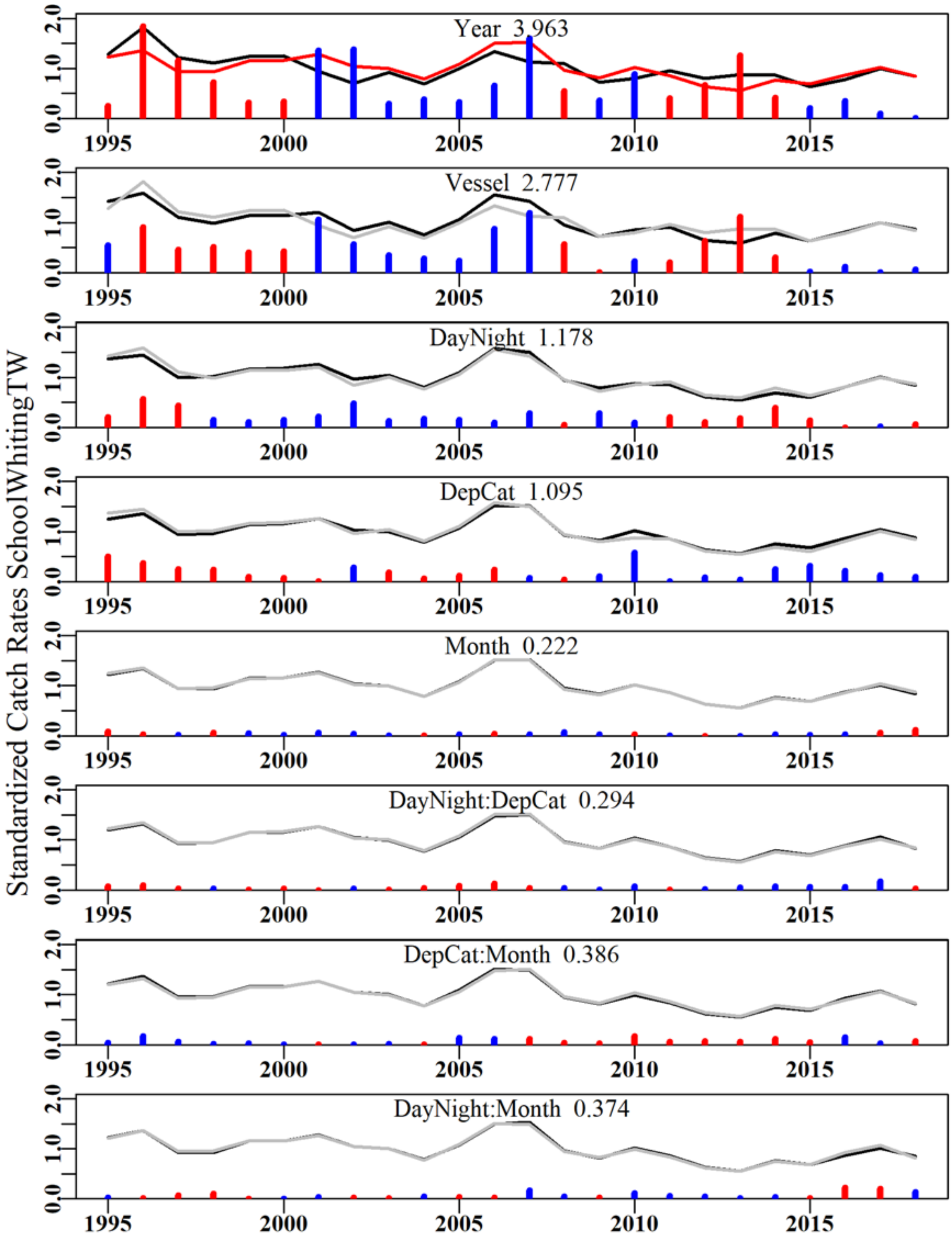

Figure 5.18. SchoolWhitingTW. The influence of each factor on the optimal standardization. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by vertical bars with blue bars indicating the optimum model is higher than the 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.

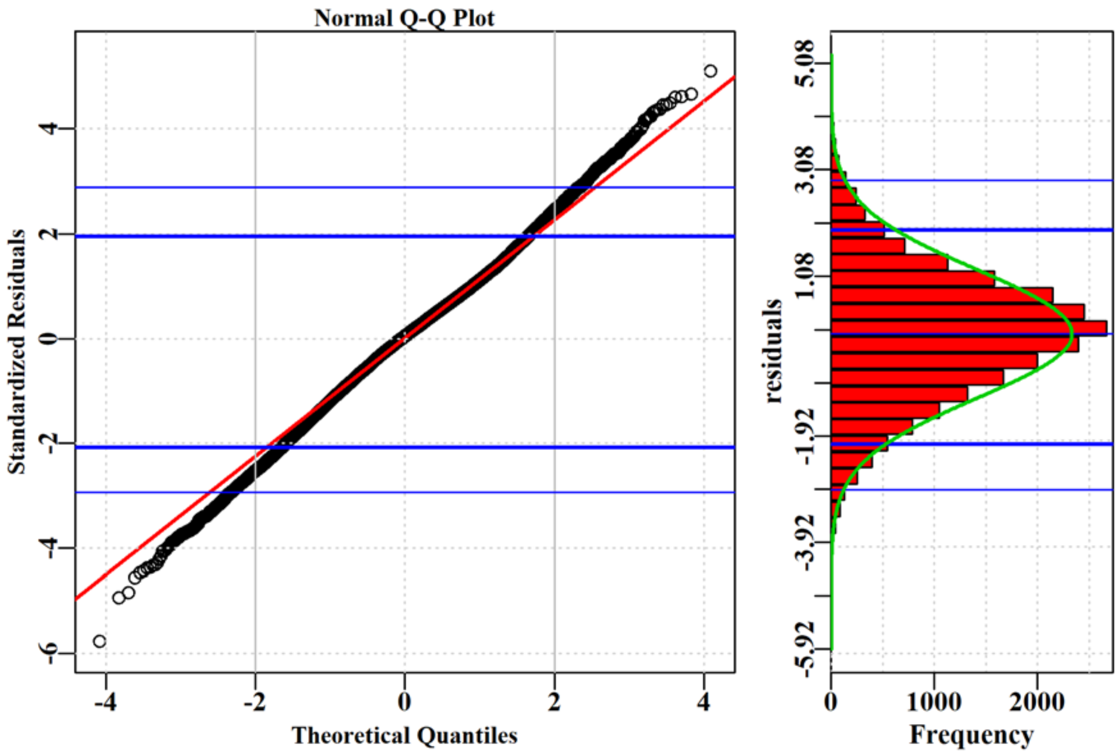

Figure 5.19. SchoolWhitingTW. diagnostic plots. The distribution of residuals from the optimum fit. The qqplot indicates the fit to the expected normality, while the histogram of residuals illustrates the 90% quantiles to indicate the intensity of any lack of fit at the margins of the distribution.

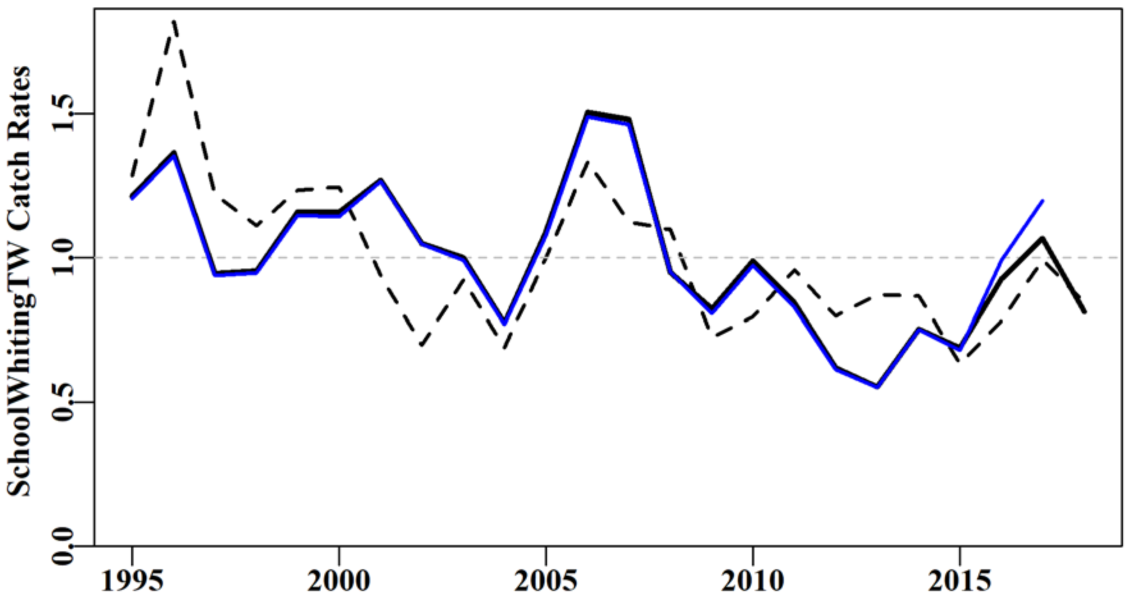

Figure 5.20. SchoolWhitingTW. A comparison of the previous year's standardization (blue line) with this year's. They should lie on top of each other, although small deviations may relate to data adjustments, particularly in very recent years.

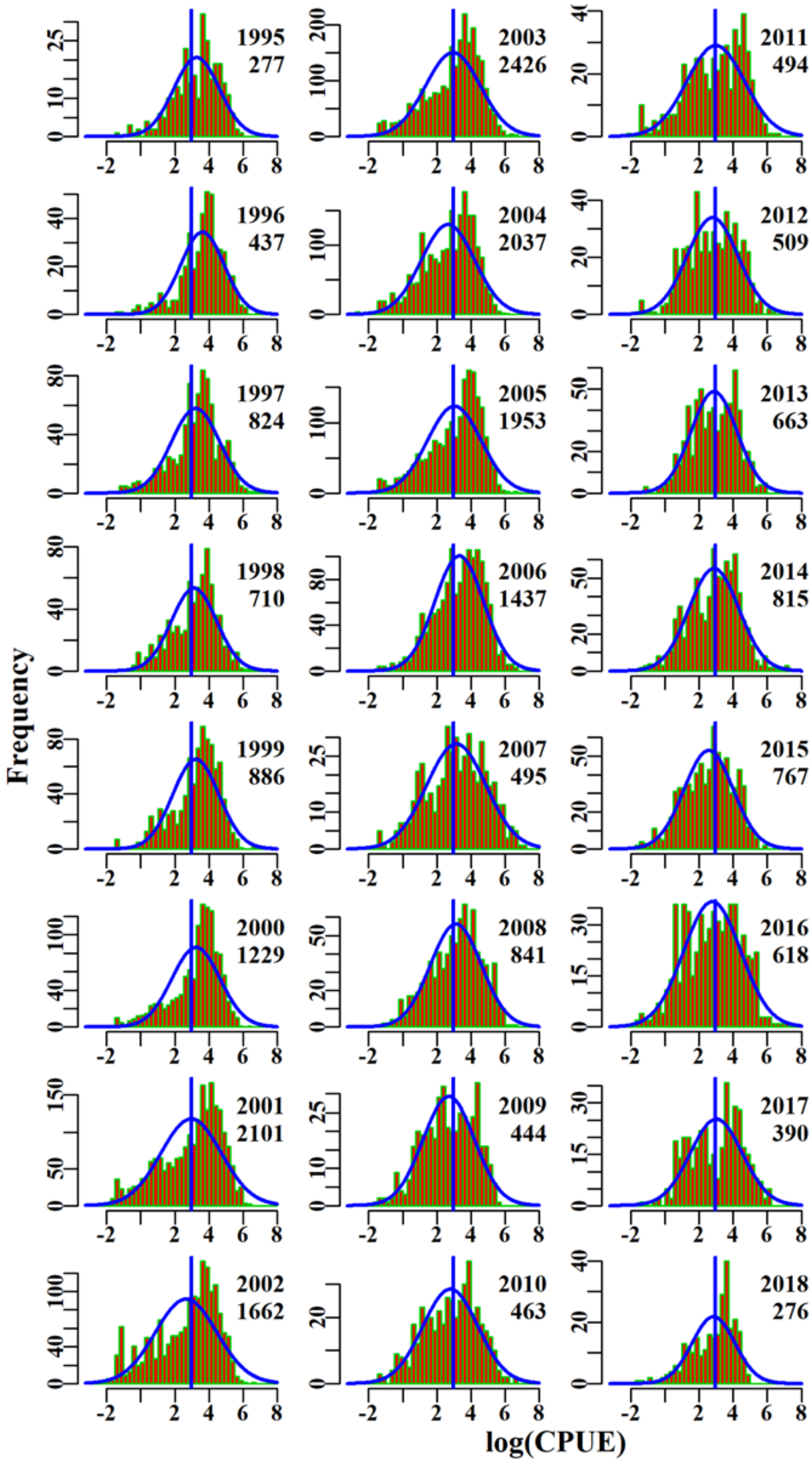

Figure 5.21. SchoolWhitingTW. The natural log(CPUE) for each year of data available the blue lines are normal distributions fitted to the histogram frequencies. The numbers in each plot are the year and number of records.

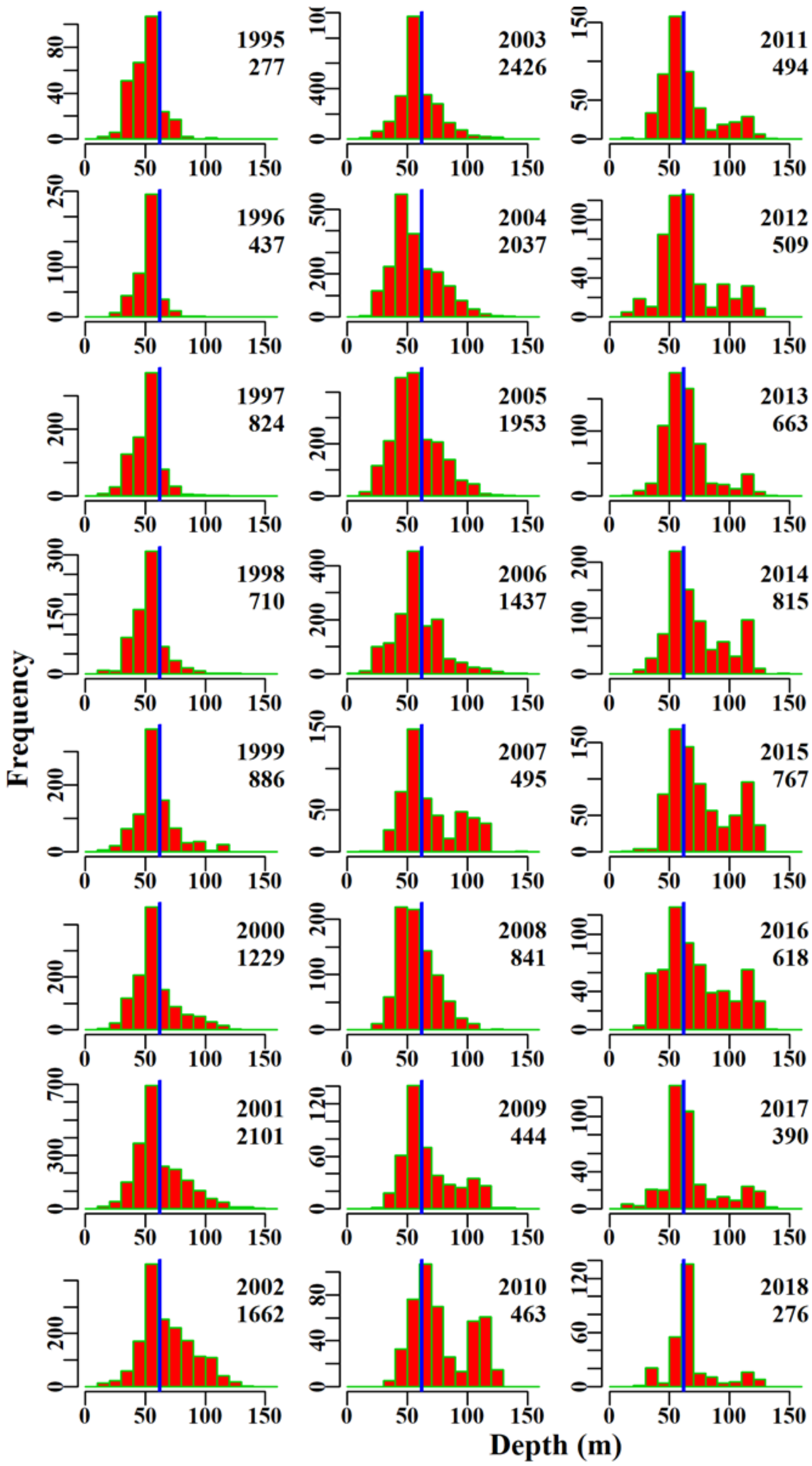

Figure 5.22. SchoolWhitingTW. The average Depth of fishing for each year of data available to illustrate the development of the fishery through time. The numbers in each plot are the year and number of records.

5.7 School Whiting TW 10 20

5.7.1 *Inferences*

School Whiting (WHS - 37330014 - *Sillago flindersi*) are taken by trawl in zones 10 and 20. All vessels and all records were employed in the analysis for the years 1995 - 2018. Catch rates were expressed as the natural log of catch per hour (catch/hr). Initial data selection was based on criteria provided in Table 5.16 from the Commonwealth logbook database. This analysis omits zone 91, which, even though the fishery is a clear and natural extension of the Commonwealth fishery (as evidenced by plotting the location of each shot) being State waters and catches they are omitted from the standardization for comparison with the complete analysis. A total of 8 statistical models were fitted sequentially to the available data, and the order of the non-interaction terms added based on the relative contribution of each term to model fit.

The terms Year, Vessel, DayNight, and DepCat and one interaction (DayNight:DepCat) had the greatest contribution to model fit, with the remaining terms each explaining < 1% of the overall variation in CPUE based on the AIC and R^2 statistics. The qqplot suggests that the assumed Normal distribution is valid.

The standardized CPUE trend is relatively noisy and flat except between 2006 - 2007 (i.e. around the time of the structural adjustment) (Figure 5.23). The log-transformed CPUE data is a close fit to a Normal distribution.

5.7.2 *Action Items and Issues*

The depth distribution of catches has not been stable from year to year, which may reflect the fact that there are only few vessels contributing seriously to this fishery.

Table 5.16. SchoolWhitingTW1020. The data selection criteria used to specify and identify the fishery data to be included in the analysis.

Property	Value
label	SchoolWhitingTW1020
csirocode	37330014
fishery	SET
depthrange	0 - 150
depthclass	10
zones	10, 20
methods	TW, TDO
years	1995 - 2018

Table 5.17. SchoolWhitingTW1020. Total catch (Total; t) is the total reported in the database, number of records used in the analysis (N), reported catch (Catch; t) in the area and depth used in the analysis and number of vessels used in the analysis (Vess). GeoM is the geometric mean of catch rates (kg/hr), standard deviation (StDev) relates to the optimum model. C<30Kg denotes the amount of catch in shots of <30kg, and %<30Kg is the percent of total. The optimum model was DayNight:DepCat.

	Total	N	Catch	Vess	GeoM	Opt	StDev	C<30Kg	P<30Kg
1995	1212.6	153	23.3	13	94.2	1.3443	0.000	0.689	0.030
1996	898.2	142	27.7	17	170.6	1.2108	0.155	0.393	0.014
1997	697.4	438	58.2	21	119.6	0.9824	0.125	1.951	0.033
1998	594.2	313	32.7	25	70.8	0.9777	0.130	1.685	0.051
1999	681.3	486	51.5	27	72.0	1.1550	0.124	2.083	0.040
2000	700.9	794	98.9	30	89.8	1.1337	0.118	2.765	0.028
2001	890.9	1453	178.9	34	87.0	1.1517	0.114	6.864	0.038
2002	788.3	1302	128.3	36	78.6	1.0321	0.115	4.992	0.039
2003	866.2	1638	192.6	38	79.1	1.0187	0.114	7.165	0.037
2004	604.9	1281	90.8	38	40.5	0.8032	0.114	7.119	0.078
2005	662.7	1254	132.9	37	65.0	1.0423	0.115	6.453	0.049
2006	667.5	948	140.3	28	79.7	1.6452	0.117	4.665	0.033
2007	535.4	434	80.5	15	122.5	1.6420	0.126	1.835	0.023
2008	502.2	522	68.3	15	81.5	0.8855	0.123	2.344	0.034
2009	462.6	376	30.3	17	46.1	0.8096	0.128	2.204	0.073
2010	408.9	385	37.8	17	55.6	0.9700	0.129	2.137	0.057
2011	373.9	422	50.0	15	84.5	0.8028	0.127	1.941	0.039
2012	435.8	426	40.0	16	57.1	0.6621	0.126	2.445	0.061
2013	510.6	505	45.4	14	50.1	0.5359	0.124	2.810	0.062
2014	698.8	693	63.4	18	58.3	0.7729	0.121	3.551	0.056
2015	741.1	647	47.6	18	39.0	0.7042	0.122	4.158	0.087
2016	698.7	544	58.2	14	66.4	0.8653	0.124	3.137	0.054
2017	746.7	322	37.8	12	67.8	1.0167	0.133	2.077	0.055
2018	589.4	185	13.6	14	34.8	0.8360	0.150	0.941	0.069

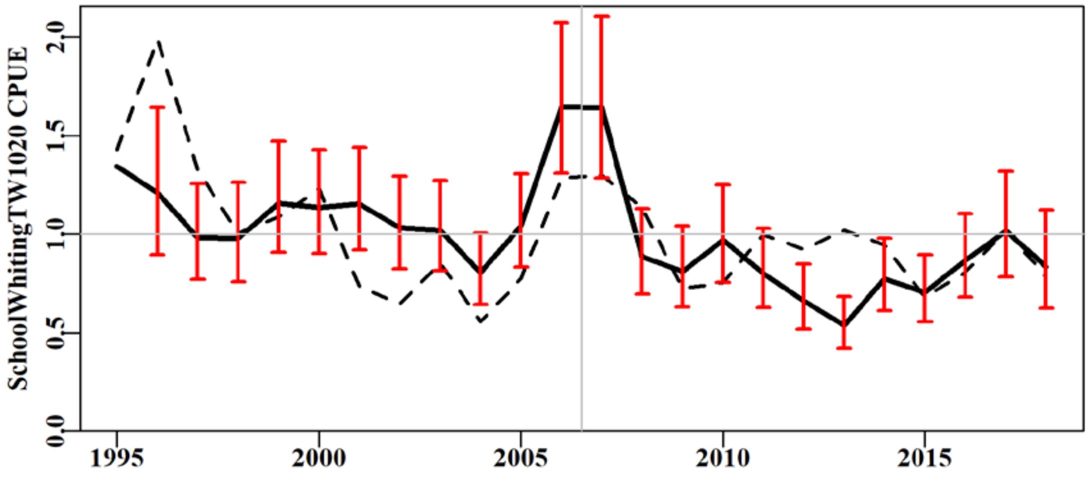

Figure 5.23. SchoolWhitingTW1020 standardization. The dashed black line represents the geometric mean catch rate, solid black line the standardized catch rates. The red bars are the 95% confidence intervals about the mean estimates. The graph scales both time-series of standardized catch rates relative to the mean of each time-series.

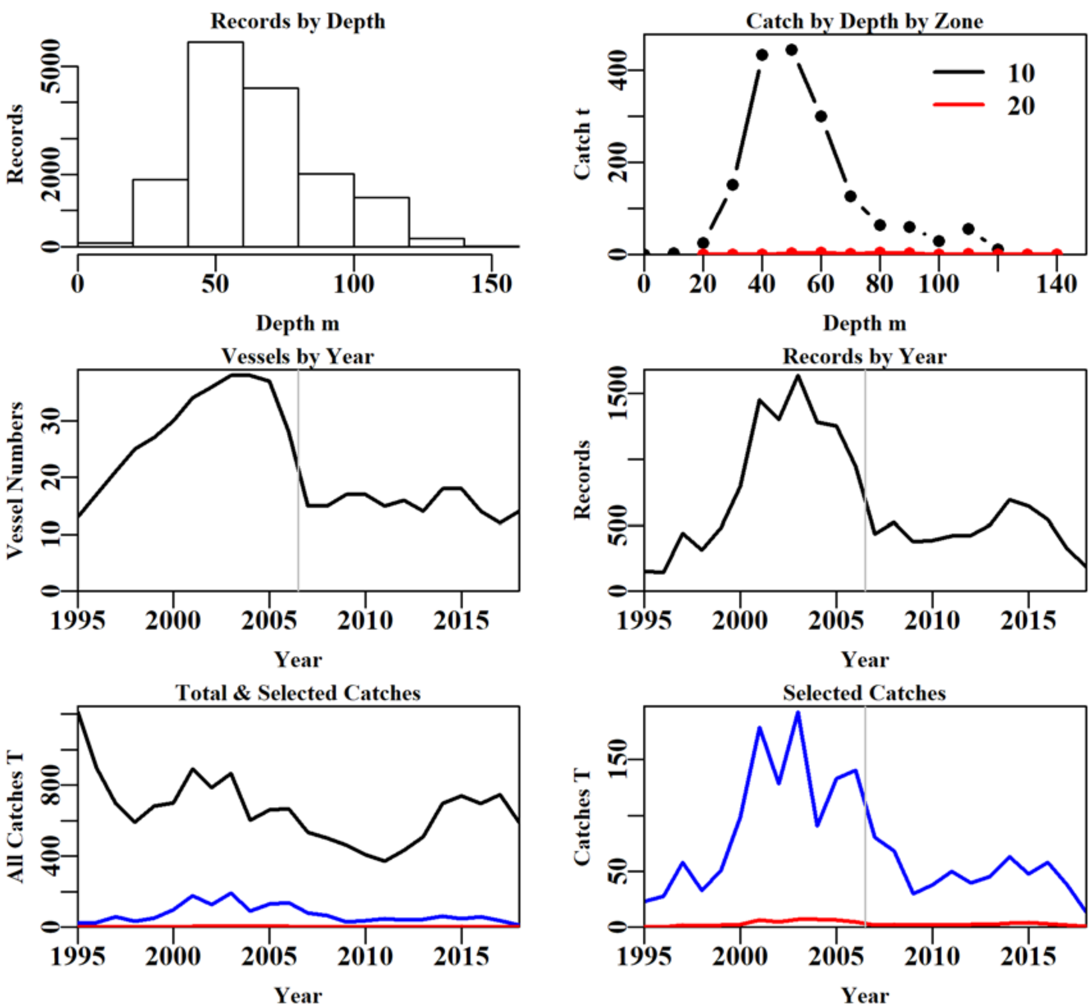

Figure 5.24. SchoolWhitingTW1020 fishery details. The bottom left plot depicts all known catches (top black line), and all selected catches used in the analysis (middle blue line); the lower red line: selected catches < 30 kg).

Table 5.18. SchoolWhitingTW1020 data selection effects. Total is the total number of records in the database, NoCE removes those records with either missing catch or effort, and then only those records are kept that meet the criteria for depth, years, zone, method and fishery.

	Total	NoCE	Depth	Years	Zones	Method	Fishery
Records	145612.00	111986.000	109912.0000	66030.00	16907.000	15690.0000	15663.000
Difference	0.00	33626.000	2074.0000	43882.00	49123.000	1217.0000	27.000
Catch	28049.29	23094.325	22682.3141	11800.28	1927.146	1731.3072	1729.134
Difference	0.00	4954.961	412.0105	10882.04	9873.129	195.8385	2.173

Table 5.19. The models used to analyse data for SchoolWhitingTW1020.

	Model
Model1	Year
Model2	Year + Vessel
Model3	Year + Vessel + DayNight
Model4	Year + Vessel + DayNight + DepCat
Model5	Year + Vessel + DayNight + DepCat + Month
Model6	Year + Vessel + DayNight + DepCat + Month + DayNight:DepCat
Model7	Year + Vessel + DayNight + DepCat + Month + DepCat:Month
Model8	Year + Vessel + DayNight + DepCat + Month + DayNight:Month

Table 5.20. SchoolWhitingTW1020. The row names are 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_r2) and the change in adjusted R^2 (%Change). The optimum model was DayNight:DepCat.

	AIC	RSS	MSS	Nobs	Npars	adj_r2	%Change
Year	16883	45886	1117	15663	24	2.2	0.00
Vessel	11118	31478	15525	15663	93	32.6	30.40
DayNight	9321	28054	18949	15663	96	39.9	7.32
DepCat	8583	26716	20287	15663	110	42.8	2.81
Month	8518	26567	20436	15663	121	43.0	0.28
DayNight:DepCat	8212	25963	21039	15663	148	44.2	1.20
DepCat:Month	8383	25879	21123	15663	259	44.0	0.98
DayNight:Month	8475	26413	20589	15663	145	43.3	0.24

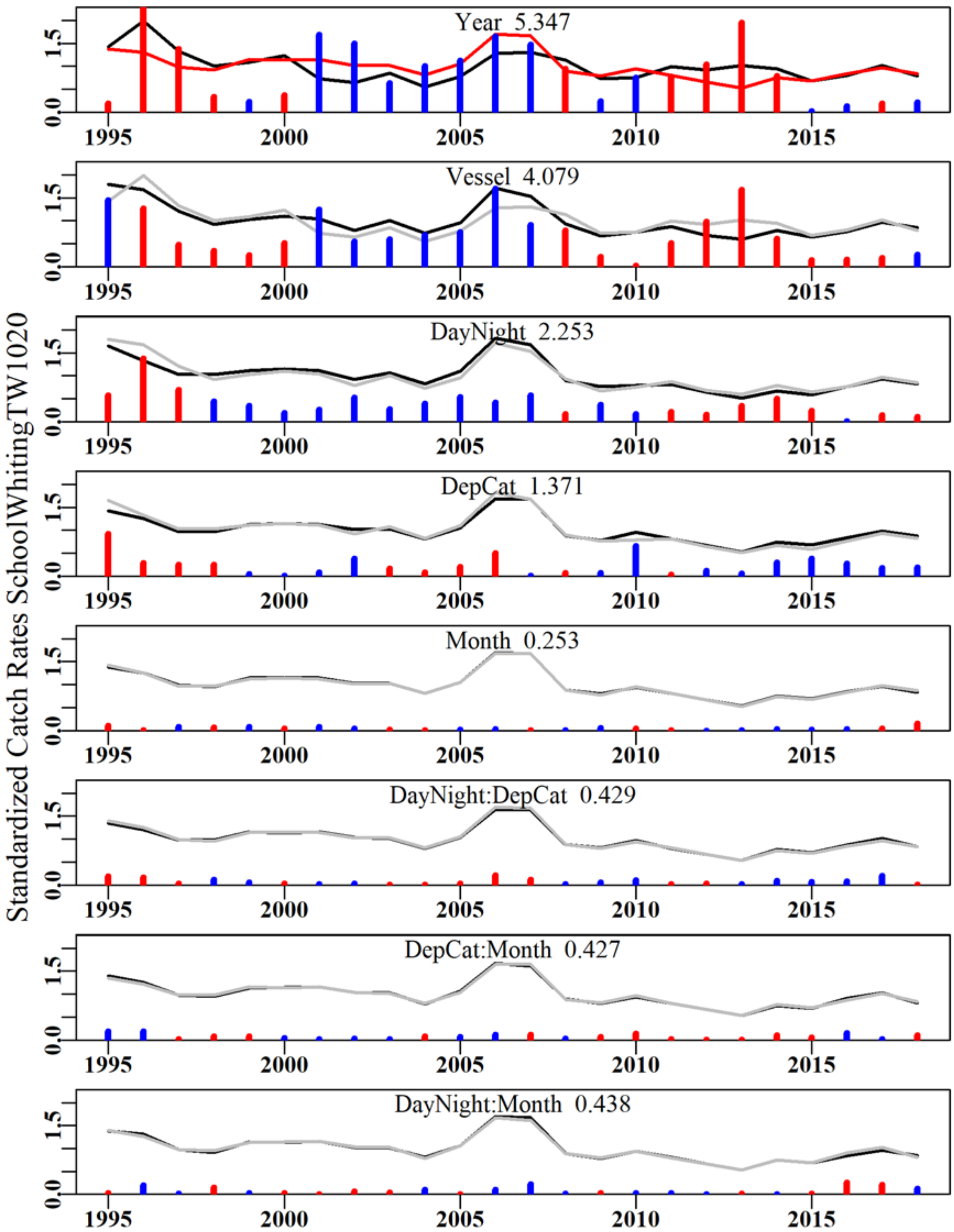

Figure 5.25. SchoolWhitingTW1020. The influence of each factor on the optimal standardization. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by vertical bars with blue bars indicating the optimum model is higher than 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.

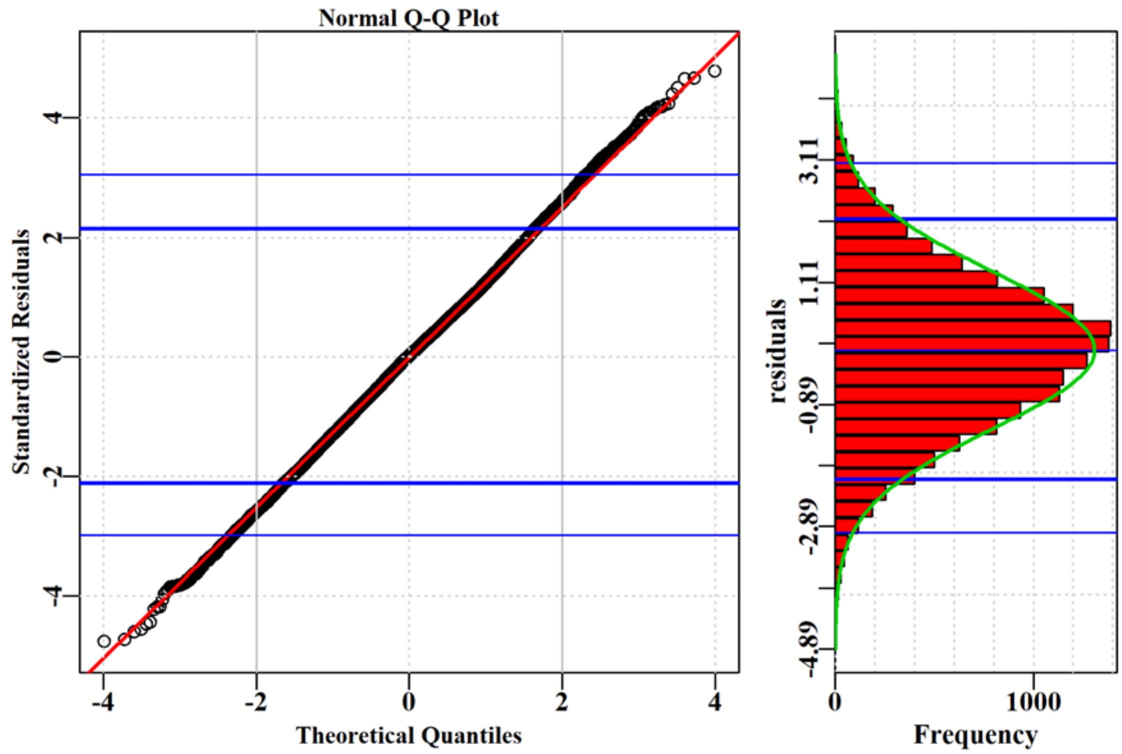

Figure 5.26. SchoolWhitingTW1020. diagnostic plots. The distribution of residuals from the optimum fit. The qqplot indicates the fit to the expected normality, while the histogram of residuals illustrates the 90% quantiles to indicate the intensity of any lack of fit at the margins of the distribution.

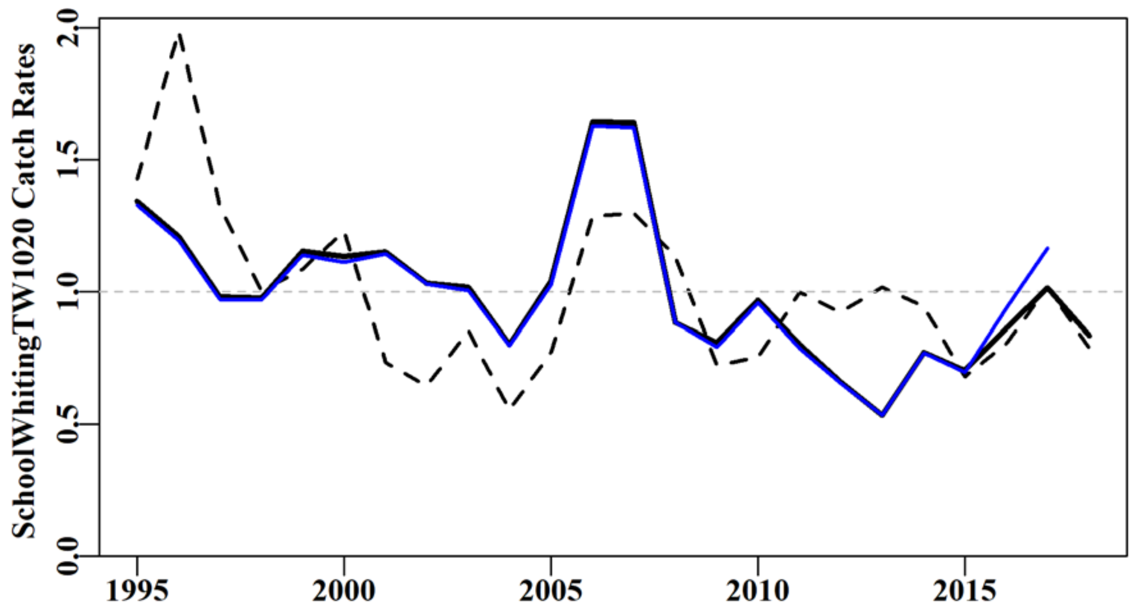

Figure 5.27. SchoolWhitingTW1020. A comparison of the previous year's standardization (blue line) with this year's. They should lie on top of each other, although small deviations may relate to data adjustments, particularly in very recent years.

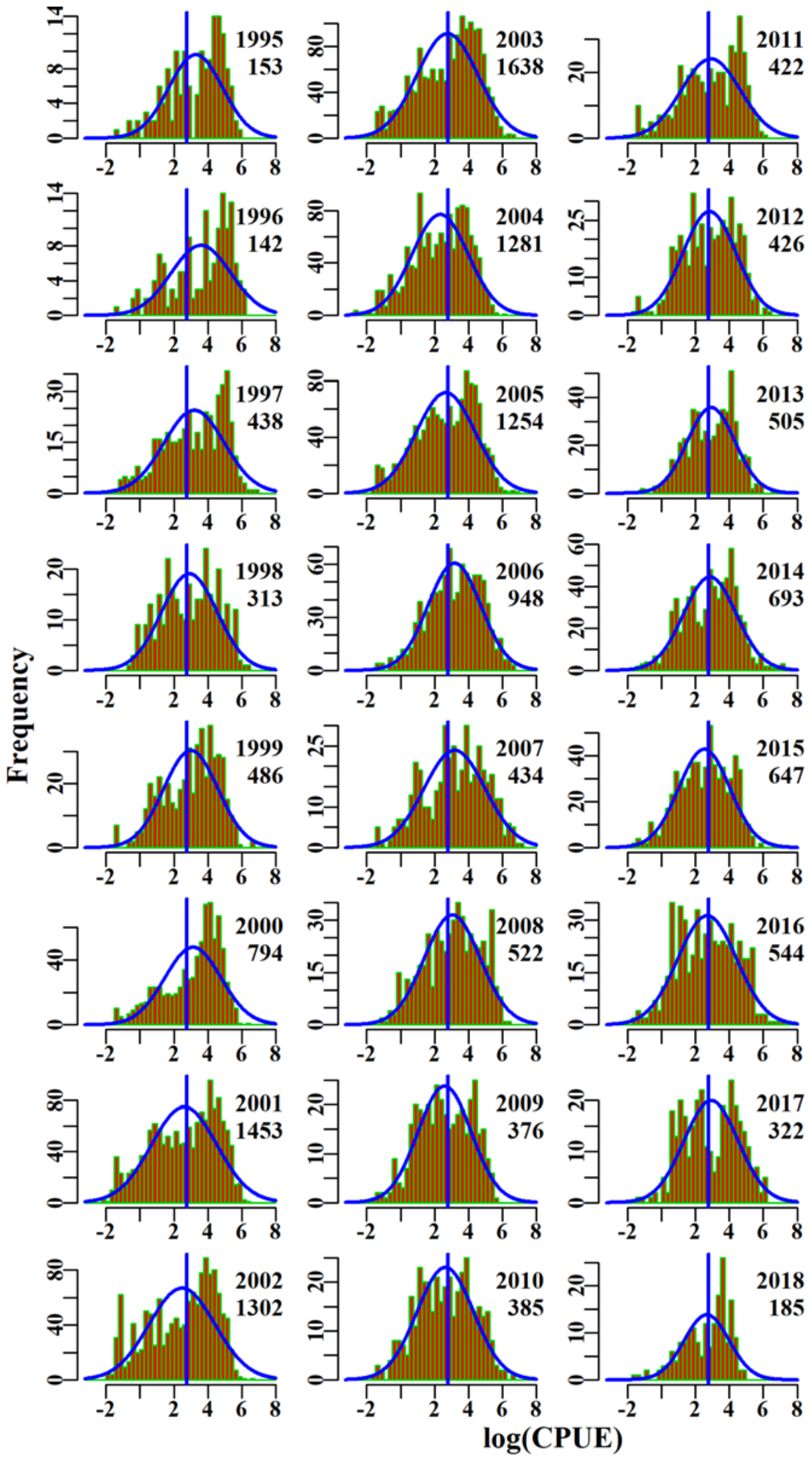

Figure 5.28. SchoolWhitingTW1020. The natural log(CPUE) for each year of data available the blue lines are normal distributions fitted to the histogram frequencies. The numbers in each plot are the year and number of records.

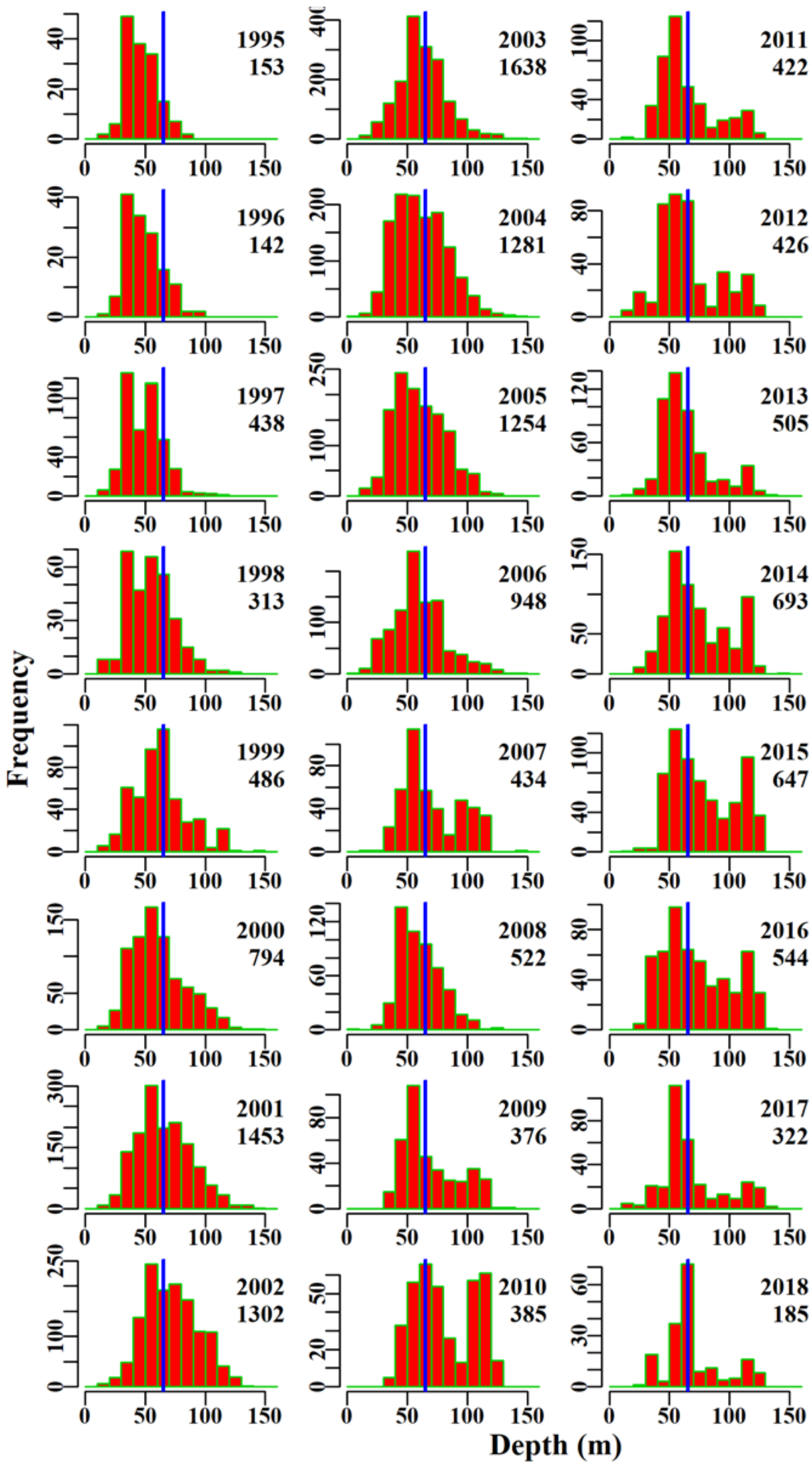

Figure 5.29. SchoolWhitingTW1020. The average Depth of fishing for each year of data available to illustrate the development of the fishery through time. The numbers in each plot are the year and number of records.

5.8 Mirror Dory 10 – 30

Mirror Dory (DOM – 37264003 – *Zenopsis nebulosa*) has a long history within the SESSF with catches being taken widely and by multiple methods. Records corresponding to the trawl fishery based on methods TW, TDO, TMO, OTT, in zones 10, 20, 30, and depths 0 to 600 within the SET fishery for the period 1986 - 2018 were used were used in the analysis. Initial data selection was based on criteria provided in Table 5.21 from the Commonwealth logbook database.

A total of 8 statistical models were fitted sequentially to the available data, and the order of the non-interaction terms added based on the relative contribution of each term to model fit.

5.8.1 *Inferences*

The terms Year, Vessel, DepCat, and Month had the greatest contribution to model fit, with the remaining terms each explaining < 1% of the overall variation in CPUE based on the AIC and R^2 statistics (Table 5.25). The qqplot suggests that the assumed Normal distribution is valid (Figure 5.33).

The Mirror Dory fishery in zones 10 - 30 exhibits large scale, apparently cyclical changes in CPUE. In an approximate manner as catches decline so do catch rates, and as catches increase so does the CPUE. This is unexpected as the intensity of fishing is usually expected to be negatively correlated with CPUE. It may be the case that catches and CPUE change relative to availability of the stock rather than the influence of the fishery on the stock. Better evidence is needed to make such an assertion with confidence. Over the period when CPUE was lower than average (about 1995 - 2004) there was an increase in small shots of < 30kg (Figure 5.31), which is suggestive of either low availability or high levels of small fish.

Standardized CPUE has declined on average from 2009 to 2016. It differs from unstandardized CPUE early in the fishery (1986 - 1990), in the second half of the fishery (2000 - 2007) and in the most recent three years (2014 - 2017). The most recent changes appear strongly correlated with changes in the average depth of fishing with a shift to more relatively shallow water fishing, compared to the second half of the fishery.

5.8.2 *Action Items and Issues*

No issues identified.

Table 5.21. MirrorDory1030. The data selection criteria used to specify and identify the fishery data to be included in the analysis.

Property	Value
label	MirrorDory1030
csirocode	37264003
fishery	SET
depthrange	0 - 600
depthclass	25
zones	10, 20, 30
methods	TW, TDO, TMO, OTT
years	1986 - 2018

Table 5.22. MirrorDory1030. Total catch (Total; t) is the total reported in the database, number of records used in the analysis (N), reported catch (Catch; t) in the area and depth used in the analysis and number of vessels used in the analysis (Vess). GeoM is the geometric mean of catch rates (kg/hr), standard deviation (StDev) relates to the optimum model. C<30Kg denotes the amount of catch in shots of <30kg, and %<30Kg is the percent of total. The optimum model was Zone:Month.

	Total	N	Catch	Vess	GeoM	Opt	StDev	C<30Kg	P<30Kg
1986	402.0	3139	367.9	80	39.2	1.2122	0.000	16.343	0.044
1987	450.8	2953	412.9	70	40.7	1.3251	0.033	15.129	0.037
1988	346.0	3065	313.1	77	33.7	1.1972	0.033	19.277	0.062
1989	591.6	2992	513.4	70	54.5	1.4367	0.033	15.795	0.031
1990	295.8	1801	253.5	61	36.5	1.3701	0.039	10.132	0.040
1991	240.3	2002	168.5	68	26.9	1.1876	0.038	16.089	0.095
1992	167.0	2031	140.3	57	22.3	1.0220	0.038	17.939	0.128
1993	306.2	2997	265.7	62	32.4	1.1124	0.034	21.976	0.083
1994	297.3	3482	260.5	62	25.9	0.9864	0.033	30.013	0.115
1995	244.9	3494	196.0	58	21.7	0.8910	0.033	33.126	0.169
1996	352.7	4377	211.5	68	16.7	0.7818	0.032	43.254	0.205
1997	459.6	4757	287.1	65	19.5	0.8335	0.032	45.256	0.158
1998	355.8	4092	230.1	55	19.4	0.7427	0.033	38.924	0.169
1999	309.5	4211	234.2	59	19.3	0.6543	0.033	39.603	0.169
2000	171.1	4593	142.5	64	11.3	0.5173	0.033	46.471	0.326
2001	243.4	4533	128.7	54	10.0	0.5186	0.033	46.396	0.361
2002	449.6	5032	194.3	53	14.0	0.6503	0.032	44.433	0.229
2003	613.9	5333	403.8	58	29.9	0.9317	0.032	40.852	0.101
2004	507.4	4256	291.0	57	25.8	0.8843	0.033	32.430	0.111
2005	579.9	4356	420.4	55	37.4	1.1297	0.033	30.059	0.071
2006	419.6	3214	296.4	44	35.4	1.1379	0.035	23.588	0.080
2007	289.6	2210	201.1	22	33.6	1.2253	0.038	16.397	0.082
2008	396.2	2476	316.9	26	48.1	1.3627	0.038	17.544	0.055
2009	476.5	2191	333.9	27	55.9	1.4481	0.039	15.733	0.047
2010	580.0	2068	378.3	25	71.5	1.2087	0.039	13.158	0.035
2011	514.5	2208	339.2	26	64.0	1.2313	0.038	14.273	0.042
2012	365.5	1712	281.3	24	66.7	0.9724	0.041	10.981	0.039
2013	279.9	1633	206.6	24	55.6	1.0083	0.041	10.502	0.051
2014	190.0	1732	112.4	25	24.7	0.8440	0.041	15.045	0.134
2015	240.4	2126	163.5	27	31.8	0.8239	0.039	17.175	0.105
2016	249.4	2062	202.0	26	42.0	0.8104	0.040	13.230	0.065
2017	224.3	1412	163.4	22	50.9	0.9525	0.044	11.230	0.069
2018	96.6	1215	58.0	18	18.9	0.5890	0.047	12.133	0.209

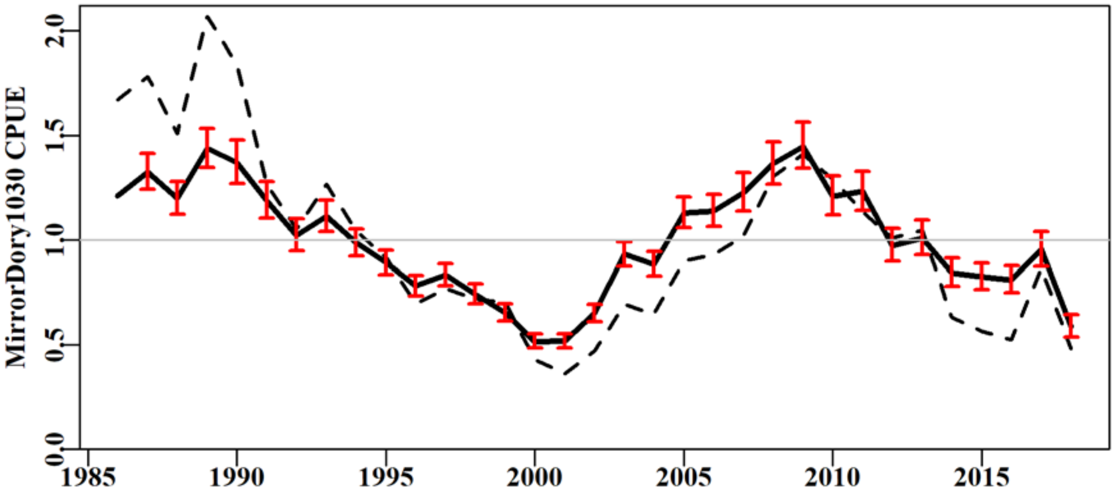

Figure 5.30. MirrorDory1030 standardization. The dashed black line represents the geometric mean catch rate, solid black line the standardized catch rates. The red bars are the 95% confidence intervals about the mean estimates. The graph scales both time-series of standardized catch rates relative to the mean of each time-series.

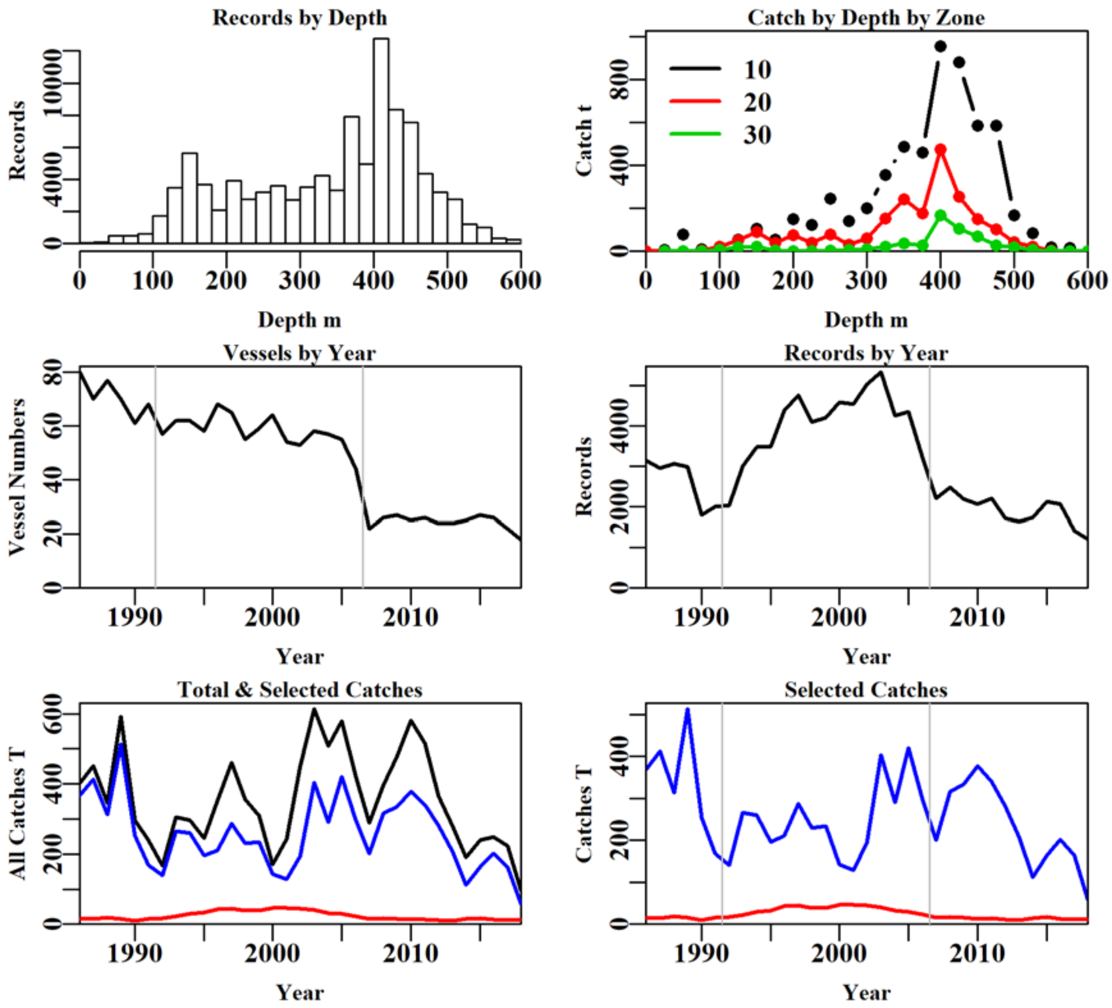

Figure 5.31. MirrorDory1030 fishery details. The bottom left plot depicts all known catches (top black line), and all selected catches used in the analysis (middle blue line); the lower red line: selected catches < 30 kg).

Table 5.23. MirrorDory1030 data selection effects. Total is the total number of records in the database, NoCE removes those records with either missing catch or effort, and then only those records are kept that meet the criteria for depth, years, zone, method and fishery.

	Total	NoCE	Depth	Years	Zones	Method	Fishery
Records	1468660	143400	141438	140609	102423	99804	99755
Difference	0	3466	1962	829	38186	2619	49
Catch	11756.96	11629.255	11457.909	11410.611	8554.55	8491.17	8488.67
Difference	0.00	127.704	171.346	47.298	2856.06	63.38	2.49

Table 5.24. The models used to analyse data for MirrorDory1030.

	Model
Model1	Year
Model2	Year + Vessel
Model3	Year + Vessel + DepCat
Model4	Year + Vessel + DepCat + Month
Model5	Year + Vessel + DepCat + Month + Zone
Model6	Year + Vessel + DepCat + Month + Zone + DayNight
Model7	Year + Vessel + DepCat + Month + Zone + DayNight + Zone:Month
Model8	Year + Vessel + DepCat + Month + Zone + DayNight + Zone:DepCat

Table 5.25. MirrorDory1030. The row names are 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_r2) and the change in adjusted R^2 (%Change). The optimum model was Zone:Month.

	AIC	RSS	MSS	Nobs	Npars	adj_r2	%Change
Year	73702	208697	19867	99755	33	8.7	0.00
Vessel	56431	174880	53684	99755	215	23.3	14.66
DepCat	45353	156424	72140	99755	239	31.4	8.08
Month	43245	153120	75445	99755	250	32.8	1.44
Zone	42366	151770	76794	99755	252	33.4	0.59
DayNight	41536	150503	78062	99755	255	34.0	0.55
Zone:Month	39773	147801	80764	99755	277	35.2	1.17
Zone:DepCat	41132	149754	78810	99755	302	34.3	0.30

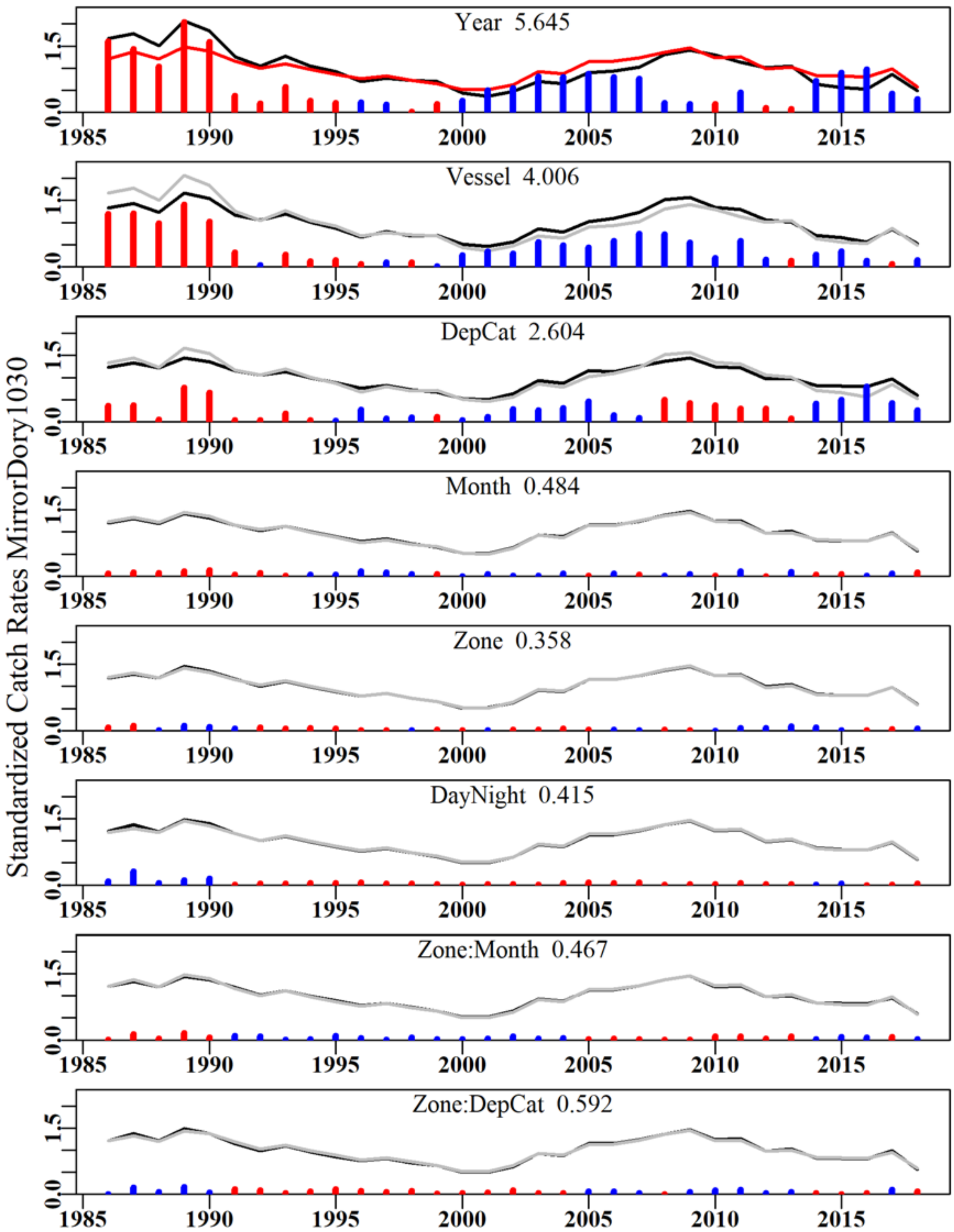

Figure 5.32. MirrorDory1030. The influence of each factor on the optimal standardization. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by vertical bars with blue bars indicating the optimum model is higher than the 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.

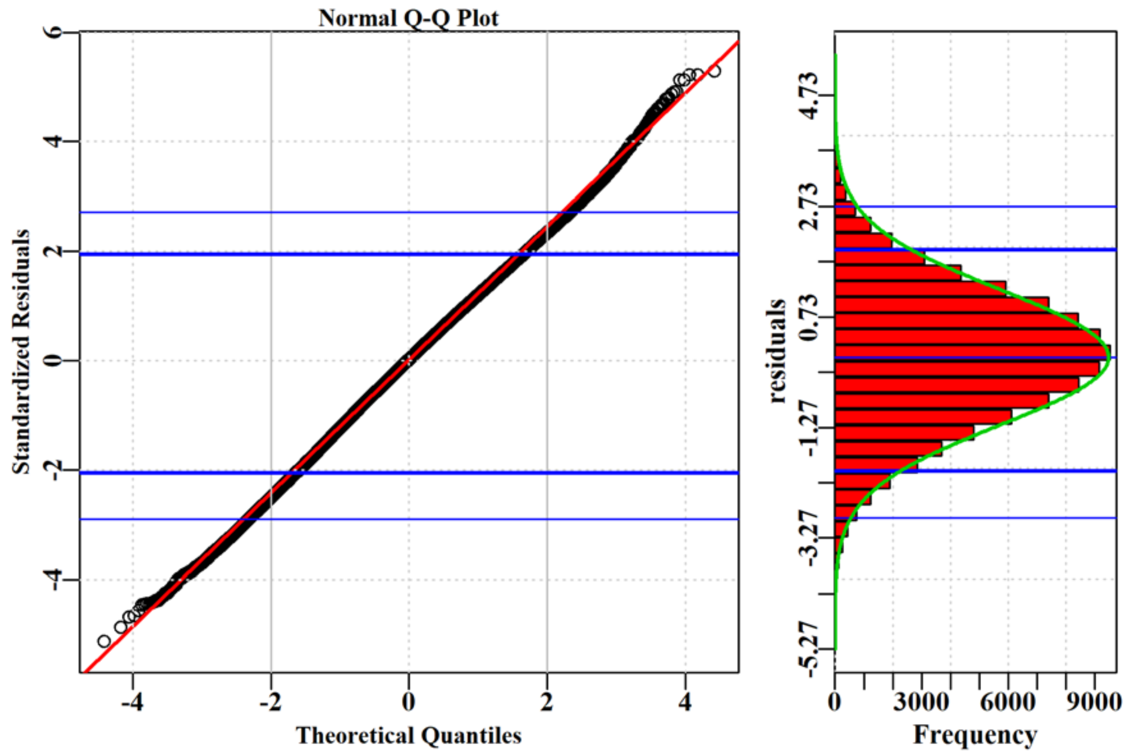

Figure 5.33. MirrorDory1030. diagnostic plots. The distribution of residuals from the optimum fit. The qqplot indicates the fit to the expected normality, while the histogram of residuals illustrates the 90% quantiles to indicate the intensity of any lack of fit at the margins of the distribution.

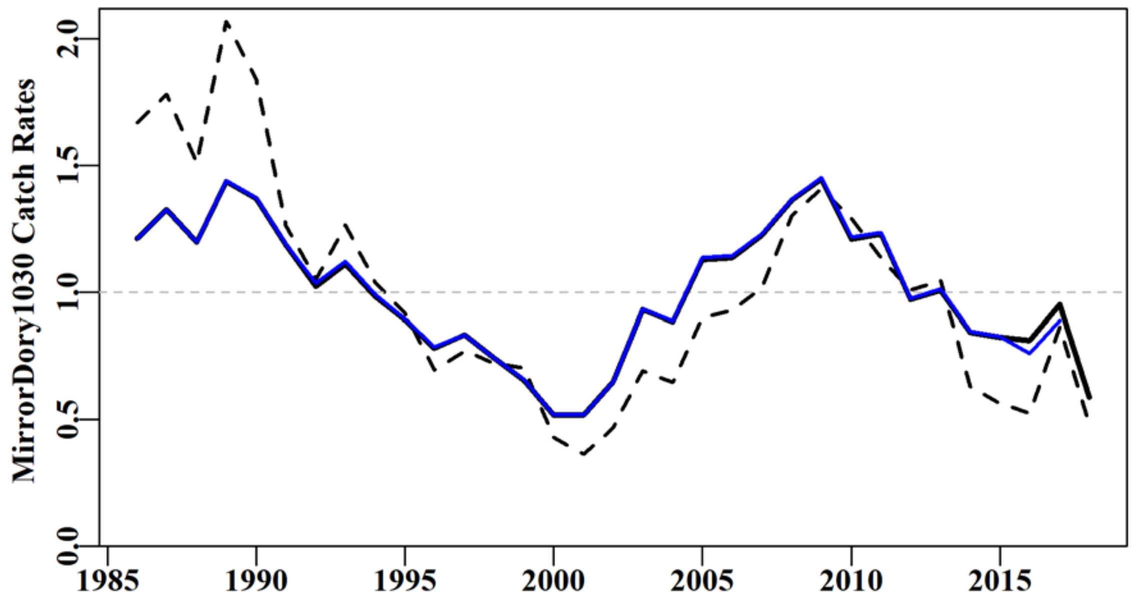

Figure 5.34. MirrorDory1030. A comparison of the previous year's standardization (blue line) with this year's. They should lie on top of each other, although small deviations may relate to data adjustments, particularly in very recent years.

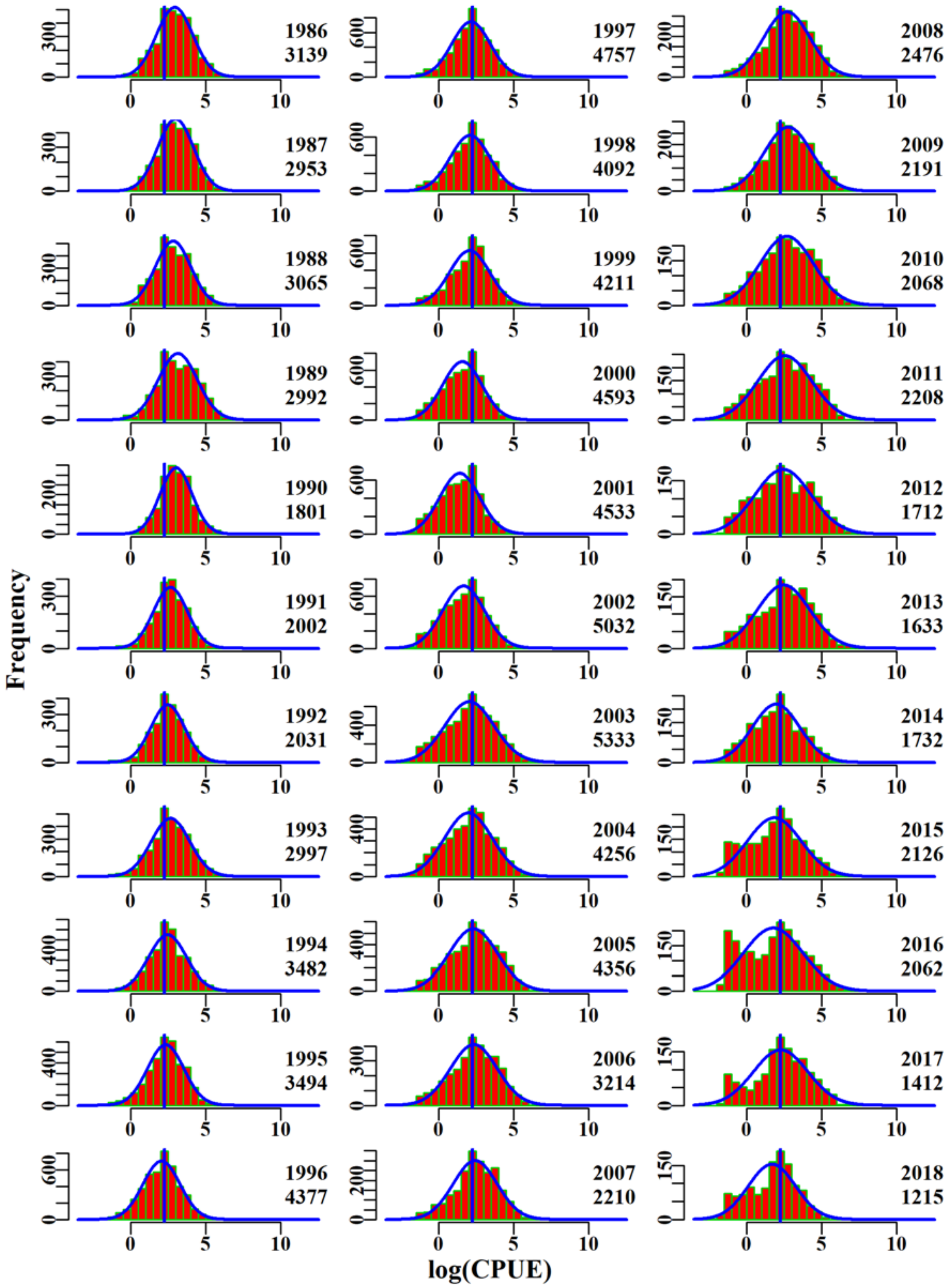

Figure 5.35. MirrorDory1030. The natural log(CPUE) for each year of data available the blue lines are normal distributions fitted to the histogram frequencies. The numbers in each plot are the year and number of records.

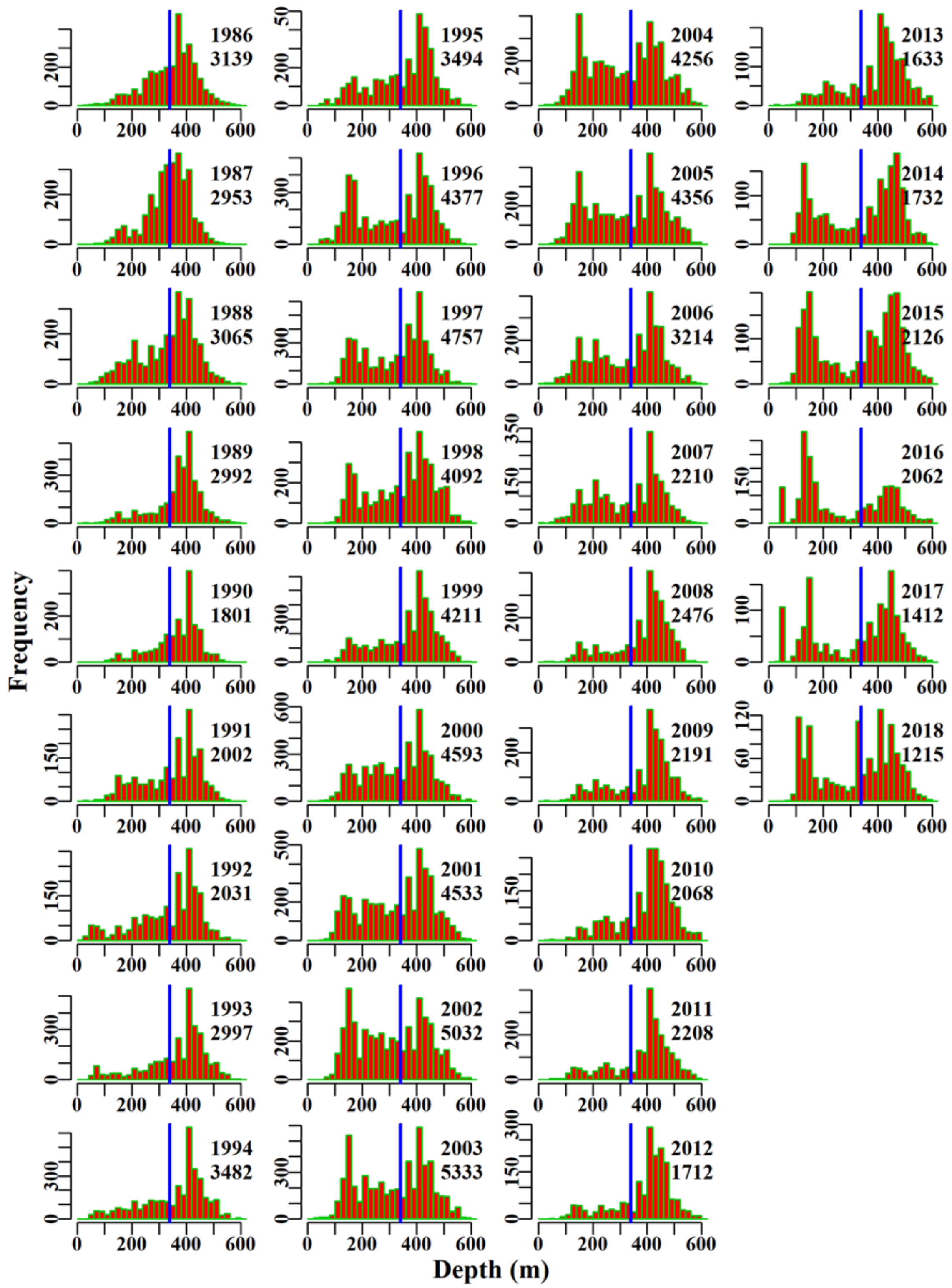

Figure 5.36. MirrorDory1030. The average Depth of fishing for each year of data available to illustrate the development of the fishery through time. The numbers in each plot are the year and number of records.

5.9 Mirror Dory 40 – 50

Trawl caught Mirror Dory (DOM – 37264003 – *Zenopsis nebulosa*) using methods TW, TDO, TMO, OTT, in zones 40, 50, and depths 0 to 600 within the SET fishery for the years 1986 - 2018 were analysed. These constitute the criteria used to select data from the Commonwealth logbook database (Table 5.26).

A total of 8 statistical models were fitted sequentially to the available data, with the order of the non-interaction terms added based on the relative contribution of each term to model fit.

5.9.1 *Inferences*

Mirror Dory catches in the west appear to be episodic with peaks in 1997, 2001 - 2003, and 2010 and 2011, which roughly coincides with minor peaks in CPUE in a manner similar to that observed in the east, although with a more rapid cycle and less extreme variation. As on the east coast in the last few years, there has been an increase of reported catches in waters of 200 m, which is unusual for Mirror Dory in the west. The statistical model fit is very good with the deviations at the extremes in the qqplot being made up of far less than 5% of records at each end.

The amount of catch remains minor until about 1995 (Table 5.27) after which the amount of catch and the number of records remains at levels that permit usable analyses, with relatively tight precision levels around the mean estimates, to be made.

5.9.2 *Action Items and Issues*

It is recommended that the CPUE time-series only be used from 1995 onwards (Figure 5.37) because catches before then are relatively minor. Whatever the case, from 1990 the CPUE trend for MirrorDory4050 appears to be relatively flat and noisy around the long term average with periods above and below.

Table 5.26. MirrorDory4050. The data selection criteria used to specify and identify the fishery data to be included in the analysis.

Property	Value
label	MirrorDory4050
csirocode	37264003
fishery	SET
depthrange	0 - 600
depthclass	30
zones	40, 50
methods	TW, TDO, TMO, OTT
years	1986 - 2018

Table 5.27. MirrorDory4050. Total catch (Total; t) is the total reported in the database, number of records used in the analysis (N), reported catch (Catch; t) in the area and depth used in the analysis and number of vessels used in the analysis (Vess). GeoM is the geometric mean of catch rates (kg/hr), standard deviation (StDev) relates to the optimum model. C<30Kg denotes the amount of catch in shots of <30kg, and %<30Kg is the percent of total. The optimum model was Zone:Month.

	Total	N	Catch	Vess	GeoM	Opt	StDev	C<30Kg	P<30Kg
1986	402.0	58	7.4	11	37.2	2.5568	0.000	0.390	0.053
1987	450.8	142	15.5	23	36.1	1.7295	0.187	0.929	0.060
1988	346.0	122	15.0	17	37.2	1.3642	0.196	0.940	0.063
1989	591.6	71	11.1	15	45.3	1.7080	0.208	0.545	0.049
1990	295.8	95	10.0	14	37.9	1.2040	0.213	0.505	0.051
1991	240.3	208	12.8	17	17.8	0.8696	0.185	2.642	0.207
1992	167.0	206	8.3	20	14.6	0.7023	0.187	1.870	0.225
1993	306.2	277	18.1	18	16.8	0.8282	0.182	3.187	0.176
1994	297.3	330	18.2	20	14.8	0.7605	0.180	4.166	0.229
1995	244.9	704	37.9	23	15.4	0.9966	0.177	7.882	0.208
1996	352.7	1433	115.0	26	23.4	1.3358	0.177	12.869	0.112
1997	459.6	1903	148.2	24	24.5	1.3522	0.176	16.696	0.113
1998	355.8	1468	116.2	20	27.5	1.2770	0.177	12.717	0.109
1999	309.5	1316	63.2	23	17.0	0.8315	0.177	13.721	0.217
2000	171.1	975	22.4	31	7.9	0.4593	0.178	11.410	0.510
2001	243.4	2461	105.8	29	14.1	0.7930	0.176	28.871	0.273
2002	449.6	3151	240.2	28	24.8	1.1723	0.176	27.990	0.117
2003	613.9	2420	154.2	28	20.7	0.9755	0.176	20.527	0.133
2004	507.4	2201	159.4	25	20.3	0.9740	0.176	16.778	0.105
2005	579.9	1761	99.7	23	15.2	0.7704	0.177	15.640	0.157
2006	419.6	1053	64.8	19	15.7	0.6408	0.178	8.754	0.135
2007	289.6	1160	63.1	16	14.3	0.5749	0.177	11.733	0.186
2008	396.2	873	57.4	17	16.1	0.6783	0.178	8.632	0.150
2009	476.5	1331	123.0	14	20.0	1.0346	0.177	9.533	0.078
2010	580.0	1582	177.0	14	26.5	1.2630	0.177	9.483	0.054
2011	514.5	1648	157.3	16	21.8	0.9589	0.177	9.446	0.060
2012	365.5	993	69.6	15	16.9	0.5624	0.178	7.420	0.107
2013	279.9	635	54.4	15	20.8	0.7584	0.179	5.055	0.093
2014	190.0	832	67.3	14	19.6	0.8727	0.178	6.618	0.098
2015	240.4	944	70.6	13	17.4	0.8968	0.178	6.918	0.098
2016	249.4	622	41.4	13	16.5	0.6596	0.180	4.790	0.116
2017	224.3	700	57.7	11	16.0	0.8847	0.180	5.651	0.098
2018	96.6	529	31.0	11	10.8	0.5541	0.181	4.534	0.146

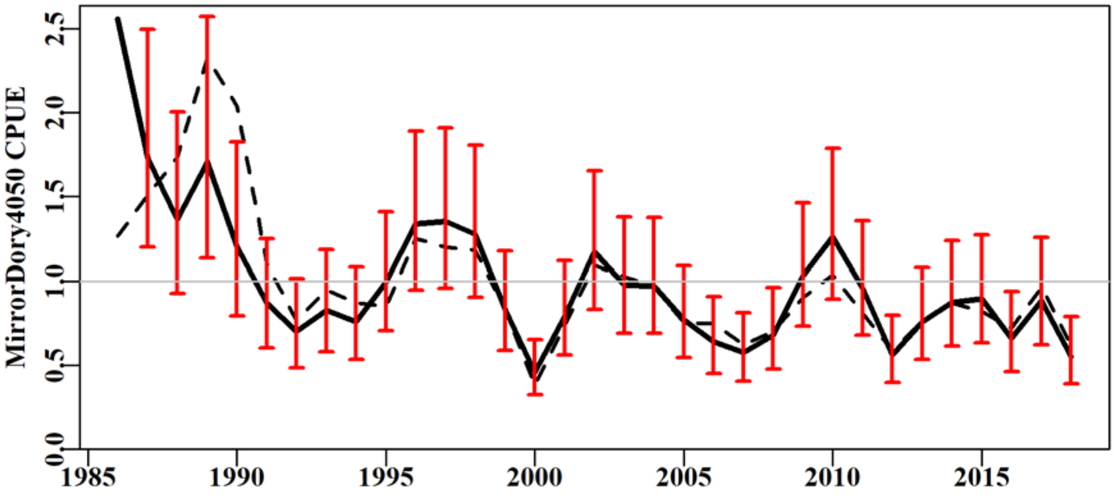

Figure 5.37. MirrorDory4050 standardization. The dashed black line represents the geometric mean catch rate, solid black line the standardized catch rates. The red bars are the 95% confidence intervals about the mean estimates. The graph scales both time-series of standardized catch rates relative to the mean of each time-series.

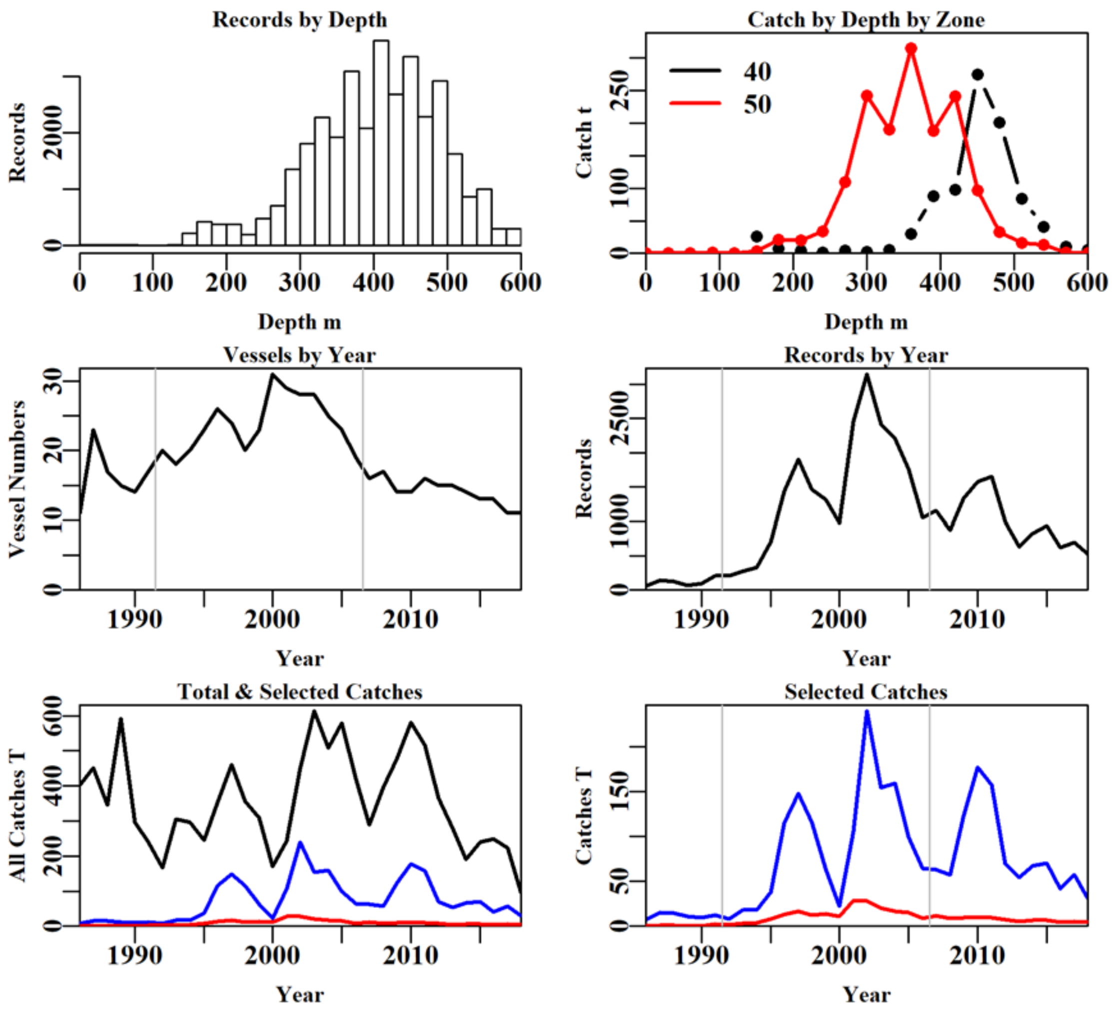

Figure 5.38. MirrorDory4050 fishery details. The bottom left plot depicts all known catches (top black line), and all selected catches used in the analysis (middle blue line); the lower red line: selected catches < 30 kg).

Table 5.28. MirrorDory4050 data selection effects. Total is the total number of records in the database, NoCE removes those records with either missing catch or effort, and then only those records are kept that meet the criteria for depth, years, zone, method and fishery.

	Total	NoCE	Depth	Years	Zones	Method	Fishery
Records	146866.00	143400.0000	141438.0000	140609.000	34387.000	34260.0000	34204.000
Difference	0.00	3466.0000	1962.0000	829.000	106222.000	127.0000	56.000
Catch	11756.96	11629.2549	11457.9088	11410.611	2422.587	2417.2065	2413.167
Difference	0.00	127.7041	171.3461	47.298	8988.024	5.3807	4.040

Table 5.29. The models used to analyse data for MirrorDory4050.

	Model
Model1	Year
Model2	Year + Vessel
Model3	Year + Vessel + Month
Model4	Year + Vessel + Month + DepCat
Model5	Year + Vessel + Month + DepCat + DayNight
Model6	Year + Vessel + Month + DepCat + DayNight + Zone
Model7	Year + Vessel + Month + DepCat + DayNight + Zone + Zone:Month
Model8	Year + Vessel + Month + DepCat + DayNight + Zone + Zone:DepCat

Table 5.30. MirrorDory4050. The row names are 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_r2) and the change in adjusted R^2 (%Change). The optimum model was Zone:Month.

	AIC	RSS	MSS	Nobs	Npars	adj_r2	%Change
Year	11381	47615	2326	34204	33	4.57	0.000
Vessel	4794	39056	10885	34204	128	21.50	16.936
Month	3203	37258	12683	34204	139	25.09	3.590
DepCat	1348	35249	14692	34204	159	29.09	3.997
DayNight	170	34050	15891	34204	162	31.50	2.407
Zone	-225	33657	16284	34204	163	32.29	0.789
Zone:Month	-618	33252	16689	34204	174	33.08	0.793
Zone:DepCat	-282	33562	16379	34204	183	32.44	0.152

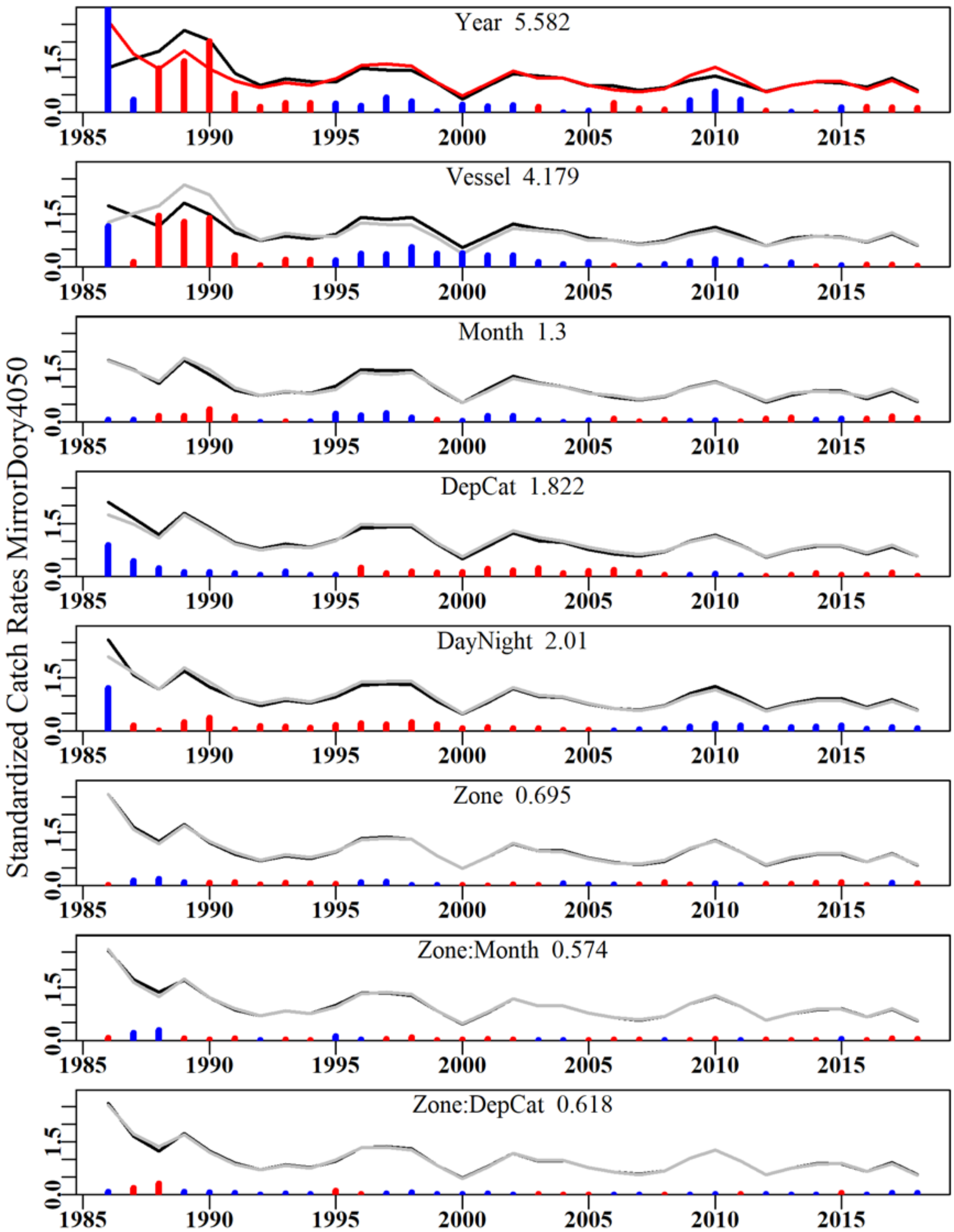

Figure 5.39. MirrorDory4050. The influence of each factor on the optimal standardization. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by vertical bars with blue bars indicating the optimum model is higher than the 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.

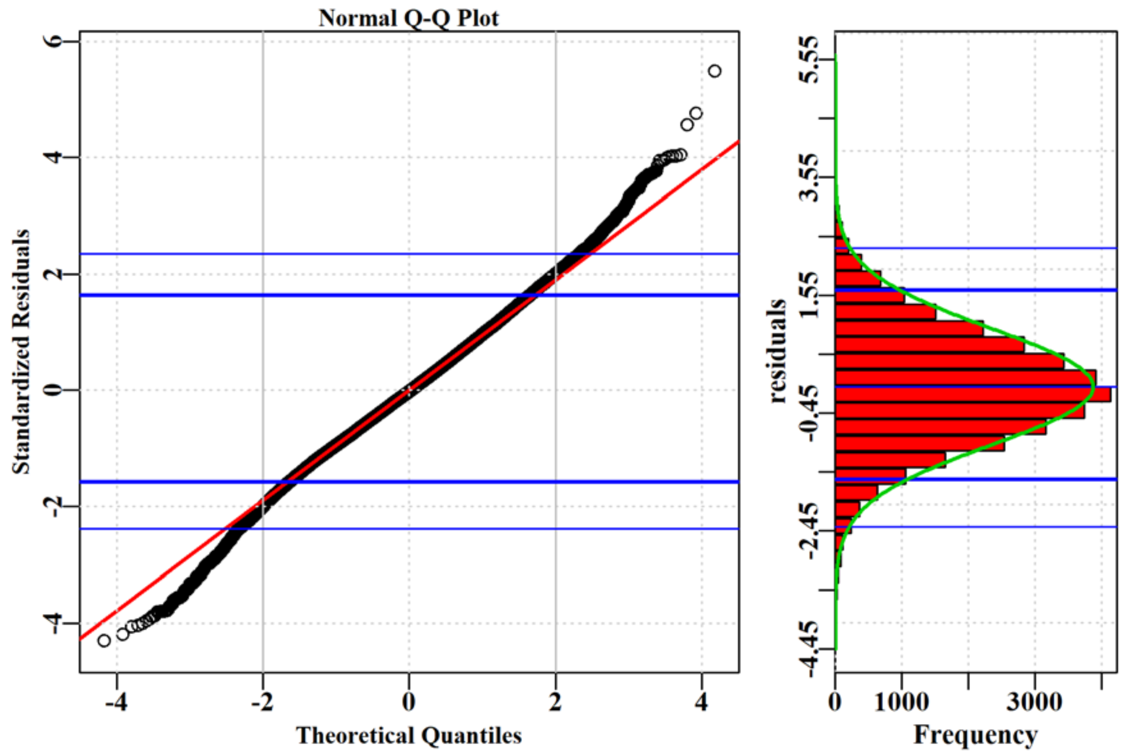

Figure 5.40. MirrorDory4050. diagnostic plots. The distribution of residuals from the optimum fit. The qqplot indicates the fit to the expected normality, while the histogram of residuals illustrates the 90% quantiles to indicate the intensity of any lack of fit at the margins of the distribution.

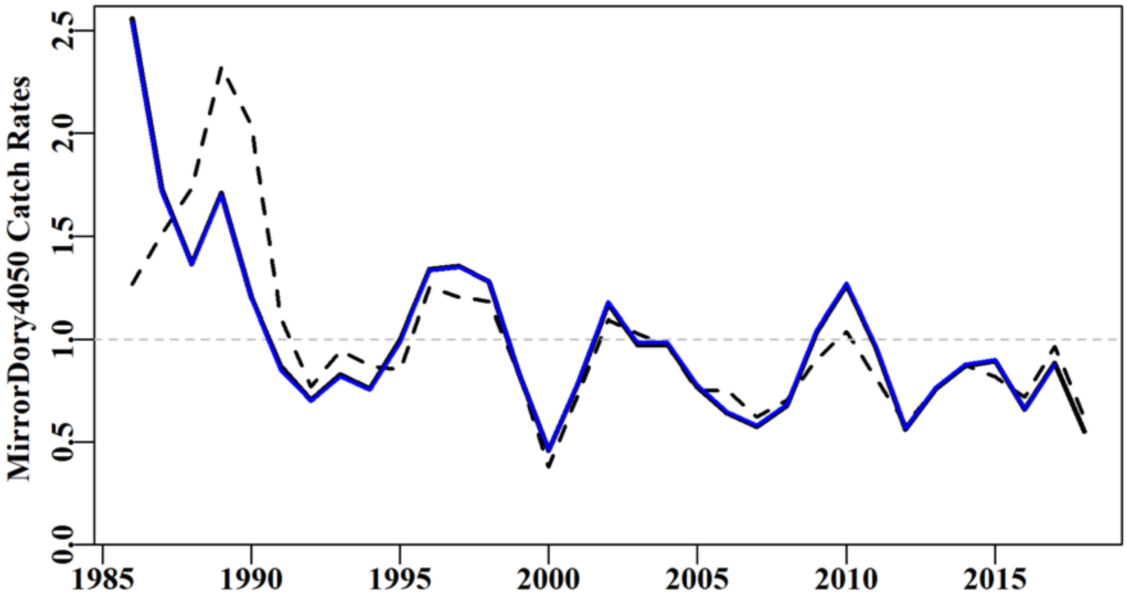

Figure 5.41. MirrorDory4050. A comparison of the previous year's standardization (blue line) with this year's. They should lie on top of each other, although small deviations may relate to data adjustments, particularly in very recent years.

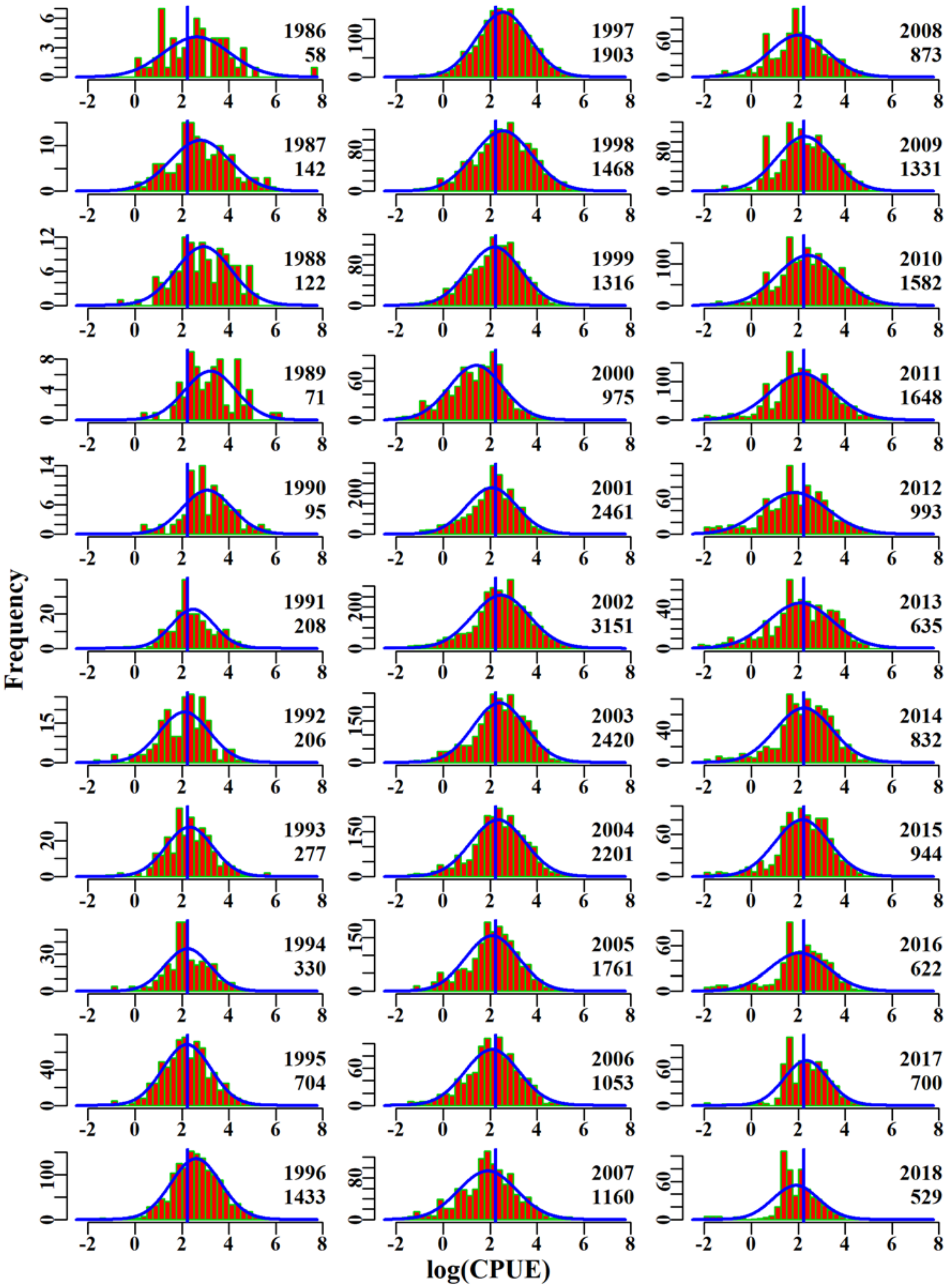

Figure 5.42. MirrorDory4050. The natural log(CPUE) for each year of data available the blue lines are normal distributions fitted to the histogram frequencies. The numbers in each plot are the year and number of records.

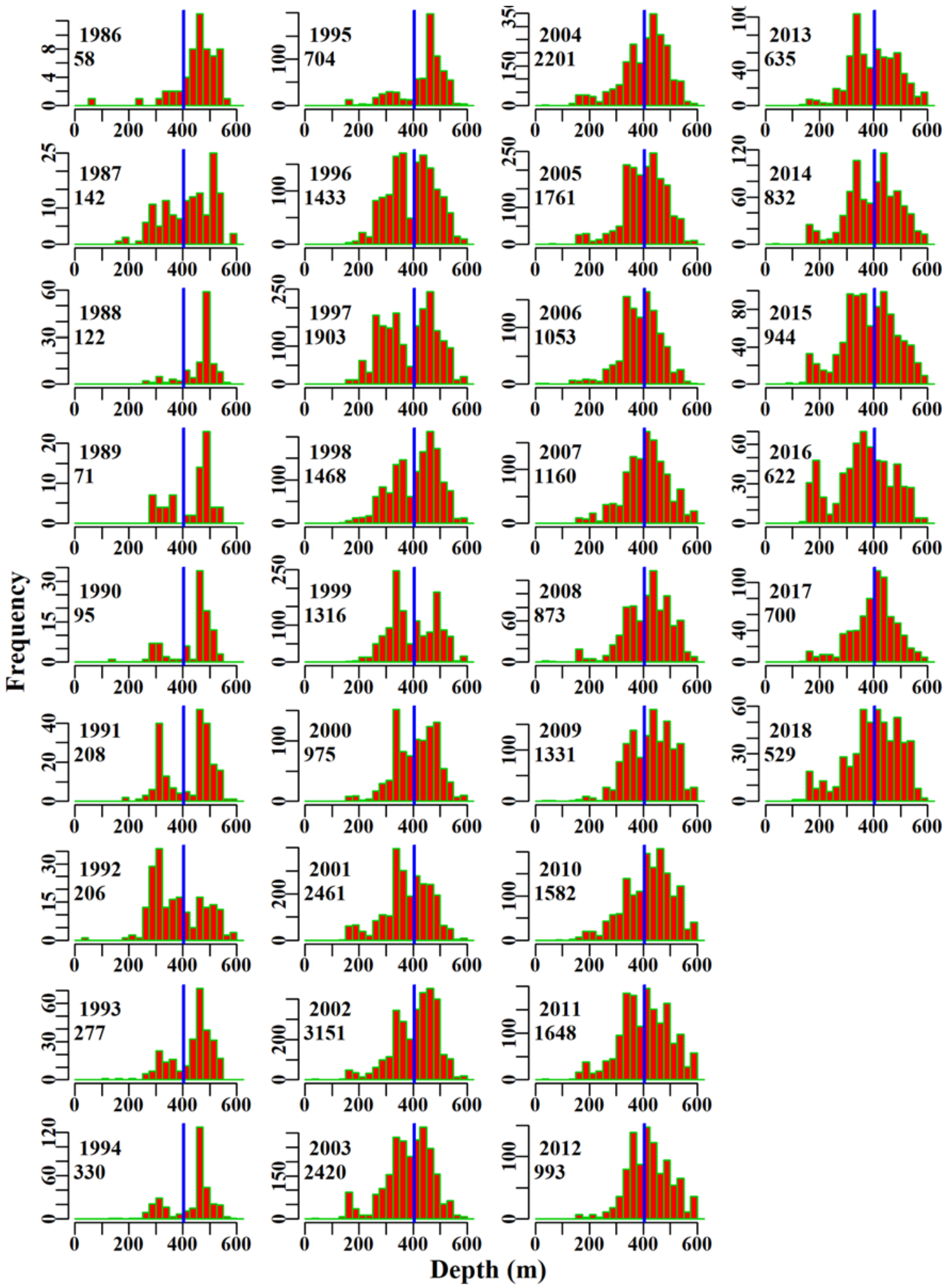

Figure 5.43. MirrorDory4050. The average Depth of fishing for each year of data available to illustrate the development of the fishery through time. The numbers in each plot are the year and number of records.

5.10 Jackass Morwong 30

Jackass Morwong (MOR – 37377003 –*Nemadactylus macropterus*) was one of the 16 species first included in the quota system in 1992, which reflects its long history within the SESSF. The criteria used to select data from the Commonwealth logbook database is based on the trawl fishery which uses methods TW, TDO, TMO, OTT, in zones 30, and depths 70 to 300 within the SET fishery for the years 1986 - 2018 (Table 5.31). A total of 7 statistical models were fitted sequentially to the available data, with the order of the non-interaction terms added based on the relative contribution of each term to model fit.

5.10.1 *Inferences*

The terms Year, Month, Vessel and DepCat had the greatest contribution to model fit, with the remaining terms each explaining < 1% of the overall variation in CPUE based on the AIC and R^2 statistics (Table 5.35). The qqplot suggests that the assumed Normal distribution is valid, with small deviations at the tails of the distribution (Figure 5.47).

Annual standardized CPUE has been below the long-term average since about 2001 and not statistically diferent from each other over these years (Figure 5.44).

5.10.2 *Action Items and Issues*

With only 69 records and 30 t of reported catch in 1986, it is recommended that the standardization analysis should begin in 1987 or 1988 (Table 5.32).

The selected depth for Jackass Morwong 30 is from 70 - 300 m, based on the recommendation from the RAG. However, there are records in Zone 30 from 0 - 500 metres but only significant catches out to 200 m or 250 m at most. The reasons for the earlier specific depth selection need to be re-iterated and an examination of the effect of making the current depth selection explored.

Catches are low in 1986 and the distribution of natural log(CPUE) only stabilizes approximately from 1989 onwards (and possibly later), which suggests that including those earlier years in the standardization should be reconsidered.

Table 5.31. JackassMorwong30. The data selection criteria used to specify and identify the fishery data to be included in the analysis.

Property	Value
label	JackassMorwong30
csirocode	37377003
fishery	SET
depthrange	70 - 300
depthclass	20
zones	30
methods	TW, TDO, TMO, OTT
years	1986 - 2018

Table 5.32. JackassMorwong30. Total catch (Total; t) is the total reported in the database, number of records used in the analysis (N), reported catch (Catch; t) in the area and depth used in the analysis and number of vessels used in the analysis (Vess). GeoM is the geometric mean of catch rates (kg/hr), standard deviation (StDev) relates to the optimum model. C<30Kg denotes the amount of catch in shots of <30kg, and %<30Kg is the percent of total. The optimum model was DayNight.

	Total	N	Catch	Vess	GeoM	Opt	StDev	C<30Kg	P<30Kg
1986	982.8	68	29.8	6	166.0	1.9287	0.000	0.255	0.009
1987	1087.7	205	57.0	13	104.4	2.1552	0.181	0.695	0.012
1988	1483.5	282	207.7	13	272.2	2.9201	0.179	0.684	0.003
1989	1667.4	687	475.0	19	231.9	3.6883	0.171	0.775	0.002
1990	1001.4	379	140.2	26	146.8	2.6905	0.172	0.901	0.006
1991	1138.1	408	184.4	29	154.7	1.7983	0.170	1.060	0.006
1992	758.3	333	106.7	18	109.0	1.9732	0.175	1.050	0.010
1993	1015.0	1031	322.3	27	104.7	1.5841	0.165	2.433	0.008
1994	818.4	759	179.1	22	71.2	1.0944	0.166	2.130	0.012
1995	789.5	821	183.7	19	68.6	1.0787	0.167	4.244	0.023
1996	827.2	888	161.3	19	54.5	1.0343	0.166	5.219	0.032
1997	1063.4	938	202.3	15	71.6	1.1400	0.166	3.422	0.017
1998	876.4	768	190.7	15	74.4	1.1125	0.166	2.123	0.011
1999	961.5	854	246.9	17	91.6	1.3174	0.166	2.310	0.009
2000	945.2	548	123.4	23	66.5	0.8262	0.168	2.126	0.017
2001	790.2	807	110.3	19	43.2	0.5309	0.165	5.349	0.049
2002	811.2	1039	108.3	15	34.7	0.4430	0.164	6.333	0.058
2003	774.6	1121	186.2	19	59.8	0.5854	0.164	5.933	0.032
2004	765.5	1494	200.8	15	41.6	0.4355	0.163	8.776	0.044
2005	784.2	1136	135.6	17	35.0	0.3263	0.164	7.263	0.054
2006	811.3	1112	152.8	14	40.5	0.4042	0.165	5.253	0.034
2007	607.9	705	110.6	8	49.8	0.5694	0.167	2.355	0.021
2008	700.4	752	117.2	9	51.2	0.5740	0.167	2.573	0.022
2009	454.4	456	53.4	10	37.8	0.4016	0.171	1.849	0.035
2010	380.0	340	54.9	9	48.8	0.4445	0.174	1.468	0.027
2011	428.0	444	47.4	8	34.6	0.2989	0.171	2.027	0.043
2012	395.6	518	88.8	8	56.1	0.3963	0.170	1.761	0.020
2013	323.9	595	102.9	10	57.8	0.4370	0.169	2.670	0.026
2014	216.6	361	53.4	9	38.6	0.2220	0.173	2.282	0.043
2015	152.5	455	30.4	11	18.5	0.1408	0.171	3.163	0.104
2016	183.4	770	48.3	10	19.5	0.1442	0.167	5.948	0.123
2017	246.2	611	37.9	9	21.3	0.1672	0.169	4.605	0.121
2018	209.7	467	26.3	9	18.2	0.1371	0.172	3.327	0.126

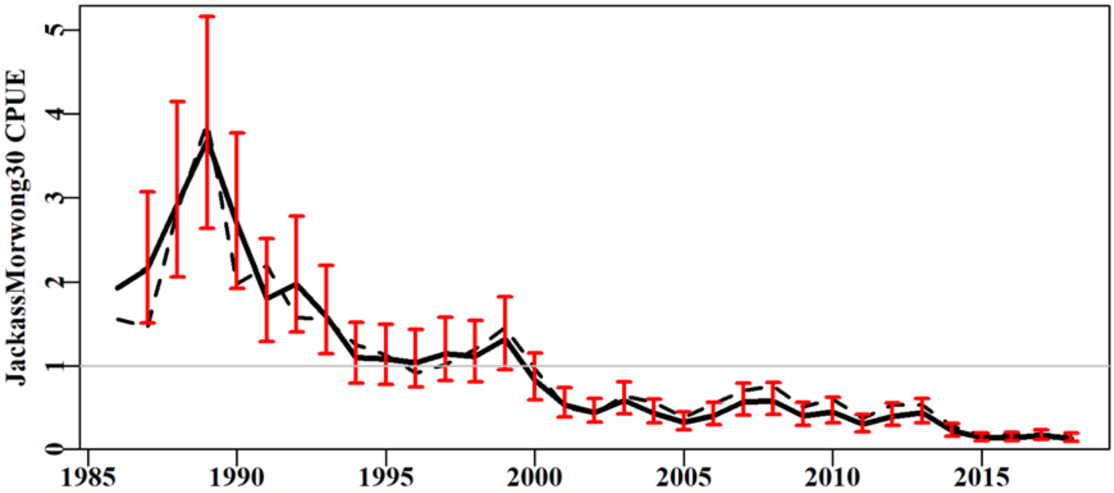

Figure 5.44. JackassMorwong30 standardization. The dashed black line represents the geometric mean catch rate, solid black line the standardized catch rates. The red bars are the 95% confidence intervals about the mean estimates. The graph scales both time-series of standardized catch rates relative to the mean of each time-series.

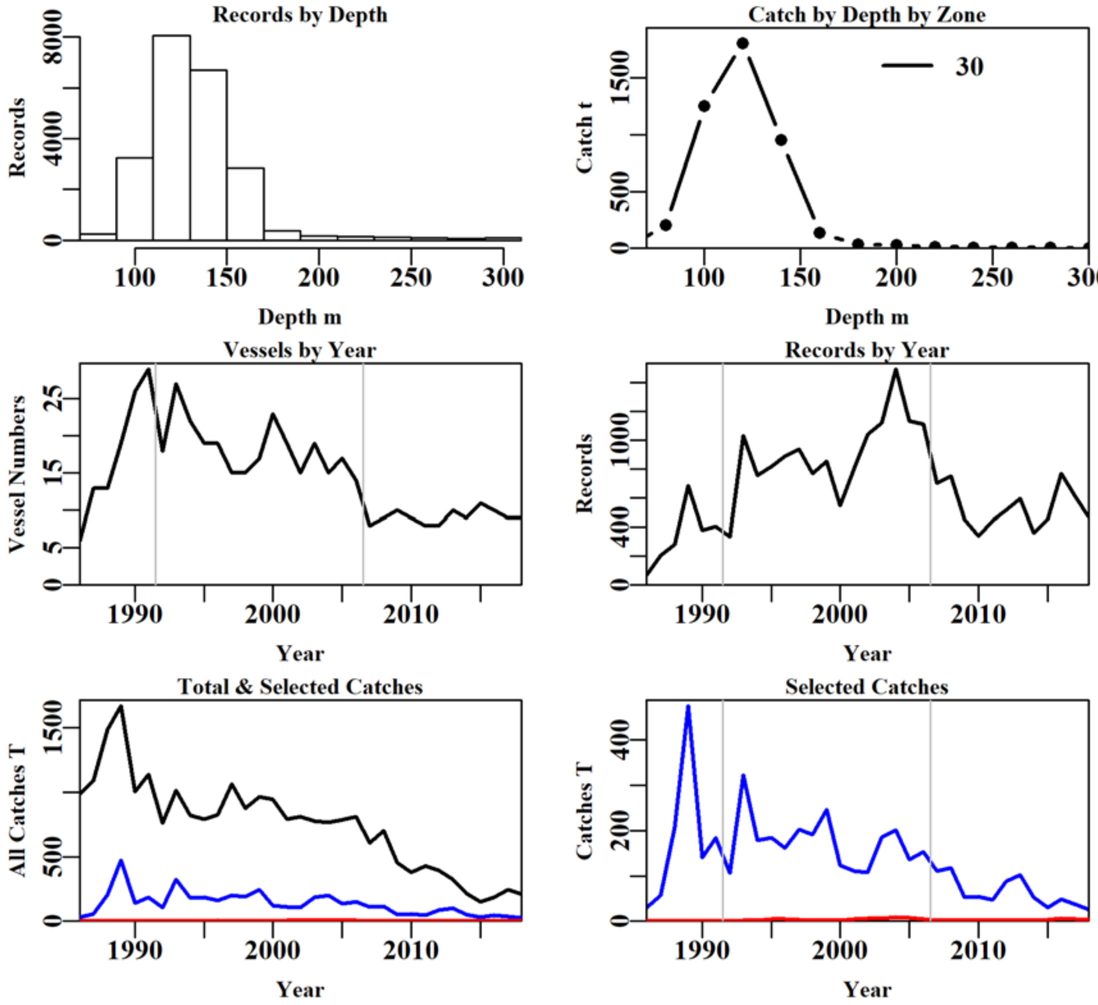

Figure 5.45. JackassMorwong30 fishery details. The bottom left plot depicts all known catches (top black line), and all selected catches used in the analysis (middle blue line); the lower red line: selected catches < 30 kg).

Table 5.33. JackassMorwong30 data selection effects. Total is the total number of records in the database, NoCE removes those records with either missing catch or effort, and then only those records are kept that meet the criteria for depth, years, zone, method and fishery.

	Total	NoCE	Depth	Years	Zones	Method	Fishery
Records	259847	238942	210468	206408	22543	22155	22152
Difference	0	20905	28474	4060	183865	388	3
Catch	25198.64	24237.97	22774.40	22150.77	4539.71	4476.29	4475.90
Difference	0.00	960.67	1463.57	623.63	17611.06	63.42	0.390

Table 5.34. The models used to analyse data for JackassMorwong30.

	Model
Model1	Year
Model2	Year + Month
Model3	Year + Month + Vessel
Model4	Year + Month + Vessel + DepCat
Model5	Year + Month + Vessel + DepCat + DayNight
Model6	Year + Month + Vessel + DepCat + DayNight + Zone:Month
Model7	Year + Month + Vessel + DepCat + DayNight + Zone:DepCat

Table 5.35. JackassMorwong30. The row names are 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_r2) and the change in adjusted R^2 (%Change). The optimum model was DayNight.

	AIC	RSS	MSS	Nobs	Npars	adj_r2	%Change
Year	12899	39537	12135	22152	33	23.4	0.00
Month	11076	36378	15294	22152	44	29.5	6.09
Vessel	9602	33741	17930	22152	140	34.3	4.83
DepCat	8999	32801	18870	22152	152	36.1	1.80
DayNight	8673	32313	19358	22152	155	37.0	0.94
Zone:Month	8673	32313	19358	22152	155	37.0	0.00
Zone:DepCat	8673	32313	19358	22152	155	37.0	0.00

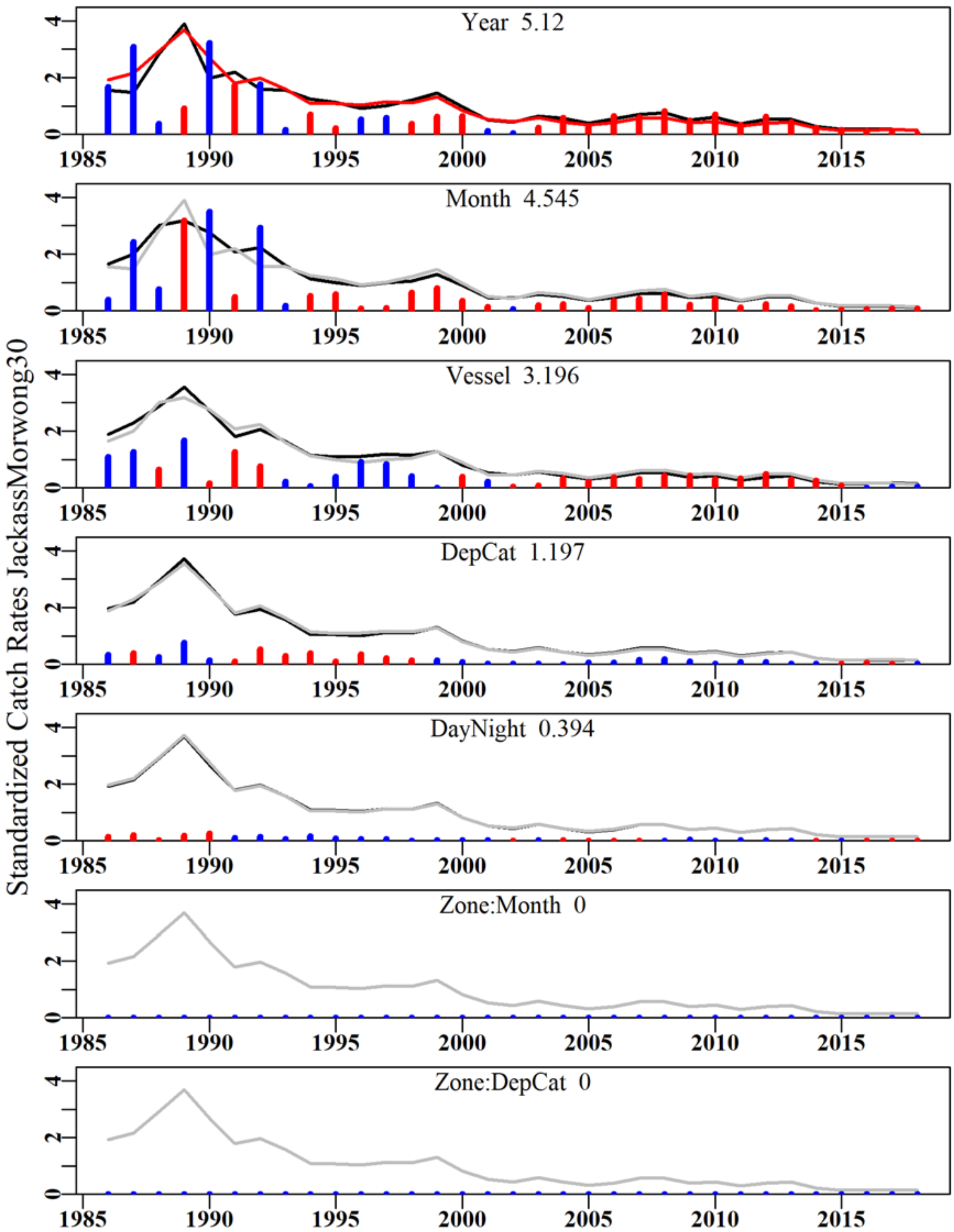

Figure 5.46. JackassMorwong30. The influence of each factor on the optimal standardization. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by vertical bars with blue bars indicating the optimum model is higher than the 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.

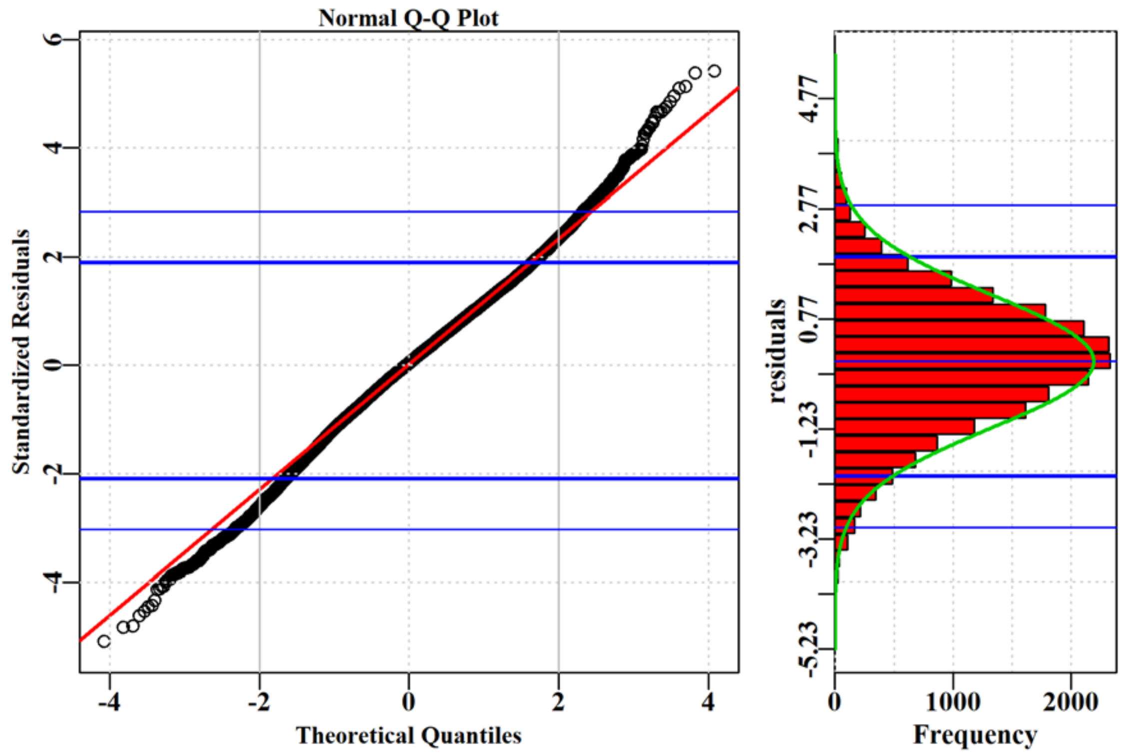

Figure 5.47. JackassMorwong30. diagnostic plots. The distribution of residuals from the optimum fit. The qqplot indicates the fit to the expected normality, while the histogram of residuals illustrates the 90% quantiles to indicate the intensity of any lack of fit at the margins of the distribution.

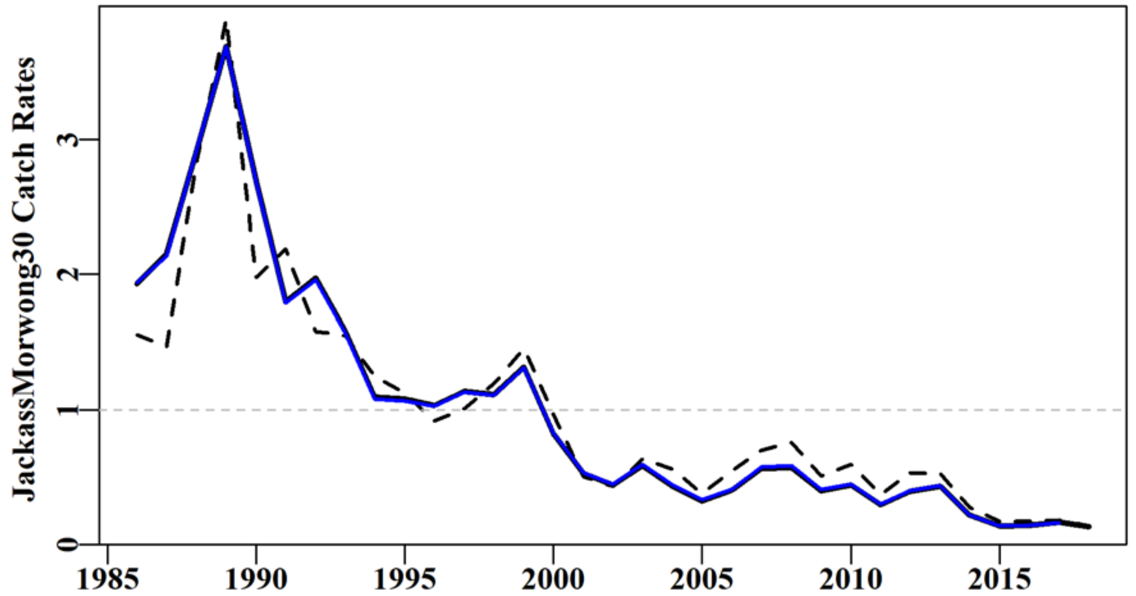

Figure 5.48. JackassMorwong30. A comparison of the previous year's standardization (blue line) with this year's. They should lie on top of each other, although small deviations may relate to data adjustments, particularly in very recent years.

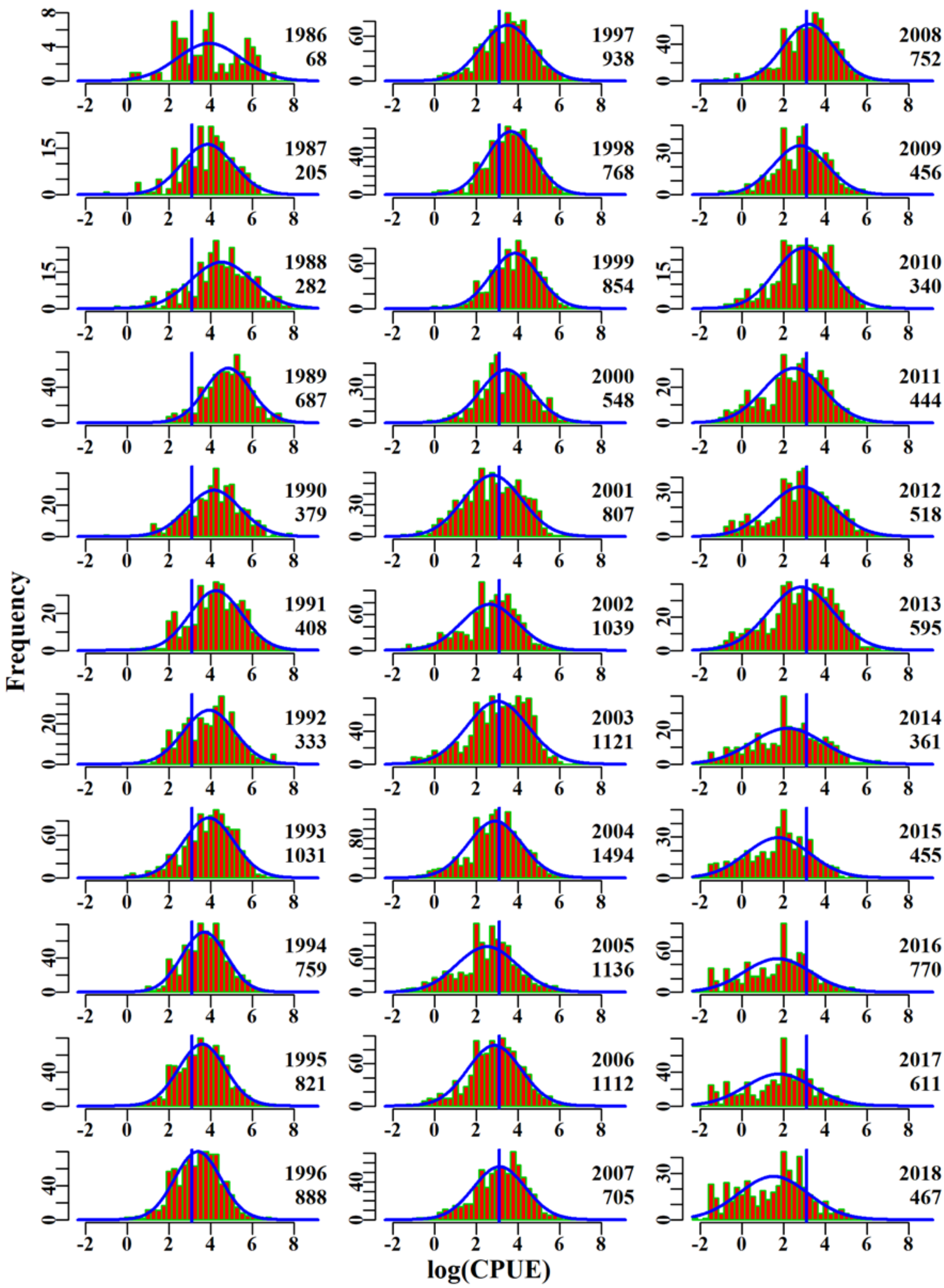

Figure 5.49. JackassMorwong30. The natural log(CPUE) for each year of data available the blue lines are normal distributions fitted to the histogram frequencies. The numbers in each plot are the year and number of records.

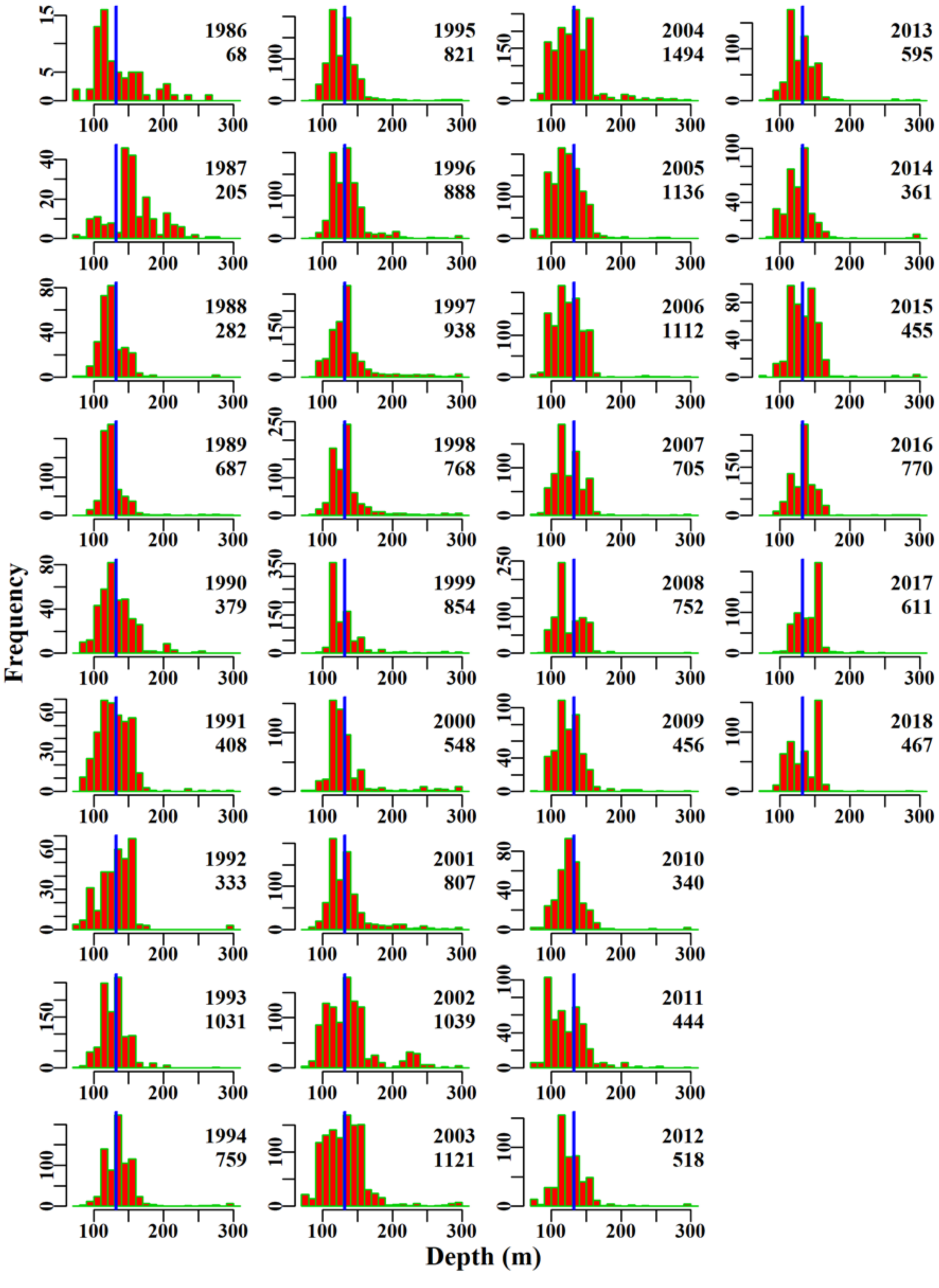

Figure 5.50. JackassMorwong30. The average Depth of fishing for each year of data available to illustrate the development of the fishery through time. The numbers in each plot are the year and number of records.

5.11 Jackass Morwong 10 – 20

Jackass Morwong (MOR–37377003 – *Nemadactylus macropterus*) was one of the 16 species first included in the quota system in 1992, which reflects its long history within the SESSF. The criteria used to select data from the Commonwealth logbook database was based on the trawl fishery which uses methods TW, TDO, TMO, OTT, in zones 10, 20, and depths 70 to 300 within the SET fishery for the years 1986 - 2018 (Table 5.36). A total of 8 statistical models were fitted sequentially to the available data, with the order of the non-interaction terms added based on the relative contribution of each term to model fit.

5.11.1 *Inferences*

The terms Year, Vessel, Month and Zone had the greatest contribution to model fit, with the remaining terms each explaining < 1% of the overall variation in CPUE, based on the AIC and R^2 statistics (Table 5.40). The qqplot suggests that the assumed Normal distribution is valid, with small deviations at the upper tail of the distribution (Figure 5.54).

Most catch are reported in zone 10 in less than 200 m. Annual standardized CPUE has been below the long term average since about 1998 with apparent periodicity (Figure 5.51).

5.11.2 *Action Items and Issues*

The structural adjustment altered the effect of the vessel factor on the standardized result. However, natural log(CPUE) has also changed in character from 2014 - 2018, with spikes of low catch rates arising.

Table 5.36. JackasssMorwong1020. The data selection criteria used to specify and identify the fishery data to be included in the analysis.

Property	Value
label	JackasssMorwong1020
csirocode	37377003
fishery	SET
depthrange	70 - 300
depthclass	20
zones	10, 20
methods	TW, TDO, TMO, OTT
years	1986 - 2018

Table 5.37. JackasssMorwong1020. Total catch (Total; t) is the total reported in the database, number of records used in the analysis (N), reported catch (Catch; t) in the area and depth used in the analysis and number of vessels used in the analysis (Vess). GeoM is the geometric mean of catch rates (kg/hr), standard deviation (StDev) relates to the optimum model. C<30Kg denotes the amount of catch in shots of <30kg, and %<30Kg is the percent of total. The optimum model was Zone:Month.

	Total	N	Catch	Vess	GeoM	Opt	StDev	C<30Kg	P<30Kg
1986	982.8	5041	685.5	87	50.9	2.0802	0.000	28.043	0.041
1987	1087.7	4231	851.6	79	69.6	2.5237	0.030	20.466	0.024
1988	1483.5	5127	1020.0	79	65.0	2.3710	0.029	25.887	0.025
1989	1667.4	4305	924.2	65	72.2	2.2449	0.030	19.307	0.021
1990	1001.4	4090	593.5	59	49.2	1.8940	0.031	21.795	0.037
1991	1138.1	4391	650.0	55	54.2	1.7415	0.031	26.145	0.040
1992	758.3	2825	377.3	47	48.7	1.3963	0.034	17.311	0.046
1993	1015.0	3320	461.7	49	45.5	1.4877	0.033	21.593	0.047
1994	818.4	4418	469.0	49	38.6	1.2963	0.031	29.317	0.063
1995	789.5	4575	433.7	47	31.6	1.1888	0.031	33.286	0.077
1996	827.2	6181	541.8	50	29.0	1.0769	0.029	45.827	0.085
1997	1063.4	5994	669.8	52	38.6	1.1934	0.030	38.284	0.057
1998	876.4	4772	435.1	46	32.0	0.9621	0.031	36.545	0.084
1999	961.5	4408	446.6	50	36.3	0.9671	0.032	31.401	0.070
2000	945.2	5615	477.9	55	29.5	0.8257	0.030	40.940	0.086
2001	790.2	4793	251.5	46	18.5	0.5659	0.031	36.983	0.147
2002	811.2	5700	328.2	44	20.4	0.6337	0.031	45.985	0.140
2003	774.6	4555	236.4	47	17.6	0.5045	0.032	35.723	0.151
2004	765.5	4178	219.7	52	17.2	0.4988	0.032	31.301	0.142
2005	784.2	4320	258.8	39	19.4	0.6067	0.032	35.033	0.135
2006	811.3	3388	273.8	36	25.2	0.7388	0.034	27.137	0.099
2007	607.9	2412	211.2	20	31.6	0.7156	0.037	17.177	0.081
2008	700.4	3105	313.1	25	30.5	0.9083	0.035	23.468	0.075
2009	454.4	2400	223.7	19	28.2	0.8251	0.037	18.584	0.083
2010	380.0	2478	184.9	19	24.5	0.5614	0.037	19.898	0.108
2011	428.0	2291	161.6	18	24.2	0.5566	0.038	17.187	0.106
2012	395.6	2111	169.7	19	27.9	0.5466	0.039	14.445	0.085
2013	323.9	1394	96.6	15	25.0	0.4526	0.044	10.082	0.104
2014	216.6	1515	76.2	17	17.2	0.3385	0.043	11.597	0.152
2015	152.5	1094	42.3	20	14.3	0.2808	0.047	8.727	0.206
2016	183.4	1127	70.5	15	24.8	0.3209	0.048	7.591	0.108
2017	246.2	1220	72.4	15	23.6	0.3829	0.047	8.940	0.123
2018	209.7	1367	76.8	15	19.1	0.3129	0.046	10.275	0.134

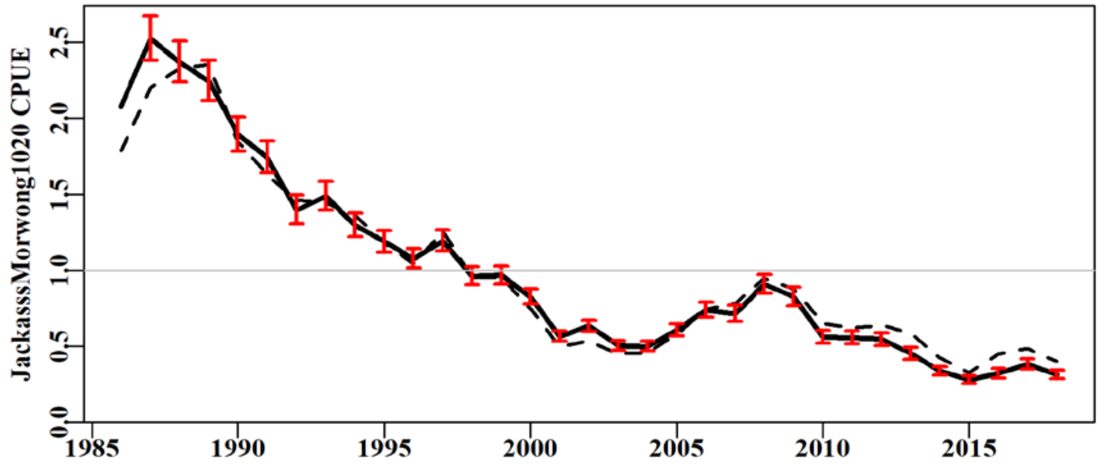

Figure 5.51. JackasssMorwong1020 standardization. The dashed black line represents the geometric mean catch rate, solid black line the standardized catch rates. The red bars are the 95% confidence intervals about the mean estimates. The graph scales both time-series of standardized catch rates relative to the mean of each time-series.

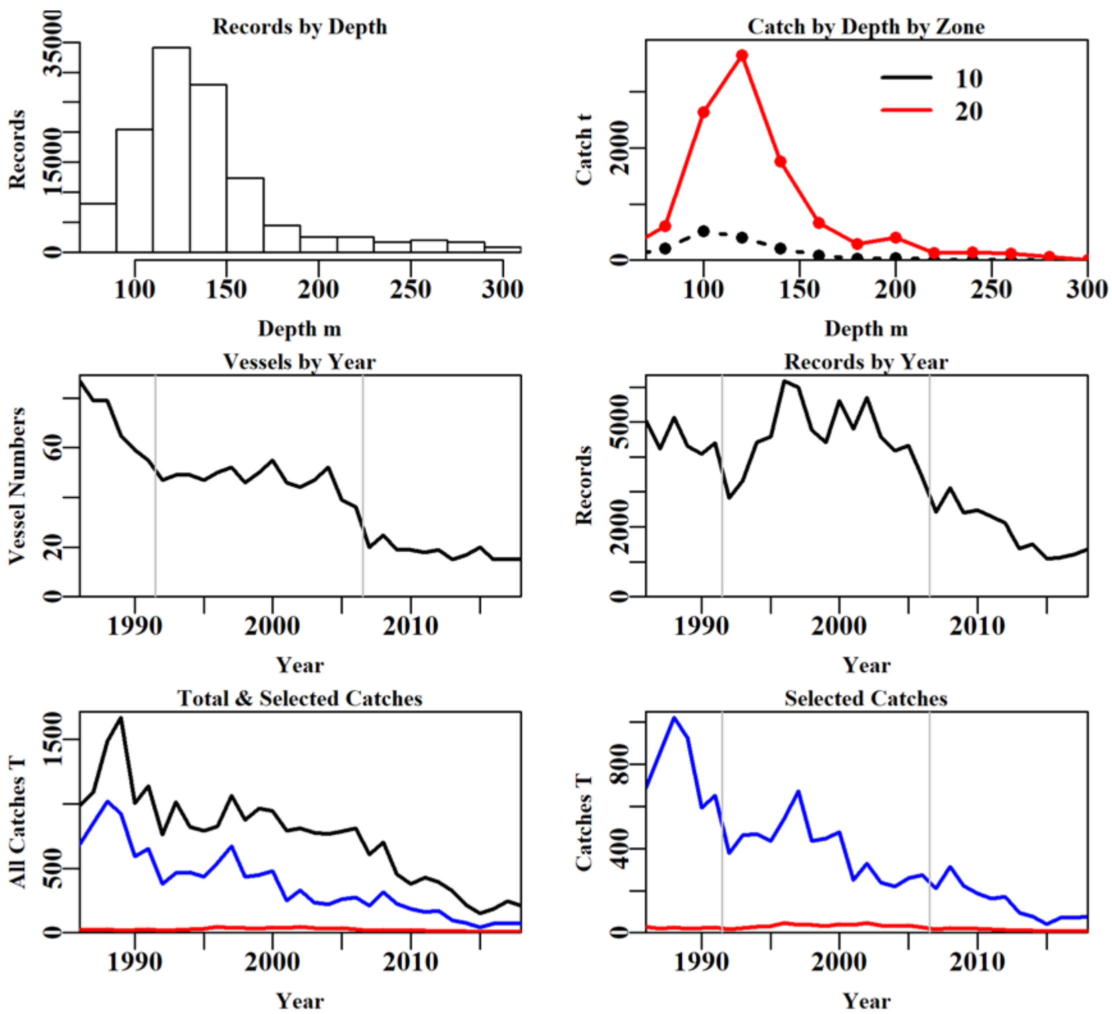

Figure 5.52. JackasssMorwong1020 fishery details. The bottom left plot depicts all known catches (top black line), and all selected catches used in the analysis (middle blue line); the lower red line: selected catches < 30 kg).

Table 5.38. JackasssMorwong1020 data selection effects. Total is the total number of records in the database, NoCE removes those records with either missing catch or effort, and then only those records are kept that meet the criteria for depth, years, zone, method and fishery.

	Total	NoCE	Depth	Years	Zones	Method	Fishery
Records	259847	238942	210468	206408	134408	118837	118741
Difference	0	20905	28474	4060	72000	15571	96
Catch	25198.64	24237.971	22774.397	22150.77	12799.28	12313.57	12305.52
Difference	0.00	960.6659	1463.574	623.625	9351.496	485.707	8.054

Table 5.39. The models used to analyse data for JackasssMorwong1020.

	Model
Model1	Year
Model2	Year + Vessel
Model3	Year + Vessel + Month
Model4	Year + Vessel + Month + Zone
Model5	Year + Vessel + Month + Zone + DepCat
Model6	Year + Vessel + Month + Zone + DepCat + DayNight
Model7	Year + Vessel + Month + Zone + DepCat + DayNight + Zone:Month
Model8	Year + Vessel + Month + Zone + DepCat + DayNight + Zone:DepCat

Table 5.40. JackasssMorwong1020. The row names are 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_r2) and the change in adjusted R^2 (%Change). The optimum model was Zone:Month.

	AIC	RSS	MSS	Nobs	Npars	adj_r2	%Change
Year	87385	247725	34427	118741	33	12.2	0.00
Vessel	73349	219441	62711	118741	213	22.1	9.91
Month	70172	213606	68546	118741	224	24.2	2.06
Zone	67896	209548	72605	118741	225	25.6	1.44
DepCat	66575	207188	74964	118741	237	26.4	0.83
DayNight	65070	204569	77584	118741	240	27.4	0.93
Zone:Month	64117	202895	79257	118741	251	27.9	0.59
Zone:DepCat	64753	203982	78170	118741	252	27.6	0.20

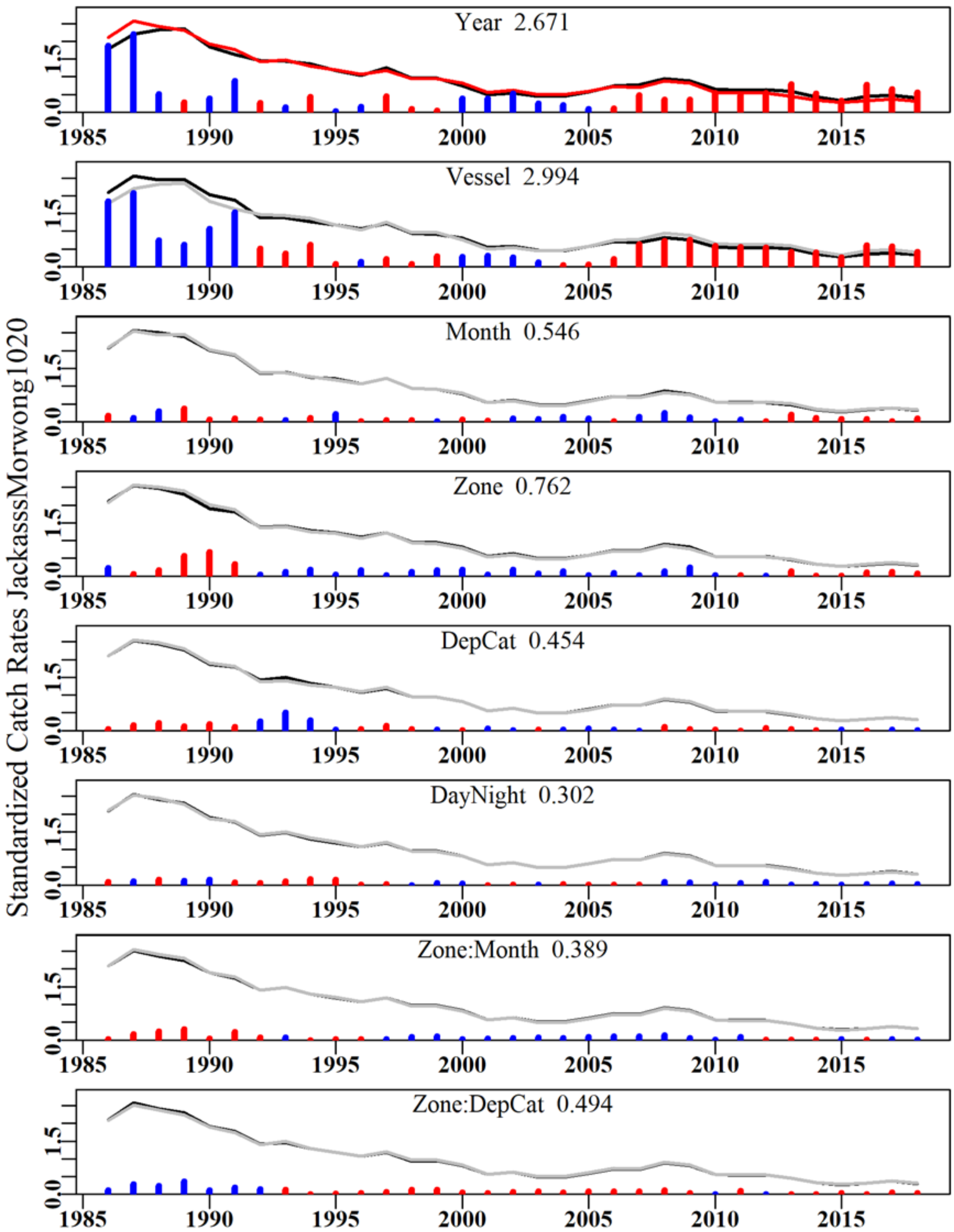

Figure 5.53. JackasssMorwong1020. The influence of each factor on the optimal standardization. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by vertical bars with blue bars indicating the optimum model is higher than 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.

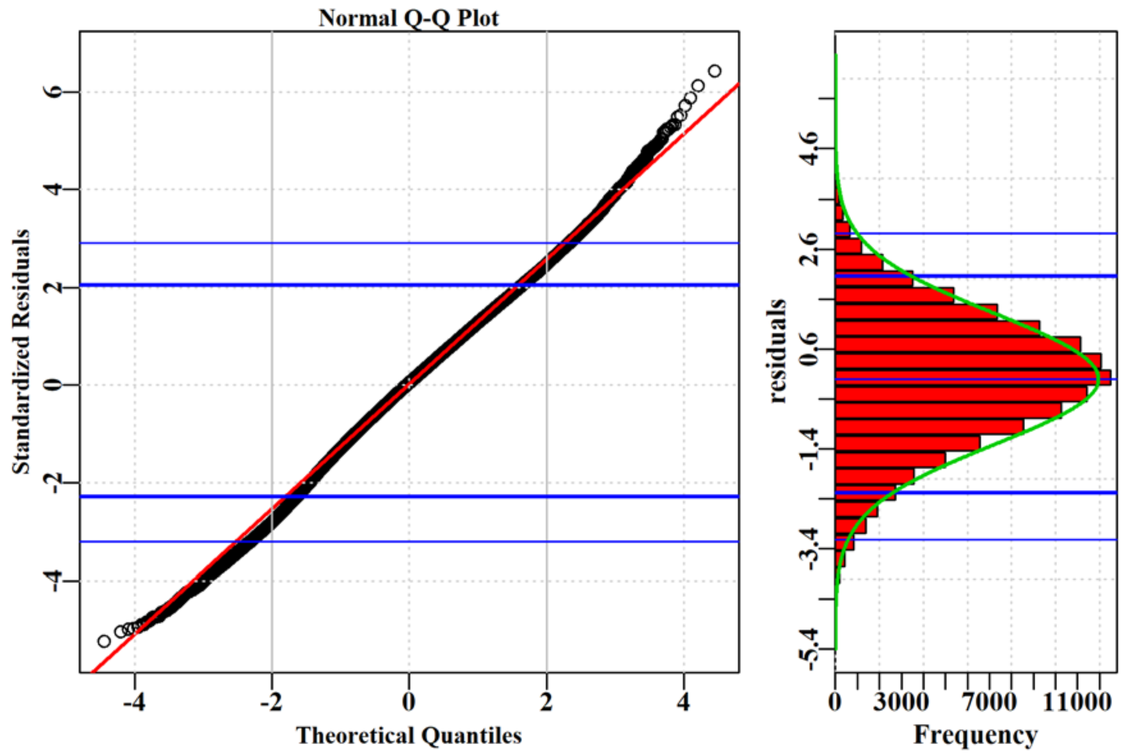

Figure 5.54. JackasssMorwong1020. diagnostic plots. The distribution of residuals from the optimum fit. The qqplot indicates the fit to the expected normality, while the histogram of residuals illustrates the 90% quantiles to indicate the intensity of any lack of fit at the margins of the distribution.

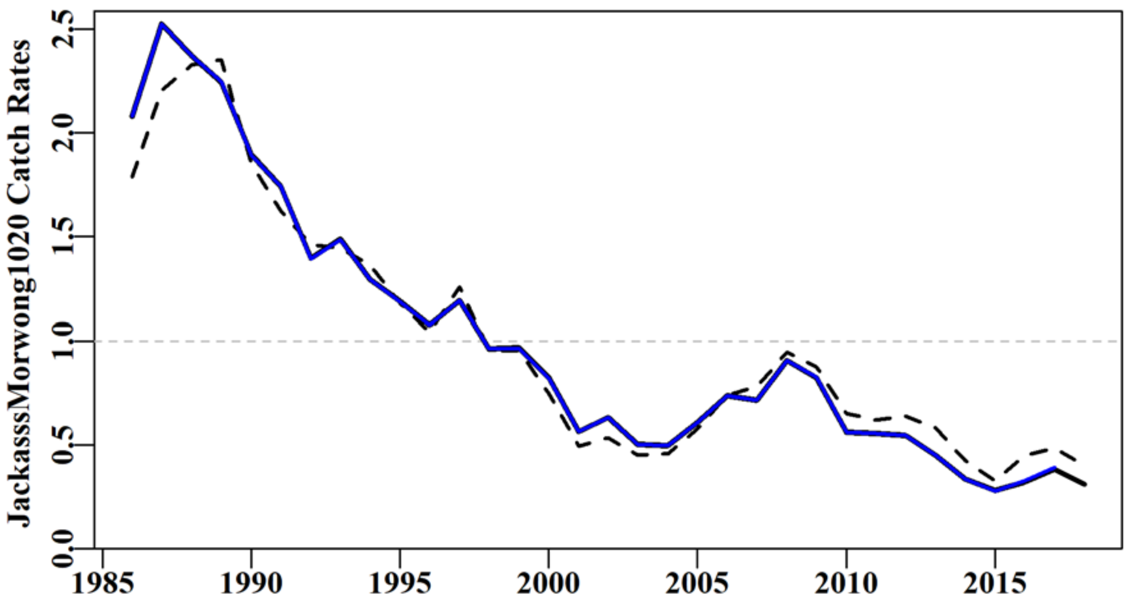

Figure 5.55. JackasssMorwong1020. A comparison of the previous year's standardization (blue line) with this year's. They should lie on top of each other, although small deviations may relate to data adjustments, particularly in very recent years.

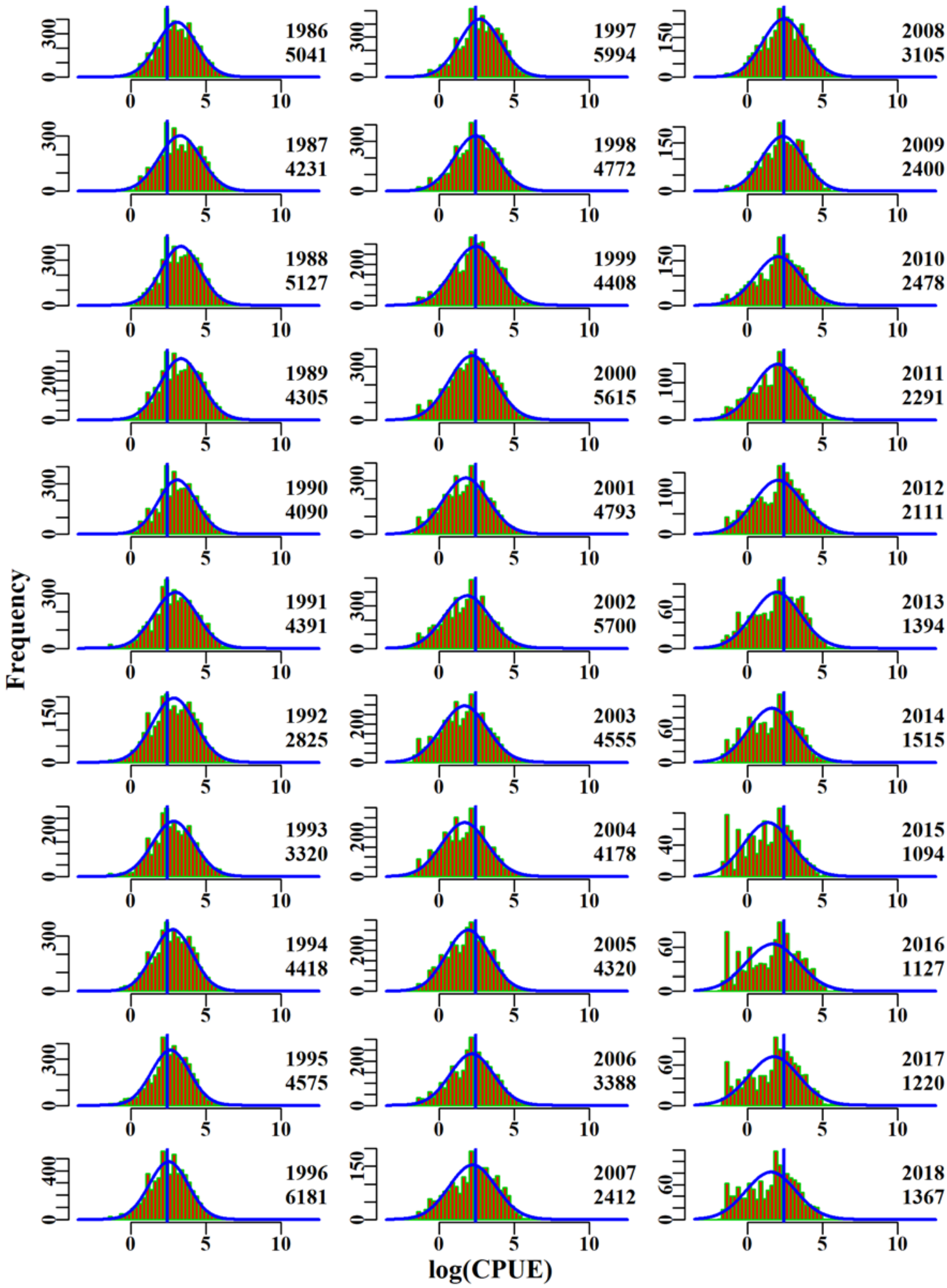

Figure 5.56. JackasssMorwong1020. The natural log(CPUE) for each year of data available the blue lines are normal distributions fitted to the histogram frequencies. The numbers in each plot are the year and number of records.

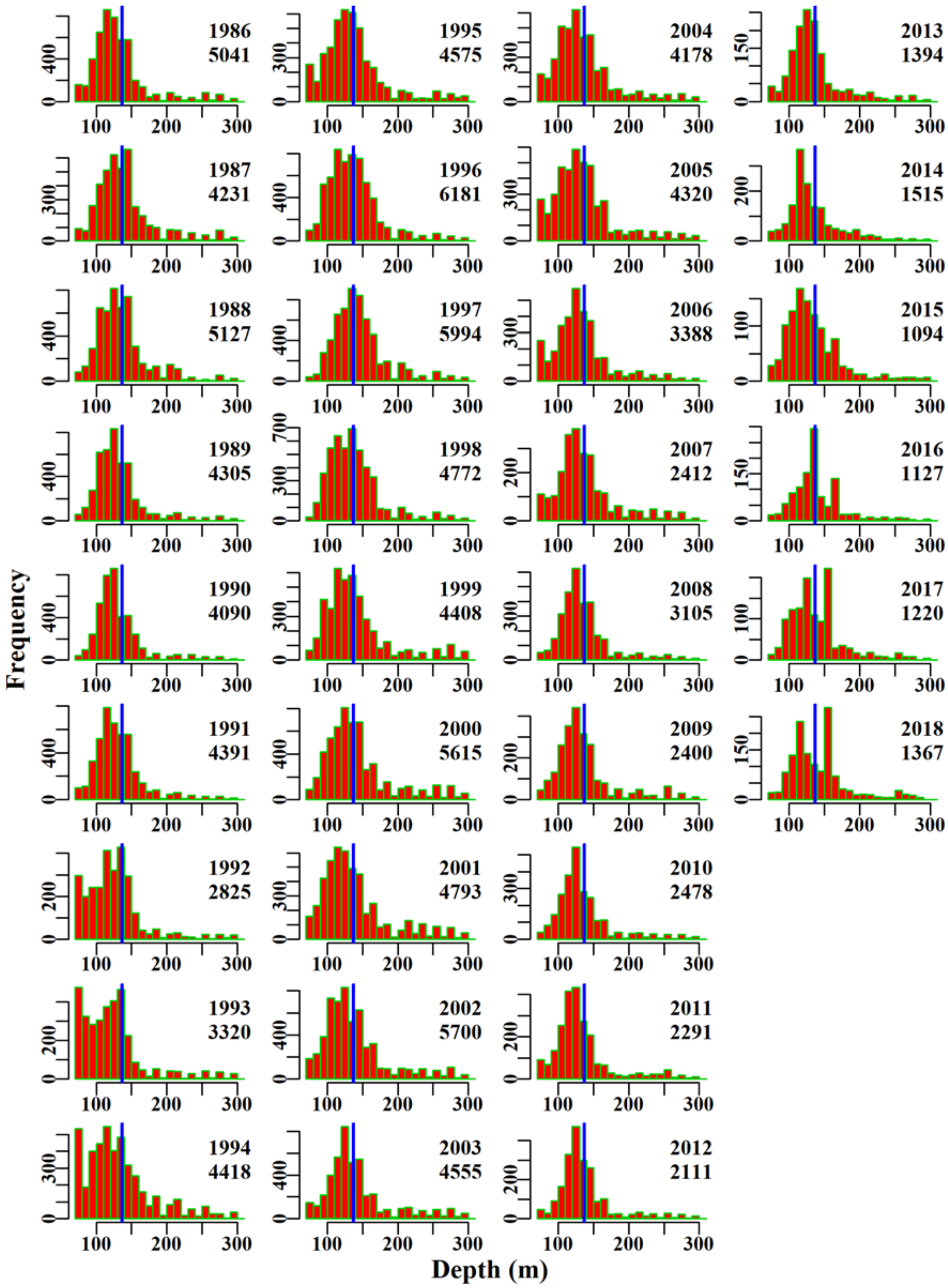

Figure 5.57. JackasssMorwong1020. The average Depth of fishing for each year of data available to illustrate the development of the fishery through time. The numbers in each plot are the year and number of records.

5.12 Jackass Morwong 40 – 50

The fishery for Jackass Morwong (MOR - 37377003 - *Nemadactylus macropterus*) in zones 40 and 50 has been variable with catches peaked over 2001 - 2006 period followed by a rapid decline following the structural adjustment. The criteria used to select data from the Commonwealth logbook database for trawl caught Jackass Morwong was based on methods TW, TDO, TMO, OTT, in zones 40, 50, and depths 70 to 360 within the SET fishery for years 1986 - 2018 (Table 5.41). A total of 8 statistical models were fitted sequentially to the available data, with the order of the non-interaction terms added based on the relative contribution of each term to model fit.

5.12.1 *Inferences*

The terms Year, DepCat, Month and Vessel had the greatest contribution to model fit, with the remaining terms each explaining < 1% of the overall variation in CPUE, based on the AIC and R^2 statistics (Table 5.45). The qqplot suggests a possible departure from Normality, as depicted by the tails of the distribution (Figure 5.61).

Most catch from zone 40 occurred at a shallower depth compared to zone 50. Since 2007, standardized CPUE has been below the long-term average, with a declining trend to 2014 and a subsequent positive trend to 2017 and a drop in 2018 (Figure 5.58).

5.12.2 *Action Items and Issues*

The vessel factor changed its influence from 2001 onwards reflecting the increase in catches from 2001 and suggesting the fishery changed remarkably at that time. The reasons behind this change should be explained in more detail.

Table 5.41. JackasssMorwong4050. The data selection criteria used to specify and identify the fishery data to be included in the analysis.

Property	Value
label	JackasssMorwong4050
csirocode	37377003
fishery	SET
depthrange	70 - 360
depthclass	20
zones	40, 50
methods	TW, TDO, TMO, OTT
years	1986 - 2018

Table 5.42. JackasssMorwong4050. Total catch (Total; t) is the total reported in the database, number of records used in the analysis (N), reported catch (Catch; t) in the area and depth used in the analysis and number of vessels used in the analysis (Vess). GeoM is the geometric mean of catch rates (kg/hr), standard deviation (StDev) relates to the optimum model. C<30Kg denotes the amount of catch in shots of <30kg, and %<30Kg is the percent of total. The optimum model was Zone:Month.

	Total	N	Catch	Vess	GeoM	Opt	StDev	C<30Kg	P<30Kg
1986	982.8	550	149.1	19	114.8	2.0841	0.000	1.928	0.013
1987	1087.7	349	58.4	21	61.0	1.6368	0.086	2.079	0.036
1988	1483.5	401	65.4	19	66.0	2.4175	0.086	1.803	0.028
1989	1667.4	345	83.2	21	74.7	1.7485	0.091	2.283	0.027
1990	1001.4	410	80.3	22	77.2	1.7682	0.092	2.303	0.029
1991	1138.1	279	40.3	26	39.8	1.1916	0.097	1.790	0.044
1992	758.3	249	28.6	14	33.0	0.9793	0.099	2.122	0.074
1993	1015.0	248	25.0	17	29.6	0.9240	0.101	2.247	0.090
1994	818.4	309	22.5	16	22.9	0.9032	0.094	2.725	0.121
1995	789.5	291	76.9	17	63.5	0.9394	0.095	2.405	0.031
1996	827.2	345	36.1	17	31.3	1.0467	0.092	2.869	0.079
1997	1063.4	489	53.9	20	26.8	0.8292	0.086	4.823	0.090
1998	876.4	266	54.6	19	42.7	0.8410	0.098	2.825	0.052
1999	961.5	382	76.9	17	42.5	0.7621	0.091	3.711	0.048
2000	945.2	429	118.9	29	79.8	1.2201	0.091	3.723	0.031
2001	790.2	920	276.8	25	104.8	1.2995	0.079	5.171	0.019
2002	811.2	850	249.4	21	95.2	1.3129	0.079	4.464	0.018
2003	774.6	649	170.7	24	85.9	1.1076	0.083	3.106	0.018
2004	765.5	674	174.5	25	77.1	1.1792	0.082	2.843	0.016
2005	784.2	717	188.5	21	77.7	1.2746	0.082	3.105	0.016
2006	811.3	799	178.3	19	57.6	1.0064	0.080	3.293	0.018
2007	607.9	585	114.2	15	44.8	0.8377	0.083	2.758	0.024
2008	700.4	466	101.5	16	55.7	0.8640	0.087	1.491	0.015
2009	454.4	409	58.3	13	34.1	0.6869	0.089	2.178	0.037
2010	380.0	408	38.2	13	20.6	0.5079	0.089	2.589	0.068
2011	428.0	621	82.8	14	27.6	0.5390	0.083	2.709	0.033
2012	395.6	341	34.5	14	23.1	0.4025	0.093	2.604	0.076
2013	323.9	463	35.7	13	15.7	0.3760	0.088	3.435	0.096
2014	216.6	252	10.1	13	8.8	0.2930	0.100	2.484	0.245
2015	152.5	154	7.0	9	8.3	0.3768	0.114	1.297	0.185
2016	183.4	255	25.0	11	18.1	0.4413	0.099	1.601	0.064
2017	246.2	494	79.5	12	29.6	0.6723	0.089	2.386	0.030
2018	209.7	224	44.4	10	33.7	0.5306	0.104	1.047	0.024

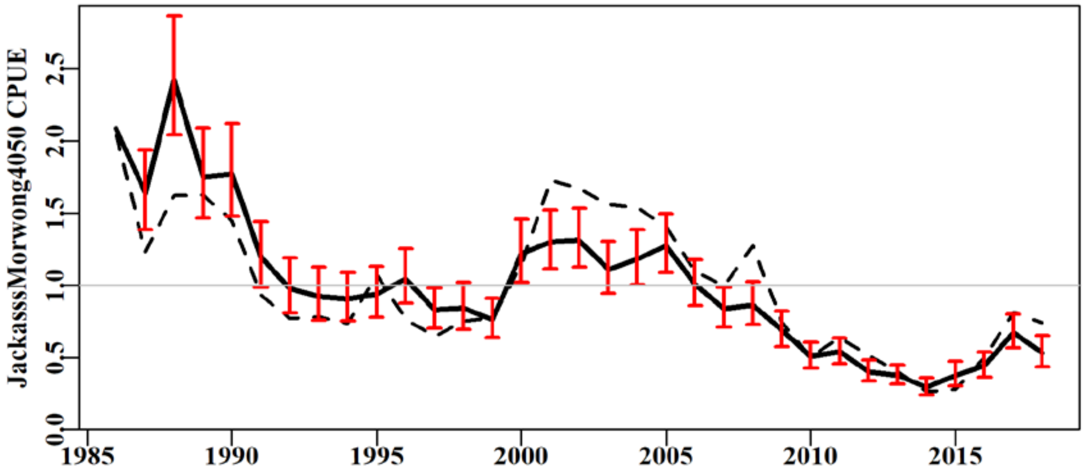

Figure 5.58. JackasssMorwong4050 standardization. The dashed black line represents the geometric mean catch rate, solid black line the standardized catch rates. The red bars are the 95% confidence intervals about the mean estimates. The graph scales both time-series of standardized catch rates relative to the mean of each time-series.

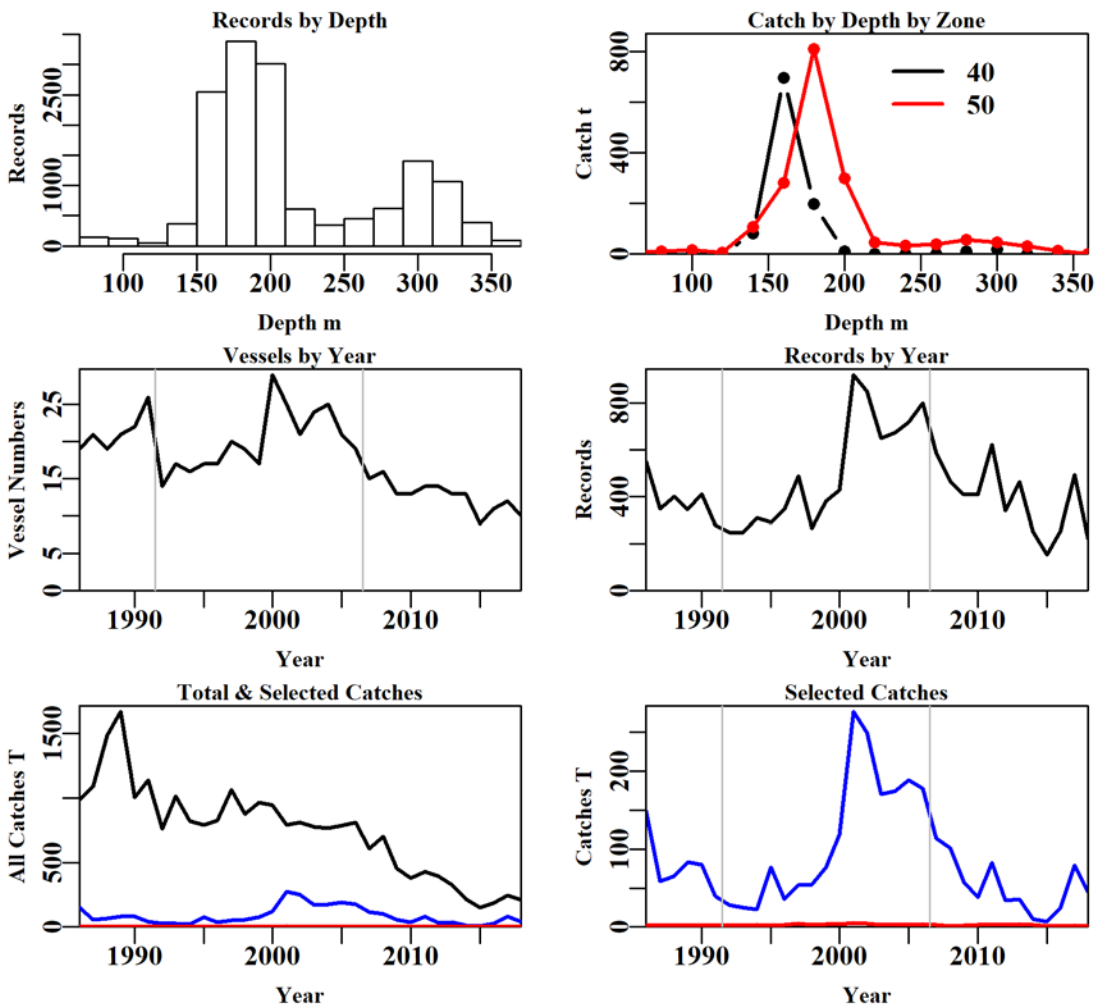

Figure 5.59. JackasssMorwong4050 fishery details. The bottom left plot depicts all known catches (top black line), and all selected catches used in the analysis (middle blue line); the lower red line: selected catches < 30 kg).

Table 5.43. JackasssMorwong4050 data selection effects. Total is the total number of records in the database, NoCE removes those records with either missing catch or effort, and then only those records are kept that meet the criteria for depth, years, zone, method and fishery.

	Total	NoCE	Depth	Years	Zones	Method	Fishery
Records	259847	238942	216019	211859	15176	14658	14623
Difference	0	20905	22923	4160	196683	518	35
Catch	25198.64	24237.97	23105.64	22472.81	2883.06	2848.22	2839.56
Difference	0	960.67	1132.33	632.83	19589.75	34.842	8.67

Table 5.44. The models used to analyse data for JackasssMorwong4050.

	Model
Model1	Year
Model2	Year + DepCat
Model3	Year + DepCat + Month
Model4	Year + DepCat + Month + Vessel
Model5	Year + DepCat + Month + Vessel + DayNight
Model6	Year + DepCat + Month + Vessel + DayNight + Zone
Model7	Year + DepCat + Month + Vessel + DayNight + Zone + Zone:Month
Model8	Year + DepCat + Month + Vessel + DayNight + Zone + Zone:DepCat

Table 5.45. JackasssMorwong4050. The row names are 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_r2) and the change in adjusted R^2 (%Change). The optimum model was Zone:Month.

	AIC	RSS	MSS	Nobs	Npars	adj_r2	%Change
Year	8232	25561	3400	14623	33	11.5	0.00
DepCat	5923	21782	7178	14623	48	24.5	13.00
Month	4647	19932	9028	14623	59	30.9	6.36
Vessel	3943	18763	10197	14623	149	34.5	3.65
DayNight	3775	18541	10419	14623	152	35.3	0.76
Zone	3655	18387	10573	14623	153	35.8	0.53
Zone:Month	3504	18171	10790	14623	164	36.5	0.71
Zone:DepCat	3560	18233	10728	14623	167	36.3	0.48

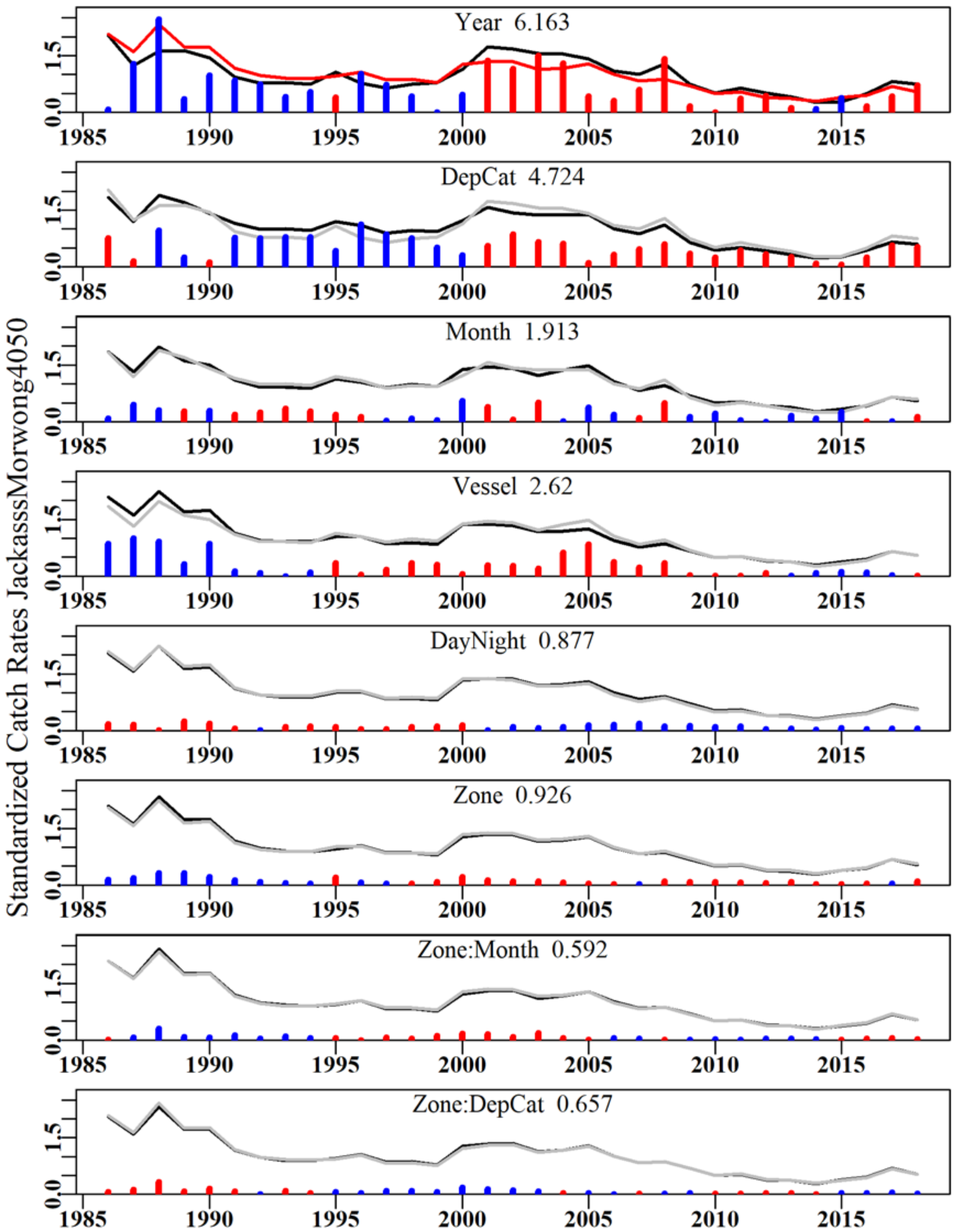

Figure 5.60. JackasssMorwong4050. The influence of each factor on the optimal standardization. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by vertical bars with blue bars indicating the optimum model is higher than 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.

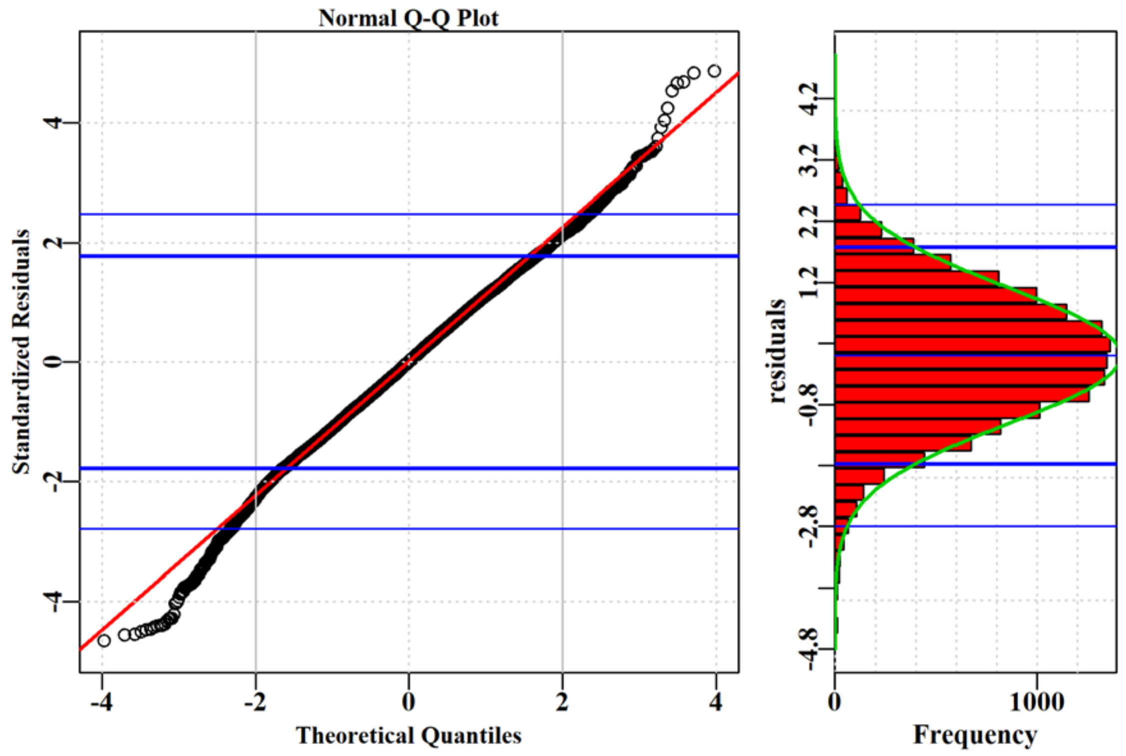

Figure 5.61. JackasssMorwong4050. diagnostic plots. The distribution of residuals from the optimum fit. The qqplot indicates the fit to the expected normality, while the histogram of residuals illustrates the 90% quantiles to indicate the intensity of any lack of fit at the margins of the distribution.

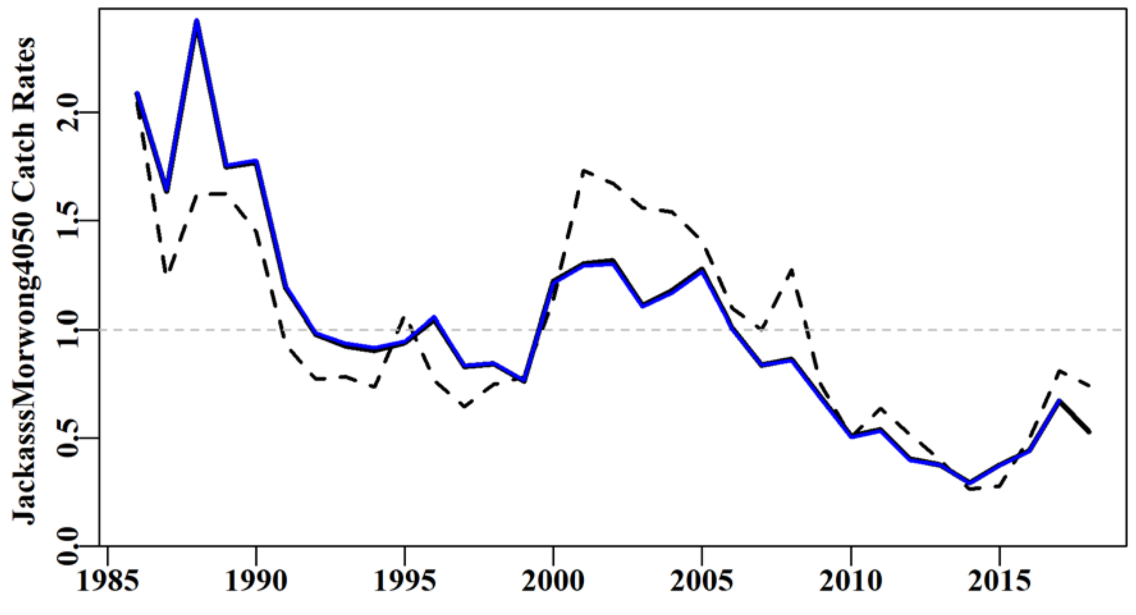

Figure 5.62. JackasssMorwong4050. A comparison of the previous year's standardization (blue line) with this year's. They should lie on top of each other, although small deviations may relate to data adjustments, particularly in very recent years.

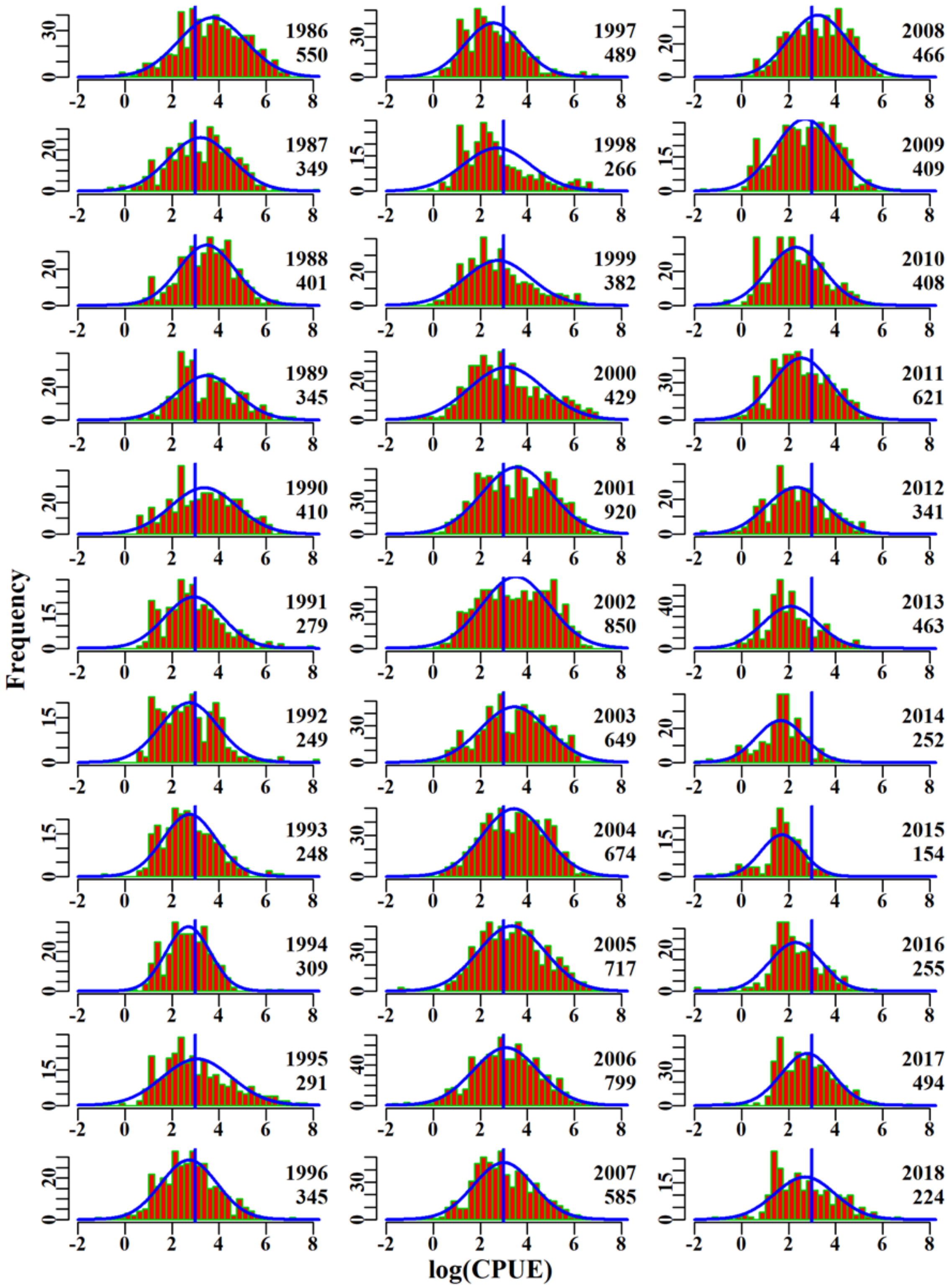

Figure 5.63. JackasssMorwong4050. The natural log(CPUE) for each year of data available the blue lines are normal distributions fitted to the histogram frequencies. The numbers in each plot are the year and number of records.

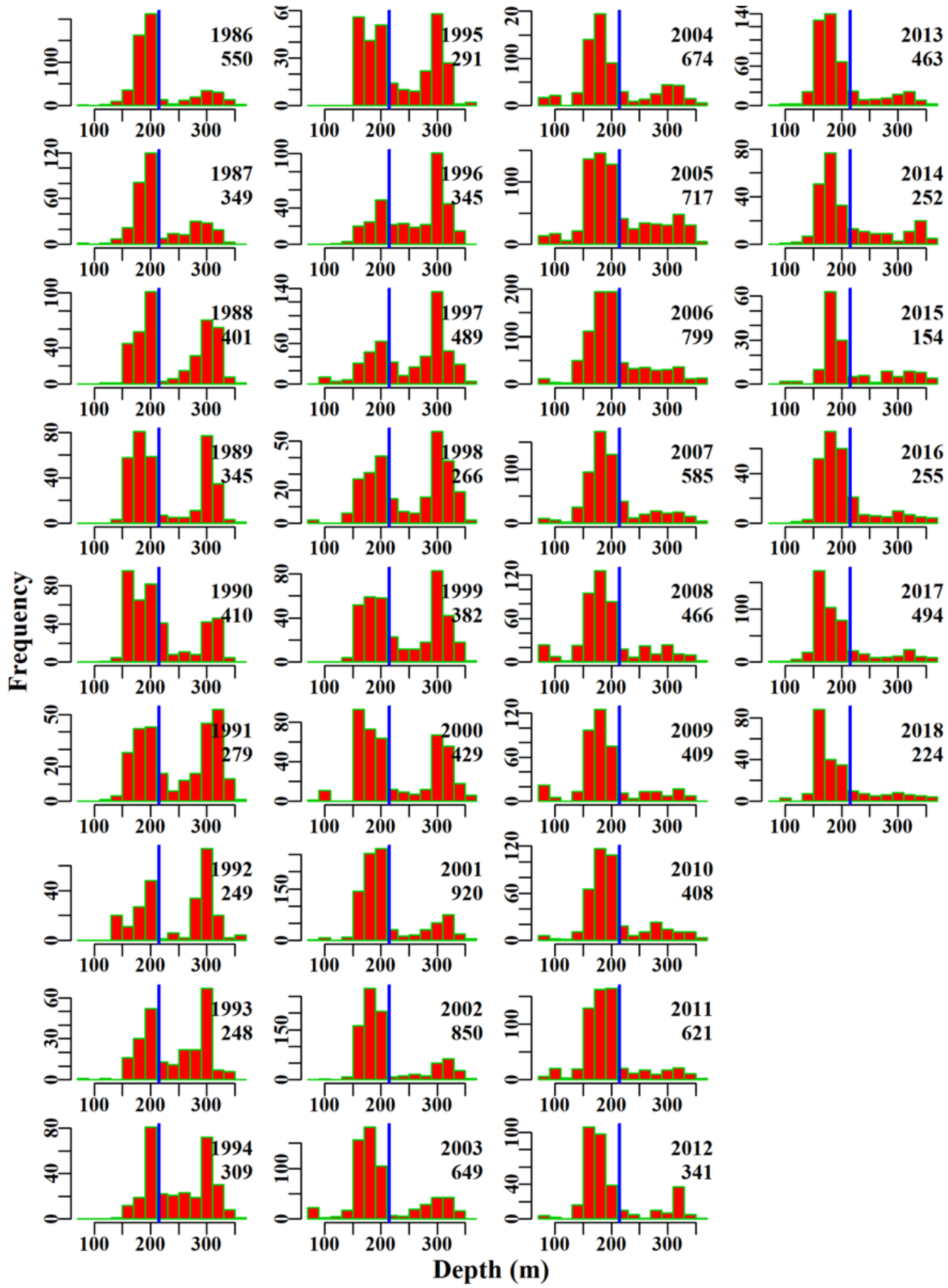

Figure 5.64. JackasssMorwong4050. The average Depth of fishing for each year of data available to illustrate the development of the fishery through time. The numbers in each plot are the year and number of records.

5.13 Silver Warehou 40 – 50

Silver Warehou (TRS–37445006 – *Seriolella punctata*) was one of the 16 species first included in the quota system in 1992, which reflects its long history within the SESSF. The criteria used to select data from the Commonwealth logbook database for trawl caught Silver Warehou was based on methods TW, TDO, OTT, TMO, in zones 40, 50, and depths 0 to 600 within the SET fishery for years 1986 - 2018 (Table 5.46). A total of 8 statistical models were fitted sequentially to the available data, with the order of the non-interaction terms added based on the relative contribution of each term to model fit.

5.13.1 *Inferences*

The terms Year, Vessel, Month and DepCat had the greatest contribution to model fit, with the remaining terms each explaining < 1% of the overall variation in CPUE, based on the AIC and R^2 statistics (Table 5.50). The qqplot suggests that the assumed Normal distribution is valid (Figure 5.68).

Annual standardized CPUE have declined since 2005, and since 2008 have been below the long-term average (Figure 5.65). The influence of the vessel factor changed was high from 2000 to about 2006 after which it was less influential.

5.13.2 *Action Items and Issues*

After consideration of Silver Warehou catches in zones 40 - 50 by year and vessel, the period around 1999 - 2006 appears exceptional, or at least contains exceptional vessels, all of which left the fishery after the structural adjustment. This suggests that there have been transitional periods in the time-series of CPUE. This **urgently** needs more attention because this may imply that CPUE may no longer be acting as a valid index of relative abundance through time.

Table 5.46. SilverWarehou4050. The data selection criteria used to specify and identify the fishery data to be included in the analysis.

Property	Value
label	SilverWarehou4050
csirocode	37445006
fishery	SET
depthrange	0 - 600
depthclass	50
zones	40, 50
methods	TW, TDO, OTT, TMO
years	1986 - 2018

Table 5.47. SilverWarehou4050. Total catch (Total; t) is the total reported in the database, number of records used in the analysis (N), reported catch (Catch; t) in the area and depth used in the analysis and number of vessels used in the analysis (Vess). GeoM is the geometric mean of catch rates (kg/hr), standard deviation (StDev) relates to the optimum model. C<30Kg denotes the amount of catch in shots of <30kg, and %<30Kg is the percent of total. The optimum model was Zone:Month.

	Total	N	Catch	Vess	GeoM	Opt	StDev	C<30Kg	P<30Kg
1986	1156.5	1118	643.2	23	201.2	1.5443	0.000	4.167	0.006
1987	782.2	723	490.0	26	279.5	1.7470	0.082	2.368	0.005
1988	1646.2	574	684.4	27	553.8	2.0118	0.087	2.295	0.003
1989	926.3	649	569.0	27	287.0	1.6916	0.089	2.663	0.005
1990	1346.6	565	296.6	26	197.1	1.1262	0.089	2.986	0.010
1991	1453.2	691	623.8	29	267.7	1.2030	0.085	3.180	0.005
1992	733.8	582	185.4	21	98.1	0.9101	0.088	3.330	0.018
1993	1815.8	1541	749.3	23	151.0	1.2625	0.073	6.998	0.009
1994	2309.5	1639	753.6	26	155.7	1.1613	0.071	7.735	0.010
1995	2002.9	1672	771.7	24	147.2	0.9552	0.071	8.948	0.012
1996	2188.2	1551	1016.2	26	209.0	1.0736	0.072	8.450	0.008
1997	2562.0	1874	1261.4	24	210.8	1.2654	0.070	9.427	0.007
1998	2166.0	1848	1196.4	22	221.7	1.4836	0.070	7.985	0.007
1999	2834.1	2735	1772.1	24	241.8	1.2201	0.067	11.412	0.006
2000	3401.6	3557	2568.9	31	321.2	1.1969	0.066	15.063	0.006
2001	2970.4	4177	2170.7	29	193.7	0.9042	0.065	20.784	0.010
2002	3841.4	4421	2944.8	27	249.0	0.9600	0.065	20.321	0.007
2003	2910.1	3398	2199.3	28	256.8	0.9954	0.066	14.878	0.007
2004	3202.1	4240	2534.4	25	164.8	1.0906	0.065	14.503	0.006
2005	2648.0	3065	2100.2	24	220.2	1.1930	0.067	11.833	0.006
2006	2191.2	2682	1680.0	21	187.2	1.0515	0.068	10.636	0.006
2007	1816.5	2764	1360.1	16	144.6	1.0616	0.068	10.282	0.008
2008	1381.2	2056	870.0	17	105.7	0.8463	0.070	9.048	0.010
2009	1285.3	2042	719.9	13	73.2	0.7344	0.070	9.352	0.013
2010	1189.4	2319	782.7	14	64.7	0.6679	0.069	11.517	0.015
2011	1108.8	2889	818.3	17	57.4	0.6430	0.067	11.542	0.014
2012	781.2	1846	546.4	15	57.3	0.4776	0.071	10.147	0.019
2013	584.1	1513	342.2	16	48.6	0.4453	0.073	8.189	0.024
2014	356.9	1540	244.0	14	29.2	0.4245	0.073	8.700	0.036
2015	368.4	1380	268.0	13	34.1	0.4602	0.074	6.634	0.025
2016	331.5	1101	172.1	13	25.2	0.3348	0.077	6.348	0.037
2017	325.7	1246	218.5	12	29.3	0.3769	0.076	5.926	0.027
2018	357.6	1236	266.8	12	32.2	0.4803	0.076	3.922	0.015

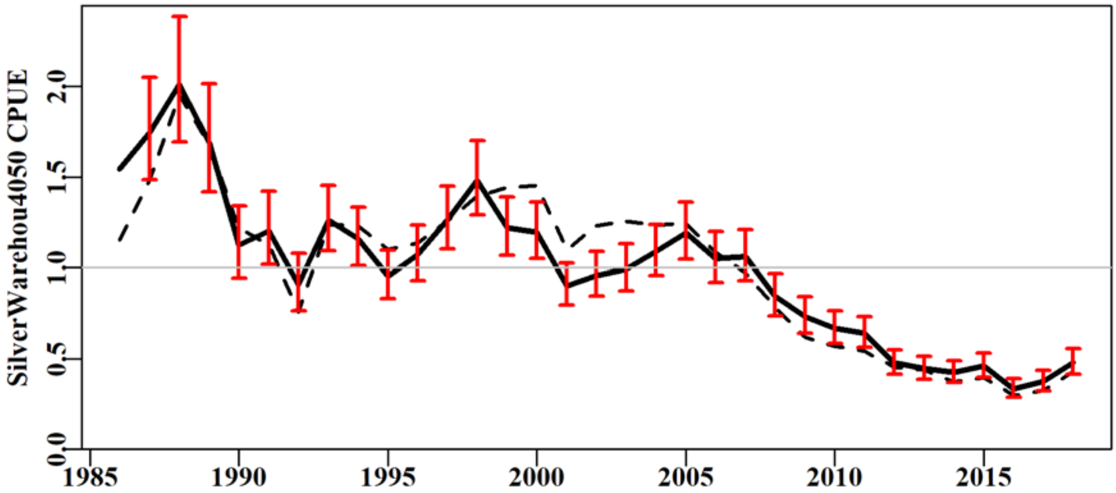

Figure 5.65. SilverWarehou4050 standardization. The dashed black line represents the geometric mean catch rate, solid black line the standardized catch rates. The red bars are the 95% confidence intervals about the mean estimates. The graph scales both time-series of standardized catch rates relative to the mean of each time-series.

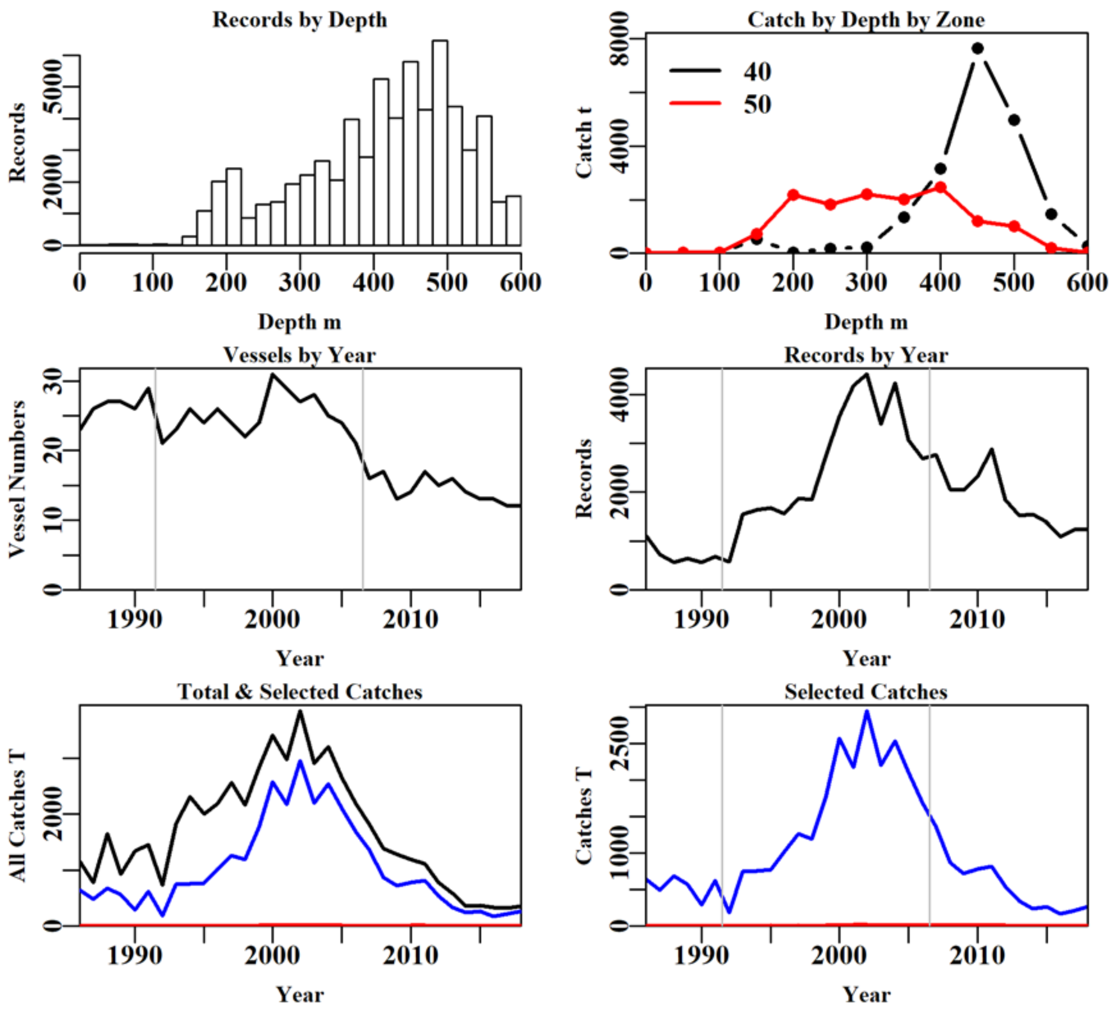

Figure 5.66. SilverWarehou4050 fishery details. The bottom left plot depicts all known catches (top black line), and all selected catches used in the analysis (middle blue line); the lower red line: selected catches < 30 kg).

Table 5.48. SilverWarehou4050 data selection effects. Total is the total number of records in the database, NoCE removes those records with either missing catch or effort, and then only those records are kept that meet the criteria for depth, years, zone, method and fishery.

	Total	NoCE	Depth	Years	Zones	Method	Fishery
Records	156012	151416	147103	145621	65558	65358	65234
Difference	0	4596	4313	1482	80063	200	124
Catch	55420.11	54931.82	53221.53	52781.80	33998.62	33949.53	33820.36
Difference	0	488.29	1710.28	439.73	18783.19	49.08	129.18

Table 5.49. The models used to analyse data for SilverWarehou4050.

	Model
Model1	Year
Model2	Year + Vessel
Model3	Year + Vessel + Month
Model4	Year + Vessel + Month + DepCat
Model5	Year + Vessel + Month + DepCat + Zone
Model6	Year + Vessel + Month + DepCat + Zone + DayNight
Model7	Year + Vessel + Month + DepCat + Zone + DayNight + Zone:Month
Model8	Year + Vessel + Month + DepCat + Zone + DayNight + Zone:DepCat

Table 5.50. SilverWarehou4050. The row names are 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_r2) and the change in adjusted R^2 (%Change). The optimum model was Zone:Month.

	AIC	RSS	MSS	Nobs	Npars	adj_r2	%Change
Year	68353	185820	13758	65234	33	6.85	0.000
Vessel	60516	164272	35306	65234	135	17.52	10.673
Month	57458	156694	42884	65234	146	21.31	3.791
DepCat	56351	154001	45577	65234	158	22.65	1.338
Zone	55418	151811	47767	65234	159	23.75	1.099
DayNight	55099	151055	48523	65234	162	24.13	0.376
Zone:Month	54873	150482	49096	65234	173	24.40	0.275
Zone:DepCat	54894	150528	49050	65234	174	24.38	0.251

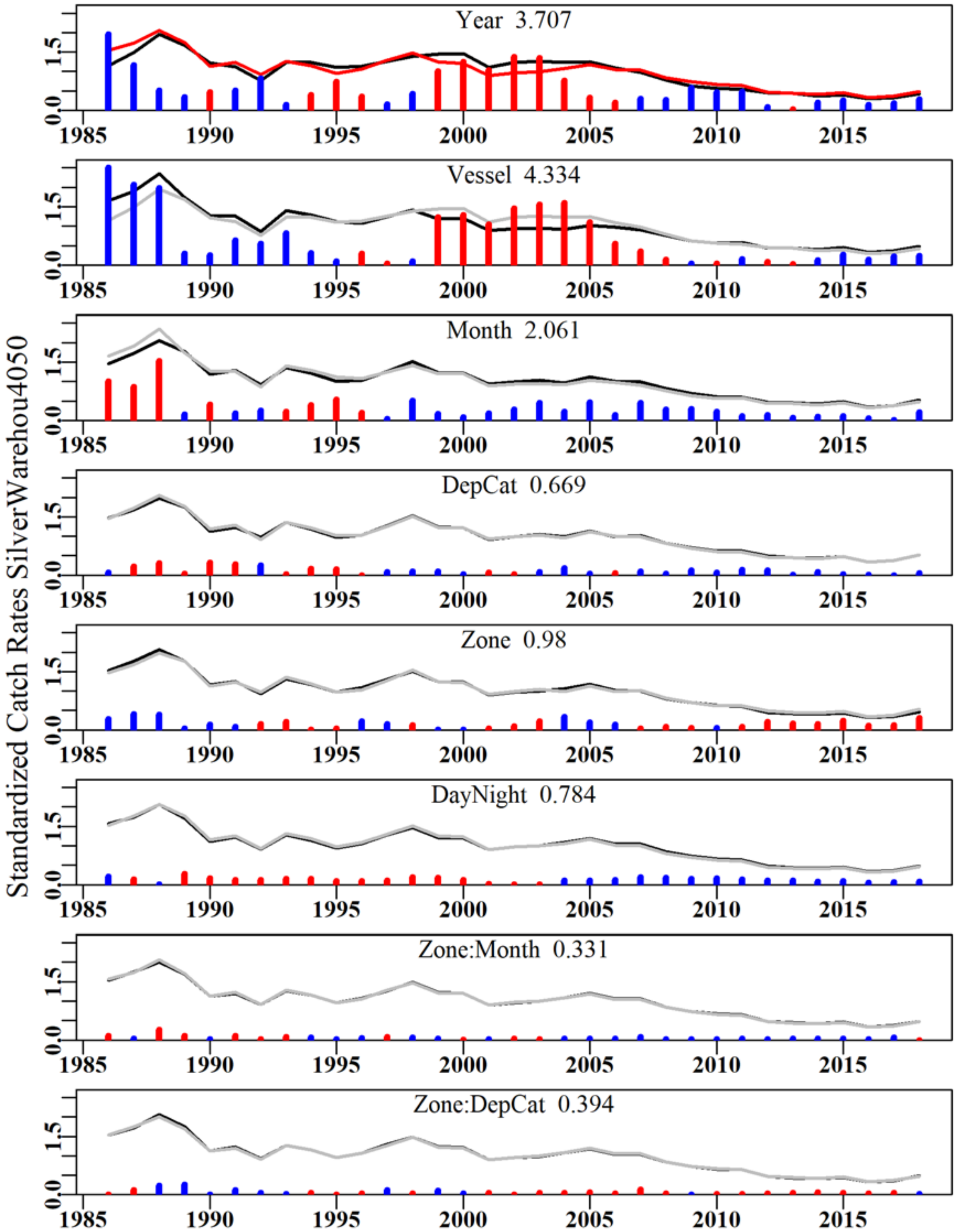

Figure 5.67. SilverWarehou4050. The influence of each factor on the optimal standardization. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by vertical bars with blue bars indicating the optimum model is higher than the 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.

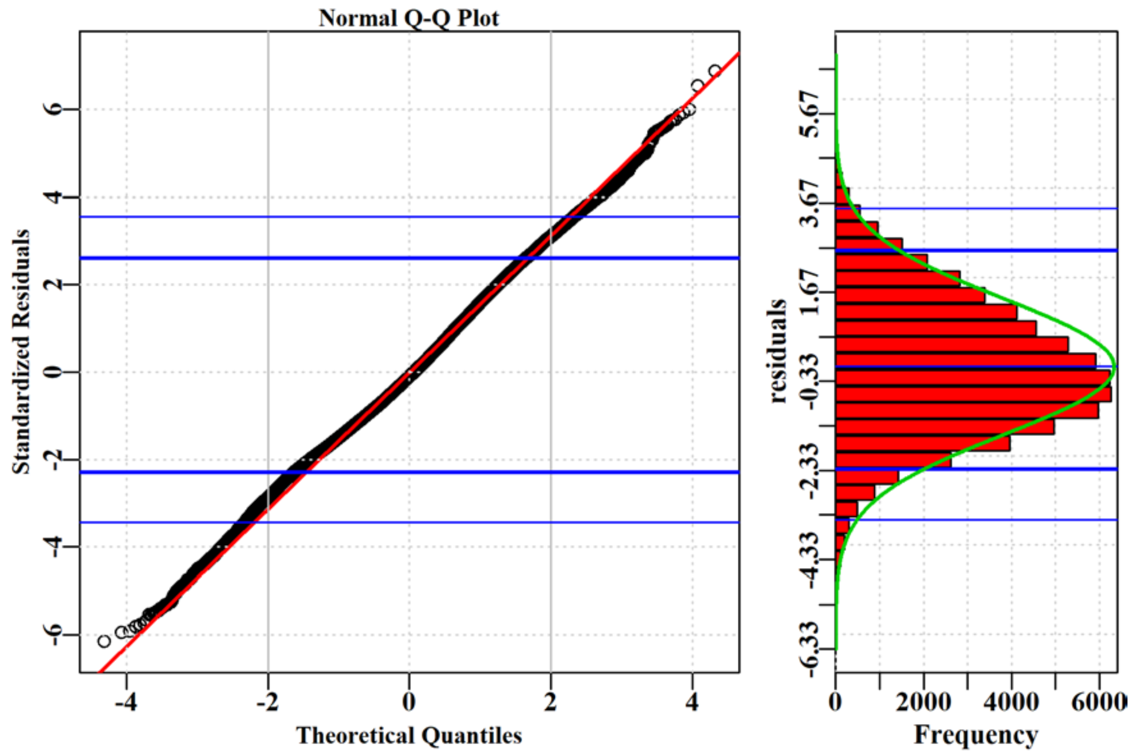

Figure 5.68. SilverWarehou4050. diagnostic plots. The distribution of residuals from the optimum fit. The qqplot indicates the fit to the expected normality, while the histogram of residuals illustrates the 90% quantiles to indicate the intensity of any lack of fit at the margins of the distribution.

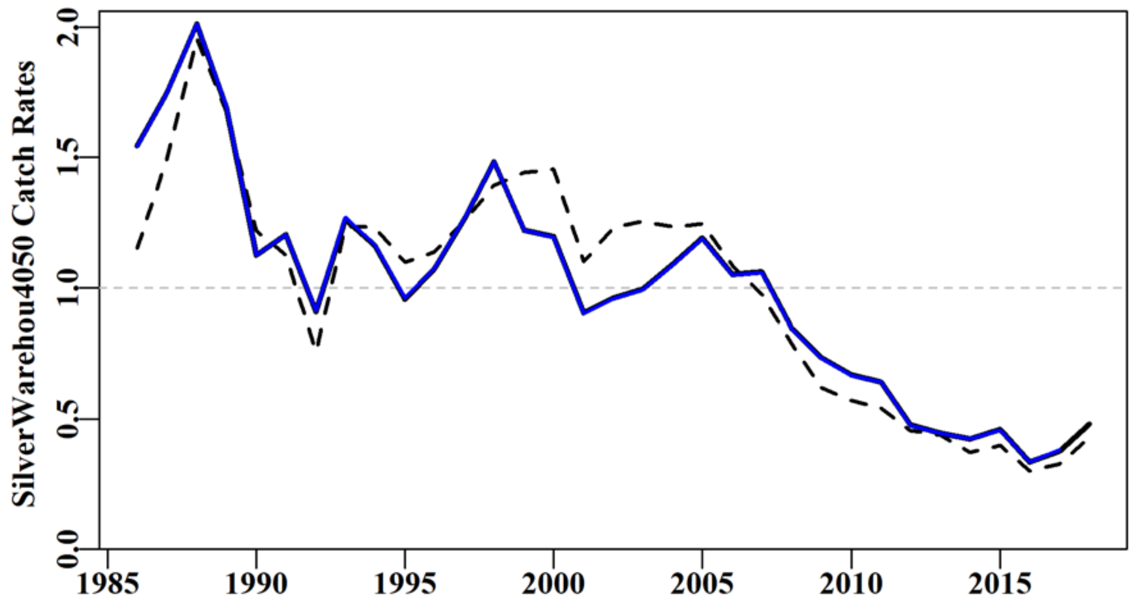

Figure 5.69. SilverWarehou4050. A comparison of the previous year's standardization (blue line) with this year's. They should lie on top of each other, although small deviations may relate to data adjustments, particularly in very recent years.

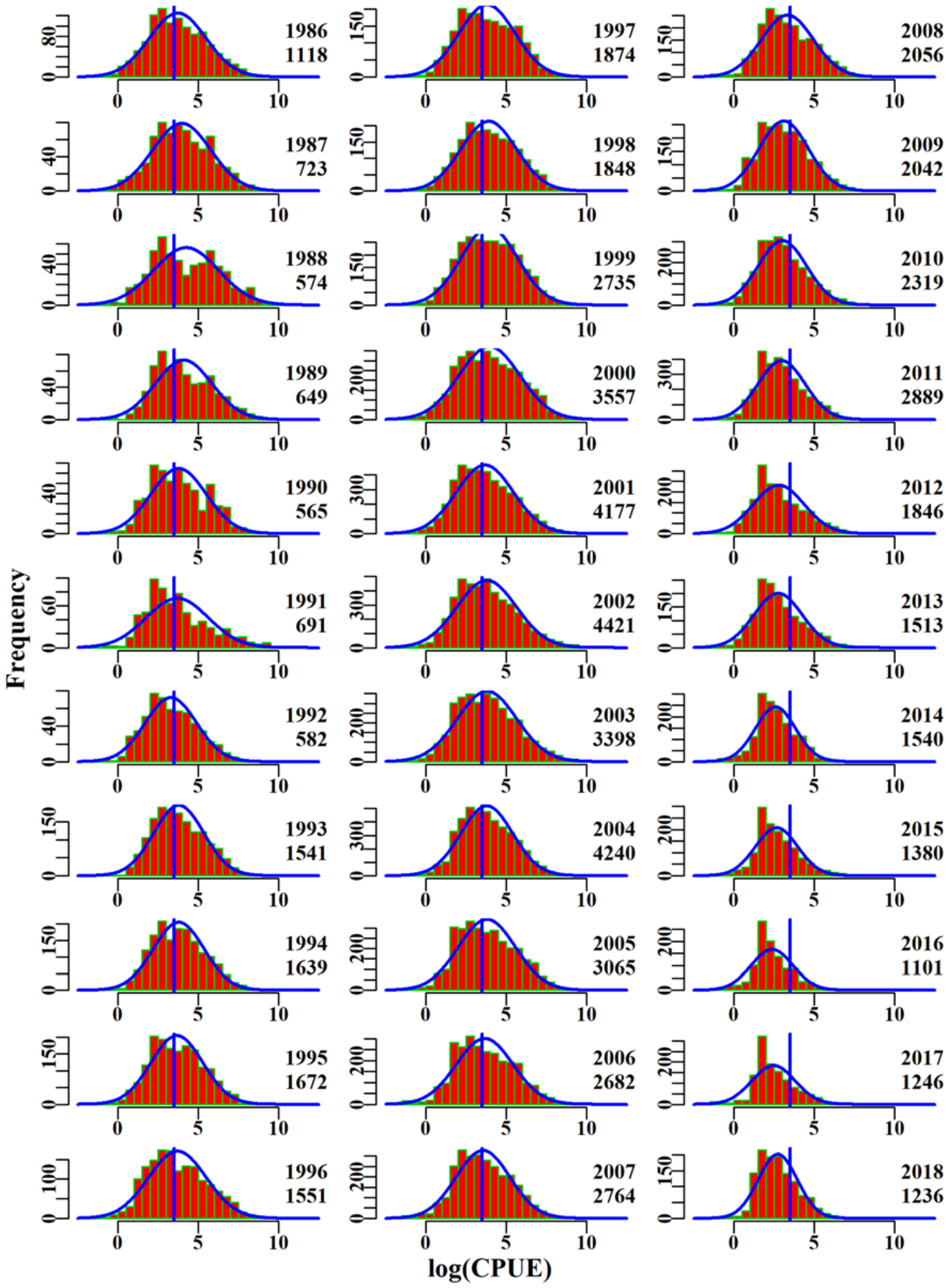

Figure 5.70. SilverWarehou4050. The natural log(CPUE) for each year of data available the blue lines are normal distributions fitted to the histogram frequencies. The numbers in each plot are the year and number of records.

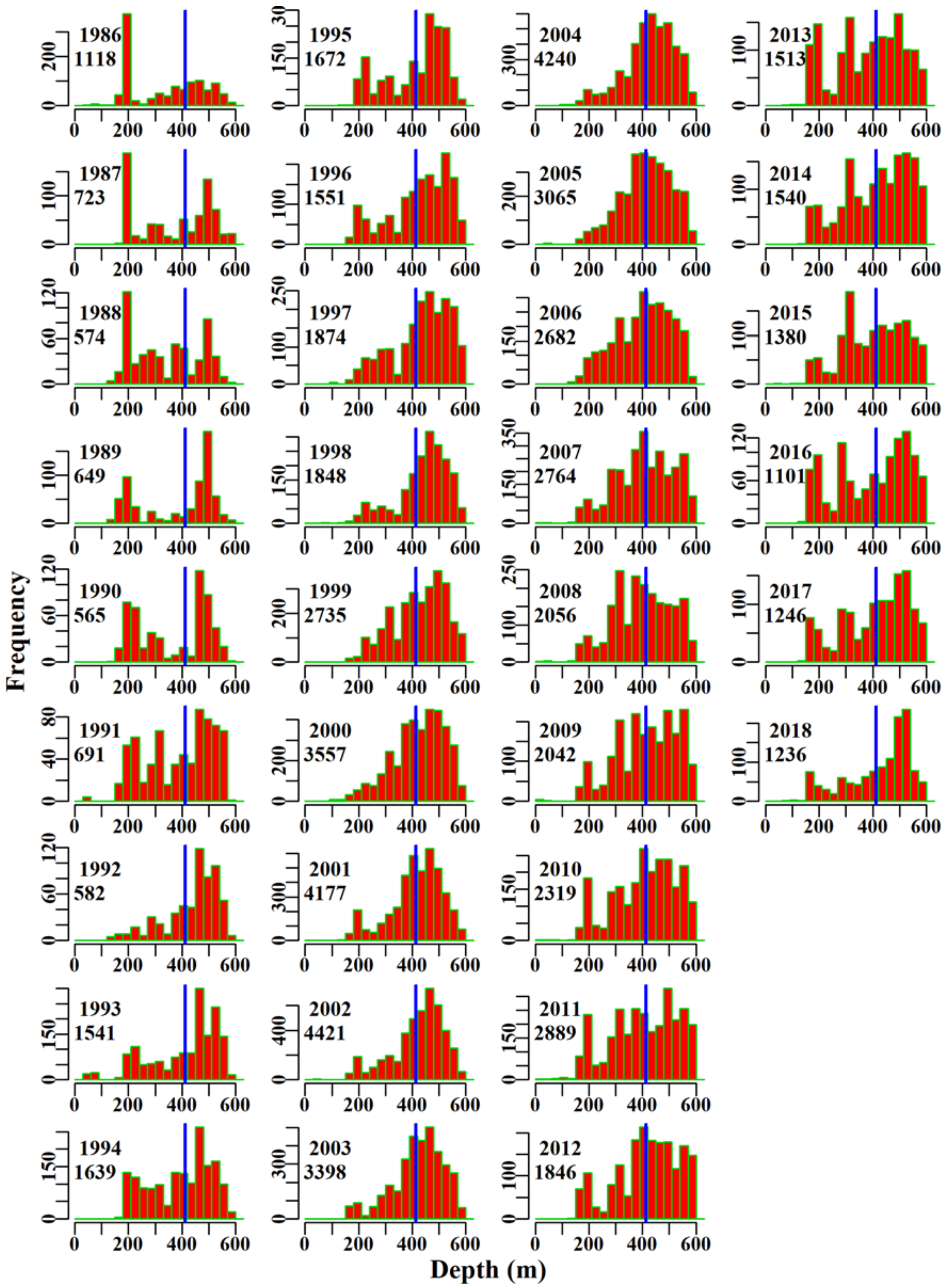

Figure 5.71. SilverWarehou4050. The average Depth of fishing for each year of data available to illustrate the development of the fishery through time. The numbers in each plot are the year and number of records.

5.14 Silver Warehou 10 – 30

Silver Warehou (TRS – 37445006 – *Seriolella punctata*) was one of the 16 species first included in the quota system in 1992, which reflects its long history within the SESSF. The criteria used to select data from the Commonwealth logbook database for trawl caught Silver Warehou was based on methods TW, TDO, OTT, TMO, in zones 10, 20, 30, and depths 0 to 600 within the SET fishery for years 1986 - 2018 (Table 5.51).

A total of 8 statistical models were fitted sequentially to the available data, with the order of the non-interaction terms added based on the relative contribution of each term to model fit.

5.14.1 *Inferences*

Most Silver Warehou in the east have been caught in zone 20 across the specified depth range between 1986 - 2018. Both the early catches and the CPUE exhibit high levels of variation and may be suspect before the introduction of quotas, prior to which they were mixed up with catches of Blue Warehou.

The terms Year, Vessel, Month and DepCat had the greatest contribution to model fit, with the remaining terms each explaining < 1% of the overall variation in CPUE, based on the AIC and R^2 statistics (Table 5.55). The qqplot suggests that the assumed Normal distribution is valid (Figure 5.75).

Annual standardized CPUE has declined since 1994 and have been below average since 1999 (Figure 5.72).

5.14.2 *Action Items and Issues*

After consideration of Silver Warehou catches in zones 10 - 30 by year and vessel the period around 1992 - 2006 appears exceptional, or at least contains exceptional vessels. This suggests that there have been transitional periods in the time-series of CPUE. This **urgently** needs more attention because of the potential implications this has for the index of relative abundance through time.

Table 5.51. SilverWarehou1030. The data selection criteria used to specify and identify the fishery data to be included in the analysis.

Property	Value
label	SilverWarehou1030
csirocode	37445006
fishery	SET
depthrange	0 - 600
depthclass	50
zones	10, 20, 30
methods	TW, TDO, OTT, TMO
years	1986 - 2018

Table 5.52. SilverWarehou1030. Total catch (Total; t) is the total reported in the database, number of records used in the analysis (N), reported catch (Catch; t) in the area and depth used in the analysis and number of vessels used in the analysis (Vess). GeoM is the geometric mean of catch rates (kg/hr), standard deviation (StDev) relates to the optimum model. C<30Kg denotes the amount of catch in shots of <30kg, and %<30Kg is the percent of total. The optimum model was Zone:DepCat.

	Total	N	Catch	Vess	GeoM	Opt	StDev	C<30Kg	P<30Kg
1986	1156.5	1318	491.7	66	113.2	1.8756	0.000	6.906	0.014
1987	782.2	778	264.8	56	112.0	1.8325	0.078	4.472	0.017
1988	1646.2	1668	926.1	69	172.0	2.3136	0.066	8.485	0.009
1989	926.3	1394	336.7	63	62.3	1.9199	0.070	9.172	0.027
1990	1346.6	1398	972.3	59	256.2	2.4563	0.071	5.674	0.006
1991	1453.2	1568	575.6	63	117.6	1.4886	0.071	9.859	0.017
1992	733.8	1254	423.8	41	110.4	1.6583	0.073	7.375	0.017
1993	1815.8	2288	970.4	49	129.4	1.6268	0.066	14.634	0.015
1994	2309.5	2852	1535.2	46	186.7	1.8026	0.065	16.832	0.011
1995	2002.9	3316	1185.2	45	112.4	1.5216	0.064	22.666	0.019
1996	2188.2	4507	1115.2	53	72.4	1.2368	0.062	32.860	0.029
1997	2562.0	3877	1036.3	48	81.8	1.2276	0.064	26.098	0.025
1998	2166.0	2847	777.6	43	72.9	1.0129	0.065	21.294	0.027
1999	2834.1	2398	905.7	43	113.2	0.8871	0.067	17.189	0.019
2000	3401.6	3160	722.0	50	79.2	0.7154	0.065	21.600	0.030
2001	2970.4	3151	637.1	40	72.1	0.6706	0.065	21.675	0.034
2002	3841.4	3981	707.8	42	60.5	0.7794	0.064	27.884	0.039
2003	2910.1	3966	567.6	50	48.1	0.7086	0.064	28.171	0.050
2004	3202.1	3570	487.0	46	43.0	0.8302	0.065	25.639	0.053
2005	2648.0	3791	429.8	42	33.9	0.7687	0.064	30.421	0.071
2006	2191.2	2948	388.7	35	33.2	0.6488	0.066	24.183	0.062
2007	1816.5	1863	274.7	23	44.4	0.5083	0.070	14.426	0.053
2008	1381.2	2301	397.8	24	43.8	0.5964	0.068	19.377	0.049
2009	1285.3	2285	366.4	23	50.0	0.6757	0.068	17.169	0.047
2010	1189.4	2085	282.0	20	40.1	0.4969	0.069	15.392	0.055
2011	1108.8	1983	215.2	22	30.5	0.4314	0.070	15.878	0.074
2012	781.2	1834	188.8	20	33.0	0.3898	0.070	14.161	0.075
2013	584.1	1447	158.9	21	37.9	0.4892	0.073	11.465	0.072
2014	356.9	1344	89.2	22	21.7	0.3363	0.074	11.540	0.129
2015	368.4	1288	64.8	22	16.2	0.2324	0.074	11.574	0.179
2016	331.5	1337	100.1	22	19.5	0.1991	0.074	9.437	0.094
2017	325.7	1069	96.0	18	39.4	0.2812	0.078	7.021	0.073
2018	357.6	1184	84.5	19	24.0	0.3815	0.077	9.104	0.108

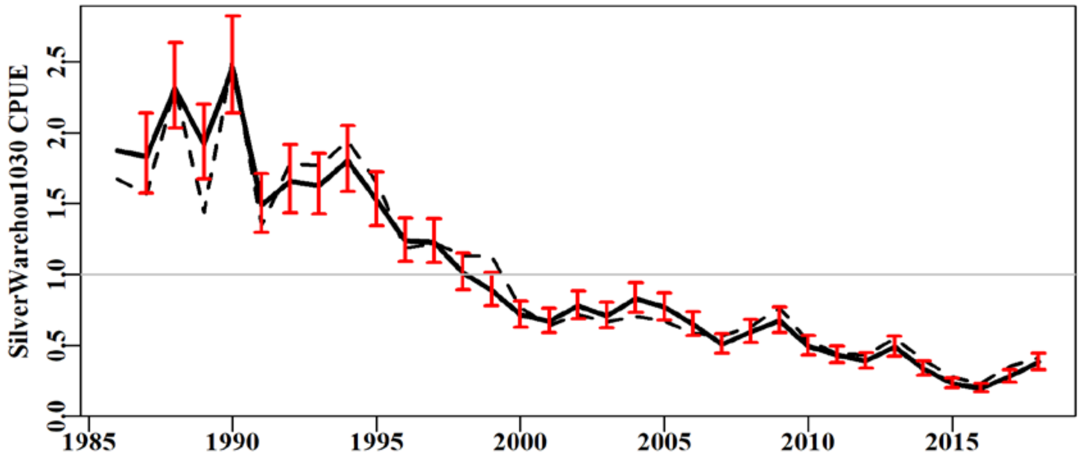

Figure 5.72. SilverWarehou1030 standardization. The dashed black line represents the geometric mean catch rate, solid black line the standardized catch rates. The red bars are the 95% confidence intervals about the mean estimates. The graph scales both time-series of standardized catch rates relative to the mean of each time-series.

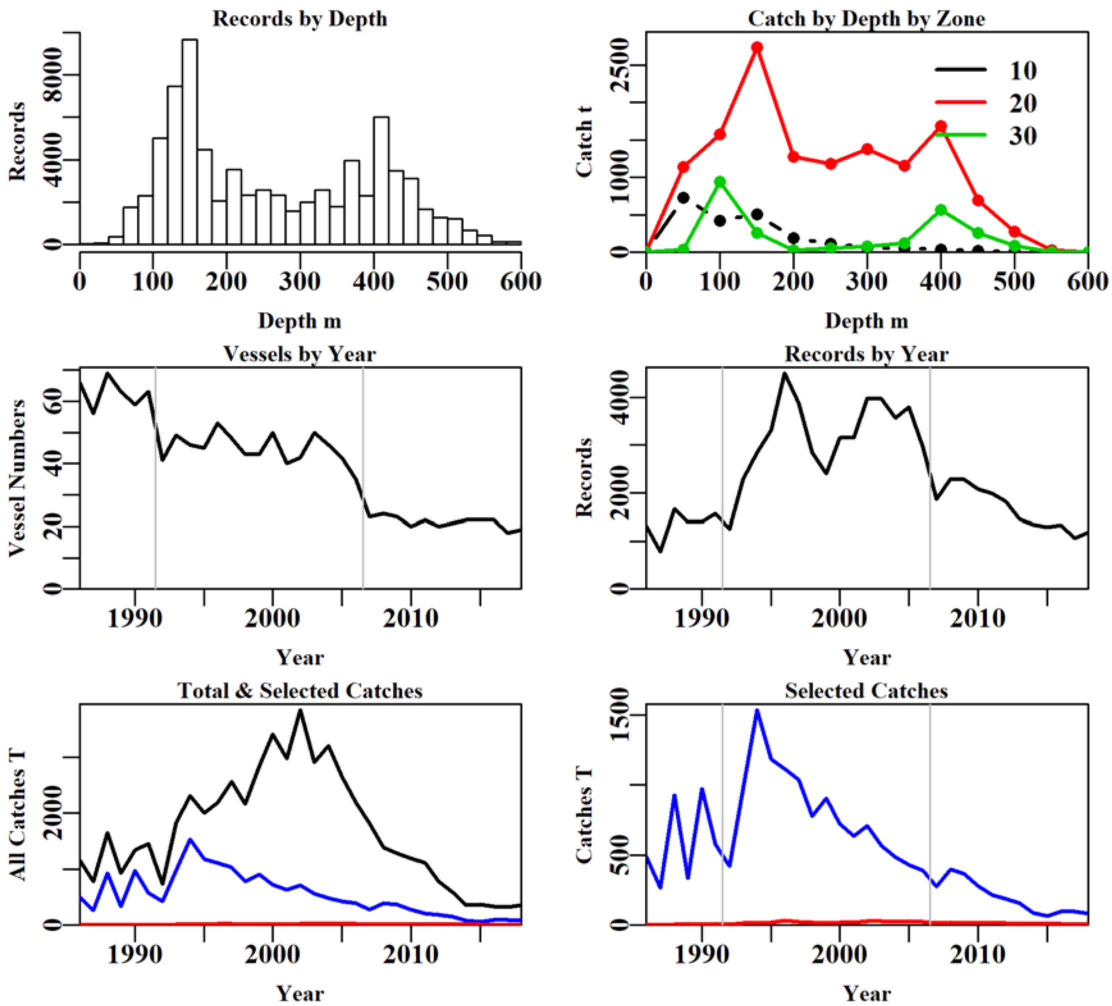

Figure 5.73. SilverWarehou1030 fishery details. The bottom left plot depicts all known catches (top black line), and all selected catches used in the analysis (middle blue line); the lower red line: selected catches < 30 kg).

Table 5.53. SilverWarehou1030 data selection effects. Total is the total number of records in the database, NoCE removes those records with either missing catch or effort, and then only those records are kept that meet the criteria for depth, years, zone, method and fishery.

	Total	NoCE	Depth	Years	Zones	Method	Fishery
Records	156012	151416	147103	145621	77583	76148	76050
Difference	0	4596	4313	1482	68038	1435	98
Catch	55420.11	54931.82	53221.53	52781.80	18265.51	17795.89	17774.61
Difference	0	488.29	1710.28	439.73	34516.29	469.63	21.28

Table 5.54. The models used to analyse data for SilverWarehou1030.

	Model
Model1	Year
Model2	Year + Vessel
Model3	Year + Vessel + Month
Model4	Year + Vessel + Month + DepCat
Model5	Year + Vessel + Month + DepCat + Zone
Model6	Year + Vessel + Month + DepCat + Zone + DayNight
Model7	Year + Vessel + Month + DepCat + Zone + DayNight + Zone:Month
Model8	Year + Vessel + Month + DepCat + Zone + DayNight + Zone:DepCat

Table 5.55. SilverWarehou1030. The row names are 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_r2) and the change in adjusted R^2 (%Change). The optimum model was Zone:DepCat.

	AIC	RSS	MSS	Nobs	Npars	adj_r2	%Change
Year	84927	232117	22155	76050	33	8.7	0.00
Vessel	78543	212404	41869	76050	216	16.2	7.55
Month	74810	202170	52102	76050	227	20.3	4.02
DepCat	73677	199119	55154	76050	239	21.4	1.19
Zone	73436	198480	55793	76050	241	21.7	0.25
DayNight	73427	198440	55832	76050	244	21.7	0.01
Zone:Month	72471	195846	58427	76050	266	22.7	1.00
Zone:DepCat	72407	195678	58595	76050	267	22.8	1.07

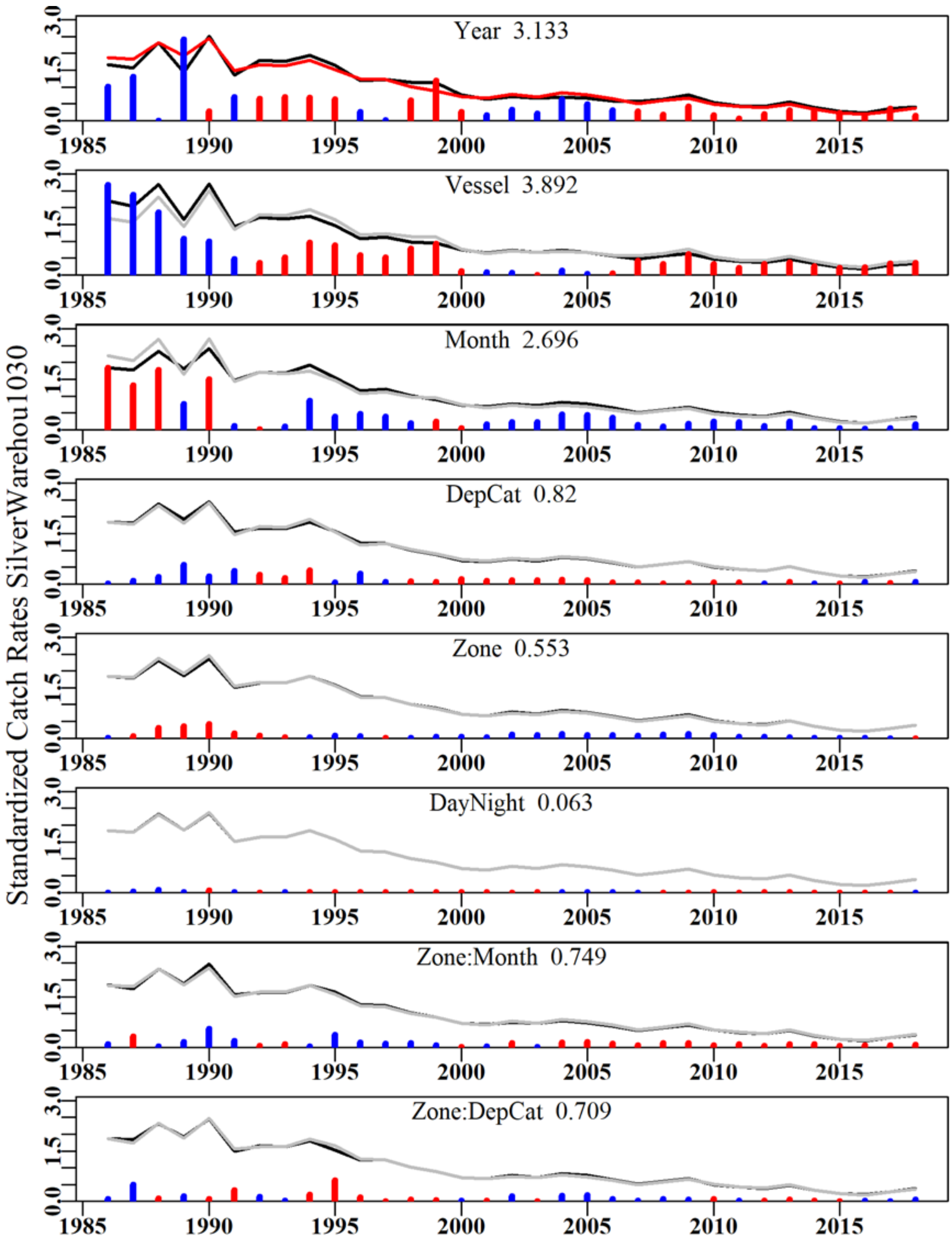

Figure 5.74. SilverWarehou1030. The influence of each factor on the optimal standardization. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by vertical bars with blue bars indicating the optimum model is higher than the 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.

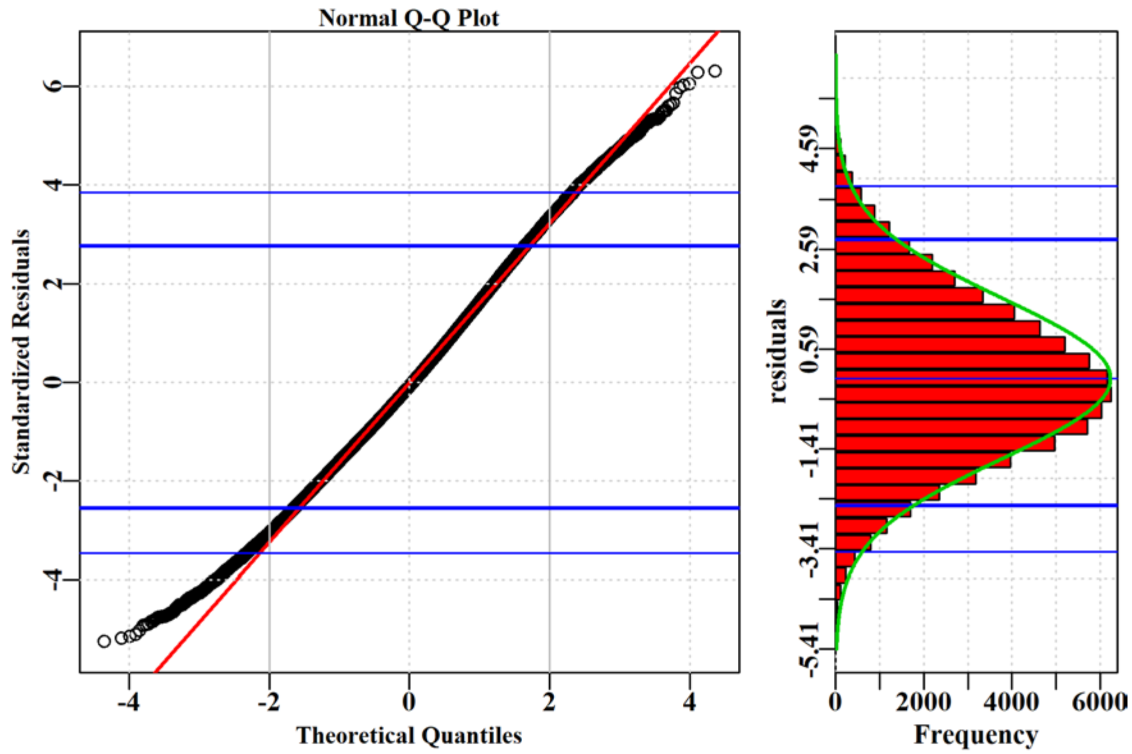

Figure 5.75. SilverWarehou1030. diagnostic plots. The distribution of residuals from the optimum fit. The qqplot indicates the fit to the expected normality, while the histogram of residuals illustrates the 90% quantiles to indicate the intensity of any lack of fit at the margins of the distribution.

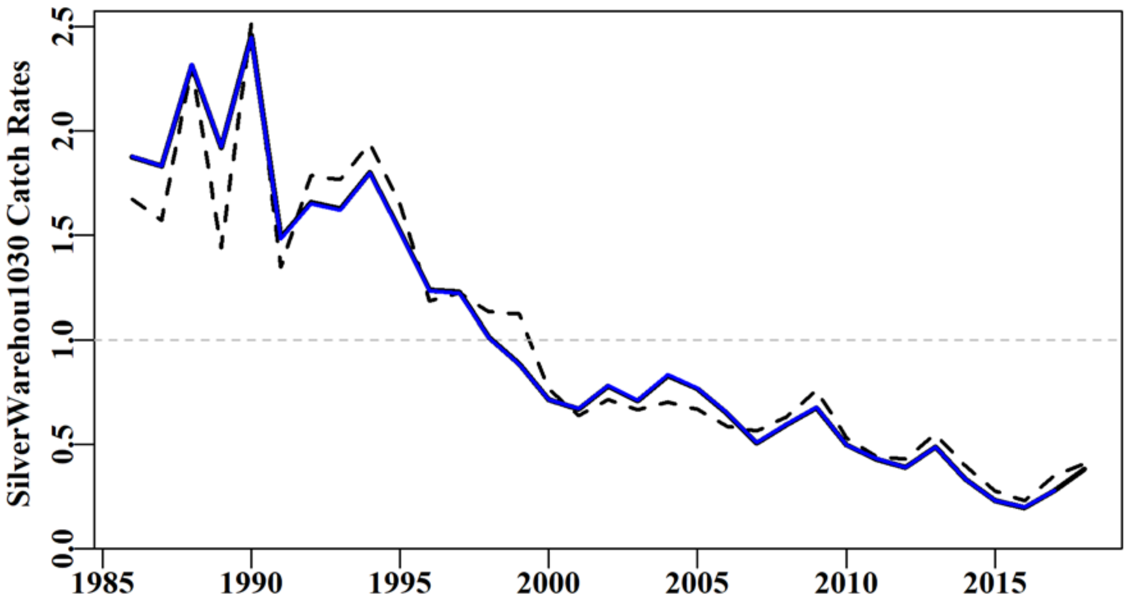

Figure 5.76. SilverWarehou1030. A comparison of the previous year's standardization (blue line) with this year's. They should lie on top of each other, although small deviations may relate to data adjustments, particularly in very recent years.

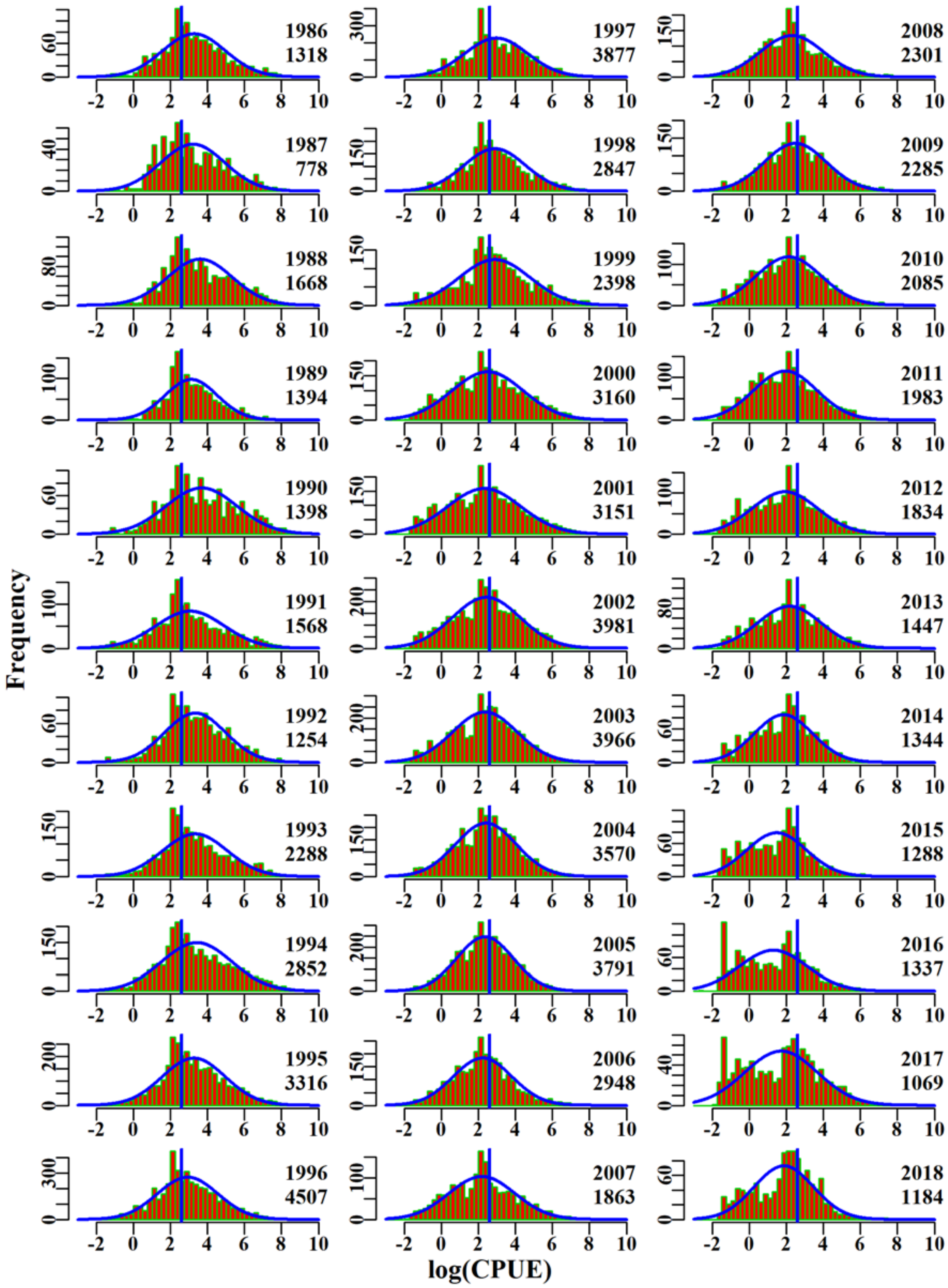

Figure 5.77. SilverWarehou1030. The natural log(CPUE) for each year of data available the blue lines are normal distributions fitted to the histogram frequencies. The numbers in each plot are the year and number of records.

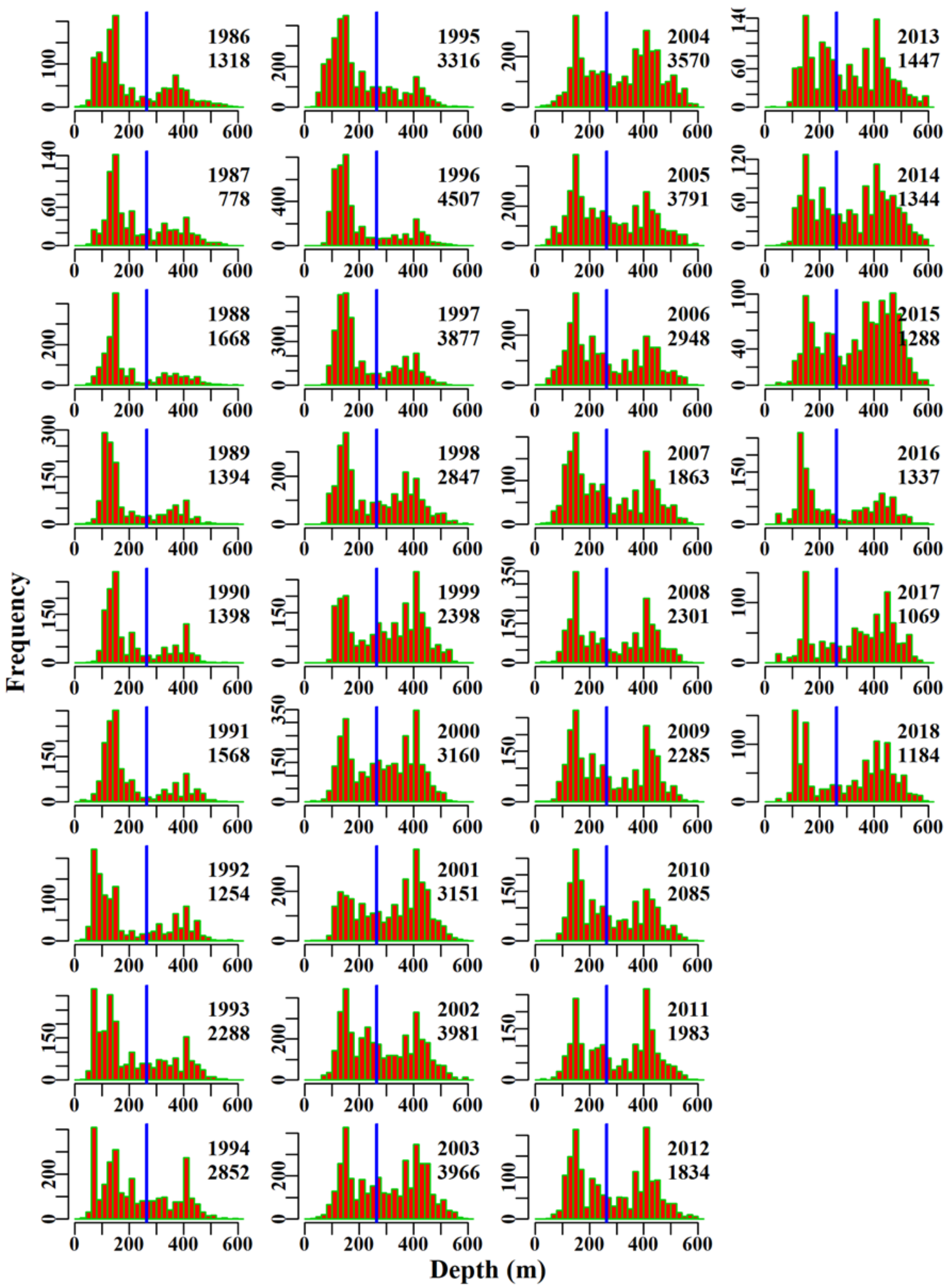

Figure 5.78. SilverWarehou1030. The average Depth of fishing for each year of data available to illustrate the development of the fishery through time. The numbers in each plot are the year and number of records.

5.15 Flathead TW 30

Tiger Flathead (FLT – 37296001 – *Neoplatycephalus richardsoni*) was one of the 16 species first included in the quota system in 1992, which reflects its long history within the SESSF. The additional generic flathead group code was added as a result of a change in recording Tiger Flathead as 37296000 (Platycephalidae) in electronic logbooks since 2013. Trawl caught flathead based on methods TW, TDO, OTT, TMO, in zones 30, and depths 0 to 300 within the SET fishery for the years 1986 - 2018 were analysed (Table 5.56). A total of 7 statistical models were fitted sequentially to the available data, with the order of the non-interaction terms added based on the relative contribution of each term to model fit.

5.15.1 *Inferences*

The amount of flathead (*Neoplatycephalus richardsoni* and Platycephalidae) catch in shots <30 kg in zone 30 is small across the analysis period.

The terms Year, Vessel, DepCat, DayNight, Month and one interaction term (Month:DepCat) had the greatest contribution to model fit, with the remaining terms each explaining < 1% of the overall variation in CPUE, based on the AIC and R^2 statistics. The qqplot suggests a small departure of the assumed Normal distribution as depicted by the lower tail of the distribution.

The annual standardized CPUE trend was noisy and flat between 1986 - 2001, and after a transitional period between 2002 - 2006 during which catches surged, was noisy and flat from 2007 to 2018 (Figure 5.79). In more recent years catches have been increasing again.

5.15.2 *Action Items and Issues*

The number of records and corresponding catch in 1986 and 1987 are very low. Also, the depth distribution is spread over a large range for these two years compared to all other years in the fishery. It is therefore recommended to remove these two years from the time series for analysis.

Table 5.56. FlatheadTW30. The data selection criteria used to specify and identify the fishery data to be included in the analysis.

Property	Value
label	FlatheadTW30
csirocode	37296001, 37296000
fishery	SET
depthrange	0 - 300
depthclass	20
zones	30
methods	TW, TDO, OTT, TMO
years	1986 - 2018

Table 5.57. FlatheadTW30. Total catch (Total; t) is the total reported in the database, number of records used in the analysis (N), reported catch (Catch; t) in the area and depth used in the analysis and number of vessels used in the analysis (Vess). GeoM is the geometric mean of catch rates (kg/hr), standard deviation (StDev) relates to the optimum model. C<30Kg denotes the amount of catch in shots of <30kg, and %<30Kg is the percent of total. The optimum model was Month:DepCat.

	Total	N	Catch	Vess	GeoM	Opt	StDev	C<30Kg	P<30Kg
1986	1892.2	70	16.7	6	67.0	0.9347	0.000	0.571	0.034
1987	2461.3	87	5.0	9	18.5	0.5687	0.192	0.985	0.196
1988	2469.5	191	39.9	9	53.1	0.9572	0.173	1.272	0.032
1989	2599.1	515	48.4	19	29.4	0.7056	0.165	3.760	0.078
1990	2032.3	248	23.4	27	34.0	0.7060	0.167	1.925	0.082
1991	2230.2	302	32.0	29	28.2	0.6682	0.163	2.614	0.082
1992	2375.4	267	33.5	15	37.6	0.6390	0.167	1.428	0.043
1993	1879.1	891	91.1	24	30.3	0.5984	0.159	6.341	0.070
1994	1710.4	608	64.2	17	31.6	0.6218	0.160	4.671	0.073
1995	1800.6	690	71.0	17	31.4	0.6983	0.160	6.187	0.087
1996	1879.9	713	61.4	17	26.7	0.6374	0.160	6.916	0.113
1997	2356.0	877	104.5	14	42.9	0.7924	0.159	5.243	0.050
1998	2306.4	700	118.2	14	55.9	0.9440	0.159	2.918	0.025
1999	3117.7	769	174.8	17	68.3	1.0559	0.160	3.464	0.020
2000	2945.6	512	83.5	20	50.1	0.8695	0.161	2.501	0.030
2001	2599.5	927	102.3	17	31.6	0.7328	0.158	4.949	0.048
2002	2876.3	1360	211.6	15	46.8	1.3397	0.157	5.332	0.025
2003	3229.9	1443	237.2	21	47.2	1.3809	0.156	3.920	0.017
2004	3222.8	1913	475.7	15	80.2	1.8667	0.156	3.784	0.008
2005	2844.1	1508	383.5	18	77.8	1.6984	0.156	3.731	0.010
2006	2585.8	1299	285.1	13	60.3	1.3764	0.157	2.395	0.008
2007	2648.3	808	170.3	8	64.1	1.1150	0.159	1.834	0.011
2008	2912.3	851	165.9	10	60.3	1.0479	0.159	2.624	0.016
2009	2460.5	590	98.9	10	49.9	1.0302	0.160	1.393	0.014
2010	2502.3	499	101.8	10	58.5	1.0081	0.161	1.737	0.017
2011	2465.9	614	128.8	9	64.5	0.9668	0.160	1.478	0.011
2012	2780.6	702	151.5	9	58.9	1.2107	0.159	1.048	0.007
2013	1941.0	828	190.8	11	65.6	1.1713	0.159	2.406	0.013
2014	2369.9	752	180.4	11	67.6	1.3479	0.159	1.213	0.007
2015	2667.9	1159	290.8	13	69.3	1.2654	0.158	2.088	0.007
2016	2775.5	1557	330.9	12	59.8	1.0769	0.157	6.682	0.020
2017	2311.7	1294	290.6	10	62.3	1.1634	0.158	3.304	0.011
2018	2000.8	1188	212.8	12	46.2	0.8042	0.158	3.601	0.017

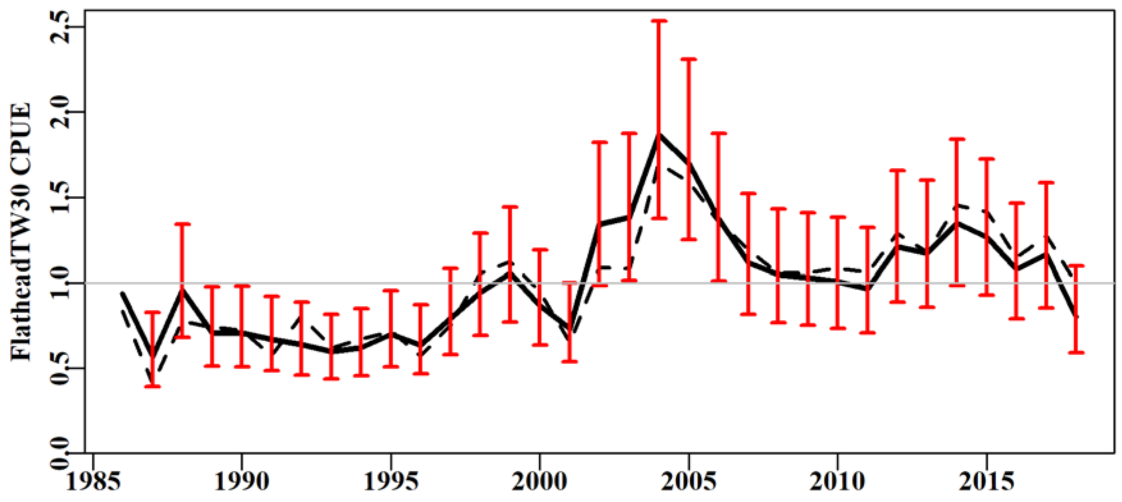

Figure 5.79. FlatheadTW30 standardization. The dashed black line represents the geometric mean catch rate, solid black line the standardized catch rates. The red bars are the 95% confidence intervals about the mean estimates. The graph scales both time-series of standardized catch rates relative to the mean of each time-series.

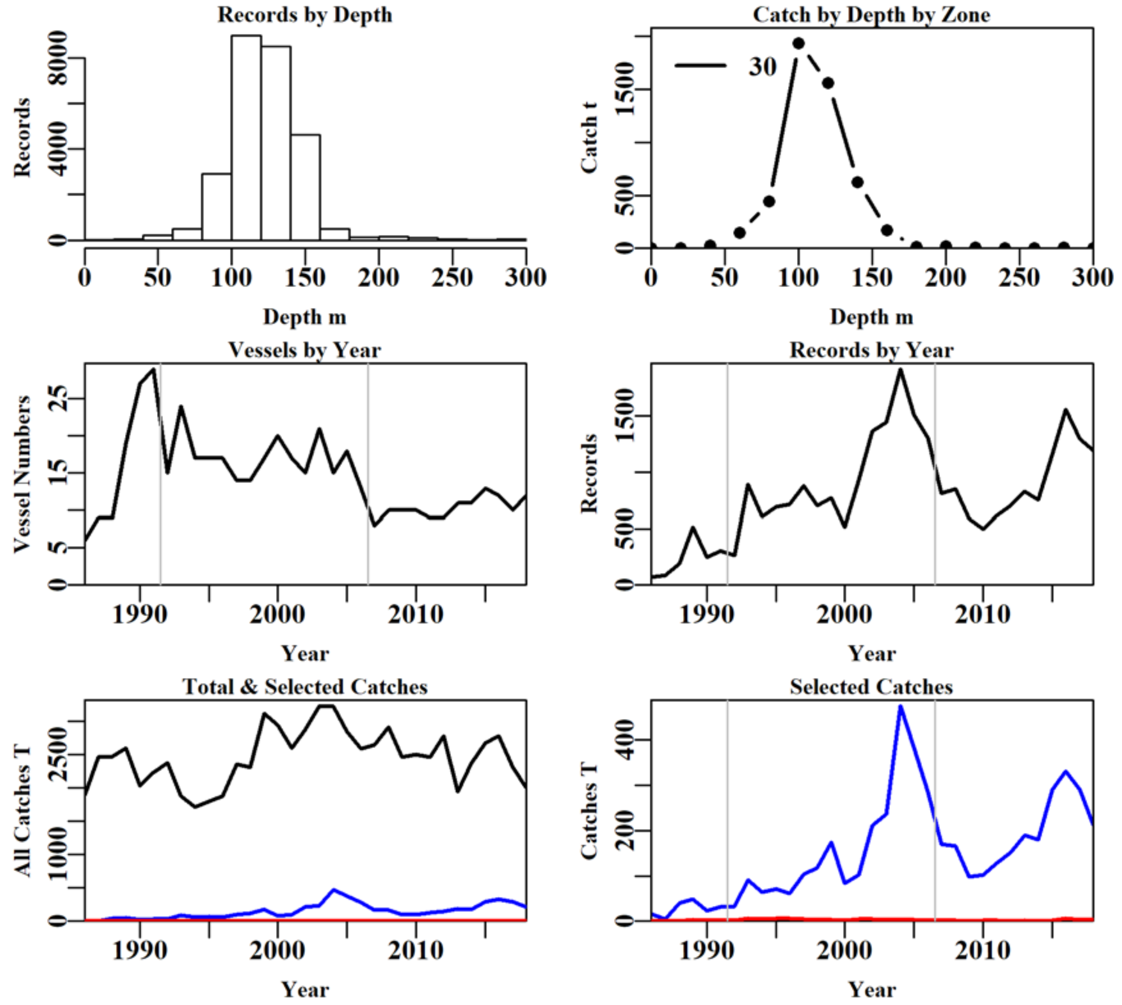

Figure 5.80. FlatheadTW30 fishery details. The bottom left plot depicts all known catches (top black line), and all selected catches used in the analysis (middle blue line); the lower red line: selected catches < 30 kg).

Table 5.58. FlatheadTW30 data selection effects. Total is the total number of records in the database, NoCE removes those records with either missing catch or effort, and then only those records are kept that meet the criteria for depth, years, zone, method and fishery.

	Total	NoCE	Depth	Years	Zones	Method	Fishery
Records	630293	541591	527589	518194	28121	26735	26732
Difference	0	88702	14002	9395	490073	1386	3
Catch	82344.13	71996.98	70647.31	69580.39	5243.11	4977.11	4976.69
Difference	0	10347.15	1349.67	1066.92	64337.28	266.01	0.42

Table 5.59. The models used to analyse data for FlatheadTW30.

	Model
Model1	Year
Model2	Year + Vessel
Model3	Year + Vessel + DepCat
Model4	Year + Vessel + DepCat + DayNight
Model5	Year + Vessel + DepCat + DayNight + Month
Model6	Year + Vessel + DepCat + DayNight + Month + Month:DepCat
Model7	Year + Vessel + DepCat + DayNight + Month + DayNight:Month

Table 5.60. FlatheadTW30. The row names are 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_r2) and the change in adjusted R^2 (%Change). The optimum model was Month:DepCat.

	AIC	RSS	MSS	Nobs	Npars	adj_r2	%Change
Year	3759	30692	2464	26732	33	7.3	0.00
Vessel	1776	28296	4861	26732	128	14.3	6.93
DepCat	538	26986	6171	26732	143	18.2	3.92
DayNight	313	26753	6404	26732	146	18.9	0.70
Month	17	26437	6719	26732	157	19.8	0.92
Month:DepCat	-623	25537	7620	26732	300	22.1	2.31
DayNight:Month	-25	26348	6808	26732	181	20.0	0.20

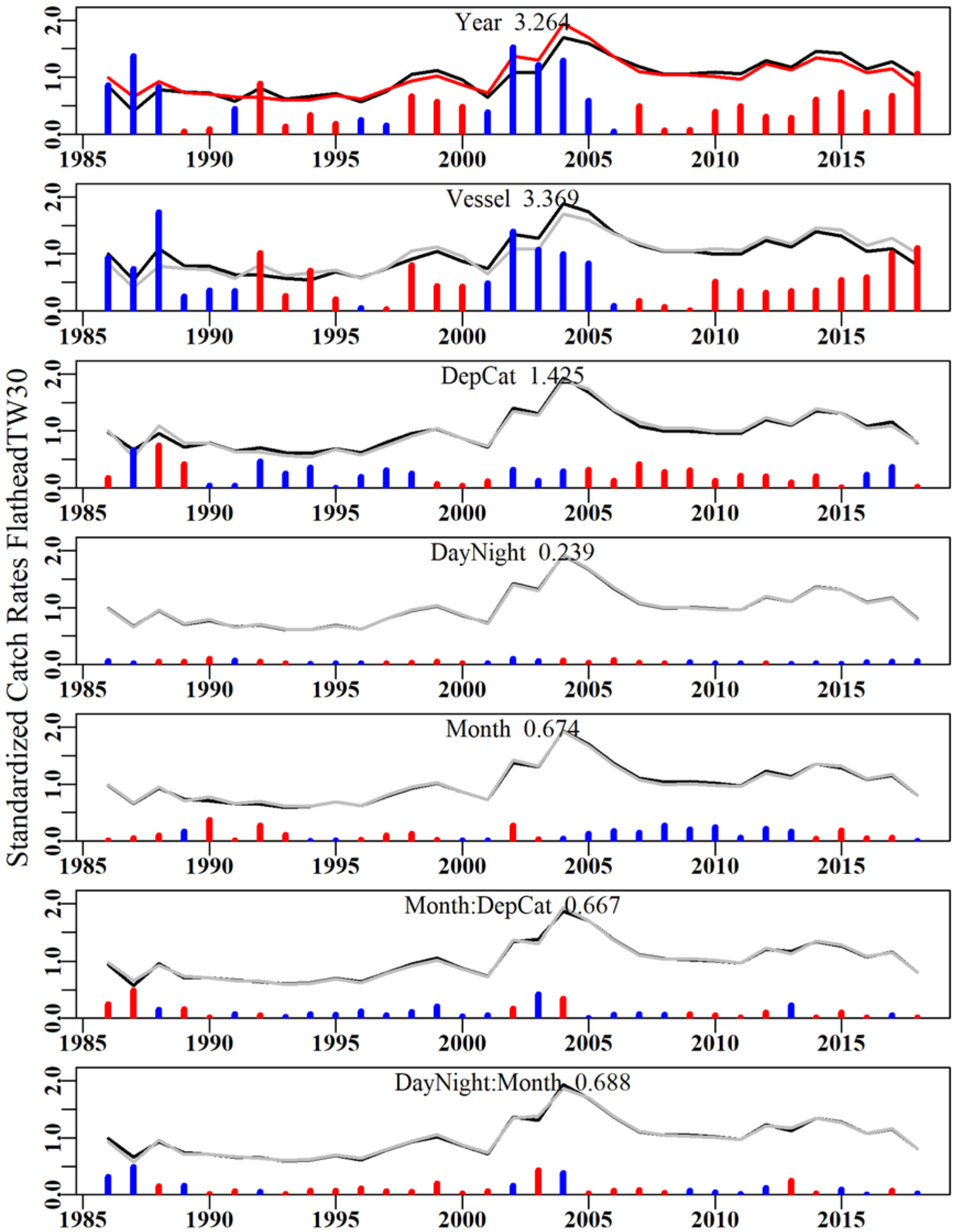

Figure 5.81. FlatheadTW30. The influence of each factor on the optimal standardization. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by vertical bars with blue bars indicating the optimum model is higher than the geometric 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.

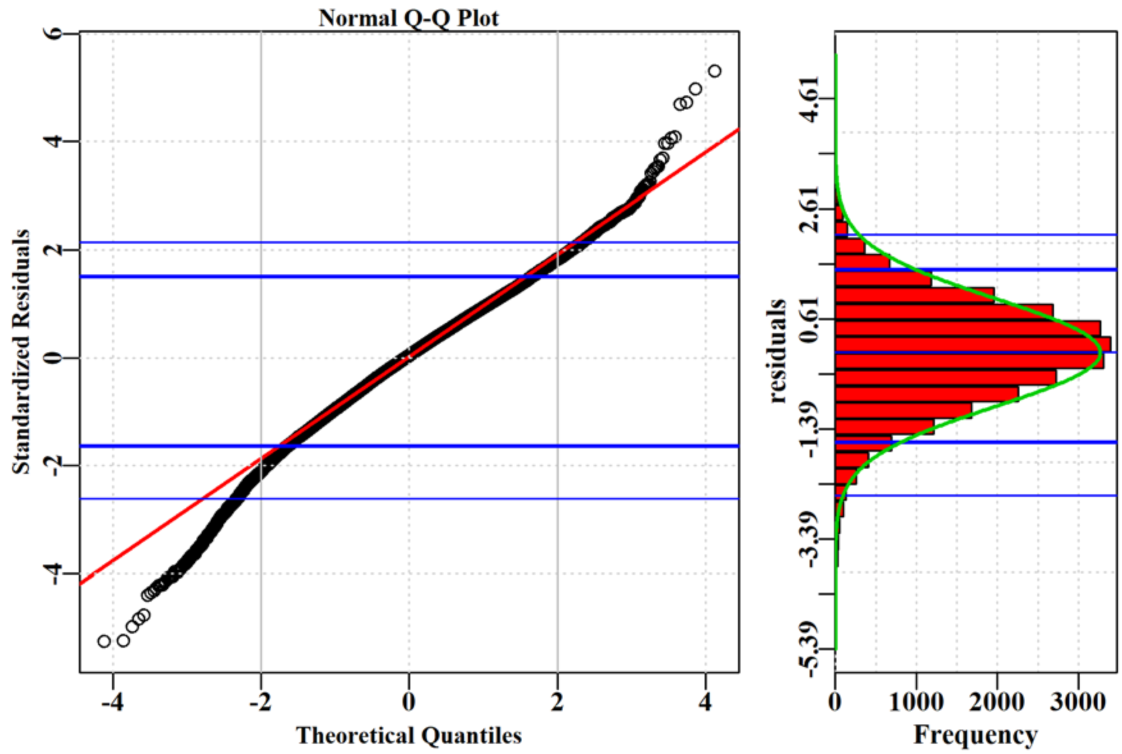

Figure 5.82. FlatheadTW30. diagnostic plots. The distribution of residuals from the optimum fit. The qqplot indicates the fit to the expected normality, while the histogram of residuals illustrates the 90% quantiles to indicate the intensity of any lack of fit at the margins of the distribution.

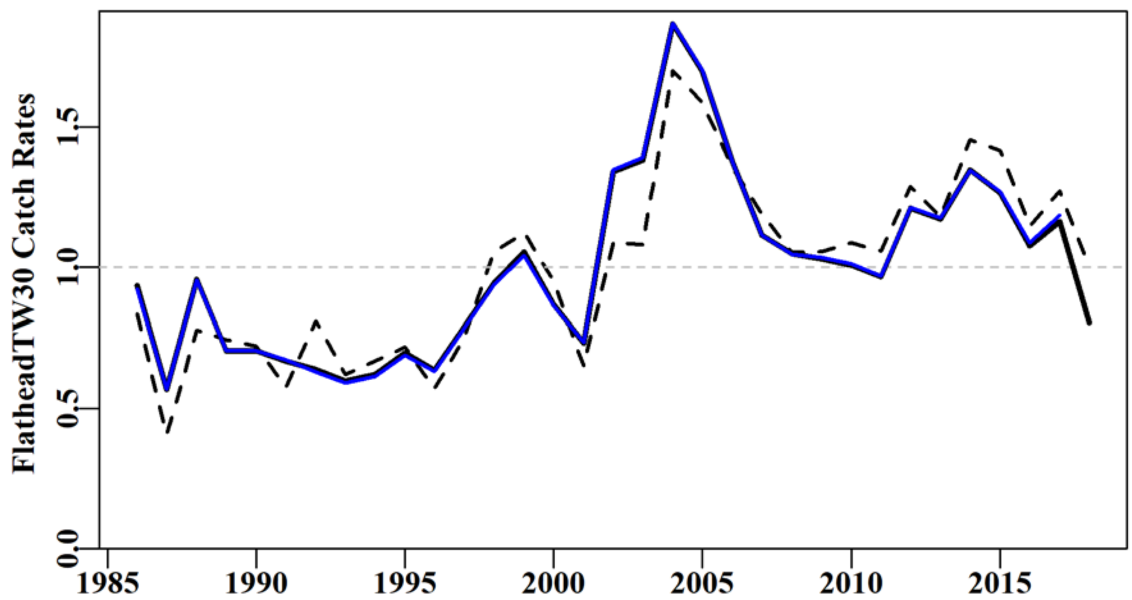

Figure 5.83. FlatheadTW30. A comparison of the previous year's standardization (blue line) with this year's. They should lie on top of each other, although small deviations may relate to data adjustments, particularly in very recent years.

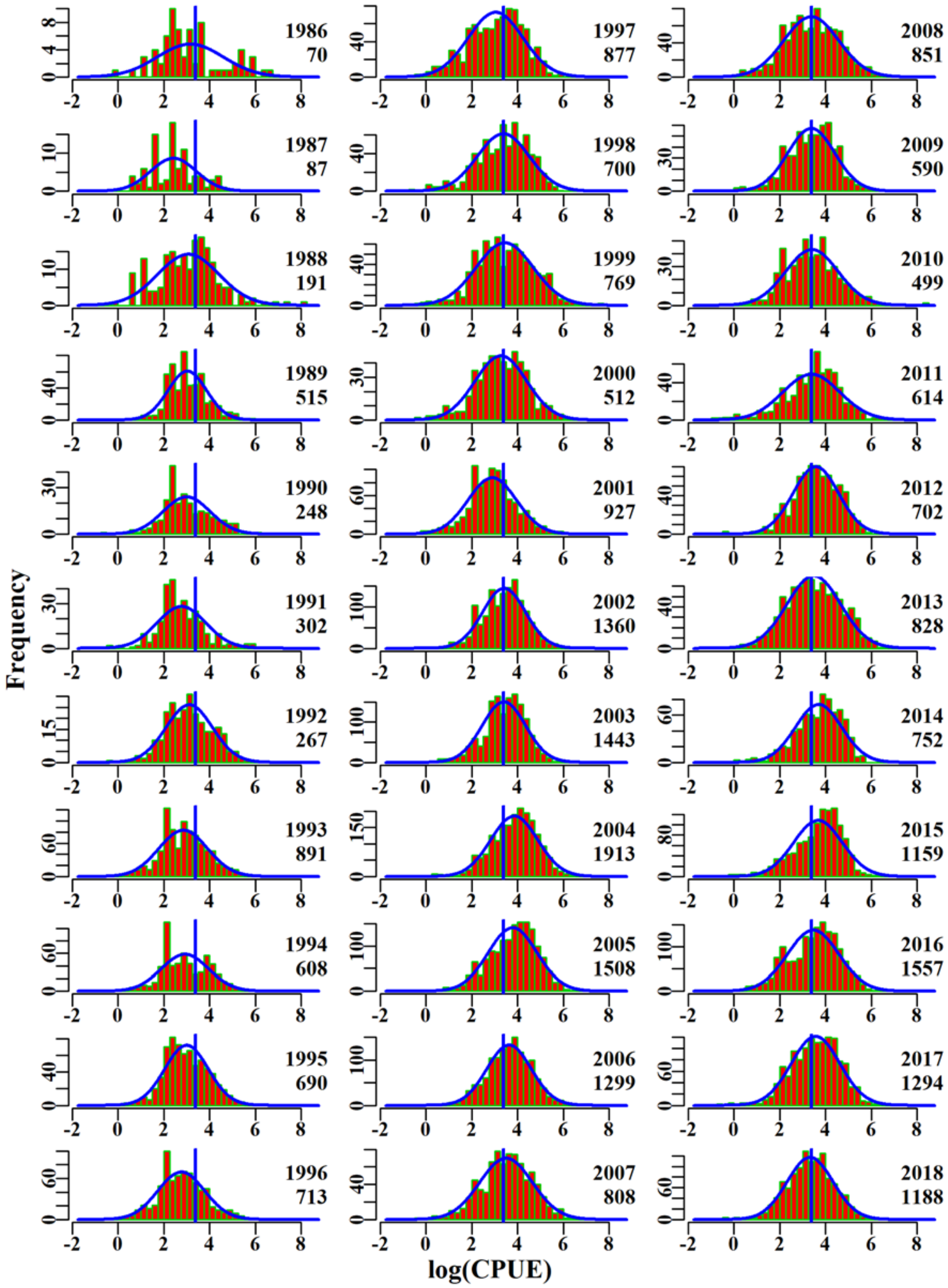

Figure 5.84. FlatheadTW30. The natural log(CPUE) for each year of data available the blue lines are normal distributions fitted to the histogram frequencies. The numbers in each plot are the year and number of records.

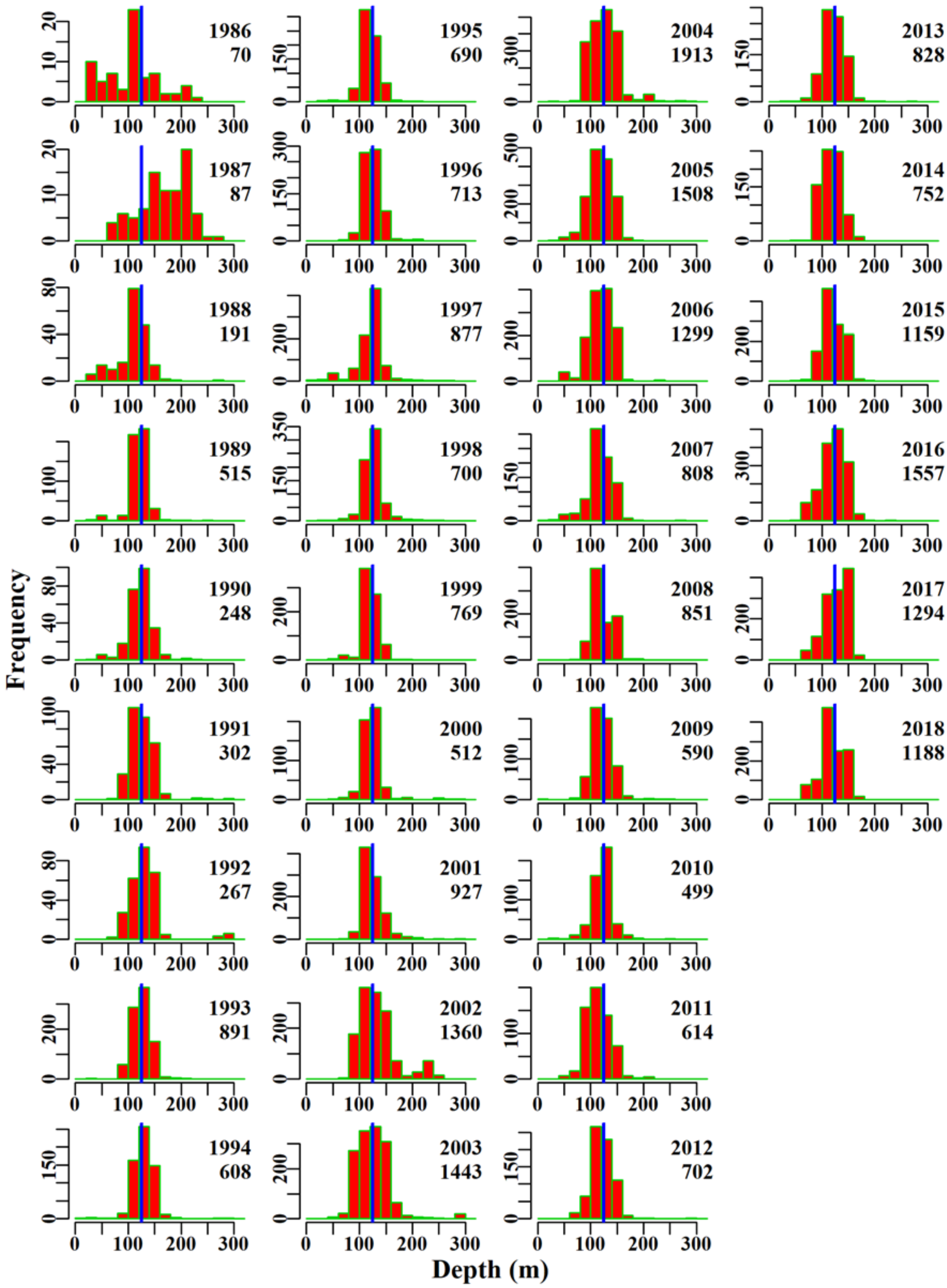

Figure 5.85. FlatheadTW30. The average Depth of fishing for each year of data available to illustrate the development of the fishery through time. The numbers in each plot are the year and number of records.

5.16 Flathead TW 10 – 20

Tiger Flathead (FLT – 37296001 – *Neoplatycephalus richardsoni*) was one of the 16 species first included in the quota system in 1992, which reflects its long history within the SESSF. The additional generic flathead group code was added as a result of a change in recording Tiger Flathead as 37296000 (Platycephalidae) in electronic logbooks since 2013. Trawl caught flathead based on methods TW, TDO, OTT, TMO, in zones 10, 20, and depths 0 to 400 within the SET fishery for the years 1986 - 2018 were analysed (Table 5.61). A total of 8 statistical models were fitted sequentially to the available data, with the order of the non-interaction terms added based on the relative contribution of each term to model fit.

5.16.1 *Inferences*

The amount of Flathead (*Neoplatycephalus richardsoni* and Platycephalidae) catch in shots <30 kg from zone 10 and 20 is small across the analysis period. Most flathead were caught in zone 10 followed by 20.

The terms Year, Vessel and DepCat had the greatest contribution to model fit, with the remaining terms each explaining < 1% of the overall variation in CPUE, based on the AIC and R^2 statistics. The qqplot suggests a small departure of the assumed Normal distribution as depicted by the lower tail of the distribution (Figure 5.89).

Annual standardized CPUE appears cyclical above and below average and has remained below average since 2017 (Figure 5.86). The structural adjustment had a profound effect upon the influence of the vessel factor reducing the standardized trend well below the nominal geometric mean CPUE.

5.16.2 *Action Items and Issues*

After consideration of Tiger Flathead catches in the east by year and vessel for the period around 1992 - 2006 appears to be different from catches by vessel from 2007. This suggests that there have been transitional periods in the time-series of CPUE. This **urgently** needs more attention because of the potential implications this has for the index of relative abundance through time.

Table 5.61. FlatheadTW1020. The data selection criteria used to specify and identify the fishery data to be included in the analysis.

Property	Value
label	FlatheadTW1020
csirocode	37296001, 37296000
fishery	SET
depthrange	0 - 400
depthclass	20
zones	10, 20
methods	TW, TDO, OTT, TMO
years	1986 - 2018

Table 5.62. FlatheadTW1020. Total catch (Total; t) is the total reported in the database, number of records used in the analysis (N), reported catch (Catch; t) in the area and depth used in the analysis and number of vessels used in the analysis (Vess). GeoM is the geometric mean of catch rates (kg/hr), standard deviation (StDev) relates to the optimum model. C<30Kg denotes the amount of catch in shots of <30kg, and %<30Kg is the percent of total. The optimum model was Zone:DepCat.

	Total	N	Catch	Vess	GeoM	Opt	StDev	C<30Kg	P<30Kg
1986	1892.2	10185	962.2	94	31.6	0.8007	0.000	64.431	0.067
1987	2461.3	8056	1004.2	86	41.6	1.0671	0.016	43.737	0.044
1988	2469.5	9149	1169.2	86	42.2	1.1680	0.016	47.288	0.040
1989	2599.1	8802	1206.0	74	44.8	1.1685	0.016	46.430	0.038
1990	2032.3	7701	1212.0	64	52.3	1.3918	0.017	27.684	0.023
1991	2230.2	7733	1134.5	57	52.0	1.3097	0.017	30.378	0.027
1992	2375.4	6860	894.8	54	43.9	1.0334	0.017	29.864	0.033
1993	1879.1	8639	982.2	57	38.8	1.0476	0.017	38.094	0.039
1994	1710.4	10190	894.7	55	29.9	0.7605	0.016	62.692	0.070
1995	1800.6	10232	985.2	54	31.6	0.8031	0.016	65.863	0.067
1996	1879.9	10984	952.3	58	29.3	0.7158	0.016	75.637	0.079
1997	2356.0	10265	988.7	61	31.2	0.7171	0.016	64.965	0.066
1998	2306.4	9953	996.8	52	32.5	0.7581	0.016	63.008	0.063
1999	3117.7	10338	1124.7	57	36.2	0.9150	0.016	56.799	0.051
2000	2945.6	12859	1641.8	60	51.9	1.0067	0.015	62.596	0.038
2001	2599.5	11659	1307.3	52	39.4	0.9701	0.016	52.699	0.040
2002	2876.3	12364	1447.6	49	39.3	1.0530	0.016	55.469	0.038
2003	3229.9	12794	1583.8	52	41.4	1.0389	0.015	58.188	0.037
2004	3222.8	12155	1336.5	52	36.4	0.9040	0.016	62.849	0.047
2005	2844.1	10588	1143.5	49	34.2	0.7764	0.016	62.412	0.055
2006	2585.8	9072	1138.0	45	40.2	0.9400	0.016	43.946	0.039
2007	2648.3	6280	1067.2	25	55.1	1.1402	0.018	21.678	0.020
2008	2912.3	7194	1307.6	27	56.3	1.2005	0.018	26.303	0.020
2009	2460.5	6214	1037.7	26	51.4	1.1085	0.018	22.375	0.022
2010	2502.3	6685	1086.7	25	49.2	1.0686	0.018	25.062	0.023
2011	2465.9	6605	1070.4	24	52.4	1.0539	0.018	23.777	0.022
2012	2780.6	6795	1149.3	25	54.6	1.1600	0.018	25.865	0.023
2013	1941.0	5587	682.8	24	37.4	0.8776	0.019	25.723	0.038
2014	2369.9	6337	943.4	25	46.0	1.0301	0.018	22.647	0.024
2015	2667.9	6358	983.6	30	48.4	1.1597	0.018	15.754	0.016
2016	2775.5	5905	888.8	27	49.1	1.0627	0.019	15.983	0.018
2017	2311.7	5345	713.8	24	43.0	0.8791	0.019	19.043	0.027
2018	2000.8	5148	715.9	25	41.5	0.9138	0.020	16.023	0.022

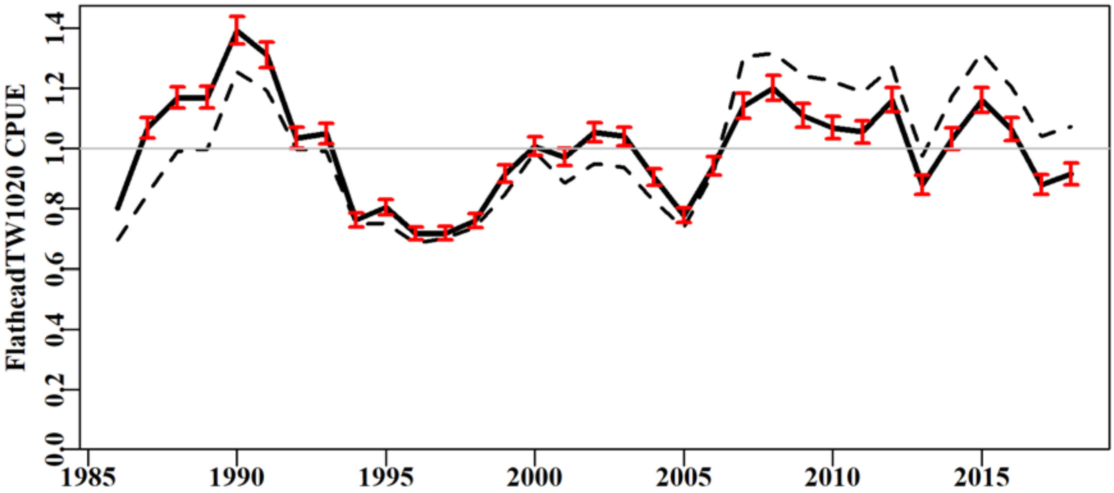

Figure 5.86. FlatheadTW1020 standardization. The dashed black line represents the geometric mean catch rate, solid black line the standardized catch rates. The red bars are the 95% confidence intervals about the mean estimates. The graph scales both time-series of standardized catch rates relative to the mean of each time-series.

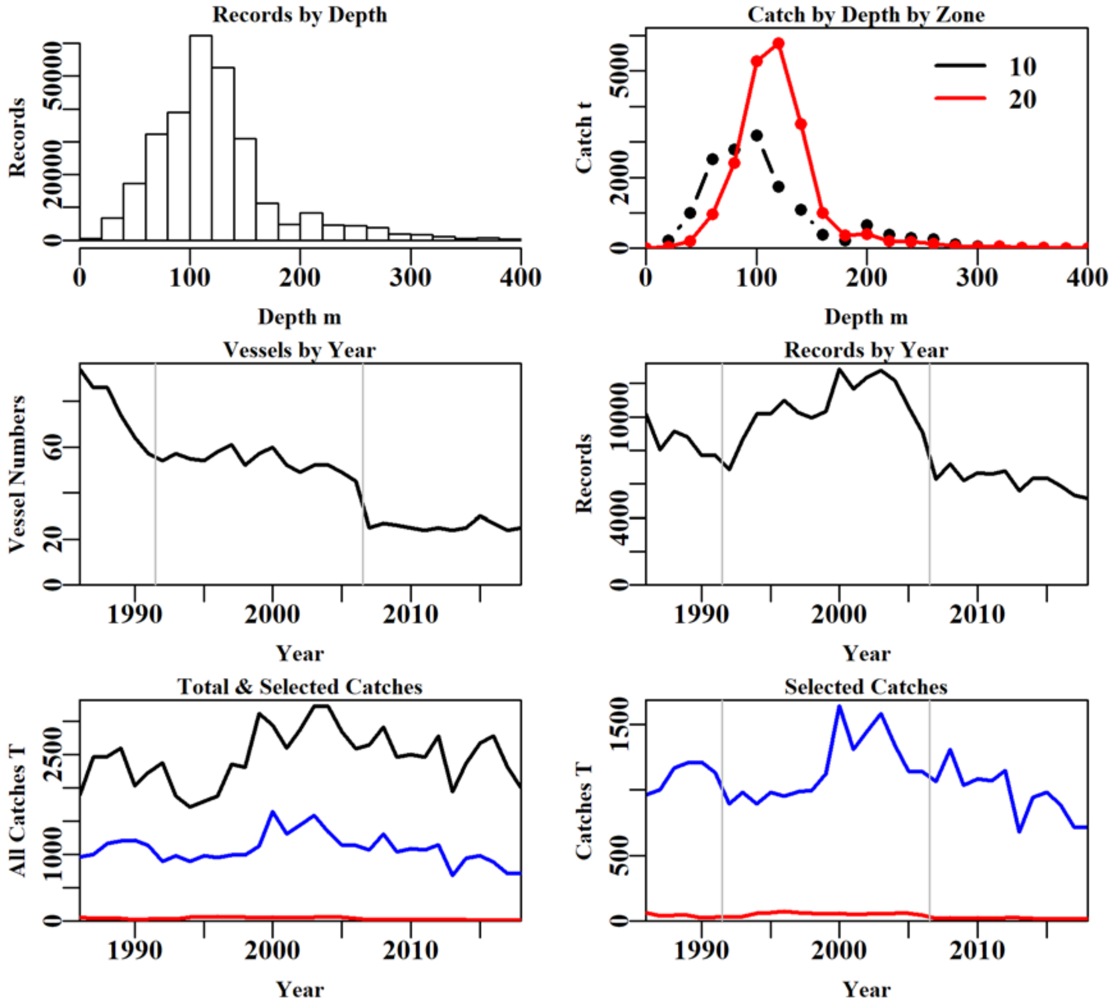

Figure 5.87. FlatheadTW1020 fishery details. The bottom left plot depicts all known catches (top black line), and all selected catches used in the analysis (middle blue line); the lower red line: selected catches < 30 kg).

Table 5.63. FlatheadTW1020 data selection effects. Total is the total number of records in the database, NoCE removes those records with either missing catch or effort, and then only those records are kept that meet the criteria for depth, years, zone, method and fishery.

	Total	NoCE	Depth	Years	Zones	Method	Fishery
Records	630293	541591	534258	524739	364269	285335	285031
Difference	0	88702	7333	9519	160470	78934	304
Catch	82344.13	71996.98	71112.85	70036.49	53139.5	35789.06	35753.39
Difference	0	10347.15	884.13	1076.35	16897.0	17350.44	35.67

Table 5.64. The models used to analyse data for FlatheadTW1020.

	Model
Model1	Year
Model2	Year + Vessel
Model3	Year + Vessel + DepCat
Model4	Year + Vessel + DepCat + Month
Model5	Year + Vessel + DepCat + Month + DayNight
Model6	Year + Vessel + DepCat + Month + DayNight + Zone
Model7	Year + Vessel + DepCat + Month + DayNight + Zone + Zone:Month
Model8	Year + Vessel + DepCat + Month + DayNight + Zone + Zone:DepCat

Table 5.65. FlatheadTW1020. The row names are 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_r2) and the change in adjusted R^2 (%Change). The optimum model was Zone:DepCat.

	AIC	RSS	MSS	Nobs	Npars	adj_r2	%Change
Year	44341	332930	11794	285031	33	3.4	0.00
Vessel	13672	298575	46148	285031	220	13.3	9.91
DepCat	5007	289594	55130	285031	240	15.9	2.60
Month	4116	288668	56055	285031	251	16.2	0.27
DayNight	3701	288242	56482	285031	254	16.3	0.12
Zone	3643	288182	56542	285031	255	16.3	0.02
Zone:Month	1308	285808	58915	285031	266	17.0	0.69
Zone:DepCat	733	285214	59509	285031	275	17.2	0.86

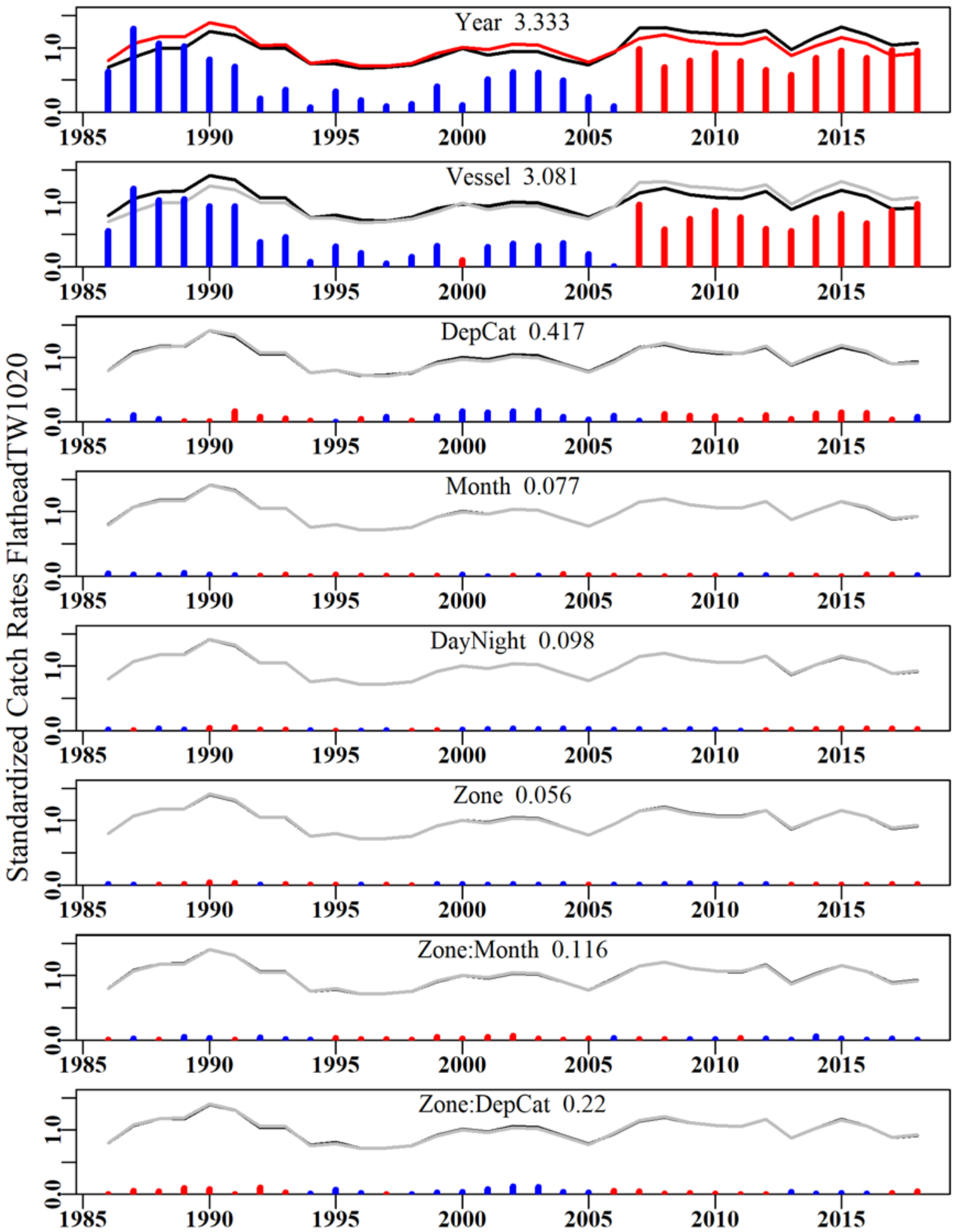

Figure 5.88. FlatheadTW1020. The influence of each factor on the optimal standardization. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by vertical bars with blue bars indicating the optimum model is higher than the 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.

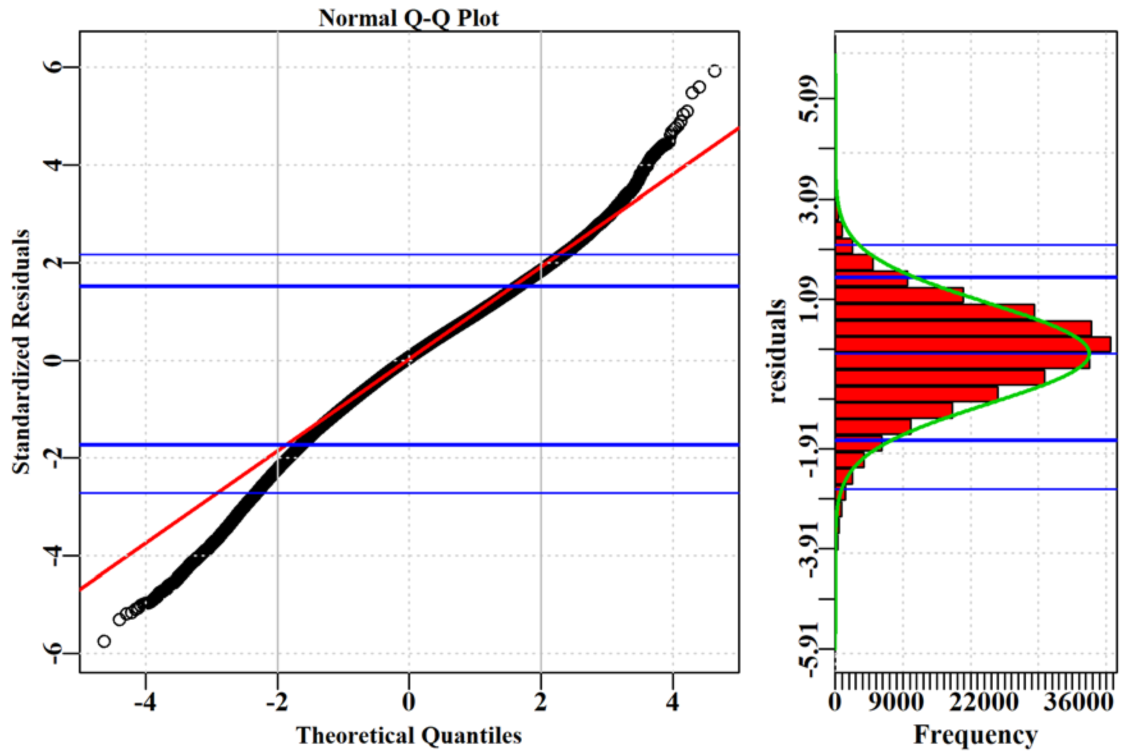

Figure 5.89. FlatheadTW1020. diagnostic plots. The distribution of residuals from the optimum fit. The qqplot indicates the fit to the expected normality, while the histogram of residuals illustrates the 90% quantiles to indicate the intensity of any lack of fit at the margins of the distribution.

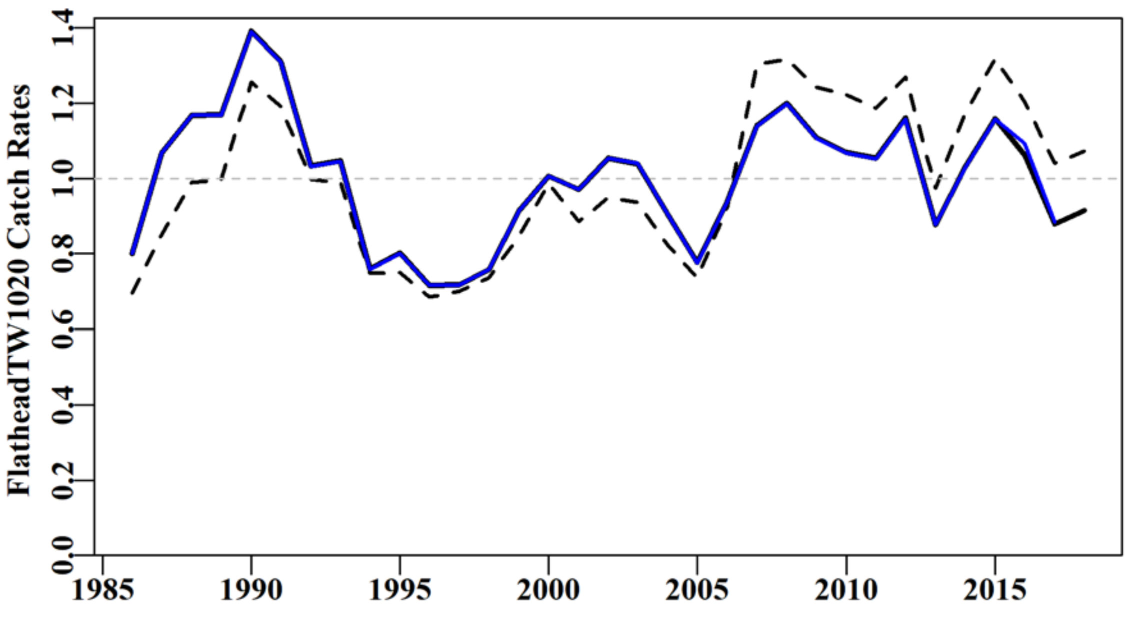

Figure 5.90. FlatheadTW1020. A comparison of the previous year's standardization (blue line) with this year's. They should lie on top of each other, although small deviations may relate to data adjustments, particularly in very recent years.

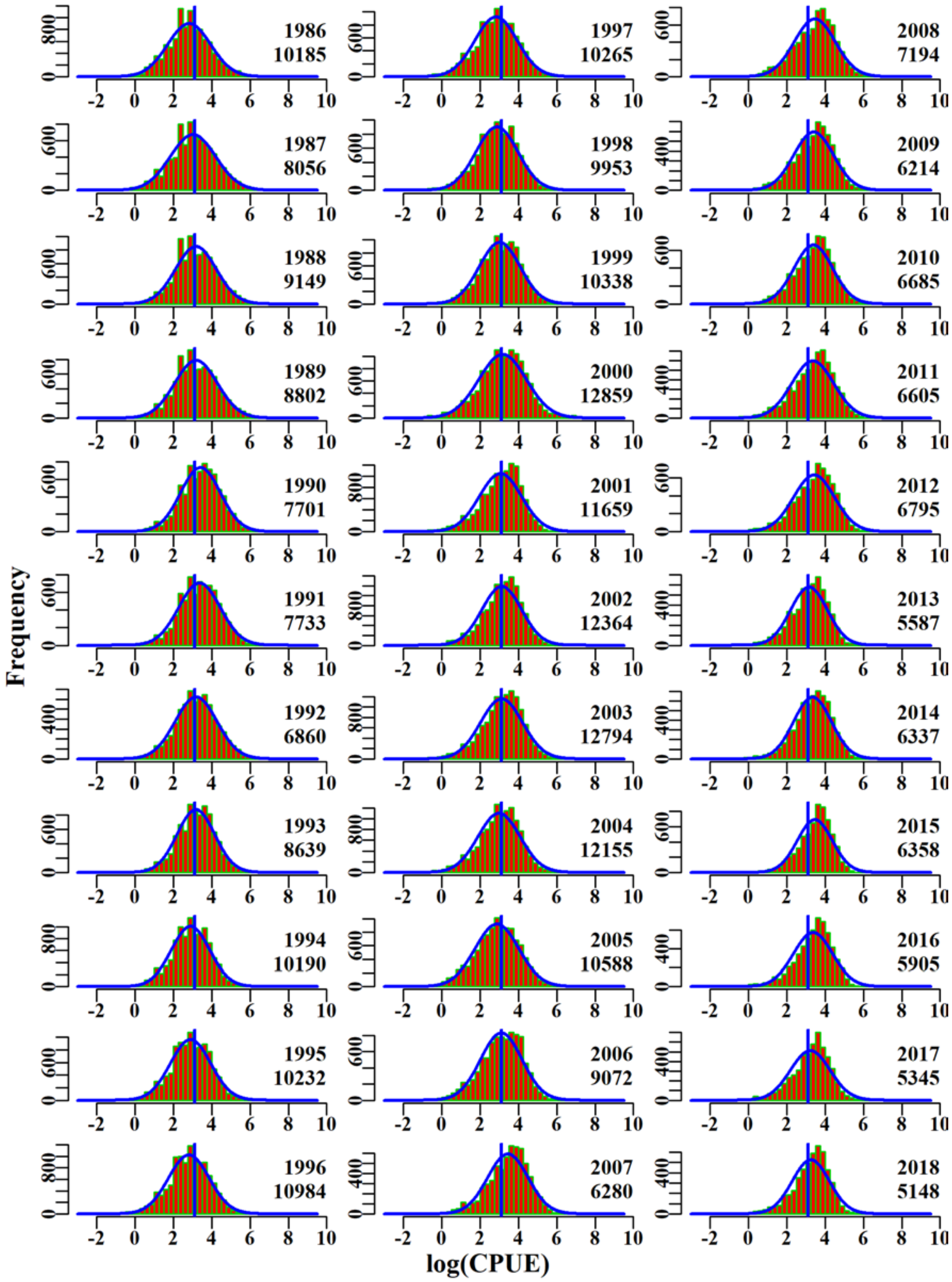

Figure 5.91. FlatheadTW1020. The natural log(CPUE) for each year of data available the blue lines are normal distributions fitted to the histogram frequencies. The numbers in each plot are the year and number of records.

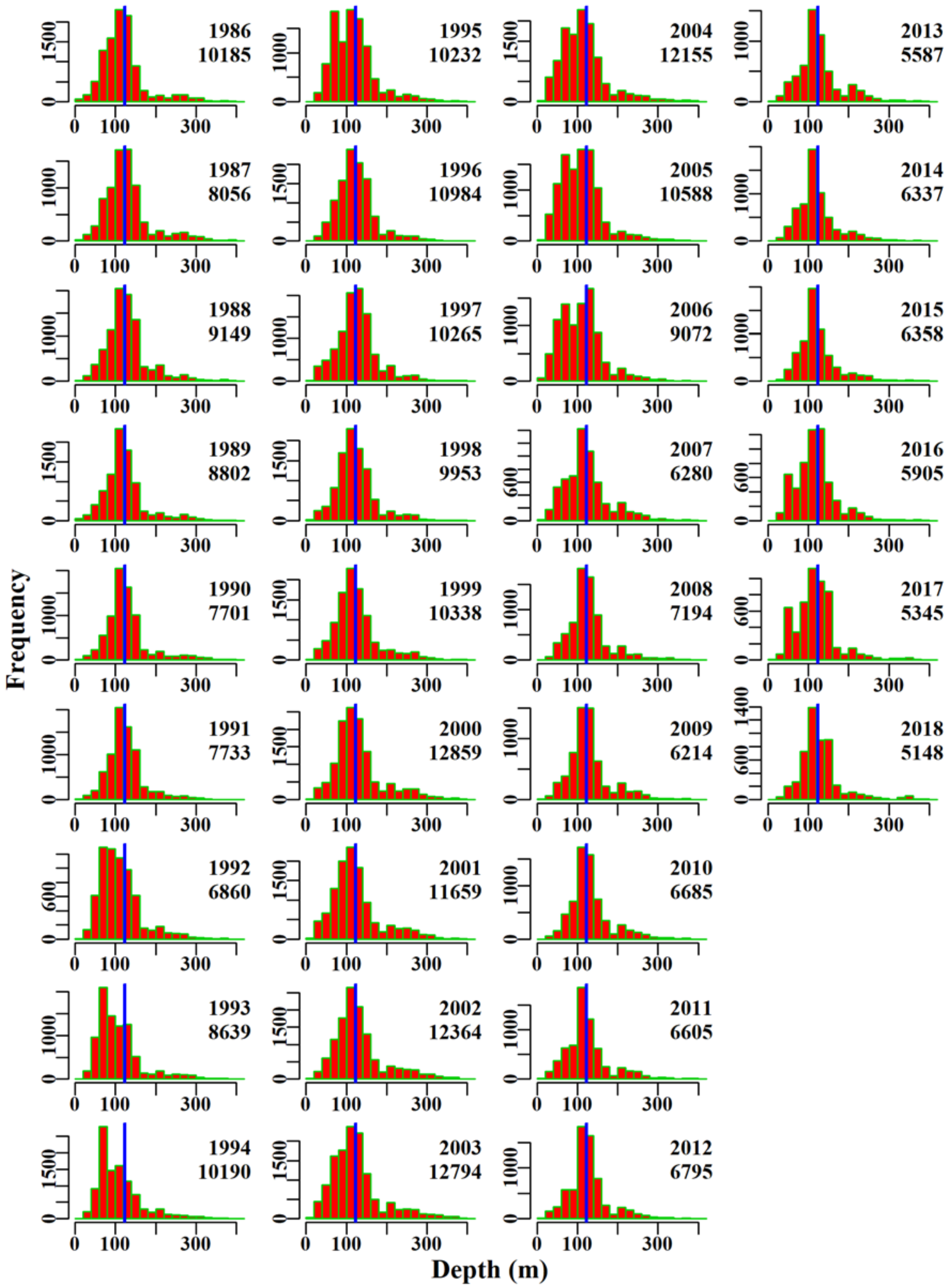

Figure 5.92. FlatheadTW1020. The average Depth of fishing for each year of data available to illustrate the development of the fishery through time. The numbers in each plot are the year and number of records.

5.17 FlatheadDS2060

Tiger Flathead (FLT – 37296001 – *Neoplatycephalus richardsoni*) was one of the 16 species first included in the quota system in 1992, which reflects its long history within the SESSF. The additional generic flathead group code was added as a result of a change in recording Tiger Flathead as 37296000 (Platycephalidae) in electronic logbooks since 2013. Danish seine caught flathead based on methods DS, in zones 20, 60, and depths 0 to 200 within the SET fishery for the years 1986 - 2018 were analysed (Table 5.66). The unit of analysis was catch/shot. A total of 8 statistical models were fitted sequentially to the available data, with the order of the non-interaction terms added based on the relative contribution of each term to model fit.

5.17.1 *Inferences*

Flathead (*Neoplatycephalus richardsoni* and Platycephalidae) taken by Danish Seine are caught in shallower depths in zone 60 compared to zone 20 (Figure 5.94), with a shift to deeper waters becoming apparent from 1997 onwards which may be related to which vessels were fishing.

The terms Year, DepCat, Month, Vessel, DayNight and one interaction term (Zone:Month) had the greatest contribution to model fit, with the remaining terms each explaining < 1% of the overall variation in CPUE, based on the AIC and R^2 statistics. The qqplot suggests a departure of the assumed Normal distribution as depicted by the lower tail of the distribution.

Some vessels have remained in this fishery since 1986 with significant catches, while other vessels have left following the structural adjustment in 2007 and not returned. Annual standardized CPUE appears cyclical above and below average and has remained above average since 2015 (Figure 5.93).

5.17.2 *Action Items and Issues*

It is recommended that an exploration of the fishery dynamics be evaluated to determine whether the CPUE values are being influenced by the species being targeted within individual shots (e.g. is there interference between shots catching mostly flathead compared to shots catching mostly School Whiting?). This will be important for determining whether estimated annual indices adequately reflect stock abundance.

Table 5.66. FlatheadDS2060. The data selection criteria used to specify and identify the fishery data to be included in the analysis.

Property	Value
label	FlatheadDS2060
csirocode	37296001, 37296000
fishery	SET
depthrange	0 - 200
depthclass	20
zones	20, 60
methods	DS
years	1986 - 2018

Table 5.67. FlatheadDS2060. Total catch (Total; t) is the total reported in the database, number of records used in the analysis (N), reported catch (Catch; t) in the area and depth used in the analysis and number of vessels used in the analysis (Vess). GeoM is the geometric mean of catch rates (kg/hr), standard deviation (StDev) relates to the optimum model. C<30Kg denotes the amount of catch in shots of <30kg, and %<30Kg is the percent of total. The optimum model was Zone:Month.

	Total	N	Catch	Vess	GeoM	Opt	StDev	C<30Kg	P<30Kg
1986	1892.2	5469	759.8	26	207.0	1.1123	0.000	26.255	0.035
1987	2461.3	5532	1340.9	23	352.7	1.5651	0.024	25.075	0.019
1988	2469.5	5745	1074.7	25	268.3	1.7082	0.023	21.449	0.020
1989	2599.1	5384	1138.0	27	297.1	1.4892	0.024	27.184	0.024
1990	2032.3	4462	568.1	24	157.2	0.9999	0.025	28.665	0.050
1991	2230.2	4463	746.5	28	215.7	1.3621	0.025	24.633	0.033
1992	2375.4	6488	1193.7	23	233.4	1.4277	0.023	27.658	0.023
1993	1879.1	5906	531.6	25	114.0	0.8820	0.024	40.217	0.076
1994	1710.4	7162	632.8	24	124.9	0.7631	0.023	40.569	0.064
1995	1800.6	5420	648.6	21	204.7	0.7798	0.024	24.806	0.038
1996	1879.9	7508	742.7	22	139.0	0.7329	0.023	44.616	0.060
1997	2356.0	8279	1136.0	20	192.2	0.9572	0.022	37.876	0.033
1998	2306.4	9800	1126.5	21	147.9	0.8096	0.022	48.033	0.043
1999	3117.7	8669	1679.4	23	269.0	1.1704	0.022	25.632	0.015
2000	2945.6	7295	1079.7	19	199.3	0.8738	0.023	32.454	0.030
2001	2599.5	7781	1066.4	19	196.4	0.8211	0.023	32.654	0.031
2002	2876.3	8124	1130.0	22	182.0	0.9752	0.023	31.327	0.028
2003	3229.9	8871	1186.6	23	168.5	1.0117	0.023	30.001	0.025
2004	3222.8	7644	1234.5	22	194.6	1.0027	0.023	24.994	0.020
2005	2844.1	7008	1104.9	22	184.3	1.0167	0.023	22.184	0.020
2006	2585.8	5461	950.5	21	233.5	0.9976	0.025	15.784	0.017
2007	2648.3	5472	1160.9	15	293.4	1.2135	0.025	14.892	0.013
2008	2912.3	6118	1261.6	15	280.1	1.0918	0.024	18.042	0.014
2009	2460.5	5433	1153.0	15	318.0	1.1256	0.025	17.949	0.016
2010	2502.3	5997	1159.0	15	274.1	1.0180	0.024	15.542	0.013
2011	2465.9	6788	1105.0	14	207.9	0.9423	0.024	20.671	0.019
2012	2780.6	7154	1370.7	14	299.4	0.8945	0.024	19.403	0.014
2013	1941.0	7200	929.5	14	168.8	0.6616	0.024	30.599	0.033
2014	2369.9	8327	1160.2	14	186.4	0.7191	0.023	32.787	0.028
2015	2667.9	8619	1311.3	15	196.1	0.7585	0.023	39.398	0.030
2016	2775.5	9247	1468.1	16	205.7	0.7935	0.023	40.806	0.028
2017	2311.7	8602	1107.9	17	164.6	0.7443	0.023	42.395	0.038
2018	2000.8	7942	833.9	18	126.2	0.5790	0.026	45.256	0.054

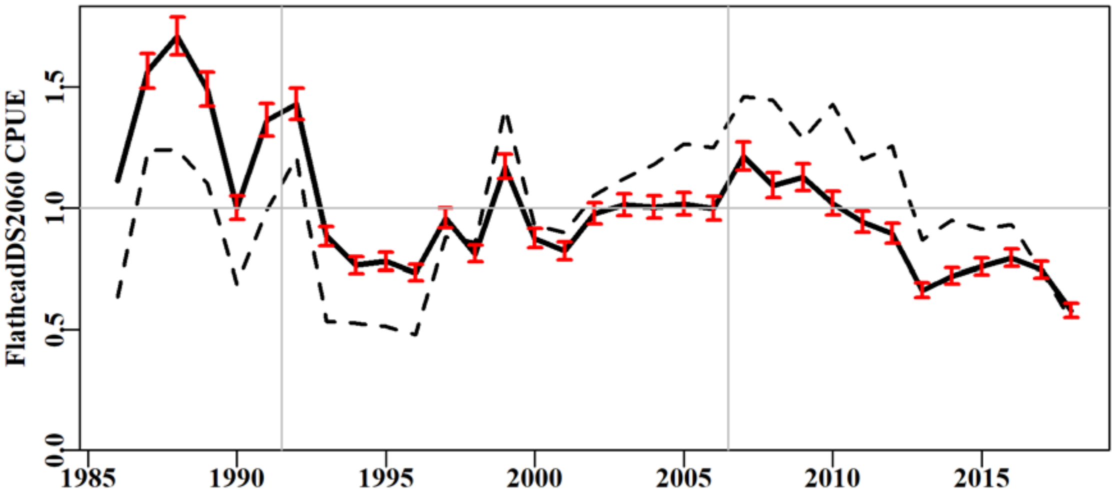

Figure 5.93. FlatheadDS2060 standardization. The dashed black line represents the geometric mean catch rate, solid black line the standardized catch rates. The red bars are the 95% confidence intervals about the mean estimates. The graph scales both time-series of standardized catch rates relative to the mean of each time-series.

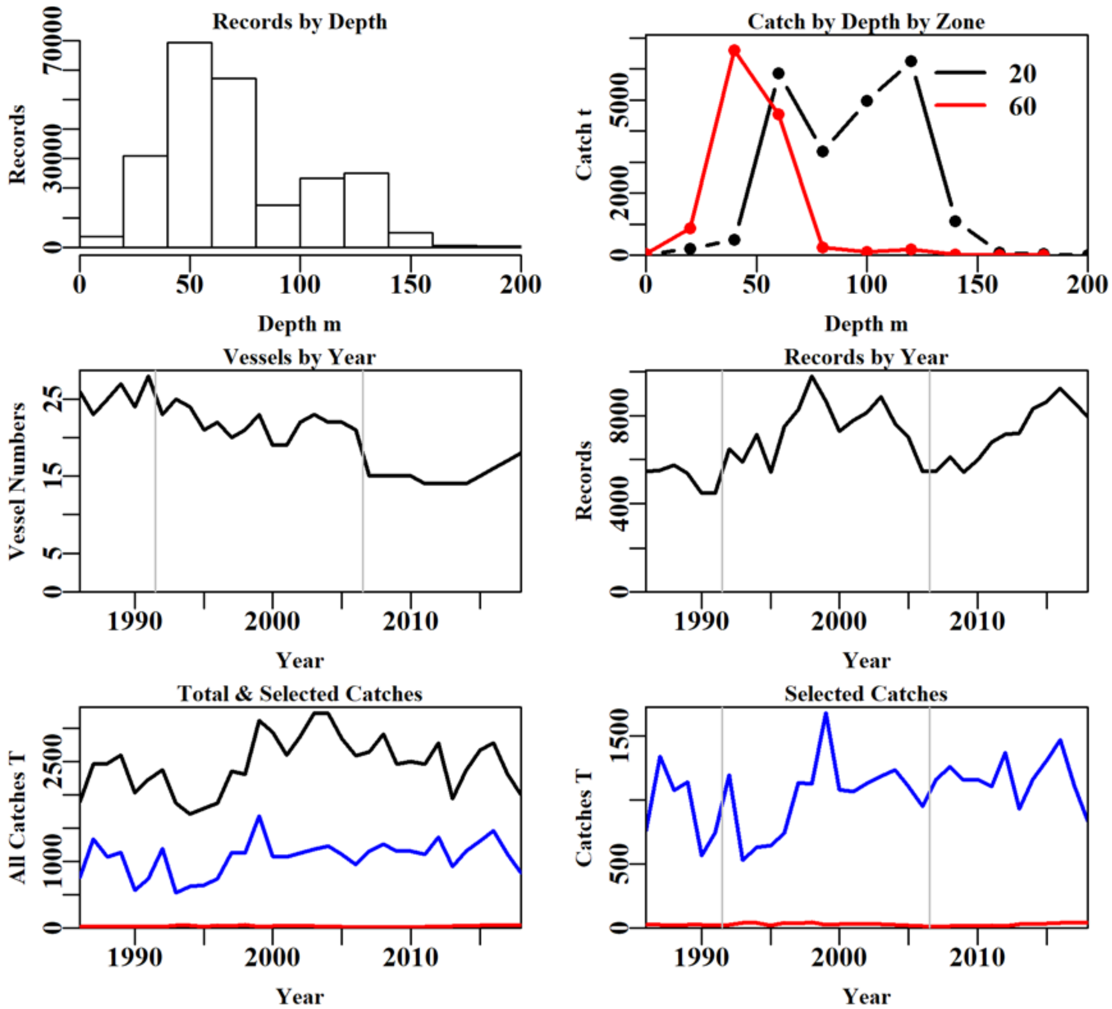

Figure 5.94. FlatheadDS2060 fishery details. The bottom left plot depicts all known catches (top black line), and all selected catches used in the analysis (middle blue line); the lower red line: selected catches < 30 kg).

Table 5.68. FlatheadDS2060 data selection effects. Total is the total number of records in the database, NoCE removes those records with either missing catch or effort, and then only those records are kept that meet the criteria for depth, years, zone, method and fishery.

	Total	NoCE	Depth	Years	Zones	Method	Fishery
Records	630293	616777	572786	563489	361501	231198	229370
Difference	0	13516	43991	9297	201988	130303	1828
Catch	82344.13	82344.13	77664.33	76610.16	55499.63	35158.98	35093.26
Difference	0	0	4679.802	1054.17	21110.53	20340.64	65.73

Table 5.69. The models used to analyse data for FlatheadDS2060.

	Model
Model1	Year
Model2	Year + DepCat
Model3	Year + DepCat + Month
Model4	Year + DepCat + Month + Vessel
Model5	Year + DepCat + Month + Vessel + DayNight
Model6	Year + DepCat + Month + Vessel + DayNight + Zone
Model7	Year + DepCat + Month + Vessel + DayNight + Zone + Zone:Month
Model8	Year + DepCat + Month + Vessel + DayNight + Zone + Zone:DepCat

Table 5.70. FlatheadDS2060. The row names are 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_r2) and the change in adjusted R^2 (%Change). The optimum model was Zone:Month.

	AIC	RSS	MSS	Nobs	Npars	adj_r2	%Change
Year	177971	498179	23645	229370	33	4.5	0.00
DepCat	115839	379932	141891	229370	43	27.2	22.66
Month	103865	360573	161251	229370	54	30.9	3.71
Vessel	90192	339547	182277	229370	108	34.9	4.01
DayNight	85240	332285	189538	229370	111	36.3	1.39
Zone	82603	328485	193339	229370	112	37.0	0.73
Zone:Month	78435	322538	199286	229370	123	38.2	1.14
Zone:DepCat	81278	326567	195257	229370	121	37.4	0.37

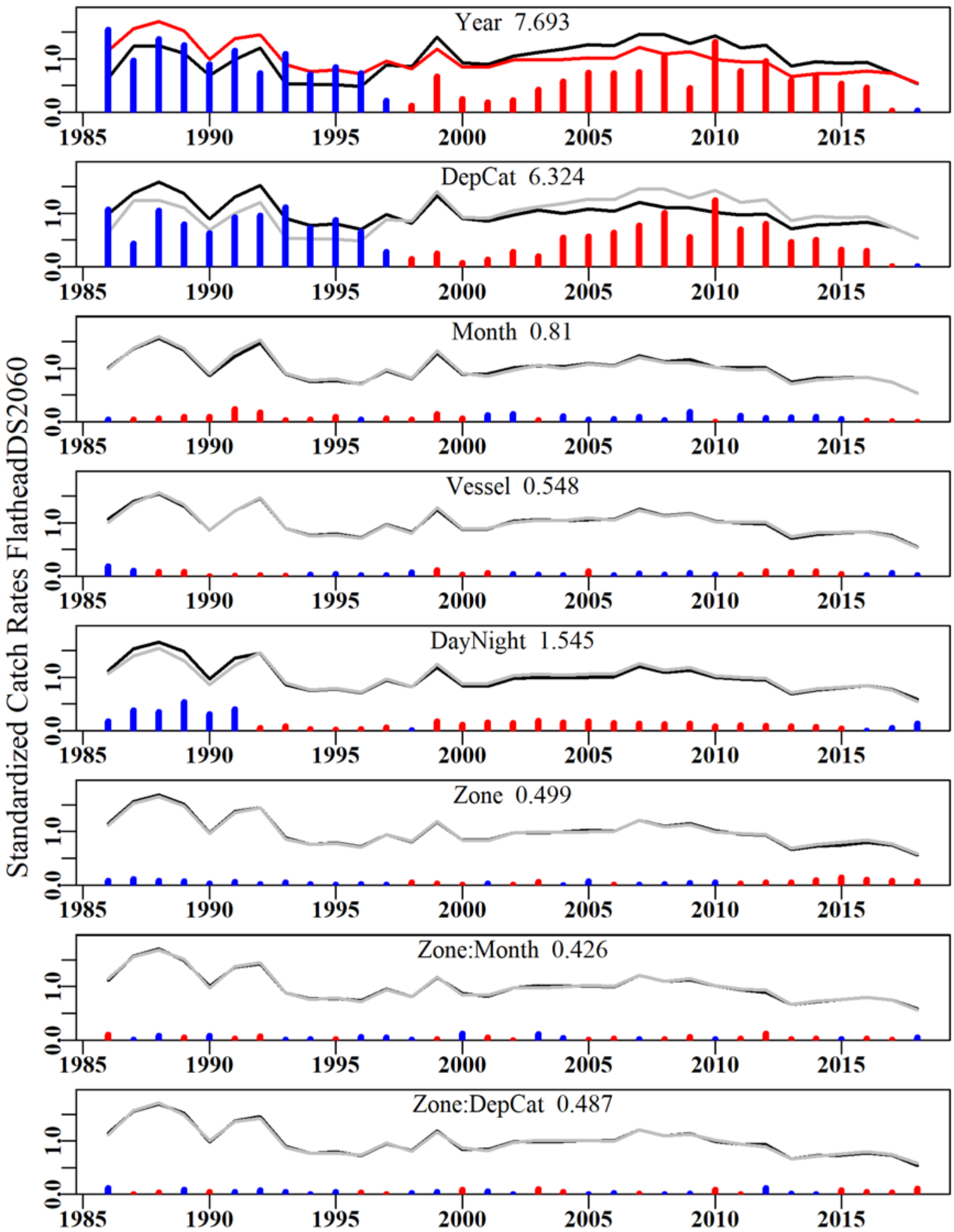

Figure 5.95. FlatheadDS2060. The influence of each factor on the optimal standardization. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by vertical bars with blue bars indicating the optimum model is higher than the 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.

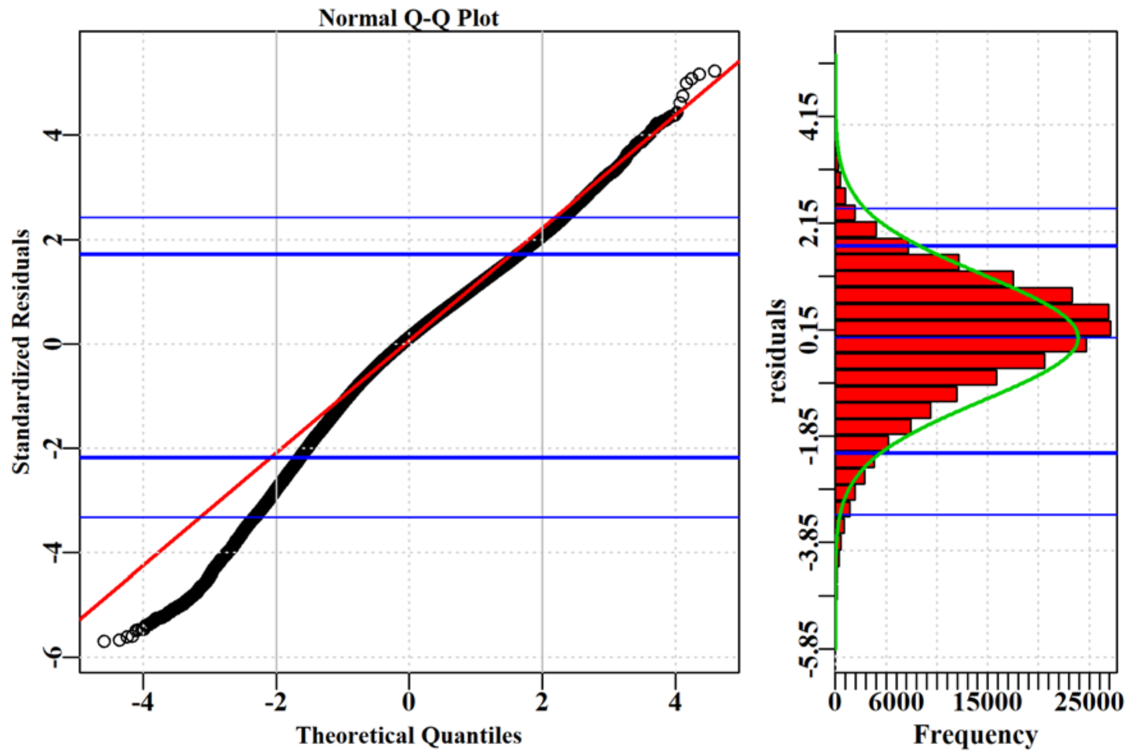

Figure 5.96. FlatheadDS2060. diagnostic plots. The distribution of residuals from the optimum fit. The qqplot indicates the fit to the expected normality, while the histogram of residuals illustrates the 90% quantiles to indicate the intensity of any lack of fit at the margins of the distribution.

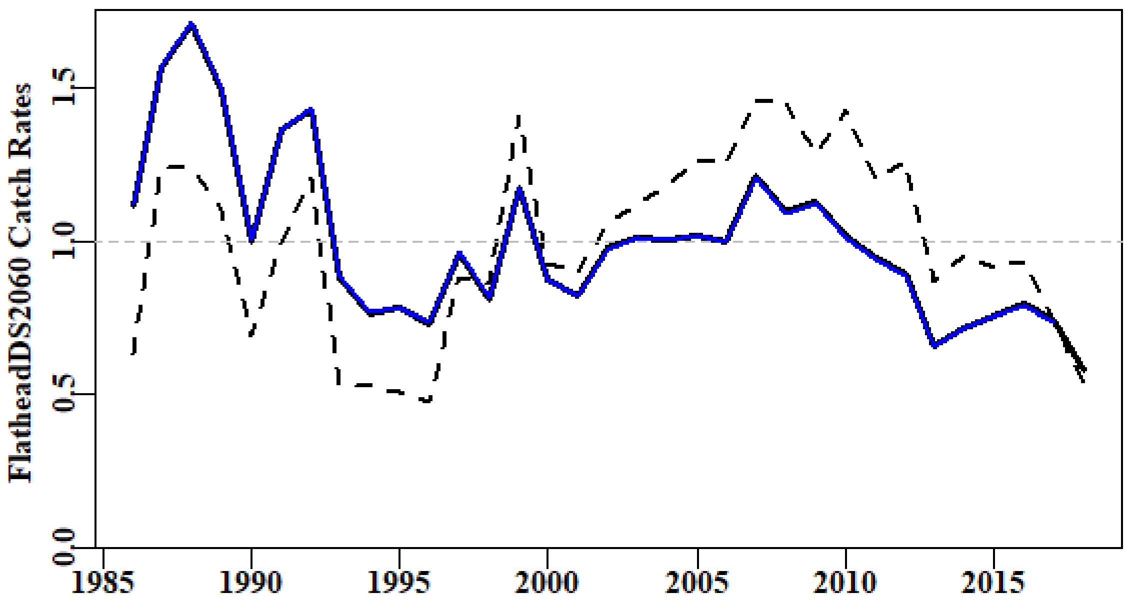

Figure 5.97. FlatheadDS2060. A comparison of the previous year's standardization (blue line) with this year's. They should lie on top of each other, although small deviations may relate to data adjustments, particularly in very recent years.

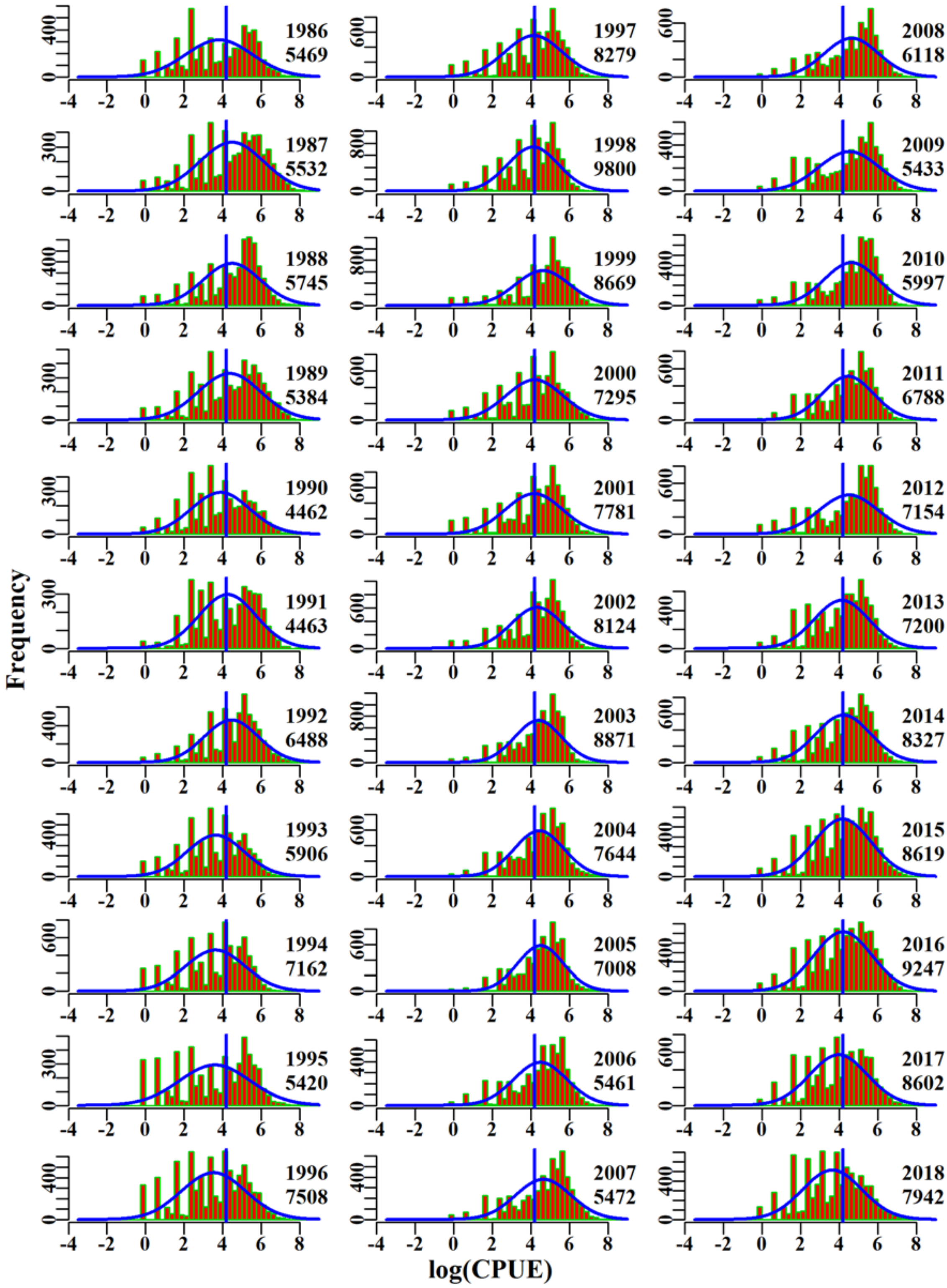

Figure 5.98. FlatheadDS2060. The natural log(CPUE) for each year of data available the blue lines are normal distributions fitted to the histogram frequencies. The numbers in each plot are the year and number of records.

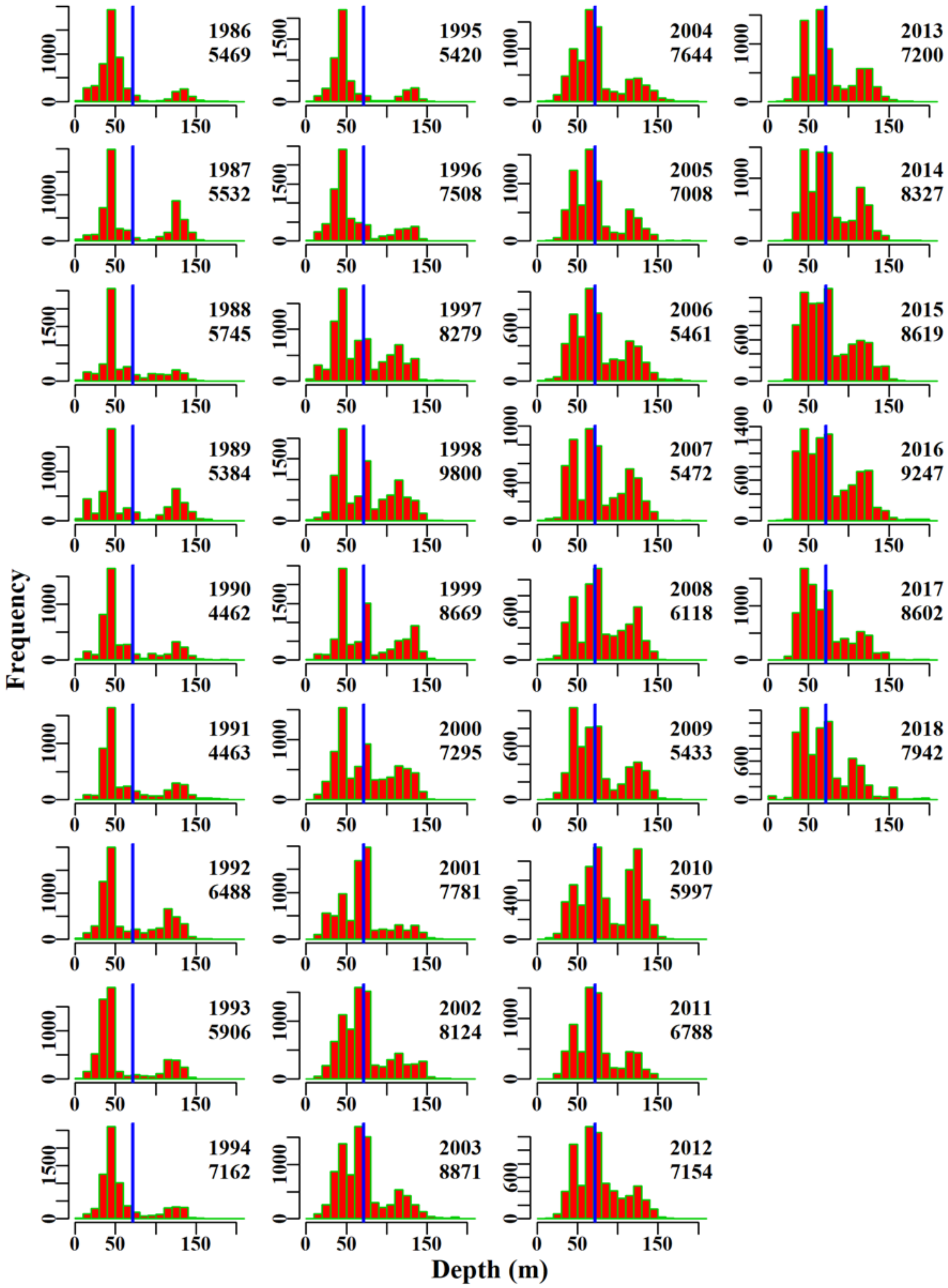

Figure 5.99. FlatheadDS2060. The average Depth of fishing for each year of data available to illustrate the development of the fishery through time. The numbers in each plot are the year and number of records.

5.18 Redfish 10 – 20

Redfish (RED – 37258003 – *Centroberyx affinis*) was one of the 16 species first included in the quota system in 1992. Redfish caught by trawl based on methods TW, TDO, TMO, OTT, in zones 10, 20, and depths 0 to 400 within the SET fishery for the years 1986 - 2018 were used in the analysis (Table 5.71). A total of 8 statistical models were fitted sequentially to the available data, with the order of the non-interaction terms added based on the relative contribution of each term to model fit.

5.18.1 *Inferences*

Most trawl caught Redfish has occurred in zone 10 across the analysis period. The total annual redfish catch of 29 t in 2018 is the second lowest recorded catch in the series (between 1986 - 2018). Large scale changes in CPUE have occurred 10 and 20. Annual standardized CPUE has declined since 1993 (Figure 5.100).

The terms Year, Vessel and DepCat had the greatest contribution to model fit, with the remaining terms each explaining < 1% of the overall variation in CPUE, based on the AIC and R^2 statistics (Table 5.75). The qqplot suggests that the assumed Normal distribution is valid (Figure 5.103).

Annual standardized CPUE has declined since 1994 and have been below average since 1999 (Figure 5.100).

5.18.2 *Action Items and Issues*

After consideration of redfish catches in zones 10 and 20 by year and vessel, the period around 1993 - 2006 appears to be different to other years. This suggests that there have been transitional periods in the time-series of CPUE. This **urgently** needs more attention because of the potential implications this has for the index of relative abundance through time.

Table 5.71. Redfish1020. The data selection criteria used to specify and identify the fishery data to be included in the analysis.

Property	Value
label	Redfish1020
csirocode	37258003
fishery	SET
depthrange	0 - 400
depthclass	25
zones	10, 20
methods	TW, TDO, TMO, OTT
years	1986 - 2018

Table 5.72. Redfish1020. Total catch (Total; t) is the total reported in the database, number of records used in the analysis (N), reported catch (Catch; t) in the area and depth used in the analysis and number of vessels used in the analysis (Vess). GeoM is the geometric mean of catch rates (kg/hr), standard deviation (StDev) relates to the optimum model. C<30Kg denotes the amount of catch in shots of <30kg, and %<30Kg is the percent of total. The optimum model was Zone:DepCat.

	Total	N	Catch	Vess	GeoM	Opt	StDev	C<30Kg	P<30Kg
1986	1687.5	5336	1598.0	87	119.3	1.9104	0.000	23.159	0.014
1987	1252.7	3903	1181.8	79	121.1	1.6386	0.034	17.828	0.015
1988	1125.5	3966	1078.0	75	95.2	1.8363	0.034	17.697	0.016
1989	714.3	2710	641.2	72	80.1	1.3571	0.038	15.566	0.024
1990	931.4	2573	785.7	58	104.9	1.7124	0.039	11.772	0.015
1991	1570.6	3320	1227.8	52	140.9	1.8943	0.037	14.869	0.012
1992	1636.7	3173	1514.1	48	198.7	2.3537	0.038	14.281	0.009
1993	1921.3	3755	1754.8	53	205.4	2.8192	0.036	16.091	0.009
1994	1487.7	5439	1329.1	53	111.4	2.0739	0.034	28.214	0.021
1995	1240.6	5675	1188.8	52	82.3	1.3503	0.033	34.359	0.029
1996	1344.0	5775	1297.5	55	90.4	1.2290	0.033	33.779	0.026
1997	1397.3	4363	1340.7	58	138.4	1.2874	0.035	25.498	0.019
1998	1553.7	4296	1526.0	49	187.0	1.5146	0.035	23.599	0.015
1999	1116.5	3934	1089.3	53	145.2	1.2634	0.036	21.181	0.019
2000	758.5	4661	734.3	53	80.4	0.8437	0.035	28.968	0.039
2001	742.3	4559	718.3	47	75.8	0.8043	0.035	29.022	0.040
2002	807.1	5188	770.8	49	69.5	0.7510	0.034	32.706	0.042
2003	615.6	4096	553.9	51	62.6	0.6437	0.036	27.500	0.050
2004	475.2	3951	447.7	50	52.0	0.5710	0.036	27.007	0.060
2005	483.5	3768	451.1	46	47.4	0.6316	0.037	26.639	0.059
2006	325.5	2573	302.3	42	46.5	0.5889	0.040	19.703	0.065
2007	216.3	1870	208.1	23	46.8	0.5786	0.045	13.417	0.064
2008	183.8	1921	179.3	25	35.3	0.5116	0.045	15.431	0.086
2009	160.5	1602	153.6	23	33.5	0.4363	0.048	12.758	0.083
2010	152.8	1838	146.2	24	28.9	0.4264	0.045	15.962	0.109
2011	87.3	1397	82.8	22	21.8	0.3121	0.050	10.828	0.131
2012	66.4	1345	61.9	21	18.2	0.2188	0.050	11.194	0.181
2013	62.7	1129	60.3	20	20.1	0.2772	0.053	9.787	0.162
2014	86.9	1410	82.6	22	25.9	0.3695	0.049	11.874	0.144
2015	52.2	1192	50.0	22	17.5	0.2260	0.053	10.106	0.202
2016	38.4	959	35.9	21	15.3	0.2001	0.057	7.644	0.213
2017	25.4	606	22.0	18	16.4	0.1938	0.068	5.182	0.235
2018	29.8	577	15.6	17	8.9	0.1749	0.074	4.295	0.276

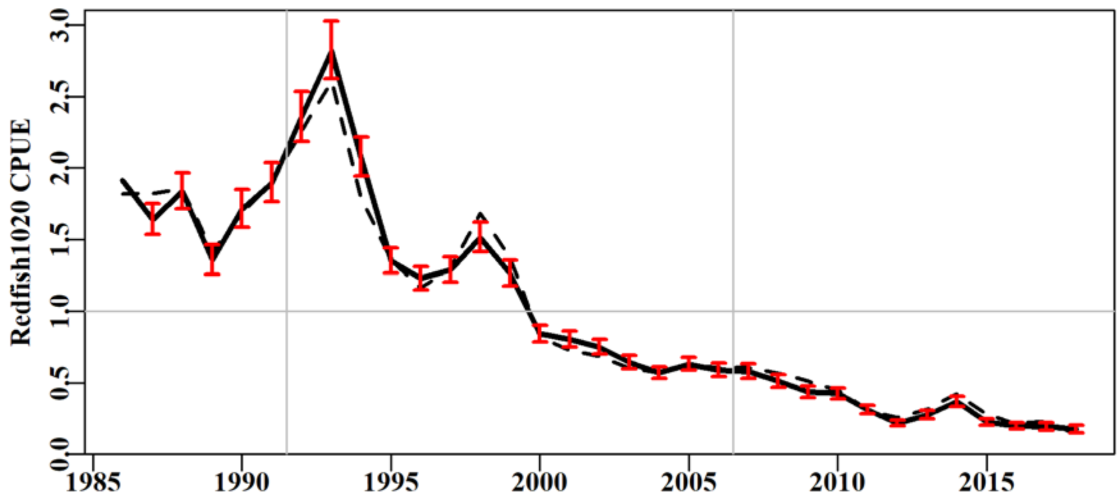

Figure 5.100. Redfish1020 standardization. The dashed black line represents the geometric mean catch rate, solid black line the standardized catch rates. The red bars are the 95% confidence intervals about the mean estimates. The graph scales both time-series of standardized catch rates relative to the mean of each time-series.

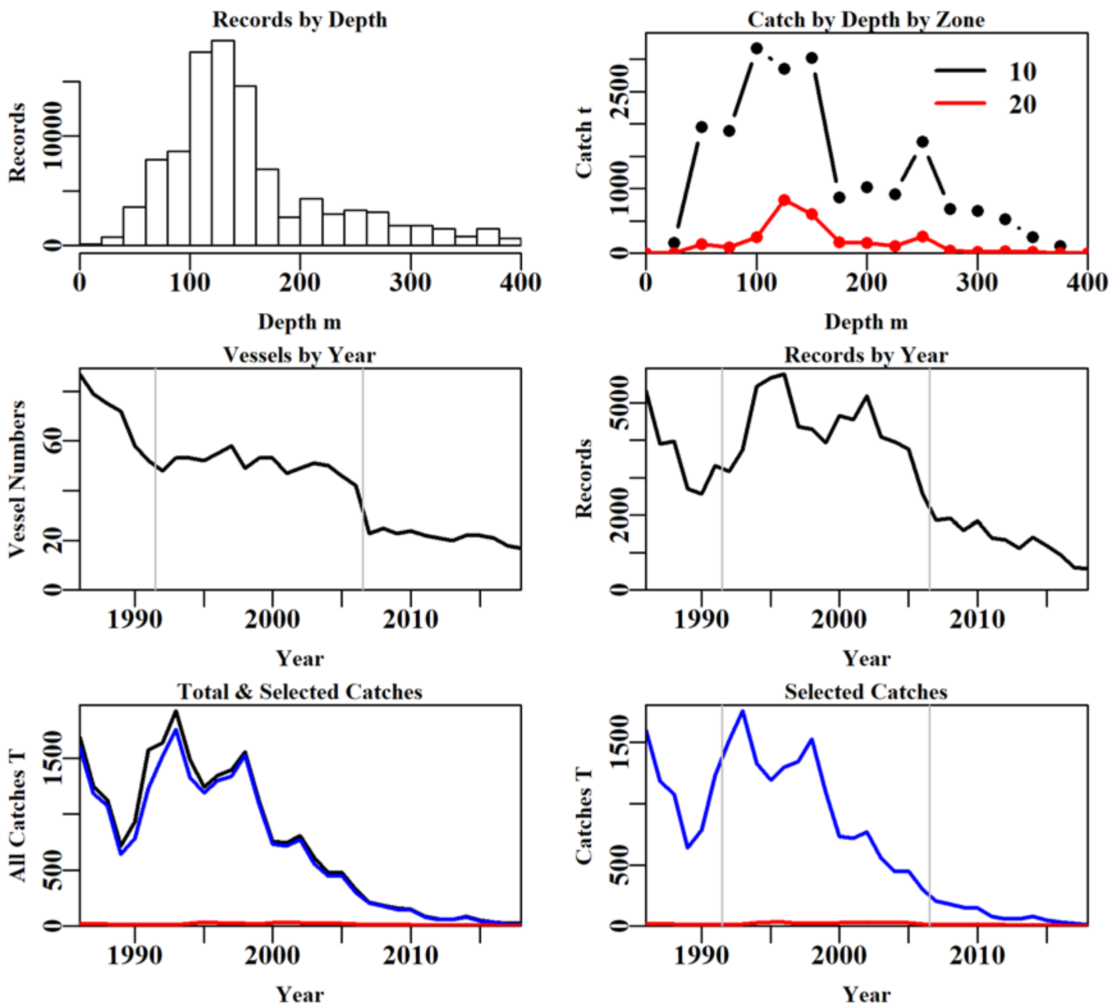

Figure 5.101. Redfish1020 fishery details. The bottom left plot depicts all known catches (top black line), and all selected catches used in the analysis (middle blue line); the lower red line: selected catches < 30 kg).

Table 5.73. Redfish1020 data selection effects. Total is the total number of records in the database, NoCE removes those records with either missing catch or effort, and then only those records are kept that meet the criteria for depth, years, zone, method and fishery.

	Total	NoCE	Depth	Years	Zones	Method	Fishery
Records	1199820	114675	111317	110386	103972	102923	102860
Difference	0	5307	3358	931	6414	1049	63
Catch	24501.16	24003.506	23592.129	23452.900	22787.17	22631.59	22629.33
Difference	0	497.65	411.38	139.22	665.73	155.57	2.260

Table 5.74. The models used to analyse data for Redfish1020.

	Model
Model1	Year
Model2	Year + Vessel
Model3	Year + Vessel + DepCat
Model4	Year + Vessel + DepCat + Zone
Model5	Year + Vessel + DepCat + Zone + DayNight
Model6	Year + Vessel + DepCat + Zone + DayNight + Month
Model7	Year + Vessel + DepCat + Zone + DayNight + Month + Zone:Month
Model8	Year + Vessel + DepCat + Zone + DayNight + Month + Zone:DepCat

Table 5.75. Redfish1020. The row names are 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_r2) and the change in adjusted R^2 (%Change). The optimum model was Zone:DepCat.

	AIC	RSS	MSS	Nobs	Npars	adj_r2	%Change
Year	111615	304248	39836	102860	33	11.5	0.00
Vessel	93936	255411	88673	102860	192	25.6	14.08
DepCat	88618	242467	101618	102860	208	29.4	3.76
Zone	87327	239439	104646	102860	209	30.3	0.88
DayNight	86672	237903	106181	102860	212	30.7	0.45
Month	86316	237031	107054	102860	223	31.0	0.25
Zone:Month	86186	236681	107403	102860	234	31.1	0.09
Zone:DepCat	85918	236043	108042	102860	239	31.2	0.28

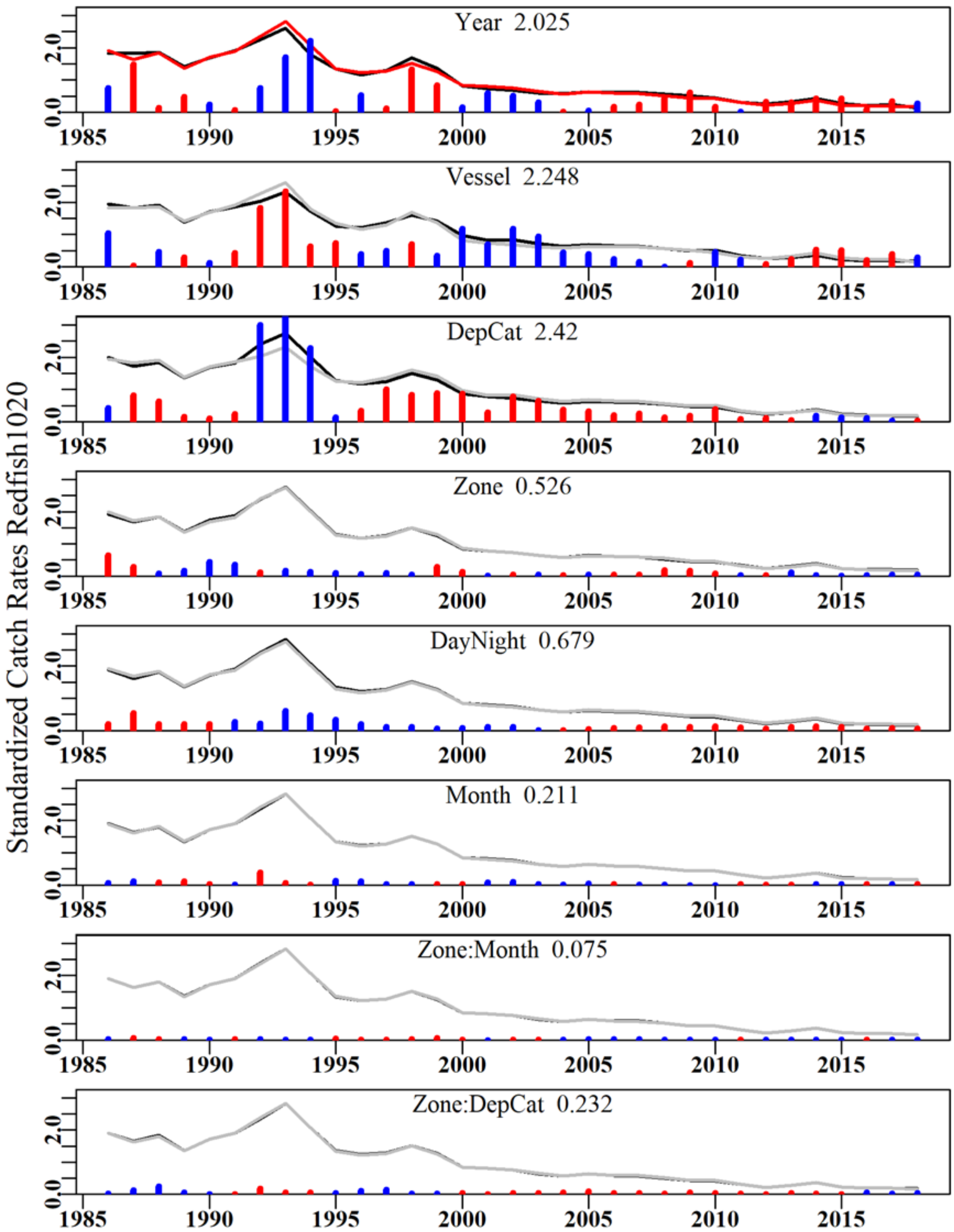

Figure 5.102. Redfish1020. The influence of each factor on the optimal standardization. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by vertical bars with blue bars indicating the optimum model is higher than the geometric 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.

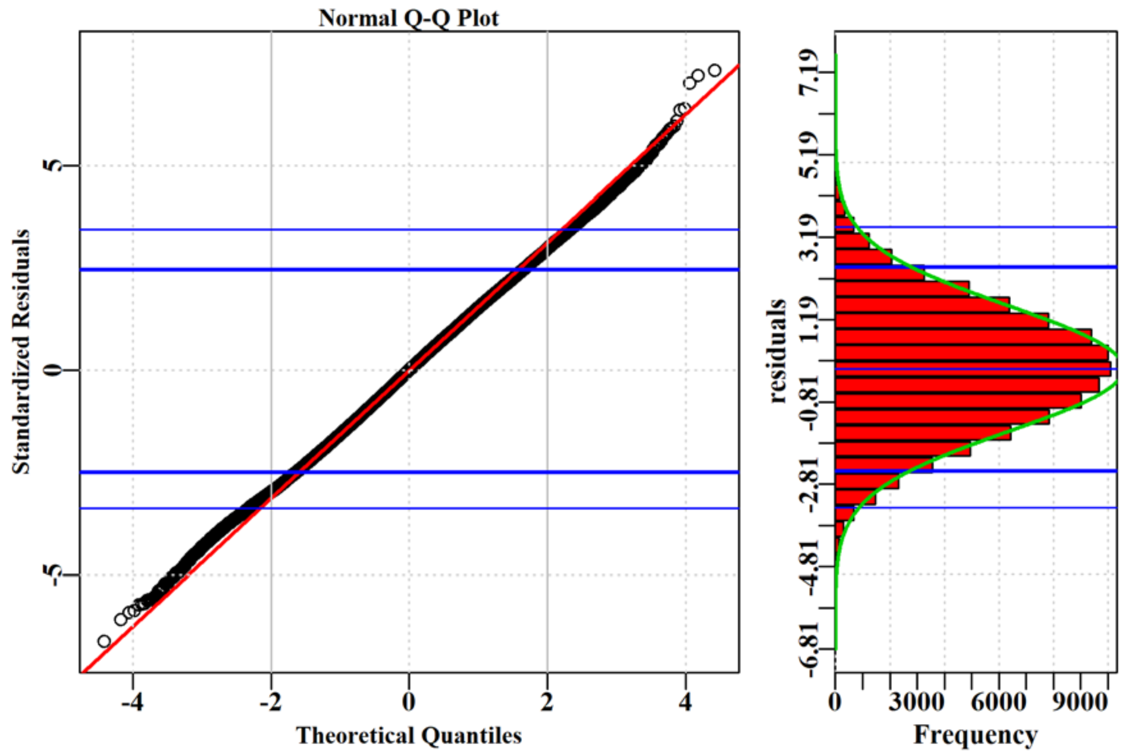

Figure 5.103. Redfish1020. diagnostic plots. The distribution of residuals from the optimum fit. The qqplot indicates the fit to the expected normality, while the histogram of residuals illustrates the 90% quantiles to indicate the intensity of any lack of fit at the margins of the distribution.

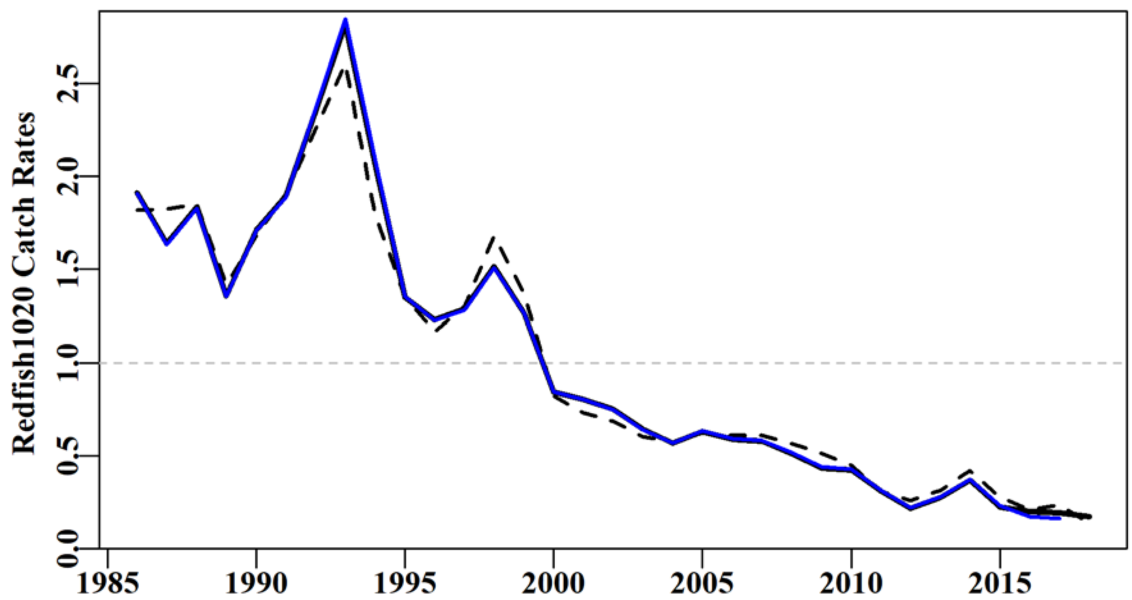

Figure 5.104. Redfish1020. A comparison of the previous year's standardization (blue line) with this year's. They should lie on top of each other, although small deviations may relate to data adjustments, particularly in very recent years.

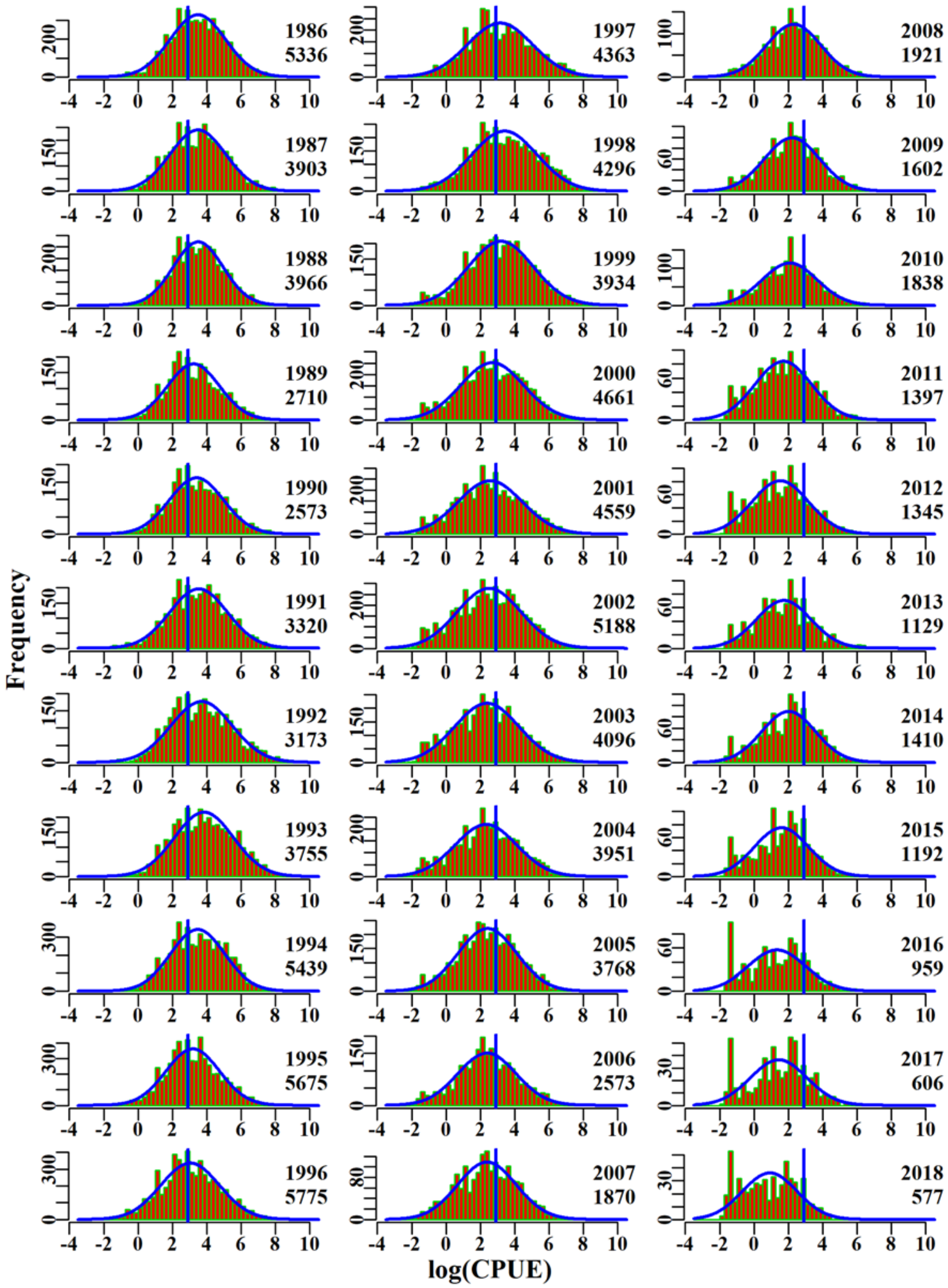

Figure 5.105. Redfish1020. The natural log(CPUE) for each year of data available the blue lines are normal distributions fitted to the histogram frequencies. The numbers in each plot are the year and number of records.

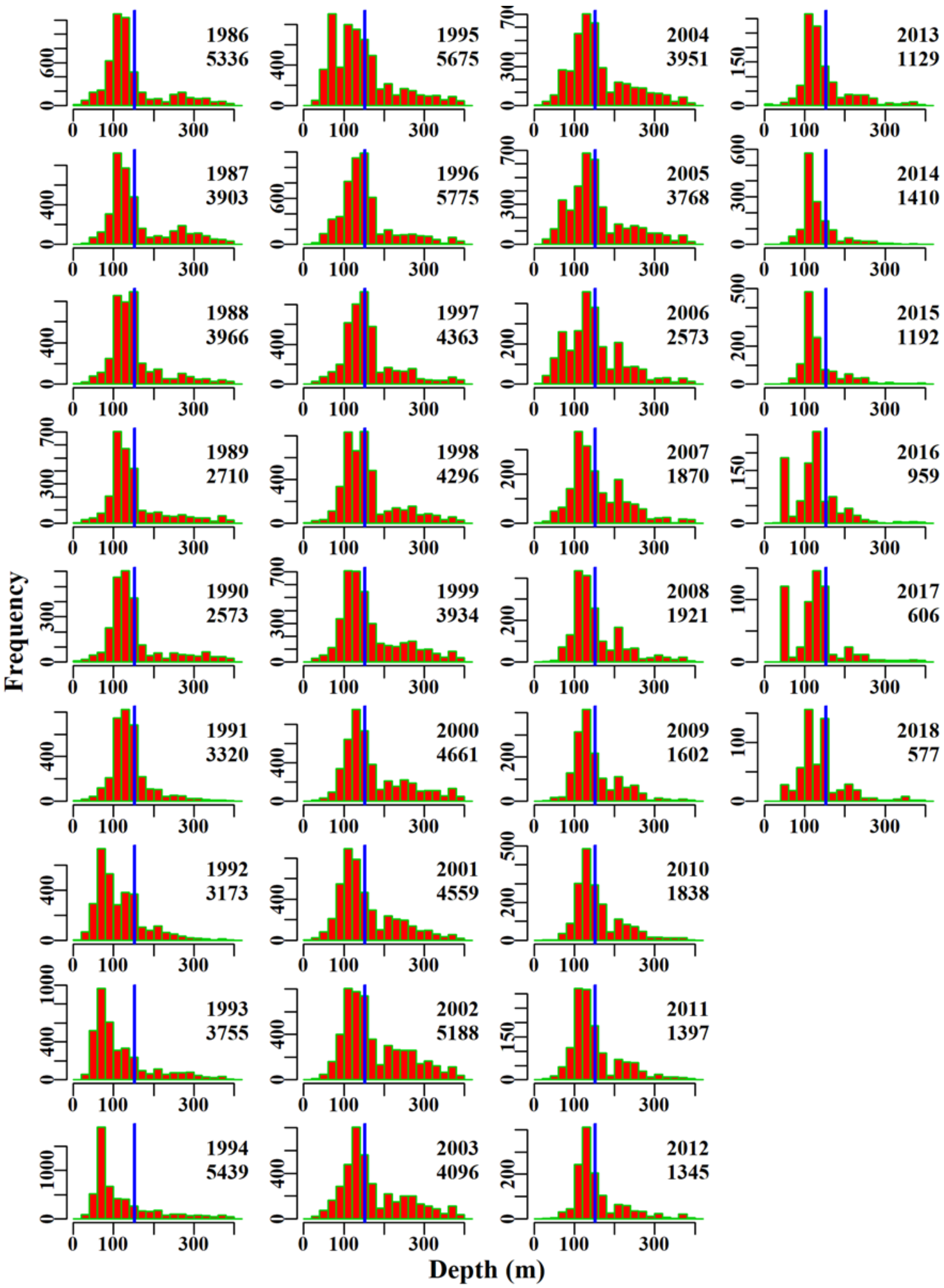

Figure 5.106. Redfish1020. The average Depth of fishing for each year of data available to illustrate the development of the fishery through time. The numbers in each plot are the year and number of records.

5.19 Blue-Eye Trevalla TW 2030

Blue-Eye Trevalla (TBE – 37445001 – *Hyperoglyphe antarctica*) was one of the 16 species first included in the quota system in 1992, which reflects its long history within the SESSF. Trawl caught Blue-Eye Trevalla based on methods TW, TDO, in zones 20, 30, and depths 0 to 1000 within the SET fishery for the years 1986 - 2018 were used in the analysis. Recently, Ocean Blue-Eye Trevalla (37445014 - *Schedophilus labyrinthicus*) was also included in this analysis. These constitute the criteria used to select data from the Commonwealth logbook database (Table 5.76). A total of 8 statistical models were fitted sequentially to the available data, with the order of the non-interaction terms added based on the relative contribution of each term to model fit.

5.19.1 *Inferences*

Catches appear to change relative to availability rather than the influence of the fishery on the stock. Over the period when CPUE was lower than average (about 1996 - 2006) there was an increase in small shots of < 30kg (Figure 5.108), which is suggestive of either low availability or high levels of small fish.

The terms Year, Vessel and Zone had the greatest contribution to model fit, with the remaining terms each explaining < 1% of the overall variation in CPUE, based on the AIC and R^2 statistics (Table 5.80). The qqplot suggests a departure from that the assumed Normal distribution as depicted by the tails of the distribution (Figure 5.110).

Annual standardized CPUE have been below average since about 1996 and relatively flat trend (Figure 5.107).

5.19.2 *Action Items and Issues*

Given the on-going low catches, and the recent even lower catches, the major changes in the fleet contributing to the fishery, the dramatically changing character of the CPUE data itself, and the recent disjunction between nominal catch rates and the standardized catch rates it is questionable whether this time-series of CPUE is indicative in any useful way of the relative abundance of Blue-Eye Trevalla. Whether this analysis should be continued should be considered.

Table 5.76. BlueEyeTW2030. The data selection criteria used to specify and identify the fishery data to be included in the analysis.

Property	Value
label	BlueEyeTW2030
csirocode	37445001, 37445014
fishery	SET
depthrange	0 - 1000
depthclass	50
zones	20, 30
methods	TW, TDO
years	1986 - 2018

Table 5.77. BlueEyeTW2030. Total catch (Total; t) is the total reported in the database, number of records used in the analysis (N), reported catch (Catch; t) in the area and depth used in the analysis and number of vessels used in the analysis (Vess). GeoM is the geometric mean of catch rates (kg/hr), standard deviation (StDev) relates to the optimum model. C<30Kg denotes the amount of catch in shots of <30kg, and %<30Kg is the percent of total. The optimum model was Zone:DepCat.

	Total	N	Catch	Vess	GeoM	Opt	StDev	C<30Kg	P<30Kg
1986	38.0	166	9.1	17	21.9	2.3827	0.000	1.453	0.159
1987	15.5	189	10.0	14	17.6	2.2768	0.137	1.769	0.177
1988	105.2	305	19.3	21	22.7	2.7943	0.130	3.404	0.176
1989	88.1	313	33.3	32	38.2	3.1162	0.133	2.849	0.086
1990	79.3	263	39.8	36	89.5	4.1221	0.135	1.574	0.040
1991	76.0	472	29.1	37	20.9	2.1484	0.127	5.477	0.188
1992	49.3	310	13.8	23	16.5	1.6018	0.134	3.321	0.241
1993	59.7	725	37.4	31	19.8	1.3142	0.124	7.126	0.190
1994	110.0	853	89.0	33	41.6	1.4869	0.124	7.877	0.089
1995	58.6	485	28.2	29	17.6	0.9922	0.128	6.015	0.213
1996	71.7	643	35.3	29	16.4	0.8068	0.126	6.625	0.188
1997	471.5	602	19.9	31	10.7	0.7422	0.128	6.481	0.326
1998	476.0	471	18.7	24	11.3	0.8626	0.130	5.166	0.277
1999	575.0	631	41.7	27	9.2	0.8818	0.127	6.515	0.156
2000	671.4	656	35.7	35	7.6	0.5444	0.125	5.636	0.158
2001	648.3	699	25.2	24	4.6	0.4796	0.125	6.042	0.240
2002	843.9	701	33.7	28	12.0	0.4707	0.127	5.847	0.173
2003	605.3	720	13.6	25	6.1	0.4714	0.127	5.452	0.401
2004	612.3	622	15.2	28	11.6	0.4650	0.128	4.486	0.296
2005	755.2	486	17.4	26	16.5	0.4706	0.131	3.086	0.178
2006	573.7	326	36.8	17	67.9	0.5726	0.135	2.087	0.057
2007	937.1	246	10.6	11	9.7	0.4730	0.141	1.652	0.156
2008	398.9	429	13.4	15	26.3	0.4333	0.135	2.720	0.203
2009	521.0	240	22.8	14	90.1	0.4153	0.142	1.294	0.057
2010	437.4	190	10.7	13	32.3	0.2859	0.148	0.979	0.091
2011	554.2	214	7.2	12	12.7	0.2956	0.145	1.192	0.166
2012	463.8	149	1.3	11	2.7	0.2708	0.154	0.924	0.694
2013	398.4	146	4.1	11	25.9	0.2345	0.156	0.921	0.224
2014	460.5	120	20.6	11	337.4	0.3086	0.163	0.554	0.027
2015	305.4	185	22.1	14	368.3	0.3027	0.151	0.833	0.038
2016	332.7	140	9.5	12	82.5	0.2556	0.158	0.775	0.082
2017	385.3	187	34.4	11	592.4	0.3500	0.151	0.840	0.024
2018	345.9	189	33.8	10	577.6	0.3714	0.150	0.703	0.021

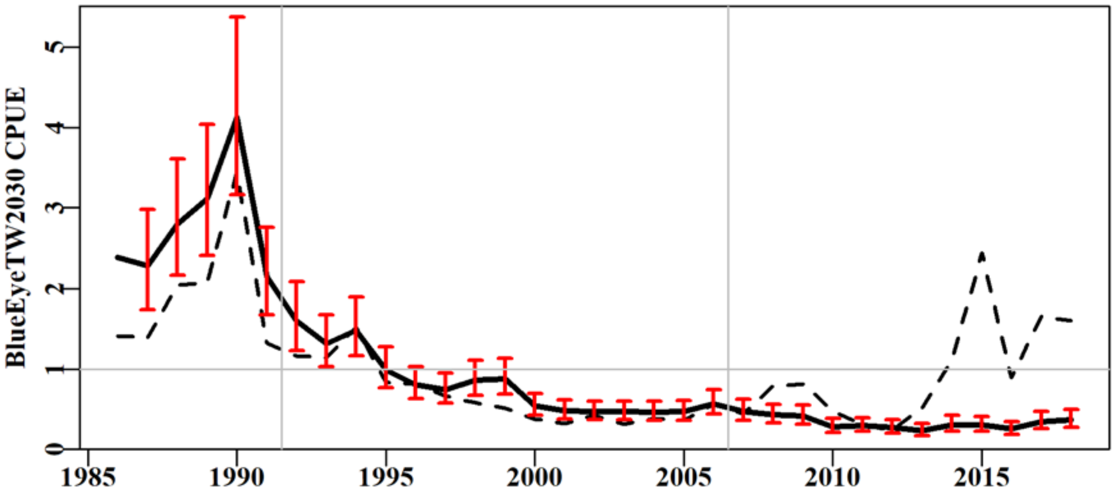

Figure 5.107. BlueEyeTW2030 standardization. The dashed black line represents the geometric mean catch rate, solid black line the standardized catch rates. The red bars are the 95% confidence intervals about the mean estimates. The graph scales both time-series of standardized catch rates relative to the mean of each time-series.

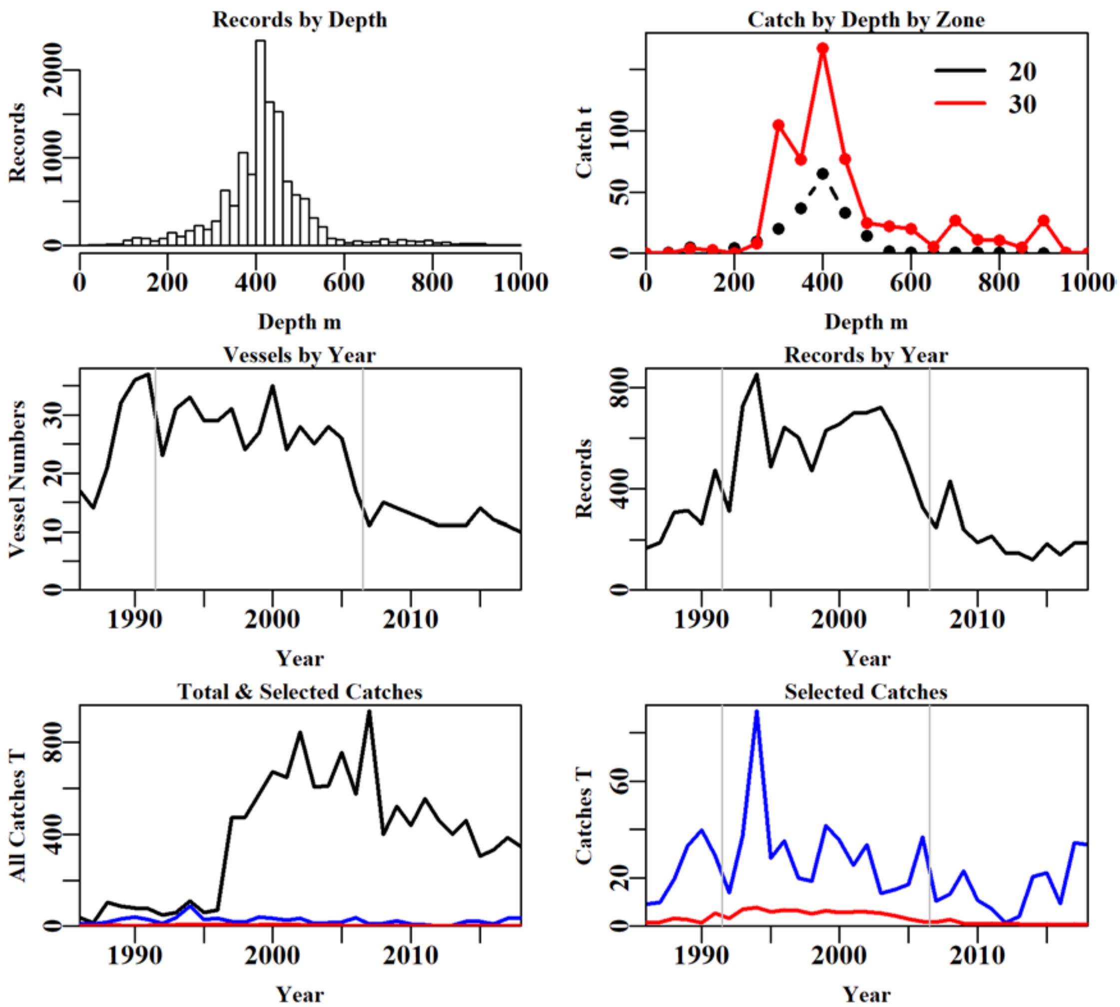

Figure 5.108. BlueEyeTW2030 fishery details. The bottom left plot depicts all known catches (top black line), and all selected catches used in the analysis (middle blue line); the lower red line: selected catches < 30 kg).

Table 5.78. BlueEyeTW2030 data selection effects. Total is the total number of records in the database, NoCE removes those records with either missing catch or effort, and then only those records are kept that meet the criteria for depth, years, zone, method and fishery.

	Total	NoCE	Depth	Years	Zones	Method	Fishery
Records	55936	35517	35268	34911	14884	13077	13073
Difference	0	20419	249	357	20027	1807	4
Catch	12689.65	4932.74	4896.23	4750.95	1445.63	792.84	792.73
Difference	0	7756.91	36.51	145.28	3305.32	652.78	0.12

Table 5.79. The models used to analyse data for BlueEyeTW2030.

	Model
Model1	Year
Model2	Year + Vessel
Model3	Year + Vessel + Zone
Model4	Year + Vessel + Zone + DepCat
Model5	Year + Vessel + Zone + DepCat + Month
Model6	Year + Vessel + Zone + DepCat + Month + DayNight
Model7	Year + Vessel + Zone + DepCat + Month + DayNight + Zone:DepCat
Model8	Year + Vessel + Zone + DepCat + Month + DayNight + Zone:Month

Table 5.80. BlueEyeTW2030. The row names are 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_r2) and the change in adjusted R^2 (%Change). The optimum model was Zone:DepCat.

	AIC	RSS	MSS	Nobs	Npars	adj_r2	%Change
Year	12863	34794	5366	13073	33	13.1	0.00
Vessel	4918	18592	21568	13073	157	53.1	40.00
Zone	4510	18018	22142	13073	158	54.6	1.44
DepCat	4454	17887	22273	13073	178	54.8	0.26
Month	4425	17816	22344	13073	189	55.0	0.14
DayNight	4395	17767	22393	13073	192	55.1	0.11
Zone:DepCat	4221	17482	22678	13073	211	55.8	0.65
Zone:Month	4361	17692	22468	13073	203	55.3	0.15

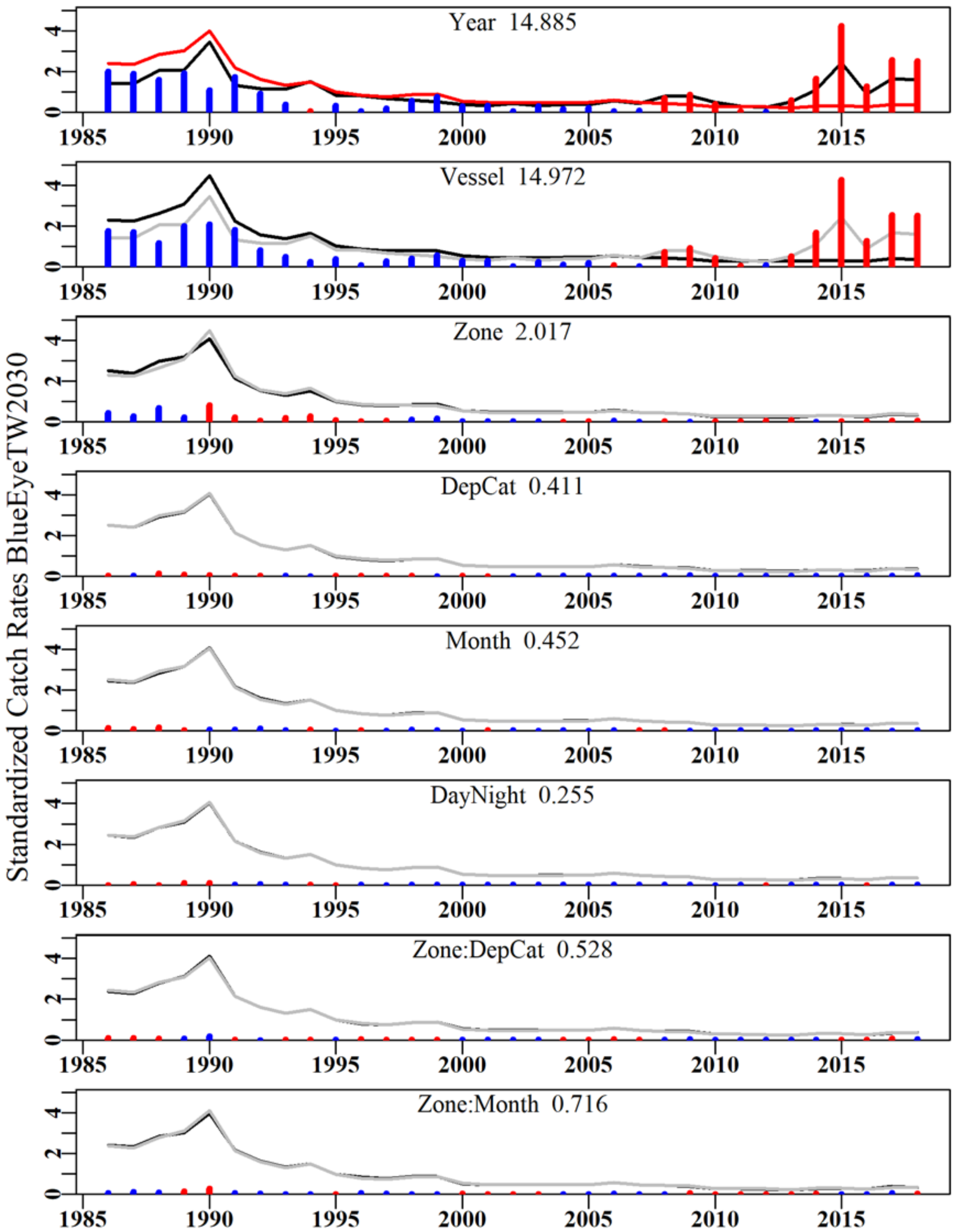

Figure 5.109. BlueEyeTW2030. The influence of each factor on the optimal standardization. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by vertical bars with blue bars indicating the optimum model is higher than the 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.

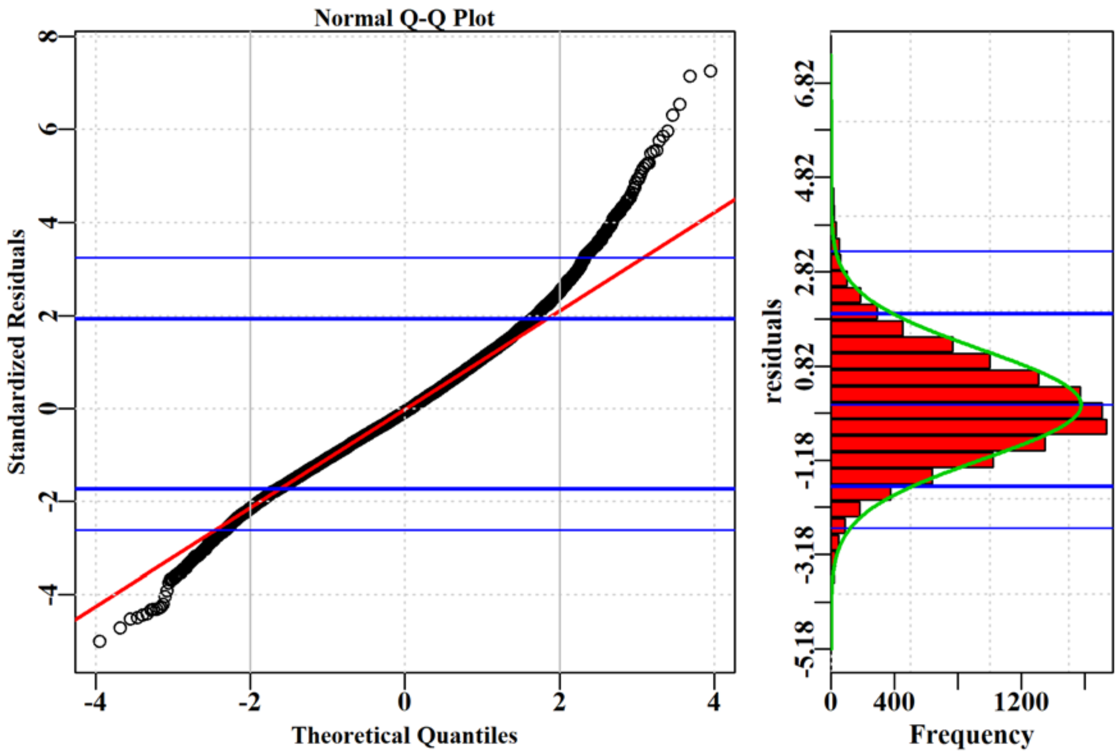

Figure 5.110. BlueEyeTW2030. diagnostic plots. The distribution of residuals from the optimum fit. The qqplot indicates the fit to the expected normality, while the histogram of residuals illustrates the 90% quantiles to indicate the intensity of any lack of fit at the margins of the distribution.

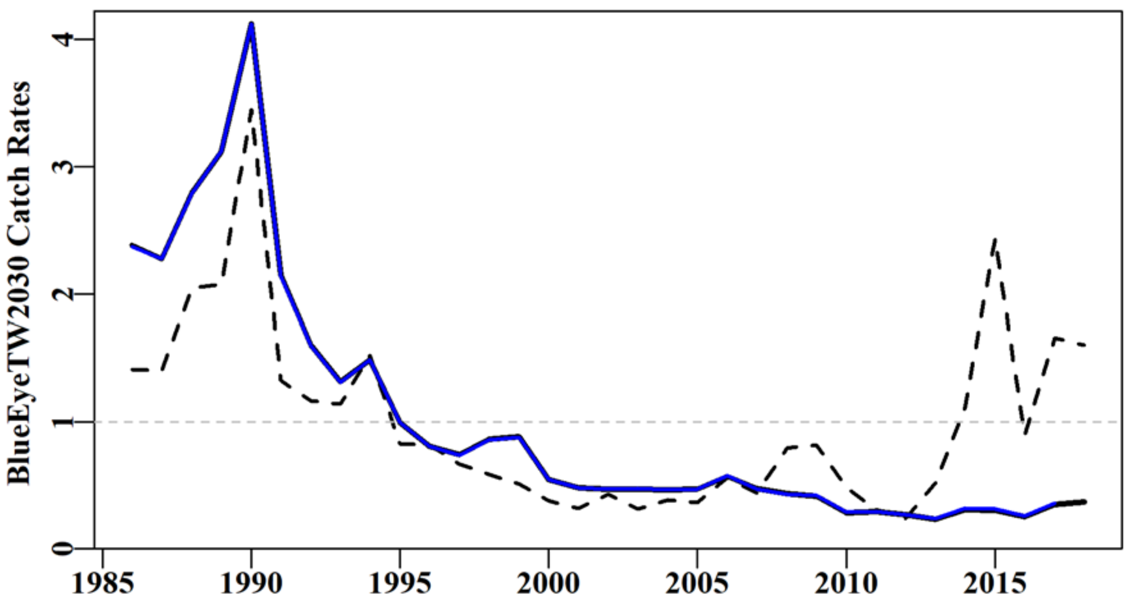

Figure 5.111. BlueEyeTW2030. A comparison of the previous year's standardization (blue line) with this year's. They should lie on top of each other, although small deviations may relate to data adjustments, particularly in very recent years.

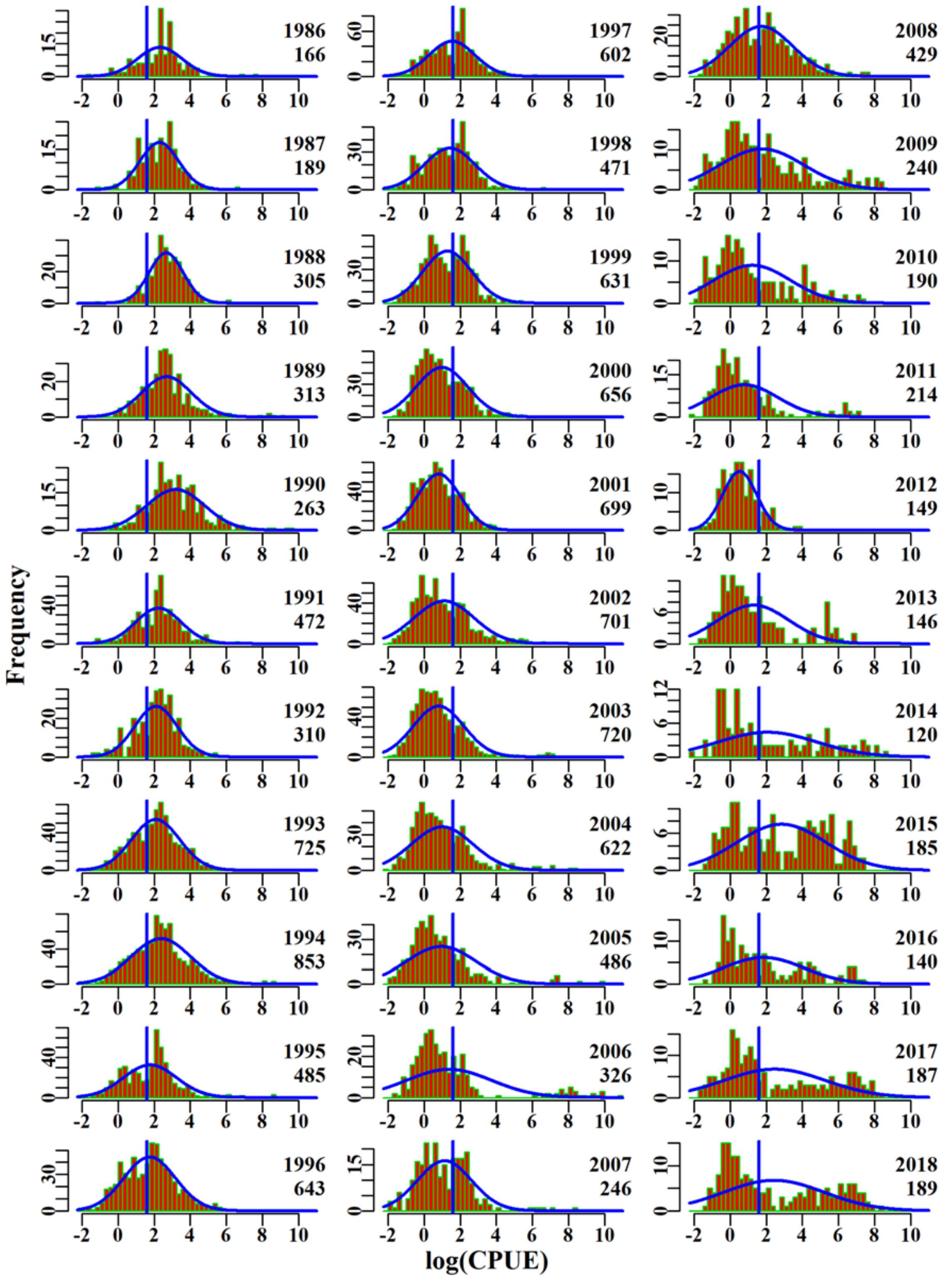

Figure 5.112. BlueEyeTW2030. The natural log(CPUE) for each year of data available the blue lines are normal distributions fitted to the histogram frequencies. The numbers in each plot are the year and number of records.

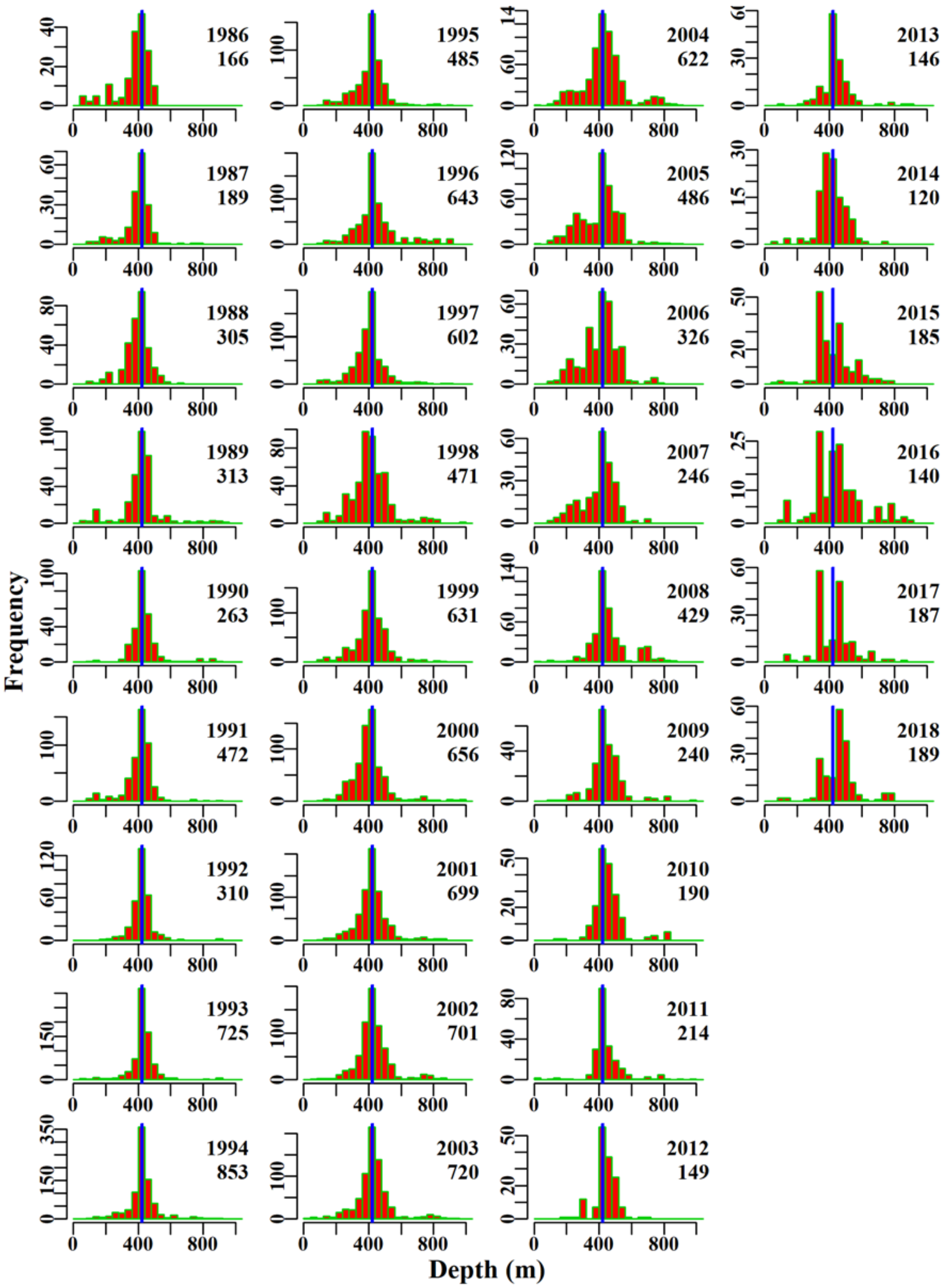

Figure 5.113. BlueEyeTW2030. The average Depth of fishing for each year of data available to illustrate the development of the fishery through time. The numbers in each plot are the year and number of records.

5.20 Blue-Eye Trevalla TW 4050

Blue-Eye Trevalla (TBE – 37445001 – *Hyperoglyphe antarctica*) was one of the 16 species first included in the quota system in 1992, which reflects its long history within the SESSF. Trawl caught Blue-Eye Trevalla based on methods TW, TDO, in zones 40, 50, and depths 0 to 1000 within the SET fishery for the years 1986 - 2018 were used in the analysis. Recently, Ocean Blue-Eye Trevalla (37445014 - *Schedophilus labyrinthicus*) was also included in this analysis. These constitute the criteria used to select data from the Commonwealth logbook database (Table 5.81).

A total of 8 statistical models were fitted sequentially to the available data, with the order of the non-interaction terms added based on the relative contribution of each term to model fit.

The sequential development of the standardization models simplifies the search for the optimum model requires a consideration of the different performance statistics such as the AIC (Akaike's Information Criterion, the smaller the better; Burnham and Anderson, 1992) or the adjusted R^2 (the larger the better; Neter et al, 1996). In addition, the examination of the various diagnostic plots and tables allows for an improved interpretation of the observed trends.

5.20.1 *Inferences*

Catches appear to change relative to availability rather than the influence of the fishery on the stock. Over the period when CPUE was lower than average (about 1992 - 2006) there was an increase in small shots of < 30kg, which suggests that these are merely bycatch to the usual fishing practices (Figure 5.115).

The terms Year, Vessel and DepCat had the greatest contribution to model fit, with the remaining terms each explaining < 1% of the overall variation in CPUE, based on the AIC and R^2 statistics (Table 5.85). The qqplot suggests a departure from that the assumed Normal distribution as depicted by the tails of the distribution (Figure 5.117).

Annual standardized CPUE have been below average since about 1996 and relatively flat trend (Figure 5.114). CPUE are consistent from 1988 - 1991 (i.e. before the introduction of quotas in 1992) but are double that following the introduction of quota. Very few vessels now contribute significant catches.

5.20.2 *Action Items and Issues*

If this analysis is to continue, then the early CPUE data from 1988 to 1991 should be explored in more detail to ensure it is representative of the fishery and does not contain systematic errors. After introducing quota CPUE distributions became more consistent through time, although relatively low numbers of observations are now contributing to a change in their character in the latest years.

Table 5.81. BlueEyeTW4050. The data selection criteria used to specify and identify the fishery data to be included in the analysis.

Property	Value
label	BlueEyeTW4050
csirocode	37445001, 37445014
fishery	SET
depthrange	0 - 1000
depthclass	50
zones	40, 50
methods	TW, TDO
years	1986 - 2018

Table 5.82. BlueEyeTW4050. Total catch (Total; t) is the total reported in the database, number of records used in the analysis (N), reported catch (Catch; t) in the area and depth used in the analysis and number of vessels used in the analysis (Vess). GeoM is the geometric mean of catch rates (kg/hr), standard deviation (StDev) relates to the optimum model. C<30Kg denotes the amount of catch in shots of <30kg, and %<30Kg is the percent of total. The optimum model was Zone:DepCat.

	Total	N	Catch	Vess	GeoM	Opt	StDev	C<30Kg	P<30Kg
1986	38.0	194	16.0	18	26.9	1.0690	0.000	1.602	0.100
1987	15.5	56	3.1	14	19.8	0.8162	0.177	0.356	0.113
1988	105.2	142	76.4	15	474.9	2.5329	0.156	0.716	0.009
1989	88.1	238	44.0	24	93.5	2.2032	0.138	2.149	0.049
1990	79.3	156	30.9	15	65.7	2.2012	0.159	1.840	0.060
1991	76.0	125	18.6	18	35.4	1.7819	0.158	1.149	0.062
1992	49.3	129	28.6	15	620.9	2.2176	0.157	0.908	0.032
1993	59.7	289	18.1	19	16.3	0.9942	0.140	3.992	0.220
1994	110.0	348	16.3	19	14.0	1.0053	0.136	5.148	0.316
1995	58.6	497	26.2	21	12.3	0.9011	0.133	6.638	0.253
1996	71.7	521	30.0	24	17.8	0.9476	0.133	6.277	0.209
1997	471.5	788	82.4	18	22.3	0.9605	0.130	7.718	0.094
1998	476.0	778	58.9	19	14.6	1.1357	0.131	8.746	0.148
1999	575.0	875	46.2	19	15.5	1.1541	0.130	9.412	0.204
2000	671.4	1104	44.6	25	13.1	0.9980	0.129	11.127	0.249
2001	648.3	966	43.4	26	15.0	0.9621	0.131	10.771	0.248
2002	843.9	803	32.3	26	13.6	0.8012	0.131	8.787	0.272
2003	605.3	389	11.0	25	8.5	0.6984	0.137	3.775	0.344
2004	612.3	848	31.2	24	10.0	0.6181	0.131	7.179	0.230
2005	755.2	507	12.7	22	7.5	0.5905	0.134	4.366	0.343
2006	573.7	527	16.2	17	7.3	0.5874	0.134	3.967	0.245
2007	937.1	530	26.1	16	12.9	0.6295	0.134	3.655	0.140
2008	398.9	321	16.4	14	14.9	0.8330	0.139	2.685	0.164
2009	521.0	342	15.8	13	10.6	0.7881	0.139	2.540	0.161
2010	437.4	423	30.9	14	15.6	0.8022	0.136	2.775	0.090
2011	554.2	379	14.7	14	6.5	0.6202	0.137	3.017	0.205
2012	463.8	251	9.0	11	4.7	0.4595	0.146	1.736	0.194
2013	398.4	202	18.7	15	10.8	0.6007	0.148	1.585	0.085
2014	460.5	216	8.7	13	6.6	0.5587	0.147	2.118	0.243
2015	305.4	106	2.7	9	5.3	0.3469	0.168	0.745	0.281
2016	332.7	92	3.3	13	7.1	0.5914	0.171	0.842	0.255
2017	385.3	227	17.3	10	18.2	0.9860	0.153	1.999	0.116
2018	345.9	193	8.4	10	7.0	0.6076	0.154	2.098	0.248

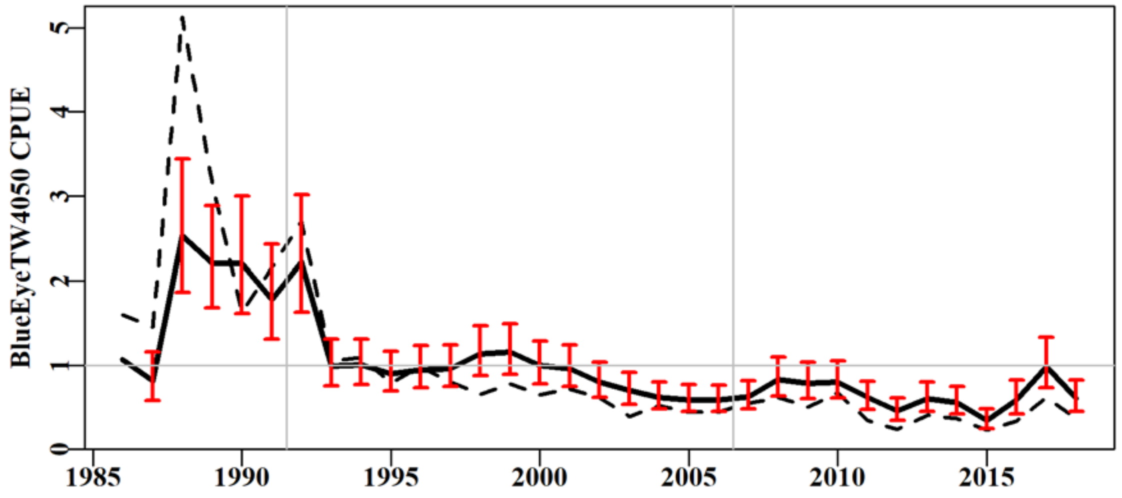

Figure 5.114. BlueEyeTW4050 standardization. The dashed black line represents the geometric mean catch rate, solid black line the standardized catch rates. The red bars are the 95% confidence intervals about the mean estimates. The graph scales both time-series of standardized catch rates relative to the mean of each time-series.

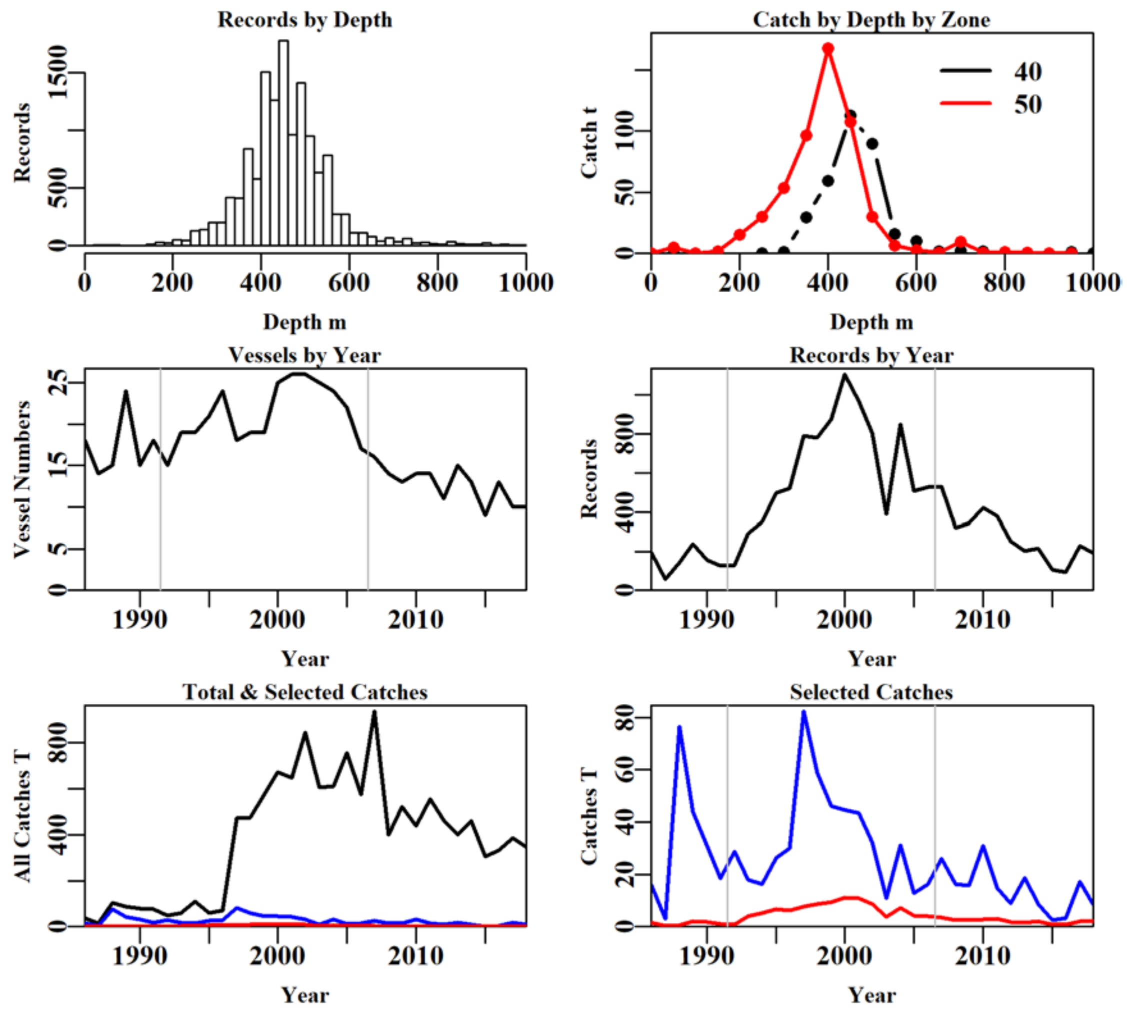

Figure 5.115. BlueEyeTW4050 fishery details. The bottom left plot depicts all known catches (top black line), and all selected catches used in the analysis (middle blue line); the lower red line: selected catches < 30 kg).

Table 5.83. BlueEyeTW4050 data selection effects. Total is the total number of records in the database, NoCE removes those records with either missing catch or effort, and then only those records are kept that meet the criteria for depth, years, zone, method and fishery.

	Total	NoCE	Depth	Years	Zones	Method	Fishery
Records	55936	35517	35268	34911	14648	13586	13562
Difference	0	20419	249	357	20263	1062	24
Catch	12689.65	4932.74	4896.23	4750.95	1208.08	859.83	859.06
Difference	0	7756.91	36.51	145.28	3542.87	348.25	0.78

Table 5.84. The models used to analyse data for BlueEyeTW4050.

	Model
Model1	Year
Model2	Year + Vessel
Model3	Year + Vessel + DepCat
Model4	Year + Vessel + DepCat + Zone
Model5	Year + Vessel + DepCat + Zone + DayNight
Model6	Year + Vessel + DepCat + Zone + DayNight + Month
Model7	Year + Vessel + DepCat + Zone + DayNight + Month + Zone:DepCat
Model8	Year + Vessel + DepCat + Zone + DayNight + Month + Zone:Month

Table 5.85. BlueEyeTW4050. The row names are 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_r2) and the change in adjusted R^2 (%Change). The optimum model was Zone:DepCat.

	AIC	RSS	MSS	Nobs	Npars	adj_r2	%Change
Year	8901	26017	3353	13562	33	11.2	0.00
Vessel	3306	17002	12368	13562	120	41.6	30.39
DepCat	2914	16470	12900	13562	140	43.3	1.74
Zone	2843	16381	12989	13562	141	43.6	0.30
DayNight	2716	16221	13149	13562	144	44.2	0.54
Month	2619	16079	13291	13562	155	44.6	0.44
Zone:DepCat	2601	16018	13352	13562	172	44.8	0.14
Zone:Month	2620	16055	13315	13562	166	44.7	0.04

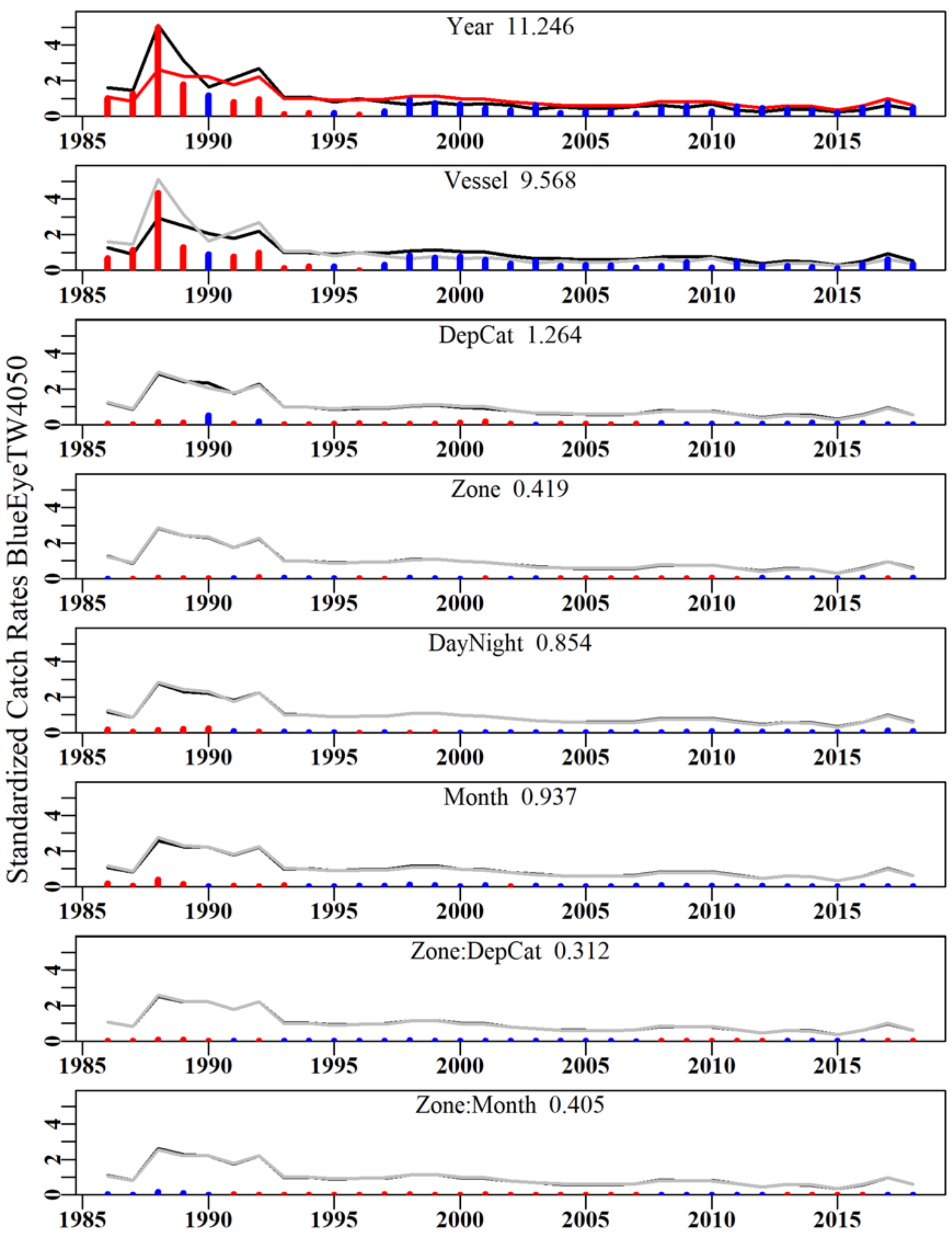

Figure 5.116. BlueEyeTW4050. The influence of each factor on the optimal standardization. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by vertical bars with blue bars indicating the optimum model is higher than the 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.

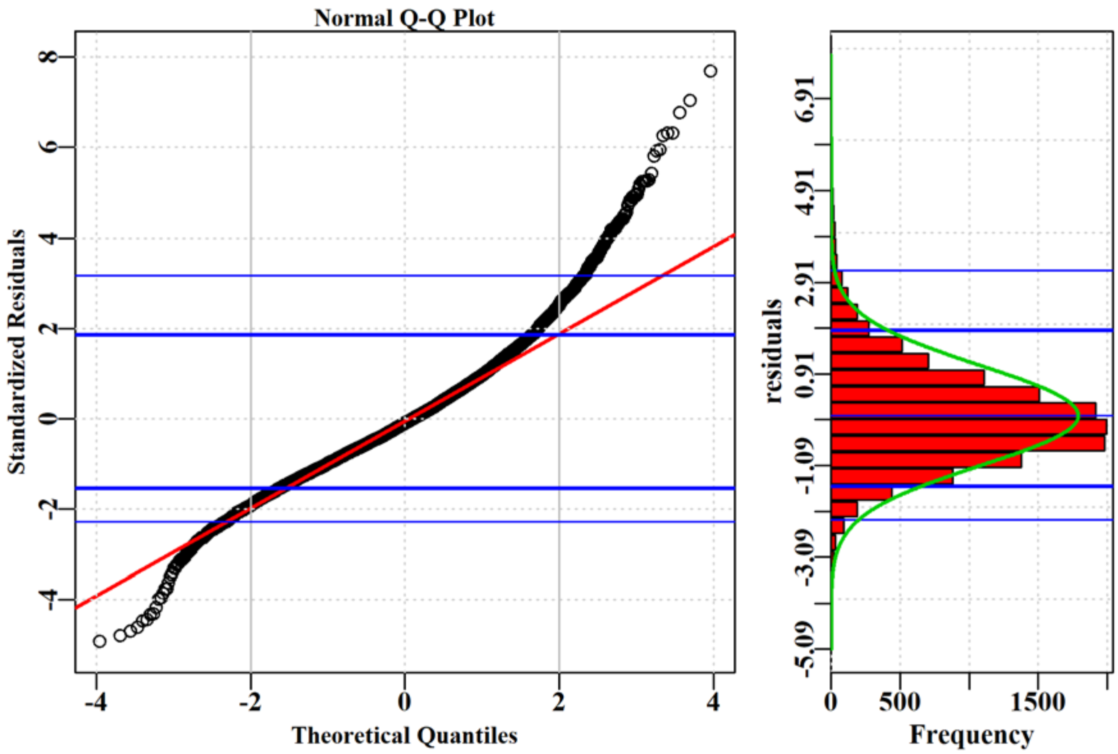

Figure 5.117. BlueEyeTW4050. diagnostic plots. The distribution of residuals from the optimum fit. The qqplot indicates the fit to the expected normality, while the histogram of residuals illustrates the 90% quantiles to indicate the intensity of any lack of fit at the margins of the distribution.

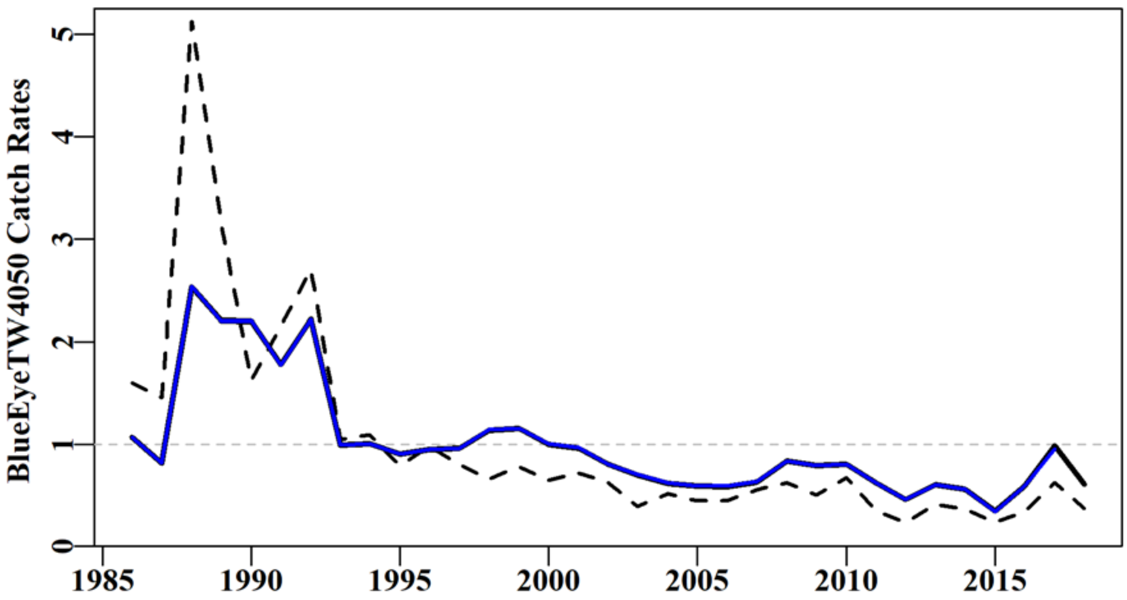

Figure 5.118. BlueEyeTW4050. A comparison of the previous year's standardization (blue line) with this year's. They should lie on top of each other, although small deviations may relate to data adjustments, particularly in very recent years.

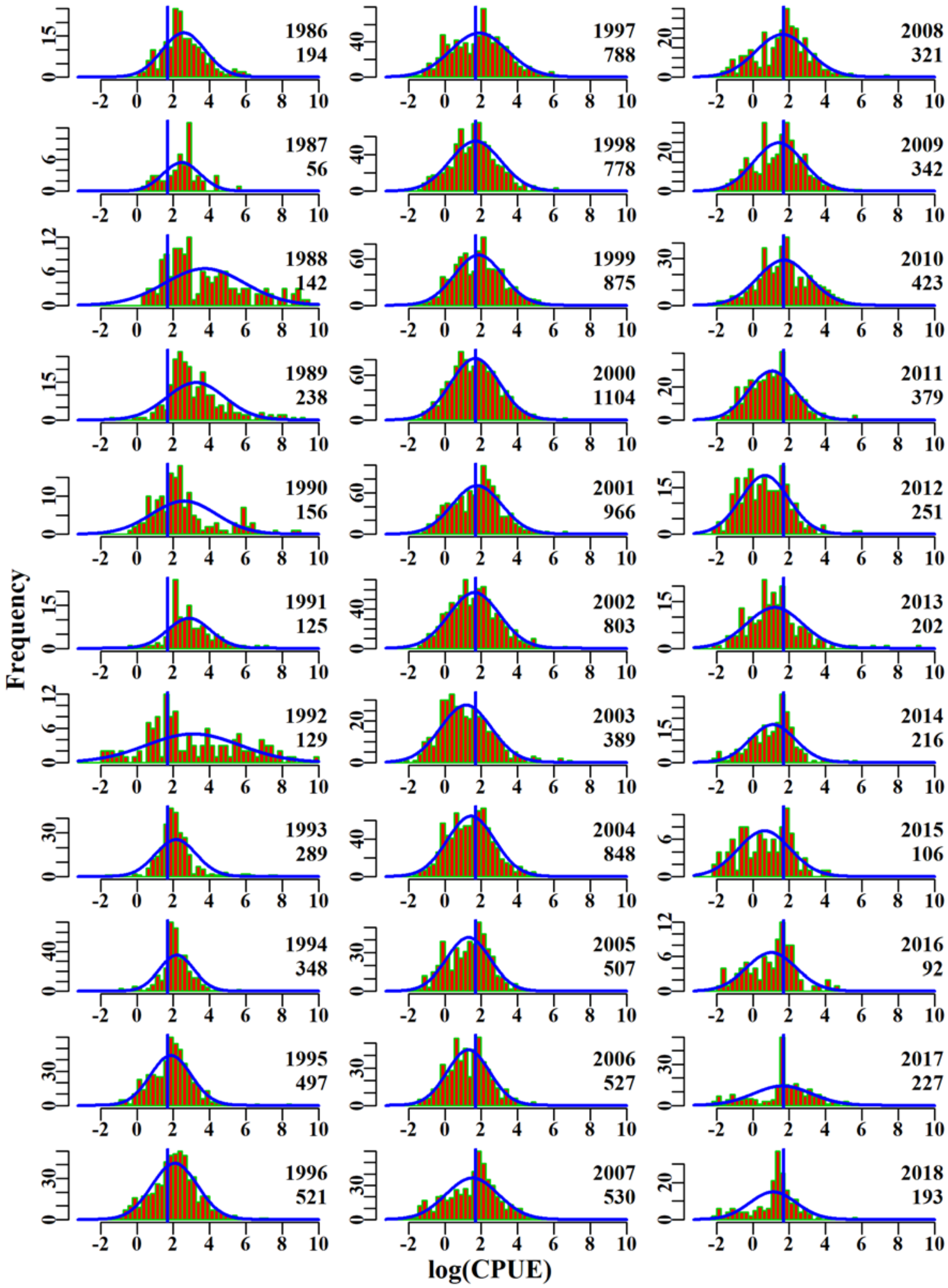

Figure 5.119. BlueEyeTW4050. The natural log(CPUE) for each year of data available the blue lines are normal distributions fitted to the histogram frequencies. The numbers in each plot are the year and number of records.

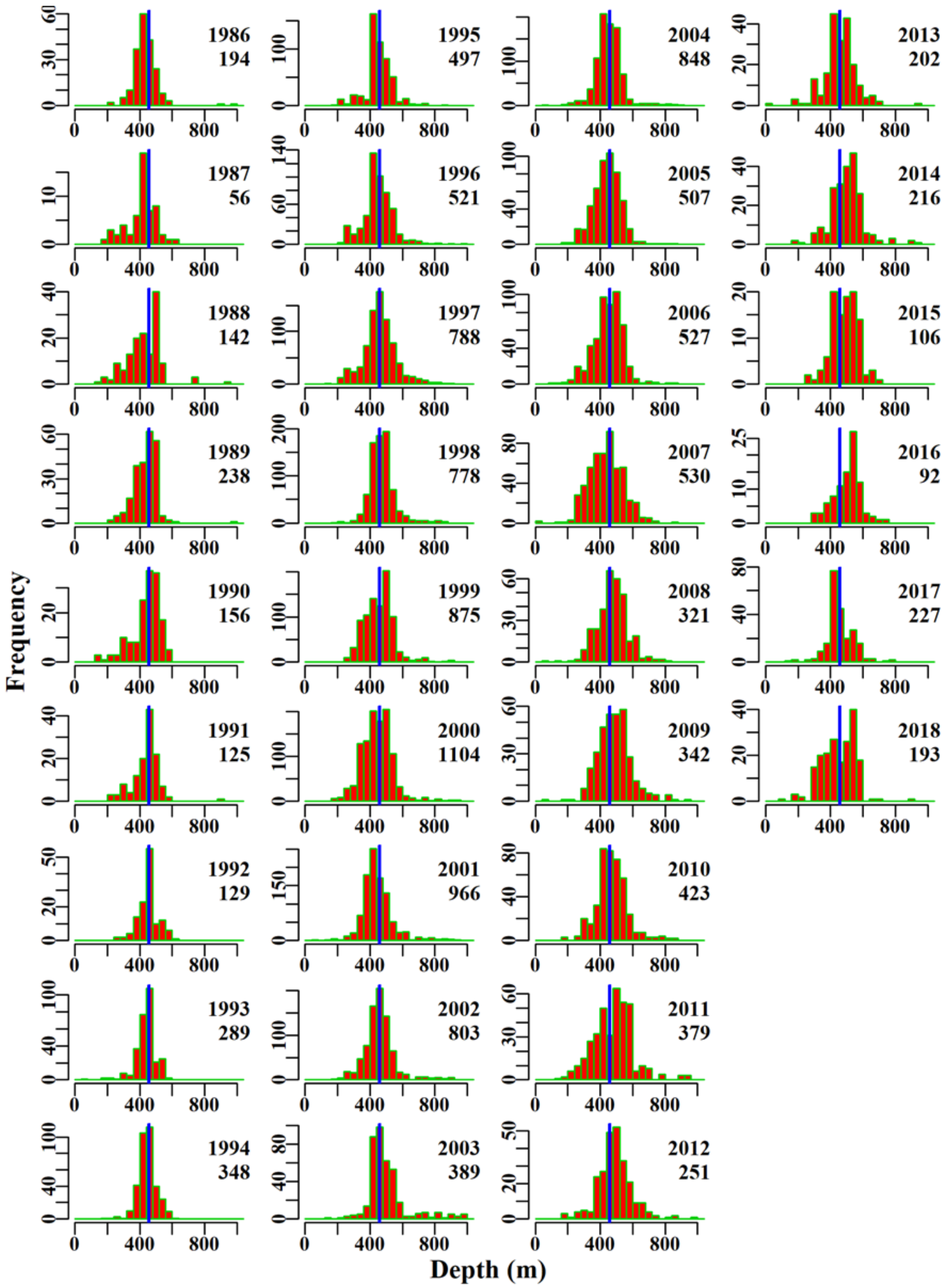

Figure 5.120. BlueEyeTW4050. The average Depth of fishing for each year of data available to illustrate the development of the fishery through time. The numbers in each plot are the year and number of records.

5.21 Blue-Grenadier Non-Spawning

Blue Grenadier (GRE – 37227001 – *Macruronus novaezelandiae*) was one of the 16 species first included in the quota system in 1992. Trawl caught Blue Grenadier based on methods TW, TDO, in zones 10, 20, 30, 40, 50, 60, and depths 100 to 1000 within the SET fishery for the years 1986 - 2018 were used in the analysis (Table 5.86).

A total of 8 statistical models were fitted sequentially to the available data, with the order of the non-interaction terms added based on the relative contribution of each term to model fit.

5.21.1 *Inferences*

Blue grenadier (non-spawning) were mostly caught in zone 50 and 40, followed by zone 20 and 30 across the analysis period.

The terms Year, Vessel, DayNight, DepCat, Zone and Month had the greatest contribution to model fit, with the remaining terms each explaining < 1% of the overall variation in CPUE, based on the AIC and R^2 statistics (Table 5.90). The qqplot suggests a slight departure from that the assumed Normal distribution as depicted by the upper tail of the distribution (Figure 5.124).

Annual standardized CPUE have been below average between 1993 - 2013, with two apparent cycles, each peaking in 1998 and 2008 respectively. Between 2013 to 2017, these annual indices were above average, and on average in 2018 (Figure 5.121).

5.21.2 *Action Items and Issues*

It is recommended that alternate statistical distributions be considered.

Table 5.86. BlueGrenadierNS. The data selection criteria used to specify and identify the fishery data to be included in the analysis.

Property	Value
label	BlueGrenadierNS
csirocode	37227001
fishery	SET
depthrange	100 - 1000
depthclass	50
zones	10, 20, 30, 40, 50, 60
methods	TW, TDO
years	1986 - 2018

Table 5.87. BlueGrenadierNS. Total catch (Total; t) is the total reported in the database, number of records used in the analysis (N), reported catch (Catch; t) in the area and depth used in the analysis and number of vessels used in the analysis (Vess). GeoM is the geometric mean of catch rates (kg/hr), standard deviation (StDev) relates to the optimum model. C<30Kg denotes the amount of catch in shots of <30kg, and %<30Kg is the percent of total. The optimum model was Zone:Month.

	Total	N	Catch	Vess	GeoM	Opt	StDev	C<30Kg	P<30Kg
1986	1205.5	3188	1183.2	92	141.8	1.5654	0.000	12.975	0.011
1987	1462.5	3561	1434.5	91	135.0	1.9987	0.034	14.597	0.010
1988	1530.1	3952	1469.1	102	129.2	2.1818	0.034	17.925	0.012
1989	1854.7	4302	1811.6	99	151.3	2.1814	0.034	18.000	0.010
1990	1710.8	3520	1468.5	92	149.1	2.1649	0.036	12.473	0.008
1991	2780.7	4243	2331.0	86	205.7	1.5438	0.034	15.704	0.007
1992	1760.8	3232	1505.6	62	178.1	1.2520	0.037	12.483	0.008
1993	1670.0	4189	1615.4	63	125.5	0.9522	0.035	19.041	0.012
1994	1341.2	4469	1306.7	66	94.2	0.8601	0.035	22.544	0.017
1995	1020.1	5059	1012.7	61	58.6	0.5935	0.034	32.505	0.032
1996	1092.7	5352	1054.4	72	56.4	0.5370	0.034	38.052	0.036
1997	1032.0	6175	993.4	73	43.8	0.5577	0.033	45.709	0.046
1998	1488.0	6584	1450.2	65	74.8	0.9018	0.033	41.062	0.028
1999	2113.3	8032	2043.8	65	89.6	0.9478	0.032	47.051	0.023
2000	1768.0	7667	1747.4	74	73.4	0.6825	0.033	49.517	0.028
2001	1062.1	7325	1020.8	60	40.3	0.3938	0.033	56.149	0.055
2002	1151.4	6331	1124.3	57	54.9	0.3909	0.034	40.900	0.036
2003	707.7	5650	667.3	56	33.8	0.3258	0.034	36.186	0.054
2004	1444.4	6362	1198.8	56	56.1	0.5475	0.034	23.385	0.020
2005	1626.5	5282	1164.6	54	66.0	0.6606	0.034	18.083	0.016
2006	1486.5	4317	1292.9	42	84.6	0.8824	0.036	11.037	0.009
2007	1312.0	3619	1193.3	27	86.6	0.7832	0.037	10.146	0.009
2008	1312.5	3365	1254.7	26	110.9	0.8650	0.037	8.968	0.007
2009	1150.9	3388	1112.5	23	89.2	0.8008	0.037	9.648	0.009
2010	1167.6	3266	1130.8	25	81.9	0.7990	0.037	8.044	0.007
2011	923.1	3907	882.3	26	49.4	0.6526	0.036	9.375	0.011
2012	645.7	3116	602.4	29	41.6	0.5190	0.038	9.802	0.016
2013	774.5	3031	733.8	26	58.0	0.9257	0.038	7.204	0.010
2014	994.1	3038	921.3	28	78.6	1.1324	0.038	6.127	0.007
2015	1069.7	2959	1046.7	29	105.5	1.2304	0.038	8.100	0.008
2016	982.3	2505	962.5	24	112.4	1.0466	0.040	5.413	0.006
2017	1262.8	2894	1216.0	23	117.4	1.1604	0.039	4.560	0.004
2018	1085.1	2822	1052.6	23	99.8	0.9632	0.039	4.949	0.005

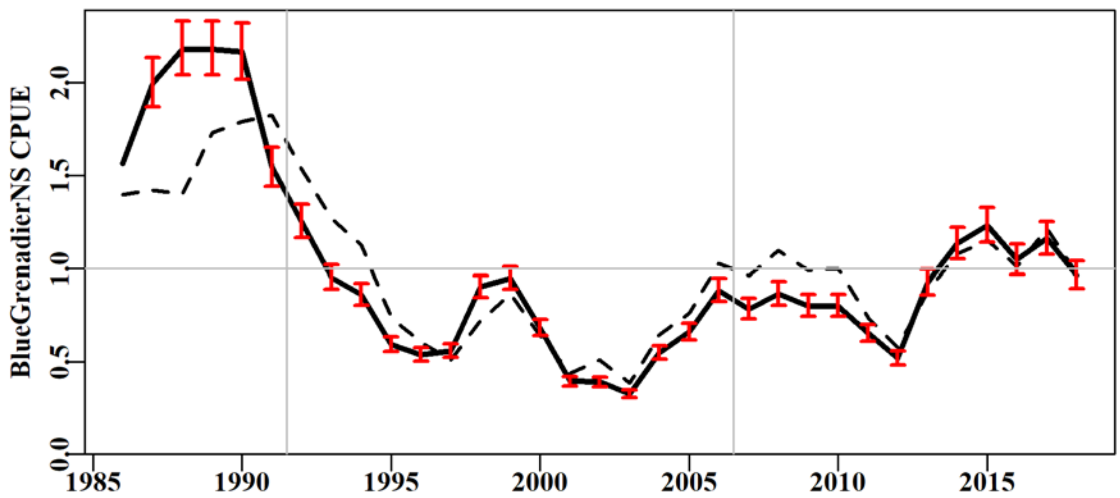

Figure 5.121. BlueGrenadierNS standardization. The dashed black line represents the geometric mean catch rate, solid black line the standardized catch rates. The red bars are the 95% confidence intervals about the mean estimates. The graph scales both time-series of standardized catch rates relative to the mean of each time-series.

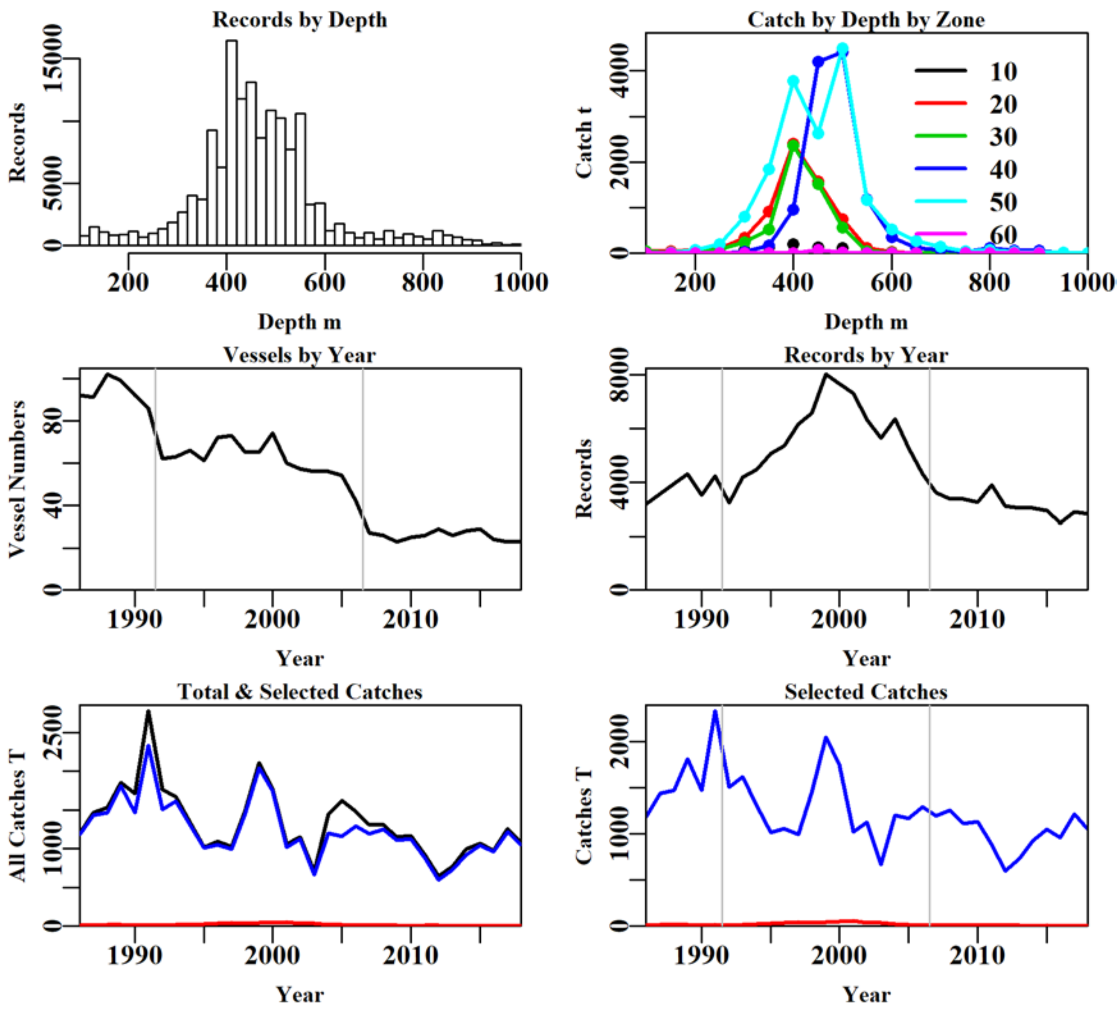

Figure 5.122. BlueGrenadierNS fishery details. The bottom left plot depicts all known catches (top black line), and all selected catches used in the analysis (middle blue line); the lower red line: selected catches < 30 kg).

Table 5.88. BlueGrenadierNS data selection effects. Total is the total number of records in the database, NoCE removes those records with either missing catch or effort, and then only those records are kept that meet the criteria for depth, years, zone, method and fishery.

	Total	NoCE	Depth	Years	Zones	Method	Fishery
Records	1698570	155911	154266	152224	148349	146804	146702
Difference	0	13946	1645	2042	3875	1545	102
Catch	44763.58	44145.549	43635.141	42864.02	41506.93	41022.11	41005.15
Difference	0	618.03	510.41	771.11	1357.09	484.82	16.96

Table 5.89. The models used to analyse data for BlueGrenadierNS.

	Model
Model1	Year
Model2	Year + Vessel
Model3	Year + Vessel + DayNight
Model4	Year + Vessel + DayNight + DepCat
Model5	Year + Vessel + DayNight + DepCat + Zone
Model6	Year + Vessel + DayNight + DepCat + Zone + Month
Model7	Year + Vessel + DayNight + DepCat + Zone + Month + Zone:DepCat
Model8	Year + Vessel + DayNight + DepCat + Zone + Month + Zone:Month

Table 5.90. BlueGrenadierNS. The row names are 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_r2) and the change in adjusted R^2 (%Change). The optimum model was Zone:Month.

	AIC	RSS	MSS	Nobs	Npars	adj_r2	%Change
Year	135158	368436	25691	146702	33	6.5	0.00
Vessel	110542	310664	83462	146702	235	21.1	14.55
DayNight	101050	291188	102939	146702	238	26.0	4.95
DepCat	92051	273797	120330	146702	256	30.4	4.41
Zone	87353	265148	128978	146702	261	32.6	2.20
Month	82797	257002	137124	146702	272	34.7	2.07
Zone:DepCat	81174	253884	140243	146702	356	35.4	0.76
Zone:Month	79411	250961	143166	146702	324	36.2	1.51

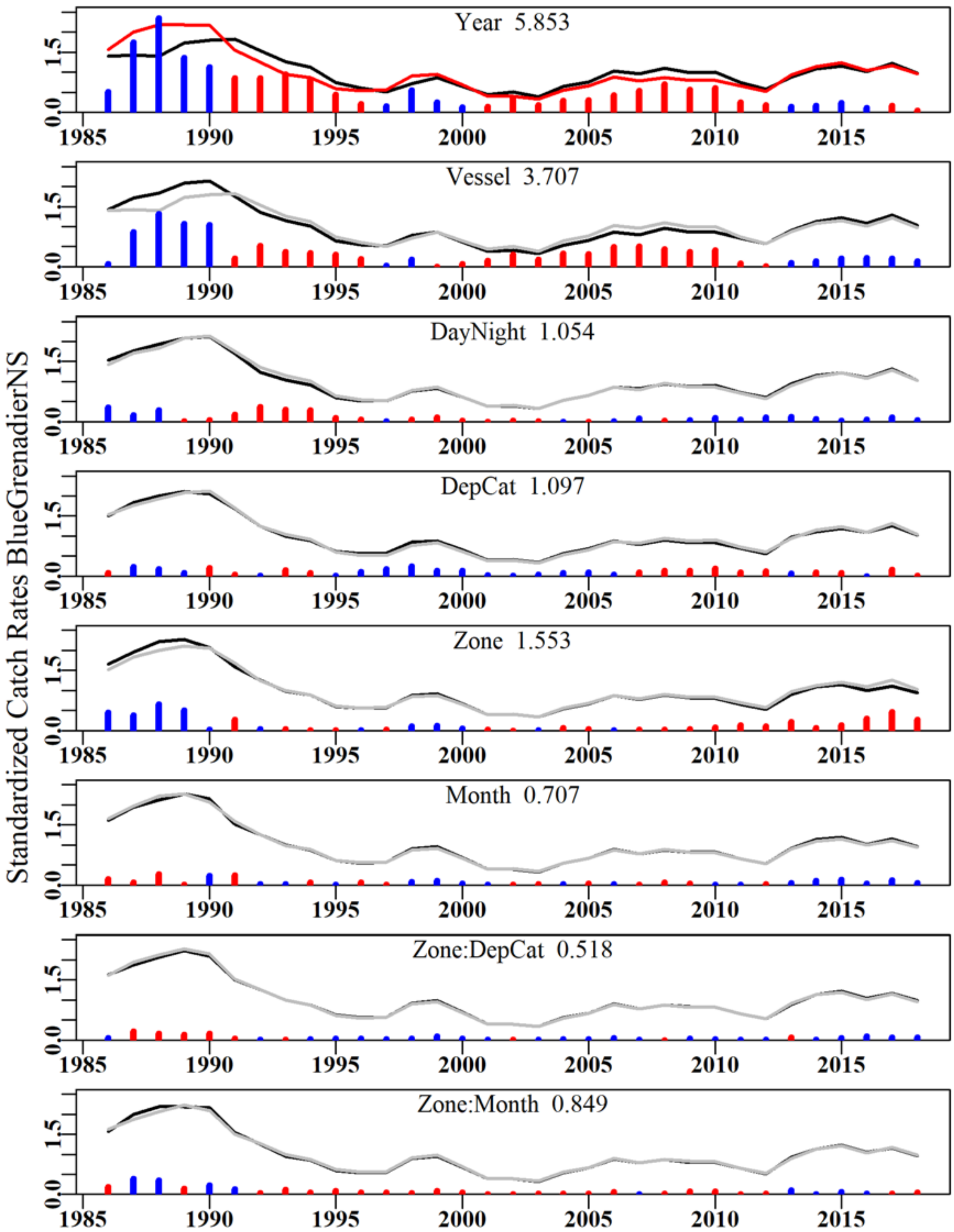

Figure 5.123. BlueGrenadierNS. The influence of each factor on the optimal standardization. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by vertical bars with blue bars indicating the optimum model is higher than the 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.

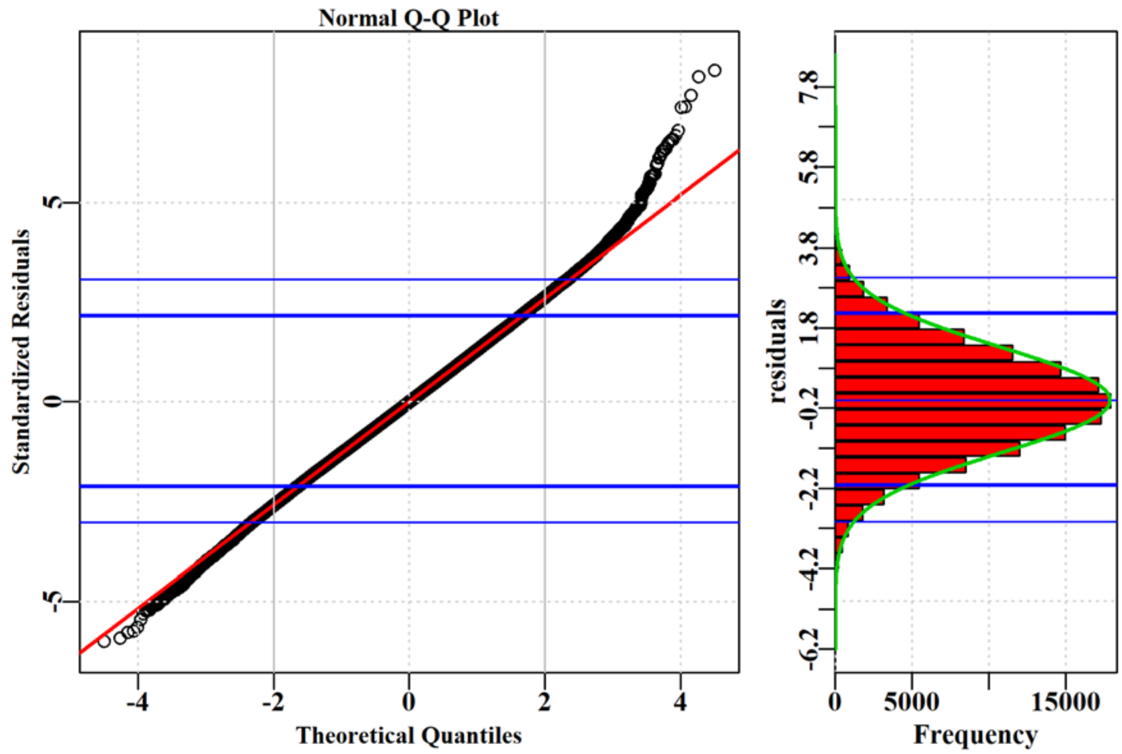

Figure 5.124. BlueGrenadierNS. diagnostic plots. The distribution of residuals from the optimum fit. The qqplot indicates the fit to the expected normality, while the histogram of residuals illustrates the 90% quantiles to indicate the intensity of any lack of fit at the margins of the distribution.

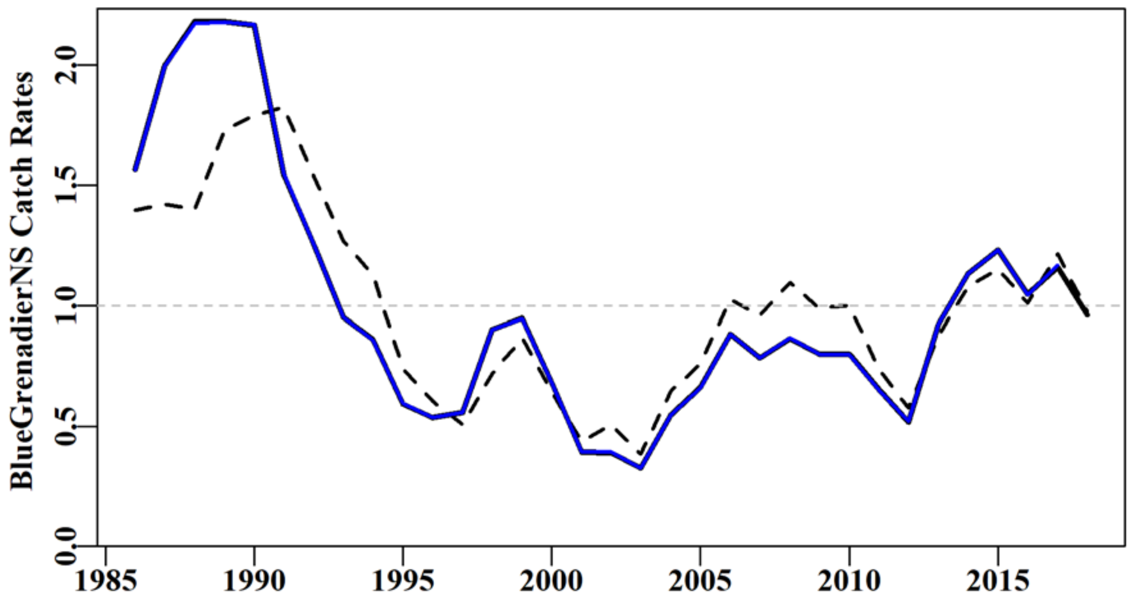

Figure 5.125. BlueGrenadierNS. A comparison of the previous year's standardization (blue line) with this year's. They should lie on top of each other, although small deviations may relate to data adjustments, particularly in very recent years.

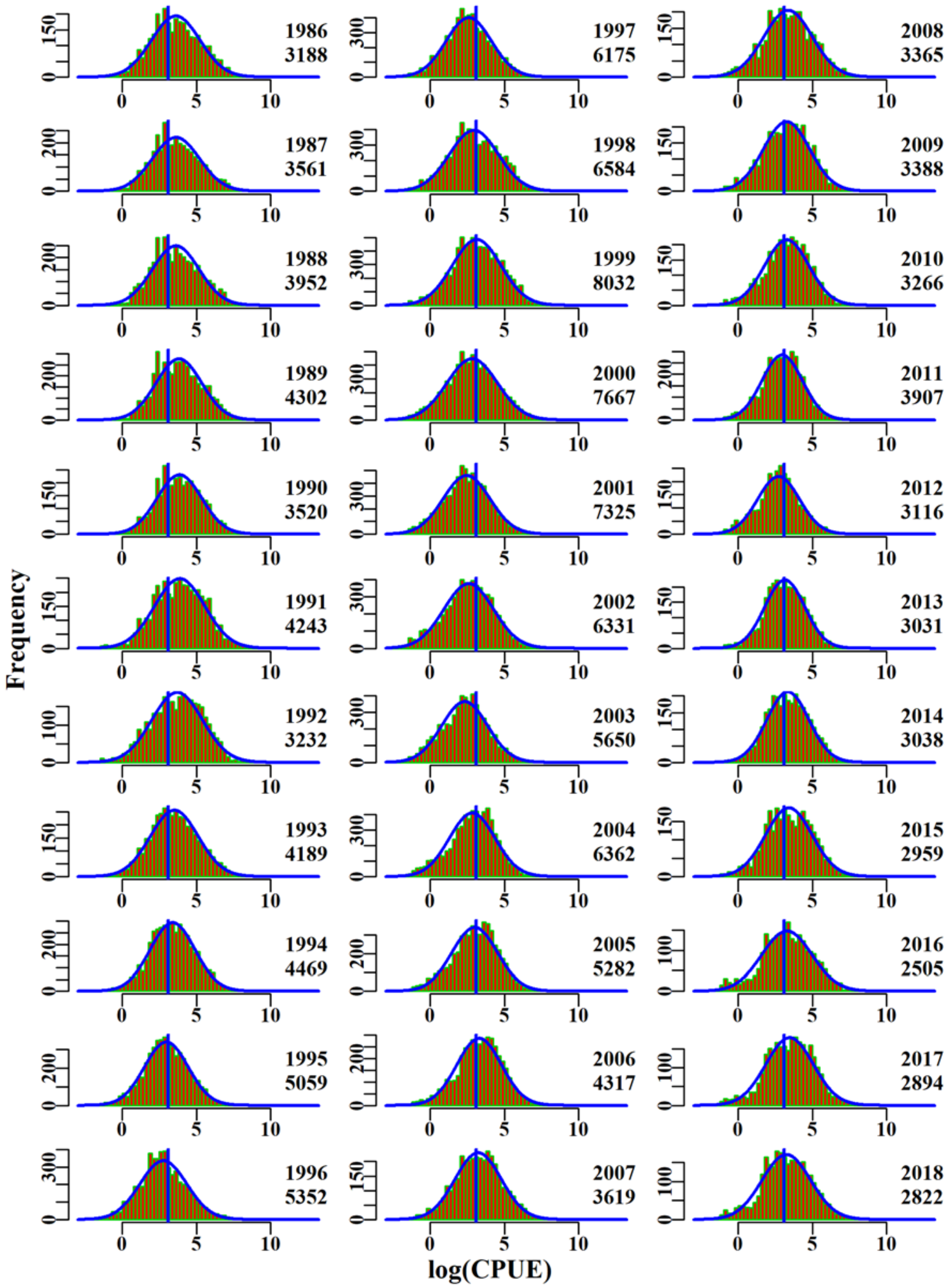

Figure 5.126. BlueGrenadierNS. The natural log(CPUE) for each year of data available the blue lines are normal distributions fitted to the histogram frequencies. The numbers in each plot are the year and number of records.

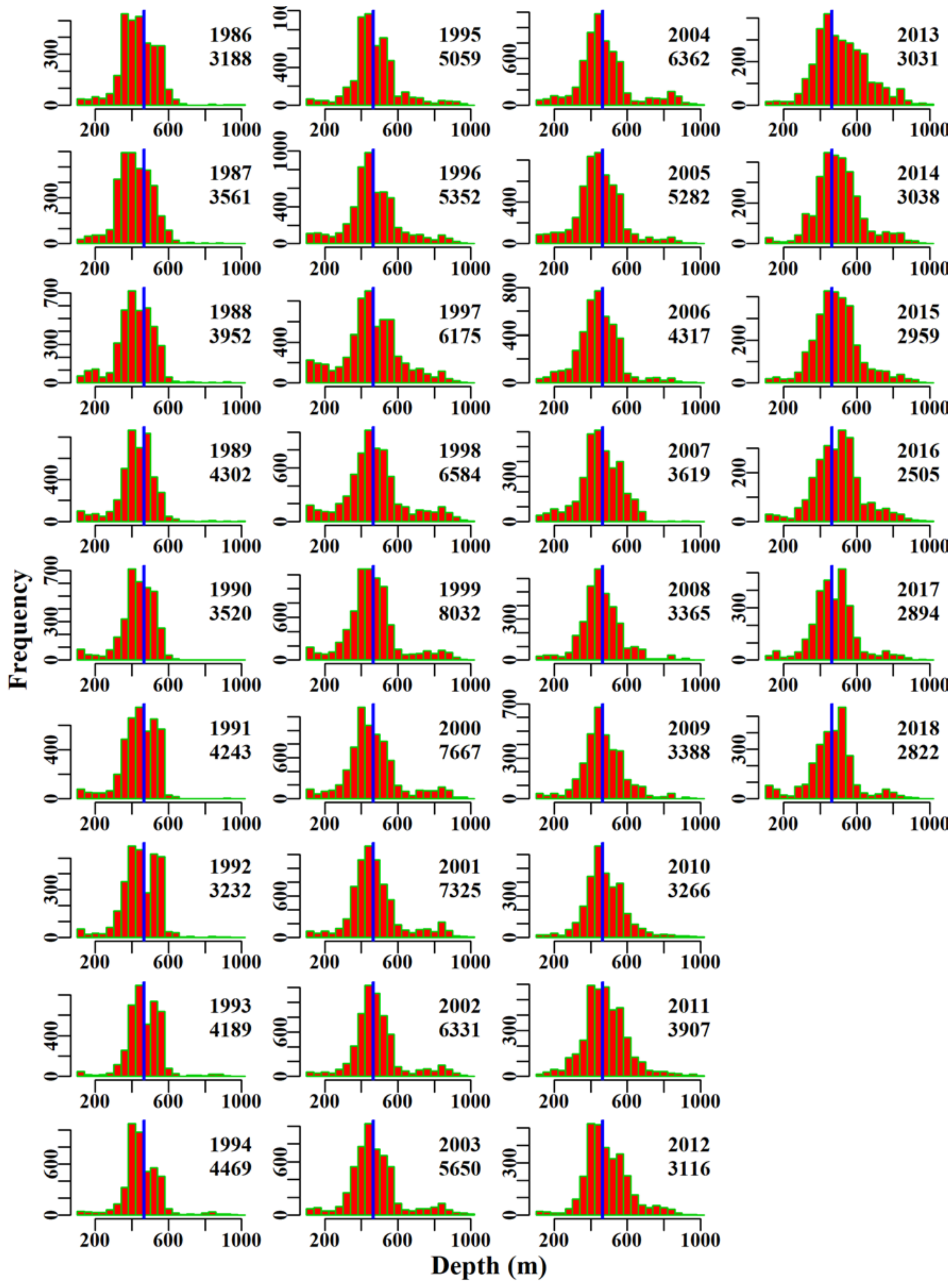

Figure 5.127. BlueGrenadierNS. The average Depth of fishing for each year of data available to illustrate the development of the fishery through time. The numbers in each plot are the year and number of records.

5.22 Pink Ling 10 – 30

Pink Ling (LIG – 37228002 –*Genypterus blacodes*) was one of the 16 species first included in the quota system in 1992, which reflects its long history within the SESSF. Pink ling caught by trawl based on methods TW, TDO, in zones 10, 20, 30, and depths 250 to 600 within the SET fishery for the years 1986 - 2018 were used in the analysis (Table 5.91). A total of 8 statistical models were fitted sequentially to the available data, with the order of the non-interaction terms added based on the relative contribution of each term to model fit.

5.22.1 *Inferences*

Pink Ling were mostly caught in zone 20, followed by zone 10 and 30 across the analysis period.

The terms Year, Vessel, DepCat and Month had the greatest contribution to model fit, with the remaining terms each explaining < 1% of the overall variation in CPUE, based on the AIC and R^2 statistics (Table 5.95). The qqplot suggests a departure from that the assumed Normal distribution as depicted by both tails of the distribution (Figure 5.131).

Annual standardized CPUE have been below average since 2001, corresponding to a relatively flat trend (Figure 5.128). The structural adjustment had a major effect upon the influence of the vessel factor from 2006 or 2007 onwards.

5.22.2 *Action Items and Issues*

A detailed consideration be given to the change in vessel effects following the structural adjustment to ensure that the time-series of Pink Ling CPUE was not broken by this management intervention.

Table 5.91. PinkLing1030. The data selection criteria used to specify and identify the fishery data to be included in the analysis.

Property	Value
label	PinkLing1030
csirocode	37228002
fishery	SET
depthrange	250 - 600
depthclass	25
zones	10, 20, 30
methods	TW, TDO
years	1986 - 2018

Table 5.92. PinkLing1030. Total catch (Total; t) is the total reported in the database, number of records used in the analysis (N), reported catch (Catch; t) in the area and depth used in the analysis and number of vessels used in the analysis (Vess). GeoM is the geometric mean of catch rates (kg/hr), standard deviation (StDev) relates to the optimum model. C<30Kg denotes the amount of catch in shots of <30kg, and %<30Kg is the percent of total. The optimum model was Zone:DepCat.

	Total	N	Catch	Vess	GeoM	Opt	StDev	C<30Kg	P<30Kg
1986	679.0	4510	498.2	80	44.9	1.1612	0.000	24.955	0.050
1987	765.1	4251	491.4	77	46.0	1.2324	0.022	22.694	0.046
1988	583.1	3603	398.3	77	40.5	1.1841	0.024	17.925	0.045
1989	678.9	3869	421.2	76	39.9	1.0233	0.023	20.150	0.048
1990	674.5	2768	411.6	67	52.7	1.4788	0.026	11.056	0.027
1991	736.8	2903	366.0	71	46.2	1.4435	0.026	13.338	0.036
1992	568.3	2417	329.4	58	45.9	1.1314	0.027	11.224	0.034
1993	892.8	3471	500.7	58	50.3	1.0784	0.025	16.847	0.034
1994	895.4	4036	468.4	62	42.7	1.1049	0.024	21.041	0.045
1995	1208.9	4346	585.6	57	49.3	1.3844	0.023	21.920	0.037
1996	1233.3	4254	666.7	63	56.2	1.3793	0.023	17.576	0.026
1997	1696.8	4772	730.9	61	52.0	1.4049	0.023	19.670	0.027
1998	1592.4	4883	728.3	56	53.1	1.3909	0.023	22.477	0.031
1999	1651.6	5934	831.1	59	48.8	1.2651	0.022	27.979	0.034
2000	1507.5	5100	658.8	63	46.3	1.1077	0.023	24.500	0.037
2001	1393.0	4555	484.9	52	38.0	0.8636	0.024	24.294	0.050
2002	1330.3	3882	360.3	52	35.2	0.7563	0.025	22.555	0.063
2003	1353.1	4277	444.3	57	38.6	0.7888	0.024	19.522	0.044
2004	1522.9	3328	345.6	54	37.1	0.7074	0.026	14.208	0.041
2005	1203.3	3370	324.5	51	32.6	0.6610	0.026	13.679	0.042
2006	1069.2	2566	321.1	38	42.1	0.7938	0.027	6.841	0.021
2007	875.9	1627	202.8	23	42.0	0.7533	0.032	4.487	0.022
2008	980.3	2342	325.4	24	46.7	0.9003	0.029	5.268	0.016
2009	775.0	1886	208.3	27	34.7	0.6453	0.030	5.024	0.024
2010	906.2	1923	265.5	23	47.0	0.7983	0.030	4.976	0.019
2011	1081.9	2122	287.3	22	46.7	0.8384	0.029	4.720	0.016
2012	1030.9	1919	268.1	24	49.5	0.8974	0.030	4.917	0.018
2013	752.9	1565	184.8	22	40.8	0.7434	0.032	4.498	0.024
2014	861.2	1642	234.9	24	49.1	0.8354	0.032	5.039	0.021
2015	721.8	1650	188.9	24	41.1	0.7264	0.032	5.273	0.028
2016	735.8	1371	180.8	25	44.2	0.7317	0.034	4.156	0.023
2017	896.7	1743	262.6	21	55.2	0.8622	0.032	4.729	0.018
2018	874.0	1486	207.0	20	48.2	0.9267	0.034	3.677	0.018

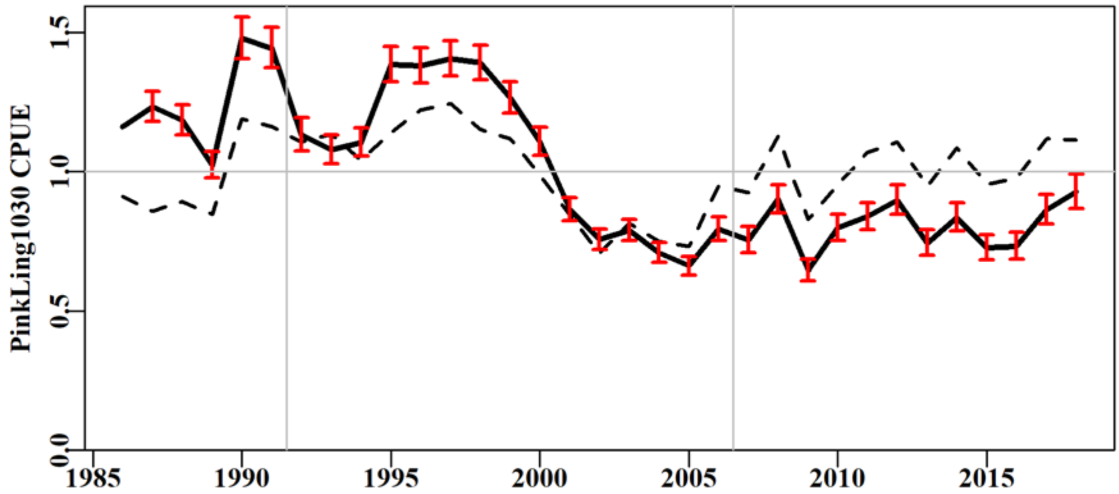

Figure 5.128. PinkLing1030 standardization. The dashed black line represents the geometric mean catch rate, solid black line the standardized catch rates. The red bars are the 95% confidence intervals about the mean estimates. The graph scales both time-series of standardized catch rates relative to the mean of each time-series.

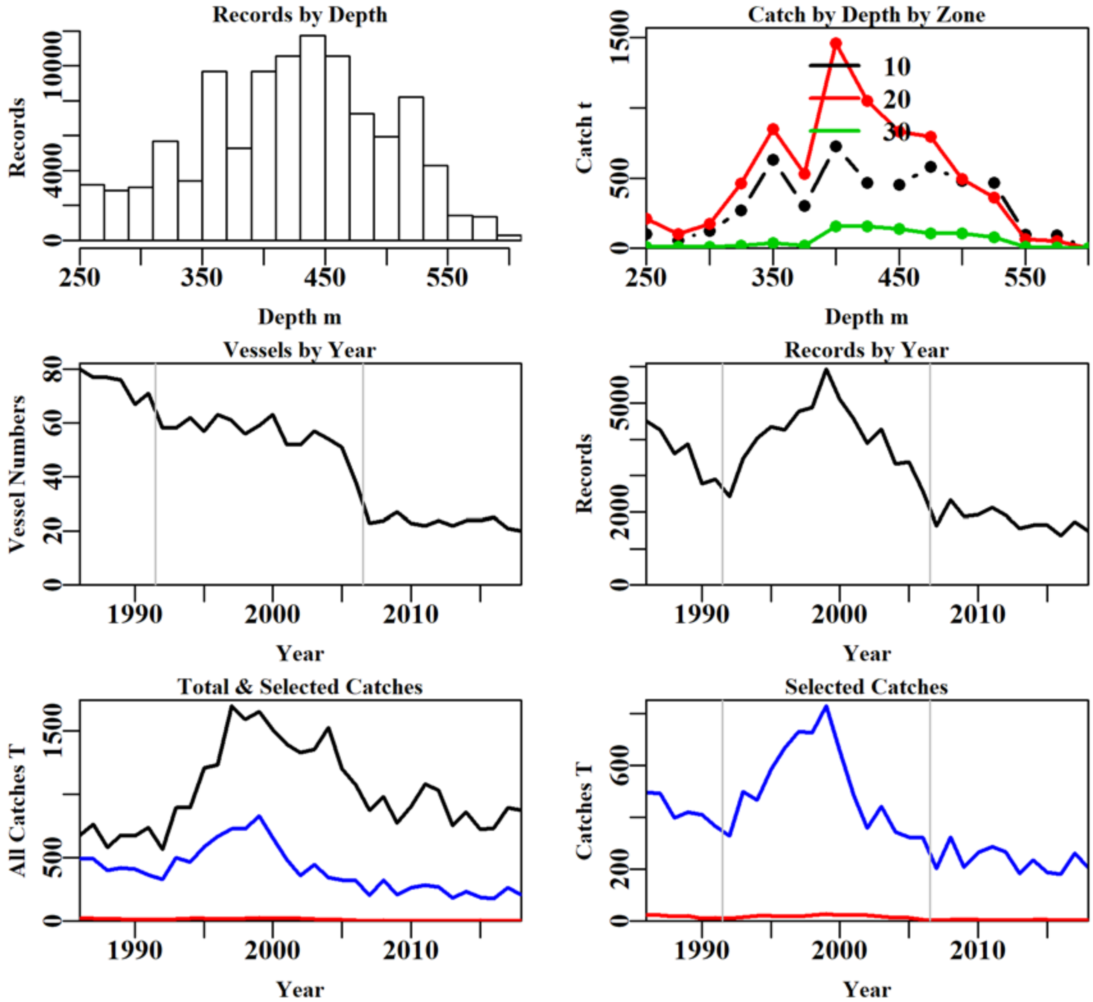

Figure 5.129. PinkLing1030 fishery details. The bottom left plot depicts all known catches (top black line), and all selected catches used in the analysis (middle blue line); the lower red line: selected catches < 30 kg).

Table 5.93. PinkLing1030 data selection effects. Total is the total number of records in the database, NoCE removes those records with either missing catch or effort, and then only those records are kept that meet the criteria for depth, years, zone, method and fishery.

	Total	NoCE	Depth	Years	Zones	Method	Fishery
Records	3123330	286307	190707	188261	106479	104405	104371
Difference	0	26026	95600	2446	81782	2074	34
Catch	34138.98	26988.127	23629.873	23262.87	13467.25	13189.46	13183.62
Difference	0	7150.86	3358.25	367.004	9795.61	277.80	5.84

Table 5.94. The models used to analyse data for PinkLing1030.

	Model
Model1	Year
Model2	Year + Vessel
Model3	Year + Vessel + DepCat
Model4	Year + Vessel + DepCat + Month
Model5	Year + Vessel + DepCat + Month + Zone
Model6	Year + Vessel + DepCat + Month + Zone + DayNight
Model7	Year + Vessel + DepCat + Month + Zone + DayNight + Zone:DepCat
Model8	Year + Vessel + DepCat + Month + Zone + DayNight + Zone:Month

Table 5.95. PinkLing1030. The row names are 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_r2) and the change in adjusted R^2 (%Change). The optimum model was Zone:DepCat.

	AIC	RSS	MSS	Nobs	Npars	adj_r2	%Change
Year	33955	144409	2768	104371	33	1.9	0.00
Vessel	16020	121174	26003	104371	220	17.5	15.64
DepCat	5333	109351	37826	104371	234	25.5	8.04
Month	1345	105230	41948	104371	245	28.3	2.80
Zone	767	104644	42533	104371	247	28.7	0.40
DayNight	603	104474	42703	104371	250	28.8	0.11
Zone:DepCat	-601	103221	43957	104371	278	29.7	0.84
Zone:Month	-491	103341	43836	104371	272	29.6	0.76

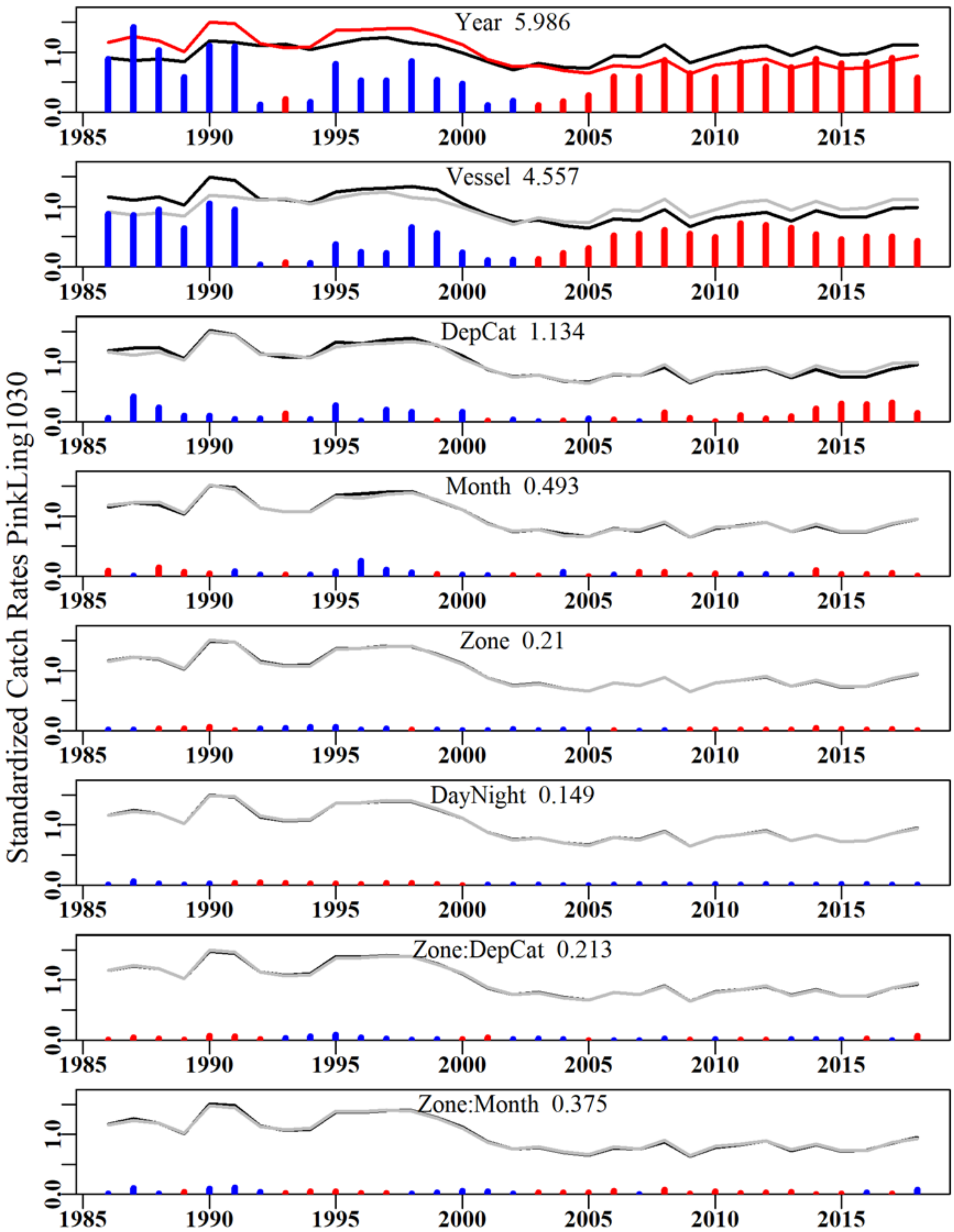

Figure 5.130. PinkLing1030. The influence of each factor on the optimal standardization. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by vertical bars with blue bars indicating the optimum model is higher than the geometric 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.

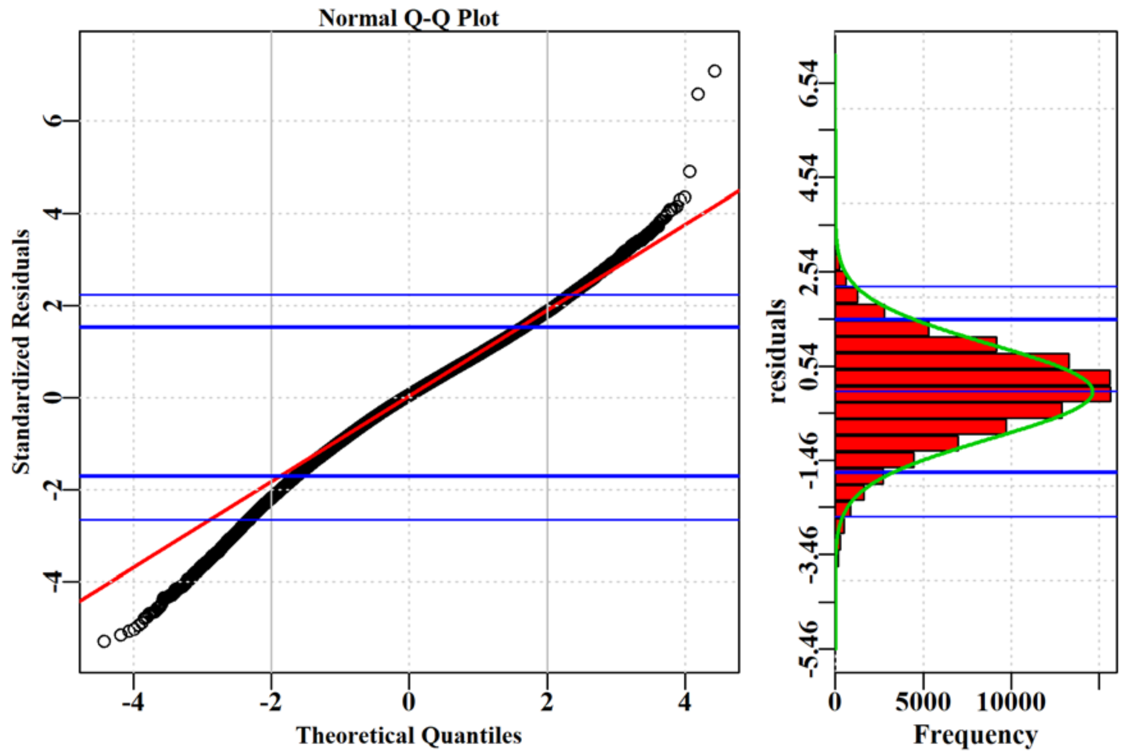

Figure 5.131. PinkLing1030. diagnostic plots. The distribution of residuals from the optimum fit. The qqplot indicates the fit to the expected normality, while the histogram of residuals illustrates the 90% quantiles to indicate the intensity of any lack of fit at the margins of the distribution.

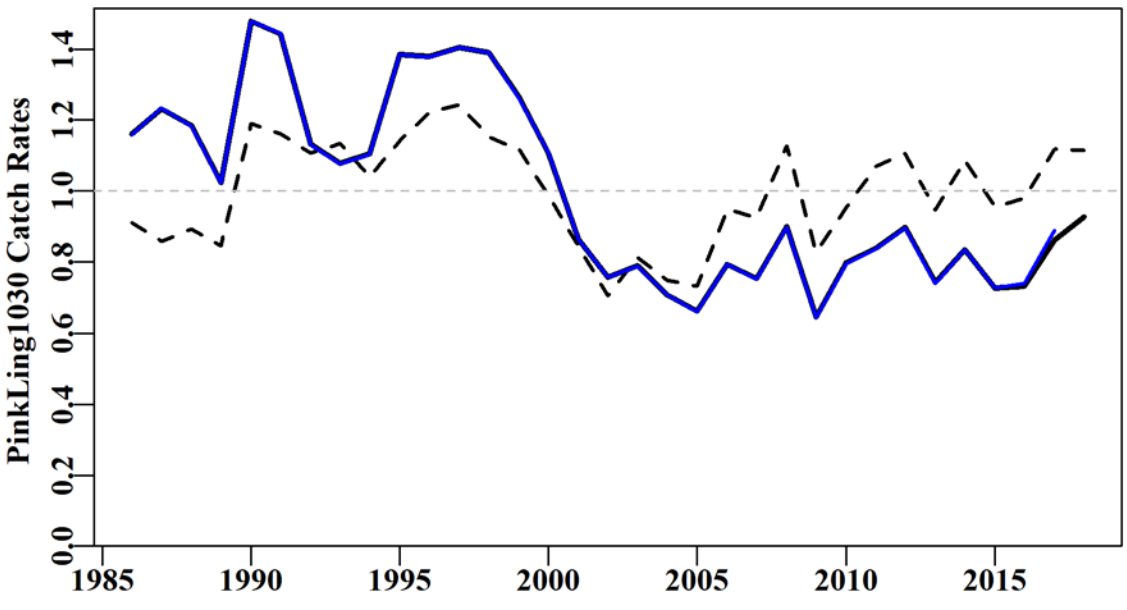

Figure 5.132. PinkLing1030. A comparison of the previous year's standardization (blue line) with this year's. They should lie on top of each other, although small deviations may relate to data adjustments, particularly in very recent years.

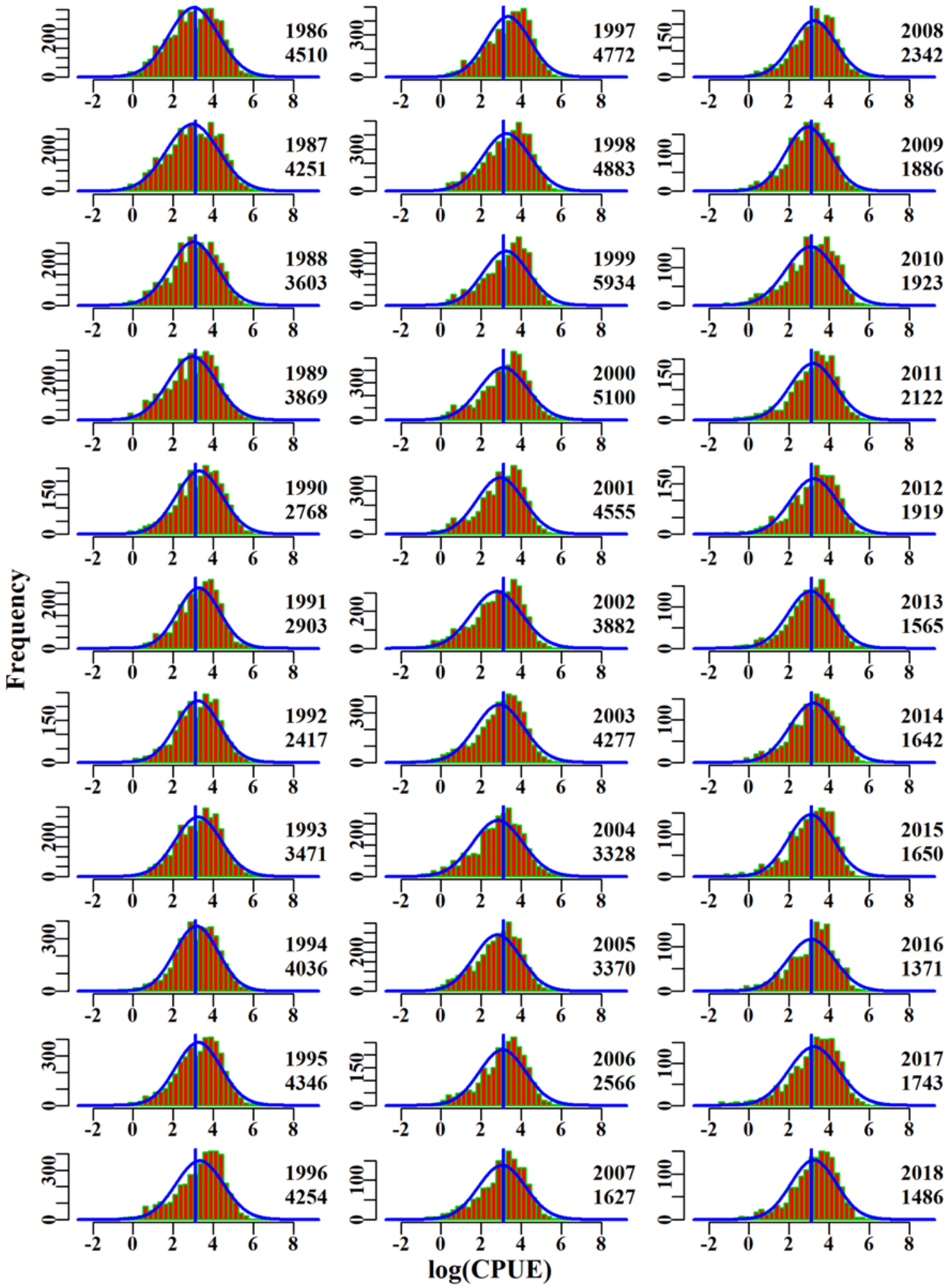

Figure 5.133. PinkLing1030. The natural log(CPUE) for each year of data available the blue lines are normal distributions fitted to the histogram frequencies. The numbers in each plot are the year and number of records.

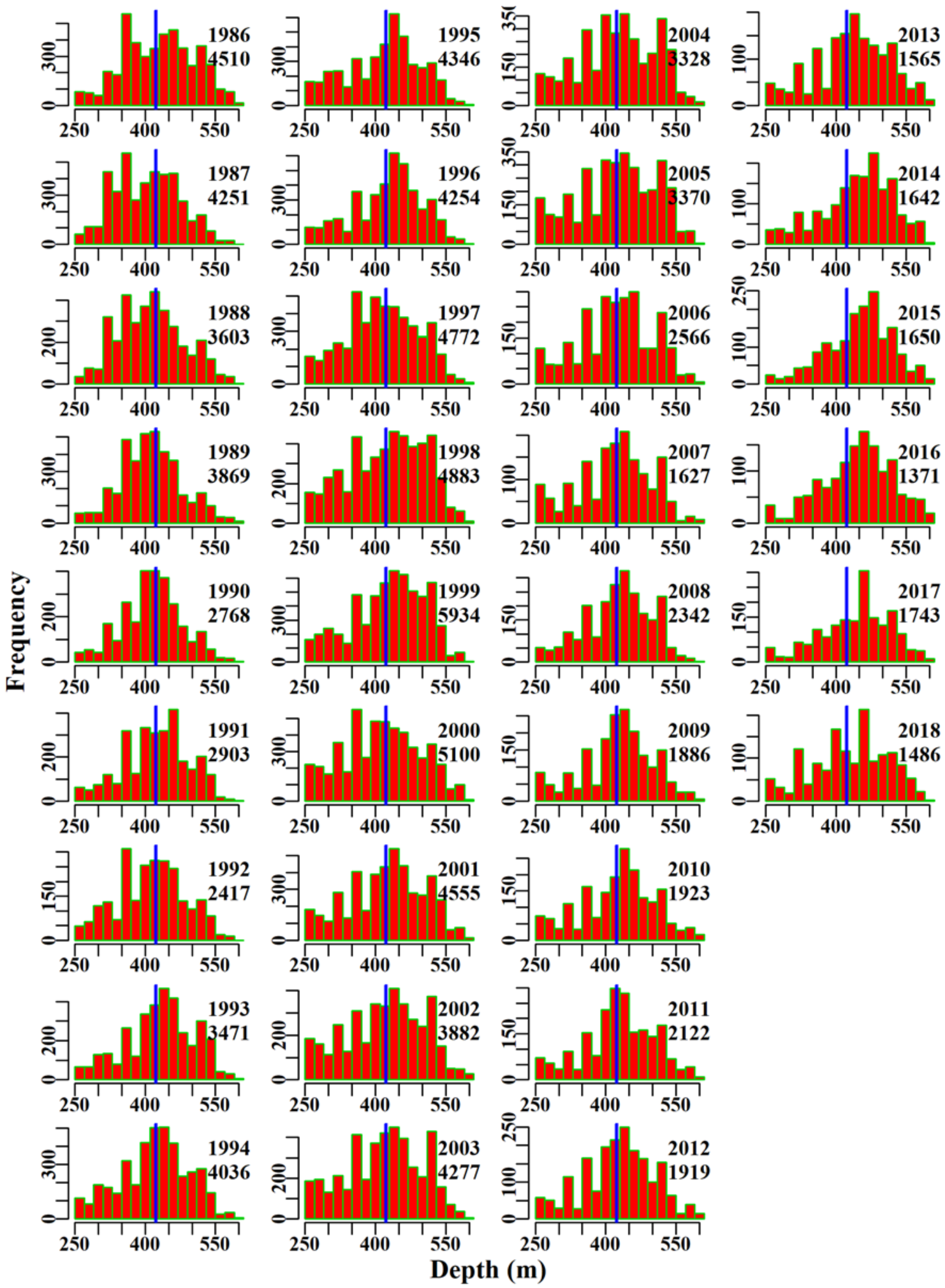

Figure 5.134. PinkLing1030. The average Depth of fishing for each year of data available to illustrate the development of the fishery through time. The numbers in each plot are the year and number of records.

5.23 Pink Ling 40 – 50

Pink Ling (LIG – 37228002 – *Genypterus blacodes*) was one of the 16 species first included in the quota system in 1992. Pink Ling based on methods TW, TDO, in zones 40, 50, and depths 200 to 800 within the SET fishery for the years 1986 - 2018 were used in the analysis (Table 5.96).

A total of 8 statistical models were fitted sequentially to the available data, with the order of the non-interaction terms added based on the relative contribution of each term to model fit.

5.23.1 *Inferences*

The majority of catch of this slope species occurred in zone 40 followed by zone 50.

The terms Year, DepCat, Vessel, Month and Zone had the greatest contribution to model fit, with the remaining terms each explaining < 1% of the overall variation in CPUE, based on the AIC and R^2 statistics (Table 5.100). The qqplot suggests a departure from that the assumed Normal distribution as depicted by both tails of the distribution (Figure 5.138).

Annual standardized CPUE reached a minimum in 2005 and have been increasing since then and have been at the long term average from 2013 – 2018, based on the 95% confidence intervals (Figure 5.135).

5.23.2 *Action Items and Issues*

Further work on the effect of the structural adjustment is required for Pink Ling in zones 40 and 50.

Table 5.96. PinkLing4050. The data selection criteria used to specify and identify the fishery data to be included in the analysis.

Property	Value
label	PinkLing4050
csirocode	37228002
fishery	SET
depthrange	200 - 800
depthclass	20
zones	40, 50
methods	TW, TDO
years	1986 - 2018

Table 5.97. PinkLing4050. Total catch (Total; t) is the total reported in the database, number of records used in the analysis (N), reported catch (Catch; t) in the area and depth used in the analysis and number of vessels used in the analysis (Vess). GeoM is the geometric mean of catch rates (kg/hr), standard deviation (StDev) relates to the optimum model. C<30Kg denotes the amount of catch in shots of <30kg, and %<30Kg is the percent of total. The optimum model was Zone:Month.

	Total	N	Catch	Vess	GeoM	Opt	StDev	C<30Kg	P<30Kg
1986	679.0	1265	112.9	23	27.8	1.1818	0.000	6.366	0.056
1987	765.1	1306	205.7	28	52.0	1.3360	0.037	5.740	0.028
1988	583.1	1025	95.5	32	28.0	1.0431	0.040	6.722	0.070
1989	678.9	1466	182.8	34	36.2	1.0693	0.038	8.690	0.048
1990	674.5	1483	135.2	32	26.7	0.9606	0.038	11.943	0.088
1991	736.8	1874	194.8	37	25.6	1.0294	0.037	11.915	0.061
1992	568.3	1629	101.9	24	17.0	0.7659	0.038	12.661	0.124
1993	892.8	2248	235.2	24	26.6	1.0359	0.036	15.744	0.067
1994	895.4	2096	246.1	24	30.8	1.2651	0.036	12.093	0.049
1995	1208.9	3503	425.5	25	31.9	1.3113	0.034	21.945	0.052
1996	1233.3	3385	446.1	26	33.1	1.3785	0.034	22.301	0.050
1997	1696.8	3716	572.2	24	37.2	1.4458	0.034	21.065	0.037
1998	1592.4	3704	555.3	21	38.2	1.4299	0.034	19.110	0.034
1999	1651.6	3784	426.2	24	30.4	1.1277	0.034	23.836	0.056
2000	1507.5	4642	508.4	31	28.6	0.9828	0.034	31.181	0.061
2001	1393.0	5084	500.3	28	24.5	0.8716	0.034	36.867	0.074
2002	1330.3	4619	428.9	27	21.5	0.7540	0.034	36.499	0.085
2003	1353.1	3806	358.4	27	20.5	0.7578	0.034	26.224	0.073
2004	1522.9	3880	302.7	25	17.7	0.7115	0.034	17.723	0.059
2005	1203.3	2650	194.9	23	15.6	0.5930	0.036	11.283	0.058
2006	1069.2	2298	207.9	21	17.9	0.6263	0.036	6.710	0.032
2007	875.9	2505	284.5	16	21.7	0.6866	0.036	7.621	0.027
2008	980.3	1777	211.8	17	24.5	0.8820	0.037	4.357	0.021
2009	775.0	1956	258.3	13	24.6	0.8565	0.037	4.144	0.016
2010	906.2	2316	268.9	14	20.9	0.8372	0.036	4.801	0.018
2011	1081.9	2772	355.3	16	21.6	0.8393	0.035	5.216	0.015
2012	1030.9	2264	333.0	14	25.8	0.8829	0.036	4.383	0.013
2013	752.9	1757	278.2	17	27.9	0.9904	0.038	3.547	0.013
2014	861.2	1943	284.6	15	24.8	0.9746	0.037	3.537	0.012
2015	721.8	1631	237.6	13	25.1	0.9550	0.038	2.614	0.011
2016	735.8	1572	231.4	13	27.6	1.0518	0.039	3.453	0.015
2017	896.7	1764	293.1	12	28.7	1.2161	0.038	1.999	0.007
2018	874.0	1685	318.0	11	30.8	1.1506	0.038	1.706	0.005

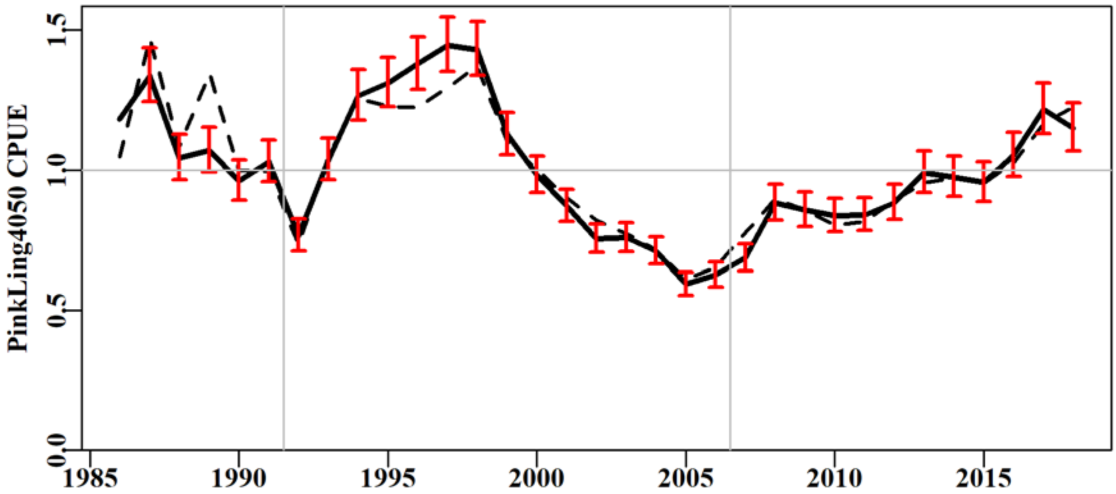

Figure 5.135. PinkLing4050 standardization. The dashed black line represents the geometric mean catch rate, solid black line the standardized catch rates. The red bars are the 95% confidence intervals about the mean estimates. The graph scales both time-series of standardized catch rates relative to the mean of each time-series.

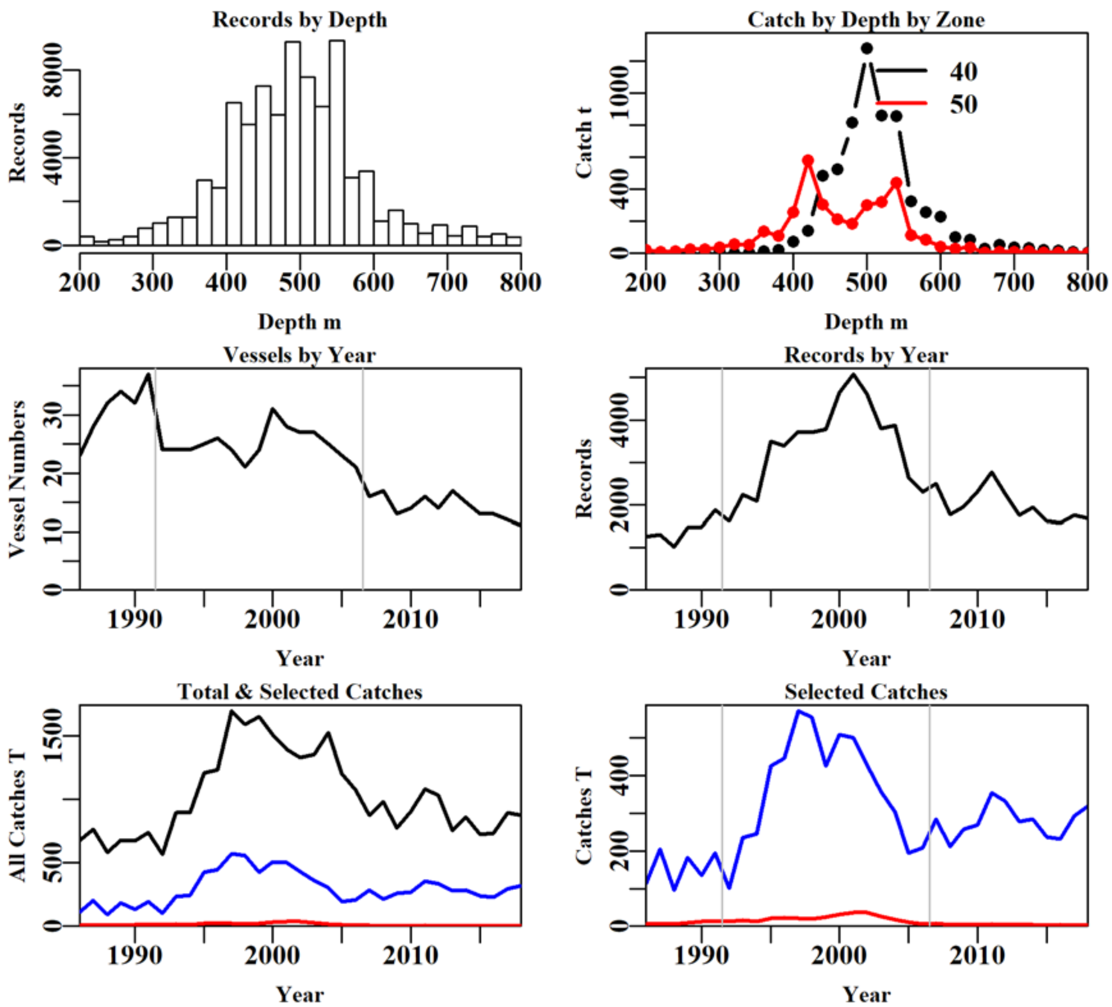

Figure 5.136. PinkLing4050 fishery details. The bottom left plot depicts all known catches (top black line), and all selected catches used in the analysis (middle blue line); the lower red line: selected catches < 30 kg).

Table 5.98. PinkLing4050 data selection effects. Total is the total number of records in the database, NoCE removes those records with either missing catch or effort, and then only those records are kept that meet the criteria for depth, years, zone, method and fishery.

	Total	NoCE	Depth	Years	Zones	Method	Fishery
Records	312333	286307	211392	208786	84415	83489	83405
Difference	0	26026	74915	2606	124371	926	84
Catch	34138.98	26988.13	25085.37	24703.45	10099.66	9795.79	9791.27
Difference	0	7150.86	1902.76	381.919	14603.79	303.87	4.518

Table 5.99. The models used to analyse data for PinkLing4050.

	Model
Model1	Year
Model2	Year + DepCat
Model3	Year + DepCat + Vessel
Model4	Year + DepCat + Vessel + Month
Model5	Year + DepCat + Vessel + Month + Zone
Model6	Year + DepCat + Vessel + Month + Zone + DayNight
Model7	Year + DepCat + Vessel + Month + Zone + DayNight + Zone:DepCat
Model8	Year + DepCat + Vessel + Month + Zone + DayNight + Zone:Month

Table 5.100. PinkLing4050. The row names are 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_r2) and the change in adjusted R^2 (%Change). The optimum model was Zone:Month.

	AIC	RSS	MSS	Nobs	Npars	adj_r2	%Change
Year	-553	82789	4030	83405	33	4.6	0.00
DepCat	-12782	71446	15372	83405	63	17.6	13.04
Vessel	-19674	65624	21194	83405	162	24.3	6.62
Month	-22636	63317	23501	83405	173	26.9	2.65
Zone	-23794	62443	24375	83405	174	27.9	1.01
DayNight	-23836	62407	24411	83405	177	28.0	0.04
Zone:DepCat	-24709	61713	25105	83405	207	28.7	0.78
Zone:Month	-25440	61202	25616	83405	188	29.3	1.38

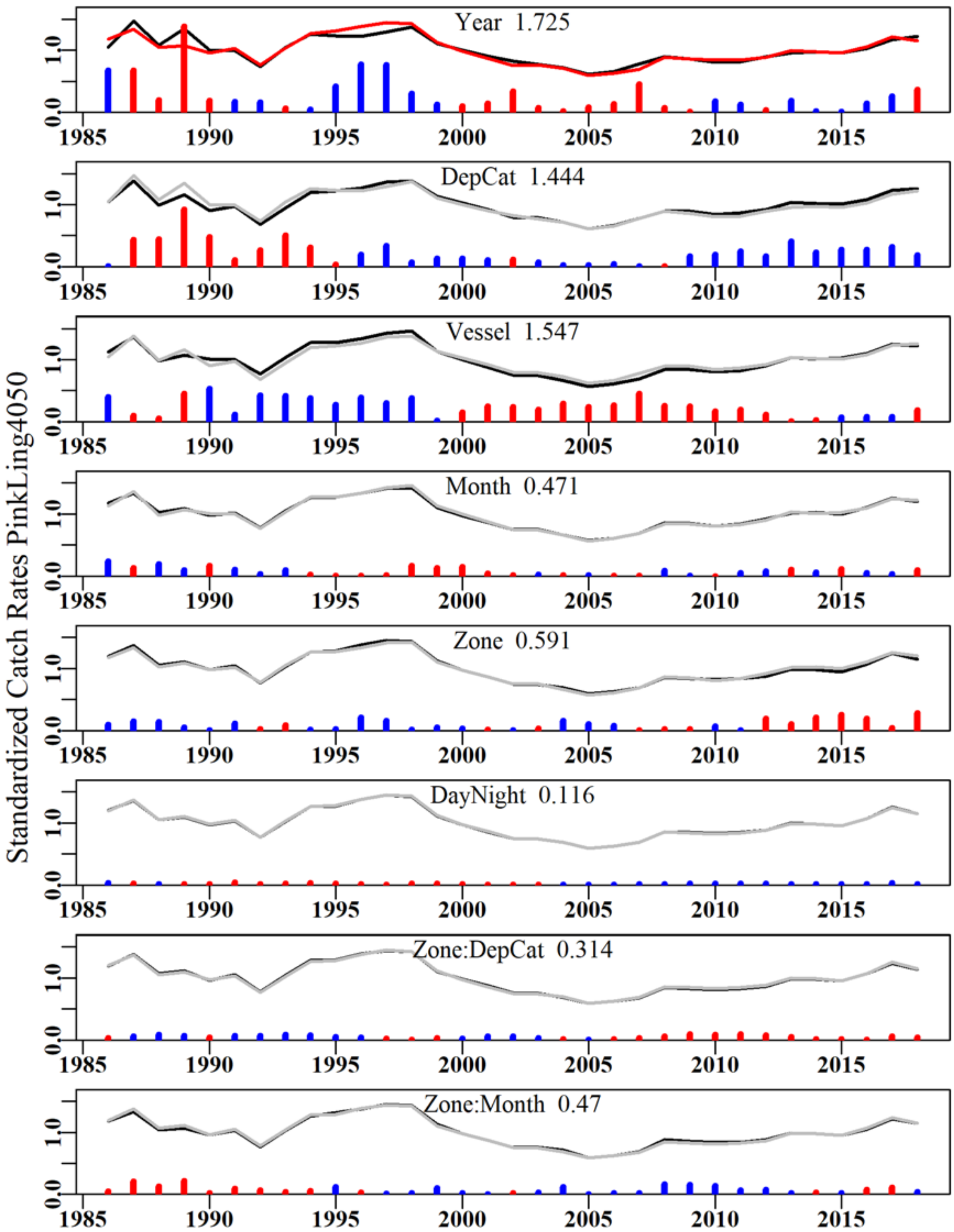

Figure 5.137. PinkLing4050. The influence of each factor on the optimal standardization. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by vertical bars with blue bars indicating the optimum model is higher than the geometric 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.

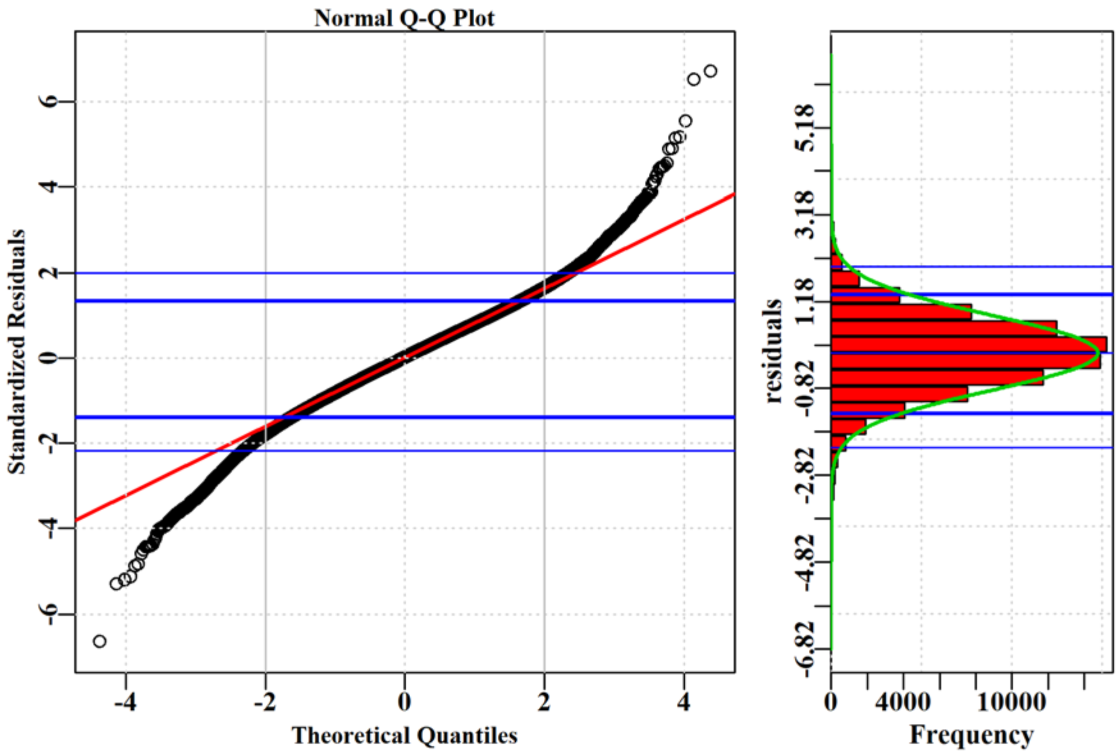

Figure 5.138. PinkLing4050. diagnostic plots. The distribution of residuals from the optimum fit. The qqplot indicates the fit to the expected normality, while the histogram of residuals illustrates the 90% quantiles to indicate the intensity of any lack of fit at the margins of the distribution.

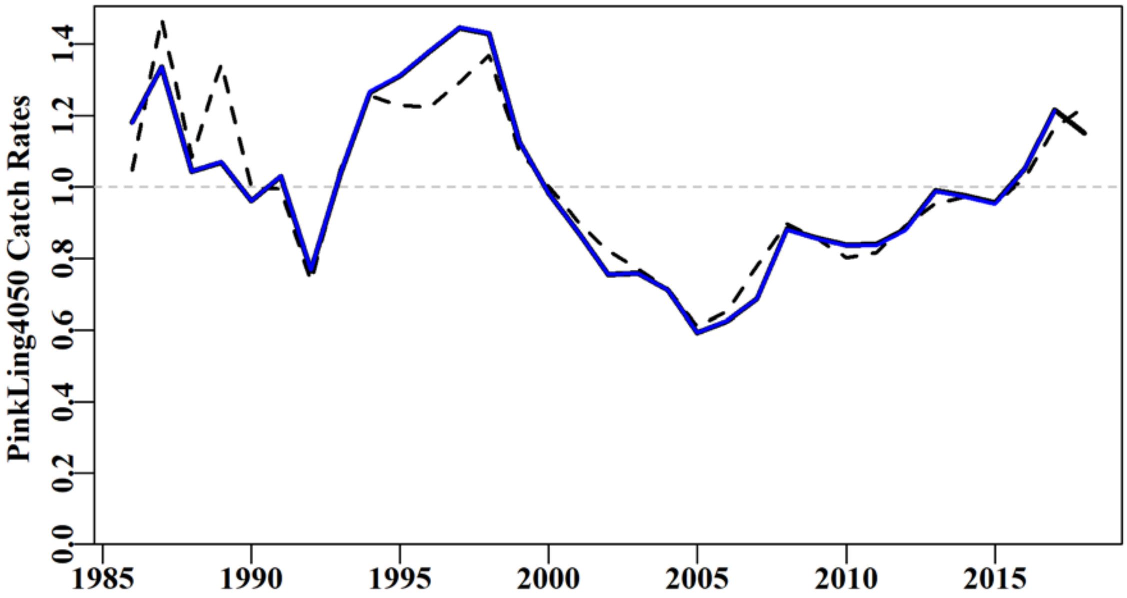

Figure 5.139. PinkLing4050. A comparison of the previous year's standardization (blue line) with this year's. They should lie on top of each other, although small deviations may relate to data adjustments, particularly in very recent years.

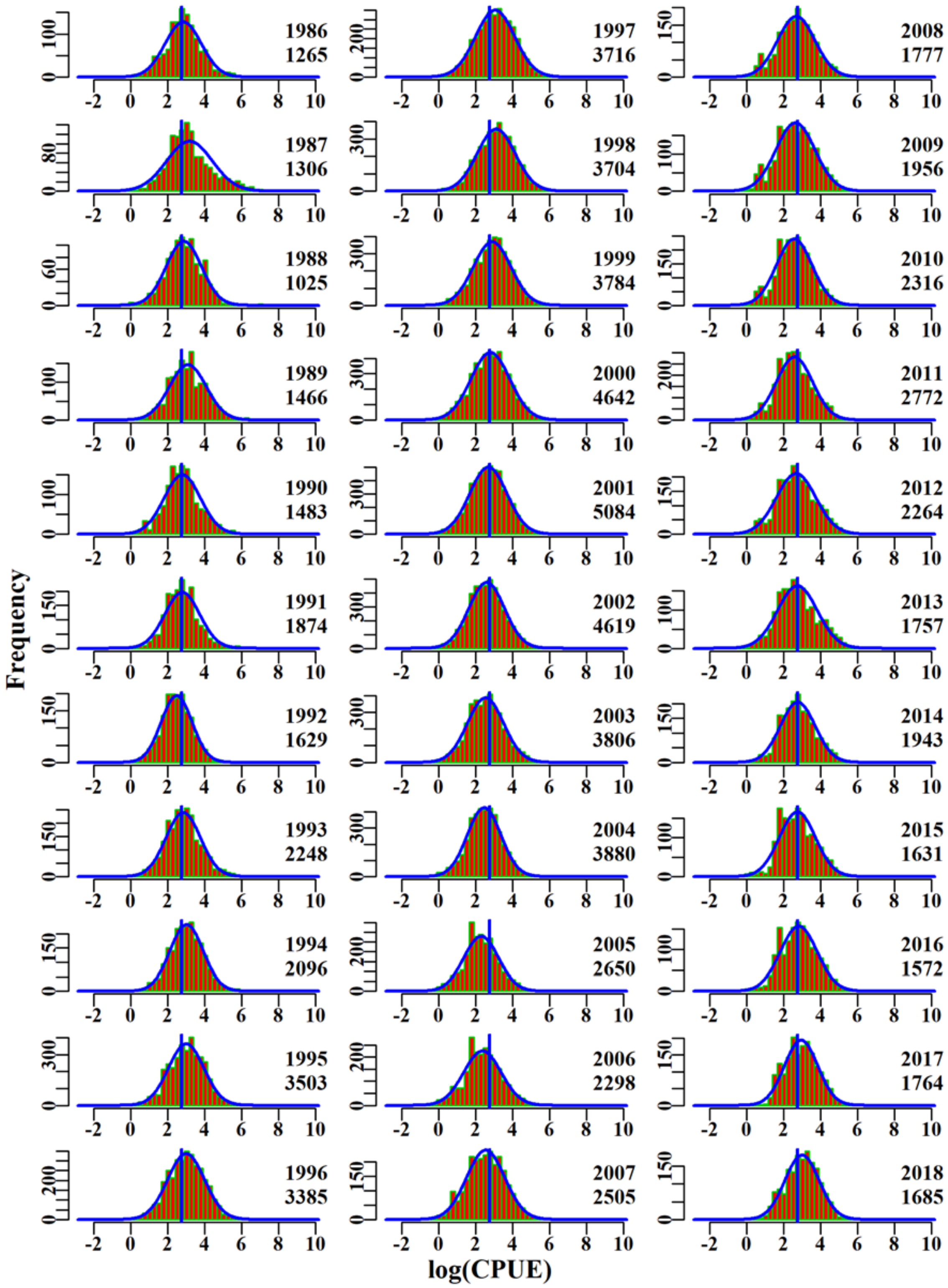

Figure 5.140. PinkLing4050. The natural log(CPUE) for each year of data available the blue lines are normal distributions fitted to the histogram frequencies. The numbers in each plot are the year and number of records.

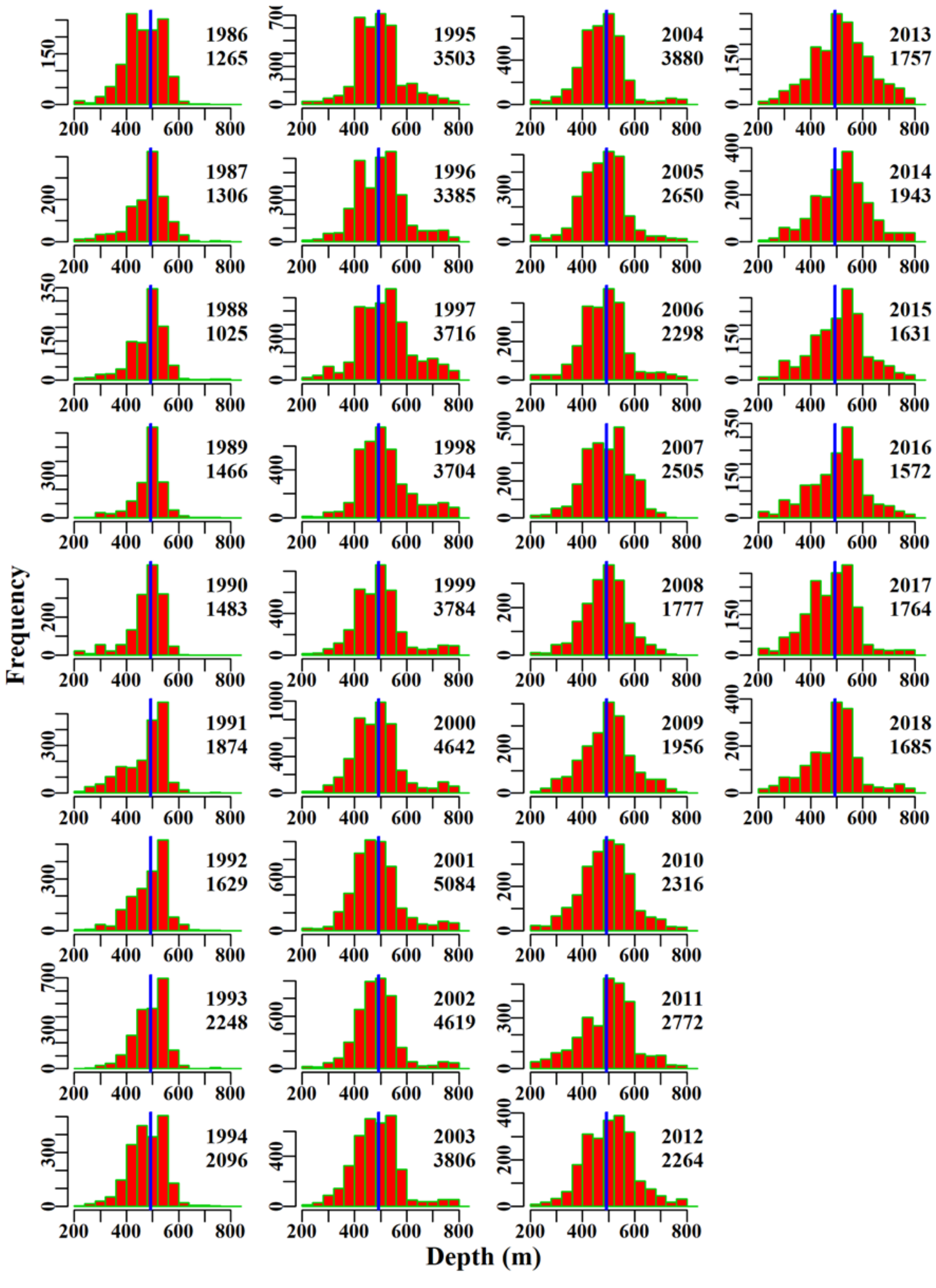

Figure 5.141. PinkLing4050. The average Depth of fishing for each year of data available to illustrate the development of the fishery through time. The numbers in each plot are the year and number of records.

5.24 Ocean Perch Offshore 1020

Offshore Ocean Perch (REG–37287001 – *Helicolenus percoides*) was one of the 16 species first included in the quota system in 1992. Trawl caught offshore Ocean Perch based on methods TW, TDO, in zones 10, 20, and depths 200 to 700 within the SET fishery for the years 1986 - 2018 were used in the analysis (Table 5.101).

A total of 8 statistical models were fitted sequentially to the available data, with the order of the non-interaction terms added based on the relative contribution of each term to model fit.

5.24.1 *Inferences*

The majority of catch of this species occurred in zone 10 followed by zone 20. Over the period when CPUE was lower than average (about 1996 - 2006) there was an increase in small shots of < 30kg (Figure 5.143), which is suggestive of either low availability or high levels of small fish.

The terms Year, Month, Vessel and DepCat had the greatest contribution to model fit, with the remaining terms each explaining < 1% of the overall variation in CPUE, based on the AIC and R^2 statistics (Table 5.105). The qqplot suggests a slight departure from that the assumed Normal distribution as depicted by both tails of the distribution (Figure 5.145).

Annual standardized CPUE have been below average and relatively flat between 1995 and 2006. The trend from 2007 has also been relatively flat and mostly just above average (Figure 5.142).

5.24.2 *Action Items and Issues*

No issues identified.

Table 5.101. OceanPerchOffshore1020. The data selection criteria used to specify and identify the fishery data to be included in the analysis.

Property	Value
label	OceanPerchOffshore1020
csirocode	37287901, 37287093, 37287001, 91287001, 92287001
fishery	SET
depthrange	200 - 700
depthclass	25
zones	10, 20
methods	TW, TDO
years	1986 - 2018

Table 5.102. OceanPerchOffshore1020. Total catch (Total; t) is the total reported in the database, number of records used in the analysis (N), reported catch (Catch; t) in the area and depth used in the analysis and number of vessels used in the analysis (Vess). GeoM is the geometric mean of catch rates (kg/hr), standard deviation (StDev) relates to the optimum model. C<30Kg denotes the amount of catch in shots of <30kg, and %<30Kg is the percent of total. The optimum model was Zone:Month.

	Total	N	Catch	Vess	GeoM	Opt	StDev	C<30Kg	P<30Kg
1986	262.4	3478	207.4	77	21.5	1.0265	0.000	27.364	0.132
1987	198.4	3137	132.8	70	15.8	0.9574	0.026	27.705	0.209
1988	188.4	2806	150.7	73	18.6	1.0665	0.027	23.405	0.155
1989	209.2	3029	159.6	67	19.6	1.0237	0.027	24.547	0.154
1990	181.7	1958	115.3	57	20.6	1.3667	0.030	15.715	0.136
1991	223.6	2073	138.0	53	24.5	1.4250	0.030	16.912	0.123
1992	169.7	1850	114.2	48	20.4	1.2080	0.030	16.166	0.142
1993	259.6	2905	197.4	52	21.7	1.2105	0.027	25.126	0.127
1994	257.3	3000	179.9	49	22.0	1.1264	0.027	26.269	0.146
1995	240.0	3138	150.0	50	18.1	0.9998	0.027	31.852	0.212
1996	263.9	3401	176.1	53	17.8	0.8897	0.026	31.446	0.179
1997	298.8	3707	192.6	53	17.2	0.9410	0.026	35.444	0.184
1998	295.0	3837	194.0	49	17.3	0.8361	0.026	36.497	0.188
1999	295.8	4398	218.4	52	16.8	0.9320	0.025	42.854	0.196
2000	270.2	4168	180.7	54	14.9	0.7770	0.026	40.560	0.224
2001	281.6	4050	184.5	43	16.7	0.8955	0.026	38.378	0.208
2002	255.3	3631	150.2	45	15.9	0.8365	0.027	32.844	0.219
2003	322.7	3944	184.5	53	17.3	0.8886	0.026	35.032	0.190
2004	316.3	3111	149.7	46	17.9	0.8955	0.028	25.834	0.173
2005	316.8	3041	167.5	46	19.9	1.0110	0.028	26.055	0.156
2006	237.6	2309	112.7	38	15.6	0.8754	0.030	22.962	0.204
2007	180.6	1519	94.7	22	20.2	1.1141	0.033	14.042	0.148
2008	184.3	1830	101.4	23	17.5	1.0163	0.032	16.250	0.160
2009	173.9	1662	98.9	23	20.0	1.0111	0.033	15.540	0.157
2010	195.6	1726	117.2	21	22.7	0.9909	0.032	14.324	0.122
2011	186.9	1843	115.5	22	23.4	0.9106	0.032	15.249	0.132
2012	183.9	1673	113.4	22	26.2	0.9618	0.033	13.219	0.117
2013	171.2	1277	102.4	20	30.1	1.0196	0.036	9.188	0.090
2014	174.4	1522	115.9	21	29.9	1.0175	0.034	10.421	0.090
2015	150.8	1404	104.9	22	31.5	0.8771	0.035	9.146	0.087
2016	132.1	982	68.0	23	25.3	0.8776	0.039	6.702	0.099
2017	155.7	1257	90.5	18	27.7	0.9792	0.036	8.123	0.090
2018	151.8	1195	89.3	17	27.0	1.0355	0.039	7.935	0.089

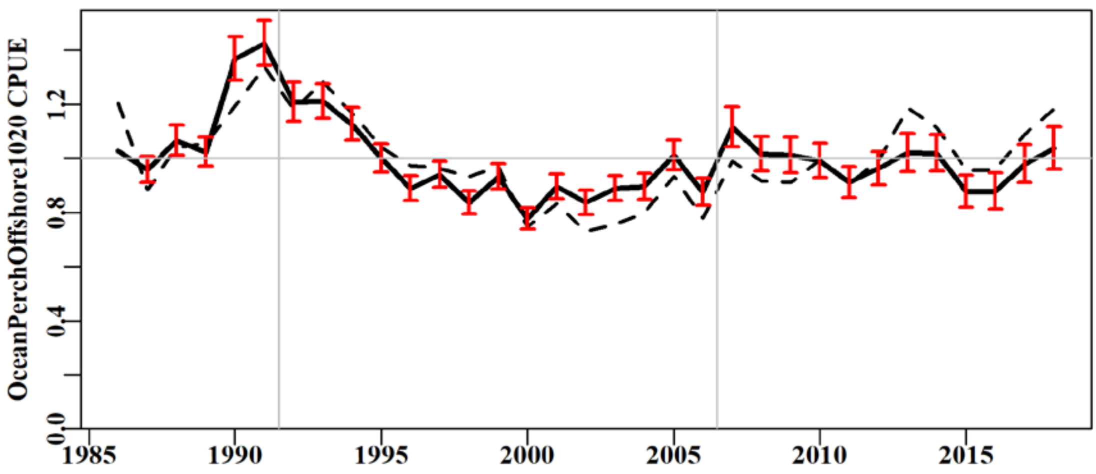

Figure 5.142. OceanPerchOffshore1020 standardization. The dashed black line represents the geometric mean catch rate, solid black line the standardized catch rates. The red bars are the 95% confidence intervals about the mean estimates. The graph scales both time-series of standardized catch rates relative to the mean of each time-series.

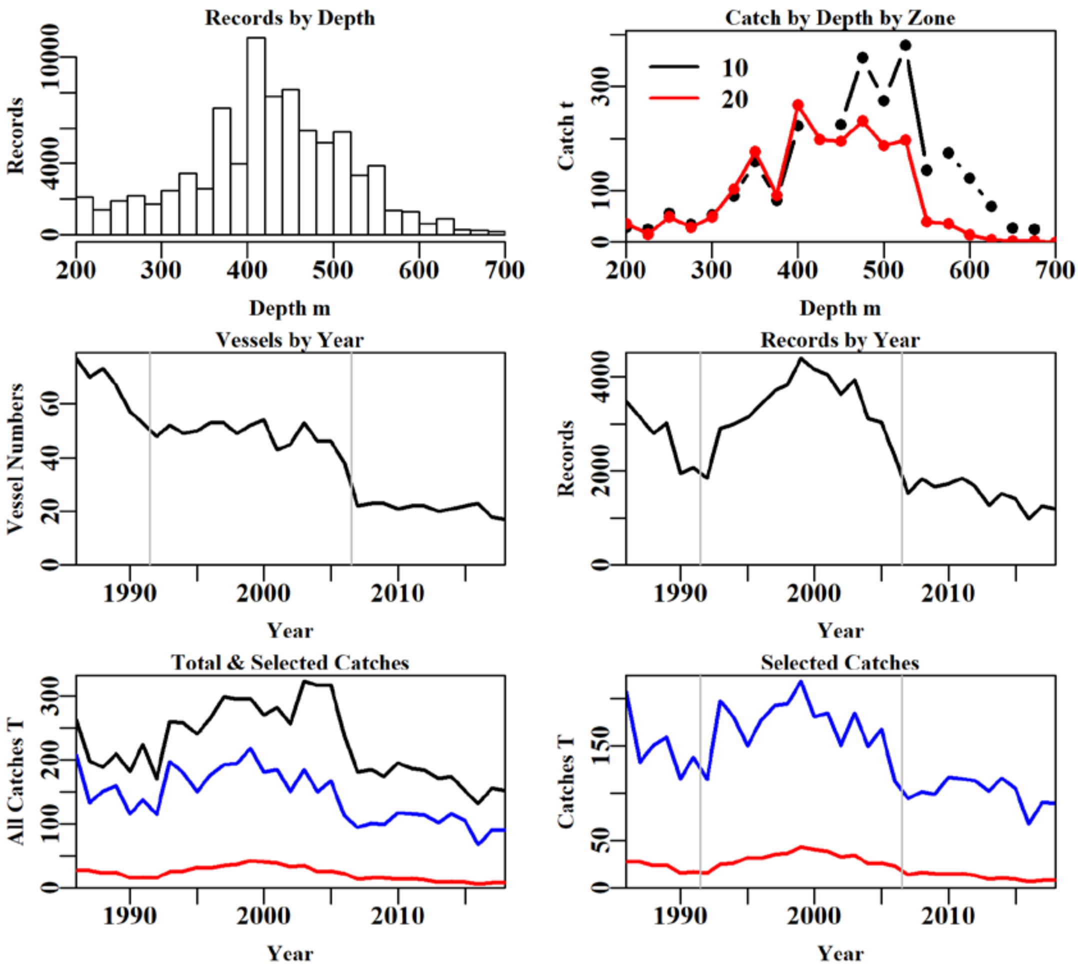

Figure 5.143. OceanPerchOffshore1020 fishery details. The bottom left plot depicts all known catches (top black line), and all selected catches used in the analysis (middle blue line); the lower red line: selected catches < 30 kg).

Table 5.103. OceanPerchOffshore1020 data selection effects. Total is the total number of records in the database, NoCE removes those records with either missing catch or effort, and then only those records are kept that meet the criteria for depth, years, zone, method and fishery.

	Total	NoCE	Depth	Years	Zones	Method	Fishery
Records	172692	156282	126573	124755	85633	84899	84861
Difference	0	16410	29709	1818	39122	734	38
Catch	7538.46	6908.37	5991.16	5855.43	4701.71	4670.07	4667.91
Difference	0	630.0834	917.2151	135.7312	1153.718	31.6398	2.161

Table 5.104. The models used to analyse data for OceanPerchOffshore1020.

	Model
Model1	Year
Model2	Year + Month
Model3	Year + Month + Vessel
Model4	Year + Month + Vessel + DepCat
Model5	Year + Month + Vessel + DepCat + DayNight
Model6	Year + Month + Vessel + DepCat + DayNight + Zone
Model7	Year + Month + Vessel + DepCat + DayNight + Zone + Zone:Month
Model8	Year + Month + Vessel + DepCat + DayNight + Zone + Zone:DepCat

Table 5.105. OceanPerchOffshore1020. The row names are 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_r2) and the change in adjusted R^2 (%Change). The optimum model was Zone:Month.

	AIC	RSS	MSS	Nobs	Npars	adj_r2	%Change
Year	26820	116313	2253	84861	33	1.9	0.00
Month	25384	114331	4236	84861	44	3.5	1.66
Vessel	11790	97035	21532	84861	207	18.0	14.44
DepCat	1144	85554	33013	84861	227	27.7	9.69
DayNight	570	84971	33595	84861	230	28.1	0.49
Zone	527	84926	33641	84861	231	28.2	0.04
Zone:Month	-1577	82825	35742	84861	242	29.9	1.77
Zone:DepCat	123	84483	34084	84861	251	28.5	0.36

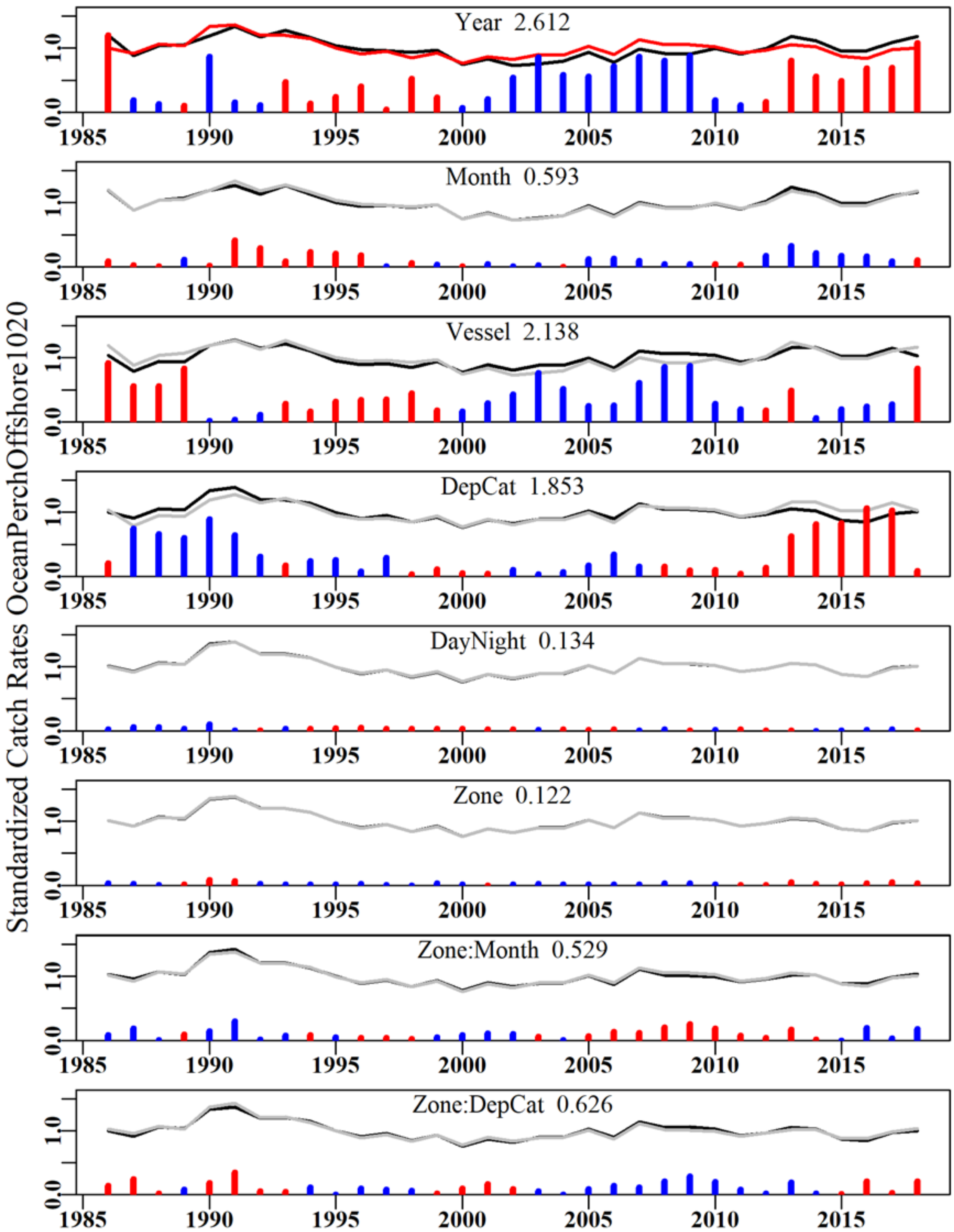

Figure 5.144. OceanPerchOffshore1020. The influence of each factor on the optimal standardization. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by vertical bars with blue bars indicating the optimum model is higher 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.

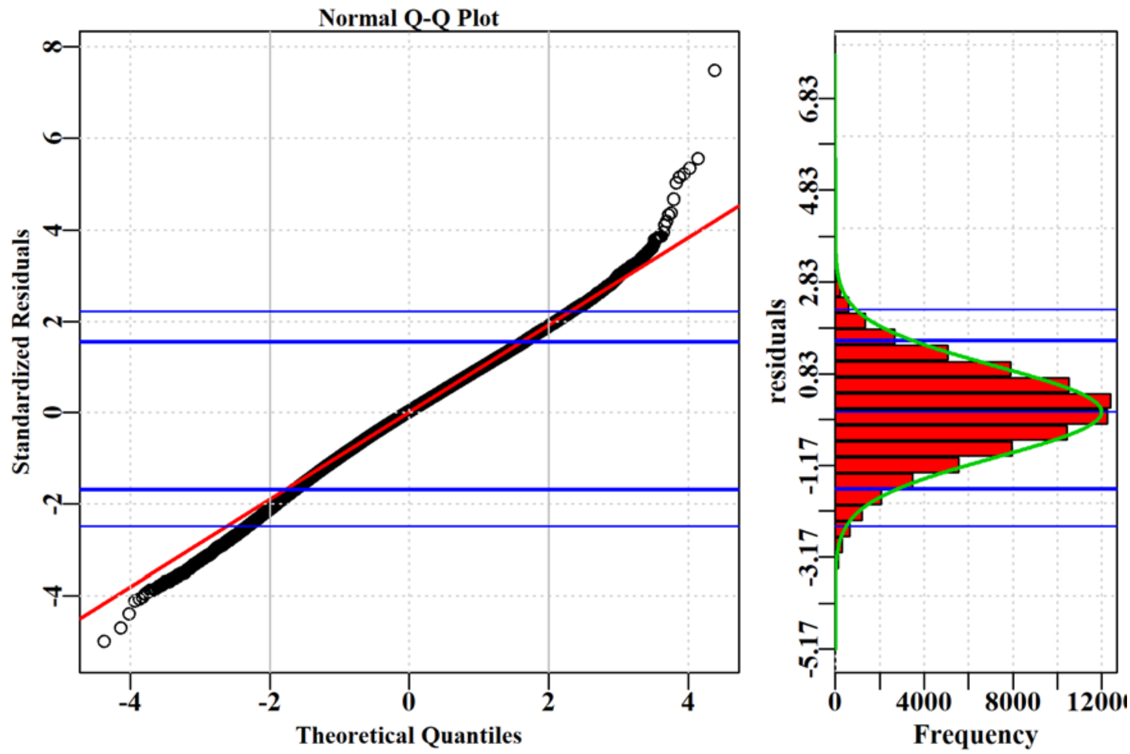

Figure 5.145. OceanPerchOffshore1020. diagnostic plots. The distribution of residuals from the optimum fit. The qqplot indicates the fit to the expected normality, while the histogram of residuals illustrates the 90% quantiles to indicate the intensity of any lack of fit at the margins of the distribution.

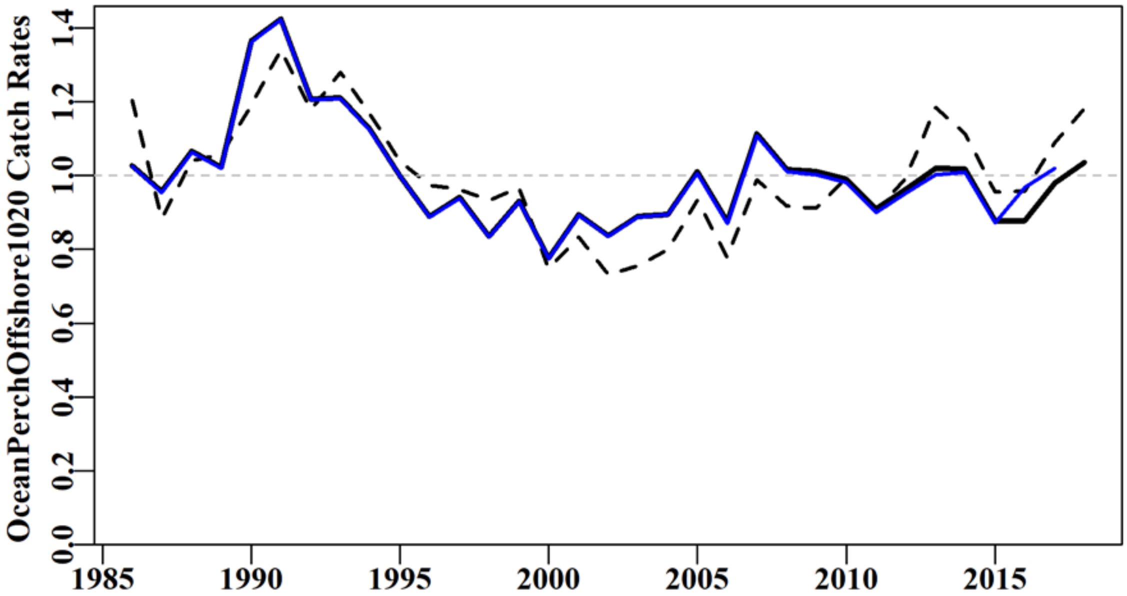

Figure 5.146. OceanPerchOffshore1020. A comparison of the previous year's standardization (blue line) with this year's. They should lie on top of each other, although small deviations may relate to data adjustments, particularly in very recent years.

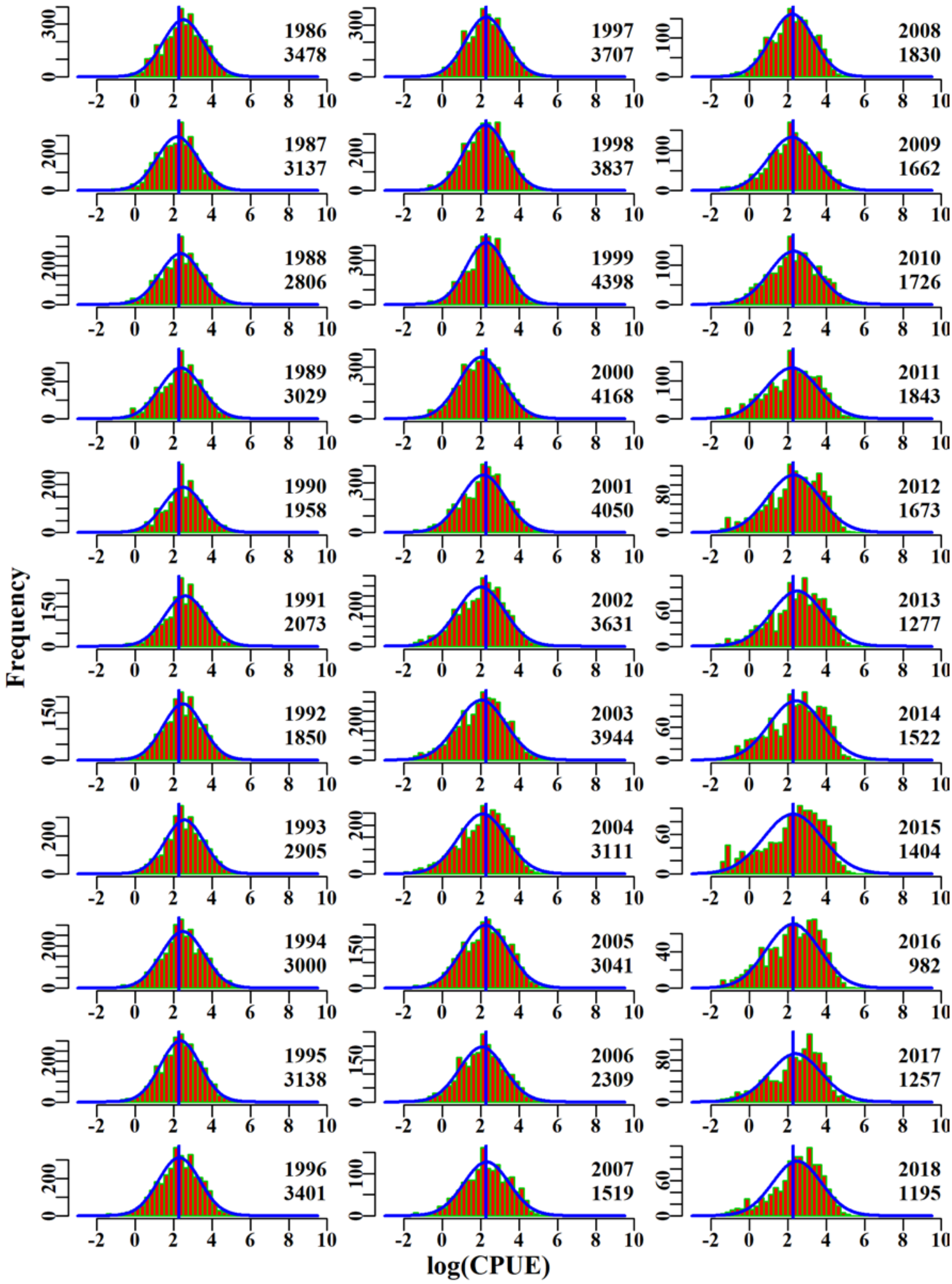

Figure 5.147. OceanPerchOffshore1020. The natural log(CPUE) for each year of data available the blue lines are normal distributions fitted to the histogram frequencies. The numbers in each plot are the year and number of records.

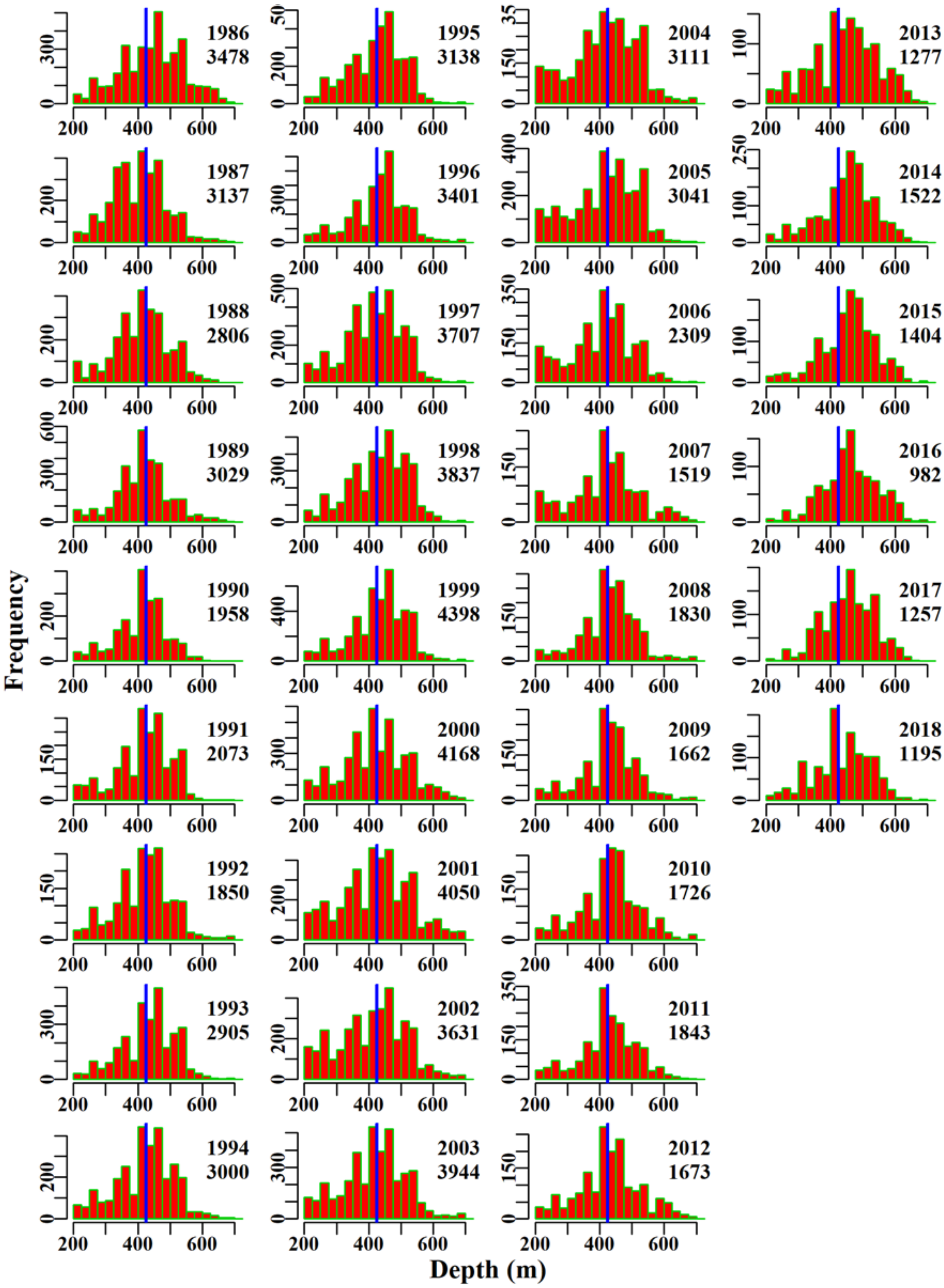

Figure 5.148. OceanPerchOffshore1020. The average Depth of fishing for each year of data available to illustrate the development of the fishery through time. The numbers in each plot are the year and number of records.

5.25 Ocean Perch Offshore 10-50

Offshore Ocean Perch (REG - 37287001 - *Helicolenus percoides*) caught by trawl based on methods TW, TDO, in zones 10, 20, 30, 40, 50, and depths 200 to 700 within the SET fishery for the years 1986 - 2018 were used in the analysis (Table 5.106).

A total of 8 statistical models were fitted sequentially to the available data.

5.25.1 *Inferences*

The majority of catch of this species occurred in zone 10 followed by zone 20 while catches in zones 30, 40, and 50 remain relatively minor. Over the period when CPUE was lower than average (about 1996 - 2006) there was an increase in small shots of < 30kg (Figure 5.150), which is suggestive of either low availability or high levels of small fish.

The terms Year, Month, Vessel and DepCat had the greatest contribution to model fit, with the remaining terms each explaining < 1% of the overall variation in CPUE, based on the AIC and R^2 statistics.

Annual standardized CPUE have been below average and relatively flat between 1995 and 2006. The trend from 2007 to 2010 has also been relatively flat, below average between 2011 to 2016 and just above average since 2017 (Figure 5.149).

5.25.2 *Action Items and Issues*

The generally lower CPUE for Offshore Ocean Perch in zones 30, 40, and 50 suggest it is not a major target species in those zones. It is recommended that the Tier 4 for Offshore Ocean Perch continue using the analysis presented in Offshore Ocean Perch for zones 10 and 20 as catch rates in those zones would seem to be more indicative of the main location for the stock.

Table 5.106. OceanPerchOffshore1050. The data selection criteria used to specify and identify the fishery data to be included in the analysis.

Property	Value
label	OceanPerchOffshore1050
csirocode	37287901, 37287093, 37287001, 91287001, 92287001
fishery	SET
depthrange	200 - 700
depthclass	25
zones	10, 20, 30, 40, 50
methods	TW, TDO
years	1986 - 2018

Table 5.107. OceanPerchOffshore1050. Total catch (Total; t) is the total reported in the database, number of records used in the analysis (N), reported catch (Catch; t) in the area and depth used in the analysis and number of vessels used in the analysis (Vess). GeoM is the geometric mean of catch rates (kg/hr), standard deviation (StDev) relates to the optimum model. C<30Kg denotes the amount of catch in shots of <30kg, and %<30Kg is the percent of total. The optimum model was Zone:Month.

	Total	N	Catch	Vess	GeoM	Opt	StDev	C<30Kg	P<30Kg
1986	262.4	3727	220.7	92	20.9	1.1066	0.000	29.820	0.135
1987	198.4	3409	144.5	93	15.7	1.0157	0.024	30.071	0.208
1988	188.4	3097	161.3	93	18.4	1.1431	0.025	26.371	0.163
1989	209.2	3412	173.2	86	18.8	1.1116	0.025	29.526	0.170
1990	181.7	2423	131.5	80	18.6	1.4045	0.027	22.128	0.168
1991	223.6	2853	169.5	87	21.3	1.4390	0.026	26.864	0.159
1992	169.7	2375	130.3	70	17.7	1.1798	0.027	22.496	0.173
1993	259.6	3643	221.8	68	19.2	1.2207	0.024	35.331	0.159
1994	257.3	3782	208.3	66	19.1	1.1687	0.024	38.140	0.183
1995	240.0	4437	191.0	69	15.2	1.0851	0.023	50.683	0.265
1996	263.9	4848	213.8	76	14.5	0.9628	0.023	53.199	0.249
1997	298.8	5594	246.5	71	13.8	1.0037	0.023	59.734	0.242
1998	295.0	5325	240.4	67	14.6	0.9273	0.023	55.634	0.231
1999	295.8	5776	255.7	72	14.8	0.9653	0.023	61.811	0.242
2000	270.2	5686	217.7	81	12.9	0.8268	0.023	59.058	0.271
2001	281.6	5960	228.9	68	13.4	0.8915	0.023	63.067	0.276
2002	255.3	5596	195.1	69	12.4	0.8503	0.023	57.058	0.292
2003	322.7	5775	231.1	66	13.4	0.9224	0.023	57.348	0.248
2004	316.3	5099	202.2	68	12.9	0.9394	0.024	50.046	0.248
2005	316.8	4505	201.2	64	14.9	0.9606	0.024	42.533	0.211
2006	237.6	3337	137.9	52	12.4	0.8564	0.026	34.920	0.253
2007	180.6	2609	121.6	33	13.6	0.9819	0.027	26.037	0.214
2008	184.3	2665	124.5	32	13.8	0.9820	0.027	25.722	0.207
2009	173.9	2705	128.7	32	13.9	0.9592	0.027	27.628	0.215
2010	195.6	2892	150.7	32	14.4	0.9795	0.027	29.748	0.197
2011	186.9	3107	146.6	30	14.6	0.8307	0.026	29.911	0.204
2012	183.9	2755	135.9	30	16.9	0.8057	0.027	23.894	0.176
2013	171.2	2304	126.2	29	17.4	0.8563	0.028	19.494	0.154
2014	174.4	2401	136.8	30	18.8	0.9142	0.028	20.536	0.150
2015	150.8	2170	124.1	31	19.8	0.8089	0.029	17.105	0.138
2016	132.1	1552	83.5	30	16.9	0.8714	0.032	12.027	0.144
2017	155.7	1808	104.6	25	20.8	0.9722	0.031	14.142	0.135
2018	151.8	1531	99.2	25	22.0	1.0570	0.032	10.868	0.110

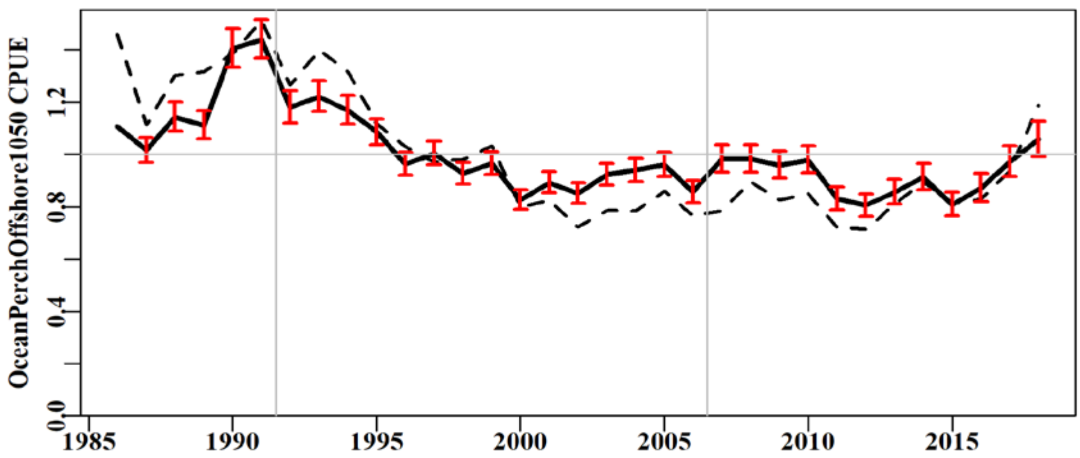

Figure 5.149. OceanPerchOffshore1050 standardization. The dashed black line represents the geometric mean catch rate, solid black line the standardized catch rates. The red bars are the 95% confidence intervals about the mean estimates. The graph scales both time-series of standardized catch rates relative to the mean of each time-series.

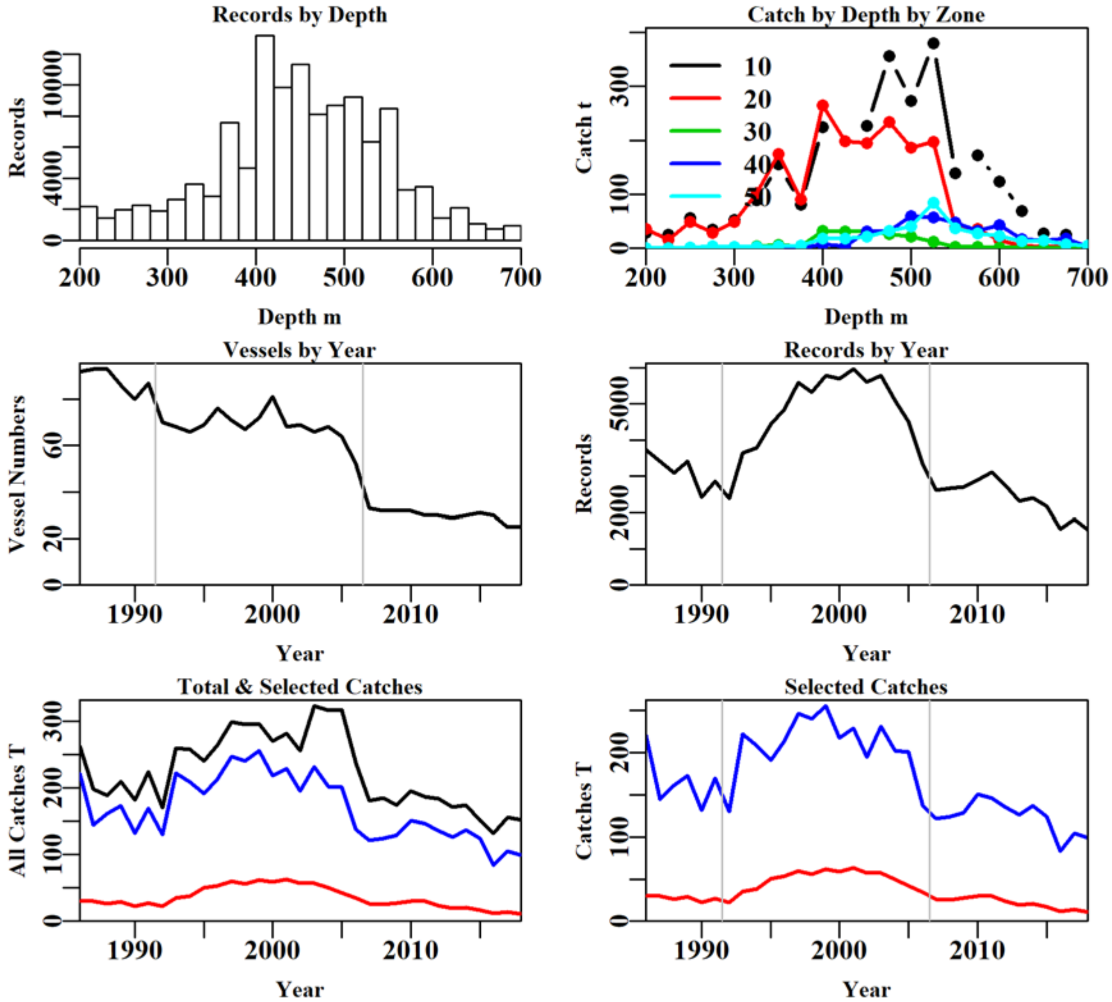

Figure 5.150. OceanPerchOffshore1050 fishery details. The bottom left plot depicts all known catches (top black line), and all selected catches used in the analysis (middle blue line); the lower red line: selected catches < 30 kg).

Table 5.108. The models used to analyse data for OceanPerchOffshore1050.

	Model
Model1	Year
Model2	Year + Month
Model3	Year + Month + Vessel
Model4	Year + Month + Vessel + DepCat
Model5	Year + Month + Vessel + DepCat + DayNight
Model6	Year + Month + Vessel + DepCat + DayNight + Zone
Model7	Year + Month + Vessel + DepCat + DayNight + Zone + Zone:Month
Model8	Year + Month + Vessel + DepCat + DayNight + Zone + Zone:DepCat

Table 5.109. OceanPerchOffshore1050. The row names are 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_r2) and the change in adjusted R^2 (%Change). The optimum model was Zone:Month.

	AIC	RSS	MSS	Nobs	Npars	adj_r2	%Change
Year	38877	165036	5921	119158	33	3.4	0.00
Month	38310	164222	6734	119158	44	3.9	0.47
Vessel	10353	129427	41529	119158	251	24.1	20.23
DepCat	1772	120394	50563	119158	271	29.4	5.28
DayNight	468	119078	51878	119158	274	30.2	0.77
Zone	-6954	111880	59077	119158	278	34.4	4.22
Zone:Month	-9637	109308	61649	119158	322	35.9	1.48
Zone:DepCat	-8699	110105	60851	119158	358	35.4	1.00

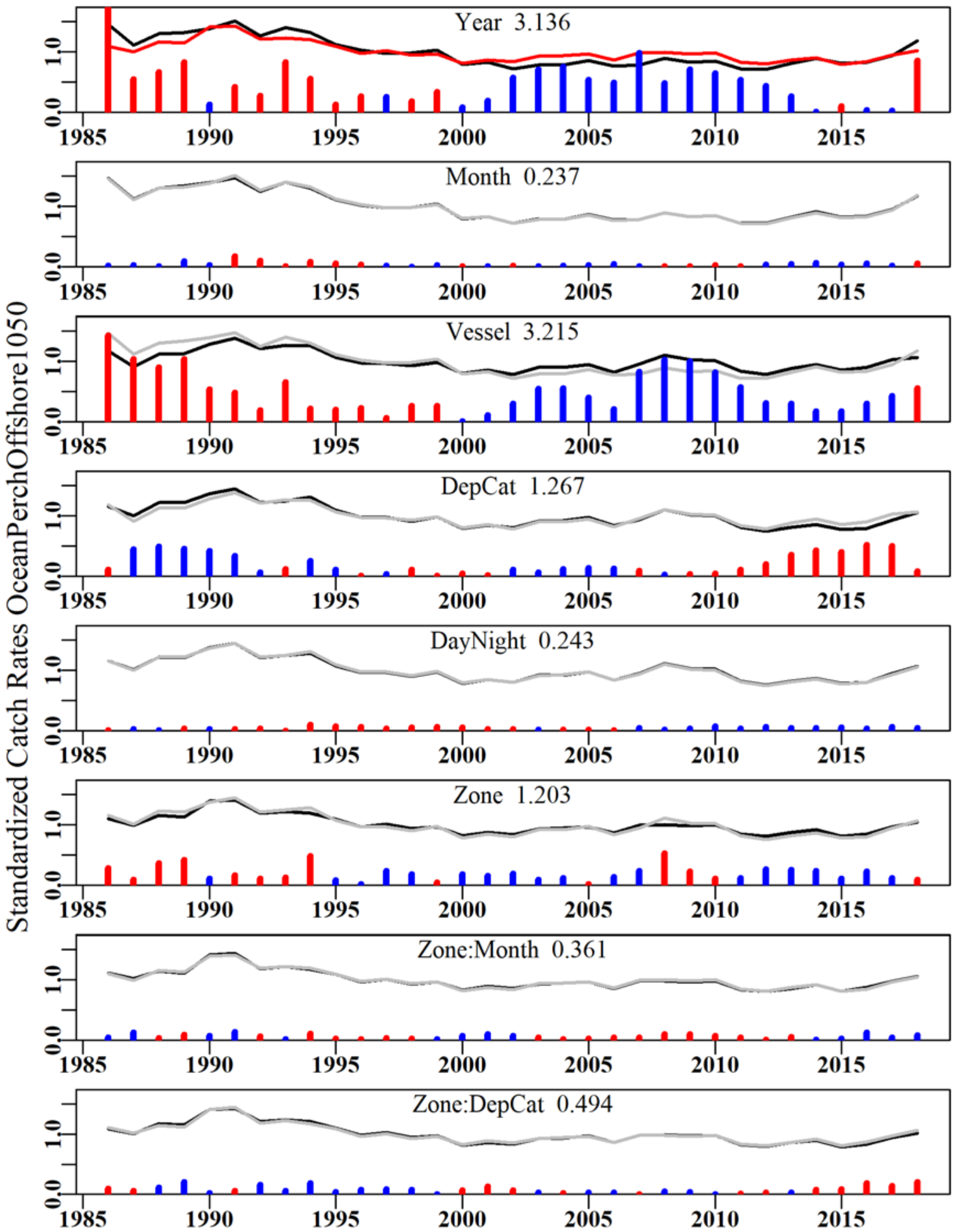

Figure 5.151. OceanPerchOffshore1050. The influence of each factor on the optimal standardization. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by vertical bars with blue bars indicating the optimum model is higher 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.

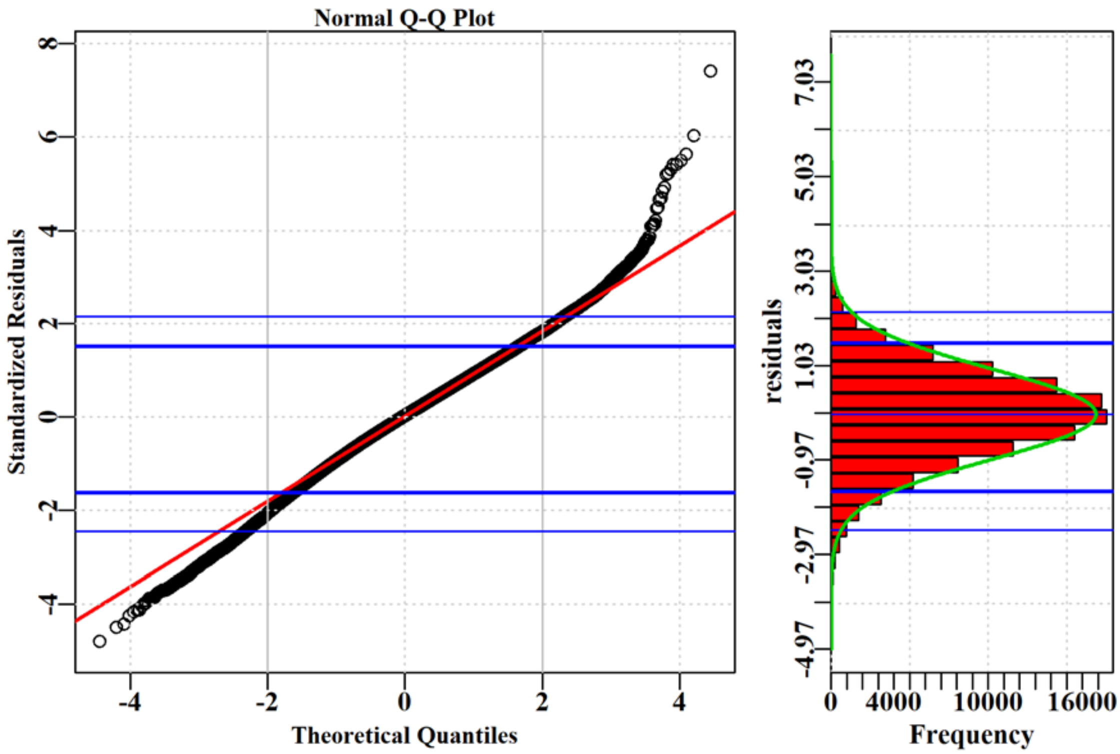

Figure 5.152. OceanPerchOffshore1050. diagnostic plots. The distribution of residuals from the optimum fit. The qqplot indicates the fit to the expected normality, while the histogram of residuals illustrates the 90% quantiles to indicate the intensity of any lack of fit at the margins of the distribution.

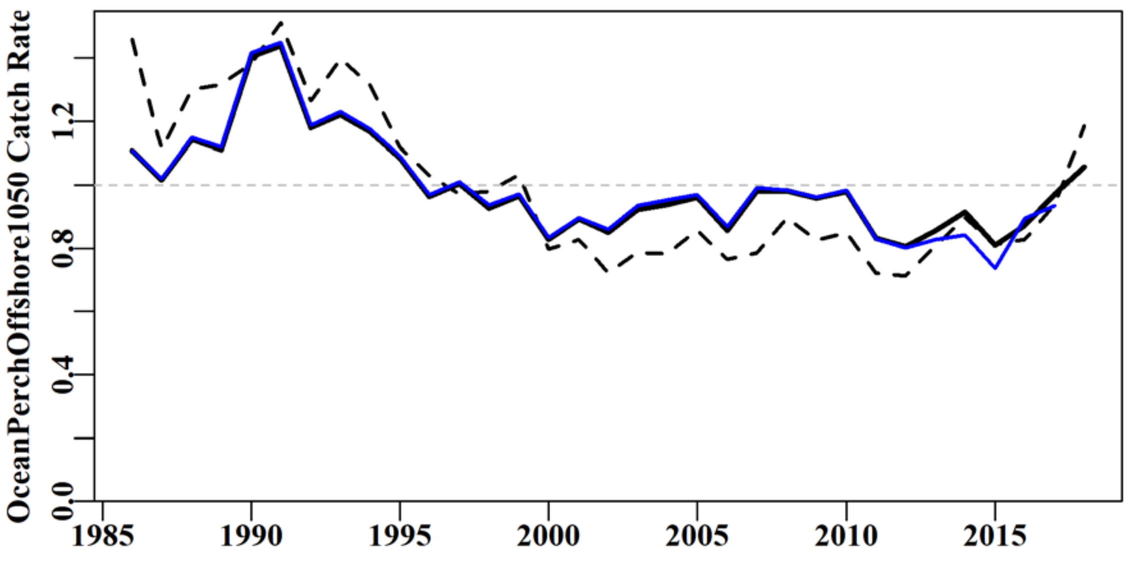

Figure 5.153. OceanPerchOffshore1050. A comparison of the previous year's standardization (blue line) with this year's. They should lie on top of each other, although small deviations may relate to data adjustments, particularly in very recent years.

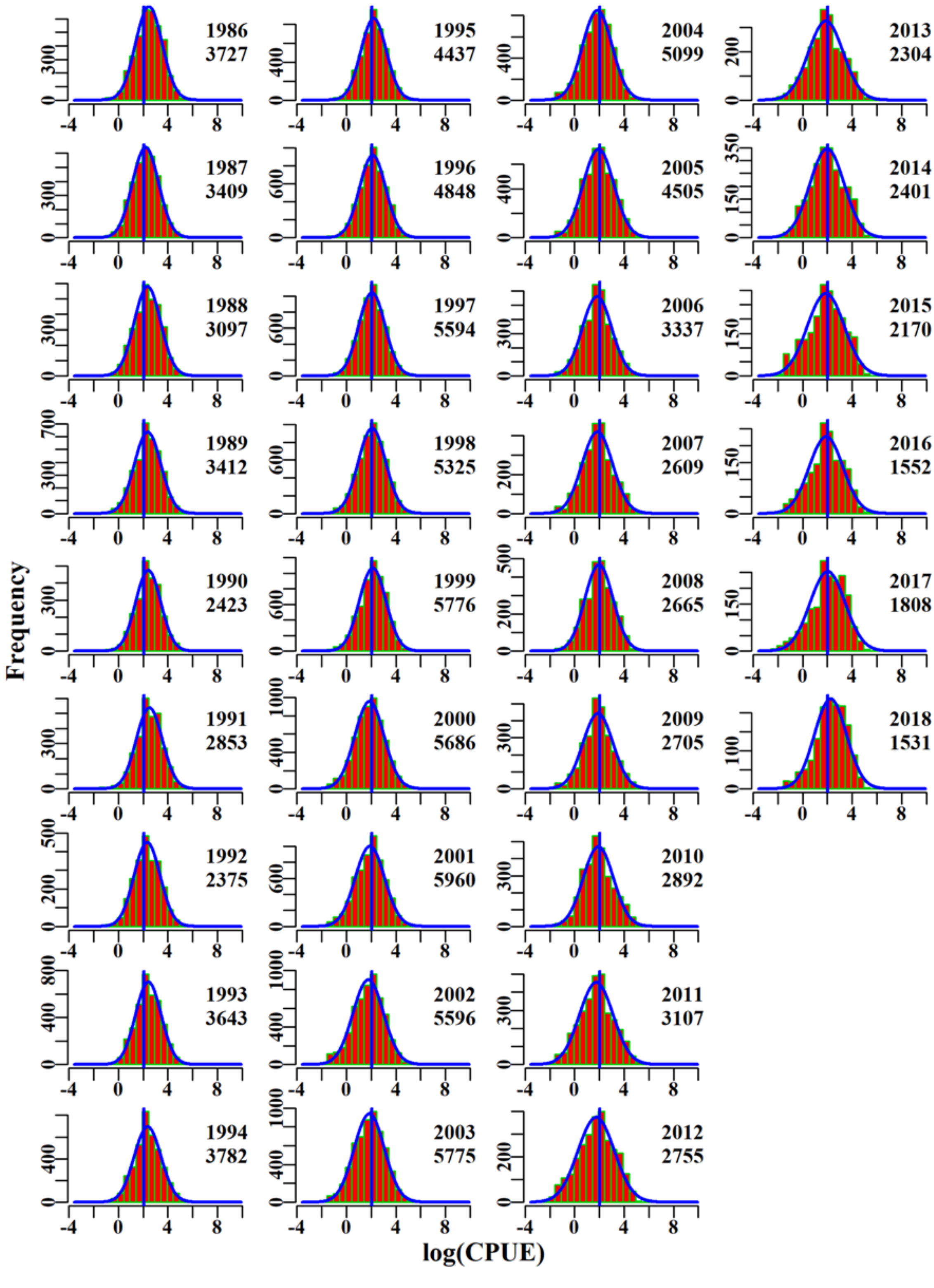

Figure 5.154. OceanPerchOffshore1050. The natural log(CPUE) for each year of data available the blue lines are normal distributions fitted to the histogram frequencies. The numbers in each plot are the year and number of records.

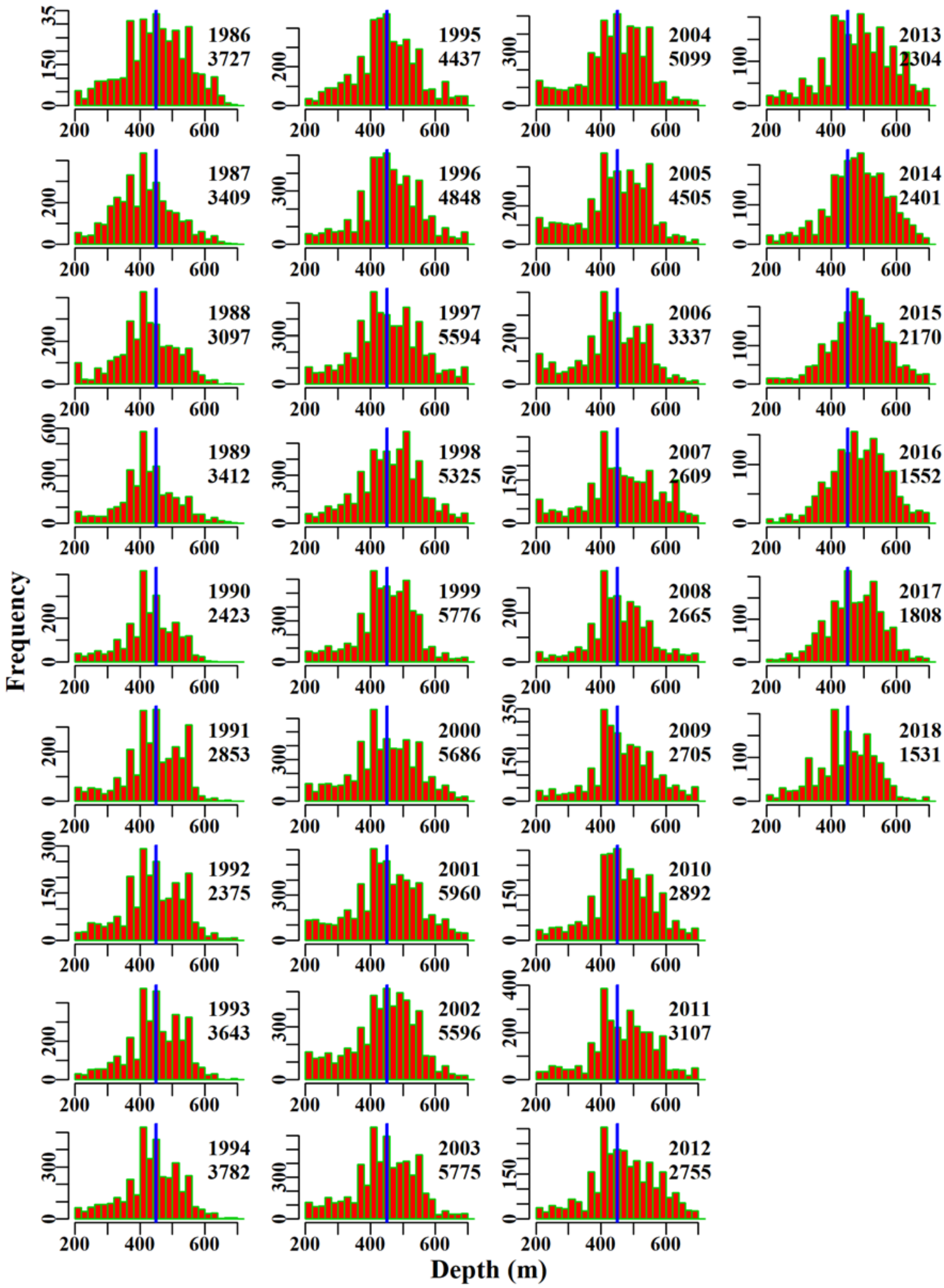

Figure 5.155. OceanPerchOffshore1050. The average Depth of fishing for each year of data available to illustrate the development of the fishery through time. The numbers in each plot are the year and number of records.

5.26 Comparison of Zones 10:20 and 10:50

Table 5.110. The reported logbook catches and records by zone, with catches first and then records for each zone in sequence. The difference between the analyses is only due to the inclusion of the catches reported in zones 30, 40, and 50.

	10	10	20	20	30	30	40	40	50	50
1986	156.950	2760	50.410	718	0.147	4	8.165	77	4.985	168
1987	94.015	2375	38.735	762	0.436	13	4.723	65	6.599	194
1988	94.771	1825	55.902	981	2.848	51	3.513	63	4.300	177
1989	100.196	1993	59.388	1036	2.157	48	5.915	115	5.531	220
1990	54.821	1055	60.477	903	1.943	57	6.390	91	7.881	317
1991	78.857	1077	59.136	996	7.086	188	8.492	150	15.909	442
1992	75.724	1043	38.504	807	1.167	47	7.235	144	7.696	334
1993	126.157	1524	71.269	1381	3.788	109	11.732	254	8.902	375
1994	113.584	1587	66.297	1413	6.452	227	14.490	262	7.501	293
1995	97.423	1935	52.557	1203	6.091	225	24.716	661	10.237	413
1996	110.279	2073	65.845	1328	7.249	229	15.802	539	14.620	679
1997	120.977	2217	71.629	1490	8.876	317	23.834	760	21.230	810
1998	130.625	2398	63.419	1439	4.364	134	19.413	664	22.618	690
1999	124.493	2460	93.942	1938	12.433	314	11.595	539	13.222	525
2000	108.089	2172	72.597	1996	8.670	241	15.340	715	13.020	562
2001	97.880	1885	86.571	2165	17.421	598	15.190	745	11.806	567
2002	81.965	1789	68.227	1842	13.187	396	16.692	878	15.037	691
2003	91.907	1693	92.553	2251	12.500	336	19.819	824	14.363	671
2004	69.578	1281	80.126	1830	13.094	366	13.241	600	26.113	1022
2005	92.629	1415	74.858	1626	8.974	300	10.216	541	14.559	623
2006	60.097	980	52.584	1329	5.702	157	8.332	392	11.233	479
2007	59.453	644	35.265	875	3.142	124	15.007	599	8.750	367
2008	48.393	704	53.036	1126	5.207	211	9.962	370	7.913	254
2009	51.817	634	47.050	1028	6.500	186	14.135	535	9.239	322
2010	69.609	770	47.630	956	5.069	146	14.458	494	13.930	526
2011	63.509	712	51.962	1131	4.392	180	11.866	594	14.840	490
2012	72.051	722	41.315	951	3.957	183	10.137	594	8.406	305
2013	58.325	517	44.041	760	4.180	181	7.537	391	12.128	455
2014	68.110	586	47.750	936	1.389	60	9.120	414	10.476	405
2015	61.210	531	43.673	873	4.408	139	6.490	347	8.310	280
2016	35.907	346	32.052	636	1.885	84	6.808	289	6.868	197
2017	34.847	398	55.607	859	3.137	141	4.495	236	6.551	174
2018	37.502	428	51.753	767	2.673	98	2.611	108	4.686	130

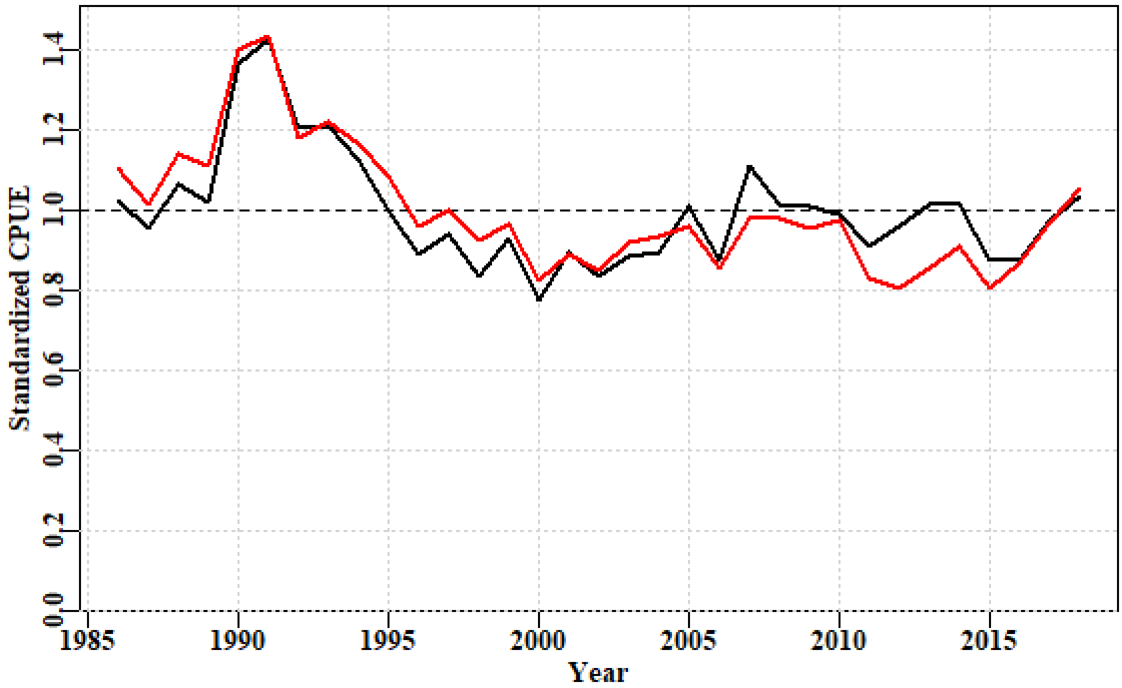

Figure 5.156. A comparison of the optimum standardization for Offshore Ocean Perch when using just Zones 10 and 20 and when including records from zones 30, 40 and 50.

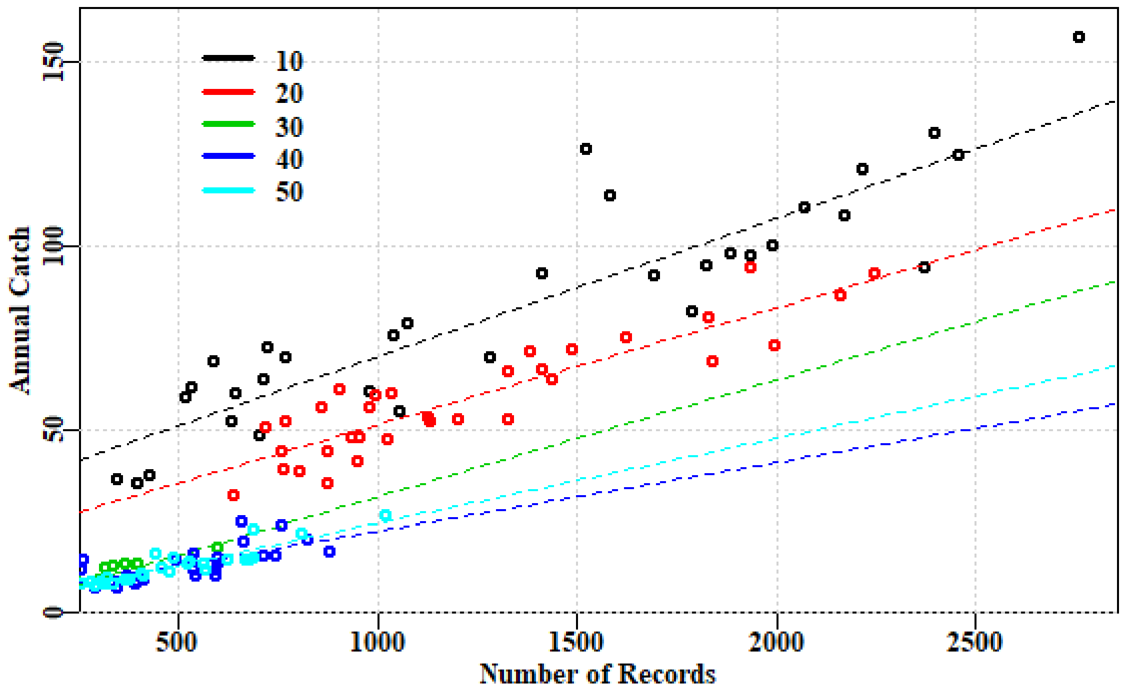

Figure 5.157. A plot of the different reported Catch vs reported number of records for each zone from 10 to 50 for Offshoure Ocean Perch. The dotted lines are the linear regressions in each case illustrating the different average ratio CPUE for each zone and that fact that CPUE in zones 30 - 50 is generally lower for the same effort than in zones 10 and 20.

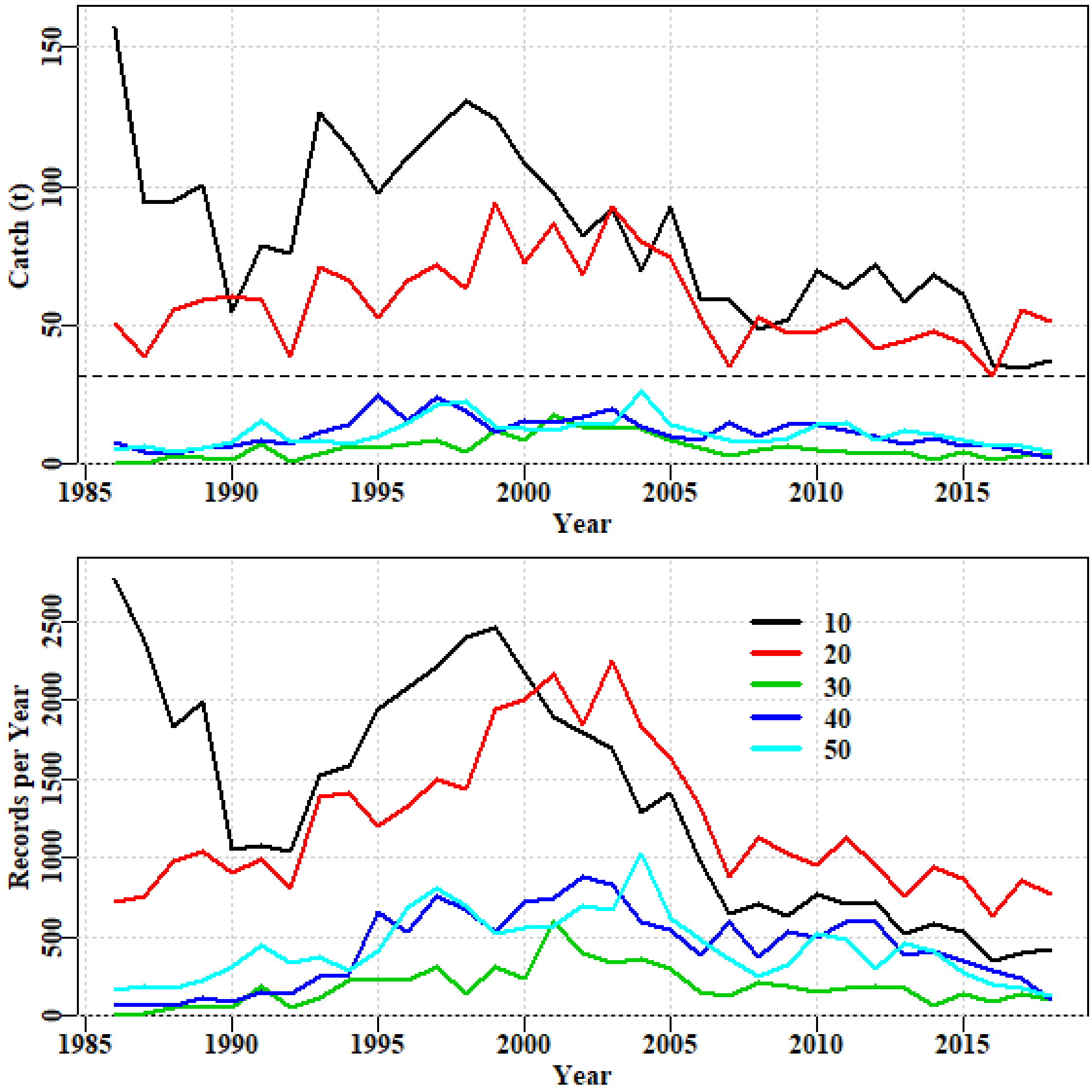

Figure 5.158. Catch and Records by Zone through time illustrating that catches in 30 to 50 have never been as great as those in zones 10 and 20 although the number of records can be relatively high.

5.27 Ocean Perch Inshore 1020

Inshore Ocean Perch (REG – 37287001 – *Helicolenus percoides*) was one of the 16 species first included in the quota system in 1992. Trawl caught inshore Ocean Perch based on methods TW, TDO, in zones 10, 20, and depths 0 to 200 within the SET fishery for the years 1986 - 2018 were analysed (Table 5.111). A total of 8 statistical models were fitted sequentially to the available data, with the order of the non-interaction terms added based on the relative contribution of each term to model fit.

5.27.1 *Inferences*

The majority of catch of this species occurred in zone 10 followed by zone 20. Small shots <30 kg appear through-out the analysis period. There was an increase in small shots of < 30 kg over the 1992 - 2006 period, which is suggestive or either low availability of high levels of small fish (Figure 5.160).

The terms Year, Month, Vessel and DepCat had the greatest contribution to model fit, with the remaining terms each explaining < 1% of the overall variation in CPUE, based on the AIC and R^2 statistics (Table 5.115). The qqplot suggests a small departure from that the assumed Normal distribution as depicted by both tails of the distribution (Figure 5.162).

Annual standardized CPUE are relatively flat and above average in the last 3 years based on upper 95% confidence limit (Figure 5.159).

5.27.2 *Action Items and Issues*

As the discarding rate continues to be very high (~90% of all catches) it is recommended that this analysis not be conducted as it may mistakenly be assumed to be informative of the stock's relative biomass through time.

Table 5.111. OceanPerchInshore1020. The data selection criteria used to specify and identify the fishery data to be included in the analysis.

Property	Value
label	OceanPerchInshore1020
csirocode	37287901, 37287093, 37287001, 91287001, 92287001
fishery	SET
depthrange	0 - 200
depthclass	10
zones	10, 20
methods	TW, TDO
years	1986 - 2018

Table 5.112. OceanPerchInshore1020. Total catch (Total; t) is the total reported in the database, number of records used in the analysis (N), reported catch (Catch; t) in the area and depth used in the analysis and number of vessels used in the analysis (Vess). GeoM is the geometric mean of catch rates (kg/hr), standard deviation (StDev) relates to the optimum model. C<30Kg denotes the amount of catch in shots of <30kg, and %<30Kg is the percent of total. The optimum model was Zone:DepCat.

	Total	N	Catch	Vess	GeoM	Opt	StDev	C<30Kg	P<30Kg
1986	262.4	338	15.2	50	11.9	0.8384	0.000	3.786	0.248
1987	198.4	403	11.9	58	10.7	0.9906	0.093	4.053	0.340
1988	188.4	517	16.5	58	11.6	1.1240	0.089	5.689	0.345
1989	209.2	436	15.0	52	12.4	1.0858	0.093	4.817	0.322
1990	181.7	438	15.0	43	11.9	1.1698	0.094	4.444	0.297
1991	223.6	478	19.4	42	16.9	1.2571	0.094	4.937	0.255
1992	169.7	261	14.0	26	19.7	1.5639	0.105	2.624	0.187
1993	259.6	446	23.3	33	20.5	1.7504	0.097	3.858	0.166
1994	257.3	544	22.3	32	15.6	1.5383	0.093	6.112	0.274
1995	240.0	592	20.8	32	13.4	1.2223	0.091	7.659	0.368
1996	263.9	679	20.6	39	11.0	1.1268	0.090	8.841	0.429
1997	298.8	554	15.2	39	10.3	1.0628	0.093	6.486	0.427
1998	295.0	633	15.0	38	9.3	0.9426	0.092	8.329	0.554
1999	295.8	666	15.3	38	8.8	0.8384	0.091	8.525	0.558
2000	270.2	1316	30.4	37	8.8	0.9851	0.087	15.227	0.501
2001	281.6	1034	23.1	34	8.7	0.9649	0.088	10.701	0.462
2002	255.3	1405	24.7	34	6.5	0.6959	0.087	12.224	0.495
2003	322.7	1069	17.0	37	5.9	0.5389	0.088	9.449	0.555
2004	316.3	944	14.7	38	6.1	0.5420	0.090	7.482	0.509
2005	316.8	850	17.3	39	7.0	0.6006	0.090	7.912	0.459
2006	237.6	585	8.9	34	4.7	0.5033	0.094	4.704	0.531
2007	180.6	386	8.6	20	9.5	0.7341	0.100	4.281	0.500
2008	184.3	317	7.6	20	8.9	0.8928	0.104	3.388	0.448
2009	173.9	259	6.0	21	8.2	0.7435	0.107	2.847	0.471
2010	195.6	275	6.3	21	8.3	0.8154	0.106	3.098	0.494
2011	186.9	244	5.2	19	7.8	0.9499	0.108	2.414	0.464
2012	183.9	372	7.3	20	7.4	0.7756	0.101	3.514	0.481
2013	171.2	218	4.9	14	7.7	0.9329	0.110	2.815	0.575
2014	174.4	152	3.0	15	6.4	0.6767	0.121	1.724	0.572
2015	150.8	119	2.5	14	6.6	0.4117	0.129	1.049	0.416
2016	132.1	262	29.2	13	45.8	1.5608	0.117	1.290	0.044
2017	155.7	216	19.8	12	33.7	1.3159	0.120	1.559	0.079
2018	151.8	189	18.0	9	32.7	1.8489	0.123	1.226	0.068

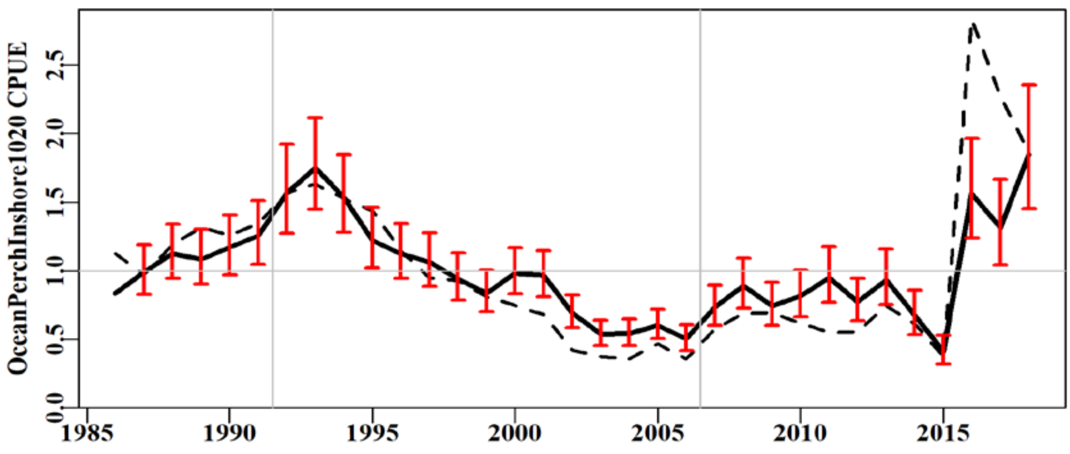

Figure 5.159. OceanPerchInshore1020 standardization. The dashed black line represents the geometric mean catch rate, solid black line the standardized catch rates. The red bars are the 95% confidence intervals about the mean estimates. The graph scales both time-series of standardized catch rates relative to the mean of each time-series.

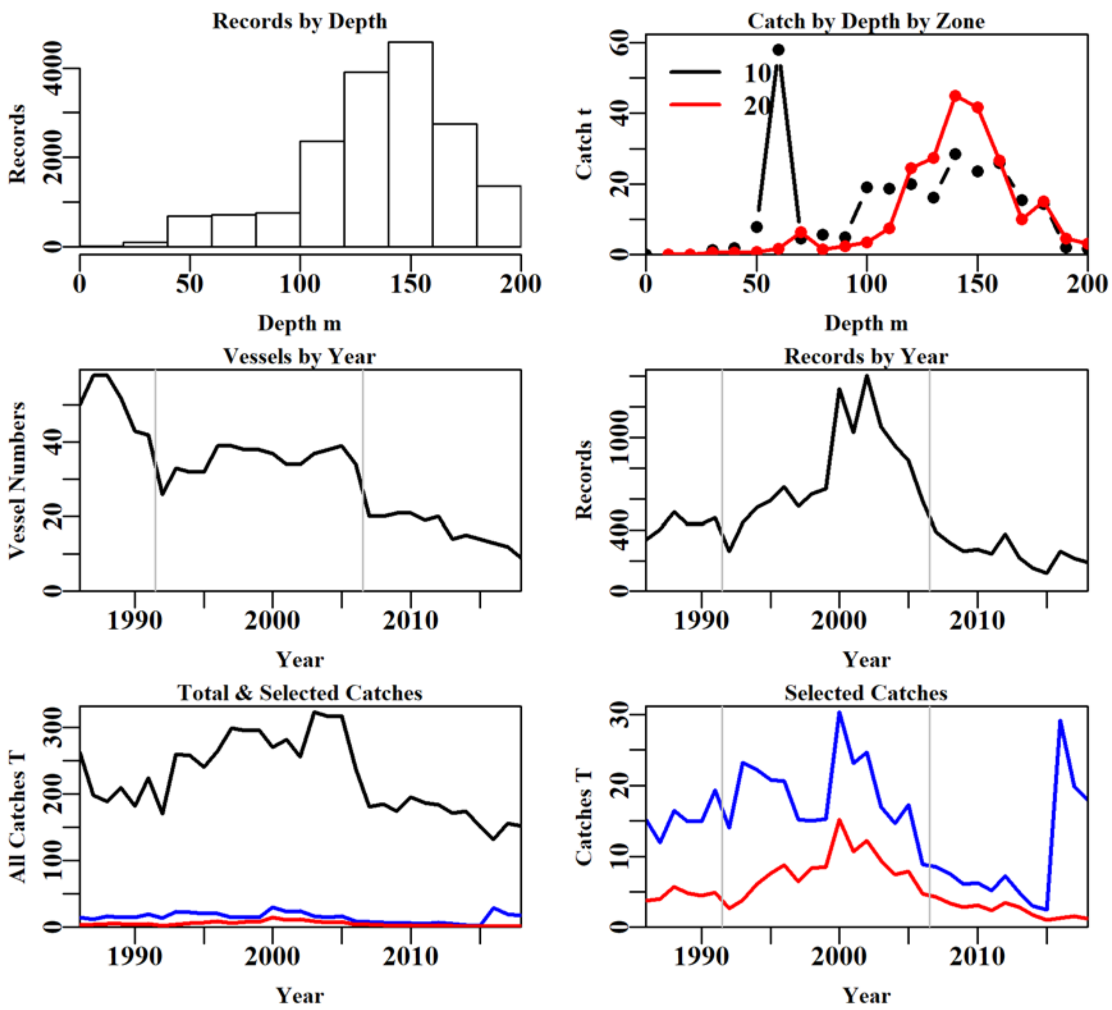

Figure 5.160. OceanPerchInshore1020 fishery details. The bottom left plot depicts all known catches (top black line), and all selected catches used in the analysis (middle blue line); the lower red line: selected catches < 30 kg).

Table 5.113. OceanPerchInshore1020 data selection effects. Total is the total number of records in the database, NoCE removes those records with either missing catch or effort, and then only those records are kept that meet the criteria for depth, years, zone, method and fishery.

	Total	NoCE	Depth	Years	Zones	Method	Fishery
Records	172692	156282	24805	24537	17538	17220	17197
Difference	0	16410	131477	268	6999	318	23
Catch	7538.46	6908.37	711.62	696.57	498.97	494.95	493.89
Difference	0	630.08	6196.75	15.05	197.60	4.02	1.06

Table 5.114. The models used to analyse data for OceanPerchInshore1020.

	Model
Model1	Year
Model2	Year + Month
Model3	Year + Month + Vessel
Model4	Year + Month + Vessel + DepCat
Model5	Year + Month + Vessel + DepCat + DayNight
Model6	Year + Month + Vessel + DepCat + DayNight + Zone
Model7	Year + Month + Vessel + DepCat + DayNight + Zone + Zone:Month
Model8	Year + Month + Vessel + DepCat + DayNight + Zone + Zone:DepCat

Table 5.115. OceanPerchInshore1020. The row names are 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_r2) and the change in adjusted R^2 (%Change). The optimum model was Zone:DepCat.

	AIC	RSS	MSS	Nobs	Npars	adj_r2	%Change
Year	6243	24629	4781	17197	33	16.1	0.00
Month	5969	24208	5202	17197	44	17.5	1.38
Vessel	2342	19264	10145	17197	195	33.7	16.27
DepCat	1760	18580	10830	17197	215	36.0	2.28
DayNight	1684	18492	10918	17197	218	36.3	0.29
Zone	1607	18407	11003	17197	219	36.6	0.29
Zone:Month	1599	18375	11035	17197	230	36.7	0.07
Zone:DepCat	1479	18230	11180	17197	238	37.1	0.54

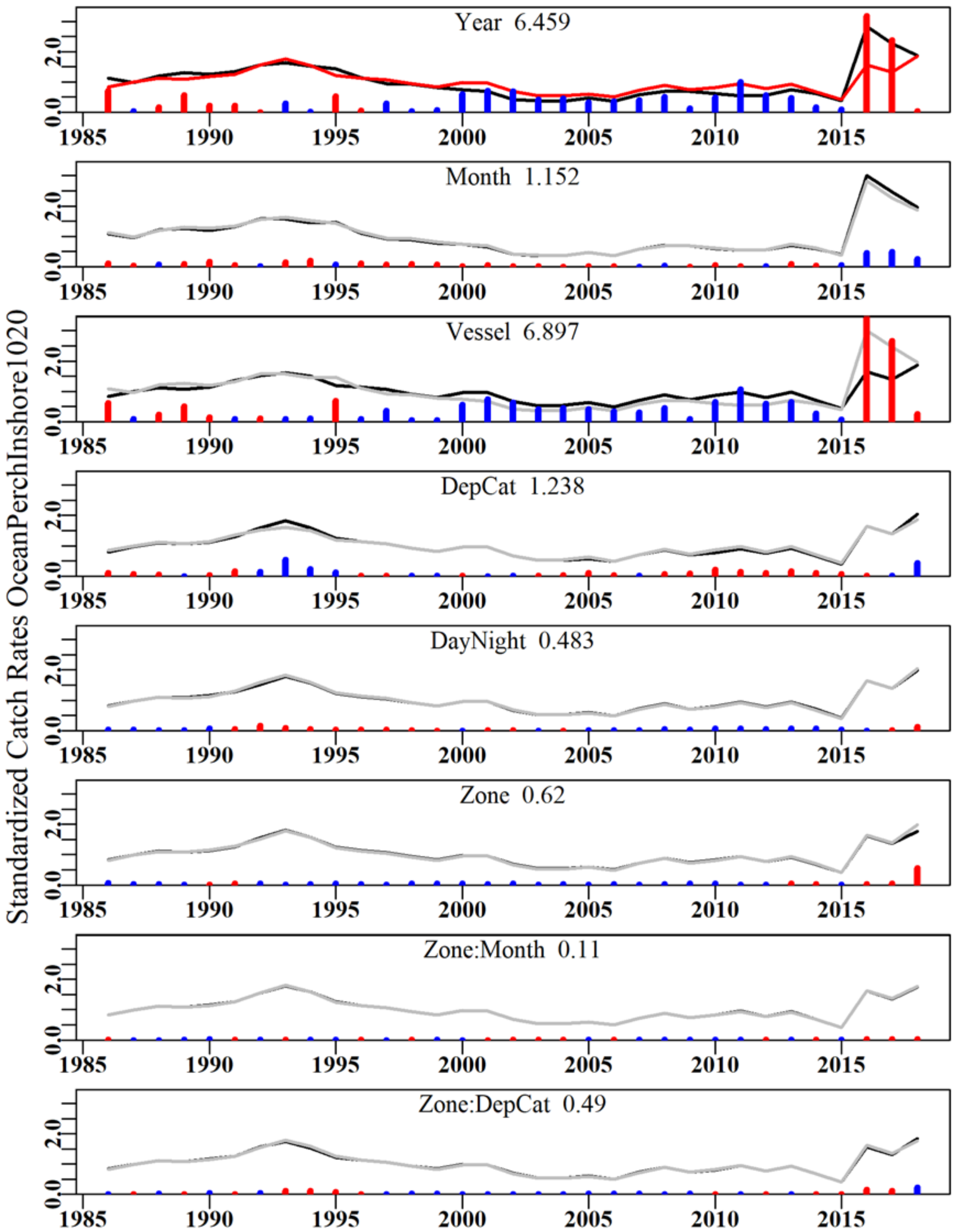

Figure 5.161. OceanPerchInshore1020. The influence of each factor on the optimal standardization. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by vertical bars with blue bars indicating the optimum model is higher than 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.

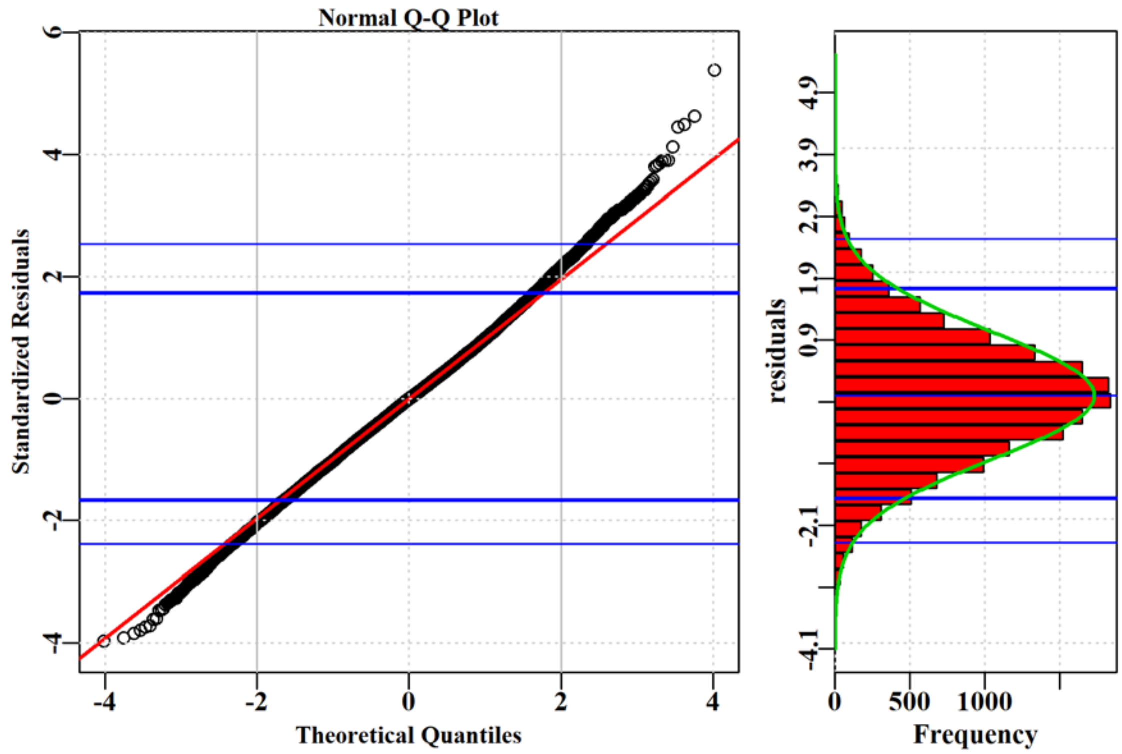

Figure 5.162. OceanPerchInshore1020. diagnostic plots. The distribution of residuals from the optimum fit. The qqplot indicates the fit to the expected normality, while the histogram of residuals illustrates the 90% quantiles to indicate the intensity of any lack of fit at the margins of the distribution.

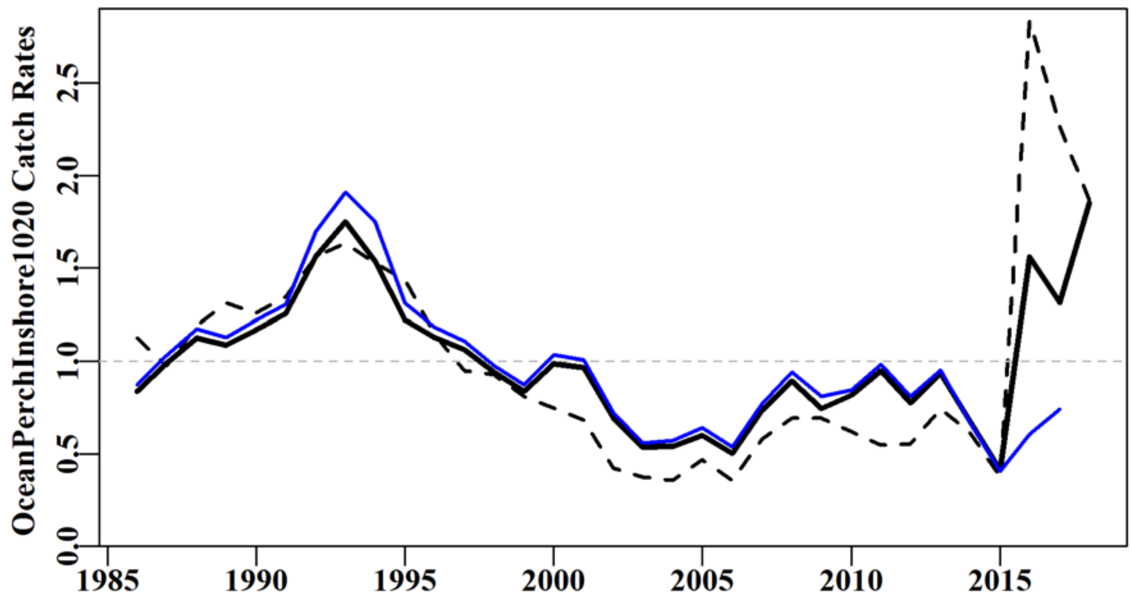

Figure 5.163. OceanPerchInshore1020. A comparison of the previous year's standardization (blue line) with this year's. They should lie on top of each other, although small deviations may relate to data adjustments, particularly in very recent years.

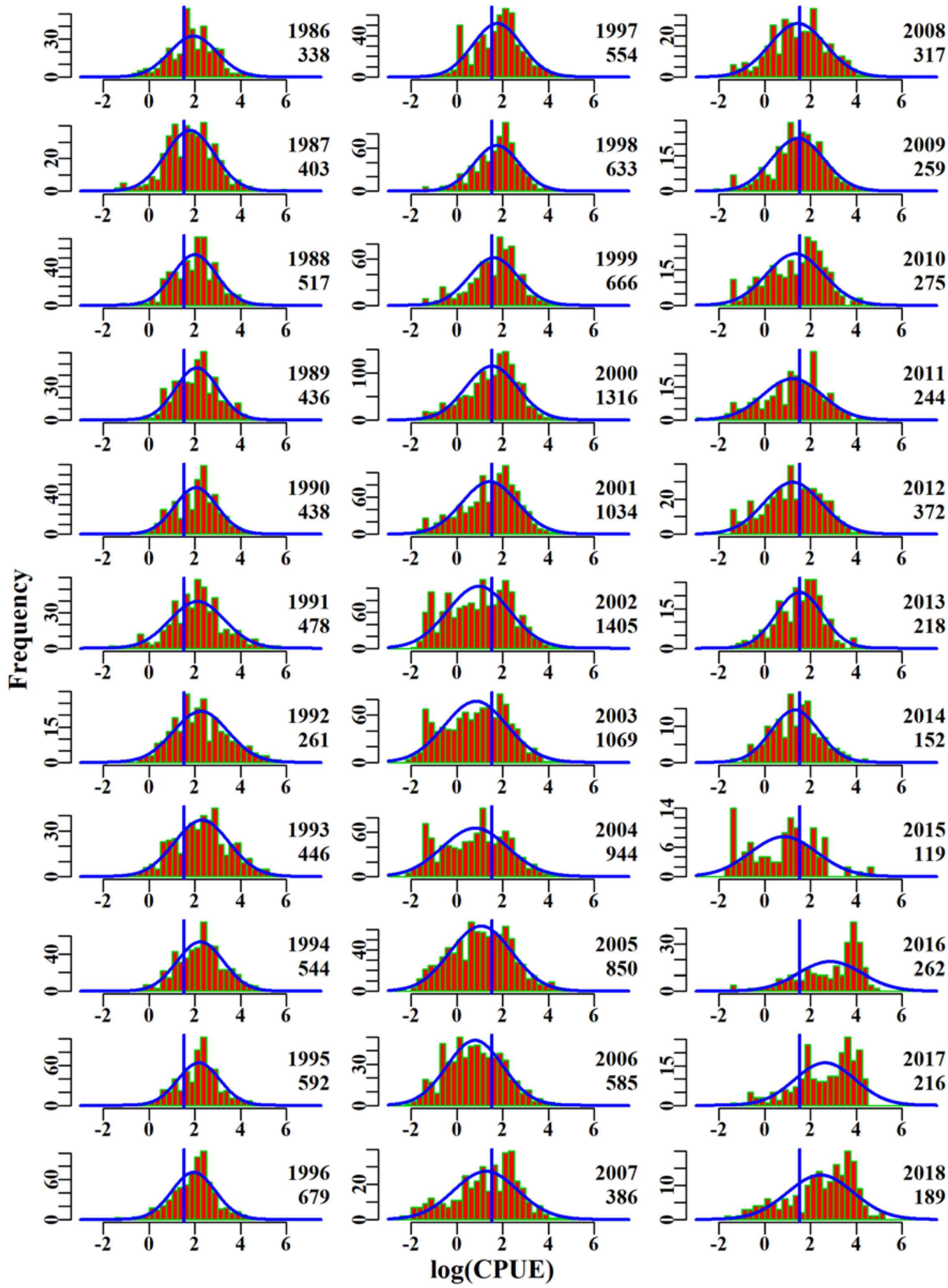

Figure 5.164. OceanPerchInshore1020. The natural log(CPUE) for each year of data available the blue lines are normal distributions fitted to the histogram frequencies. The numbers in each plot are the year and number of records.

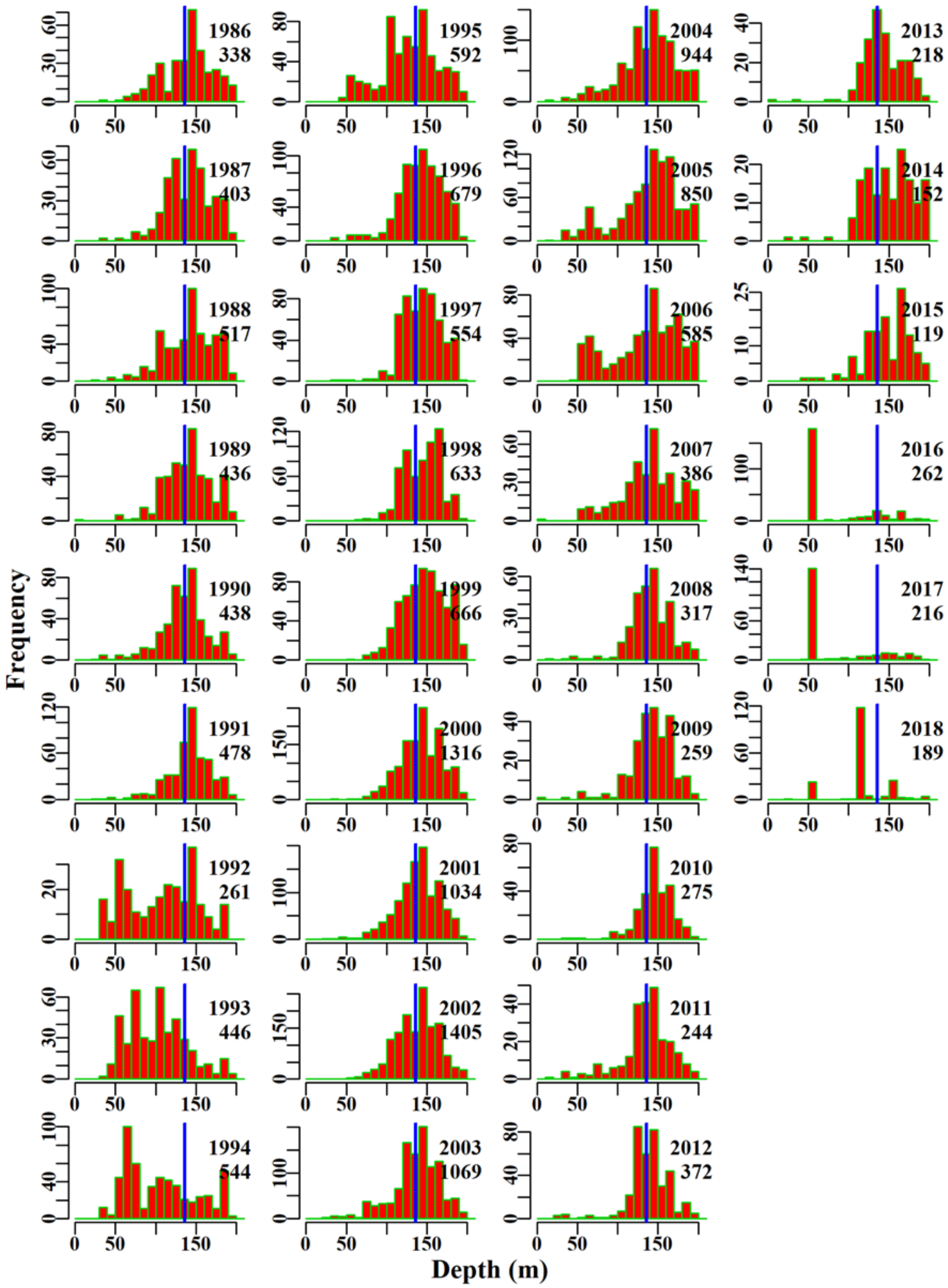

Figure 5.165. OceanPerchInshore1020. The average Depth of fishing for each year of data available to illustrate the development of the fishery through time. The numbers in each plot are the year and number of records.

5.28 Ocean Jackets 1050

Ocean Jackets (LTC – 37465006 – *Nelusetta ayraudi* and Leather Jackets LTH – 37465000). Trawl caught Ocean Jackets based on methods TW, TDO, in zones 10, 20, 30, 40, 50, and depths 0 to 300 within the SET fishery for the years 1986 - 2018 were analysed (Table 5.116). A total of 8 statistical models were fitted sequentially to the available data, with the order of the non-interaction terms added based on the relative contribution of each term to model fit.

5.28.1 *Inferences*

The majority of catch of this species occurred in zone 10 followed by zone 20, with minimal catches in the remaining zones. Small shots <30 kg appear through-out the analysis period. There was an increase in small shots of < 30kg over the 1992 - 2006 period, which is suggestive of either low availability or high levels of small fish (Figure 5.167).

The terms Year and Vessel had the greatest contribution to model fit, with the remaining terms each explaining < 1% of the overall variation in CPUE, based on the AIC and R^2 statistics (Table 5.120). The qqplot suggests a small departure from that the assumed Normal distribution as depicted by both tails of the distribution (Figure 5.169).

Annual standardized CPUE are relatively flat and below average between 1986-2004 reflecting the relatively low catches at the time. It increased rapidly along with catches from 2003 - 2007 after which it has continued to be relatively high (declining slightly from 2007 - 2016) and dropped to just above average in 2018 (Figure 5.166).

5.28.2 *Action Items and Issues*

No issues identified.

Table 5.116. OceanJackets1050. The data selection criteria used to specify and identify the fishery data to be included in the analysis.

Property	Value
label	OceanJackets1050
csirocode	37465006, 37465000
fishery	SET
depthrange	0 - 300
depthclass	20
zones	10, 20, 30, 40, 50
methods	TW, TDO
years	1986 - 2018

Table 5.117. OceanJackets1050. Total catch (Total; t) is the total reported in the database, number of records used in the analysis (N), reported catch (Catch; t) in the area and depth used in the analysis and number of vessels used in the analysis (Vess). GeoM is the geometric mean of catch rates (kg/hr), standard deviation (StDev) relates to the optimum model. C<30Kg denotes the amount of catch in shots of <30kg, and %<30Kg is the percent of total. The optimum model was Zone:DepCat.

	Total	N	Catch	Vess	GeoM	Opt	StDev	C<30Kg	P<30Kg
1986	56.4	2471	44.7	75	7.3	0.6176	0.000	26.955	0.603
1987	53.4	1432	28.0	61	7.6	0.6581	0.037	16.203	0.579
1988	66.3	1905	45.6	66	8.8	0.7936	0.035	22.651	0.497
1989	71.7	1800	32.6	65	6.9	0.6815	0.035	20.112	0.617
1990	91.0	1542	33.0	46	7.6	0.6707	0.037	16.489	0.499
1991	170.5	1324	24.7	46	6.7	0.5840	0.039	15.239	0.617
1992	88.9	1187	24.5	41	6.8	0.5963	0.040	14.447	0.591
1993	71.9	1325	28.9	42	6.9	0.6423	0.040	16.806	0.581
1994	74.4	1436	34.4	45	8.3	0.7228	0.039	19.246	0.559
1995	140.2	2216	58.9	41	9.0	0.7159	0.035	27.382	0.465
1996	199.6	2553	71.5	53	9.9	0.7429	0.034	30.221	0.423
1997	177.4	1993	52.1	51	9.5	0.6778	0.036	21.864	0.420
1998	189.9	2479	67.7	44	9.4	0.6759	0.034	27.232	0.402
1999	202.8	2682	88.0	52	10.6	0.7937	0.034	31.123	0.354
2000	198.8	2982	73.2	53	7.7	0.6384	0.033	37.466	0.512
2001	222.6	3194	64.4	55	6.5	0.5678	0.033	37.862	0.588
2002	378.5	4865	199.1	61	10.8	0.6807	0.031	52.170	0.262
2003	482.3	5464	185.8	58	9.8	0.6452	0.031	54.008	0.291
2004	692.6	6200	311.4	60	16.0	1.0532	0.030	56.415	0.181
2005	890.6	5131	341.2	54	21.1	1.1944	0.031	39.369	0.115
2006	741.5	4599	300.1	50	21.2	1.3238	0.032	34.980	0.117
2007	564.8	3073	284.1	27	31.3	1.5863	0.034	19.765	0.070
2008	490.4	3519	316.3	29	28.9	1.5055	0.033	23.006	0.073
2009	610.0	3229	374.2	28	36.6	1.6895	0.034	19.665	0.053
2010	483.9	3201	294.0	29	30.5	1.3845	0.034	20.507	0.070
2011	487.4	3192	274.6	29	30.0	1.3126	0.034	21.184	0.077
2012	519.7	3405	340.4	30	33.6	1.5032	0.034	21.441	0.063
2013	488.5	2816	262.7	27	28.7	1.5015	0.035	16.442	0.063
2014	512.0	3362	273.0	28	24.5	1.3454	0.034	21.360	0.078
2015	414.9	3066	248.0	31	25.7	1.2963	0.034	19.929	0.080
2016	467.1	2600	238.5	28	29.8	1.3869	0.035	16.977	0.071
2017	424.9	1847	219.0	25	44.2	1.7133	0.038	7.816	0.036
2018	306.5	1366	113.5	22	27.5	1.0985	0.042	7.296	0.064

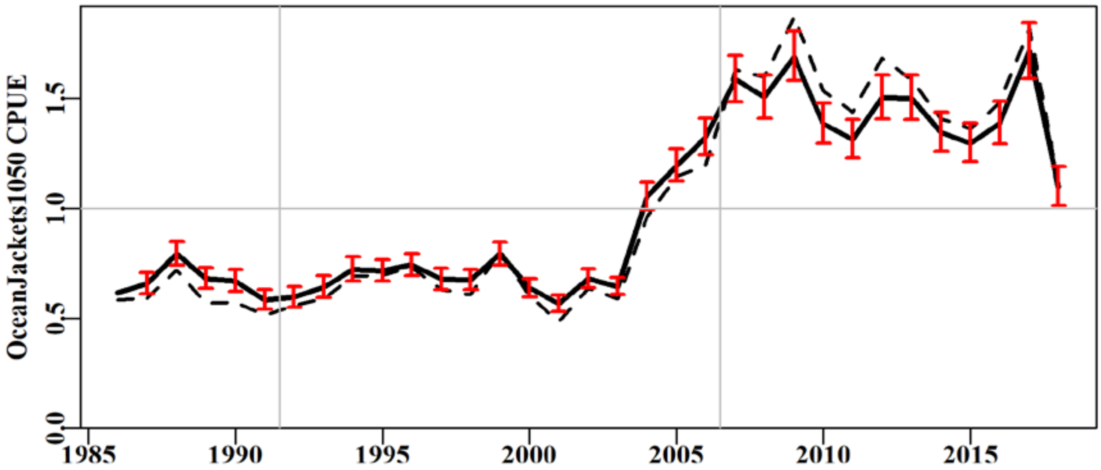

Figure 5.166. OceanJackets1050 standardization. The dashed black line represents the geometric mean catch rate, solid black line the standardized catch rates. The red bars are the 95% confidence intervals about the mean estimates. The graph scales both time-series of standardized catch rates relative to the mean of each time-series.

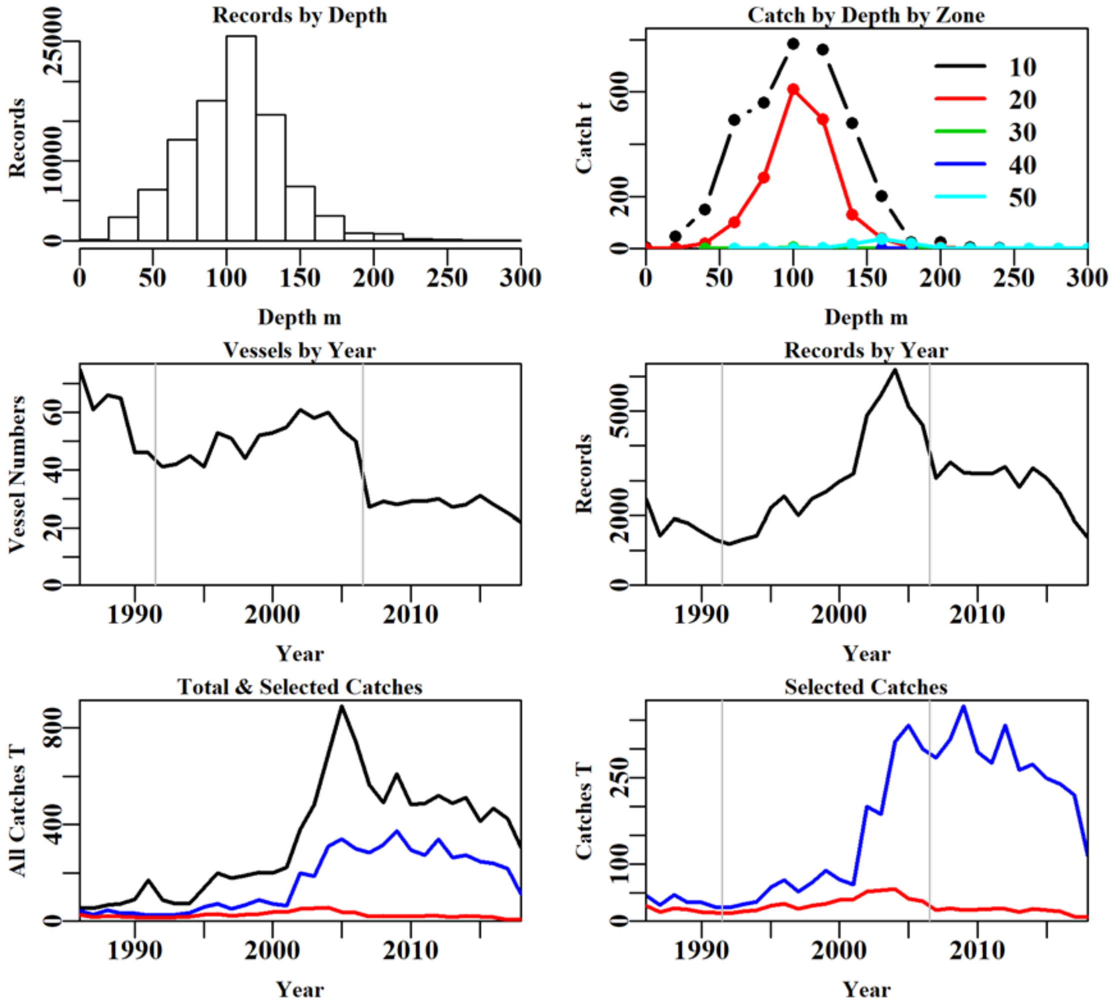

Figure 5.167. OceanJackets1050 fishery details. The bottom left plot depicts all known catches (top black line), and all selected catches used in the analysis (middle blue line); the lower red line: selected catches < 30 kg).

Table 5.118. OceanJackets1050 data selection effects. Total is the total number of records in the database, NoCE removes those records with either missing catch or effort, and then only those records are kept that meet the criteria for depth, years, zone, method and fishery.

	Total	NoCE	Depth	Years	Zones	Method	Fishery
Records	1813050	169781	167595	163651	99105	93631	93456
Difference	0	11524	2186	3944	64546	5474	175
Catch	11599.75	11460.523	11280.26	10753.62	5432.94	5362.49	5348.16
Difference	0	139.23	180.26	526.64	5320.68	70.44	14.34

Table 5.119. The models used to analyse data for OceanJackets1050.

	Model
Model1	Year
Model2	Year + Vessel
Model3	Year + Vessel + DepCat
Model4	Year + Vessel + DepCat + Month
Model5	Year + Vessel + DepCat + Month + Zone
Model6	Year + Vessel + DepCat + Month + Zone + DayNight
Model7	Year + Vessel + DepCat + Month + Zone + DayNight + Zone:Month
Model8	Year + Vessel + DepCat + Month + Zone + DayNight + Zone:DepCat

Table 5.120. OceanJackets1050. The row names are 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_r2) and the change in adjusted R^2 (%Change). The optimum model was Zone:DepCat.

	AIC	RSS	MSS	Nobs	Npars	adj_r2	%Change
Year	23794	120468	17705	93456	33	12.8	0.00
Vessel	10444	104041	34131	93456	208	24.5	11.75
DepCat	9936	103444	34728	93456	223	25.0	0.42
Month	9028	102421	35752	93456	234	25.7	0.73
Zone	8217	101527	36646	93456	238	26.3	0.65
DayNight	8076	101367	36805	93456	241	26.4	0.11
Zone:Month	7875	101064	37108	93456	280	26.6	0.19
Zone:DepCat	7045	100177	37995	93456	277	27.3	0.84

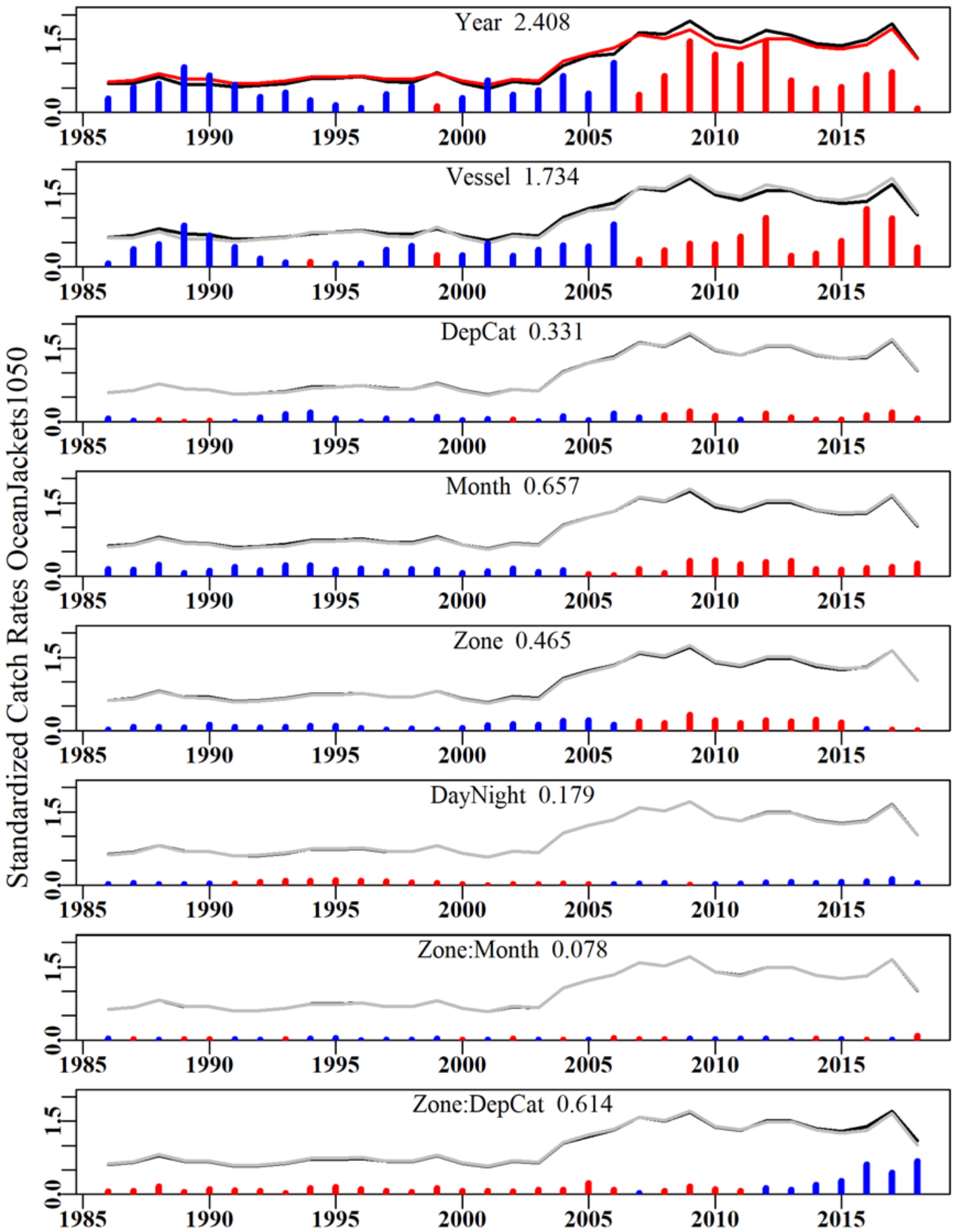

Figure 5.168. OceanJackets1050. The influence of each factor on the optimal standardization. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by vertical bars with blue bars indicating the optimum model is higher than the 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.

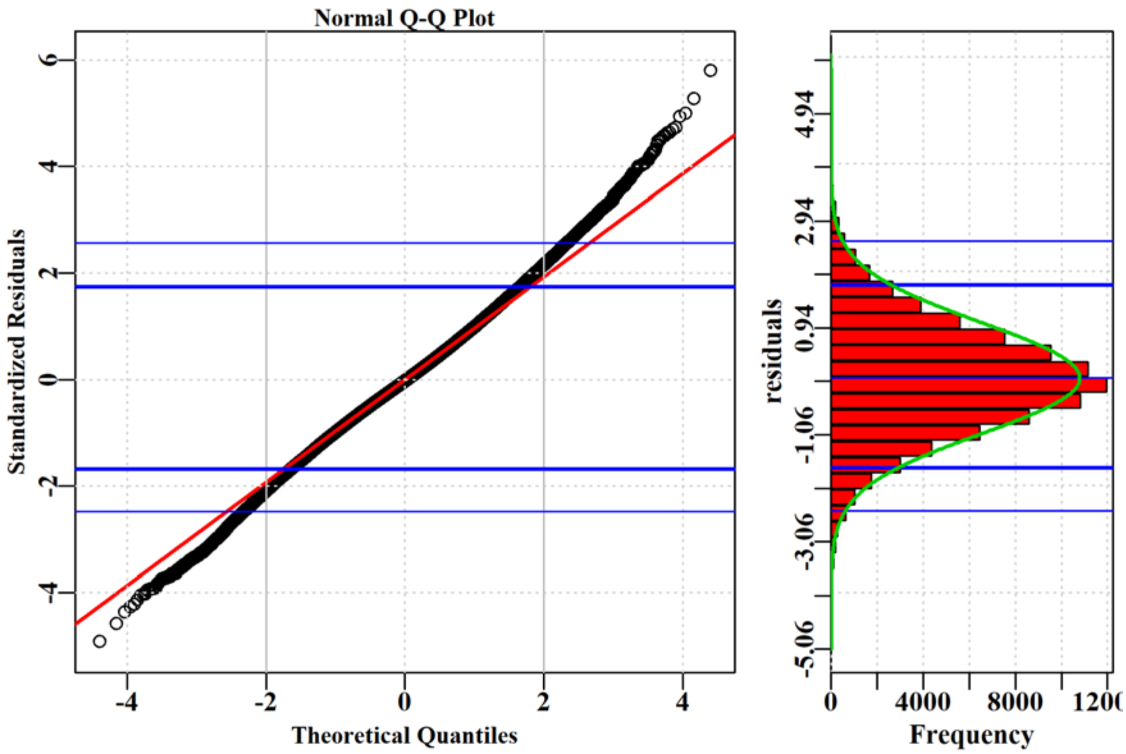

Figure 5.169. OceanJackets1050. diagnostic plots. The distribution of residuals from the optimum fit. The qqplot indicates the fit to the expected normality, while the histogram of residuals illustrates the 90% quantiles to indicate the intensity of any lack of fit at the margins of the distribution.

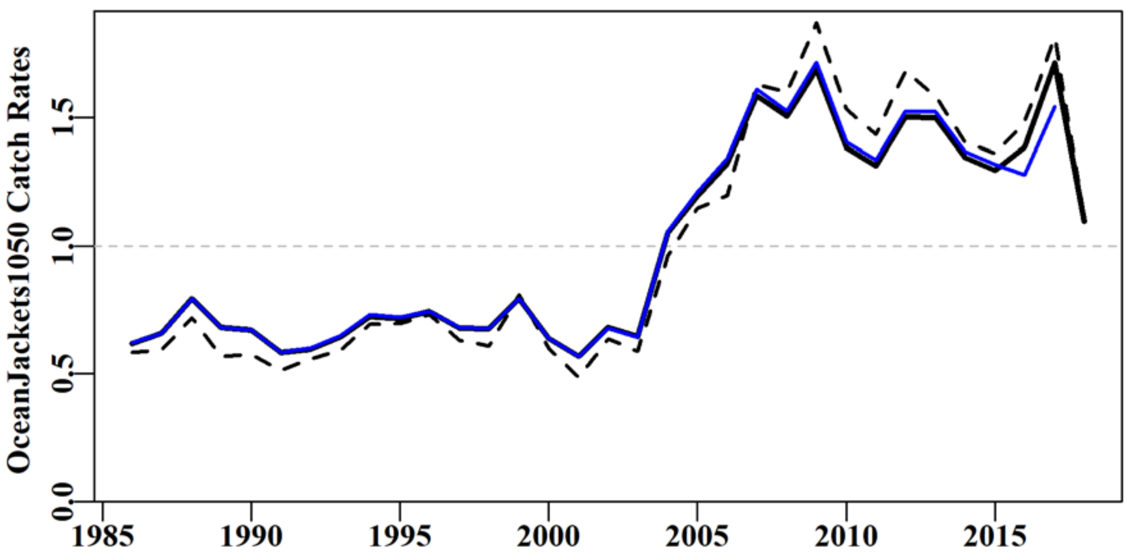

Figure 5.170. OceanJackets1050. A comparison of the previous year's standardization (blue line) with this year's. They should lie on top of each other, although small deviations may relate to data adjustments, particularly in very recent years.

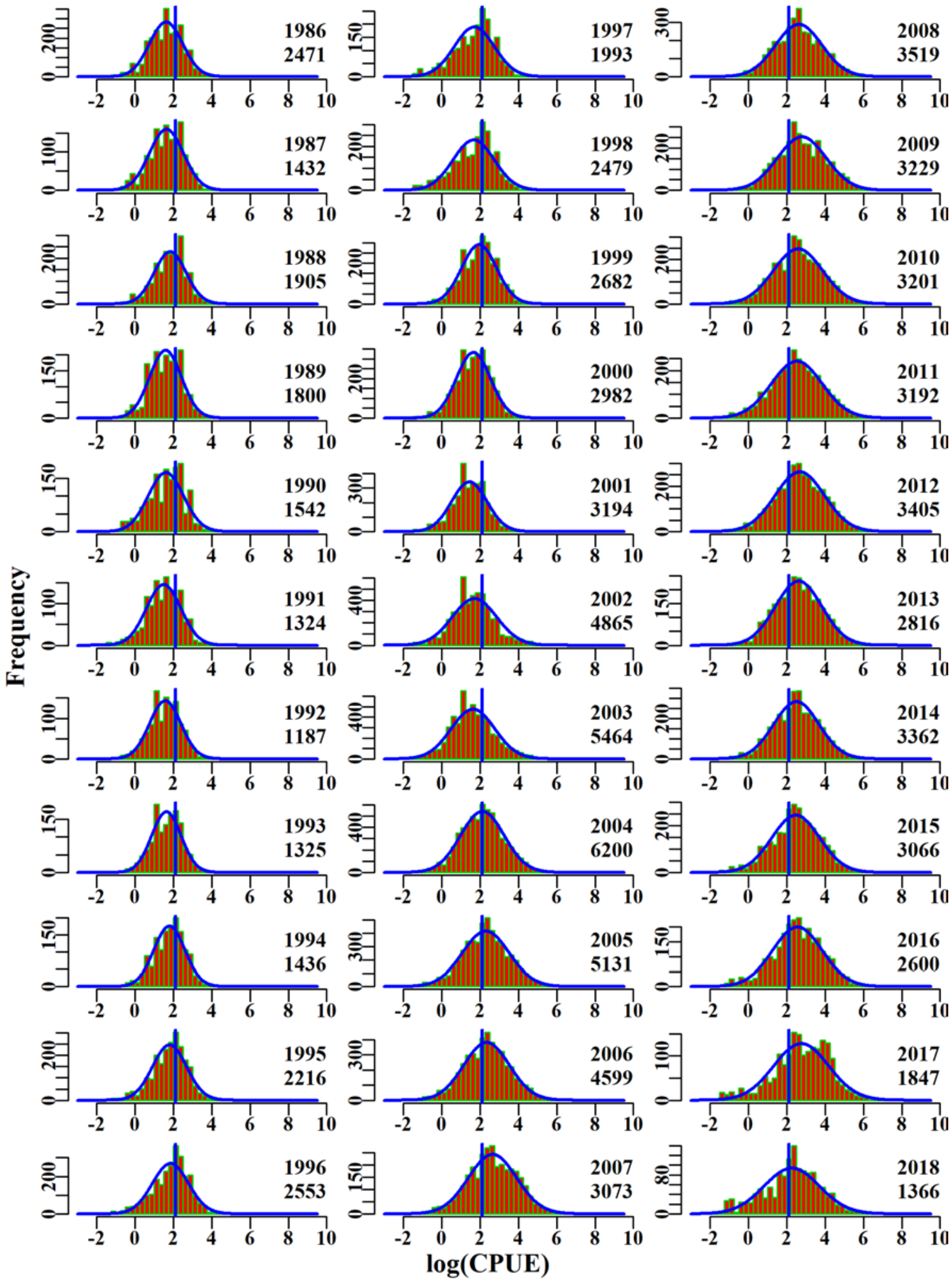

Figure 5.171. OceanJackets1050. The natural log(CPUE) for each year of data available the blue lines are normal distributions fitted to the histogram frequencies. The numbers in each plot are the year and number of records.

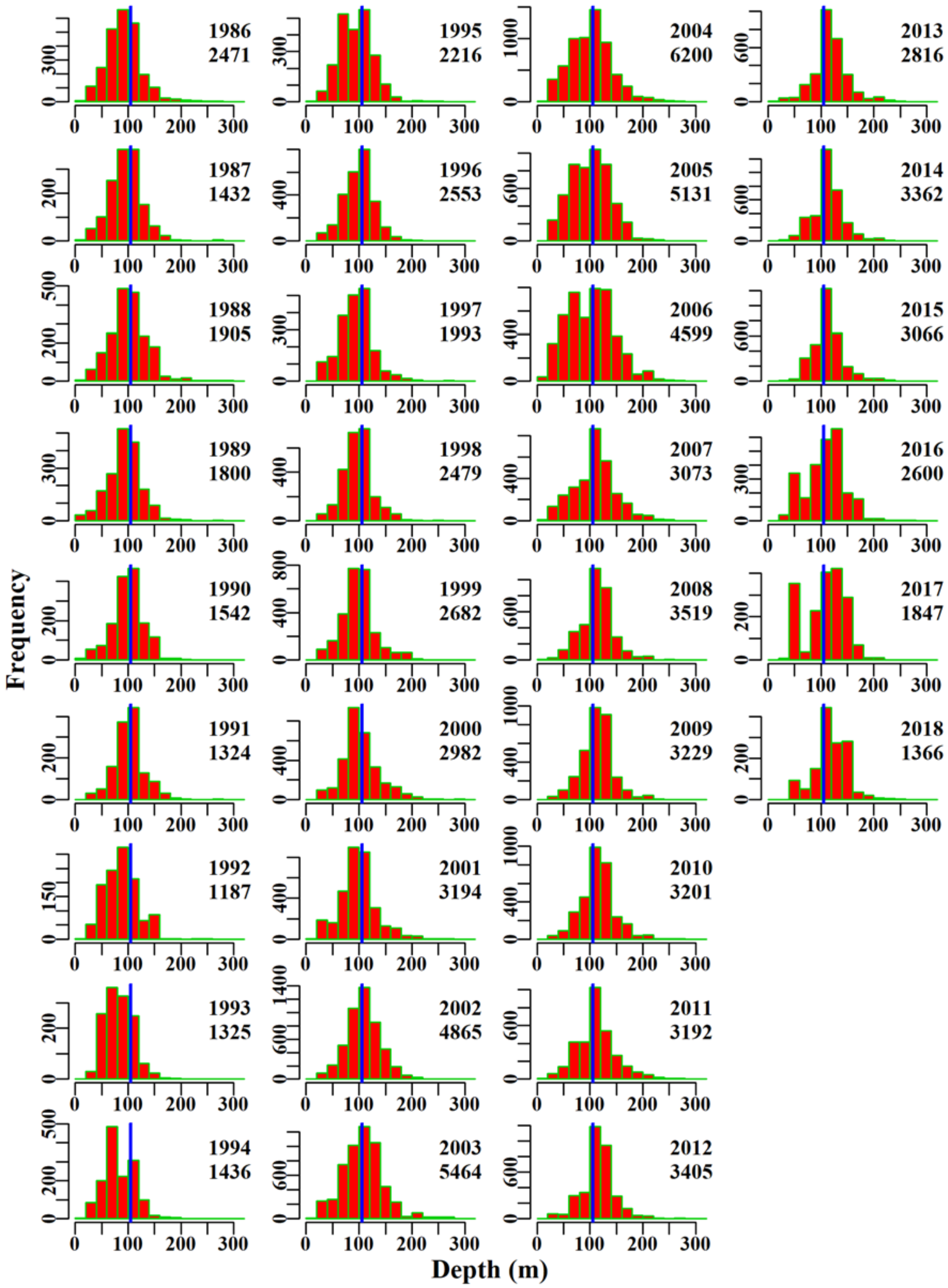

Figure 5.172. OceanJackets1050. The average Depth of fishing for each year of data available to illustrate the development of the fishery through time. The numbers in each plot are the year and number of records.

5.29 Ocean Jackets GAB

Ocean Jackets (LTC – 37465006 – *Nelusetta ayraudi* and Leather Jackets LTH – 37465000). Trawl caught Ocean Jackets based on methods TW, TDO, in zones 82, 83, and depths 0 to 300 within the GAB fishery for the years 1986 - 2018 were analysed. These constitute the criteria used to select data from the Commonwealth logbook database (Table 5.121).

A total of 8 statistical models were fitted sequentially to the available data, with the order of the non-interaction terms added based on the relative contribution of each term to model fit.

5.29.1 *Inferences*

The majority of catch of this species occurred in zone 83 followed by zone 82 in the GAB. A large spike of catches occurred from 2002 - 2006, which declined rapidly following the structural adjustment, although this may not have caused the decline in the GAB.

The terms Year, DayNight, Vessel DepCat and Month had the greatest contribution to model fit, with the remaining terms each explaining < 1% of the overall variation in CPUE, based on the AIC and R^2 statistics (Table 5.125). The qqplot suggests a small departure from that the assumed Normal distribution as depicted by both tails of the distribution (Figure 5.176).

Annual standardized CPUE are noisy and flat across the 1986 - 2018 period (Figure 5.173) but catches and numbers were low from 1986 – 1989.

5.29.2 *Action Items and Issues*

No issues identified.

Table 5.121. OceanJacketsGAB. The data selection criteria used to specify and identify the fishery data to be included in the analysis.

Property	Value
label	OceanJacketsGAB
csirocode	37465006, 37465000
fishery	GAB
depthrange	0 - 300
depthclass	20
zones	82, 83
methods	TW, TDO
years	1986 - 2018

Table 5.122. OceanJacketsGAB. Total catch (Total; t) is the total reported in the database, number of records used in the analysis (N), reported catch (Catch; t) in the area and depth used in the analysis and number of vessels used in the analysis (Vess). GeoM is the geometric mean of catch rates (kg/hr), standard deviation (StDev) relates to the optimum model. C<30Kg denotes the amount of catch in shots of <30kg, and %<30Kg is the percent of total. The optimum model was Zone:Month.

	Total	N	Catch	Vess	GeoM	Opt	StDev	C<30Kg	P<30Kg
1986	56.4	137	8.0	1	15.1	1.2507	0.000	2.520	0.317
1987	53.4	206	21.7	3	22.9	1.0251	0.105	2.270	0.105
1988	66.3	244	15.6	7	20.8	1.2240	0.186	1.603	0.103
1989	71.7	570	34.5	7	18.0	1.2370	0.183	4.168	0.121
1990	91.0	916	51.2	11	15.7	0.8197	0.181	8.675	0.169
1991	170.5	1247	139.2	8	26.8	1.0427	0.180	6.465	0.046
1992	88.9	921	57.1	7	14.0	0.8889	0.180	9.354	0.164
1993	71.9	813	38.4	4	9.9	0.6044	0.180	9.442	0.246
1994	74.4	736	36.1	5	10.6	0.5358	0.181	7.495	0.208
1995	140.2	1311	78.0	5	12.9	0.6985	0.179	12.907	0.165
1996	199.6	1712	122.3	6	14.9	0.8160	0.179	15.049	0.123
1997	177.4	2123	119.5	9	11.8	0.6713	0.179	21.575	0.180
1998	189.9	1787	115.6	9	13.8	0.7265	0.179	16.270	0.141
1999	202.8	1573	108.4	7	13.6	0.8270	0.179	12.140	0.112
2000	198.8	1551	122.2	5	17.4	0.8490	0.179	11.172	0.091
2001	222.6	1992	146.1	6	15.5	0.8803	0.179	12.521	0.086
2002	378.5	1793	148.1	6	16.3	0.9380	0.179	11.991	0.081
2003	482.3	2791	275.1	9	19.3	1.0680	0.179	11.385	0.041
2004	692.6	3399	360.3	9	20.9	1.1673	0.179	13.172	0.037
2005	890.6	4287	519.8	10	23.8	1.2364	0.179	14.604	0.028
2006	741.5	3573	405.1	11	21.4	0.9569	0.179	11.905	0.029
2007	564.8	2591	248.8	8	19.8	0.8566	0.179	10.479	0.042
2008	490.4	2314	144.0	6	12.9	0.7399	0.179	14.610	0.101
2009	610.0	2139	218.4	4	20.9	1.0327	0.179	11.145	0.051
2010	483.9	1777	167.1	4	19.0	1.1735	0.180	5.245	0.031
2011	487.4	1853	190.5	4	21.1	1.1861	0.180	5.501	0.029
2012	519.7	1714	154.6	5	17.3	1.1342	0.180	3.205	0.021
2013	488.5	2210	203.9	6	17.4	1.2491	0.179	1.018	0.005
2014	512.0	2013	206.7	6	18.4	1.2916	0.180	0.332	0.002
2015	414.9	1569	148.5	3	18.4	1.2391	0.180	0.894	0.006
2016	467.1	1654	203.1	4	23.8	1.2969	0.180	4.774	0.024
2017	424.9	1602	181.9	4	21.8	1.1929	0.180	10.149	0.056
2018	306.5	1499	148.5	4	19.6	1.1439	0.180	10.178	0.069

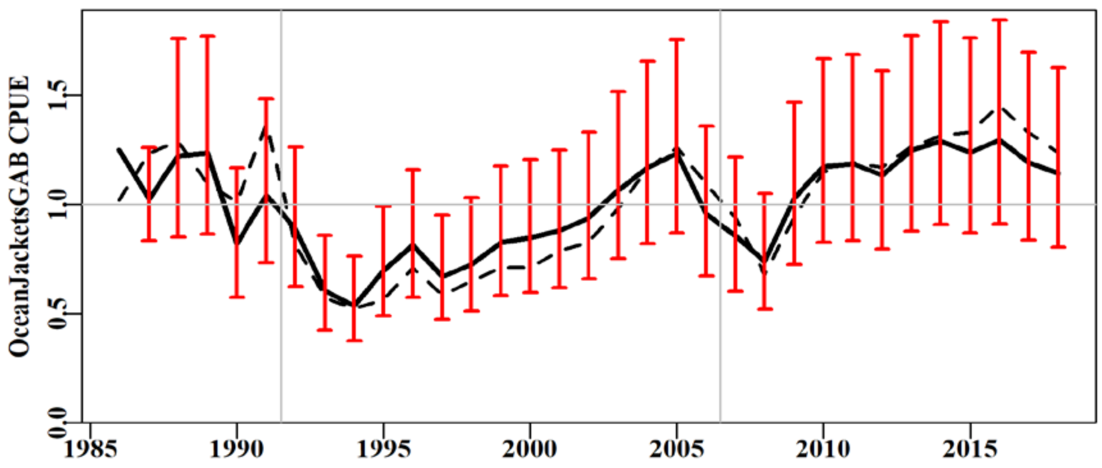

Figure 5.173. OceanJacketsGAB standardization. The dashed black line represents the geometric mean catch rate, solid black line the standardized catch rates. The red bars are the 95% confidence intervals about the mean estimates. The graph scales both time-series of standardized catch rates relative to the mean of each time-series.

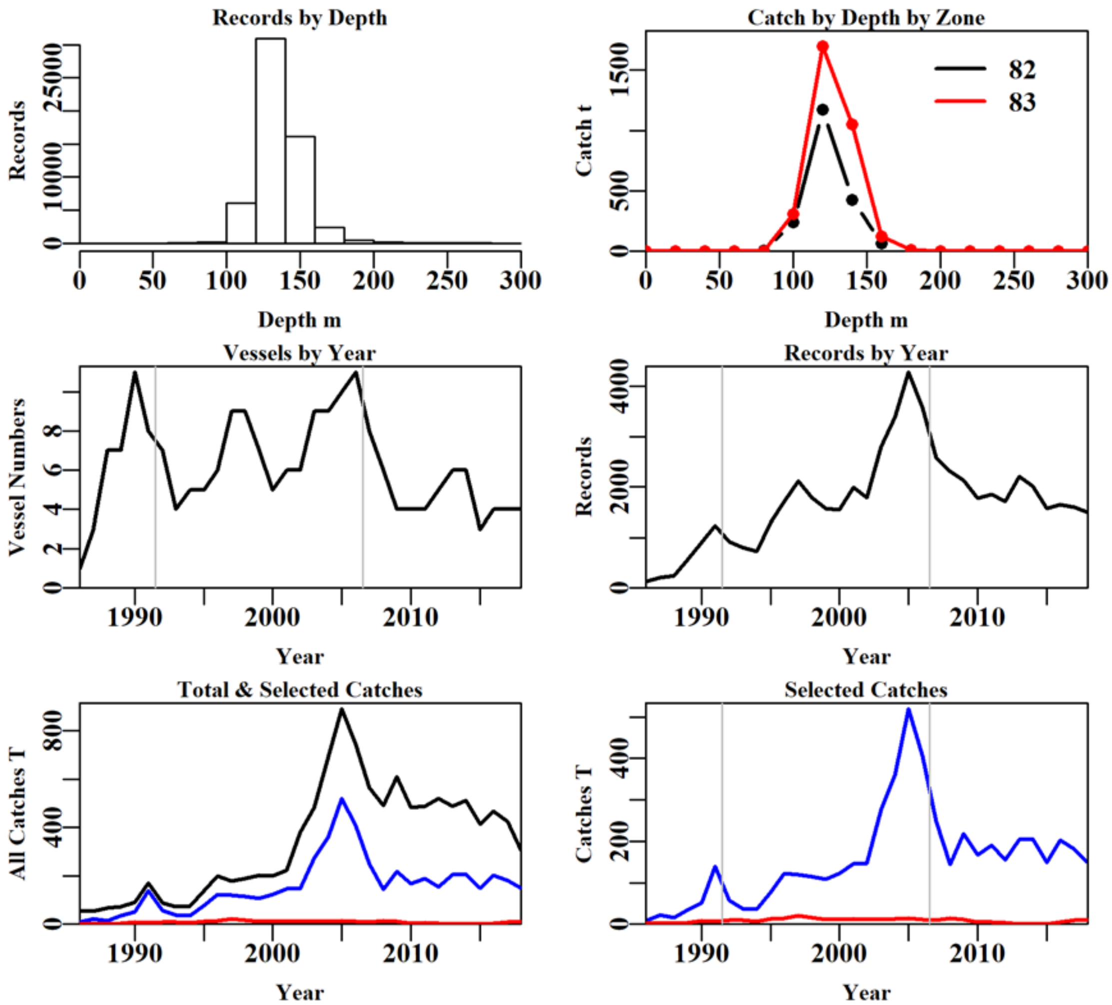

Figure 5.174. OceanJacketsGAB fishery details. The bottom left plot depicts all known catches (top black line), and all selected catches used in the analysis (middle blue line); the lower red line: selected catches < 30 kg).

Table 5.123. OceanJacketsGAB data selection effects. Total is the total number of records in the database, NoCE removes those records with either missing catch or effort, and then only those records are kept that meet the criteria for depth, years, zone, method and fishery.

	Total	NoCE	Depth	Years	Zones	Method	Fishery
Records	181305	169999	167802	163858	58766	56632	56617
Difference	0	11306	2197	3944	105092	2134	15
Catch	11599.75	11460.97	11280.68	10754.04	5163.90	5138.69	5138.15
Difference	0	138.78	180.29	526.64	5590.14	25.21	0.54

Table 5.124. The models used to analyse data for OceanJacketsGAB.

	Model
Model1	Year
Model2	Year + DayNight
Model3	Year + DayNight + Vessel
Model4	Year + DayNight + Vessel + DepCat
Model5	Year + DayNight + Vessel + DepCat + Month
Model6	Year + DayNight + Vessel + DepCat + Month + Zone
Model7	Year + DayNight + Vessel + DepCat + Month + Zone + Zone:Month
Model8	Year + DayNight + Vessel + DepCat + Month + Zone + Zone:DepCat

Table 5.125. OceanJacketsGAB. The row names are 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_r2) and the change in adjusted R^2 (%Change). The optimum model was Zone:Month.

	AIC	RSS	MSS	Nobs	Npars	adj_r2	%Change
Year	1411	57978	4501	56617	33	7.2	0.00
DayNight	-4939	51821	10658	56617	36	17.0	9.86
Vessel	-7617	49361	13118	56617	74	20.9	3.89
DepCat	-10683	46734	15745	56617	89	25.1	4.19
Month	-11953	45680	16799	56617	100	26.8	1.68
Zone	-11955	45677	16802	56617	101	26.8	0.00
Zone:Month	-12138	45512	16967	56617	112	27.0	0.25
Zone:DepCat	-11967	45643	16837	56617	116	26.8	0.04

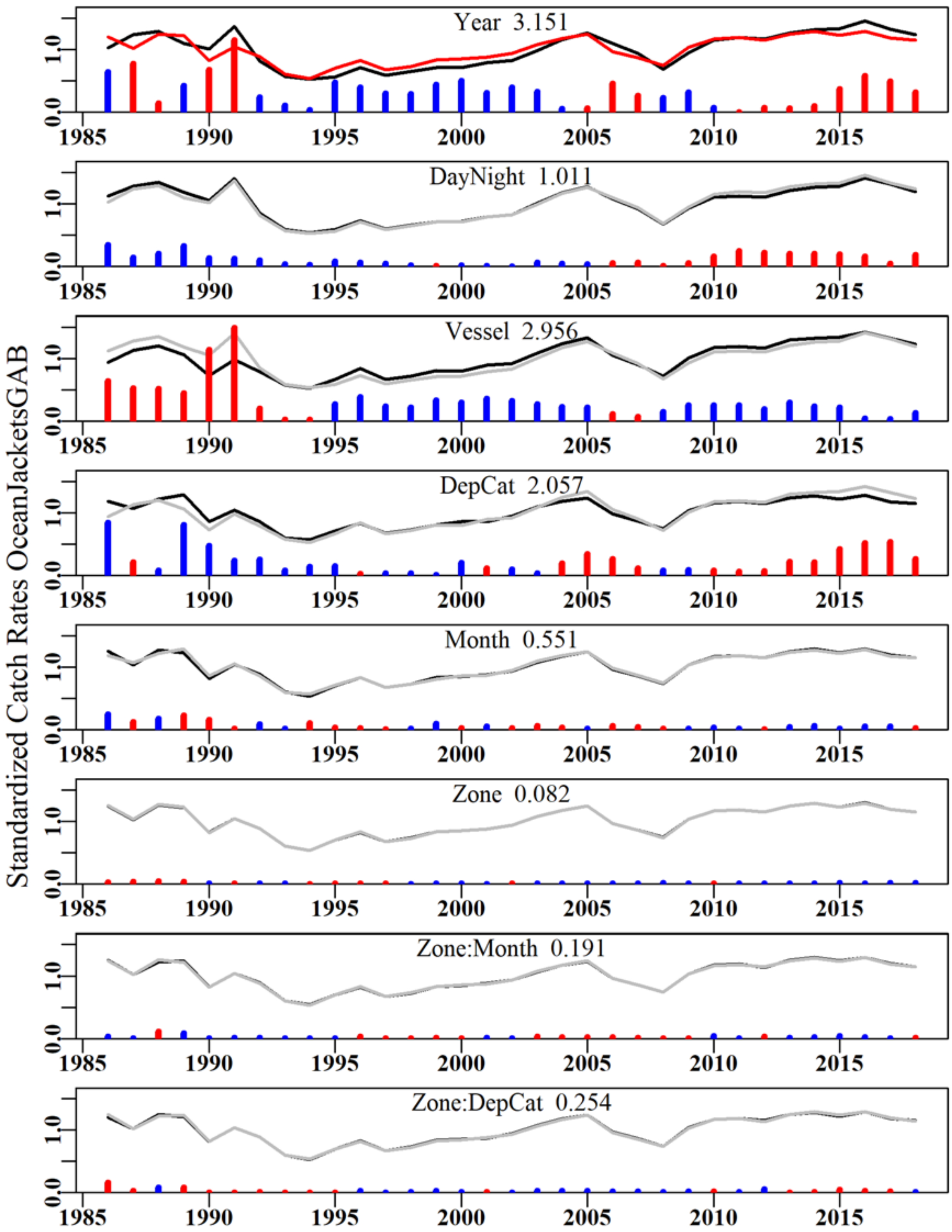

Figure 5.175. OceanJacketsGAB. The influence of each factor on the optimal standardization. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by vertical bars with blue bars indicating the optimum model is higher than the 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.

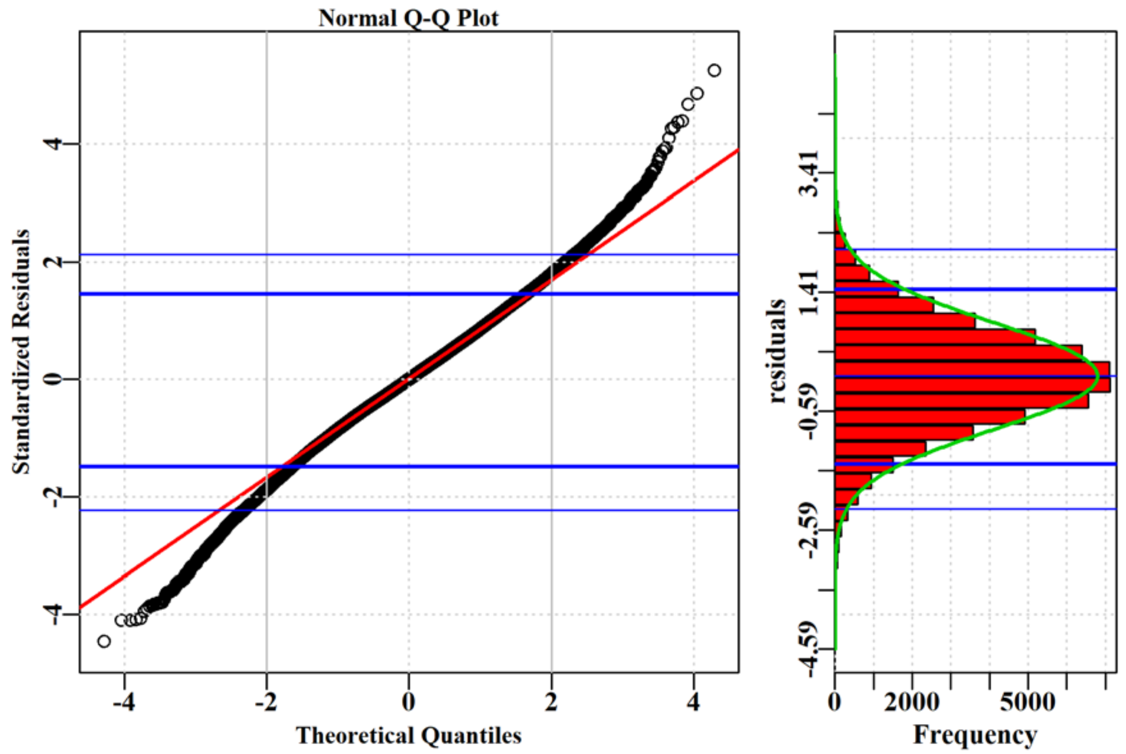

Figure 5.176. OceanJacketsGAB. diagnostic plots. The distribution of residuals from the optimum fit. The qqplot indicates the fit to the expected normality, while the histogram of residuals illustrates the 90% quantiles to indicate the intensity of any lack of fit at the margins of the distribution.

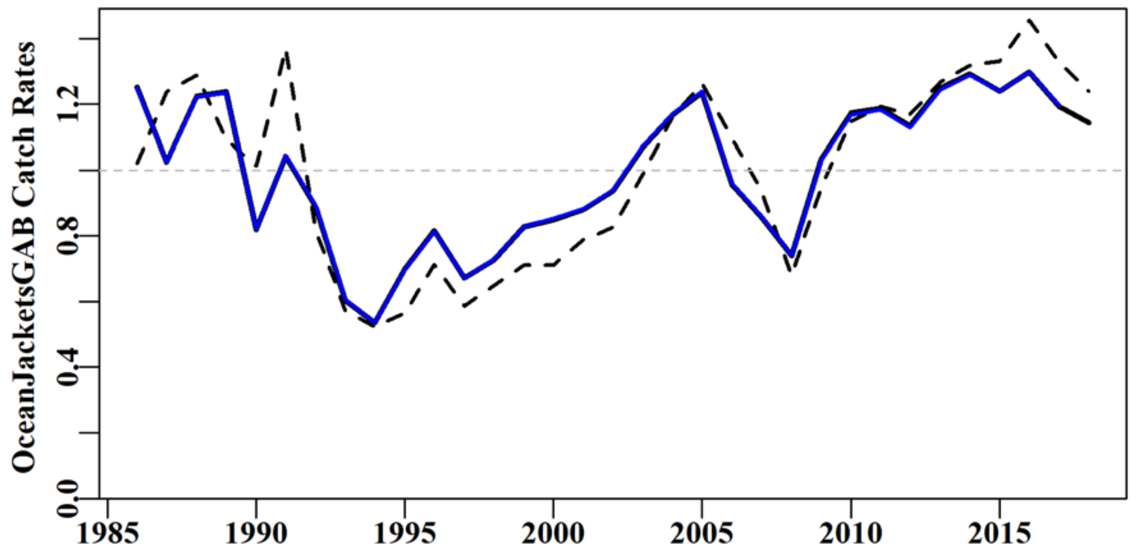

Figure 5.177. OceanJacketsGAB. A comparison of the previous year's standardization (blue line) with this year's. They should lie on top of each other, although small deviations may relate to data adjustments, particularly in very recent years.

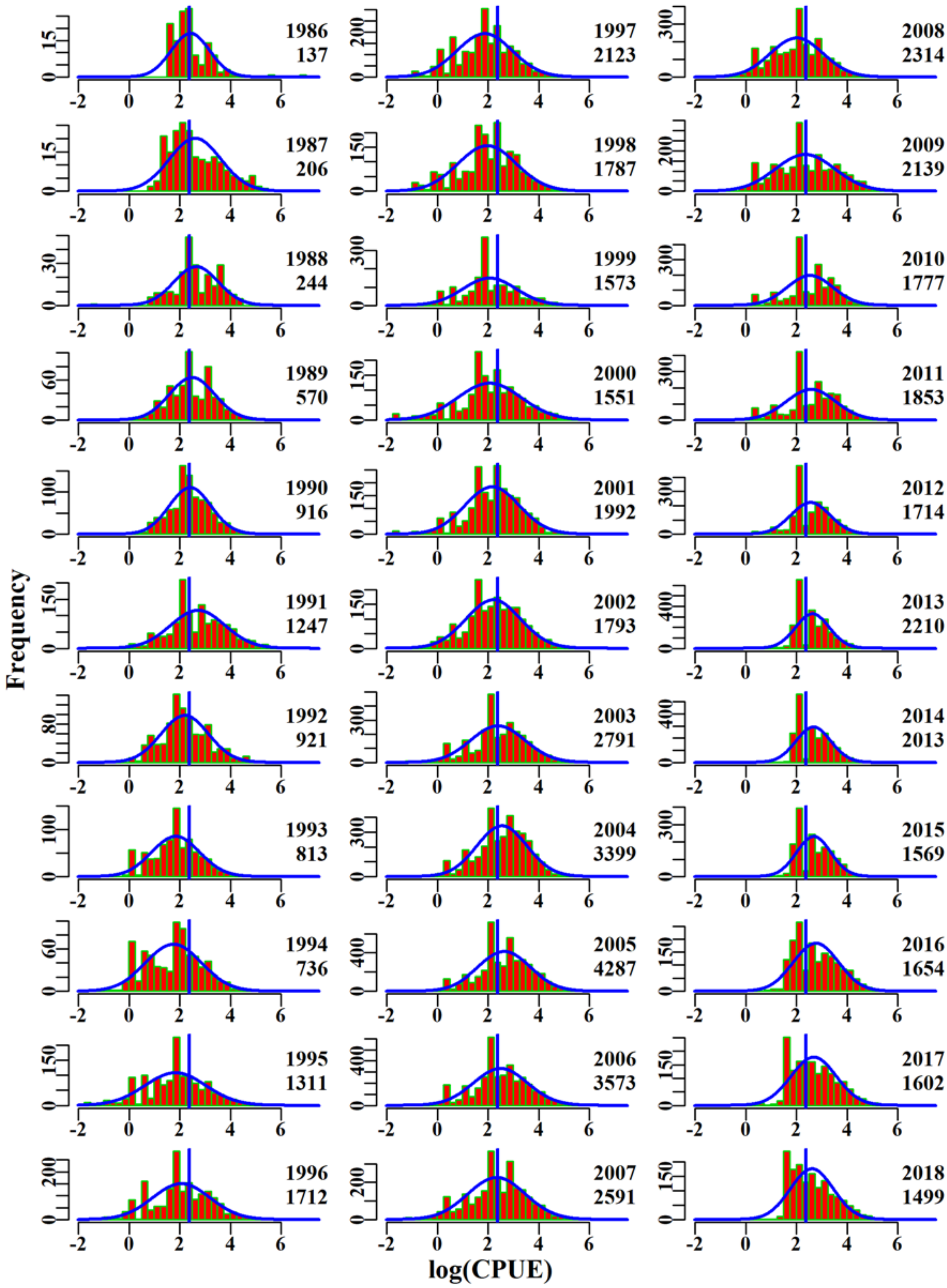

Figure 5.178. OceanJacketsGAB. The natural log(CPUE) for each year of data available the blue lines are normal distributions fitted to the histogram frequencies. The numbers in each plot are the year and number of records.

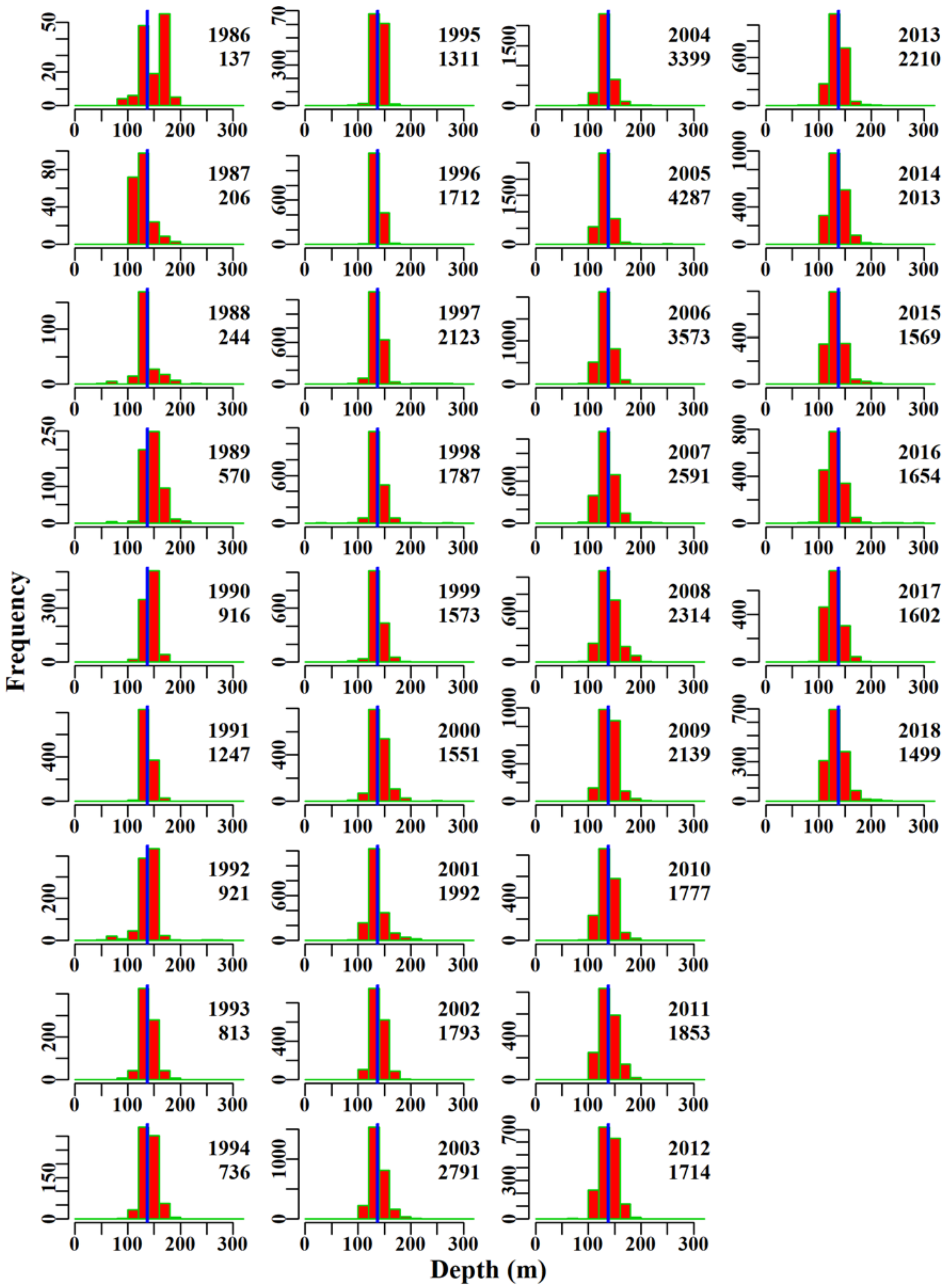

Figure 5.179. OceanJacketsGAB. The average Depth of fishing for each year of data available to illustrate the development of the fishery through time. The numbers in each plot are the year and number of records.

5.30 Western Gemfish 4050

For Western Gemfish (GEM– 37439002 – *Rexea solandri*) in zones 40 and 50, initial data selection was conducted according to the details given in Table 5.126.

A total of 8 statistical models were fitted sequentially to the available data, with the order of the non-interaction terms added based on the relative contribution of each term to model fit.

5.30.1 *Inferences*

The majority of catch of this species occurred in zone 50 with minimal catches in zone 50.

The terms Year, DepCat, DayNight and Vessel had the greatest contribution to model fit, with the remaining terms each explaining < 1% of the overall variation in CPUE, based on the AIC and R^2 statistics (Table 5.130). The qqplot suggests a small departure from that the assumed Normal distribution as depicted by the upper tail of the distribution (Figure 5.183).

Annual standardized CPUE are noisy and flat since 1992 and consistently mostly below average since 2001 (Figure 5.180).

5.30.2 *Action Items and Issues*

No issues identified.

Table 5.126. gemfish4050. The data selection criteria used to specify and identify the fishery data to be included in the analysis.

Property	Value
label	gemfish4050
csirocode	37439002, 91439002, 92439002
fishery	SET
depthrange	100 - 700
depthclass	50
zones	40, 50
methods	TW, TDO, OTT
years	1986 - 2018

Table 5.127. gemfish4050. Total catch (Total; t) is the total reported in the database, number of records used in the analysis (N), reported catch (Catch; t) in the area and depth used in the analysis and number of vessels used in the analysis (Vess). GeoM is the geometric mean of catch rates (kg/hr), standard deviation (StDev) relates to the optimum model. C<30Kg denotes the amount of catch in shots of <30kg, and %<30Kg is the percent of total. The optimum model was Zone:Month.

	Total	N	Catch	Vess	GeoM	Opt	StDev	C<30Kg	P<30Kg
1986	307.7	1681	306.8	24	63.5	2.4427	0.000	5.837	0.019
1987	250.2	1210	248.2	26	68.3	2.3155	0.045	4.464	0.018
1988	223.4	1204	220.5	27	63.1	2.3204	0.047	6.723	0.030
1989	156.7	1076	156.6	28	50.0	1.9460	0.049	6.139	0.039
1990	135.2	1023	134.4	24	44.1	1.4876	0.053	8.274	0.062
1991	268.5	1353	247.4	25	57.4	1.4602	0.050	7.115	0.029
1992	89.7	661	80.7	15	43.1	0.9958	0.058	4.224	0.052
1993	101.8	711	101.4	16	40.0	0.9683	0.057	5.646	0.056
1994	96.0	825	95.0	18	33.5	1.0384	0.054	5.739	0.060
1995	84.0	961	83.9	21	29.1	0.9167	0.053	8.373	0.100
1996	142.9	1130	142.5	26	44.2	0.9758	0.050	9.811	0.069
1997	152.9	1373	152.3	21	42.6	0.8673	0.048	11.465	0.075
1998	122.4	1255	121.9	20	40.2	0.9285	0.050	10.284	0.084
1999	176.9	1685	175.5	18	37.2	0.8761	0.047	14.406	0.082
2000	231.9	1904	229.0	28	57.3	0.9572	0.047	14.844	0.065
2001	168.5	1668	168.2	26	45.0	0.7616	0.048	13.752	0.082
2002	85.9	1395	85.1	23	19.9	0.5752	0.049	13.043	0.153
2003	122.7	1045	121.5	23	41.0	0.6652	0.052	7.667	0.063
2004	107.1	1212	105.2	22	25.4	0.6301	0.052	8.132	0.077
2005	116.1	1053	114.1	18	32.9	0.6586	0.053	5.770	0.051
2006	104.7	882	101.6	17	25.5	0.5372	0.056	4.491	0.044
2007	60.0	688	57.2	14	20.1	0.5067	0.059	3.687	0.064
2008	55.4	747	52.8	13	14.9	0.5958	0.058	4.709	0.089
2009	60.0	926	56.2	12	12.9	0.6556	0.055	6.100	0.108
2010	90.1	1364	86.1	14	12.9	0.7113	0.051	8.024	0.093
2011	55.2	1063	53.5	12	10.1	0.7109	0.053	6.881	0.129
2012	49.6	710	46.4	13	13.6	0.6719	0.059	4.037	0.087
2013	42.2	571	37.8	14	13.2	0.5966	0.062	3.080	0.081
2014	70.5	669	68.9	14	25.2	0.8295	0.060	2.098	0.030
2015	48.7	653	46.2	12	17.2	0.6889	0.061	2.041	0.044
2016	53.3	658	50.6	13	17.8	0.7837	0.060	2.161	0.043
2017	82.9	853	81.5	10	20.3	1.0686	0.059	1.039	0.013
2018	44.3	623	43.9	10	12.8	0.8561	0.063	1.084	0.025

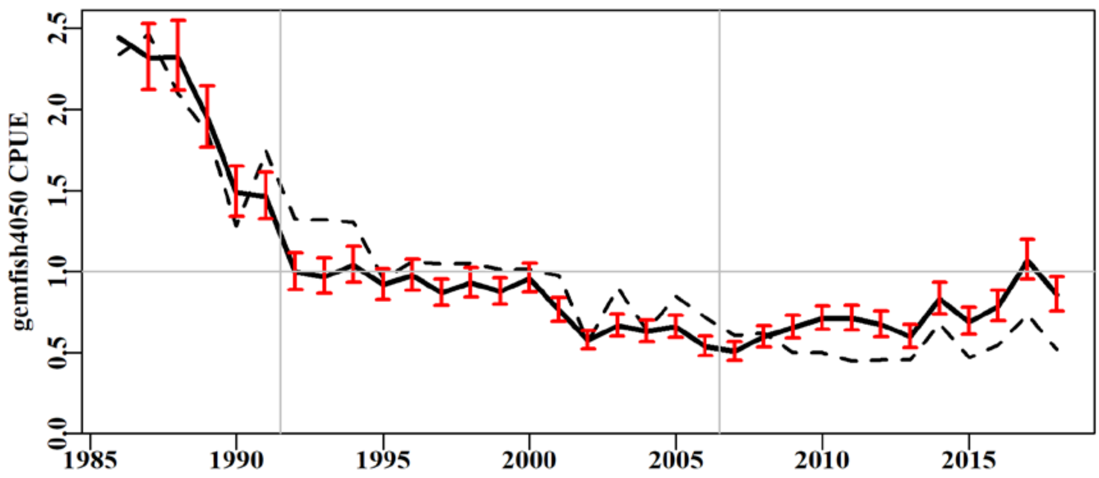

Figure 5.180. gemfish4050 standardization. The dashed black line represents the geometric mean catch rate, solid black line the standardized catch rates. The red bars are the 95% confidence intervals about the mean estimates. The graph scales both time-series of standardized catch rates relative to the mean of each time-series.

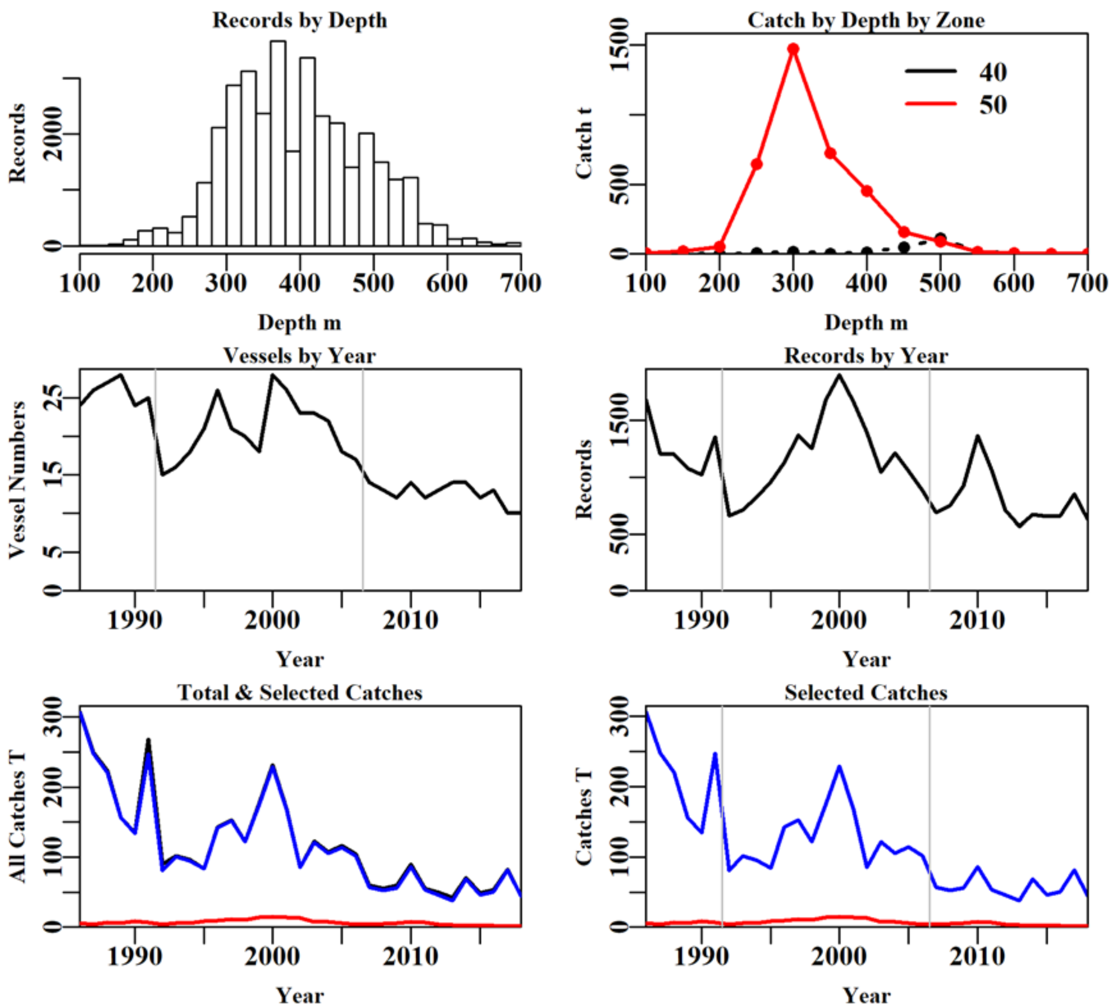

Figure 5.181. gemfish4050 fishery details. The bottom left plot depicts all known catches (top black line), and all selected catches used in the analysis (middle blue line); the lower red line: selected catches < 30 kg).

Table 5.128. gemfish4050 data selection effects. Total is the total number of records in the database, NoCE removes those records with either missing catch or effort, and then only those records are kept that meet the criteria for depth, years, zone, method and fishery.

	Total	NoCE	Depth	Years	Zones	Method	Fishery
Records	38055	36357	36026	35163	35163	34875	34832
Difference	0	1698	331	863	0	288	43
Catch	4123.65	4084.91	4064.59	3898.36	3898.36	3874.75	3873.17
Difference	0	38.74	20.33	166.23	0	23.61	1.59

Table 5.129. The models used to analyse data for gemfish4050.

	Model
Model1	Year
Model2	Year + DepCat
Model3	Year + DepCat + Vessel
Model4	Year + DepCat + Vessel + Zone
Model5	Year + DepCat + Vessel + Zone + DayNight
Model6	Year + DepCat + Vessel + Zone + DayNight + Month
Model7	Year + DepCat + Vessel + Zone + DayNight + Month + Zone:Month
Model8	Year + DepCat + Vessel + Zone + DayNight + Month + Zone:DepCat

Table 5.130. gemfish4050. The row names are 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_r2) and the change in adjusted R^2 (%Change). The optimum model was Zone:Month.

	AIC	RSS	MSS	Nobs	Npars	adj_r2	%Change
Year	23340	67946	8654	34832	33	11.2	0.00
DepCat	14254	52310	24290	34832	45	31.6	20.41
Vessel	8799	44493	32107	34832	136	41.7	10.07
Zone	8699	44364	32236	34832	137	41.9	0.17
DayNight	8054	43542	33058	34832	140	42.9	1.07
Month	7687	43058	33542	34832	151	43.5	0.62
Zone:Month	7384	42659	33941	34832	162	44.1	0.51
Zone:DepCat	7594	42916	33684	34832	162	43.7	0.17

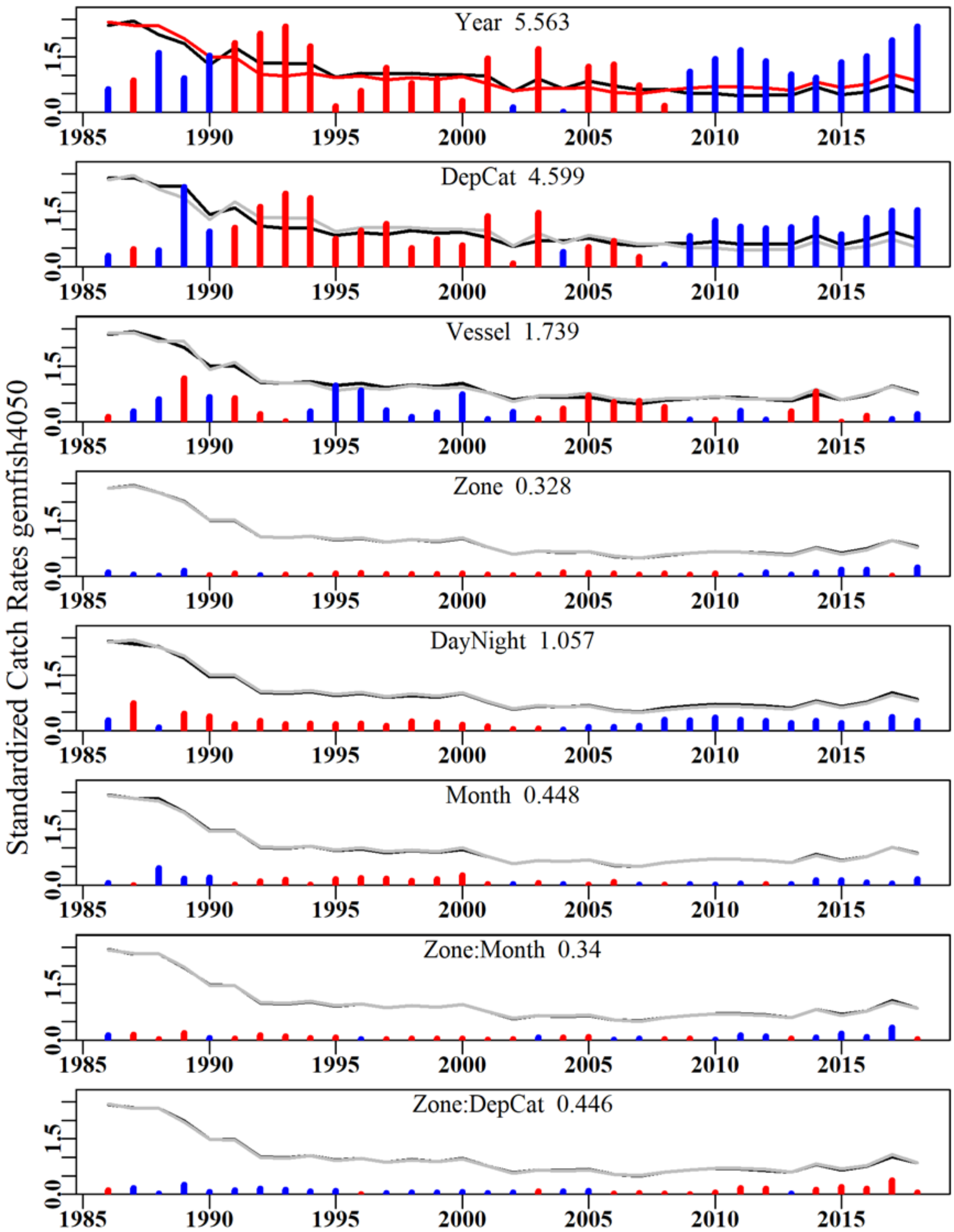

Figure 5.182. gemfish4050. The influence of each factor on the optimal standardization. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by vertical bars with blue bars indicating the optimum model is higher than the geometric 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.

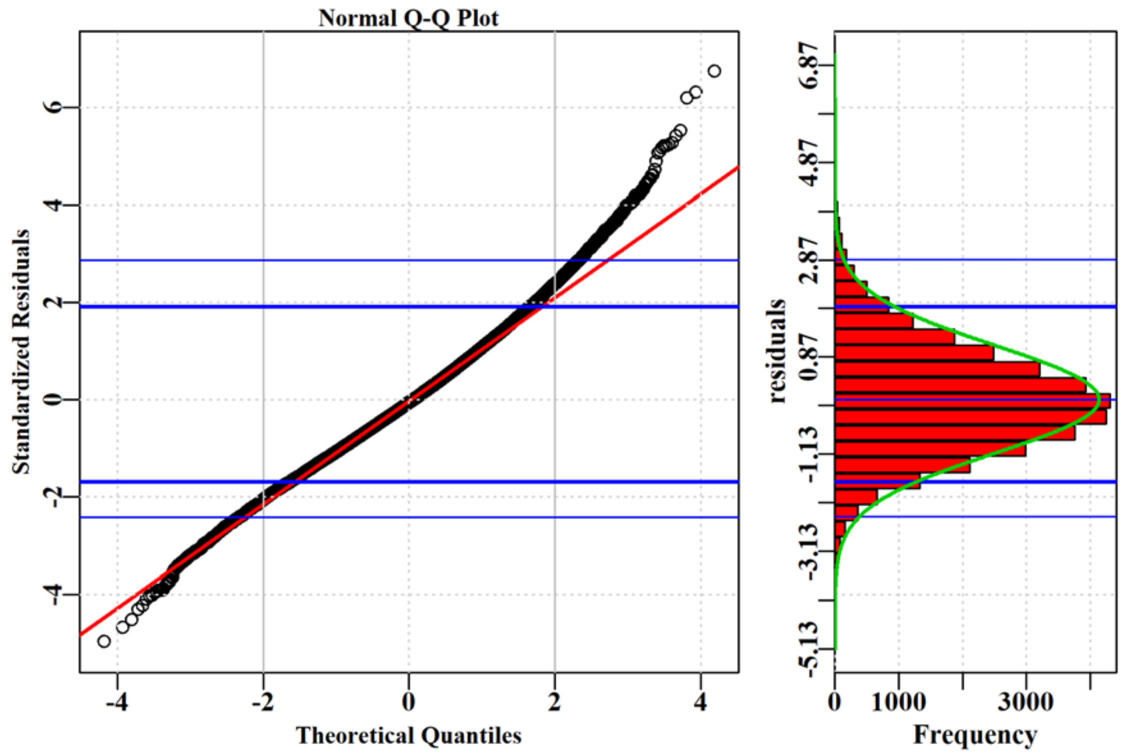

Figure 5.183. gemfish4050. diagnostic plots. The distribution of residuals from the optimum fit. The qqplot indicates the fit to the expected normality, while the histogram of residuals illustrates the 90% quantiles to indicate the intensity of any lack of fit at the margins of the distribution.

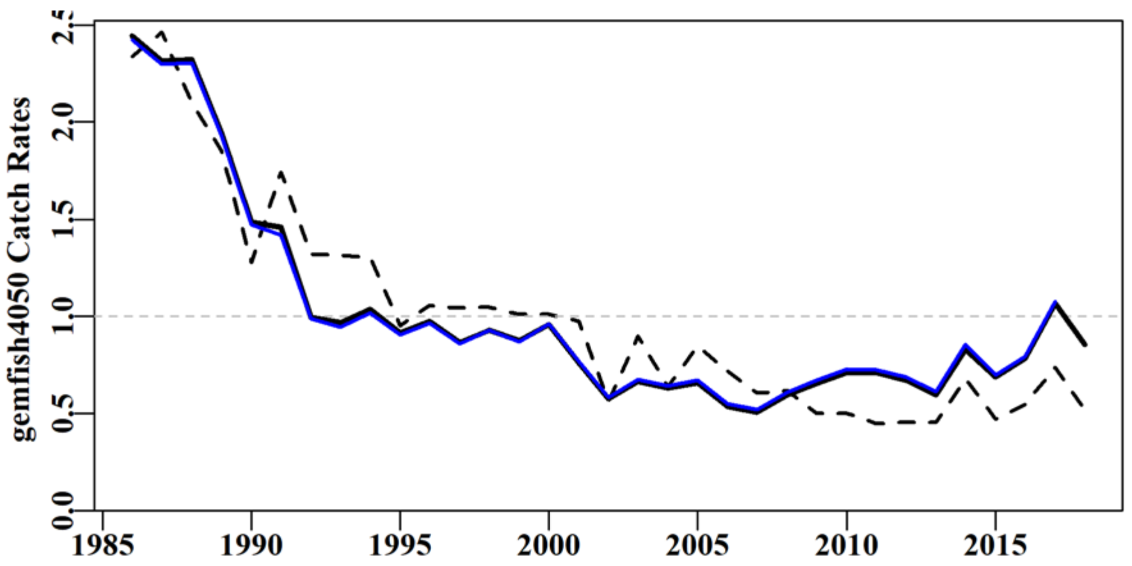

Figure 5.184. gemfish4050. A comparison of the previous year's standardization (blue line) with this year's. They should lie on top of each other, although small deviations may relate to data adjustments, particularly in very recent years.

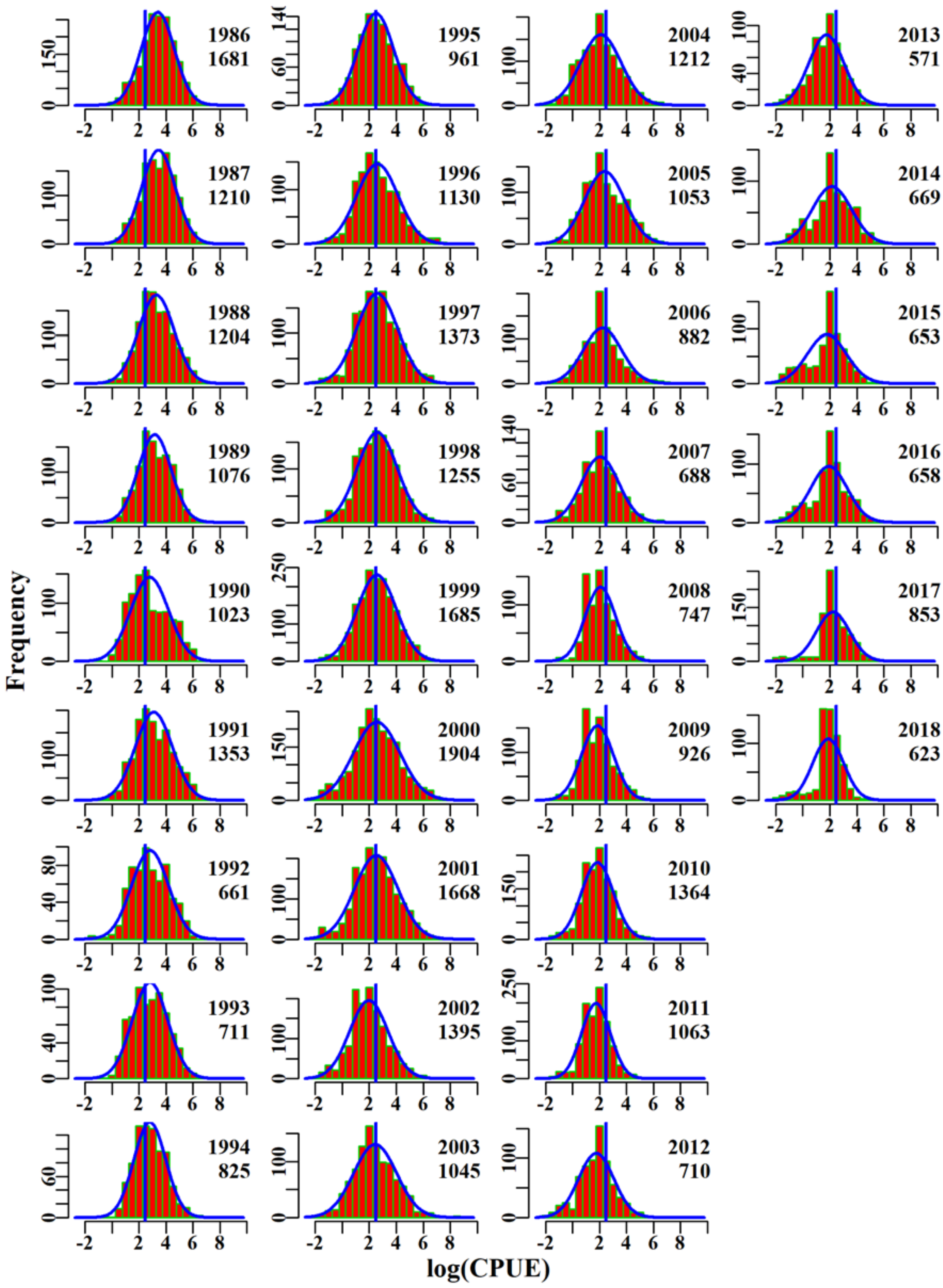

Figure 5.185. gemfish4050. The natural log(CPUE) for each year of data available the blue lines are normal distributions fitted to the histogram frequencies. The numbers in each plot are the year and number of records.

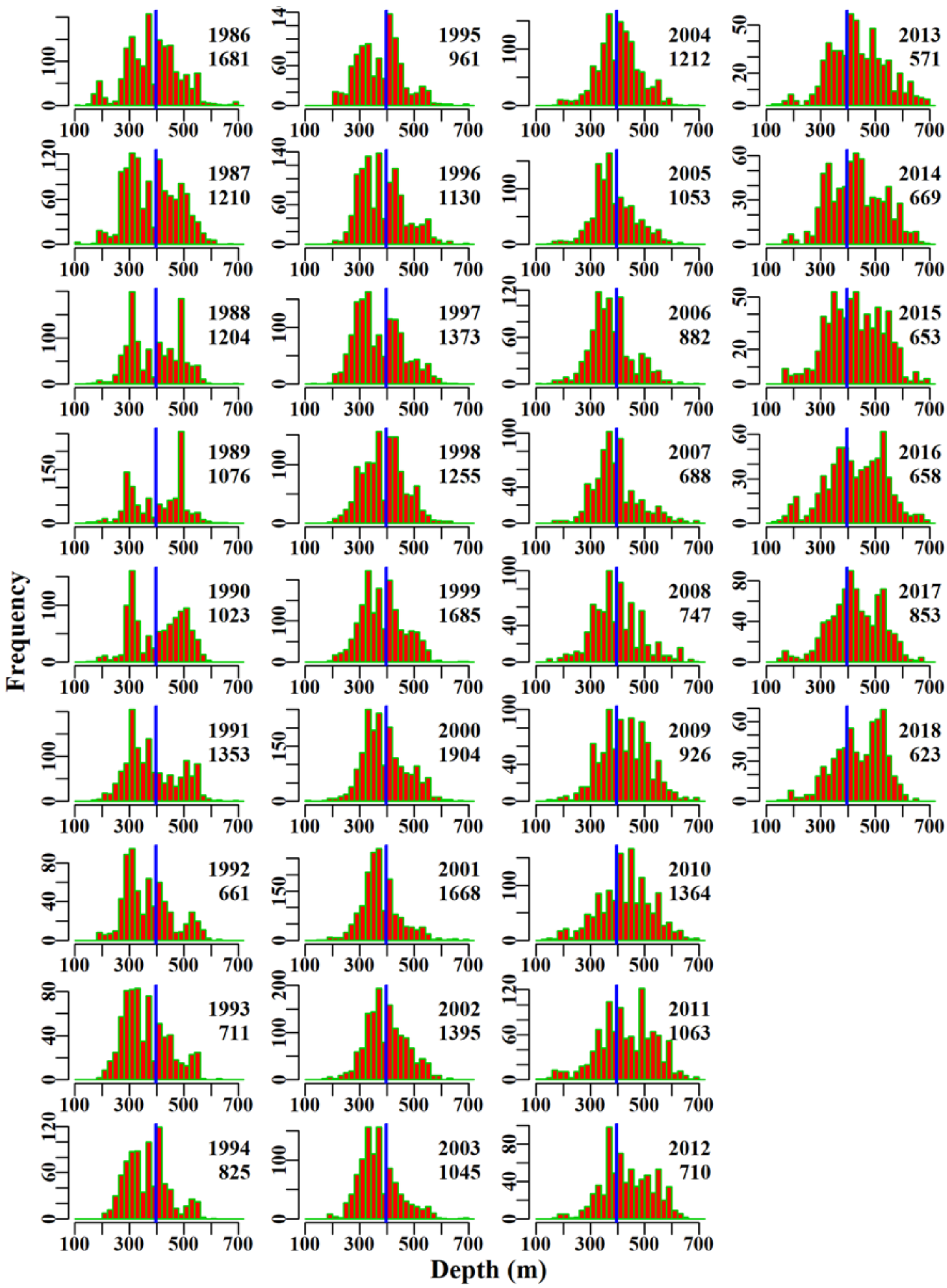

Figure 5.186. gemfish4050. The average Depth of fishing for each year of data available to illustrate the development of the fishery through time. The numbers in each plot are the year and number of records.

5.31 Western Gemfish 4050GAB

For Western Gemfish (GEM– 37439002 – *Rexea solandri*) in zones 40 and 50 and the GAB, initial data selection was conducted according to the details given in Table 5.131.

A total of 8 statistical models were fitted sequentially to the available data, with the order of the non-interaction terms added based on the relative contribution of each term to model fit.

5.31.1 Inferences

The majority of catch of this species occurred in zone 50 followed by zone 82 and minimal catches in the remaining zones.

The terms Year, DepCat, Vessel, Zone and DayNight had the greatest contribution to model fit, with the remaining terms each explaining < 1% of the overall variation in CPUE, based on the AIC and R^2 statistics (Table 5.135). The qqplot suggests the assumed Normal distribution is valid with a slight departure as depicted by the tails of the distribution (Figure 5.190).

Annual standardized CPUE have been consistenly below average and flat since 1999 (Figure 5.187). However, the CPUE from 1986 - 1994 is more representative of zone 50 than of the GAB. Given recent evidence that the stocks of Western Gemfish in the GAB and most of Zone 50 are different biological stocks it is doubtful that these data should be combined.

5.31.2 Action Items and Issues

This analysis is recommended to be abandoned as misleading through it combining the data from two biological stocks.

Table 5.131. gemfish4050GAB. The data selection criteria used to specify and identify the fishery data to be included in the analysis.

Property	Value
label	gemfish4050GAB
csirocode	37439002, 91439002, 92439002
fishery	SET_GAB
depthrange	100 - 650
depthclass	50
zones	40, 50, 82, 83, 84, 85
methods	TW, TDO, OTT
years	1986 - 2018

Table 5.132. gemfish4050GAB. Total catch (Total; t) is the total reported in the database, number of records used in the analysis (N), reported catch (Catch; t) in the area and depth used in the analysis and number of vessels used in the analysis (Vess). GeoM is the geometric mean of catch rates (kg/hr), standard deviation (StDev) relates to the optimum model. C<30Kg denotes the amount of catch in shots of <30kg, and %<30Kg is the percent of total. The optimum model was Zone:Month.

	Total	N	Catch	Vess	GeoM	Opt	StDev	C<30Kg	P<30Kg
1986	308.9	1700	306.5	25	62.3	2.3620	0.000	6.369	0.021
1987	263.8	1283	261.5	29	67.9	2.1967	0.046	5.264	0.020
1988	260.2	1399	254.9	36	63.3	2.0945	0.048	8.098	0.032
1989	185.3	1397	184.8	37	45.6	1.6286	0.049	8.774	0.047
1990	146.2	1231	145.2	35	38.5	1.4055	0.053	10.504	0.072
1991	300.0	1560	278.4	32	56.2	1.3806	0.050	8.992	0.032
1992	105.7	797	96.7	21	41.4	1.0220	0.057	5.404	0.056
1993	108.7	892	108.2	20	35.4	0.8578	0.056	7.358	0.068
1994	110.8	1037	109.8	24	33.3	0.8787	0.053	7.391	0.067
1995	106.9	1284	106.7	26	27.1	0.8575	0.051	11.458	0.107
1996	162.9	1576	161.7	32	30.7	0.9682	0.049	15.841	0.098
1997	214.8	2090	214.1	28	32.8	0.8618	0.047	19.333	0.090
1998	208.1	1964	207.2	26	35.9	1.0008	0.048	16.454	0.079
1999	323.9	2324	320.4	24	42.6	1.0060	0.047	17.891	0.056
2000	264.1	2330	261.2	32	52.9	0.8588	0.047	17.639	0.068
2001	259.9	2333	258.6	30	47.1	0.8008	0.047	17.391	0.067
2002	129.7	1748	128.5	28	20.4	0.6144	0.049	15.336	0.119
2003	207.5	1605	200.9	33	34.3	0.6700	0.050	11.011	0.055
2004	488.2	1942	480.3	30	48.1	0.7162	0.050	11.003	0.023
2005	389.6	1871	378.4	27	50.5	0.7217	0.050	8.591	0.023
2006	463.3	1614	437.1	26	56.6	0.6719	0.051	6.624	0.015
2007	426.7	1398	416.6	20	63.7	0.6084	0.052	5.950	0.014
2008	169.0	1237	155.7	18	19.5	0.6554	0.053	7.665	0.049
2009	113.5	1266	104.9	16	13.7	0.6816	0.052	8.242	0.079
2010	139.6	1700	128.4	18	12.7	0.7446	0.050	10.095	0.079
2011	87.3	1285	74.8	16	10.4	0.7566	0.052	8.266	0.110
2012	108.2	1044	102.1	18	16.4	0.8107	0.055	5.471	0.054
2013	55.9	707	47.2	20	13.2	0.6940	0.060	3.150	0.067
2014	97.7	838	89.1	17	24.5	0.9036	0.058	2.300	0.026
2015	57.0	716	50.2	14	16.5	0.7471	0.061	2.236	0.045
2016	55.8	678	51.2	15	17.2	0.8435	0.062	2.312	0.045
2017	86.0	933	83.7	13	18.8	1.0618	0.058	1.277	0.015
2018	46.9	699	46.2	13	11.9	0.9182	0.062	1.507	0.033

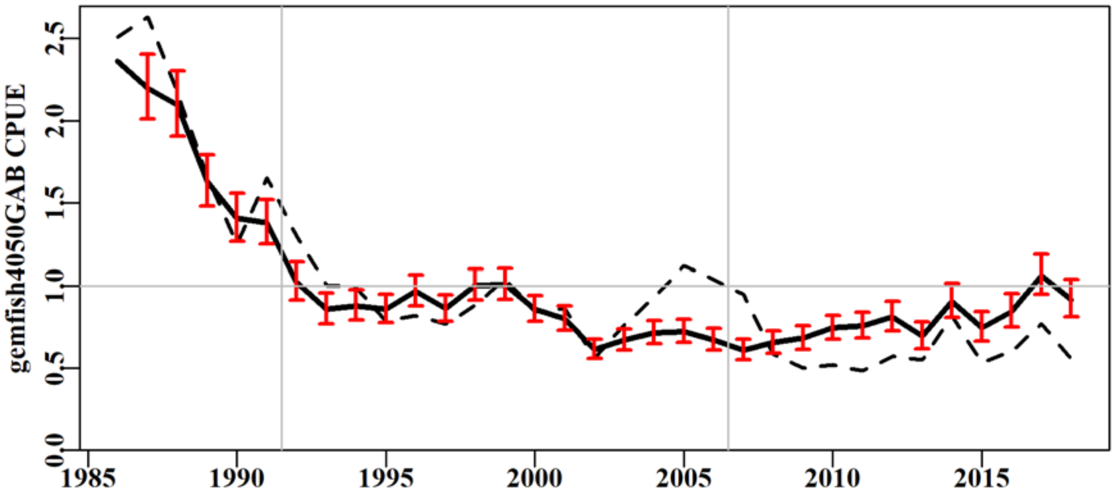

Figure 5.187. gemfish4050GAB standardization. The dashed black line represents the geometric mean catch rate, solid black line the standardized catch rates. The red bars are the 95% confidence intervals about the mean estimates. The graph scales both time-series of standardized catch rates relative to the mean of each time-series.

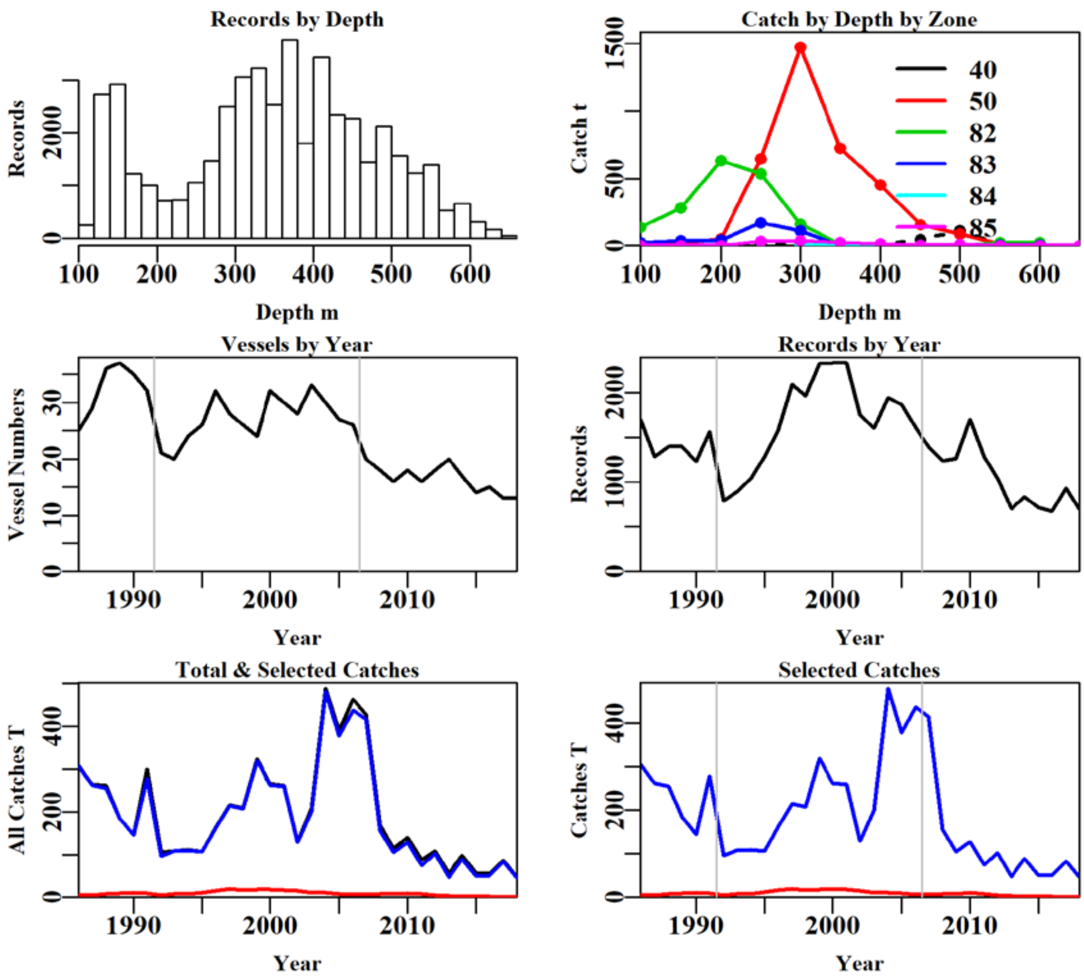

Figure 5.188. gemfish4050GAB fishery details. The bottom left plot depicts all known catches (top black line), and all selected catches used in the analysis (middle blue line); the lower red line: selected catches < 30 kg).

Table 5.133. gemfish4050GAB data selection effects. Total is the total number of records in the database, NoCE removes those records with either missing catch or effort, and then only those records are kept that meet the criteria for depth, years, zone, method and fishery.

	Total	NoCE	Depth	Years	Zones	Method	Fishery
Records	52873	51478	50526	49432	49432	46523	46478
Difference	0	1395	952	1094	0	2909	45
Catch	6659.96	6631.43	6568.78	6386.08	6386.08	6252.92	6251.18
Difference	0	28.53	62.65	182.71	0	133.16	1.74

Table 5.134. The models used to analyse data for gemfish4050GAB.

	Model
Model1	Year
Model2	Year + DepCat
Model3	Year + DepCat + Vessel
Model4	Year + DepCat + Vessel + Zone
Model5	Year + DepCat + Vessel + Zone + DayNight
Model6	Year + DepCat + Vessel + Zone + DayNight + Month
Model7	Year + DepCat + Vessel + Zone + DayNight + Month + Zone:Month
Model8	Year + DepCat + Vessel + Zone + DayNight + Month + Zone:DepCat

Table 5.135. gemfish4050GAB. The row names are 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_r2) and the change in adjusted R^2 (%Change). The optimum model was Zone:Month.

	AIC	RSS	MSS	Nobs	Npars	adj_r2	%Change
Year	38600	106492	8970	46478	33	7.7	0.00
DepCat	25005	79446	36016	46478	44	31.1	23.42
Vessel	16868	66366	49096	46478	156	42.3	11.20
Zone	16049	65194	50268	46478	161	43.3	1.01
DayNight	14974	63695	51767	46478	164	44.6	1.30
Month	14773	63389	52073	46478	175	44.9	0.25
Zone:Month	13704	61804	53658	46478	229	46.2	1.32
Zone:DepCat	14281	62582	52880	46478	227	45.5	0.64

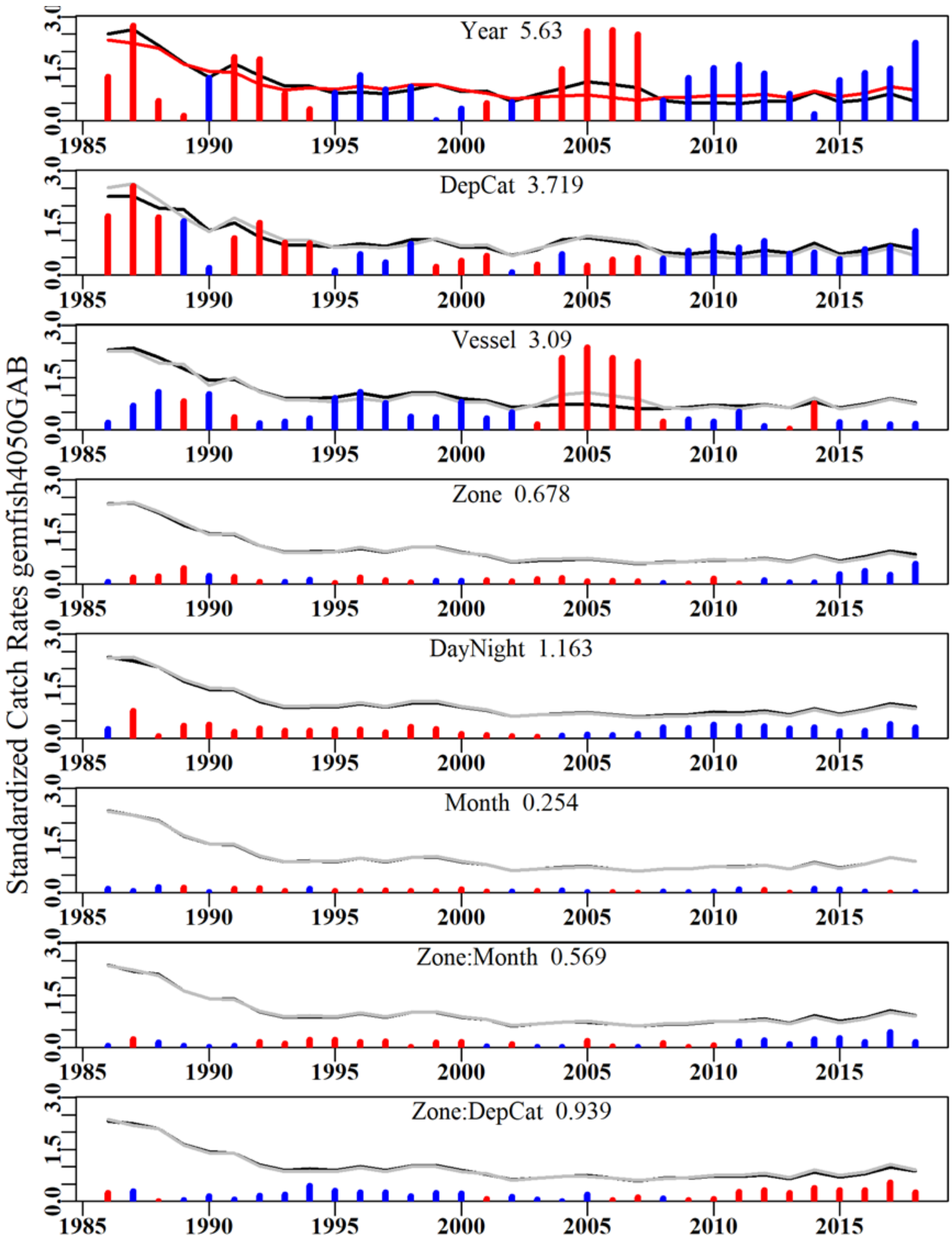

Figure 5.189. gemfish4050GAB. The influence of each factor on the optimal standardization. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by vertical bars with blue bars indicating the optimum model is higher than the 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.

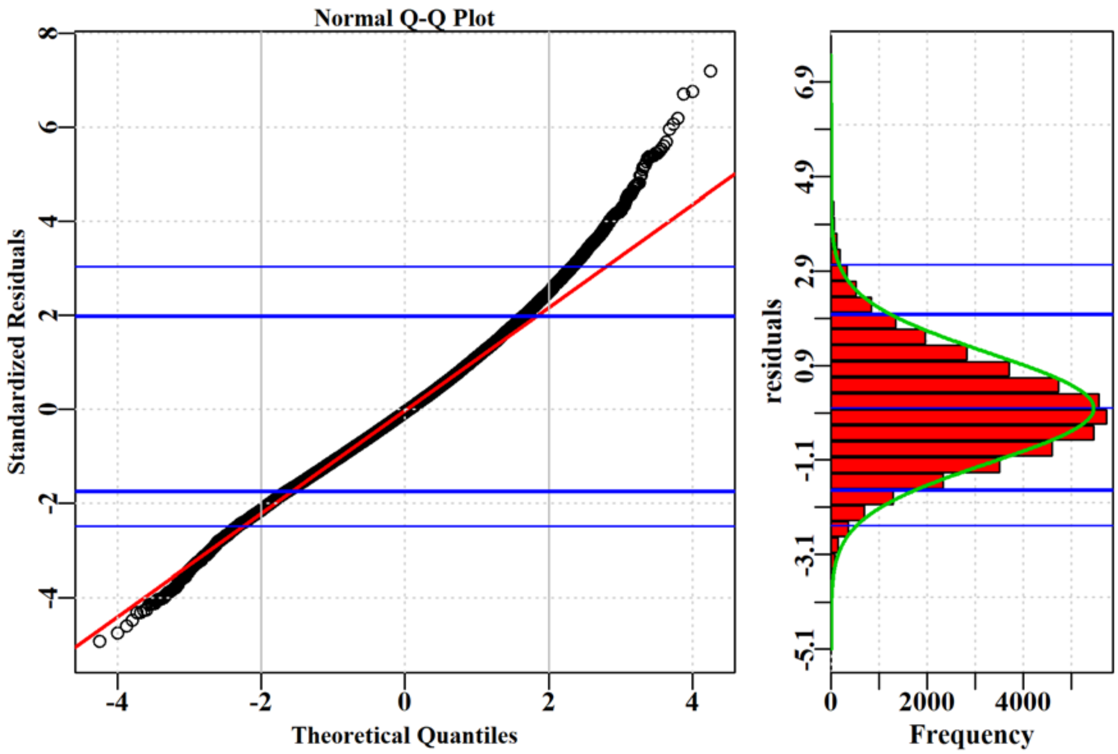

Figure 5.190. gemfish4050GAB. diagnostic plots. The distribution of residuals from the optimum fit. The qqplot indicates the fit to the expected normality, while the histogram of residuals illustrates the 90% quantiles to indicate the intensity of any lack of fit at the margins of the distribution.

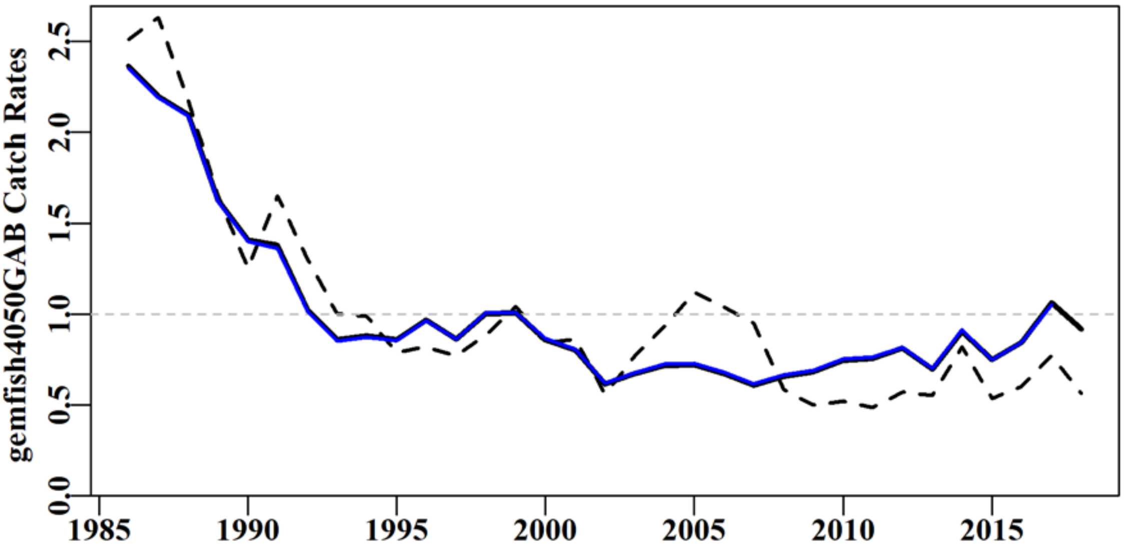

Figure 5.191. gemfish4050GAB. A comparison of the previous year's standardization (blue line) with this year's. They should lie on top of each other, although small deviations may relate to data adjustments, particularly in very recent years.

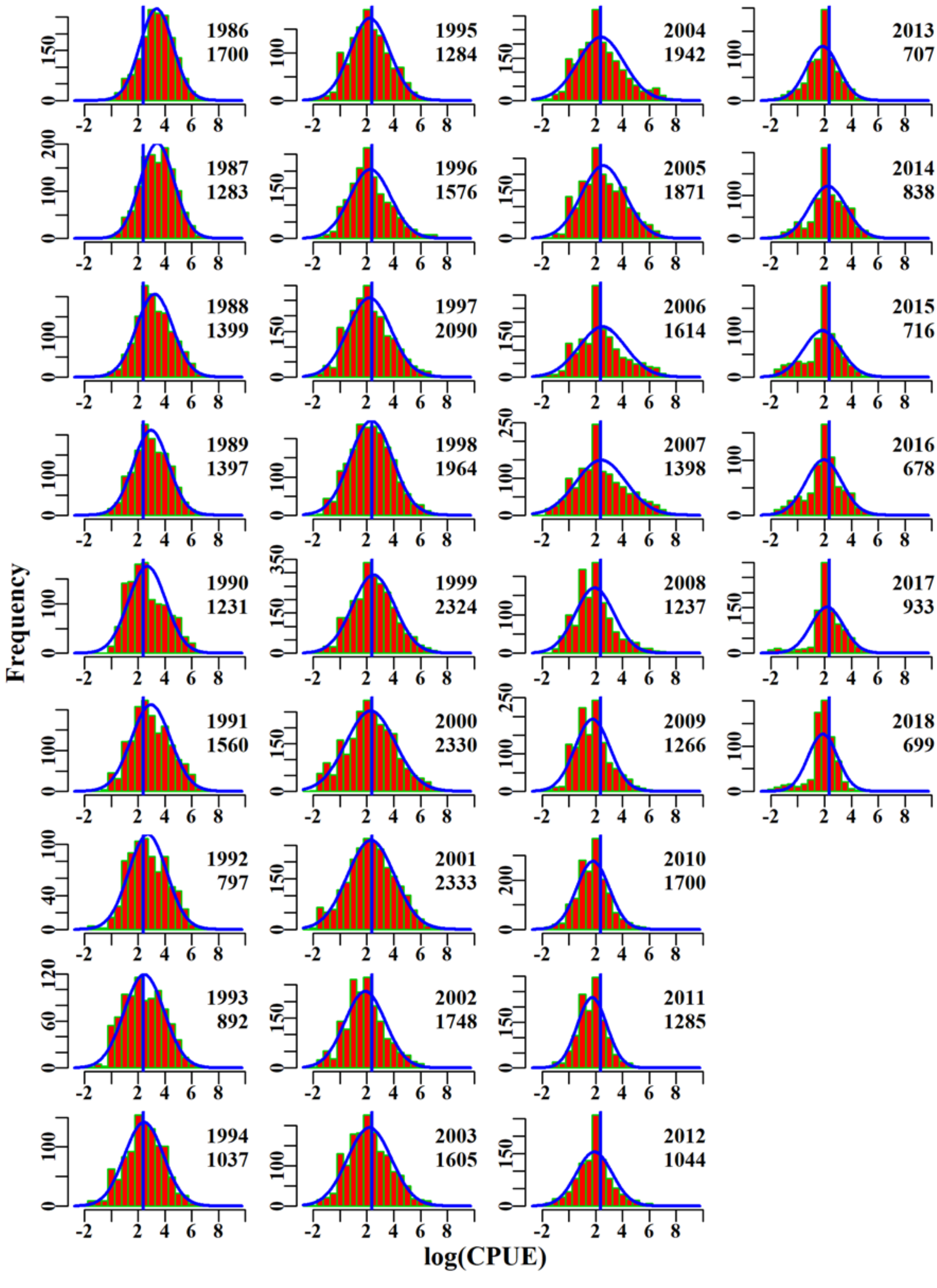

Figure 5.192. gemfish4050GAB. The natural log(CPUE) for each year of data available the blue lines are normal distributions fitted to the histogram frequencies. The numbers in each plot are the year and number of records.

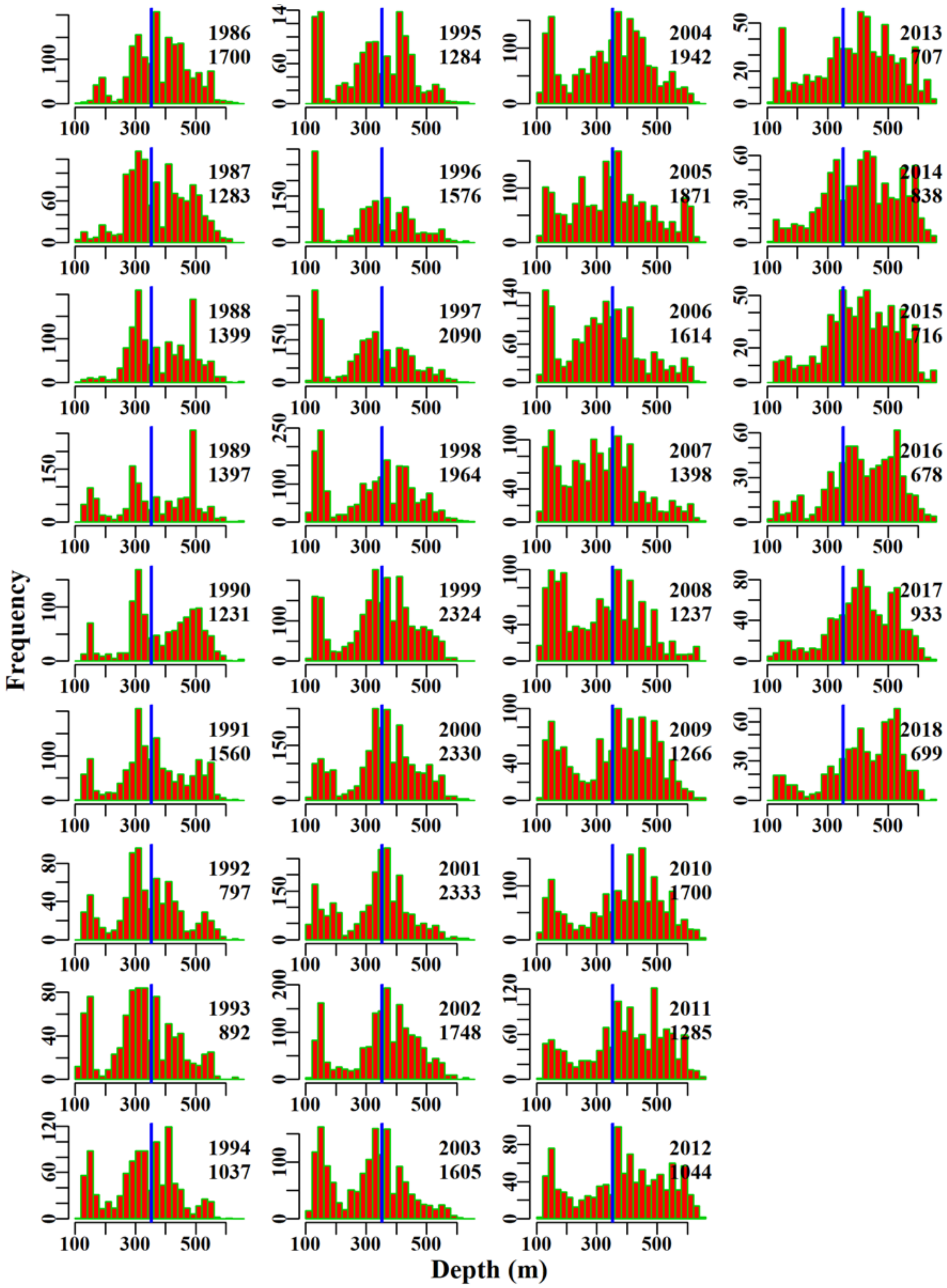

Figure 5.193. gemfish4050GAB. The average Depth of fishing for each year of data available to illustrate the development of the fishery through time. The numbers in each plot are the year and number of records.

5.32 Western Gemfish GAB

For Western Gemfish (GEM – 37439002 – *Rexea solandri*) in zones in the GAB, initial data selection was conducted according to the details given in Table 5.136.

A total of 8 statistical models were fitted sequentially to the available data, with the order of the non-interaction terms added based on the relative contribution of each term to model fit.

5.32.1 *Inferences*

The majority of catch of this species occurred in zone 82 followed by zone 83 with minimal catches in the remaining GAB zones. There was a small number of records (30) and corresponding catch (0.7 t) in 2016 across these zones. There were very high catches between 2004-2007.

The terms Year and Vessel had the greatest contribution to model fit, with the remaining terms each explaining < 1% of the overall variation in CPUE, based on the AIC and R^2 statistics (Table 5.140). The qqplot suggests a small departure from that the assumed Normal distribution as depicted by the upper tail of the distribution (Figure 5.197).

Annual standardized CPUE are noisy and flat across the years analysed (Figure 5.194), with the effect of the exceptional vessel being accounted for in the standardization.

5.32.2 *Action Items and Issues*

No issues identified.

Table 5.136. gemfishGAB. The data selection criteria used to specify and identify the fishery data to be included in the analysis.

Property	Value
label	gemfishGAB
csirocode	37439002, 91439002, 92439002
fishery	GAB
depthrange	100 - 650
depthclass	50
zones	82, 83, 84, 85
methods	TW, TDO, OTT
years	1995 - 2018

Table 5.137. gemfishGAB. Total catch (Total; t) is the total reported in the database, number of records used in the analysis (N), reported catch (Catch; t) in the area and depth used in the analysis and number of vessels used in the analysis (Vess). GeoM is the geometric mean of catch rates (kg/hr), standard deviation (StDev) relates to the optimum model. C<30Kg denotes the amount of catch in shots of <30kg, and %<30Kg is the percent of total. The optimum model was Zone:Month.

	Total	N	Catch	Vess	GeoM	Opt	StDev	C<30Kg	P<30Kg
1995	181.7	324	22.5	5	13.2	0.7268	0.000	3.093	0.138
1996	382.2	448	19.2	7	7.1	0.9328	0.093	6.034	0.314
1997	572.0	718	61.7	9	12.9	0.9232	0.089	7.883	0.128
1998	404.8	708	85.3	8	24.8	1.3914	0.090	6.170	0.072
1999	448.7	643	144.9	7	59.0	1.6880	0.093	3.520	0.024
2000	336.5	427	32.2	6	14.6	0.5900	0.098	2.800	0.087
2001	331.5	670	90.3	7	42.9	0.9904	0.092	3.634	0.040
2002	195.9	351	43.2	6	20.7	0.8785	0.102	2.283	0.053
2003	268.0	559	79.2	10	20.7	0.8337	0.097	3.308	0.042
2004	569.0	732	375.2	10	116.2	1.0997	0.097	2.901	0.008
2005	511.8	818	264.3	10	83.4	0.9802	0.097	2.821	0.011
2006	544.9	732	335.7	11	133.6	0.9424	0.097	2.133	0.006
2007	599.1	713	359.6	9	174.3	0.8204	0.095	2.271	0.006
2008	294.9	494	103.2	7	28.0	0.8531	0.097	2.975	0.029
2009	194.9	347	48.9	4	15.2	0.7853	0.104	2.161	0.044
2010	220.7	345	42.7	4	11.7	0.8234	0.104	2.100	0.049
2011	147.7	229	21.5	4	12.4	0.8763	0.115	1.421	0.066
2012	168.6	334	55.8	5	23.0	1.2652	0.107	1.435	0.026
2013	103.8	148	9.7	6	11.6	1.1770	0.132	0.154	0.016
2014	130.3	176	20.2	5	20.7	1.1918	0.133	0.246	0.012
2015	86.6	68	4.1	2	10.5	1.1208	0.173	0.206	0.050
2016	74.6	30	0.7	3	7.4	0.7791	0.245	0.196	0.273
2017	119.2	85	2.6	4	7.8	0.8036	0.160	0.312	0.120
2018	74.3	77	2.3	4	6.9	1.5272	0.167	0.423	0.184

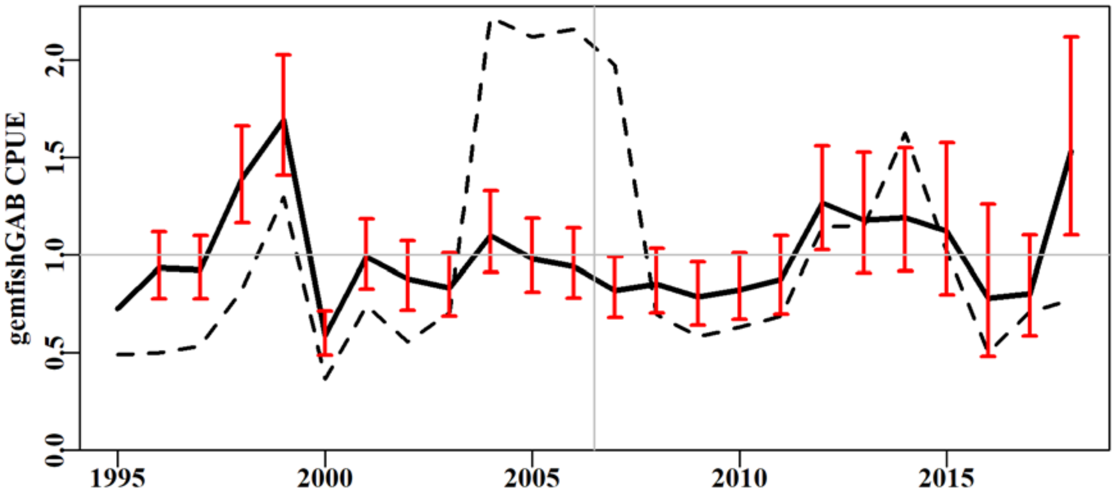

Figure 5.194. gemfishGAB standardization. The dashed black line represents the geometric mean catch rate, solid black line the standardized catch rates. The red bars are the 95% confidence intervals about the mean estimates. The graph scales both time-series of standardized catch rates relative to the mean of each time-series.

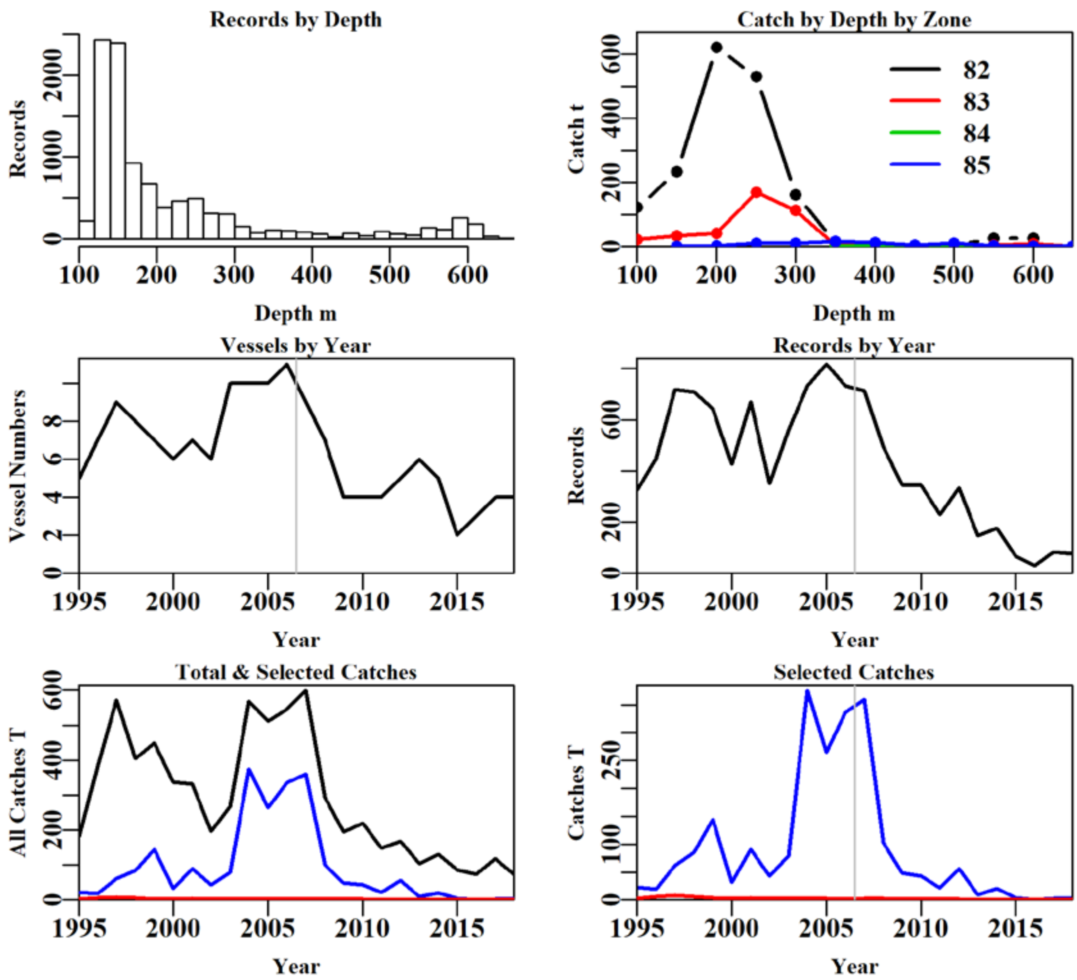

Figure 5.195. gemfishGAB fishery details. The bottom left plot depicts all known catches (top black line), and all selected catches used in the analysis (middle blue line); the lower red line: selected catches < 30 kg).

Table 5.138. gemfishGAB data selection effects. Total is the total number of records in the database, NoCE removes those records with either missing catch or effort, and then only those records are kept that meet the criteria for depth, years, zone, method and fishery.

	Total	NoCE	Depth	Years	Zones	Method	Fishery
Records	132969	125828	123421	84965	12039	10190	10176
Difference	0	7141	2407	38456	72926	1849	14
Catch	23739.13	23501.24	23270.90	6862.53	2314.71	2226.14	2225.12
Difference	0	237.88	230.34	16408.38	4547.82	88.56	1.02

Table 5.139. The models used to analyse data for gemfishGAB.

	Model
Model1	Year
Model2	Year + DepCat
Model3	Year + DepCat + Vessel
Model4	Year + DepCat + Vessel + Zone
Model5	Year + DepCat + Vessel + Zone + DayNight
Model6	Year + DepCat + Vessel + Zone + DayNight + Month
Model7	Year + DepCat + Vessel + Zone + DayNight + Month + Zone:Month
Model8	Year + DepCat + Vessel + Zone + DayNight + Month + Zone:DepCat

Table 5.140. gemfishGAB. The row names are 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_r2) and the change in adjusted R^2 (%Change). The optimum model was Zone:Month.

	AIC	RSS	MSS	Nobs	Npars	adj_r2	%Change
Year	11117	30198	3438	10176	24	10.0	0.00
DepCat	7436	20987	12649	10176	35	37.4	27.38
Vessel	5881	17932	15704	10176	58	46.4	8.99
Zone	5493	17250	16385	10176	61	48.4	2.02
DayNight	5122	16623	17012	10176	64	50.3	1.86
Month	4839	16133	17503	10176	75	51.7	1.41
Zone:Month	4547	15578	18058	10176	107	53.2	1.51
Zone:DepCat	4759	15921	17715	10176	102	52.2	0.51

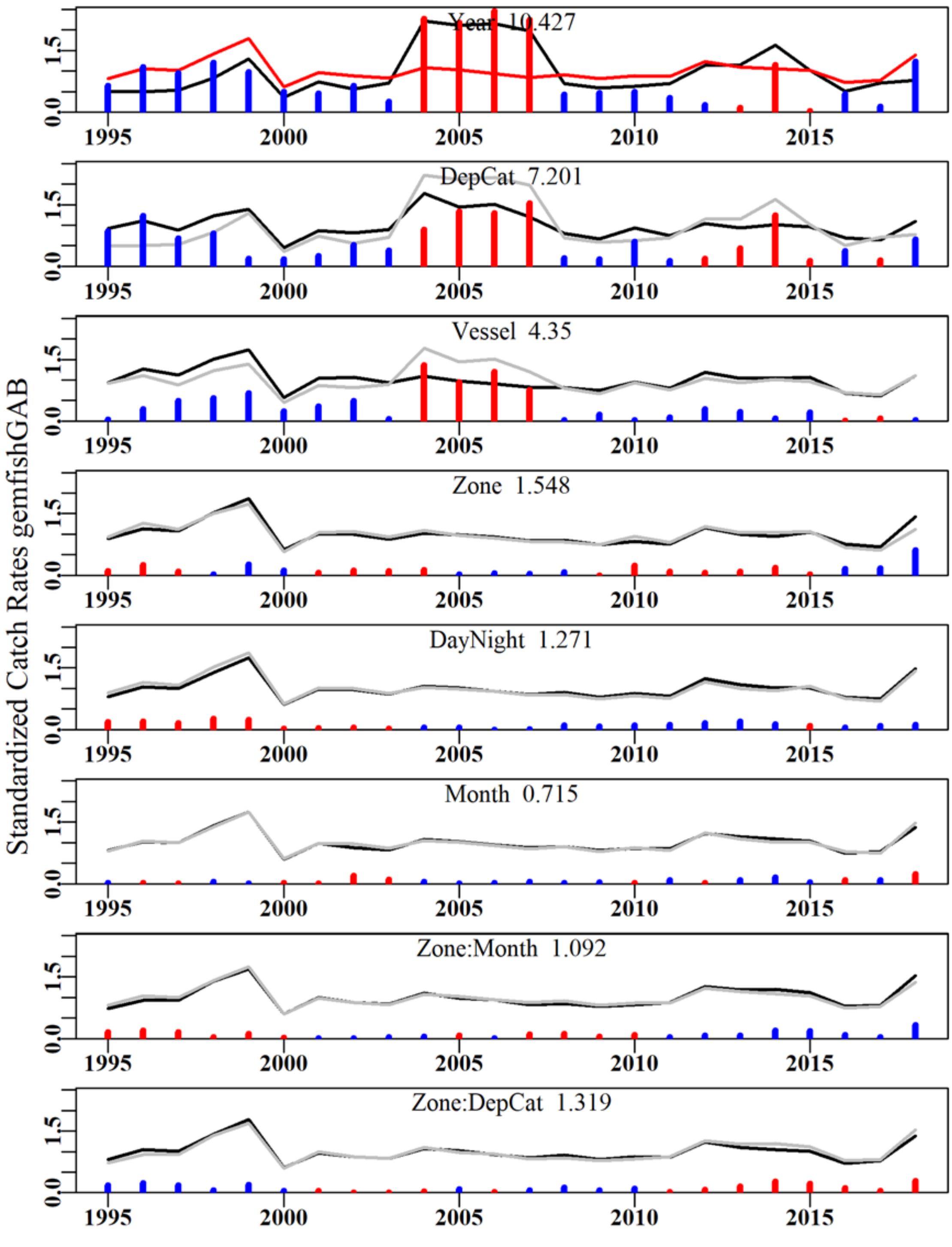

Figure 5.196. gemfishGAB. The influence of each factor on the optimal standardization. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by vertical bars with blue bars indicating the optimum model is higher than the geometric 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.

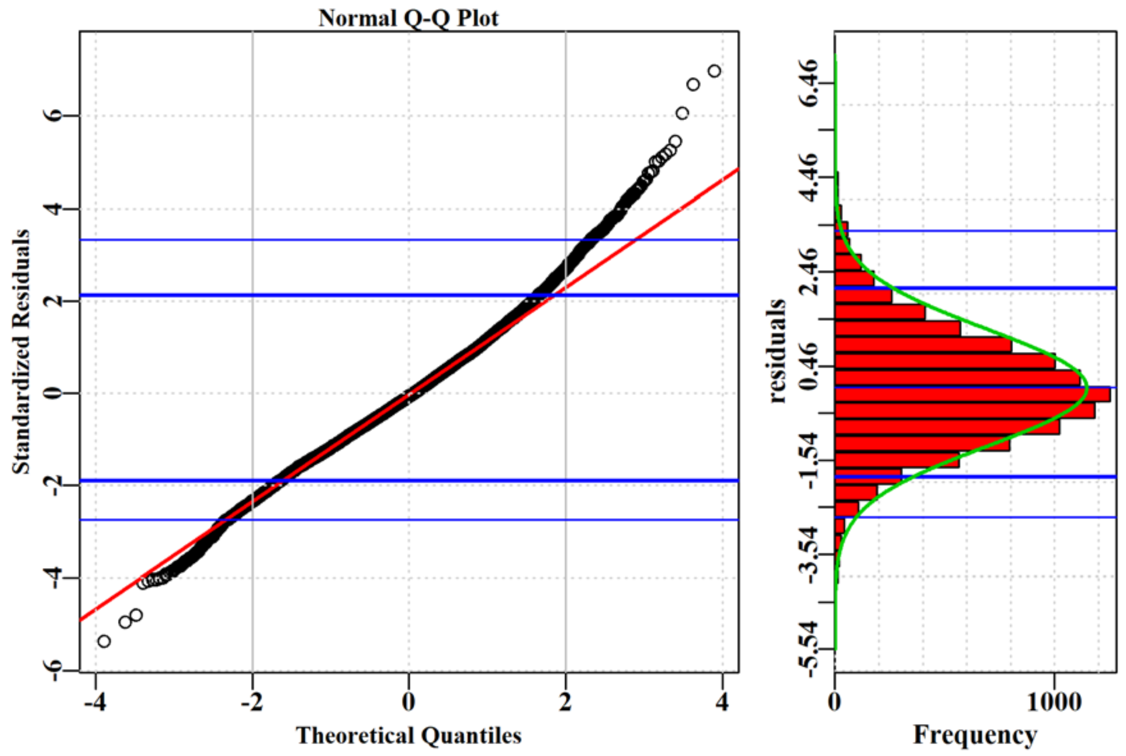

Figure 5.197. gemfishGAB. diagnostic plots. The distribution of residuals from the optimum fit. The qqplot indicates the fit to the expected normality, while the histogram of residuals illustrates the 90% quantiles to indicate the intensity of any lack of fit at the margins of the distribution.

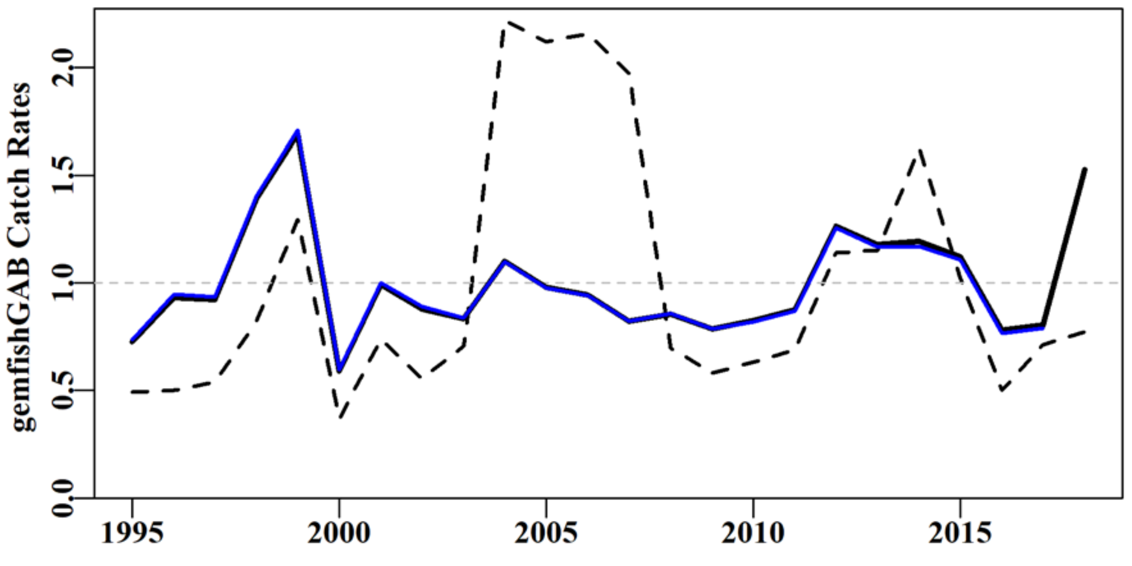

Figure 5.198. gemfishGAB. A comparison of the previous year's standardization (blue line) with this year's. They should lie on top of each other, although small deviations may relate to data adjustments, particularly in very recent years.

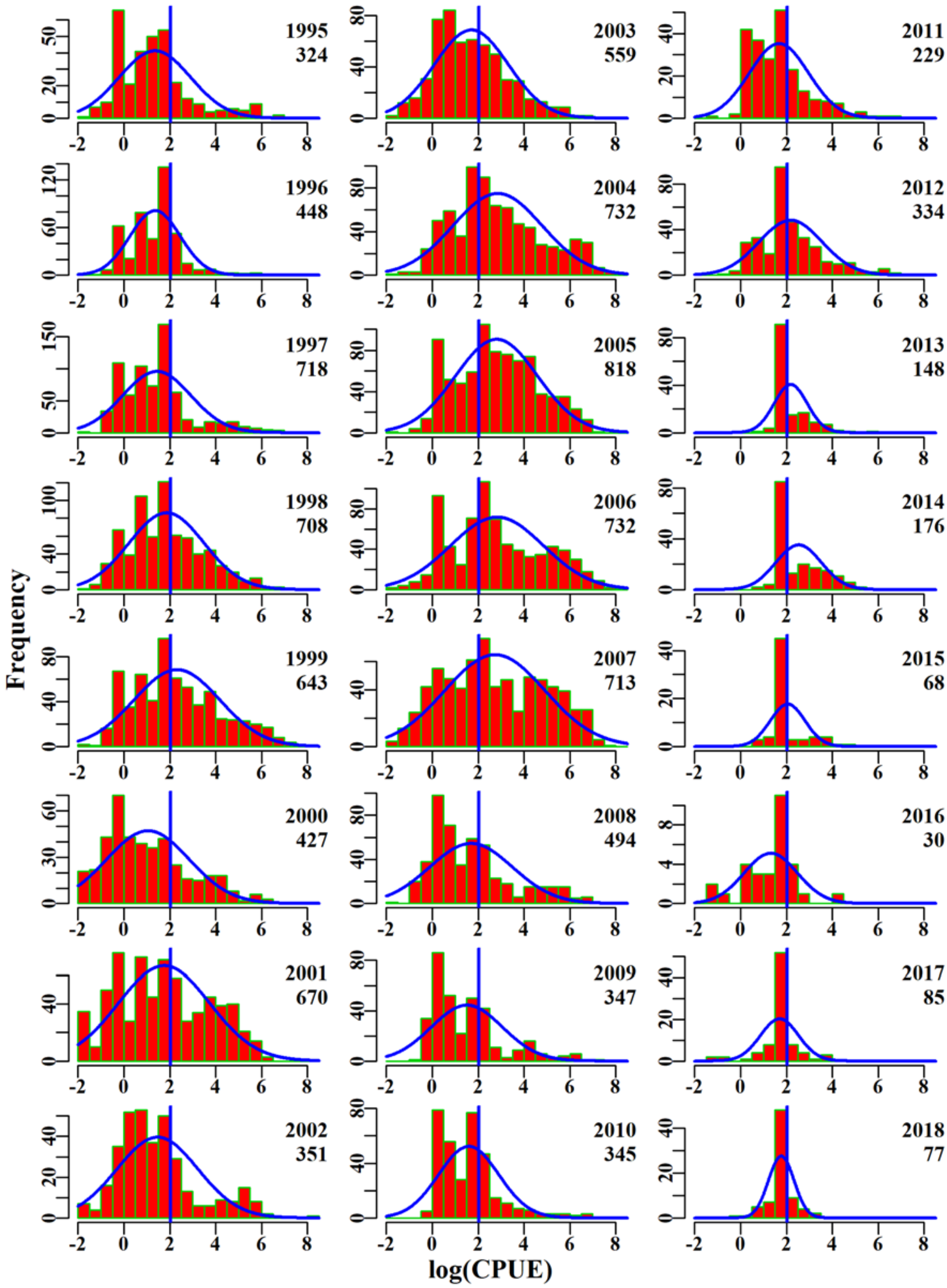

Figure 5.199. gemfishGAB. The natural log(CPUE) for each year of data available the blue lines are normal distributions fitted to the histogram frequencies. The numbers in each plot are the year and number of records.

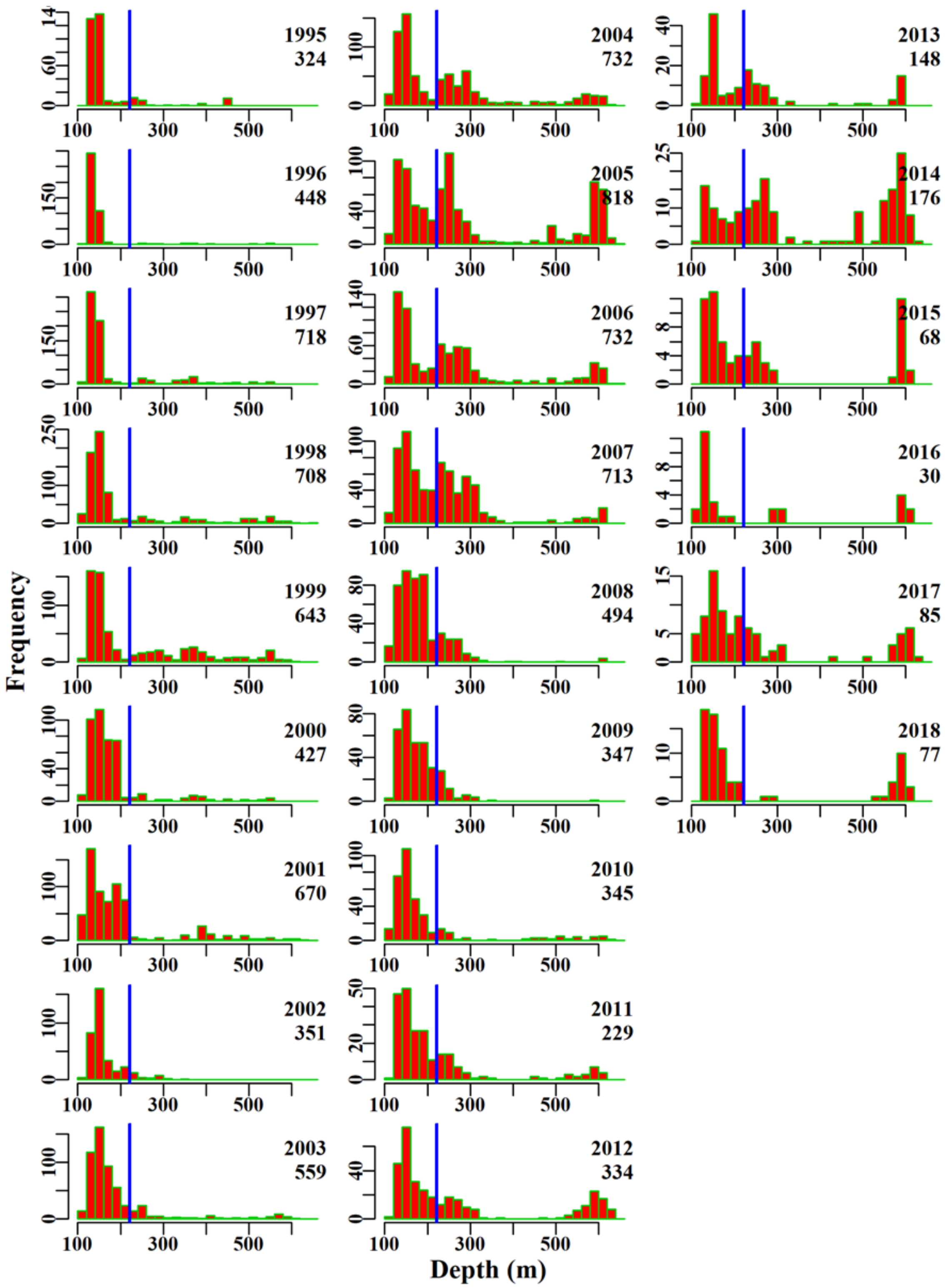

Figure 5.200. gemfishGAB. The average Depth of fishing for each year of data available to illustrate the development of the fishery through time. The numbers in each plot are the year and number of records.

5.33 Blue Warehou 10 – 30

For Blue Warehou (TRT – 37445005 – *Seriolella brama*) in zones 10 to 30, initial data selection was conducted according to the details given in Table 5.141.

A total of 8 statistical models were fitted sequentially to the available data, with the order of the non-interaction terms added based on the relative contribution of each term to model fit.

5.33.1 *Inferences*

The majority of catch of this species occurred in zone 20 followed by zones 30 and 10. Large catches continued from about 1988 - 1998 and have since dropped to trivial levels and have been below 10 t since 2011.

The terms Year and Vessel had the greatest contribution to model fit, with the remaining terms each explaining < 1% of the overall variation in CPUE, based on the AIC and R^2 statistics (Table 5.145). The qqplot suggests a that the assumed Normal distribution is valid as depicted with slight departures from the tails of the distribution (Figure 5.204).

Annual standardized CPUE trend is flat since 1992 and consistently below average since 1999 (Figure 5.201).

5.33.2 *Action Items and Issues*

No issues identified.

Table 5.141. bluewarehou1030. The data selection criteria used to specify and identify the fishery data to be included in the analysis.

Property	Value
label	bluewarehou1030
csirocode	37445005, 91445005, 92445005
fishery	SET
depthrange	0 - 400
depthclass	25
zones	10, 20, 30
methods	TW, TDO, OTT
years	1986 - 2018

Table 5.142. bluewarehou1030. Total catch (Total; t) is the total reported in the database, number of records used in the analysis (N), reported catch (Catch; t) in the area and depth used in the analysis and number of vessels used in the analysis (Vess). GeoM is the geometric mean of catch rates (kg/hr), standard deviation (StDev) relates to the optimum model. C<30Kg denotes the amount of catch in shots of <30kg, and %<30Kg is the percent of total. The optimum model was Zone:Month.

	Total	N	Catch	Vess	GeoM	Opt	StDev	C<30Kg	P<30Kg
1986	211.9	700	138.7	40	69.8	2.2334	0.000	3.563	0.026
1987	405.9	457	168.2	40	84.9	2.6790	0.105	2.506	0.015
1988	544.0	772	333.6	33	122.0	3.2946	0.095	3.566	0.011
1989	776.0	1172	654.9	41	180.8	4.3544	0.092	4.010	0.006
1990	881.4	816	504.6	41	182.2	3.9336	0.097	3.118	0.006
1991	1284.2	1553	462.3	54	99.9	2.2079	0.092	8.987	0.019
1992	934.4	1329	401.3	40	96.2	1.8374	0.093	8.152	0.020
1993	829.6	2174	428.5	45	61.2	1.4383	0.090	14.159	0.033
1994	944.8	2428	469.7	43	63.7	1.3668	0.088	16.815	0.036
1995	815.4	2631	467.1	44	59.6	1.2275	0.088	19.900	0.043
1996	724.4	3543	530.7	48	53.9	1.3478	0.087	26.062	0.049
1997	935.2	2467	403.0	42	57.3	1.3083	0.090	16.367	0.041
1998	903.2	2552	457.2	39	65.4	1.1941	0.089	17.177	0.038
1999	591.1	1640	131.6	39	27.2	0.6437	0.092	12.412	0.094
2000	470.5	2221	185.7	41	25.1	0.5492	0.090	15.442	0.083
2001	285.5	1469	57.3	33	11.1	0.3238	0.094	10.220	0.178
2002	290.5	1854	62.9	36	8.1	0.2456	0.092	12.452	0.198
2003	234.0	1311	40.8	38	6.1	0.1883	0.095	8.270	0.203
2004	232.4	1243	51.8	38	11.5	0.2566	0.097	8.430	0.163
2005	289.1	820	21.2	33	5.6	0.1783	0.101	4.649	0.219
2006	379.5	772	25.6	28	8.3	0.2041	0.102	4.635	0.181
2007	177.8	577	16.5	14	5.8	0.2117	0.107	3.838	0.233
2008	163.3	730	26.5	18	8.7	0.2917	0.103	5.475	0.207
2009	135.2	443	35.7	15	21.6	0.3624	0.112	2.854	0.080
2010	129.3	361	11.7	15	7.6	0.2239	0.118	2.212	0.189
2011	103.3	427	9.6	13	5.0	0.1854	0.114	2.601	0.270
2012	52.3	346	9.8	14	5.8	0.1507	0.119	1.872	0.192
2013	68.0	163	3.7	17	5.8	0.1415	0.147	0.934	0.255
2014	15.3	88	1.8	12	3.7	0.0946	0.183	0.376	0.211
2015	5.4	55	1.6	9	8.0	0.1106	0.223	0.302	0.190
2016	18.8	190	6.8	14	8.0	0.1009	0.142	0.992	0.147
2017	16.4	280	3.9	12	2.6	0.0459	0.127	1.085	0.280
2018	39.0	231	3.9	9	4.1	0.0680	0.135	1.330	0.338

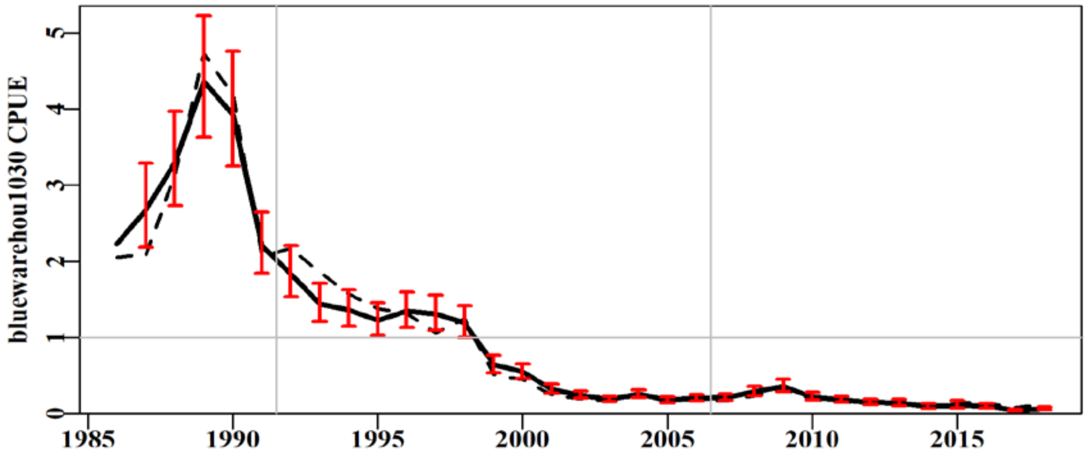

Figure 5.201. bluewarehou1030 standardization. The dashed black line represents the geometric mean catch rate, solid black line the standardized catch rates. The red bars are the 95% confidence intervals about the mean estimates. The graph scales both time-series of standardized catch rates relative to the mean of each time-series.

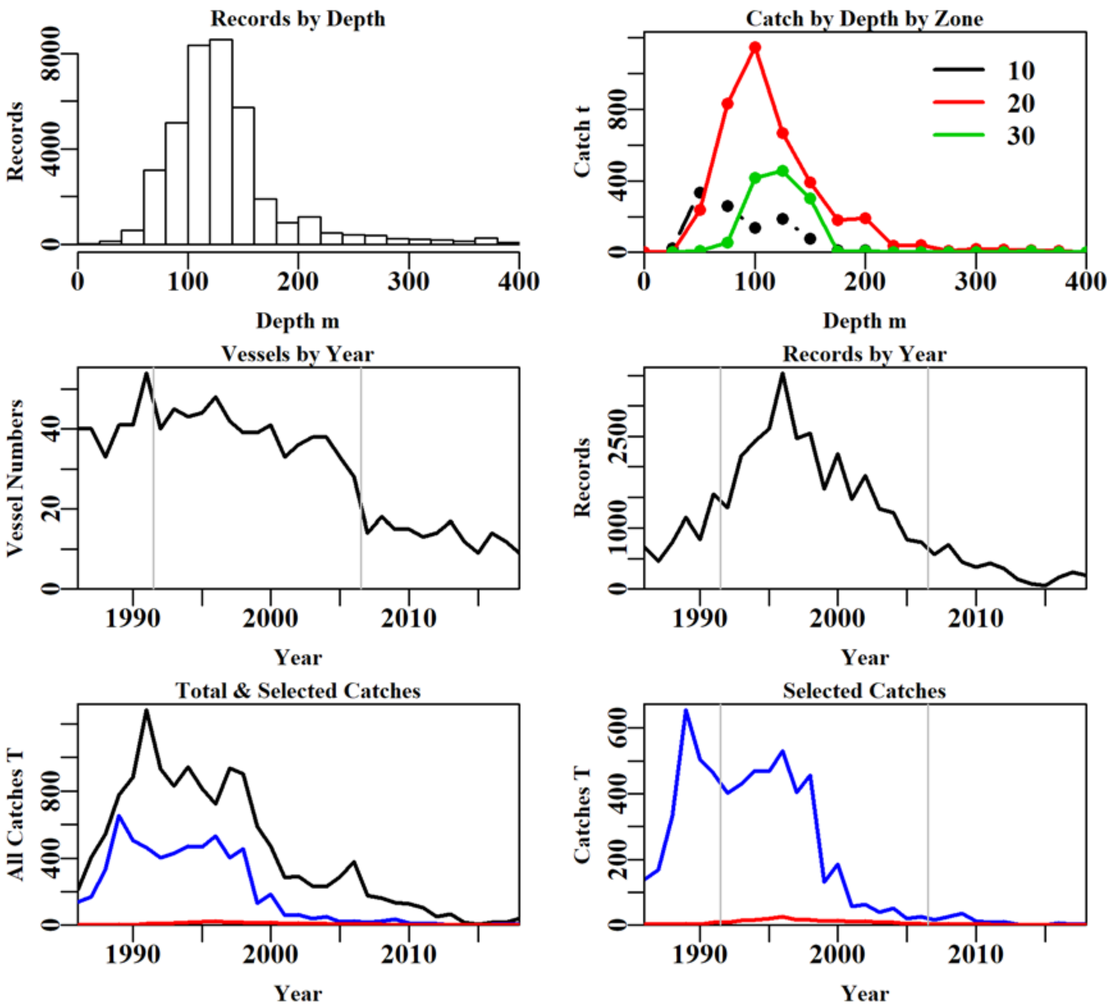

Figure 5.202. bluewarehou1030 fishery details. The bottom left plot depicts all known catches (top black line), and all selected catches used in the analysis (middle blue line); the lower red line: selected catches < 30 kg).

Table 5.143. bluewarehou1030 fishery details. The bottom left plot depicts all known catches (top black line), and all selected catches used in the analysis (middle blue line); the lower red line: selected catches < 30 kg).

	Total	NoCE	Depth	Years	Zones	Method	Fishery
Records	67686	61789	58957	58623	40835	37872	37815
Difference	0	5897	2832	334	17788	2963	57
Catch	13962.5	13576.04	12842.19	12790.86	6714.89	6130.25	6128.11
Difference	0	386.46	733.85	51.33	6075.97	584.64	2.14

Table 5.144. The models used to analyse data for bluewarehou1030.

	Model
Model1	Year
Model2	Year + Vessel
Model3	Year + Vessel + DepCat
Model4	Year + Vessel + DepCat + Month
Model5	Year + Vessel + DepCat + Month + Zone
Model6	Year + Vessel + DepCat + Month + Zone + DayNight
Model7	Year + Vessel + DepCat + Month + Zone + DayNight + Zone:Month
Model8	Year + Vessel + DepCat + Month + Zone + DayNight + Zone:DepCat

Table 5.145. bluewarehou1030. The row names are 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_r2) and the change in adjusted R^2 (%Change). The optimum model was Zone:Month.

	AIC	RSS	MSS	Nobs	Npars	adj_r2	%Change
Year	37812	102605	41036	37815	33	28.5	0.00
Vessel	33051	89670	53970	37815	200	37.2	8.73
DepCat	32583	88493	55147	37815	216	38.0	0.80
Month	32391	87993	55648	37815	227	38.4	0.33
Zone	31998	87074	56567	37815	229	39.0	0.64
DayNight	31913	86865	56776	37815	232	39.2	0.14
Zone:Month	31627	86111	57530	37815	254	39.6	0.49
Zone:DepCat	31677	86189	57452	37815	262	39.6	0.43

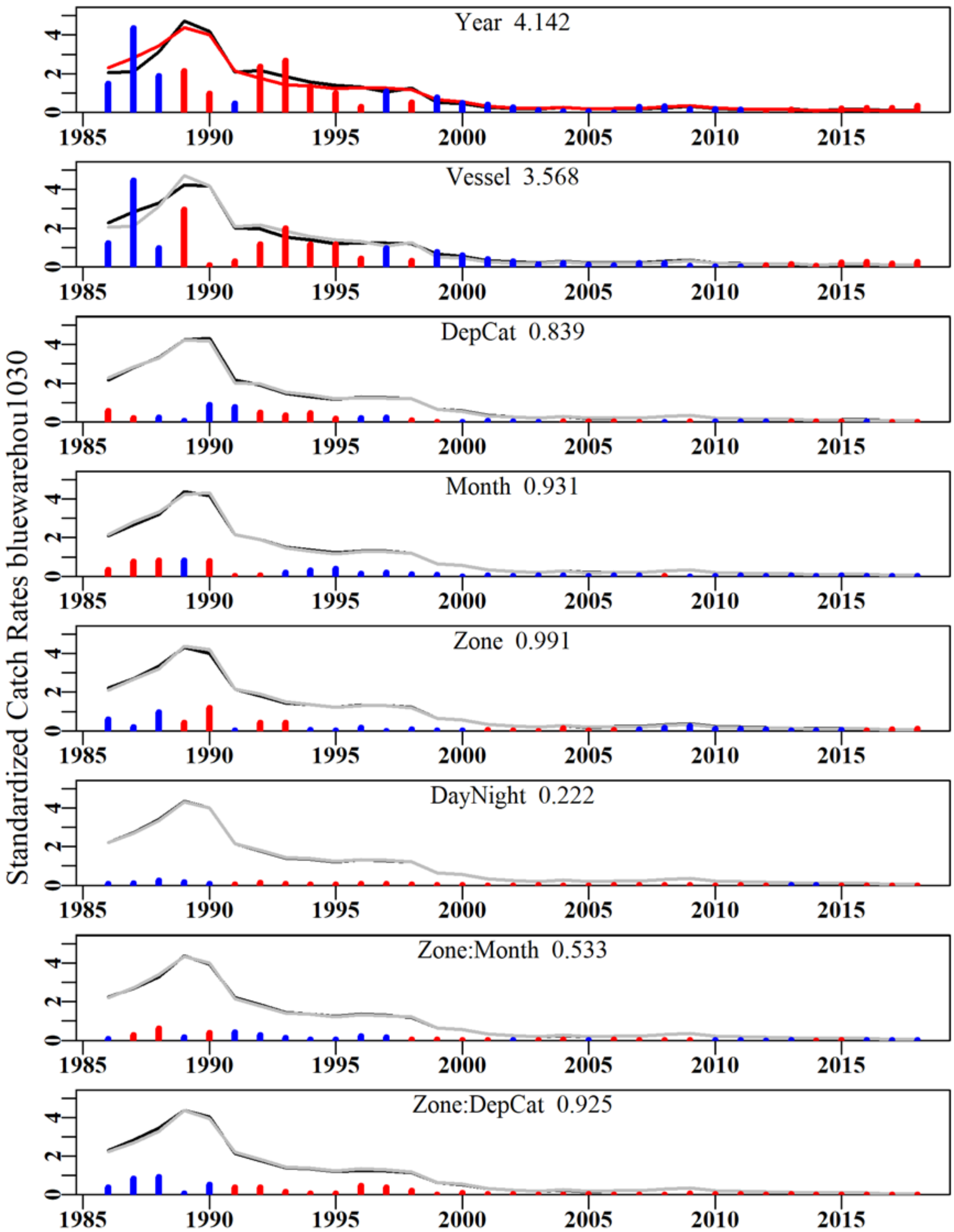

Figure 5.203. bluewarehou1030. The influence of each factor on the optimal standardization. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by vertical bars with blue bars indicating the optimum model is higher than the 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.

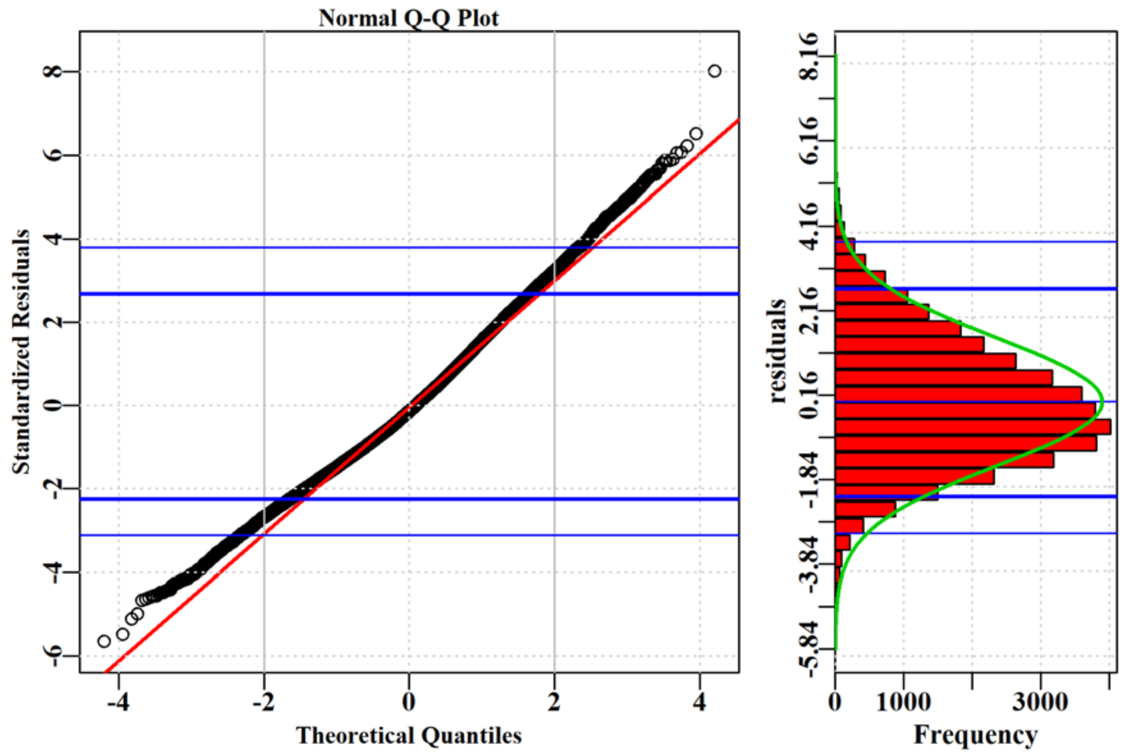

Figure 5.204. bluewarehou1030. diagnostic plots. The distribution of residuals from the optimum fit. The qqplot indicates the fit to the expected normality, while the histogram of residuals illustrates the 90% quantiles to indicate the intensity of any lack of fit at the margins of the distribution.

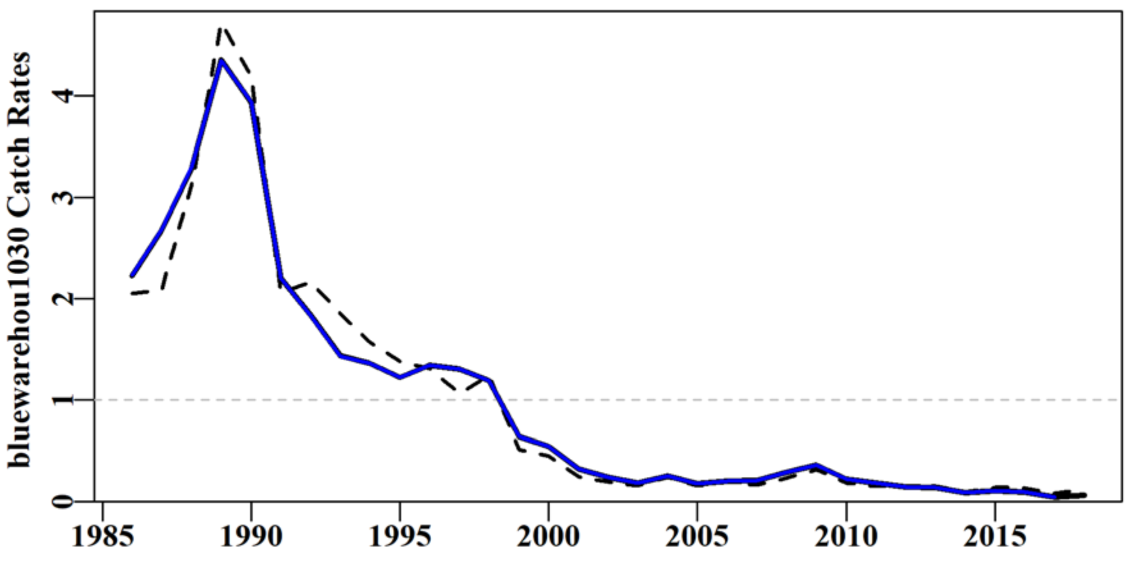

Figure 5.205. bluewarehou1030. A comparison of the previous year's standardization (blue line) with this year's. They should lie on top of each other, although small deviations may relate to data adjustments, particularly in very recent years.

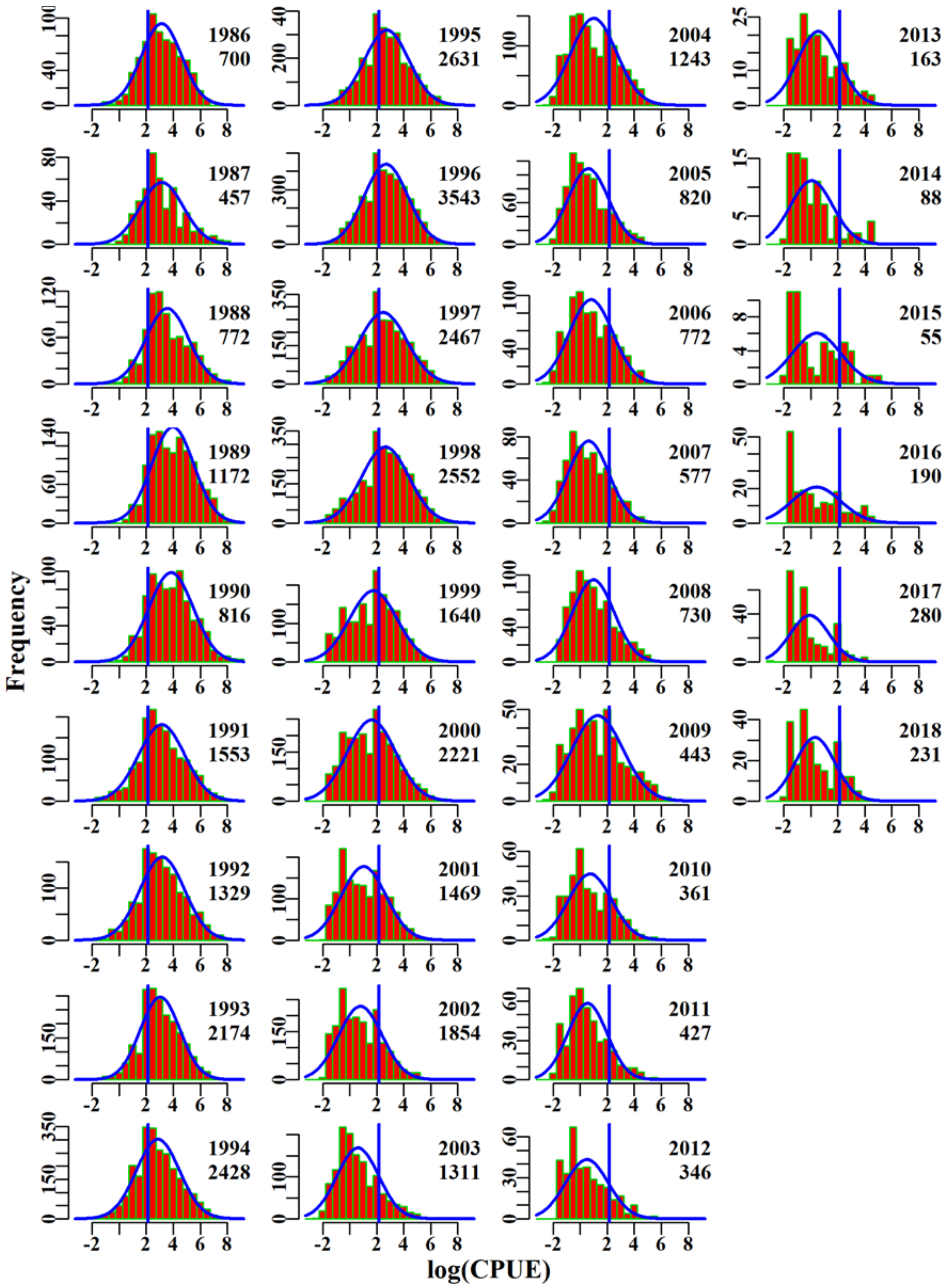

Figure 5.206. bluewarehou1030. The natural log(CPUE) for each year of data available the blue lines are normal distributions fitted to the histogram frequencies. The numbers in each plot are the year and number of records.

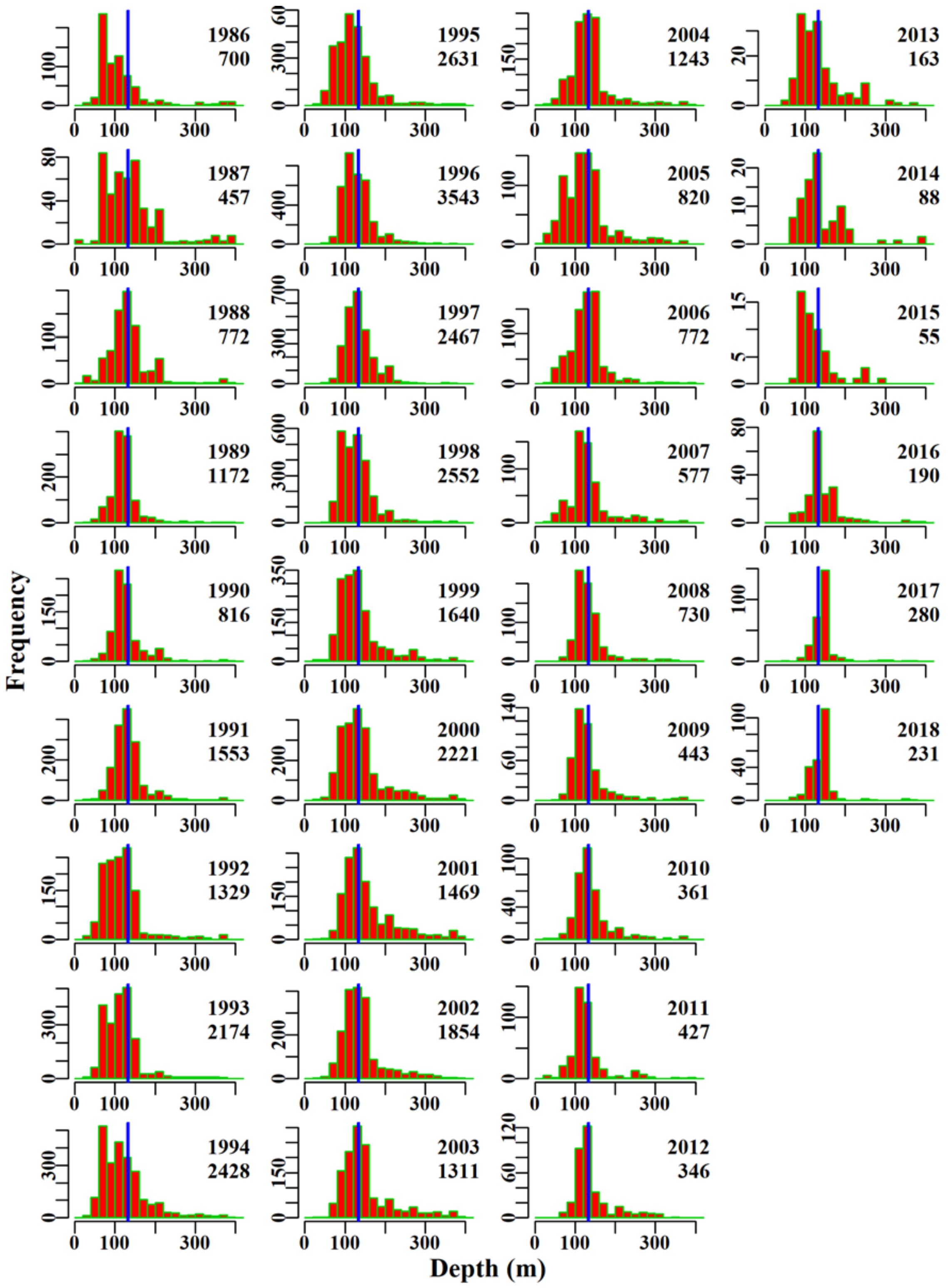

Figure 5.207. bluewarehou1030. The average Depth of fishing for each year of data available to illustrate the development of the fishery through time. The numbers in each plot are the year and number of records.

5.34 Blue Warehou 40 – 50

For Blue Warehou (TRT – 37445005 – *Seriolella brama*) in zones 40 and 50, initial data selection was conducted according to the details given in Table 5.146.

A total of 8 statistical models were fitted sequentially to the available data, with the order of the non-interaction terms determined by which accounted for the most variation as they were added. The sequential development of the standardization models simplifies the search for the optimum model requires a consideration of the different performance statistics such as the AIC (Akaike's Information Criterion, the smaller the better; Burnham and Anderson, 1992) or the adjusted R^2 (the larger the better; Neter et al, 1996).

5.34.1 *Inferences*

The majority of catch of this species occurred in zone 50 and minimal catches occurred in the remaining zone (40). There were small record numbers (17 and 42) and corresponding catch (0.6 t and 2.6 t) in 2015 and 2016 respectively. This also corresponds to the lowest catches across the years analysed.

The terms Year, Vessel, Month and DepCat had the greatest contribution to model fit, with the remaining terms each explaining < 1% of the overall variation in CPUE, based on the AIC and R^2 statistics (Table 5.150). The qqplot suggests that the assumed Normal distribution is valid with a slight departure in the lower tail of the distribution (Figure 5.211).

Annual standardized CPUE trend is flat since 1992 and mostly below average (Figure 5.208). Catch rates prior to the introduction of quotas are highly variable both within years and between years. At that time Blue Warehou data was mixed with Silver warehou data so this early data is less trustworthy. Data are now so sparse that the analysis results can no longer be trusted to represent the stock.

5.34.2 *Action Items and Issues*

Exploration of the early CPUE data could be made to examine whether there are obvious or consistent errors leading to mean CPUE values 4 times greater than the long term average.

Table 5.146. bluewarehou4050. The data selection criteria used to specify and identify the fishery data to be included in the analysis.

Property	Value
label	bluewarehou4050
csirocode	37445005, 91445005, 92445005
fishery	SET
depthrange	0 - 600
depthclass	25
zones	40, 50
methods	TW, TDO, OTT
years	1986 - 2018

Table 5.147. bluewarehou4050. Total catch (Total; t) is the total reported in the database, number of records used in the analysis (N), reported catch (Catch; t) in the area and depth used in the analysis and number of vessels used in the analysis (Vess). GeoM is the geometric mean of catch rates (kg/hr), standard deviation (StDev) relates to the optimum model. C<30 kg denotes the amount of catch in shots of <30 kg, and %<30 kg is the percent of total. The optimum model was Zone:Month.

	Total	N	Catch	Vess	GeoM	Opt	StDev	C<30Kg	P<30Kg
1986	211.9	159	71.4	14	162.6	3.6540	0.000	0.759	0.011
1987	405.9	183	215.6	10	635.9	3.7993	0.241	0.334	0.002
1988	544.0	179	198.0	12	566.9	1.6560	0.250	0.700	0.004
1989	776.0	56	81.3	13	562.1	4.3303	0.309	0.235	0.003
1990	881.4	439	298.1	13	341.8	1.6873	0.235	2.210	0.007
1991	1284.2	595	647.1	18	850.7	2.8406	0.233	1.060	0.002
1992	934.4	536	429.7	17	473.1	1.5187	0.235	1.733	0.004
1993	829.6	494	362.7	21	413.0	1.1721	0.236	1.700	0.005
1994	944.8	820	444.1	21	245.7	1.2873	0.231	2.525	0.006
1995	815.4	820	323.6	22	155.8	0.8754	0.229	4.180	0.013
1996	724.4	696	180.9	24	87.2	0.5839	0.230	4.248	0.023
1997	935.2	430	243.5	23	354.0	0.6157	0.236	3.038	0.012
1998	903.2	582	354.5	19	459.4	0.9511	0.234	2.728	0.008
1999	591.1	687	169.4	19	122.7	0.5244	0.233	4.505	0.027
2000	470.5	651	203.6	24	157.7	0.4176	0.234	3.736	0.018
2001	285.5	685	194.0	23	98.5	0.4311	0.233	4.249	0.022
2002	290.5	528	217.9	23	184.0	0.5485	0.236	2.977	0.014
2003	234.0	361	172.4	19	185.9	0.5011	0.241	2.421	0.014
2004	232.4	430	158.8	21	136.3	0.5502	0.238	2.276	0.014
2005	289.1	457	257.4	18	333.5	0.8711	0.238	1.735	0.007
2006	379.5	693	337.5	16	212.7	0.5917	0.235	3.736	0.011
2007	177.8	462	147.7	16	116.3	0.4955	0.238	2.541	0.017
2008	163.3	349	117.0	12	88.9	0.4051	0.241	2.016	0.017
2009	135.2	308	89.0	11	70.1	0.2976	0.243	1.337	0.015
2010	129.3	407	105.3	12	52.7	0.3500	0.238	1.833	0.017
2011	103.3	517	77.8	14	31.2	0.3227	0.237	2.225	0.029
2012	52.3	254	30.7	14	22.3	0.1838	0.248	1.654	0.054
2013	68.0	304	57.9	13	37.3	0.2533	0.244	1.522	0.026
2014	15.3	60	11.6	9	48.9	0.1798	0.304	0.457	0.039
2015	5.4	17	0.6	5	5.9	0.0778	0.438	0.049	0.085
2016	18.8	42	2.6	8	11.6	0.2694	0.333	0.243	0.094
2017	16.4	84	7.3	8	14.5	0.5007	0.288	0.592	0.081
2018	39.0	164	25.2	8	21.9	0.2570	0.258	0.464	0.018

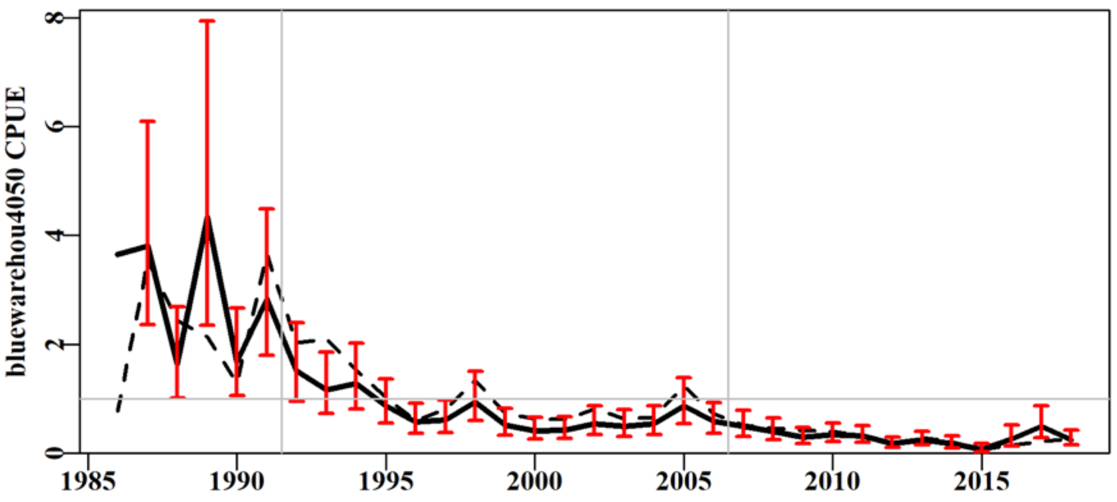

Figure 5.208. bluewarehou4050 standardization. The dashed black line represents the geometric mean catch rate, solid black line the standardized catch rates. The red bars are the 95% confidence intervals about the mean estimates. The graph scales both time-series of standardized catch rates relative to the mean of each time-series.

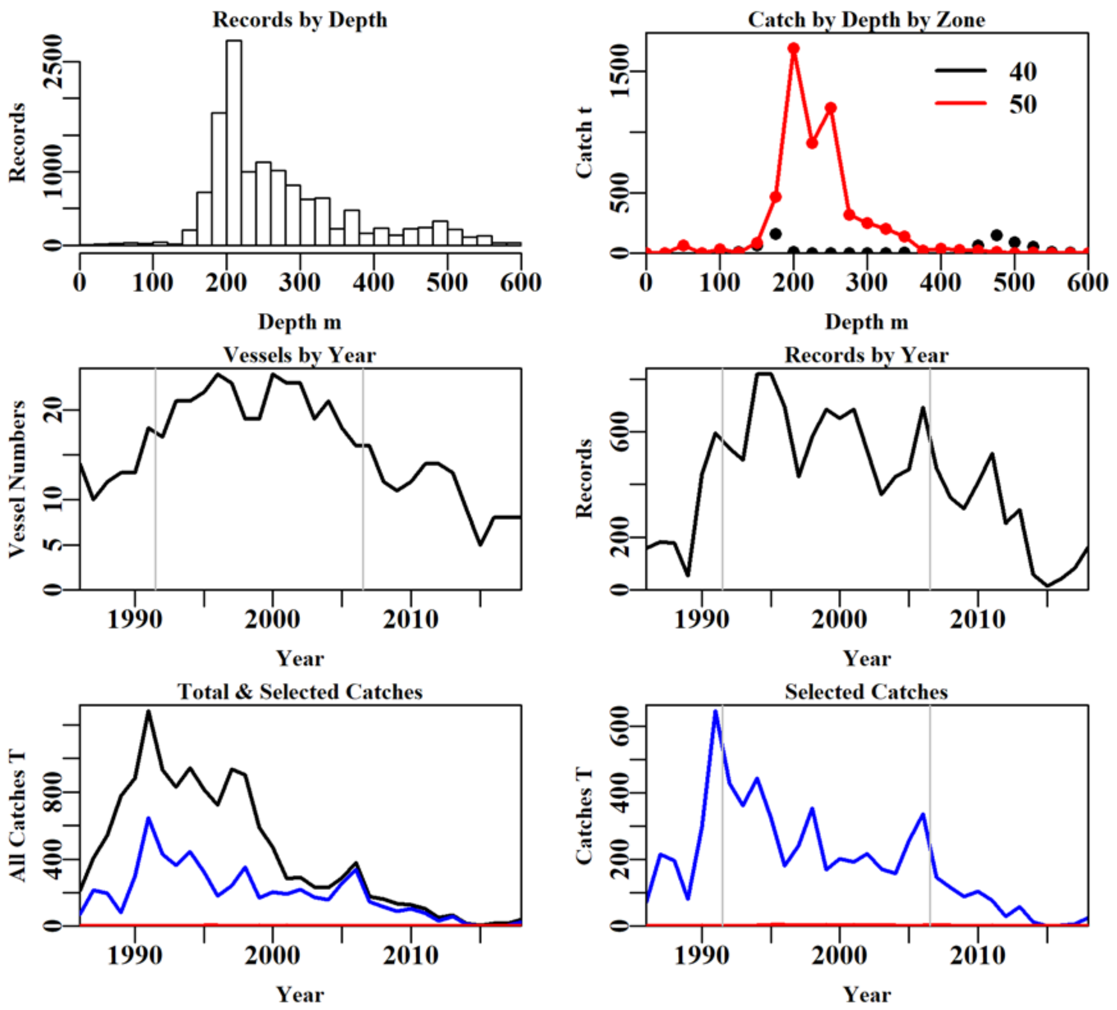

Figure 5.209. bluewarehou4050 fishery details. The bottom left plot depicts all known catches (top black line), and all selected catches used in the analysis (middle blue line); the lower red line: selected catches < 30 kg).

Table 5.148. bluewarehou4050 data selection effects. Total is the total number of records in the database, NoCE removes those records with either missing catch or effort, and then only those records are kept that meet the criteria for depth, years, zone, method and fishery.

	Total	NoCE	Depth	Years	Zones	Method	Fishery
Records	67686	61789	61288	60924	14227	13470	13449
Difference	0	5897	501	364	46697	757	21
Catch	13962.5	13576.04	13477.63	13402.61	6376.45	6237.30	6234.15
Difference	0	386.46	98.41	75.02	7026.16	139.16	3.15

Table 5.149. The models used to analyse data for bluewarehou4050.

	Model
Model1	Year
Model2	Year + Vessel
Model3	Year + Vessel + Month
Model4	Year + Vessel + Month + DepCat
Model5	Year + Vessel + Month + DepCat + Zone
Model6	Year + Vessel + Month + DepCat + Zone + DayNight
Model7	Year + Vessel + Month + DepCat + Zone + DayNight + Zone:Month
Model8	Year + Vessel + Month + DepCat + Zone + DayNight + Zone:DepCat

Table 5.150. bluewarehou4050. The row names are 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_r2) and the change in adjusted R^2 (%Change). The optimum model was Zone:Month.

	AIC	RSS	MSS	Nobs	Npars	adj_r2	%Change
Year	14742	40050	6307	13449	33	13.4	0.00
Vessel	13567	36249	10109	13449	116	21.1	7.73
Month	12543	33537	12821	13449	127	27.0	5.84
DepCat	11864	31773	14585	13449	151	30.7	3.72
Zone	11862	31764	14594	13449	152	30.7	0.01
DayNight	11812	31630	14728	13449	155	31.0	0.28
Zone:Month	11779	31503	14855	13449	166	31.2	0.22
Zone:DepCat	11809	31525	14832	13449	176	31.1	0.12

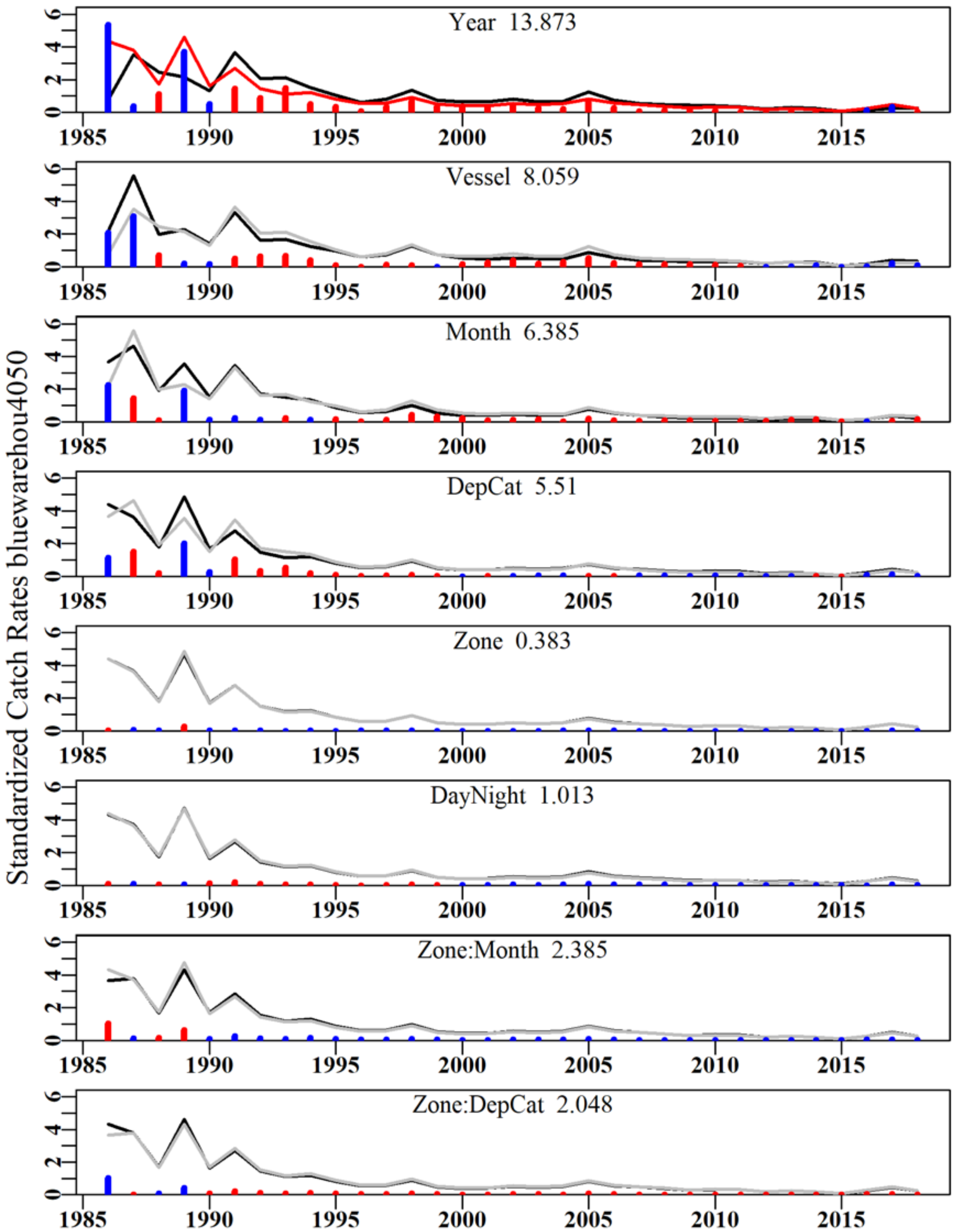

Figure 5.210. bluewarehou4050. The influence of each factor on the optimal standardization. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by vertical bars with blue bars indicating the optimum model is higher than the 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.

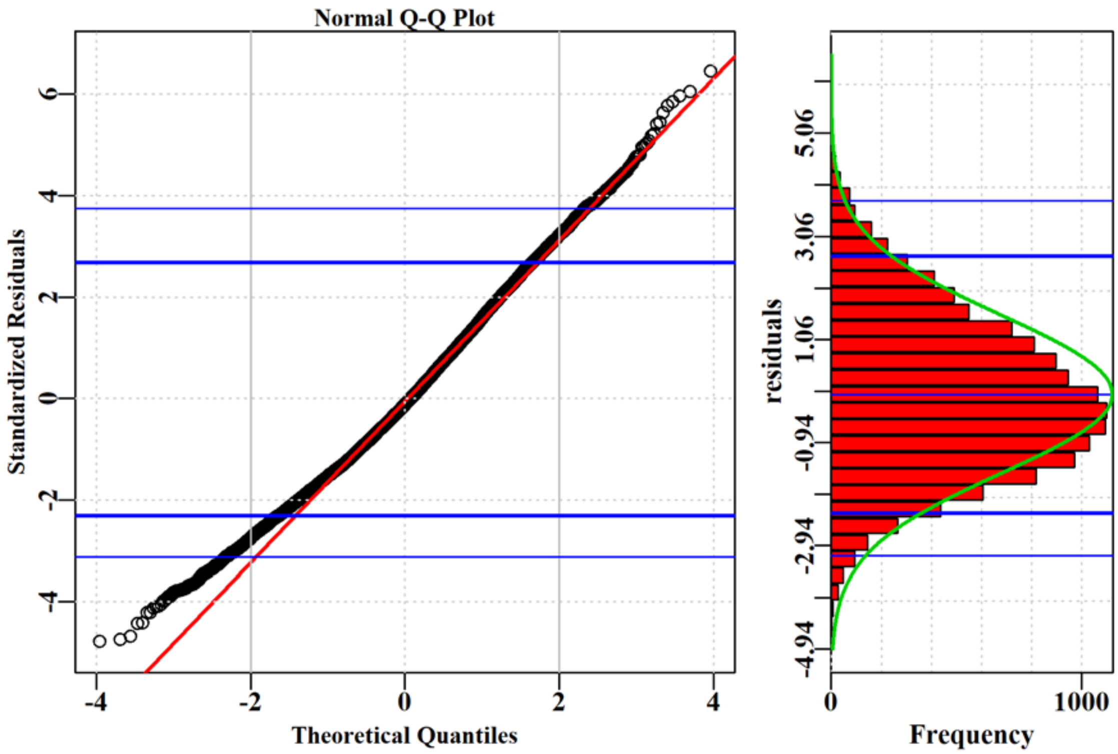

Figure 5.211. bluewarehou4050. diagnostic plots. The distribution of residuals from the optimum fit. The qqplot indicates the fit to the expected normality, while the histogram of residuals illustrates the 90% quantiles to indicate the intensity of any lack of fit at the margins of the distribution.

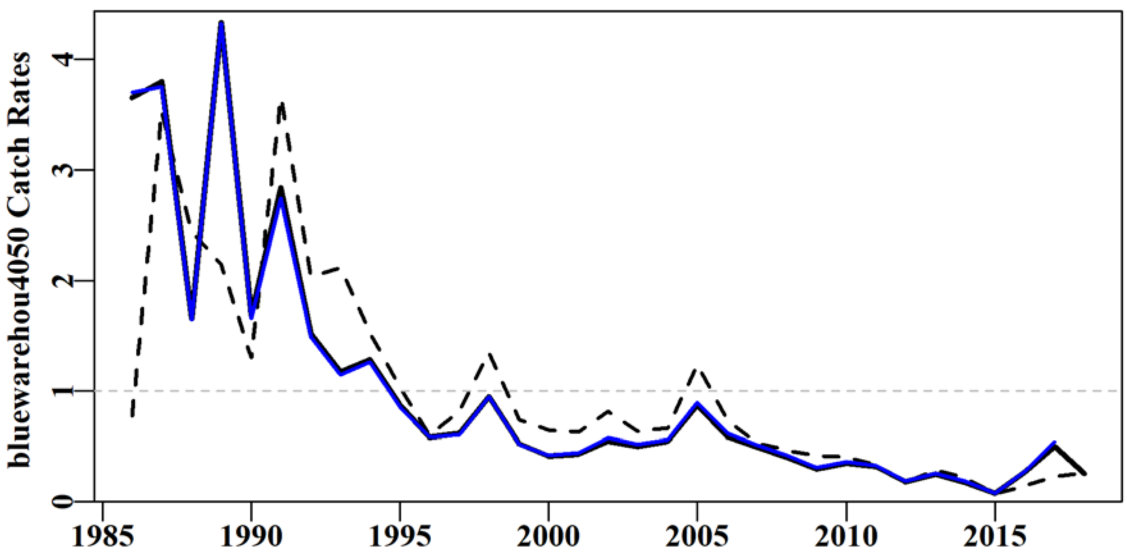

Figure 5.212. bluewarehou4050. A comparison of the previous year's standardization (blue line) with this year's. They should lie on top of each other, although small deviations may relate to data adjustments, particularly in very recent years.

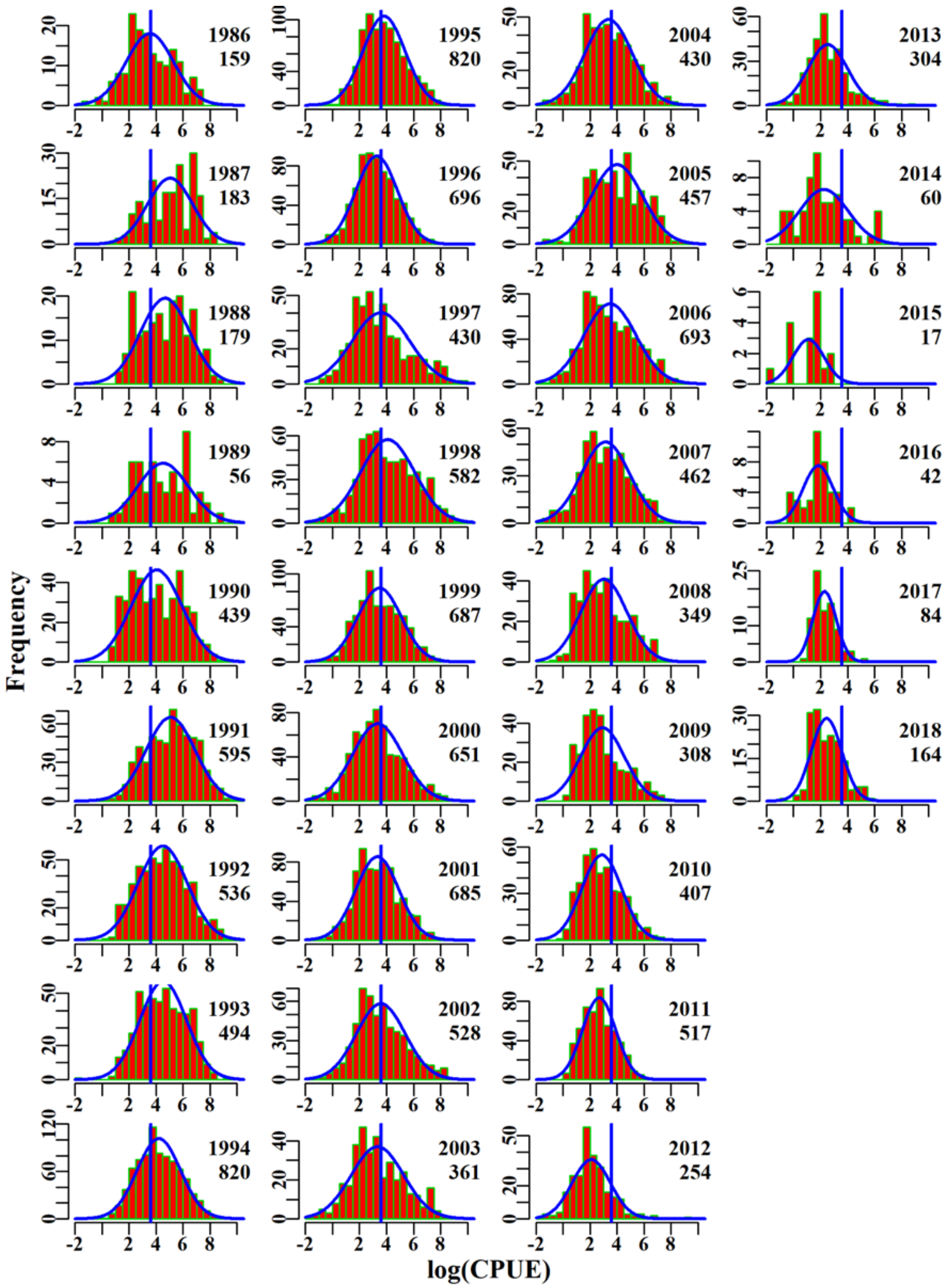

Figure 5.213. bluewarehou4050. The natural log(CPUE) for each year of data available the blue lines are normal distributions fitted to the histogram frequencies. The numbers in each plot are the year and number of records.

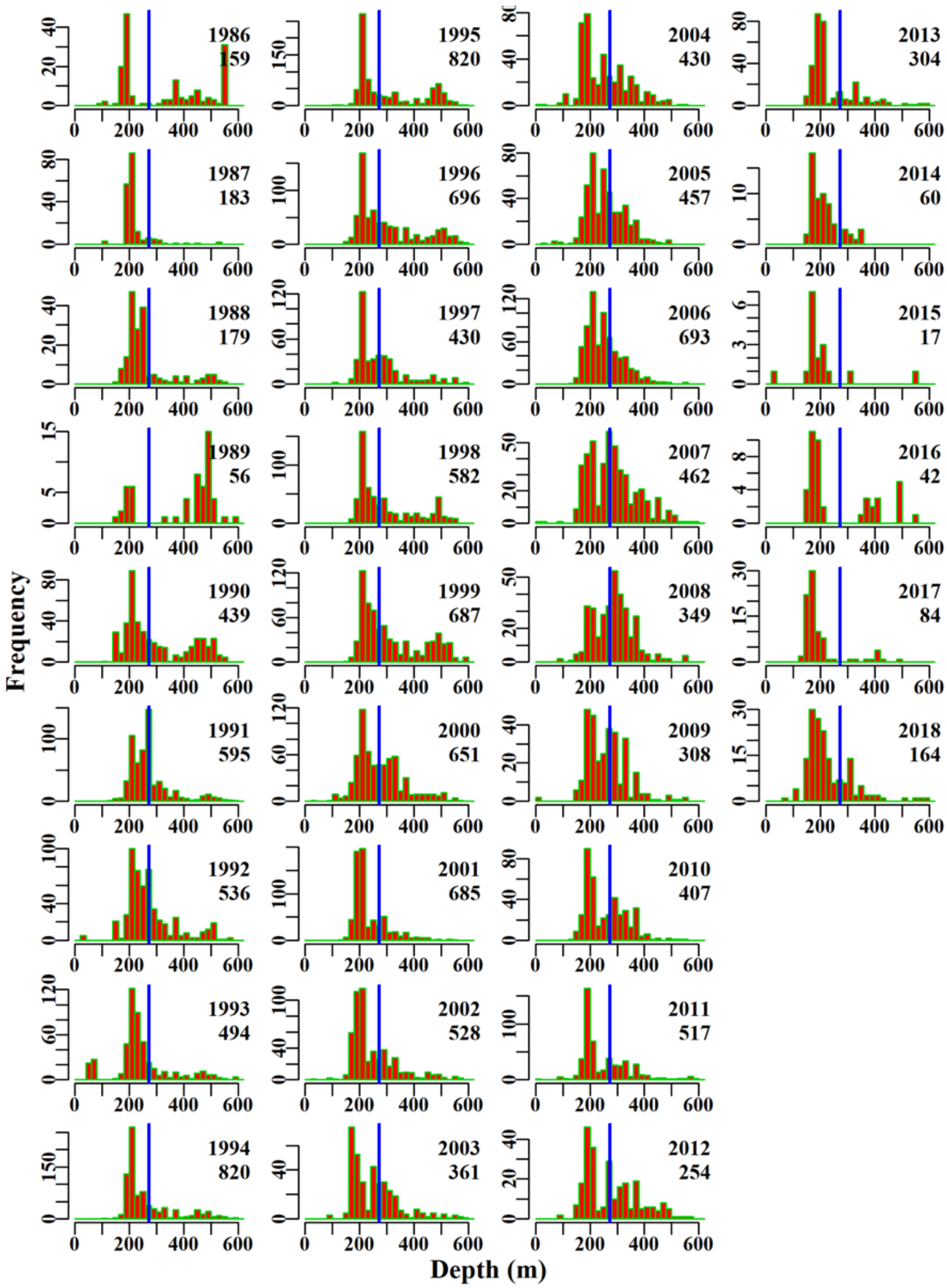

Figure 5.214. bluewarehou4050. The average Depth of fishing for each year of data available to illustrate the development of the fishery through time. The numbers in each plot are the year and number of records

5.35 Deepwater Flathead

The initial data selection for Deepwater Flathead (FLD – 37296002 – *Platycephalus conatus*) in the GAB was conducted according to the details given in Table 5.151.

A total of 9 statistical models were fitted sequentially to the available data, with the order of the non-interaction terms added based on the relative contribution of each term to model fit.

5.35.1 *Inferences*

The majority of catch of this species occurred in longitude 129-130 (degrees longitude - take the place of zones to provide more detail).

The terms Year, Vessel, Zone, Month, DepCat, DayNight and three interaction terms (Zone:Month, Zone:Vessel and Zone:DepCat) had the greatest contribution to model fit, with the remaining terms each explaining < 1% of the overall variation in CPUE, based on the AIC and R^2 statistics (Table 5.154). The qqplot suggests a departure from the assumed Normal distribution as depicted by the tails of the distribution (Figure 5.218).

Annual standardized CPUE has been cyclical in the early years following the ups and downs of catches (prior to 2007) and relatively flat and mostly below average since 2007 (Figure 5.215).

5.35.2 *Action Items and Issues*

No issues identified.

Table 5.151. deepwaterflathead. The data selection criteria used to specify and identify the fishery data to be included in the analysis.

Property	Value
label	deepwaterflathead
csirocode	37296002
fishery	GAB
depthrange	50 - 350
depthclass	25
zones	82, 83, 84, 85
methods	TW, TDO, OTT, PTB
years	1986 - 2018

Table 5.152. deepwaterflathead. Total catch (Total; t) is the total reported in the database, number of records used in the analysis (N), reported catch (Catch; t) in the area and depth used in the analysis and number of vessels used in the analysis (Vess). GeoM is the geometric mean of catch rates (kg/hr), standard deviation (StDev) relates to the optimum model. C<30Kg denotes the amount of catch in shots of <30kg, and %<30Kg is the percent of total. The optimum model was Zone:DepCat.

	Total	N	Catch	Vess	GeoM	Opt	StDev	C<30Kg	P<30Kg
1987	80.3	229	44.3	3	62.5	0.5226	0.000	0.195	0.004
1988	317.2	532	260.6	4	196.0	1.0601	0.055	0.732	0.003
1989	402.6	944	345.6	6	100.3	1.0343	0.053	0.803	0.002
1990	430.2	1297	393.9	6	90.8	1.0106	0.052	0.900	0.002
1991	621.0	1465	513.5	8	85.5	0.9717	0.051	0.819	0.002
1992	524.1	958	499.5	3	117.9	1.2351	0.052	0.345	0.001
1993	593.1	881	580.7	5	149.5	1.6637	0.053	0.570	0.001
1994	1285.9	1683	1233.7	6	173.4	2.0538	0.050	0.327	0.000
1995	1585.1	1849	1552.3	5	176.6	1.9618	0.050	0.030	0.000
1996	1499.2	2726	1450.5	6	110.2	1.3052	0.049	0.405	0.000
1997	1030.0	2684	944.5	7	72.0	0.9045	0.049	1.340	0.001
1998	690.4	2401	669.2	7	57.0	0.6969	0.050	3.280	0.005
1999	571.0	2040	541.3	7	53.6	0.8223	0.051	1.530	0.003
2000	845.6	2378	773.9	5	67.5	0.9019	0.050	1.857	0.002
2001	973.1	2411	910.5	5	75.6	1.0820	0.050	1.207	0.001
2002	1708.9	3113	1613.1	8	103.5	1.4920	0.050	0.900	0.001
2003	2260.6	4468	2156.6	10	93.8	1.4886	0.050	0.387	0.000
2004	2155.2	5349	2054.2	9	74.5	1.1745	0.049	0.923	0.000
2005	1426.0	5014	1238.5	10	49.5	0.7455	0.050	1.642	0.001
2006	1014.2	4151	947.2	10	45.9	0.6848	0.050	1.667	0.002
2007	1039.9	3659	908.2	6	50.8	0.7631	0.050	2.978	0.003
2008	813.2	3086	766.5	4	50.6	0.9111	0.050	2.089	0.003
2009	849.4	3193	824.6	4	52.3	0.8043	0.050	2.793	0.003
2010	966.8	2803	927.0	4	67.8	1.0191	0.050	1.300	0.001
2011	963.2	3269	789.3	4	47.1	0.8144	0.050	1.490	0.002
2012	1019.8	3448	842.3	4	48.3	0.8161	0.050	1.724	0.002
2013	874.7	3232	649.3	4	39.1	0.7165	0.050	2.080	0.003
2014	588.6	2572	485.3	4	37.5	0.6606	0.051	2.314	0.005
2015	593.9	2248	472.0	3	42.2	0.7405	0.051	1.574	0.003
2016	737.3	2528	590.8	4	48.6	0.7792	0.051	2.013	0.003
2017	547.4	2453	431.2	3	36.6	0.5878	0.051	3.474	0.008
2018	396.3	1774	299.8	4	35.8	0.5753	0.051	2.277	0.008

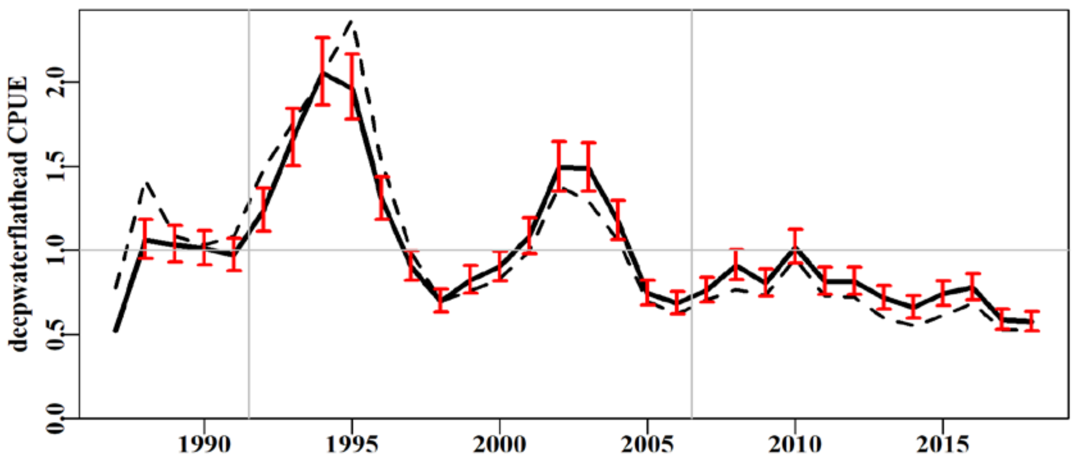

Figure 5.215. deepwaterflathead standardization. The dashed black line represents the geometric mean catch rate, solid black line the standardized catch rates. The red bars are the 95% confidence intervals about the mean estimates. The graph scales both time-series of standardized catch rates relative to the mean of each time-series.

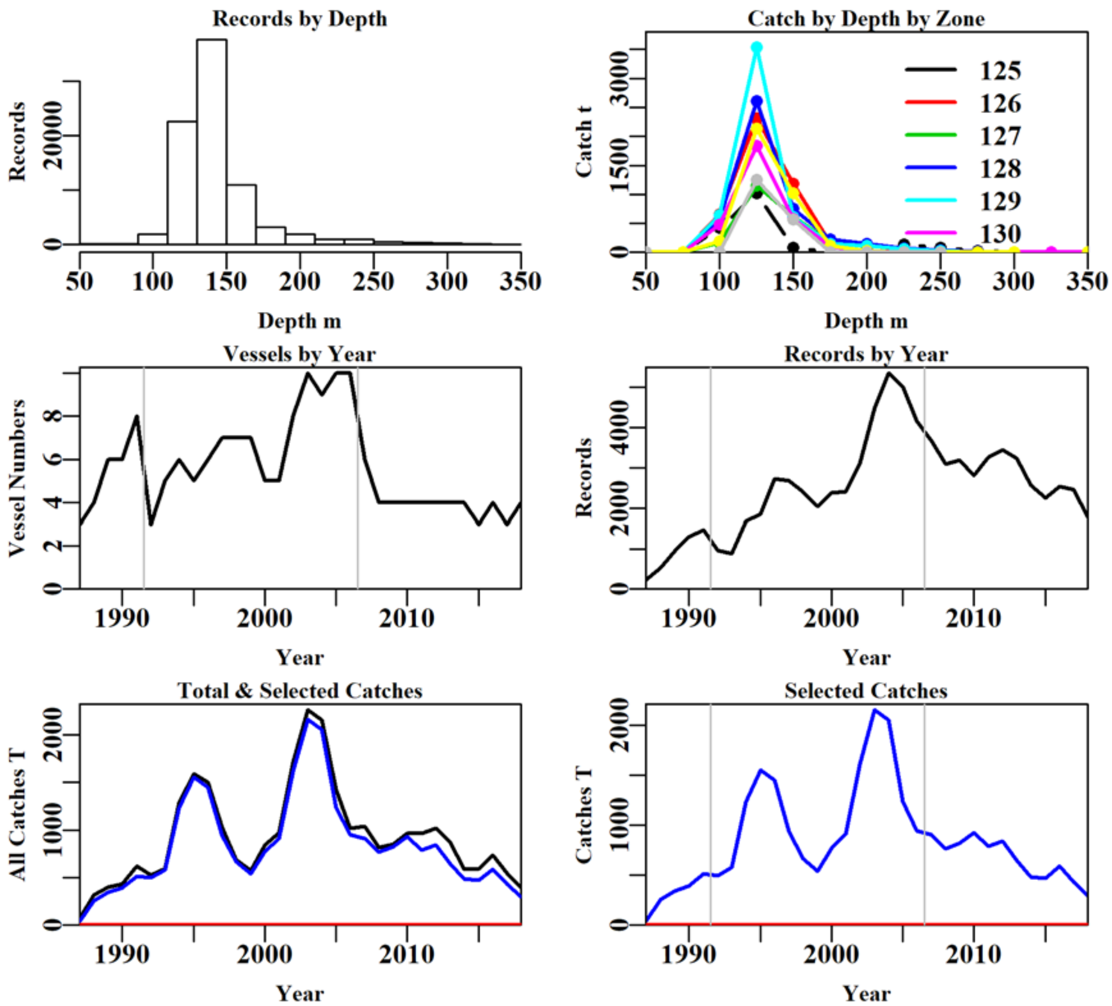

Figure 5.216. deepwaterflathead fishery details. The bottom left plot depicts all known catches (top black line), and all selected catches used in the analysis (middle blue line); the lower red line: selected catches < 30 kg).

Table 5.153. The models used to analyse data for deepwaterflathead.

	Model
Model1	Year
Model2	Year + Vessel
Model3	Year + Vessel + Zone
Model4	Year + Vessel + Zone + Month
Model5	Year + Vessel + Zone + Month + DepCat
Model6	Year + Vessel + Zone + Month + DepCat + DayNight
Model7	Year + Vessel + Zone + Month + DepCat + DayNight + Zone:Month
Model8	Year + Vessel + Zone + Month + DepCat + DayNight + Zone:Vessel
Model9	Year + Vessel + Zone + Month + DepCat + DayNight + Zone:DepCat

Table 5.154. deepwaterflathead. The row names are 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_r2) and the change in adjusted R^2 (%Change). The optimum model was Zone:DepCat.

	AIC	RSS	MSS	Nobs	Npars	adj_r2	%Change
Year	-38409	50226	10488	80838	32	17.2	0.00
Vessel	-44116	46780	13934	80838	51	22.9	5.66
Zone	-50670	43129	17585	80838	58	28.9	6.01
Month	-54020	41367	19347	80838	69	31.8	2.89
DepCat	-55427	40641	20073	80838	81	33.0	1.19
DayNight	-57404	39657	21057	80838	84	34.6	1.62
Zone:Month	-58632	38984	21729	80838	161	35.7	1.05
Zone:Vessel	-59510	38515	22198	80838	211	36.4	1.78
Zone:DepCat	-59803	38428	22286	80838	157	36.6	1.97

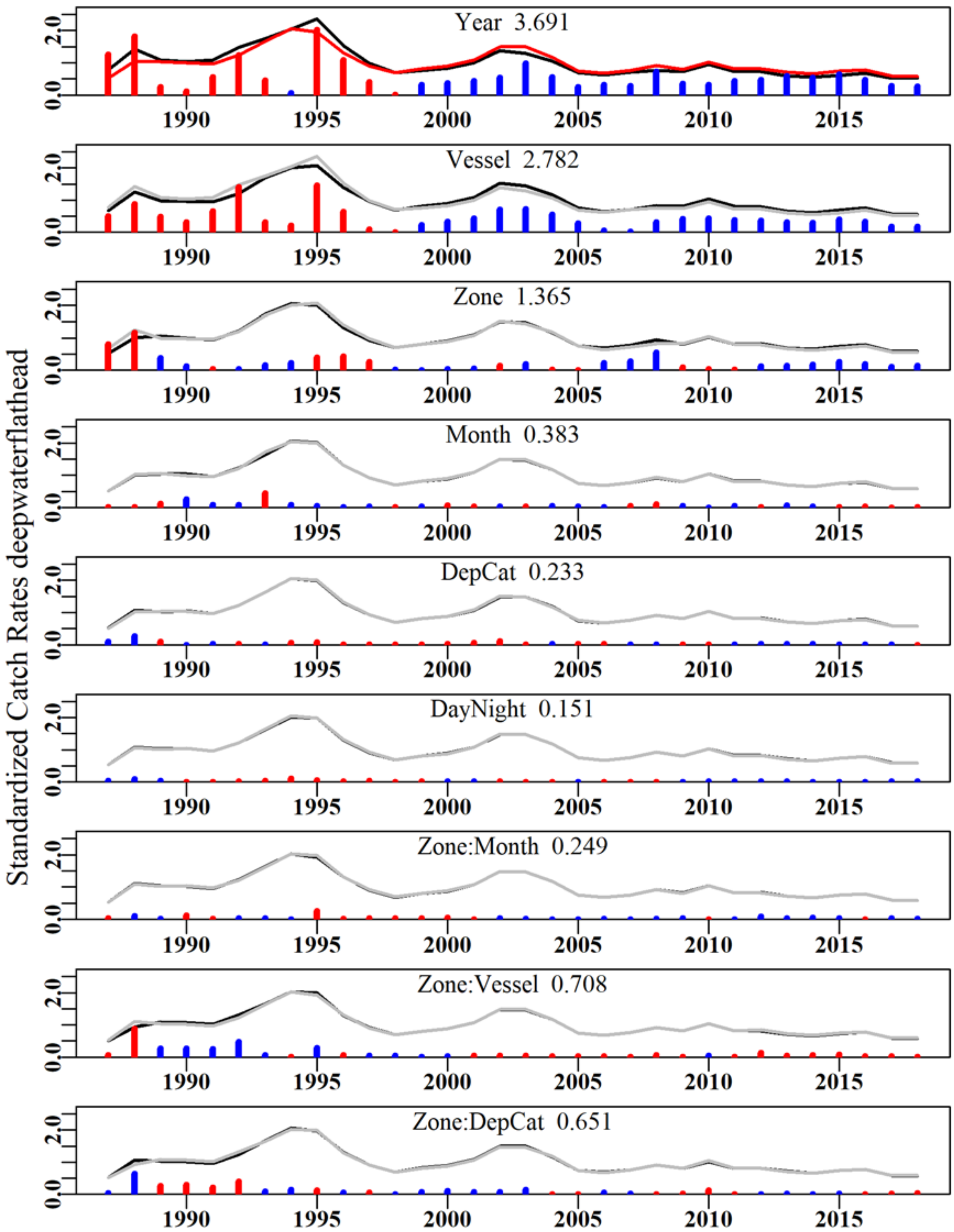

Figure 5.217. deepwaterflathead. The influence of each factor on the optimal standardization. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by vertical bars with blue bars indicating the optimum model is higher than 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.

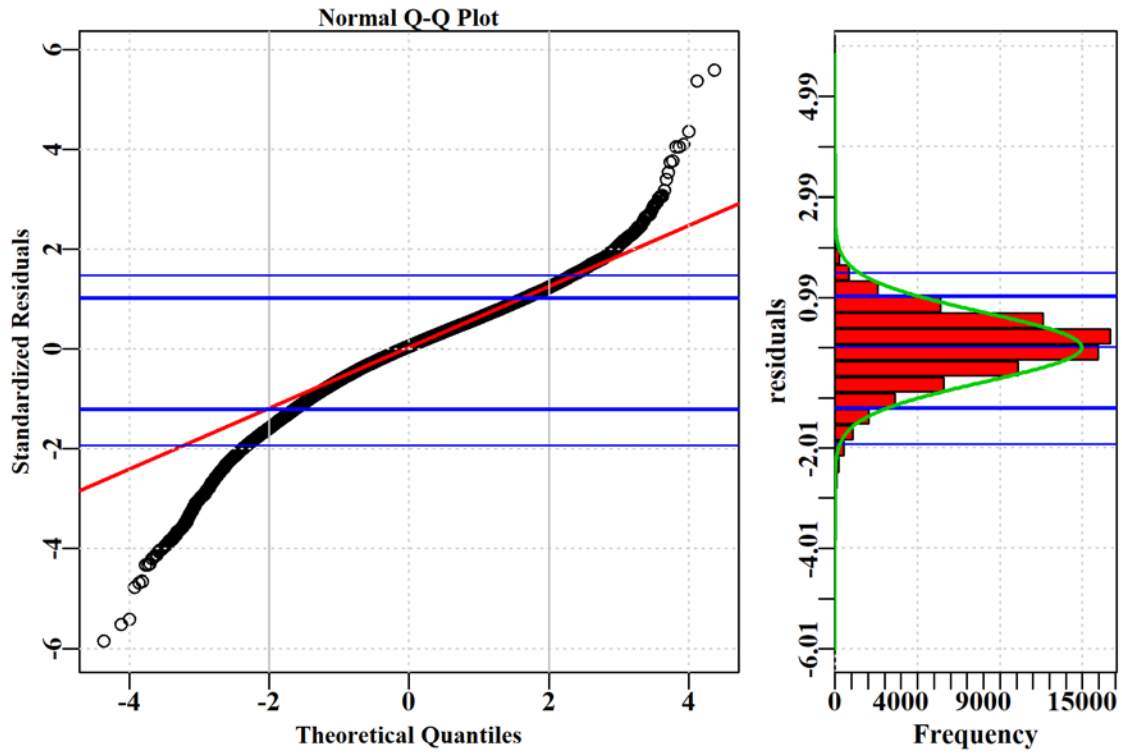

Figure 5.218. deepwaterflathead. diagnostic plots. The distribution of residuals from the optimum fit. The qqplot indicates the fit to the expected normality, while the histogram of residuals illustrates the 90% quantiles to indicate the intensity of any lack of fit at the margins of the distribution.

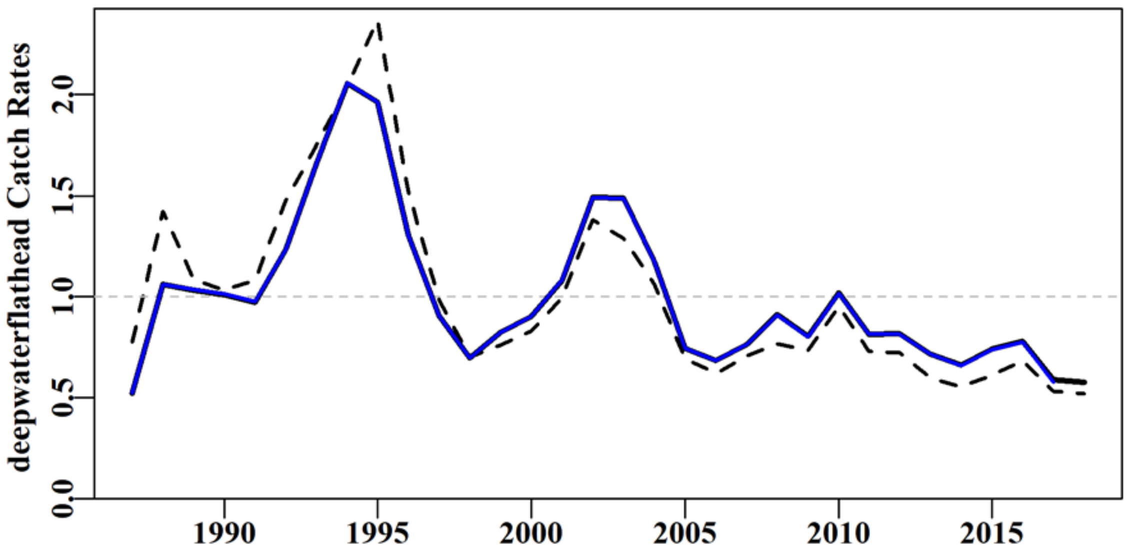

Figure 5.219. deepwaterflathead. A comparison of the previous year's standardization (blue line) with this year's. They should lie on top of each other, although small deviations may relate to data adjustments, particularly in very recent years.

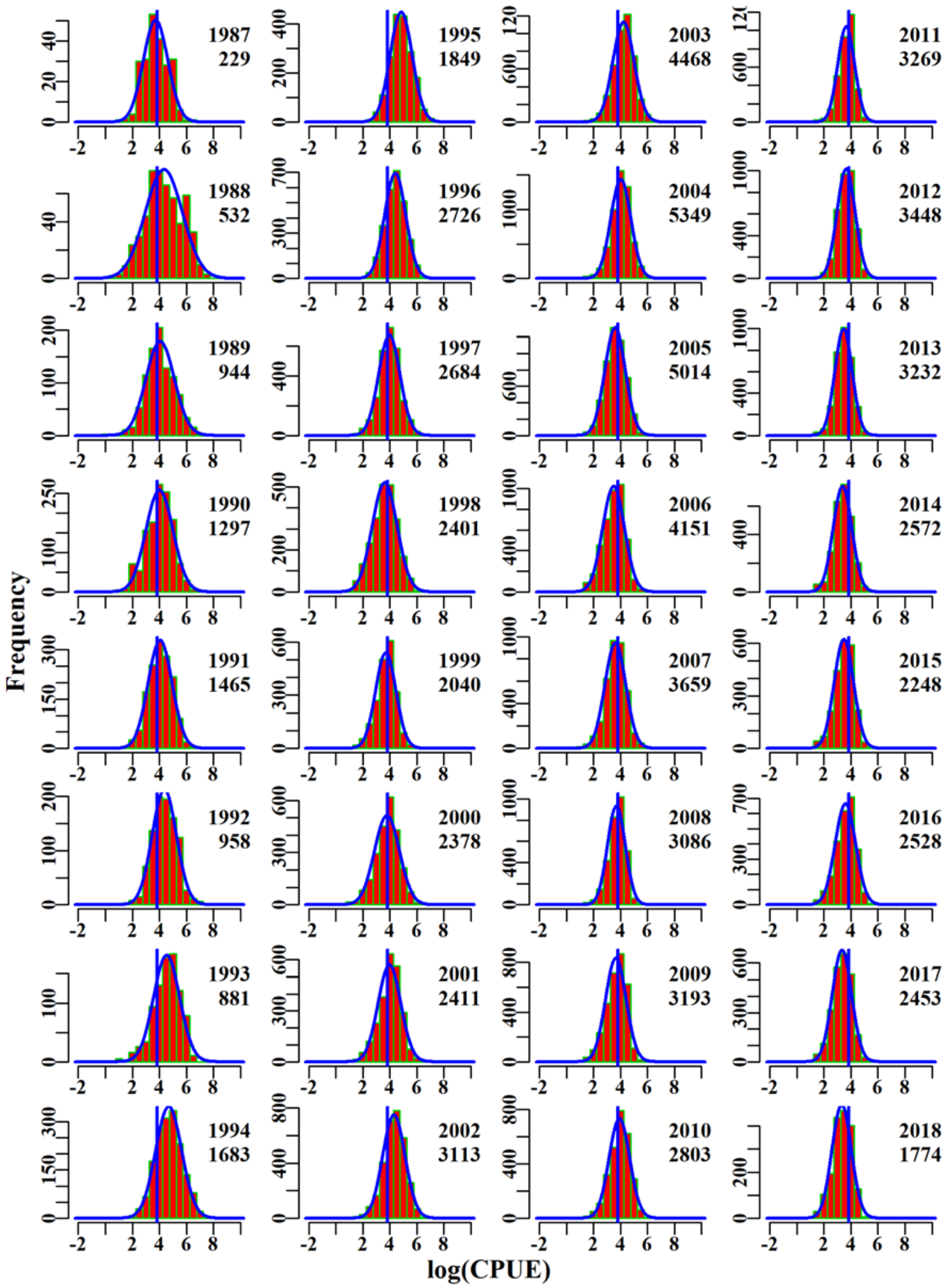

Figure 5.220. deepwaterflathead. The natural log(CPUE) for each year of data available the blue lines are normal distributions fitted to the histogram frequencies. The numbers in each plot are the year and number of records.

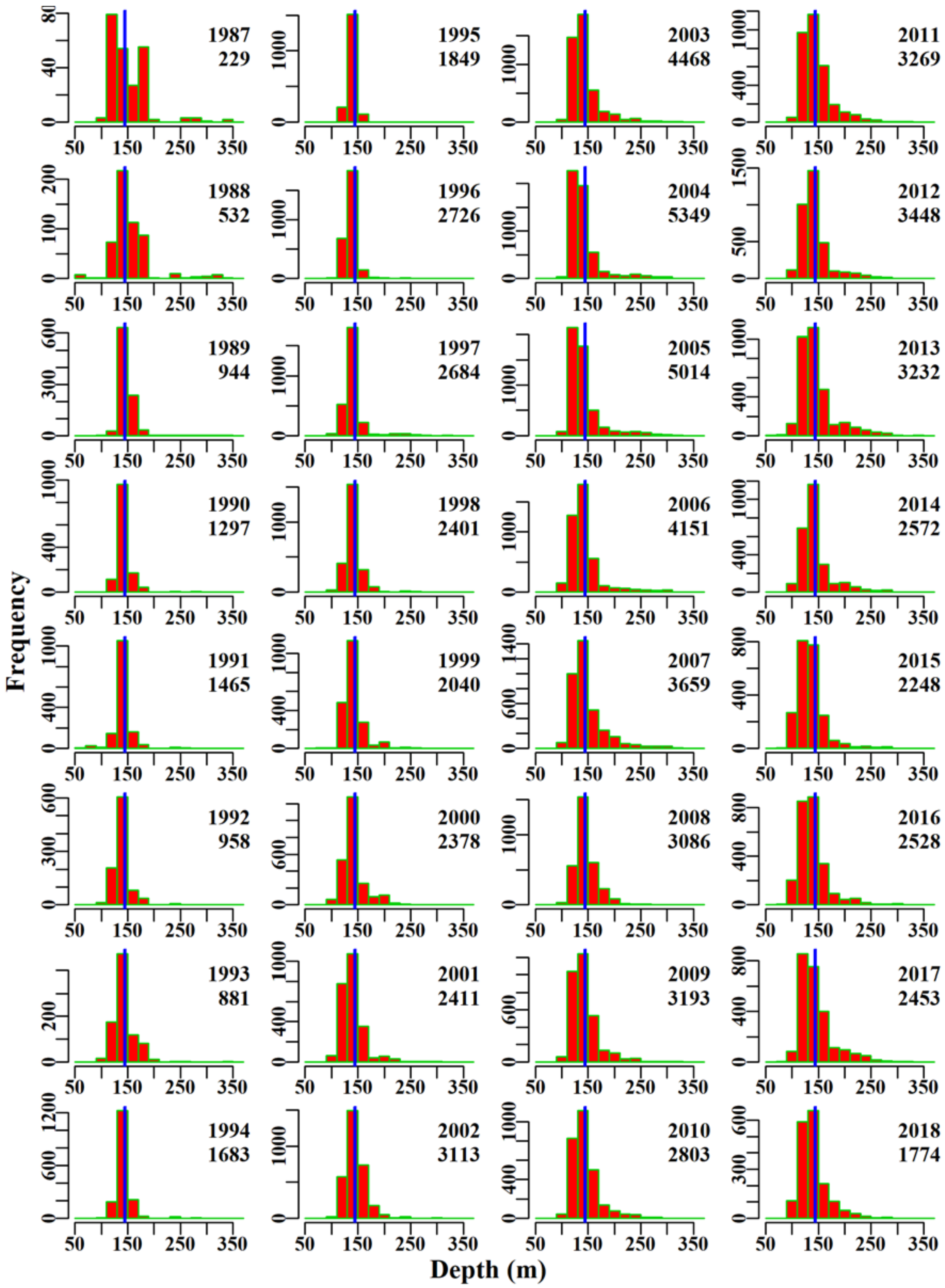

Figure 5.221. deepwaterflathead. The average Depth of fishing for each year of data available to illustrate the development of the fishery through time. The numbers in each plot are the year and number of records.

5.36 Bight Redfish

Initial data selection for Bight Redfish (FLD – 37258004 – *Centroberyx gerrardi*) in the GAB was conducted according to the detials given in Table 5.155.

A total of 9 statistical models were fitted sequentially to the available data, with the order of the non-interaction terms added based on the relative contribution of each term to model fit.

5.36.1 *Inferences*

The majority of catch of this species occurred in zone 126, again with degree longitude taking the place of zones to provide more detail.

The terms Year, DayNight, Zone, Month, Vessel and interaction two terms (Zone:Month, Zone:DepCat) had the greatest contribution to model fit, with the remaining terms each explaining < 1% of the overall variation in CPUE, based on the AIC and R^2 statistics (Table 5.158). The qqplot suggests a departure from the assumed Normal distribution as depicted by the tails of the distribution (Figure 5.225).

Annual standardized CPUE trend is flat since 1992 and oscillating between above and below average (Figure 5.222), and this is despite major changes in the distribution of the natural log(CPUE) from 2012 - 2018. The number of vessels involved in the fishery are now low (< 10 since 2006), so the interpretation of CPUE should also consider which vessels are fishing and where.

5.36.2 *Action Items and Issues*

No issues identified.

Table 5.155. bightredfish. The data selection criteria used to specify and identify the fishery data to be included in the analysis.

Property	Value
label	bightredfish
csirocode	37258004
fishery	GAB
depthrange	50 - 300
depthclass	25
zones	82, 83
methods	TW, TDO, OTT, PTB
years	1986 - 2018

Table 5.156. bightredfish. Total catch (Total; t) is the total reported in the database, number of records used in the analysis (N), reported catch (Catch; t) in the area and depth used in the analysis and number of vessels used in the analysis (Vess). GeoM is the geometric mean of catch rates (kg/hr), standard deviation (StDev) relates to the optimum model. C<30Kg denotes the amount of catch in shots of <30kg, and %<30Kg is the percent of total. The optimum model was Zone:DepCat.

	Total	N	Catch	Vess	GeoM	Opt	StDev	C<30Kg	P<30Kg
1987	47.4	152	24.6	3	51.6	2.5623	0.000	0.090	0.004
1988	88.0	404	68.1	4	60.9	2.4517	0.112	0.885	0.013
1989	173.6	737	148.2	6	62.1	1.5382	0.108	2.017	0.014
1990	290.1	1045	252.8	8	75.1	1.4084	0.106	2.220	0.009
1991	274.0	1015	220.9	7	58.7	1.2932	0.104	3.790	0.017
1992	132.1	719	117.0	3	39.7	0.9523	0.107	3.816	0.033
1993	108.7	688	105.9	5	37.2	0.9084	0.108	4.561	0.043
1994	163.6	1274	159.0	6	35.8	0.6177	0.104	7.128	0.045
1995	176.9	1396	175.4	5	30.2	0.7349	0.104	7.773	0.044
1996	334.1	2029	328.7	6	37.8	0.8966	0.102	10.358	0.032
1997	375.9	1922	366.0	7	46.2	0.9406	0.103	9.838	0.027
1998	442.2	1794	434.0	7	57.1	1.1019	0.103	8.723	0.020
1999	328.3	1495	327.2	7	52.0	0.9718	0.105	5.404	0.017
2000	397.5	1715	390.3	5	64.5	0.8591	0.104	6.689	0.017
2001	228.9	1641	227.7	5	34.9	0.6730	0.104	7.421	0.033
2002	374.5	2123	369.8	8	37.2	0.7201	0.103	9.152	0.025
2003	853.2	3144	845.0	10	57.8	0.9862	0.103	8.796	0.010
2004	882.2	3782	754.4	9	42.7	0.9540	0.103	15.491	0.021
2005	759.5	3532	718.2	10	43.0	0.9101	0.103	13.678	0.019
2006	958.4	3294	930.1	9	72.1	0.9977	0.103	10.318	0.011
2007	756.0	2744	683.8	6	67.8	0.9275	0.103	11.605	0.017
2008	661.5	2427	643.1	4	68.0	0.9927	0.104	9.294	0.014
2009	462.6	2307	453.4	4	48.4	0.9282	0.104	11.703	0.026
2010	285.3	1858	280.8	4	34.8	0.7396	0.104	10.622	0.038
2011	329.1	2184	321.2	4	30.7	0.7420	0.104	10.872	0.034
2012	266.4	1881	259.5	4	26.7	0.6629	0.105	14.511	0.056
2013	198.2	1519	191.4	4	22.9	0.5994	0.105	12.283	0.064
2014	238.1	1428	235.6	4	32.1	0.6496	0.106	8.433	0.036
2015	173.6	1193	170.5	3	29.8	0.6367	0.107	5.431	0.032
2016	437.9	1800	434.4	4	39.6	0.8866	0.105	8.295	0.019
2017	281.2	1425	277.3	3	45.9	0.9180	0.106	5.984	0.022
2018	182.0	1004	179.7	4	41.6	0.8385	0.108	5.222	0.029

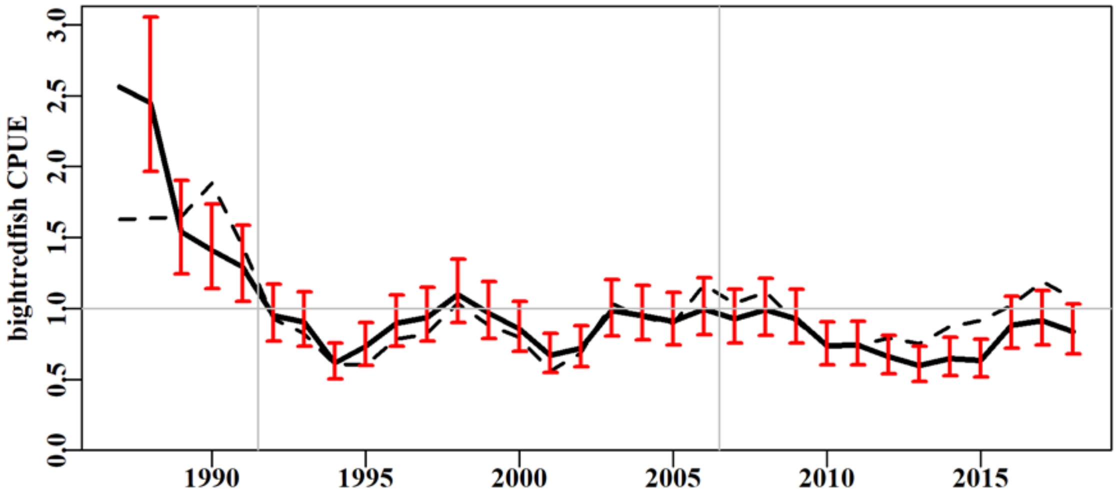

Figure 5.222. bightredfish standardization. The dashed black line represents the geometric mean catch rate, solid black line the standardized catch rates. The red bars are the 95% confidence intervals about the mean estimates. The graph scales both time-series of standardized catch rates relative to the mean of each time-series.

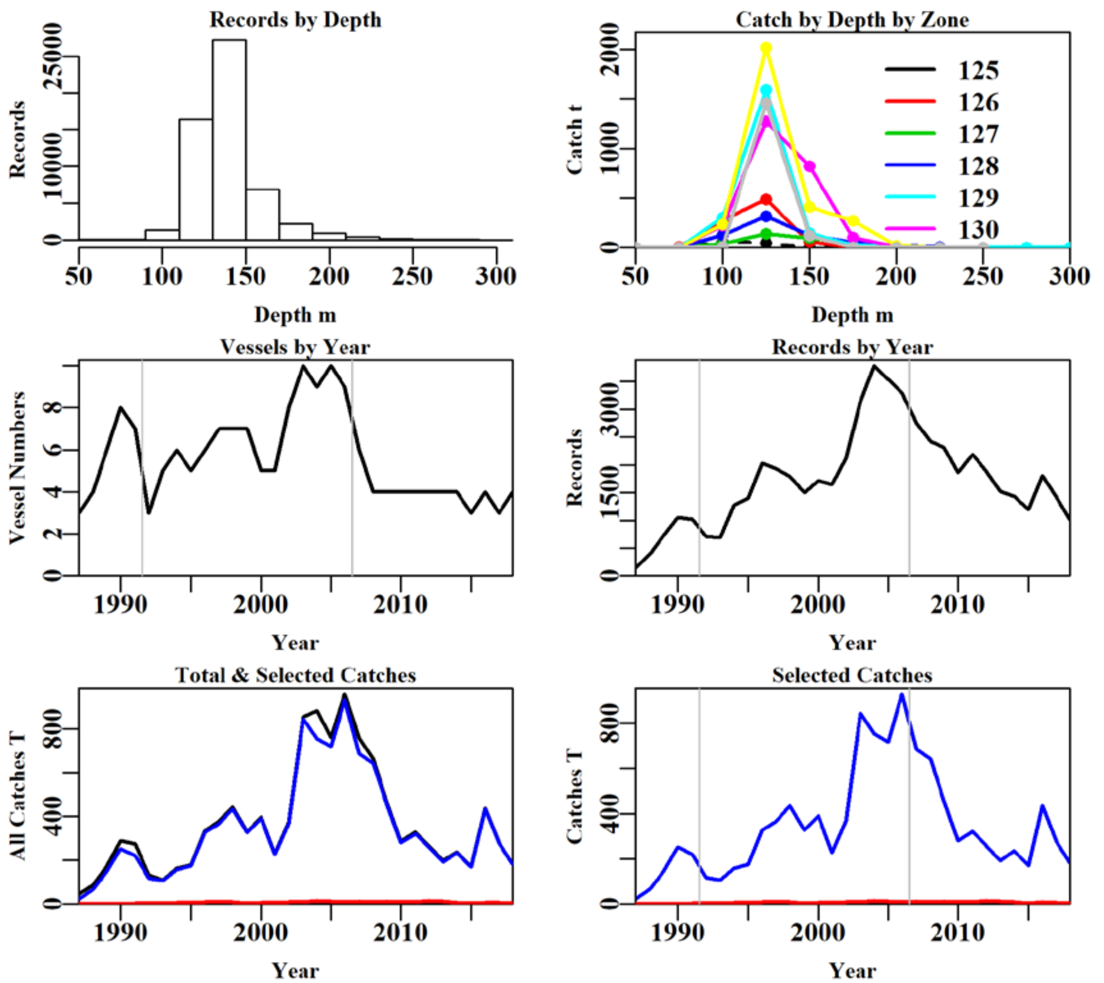

Figure 5.223. bightredfish fishery details. The bottom left plot depicts all known catches (top black line), and all selected catches used in the analysis (middle blue line); the lower red line: selected catches < 30 kg).

Table 5.157. The models used to analyse data for bightredfish.

	Model
Model1	Year
Model2	Year + DayNight
Model3	Year + DayNight + Zone
Model4	Year + DayNight + Zone + Month
Model5	Year + DayNight + Zone + Month + Vessel
Model6	Year + DayNight + Zone + Month + Vessel + DepCat
Model7	Year + DayNight + Zone + Month + Vessel + DepCat + Zone:Month
Model8	Year + DayNight + Zone + Month + Vessel + DepCat + Zone:Vessel
Model9	Year + DayNight + Zone + Month + Vessel + DepCat + Zone:DepCat

Table 5.158. bightredfish. The row names are 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_r2) and the change in adjusted R^2 (%Change). The optimum model was Zone:DepCat.

	AIC	RSS	MSS	Nobs	Npars	adj_r2	%Change
Year	33732	101570	3133	55178	32	2.9	0.00
DayNight	28259	91968	12734	55178	35	12.1	9.17
Zone	22605	82989	21713	55178	42	20.7	8.57
Month	18230	76632	28070	55178	53	26.7	6.06
Vessel	16986	74873	29830	55178	72	28.4	1.66
DepCat	16780	74567	30135	55178	82	28.7	0.28
Zone:Month	15839	73102	31601	55178	159	30.0	1.30
Zone:Vessel	16115	73335	31368	55178	209	29.7	1.02
Zone:DepCat	15285	72414	32289	55178	143	30.7	1.98

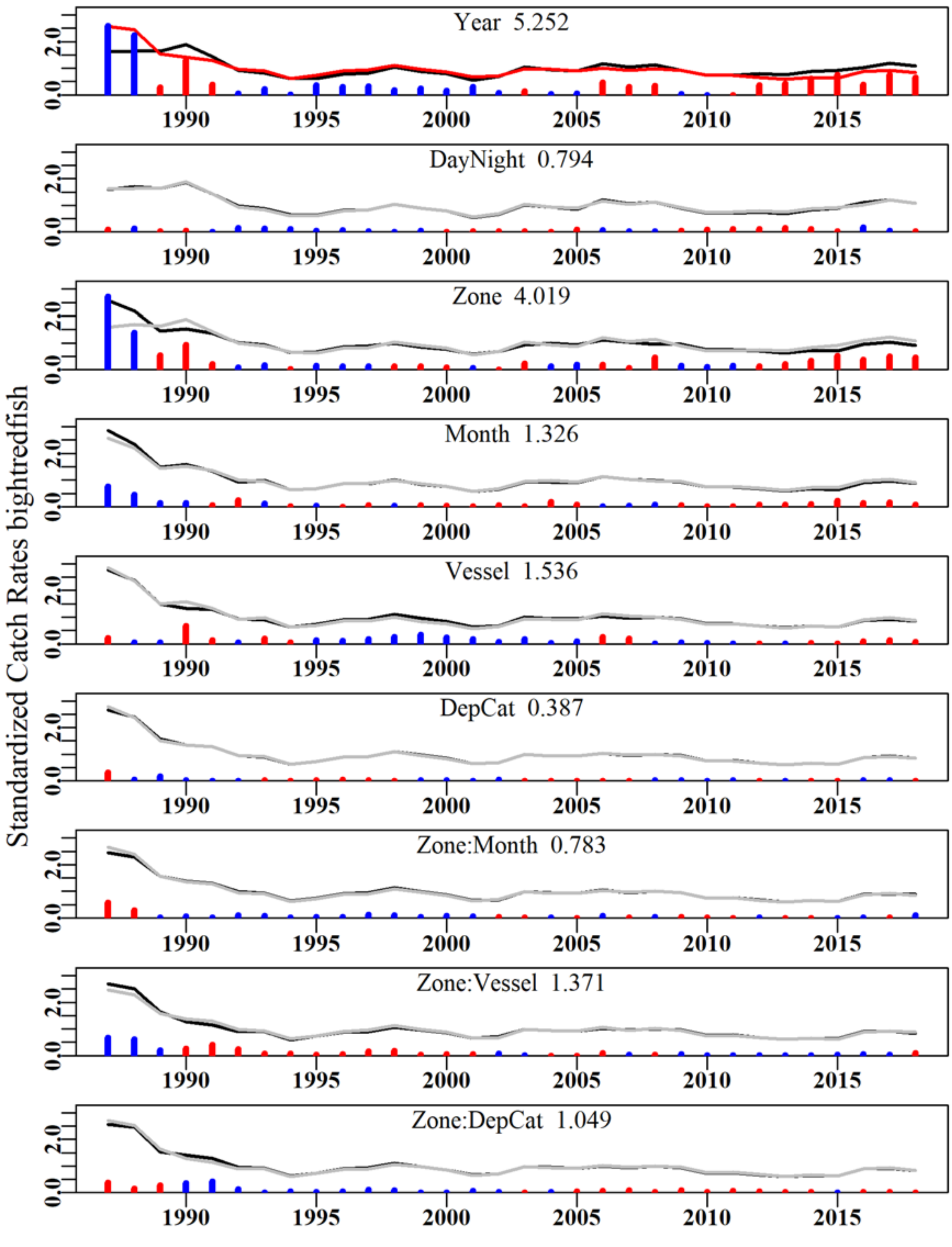

Figure 5.224. bightredfish. The influence of each factor on the optimal standardization. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by vertical bars with blue bars indicating the optimum model is higher than the geometric 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.

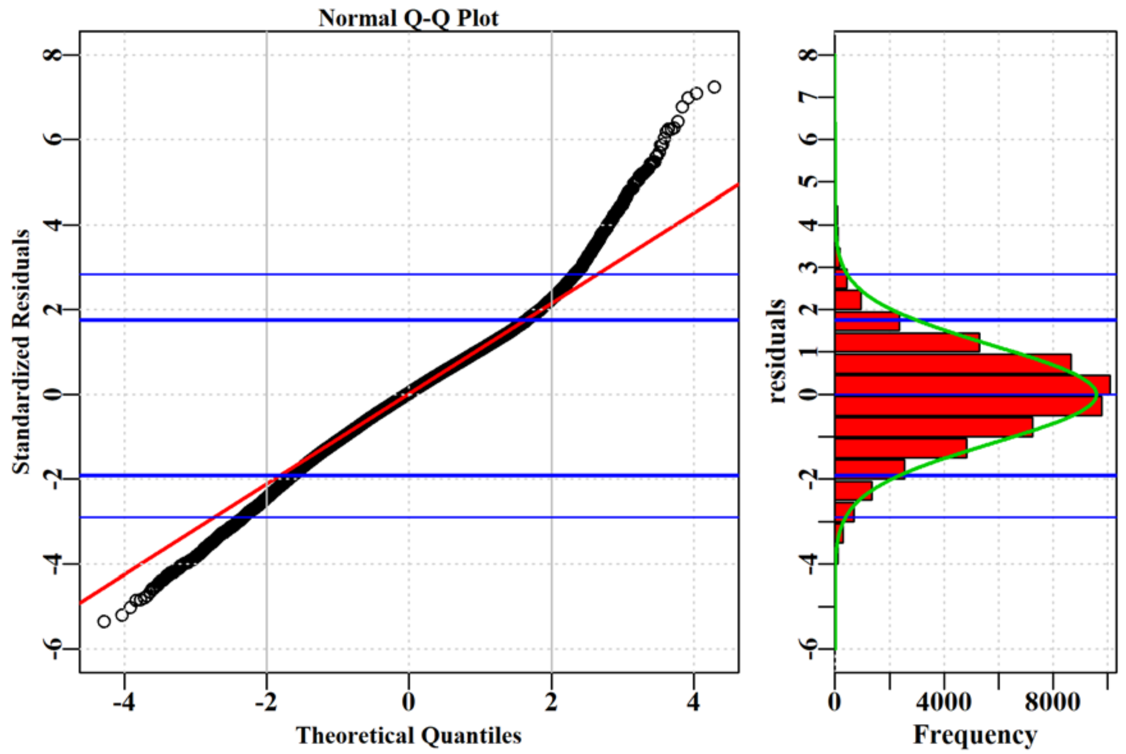

Figure 5.225. bightredfish. diagnostic plots. The distribution of residuals from the optimum fit. The qqplot indicates the fit to the expected normality, while the histogram of residuals illustrates the 90% quantiles to indicate the intensity of any lack of fit at the margins of the distribution.

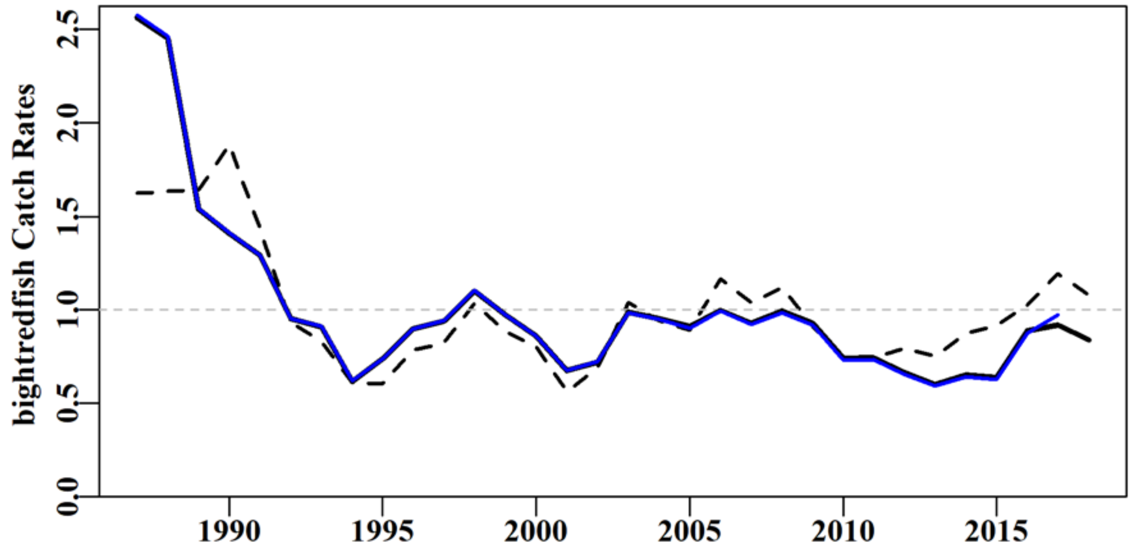

Figure 5.226. bightredfish. A comparison of the previous year's standardization (blue line) with this year's. They should lie on top of each other, although small deviations may relate to data adjustments, particularly in very recent years.

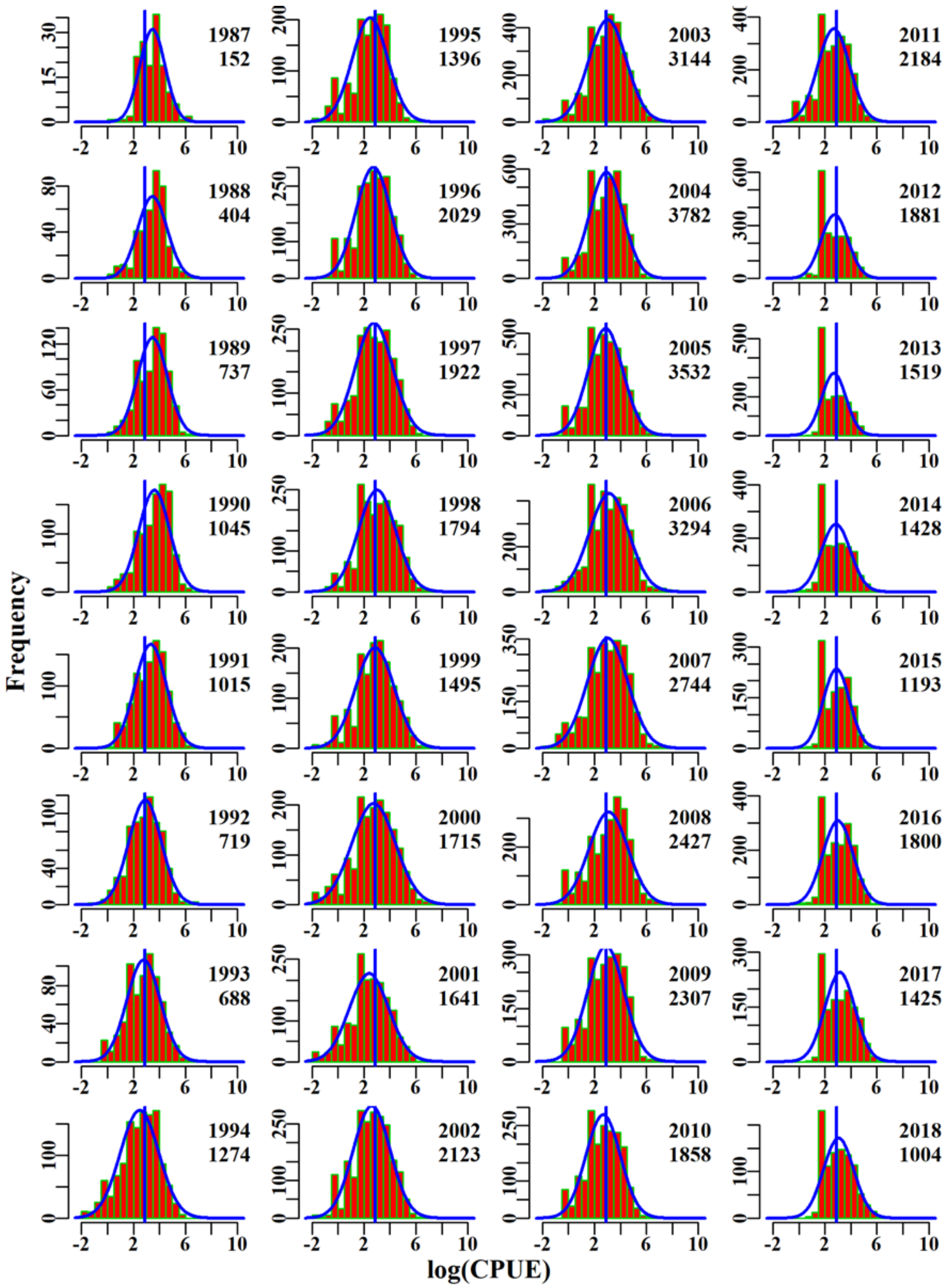

Figure 5.227. bightredfish. The natural log(CPUE) for each year of data available the blue lines are normal distributions fitted to the histogram frequencies. The numbers in each plot are the year and number of records.

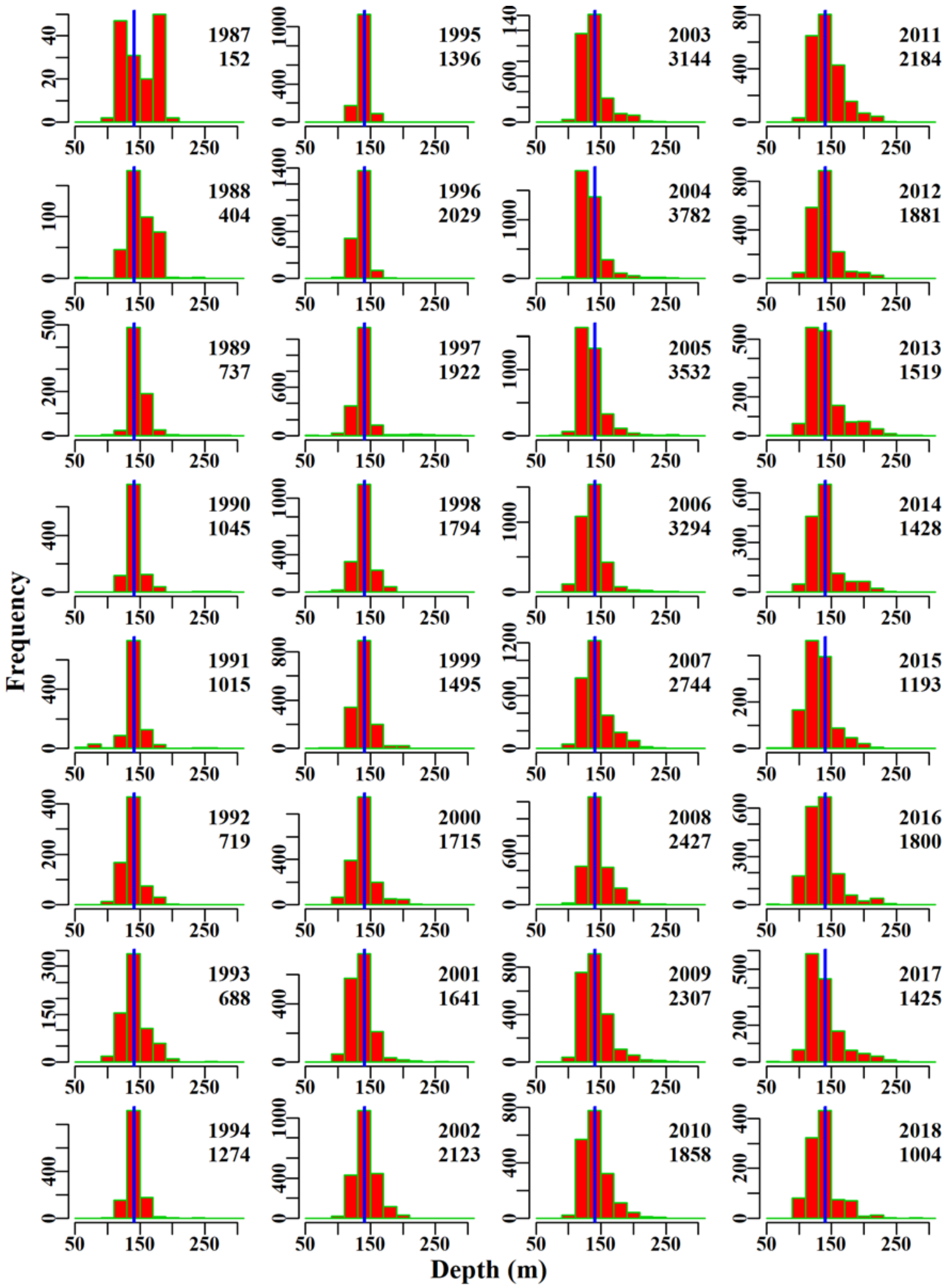

Figure 5.228. bightredfish. The average Depth of fishing for each year of data available to illustrate the development of the fishery through time. The numbers in each plot are the year and number of records.

5.37 Ribaldo 10-50

Initial data selection for Ribaldo (RBD – 37224002 – *Mora moro*) in the SET was conducted according to the detials given in Table 5.159.

A total of 8 statistical models were fitted sequentially to the available data, with the order of the non-interaction terms added based on the relative contribution of each term to model fit.

5.37.1 *Inferences*

The majority of catch of this species occurred in zone 40, 50, 20 and 30 and minimal catches in zone 10. There were increases in catches <30 kg during the 1995-2005 period.

The terms Year, Vessel, DepCat, Zone and interaction two terms (Zone:Month, Zone:DepCat) had the greatest contribution to model fit, with the remaining terms each explaining < 1% of the overall variation in CPUE, based on the AIC and R^2 statistics (Table 5.163). The qqplot suggests a departure from the assumed Normal distribution as depicted by the tails of the distribution (Figure 5.232).

The number of records by depth was highly variable and sometimes bimodal from 1986 - 1994, after which the number of records increased and the distributions became more consistent through time. The number of vessels contributing to the fishery also increased markedly after 2003. It is questionable whether the earlier years of CPUE are representative of the whole stock.

Annual standardized CPUE trend is noisy and relatively flat since 1996 and mostly below average (Figure 5.229).

5.37.2 *Action Items and Issues*

It is recommended that the geographical distribution of catches be explored to determine how representative of the entire stock's distribution the early years are.

Table 5.159. RibaldoTW. The data selection criteria used to specify and identify the fishery data to be included in the analysis.

Property	Value
label	RibaldoTW
csirocode	37224002
fishery	SET
depthrange	0 - 1000
depthclass	50
zones	10, 20, 30, 40, 50
methods	TW, TDO, OTT, PTB, TMO
years	1986 - 2018

Table 5.160. RibaldoTW. Total catch (Total; t) is the total reported in the database, number of records used in the analysis (N), reported catch (Catch; t) in the area and depth used in the analysis and number of vessels used in the analysis (Vess). GeoM is the geometric mean of catch rates (kg/hr), standard deviation (StDev) relates to the optimum model. C<30Kg denotes the amount of catch in shots of <30kg, and %<30Kg is the percent of total. The optimum model was Zone:Month.

	Total	N	Catch	Vess	GeoM	Opt	StDev	C<30Kg	P<30Kg
1986	4.1	72	3.5	11	24.3	2.2212	0.000	0.655	0.186
1987	7.9	158	7.3	14	16.5	1.3216	0.139	1.509	0.207
1988	10.9	122	7.9	22	25.7	2.0710	0.154	0.855	0.108
1989	11.3	136	7.7	14	30.2	1.8666	0.152	1.114	0.144
1990	3.7	58	2.3	11	14.0	1.4613	0.173	0.648	0.287
1991	7.8	145	5.2	22	11.9	1.4574	0.152	1.697	0.329
1992	13.3	226	11.7	26	16.1	1.4424	0.143	1.982	0.170
1993	22.8	330	19.8	37	18.8	1.2303	0.143	3.424	0.173
1994	41.9	423	23.6	30	18.5	1.3477	0.140	4.945	0.209
1995	90.3	1139	85.9	26	18.9	1.4842	0.137	10.299	0.120
1996	82.3	1483	76.6	32	15.0	1.1231	0.137	14.889	0.194
1997	103.1	1708	96.2	30	14.0	0.9704	0.136	16.008	0.166
1998	99.9	1665	91.9	33	13.6	0.9231	0.136	16.781	0.183
1999	72.1	1132	59.7	32	12.6	0.8352	0.137	13.618	0.228
2000	66.8	1173	53.8	42	10.5	0.7679	0.137	12.935	0.240
2001	82.5	1129	52.6	37	9.9	0.7120	0.137	12.191	0.232
2002	157.8	1139	57.0	30	10.0	0.6515	0.137	11.246	0.197
2003	180.8	1302	65.6	35	10.0	0.6302	0.137	12.107	0.184
2004	181.1	1253	66.1	33	11.1	0.6854	0.137	7.617	0.115
2005	90.4	649	28.4	32	9.5	0.6070	0.139	3.891	0.137
2006	122.6	619	31.2	34	11.5	0.6326	0.139	3.234	0.104
2007	78.3	398	15.3	24	8.6	0.4525	0.142	2.556	0.167
2008	78.5	356	16.9	24	9.9	0.5962	0.143	2.272	0.134
2009	105.0	554	31.9	20	11.9	0.6675	0.140	3.169	0.099
2010	91.9	672	36.6	22	11.6	0.6961	0.139	5.060	0.138
2011	93.9	849	44.1	20	9.9	0.6957	0.138	4.554	0.103
2012	107.2	707	39.8	19	11.7	0.6969	0.139	3.542	0.089
2013	122.7	916	68.4	23	14.5	0.8482	0.138	3.885	0.057
2014	138.2	855	59.9	22	12.5	0.8230	0.138	4.387	0.073
2015	99.8	743	50.8	25	13.3	0.8194	0.139	3.530	0.070
2016	66.6	599	40.2	20	12.6	0.7346	0.140	3.272	0.081
2017	80.9	590	41.5	18	15.1	0.7931	0.140	2.659	0.064
2018	94.0	626	43.7	17	13.5	0.7350	0.140	3.181	0.073

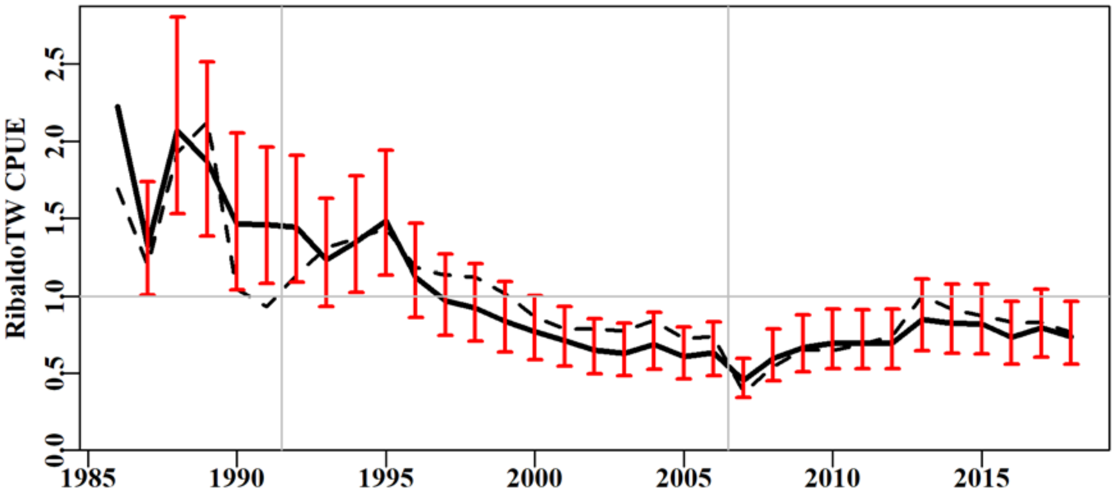

Figure 5.229. RibaldoTW standardization. The dashed black line represents the geometric mean catch rate, solid black line the standardized catch rates. The red bars are the 95% confidence intervals about the mean estimates. The graph scales both time-series of standardized catch rates relative to the mean of each time-series.

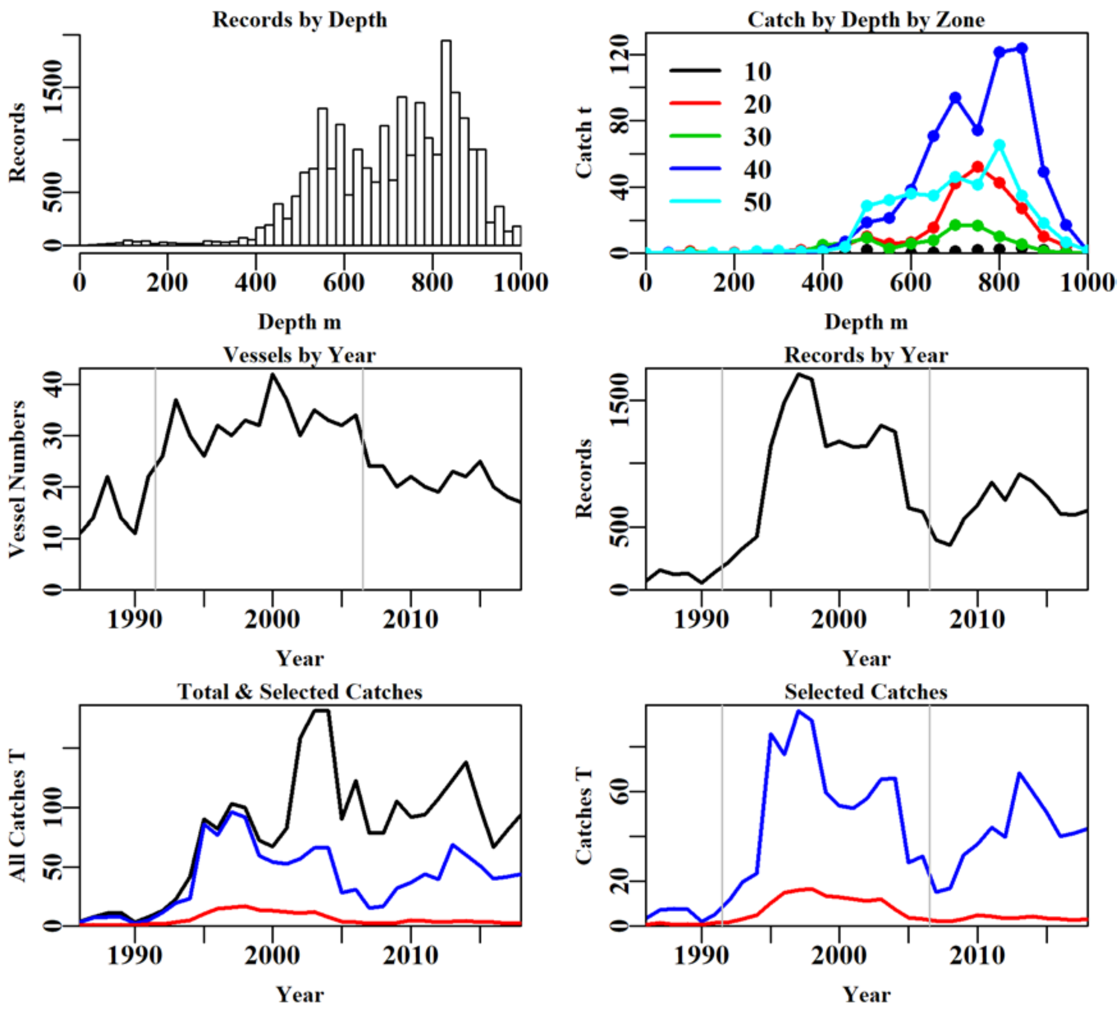

Figure 5.230. RibaldoTW fishery details. The bottom left plot depicts all known catches (top black line), and all selected catches used in the analysis (middle blue line); the lower red line: selected catches < 30 kg).

Table 5.161. RibaldoTW data selection effects. Total is the total number of records in the database, NoCE removes those records with either missing catch or effort, and then only those records are kept that meet the criteria for depth, years, zone, method and fishery.

	Total	NoCE	Depth	Years	Zones	Method	Fishery
Records	35395	27734	26745	26337	24280	23936	23926
Difference	0	7661	989	408	2057	344	10
Catch	2650.31	1622.55	1573.54	1534.95	1371.03	1343.51	1342.92
Difference	0	1027.76	49.013	38.59	163.92	27.52	0.59

Table 5.162. The models used to analyse data for RibaldoTW.

	Model
Model1	Year
Model2	Year + Vessel
Model3	Year + Vessel + DepCat
Model4	Year + Vessel + DepCat + Zone
Model5	Year + Vessel + DepCat + Zone + DayNight
Model6	Year + Vessel + DepCat + Zone + DayNight + Month
Model7	Year + Vessel + DepCat + Zone + DayNight + Month + Zone:Month
Model8	Year + Vessel + DepCat + Zone + DayNight + Month + Zone:DepCat

Table 5.163. RibaldoTW. The row names are 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_r2) and the change in adjusted R^2 (%Change). The optimum model was Zone:Month.

	AIC	RSS	MSS	Nobs	Npars	adj_r2	%Change
Year	-1138	22751	1672	23926	33	6.7	0.00
Vessel	-3367	20504	3919	23926	163	15.5	8.75
DepCat	-6701	17807	6616	23926	183	26.5	11.06
Zone	-7366	17313	7110	23926	187	28.6	2.03
DayNight	-7498	17214	7209	23926	190	29.0	0.40
Month	-7549	17161	7262	23926	201	29.1	0.18
Zone:Month	-8121	16695	7728	23926	245	30.9	1.80
Zone:DepCat	-7980	16749	7674	23926	276	30.6	1.48

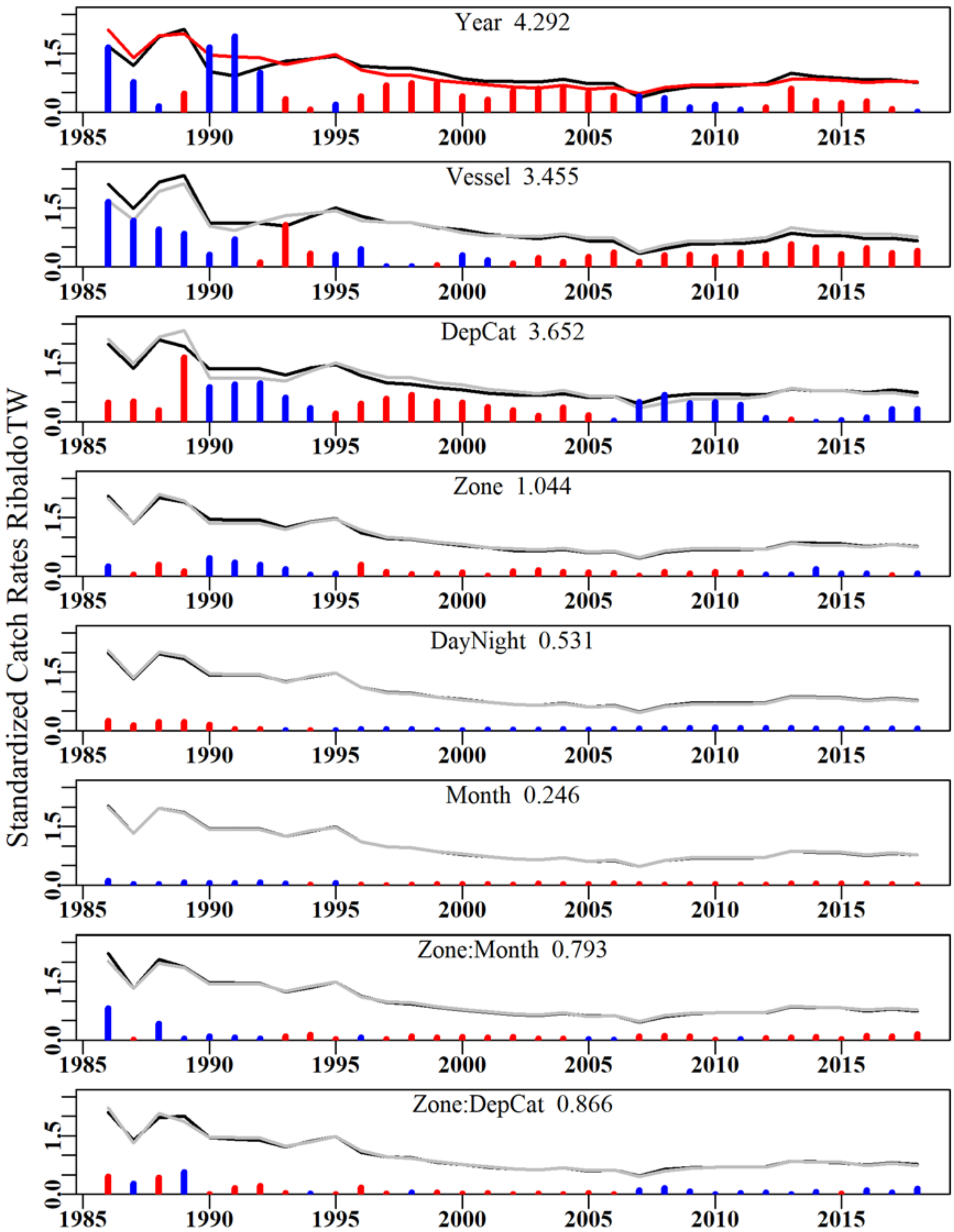

Figure 5.231. RibaldoTW. The influence of each factor on the optimal standardization. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by vertical bars with blue bars indicating the optimum model is higher than the geometric 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.

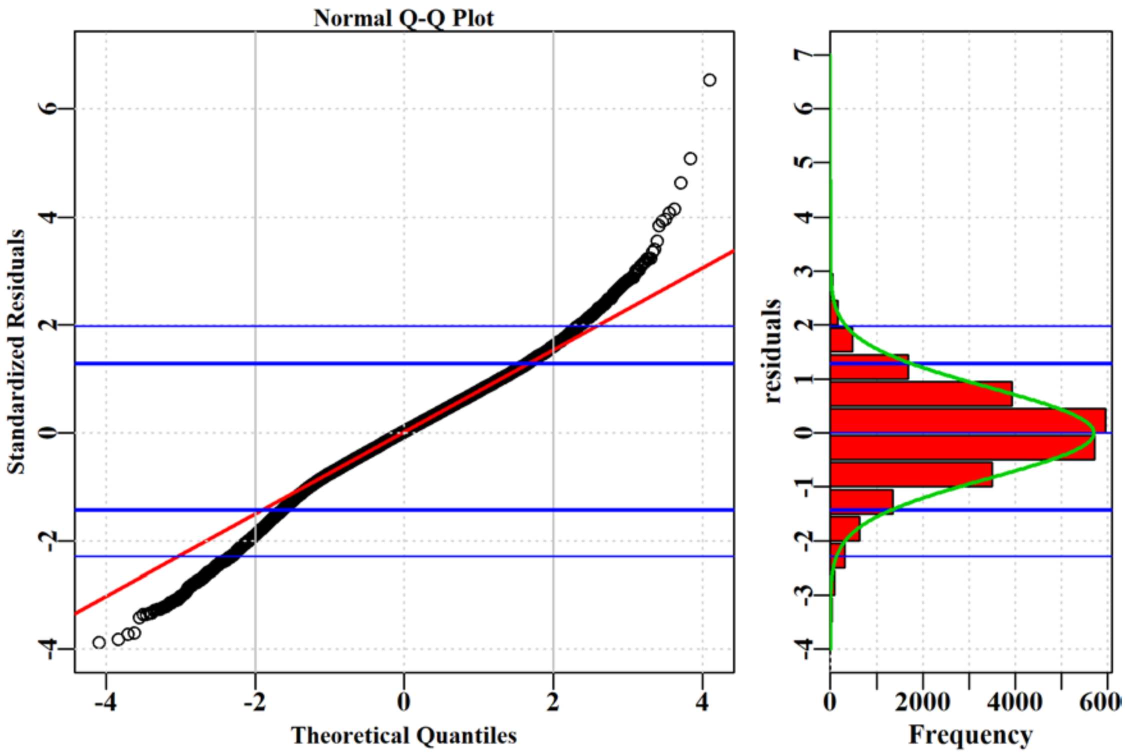

Figure 5.232. RibaldoTW. diagnostic plots. The distribution of residuals from the optimum fit. The qqplot indicates the fit to the expected normality, while the histogram of residuals illustrates the 90% quantiles to indicate the intensity of any lack of fit at the margins of the distribution.

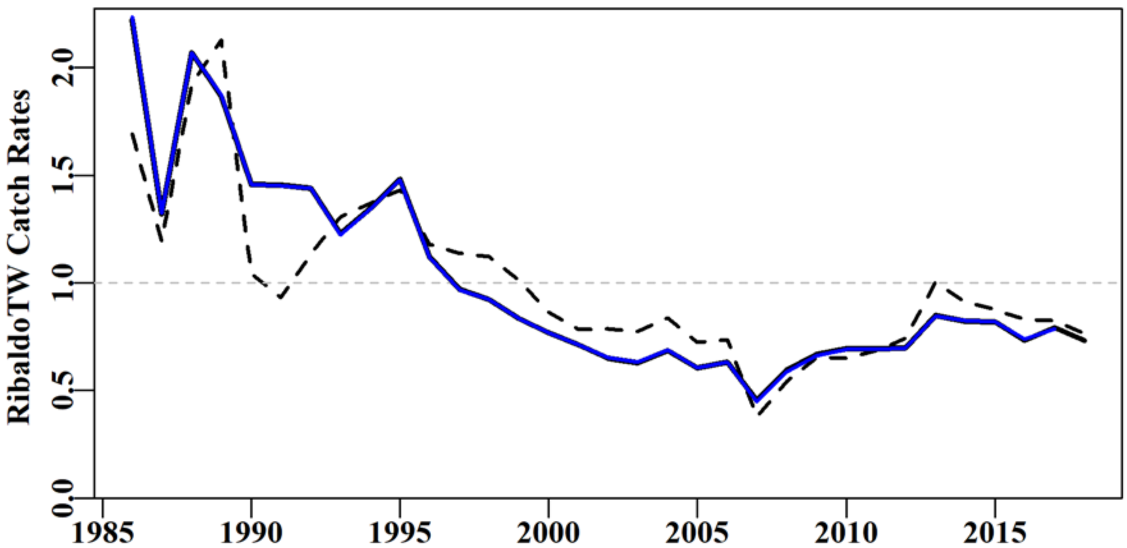

Figure 5.233. RibaldoTW. A comparison of the previous year's standardization (blue line) with this year's. They should lie on top of each other, although small deviations may relate to data adjustments, particularly in very recent years.

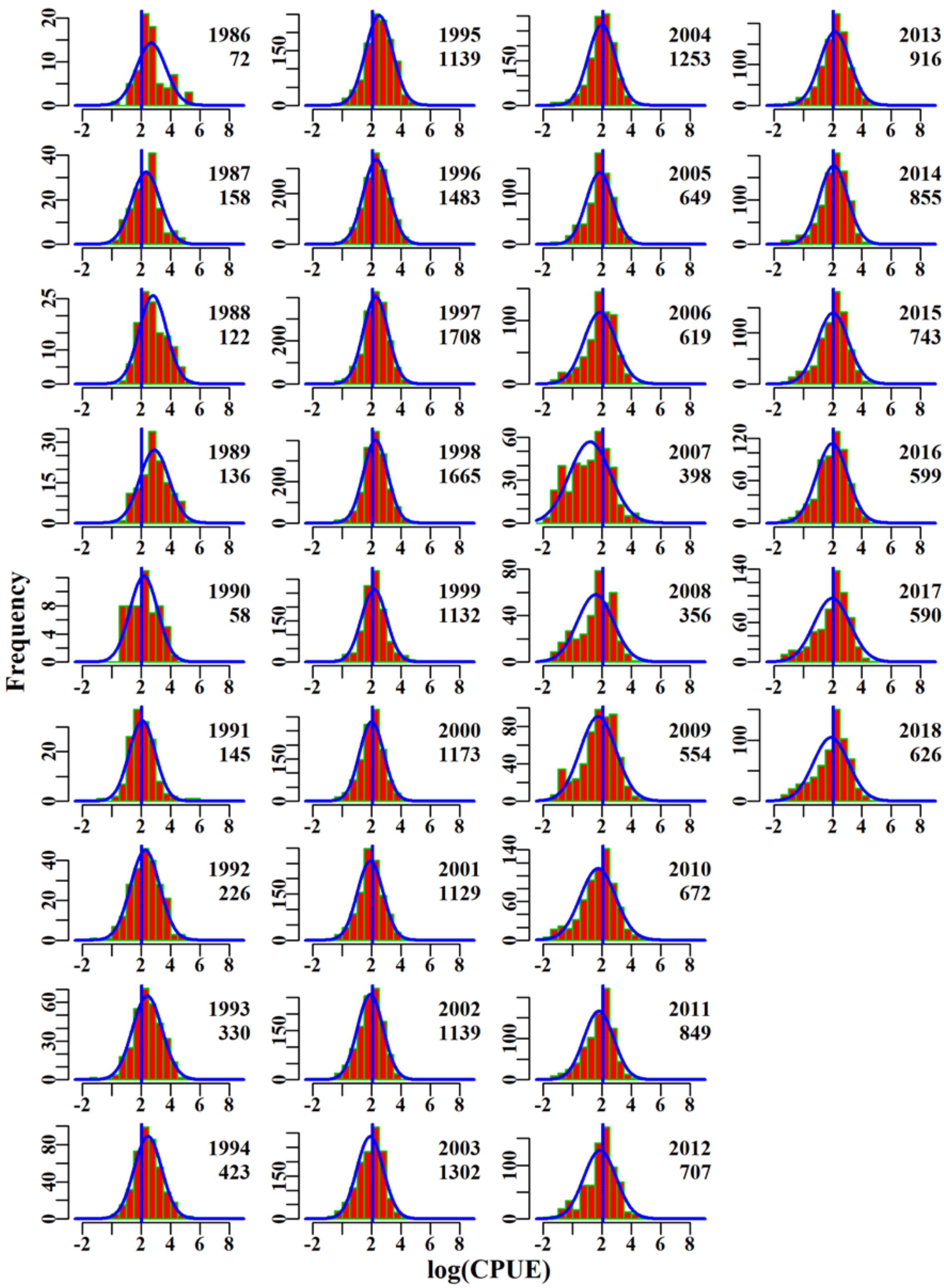

Figure 5.234. RibaldoTW. The natural log(CPUE) for each year of data available the blue lines are normal distributions fitted to the histogram frequencies. The numbers in each plot are the year and number of records.

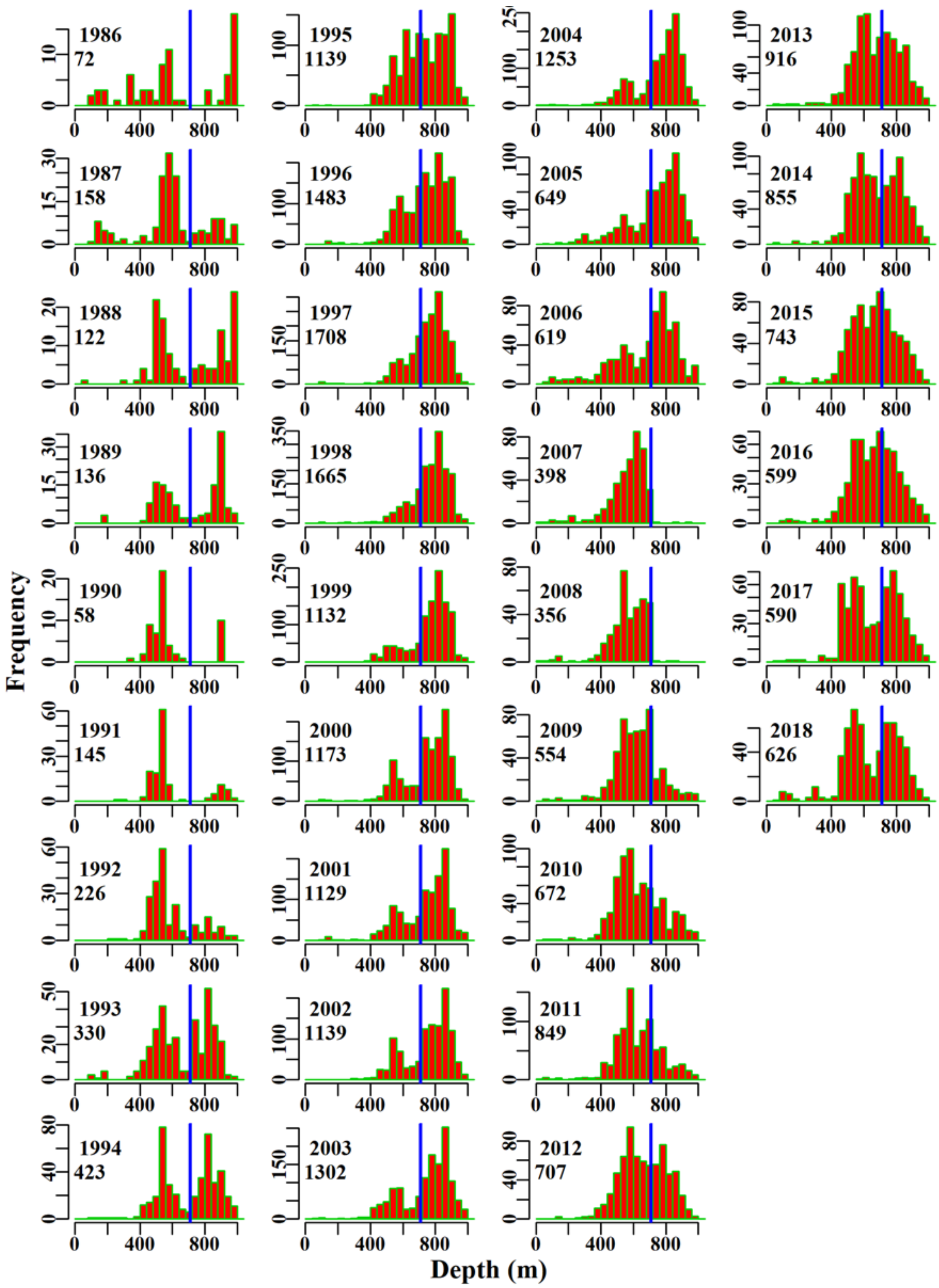

Figure 5.235. RibaldoTW. The average Depth of fishing for each year of data available to illustrate the development of the fishery through time. The numbers in each plot are the year and number of records.

5.38 RibaldoAL

Initial data selection for Ribaldo (RBD – 37224002 – *Mora moro*) in the SEN and GHT was conducted according to the detials given in Table 5.164.

A total of 7 statistical models were fitted sequentially to the available data, with the order of the non-interaction terms added based on the relative contribution of each term to model fit.

5.38.1 *Inferences*

The majority of catch occurred in zone 20, 30 and 40.

The terms Year, Vessel, DepCat, Zone and interaction term (Zone:Month) had the greatest contribution to model fit, with the remaining terms each explaining < 1% of the overall variation in CPUE, based on the AIC and R^2 statistics (Table 5.168). Few vessels have ever contributed to this fishery and the early years are only made up from the catches of low vessel numbers. The qqplot suggests that the assumed Normal distribution is valid with a slight departure as depicted by the upper tail of the distribution (Figure 5.239).

Annual standardized CPUE trend is noisy and relatively flat since about 2005 and mostly below average (Figure 5.236).

5.38.2 *Action Items and Issues*

The first two or three years of data need to be examined to determine how representative these data are of the whole stock. It may also benefit from being converted to catch-per-hook rather than catch-per-shot.

Table 5.164. RibaldoAL. The data selection criteria used to specify and identify the fishery data to be included in the analysis.

Property	Value
label	RibaldoAL
csirocode	37224002
fishery	SEN_GHT
depthrange	0 - 1000
depthclass	50
zones	20, 30, 40, 50, 83, 84, 85
methods	AL
years	2001 - 2018

Table 5.165. RibaldoAL. Total catch (Total; t) is the total reported in the database, number of records used in the analysis (N), reported catch (Catch; t) in the area and depth used in the analysis and number of vessels used in the analysis (Vess). GeoM is the geometric mean of catch rates (kg/hr), standard deviation (StDev) relates to the optimum model. C<30Kg denotes the amount of catch in shots of <30kg, and %<30Kg is the percent of total. The optimum model was Zone:Month.

	Total	N	Catch	Vess	GeoM	Opt	StDev	C<30Kg	P<30Kg
2001	82.5	63	15.7	2	268.8	1.0907	0.000	0.205	0.013
2002	157.8	257	94.7	4	455.0	2.6369	0.189	0.878	0.009
2003	180.8	336	102.7	7	359.3	1.9740	0.185	1.553	0.015
2004	181.1	713	96.6	11	131.9	1.7865	0.180	5.324	0.055
2005	90.4	308	37.1	7	127.7	1.1160	0.186	2.417	0.065
2006	122.6	605	65.4	8	123.5	1.0823	0.180	3.488	0.053
2007	78.3	386	27.8	6	73.2	0.6477	0.183	2.580	0.093
2008	78.5	401	56.8	6	168.8	0.7738	0.181	2.130	0.038
2009	105.0	432	68.3	6	218.5	0.7542	0.179	2.266	0.033
2010	91.9	381	51.7	5	175.7	0.7177	0.181	1.811	0.035
2011	93.9	354	46.3	5	163.8	0.8461	0.182	1.871	0.040
2012	107.2	293	58.4	6	282.2	0.8040	0.184	1.228	0.021
2013	122.7	275	49.8	5	241.2	0.6432	0.186	1.143	0.023
2014	138.2	266	66.1	5	503.2	0.6953	0.186	0.853	0.013
2015	99.8	196	35.0	3	270.3	0.6293	0.190	0.865	0.025
2016	66.6	238	23.2	3	129.5	0.4240	0.188	1.365	0.059
2017	80.9	296	36.8	3	149.6	0.5663	0.184	1.459	0.040
2018	94.0	140	22.0	3	229.6	0.8120	0.203	0.515	0.023

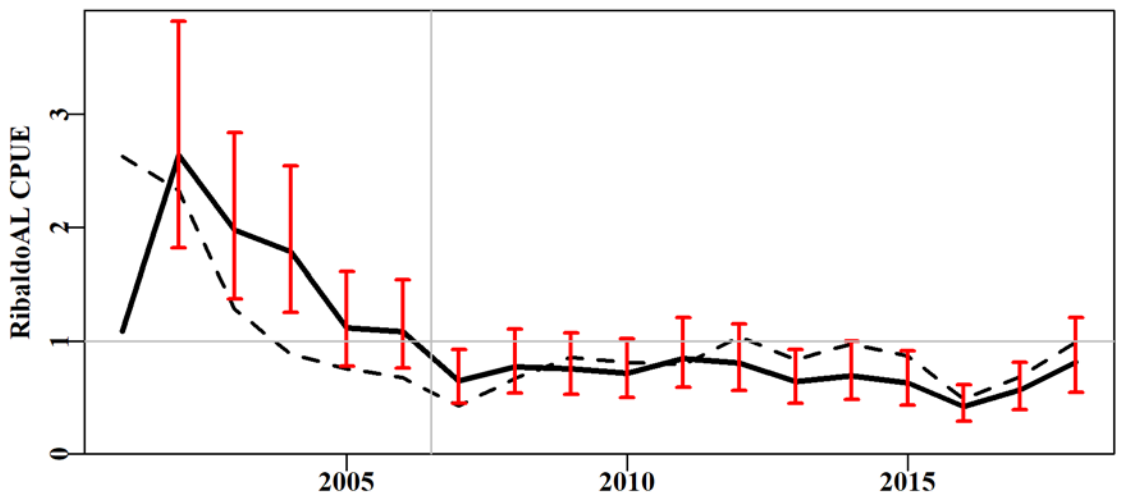

Figure 5.236. RibaldoAL standardization. The dashed black line represents the geometric mean catch rate, solid black line the standardized catch rates. The red bars are the 95% confidence intervals about the mean estimates. The graph scales both time-series of standardized catch rates relative to the mean of each time-series.

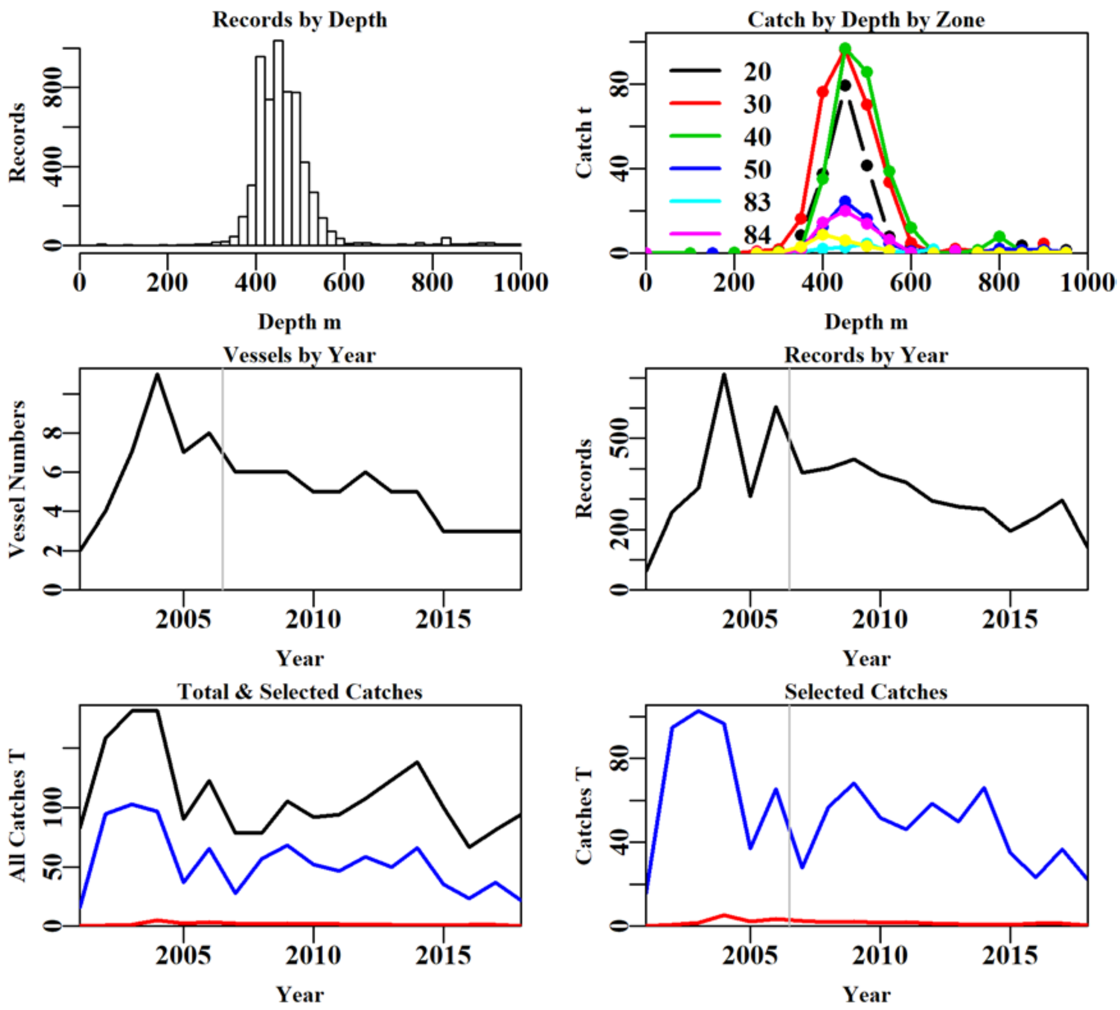

Figure 5.237. RibaldoAL fishery details. The bottom left plot depicts all known catches (top black line), and all selected catches used in the analysis (middle blue line); the lower red line: selected catches < 30 kg).

Table 5.166. RibaldoAL data selection effects. Total is the total number of records in the database, NoCE removes those records with either missing catch or effort, and then only those records are kept that meet the criteria for depth, years, zone, method and fishery.

	Total	NoCE	Depth	Years	Zones	Method	Fishery
Records	35395	34976	33920	22200	21247	5965	5940
Difference	0	419	1056	11720	953	15282	25
Catch	2650.31	2650.31	2587.31	1930.00	1828.315	957.36	954.22
Difference	0	0	63.0	657.31	101.69	870.95	3.14

Table 5.167. The models used to analyse data for RibaldoAL.

	Model
Model1	Year
Model2	Year + Vessel
Model3	Year + Vessel + DepCat
Model4	Year + Vessel + DepCat + Zone
Model5	Year + Vessel + DepCat + Zone + Month
Model6	Year + Vessel + DepCat + Zone + Month + Zone:Month
Model7	Year + Vessel + DepCat + Zone + Month + Zone:DepCat

Table 5.168. RibaldoAL. The row names are 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_r2) and the change in adjusted R^2 (%Change). The optimum model was Zone:Month.

	AIC	RSS	MSS	Nobs	Npars	adj_r2	%Change
Year	5815	15715	746	5940	18	4.3	0.00
Vessel	3724	11003	5458	5940	31	32.8	28.55
DepCat	3284	10157	6304	5940	49	37.8	4.98
Zone	3162	9929	6532	5940	55	39.1	1.33
Month	3118	9819	6642	5940	66	39.7	0.56
Zone:Month	2977	9381	7080	5940	131	41.7	2.05
Zone:DepCat	3105	9580	6881	5940	133	40.5	0.79

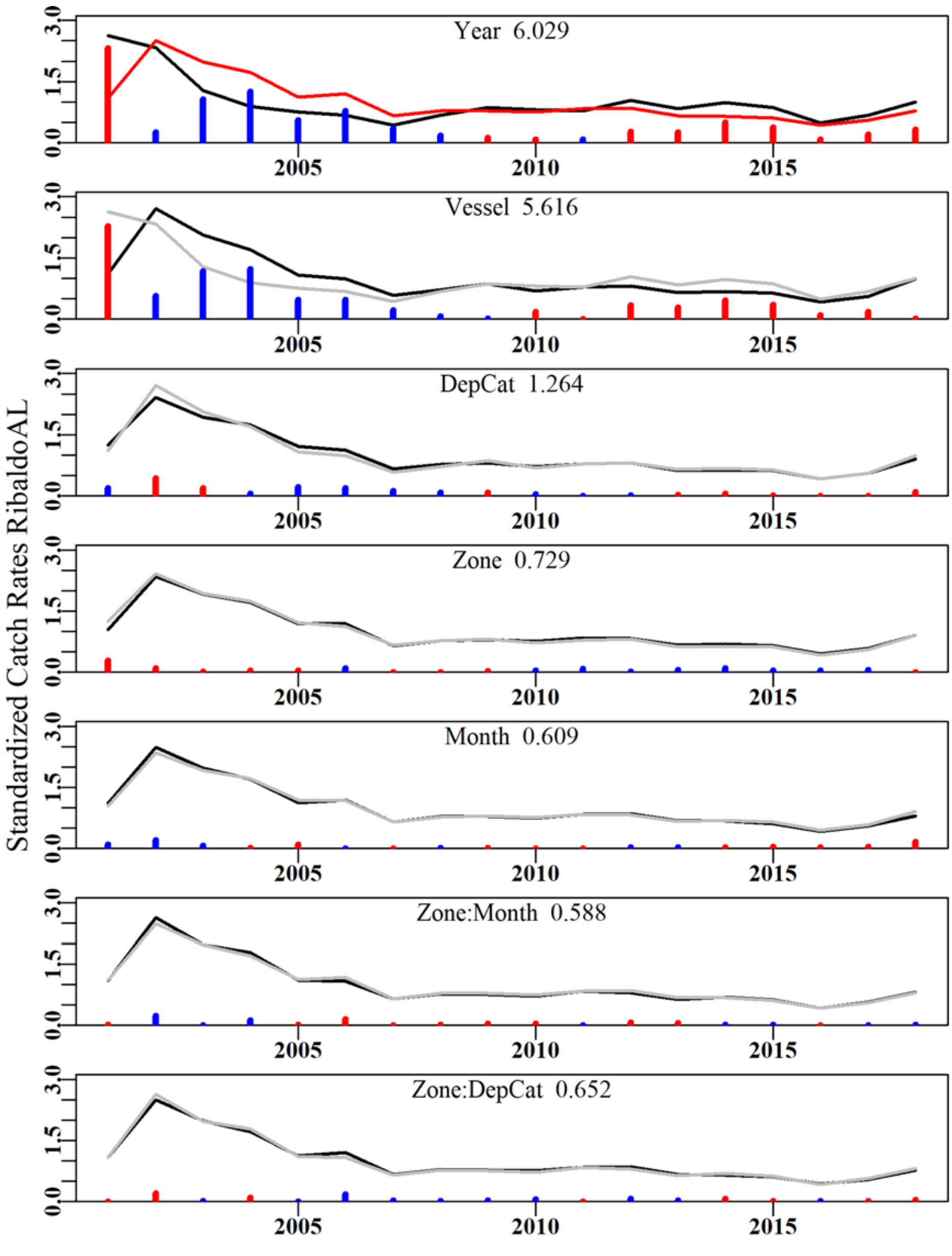

Figure 5.238. RibaldoAL. The influence of each factor on the optimal standardization. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by vertical bars with blue bars indicating the optimum model is higher than the geometric 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.

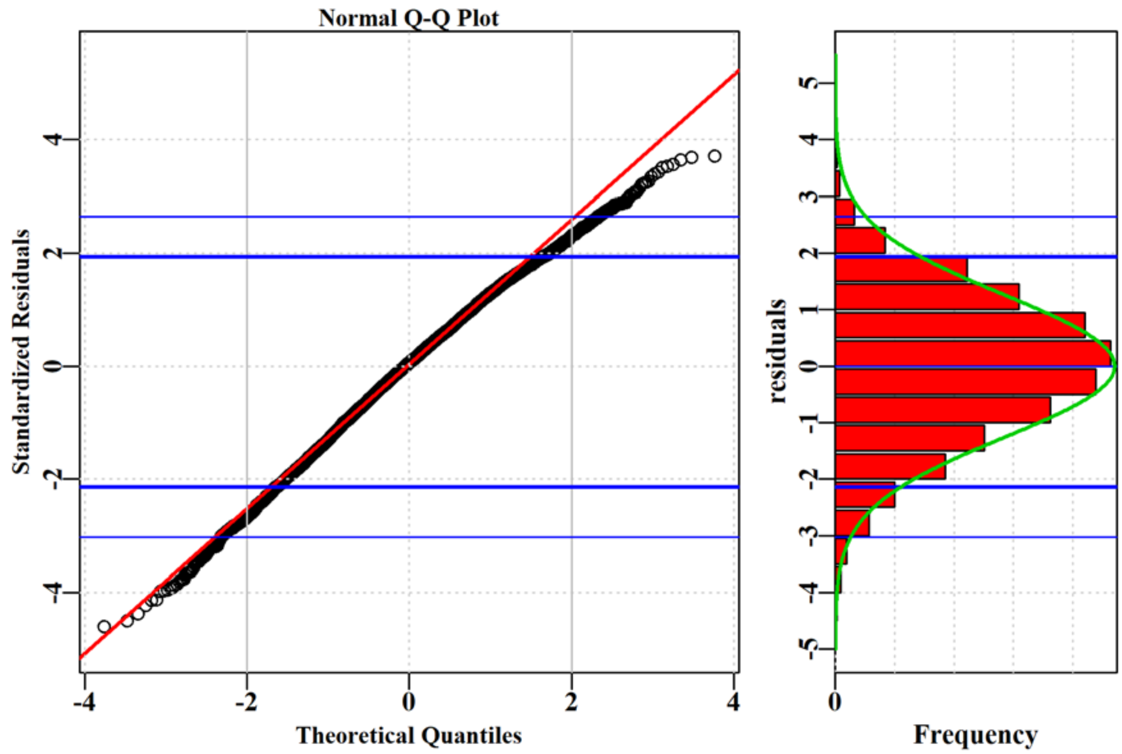

Figure 5.239. RibaldoAL. diagnostic plots. The distribution of residuals from the optimum fit. The qqplot indicates the fit to the expected normality, while the histogram of residuals illustrates the 90% quantiles to indicate the intensity of any lack of fit at the margins of the distribution.

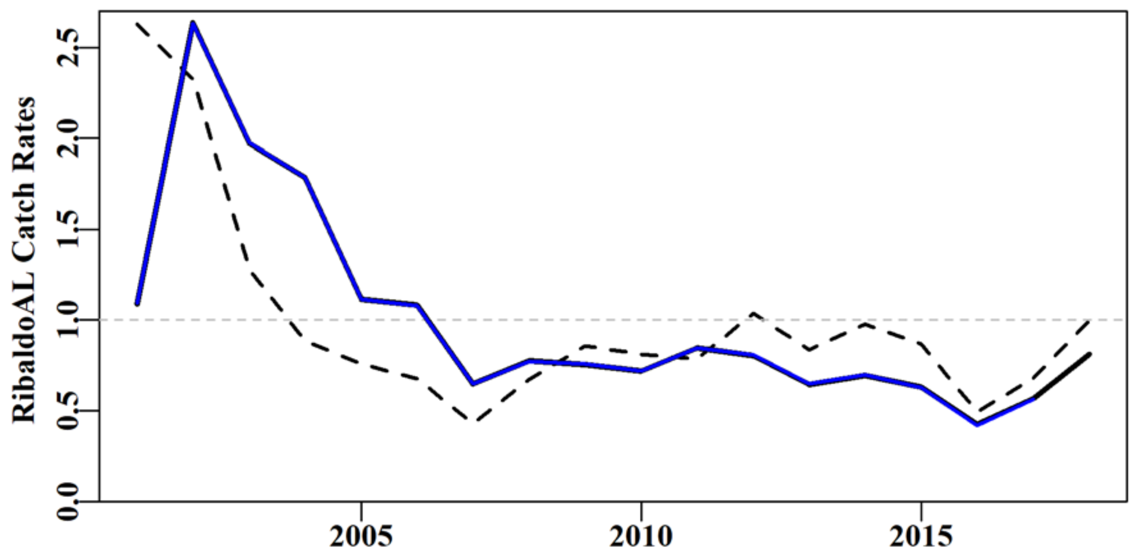

Figure 5.240. RibaldoAL. A comparison of the previous year's standardization (blue line) with this year's. They should lie on top of each other, although small deviations may relate to data adjustments, particularly in very recent years.

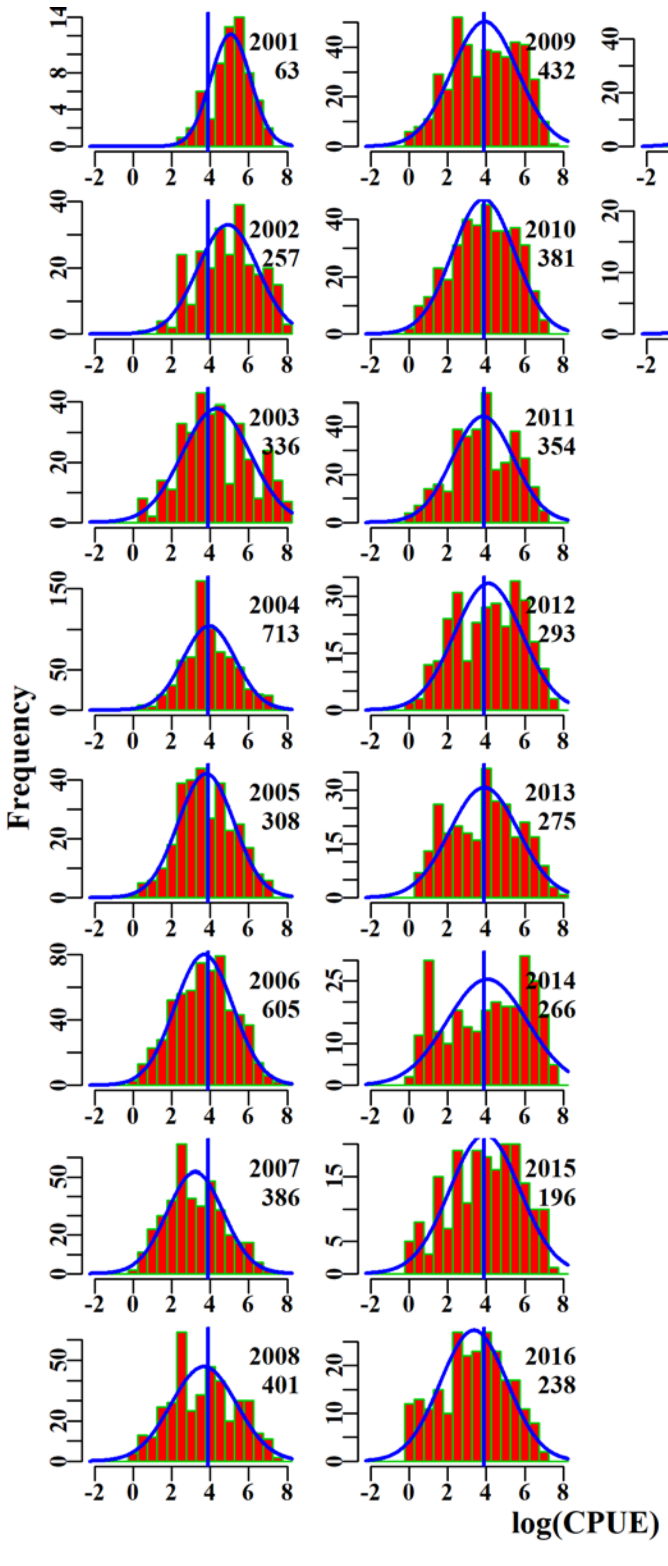

Figure 5.241. RibaldoAL. The natural log(CPUE) for each year of data available the blue lines are normal distributions fitted to the histogram frequencies. The numbers in each plot are the year and number of records.

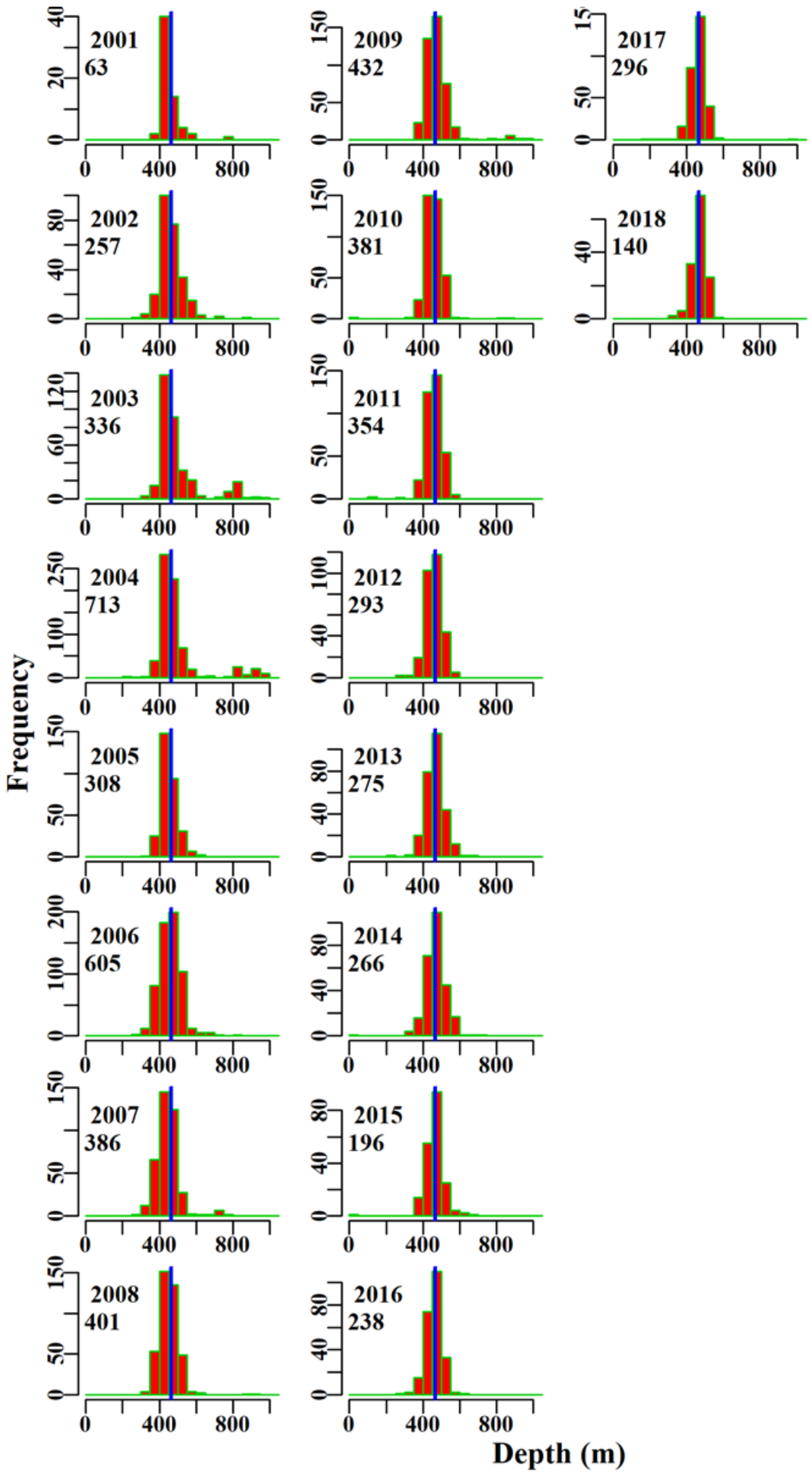

Figure 5.242. RibaldoAL. The average Depth of fishing for each year of data available to illustrate the development of the fishery through time. The numbers in each plot are the year and number of records.

5.39 Silver Trevally 1020

Initial data selection for Silver Trevally (TRE – 37337062 – *Pseudocaranx dentex*) in the SET was conducted according to the details given in Table 5.169.

A total of 8 statistical models were fitted sequentially to the available data, with the order of the non-interaction terms added based on the relative contribution of each term to model fit.

5.39.1 *Inferences*

The majority of catch of this species occurred in zone 10, followed by 20.

The terms Year, Vessel and DepCat had the greatest contribution to model fit, with the remaining terms each explaining < 1% of the overall variation in CPUE, based on the AIC and R^2 statistics (Table 5.173). The qqplot suggests that the assumed Normal distribution is valid with a slight depature as depicted at the lower tail of the distribution (Figure 5.246).

Annual standardized CPUE trend is noisy and relatively flat since about 1992 and has remained below average since 2011 (Figure 5.243). A major change from the nominal geometric mean occurs from 2013 onwards and this is mainly due to changes in the vessels operating, the depths in which they fish, and the reduced amount of fish being caught. The number of vessels actively contributing to this fishery has now reduced to low numbers and this may also be related to the recent major deviation from the nominal catch rate.

5.39.2 *Action Items and Issues*

Further exploration of the reasons behind the recent deviation of the standardized time-series from the nominal geometric mean are required to provide a more detailed explanation for these changed dynamics.

Table 5.169. SilverTrevally1020. The data selection criteria used to specify and identify the fishery data to be included in the analysis.

Property	Value
label	SilverTrevally1020
csirocode	37337062
fishery	SET
depthrange	0 - 200
depthclass	20
zones	10, 20
methods	TW, TDO, OTT, PTB, TMO
years	1986 - 2018

Table 5.170. SilverTrevally1020. Total catch (Total; t) is the total reported in the database, number of records used in the analysis (N), reported catch (Catch; t) in the area and depth used in the analysis and number of vessels used in the analysis (Vess). GeoM is the geometric mean of catch rates (kg/hr), standard deviation (StDev) relates to the optimum model. C<30Kg denotes the amount of catch in shots of <30kg, and %<30Kg is the percent of total. The optimum model was Zone:Month.

	Total	N	Catch	Vess	GeoM	Opt	StDev	C<30Kg	P<30Kg
1986	469.5	1976	306.3	74	49.4	1.0968	0.000	14.045	0.046
1987	198.5	1253	133.7	64	43.6	1.2886	0.057	9.101	0.068
1988	278.5	1581	244.0	56	51.4	1.4831	0.052	12.112	0.050
1989	376.2	2193	332.7	62	60.6	1.8875	0.048	13.682	0.041
1990	450.4	2081	344.2	53	59.7	2.2192	0.050	11.655	0.034
1991	340.7	2210	250.2	50	43.7	1.9294	0.050	14.181	0.057
1992	296.5	1688	249.0	45	40.9	1.1818	0.053	11.715	0.047
1993	377.7	2264	281.1	49	42.7	1.1884	0.050	16.074	0.057
1994	392.8	3282	360.0	48	38.8	1.0082	0.047	24.712	0.069
1995	413.4	3347	383.2	48	44.6	1.1356	0.046	25.171	0.066
1996	340.6	3208	315.3	53	39.8	1.0288	0.047	24.514	0.078
1997	328.8	2815	292.9	56	53.7	1.0038	0.048	19.728	0.067
1998	210.1	2287	177.6	46	39.0	0.7675	0.049	17.833	0.100
1999	166.1	1857	114.4	45	31.9	0.7524	0.052	13.539	0.118
2000	154.8	2010	122.9	49	26.3	0.5819	0.051	14.713	0.120
2001	270.2	3255	229.0	45	36.3	0.7041	0.046	21.930	0.096
2002	232.8	2776	209.6	44	38.3	0.6612	0.048	17.710	0.085
2003	337.9	2732	277.9	49	59.7	0.7062	0.048	16.611	0.060
2004	458.2	3316	365.1	45	64.3	0.8642	0.047	19.378	0.053
2005	291.1	2301	240.1	43	59.0	0.7520	0.050	13.644	0.057
2006	247.3	1684	209.0	39	82.8	0.8174	0.053	9.278	0.044
2007	172.7	832	115.4	22	89.2	0.7962	0.064	4.408	0.038
2008	128.4	1054	95.8	23	49.0	0.9187	0.060	6.864	0.072
2009	164.1	1142	135.3	23	57.8	0.9242	0.059	6.689	0.049
2010	240.2	1231	191.3	24	99.9	1.1746	0.058	6.212	0.032
2011	193.5	1103	175.3	20	112.9	1.0051	0.059	5.548	0.032
2012	139.7	954	129.0	21	99.1	0.7908	0.062	5.062	0.039
2013	122.8	720	112.9	19	97.4	0.8400	0.067	3.918	0.035
2014	107.0	887	97.8	20	62.4	0.6417	0.063	5.216	0.053
2015	79.5	570	73.1	22	69.7	0.6710	0.073	2.914	0.040
2016	52.4	388	49.5	18	109.4	0.8032	0.084	1.858	0.038
2017	52.9	398	45.0	15	78.0	0.7318	0.083	2.172	0.048
2018	37.7	194	29.3	13	132.7	0.6446	0.115	1.180	0.040

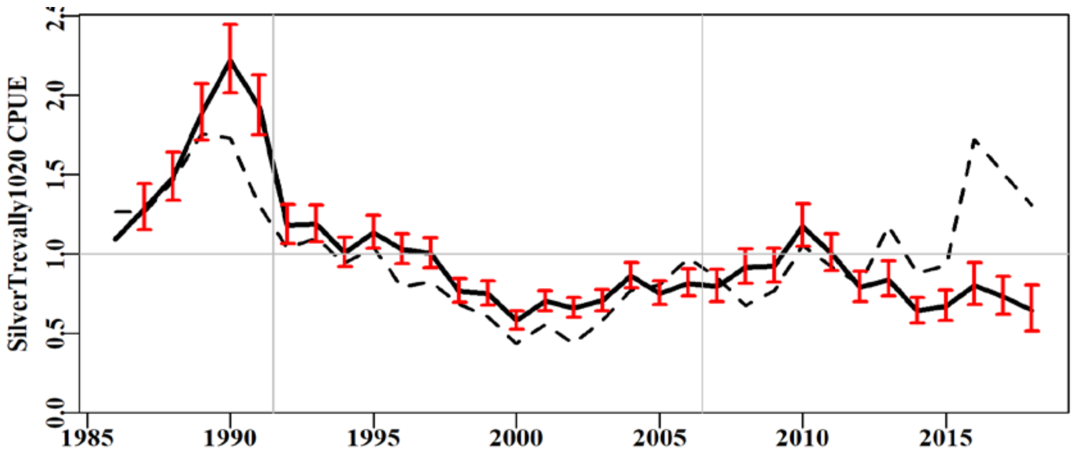

Figure 5.243. SilverTrevally1020 standardization. The dashed black line represents the geometric mean catch rate, solid black line the standardized catch rates. The red bars are the 95% confidence intervals about the mean estimates. The graph scales both time-series of standardized catch rates relative to the mean of each time-series.

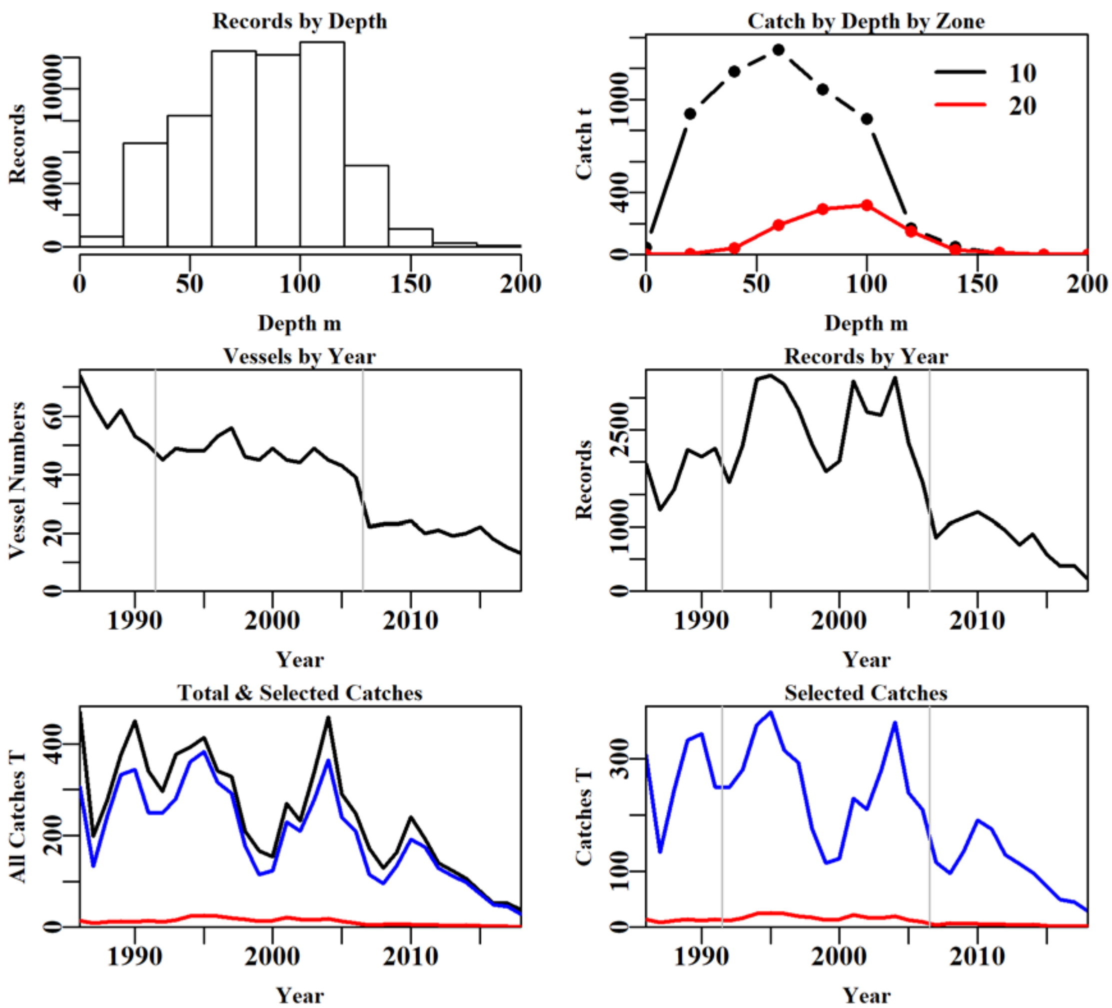

Figure 5.244. SilverTrevally1020 fishery details. The bottom left plot depicts all known catches (top black line), and all selected catches used in the analysis (middle blue line); the lower red line: selected catches < 30 kg).

Table 5.171. SilverTrevally1020 data selection effects. Total is the total number of records in the database, NoCE removes those records with either missing catch or effort, and then only those records are kept that meet the criteria for depth, years, zone, method and fishery.

	Total	NoCE	Depth	Years	Zones	Method	Fishery
Records	76142	72975	71390	70511	61030	59645	59589
Difference	0	3167	1585	879	9481	1385	56
Catch	8277.82	8101.43	7813.39	7659.27	6733.82	6694.53	6687.56
Difference	0	176.39	288.05	154.12	925.45	39.29	6.97

Table 5.172. The models used to analyse data for SilverTrevally1020.

	Model
Model1	Year
Model2	Year + Vessel
Model3	Year + Vessel + DepCat
Model4	Year + Vessel + DepCat + Month
Model5	Year + Vessel + DepCat + Month + DayNight
Model6	Year + Vessel + DepCat + Month + DayNight + Zone
Model7	Year + Vessel + DepCat + Month + DayNight + Zone + Zone:Month
Model8	Year + Vessel + DepCat + Month + DayNight + Zone + Zone:DepCat

Table 5.173. SilverTrevally1020. The row names are 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_r2) and the change in adjusted R^2 (%Change). The optimum model was Zone:Month.

	AIC	RSS	MSS	Nobs	Npars	adj_r2	%Change
Year	62574	170111	8008	59589	33	4.4	0.00
Vessel	48601	133843	44275	59589	191	24.6	20.17
DepCat	45300	126588	51531	59589	201	28.7	4.07
Month	44586	125034	53085	59589	212	29.6	0.86
DayNight	43748	123274	54845	59589	215	30.5	0.99
Zone	43720	123214	54905	59589	216	30.6	0.03
Zone:Month	43578	122873	55246	59589	227	30.8	0.18
Zone:DepCat	43696	123125	54993	59589	225	30.6	0.04

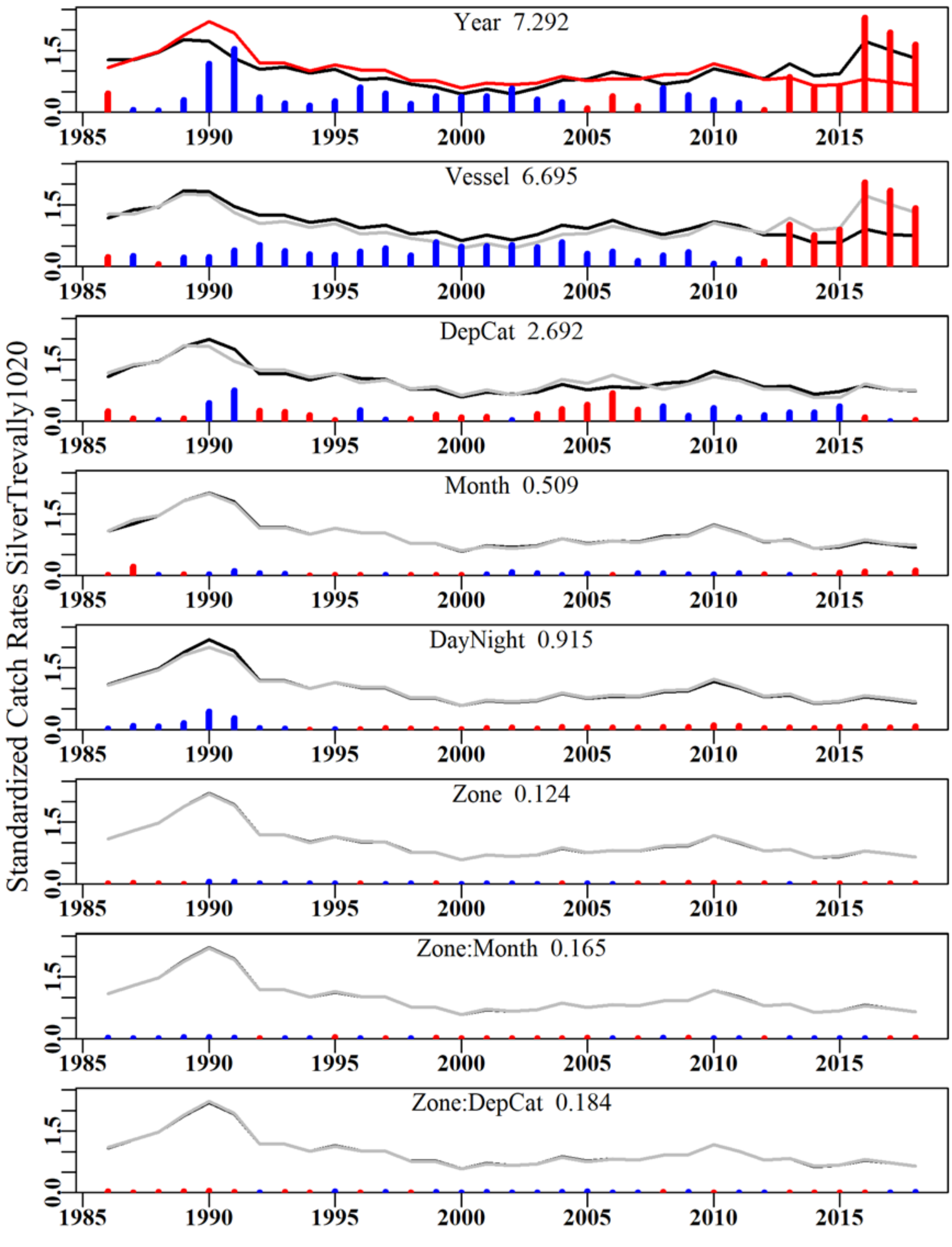

Figure 5.245. SilverTrevally1020. The influence of each factor on the optimal standardization. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by vertical bars with blue bars indicating the optimum model is higher than 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.

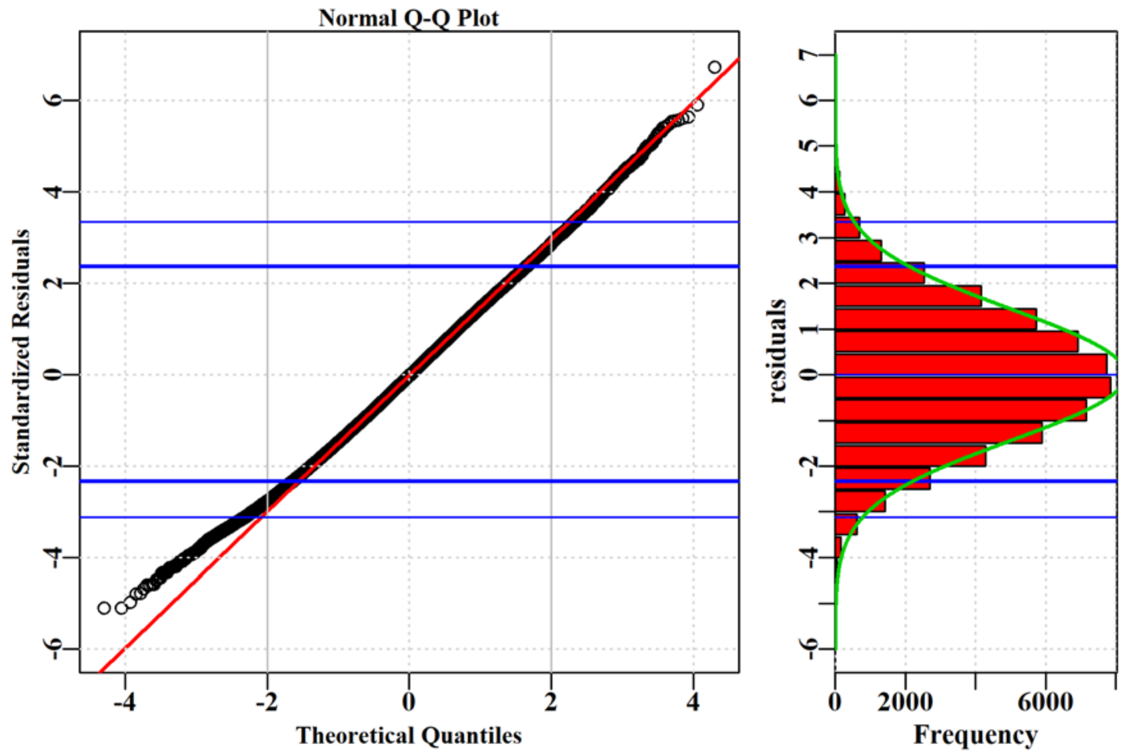

Figure 5.246. SilverTrevally1020. diagnostic plots. The distribution of residuals from the optimum fit. The qqplot indicates the fit to the expected normality, while the histogram of residuals illustrates the 90% quantiles to indicate the intensity of any lack of fit at the margins of the distribution.

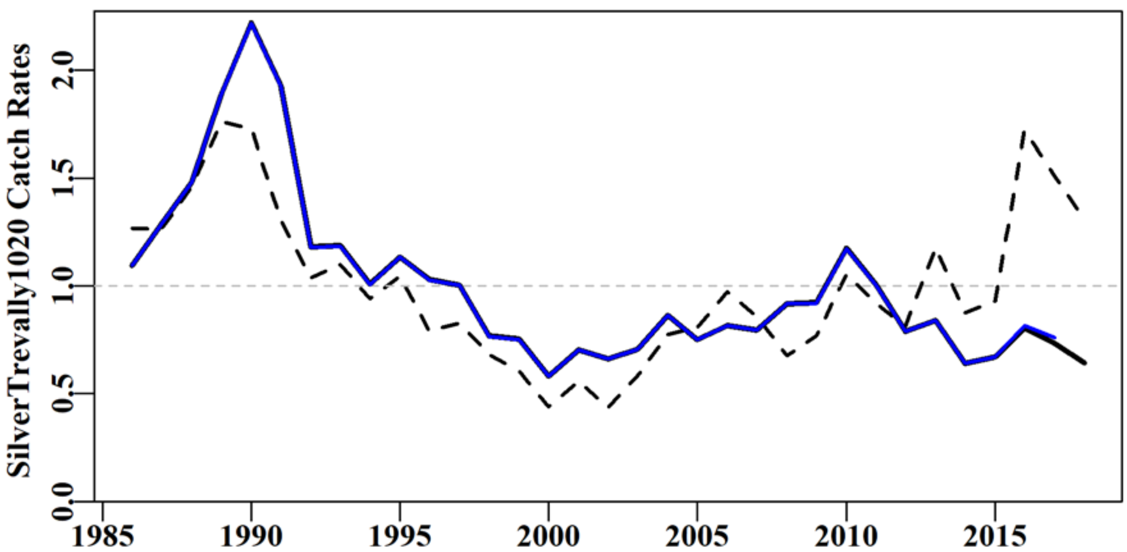

Figure 5.247. SilverTrevally1020. A comparison of the previous year's standardization (blue line) with this year's. They should lie on top of each other, although small deviations may relate to data adjustments, particularly in very recent years.

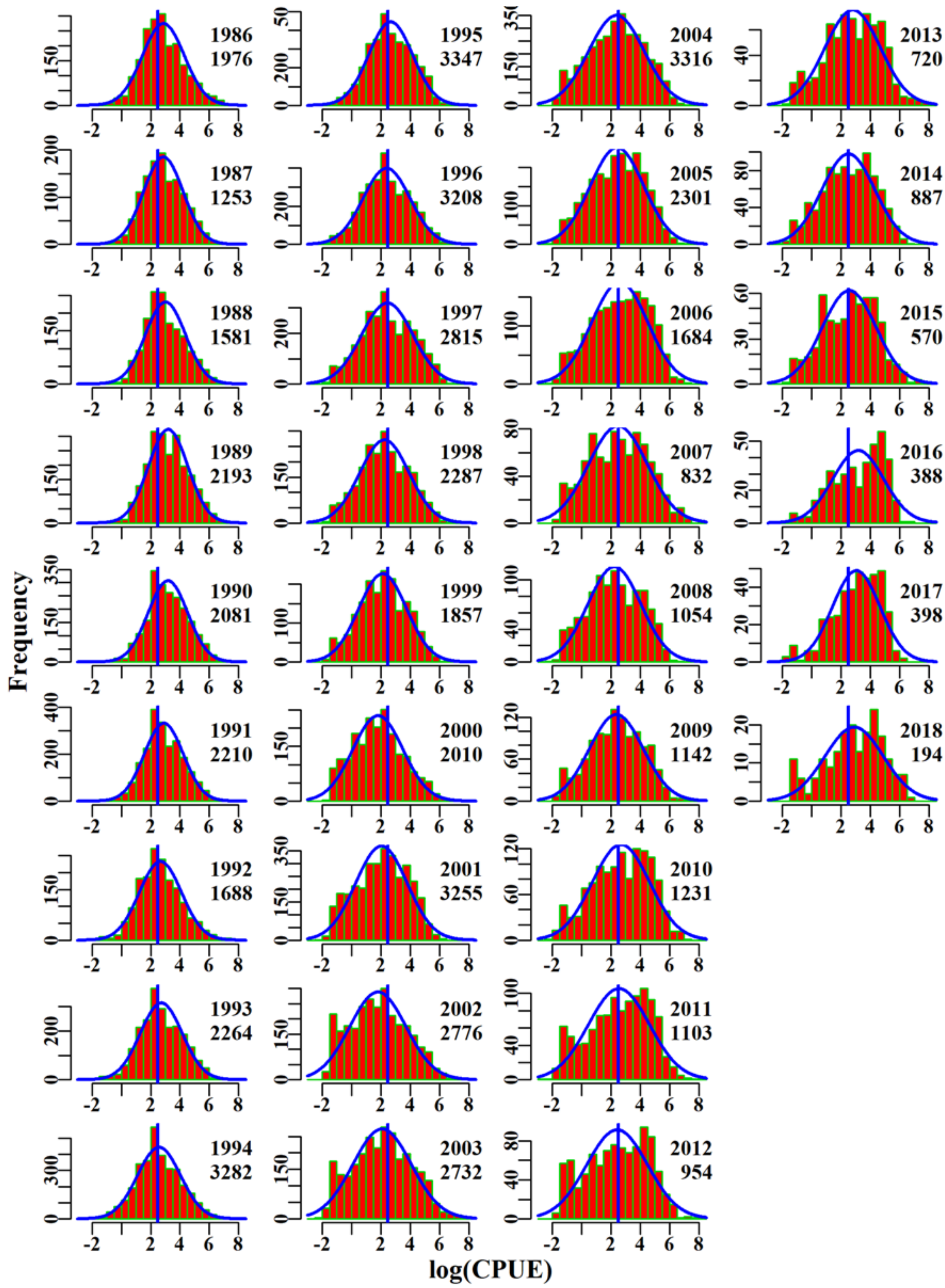

Figure 5.248. SilverTrevally1020. The natural log(CPUE) for each year of data available the blue lines are normal distributions fitted to the histogram frequencies. The numbers in each plot are the year and number of records.

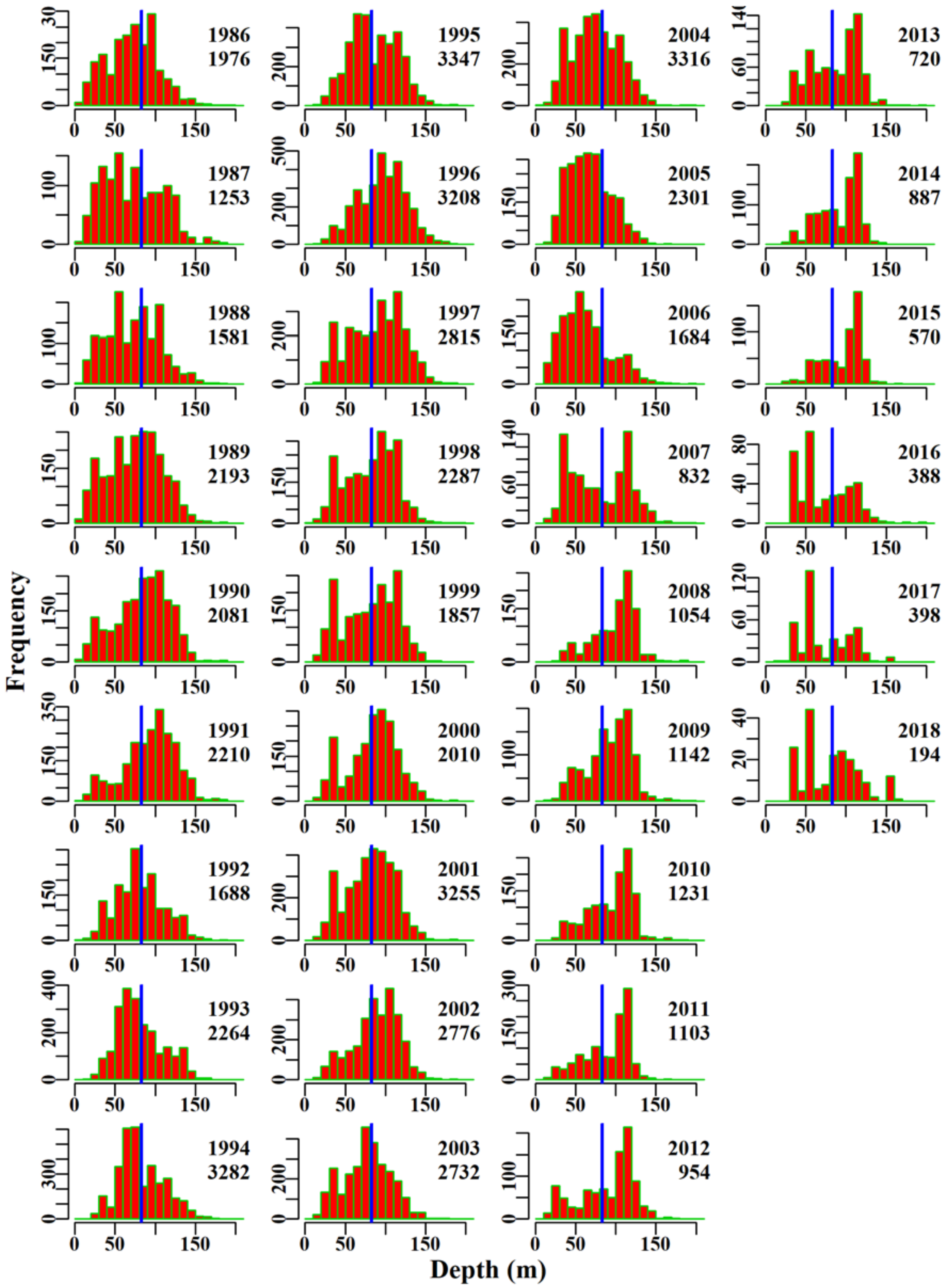

Figure 5.249. SilverTrevally1020. The average Depth of fishing for each year of data available to illustrate the development of the fishery through time. The numbers in each plot are the year and number of records.

5.40 Silver Trevally 1020 – No MPA

Initial data selection for Silver Trevally (TRE - 37337062 - *Pseudocaranx dentex*) in the SET was conducted according to the details given in Table 5.174 and then records reported as State waters, which includes the Bateman's Bay MPA were excluded.

A total of 8 statistical models were fitted sequentially to the available data.

5.40.1 *Inferences*

The majority of catch of this species occurred in zone 10, followed by 20.

The terms Year, Vessel, DepCat and Month had the greatest contribution to model fit, with the remaining terms each explaining < 1% of the overall variation in CPUE, based on the AIC and R^2 statistics. The qqplot suggests that the assumed Normal distribution is valid with a slight departure as depicted at the lower tail of the distribution (Figure 5.253).

Annual standardized CPUE trend is noisy and relatively flat since about 2012 and below average (Figure 5.250). A deviation similar to that in the 'include MPA' scenario is apparent where the standardized trend deviates markedly from the nominal geometric mean trend from 2013 - 2017 and for the same reasons of changes in vessels fishing, low numbers of significantly contributing vessels, changes in the depth distribution of fishing and lower catches and numbers of records.

5.40.2 *Action Items and Issues*

Further exploration of the reasons behind the recent deviation of the standardized time-series from the nominal geometric mean are required to provide a more detailed explanation for these changed dynamics.

Table 5.174. SilverTrevally1020nompa. The data selection criteria used to specify and identify the fishery data to be included in the analysis.

Property	Value
label	SilverTrevally1020nompa
csirocode	37337062
fishery	SET
depthrange	0 - 200
depthclass	20
zones	10, 20
methods	TW, TDO, OTT, PTB, TMO
years	1986 - 2018

Table 5.175. SilverTrevally1020nompa. Total catch (Total; t) is the total reported in the database, number of records used in the analysis (N), reported catch (Catch; t) in the area and depth used in the analysis and number of vessels used in the analysis (Vess). GeoM is the geometric mean of catch rates (kg/hr), standard deviation (StDev) relates to the optimum model. C<30Kg denotes the amount of catch in shots of <30kg, and %<30Kg is the percent of total. The optimum model was Zone:Month.

	Total	N	Catch	Vess	GeoM	Opt	StDev	C<30Kg	P<30Kg
1986	469.5	1765	285.3	74	49.0	1.2040	0.000	12.762	0.045
1987	198.5	1077	120.9	62	45.8	1.4433	0.061	7.630	0.063
1988	278.5	1258	226.7	53	59.1	1.8604	0.056	9.599	0.042
1989	376.2	1846	282.5	62	56.2	1.9830	0.051	12.318	0.044
1990	450.4	1834	292.0	52	55.1	2.3356	0.052	10.697	0.037
1991	340.7	1953	218.0	49	42.5	2.0629	0.053	12.522	0.057
1992	296.5	1356	170.7	45	34.6	1.2561	0.057	9.742	0.057
1993	377.7	1407	152.3	48	35.2	1.2899	0.057	10.899	0.072
1994	392.8	2073	176.8	47	28.2	1.0253	0.053	16.809	0.095
1995	413.4	1942	179.2	44	31.5	1.1495	0.053	16.202	0.090
1996	340.6	2179	177.6	49	27.6	0.9979	0.053	18.281	0.103
1997	328.8	1647	115.7	49	24.9	0.9352	0.056	13.637	0.118
1998	210.1	1226	64.0	42	19.4	0.6635	0.059	10.434	0.163
1999	166.1	1022	49.0	40	17.3	0.6728	0.062	8.024	0.164
2000	154.8	1244	54.5	46	13.9	0.5181	0.059	9.600	0.176
2001	270.2	2024	121.5	43	23.7	0.6349	0.053	13.786	0.113
2002	232.8	1812	97.7	39	19.0	0.5115	0.055	11.638	0.119
2003	337.9	1526	89.8	49	21.9	0.5220	0.056	9.592	0.107
2004	458.2	1868	151.7	43	36.8	0.7512	0.054	11.342	0.075
2005	291.1	1013	98.7	41	41.5	0.6505	0.062	6.210	0.063
2006	247.3	695	79.3	37	59.7	0.8271	0.069	4.529	0.057
2007	172.7	557	79.2	21	92.1	0.9545	0.075	2.895	0.037
2008	128.4	887	80.6	22	46.9	0.9206	0.065	5.931	0.074
2009	164.1	933	107.0	23	55.7	0.9168	0.064	5.623	0.053
2010	240.2	1011	152.6	24	89.7	1.1674	0.063	5.213	0.034
2011	193.5	910	149.6	20	113.8	1.0052	0.065	4.590	0.031
2012	139.7	733	97.6	21	72.6	0.7283	0.069	4.241	0.043
2013	122.8	520	72.4	19	70.9	0.8010	0.076	2.924	0.040
2014	107.0	673	66.7	20	51.2	0.6028	0.070	4.127	0.062
2015	79.5	473	61.2	21	67.6	0.6758	0.079	2.422	0.040
2016	52.4	288	33.6	18	89.7	0.7466	0.095	1.528	0.045
2017	52.9	290	33.4	15	70.2	0.7421	0.095	1.614	0.048
2018	37.7	119	14.0	13	68.2	0.4443	0.143	0.837	0.060

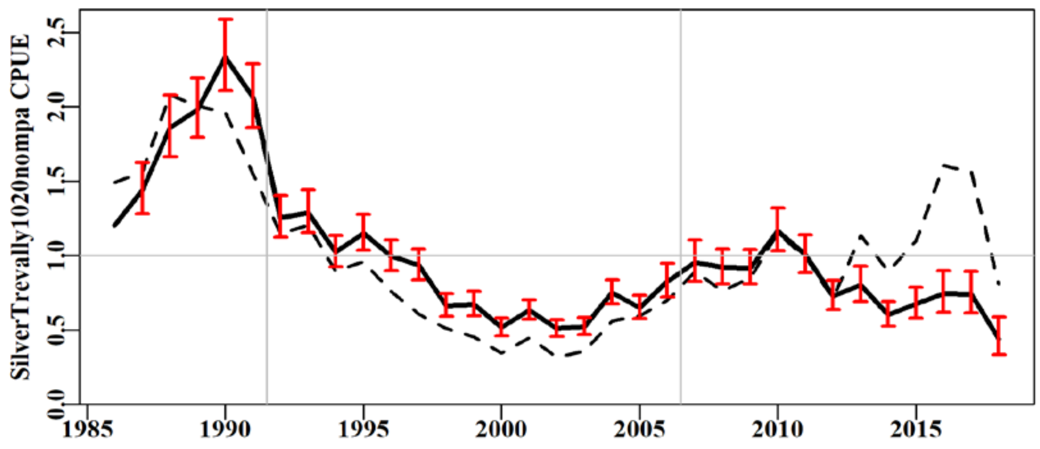

Figure 5.250. SilverTrevally1020nompa standardization. The dashed black line represents the geometric mean catch rate, solid black line the standardized catch rates. The red bars are the 95% confidence intervals about the mean estimates. The graph scales both time-series of standardized catch rates relative to the mean of each time-series.

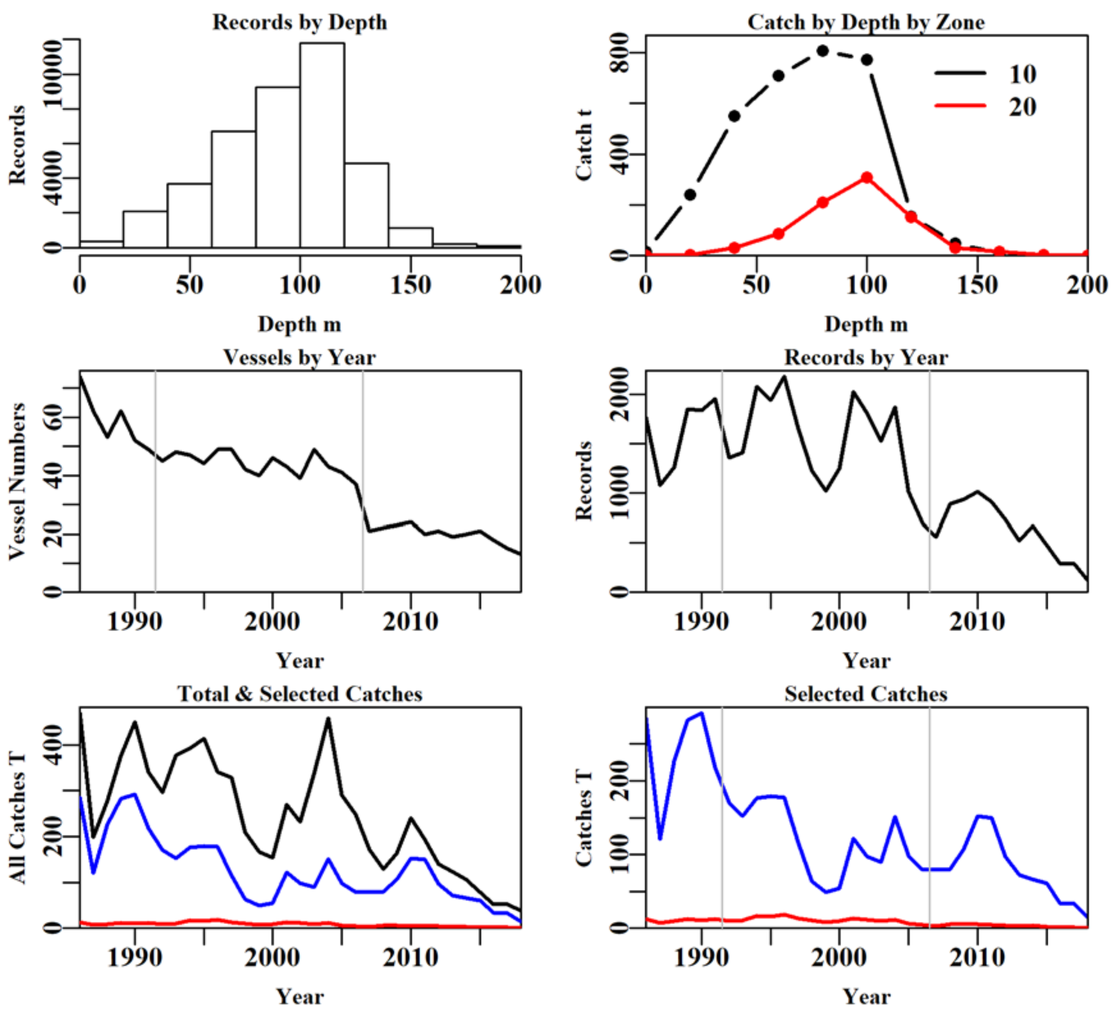

Figure 5.251. SilverTrevally1020nompa fishery details. The bottom left plot depicts all known catches (top black line), and all selected catches used in the analysis (middle blue line); the lower red line: selected catches < 30 kg).

Table 5.176. SilverTrevally1020nompa data selection effects. Total is the total number of records in the database, NoCE removes those records with either missing catch or effort, and then only those records are kept that meet the criteria for depth, years, zone, method and fishery.

	Total	NoCE	Depth	Years	Zones	Method	Fishery	NoMPA
Records	761420	72975	71390	70511	61030	59645	59589	40161
Difference	0	3167	1585	879	9481	1385	56	19428
Catch	8277.822	8101.432	7813.398	7659.274	6733.82	6694.53	6687.56	4151.80
Difference	0	176.39	288.05	154.12	925.45	39.29	6.97	2535.76

Table 5.177. The models used to analyse data for SilverTrevally1020nompa.

	Model
Model1	Year
Model2	Year + Vessel
Model3	Year + Vessel + DepCat
Model4	Year + Vessel + DepCat + Month
Model5	Year + Vessel + DepCat + Month + DayNight
Model6	Year + Vessel + DepCat + Month + DayNight + Zone
Model7	Year + Vessel + DepCat + Month + DayNight + Zone + Zone:Month
Model8	Year + Vessel + DepCat + Month + DayNight + Zone + Zone:DepCat

Table 5.178. SilverTrevally1020nompa. The row names are 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_r2) and the change in adjusted R^2 (%Change). The optimum model was Zone:Month.

	AIC	RSS	MSS	Nobs	Npars	adj_r2	%Change
Year	39451	107080	12220	40161	33	10.2	0.00
Vessel	30748	85549	33751	40161	189	28.0	17.78
DepCat	29585	83067	36234	40161	199	30.0	2.07
Month	28847	81511	37789	40161	210	31.3	1.29
DayNight	28223	80241	39059	40161	213	32.4	1.06
Zone	28171	80134	39166	40161	214	32.5	0.09
Zone:Month	28079	79906	39395	40161	225	32.6	0.17
Zone:DepCat	28149	80054	39246	40161	223	32.5	0.05

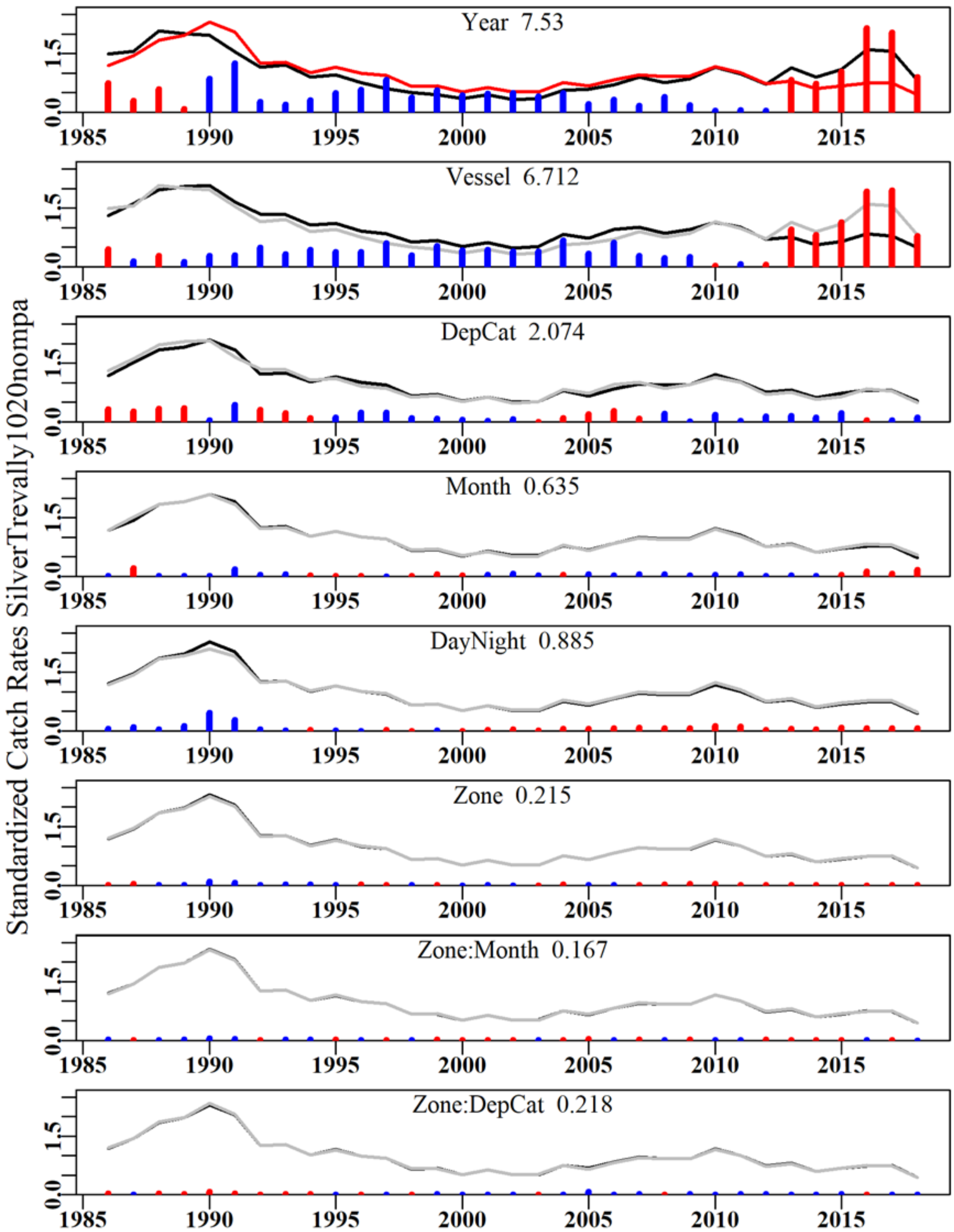

Figure 5.252. SilverTrevally1020nompa. The influence of each factor on the optimal standardization. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by vertical bars with blue bars indicating the optimum model is higher 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.

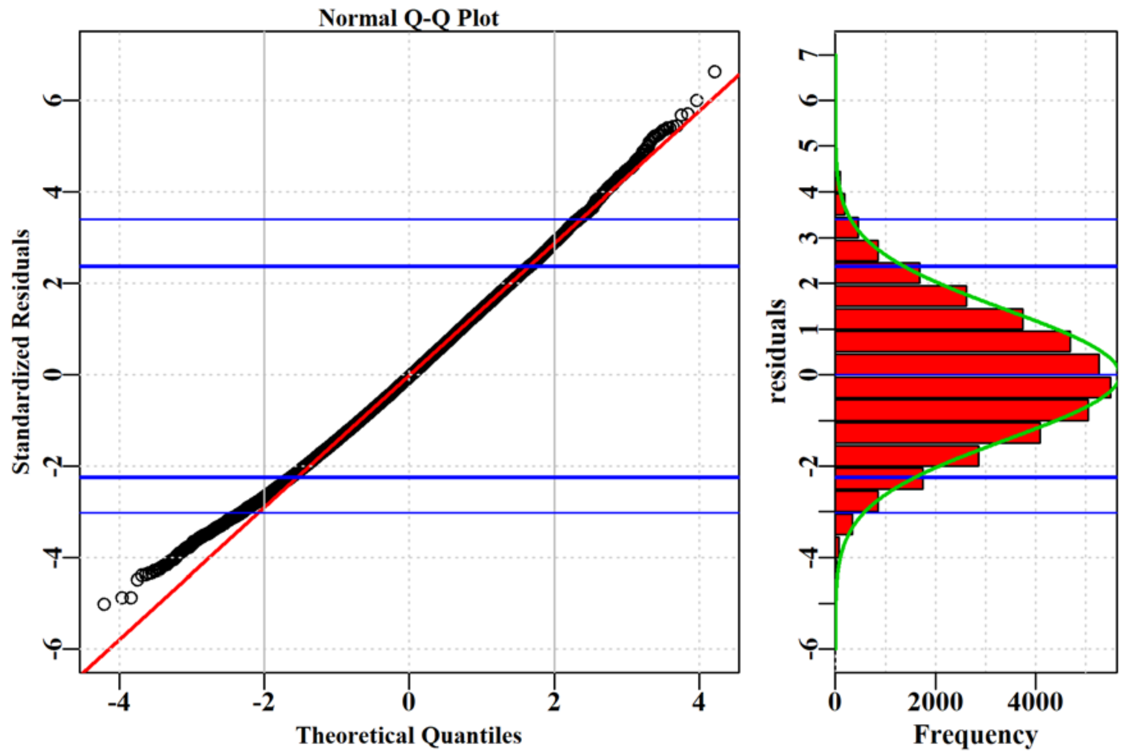

Figure 5.253. SilverTrevally1020nompa. diagnostic plots. The distribution of residuals from the optimum fit. The qqplot indicates the fit to the expected normality, while the histogram of residuals illustrates the 90% quantiles to indicate the intensity of any lack of fit at the margins of the distribution.

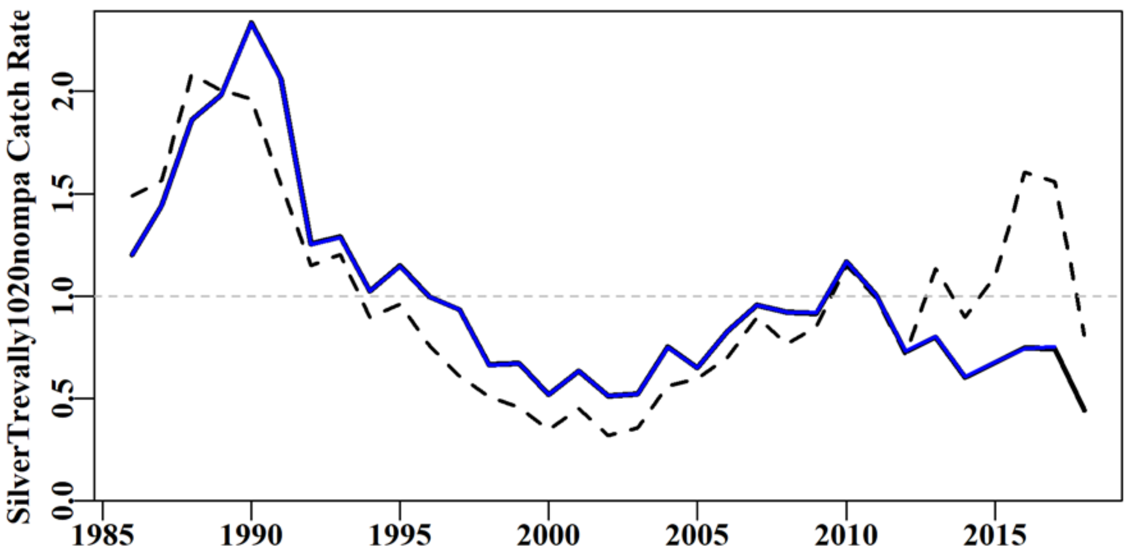

Figure 5.254. SilverTrevally1020nompa. A comparison of the previous year's standardization (blue line) with this year's. They should lie on top of each other, although small deviations may relate to data adjustments, particularly in very recent years.

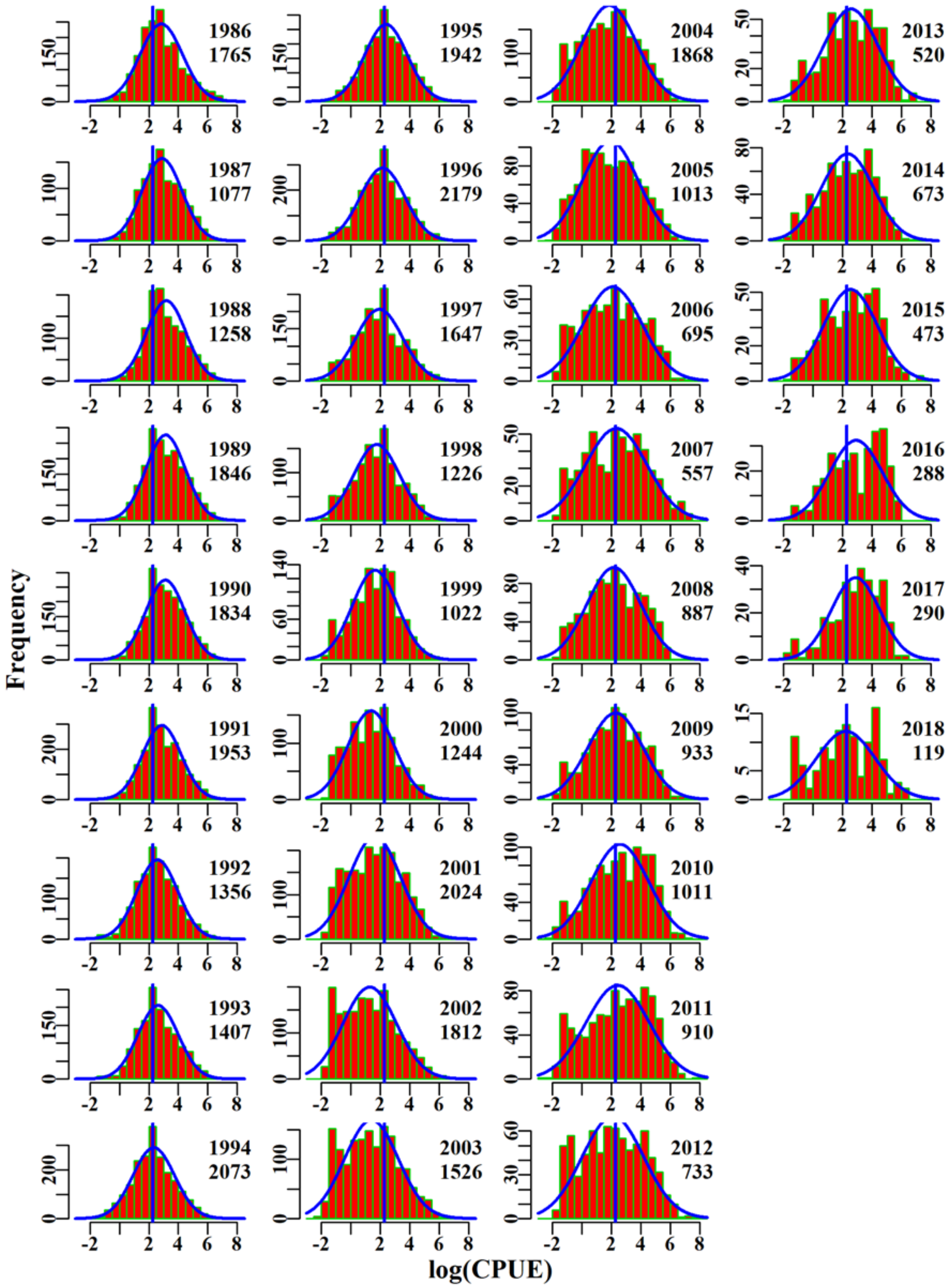

Figure 5.255. SilverTrevally1020nompa. The natural log(CPUE) for each year of data available the blue lines are normal distributions fitted to the histogram frequencies. The numbers in each plot are the year and number of records.

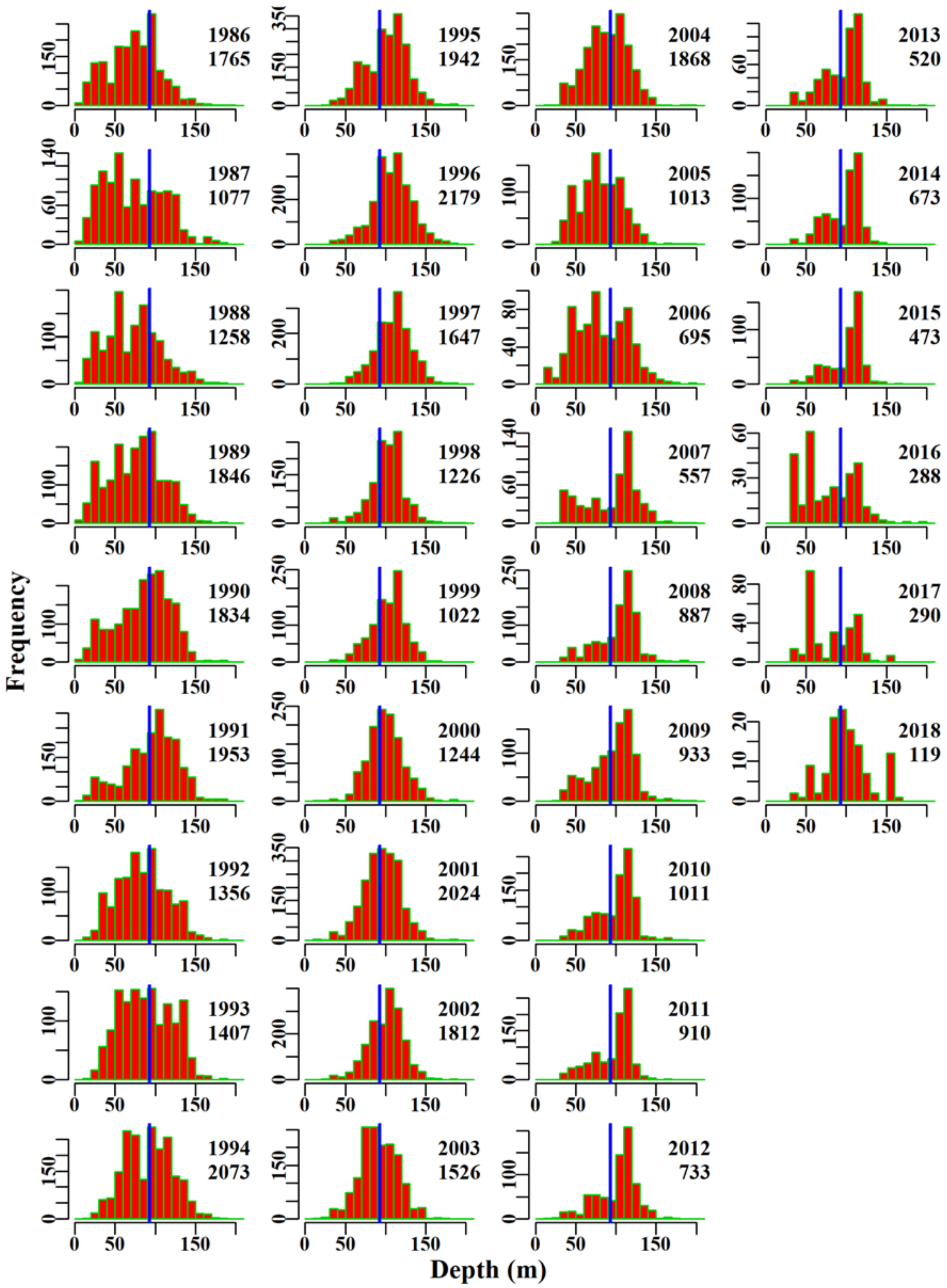

Figure 5.256. SilverTrevally1020nompa. The average Depth of fishing for each year of data available to illustrate the development of the fishery through time. The numbers in each plot are the year and number of records.

5.41 Royal Red Prawn 10

Initial data selection for Royal Red Prawn (PRR – 28714005 – *Haliporoides sibogae*) in the SET was conducted according to the details given in Table 5.179.

A total of 8 statistical models were fitted sequentially to the available data, with the order of the non-interaction terms added based on the relative contribution of each term to model fit.

5.41.1 *Inferences*

The terms Year, DepCat, Vessel, Month and one interaction term (Month:DepCat) had the greatest contribution to model fit, with the remaining terms each explaining < 1% of the overall variation in CPUE, based on the AIC and R^2 statistics (Table 5.183). The qqplot suggests a departure from the assumed Normal distribution as depicted at the lower tail (<5% of records) of the distribution (Figure 5.260).

Annual standardized CPUE trend is noisy and relatively flat across the years analysed (Figure 5.257). From 2013 - 2016 the standardized trend deviates from the nominal geometric mean trend such that the trend stays on the long-term average catch rate while the geometric mean appears to rise well above it. There are now very few vessels contributing to this fishery and it appears that they are fishing in more focused depths. With so few vessels actively involved in the fishery the standardization can be expected to become more uncertain and dependent on their specific fishing activities.

5.41.2 *Actions Items and Issues*

Fishing behaviour appears to have changed in 2018, as evidenced by the distribution of records of catch at depth, why this has occurred remains unknown.

Table 5.179. RoyalRedPrawn. The data selection criteria used to specify and identify the fishery data to be included in the analysis.

Property	Value
label	RoyalRedPrawn
csirocode	28714005
fishery	SET
depthrange	200 - 700
depthclass	40
zones	10
methods	TW, TDO, OTT, PTB, TMO
years	1986 - 2018

Table 5.180. RoyalRedPrawn. Total catch (Total; t) is the total reported in the database, number of records used in the analysis (N), reported catch (Catch; t) in the area and depth used in the analysis and number of vessels used in the analysis (Vess). GeoM is the geometric mean of catch rates (kg/hr), standard deviation (StDev) relates to the optimum model. C<30Kg denotes the amount of catch in shots of <30kg, and %<30Kg is the percent of total. The optimum model was Month:DepCat.

	Total	N	Catch	Vess	GeoM	Opt	StDev	C<30Kg	P<30Kg
1986	277.7	1591	231.7	47	71.7	0.6763	0.000	6.689	0.029
1987	351.3	1763	324.7	47	93.0	0.8534	0.038	4.739	0.015
1988	362.5	1392	343.3	41	124.5	0.9390	0.041	3.627	0.011
1989	329.3	1143	310.8	39	139.3	0.8037	0.043	3.462	0.011
1990	337.1	719	308.6	25	175.4	1.5188	0.050	0.615	0.002
1991	334.1	728	296.3	29	183.2	1.3257	0.050	1.447	0.005
1992	166.9	426	142.3	19	164.7	0.9876	0.059	0.728	0.005
1993	298.8	671	232.1	21	172.6	1.1747	0.050	1.377	0.006
1994	359.8	650	234.3	26	169.5	1.1144	0.050	1.308	0.006
1995	335.6	1066	252.3	25	105.3	0.8787	0.044	1.862	0.007
1996	360.8	1212	272.1	24	95.5	0.7786	0.042	1.653	0.006
1997	252.7	850	165.2	21	86.8	0.7293	0.047	1.309	0.008
1998	233.3	1228	190.0	23	67.7	0.7631	0.043	2.549	0.013
1999	367.0	1579	342.8	25	84.5	0.7804	0.041	2.569	0.007
2000	434.9	1537	398.2	27	127.1	0.9745	0.041	3.619	0.009
2001	276.8	1313	228.9	22	75.7	0.8186	0.043	3.874	0.017
2002	484.2	1735	415.8	23	131.5	0.9802	0.040	4.529	0.011
2003	230.8	796	161.8	26	114.9	1.0090	0.049	3.164	0.020
2004	193.9	569	167.4	22	206.8	1.0267	0.054	2.108	0.013
2005	173.9	587	152.8	21	149.1	0.9320	0.054	2.192	0.014
2006	192.3	453	177.3	17	295.8	1.1269	0.058	1.714	0.010
2007	121.5	323	115.7	9	249.3	0.7671	0.066	1.480	0.013
2008	75.8	252	70.6	8	220.9	0.6542	0.075	1.340	0.019
2009	68.8	248	67.3	9	159.3	0.8286	0.079	0.647	0.010
2010	96.8	343	82.8	9	138.1	0.8299	0.066	1.561	0.019
2011	110.9	288	107.9	8	207.2	1.1975	0.071	0.510	0.005
2012	126.5	359	120.5	9	167.3	0.9219	0.065	1.002	0.008
2013	212.2	416	198.1	9	280.6	1.1772	0.069	0.643	0.003
2014	121.7	348	118.3	11	178.1	0.9433	0.066	0.535	0.005
2015	126.5	345	119.8	8	219.9	0.9587	0.068	0.723	0.006
2016	145.3	323	136.9	9	273.9	1.1141	0.067	0.733	0.005
2017	137.1	308	133.2	8	270.3	1.2548	0.072	0.490	0.004
2018	164.5	307	160.6	4	353.9	2.1611	0.085	0.708	0.004

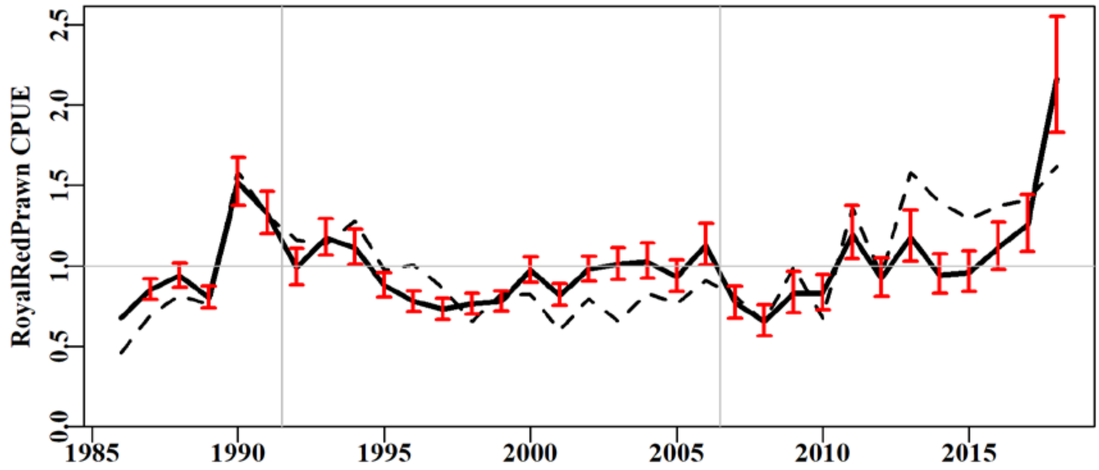

Figure 5.257. RoyalRedPrawn standardization. The dashed black line represents the geometric mean catch rate, solid black line the standardized catch rates. The red bars are the 95% confidence intervals about the mean estimates. The graph scales both time-series of standardized catch rates relative to the mean of each time-series.

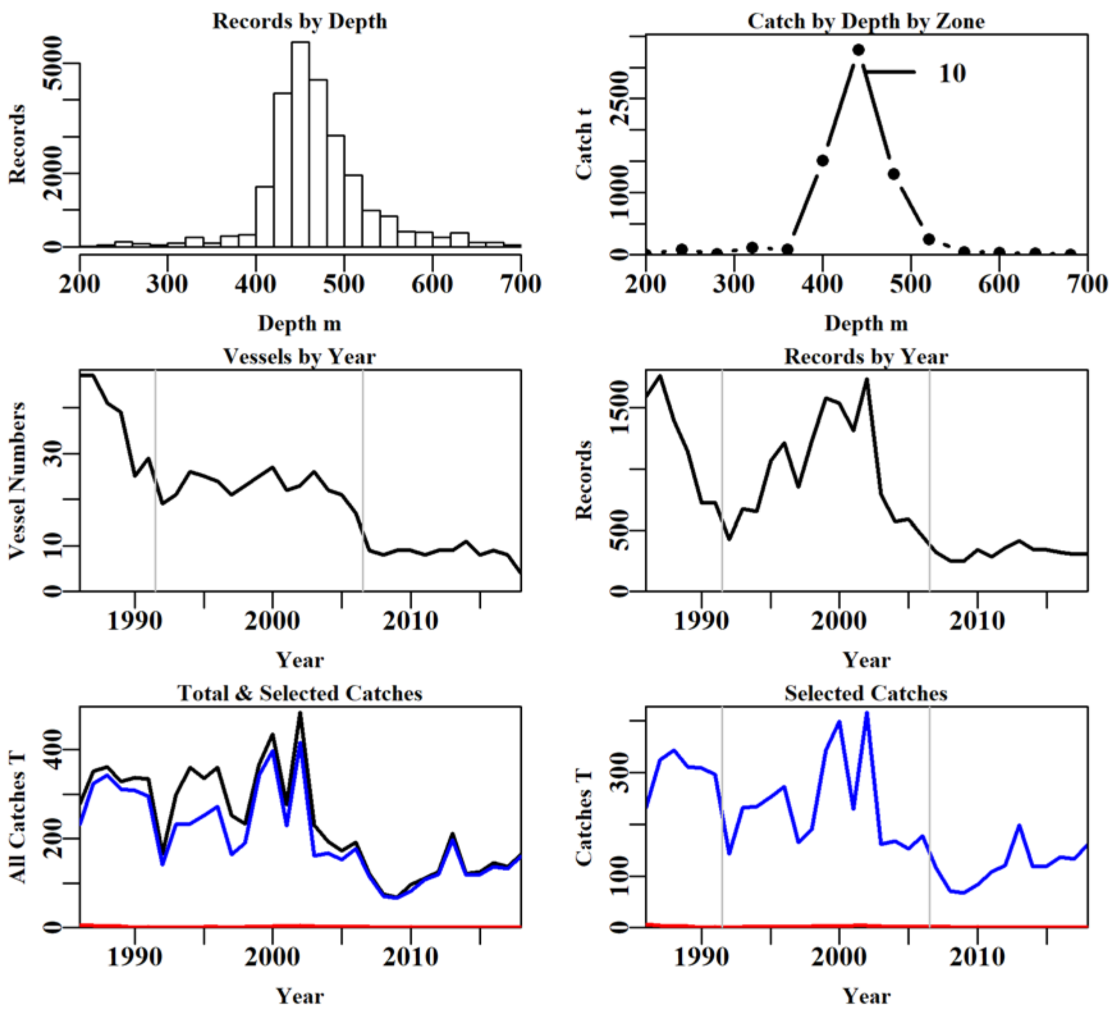

Figure 5.258. RoyalRedPrawn fishery details. The bottom left plot depicts all known catches (top black line), and all selected catches used in the analysis (middle blue line); the lower red line: selected catches < 30 kg).

Table 5.181. RoyalRedPrawn data selection effects. Total is the total number of records in the database, NoCE removes those records with either missing catch or effort, and then only those records are kept that meet the criteria for depth, years, zone, method and fishery.

	Total	NoCE	Depth	Years	Zones	Method	Fishery
Records	40920	33462	32965	32460	25993	25868	25868
Difference	0	7458	497	505	6467	125	0
Catch	7953.46	7861.80	7762.59	7670.66	6818.70	6780.29	6780.29
Difference	0	91.66	99.21	91.94	851.95	38.42	0

Table 5.182. The models used to analyse data for RoyalRedPrawn.

	Model
Model1	Year
Model2	Year + DepCat
Model3	Year + DepCat + Vessel
Model4	Year + DepCat + Vessel + Month
Model5	Year + DepCat + Vessel + Month + DayNight
Model6	Year + DepCat + Vessel + Month + DayNight + DayNight:DepCat
Model7	Year + DepCat + Vessel + Month + DayNight + Month:DepCat
Model8	Year + DepCat + Vessel + Month + DayNight + DayNight:Month

Table 5.183. RoyalRedPrawn. The row names are 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_r2) and the change in adjusted R^2 (%Change). The optimum model was Month:DepCat.

	AIC	RSS	MSS	Nobs	Npars	adj_r2	%Change
Year	14847	45807	2370	25868	33	4.8	0.00
DepCat	10232	38286	9891	25868	45	20.4	15.59
Vessel	3873	29741	18436	25868	132	38.0	17.56
Month	2151	27802	20375	25868	143	42.0	4.02
DayNight	1954	27584	20592	25868	146	42.4	0.45
DayNight:DepCat	1847	27401	20776	25868	179	42.7	0.31
Month:DepCat	1404	26738	21439	25868	274	43.9	1.49
DayNight:Month	1949	27512	20665	25868	178	42.5	0.08

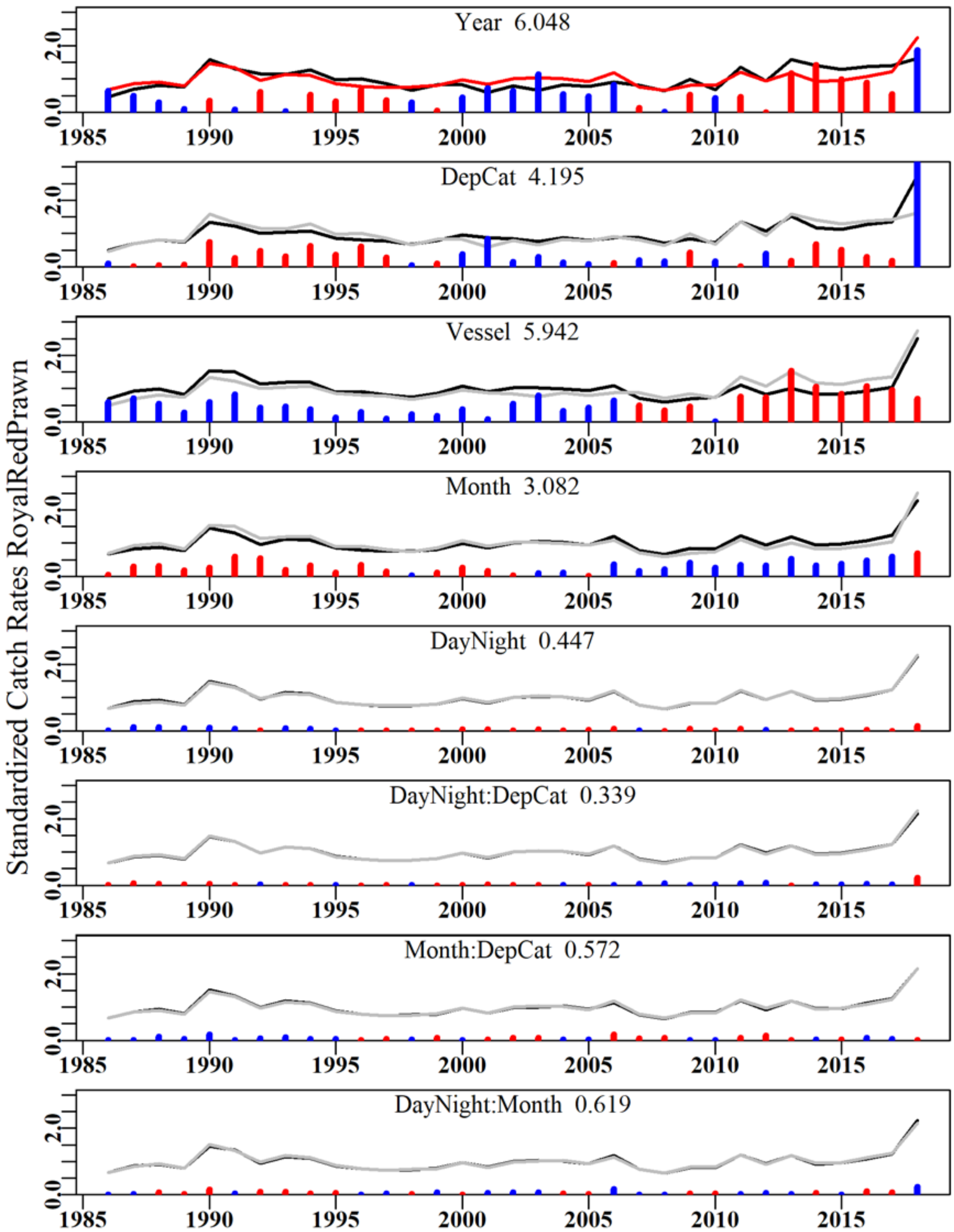

Figure 5.259. RoyalRedPrawn. The influence of each factor on the optimal standardization. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by vertical bars with blue bars indicating the optimum model is higher than the 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.

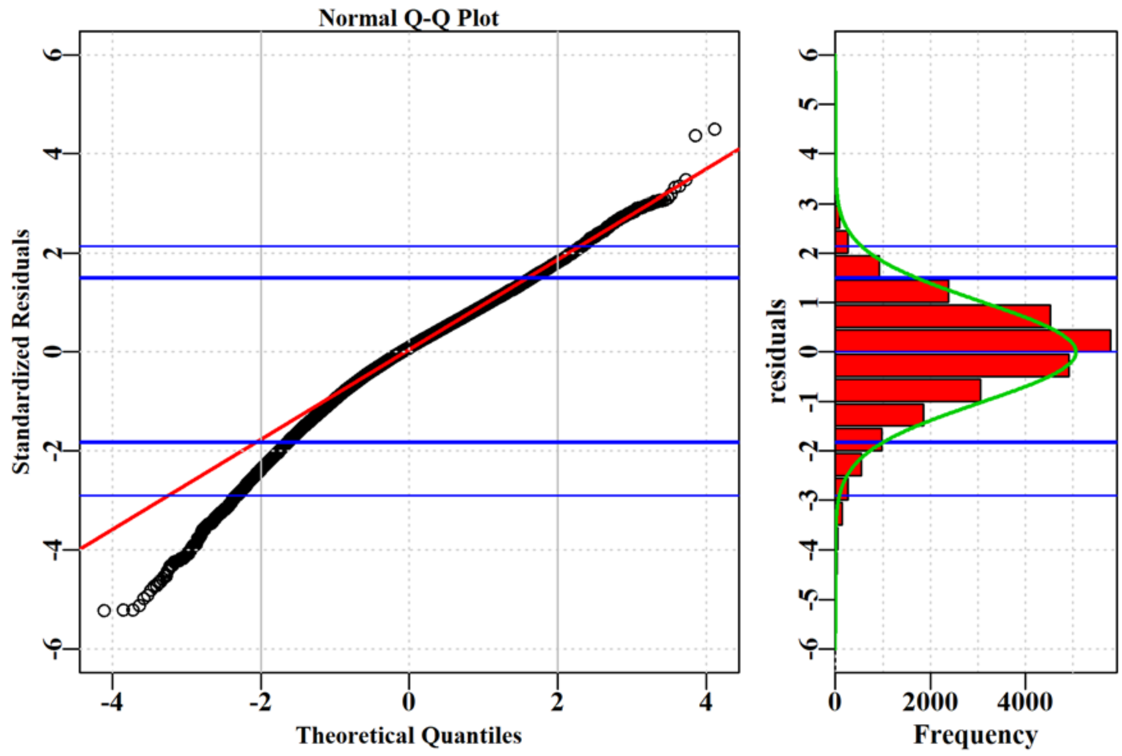

Figure 5.260. RoyalRedPrawn. diagnostic plots. The distribution of residuals from the optimum fit. The qqplot indicates the fit to the expected normality, while the histogram of residuals illustrates the 90% quantiles to indicate the intensity of any lack of fit at the margins of the distribution.

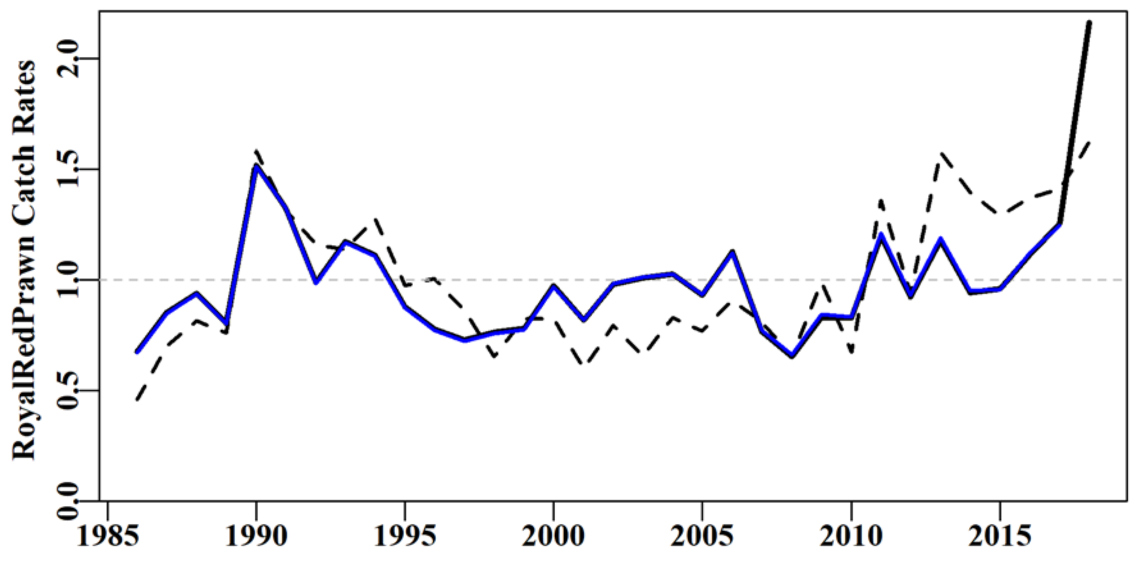

Figure 5.261. RoyalRedPrawn. A comparison of the previous year's standardization (blue line) with this year's. They should lie on top of each other, although small deviations may relate to data adjustments, particularly in very recent years.

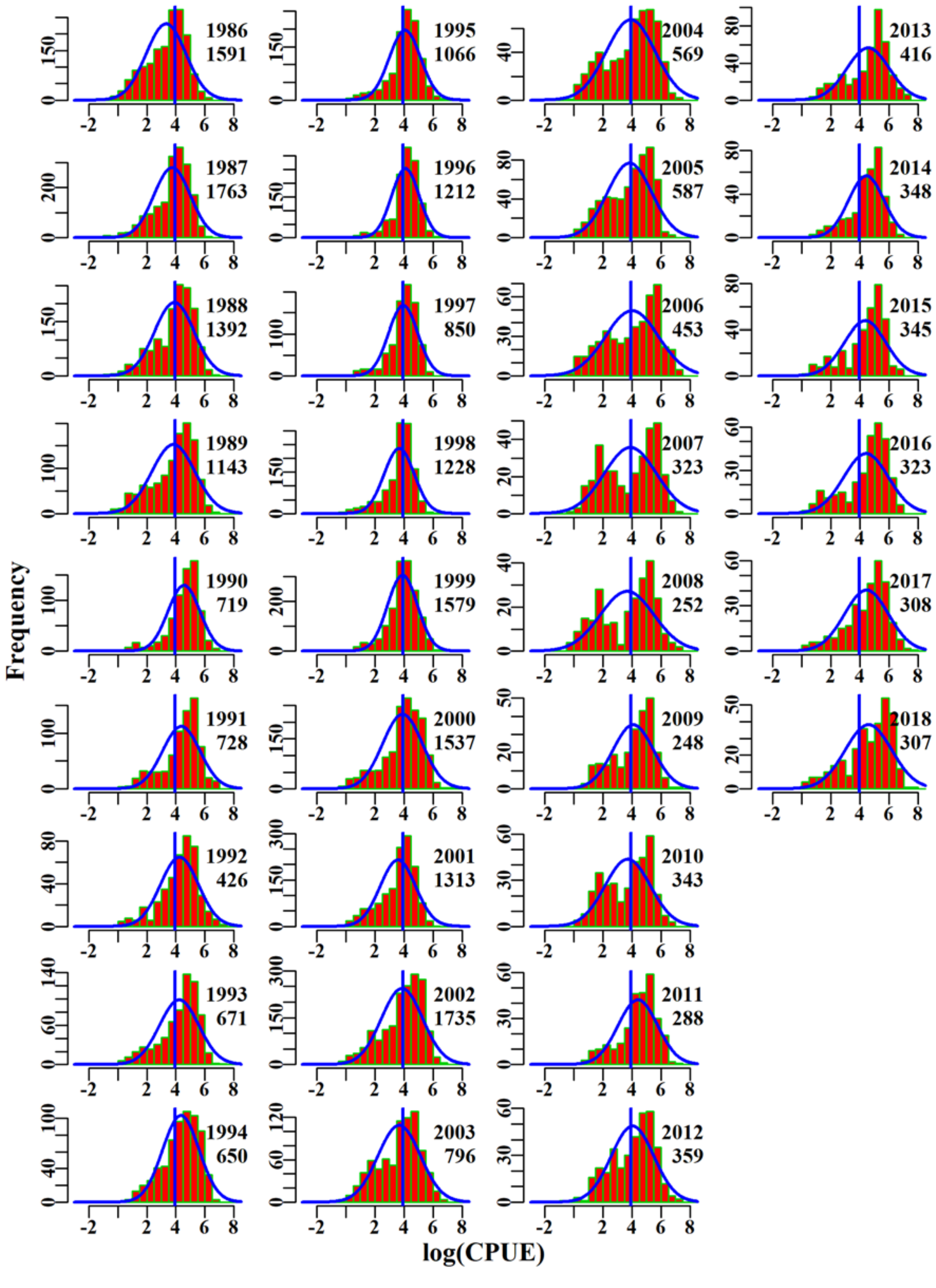

Figure 5.262. RoyalRedPrawn. The natural log(CPUE) for each year of data available the blue lines are normal distributions fitted to the histogram frequencies. The numbers in each plot are the year and number of records.

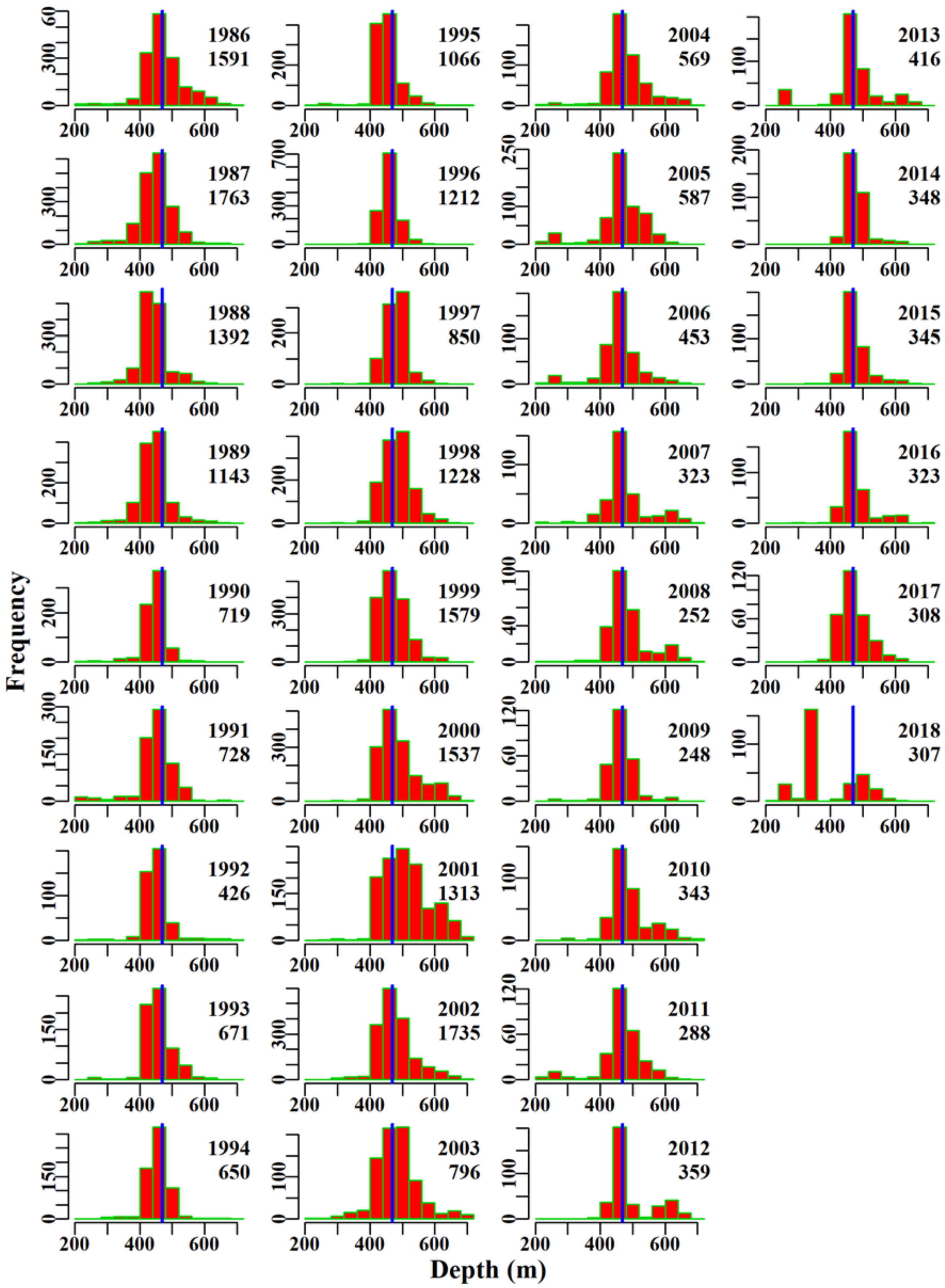

Figure 5.263. RoyalRedPrawn. The average Depth of fishing for each year of data available to illustrate the development of the fishery through time. The numbers in each plot are the year and number of records.

5.42 Eastern Gemfish NonSpawning

For non-spawning Eastern Gemfish (GEM – 37439002 – *Rexea solandri*) in the SET, initial data selection was conducted according to the detials given in Table 5.184.

A total of 8 statistical models were fitted sequentially to the available data, with the order of the non-interaction terms added based on the relative contribution of each term to model fit.

5.42.1 *Inferences*

The majority of catch of this species occurred in zone 10, followed by 20 and 30.

The terms Year, Vessel and DepCat had the greatest contribution to model fit, with the remaining terms each explaining < 1% of the overall variation in CPUE, based on the AIC and R^2 statistics (Table 5.188). The qqplot suggests that the assumed Normal distribution is valid with a slight depature as depicted at the lower tail of the distribution (Figure 5.267).

Following a large spike in catch rates in the late 1980s, which coincided with a large spike in catches, the annual standardized CPUE trend dropped rapidly despite large reductions in catches and, since 1995 has been relatively flat and below average although with what looks like a 14 - 15 year cycle of rise and fall (Figure 5.264). There have been efforts to actively avoid Eastern Gemfish for the last few years and this may have been reflected in the change apparent in the depth of fishing. It does mean that the most recent catch rates, from about 2013, will not be representative of even the depleted stock state.

5.42.2 *Action Items and Issues*

No issues identified.

Table 5.184. EasternGemfishNonSp. The data selection criteria used to specify and identify the fishery data to be included in the analysis.

Property	Value
label	EasternGemfishNonSp
csirocode	37439002
fishery	SET
depthrange	0 - 600
depthclass	40
zones	10, 20, 30, 40
methods	TW, TDO, OTT, PTB, TMO
years	1986 - 2018

Table 5.185. EasternGemfishNonSp. Total catch (Total; t) is the total reported in the database, number of records used in the analysis (N), reported catch (Catch; t) in the area and depth used in the analysis and number of vessels used in the analysis (Vess). GeoM is the geometric mean of catch rates (kg/hr), standard deviation (StDev) relates to the optimum model. C<30Kg denotes the amount of catch in shots of <30kg, and %<30Kg is the percent of total. The optimum model was Zone:DepCat.

	Total	N	Catch	Vess	GeoM	Opt	StDev	C<30Kg	P<30Kg
1986	647.9	2028	389.4	85	50.9	2.7682	0.000	13.705	0.035
1987	1027.6	1882	761.6	74	121.6	3.8058	0.043	9.656	0.013
1988	744.5	2187	497.2	77	64.7	3.1173	0.043	13.954	0.028
1989	306.7	1427	143.5	69	29.5	2.0426	0.048	13.936	0.097
1990	251.0	745	87.3	68	35.6	2.0515	0.058	5.730	0.066
1991	367.6	719	63.3	71	23.6	1.3634	0.059	7.059	0.111
1992	243.5	682	134.6	50	41.0	1.8913	0.060	4.859	0.036
1993	183.3	1521	93.7	58	20.2	1.4992	0.048	14.627	0.156
1994	148.2	1820	63.1	55	12.9	1.0415	0.046	18.222	0.289
1995	137.7	1683	49.9	54	11.5	0.9325	0.047	18.718	0.375
1996	223.7	1938	55.5	61	9.8	0.7279	0.046	18.655	0.336
1997	265.6	1775	65.3	58	9.5	0.7594	0.049	18.355	0.281
1998	238.8	1241	45.5	49	9.9	0.7123	0.051	12.901	0.283
1999	318.2	1342	30.3	53	7.2	0.5229	0.051	12.684	0.419
2000	248.6	1713	32.2	58	6.2	0.4677	0.048	15.019	0.466
2001	239.3	1636	32.1	50	4.7	0.3752	0.049	12.320	0.384
2002	146.9	1612	19.0	50	3.0	0.2899	0.049	10.864	0.571
2003	205.5	1574	20.0	48	3.7	0.3172	0.050	10.222	0.512
2004	454.9	1759	38.4	54	6.9	0.4452	0.049	12.383	0.322
2005	436.3	1711	40.4	48	7.3	0.4762	0.049	12.613	0.312
2006	425.6	1316	32.0	43	7.1	0.5029	0.052	10.140	0.317
2007	495.6	779	28.0	22	10.2	0.6694	0.059	5.844	0.209
2008	203.9	828	34.7	26	14.6	0.8973	0.058	6.769	0.195
2009	146.9	501	25.3	27	24.6	0.9278	0.068	3.767	0.149
2010	150.5	680	21.9	23	10.0	0.6670	0.061	5.334	0.244
2011	101.2	776	21.8	22	8.4	0.6081	0.060	5.621	0.258
2012	130.2	697	21.7	23	9.4	0.5795	0.062	4.917	0.227
2013	80.4	585	23.2	23	14.8	0.6529	0.066	4.098	0.177
2014	104.5	516	9.6	23	6.0	0.3866	0.068	3.437	0.356
2015	68.6	619	16.1	24	10.3	0.4298	0.065	3.447	0.214
2016	53.4	441	8.1	23	6.7	0.2928	0.073	3.047	0.375
2017	102.8	577	19.3	20	14.2	0.3216	0.067	3.544	0.183
2018	57.5	546	16.5	20	13.7	0.4571	0.070	3.394	0.206

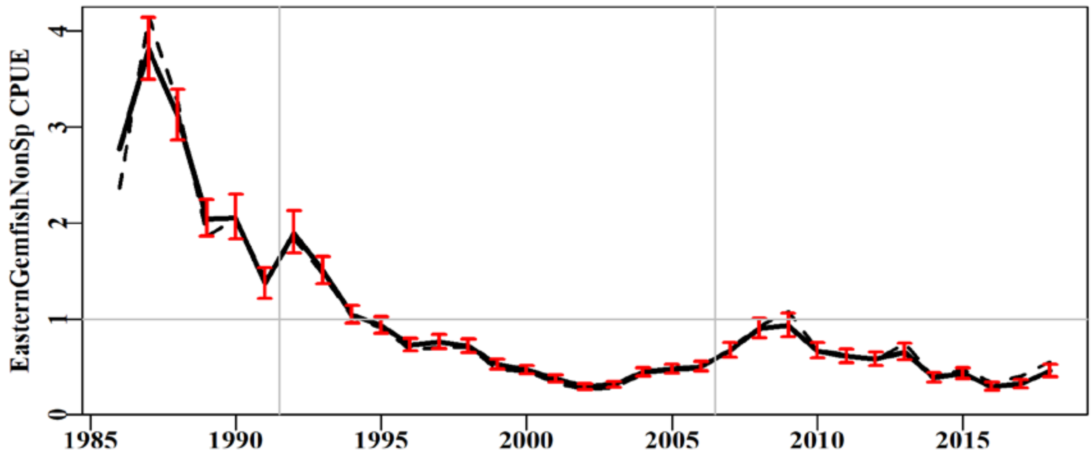

Figure 5.264. EasternGemfishNonSp standardization. The dashed black line represents the geometric mean catch rate, solid black line the standardized catch rates. The red bars are the 95% confidence intervals about the mean estimates. The graph scales both time-series of standardized catch rates relative to the mean of each time-series.

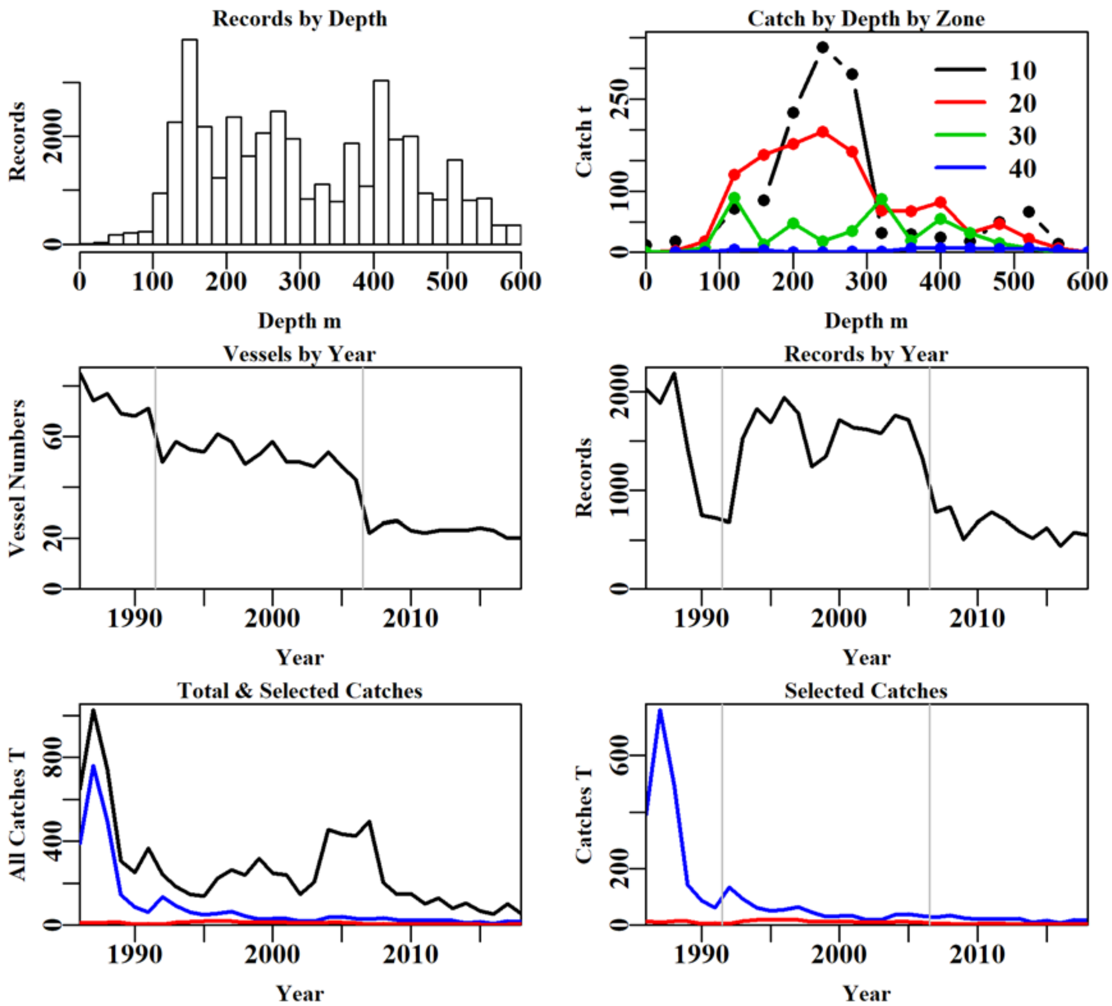

Figure 5.265. EasternGemfishNonSp fishery details. The bottom left plot depicts all known catches (top black line), and all selected catches used in the analysis (middle blue line); the lower red line: selected catches < 30 kg).

Table 5.186. EasternGemfishNonSp data selection effects. Total is the total number of records in the database, NoCE removes those records with either missing catch or effort, and then only those records are kept that meet the criteria for depth, years, zone, method and fishery.

	Total	NoCE	Depth	Years	Zones	Method	Fishery
Records	94014	82960	81013	78856	40641	39900	39856
Difference	0	11054	1947	2157	38215	741	44
Catch	9256.89	8998.07	8797.23	8509.57	2981.31	2943.17	2940.51
Difference	0	258.80	200.86	287.65	5528.26	38.14	2.66

Table 5.187. The models used to analyse data for EasternGemfishNonSp.

	Model
Model1	Year
Model2	Year + Vessel
Model3	Year + Vessel + DepCat
Model4	Year + Vessel + DepCat + Month
Model5	Year + Vessel + DepCat + Month + DayNight
Model6	Year + Vessel + DepCat + Month + DayNight + Zone
Model7	Year + Vessel + DepCat + Month + DayNight + Zone + Zone:DepCat
Model8	Year + Vessel + DepCat + Month + DayNight + Zone + Zone:Month

Table 5.188. EasternGemfishNonSp. The row names are 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_r2) and the change in adjusted R^2 (%Change). The optimum model was Zone:DepCat.

	AIC	RSS	MSS	Nobs	Npars	adj_r2	%Change
Year	26243	76866	23786	39856	33	23.6	0.00
Vessel	20059	65193	35458	39856	223	34.9	11.30
DepCat	18389	62473	38179	39856	238	37.6	2.69
Month	17865	61623	39029	39856	249	38.4	0.83
DayNight	17527	61092	39560	39856	252	38.9	0.53
Zone	17182	60556	40096	39856	255	39.5	0.53
Zone:DepCat	16601	59549	41103	39856	299	40.4	0.94
Zone:Month	16864	59976	40676	39856	288	40.0	0.53

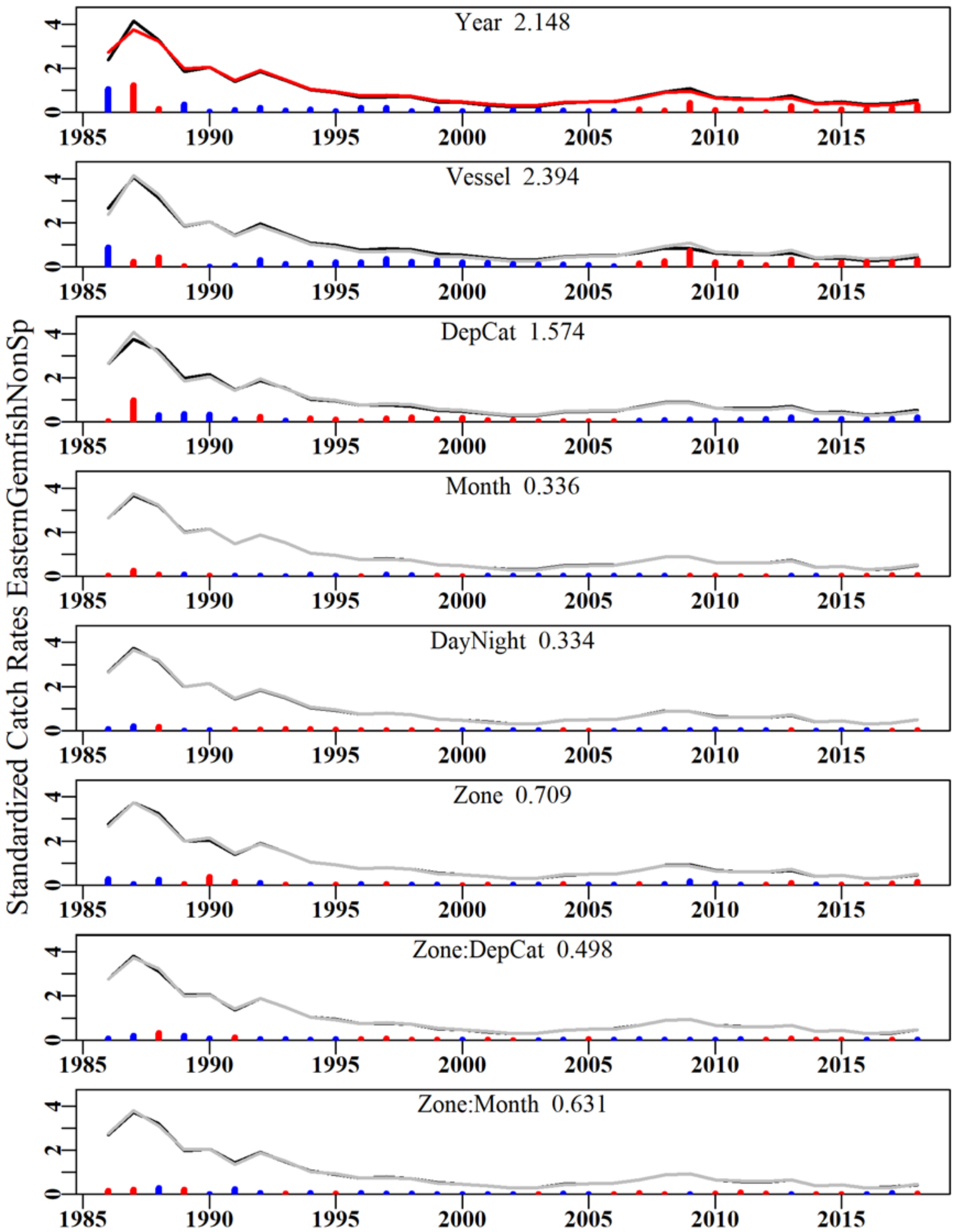

Figure 5.266. EasternGemfishNonSp. The influence of each factor on the optimal standardization. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by vertical bars with blue bars indicating the optimum model is higher than 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.

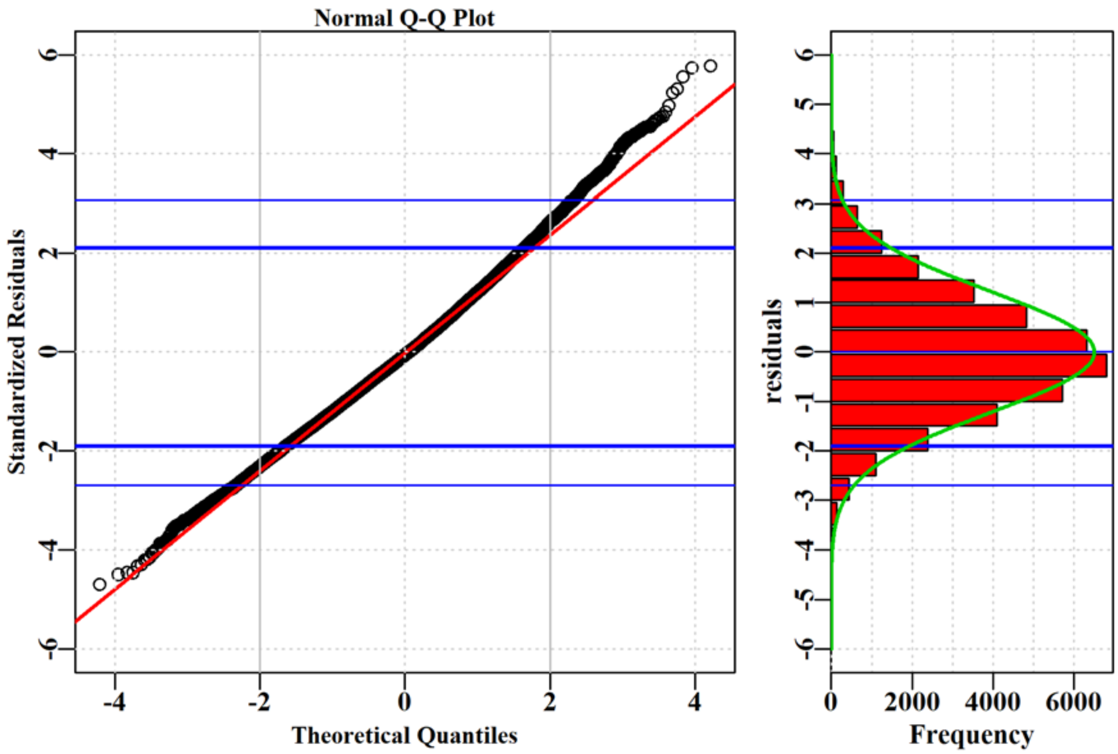

Figure 5.267. EasternGemfishNonSp. diagnostic plots. The distribution of residuals from the optimum fit. The qqplot indicates the fit to the expected normality, while the histogram of residuals illustrates the 90% quantiles to indicate the intensity of any lack of fit at the margins of the distribution.

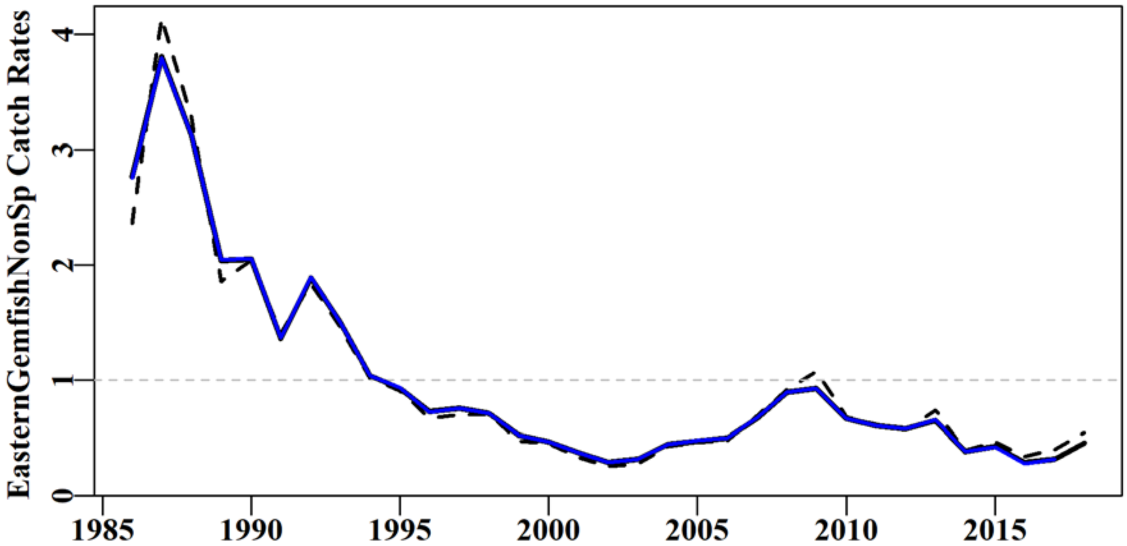

Figure 5.268. EasternGemfishNonSp. A comparison of the previous year's standardization (blue line) with this year's. They should lie on top of each other, although small deviations may relate to data adjustments, particularly in very recent years.

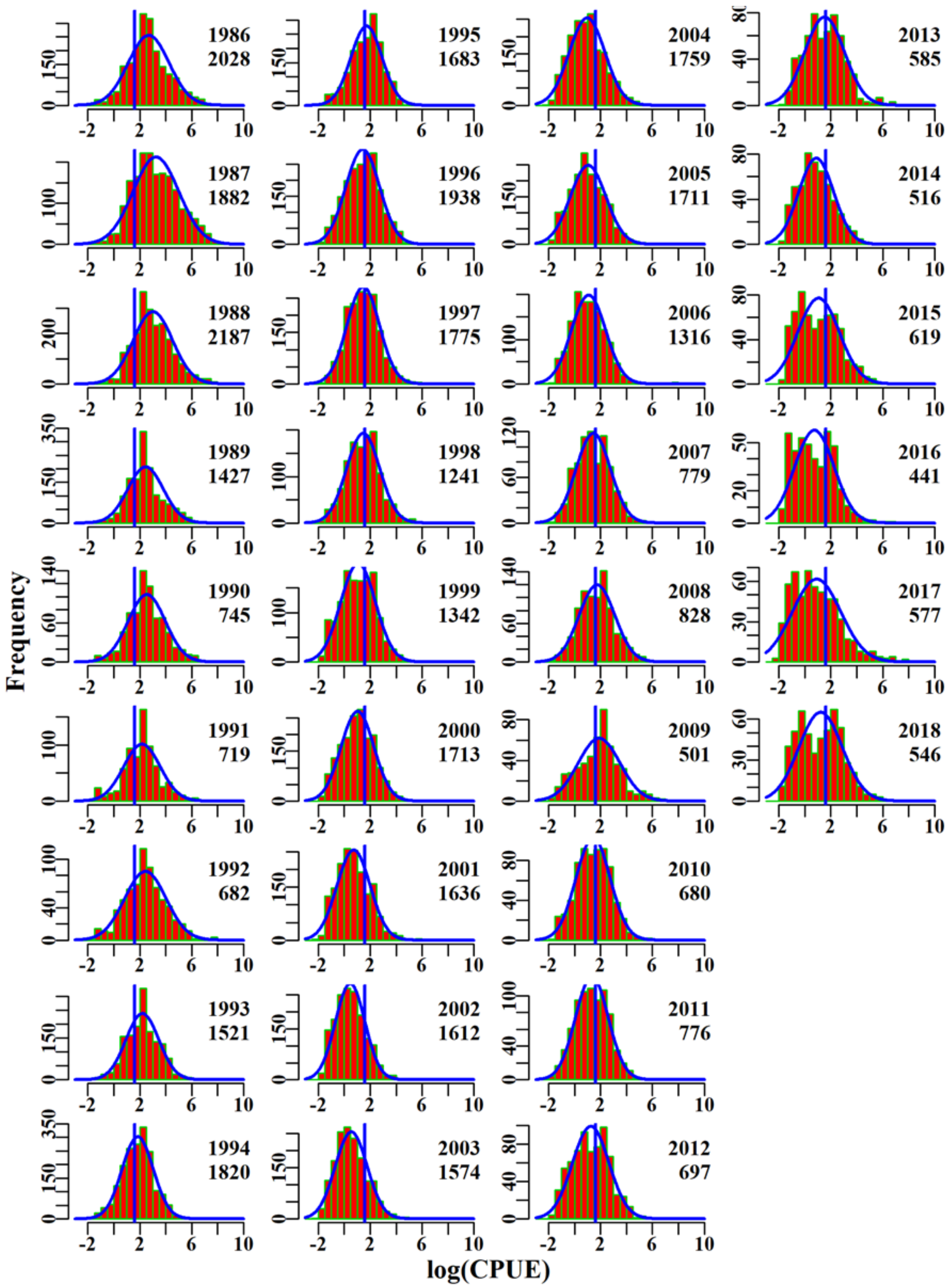

Figure 5.269. EasternGemfishNonSp. The natural log(CPUE) for each year of data available the blue lines are normal distributions fitted to the histogram frequencies. The numbers in each plot are the year and number of records.

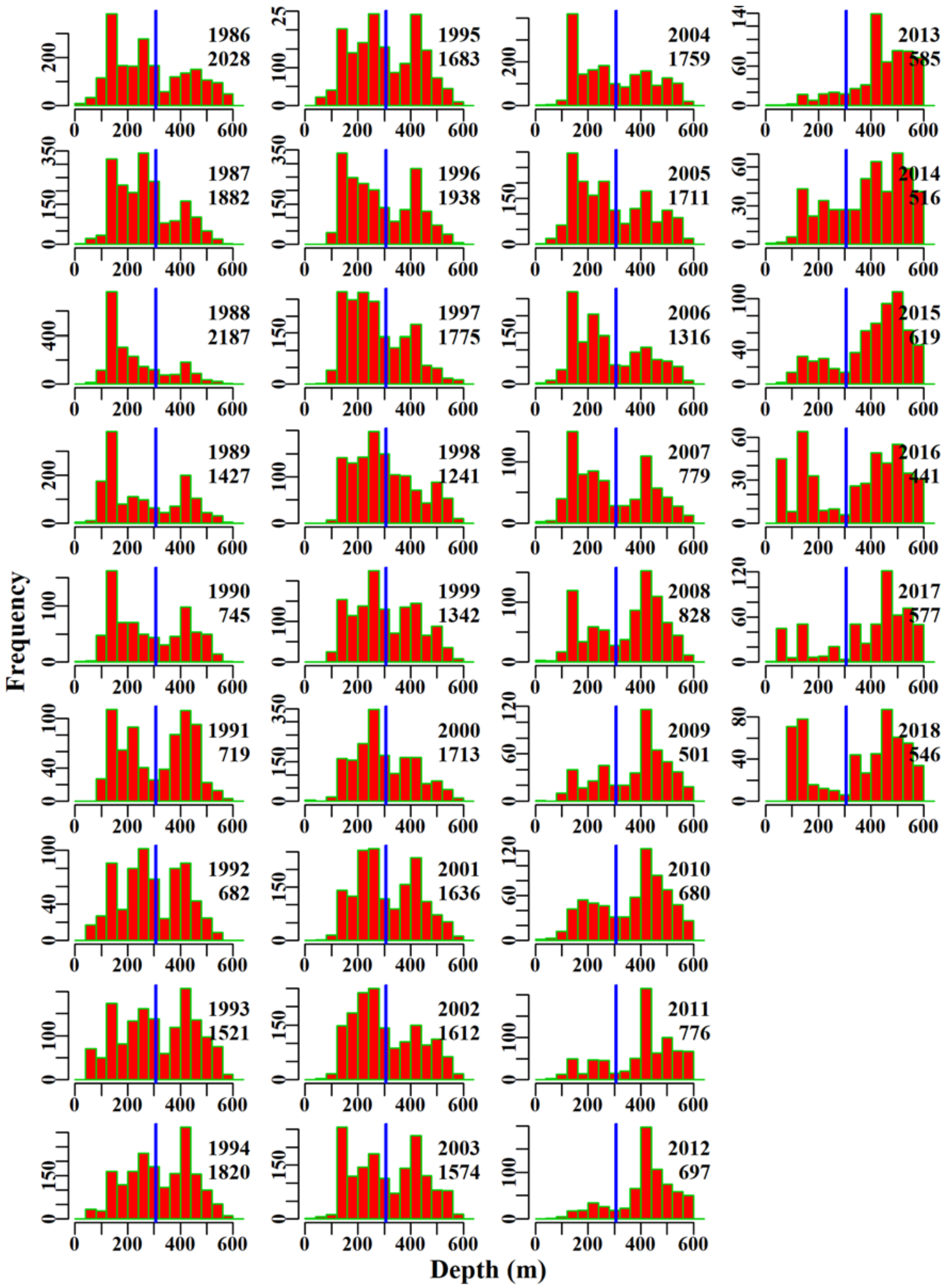

Figure 5.270. EasternGemfishNonSp. The average Depth of fishing for each year of data available to illustrate the development of the fishery through time. The numbers in each plot are the year and number of records.

5.43 Eastern Gemfish Spawning

Initial data selection for the Eastern Gemfish spawning run fishery (GEM - 37439002 - *Rexea solandri*) in the SET was conducted according to the details given in Table 5.189. In addition, specific Eastern Gemfish survey vessels and trips are removed from the data to be analysed as not being typical of standard fishing in recent years.

A total of 8 statistical models were fitted sequentially to the available data, with the order of the non-interaction terms added based on the relative contribution of each term to model fit.

5.43.1 *Inferences*

The majority of catch of this species occurred in zone 10, followed by 20 and minimal catches in the remaining zones. Even though survey vessel data were removed there were still increased catches in 1996, 1997, and 1998, but after that catches have been less than 42 t since 2000.

The terms Year, Vessel, Month, DepCat and one interaction term (Zone:Month) had the greatest contribution to model fit, with the remaining terms each explaining < 1% of the overall variation in CPUE, based on the AIC and R^2 statistics (Table 5.193). The qqplot suggests that the assumed Normal distribution is valid with a slight depature as depicted at the upper tail of the distribution (Figure 5.274).

Annual standardized CPUE trend has declined since 2010 and remained below average since 2011 (Figure 5.271). This reflects what appears to be a longer term cycle of CPUE values, which suggests that CPUE values would soon be expected to rise. However, as the very low catches since the past two years indicate that industry avoidance strategies are effective and this means the recent CPUE may not provide an unbiased representation of the stock status.

5.43.2 *Action Items and Issues*

No issues identified.

Table 5.189. EasternGemfishSp. The data selection criteria used to specify and identify the fishery data to be included in the analysis.

Property	Value
label	EasternGemfishSp
csirocode	37439002
fishery	SET
depthrange	300 - 500
depthclass	20
zones	10, 20, 30, 40
methods	TW, TDO, OTT, PTB, TMO
years	1993 - 2018

Table 5.190. EasternGemfishSp. Total catch (Total; t) is the total reported in the database, number of records used in the analysis (N), reported catch (Catch; t) in the area and depth used in the analysis and number of vessels used in the analysis (Vess). GeoM is the geometric mean of catch rates (kg/hr), standard deviation (StDev) relates to the optimum model. C<30Kg denotes the amount of catch in shots of <30kg, and %<30Kg is the percent of total. The optimum model was Zone:Month.

	Total	N	Catch	Vess	GeoM	Opt	StDev	C<30Kg	P<30Kg
1993	205.9	819	132.9	50	40.2	2.3719	0.000	5.357	0.040
1994	97.2	814	48.6	47	22.1	1.5550	0.062	7.120	0.146
1995	57.2	657	21.9	48	12.1	1.0458	0.066	7.390	0.338
1996	197.6	768	135.1	49	35.3	1.3100	0.064	6.914	0.051
1997	342.5	1225	268.0	47	62.6	1.9565	0.059	7.393	0.028
1998	188.9	879	144.6	46	40.5	1.3032	0.063	7.610	0.053
1999	168.5	1064	87.9	45	21.7	1.0694	0.061	10.350	0.118
2000	103.4	1176	37.0	44	9.9	0.7233	0.062	11.959	0.323
2001	102.6	853	32.7	47	11.7	0.7349	0.065	8.229	0.252
2002	54.1	922	22.4	42	7.3	0.5304	0.065	8.882	0.396
2003	75.0	959	31.5	48	10.7	0.7467	0.064	8.516	0.270
2004	220.2	625	19.7	44	9.8	0.7089	0.071	5.296	0.269
2005	143.2	635	21.4	40	10.2	0.6313	0.070	5.958	0.278
2006	228.1	567	34.6	35	18.3	0.9846	0.072	4.245	0.123
2007	132.8	305	25.3	19	25.0	1.2066	0.087	1.730	0.068
2008	65.1	441	34.9	23	23.1	1.4663	0.080	3.376	0.097
2009	63.1	404	35.2	22	26.5	1.3644	0.081	3.176	0.090
2010	77.8	378	41.0	24	31.1	1.4571	0.081	2.484	0.061
2011	47.1	408	26.7	21	17.2	1.0294	0.080	3.392	0.127
2012	41.7	379	28.0	21	18.3	0.6705	0.083	3.279	0.117
2013	33.9	290	16.0	20	18.2	0.8542	0.089	2.873	0.179
2014	30.8	368	11.2	19	8.7	0.6059	0.083	3.000	0.267
2015	18.8	320	7.8	20	8.0	0.4655	0.087	2.591	0.333
2016	18.8	278	4.9	20	4.9	0.3561	0.092	2.060	0.424
2017	16.0	195	5.0	18	8.5	0.4645	0.104	1.318	0.265
2018	14.0	180	6.2	16	10.3	0.3878	0.110	1.391	0.226

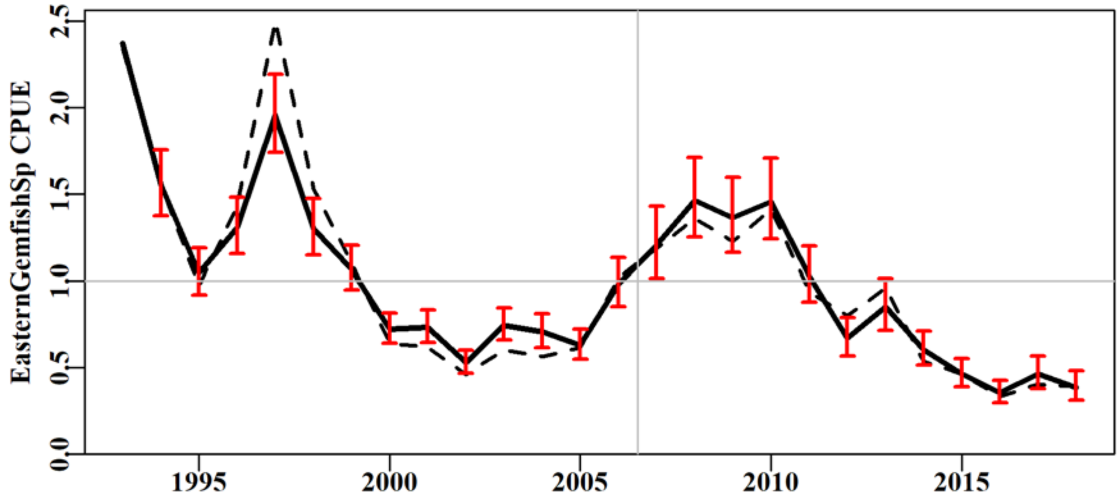

Figure 5.271. EasternGemfishSp standardization. The dashed black line represents the geometric mean catch rate, solid black line the standardized catch rates. The red bars are the 95% confidence intervals about the mean estimates. The graph scales both time-series of standardized catch rates relative to the mean of each time-series.

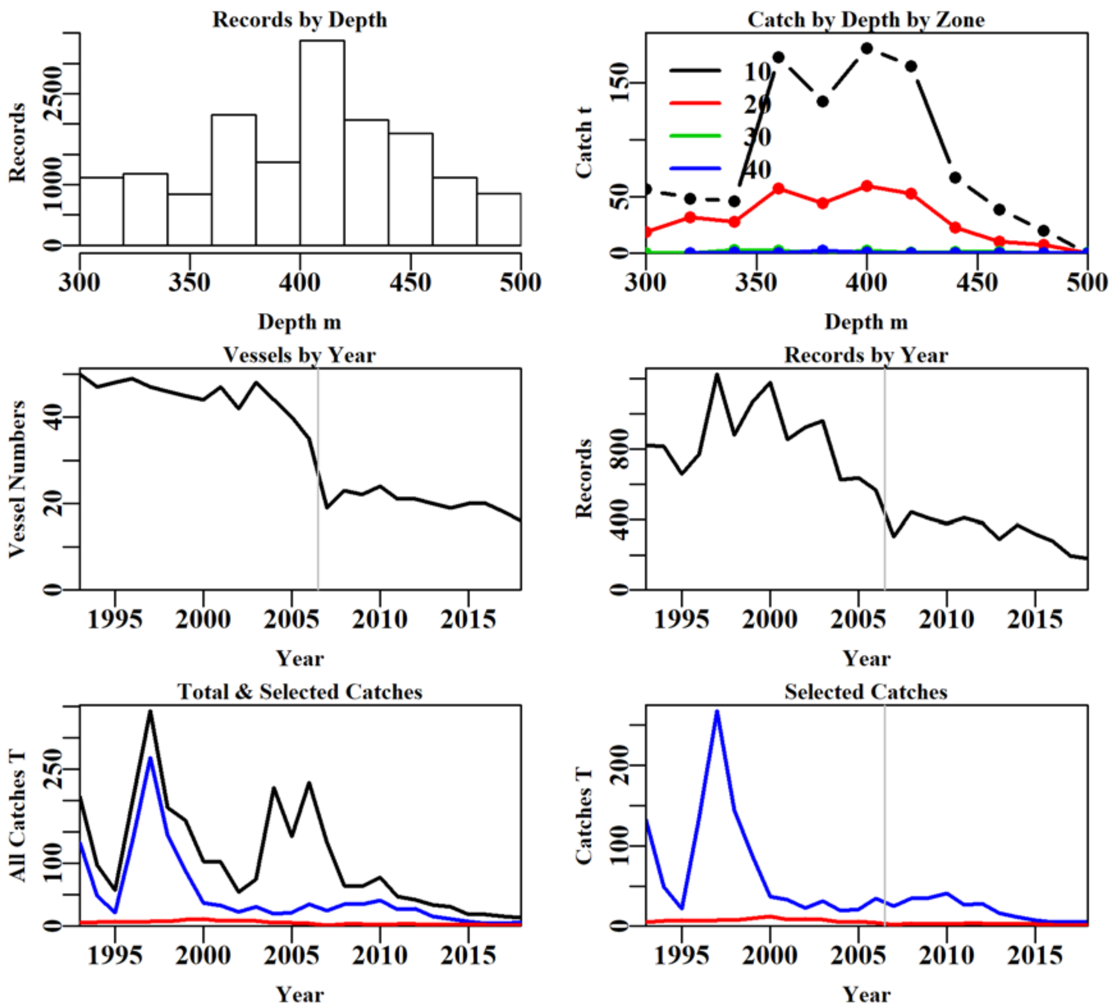

Figure 5.272. EasternGemfishSp fishery details. The bottom left plot depicts all known catches (top black line), and all selected catches used in the analysis (middle blue line); the lower red line: selected catches < 30 kg).

Table 5.191. EasternGemfishSp data selection effects. Total is the total number of records in the database, NoCE removes those records with either missing catch or effort, and then only those records are kept that meet the criteria for depth, years, zone, method and fishery.

	Total	NoCE	Depth	Years	Zones	Method	Fishery
Records	50907	45464	31683	20881	16039	15909	15909
Difference	0	5443	13781	10802	4842	130	0
Catch	16324.83	16070.23	14085.85	2034.13	1299.99	1280.46	1280.46
Difference	0	254.60	1984.38	12051.72	734.14	19.53	0

Table 5.192. The models used to analyse data for EasternGemfishSp.

	Model
Model1	Year
Model2	Year + Vessel
Model3	Year + Vessel + Month
Model4	Year + Vessel + Month + DepCat
Model5	Year + Vessel + Month + DepCat + DayNight
Model6	Year + Vessel + Month + DepCat + DayNight + Zone
Model7	Year + Vessel + Month + DepCat + DayNight + Zone + Zone:Month
Model8	Year + Vessel + Month + DepCat + DayNight + Zone + Zone:DepCat

Table 5.193. EasternGemfishSp. The row names are 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_r2) and the change in adjusted R^2 (%Change). The optimum model was Zone:Month.

	AIC	RSS	MSS	Nobs	Npars	adj_r2	%Change
Year	9268	28395	4711	15909	26	14.1	0.00
Vessel	7509	25079	8027	15909	134	23.6	9.51
Month	6672	23784	9322	15909	137	27.5	3.93
DepCat	6326	23244	9862	15909	147	29.1	1.60
DayNight	6221	23082	10025	15909	150	29.6	0.48
Zone	6217	23067	10039	15909	153	29.7	0.03
Zone:Month	5971	22689	10418	15909	162	30.8	1.11
Zone:DepCat	6208	22977	10130	15909	180	29.8	0.16

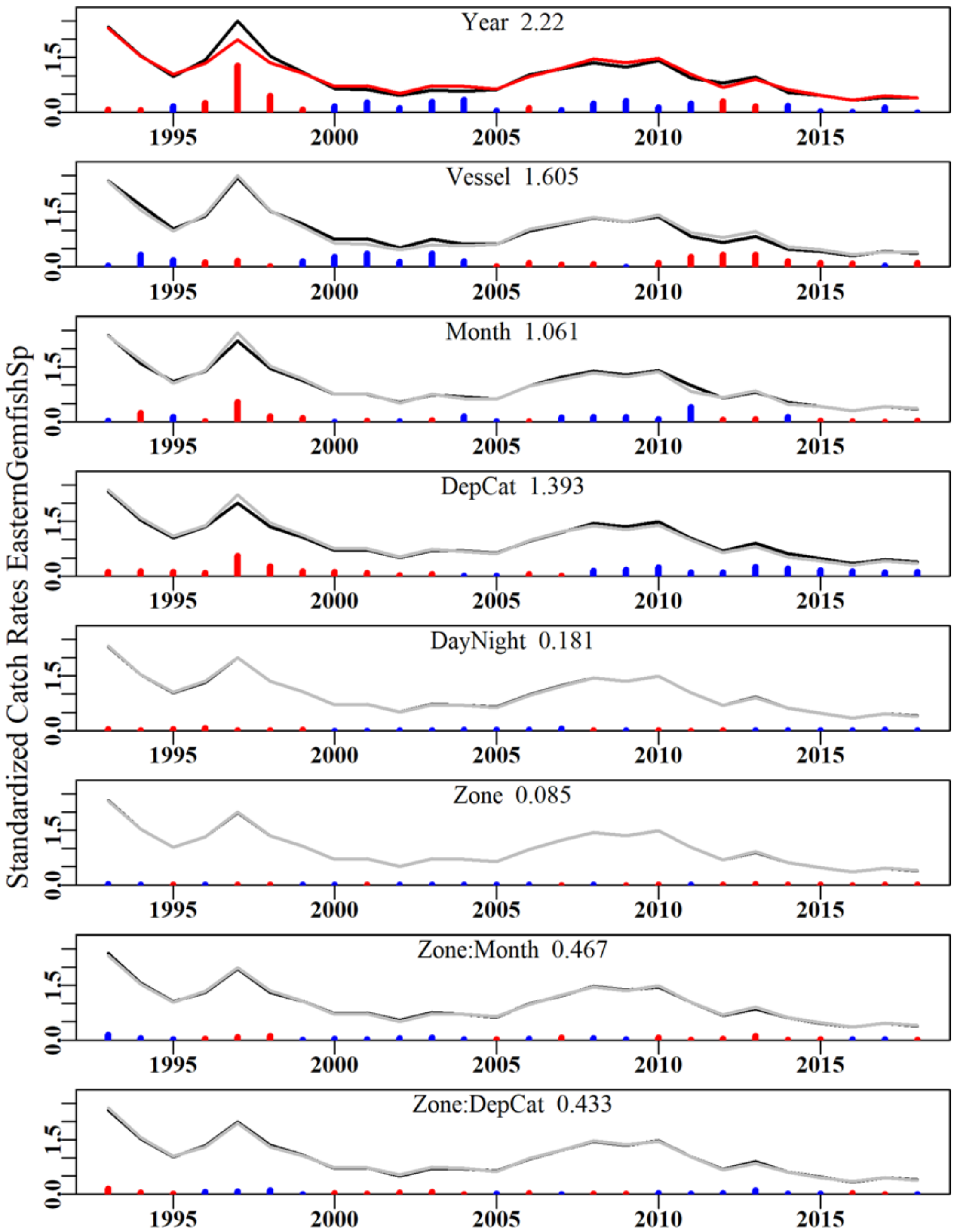

Figure 5.273. EasternGemfishSp. The influence of each factor on the optimal standardization. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by vertical bars with blue bars indicating the optimum model is higher than the 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.

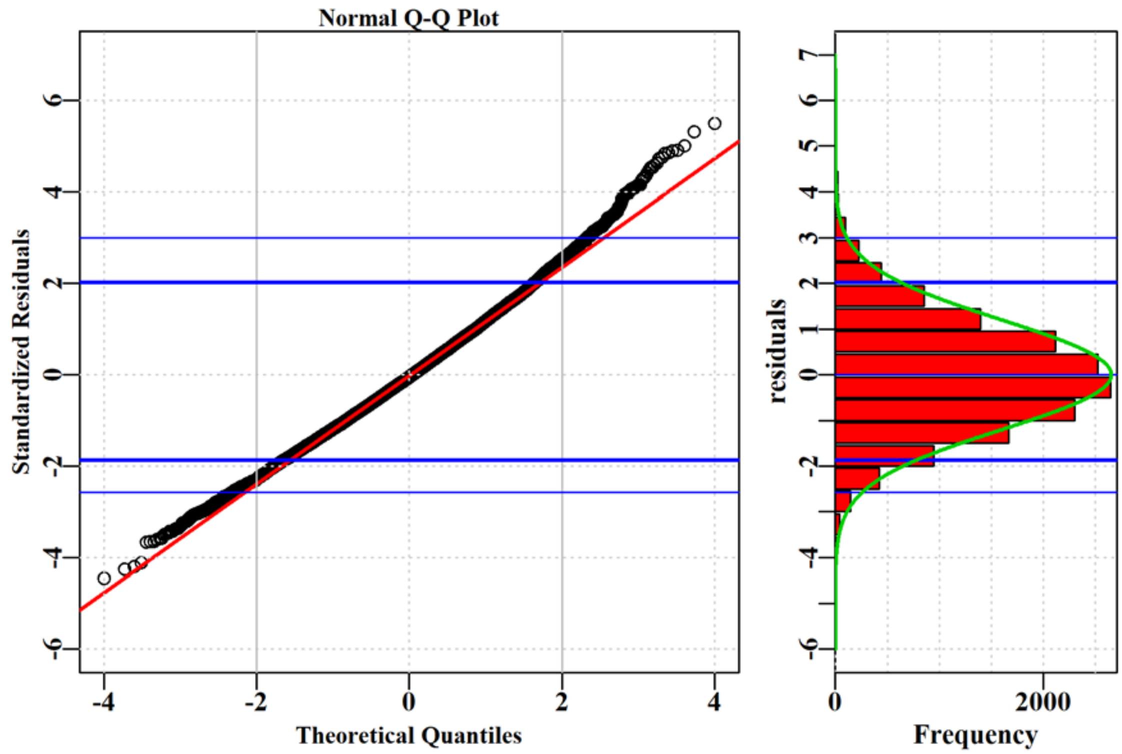

Figure 5.274. EasternGemfishSp. diagnostic plots. The distribution of residuals from the optimum fit. The qqplot indicates the fit to the expected normality, while the histogram of residuals illustrates the 90% quantiles to indicate the intensity of any lack of fit at the margins of the distribution.

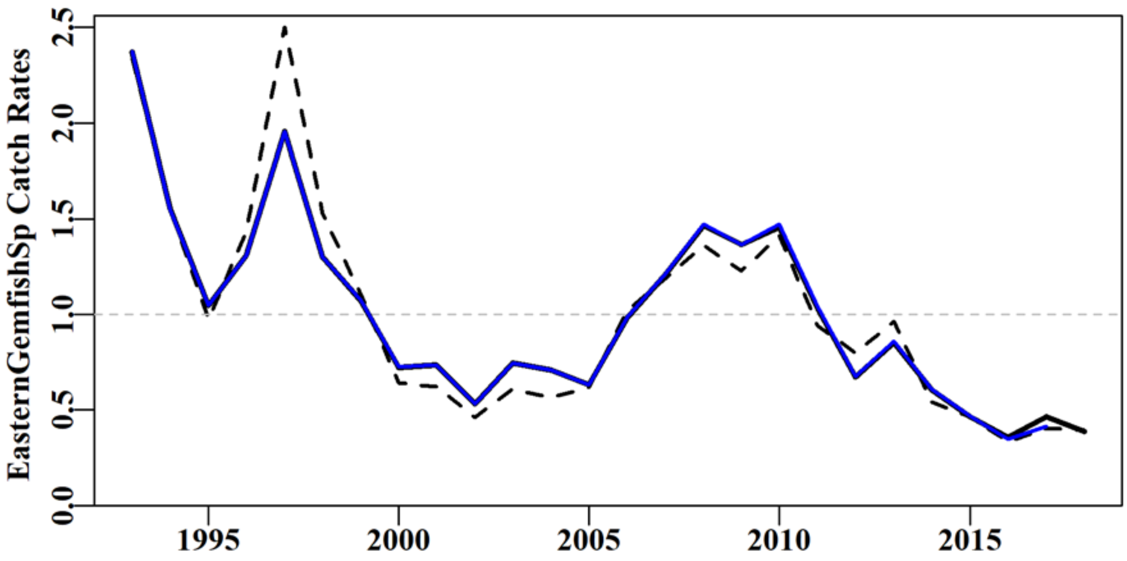

Figure 5.275. EasternGemfishSp. A comparison of the previous year's standardization (blue line) with this year's. They should lie on top of each other, although small deviations may relate to data adjustments, particularly in very recent years.

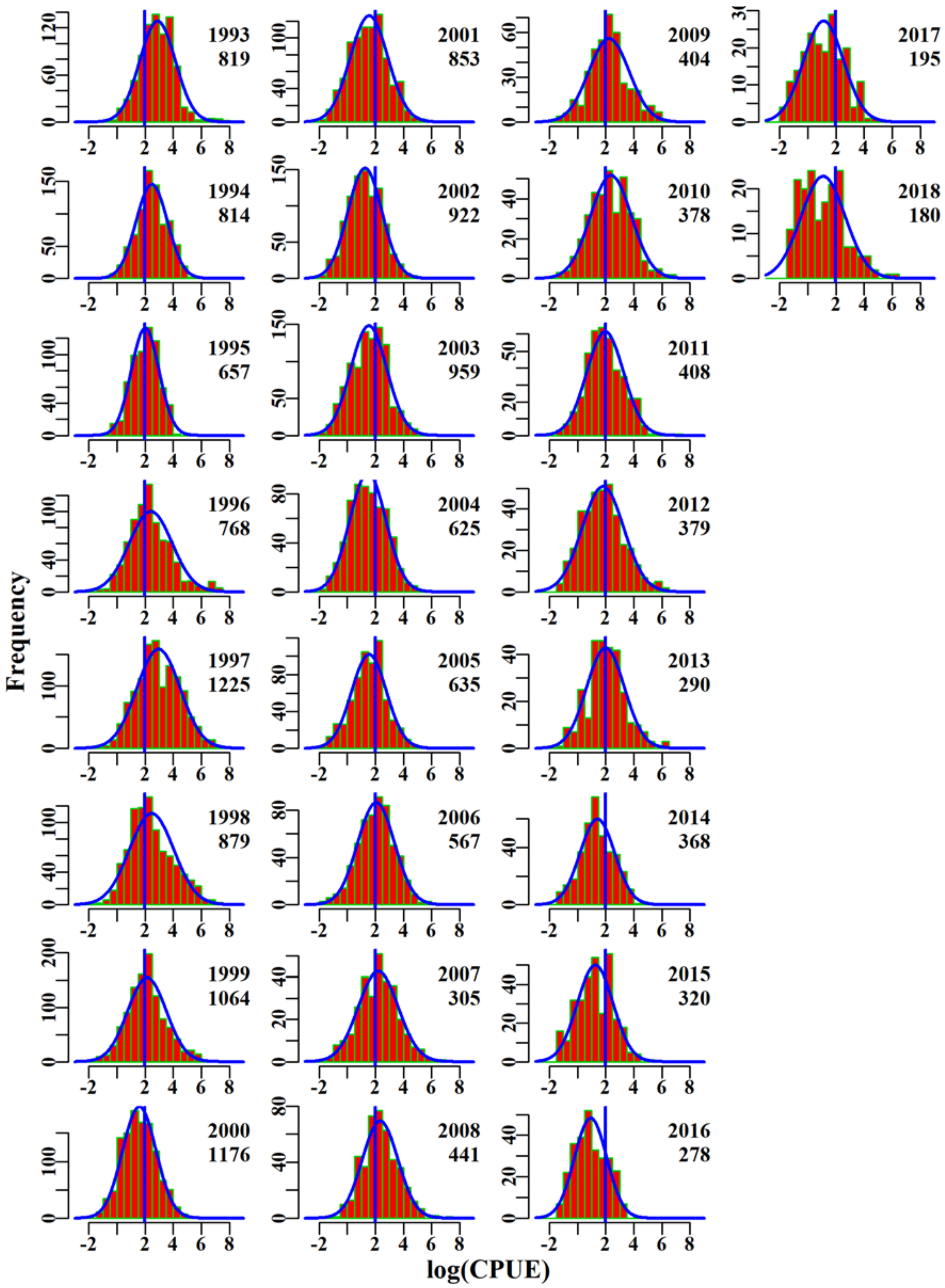

Figure 5.276. EasternGemfishSp. The natural log(CPUE) for each year of data available the blue lines are normal distributions fitted to the histogram frequencies. The numbers in each plot are the year and number of records.

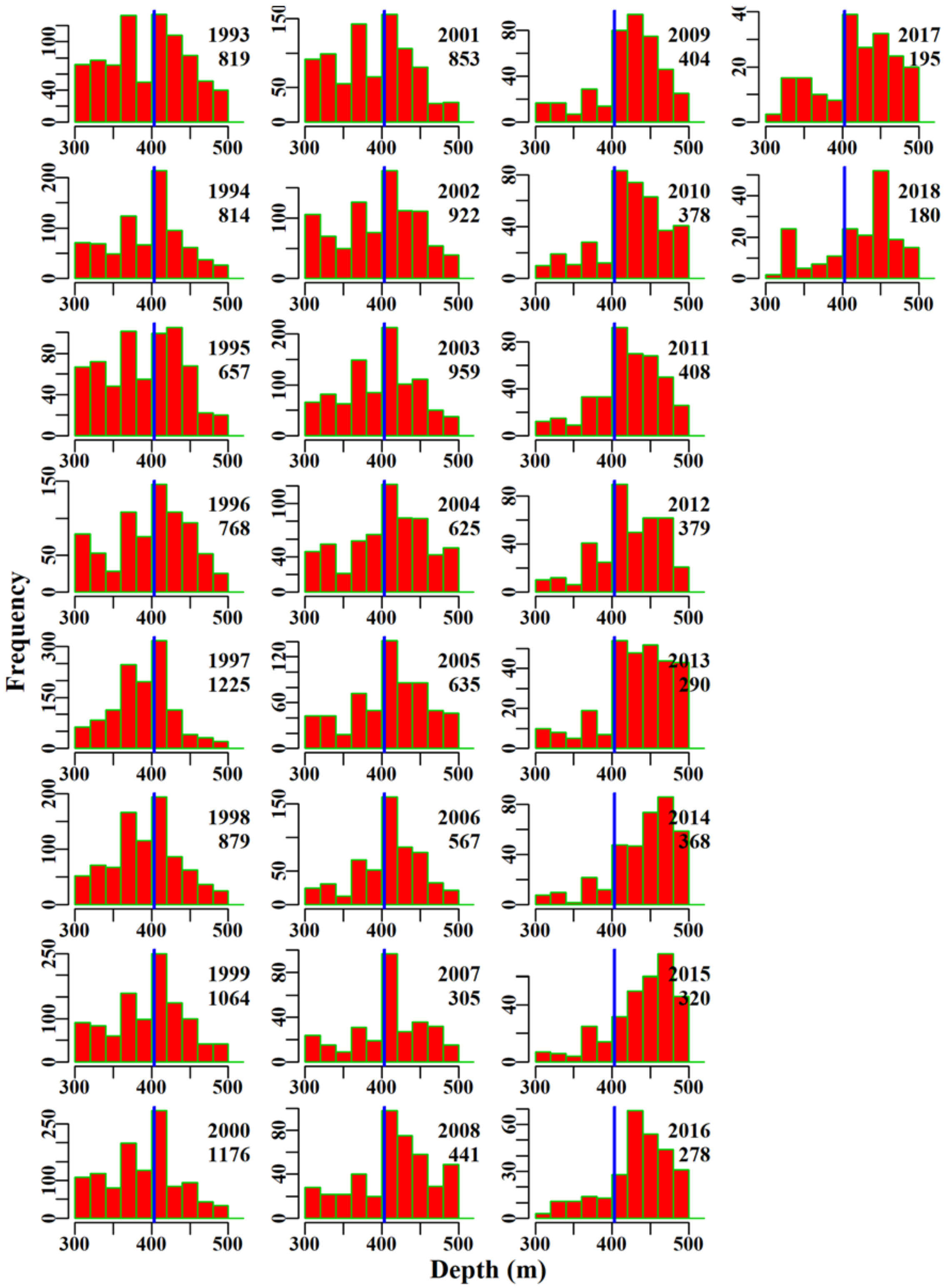

Figure 5.277. EasternGemfishSp. The average Depth of fishing for each year of data available to illustrate the development of the fishery through time. The numbers in each plot are the year and number of records.

5.44 Alfonsino

Initial data selection for Alfonsino (ALF - 37258002 - *Beryx splendens*) in the SET was conducted according to the details given in Table 5.194.

A total of 7 statistical models were fitted sequentially to the available data

5.44.1 *Inferences*

The terms Year, DepCat, Vessel, Month and one interaction term (Month:DepCat) had the greatest contribution to model fit, with the remaining terms each explaining < 1% of the overall variation in CPUE, based on the AIC and R^2 statistics. The qqplot indicates that less than 5% of records, those in the lower tail of the distribution, deviate from the assumption of normality.

Annual standardized CPUE trend is noisy and relatively flat across the years analysed (Figure 5.278). From 2013 - 2015 the standardized trend deviates from the nominal geometric mean trend such that the trend stays on the long term average catch rate while the geometric mean appears to rise well above it. There are now very few vessels contributing to this fishery and it appears that they are fishing in more focused depths. With so few vessels actively involved in the fishery the standardization can be expected to become more uncertain and dependent on their specific fishing activities.

5.44.2 *Action Items and Issues*

No issues identified.

Table 5.194. Alfonsino. The data selection criteria used to specify and identify the fishery data to be included in the analysis.

Property	Value
label	Alfonsino
csirocode	37258002
fishery	SET
depthrange	0 - 1000
depthclass	50
zones	10, 20, 30, 40, 50, 60, 70, 80, 81, 82, 83, 84, 85, 91, 92
methods	TW, TDO, OTT, PTB, TMO
years	1986 - 2018

Table 5.195. Alfonsino. Total catch (Total; t) is the total reported in the database, number of records used in the analysis (N), reported catch (Catch; t) in the area and depth used in the analysis and number of vessels used in the analysis (Vess). GeoM is the geometric mean of catch rates (kg/hr), standard deviation (StDev) relates to the optimum model. C<30Kg denotes the amount of catch in shots of <30kg, and %<30Kg is the percent of total. The optimum model was Zone:DepCat.

	Total	N	Catch	Vess	GeoM	Opt	StDev	C<30Kg	P<30Kg
1988	0.5	8	0.5	2	52.7	1.3892	0.000	0.138	0.257
1989	2.6	11	2.3	5	62.0	1.8673	0.653	0.120	0.052
1990	3.6	31	3.6	12	33.7	1.8566	0.595	0.352	0.097
1991	5.7	68	5.3	22	30.9	0.6939	0.566	0.962	0.182
1992	18.7	72	17.8	18	96.6	1.3803	0.531	0.565	0.032
1993	5.2	68	5.0	15	25.3	1.3035	0.550	0.826	0.164
1994	15.6	100	7.8	22	40.1	1.9160	0.550	1.137	0.146
1995	8.6	72	7.4	16	36.6	1.0189	0.560	0.834	0.113
1996	12.4	63	12.0	14	51.5	1.5333	0.565	0.727	0.061
1997	11.8	65	7.5	16	24.5	1.0690	0.568	0.805	0.107
1998	6.8	62	3.4	11	22.9	1.9951	0.574	0.501	0.146
1999	55.0	163	8.3	20	22.1	1.5293	0.551	1.971	0.238
2000	504.6	177	35.3	21	88.3	1.3900	0.555	2.463	0.070
2001	337.9	144	5.6	24	17.3	0.8086	0.555	1.948	0.350
2002	2643.0	222	24.9	31	153.3	1.0248	0.551	1.786	0.072
2003	1819.6	126	6.0	24	18.0	0.8187	0.556	1.589	0.264
2004	1411.3	172	16.1	27	19.7	0.9772	0.553	1.448	0.090
2005	445.2	161	7.9	24	23.6	0.9188	0.552	1.366	0.174
2006	458.4	223	11.0	22	29.8	1.1095	0.549	1.893	0.172
2007	530.2	205	8.5	13	15.4	1.1765	0.550	1.774	0.209
2008	260.2	359	48.2	13	37.6	1.1664	0.545	3.158	0.065
2009	98.8	336	15.3	14	24.2	0.8405	0.546	3.030	0.197
2010	57.9	261	8.8	16	10.1	0.5122	0.549	1.798	0.204
2011	807.2	229	4.3	15	4.6	0.4238	0.549	1.712	0.401
2012	616.1	131	1.9	14	4.3	0.3405	0.556	0.826	0.436
2013	225.6	95	3.7	14	8.5	0.2993	0.560	0.793	0.214
2014	85.0	100	5.9	12	85.4	0.4171	0.558	0.703	0.120
2015	76.2	178	13.5	13	120.1	0.3807	0.552	0.731	0.054
2016	23.3	96	3.2	10	18.9	0.2117	0.560	0.321	0.100
2017	8.2	136	6.1	12	27.8	0.2784	0.555	0.740	0.122
2018	8.4	151	5.3	12	21.3	0.3529	0.554	0.843	0.160

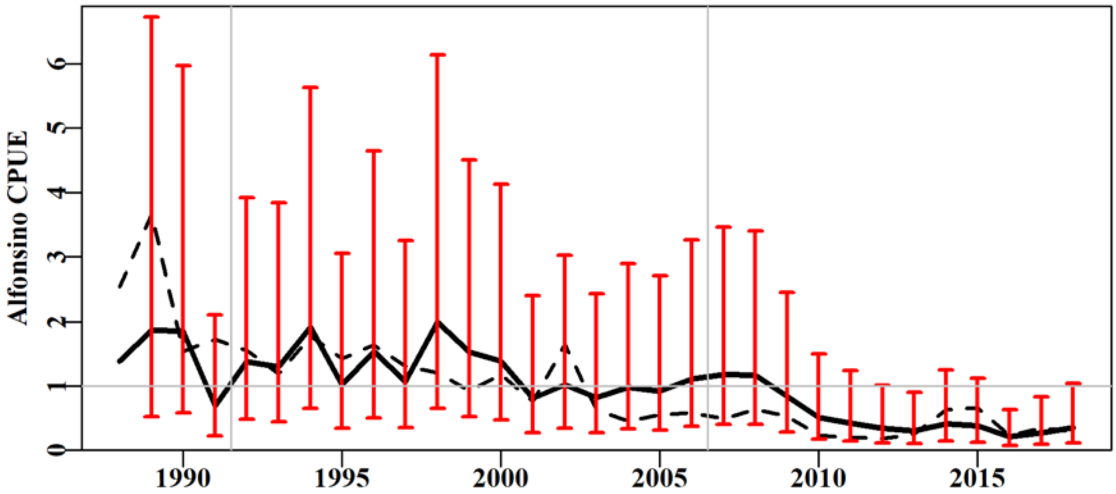

Figure 5.278. Alfonsino standardization. The dashed black line represents the geometric mean catch rate, solid black line the standardized catch rates. The red bars are the 95% confidence intervals about the mean estimates. The graph scales both time-series of standardized catch rates relative to the mean of each time-series.

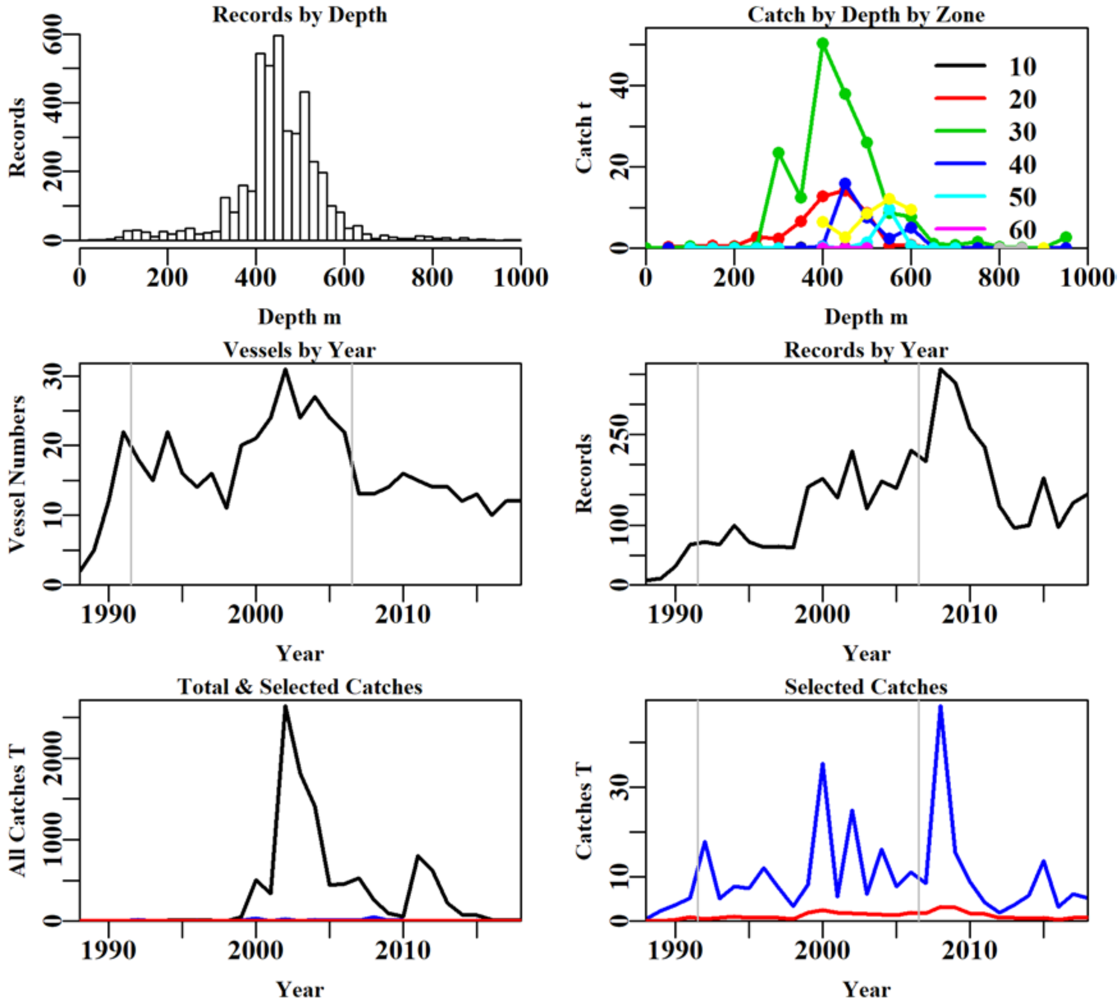

Figure 5.279. Alfonsino fishery details. The bottom left plot depicts all known catches (top black line), and all selected catches used in the analysis (middle blue line); the lower red line: selected catches < 30 kg).

Table 5.196. Alfonsino data selection effects. Total is the total number of records in the database, NoCE removes those records with either missing catch or effort, and then only those records are kept that meet the criteria for depth, years, zone, method and fishery.

	Total	NoCE	Depth	Years	Zones	Method	Fishery
Records	13652	9879	9766	9659	6363	5911	4285
Difference	0	3773	113	107	3296	452	1626
Catch	10567.77	10483.09	10372.32	10368.43	1914.57	1905.06	312.41
Difference	0	84.69	110.77	3.89	8453.86	9.518	1592.64

Table 5.197. The models used to analyse data for Alfonsino.

	Model
Model1	Year
Model2	Year + Vessel
Model3	Year + Vessel + DepCat
Model4	Year + Vessel + DepCat + Zone
Model5	Year + Vessel + DepCat + Zone + DayNight
Model6	Year + Vessel + DepCat + Zone + DayNight + Month
Model7	Year + Vessel + DepCat + Zone + DayNight + Month + Zone:DepCat

Table 5.198. Alfonsino. The row names are 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_r2) and the change in adjusted R^2 (%Change). The optimum model was Zone:DepCat.

	AIC	RSS	MSS	Nobs	Npars	adj_r2	%Change
Year	5149	14045	1908	4285	31	11.3	0.00
Vessel	2847	7814	8138	4285	136	49.4	38.09
DepCat	2791	7645	8307	4285	155	50.3	0.87
Zone	2581	7255	8697	4285	162	52.7	2.46
DayNight	2550	7197	8756	4285	164	53.1	0.36
Month	2493	7065	8887	4285	175	53.8	0.73
Zone:DepCat	2465	6832	9121	4285	233	54.7	0.89

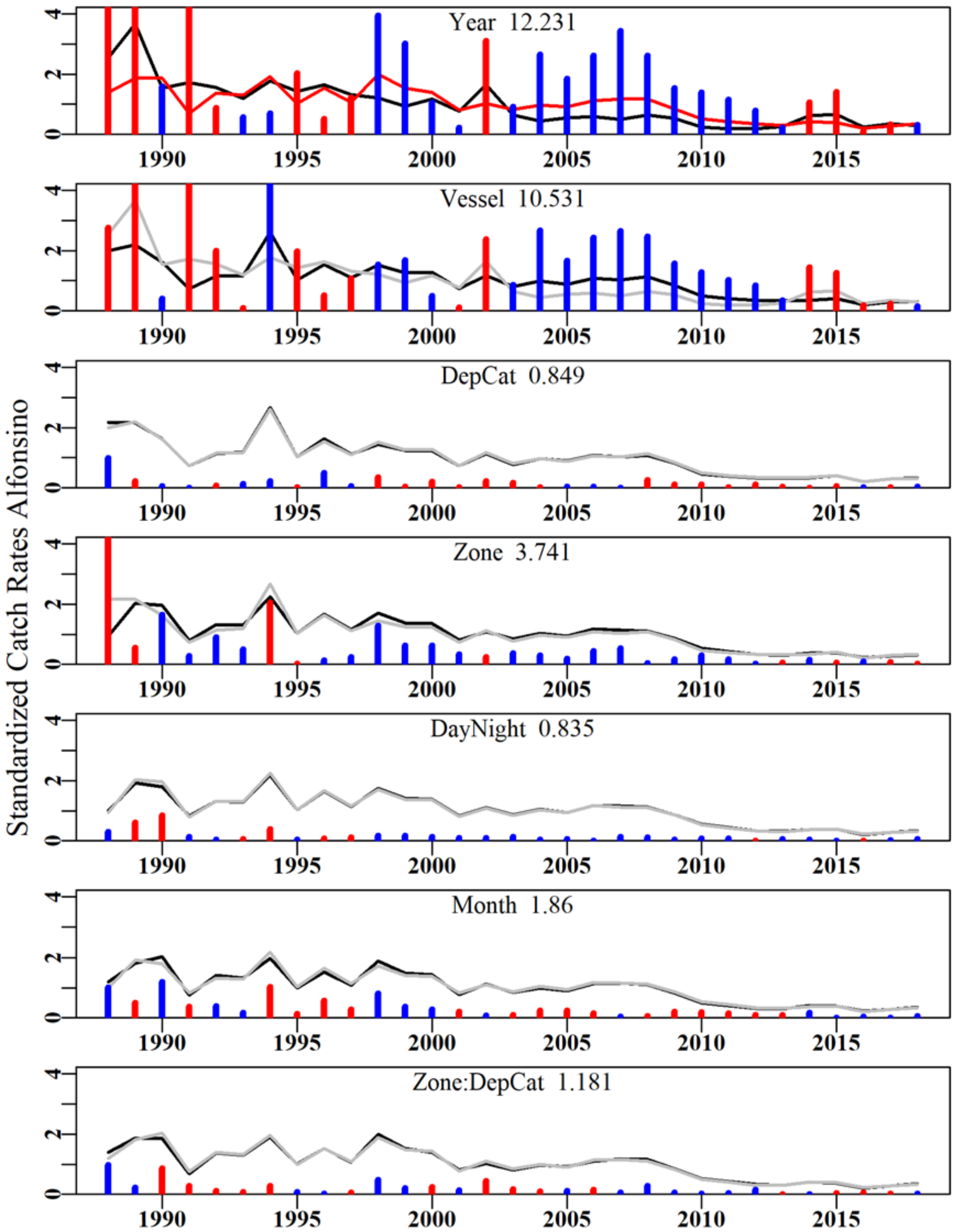

Figure 5.280. Alfonsino. The influence of each factor on the optimal standardization. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by vertical bars with blue bars indicating the optimum model is higher than the geometric 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.

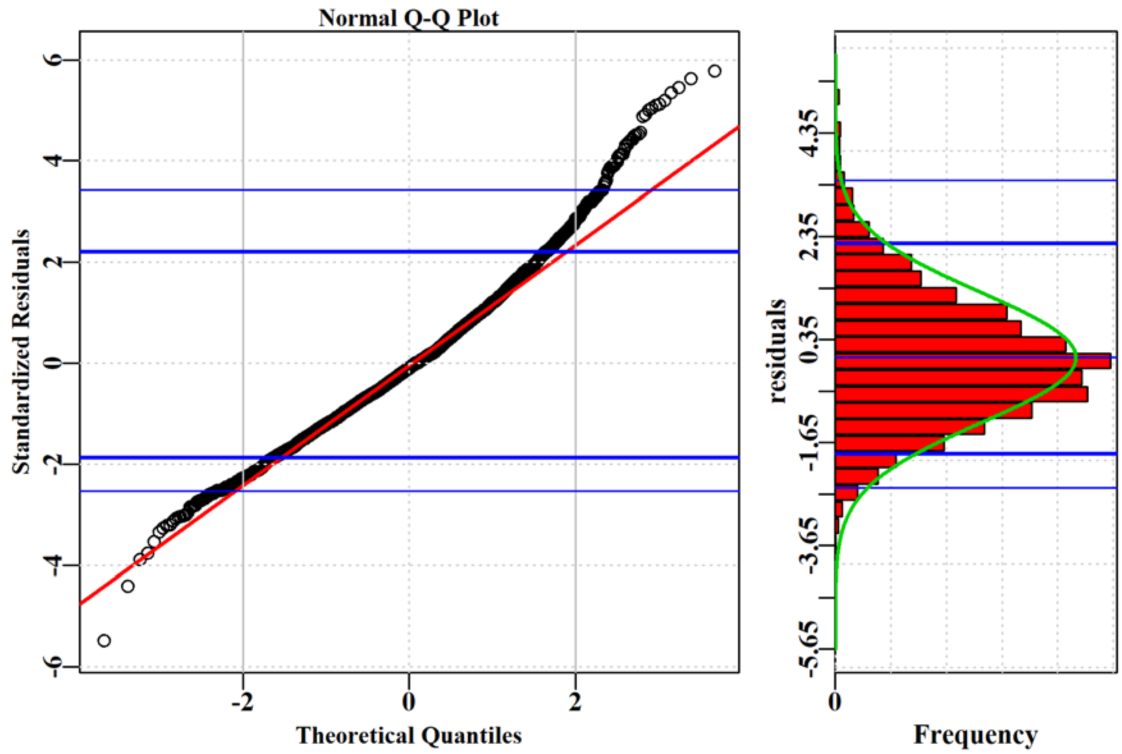

Figure 5.281. Alfonsino. diagnostic plots. The distribution of residuals from the optimum fit. The qqplot indicates the fit to the expected normality, while the histogram of residuals illustrates the 90% quantiles to indicate the intensity of any lack of fit at the margins of the distribution.

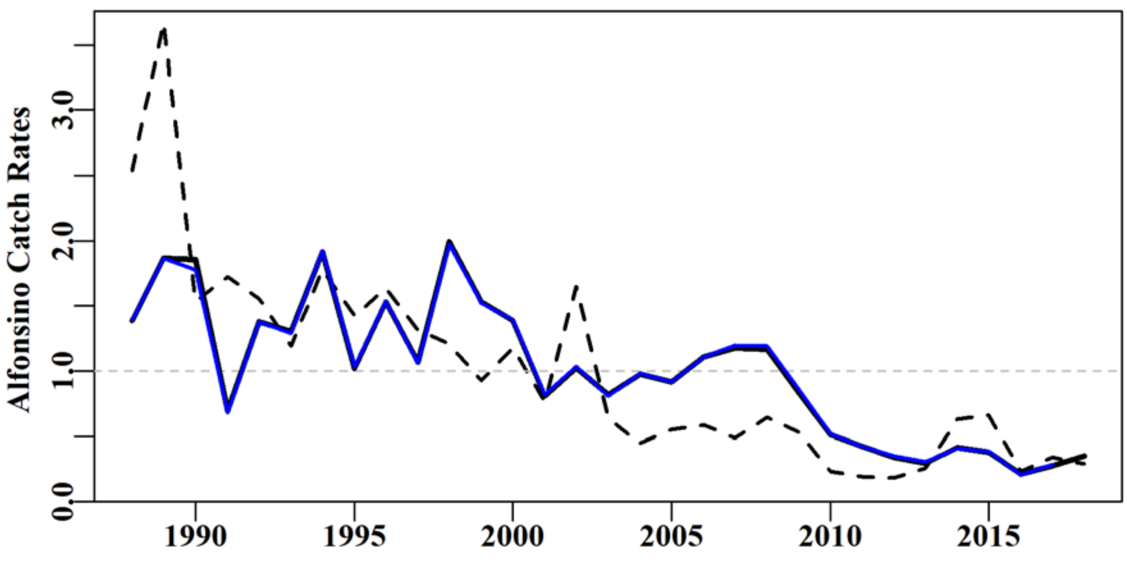

Figure 5.282. Alfonsino. A comparison of the previous year's standardization (blue line) with this year's. They should lie on top of each other, although small deviations may relate to data adjustments, particularly in very recent years.

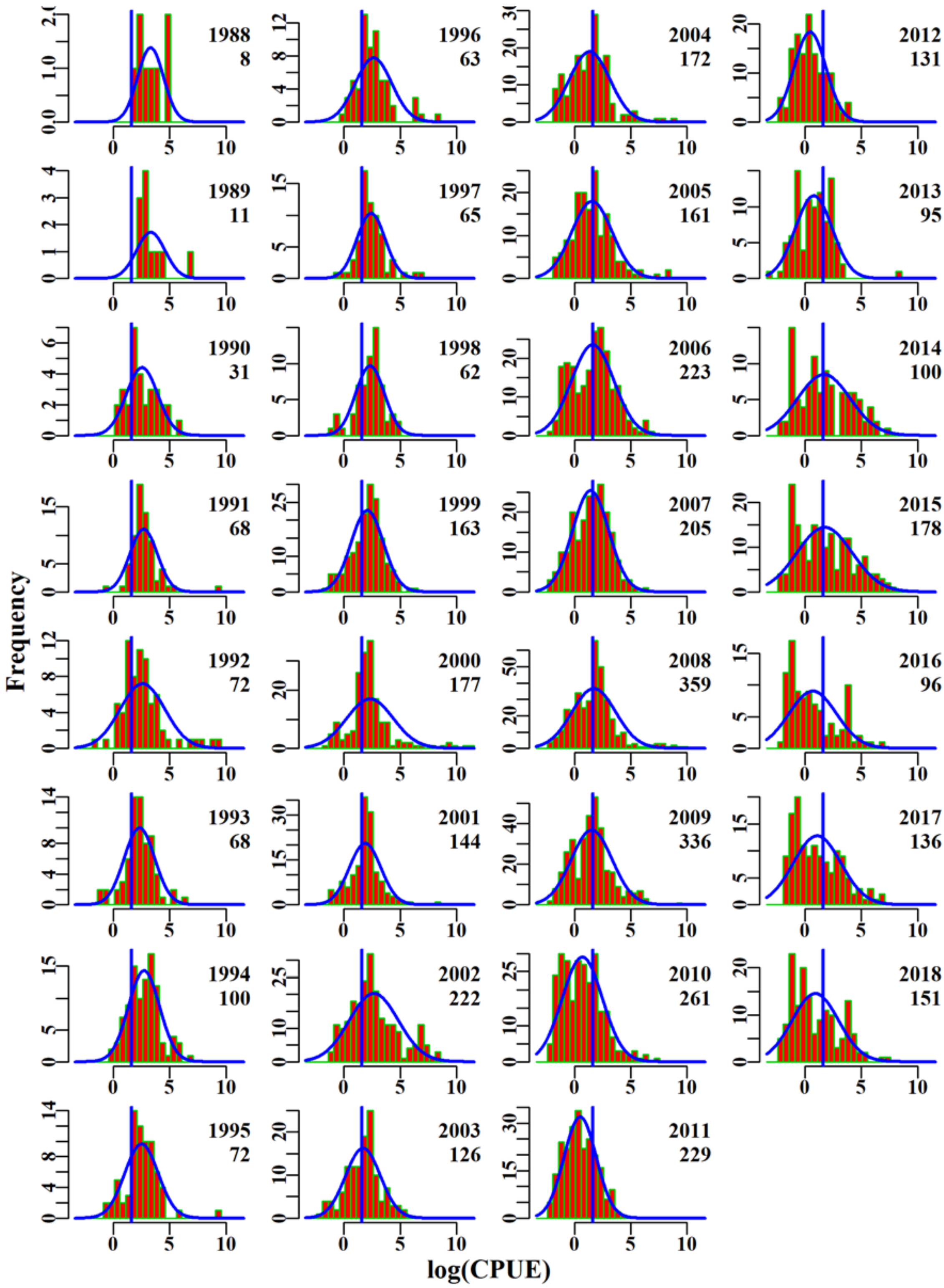

Figure 5.283. Alfonsino. The natural log(CPUE) for each year of data available the blue lines are normal distributions fitted to the histogram frequencies. The numbers in each plot are the year and number of records.

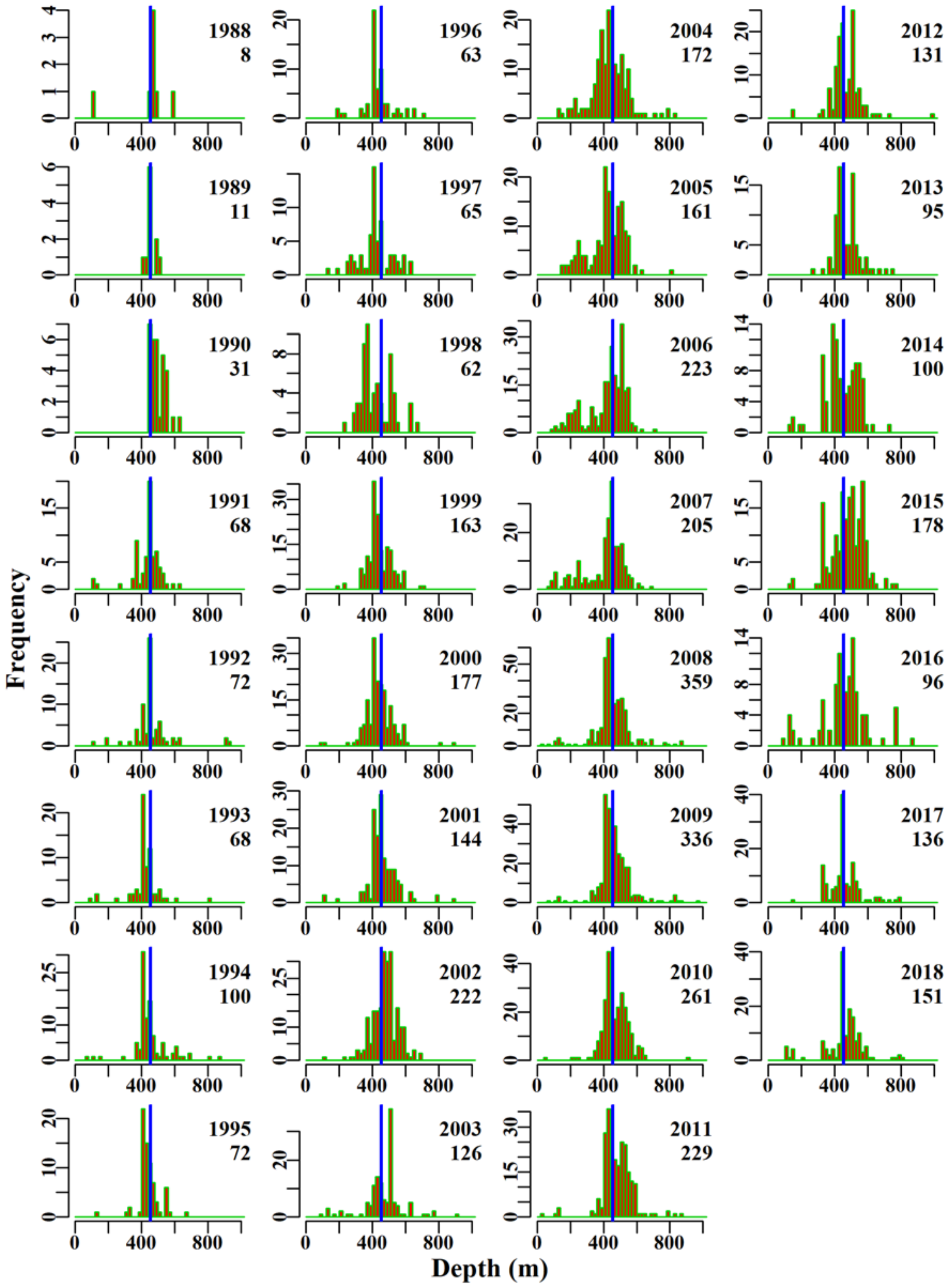

Figure 5.284. Alfonsino. The average Depth of fishing for each year of data available to illustrate the development of the fishery through time. The numbers in each plot are the year and number of records.

5.45 References

Burnham, K.P. and D.R. Anderson (2002) *Model Selection and Inference. A Practical Information-Theoretic Approach.* Second Edition Springer-Verlag, New York. 488 p.

Neter, J., Kutner, M.H., Nachtsheim, C.J, and W. Wasserman (1996) *Applied Linear Statistical Models.* Richard D. Irwin, Chicago. 1408 p.

R Core Team (2017). *R: A language and environment for statistical computing.* R Foundation for Statistical Computing, Vienna, Austria. URL https://www.R-project.org/.

5.46 Appendix 1: Executive Summary: Draft CPUE standardizations for selected SESSF Species (data to 2018)

5.46.1 *Summary*

This document attempts to summarize the main findings made in Sporcic (2019) regarding the standardization of 40 fisheries using statistical models customized to suit each set of circumstances. Visual summaries of all optimum statistical models are presented along with tables of the properties of each dataset and any issues that the standardizations may have raised for each species.

Documented are the statistical standardization of the commercial catch and effort data for 21 species, distributed across 40 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 Trevalla, Blue Grenadier, Silver Warehou, Blue Warehou, Pink Ling, Western Gemfish, Ocean Perch, John Dory, Mirror Dory, Ribaldo, Ocean Jackets, Deepwater Flathead and Bight Redfish.

Standardized CPUE has generally increased since about 2005 for pink ling west. Other species/stocks have shown shorter term increases over the last two to three years e.g., Pink Ling east, Royal Red Prawn and Inshore Ocean Perch. Standardized CPUE has increased in the last two years for Silver Warehou east and Silver Warehou west, after at least a ten-year general decline. Standardized CPUE has remained near the long-term average over the last six years for Blue Grenadier (non-spawning) with these indices all higher than those between 2000-13. By contrast, standardized CPUE has (i) declined for Flathead - Danish seine (zone 20-60) since 2016 and more generally since 2007 and (ii) fluctuated around the long-term average for both Flathead (zone 10, 20) and Flathead (zone 30) since 2000.

5.46.2 *Introduction*

The latest CPUE standardization document (Sporcic, 2019) has been produced to reduce the tedious repetitive aspects of relatively routine analyses typically requierd when dealing with fisheries statistics. Such automation is only suitable for processes that have achieved a degree of agreement concerning methods and details. In the SESSF, CPUE standardizations have been produced and developed since the late 1990s (e.g. Haddon, 1999) and they make an ideal candidate for such automation. Changes in methodology are uncommon from year to year and there are very many analyses to be conducted.

The final document is relatively long because now many more diagnostic plots and tables can be included to enhance our capacity to understand what factors potentially influence catch rates.

This document aims to summarize the results within (Sporcic 2019) across all species and tabulate any issues raised by the data from particular species.

5.46.3 *Methods*

Part of the output from Sporcic (2019) is a table of the optimum statistical models for each fishery analysed. To provide a visual summary of these outcomes all 40 CPUE trends are individually plotted and a Loess curve fitted to the annual mean CPUE estimates to illustrate the general trend. In addition, the root mean square error (RMSE), sometimes referred to as the root mean squared deviation (RMSD), is calculated to provide an indication of how variable the mean annual estimates are around the central trend line. Essentially this is attempting to measure the average difference between two time series. The equation used for the RMSE was:

$$RSME = \sqrt{\frac{\sum_{i=1}^{n}\left(\hat{I}_i - \hat{L}_i\right)^2}{n}}$$

where $\hat{I}_i$ is the expected mean CPUE in year *i*, $\hat{L}_i$ is the predicted Loess trend value for year *i*, and *n* is the number of years. The *loess* function in **R** was used for the calculations (R Core Team, 2017).

Two forms of the same data were plotted; the first with a constant y-axis scale to provide a visual impression of the variation of CPUE through time in each fishery relative to every other fishery, and a second where each plot is given its own y-axis scale to maximize the vertical contrast and exhibit the details of any trends that exist.

5.46.3.1 Analyses Included

For some species/fisheries analysed, the conclusion reached was that they were there primarily for historical reasons. Thus, prior to Mirror Dory being considered separately on the east and west coasts (MirrorDory 10, 20, and 30, and Mirror Dory 40 and 50) a single analysis of the whole of Mirror Dory was made. This has the potential to be confusing, so is no longer produced in this report. Such decisions are required for Inshore Ocean Perch and Western Gemfish4050GAB; Mirror Dory 10-50, here, has already been omitted, a decision to confirm that is required.

5.46.4 *Action Items and Issues by Fishery*

5.46.4.1 Introduction

The Action Items and Issues section from each fishery's analyses is extracted and printed to be considered for further action. Where a fishery/species is listed with no action items below it this implies none were written in the original document (Sporcic, 2019). The intent of this section is to highlight to the RAG and other stakeholders, potential issues that would receive further attention to resolve.

JohnDory1020

A potential change in fishing behaviour is suggested to have occurred since about 2014, which is evidenced by changes in the distribution of log-transformed CPUE each year. From 2014 a number of widely spread spikes in the histograms have become apparent, most especially in 2015, 2016 and 2017. The underlying driver for these changes is not immediately apparent.

SchoolWhiting60

Further work is required to determine the reason behind the frequent occurrence of spikes of low values of catch-per-shot and how they may best be described or explained.

SchoolWhitingTW102091

Again, the last three years 2014 - 2016 appear to have exhibited an alteration in fishing behaviour as evidenced by the changing distributions of records of catch at depth, why this has occurred in the last three years remains unknown.

SchoolWhitingTW1020

The depth distribution of catches has not been stable from year to year, which may reflect the fact that there are only few vessels contributing seriously to this fishery.

MirrorDory1030

No issues identified.

MirrorDory4050

It is recommended that the CPUE time-series only be used from 1995 onwards because catches before then are relatively minor. Whatever the case, from 1990 the CPUE trend for Mirror Dory appears to be relatively flat and noisy around the long-term average with periods above and below.

JackassMorwong30

With only 69 records and 30 t of reported catch in 1986, it is recommended that the standardization analysis should begin in 1987 or 1988.

The selected depth for Jackass Morwong 30 is from 70 - 300 m, recommended by the RAG. However, there are records in Zone 30 from 0 - 500 metres but only significant catches out to 200 m or 250 m at most. The reasons for the earlier specific depth selection need to be re-iterated and an examination of the effect of making the current depth selection explored.

JackasssMorwong1020

The structural adjustment altered the effect of the vessel factor on the standardized result. However, log(CPUE) has also changed in character from 2014 - 2018, with spikes of low catch rates arising.

JackasssMorwong4050

The vessel factor changed its influence from 2001 onwards reflecting the increase in catches from 2001 and suggesting the fishery changed remarkably at that time. The reasons behind this change should be explained in more detail.

SilverWarehou4050

After consideration of Silver Warehou catches in zones 40 - 50 by year and vessel, the period around 1999 - 2006 appears exceptional, or at least contains exceptional vessels, all of which left the fishery after the structural adjustment. This suggests that there have been transitional periods in the time-series of CPUE. This **urgently** needs more attention because this may imply that CPUE may no longer be acting as a valid index of relative abundance through time.

SilverWarehou1030

After consideration of Silver Warehou catches in zones 10 - 30 by year and vessel the period around 1992 - 2006 appears exceptional, or at least contains exceptional vessels. This suggests that there have been transitional periods in the time-series of CPUE. This **urgently** needs more attention because of the potential implications this has for the index of relative abundance through time.

FlatheadTW30

The number of records and corresponding catch in 1986 and 1987 are very low. Also, the depth distribution is spread over a large range for these two years compared to all other years in the fishery. It is therefore recommended to remove these two years from the time series for analysis.

FlatheadTW1020

After consideration of Tiger Flathead catches in the east by year and vessel for the period around 1992 - 2006 appears to be different from catches by vessel from 2007. This suggests that there have been transitional periods in the time-series of CPUE. This **urgently** needs more attention because of the potential implications this has for the index of relative abundance through time.

FlatheadDS2060

It is recommended that an exploration of the fishery dynamics be evaluated to determine whether the CPUE values are being influenced by the species being targeted within individual shots (e.g. is there interference between shots catching mostly flathead compared to shots catching mostly School Whiting?). This will be importnat for determining whether estimated annual indices adequately reflect stock abundance.

Redfish1020

After consideration of redfish catches in zones 10 and 20 by year and vessel, the period around 1993 - 2006 appears to be different to other years. This suggests that there have been transitional periods in the time-series of CPUE. This **urgently** needs more attention because of the potential implications this has for the index of relative abundance through time.

BlueEyeTW2030

Given the on-going low catches, and the recent even lower catches, the major changes in the fleet contributing to the fishery, the dramatically changing character of the CPUE data itself, and the recent disjunction between nominal catch rates and the standardized catch rates it is questionable whether this time-series of CPUE is indicative in any useful way of the relative abundance of Blue-Eye Trevalla. Whether this analysis should be continued should be considered.

BlueEyeTW4050

If this analysis is to continue, then the early CPUE data from 1988 to 1991 should be explored in more detail to ensure it is representative of the fishery and does not contain systematic errors. After introducing quota CPUE distributions became more consistent through time, although relatively low numbers of observations are now contributing to a change in their character in the latest years.

BlueGrenadierNS

It is recommended that alternate statistical distributions be considered.

PinkLing1030

A detailed consideration be given to the change in vessel effects following the structural adjustment to ensure that the time-series of Pink Ling CPUE was not broken by this management intervention.

PinkLing4050

Further work on the effect of the structural adjustment is required for Pink Ling in zones 40 and 50.

OceanPerchOffshore1020
No issues identified.

OceanPerchOffshore1050

The generally lower CPUE for Offshore Ocean Perch in zones 30, 40, and 50 suggest it is not a major target species in those zones. It is recommended that the Tier 4 for Offshore Ocean Perch continue using the analysis presented in Offshore Ocean Perch for zones 10 and 20 as catch rates in those zones would seem to be more indicative of the main location for the stock.

OceanPerchInshore1020

As the discarding rate continues to be very high (~90% of all catches) it is recommended that this analysis not be conducted as it may mistakenly be assumed to be informative of the stock's relative biomass through time.

OceanJackets1050

No issues identified.

OceanJacketsGAB

No issues identified.

gemfish4050

No issues identified.

gemfish4050GAB

This analysis is recommended to be abandoned as misleading through it combining the data from two biological stocks.

gemfishGAB

No issues identified.

bluewarehou1030

No issues identified.

bluewarehou4050

Exploration of the early CPUE data could be made to examine whether there are obvious or consistent errors leading to mean CPUE values 4 times greater than the long-term average.

deepwaterflathead

No issues identified.

bightredfish

No issues identified.

RibaldoTW

It is recommended that the geographical distribution of catches be explored to determine how representative of the entire stock's distribution the early years are.

RibaldoAL

The first two or three years of data need to be examined to detemine how representative these data are of the whole stock. It may also benefit from being converted to catch-per-hook rather than catch-per-shot.

SilverTrevally1020

Further exploration of the reasons behind the recent deviation of the standardized time-series from the nominal geometric mean are required to provide a more detailed explanation for these changed dynamics.

SilverTrevally1020nompa

Further exploration of the reasons behind the recent deviation of the standardized time-series from the nominal geometric mean are required to provide a more detailed explanation for these changed dynamics.

RoyalRedPrawn

Fishing behaviour appears to have changed in 2018, as evidenced by the distribution of records of catch at depth, why this has occurred remains unknown.

EasternGemfishNonSp

No issues identified.

EasternGemfishSp

No issues identified.

Alfonsino

No issues identified.

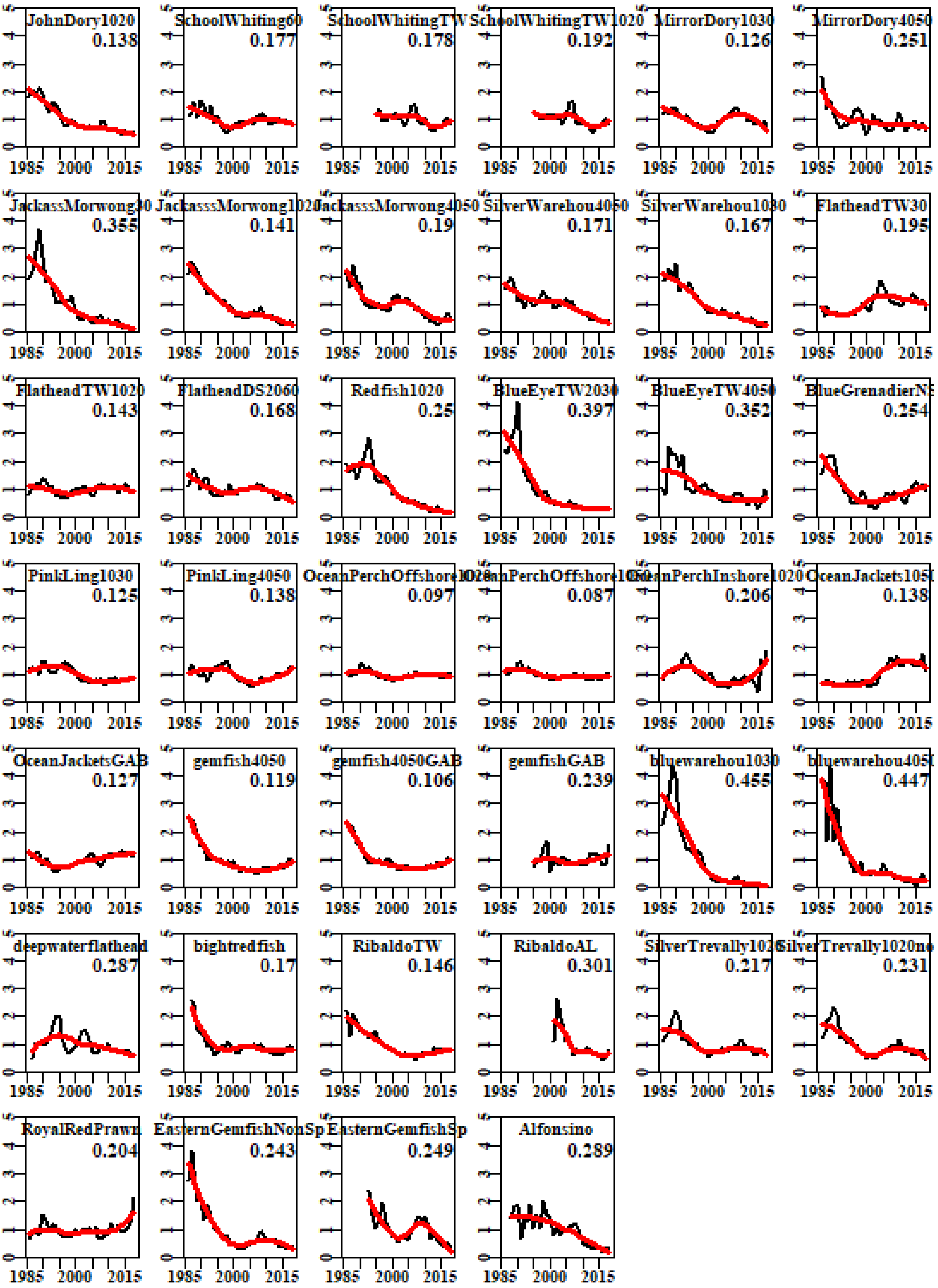

Figure A 7.1. The optimal standardized CPUE trend for each fishery analysed. In each case, the black line represents the standardization and the red line is a loess best fitting trend. The title in each plot is the fishery and the number at top right is the root mean squared deviation. All y-axes have a maximum of 5.0.

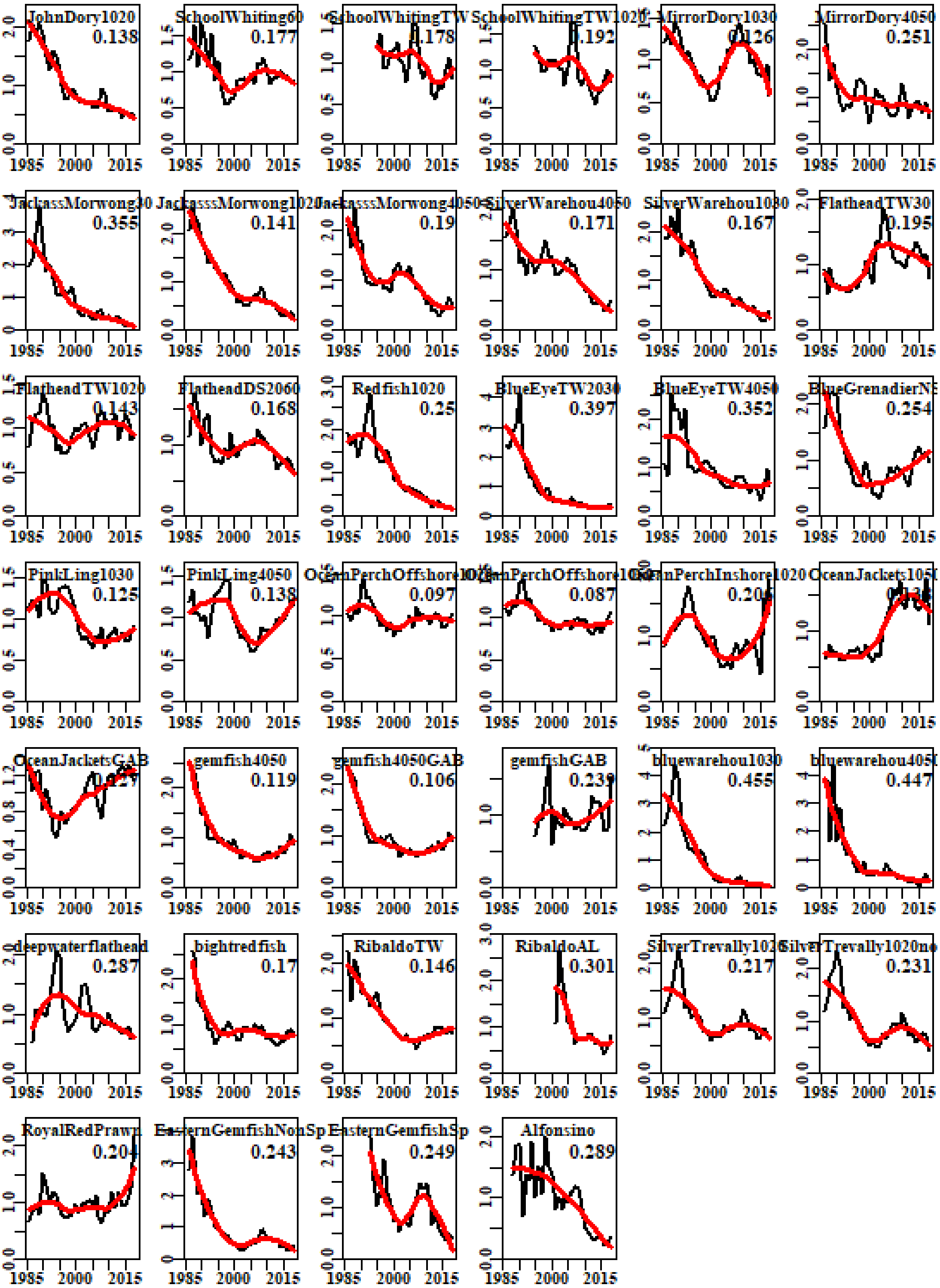

Figure A 7.2. The optimal standardized CPUE trend for each fishery analysed. In each case, the black line represents the standardization and the red line is a loess best fitting trend. The title in each plot is the fishery and the number at top right is the root mean squared deviation. All y-axes have individual scales.

Table A 7.1. The basic properties of each dataset, including the number of observations used in the optimum analysis, the number of parameters fitted in the optimum model, and the proportion of the total variation the model accounted for, and the shallowest and deepest depths.

Species label	Nobs	Npars	Adj_r2	Ldepth	Udepth	RMSE
JohnDory1020	146948	238	25.56	0	200	0.138
SchoolWhiting60	92105	142	13.29	0	100	0.177
SchoolWhitingTW	22754	260	40.73	0	140	0.178
SchoolWhitingTW1020	15663	148	44.24	0	140	0.192
MirrorDory1030	99755	277	35.16	0	600	0.126
MirrorDory4050	34204	174	33.08	0	600	0.251
JackassMorwong30	22152	155	37.03	60	300	0.355
JackasssMorwong1020	118741	251	27.94	60	300	0.141
JackasssMorwong4050	14623	164	36.55	60	360	0.190
SilverWarehou4050	65234	173	24.40	0	600	0.171
SilverWarehou1030	76050	267	22.77	0	600	0.167
FlatheadTW30	26732	300	22.11	0	300	0.195
FlatheadTW1020	285031	275	17.18	0	180	0.143
FlatheadDS2060	229370	123	38.16	0	200	0.168
Redfish1020	102860	239	31.24	0	400	0.250
BlueEyeTW2030	13073	211	55.76	0	1000	0.397
BlueEyeTW4050	13562	172	44.77	0	1000	0.352
BlueGrenadierNS	146702	324	36.18	100	450	0.254
PinkLing1030	104371	278	29.68	250	600	0.125
PinkLing4050	83405	188	29.35	200	780	0.138
OceanPerchOffshore1020	84861	242	29.95	200	700	0.097
OceanPerchOffshore1050	119158	322	35.89	200	700	0.087
OceanPerchInshore1020	17197	238	37.15	0	200	0.206
OceanJackets1050	93456	277	27.28	0	300	0.138
OceanJacketsGAB	56617	112	27.01	0	300	0.127
gemfish4050	34832	162	44.05	100	700	0.119
gemfish4050GAB	46478	229	46.21	100	650	0.106
gemfishGAB	10176	107	53.20	100	650	0.239
bluewarehou1030	37815	254	39.65	0	400	0.455
bluewarehou4050	13449	166	31.20	0	600	0.447
deepwaterflathead	80838	157	36.58	50	250	0.287
bightredfish	55178	143	30.66	50	300	0.170
RibaldoTW	23926	245	30.94	0	1000	0.146
RibaldoAL	5940	131	41.73	0	950	0.301
SilverTrevally1020	59589	227	30.75	0	200	0.217
SilverTrevally1020nompa	40161	225	32.65	0	200	0.231
RoyalRedPrawn	25868	274	43.91	200	680	0.204
EasternGemfishNonSp	39856	299	40.39	0	600	0.243
EasternGemfishSp	15909	162	30.77	300	500	0.249
Alfonsino	4285	233	54.72	0	950	0.289

5.46.5 *Acknowledgements*

Thanks goes to the CSIRO database team for their preliminary processing of the catch and effort data as received from the Australian Fisheries management Authority.

5.46.6 *References*

Haddon, M. (1999). Standardization of Catch/Effort data from the South-East Pink Ling Fishery. South East Fishery Assessment Group Paper. 16p.

Sporcic, M. (2019). Draft CPUE standardizations for selected SESSF Species (data to 2018). CSIRO Oceans and Atmosphere, Hobart. 331 p.

R Core Team (2017). *R: A language and environment for statistical computing.* R Foundation for Statistical Computing, Vienna, Austria. URL https://www.R-project.org/.

6. Statistical CPUE (catch-per-hook) Standardizations for Blue-Eye Trevalla (Auto-line and Drop line) in the SESSF (data to 2018)

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6.1 Executive Summary

This report is an update of standardized CPUE (catch per hook) indices for Blue-Eye Trevalla which includes data in 2018 based on the same method proposed in Haddon and Sporcic (2018).

In 2014, analyses based on catch-per-record were no longer considered to adequately represent the state of the Blue-Eye stock due to the advent of a number of issues: 1) a reported expansion of whale depredations on auto-line catches in association with the changed behaviour of the fishing vessels in the presence of whales, 2) a restriction of fishing location options due to an increase in the number of marine closures over known Blue-Eye fishing grounds, and 3) a movement of fishing effort much further north off the east coast of New South Wales and Queensland has altered the reliability of the current CPUE analyses as an indicator of Blue-Eye relative abundance across the range of the fishery. As a result the 2013 CPUE standardizations for Blue-Eye, and the Tier 4 analyses dependent upon them, were no longer considered to provide an adequate representation of trends across and within the Blue-Eye fishery, which could leave the stock status uncertain.

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

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

One of the foundations of the current Tier 4 Blue-Eye 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, each method alone only had a rather short time-series of usable CPUE (sufficient catches, records and representative coverage of the fishery) that could be used for assessment purposes. Now catch-per-hook is used as the basis for the standardization but the

combination of drop-line and auto-line is still required to maintain the CPUE estimates within the early reference period of 1997 – 2006.

An objective of the current work was to repeat previous analyses used to generate the total-hooks-set per record but including all the most recent data. Separate data selection rules and database manipulations (separate algorithms) developed for Drop-Line and Auto-Line data sets (Haddon, 2016) were repeated with updated datasets such that the outcome provided estimates of the total number of hooks set for each record. These data were used to generate catch-per-hook catch rate data which were in turn used in catch rate standardizations for the two methods.

The two time series of CPUE were combined using catch weighting and scaling the two series to the same mean CPUE of 1.0 for the period of 2002 - 2006, which was the period of overlap. For the catch-per-hook data to be acceptable required there to be sufficient records to provide a reasonable spatial coverage of the fishery as well as reasonably precise estimates of the annual mean values. Drop-Line CPUE were acceptable from 1997 - 2006 and Auto-Line data were acceptable from 2002 - 2018.

The analysis using catch-per-hook exhibits a noisy but flat trajectory not seen in the catch-per-record, which appears to be declining. All analyses have limited numbers of observations and hence are relatively uncertain. Given this uncertainty it does not matter greatly whether the analysis of catch-per-hook is restricted to zones 20 - 50, as has been done previously, or extended to include the GAB zones 83, 84, and 85.

Until management decisions are made concerning which geographical management units are to be used with Blue-Eye it would appear to be potentially misleading to omit the GAB auto-line catches when analysing auto-line CPUE. The GAB catches are included in the TAC allocated to Blue-Eye and it is assumed that decisions to fish in different locations are made in the context of the full geographical range (implied management unit) available within which to take the TAC. It is thus recommended that, unless decisions are made to alter the implicit management unit currently used, the CPUE time-series relating to SESSF zones 20, 30, 40, 50, 83, 84, and 85, be used in subsequent Tier 4 analyses rather than the series relating only to zones 20 to 50.

6.2 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 juvenile stages are widely dispersed. Not only is it patchily distributed but the fishery differs markedly by area through the application of different methods and histories of exploitation. The differences in exploitation history along with sampling different areas in different years may have been sufficient to have led to the appearance of heterogeneity in the biological characteristics of different populations. There is little consistency between consecutive years in the age structure and length structure of samples (Figure 6.1); for example, cohort progression is difficult or impossible to follow. This lack of consistency has thwarted previous attempts at applying a Tier 1 integrated assessment to Blue-Eye and has made the application of the Tier 3 catch-curve approach equally problematical (Fay, 2007a, b). Such spatial heterogeneity has recently been reviewed and further evidence presented, all of which supported the notion that there were spatially structured differences between Blue-Eye populations between regions around the south-east of Australia (Williams et al., 2016).

Table 6.1. The number of records and catches (t) per year for auto-line, drop-line, and trawl vessels reporting catches of Blue-Eye Trevalla from 1997 - 2016. Data filters were to restrict the fisheries included to SET, GAB, SEN, GHT, SSF, SSG, and SSH. Methods were limited to AL, DL, TW, and TDO. Finally only CAAB code = 37445001 that identifies *Hyperoglyphe antarctica* were included.

	AL-Catch	AL-Record	DL-Catch	DL-Record	TW-Catch	TW-Record
1997	0.267	3	271.942	575	104.567	1500
1998	27.253	50	343.505	738	82.074	1398
1999	61.590	77	377.032	981	100.329	1712
2000	90.931	93	384.409	1078	95.042	1893
2001	47.884	76	335.873	799	90.218	1809
2002	134.067	234	223.074	619	67.998	1548
2003	219.676	487	221.649	587	28.918	1210
2004	329.608	1345	158.491	520	48.767	1559
2005	301.303	1150	93.779	368	42.969	1169
2006	354.582	1098	114.639	328	66.105	924
2007	455.096	667	46.011	129	38.321	834
2008	281.384	621	15.549	76	36.046	806
2009	325.893	590	30.158	112	39.386	618
2010	236.620	495	42.023	253	43.480	647
2011	267.318	567	59.381	244	23.268	626
2012	217.815	475	34.107	140	10.792	425
2013	190.515	363	7.762	54	22.893	359
2014	227.041	305	10.242	68	29.381	340
2015	192.782	277	52.161	98	25.128	301
2016	190.073	305	85.703	127	12.871	244
2017	251.164	345	61.503	171	52.961	425
2018	104.564	168	51.799	151	42.332	387

The Blue-Eye fishery has a relatively long history and while there is a long history of catches by trawl the majority of the catch has always been taken by line methods (generally less than 10% of catches are taken by trawl since 2003; Table 6.1). Unfortunately, fisheries data from line methods, in the GHT fishery, only began to be collected comprehensively from late in 1997 onwards (Table 6.1). 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 6.1, Figure 6.2). 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 6.2; Table 6.1).

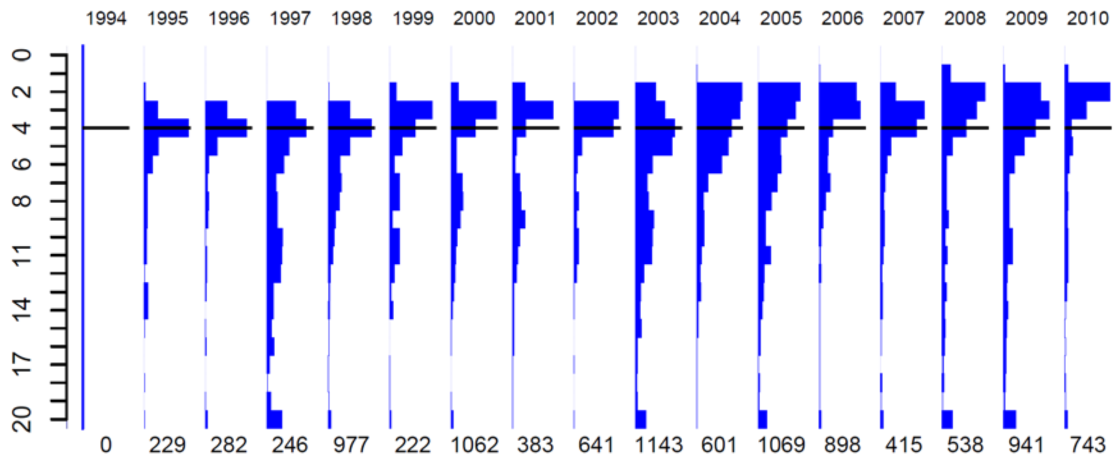

Figure 6.1. Age distributions sampled from the catches of Blue-Eye (*Hyperoglyphe antarctica*) for the years 1995 - 2010 (Thomson et al, 2016). The sample sizes in the bottom row of numbers should be sufficient to provide a good representation if the stock were homogeneous in its properties.

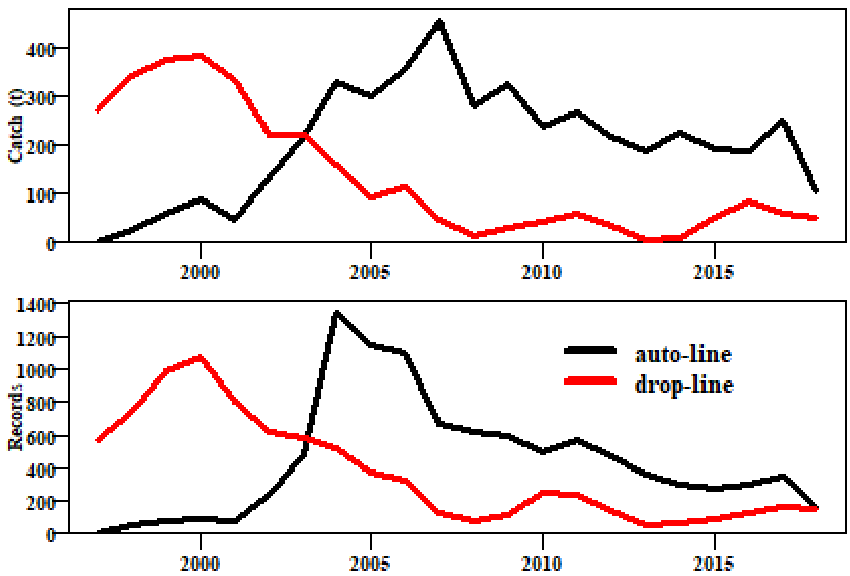

Figure 6.2. The trends in the number of records and catches of Blue-Eye from 1997 - 2018 by the two main line methods (Table 6.1); most catches are now taken by auto-line.

In the two years, 2013 - 2014, the drop-line catches dropped to 10 t or less while auto-line catches continue to dominate the fishery. However, in 2015, drop-line catches increased to about 47 t, while auto-line catches dropped by about 30 t from the previous year (Table 6.1; Figure 6.2).

6.2.1 *Current Management*

When the Harvest Strategy Policy was implemented in 2007 (DAFF, 2007) a Tier 4 assessment was used to provide advice on annual recommended biological catch (RBC) levels for Blue-Eye instead of a Tier 1 assessment (after both a Tier 1 statistical catch-at-age model and a Tier 3 catch-curve approach were rejected; Fay, 2007a, b). The Tier 4 uses standardized CPUE as an empirical performance measure of relative abundance that is assumed to be representative of the whole stock. The average

CPUE across a target period is selected by the RAG to provide the target reference point, which implies a limit CPUE reference point (0.41667 x target reference point) below which targeted fishing is to stop. In between the target and the limit there is a harvest control rule that reduces the RBC as CPUE declines. The appropriate characterization of CPUE is therefore very important in this fishery (Little et al., 2011; Haddon, 2014b).

By 2007 the auto-line fishery was already dominating the Blue-Eye fishery but the time series of significant catches by that method was relatively short (only six years from 2002 - 2007; Table 6.1 and Figure 6.2). 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 logbook records there was, and sometimes still is, often confusion in how to record effort (in terms of number of lines and number of hooks per line, or number of line drops, or length of main line) so it was not feasible at that time to estimate CPUE as a catch-per-hook. Instead CPUE was based on catch-per-record, which was equivalent to catch-per-day. The CPUE standardization conducted in 2008 on data from 1997 - 2007 (Haddon, 2009) was the first time that the catch-per-day data from drop-line was combined with auto-line catch-per-day data, with a justification presented to the RAGs. This was followed in 2009 by a summary of the separate auto-line and drop-line CPUE and a more detailed defence for their combination (Haddon, 2010). While it was appreciated that the two methods are very different, the intent of combining their data was always to extent the time series of line-caught Blue-Eye back to 1997 rather than 2002. Despite this extension of time, the early Tier 4 Blue-Eye analyses had overlap between the reference period (1997 - 2006) and the CPUE over the final four years (2004 - 2007); it took three more years for that 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). 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 time-series might be more difficult to combime validly. The method of processing the data and clarifying the database issues has now been worked through (Haddon, 2015b,2016; Haddon and Sporcic (2018)).

Table 6.2. Catch by SESSF Zone of Blue-Eye (*Hyperoglyphe antarctica*). Data filtered on species, fisheries and are restricted to catches by auto line and drop-line. Only Zones 20, 30, 40, 50, 83, 84, 85, 91, and 92 have significant catches.

	20	30	40	50	83	84	85	91	92
1997	81.546	80.730	40.989	45.977			5.778	5.503	
1998	72.374	159.187	64.648	40.856			1.968	1.590	
1999	64.636	193.056	78.726	55.078			0.972	21.590	0.050
2000	38.413	244.359	119.280	59.822		0.357	5.504	1.100	0.750
2001	20.659	222.357	87.241	29.127	0.150	2.814	4.345	3.186	4.740
2002	34.257	152.365	63.106	56.887		1.561	5.380	33.664	7.850
2003	46.456	144.738	117.674	39.364		27.547	4.875	57.910	2.400
2004	69.567	137.520	94.846	50.727	12.610	61.083	53.409	5.045	0.180
2005	85.138	103.016	59.525	43.673	19.478	29.313	41.815	4.881	4.700
2006	67.365	122.376	80.766	27.767	31.405	43.306	77.628	10.375	2.500
2007	49.258	228.395	41.324	28.367	29.801	106.441	15.337		
2008	44.786	112.203	51.837	13.668	28.942	32.267	13.214		
2009	51.046	137.503	79.919	38.055	1.633	15.368	15.415	10.515	1.350
2010	25.642	86.945	51.006	69.919	6.549	9.532	15.929	7.932	3.935
2011	30.838	92.670	42.424	18.131	20.576	40.692	14.159	33.688	23.081
2012	21.176	66.602	71.830	17.454	8.417	9.736	3.752	42.938	10.017
2013	13.151	51.497	84.457	14.594	0.465	16.158	13.250	1.131	
2014	3.878	71.226	87.235	21.989	2.107	33.759	11.629	4.505	0.510
2015	9.031	54.336	75.865	24.084	2.490	22.160	3.621	37.833	9.872
2016	7.557	49.053	69.982	35.283		29.283	9.576	42.901	26.211
2017	9.615	65.340	83.638	40.785	1.800	58.788	11.969	26.998	11.215
2018	12.597	52.794	40.736	17.217	1.158	13.044	6.346	6.569	5.320

6.2.2 *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 6.5) 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 five to seven 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.

Multiple issues have risen to cast doubt on the use of the combined auto-line and drop-line CPUE data based on catch-per-day or catch-per-record; 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) an examination of the line data was made to determine whether it would be possible to go through the database records for the Blue-Eye fishery and generate a catch-per-hook index to see if the use of the rather crude catch-per-day index was affecting the outcome of the standardization. This was done and now a repeatable method is available.

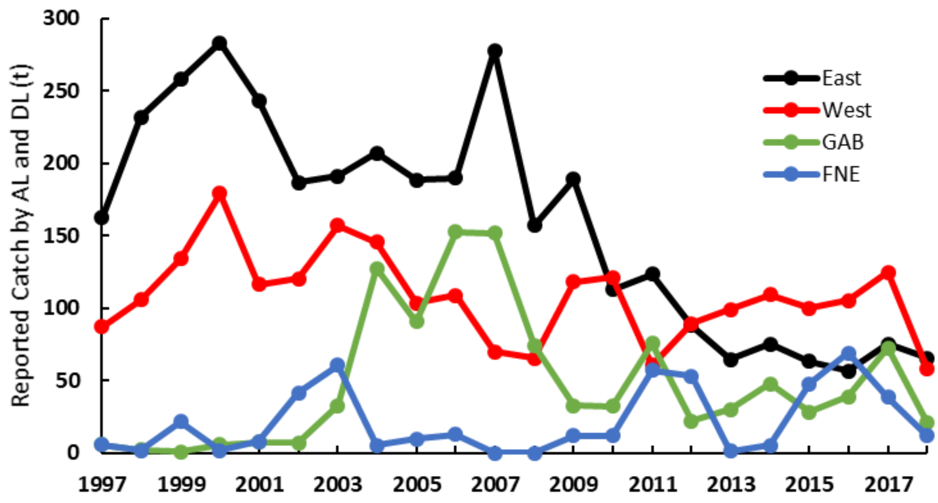

Figure 6.3. The total reported catches from 1997 - 2018 taken by auto-line and drop-line combined across the east (zones 20, 30), the west (zones 40, 50), the GAB (zones 83, 84, 85) and the far north east (zones 91, 92).

6.2.3 *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 as done previously.
2. Review and amend the database records for the auto-line fishery to allow for the calculation of a catch-per-hook CPUE as done previously.
3. Compare the catch-per-hook standardized data for the two fisheries with that from the catch-per-day standardization for Blue-Eye Trevalla.

6.2.4 *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. 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.
3. The same process of amending the database where appropriate followed by a re-analysis will be applied to the auto-line fishery.

The implications of these analyses will be examined in the discussion.

6.3 Catch Rate Standardization

6.3.1 Data Selection

Blue-Eye trevalla 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, 2016a).

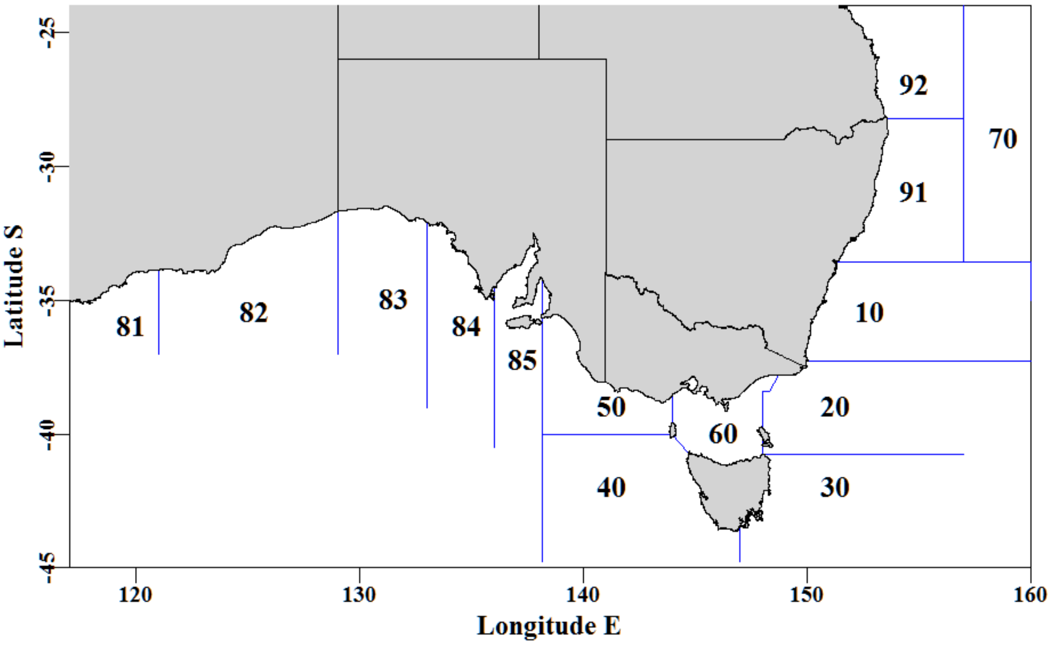

Figure 6.4. A schematic diagram depicting the statistical reporting zones in the SESSF, as used in this document. The GAB fishery is to the west of Zone 50. The main SESSF trawl zones are zones 10 - 50. Each zone extends out to the boundary of the EEZ, except for zones 50 and 60, and for zones 92 and 91, which are bounded by zone 70.

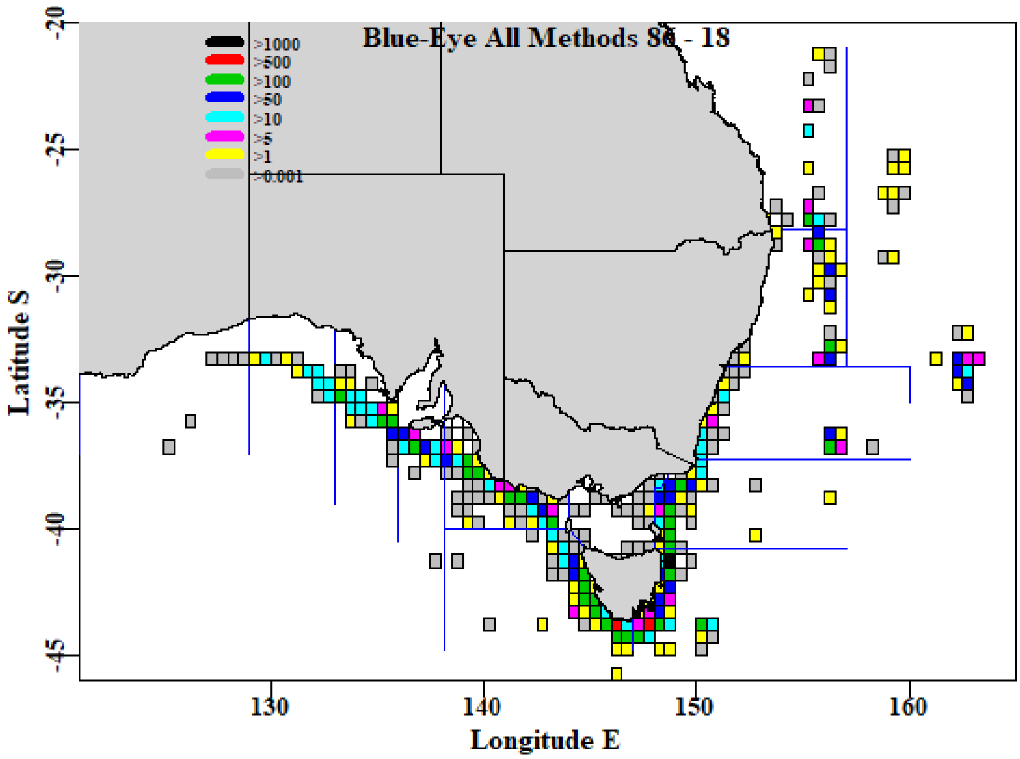

Figure 6.5. All reported catches of Blue-Eye by all methods from 1986 - 2018 in 0.5 degree squares. At least two records per square were required for inclusion in the map (all data were used in the analyses). The legend units are in tonnes summed across all years.

6.3.2 *General Linear Modelling*

Where trawling was the method used, catch rates were kilograms per hour fished. For the drop-line and auto-line methods, except for an analyses of catch-per-day for comparison, the database effort values were processed to generate total number of hooks set in a consistent manner. 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. In addition, there were interaction terms which could sometimes be fitted, such as Month:Zone or Month: DepthCategory, although with the use of finer spatial areas other simpler models or more idiosyncratic terms were occasionally used. Thus, the CPUE, conditioned on positive catches of the species of interest, was statistically modelled with a normal GLM on log-transformed CPUE data:

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

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.).

6.3.3 *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:

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

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

$$CE_t = \frac{CPUE_t}{(\sum CPUE_t)/n}$$

where $CPUE_t$ is the yearly coefficients from the standardization, $(\sum CPUE_t)/n$ 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.

6.4 Results

6.4.1 *Reported Catches*

Blue-Eye have been a target species before the formation of the SESSF, with large early 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 6.5). 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 6.3. The number of observations available taken by auto-line as determined by the data selection made on the complete catch and effort dataset on Blue-Eye.

	Total	Method	Depth	Years	Zones	Fishery
Records	54927	10353	9745	9738	9235	9197
Difference	0	44574	608	7	503	38
Catch	11366.51	4711.32	4446.26	4445.42	4148.00	4126.53
DeltaC	0	6655.20	265.06	0.839	297.42	21.47
%DiffC	0	58.55	5.63	0.019	6.69	0.52

Table 6.4. Catch by SESSF Zone of Blue-Eye (*Hyperoglyphe antarctica*) taken by auto-line. Total is all Blue-Eye catches by any method and any zone, Other is all other catches except for auto-line in zones 20, 30, 40, 50, 83, 94, and 85. AL is all catches in 20 - 85 taken by auto-line.

Year	Total	Other	AL	20	30	40	50	83	84	85
1997	464.069	463.802	0.267			0.267				
1998	444.979	429.990	14.989		0.033	14.956				
1999	546.140	499.471	46.670	35.575	1.725	9.370				
2000	657.408	629.109	28.299	12.210	6.061	10.028				
2001	580.054	539.822	40.232	2.000	23.634	14.598				
2002	462.267	330.901	131.366	2.640	65.100	42.326	21.300			
2003	561.987	405.001	156.986	20.574	93.788	38.724	3.900			
2004	599.703	329.952	269.751	55.986	81.121	71.255	22.214	5.418	15.321	18.437
2005	441.190	143.057	298.133	84.748	59.833	57.163	37.012	19.058	5.185	35.135
2006	534.261	189.853	344.407	67.075	66.585	78.303	25.309	31.117	0.330	75.689
2007	553.064	106.325	446.738	47.066	195.262	41.074	23.907	29.791	94.300	15.337
2008	333.972	56.072	277.900	44.439	98.763	50.407	11.408	27.543	32.127	13.214
2009	410.379	97.550	312.829	47.036	124.045	79.403	30.518	1.633	15.368	14.826
2010	379.022	149.080	229.942	25.422	66.128	47.497	63.093	5.764	7.153	14.884
2011	430.158	204.617	225.541	30.835	69.045	37.861	14.159	20.576	40.127	12.938
2012	313.769	133.744	180.025	21.176	55.333	70.428	11.183	8.417	9.736	3.752
2013	263.734	77.749	185.985	13.151	45.406	84.451	13.334	0.465	16.152	13.025
2014	304.346	84.788	219.558	3.866	66.351	87.153	19.442	0.607	31.049	11.089
2015	274.367	90.632	183.735	9.031	51.790	75.712	22.563	0.541	20.487	3.611
2016	299.199	116.549	182.650	6.620	35.581	68.554	33.036		29.283	9.576
2017	380.820	133.130	247.690	9.615	45.641	83.106	36.770	1.800	58.788	11.969
2018	338.247	235.411	102.837	4.659	29.690	35.292	12.647	1.158	13.044	6.346

Table 6.5. Early estimates of total Blue-Eye Trevalla catches, tonnes, across all methods within the SET area. The North Barrenjoey is included as being extra South-East Trawl area catches. Tilzey (1998) is only for catches north of Barrenjoey. Recent catches from 2005 are derived from Catch Documentation Records (CDR).

Year	Recent	Tilzey1998	Tilzey1999	Smith_Wayte2002
1980			207	207
1981			257	257
1982			276	276
1983			236	236
1984		7	388	350
1985		9	510	525
1986		38	285	341
1987		105	345	468
1988		210	505	725
1989		174	531	717
1990		243	647	819
1991		181	599	717
1992		60	633	643
1993		38	634	628
1994	801.327	27	729	730
1995	740.046	19	716	725
1996	893.428	16	868	890
1997	733.985		1040	989
1998	472.287			566
1999	572.689			651
2000	656.847			710
2001	586.572			648
2002	512.111			
2003	588.064			
2004	633.794			
2005	496.316			
2006	546.700			
2007	740.396			
2008	438.611			
2009	418.548			
2010	393.971			
2011	354.600			
2012	332.397			
2013	354.972			
2014	269.331			
2015	299.075			
2016	433.325			
2017	553.909			
2018	354.230			

6.4.2 *Effort Units*

GHT effort reporting is in terms of the main *EffortCode* with an *EffortSubCode* included. There are two main codes although there are also 56 records with unknown Code and SubCode (Table 6.6). Initially in 1997 and 1998 the main unit of effort was the Number-of-Lines-Set (NLS), however, as this could lead to confusion of whether total hooks set meant per line set or the total for the day it is fortunate that NLS was made obsolete sometime in 1999. This in turn led to the major issue with the auto-line effort reporting being that the Total Hooks Set switched from being an EffortSubCode to being an EffortCode sometime in 1999 (Table 6.7). This source of confusion appears to have propagated confusion in the log-book entries for a number of years following the changes and is the main reason this data needs review.

Table 6.6. A tabulation of the different Unit types identified (rows) and Sub-Units codes identified (columns). NLS is number of lines per shot (obsolete after 1999) and THS is Total Number of Hooks per Shot, finally TLM is Total Length of Mainline used.

	Unknown	THS	TLM
Unknown	56	0	0
NLS	0	71	0
THS	0	0	9070

Even before database confusions such as the switch of Total-Hooks-Set was corrected as best it could be, the number of records available for CPUE standardization only rose above 100 from 2002 onwards. From 1997 - 2001 the number of records were sparse as was the geographical spread of the distribution of catch (Table 6.7). In 2000 the catches and records are also distorted by relatively high catches being taken down on the Cascade Plateau, although the auto-line catches from that area are only minor.

Table 6.7. The catches and number of records in each year under the different EffortCodes. NLS is number of lines per shot (obsolete after 1999) and THS is Total Number of Hooks per Shot.

Year	Unknown	NLS	THS	Unknown	NLS	THS
1997		0.267		0	3	0
1998		14.989		0	28	0
1999		43.727	2.943	0	40	9
2000			28.299	0	0	29
2001			40.232	0	0	65
2002			131.366	0	0	226
2003			156.986	0	0	433
2004	2.89		266.861	56	0	1140
2005			298.133	0	0	1135
2006			344.407	0	0	1074
2007			446.738	0	0	650
2008			277.900	0	0	612
2009			312.829	0	0	556
2010			229.942	0	0	489
2011			225.541	0	0	529
2012			180.025	0	0	434
2013			185.985	0	0	352
2014			219.558	0	0	292
2015			183.735	0	0	251
2016			182.650	0	0	291
2017			247.690	0	0	340
2018			102.837	0	0	163

6.4.3 *Vessels per Year*

A total of 14 vessels have reported catches of Blue-Eye caught using auto-line since 1997, although a maximum of 11 report in any single year (Figure 6.6). The active fleet expanded between 2002 - 2004. The structural adjustment occurred from November 2005 to November 2006 and that (along with TAC changes) appears to have stabilized numbers at about six vessels, with only three or four contributing in recent years. However, the four lowest catching vessels, across all years 1997 - 2018, have only landed totals of either 0.815, 3.55, 6.0, or 6.256 t of Blue-Eye in between 1 - 6 years of fishing. By selecting only those vessels catching more than 10 tonnes across all years a more representative number of vessels reporting significant catches per year is obtained (Figure 6.6). However, for the standardization analysis no selection on minimum catch was made.

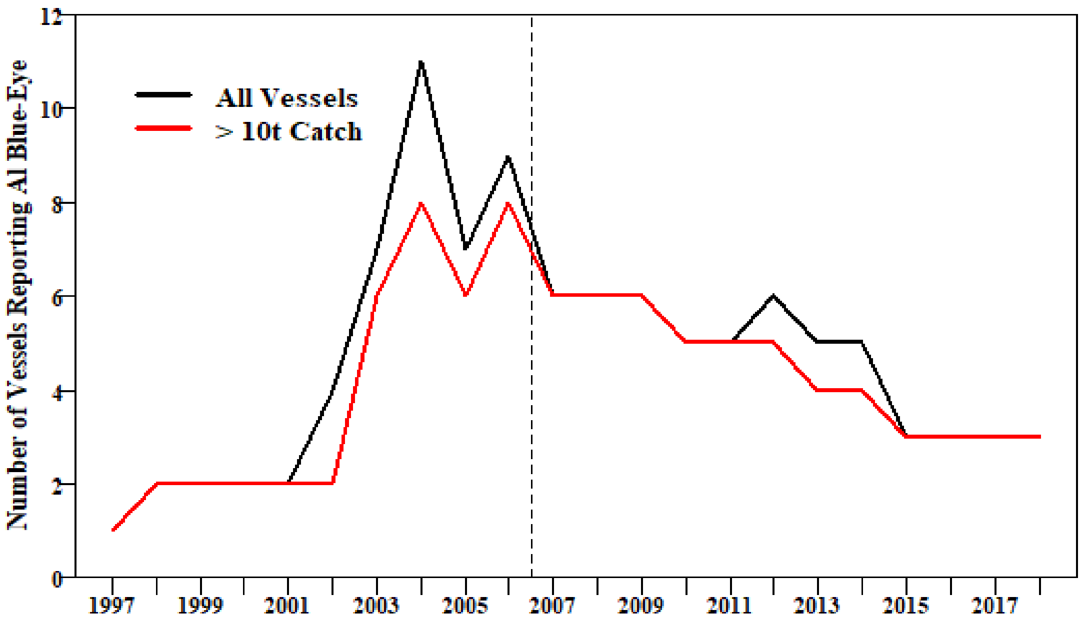

Figure 6.6. The number of auto-line vessels reporting Blue-Eye catches per year of the fishery compared with the number of vessels that caught more than a total of 10 tonnes over the 20 years from 1997 - 2018. Vertical dashed line is 2006.5, identifying the structural adjustment.

6.4.4 *Catch-per-Hook*

Table 6.8. The data selection criteria used followed by the steps in the database manipulations that were used to generate a relatively clean column of total-hooks-set for Auto-Line. EV = EffortValue and ESV - EFFortSubValue within the database..

Step	Description
Total	All Blue-Eye records in the AFMA catch and Effort database
Method	Only those records reporting a method of ‘AL’
Depth	Only depths between 200 - 600 metres
Years	Only data from 1997 - 2015
Zones	Only records reporting zones 20, 30, 40, 50, 83, 84, 85
Fishery	Only records reporting either ‘SEN’ or ‘GHT’
E-THS	Transfer the EV to hooks
9798ESV	Transfer ESV recorded as THS to hooks
H0-ESVgt0	Transfer the ESV if it was > 0 and the EV = 0
noEffort	Remove records with no effort; neither EV nor ESV
ESVgtUV	Transfer ESV which are > EV where EV > 1000 and hooks > 20
CEgt10	Remove 2 remaining records with CPUE > 10Kg/hook
Hlt1000	Remove 2 records with fewer than 1000 hooks.

Table 6.9. The sequence of data selection and editing and their effects on the amount of Blue-Eye catch and number of records. The manipulation codes are described in Table 6.8.

	Records	Difference	Catch	DeltaC	%DiffC
Total	54927	0	11366.515	0.000	0.00
Method	10353	44574	4711.316	6655.200	100.00
Depth	9745	608	4446.258	265.058	94.37
Years	9738	7	4445.420	0.839	94.36
Zones	9235	503	4147.999	297.421	88.04
Fishery	9197	38	4126.531	21.468	87.59
U-THS	9197	0	4126.531	0.000	87.59
9798SUV	9197	0	4126.531	0.000	87.59
H0-SUVgt0	9197	0	4126.531	0.000	87.59
noEffort	9115	82	4120.028	6.502	87.45
SUVgtUV	9115	0	4120.028	0.000	87.45
CEgt10	9105	10	4109.348	10.680	87.22
Hlt1000	9064	41	4092.331	17.018	86.86

Once catch-per-hook CPUE data were available these could then be standardized using standard methods (Figure 6.7). Standardizations only begin in 2002 after which sufficient data to be representative are available.

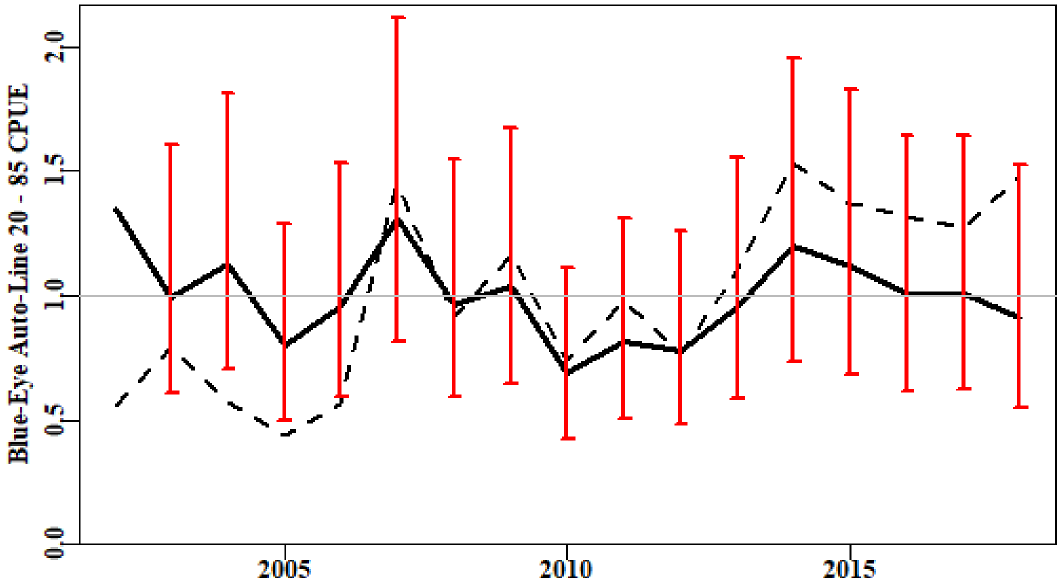

Figure 6.7. The standardized CPUE for Blue-Eye taken by auto-line from 2002 - 2018 from zones 20, 30, 40, 50, 83, 84 and 85. While the error bars are wide note the relative flattening of the trend in the solid standardized trend compared to the increasing trend in the unstandardized geometric mean (dashed line).

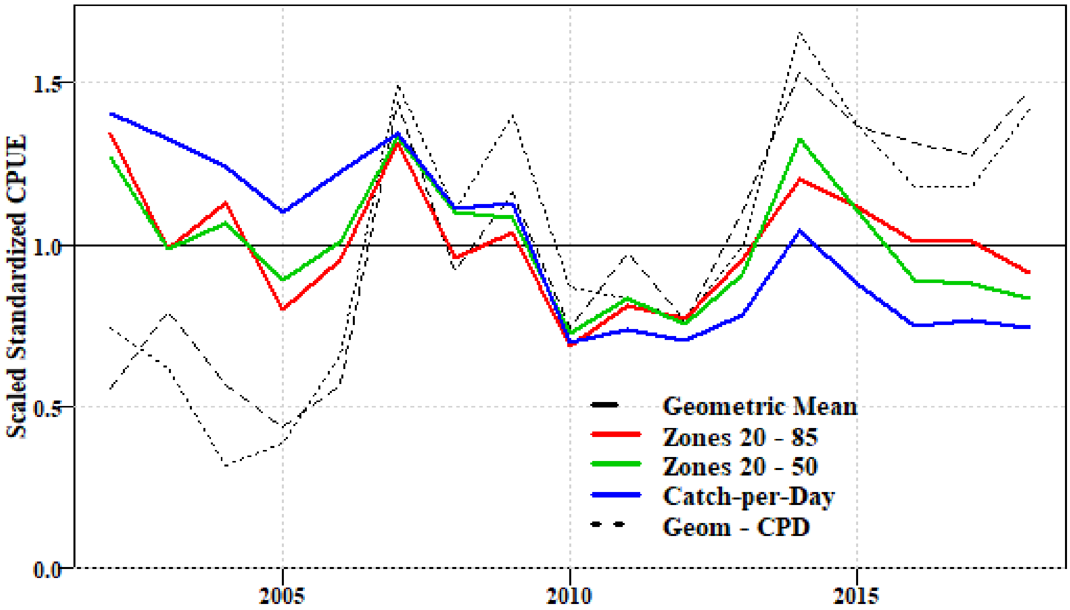

Figure 6.8. A comparison of the standardized catch rates for auto-line vessels using catch-per-day (blue line and dotted black line), and catch-per-hook (red, green, and dashed black line). All three main lines have high levels of uncertainty (e.g. Figure 6.7), but the relative flattening of the catch-per-hook trajectory is clear. All trends were scaled to an average of 1.0.

The optimum statistical model fitted to the available data from 2002 - 2018 was LnCE = Year + Vessel + Month + Zone + DepCat + DayNight + Month:Zone in each case. Catch-per-hook from zones 20 - 85 and from zones 20 - 50, were compared with the catch-per-day analysis from zones 20 - 50 (Table 6.10; Figure 6.7). Only minor differences are apparent between the inclusion of the GAB data (zones 83 - 85) and considering only zones 20 - 50. However, the catch-per-hook estimates generate a flatter trend than that deriving from the catch-per-day analysis.

Table 6.10. The geometric mean unstandardized CPUE for zones 20 - 85 by catch-per-hook (Geom-cph) and catch-per-day (Geom-cpd), and the optimum models from standardizations of all Auto-Line Blue-Eye catches as catch-per-hook (cph) from zones 20 - 85 (y2085), zones 20 - 50 (y2050), and as catch-per-day (cpd) for zones 20 - 50 (yCPD). The final column is the total reported catch from the records included in the 20-85 AL CPUE analyses.

Year	Geom-cph	Geom-cpd	z2085	z2050	ceCPD	AL Catch
2002	0.5558	0.7439	1.3457	1.2687	1.4075	131.366
2003	0.7925	0.6212	0.9889	0.9872	1.3282	156.966
2004	0.5671	0.3216	1.1263	1.0648	1.2421	265.447
2005	0.4391	0.3874	0.8031	0.8927	1.0993	297.430
2006	0.5623	0.6594	0.9520	1.0113	1.2266	344.008
2007	1.4397	1.4968	1.3138	1.3323	1.3465	445.329
2008	0.9216	1.1078	0.9588	1.0996	1.1141	275.976
2009	1.1654	1.3977	1.0363	1.0860	1.1303	302.036
2010	0.7439	0.8691	0.6875	0.7245	0.7006	228.394
2011	0.9756	0.8357	0.8134	0.8333	0.7363	223.640
2012	0.7674	0.7670	0.7752	0.7526	0.7037	179.075
2013	1.0997	0.9912	0.9536	0.9074	0.7832	184.361
2014	1.5332	1.6555	1.1998	1.3249	1.0442	219.558
2015	1.3657	1.3706	1.1166	1.1086	0.8810	183.373
2016	1.3157	1.1811	1.0073	0.8923	0.7474	182.650
2017	1.2742	1.1794	1.0091	0.8796	0.7677	247.690
2018	1.4812	1.4146	0.9128	0.8342	0.7414	100.856

6.4.5 *Combine Drop-Line with Auto-Line*

With a standardized Drop-Line CPUE index available for 1997 - 2006, and an auto-line index from 2002 - 2018 the standardized time series in each case are both scaled to have a mean of 1.0 during the overlap period of 2002 - 2006, and both series (using catch-per-hook CPUE) exhibit similar variation around the longer term average of 1.0. For the provision of management advice it would be possible to use a catch-weighted average of the two lines over the period of overlap (Figure 6.9; Table 6.11).

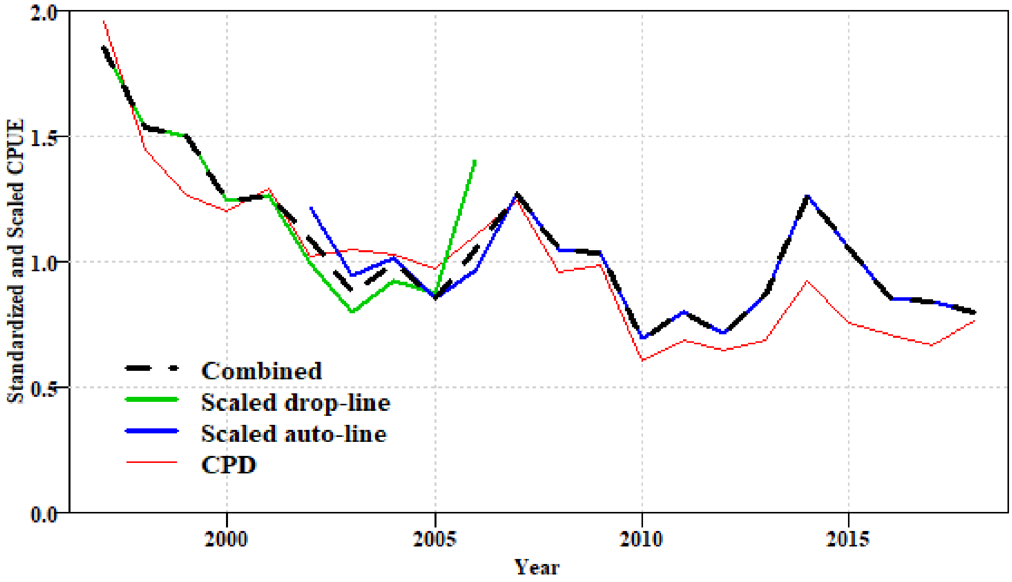

Figure 6.9. A comparison of Blue-Eye standardized catch-per-hook estimates for Drop-Line and Auto-Line catches of Blue-Eye from zones 20 - 50. A catch-weighted average of the lines from the two methods leads to a compromise in the years 2002 - 2006. If the 2001 auto-line estimates had been included this would have raised the average in 2001 slightly but at that point in time Drop-Line catches still dominated (Table 6.1). Catch-per-Day across the combined Drop-Line and Auto-Line catches is include as a dotted line.

Table 6.11. The optimum standardized CPUE (scaled to a mean of 1.0) for both drop-line, ceDL, and auto-line, ceAL, all for zones 20 - 50. These are re-scaled so that the average CPUE between 2002 - 2006 = 1.0 in both cases (columns with a scale prefix). The catch weighted CPUE (combined) is only catch weighted over the 2002 - 2006 overlap period. The relative catches by method are in alC (auto-line) and dlC (drop-line). ceCPD is the optimum standardized CPUE as measured by catch-per-day.

Year	ceDL	ceAL	scaleDL	scaleAL	combined	ceCPD	alC	dlC
1997	1.4977		1.8588		1.8588	1.9602	0.267	242.435
1998	1.2406		1.5397		1.5397	1.4449	14.989	318.441
1999	1.2115		1.5036		1.5036	1.2685	46.670	336.133
2000	1.0037		1.2457		1.2457	1.2027	28.299	372.543
2001	1.0179		1.2633		1.2633	1.2950	40.232	311.101
2002	0.8013	1.2687	0.9945	1.2141	1.0891	1.0224	131.366	173.513
2003	0.6441	0.9872	0.7994	0.9447	0.8775	1.0488	156.986	135.032
2004	0.7456	1.0648	0.9254	1.0190	0.9940	1.0290	230.575	84.059
2005	0.7079	0.8927	0.8786	0.8543	0.8584	0.9715	238.755	48.581
2006	1.1297	1.0113	1.4021	0.9678	1.0504	1.1080	237.272	55.729
2007		1.3323		1.2750	1.2750	1.2453	307.310	38.766
2008		1.0996		1.0523	1.0523	0.9582	205.017	15.299
2009		1.0860		1.0393	1.0393	0.9872	281.002	17.818
2010		0.7245		0.6933	0.6933	0.6092	202.140	24.755
2011		0.8333		0.7975	0.7975	0.6908	151.900	30.748
2012		0.7526		0.7202	0.7202	0.6484	158.120	17.928
2013		0.9074		0.8684	0.8684	0.6875	156.342	7.003
2014		1.3249		1.2679	1.2679	0.9236	176.813	3.853
2015		1.1086		1.0609	1.0609	0.7561	159.096	1.727
2016		0.8923		0.8539	0.8539	0.7093	143.792	14.368
2017		0.8796		0.8417	0.8417	0.6703	175.133	22.810
2018		0.8342		0.7983	0.7983	0.7629	82.288	39.403

6.5 Discussion

6.5.1 *Assumptions about CPUE*

There are some important assumptions in the analyses conducted in this document. These assumptions apply to all species whose stock status assessments rely on CPUE. The first assumption is that changes in CPUE directly reflect changes in the relative stock abundance rather than the influence of other factors such as the structural adjustment, or reduced catch rates through whale depredations or from whale avoidance behaviour from shifting into less optimal CPUE areas. In addition, the various closures in the south-east are assumed to have little or only minor effects on catch rates as are the recent reductions in TAC, which mostly coincide with the introduction of important Blue-Eye closures on the east coast of Tasmania. In addition, there would appear to have been large and sudden changes in the fishing behaviours with regard the total number of hooks set in a shot (Haddon, 2016a). CPUE reflects fishing behaviour and, potentially, any factor that may lead to a change in fishing be-haviour 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.

6.5.2 *Other Factors Affecting CPUE*

There are some influential factors whose potential effects upon CPUE would be diffi-cult to identify and isolate as a confounding effect with stock size. Any influence that occurs as an apparently instant transition so that for a sequence of years it is not there but after a given date it is present (such as the introduction of a closure, or a change in almost all the vessels fishing following the structural adjustment, or a limitation placed on maximum effort or catch per day) is very difficult to correct for, if at all.

In the case of a closure, if the closure is on favoured fishing grounds then there will undoubtedly be a change in fishing behaviour (which, in the case of Blue-Eye is con-founded with reductions in TAC). While it is known where the vessels would not be operating it is not known where effort that would have been expended in the now closed region will be transferred to.

The structural adjustment between Nov 2005 - Nov 2006 led to a reduction in the number of vessels operating in the Blue-Eye fishery and this is very apparent in the trawl fleet and the drop-line fleet, both of which decline significantly in numbers from 2005 - 2007 onwards. Such a reduction in vessel numbers, and which vessels are actually fishing, may have altered fishing behaviour in ways that are not characterized in the standardization. In the case of Blue-Eye drop-line vessels, a major change did occur in how effort was being reported with the proportion of records reporting single lines instead of multiple lines increasing dramatically (Haddon, 2015). This is mixed up with the big change in the vessels actually fishing with most significant drop-line 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 between years across the different important statistical reporting zones within the SESSF. This is especially the case with auto-line following its adoption in 1997; for example, there were significant catches in only four zones, 20 - 50, from 2002 onwards and catching in the GAB only started to become important from 2003/2004 onwards. Similarly, although also inversely, after 2006 reducing catches by drop-lining meant they did not occur consistently every year in all four zones 20 - 50 and have remained at low and declining levels (< 20t) throughout that period.

6.5.3 *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 others 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 different time-series of CPUE than when catch-per-day or record is used. The use of catch-per-day avoids the issue of the remarkable change in effort reporting that appears to have followed the structural adjustment. Intuitively, however, catch-per-hook appears a more realistic reflection of the variation of practice within the fishery. It is certainly an area that requires further analysis and consideration.

Using catch-per-record means that when significant changes occur in fishing behaviour these would be missed. By missing such major changes, inappropriate data can contin-ue to be used as still representing the fishery. Thus, if catch-per-record data is to con-tinue being used for the provision of management advice then some extra data selec-tion will need to be made to focus on those fishing events that are more typical of the fishery. However, what such data selection would entail is not known.

The auto-line fleet only began to expand and distribute catches from about 2002 on-wards, 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.

Even though the GAB only began to be seriously fished by auto-line vessels from 2003/2004 onwards, it has become an important part of the fishery. Catches from the GAB (and the far North East) are counted against the available quota/TAC for Blue-Eye and decisions concerning where to fish presumably entail a consideration of all areas available to be fished. Currently the tier 4 assessment uses only the standardization from zones 20 - 50, which reflects the earlier usage. However, until decisions are made about exactly what geographical management units are to be used with Blue-Eye it would appear that leaving out the GAB zones with significant catches would have the potential to generate misleading results. It would seem sensible therefore to use the standardization from zones 20 - 85 rather than just 20 to 50. As it happens the inclusion of the GAB catches in the analysis of catch-per-hook does not alter the trend in standardized CPUE in any important way.

6.6 Conclusions

The diversity of methods used to fish for Blue-Eye and the patchy nature of the fishing grounds mean that there is no simple, catch-all analysis that can be used to summarize the fishery as a whole. Nevertheless, it remains possible to focus on the methods that lead to the greatest proportion of the catches.

- It has proven possible to develop relatively simple algorithms, which if followed lead to the clarification of effort in terms of total hooks set that in turn allows for an alternative, intuitively more realistic measure of CPUE.
- Separate and different algorithms for handing the drop-line and auto-line data within the catch and effort database are required to enable effort in each case to be characterized in terms of total number of hooks set.
- Using those algorithms the drop-line and auto-line data have again been re-structured and catch-rates estimates in terms of kg/hook for both methods have been generated.
- As has been done previously, it was possible to combine the two, using a catch weighted approach over the overlap period. When this was done for both the catch-per-hook and catch-per-day data the outcome of the standardization was rather different. The combined standardized CPUE has been noisy but relatively flat since 2002, whereas the trend catch-per-day CPUE has been noisy but downwards since about 1998.

Given the current structure of the auto-line fishery, which dominates recent catches, it is recommended that the CPUE time-series from zones 20, 30, 40, 50, 83, 84, and 85, be used in subsequent Tier 4 analyses. This would be more representative of the current fishery as it is presently pursued than restricting the series to zones 20 - 50 only.

6.7 Acknowledgements

Thanks goes to the CSIRO database team for their preliminary processing of the catch and effort data as received from the Australian Fisheries management Authority.

6.8 References

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7. Statistical CPUE standardizations for selected deepwater SESSF Species (data to 2018).

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7.1 Introduction

Commercial catch and effort (CPUE) data are used in very many fishery stock assessments in Australia as an index of relative abundance. Using CPUE in this way assumes there is a direct relationship between CPUE and exploitable biomass. However, many other factors can influence CPUEs, 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 dynamics. 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 CPUE 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 CPUE are required entails its own set of conditions and selection of data. This report updates standardized indices (based on data to 2017 inclusive) for selected deepwater species within Australia's Southern and Eastern Scalefish and Shark Fishery (SESSF). It also provides additional analyses for eastern and western deepwater sharks which either include or exclude closures.

7.1.1 *The Limits of Standardization*

The use of commercial CPUE as an index of the relative abundance of exploitable biomass can be misleading when there are factors that significantly influence CPUE but cannot be accounted for in a generalized linear model (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 CPUE 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 CPUE would tend to bias CPUE 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.

7.2 Methods

7.2.1 Catch Rate Standardization

7.2.1.1 Preliminary Data Selection

The methods used when standardizing commercial catch and effort data in the SESSF continue to be discussed in the Commonwealth stock assessment RAGs because the catch rate time series (and associated standardized indices) are very influential in many of the assessments. Data were initially selected from the ORACLE database by CAAB code to obtain all data relating to a given species. Then selections were made using R (R Core Team, 2017) with respect to 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 within the years specified for each analysis.

7.2.1.2 General Linear Modelling

In each case, CPUE, generally as kilograms per hour fished (though sometimes as catch per shot e.g. School Whiting caught by Danish Seine, or catch-per-hook for Blue-Eye Trevalla), 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. 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:

$$Ln(CPUE_i) = \alpha_0 + \alpha_1 x_{i,1} + \alpha_2 x_{i,2} + \sum_{j=3}^{N} \alpha_i x_{i,j} + \varepsilon_i$$

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 (where α_0 is the intercept, α_1 is the coefficient for the first factor, etc.).

7.2.1.3 The Mean Year Estimates

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:

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

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

$$CE_t = \frac{CPUE_t}{(\sum CPUE_t)/n}$$

where $CPUE_t$ is the yearly coefficients from the standardization, $\sum CPUE_t/n$ 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.

7.2.1.4 Model Development and Selection

In each case an array of statistical models are fitted sequentially to the available data, with the order of the non-interaction terms being determined by the relative contribution of each term to model fit.

This sequential development of the standardization models for each species simplifies the search for the optimum model and requires a consideration of different performance statistics such as the AIC (Akaike's Information Criterion, the smaller the better; Burnham and Anderson, 1992) or adjusted R^2 (the larger the better; Neter et al, 1996). In addition, the examination of the various diagnostic plots and tables allows for an improved interpretation of the observed trends.

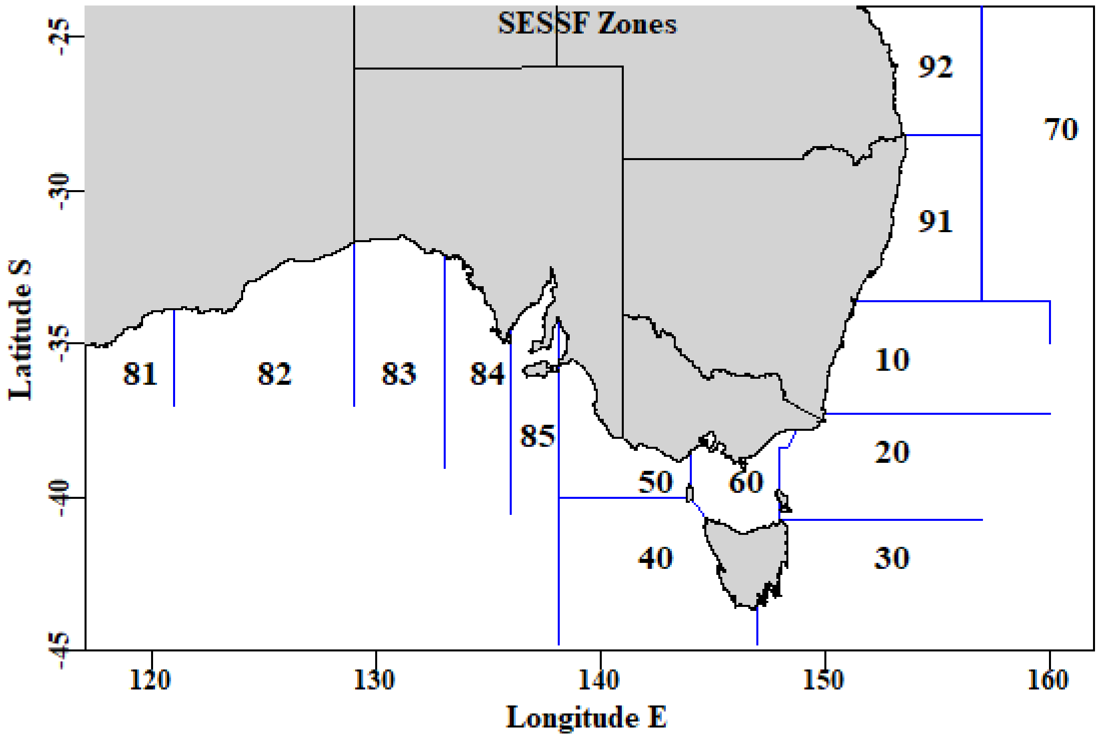

Figure 7.1. The statistical reporting zones in the SESSF.

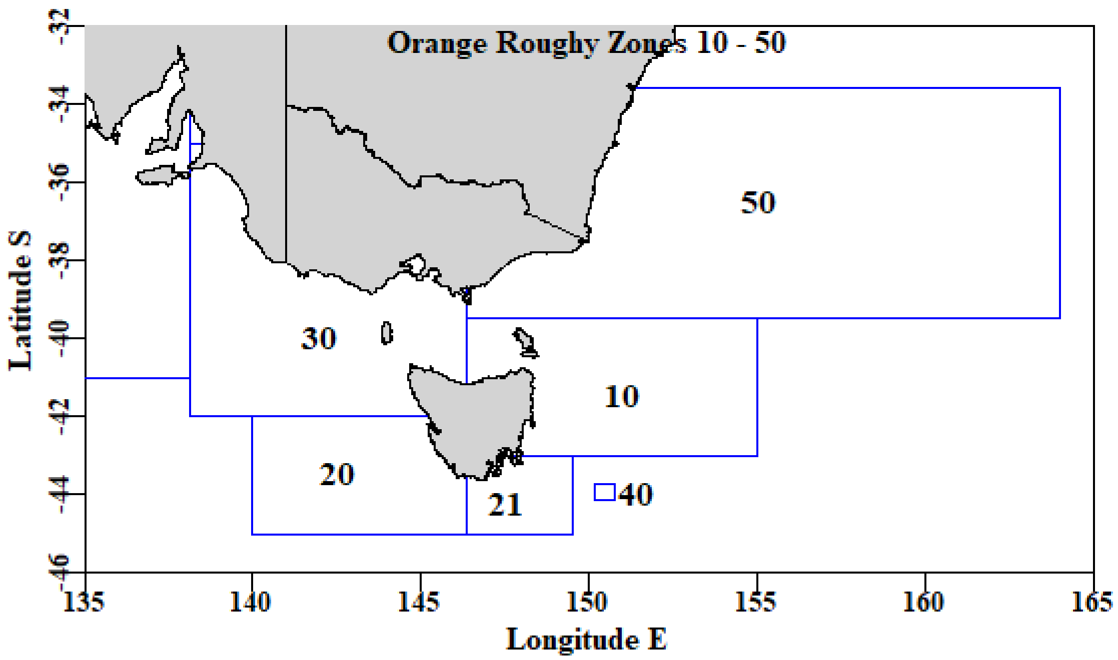

Figure 7.2 The Orange Roughy zones used to describe the deepwater fisheries.

7.3 Eastern Deepwater Sharks

This basket quota group is made up of many recognized species but only nine have any records, and only seven 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).

Catches declined steadily from 1996 to a low in 2007 when the 700 m closure was introduced. Since this was modified in 2009 (and 2016) catches have increased again to reach the low 23 t per annum with very few vessels contributing significantly to this fishery. Nevertheless, fishing appears to be consistent and the standardized CPUE trend has been essentially low and flat since 2010.

In Commonwealth waters, catches were primarily from Orange roughy zones 10, 20, 21, 40 and 50, and in depths 600 to 1250 m. Catch rates were expressed as the natural log of catch per hour (catch/hr). The years analysed were 1995 - 2018 (Table 7.1).

A total of 8 statistical models were fitted sequentially to the available data, and the order of the non-interaction terms added based on the relative contribution of each term to model fit.

7.3.1 *Inferences*

This remains a locally important but minor fishery. The first two years appear relatively high but have relatively unusual distributions of effort with disproportionately large amounts of very short shots. The largest catch in this time-series also occurred in 1996 with catches declining especially after 1998. There was a large increase in the number of vessels reporting Eastern Deepwater Sharks in 1996 onwards, followed by a reduction in vessel numbers around the time of the structural adjustment (~2007). The majority of catch occurred in ORzone 50, 20 followed by 10.

The terms Year, Vessel DepCat, Month, DayNight, ORzone and one interaction (ORzone:DepCat) had the greatest contribution to model fit based on the AIC and R2 statistics (Table 7.5). The qqplot suggests that the assumed Normal distribution of the log-transformed CPUE, is valid, with slight deviations as depicted from both tails of the distribution (Figure 7.6).

Standardized CPUE exhibits a flat trend below the long-term average since 2010 (Figure 7.3).

7.3.2 *Action Items and Issues*

It remains questionable whether the years 1995 and 1996 should be included in the analysis as the effort distribution in those years is skewed low. A more detailed spatial analysis may provide details of where fishing occurred and whether those years are exceptional in other ways.

Table 7.1. EasternDeepSharks. The data selection criteria used to specify and identify the fishery data to be included in the analysis.

Property	Value
label	EasternDeepSharks
csirocode	37020000, 37020002, 37020003, 37020004, 37020005, 37020012, 37020013, 37020015,
fishery	SET
depthrange	600 - 1250
depthclass	50
zones	10, 20, 21, 40, 50
methods	TW, TDO, OTT, PTB, TMO
years	1995 - 2018

Table 7.2. EasternDeepSharks. Total catch (Total; t) is the total reported in the database, number of records used in the analysis (N), reported catch (Catch; t) in the area and depth used in the analysis and number of vessels used in the analysis (Vess). GeoM is the geometric mean of catch rates (kg/hr), standard deviation (StDev) relates to the optimum model. C<30Kg denotes the amount of catch in shots of <30kg, and P<30Kg is the proportion of total. The optimum model was ORzone:DepCat.

	Total	N	Catch	Vess	GeoM	Opt	StDev	C<30Kg	P<30Kg
1995	595.4	553	178.7	17	213.2	2.8315	0.000	1.602	0.009
1996	834.2	1094	348.3	25	113.4	2.7333	0.065	2.975	0.009
1997	851.0	997	206.2	25	62.2	1.6913	0.064	3.610	0.018
1998	838.5	1203	221.1	24	53.4	1.4531	0.064	5.039	0.023
1999	731.3	1078	167.1	24	43.8	1.2054	0.064	4.500	0.027
2000	683.5	904	177.6	37	54.7	1.2727	0.067	3.152	0.018
2001	572.8	954	144.9	28	49.9	1.1192	0.070	4.746	0.033
2002	516.0	932	156.3	26	48.8	1.1020	0.069	4.419	0.028
2003	360.8	999	125.9	24	37.4	0.8027	0.070	5.953	0.047
2004	377.7	706	96.1	26	34.9	0.8044	0.073	3.886	0.040
2005	202.8	427	62.7	13	38.8	0.8049	0.081	2.274	0.036
2006	178.1	373	38.0	19	32.6	0.7702	0.085	3.046	0.080
2007	56.4	49	2.8	13	12.8	0.6572	0.172	0.418	0.147
2008	51.8	79	10.5	8	25.4	0.9793	0.141	0.434	0.041
2009	83.1	183	27.6	11	36.3	0.9179	0.103	0.892	0.032
2010	77.4	212	20.3	11	21.6	0.5633	0.097	1.445	0.071
2011	78.9	165	16.2	13	21.4	0.5392	0.106	0.849	0.052
2012	82.8	231	21.7	13	21.3	0.5343	0.098	1.380	0.063
2013	102.2	213	17.1	10	20.5	0.5248	0.100	1.640	0.096
2014	104.8	374	29.3	12	19.0	0.5429	0.092	1.581	0.054
2015	86.7	401	23.7	12	23.4	0.5204	0.094	1.916	0.081
2016	93.0	299	25.6	14	26.9	0.5036	0.102	1.206	0.047
2017	97.4	309	27.5	11	25.5	0.5536	0.104	0.954	0.035
2018	89.4	400	30.6	15	29.0	0.5729	0.101	1.317	0.043

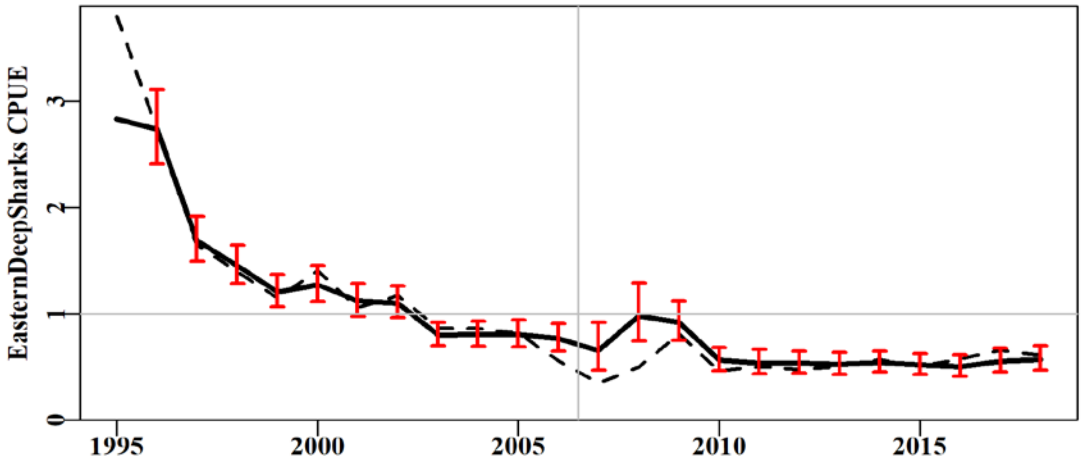

Figure 7.3. EasternDeepSharks standardization. The dashed black line represents the geometric mean catch rate, solid black line the standardized catch rates. The red bars are the 95% confidence intervals about the mean estimates. The graph scales both time-series of standardized catch rates relative to the mean of each time-series.

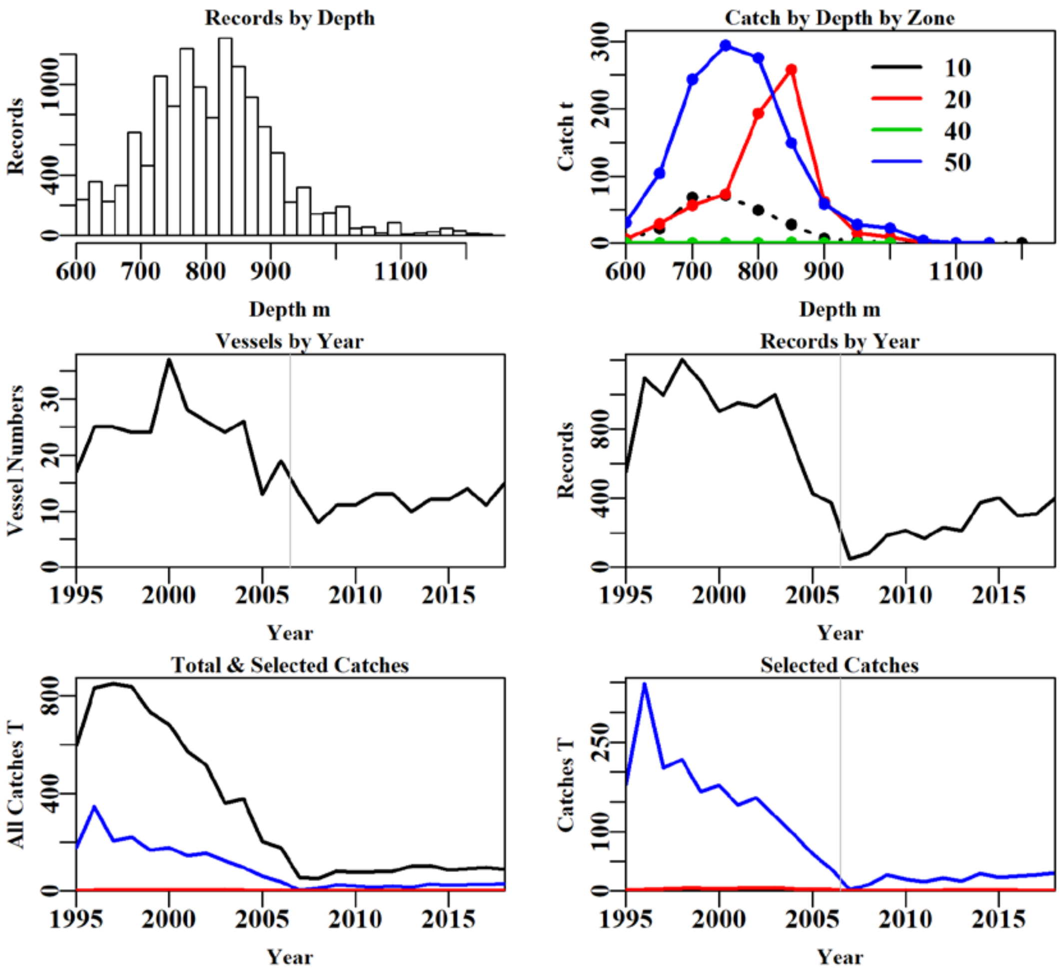

Figure 7.4. EasternDeepSharks fishery details. The bottom left plot depicts all known catches (top black line), and all selected catches used in the analysis (middle blue line); the lower red line: selected catches < 30 kg).

Table 7.3. EasternDeepSharks data selection effects. Total is the total number of records in the database, NoCE removes those records with either missing catch or effort, and then only those records are kept that meet the criteria for depth, years, zone, method, and fishery.

	Total	Method	Years	ORZones	Fishery	Depth	NoCE
Records	358847	233184	94834	54414	54153	13135	12397
Difference	0	125663	138350	40420	261	41018	738

Table 7.4. The models used to analyse data for EasternDeepSharks.

	Model
Model1	Year
Model2	Year + Vessel
Model3	Year + Vessel + DepCat
Model4	Year + Vessel + DepCat + Month
Model5	Year + Vessel + DepCat + Month + DayNight
Model6	Year + Vessel + DepCat + Month + DayNight + ORzone
Model7	Year + Vessel + DepCat + Month + DayNight + ORzone + ORzone:DepCat
Model8	Year + Vessel + DepCat + Month + DayNight + ORzone + ORzone:Month

Table 7.5. EasternDeepSharks. The row names are 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_r2) and the change in adjusted R^2 (%Change). The optimum model was ORzone:DepCat.

	AIC	RSS	MSS	Nobs	Npars	adj_r2	%Change
Year	4805	18195	3480	12397	24	15.9	0.00
Vessel	3288	15909	5766	12397	98	26.0	10.13
DepCat	2437	14824	6850	12397	110	31.0	4.98
Month	2409	14765	6910	12397	121	31.2	0.22
DayNight	2390	14737	6938	12397	123	31.3	0.12
ORzone	2267	14585	7090	12397	126	32.0	0.69
ORzone:DepCat	2134	14362	7313	12397	155	32.9	0.88
ORzone:Month	2192	14432	7243	12397	154	32.6	0.56

Table 7.6. EasternDeepSharks. Total catch (t) in the fishery under each separate CAAB code included in the basket species.

Name	CAAB Code	Total Catch (t)
Dogfishes	37020000	615.626
Black	37020002	75.522716
Brier	37020003	93.347
Platypus	37020004	129.434
Plunket	37020013	0.216
Pearl	37020905	492.24324
Roughskin	37020906	225.462
Lantern	37020907	9.5
OtherSharks	37990003	526.8015

Table 7.7. EasternDeepSharks. Annual catch (t) by CAAB code for a basket species.

	37020000	37020002	37020003	37020004	37020013	37020905	37020906	37020907	37990003
1995	87.798								89.805
1996	161.612								186.328
1997	97.410	8.738							100.059
1998	117.504	27.912							74.796
1999	97.048	25.261							44.780
2000	40.940	1.590		11.855		64.210	45.591		13.409
2001	10.546		11.750	25.495		58.146	29.351		8.868
2002	0.982		22.883	25.870	0.060	72.081	27.096		6.581
2003	0.573		14.550	18.104		59.777	32.702		0.070
2004	0.018		14.265	16.834		40.527	21.341	2.0	0.243
2005			6.245	11.025		28.687	8.959	7.5	0.250
2006	0.028		3.885	7.740		18.852	6.870		0.190
2007	0.060			0.395		1.643	0.482		0.270
2008	0.200			0.827		6.833	2.614		
2009	0.051		0.210	0.128		14.082	12.811		0.042
2010	0.754		0.020	1.075		12.679	5.080		0.015
2011	0.005			0.260	0.040	8.744	6.862		0.033
2012	0.029		0.497	1.512		10.375	9.018		
2013		0.030	1.155	1.446		9.032	5.438		
2014		2.605	3.030	0.942		17.943	4.510		0.095
2015	0.035	2.862	3.884	3.170		11.558	1.621		0.052
2016	0.005	2.123	4.033	0.770	0.060	15.831	2.738		
2017	0.005	1.898	4.030	1.986		16.635	2.029		0.825
2018	0.023	2.504	2.910		0.056	24.608	0.349		0.090

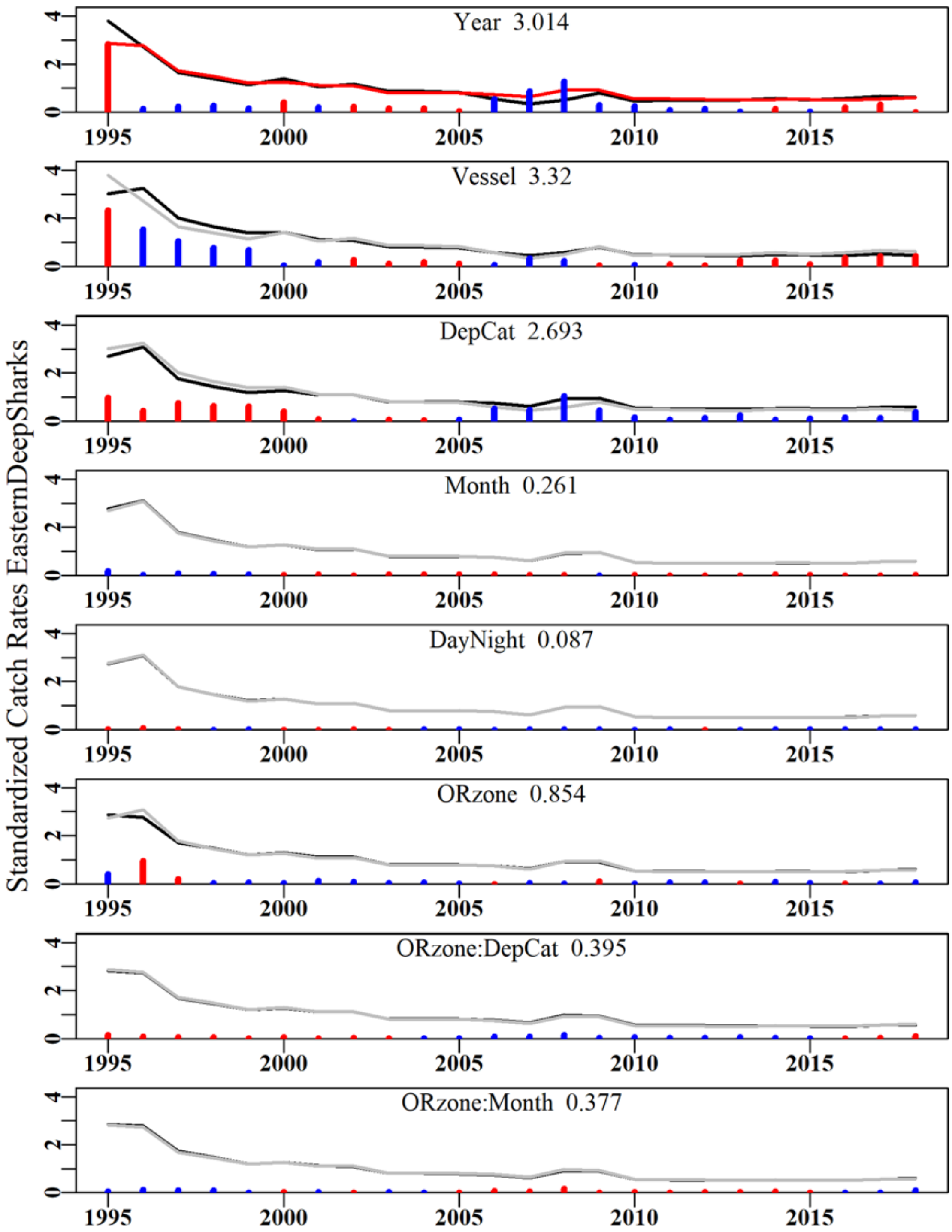

Figure 7.5. EasternDeepSharks. The influence of each factor on the optimal standardization. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by vertical bars with blue bars indicating the optimum model is higher than the 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.

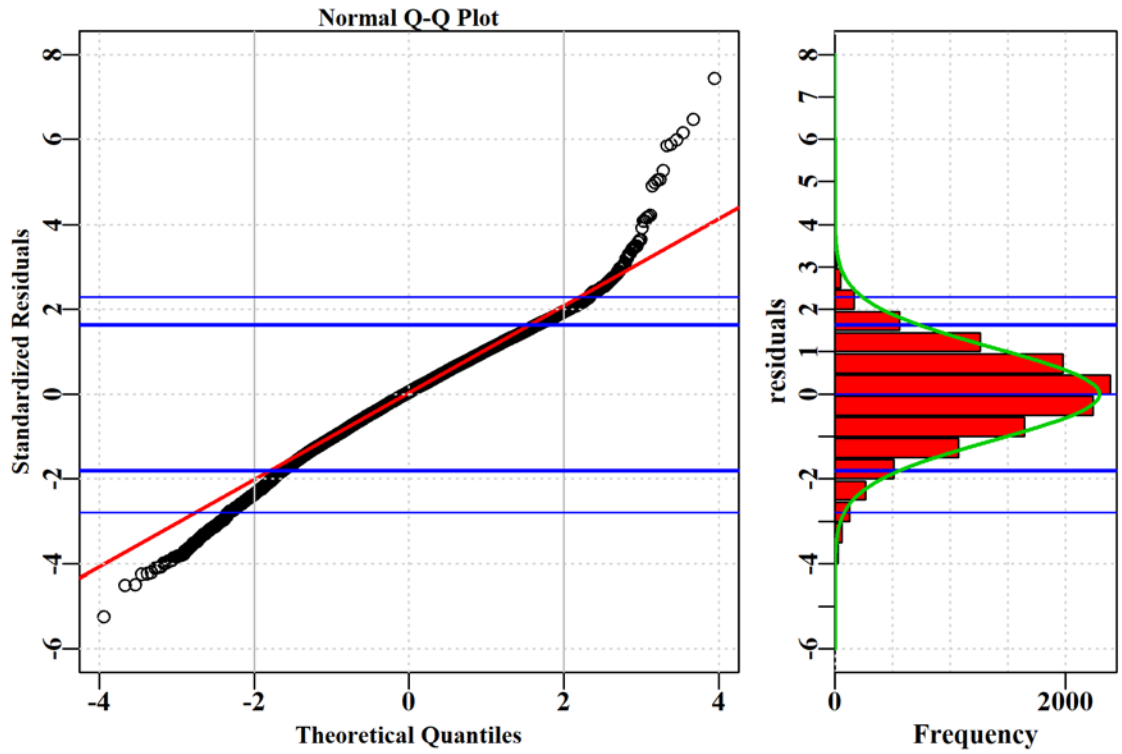

Figure 7.6. EasternDeepSharks. Diagnostic plots. The distribution of residuals from the optimum fit. The qqplot indicates the fit to the expected normality, while the histogram of residuals also illustrates the 1%, 5%, 95% and 99% quantiles to indicate the intensity of any lack of fit at the margins of the distribution (reflected also in the qqplot.

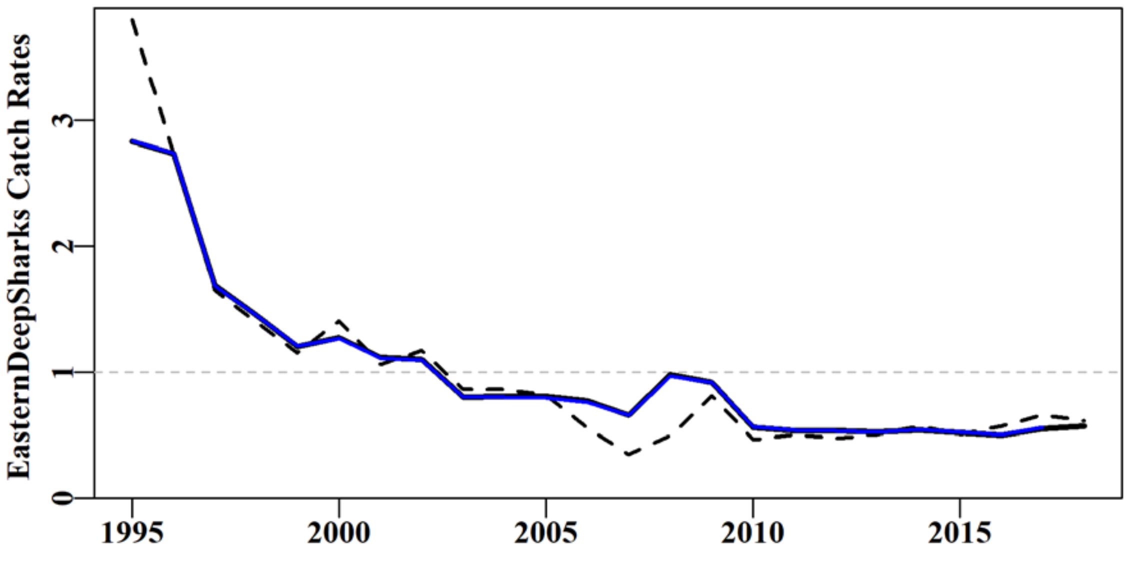

Figure 7.7. EasternDeepSharks. A comparison of the previous year's standardization (blue line) with this year's. They should lie on top of each other, although small deviations may relate to data adjustments, particularly in very recent years.

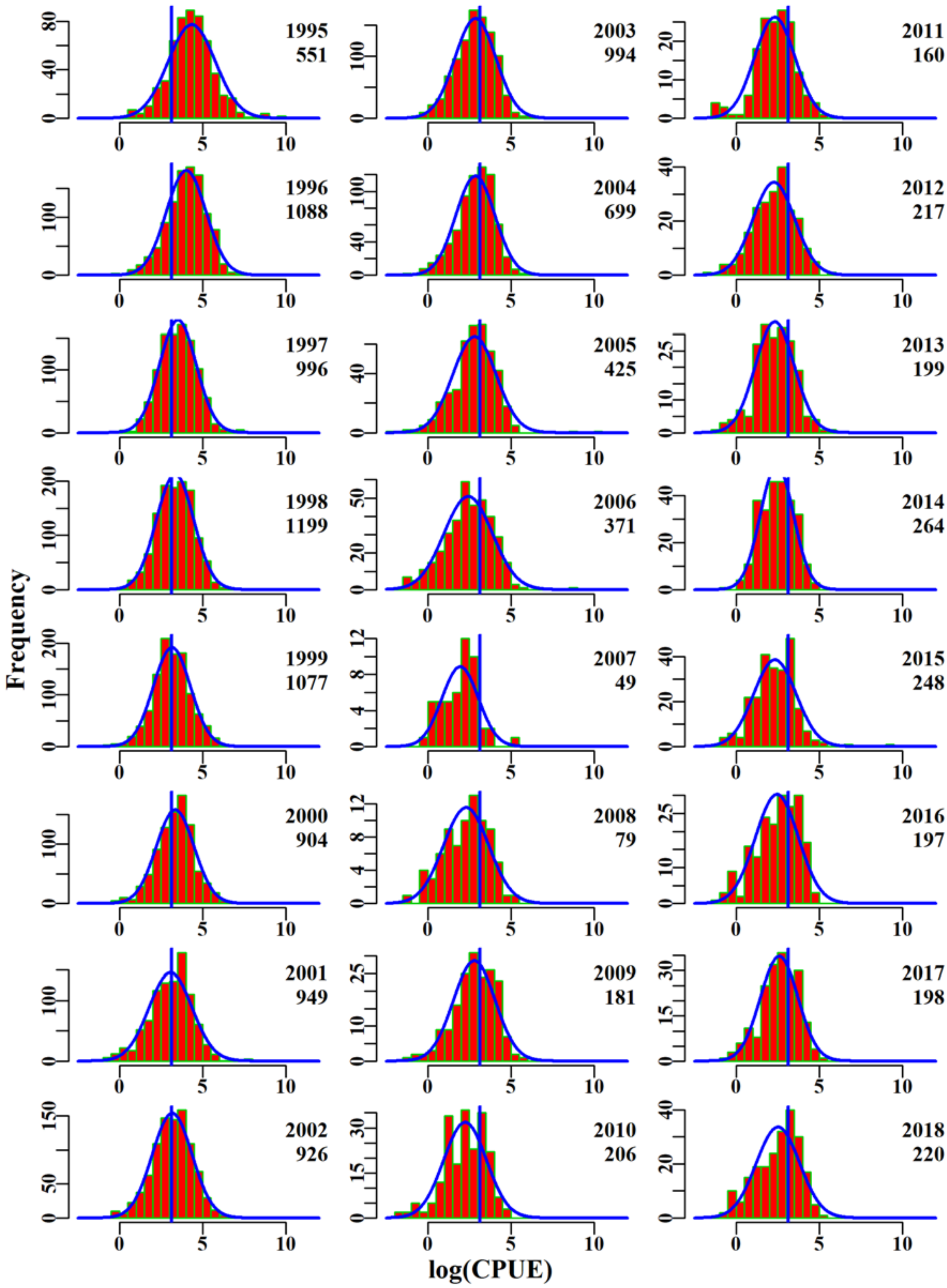

Figure 7.8. EasternDeepSharks. The natural log(CPUE) for each year of data available the blue lines are normal distributions fitted to the histogram frequencies. The numbers in each plot are the year and number of records. The vertical blue line is the average across all years.

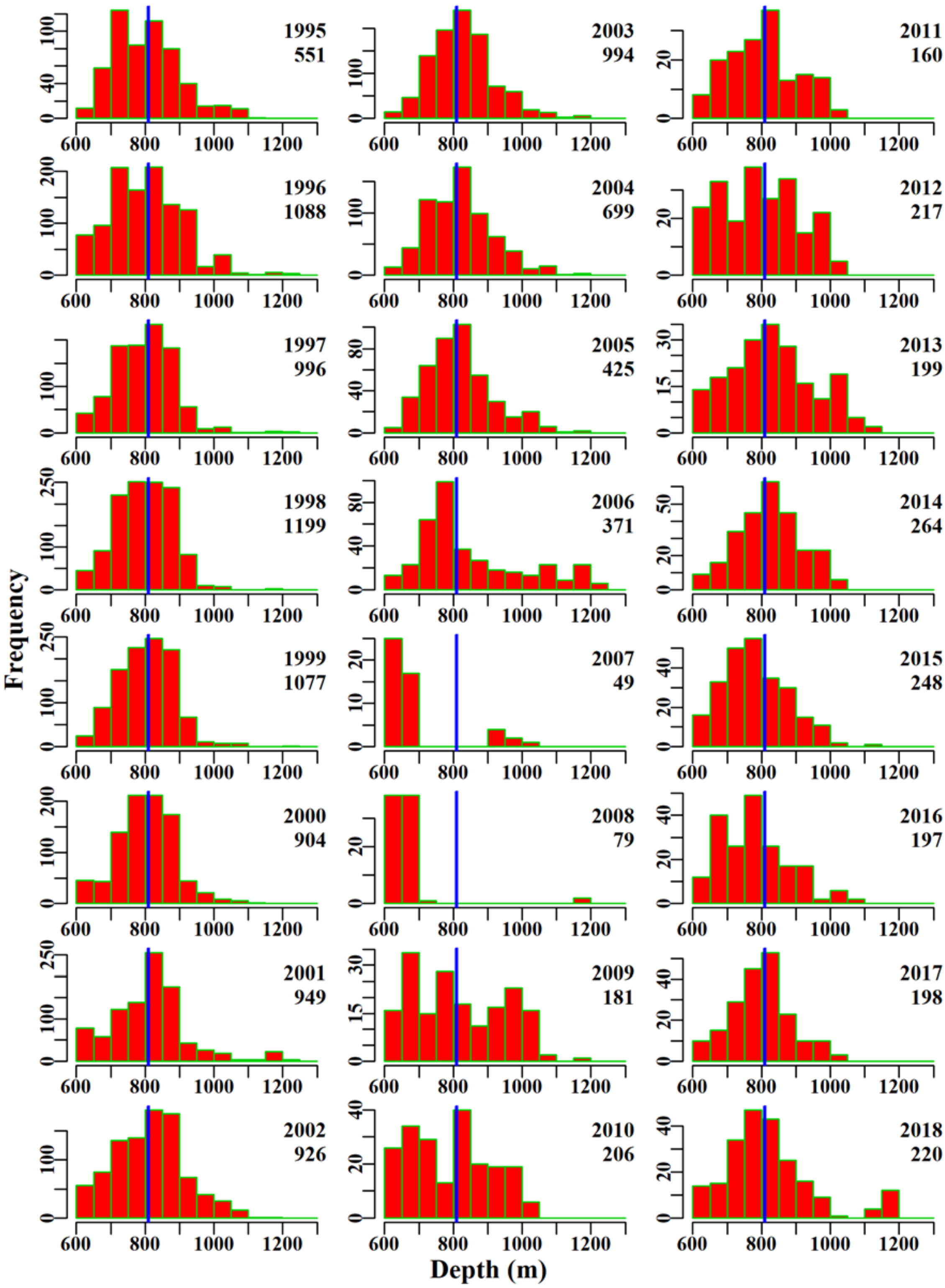

Figure 7.9. EasternDeepSharks. The average Depth of fishing for each year of data available to illustrate the development of the fishery through time. The numbers in each plot are the year and number of records. The vertical blue line is the average across all years.

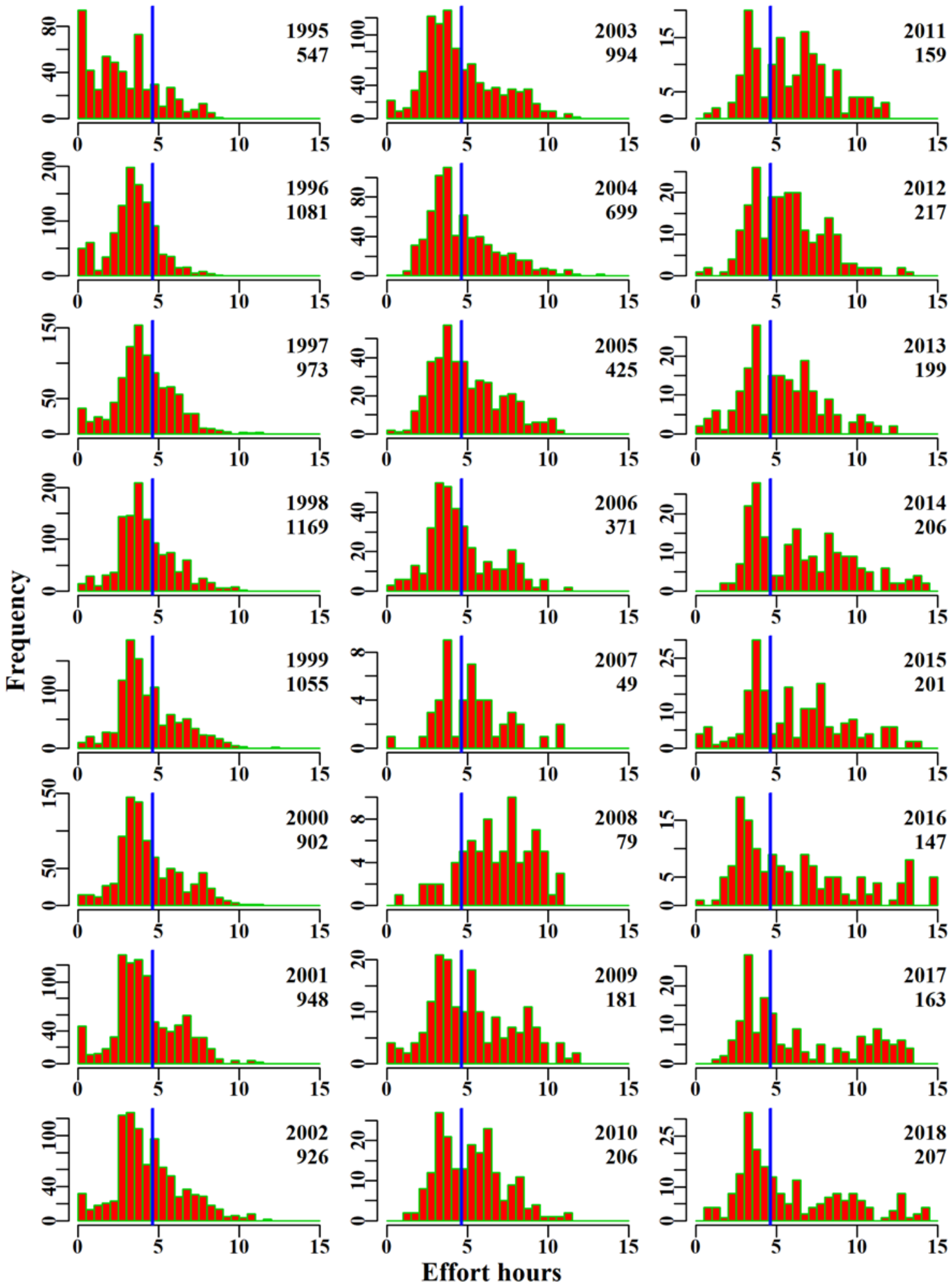

Figure 7.10. EasternDeepSharks. The frequency distribution of effort each year for the available data. The numbers in each plot are the year and number of records. The vertical blue line is the average across all years.

7.4 Eastern Deepwater Sharks – without closures

In Commonwealth waters eastern deepwater sharks were taken by demersal trawl from Orange roughy zones 10, 20, 21, 40 and 50, and in depths 600 to 1250 m. Catch rates were expressed as the natural log of catch per hour (catch/hr). The years analysed were 1995 - 2018 (Table 7.8). In addition, catches corresponding to closures were omitted from analyses.

A total of 8 statistical models were fitted sequentially to the available data, and the order of the non-interaction terms added based on the relative contribution of each term to model fit.

7.4.1 *Inferences*

The removal of catches from closures through out the time series resulted in a further 1967 observations omitted from analyses. The majority of catch occurred in ORzone 50, 20 followed by 10.

The terms Year, Vessel and DepCat had the greatest contribution to model fit, with the remaining terms each explaining < 1% of the overall variation in CPUE based on the AIC and R2 statistics (Table 7.12). The qqplot suggests that the assumed Normal distribution of the log-transformed CPUE, is valid, with slight deviations as depicted from the lower tail of the distribution (Figure 7.14).

Standardized CPUE exhibits a relatively flat trend and below the long-term average since 2010 (Figure 7.11).

The removal of catch from the 700 m closure, made minimal differences to standardized CPUE compared to CPUE indices which included them in analyses.

7.4.2 *Action Items and Issues*

See Actions and Issues for eastern deepwater shark with closures.

Table 7.8. EasternDeepSharks. The data selection criteria used to specify and identify the fishery data to be included in the analysis.

Property	Value
label	EasternDeepSharks
csirocode	37020000, 37020002, 37020003, 37020004, 37020005, 37020012, 37020013, 37020015,
fishery	SET
depthrange	600 - 1250
depthclass	50
zones	10, 20, 21, 40, 50
methods	TW, TDO, OTT, PTB, TMO
years	1995 - 2018

Table 7.9. EasternDeepSharks. Total catch (Total; t) is the total reported in the database, number of records used in the analysis (N), reported catch (Catch; t) in the area and depth used in the analysis and number of vessels used in the analysis (Vess). GeoM is the geometric mean of catch rates (kg/hr), standard deviation (StDev) relates to the optimum model. C<30Kg denotes the amount of catch in shots of <30kg, and P<30Kg is the proportion of total. The optimum model was ORzone:DepCat.

	Total	N	Catch	Vess	GeoM	Opt	StDev	C<30Kg	P<30Kg
1995	595.4	279	82.2	16	123.5	2.5923	0.000	0.612	0.007
1996	834.2	872	287.9	23	106.5	2.6954	0.081	1.975	0.007
1997	851.0	790	157.2	24	52.7	1.6703	0.078	2.613	0.017
1998	838.5	1051	192.4	23	52.0	1.4012	0.077	4.611	0.024
1999	731.3	946	146.6	22	43.8	1.1772	0.078	4.131	0.028
2000	683.5	774	154.4	36	54.3	1.2502	0.081	2.631	0.017
2001	572.8	790	119.5	27	46.0	1.1543	0.084	4.042	0.034
2002	516.0	788	130.8	25	46.5	1.1705	0.084	3.934	0.030
2003	360.8	808	97.9	22	34.0	0.8080	0.084	4.643	0.047
2004	377.7	596	77.1	25	32.7	0.8252	0.087	3.228	0.042
2005	202.8	340	43.6	12	33.8	0.7907	0.096	1.818	0.042
2006	178.1	276	30.4	17	29.9	0.7898	0.101	2.130	0.070
2007	56.4	49	2.8	13	12.8	0.7418	0.176	0.418	0.147
2008	51.8	75	9.4	8	23.9	1.0091	0.149	0.434	0.046
2009	83.1	180	27.1	11	36.5	0.9724	0.112	0.892	0.033
2010	77.4	203	19.1	11	21.5	0.5911	0.108	1.391	0.073
2011	78.9	156	14.7	13	20.2	0.5192	0.116	0.837	0.057
2012	82.8	221	21.5	13	21.9	0.5709	0.108	1.302	0.061
2013	102.2	196	16.2	10	21.0	0.5362	0.111	1.408	0.087
2014	104.8	372	29.1	12	19.0	0.5482	0.102	1.581	0.054
2015	86.7	379	22.8	11	22.8	0.5319	0.105	1.876	0.082
2016	93.0	299	25.6	14	26.9	0.5004	0.110	1.206	0.047
2017	97.4	302	26.2	11	25.6	0.5714	0.113	0.954	0.036
2018	89.4	393	29.5	14	29.0	0.5823	0.110	1.317	0.045

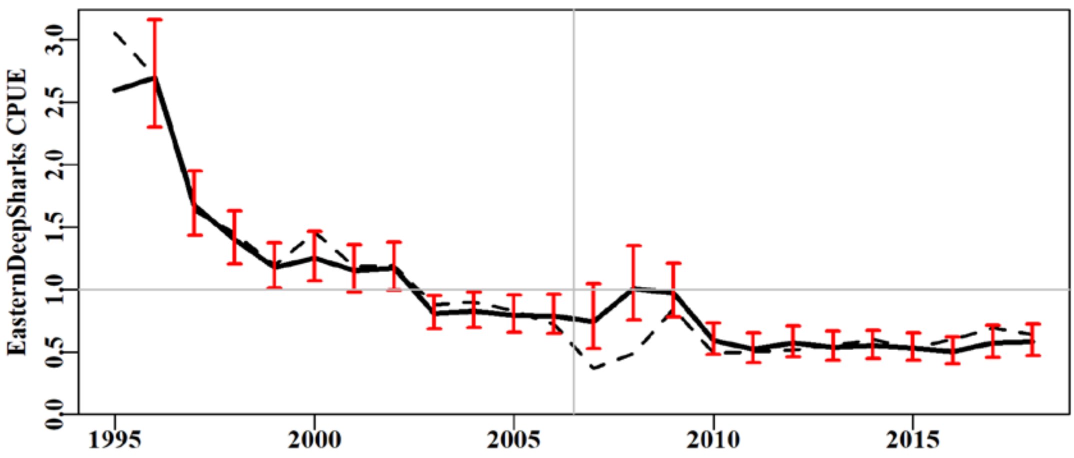

Figure 7.11. EasternDeepSharks standardization. The dashed black line represents the geometric mean catch rate, solid black line the standardized catch rates. The red bars are the 95% confidence intervals about the mean estimates. The graph scales both time-series of standardized catch rates relative to the mean of each time-series..

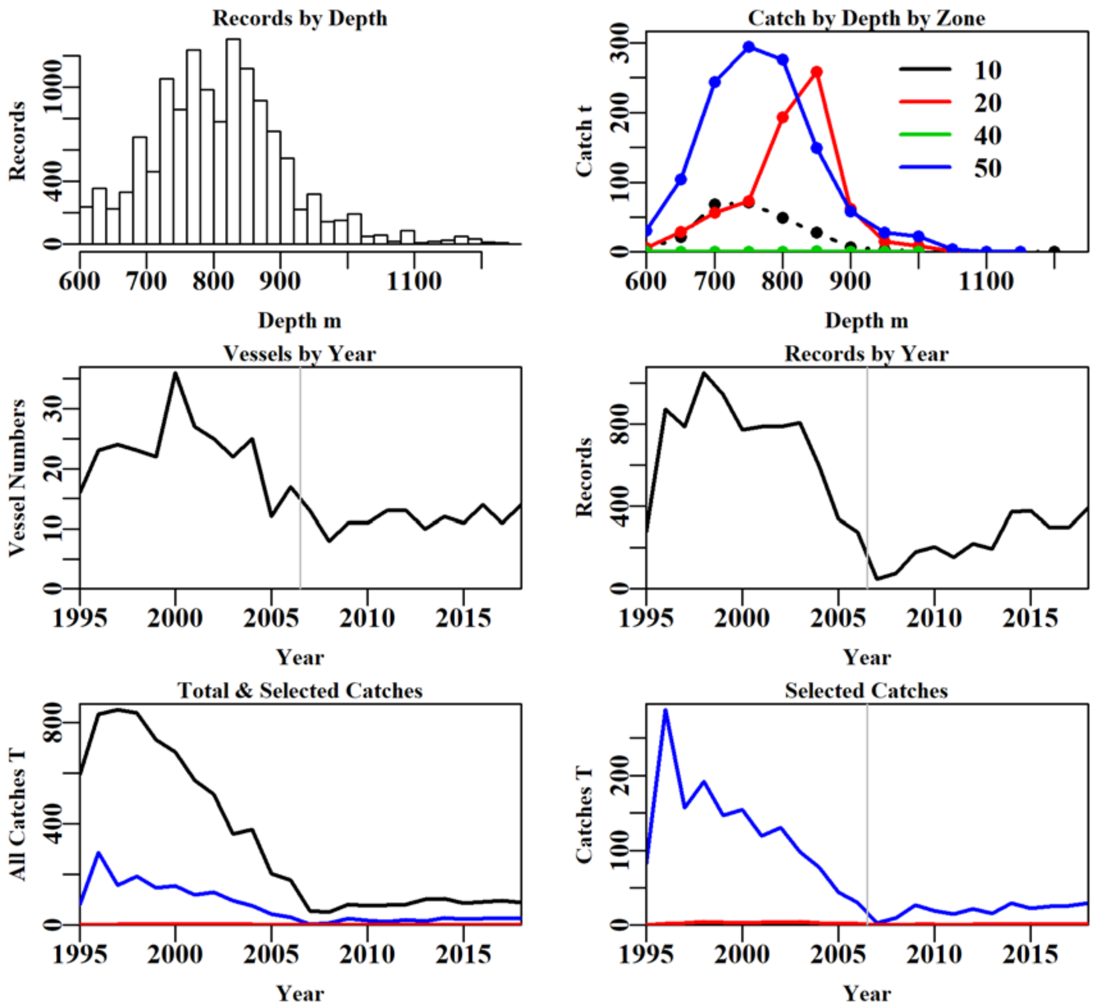

Figure 7.12. EasternDeepSharks fishery details. The bottom left plot depicts all known catches (top black line), and all selected catches used in the analysis (middle blue line); the lower red line: selected catches < 30 kg).

Table 7.10. EasternDeepSharks data selection effects. Total is the total number of records in the database, NoCE removes those records with either missing catch or effort, and then only those records are kept that meet the criteria for depth, years, zone, method, and fishery.

	Total	Method	Years	ORZones	Fishery	Depth	NoCE	Closure
Records	358847	233184	94834	54414	54153	13135	12397	10426
Difference	0	125663	138350	40420	261	41018	738	1971

Table 7.11. The models used to analyse data for EasternDeepSharks.

	Model
Model1	Year
Model2	Year + Vessel
Model3	Year + Vessel + DepCat
Model4	Year + Vessel + DepCat + Month
Model5	Year + Vessel + DepCat + Month + DayNight
Model6	Year + Vessel + DepCat + Month + DayNight + ORzone
Model7	Year + Vessel + DepCat + Month + DayNight + ORzone + ORzone:DepCat
Model8	Year + Vessel + DepCat + Month + DayNight + ORzone + ORzone:Month

Table 7.12. EasternDeepSharks. The row names are 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_r2) and the change in adjusted R^2 (%Change). The optimum model was ORzone:DepCat.

	AIC	RSS	MSS	Nobs	Npars	adj_r2	%Change
Year	3260	14187	2378	10426	24	14.2	0.00
Vessel	2131	12557	4008	10426	96	23.5	9.33
DepCat	1688	12007	4558	10426	108	26.8	3.27
Month	1666	11956	4609	10426	119	27.0	0.23
DayNight	1658	11943	4622	10426	121	27.1	0.07
ORzone	1522	11784	4781	10426	123	28.0	0.96
ORzone:DepCat	1427	11627	4938	10426	145	28.8	0.81
ORzone:Month	1472	11677	4888	10426	145	28.5	0.50

Table 7.13. EasternDeepSharks. Total catch (t) in the fishery under each separate CAAB code included in the basket species.

Name	CAAB Code	Total Catch (t)
Dogfishes	37020000	474.035
Black	37020002	62.316716
Brier	37020003	81.487
Platypus	37020004	101.543
Plunket	37020013	0.216
Pearl	37020905	429.78544
Roughskin	37020906	187.07
OtherSharks	37990003	421.6835

Table 7.14. EasternDeepSharks. Annual catch (t) by CAAB code for a basket species.

	37020000	37020002	37020003	37020004	37020013	37020905	37020906	37990003
1995	43.607							38.640
1996	123.335							164.317
1997	65.567	5.929						85.663
1998	105.444	21.189						64.865
1999	84.386	21.840						40.420
2000	39.120	1.590		10.970		54.908	35.868	11.960
2001	10.036		11.330	16.180		51.152	22.991	7.108
2002	0.982		19.583	22.565	0.060	58.591	21.739	6.571
2003	0.573		12.370	12.979		47.863	23.849	0.070
2004	0.018		10.865	13.448		32.821	18.906	0.218
2005			4.485	7.995		23.272	7.633	0.240
2006			3.085	5.655		16.096	5.027	0.190
2007	0.060			0.395		1.643	0.482	0.270
2008				0.827		6.583	2.019	
2009	0.051		0.210	0.128		13.837	12.611	0.042
2010	0.754		0.020	1.025		11.699	4.886	0.015
2011	0.005			0.260	0.040	7.949	6.100	0.033
2012	0.029		0.497	1.512		10.192	8.938	
2013		0.030	1.155	1.446		8.600	4.968	
2014		2.605	3.030	0.942		17.768	4.510	0.095
2015	0.035	2.712	3.884	2.880		11.416	1.589	0.052
2016	0.005	2.123	4.033	0.770	0.060	15.831	2.738	
2017	0.005	1.832	4.030	1.566		15.960	1.917	0.825
2018	0.023	2.467	2.910		0.056	23.604	0.299	0.090

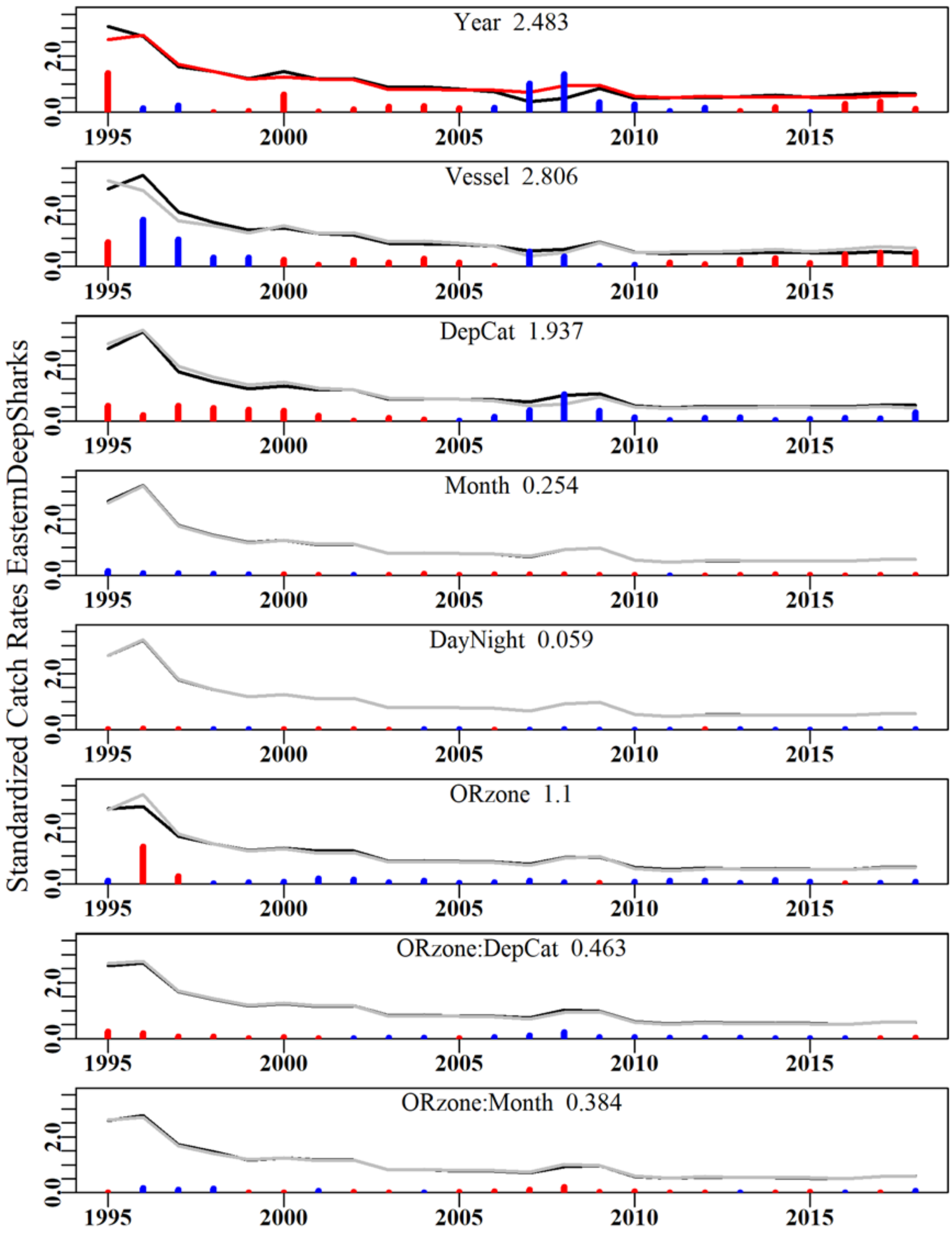

Figure 7.13. EasternDeepSharks. The influence of each factor on the optimal standardization. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by vertical bars with blue bars indicating the optimum model is higher than the 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.

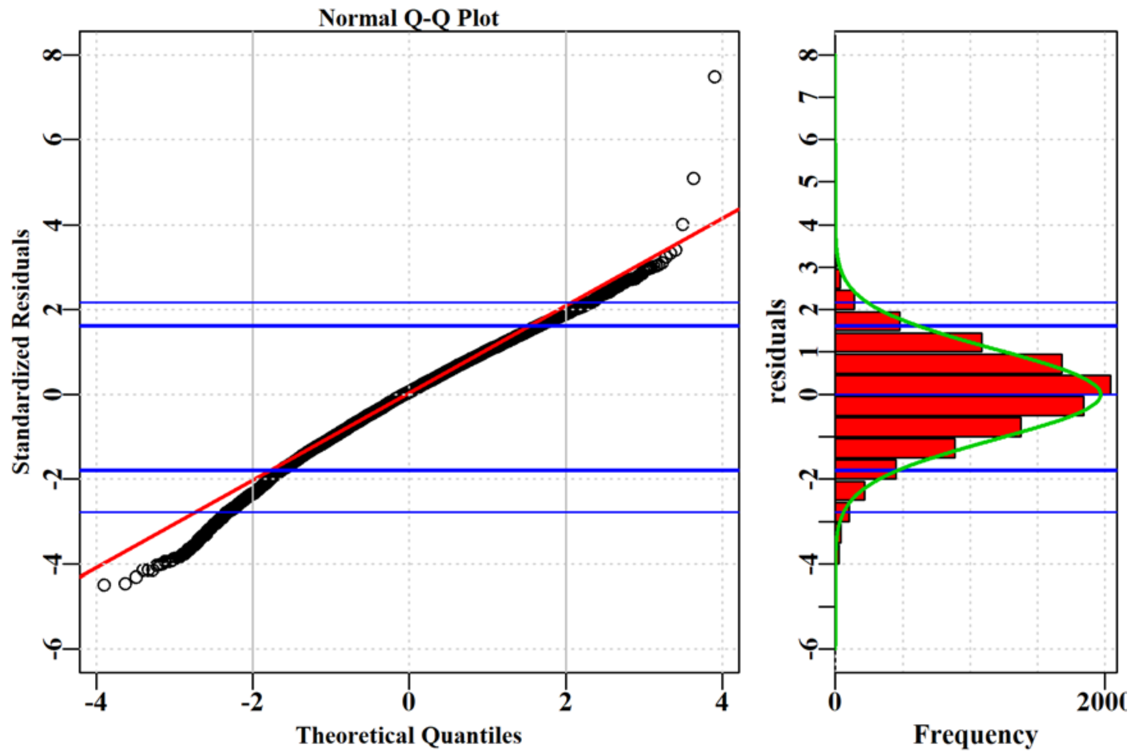

Figure 7.14. EasternDeepSharks. Diagnostic plots. The distribution of residuals from the optimum fit. The qqplot indicates the fit to the expected normality, while the histogram of residuals also illustrates the 1%, 5%, 95% and 99% quantiles to indicate the intensity of any lack of fit at the margins of the distribution (reflected also in the qqplot.

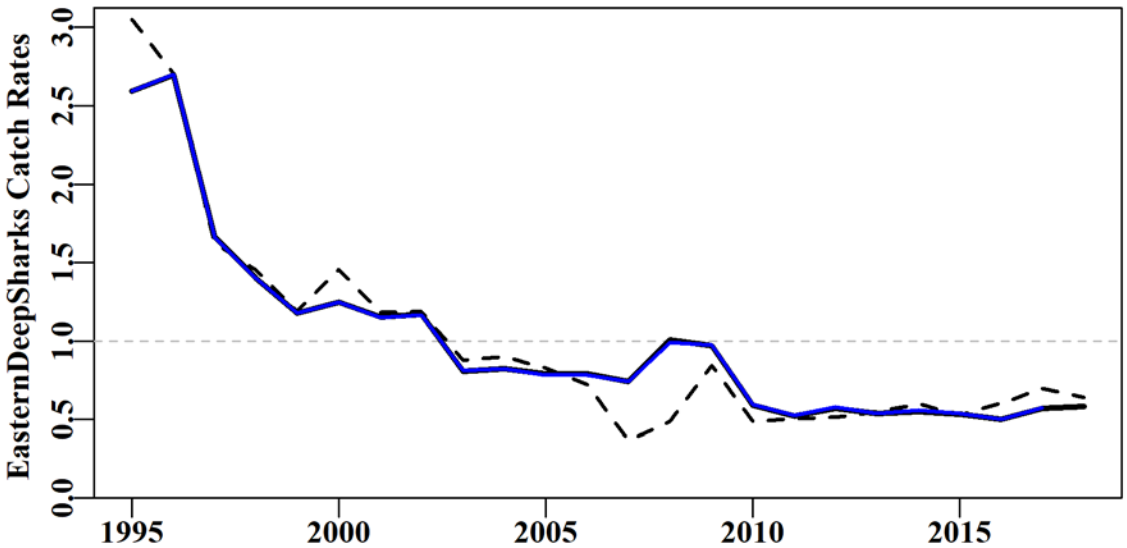

Figure 7.15. EasternDeepSharks. A comparison of the previous year's standardization (blue line) with this year's. They should lie on top of each other, although small deviations may relate to data adjustments, particularly in very recent years.

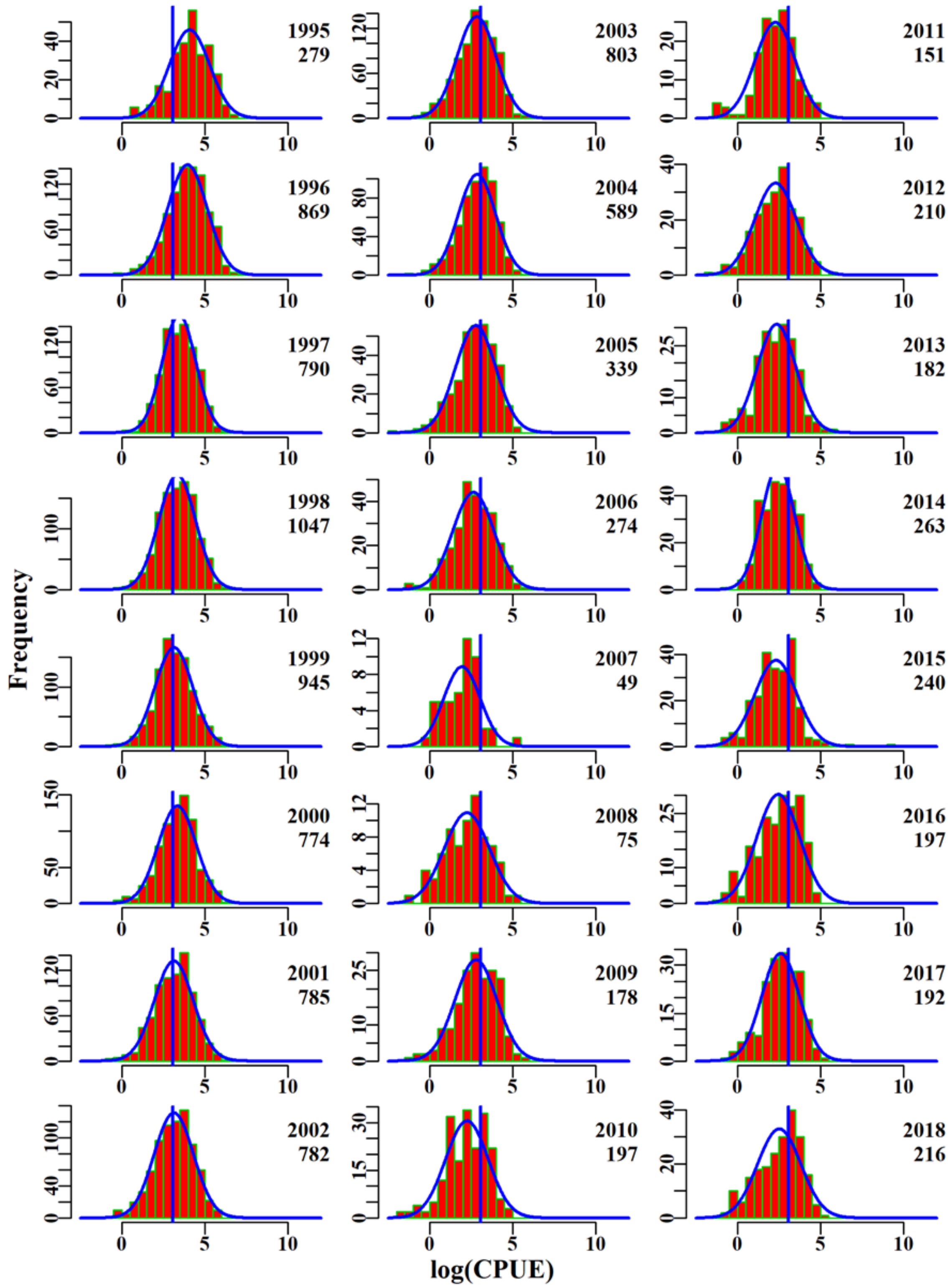

Figure 7.16. EasternDeepSharks. The natural log(CPUE) for each year of data available the blue lines are normal distributions fitted to the histogram frequencies. The numbers in each plot are the year and number of records. The vertical blue line is the average across all years.

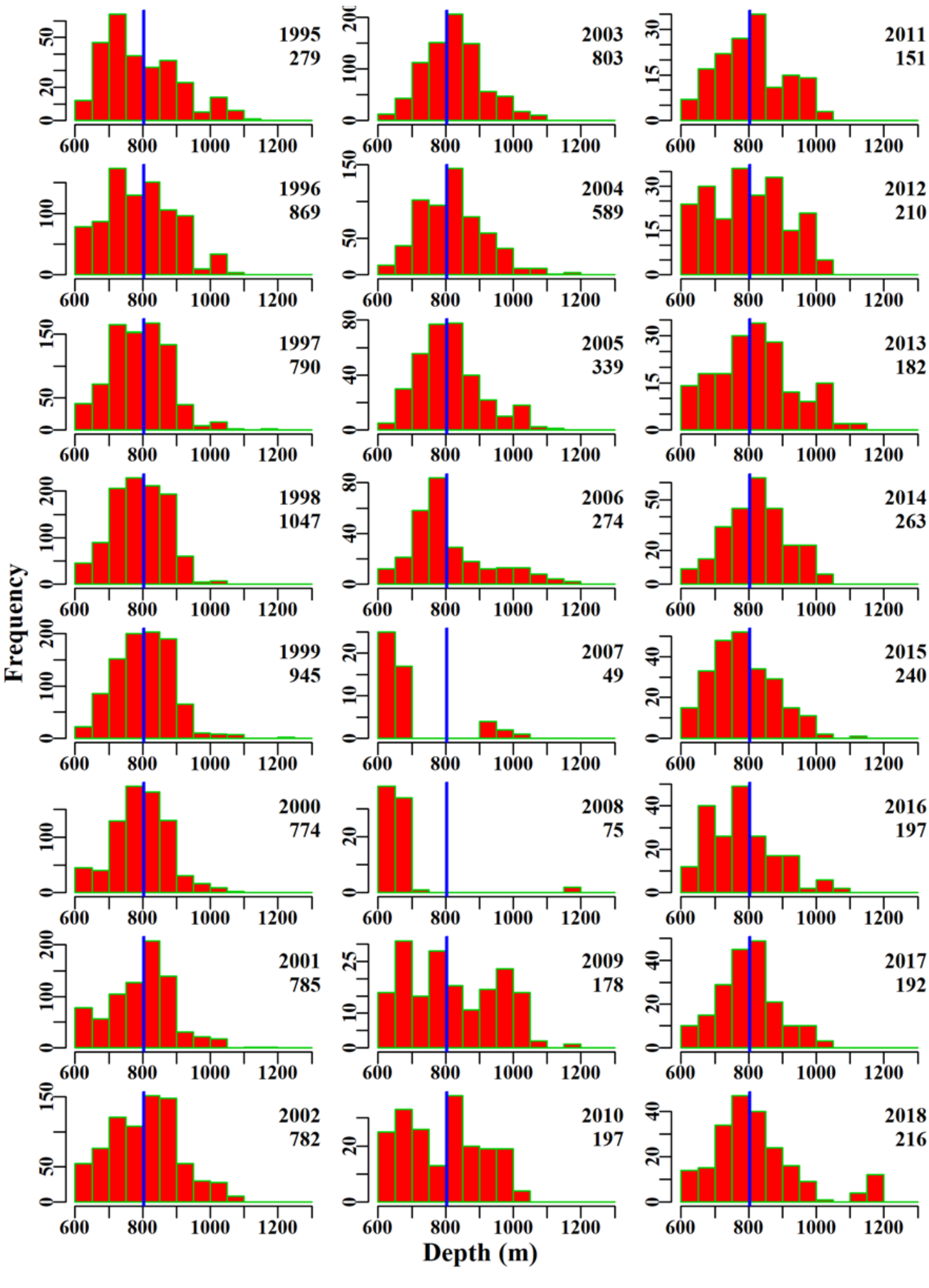

Figure 7.17. EasternDeepSharks. The average Depth of fishing for each year of data available to illustrate the development of the fishery through time. The numbers in each plot are the year and number of records. The vertical blue line is the average across all years.

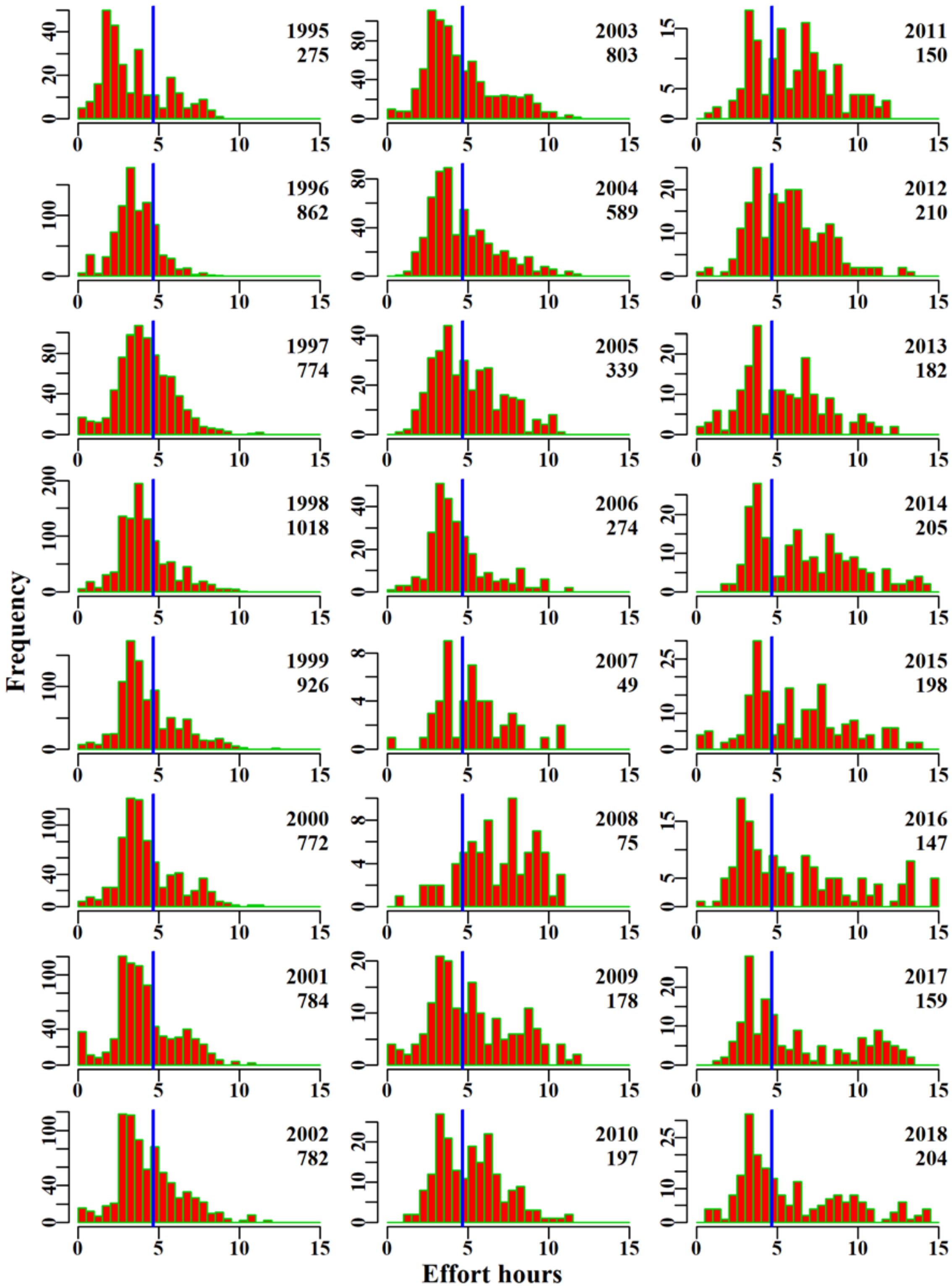

Figure 7.18. EasternDeepSharks. The frequency distribution of effort each year for the available data. The numbers in each plot are the year and number of records. The vertical blue line is the average across all years.

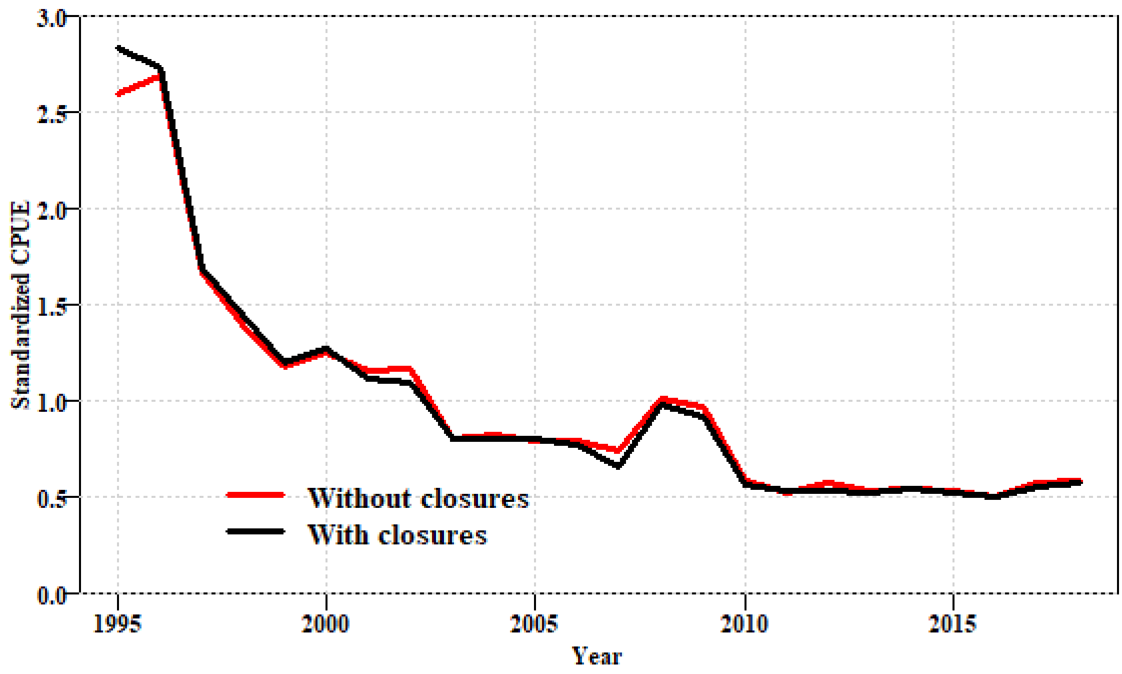

Figure 7.19. Standardized CPUE indices with and without closures.

7.5 Western Deepwater Sharks

This basket quota group is made up of many recognized species but only nine have any records, and only seven 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 western deepwater sharks have been described in Haddon (2014b).

In Commonwealth waters western deepwater sharks were taken by demersal trawl from Orange roughy zone 30, and in depths 600 to 1100 m. Catch rates were expressed as the natural log of catch per hour (catch/hr). The years analysed were 1995 - 2018 (Table 7.15).

A total of 8 statistical models were fitted sequentially to the available data, and the order of the non-interaction terms added based on the relative contribution of each term to model fit.

7.5.1 *Inferences*

As with the eastern deepwater sharks, catches of western deepwater sharks declined from a high in 1997 and 1998 to a low in 2007 on the introduction of the 700 m closure, picking up again after the modifications in 2009 and 2016, with an average of 57 t over the last five years.

The terms Year, Vessel and DepCat had the greatest contribution to model fit, based on the AIC and R2 statistics (Table 7.19). The qqplot suggests that the assumed Normal distribution of the log-transformed CPUE, is valid, with slight deviations as depicted from both tails of the distribution (Figure 7.23).

Standardized CPUE has exhibited an approximate cycle since about 1998 - 2017 with lows in 2005 and 2012-2014 and highs (corresponding to the long-term average) from 1998-2003, 2008-2010 and has returned to the long-term average in 2018 (Figure 7.20).

The depth of fishing appears very influential but also the spread of catch among vessels changes and appears to have been relatively stable for the last five years.

7.5.2 *Action Items and Issues*

No issues identified.

Table 7.15. WesternDeepSharks. The data selection criteria used to specify and identify the fishery data to be included in the analysis.

Property	Value
label	WesternDeepSharks
csirocode	37020000, 37020002, 37020003, 37020004, 37020005, 37020012, 37020013, 37020015, 37020019, 37020021, 37020024, 37020025, 37020027, 37020028, 37020029, 37020030, 37020031, 37020032, 37020033, 37020905, 37020906, 37020907, 37990003
fishery	SET
depthrange	600 - 1100
depthclass	50
zones	30
methods	TW, TDO, OTT, PTB, TMO
years	1995 - 2018

Table 7.16. WesternDeepSharks. Total catch (Total; t) is the total reported in the database, number of records used in the analysis (N), reported catch (Catch; t) in the area and depth used in the analysis and number of vessels used in the analysis (Vess). GeoM is the geometric mean of catch rates (kg/hr), standard deviation (StDev) relates to the optimum model. C<30Kg denotes the amount of catch in shots of <30kg, and P<30Kg is the proportion of total. The optimum model was Vessel:DepCat.

	Total	N	Catch	Vess	GeoM	Opt	StDev	C<30Kg	P<30Kg
1995	595.4	694	103.2	11	43.0	1.6721	0.000	3.683	0.036
1996	834.2	1347	189.9	25	38.6	1.7780	0.047	8.613	0.045
1997	851.0	2322	339.9	22	37.0	1.4644	0.044	12.084	0.036
1998	838.5	3234	405.9	19	29.2	1.1354	0.043	17.614	0.043
1999	731.3	2449	321.4	22	28.8	1.1097	0.044	13.384	0.042
2000	683.5	2031	318.5	22	34.0	1.2512	0.046	8.361	0.026
2001	572.8	1929	244.3	20	27.3	0.9804	0.046	10.879	0.045
2002	516.0	1675	251.0	18	28.5	1.0353	0.047	7.883	0.031
2003	360.8	1459	167.7	18	20.9	0.7912	0.048	8.009	0.048
2004	377.7	1819	212.8	15	22.4	0.8070	0.047	10.673	0.050
2005	202.8	862	84.1	13	20.5	0.7061	0.052	6.061	0.072
2006	178.1	616	69.4	13	22.3	0.8397	0.056	3.798	0.055
2007	56.4	111	8.8	9	20.7	0.8922	0.103	0.611	0.070
2008	51.8	118	15.5	8	25.1	1.1163	0.102	0.312	0.020
2009	83.1	226	33.4	10	25.8	1.1582	0.078	1.032	0.031
2010	77.4	274	36.0	9	25.7	1.0408	0.073	1.886	0.052
2011	78.9	309	38.0	11	22.4	0.8909	0.069	1.479	0.039
2012	82.8	379	35.4	10	15.7	0.6110	0.068	2.740	0.077
2013	102.2	683	66.7	12	15.2	0.6066	0.059	4.098	0.061
2014	104.8	772	55.3	9	13.9	0.5604	0.061	3.797	0.069
2015	86.7	579	49.1	8	17.3	0.6514	0.066	2.150	0.044
2016	93.0	563	55.6	10	25.2	0.9050	0.069	1.881	0.034
2017	97.4	628	57.3	10	26.4	0.9134	0.068	2.495	0.044
2018	89.4	479	50.6	10	30.7	1.0833	0.075	1.308	0.026

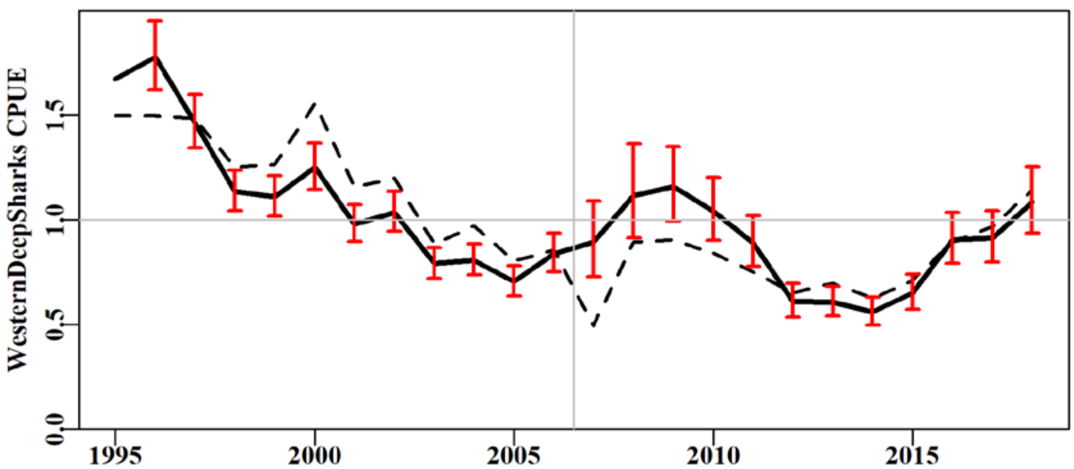

Figure 7.20. WesternDeepSharks standardization. The dashed black line represents the geometric mean catch rate, solid black line the standardized catch rates. The red bars are the 95% confidence intervals about the mean estimates. The graph scales both time-series of standardized catch rates relative to the mean of each time-series.

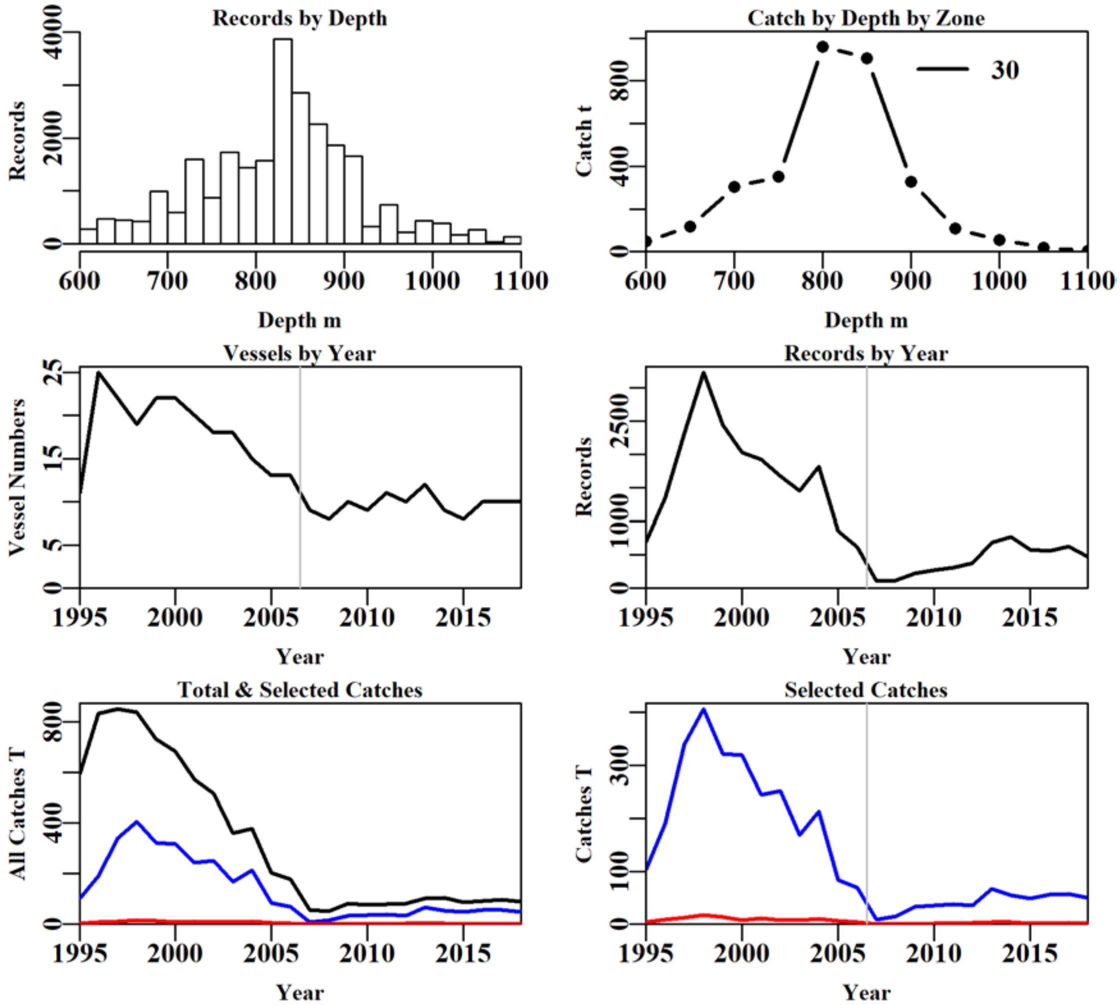

Figure 7.21. WesternDeepSharks fishery details. The bottom left plot depicts all known catches (top black line), and all selected catches used in the analysis (middle blue line); the lower red line: selected catches < 30 kg).

Table 7.17. WesternDeepSharks data selection effects. Total is the total number of records in the database, NoCE removes those records with either missing catch or effort, and then only those records are kept that meet the criteria for depth, years, zone, method, and fishery.

	Total	Method	Years	ORZones	Fishery	Depth	NoCE
Records	358847	233184	94834	31486	31470	25558	24270
Difference	0	125663	138350	63348	16	5912	1288

Table 7.18. The models used to analyse data for WesternDeepSharks.

	Model
Model1	Year
Model2	Year + Vessel
Model3	Year + Vessel + DepCat
Model4	Year + Vessel + DepCat + Month
Model5	Year + Vessel + DepCat + Month + DayNight
Model6	Year + Vessel + DepCat + Month + DayNight + inout
Model7	Year + Vessel + DepCat + Month + DayNight + inout + Vessel:DepCat
Model8	Year + Vessel + DepCat + Month + DayNight + inout + Vessel:Month

Table 7.19. WesternDeepSharks. The row names are 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_r2) and the change in adjusted R^2 (%Change). The optimum model was Vessel:DepCat.

	AIC	RSS	MSS	Nobs	Npars	adj_r2	%Change
Year	1831	26120	1612	24270	24	5.7	0.00
Vessel	397	24528	3203	24270	70	11.3	5.58
DepCat	-2040	22166	5565	24270	80	19.8	8.51
Month	-2195	22006	5726	24270	91	20.4	0.55
DayNight	-2271	21932	5800	24270	94	20.6	0.26
inout	-2351	21858	5874	24270	95	20.9	0.26
Vessel:DepCat	-3076	20735	6996	24270	372	24.1	3.19
Vessel:Month	-2515	21106	6626	24270	438	22.5	1.62

Table 7.20. WesternDeepSharks. Total catch (t) in the fishery under each separate CAAB code included in the basket species.

Name	CAAB Code	Total Catch (t)
Dogfishes	37020000	513.867
Black	37020002	336.322
Platypus	37020004	243.505
Plunket	37020013	0.224
Pearl	37020905	936.203
Roughskin	37020906	564.033
OtherSharks	37990003	615.498

Table 7.21. WesternDeepSharks. Annual catch (t) by CAAB code for a basket species.

	37020000	37020002	37020004	37020013	37020905	37020906	37990003
1995	49.067						54.103
1996	96.147						93.748
1997	122.528	34.694					182.673
1998	124.297	148.115					133.438
1999	95.570	120.258					105.550
2000	19.477	12.928	16.289		105.249	135.170	29.349
2001	0.125		26.184		107.183	103.619	7.196
2002	0.050		36.770		146.988	63.587	3.585
2003	0.050		20.423		87.114	59.161	0.964
2004	0.100		20.871		117.339	74.353	0.107
2005	1.090		11.035		46.334	22.985	2.675
2006	0.384		9.550		41.507	17.951	
2007	1.588		0.300		5.680	1.206	
2008	0.708		2.518		6.817	5.362	0.120
2009	1.030		2.111		14.536	15.717	
2010	0.177		3.388		12.024	20.436	
2011	0.362		3.078		18.177	14.950	1.460
2012	0.403		4.212		24.368	6.344	0.030
2013	0.356	1.448	23.806		26.037	15.005	
2014	0.200	4.804	20.989		25.240	4.095	0.000
2015	0.094	4.004	20.890		21.772	2.299	0.060
2016	0.000	3.615	16.667		33.842	1.125	0.390
2017	0.000	3.677	3.070	0.224	49.759	0.543	0.050
2018	0.064	2.779	1.355		46.237	0.125	0.000

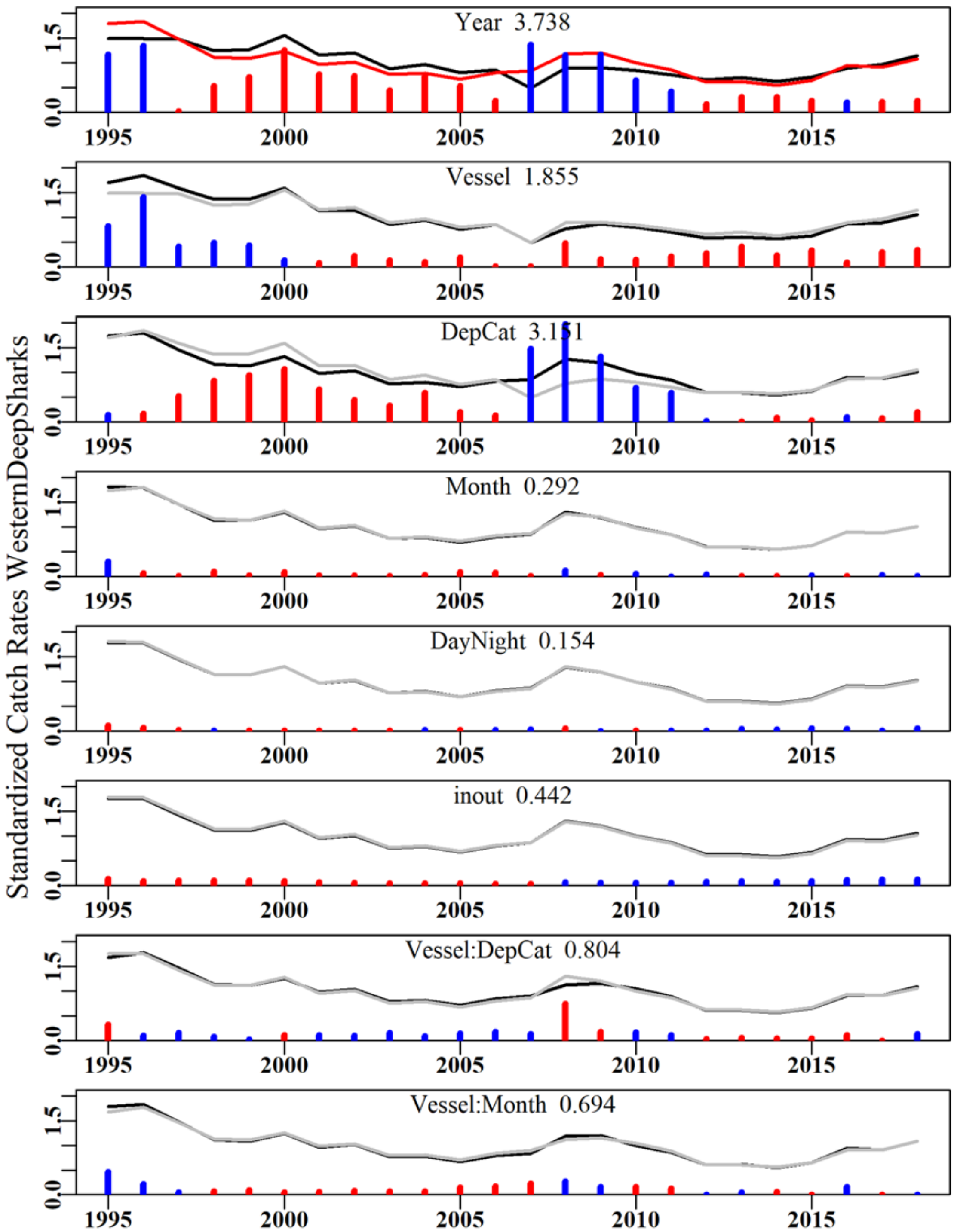

Figure 7.22. WesternDeepSharks. The influence of each factor on the optimal standardization. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by vertical bars with blue bars indicating the optimum model is higher than the 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.

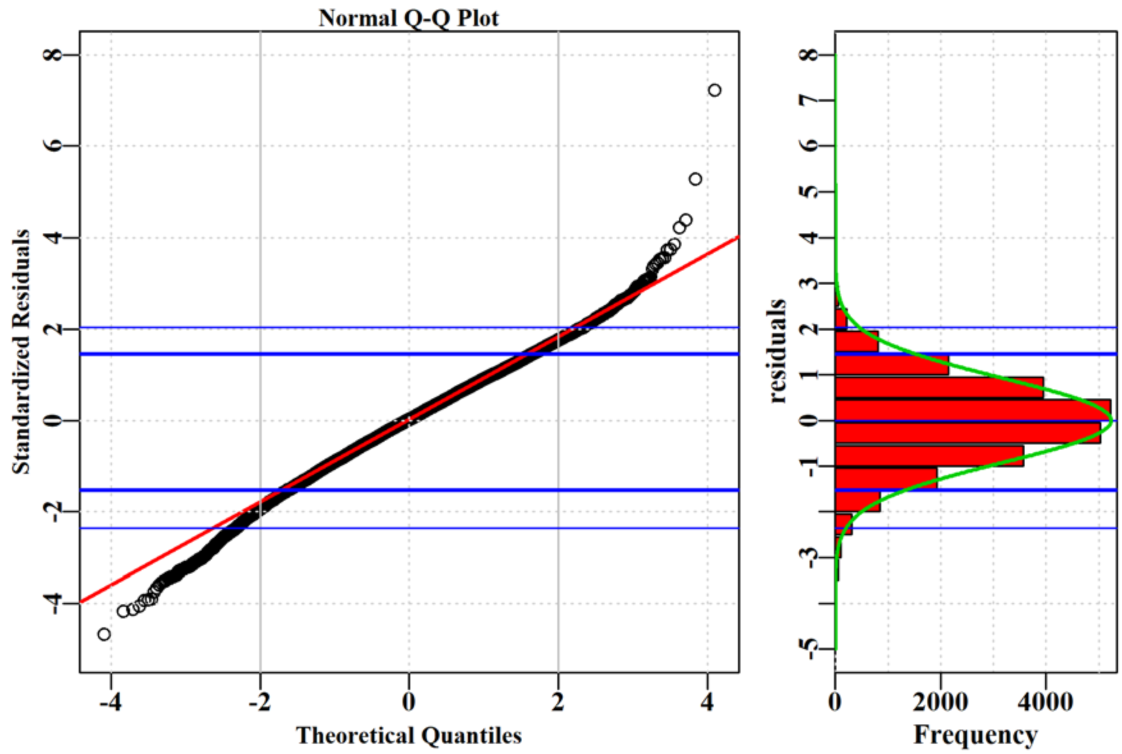

Figure 7.23. WesternDeepSharks. Diagnostic plots. The distribution of residuals from the optimum fit. The qqplot indicates the fit to the expected normality, while the histogram of residuals also illustrates the 1%, 5%, 95% and 99% quantiles to indicate the intensity of any lack of fit at the margins of the distribution (reflected also in the qqplot.

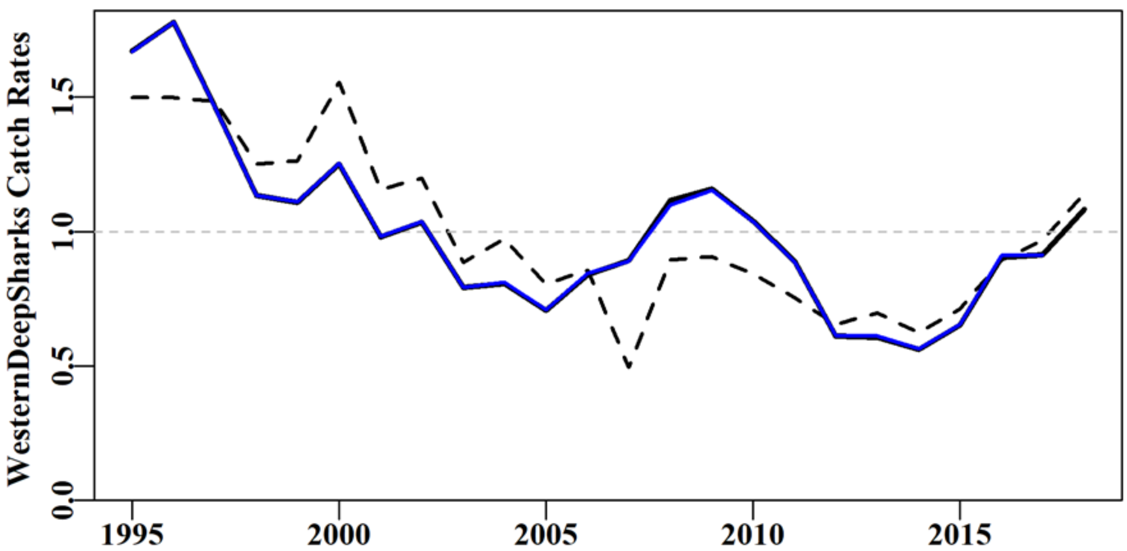

Figure 7.24. WesternDeepSharks. A comparison of the previous year's standardization (blue line) with this year's. They should lie on top of each other, although small deviations may relate to data adjustments, particularly in very recent years.

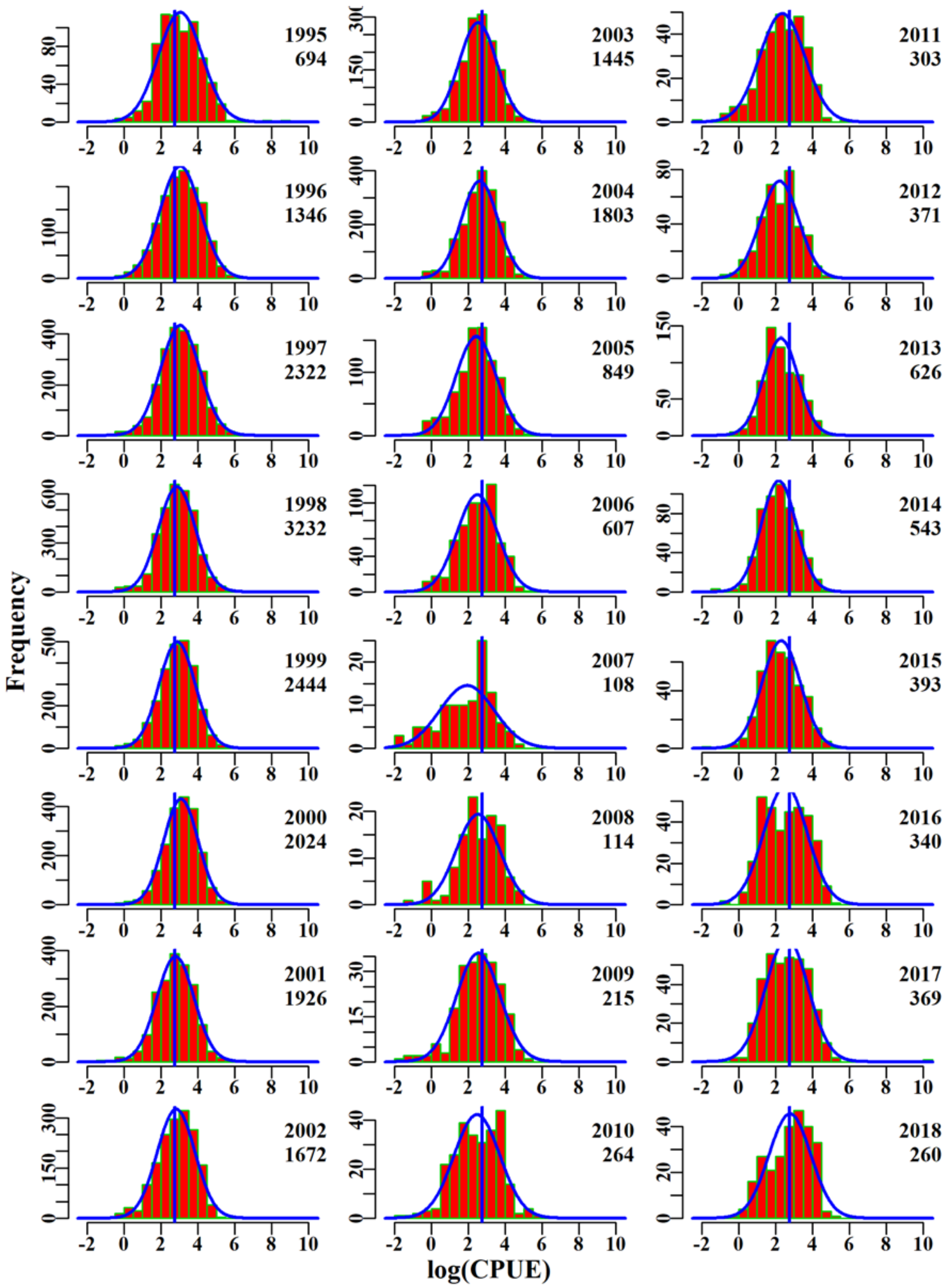

Figure 7.25. WesternDeepSharks. The natural log(CPUE) for each year of data available the blue lines are normal distributions fitted to the histogram frequencies. The numbers in each plot are the year and number of records. The vertical blue line is the average across all years.

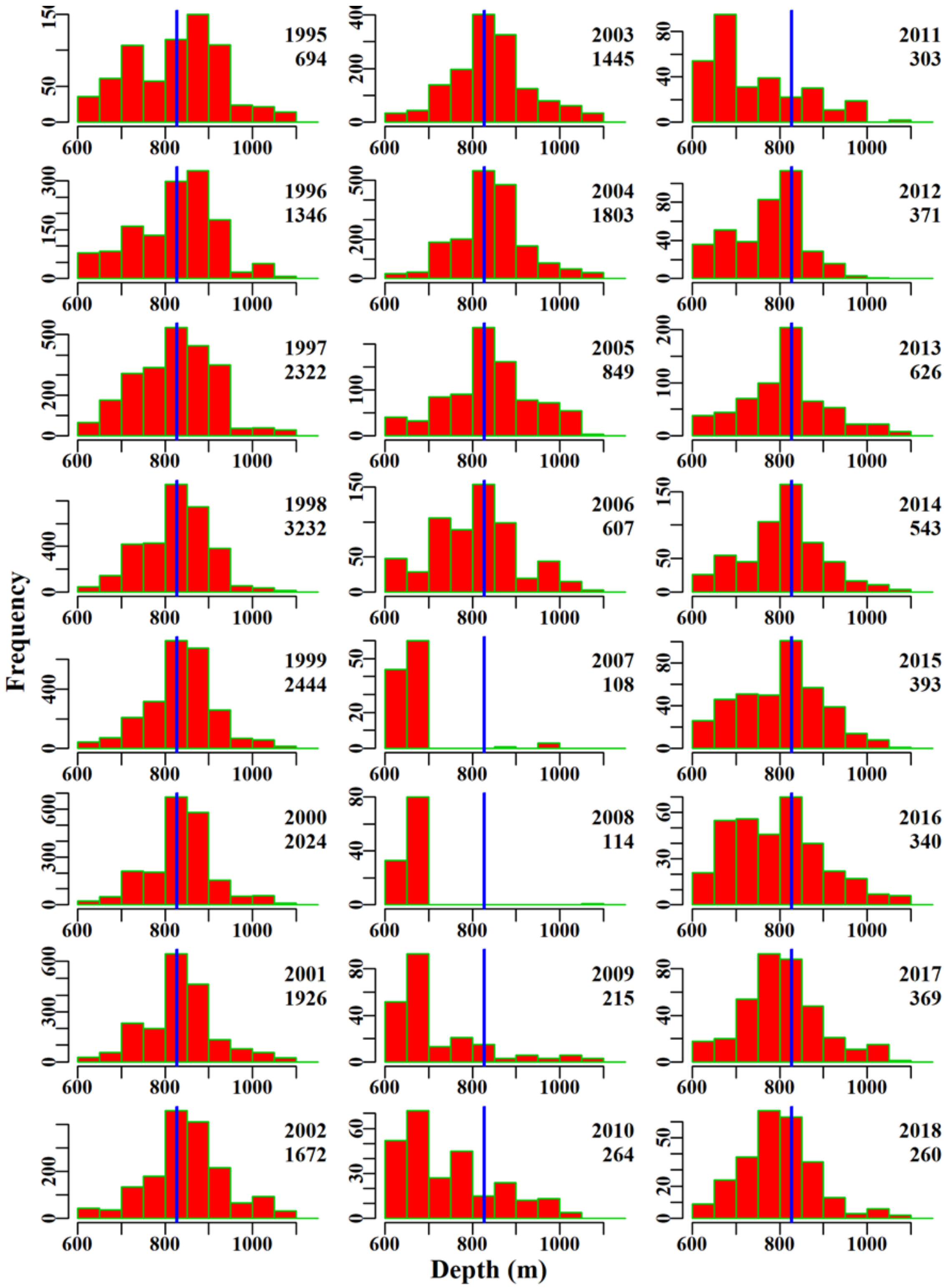

Figure 7.26. WesternDeepSharks. The average Depth of fishing for each year of data available to illustrate the development of the fishery through time. The numbers in each plot are the year and number of records. The vertical blue line is the average across all years.

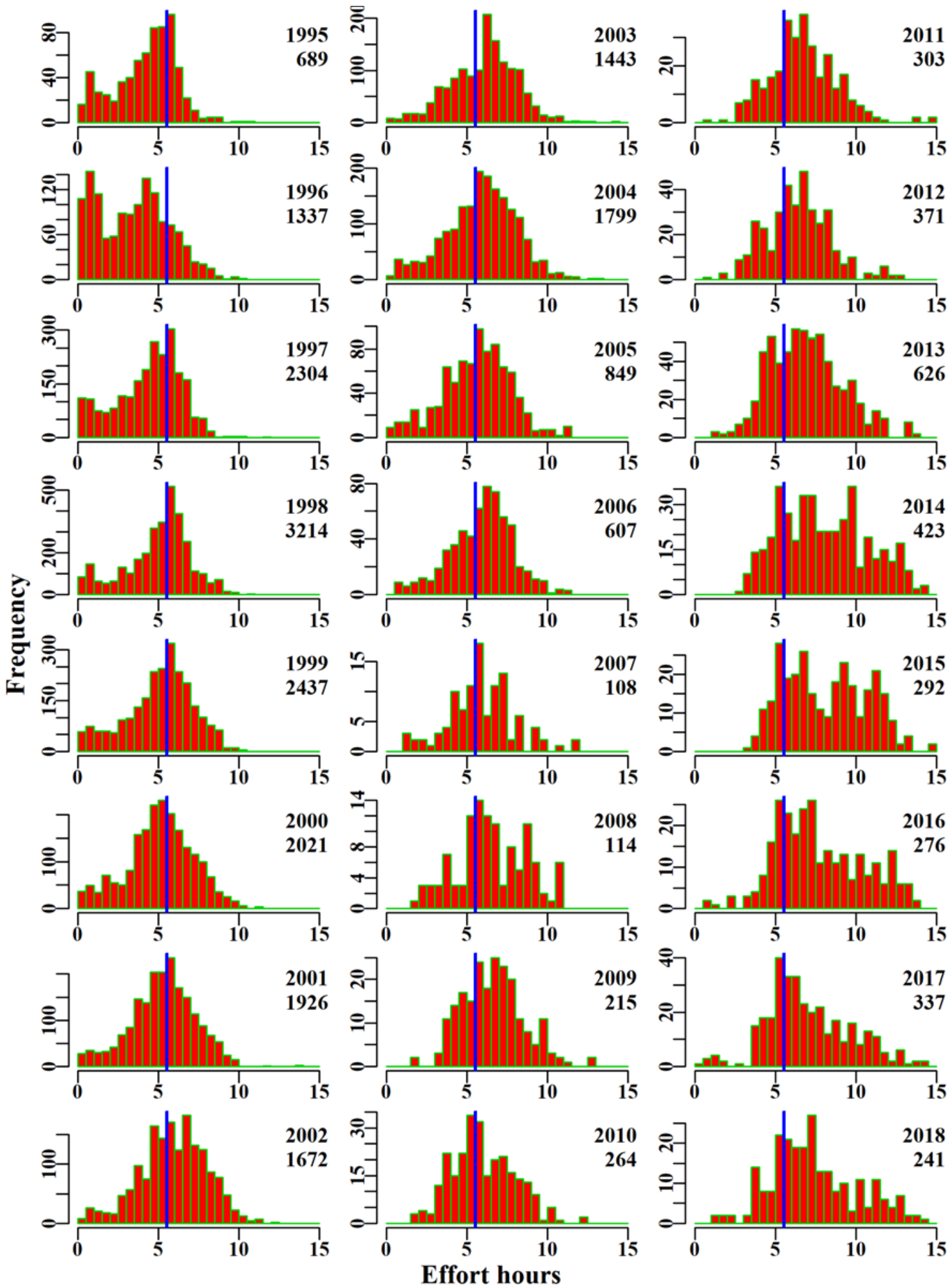

Figure 7.27. WesternDeepSharks. The frequency distribution of effort each year for the available data. The numbers in each plot are the year and number of records. The vertical blue line is the average across all years.

7.6 Western Deepwater Sharks – without closures

In Commonwealth waters western deepwater sharks were taken by demersal trawl from Orange roughy zone 30, and in depths 600 to 1100 m. Catch rates were expressed as the natural log of catch per hour (catch/hr). The years analysed were 1995 – 2018 (Table 7.22). Also, the 700 m closure was omitted from analyses.

A total of 7 statistical models were fitted sequentially to the available data, and the order of the non-interaction terms added based on the relative contribution of each term to model fit.

7.6.1 *Inferences*

The terms Year, Vessel and DepCat and one interaction (Vessel:DepCat) had the greatest contribution to model fit, based on the AIC and R2 statistics (Table 7.26). The qqplot suggests that the assumed Normal distribution of the log-transformed CPUE, is valid, with slight deviations as depicted from both tails of the distribution (Figure 7.31).

Standardized CPUE have exhibited an approximate cycle since about 1998 - 2017 with lows in 2005 and 2012-2014 and highs (corresponding to the long-term average) from 1998-2003 and 2008-2010 and has returned to the long-term average in 2018 (Figure 7.28).

The removal of catch from the 700 m closure, made minimal differences to standardized CPUE compared to CPUE indices which included them in analyses.

7.6.2 *Action Items and Issues*

No issues identified.

Table 7.22. WesternDeepSharks. The data selection criteria used to specify and identify the fishery data to be included in the analysis.

Property	Value
label	WesternDeepSharks
csirocode	37020000, 37020002, 37020003, 37020004, 37020005, 37020012, 37020013, 37020015,
fishery	SET
depthrange	600 - 1100
depthclass	50
zones	30
methods	TW, TDO, OTT, PTB, TMO
years	1995 - 2018

Table 7.23. WesternDeepSharks. Total catch (Total; t) is the total reported in the database, number of records used in the analysis (N), reported catch (Catch; t) in the area and depth used in the analysis and number of vessels used in the analysis (Vess). GeoM is the geometric mean of catch rates (kg/hr), standard deviation (StDev) relates to the optimum model. C<30Kg denotes the amount of catch in shots of <30kg, and P<30Kg is the proportion of total. The optimum model was Vessel:DepCat.

	Total	N	Catch	Vess	GeoM	Opt	StDev	C<30Kg	P<30Kg
1995	595.4	485	75.2	9	37.0	1.5892	0.000	2.431	0.032
1996	834.2	877	143.2	22	40.1	1.8175	0.058	4.821	0.034
1997	851.0	1632	253.3	20	37.1	1.4885	0.053	7.097	0.028
1998	838.5	2212	273.8	19	28.7	1.1459	0.052	11.061	0.040
1999	731.3	1654	201.9	21	25.2	1.0576	0.053	8.653	0.043
2000	683.5	1369	210.9	22	31.5	1.2569	0.055	5.361	0.025
2001	572.8	1307	165.2	19	25.8	1.0029	0.055	6.746	0.041
2002	516.0	1093	167.6	17	30.1	1.0842	0.056	4.977	0.030
2003	360.8	997	113.5	16	20.0	0.8397	0.057	5.266	0.046
2004	377.7	1225	144.8	14	22.4	0.8248	0.056	7.545	0.052
2005	202.8	573	56.4	13	20.2	0.7181	0.063	3.984	0.071
2006	178.1	438	52.0	13	23.3	0.9114	0.067	2.530	0.049
2007	56.4	98	7.9	9	19.0	0.8646	0.112	0.548	0.069
2008	51.8	114	15.1	8	25.6	1.1766	0.108	0.312	0.021
2009	83.1	212	31.7	9	26.2	1.1776	0.085	0.942	0.030
2010	77.4	256	33.4	9	25.0	1.0279	0.080	1.776	0.053
2011	78.9	293	35.5	11	22.0	0.8769	0.076	1.404	0.040
2012	82.8	370	34.4	10	15.7	0.5950	0.075	2.684	0.078
2013	102.2	659	64.0	12	15.3	0.6007	0.067	3.959	0.062
2014	104.8	758	54.2	9	13.9	0.5371	0.068	3.734	0.069
2015	86.7	570	48.0	8	17.2	0.6275	0.072	2.125	0.044
2016	93.0	540	52.0	10	25.1	0.8623	0.076	1.781	0.034
2017	97.4	619	54.8	10	26.1	0.8745	0.075	2.495	0.046
2018	89.4	472	49.5	10	30.8	1.0428	0.081	1.308	0.026

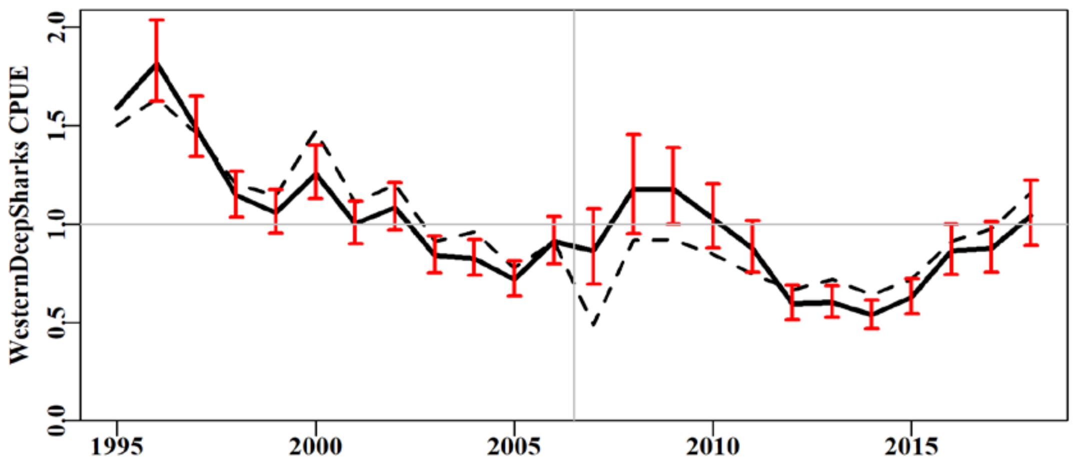

Figure 7.28. WesternDeepSharks standardization. The dashed black line represents the geometric mean catch rate, solid black line the standardized catch rates. The red bars are the 95% confidence intervals about the mean estimates. The graph scales both time-series of standardized catch rates relative to the mean of each time-series.

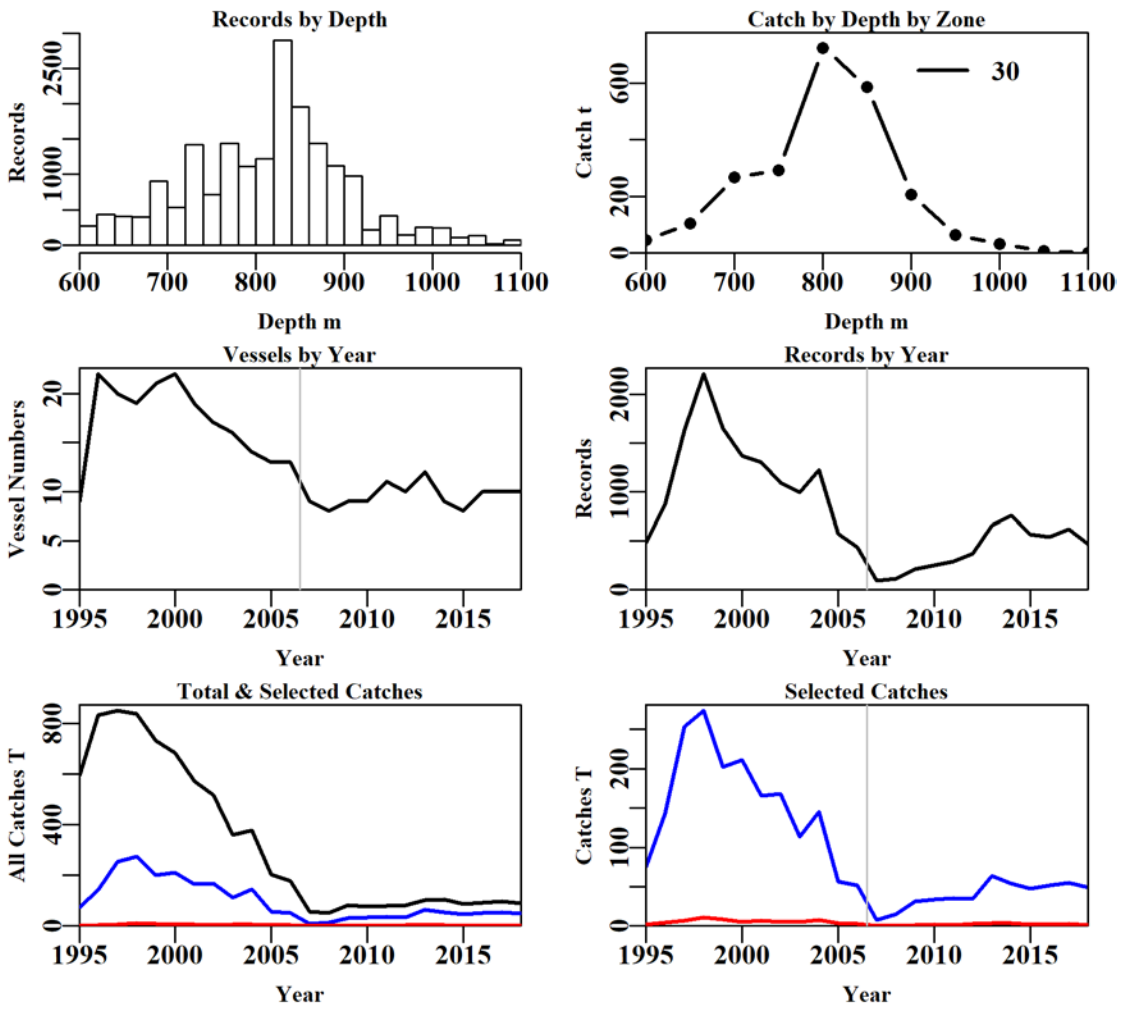

Figure 7.29. WesternDeepSharks fishery details. The bottom left plot depicts all known catches (top black line), and all selected catches used in the analysis (middle blue line); the lower red line: selected catches < 30 kg).

Table 7.24. WesternDeepSharks data selection effects. Total is the total number of records in the database, NoCE removes those records with either missing catch or effort, and then only those records are kept that meet the criteria for depth, years, zone, method, and fishery.

	Total	Method	Years	ORZones	Fishery	Depth	NoCE	Closure
Records	358847	233184	94834	31486	31470	25558	24270	0
Difference	0	125663	138350	63348	16	5912	1288	24270

Table 7.25. The models used to analyse data for WesternDeepSharks.

	Model
Model1	Year
Model2	Year + Vessel
Model3	Year + Vessel + DepCat
Model4	Year + Vessel + DepCat + Month
Model5	Year + Vessel + DepCat + Month + DayNight
Model6	Year + Vessel + DepCat + Month + DayNight + Vessel:DepCat
Model7	Year + Vessel + DepCat + Month + DayNight + Vessel:Month

Table 7.26. WesternDeepSharks. The row names are 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_r2) and the change in adjusted R^2 (%Change). The optimum model was Vessel:DepCat.

	AIC	RSS	MSS	Nobs	Npars	adj_r2	%Change
Year	1680	19282	1181	17572	24	5.6	0.00
Vessel	582	18022	2441	17572	69	11.6	5.94
DepCat	-1293	16179	4285	17572	79	20.6	9.00
Month	-1422	16041	4423	17572	90	21.2	0.63
DayNight	-1468	15996	4468	17572	92	21.4	0.21
Vessel:DepCat	-1851	15201	5263	17572	348	24.2	2.79
Vessel:Month	-1414	15448	5015	17572	425	22.6	1.22

Table 7.27. WesternDeepSharks. Total catch (t) in the fishery under each separate CAAB code included in the basket species.

Name	CAAB Code	Total Catch (t)
Dogfishes	37020000	379.619
Black	37020002	207.233
Platypus	37020004	226.366
Plunket	37020013	0.224
Pearl	37020905	694.859
Roughskin	37020906	386.413
OtherSharks	37990003	443.777

Table 7.28. WesternDeepSharks. Annual catch (t) by CAAB code for a basket species.

	37020000	37020002	37020004	37020013	37020905	37020906	37990003
1995	36.762						38.457
1996	76.244						67.003
1997	95.350	26.397					131.570
1998	88.201	87.064					98.510
1999	62.157	65.597					74.173
2000	14.442	8.743	13.974		71.028	79.979	22.779
2001	0.100		22.569		71.369	66.330	4.866
2002	0.050		34.762		89.008	40.492	3.285
2003	0.050		17.986		54.930	39.630	0.934
2004	0.095		18.316		76.030	50.351	0.050
2005	1.058		10.186		30.883	13.618	0.635
2006	0.224		8.186		30.348	13.246	
2007	1.524		0.250		5.257	0.861	
2008	0.708		2.326		6.667	5.330	0.085
2009	1.030		2.111		13.631	14.907	
2010	0.177		3.058		10.793	19.356	
2011	0.362		2.948		17.152	14.035	0.960
2012	0.403		4.212		23.618	6.163	0.030
2013	0.356	1.448	23.362		24.603	14.256	
2014	0.200	4.754	20.829		24.574	3.872	0.000
2015	0.094	3.954	20.665		20.997	2.274	0.000
2016		3.215	16.577		30.764	1.045	0.390
2017	0.000	3.282	3.070	0.224	47.659	0.543	0.050
2018	0.032	2.779	0.980		45.548	0.125	0.000

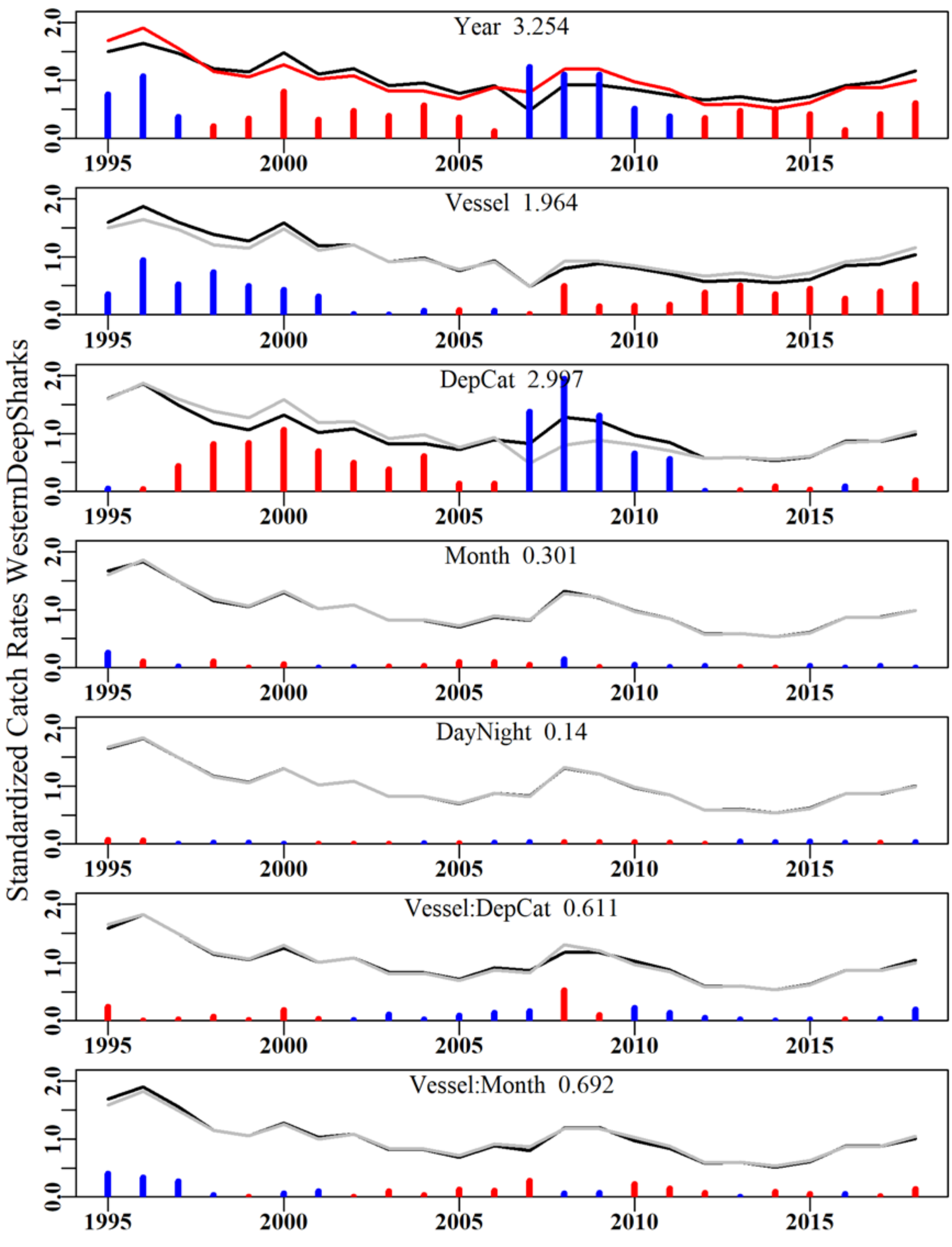

Figure 7.30. WesternDeepSharks. The influence of each factor on the optimal standardization. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by vertical bars with blue bars indicating the optimum model is higher than the 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.

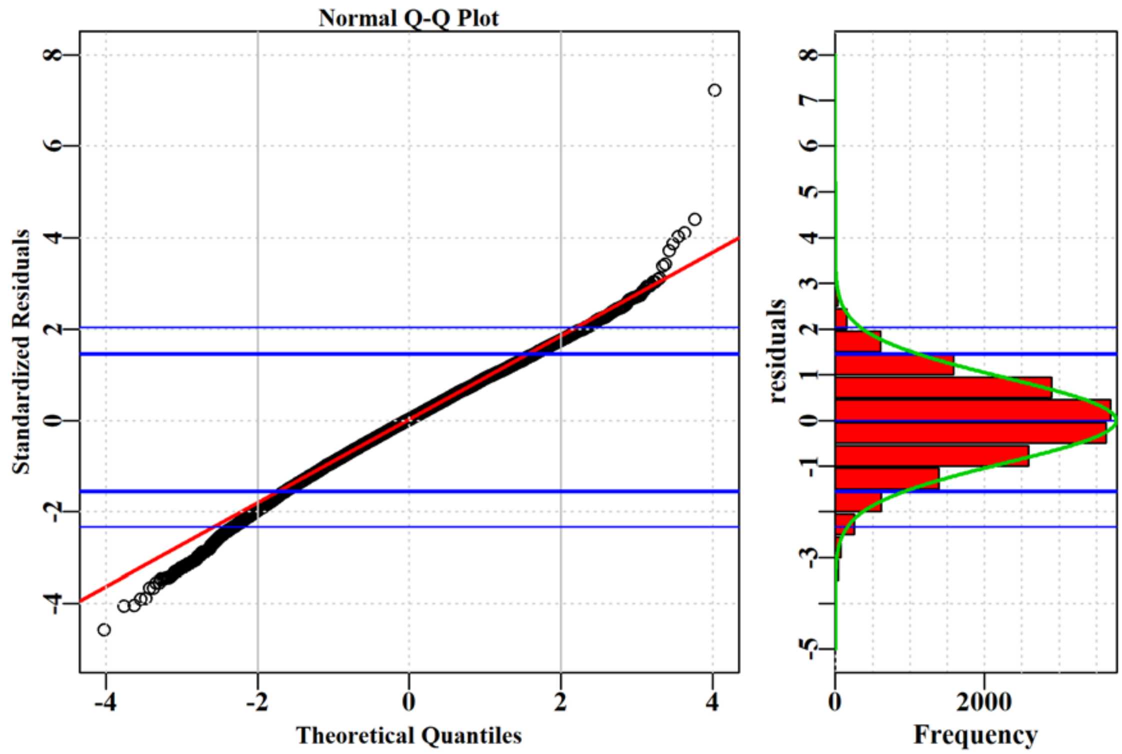

Figure 7.31. WesternDeepSharks. Diagnostic plots. The distribution of residuals from the optimum fit. The qqplot indicates the fit to the expected normality, while the histogram of residuals also illustrates the 1%, 5%, 95% and 99% quantiles to indicate the intensity of any lack of fit at the margins of the distribution (reflected also in the qqplot.

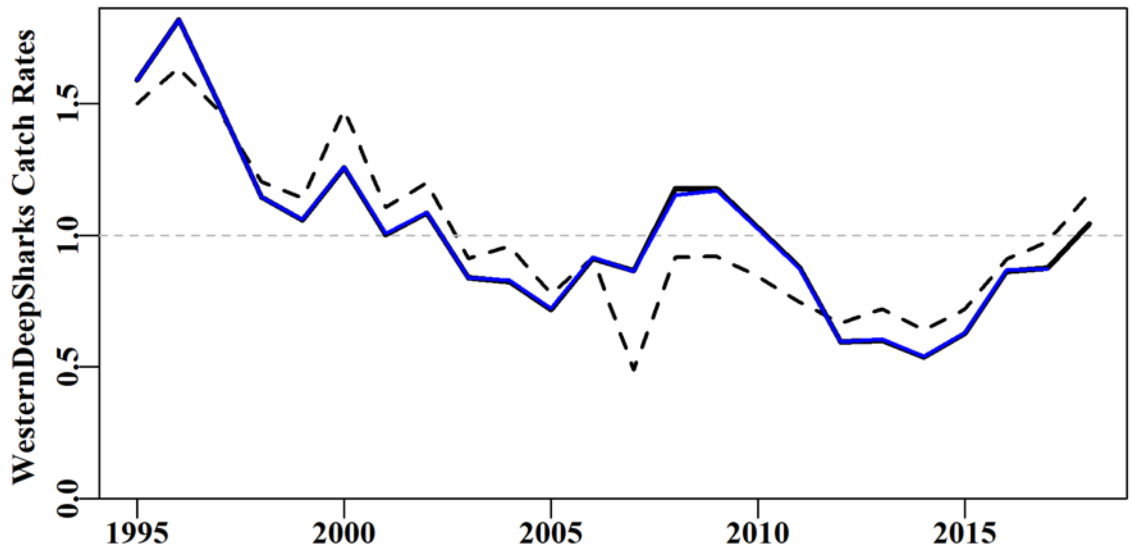

Figure 7.32. WesternDeepSharks. A comparison of the previous year's standardization (blue line) with this year's. They should lie on top of each other, although small deviations may relate to data adjustments, particularly in very recent years.

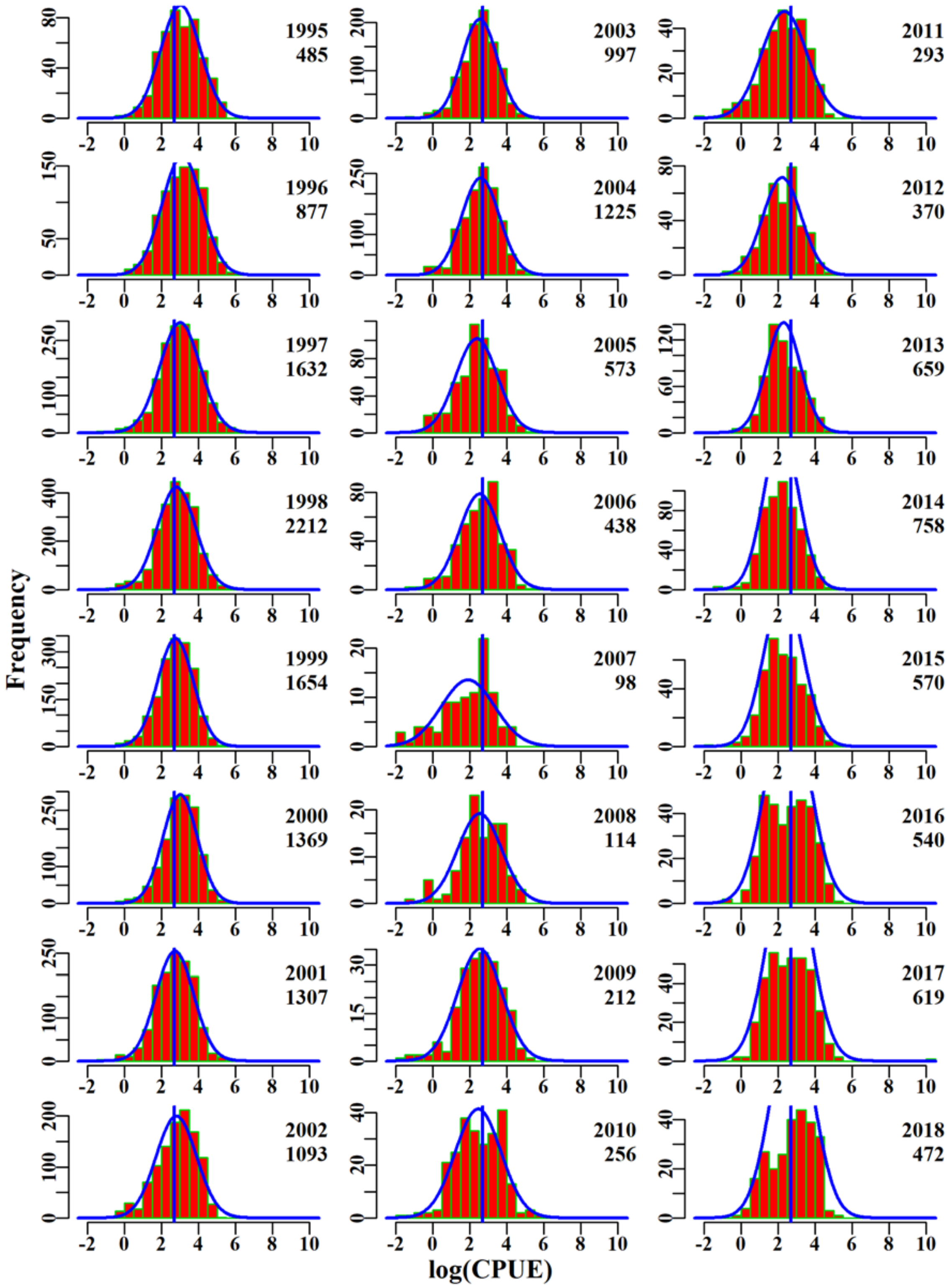

Figure 7.33. WesternDeepSharks. The natural log(CPUE) for each year of data available the blue lines are normal distributions fitted to the histogram frequencies. The numbers in each plot are the year and number of records. The vertical blue line is the average across all years.

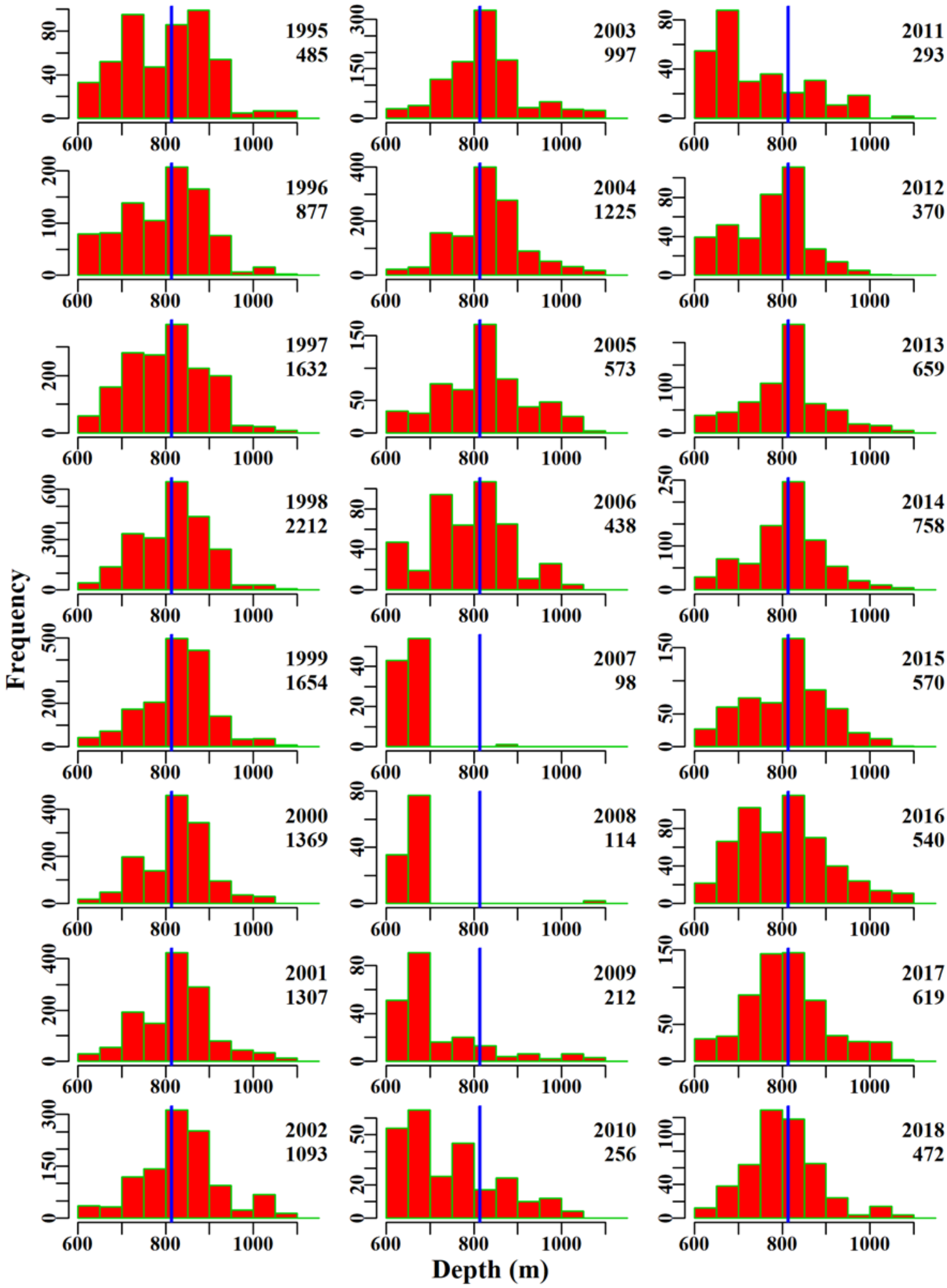

Figure 7.34. WesternDeepSharks. The average Depth of fishing for each year of data available to illustrate the development of the fishery through time. The numbers in each plot are the year and number of records. The vertical blue line is the average across all years.

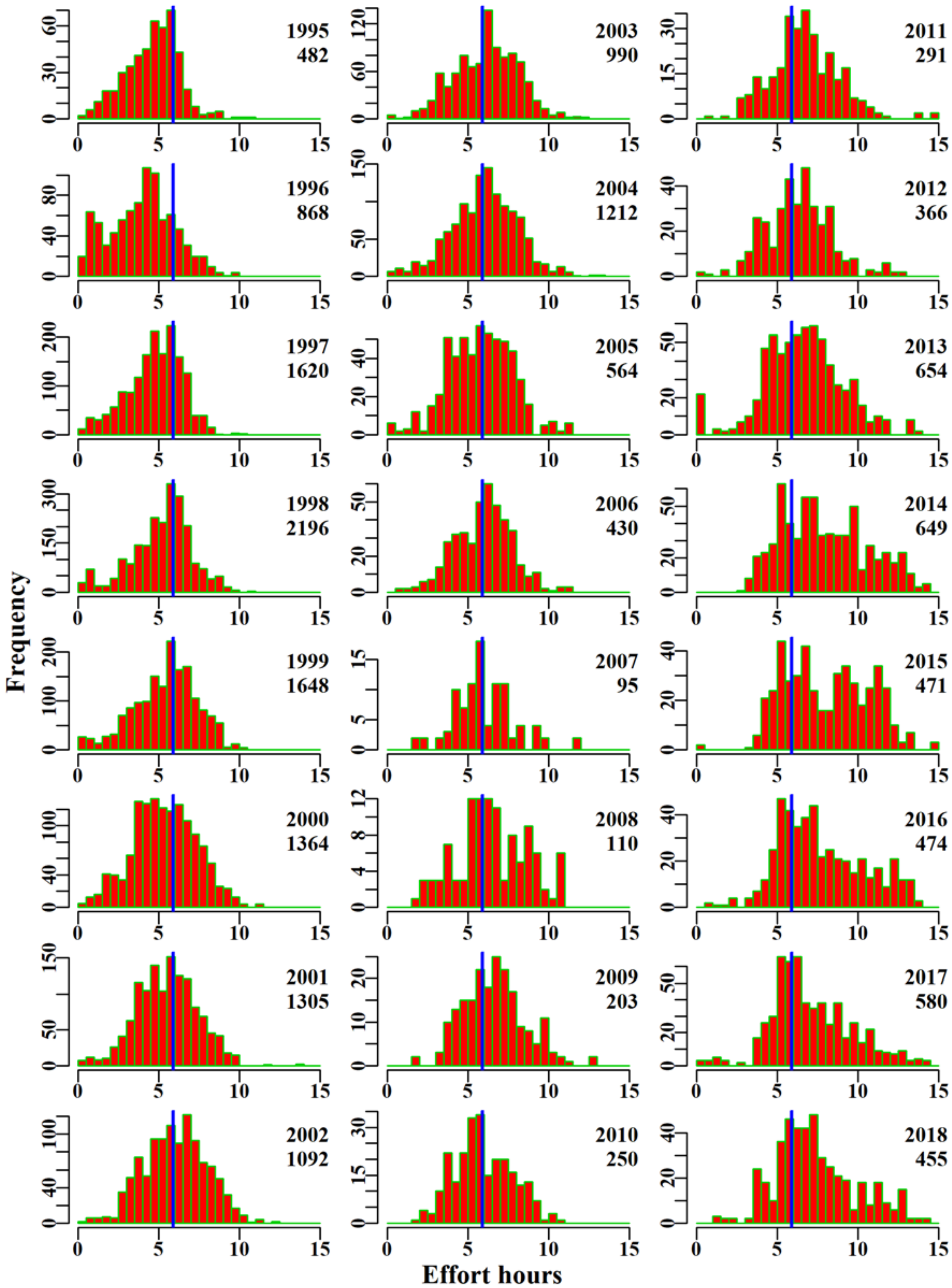

Figure 7.35. WesternDeepSharks. The frequency distribution of effort each year for the available data. The numbers in each plot are the year and number of records. The vertical blue line is the average across all years.

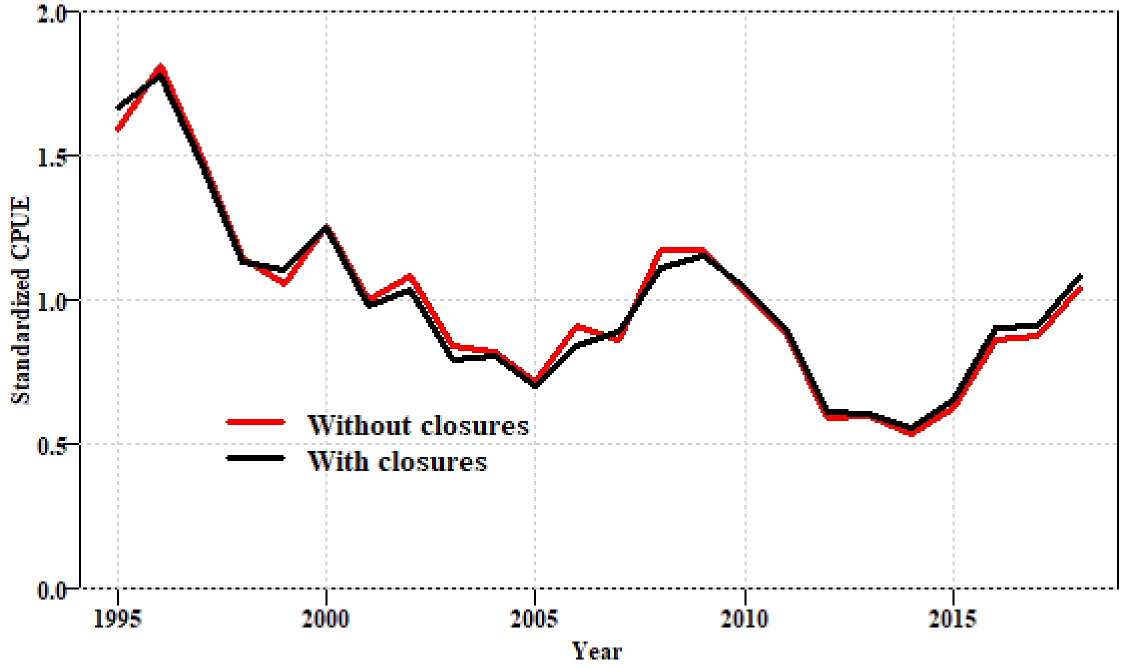

Figure 7.36. Standardized CPUE indices with and without closures.

7.7 Mixed Oreos

Mixed Oreos is another basket quota species made up of Spiky, Oxeye, Warty, Black, Rough Oreos as well as the catchall category OreoDory, which has only been used in more recent years.

In Commonwealth waters mixed oreos were taken by demersal trawl from Orange roughy zones 10, 20, 21, 30 and 50, and in depths 500 to 1200 m. Catch rates were expressed as the natural log of catch per hour (catch/hr). The years analysed were 1986 - 2018 (Table 7.29).

A total of 9 statistical models were fitted sequentially to the available data, and the order of the non-interaction terms added based on the relative contribution of each term to model fit.

7.7.1 *Inferences*

Catches have been variable through time with spikes in 1992 and elevated catches from 1995 - 2001 after which catches declined and have remained relatively low since the 700 m closure in 2007 but have increased to a mean of 113 t from 2013 - 2018. The majority of catch occurred in ORzone 30, 20 followed by 50.

The terms Year, Vessel, DepCat, ORzone, DayNight, Month and one interaction (ORzone:DepCat) had the greatest contribution to model fit, with the remaining terms each explaining < 1% of the overall variation in CPUE based on the AIC and R2 statistics (Table 7.33). The qqplot suggests that the assumed Normal distribution of the log-transformed CPUE, may be valid, with slight deviations as depicted from both tails of the distribution (Figure 7.40).

After an initial period of great volatility between 1986 - 1994 the standardized CPUE have been essentially flat and stable since 2000 (Figure 7.37).

7.7.2 *Action Items and Issues*

The data from the earlier period from 1986 - 1994 should be explored further to try to explain the enormous volatility in CPUE. The nominal geometric mean catchrates go to extremes in 1990 and 1992 and reasons for such variability need to be elucidated. It would appear a different kind of targeting was occurring at that time, which may indicate the effects of fishing aggregations rather than the fishing of background densities as currently occurs. Very different vessels were involved at that time and from 1988 - 1994 most effort records are for times <= 1.5 hours whereas from 1995 onwards almost all effort has been for longer than 2 hours. Since 2015 the occurrence of <= 1 hour shots returned in noticeable numbers.

Table 7.29. MixedOreos. The data selection criteria used to specify and identify the fishery data to be included in the analysis.

Property	Value
label	MixedOreos
csirocode	37266000, 37266001, 37266002, 37266004, 37266005, 37266006, 37266901, 37266902
fishery	SET
depthrange	500 - 1200
depthclass	50
zones	10, 20, 21, 30, 50
methods	TW, TDO, OTT, PTB, TMO
years	1986 - 2018

Table 7.30. MixedOreos. Total catch (Total; t) is the total reported in the database, number of records used in the analysis (N), reported catch (Catch; t) in the area and depth used in the analysis and number of vessels used in the analysis (Vess). GeoM is the geometric mean of catch rates (kg/hr), standard deviation (StDev) relates to the optimum model. C<30Kg denotes the amount of catch in shots of <30kg, and P<30Kg is the proportion of total. The optimum model was ORzone:DepCat

	Total	N	Catch	Vess	GeoM	Opt	StDev	C<30Kg	P<30Kg
1986	56.6	191	54.2	12	168.5	1.0676	0.000	0.974	0.018
1987	90.2	242	73.6	21	194.4	2.0756	0.142	1.123	0.015
1988	157.2	257	43.3	17	102.9	1.7182	0.145	1.468	0.034
1989	749.2	480	216.7	26	1429.3	3.0391	0.128	1.948	0.009
1990	1100.4	461	258.4	30	5108.2	4.8582	0.137	0.650	0.003
1991	1136.2	340	87.2	35	437.6	1.6223	0.137	0.912	0.010
1992	3354.0	626	611.8	32	4715.6	3.3561	0.119	2.503	0.004
1993	1097.4	840	282.7	39	517.3	1.8163	0.119	4.188	0.015
1994	1112.3	1095	284.2	34	266.2	1.2186	0.117	7.405	0.026
1995	1027.7	1768	498.0	30	96.4	1.1048	0.115	10.328	0.021
1996	785.3	2101	417.9	33	77.1	0.7826	0.115	12.888	0.031
1997	2091.1	2281	575.7	34	69.0	0.8197	0.115	11.973	0.021
1998	2042.3	2353	666.9	33	87.6	1.0184	0.115	11.177	0.017
1999	905.8	1915	441.8	34	72.3	0.8445	0.115	10.149	0.023
2000	1059.7	1727	376.5	43	63.2	0.6182	0.115	10.109	0.027
2001	1140.0	1946	402.7	38	63.7	0.6191	0.115	10.745	0.027
2002	857.2	1459	213.3	37	41.8	0.4334	0.116	9.990	0.047
2003	886.0	1455	228.4	30	43.8	0.4239	0.116	8.497	0.037
2004	639.8	1445	180.7	31	36.9	0.4078	0.117	10.133	0.056
2005	503.1	847	101.4	22	36.5	0.3405	0.120	5.384	0.053
2006	214.3	703	88.2	27	43.1	0.3709	0.121	5.310	0.060
2007	135.2	402	68.0	19	74.6	0.4251	0.128	2.466	0.036
2008	78.4	298	48.4	16	37.2	0.3140	0.133	1.784	0.037
2009	191.2	501	73.4	18	35.2	0.3302	0.125	3.926	0.053
2010	238.0	504	76.3	15	33.7	0.3017	0.124	3.874	0.051
2011	107.0	593	86.0	19	29.7	0.3053	0.123	4.555	0.053
2012	82.9	526	71.3	16	29.4	0.2781	0.125	4.317	0.061
2013	165.3	770	152.0	19	36.2	0.3648	0.121	6.013	0.040
2014	151.1	724	130.6	17	32.3	0.4324	0.122	3.913	0.030
2015	136.1	715	110.4	17	68.0	0.4657	0.122	3.809	0.035
2016	148.7	645	114.1	18	93.0	0.4454	0.123	2.950	0.026
2017	157.5	588	80.1	18	61.1	0.3929	0.122	3.406	0.043
2018	152.0	588	93.2	16	72.1	0.3888	0.124	3.266	0.035

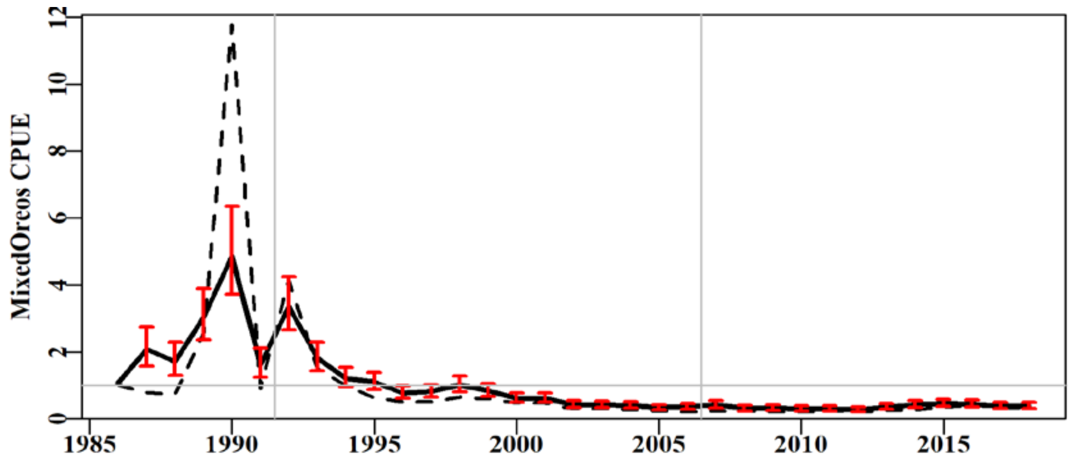

Figure 7.37. MixedOreos standardization. The dashed black line represents the geometric mean catch rate, solid black line the standardized catch rates. The red bars are the 95% confidence intervals about the mean estimates. The graph scales both time-series of standardized catch rates relative to the mean of each time-series.

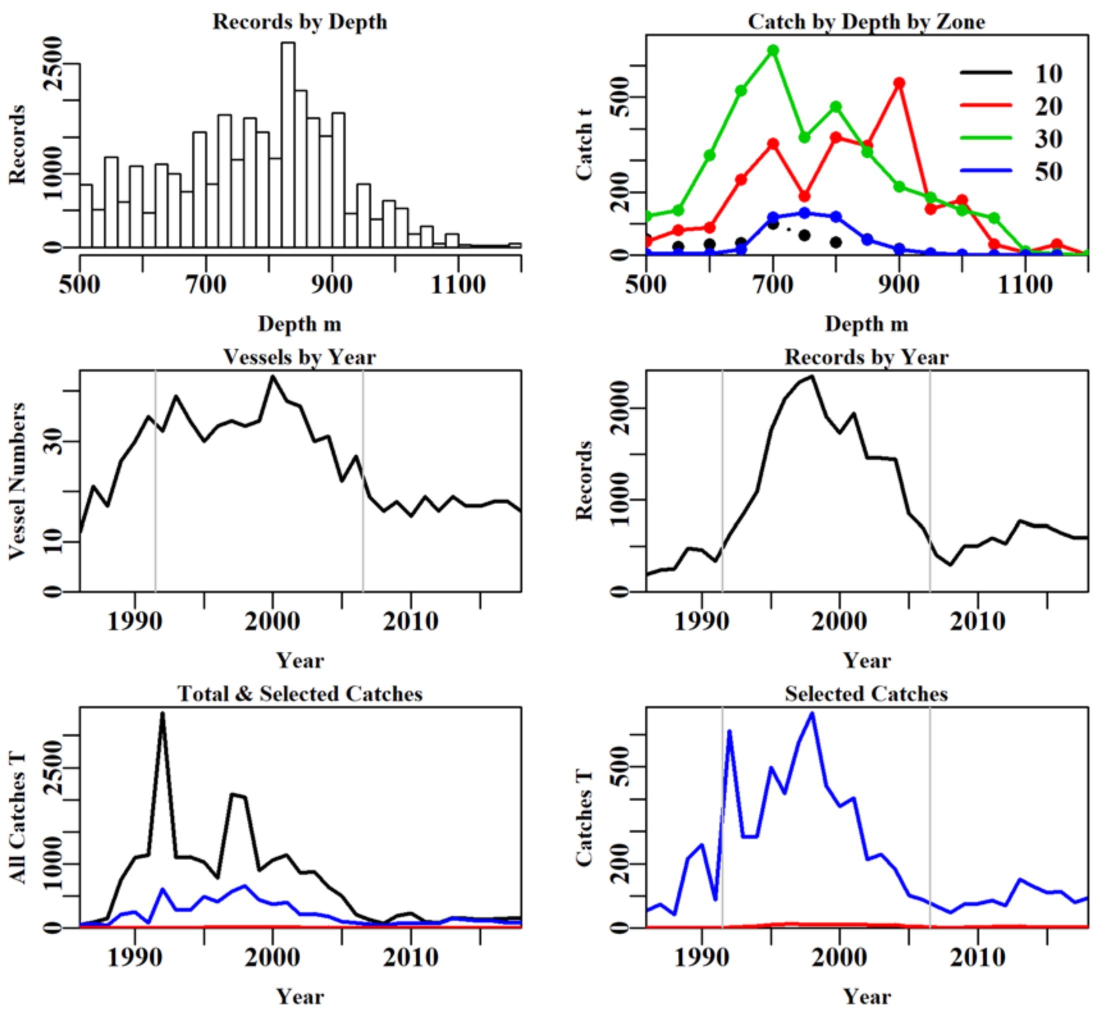

Figure 7.38. MixedOreos fishery details. The bottom left plot depicts all known catches (top black line), and all selected catches used in the analysis (middle blue line); the lower red line: selected catches < 30 kg).

Table 7.31. MixedOreos data selection effects. Total is the total number of records in the database, NoCE removes those records with either missing catch or effort, and then only those records are kept that meet the criteria for depth, years, zone, method, and fishery.

	Total	Method	Years	ORZones	Fishery	Depth	NoCE	CAAB
Records	57751	56065	55765	44163	44130	41472	40246	30415
Difference	0	1686	300	11602	33	2658	1226	9831

Table 7.32. The models used to analyse data for MixedOreos.

	Model
Model1	Year
Model2	Year + Vessel
Model3	Year + Vessel + DepCat
Model4	Year + Vessel + DepCat + ORzone
Model5	Year + Vessel + DepCat + ORzone + DayNight
Model6	Year + Vessel + DepCat + ORzone + DayNight + Month
Model7	Year + Vessel + DepCat + ORzone + DayNight + Month + inout
Model8	Year + Vessel + DepCat + ORzone + DayNight + Month + inout + ORzone:DepCat
Model9	Year + Vessel + DepCat + ORzone + DayNight + Month + inout + DepCat:Month

Table 7.33. MixedOreos. The row names are 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_r2) and the change in adjusted R^2 (%Change). The optimum model was ORzone:DepCat.

	AIC	RSS	MSS	Nobs	Npars	adj_r2	%Change
Year	22084	62732	13301	30415	33	17.4	0.00
Vessel	17274	53141	22892	30415	151	29.8	12.35
DepCat	15303	49760	26273	30415	165	34.2	4.44
ORzone	14193	47967	28066	30415	168	36.6	2.36
DayNight	13131	46313	29720	30415	171	38.7	2.18
Month	12526	45368	30665	30415	182	40.0	1.23
inout	12460	45266	30767	30415	183	40.1	0.13
ORzone:DepCat	11967	44419	31614	30415	224	41.1	1.04
DepCat:Month	12155	44390	31643	30415	328	41.0	0.88

Table 7.34. MixedOreos. Total catch (t) in the fishery under each separate CAAB code included in the basket species.

Name	CAAB Code	Total Catch (t)
Spiky	37266001	6006.699775
Oxeye	37266002	243.068
Warty	37266004	236.992
Black	37266005	8.045
OreoDory	37266902	642.5084

Table 7.35. MixedOreos. Annual catch (t) by CAAB code for a basket species.

	37266001	37266002	37266004	37266005	37266006	37266902
1986	19.269	3.208	31.697			
1987	40.574	13.810	19.185			
1988	13.710	9.529	20.029			
1989	175.798	27.470	13.441			
1990	252.546	3.560	2.257			
1991	84.001	2.682	0.528			
1992	599.036	11.695	1.050			
1993	276.044	3.610	3.031			
1994	262.489	3.103	18.620			
1995	466.522	17.165	14.320			
1996	401.701	0.550	15.606			
1997	550.597	4.925	20.190			
1998	641.770	0.340	24.806			
1999	430.502	0.080	11.215			
2000	345.457	0.030	30.987			
2001	396.244	0.400	6.060			
2002	211.641	0.095	1.595			
2003	228.084		0.300			
2004	179.071	0.060	1.540			
2005	92.236	1.679				7.510
2006	36.559	8.732				42.881
2007	11.311	9.880				46.767
2008	6.983	0.950				40.516
2009	6.851	1.388				65.148
2010	8.061	0.660				67.539
2011	6.802	7.875				71.298
2012	8.235	13.501				49.585
2013	18.108	14.145				119.749
2014	56.376	22.342	2.895	0.000		48.998
2015	71.652	19.153	0.000	0.000		19.559
2016	57.079	25.402		0.000	0	31.654
2017	47.625	7.939		0.200		24.331
2018	60.362	11.896	0.875	7.845		12.185

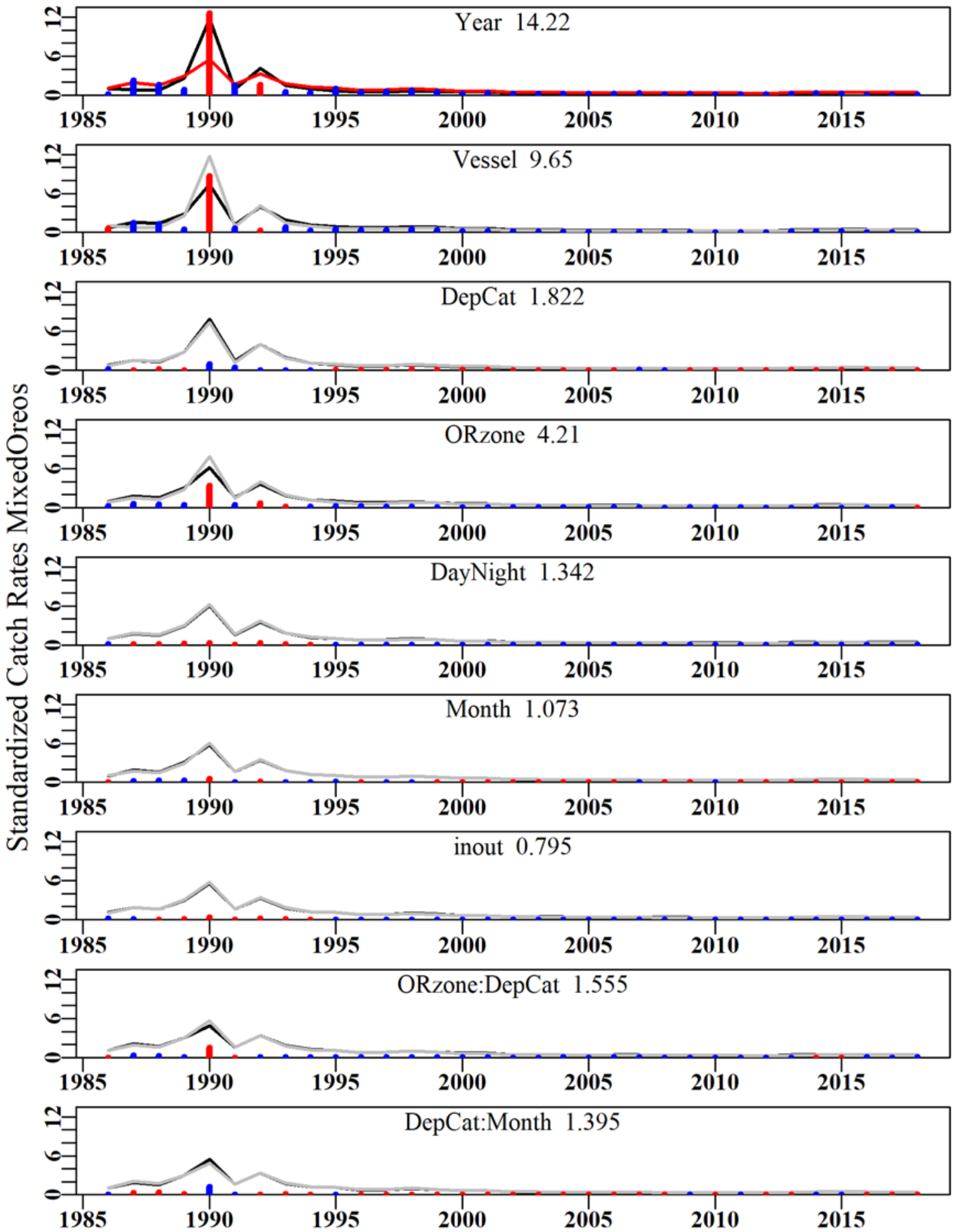

Figure 7.39. MixedOreos. The influence of each factor on the optimal standardization. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by vertical bars with blue bars indicating the optimum model is higher than the geometric 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.

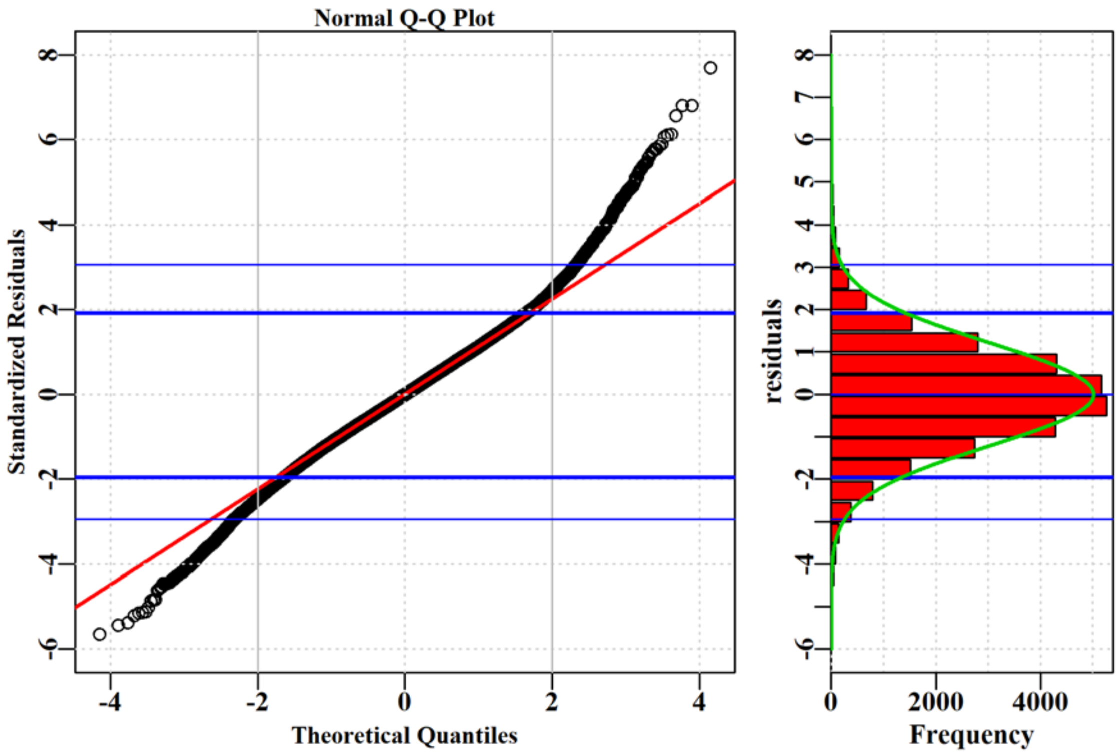

Figure 7.40. MixedOreos. Diagnostic plots. The distribution of residuals from the optimum fit. The qqplot indicates the fit to the expected normality, while the histogram of residuals also illustrates the 1%, 5%, 95% and 99% quantiles to indicate the intensity of any lack of fit at the margins of the distribution (reflected also in the qqplot.

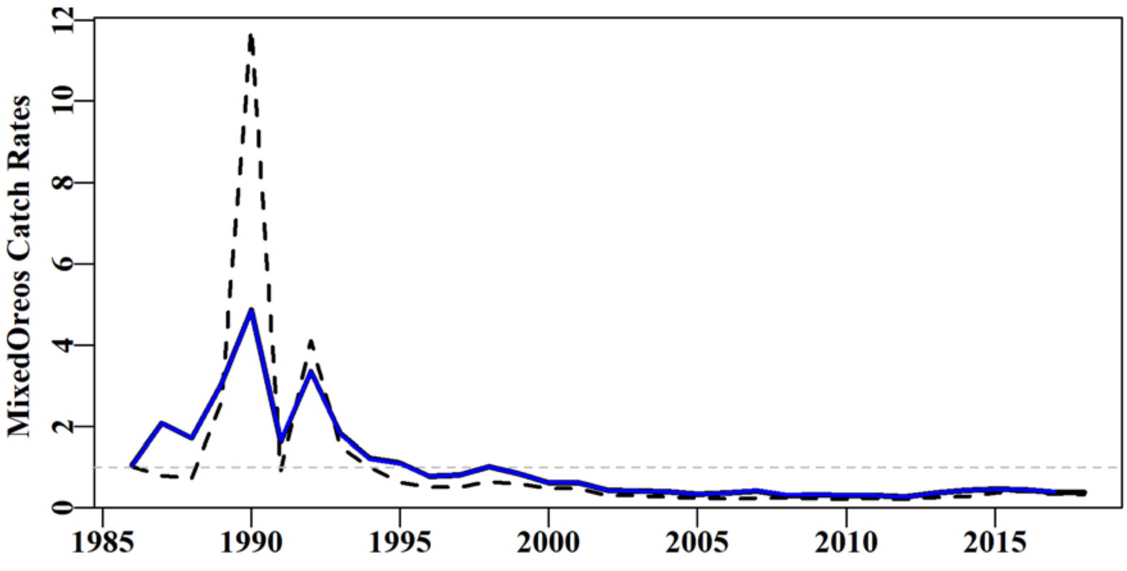

Figure 7.41. MixedOreos. A comparison of the previous year's standardization (blue line) with this year's. They should lie on top of each other, although small deviations may relate to data adjustments, particularly in very recent years.

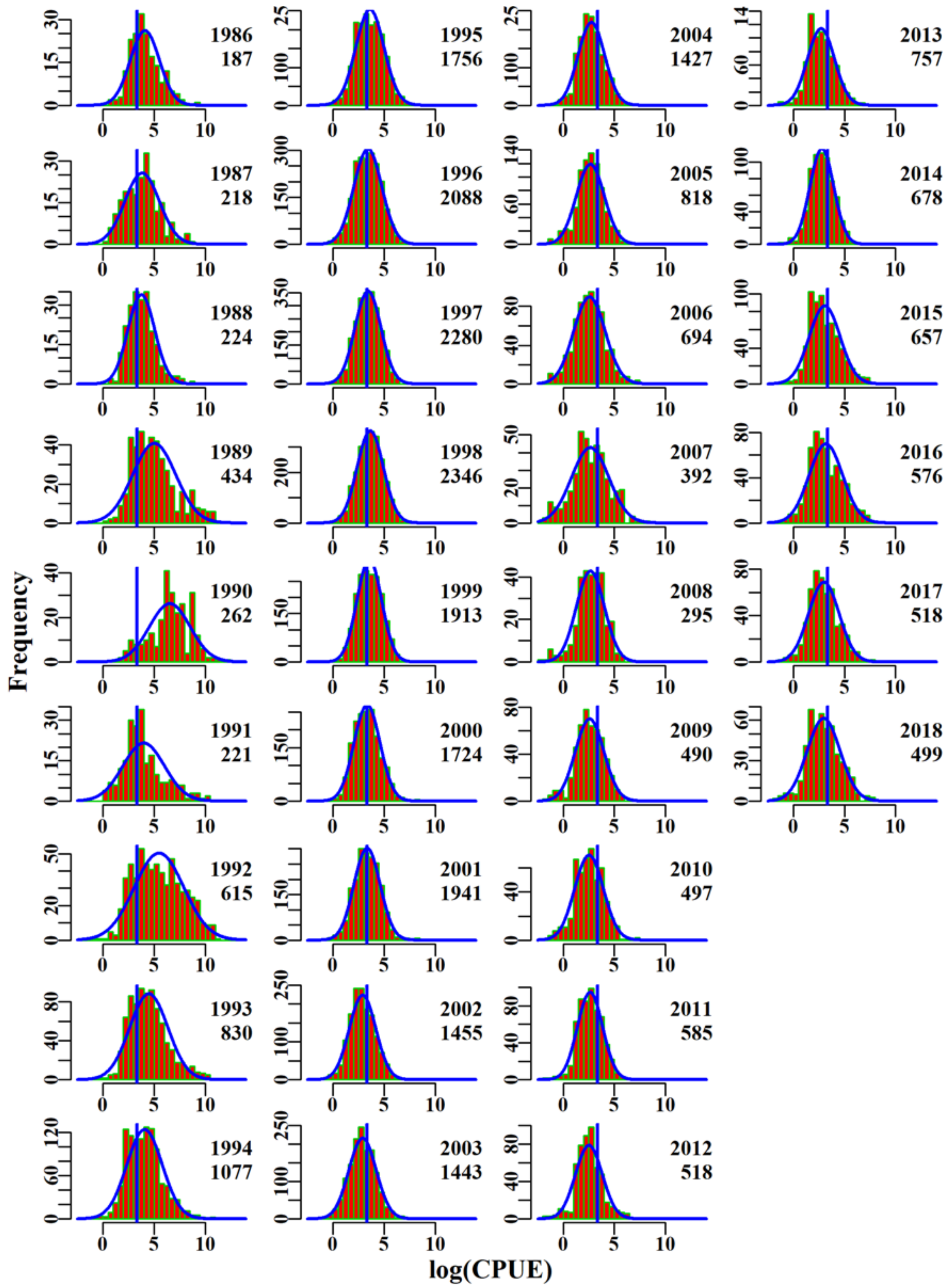

Figure 7.42. MixedOreos. The natural log(CPUE) for each year of data available the blue lines are normal distributions fitted to the histogram frequencies. The numbers in each plot are the year and number of records. The vertical blue line is the average across all years.

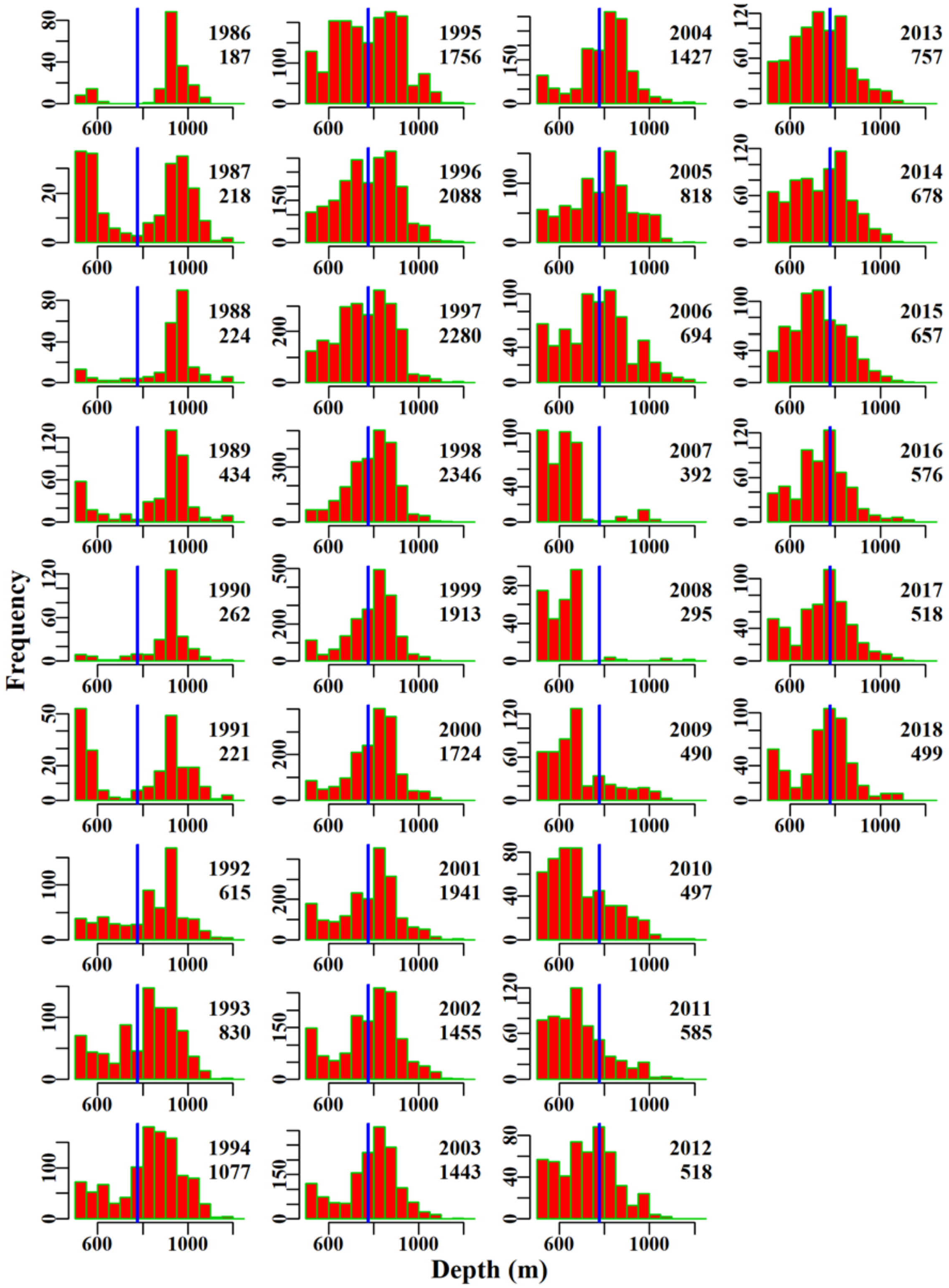

Figure 7.43. MixedOreos. The average Depth of fishing for each year of data available to illustrate the development of the fishery through time. The numbers in each plot are the year and number of records. The vertical blue line is the average across all years.

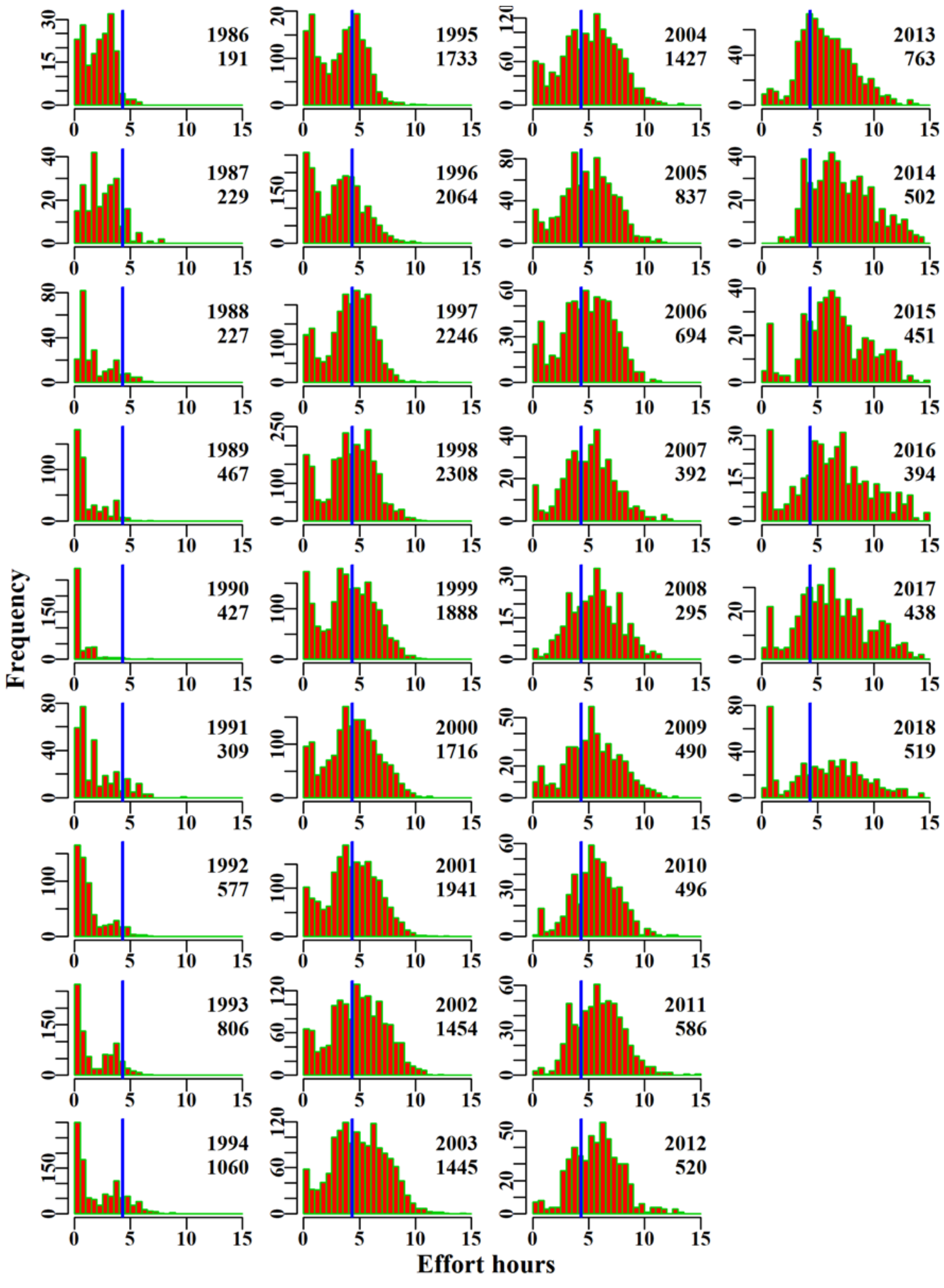

Figure 7.44. MixedOreos. The frequency distribution of effort each year for the available data. The numbers in each plot are the year and number of records. The vertical blue line is the average across all years.

7.8 Mixed Oreos 95

Mixed Oreos is another basket quota species made up of Spiky, Oxeye, Warty, Black, Rough Oreos as well as the catchall category OreoDory, which has only been used in more recent years.

In Commonwealth waters mixed oreos were taken by demersal trawl from Orange roughy zones 10, 20, 21, 30 and 50, and in depths 500 to 1200 m. Catch rates were expressed as the natural log of catch per hour (catch/hr). The years analysed were 1995 - 2018 (Table 7.36).

A total of 9 statistical models were fitted sequentially to the available data, and the order of the non-interaction terms added based on the relative contribution of each term to model fit.

7.8.1 *Inferences*

Catches declined from 1995 - 2002 and have remained relatively low since the 700 m closure in 2007 but have increased to a mean of 96 t from 2013 - 2017 perhaps due to the introduction of electronic monitoring over this period. The majority of catch occurred in ORzone 30, 20 followed by 50.

The terms Year, Vessel, DepCat, ORzone, DayNight, Month and two interactions (ORzone:DepCat; ORzone:DepCat) had the greatest contribution to model fit, with the remaining terms each explaining < 1% of the overall variation in CPUE based on the AIC and R2 statistics (Table 7.40). The qqplot suggests that the assumed Normal distribution of the log-transformed CPUE, may be valid, with slight deviations as depicted from both tails of the distribution (Figure 7.48).

Standardized CPUE have been essentially flat, below the long-term average and stable since 2002.

7.8.2 *Action Items and Issues*

The data from the earlier period from 1986 - 1994 should be explored further to try to explain the enormous volatility in CPUE. The nominal geometric mean CPUE go to extremes in 1990 and 1992 and reasons for such variability need to be elucidated. It would appear a different kind of targeting was occurring at that time, which may indicate the effects of fishing aggregations rather than the fishing of background densities as currently occurs. Very different vessels were involved at that time and from 1988 - 1994 most effort records are for times <= 1.5 hours whereas from 1995 onwards almost all effort has been for longer than 2 hours. In 2015 and 2016 the occurrence of <= 1 hour shots returned in noticeable numbers.

Table 7.36. MixedOreos95. The data selection criteria used to specify and identify the fishery data to be included in the analysis.

Property	Value
label	MixedOreos95
csirocode	37266000, 37266001, 37266002, 37266004, 37266005, 37266006, 37266901, 37266902
fishery	SET
depthrange	500 - 1200
depthclass	50
zones	10, 20, 21, 30, 50
methods	TW, TDO, OTT, PTB, TMO
years	1995 - 2018

Table 7.37. MixedOreos95. Total catch (Total; t) is the total reported in the database, number of records used in the analysis (N), reported catch (Catch; t) in the area and depth used in the analysis and number of vessels used in the analysis (Vess). GeoM is the geometric mean of catch rates (kg/hr), standard deviation (StDev) relates to the optimum model. C<30Kg denotes the amount of catch in shots of <30kg, and P<30Kg is the proportion of total. The optimum model was DepCat:Month.

	Total	N	Catch	Vess	GeoM	Opt	StDev	C<30Kg	P<30Kg
1995	1027.7	1292	431.16	24	75.59	2.6401	0.000	6.020	0.014
1996	785.3	1460	364.82	32	60.08	1.7791	0.043	7.537	0.021
1997	2091.1	1940	496.66	29	56.58	1.7362	0.041	8.388	0.017
1998	2042.3	1948	627.02	29	71.75	2.0489	0.041	6.666	0.011
1999	905.8	1550	419.37	30	57.75	1.7114	0.043	6.168	0.015
2000	1059.7	1476	335.44	40	47.25	1.2993	0.044	7.805	0.023
2001	1140.0	1687	349.51	36	44.53	1.2507	0.044	8.657	0.025
2002	857.2	1293	200.98	32	30.31	0.8669	0.046	8.291	0.041
2003	886.0	1325	207.50	27	31.31	0.8538	0.046	7.526	0.036
2004	639.8	1284	165.58	28	24.55	0.7340	0.047	8.842	0.053
2005	503.1	772	94.99	21	26.45	0.6569	0.053	4.942	0.052
2006	214.3	617	82.49	25	28.66	0.6483	0.056	4.514	0.055
2007	135.2	366	64.07	19	46.59	0.6996	0.066	2.208	0.034
2008	78.4	288	48.02	16	36.70	0.5912	0.073	1.711	0.036
2009	191.2	452	68.78	18	28.83	0.6565	0.062	3.370	0.049
2010	238.0	476	67.37	15	26.64	0.5882	0.061	3.796	0.056
2011	107.0	579	83.55	19	27.59	0.5981	0.058	4.447	0.053
2012	82.9	502	67.72	15	24.47	0.5594	0.061	4.098	0.061
2013	165.3	731	145.24	19	31.32	0.6613	0.056	5.689	0.039
2014	151.1	711	129.47	17	31.11	0.8221	0.057	3.775	0.029
2015	136.1	596	87.34	17	26.42	0.7114	0.060	3.313	0.038
2016	148.7	486	81.14	18	30.87	0.6466	0.064	2.339	0.029
2017	157.5	477	61.99	18	25.04	0.6361	0.065	2.623	0.042
2018	152.0	470	72.95	15	30.12	0.6041	0.067	2.468	0.034

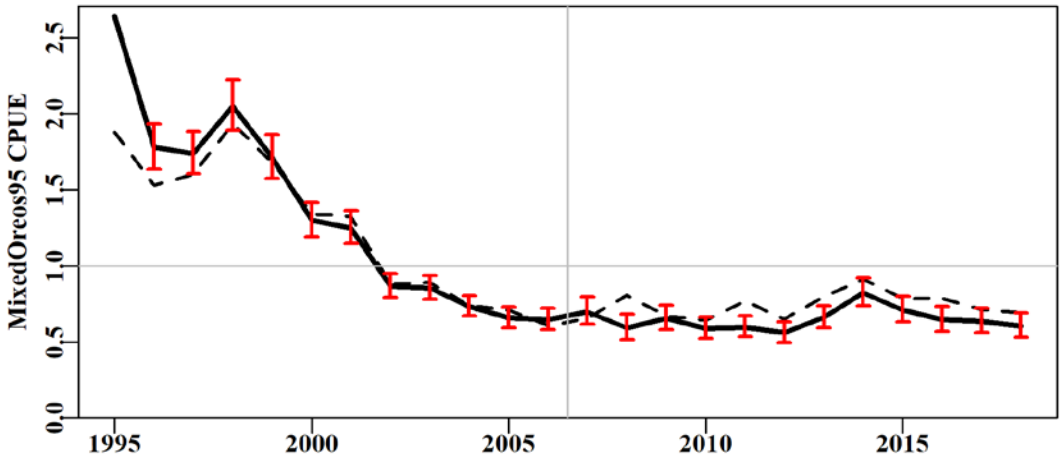

Figure 7.45. MixedOreos95 standardization. The dashed black line represents the geometric mean catch rate, solid black line the standardized catch rates. The red bars are the 95% confidence intervals about the mean estimates. The graph scales both time-series of standardized catch rates relative to the mean of each time-series.

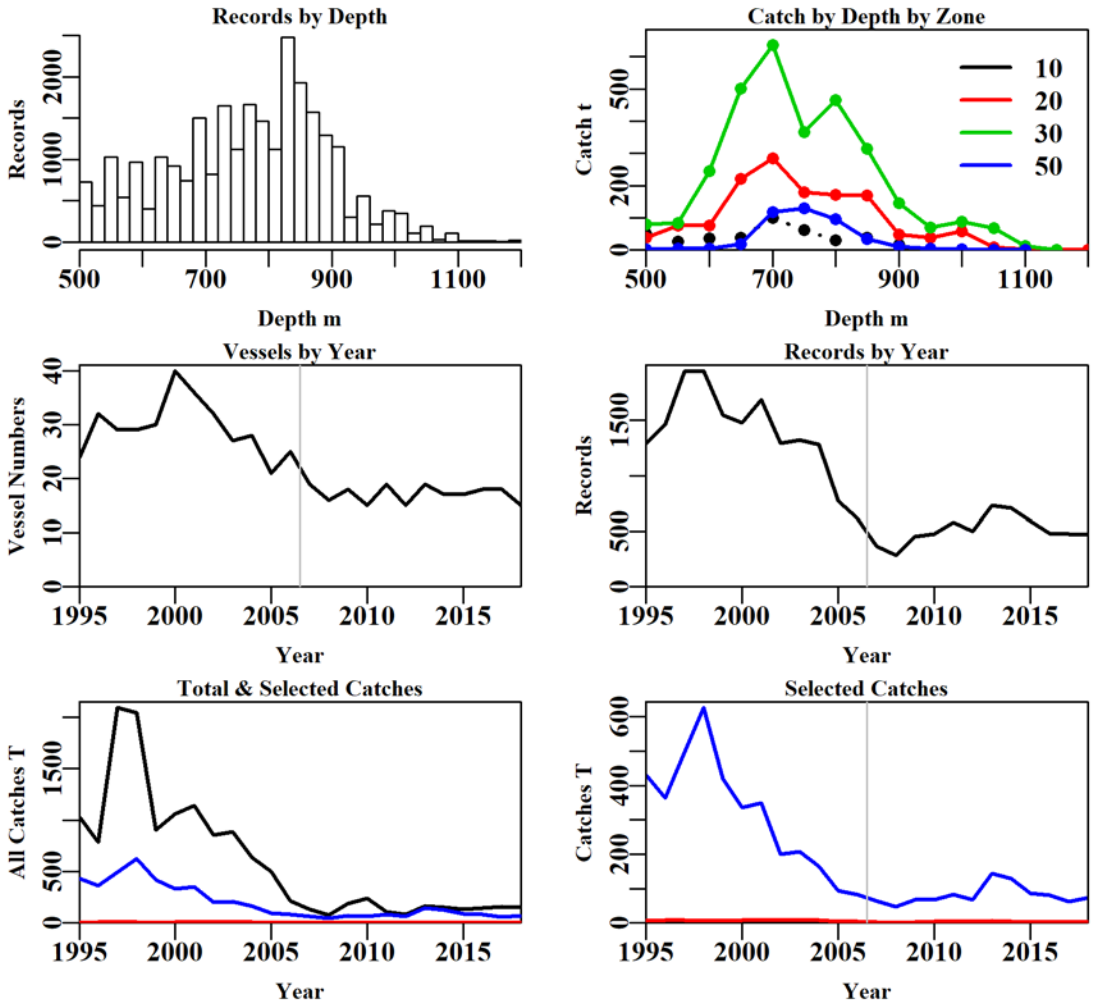

Figure 7.46. MixedOreos95 fishery details. The bottom left plot depicts all known catches (top black line), and all selected catches used in the analysis (middle blue line); the lower red line: selected catches < 30 kg).

Table 7.38. MixedOreos95 data selection effects. Total is the total number of records in the database, NoCE removes those records with either missing catch or effort, and then only those records are kept that meet the criteria for depth, years, zone, method, and fishery.

	Total	Method	Years	ORZones	Fishery	Depth	CAAB	NoCE	EFF1.5
Records	57751	56065	42345	33935	33902	31799	26854	26347	22479
Difference	0	1686	13720	8410	33	2103	4945	507	3868

Table 7.39. The models used to analyse data for MixedOreos95.

	Model
Model1	Year
Model2	Year + Vessel
Model3	Year + Vessel + DepCat
Model4	Year + Vessel + DepCat + ORzone
Model5	Year + Vessel + DepCat + ORzone + DayNight
Model6	Year + Vessel + DepCat + ORzone + DayNight + Month
Model7	Year + Vessel + DepCat + ORzone + DayNight + Month + inout
Model8	Year + Vessel + DepCat + ORzone + DayNight + Month + inout + ORzone:DepCat
Model9	Year + Vessel + DepCat + ORzone + DayNight + Month + inout + DepCat:Month

Table 7.40. MixedOreos95. The row names are 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_r2) and the change in adjusted R^2 (%Change). The optimum model was DepCat:Month.

	AIC	RSS	MSS	Nobs	Npars	adj_r2	%Change
Year	9147	33696	3472	22479	24	9.2	0.00
Vessel	7347	30898	6270	22479	98	16.5	7.26
DepCat	4685	27413	9754	22479	112	25.9	9.37
ORzone	4241	26870	10298	22479	115	27.3	1.46
DayNight	3120	25559	11609	22479	117	30.9	3.54
Month	2420	24750	12417	22479	128	33.0	2.15
inout	2421	24749	12419	22479	129	33.0	0.00
ORzone:DepCat	1979	24186	12982	22479	167	34.4	1.41
DepCat:Month	2020	24009	13158	22479	270	34.6	1.59

Table 7.41. MixedOreos95. Total catch (t) in the fishery under each separate CAAB code included in the basket species.

Name	CAAB Code	Total Catch (t)
Spiky	37266001	3962.9977
Oxeye	37266002	143.377
Warty	37266004	65.657
OreoDory	37266902	581.1579

Table 7.42. MixedOreos95. Annual catch (t) by CAAB code for a basket species.

	37266001	37266002	37266004	37266005	37266006	37266902
1995	414.889	4.475	11.800			
1996	350.680	0.430	13.715			
1997	481.832	4.925	9.900			
1998	614.581	0.240	12.200			
1999	411.353	0.080	7.940			
2000	333.411	0.030	1.997			
2001	347.609	0.400	1.505			
2002	199.844	0.095	1.040			
2003	207.250		0.250			
2004	164.014	0.030	1.540			
2005	86.798	0.949				7.240
2006	32.434	8.440				41.620
2007	9.793	9.880				44.401
2008	6.923	0.950				40.147
2009	6.181	1.388				61.207
2010	6.406	0.660				60.307
2011	6.802	7.875				68.875
2012	8.065	11.851				47.802
2013	17.635	13.435				114.174
2014	56.266	21.905	2.895			48.403
2015	59.225	16.415	0.000			11.699
2016	45.674	19.496				15.972
2017	44.375	7.929				9.691
2018	50.957	11.499	0.875			9.620

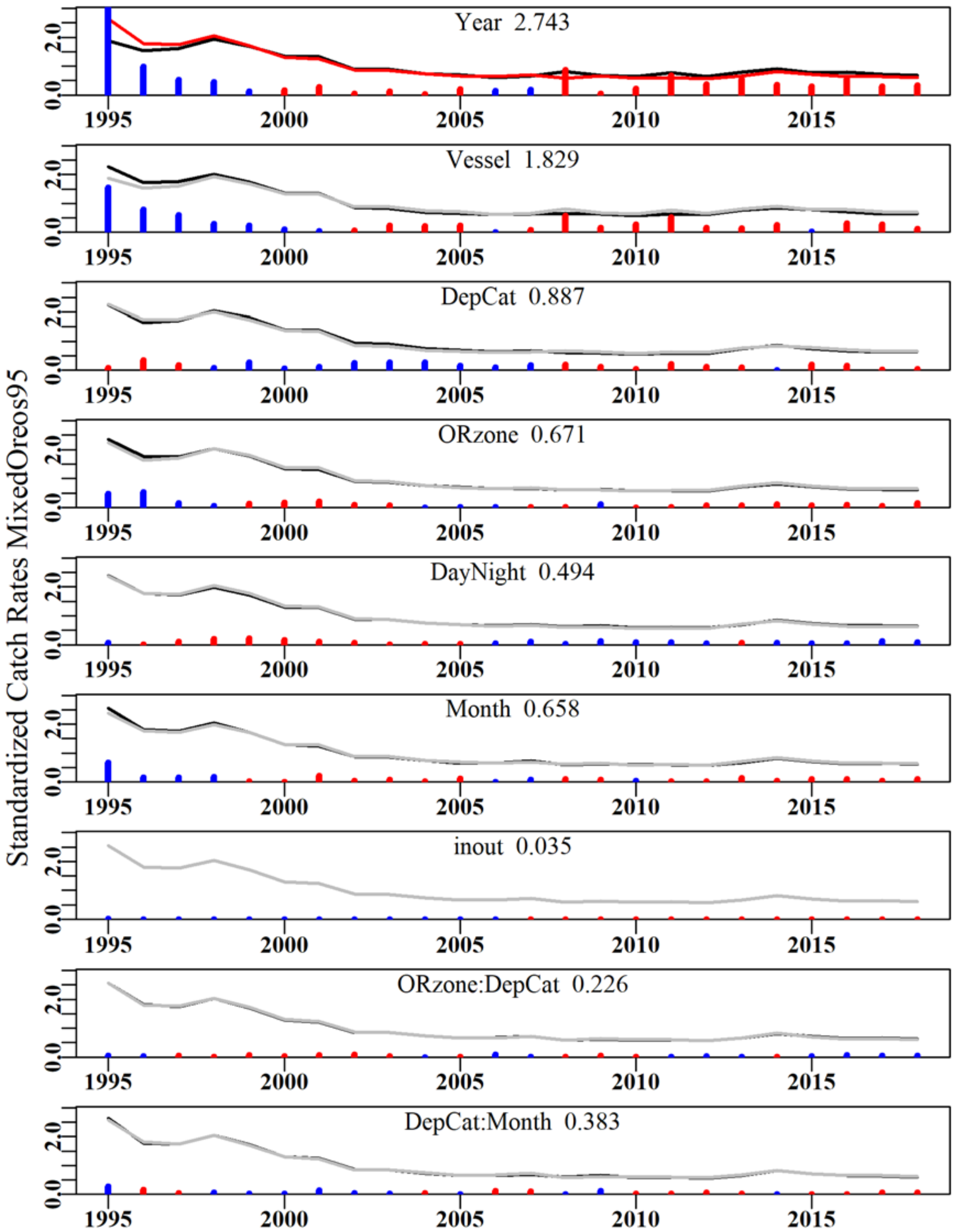

Figure 7.47. MixedOreos95. The influence of each factor on the optimal standardization. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by vertical bars with blue bars indicating the optimum model is higher than the geometric 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.

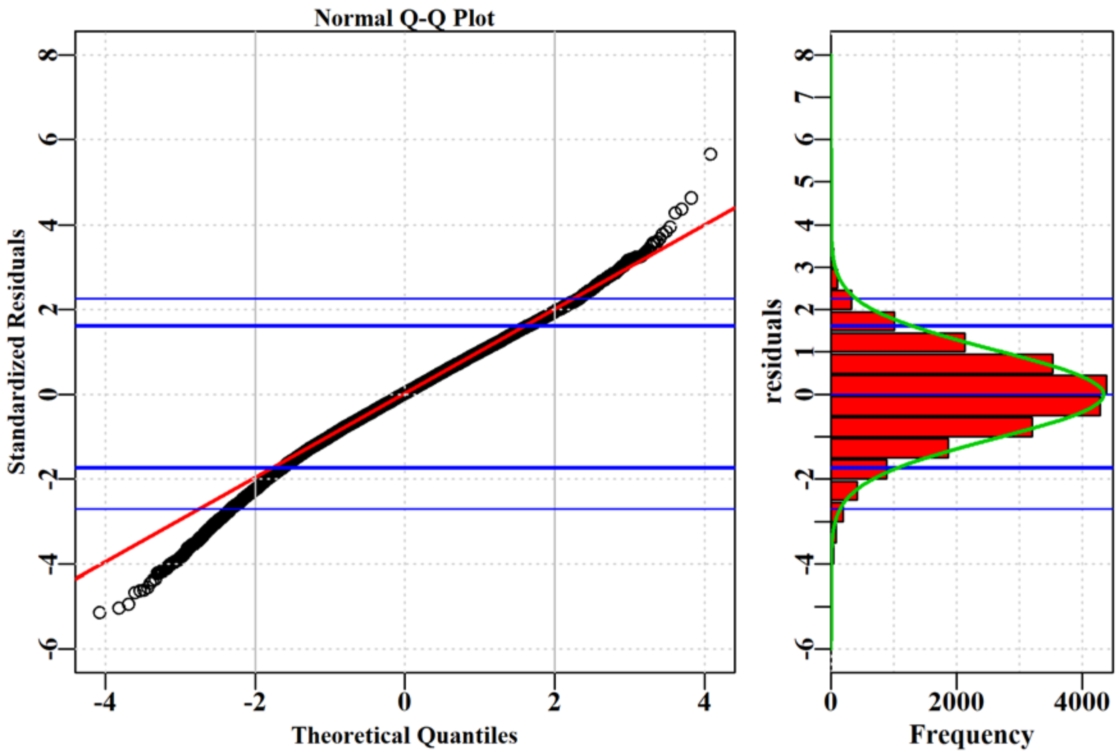

Figure 7.48. MixedOreos95. Diagnostic plots. The distribution of residuals from the optimum fit. The qqplot indicates the fit to the expected normality, while the histogram of residuals also illustrates the 1%, 5%, 95% and 99% quantiles to indicate the intensity of any lack of fit at the margins of the distribution (reflected also in the qqplot.

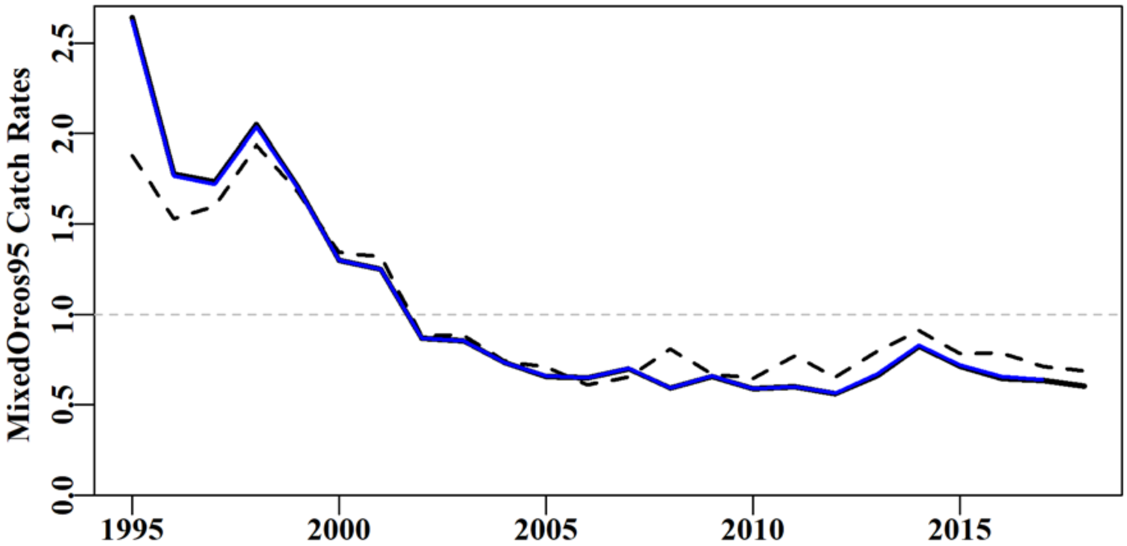

Figure 7.49. MixedOreos95. A comparison of the previous year's standardization (blue line) with this year's. They should lie on top of each other, although small deviations may relate to data adjustments, particularly in very recent years.

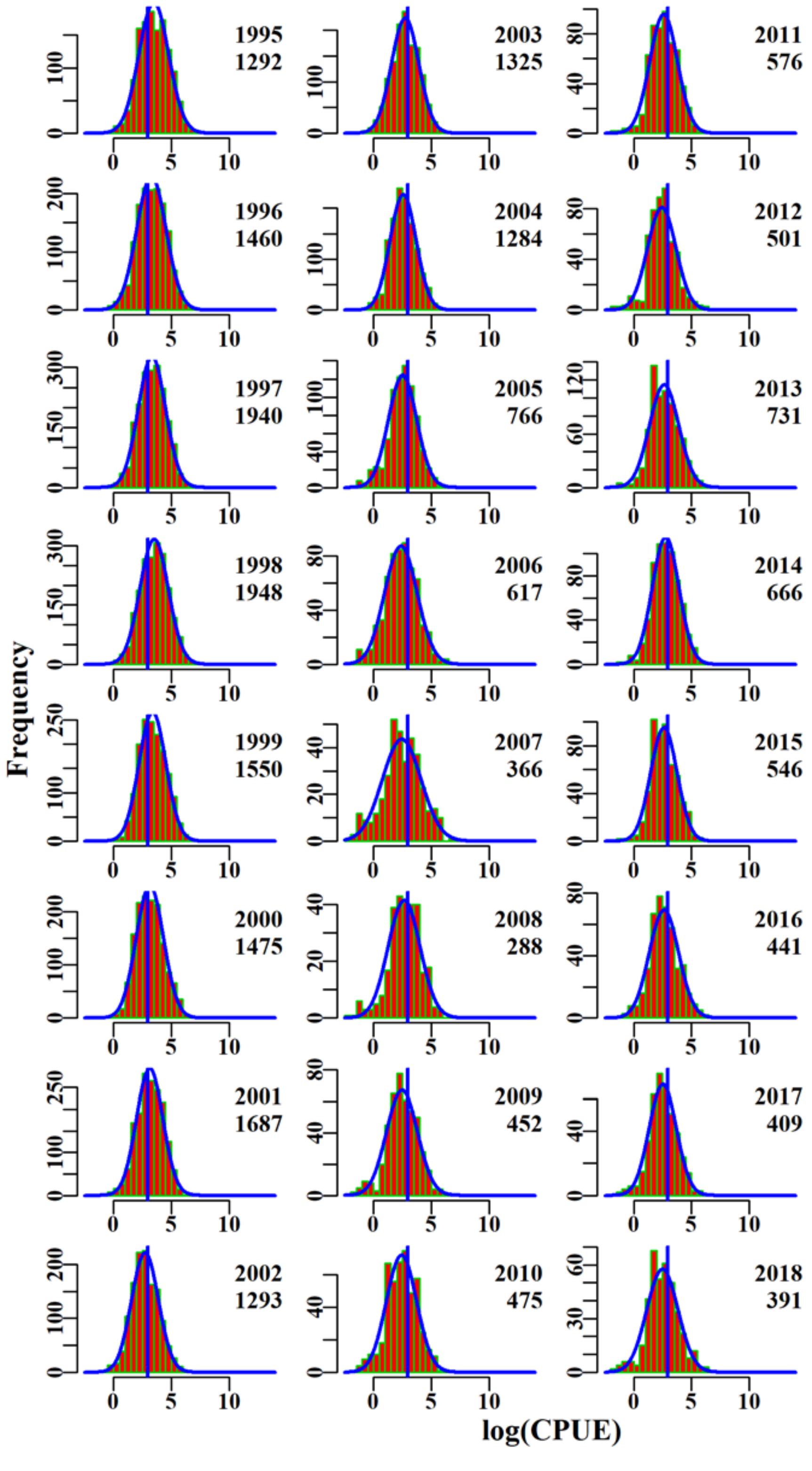

Figure 7.50. MixedOreos95. The natural log(CPUE) for each year of data available the blue lines are normal distributions fitted to the histogram frequencies. The numbers in each plot are the year and number of records. The vertical blue line is the average across all years.

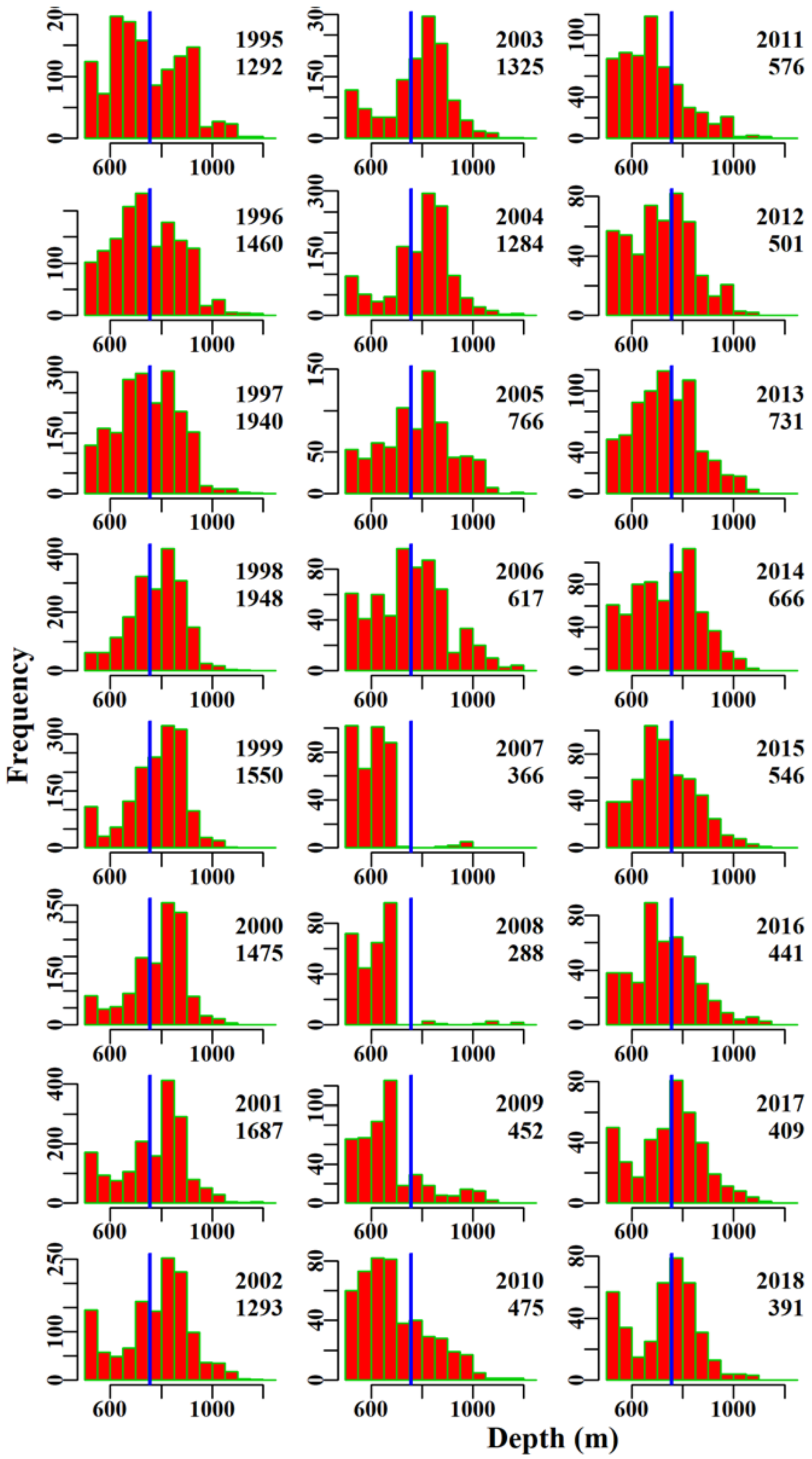

Figure 7.51. MixedOreos95. The average Depth of fishing for each year of data available to illustrate the development of the fishery through time. The numbers in each plot are the year and number of records. The vertical blue line is the average across all years.

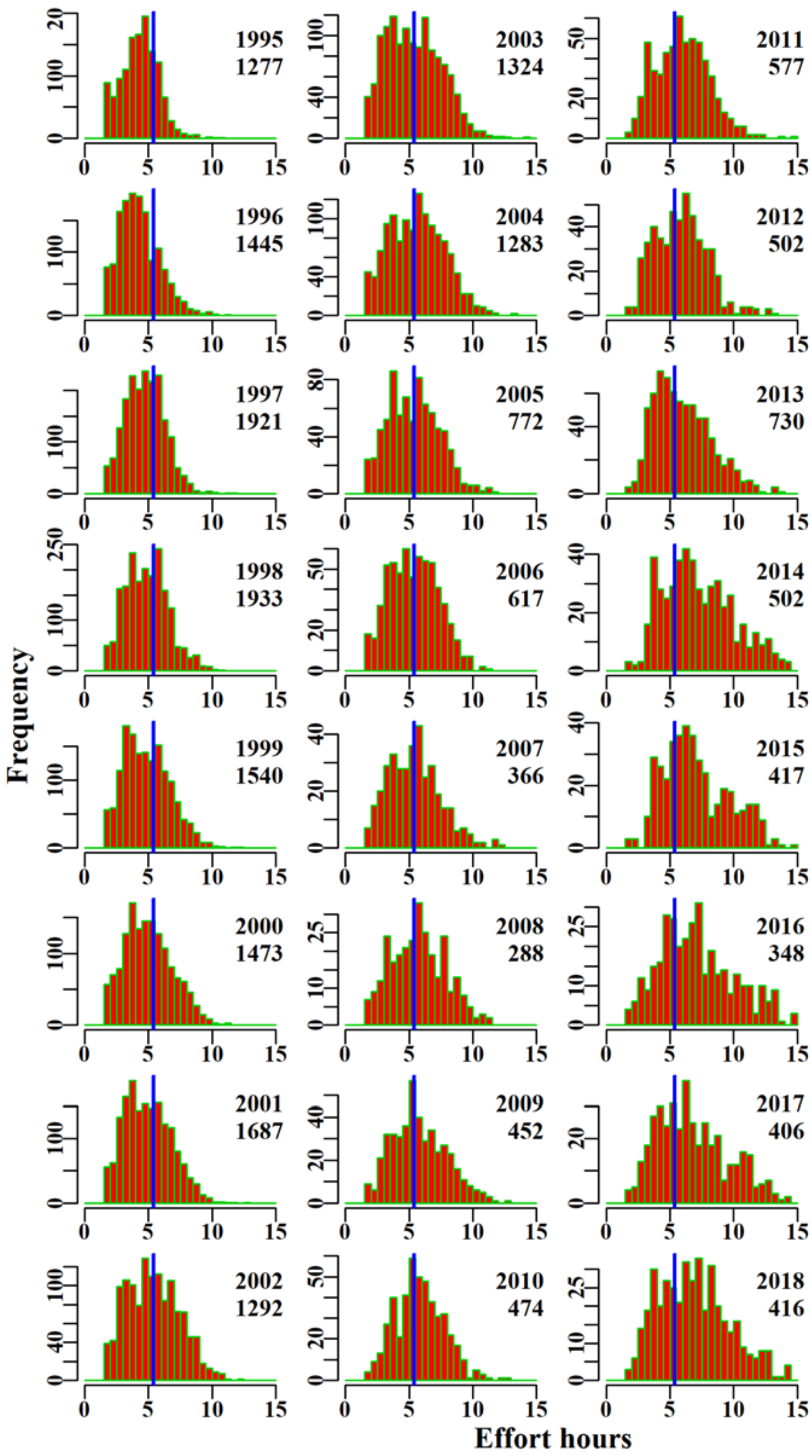

Figure 7.52. MixedOreos95. The frequency distribution of effort each year for the available data. The numbers in each plot are the year and number of records. The vertical blue line is the average across all years.

7.9 Acknowledgements

Thanks goes to the CSIRO database team for their preliminary processing of the catch and effort data as received from the Australian Fisheries management Authority.

7.10 General References

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8. CPUE standardizations for selected shark SESSF species (data to 2018)

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8.1 Executive Summary

This report focuses on data from years 1995 - 2018 available in the Commonwealth Logbook database. The logbook database contains records relating to all methods and areas and allow for a detailed analysis, which is required to provide a complete view of the current state of the fishery.

Reported catch of school shark in 2017 is the largest since 2010, and those from trawling do not appear to be targeted, as evidenced by the large proportion of < 30 kg shots present in the logbook data. Nevertheless, the areas where they are caught have not changed greatly and yet the standardized catch-per-unit effort (CPUE) has continued to increase, except 2014 and 2017.

There has been a decrease in reported gillnet catches of gummy shark in 2018 in South Australia and Bass Strait. Standardized CPUE in South Australia has dropped to the long-term average (based on 95% confidence interval) in 2018 and has remained at the long-term average in 2017 and 2018 in Bass Strait. Similarly, standardized CPUE of gillnet caught gummy shark around Tasmania remained flat since 2014 and at the long-term average since 2016 (based on 95% confidence interval). Reported catch by bottom line was 229 t in 2013 and 226 t in 2014, dropped to 187 t in 2015, dropped to 147 t in 2016, increased to 289 t in 2017 and decreased to 252 t in 2018. Also, there was an increase of ~5 t reported (i.e. 83 t to 87 t) in 2016 relative to 2015, an increase of ~3 t reported (i.e. 87 t to 90 t) in 2017 relative to 2016 and a further 15.7 t reported increase (i.e., 90 t to 105.7 t) in 2018 relative to 2017 for trawl. The 2018 catch of trawl caught gummy shark is the largest in the series (i.e., since 1986). Standardized CPUE for trawl have increased steadily since 2012, remaining significantly above the long-term average. By contrast, standardized CPUE for bottom line have remained flat and noisy since 2012. These analyses used number of operations as the effort unit and ignore zero catches. It would be desirable, in future, to perform analyses that include (i) alternative effort unit(s), e.g. total net length and (ii) targeted gummy shark shots with no associated catches.

Sawshark are considered to be a bycatch group which is supported by the high proportion of < 30 kg. Catches are reported by both gillnet, trawl and Danish seine. Standardized CPUE for gillnets exhibits a steady decline since about 2001, with small increases in recent years, except in 2017. However, a detailed analysis should be considered that uses net length as an effort unit instead of shot. Trawl caught sawshark standardized indices exhibit a noisy but flat trend, with an increase in 2014 reaching the long-term average and an overall decrease below the long-term average in 2016, followed by a small increase in 2017 and 2018. By contrast, sawshark standardized CPUE by Danish seine (which has the highest proportion of shots < 30 kg among methods) has been flat and below the long-term average over 2002-14 period and increased above the long-term average in 2015, although not significantly so, and remained at the long-term average since then. However, this species group is also discarded (16% to 28%; discarded for 2011-2017) may artificially inflate these estimates.

Like school shark, elephant fish are a non-targeted species, as indicated by the large proportion of small shots (i.e. <30 kg). Gillnet standardized CPUE is flat and noisy, while decreased in 2015, increased in 2016, decreased in 2017 and increased in 2018. However, this analysis ignores discarding (e.g., 0.52 in 2017) and uses number of shots instead of net length as a unit of effort. In recent years discard rates for elephant fish have been very high, which may imply that their CPUE is in fact increasing. It would be desirable, in the future to perform analyses that account for discards.

8.2 Introduction

Commercial catch per unit effort (CPUE) data are used in many fishery stock assessments in Australia as an index of relative abundance. Using CPUE in this way assumes 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 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 dynamics. 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 2017 inclusive) for gummy shark (South Australia-gillnet; Bass Strait-gillnet; Tasmania gillnet; trawl; Bottom Line), school shark (Trawl), sawshark (gillnet; trawl; danish seine) and elephant fish (gillnet) within Australia’s Southern and Eastern Scalefish and Shark Fishery (SESSF).

8.2.1 *The Limits of Standardization*

The use of commercial CPUE as an index of the relative abundance of exploitable biomass can be misleading when there are factors that significantly influence CPUE but cannot be accounted for in a generalized linear model (GLM) standardization analysis. Over the last two decades there have been a number of major management interventions in the 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 so as to avoid having to discard and to stay within the bounds of their own quota holdings. Such influences on catch rates would tend to bias 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.

8.3 Methods

8.3.1 *Catch Rate Standardization*

8.3.1.1 Preliminary Data Selection

The methods used when standardizing commercial catch and effort data in the SESSF continue to be discussed in the Commonwealth stock assessment RAGs because the catch rate time series (and associated standardized indices) are very influential in many of the assessments. Data were initially selected from the ORACLE database by CAAB code to obtain all data relating to a given species. Then selections were made using R (R Core Team, 2017) with respect to 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 within the years specified for each analysis.

8.3.1.2 General Linear Modelling

In each case, catch rates, generally as kilograms per hour fished (though sometimes as catch per shot e.g. School Whiting caught by Danish Seine, or catch-per-hook for Blue-Eye Trevalla), 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 of the form: Ln(CPUE) = Year + Vessel + Month + Depth Category + Zone + DayNight. 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:

$$Ln(CPUE_i) = \alpha_0 + \alpha_1 x_{i,1} + \alpha_2 x_{i,2} + \sum_{j=3}^{N} \alpha_i x_{i,j} + \varepsilon_i$$

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 (where α_0 is the intercept, α_1 is the coefficient for the first factor, etc.).

8.3.1.3 The Mean Year Estimates

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:

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

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

$$CE_t = \frac{CPUE_t}{(\sum CPUE_t)/n}$$

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

8.3.1.4 Model Development Selection

In each case an array of statistical models are fitted sequentially to the available data, with the order of the non-interaction terms being determined by the relative contribution of each term to model fit.

This sequential development of the standardization models for each species simplifies the search for the optimum model and requires a consideration of different performance statistics such as the AIC (Akaike's Information Criterion, the smaller the better; Burnham and Anderson, 1992) or adjusted R^2 (the larger the better; Neter et al, 1996). In addition, the examination of the various diagnostic plots and tables allows for an improved interpretation of the observed trends.

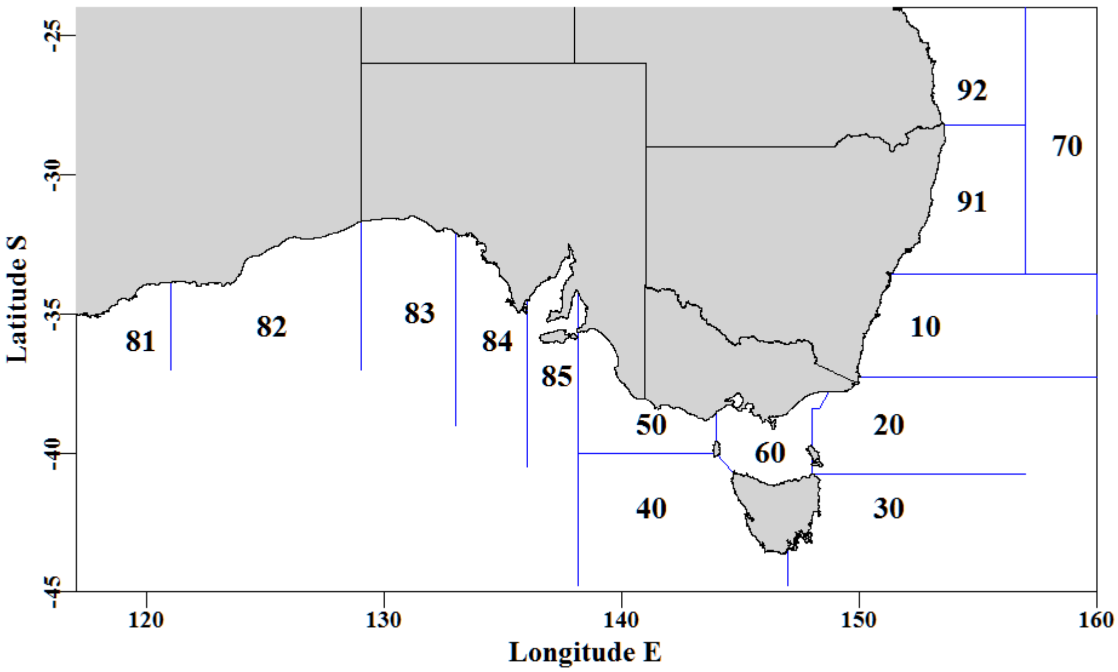

Figure 8.1. The statistical reporting zones in the SESSF.

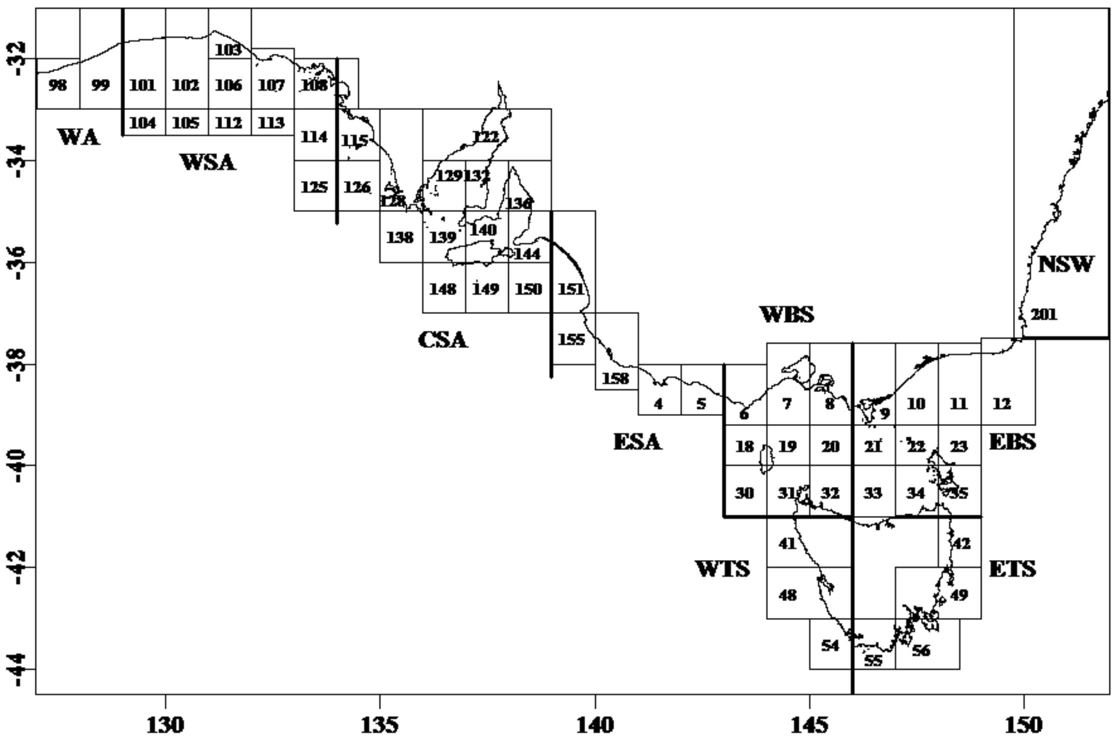

Figure 8.2. Shark statistical reporting areas and statistical regions. WA is Western Australia, WSA is Western South Australia, CSA is Central South Australia, ESA is Eastern South Australia (sometimes known as SAV - South Australia Victoria), WBS is Western Bass Strait, EBS is Eastern Bass Strait, NSW is New South Wales, ETS is Eastern Tasmania and WTS is Western Tasmania.

8.4 Gummy shark: South Australia Gillnet

Positive non-zero records of catch per shot were employed in the statistical standardization analyses for gummy shark caught by gillnets. Shots from deeper waters between 2006-12 have been investigated and verified. Further investigation should be considered to determine whether total net length could be used as an alternative effort unit in standardization analyses.

A total of 7 statistical models were fitted sequentially to the available data, and the order of the non-interaction terms added based on the relative contribution of each term to model fit.

8.4.1 *Inferences*

The majority of catch occurred in Shark regions 2, 1, 9 followed by 3.

The terms Year, Vessel, DepCat, Month, SharkRegion and one interaction (SharkRegion:DepCat) had the greatest contribution to model fit based on the AIC and R2 statistics (Table 8.5). The qqplot suggests that the assumed Normal distribution is valid, with slight deviations as depicted from both tails of the distribution (Figure 8.6). Standardized CPUE exhibits a postive trend since 2012 and has been above the long- term average since 2016 (Figure 8.4).

8.4.2 *Action Items and Issues*

A further consideration of whether or not to consider the CPUE time-series as a valid index of relative abundance for gummy shark needs to be explored.

Table 8.1. GummySharkSA. The data selection criteria used to specify and identify the fishery data to be included in the analysis.

Property	Value
label	GummySharkSA
csirocode	37017001
fishery	GHT_SEN_SSF_SSG_SSH
depthrange	0 - 160
depthclass	20
zones	1, 2, 3, 9
methods	GN
years	1997 - 2018

Table 8.2. GummySharkSA. Total catch (Total; t) is the total reported in the database, number of records used in the analysis (N), reported catch (Catch; t) in the area and depth used in the analysis and number of vessels used in the analysis (Vess). GeoM is the geometric mean of catch rates (kg/shot), standard deviation (StDev) relates to the optimum model. C<30Kg denotes the amount of catch in shots of <30kg, and P<30Kg is the proportion of total. The optimum model was SharkRegion:DepCat.

	Total	N	Catch	Vess	GeoM	Opt	StDev	C<30Kg	P<30Kg
1997	952.1	4826	431.9	56	96.2	1.0800	0.000	27.199	0.063
1998	1401.1	7367	521.1	53	72.6	0.8668	0.022	50.807	0.097
1999	1923.8	6842	648.7	49	100.1	1.0436	0.023	38.963	0.060
2000	2436.9	6072	875.6	37	160.3	1.4965	0.024	24.242	0.028
2001	1703.3	5541	414.7	35	81.6	0.8120	0.025	30.145	0.073
2002	1527.1	5846	437.3	32	80.5	0.8739	0.025	35.877	0.082
2003	1653.0	5943	495.9	37	93.6	0.9444	0.025	33.592	0.068
2004	1669.9	5654	476.6	40	95.4	0.9683	0.026	30.295	0.064
2005	1573.2	5137	483.7	29	104.4	1.0431	0.027	27.698	0.057
2006	1577.1	5968	548.7	28	100.6	1.0722	0.026	31.127	0.057
2007	1575.0	4549	438.5	29	107.0	1.1269	0.027	22.012	0.050
2008	1727.7	4907	543.5	23	122.4	1.3179	0.027	21.515	0.040
2009	1500.9	5157	418.2	23	87.4	1.0073	0.027	30.674	0.073
2010	1404.8	5258	389.8	28	79.6	0.8824	0.027	32.880	0.084
2011	1364.7	3272	229.0	19	78.3	0.7769	0.030	21.004	0.092
2012	1304.2	1371	83.0	15	62.3	0.5834	0.039	10.043	0.121
2013	1307.6	800	60.5	18	77.6	0.6212	0.048	5.370	0.089
2014	1389.1	1462	126.0	19	96.5	0.8236	0.040	7.559	0.060
2015	1545.1	1544	151.6	15	105.7	0.9944	0.040	7.796	0.051
2016	1586.5	1062	134.5	11	132.4	1.2303	0.048	3.783	0.028
2017	1561.3	898	110.2	13	134.8	1.3260	0.052	2.647	0.024
2018	1560.1	1362	141.1	12	112.1	1.1087	0.049	4.865	0.034

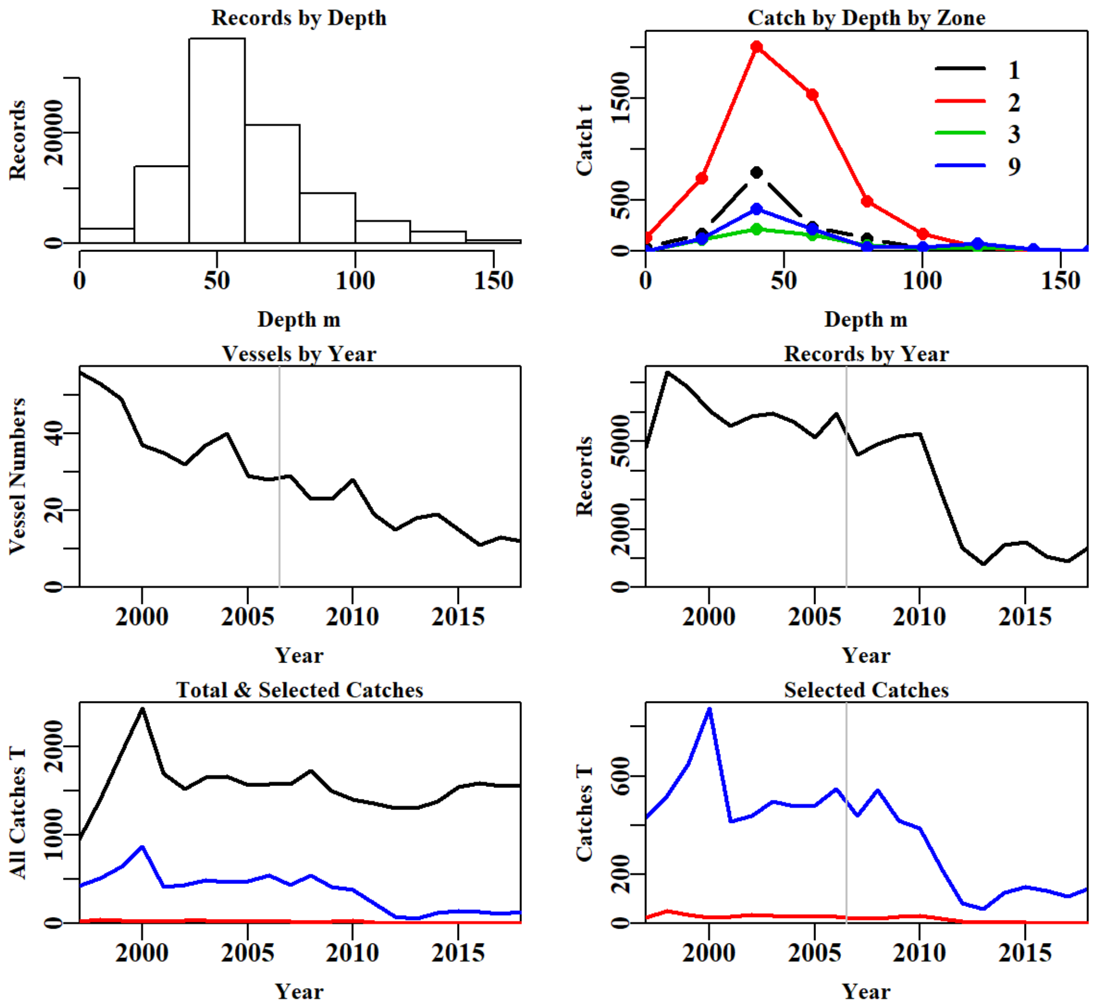

Figure 8.3. GummySharkSA fishery details. The bottom left plot depicts all known catches (top black line), and all selected catches used in the analysis (middle blue line); the lower red line: selected catches < 30 kg).

Table 8.3. GummySharkSA data selection effects. Total is the total number of records in the database, NoCE removes those records with either missing catch or effort, and then only those records are kept that meet the criteria for depth, years, zone, method, and fishery.

	Records	Difference	Catch	Difference
Total	405328	0	34938.920	0.000
NoCE	395465	9863	34938.920	0.000
Depth	367496	27969	33905.661	1033.260
Years	354493	13003	33282.233	623.427
Zones	124486	230007	10289.330	22992.904
Method	90838	33648	8160.171	2129.159
Fishery	90838	0	8160.171	0.000

Table 8.4. The models used to analyse data for GummySharkSA.

	Model
Model1	Year
Model2	Year + Vessel
Model3	Year + Vessel + DepCat
Model4	Year + Vessel + DepCat + SharkRegion
Model5	Year + Vessel + DepCat + SharkRegion + Month
Model6	Year + Vessel + DepCat + SharkRegion + Month + SharkRegion:DepCat
Model7	Year + Vessel + DepCat + SharkRegion + Month + SharkRegion:Month

Table 8.5. GummySharkSA. The row names are 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_r2) and the change in adjusted R^2 (%Change). The optimum model was SharkRegion:DepCat.

	AIC	RSS	MSS	Nobs	Npars	adj_r2	%Change
Year	29371	125452	3698	90838	22	2.8	0.00
Vessel	25145	119382	9769	90838	162	7.4	4.56
DepCat	24315	118275	10876	90838	170	8.3	0.85
SharkRegion	24025	117890	11261	90838	173	8.5	0.30
Month	22767	116240	12911	90838	184	9.8	1.27
SharkRegion:DepCat	21836	114994	14156	90838	208	10.8	0.94
SharkRegion:Month	22378	115660	13491	90838	217	10.2	0.42

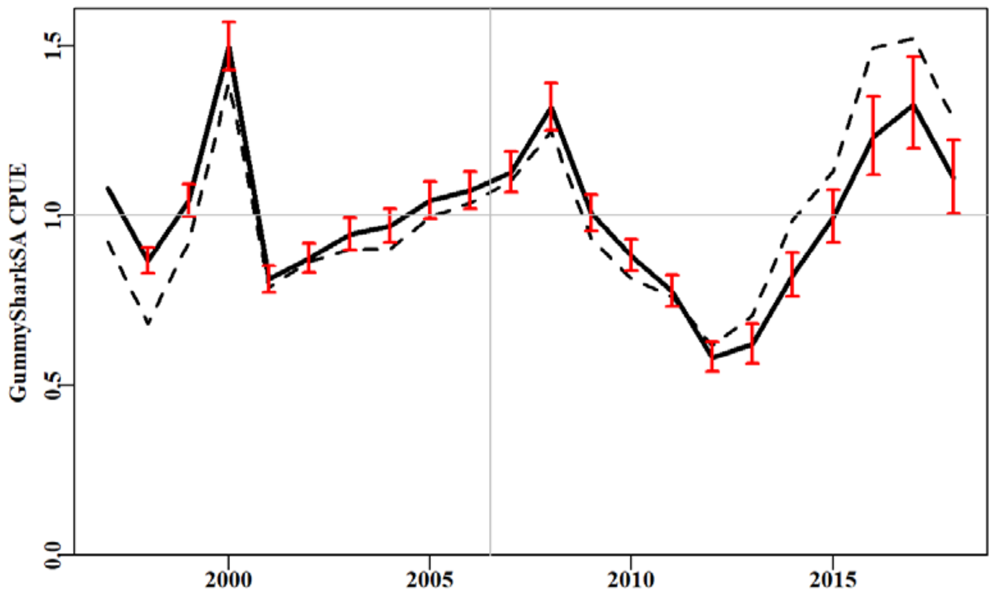

Figure 8.4. GummySharkSA standardization. The dashed black line represents the geometric mean catch rate, solid black line the standardized catch rates. The red bars are the 95% confidence intervals about the mean estimates. The graph scales both time-series of standardized catch rates relative to the mean of each time-series.

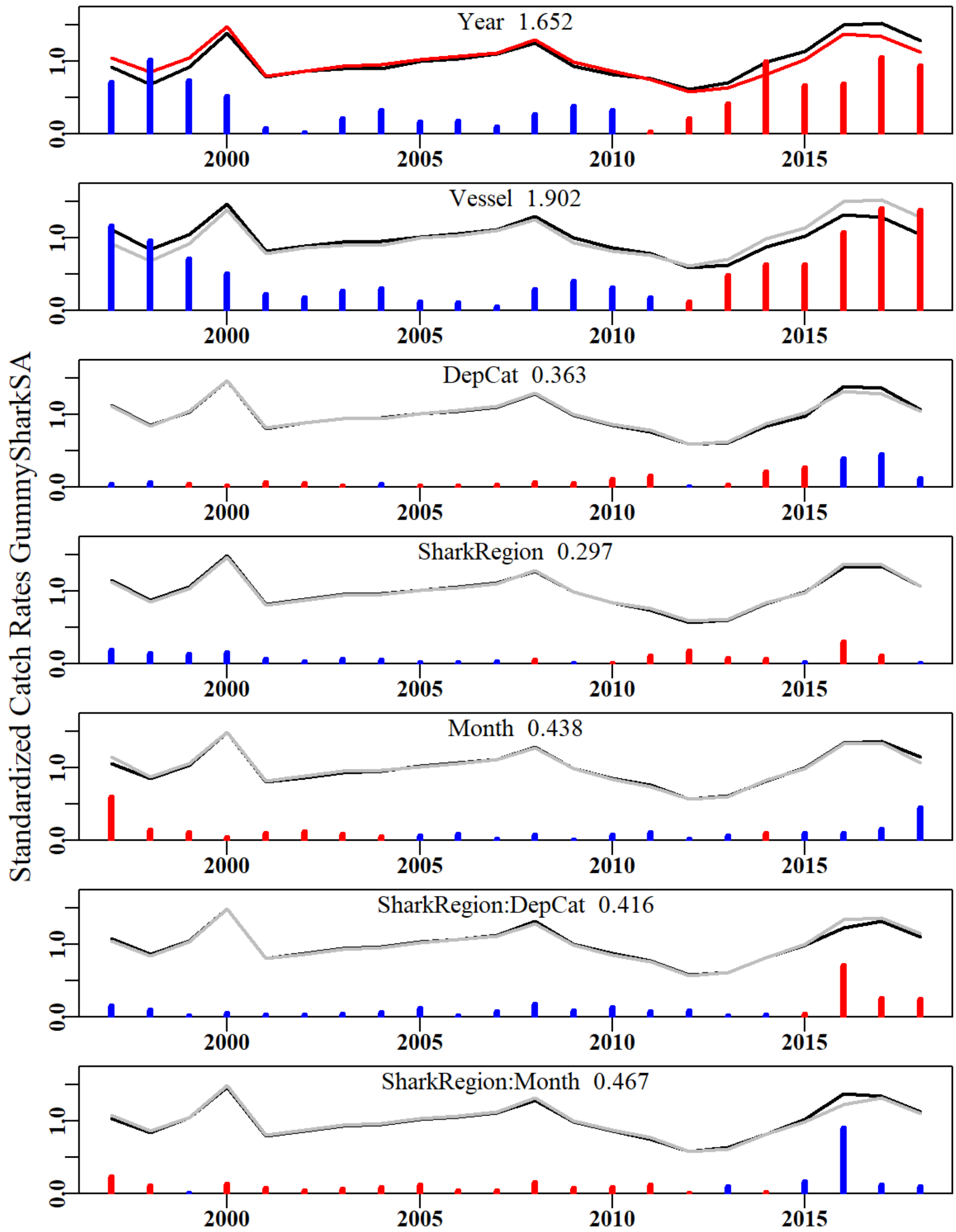

Figure 8.5. GummySharkSA. The influence of each factor on the optimal standardization. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by vertical bars with blue bars indicating the optimum model is higher than the geometric mean and red bars indicating it is lower. The top graph bars are the sum of all the bars in the graphs below. The graphs for individual factors are cumulative. Thus the second graph has the geometric mean (grey line) and the effect of adding Year + factor2 (Model 2). In the third graph, the grey line represents Model 2 and the black line the effect of adding factor3 to the model. The remaining graphs continue in the same cumulative manner except for the interaction terms which are added singularly to the final single factor model.

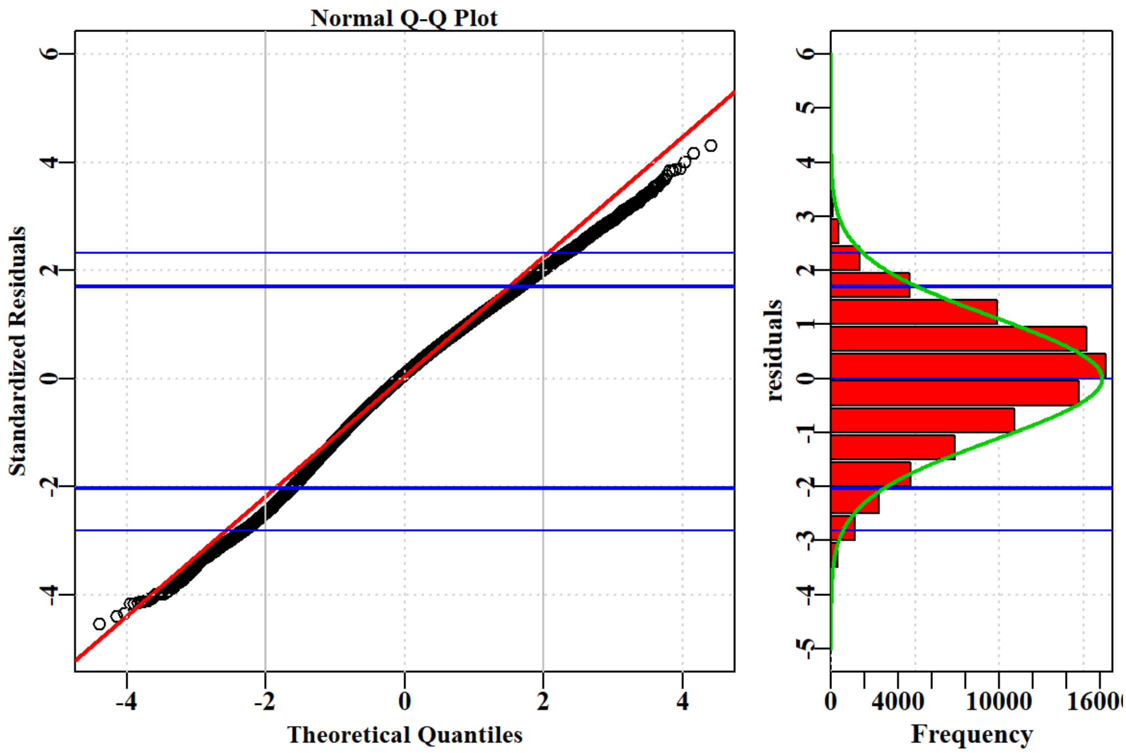

Figure 8.6. GummySharkSA. Diagnostic plots. The distribution of residuals from the optimum fit. The qqplot indicates the fit to the expected normality, while the histogram of residuals also illustrates the 1%, 5%, 95% and 99% quantiles to indicate the intensity of any lack of fit at the margins of the distribution (reflected also in the qqplot.

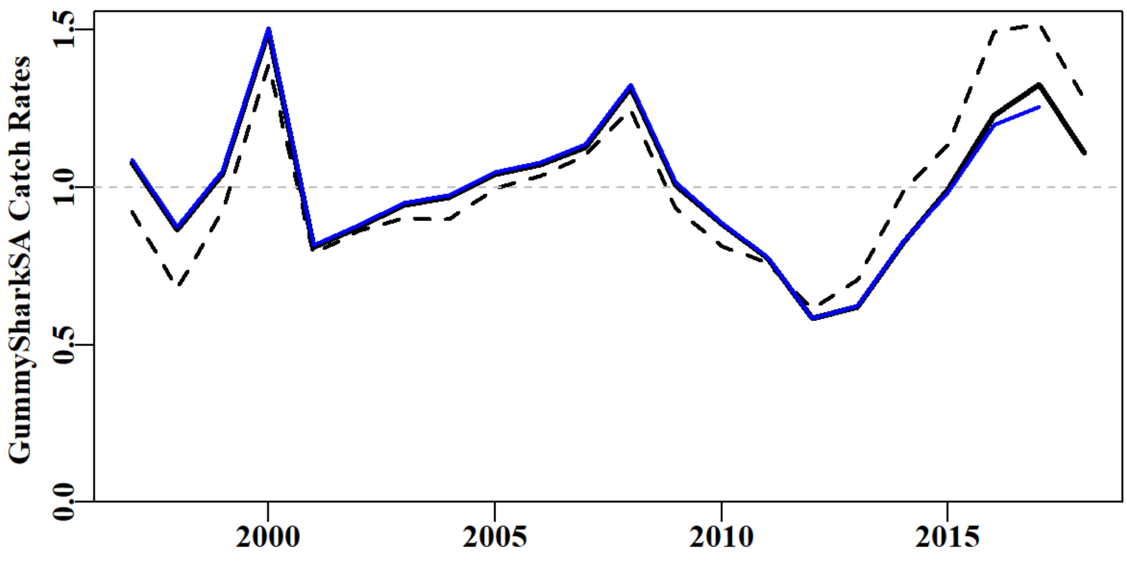

Figure 8.7. GummySharkSA. A comparison of the previous year's standardization (blue line) with this year's. They should lie on top of each other, although small deviations may relate to data adjustments, particularly in very recent years.

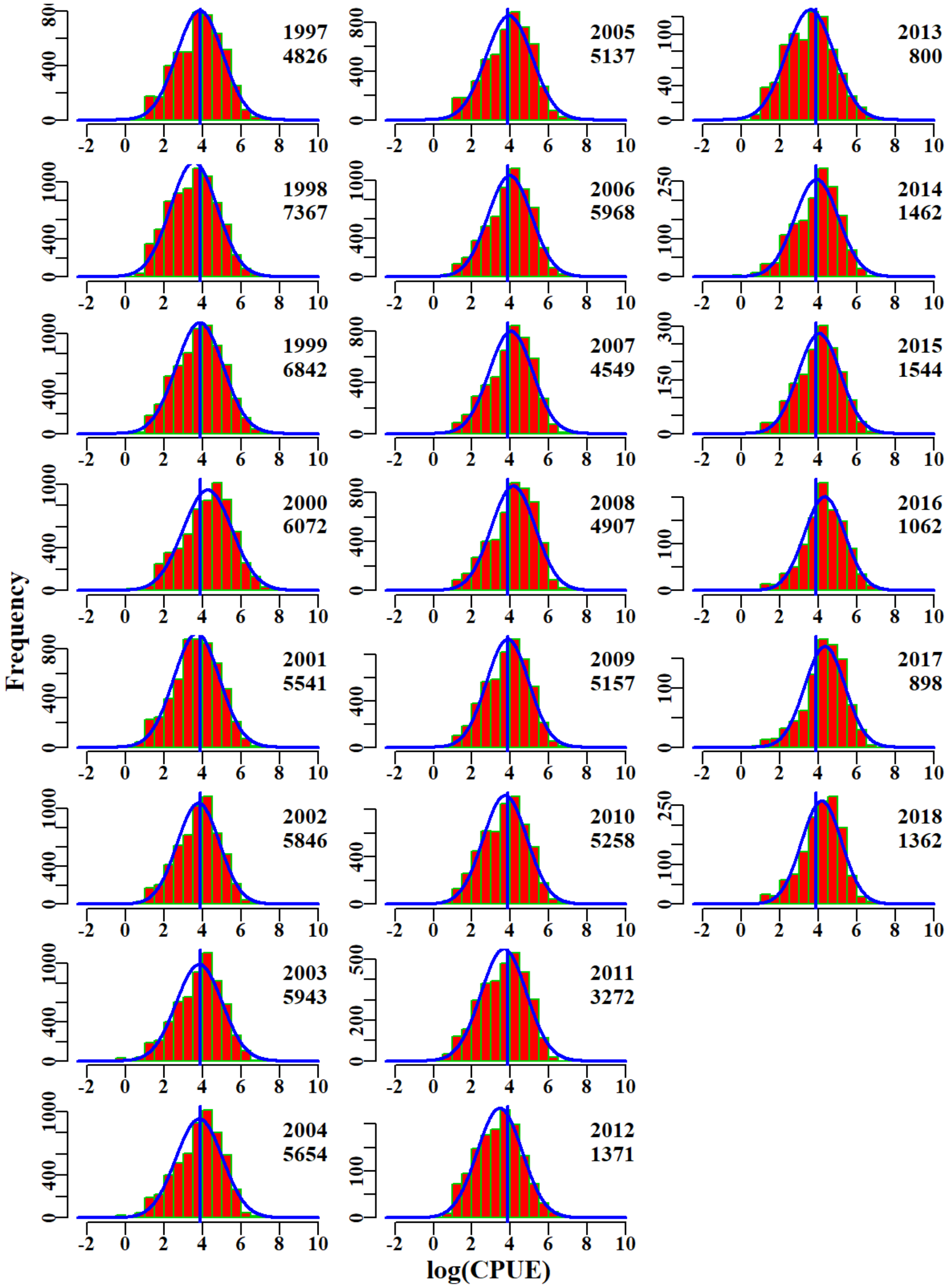

Figure 8.8. GummySharkSA. The natural log(CPUE) for each year of data available the blue lines are normal distributions fitted to the histogram frequencies. The numbers in each plot are the year and number of records. The vertical blue line is the average across all years.

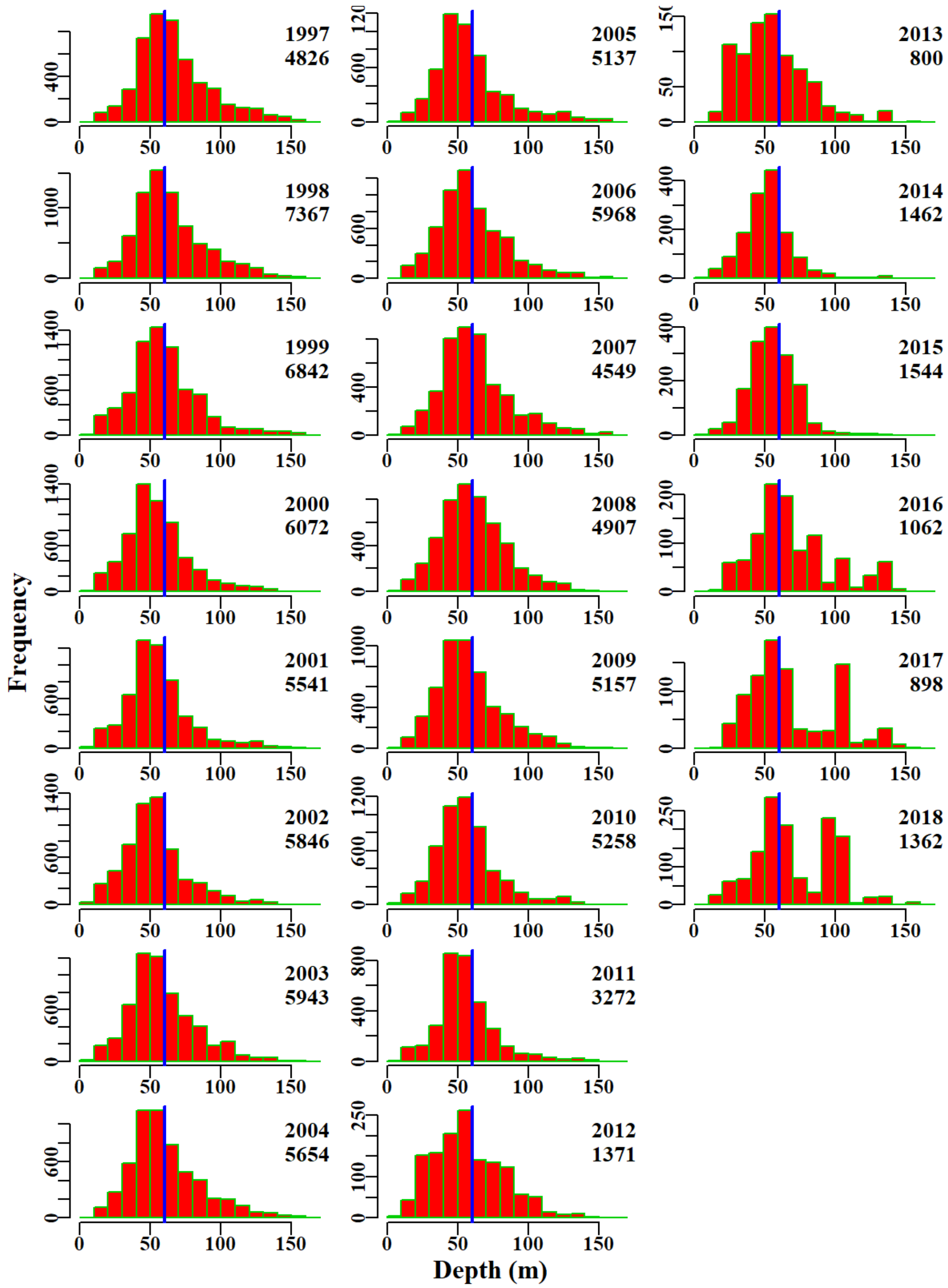

Figure 8.9. GummySharkSA. The average Depth of fishing for each year of data available to illustrate the development of the fishery through time. The numbers in each plot are the year and number of records. The vertical blue line is the average across all years.

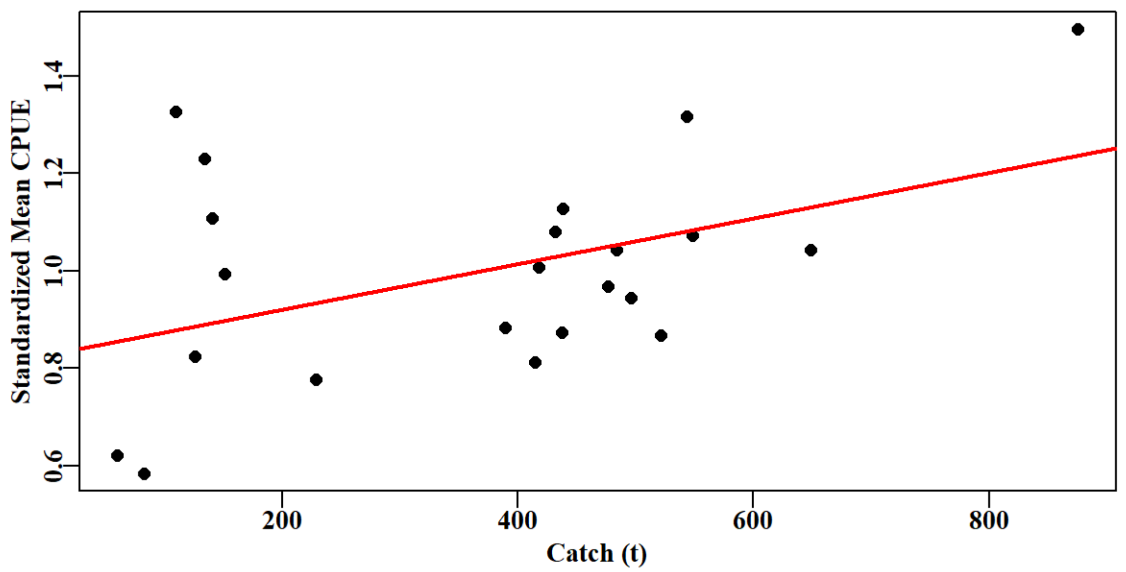

Figure 8.10. GummySharkSA. The linear relationship between annual mean CPUE and annual catch.

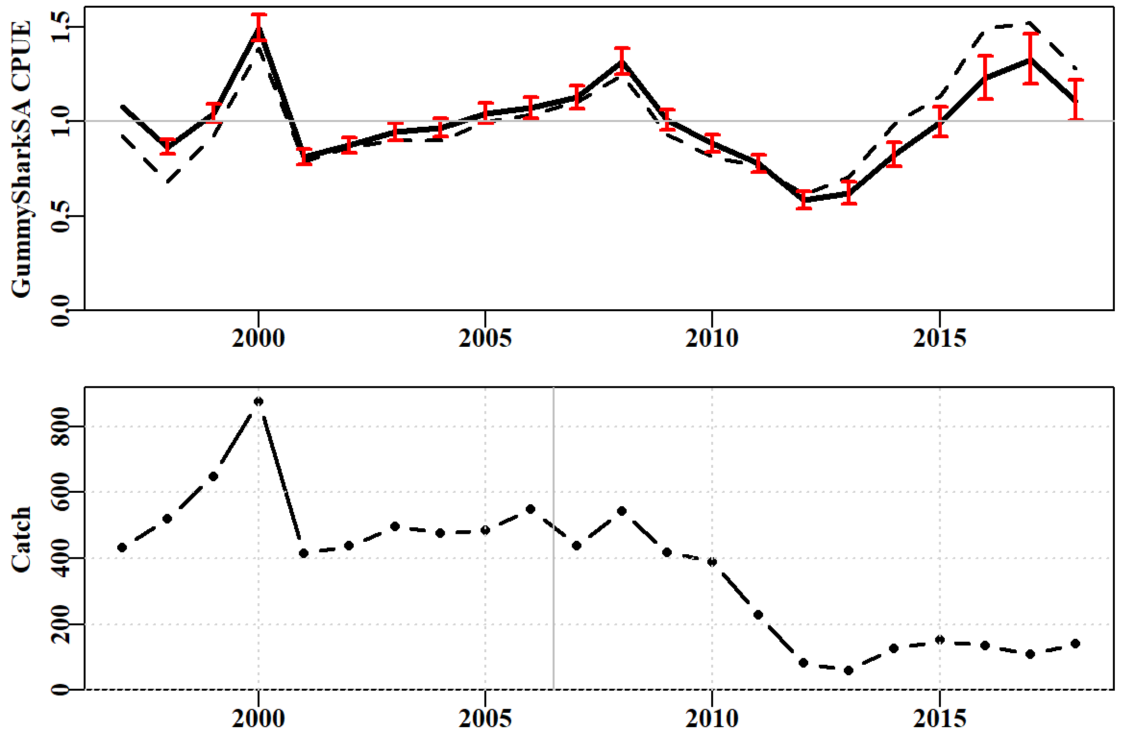

Figure 8.11. GummySharkSA. CPUE is correlated with catches through time. CPUE in the top plot and annual catch (t) in the lower plot.

8.5 Gummy shark: Bass Strait 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.

A total of 7 statistical models were fitted sequentially to the available data, and the order of the non-interaction terms added based on the relative contribution of each term to model fit.

8.5.1 Inferences

The majority of catch occurred in Shark regions 5 followed by 4.

The terms Year, Vessel, DepCat, SharkRegion, Month and one interaction (SharkRegion:Month) had the greatest contribution to model fit based on the AIC and R2 statistics (Table 8.10). The first two terms Year and Vessel contributed the most to the overall model fit. The qqplot suggests a slight departure from the assumed Normal distribution, as depicted from both tails of the distribution (Figure 8.15). Standardized CPUE is cyclical over the series, decreasing in 2016 and dropping just below the long-term average in 2017 (Figure 8.13).

8.5.2 Action Items and Issues

A further consideration of whether or not to consider the CPUE time-series as a valid index of relative abundance for gummy shark needs to be explored.

Table 8.6. GummySharkBS. The data selection criteria used to specify and identify the fishery data to be included in the analysis.

Property	Value
label	GummySharkBS
csirocode	37017001
fishery	GHT_SEN_SSF_SSG_SSH
depthrange	0 - 160
depthclass	20
zones	4, 5
methods	GN
years	1997 - 2018

Table 8.7. GummySharkBS. Total catch (Total; t) is the total reported in the database, number of records used in the analysis (N), reported catch (Catch; t) in the area and depth used in the analysis and number of vessels used in the analysis (Vess). GeoM is the geometric mean of catch rates (kg/shot), standard deviation (StDev) relates to the optimum model. C<30Kg denotes the amount of catch in shots of <30kg, and P<30Kg is the proportion of total. The optimum model was SharkRegion:DepCat.

	Total	N	Catch	Vess	GeoM	Opt	StDev	C<30Kg	P<30Kg
1997	952.1	4397	417.0	50	103.8	0.6524	0.000	23.872	0.057
1998	1401.1	5947	704.8	51	132.4	0.7925	0.024	26.642	0.038
1999	1923.8	6666	1030.9	56	176.6	1.0385	0.024	25.060	0.024
2000	2436.9	6922	1257.5	49	211.5	1.1293	0.024	22.653	0.018
2001	1703.3	6318	1051.1	47	202.3	1.0018	0.024	20.486	0.019
2002	1527.1	6299	833.8	47	157.5	0.8203	0.025	24.050	0.029
2003	1653.0	6626	883.3	44	159.9	0.8109	0.024	25.951	0.029
2004	1669.9	6289	879.9	41	162.5	0.8780	0.025	21.121	0.024
2005	1573.2	5280	811.4	39	171.0	0.9717	0.026	15.256	0.019
2006	1577.1	4064	727.6	33	201.4	1.1044	0.027	10.785	0.015
2007	1575.0	3479	873.9	25	291.6	1.3529	0.028	7.472	0.009
2008	1727.7	3671	954.6	26	301.9	1.4457	0.028	7.287	0.008
2009	1500.9	4089	831.5	28	233.8	1.2623	0.027	9.391	0.011
2010	1404.8	4408	738.0	31	191.3	1.0121	0.027	13.268	0.018
2011	1364.7	5171	797.9	32	173.6	0.9105	0.026	18.833	0.024
2012	1304.2	5441	780.2	37	162.2	0.8742	0.026	19.117	0.025
2013	1307.6	5347	757.9	36	160.6	0.8404	0.026	21.012	0.028
2014	1389.1	5261	813.4	36	175.7	0.8952	0.026	18.070	0.022
2015	1545.1	4945	979.5	30	233.4	1.0958	0.027	13.152	0.013
2016	1586.5	5124	1107.4	31	251.0	1.2241	0.026	13.045	0.012
2017	1561.3	5808	939.6	30	184.2	0.9362	0.026	17.749	0.019
2018	1560.1	5117	786.0	31	173.9	0.9510	0.027	16.386	0.021

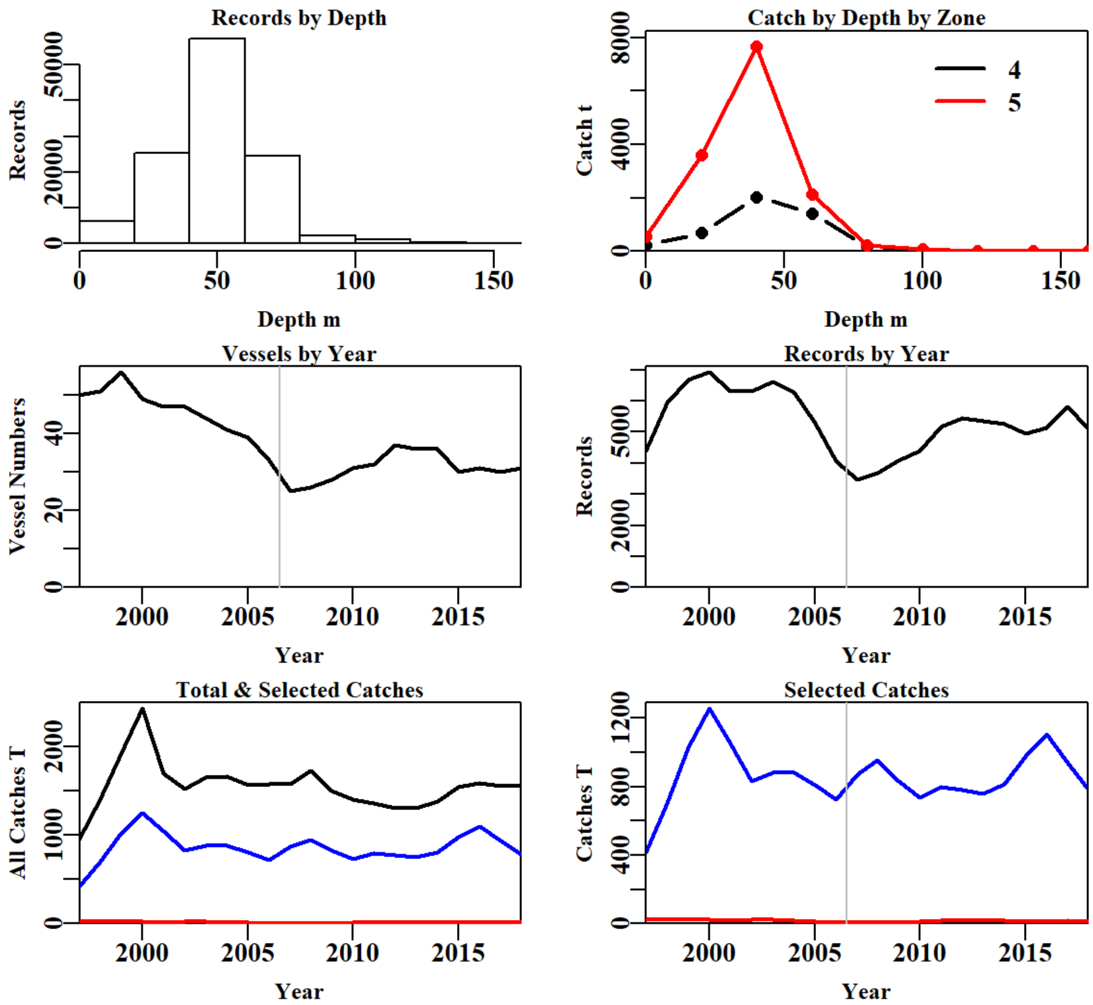

Figure 8.12. GummySharkBS fishery details. The bottom left plot depicts all known catches (top black line), and all selected catches used in the analysis (middle blue line); the lower red line: selected catches < 30 kg).

Table 8.8. GummySharkBS data selection effects. Total is the total number of records in the database, NoCE removes those records with either missing catch or effort, and then only those records are kept that meet the criteria for depth, years, zone, method, and fishery.

	Records	Difference	Catch	Difference
Total	405328	0	34938.92	0.000
NoCE	395465	9863	34938.92	0.000
Depth	367496	27969	33905.66	1033.260
Years	354493	13003	33282.23	623.427
Zones	183739	170754	20275.10	13007.136
Method	116673	67066	18957.53	1317.567
Fishery	116669	4	18957.07	0.459

Table 8.9. The models used to analyse data for GummySharkBS.

	Model
Model1	Year
Model2	Year + Vessel
Model3	Year + Vessel + DepCat
Model4	Year + Vessel + DepCat + SharkRegion
Model5	Year + Vessel + DepCat + SharkRegion + Month
Model6	Year + Vessel + DepCat + SharkRegion + Month + SharkRegion:DepCat
Model7	Year + Vessel + DepCat + SharkRegion + Month + SharkRegion:Month

Table 8.10. GummySharkBS. The row names are 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_r2) and the change in adjusted R^2 (%Change). The optimum model was SharkRegion:DepCat.

	AIC	RSS	MSS	Nobs	Npars	adj_r2	%Change
Year	46148	173211	5715	116669	22	3.2	0.00
Vessel	37825	160951	17975	116669	143	9.9	6.76
DepCat	36972	159756	19170	116669	151	10.6	0.66
SharkRegion	36967	159746	19179	116669	152	10.6	0.00
Month	36226	158706	20220	116669	163	11.2	0.57
SharkRegion:DepCat	36141	158571	20355	116669	170	11.2	0.07
SharkRegion:Month	35931	158274	20651	116669	174	11.4	0.23

Figure 8.13. GummySharkBS standardization. The dashed black line represents the geometric mean catch rate, solid black line the standardized catch rates. The red bars are the 95% confidence intervals about the mean estimates. The graph scales both time-series of standardized catch rates relative to the mean of each time-series.

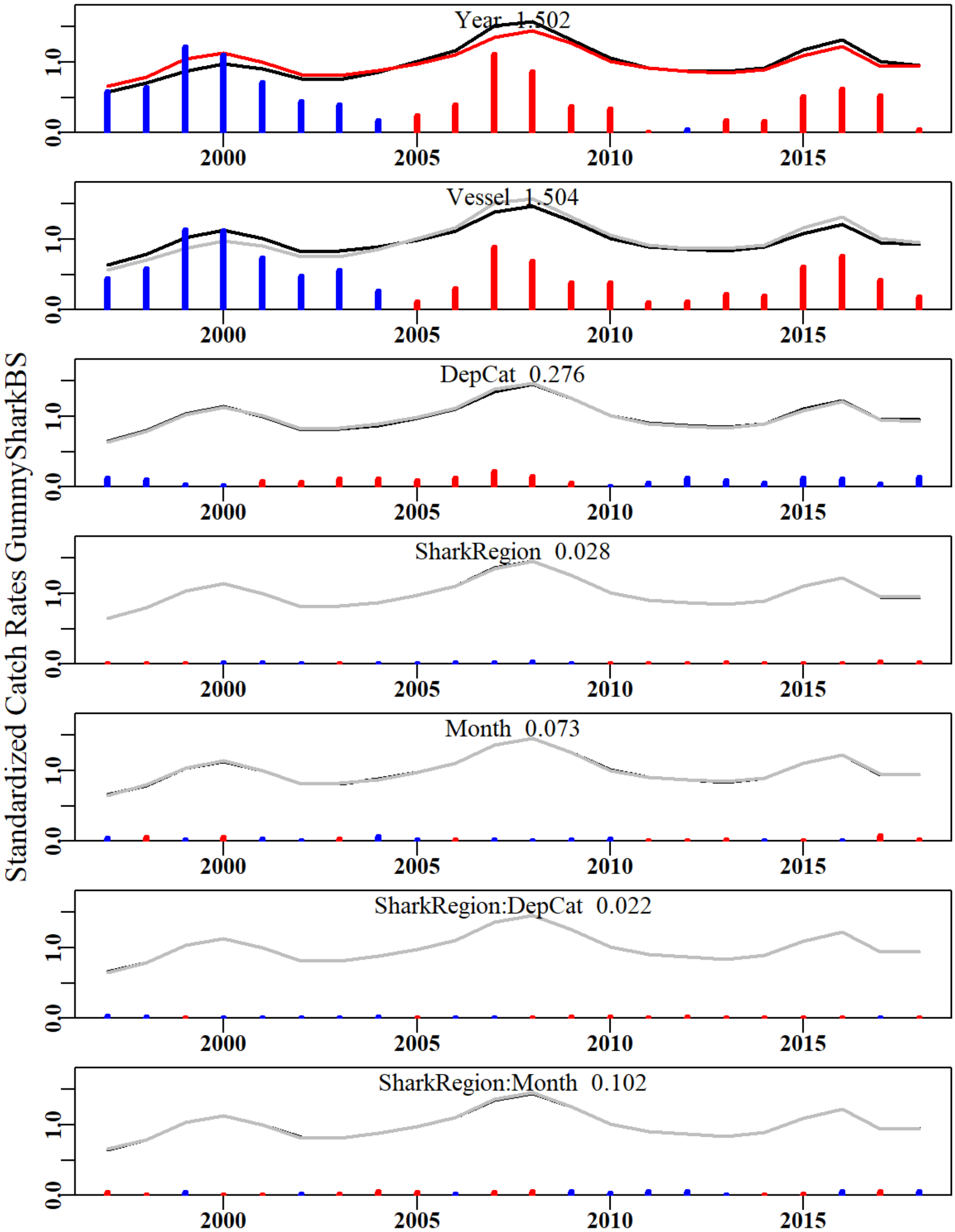

Figure 8.14. GummySharkBS. The influence of each factor on the optimal standardization. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by vertical bars with blue bars indicating the optimum model is higher than the geometric mean and red bars indicating it is lower. The top graph bars are the sum of all the bars in the graphs below. The graphs for individual factors are cumulative. Thus the second graph has the geometric mean (grey line) and the effect of adding Year + factor2 (Model 2). In the third graph, the grey line represents Model 2 and the black line the effect of adding factor3 to the model. The remaining graphs continue in the same cumulative manner except for the interaction terms which are added singularly to the final single factor model.

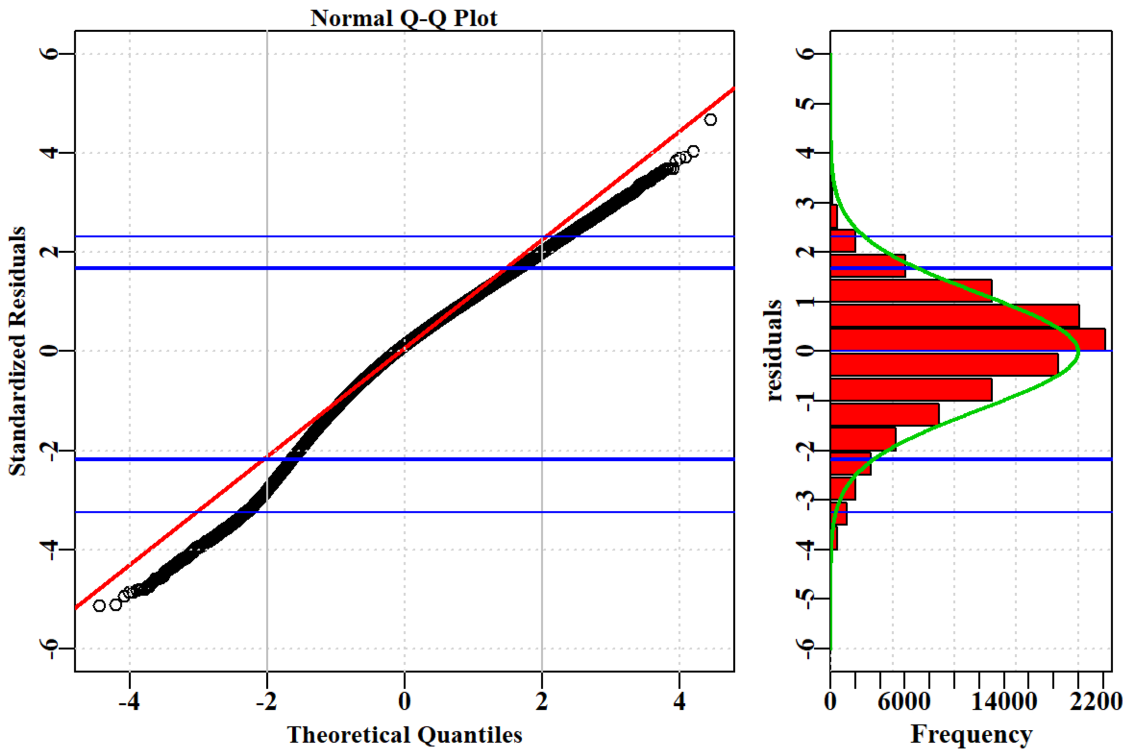

Figure 8.15. GummySharkBS. Diagnostic plots. The distribution of residuals from the optimum fit. The qqplot indicates the fit to the expected normality, while the histogram of residuals also illustrates the 1%, 5%, 95% and 99% quantiles to indicate the intensity of any lack of fit at the margins of the distribution (reflected also in the qqplot.

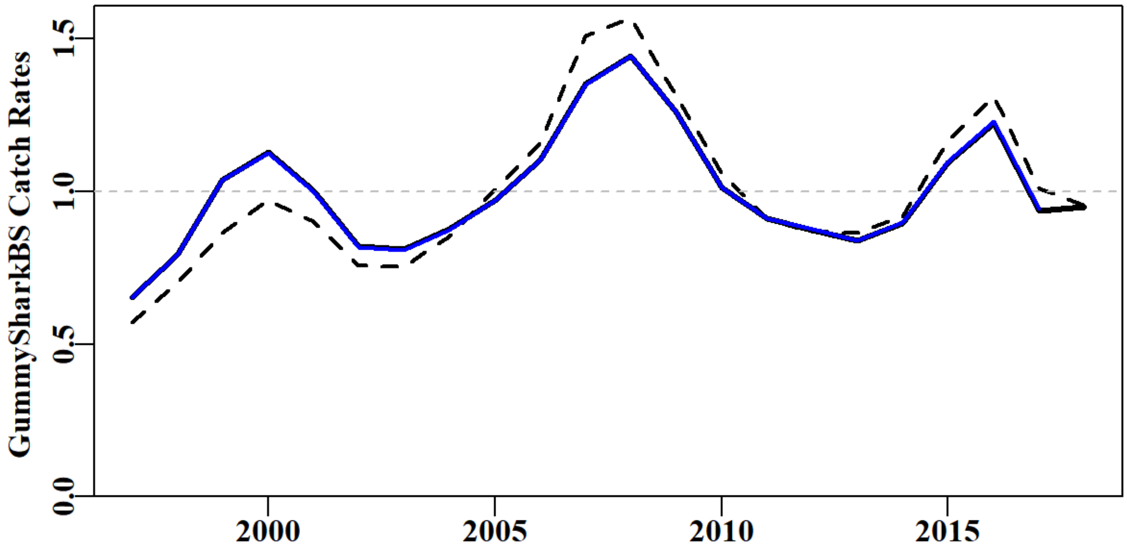

Figure 8.16. GummySharkBS. A comparison of the previous year's standardization (blue line) with this year's. They should lie on top of each other, although small deviations may relate to data adjustments, particularly in very recent years.

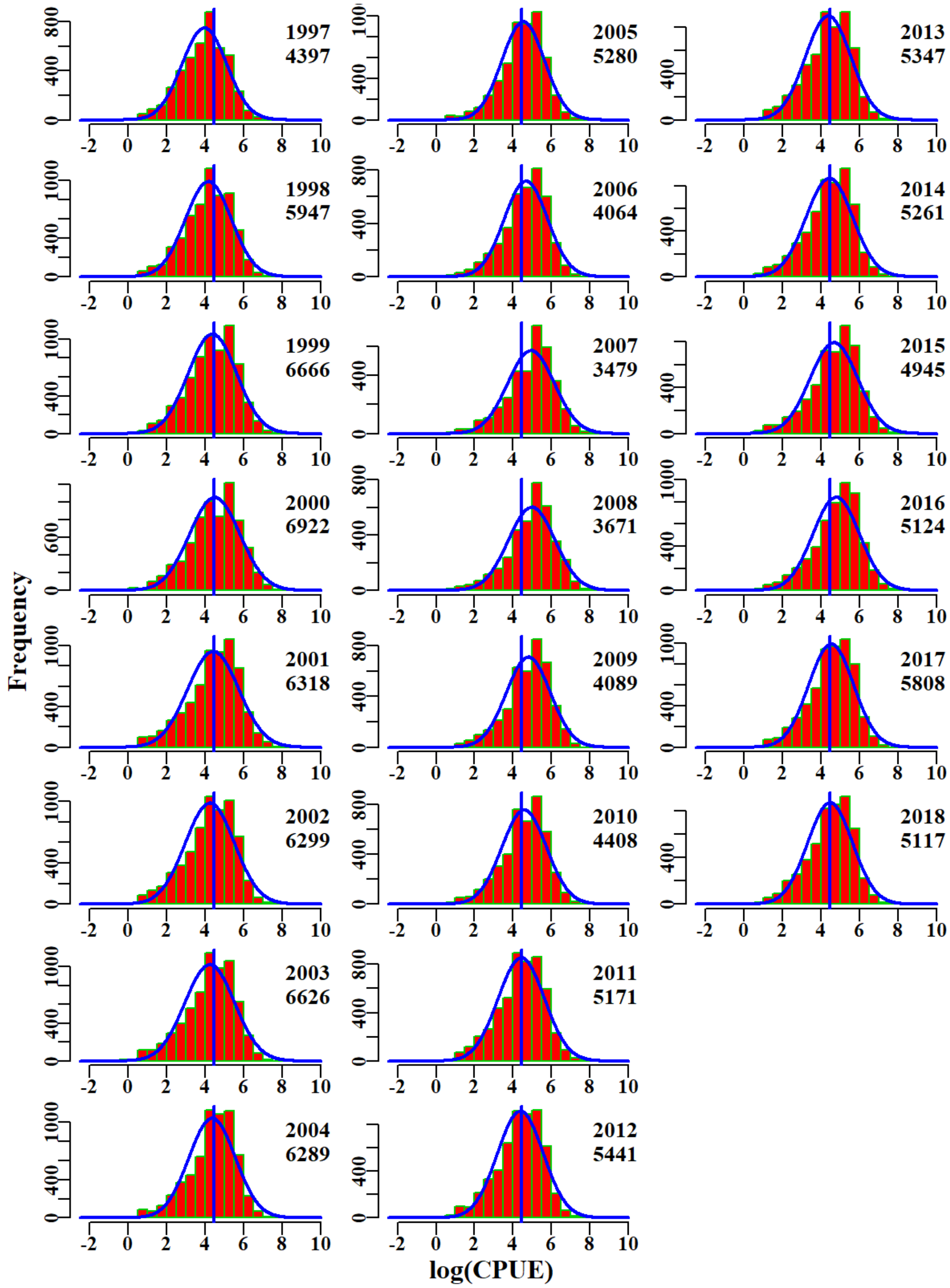

Figure 8.17. GummySharkBS. The natural log(CPUE) for each year of data available the blue lines are normal distributions fitted to the histogram frequencies. The numbers in each plot are the year and number of records. The vertical blue line is the average across all years.

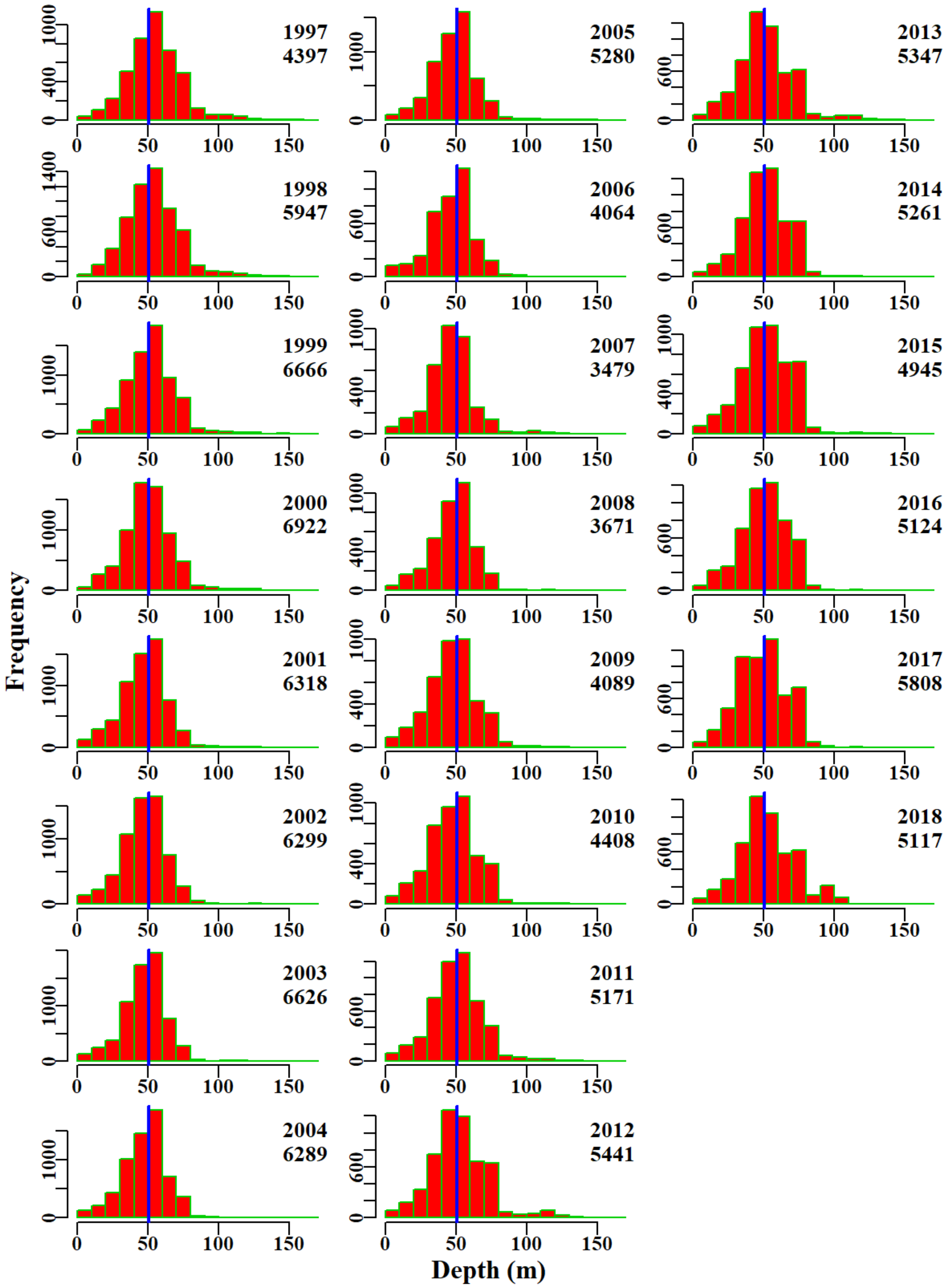

Figure 8.18. GummySharkBS. The average Depth of fishing for each year of data available to illustrate the development of the fishery through time. The numbers in each plot are the year and number of records. The vertical blue line is the average across all years.

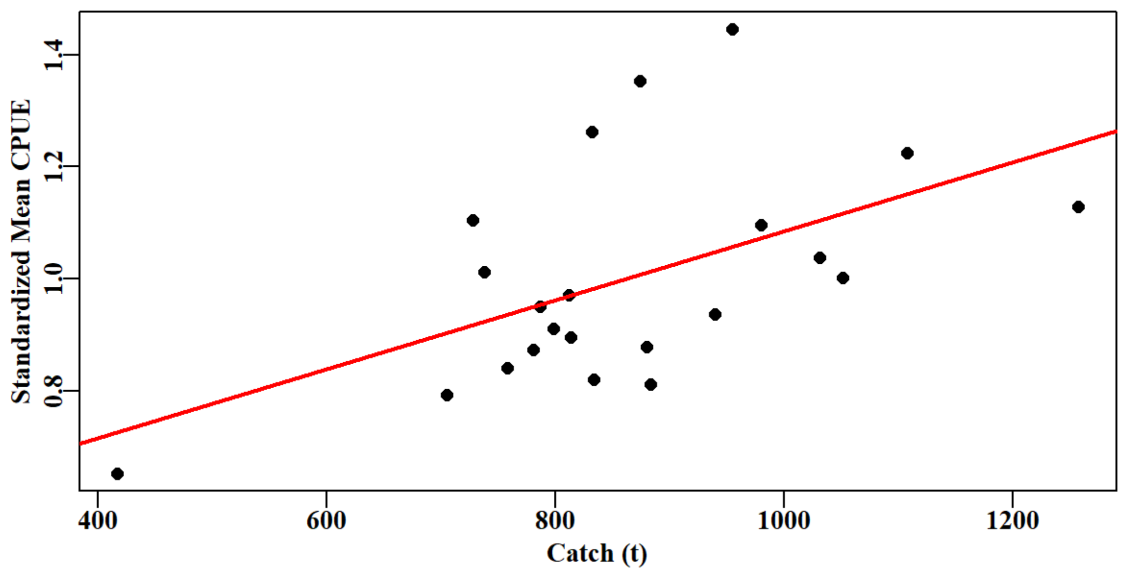

Figure 8.19. GummySharkBS. The linear relationship between Annual mean CPUE and Annual Catch.

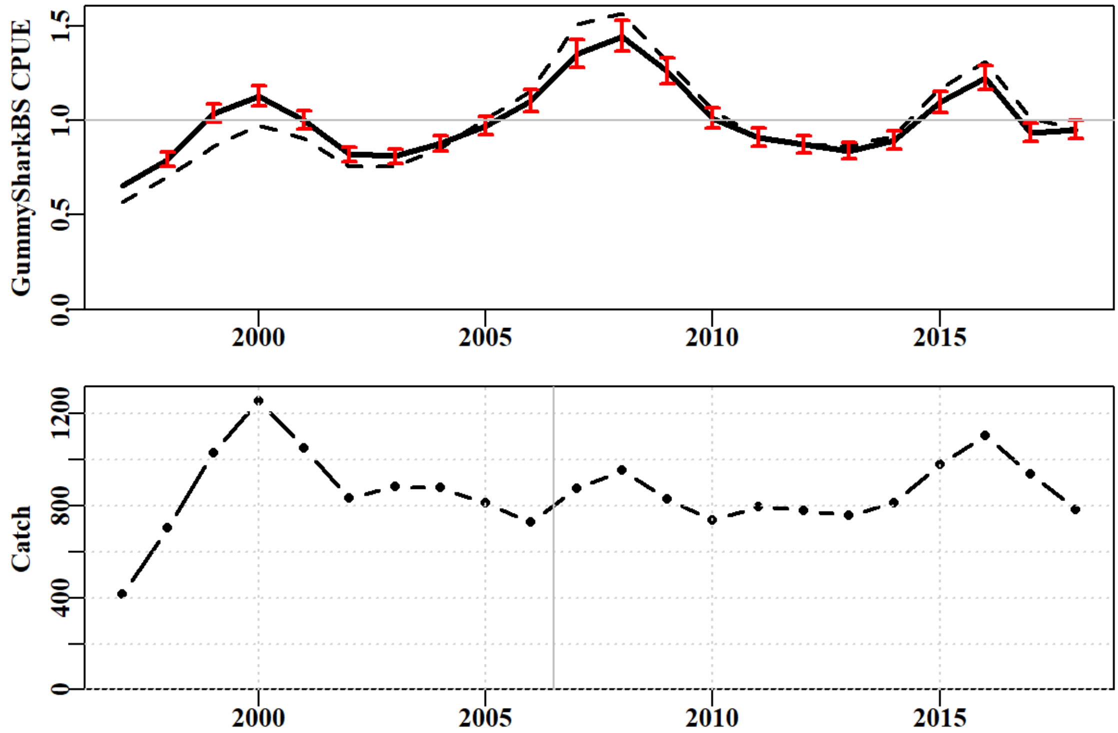

Figure 8.20. GummySharkBS. CPUE is correlated with catches through time. CPUE in the top plot and annual catch (t) in the lower plot.

8.6 Gummy shark: Tasmania Gillnet

Positive non-zero records of catch per shot were employed in the statistical standardization analyses for gummy shark caught by gillnets. Shots from shallow waters between 2002-05 have been investigated and verified. Further investigation should be considered to determine whether total net length could be used as an alternative effort unit in standardization analyses.

A total of 7 statistical models were fitted sequentially to the available data, and the order of the non-interaction terms added based on the relative contribution of each term to model fit.

8.6.1 *Inferences*

The majority of catch occurred in Shark regions 7 followed by 6.

The terms Year, Vessel, DepCat, SharkRegion, Month and one interaction (SharkRegion:Month) had the greatest contribution to model fit based on the AIC and R2 statistics (Table 8.15). The first two terms Year and Vessel contributed the most to the overall model fit. The qqplot suggests a slight departure from the assumed Normal distribution, as depicted from the lower tail of the distribution (Figure 8.24). Standardized CPUE has been mostly flat since 1999 and has been at the long-term average since 2016, accounting for the 95% confidence interval (Figure 8.22).

8.6.2 *Action Items and Issues*

A further consideration of whether or not to consider the CPUE time-series as a valid index of relative abundance for gummy shark needs to be explored.

Table 8.11. GummySharkTA. The data selection criteria used to specify and identify the fishery data to be included in the analysis.

Property	Value
label	GummySharkTA
csirocode	37017001
fishery	GHT_SEN_SSF_SSG_SSH
depthrange	0 - 160
depthclass	20
zones	6, 7
methods	GN
years	1997 - 2018

Table 8.12. GummySharkTA. Total catch (Total; t) is the total reported in the database, number of records used in the analysis (N), reported catch (Catch; t) in the area and depth used in the analysis and number of vessels used in the analysis (Vess). GeoM is the geometric mean of catch rates (kg/shot), standard deviation (StDev) relates to the optimum model. C<30Kg denotes the amount of catch in shots of <30kg, and P<30Kg is the proportion of total. The optimum model was SharkRegion:Month.

	Total	N	Catch	Vess	GeoM	Opt	StDev	C<30Kg	P<30Kg
1997	952.1	203	17.3	14	96.0	0.7611	0.000	1.231	0.071
1998	1401.1	529	55.3	14	122.1	0.7103	0.107	3.061	0.055
1999	1923.8	854	102.0	18	134.8	0.9861	0.105	3.926	0.038
2000	2436.9	544	82.6	18	169.2	1.1994	0.111	1.909	0.023
2001	1703.3	600	65.1	21	125.2	1.2409	0.115	2.672	0.041
2002	1527.1	781	100.4	26	159.5	1.1624	0.114	3.399	0.034
2003	1653.0	873	90.5	23	118.0	1.2906	0.115	4.674	0.052
2004	1669.9	917	120.9	26	169.0	1.2324	0.114	3.893	0.032
2005	1573.2	657	85.8	15	157.2	1.1144	0.117	2.646	0.031
2006	1577.1	697	116.8	15	191.0	1.2540	0.117	2.334	0.020
2007	1575.0	835	95.3	14	135.6	1.0661	0.116	4.041	0.042
2008	1727.7	635	61.8	14	109.9	0.9259	0.118	3.464	0.056
2009	1500.9	527	67.2	14	160.0	1.0978	0.123	2.199	0.033
2010	1404.8	534	75.5	14	172.2	1.0947	0.123	2.089	0.028
2011	1364.7	687	102.7	13	178.8	0.9087	0.125	2.212	0.022
2012	1304.2	1119	130.0	18	126.8	0.9638	0.121	5.852	0.045
2013	1307.6	910	96.6	15	111.5	0.7962	0.124	4.804	0.050
2014	1389.1	482	65.1	13	144.0	0.7190	0.132	2.146	0.033
2015	1545.1	359	53.4	11	166.6	0.6976	0.132	1.439	0.027
2016	1586.5	344	68.1	7	235.9	0.9701	0.132	0.952	0.014
2017	1561.3	497	85.1	13	198.2	1.0100	0.128	1.258	0.015
2018	1560.1	362	46.6	10	137.4	0.7985	0.135	1.670	0.036

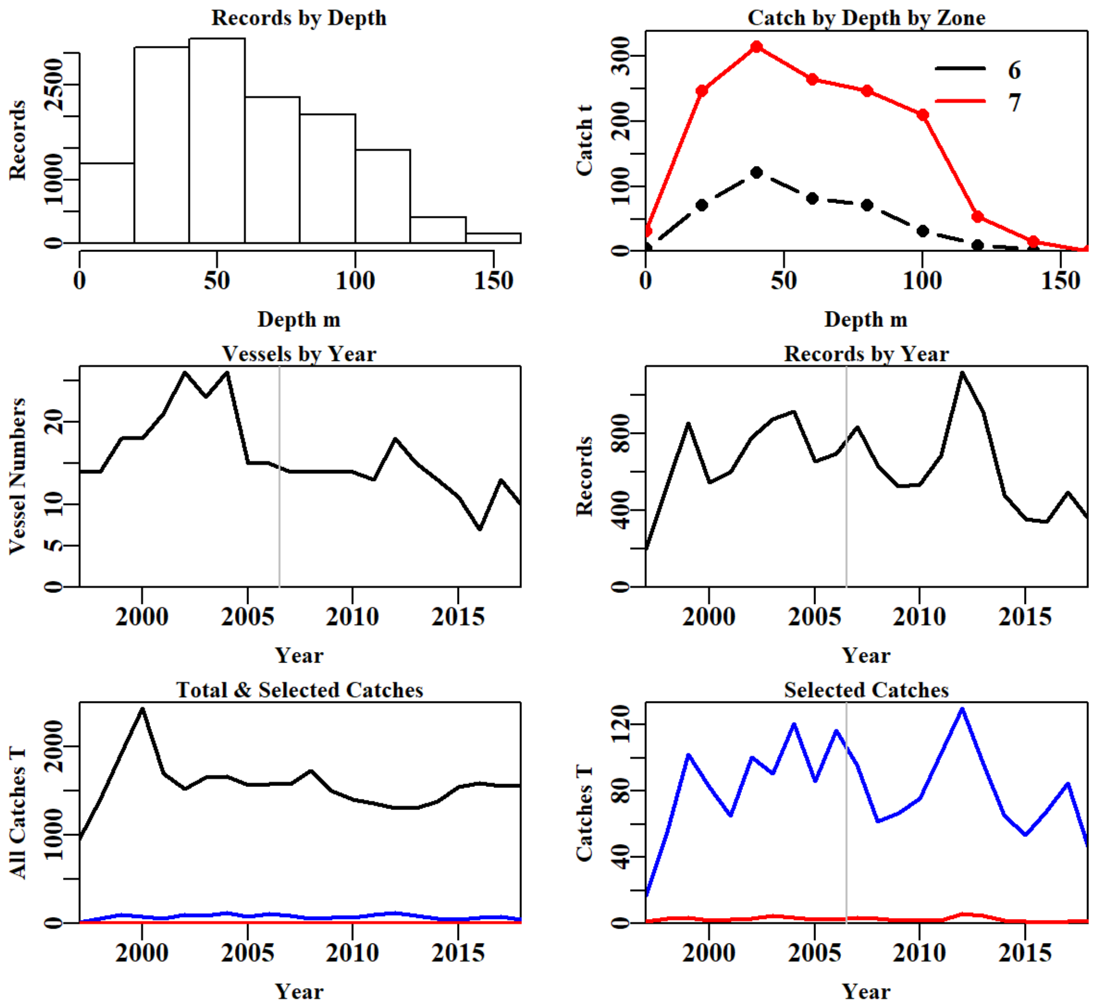

Figure 8.21. GummySharkTA fishery details. The bottom left plot depicts all known catches (top black line), and all selected catches used in the analysis (middle blue line); the lower red line: selected catches < 30 kg).

Table 8.13. GummySharkTA data selection effects. Total is the total number of records in the database, NoCE removes those records with either missing catch or effort, and then only those records are kept that meet the criteria for depth, years, zone, method, and fishery.

	Records	Difference	Catch	Difference
Total	405328	0	34938.920	0.000
NoCE	395465	9863	34938.920	0.000
Depth	367496	27969	33905.661	1033.260
Years	354493	13003	33282.233	623.427
Zones	23121	331372	2138.445	31143.789
Method	13946	9175	1784.086	354.359
Fishery	13946	0	1784.086	0.000

Table 8.14. The models used to analyse data for GummySharkTA.

	Model
Model1	Year
Model2	Year + Vessel
Model3	Year + Vessel + DepCat
Model4	Year + Vessel + DepCat + SharkRegion
Model5	Year + Vessel + DepCat + SharkRegion + Month
Model6	Year + Vessel + DepCat + SharkRegion + Month + SharkRegion:DepCat
Model7	Year + Vessel + DepCat + SharkRegion + Month + SharkRegion:Month

Table 8.15. GummySharkTA. The row names are 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_r2) and the change in adjusted R^2 (%Change). The optimum model was SharkRegion:Month.

	AIC	RSS	MSS	Nobs	Npars	adj_r2	%Change
Year	6994	22954	701	13946	22	2.8	0.00
Vessel	1612	15423	8232	13946	104	34.3	31.50
DepCat	1586	15376	8280	13946	112	34.5	0.16
SharkRegion	1585	15374	8282	13946	113	34.5	0.01
Month	1259	14995	8661	13946	124	36.0	1.56
SharkRegion:DepCat	1217	14935	8721	13946	131	36.3	0.22
SharkRegion:Month	1202	14909	8747	13946	135	36.4	0.31

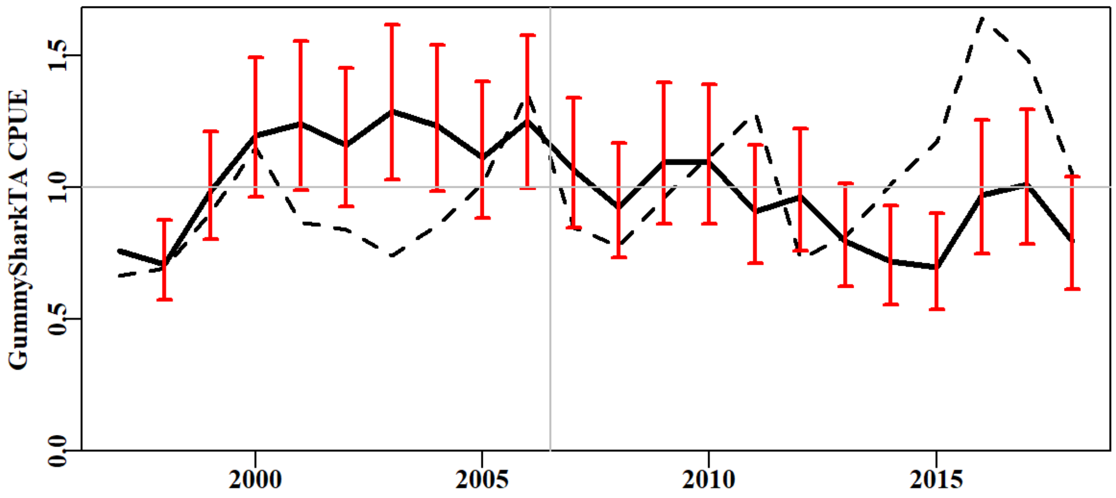

Figure 8.22. GummySharkTA standardization. The dashed black line represents the geometric mean catch rate, solid black line the standardized catch rates. The red bars are the 95% confidence intervals about the mean estimates. The graph scales both time-series of standardized catch rates relative to the mean of each time-series.

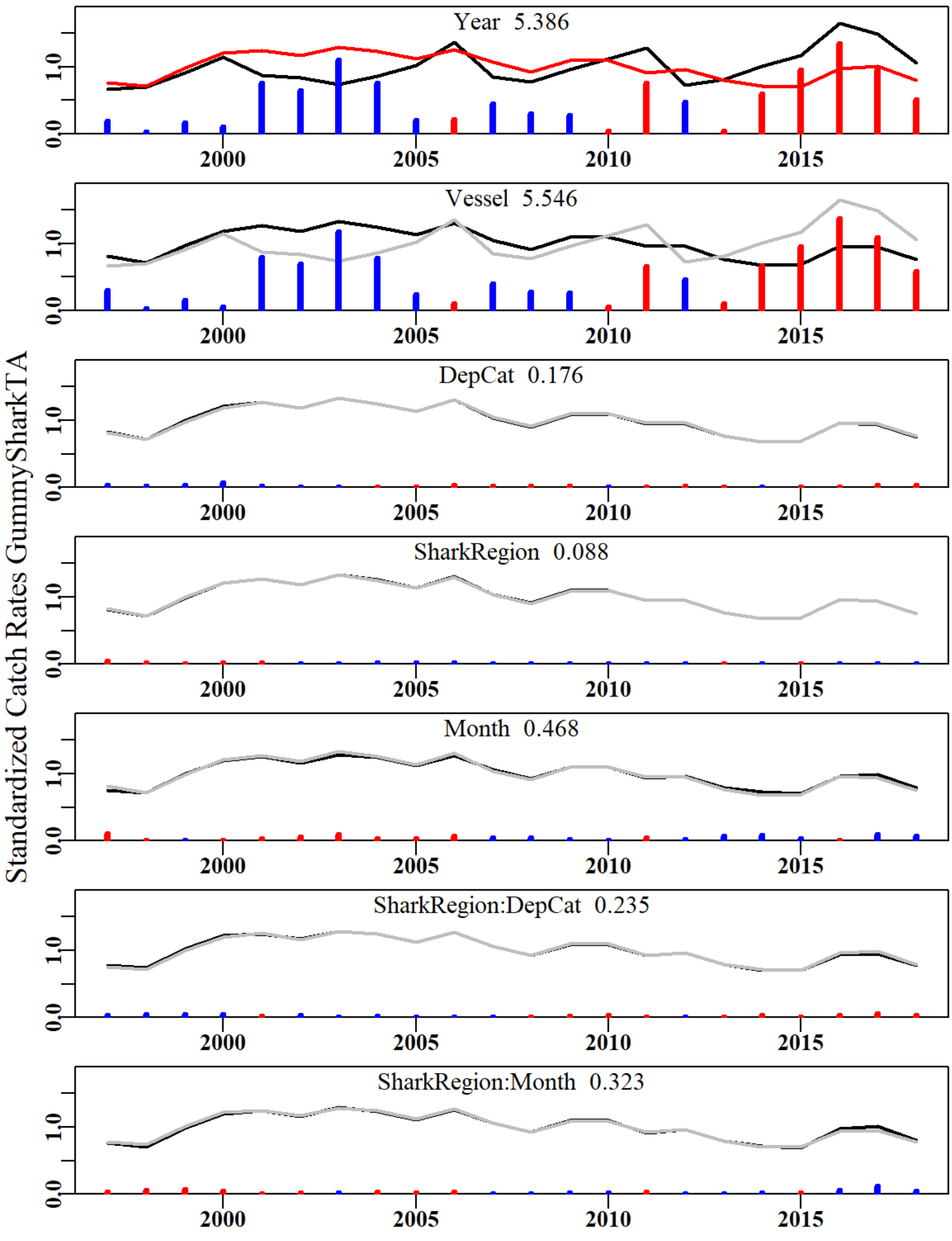

Figure 8.23. GummySharkTA. The influence of each factor on the optimal standardization. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by vertical bars with blue bars indicating the optimum model is higher than the geometric mean and red bars indicating it is lower. The top graph bars are the sum of all the bars in the graphs below. The graphs for individual factors are cumulative. Thus the second graph has the geometric mean (grey line) and the effect of adding Year + factor2 (Model 2). In the third graph, the grey line represents Model 2 and the black line the effect of adding factor3 to the model. The remaining graphs continue in the same cumulative manner except for the interaction terms which are added singularly to the final single factor model.

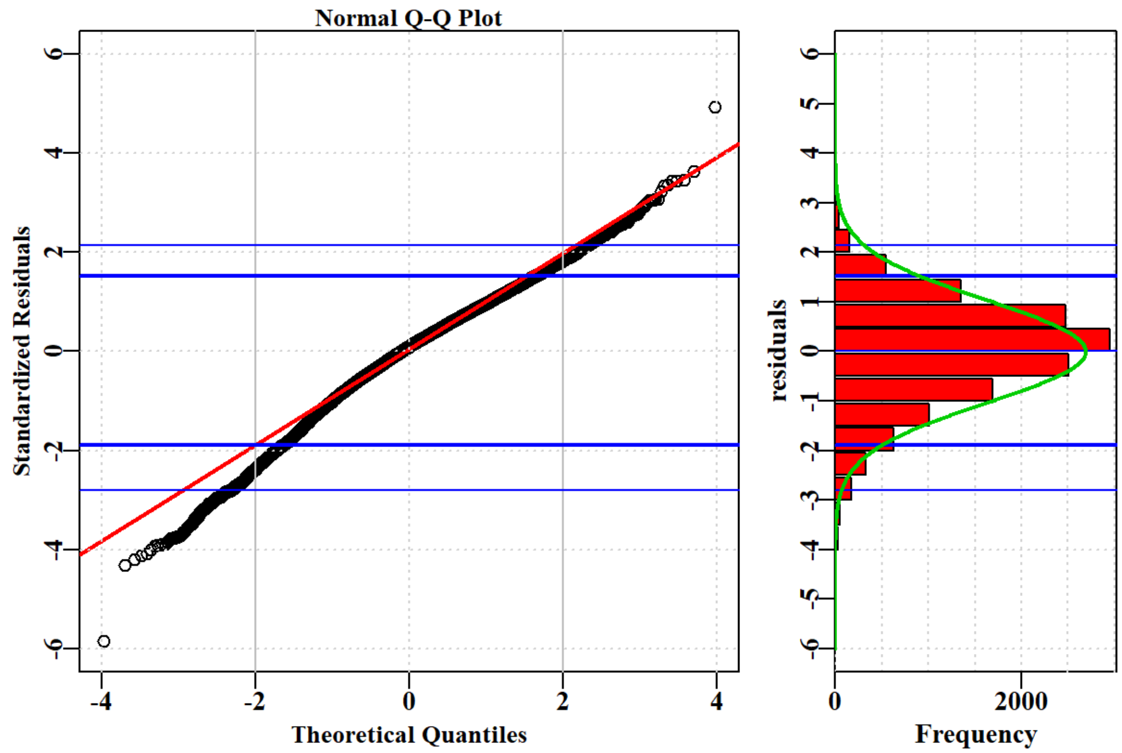

Figure 8.24. GummySharkTA. Diagnostic plots. The distribution of residuals from the optimum fit. The qqplot indicates the fit to the expected normality, while the histogram of residuals also illustrates the 1%, 5%, 95% and 99% quantiles to indicate the intensity of any lack of fit at the margins of the distribution (reflected also in the qqplot).

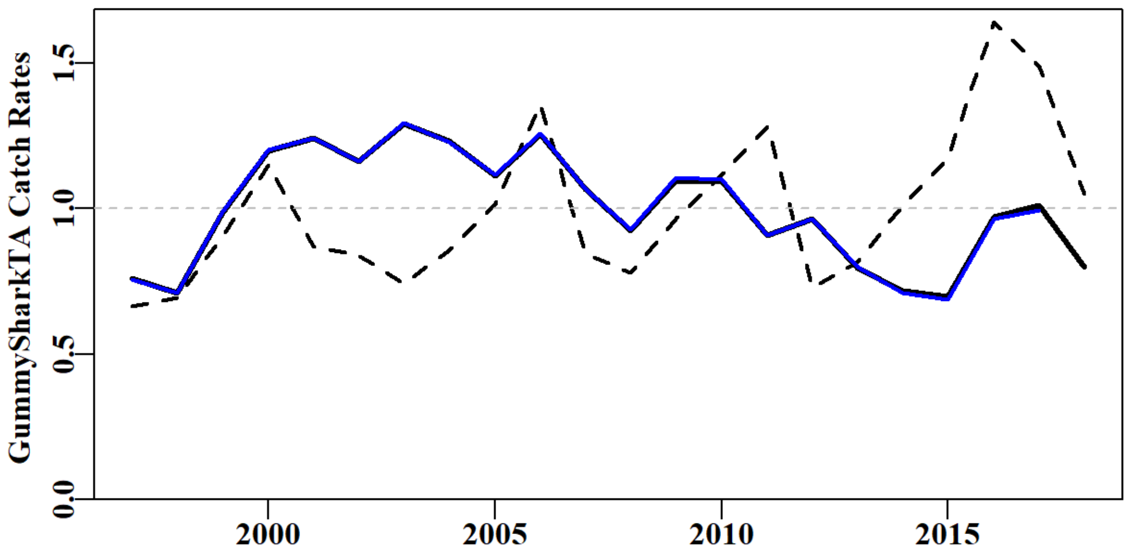

Figure 8.25. GummySharkTA. A comparison of the previous year's standardization (blue line) with this year's. They should lie on top of each other, although small deviations may relate to data adjustments, particularly in very recent years.

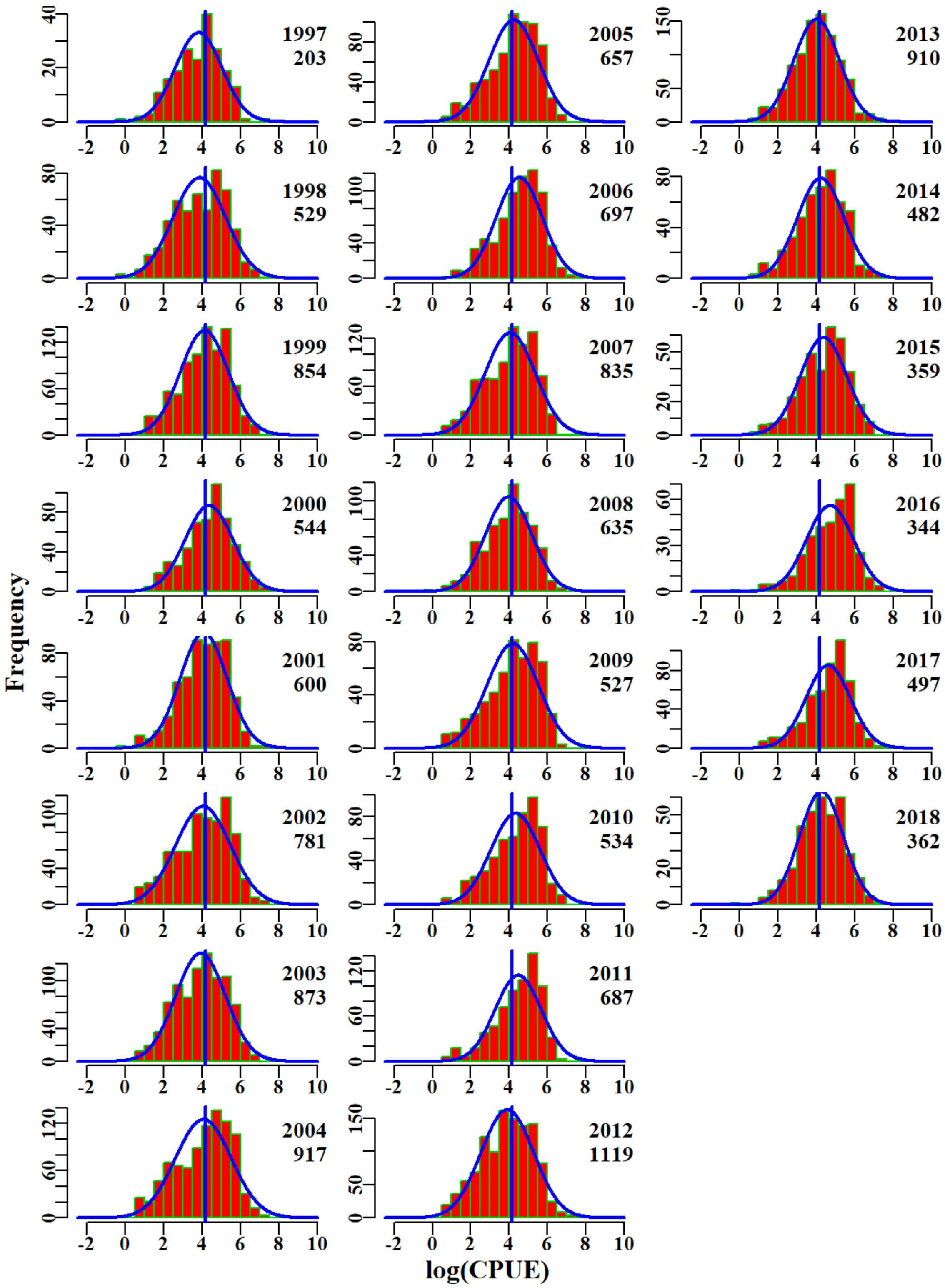

Figure 8.26. GummySharkTA. The natural log(CPUE) for each year of data available the blue lines are normal distributions fitted to the histogram frequencies. The numbers in each plot are the year and number of records. The vertical blue line is the average across all years.

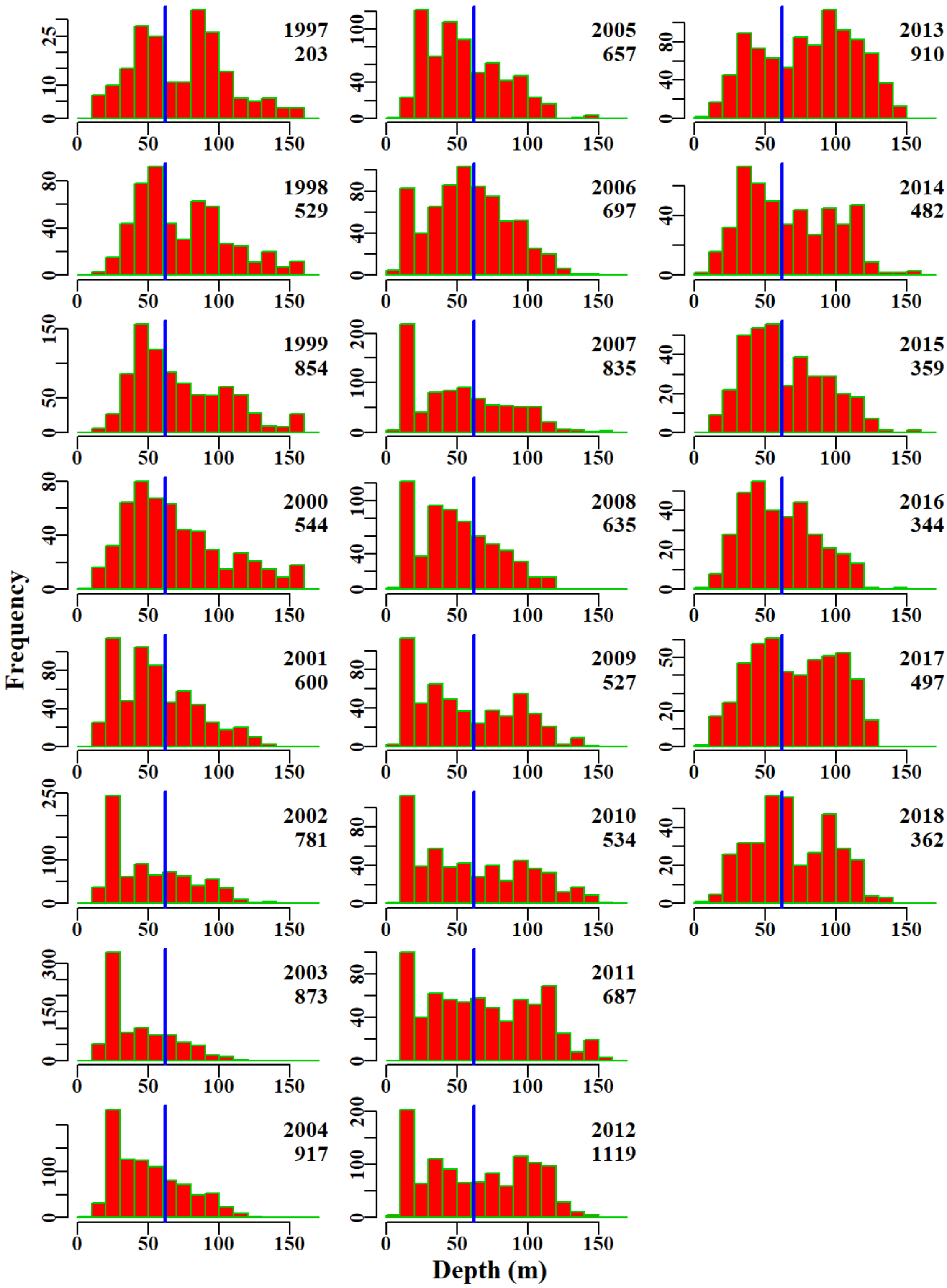

Figure 8.27. GummySharkTA. The average Depth of fishing for each year of data available to illustrate the development of the fishery through time. The numbers in each plot are the year and number of records. The vertical blue line is the average across all years.

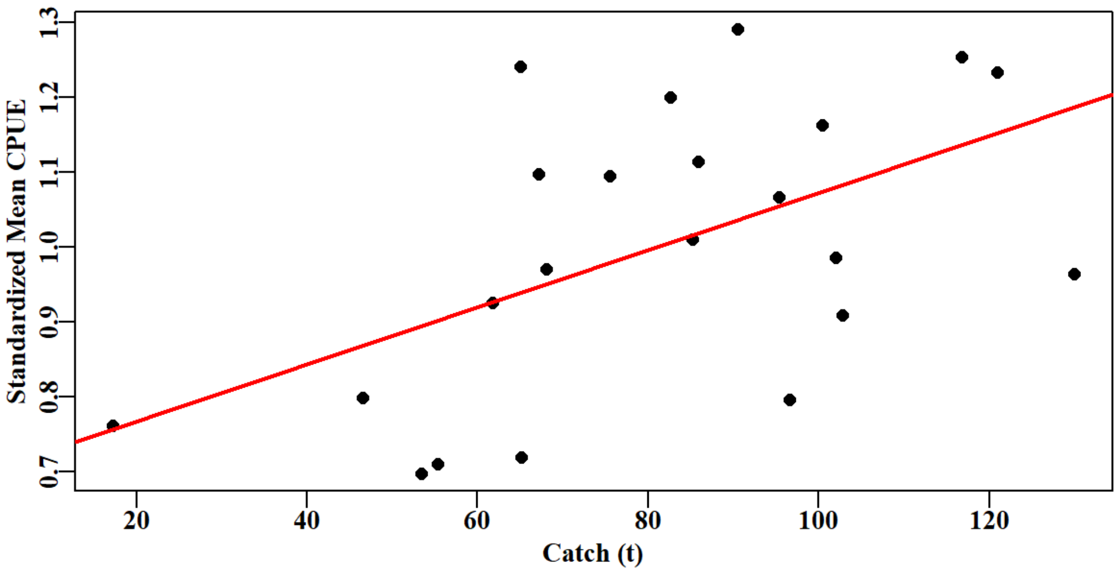

Figure 8.28. GummySharkTA. The linear relationship between Annual mean CPUE and Annual Catch.

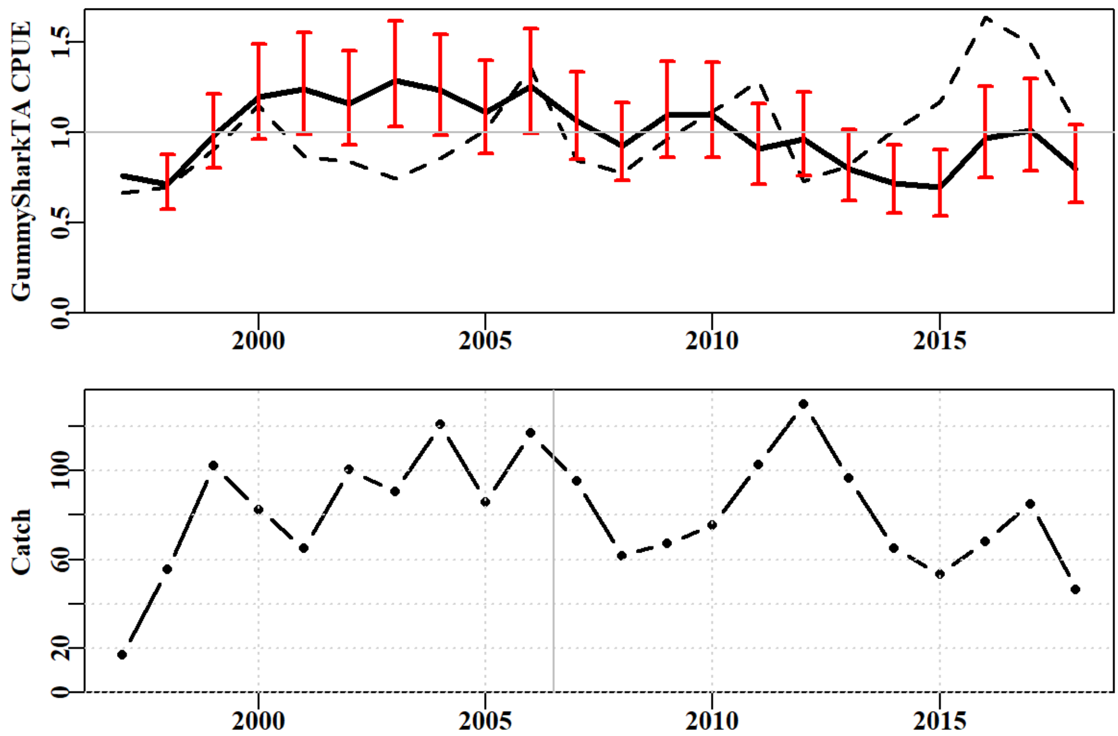

Figure 8.29. GummySharkTA. CPUE is correlated with catches through time. CPUE in the top plot and annual catch (t) in the lower plot.

8.7 Gummy shark: Trawl

CPUE (catch/hour) analysis used shots that reported catches of gummy shark (non zero shots), and included a factor for shark zones, more consistent with gillnet and line standardizations than the SESSF trawl zones previously considered (Haddon, 2014). The proportion of zero gummy shark catches reported by trawl (based on all records) is >60%. Since gummy shark are not targeted by trawl vessels, it is inappropriate to include zero catches in the analysis.

A total of 8 statistical models were fitted sequentially to the available data, and the order of the non-interaction terms added based on the relative contribution of each term to model fit.

8.7.1 Inferences

The majority of catch occurred in Shark regions 2, 1 followed by 5.

The terms Year, Vessel, DepCat, SharkRegion, Month, DayNight and one interaction (SharkRegion:Month) had the greatest contribution to model fit based on the AIC and R2 statistics (Table 8.20). The qqplot suggests a slight departure from the assumed Normal distribution, as depicted from the upper tail of the distribution (Figure 8.33). Annual standardized CPUE has been mostly flat and below the long-term average between 1997 and 2007. By contrast, standardized CPUE has increased significantly above the long-term average since 2008 (except 2011) (Figure 8.31).

8.7.2 Action Items and Issues

A further consideration of whether or not to consider the CPUE time-series as a valid index of relative abundance for gummy shark needs to be explored.

Table 8.16. GummySharkTW. The data selection criteria used to specify and identify the fishery data to be included in the analysis.

Property	Value
label	GummySharkTW
csirocode	37017001
fishery	SET_GAB
depthrange	0 - 500
depthclass	20
zones	1, 2, 3, 4, 5, 6, 7, 8, 9, 10
methods	TW, TDO, OTT
years	1996 - 2018

Table 8.17. GummySharkTW. Total catch (Total; t) is the total reported in the database, number of records used in the analysis (N), reported catch (Catch; t) in the area and depth used in the analysis and number of vessels used in the analysis (Vess). GeoM is the geometric mean of catch rates (kg/hr), standard deviation (StDev) relates to the optimum model. C<30Kg denotes the amount of catch in shots of <30kg, and P<30Kg is the proportion of total. The optimum model was SharkRegion:DepCat.

	Total	N	Catch	Vess	GeoM	Opt	StDev	C<30Kg	P<30Kg
1996	49.4	2234	40.5	72	5.2	0.9813	0.000	24.951	0.616
1997	952.1	2778	43.6	77	4.5	0.8663	0.028	28.084	0.643
1998	1401.1	2462	39.2	62	4.5	0.8596	0.029	27.357	0.698
1999	1923.8	2395	38.2	69	4.7	0.8925	0.029	23.234	0.609
2000	2436.9	3141	50.4	76	4.8	0.7848	0.028	29.821	0.591
2001	1703.3	3355	56.5	63	4.6	0.7707	0.028	30.462	0.539
2002	1527.1	3994	61.2	67	4.1	0.7306	0.027	34.925	0.571
2003	1653.0	4572	80.4	73	4.4	0.7884	0.027	40.661	0.506
2004	1669.9	4788	89.4	73	4.6	0.8037	0.027	43.556	0.487
2005	1573.2	5056	95.9	70	4.6	0.8143	0.027	48.241	0.503
2006	1577.1	4896	102.1	62	5.0	0.8391	0.027	43.956	0.431
2007	1575.0	3598	84.9	37	5.6	0.8513	0.028	34.983	0.412
2008	1727.7	3769	86.3	36	5.4	1.0075	0.028	38.720	0.448
2009	1500.9	3492	87.6	31	5.8	1.0983	0.028	37.903	0.432
2010	1404.8	3640	90.2	33	5.9	1.0929	0.028	39.510	0.438
2011	1364.7	4289	100.7	32	5.5	1.0014	0.027	43.337	0.430
2012	1304.2	3816	101.8	31	6.2	1.1147	0.028	40.763	0.401
2013	1307.6	3513	96.9	33	6.6	1.2497	0.028	43.274	0.447
2014	1389.1	3159	91.3	34	6.9	1.2197	0.029	37.298	0.408
2015	1545.1	2939	82.9	36	6.9	1.1862	0.029	35.122	0.423
2016	1586.5	2844	86.7	34	7.7	1.2235	0.030	32.200	0.371
2017	1561.3	2860	90.0	33	8.0	1.3116	0.030	32.544	0.361
2018	1560.1	2848	105.7	31	9.5	1.5121	0.030	28.449	0.269

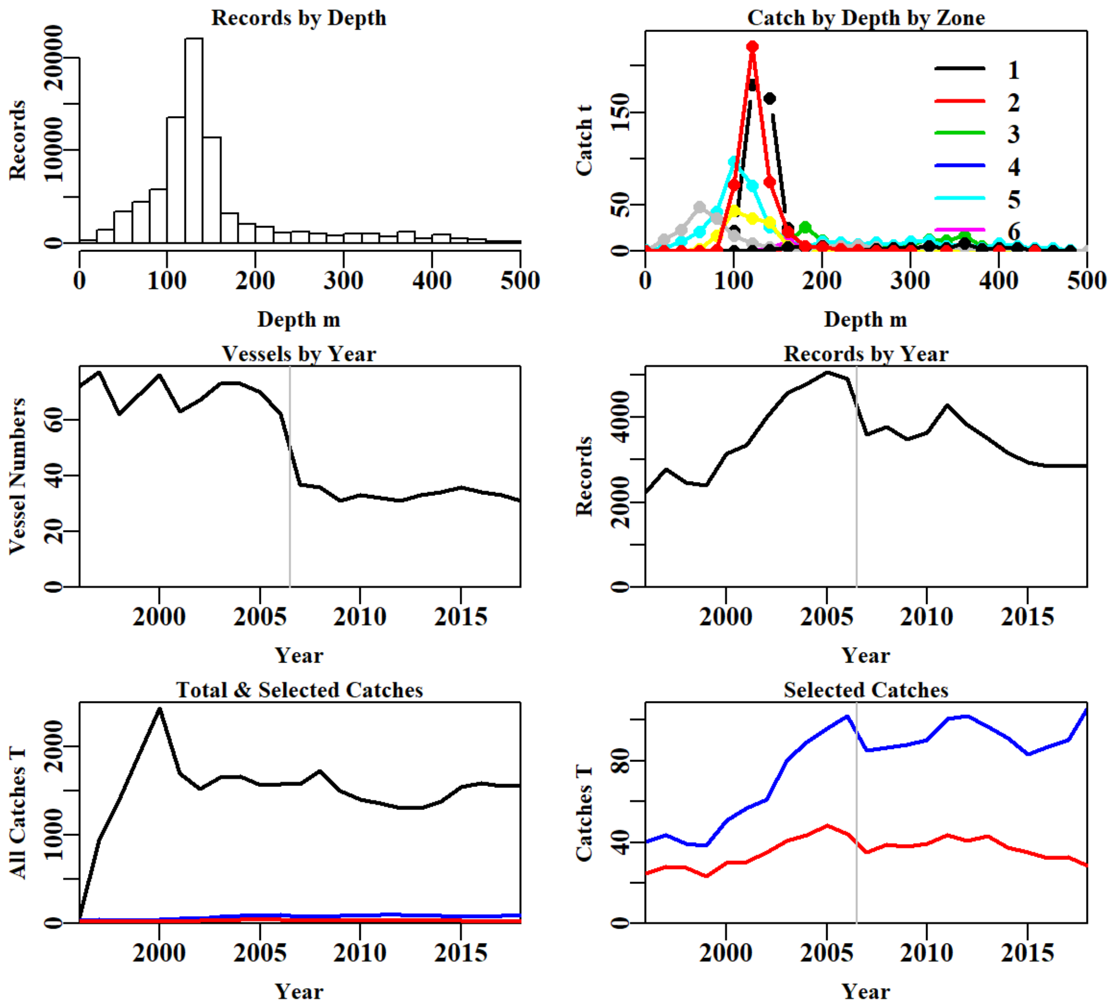

Figure 8.30. GummySharkTW fishery details. The bottom left plot depicts all known catches (top black line), and all selected catches used in the analysis (middle blue line); the lower red line: selected catches < 30 kg).

Table 8.18. GummySharkTW data selection effects. Total is the total number of records in the database, NoCE removes those records with either missing catch or effort, and then only those records are kept that meet the criteria for depth, years, zone, method, and fishery.

	Records	Difference	Catch	Difference
Total	405328	0	34938.920	0.000
NoCE	268058	137270	21455.751	13483.169
Depth	265934	2124	21349.930	105.821
Years	255498	10436	20773.764	576.166
Zones	254743	755	20744.733	29.031
Method	80706	174037	1804.556	18940.177
Fishery	80438	268	1802.489	2.067

Table 8.19. The models used to analyse data for GummySharkTW.

	Model
Model1	Year
Model2	Year + Vessel
Model3	Year + Vessel + DepCat
Model4	Year + Vessel + DepCat + SharkRegion
Model5	Year + Vessel + DepCat + SharkRegion + Month
Model6	Year + Vessel + DepCat + SharkRegion + Month + DayNight
Model7	Year + Vessel + DepCat + SharkRegion + Month + DayNight + SharkRegion:DepCat
Model8	Year + Vessel + DepCat + SharkRegion + Month + DayNight + SharkRegion:Month

Table 8.20. GummySharkTW. The row names are 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_r2) and the change in adjusted R^2 (%Change). The optimum model was SharkRegion:DepCat.

	AIC	RSS	MSS	Nobs	Npars	adj_r2	%Change
Year	10818	91965	3184	80438	23	3.3	0.00
Vessel	-1885	78269	16880	80438	157	17.6	14.26
DepCat	-3483	76682	18467	80438	182	19.2	1.65
SharkRegion	-4295	75894	19255	80438	191	20.0	0.82
Month	-6200	74098	21051	80438	202	21.9	1.88
DayNight	-7336	73054	22095	80438	205	23.0	1.10
SharkRegion:DepCat	-8848	71364	23785	80438	390	24.6	1.61
SharkRegion:Month	-7978	72295	22854	80438	304	23.7	0.71

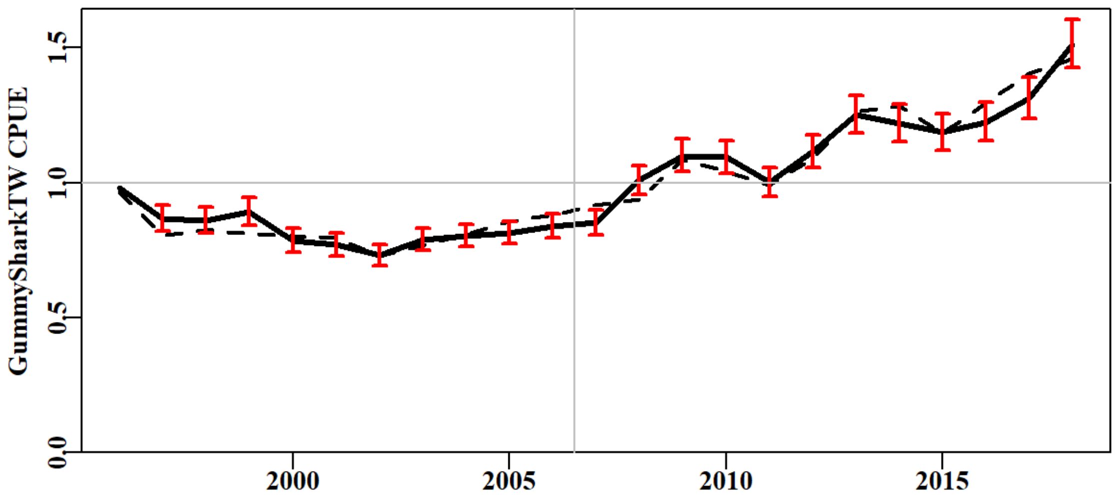

Figure 8.31. GummySharkTW standardization. The dashed black line represents the geometric mean catch rate, solid black line the standardized catch rates. The red bars are the 95% confidence intervals about the mean estimates. The graph scales both time-series of standardized catch rates relative to the mean of each time-series.

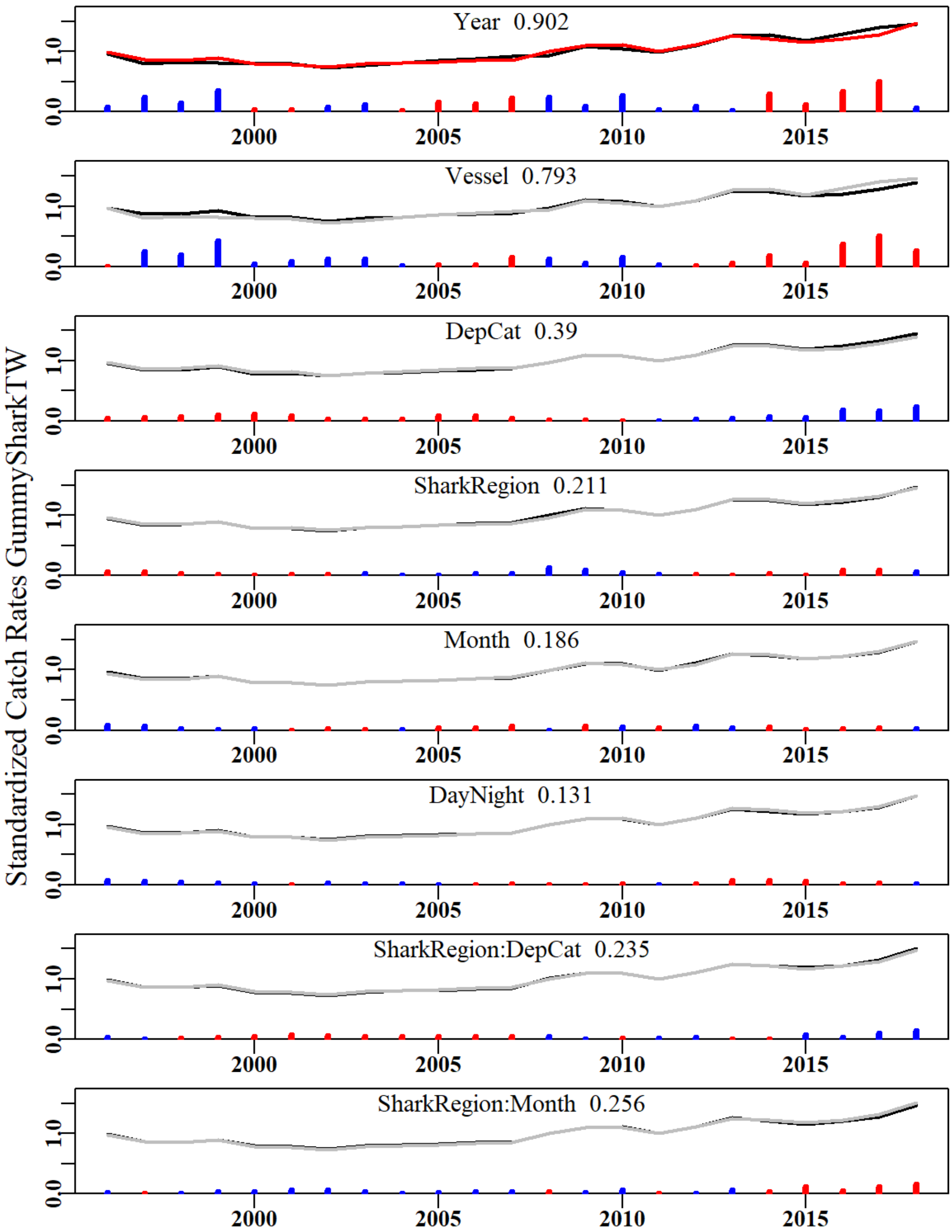

Figure 8.32. GummySharkTW. The influence of each factor on the optimal standardization. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by vertical bars with blue bars indicating the optimum model is higher than the geometric mean and red bars indicating it is lower. The top graph bars are the sum of all the bars in the graphs below. The graphs for individual factors are cumulative. Thus the second graph has the geometric mean (grey line) and the effect of adding Year + factor2 (Model 2). In the third graph, the grey line represents Model 2 and the black line the effect of adding factor3 to the model. The remaining graphs continue in the same cumulative manner except for the interaction terms which are added singularly to the final single factor model.

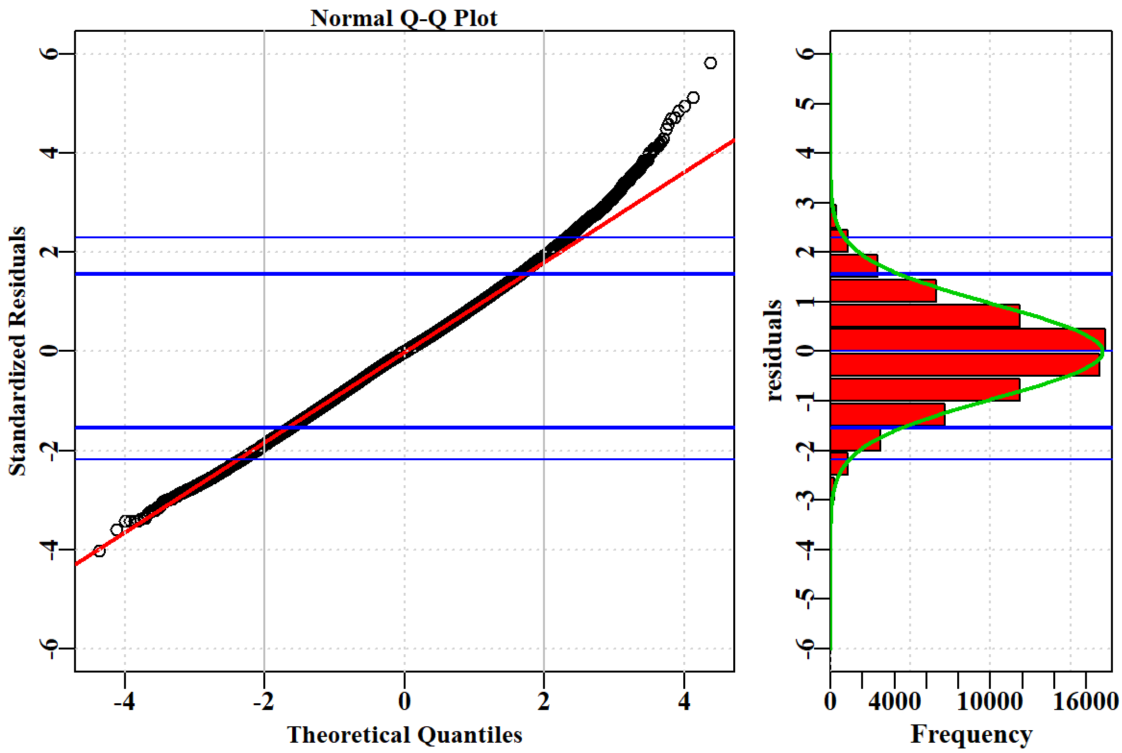

Figure 8.33. GummySharkTW. Diagnostic plots. The distribution of residuals from the optimum fit. The qqplot indicates the fit to the expected normality, while the histogram of residuals also illustrates the 1%, 5%, 95% and 99% quantiles to indicate the intensity of any lack of fit at the margins of the distribution (reflected also in the qqplot).

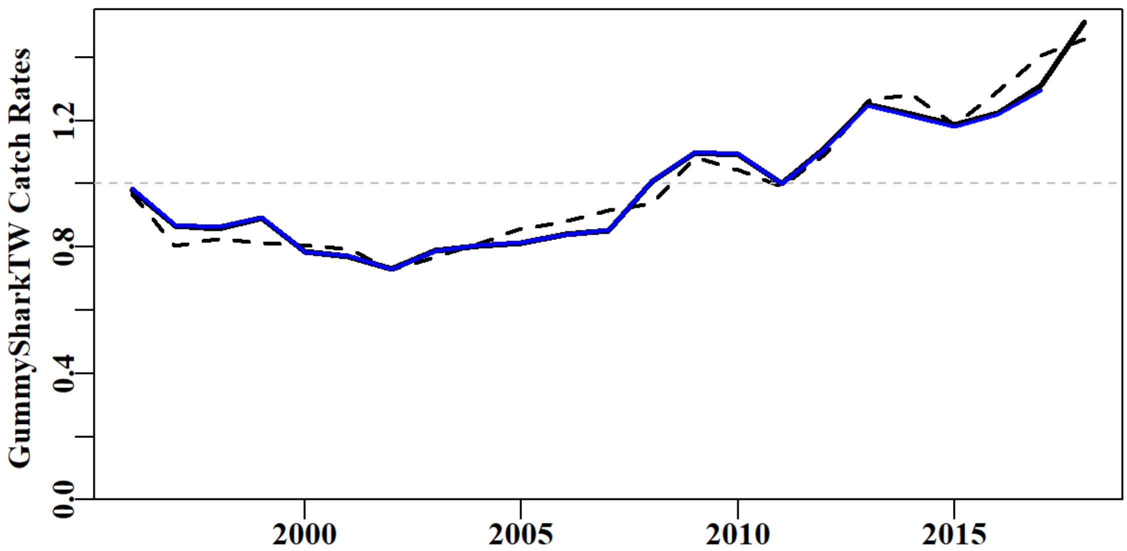

Figure 8.34. GummySharkTW. A comparison of the previous year's standardization (blue line) with this year's. They should lie on top of each other, although small deviations may relate to data adjustments, particularly in very recent years.

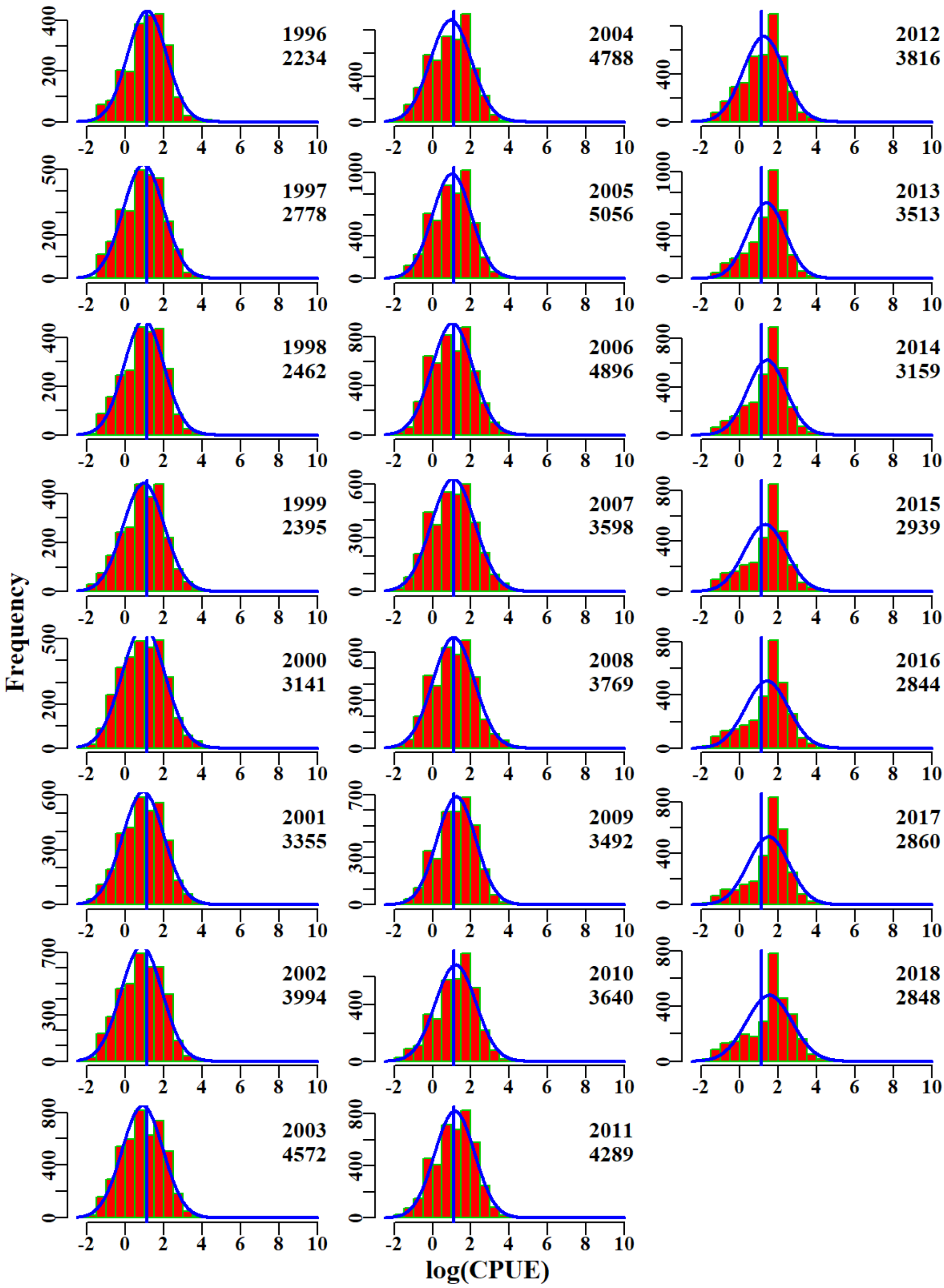

Figure 8.35. GummySharkTW. The natural log(CPUE) for each year of data available the blue lines are normal distributions fitted to the histogram frequencies. The numbers in each plot are the year and number of records. The vertical blue line is the average across all years.

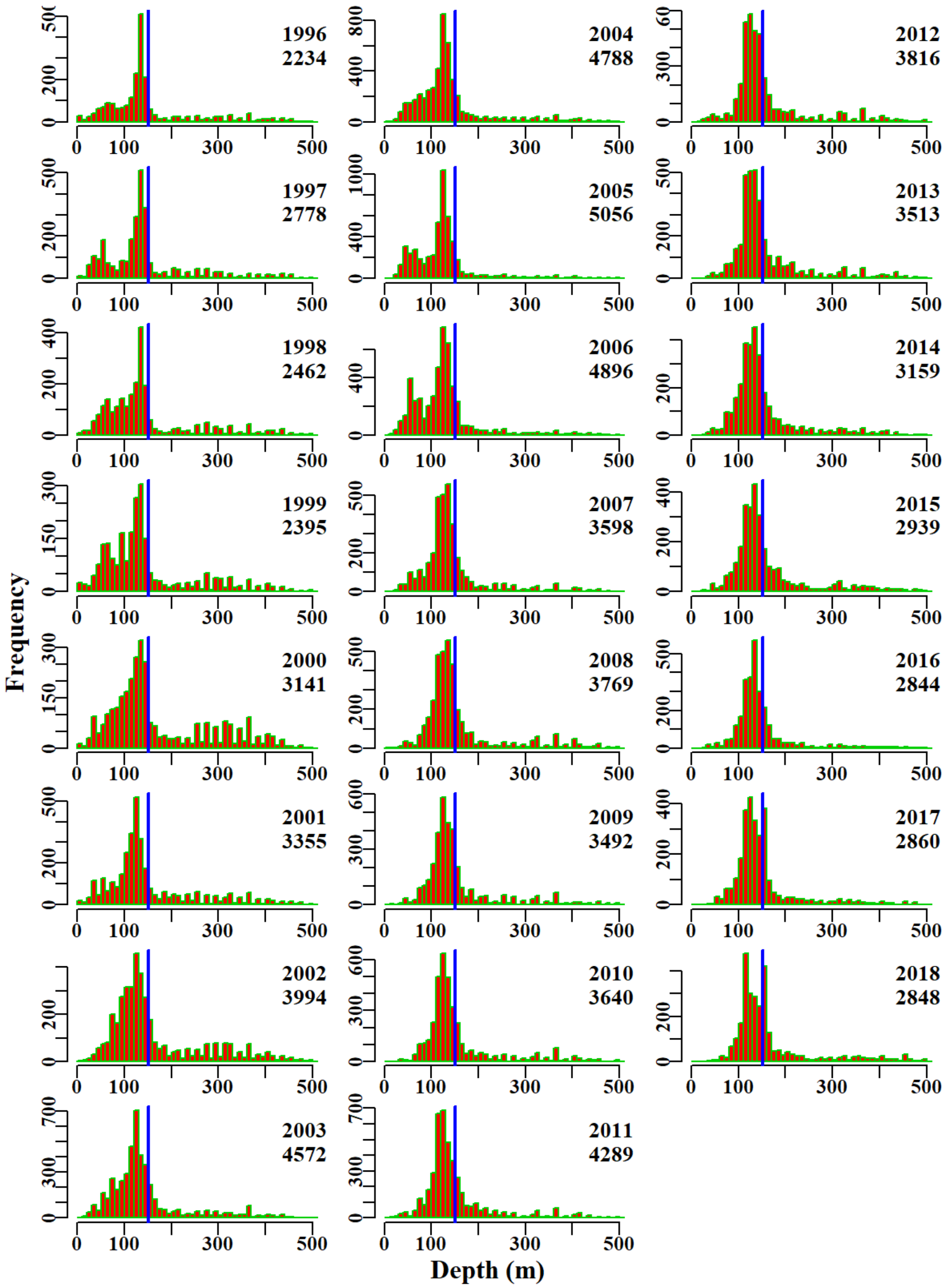

Figure 8.36. GummySharkTW. The average Depth of fishing for each year of data available to illustrate the development of the fishery through time. The numbers in each plot are the year and number of records. The vertical blue line is the average across all years.

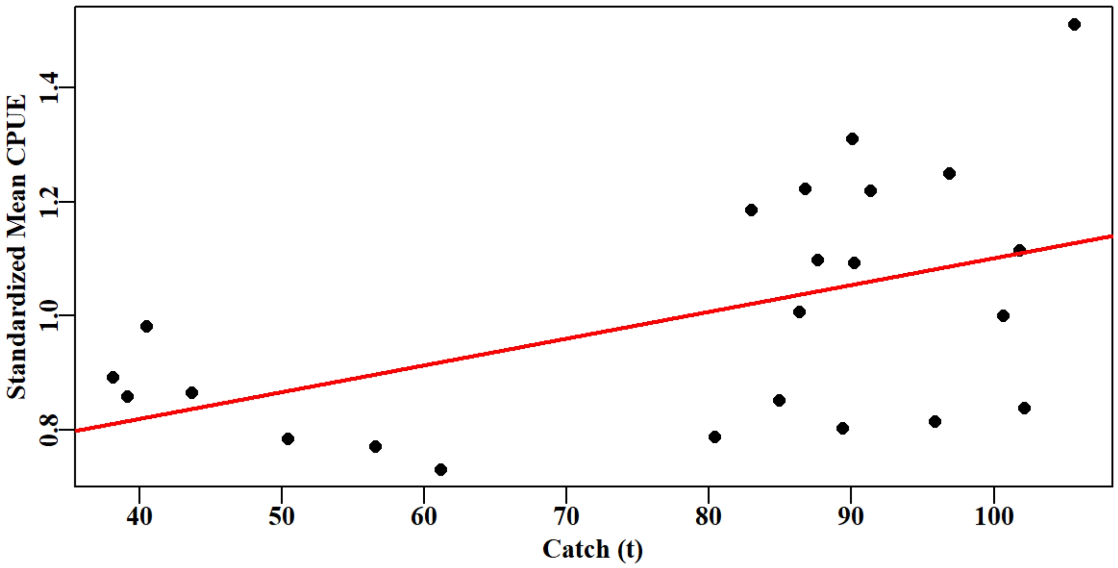

Figure 8.37. GummySharkTW. The linear relationship between Annual mean CPUE and Annual Catch.

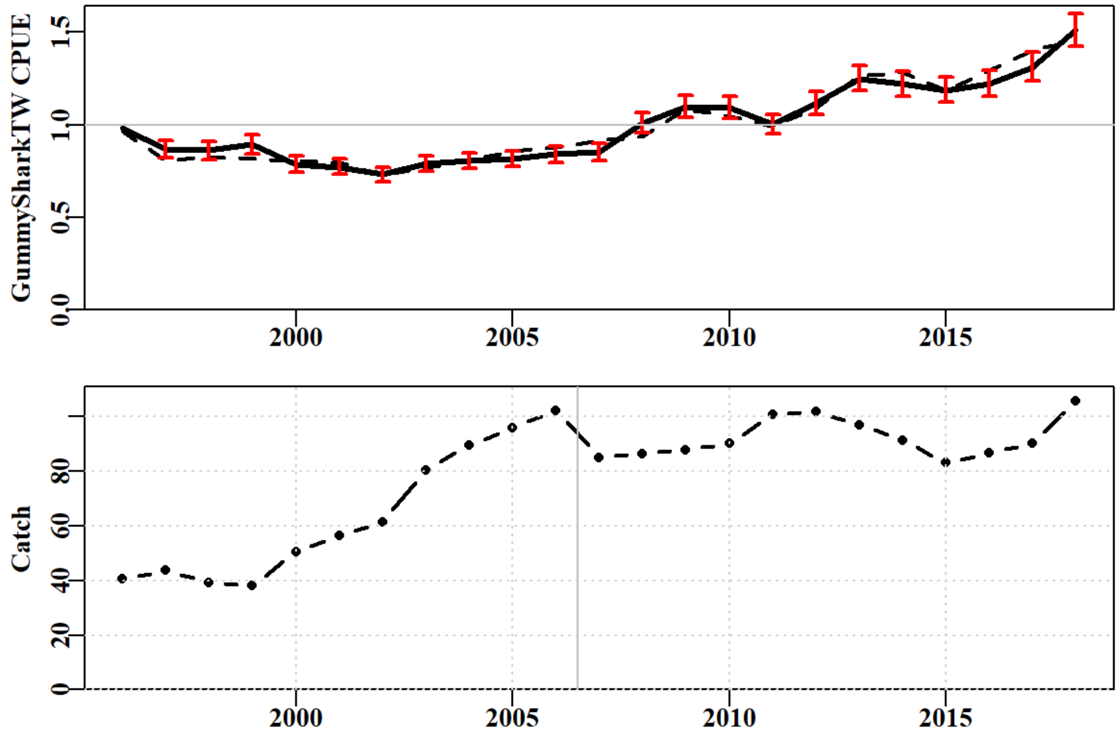

Figure 8.38. GummySharkTW. The linear relationship between annual mean CPUE and annual Catch.

8.8 Gummy shark: Bottom Line

Records pertaining to shark zones 8 and 10 were omitted from analysis since they contributed very little to the overall catch (8: 0.02 %; 10: 0.007 %; less than one tonne in each shark zone). Furthermore, non-zero catches per shot were employed in the statistical standardization analyses for gummy shark caught by bottom line. Currently, effort units are recorded inconsistently in the logbook database for bottom line caught gummy shark. Any of three alternative pairs of units can be recorded for a shot:(i) THS (total hooks per set) and TLM (total length of mainline used); (ii) NLP (number of lines per shot) and THS (total number of hooks per set); and (iii) NLS (total number lines per shot) and THS (total number of hooks per shot) and/or HRS (hours). No clear method was apparent for including these inconsistent effort units in a single standardization. However the alternative is to assume that every fishing operation has the same probability of catching sharks, regardless of the number of hooks used, length of line, or soak time. A detailed analysis of these effort units should be investigated to determine whether (i) through to (iii) or some combination could be used as an alternative effort unit in the standardization analyses.

A total of 8 statistical models were fitted sequentially to the available data, and the order of the non-interaction terms added based on the relative contribution of each term to model fit.

8.8.1 Inferences

The majority of catch occurred in Shark regions 2, 5 followed by 3.

The terms Year, Vessel, DepCat, SharkRegion, Month and one interaction (SharkRegion:Month) had the greatest contribution to model fit based on the AIC and R2 statistics (Table 8.25). The qqplot suggests a slight departure from the assumed Normal distribution, as depicted from both tails of the distribution (Figure 8.42). Annual standardized CPUE has been noisy and mostly flat since the start of the time series (Figure 8.40).

8.8.2 Action Items and Issues

A further consideration of whether or not to consider the CPUE time-series as a valid index of relative abundance for gummy shark needs to be explored.

Table 8.21. GummySharkBL. The data selection criteria used to specify and identify the fishery data to be included in the analysis.

Property	Value
label	GummySharkBL
csirocode	37017001
fishery	GHT_SSF_,SEN_SSH_SSG
depthrange	0 - 200
depthclass	20
zones	1, 2, 3, 4, 5, 6, 7, 8, 9, 10
methods	BL
years	1998 - 2018

Table 8.22. GummySharkBL. Total catch (Total; t) is the total reported in the database, number of records used in the analysis (N), reported catch (Catch; t) in the area and depth used in the analysis and number of vessels used in the analysis (Vess). GeoM is the geometric mean of catch rates (kg/hr), standard deviation (StDev) relates to the optimum model. C<30Kg denotes the amount of catch in shots of <30kg, and P<30Kg is the proportion of total. The optimum model was SharkRegion:Month.

	Total	N	Catch	Vess	GeoM	Opt	StDev	C<30Kg	P<30Kg
1998	1401.1	72	8.5	3	123.8	1.0113	0.000	0.180	0.021
1999	1923.8	333	46.7	13	150.8	1.1767	0.157	0.656	0.014
2000	2436.9	481	111.4	14	276.2	1.3286	0.189	0.927	0.008
2001	1703.3	541	58.7	23	130.4	0.7889	0.192	2.494	0.043
2002	1527.1	495	59.0	21	136.5	0.8834	0.193	2.242	0.038
2003	1653.0	619	64.5	27	120.3	0.7716	0.192	2.949	0.046
2004	1669.9	640	66.9	24	119.8	0.8042	0.191	2.912	0.044
2005	1573.2	578	59.6	24	117.9	0.9481	0.193	2.713	0.046
2006	1577.1	495	48.7	19	105.5	1.0301	0.194	2.909	0.060
2007	1575.0	625	54.4	19	88.9	0.9165	0.193	4.651	0.085
2008	1727.7	599	50.1	16	91.8	0.6785	0.195	4.368	0.087
2009	1500.9	819	67.0	15	86.4	0.7756	0.194	5.516	0.082
2010	1404.8	684	72.0	19	119.4	0.9266	0.194	3.713	0.052
2011	1364.7	1045	87.2	28	96.2	1.0118	0.194	5.974	0.069
2012	1304.2	1407	124.2	24	97.8	1.0307	0.193	7.392	0.060
2013	1307.6	2515	229.1	27	100.5	1.1371	0.193	13.533	0.059
2014	1389.1	2758	225.7	29	89.6	0.9727	0.193	17.426	0.077
2015	1545.1	1948	187.3	28	106.9	1.2398	0.193	11.015	0.059
2016	1586.5	1388	147.4	25	120.1	0.9947	0.194	7.387	0.050
2017	1561.3	1876	289.3	32	184.5	1.2037	0.193	7.760	0.027
2018	1560.1	1844	251.7	38	154.9	1.3695	0.194	8.875	0.035

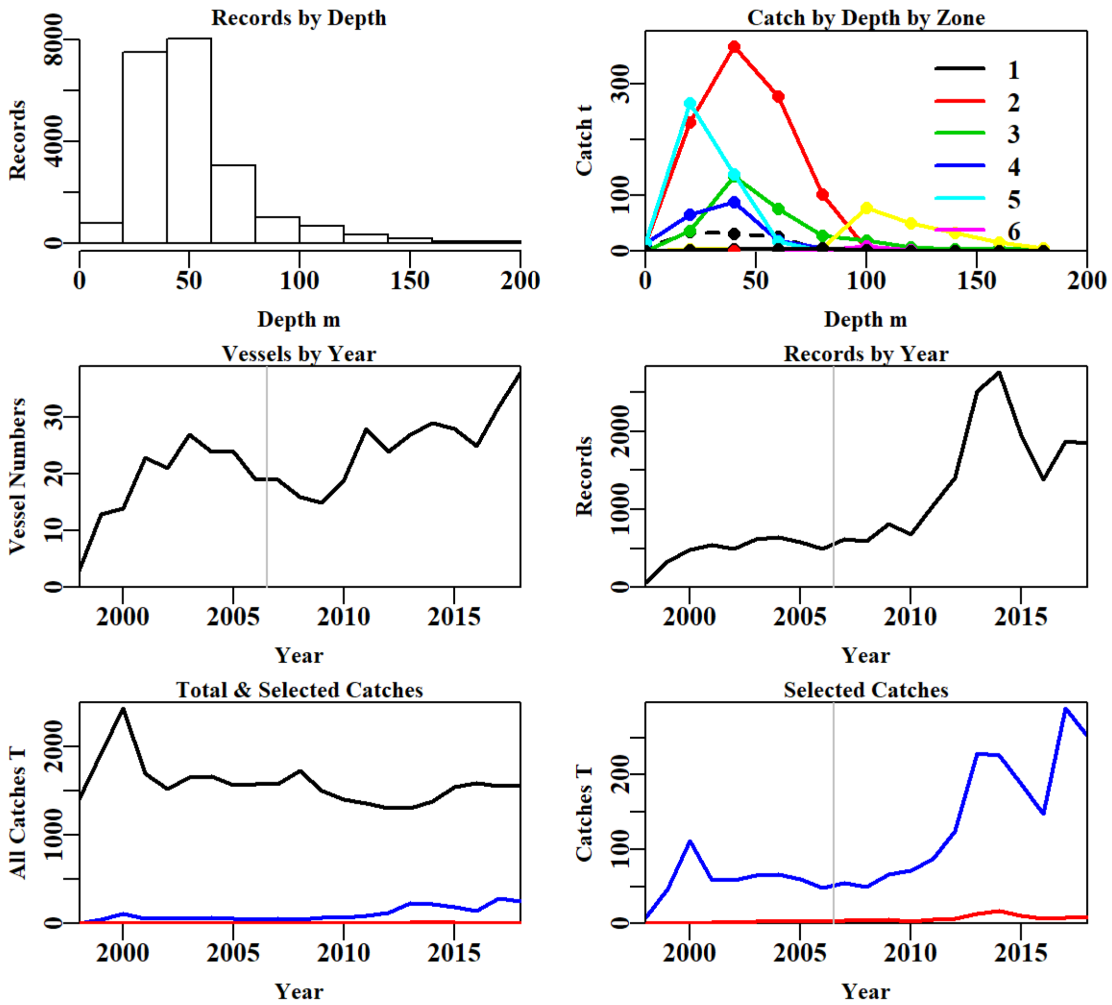

Figure 8.39. GummySharkBL fishery details. The bottom left plot depicts all known catches (top black line), and all selected catches used in the analysis (middle blue line); the lower red line: selected catches < 30 kg).

Table 8.23. GummySharkBL data selection effects. Total is the total number of records in the database, NoCE removes those records with either missing catch or effort, and then only those records are kept that meet the criteria for depth, years, zone, method, and fishery.

	Records	Difference	Catch	Difference
Total	405328	0	34938.920	0.000
NoCE	395465	9863	34938.920	0.000
Depth	373918	21547	34107.971	830.949
Years	345999	27919	32538.636	1569.334
Zones	345694	305	32506.087	32.549
Method	22141	323553	2349.206	30156.880
Fishery	21762	379	2309.480	39.727

Table 8.24. The models used to analyse data for GummySharkBL.

	Model
Model1	Year
Model2	Year + Vessel
Model3	Year + Vessel + DepCat
Model4	Year + Vessel + DepCat + SharkRegion
Model5	Year + Vessel + DepCat + SharkRegion + Month
Model6	Year + Vessel + DepCat + SharkRegion + Month + DayNight
Model7	Year + Vessel + DepCat + SharkRegion + Month + DayNight + SharkRegion:DepCat
Model8	Year + Vessel + DepCat + SharkRegion + Month + DayNight + SharkRegion:Month

Table 8.25. GummySharkBL. The row names are 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_r2) and the change in adjusted R^2 (%Change). The optimum model was SharkRegion:Month.

	AIC	RSS	MSS	Nobs	Npars	adj_r2	%Change
Year	8936	32749	1497	21762	21	4.3	0.00
Vessel	693	22126	12120	21762	166	34.9	30.61
DepCat	408	21821	12425	21762	175	35.8	0.87
SharkRegion	340	21734	12512	21762	184	36.0	0.23
Month	310	21682	12563	21762	195	36.1	0.12
DayNight	310	21676	12569	21762	198	36.1	0.01
SharkRegion:DepCat	254	21510	12736	21762	254	36.5	0.33
SharkRegion:Month	137	21351	12894	21762	276	36.9	0.73

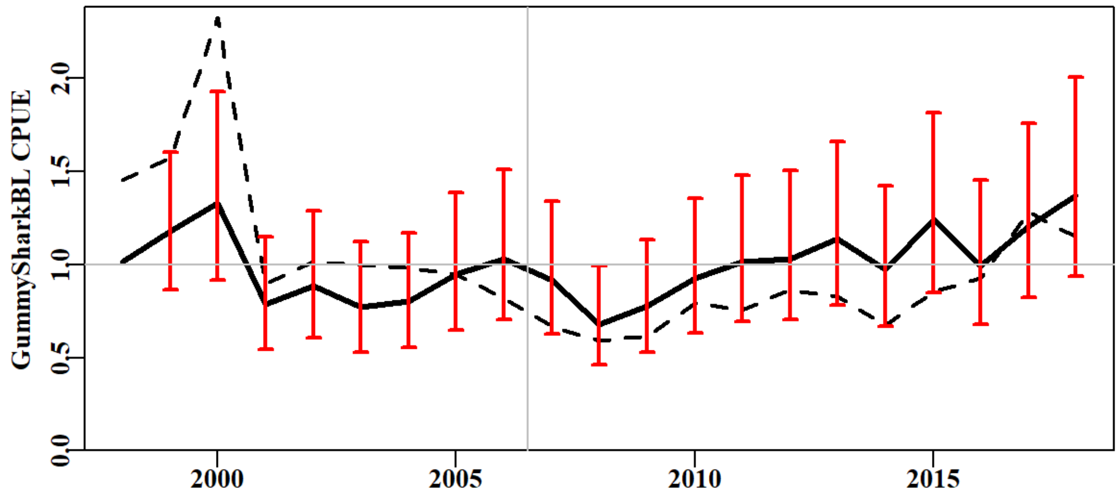

Figure 8.40. GummySharkBL standardization. The dashed black line represents the geometric mean catch rate, solid black line the standardized catch rates. The red bars are the 95% confidence intervals about the mean estimates. The graph scales both time-series of standardized catch rates relative to the mean of each time-series.

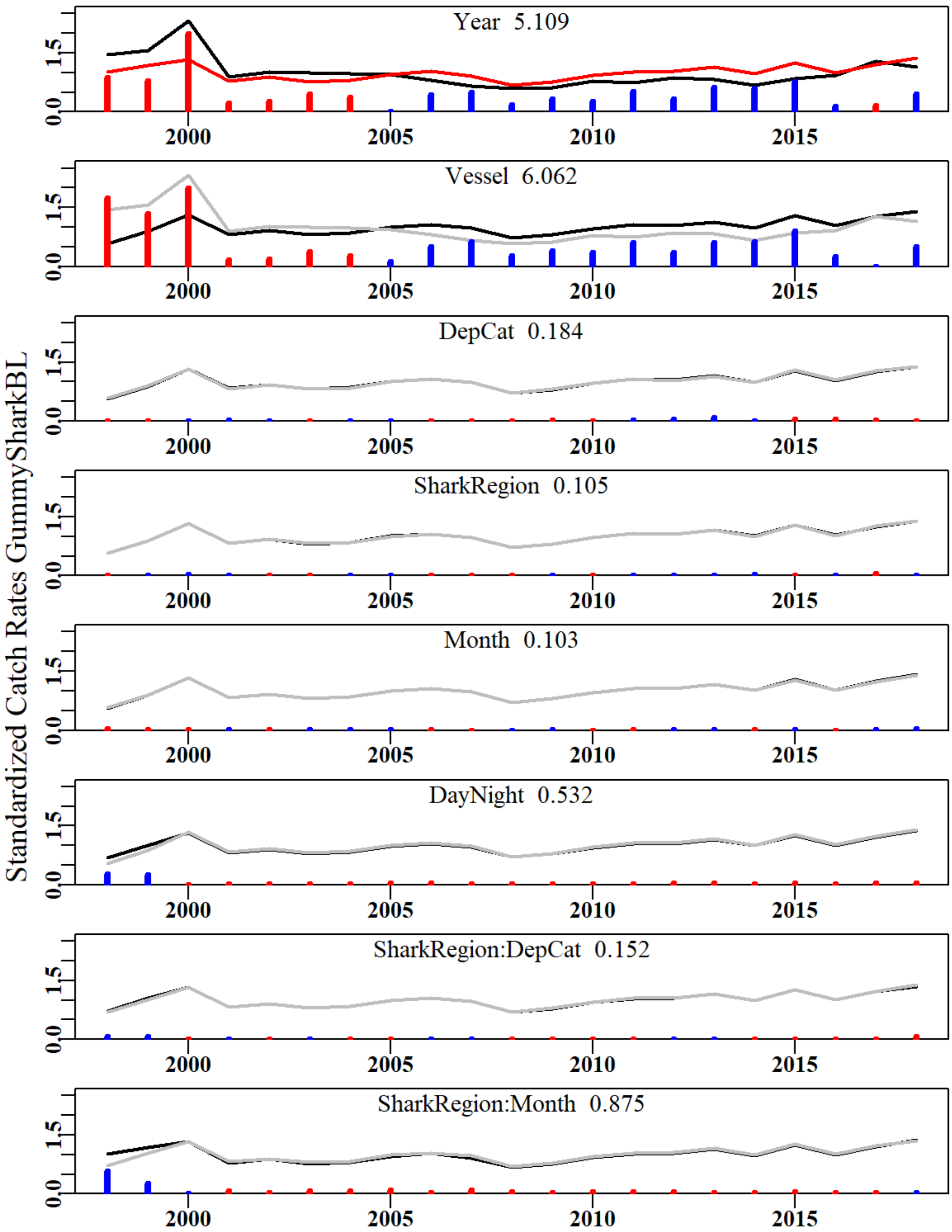

Figure 8.41. GummySharkBL. The influence of each factor on the optimal standardization. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by vertical bars with blue bars indicating the optimum model is higher than the geometric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

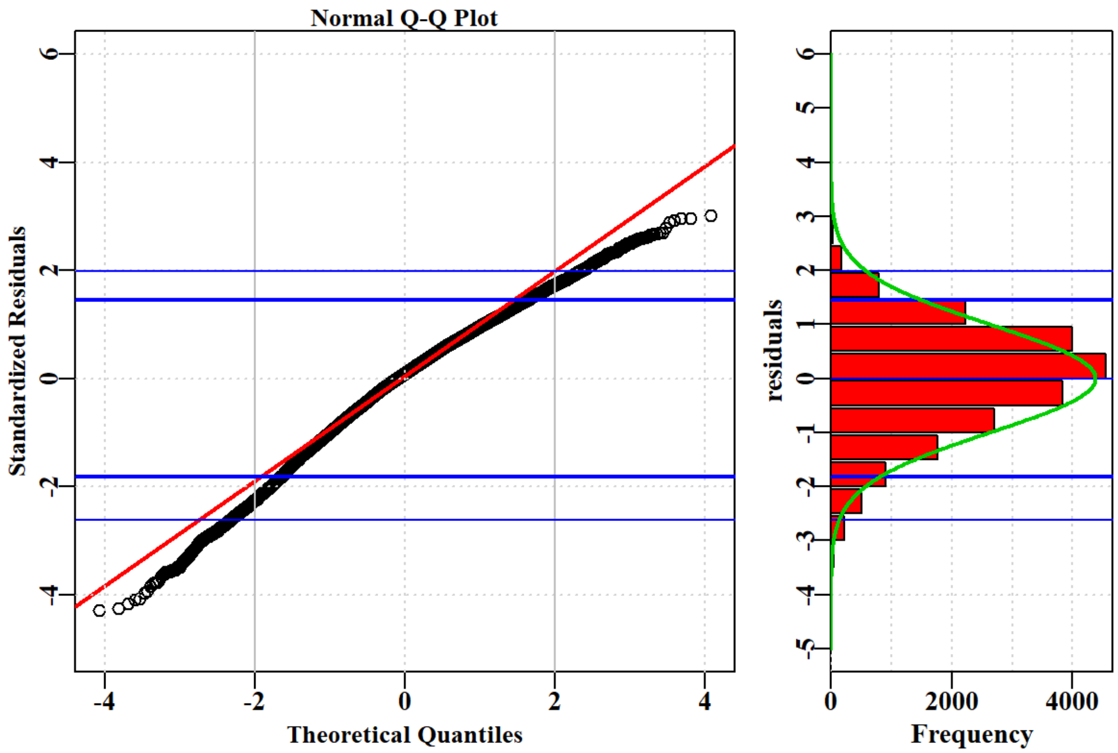

Figure 8.42. GummySharkBL. Diagnostic plots. The distribution of residuals from the optimum fit. The qqplot indicates the fit to the expected normality, while the histogram of residuals also illustrates the 1%, 5%, 95% and 99% quantiles to indicate the intensity of any lack of fit at the margins of the distribution (reflected also in the qqplot).

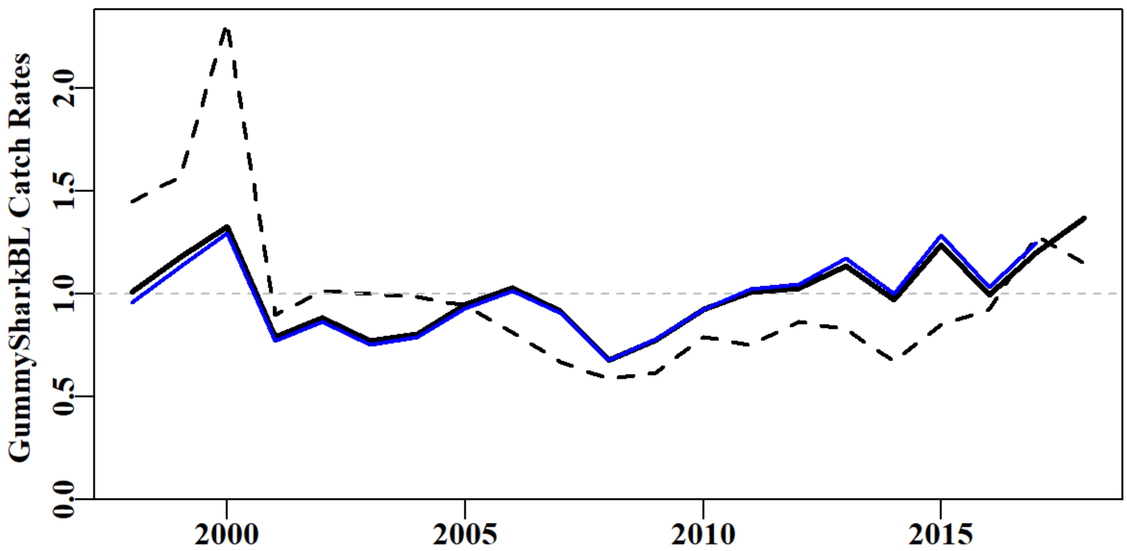

Figure 8.43. GummySharkBL. A comparison of the previous year's standardization (blue line) with this year's. They should lie on top of each other, although small deviations may relate to data adjustments, particularly in very recent years.

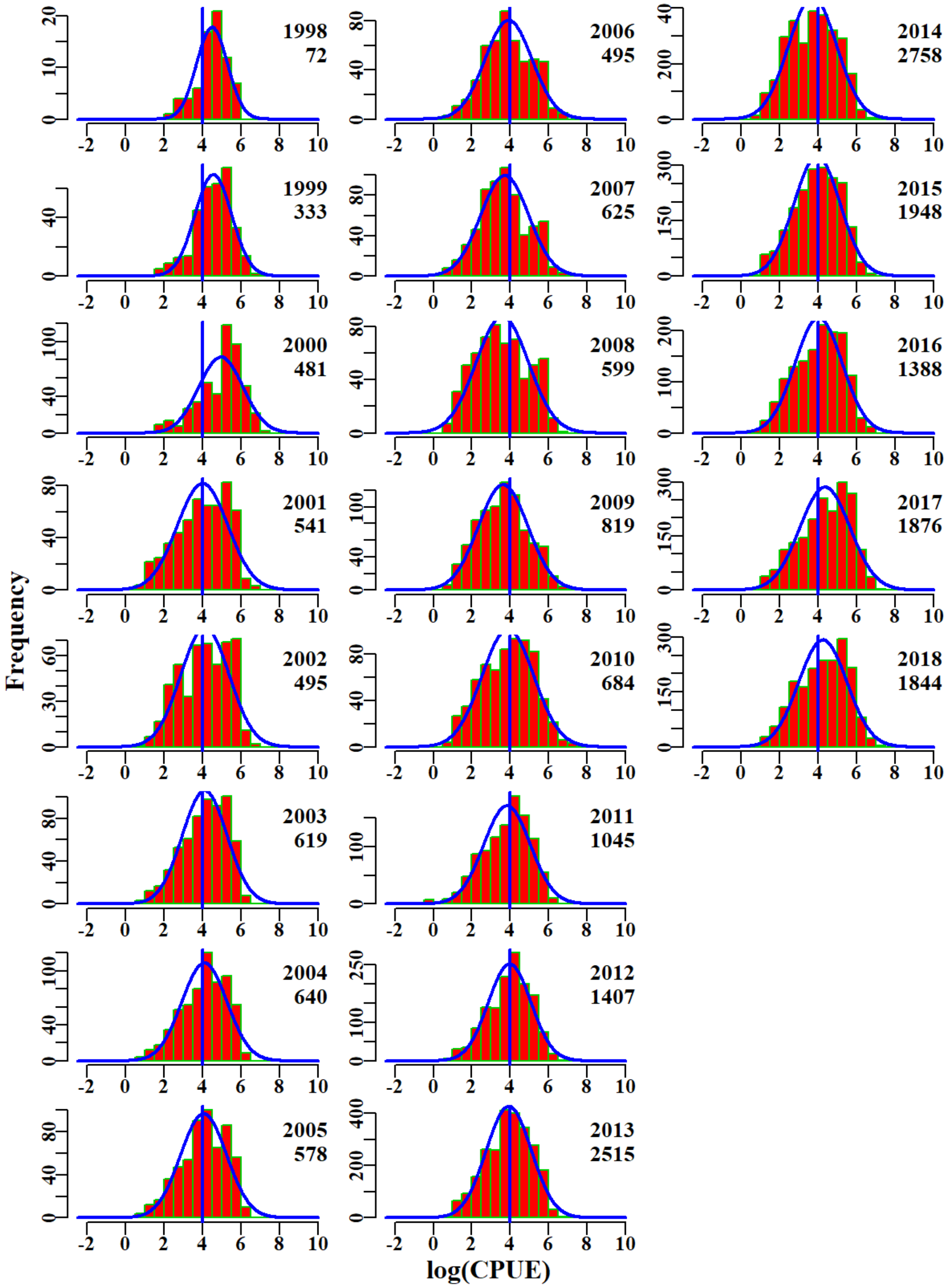

Figure 8.44. GummySharkBL. The natural log(CPUE) for each year of data available the blue lines are normal distributions fitted to the histogram frequencies. The numbers in each plot are the year and number of records. The vertical blue line is the average across all years.

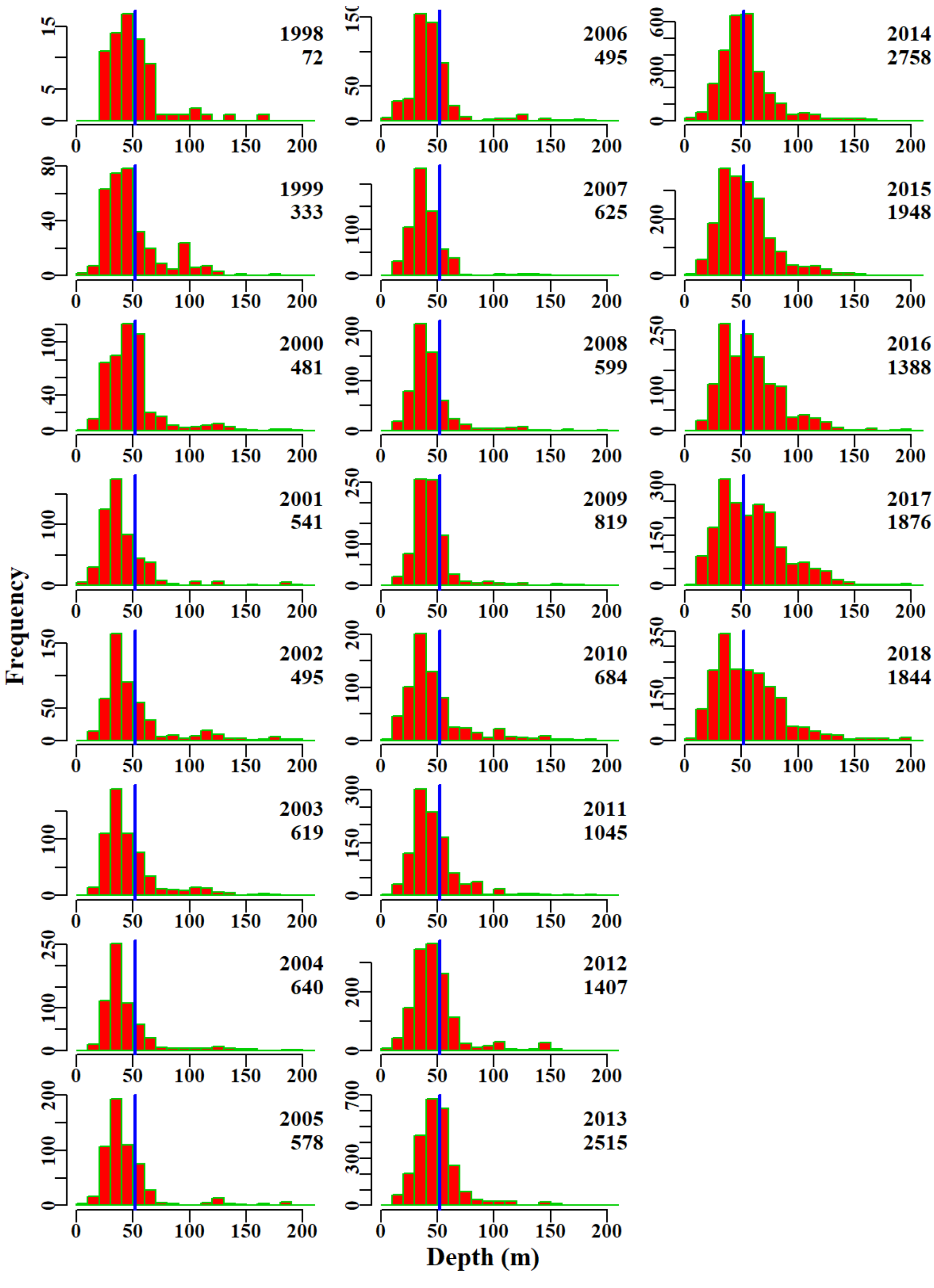

Figure 8.45. GummySharkBL. The average Depth of fishing for each year of data available to illustrate the development of the fishery through time. The numbers in each plot are the year and number of records. The vertical blue line is the average across all years.

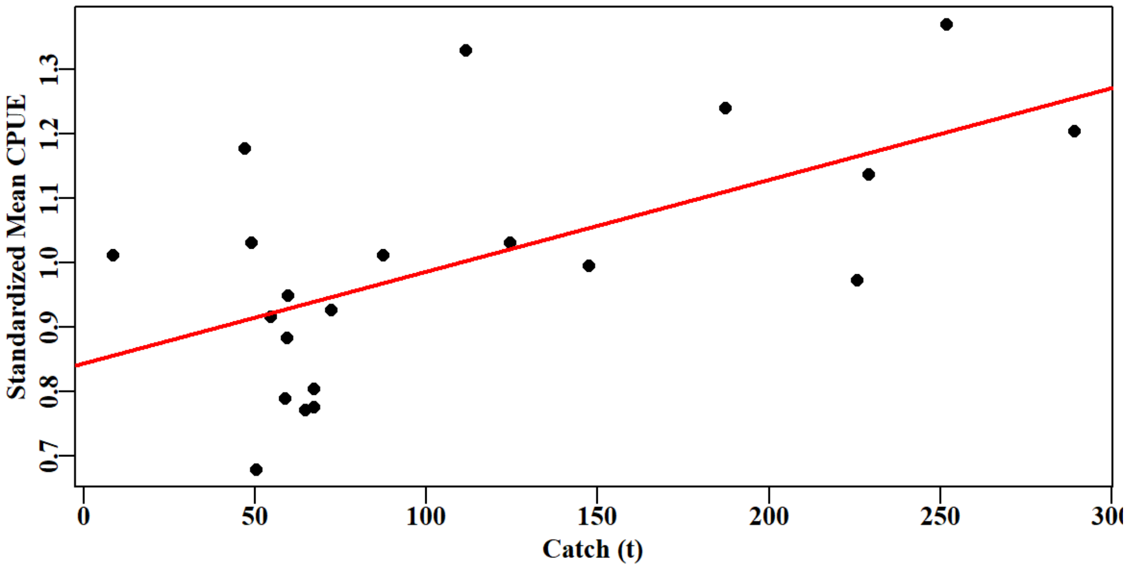

Figure 8.46. GummySharkBL. The linear relationship between Annual mean CPUE and Annual Catch.

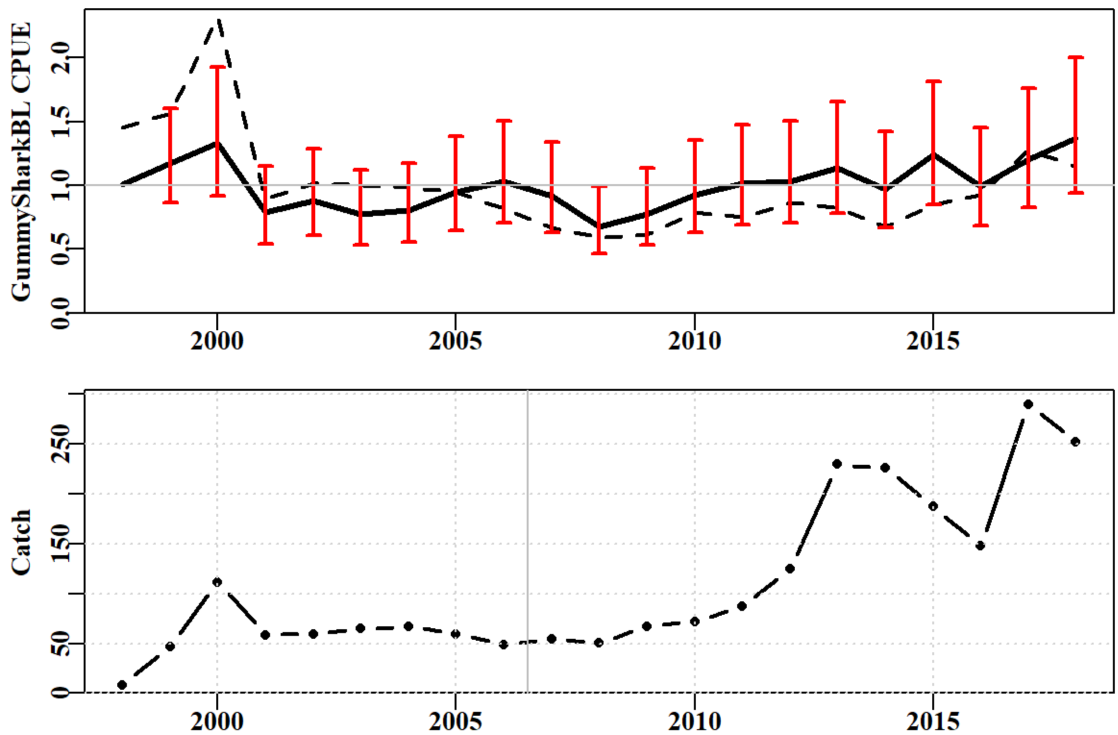

Figure 8.47. GummySharkBL. CPUE is correlated with catches through time. CPUE in the top plot and annual catch (t) in the lower plot.

8.9 School shark: Trawl

Given the change from targeting, to increasingly active avoidance of school shark 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. There were various data selections made with respect to gear types, depths and years prior to data analysis.

A total of 8 statistical models were fitted sequentially to the available data, and the order of the non-interaction terms added based on the relative contribution of each term to model fit.

8.9.1 *Inferences*

The majority of catch occurred in Shark region 6.

The terms Year, Vessel, DepCat, SharkRegion, Month, DayNight and one interaction (SharkRegion:Month) had the greatest contribution to model fit based on the AIC and R2 statistics (Table 8.30). The first two terms had the greatest contribution to model fit. The qqplot suggests a slight departure from the assumed Normal distribution, as depicted from the upper tail of the distribution (Figure 8.51). Annual standardized CPUE has been significantly above the long-term average since 2013. There was a slight decrease in standardized CPUE in 2017 relative to 2016 (Figure 8.49).

8.9.2 *Action Items and Issues*

Table 8.26. SchoolSharkTW. The data selection criteria used to specify and identify the fishery data to be included in the analysis.

Property	Value
label	SchoolSharkTW
csirocode	37017008
fishery	SET_GAB
depthrange	0 - 600
depthclass	25
zones	1, 2, 3, 4, 5, 6, 7, 8, 9, 10
methods	TW, TDO, OTT
years	1996 - 2018

Table 8.27. SchoolSharkTW. Total catch (Total; t) is the total reported in the database, number of records used in the analysis (N), reported catch (Catch; t) in the area and depth used in the analysis and number of vessels used in the analysis (Vess). GeoM is the geometric mean of catch rates (kg/hr), standard deviation (StDev) relates to the optimum model. C<30Kg denotes the amount of catch in shots of <30kg, and P<30Kg is the proportion of total. The optimum model was SharkRegion:Month.

	Total	N	Catch	Vess	GeoM	Opt	StDev	C<30Kg	P<30Kg
1996	29.1	922	24.4	67	7.6	1.2054	0.000	11.882	0.486
1997	457.0	1187	23.7	60	6.4	1.0524	0.043	13.246	0.560
1998	562.0	957	19.8	51	6.0	0.9854	0.045	10.817	0.546
1999	490.6	759	14.1	51	5.4	0.8998	0.050	9.078	0.644
2000	464.9	919	16.6	70	5.0	0.7701	0.048	8.720	0.524
2001	190.6	859	15.7	47	5.2	0.7558	0.049	8.919	0.568
2002	219.5	943	16.9	57	5.2	0.7935	0.048	9.283	0.550
2003	218.2	767	13.2	59	4.8	0.7298	0.051	7.482	0.568
2004	200.3	697	13.3	54	4.5	0.7524	0.053	6.954	0.521
2005	210.3	517	8.3	45	4.2	0.7833	0.056	4.784	0.577
2006	212.0	570	10.9	47	4.9	0.7846	0.055	5.154	0.474
2007	197.8	348	7.3	32	5.9	0.8234	0.064	3.469	0.474
2008	234.4	404	9.0	30	5.7	0.9948	0.061	3.817	0.425
2009	253.1	438	13.6	28	6.7	1.0523	0.059	4.441	0.326
2010	180.1	428	12.6	26	7.2	0.9941	0.060	4.007	0.318
2011	182.4	449	13.8	28	6.8	0.9804	0.059	4.004	0.290
2012	136.0	342	10.9	26	8.2	1.0554	0.064	2.979	0.274
2013	150.0	372	18.3	32	12.2	1.1562	0.064	3.218	0.176
2014	200.0	394	11.2	26	7.1	1.1153	0.061	3.829	0.341
2015	146.9	333	12.3	26	8.1	1.1752	0.065	3.557	0.290
2016	133.9	363	14.1	26	8.7	1.3529	0.063	4.188	0.297
2017	225.6	544	20.8	22	8.5	1.3567	0.059	5.831	0.280
2018	153.5	525	23.9	25	9.5	1.4307	0.060	5.545	0.232

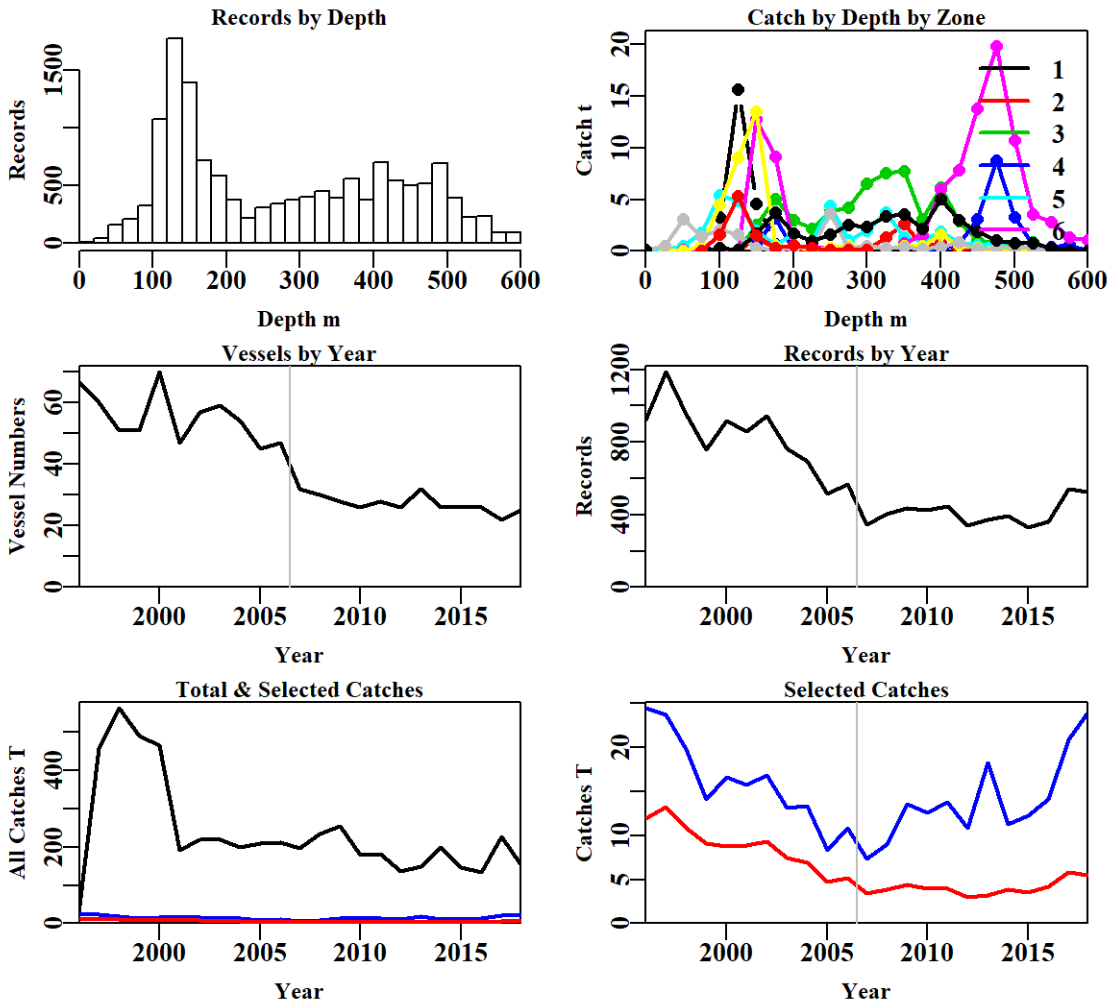

Figure 8.48. SchoolSharkTW fishery details. The bottom left plot depicts all known catches (top black line), and all selected catches used in the analysis (middle blue line); the lower red line: selected catches < 30 kg).

Table 8.28. SchoolSharkTW data selection effects. Total is the total number of records in the database, NoCE removes those records with either missing catch or effort, and then only those records are kept that meet the criteria for depth, years, zone, method, and fishery.

	Records	Difference	Catch	Difference
Total	113458	0	5672.229	0.000
NoCE	71238	42220	3477.954	2194.276
Depth	70561	677	3443.863	34.091
Years	65471	5090	3243.725	200.138
Zones	65251	220	3240.184	3.541
Method	14038	51213	344.656	2895.528
Fishery	14037	1	344.646	0.010

Table 8.29. The models used to analyse data for SchoolSharkTW.

	Model
Model1	Year
Model2	Year + Vessel
Model3	Year + Vessel + DepCat
Model4	Year + Vessel + DepCat + SharkRegion
Model5	Year + Vessel + DepCat + SharkRegion + Month
Model6	Year + Vessel + DepCat + SharkRegion + Month + DayNight
Model7	Year + Vessel + DepCat + SharkRegion + Month + DayNight + SharkRegion:DepCat
Model8	Year + Vessel + DepCat + SharkRegion + Month + DayNight + SharkRegion:Month

Table 8.30. SchoolSharkTW. The row names are 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_r2) and the change in adjusted R^2 (%Change). The optimum model was SharkRegion:Month.

	AIC	RSS	MSS	Nobs	Npars	adj_r2	%Change
Year	3139	17498	512	14037	23	2.7	0.00
Vessel	-368	13365	4645	14037	160	24.9	22.25
DepCat	-1101	12642	5368	14037	184	28.9	3.94
SharkRegion	-1806	12007	6003	14037	193	32.4	3.53
Month	-1898	11911	6099	14037	204	32.9	0.49
DayNight	-1959	11854	6156	14037	207	33.2	0.31
SharkRegion:DepCat	-2124	11443	6567	14037	372	34.7	1.54
SharkRegion:Month	-2202	11489	6521	14037	305	34.8	1.59

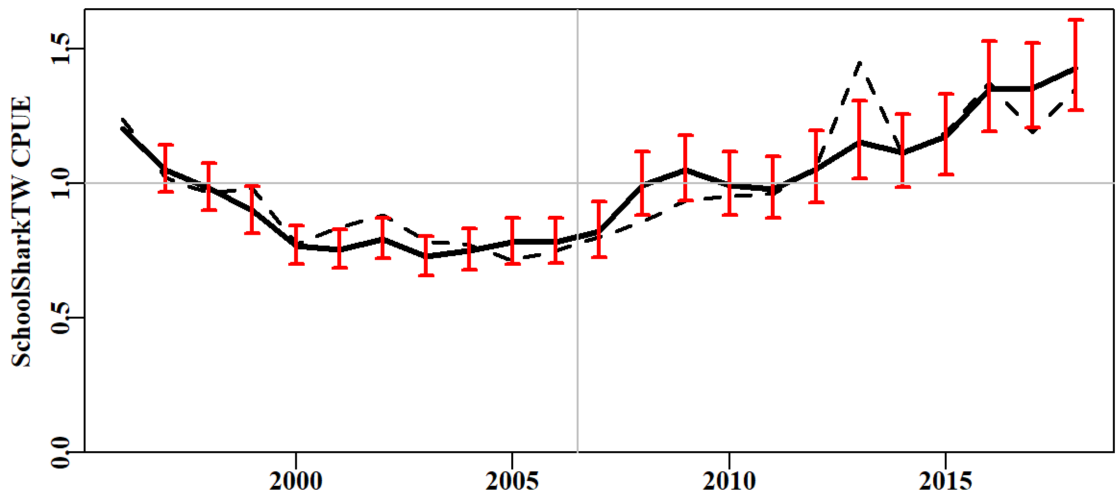

Figure 8.49. SchoolSharkTW standardization. The dashed black line represents the geometric mean catch rate, solid black line the standardized catch rates. The red bars are the 95% confidence intervals about the mean estimates. The graph scales both time-series of standardized catch rates relative to the mean of each time-series.

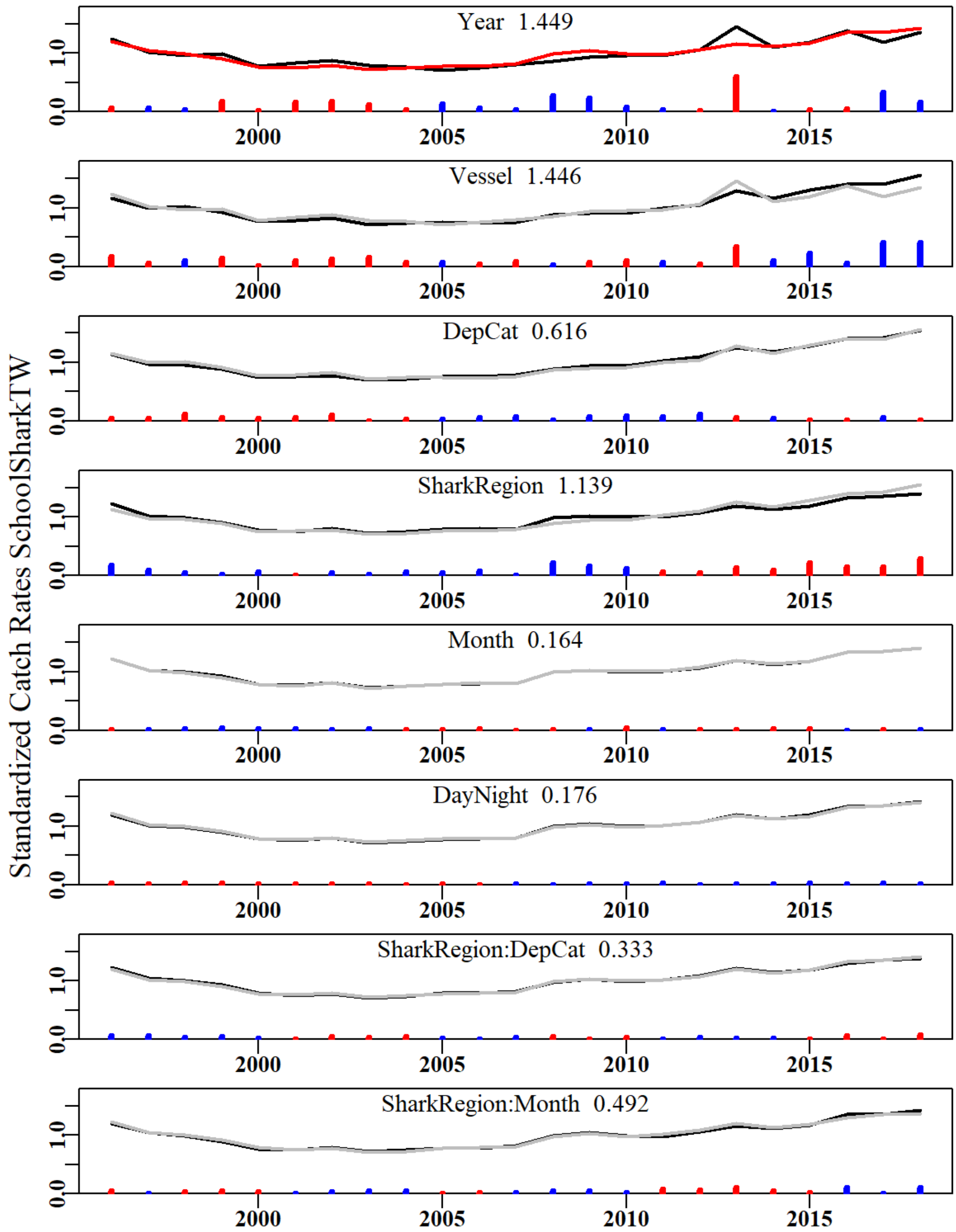

Figure 8.50. SchoolSharkTW. The influence of each factor on the optimal standardization. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by vertical bars with blue bars indicating the optimum model is higher than the geometric mean and red bars indicating it is lower. The top graph bars are the sum of all the bars in the graphs below. The graphs for individual factors are cumulative. Thus the second graph has the geometric mean (grey line) and the effect of adding Year + factor2 (Model 2). In the third graph, the grey line represents Model 2 and the black line the effect of adding factor3 to the model. The remaining graphs continue in the same cumulative manner except for the interaction terms which are added singularly to the final single factor model.

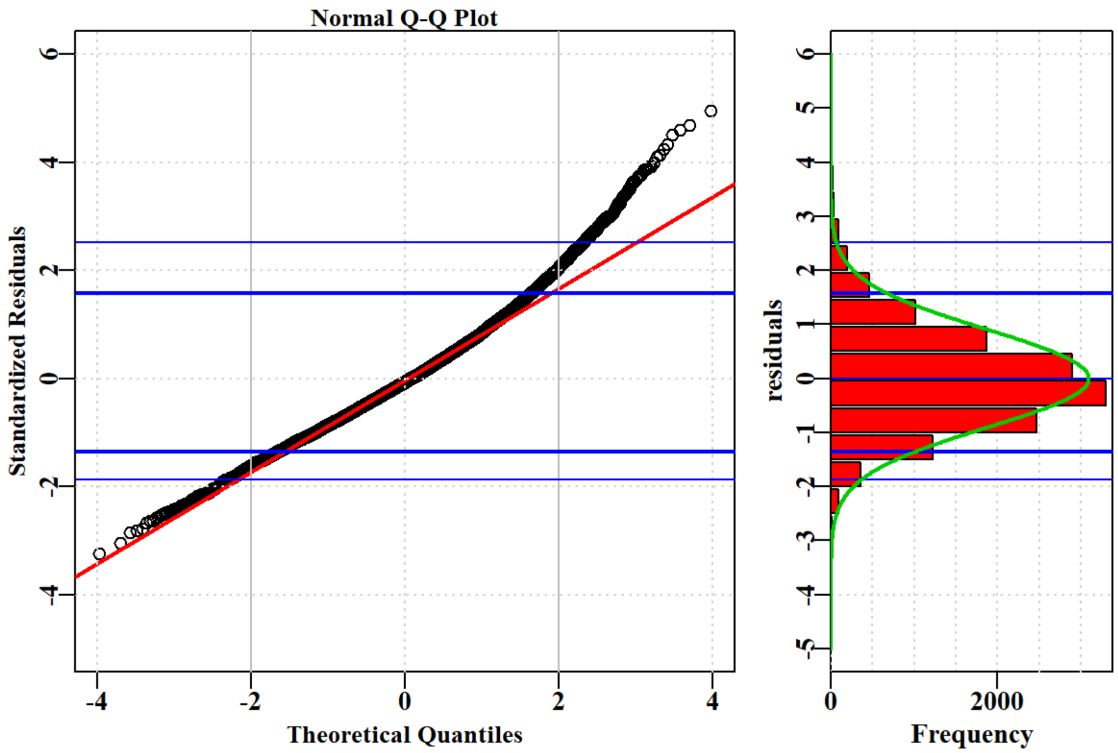

Figure 8.51. SchoolSharkTW. Diagnostic plots. The distribution of residuals from the optimum fit. The qqplot indicates the fit to the expected normality, while the histogram of residuals also illustrates the 1%, 5%, 95% and 99% quantiles to indicate the intensity of any lack of fit at the margins of the distribution (reflected also in the qqplot).

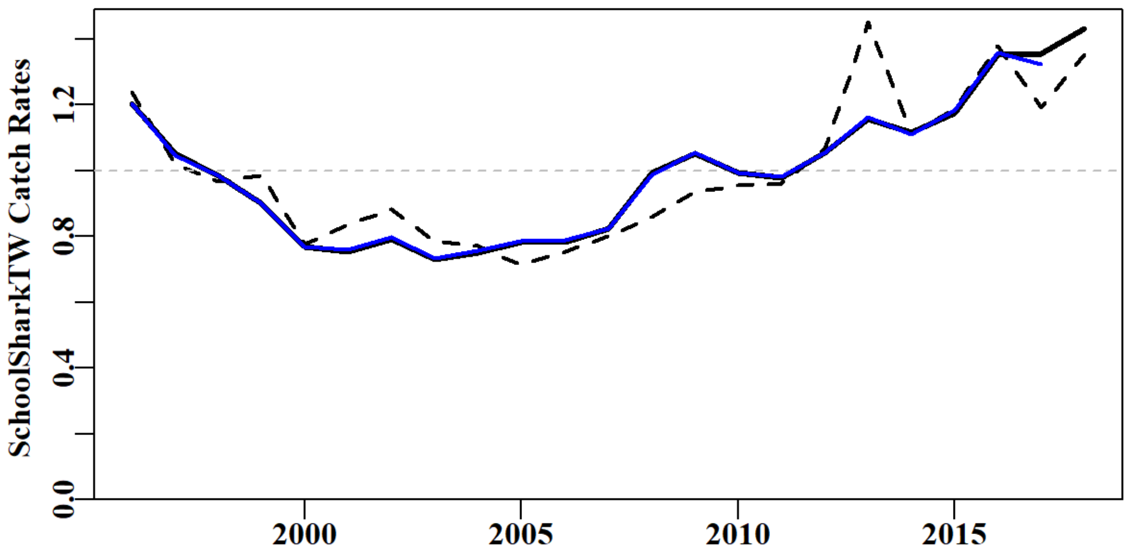

Figure 8.52. SchoolSharkTW. A comparison of the previous year's standardization (blue line) with this year's. They should lie on top of each other, although small deviations may relate to data adjustments, particularly in very recent years.

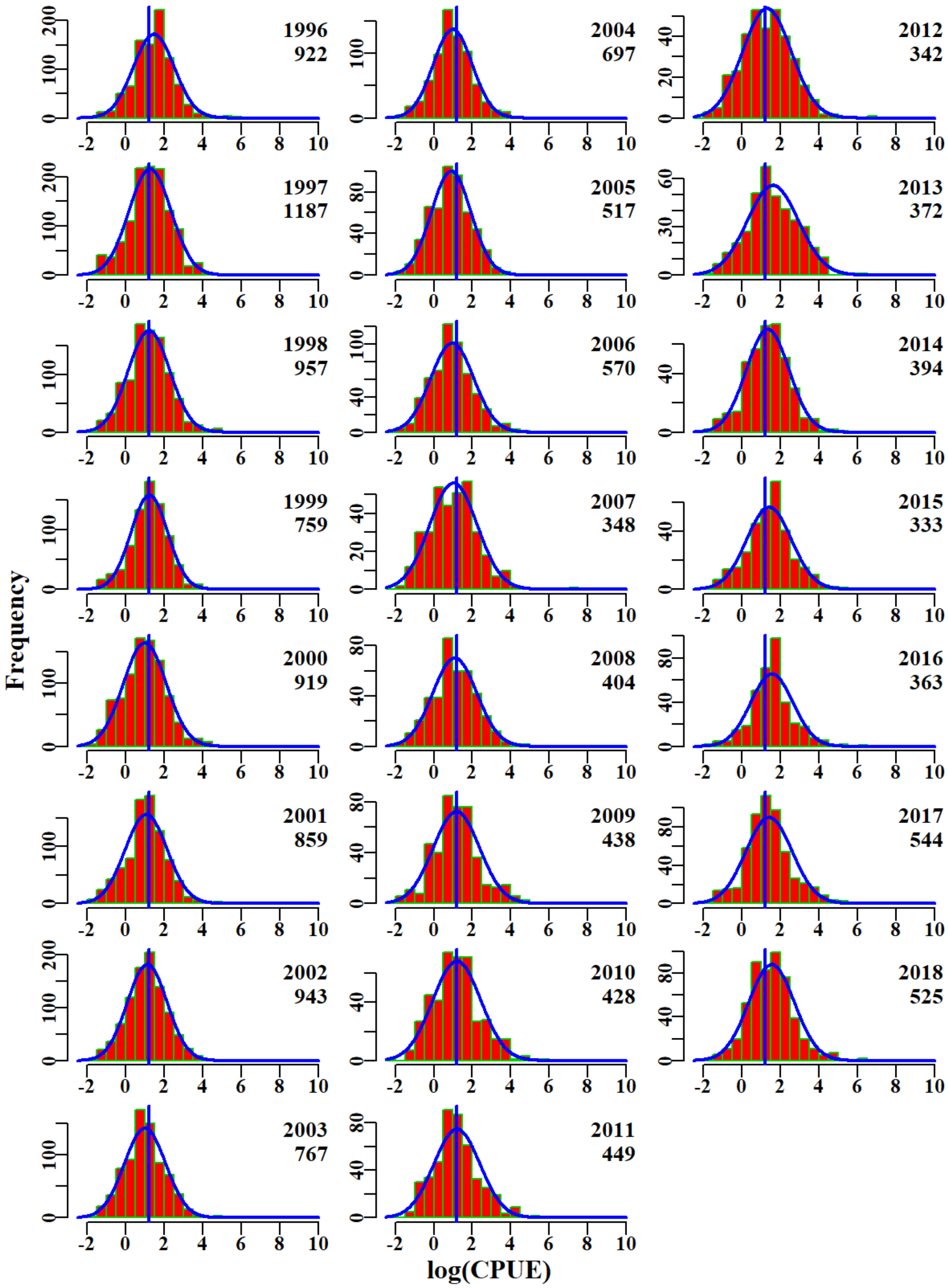

Figure 8.53. SchoolSharkTW. The natural log(CPUE) for each year of data available the blue lines are normal distributions fitted to the histogram frequencies. The numbers in each plot are the year and number of records. The vertical blue line is the average across all years.

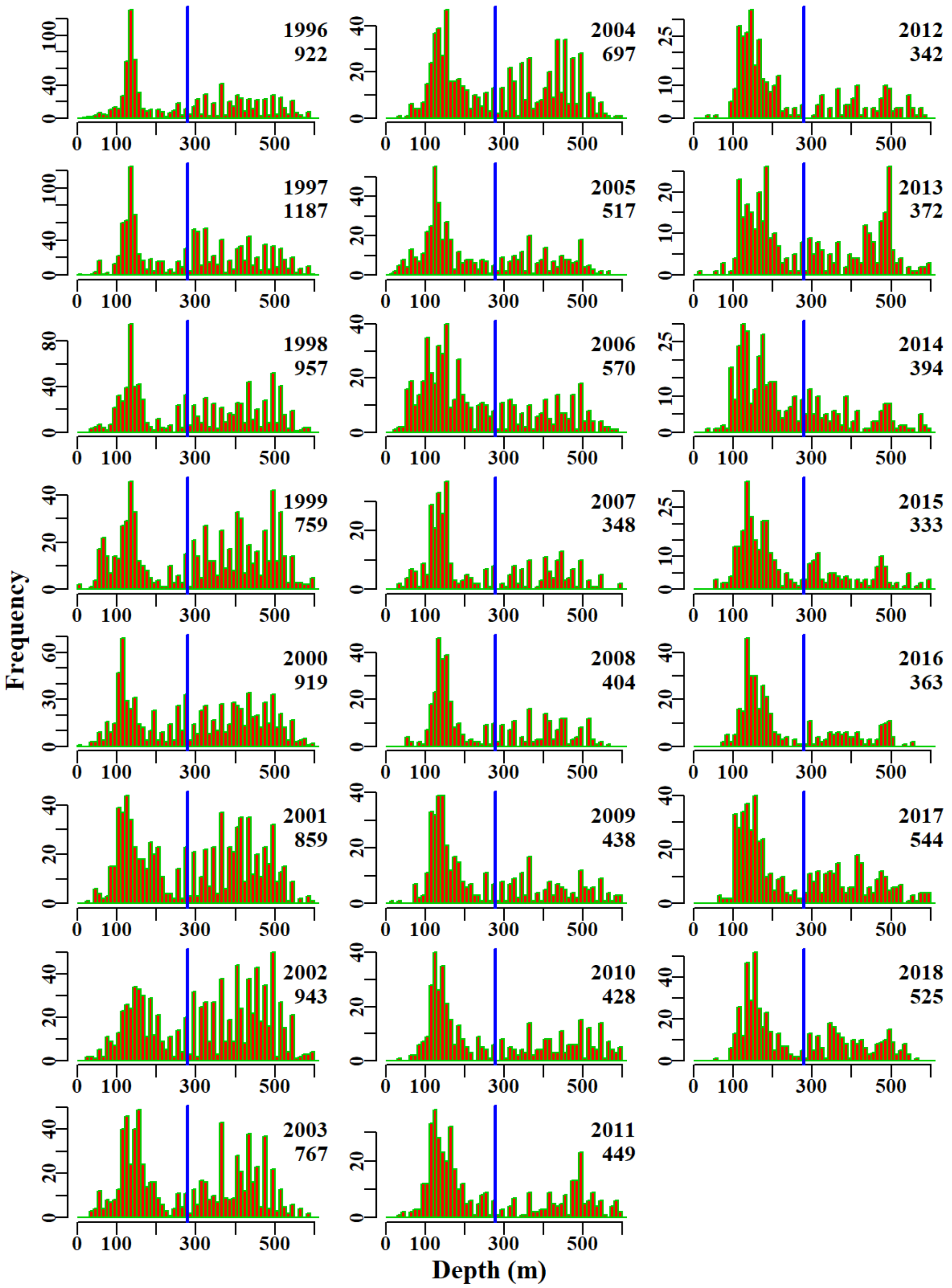

Figure 8.54. SchoolSharkTW. The average Depth of fishing for each year of data available to illustrate the development of the fishery through time. The numbers in each plot are the year and number of records. The vertical blue line is the average across all years.

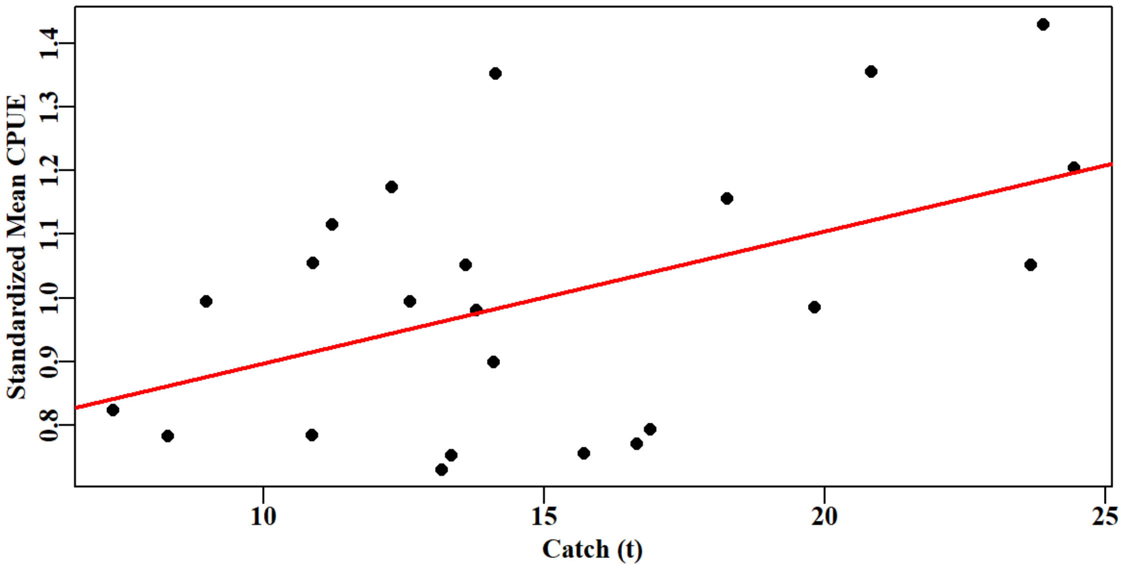

Figure 8.55. SchoolSharkTW. The linear relationship between Annual mean CPUE and Annual Catch.

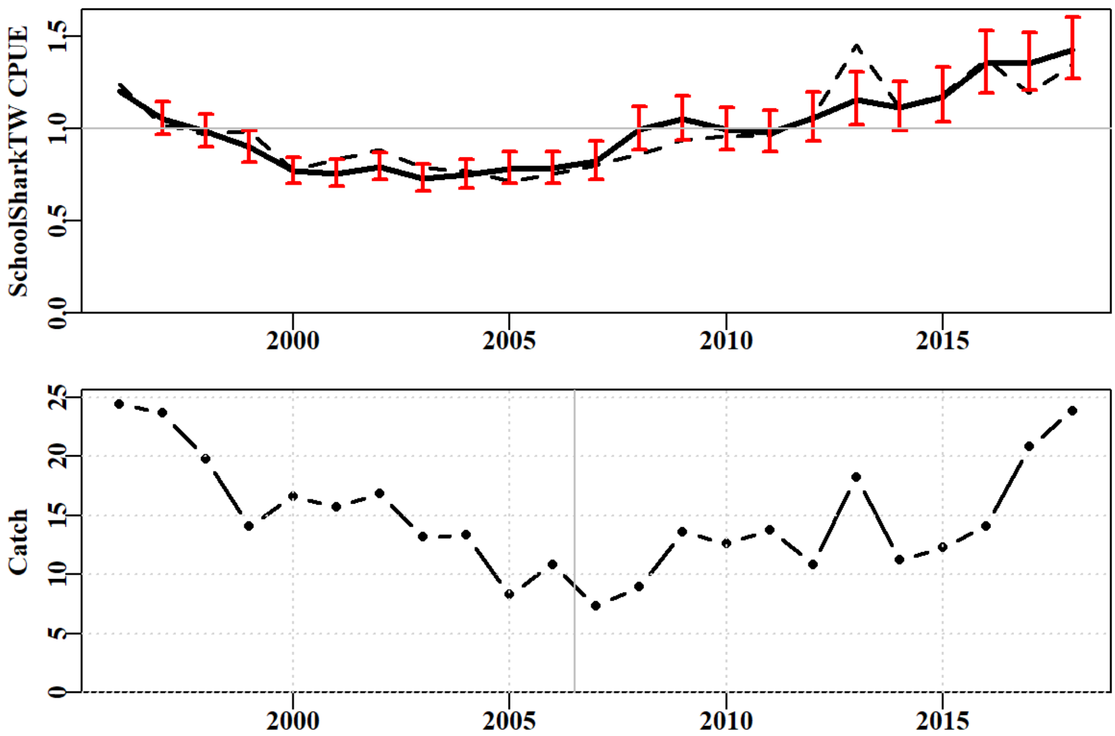

Figure 8.56. SchoolSharkTW. CPUE is correlated with catches through time. CPUE in the top plot and annual catch (t) in the lower plot.

8.10 Sawshark Gillnet

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

8.10.1 *Inferences*

There is a strong correlation between total annual catch and annual standardized CPUE estimates. In addition, the large proportion of the total catch taken in shots of < 30kg indicates the by-product nature of this fishery (confirmed by the large proportion of discards from this fishery). The majority of catch occurred in Shark region 5, followed by 4.

The terms Year, Vessel, DepCat, SharkRegion, Month and one interaction (SharkRegion:Month) had the greatest contribution to model fit based on the AIC and R2 statistics (Table 8.35). The qqplot suggests the assumed Normal distribution is valid, with slight deviations as depicted from both tails of the distribution (Figure 8.60). Annual standardized CPUE has been below the long-term average since 2009, with minor increases over the 2014-2016 period, followed by a slight drop in 2017 and an increase in 2018 (Figure 8.58).

8.10.2 *Action Items and Issues*

A further consideration of whether or not to consider the CPUE time-series as a valid index of relative abundance for sawshark needs to be explored.

Table 8.31. SawShark. The data selection criteria used to specify and identify the fishery data to be included in the analysis.

Property	Value
label	SawShark
csirocode	37023002, 37023001, 37023000, 37023900
fishery	GHT_SEN_SSF_SSG_SSH
depthrange	0 - 150
depthclass	10
zones	1, 2, 3, 4, 5, 6, 7, 8, 9
methods	GN
years	1997 - 2018

Table 8.32. SawShark. Total catch (Total; t) is the total reported in the database, number of records used in the analysis (N), reported catch (Catch; t) in the area and depth used in the analysis and number of vessels used in the analysis (Vess). GeoM is the geometric mean of catch rates (kg/shot), standard deviation (StDev) relates to the optimum model. C<30Kg denotes the amount of catch in shots of <30kg, and P<30Kg is the proportion of total. The optimum model was SharkRegion:Month.

	Total	N	Catch	Vess	GeoM	Opt	StDev	C<30Kg	P<30Kg
1997	214.2	4722	146.9	81	32.8	1.2496	0.000	40.042	0.273
1998	284.2	6875	225.0	81	33.7	1.2480	0.023	49.272	0.219
1999	295.6	7638	229.4	85	31.3	1.3356	0.022	58.951	0.257
2000	361.7	7192	275.4	76	39.4	1.7127	0.023	56.498	0.205
2001	340.7	6483	260.1	80	41.7	1.7832	0.023	48.260	0.186
2002	256.6	6251	157.3	77	26.7	1.0874	0.024	47.071	0.299
2003	319.7	6955	190.3	81	29.3	1.1122	0.023	48.450	0.255
2004	314.9	6560	190.8	73	30.7	1.1579	0.024	47.709	0.250
2005	296.7	5783	169.8	62	29.9	1.0500	0.024	42.053	0.248
2006	317.7	5270	155.6	58	30.6	1.0595	0.025	34.869	0.224
2007	214.5	4710	105.9	44	22.3	0.9147	0.026	29.244	0.276
2008	211.7	4651	114.4	44	26.2	1.0514	0.026	30.916	0.270
2009	191.5	4872	88.5	44	18.6	0.8921	0.026	34.081	0.385
2010	192.5	5080	91.4	47	18.7	0.8622	0.026	36.924	0.404
2011	197.0	5331	102.4	46	18.9	0.8248	0.025	38.456	0.376
2012	158.6	4606	73.8	42	16.0	0.6571	0.026	32.666	0.443
2013	165.7	4355	70.7	39	16.4	0.6195	0.027	34.782	0.492
2014	167.2	4179	80.7	38	19.3	0.6683	0.027	32.266	0.400
2015	164.2	4077	75.8	35	19.0	0.6674	0.027	31.405	0.414
2016	164.6	4382	95.5	33	22.2	0.7259	0.027	34.467	0.361
2017	178.8	5060	97.0	35	19.0	0.6442	0.026	38.468	0.397
2018	169.9	4593	85.6	33	18.2	0.6763	0.027	34.862	0.407

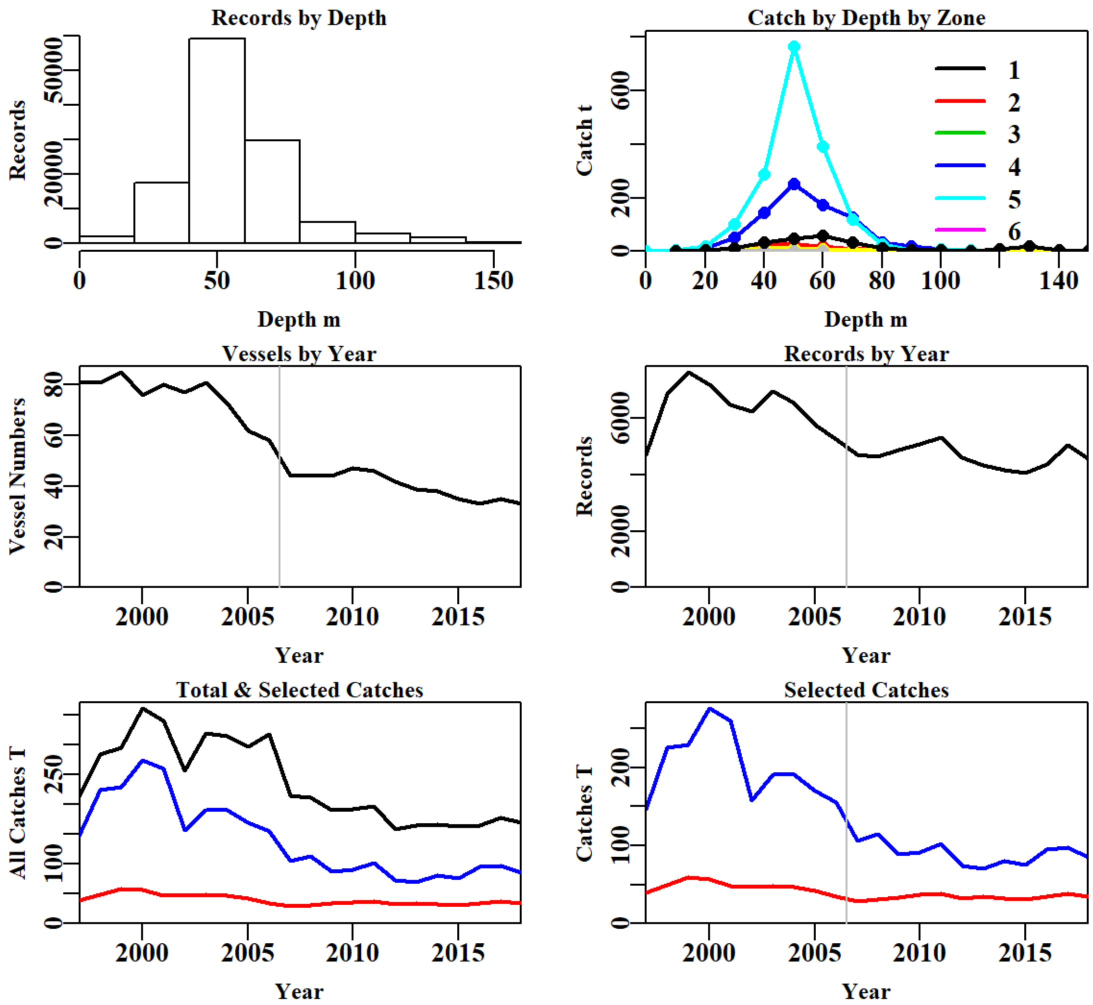

Figure 8.57. SawShark fishery details. The bottom left plot depicts all known catches (top black line), and all selected catches used in the analysis (middle blue line); the lower red line: selected catches < 30 kg).

Table 8.33. SawShark data selection effects. Total is the total number of records in the database, NoCE removes those records with either missing catch or effort, and then only those records are kept that meet the criteria for depth, years, zone, method, and fishery.

	Records	Difference	Catch	Difference
Total	255697	0	5664.343	0.000
NoCE	250075	5622	5664.343	0.000
Depth	222203	27872	4592.828	1071.514
Years	207100	15103	4257.686	335.142
Zones	202048	5052	4108.760	148.926
Method	119629	82419	3082.463	1026.297
Fishery	119625	4	3082.353	0.110

Table 8.34. The models used to analyse data for SawShark.

	Model
Model1	Year
Model2	Year + Vessel
Model3	Year + Vessel + DepCat
Model4	Year + Vessel + DepCat + SharkRegion
Model5	Year + Vessel + DepCat + SharkRegion + Month
Model6	Year + Vessel + DepCat + SharkRegion + Month + SharkRegion:DepCat
Model7	Year + Vessel + DepCat + SharkRegion + Month + SharkRegion:Month

Table 8.35. SawShark. The row names are 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_r2) and the change in adjusted R^2 (%Change). The optimum model was SharkRegion:Month.

	AIC	RSS	MSS	Nobs	Npars	adj_r2	%Change
Year	73220	220538	8089	119625	22	3.5	0.00
Vessel	48631	178986	49641	119625	214	21.6	18.05
DepCat	41230	168206	60421	119625	229	26.3	4.71
SharkRegion	35754	160659	67969	119625	237	29.6	3.30
Month	33468	157589	71039	119625	248	30.9	1.34
SharkRegion:DepCat	29921	152712	75916	119625	355	33.0	2.08
SharkRegion:Month	29071	151680	76947	119625	335	33.5	2.54

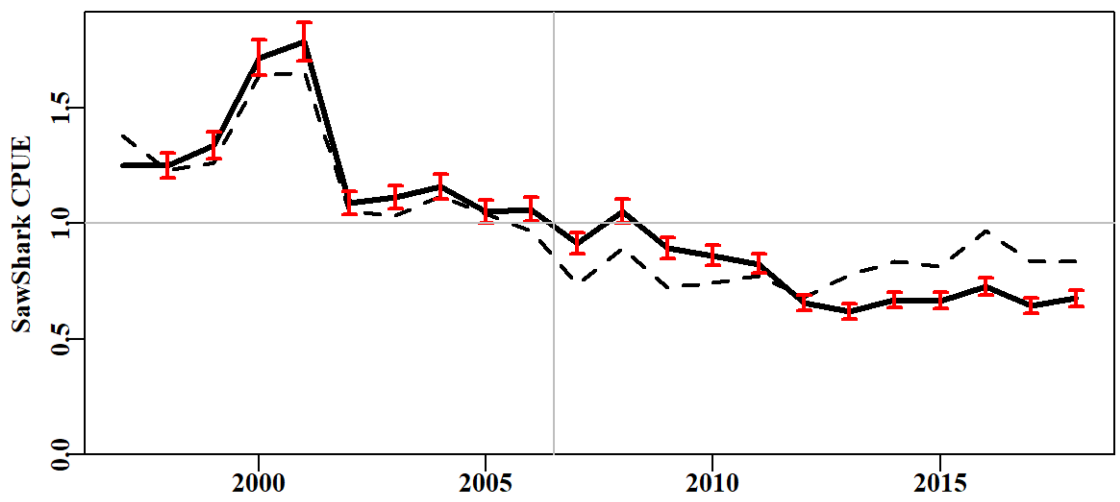

Figure 8.58. SawShark standardization. The dashed black line represents the geometric mean catch rate, solid black line the standardized catch rates. The red bars are the 95% confidence intervals about the mean estimates. The graph scales both time-series of standardized catch rates relative to the mean of each time-series.

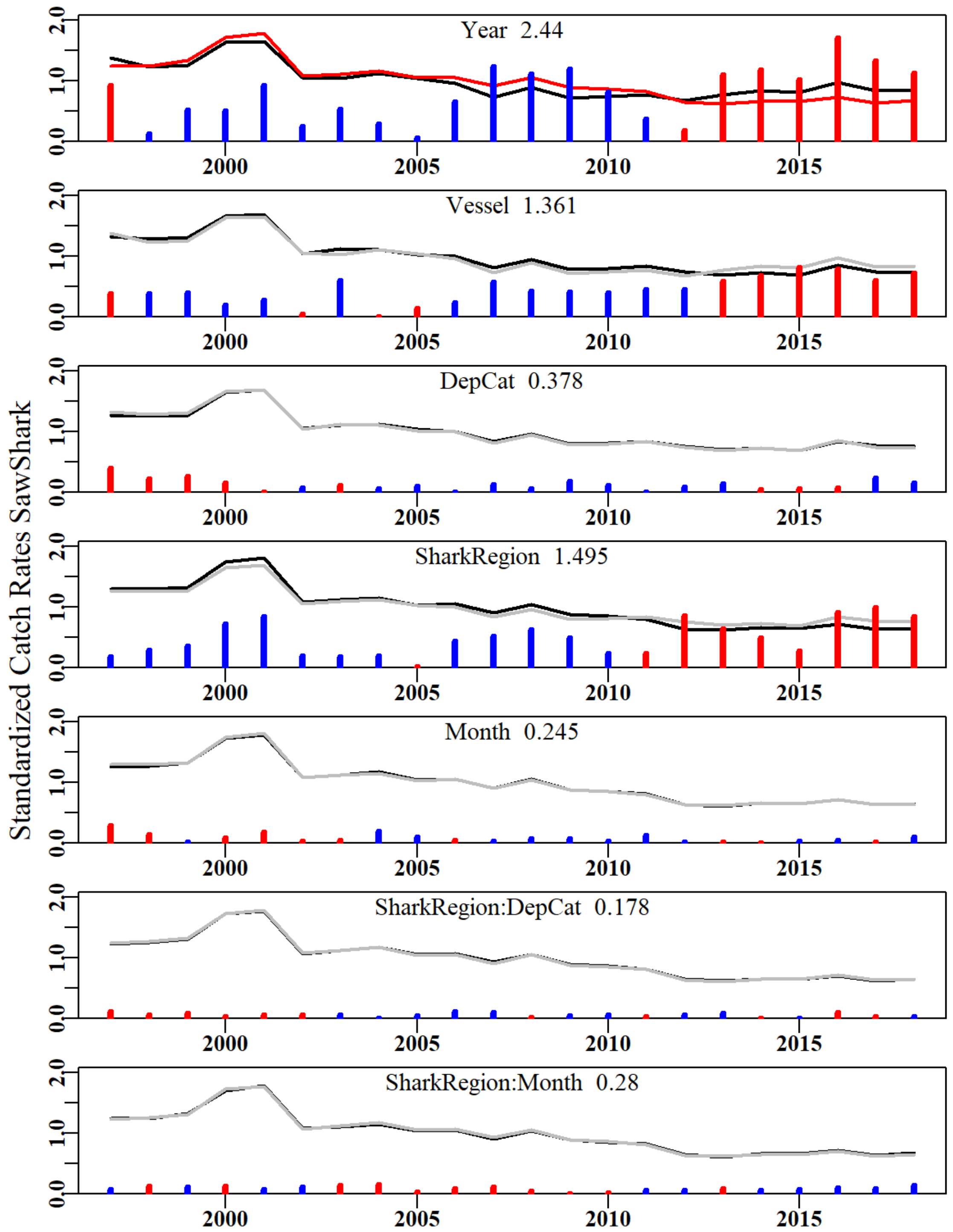

Figure 8.59. SawShark. The influence of each factor on the optimal standardization. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by vertical bars with blue bars indicating the optimum model is higher than the geometric mean and red bars indicating it is lower. The top graph bars are the sum of all the bars in the graphs below. The graphs for individual factors are cumulative. Thus the second graph has the geometric mean (grey line) and the effect of adding Year + factor2 (Model 2). In the third graph, the grey line represents Model 2 and the black line the effect of adding factor3 to the model. The remaining graphs continue in the same cumulative manner except for the interaction terms which are added singularly to the final single factor model.

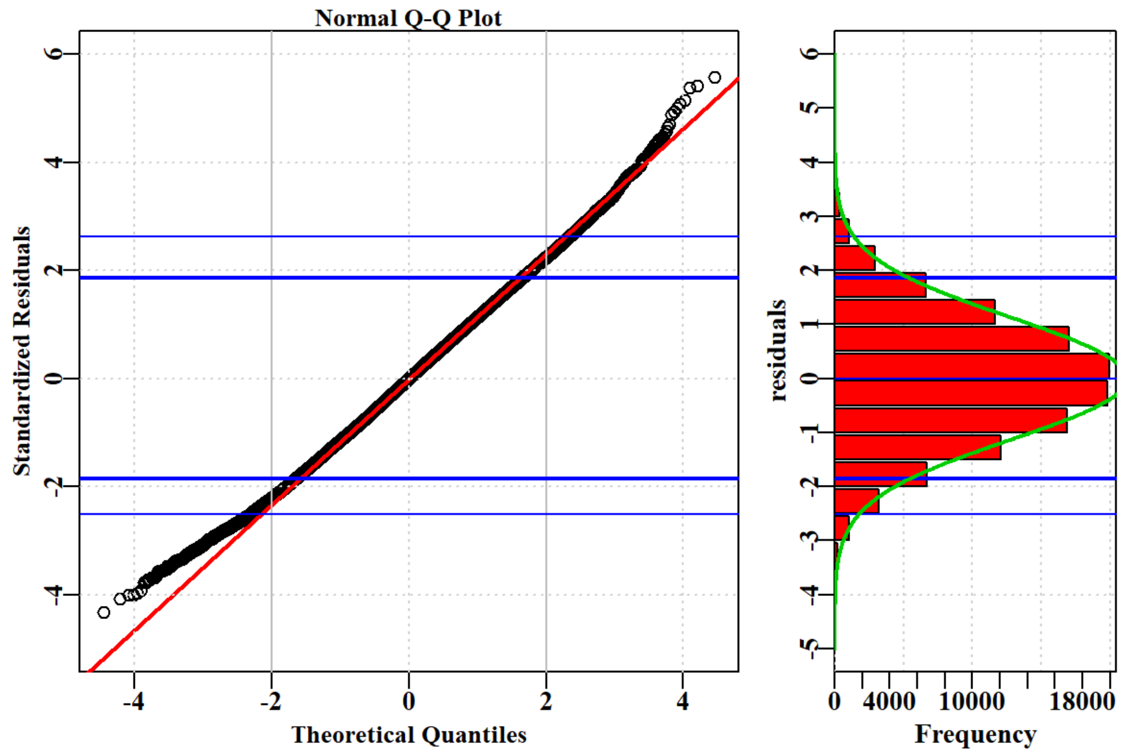

Figure 8.60. SawShark. Diagnostic plots. The distribution of residuals from the optimum fit. The qqplot indicates the fit to the expected normality, while the histogram of residuals also illustrates the 1%, 5%, 95% and 99% quantiles to indicate the intensity of any lack of fit at the margins of the distribution (reflected also in the qqplot.

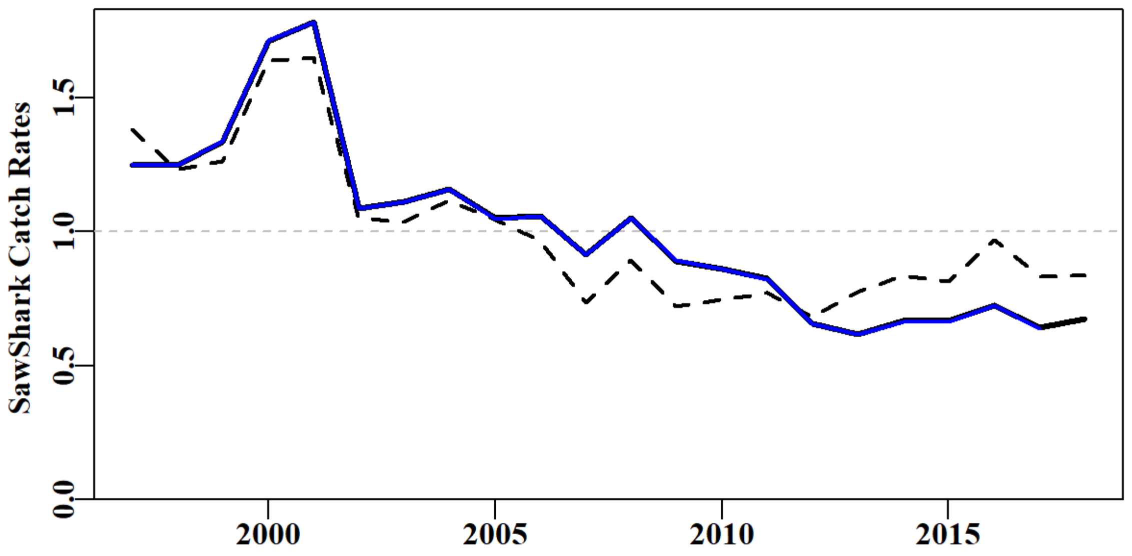

Figure 8.61. SawShark. A comparison of the previous year's standardization (blue line) with this year's. They should lie on top of each other, although small deviations may relate to data adjustments, particularly in very recent years.

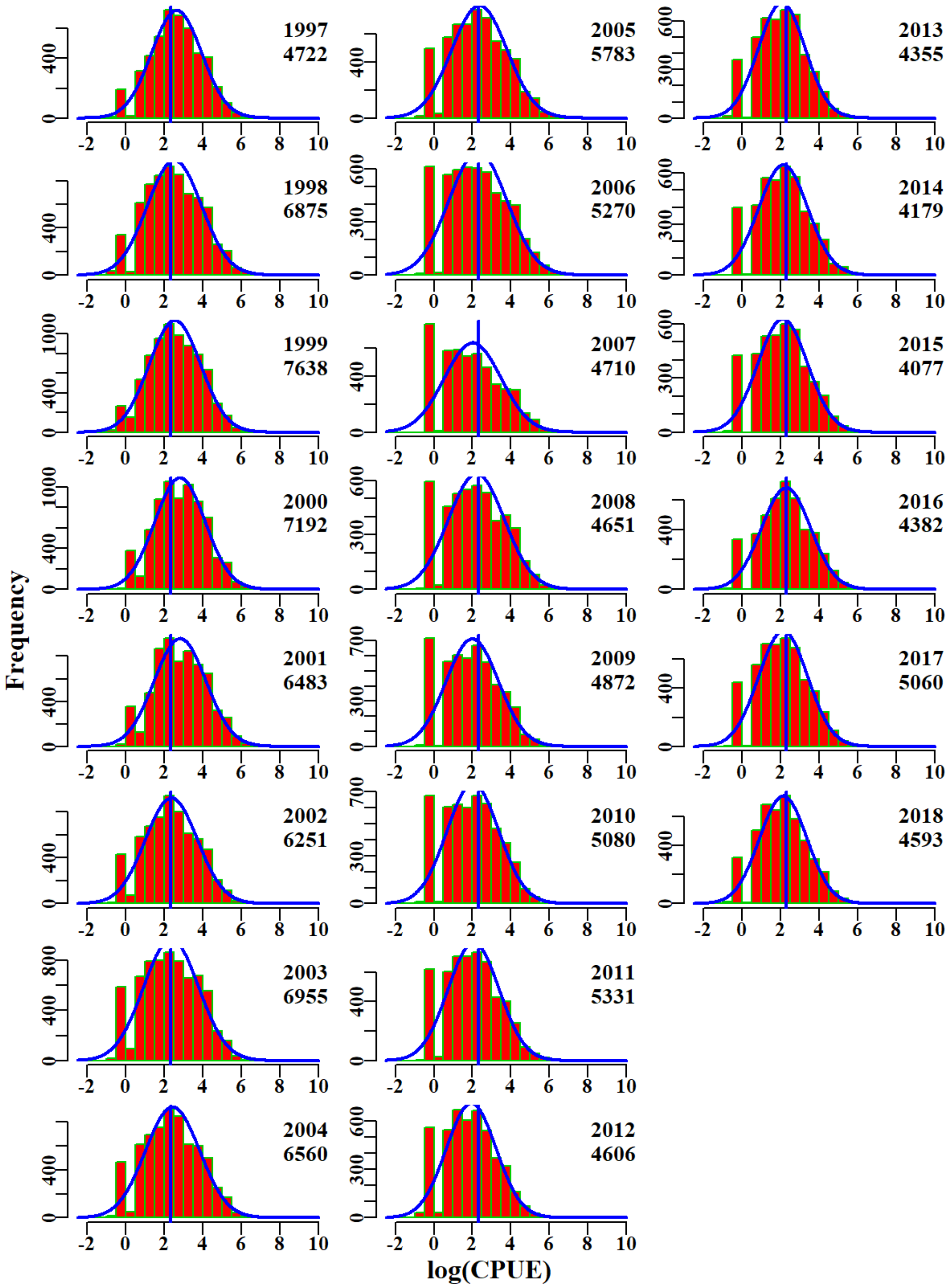

Figure 8.62. SawShark. The natural log(CPUE) for each year of data available the blue lines are normal distributions fitted to the histogram frequencies. The numbers in each plot are the year and number of records. The vertical blue line is the average across all years.

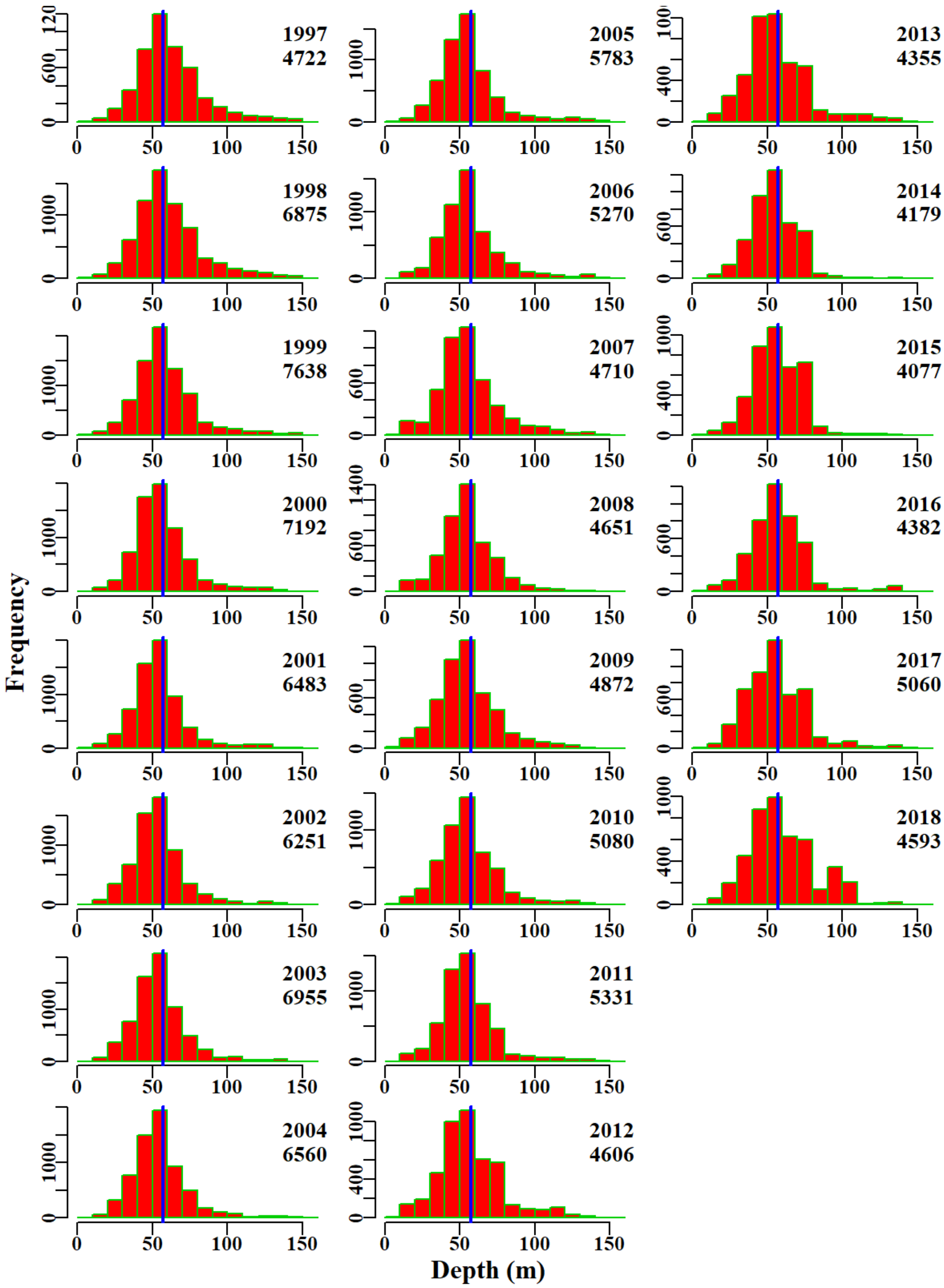

Figure 8.63. SawShark. The average Depth of fishing for each year of data available to illustrate the development of the fishery through time. The numbers in each plot are the year and number of records. The vertical blue line is the average across all years.

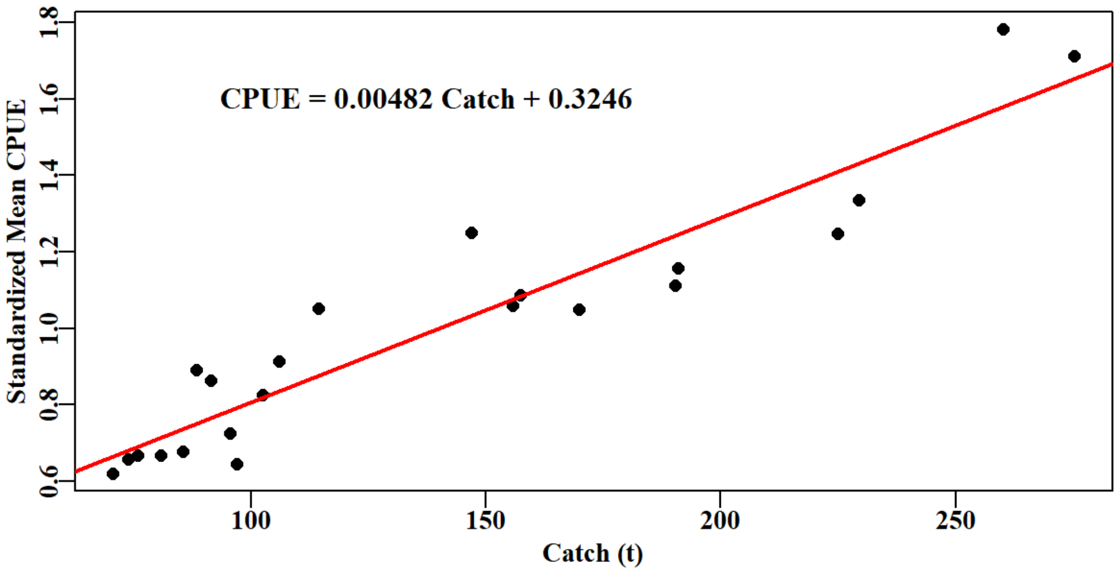

Figure 8.64. SawShark. The linear relationship between Annual mean CPUE and Annual Catch.

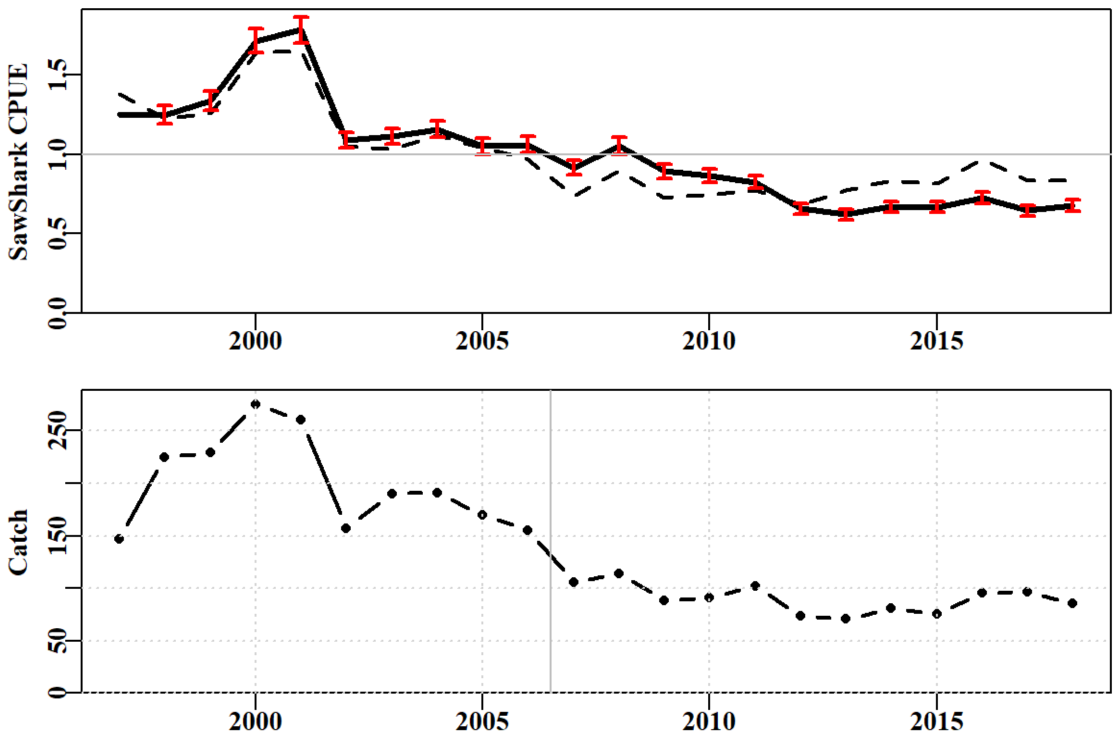

Figure 8.65. SawShark. CPUE is correlated with catches through time. CPUE in the top plot and annual catch (t) in the lower plot.

8.11 Sawshark Trawl

Non-zero records of catch per hour were employed in the statistical standardization analyses for sawshark caught by trawl.

A total of 8 statistical models were fitted sequentially to the available data, and the order of the non-interaction terms added based on the relative contribution of each term to model fit.

8.11.1 *Inferences*

The majority of catch occurred in Shark region 1, 2 and 5.

The terms Year, Vessel, DepCat, SharkRegion, Month, DayNigh and one interaction (SharkRegion:Month) had the greatest contribution to model fit based on the AIC and R2 statistics (Table 8.40). The terms Year, Vessel and SharkRegion had the greatest contribution to model fit. The qqplot suggests the assumed Normal distribution is valid, with slight deviations as depicted from both tails of the distribution (Figure 8.69). Annual standardized CPUE has increased in 2017 compared to 2016 and is below the long-term average (Figure 8.67). Similarly, annual standardized CPUE has increased in 2018 compared to 2017, and at the long-term average.

8.11.2 *Action Items and Issues*

A further consideration of whether or not to consider the CPUE time-series as a valid index of relative abundance for sawshark needs to be explored.

Table 8.36. SawSharkTrawl. The data selection criteria used to specify and identify the fishery data to be included in the analysis.

Property	Value
label	SawSharkTrawl
csirocode	37023002, 37023001, 37023000, 37023900
fishery	SET_GAB
depthrange	0 - 500
depthclass	20
zones	1, 2, 3, 4, 5, 6, 7, 8, 9, 10
methods	TW, TDO, OTT, PTB
years	1995 - 2018

Table 8.37. SawSharkTrawl. Total catch (Total; t) is the total reported in the database, number of records used in the analysis (N), reported catch (Catch; t) in the area and depth used in the analysis and number of vessels used in the analysis (Vess). GeoM is the geometric mean of catch rates (kg/hr), standard deviation (StDev) relates to the optimum model. C<30Kg denotes the amount of catch in shots of <30kg, and P<30Kg is the proportion of total. The optimum model was SharkRegion:Month.

	Total	N	Catch	Vess	GeoM	Opt	StDev	C<30Kg	P<30Kg
1995	57.1	1764	51.7	54	7.9	1.3181	0.000	17.727	0.343
1996	67.5	1992	59.9	60	8.1	1.3360	0.035	19.324	0.323
1997	214.2	2443	59.4	60	6.5	1.1886	0.035	24.417	0.411
1998	284.2	1694	47.9	54	6.8	1.0913	0.038	16.888	0.353
1999	295.6	1813	51.2	50	7.6	1.2493	0.037	17.384	0.339
2000	361.7	2361	69.0	65	10.2	1.0988	0.036	23.081	0.335
2001	340.7	2555	68.1	54	6.9	1.0633	0.036	23.629	0.347
2002	256.6	3298	70.8	68	5.9	0.9451	0.034	28.762	0.406
2003	319.7	4400	100.8	75	5.7	0.8670	0.033	34.943	0.347
2004	314.9	4270	95.4	76	6.3	0.8472	0.033	33.848	0.355
2005	296.7	4931	104.6	71	5.7	0.8498	0.033	40.154	0.384
2006	317.7	4625	137.2	64	7.4	0.9401	0.033	33.402	0.243
2007	214.5	2561	82.0	39	7.4	0.8125	0.036	20.114	0.245
2008	211.7	2891	71.6	40	5.6	0.8580	0.035	24.796	0.346
2009	191.5	2806	78.4	34	6.7	1.0894	0.035	25.884	0.330
2010	192.5	3138	80.4	37	5.9	0.9849	0.035	29.956	0.373
2011	197.0	2914	66.8	36	5.5	0.8832	0.035	25.062	0.375
2012	158.6	2426	60.5	36	6.2	0.8768	0.036	21.854	0.361
2013	165.7	2526	70.0	36	6.7	1.0182	0.036	26.220	0.375
2014	167.2	2261	70.1	36	7.5	1.0225	0.037	24.565	0.351
2015	164.2	2213	59.4	36	7.0	0.9377	0.037	22.834	0.385
2016	164.6	1977	47.2	37	6.7	0.8541	0.038	19.457	0.412
2017	178.8	1970	59.6	33	7.9	0.9144	0.038	19.137	0.321
2018	169.9	2076	59.0	31	7.9	0.9536	0.038	20.263	0.344

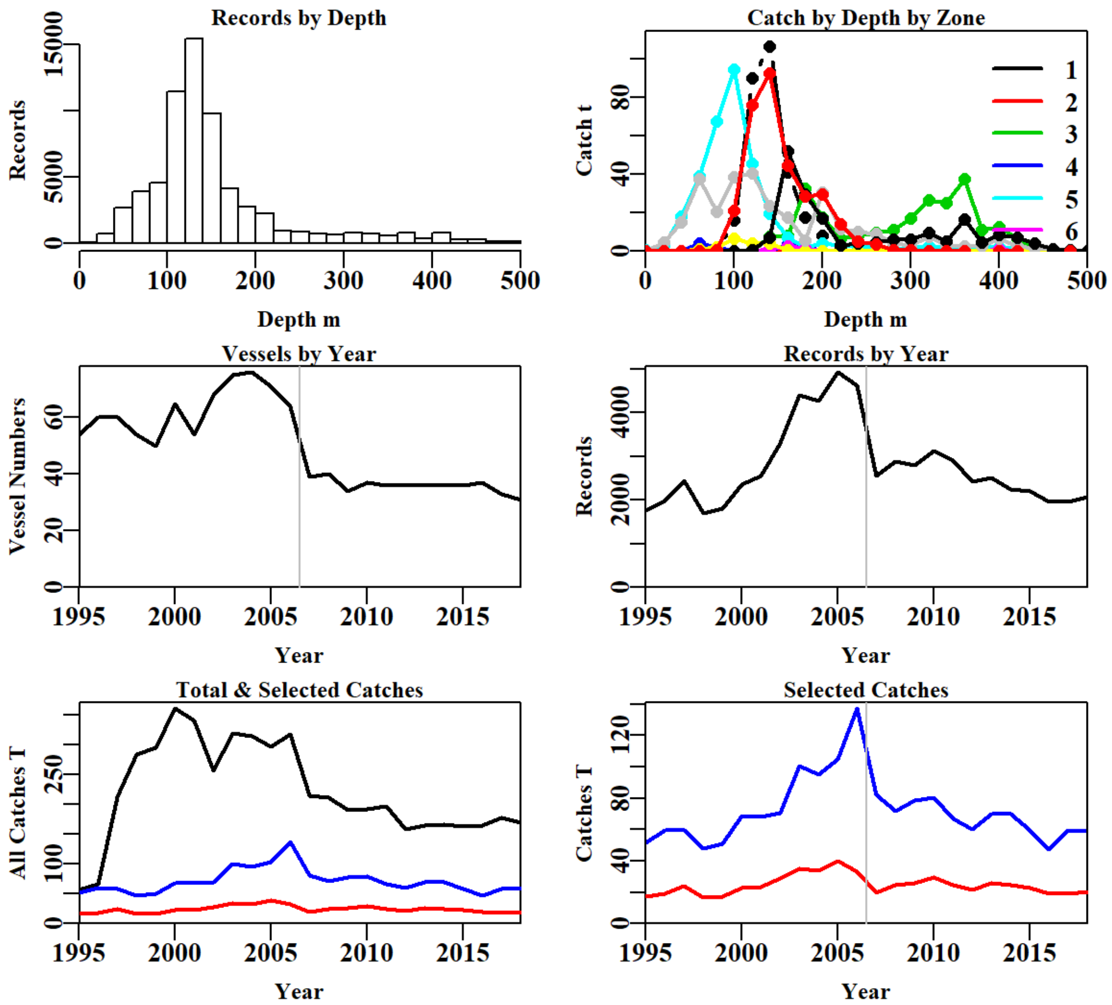

Figure 8.66. SawSharkTrawl fishery details. The bottom left plot depicts all known catches (top black line), and all selected catches used in the analysis (middle blue line); the lower red line: selected catches < 30 kg).

Table 8.38. SawSharkTrawl data selection effects. Total is the total number of records in the database, NoCE removes those records with either missing catch or effort, and then only those records are kept that meet the criteria for depth, years, zone, method, and fishery.

	Records	Difference	Catch	Difference
Total	255697	0	5664.343	0.000
NoCE	187811	67886	4115.998	1548.344
Depth	186178	1633	4080.046	35.952
Years	172733	13445	3731.273	348.773
Zones	172455	278	3726.862	4.411
Method	65994	106461	1722.385	2004.478
Fishery	65905	89	1721.004	1.381

Table 8.39. The models used to analyse data for SawSharkTrawl.

	Model
Model1	Year
Model2	Year + Vessel
Model3	Year + Vessel + DepCat
Model4	Year + Vessel + DepCat + SharkRegion
Model5	Year + Vessel + DepCat + SharkRegion + Month
Model6	Year + Vessel + DepCat + SharkRegion + Month + DayNight
Model7	Year + Vessel + DepCat + SharkRegion + Month + DayNight + SharkRegion:DepCat
Model8	Year + Vessel + DepCat + SharkRegion + Month + DayNight + SharkRegion:Month

Table 8.40. SawSharkTrawl. The row names are 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_r2) and the change in adjusted R^2 (%Change). The optimum model was SharkRegion:Month.

	AIC	RSS	MSS	Nobs	Npars	adj_r2	%Change
Year	30604	104778	1097	65905	24	1.0	0.00
Vessel	11428	78004	27871	65905	160	26.1	25.14
DepCat	9325	75497	30379	65905	185	28.5	2.35
SharkRegion	7131	73005	32870	65905	194	30.8	2.35
Month	5579	71282	34593	65905	205	32.5	1.62
DayNight	5491	71181	34695	65905	208	32.6	0.09
SharkRegion:DepCat	4142	69337	36538	65905	398	34.1	1.56
SharkRegion:Month	3425	68777	37098	65905	307	34.7	2.18

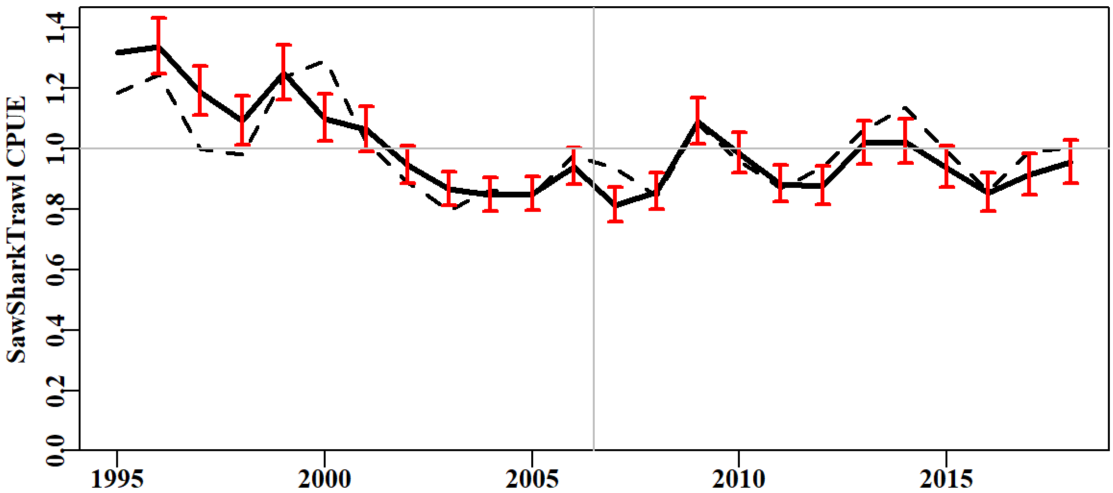

Figure 8.67. SawSharkTrawl standardization. The dashed black line represents the geometric mean catch rate, solid black line the standardized catch rates. The red bars are the 95% confidence intervals about the mean estimates. The graph scales both time-series of standardized catch rates relative to the mean of each time-series.

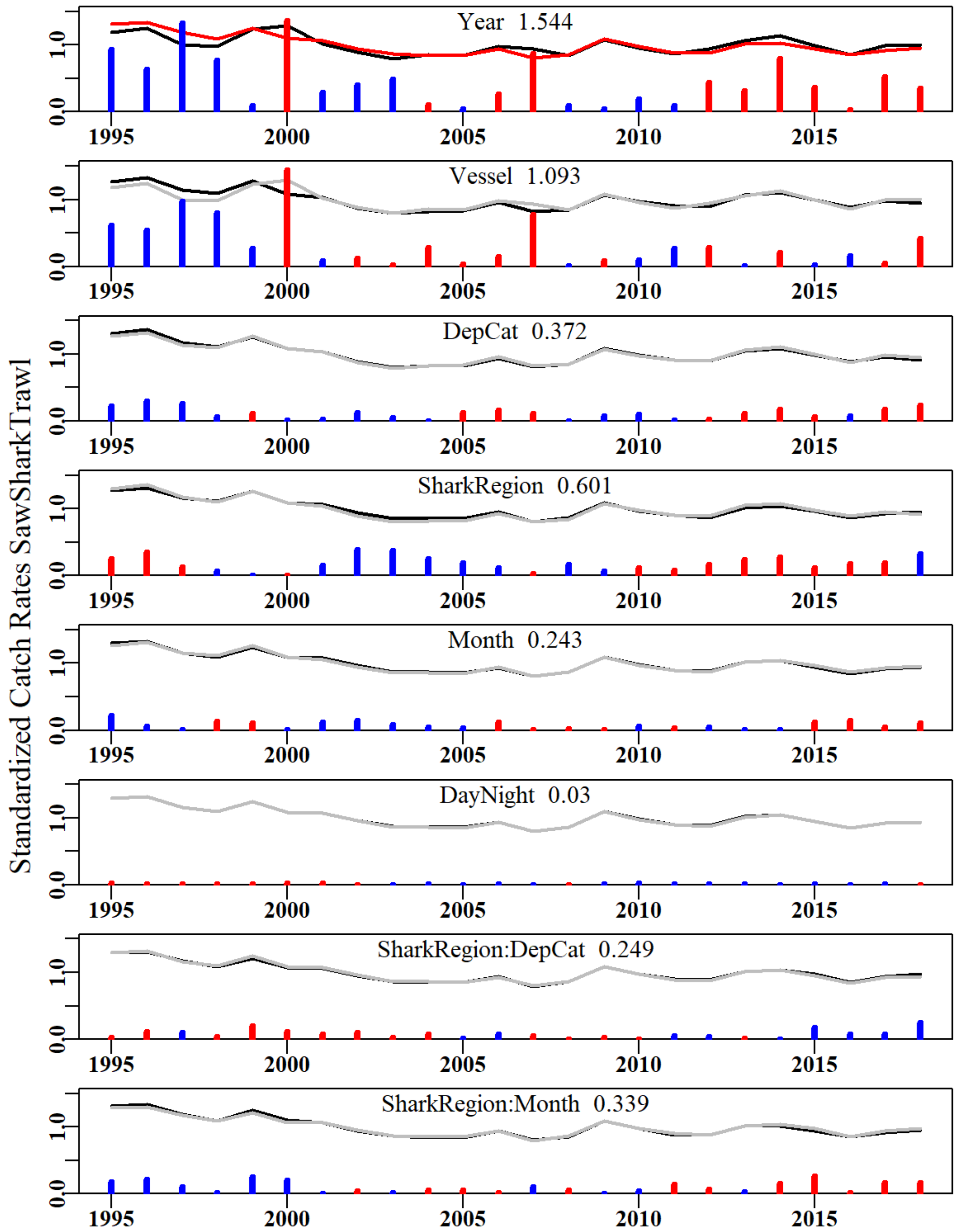

Figure 8.68. SawSharkTrawl. The influence of each factor on the optimal standardization. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by vertical bars with blue bars indicating the optimum model is higher than the geometric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

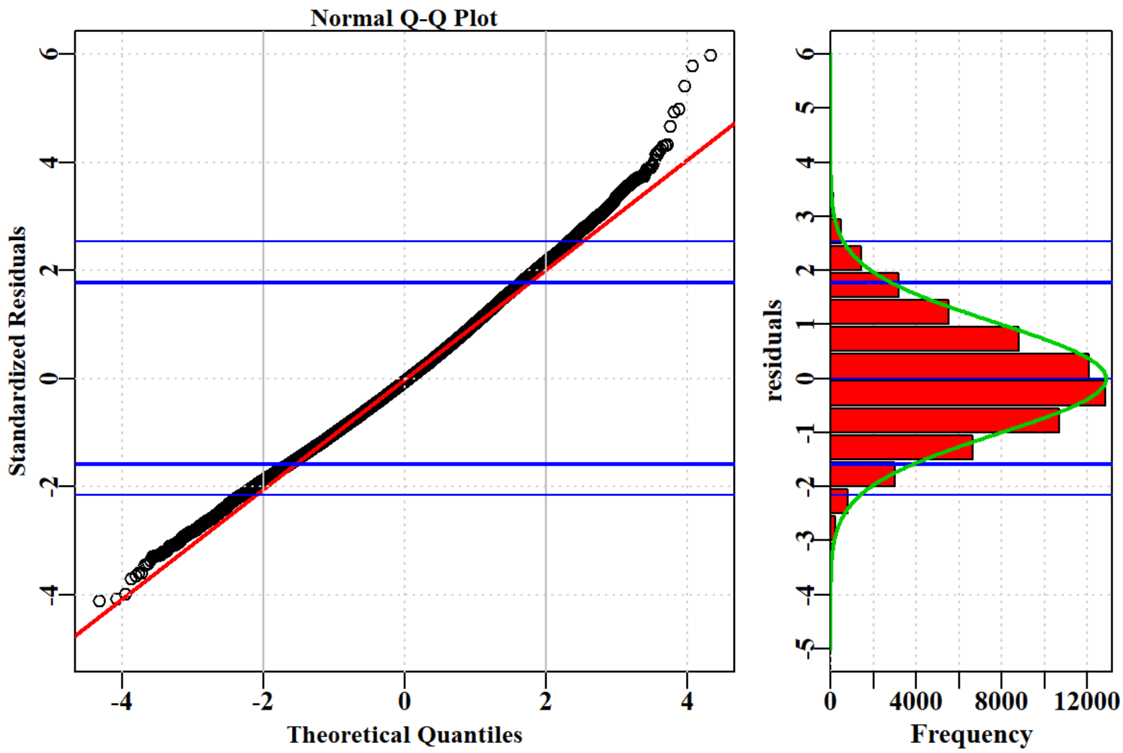

Figure 8.69. SawSharkTrawl. Diagnostic plots. The distribution of residuals from the optimum fit. The qqplot indicates the fit to the expected normality, while the histogram of residuals also illustrates the 1%, 5%, 95% and 99% quantiles to indicate the intensity of any lack of fit at the margins of the distribution (reflected also in the qqplot).

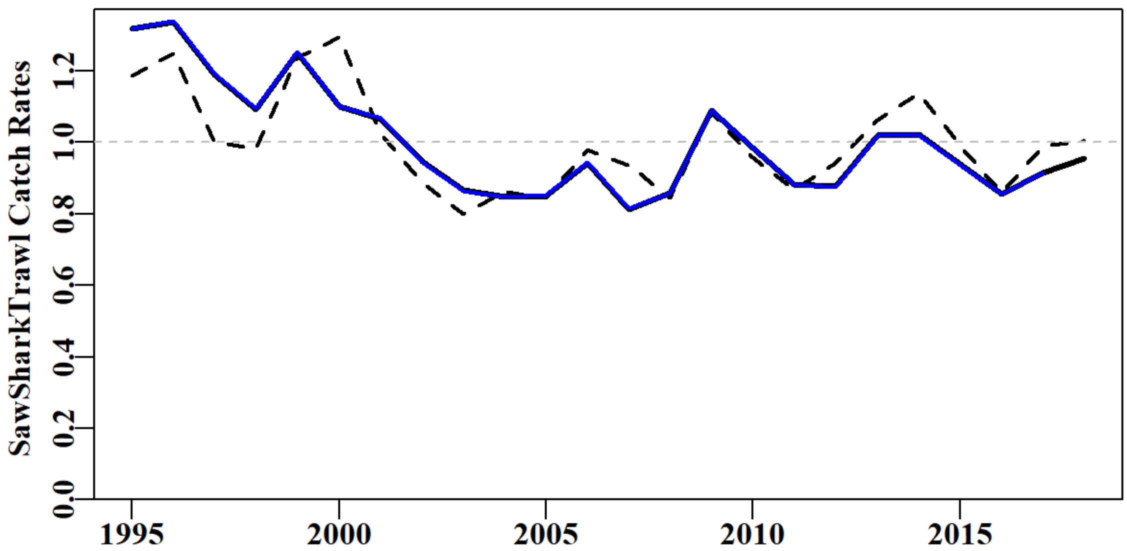

Figure 8.70. SawSharkTrawl. A comparison of the previous year's standardization (blue line) with this year's. They should lie on top of each other, although small deviations may relate to data adjustments, particularly in very recent years.

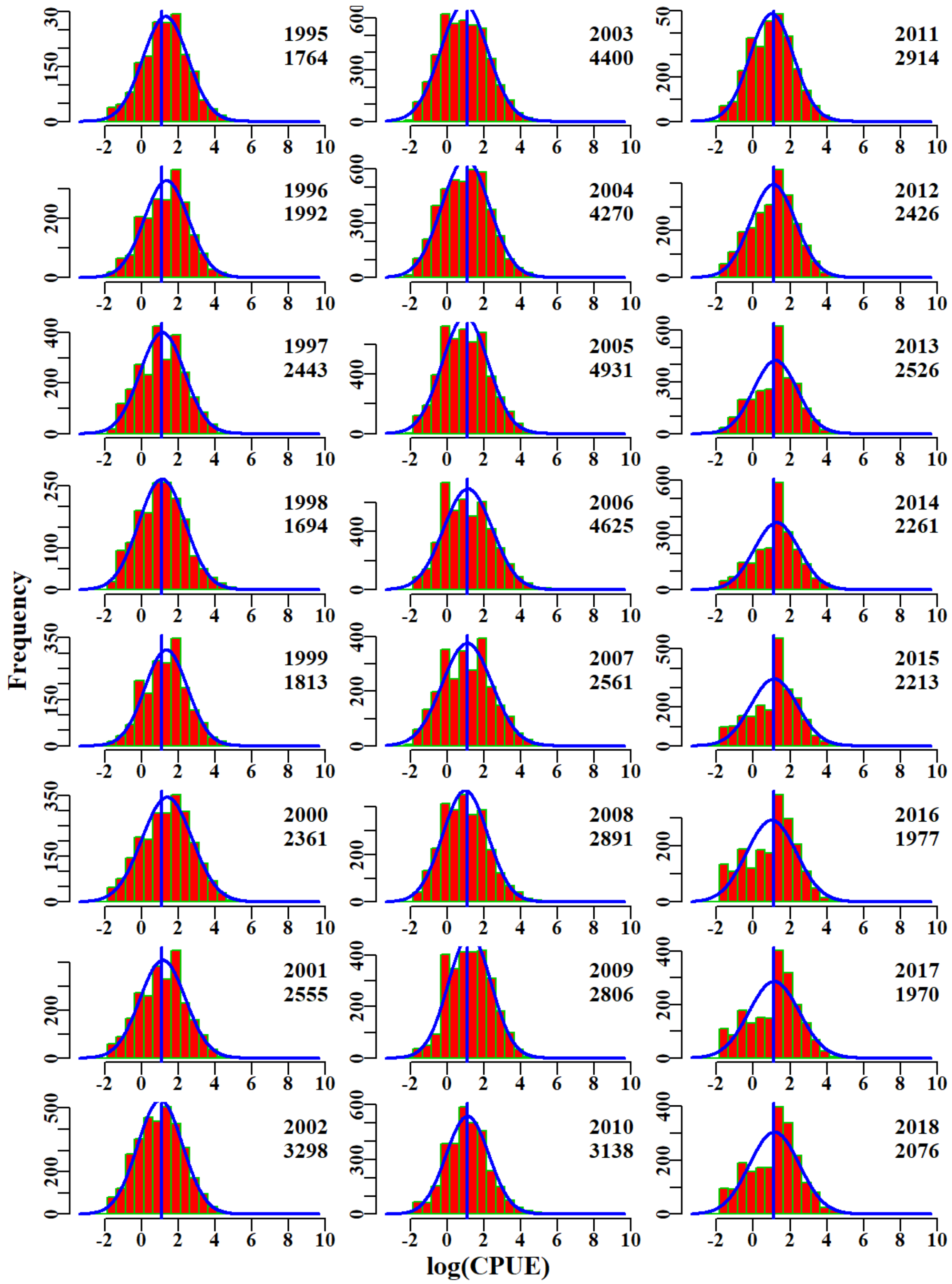

Figure 8.71. SawSharkTrawl. The natural log(CPUE) for each year of data available the blue lines are normal distributions fitted to the histogram frequencies. The numbers in each plot are the year and number of records. The vertical blue line is the average across all years.

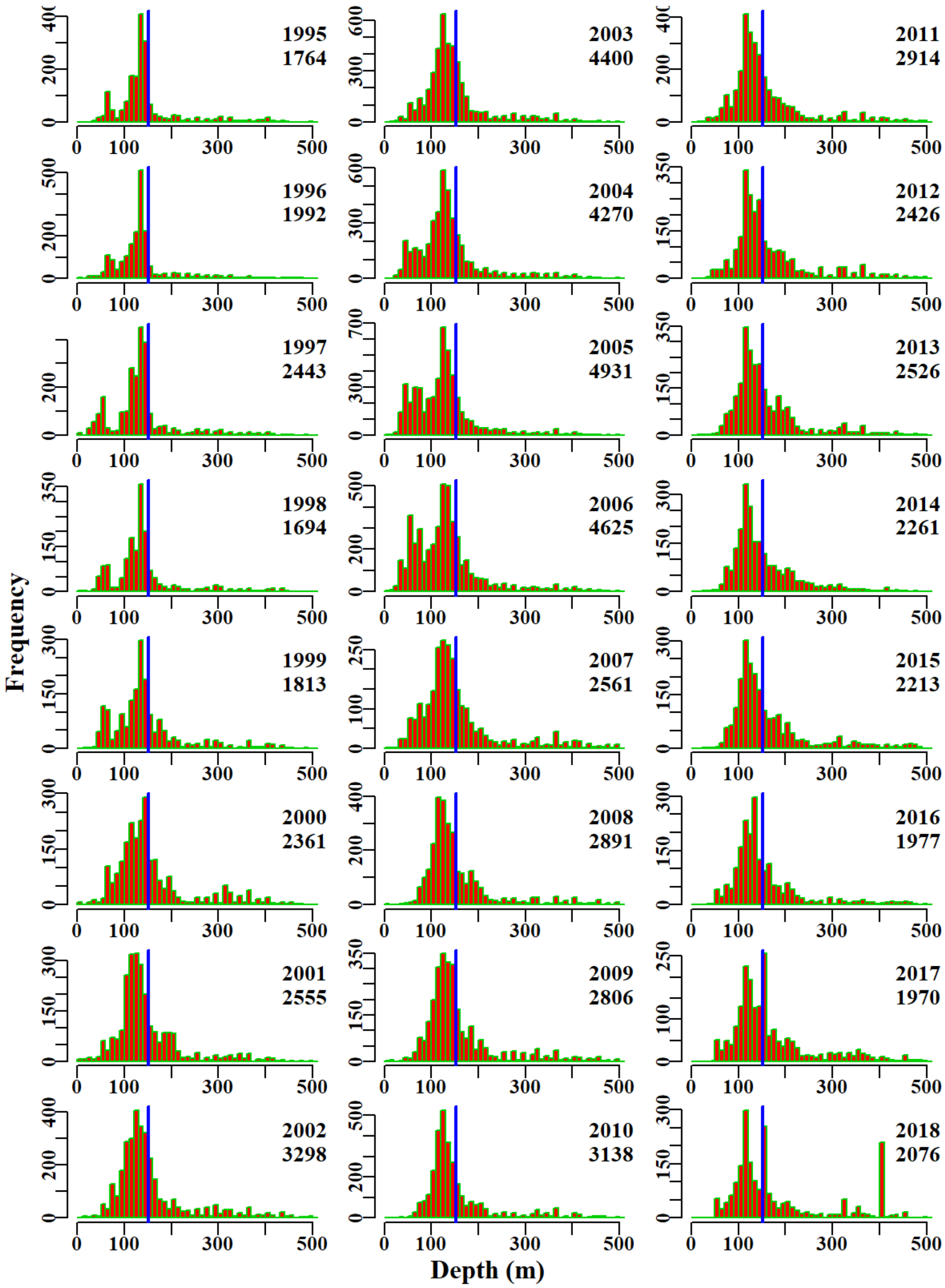

Figure 8.72. SawSharkTrawl. The average Depth of fishing for each year of data available to illustrate the development of the fishery through time. The numbers in each plot are the year and number of records. The vertical blue line is the average across all years.

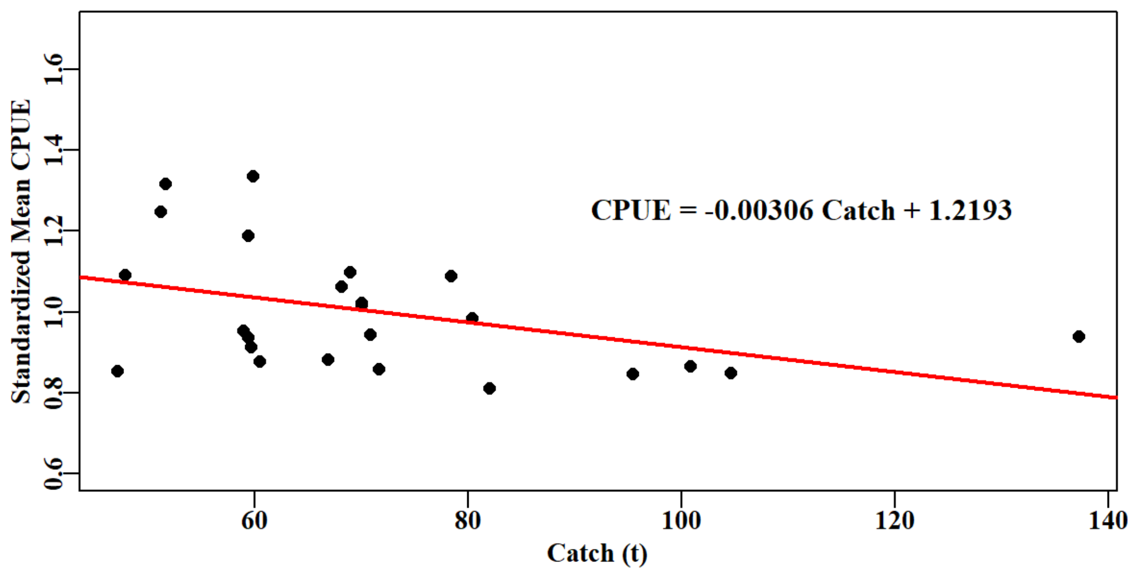

Figure 8.73. SawSharkTrawl The linear relationship between Annual mean CPUE and Annual Catch.

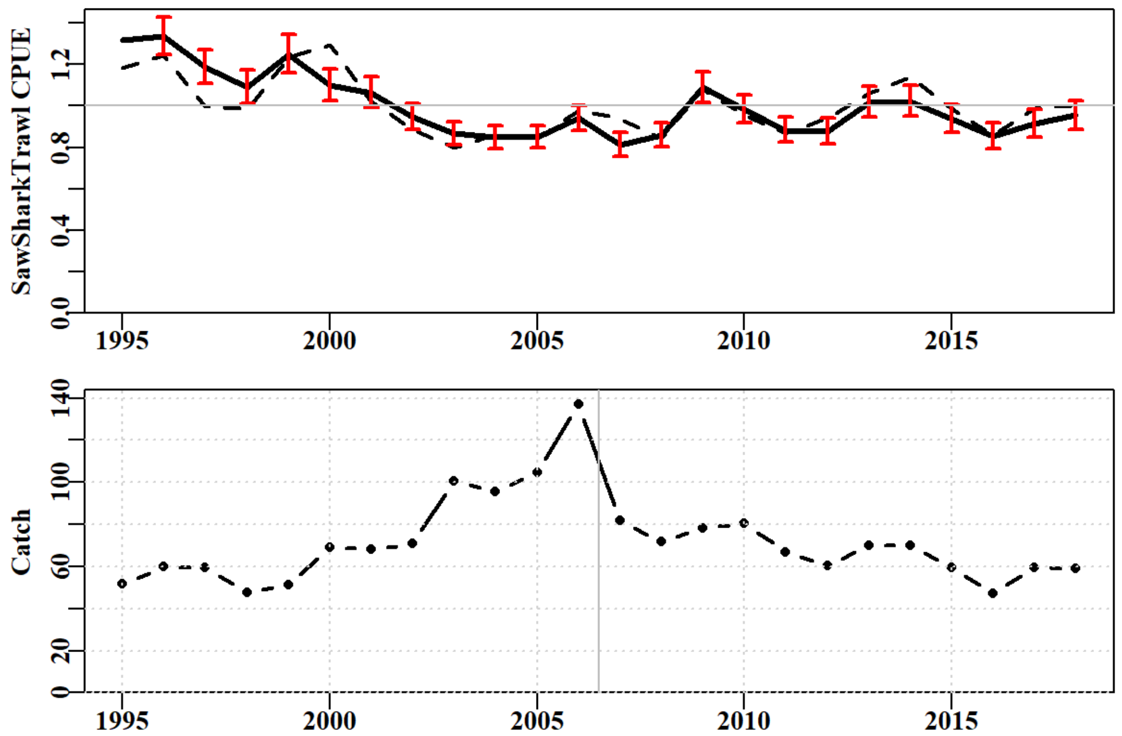

Figure 8.74. SawSharkTrawl. The linear relationship between Annual mean CPUE and Annual Catch.

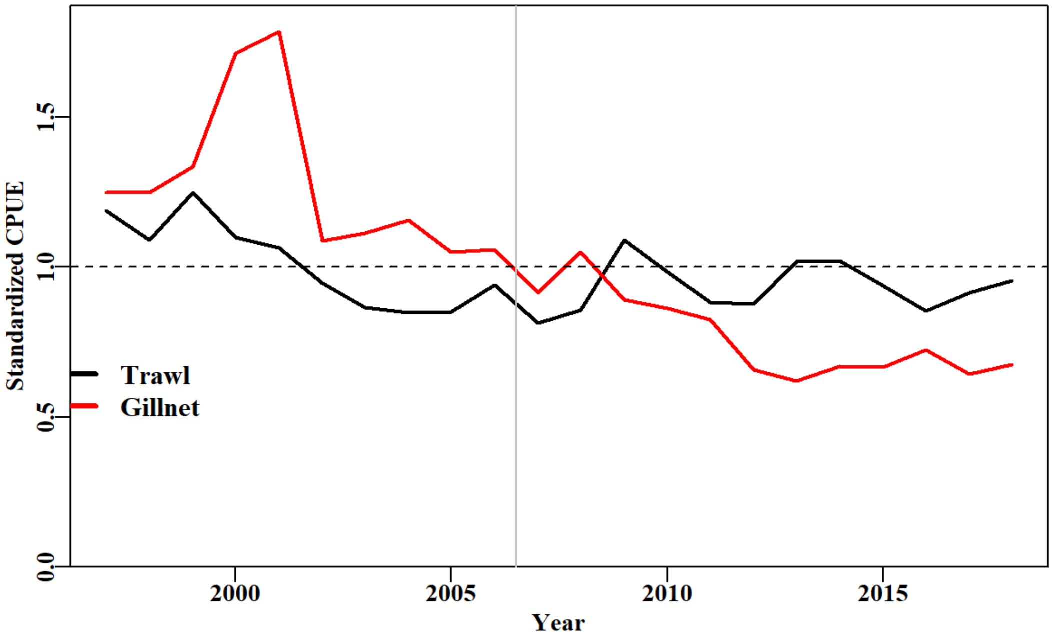

Figure 8.75. SawSharkTrawl. Annual sawshark standardized CPUE taken by trawl and gillnet.

8.12 Sawshark Danish Seine

A large proportion of records contain missing effort entries, so CPUE used in the analyses was kg/shot. Data pertaining to Shark Zones 4 and 5 (Western and Eastern Bass Strait respectively) were used in the analysis.

A total of 8 statistical models were fitted sequentially to the available data, and the order of the non-interaction terms added based on the relative contribution of each term to model fit.

8.12.1 *Inferences*

The majority of catch occurred in Shark region 5, followed by 4.

The terms Year, Vessel, DepCat, SharkRegion, Month, DayNigh and one interaction (SharkRegion:Month) had the greatest contribution to model fit based on the AIC and R2 statistics (Table 8.45). The terms Year, Vessel, Depcat and Month had the greatest contribution to model fit. The qqplot suggests the assumed Normal distribution may be valid, with slight deviations as depicted from both tails of the distribution (Figure 8.77). Annual standardized CPUE has remained similar and at the long-term average since 2015 (Figure 8.79).

8.12.2 *Action Items and Issues*

A further consideration of whether or not to consider the CPUE time-series as a valid index of relative abundance for Saw Sharks could be explored. SharkRAG recommended that sawshark-Danish seine standardized CPUE would not be used as a relative index of abundance (SharkRAG Meeting 1, October 2015).

Table 8.41. SawShark_DS. The data selection criteria used to specify and identify the fishery data to be included in the analysis.

Property	Value
label	SawShark_DS
csirocode	37023002, 37023001, 37023000, 37023900
fishery	SET_GAB
depthrange	0 - 240
depthclass	20
zones	4, 5
methods	DS
years	1997 - 2018

Table 8.42. SawShark_DS. Total catch (Total; t) is the total reported in the database, number of records used in the analysis (N), reported catch (Catch; t) in the area and depth used in the analysis and number of vessels used in the analysis (Vess). GeoM is the geometric mean of catch rates (kg/shot), standard deviation (StDev) relates to the optimum model. C<30Kg denotes the amount of catch in shots of <30kg, and P<30Kg is the proportion of total. The optimum model was SharkRegion:Month.

	Total	N	Catch	Vess	GeoM	Opt	StDev	C<30Kg	P<30Kg
1997	214.2	428	4.0	13	9.2	1.3877	0.000	3.588	0.904
1998	284.2	481	6.7	12	13.9	1.6218	0.068	4.918	0.732
1999	295.6	611	6.4	13	10.0	1.2771	0.064	4.834	0.752
2000	361.7	396	7.1	11	16.9	1.8896	0.072	3.528	0.495
2001	340.7	504	7.0	12	13.2	1.0706	0.071	4.367	0.626
2002	256.6	2646	23.5	22	8.4	0.8981	0.057	16.749	0.712
2003	319.7	2971	21.5	22	6.8	0.7932	0.057	17.384	0.807
2004	314.9	3123	23.5	22	6.7	0.7337	0.057	16.076	0.685
2005	296.7	2556	16.8	22	5.7	0.6525	0.058	12.194	0.724
2006	317.7	2189	17.4	19	7.2	0.7638	0.058	12.133	0.698
2007	214.5	2194	20.9	15	8.5	0.8506	0.058	12.614	0.603
2008	211.7	2406	21.9	15	8.4	0.8934	0.058	14.783	0.675
2009	191.5	2793	20.8	15	6.6	0.8585	0.058	14.690	0.707
2010	192.5	2334	16.7	15	6.7	0.8821	0.058	13.213	0.791
2011	197.0	2795	24.6	14	8.3	0.8578	0.058	17.446	0.709
2012	158.6	2164	20.0	14	8.6	0.8394	0.059	13.778	0.688
2013	165.7	2486	20.5	14	7.7	0.8613	0.058	15.319	0.747
2014	167.2	1706	13.1	14	6.9	0.7665	0.060	9.634	0.736
2015	164.2	2103	23.7	15	10.3	1.0627	0.059	13.550	0.573
2016	164.6	1858	18.9	15	9.1	1.0108	0.060	11.673	0.618
2017	178.8	1711	15.9	16	8.2	0.9828	0.060	9.713	0.610
2018	169.9	1883	20.1	17	9.1	1.0460	0.063	10.731	0.534

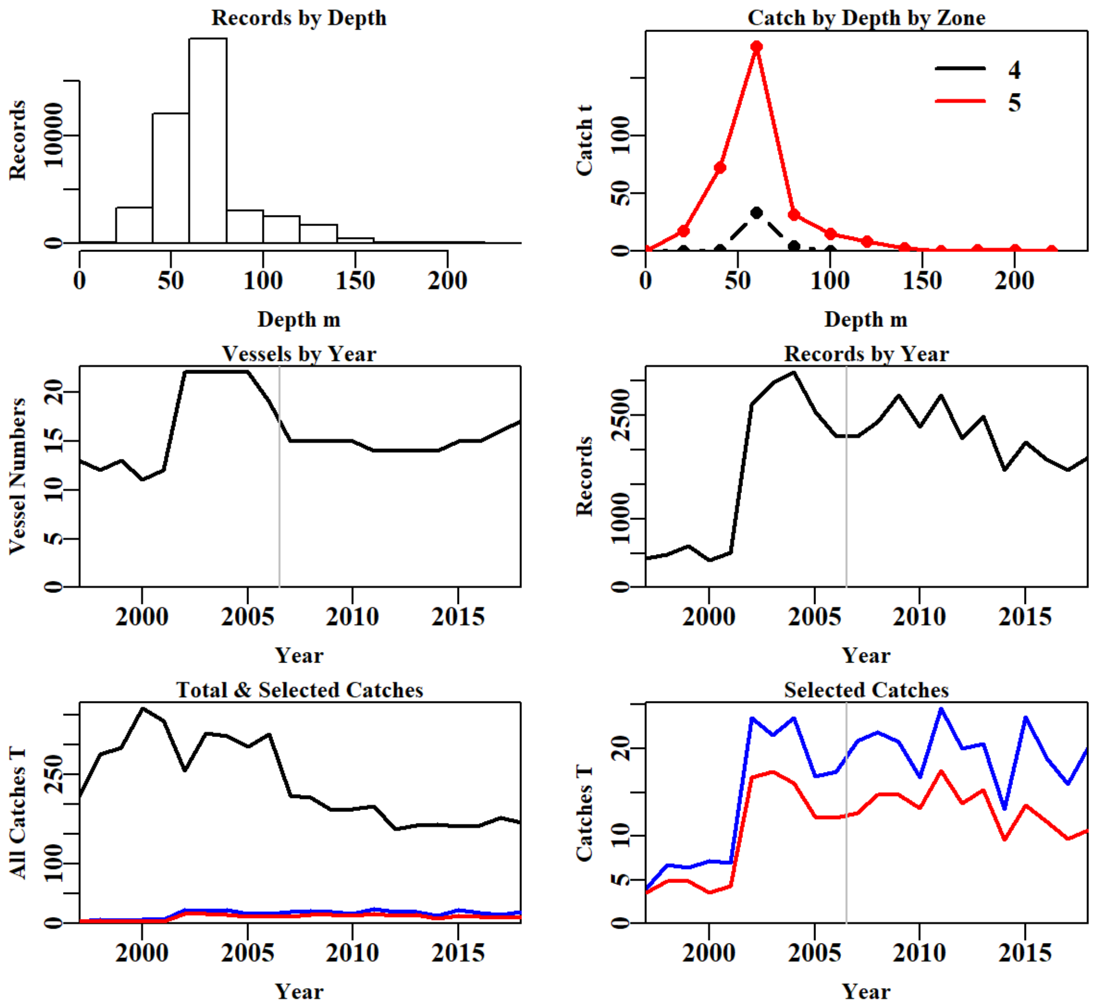

Figure 8.76. SawShark_DS fishery details. The bottom left plot depicts all known catches (top black line), and all selected catches used in the analysis (middle blue line); the lower red line: selected catches < 30 kg).

Table 8.43. SawShark_DS data selection effects. Total is the total number of records in the database, NoCE removes those records with either missing catch or effort, and then only those records are kept that meet the criteria for depth, years, zone, method, and fishery.

	Records	Difference	Catch	Difference
Total	255697	0	5664.343	0.000
NoCE	250075	5622	5664.343	0.000
Depth	238736	11339	5202.089	462.253
Years	221630	17106	4786.141	415.948
Zones	146022	75608	3198.246	1587.895
Method	42715	103307	373.067	2825.179
Fishery	42338	377	371.032	2.035

Table 8.44. The models used to analyse data for SawShark_DS.

	Model
Model1	Year
Model2	Year + Vessel
Model3	Year + Vessel + DepCat
Model4	Year + Vessel + DepCat + SharkRegion
Model5	Year + Vessel + DepCat + SharkRegion + Month
Model6	Year + Vessel + DepCat + SharkRegion + Month + DayNight
Model7	Year + Vessel + DepCat + SharkRegion + Month + DayNight + SharkRegion:DepCat
Model8	Year + Vessel + DepCat + SharkRegion + Month + DayNight + SharkRegion:Month

Table 8.45. SawShark_DS. The row names are 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_r2) and the change in adjusted R^2 (%Change). The optimum model was SharkRegion:Month.

	AIC	RSS	MSS	Nobs	Npars	adj_r2	%Change
Year	5997	48730	1496	42338	22	2.9	0.00
Vessel	4034	46450	3777	42338	55	7.4	4.47
DepCat	1908	44152	6074	42338	66	12.0	4.56
SharkRegion	1652	43883	6343	42338	67	12.5	0.53
Month	1148	43342	6885	42338	78	13.6	1.06
DayNight	1032	43217	7009	42338	81	13.8	0.24
SharkRegion:DepCat	881	43051	7176	42338	87	14.1	0.32
SharkRegion:Month	814	42972	7254	42338	92	14.3	0.47

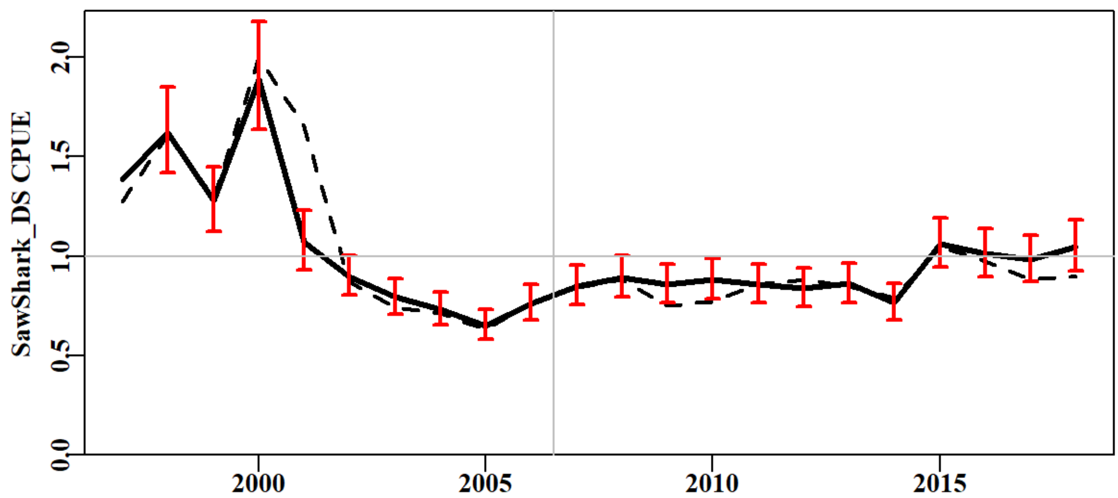

Figure 8.77. SawShark_DS standardization. The dashed black line represents the geometric mean catch rate, solid black line the standardized catch rates. The red bars are the 95% confidence intervals about the mean estimates. The graph scales both time-series of standardized catch rates relative to the mean of each time-series.

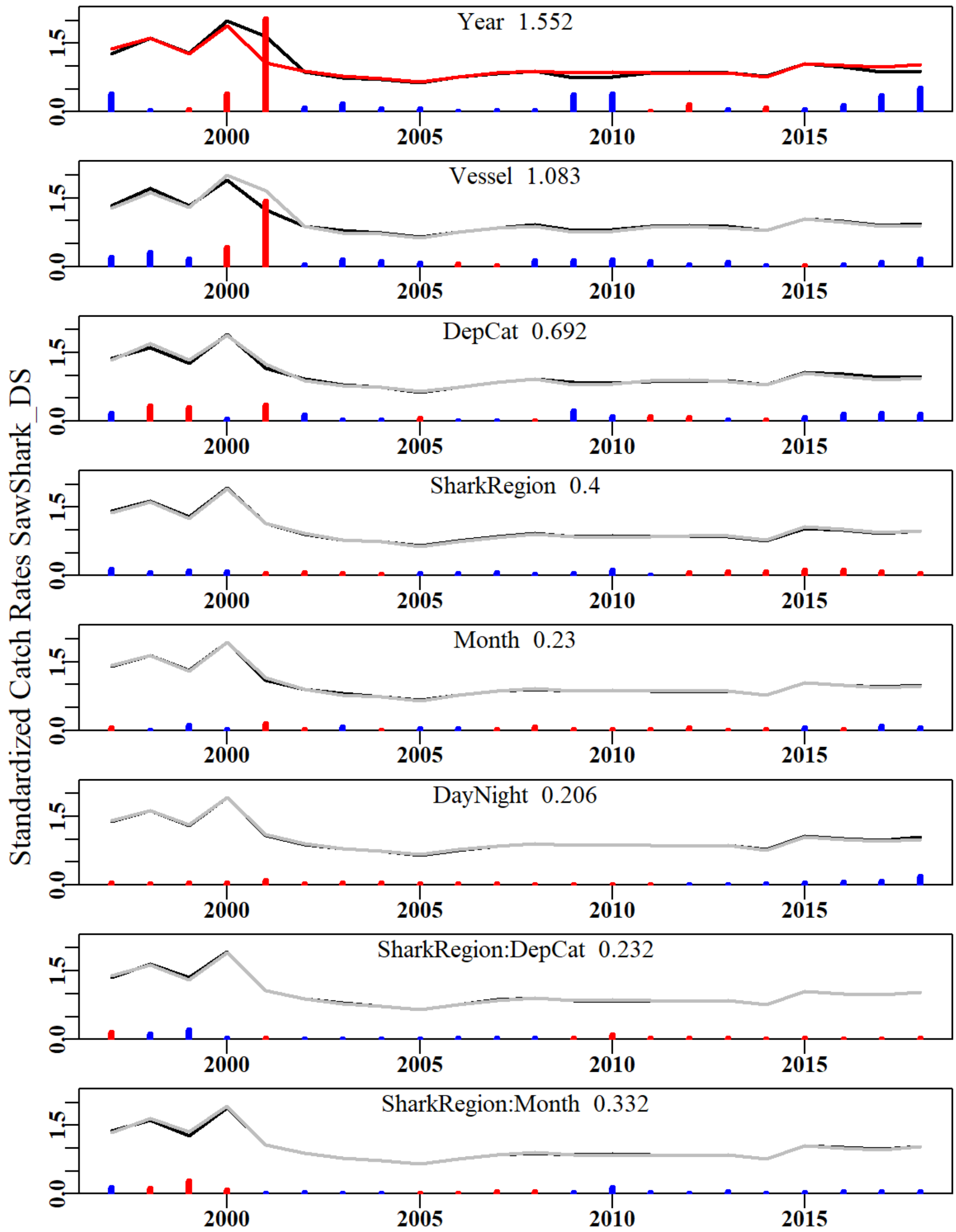

Figure 8.78. SawShark_DS. The influence of each factor on the optimal standardization. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by vertical bars with blue bars indicating the optimum model is higher than the geometric mean and red bars indicating it is lower. The top graph bars are the sum of all the bars in the graphs below. The graphs for individual factors are cumulative. Thus the second graph has the geometric mean (grey line) and the effect of adding Year + factor2 (Model 2). In the third graph, the grey line represents Model 2 and the black line the effect of adding factor3 to the model. The remaining graphs continue in the same cumulative manner except for the interaction terms which are added singularly to the final single factor model.

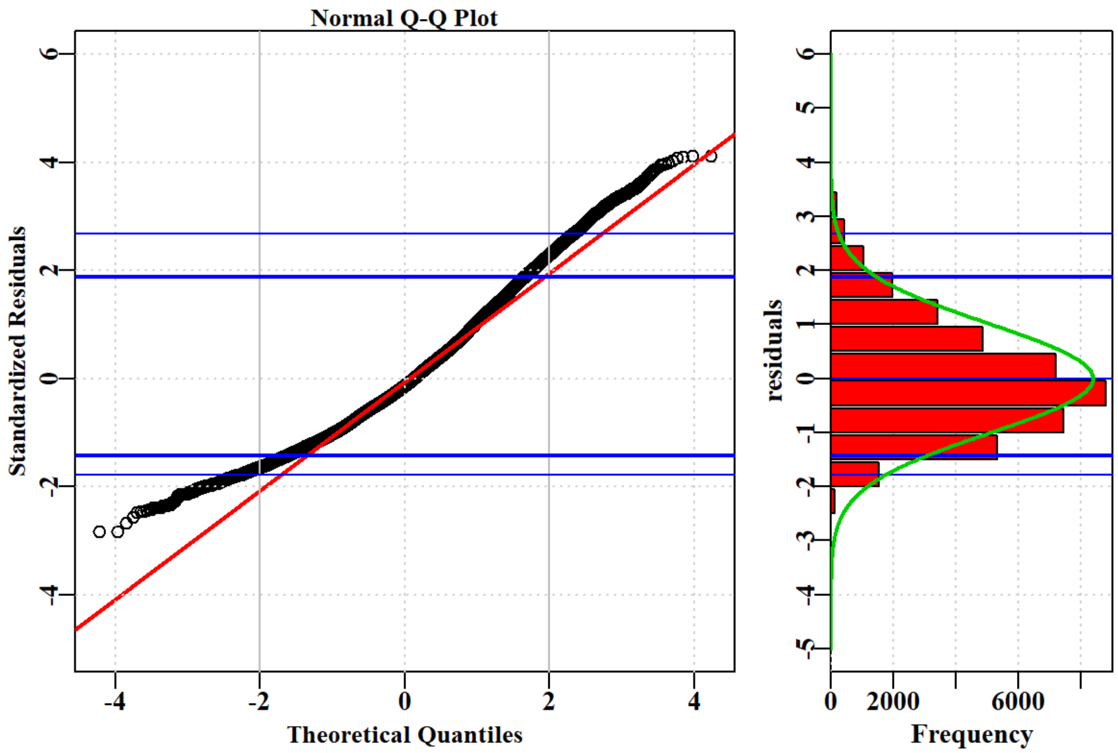

Figure 8.79. SawShark_DS. Diagnostic plots. The distribution of residuals from the optimum fit. The qqplot indicates the fit to the expected normality, while the histogram of residuals also illustrates the 1%, 5%, 95% and 99% quantiles to indicate the intensity of any lack of fit at the margins of the distribution (reflected also in the qqplot).

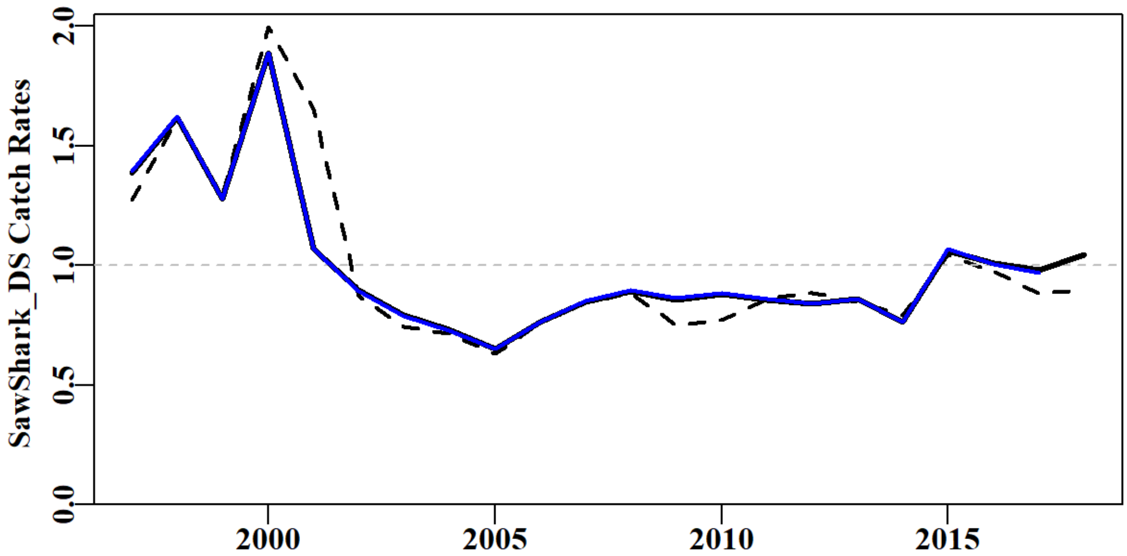

Figure 8.80. SawShark_DS. A comparison of the previous year's standardization (blue line) with this year's. They should lie on top of each other, although small deviations may relate to data adjustments, particularly in very recent years.

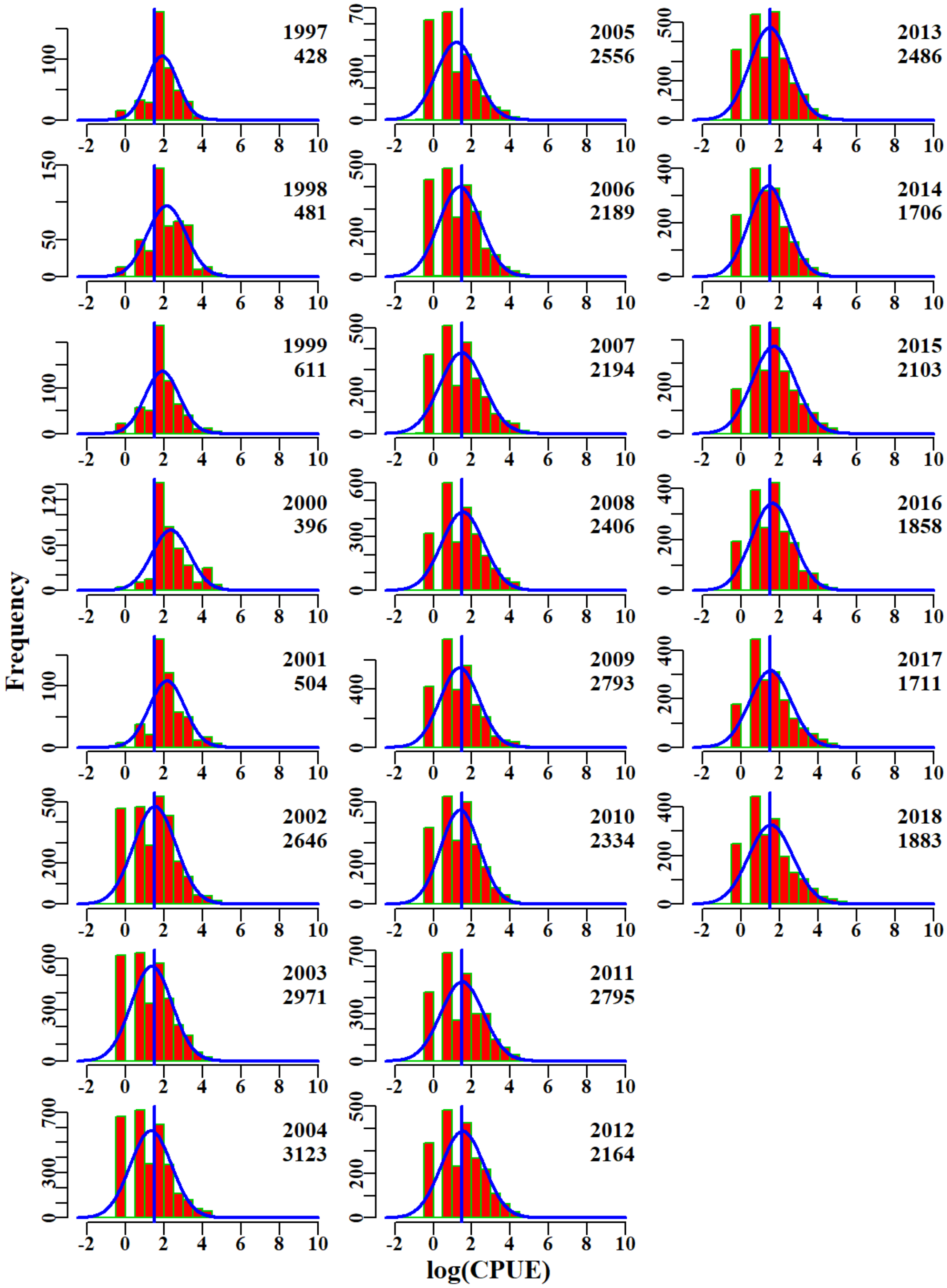

Figure 8.81. SawShark_DS. The natural log(CPUE) for each year of data available the blue lines are normal distributions fitted to the histogram frequencies. The numbers in each plot are the year and number of records. The vertical blue line is the average across all years.

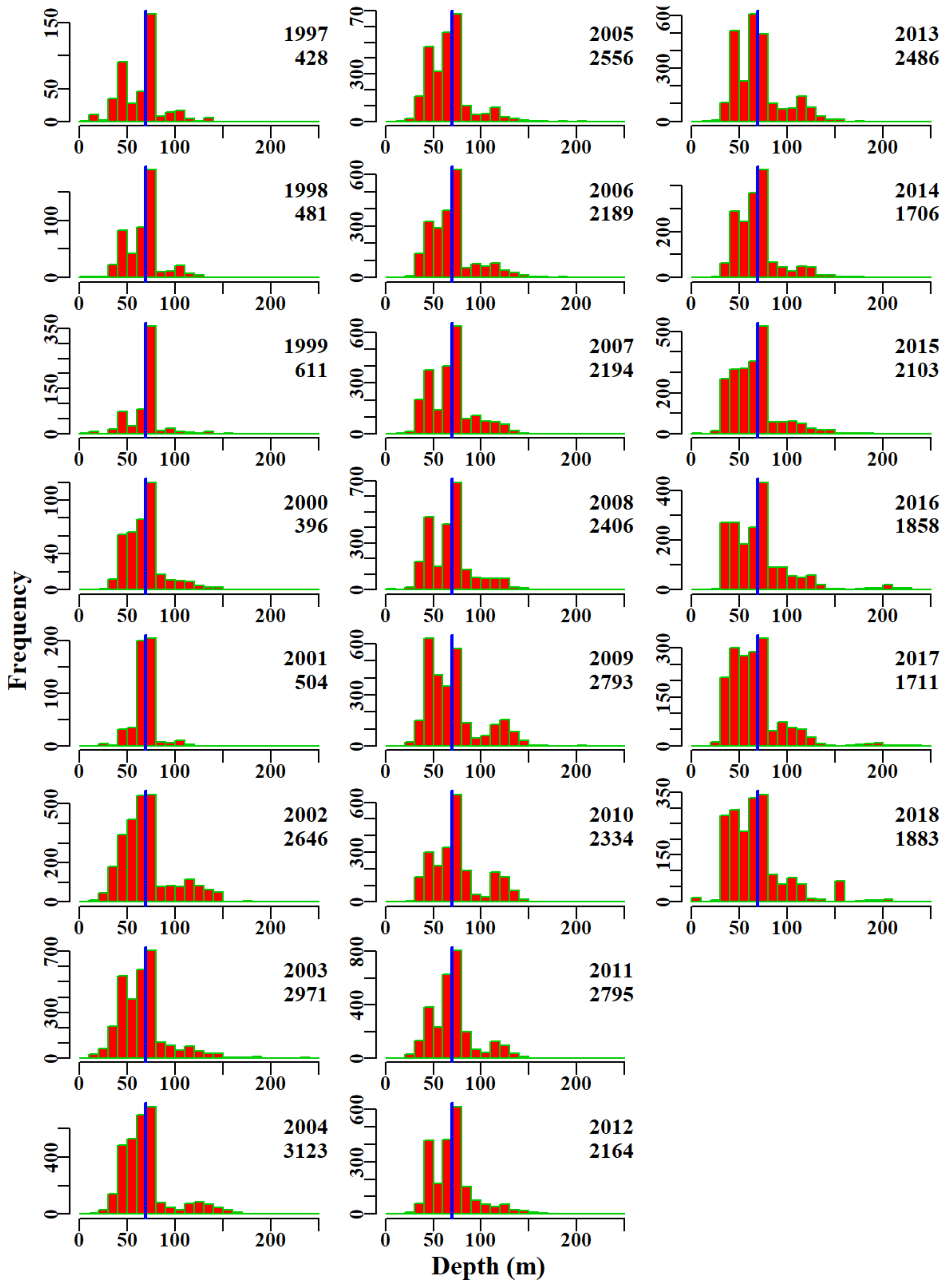

Figure 8.82. SawShark_DS. The average Depth of fishing for each year of data available to illustrate the development of the fishery through time. The numbers in each plot are the year and number of records. The vertical blue line is the average across all years.

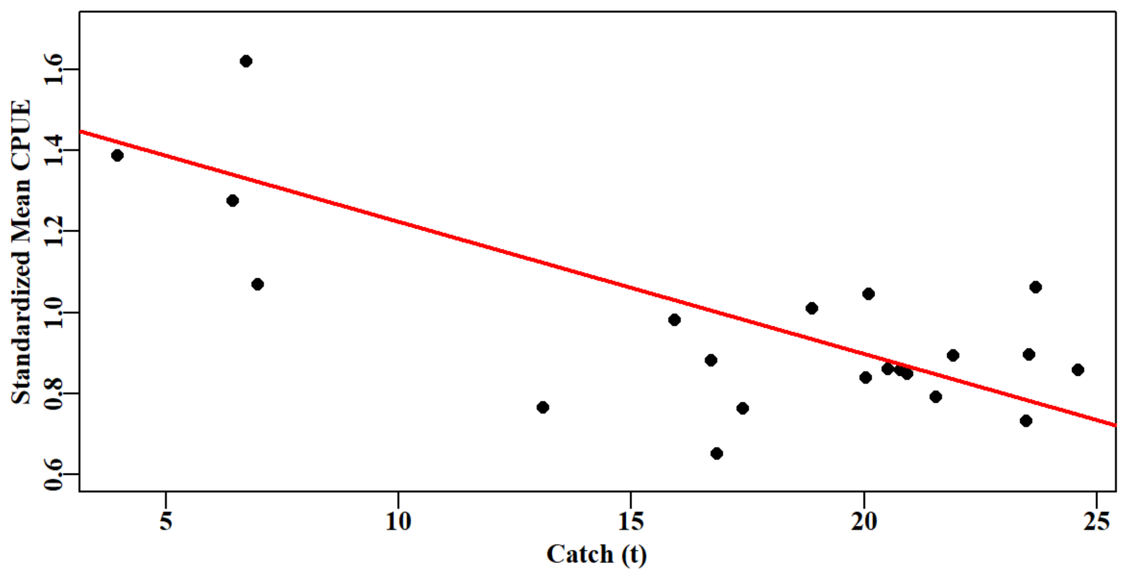

Figure 8.83. SawShark_DS. The linear relationship between Annual mean CPUE and Annual Catch.

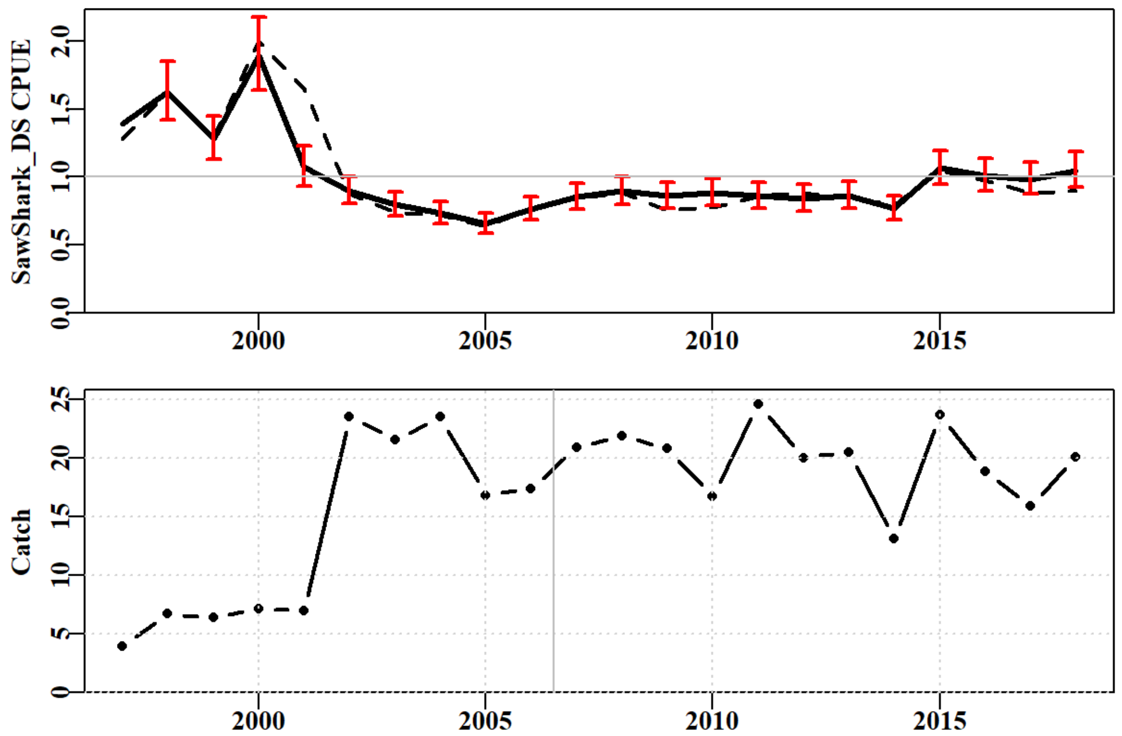

Figure 8.84. SawShark_DS. The linear relationship between annual mean CPUE and annual Catch.

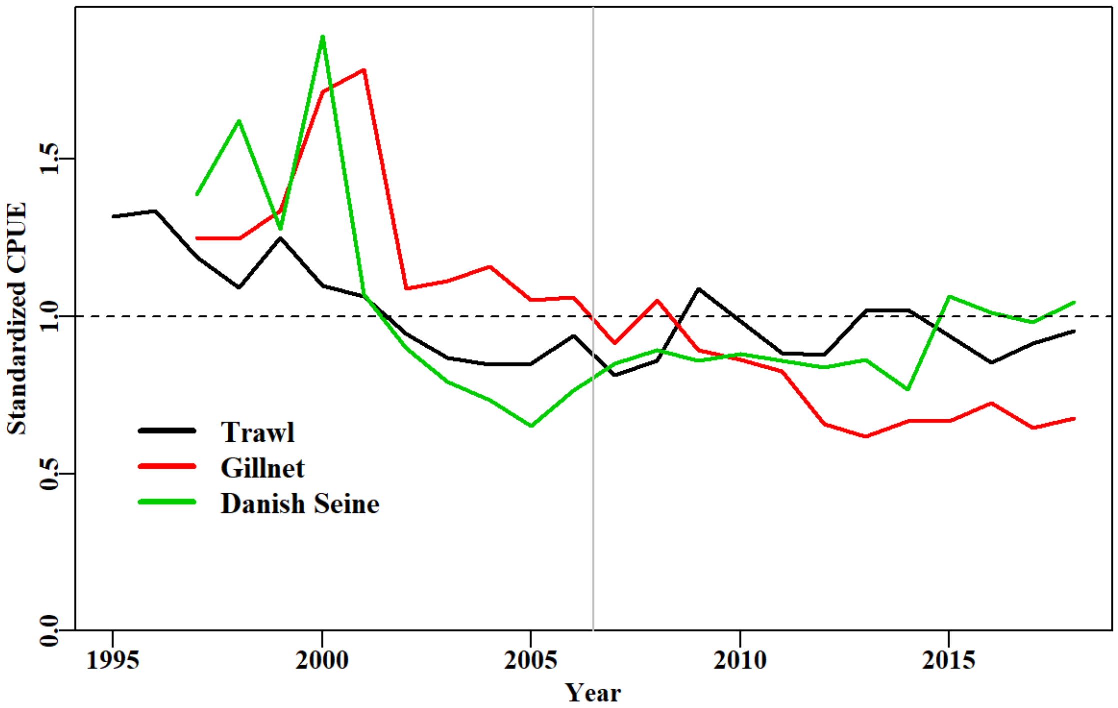

Figure 8.85. Sawshark CPUE from Trawl compared with that from Gillnet and Danish Seine.

8.13 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 8.86). The preliminary estimate of the proportion discarded for 2017 is 0.52, corresponding to 108.2 t (Castillo-Jordán et al. 2018). Given the high proportion of discards, it is questionable as to whether an analysis including zero catches would be valid. Therefore, only non-zero shots were analysed. The use of effort in units of net length should be investigated for future analyses. Exploratory analyses shows inconsistency in the recording of gillnet effort units in the logbook database, particularly in 1997 and 1998 compared to later years. A detailed effort analysis is required towards utilizing this in subsequent standardizations.

A total of 7 statistical models were fitted sequentially to the available data, and the order of the non-interaction terms added based on the relative contribution of each term to model fit.

8.13.1 *Inferences*

As with sawshark taken by gillnet there is a strong correlation between total annual catch and annual standardized CPUE estimates of elephantfish. In addition, the large proportion of the total catch taken in shots of < 30 kg indicates the by-product nature of this fishery (confirmed by the large proportion of discards from this fishery).

The majority of catch occurred in Shark region 5, followed by 4.

The terms Year, Vessel, Month, DepCat, SharkRegion and one interaction (SharkRegion:Month) had the greatest contribution to model fit based on the AIC and R2 statistics (Table 8.50). The terms Year and Vessel had the greatest contribution to model fit. The qqplot suggests the assumed Normal distribution may be valid, with a slight deviation as depicted from the lower tail of the distribution (Figure 8.89). Annual standardized CPUE has remained below the long-term average since 2014, with a slight increase in 2016 followed by a decrease in 2017 and an increase in 2018 (Figure 8.87).

8.13.2 *Action Items and Issues*

Exploration of other CPUE trends from other methods may illustrate whether this measure of CPUE constitutes a valid index of relative abundance for Elephantfish.

Table 8.46. ElephantFishGN. The data selection criteria used to specify and identify the fishery data to be included in the analysis.

Property	Value
label	ElephantFishGN
csirocode	37043000, 37043001
fishery	GHT_SEN_SSF_SSG_SSH
depthrange	0 - 160
depthclass	20
zones	2, 3, 4, 5, 6, 7
methods	GN
years	1997 - 2018

Table 8.47. ElephantFishGN. Total catch (Total; t) is the total reported in the database, number of records used in the analysis (N), reported catch (Catch; t) in the area and depth used in the analysis and number of vessels used in the analysis (Vess). GeoM is the geometric mean of catch rates (kg/shot), standard deviation (StDev) relates to the optimum model. C<30Kg denotes the amount of catch in shots of <30kg, and P<30Kg is the proportion of total. The optimum model was SharkRegion:Month.

	Total	N	Catch	Vess	GeoM	Opt	StDev	C<30Kg	P<30Kg
1997	32.0	1441	25.3	56	15.8	0.9534	0.000	9.166	0.362
1998	51.9	2111	41.4	57	16.1	0.8894	0.047	12.658	0.306
1999	69.0	2772	54.5	65	17.4	1.0451	0.046	17.654	0.324
2000	78.7	2708	62.0	57	18.5	1.3068	0.046	19.903	0.321
2001	88.8	2746	71.2	62	22.6	1.3433	0.047	19.152	0.269
2002	59.4	2100	36.9	61	16.0	0.9709	0.049	13.464	0.365
2003	71.2	2151	41.8	60	15.8	0.9572	0.049	12.979	0.311
2004	64.8	1746	30.2	51	14.7	0.9195	0.051	10.598	0.351
2005	66.4	1845	32.1	40	16.0	0.9436	0.050	11.385	0.355
2006	53.3	1638	30.8	42	16.0	1.0212	0.052	9.758	0.317
2007	51.7	1737	32.2	38	16.9	1.0968	0.052	11.584	0.360
2008	61.4	1988	38.1	34	18.1	1.1553	0.050	13.550	0.356
2009	65.3	2072	42.8	35	21.2	1.3459	0.050	15.337	0.358
2010	56.7	2223	33.9	35	14.6	1.0538	0.050	14.395	0.425
2011	50.5	2637	33.3	35	11.4	0.9091	0.050	17.380	0.522
2012	65.9	2625	43.2	38	15.6	1.0515	0.049	17.456	0.404
2013	61.9	2409	36.2	34	14.4	0.9783	0.050	17.456	0.483
2014	47.4	2159	29.1	31	12.8	0.8799	0.050	15.225	0.522
2015	49.3	1784	27.6	27	14.1	0.8217	0.052	11.053	0.400
2016	49.0	2042	34.6	27	14.7	0.8435	0.050	12.489	0.361
2017	40.8	1954	25.0	24	11.2	0.7023	0.051	11.711	0.468
2018	43.4	1933	25.9	27	12.0	0.8114	0.052	11.308	0.437

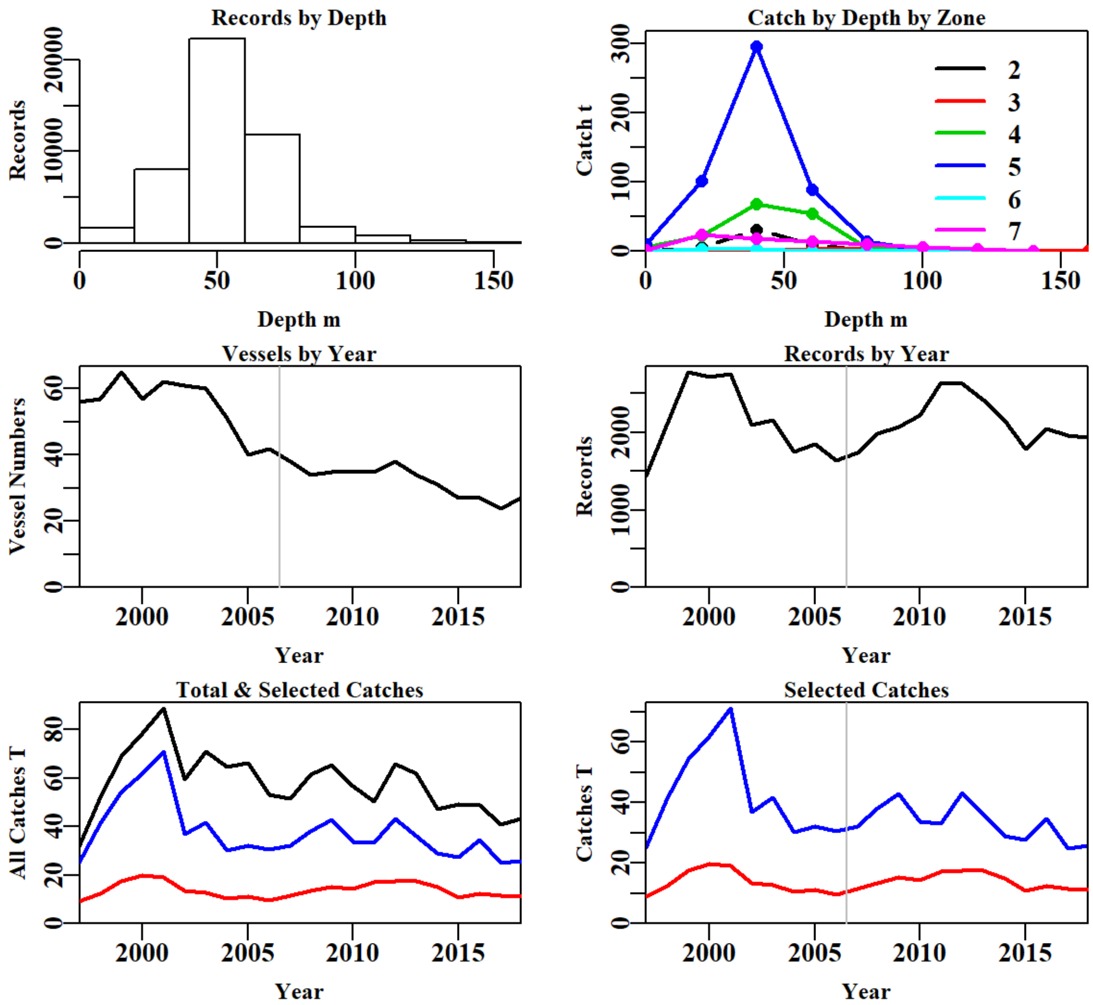

Figure 8.86. ElephantFishGN fishery details. The bottom left plot depicts all known catches (top black line), and all selected catches used in the analysis (middle blue line); the lower red line: selected catches < 30 kg).

Table 8.48. ElephantFishGN data selection effects. Total is the total number of records in the database, NoCE removes those records with either missing catch or effort, and then only those records are kept that meet the criteria for depth, years, zone, method, and fishery.

	Records	Difference	Catch	Difference
Total	90597	0	1341.450	0.000
NoCE	83139	7458	1341.450	0.000
Depth	75662	7477	1250.327	91.123
Years	73577	2085	1205.423	44.903
Zones	70254	3323	1141.925	63.498
Method	46823	23431	827.886	314.039
Fishery	46821	2	827.882	0.004

Table 8.49. The models used to analyse data for ElephantFishGN.

	Model
Model1	Year
Model2	Year + Vessel
Model3	Year + Vessel + Month
Model4	Year + Vessel + Month + DepCat
Model5	Year + Vessel + Month + DepCat + SharkRegion
Model6	Year + Vessel + Month + DepCat + SharkRegion + SharkRegion:DepCat
Model7	Year + Vessel + Month + DepCat + SharkRegion + SharkRegion:Month

Table 8.50. ElephantFishGN. The row names are 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_r2) and the change in adjusted R^2 (%Change). The optimum model was SharkRegion:Month.

	AIC	RSS	MSS	Nobs	Npars	adj_r2	%Change
Year	27035	83330	1088	46821	22	1.2	0.00
Vessel	23939	77473	6945	46821	180	7.9	6.63
Month	23728	77088	7330	46821	191	8.3	0.44
DepCat	23710	77033	7384	46821	199	8.4	0.05
SharkRegion	23502	76675	7743	46821	204	8.8	0.42
SharkRegion:DepCat	23278	76199	8219	46821	238	9.3	0.50
SharkRegion:Month	23077	75804	8614	46821	259	9.7	0.93

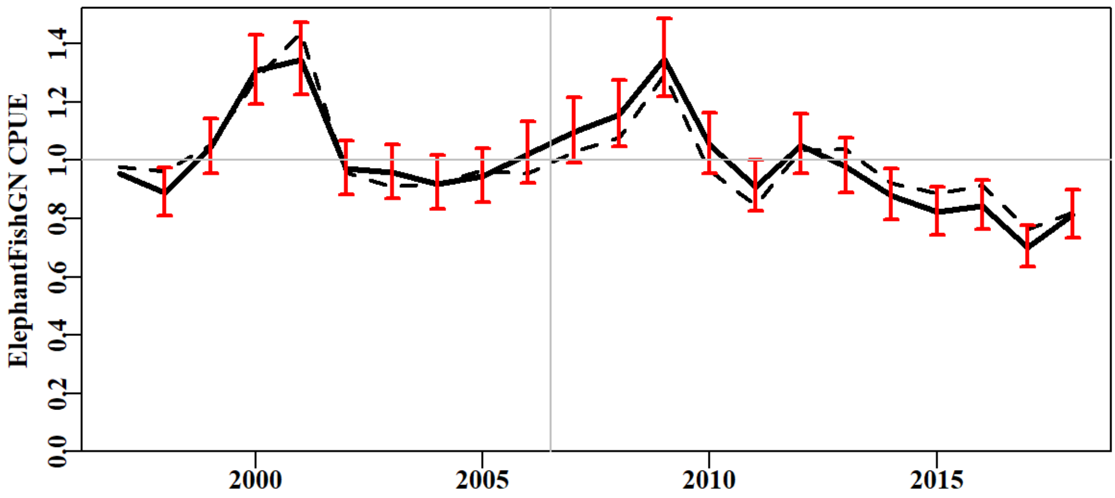

Figure 8.87. ElephantFishGN standardization. The dashed black line represents the geometric mean catch rate, solid black line the standardized catch rates. The red bars are the 95% confidence intervals about the mean estimates. The graph scales both time-series of standardized catch rates relative to the mean of each time-series.

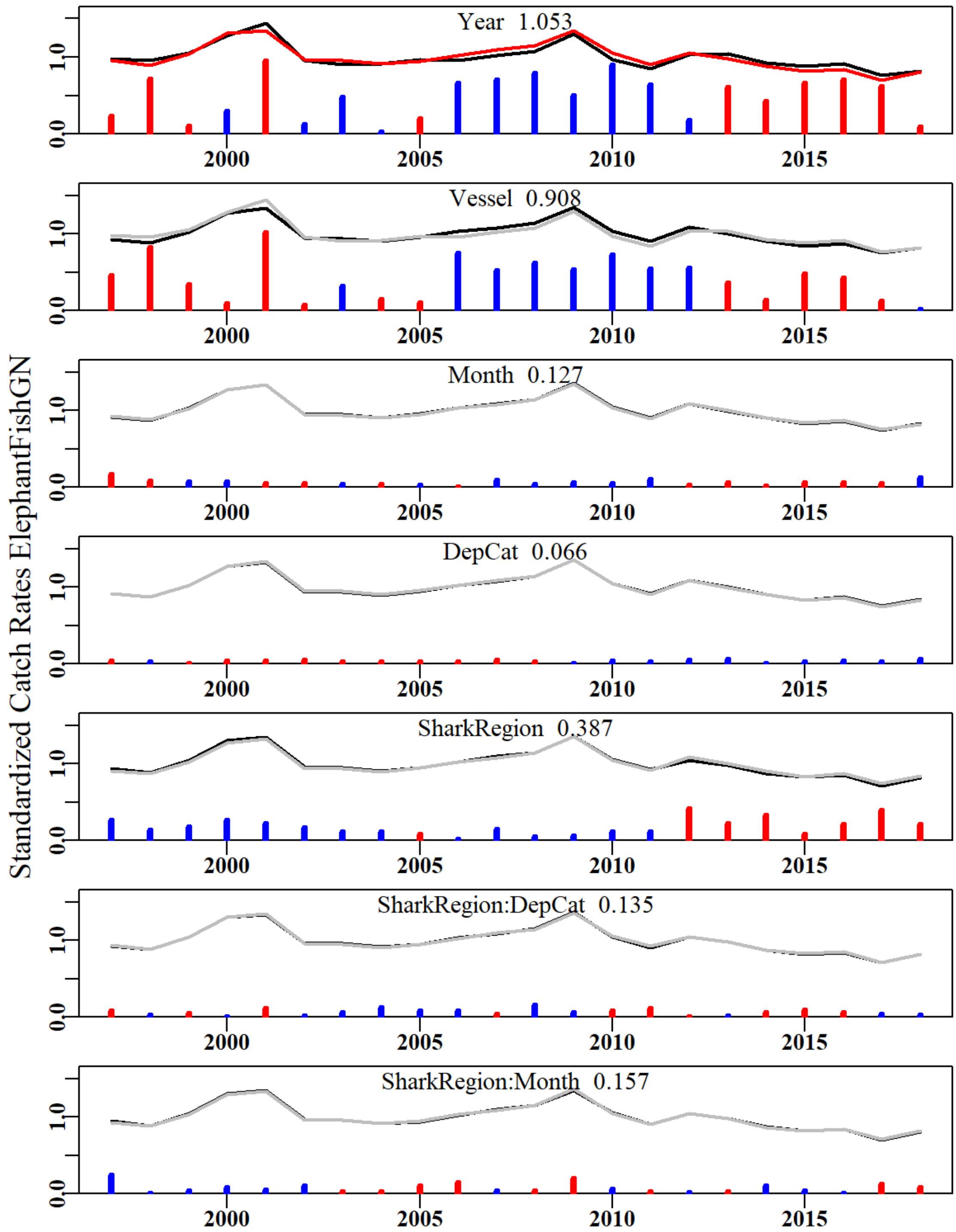

Figure 8.88. ElephantFishGN. The influence of each factor on the optimal standardization. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by vertical bars with blue bars indicating the optimum model is higher than the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

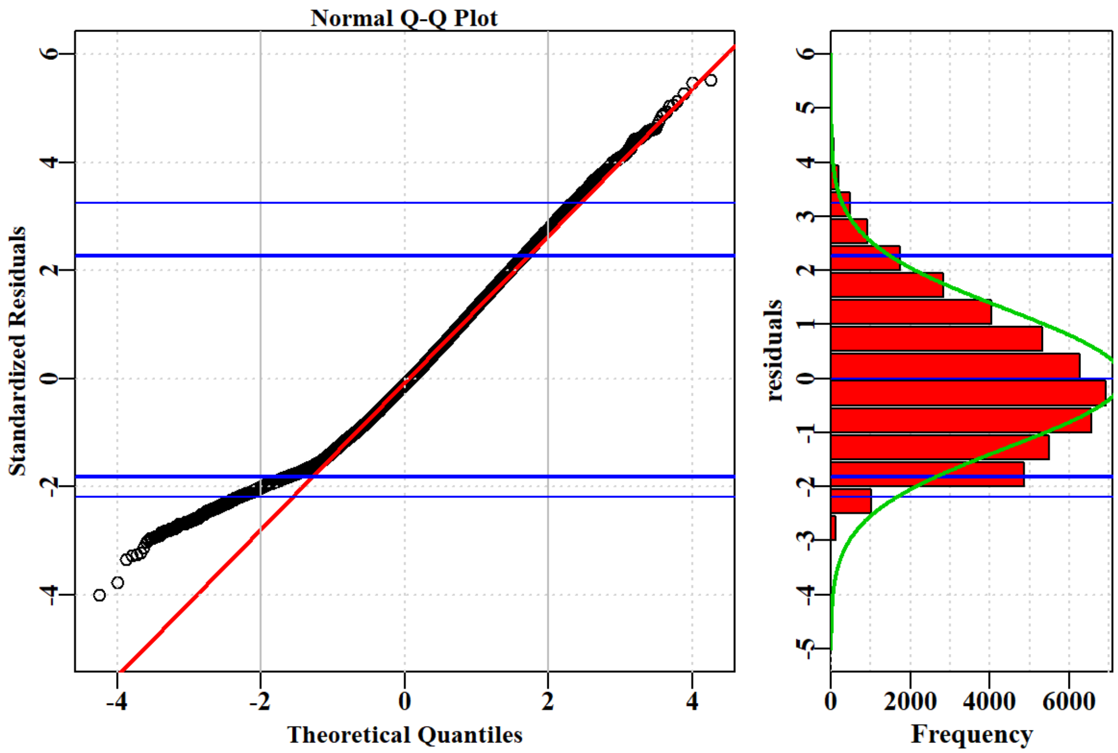

Figure 8.89. ElephantFishGN. Diagnostic plots. The distribution of residuals from the optimum fit. The qqplot indicates the fit to the expected normality, while the histogram of residuals also illustrates the 1%, 5%, 95% and 99% quantiles to indicate the intensity of any lack of fit at the margins of the distribution (reflected also in the qqplot).

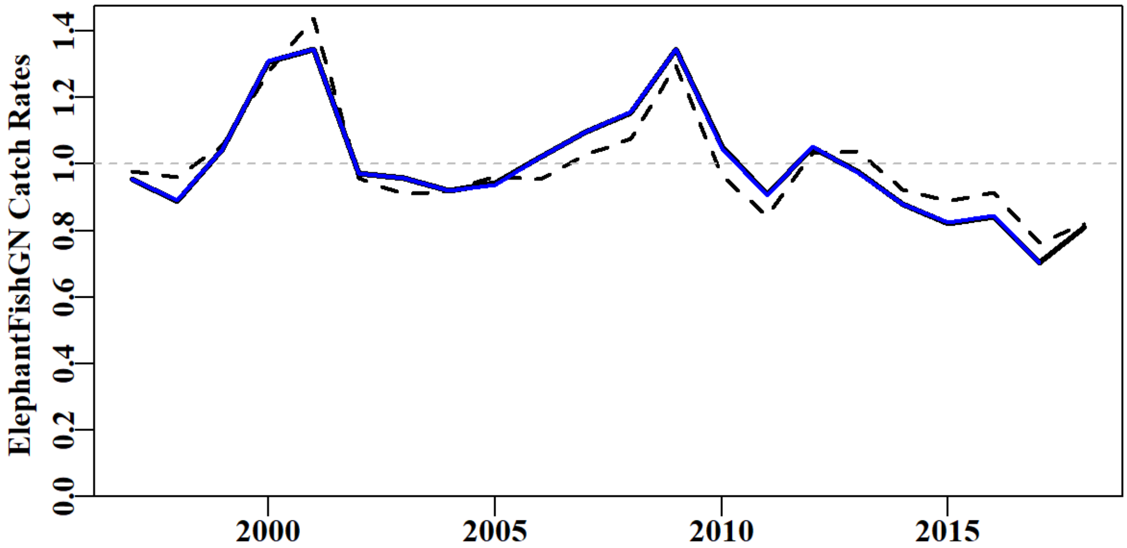

Figure 8.90. ElephantFishGN. A comparison of the previous year's standardization (blue line) with this year's. They should lie on top of each other, although small deviations may relate to data adjustments, particularly in very recent years.

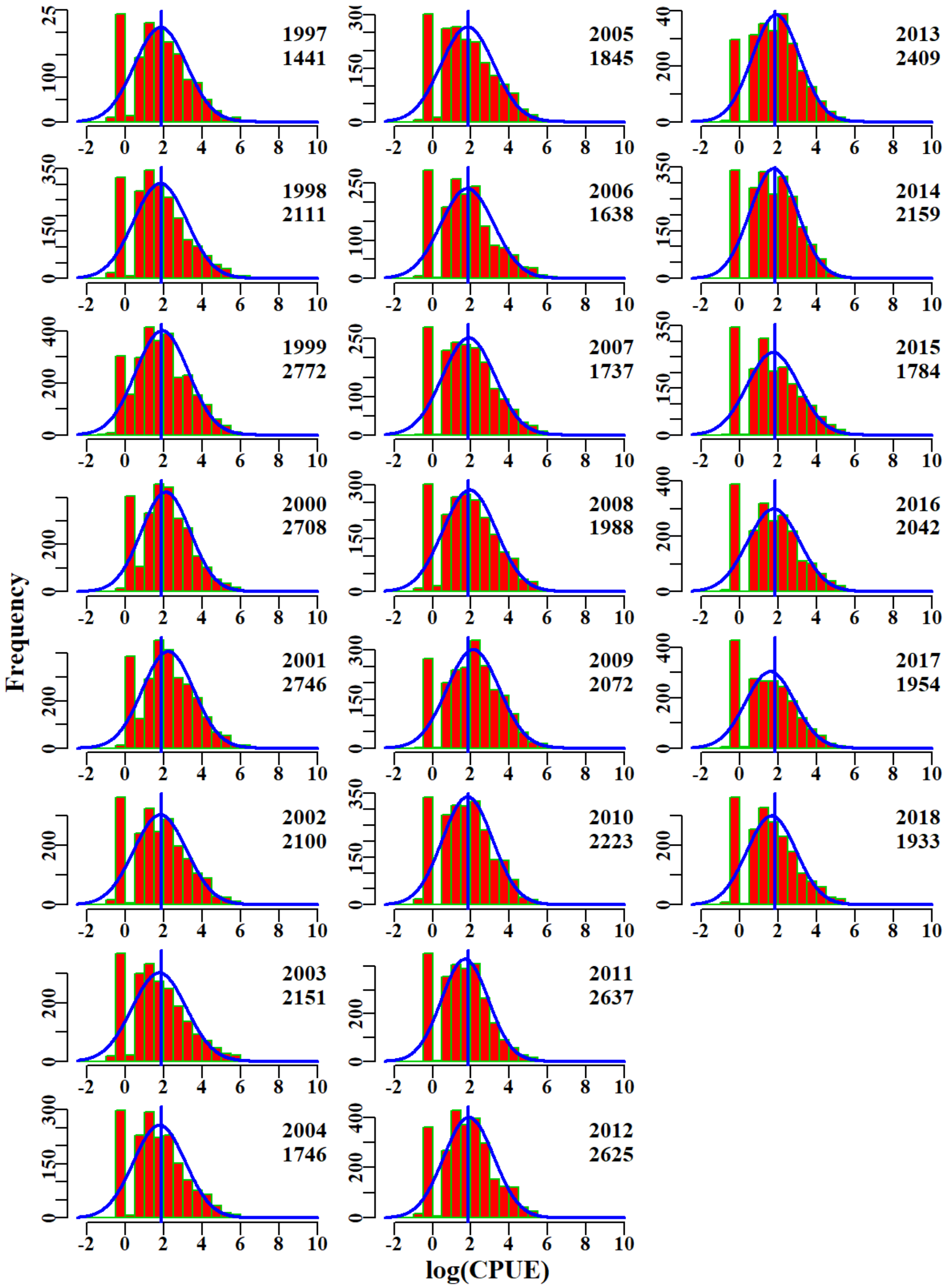

Figure 8.91. ElephantFishGN. The natural log(CPUE) for each year of data available the blue lines are normal distributions fitted to the histogram frequencies. The numbers in each plot are the year and number of records. The vertical blue line is the average across all years.

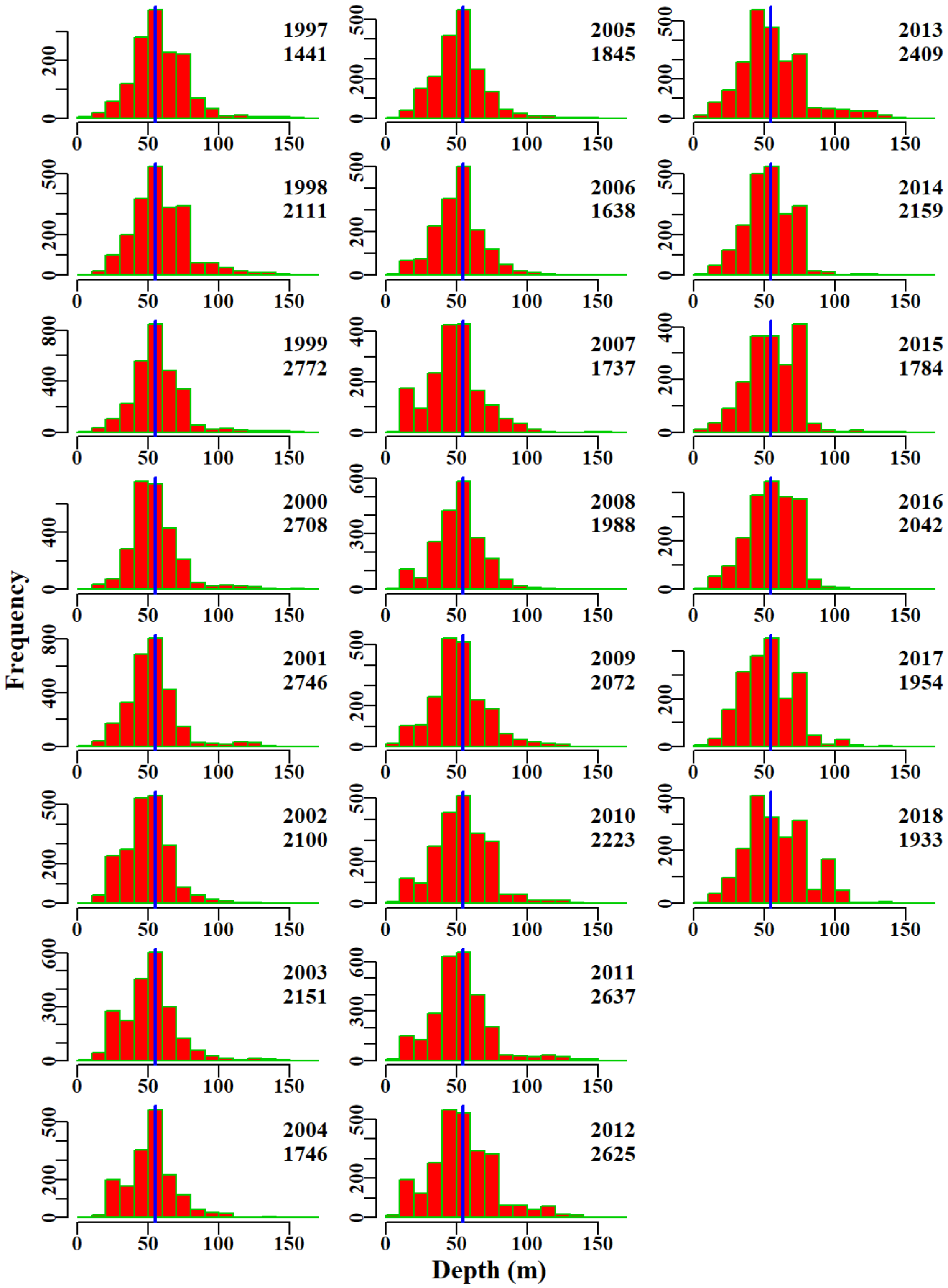

Figure 8.92. ElephantFishGN. The average Depth of fishing for each year of data available to illustrate the development of the fishery through time. The numbers in each plot are the year and number of records. The vertical blue line is the average across all years.

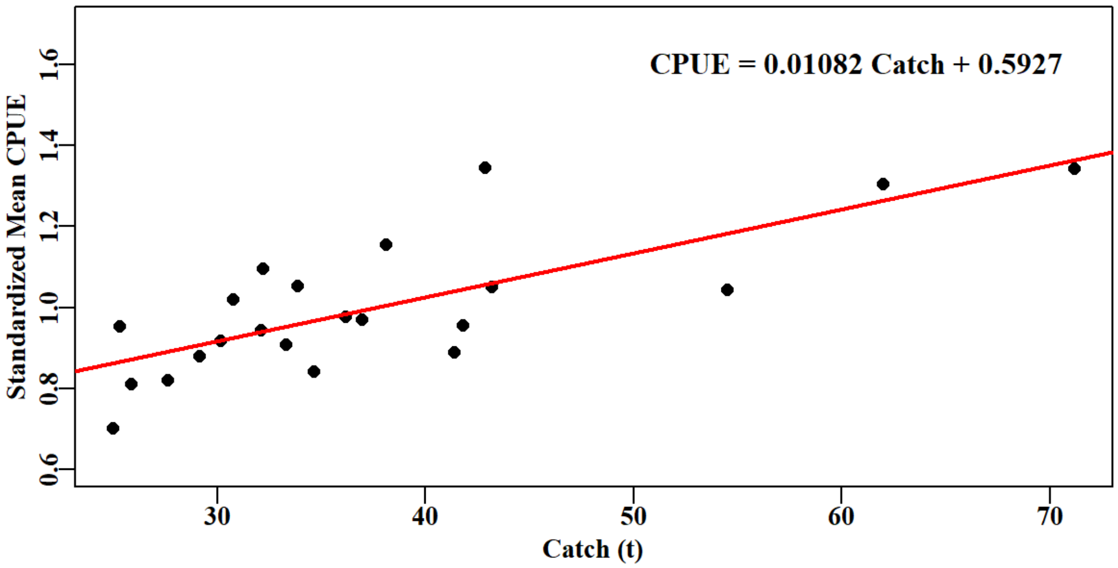

Figure 8.93. ElephantFishGN. The linear relationship between Annual mean CPUE and Annual Catch.

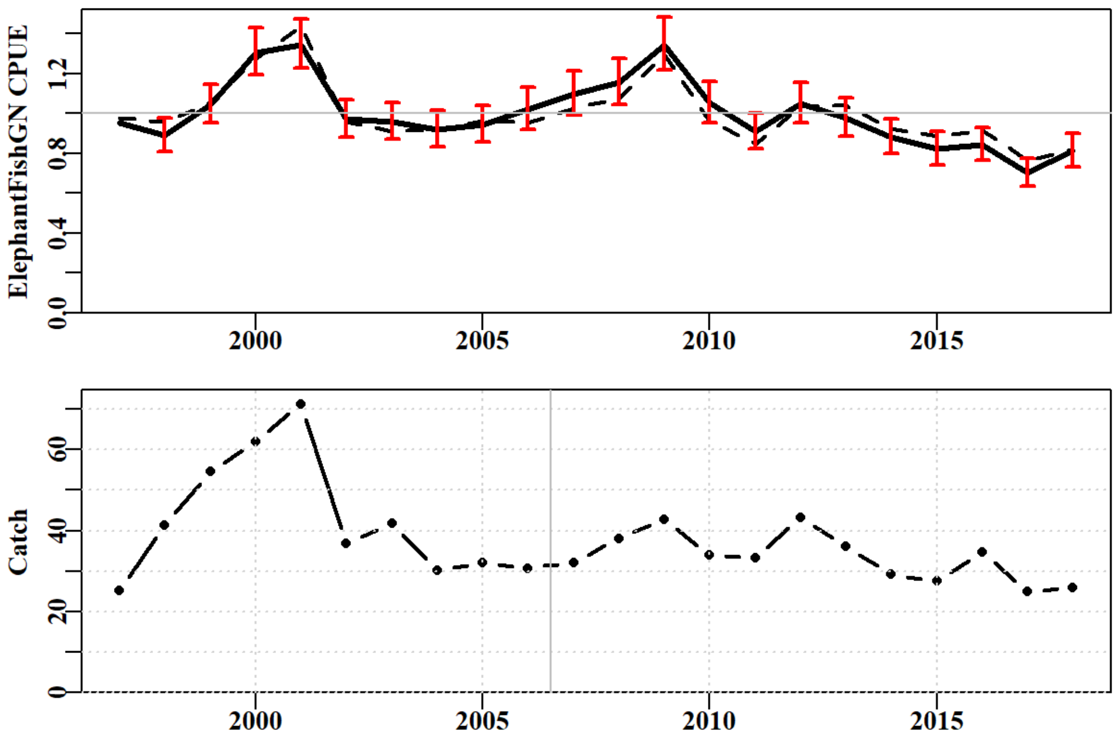

Figure 8.94. ElephantFishGN. CPUE is correlated with catches through time. CPUE in the top plot and annual catch (t) in the lower plot.

8.14 Acknowledgements

Thanks goes to the CSIRO database team for their preliminary processing of the catch and effort data as received from the Australian Fisheries Management Authority (AFMA). In addition, one co-author is indebted to FRDC for funding the project 2012/201 ‘Improving Catch Rate Standardizations’, which provided the time to explore ways of making the mass production of CPUE standardizations more efficient and defensible.

8.15 General References

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9. Tier 4 Assessments for Mirror Dory (data to 2018)

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9.1 Executive Summary

Two Tier 4 analyses have been performed for the following species and/or fisheries:

- Mirror Dory East
- Mirror Dory West

The RBC estimated for Mirror Dory East declined from 140.4 t in 2018 (Sporcic, 2018) to 92.7 t in 2019. Such decline in RBC of approximately 48 t could be attributed to a drop in the most recent standardized CPUE (including discards) and hence the mean of the most recent 4-year average which are used to calculate the RBC. The 2019 RBC is greater than the 2018 reported catch of approximately 79.8 t for this species.

The RBC estimated for Mirror Dory West declined from 94.8 t in 2018 (Sporcic, 2018) to 76.7 t in 2019. Such decline in RBC of approximately 18 t could be attributed to a drop in the most recent standardized CPUE and hence the mean of the most recent 4-year average which are used to calculate the RBC. The 2019 RBC is greater than the 2018 reported catch of approximately 37.4 t for this species.

In summary, the 2019 RBC estimate for Mirror Dory East is 92.7 t and for Mirror Dory West is 76.7 t, with a combined RBC (i.e., East and West) of 169.4 t.

9.2 Introduction

9.2.1 *Tier 4 Harvest Control Rule*

The Tier 4 harvest control rules are the default procedure applied to species which only have catches and catch per unit effort (CPUE) data available; specifically, there is no other 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 Tier 4 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)).

Tier 4 analyses require as a minimum, a time series of total catches and of standardized CPUE, along with an agreed reference period and reference points.

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).

9.2.2 *Tier 4 Assumptions*

9.2.2.1 Informative CPUE

There is a linear relationship between catch rates and exploitable biomass; *if there is hyper-stability (catch rates remain stable while stock size changes) or hyper-depletion (catch rates decline much faster than stock size changes) then the standard Tier 4 analysis would provide biased results*.

9.2.2.2 Consistent CPUE Through Time

The character of the estimated catch rates has not changed in significant ways through the period from the start of the reference period to the end of the most recent year; *If there has been significant effort creep altering the catchability, or there have been changes to the fleet that have altered the relative efficiency of the vessels fishing, or the catchability of the species by the fleet has been altered by other changes then the comparability of recent catch rates with the target period may be compromised. Such changes would obviously reduce the responsiveness of the Tier 4 method to change and may generate completely inappropriate management advice. Included in this clause are the effects of targeting or not targeting of deep water or aggregated species. When catch rates are extremely variable through time, such that mean estimates become unreliable measures of stock status, then the Tier 4 approach cannot be validly applied*.

9.2.2.3 Plausible Target Reference Period

The reference period provides a good estimate of the stock when at a depletion level of 48 % unfished spawning biomass; *the Tier 4 method is based on catch rates and thus relates to exploitable biomass and not spawning biomass. As a minimum the reference period will refer to a period when the stock was in an acceptable, productive and sustainable state. But there can be no guarantees that the target aimed for is really* $B_{48\%}$.

9.2.2.4 Accurate Total Catch History

Accurate estimates are required for all catches from the stock under consideration during the accepted target period, irrespective of what method was used or whether it was retained or discarded. *This assumption is especially vulnerable to being breached when large proportions of catches are discarded. While there is a procedure for adjusting the standardized CPUE for these missed catches the uncertainty over the actual amount of fish killed remains.*

9.2.3 *Some Implications of the Assumptions*

The outcomes of the Tier 4 analysis should not be regarded with the same confidence as those from Tier 1 assessments. Even though they are termed stock assessments, in actuality they are empirical considerations of catches and CPUE. Any uncertainty in the catch or CPUE time series is propagated directly through to the outputs of the analysis. For quota species the catches and reported CPUE is usually relatively well founded because of the quota catch disposal records and other compliance requirements. However, where there is a relatively high degree or variable discarding of catches this can lead to much greater levels of uncertainty.

At some point soon the assessments for those species that are conducted using a Tier 4 analysis should be reviewed for their inter-annual consistency and how the fishery has been responding to the management advice derived from the Tier 4 assessments.

9.3 Mirror Dory East Discard

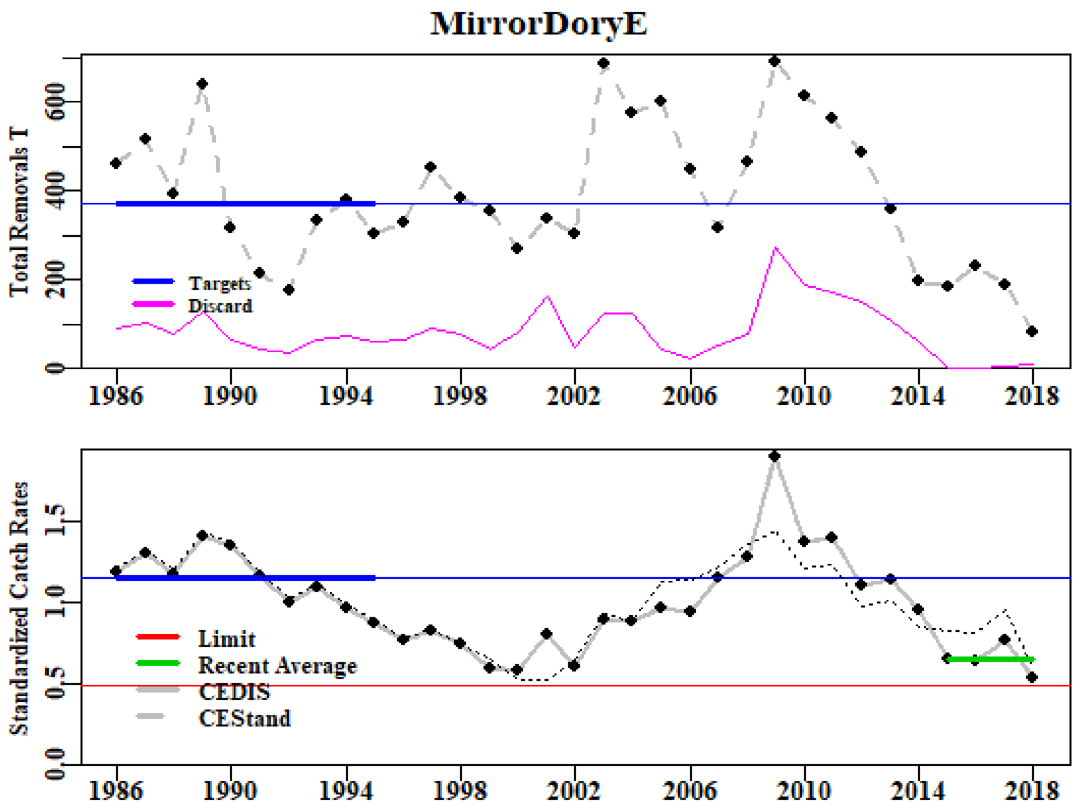

Figure 9.1. Mirror Dory 10 - 30 Discard. Top plot is the total removals with the fine line illustrating the target catch. Bottom plot represents the standardized catch rates with the upper fine line representing the target catch rate and the lower line the limit catch rate. Thickened lines represents the reference period for catches, catch rates, and the recent average catch rate. The thin black dotted line is the unmodified standardized CPUE before the inclusion of discards.

Table 9.1. Mirror Dory 10 - 30 Discard RBC calculations. Ctarg and CPUEtarg are the targets identified in the figure above, CPUELim is 20% of the B0 proxy (which relate to the CPUEtarg), and the most recent 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. E: East; W: West.

Parameter	Value		Parameter	Value
Reference_Years	1986 - 1995	|	Scaling	0.2486
CE_Target	1.1542	|	Last Year's Combined (E + W)	253
CE_Limit	0.4809	|	Ctarg	372.739
CE_Recent	0.6482	|	RBC	92.654
Wt_Discard	6.648	|		

Table 9.2. Mirror Dory 10 - 30 Discard data for the Tier 4 calculations. Total (t) is the sum of Discards, State, Non Trawl, SEF2 and CDR catches. All values in Tonnes. CE is the standardized catch rate (Sporcic, 2019). Discards are estimates from 1986 to present. The ratio of discards to catch over the 1998 - 2006 period was used to estimate the discards between 1986 and 1997.

Year	Catch	Discards	Total	(D/C)+1	CE	DiscCE	TAC (t)	State
1986	368.0	91.091	459.076	1.248	1.2122	1.1916	-	
1987	413.6	102.375	515.946	1.248	1.3251	1.3026	-	
1988	313.2	77.539	390.776	1.248	1.1972	1.1769	-	
1989	513.7	127.170	640.906	1.248	1.4367	1.4123	-	
1990	254.4	62.969	317.349	1.248	1.3701	1.3469	-	
1991	171.0	42.318	213.272	1.248	1.1876	1.1675	-	
1992	140.4	34.765	175.206	1.248	1.0220	1.0047	-	
1993	267.1	66.116	333.207	1.248	1.1124	1.0935	800	
1994	303.6	75.158	378.778	1.248	0.9864	0.9697	800	21.509
1995	242.8	60.097	302.874	1.248	0.8910	0.8759	800	21.609
1996	262.4	64.963	327.398	1.248	0.7818	0.7685	800	21.477
1997	361.4	89.460	450.857	1.248	0.8335	0.8194	800	21.590
1998	303.2	79.350	382.595	1.262	0.7427	0.7384	800	27.041
1999	310.5	42.255	352.712	1.136	0.6543	0.5858	800	36.959
2000	189.7	81.131	270.798	1.428	0.5173	0.5820	800	11.174
2001	172.8	164.476	337.248	1.952	0.5186	0.7977	800	10.399
2002	257.2	45.712	302.928	1.178	0.6503	0.6035	640	21.701
2003	563.2	124.889	688.093	1.222	0.9317	0.8970	576	68.462
2004	451.9	122.608	574.544	1.271	0.8843	0.8859	576	106.415
2005	557.5	44.291	601.778	1.079	1.1297	0.9609	700	73.457
2006	426.6	23.351	449.926	1.055	1.1379	0.9457	634	85.429
2007	264.5	50.836	315.360	1.192	1.2253	1.1511	788	28.716
2008	390.3	75.461	465.807	1.193	1.3627	1.2814	634	22.090
2009	416.4	274.023	690.407	1.658	1.4481	1.8920	718	35.112
2010	428.7	186.822	615.559	1.436	1.2087	1.3675	718	12.019
2011	391.4	170.552	561.949	1.436	1.2313	1.3930	718	6.091
2012	339.3	147.835	487.099	1.436	0.9724	1.1001	718	5.630
2013	248.9	108.442	357.306	1.436	1.0083	1.1407	1077	5.632
2014	137.9	60.085	197.973	1.436	0.8440	0.9549	808	1.787
2015	184.3	1.113	185.429	1.006	0.8239	0.6531	437	1.789
2016	230.5	1.353	231.828	1.006	0.8104	0.6423	325	5.716
2017	183.8	4.552	188.314	1.025	0.9525	0.7691	235	0.324
2018	70.1	9.712	79.829	1.139	0.5890	0.5284	253	0.325

9.3.1 *Discussion*

The most recent catch and standardized CPUE has decreased. Usually, the Tier 4 method used to assess Mirror Dory East includes discards in the catches and CPUE (see Methods in Appendix). However, between 2015-17 the discards of Mirror Dory in the east have been small while the most recent estimate increased from 4.6 t to 9.7 t (Table 9.2). Such relatively low estimated discards have the potential to distort the analysis (especially given the recent years' discards are weighted more heavily).

Discard estimates used for Mirror Dory East were based on Burch et al. (2019), except for the 2018 estimate. Since the coefficient of variation (CV) of the 2018 discard estimate was greater than 100 % (i.e., ~189 %; Table 9.2; Deng et al. 2019), it was agreed by SESSFRAG (meeting 20-22 August 2019) that the 2018 discard estimate be replaced with the 2017 estimate (0.02; CV: 52 %).

The RBC estimated for Mirror Dory East declined from 140.4 t in 2018 (Sporcic, 2018) to 92.7 t in 2019 (Table 9.1). Such decline in RBC of approximately 48 t could be attributed to a drop in the most recent standardized CPUE (including discards) and hence the mean of the most recent 4-year average which are used to calculate the RBC. The 2019 RBC is greater than the 2018 reported catch of approximately 79.8 t for this species (Total = 79.8 t; Table 9.2).

9.4 Mirror Dory West

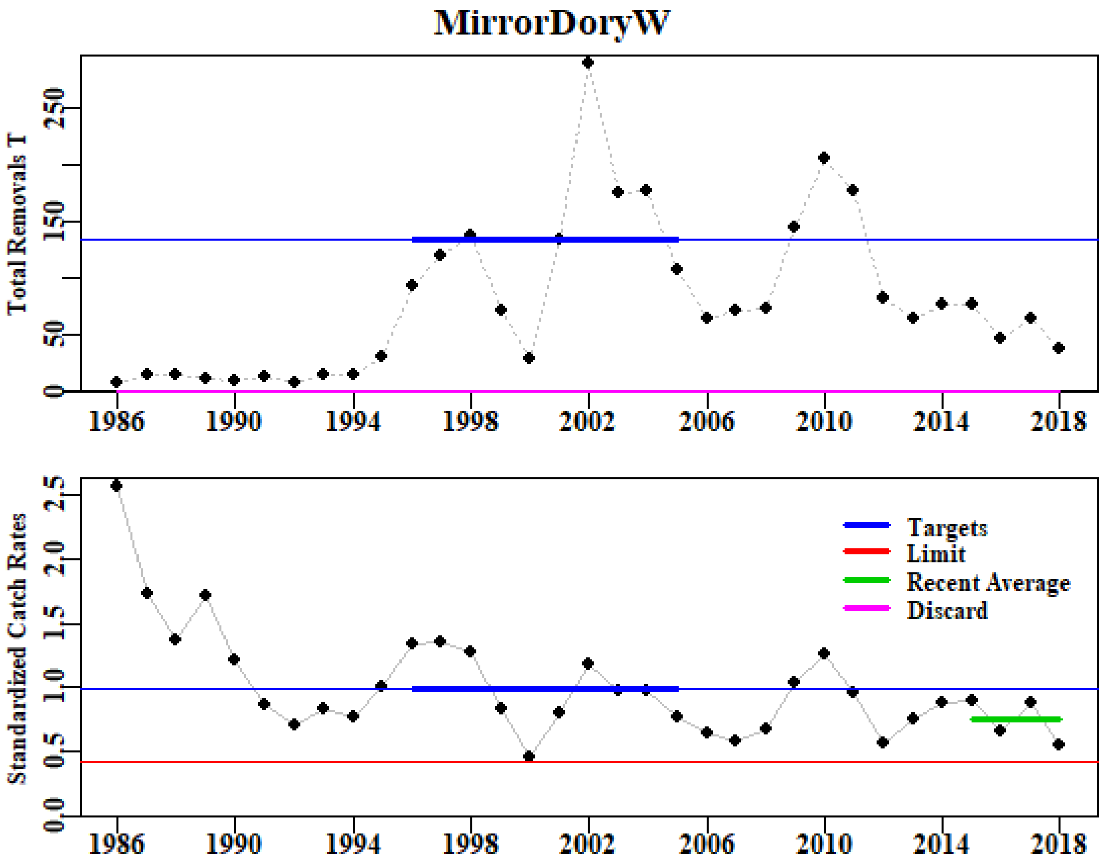

Figure 9.2. Mirror Dory 40 - 50. Top plot is the total removals with the fine line illustrating the target catch. Bottom plot represents the standardized catch rates with the upper fine line representing the target catch rate and the lower line the limit catch rate. Thickened lines represents the reference period for catches, catch rates, and the recent average catch rate.

Table 9.3. Mirror Dory 40 - 50 RBC calculations. Ctarg and CPUEtarg are the targets identified in the figure above, CPUELim is 20% of the B0 proxy (which relate to the CPUEtarg), and the most recent 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. E: East; W: West.

Parameter	Value		Parameter	Value
Reference_Years	1996 - 2005	|	Scaling	0.577
CE_Target	0.9941	|	Last Year's Combined (E + W)	253
CE_Limit	0.4142	|	Ctarg	132.98
CE_Recent	0.7488	|	RBC	76.728
Wt_Discard	0	|		

Table 9.4. Mirror Dory 40 - 50 data for the Tier 4 calculations. Total (t) is the sum of Discards, State, Non Trawl, SEF2 and CDR catches. All values in Tonnes. CE is the standardized catch rate (Sporcic, 2019). GeoMean is the geometric mean catch rates.

Year	Catch	Discards	Total	State	CE	GeoMean	TAC (t)
1986	7		7.400		2.5568	37.2	-
1987	16		15.500		1.7295	36.1	-
1988	15		15.000		1.3642	37.2	-
1989	11		11.100		1.7080	45.3	-
1990	10		10.000		1.2040	37.9	-
1991	13		12.800		0.8696	17.8	-
1992	8		8.300		0.7023	14.6	-
1993	15		14.753		0.8282	16.8	800
1994	15		14.844	0.361	0.7605	14.8	800
1995	31		30.848	0.765	0.9966	15.4	800
1996	93		93.491	0.238	1.3358	23.4	800
1997	120		120.196	0.350	1.3522	24.5	800
1998	136		136.396	0.214	1.2770	27.5	800
1999	72		71.890	0.220	0.8315	17.0	800
2000	28		28.005	0.214	0.4593	7.9	800
2001	134		133.977	0.215	0.7930	14.1	800
2002	288		288.207	0.216	1.1723	24.8	640
2003	175		175.140	0.274	0.9755	20.7	576
2004	176		175.911	0.024	0.9740	20.3	576
2005	107		106.584	0.039	0.7704	15.2	700
2006	65		64.651	0.005	0.6408	15.7	634
2007	71		71.390	0.005	0.5749	14.3	788
2008	74		74.123	0.014	0.6783	16.1	634
2009	145		144.958	0.000	1.0346	20.0	718
2010	204		204.199	0.000	1.2630	26.5	718
2011	177		177.025	0.001	0.9589	21.8	718
2012	82		82.141	0.000	0.5624	16.9	1077
2013	65		65.201	0.000	0.7584	20.8	1077
2014	77		76.918	0.000	0.8727	19.6	808
2015	77		77.273	0.001	0.8968	17.4	437
2016	46		46.371	0.001	0.6596	16.5	325
2017	65		64.532	0.001	0.8847	16.0	235
2018	37		37.388	0.001	0.5541	10.8	253

9.4.1 *Discussion*

Generally, increases and decreases in catches and CPUE in the western SESSF zones occur more rapidly than in the eastern zones. With the fishery only beginning to report significant catches from about 1996 onwards the reference period used is relatively recent. Nevertheless, there are now nine years between the reference period and the start of the most recent four years used to denote the current state of the fishery.

The RBC estimated for Mirror Dory West declined from 94.8 t in 2018 (Sporcic, 2018) to 76.7 t in 2019 (Table 9.3). Such decline in RBC of approximately 18 t could be attributed to a drop in the most recent standardized CPUE and hence the mean of the most recent 4-year average which are used to calculate the RBC. The 2019 RBC is greater than the 2018 reported catch of approximately 37.4 t for this species (Total = 37.4 t; Table 9.4).

9.5 Acknowledgements

Thanks goes to the CSIRO database team for their processing of the catch and effort (CPUE) and Catch Disposal Record (CDR) data as received from the Australian Fisheries Management Authority. Thanks also goes to Geoff Tuck (CSIRO) for reviewing this report.

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9.7 Appendix: Methods

9.7.1 Tier 4 Harvest Control Rule

The data required are time series of catches and standardized CPUE. 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 (e.g., Haddon, 2014). 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 CPUE 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 N. Klaer and J. Upston of CSIRO. All catch rate data were derived from the standard commercial catch and effort database processed by the data services Team at CSIRO Hobart.

Standard analyses were set up in the statistical software, R Core Team (2019), which provided the tables and graphs required for the Tier 4 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. 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.

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

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:

$$RBC_y = 1.5RBC_{y-1} \quad RBC_y > 1.5RBC_{y-1}$$
$$RBC_y = 0.5RBC_{y-1} \quad RBC_y < 0.5RBC_{y-1}$$

Where

1. RBC_y is the RBC in year y,
2. $CPUE_{\text{targ}}$ is the target CPUE for the species,
3. $CPUE_{\text{lim}}$ is the limit CPUE for the species = 0.4 * $CPUE_{\text{targ}}$,
4. $\overline{CPUE}$ is the average CPUE over the past m years; m tends to be the most recent four years,
5. 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. This is an average of the total removals for the selected reference period, including any discards.

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

where L_y represents the landings in year *y*.

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

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.

Percent discards are estimated from ISMP observations from 1998 to the current year. Discards for earlier years, prior to ISMP sampling, are generally 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:

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

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

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

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 %):

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

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. Where a fishery was not con-sidered to be fully developed the target catch rate, $CPUE_{\text{targ}}$, 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 CPUE are illustrated with the target CPUE and the limit CPUE. Finally, where the data are available, plots are given of the Total removals contrasted with State removals, and of discards and non-trawl catches.

9.7.2 *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 CPUE. This is an important question because standardized commercial CPUE are used in Australian stock assessments as an index of relative abundance (e.g., Haddon, 2014); 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).

9.7.3 *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 CPUE has been developed it should be noted that this ignores all complications relating to unknown aspects of discarding behaviour (e.g., Is the discard rate constant across all catch sizes, across all vessels, across all areas?). 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 CPUE and apply that to the standardized CPUE (Haddon, 2010). 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

$$\hat{I}_{R,t} = \frac{\sum C_t}{\sum E_t}$$

where $\hat{I}_{R,t}$ is the ratio mean CPUE for year *t*, $\sum C_t$ is the sum of landed catches in year *t*, and $\sum E_t$ is the sum of effort (as hours trawled) in year *t*. If $\sum D_t$ is the sum of discards in year *t* then the discard incremented ratio mean CPUE would be:

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

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

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

where I_t is the CPUE estimate to be modified by the inclusion of discards. If this is the ratio mean then the augmented catch rates would be identical to the first equation dealing with $\sum D_t$. In practice, the catch rates used with the multiplier are the standardized catch rates (e.g. Haddon, 2014).

9.7.4 *The Limitations of Including Discards*

The discard rates are estimated as the proportion of the total catch (= landed catch plus discards), which means that discard proportions greater than 0.5 imply that more fish are discarded than landed. To calculate the discarded catches from a discard rate and the landed catches we use:

$$D_t = \left(\frac{C_t}{1 - P_t}\right) - C_t$$

where D_t is the discarded catches in year *t*, C_t is the total landed catches in year *t*, and P_t is the proportion of discards in year *t*. Because the divisor is $1 - P_t$ as P_t tends to 1.0 the divisor becomes very small and hence acts as a multiplier on total landed catch C_t. The effect of this is that when P_t is estimated to be above 0.5 the multiplying effect in the calculation of discards becomes grossly exaggerated (Figure 9.3).

It is recommended that once discard proportions are estimated to be above 0.5 or 0.6 then attention needs to be paid to whether or not the inclusion of discards into the CPUE and the calculation of the RBC can be considered valid. In such cases, for example Inshore Ocean Perch, the Tier 4 analysis may need to be rejected and some alternative adopted.

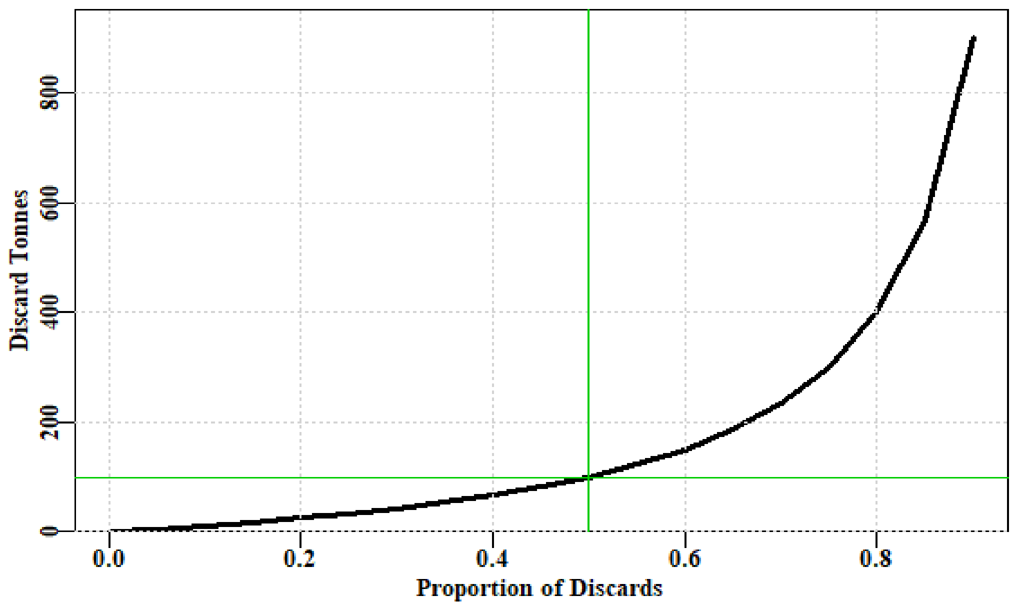

Figure 9.3. The influence of the proportion discarded on estimates of discarded catches. As the proportion of discards approaches 1.0 the multiplying effect in the estimation of discard amounts becomes greatly amplified.

9.7.5 *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 CPUE 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 CPUE, which has an associated target catch. An estimate of current CPUE (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 CPUE. For this reason the use of standardized CPUE should be an improvement over using, for example, the observed arithmetic or geometric mean CPUE. CPUE 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 CPUE proxy for B_{MEY}).
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 for which CPUE targeted is calculated.

10. Tier 4 Assessments for Western Gemfish (data to 2018)

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10.1 Executive Summary

A Tier 4 analyses has been performed for the following species and/or fisheries:

- Western Gemfish Zone 50

The RBC estimated for Western Gemfish declined from 436.29 t in 2017 (Haddon and Sporcic, 2017) to 423.1 t in 2019.

10.2 Introduction

10.2.1 *Tier 4 Harvest Cntrol Rule*

The Tier 4 harvest control rules are the default procedure applied to species which only have catches and catch per unit effort (CPUE) data available; specifically, there is no other 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 Tier 4 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).

Tier 4 analyses require as a minimum, a time series of total catches and of standardized CPUE, along with an agreed reference period and reference points.

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).

10.2.2 ***Tier 4 Assumptions***

10.2.2.1 Information CPUE

There is a linear relationship between catch rates and exploitable biomass; *if there is hyper-stability (catch rates remain stable while stock size changes) or hyper-depletion (catch rates decline much faster than stock size changes) then the standard Tier 4 analysis would provide biased results*.

10.2.2.2 Consistent CPUE Through Time

The character of the estimated catch rates has not changed in significant ways through the period from the start of the reference period to the end of the most recent year; *If there has been significant effort creep altering the catchability, or there have been changes to the fleet that have altered the relative efficiency of the vessels fishing, or the catchability of the species by the fleet has been altered by other changes then the comparability of recent catch rates with the target period may be compromised. Such changes would obviously reduce the responsiveness of the Tier 4 method to change and may generate completely inappropriate management advice. Included in this clause are the effects of targeting or not targeting of deep water or aggregated species. When catch rates are extremely variable through time, such that mean estimates become unreliable measures of stock status, then the Tier 4 approach cannot be validly applied*.

10.2.2.3 Plausible Target Reference Period

The reference period provides a good estimate of the stock when at a depletion level of 48 % unfished spawning biomass; *the Tier 4 method is based on catch rates and thus relates to exploitable biomass and not spawning biomass. As a minimum the reference period will refer to a period when the stock was in an acceptable, productive and sustainable state. But there can be no guarantees that the target aimed for is really* $B_{48\%}$.

10.2.2.4 Accurate Total Catch History

Accurate estimates are required for all catches from the stock under consideration during the accepted target period, irrespective of what method was used or whether it was retained or discarded. *This assumption is especially vulnerable to being breached when large proportions of catches are discarded. While there is a procedure for adjusting the standardized CPUE for these missed catches the uncertainty over the actual amount of fish killed remains.*

10.2.3 ***Some Implications of the Assumptions***

The outcomes of the Tier 4 analysis should not be regarded with the same confidence as those from Tier 1 assessments. Even though they are termed stock assessments, in actuality they are empirical considerations of catches and CPUE. Any uncertainty in the catch or CPUE time series is propagated directly through to the outputs of the analysis. For quota species the catches and reported CPUE is usually relatively well founded because of the quota catch disposal records and other compliance requirements. However, where there is a relatively high degree or variable discarding of catches this can lead to much greater levels of uncertainty.

At some point soon the assessments for those species that are conducted using a Tier 4 analysis should be reviewed for their inter-annual consistency and how the fishery has been responding to the management advice derived from the Tier 4 assessments.

10.3 Western Gemfish Zone 50 Discard

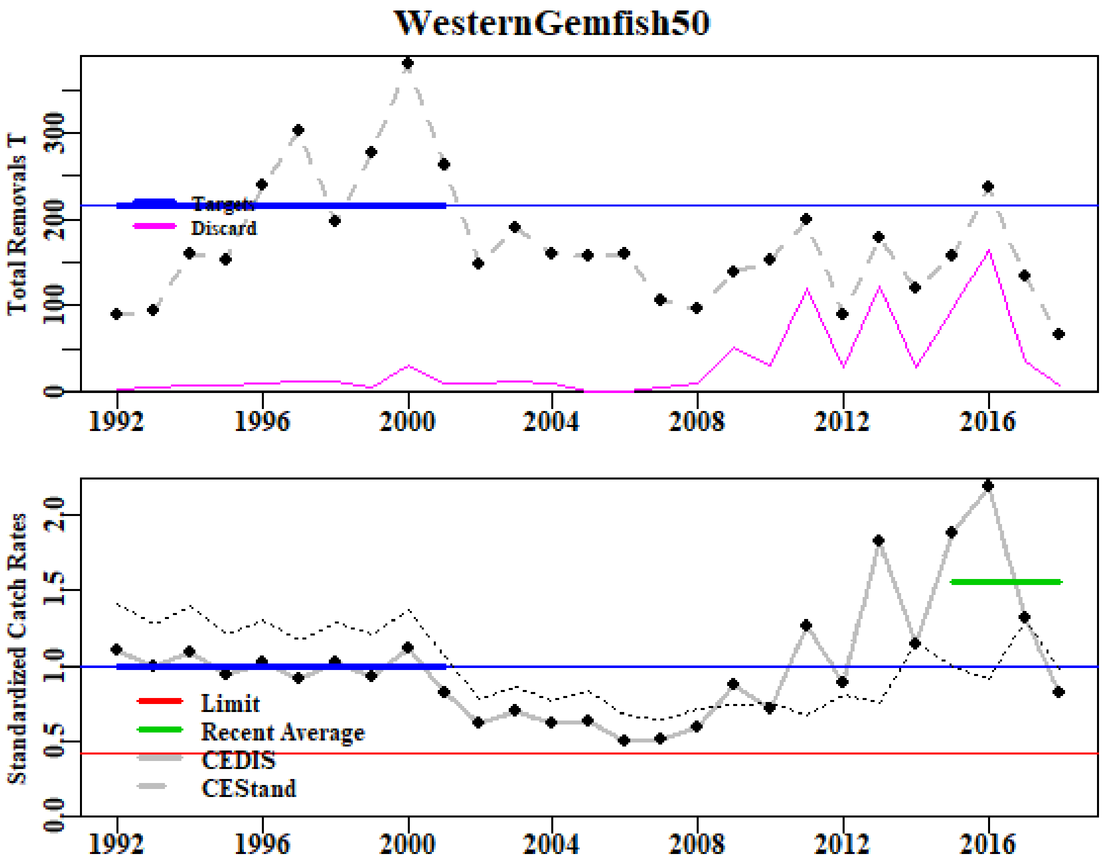

Figure 10.1. WesternGemfish50 Discard. Top plot is the total removals with the fine line illustrating the target catch. Bottom plot represents the standardized catch rates with the upper fine line representing the target catch rate and the lower line the limit catch rate. Thickened lines represents the reference period for catches, catch rates, and the recent average catch rate. The thin black dotted line is the unmodified standardized CPUE before the inclusion of discards.

Table 10.1. WesternGemfish50 Discard RBC calculations. Ctarg and CPUEtarg are the targets identified in the figure above, CPUELim is 20% of the B0 proxy (which relate to the CPUEtarg), and the most recent CPUE is the average catch rate over the last four years. Wt_Discard is the weighted average discards from the last four years.

Parameter	Value		Parameter	Value
Reference_Years	1992 - 2001	|	Scaling	1.9651
CE_Target	0.9942	|	Last Year's TAC (t)	200
CE_Limit	0.4143	|	Ctarg	215.289
CE_Recent	1.0418	|	RBC	423.058
Wt_Discard	41.74	|	-	-

Table 10.2. WesternGemfish50 Discard data for the Tier 4 calculations. Total (t) is the sum of Discards, State, Non Trawl and SEF2 catches. All values in Tonnes. CE is the standardized catch rate. GeoMean is the geometric mean catch rates. Discards are estimates from 1998 to present. The ratio of discards to catch over the 1998 - 2006 period was used to estimate the discards between 1992 and 1997, the proportion of which is the PDiscard.

Year	Catch	Discards	Total	(D/C)+1	CE	DiscCE	TAC
1992	84.4	3.820	88.204	1.045	1.4106	1.1017	300
1993	90.5	4.097	94.586	1.045	1.2741	0.9950	300
1994	153.1	6.930	160.016	1.045	1.3929	1.0879	300
1995	146.9	6.652	153.592	1.045	1.2098	0.9449	300
1996	228.4	10.339	238.717	1.045	1.3056	1.0197	300
1997	288.8	13.076	301.914	1.045	1.1637	0.9088	300
1998	185.4	12.000	197.373	1.065	1.2878	1.0245	300
1999	271.8	5.010	276.802	1.018	1.2097	0.9205	300
2000	349.2	29.997	379.235	1.086	1.3774	1.1176	300
2001	253.5	9.002	262.452	1.036	1.0619	0.8216	330
2002	138.9	9.135	148.052	1.066	0.7727	0.6153	330
2003	177.5	12.584	190.092	1.071	0.8654	0.6925	300
2004	149.8	8.923	158.765	1.060	0.7710	0.6104	300
2005	156.6	1.582	158.199	1.010	0.8332	0.6289	300
2006	159.8	0.545	160.319	1.003	0.6676	0.5005	167
2007	99.5	5.125	104.596	1.052	0.6457	0.5073	200
2008	86.7	9.034	95.702	1.104	0.7129	0.5882	167
2009	87.6	51.075	138.677	1.583	0.7388	0.8738	125
2010	121.7	31.956	153.633	1.263	0.7491	0.7067	109
2011	79.7	120.448	200.158	2.511	0.6709	1.2588	94
2012	60.4	28.715	89.159	1.475	0.8066	0.8890	199
2013	54.1	123.223	177.357	3.276	0.7476	1.8300	199
2014	91.2	29.035	120.214	1.318	1.1579	1.1406	199
2015	61.9	95.934	157.787	2.551	0.9877	1.8827	183
2016	73.4	163.615	237.022	3.229	0.9069	2.1880	247
2017	97.7	35.690	133.387	1.365	1.2981	1.3242	199
2018	59.0	7.522	66.519	1.127	0.9743	0.8208	200

10.3.1 *Discussion*

The RBC estimated for Western Gemfish Zone 50 declined from 436.29 t in 2017 (Haddon and Sporcic, 2017) to 423.1 t in 2019 (Table 10.1). Such decline in RBC of approximately 13 t could be attributed to a drop in the most recent standardized CPUE (including discards) and hence the mean of the most recent 4-year average which are used to calculate the RBC.

10.4 Acknowledgements

Thanks goes to the CSIRO database team for their preliminary processing of the catch and effort (CPUE) and Catch Disposal Record (CDR) data as received from the Australian Fisheries Management Authority.

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10.6 Appendix: Methods

10.6.1 *Tier 4 Harvest Control Rule*

The data required are time series of catches and standardized CPUE. 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 (e.g., Haddon, 2014). 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 CPUE 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 N. Klaer and J. Upston of CSIRO. All catch rate data were derived from the standard commercial catch and effort database processed by the data services Team at CSIRO Hobart.

Standard analyses were set up in the statistical software, R Core Team (2019), which provided the tables and graphs required for the Tier 4 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. 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.

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

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:

$$RBC_y = 1.5RBC_{y-1} \quad RBC_y > 1.5RBC_{y-1}$$
$$RBC_y = 0.5RBC_{y-1} \quad RBC_y < 0.5RBC_{y-1}$$

where

1. RBC_y is the RBC in year *y*,
2. $CPUE_{targ}$ is the target CPUE for the species,
3. $CPUE_{lim}$ is the limit CPUE for the species = 0.4 * $CPUE_{targ}$,
4. $\overline{CPUE}$ is the average CPUE over the past *m* years; *m* tends to be the most recent four years,
5. 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. This is an average of the total removals for the selected reference period, including any discards.

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

where L_y represents the landings in year *y*.

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

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.

Percent discards are estimated from ISMP observations from 1998 to the current year. Discards for earlier years, prior to ISMP sampling, are generally 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:

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

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

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

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 %):

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

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. Where a fishery was not con-sidered to be fully developed the target catch rate, $CPUE_{\text{targ}}$, 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 CPUE are illustrated with the target CPUE and the limit CPUE. Finally, where the data are available, plots are given of the Total removals contrasted with State removals, and of discards and non-trawl catches.

10.6.2 *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 CPUE. This is an important question because standardized commercial CPUE are used in Australian stock assessments as an index of relative abundance (e.g., Haddon, 2014); 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).

10.6.2.1 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 CPUE has been developed it should be noted that this ignores all complications relating to unknown aspects of discarding behaviour (e.g., Is the discard rate constant across all catch sizes, across all vessels, across all areas?). 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 CPUE and apply that to the standardized CPUE (Haddon, 2010). 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

$$\hat{I}_{R,t} = \frac{\sum C_t}{\sum E_t}$$

where $\hat{I}_{R,t}$ is the ratio mean CPUE for year *t*, $\sum C_t$ is the sum of landed catches in year *t*, and $\sum E_t$ is the sum of effort (as hours trawled) in year *t*. If $\sum D_t$ is the sum of discards in year *t* then the discard incremented ratio mean CPUE would be:

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

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

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

where I_t is the CPUE estimate to be modified by the inclusion of discards. If this is the ratio mean then the augmented catch rates would be identical to the first equation dealing with $\sum D_t$. In practice, the catch rates used with the multiplier are the standardized catch rates (e.g. Haddon, 2014).

10.6.2.2 The Limitations of Including Discards

The discard rates are estimated as the proportion of the total catch (= landed catch plus discards), which means that discard proportions greater than 0.5 imply that more fish are discarded than landed. To calculate the discarded catches from a discard rate and the landed catches we use:

$$D_t = \left(\frac{C_t}{1 - P_t}\right) - C_t$$

where D_t is the discarded catches in year *t*, C_t is the total landed catches in year *t*, and P_t is the proportion of discards in year *t*. Because the divisor is $1 - P_t$ as P_t tends to 1.0 the divisor becomes very small and hence acts as a multiplier on total landed catch C_t. The effect of this is that when P_t is estimated to be above 0.5 the multiplying effect in the calculation of discards becomes grossly exaggerated (Figure 10.2).

It is recommended that once discard proportions are estimated to be above 0.5 or 0.6 then attention needs to be paid to whether or not the inclusion of discards into the CPUE and the calculation of the RBC can be considered valid. In such cases, for example Inshore Ocean Perch, the Tier 4 analysis may need to be rejected and some alternative adopted.

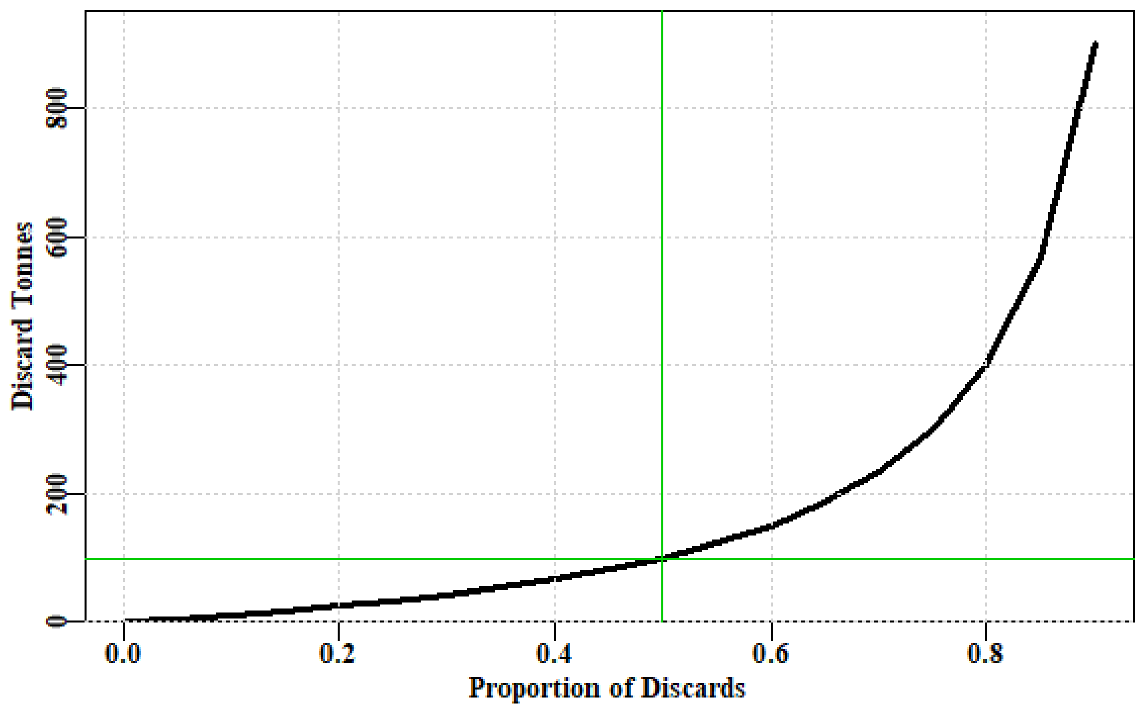

Figure 10.2. The influence of the proportion discarded on estimates of discarded catches. As the proportion of discards approaches 1.0 the multiplying effect in the estimation of discard amounts becomes greatly amplified.

10.6.3 *Selection of Reference Points*

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 CPUE 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 CPUE, which has an associated target catch. An estimate of current CPUE (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 CPUE. For this reason the use of standardized CPUE should be an improvement over using, for example, the observed arithmetic or geometric mean CPUE. CPUE 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 CPUE proxy for B_{MEY}).
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 for which CPUE targeted is calculated.

11. 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.

12. Conclusion

- Provide quantitative and qualitative species assessments in support of the four SESSFRAG assessment groups, including RBC calculations within the SESSF harvest strategy framework.

The 2019 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 (deepwater flathead, tiger flathead and Bight redfish), a projection update for school whiting, as well as cpue standardisations for shelf, slope, deepwater and shark species and Tier 4 analyses. Typical assessment outputs provided indications of current stock status and an application of the Commonwealth Harvest Strategy framework. This framework is based on a set of assessment methods and associated harvest control rules, with the decision to apply a particular combination dependent on the type and quality of information available to determine stock status (Tiers 1 to 5).

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 (non-Tier 1):

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. Summarized are the main findings regarding the standardization for 21 species, distributed across 40 different combinations of stocks and fisheries using statistical models customized to suit each set of circumstances. The results from the standardisations are a key input to Tier 4 and Tier 1 assessments.

Standardized CPUE has generally increased since about 2005 for pink ling west. Other species/stocks have shown shorter term increases over the last two to three years e.g., pink ling east, royal red prawn and inshore ocean perch. Standardized CPUE has increased in the last two years for silver warehou east and silver warehou west, after at least a ten-year general decline. Standardized CPUE has remained near the long-term average over the last six years for blue grenadier (non-spawning) with these indices all higher than those between 2000-2013. By contrast, standardized CPUE has declined for tiger flathead - Danish seine (zone 20-60) since 2016 and more generally since 2007 and fluctuated around the long-term average for both tiger flathead in zone 10, 20 (combined) and zone 30 since 2000. For eastern deepwater sharks, the standardized CPUE trend has been essentially low and flat since 2010. For western deepwater sharks, the standardized CPUE has exhibited an approximate cycle since about 1998 - 2017 with lows in 2005 and 2012-2014 and highs (corresponding to the long-term average) from 1998-2003, 2008-2010 and has returned to the long-term average in 2018. For mixed oreos, the standardized CPUE has been essentially flat and stable since 2000. The CPUE for blue eye using catch-per-hook exhibits a noisy but flat trajectory. For school shark caught by trawl the CPUE trend has continued to increase since 2003. For gummy shark caught by gillnet, standardized CPUE in South Australia has dropped to the long-term average in 2018 and in Bass Strait it has remained at the long-term average in 2017 and 2018. Similarly, standardized CPUE of gillnet caught gummy shark around Tasmania has remained flat since 2014 and at the long-term average since 2016. Standardized CPUE for trawl has increased steadily since 2012, remaining significantly above the long-term average. By contrast, standardized CPUE for bottom line has remained flat and noisy since 2012. For sawshark, standardized CPUE for gillnets exhibits a steady decline since about 2001, with small increases in recent years, except in 2017. Trawl caught sawshark standardized indices exhibit a noisy but flat trend, with a small increase in 2017 and 2018. Sawshark standardized CPUE by Danish seine has been flat and below the long-term average over the 2002-14 period and increased above the long-term average in 2015. For elephant fish, gillnet standardized CPUE is flat and noisy, with an increase shown in 2018.

In 2019, Tier 4 analyses were performed for the following species and/or species groups: mirror dory east, mirror dory west, and western gemfish (Zone 50). The RBC estimated for mirror dory east is 92.7t. The 2019 RBC is greater than the 2018 reported catch of approximately 79.8 t for this species. The RBC estimated for mirror dory west is 76.7t in 2019. The 2019 RBC is greater than the 2018 reported catch of approximately 37.4 t for this species. The combined RBC (i.e., east and west) for mirror dory is 169.4 t. The RBC estimated for western gemfish is 423.1 t.

13. Appendix: Intellectual Property

No intellectual property has arisen from the project that is likely to lead to significant commercial benefits, patents or licenses.

14. Appendix: Project Staff

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