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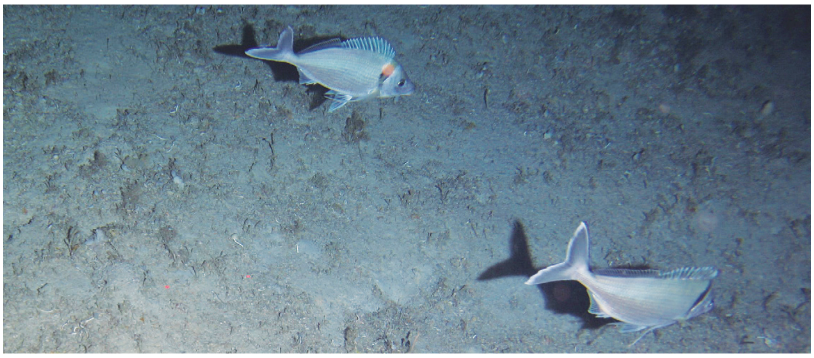
Stock Assessment for the Southern and Eastern Scalefish and Shark Fishery: 2018 and 2019



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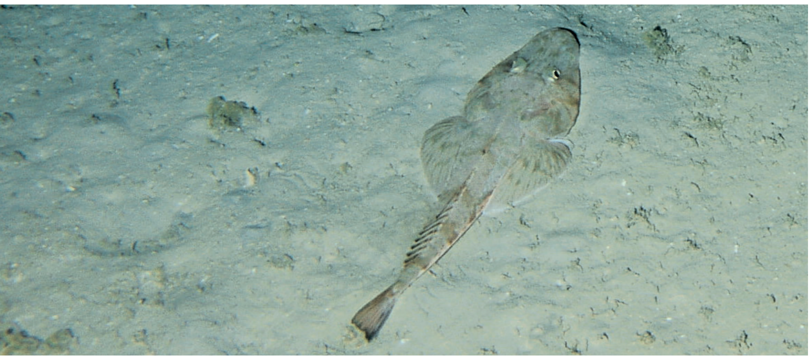

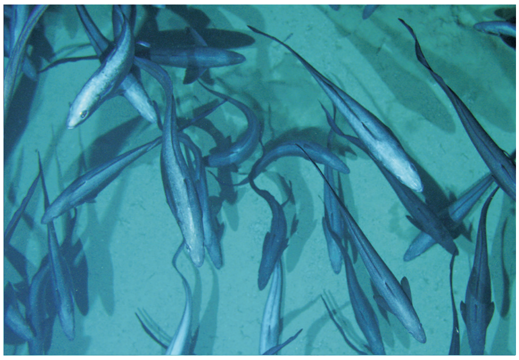

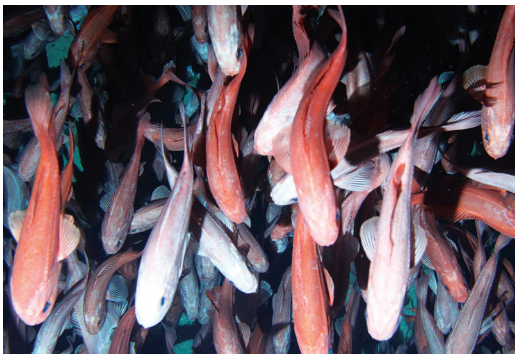

Principal investigator **G.N. Tuck**

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

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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 2018. 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 2018.

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

Part 2: 2018

G.N. Tuck
June 2020
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Australian Fisheries Management Authority

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

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1. Non-Technical Summary

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

PRINCIPAL INVESTIGATOR: Dr Geoffrey N. Tuck

ADDRESS: CSIRO Oceans and Atmosphere
GPO Box 1538
Hobart, TAS 7001
Australia
Telephone: 03 6232 5222 Fax: 03 6232 5053

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 - 2018

The 2018 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.

Summary graphs are provided across all species as well as more detailed information for each stock. Out of 40 stocks, there were eight whose standardized CPUE have increased over the last five years; 11 stocks where catch rates were stable and 20 stocks whose catch rates have declined over the last five years. In addition, there was an increase in standardized CPUE in 2017 from 2016 for 32 stocks/combinations of fisheries. 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, 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. Standardized CPUE exhibits a relatively flat trend below the long-term average 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.

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. 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 almost returned to the long-term average in 2017. 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. 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 mixed Oreos, 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 117 t from 2013 - 2017. 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. 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 is the largest since 2010. Trawl caught school shark do not appear to be targeted, as evidenced by the large proportion of < 30 kg shots present in 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, with the exception of 2014 and 2017.

There has been a decrease in reported gillnet catches of gummy shark in 2017 in South Australia and Bass Strait. However, standardized CPUE in South Australia has increased since 2013, and has dropped to the long-term average in 2017 in Bass Strait. By contrast, standardized CPUE of gillnet caught gummy shark around Tasmania remained flat since 2014 and increasing to the long-term average in 2016 and 2017. Standardized CPUE for trawl has increased steadily since 2012, remaining above the long-term average. By contrast, standardized CPUE for bottom line has remained flat and noisy since 2012.

Sawshark are considered to be a bycatch group. This 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. By contrast, sawshark standardized CPUE by Danish seine has been flat since 2006 and increased above the long-term average in 2015, although not significantly so, and decreased to below the long term average in 2017.

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 and decreased in 2017. However, this analysis ignores discarding (~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.

Tier 4 analyses 1986 - 2017

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 2018, Tier 4 analyses have been performed for the following species and/or species groups: mirror dory east, mirror dory west, eastern deepwater shark, western deepwater shark and blue eye trevalla (Zone 20 - 50). For mirror dory east (with discards), after a series of declining catch rates the 2017 point increased. The RBC is 140 t. For mirror dory west, the catch rates are generally flat but cyclical. The RBC is 95 t. For eastern deepwater shark the catch rate trend is low and near the limit, but stable. The RBC is 10 t. For western deepwater shark the catch rate trend has seen an increase over the last 4 years and is above target. The RBC is 235 t. For blue-eye (non-trawl) the catch rate trend is relatively stable between the target and limit. The RBC is 439 t.

Tier 5 for Blue-eye

Two methods were used as Tier 5 assessments for blue-eye on the eastern seamounts. These were an age-structured stock reduction analysis and catch MSY (cMSY). Note that uncertainty remains regarding many aspects of their biology and the fishery (e.g. selectivity and growth). The uncertainty regarding their natural mortality and steepness was covered by conducting a series of analyses using a matrix of values of ranging from 0.08 - 0.12 for natural mortality and 0.6 - 0.8 for steepness. For the seamounts, all analyses were assumed to have started with an unfished stock. There was additional uncertainty associated with the value for maximum harvest rate. An array of values between 0.25 - 0.5 were all trialed with the full array of natural mortality and steepness combinations.

Constant catches leading to relative stability in depletion were estimated at about 25 t for lower productivity combinations of natural mortality and steepness (0.08, 0.6) and 48 t for higher productivity combinations (0.12, 0.8). This is comparable to the estimate of approximately 40 t from the catch-MSY analysis that was predicted to lead to the mean depletion remaining stable in the projections.

While the catch-MSY analysis for the Blue-Eye from the eastern seamounts remains highly uncertain, it generates what appears to be a relatively robust estimate of MSY of about 46 - 50 t. The current depletion is estimated to be about 0.33 Bo although the uncertainty about that value is extreme. This analysis assumes that the catch time series reflects changes in depletion of Blue-Eye. However, this may not be the case, as other factors unrelated to abundance can influence this (e.g. management changes - catch limits; marine closures; gear restrictions, fisher behaviour etc.).

Fisheries that only have catch data but that also require management advice are only marginally served by catch only assessment methods. The application of these methods is effectively an admission that such a fishery should be classed exploratory. This implies that evidence needs to be gathered concerning any impact the exploratory fishing has upon the stock being fished.

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. Statistical CPUE standardisations for selected SESSF species (data to 2017)

Miriana Sporcic and Malcolm Haddon

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

5.1 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. The 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 statistical modelling procedures 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 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 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.

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, $(\sum CPUEt)/n$ 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.

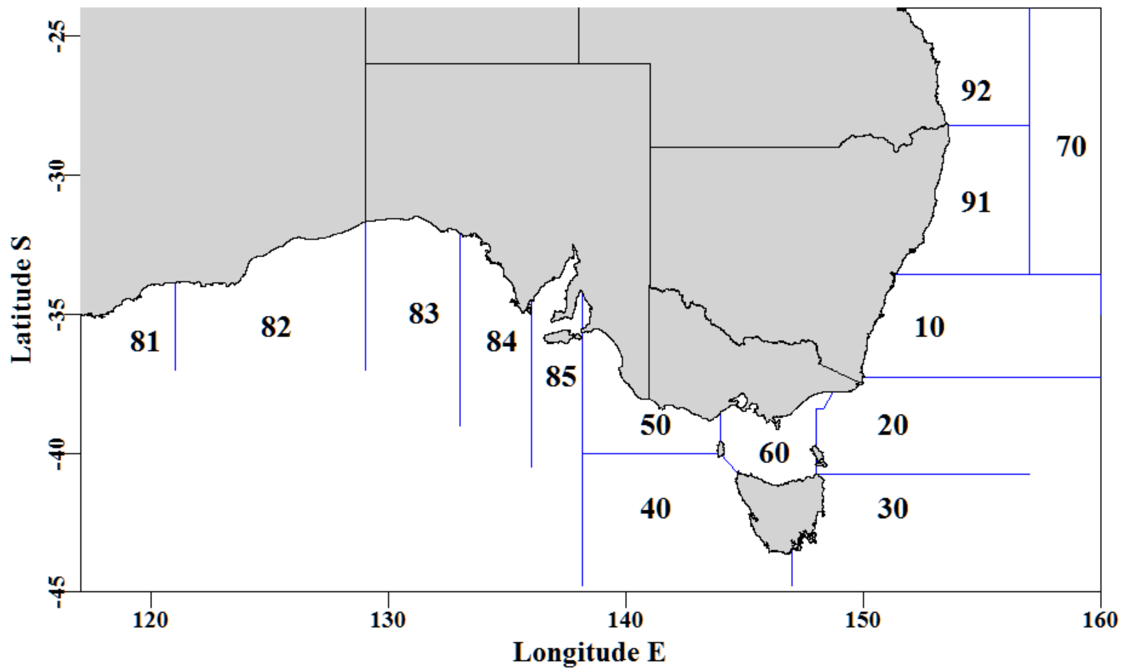


Figure 5.1. The statistical reporting zones in the SESSF.

5.4 John Dory 10 – 20

John Dory (DOJ– 37264004 – *Zeus faber*) have been primarily caught by trawl in zones 10 and 20 between the years 1986 - 2017. 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, has low 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 and 2016. 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 - 2017

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	1.7530	0.000	66.553	0.329
1987	206.1	4638	180.9	78	14.5	2.0277	0.021	43.254	0.239
1988	182.0	4532	161.2	73	13.5	1.8768	0.021	45.311	0.281
1989	217.9	4786	186.9	70	14.2	2.0501	0.021	49.093	0.263
1990	167.9	3674	135.7	60	13.0	1.8710	0.023	39.868	0.294
1991	172.3	4001	125.2	53	11.9	1.4919	0.023	43.575	0.348
1992	130.8	3886	107.9	49	9.6	1.2557	0.023	42.917	0.398
1993	240.4	5353	179.1	55	11.6	1.5784	0.022	57.555	0.321
1994	267.9	6505	207.7	55	11.1	1.4910	0.021	72.298	0.348
1995	185.7	6033	167.1	52	10.1	1.2638	0.021	68.473	0.410
1996	160.8	6339	145.0	58	8.4	0.9946	0.021	67.184	0.463
1997	87.8	4386	77.9	60	6.2	0.7730	0.023	43.209	0.555
1998	109.0	5079	98.2	53	6.9	0.8022	0.022	52.297	0.533
1999	132.8	5534	120.1	56	7.7	0.9440	0.021	57.792	0.481
2000	164.1	6955	146.6	59	7.2	0.8768	0.020	66.790	0.456
2001	129.3	6611	116.1	50	5.8	0.7365	0.021	61.558	0.530
2002	151.0	6663	135.9	49	6.7	0.7208	0.021	58.195	0.428
2003	156.9	6518	136.7	51	6.7	0.6993	0.021	59.400	0.434
2004	166.0	7051	147.0	51	6.8	0.7381	0.021	65.525	0.446
2005	107.4	4894	88.0	48	5.7	0.6120	0.022	41.054	0.466
2006	85.4	3706	71.0	43	5.8	0.6854	0.024	34.230	0.482
2007	62.5	2822	51.3	23	6.0	0.6238	0.026	25.586	0.498
2008	116.8	3800	102.1	26	8.8	0.9419	0.024	37.392	0.366
2009	91.7	3097	79.0	23	8.4	0.8698	0.025	31.271	0.396
2010	62.0	2952	51.1	24	5.4	0.5527	0.026	27.963	0.548
2011	74.8	3337	56.3	22	5.4	0.5776	0.025	31.341	0.557
2012	67.1	3336	55.9	22	5.4	0.5734	0.025	31.500	0.563
2013	63.5	2659	48.5	22	5.7	0.6000	0.026	24.778	0.511
2014	46.6	2637	35.3	23	3.8	0.4483	0.026	21.683	0.614
2015	73.6	2789	54.6	29	5.7	0.5680	0.026	24.484	0.448
2016	66.9	2026	35.3	24	5.2	0.4728	0.030	17.250	0.488
2017	68.6	1735	34.9	21	6.0	0.5299	0.031	15.516	0.445

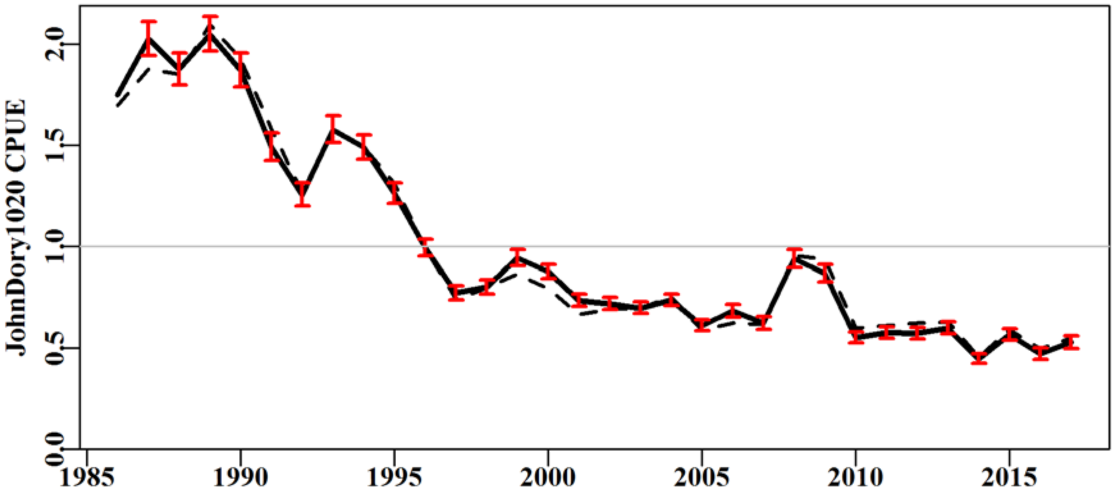


Figure 5.2. JohnDory1020 standardization. The dashed black line represents the geometric mean catch rate, solid black line the standardized catch rates. The red bars are the 95% confidence intervals about the mean estimates. The graph scales both time-series of standardized catch rates relative to the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

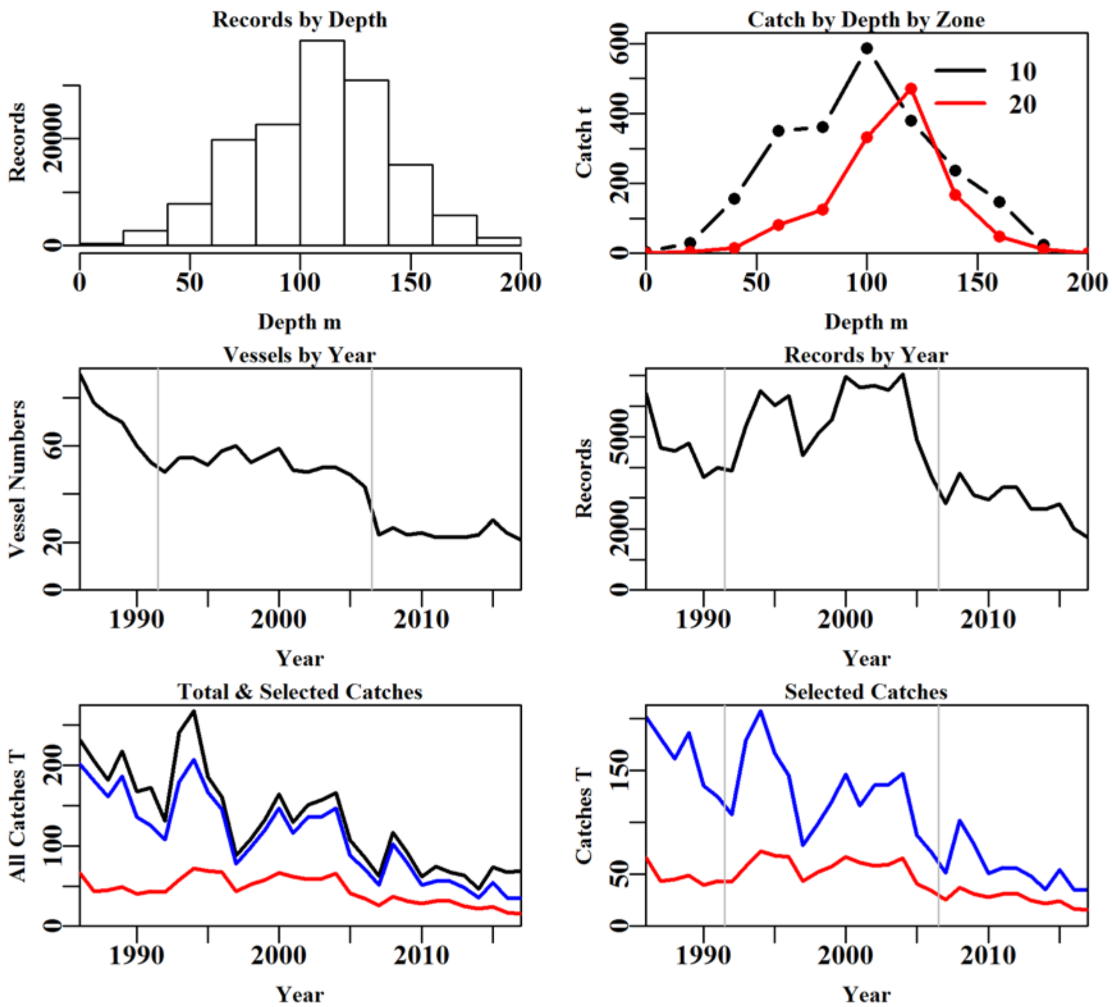


Figure 5.3. JohnDory1020 fishery details. The bottom left plot depicts all known catches (top black line), and all selected catches used in the analysis (middle blue line); the lower red line: selected catches < 30 kg).

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	234043	213015	206701	203509	171119	144869	144748
Difference	0	21028	6314	3192	32390	26250	121
Catch	4312.743	4178.5739	4029.8112	3967.2528	3668.1439	3542.4410	3540.698
Difference	0.000	134.1691	148.7627	62.5584	299.1089	125.7029	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	31214	179504	26931	144748	32	13.0	0.00
Vessel	15559	160725	45711	144748	202	22.0	9.01
DayNight	13216	158137	48298	144748	205	23.3	1.25
DepCat	11481	156232	50204	144748	215	24.2	0.92
Month	10279	154916	51519	144748	226	24.8	0.63
Zone	10244	154877	51559	144748	227	24.9	0.02
Zone:Month	9646	154215	52220	144748	238	25.2	0.32
Zone:DepCat	9020	153554	52882	144748	236	25.5	0.64

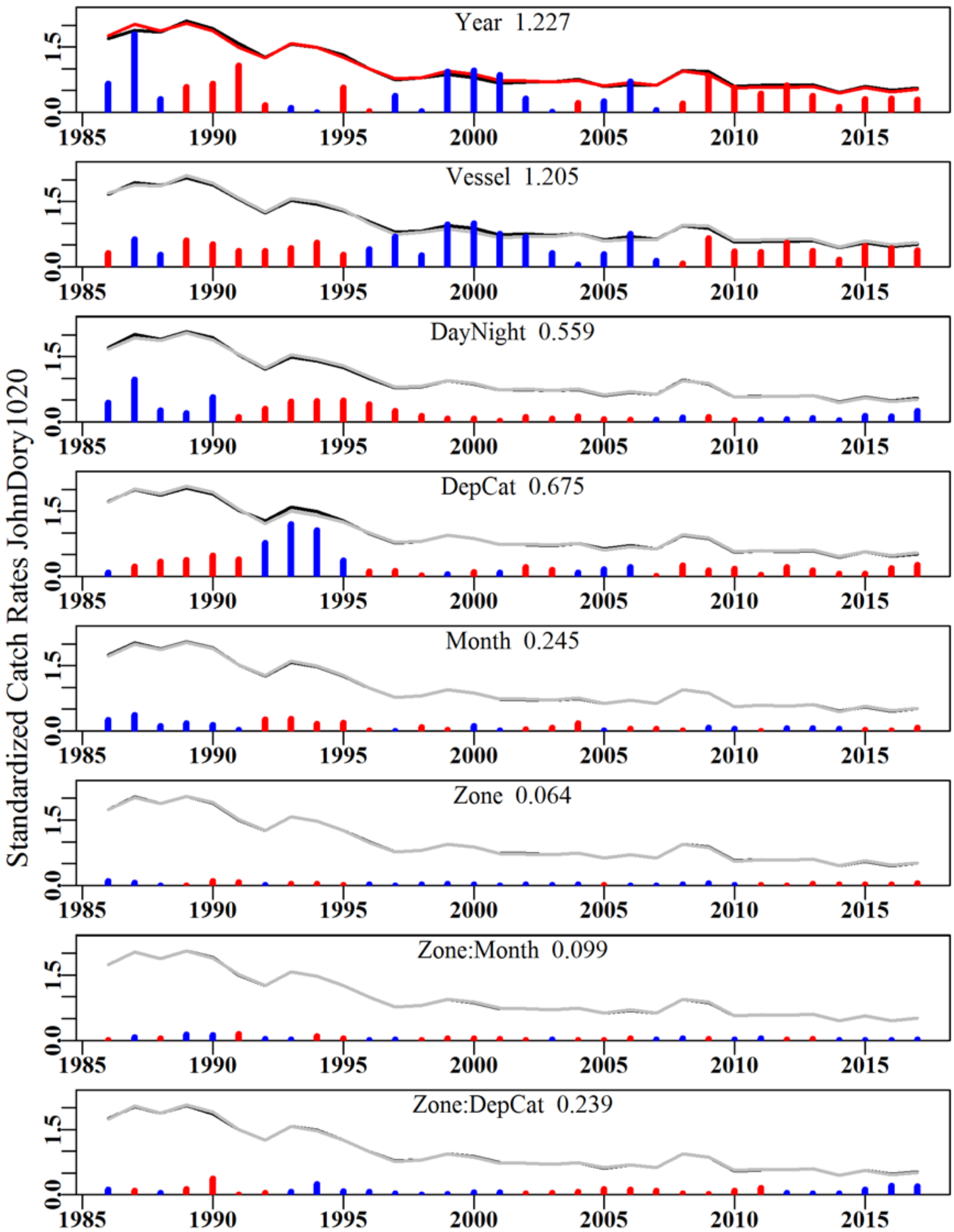


Figure 5.4. JohnDory1020. The influence of each factor on the optimal standardization. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by vertical bars with blue bars indicating the optimum model is higher than the geometric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

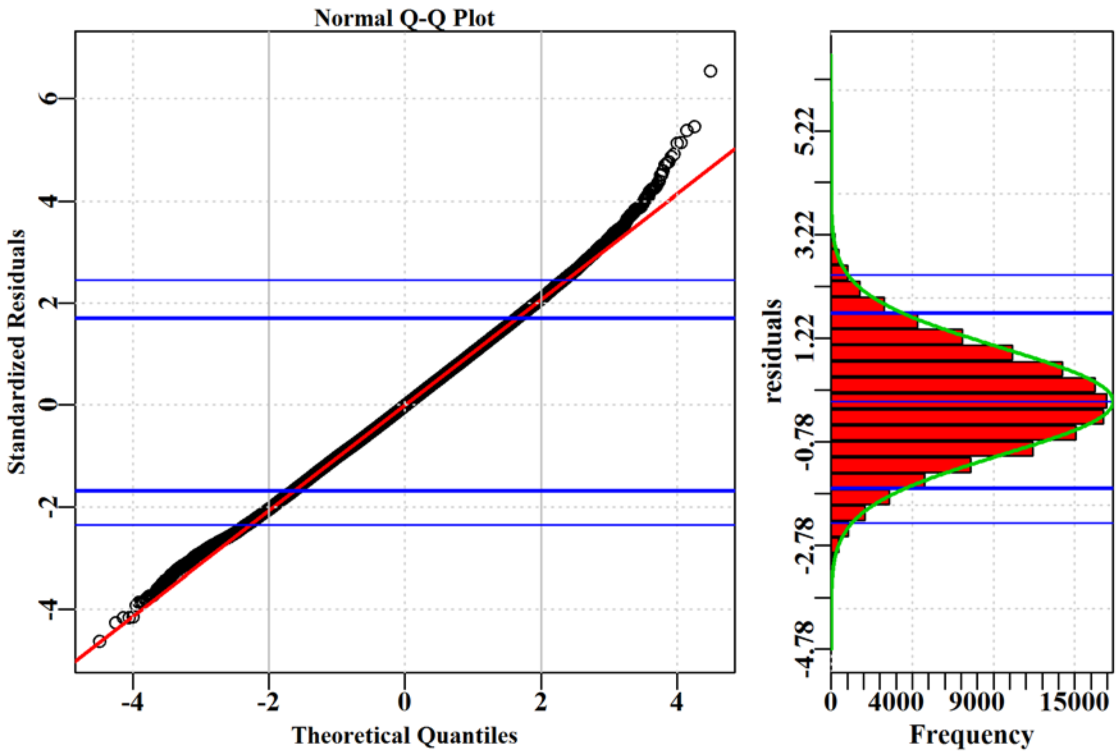


Figure 5.5. JohnDory1020. diagnostic plots. The distribution of residuals from the optimum fit. The qqplot indicates the fit to the expected normality, while the histogram of residuals illustrates the 90% quantiles to indicate the intensity of any lack of fit at the margins of the distribution.

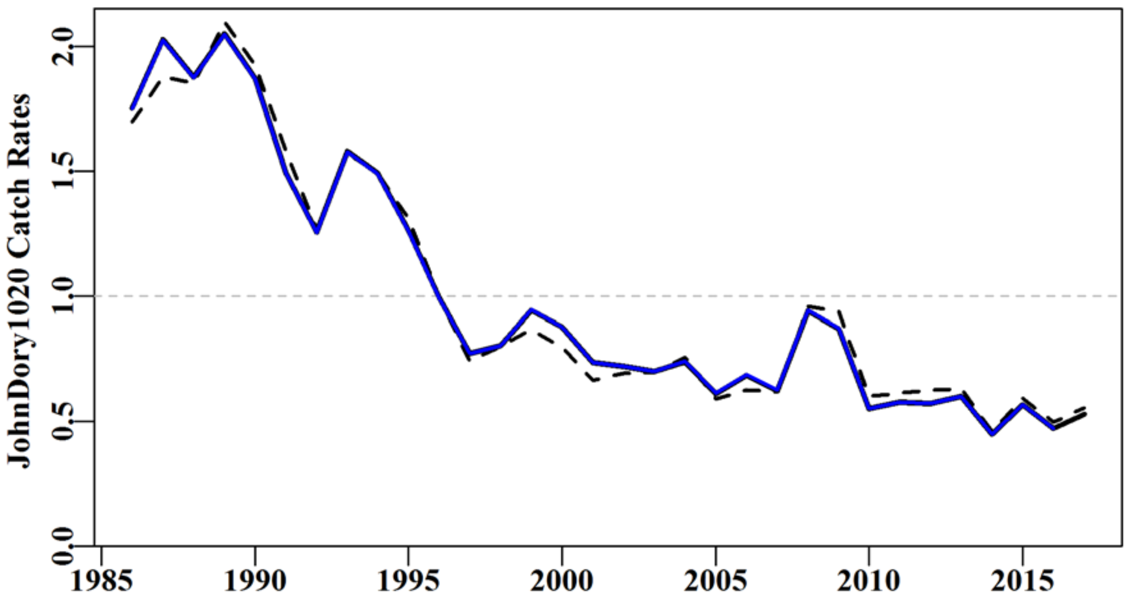


Figure 5.6. JohnDory1020. A comparison of the previous year's standardization (blue line) with this year's. They should lie on top of each other, although small deviations may relate to data adjustments, particularly in very recent years.

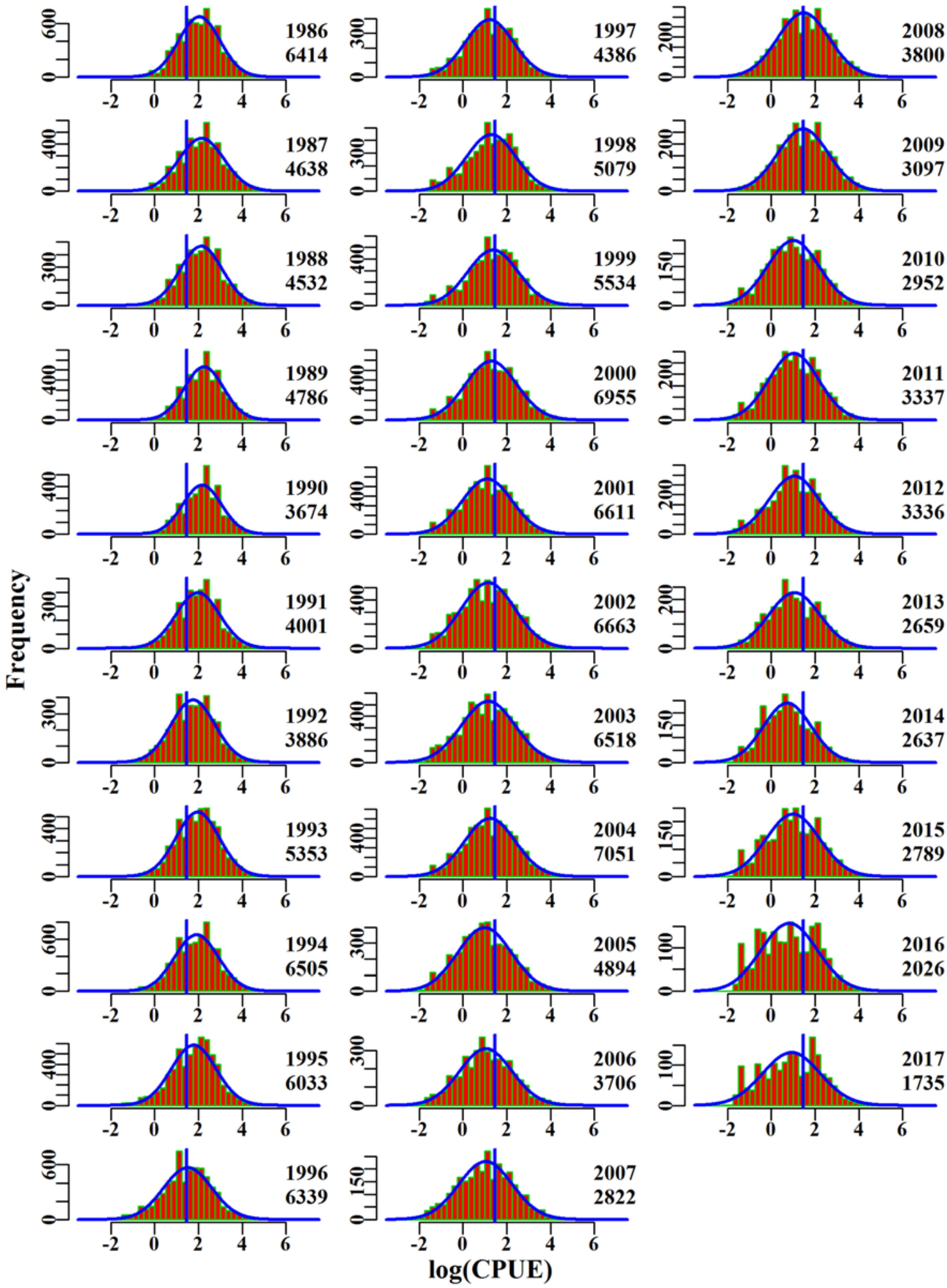


Figure 5.7. JohnDory1020. The log(CPUE) for each year of data available the blue lines are normal distributions fitted to the histogram frequencies. The numbers in each plot are the year and number of records.

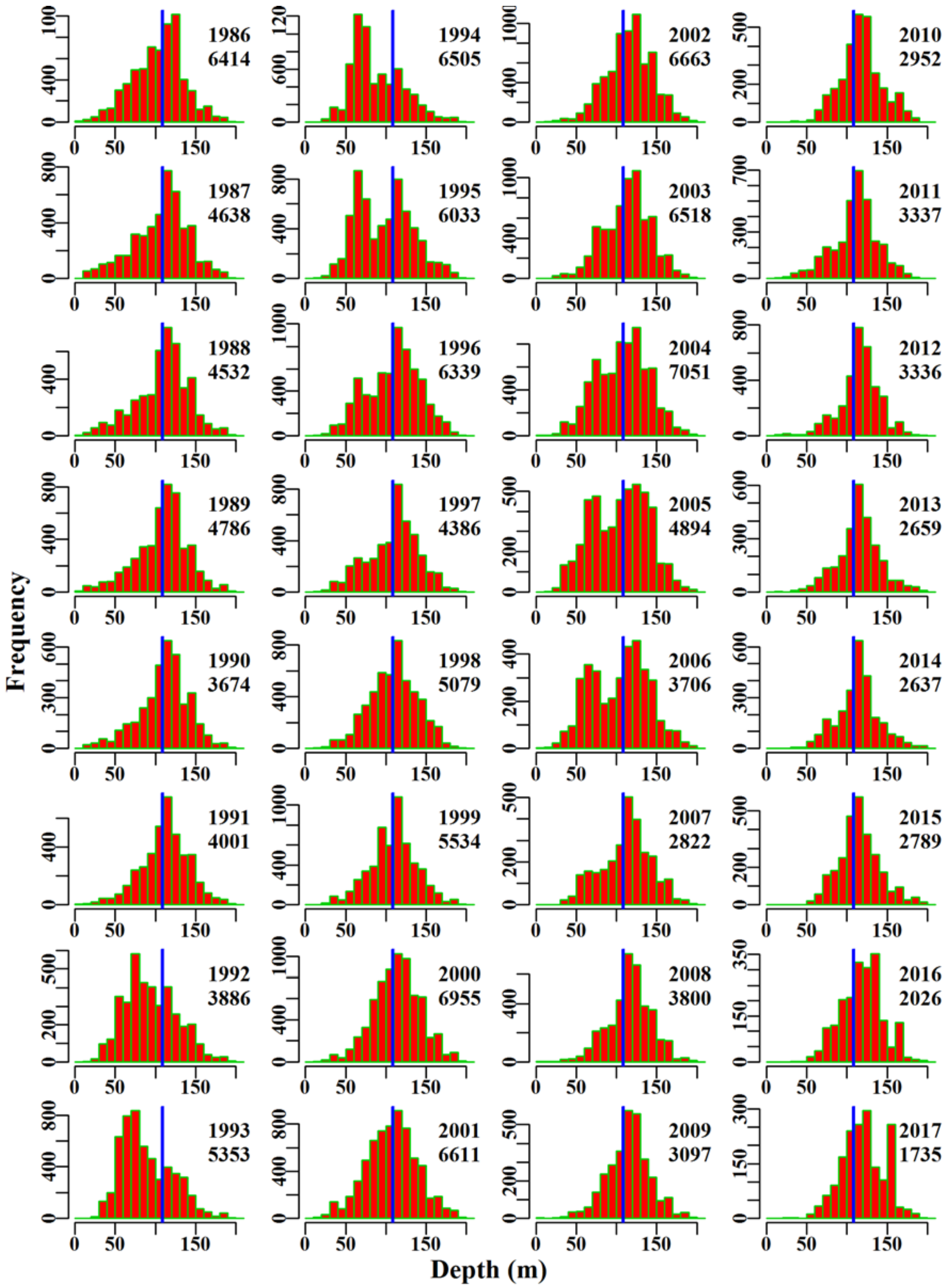


Figure 5.8. JohnDory1020. The average Depth of fishing for each year of data available to illustrate the development of the fishery through time. The numbers in each plot are the year and number of records.

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. Catch rates were expressed as the natural log of catch per shot (catch/shot). The years analysed were 1986 - 2017. Initial data selection was based on criteria provided in Table 5.6. 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 dropping below the long term average based on 95% CIs (Figure 5.9).

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 from 2014 - 2016, 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 - 2017

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	1.1422	0.000	18.476	0.016
1987	996.0	4058	909.2	23	271.6	1.2659	0.029	12.131	0.013
1988	1255.7	3767	1157.7	25	375.6	1.6121	0.030	10.303	0.009
1989	1061.5	4421	989.1	26	260.6	1.0703	0.029	14.045	0.014
1990	1930.4	6082	1803.1	24	351.5	1.6510	0.027	15.136	0.008
1991	1630.3	4645	1456.3	26	407.7	1.4606	0.029	10.954	0.008
1992	854.1	2906	751.3	23	362.0	1.0575	0.033	8.103	0.011
1993	1694.9	4784	1496.0	24	441.7	1.5095	0.029	9.902	0.007
1994	946.2	4406	864.6	23	273.8	0.8816	0.029	12.619	0.015
1995	1212.6	4198	1050.0	21	337.1	1.1187	0.030	9.197	0.009
1996	898.2	4126	692.3	22	223.6	0.7358	0.030	13.981	0.020
1997	697.4	3066	442.1	20	202.5	0.5537	0.032	11.232	0.025
1998	594.2	2913	447.6	20	211.5	0.5356	0.033	10.661	0.024
1999	681.3	1870	411.5	21	345.1	0.6131	0.039	6.013	0.015
2000	700.9	1916	343.9	18	266.9	0.6381	0.038	7.058	0.021
2001	890.9	1990	424.6	19	296.0	0.8852	0.039	6.779	0.016
2002	788.3	2186	428.2	20	258.4	0.8692	0.037	7.753	0.018
2003	866.2	2338	460.0	20	275.4	0.9127	0.037	7.942	0.017
2004	604.9	1751	332.0	20	264.4	0.8341	0.040	6.951	0.021
2005	662.7	1562	296.4	20	255.6	0.9299	0.041	4.883	0.016
2006	667.5	1404	263.4	18	258.3	0.8375	0.043	5.336	0.020
2007	535.4	1469	343.1	14	330.0	1.1061	0.042	4.479	0.013
2008	502.2	1248	313.7	15	370.2	1.0991	0.045	4.280	0.014
2009	462.6	1548	347.6	15	309.7	1.1780	0.042	5.171	0.015
2010	408.9	1167	270.8	15	339.6	1.0398	0.046	4.199	0.016
2011	373.9	1564	257.2	14	198.8	0.8323	0.042	6.430	0.025
2012	435.8	1562	302.3	14	262.7	0.8993	0.042	5.604	0.019
2013	510.6	1765	336.1	14	249.9	0.9160	0.040	6.569	0.020
2014	698.8	2047	480.8	14	336.2	1.0169	0.039	6.106	0.013
2015	741.1	2449	563.7	14	327.5	0.9661	0.037	7.530	0.013
2016	698.7	2326	556.4	15	304.4	0.9437	0.038	7.843	0.014
2017	746.7	2379	633.9	16	380.2	0.8886	0.038	6.235	0.010

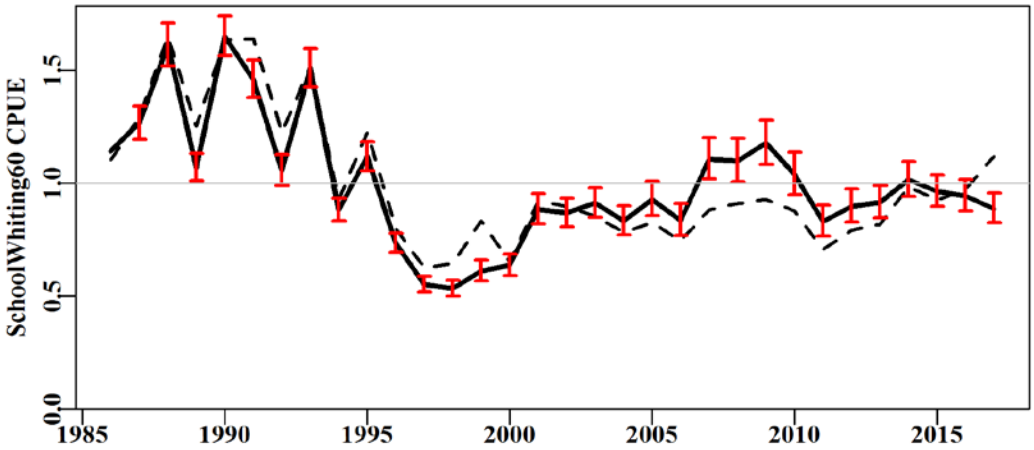


Figure 5.9. SchoolWhiting60 standardization. The dashed black line represents the geometric mean catch rate, solid black line the standardized catch rates. The red bars are the 95% confidence intervals about the mean estimates. The graph scales both time-series of standardized catch rates relative to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

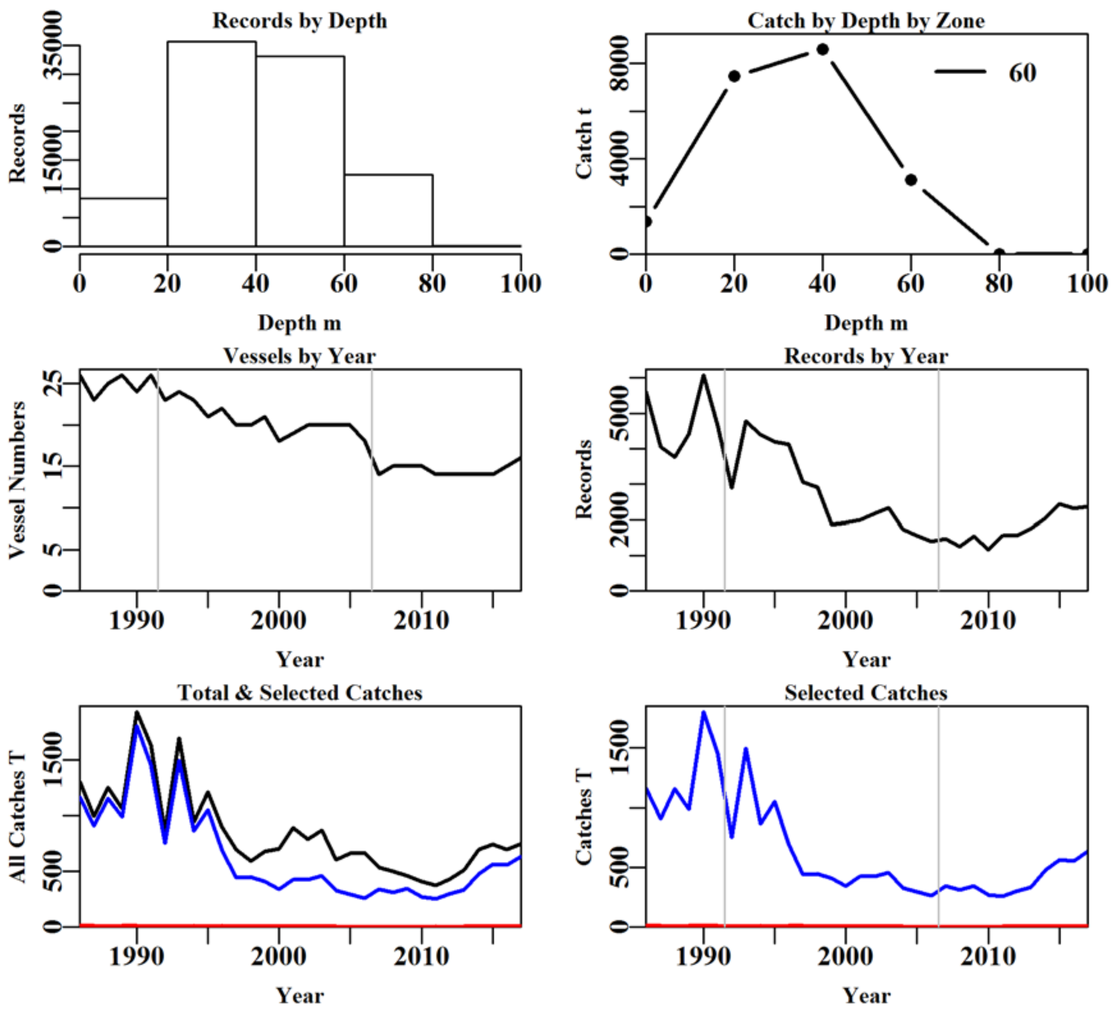


Figure 5.10. SchoolWhiting60 fishery details. The bottom left plot depicts all known catches (top black line), and all selected catches used in the analysis (middle blue line); the lower red line: selected catches < 30 kg).

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	141494.00	133171.00	128365.0000	126231.00	95195.00	92458.0000	89529.000
Difference	0.00	8323.00	4806.0000	2134.00	31036.00	2737.0000	2929.000
Catch	27502.92	27502.92	26776.8800	26328.00	21696.68	21281.8662	20592.182
Difference	0.00	0.00	726.0415	448.88	4631.32	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	65094	185104	7700	89529	32	4.0	0.00
DayNight	61355	177522	15282	89529	35	7.9	3.93
Vessel	58476	171719	21085	89529	83	10.9	2.96
Month	57341	169513	23291	89529	94	12.0	1.13
DepCat	56867	168600	24204	89529	99	12.5	0.47
DayNight:DepCat	56648	168146	24658	89529	110	12.7	0.22
DepCat:Month	56278	167341	25463	89529	140	13.1	0.61
DayNight:Month	56601	167977	24827	89529	132	12.7	0.29

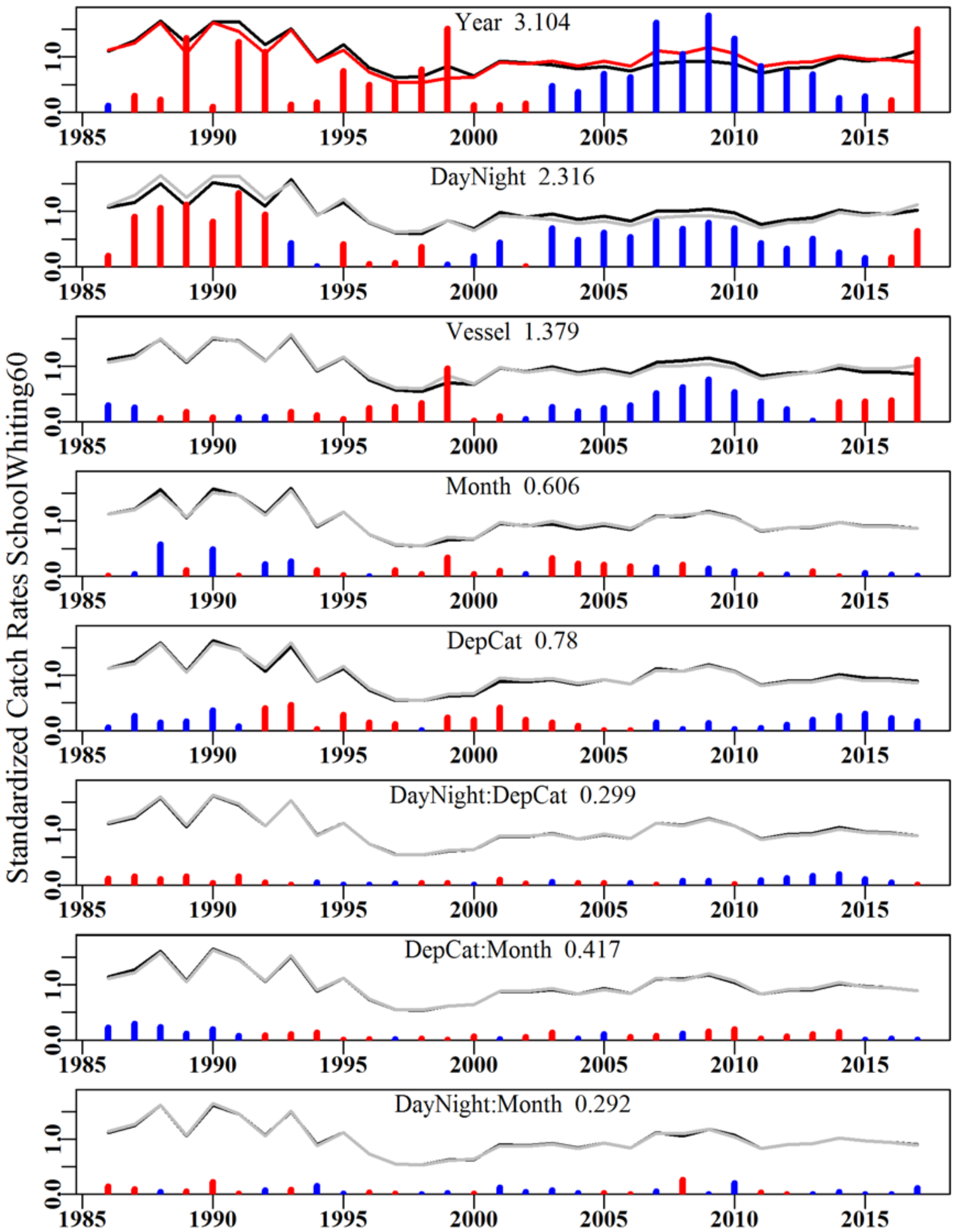


Figure 5.11. SchoolWhiting60. The influence of each factor on the optimal standardization. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by vertical bars with blue bars indicating the optimum model is higher than the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

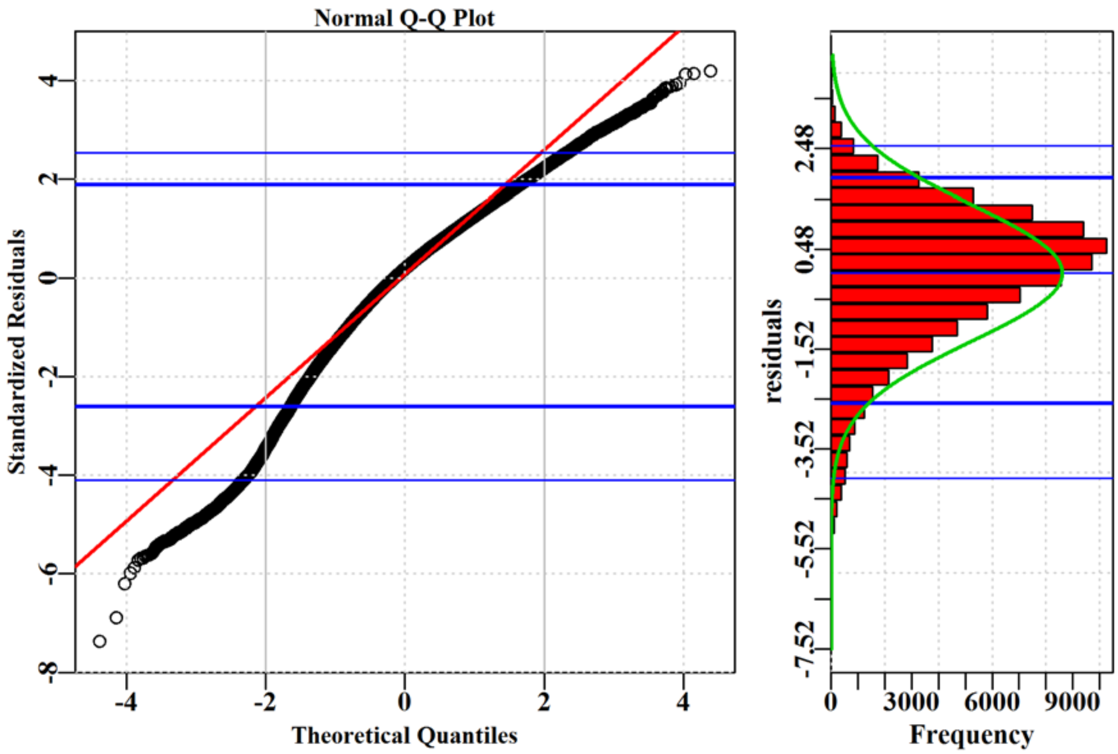


Figure 5.12. SchoolWhiting60. diagnostic plots. The distribution of residuals from the optimum fit. The qqplot indicates the fit to the expected normality, while the histogram of residuals illustrates the 90% quantiles to indicate the intensity of any lack of fit at the margins of the distribution.

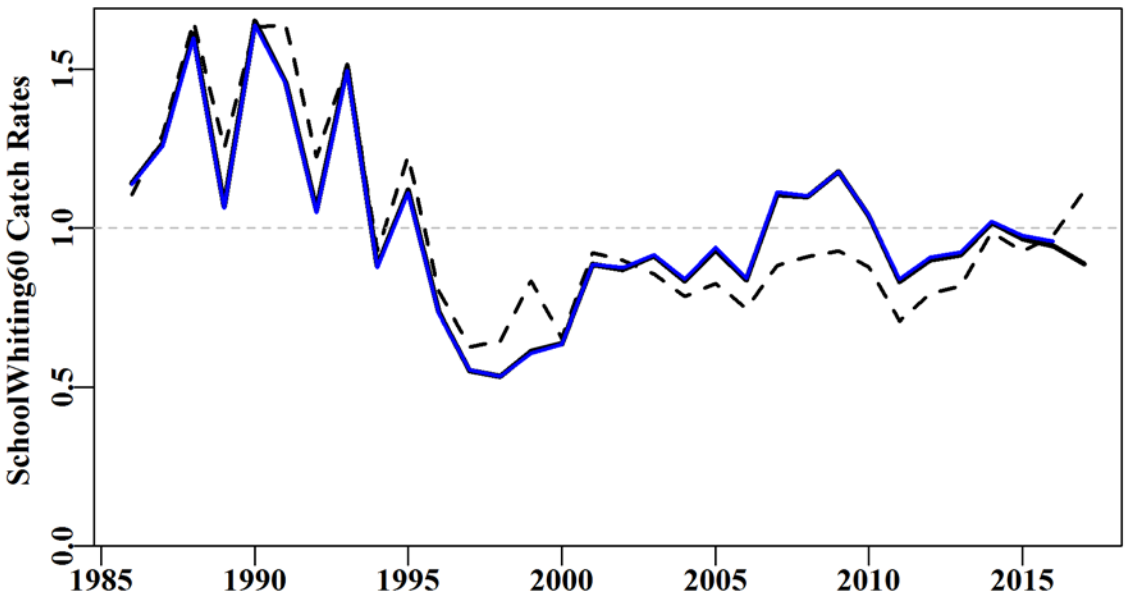


Figure 5.13. SchoolWhiting60. A comparison of the previous year's standardization (blue line) with this year's. They should lie on top of each other, although small deviations may relate to data adjustments, particularly in very recent years.

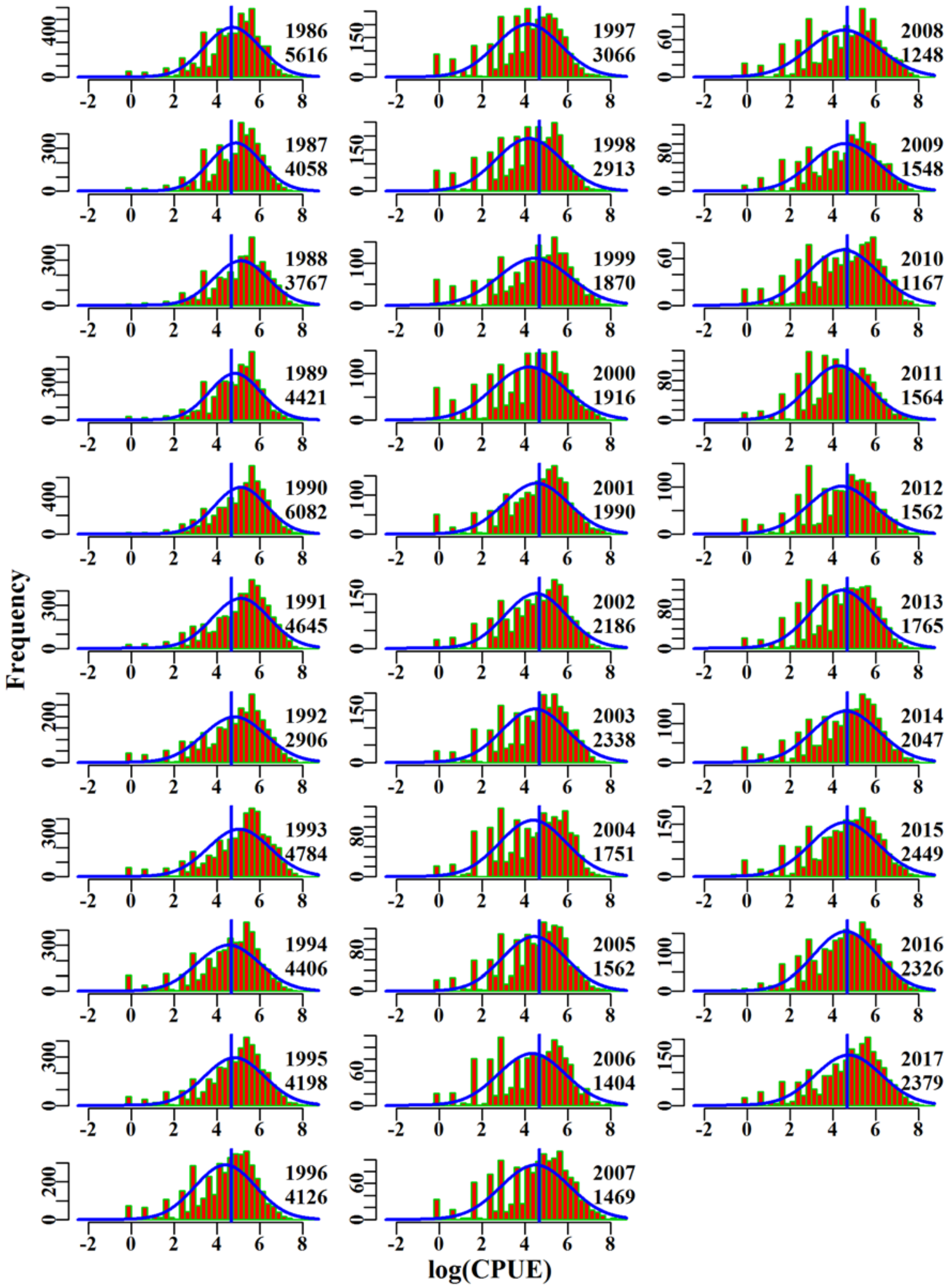


Figure 5.14. SchoolWhiting60. The log(CPUE) for each year of data available the blue lines are normal distributions fitted to the histogram frequencies. The numbers in each plot are the year and number of records.

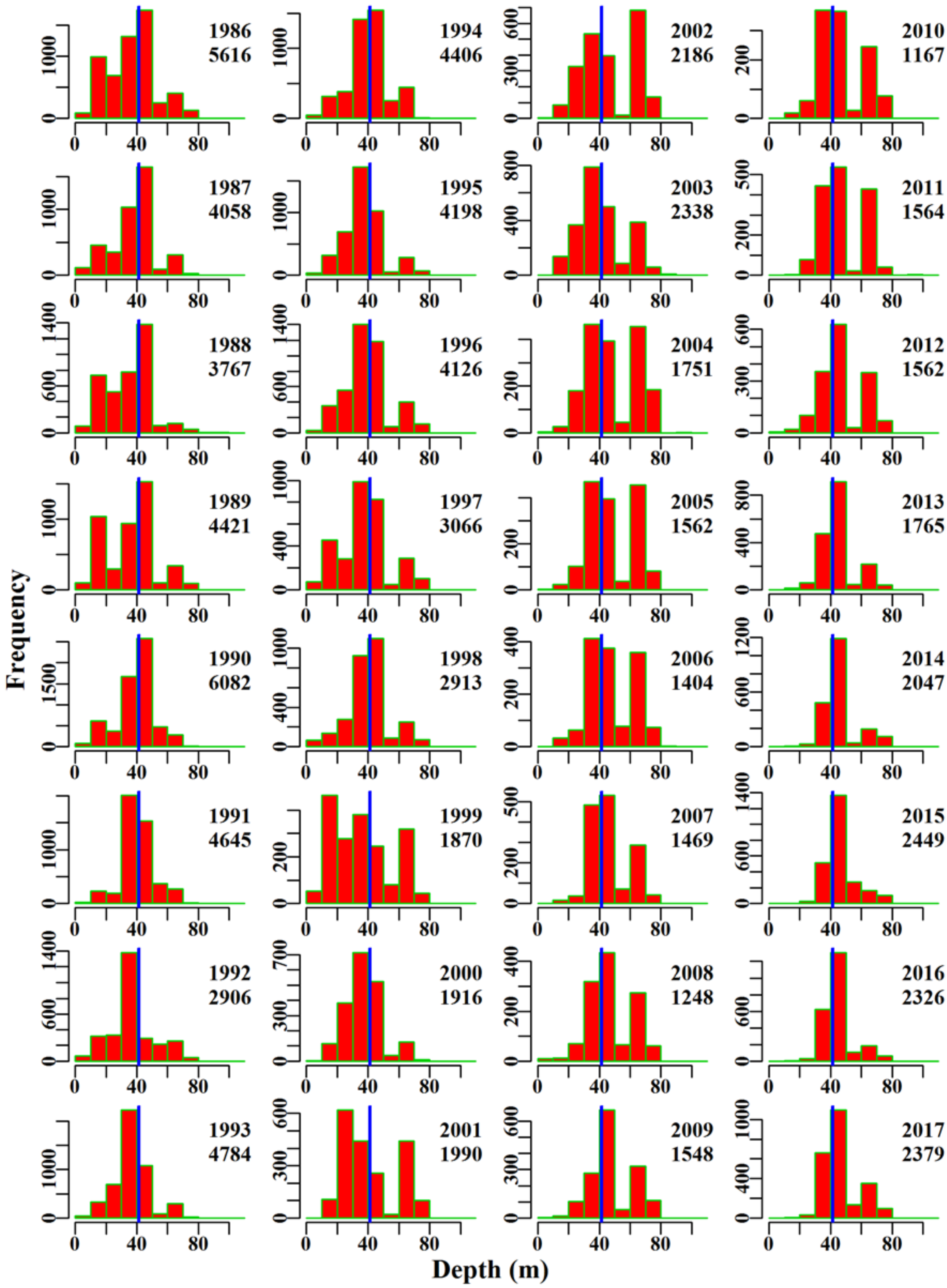


Figure 5.15. SchoolWhiting60. The average Depth of fishing for each year of data available to illustrate the development of the fishery through time. The numbers in each plot are the year and number of records.

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 - 2017. 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 - 2017

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	1.1947	0.000	1.046	0.026
1996	898.2	437	75.1	21	83.2	1.3424	0.095	0.806	0.011
1997	697.4	824	97.0	23	68.0	0.9313	0.086	2.771	0.029
1998	594.2	710	81.1	25	54.6	0.9404	0.087	2.844	0.035
1999	681.3	886	107.1	27	63.2	1.1377	0.085	2.809	0.026
2000	700.9	1229	154.4	30	69.6	1.1341	0.082	3.735	0.024
2001	890.9	2101	309.2	34	92.7	1.2538	0.080	7.896	0.026
2002	788.3	1662	172.1	36	73.2	1.0380	0.081	6.024	0.035
2003	866.2	2426	291.3	40	68.7	0.9831	0.079	9.290	0.032
2004	604.9	2037	186.2	39	48.0	0.7632	0.080	9.837	0.053
2005	662.7	1953	250.4	37	71.4	1.0697	0.080	7.556	0.030
2006	667.5	1437	225.6	28	75.4	1.4775	0.082	5.825	0.026
2007	535.4	495	86.7	15	105.5	1.4511	0.094	2.110	0.024
2008	502.2	841	107.4	15	68.1	0.9416	0.087	3.724	0.035
2009	462.6	444	36.8	17	46.7	0.8014	0.096	2.629	0.071
2010	408.9	463	47.6	17	60.4	0.9671	0.096	2.282	0.048
2011	373.9	494	64.5	15	83.4	0.8208	0.095	2.313	0.036
2012	435.8	509	45.3	16	49.7	0.6084	0.094	3.115	0.069
2013	510.6	663	57.0	14	44.4	0.5479	0.090	4.006	0.070
2014	698.8	815	71.4	18	52.2	0.7469	0.088	4.168	0.058
2015	741.1	767	55.2	18	36.7	0.6756	0.089	4.944	0.090
2016	698.7	578	66.2	14	70.2	0.9840	0.093	3.074	0.046
2017	746.7	343	44.7	11	72.7	1.1894	0.103	1.795	0.040

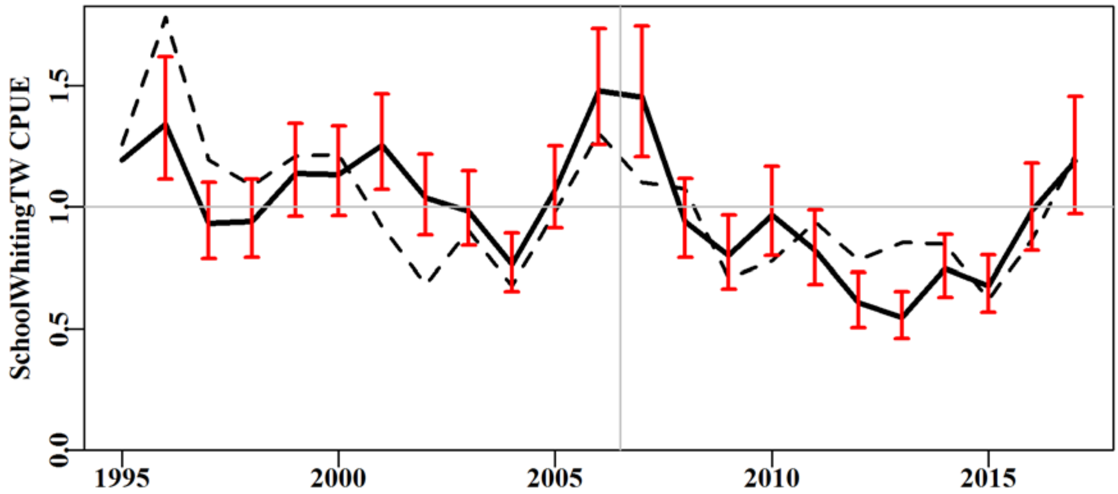


Figure 5.16. SchoolWhitingTW standardization. The dashed black line represents the geometric mean catch rate, solid black line the standardized catch rates. The red bars are the 95% confidence intervals about the mean estimates. The graph scales both time-series of standardized catch rates relative to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

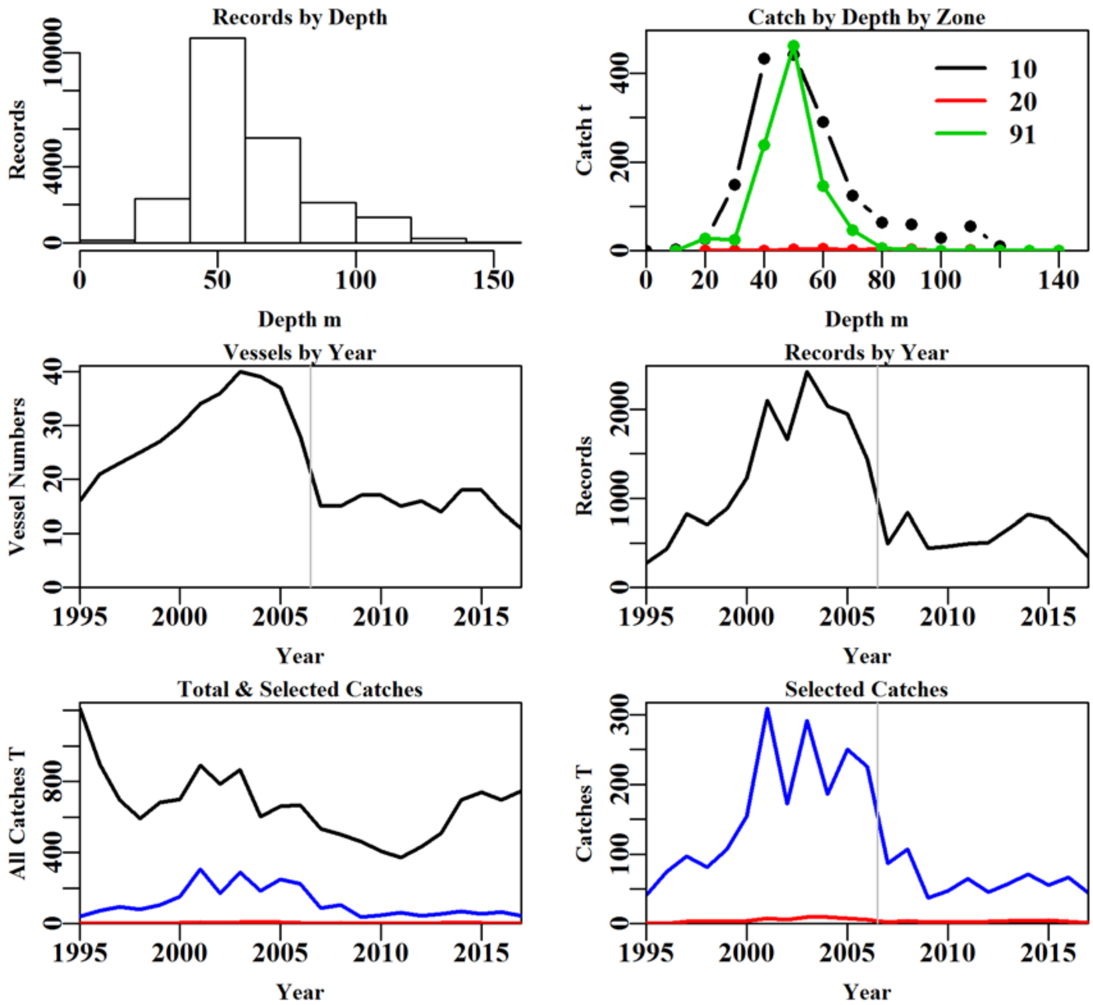


Figure 5.17. SchoolWhitingTW fishery details. The bottom left plot depicts all known catches (top black line), and all selected catches used in the analysis (middle blue line); the lower red line: selected catches < 30 kg).

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	141494	108239	106241	62772	23425	22418	22391
Difference	0	33255	1998	43469	39347	1007	27
Catch	27502.92	22552.827	22146.7188	11220.93	2851.643	2675.2205	2673.048
Difference	0.00	4950.094	406.1085	10925.79	8369.287	176.4225	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	19910	54370	1226	22391	23	2.1	0.00
Vessel	12217	38327	17269	22391	91	30.8	28.67
DayNight	10079	34828	20768	22391	94	37.1	6.31
DepCat	9176	33409	22188	22391	108	39.6	2.53
Month	9111	33280	22316	22391	119	39.8	0.20
DayNight:DepCat	8831	32786	22810	22391	146	40.6	0.82
DepCat:Month	8892	32549	23048	22391	258	40.8	0.95
DayNight:Month	9039	33102	22495	22391	143	40.1	0.26

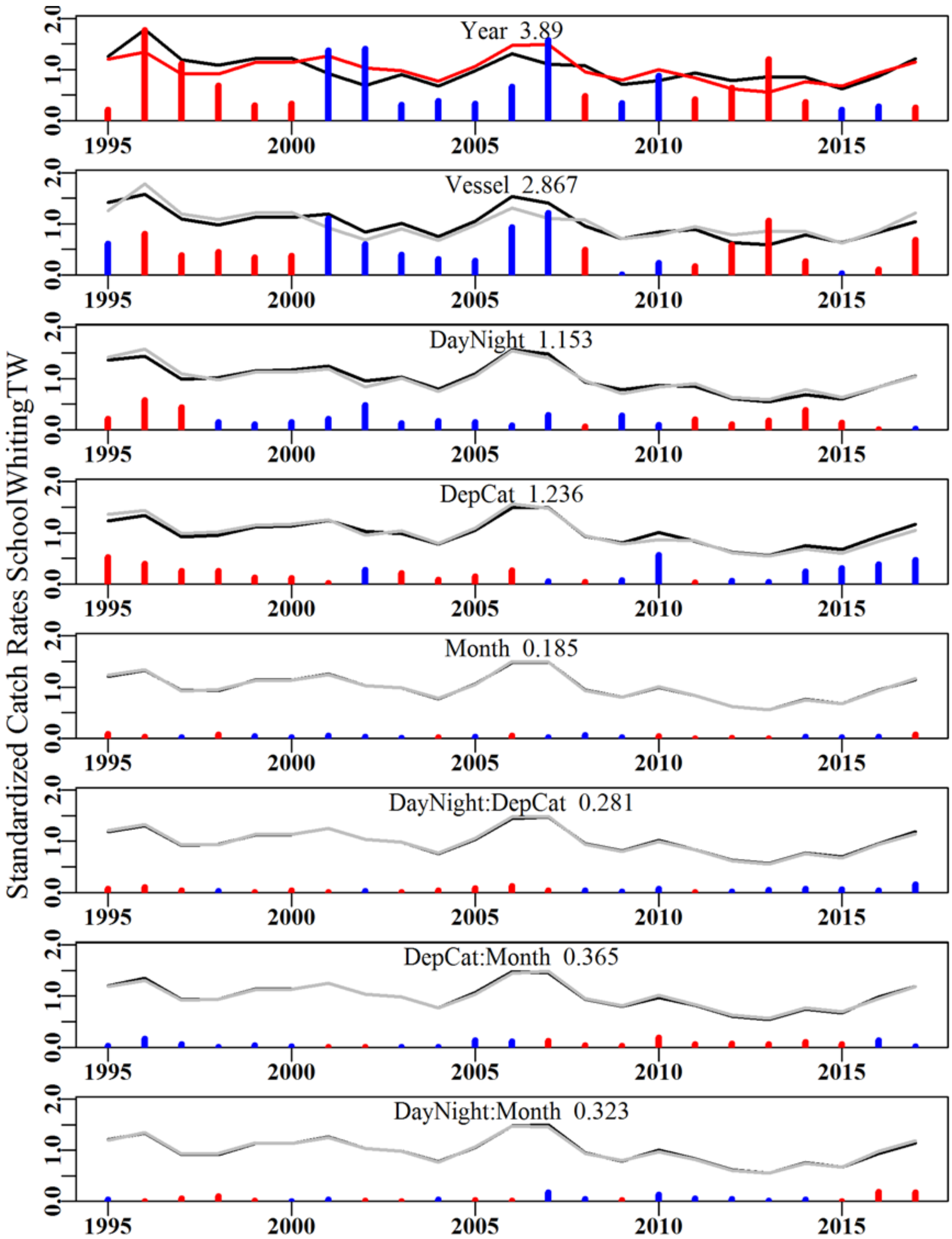


Figure 5.18. SchoolWhitingTW. The influence of each factor on the optimal standardization. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by vertical bars with blue bars indicating the optimum model is higher than the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

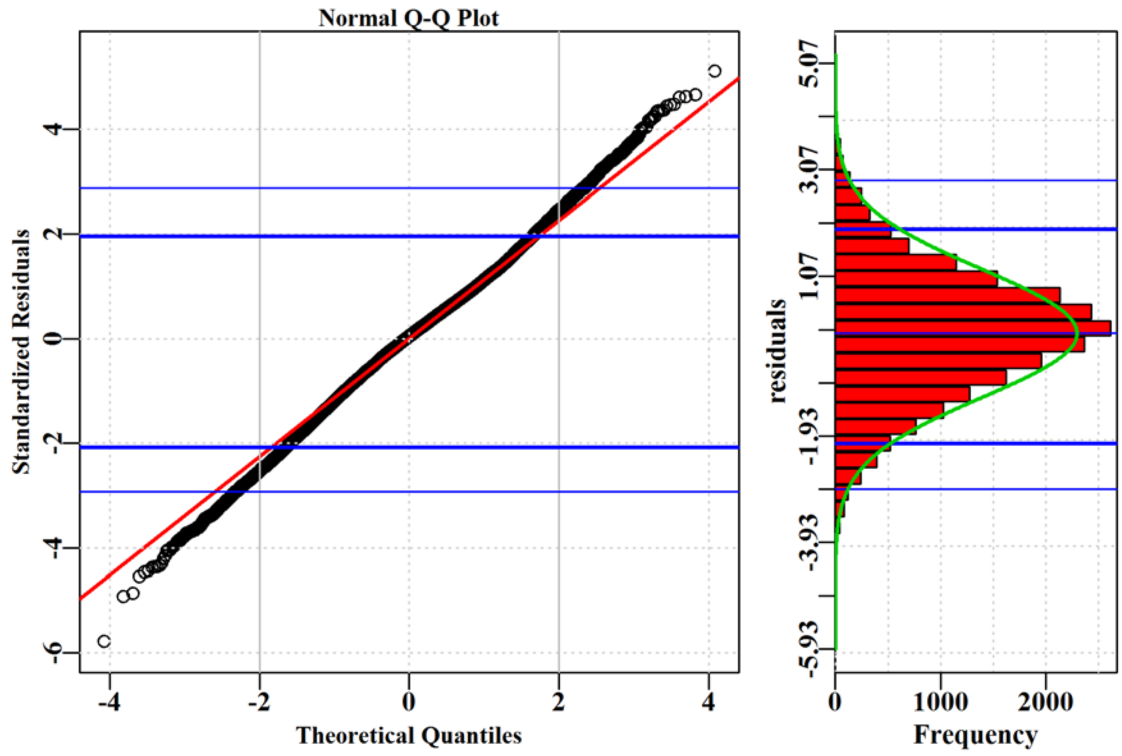


Figure 5.19. SchoolWhitingTW. diagnostic plots. The distribution of residuals from the optimum fit. The qqplot indicates the fit to the expected normality, while the histogram of residuals illustrates the 90% quantiles to indicate the intensity of any lack of fit at the margins of the distribution.

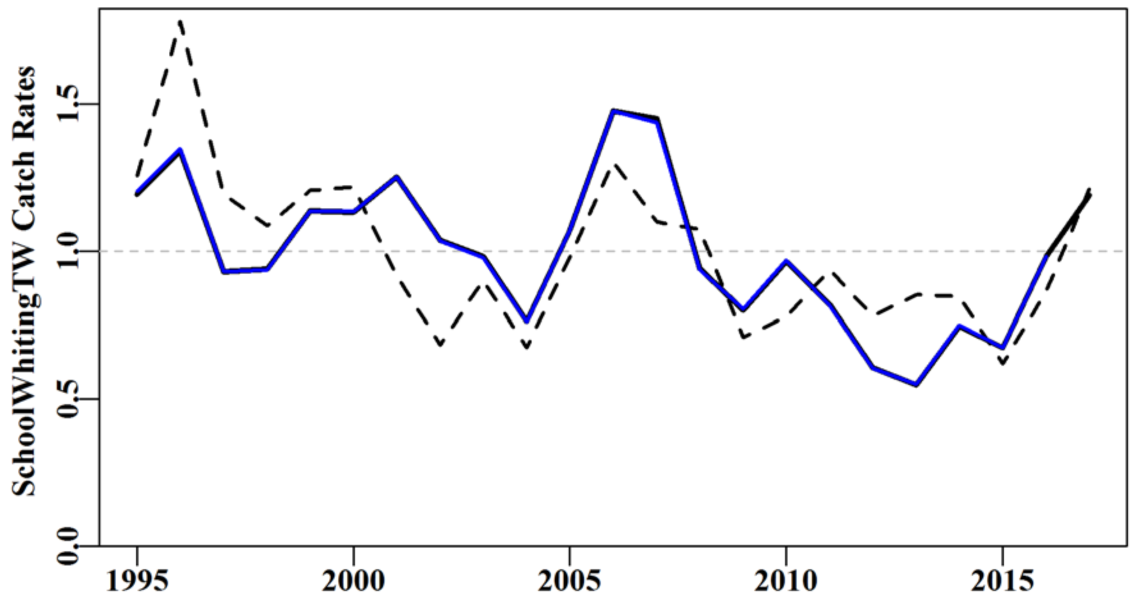


Figure 5.20. SchoolWhitingTW. A comparison of the previous year's standardization (blue line) with this year's. They should lie on top of each other, although small deviations may relate to data adjustments, particularly in very recent years.

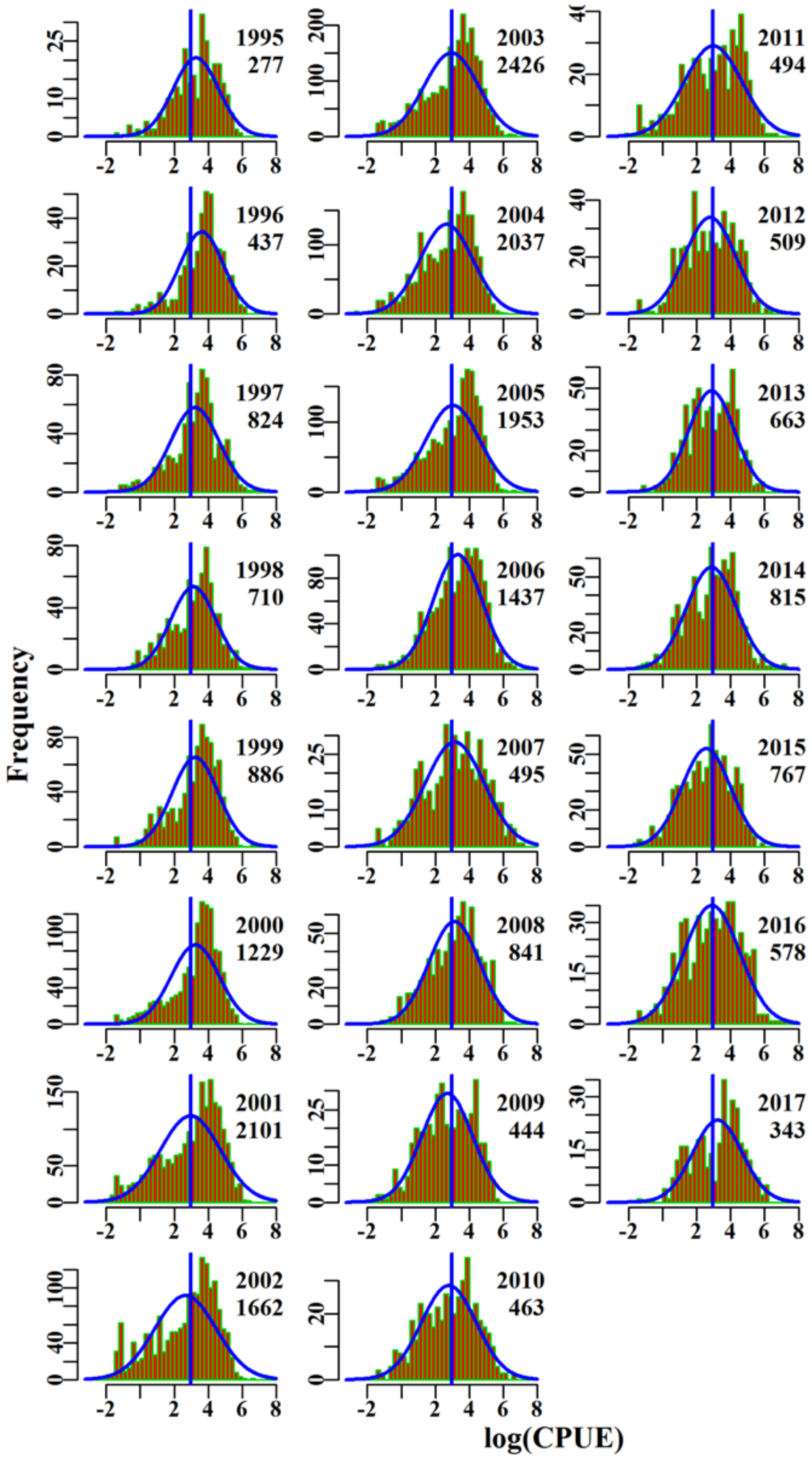


Figure 5.21. SchoolWhitingTW. The log(CPUE) for each year of data available the blue lines are normal distributions fitted to the histogram frequencies. The numbers in each plot are the year and number of records.

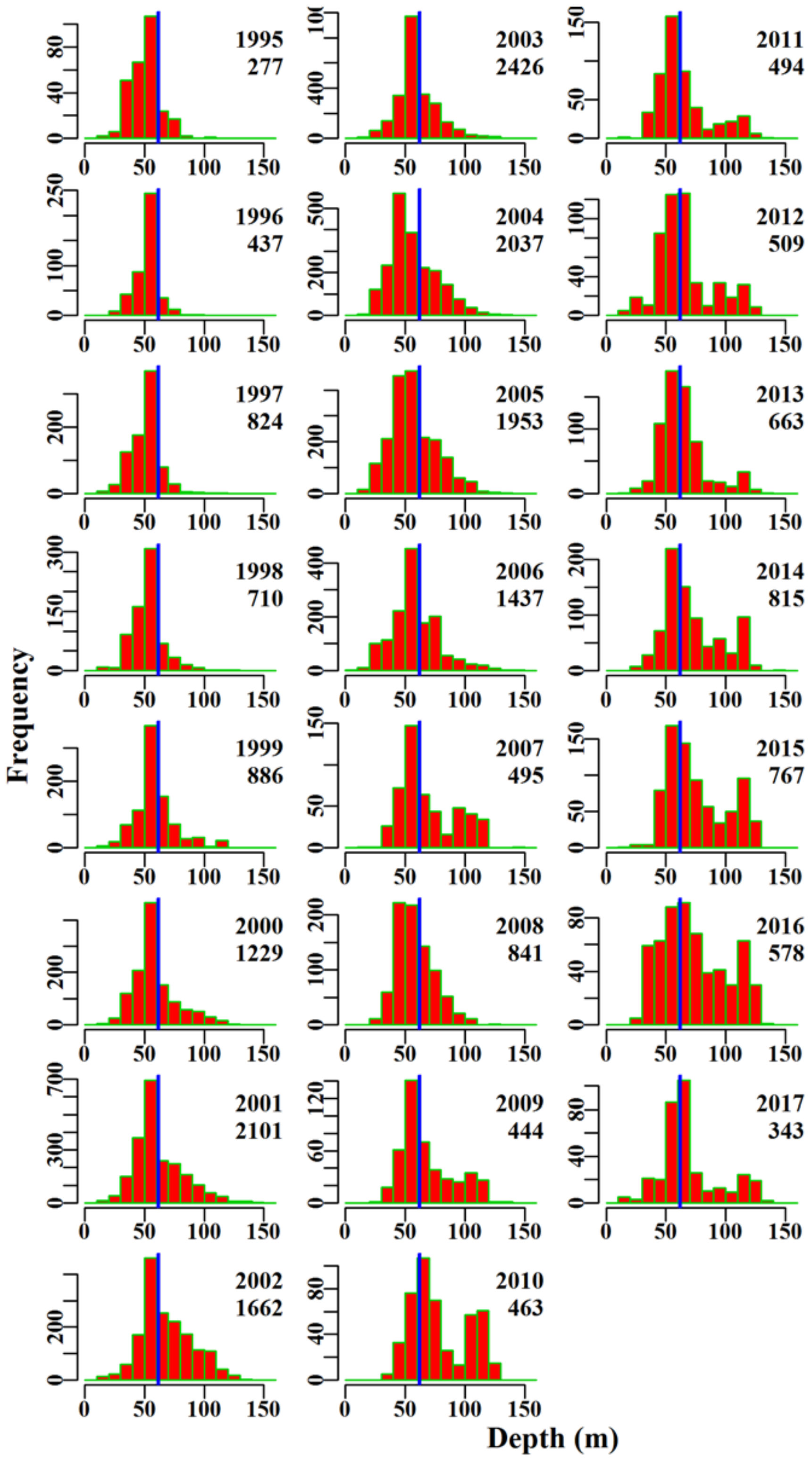


Figure 5.22. SchoolWhitingTW. The average Depth of fishing for each year of data available to illustrate the development of the fishery through time. The numbers in each plot are the year and number of records.

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 - 2017. 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 (Figure 5.19).

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).

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 - 2017

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	1.3203	0.000	0.689	0.030
1996	898.2	142	27.7	17	170.6	1.1877	0.155	0.393	0.014
1997	697.4	438	58.2	21	119.6	0.9647	0.125	1.951	0.033
1998	594.2	313	32.7	25	70.8	0.9634	0.130	1.685	0.051
1999	681.3	486	51.5	27	72.0	1.1306	0.124	2.083	0.040
2000	700.9	794	98.9	30	89.8	1.1040	0.118	2.765	0.028
2001	890.9	1453	178.9	34	87.0	1.1366	0.114	6.864	0.038
2002	788.3	1302	128.3	36	78.6	1.0232	0.115	4.992	0.039
2003	866.2	1638	192.6	38	79.1	0.9998	0.114	7.165	0.037
2004	604.9	1281	90.8	38	40.5	0.7907	0.115	7.119	0.078
2005	662.7	1254	132.9	37	65.0	1.0202	0.115	6.453	0.049
2006	667.5	948	140.3	28	79.7	1.6170	0.117	4.665	0.033
2007	535.4	434	80.5	15	122.5	1.6110	0.126	1.835	0.023
2008	502.2	522	68.3	15	81.5	0.8776	0.123	2.344	0.034
2009	462.6	376	30.3	17	46.1	0.7875	0.128	2.204	0.073
2010	408.9	385	37.8	17	55.6	0.9529	0.129	2.137	0.057
2011	373.9	422	50.0	15	84.5	0.7824	0.127	1.941	0.039
2012	435.8	426	40.0	16	57.1	0.6515	0.126	2.445	0.061
2013	510.6	505	45.4	14	50.1	0.5316	0.124	2.810	0.062
2014	698.8	693	63.4	18	58.3	0.7643	0.121	3.551	0.056
2015	741.1	647	47.6	18	39.0	0.6924	0.122	4.158	0.087
2016	698.7	504	57.8	14	73.7	0.9330	0.125	2.824	0.049
2017	746.7	275	36.8	11	79.0	1.1575	0.136	1.620	0.044

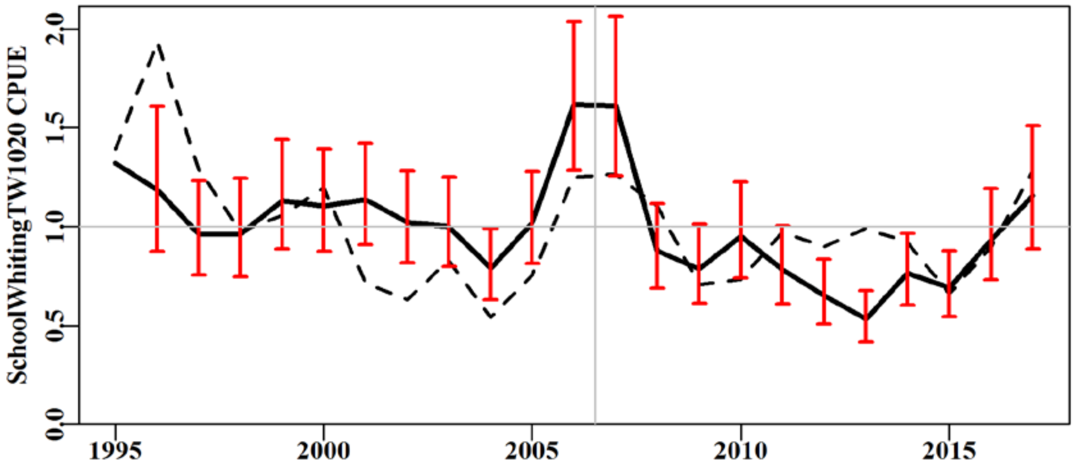


Figure 5.23. SchoolWhitingTW1020 standardization. The dashed black line represents the geometric mean catch rate, solid black line the standardized catch rates. The red bars are the 95% confidence intervals about the mean estimates. The graph scales both time-series of standardized catch rates relative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

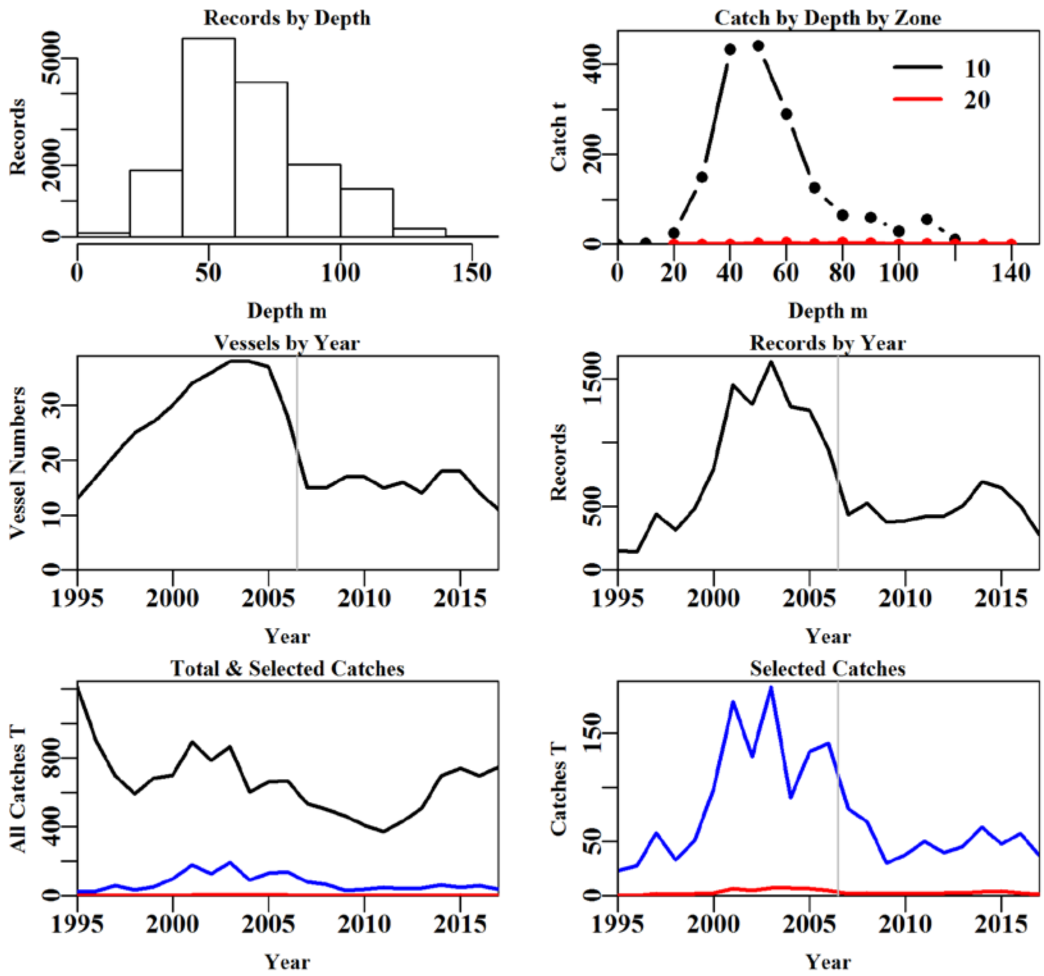


Figure 5.24. SchoolWhitingTW1020 fishery details. The bottom left plot depicts all known catches (top black line), and all selected catches used in the analysis (middle blue line); the lower red line: selected catches < 30 kg).

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	141494	108239	106241	62772	16421	15418	15391
Difference	0	33255	1998	43469	46351	1003	27
Catch	27502.92	22552.827	22146.7188	11220.93	1892.033	1716.2558	1714.083
Difference	0.00	4950.094	406.1085	10925.79	9328.896	175.7775	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	16637	45229	1150	15391	23	2.3	0.00
Vessel	11047	31178	15201	15391	91	32.4	30.04
DayNight	9250	27731	18648	15391	94	39.8	7.46
DepCat	8463	26301	20077	15391	108	42.9	3.05
Month	8398	26152	20226	15391	119	43.2	0.28
DayNight:DepCat	8100	25562	20817	15391	146	44.4	1.18
DepCat:Month	8278	25489	20890	15391	257	44.1	0.94
DayNight:Month	8357	26002	20377	15391	143	43.4	0.24

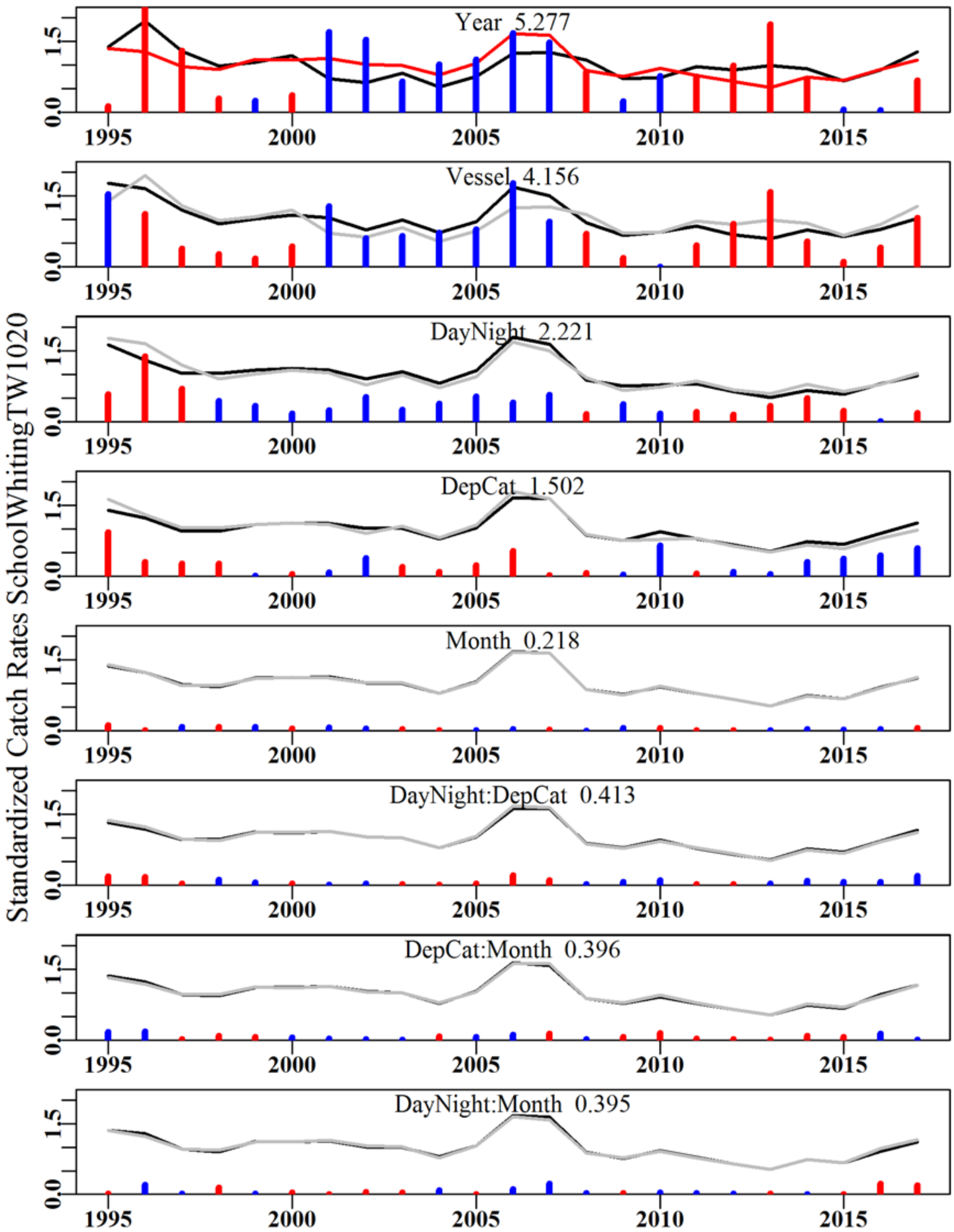


Figure 5.25. SchoolWhitingTW1020. The influence of each factor on the optimal standardization. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by vertical bars with blue bars indicating the optimum model is higher than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

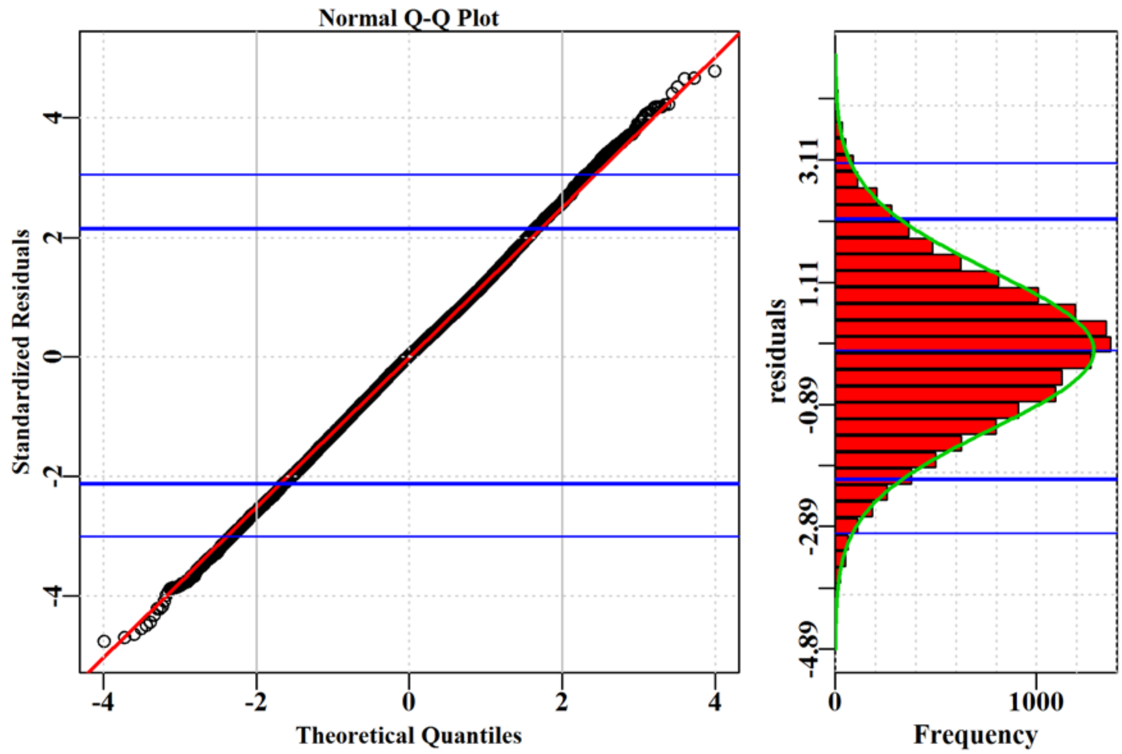


Figure 5.26. SchoolWhitingTW1020. diagnostic plots. The distribution of residuals from the optimum fit. The qqplot indicates the fit to the expected normality, while the histogram of residuals illustrates the 90% quantiles to indicate the intensity of any lack of fit at the margins of the distribution.

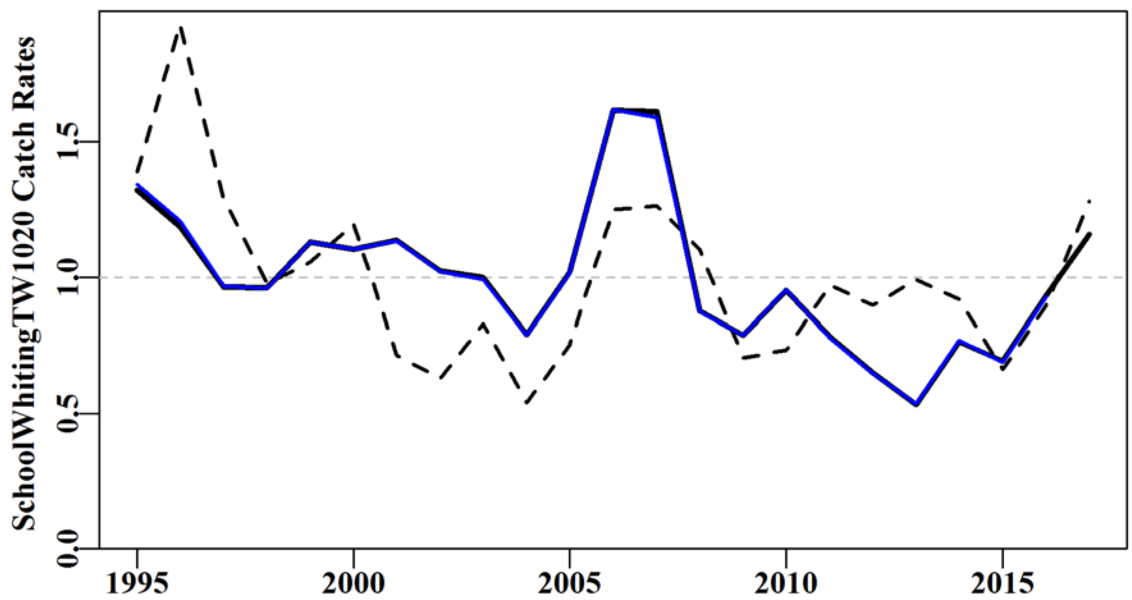


Figure 5.27. SchoolWhitingTW1020. A comparison of the previous year's standardization (blue line) with this year's. They should lie on top of each other, although small deviations may relate to data adjustments, particularly in very recent years.

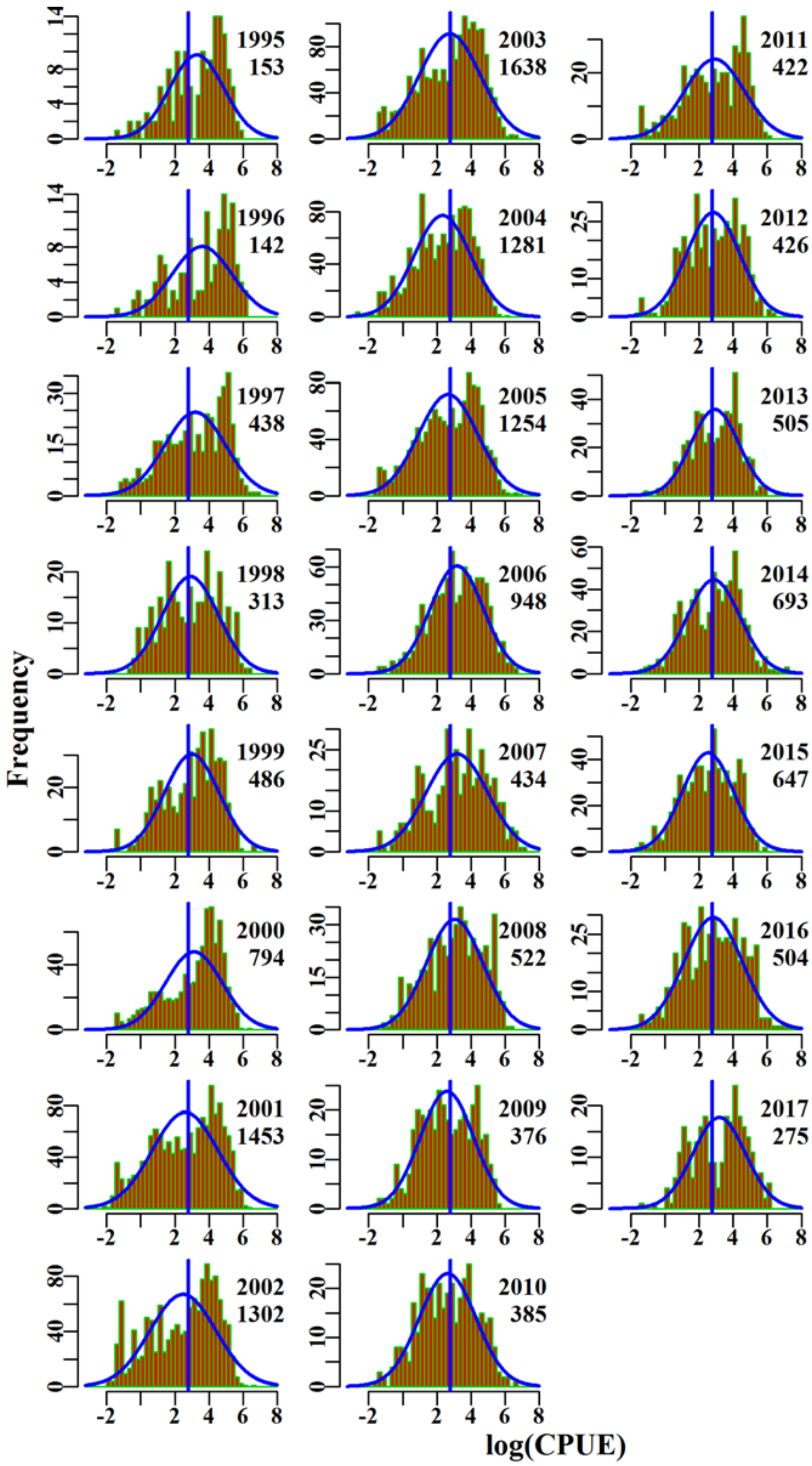


Figure 5.28. SchoolWhitingTW1020. The log(CPUE) for each year of data available the blue lines are normal distributions fitted to the histogram frequencies. The numbers in each plot are the year and number of records.

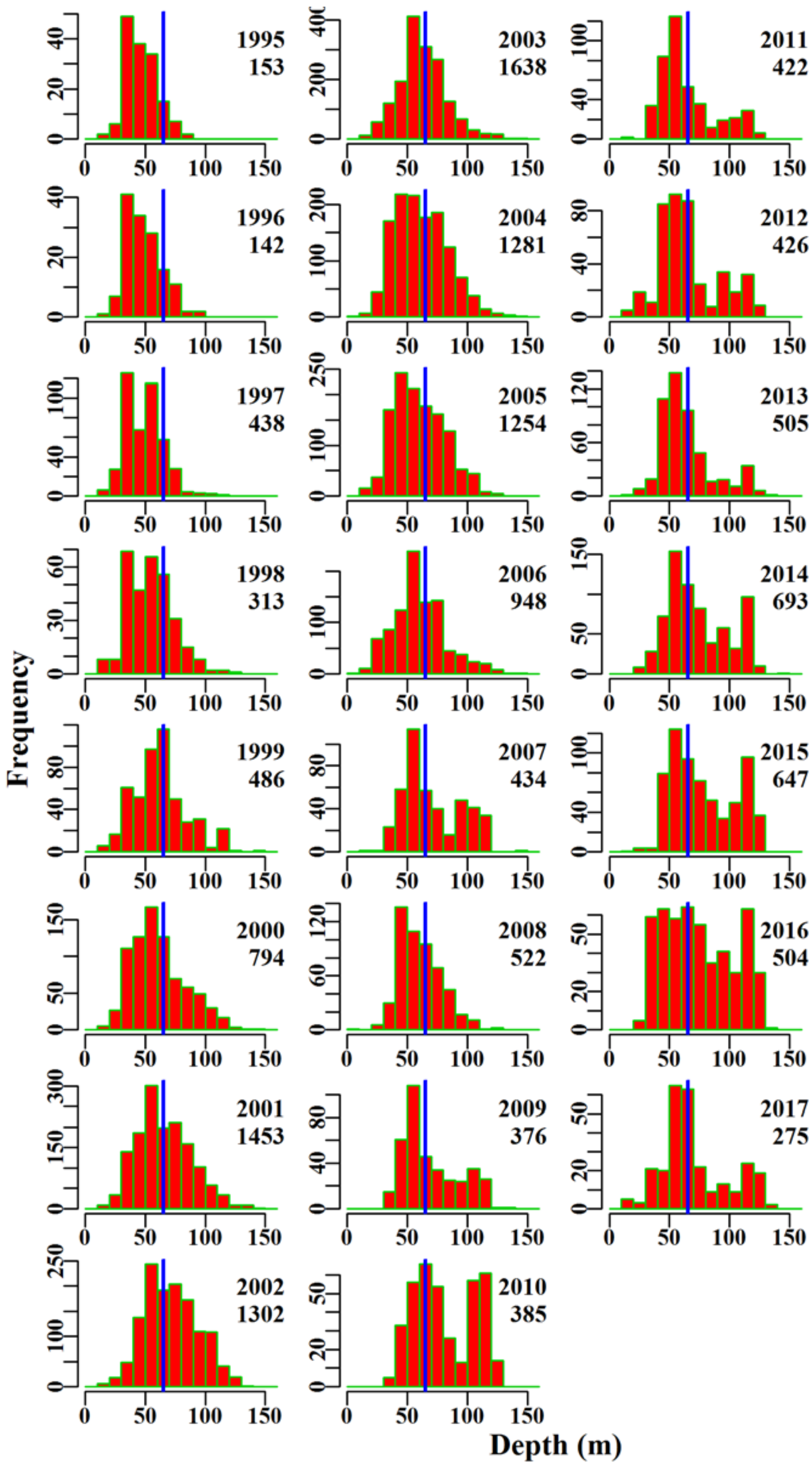


Figure 5.29. SchoolWhitingTW1020. The average Depth of fishing for each year of data available to illustrate the development of the fishery through time. The numbers in each plot are the year and number of records.

5.8 Mirror Dory 10 – 30

Mirror Dory (DOM – 37264003 – *Zenopsis nebulosus*) 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 - 2017 were used in the analysis (Table 5.21).

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 does CPUE, 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 and increased in 2017. It differs from geometric mean CPUE early in the fishery (1986 - 1990), in the second half of the fishery (2000 - 2007) and in the most recent four years (2014 - 2017). The most recent changes appear strongly correlated with changes in average fishing depth with a shift to fishing in more relatively shallow water, 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 - 2017

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	1.1982	0.000	16.343	0.044
1987	450.8	2953	412.9	70	40.7	1.3086	0.033	15.129	0.037
1988	346.0	3065	313.1	77	33.7	1.1832	0.033	19.277	0.062
1989	591.6	2992	513.4	70	54.5	1.4209	0.033	15.795	0.031
1990	295.8	1801	253.5	61	36.5	1.3546	0.038	10.132	0.040
1991	240.3	2002	168.5	68	26.9	1.1750	0.038	16.089	0.095
1992	167.0	2031	140.3	57	22.3	1.0219	0.038	17.939	0.128
1993	306.2	2997	265.7	62	32.4	1.1081	0.034	21.976	0.083
1994	297.3	3482	260.5	62	25.9	0.9811	0.033	30.013	0.115
1995	244.9	3494	196.0	58	21.7	0.8838	0.033	33.126	0.169
1996	352.7	4377	211.5	68	16.7	0.7751	0.032	43.254	0.205
1997	459.6	4757	287.1	65	19.5	0.8227	0.032	45.256	0.158
1998	355.8	4092	230.1	55	19.4	0.7330	0.032	38.924	0.169
1999	309.5	4211	234.2	59	19.3	0.6482	0.033	39.603	0.169
2000	171.1	4593	142.5	64	11.3	0.5122	0.032	46.471	0.326
2001	243.4	4533	128.7	54	10.0	0.5125	0.033	46.396	0.361
2002	449.6	5032	194.3	53	14.0	0.6427	0.032	44.433	0.229
2003	613.9	5333	403.8	58	29.9	0.9222	0.032	40.852	0.101
2004	507.4	4256	291.0	57	25.8	0.8755	0.033	32.430	0.111
2005	579.9	4356	420.4	55	37.4	1.1224	0.033	30.059	0.071
2006	419.6	3214	296.4	44	35.4	1.1291	0.035	23.588	0.080
2007	289.6	2210	201.1	22	33.6	1.2151	0.038	16.397	0.082
2008	396.2	2476	316.9	26	48.1	1.3502	0.037	17.544	0.055
2009	476.5	2191	333.9	27	55.9	1.4348	0.038	15.733	0.047
2010	580.0	2068	378.3	25	71.5	1.2021	0.039	13.158	0.035
2011	514.5	2208	339.2	26	64.0	1.2191	0.038	14.273	0.042
2012	365.5	1712	281.3	24	66.7	0.9633	0.041	10.981	0.039
2013	279.9	1633	206.6	24	55.6	1.0005	0.041	10.502	0.051
2014	190.0	1732	112.4	25	24.7	0.8364	0.041	15.045	0.134
2015	240.4	2126	163.5	27	31.8	0.8165	0.039	17.175	0.105
2016	249.4	2062	202.0	26	42.0	0.7520	0.040	13.230	0.065
2017	224.3	1412	163.4	22	50.9	0.8789	0.044	11.230	0.069

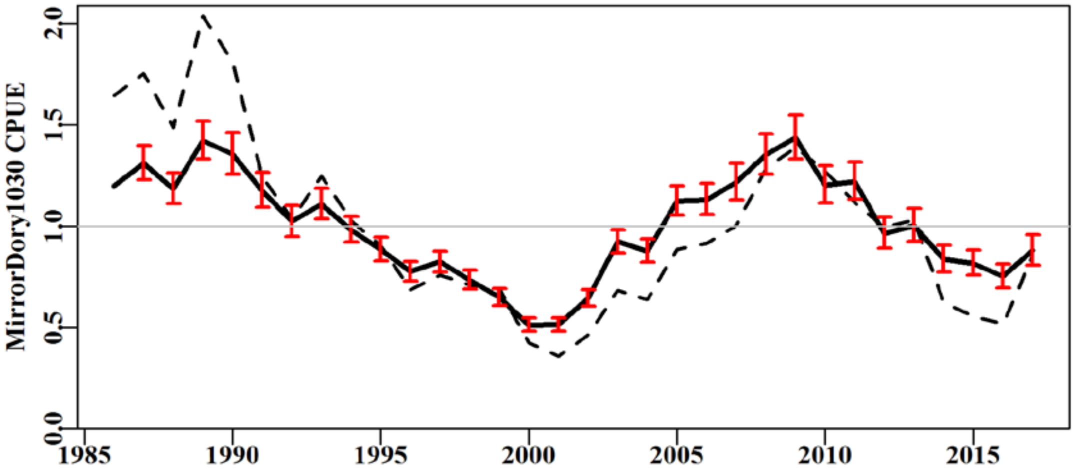


Figure 5.30. MirrorDory1030 standardization. The dashed black line represents the geometric mean catch rate, solid black line the standardized catch rates. The red bars are the 95% confidence intervals about the mean estimates. The graph scales both time-series of standardized catch rates relative to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

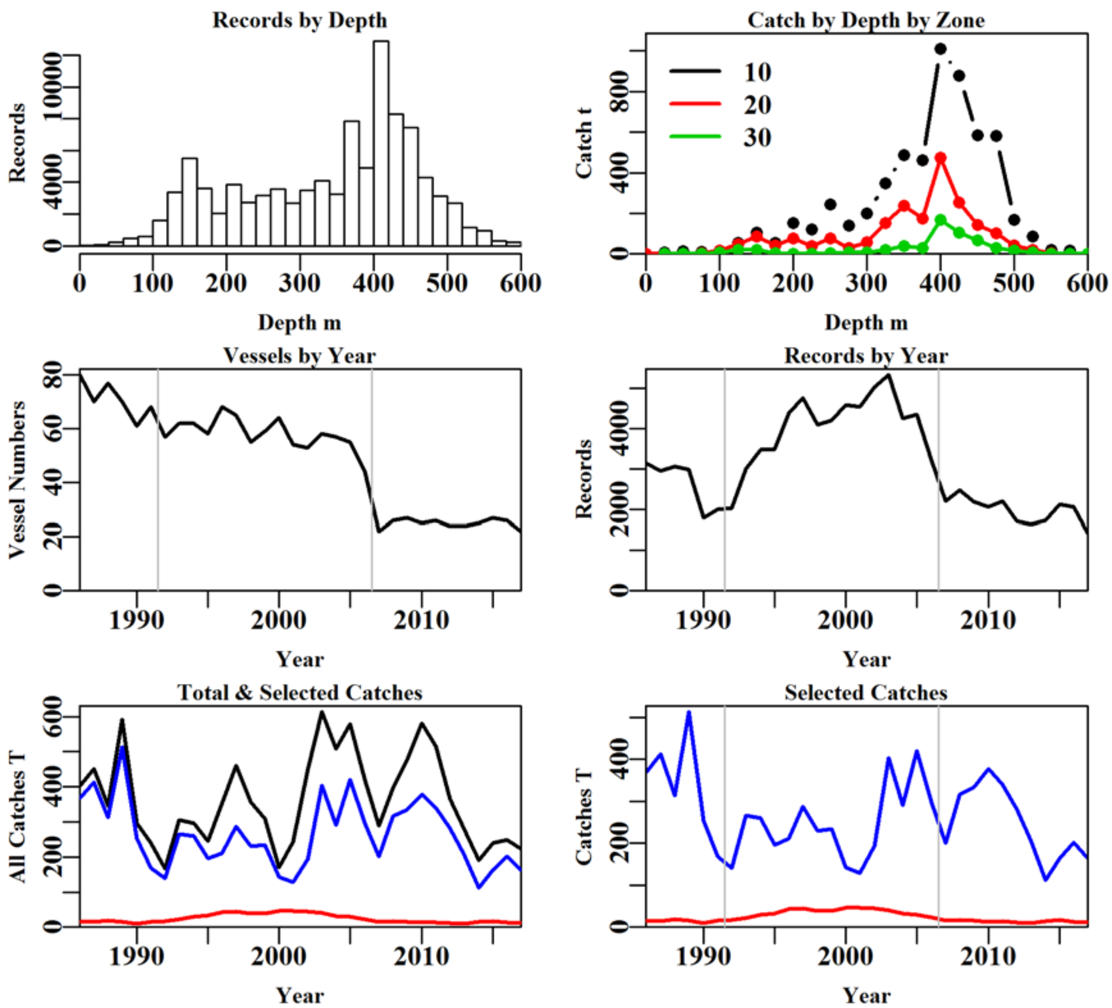


Figure 5.31. MirrorDory1030 fishery details. The bottom left plot depicts all known catches (top black line), and all selected catches used in the analysis (middle blue line); the lower red line: selected catches < 30 kg).

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	144349	141157	139201	138677	101092	98589	98540
Difference	0	3192	1956	524	37585	2503	49
Catch	11652.29	11524.6649	11353.4358	11314.312	8495.070	8433.18342	8430.6902
Difference	0.00	127.6204	171.2292	39.124	2819.241	61.88705	2.4932

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	72568	205664	19466	98540	32	8.6	0.00
Vessel	55450	172235	52895	98540	213	23.3	14.71
DepCat	44375	153851	71279	98540	237	31.5	8.17
Month	42322	150644	74486	98540	248	32.9	1.42
Zone	41423	149270	75860	98540	250	33.5	0.61
DayNight	40612	148037	77093	98540	253	34.1	0.55
Zone:Month	38885	145401	79729	98540	275	35.2	1.16
Zone:DepCat	40258	147366	77764	98540	300	34.3	0.27

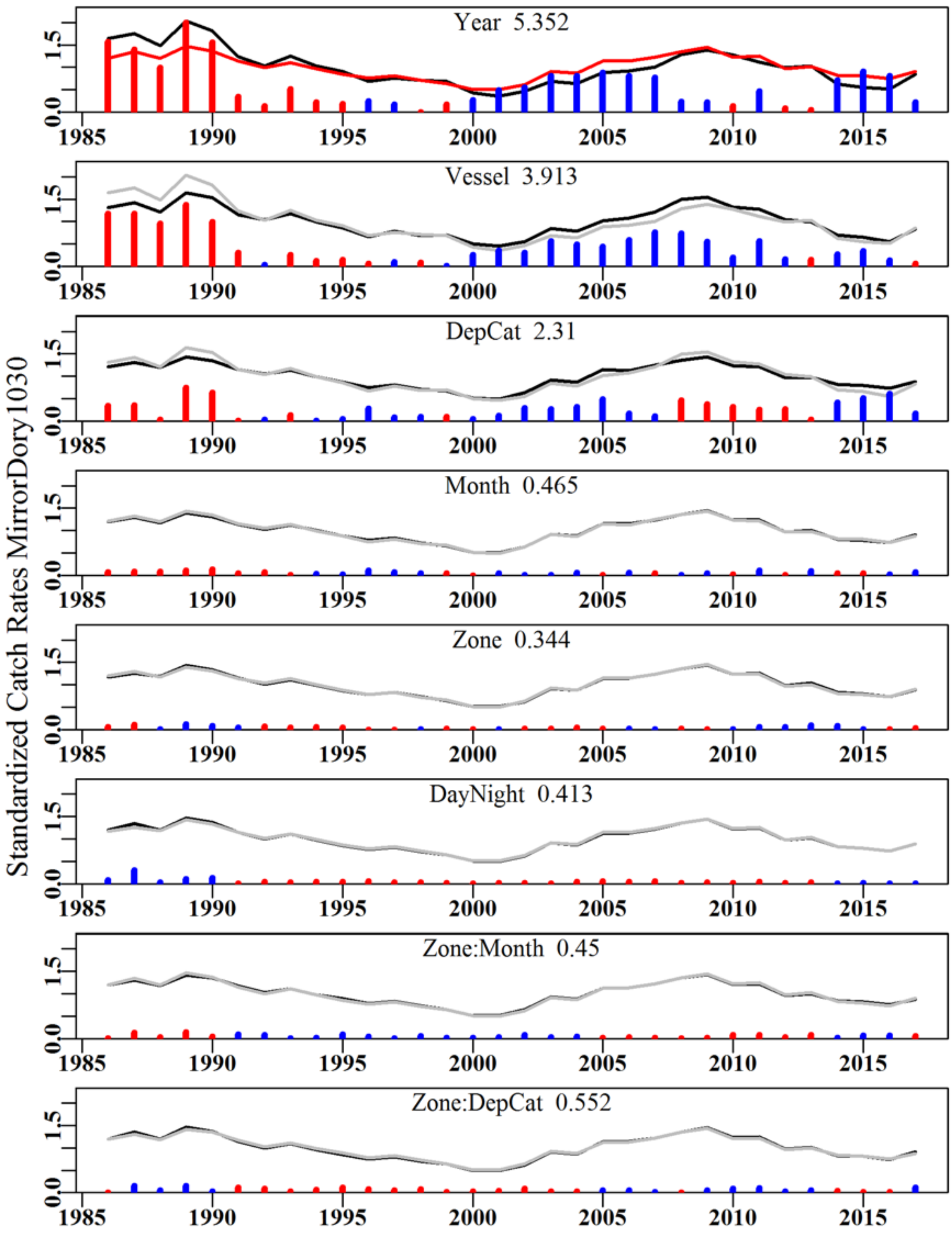


Figure 5.32. MirrorDory1030. The influence of each factor on the optimal standardization. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by vertical bars with blue bars indicating the optimum model is higher than the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

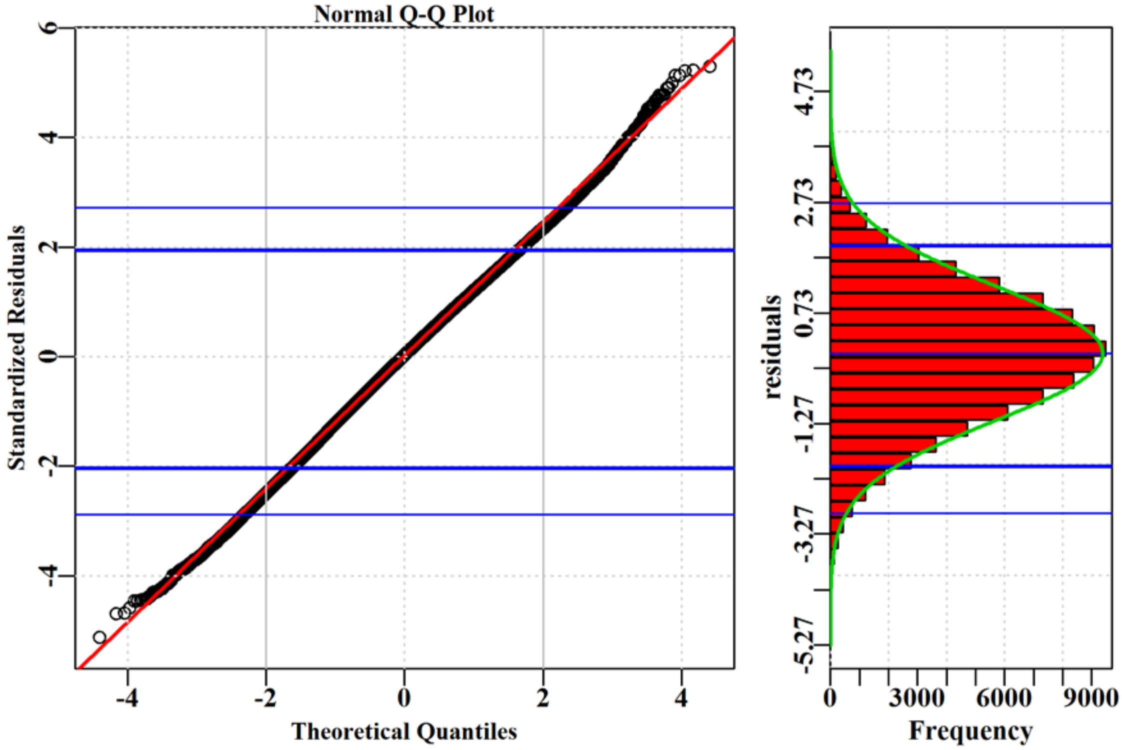


Figure 5.33. MirrorDory1030. diagnostic plots. The distribution of residuals from the optimum fit. The qqplot indicates the fit to the expected normality, while the histogram of residuals illustrates the 90% quantiles to indicate the intensity of any lack of fit at the margins of the distribution.

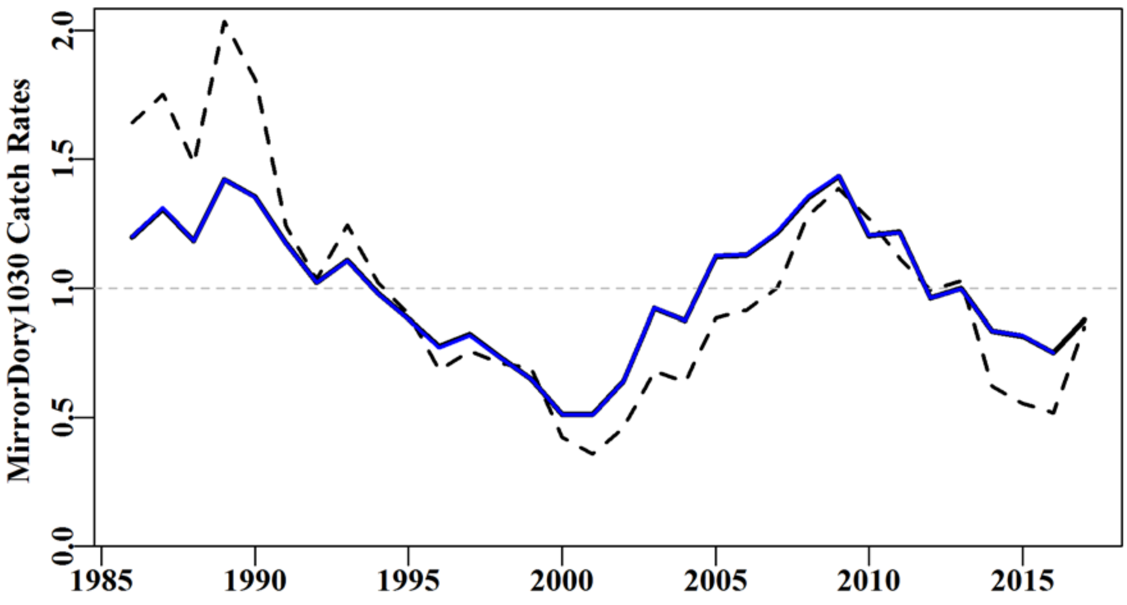


Figure 5.34. MirrorDory1030. A comparison of the previous year’s standardization (blue line) with this year’s. They should lie on top of each other, although small deviations may relate to data adjustments, particularly in very recent years.

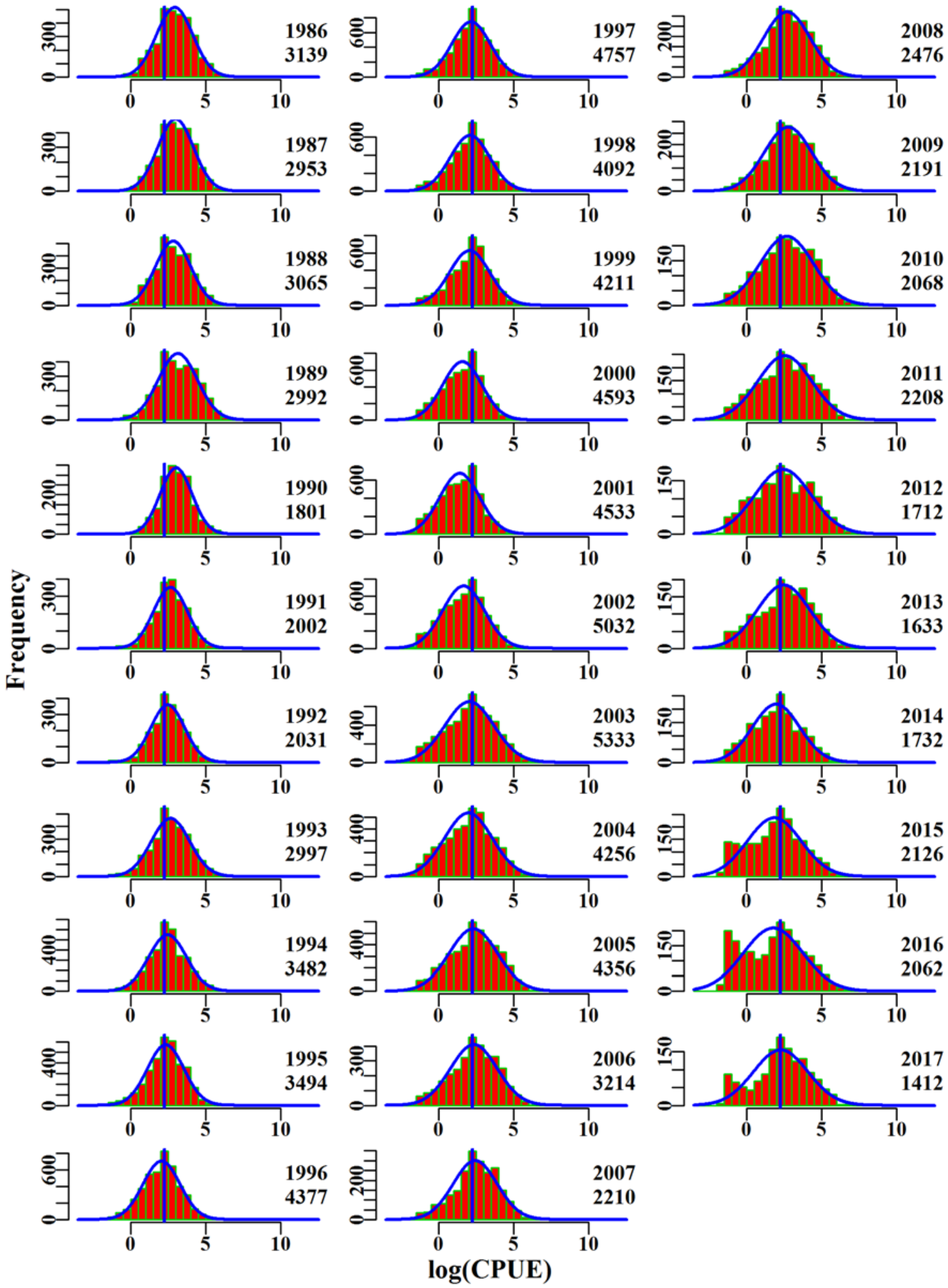


Figure 5.35. MirrorDory1030. The log(CPUE) for each year of data available the blue lines are normal distributions fitted to the histogram frequencies. The numbers in each plot are the year and number of records.

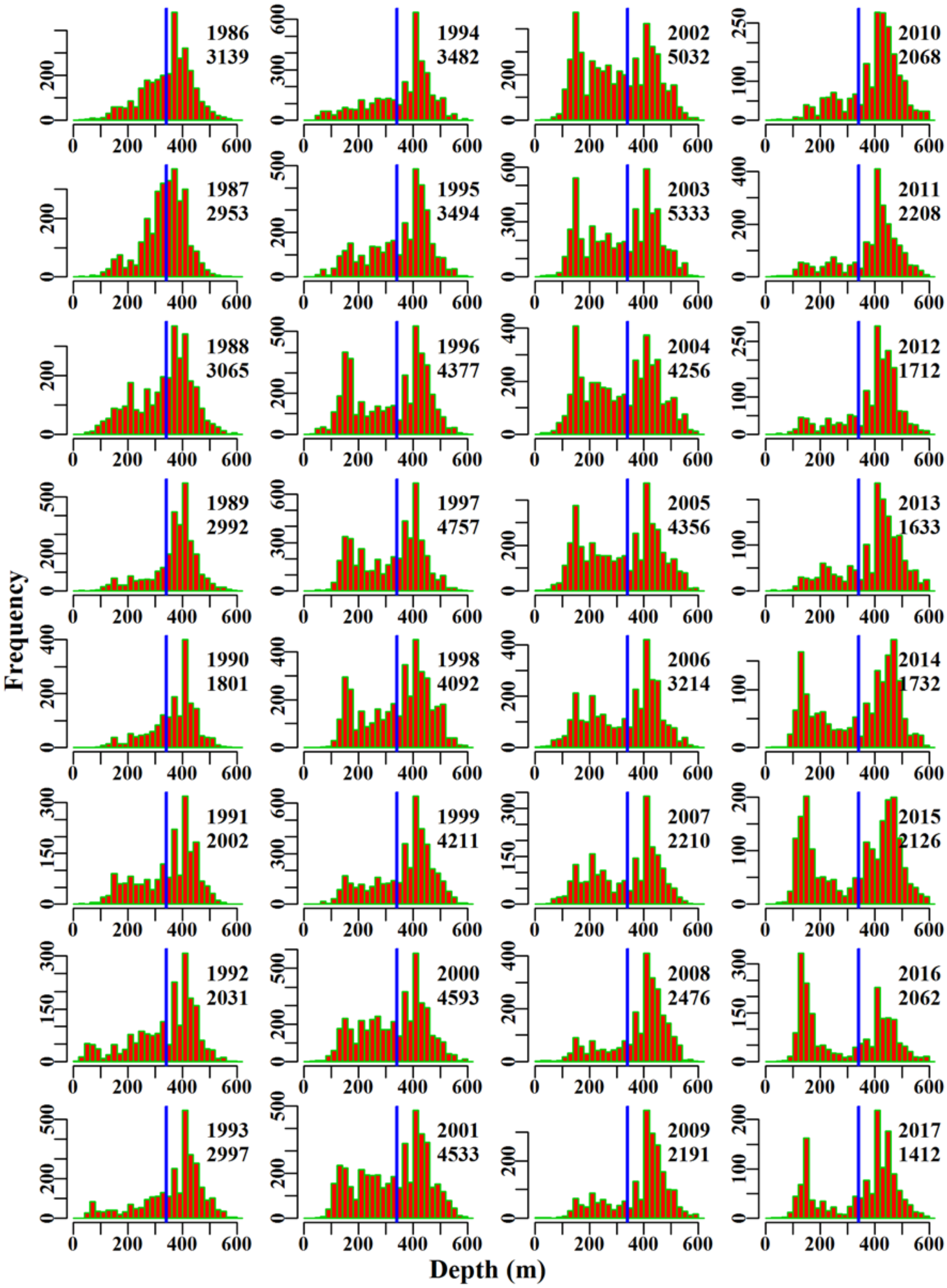


Figure 5.36. MirrorDory1030. The average Depth of fishing for each year of data available to illustrate the development of the fishery through time. The numbers in each plot are the year and number of records.

5.9 Mirror Dory 40 – 50

Trawl caught Mirror Dory (DOM – 37264003 – *Zenopsis nebulosus*) using methods TW, TDO, TMO, OTT, in zones 40, 50, and depths 0 to 600 within the SET fishery for the years 1986 - 2017 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 qqplot suggests that the assumed Normal distribution is valid with the deviations at the extremes 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 - 2017

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	2.5065	0.000	0.390	0.053
1987	450.8	142	15.5	23	36.1	1.6902	0.187	0.929	0.060
1988	346.0	122	15.0	17	37.2	1.3418	0.197	0.940	0.063
1989	591.6	71	11.1	15	45.3	1.6776	0.209	0.545	0.049
1990	295.8	95	10.0	14	37.9	1.1809	0.213	0.505	0.051
1991	240.3	208	12.8	17	17.8	0.8390	0.185	2.642	0.207
1992	167.0	206	8.3	20	14.6	0.6899	0.187	1.870	0.225
1993	306.2	277	18.1	18	16.8	0.8078	0.183	3.187	0.176
1994	297.3	330	18.2	20	14.8	0.7446	0.181	4.166	0.229
1995	244.9	704	37.9	23	15.4	0.9718	0.177	7.882	0.208
1996	352.7	1433	115.0	26	23.4	1.3141	0.177	12.869	0.112
1997	459.6	1903	148.2	24	24.5	1.3306	0.177	16.696	0.113
1998	355.8	1468	116.2	20	27.5	1.2597	0.177	12.717	0.109
1999	309.5	1316	63.2	23	17.0	0.8197	0.177	13.721	0.217
2000	171.1	975	22.4	30	7.9	0.4551	0.178	11.410	0.510
2001	243.4	2461	105.8	29	14.1	0.7886	0.176	28.871	0.273
2002	449.6	3151	240.2	28	24.8	1.1661	0.176	27.990	0.117
2003	613.9	2420	154.2	28	20.7	0.9702	0.176	20.527	0.133
2004	507.4	2201	159.4	25	20.3	0.9700	0.177	16.778	0.105
2005	579.9	1761	99.7	23	15.2	0.7665	0.177	15.640	0.157
2006	419.6	1053	64.8	19	15.7	0.6387	0.178	8.754	0.135
2007	289.6	1160	63.1	16	14.3	0.5728	0.178	11.733	0.186
2008	396.2	873	57.4	17	16.1	0.6743	0.178	8.632	0.150
2009	476.5	1331	123.0	14	20.0	1.0286	0.177	9.533	0.078
2010	580.0	1582	177.0	14	26.5	1.2548	0.177	9.483	0.054
2011	514.5	1648	157.3	16	21.8	0.9542	0.177	9.446	0.060
2012	365.5	993	69.6	15	16.9	0.5584	0.178	7.420	0.107
2013	279.9	635	54.4	15	20.8	0.7540	0.180	5.055	0.093
2014	190.0	832	67.3	14	19.6	0.8673	0.179	6.618	0.098
2015	240.4	944	70.6	13	17.4	0.8885	0.178	6.918	0.098
2016	249.4	622	41.4	13	16.5	0.6516	0.180	4.790	0.116
2017	224.3	700	57.7	11	16.0	0.8662	0.180	5.651	0.098

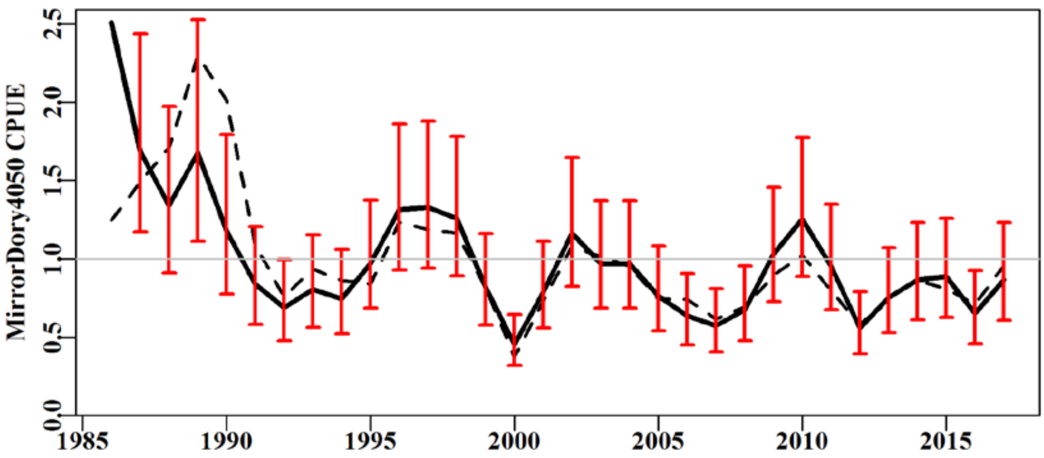


Figure 5.37. MirrorDory4050 standardization. The dashed black line represents the geometric mean catch rate, solid black line the standardized catch rates. The red bars are the 95% confidence intervals about the mean estimates. The graph scales both time-series of standardized catch rates relative to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

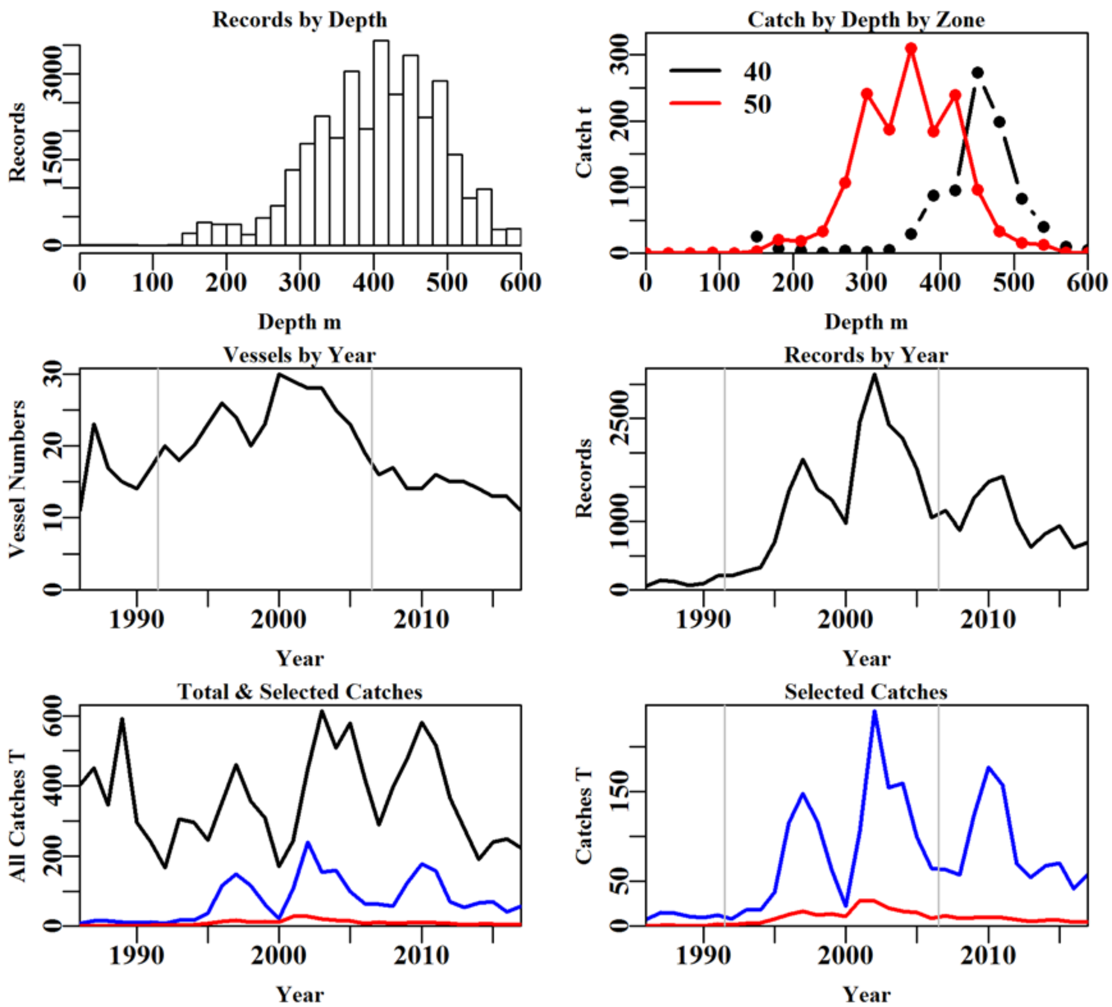


Figure 5.38. MirrorDory4050 fishery details. The bottom left plot depicts all known catches (top black line), and all selected catches used in the analysis (middle blue line); the lower red line: selected catches < 30 kg).

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	1443490	141157	139201	138677	33846	33731	33675
Difference	0	3192	1956	524	104831	115	56
Catch	11652.29	11524.6649	11353.4358	11314.312	2390.709	2386.2085	2382.169
Difference	0.00	127.6204	171.2292	39.124	8923.603	4.5007	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	11366	47105	2260	33675	32	4.49	0.000
Vessel	4796	38542	10823	33675	125	21.64	17.145
Month	3259	36798	12566	33675	136	25.16	3.521
DepCat	1436	34818	14547	33675	156	29.14	3.986
DayNight	290	33647	15718	33675	159	31.52	2.377
Zone	-98	33259	16105	33675	160	32.31	0.787
Zone:Month	-488	32855	16510	33675	171	33.11	0.802
Zone:DepCat	-154	33165	16200	33675	180	32.46	0.153

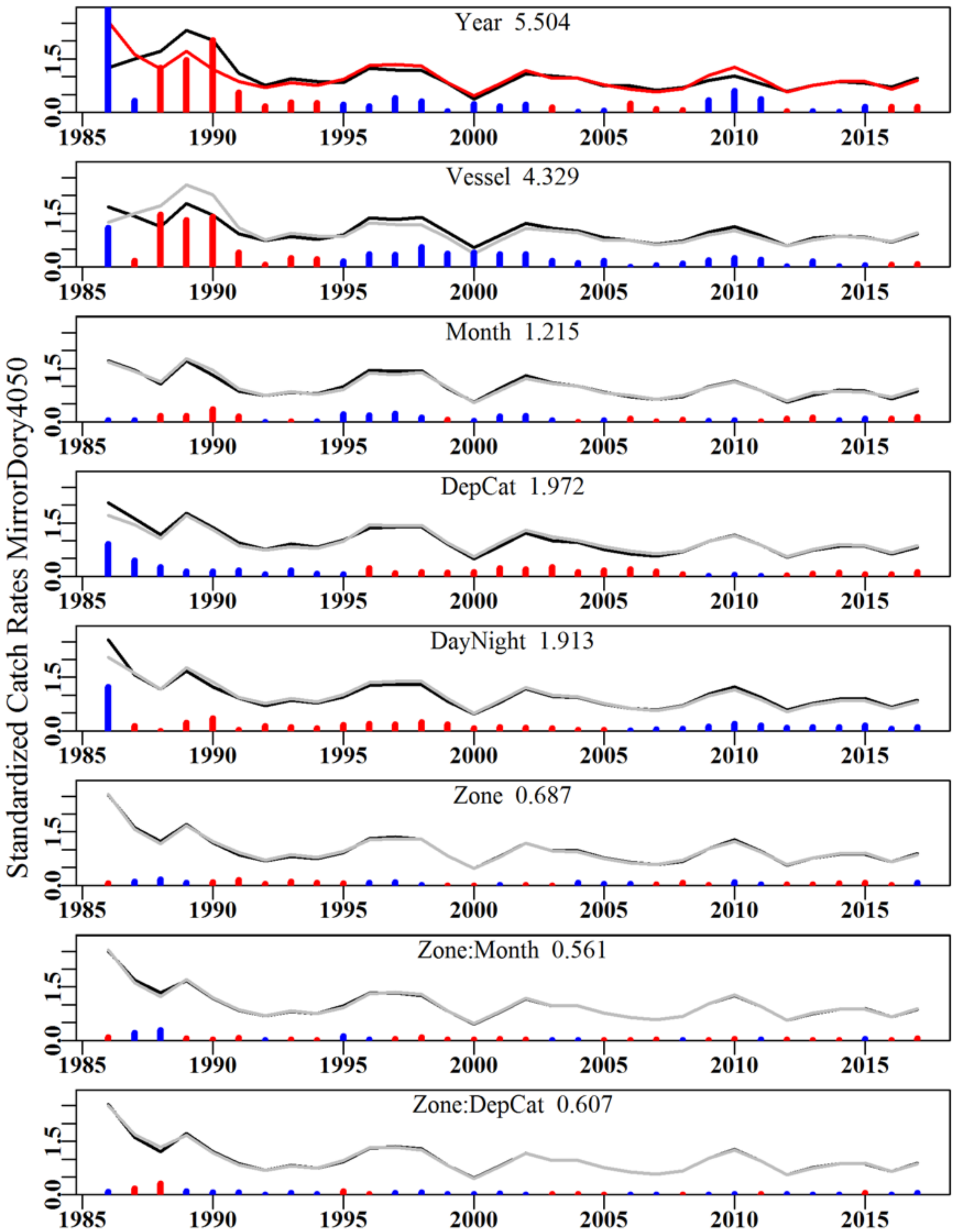


Figure 5.39. MirrorDory4050. The influence of each factor on the optimal standardization. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by vertical bars with blue bars indicating the optimum model is higher than the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

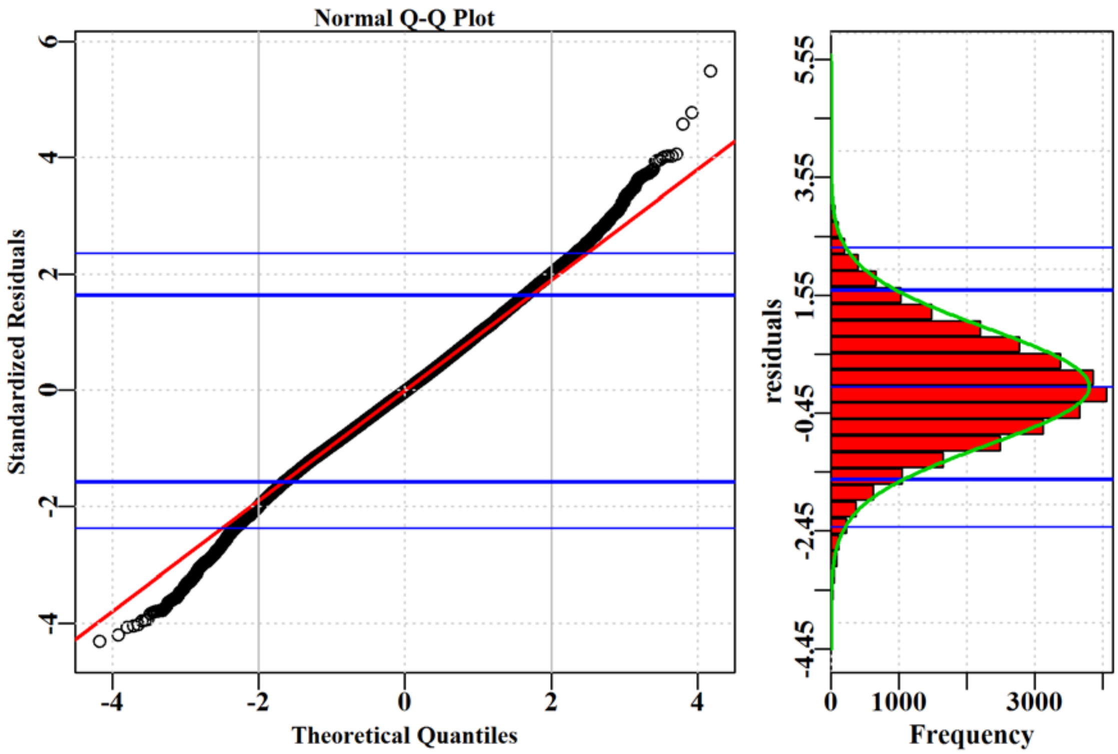


Figure 5.40. MirrorDory4050. diagnostic plots. The distribution of residuals from the optimum fit. The qqplot indicates the fit to the expected normality, while the histogram of residuals illustrates the 90% quantiles to indicate the intensity of any lack of fit at the margins of the distribution.

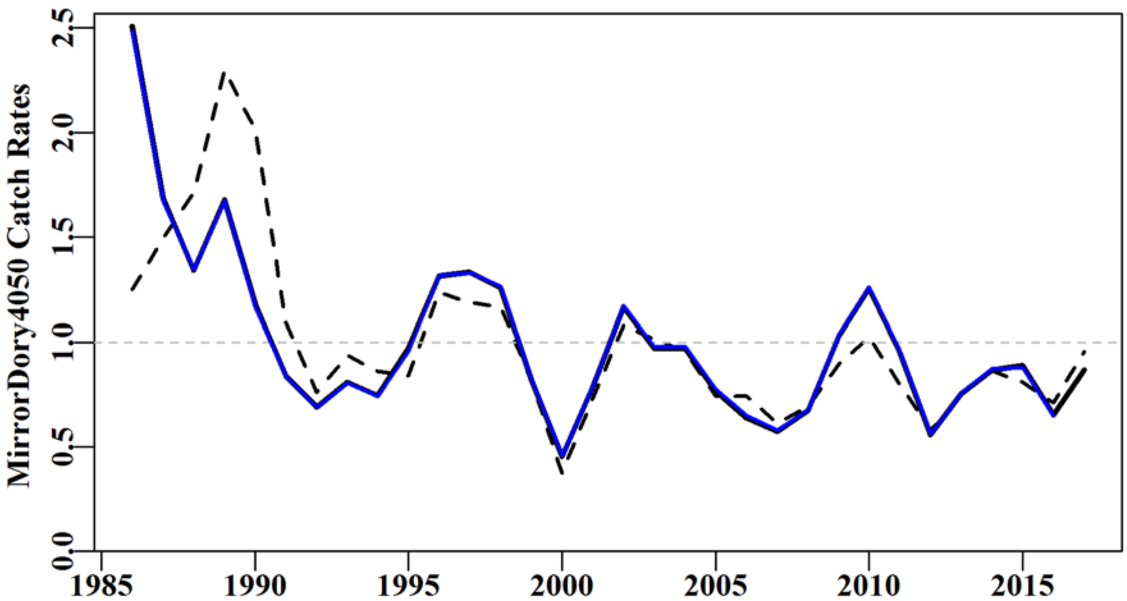


Figure 5.41. MirrorDory4050. A comparison of the previous year's standardization (blue line) with this year's. They should lie on top of each other, although small deviations may relate to data adjustments, particularly in very recent years.

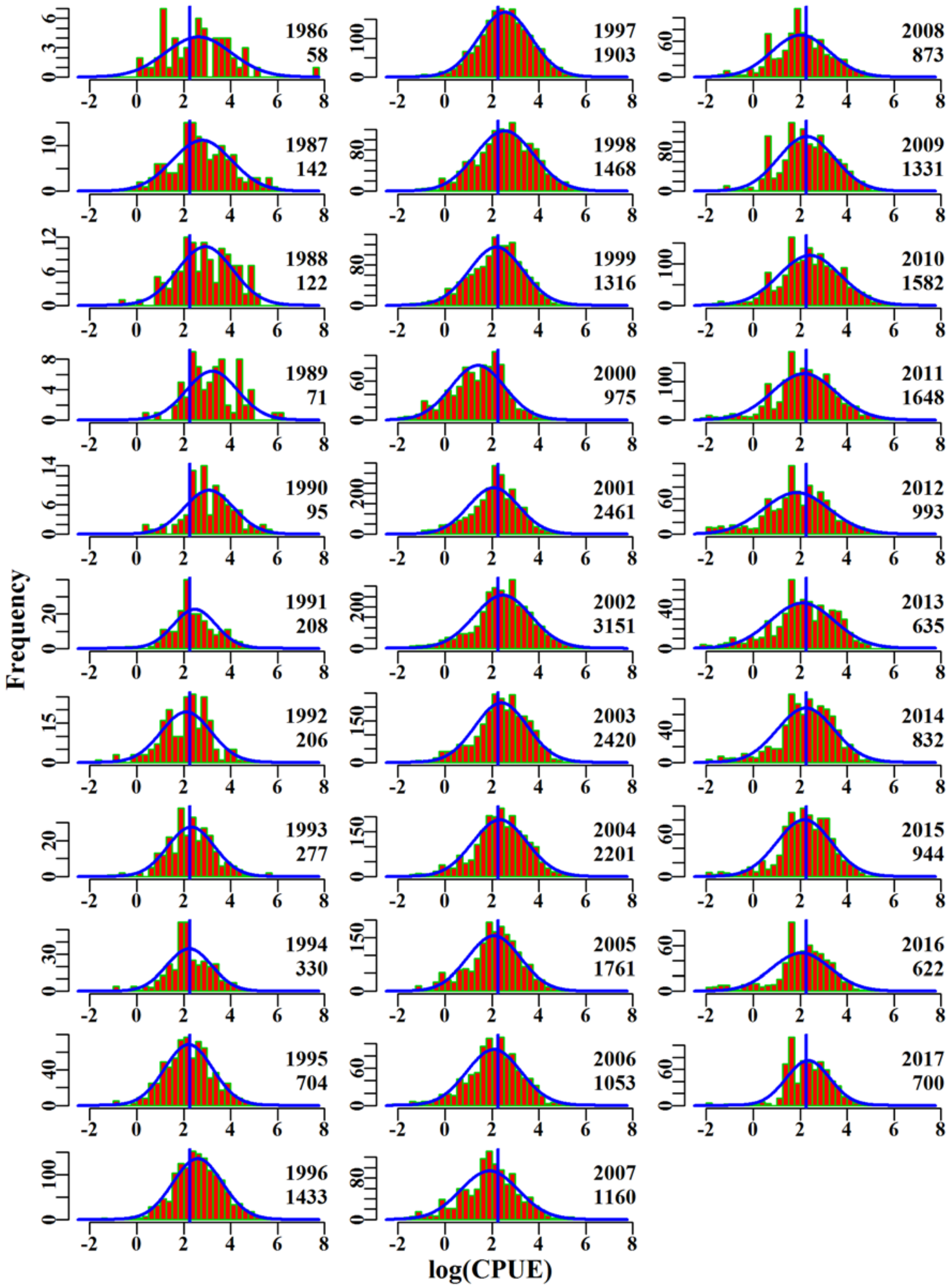


Figure 5.42. MirrorDory4050. The log(CPUE) for each year of data available the blue lines are normal distributions fitted to the histogram frequencies. The numbers in each plot are the year and number of records.

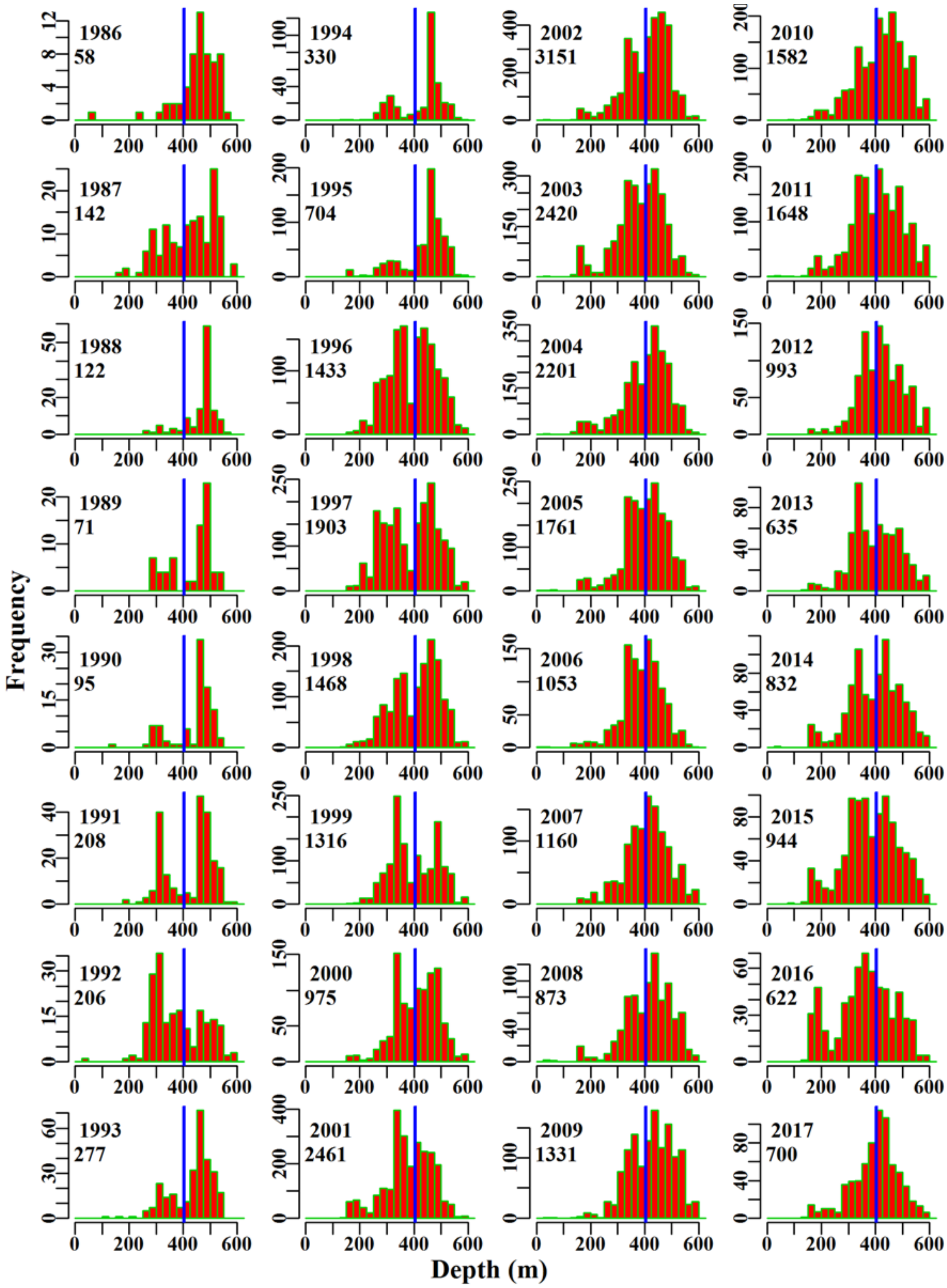


Figure 5.43. MirrorDory4050. The average Depth of fishing for each year of data available to illustrate the development of the fishery through time. The numbers in each plot are the year and number of records.

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 - 2017 (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 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 - 2017

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	1.8902	0.000	0.255	0.009
1987	1087.7	205	57.0	13	104.4	2.0775	0.180	0.695	0.012
1988	1483.5	282	207.7	13	272.2	2.8482	0.178	0.684	0.003
1989	1667.4	687	475.0	19	231.9	3.5918	0.170	0.775	0.002
1990	1001.4	379	140.2	26	146.8	2.6112	0.171	0.901	0.006
1991	1138.1	408	184.4	29	154.7	1.7417	0.169	1.060	0.006
1992	758.3	333	106.7	18	109.0	1.9095	0.174	1.050	0.010
1993	1015.0	1031	322.3	27	104.7	1.5305	0.164	2.433	0.008
1994	818.4	759	179.1	22	71.2	1.0539	0.165	2.130	0.012
1995	789.5	821	183.7	19	68.6	1.0402	0.166	4.244	0.023
1996	827.2	888	161.3	19	54.5	1.0014	0.165	5.219	0.032
1997	1063.4	938	202.3	15	71.6	1.1044	0.165	3.422	0.017
1998	876.4	768	190.7	15	74.4	1.0785	0.165	2.123	0.011
1999	961.5	854	246.9	17	91.6	1.2768	0.166	2.310	0.009
2000	945.2	548	123.4	23	66.5	0.8077	0.168	2.126	0.017
2001	790.2	807	110.3	19	43.2	0.5222	0.164	5.349	0.049
2002	811.2	1039	108.3	15	34.7	0.4385	0.163	6.333	0.058
2003	774.6	1121	186.2	19	59.8	0.5798	0.163	5.933	0.032
2004	765.5	1494	200.8	15	41.6	0.4317	0.162	8.776	0.044
2005	784.2	1136	135.6	17	35.0	0.3243	0.163	7.263	0.054
2006	811.3	1112	152.8	14	40.5	0.4021	0.164	5.253	0.034
2007	607.9	705	110.6	8	49.8	0.5635	0.166	2.355	0.021
2008	700.4	752	117.2	9	51.2	0.5693	0.166	2.573	0.022
2009	454.4	456	53.4	10	37.8	0.3994	0.170	1.849	0.035
2010	380.0	340	54.9	9	48.8	0.4393	0.173	1.468	0.027
2011	428.0	444	47.4	8	34.6	0.2951	0.170	2.027	0.043
2012	395.6	518	88.8	8	56.1	0.3915	0.169	1.761	0.020
2013	323.9	595	102.9	10	57.8	0.4300	0.168	2.670	0.026
2014	216.6	361	53.4	9	38.6	0.2153	0.172	2.282	0.043
2015	152.5	455	30.4	11	18.5	0.1370	0.170	3.163	0.104
2016	183.4	770	48.3	10	19.5	0.1393	0.166	5.948	0.123
2017	246.2	611	37.9	9	21.3	0.1579	0.168	4.605	0.121

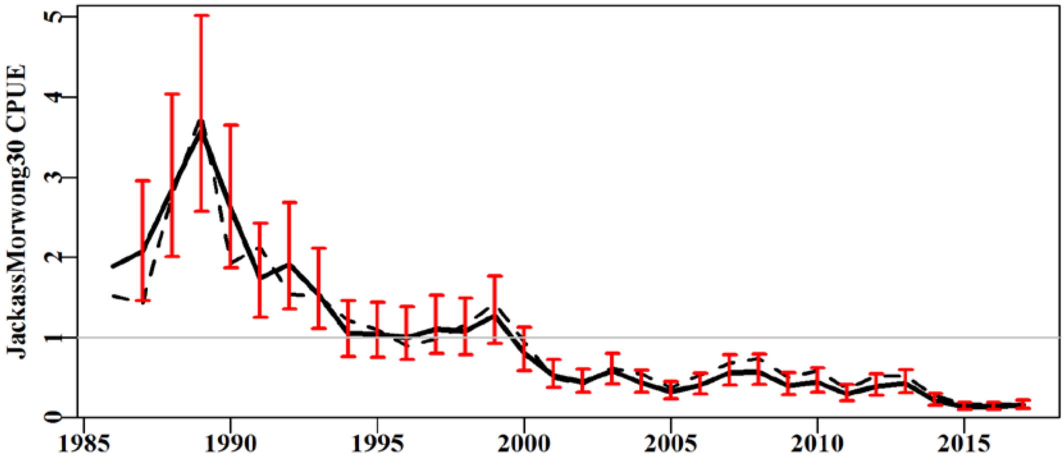


Figure 5.44. JackassMorwong30 standardization. The dashed black line represents the geometric mean catch rate, solid black line the standardized catch rates. The red bars are the 95% confidence intervals about the mean estimates. The graph scales both time-series of standardized catch rates relative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

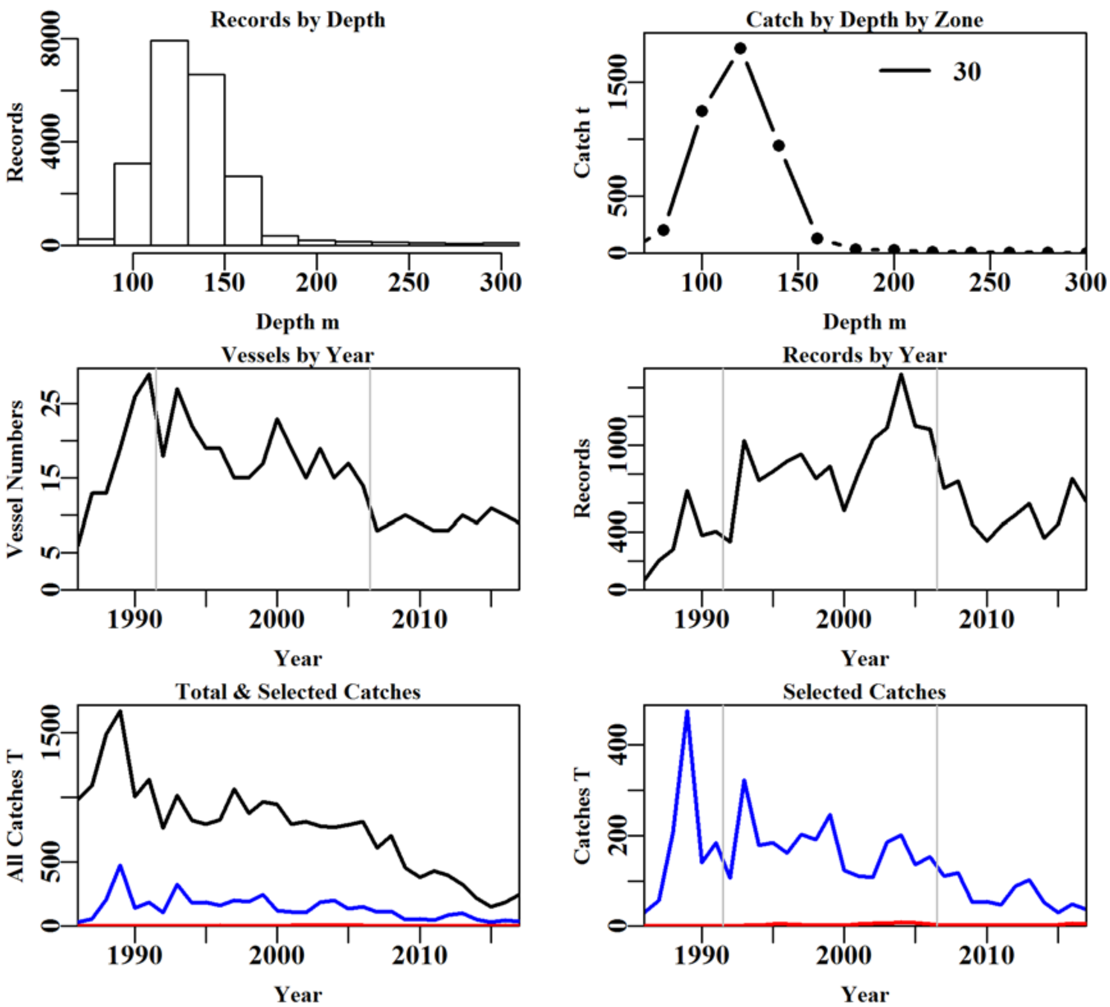


Figure 5.45. JackassMorwong30 fishery details. The bottom left plot depicts all known catches (top black line), and all selected catches used in the analysis (middle blue line); the lower red line: selected catches < 30 kg).

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	255396	235337	207303	203453	22040	21688	21685
Difference	0	20059	28034	3850	181413	352	3
Catch	24969.53	24029.4847	22573.648	21964.491	4512.896	4449.9609	4449.571
Difference	0.00	940.0466	1455.837	609.157	17451.595	62.9346	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	12365	38240	10918	21685	32	22.1	0.00
Month	10514	35075	14082	21685	43	28.5	6.41
Vessel	9132	32622	16535	21685	138	33.2	4.71
DepCat	8547	31719	17439	21685	150	35.0	1.81
DayNight	8239	31264	17894	21685	153	36.0	0.92
Zone:Month	8239	31264	17894	21685	153	36.0	0.00
Zone:DepCat	8239	31264	17894	21685	153	36.0	0.00

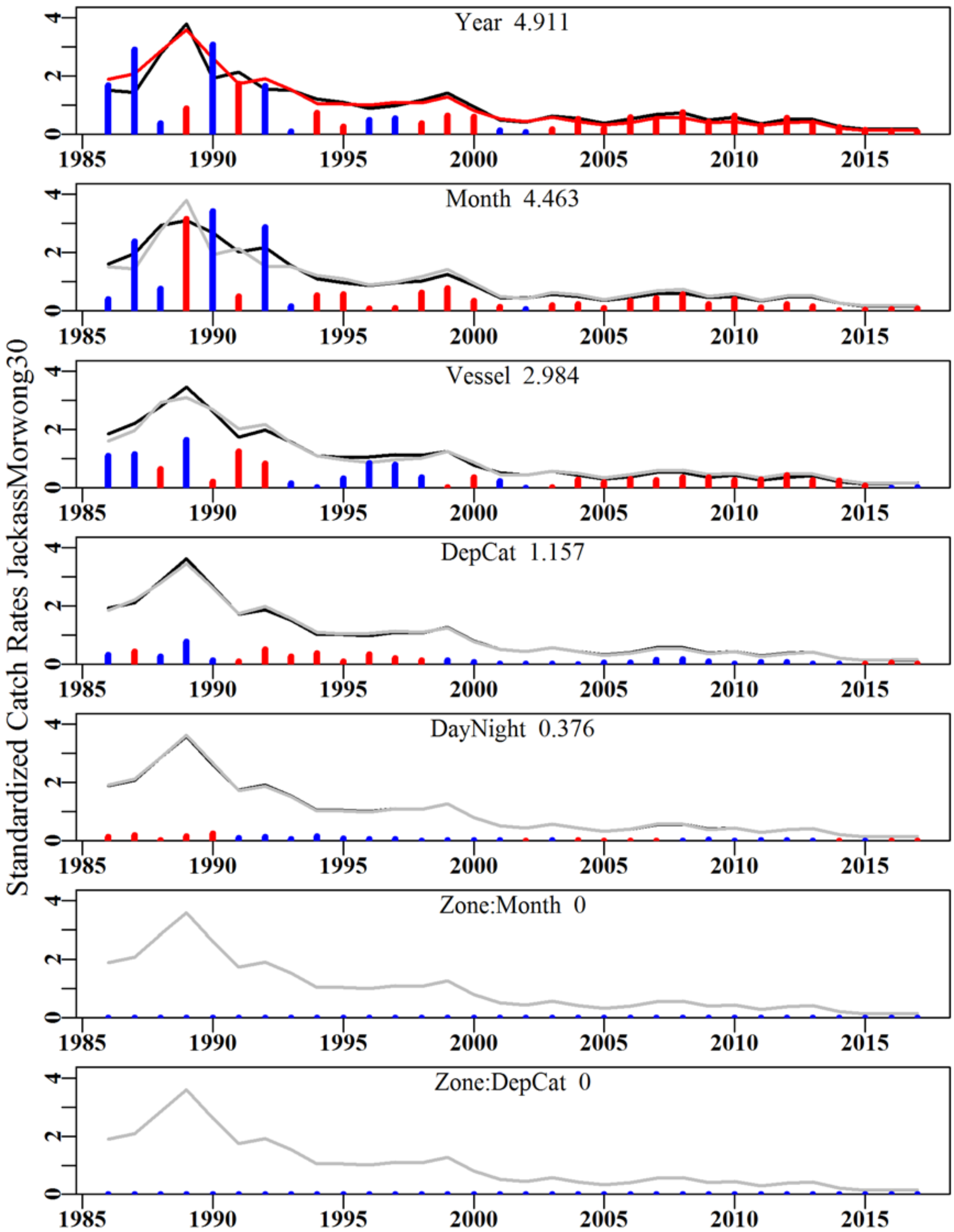


Figure 5.46. JackassMorwong30. The influence of each factor on the optimal standardization. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by vertical bars with blue bars indicating the optimum model is higher than the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

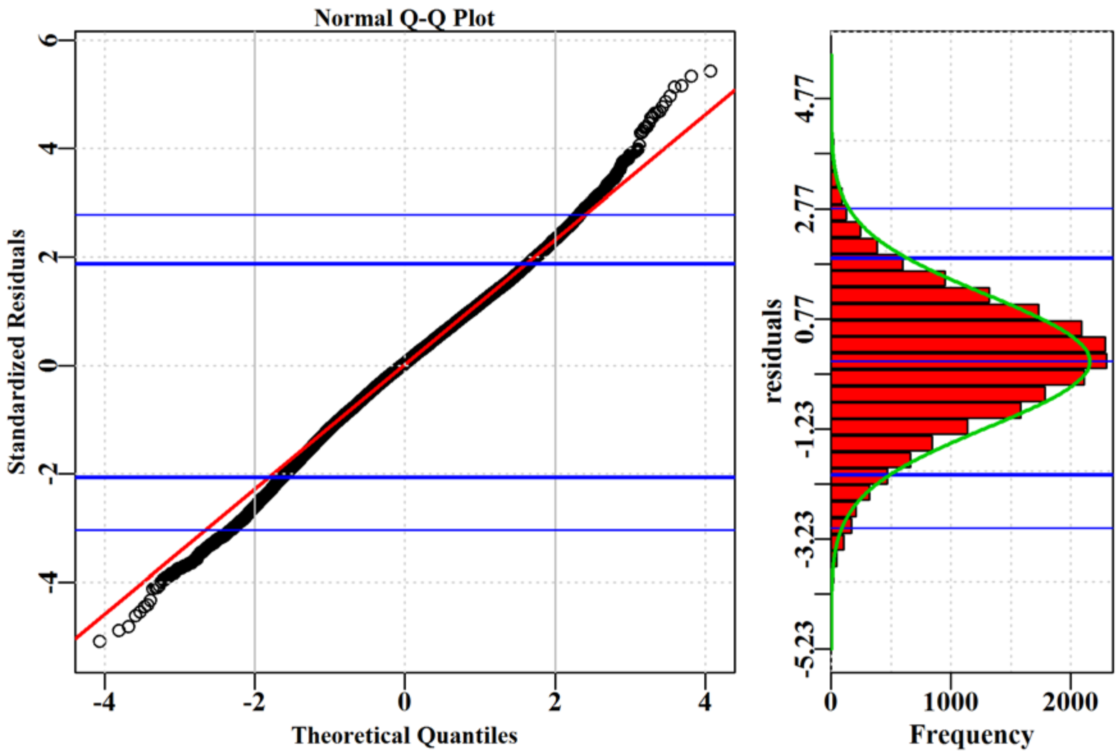


Figure 5.47. JackassMorwong30 diagnostic plots. The distribution of residuals from the optimum fit. The qqplot indicates the fit to the expected normality, while the histogram of residuals illustrates the 90% quantiles to indicate the intensity of any lack of fit at the margins of the distribution.

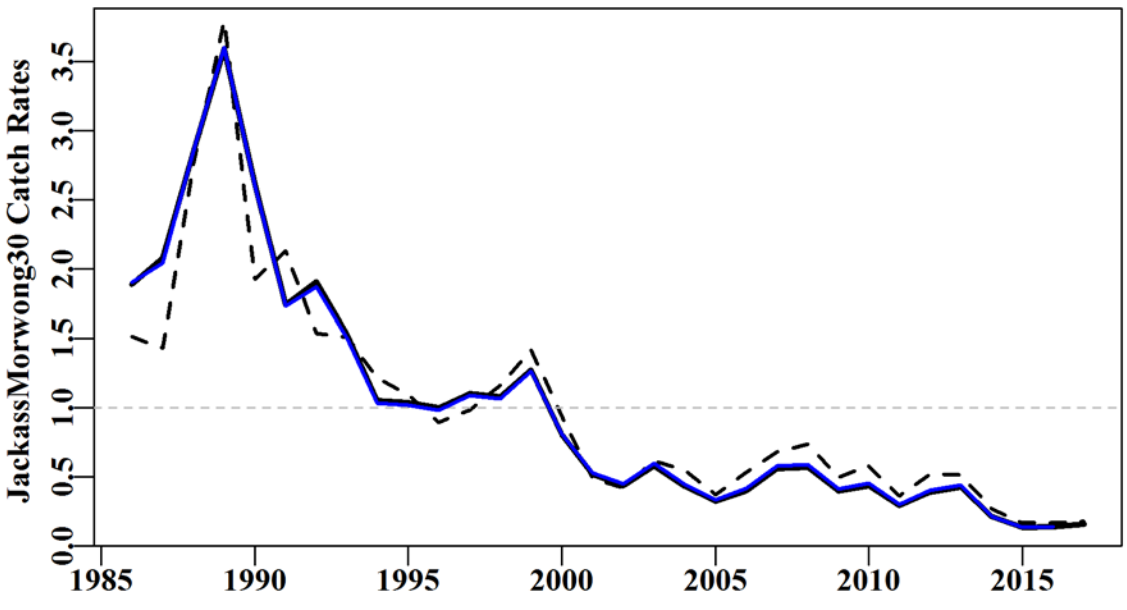


Figure 5.48. JackassMorwong30. A comparison of the previous year's standardization (blue line) with this year's. They should lie on top of each other, although small deviations may relate to data adjustments, particularly in very recent years.

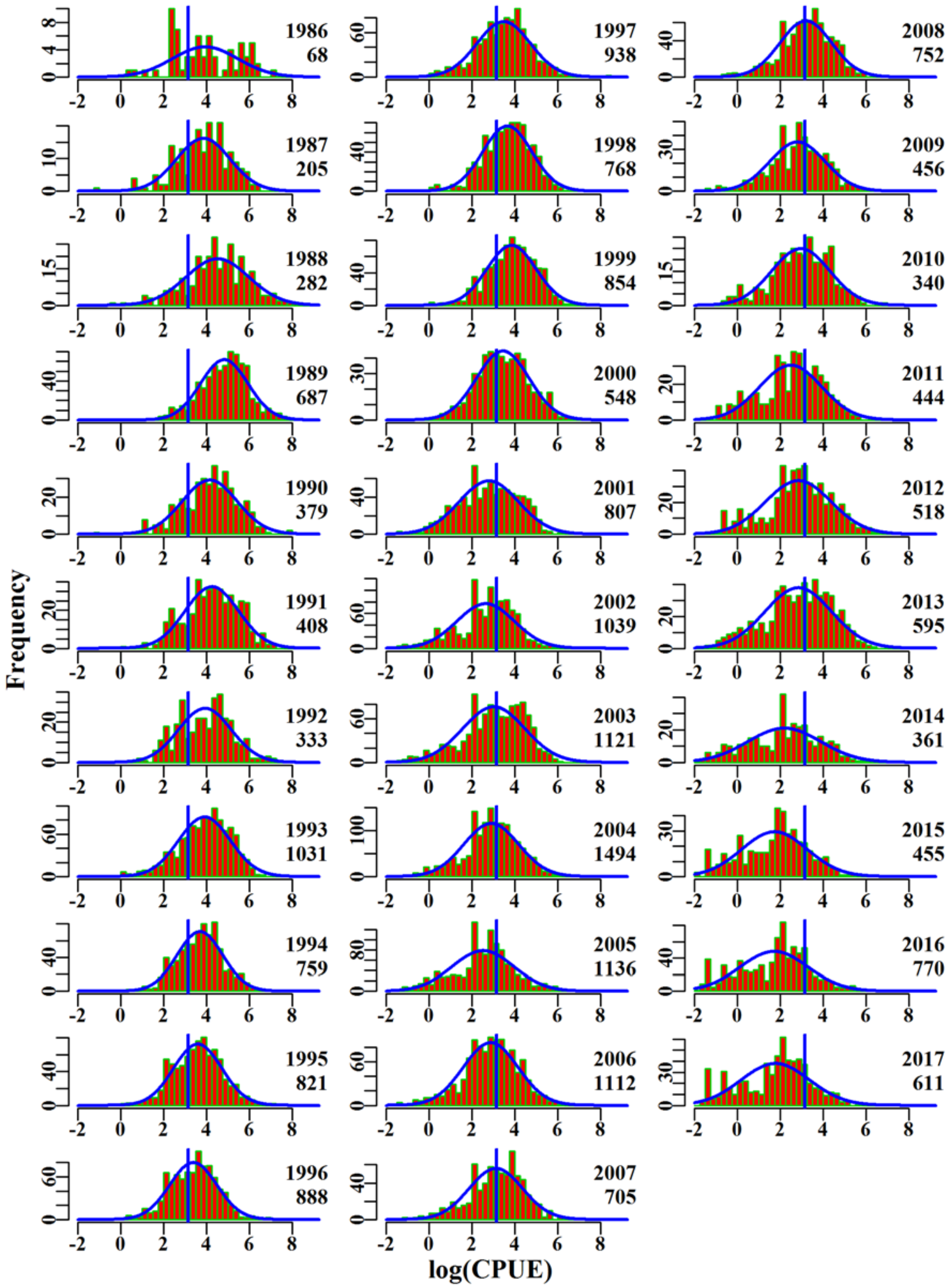


Figure 5.49. JackassMorwong30. The log(CPUE) for each year of data available the blue lines are normal distributions fitted to the histogram frequencies. The numbers in each plot are the year and number of records.

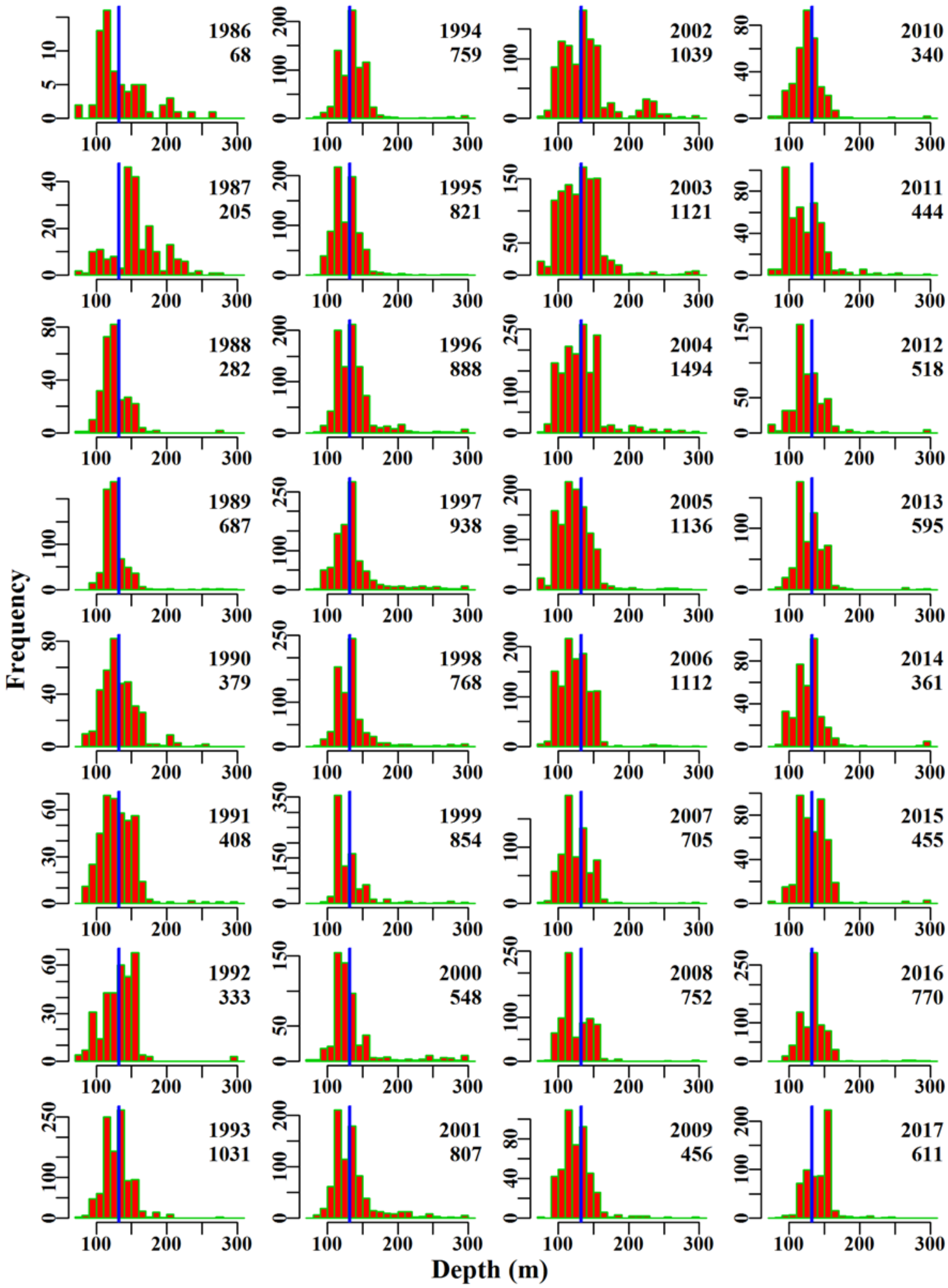


Figure 5.50. JackassMorwong30. The average Depth of fishing for each year of data available to illustrate the development of the fishery through time. The numbers in each plot are the year and number of records.

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 - 2017 (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, log(CPUE) has also changed in character from 2014 - 2017, 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 - 2017

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	2.0373	0.000	28.043	0.041
1987	1087.7	4231	851.6	79	69.6	2.4709	0.029	20.466	0.024
1988	1483.5	5127	1020.0	79	65.0	2.3206	0.029	25.887	0.025
1989	1667.4	4305	924.2	65	72.2	2.1983	0.030	19.307	0.021
1990	1001.4	4090	593.5	59	49.2	1.8530	0.031	21.795	0.037
1991	1138.1	4391	650.0	55	54.2	1.7046	0.031	26.145	0.040
1992	758.3	2825	377.3	47	48.7	1.3649	0.034	17.311	0.046
1993	1015.0	3320	461.7	49	45.5	1.4543	0.033	21.593	0.047
1994	818.4	4418	469.0	49	38.6	1.2678	0.031	29.317	0.063
1995	789.5	4575	433.7	47	31.6	1.1627	0.031	33.286	0.077
1996	827.2	6181	541.8	50	29.0	1.0534	0.029	45.827	0.085
1997	1063.4	5994	669.8	52	38.6	1.1677	0.030	38.284	0.057
1998	876.4	4772	435.1	46	32.0	0.9411	0.031	36.545	0.084
1999	961.5	4408	446.6	50	36.3	0.9458	0.032	31.401	0.070
2000	945.2	5615	477.9	55	29.5	0.8076	0.030	40.940	0.086
2001	790.2	4793	251.5	46	18.5	0.5531	0.031	36.983	0.147
2002	811.2	5700	328.2	44	20.4	0.6194	0.030	45.985	0.140
2003	774.6	4555	236.4	47	17.6	0.4940	0.031	35.723	0.151
2004	765.5	4178	219.7	52	17.2	0.4877	0.032	31.301	0.142
2005	784.2	4320	258.8	39	19.4	0.5943	0.032	35.033	0.135
2006	811.3	3388	273.8	36	25.2	0.7225	0.034	27.137	0.099
2007	607.9	2412	211.2	20	31.6	0.6997	0.037	17.177	0.081
2008	700.4	3105	313.1	25	30.5	0.8883	0.035	23.468	0.075
2009	454.4	2400	223.7	19	28.2	0.8087	0.037	18.584	0.083
2010	380.0	2478	184.9	19	24.5	0.5513	0.037	19.898	0.108
2011	428.0	2291	161.6	18	24.2	0.5436	0.038	17.187	0.106
2012	395.6	2111	169.7	19	27.9	0.5349	0.039	14.445	0.085
2013	323.9	1394	96.6	15	25.0	0.4424	0.044	10.082	0.104
2014	216.6	1515	76.2	17	17.2	0.3316	0.042	11.597	0.152
2015	152.5	1094	42.3	20	14.3	0.2741	0.047	8.727	0.206
2016	183.4	1127	70.5	15	24.8	0.3205	0.048	7.591	0.108
2017	246.2	1220	72.4	15	23.6	0.3841	0.047	8.940	0.123

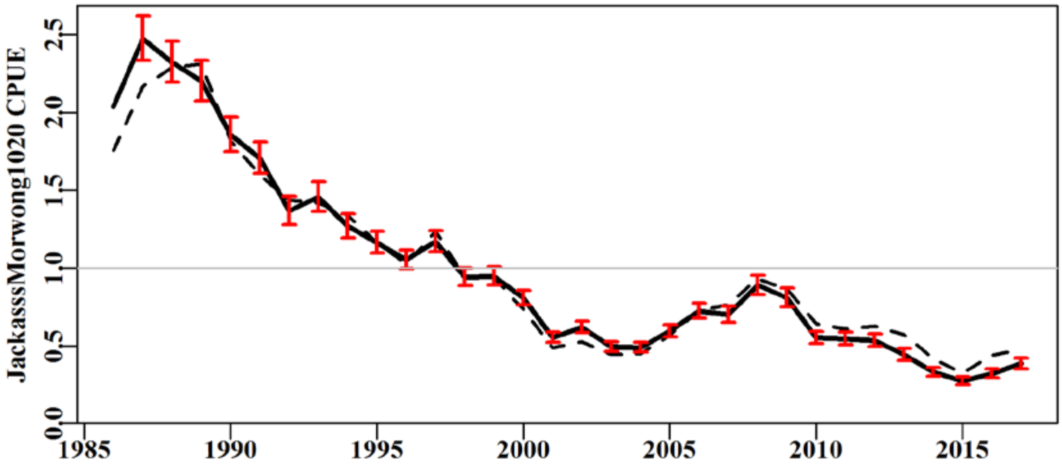


Figure 5.51. JackasssMorwong1020 standardization. The dashed black line represents the geometric mean catch rate, solid black line the standardized catch rates. The red bars are the 95% confidence intervals about the mean estimates. The graph scales both time-series of standardized catch rates relative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

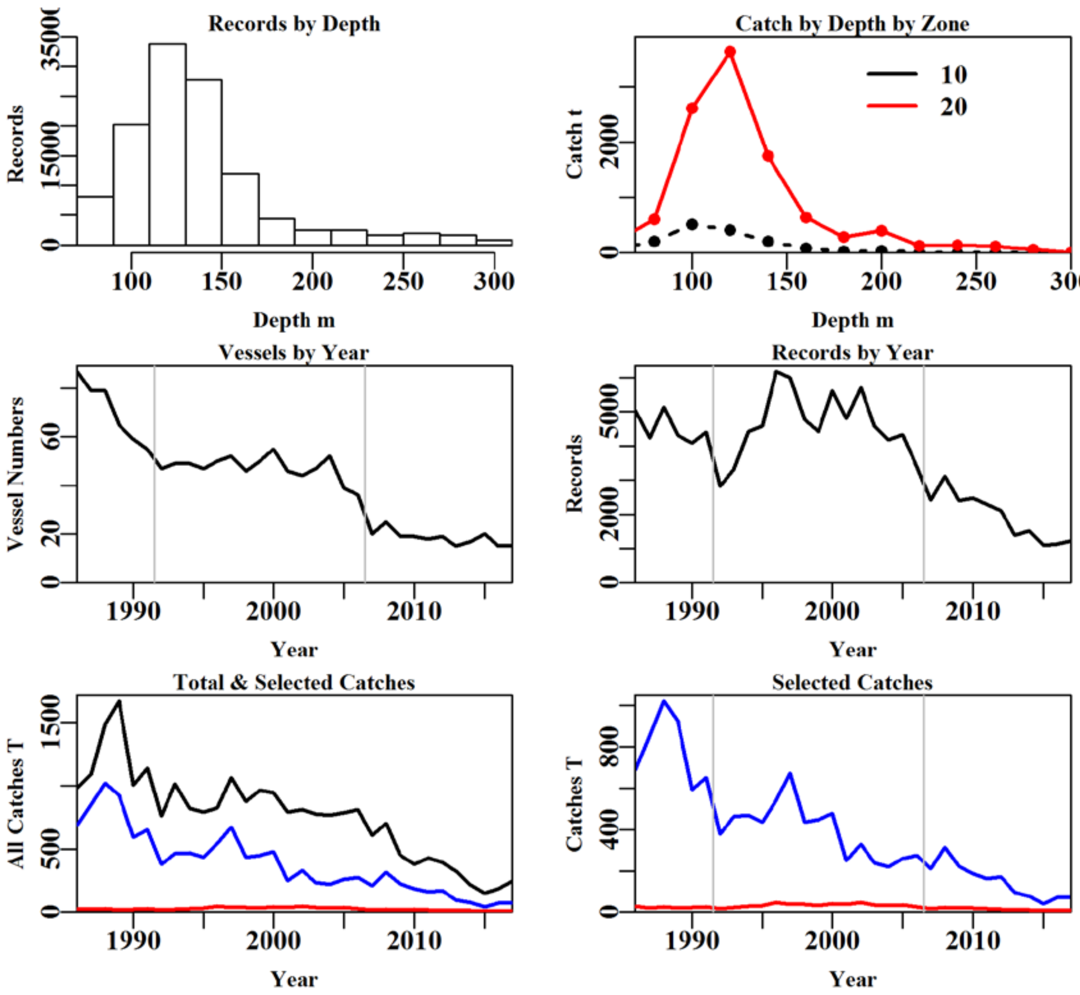


Figure 5.52. JackasssMorwong1020 fishery details. The bottom left plot depicts all known catches (top black line), and all selected catches used in the analysis (middle blue line); the lower red line: selected catches < 30 kg).

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	2553960	235337	207303	203453	132777	117470	117374
Difference	0	20059	28034	3850	70676	15307	96
Catch	24969.53	24029.4847	22573.648	21964.491	12720.335	12236.734	12228.680
Difference	0.00	940.0466	1455.837	609.157	9244.156	483.601	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	85922	243923	33369	117374	32	12.0	0.00
Vessel	71886	215773	61519	117374	211	22.0	10.04
Month	68791	210118	67175	117374	222	24.1	2.04
Zone	66495	206044	71248	117374	223	25.6	1.47
DepCat	65167	203684	73609	117374	235	26.4	0.85
DayNight	63694	201134	76158	117374	238	27.3	0.92
Zone:Month	62757	199497	77795	117374	249	27.9	0.58
Zone:DepCat	63389	200571	76721	117374	250	27.5	0.20

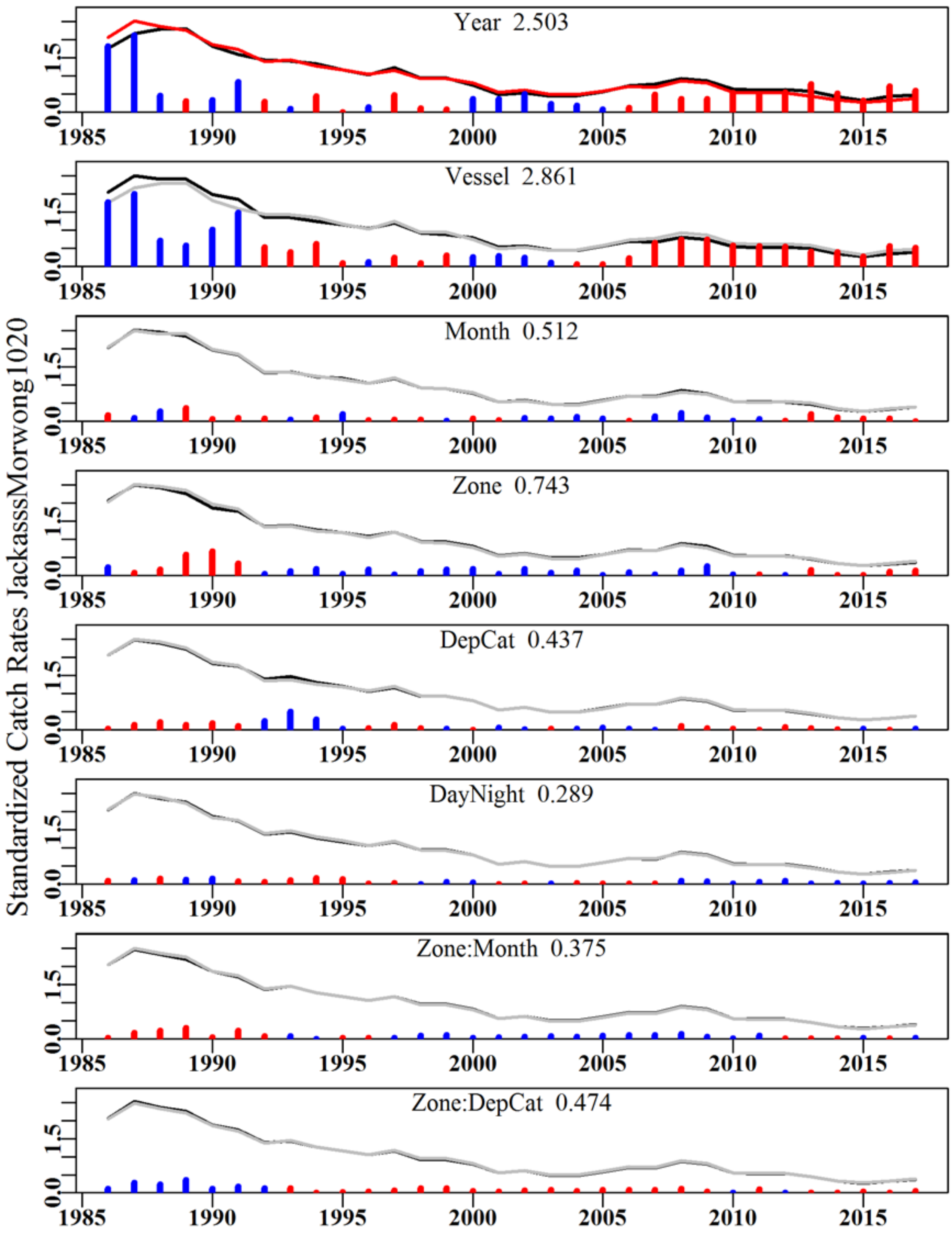


Figure 5.53. JackasssMorwong1020. The influence of each factor on the optimal standardization. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by vertical bars with blue bars indicating the optimum model is higher than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

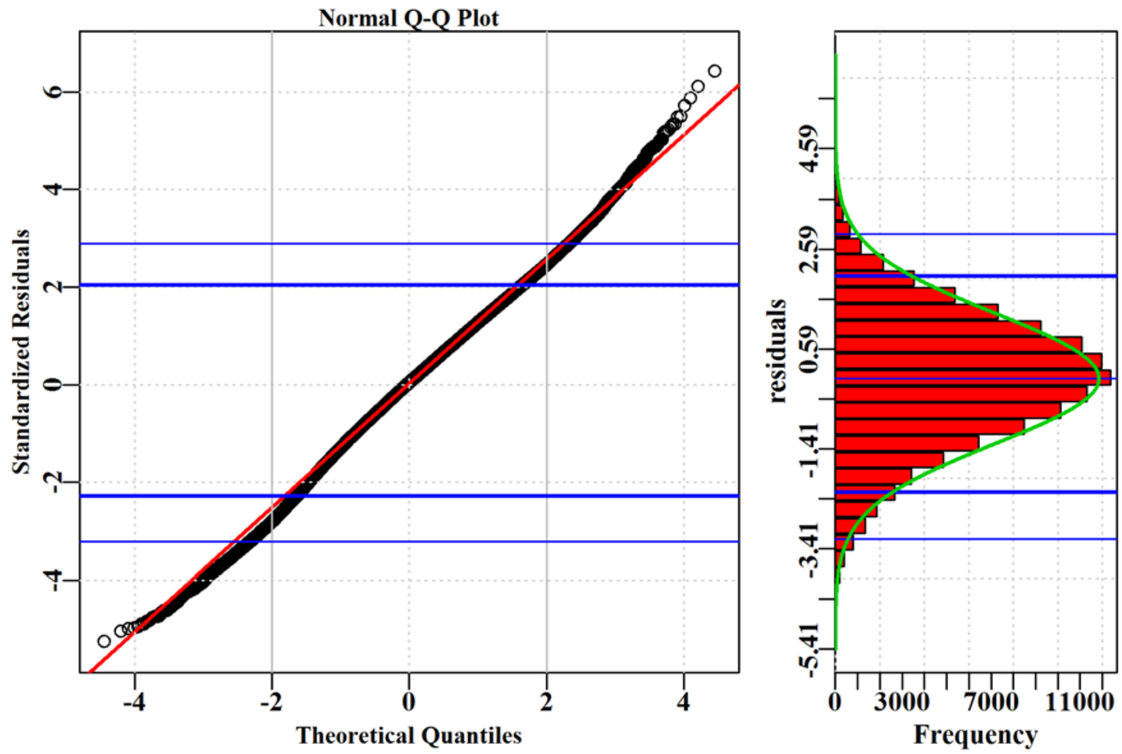


Figure 5.54. JackasssMorwong1020 diagnostic plots. The distribution of residuals from the optimum fit. The qqplot indicates the fit to the expected normality, while the histogram of residuals illustrates the 90% quantiles to indicate the intensity of any lack of fit at the margins of the distribution.

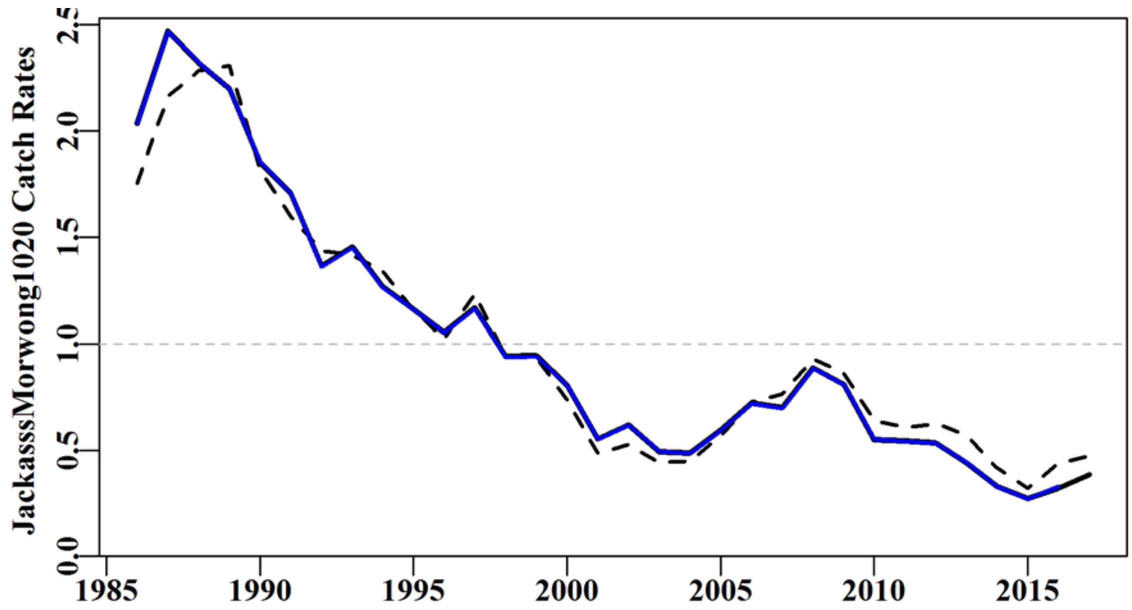


Figure 5.55. JackasssMorwong1020. A comparison of the previous year's standardization (blue line) with this year's. They should lie on top of each other, although small deviations may relate to data adjustments, particularly in very recent years.

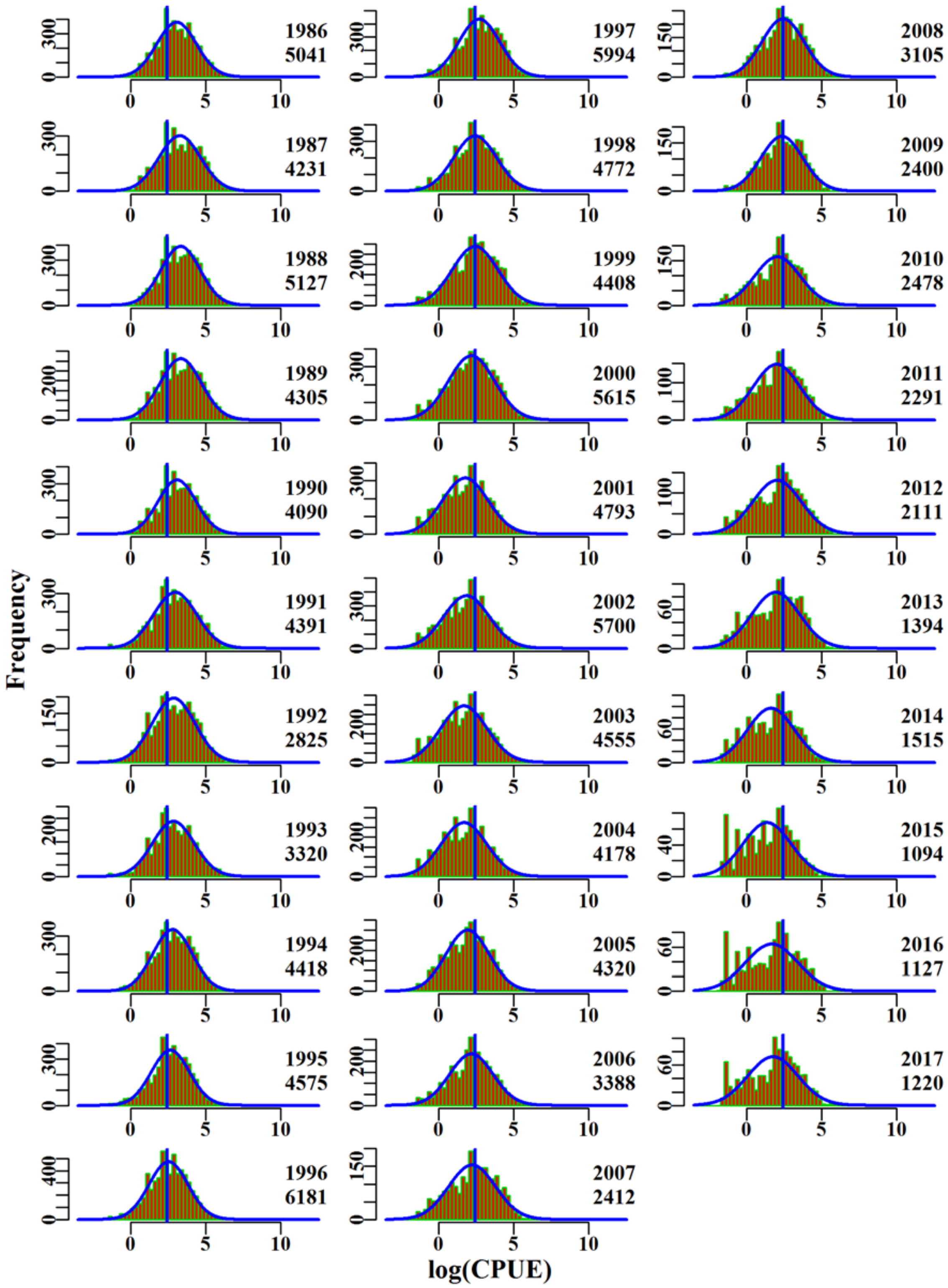


Figure 5.56. JackasssMorwong1020. The log(CPUE) for each year of data available the blue lines are normal distributions fitted to the histogram frequencies. The numbers in each plot are the year and number of records.

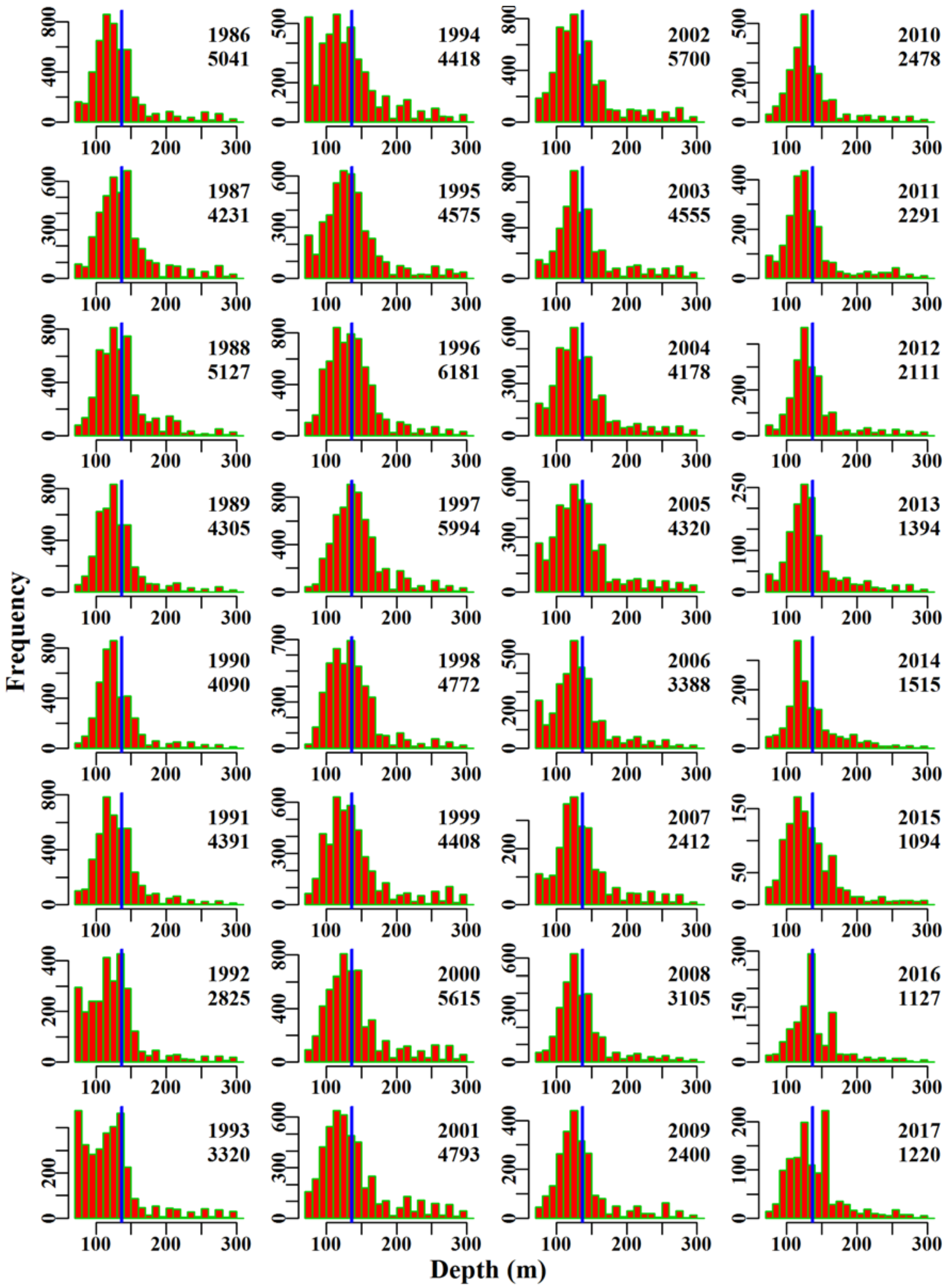


Figure 5.57. JackasssMorwong1020. The average Depth of fishing for each year of data available to illustrate the development of the fishery through time. The numbers in each plot are the year and number of records.

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 - 2017 (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 Normaility, 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 thereafter (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 - 2017

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	2.0604	0.000	1.928	0.013
1987	1087.7	349	58.4	21	61.0	1.6170	0.086	2.079	0.036
1988	1483.5	401	65.4	19	66.0	2.3917	0.086	1.803	0.028
1989	1667.4	345	83.2	21	74.7	1.7277	0.091	2.283	0.027
1990	1001.4	410	80.3	22	77.2	1.7507	0.092	2.303	0.029
1991	1138.1	279	40.3	26	39.8	1.1828	0.097	1.790	0.044
1992	758.3	249	28.6	14	33.0	0.9694	0.099	2.122	0.074
1993	1015.0	248	25.0	17	29.6	0.9236	0.101	2.247	0.090
1994	818.4	309	22.5	16	22.9	0.9016	0.094	2.725	0.121
1995	789.5	291	76.9	17	63.5	0.9309	0.095	2.405	0.031
1996	827.2	345	36.1	17	31.3	1.0428	0.092	2.869	0.079
1997	1063.4	489	53.9	20	26.8	0.8219	0.086	4.823	0.090
1998	876.4	266	54.6	19	42.7	0.8328	0.098	2.825	0.052
1999	961.5	382	76.9	17	42.5	0.7547	0.091	3.711	0.048
2000	945.2	429	118.9	28	79.8	1.1947	0.091	3.723	0.031
2001	790.2	920	276.8	25	104.8	1.2730	0.079	5.171	0.019
2002	811.2	850	249.4	21	95.2	1.2808	0.079	4.464	0.018
2003	774.6	649	170.7	24	85.9	1.0850	0.083	3.106	0.018
2004	765.5	674	174.5	25	77.1	1.1507	0.082	2.843	0.016
2005	784.2	717	188.5	21	77.7	1.2466	0.082	3.105	0.016
2006	811.3	799	178.3	19	57.6	0.9877	0.080	3.293	0.018
2007	607.9	585	114.2	15	44.8	0.8244	0.083	2.758	0.024
2008	700.4	466	101.5	16	55.7	0.8451	0.087	1.491	0.015
2009	454.4	409	58.3	13	34.1	0.6693	0.089	2.178	0.037
2010	380.0	408	38.2	13	20.6	0.4970	0.089	2.589	0.068
2011	428.0	621	82.8	14	27.6	0.5248	0.083	2.709	0.033
2012	395.6	341	34.5	14	23.1	0.3920	0.093	2.604	0.076
2013	323.9	463	35.7	13	15.7	0.3694	0.088	3.435	0.096
2014	216.6	252	10.1	13	8.8	0.2875	0.100	2.484	0.245
2015	152.5	154	7.0	9	8.3	0.3685	0.115	1.297	0.185
2016	183.4	255	25.0	11	18.1	0.4318	0.100	1.601	0.064
2017	246.2	494	79.5	12	29.6	0.6640	0.089	2.386	0.030

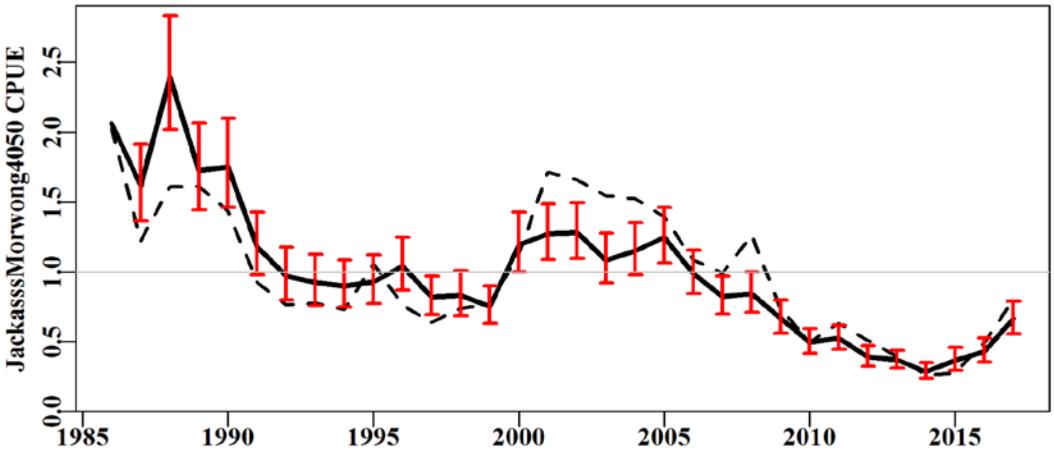


Figure 5.58. JackasssMorwong4050 standardization. The dashed black line represents the geometric mean catch rate, solid black line the standardized catch rates. The red bars are the 95% confidence intervals about the mean estimates. The graph scales both time-series of standardized catch rates relative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

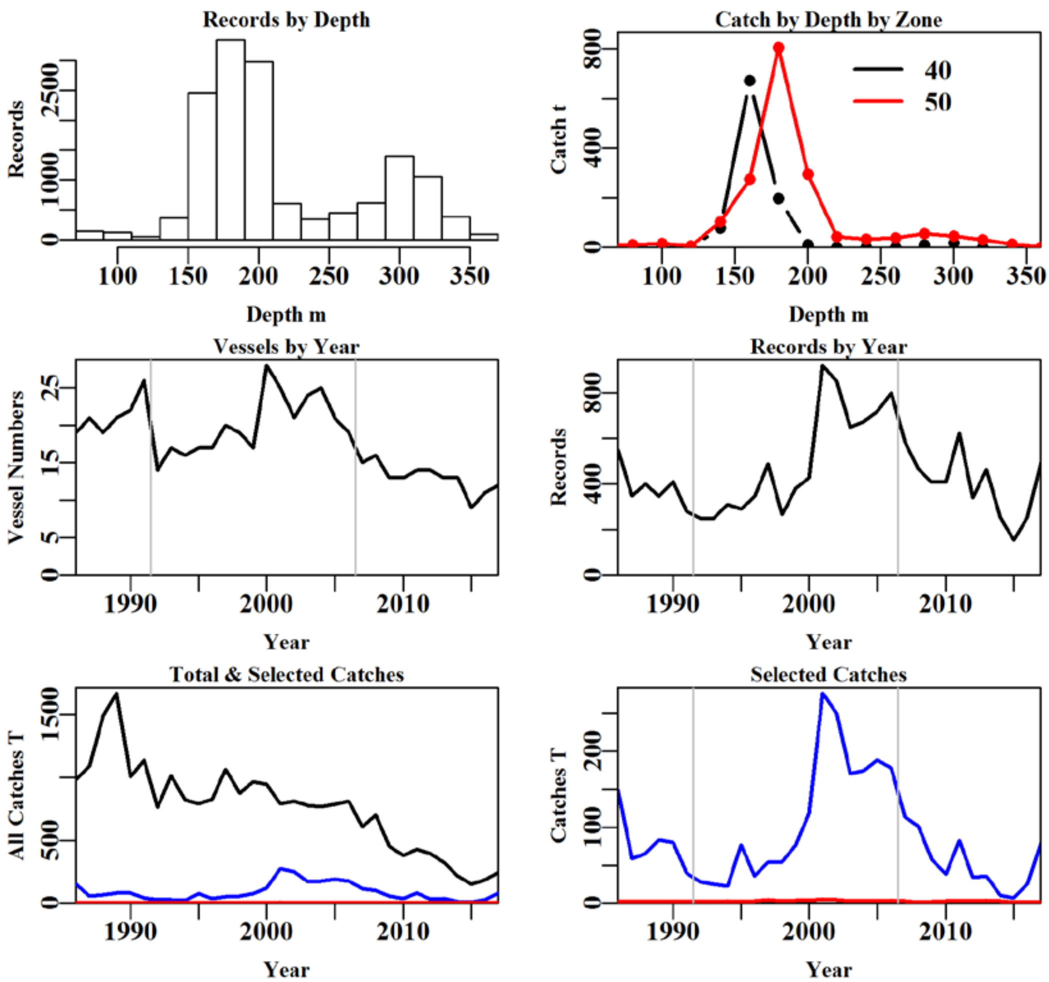


Figure 5.59. JackasssMorwong4050 fishery details. The bottom left plot depicts all known catches (top black line), and all selected catches used in the analysis (middle blue line); the lower red line: selected catches < 30 kg).

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	255396	235337	212778	208855	14940	14434	14399
Difference	0	20059	22559	3923	193915	506	35
Catch	24969.53	24029.4847	22902.797	22284.962	2838.587	2803.7910	2795.125
Difference	0.00	940.0466	1126.688	617.835	19446.375	34.7958	8.666

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	8118	25191	3378	14399	32	11.6	0.00
DepCat	5843	21464	7105	14399	47	24.6	12.99
Month	4583	19637	8933	14399	58	31.0	6.36
Vessel	3881	18473	10097	14399	147	34.7	3.68
DayNight	3721	18260	10309	14399	150	35.4	0.74
Zone	3606	18113	10456	14399	151	35.9	0.52
Zone:Month	3455	17897	10673	14399	162	36.6	0.72
Zone:DepCat	3512	17960	10610	14399	165	36.4	0.48

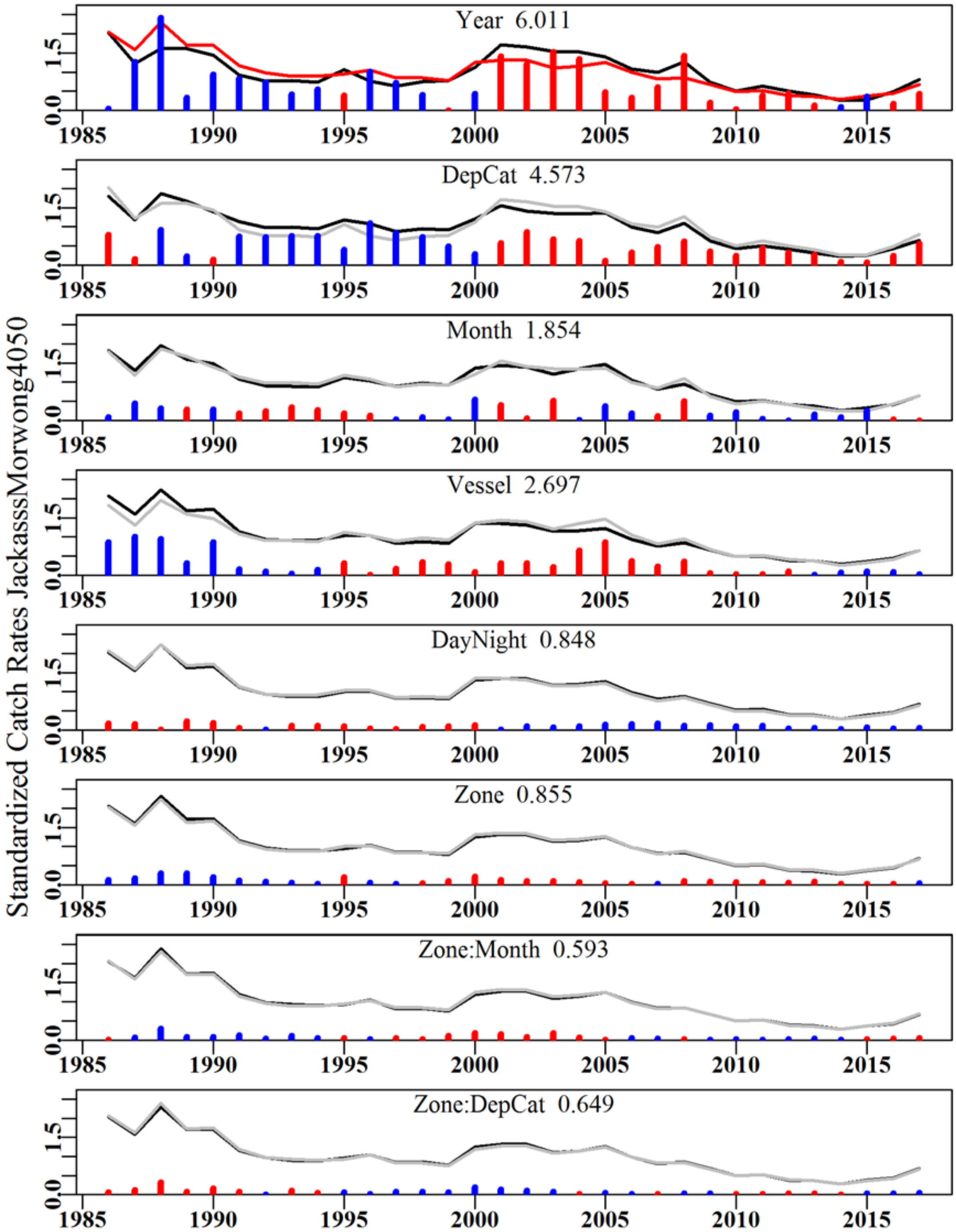


Figure 5.60. JackasssMorwong4050. The influence of each factor on the optimal standardization. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by vertical bars with blue bars indicating the optimum model is higher than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

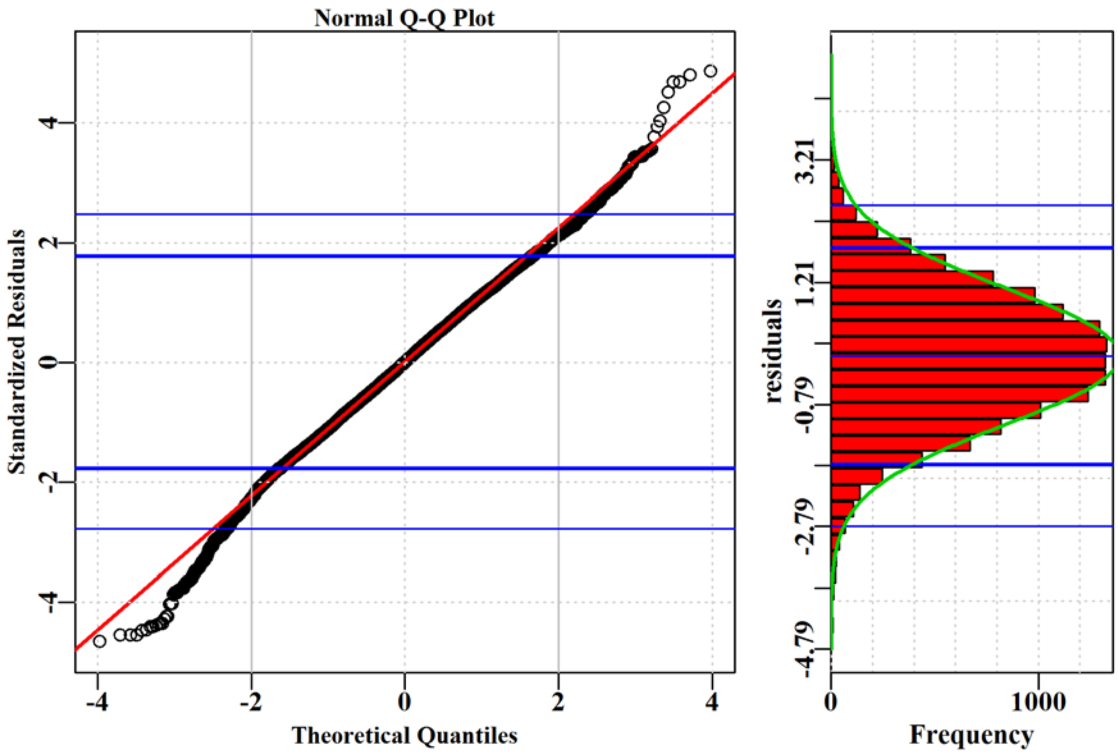


Figure 5.61. JackasssMorwong4050 diagnostic plots. The distribution of residuals from the optimum fit. The qqplot indicates the fit to the expected normality, while the histogram of residuals illustrates the 90% quantiles to indicate the intensity of any lack of fit at the margins of the distribution.

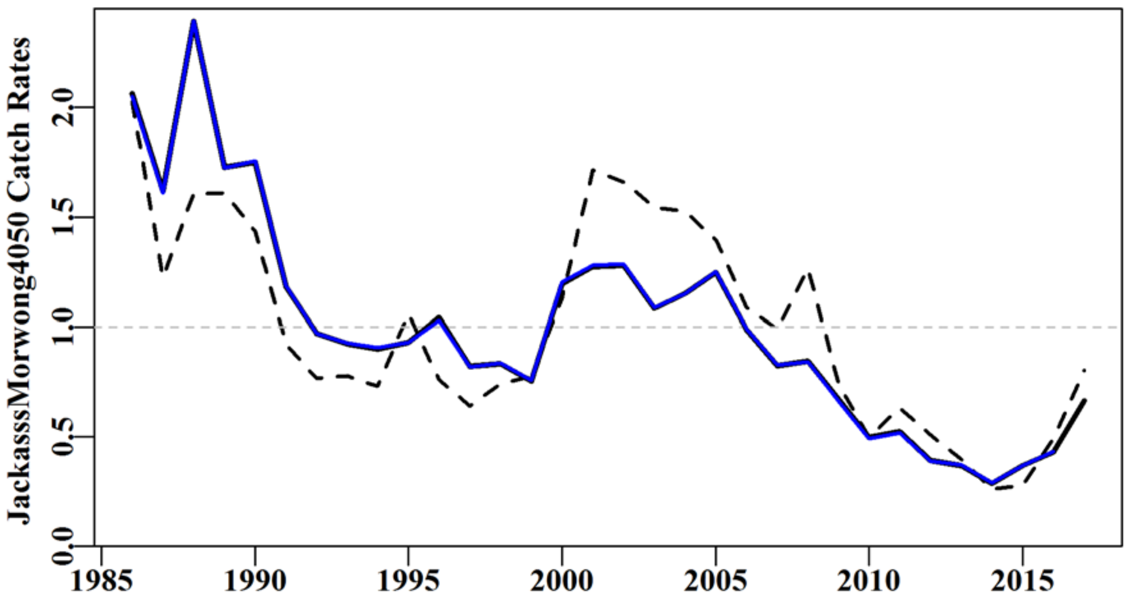


Figure 5.62. JackasssMorwong4050. A comparison of the previous year's standardization (blue line) with this year's. They should lie on top of each other, although small deviations may relate to data adjustments, particularly in very recent years.

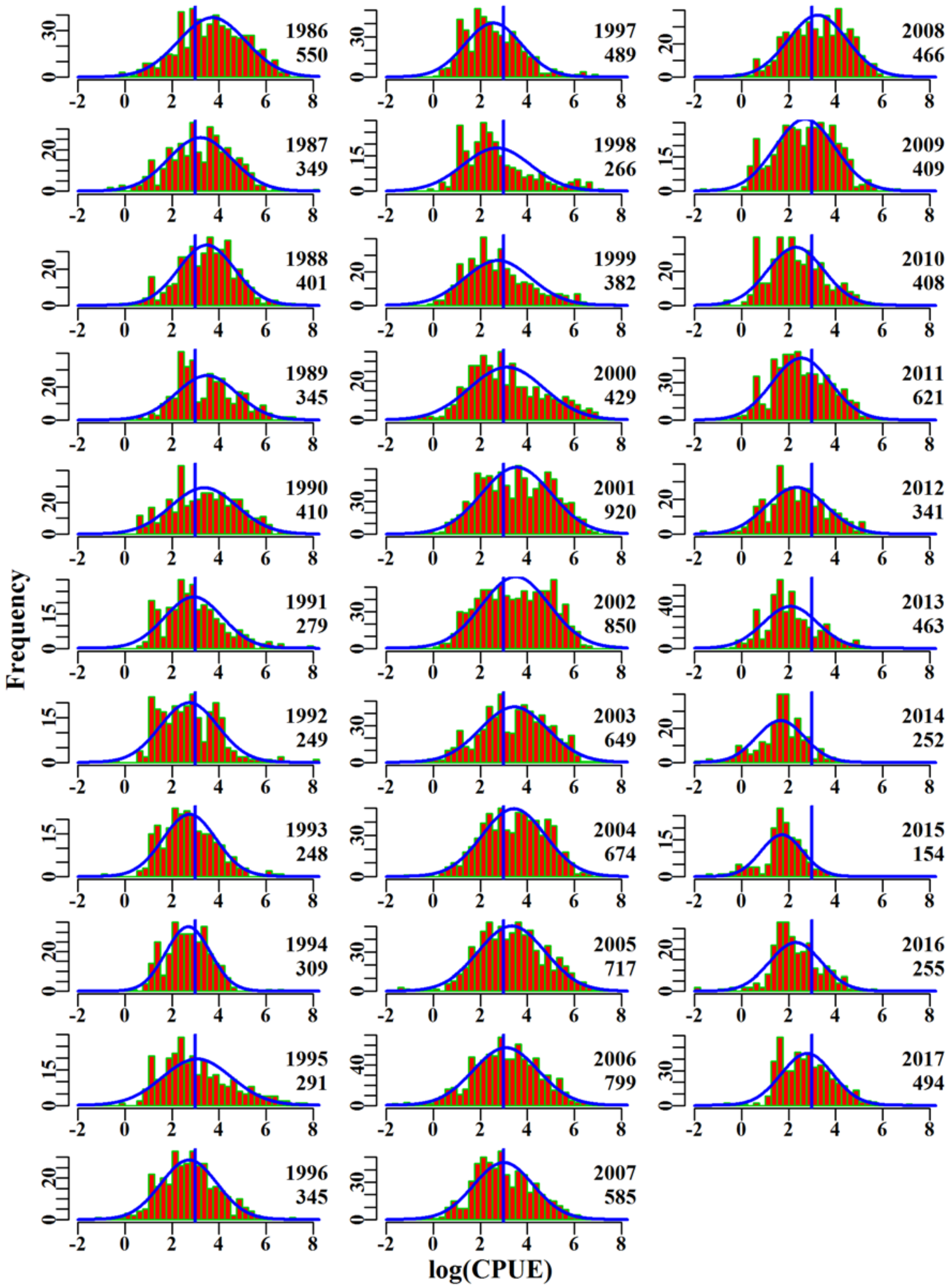


Figure 5.63. JackasssMorwong4050. The log(CPUE) for each year of data available the blue lines are normal distributions fitted to the histogram frequencies. The numbers in each plot are the year and number of records.

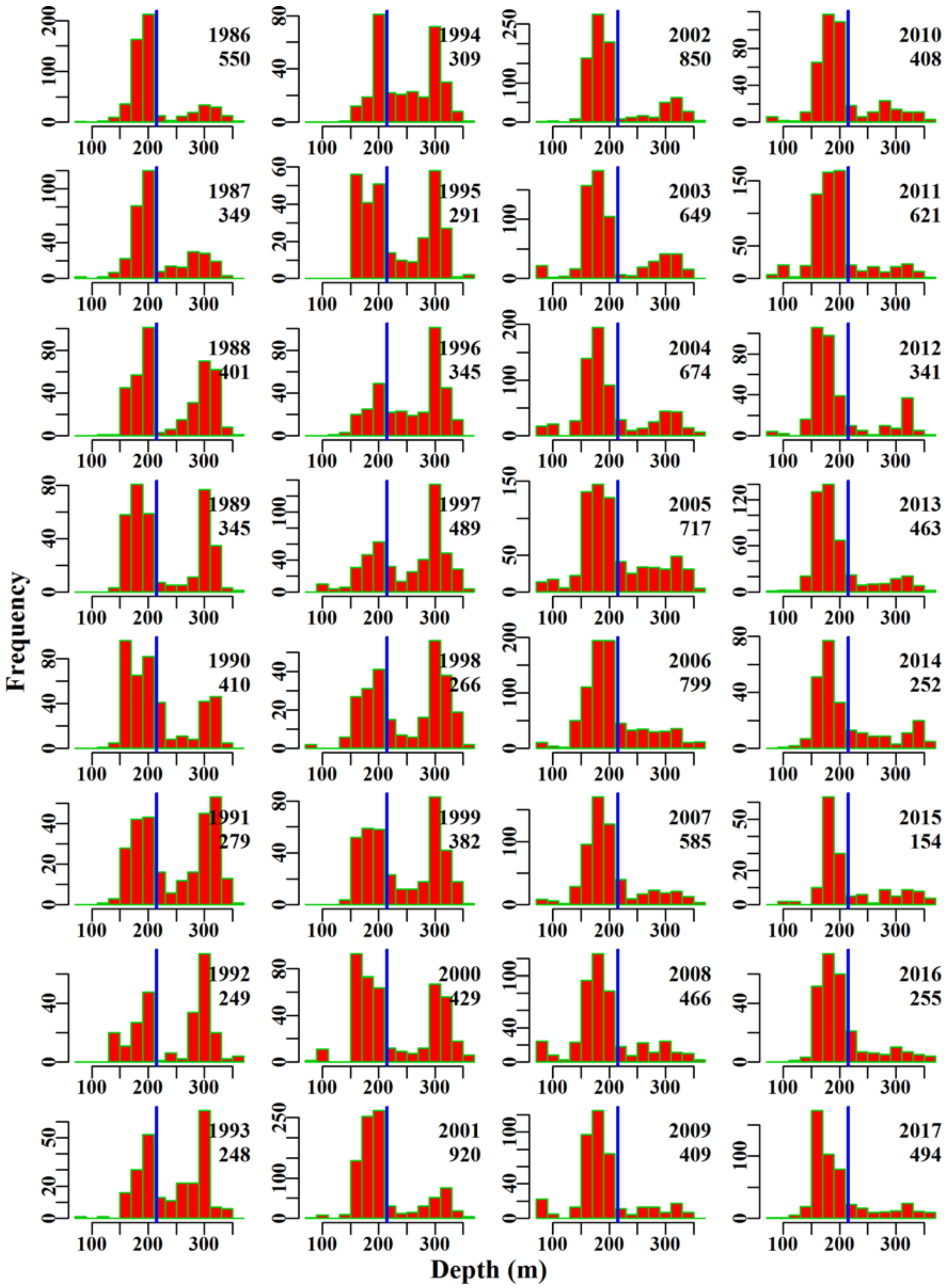


Figure 5.64. JackasssMorwong4050. The average Depth of fishing for each year of data available to illustrate the development of the fishery through time. The numbers in each plot are the year and number of records.

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 - 2017 (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, DepCat 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 5.50). 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 - 2017

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	1.5187	0.000	4.167	0.006
1987	782.2	723	490.0	26	279.5	1.7189	0.082	2.368	0.005
1988	1646.2	574	684.4	27	553.8	1.9792	0.087	2.295	0.003
1989	926.3	649	569.0	27	287.0	1.6704	0.090	2.663	0.005
1990	1346.6	565	296.6	26	197.1	1.1067	0.089	2.986	0.010
1991	1453.2	691	623.8	29	267.7	1.1860	0.085	3.180	0.005
1992	733.8	582	185.4	21	98.1	0.8972	0.088	3.330	0.018
1993	1815.8	1541	749.3	23	151.0	1.2495	0.073	6.998	0.009
1994	2309.5	1639	753.6	26	155.7	1.1453	0.071	7.735	0.010
1995	2002.9	1672	771.7	24	147.2	0.9454	0.071	8.948	0.012
1996	2188.2	1551	1016.2	26	209.0	1.0590	0.072	8.450	0.008
1997	2562.0	1874	1261.4	24	210.8	1.2475	0.070	9.427	0.007
1998	2166.0	1848	1196.4	22	221.7	1.4606	0.071	7.985	0.007
1999	2834.1	2735	1772.1	24	241.8	1.2025	0.067	11.412	0.006
2000	3401.6	3557	2568.9	30	321.2	1.1749	0.066	15.063	0.006
2001	2970.4	4177	2170.7	29	193.7	0.8867	0.065	20.784	0.010
2002	3841.4	4421	2944.8	27	249.0	0.9423	0.065	20.321	0.007
2003	2910.1	3398	2199.3	28	256.8	0.9776	0.066	14.878	0.007
2004	3202.1	4240	2534.4	25	164.8	1.0707	0.065	14.503	0.006
2005	2648.0	3065	2100.2	24	220.2	1.1706	0.067	11.833	0.006
2006	2191.2	2682	1680.0	21	187.2	1.0324	0.068	10.636	0.006
2007	1816.5	2764	1360.1	16	144.6	1.0432	0.068	10.282	0.008
2008	1381.2	2056	870.0	17	105.7	0.8300	0.070	9.048	0.010
2009	1285.3	2042	719.9	13	73.2	0.7206	0.070	9.352	0.013
2010	1189.4	2319	782.7	14	64.7	0.6552	0.069	11.517	0.015
2011	1108.8	2889	818.3	17	57.4	0.6313	0.067	11.542	0.014
2012	781.2	1846	546.4	15	57.3	0.4681	0.071	10.147	0.019
2013	584.1	1513	342.2	16	48.6	0.4376	0.073	8.189	0.024
2014	356.9	1540	244.0	14	29.2	0.4170	0.073	8.700	0.036
2015	368.4	1380	268.0	13	34.1	0.4508	0.075	6.634	0.025
2016	331.5	1101	172.1	13	25.2	0.3288	0.077	6.348	0.037
2017	325.7	1246	218.5	12	29.3	0.3754	0.077	5.926	0.027

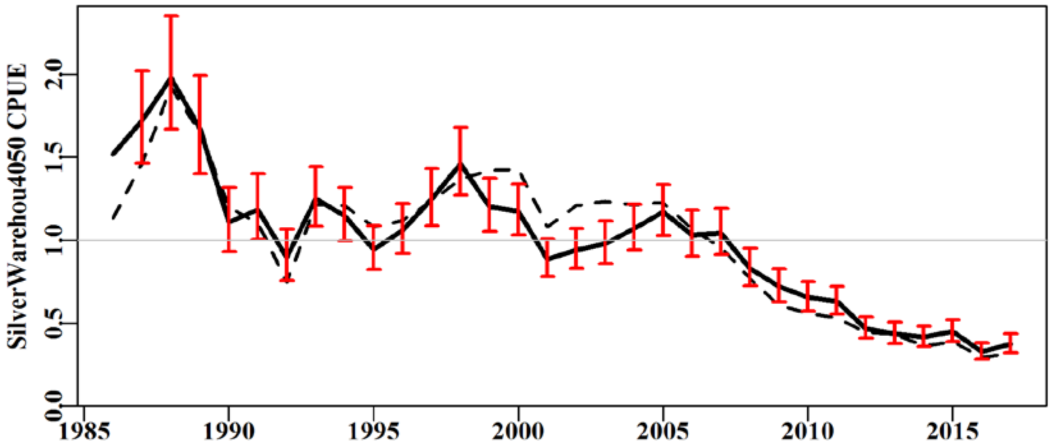


Figure 5.65. SilverWarehou4050 standardization. The dashed black line represents the geometric mean catch rate, solid black line the standardized catch rates. The red bars are the 95% confidence intervals about the mean estimates. The graph scales both time-series of standardized catch rates relative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

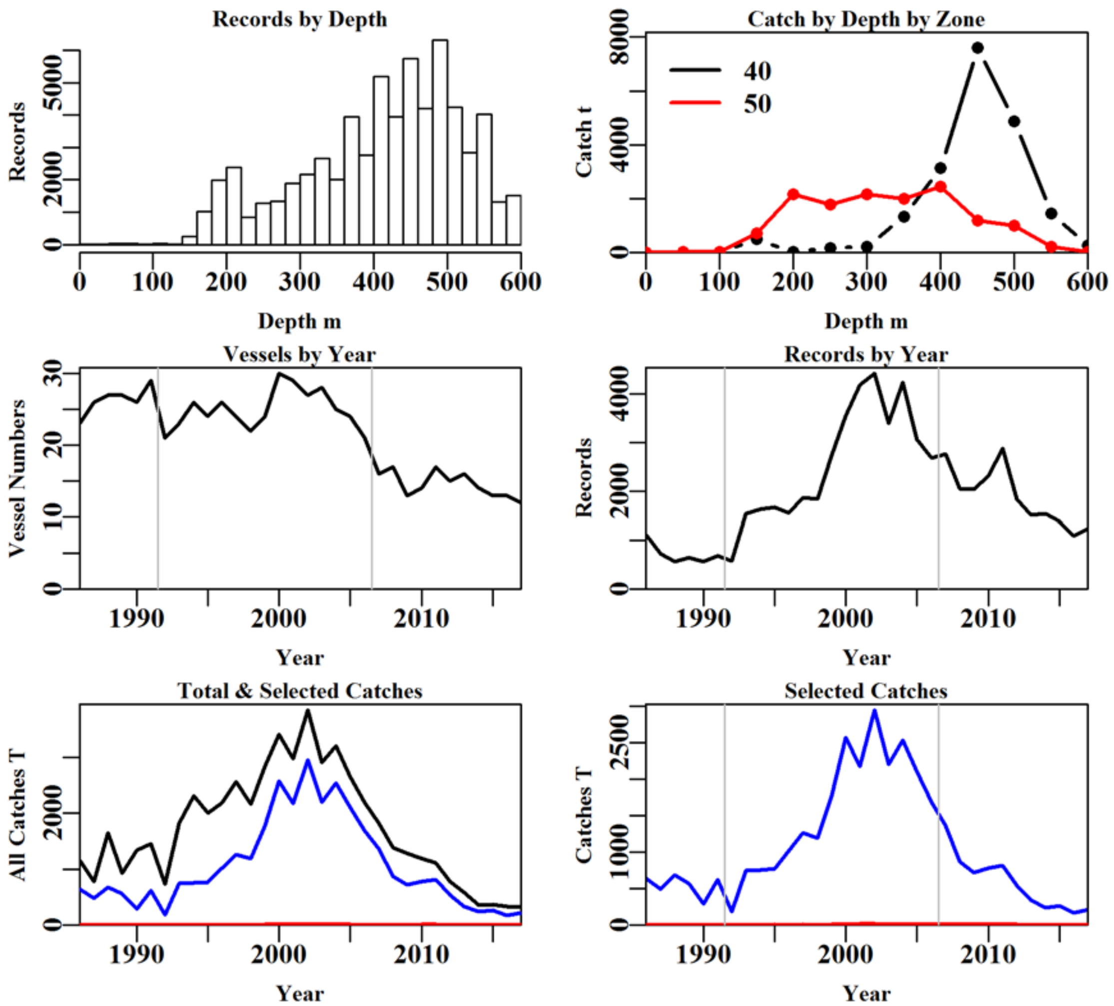


Figure 5.66. SilverWarehou4050 fishery details. The bottom left plot depicts all known catches (top black line), and all selected catches used in the analysis (middle blue line); the lower red line: selected catches < 30 kg).

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	152707	148574	144296	143139	64310	64122	63998
Differencee	0	4133	4278	1157	78829	188	124
Catch	55049.13	54561.1998	52853.112	52427.045	33731.71	33682.6935	33553.516
Difference	0.00	487.9341	1708.088	426.067	18695.33	49.0182	129.177

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	67639	183966	12990	63998	32	6.55	0.000
Vessel	59805	162262	34694	63998	132	17.45	10.896
Month	56827	154830	42126	63998	143	21.21	3.767
DepCat	55726	152133	44822	63998	155	22.57	1.358
Zone	54837	150029	46927	63998	156	23.64	1.070
DayNight	54526	149288	47668	63998	159	24.01	0.374
Zone:Month	54307	148727	48229	63998	170	24.29	0.272
Zone:DepCat	54319	148751	48205	63998	171	24.27	0.259

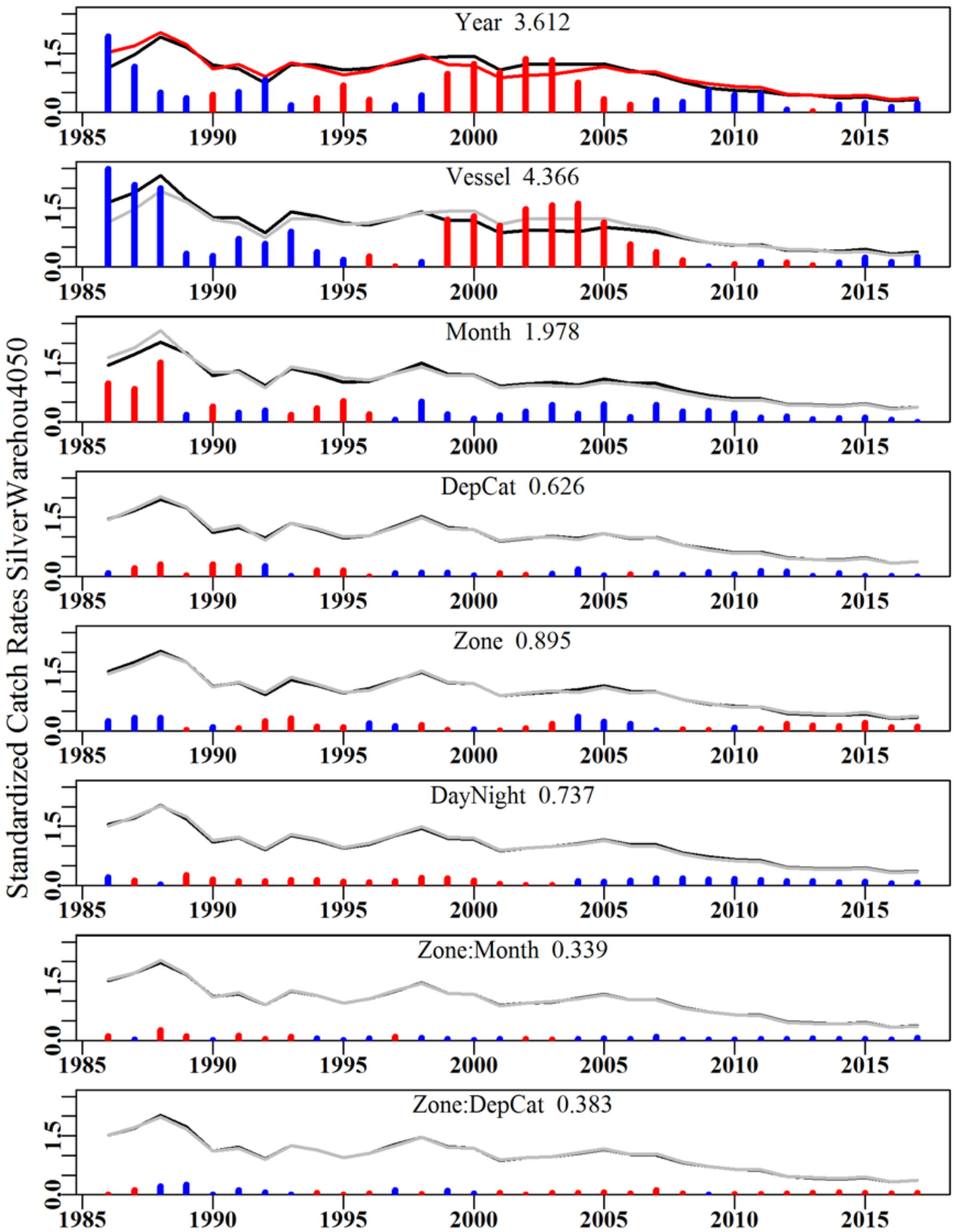


Figure 5.67. SilverWarehou4050. The influence of each factor on the optimal standardization. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by vertical bars with blue bars indicating the optimum model is higher than the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

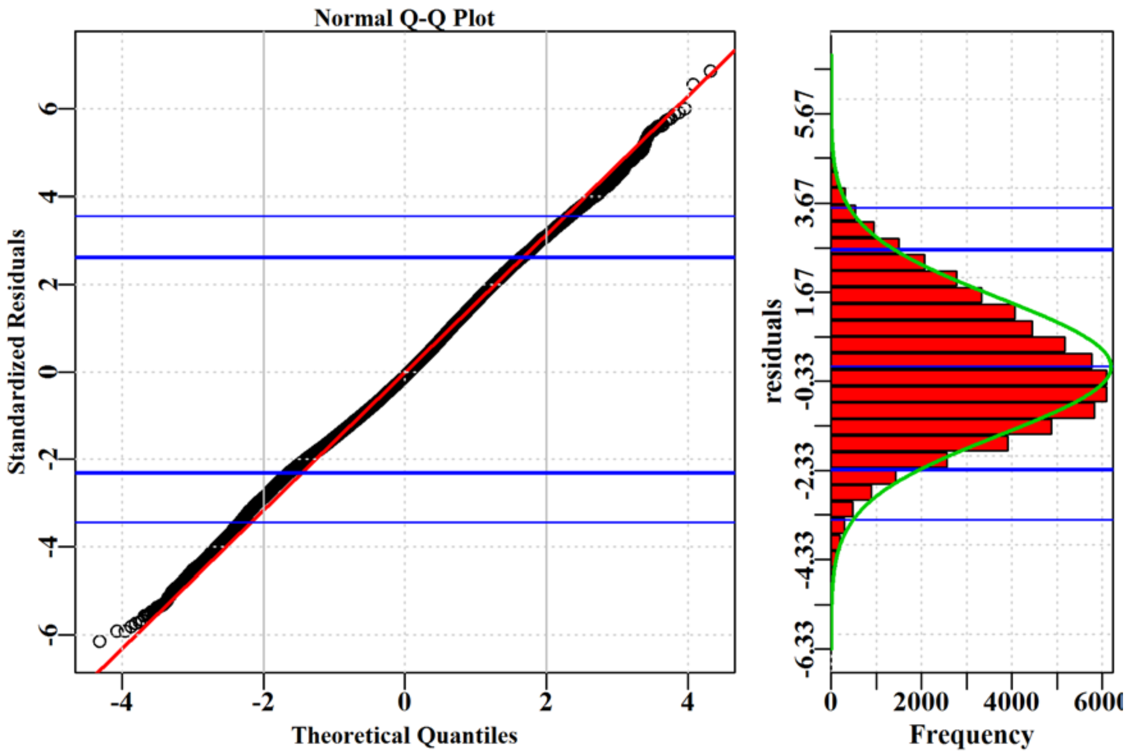


Figure 5.68. SilverWarehou4050. diagnostic plots. The distribution of residuals from the optimum fit. The qqplot indicates the fit to the expected normality, while the histogram of residuals illustrates the 90% quantiles to indicate the intensity of any lack of fit at the margins of the distribution.

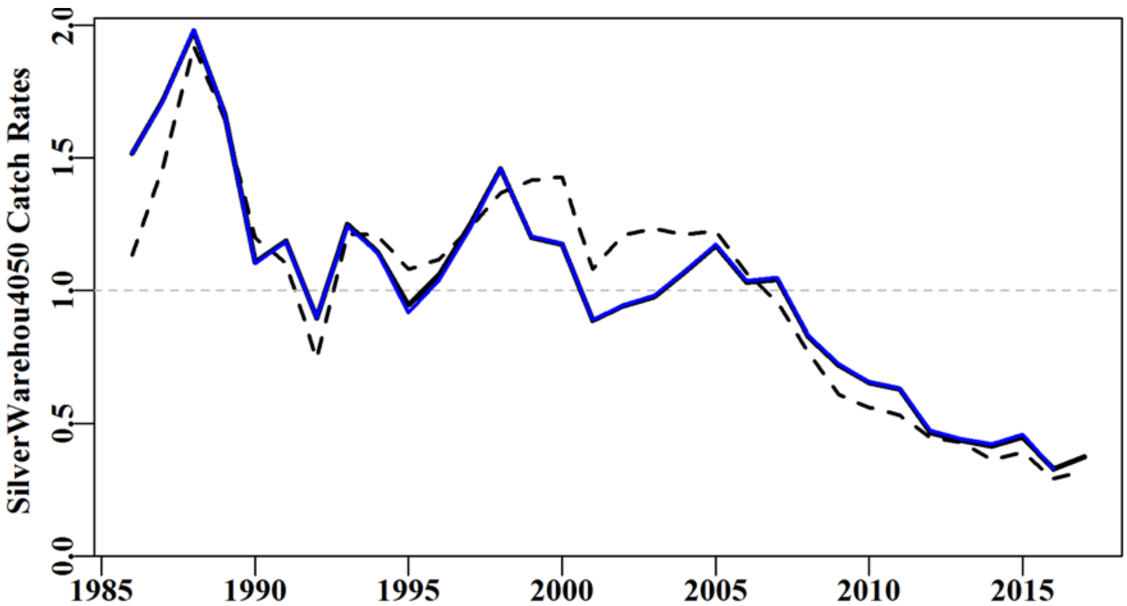


Figure 5.69. SilverWarehou4050. A comparison of the previous year's standardization (blue line) with this year's. They should lie on top of each other, although small deviations may relate to data adjustments, particularly in very recent years.

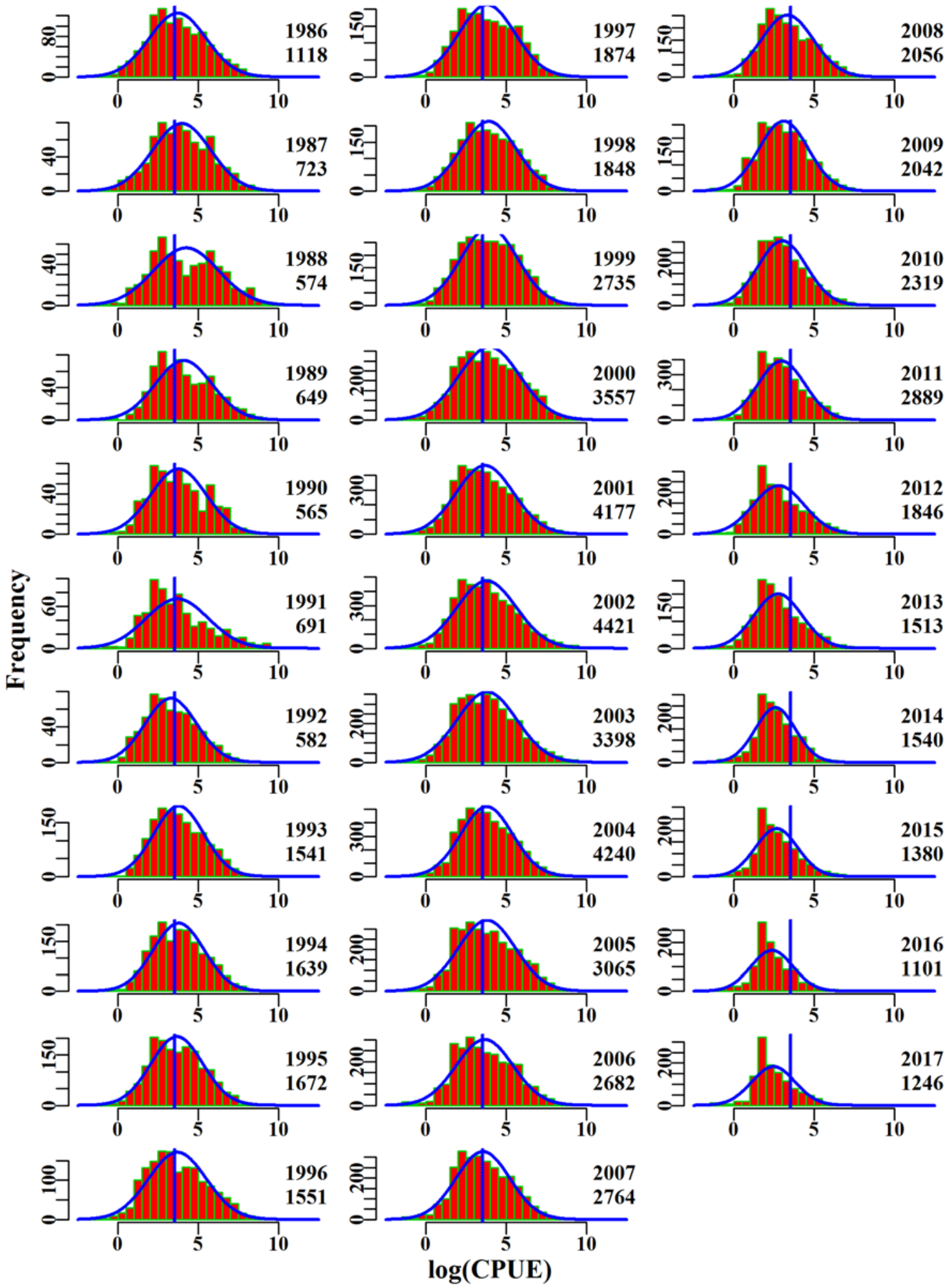


Figure 5.70. SilverWarehou4050. The log(CPUE) for each year of data available the blue lines are normal distributions fitted to the histogram frequencies. The numbers in each plot are the year and number of records.

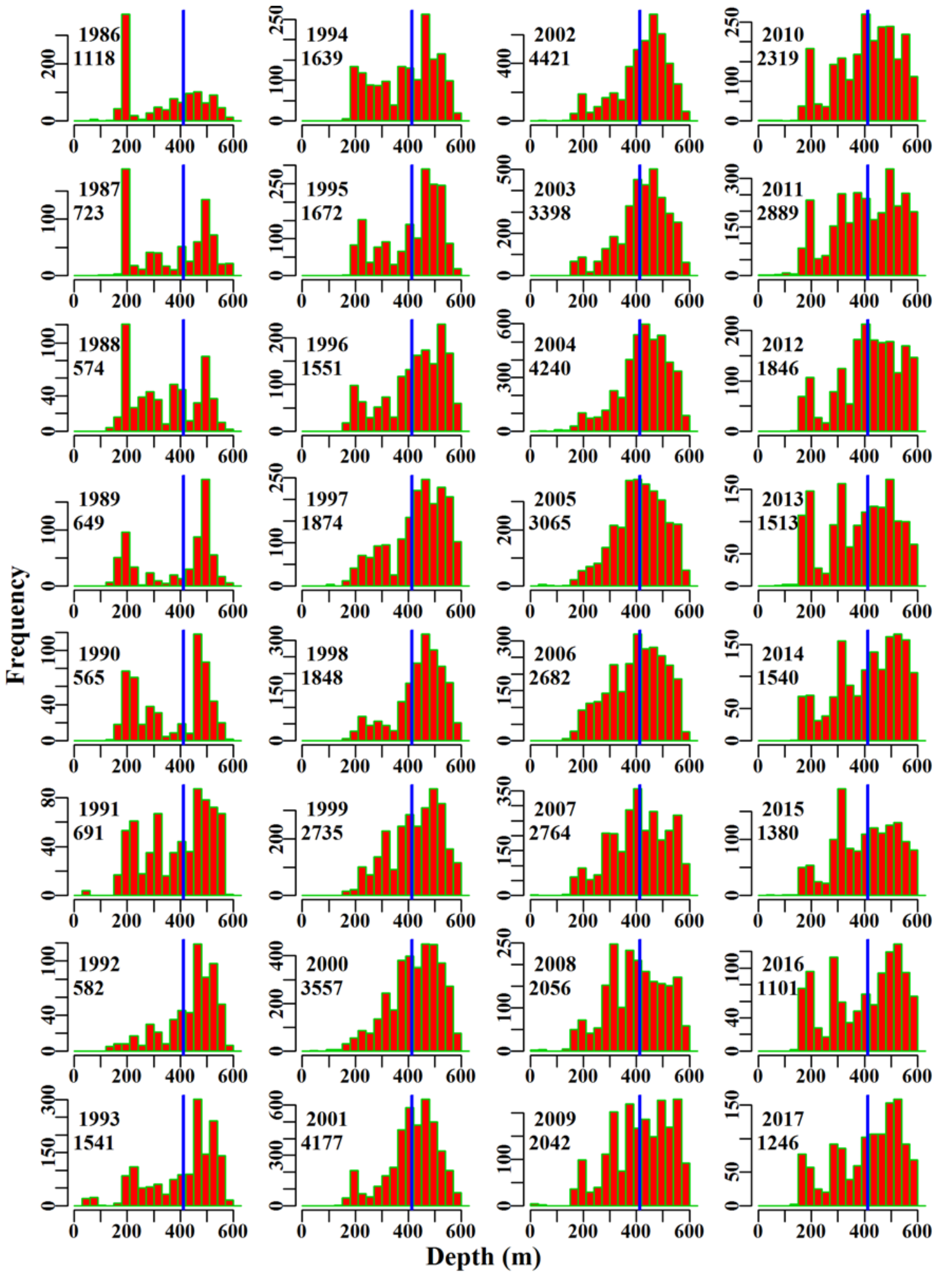


Figure 5.71. SilverWarehou4050. The average Depth of fishing for each year of data available to illustrate the development of the fishery through time. The numbers in each plot are the year and number of records.

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 - 2017 (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 - 2017. 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 with small deviations at the upper tail of the distribution (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 - 2017

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	1.8436	0.000	6.906	0.014
1987	782.2	778	264.8	56	112.0	1.7988	0.078	4.472	0.017
1988	1646.2	1668	926.1	69	172.0	2.2746	0.066	8.485	0.009
1989	926.3	1394	336.7	63	62.3	1.8868	0.070	9.172	0.027
1990	1346.6	1398	972.3	59	256.2	2.4035	0.071	5.674	0.006
1991	1453.2	1568	575.6	63	117.6	1.4539	0.071	9.859	0.017
1992	733.8	1254	423.8	41	110.4	1.6202	0.073	7.375	0.017
1993	1815.8	2288	970.4	49	129.4	1.5893	0.067	14.634	0.015
1994	2309.5	2852	1535.2	46	186.7	1.7643	0.065	16.832	0.011
1995	2002.9	3316	1185.2	45	112.4	1.4884	0.064	22.666	0.019
1996	2188.2	4507	1115.2	53	72.4	1.2115	0.062	32.860	0.029
1997	2562.0	3877	1036.3	48	81.8	1.2000	0.064	26.098	0.025
1998	2166.0	2847	777.6	43	72.9	0.9905	0.065	21.294	0.027
1999	2834.1	2398	905.7	43	113.2	0.8676	0.067	17.189	0.019
2000	3401.6	3160	722.0	50	79.2	0.7031	0.065	21.600	0.030
2001	2970.4	3151	637.1	40	72.1	0.6591	0.065	21.675	0.034
2002	3841.4	3981	707.8	42	60.5	0.7676	0.064	27.884	0.039
2003	2910.1	3966	567.6	50	48.1	0.6999	0.064	28.171	0.050
2004	3202.1	3570	487.0	46	43.0	0.8190	0.065	25.639	0.053
2005	2648.0	3791	429.8	42	33.9	0.7572	0.064	30.421	0.071
2006	2191.2	2948	388.7	35	33.2	0.6393	0.066	24.183	0.062
2007	1816.5	1863	274.7	23	44.4	0.5023	0.070	14.426	0.053
2008	1381.2	2301	397.8	24	43.8	0.5884	0.068	19.377	0.049
2009	1285.3	2285	366.4	23	50.0	0.6661	0.068	17.169	0.047
2010	1189.4	2085	282.0	20	40.1	0.4891	0.069	15.392	0.055
2011	1108.8	1983	215.2	22	30.5	0.4243	0.070	15.878	0.074
2012	781.2	1834	188.8	20	33.0	0.3828	0.070	14.161	0.075
2013	584.1	1447	158.9	21	37.9	0.4793	0.073	11.465	0.072
2014	356.9	1344	89.2	22	21.7	0.3291	0.074	11.540	0.129
2015	368.4	1288	64.8	22	16.2	0.2275	0.074	11.574	0.179
2016	331.5	1337	100.1	22	19.5	0.1967	0.075	9.437	0.094
2017	325.7	1069	96.0	18	39.4	0.2761	0.078	7.021	0.073

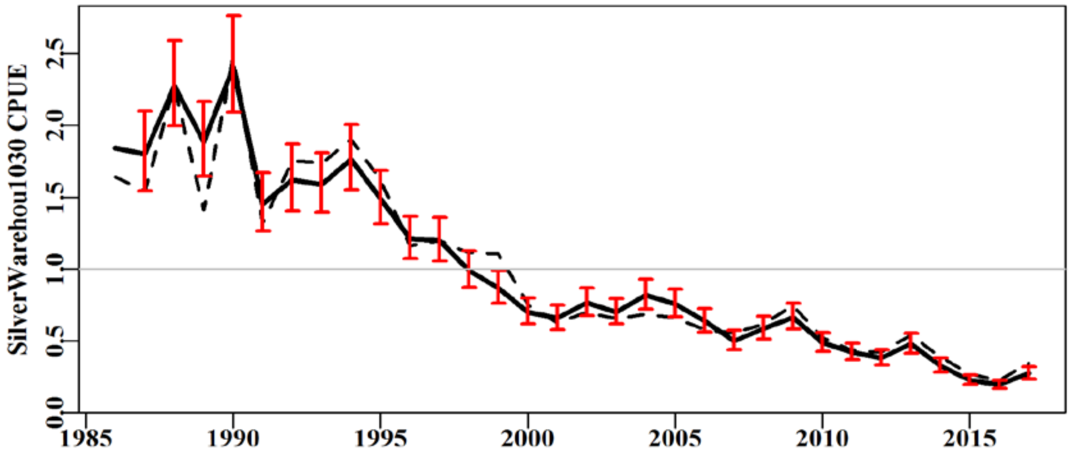


Figure 5.72. SilverWarehou1030 standardization. The dashed black line represents the geometric mean catch rate, solid black line the standardized catch rates. The red bars are the 95% confidence intervals about the mean estimates. The graph scales both time-series of standardized catch rates relative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

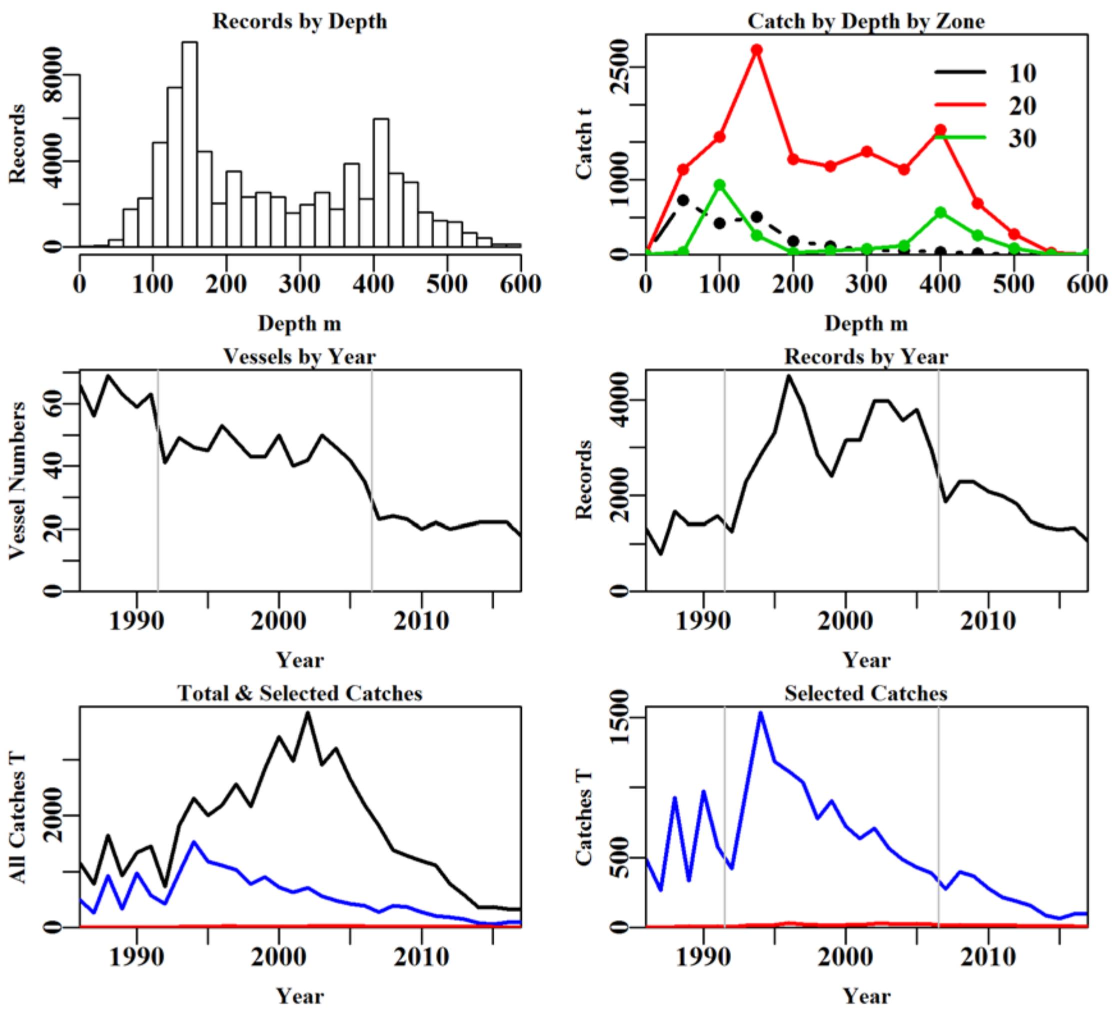


Figure 5.73. SilverWarehou1030 fishery details. The bottom left plot depicts all known catches (top black line), and all selected catches used in the analysis (middle blue line); the lower red line: selected catches < 30 kg).

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	152707	148574	144296	143139	76390	74964	74866
Difference	0	4133	4278	1157	66749	1426	98
Catch	55049.13	54561.1998	52853.112	52427.045	18181.01	17711.4055	17690.130
Difference	0.00	487.9341	1708.088	426.067	34246.04	469.6009	21.275

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	83767	229004	21510	74866	32	8.5	0.00
Vessel	77482	209548	40966	74866	213	16.1	7.57
Month	73713	199201	51313	74866	224	20.2	4.13
DepCat	72608	196219	54295	74866	236	21.4	1.18
Zone	72357	195552	54962	74866	238	21.7	0.26
DayNight	72346	195509	55005	74866	241	21.7	0.01
Zone:Month	71395	192927	57587	74866	263	22.7	1.01
Zone:DepCat	71360	192831	57684	74866	264	22.8	1.05

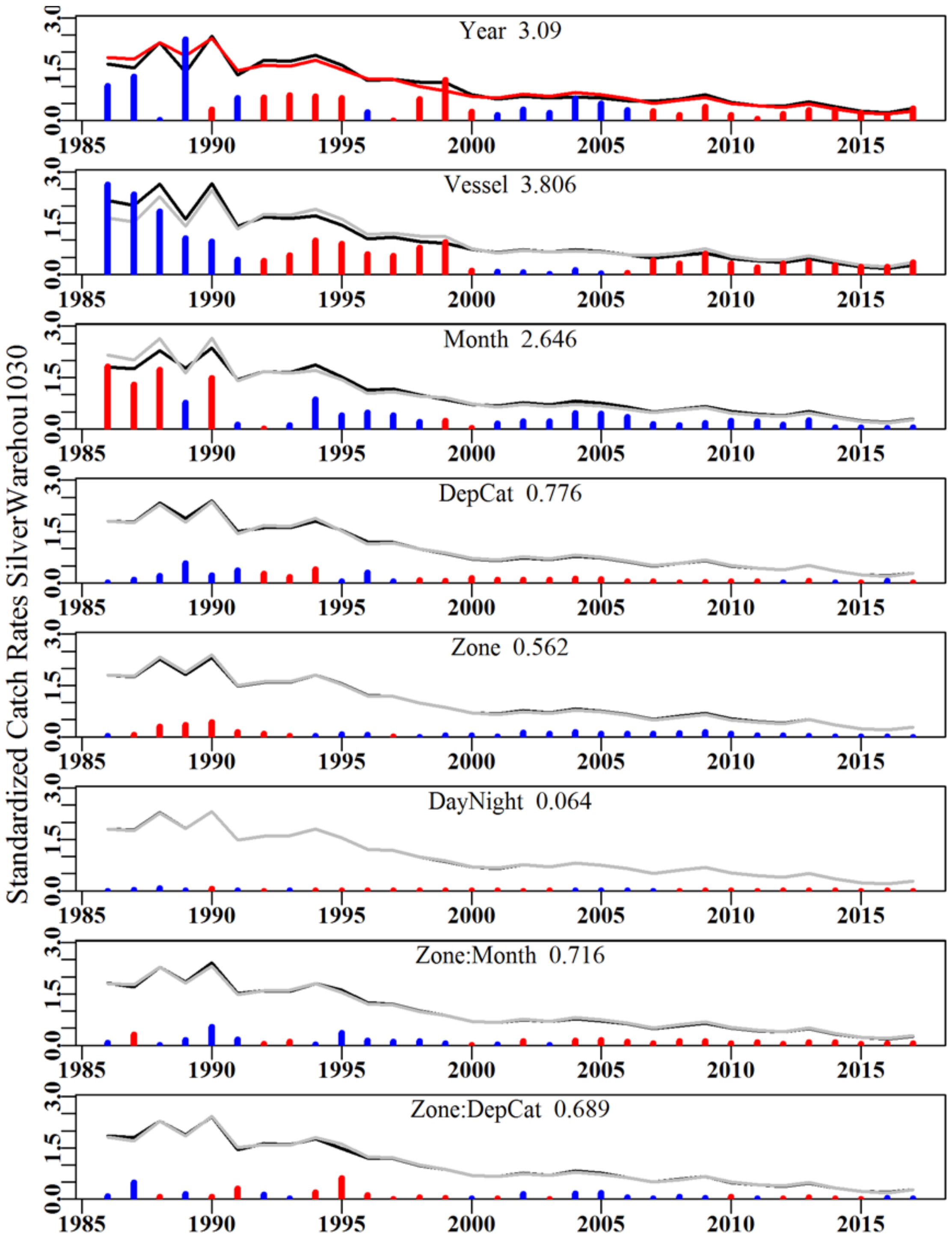


Figure 5.74. SilverWarehou1030. The influence of each factor on the optimal standardization. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by vertical bars with blue bars indicating the optimum model is higher than the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

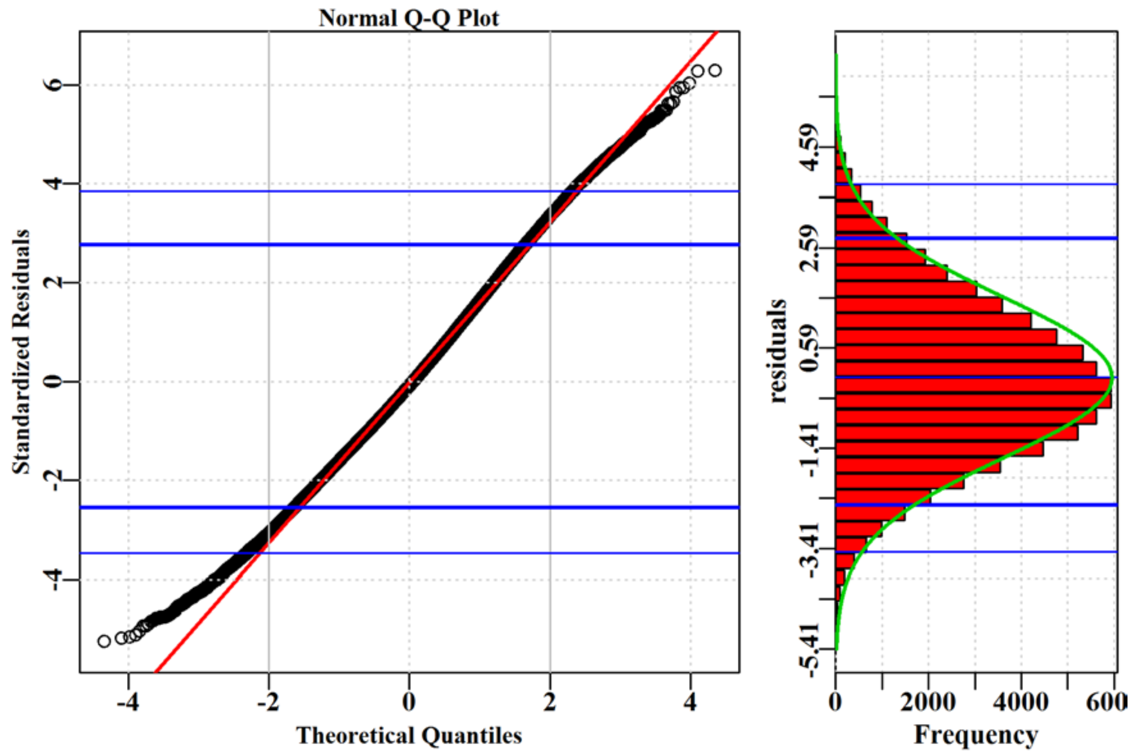


Figure 5.75. SilverWarehou1030 diagnostic plots. The distribution of residuals from the optimum fit. The qqplot indicates the fit to the expected normality, while the histogram of residuals illustrates the 90% quantiles to indicate the intensity of any lack of fit at the margins of the distribution.

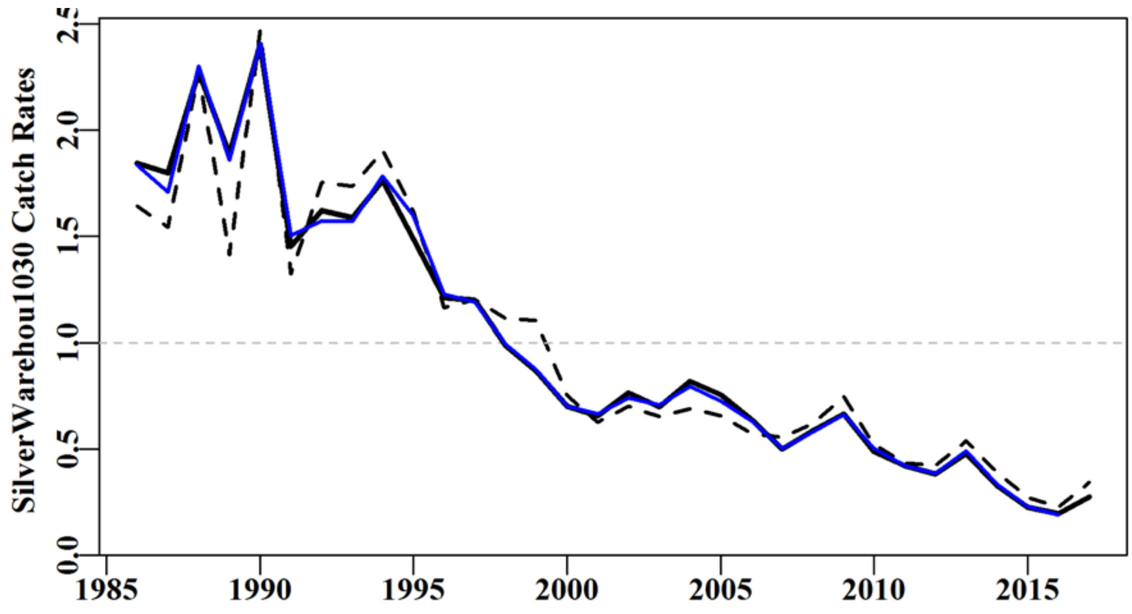


Figure 5.76. SilverWarehou1030. A comparison of the previous year's standardization (blue line) with this year's. They should lie on top of each other, although small deviations may relate to data adjustments, particularly in very recent years.

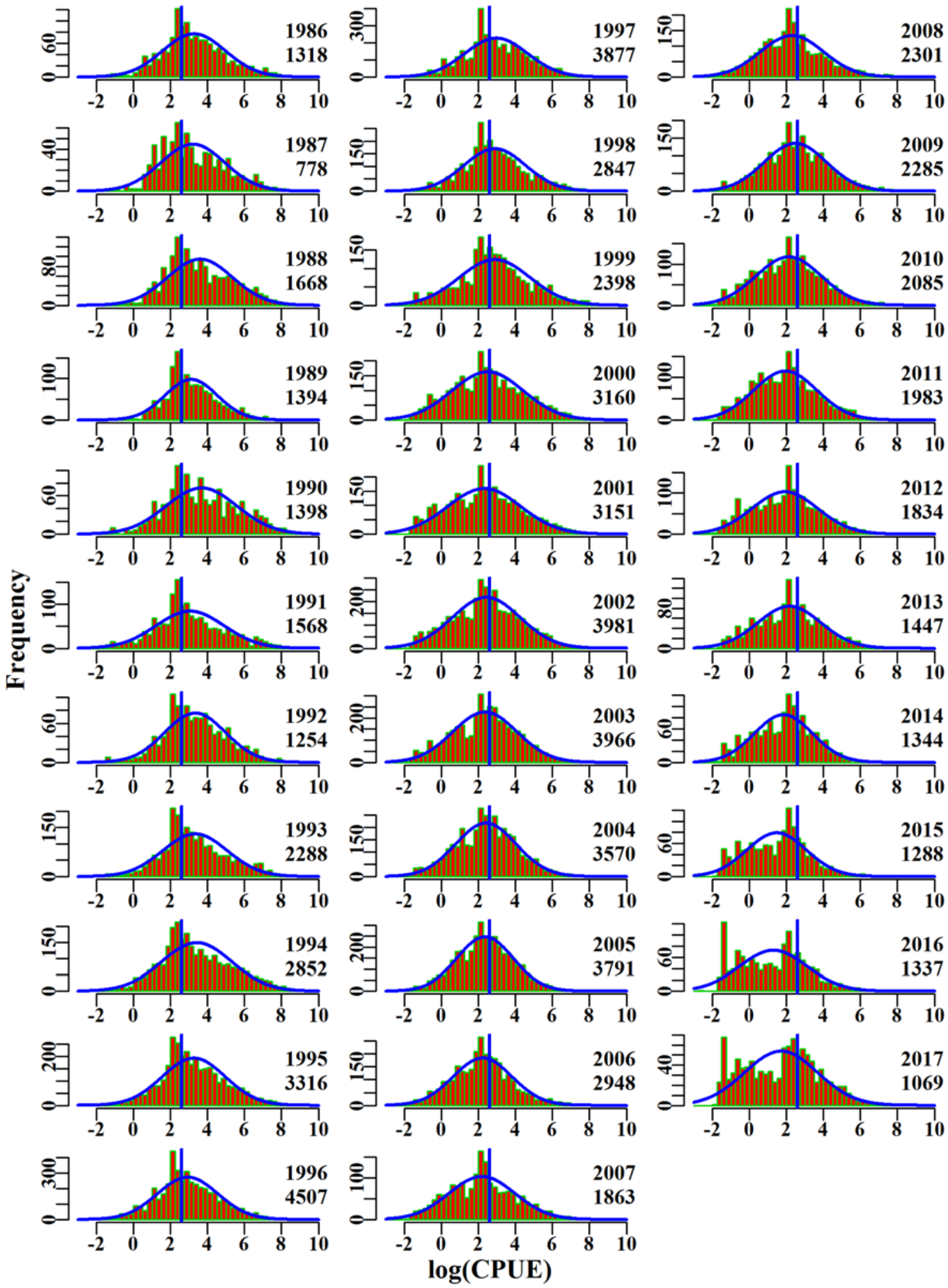


Figure 5.77. SilverWarehou1030. The log(CPUE) for each year of data available the blue lines are normal distributions fitted to the histogram frequencies. The numbers in each plot are the year and number of records.

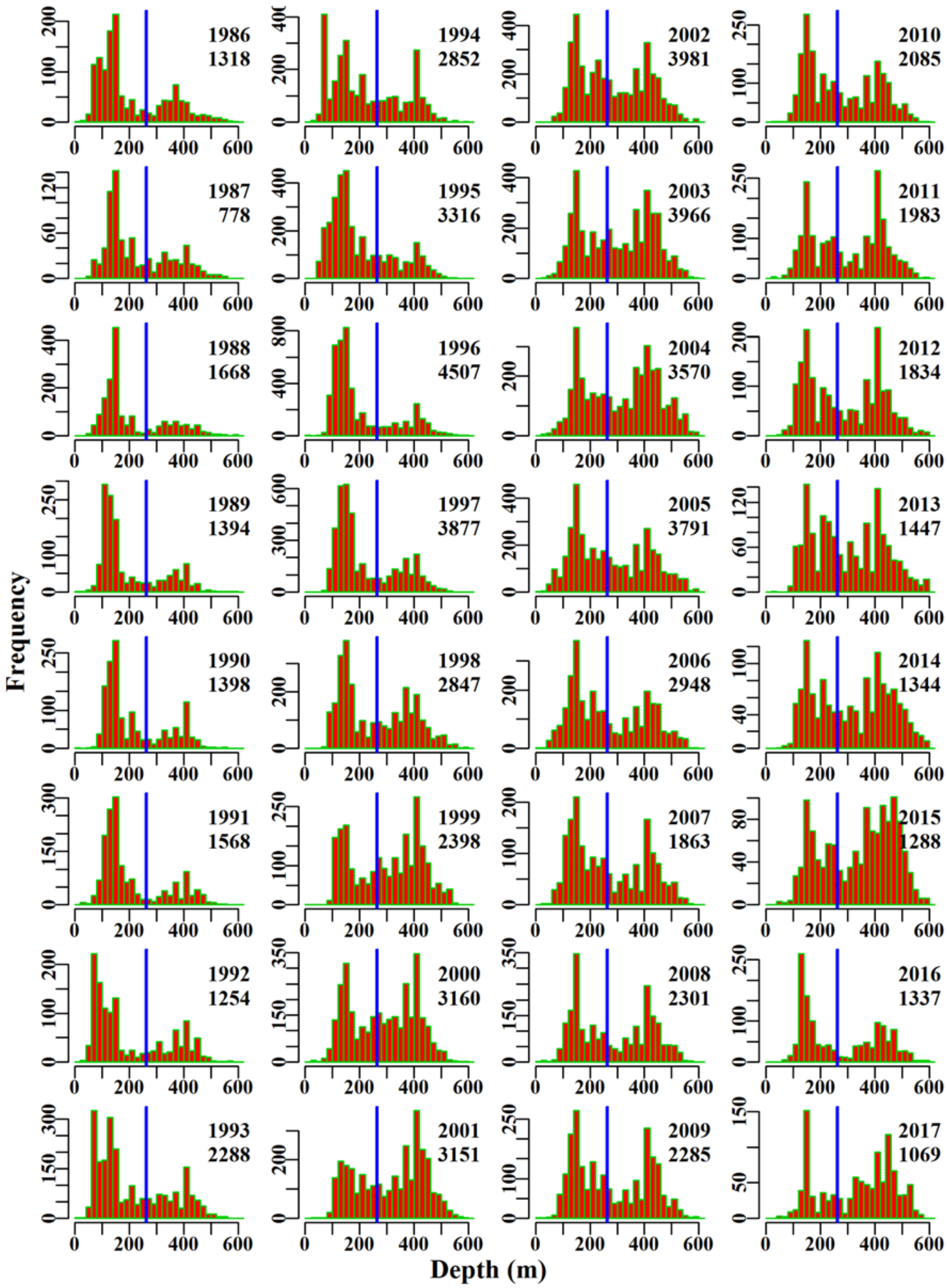


Figure 5.78. SilverWarehou1030. The average Depth of fishing for each year of data available to illustrate the development of the fishery through time. The numbers in each plot are the year and number of records.

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 - 2017 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 2017 (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 distibution 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 - 2017

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	0.9187	0.000	0.571	0.034
1987	2461.3	87	5.0	9	18.5	0.5641	0.192	0.985	0.196
1988	2469.5	191	39.9	9	53.1	0.9489	0.173	1.272	0.032
1989	2599.1	515	48.4	19	29.4	0.7018	0.165	3.760	0.078
1990	2032.3	248	23.4	27	34.0	0.7003	0.167	1.925	0.082
1991	2230.2	302	32.0	29	28.2	0.6685	0.163	2.614	0.082
1992	2375.4	267	33.5	15	37.6	0.6256	0.167	1.428	0.043
1993	1879.1	891	91.1	24	30.3	0.5881	0.159	6.341	0.070
1994	1710.4	608	64.2	17	31.6	0.6110	0.160	4.671	0.073
1995	1800.6	690	71.0	17	31.4	0.6840	0.160	6.187	0.087
1996	1879.9	713	61.4	17	26.7	0.6280	0.160	6.916	0.113
1997	2356.0	877	104.5	14	42.9	0.7818	0.159	5.243	0.050
1998	2306.4	700	118.2	14	55.9	0.9331	0.159	2.918	0.025
1999	3117.7	769	174.8	17	68.3	1.0352	0.160	3.464	0.020
2000	2945.6	512	83.5	20	50.1	0.8593	0.161	2.501	0.030
2001	2599.5	927	102.3	17	31.6	0.7292	0.158	4.949	0.048
2002	2876.3	1360	211.6	15	46.8	1.3394	0.157	5.332	0.025
2003	3229.9	1443	237.2	21	47.2	1.3824	0.156	3.920	0.017
2004	3222.8	1913	475.7	15	80.2	1.8584	0.156	3.784	0.008
2005	2844.1	1508	383.5	18	77.8	1.6918	0.156	3.731	0.010
2006	2585.8	1299	285.1	13	60.3	1.3694	0.157	2.395	0.008
2007	2648.3	808	170.3	8	64.1	1.1077	0.159	1.834	0.011
2008	2912.3	851	165.9	10	60.3	1.0412	0.159	2.624	0.016
2009	2460.5	590	98.9	10	49.9	1.0281	0.160	1.393	0.014
2010	2502.3	499	101.8	10	58.5	1.0066	0.161	1.737	0.017
2011	2465.9	614	128.8	9	64.5	0.9641	0.160	1.478	0.011
2012	2780.6	702	151.5	9	58.9	1.2045	0.159	1.048	0.007
2013	1941.0	828	190.8	11	65.6	1.1702	0.159	2.406	0.013
2014	2369.9	752	180.4	11	67.6	1.3369	0.159	1.213	0.007
2015	2667.9	1159	290.8	13	69.3	1.2621	0.158	2.088	0.007
2016	2775.5	1557	330.9	12	59.8	1.0801	0.157	6.682	0.020
2017	2316.8	1294	290.6	10	62.3	1.1795	0.158	3.304	0.011

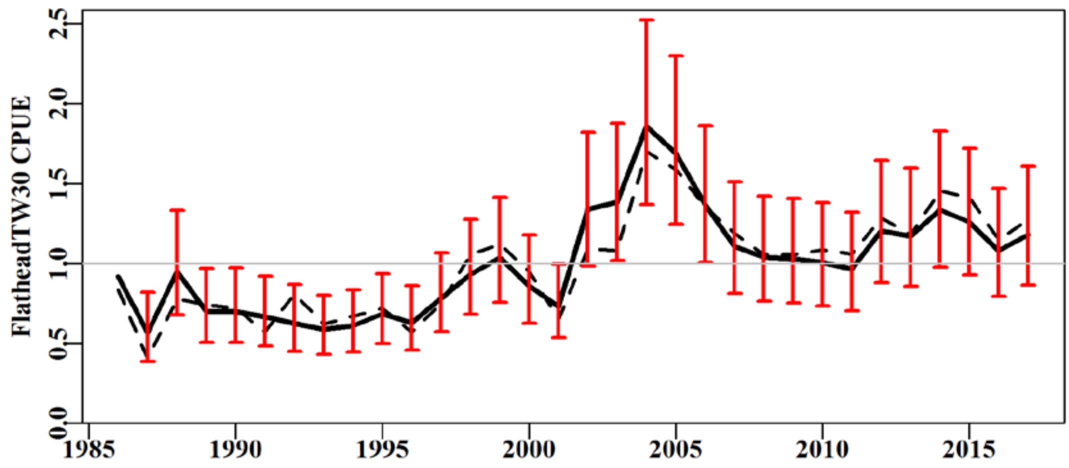


Figure 5.79. FlatheadTW30 standardization. The dashed black line represents the geometric mean catch rate, solid black line the standardized catch rates. The red bars are the 95% confidence intervals about the mean estimates. The graph scales both time-series of standardized catch rates relative to the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

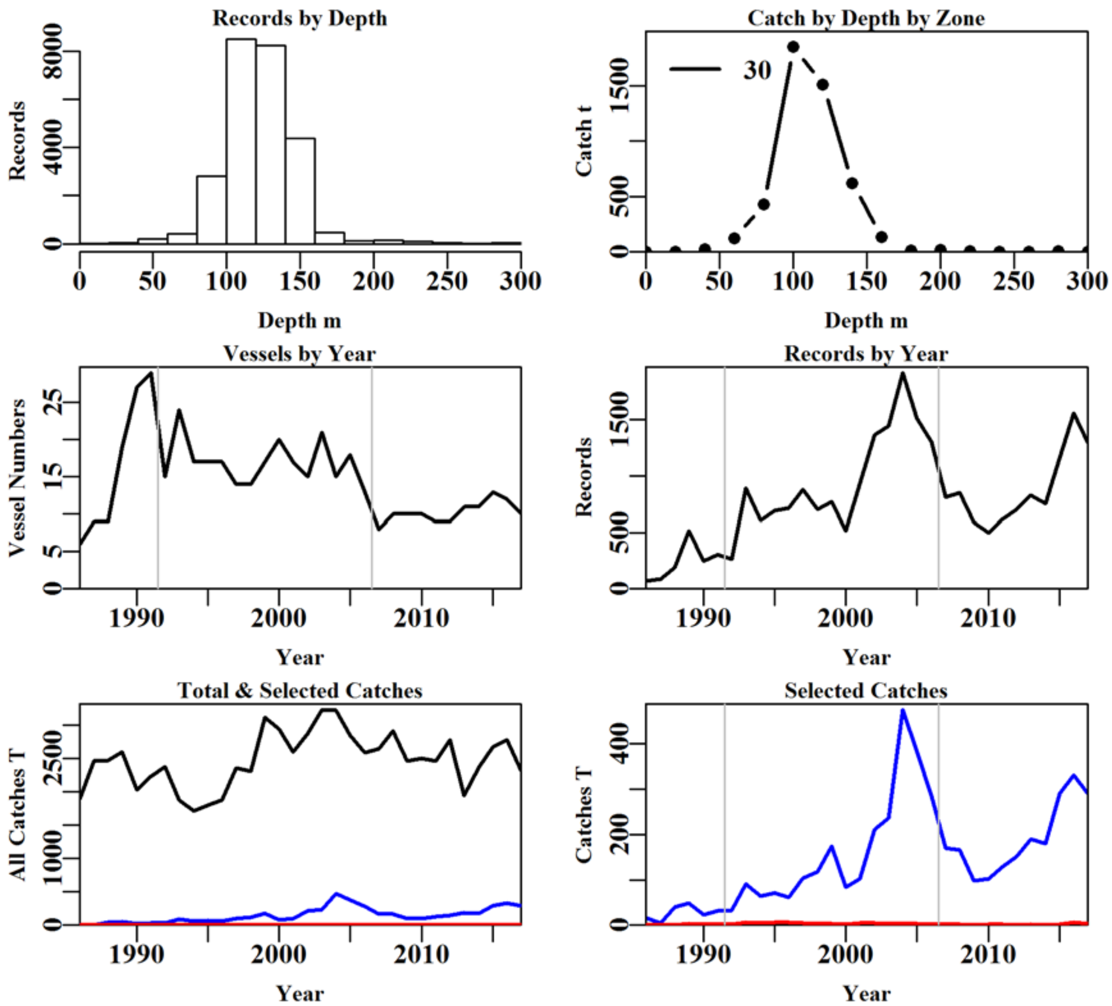


Figure 5.80. FlatheadTW30 fishery details. The bottom left plot depicts all known catches (top black line), and all selected catches used in the analysis (middle blue line); the lower red line: selected catches < 30 kg).

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	611386	524453	510220	501578	26390	255470	255440
Difference	0	86933	14233	8642	475188	843	3
Catch	80360.77	70041.38	68650.582	67572.187	4920.793	4764.3198	4763.90
Difference	0.00	10319.39	1390.801	1078.395	62651.394	156.4727	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	3720	29475	2459	25544	32	7.6	0.00
Vessel	1809	27151	4783	25544	125	14.6	6.97
DepCat	578	25844	6090	25544	140	18.6	4.07
DayNight	319	25577	6357	25544	143	19.5	0.83
Month	21	25259	6675	25544	154	20.4	0.97
Month:DepCat	-589	24390	7544	25544	296	22.7	2.30
DayNight:Month	-14	25177	6757	25544	178	20.6	0.18

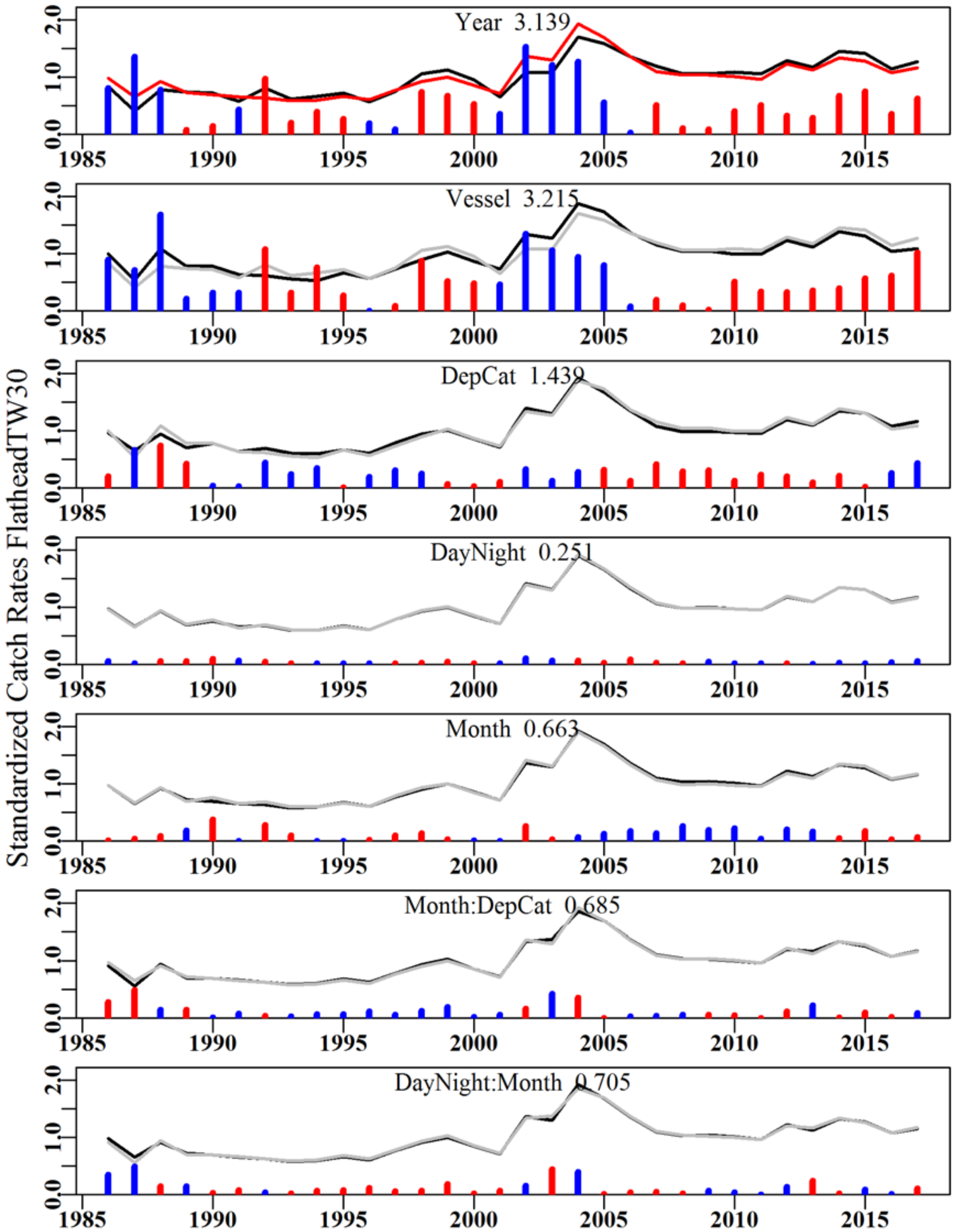


Figure 5.81. FlatheadTW30. The influence of each factor on the optimal standardization. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by vertical bars with blue bars indicating the optimum model is higher than the geometric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

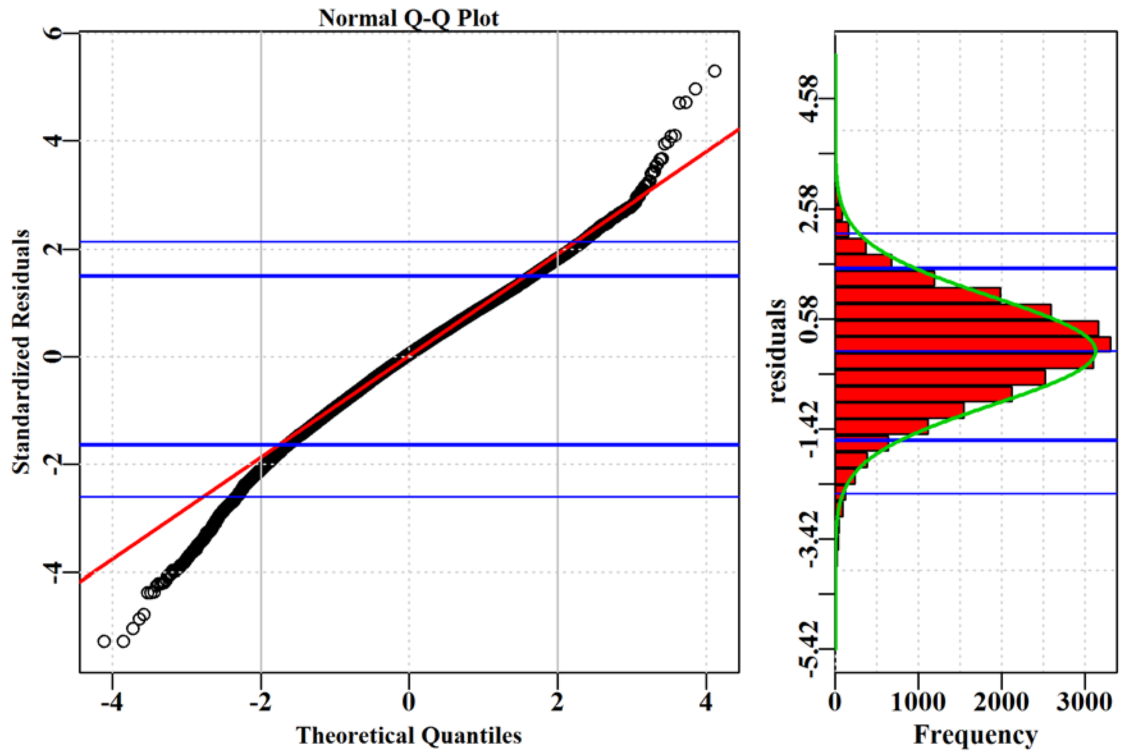


Figure 5.82. FlatheadTW30 diagnostic plots. The distribution of residuals from the optimum fit. The qqplot indicates the fit to the expected normality, while the histogram of residuals illustrates the 90% quantiles to indicate the intensity of any lack of fit at the margins of the distribution.

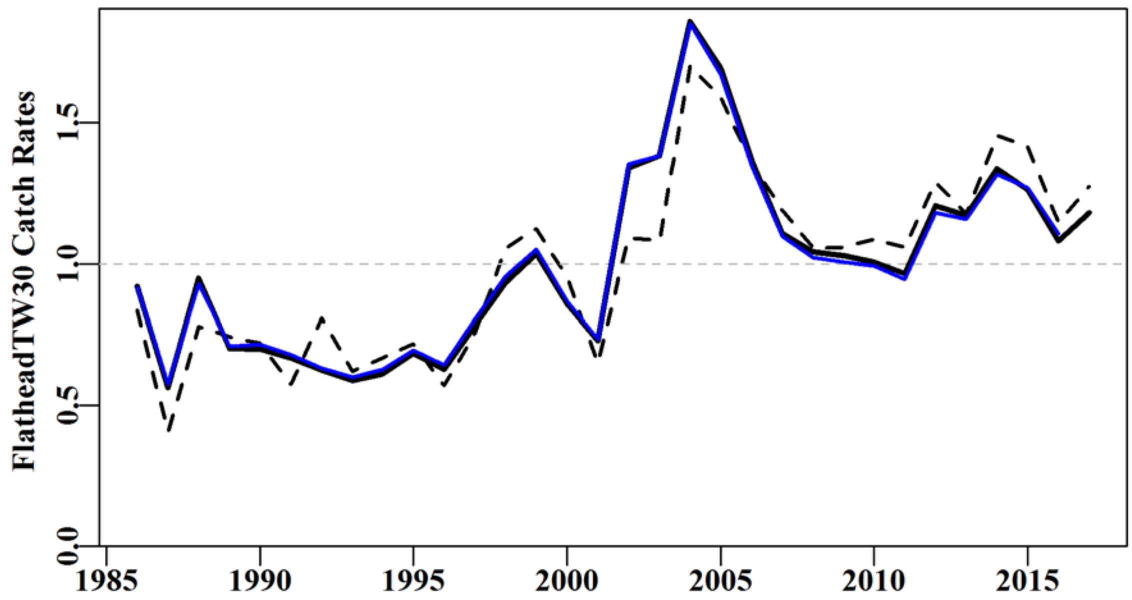


Figure 5.83. FlatheadTW30. A comparison of the previous year's standardization (blue line) with this year's. They should lie on top of each other, although small deviations may relate to data adjustments, particularly in very recent years.

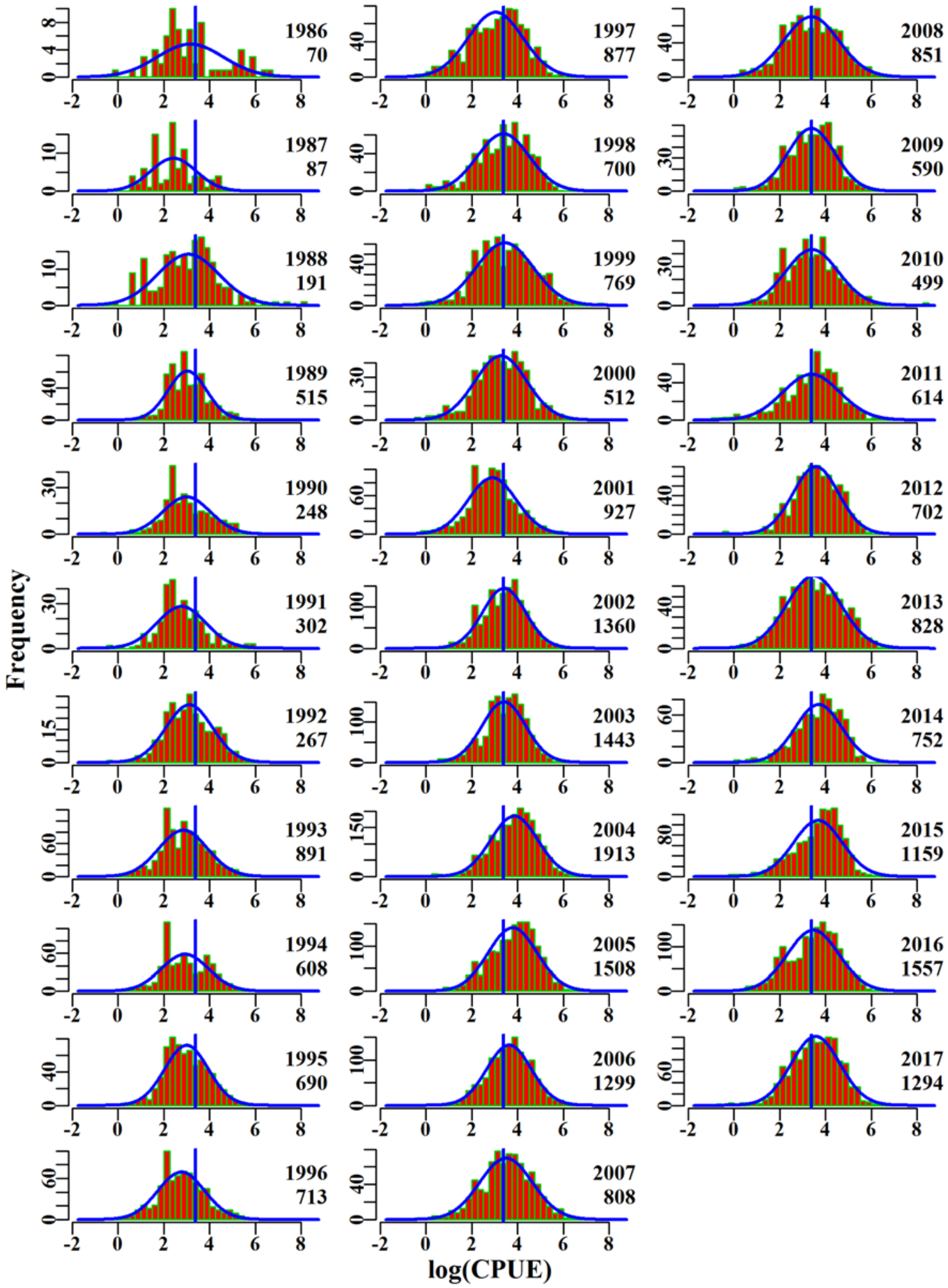


Figure 5.84. FlatheadTW30. The log(CPUE) for each year of data available the blue lines are normal distributions fitted to the histogram frequencies. The numbers in each plot are the year and number of records.

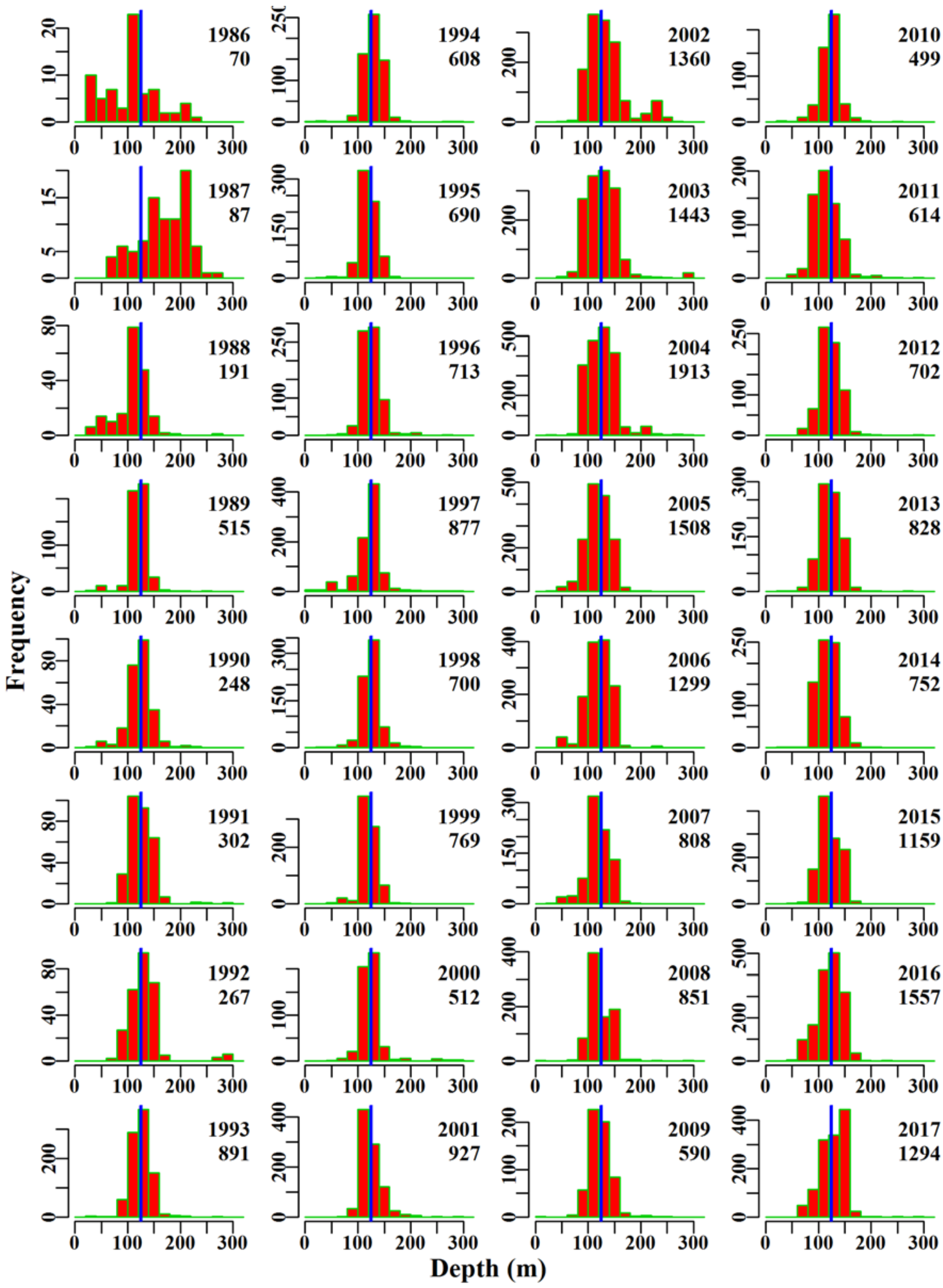


Figure 5.85. FlatheadTW30. The average Depth of fishing for each year of data available to illustrate the development of the fishery through time. The numbers in each plot are the year and number of records.

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 - 2017 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. It has remained above average in 2015 and 2016 and dropped below average in 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 - 2017

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	0.7981	0.000	64.431	0.067
1987	2461.3	8056	1004.2	86	41.6	1.0642	0.016	43.737	0.044
1988	2469.5	9149	1169.2	86	42.2	1.1643	0.016	47.288	0.040
1989	2599.1	8802	1206.0	74	44.8	1.1642	0.016	46.430	0.038
1990	2032.3	7701	1212.0	64	52.3	1.3870	0.017	27.684	0.023
1991	2230.2	7733	1134.5	57	52.0	1.3049	0.017	30.378	0.027
1992	2375.4	6860	894.8	54	43.9	1.0283	0.017	29.864	0.033
1993	1879.1	8639	982.2	57	38.8	1.0421	0.017	38.094	0.039
1994	1710.4	10190	894.7	55	29.9	0.7561	0.016	62.692	0.070
1995	1800.6	10232	985.2	54	31.6	0.7994	0.016	65.863	0.067
1996	1879.9	10984	952.3	58	29.3	0.7132	0.016	75.637	0.079
1997	2356.0	10265	988.7	61	31.2	0.7149	0.016	64.965	0.066
1998	2306.4	9953	996.8	52	32.5	0.7554	0.016	63.008	0.063
1999	3117.7	10338	1124.7	57	36.2	0.9113	0.016	56.799	0.051
2000	2945.6	12859	1641.8	60	51.9	1.0034	0.015	62.596	0.038
2001	2599.5	11659	1307.3	52	39.4	0.9674	0.016	52.699	0.040
2002	2876.3	12364	1447.6	49	39.3	1.0514	0.016	55.469	0.038
2003	3229.9	12794	1583.8	52	41.4	1.0370	0.015	58.188	0.037
2004	3222.8	12155	1336.5	52	36.4	0.9015	0.016	62.849	0.047
2005	2844.1	10588	1143.5	49	34.2	0.7734	0.016	62.412	0.055
2006	2585.8	9072	1138.0	45	40.2	0.9360	0.017	43.946	0.039
2007	2648.3	6280	1067.2	25	55.1	1.1357	0.018	21.678	0.020
2008	2912.3	7194	1307.6	27	56.3	1.1955	0.018	26.303	0.020
2009	2460.5	6214	1037.7	26	51.4	1.1035	0.018	22.375	0.022
2010	2502.3	6685	1086.7	25	49.2	1.0638	0.018	25.062	0.023
2011	2465.9	6605	1070.4	24	52.4	1.0491	0.018	23.777	0.022
2012	2780.6	6795	1149.3	25	54.6	1.1537	0.018	25.865	0.023
2013	1941.0	5587	682.8	24	37.4	0.8744	0.019	25.723	0.038
2014	2369.9	6337	943.4	25	46.0	1.0255	0.018	22.647	0.024
2015	2667.9	6358	983.6	30	48.4	1.1541	0.018	15.754	0.016
2016	2775.5	5437	844.2	27	50.4	1.0901	0.019	14.673	0.017
2017	2316.8	4847	665.9	23	44.1	0.8812	0.020	18.208	0.027

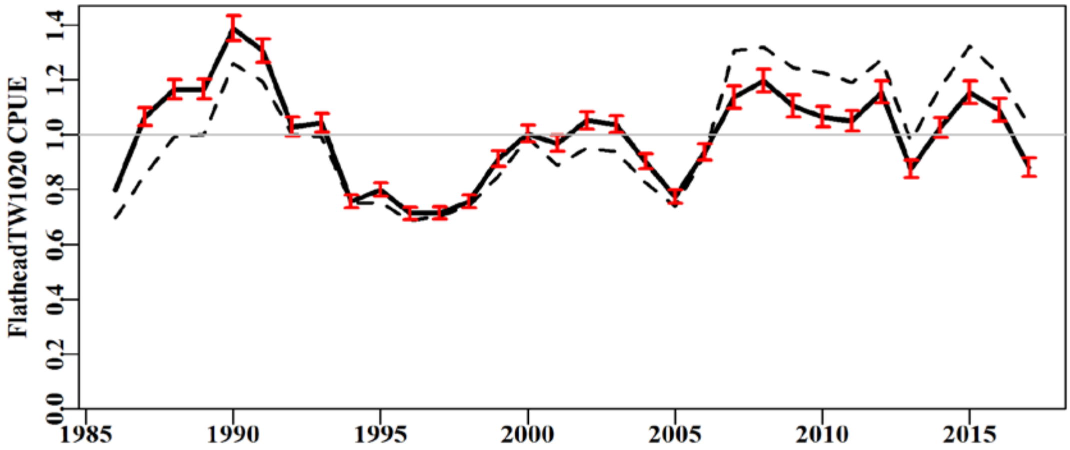


Figure 5.86. FlatheadTW1020 standardization. The dashed black line represents the geometric mean catch rate, solid black line the standardized catch rates. The red bars are the 95% confidence intervals about the mean estimates. The graph scales both time-series of standardized catch rates relative to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

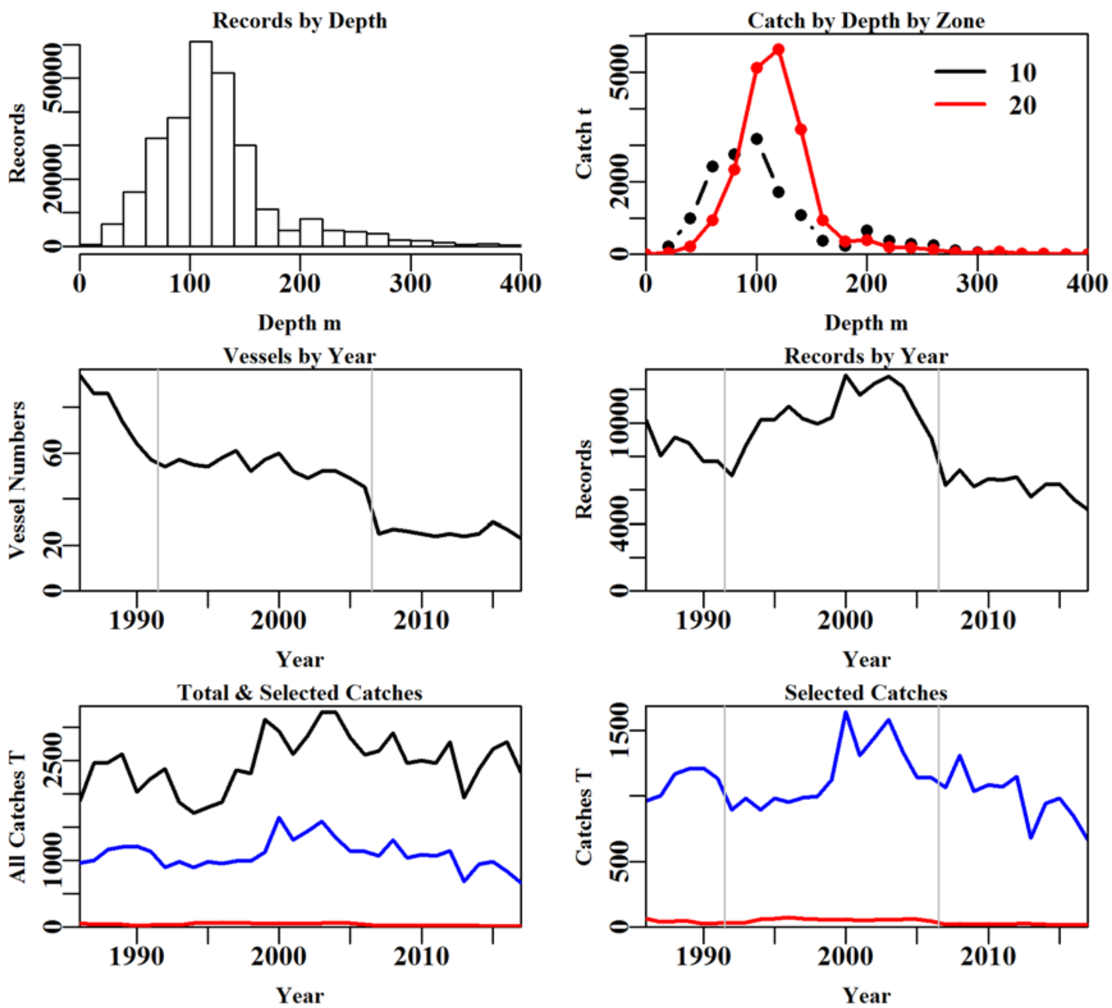


Figure 5.87. FlatheadTW1020 fishery details. The bottom left plot depicts all known catches (top black line), and all selected catches used in the analysis (middle blue line); the lower red line: selected catches < 30 kg).

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	611386	524453	516741	507998	353861	279221	278917
Difference	0	86933	7712	8743	154137	74640	304
Catch	80360.77	70041.38	69102.4535	68017.139	51715.33	34980.67	34944.993
Difference	0.00	10319.39	938.9292	1085.315	16301.81	16734.66	35.674

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	44849	327498	11694	278917	32	3.4	0.00
Vessel	14887	293749	45443	278917	218	13.3	9.89
DepCat	6162	284661	54531	278917	238	16.0	2.68
Month	5246	283706	55486	278917	249	16.3	0.28
DayNight	4858	283306	55887	278917	252	16.4	0.12
Zone	4803	283247	55945	278917	253	16.4	0.02
Zone:Month	2536	280932	58260	278917	264	17.1	0.68
Zone:DepCat	1923	280297	58895	278917	273	17.3	0.86

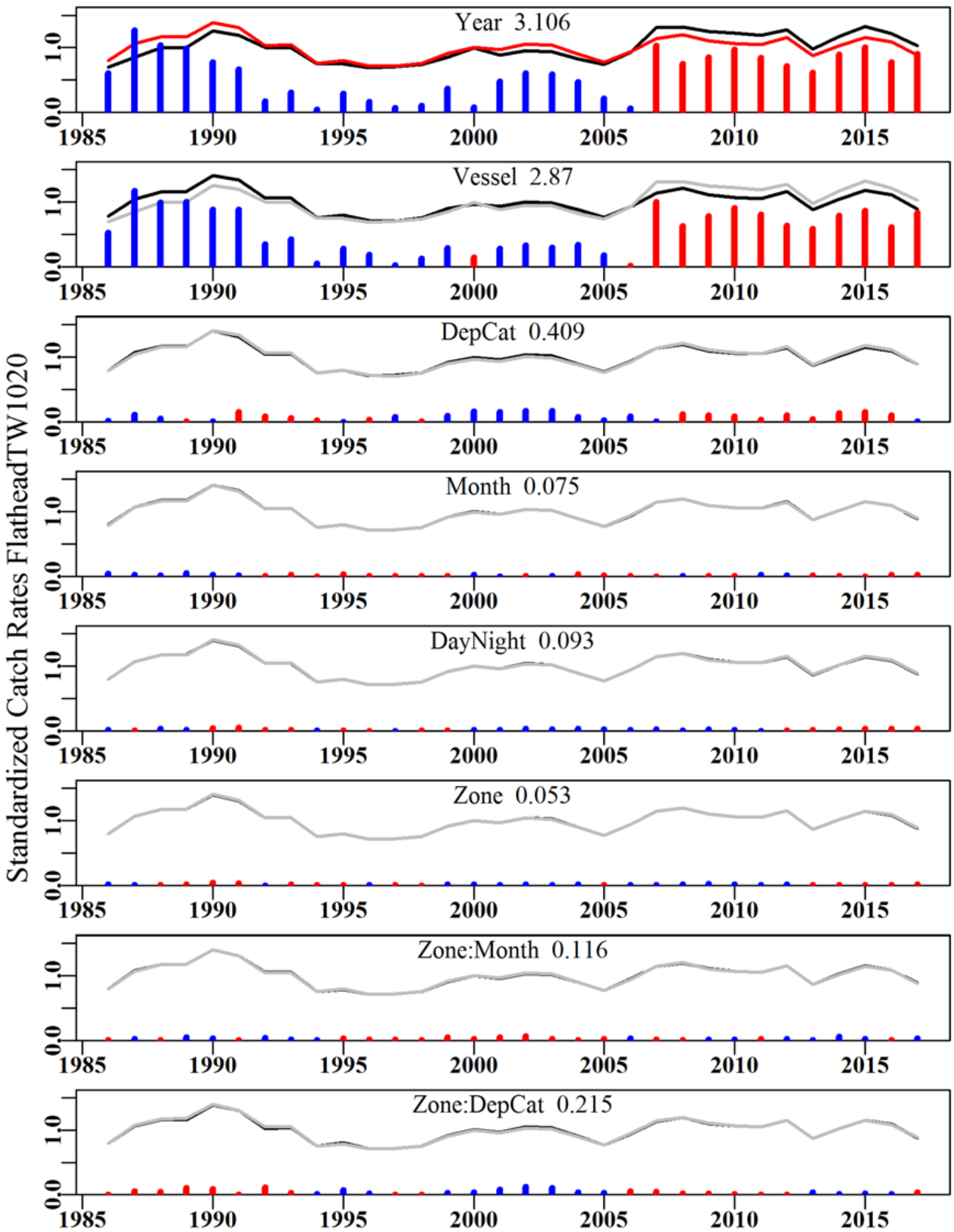


Figure 5.88. FlatheadTW1020. The influence of each factor on the optimal standardization. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by vertical bars with blue bars indicating the optimum model is higher than the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

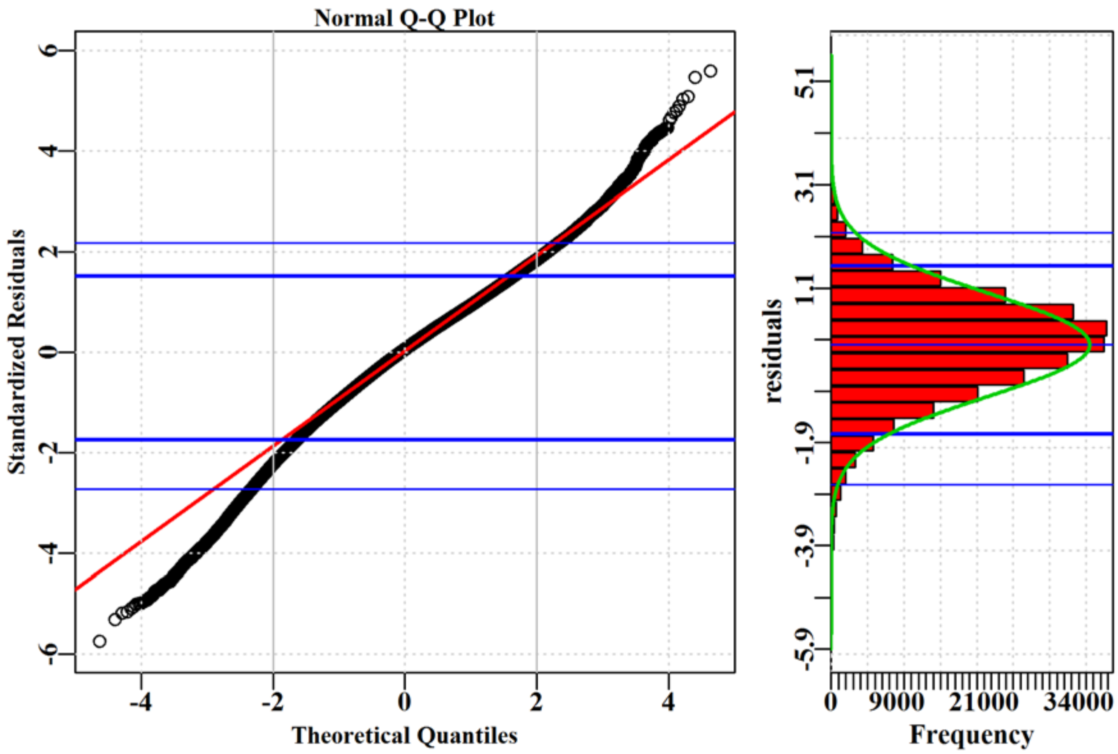


Figure 5.89. FlatheadTW1020. diagnostic plots. The distribution of residuals from the optimum fit. The qqplot indicates the fit to the expected normality, while the histogram of residuals illustrates the 90% quantiles to indicate the intensity of any lack of fit at the margins of the distribution.

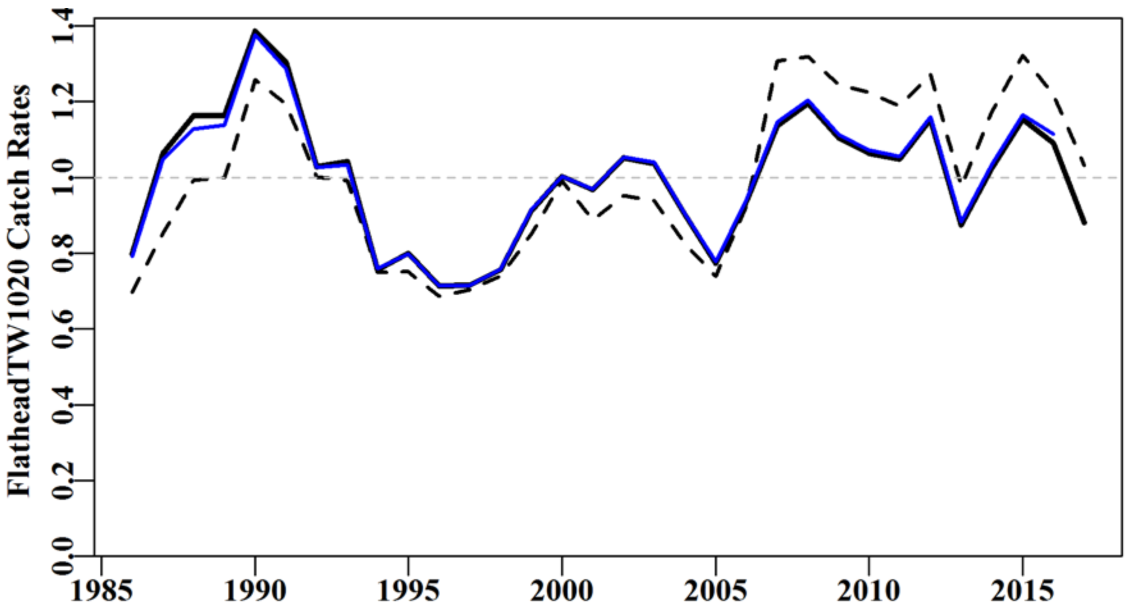


Figure 5.90. FlatheadTW1020. A comparison of the previous year's standardization (blue line) with this year's. They should lie on top of each other, although small deviations may relate to data adjustments, particularly in very recent years.

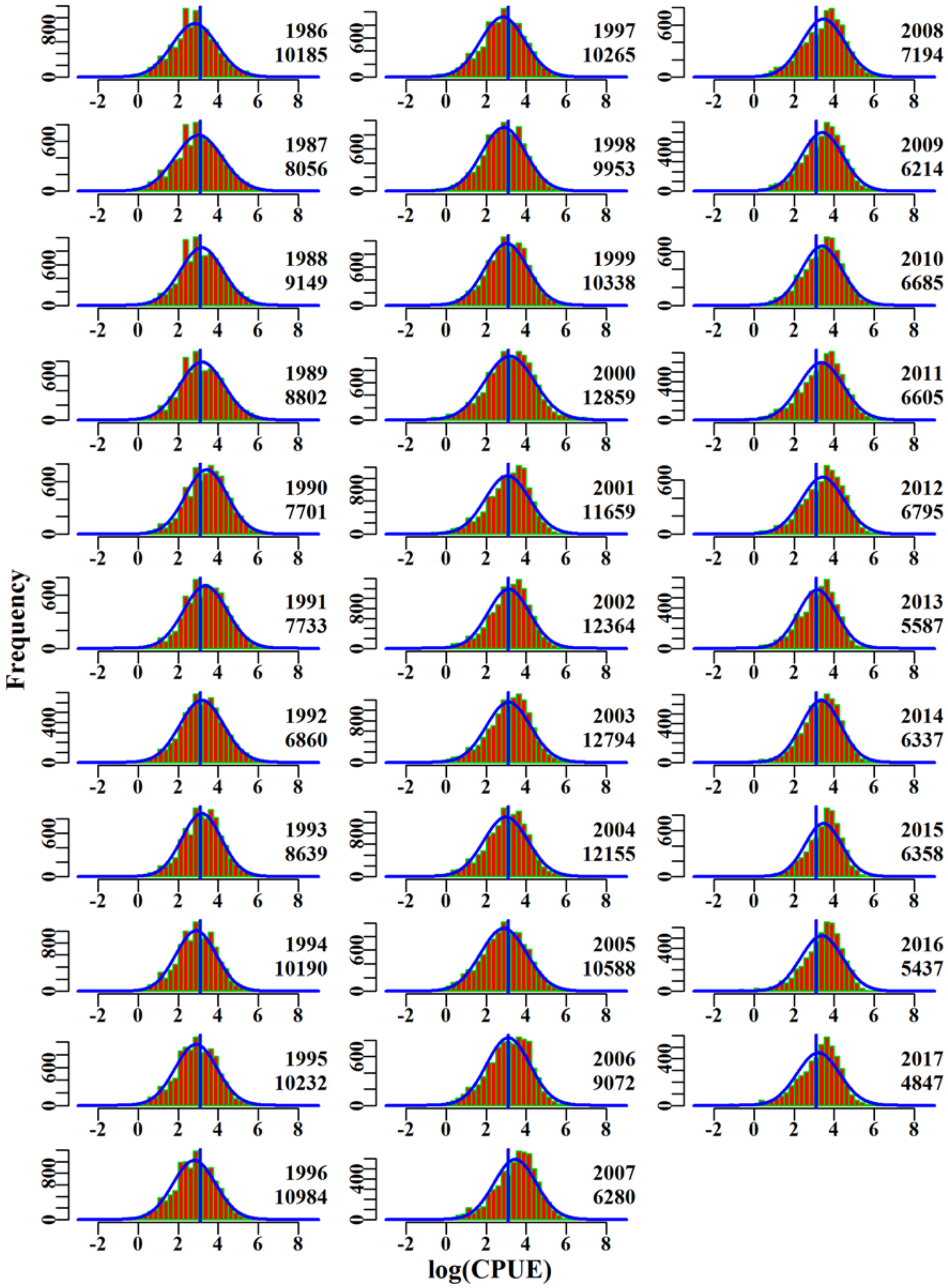


Figure 5.91. FlatheadTW1020. The log(CPUE) for each year of data available the blue lines are normal distributions fitted to the histogram frequencies. The numbers in each plot are the year and number of records.

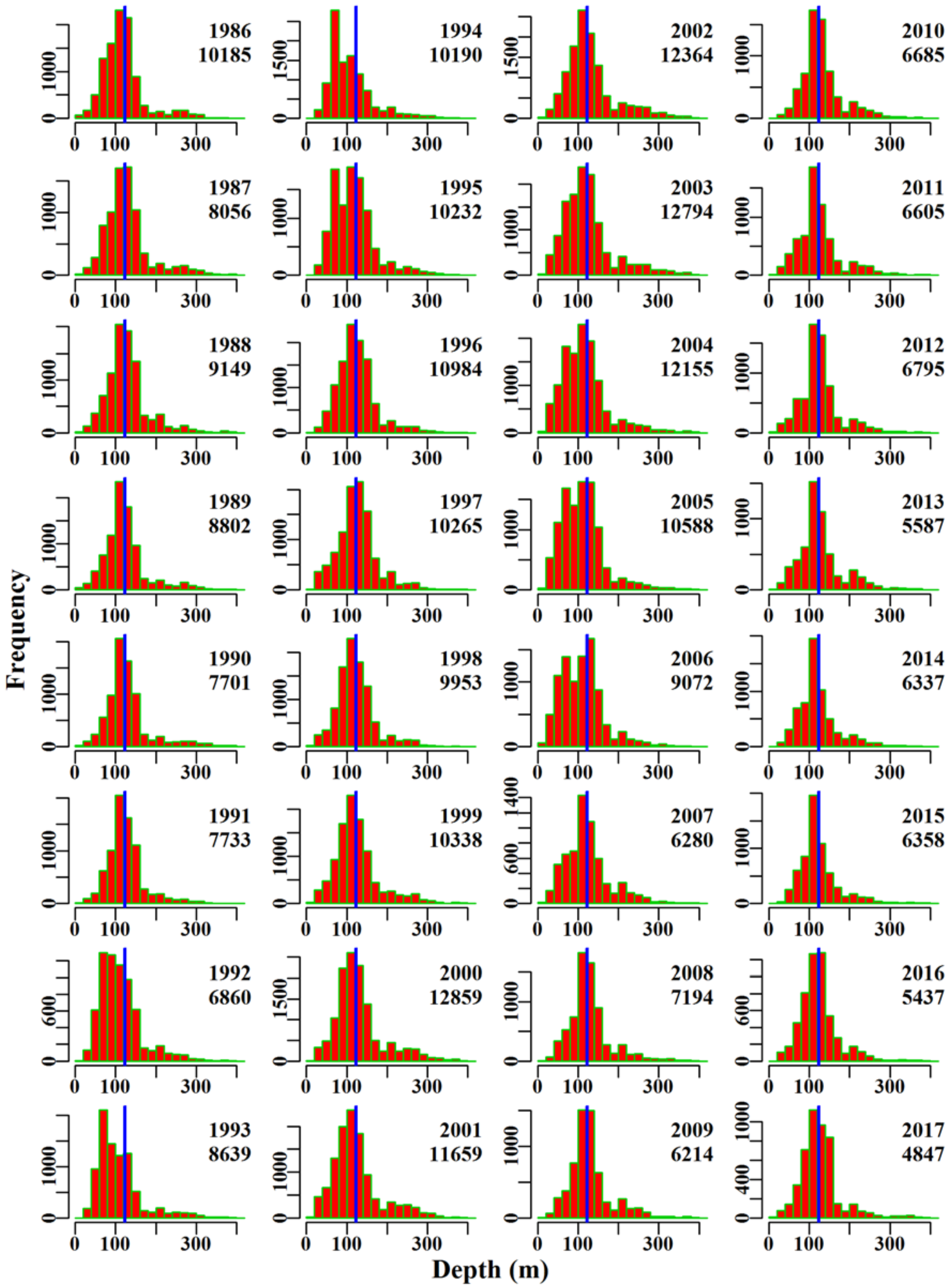


Figure 5.92. FlatheadTW1020. The average Depth of fishing for each year of data available to illustrate the development of the fishery through time. The numbers in each plot are the year and number of records.

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 - 2017 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 below average since 2011 (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 - 2017

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	1.1036	0.000	26.255	0.035
1987	2461.3	5532	1340.9	23	352.7	1.5515	0.023	25.075	0.019
1988	2469.5	5745	1074.7	25	268.3	1.6911	0.023	21.449	0.020
1989	2599.1	5384	1138.0	27	297.1	1.4780	0.024	27.184	0.024
1990	2032.3	4462	568.1	24	157.2	0.9917	0.025	28.665	0.050
1991	2230.2	4463	746.5	28	215.7	1.3453	0.025	24.633	0.033
1992	2375.4	6488	1193.7	23	233.4	1.4148	0.023	27.658	0.023
1993	1879.1	5906	531.6	25	114.0	0.8779	0.023	40.217	0.076
1994	1710.4	7162	632.8	24	124.9	0.7573	0.023	40.569	0.064
1995	1800.6	5420	648.6	21	204.7	0.7753	0.024	24.806	0.038
1996	1879.9	7508	742.7	22	139.0	0.7277	0.022	44.616	0.060
1997	2356.0	8279	1136.0	20	192.2	0.9500	0.022	37.876	0.033
1998	2306.4	9800	1126.5	21	147.9	0.8014	0.022	48.033	0.043
1999	3117.7	8669	1679.4	23	269.0	1.1598	0.022	25.632	0.015
2000	2945.6	7295	1079.7	19	199.3	0.8626	0.023	32.454	0.030
2001	2599.5	7781	1066.4	19	196.4	0.8095	0.023	32.654	0.031
2002	2876.3	8124	1130.0	22	182.0	0.9586	0.023	31.327	0.028
2003	3229.9	8871	1186.6	23	168.5	0.9984	0.022	30.001	0.025
2004	3222.8	7644	1234.5	22	194.6	0.9879	0.023	24.994	0.020
2005	2844.1	7008	1104.9	22	184.3	1.0005	0.023	22.184	0.020
2006	2585.8	5461	950.5	21	233.5	0.9830	0.025	15.784	0.017
2007	2648.3	5472	1160.9	15	293.4	1.1912	0.025	14.892	0.013
2008	2912.3	6118	1261.6	15	280.1	1.0725	0.024	18.042	0.014
2009	2460.5	5433	1153.0	15	318.0	1.1056	0.025	17.949	0.016
2010	2502.3	5997	1159.0	15	274.1	0.9960	0.024	15.542	0.013
2011	2465.9	6788	1105.0	14	207.9	0.9254	0.024	20.671	0.019
2012	2780.6	7154	1370.7	14	299.4	0.8769	0.023	19.403	0.014
2013	1941.0	7200	929.5	14	168.8	0.6491	0.023	30.599	0.033
2014	2369.9	8327	1160.2	14	186.4	0.7069	0.023	32.787	0.028
2015	2667.9	8619	1311.3	15	196.1	0.7459	0.023	39.398	0.030
2016	2775.5	9247	1468.1	16	205.7	0.7762	0.023	40.806	0.028
2017	2316.8	8602	1107.9	17	164.6	0.7284	0.023	42.395	0.038

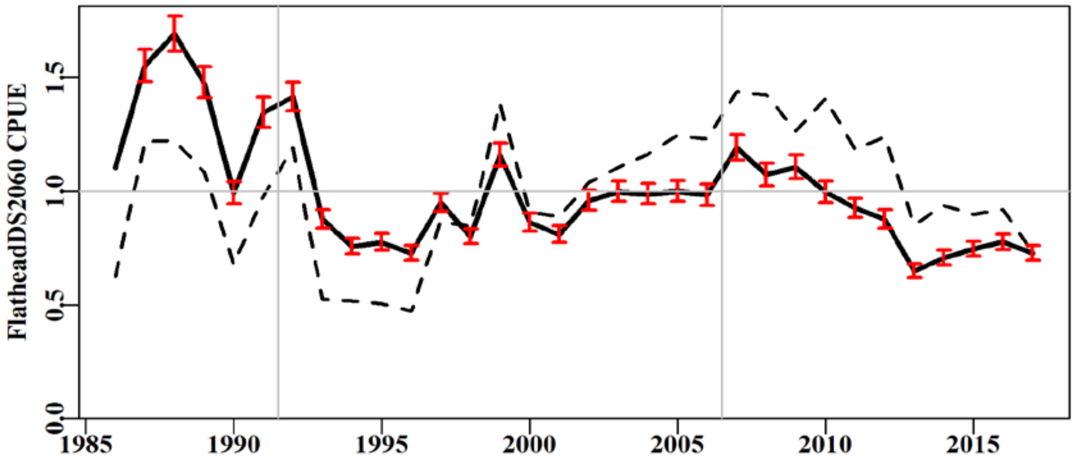


Figure 5.93. FlatheadDS2060 standardization. The dashed black line represents the geometric mean catch rate, solid black line the standardized catch rates. The red bars are the 95% confidence intervals about the mean estimates. The graph scales both time-series of standardized catch rates relative to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

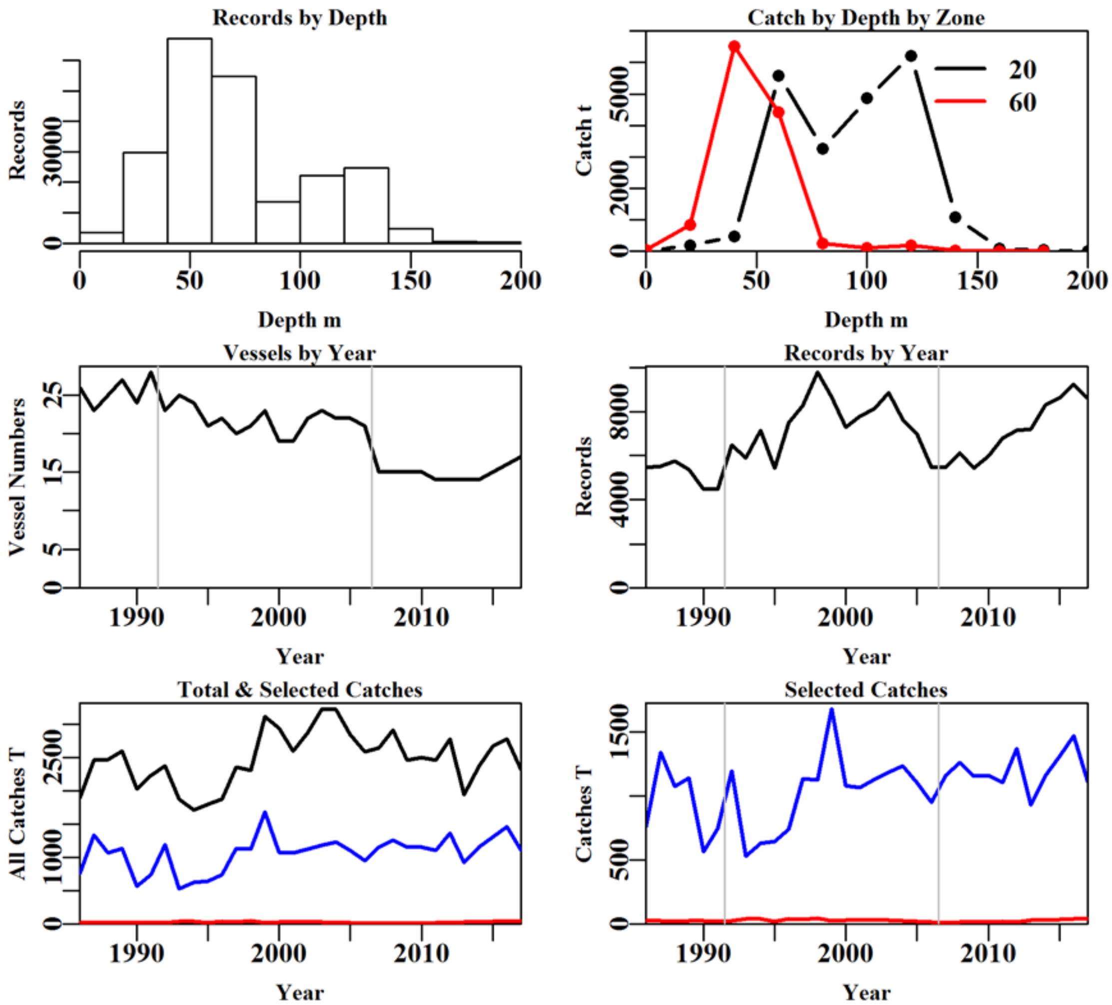


Figure 5.94. FlatheadDS2060 fishery details. The bottom left plot depicts all known catches (top black line), and all selected catches used in the analysis (middle blue line); the lower red line: selected catches < 30 kg).

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	611386	599260	555450	546866	349902	223256	221428
Difference	0	12126	43810	8584	196964	126646	1828
Catch	80360.77	80360.77	75679.591	74612.576	54117.83	34325.12	34259.3885
Difference	0.00	0.00	4681.183	1067.015	20494.74	19792.72	65.7285

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	170993	479161	20966	221428	32	4.2	0.00
DepCat	108371	361093	139034	221428	42	27.8	23.61
Month	97034	343036	157091	221428	53	31.4	3.61
Vessel	84282	323685	176442	221428	106	35.2	3.85
DayNight	79496	316755	183372	221428	109	36.6	1.39
Zone	77136	313394	186733	221428	110	37.3	0.67
Zone:Month	72842	307345	192782	221428	121	38.5	1.21
Zone:DepCat	76027	311802	188325	221428	119	37.6	0.32

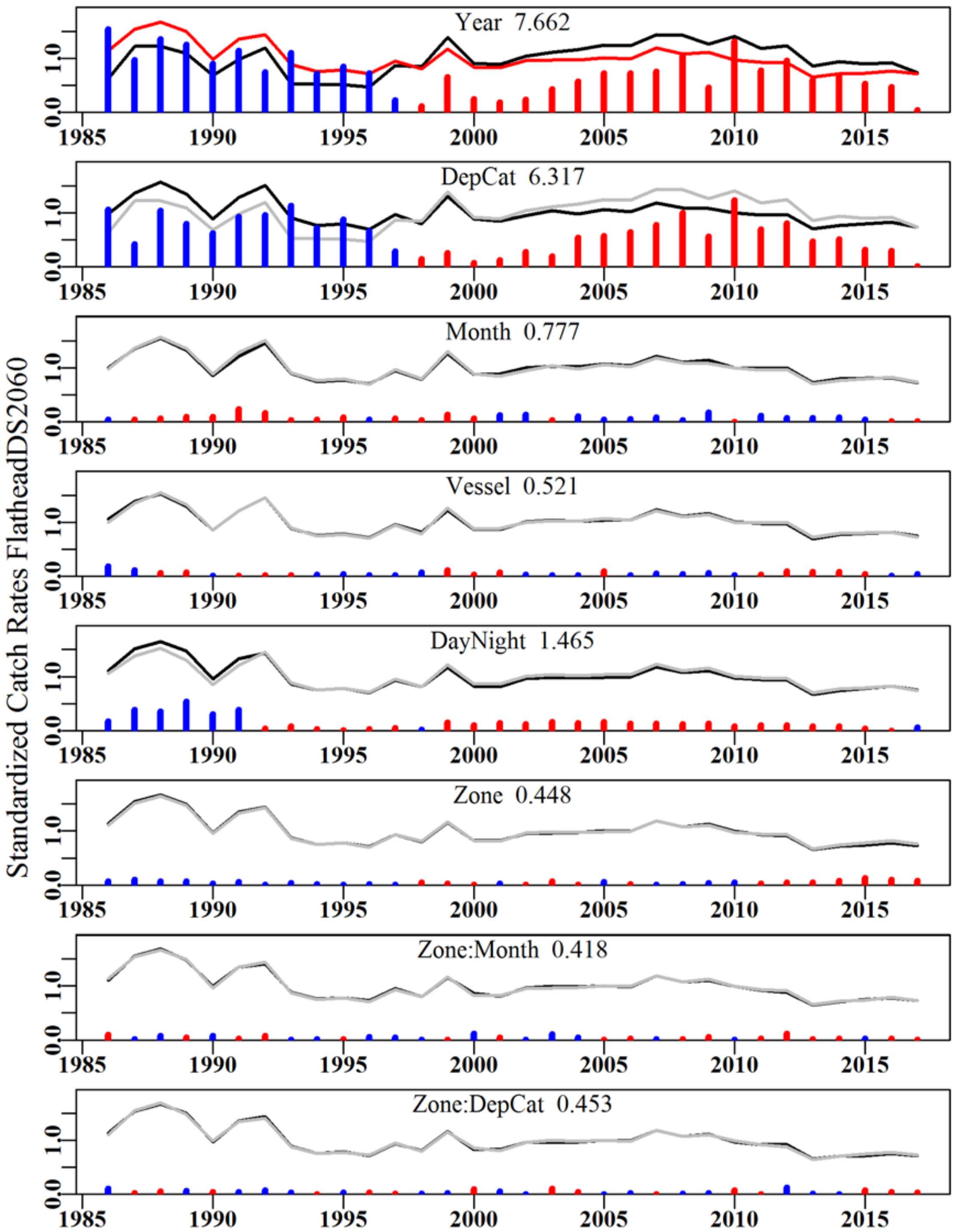


Figure 5.95. FlatheadDS2060. The influence of each factor on the optimal standardization. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by vertical bars with blue bars indicating the optimum model is higher than the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

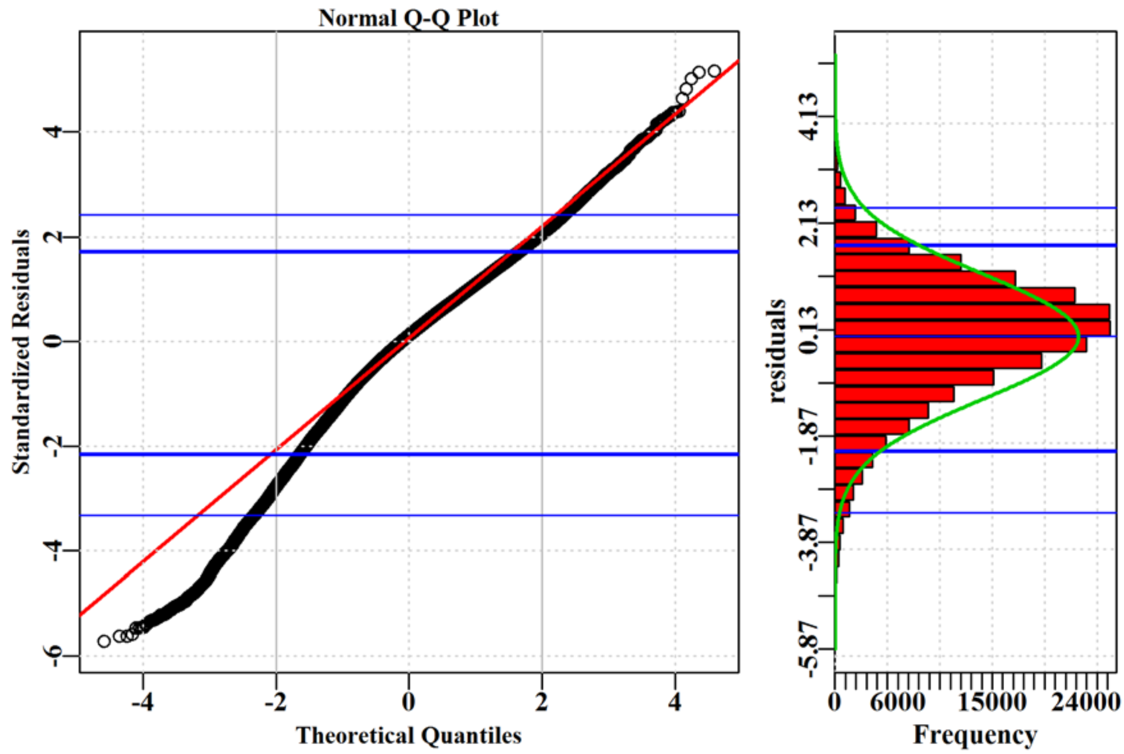


Figure 5.96. FlatheadDS2060 diagnostic plots. The distribution of residuals from the optimum fit. The qqplot indicates the fit to the expected normality, while the histogram of residuals illustrates the 90% quantiles to indicate the intensity of any lack of fit at the margins of the distribution.

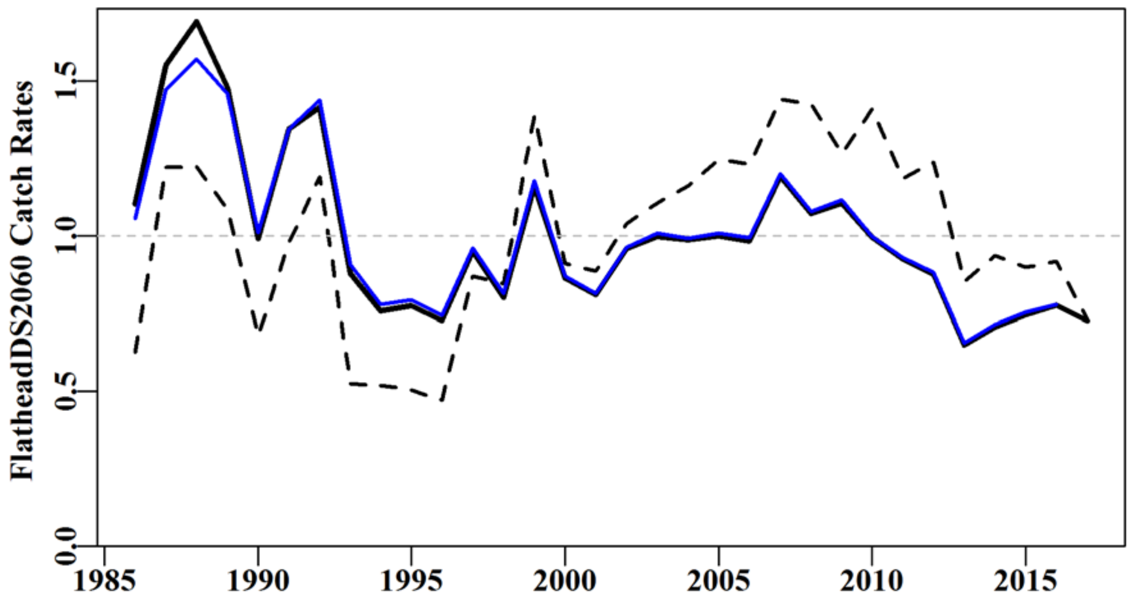


Figure 5.97. FlatheadDS2060. A comparison of the previous year's standardization (blue line) with this year's. They should lie on top of each other, although small deviations may relate to data adjustments, particularly in very recent years.

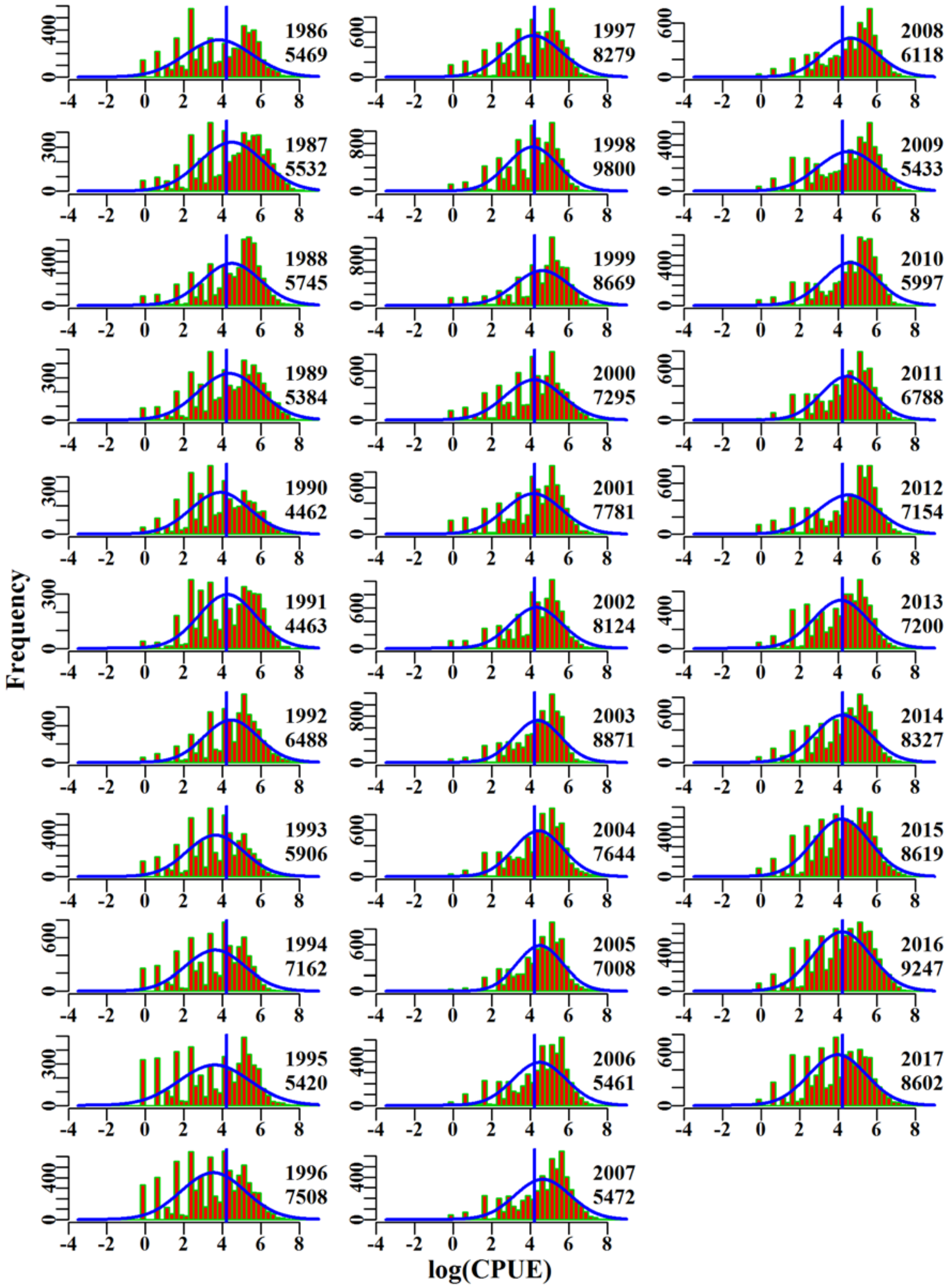


Figure 5.98. FlatheadDS2060. The log(CPUE) for each year of data available the blue lines are normal distributions fitted to the histogram frequencies. The numbers in each plot are the year and number of records.

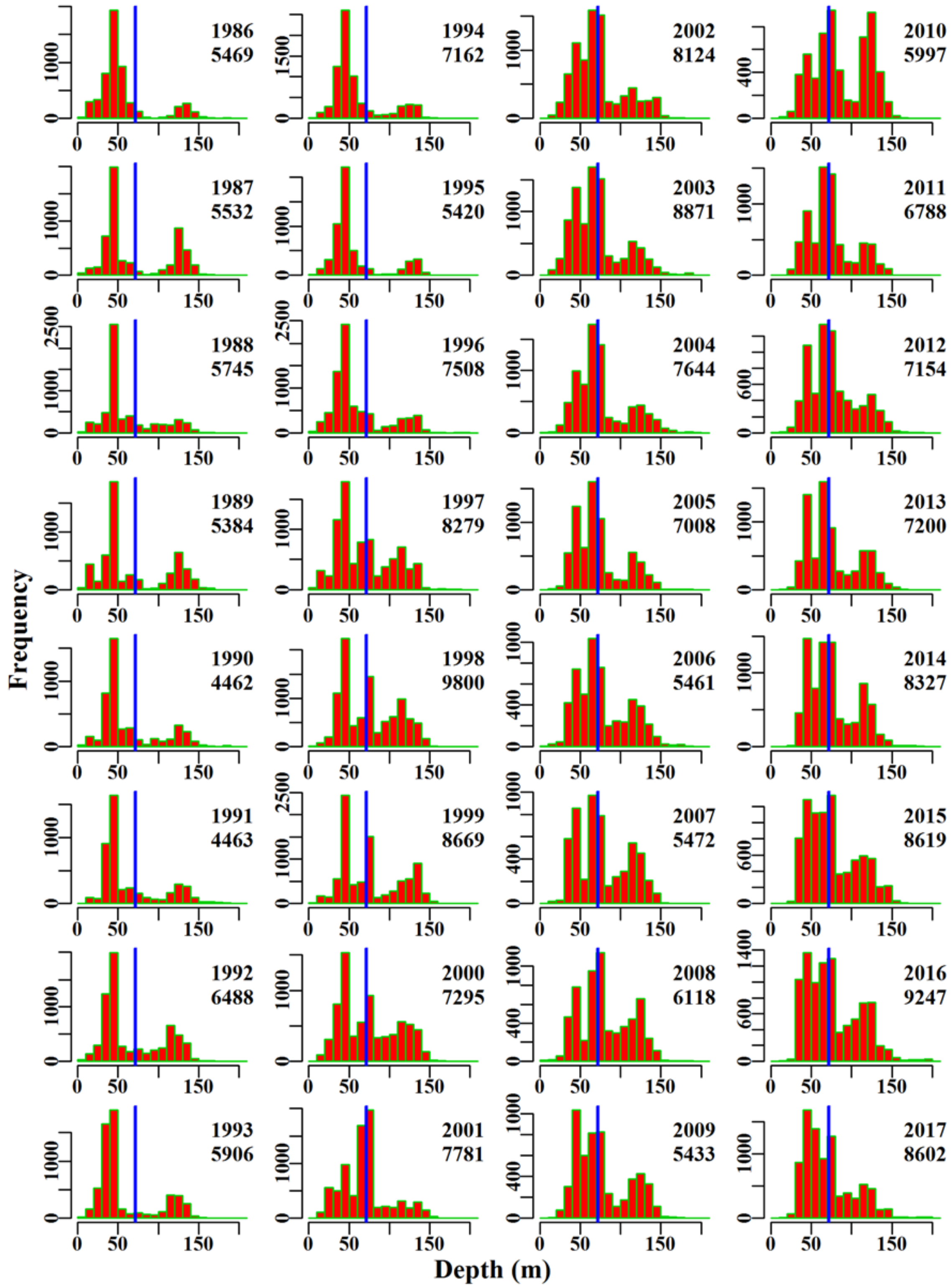


Figure 5.99. FlatheadDS2060. The average Depth of fishing for each year of data available to illustrate the development of the fishery through time. The numbers in each plot are the year and number of records.

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 - 2017 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 2017 was less compared to the previous year (38 t) and the lowest recorded in the series (i.e. from 1986 to 2017). 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 - 2017

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	1.8590	0.000	23.159	0.014
1987	1252.7	3903	1181.8	79	121.1	1.5917	0.034	17.828	0.015
1988	1125.5	3966	1078.0	75	95.2	1.7839	0.034	17.697	0.016
1989	714.3	2710	641.2	72	80.1	1.3186	0.038	15.566	0.024
1990	931.4	2573	785.7	58	104.9	1.6637	0.039	11.772	0.015
1991	1570.6	3320	1227.8	52	140.9	1.8389	0.037	14.869	0.012
1992	1636.7	3173	1514.1	48	198.7	2.3079	0.038	14.281	0.009
1993	1921.3	3755	1754.8	53	205.4	2.7747	0.036	16.091	0.009
1994	1487.7	5439	1329.1	53	111.4	2.0445	0.034	28.214	0.021
1995	1240.6	5675	1188.8	52	82.3	1.3198	0.033	34.359	0.029
1996	1344.0	5775	1297.5	55	90.4	1.1954	0.033	33.779	0.026
1997	1397.3	4363	1340.7	58	138.4	1.2497	0.035	25.498	0.019
1998	1553.7	4296	1526.0	49	187.0	1.4711	0.035	23.599	0.015
1999	1116.5	3934	1089.3	53	145.2	1.2308	0.036	21.181	0.019
2000	758.5	4661	734.3	53	80.4	0.8244	0.035	28.968	0.039
2001	742.3	4559	718.3	47	75.8	0.7829	0.035	29.022	0.040
2002	807.1	5188	770.8	49	69.5	0.7301	0.034	32.706	0.042
2003	615.6	4096	553.9	51	62.6	0.6258	0.036	27.500	0.050
2004	475.2	3951	447.7	50	52.0	0.5561	0.036	27.007	0.060
2005	483.5	3768	451.1	46	47.4	0.6182	0.037	26.639	0.059
2006	325.5	2573	302.3	42	46.5	0.5774	0.040	19.703	0.065
2007	216.3	1870	208.1	23	46.8	0.5694	0.045	13.417	0.064
2008	183.8	1921	179.3	25	35.3	0.5036	0.045	15.431	0.086
2009	160.5	1602	153.6	23	33.5	0.4311	0.048	12.758	0.083
2010	152.8	1838	146.2	24	28.9	0.4192	0.046	15.962	0.109
2011	87.3	1397	82.8	22	21.8	0.3063	0.050	10.828	0.131
2012	66.4	1345	61.9	21	18.2	0.2149	0.050	11.194	0.181
2013	62.7	1129	60.3	20	20.1	0.2726	0.053	9.787	0.162
2014	86.9	1410	82.6	22	25.9	0.3654	0.049	11.874	0.144
2015	52.2	1192	50.0	22	17.5	0.2251	0.053	10.106	0.202
2016	38.4	779	24.3	21	11.7	0.1690	0.062	6.289	0.259
2017	28.5	487	14.4	17	13.1	0.1590	0.075	4.349	0.301

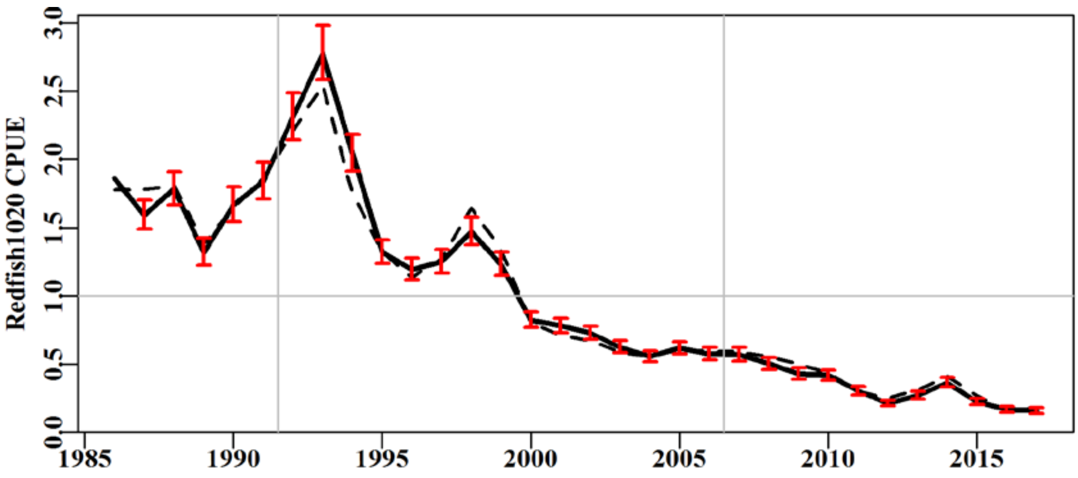


Figure 5.100. Redfish1020 standardization. The dashed black line represents the geometric mean catch rate, solid black line the standardized catch rates. The red bars are the 95% confidence intervals about the mean estimates. The graph scales both time-series of standardized catch rates relative to the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

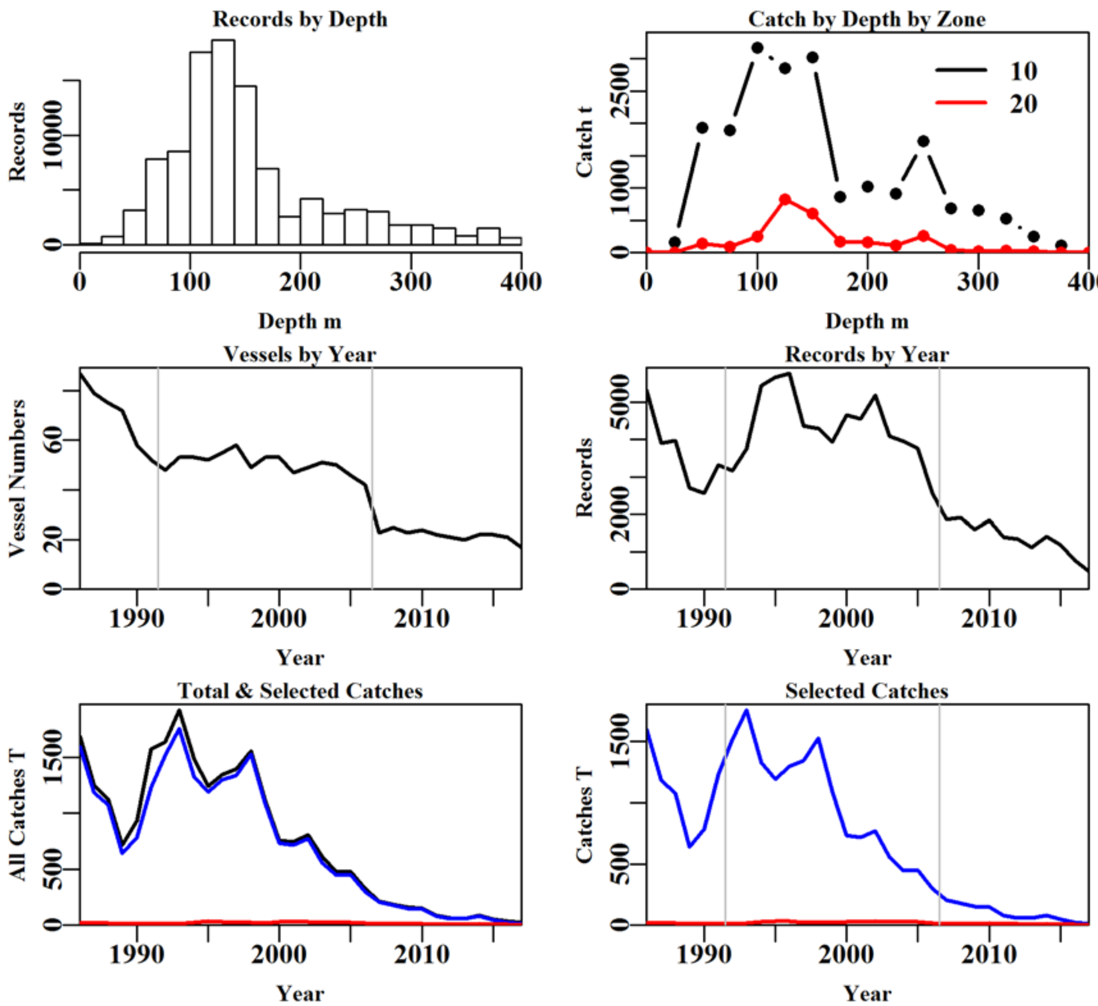


Figure 5.101. Redfish1020 fishery details. The bottom left plot depicts all known catches (top black line), and all selected catches used in the analysis (middle blue line); the lower red line: selected catches < 30 kg).

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	119122	113929	110497	109477	103083	102043	101984
Difference	0	5193	3432	1020	6394	1040	59
Catch	24490.17	23992.5471	23576.8046	23420.239	22752.1054	22596.5740	22594.5759
Difference	0.00	497.6199	415.7425	156.566	668.1332	155.5315	1.9981

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	110751	301918	37870	101984	32	11.1	0.00
Vessel	93344	253755	86033	101984	190	25.2	14.06
DepCat	87974	240664	99124	101984	206	29.0	3.85
Zone	86686	237638	102150	101984	207	29.9	0.89
DayNight	86031	236104	103684	101984	210	30.4	0.45
Month	85681	235245	104543	101984	221	30.6	0.25
Zone:Month	85550	234890	104898	101984	232	30.7	0.10
Zone:DepCat	85274	234233	105555	101984	237	30.9	0.29

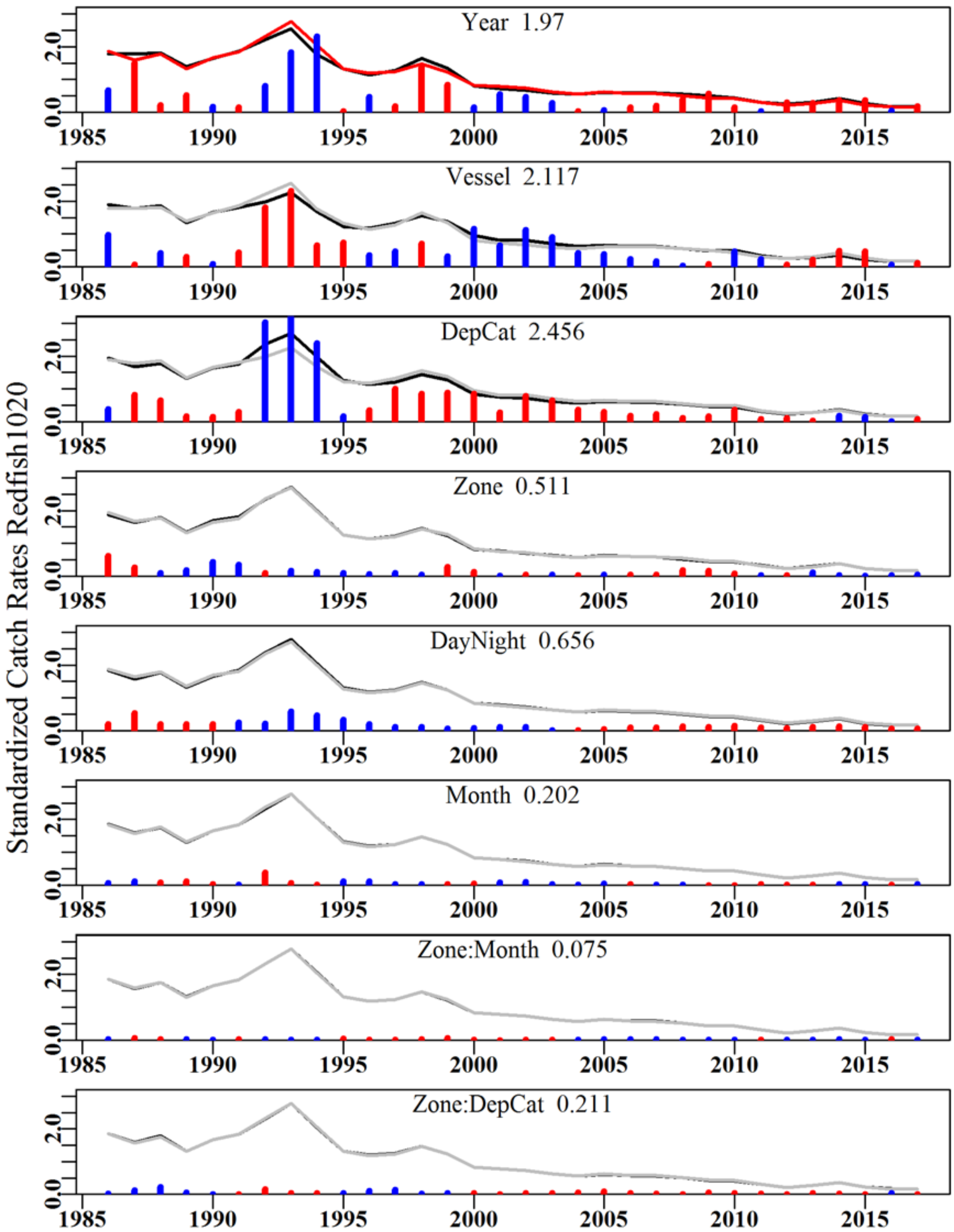


Figure 5.102. Redfish1020. The influence of each factor on the optimal standardization. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by vertical bars with blue bars indicating the optimum model is higher than the geometric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

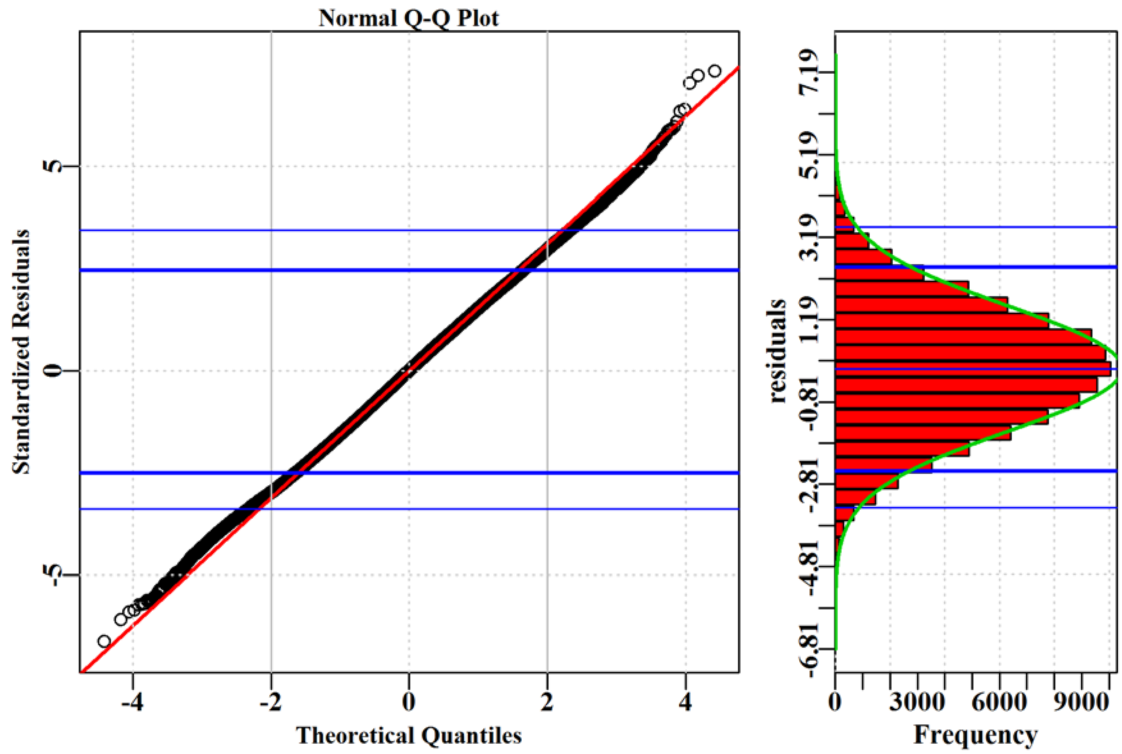


Figure 5.103. Redfish1020. diagnostic plots. The distribution of residuals from the optimum fit. The qqplot indicates the fit to the expected normality, while the histogram of residuals illustrates the 90% quantiles to indicate the intensity of any lack of fit at the margins of the distribution.

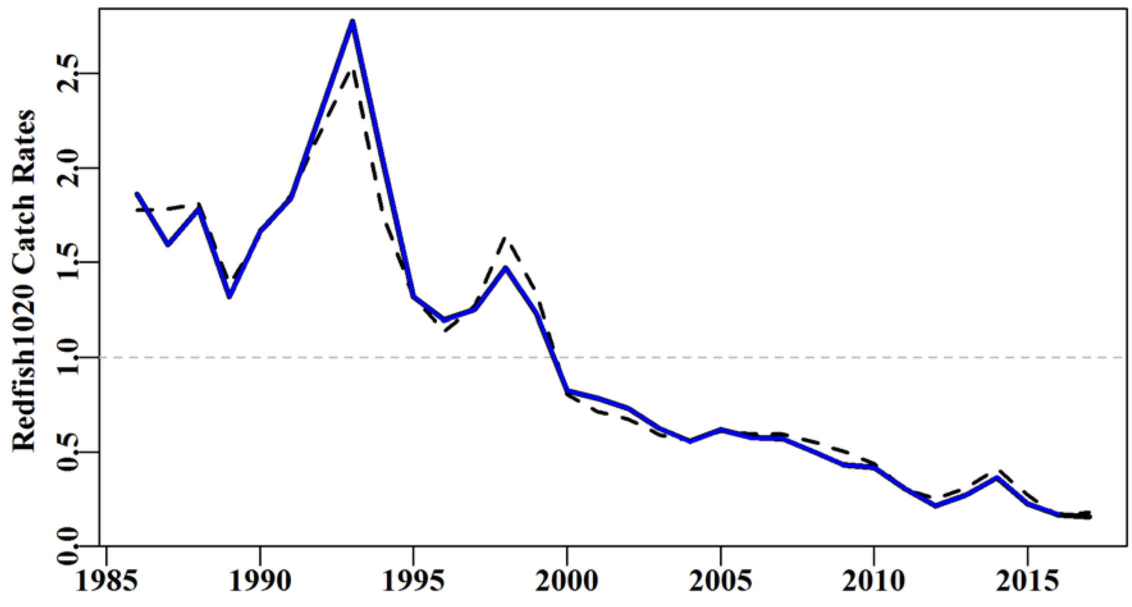


Figure 5.104. Redfish1020. A comparison of the previous year's standardization (blue line) with this year's. They should lie on top of each other, although small deviations may relate to data adjustments, particularly in very recent years.

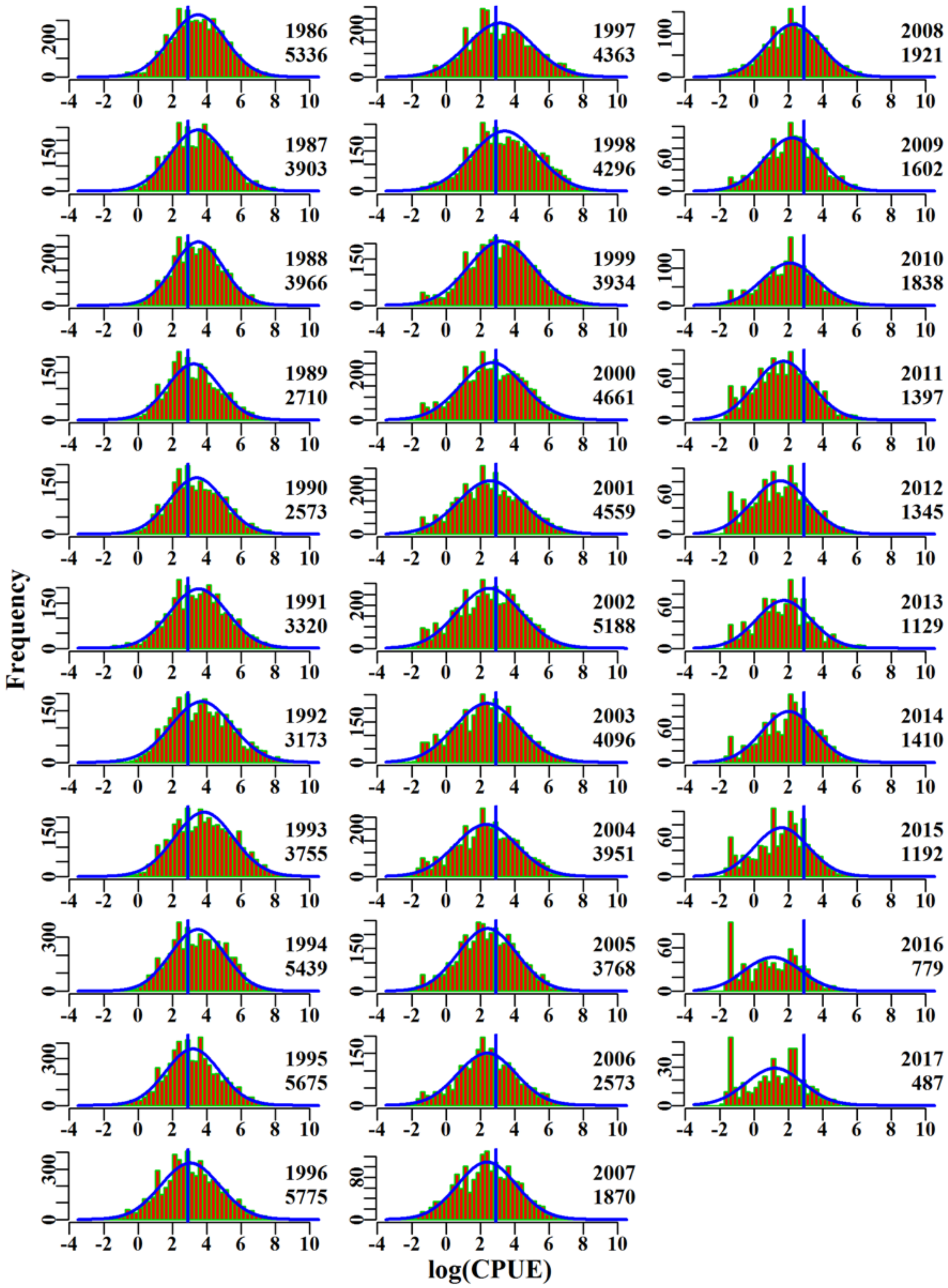


Figure 5.105. Redfish1020. The log(CPUE) for each year of data available the blue lines are normal distributions fitted to the histogram frequencies. The numbers in each plot are the year and number of records.

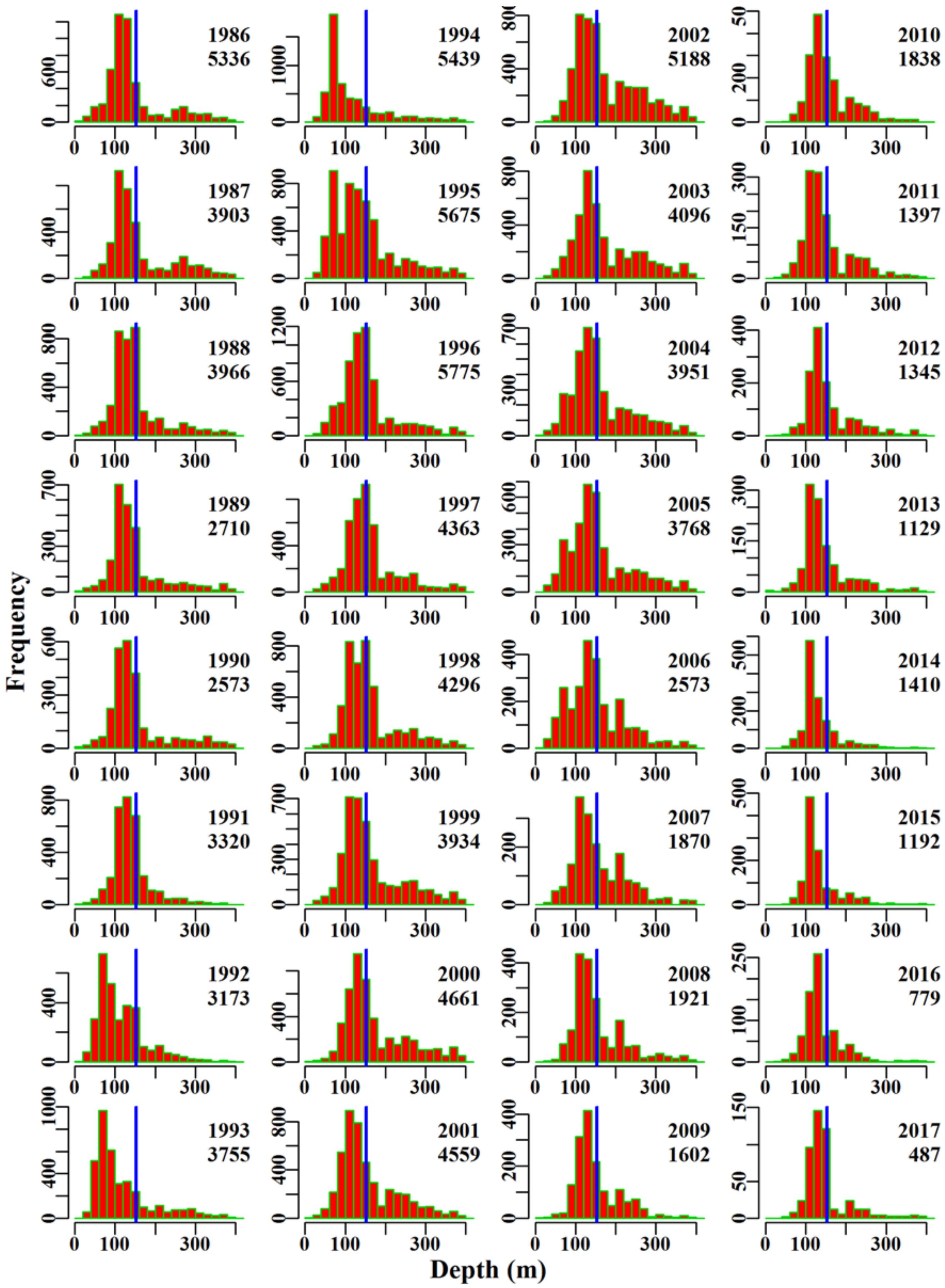


Figure 5.106. Redfish1020. The average Depth of fishing for each year of data available to illustrate the development of the fishery through time. The numbers in each plot are the year and number of records.

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 - 2017 were used in the analysis. Recently, Ocean Blue-Eye Trevalla (37445014 - *Schedophilus labyrinthicus*) was also included in this analysis (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 - 2017

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	2.3255	0.000	1.453	0.159
1987	15.5	189	10.0	14	17.6	2.2305	0.137	1.769	0.177
1988	105.2	305	19.3	21	22.7	2.7335	0.130	3.404	0.176
1989	88.1	313	33.3	32	38.2	3.0595	0.132	2.849	0.086
1990	79.3	263	39.8	36	89.5	4.0442	0.135	1.574	0.040
1991	76.0	472	29.1	37	20.9	2.0994	0.127	5.477	0.188
1992	49.3	310	13.8	23	16.5	1.5640	0.134	3.321	0.241
1993	59.7	725	37.4	31	19.8	1.2846	0.124	7.126	0.190
1994	110.0	853	89.0	33	41.6	1.4557	0.123	7.877	0.089
1995	58.6	485	28.2	29	17.6	0.9727	0.128	6.015	0.213
1996	71.7	643	35.3	29	16.4	0.7897	0.126	6.625	0.188
1997	471.5	602	19.9	31	10.7	0.7248	0.128	6.481	0.326
1998	476.0	471	18.7	24	11.3	0.8414	0.130	5.166	0.277
1999	575.0	631	41.7	27	9.2	0.8630	0.127	6.515	0.156
2000	671.4	656	35.7	35	7.6	0.5330	0.125	5.636	0.158
2001	648.3	699	25.2	24	4.6	0.4697	0.125	6.042	0.240
2002	843.9	701	33.7	28	12.0	0.4635	0.127	5.847	0.173
2003	605.3	720	13.6	25	6.1	0.4640	0.126	5.452	0.401
2004	612.3	622	15.2	28	11.6	0.4569	0.128	4.486	0.296
2005	755.2	486	17.4	26	16.5	0.4629	0.131	3.086	0.178
2006	573.7	326	36.8	17	67.9	0.5635	0.135	2.087	0.057
2007	937.1	246	10.6	11	9.7	0.4625	0.141	1.652	0.156
2008	398.9	429	13.4	15	26.3	0.4227	0.134	2.720	0.203
2009	521.0	240	22.8	14	90.1	0.4112	0.142	1.294	0.057
2010	437.4	190	10.7	13	32.3	0.2846	0.147	0.979	0.091
2011	554.2	214	7.2	12	12.7	0.2906	0.144	1.192	0.166
2012	463.8	149	1.3	11	2.7	0.2645	0.154	0.924	0.694
2013	398.4	146	4.1	11	25.9	0.2331	0.155	0.921	0.224
2014	460.5	120	20.6	11	337.4	0.3117	0.163	0.554	0.027
2015	305.4	185	22.1	14	368.3	0.3094	0.151	0.833	0.038
2016	332.7	140	9.5	12	82.5	0.2543	0.158	0.775	0.082
2017	385.3	187	34.4	11	592.4	0.3534	0.151	0.840	0.024

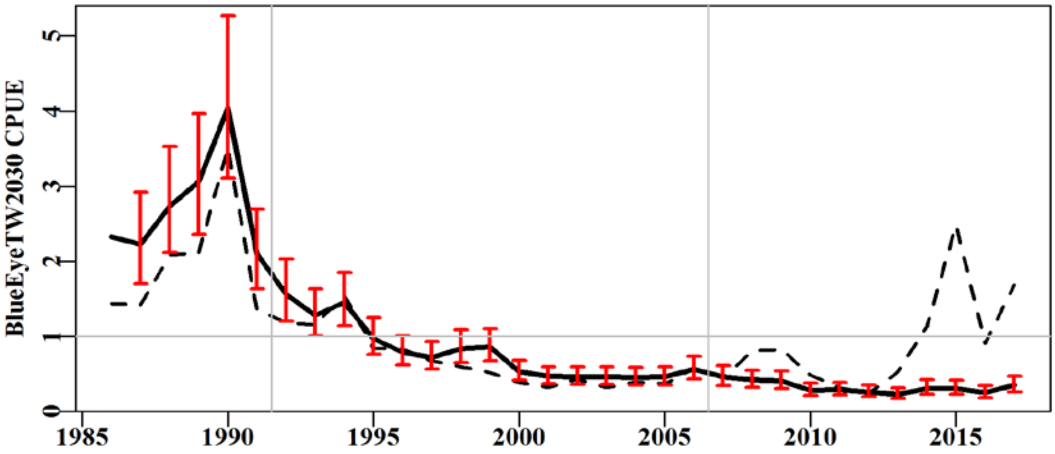


Figure 5.107. BlueEyeTW2030 standardization. The dashed black line represents the geometric mean catch rate, solid black line the standardized catch rates. The red bars are the 95% confidence intervals about the mean estimates. The graph scales both time-series of standardized catch rates relative to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

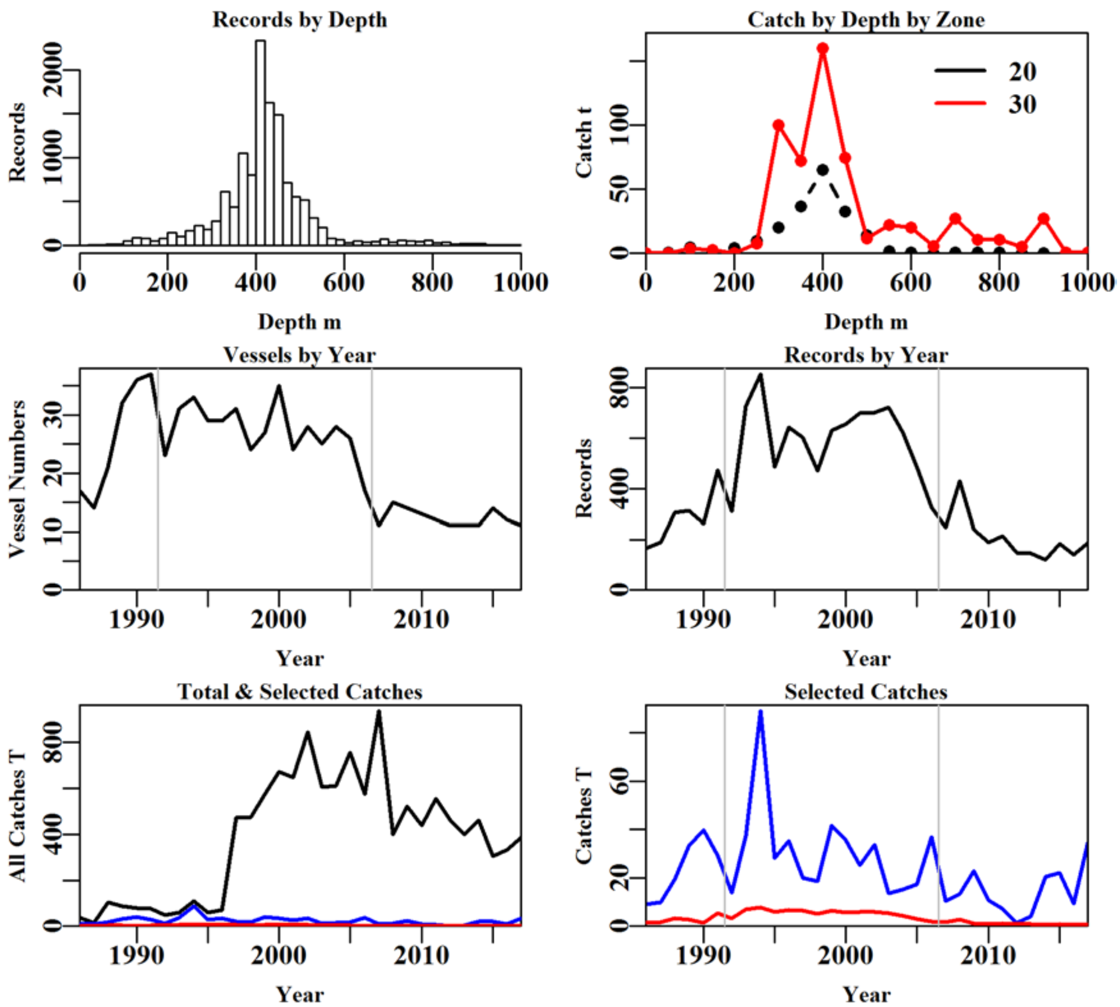


Figure 5.108. BlueEyeTW2030 fishery details. The bottom left plot depicts all known catches (top black line), and all selected catches used in the analysis (middle blue line); the lower red line: selected catches < 30 kg).

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	54602	34654	34423	34297	14654	12888	12884
Difference	0	19948	231	126	19643	1766	4
Catch	12297.33	4619.172	4595.8210	4581.4348	1396.182	759.0034	758.8854
Difference	0.00	7678.162	23.3505	14.3862	3185.253	637.1783	0.1180

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	12303	33312	5242	12884	32	13.4	0.00
Vessel	4822	18287	20266	12884	155	52.0	38.61
Zone	4416	17717	20836	12884	156	53.5	1.49
DepCat	4357	17581	20973	12884	176	53.8	0.29
Month	4325	17508	21046	12884	187	53.9	0.15
DayNight	4295	17459	21094	12884	190	54.0	0.12
Zone:DepCat	4112	17162	21392	12884	209	54.8	0.71
Zone:Month	4263	17386	21168	12884	201	54.2	0.15

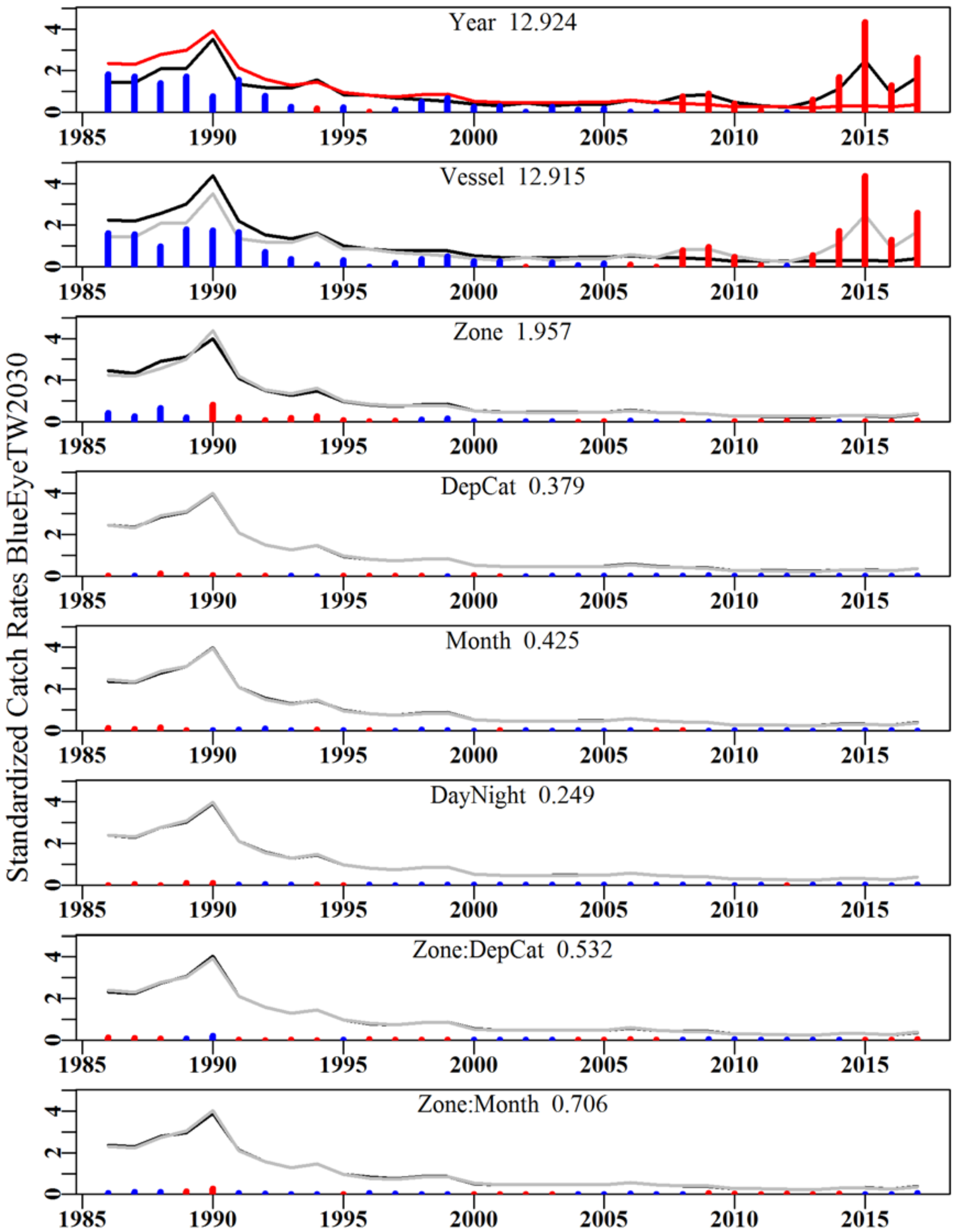


Figure 5.109. BlueEyeTW2030. The influence of each factor on the optimal standardization. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by vertical bars with blue bars indicating the optimum model is higher than the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

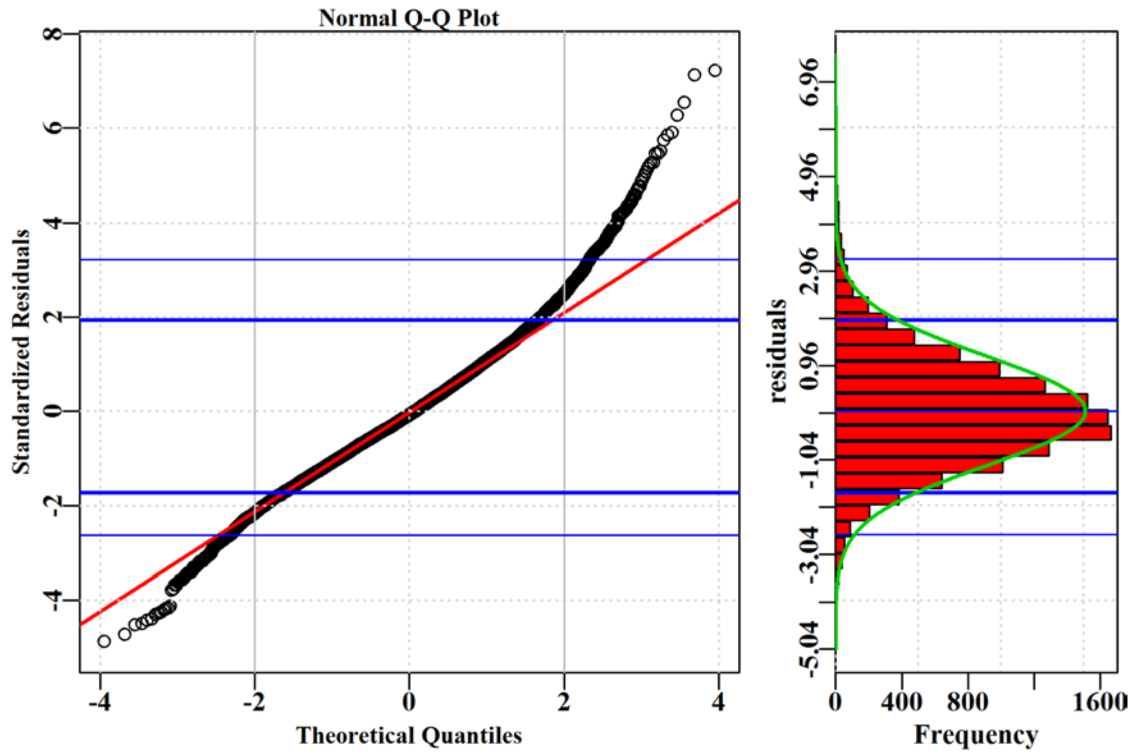


Figure 5.110. BlueEyeTW2030. diagnostic plots. The distribution of residuals from the optimum fit. The qqplot indicates the fit to the expected normality, while the histogram of residuals illustrates the 90% quantiles to indicate the intensity of any lack of fit at the margins of the distribution.

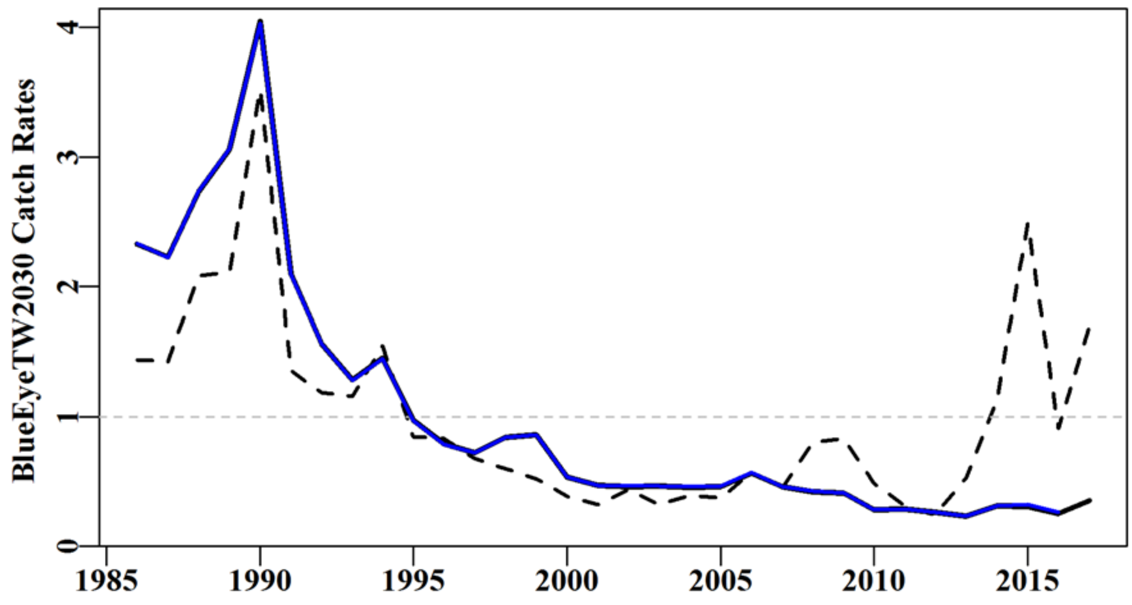


Figure 5.111. BlueEyeTW2030. A comparison of the previous year's standardization (blue line) with this year's. They should lie on top of each other, although small deviations may relate to data adjustments, particularly in very recent years.

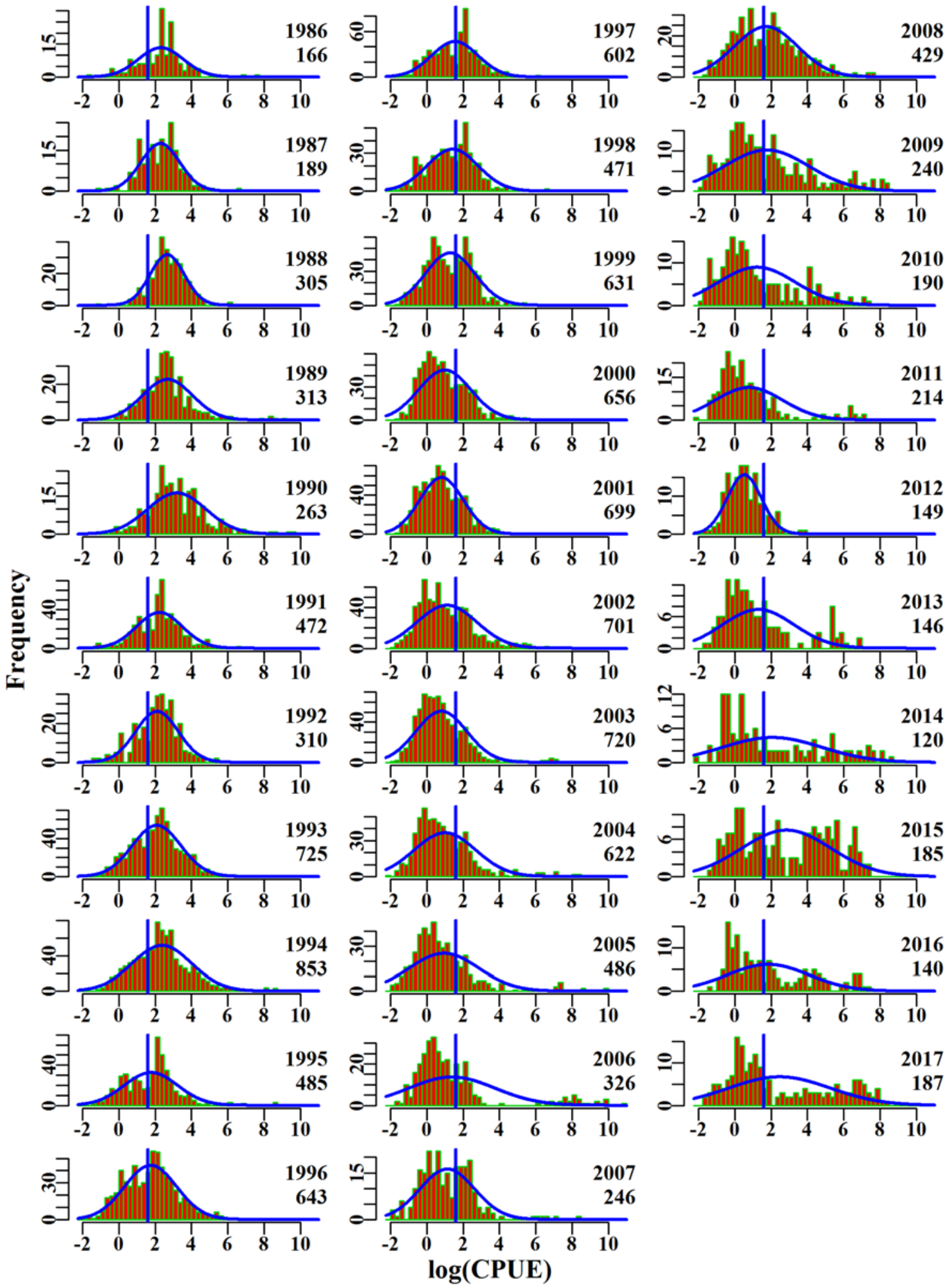


Figure 5.112. BlueEyeTW2030. The log(CPUE) for each year of data available the blue lines are normal distributions fitted to the histogram frequencies. The numbers in each plot are the year and number of records.

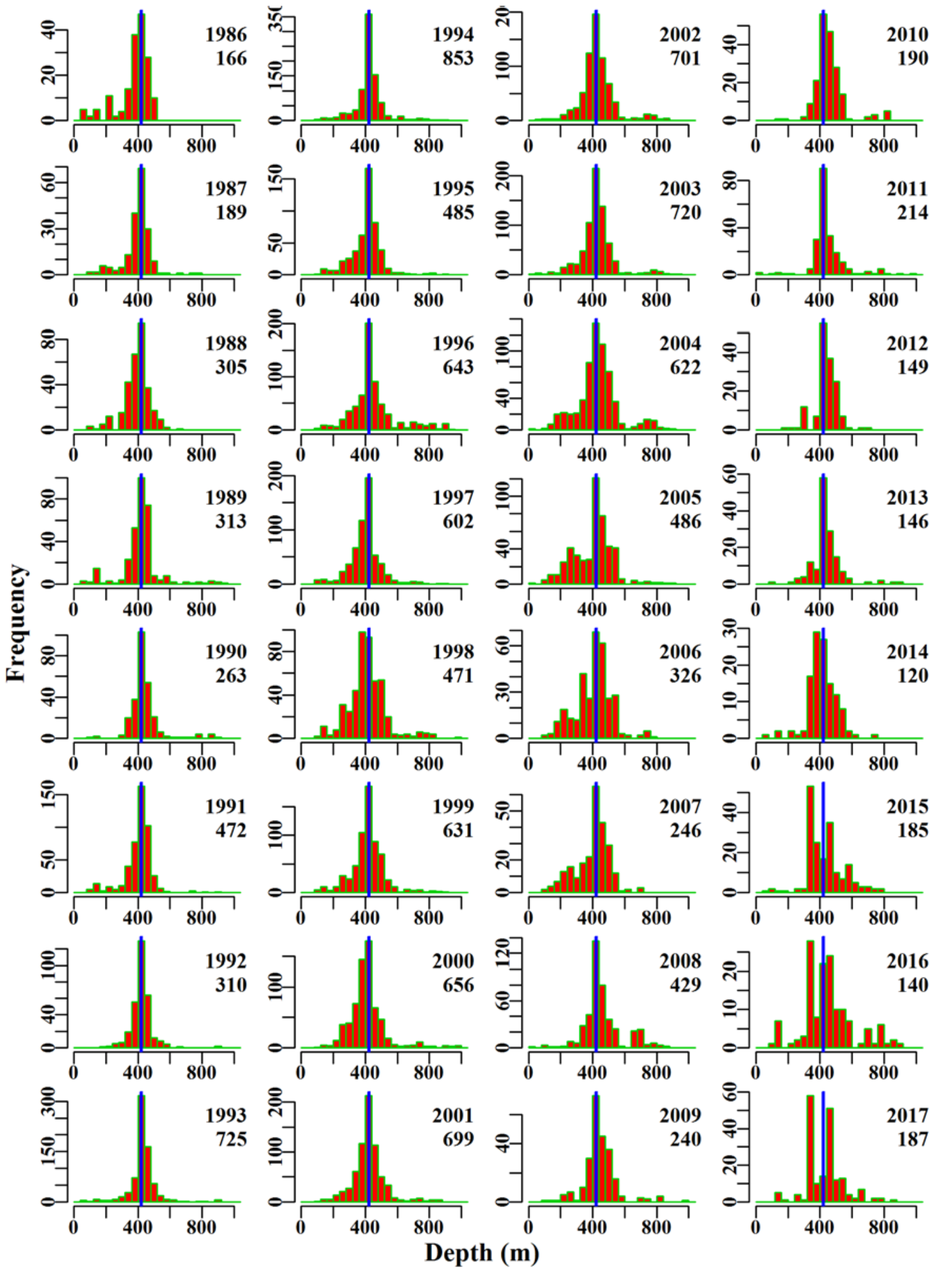


Figure 5.113. BlueEyeTW2030. The average Depth of fishing for each year of data available to illustrate the development of the fishery through time. The numbers in each plot are the year and number of records.

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 - 2017 were used in the analysis. Recently, Ocean Blue-Eye Trevalla (37445014 - *Schedophilus labyrinthicus*) was also included in this analysis (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.

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 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 through to 2016 and relatively flat trend. However, the 2017 CPUE index is close to average (Figure 5.114). CPUE are consistent from 1988 - 1991 (i.e. before the introduction of quotas in 1992), but are double 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 - 2017

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	1.0523	0.000	1.602	0.100
1987	15.5	56	3.1	14	19.8	0.8080	0.177	0.356	0.113
1988	105.2	142	76.4	15	474.9	2.5071	0.157	0.716	0.009
1989	88.1	238	44.0	24	93.5	2.1732	0.138	2.149	0.049
1990	79.3	156	30.9	15	65.7	2.1780	0.159	1.840	0.060
1991	76.0	125	18.6	18	35.4	1.7494	0.159	1.149	0.062
1992	49.3	129	28.6	15	620.9	2.1920	0.157	0.908	0.032
1993	59.7	289	18.1	19	16.3	0.9807	0.140	3.992	0.220
1994	110.0	348	16.3	19	14.0	0.9939	0.136	5.148	0.316
1995	58.6	497	26.2	21	12.3	0.8913	0.133	6.638	0.253
1996	71.7	521	30.0	24	17.8	0.9359	0.133	6.277	0.209
1997	471.5	788	82.4	18	22.3	0.9488	0.130	7.718	0.094
1998	476.0	778	58.9	19	14.6	1.1250	0.131	8.746	0.148
1999	575.0	875	46.2	19	15.5	1.1411	0.130	9.412	0.204
2000	671.4	1104	44.6	25	13.1	0.9908	0.129	11.127	0.249
2001	648.3	966	43.4	26	15.0	0.9556	0.131	10.771	0.248
2002	843.9	803	32.3	26	13.6	0.7962	0.131	8.787	0.272
2003	605.3	389	11.0	25	8.5	0.6942	0.137	3.775	0.344
2004	612.3	848	31.2	24	10.0	0.6141	0.131	7.179	0.230
2005	755.2	507	12.7	22	7.5	0.5854	0.134	4.366	0.343
2006	573.7	527	16.2	17	7.3	0.5834	0.134	3.967	0.245
2007	937.1	530	26.1	16	12.9	0.6255	0.134	3.655	0.140
2008	398.9	321	16.4	14	14.9	0.8252	0.139	2.685	0.164
2009	521.0	342	15.8	13	10.6	0.7805	0.139	2.540	0.161
2010	437.4	423	30.9	14	15.6	0.7924	0.136	2.775	0.090
2011	554.2	379	14.7	14	6.5	0.6157	0.137	3.017	0.205
2012	463.8	251	9.0	11	4.7	0.4568	0.146	1.736	0.194
2013	398.4	202	18.7	15	10.8	0.5955	0.148	1.585	0.085
2014	460.5	216	8.7	13	6.6	0.5517	0.148	2.118	0.243
2015	305.4	106	2.7	9	5.3	0.3357	0.168	0.745	0.281
2016	332.7	92	3.3	13	7.1	0.5829	0.171	0.842	0.255
2017	385.3	227	17.3	10	18.2	0.9417	0.155	1.999	0.116

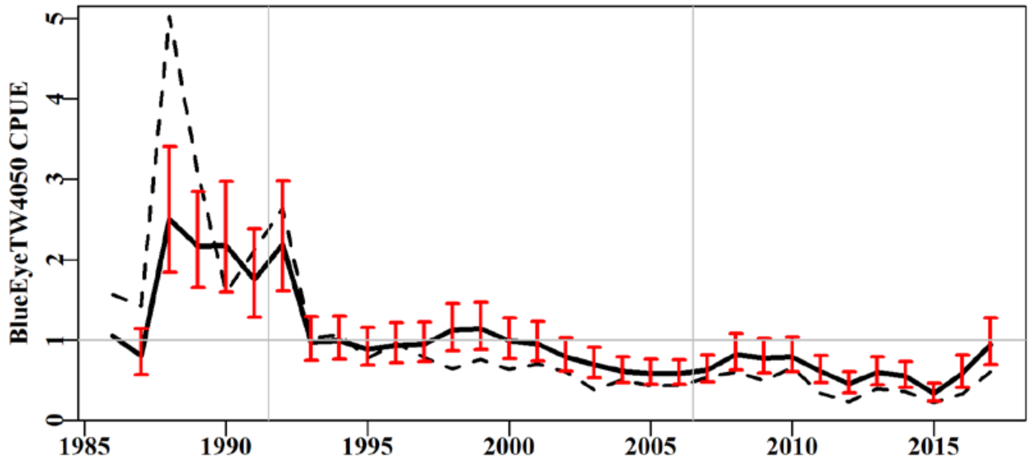


Figure 5.114. BlueEyeTW4050 standardization. The dashed black line represents the geometric mean catch rate, solid black line the standardized catch rates. The red bars are the 95% confidence intervals about the mean estimates. The graph scales both time-series of standardized catch rates relative to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

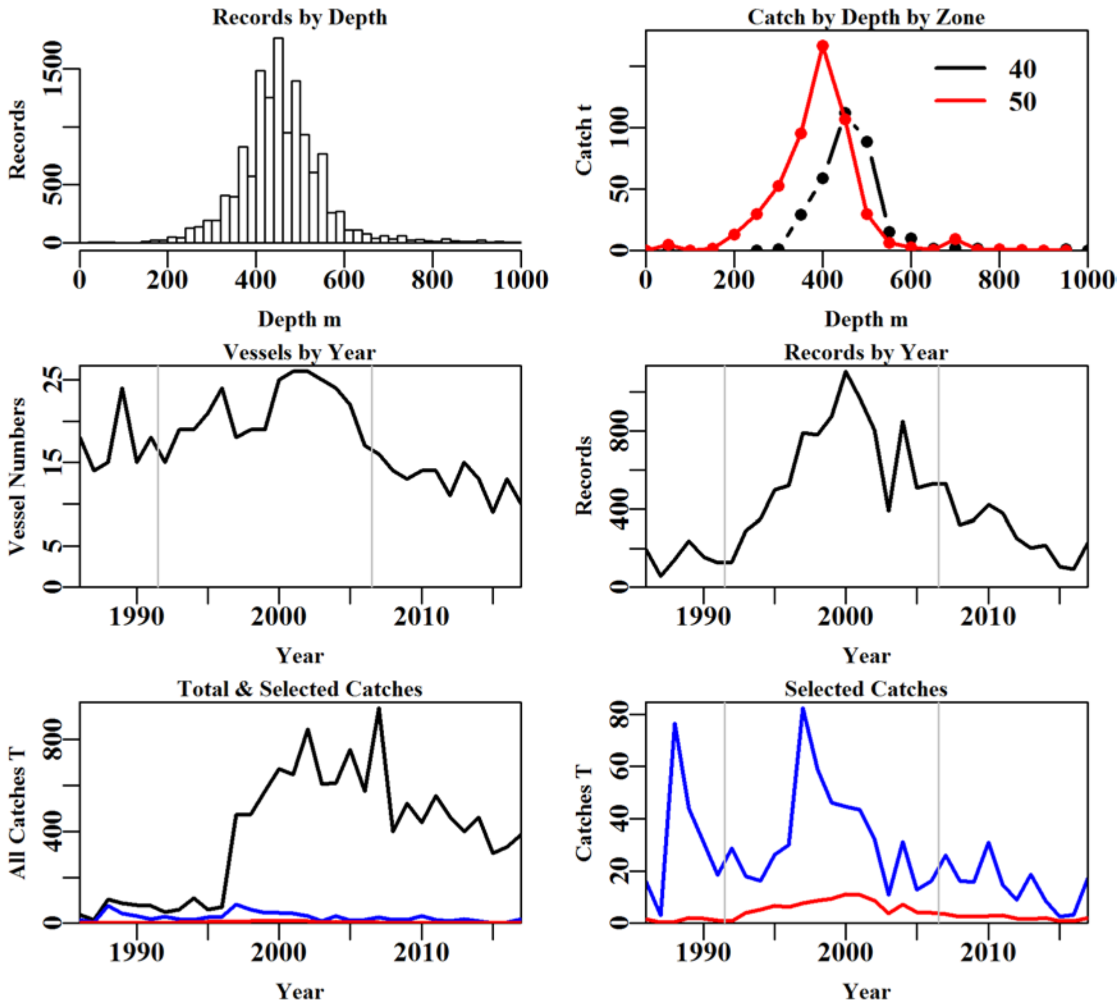


Figure 5.115. BlueEyeTW4050 fishery details. The bottom left plot depicts all known catches (top black line), and all selected catches used in the analysis (middle blue line); the lower red line: selected catches < 30 kg).

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	54602	34654	34423	34297	14311	13393	13369
Difference	0	19948	231	126	19986	918	24
Catch	12297.33	4619.172	4595.8210	4581.4348	1124.189	851.3865	850.6115
Difference	0.00	7678.162	23.3505	14.3862	3457.246	272.8026	0.7750

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	8799	25696	3284	13369	32	11.1	0.00
Vessel	3307	16823	12157	13369	117	41.4	30.31
DepCat	2926	16302	12678	13369	137	43.2	1.73
Zone	2852	16210	12770	13369	138	43.5	0.32
DayNight	2730	16056	12924	13369	141	44.0	0.52
Month	2635	15915	13065	13369	152	44.5	0.44
Zone:DepCat	2617	15854	13126	13369	169	44.6	0.14
Zone:Month	2635	15890	13090	13369	163	44.5	0.04

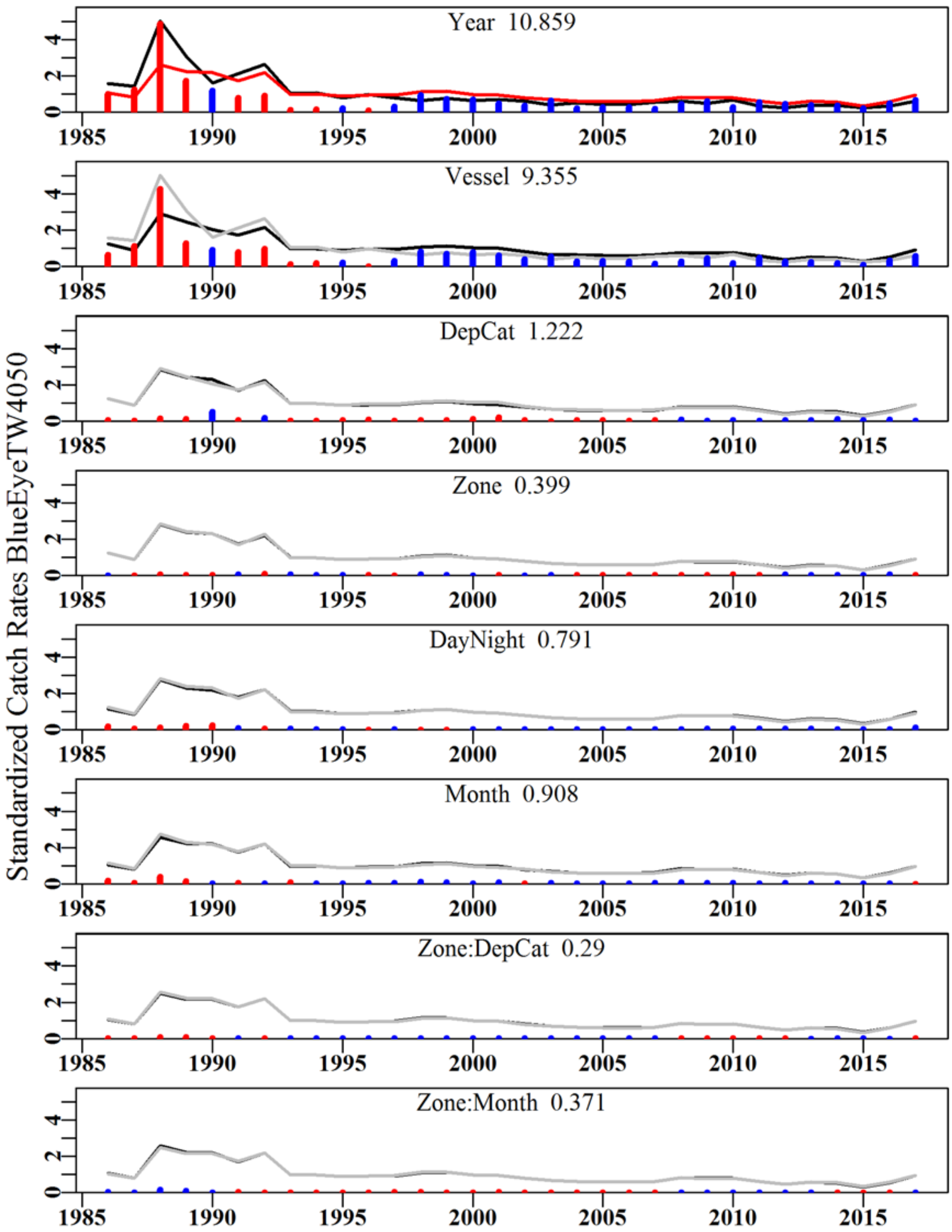


Figure 5.116. BlueEyeTW4050. The influence of each factor on the optimal standardization. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by vertical bars with blue bars indicating the optimum model is higher than the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

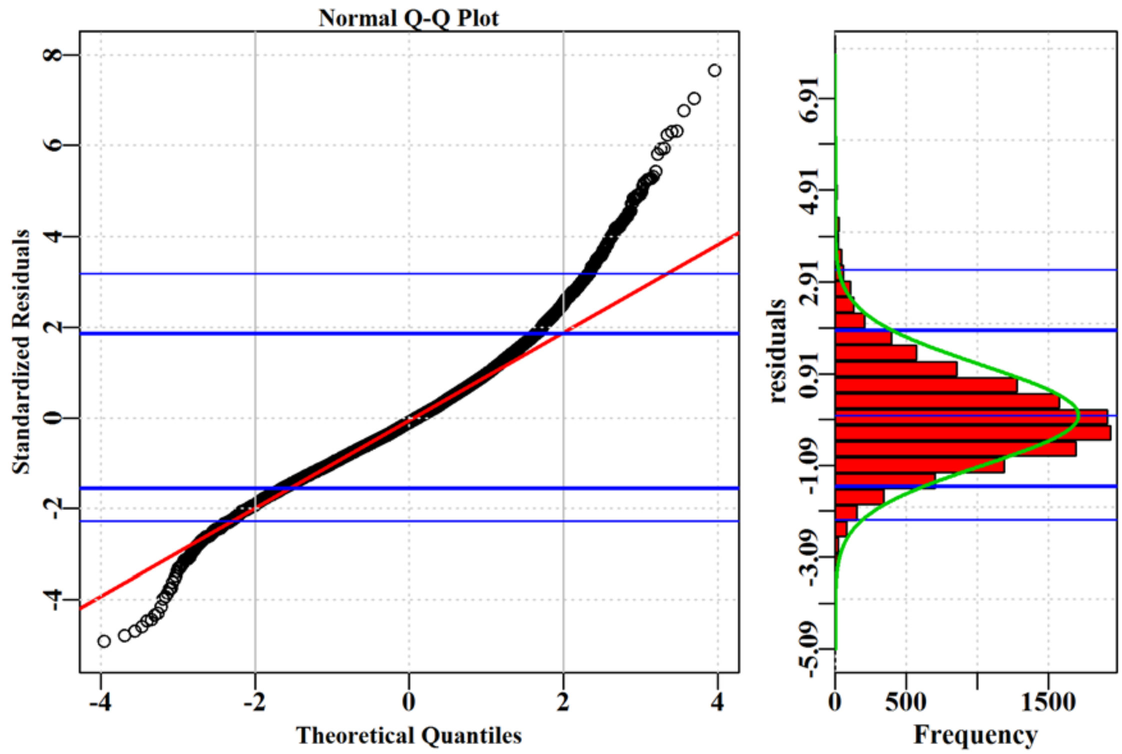


Figure 5.117. BlueEyeTW4050. diagnostic plots. The distribution of residuals from the optimum fit. The qqplot indicates the fit to the expected normality, while the histogram of residuals illustrates the 90% quantiles to indicate the intensity of any lack of fit at the margins of the distribution.

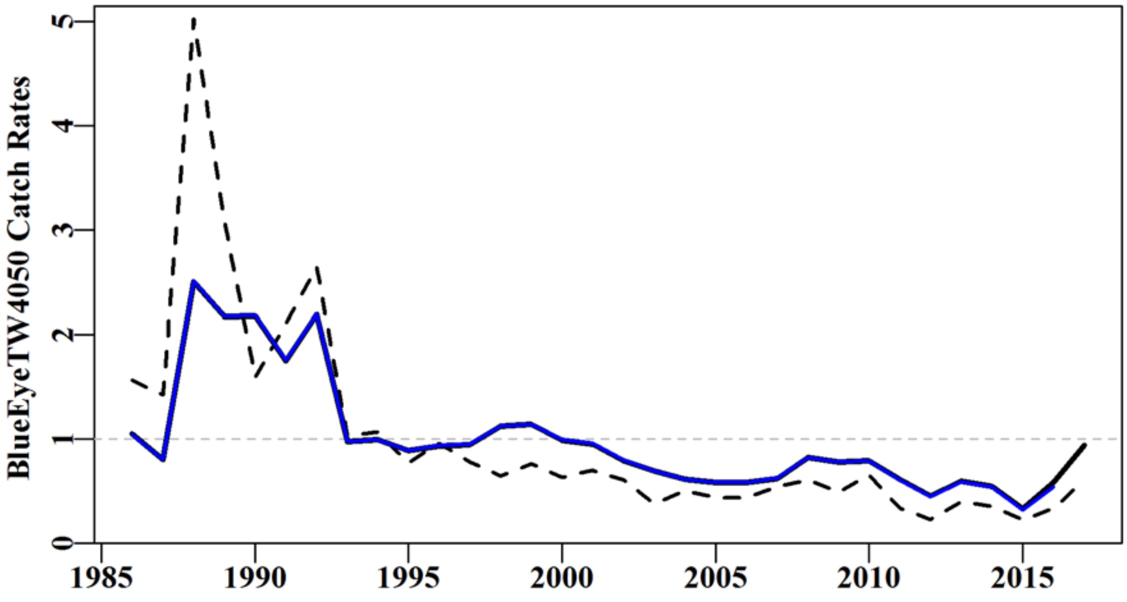


Figure 5.118. BlueEyeTW4050. A comparison of the previous year's standardization (blue line) with this year's. They should lie on top of each other, although small deviations may relate to data adjustments, particularly in very recent years.

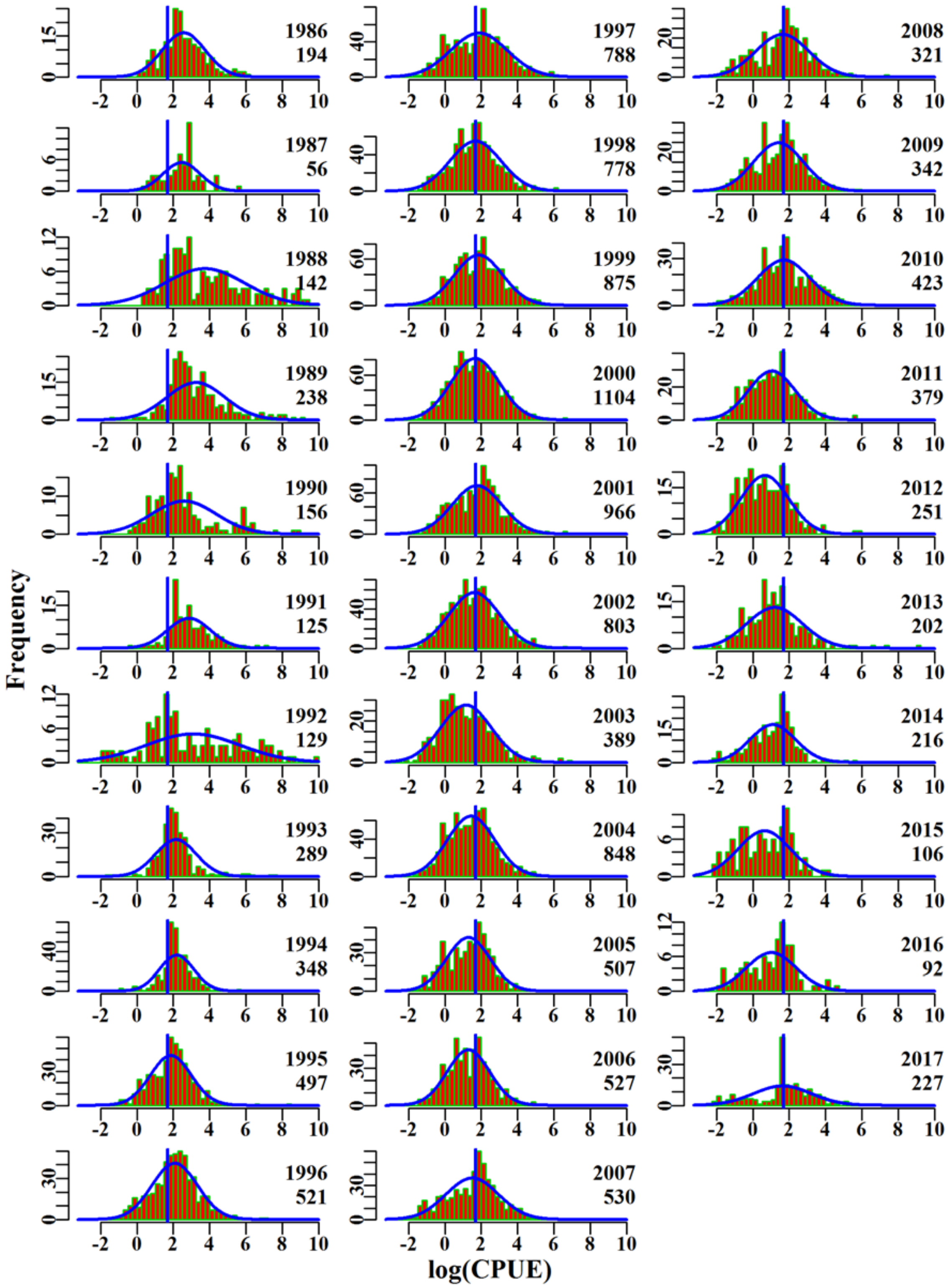


Figure 5.119. BlueEyeTW4050. The log(CPUE) for each year of data available the blue lines are normal distributions fitted to the histogram frequencies. The numbers in each plot are the year and number of records.

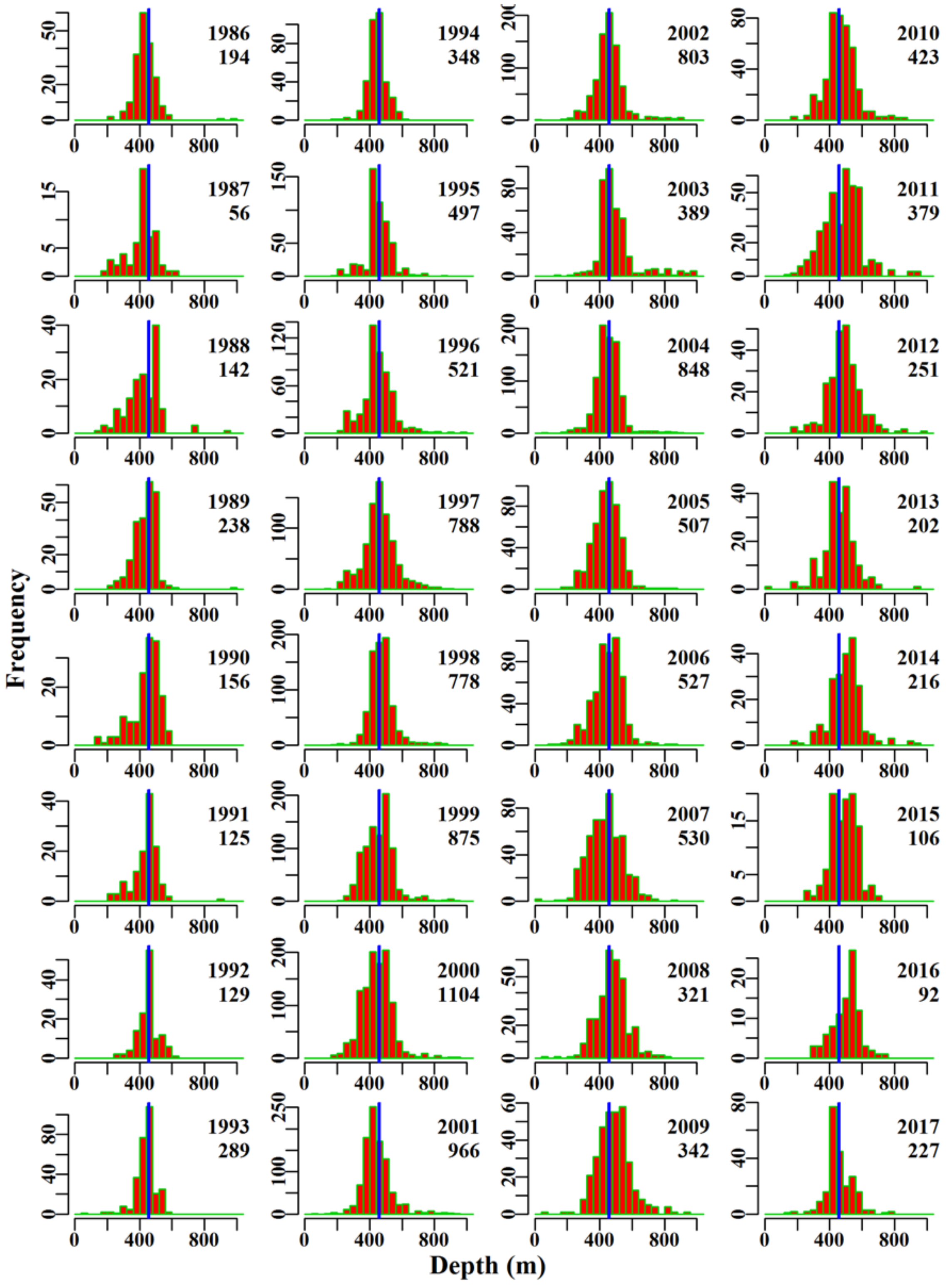


Figure 5.120. BlueEyeTW4050. The average Depth of fishing for each year of data available to illustrate the development of the fishery through time. The numbers in each plot are the year and number of records.

5.21 Blue-Grenadier Non-Spawning

Blue Grenadier (GRE – 37227001 – *Macroronus 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 - 2017 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 40 and 50, followed by zone 20 and 30 across the analysis period.

The terms Year, Vessel, DayNight, DepCat, Zone and Month 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 5.90). 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. Since 2014, these annual indices were above average (Figure 5.121).

5.21.2 *Action Items and Issues*

No issues identified.

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 - 2017

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	1.5611	0.000	12.975	0.011
1987	1462.5	3561	1434.5	91	135.0	1.9940	0.034	14.597	0.010
1988	1530.1	3952	1469.1	102	129.2	2.1709	0.034	17.925	0.012
1989	1854.7	4302	1811.6	99	151.3	2.1776	0.034	18.000	0.010
1990	1710.8	3520	1468.5	92	149.1	2.1660	0.036	12.473	0.008
1991	2780.7	4243	2331.0	86	205.7	1.5450	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	0.9511	0.035	19.041	0.012
1994	1341.2	4469	1306.7	66	94.2	0.8586	0.035	22.544	0.017
1995	1020.1	5059	1012.7	61	58.6	0.5937	0.034	32.505	0.032
1996	1092.7	5352	1054.4	72	56.4	0.5361	0.034	38.052	0.036
1997	1032.0	6175	993.4	73	43.8	0.5574	0.033	45.709	0.046
1998	1488.0	6584	1450.2	65	74.8	0.9010	0.033	41.062	0.028
1999	2113.3	8032	2043.8	65	89.6	0.9466	0.032	47.051	0.023
2000	1768.0	7667	1747.4	73	73.4	0.6815	0.033	49.517	0.028
2001	1062.1	7325	1020.8	60	40.3	0.3927	0.033	56.149	0.055
2002	1151.4	6331	1124.3	57	54.9	0.3910	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	0.5474	0.034	23.385	0.020
2005	1626.5	5282	1164.6	54	66.0	0.6594	0.034	18.083	0.016
2006	1486.5	4317	1292.9	42	84.6	0.8803	0.035	11.037	0.009
2007	1312.0	3619	1193.3	27	86.6	0.7820	0.036	10.146	0.009
2008	1312.5	3365	1254.7	26	110.9	0.8643	0.037	8.968	0.007
2009	1150.9	3388	1112.5	23	89.2	0.8004	0.037	9.648	0.009
2010	1167.6	3266	1130.8	25	81.9	0.7975	0.037	8.044	0.007
2011	923.1	3907	882.3	26	49.4	0.6511	0.036	9.375	0.011
2012	645.7	3116	602.4	29	41.6	0.5187	0.038	9.802	0.016
2013	774.5	3031	733.8	26	58.0	0.9243	0.038	7.204	0.010
2014	994.1	3038	921.3	28	78.6	1.1316	0.038	6.127	0.007
2015	1069.7	2959	1046.7	29	105.5	1.2303	0.038	8.100	0.008
2016	982.3	2511	962.7	24	112.0	1.0448	0.040	5.503	0.006
2017	1262.8	2913	1217.9	24	116.4	1.1656	0.039	4.657	0.004

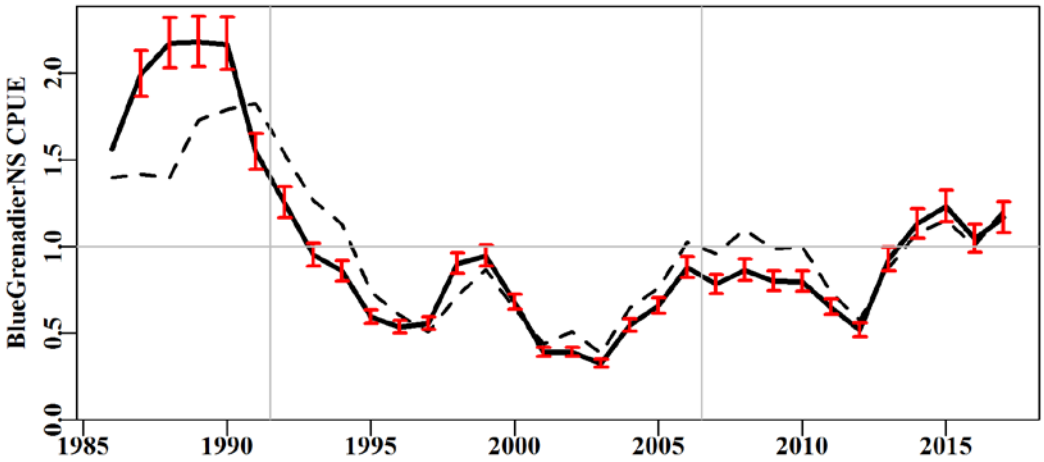


Figure 5.121. BlueGrenadierNS standardization. The dashed black line represents the geometric mean catch rate, solid black line the standardized catch rates. The red bars are the 95% confidence intervals about the mean estimates. The graph scales both time-series of standardized catch rates relative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

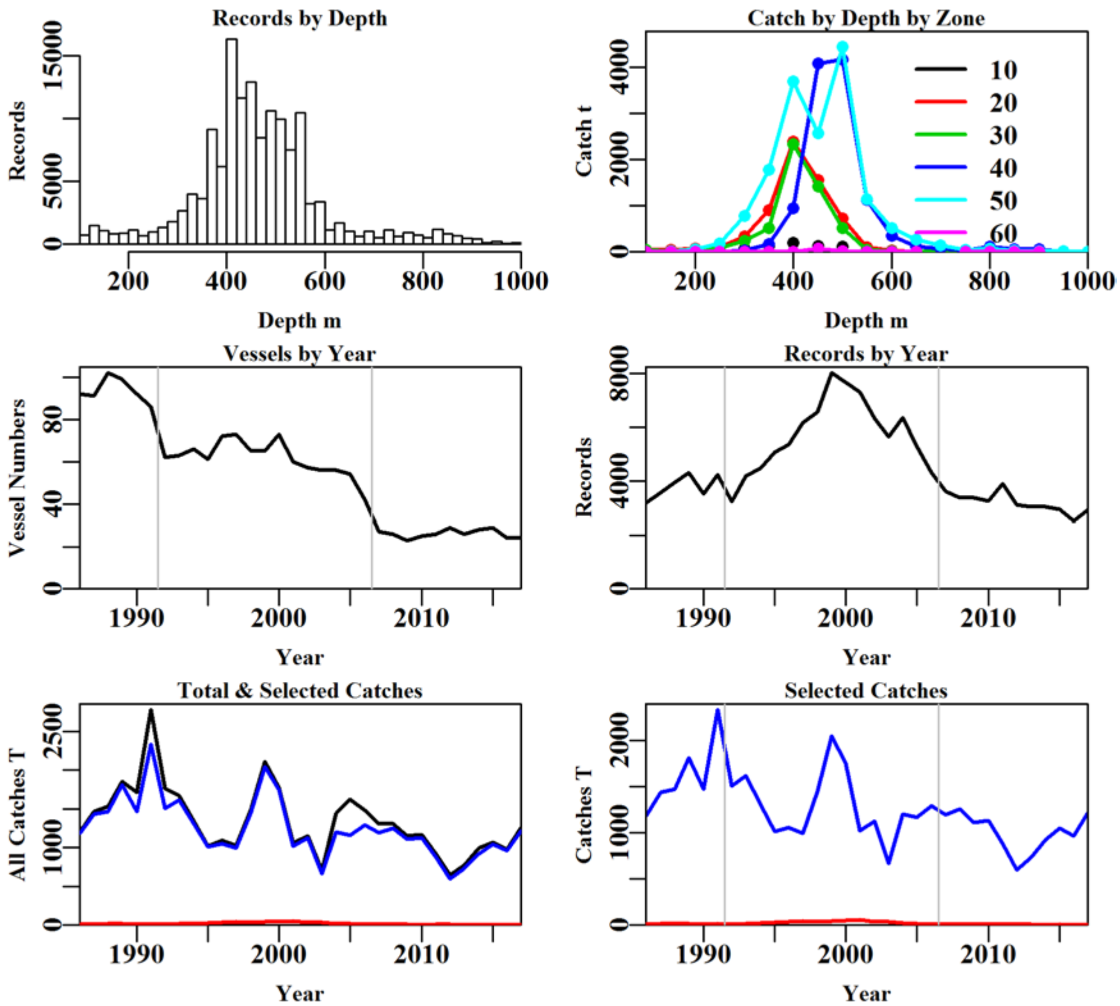


Figure 5.122. BlueGrenadierNS fishery details. The bottom left plot depicts all known catches (top black line), and all selected catches used in the analysis (middle blue line); the lower red line: selected catches < 30 kg).

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	1647720	152501	150893	149244	145438	144007	143905
Difference	0	12271	1608	1649	3806	143	102
Catch	43536.78	42923.1209	42419.1603	41790.086	40453.902	39971.5332	39954.5737
Difference	0.00	613.6587	503.9606	629.074	1336.184	482.3687	16.9595

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	132340	360808	25628	143905	32	6.6	0.00
Vessel	107916	303635	82801	143905	233	21.3	14.69
DayNight	98708	284802	101634	143905	236	26.2	4.88
DepCat	89769	267584	118853	143905	254	30.6	4.45
Zone	85325	259428	127008	143905	259	32.7	2.11
Month	80805	251369	135068	143905	270	34.8	2.08
Zone:DepCat	79232	248345	138092	143905	354	35.6	0.75
Zone:Month	77510	245501	140935	143905	322	36.3	1.50

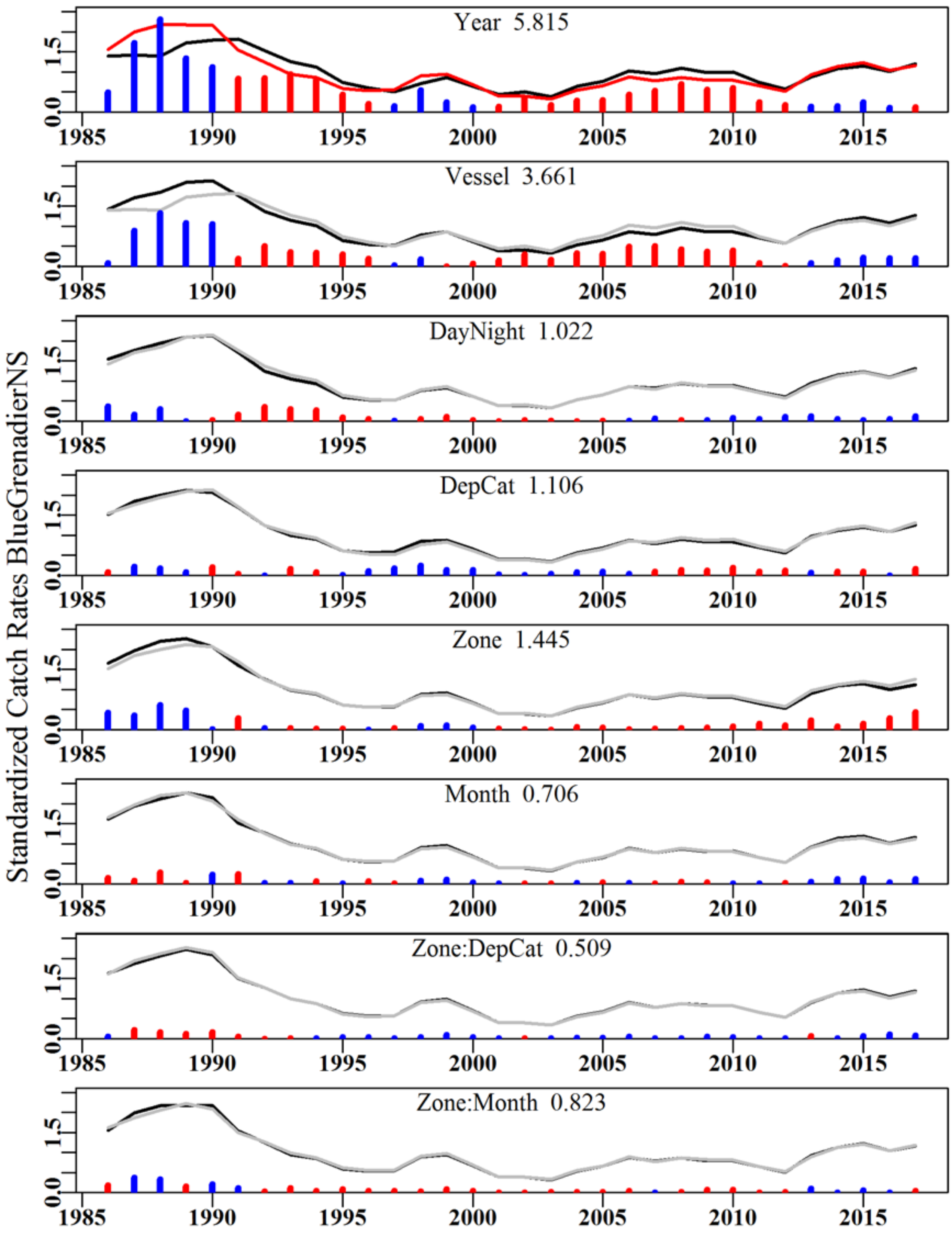


Figure 5.123. BlueGrenadierNS. The influence of each factor on the optimal standardization. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by vertical bars with blue bars indicating the optimum model is higher than the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

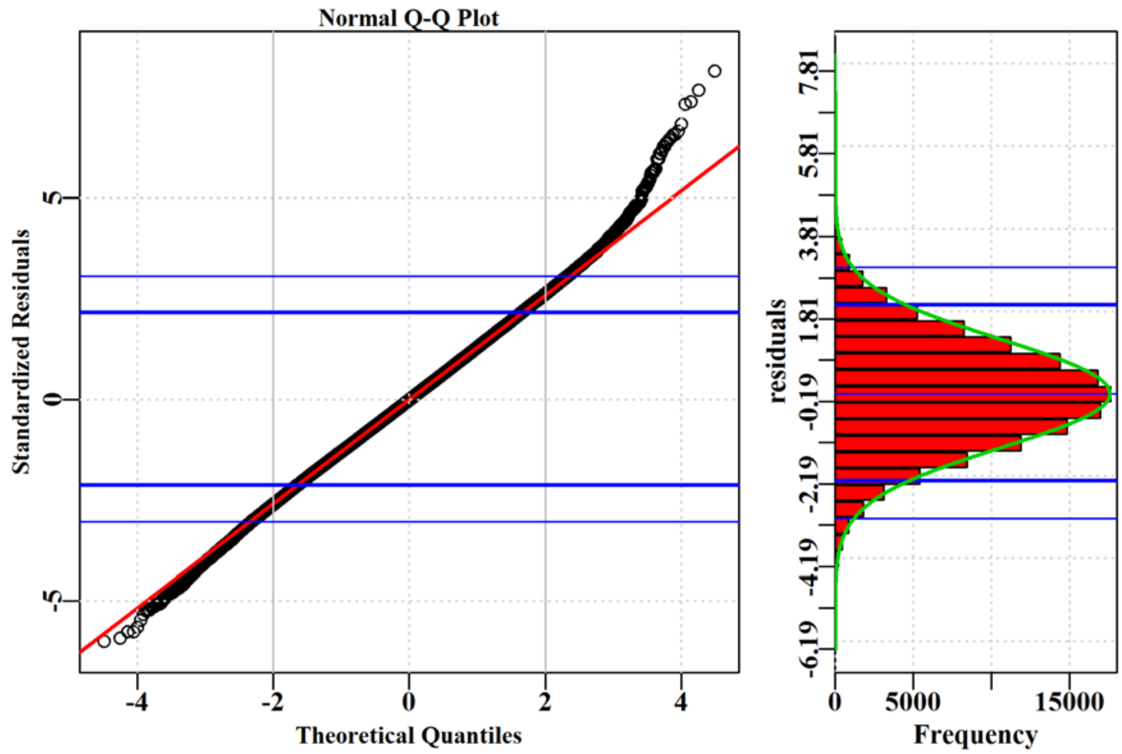


Figure 5.124. BlueGrenadierNS. diagnostic plots. The distribution of residuals from the optimum fit. The qqplot indicates the fit to the expected normality, while the histogram of residuals illustrates the 90% quantiles to indicate the intensity of any lack of fit at the margins of the distribution.

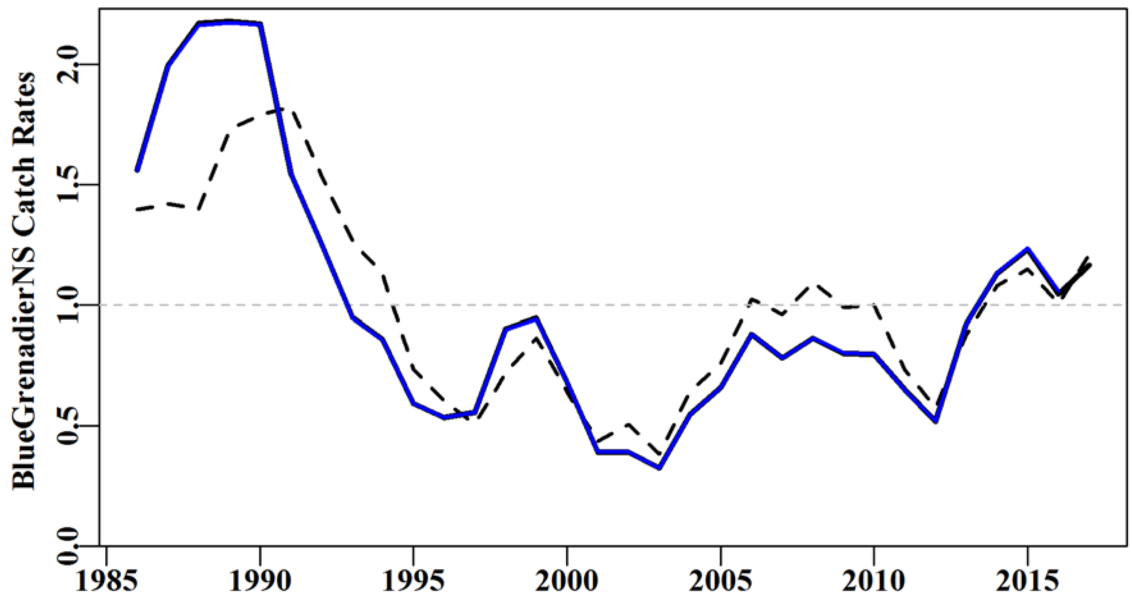


Figure 5.125. BlueGrenadierNS. A comparison of the previous year's standardization (blue line) with this year's. They should lie on top of each other, although small deviations may relate to data adjustments, particularly in very recent years.

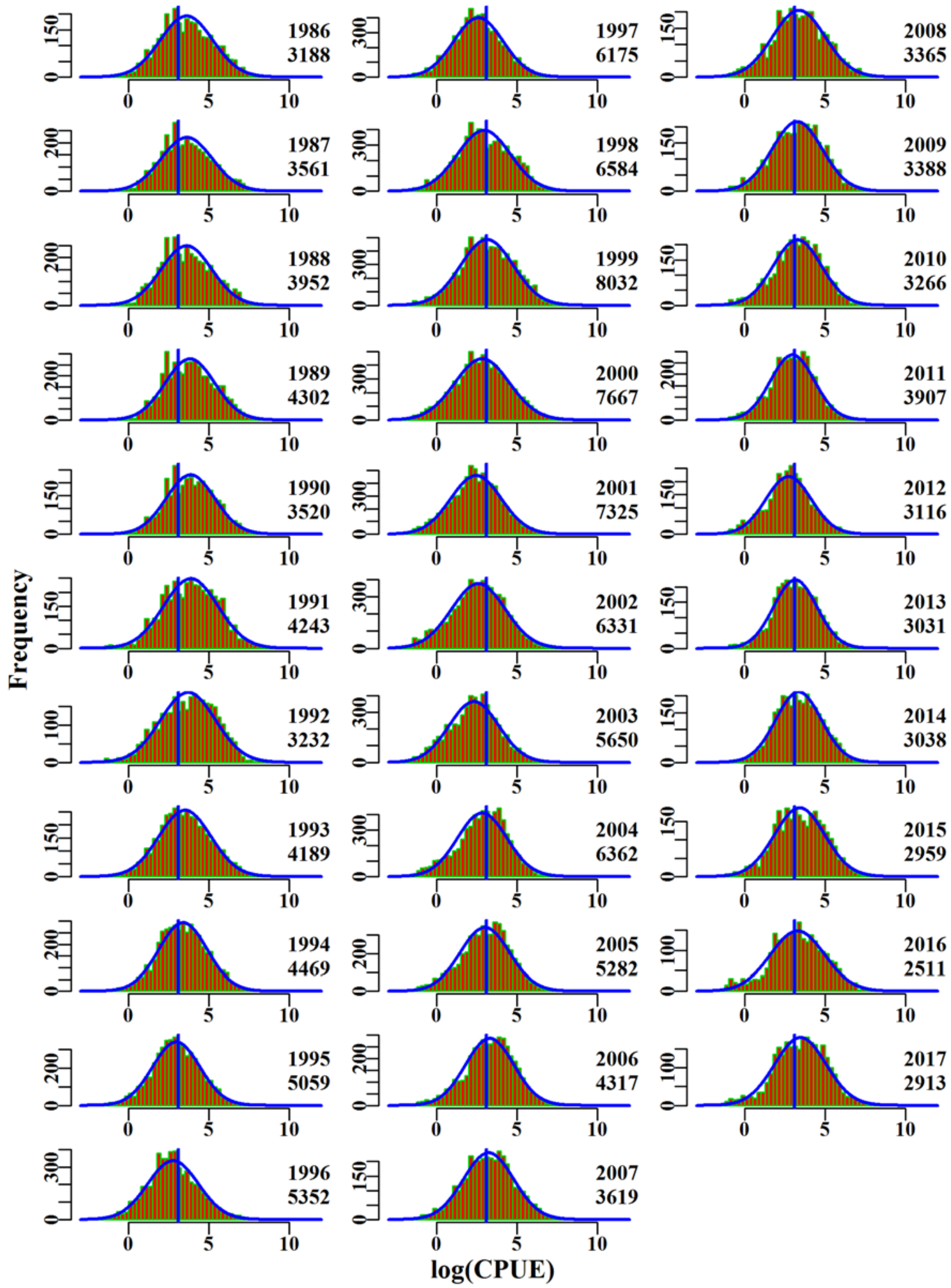


Figure 5.126. BlueGrenadierNS. The log(CPUE) for each year of data available the blue lines are normal distributions fitted to the histogram frequencies. The numbers in each plot are the year and number of records.

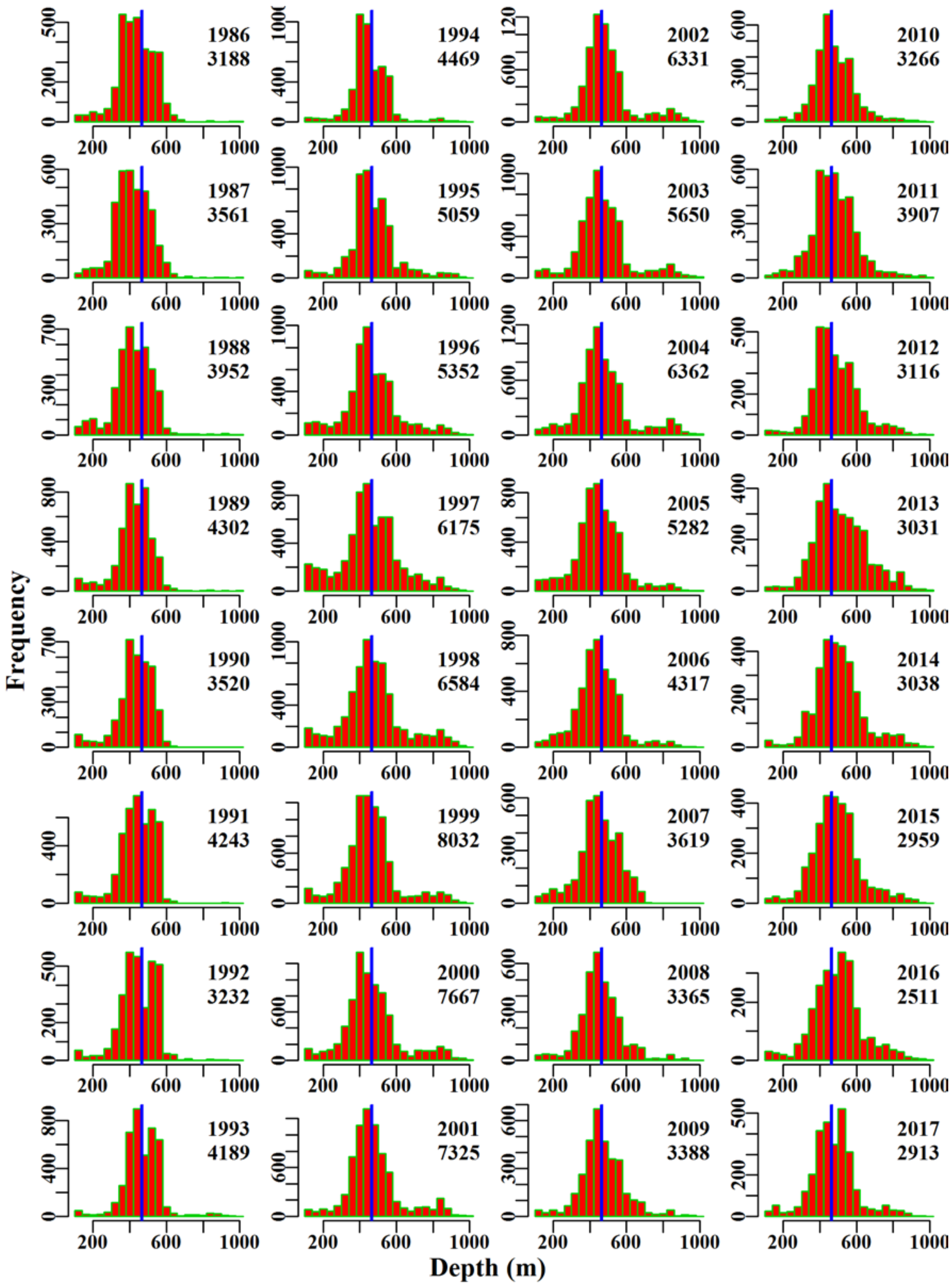


Figure 5.127. BlueGrenadierNS. The average Depth of fishing for each year of data available to illustrate the development of the fishery through time. The numbers in each plot are the year and number of records.

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. Trawl caught pink ling based on methods TW, TDO, in zones 10, 20, 30, and depths 250 to 600 within the SET fishery for the years 1986 - 2017 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 - 2017

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	1.1571	0.000	24.955	0.050
1987	765.1	4251	491.4	77	46.0	1.2302	0.022	22.694	0.046
1988	583.1	3603	398.3	77	40.5	1.1807	0.024	17.925	0.045
1989	678.9	3869	421.2	76	39.9	1.0206	0.023	20.150	0.048
1990	674.5	2768	411.6	67	52.7	1.4747	0.026	11.056	0.027
1991	736.8	2903	366.0	71	46.2	1.4413	0.026	13.338	0.036
1992	568.3	2417	329.4	58	45.9	1.1280	0.027	11.224	0.034
1993	892.8	3471	500.7	58	50.3	1.0747	0.025	16.847	0.034
1994	895.4	4036	468.4	62	42.7	1.1015	0.024	21.041	0.045
1995	1208.9	4346	585.6	57	49.3	1.3811	0.023	21.920	0.037
1996	1233.3	4254	666.7	63	56.2	1.3751	0.023	17.576	0.026
1997	1696.8	4772	730.9	61	52.0	1.4013	0.023	19.670	0.027
1998	1592.4	4883	728.3	56	53.1	1.3864	0.023	22.477	0.031
1999	1651.6	5934	831.1	59	48.8	1.2597	0.022	27.979	0.034
2000	1507.5	5100	658.8	63	46.3	1.1060	0.023	24.500	0.037
2001	1393.0	4555	484.9	52	38.0	0.8616	0.024	24.294	0.050
2002	1330.3	3882	360.3	52	35.2	0.7547	0.025	22.555	0.063
2003	1353.1	4277	444.3	57	38.6	0.7855	0.024	19.522	0.044
2004	1522.9	3328	345.6	54	37.1	0.7052	0.026	14.208	0.041
2005	1203.3	3370	324.5	51	32.6	0.6581	0.026	13.679	0.042
2006	1069.2	2566	321.1	38	42.1	0.7913	0.027	6.841	0.021
2007	875.9	1627	202.8	23	42.0	0.7496	0.032	4.487	0.022
2008	980.3	2342	325.4	24	46.7	0.8963	0.029	5.268	0.016
2009	775.0	1886	208.3	27	34.7	0.6412	0.030	5.024	0.024
2010	906.2	1923	265.5	23	47.0	0.7937	0.030	4.976	0.019
2011	1081.9	2122	287.3	22	46.7	0.8336	0.029	4.720	0.016
2012	1030.9	1919	268.1	24	49.5	0.8932	0.030	4.917	0.018
2013	752.9	1565	184.8	22	40.8	0.7381	0.032	4.498	0.024
2014	861.2	1642	234.9	24	49.1	0.8322	0.032	5.039	0.021
2015	721.8	1650	188.9	24	41.1	0.7245	0.032	5.273	0.028
2016	735.8	1540	193.8	25	41.5	0.7365	0.033	5.136	0.026
2017	896.7	1876	277.2	22	53.1	0.8863	0.031	5.174	0.019

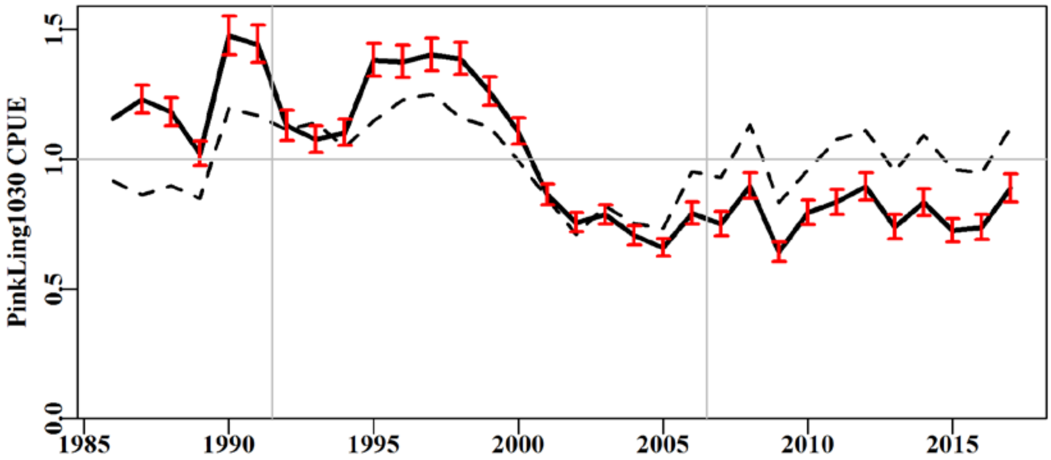


Figure 5.128. PinkLing1030 standardization. The dashed black line represents the geometric mean catch rate, solid black line the standardized catch rates. The red bars are the 95% confidence intervals about the mean estimates. The graph scales both time-series of standardized catch rates relative to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

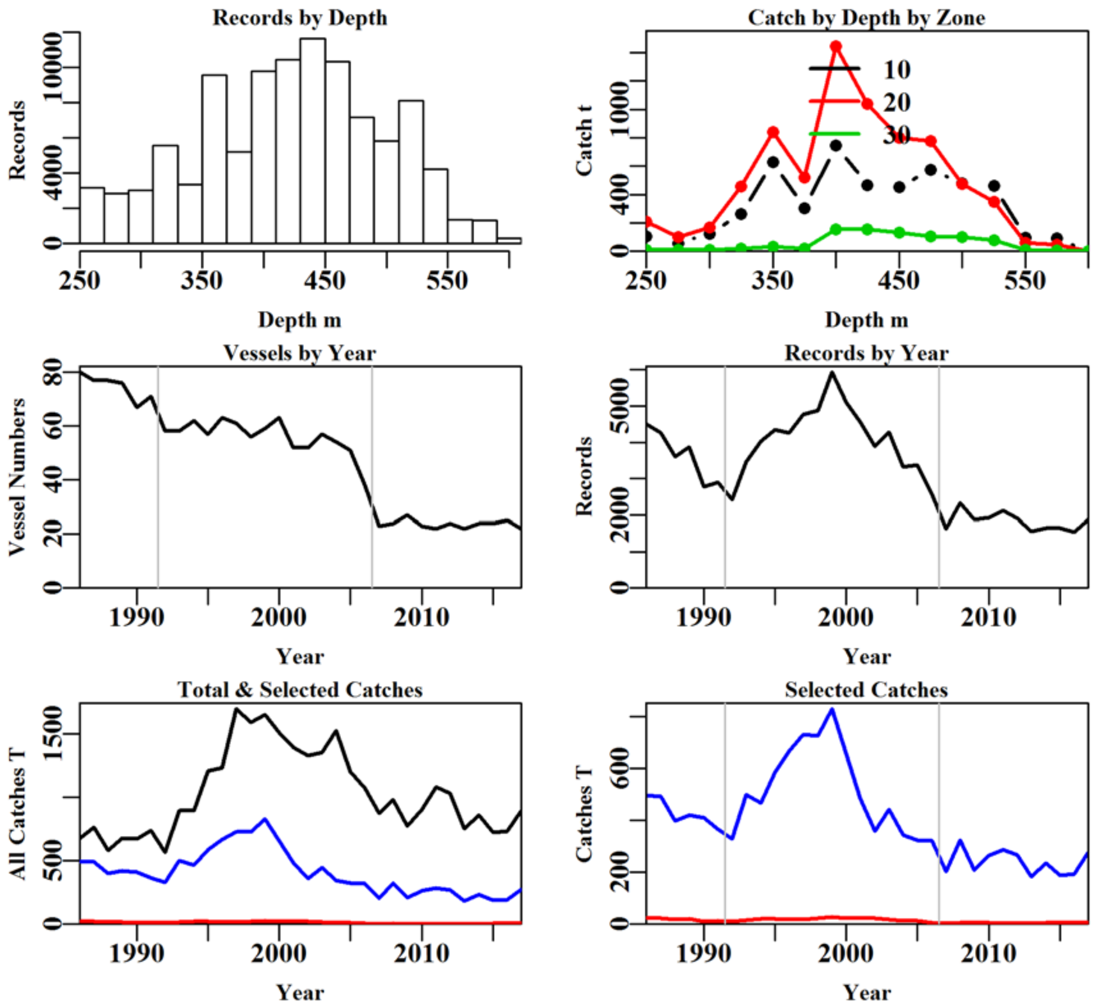


Figure 5.129. PinkLing1030 fishery details. The bottom left plot depicts all known catches (top black line), and all selected catches used in the analysis (middle blue line); the lower red line: selected catches < 30 kg).

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	305762	280936	187423	185309	105258	103221	103187
Difference	0	24826	93513	2114	80051	2037	34
Catch	33220.78	26120.46	22863.248	22583.7557	13249.791	13010.0037	13004.1669
Difference	0.00	7100.317	3257.219	279.4923	9333.965	239.7871	5.8368

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	33529	142717	2749	103187	32	1.9	0.00
Vessel	15687	119622	25843	103187	218	17.6	15.73
DepCat	5137	107967	37498	103187	232	25.6	8.02
Month	1162	103865	41601	103187	243	28.4	2.82
Zone	581	103278	42188	103187	245	28.8	0.40
DayNight	423	103114	42351	103187	248	28.9	0.11
Zone:DepCat	-755	101888	43577	103187	276	29.8	0.83
Zone:Month	-665	101989	43477	103187	270	29.7	0.76

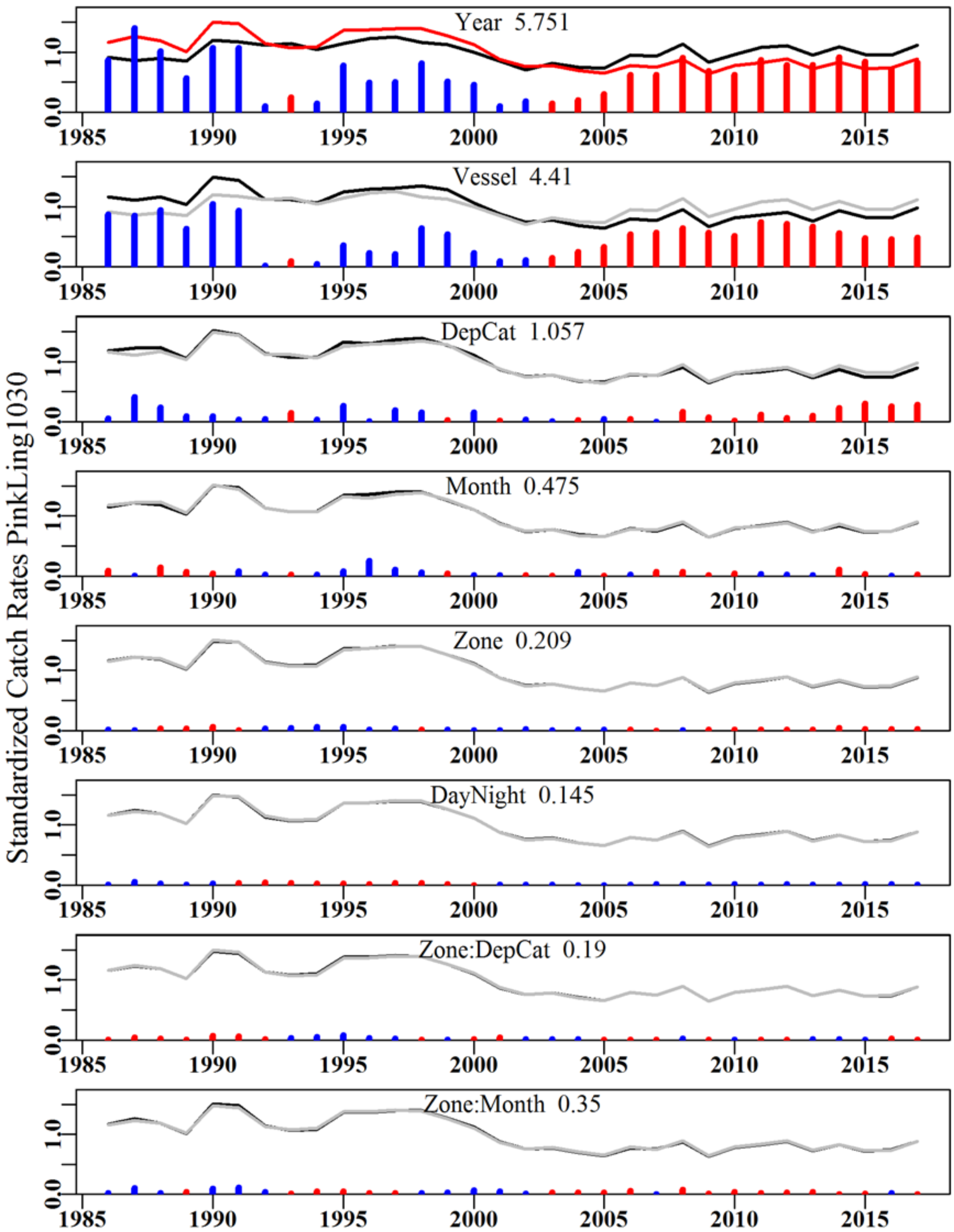


Figure 5.130. PinkLing1030. The influence of each factor on the optimal standardization. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by vertical bars with blue bars indicating the optimum model is higher than the geometric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

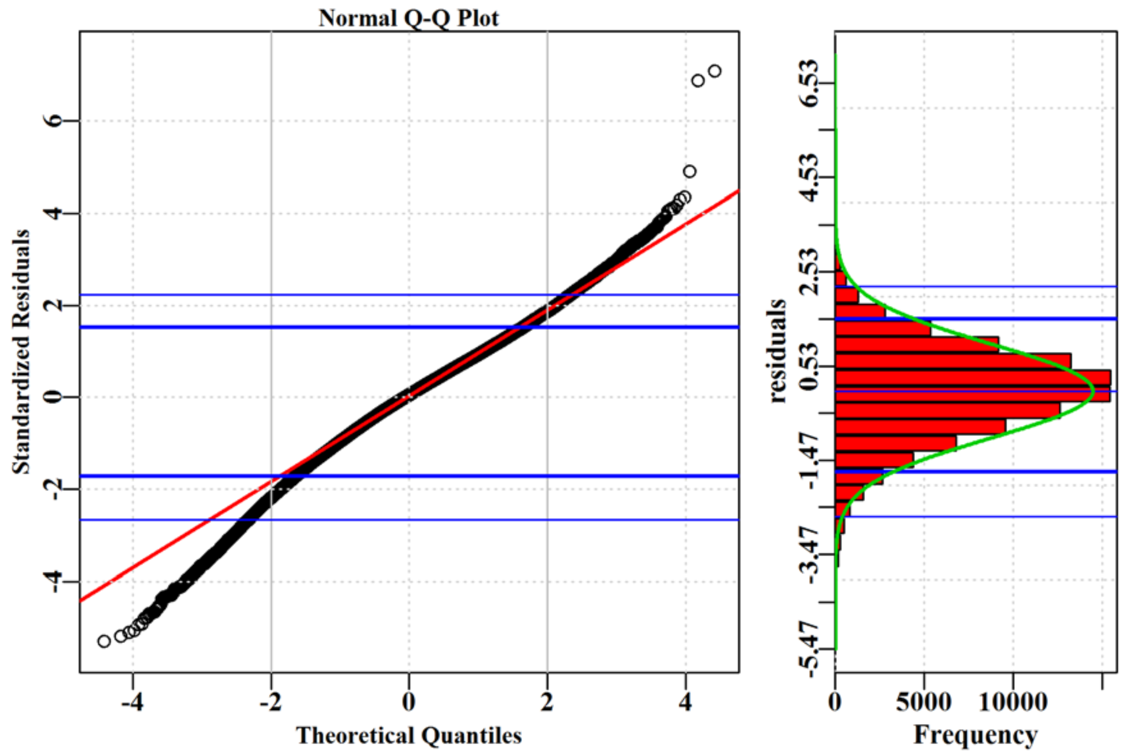


Figure 5.131. PinkLing1030. diagnostic plots. The distribution of residuals from the optimum fit. The qqplot indicates the fit to the expected normality, while the histogram of residuals illustrates the 90% quantiles to indicate the intensity of any lack of fit at the margins of the distribution.

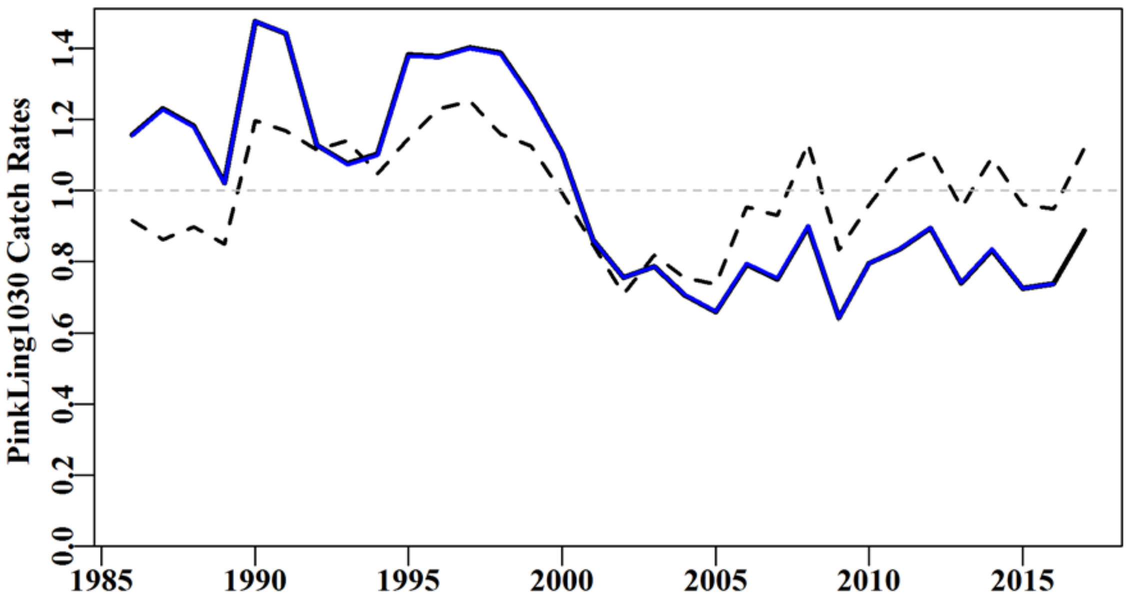


Figure 5.132. PinkLing1030. A comparison of the previous year's standardization (blue line) with this year's. They should lie on top of each other, although small deviations may relate to data adjustments, particularly in very recent years.

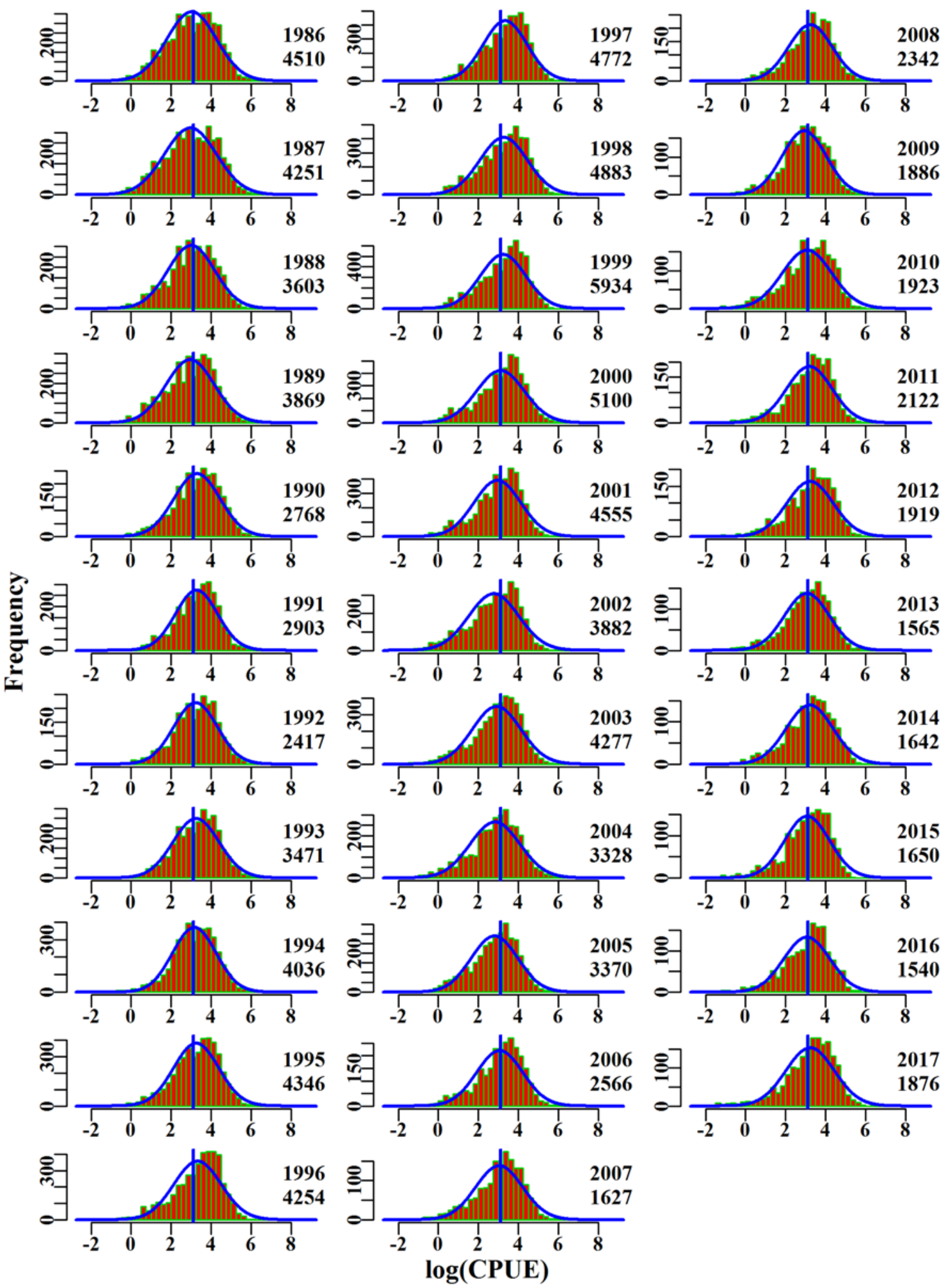


Figure 5.133. PinkLing1030. The log(CPUE) for each year of data available the blue lines are normal distributions fitted to the histogram frequencies. The numbers in each plot are the year and number of records.

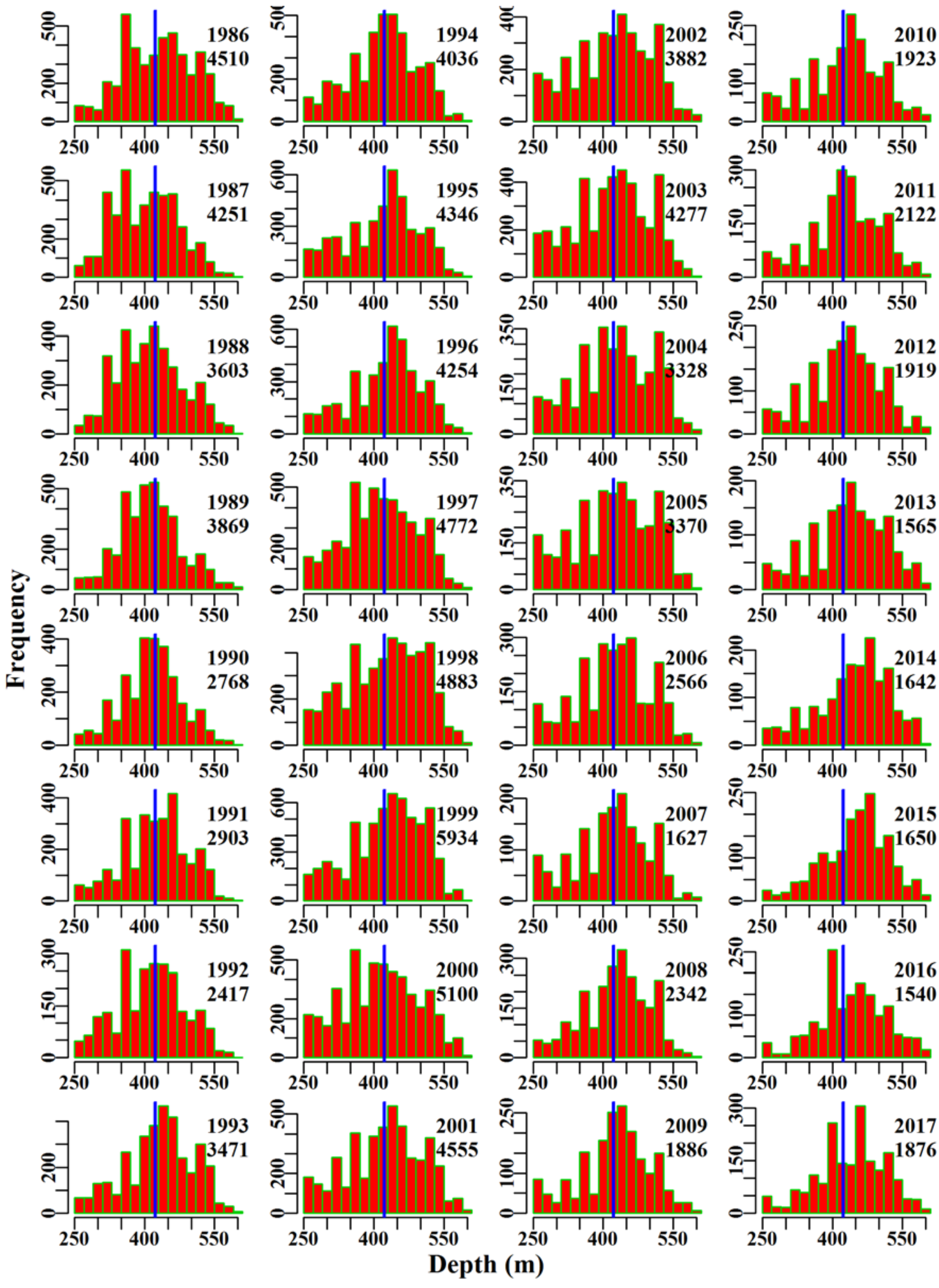


Figure 5.134. PinkLing1030. The average Depth of fishing for each year of data available to illustrate the development of the fishery through time. The numbers in each plot are the year and number of records.

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. Trawl caught Pink Ling based on methods TW, TDO, in zones 40, 50, and depths 200 to 800 within the SET fishery for the years 1986 - 2017 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 and one interaction (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 5.100). 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 – 2016 and above average in 2017 (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 - 2017

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	1.1858	0.000	6.366	0.056
1987	765.1	1306	205.7	28	52.0	1.3426	0.037	5.740	0.028
1988	583.1	1025	95.5	32	28.0	1.0489	0.040	6.722	0.070
1989	678.9	1466	182.8	34	36.2	1.0752	0.038	8.690	0.048
1990	674.5	1483	135.2	32	26.7	0.9664	0.039	11.943	0.088
1991	736.8	1874	194.8	37	25.6	1.0356	0.037	11.915	0.061
1992	568.3	1629	101.9	24	17.0	0.7707	0.038	12.661	0.124
1993	892.8	2248	235.2	24	26.6	1.0431	0.036	15.744	0.067
1994	895.4	2096	246.1	24	30.8	1.2739	0.036	12.093	0.049
1995	1208.9	3503	425.5	25	31.9	1.3191	0.034	21.945	0.052
1996	1233.3	3385	446.1	26	33.1	1.3872	0.035	22.301	0.050
1997	1696.8	3716	572.2	24	37.2	1.4551	0.034	21.065	0.037
1998	1592.4	3704	555.3	21	38.2	1.4387	0.034	19.110	0.034
1999	1651.6	3784	426.2	24	30.4	1.1341	0.034	23.836	0.056
2000	1507.5	4642	508.4	30	28.6	0.9881	0.034	31.181	0.061
2001	1393.0	5084	500.3	28	24.5	0.8757	0.034	36.867	0.074
2002	1330.3	4619	428.9	27	21.5	0.7581	0.034	36.499	0.085
2003	1353.1	3806	358.4	27	20.5	0.7614	0.034	26.224	0.073
2004	1522.9	3880	302.7	25	17.7	0.7149	0.034	17.723	0.059
2005	1203.3	2650	194.9	23	15.6	0.5957	0.036	11.283	0.058
2006	1069.2	2298	207.9	21	17.9	0.6295	0.036	6.710	0.032
2007	875.9	2505	284.5	16	21.7	0.6896	0.036	7.621	0.027
2008	980.3	1777	211.8	17	24.5	0.8847	0.037	4.357	0.021
2009	775.0	1956	258.3	13	24.6	0.8595	0.037	4.144	0.016
2010	906.2	2316	268.9	14	20.9	0.8396	0.036	4.801	0.018
2011	1081.9	2772	355.3	16	21.6	0.8403	0.036	5.216	0.015
2012	1030.9	2264	333.0	14	25.8	0.8830	0.036	4.383	0.013
2013	752.9	1757	278.2	17	27.9	0.9930	0.038	3.547	0.013
2014	861.2	1943	284.6	15	24.8	0.9772	0.037	3.537	0.012
2015	721.8	1631	237.6	13	25.1	0.9565	0.039	2.614	0.011
2016	735.8	1572	231.4	13	27.6	1.0567	0.039	3.453	0.015
2017	896.7	1764	293.1	12	28.7	1.2197	0.038	1.999	0.007

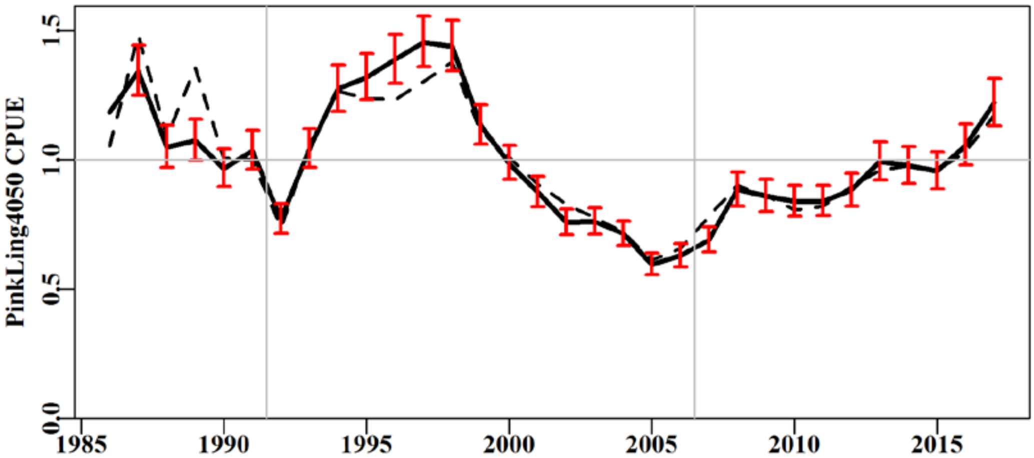


Figure 5.135. PinkLing4050 standardization. The dashed black line represents the geometric mean catch rate, solid black line the standardized catch rates. The red bars are the 95% confidence intervals about the mean estimates. The graph scales both time-series of standardized catch rates relative to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

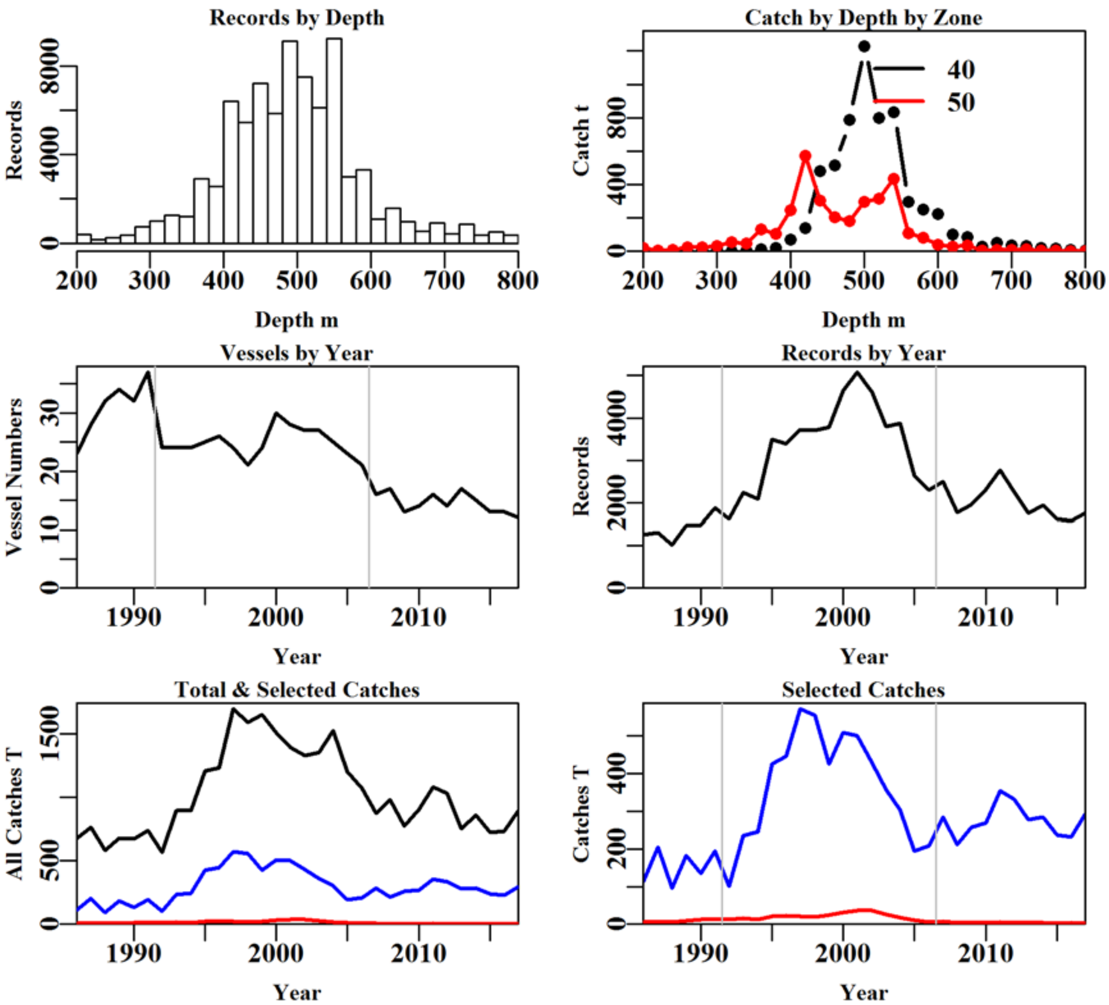


Figure 5.136. PinkLing4050 fishery details. The bottom left plot depicts all known catches (top black line), and all selected catches used in the analysis (middle blue line); the lower red line: selected catches < 30 kg).

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	305762	280936	207780	205520	82616	81804	81720
Difference	0	24826	73156	2260	122904	812	84
Catch	33220.78	26120.467	24291.718	23998.8763	9641.817	9477.826	9473.3077
Difference	0.00	7100.317	1828.749	292.8419	14357.059	163.991	4.5181

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	-326	81331	3933	81720	32	4.6	0.00
DepCat	-12148	70325	14938	81720	62	17.5	12.88
Vessel	-19008	64507	20756	81720	160	24.2	6.74
Month	-21885	62259	23004	81720	171	26.8	2.63
Zone	-23043	61382	23881	81720	172	27.9	1.03
DayNight	-23077	61352	23912	81720	175	27.9	0.03
Zone:DepCat	-23945	60659	24604	81720	205	28.7	0.79
Zone:Month	-24660	60159	25104	81720	186	29.3	1.39

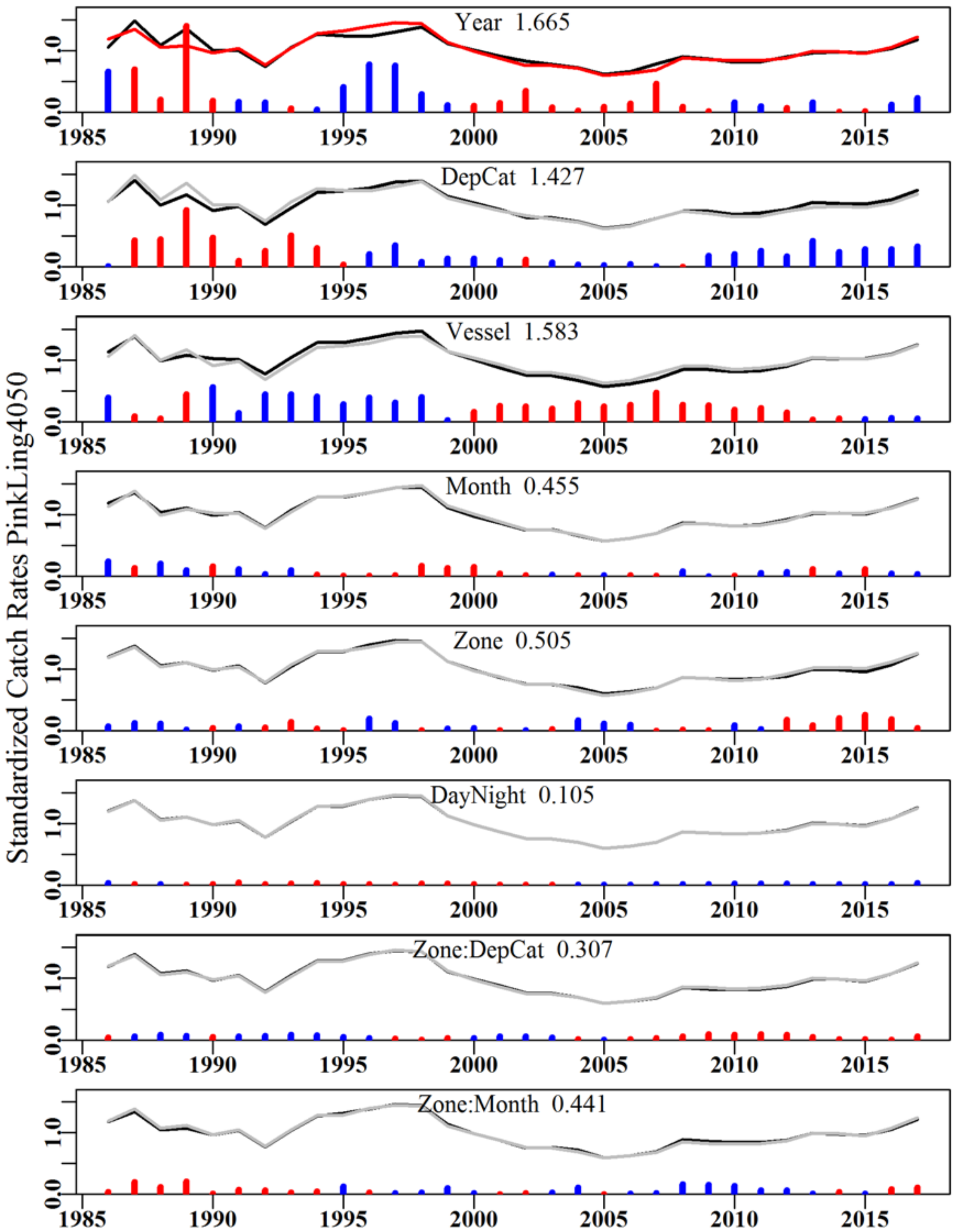


Figure 5.137. PinkLing4050. The influence of each factor on the optimal standardization. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by vertical bars with blue bars indicating the optimum model is higher than the geometric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

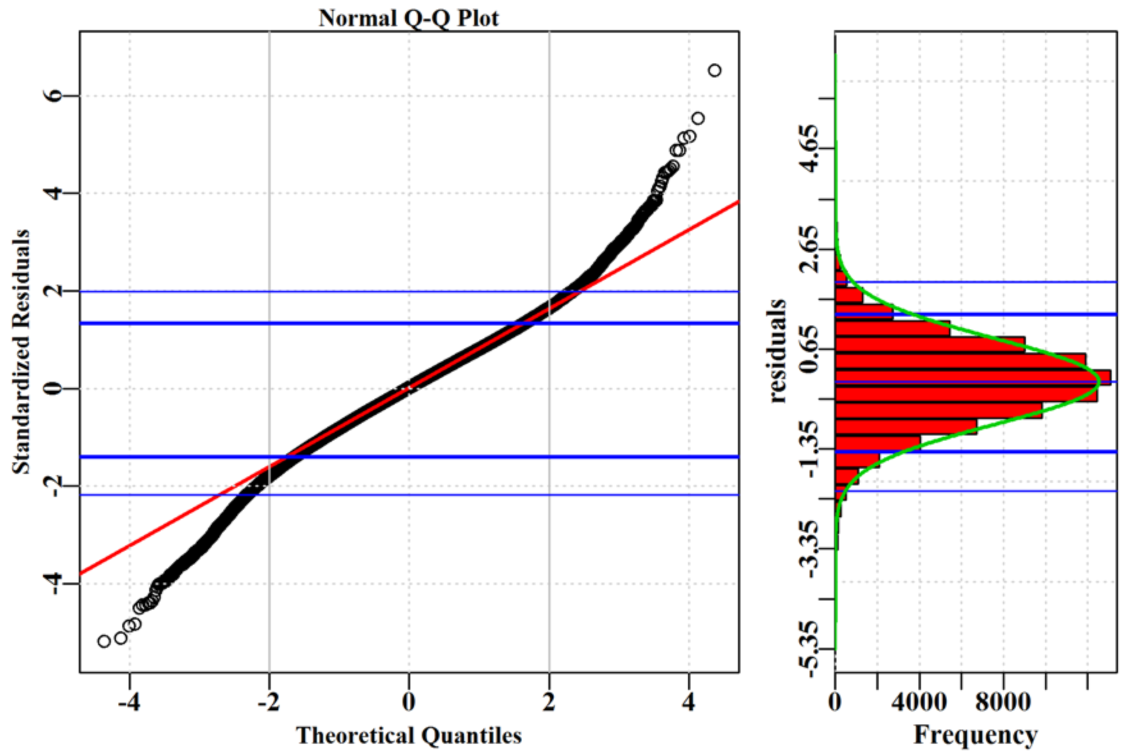


Figure 5.138. PinkLing4050. diagnostic plots. The distribution of residuals from the optimum fit. The qqplot indicates the fit to the expected normality, while the histogram of residuals illustrates the 90% quantiles to indicate the intensity of any lack of fit at the margins of the distribution.

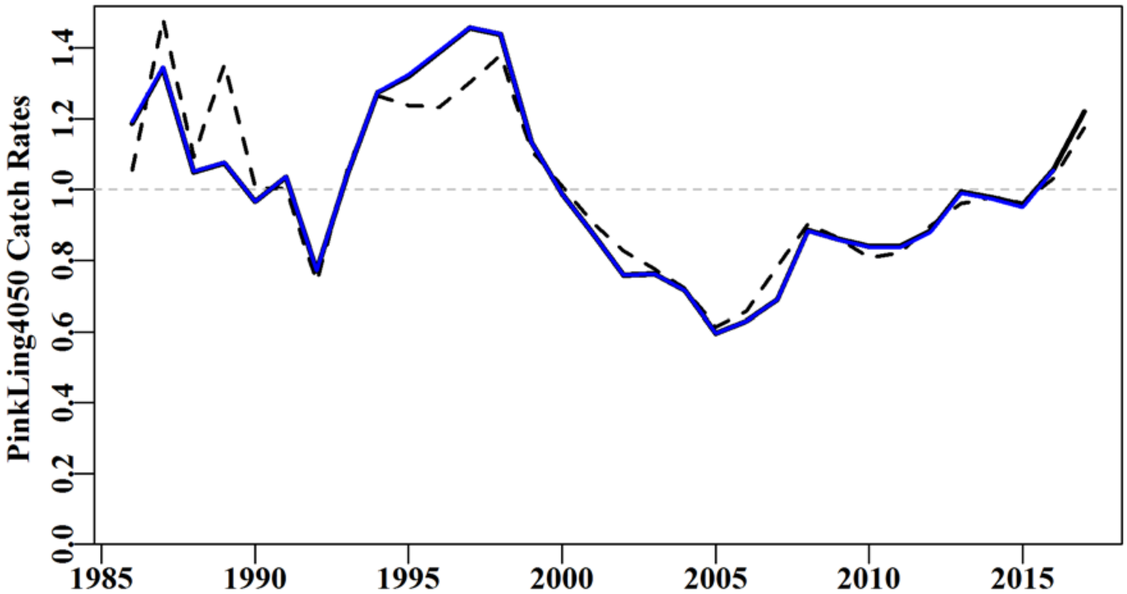


Figure 5.139. PinkLing4050. A comparison of the previous year's standardization (blue line) with this year's. They should lie on top of each other, although small deviations may relate to data adjustments, particularly in very recent years.

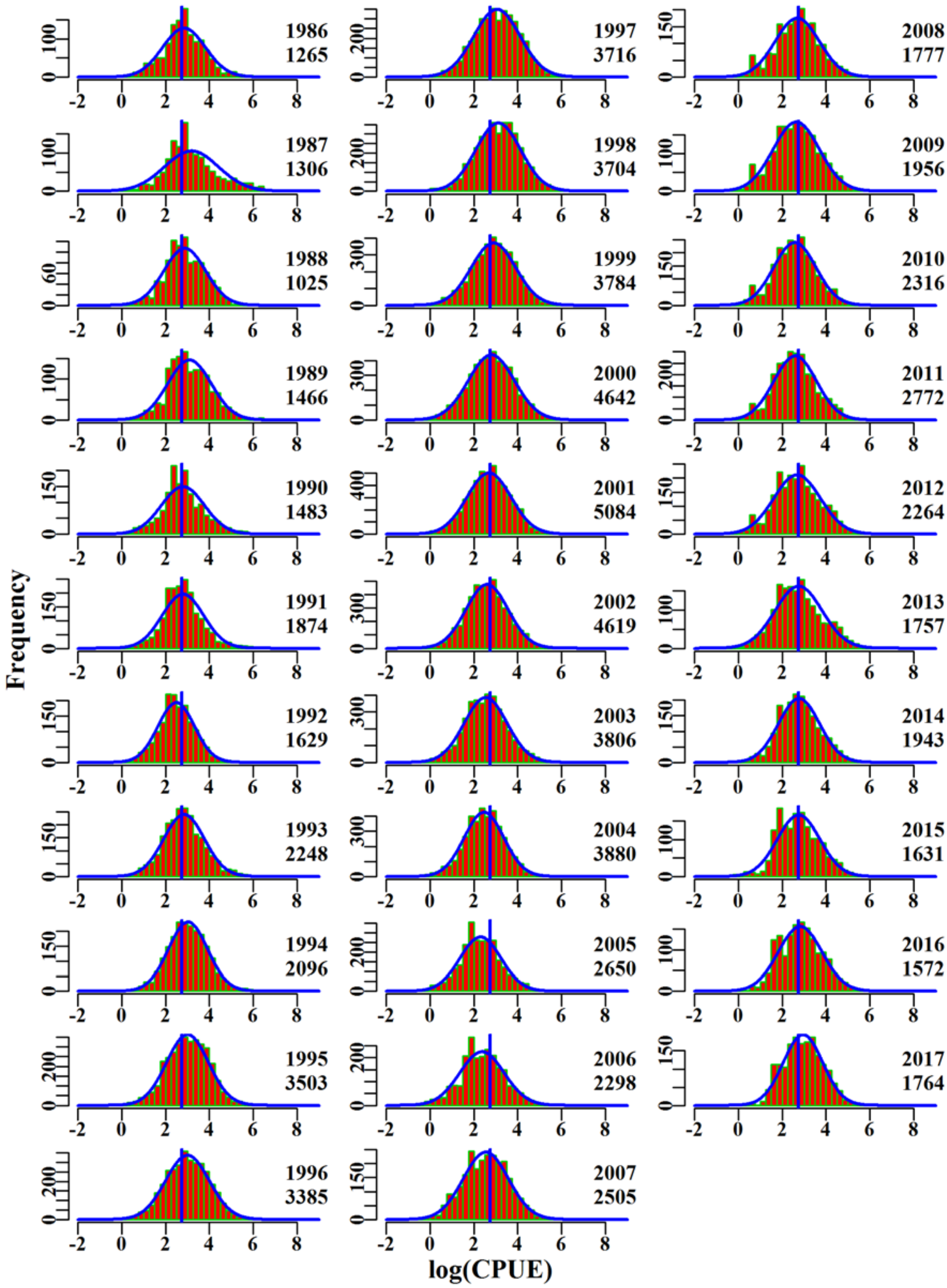


Figure 5.140. PinkLing4050. The log(CPUE) for each year of data available the blue lines are normal distributions fitted to the histogram frequencies. The numbers in each plot are the year and number of records.

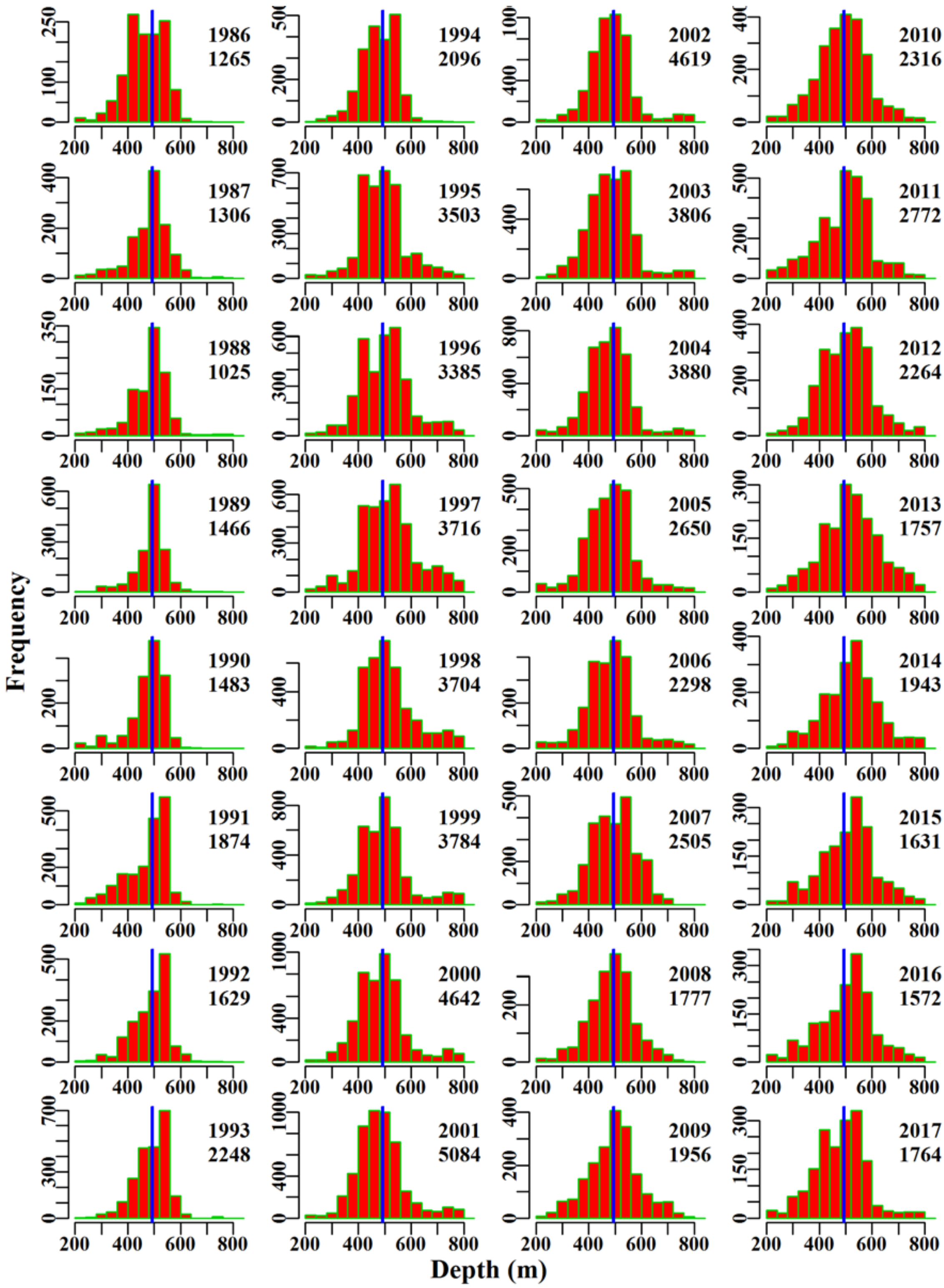


Figure 5.141. PinkLing4050. The average Depth of fishing for each year of data available to illustrate the development of the fishery through time. The numbers in each plot are the year and number of records.

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 - 2017 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 - 2017

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	1.0255	0.000	27.364	0.132
1987	198.4	3137	132.8	70	15.8	0.9551	0.026	27.705	0.209
1988	188.4	2806	150.7	73	18.6	1.0643	0.027	23.405	0.155
1989	209.2	3029	159.6	67	19.6	1.0215	0.027	24.547	0.154
1990	181.7	1958	115.3	57	20.6	1.3644	0.030	15.715	0.136
1991	223.6	2073	138.0	53	24.5	1.4246	0.030	16.912	0.123
1992	169.7	1850	114.2	48	20.4	1.2065	0.030	16.166	0.142
1993	259.6	2905	197.4	52	21.7	1.2100	0.027	25.126	0.127
1994	257.3	3000	179.9	49	22.0	1.1245	0.027	26.269	0.146
1995	240.0	3138	150.0	50	18.1	0.9994	0.027	31.852	0.212
1996	263.9	3401	176.1	53	17.8	0.8884	0.026	31.446	0.179
1997	298.8	3707	192.6	53	17.2	0.9396	0.026	35.444	0.184
1998	295.0	3837	194.0	49	17.3	0.8353	0.026	36.497	0.188
1999	295.8	4398	218.4	52	16.8	0.9307	0.025	42.854	0.196
2000	270.2	4168	180.7	54	14.9	0.7761	0.026	40.560	0.224
2001	281.6	4050	184.5	43	16.7	0.8947	0.026	38.378	0.208
2002	255.3	3631	150.2	45	15.9	0.8372	0.027	32.844	0.219
2003	322.7	3944	184.5	53	17.3	0.8881	0.026	35.032	0.190
2004	316.3	3111	149.7	46	17.9	0.8952	0.028	25.834	0.173
2005	316.8	3041	167.5	46	19.9	1.0070	0.028	26.055	0.156
2006	237.6	2309	112.7	38	15.6	0.8719	0.030	22.962	0.204
2007	180.6	1519	94.7	22	20.2	1.1098	0.033	14.042	0.148
2008	184.3	1830	101.4	23	17.5	1.0121	0.032	16.250	0.160
2009	173.9	1662	98.9	23	20.0	1.0029	0.033	15.540	0.157
2010	195.6	1726	117.2	21	22.7	0.9834	0.032	14.324	0.122
2011	186.9	1843	115.5	22	23.4	0.9017	0.032	15.249	0.132
2012	183.9	1673	113.4	22	26.2	0.9536	0.033	13.219	0.117
2013	171.2	1277	102.4	20	30.1	1.0042	0.035	9.188	0.090
2014	174.4	1522	115.9	21	29.9	1.0109	0.034	10.421	0.090
2015	150.8	1404	104.9	22	31.5	0.8726	0.035	9.146	0.087
2016	132.1	1160	94.9	23	31.1	0.9682	0.037	7.177	0.076
2017	155.7	1397	108.3	19	29.7	1.0205	0.035	8.707	0.080

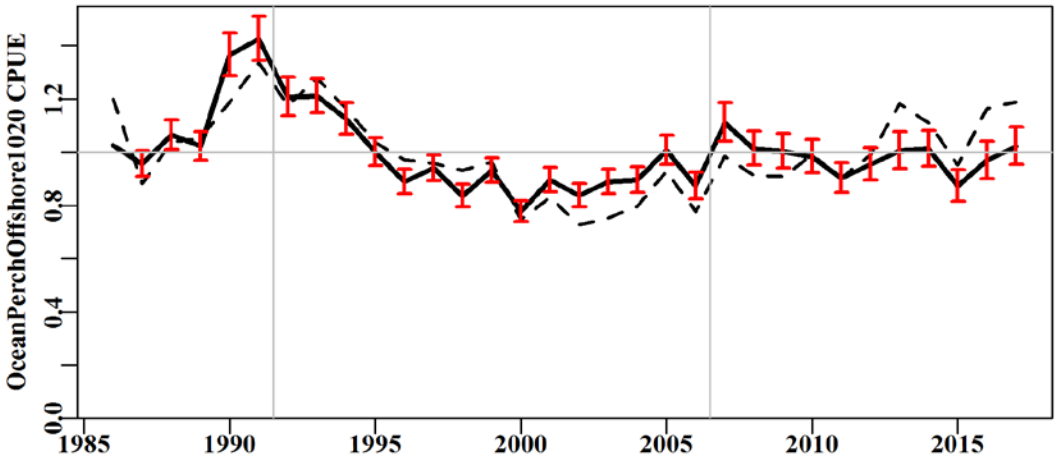


Figure 5.142. OceanPerchOffshore1020 standardization. The dashed black line represents the geometric mean catch rate, solid black line the standardized catch rates. The red bars are the 95% confidence intervals about the mean estimates. The graph scales both time-series of standardized catch rates relative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

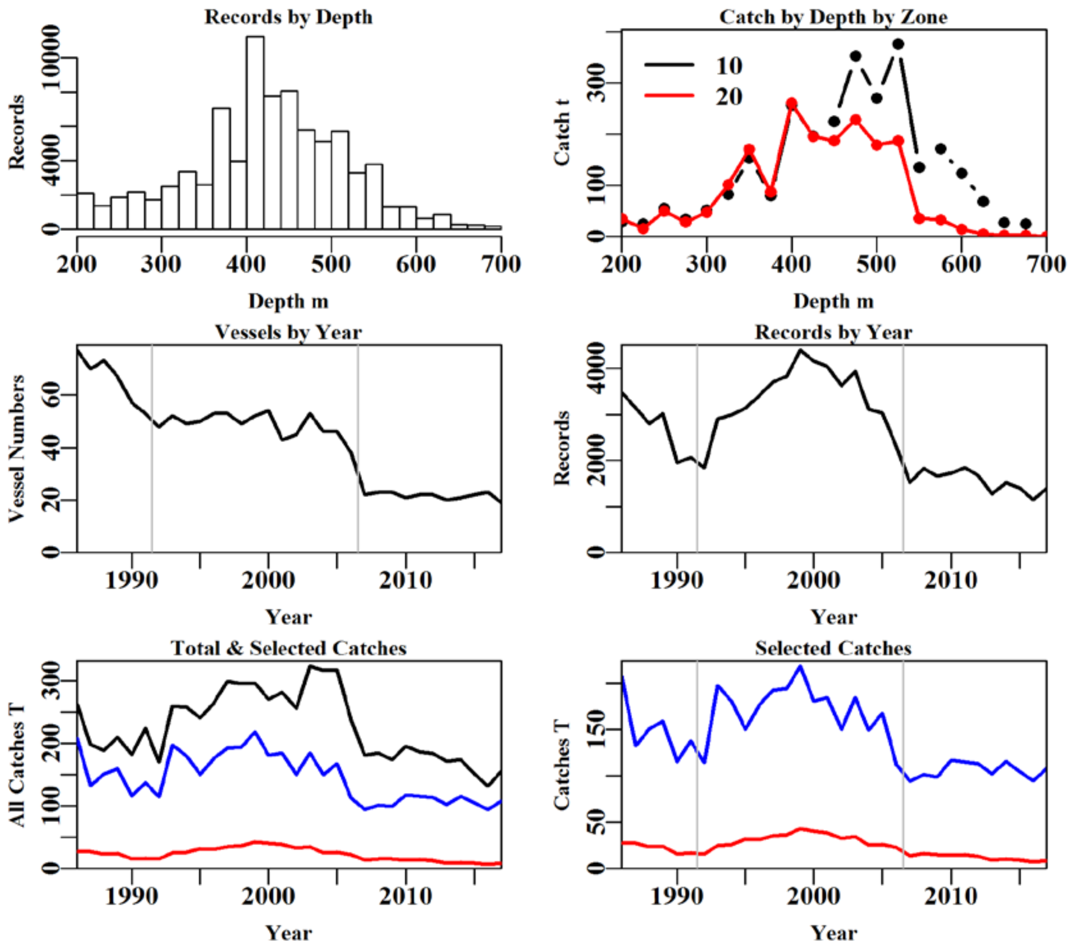


Figure 5.143. OceanPerchOffshore1020 fishery details. The bottom left plot depicts all known catches (top black line), and all selected catches used in the analysis (middle blue line); the lower red line: selected catches < 30 kg).

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	168782	153490	124743	123330	84740	84022	83984
Difference	0	15292	28747	1413	38590	718	38
Catch	7359.218	6736.9694	5903.1463	5791.652	4653.804	4625.5786	4623.418
Difference	0.000	622.2486	833.8231	111.494	1137.848	28.2258	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	26406	114926	2291	83984	32	1.9	0.00
Month	25011	113003	4214	83984	43	3.5	1.63
Vessel	11363	95684	21533	83984	205	18.2	14.62
DepCat	947	84482	32734	83984	225	27.7	9.56
DayNight	393	83921	33296	83984	228	28.2	0.48
Zone	352	83878	33339	83984	229	28.2	0.04
Zone:Month	-1772	81761	35455	83984	240	30.0	1.80
Zone:DepCat	-24	83464	33753	83984	249	28.6	0.34

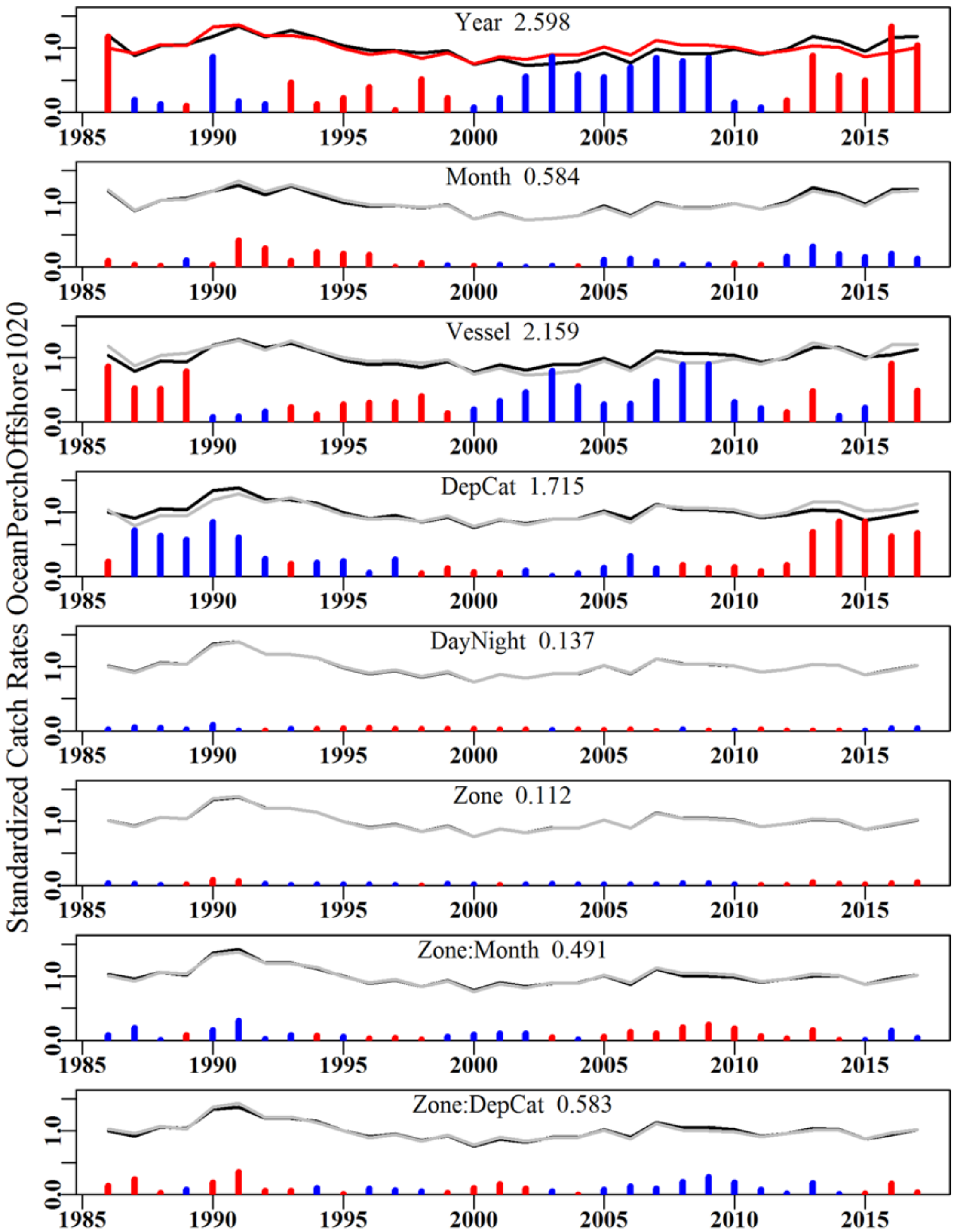


Figure 5.144. OceanPerchOffshore1020. The influence of each factor on the optimal standardization. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by vertical bars with blue bars indicating the optimum model is higher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

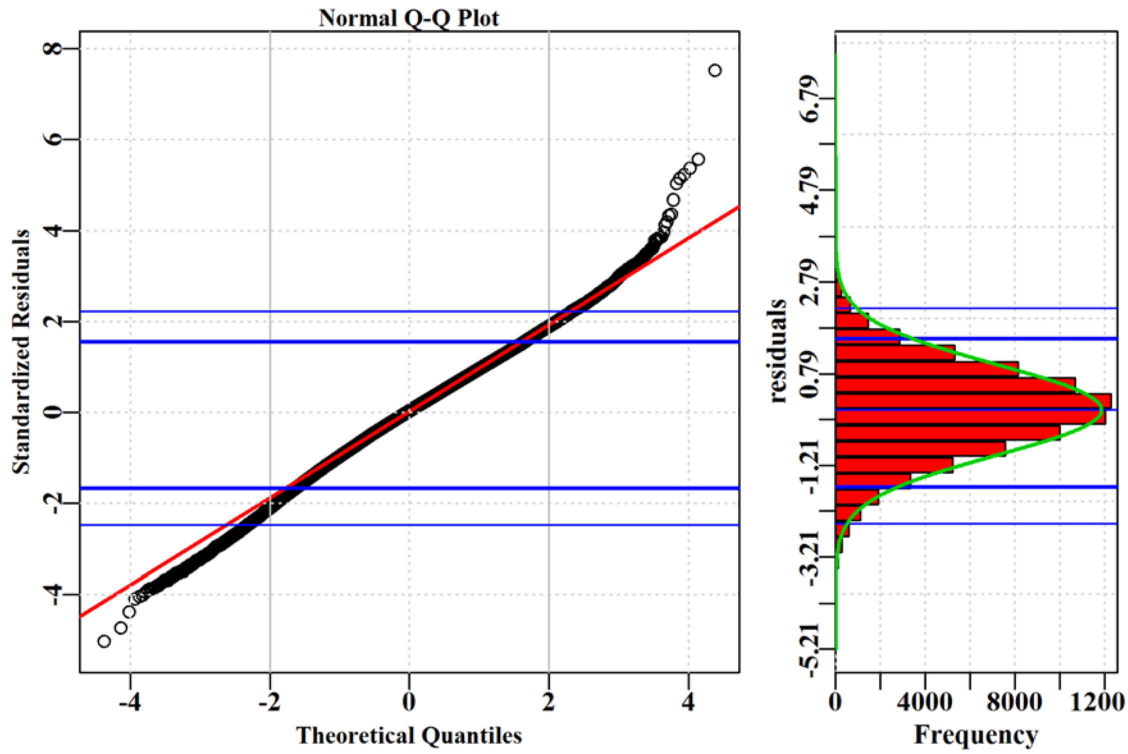


Figure 5.145. OceanPerchOffshore1020. diagnostic plots. The distribution of residuals from the optimum fit. The qqplot indicates the fit to the expected normality, while the histogram of residuals illustrates the 90% quantiles to indicate the intensity of any lack of fit at the margins of the distribution.

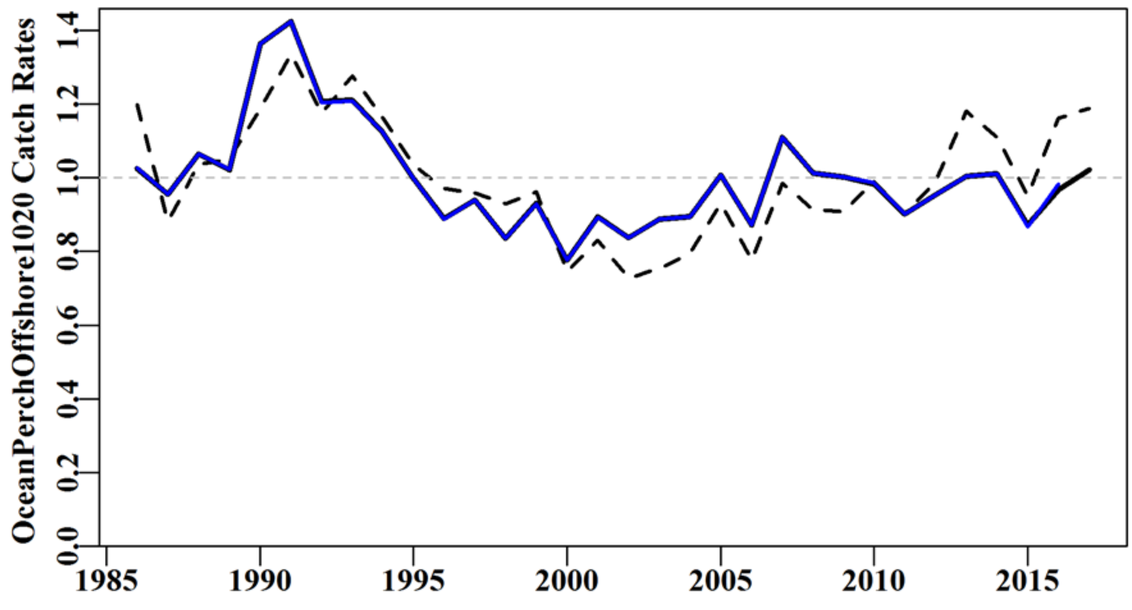


Figure 5.146. OceanPerchOffshore1020. A comparison of the previous year's standardization (blue line) with this year's. They should lie on top of each other, although small deviations may relate to data adjustments, particularly in very recent years.

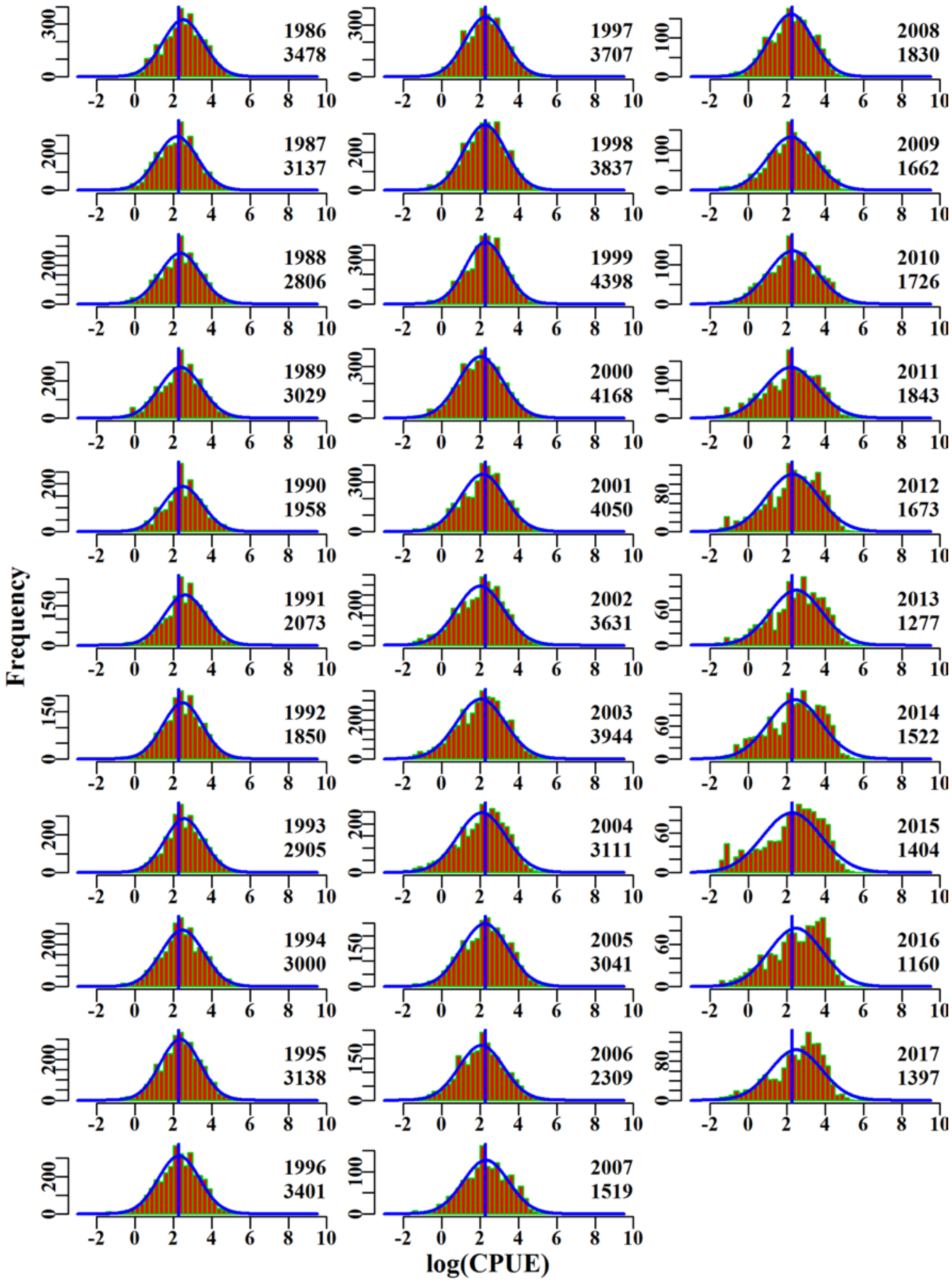


Figure 5.147. OceanPerchOffshore1020. The log(CPUE) for each year of data available the blue lines are normal distributions fitted to the histogram frequencies. The numbers in each plot are the year and number of records.

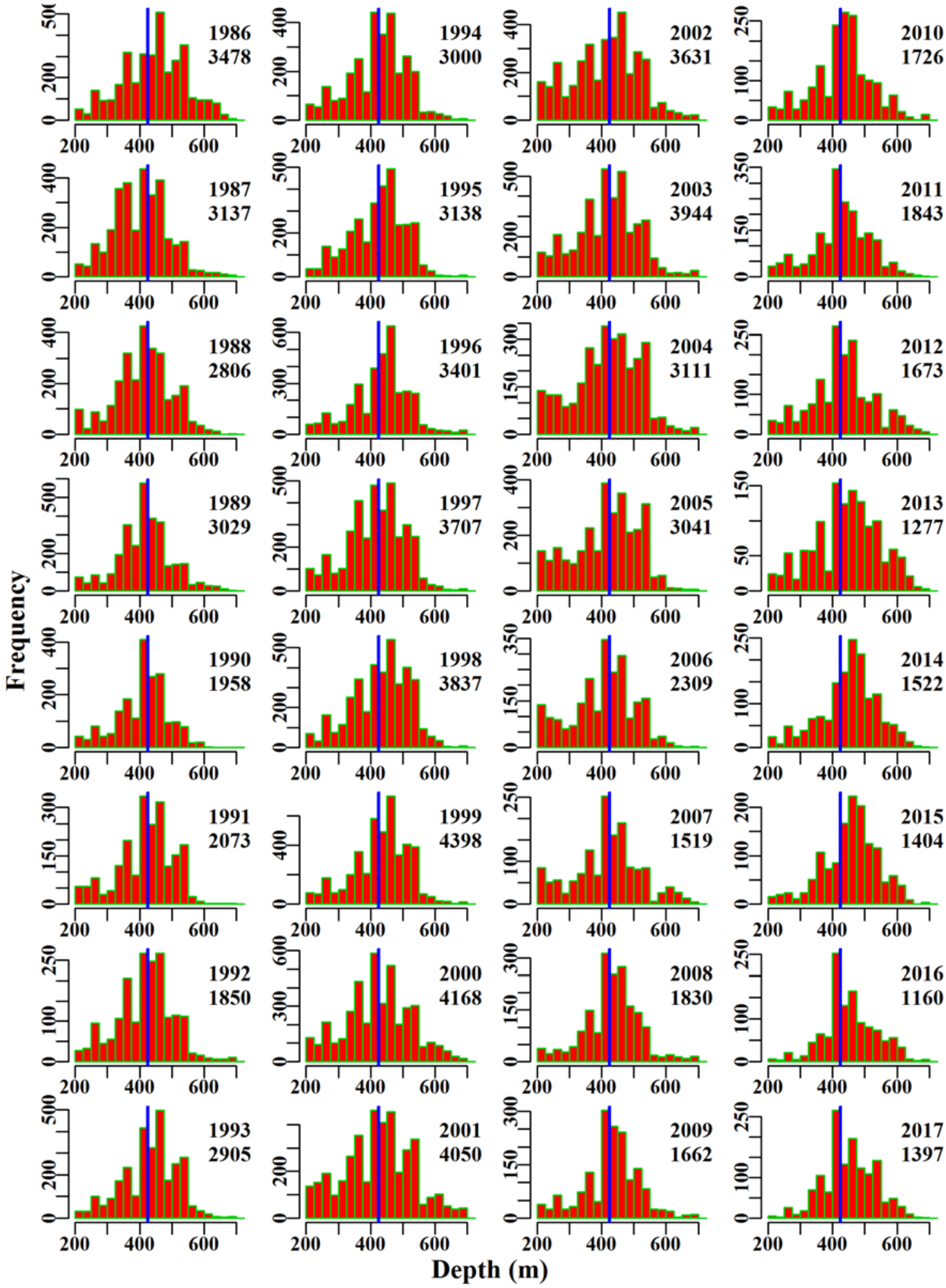


Figure 5.148. OceanPerchOffshore1020. The average Depth of fishing for each year of data available to illustrate the development of the fishery through time. The numbers in each plot are the year and number of records.

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 - 2017 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 and one interaction (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.

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 at average before dropping in 2015and increasing to just below average in 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 - 2017

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	1.1099	0.000	29.820	0.135
1987	198.3	3409	144.5	93	15.7	1.0225	0.024	30.071	0.208
1988	186.7	3097	161.3	93	18.4	1.1513	0.025	26.371	0.163
1989	206.3	3412	173.2	86	18.8	1.1204	0.024	29.526	0.170
1990	180.6	2423	131.5	80	18.6	1.4200	0.027	22.128	0.168
1991	223.2	2853	169.5	87	21.3	1.4529	0.026	26.864	0.159
1992	169.7	2375	130.3	70	17.7	1.1913	0.027	22.496	0.173
1993	259.3	3643	221.8	68	19.2	1.2333	0.024	35.331	0.159
1994	257.2	3782	208.3	66	19.1	1.1775	0.024	38.140	0.183
1995	240.0	4437	191.0	69	15.2	1.0939	0.023	50.683	0.265
1996	263.2	4848	213.8	76	14.5	0.9707	0.023	53.199	0.249
1997	296.3	5594	246.5	71	13.8	1.0126	0.023	59.734	0.242
1998	292.1	5325	240.4	67	14.6	0.9380	0.023	55.634	0.231
1999	290.7	5776	255.7	72	14.8	0.9738	0.023	61.811	0.242
2000	269.8	5686	217.7	80	12.9	0.8349	0.023	59.058	0.271
2001	281.6	5960	228.9	68	13.4	0.8980	0.023	63.067	0.276
2002	255.3	5596	195.1	69	12.4	0.8606	0.023	57.058	0.292
2003	322.7	5775	231.1	66	13.4	0.9375	0.023	57.348	0.248
2004	316.3	5099	202.2	68	12.9	0.9550	0.024	50.046	0.248
2005	316.8	4505	201.2	64	14.9	0.9721	0.024	42.533	0.211
2006	237.6	3337	137.9	52	12.4	0.8687	0.026	34.920	0.253
2007	180.6	2609	121.6	33	13.6	0.9935	0.027	26.037	0.214
2008	184.3	2665	124.5	32	13.8	0.9854	0.027	25.722	0.207
2009	173.9	2705	128.7	32	13.9	0.9630	0.027	27.628	0.215
2010	195.6	2892	150.7	32	14.4	0.9849	0.027	29.748	0.197
2011	186.8	3107	146.6	30	14.6	0.8304	0.026	29.911	0.204
2012	180.6	2755	135.9	30	16.9	0.8029	0.027	23.894	0.176
2013	166.4	2208	122.5	29	17.9	0.8296	0.029	18.404	0.150
2014	141.6	1649	107.5	28	23.6	0.8437	0.031	11.674	0.109
2015	125.2	1539	99.2	27	24.4	0.7383	0.032	9.456	0.095
2016	111.6	1209	92.0	28	27.5	0.8965	0.035	7.163	0.078
2017	124.6	1210	94.9	21	28.4	0.9371	0.035	7.968	0.084

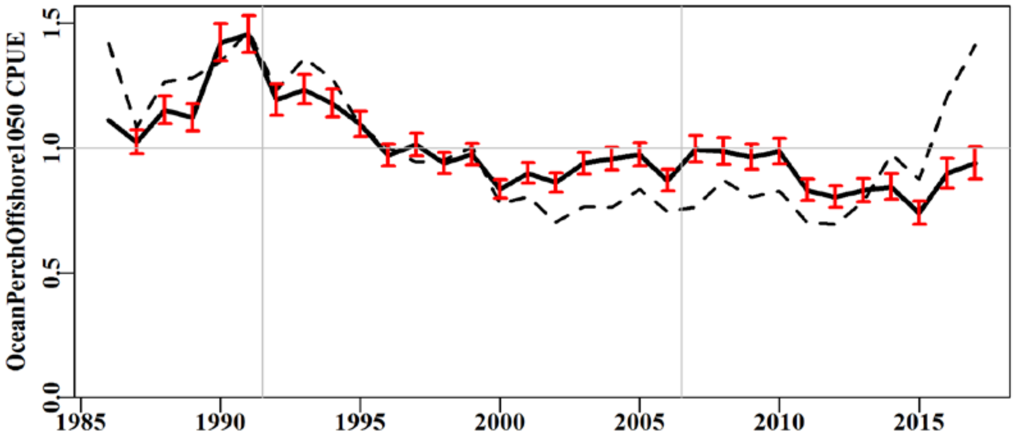


Figure 5.149. OceanPerchOffshore1050 standardization. The dashed black line represents the geometric mean catch rate, solid black line the standardized catch rates. The red bars are the 95% confidence intervals about the mean estimates. The graph scales both time-series of standardized catch rates relative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

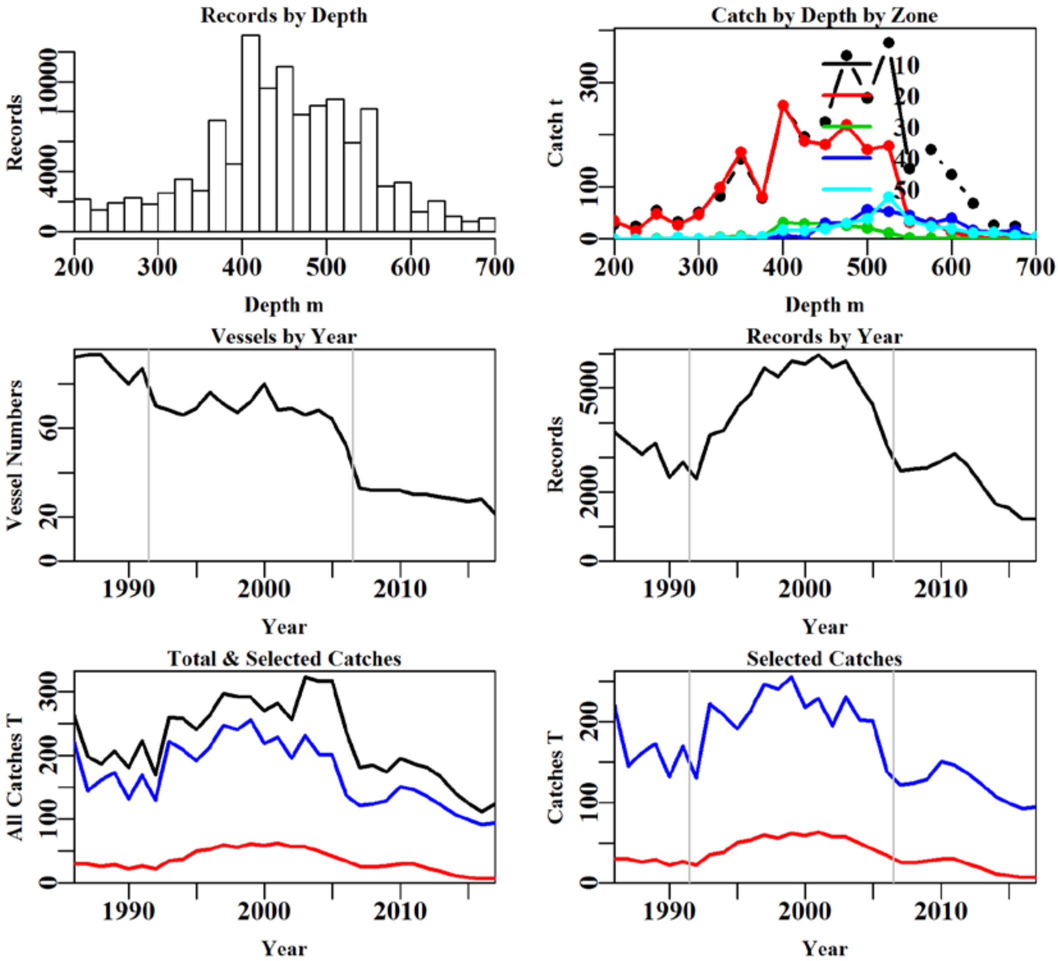


Figure 5.150. OceanPerchOffshore1050 fishery details. The bottom left plot depicts all known catches (top black line), and all selected catches used in the analysis (middle blue line); the lower red line: selected catches < 30 kg).

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	36682	158313	6024	115207	32	3.6	0.00
Month	36162	157570	6767	115207	43	4.1	0.44
Vessel	9079	124116	40221	115207	249	24.3	20.23
DepCat	680	115350	48987	115207	269	29.6	5.33
DayNight	-499	114169	50168	115207	272	30.4	0.72
Zone	-7532	107400	56937	115207	276	34.5	4.13
Zone:Month	-10239	104826	59511	115207	320	36.0	1.55
Zone:DepCat	-9112	105790	58547	115207	356	35.4	0.94

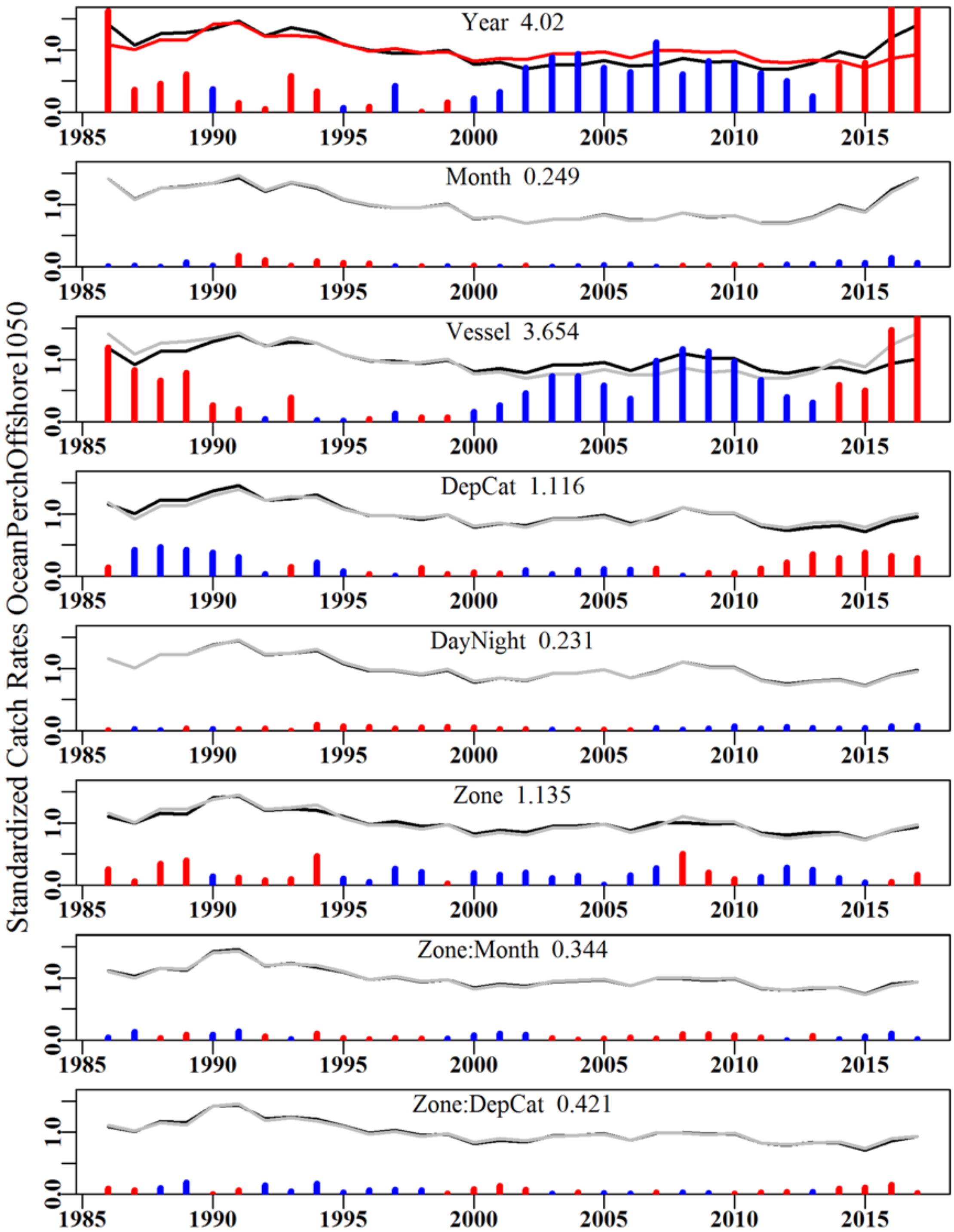


Figure 5.151. OceanPerchOffshore1050. The influence of each factor on the optimal standardization. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by vertical bars with blue bars indicating the optimum model is higher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

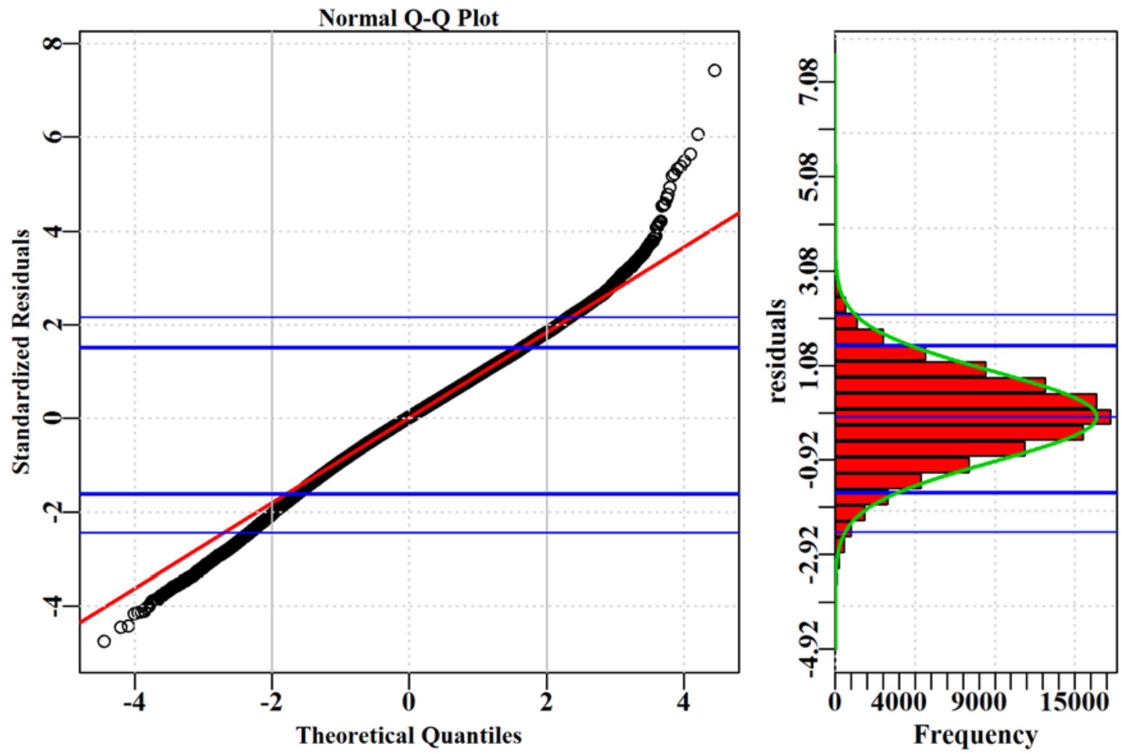


Figure 5.152. OceanPerchOffshore1050. diagnostic plots. The distribution of residuals from the optimum fit. The qqplot indicates the fit to the expected normality, while the histogram of residuals illustrates the 90% quantiles to indicate the intensity of any lack of fit at the margins of the distribution.

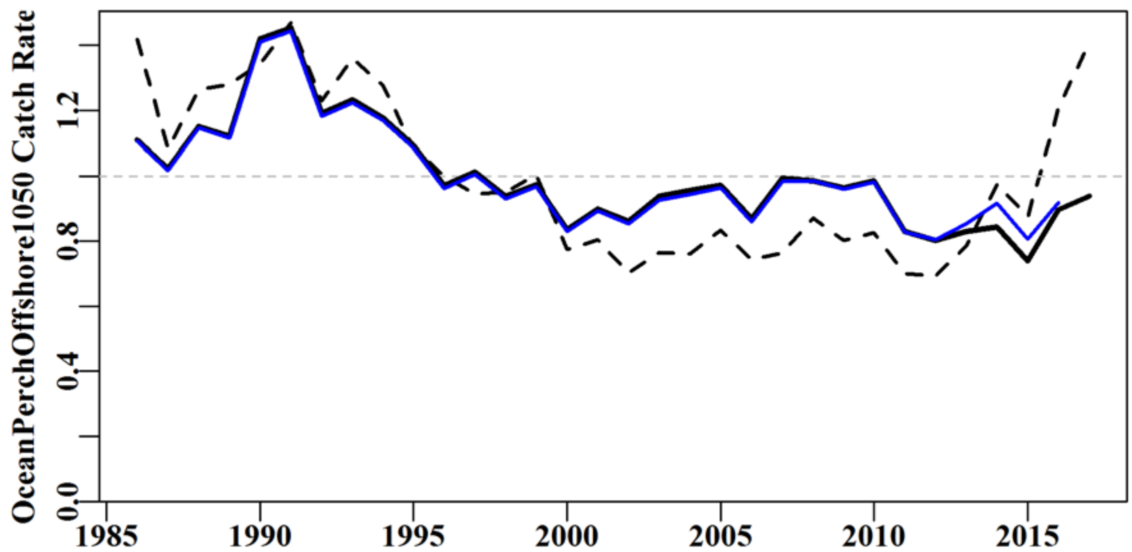


Figure 5.153. OceanPerchOffshore1050. A comparison of the previous year's standardization (blue line) with this year's. They should lie on top of each other, although small deviations may relate to data adjustments, particularly in very recent years.

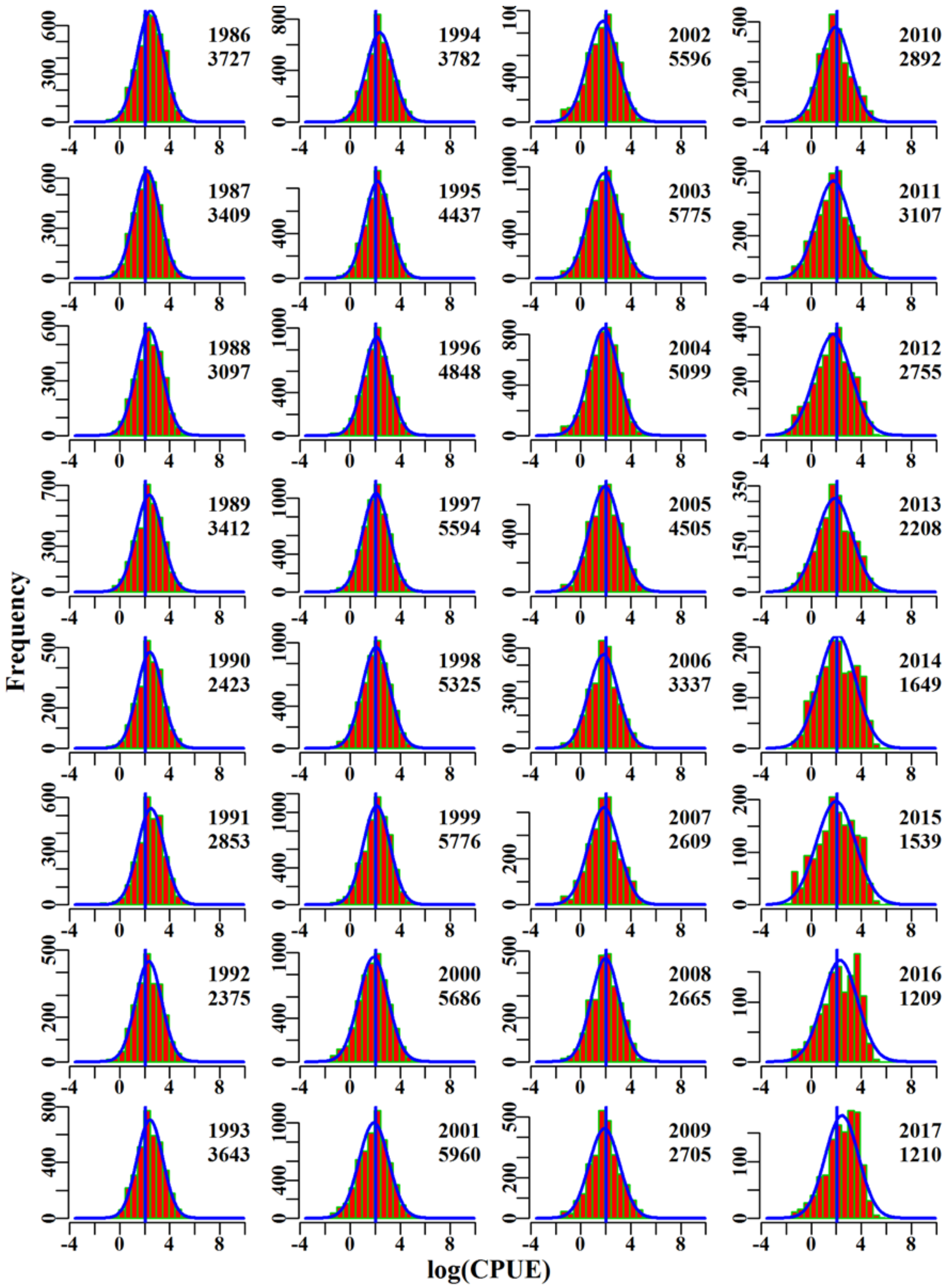


Figure 5.154. OceanPerchOffshore1050. The log(CPUE) for each year of data available the blue lines are normal distributions fitted to the histogram frequencies. The numbers in each plot are the year and number of records.

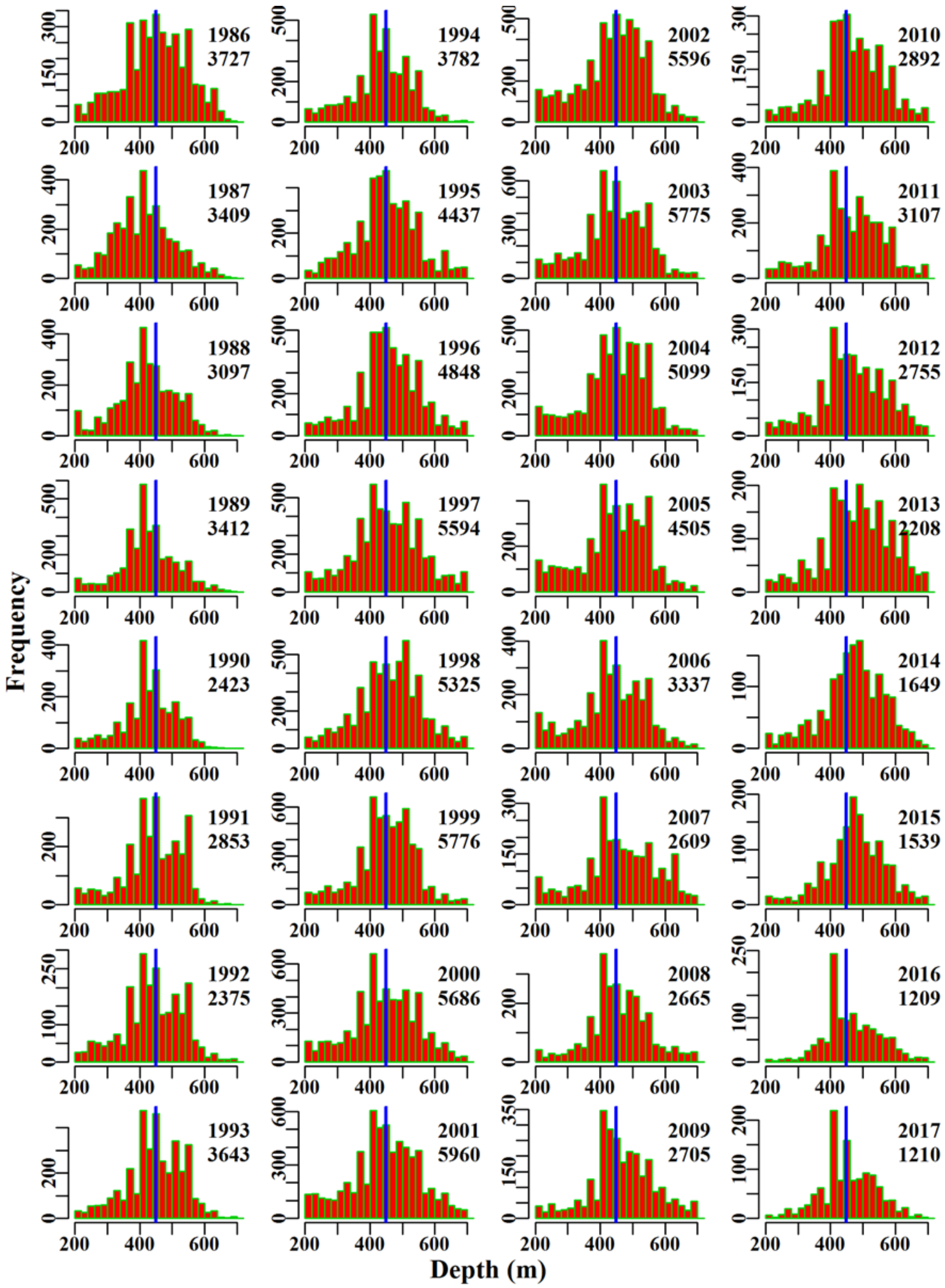


Figure 5.155. OceanPerchOffshore1050. The average Depth of fishing for each year of data available to illustrate the development of the fishery through time. The numbers in each plot are the year and number of records.

5.26 Comparison of Zones 10:20 and 10:50

Table 5.110. The reported log-book catches and records by zone, with catches first and then records for each zone in sequence. The difference between the analyses is only die 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	58.235	515	41.913	714	4.038	171	7.537	391	10.788	417
2014	67.190	573	28.259	596	1.200	52	4.464	190	6.425	238
2015	59.821	508	27.503	595	4.146	122	2.192	112	5.548	202
2016	62.318	516	23.032	450	1.467	68	1.986	68	3.200	107
2017	52.119	528	37.089	483	2.341	111	0.814	26	2.528	62

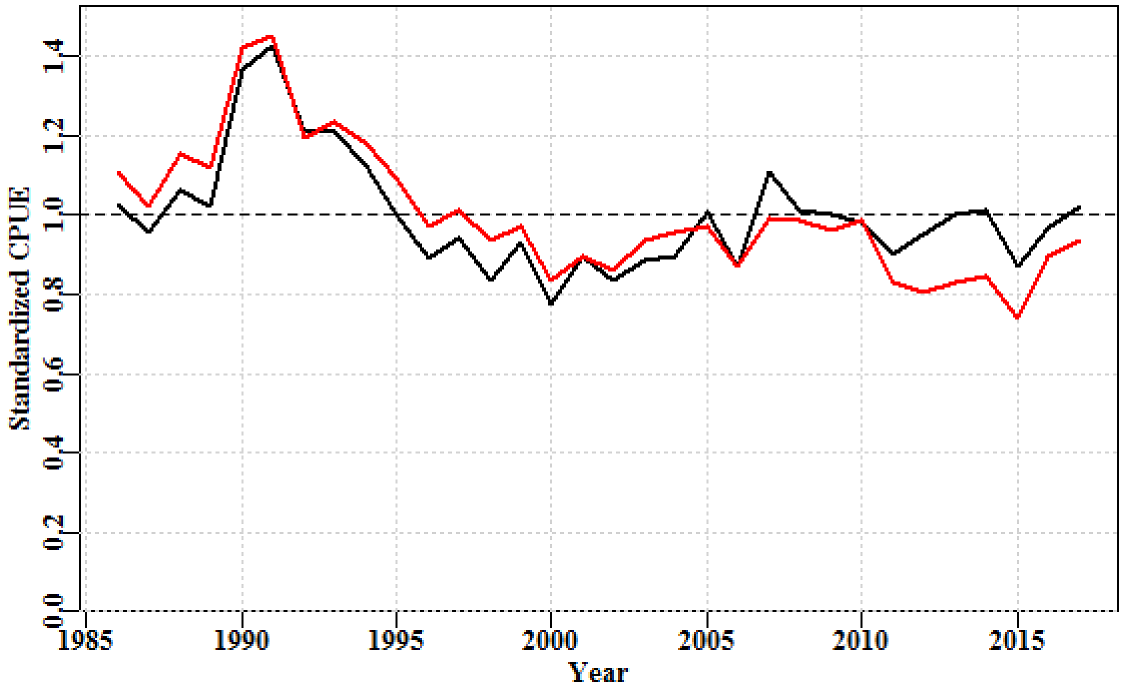


Figure 5.156. A comparison of the optimum standardization for Offshore Ocean Perch when using just Zones 10 and 20 (red) and when including records from zones 30, 40 , and 50 (black).

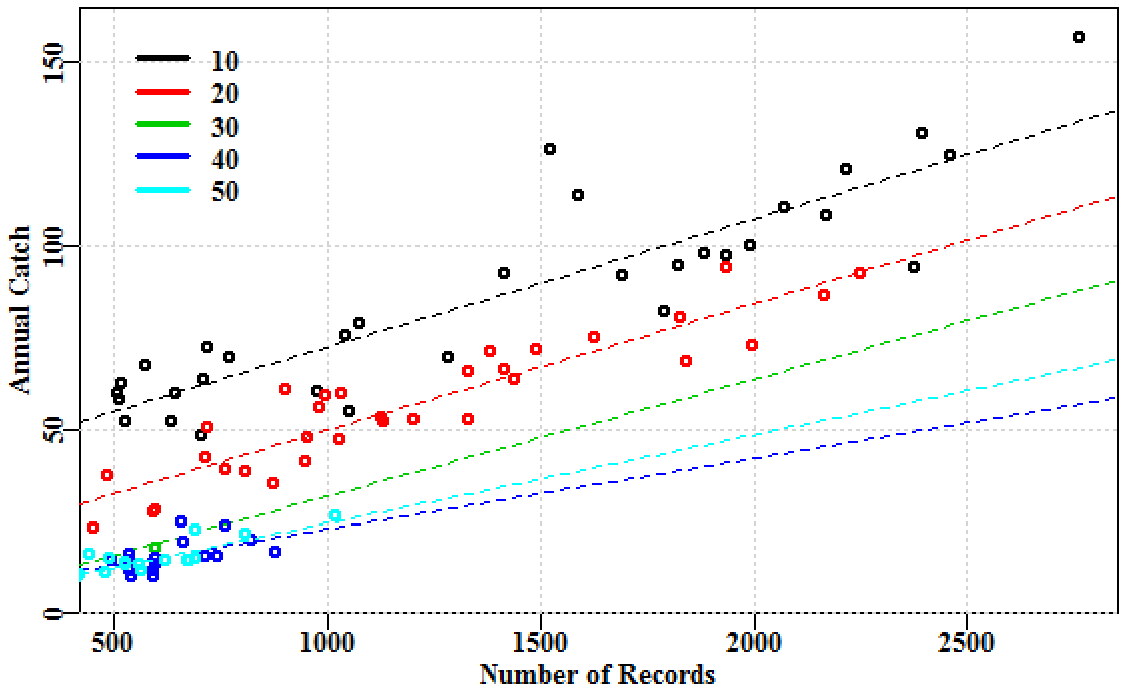
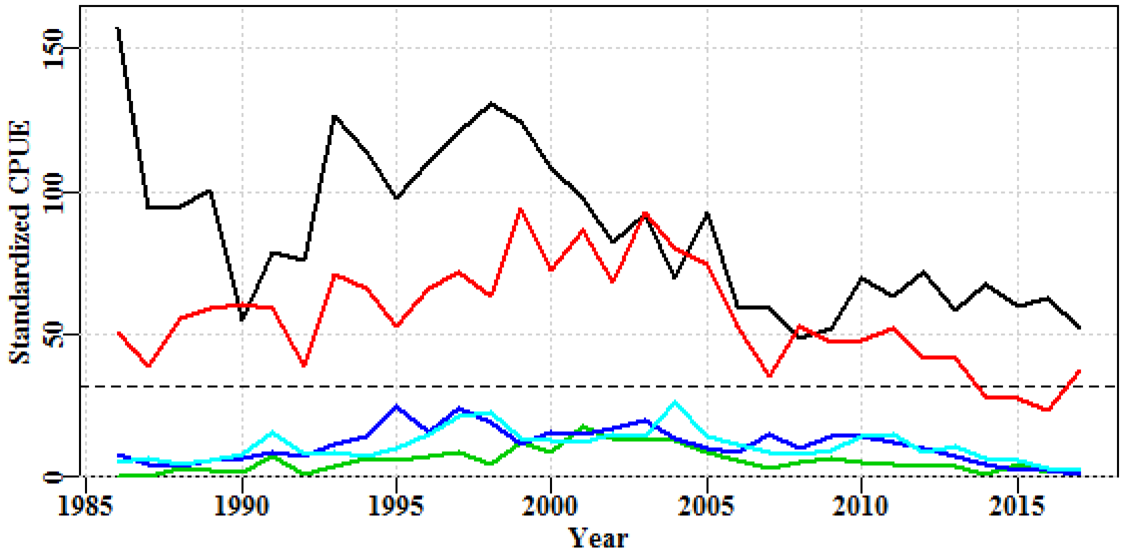


Figure 5.157. A plot of the different reported Catch vs reported number of records for each zone from 10 to 50 for Offshoure Ocean Perch. The dotted lines are the linear regressions in each case illustrating the different average ratio CPUE for each zone and that fact that CPUE in zones 30 - 50 is generally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



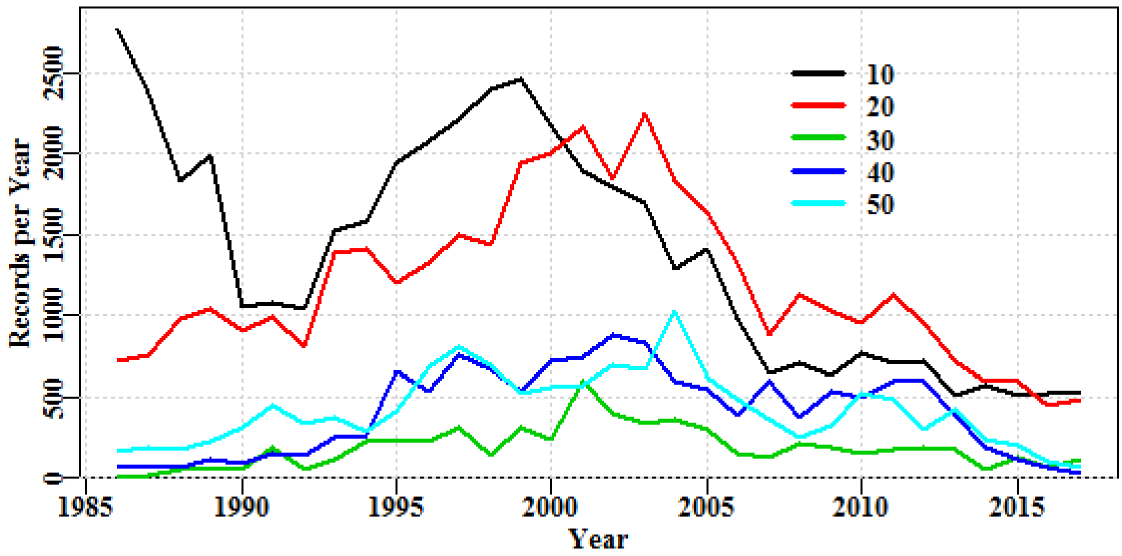


Figure 5.158. Catch and Records by Zone through time illustrating that catches in 30 to 50 have never been as great as those in zones 10 and 20 although the number of records can be relatively high.

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 - 2017 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 < 30kg 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 just above average in the last 10 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 - 2017

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	0.8975	0.000	3.786	0.248
1987	198.3	403	11.9	58	10.7	1.0577	0.092	4.053	0.340
1988	186.7	517	16.5	58	11.6	1.2058	0.089	5.689	0.345
1989	206.3	436	15.0	52	12.4	1.1599	0.093	4.817	0.322
1990	180.6	438	15.0	43	11.9	1.2537	0.094	4.444	0.297
1991	223.2	478	19.4	42	16.9	1.3397	0.093	4.937	0.255
1992	169.7	261	14.0	26	19.7	1.7457	0.105	2.624	0.187
1993	259.3	446	23.3	33	20.5	1.9606	0.096	3.858	0.166
1994	257.2	544	22.3	32	15.6	1.8019	0.093	6.112	0.274
1995	240.0	592	20.8	32	13.4	1.3481	0.090	7.659	0.368
1996	263.2	679	20.6	39	11.0	1.2143	0.090	8.841	0.429
1997	296.3	554	15.2	39	10.3	1.1372	0.093	6.486	0.427
1998	292.1	633	15.0	38	9.3	1.0011	0.091	8.329	0.554
1999	290.7	666	15.3	38	8.8	0.8963	0.091	8.525	0.558
2000	269.8	1316	30.4	37	8.8	1.0626	0.086	15.227	0.501
2001	281.6	1034	23.1	34	8.7	1.0331	0.088	10.701	0.462
2002	255.3	1405	24.7	34	6.5	0.7437	0.087	12.224	0.495
2003	322.7	1069	17.0	37	5.9	0.5748	0.088	9.449	0.555
2004	316.3	944	14.7	38	6.1	0.5868	0.089	7.482	0.509
2005	316.8	850	17.3	39	7.0	0.6589	0.090	7.912	0.459
2006	237.6	585	8.9	34	4.7	0.5526	0.093	4.704	0.531
2007	180.6	386	8.6	20	9.5	0.7914	0.100	4.281	0.500
2008	184.3	317	7.6	20	8.9	0.9674	0.103	3.388	0.448
2009	173.9	259	6.0	21	8.2	0.8324	0.107	2.847	0.471
2010	195.6	275	6.3	21	8.3	0.8679	0.105	3.098	0.494
2011	186.8	244	5.2	19	7.8	1.0096	0.108	2.414	0.464
2012	180.6	372	7.3	20	7.4	0.8330	0.100	3.514	0.481
2013	166.4	215	4.8	14	7.7	0.9785	0.110	2.745	0.569
2014	141.6	146	2.9	15	6.4	0.6867	0.122	1.572	0.549
2015	125.2	117	2.5	12	6.5	0.4170	0.129	1.019	0.414
2016	111.6	71	1.6	11	6.8	0.6212	0.157	0.720	0.465
2017	124.6	67	1.6	9	7.3	0.7630	0.158	0.925	0.572

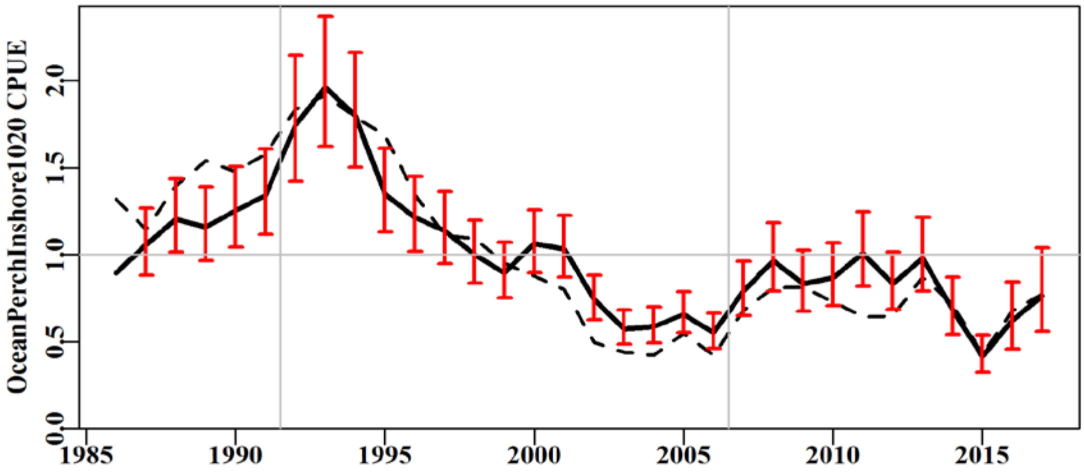


Figure 5.159. OceanPerchInshore1020 standardization. The dashed black line represents the geometric mean catch rate, solid black line the standardized catch rates. The red bars are the 95% confidence intervals about the mean estimates. The graph scales both time-series of standardized catch rates relative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

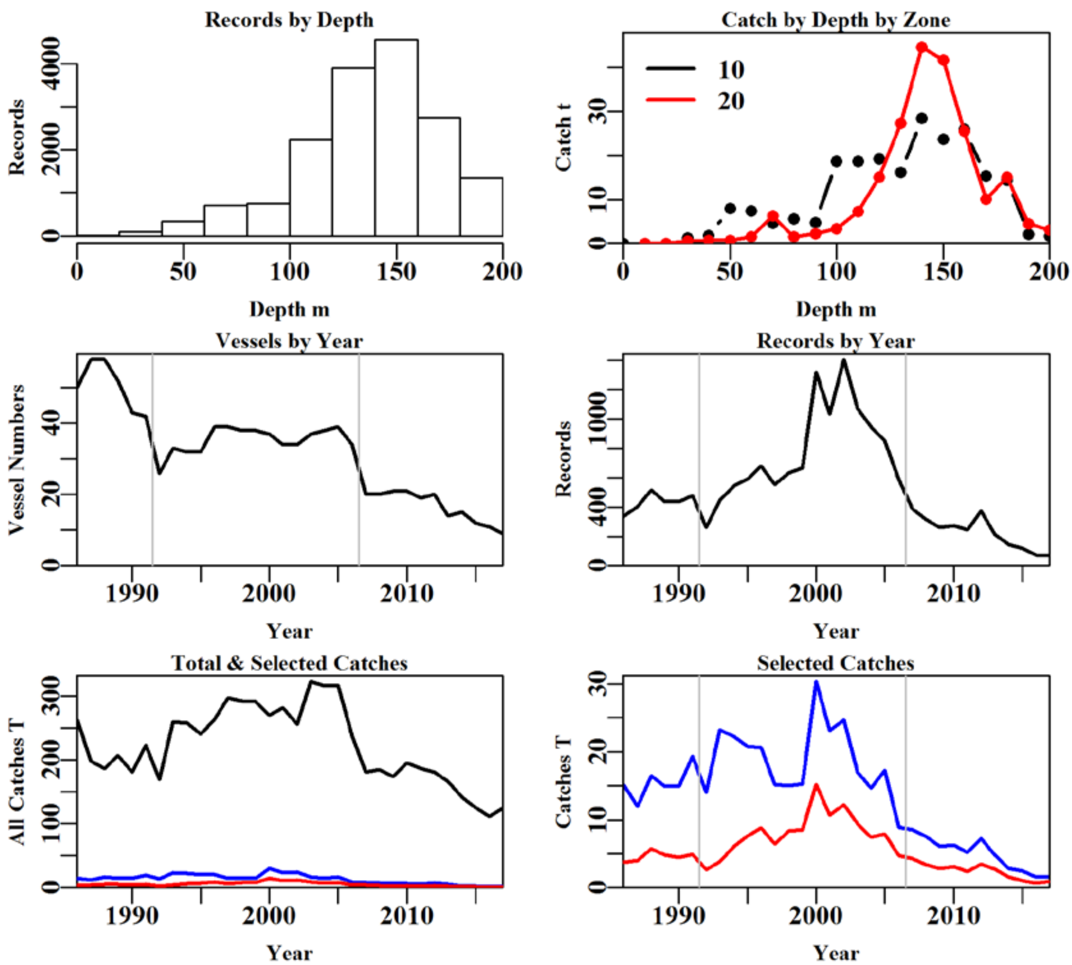


Figure 5.160. OceanPerchInshore1020 fishery details. The bottom left plot depicts all known catches (top black line), and all selected catches used in the analysis (middle blue line); the lower red line: selected catches < 30 kg).

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	164511	149303	23350	23172	16966	16680	16657
Difference	0	15208	125953	178	6206	286	23
Catch	7216.115	6594.4764	613.7752	608.0022	434.7118	430.8353	429.7788
Difference	0.000	621.6386	5980.7012	5.7730	173.2904	3.8765	1.0565

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	5801	23505	3893	16657	32	14.0	0.00
Month	5516	23077	4322	16657	43	15.6	1.51
Vessel	2152	18519	8879	16657	193	31.6	16.06
DepCat	1503	17769	9629	16657	213	34.3	2.69
DayNight	1439	17695	9704	16657	216	34.6	0.26
Zone	1361	17611	9788	16657	217	34.9	0.31
Zone:Month	1359	17585	9814	16657	228	34.9	0.05
Zone:DepCat	1253	17457	9942	16657	236	35.4	0.49

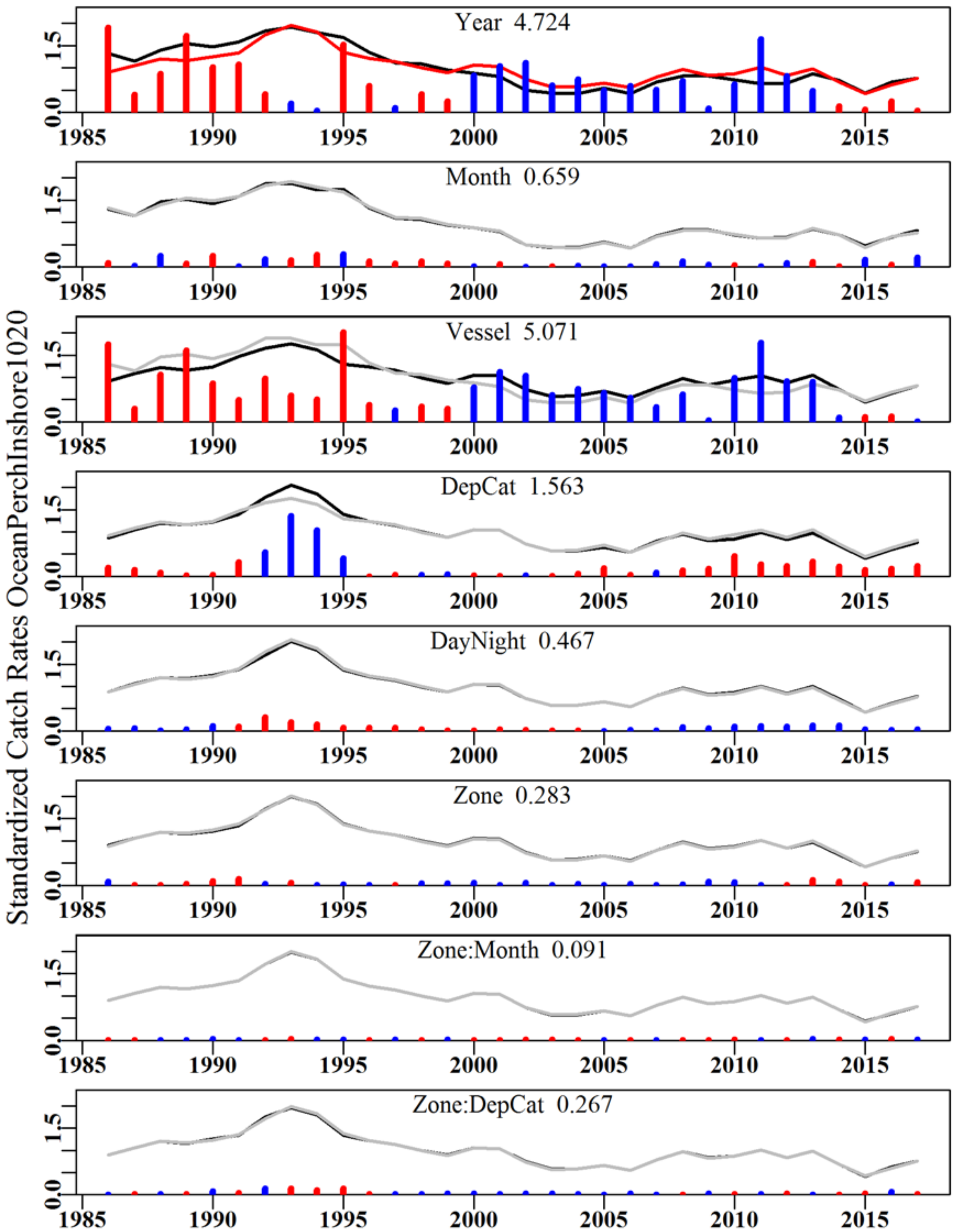


Figure 5.161. OceanPerchInshore1020. The influence of each factor on the optimal standardization. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by vertical bars with blue bars indicating the optimum model is higher than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

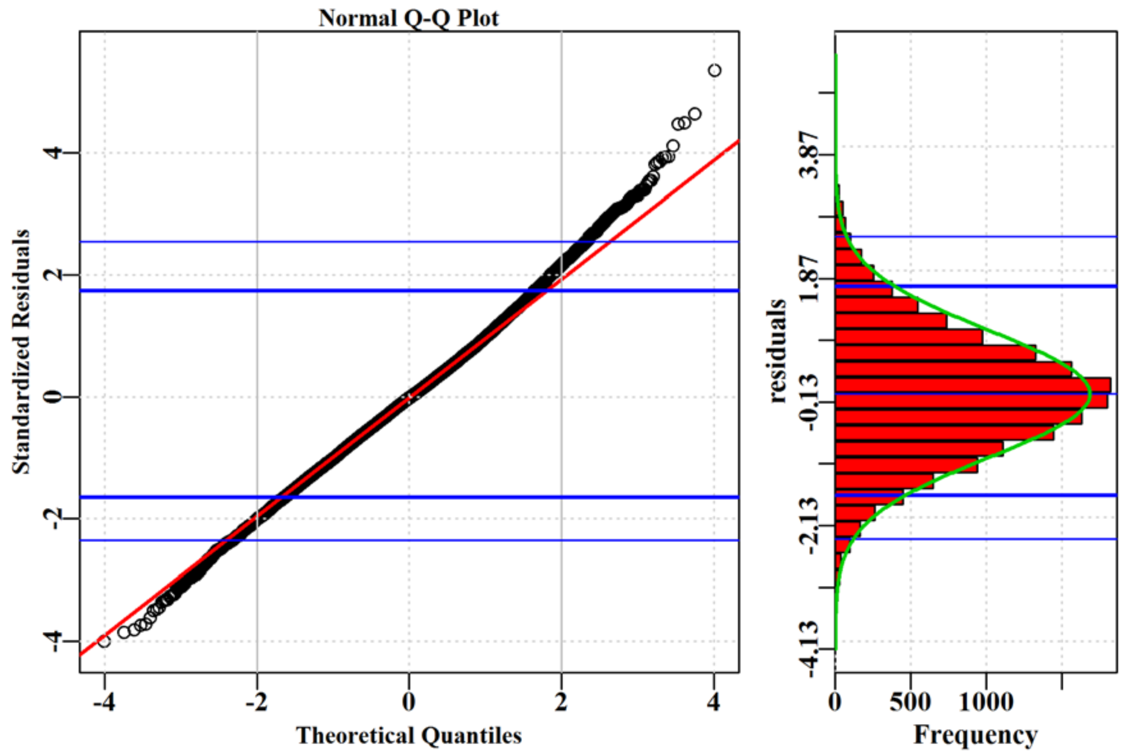


Figure 5.162. OceanPerchInshore1020. diagnostic plots. The distribution of residuals from the optimum fit. The qqplot indicates the fit to the expected normality, while the histogram of residuals illustrates the 90% quantiles to indicate the intensity of any lack of fit at the margins of the distribution.

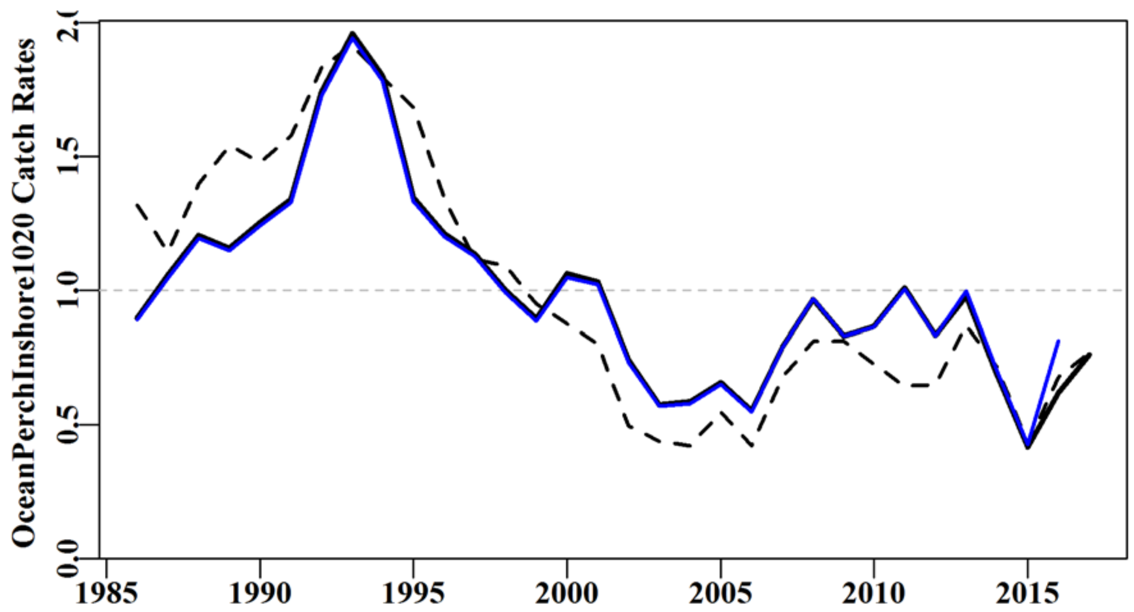


Figure 5.163. OceanPerchInshore1020. A comparison of the previous year's standardization (blue line) with this year's. They should lie on top of each other, although small deviations may relate to data adjustments, particularly in very recent years.

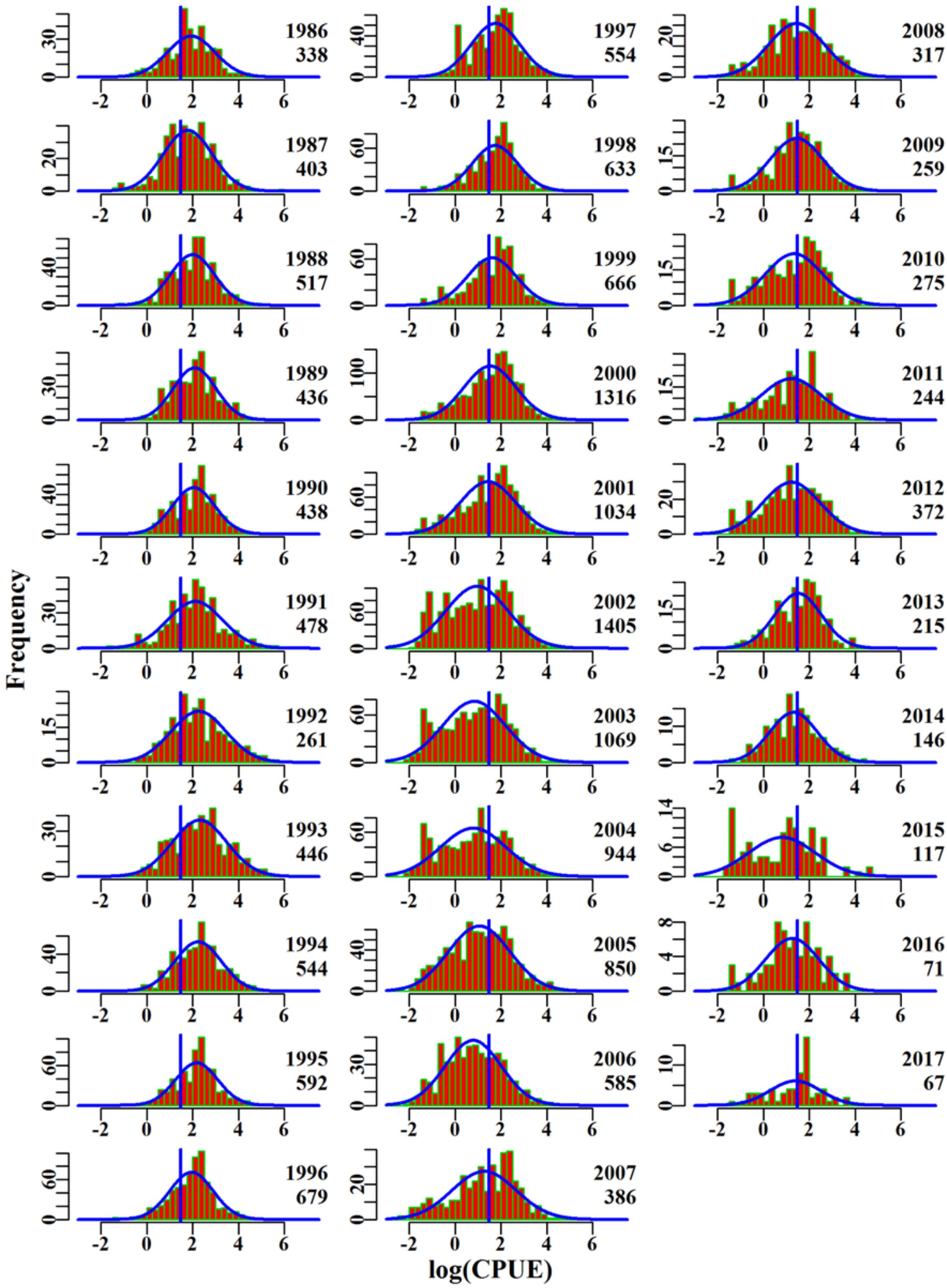


Figure 5.164. OceanPerchInshore1020. The log(CPUE) for each year of data available the blue lines are normal distributions fitted to the histogram frequencies. The numbers in each plot are the year and number of records.

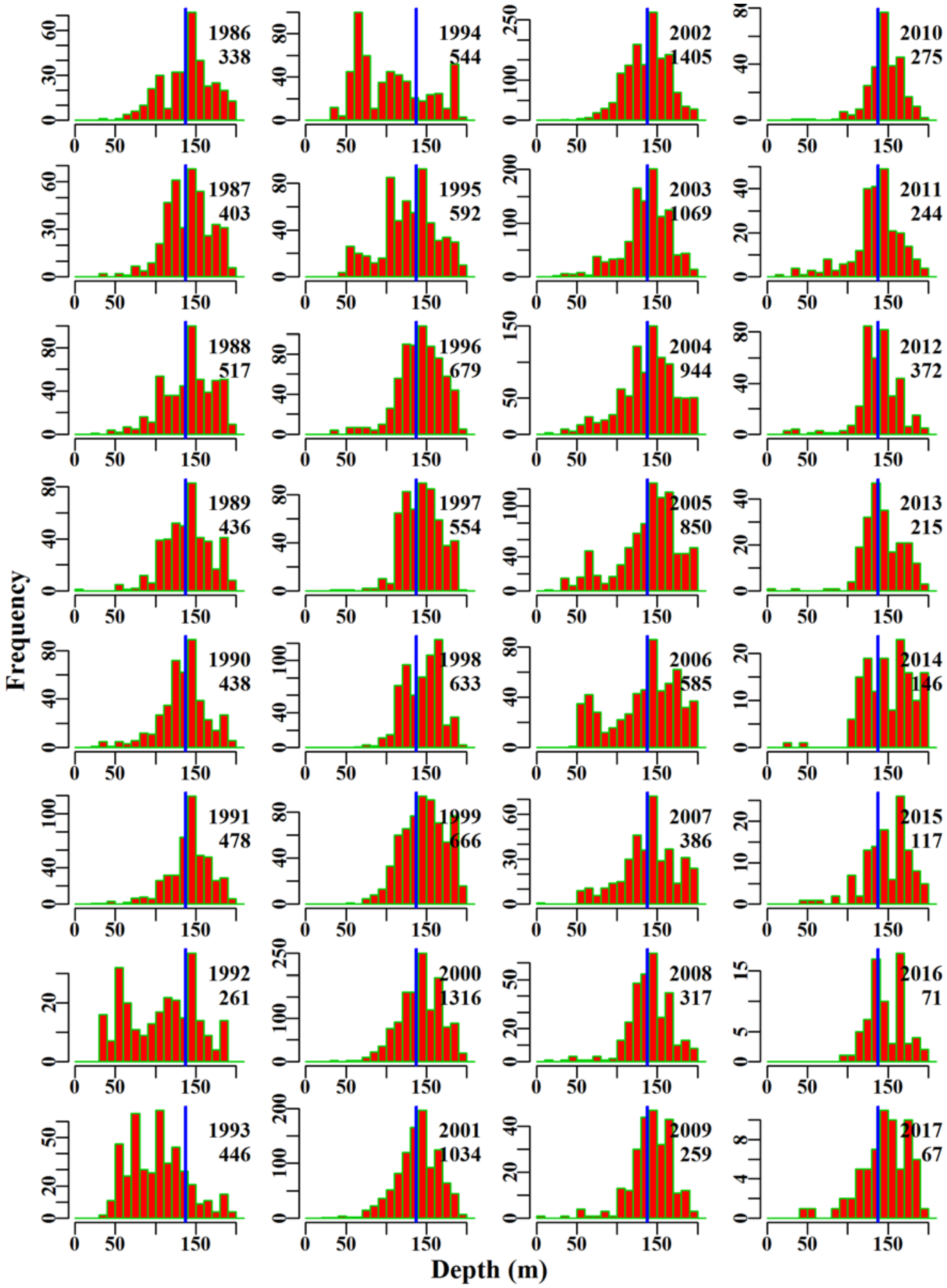


Figure 5.165. OceanPerchInshore1020. The average Depth of fishing for each year of data available to illustrate the development of the fishery through time. The numbers in each plot are the year and number of records.

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 - 2017 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 relatively high (declining slightly from 2007 - 2016) (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 - 2017

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	0.6221	0.000	26.955	0.603
1987	53.4	1432	28.0	61	7.6	0.6612	0.037	16.203	0.579
1988	66.3	1905	45.6	66	8.8	0.7955	0.035	22.651	0.497
1989	71.7	1800	32.6	65	6.9	0.6838	0.035	20.112	0.617
1990	91.0	1542	33.0	46	7.6	0.6729	0.037	16.489	0.499
1991	170.5	1324	24.7	46	6.7	0.5852	0.039	15.239	0.617
1992	88.9	1187	24.5	41	6.8	0.6022	0.040	14.447	0.591
1993	71.9	1325	28.9	42	6.9	0.6509	0.040	16.806	0.581
1994	74.4	1436	34.4	45	8.3	0.7340	0.038	19.246	0.559
1995	140.2	2216	58.9	41	9.0	0.7226	0.035	27.382	0.465
1996	199.6	2553	71.5	53	9.9	0.7468	0.034	30.221	0.423
1997	177.4	1993	52.1	51	9.5	0.6829	0.036	21.864	0.420
1998	189.9	2479	67.7	44	9.4	0.6783	0.034	27.232	0.402
1999	202.8	2682	88.0	52	10.6	0.7975	0.034	31.123	0.354
2000	198.8	2982	73.2	53	7.7	0.6412	0.033	37.466	0.512
2001	222.6	3194	64.4	55	6.5	0.5708	0.033	37.862	0.588
2002	378.5	4865	199.1	61	10.8	0.6799	0.031	52.170	0.262
2003	482.3	5464	185.8	58	9.8	0.6465	0.030	54.008	0.291
2004	692.6	6200	311.4	60	16.0	1.0595	0.030	56.415	0.181
2005	890.6	5131	341.2	54	21.1	1.2142	0.031	39.369	0.115
2006	741.5	4599	300.1	50	21.2	1.3474	0.031	34.980	0.117
2007	564.8	3073	284.1	27	31.3	1.6168	0.034	19.765	0.070
2008	490.4	3519	316.3	29	28.9	1.5317	0.033	23.006	0.073
2009	610.0	3229	374.2	28	36.6	1.7217	0.034	19.665	0.053
2010	483.9	3201	294.0	29	30.5	1.4096	0.034	20.507	0.070
2011	487.4	3192	274.6	29	30.0	1.3388	0.034	21.184	0.077
2012	519.7	3405	340.4	30	33.6	1.5319	0.033	21.441	0.063
2013	488.5	2816	262.7	27	28.7	1.5273	0.034	16.442	0.063
2014	512.0	3362	273.0	28	24.5	1.3725	0.033	21.360	0.078
2015	414.9	3066	248.0	31	25.7	1.3230	0.034	19.929	0.080
2016	467.1	2286	194.9	28	26.3	1.2814	0.036	15.553	0.080
2017	424.9	1498	174.0	24	40.7	1.5498	0.040	6.344	0.036

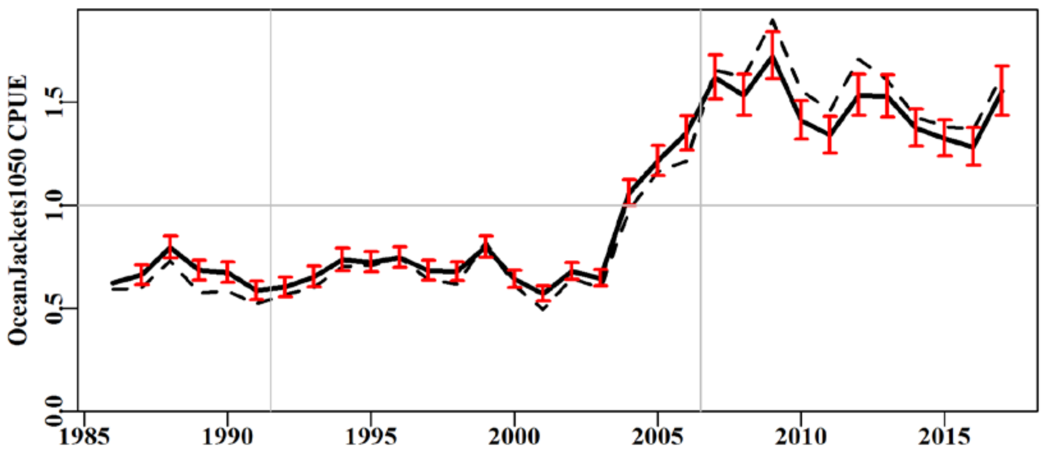


Figure 5.166. OceanJackets1050 standardization. The dashed black line represents the geometric mean catch rate, solid black line the standardized catch rates. The red bars are the 95% confidence intervals about the mean estimates. The graph scales both time-series of standardized catch rates relative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

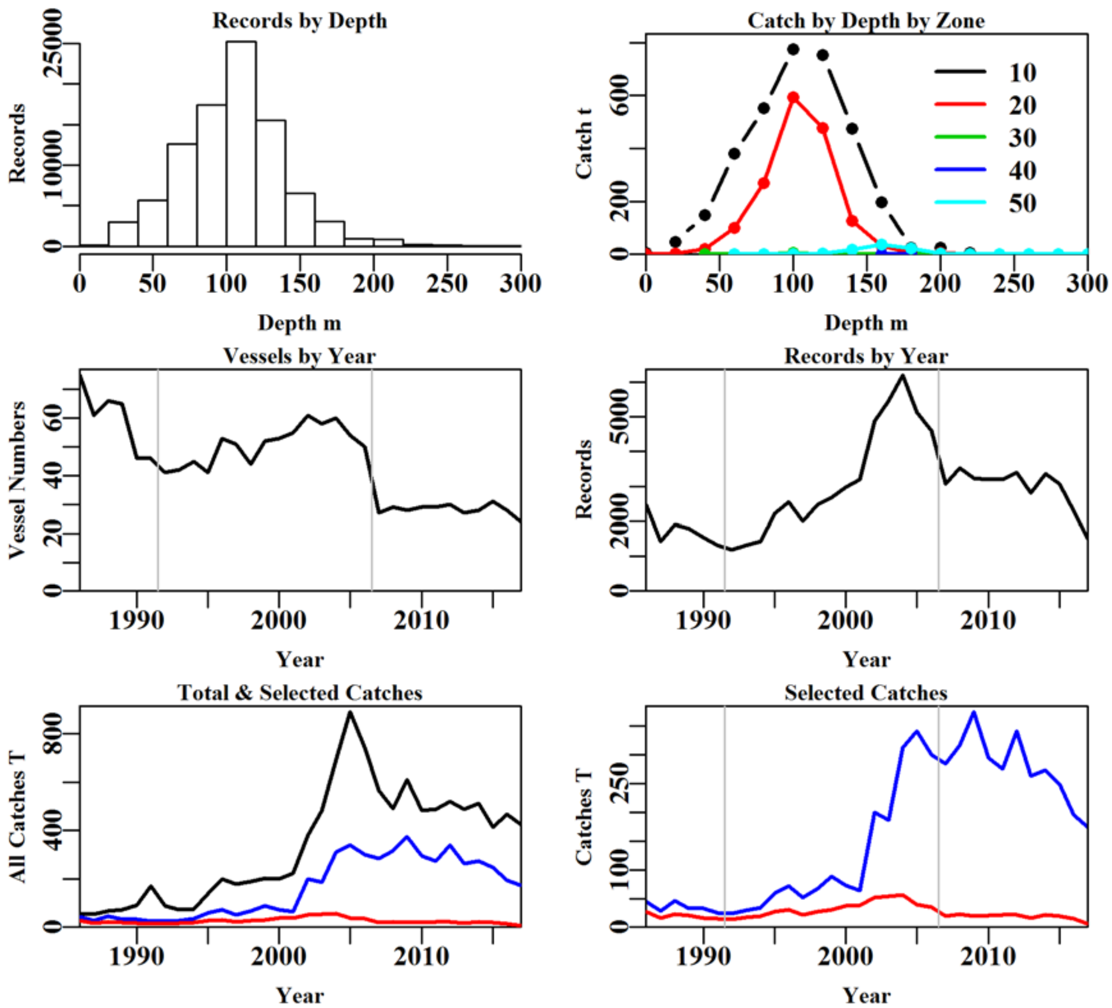


Figure 5.167. OceanJackets1050 fishery details. The bottom left plot depicts all known catches (top black line), and all selected catches used in the analysis (middle blue line); the lower red line: selected catches < 30 kg).

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	175709	165917	163415	159585	96868	91596	91427
Difference	0	9792	2502	3830	62717	5272	169
Catch	11300.49	11162.2116	10919.659	10393.7641	5228.019	5159.96755	5146.0108
Difference	0.00	138.2808	242.553	525.8945	5165.745	68.05115	13.9567

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	22079	116318	17075	91427	32	12.8	0.00
Vessel	8813	100226	33167	91427	206	24.7	11.92
DepCat	8249	99577	33816	91427	221	25.2	0.48
Month	7395	98628	34765	91427	232	25.9	0.70
Zone	6622	97789	35604	91427	236	26.5	0.63
DayNight	6480	97630	35763	91427	239	26.6	0.12
Zone:Month	6276	97329	36064	91427	278	26.8	0.19
Zone:DepCat	5449	96460	36933	91427	275	27.5	0.85

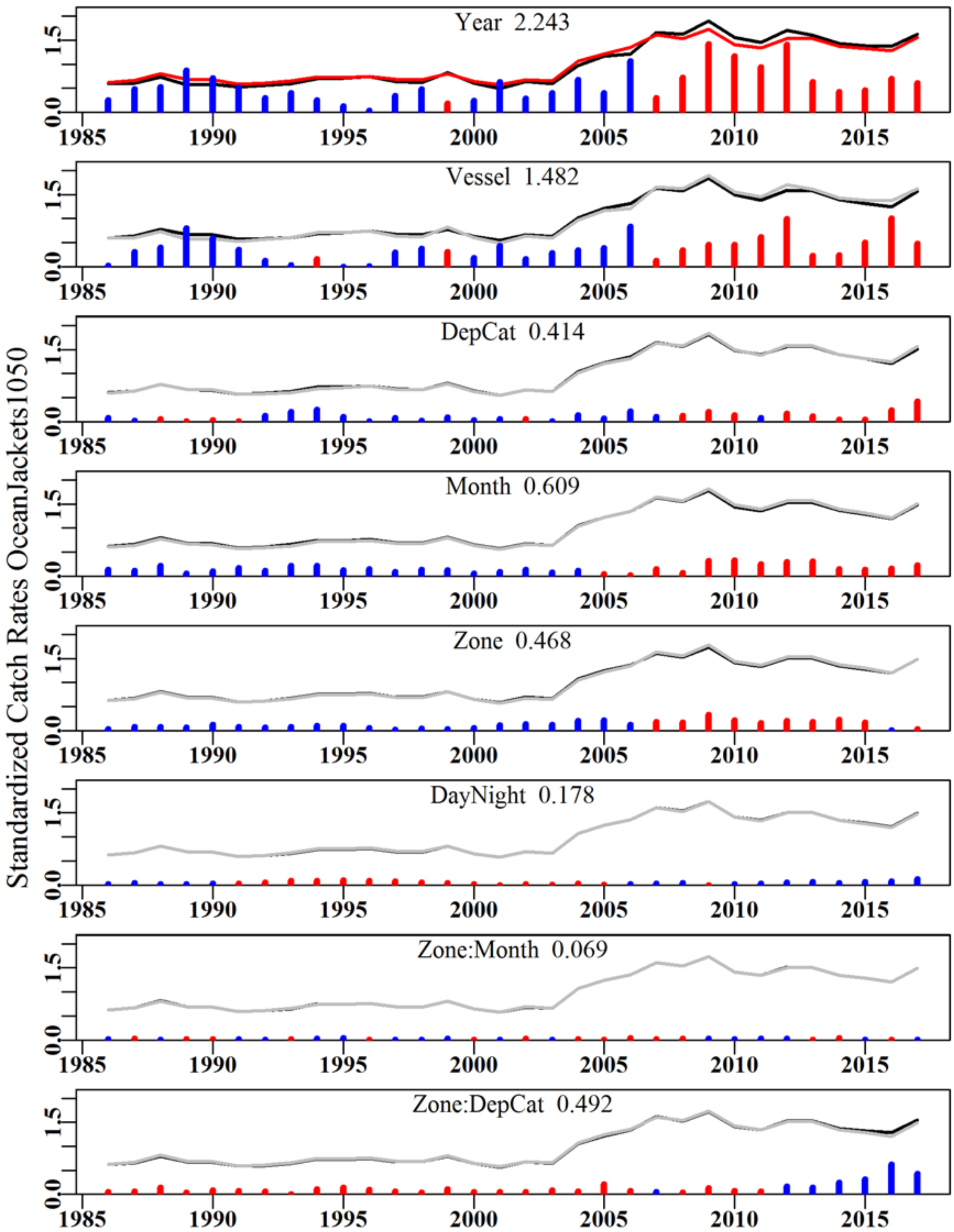


Figure 5.168. OceanJackets1050. The influence of each factor on the optimal standardization. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by vertical bars with blue bars indicating the optimum model is higher than the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

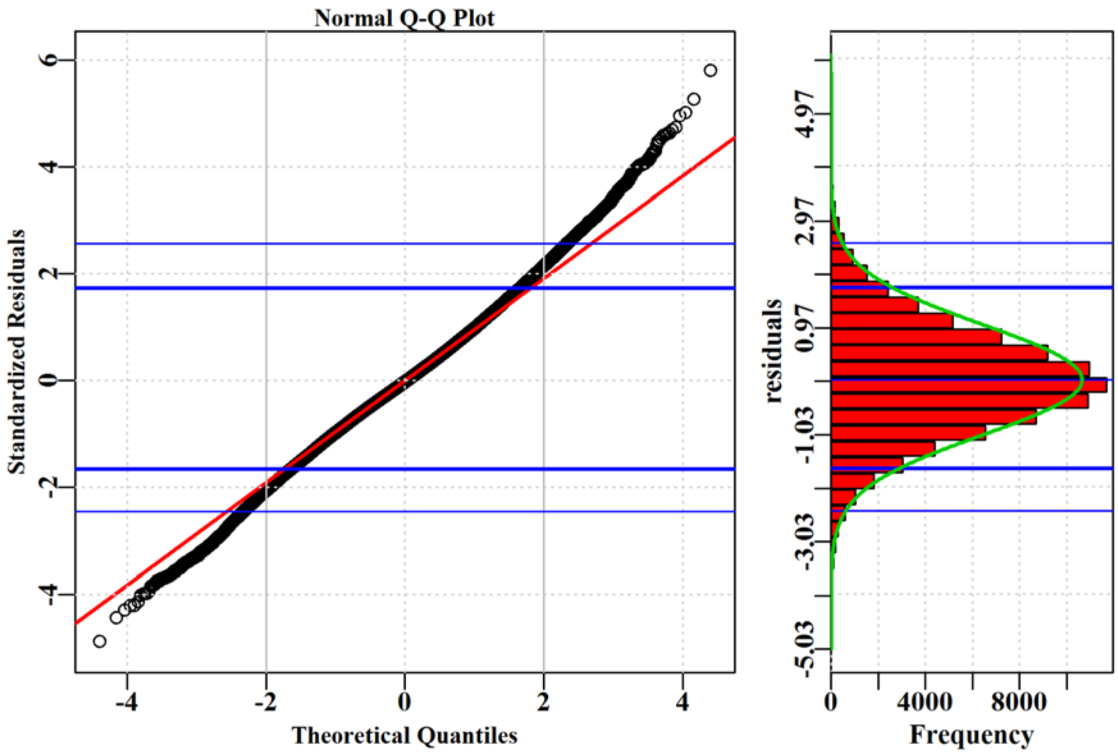


Figure 5.169. OceanJackets1050. diagnostic plots. The distribution of residuals from the optimum fit. The qqplot indicates the fit to the expected normality, while the histogram of residuals illustrates the 90% quantiles to indicate the intensity of any lack of fit at the margins of the distribution.

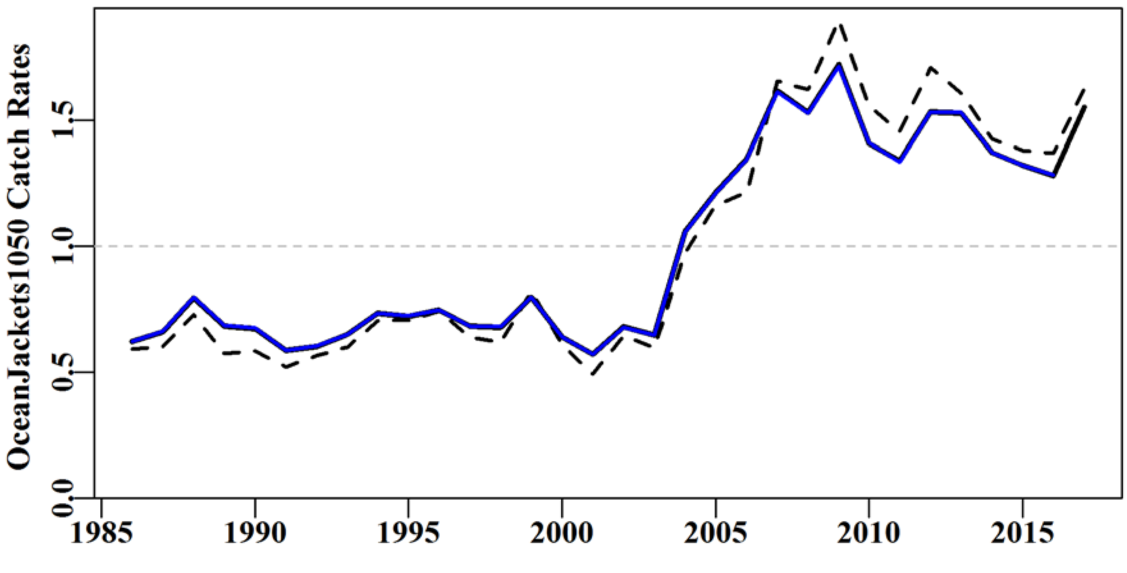


Figure 5.170. OceanJackets1050. A comparison of the previous year's standardization (blue line) with this year's. They should lie on top of each other, although small deviations may relate to data adjustments, particularly in very recent years.

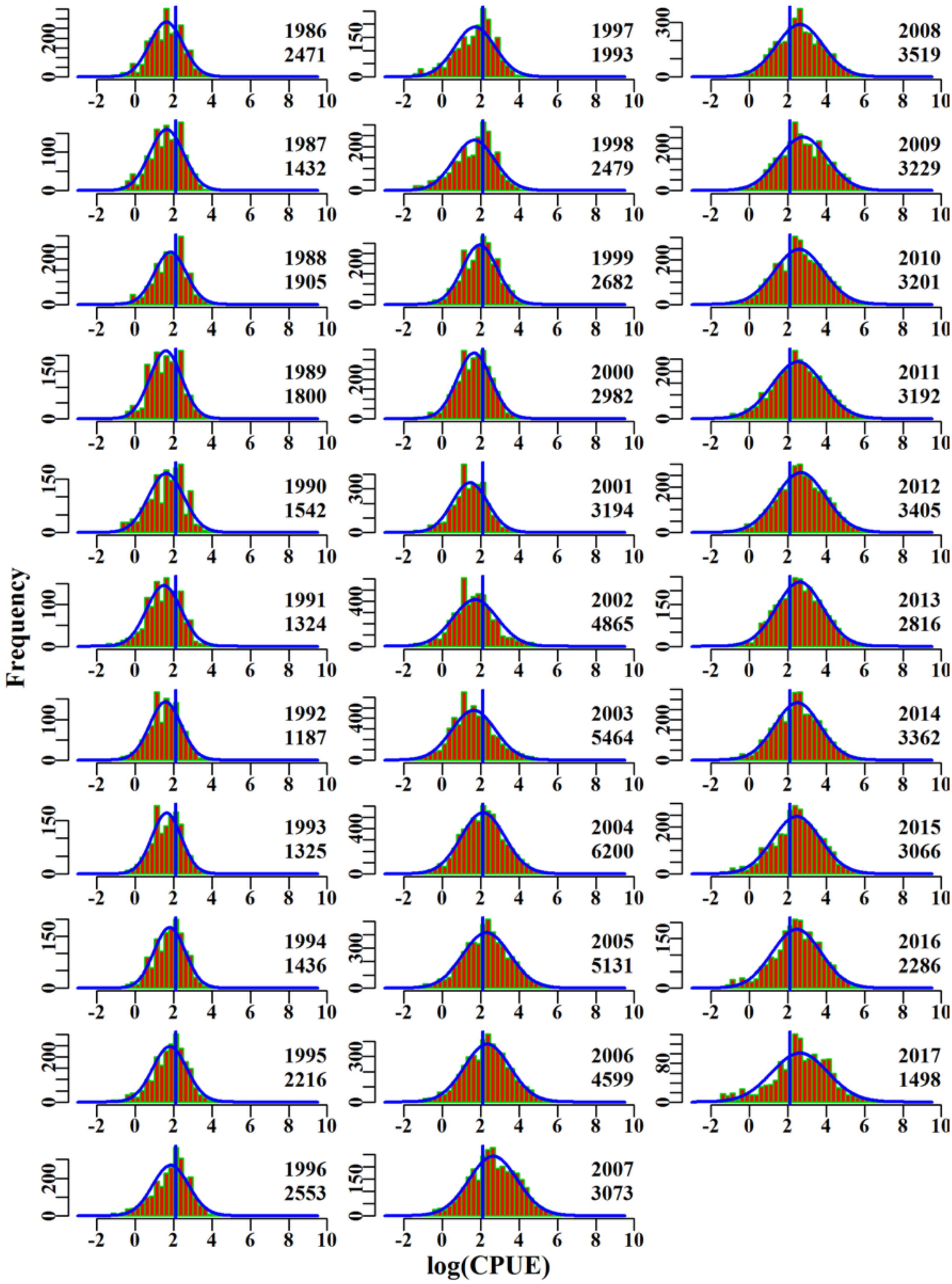


Figure 5.171. OceanJackets1050. The log(CPUE) for each year of data available the blue lines are normal distributions fitted to the histogram frequencies. The numbers in each plot are the year and number of records.

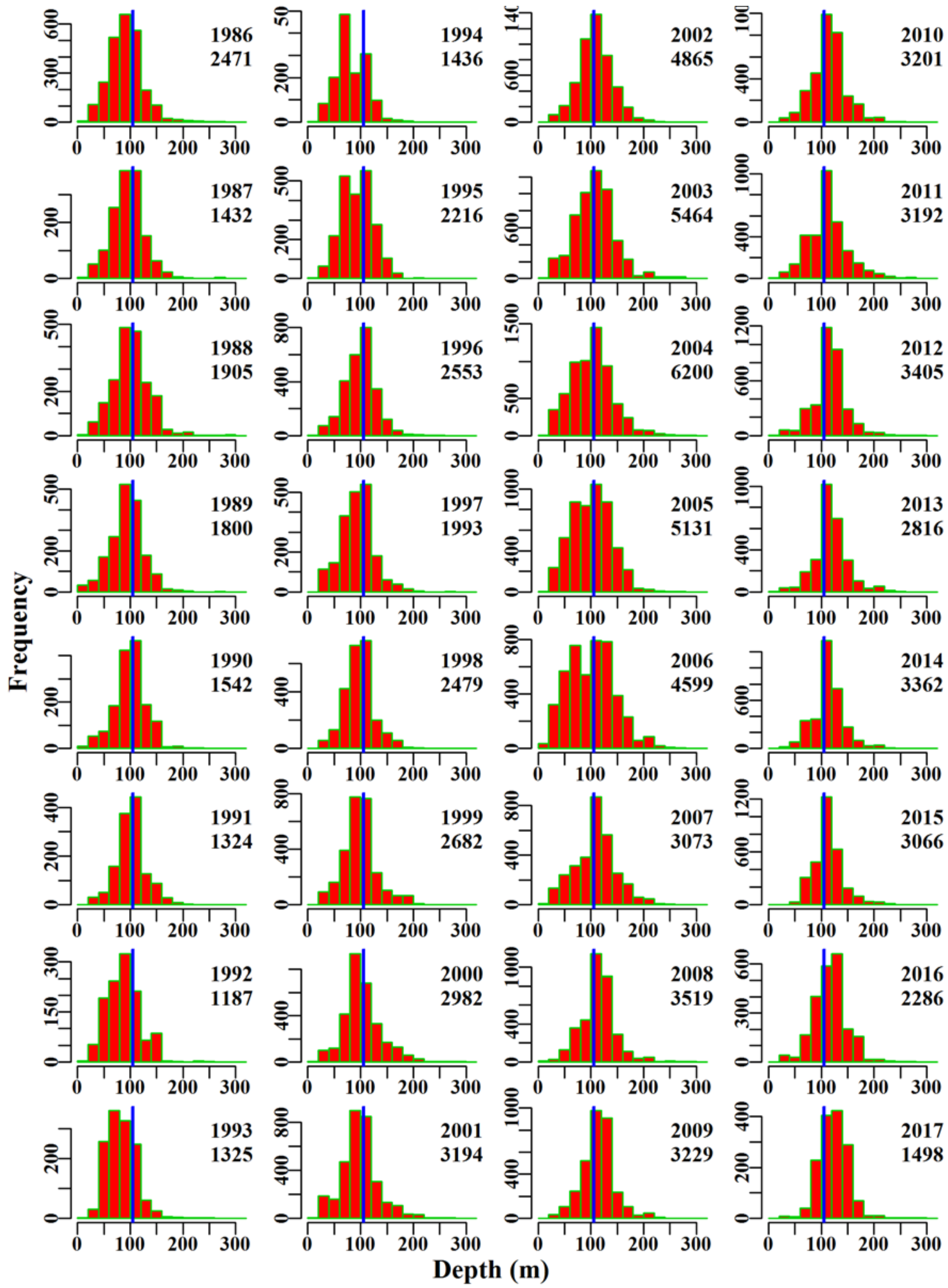


Figure 5.172. OceanJackets1050. The average Depth of fishing for each year of data available to illustrate the development of the fishery through time. The numbers in each plot are the year and number of records.

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 - 2017 were analysed (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 - 2016 period (Figure 5.173), but catches and numbers of records 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 - 2017

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	1.2552	0.000	2.520	0.317
1987	53.4	206	21.7	3	22.9	1.0299	0.106	2.270	0.105
1988	66.3	244	15.6	7	20.8	1.2281	0.186	1.603	0.103
1989	71.7	570	34.5	7	18.0	1.2404	0.184	4.168	0.121
1990	91.0	916	51.2	11	15.7	0.8244	0.181	8.675	0.169
1991	170.5	1247	139.2	8	26.8	1.0491	0.181	6.465	0.046
1992	88.9	921	57.1	7	14.0	0.8963	0.181	9.354	0.164
1993	71.9	813	38.4	4	9.9	0.6089	0.181	9.442	0.246
1994	74.4	736	36.1	5	10.6	0.5385	0.181	7.495	0.208
1995	140.2	1311	78.0	5	12.9	0.7010	0.180	12.907	0.165
1996	199.6	1712	122.3	6	14.9	0.8183	0.180	15.049	0.123
1997	177.4	2123	119.5	9	11.8	0.6747	0.180	21.575	0.180
1998	189.9	1787	115.6	9	13.8	0.7313	0.180	16.270	0.141
1999	202.8	1573	108.4	7	13.6	0.8323	0.180	12.140	0.112
2000	198.8	1551	122.2	5	17.4	0.8564	0.180	11.172	0.091
2001	222.6	1992	146.1	6	15.5	0.8869	0.180	12.521	0.086
2002	378.5	1793	148.1	6	16.3	0.9439	0.180	11.991	0.081
2003	482.3	2791	275.1	9	19.3	1.0763	0.180	11.385	0.041
2004	692.6	3399	360.3	9	20.9	1.1746	0.180	13.172	0.037
2005	890.6	4287	519.8	10	23.8	1.2444	0.180	14.604	0.028
2006	741.5	3573	405.1	11	21.4	0.9637	0.180	11.905	0.029
2007	564.8	2591	248.8	8	19.8	0.8627	0.180	10.479	0.042
2008	490.4	2314	144.0	6	12.9	0.7430	0.180	14.610	0.101
2009	610.0	2139	218.4	4	20.9	1.0335	0.180	11.145	0.051
2010	483.9	1777	167.1	4	19.0	1.1724	0.180	5.245	0.031
2011	487.4	1853	190.5	4	21.1	1.1883	0.180	5.501	0.029
2012	519.7	1714	154.6	5	17.3	1.1339	0.180	3.205	0.021
2013	488.5	2210	203.9	6	17.4	1.2485	0.180	1.018	0.005
2014	512.0	2013	206.7	6	18.4	1.2932	0.180	0.332	0.002
2015	414.9	1569	148.5	3	18.4	1.2453	0.181	0.894	0.006
2016	467.1	1654	203.1	4	23.8	1.3042	0.181	4.774	0.024
2017	424.9	1602	181.9	4	21.8	1.2003	0.181	10.149	0.056

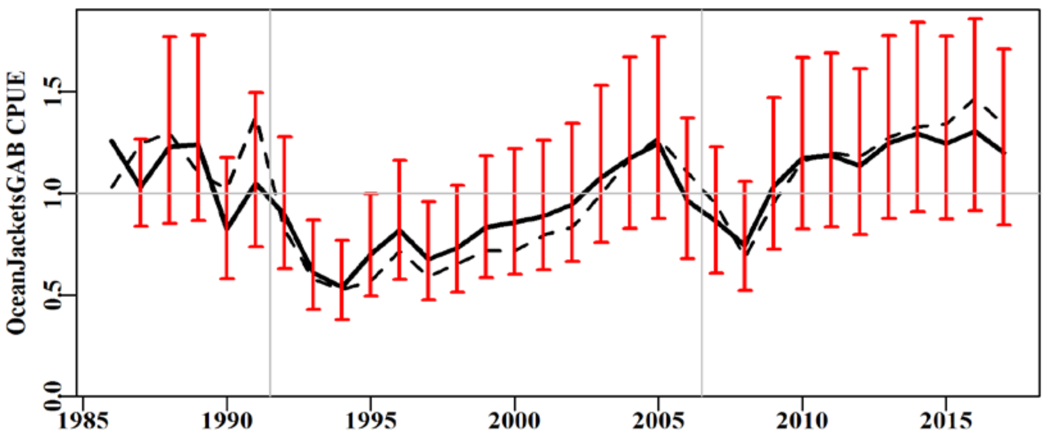


Figure 5.173. OceanJacketsGAB standardization. The dashed black line represents the geometric mean catch rate, solid black line the standardized catch rates. The red bars are the 95% confidence intervals about the mean estimates. The graph scales both time-series of standardized catch rates relative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

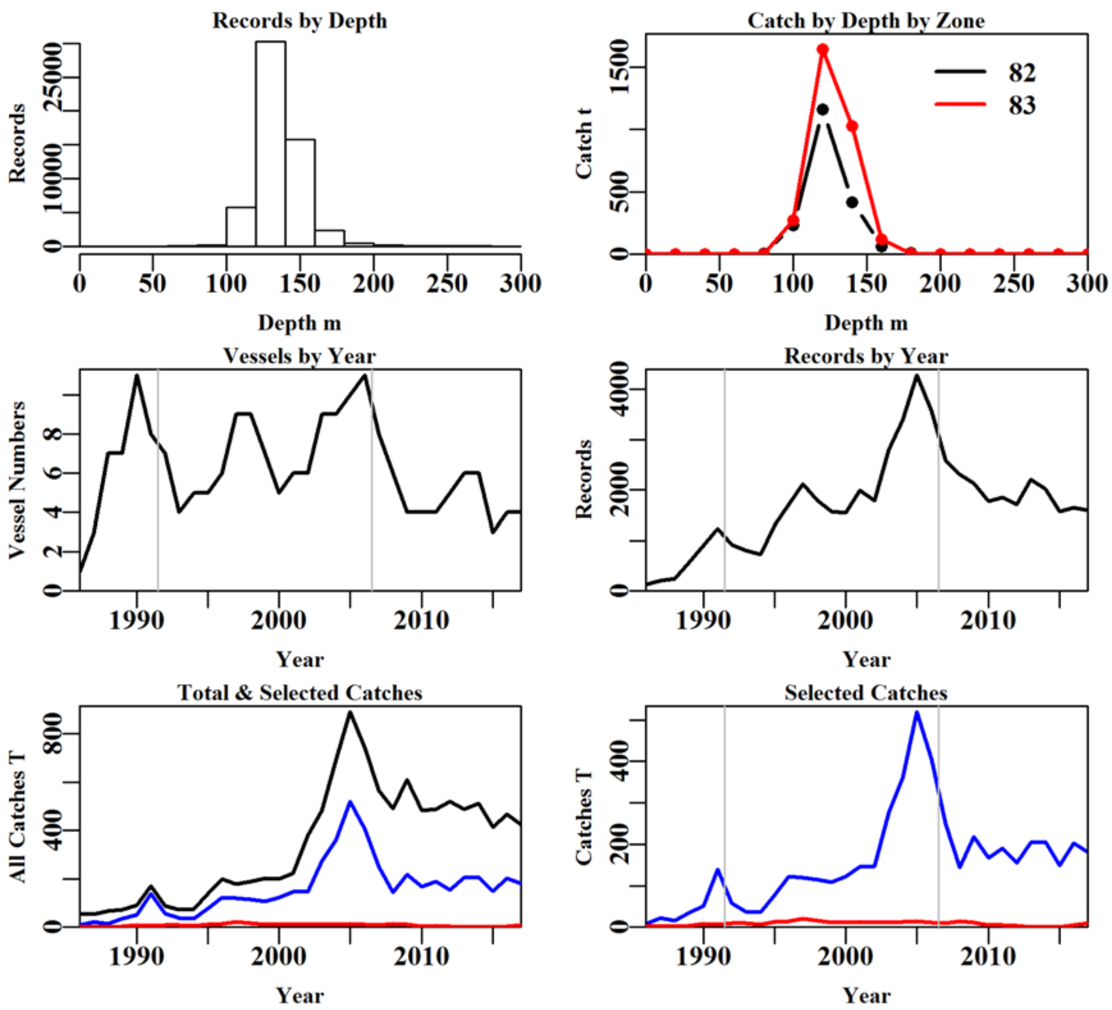


Figure 5.174. OceanJacketsGAB fishery details. The bottom left plot depicts all known catches (top black line), and all selected catches used in the analysis (middle blue line); the lower red line: selected catches < 30 kg).

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	175709	166129	163616	159786	57010	55133	55118
Difference	0	9580	2513	3830	102776	1877	15
Catch	11300.49	11162.646	10920.060	10394.1659	5012.524	4990.2372	4989.698
Difference	0.00	137.846	242.586	525.8945	5381.642	22.2863	0.539

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	1807	56889	4415	55118	32	7.1	0.00
DayNight	-4322	50896	10408	55118	35	16.9	9.78
Vessel	-6962	48449	12855	55118	73	20.9	3.94
DepCat	-9931	45883	15421	55118	88	25.0	4.17
Month	-11205	44818	16486	55118	99	26.8	1.73
Zone	-11211	44811	16493	55118	100	26.8	0.01
Zone:Month	-11404	44637	16667	55118	111	27.0	0.27
Zone:DepCat	-11213	44785	16519	55118	115	26.8	0.02

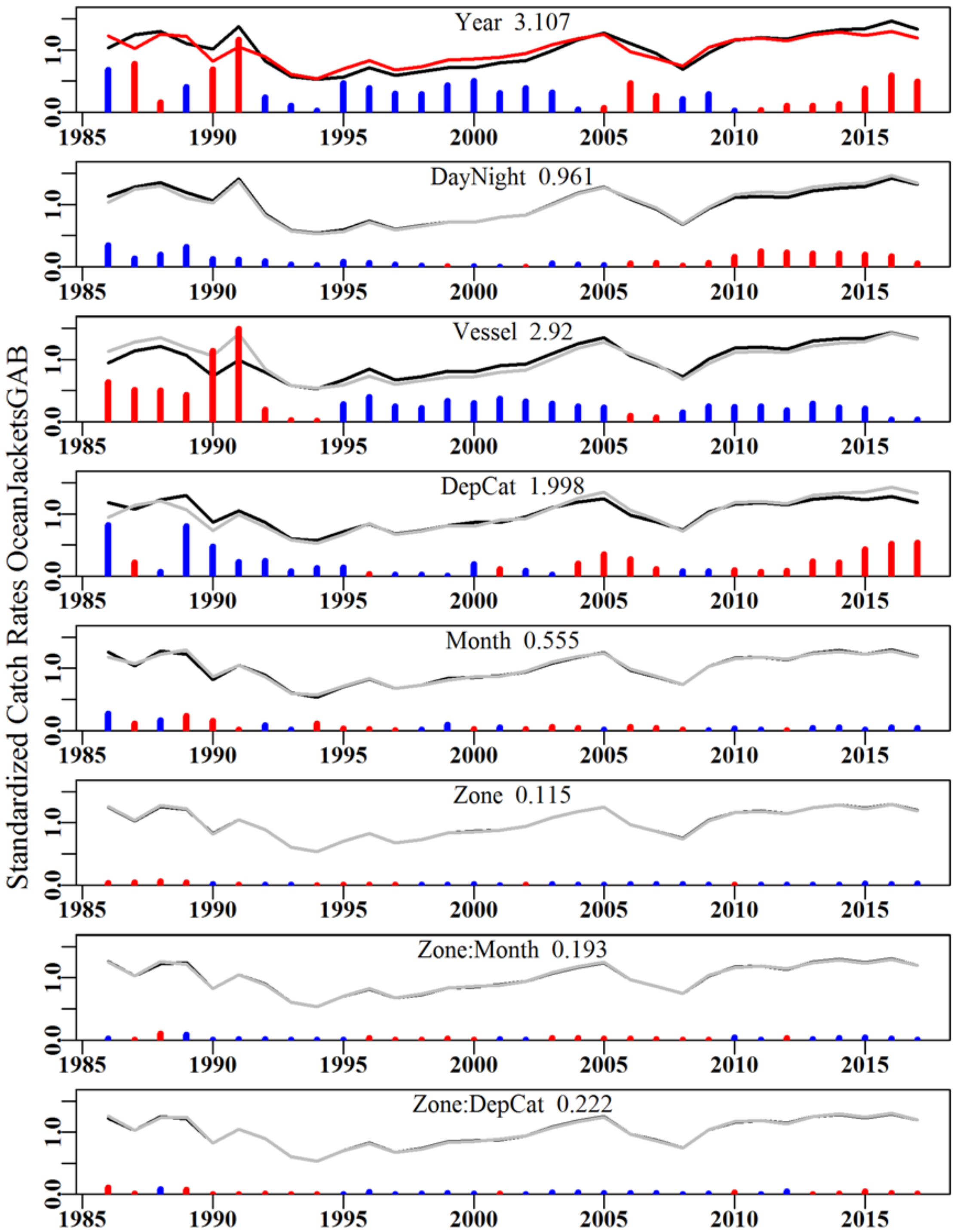


Figure 5.175. OceanJacketsGAB. The influence of each factor on the optimal standardization. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by vertical bars with blue bars indicating the optimum model is higher than the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

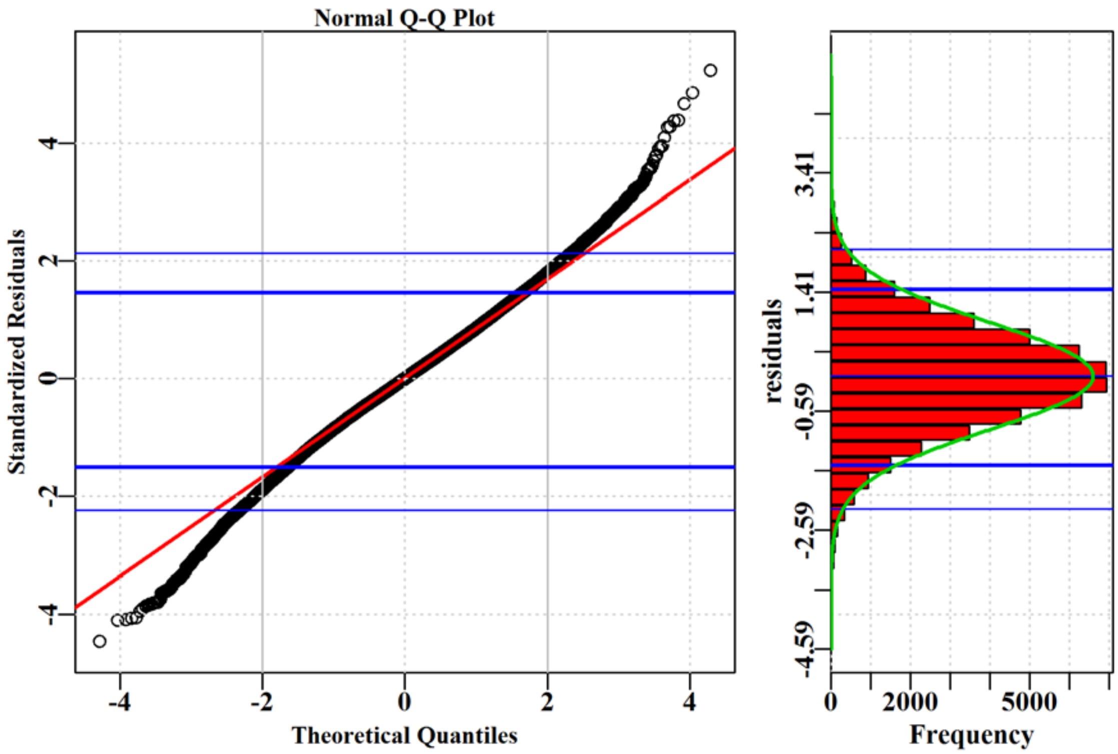


Figure 5.176. OceanJacketsGAB. diagnostic plots. The distribution of residuals from the optimum fit. The qqplot indicates the fit to the expected normality, while the histogram of residuals illustrates the 90% quantiles to indicate the intensity of any lack of fit at the margins of the distribution

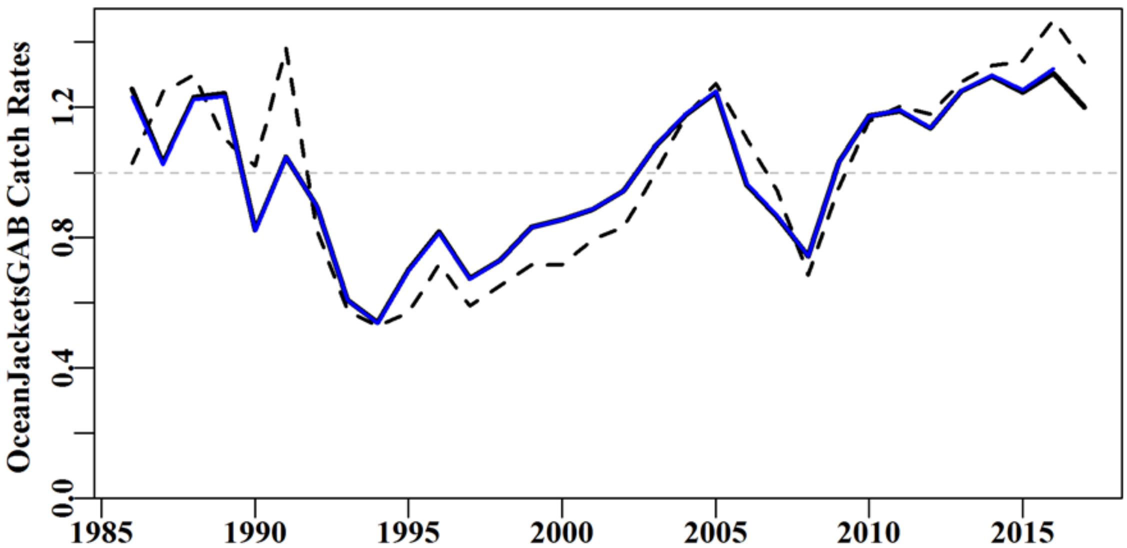


Figure 5.177. OceanJacketsGAB. A comparison of the previous year's standardization (blue line) with this year's. They should lie on top of each other, although small deviations may relate to data adjustments, particularly in very recent years.

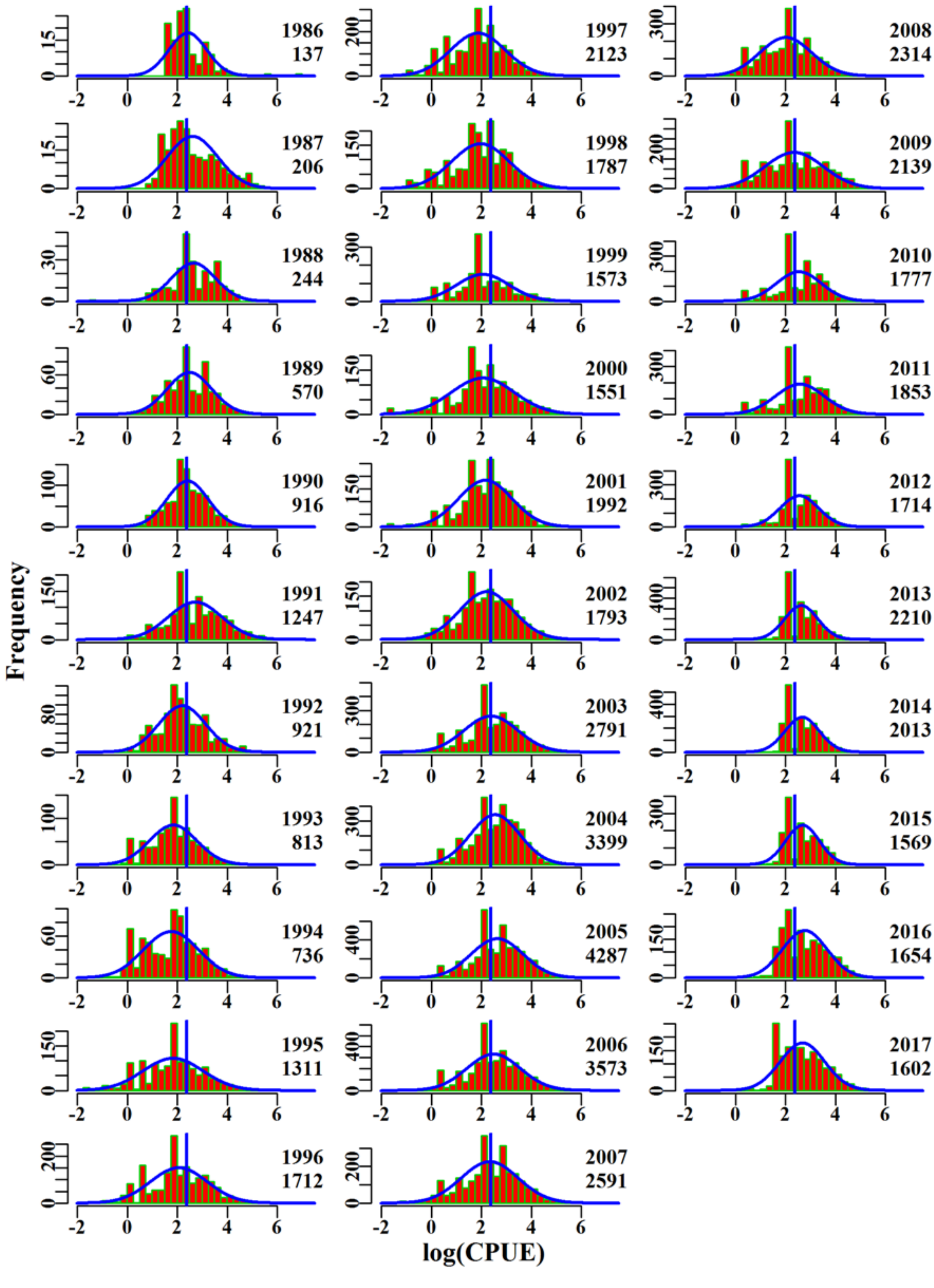


Figure 5.178. OceanJacketsGAB. The log(CPUE) for each year of data available the blue lines are normal distributions fitted to the histogram frequencies. The numbers in each plot are the year and number of records.

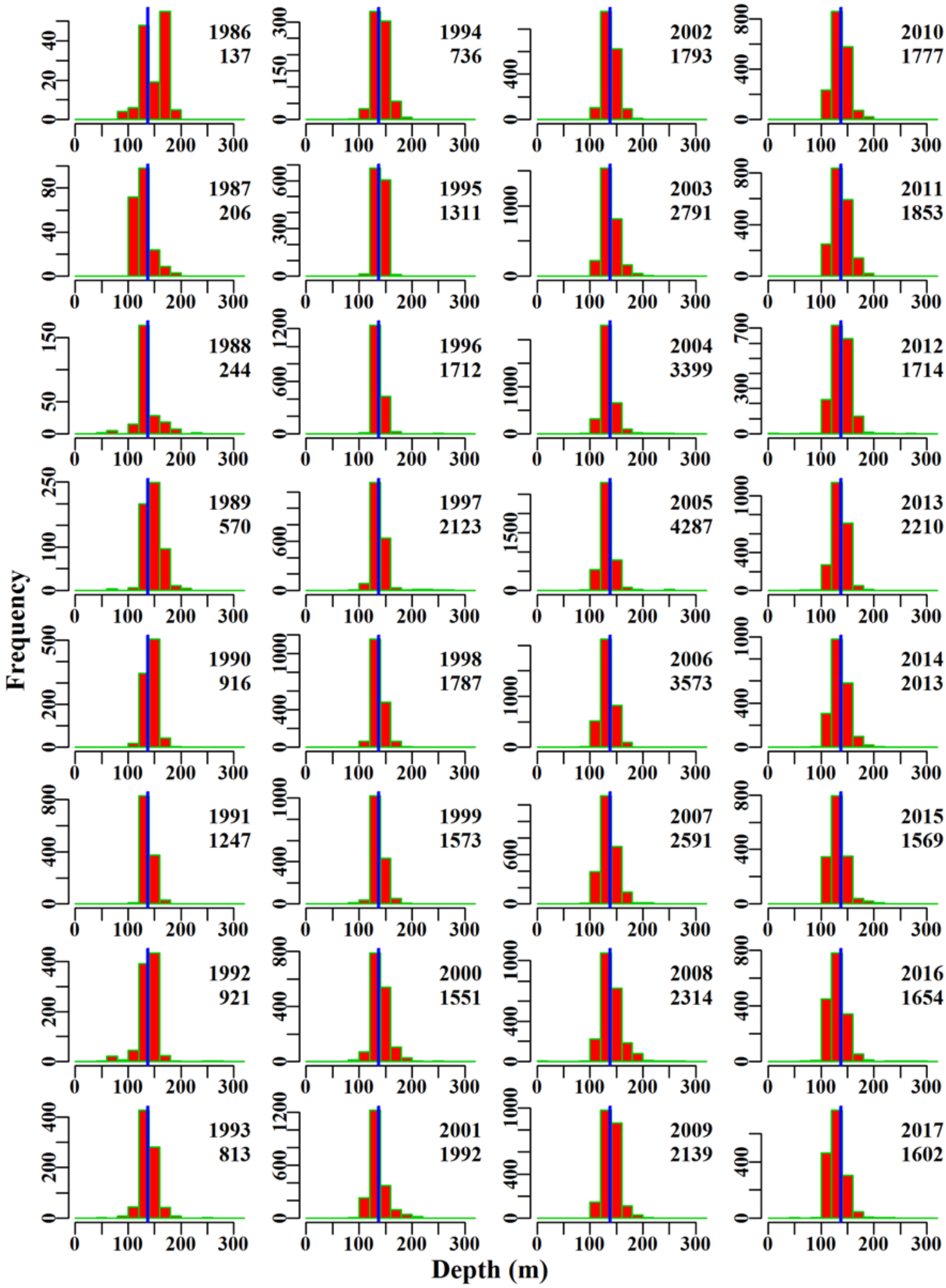


Figure 5.179. OceanJacketsGAB. The average Depth of fishing for each year of data available to illustrate the development of the fishery through time. The numbers in each plot are the year and number of records.

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 40.

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 below average over 2001-2016, and slightly above average in 2017 (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 - 2017

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	2.4116	0.000	5.837	0.019
1987	250.2	1210	248.2	26	68.3	2.2878	0.045	4.464	0.018
1988	223.4	1204	220.5	27	63.1	2.2931	0.047	6.723	0.030
1989	156.7	1076	156.6	28	50.0	1.9218	0.050	6.139	0.039
1990	135.2	1023	134.4	24	44.1	1.4655	0.053	8.274	0.062
1991	268.5	1353	247.4	25	57.4	1.4131	0.050	7.115	0.029
1992	89.7	661	80.7	15	43.1	0.9826	0.058	4.224	0.052
1993	101.8	711	101.4	16	40.0	0.9418	0.057	5.646	0.056
1994	96.0	825	95.0	18	33.5	1.0139	0.055	5.739	0.060
1995	84.0	961	83.9	21	29.1	0.9018	0.053	8.373	0.100
1996	142.9	1130	142.5	26	44.2	0.9609	0.050	9.811	0.069
1997	152.9	1373	152.3	21	42.6	0.8540	0.049	11.465	0.075
1998	122.4	1255	121.9	20	40.2	0.9228	0.050	10.284	0.084
1999	176.9	1685	175.5	18	37.2	0.8669	0.048	14.406	0.082
2000	231.9	1904	229.0	27	57.3	0.9580	0.047	14.844	0.065
2001	168.5	1668	168.2	26	45.0	0.7646	0.048	13.752	0.082
2002	85.9	1395	85.1	23	19.9	0.5800	0.050	13.043	0.153
2003	122.7	1045	121.5	23	41.0	0.6714	0.052	7.667	0.063
2004	107.1	1212	105.2	22	25.4	0.6393	0.052	8.132	0.077
2005	116.1	1053	114.1	18	32.9	0.6671	0.053	5.770	0.051
2006	104.7	882	101.6	17	25.5	0.5477	0.056	4.491	0.044
2007	60.0	688	57.2	14	20.1	0.5174	0.059	3.687	0.064
2008	55.4	747	52.8	13	14.9	0.6064	0.058	4.709	0.089
2009	60.0	926	56.2	12	12.9	0.6698	0.055	6.100	0.108
2010	90.1	1364	86.1	14	12.9	0.7249	0.051	8.024	0.093
2011	55.2	1063	53.5	12	10.1	0.7193	0.053	6.881	0.129
2012	49.6	710	46.4	13	13.6	0.6839	0.059	4.037	0.087
2013	42.2	571	37.8	14	13.2	0.6080	0.062	3.080	0.081
2014	70.5	669	68.9	14	25.2	0.8506	0.060	2.098	0.030
2015	48.7	653	46.2	12	17.2	0.6930	0.061	2.041	0.044
2016	53.3	658	50.6	13	17.8	0.7905	0.061	2.161	0.043
2017	82.9	853	81.5	10	20.3	1.0708	0.059	1.039	0.013

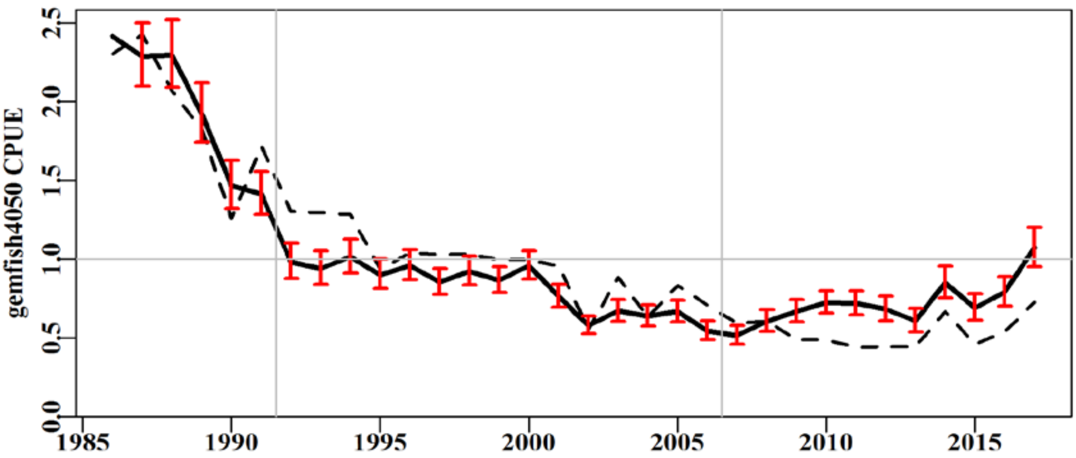


Figure 5.180. gemfish4050 standardization. The dashed black line represents the geometric mean catch rate, solid black line the standardized catch rates. The red bars are the 95% confidence intervals about the mean estimates. The graph scales both time-series of standardized catch rates relative to the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

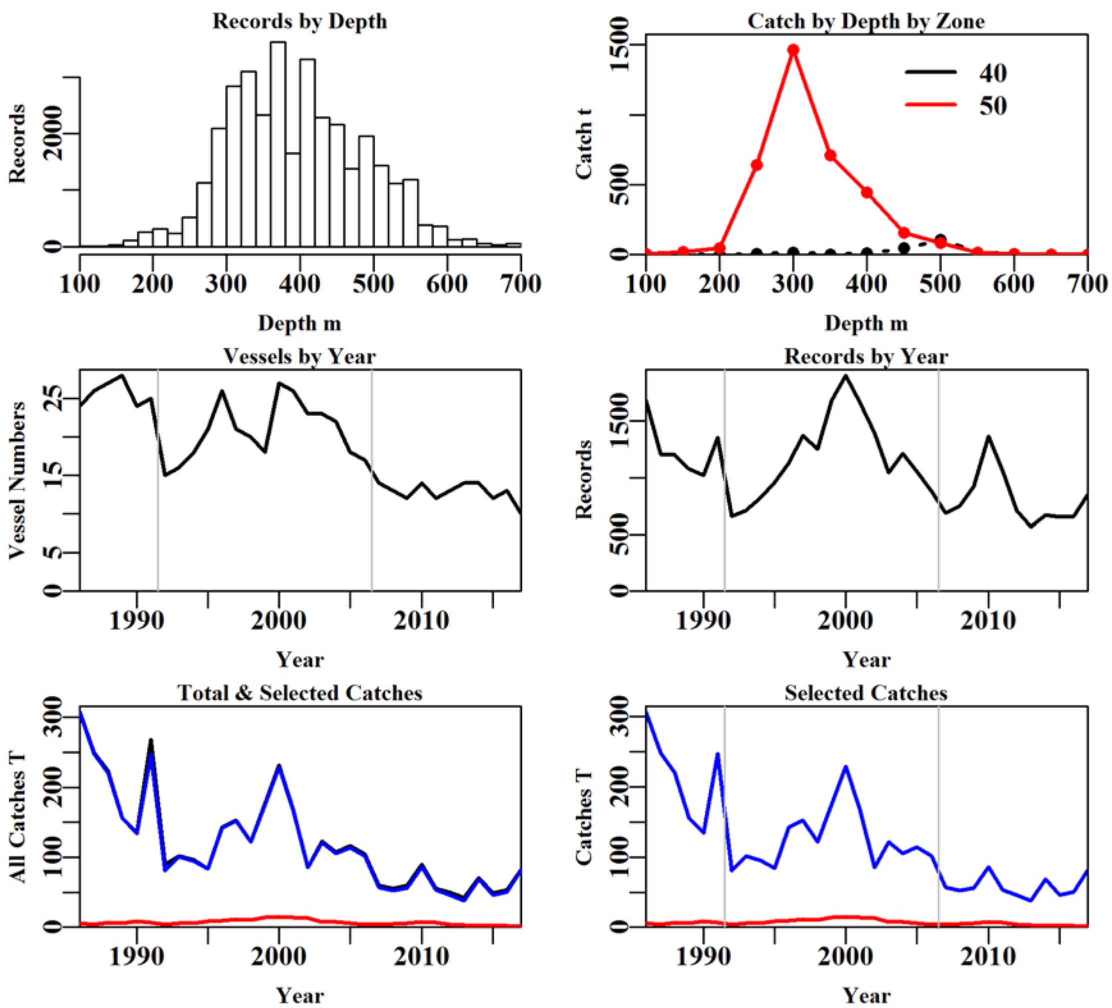


Figure 5.181. gemfish4050 fishery details. The bottom left plot depicts all known catches (top black line), and all selected catches used in the analysis (middle blue line); the lower red line: selected catches < 30 kg).

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	37118	35631	35302	34528	34528	34252	34209
Difference	0	1487	329	774	0	276	43
Catch	4057.675	4019.00639	3998.68413	3854.3319	3854.332	3830.82971	3829.245
Difference	0.000	38.66817	20.32225	144.3522	0.000	23.50218	1.585

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	23121	67120	8427	34209	32	11.1	0.00
DepCat	14159	51615	23932	34209	44	31.6	20.52
Vessel	8876	43997	31550	34209	134	41.5	9.94
Zone	8774	43863	31684	34209	135	41.7	0.18
DayNight	8154	43067	32480	34209	138	42.8	1.05
Month	7783	42576	32971	34209	149	43.4	0.63
Zone:Month	7501	42200	33348	34209	160	43.9	0.48
Zone:DepCat	7692	42435	33112	34209	160	43.6	0.17

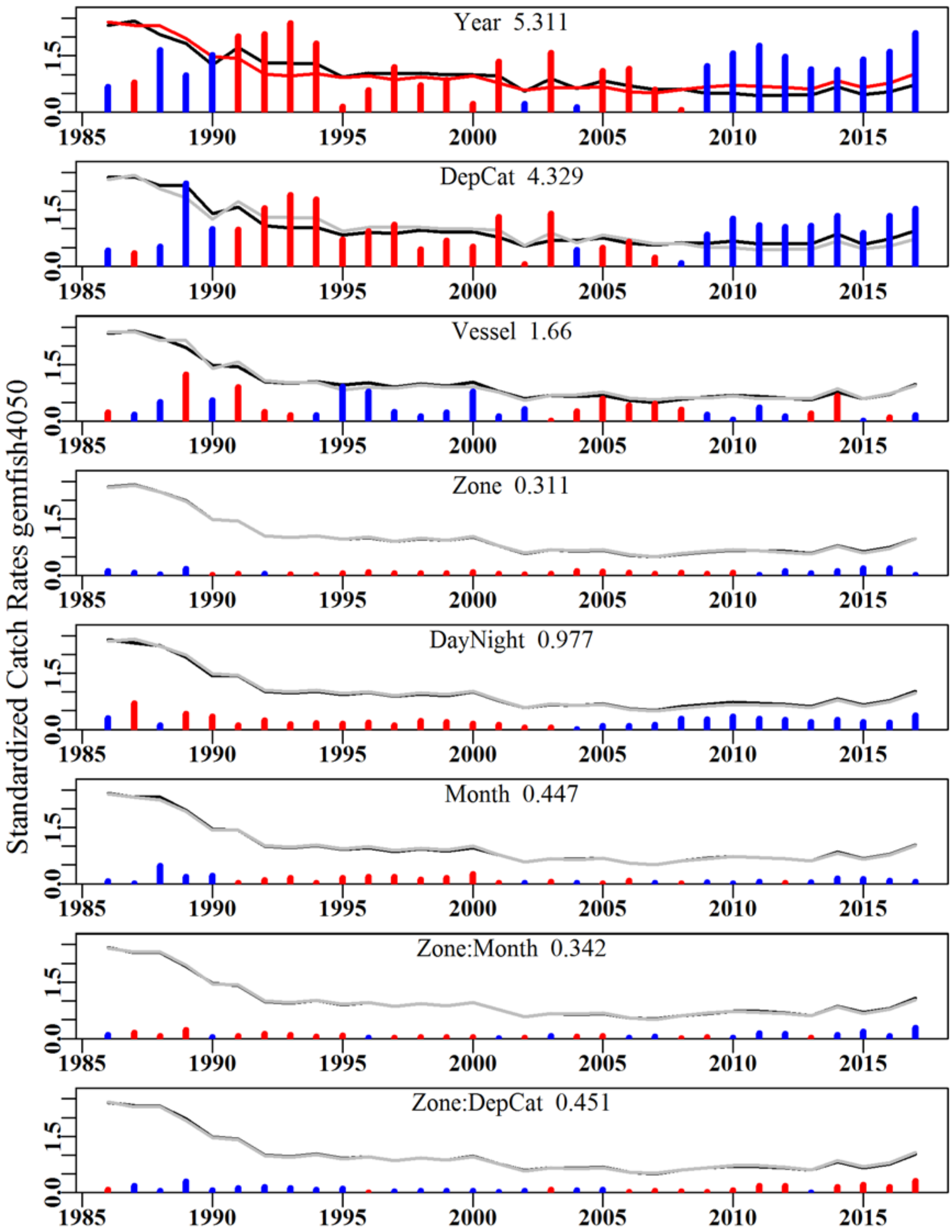


Figure 5.182. gemfish4050. The influence of each factor on the optimal standardization. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by vertical bars with blue bars indicating the optimum model is higher than the geometric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

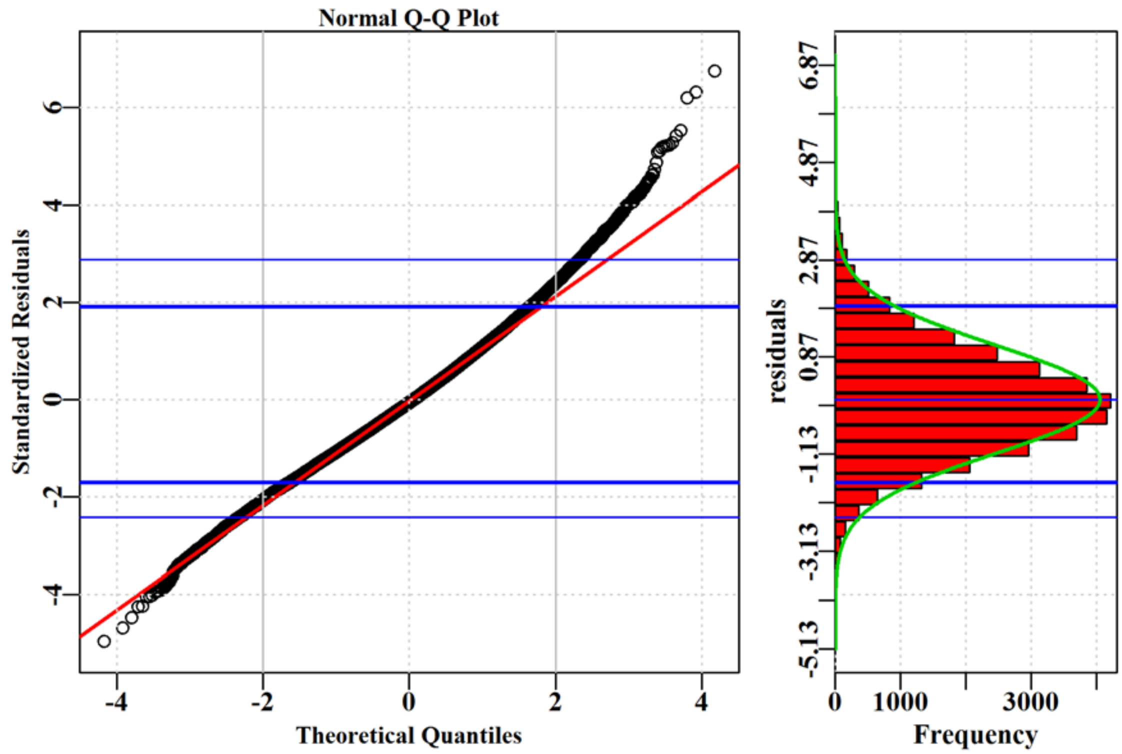


Figure 5.183. gemfish4050. diagnostic plots. The distribution of residuals from the optimum fit. The qqplot indicates the fit to the expected normality, while the histogram of residuals illustrates the 90% quantiles to indicate the intensity of any lack of fit at the margins of the distribution.

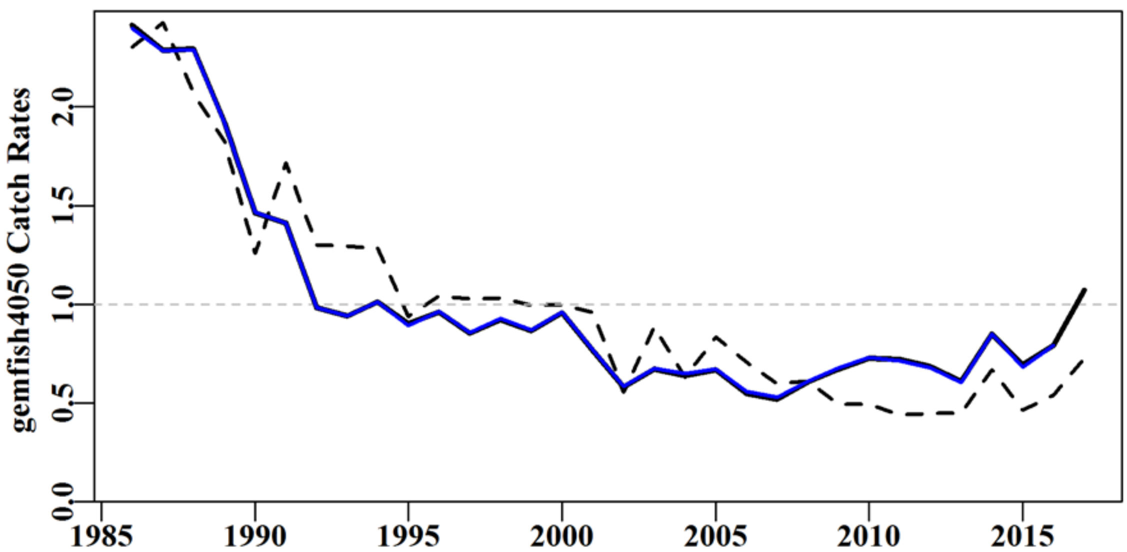


Figure 5.184. gemfish4050. A comparison of the previous year's standardization (blue line) with this year's. They should lie on top of each other, although small deviations may relate to data adjustments, particularly in very recent years.

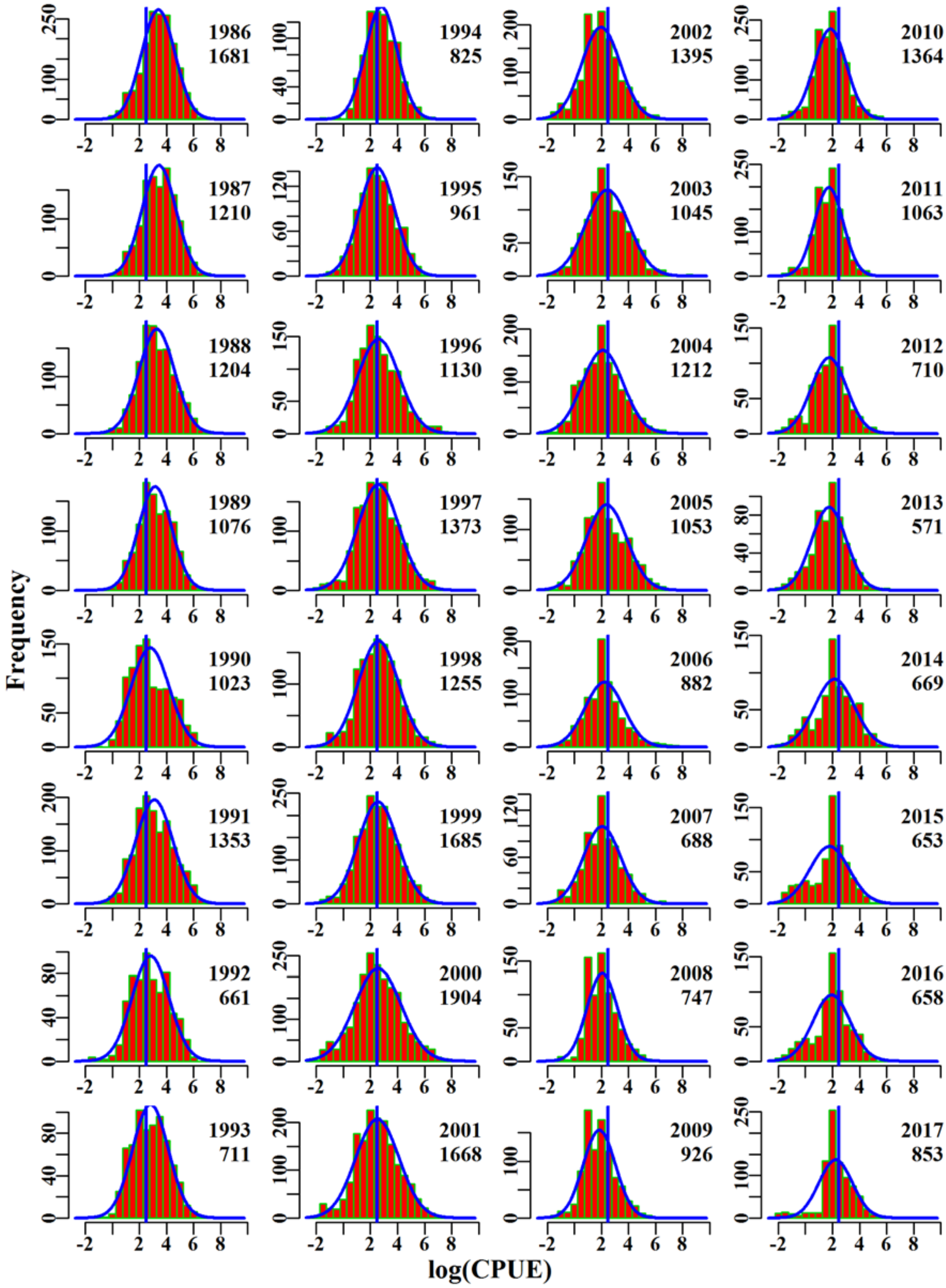


Figure 5.185. gemfish4050. The log(CPUE) for each year of data available the blue lines are normal distributions fitted to the histogram frequencies. The numbers in each plot are the year and number of records.

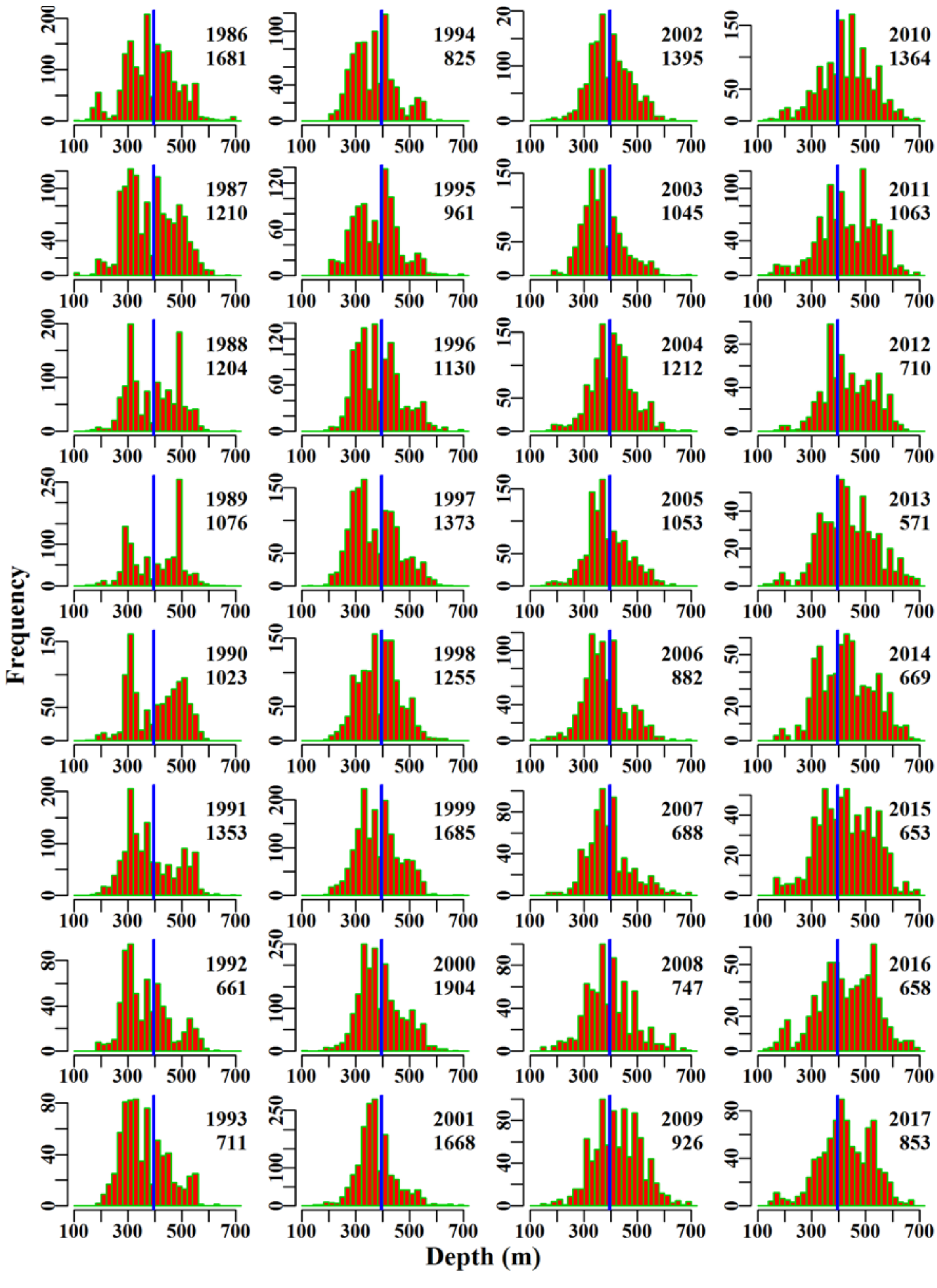


Figure 5.186. gemfish4050. The average Depth of fishing for each year of data available to illustrate the development of the fishery through time. The numbers in each plot are the year and number of records.

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, DayNight and one interaction (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 5.135). The qqplot suggests the assumed Normal distribution is valid with a slight departure as depicted by the upper tail 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 - 2017

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	2.3430	0.000	6.369	0.021
1987	263.8	1283	261.5	29	67.9	2.1832	0.046	5.264	0.020
1988	260.2	1399	254.9	36	63.3	2.0827	0.048	8.098	0.032
1989	185.3	1397	184.8	37	45.6	1.6180	0.049	8.774	0.047
1990	146.2	1231	145.2	35	38.5	1.3959	0.053	10.504	0.072
1991	300.0	1560	278.4	32	56.2	1.3569	0.050	8.992	0.032
1992	105.7	797	96.7	21	41.4	1.0151	0.057	5.404	0.056
1993	108.7	892	108.2	20	35.4	0.8475	0.056	7.358	0.068
1994	110.8	1037	109.8	24	33.3	0.8705	0.053	7.391	0.067
1995	106.9	1284	106.7	26	27.1	0.8507	0.051	11.458	0.107
1996	162.9	1576	161.7	32	30.7	0.9626	0.049	15.841	0.098
1997	214.8	2090	214.1	28	32.8	0.8582	0.047	19.333	0.090
1998	208.1	1964	207.2	26	35.9	1.0018	0.048	16.454	0.079
1999	323.9	2324	320.4	24	42.6	1.0031	0.047	17.891	0.056
2000	264.1	2330	261.2	31	52.9	0.8608	0.047	17.639	0.068
2001	259.9	2333	258.6	30	47.1	0.8036	0.047	17.391	0.067
2002	129.7	1748	128.5	28	20.4	0.6180	0.049	15.336	0.119
2003	207.5	1605	200.9	33	34.3	0.6731	0.050	11.011	0.055
2004	488.2	1942	480.3	30	48.1	0.7213	0.050	11.003	0.023
2005	389.6	1871	378.4	27	50.5	0.7256	0.050	8.591	0.023
2006	463.3	1614	437.1	26	56.6	0.6767	0.051	6.624	0.015
2007	426.7	1398	416.6	20	63.7	0.6143	0.052	5.950	0.014
2008	169.0	1237	155.7	18	19.5	0.6619	0.053	7.665	0.049
2009	113.5	1266	104.9	16	13.7	0.6886	0.052	8.242	0.079
2010	139.6	1700	128.4	18	12.7	0.7506	0.050	10.095	0.079
2011	87.3	1285	74.8	16	10.4	0.7593	0.052	8.266	0.110
2012	108.2	1044	102.1	18	16.4	0.8150	0.055	5.471	0.054
2013	55.9	707	47.2	20	13.2	0.6977	0.061	3.150	0.067
2014	97.7	838	89.1	17	24.5	0.9109	0.058	2.300	0.026
2015	57.0	716	50.2	14	16.5	0.7450	0.061	2.236	0.045
2016	55.8	678	51.2	15	17.2	0.8401	0.062	2.312	0.045
2017	86.0	933	83.7	13	18.8	1.0483	0.059	1.277	0.015

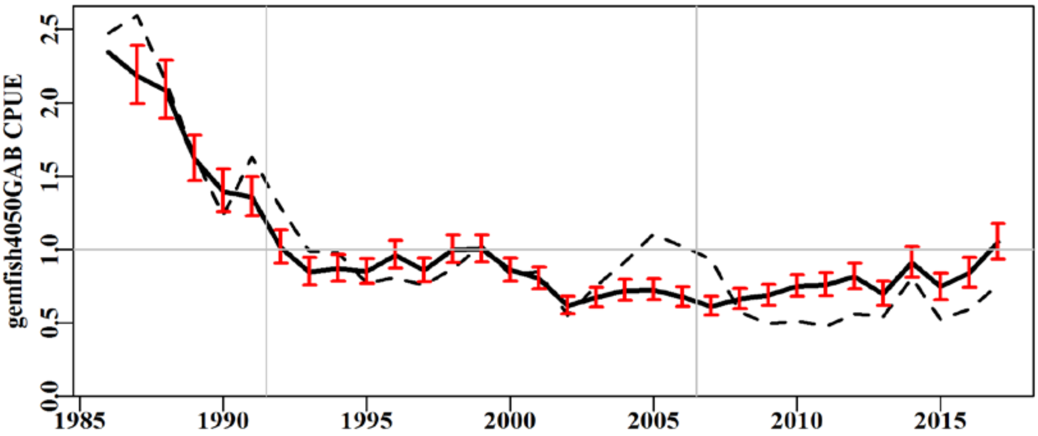


Figure 5.187. gemfish4050GAB standardization. The dashed black line represents the geometric mean catch rate, solid black line the standardized catch rates. The red bars are the 95% confidence intervals about the mean estimates. The graph scales both time-series of standardized catch rates relative to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

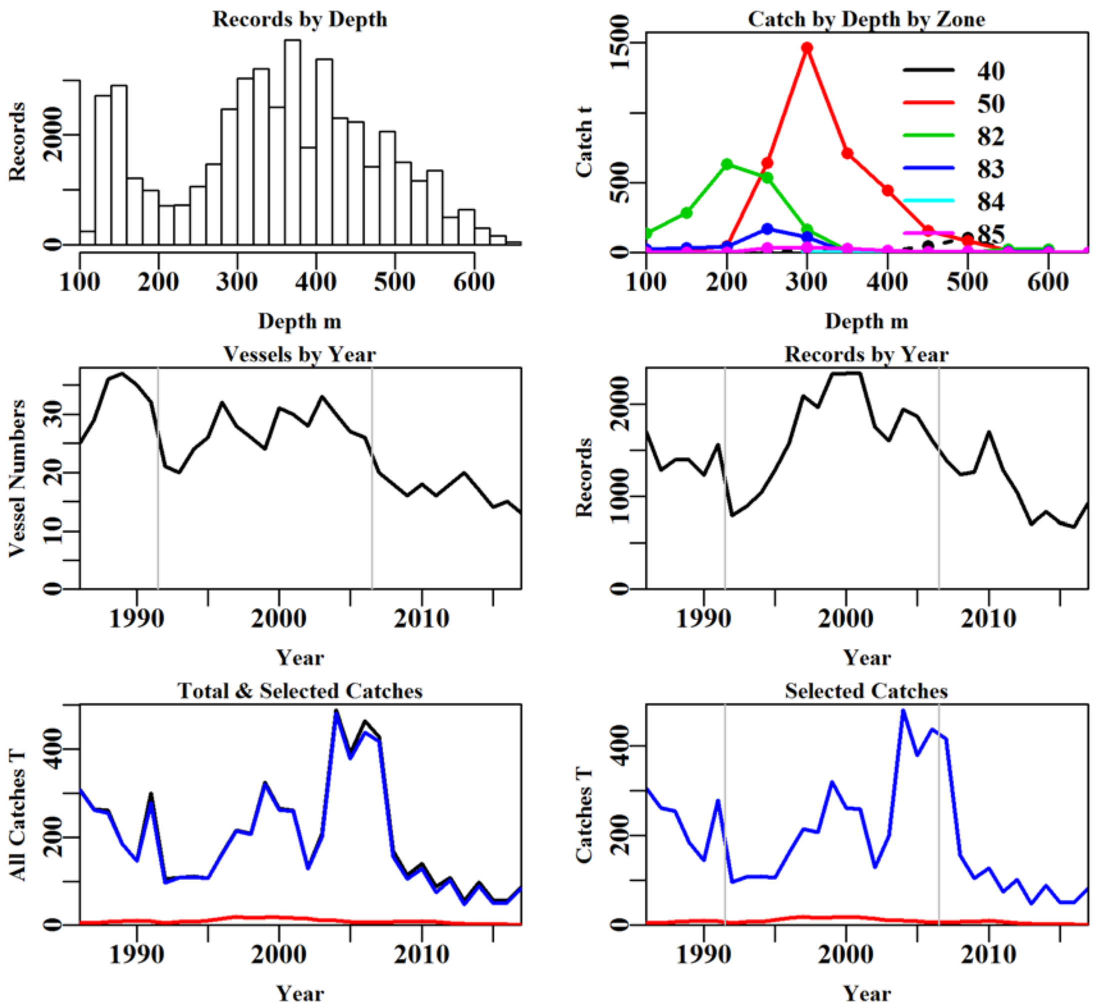


Figure 5.188. gemfish4050GAB fishery details. The bottom left plot depicts all known catches (top black line), and all selected catches used in the analysis (middle blue line); the lower red line: selected catches < 30 kg).

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	51832	50658	49710	48679	48679	45824	45779
Difference	0	11740	948	1031	0	2855	45
Catch	6592.213	6563.72275	6501.1584	6339.3283	6339.328	6206.733	6204.99715
Difference	0.000	28.49008	62.5643	161.8301	0.000	132.595	1.73625

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	38345	105641	8795	45779	32	7.6	0.00
DepCat	24883	78688	35748	45779	43	31.2	23.55
Vessel	16880	65748	48687	45779	154	42.4	11.18
Zone	16050	64553	49883	45779	159	43.4	1.04
DayNight	15005	63087	51348	45779	162	44.7	1.28
Month	14804	62780	51655	45779	173	44.9	0.26
Zone:Month	13744	61199	53237	45779	227	46.3	1.32
Zone:DepCat	14317	61976	52460	45779	225	45.6	0.64

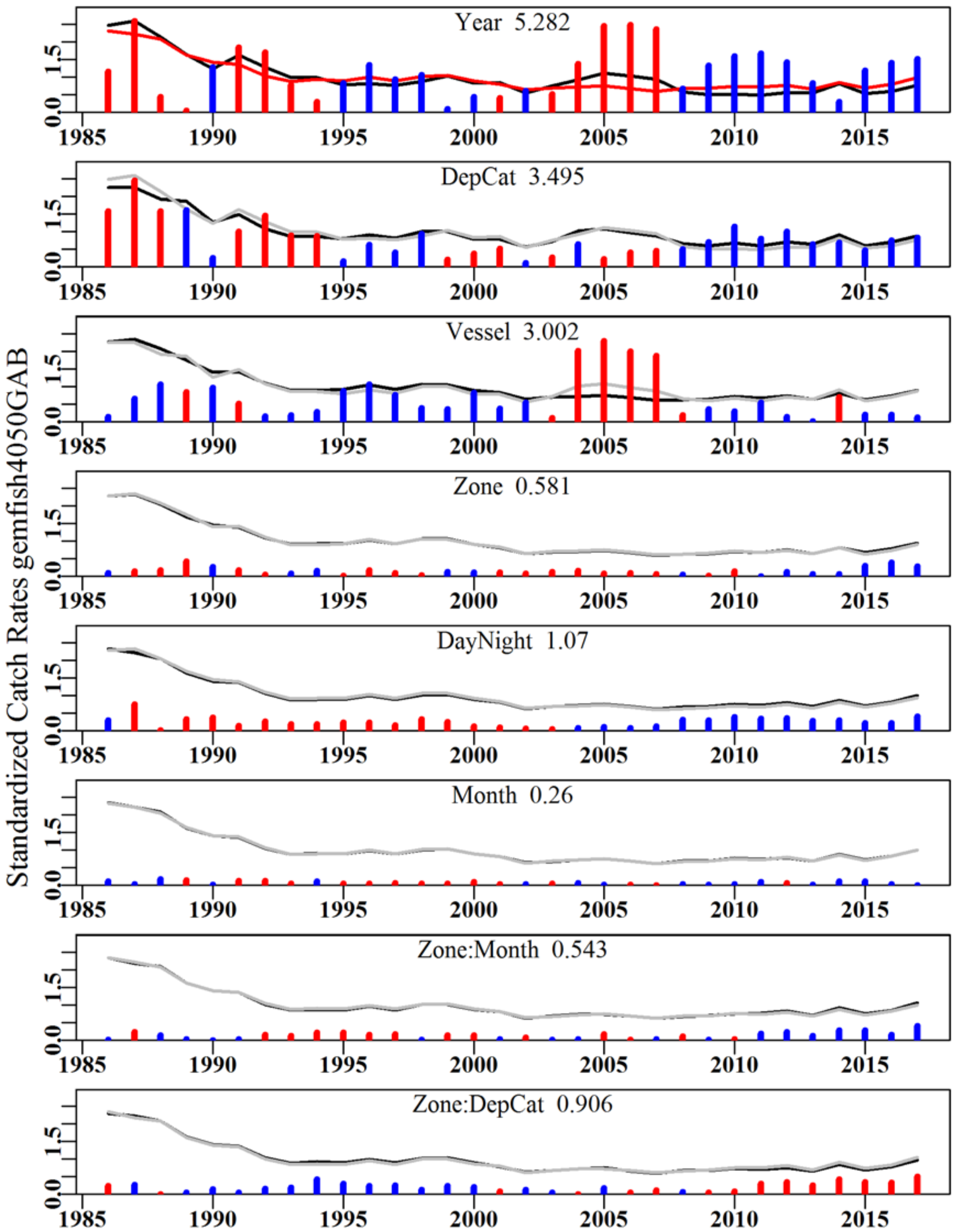


Figure 5.189. gemfish4050GAB. The influence of each factor on the optimal standardization. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by vertical bars with blue bars indicating the optimum model is higher than the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

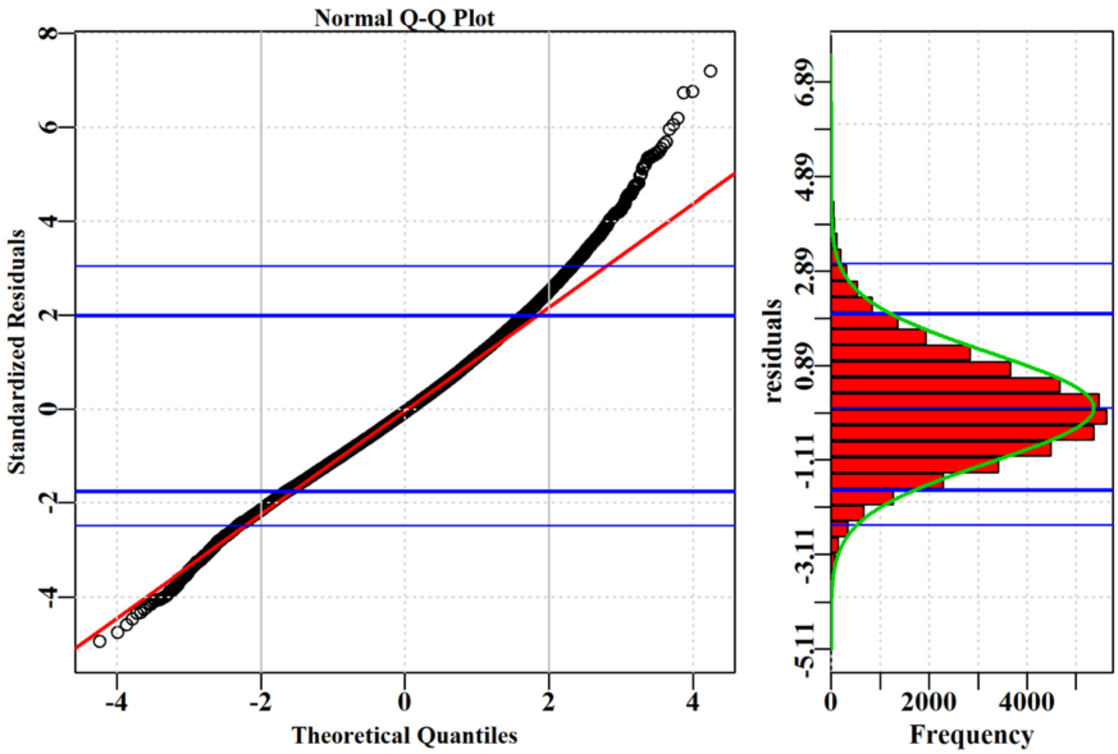


Figure 5.190. gemfish4050GAB. diagnostic plots. The distribution of residuals from the optimum fit. The qqplot indicates the fit to the expected normality, while the histogram of residuals illustrates the 90% quantiles to indicate the intensity of any lack of fit at the margins of the distribution.

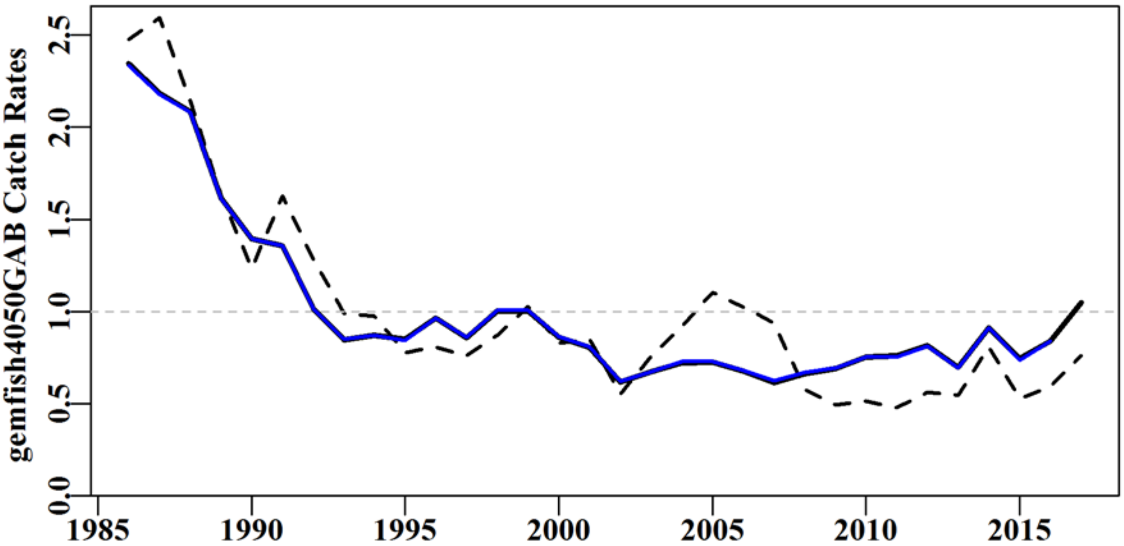


Figure 5.191. gemfish4050GAB. A comparison of the previous year's standardization (blue line) with this year's. They should lie on top of each other, although small deviations may relate to data adjustments, particularly in very recent years.

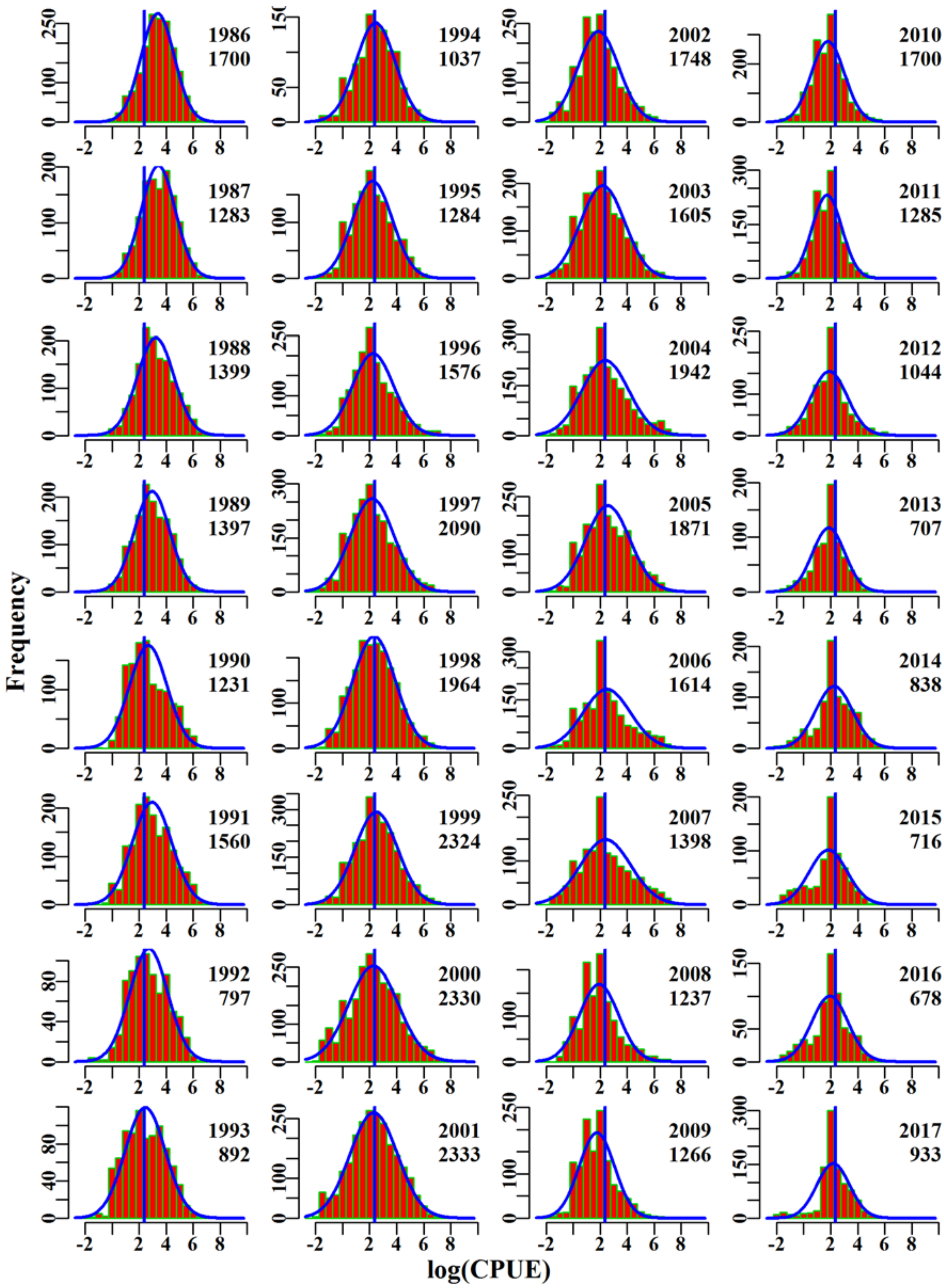


Figure 5.192. gemfish4050GAB. The log(CPUE) for each year of data available the blue lines are normal distributions fitted to the histogram frequencies. The numbers in each plot are the year and number of records.

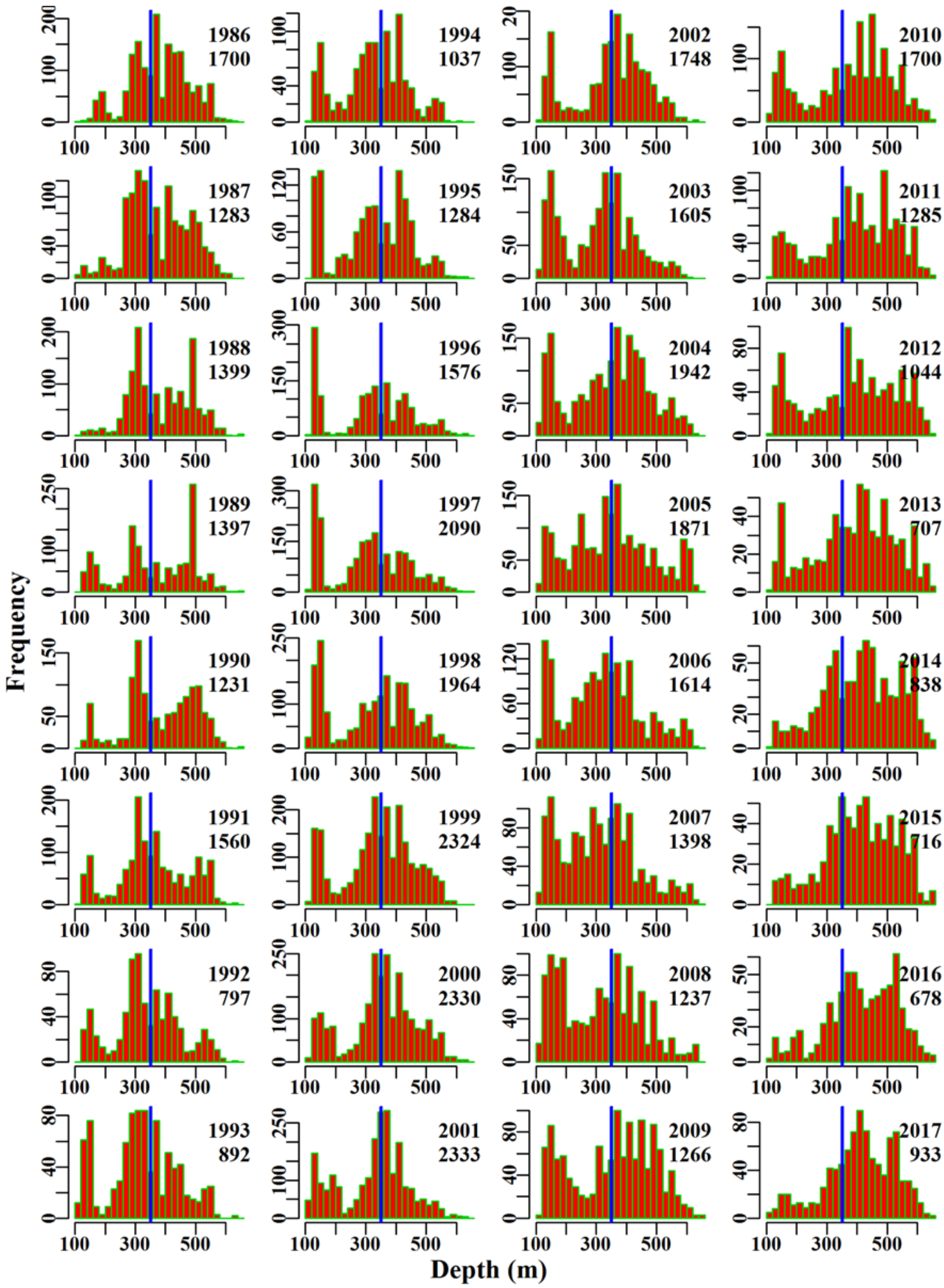


Figure 5.193. gemfish4050GAB. The average Depth of fishing for each year of data available to illustrate the development of the fishery through time. The numbers in each plot are the year and number of records.

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 detials 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 reamaining 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 - 2017

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	0.7530	0.000	3.093	0.138
1996	382.2	448	19.2	7	7.1	0.9678	0.093	6.034	0.314
1997	572.0	718	61.7	9	12.9	0.9578	0.089	7.883	0.128
1998	404.8	708	85.3	8	24.8	1.4383	0.090	6.170	0.072
1999	448.7	643	144.9	7	59.0	1.7467	0.093	3.520	0.024
2000	336.5	427	32.2	6	14.6	0.6095	0.099	2.800	0.087
2001	331.5	670	90.3	7	42.9	1.0245	0.092	3.634	0.040
2002	195.9	351	43.2	6	20.7	0.9110	0.102	2.283	0.053
2003	268.0	559	79.2	10	20.7	0.8568	0.097	3.308	0.042
2004	569.0	732	375.2	10	116.2	1.1229	0.097	2.901	0.008
2005	511.8	818	264.3	10	83.4	0.9990	0.098	2.821	0.011
2006	544.9	732	335.7	11	133.6	0.9639	0.097	2.133	0.006
2007	599.1	713	359.6	9	174.3	0.8395	0.095	2.271	0.006
2008	294.9	494	103.2	7	28.0	0.8777	0.097	2.975	0.029
2009	194.9	347	48.9	4	15.2	0.8038	0.104	2.161	0.044
2010	220.7	345	42.7	4	11.7	0.8392	0.104	2.100	0.049
2011	147.7	229	21.5	4	12.4	0.8898	0.116	1.421	0.066
2012	168.6	334	55.8	5	23.0	1.2838	0.107	1.435	0.026
2013	103.8	148	9.7	6	11.6	1.1939	0.132	0.154	0.016
2014	130.3	176	20.2	5	20.7	1.1964	0.134	0.246	0.012
2015	86.6	68	4.1	2	10.5	1.1333	0.174	0.206	0.050
2016	74.6	30	0.7	3	7.4	0.7845	0.246	0.196	0.273
2017	119.2	85	2.6	4	7.8	0.8069	0.161	0.312	0.120

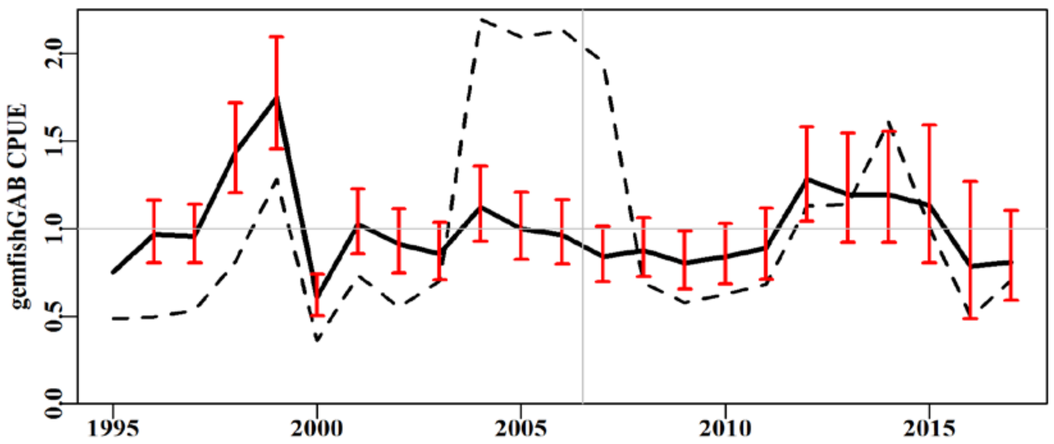


Figure 5.194. gemfishGAB standardization. The dashed black line represents the geometric mean catch rate, solid black line the standardized catch rates. The red bars are the 95% confidence intervals about the mean estimates. The graph scales both time-series of standardized catch rates relative to the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

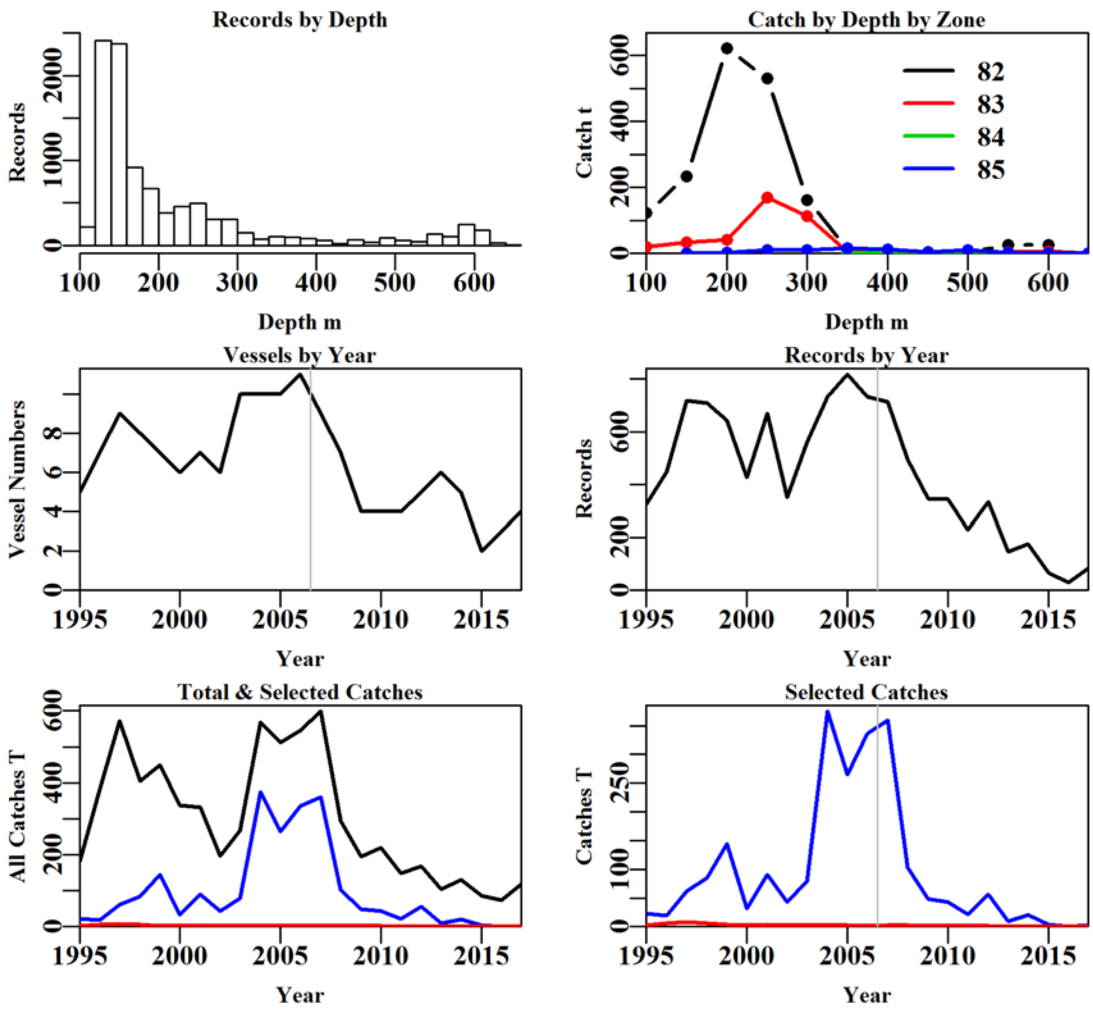


Figure 5.195. gemfishGAB fishery details. The bottom left plot depicts all known catches (top black line), and all selected catches used in the analysis (middle blue line); the lower red line: selected catches < 30 kg).

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	130438	123952	121646	83387	11931	10113	10099
Difference	0	6486	2306	38259	71456	1818	14
Catch	23637.04	23398.0624	23169.8127	6789.269	2312.109	2223.8397	2222.81844
Difference	0.00	238.9799	228.2497	16380.543	4477.160	88.2694	1.02125

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	11100	30174	3433	10099	23	10.0	0.00
DepCat	7430	20935	12672	10099	34	37.5	27.48
Vessel	5870	17857	15750	10099	57	46.6	9.07
Zone	5474	17160	16448	10099	60	48.6	2.07
DayNight	5105	16534	17073	10099	63	50.5	1.86
Month	4827	16050	17557	10099	74	51.9	1.40
Zone:Month	4532	15490	18117	10099	106	53.4	1.53
Zone:DepCat	4747	15839	17768	10099	101	52.4	0.50

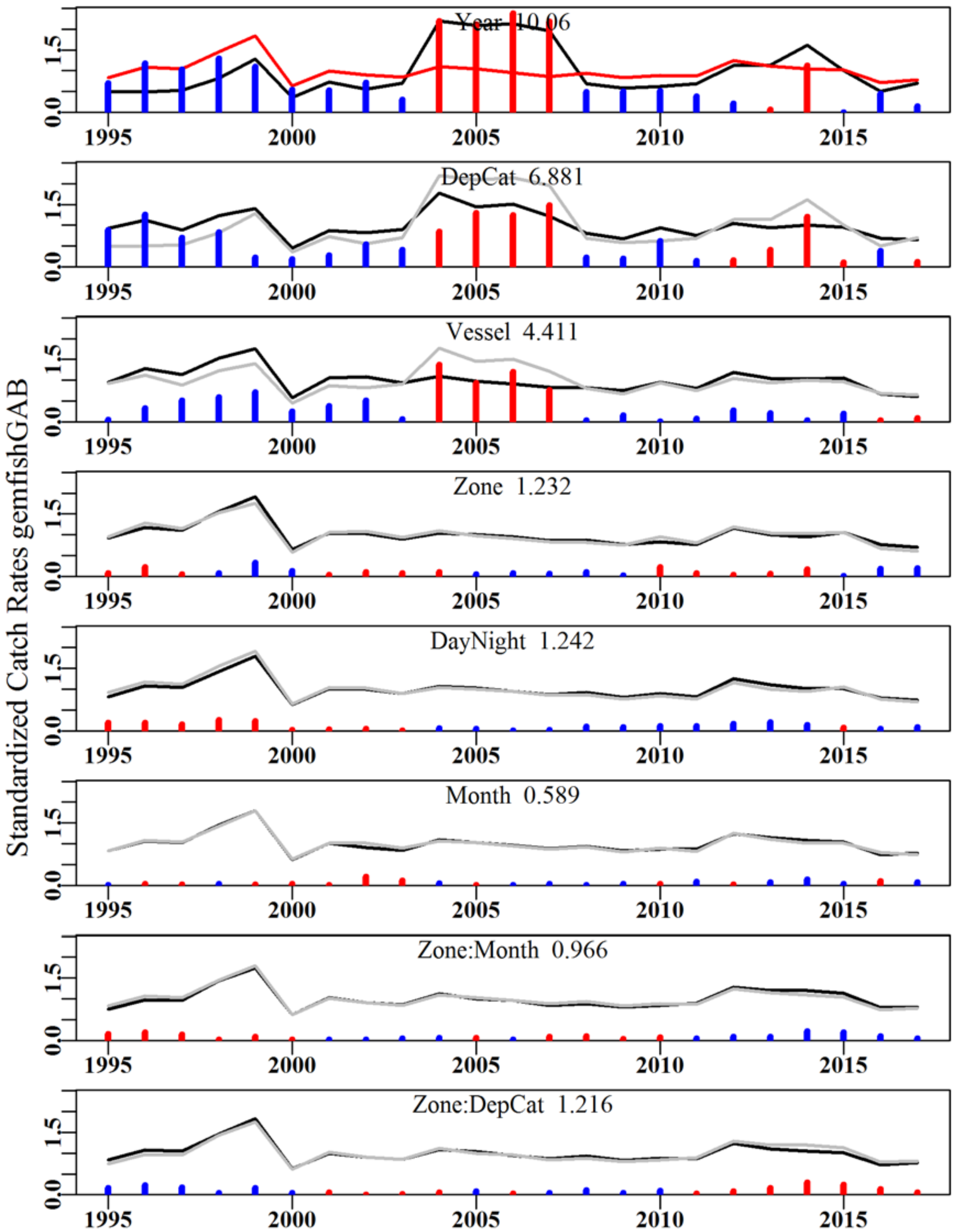


Figure 5.196. gemfishGAB. The influence of each factor on the optimal standardization. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by vertical bars with blue bars indicating the optimum model is higher than the geometric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

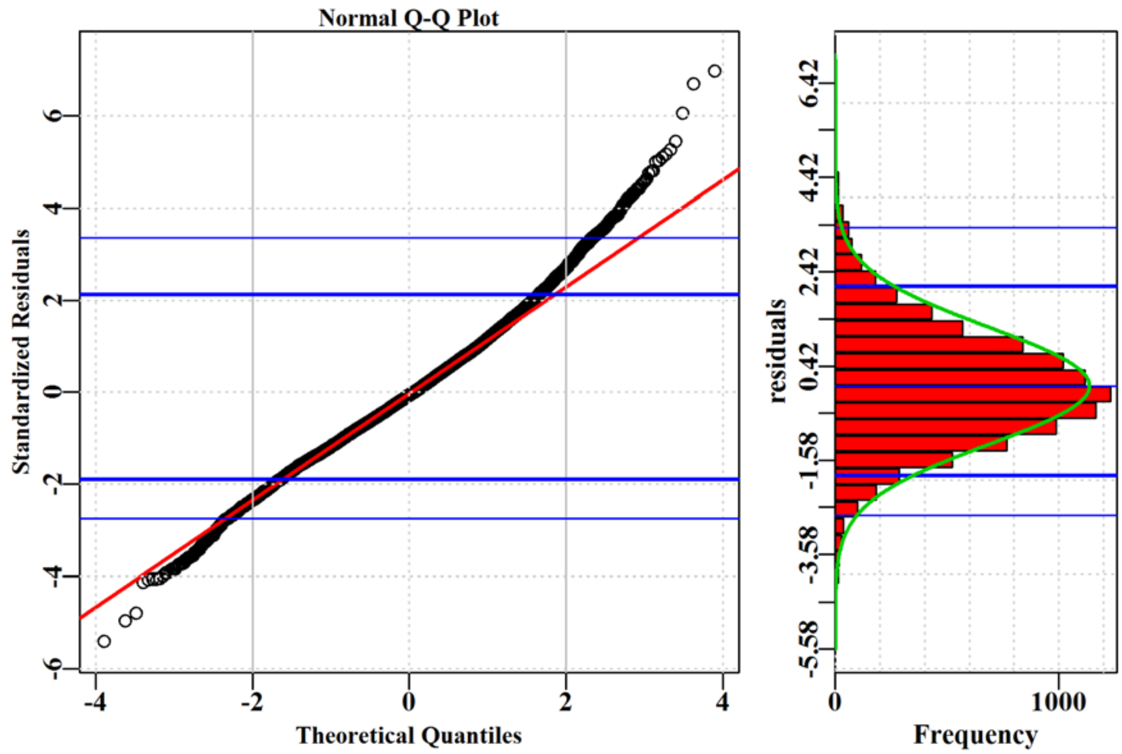


Figure 5.197. gemfishGAB. diagnostic plots. The distribution of residuals from the optimum fit. The qqplot indicates the fit to the expected normality, while the histogram of residuals illustrates the 90% quantiles to indicate the intensity of any lack of fit at the margins of the distribution.

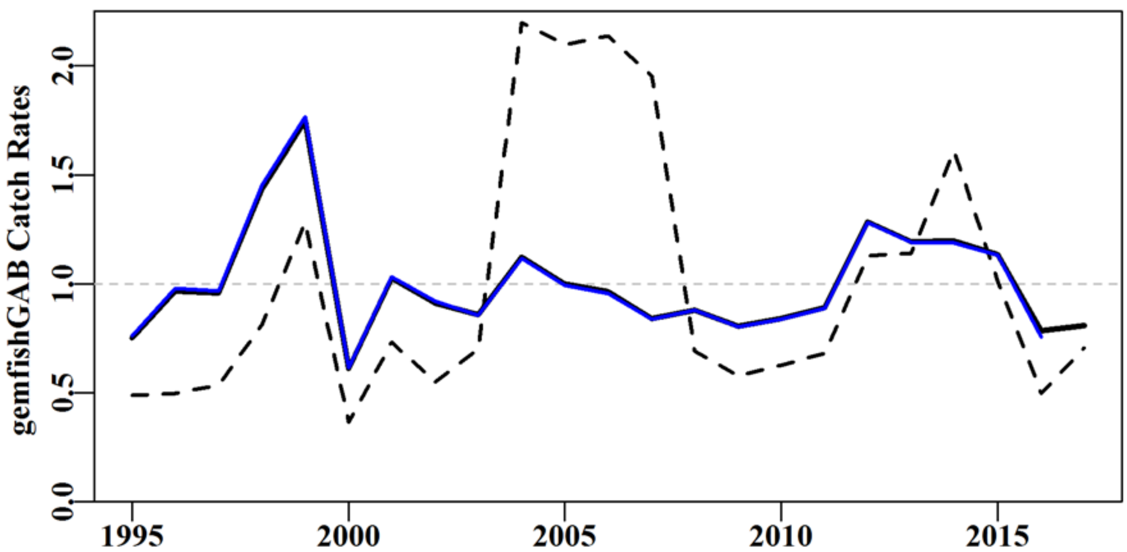


Figure 5.198. gemfishGAB. A comparison of the previous year's standardization (blue line) with this year's. They should lie on top of each other, although small deviations may relate to data adjustments, particularly in very recent years.

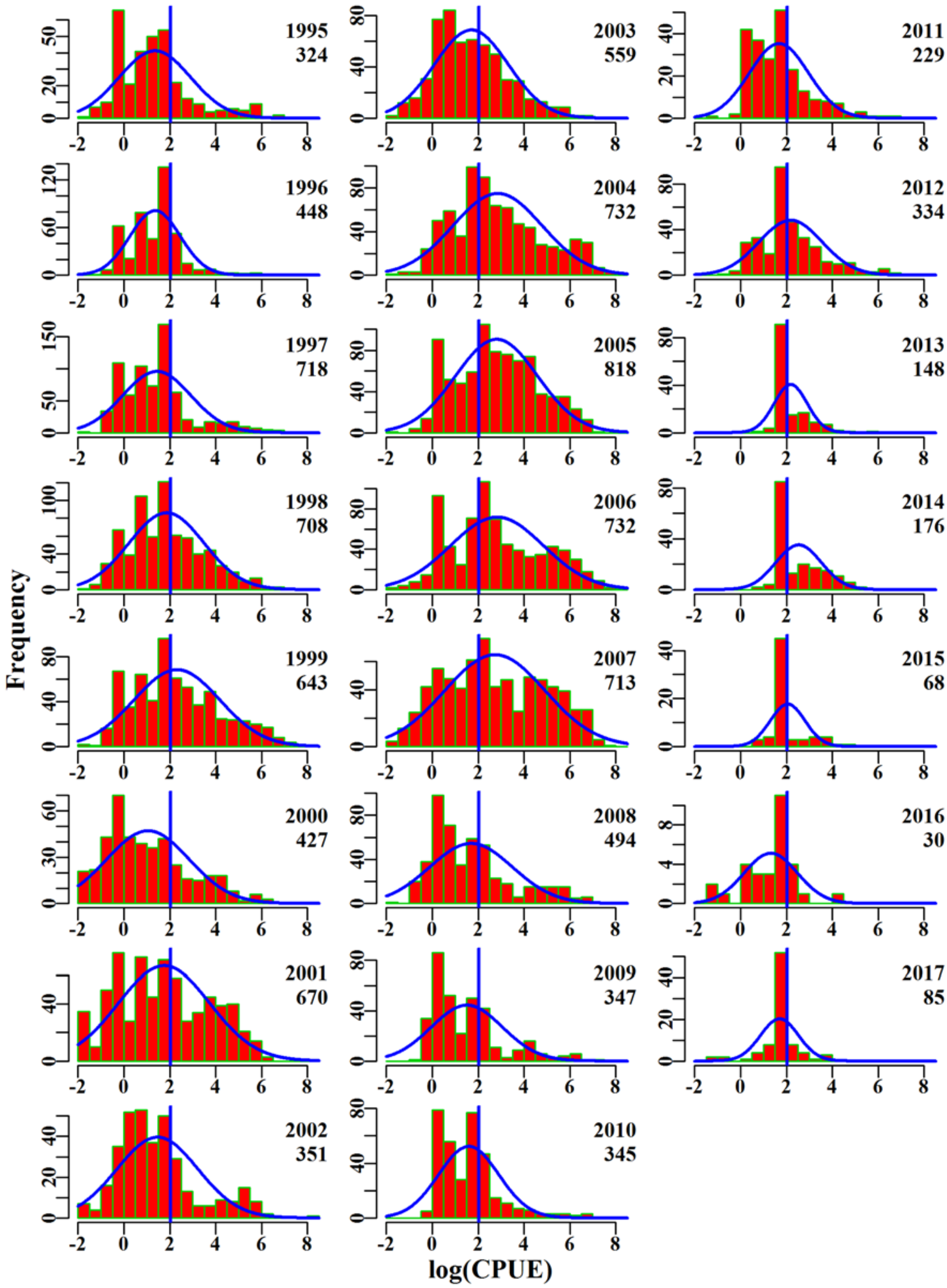


Figure 5.199. gemfishGAB. The log(CPUE) for each year of data available the blue lines are normal distributions fitted to the histogram frequencies. The numbers in each plot are the year and number of records.

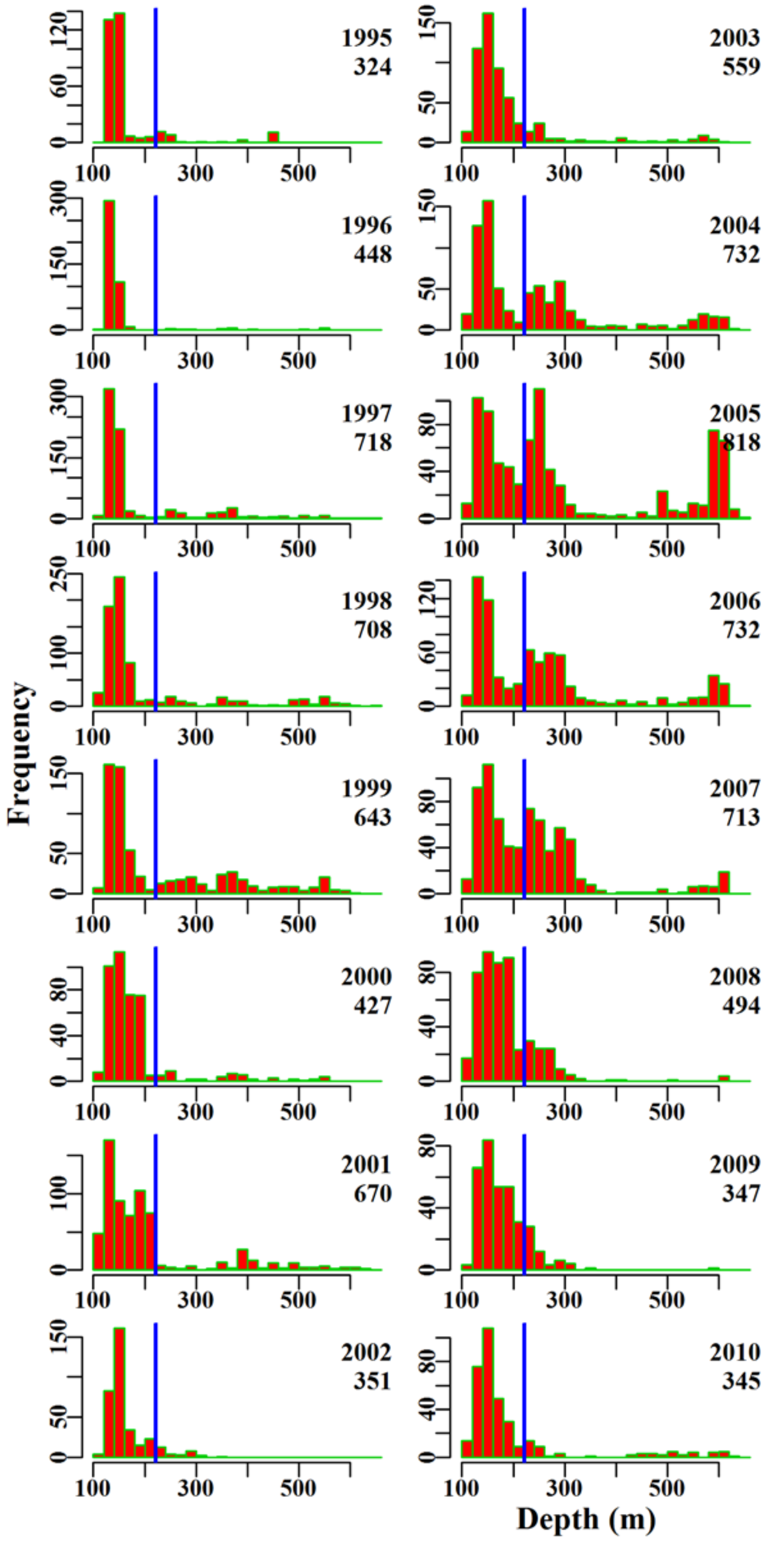


Figure 5.200. gemfishGAB. The average Depth of fishing for each year of data available to illustrate the development of the fishery through time. The numbers in each plot are the year and number of records.

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 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 - 2017

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	2.1743	0.000	3.563	0.026
1987	405.9	457	168.2	40	84.9	2.6112	0.105	2.506	0.015
1988	544.0	772	333.6	33	122.0	3.2134	0.095	3.566	0.011
1989	776.0	1172	654.9	41	180.8	4.2299	0.093	4.010	0.006
1990	881.4	816	504.6	41	182.2	3.8249	0.097	3.118	0.006
1991	1284.2	1553	462.3	54	99.9	2.1417	0.092	8.987	0.019
1992	934.4	1329	401.3	40	96.2	1.7811	0.093	8.152	0.020
1993	829.6	2174	428.5	45	61.2	1.3928	0.090	14.159	0.033
1994	944.8	2428	469.7	43	63.7	1.3250	0.088	16.815	0.036
1995	815.4	2631	467.1	44	59.6	1.1899	0.088	19.900	0.043
1996	724.4	3543	530.7	48	53.9	1.3079	0.087	26.062	0.049
1997	935.2	2467	403.0	42	57.3	1.2686	0.090	16.367	0.041
1998	903.2	2552	457.2	39	65.4	1.1589	0.089	17.177	0.038
1999	591.1	1640	131.6	39	27.2	0.6247	0.092	12.412	0.094
2000	470.5	2221	185.7	41	25.1	0.5342	0.090	15.442	0.083
2001	285.5	1469	57.3	33	11.1	0.3140	0.094	10.220	0.178
2002	290.5	1854	62.9	36	8.1	0.2390	0.092	12.452	0.198
2003	234.0	1311	40.8	38	6.1	0.1831	0.095	8.270	0.203
2004	232.4	1243	51.8	38	11.5	0.2489	0.097	8.430	0.163
2005	289.1	820	21.2	33	5.6	0.1737	0.101	4.649	0.219
2006	379.5	772	25.6	28	8.3	0.1980	0.103	4.635	0.181
2007	177.8	577	16.5	14	5.8	0.2063	0.107	3.838	0.233
2008	163.3	730	26.5	18	8.7	0.2844	0.103	5.475	0.207
2009	135.2	443	35.7	15	21.6	0.3534	0.112	2.854	0.080
2010	129.3	361	11.7	15	7.6	0.2180	0.118	2.212	0.189
2011	103.3	427	9.6	13	5.0	0.1804	0.114	2.601	0.270
2012	52.3	346	9.8	14	5.8	0.1468	0.119	1.872	0.192
2013	68.0	163	3.7	17	5.8	0.1369	0.147	0.934	0.255
2014	15.3	88	1.8	12	3.7	0.0917	0.183	0.376	0.211
2015	5.4	55	1.6	9	8.0	0.1062	0.223	0.302	0.190
2016	18.8	190	6.8	14	8.0	0.0971	0.142	0.992	0.147
2017	16.4	280	3.9	12	2.6	0.0439	0.128	1.085	0.280

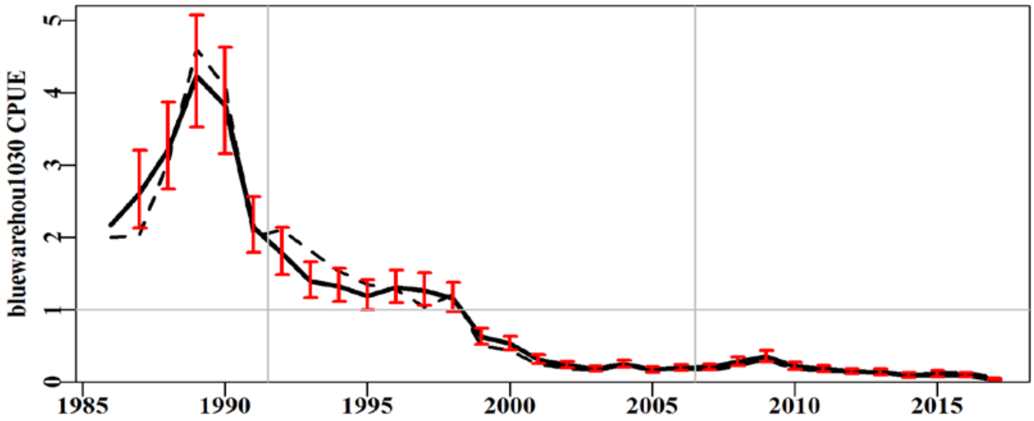


Figure 5.201. bluewarehou1030 standardization. The dashed black line represents the geometric mean catch rate, solid black line the standardized catch rates. The red bars are the 95% confidence intervals about the mean estimates. The graph scales both time-series of standardized catch rates relative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

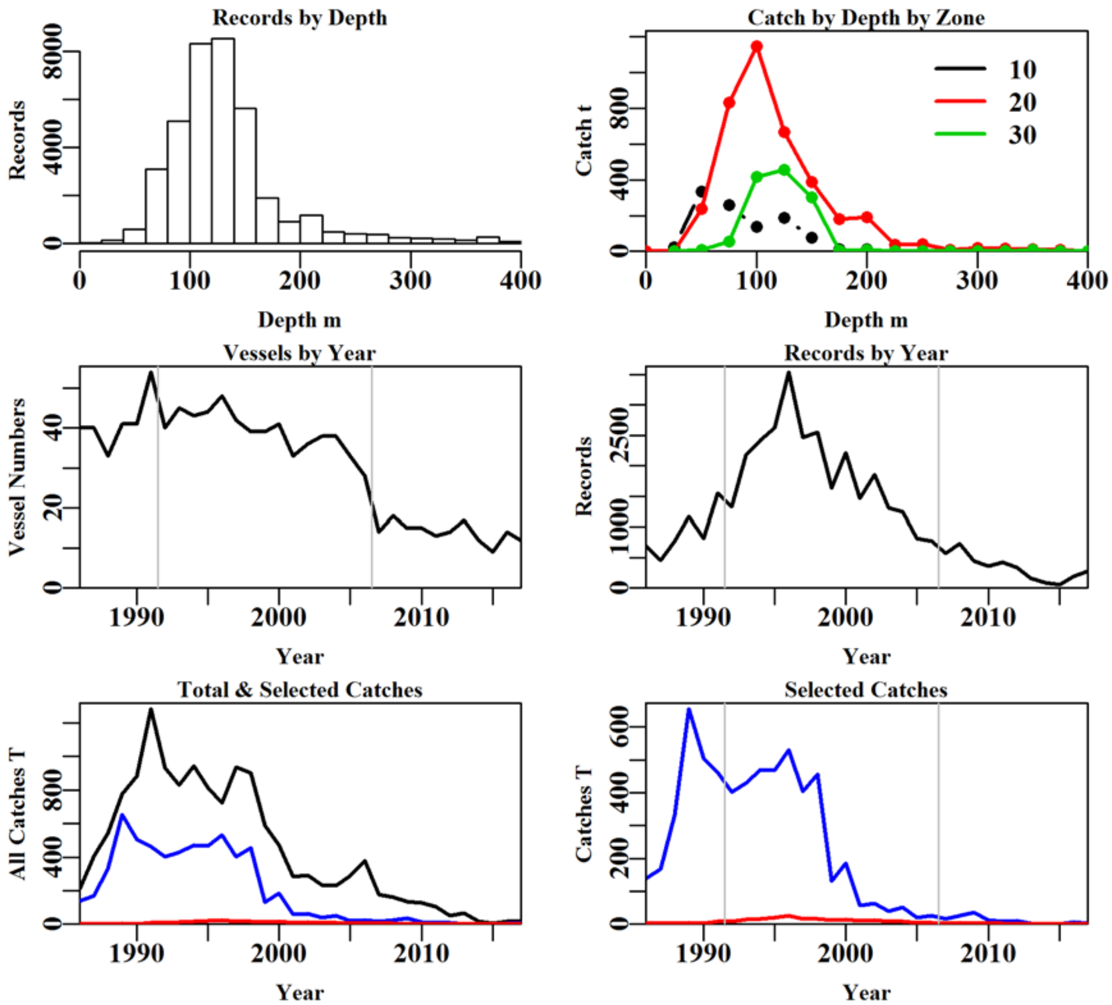


Figure 5.202. bluewarehou1030 fishery details. The bottom left plot depicts all known catches (top black line), and all selected catches used in the analysis (middle blue line); the lower red line: selected catches < 30 kg).

Table 5.143. bluewarehou1030 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	66694	61111	58294	57944	40574	37641	37584
Difference	0	5583	2817	350	17370	2933	57
Catch	13919.79	13533.3656	12799.9074	12752.2560	6710.769	6126.3133	6124.174
Difference	0.00	386.4257	733.4582	47.6514	6041.487	584.4557	2.139

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	37626	102104	40252	37584	32	28.2	0.00
Vessel	32880	89201	53155	37584	198	37.0	8.79
DepCat	32408	88012	54344	37584	214	37.8	0.81
Month	32224	87532	54824	37584	225	38.1	0.32
Zone	31815	86574	55782	37584	227	38.8	0.67
DayNight	31730	86365	55991	37584	230	39.0	0.14
Zone:Month	31448	85619	56737	37584	252	39.5	0.49
Zone:DepCat	31496	85692	56664	37584	260	39.4	0.43

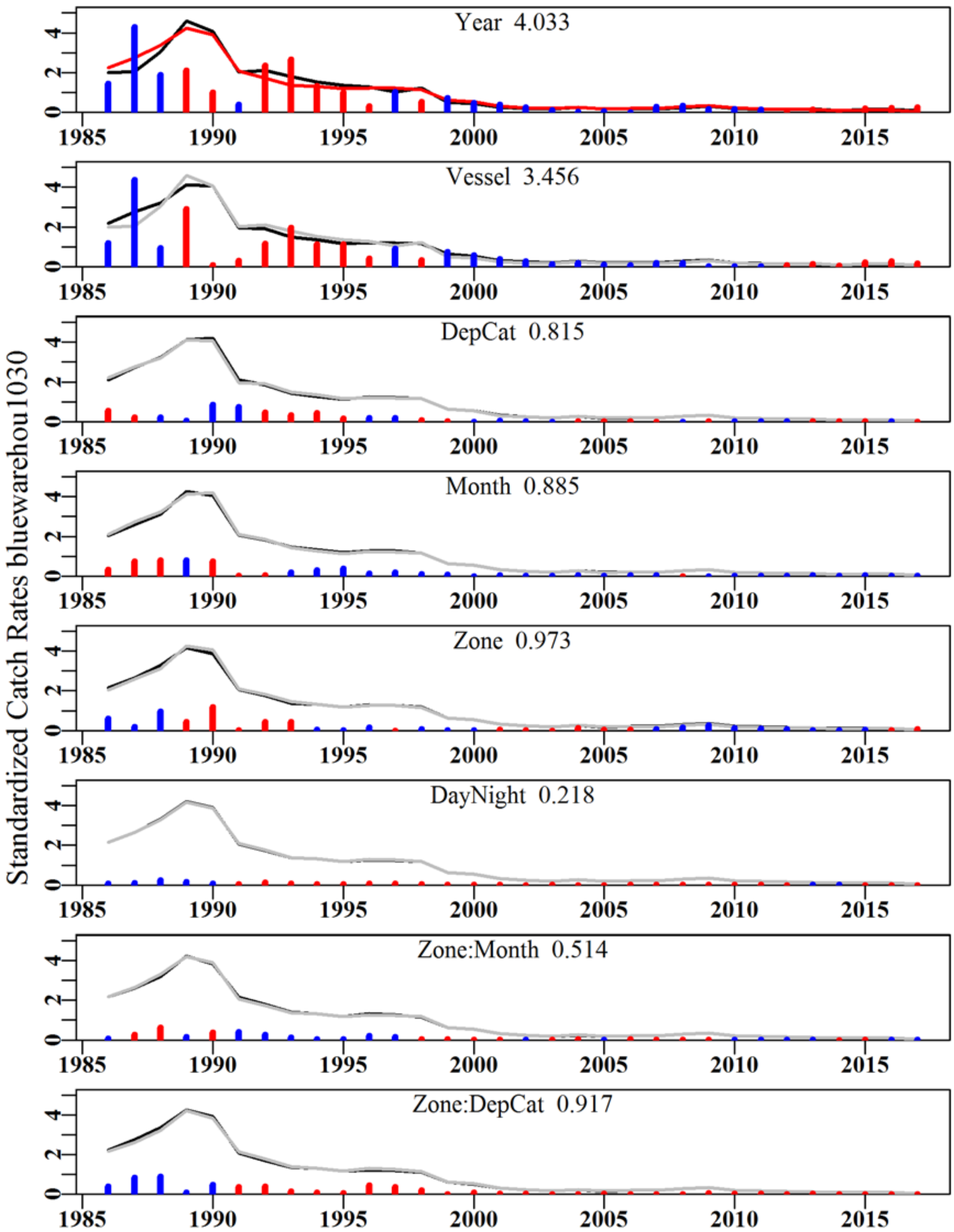


Figure 5.203. bluewarehou1030. The influence of each factor on the optimal standardization. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by vertical bars with blue bars indicating the optimum model is higher than the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

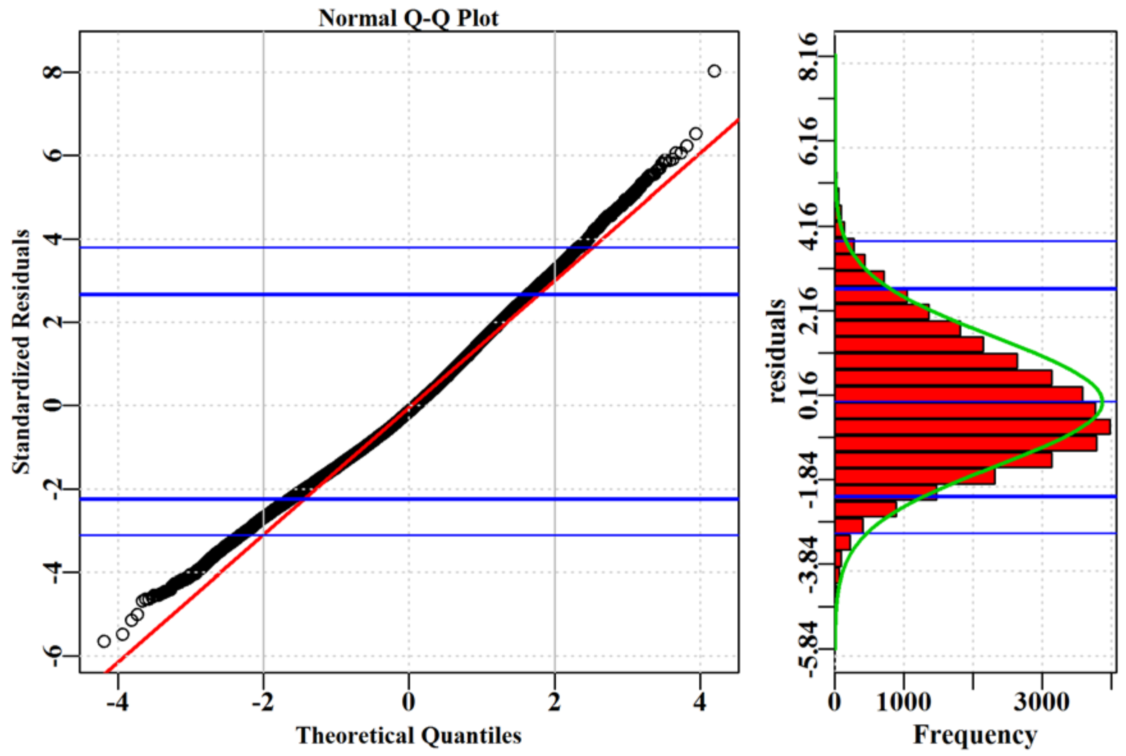


Figure 5.204. bluewarehou1030. diagnostic plots. The distribution of residuals from the optimum fit. The qqplot indicates the fit to the expected normality, while the histogram of residuals illustrates the 90% quantiles to indicate the intensity of any lack of fit at the margins of the distribution.

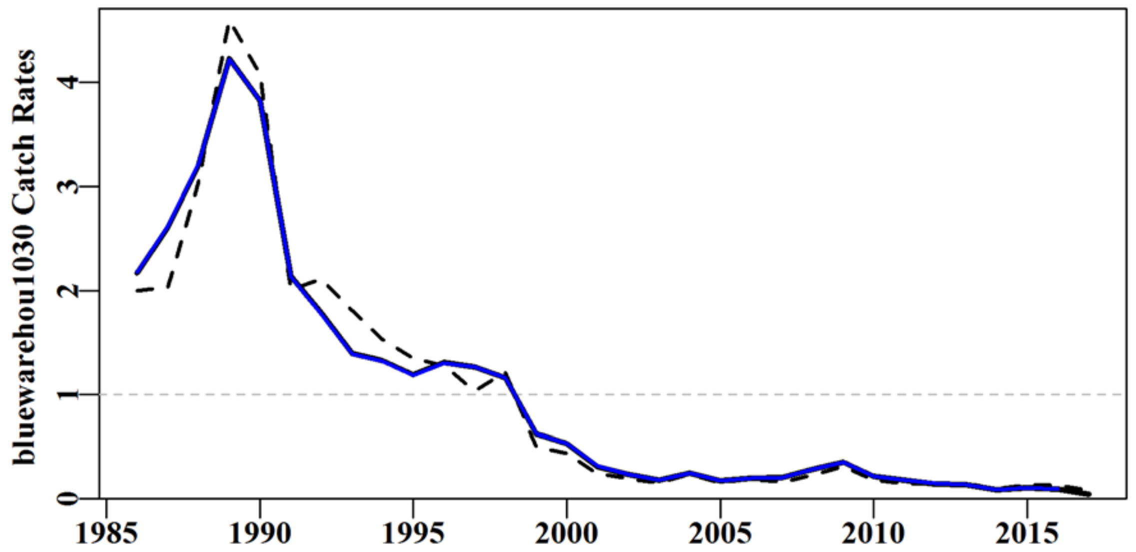


Figure 5.205. bluewarehou1030. A comparison of the previous year's standardization (blue line) with this year's. They should lie on top of each other, although small deviations may relate to data adjustments, particularly in very recent years.

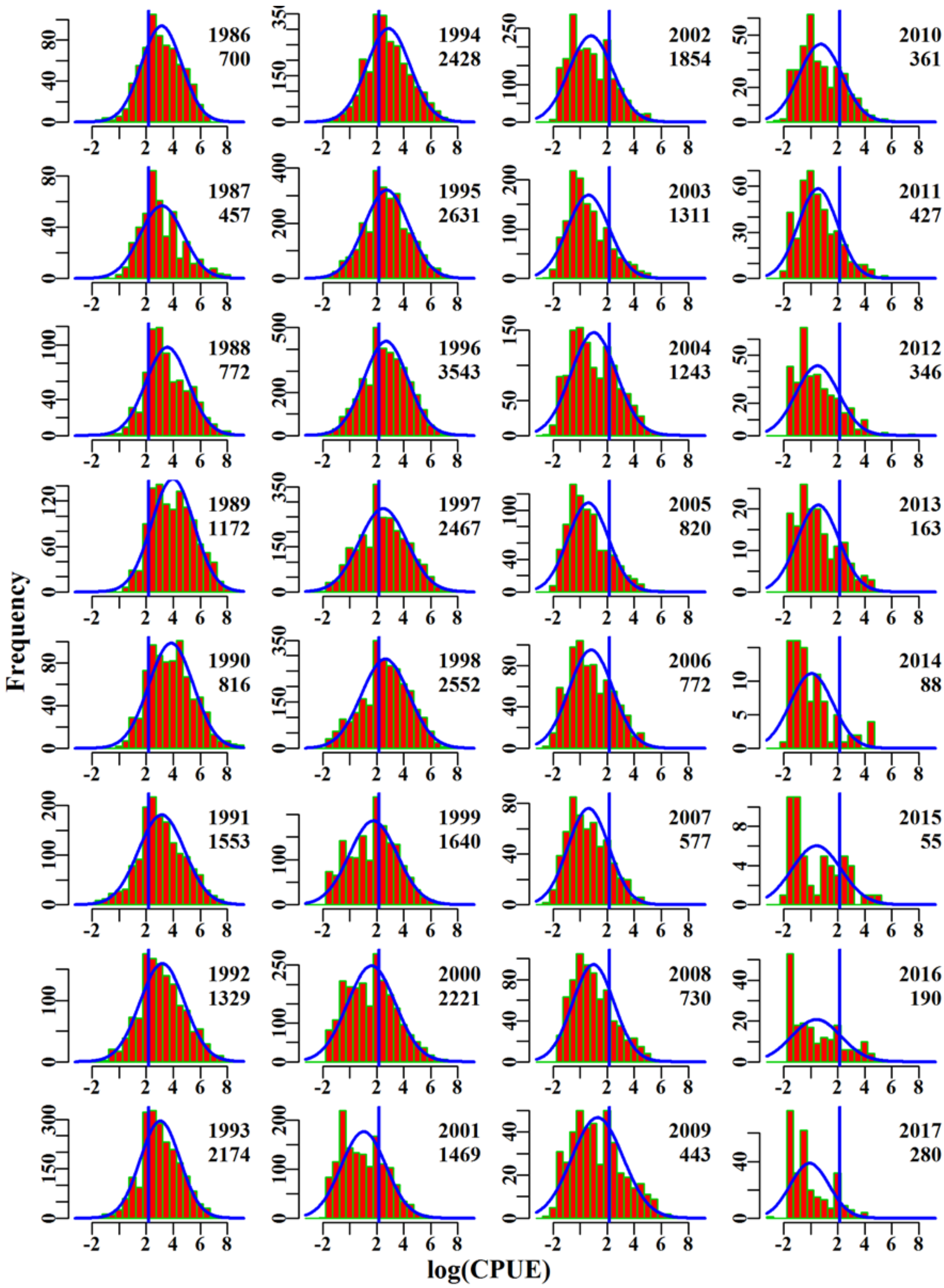


Figure 5.206. bluewarehou1030. The log(CPUE) for each year of data available the blue lines are normal distributions fitted to the histogram frequencies. The numbers in each plot are the year and number of records.

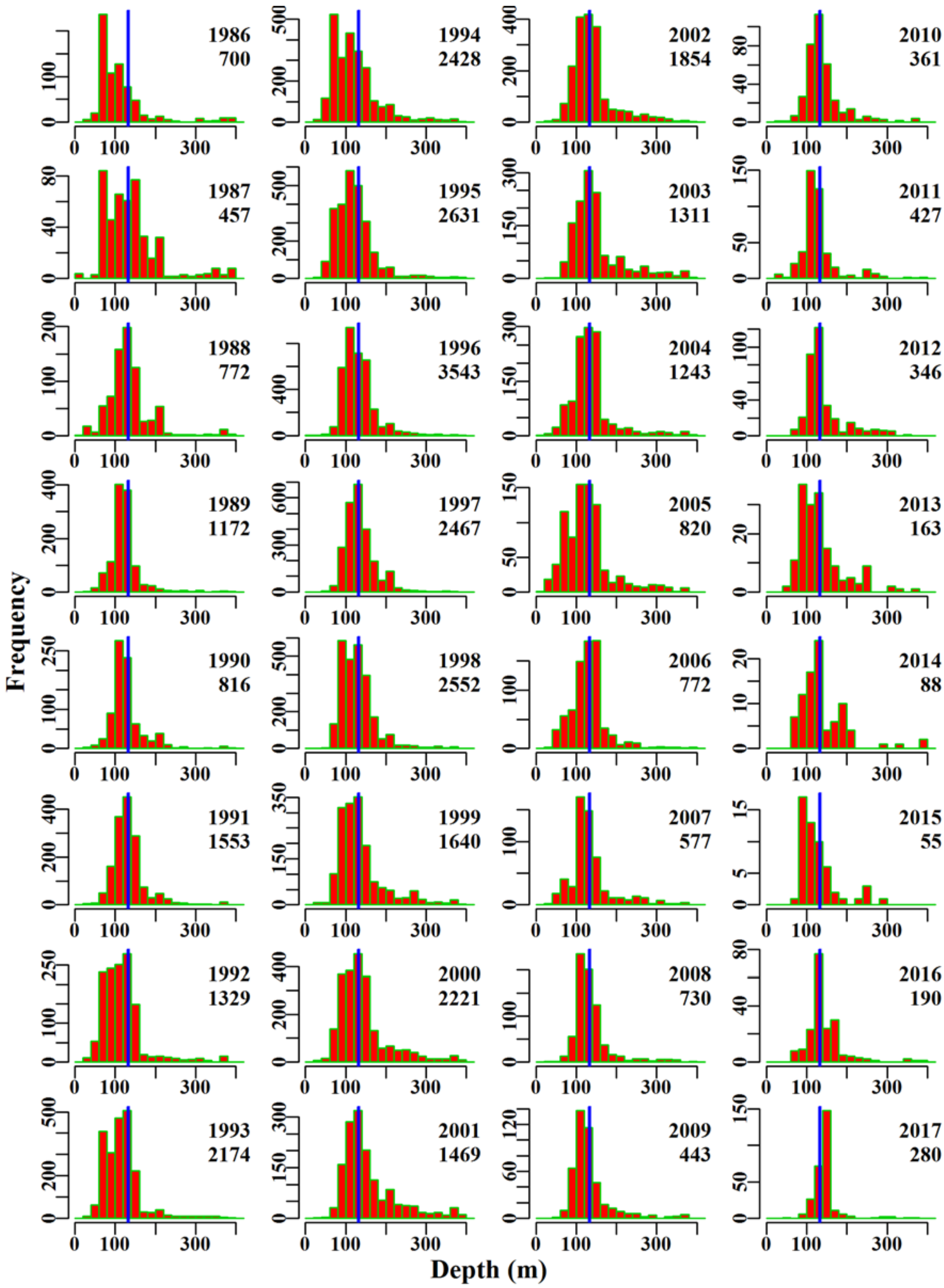


Figure 5.207. bluewarehou1030. The average Depth of fishing for each year of data available to illustrate the development of the fishery through time. The numbers in each plot are the year and number of records.

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 detials 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.

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 (18 and 42) and coresponding 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 - 2017

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<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	159	71.4	14	162.6	3.6163	0.000	0.759	0.011
1987	405.9	183	215.6	10	635.9	3.6676	0.242	0.334	0.002
1988	544.0	179	198.0	12	566.9	1.6074	0.250	0.700	0.004
1989	776.0	56	81.3	13	562.1	4.2291	0.310	0.235	0.003
1990	881.4	439	298.1	13	341.8	1.6178	0.236	2.210	0.007
1991	1284.2	595	647.1	18	850.7	2.6827	0.234	1.060	0.002
1992	934.4	536	429.7	17	473.1	1.4548	0.235	1.733	0.004
1993	829.6	494	362.7	21	413.0	1.1175	0.237	1.700	0.005
1994	944.8	820	444.1	21	245.7	1.2334	0.232	2.525	0.006
1995	815.4	820	323.6	22	155.8	0.8387	0.230	4.180	0.013
1996	724.4	696	180.9	24	87.2	0.5673	0.231	4.248	0.023
1997	935.2	430	243.5	23	354.0	0.5938	0.237	3.038	0.012
1998	903.2	582	354.5	19	459.4	0.9248	0.235	2.728	0.008
1999	591.1	687	169.4	19	122.7	0.5092	0.234	4.505	0.027
2000	470.5	651	203.6	24	157.7	0.4138	0.235	3.736	0.018
2001	285.5	685	194.0	23	98.5	0.4357	0.233	4.249	0.022
2002	290.5	528	217.9	23	184.0	0.5637	0.236	2.977	0.014
2003	234.0	361	172.4	19	185.9	0.5058	0.242	2.421	0.014
2004	232.4	430	158.8	21	136.3	0.5491	0.239	2.276	0.014
2005	289.1	457	257.4	18	333.5	0.8750	0.239	1.735	0.007
2006	379.5	693	337.5	16	212.7	0.6021	0.235	3.736	0.011
2007	177.8	462	147.7	16	116.3	0.5037	0.239	2.541	0.017
2008	163.3	349	117.0	12	88.9	0.4105	0.242	2.016	0.017
2009	135.2	308	89.0	11	70.1	0.3055	0.244	1.337	0.015
2010	129.3	407	105.3	12	52.7	0.3543	0.239	1.833	0.017
2011	103.3	517	77.8	14	31.2	0.3209	0.237	2.225	0.029
2012	52.3	254	30.7	14	22.3	0.1841	0.249	1.654	0.054
2013	68.0	304	57.9	13	37.3	0.2518	0.245	1.522	0.026
2014	15.3	60	11.6	9	48.9	0.1870	0.306	0.457	0.039
2015	5.4	17	0.6	5	5.9	0.0784	0.440	0.049	0.085
2016	18.8	42	2.6	8	11.6	0.2702	0.335	0.243	0.094
2017	16.4	84	7.3	8	14.5	0.5278	0.290	0.592	0.081

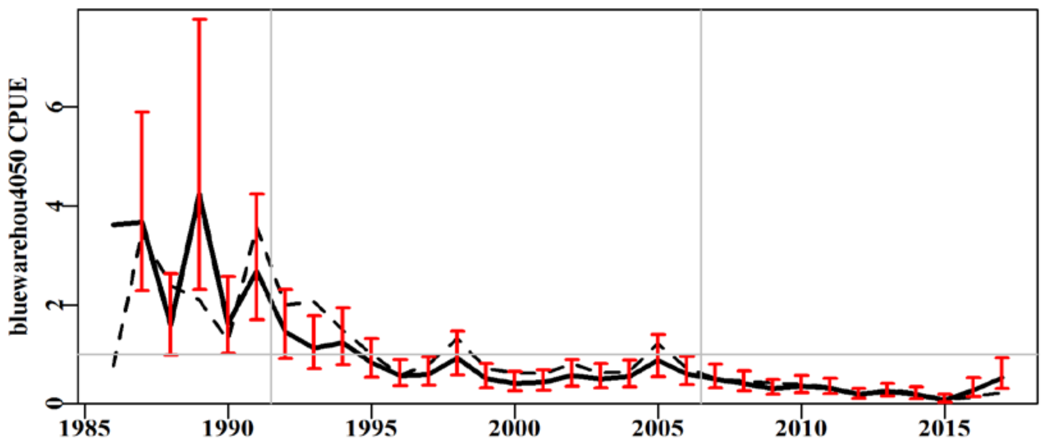


Figure 5.208. bluewarehou4050 standardization. The dashed black line represents the geometric mean catch rate, solid black line the standardized catch rates. The red bars are the 95% confidence intervals about the mean estimates. The graph scales both time-series of standardized catch rates relative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

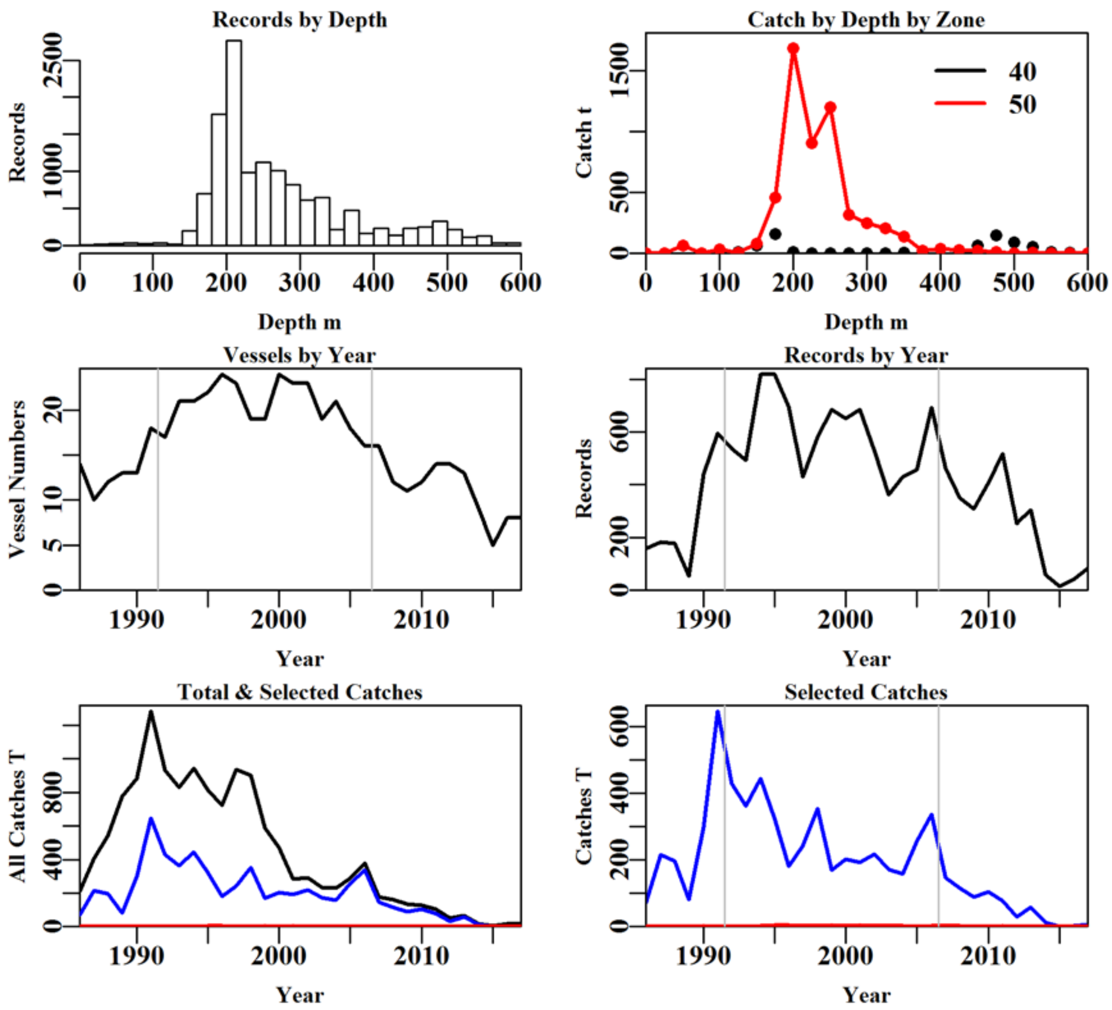


Figure 5.209. bluewarehou4050 fishery details. The bottom left plot depicts all known catches (top black line), and all selected catches used in the analysis (middle blue line); the lower red line: selected catches < 30 kg).

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	66694	61111	60613	60234	14058	13306	13285
Difference	0	5583	498	379	46176	752	21
Catch	13919.79	13533.3656	13435.01683	13363.7204	6351.203	6212.0886	6208.937
Difference	0.00	386.4257	98.34875	71.2964	7012.517	139.1147	3.152

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	14654	39841	6086	13285	32	13.0	0.00
Vessel	13511	36107	9820	13285	114	20.7	7.66
Month	12484	33365	12561	13285	125	26.7	5.96
DepCat	11792	31559	14368	13285	149	30.5	3.84
Zone	11791	31550	14377	13285	150	30.5	0.01
DayNight	11737	31409	14518	13285	153	30.8	0.29
Zone:Month	11703	31275	14652	13285	164	31.1	0.24
Zone:DepCat	11735	31304	14623	13285	174	30.9	0.12

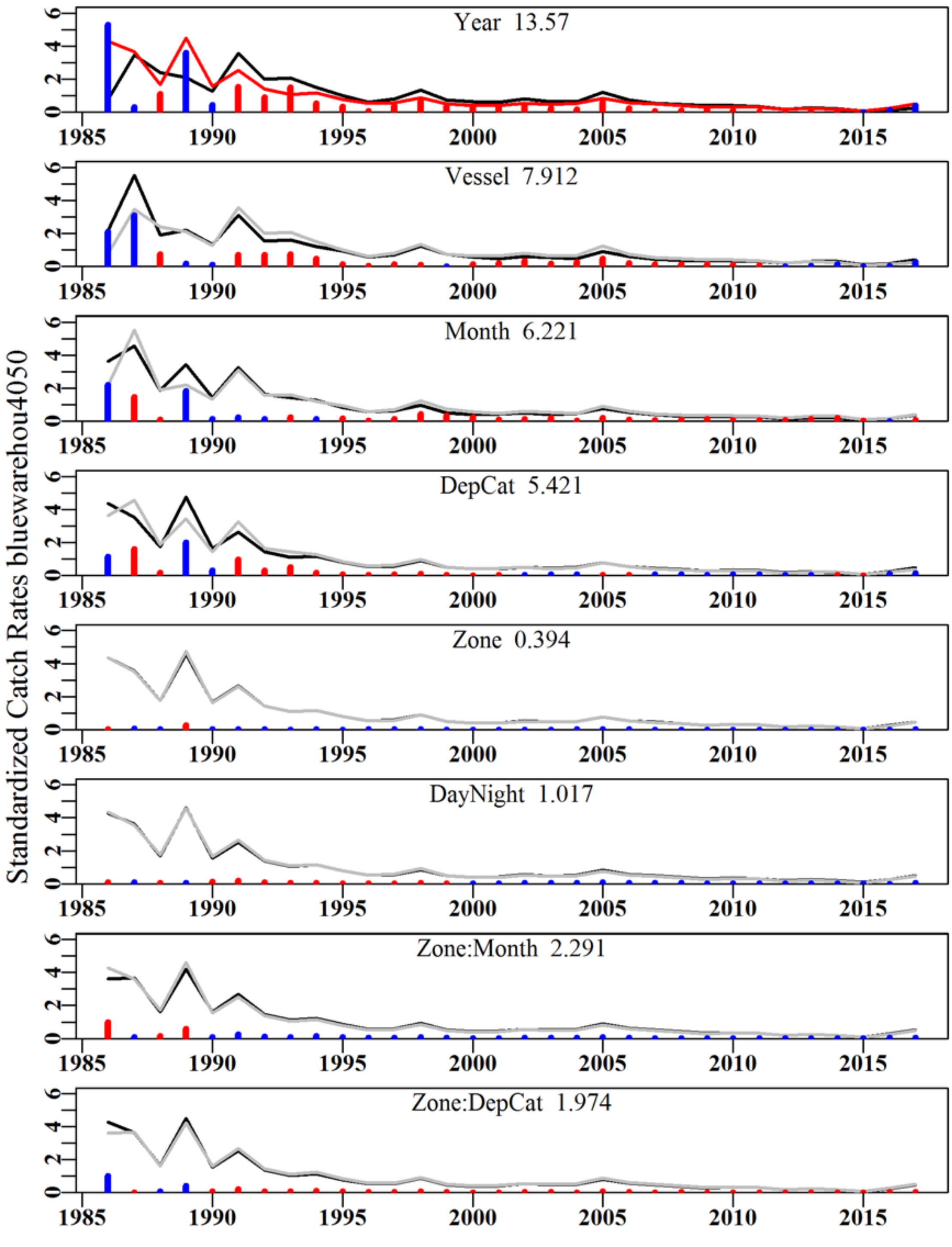


Figure 5.210. bluewarehou4050. The influence of each factor on the optimal standardization. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by vertical bars with blue bars indicating the optimum model is higher than the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

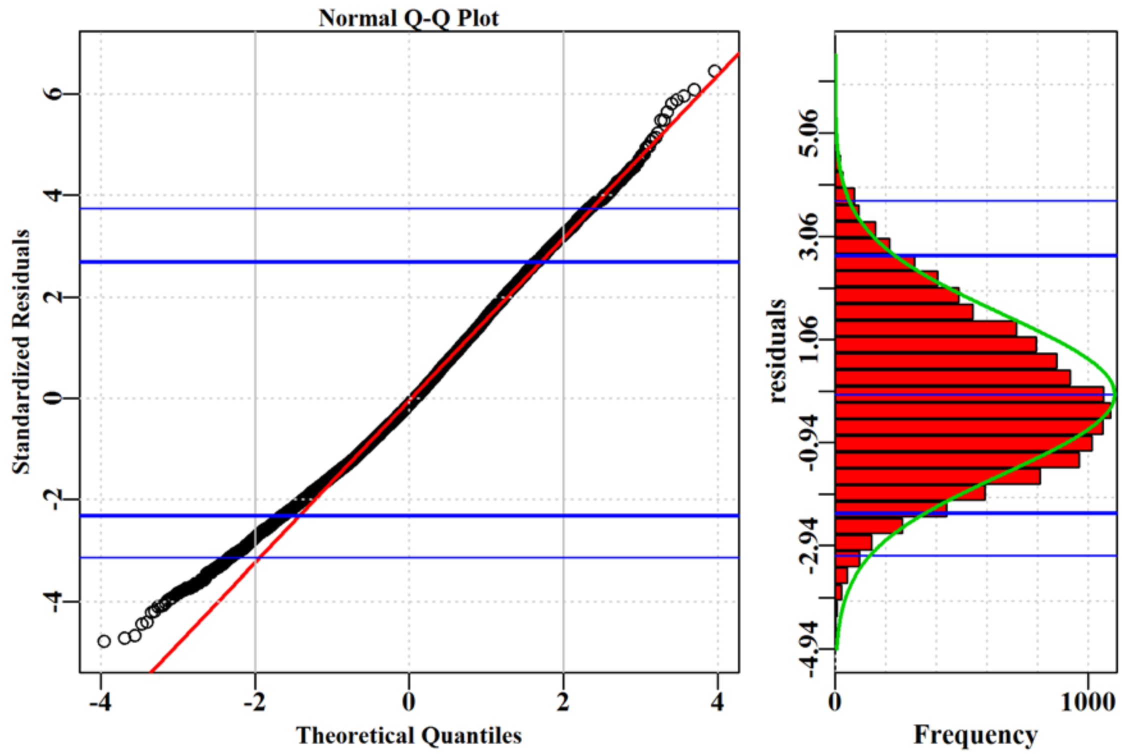


Figure 5.211. bluewarehou4050. diagnostic plots. The distribution of residuals from the optimum fit. The qqplot indicates the fit to the expected normality, while the histogram of residuals illustrates the 90% quantiles to indicate the intensity of any lack of fit at the margins of the distribution.

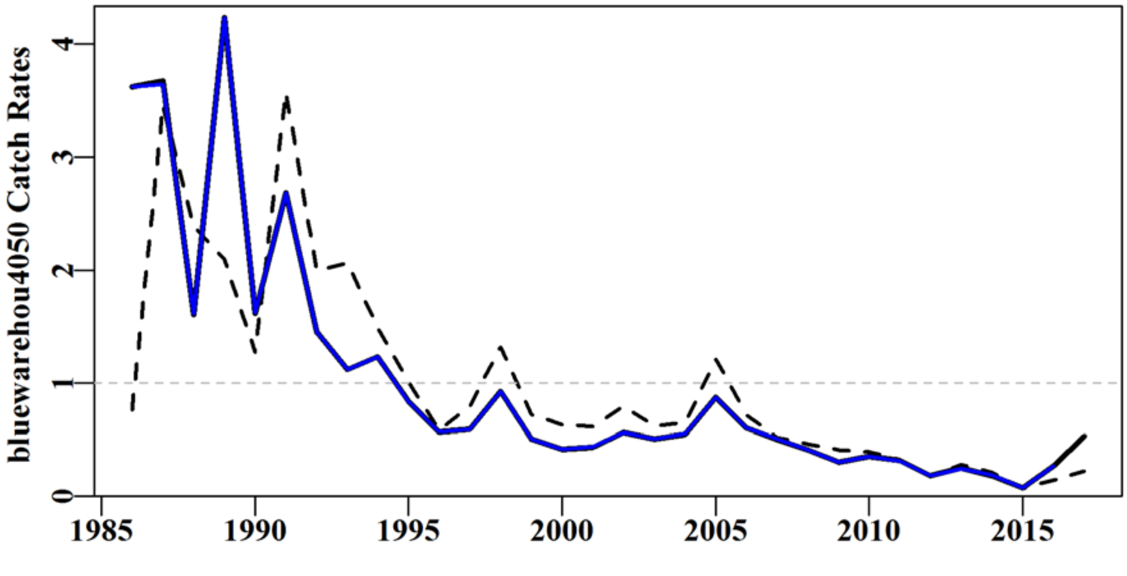


Figure 5.212. bluewarehou4050. A comparison of the previous year's standardization (blue line) with this year's. They should lie on top of each other, although small deviations may relate to data adjustments, particularly in very recent years.

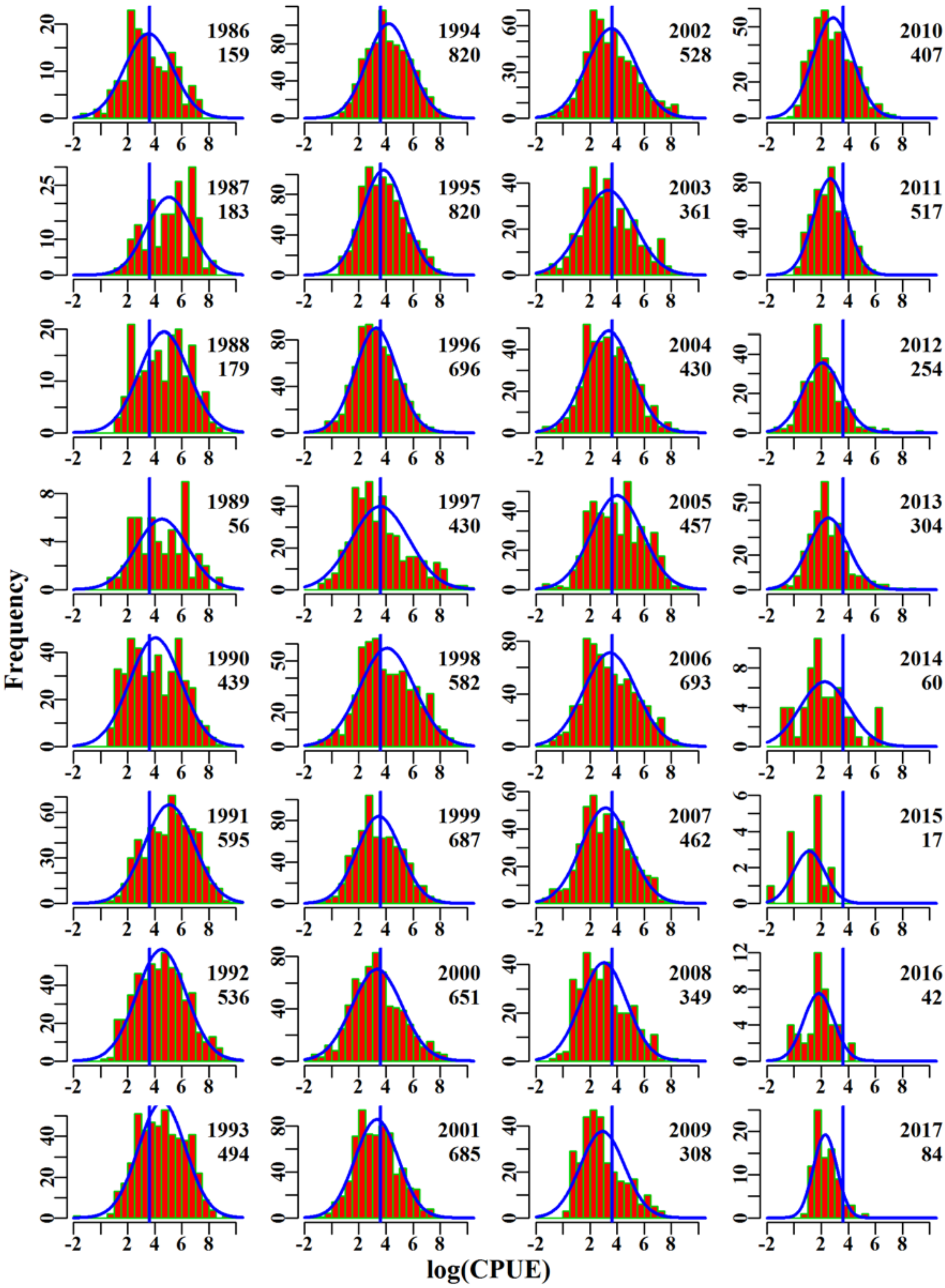


Figure 5.213. bluewarehou4050. The log(CPUE) for each year of data available the blue lines are normal distributions fitted to the histogram frequencies. The numbers in each plot are the year and number of records.

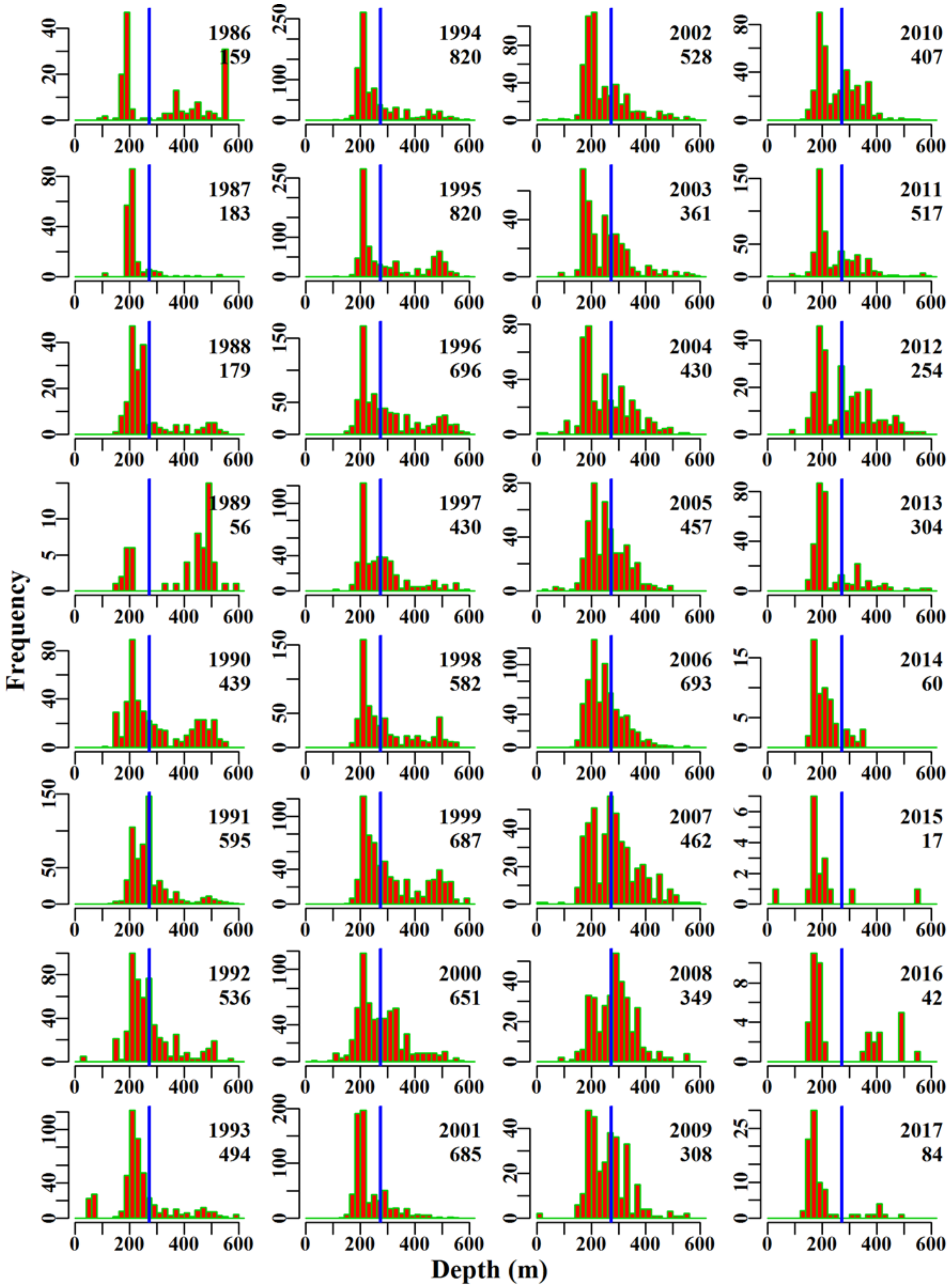


Figure 5.214. bluewarehou4050. The average Depth of fishing for each year of data available to illustrate the development of the fishery through time. The numbers in each plot are the year and number of records.

5.35 Deepwater Flathead

The initial data selection for Deepwater Flathead (FLD – 37296002 – *Platycephaus conatus*) in the GAB was conducted according to the detials 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, 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 - 2017

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	0.5156	0.000	0.195	0.004
1988	317.2	532	260.6	4	196.0	1.0471	0.056	0.732	0.003
1989	402.6	944	345.6	6	100.3	1.0210	0.053	0.803	0.002
1990	430.2	1297	393.9	6	90.8	0.9999	0.052	0.900	0.002
1991	621.0	1465	513.5	8	85.5	0.9628	0.051	0.819	0.002
1992	524.1	958	499.5	3	117.9	1.2204	0.052	0.345	0.001
1993	593.1	881	580.7	5	149.5	1.6423	0.053	0.570	0.001
1994	1285.9	1683	1233.7	6	173.4	2.0297	0.050	0.327	0.000
1995	1585.1	1849	1552.3	5	176.6	1.9352	0.050	0.030	0.000
1996	1499.2	2726	1450.5	6	110.2	1.2885	0.049	0.405	0.000
1997	1030.0	2684	944.5	7	72.0	0.8932	0.049	1.340	0.001
1998	690.4	2401	669.2	7	57.0	0.6882	0.050	3.280	0.005
1999	571.0	2040	541.3	7	53.6	0.8118	0.051	1.530	0.003
2000	845.6	2378	773.9	5	67.5	0.8907	0.050	1.857	0.002
2001	973.1	2411	910.5	5	75.6	1.0690	0.050	1.207	0.001
2002	1708.9	3113	1613.1	8	103.5	1.4741	0.050	0.900	0.001
2003	2260.6	4468	2156.6	10	93.8	1.4681	0.050	0.387	0.000
2004	2155.2	5349	2054.2	9	74.5	1.1588	0.050	0.923	0.000
2005	1426.0	5014	1238.5	10	49.5	0.7355	0.050	1.642	0.001
2006	1014.2	4151	947.2	10	45.9	0.6755	0.050	1.667	0.002
2007	1039.9	3659	908.2	6	50.8	0.7526	0.050	2.978	0.003
2008	813.2	3086	766.5	4	50.6	0.8982	0.050	2.089	0.003
2009	849.4	3193	824.6	4	52.3	0.7920	0.050	2.793	0.003
2010	966.8	2803	927.0	4	67.8	1.0037	0.050	1.300	0.001
2011	963.2	3269	789.3	4	47.1	0.8020	0.050	1.490	0.002
2012	1019.8	3448	842.3	4	48.3	0.8038	0.050	1.724	0.002
2013	874.7	3232	649.3	4	39.1	0.7065	0.050	2.080	0.003
2014	588.6	2572	485.3	4	37.5	0.6505	0.051	2.314	0.005
2015	593.9	2248	472.0	3	42.2	0.7280	0.051	1.574	0.003
2016	737.3	2528	590.8	4	48.6	0.7667	0.051	2.013	0.003
2017	370.0	1660	302.5	3	37.6	0.5687	0.052	2.404	0.008

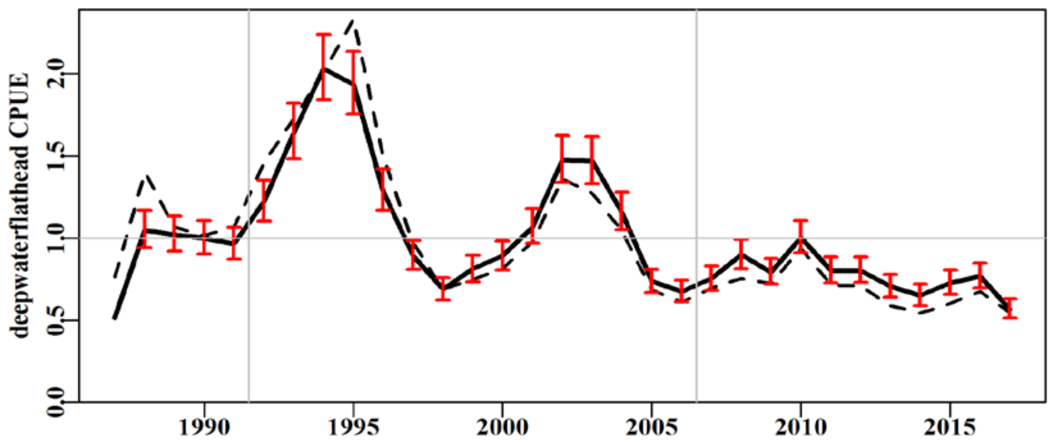


Figure 5.215. deepwaterflathead standardization. The dashed black line represents the geometric mean catch rate, solid black line the standardized catch rates. The red bars are the 95% confidence intervals about the mean estimates. The graph scales both time-series of standardized catch rates relative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

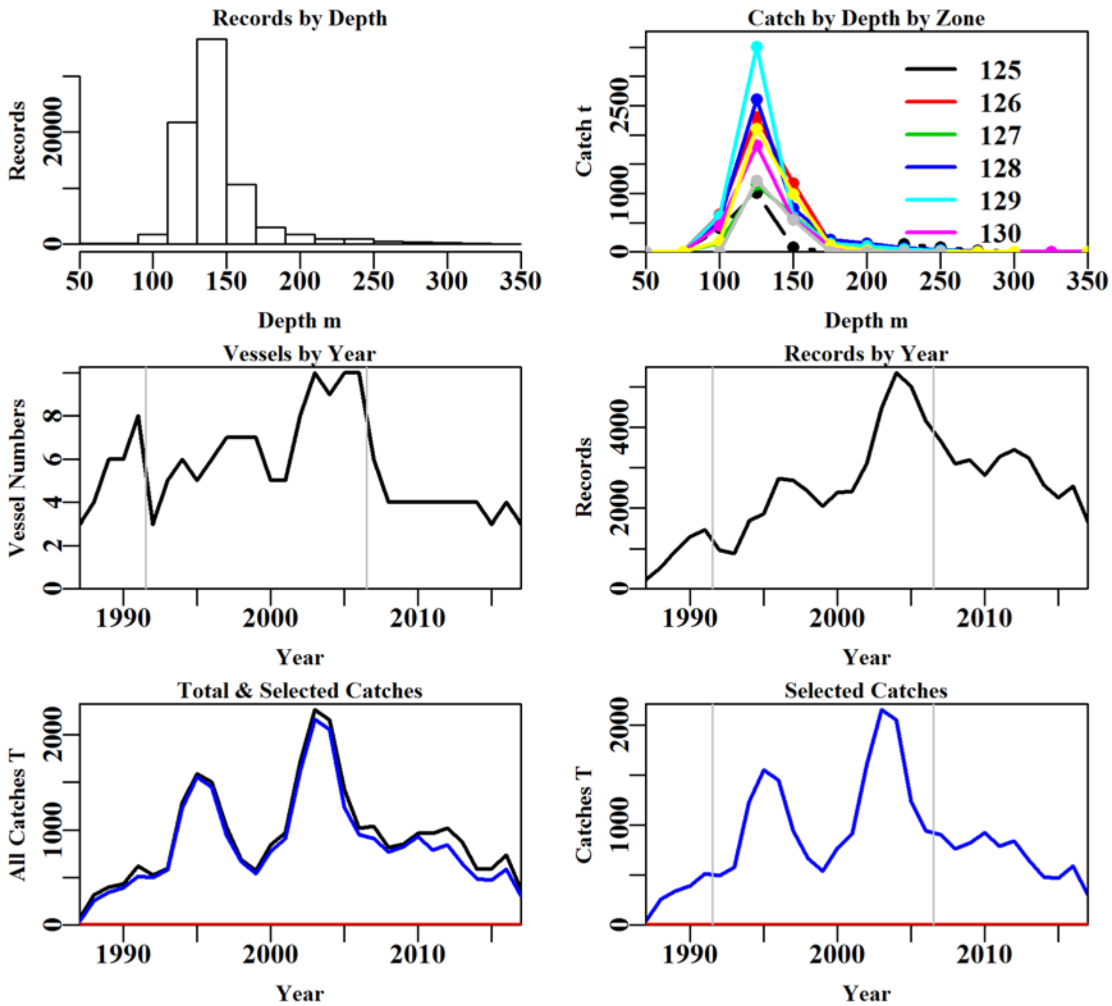


Figure 5.216. deepwaterflathead fishery details. The bottom left plot depicts all known catches (top black line), and all selected catches used in the analysis (middle blue line); the lower red line: selected catches < 30 kg).

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	-36843	48846	9738	78271	31	16.6	0.00
Vessel	-42250	45564	13020	78271	50	22.2	5.59
Zone	-48669	41969	16615	78271	57	28.3	6.13
Month	-52071	40172	18412	78271	68	31.4	3.06
DepCat	-53486	39441	19143	78271	80	32.6	1.24
DayNight	-55467	38452	20132	78271	83	34.3	1.69
Zone:Month	-56718	37768	20816	78271	160	35.4	1.10
Zone:Vessel	-57557	37317	21267	78271	210	36.1	1.84
Zone:DepCat	-57834	37237	21347	78271	156	36.3	2.02

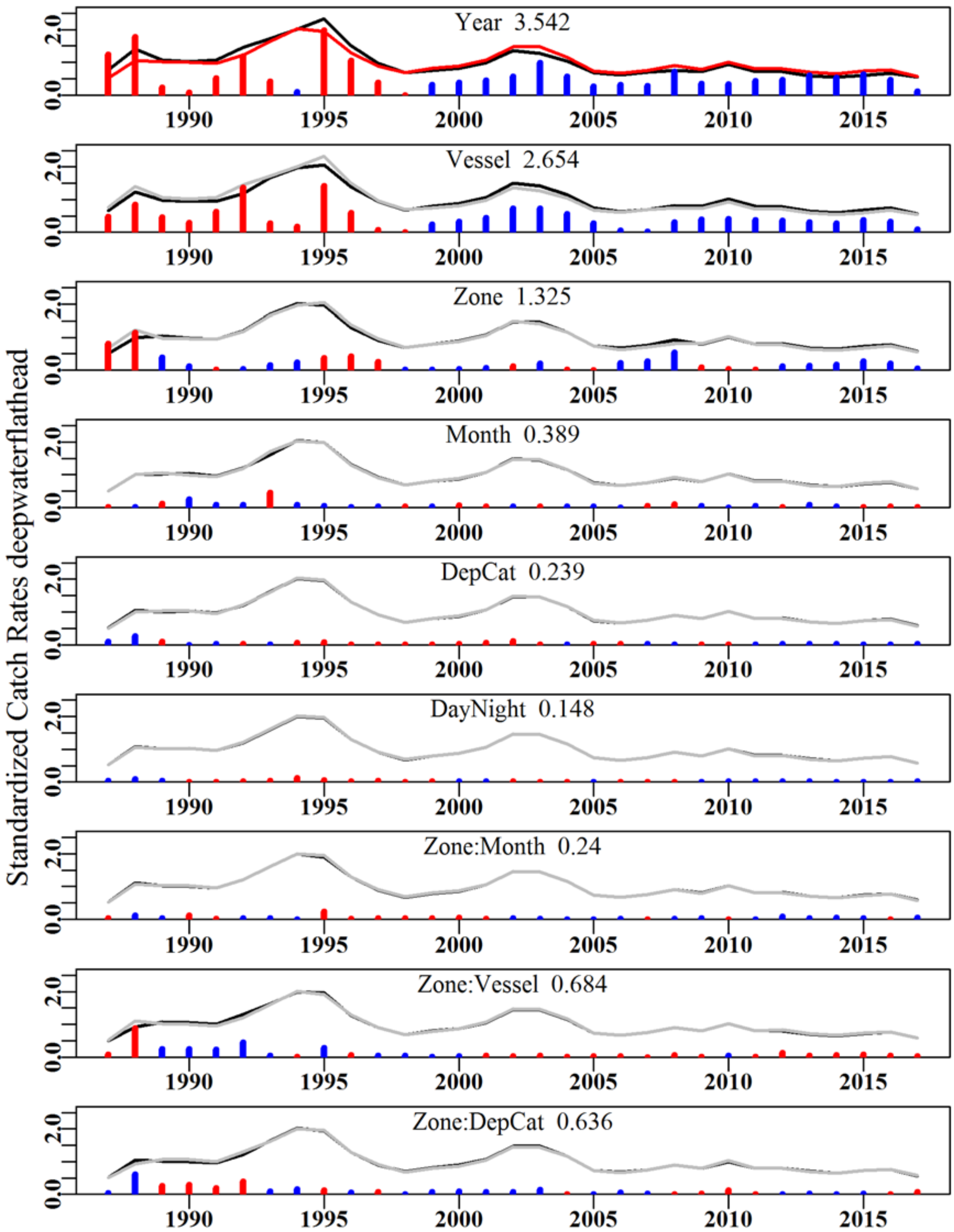


Figure 5.217. deepwaterflathead. The influence of each factor on the optimal standardization. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by vertical bars with blue bars indicating the optimum model is higher than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

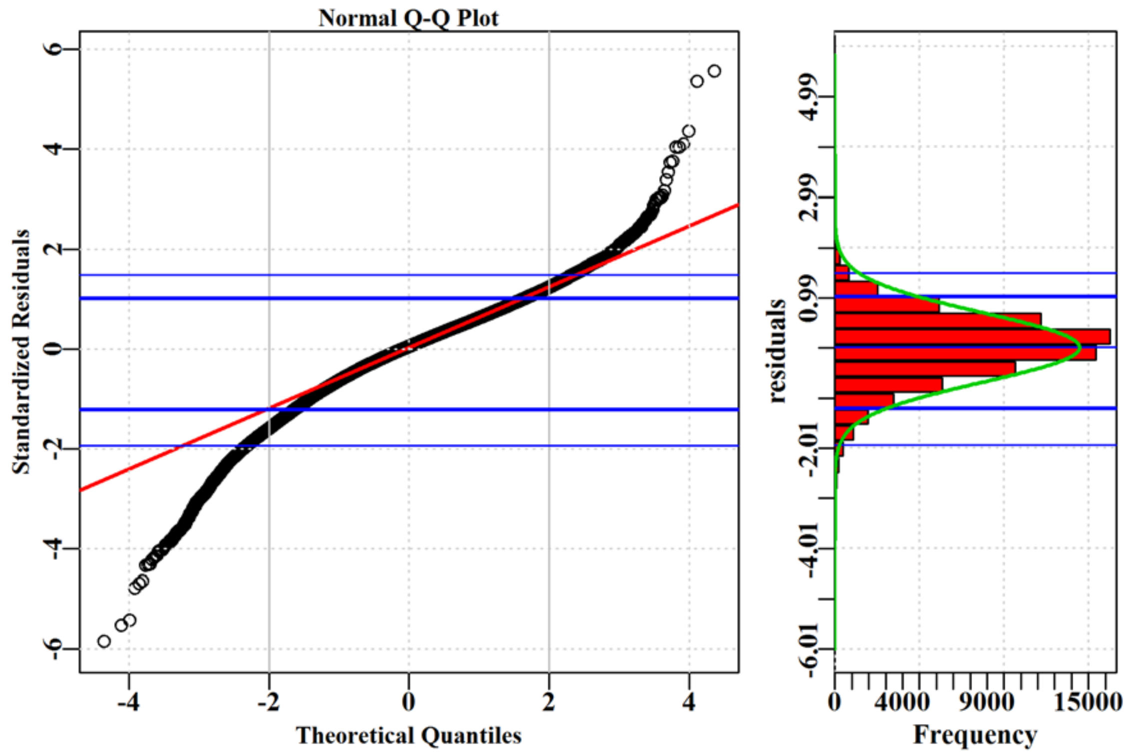


Figure 5.218. deepwaterflathead. diagnostic plots. The distribution of residuals from the optimum fit. The qqplot indicates the fit to the expected normality, while the histogram of residuals illustrates the 90% quantiles to indicate the intensity of any lack of fit at the margins of the distribution.

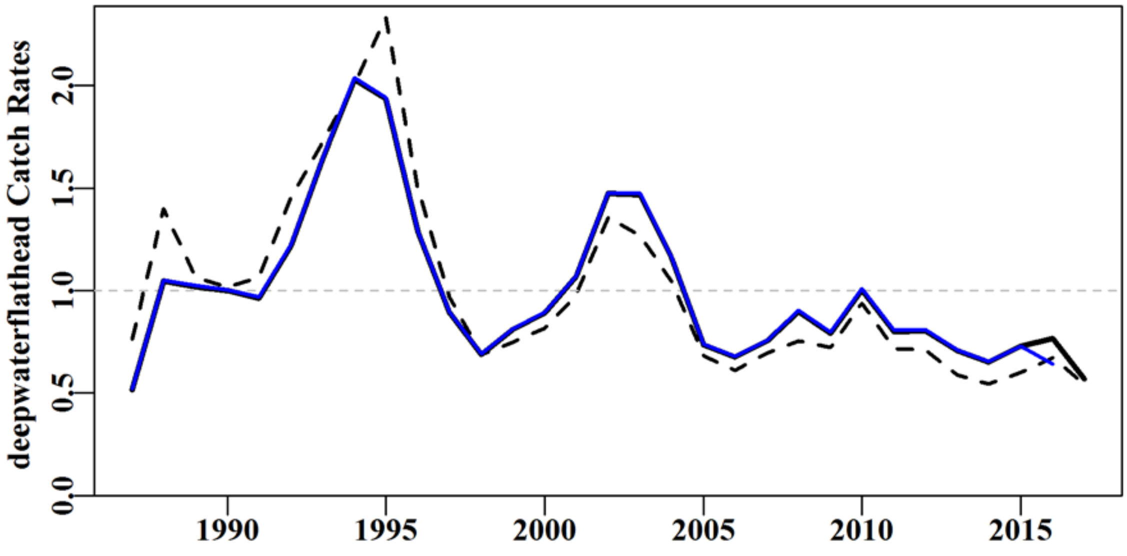


Figure 5.219. deepwaterflathead. A comparison of the previous year's standardization (blue line) with this year's. They should lie on top of each other, although small deviations may relate to data adjustments, particularly in very recent years.

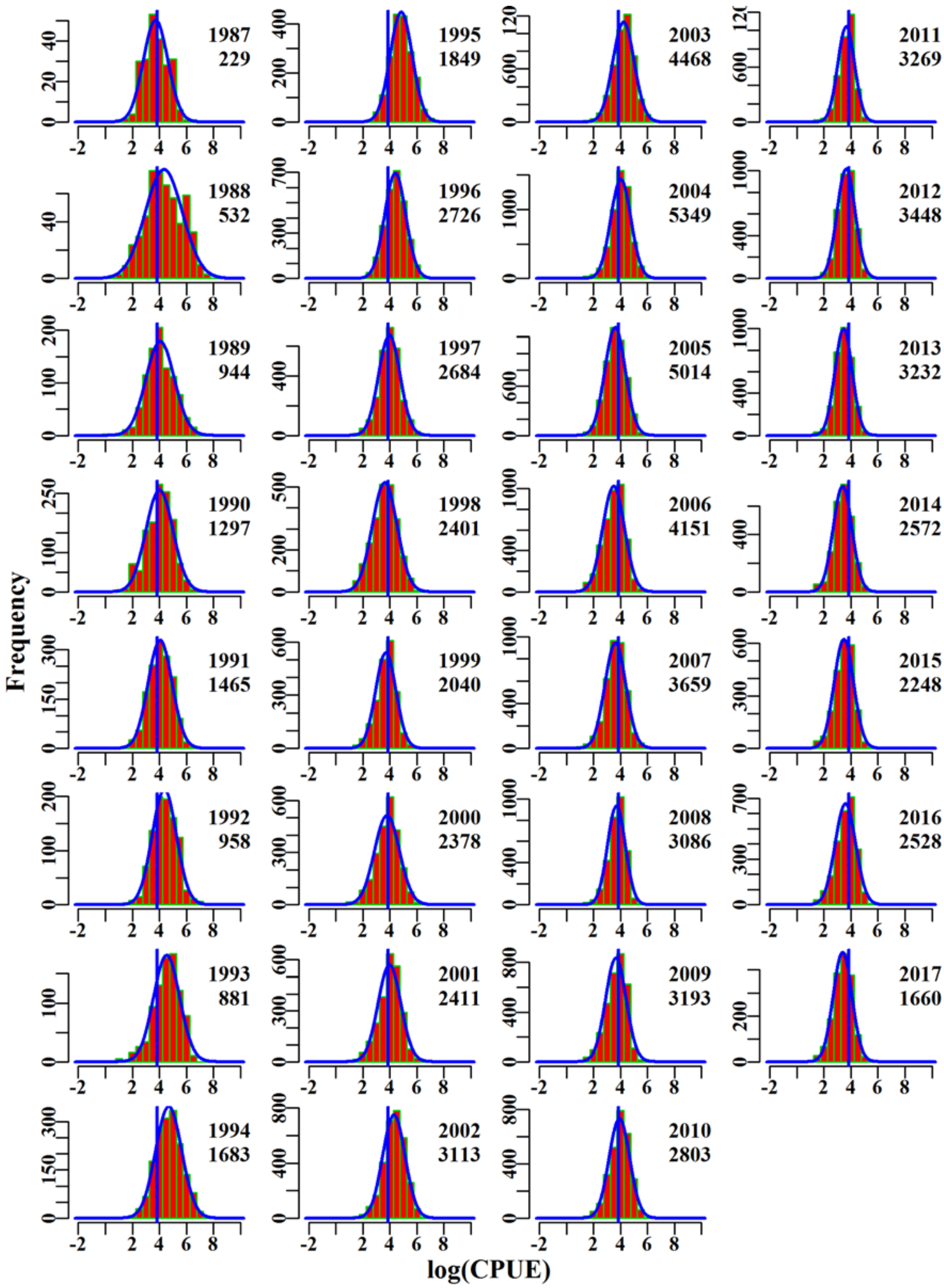


Figure 5.220. deepwaterflathead. The log(CPUE) for each year of data available the blue lines are normal distributions fitted to the histogram frequencies. The numbers in each plot are the year and number of records.

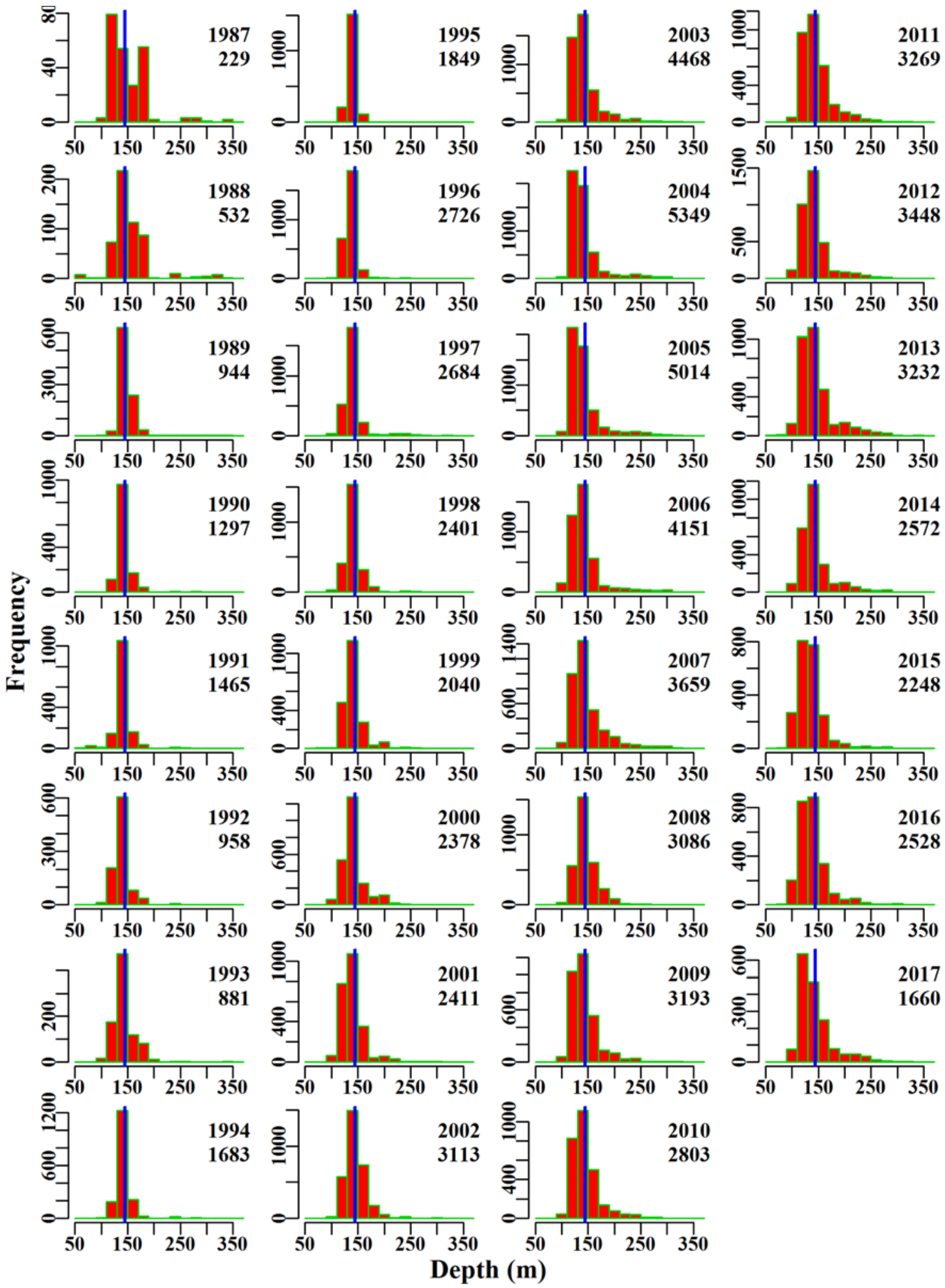


Figure 5.221. deepwaterflathead. The average Depth of fishing for each year of data available to illustrate the development of the fishery through time. The numbers in each plot are the year and number of records.

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 log(CPUE) from 2012 - 2016. 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 - 2017

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	2.5648	0.000	0.090	0.004
1988	88.0	404	68.1	4	60.9	2.4508	0.112	0.885	0.013
1989	173.6	737	148.2	6	62.1	1.5337	0.108	2.017	0.014
1990	290.1	1045	252.8	8	75.1	1.4055	0.106	2.220	0.009
1991	274.0	1015	220.9	7	58.7	1.2847	0.104	3.790	0.017
1992	132.1	719	117.0	3	39.7	0.9490	0.107	3.816	0.033
1993	108.7	688	105.9	5	37.2	0.9083	0.108	4.561	0.043
1994	163.6	1274	159.0	6	35.8	0.6164	0.104	7.128	0.045
1995	176.9	1396	175.4	5	30.2	0.7335	0.104	7.773	0.044
1996	334.1	2029	328.7	6	37.8	0.8938	0.102	10.358	0.032
1997	375.9	1922	366.0	7	46.2	0.9365	0.103	9.838	0.027
1998	442.2	1794	434.0	7	57.1	1.0989	0.103	8.723	0.020
1999	328.3	1495	327.2	7	52.0	0.9683	0.105	5.404	0.017
2000	397.5	1715	390.3	5	64.5	0.8567	0.104	6.689	0.017
2001	228.9	1641	227.7	5	34.9	0.6707	0.104	7.421	0.033
2002	374.5	2123	369.8	8	37.2	0.7175	0.103	9.152	0.025
2003	853.2	3144	845.0	10	57.8	0.9775	0.103	8.796	0.010
2004	882.2	3782	754.4	9	42.7	0.9431	0.103	15.491	0.021
2005	759.5	3532	718.2	10	43.0	0.8982	0.103	13.678	0.019
2006	958.4	3294	930.1	9	72.1	0.9888	0.103	10.318	0.011
2007	756.0	2744	683.8	6	67.8	0.9157	0.103	11.605	0.017
2008	661.5	2427	643.1	4	68.0	0.9786	0.104	9.294	0.014
2009	462.6	2307	453.4	4	48.4	0.9148	0.104	11.703	0.026
2010	285.3	1858	280.8	4	34.8	0.7272	0.104	10.622	0.038
2011	329.1	2184	321.2	4	30.7	0.7285	0.104	10.872	0.034
2012	266.4	1881	259.5	4	26.7	0.6492	0.105	14.511	0.056
2013	198.2	1519	191.4	4	22.9	0.5891	0.105	12.283	0.064
2014	238.1	1428	235.6	4	32.1	0.6380	0.106	8.433	0.036
2015	173.7	1193	170.5	3	29.8	0.6250	0.107	5.431	0.032
2016	438.1	1800	434.4	4	39.6	0.8680	0.105	8.295	0.019
2017	189.5	945	187.8	3	49.0	0.9694	0.109	4.111	0.022

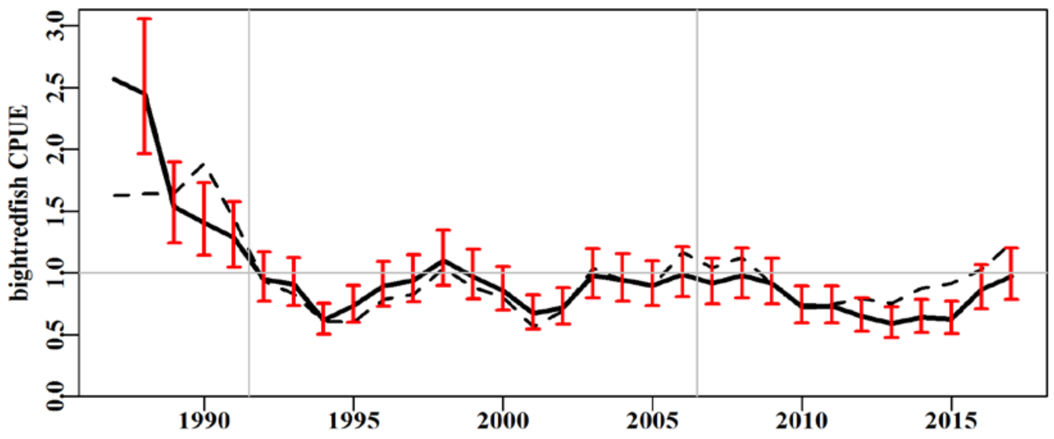


Figure 5.222. bightredfish standardization. The dashed black line represents the geometric mean catch rate, solid black line the standardized catch rates. The red bars are the 95% confidence intervals about the mean estimates. The graph scales both time-series of standardized catch rates relative to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

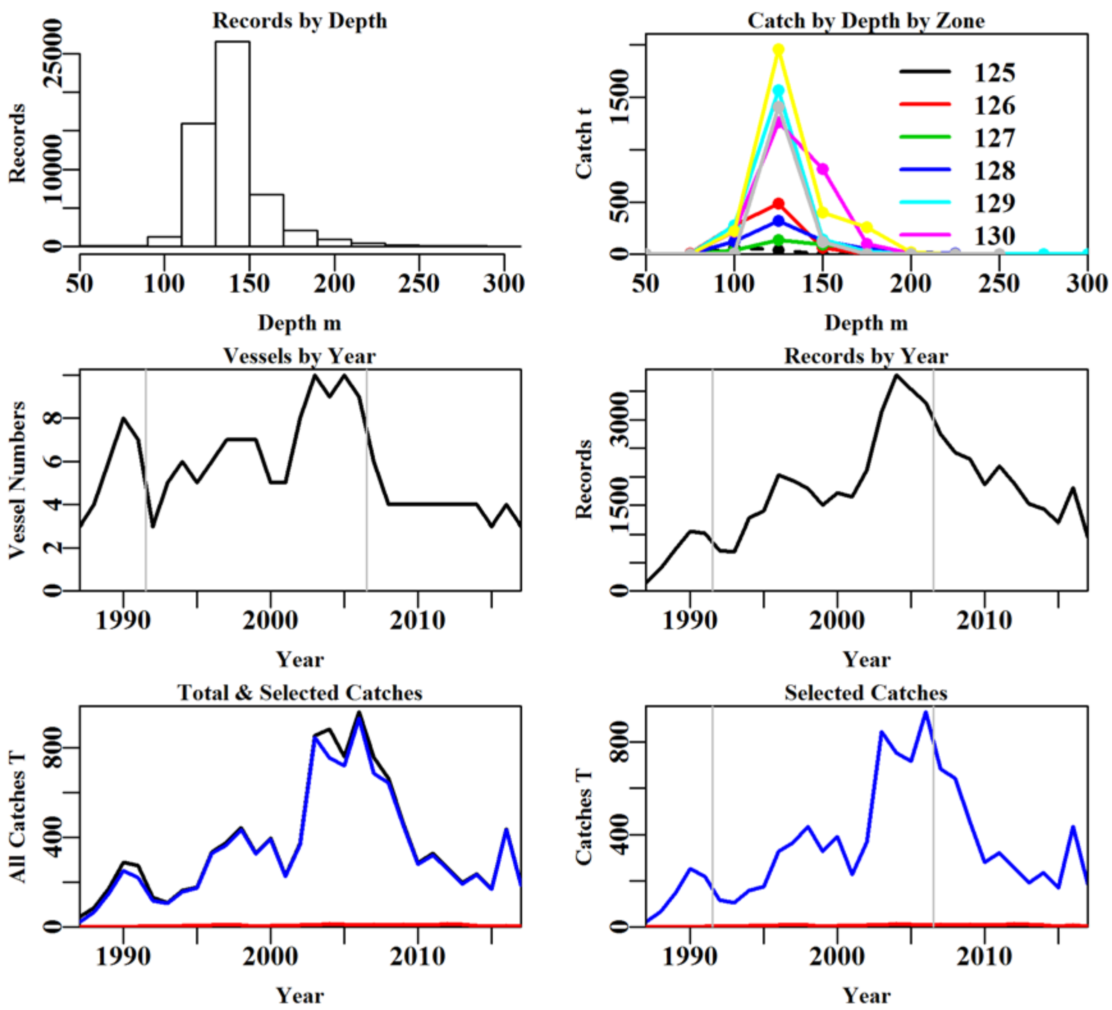


Figure 5.223. bightredfish fishery details. The bottom left plot depicts all known catches (top black line), and all selected catches used in the analysis (middle blue line); the lower red line: selected catches < 30 kg).

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	33239	99610	3090	53703	31	3.0	0.00
DayNight	27685	89812	12888	53703	34	12.5	9.54
Zone	22088	80902	21798	53703	41	21.2	8.67
Month	17789	74648	28052	53703	52	27.2	6.08
Vessel	16506	72834	29866	53703	71	29.0	1.74
DepCat	16306	72537	30163	53703	81	29.3	0.28
Zone:Month	15371	71080	31620	53703	158	30.6	1.32
Zone:Vessel	15686	71366	31334	53703	208	30.2	0.98
Zone:DepCat	14866	70456	32244	53703	142	31.2	1.95

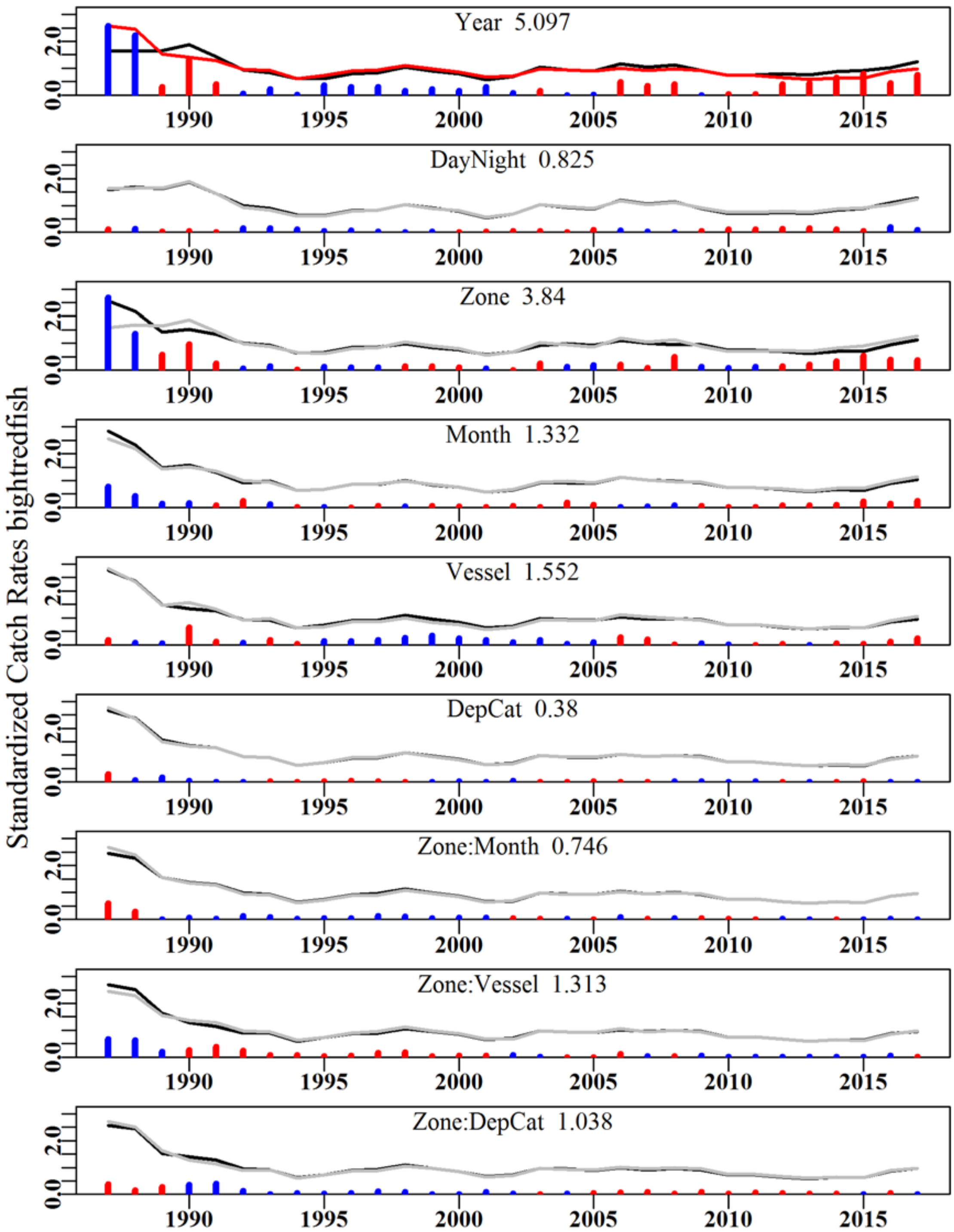


Figure 5.224. bightredfish. The influence of each factor on the optimal standardization. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by vertical bars with blue bars indicating the optimum model is higher than the geometric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

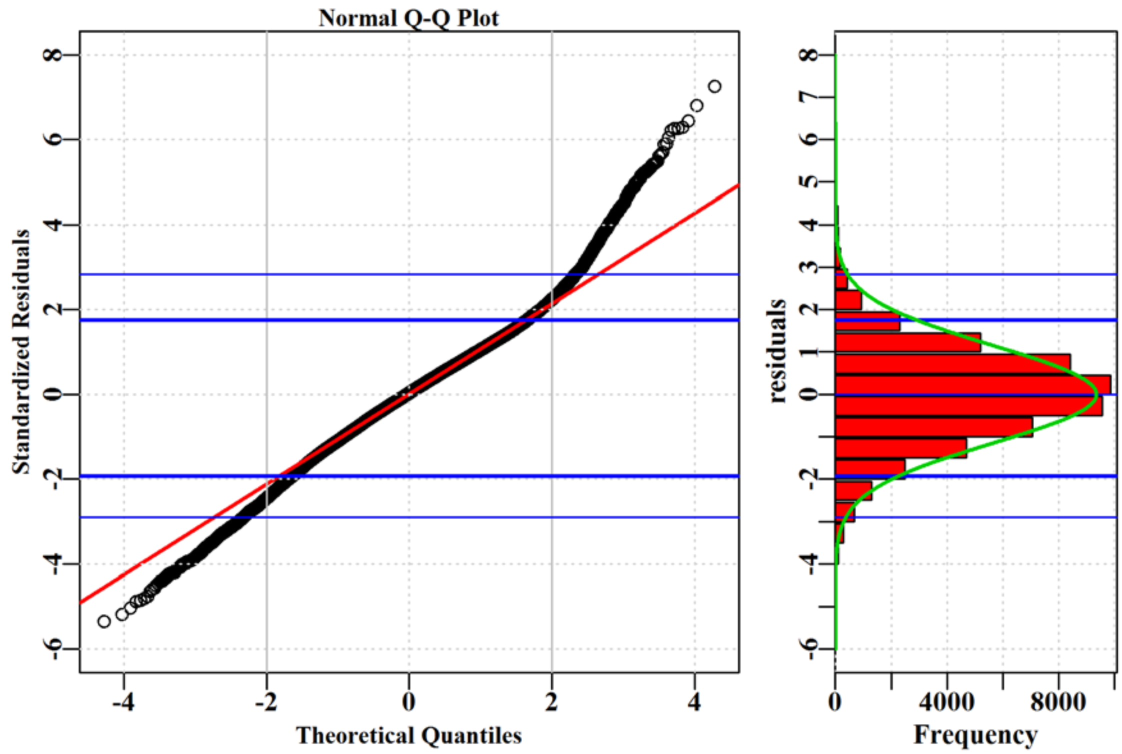


Figure 5.225. bightredfish. diagnostic plots. The distribution of residuals from the optimum fit. The qqplot indicates the fit to the expected normality, while the histogram of residuals illustrates the 90% quantiles to indicate the intensity of any lack of fit at the margins of the distribution.

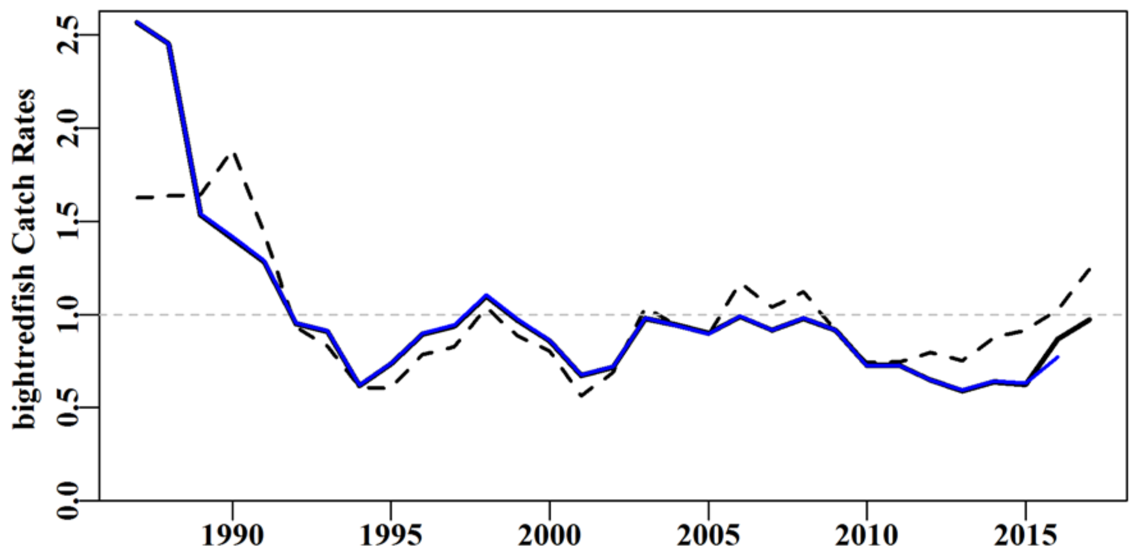


Figure 5.226. bightredfish. A comparison of the previous year's standardization (blue line) with this year's. They should lie on top of each other, although small deviations may relate to data adjustments, particularly in very recent years.

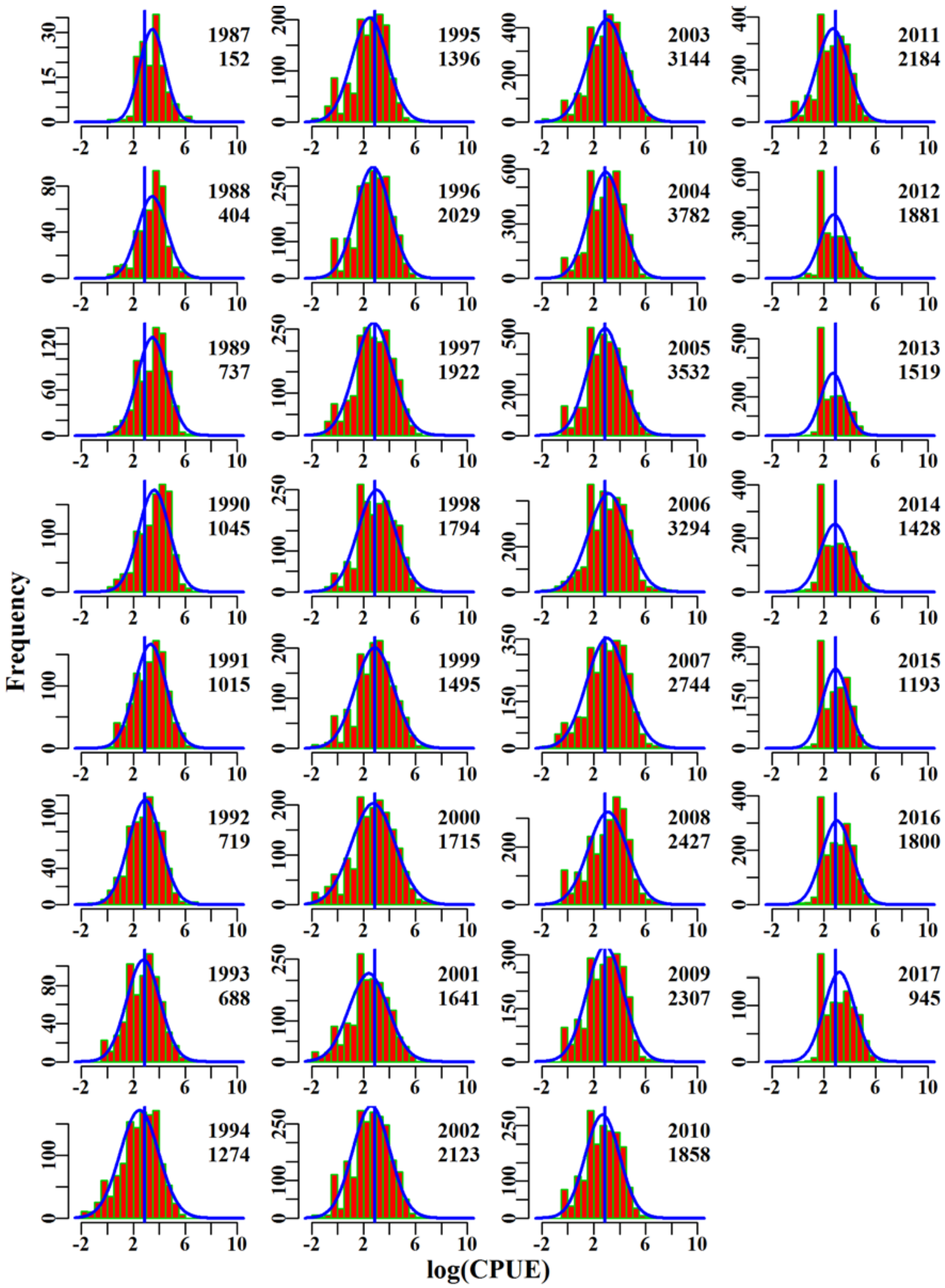


Figure 5.227. bightredfish. The log(CPUE) for each year of data available the blue lines are normal distributions fitted to the histogram frequencies. The numbers in each plot are the year and number of records.

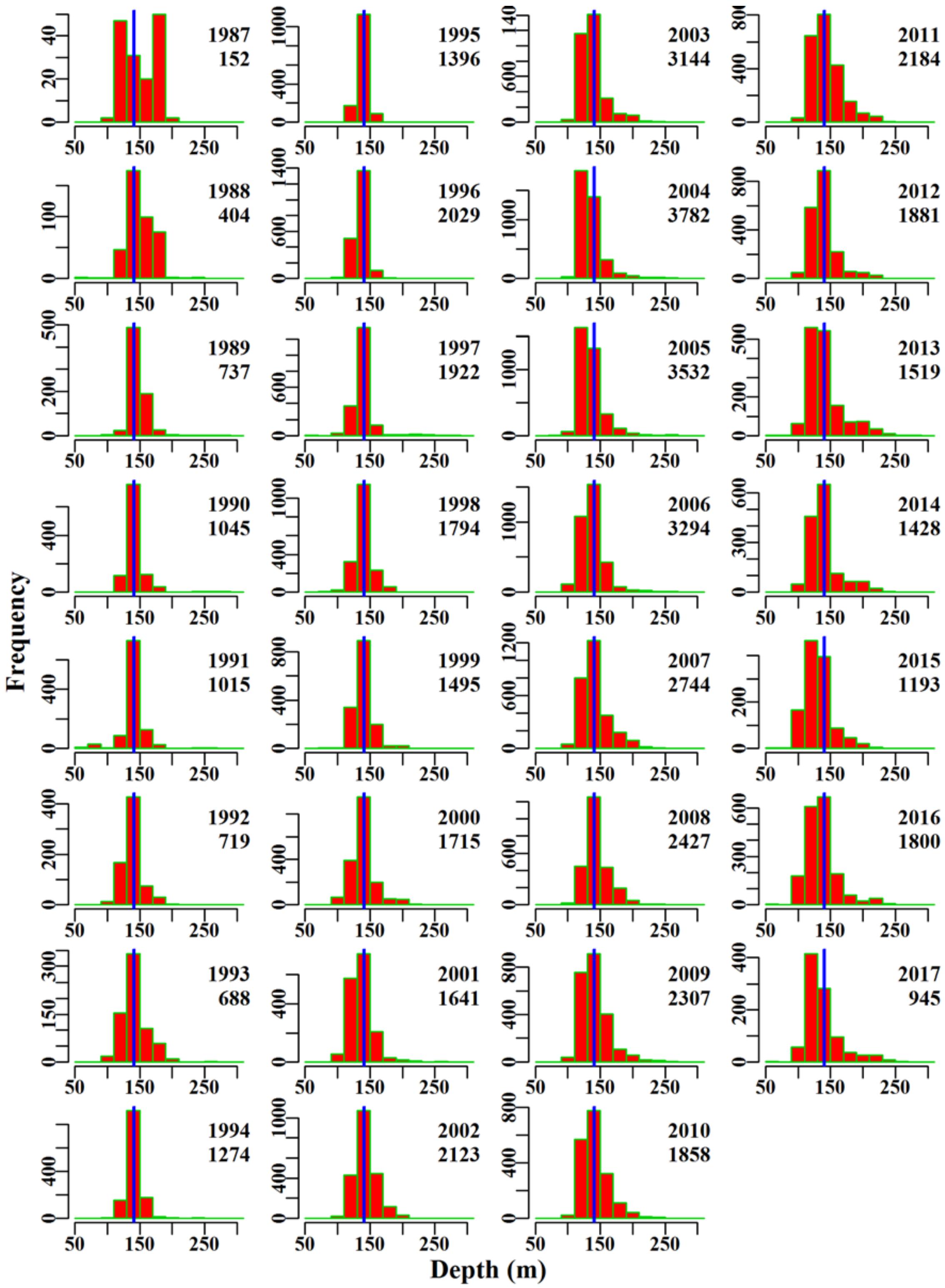


Figure 5.228. bightredfish. The average Depth of fishing for each year of data available to illustrate the development of the fishery through time. The numbers in each plot are the year and number of records.

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 - 2017

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	2.2194	0.000	0.655	0.186
1987	7.9	158	7.3	14	16.5	1.3152	0.138	1.509	0.207
1988	10.9	122	7.9	22	25.7	2.0538	0.154	0.855	0.108
1989	11.3	136	7.7	14	30.2	1.8583	0.151	1.114	0.144
1990	3.7	58	2.3	11	14.0	1.4476	0.173	0.648	0.287
1991	7.8	145	5.2	22	11.9	1.4414	0.151	1.697	0.329
1992	13.3	226	11.7	26	16.1	1.4303	0.142	1.982	0.170
1993	22.8	330	19.8	37	18.8	1.2157	0.142	3.424	0.173
1994	41.9	423	23.6	30	18.5	1.3338	0.140	4.945	0.209
1995	90.3	1139	85.9	26	18.9	1.4696	0.136	10.299	0.120
1996	82.3	1483	76.6	32	15.0	1.1125	0.136	14.889	0.194
1997	103.1	1708	96.2	30	14.0	0.9615	0.136	16.008	0.166
1998	99.9	1665	91.9	33	13.6	0.9167	0.136	16.781	0.183
1999	72.1	1132	59.7	32	12.6	0.8273	0.136	13.618	0.228
2000	66.8	1173	53.8	41	10.5	0.7627	0.136	12.935	0.240
2001	82.5	1129	52.6	37	9.9	0.7068	0.136	12.191	0.232
2002	157.8	1139	57.0	30	10.0	0.6481	0.136	11.246	0.197
2003	180.8	1302	65.6	35	10.0	0.6269	0.136	12.107	0.184
2004	181.1	1253	66.1	33	11.1	0.6828	0.136	7.617	0.115
2005	90.4	649	28.4	32	9.5	0.6020	0.138	3.891	0.137
2006	122.6	619	31.2	34	11.5	0.6276	0.138	3.234	0.104
2007	78.3	398	15.3	24	8.6	0.4446	0.141	2.556	0.167
2008	78.5	356	16.9	24	9.9	0.5844	0.142	2.272	0.134
2009	105.0	554	31.9	20	11.9	0.6582	0.139	3.169	0.099
2010	91.9	672	36.6	22	11.6	0.6861	0.138	5.060	0.138
2011	93.9	849	44.1	20	9.9	0.6863	0.137	4.554	0.103
2012	107.2	707	39.8	19	11.7	0.6912	0.138	3.542	0.089
2013	122.7	916	68.4	23	14.5	0.8396	0.137	3.885	0.057
2014	138.2	855	59.9	22	12.5	0.8203	0.137	4.387	0.073
2015	99.8	743	50.8	25	13.3	0.8138	0.138	3.530	0.070
2016	66.6	599	40.2	20	12.6	0.7343	0.139	3.272	0.081
2017	80.9	590	41.5	18	15.1	0.7812	0.139	2.659	0.064

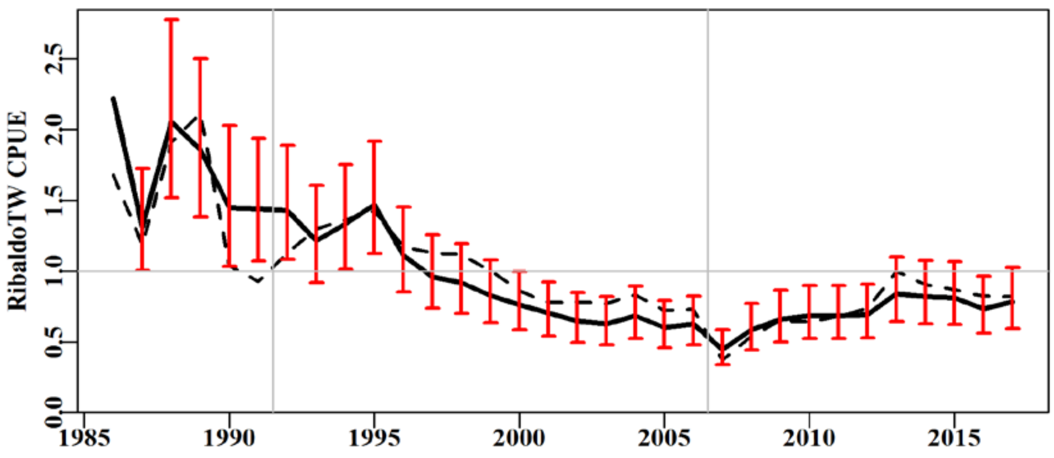


Figure 5.229. RibaldoTW standardization. The dashed black line represents the geometric mean catch rate, solid black line the standardized catch rates. The red bars are the 95% confidence intervals about the mean estimates. The graph scales both time-series of standardized catch rates relative to the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

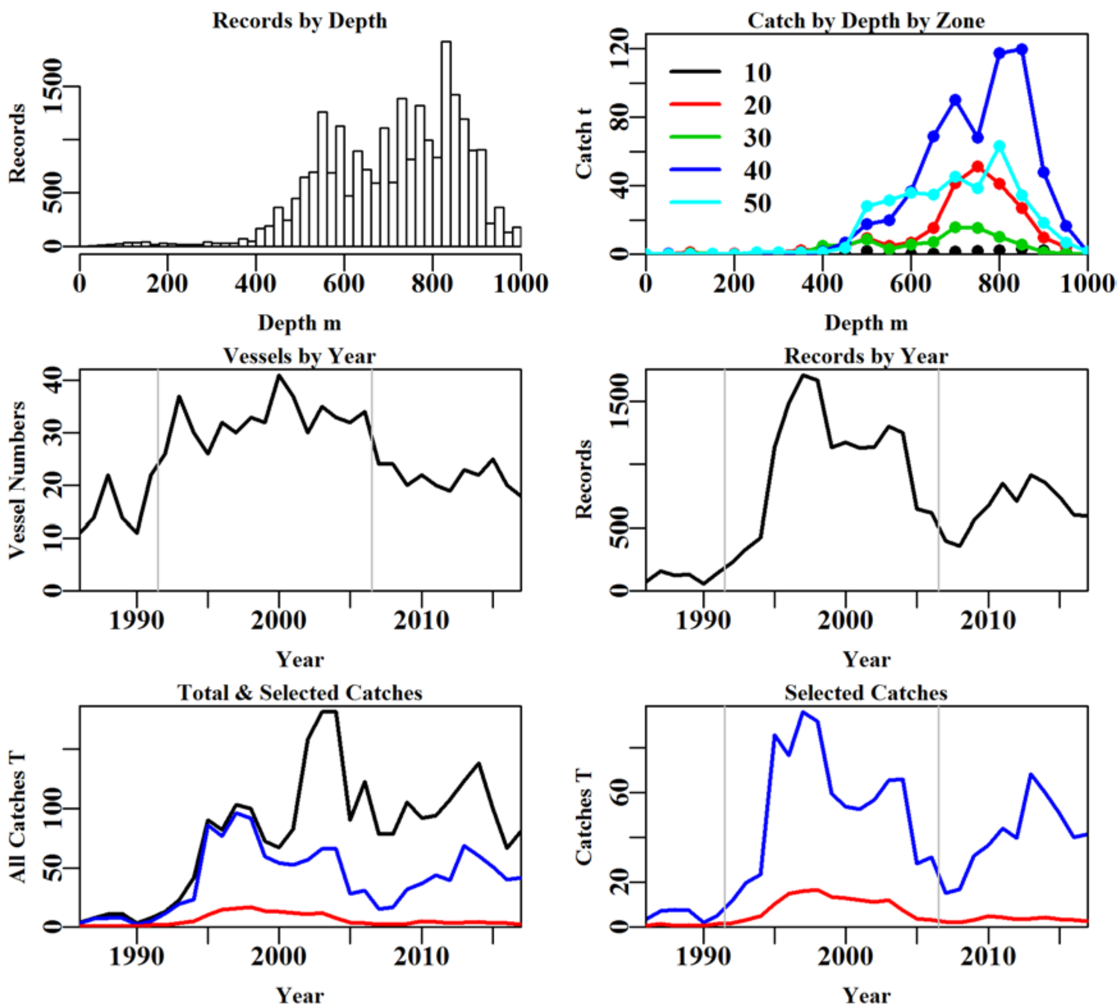


Figure 5.230. RibaldoTW fishery details. The bottom left plot depicts all known catches (top black line), and all selected catches used in the analysis (middle blue line); the lower red line: selected catches < 30 kg).

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	34057	26674	25695	25514	23516	23310	23300
Difference	0	7383	979	181	1998	206	10
Catch	2545.262	1523.998	1475.27625	1464.407	1306.1798	1299.8527	1299.2670
Difference	0.000	1021.264	48.72195	10.869	158.2275	6.3271	0.5857

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	-1432	21851	1653	23300	32	6.9	0.00
Vessel	-3578	19709	3795	23300	161	15.6	8.66
DepCat	-6714	17197	6307	23300	181	26.3	10.70
Zone	-7400	16693	6811	23300	185	28.4	2.15
DayNight	-7521	16602	6902	23300	188	28.8	0.38
Month	-7581	16543	6961	23300	199	29.0	0.22
Zone:Month	-8144	16088	7417	23300	243	30.8	1.82
Zone:DepCat	-7981	16158	7347	23300	274	30.4	1.43

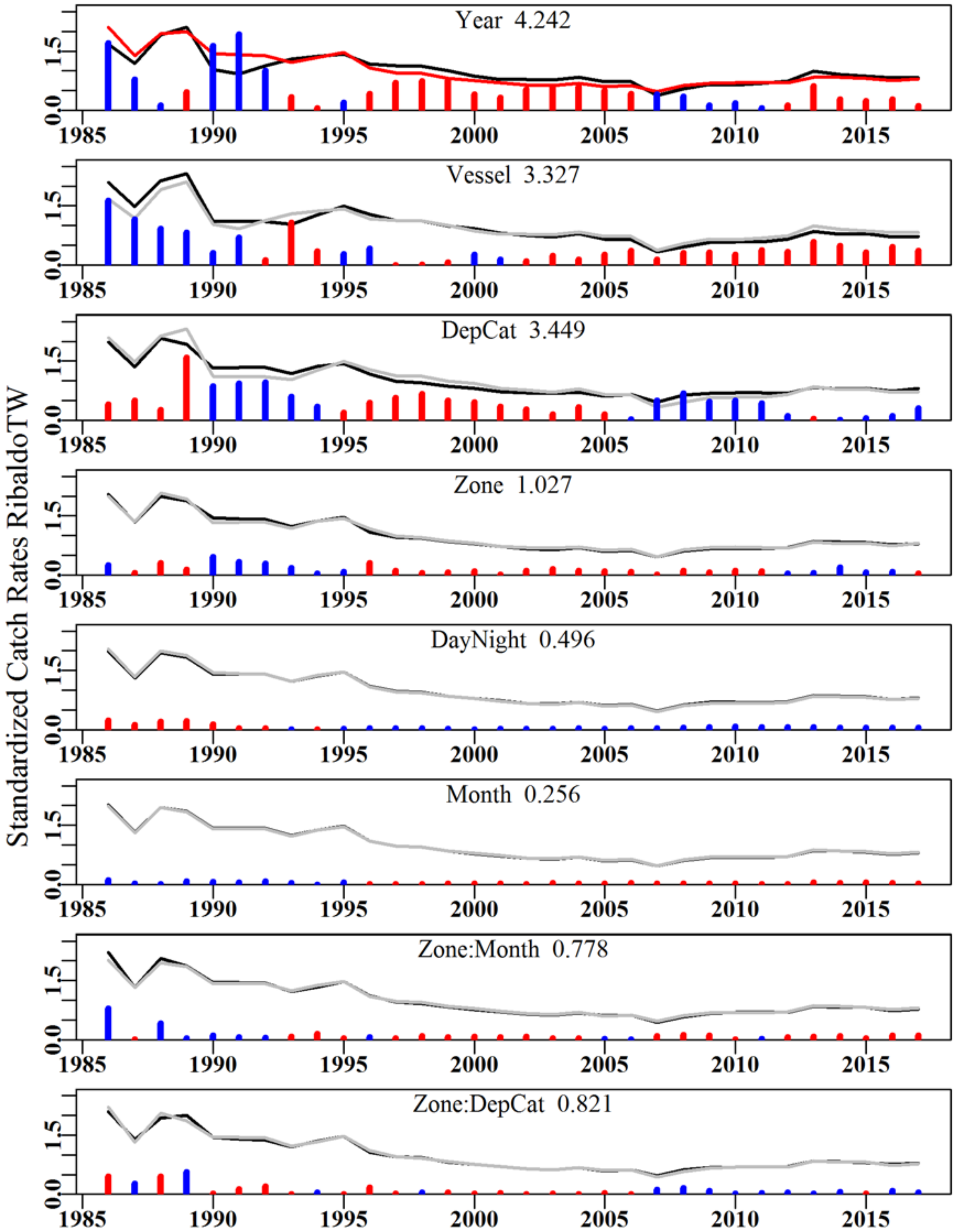


Figure 5.231. RibaldoTW. The influence of each factor on the optimal standardization. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by vertical bars with blue bars indicating the optimum model is higher than the geometric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

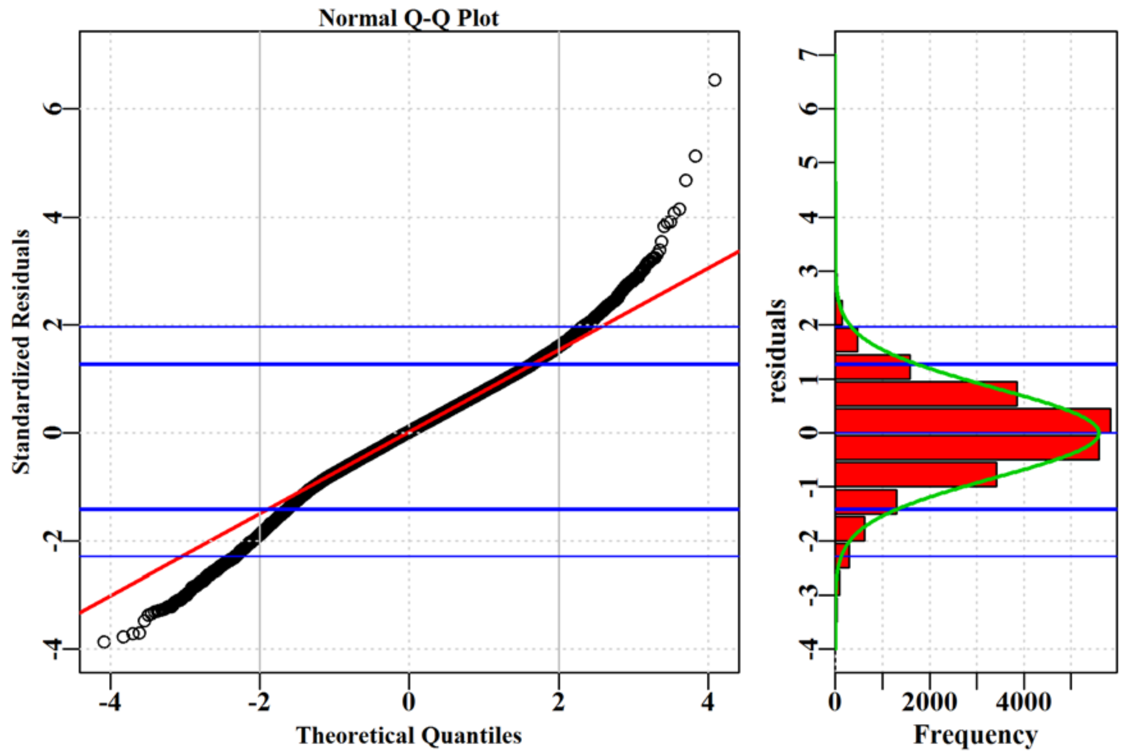


Figure 5.232. RibaldoTW. diagnostic plots. The distribution of residuals from the optimum fit. The qqplot indicates the fit to the expected normality, while the histogram of residuals illustrates the 90% quantiles to indicate the intensity of any lack of fit at the margins of the distribution.

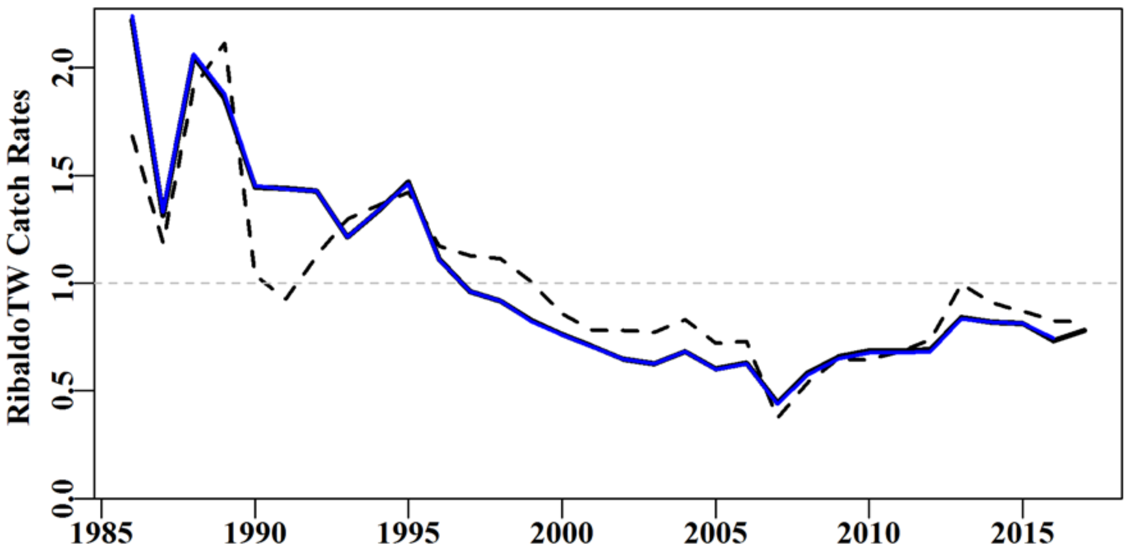


Figure 5.233. RibaldoTW. A comparison of the previous year's standardization (blue line) with this year's. They should lie on top of each other, although small deviations may relate to data adjustments, particularly in very recent years.

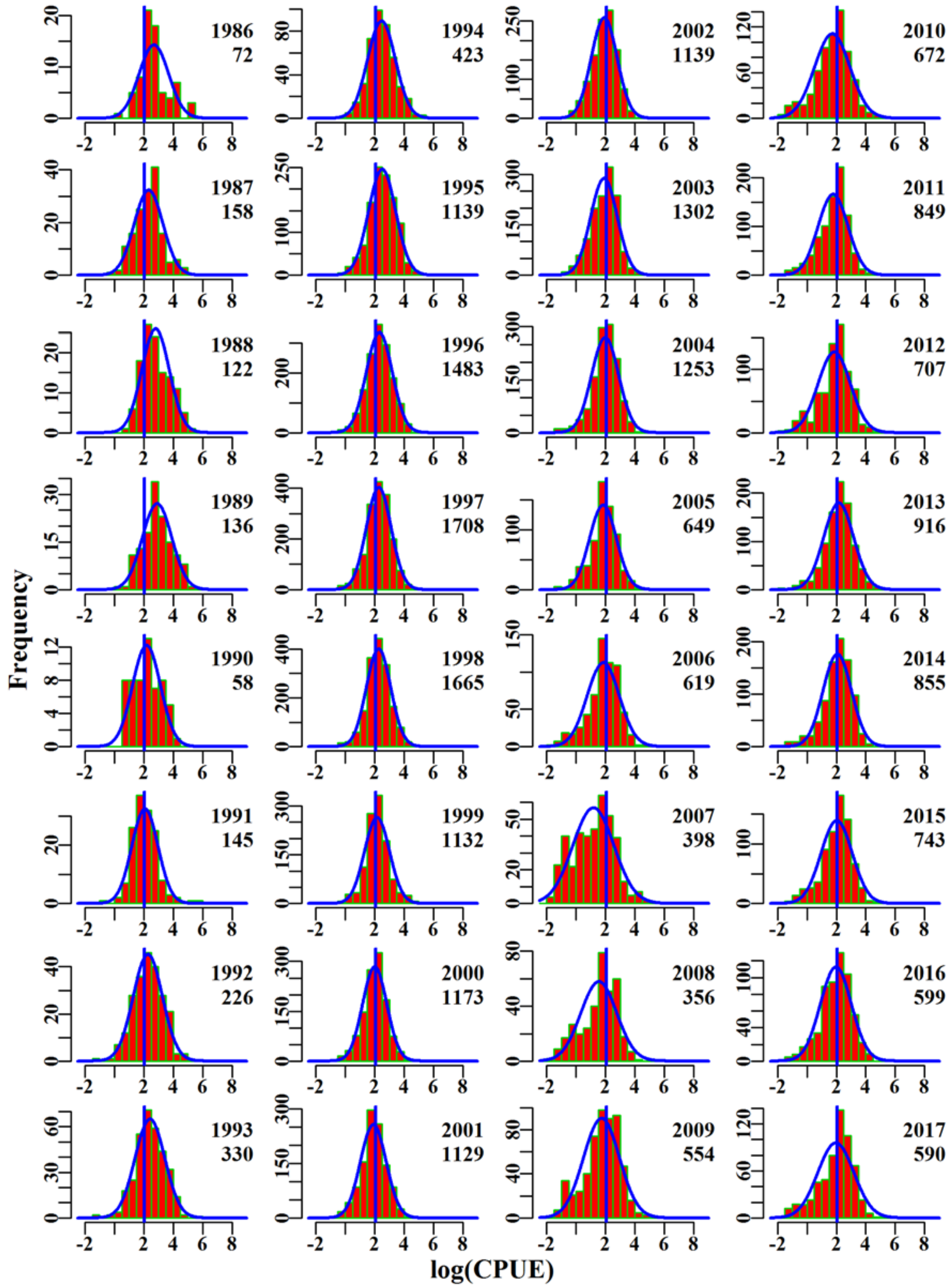


Figure 5.234. RibaldoTW. The log(CPUE) for each year of data available the blue lines are normal distributions fitted to the histogram frequencies. The numbers in each plot are the year and number of records.

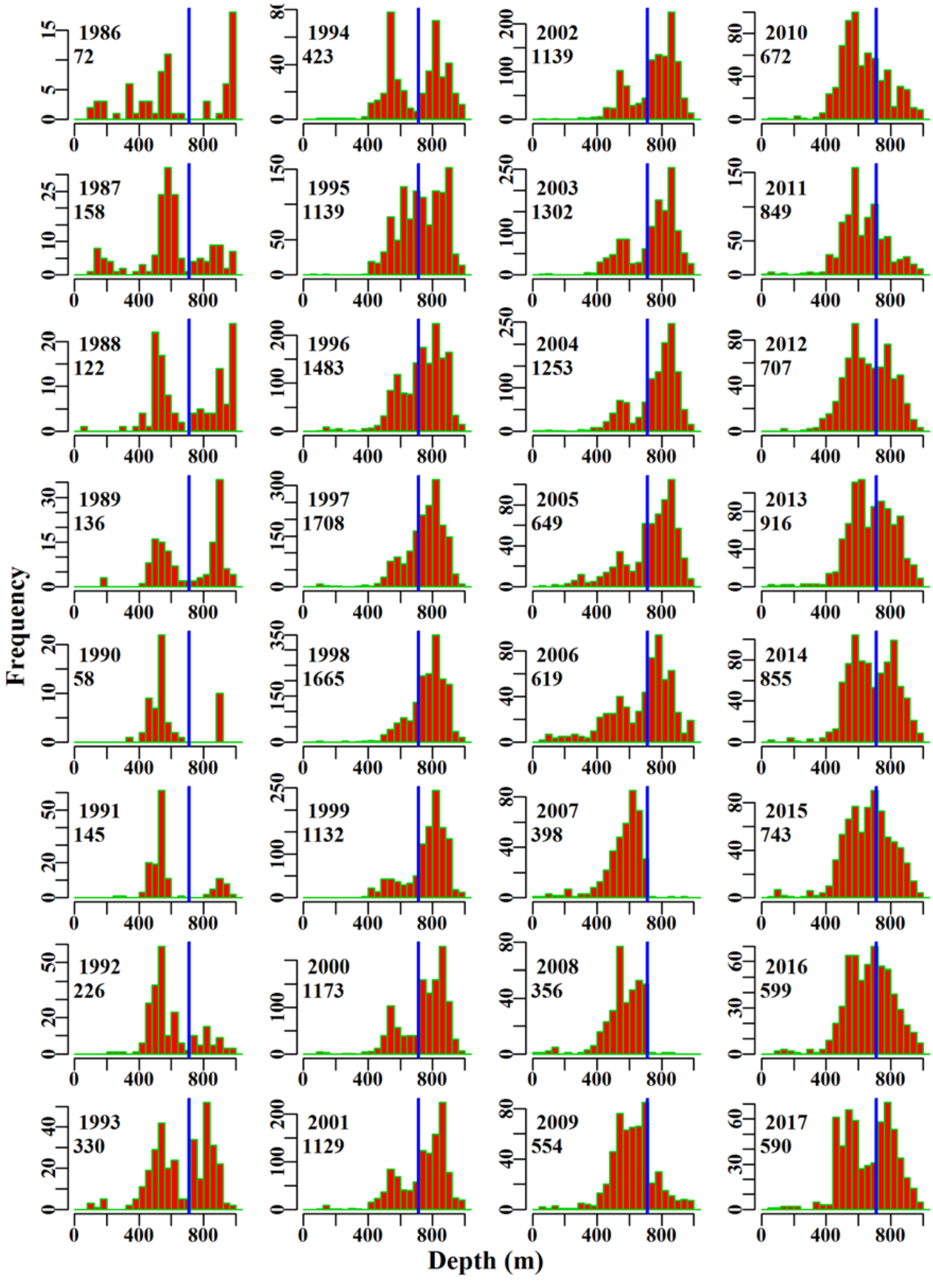


Figure 5.235. RibaldoTW. The average Depth of fishing for each year of data available to illustrate the development of the fishery through time. The numbers in each plot are the year and number of records.

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 - 2017

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	1.0805	0.000	0.205	0.013
2002	157.8	257	94.7	4	455.0	2.6050	0.188	0.878	0.009
2003	180.8	336	102.7	7	359.3	1.9557	0.185	1.553	0.015
2004	181.1	713	96.6	11	131.9	1.7654	0.179	5.324	0.055
2005	90.4	308	37.1	7	127.7	1.1013	0.185	2.417	0.065
2006	122.6	605	65.4	8	123.5	1.0692	0.180	3.488	0.053
2007	78.3	386	27.8	6	73.2	0.6415	0.183	2.580	0.093
2008	78.5	401	56.8	6	168.8	0.7644	0.180	2.130	0.038
2009	105.0	432	68.3	6	218.5	0.7507	0.178	2.266	0.033
2010	91.9	381	51.7	5	175.7	0.7126	0.180	1.811	0.035
2011	93.9	354	46.3	5	163.8	0.8379	0.181	1.871	0.040
2012	107.2	293	58.4	6	282.2	0.7968	0.183	1.228	0.021
2013	122.7	275	49.8	5	241.2	0.6397	0.185	1.143	0.023
2014	138.2	266	66.1	5	503.2	0.6894	0.185	0.853	0.013
2015	99.8	196	35.0	3	270.3	0.6204	0.190	0.865	0.025
2016	66.6	238	23.2	3	129.5	0.4126	0.188	1.365	0.059
2017	80.9	293	36.3	3	148.9	0.5569	0.184	1.429	0.039

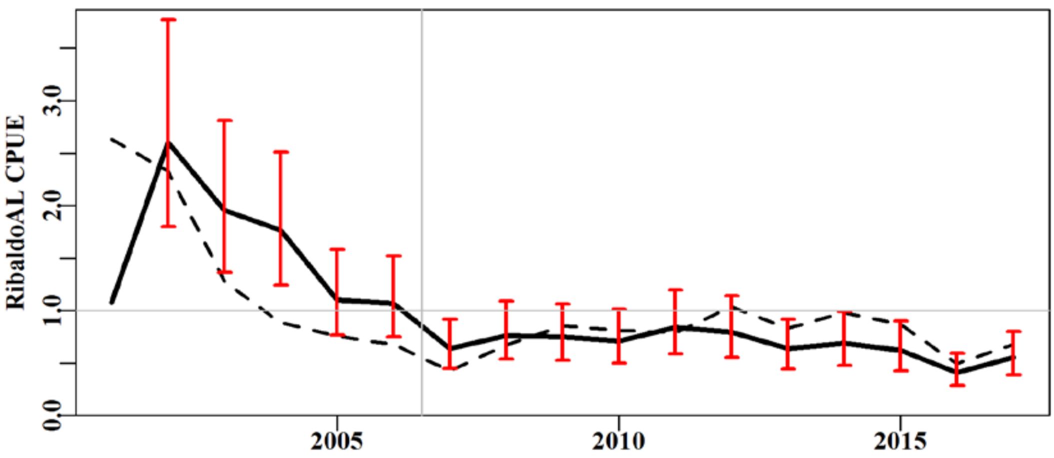


Figure 5.236. RibaldoAL standardization. The dashed black line represents the geometric mean catch rate, solid black line the standardized catch rates. The red bars are the 95% confidence intervals about the mean estimates. The graph scales both time-series of standardized catch rates relative to the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

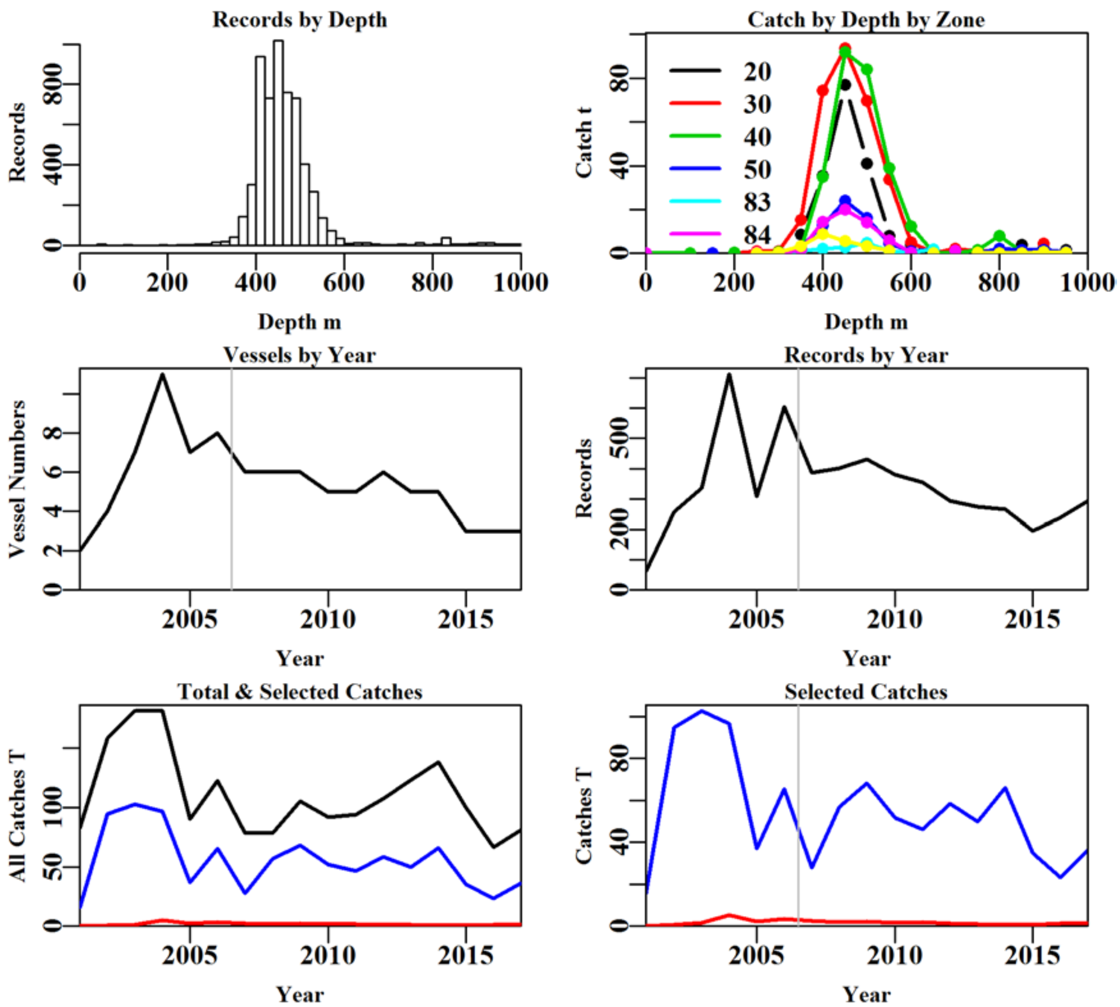


Figure 5.237. RibaldoAL fishery details. The bottom left plot depicts all known catches (top black line), and all selected catches used in the analysis (middle blue line); the lower red line: selected catches < 30 kg).

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	34057	33832	32786	21204	20276	5825	5797
Difference	0	225	1046	11582	928	14451	28
Catch	2545.262	2545.262	2482.55710	1836.8117	1735.9521	935.3928	931.7169
Difference	0.000	0.000	62.70515	645.7455	100.8596	800.5592	3.6760

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	5668	15320	742	5797	17	4.4	0.00
Vessel	3584	10646	5416	5797	30	33.4	29.03
DepCat	3150	9818	6244	5797	48	38.4	4.99
Zone	3042	9616	6446	5797	54	39.6	1.21
Month	2996	9504	6558	5797	65	40.2	0.59
Zone:Month	2865	9085	6977	5797	130	42.2	1.98
Zone:DepCat	2984	9268	6794	5797	132	41.0	0.80

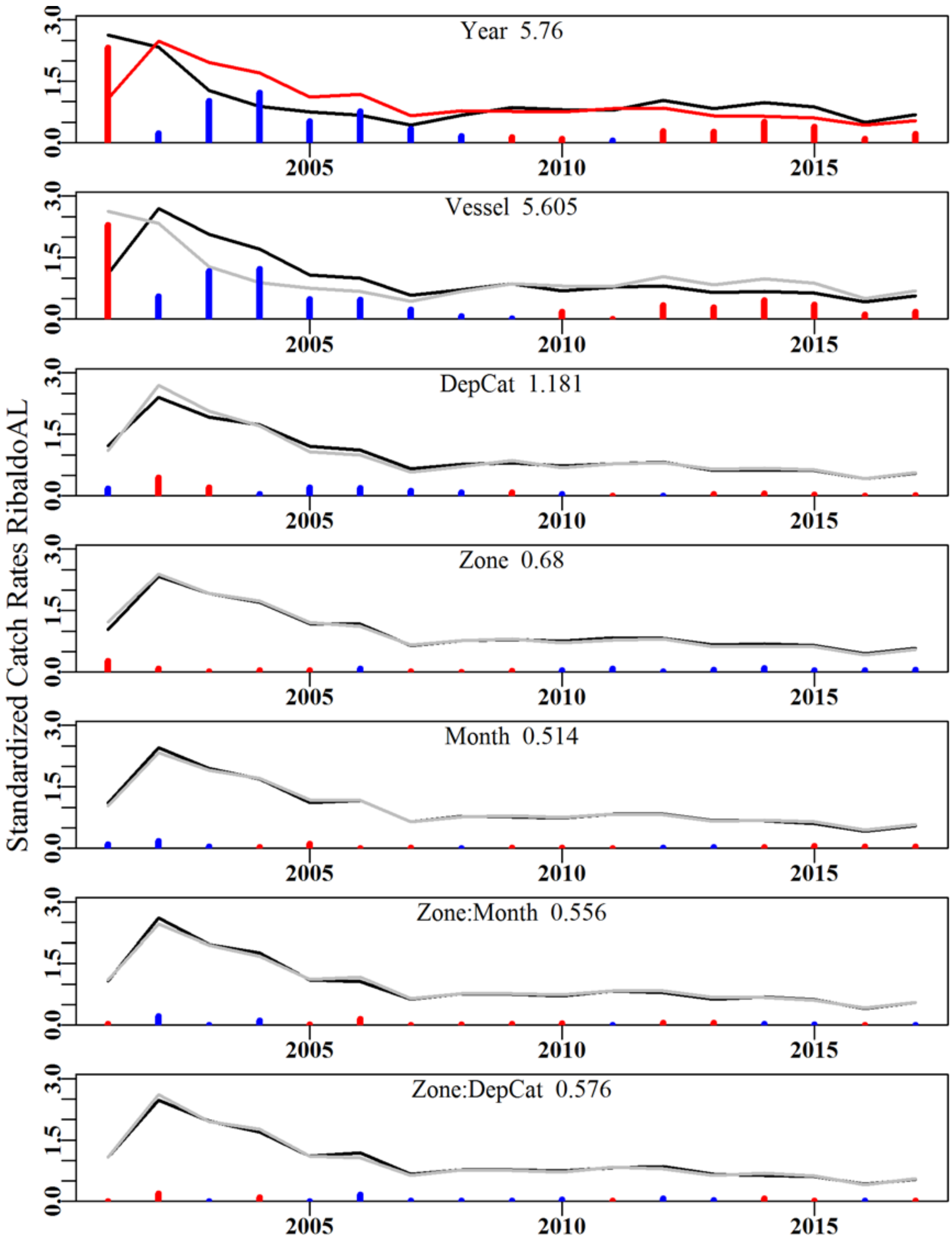


Figure 5.238. RibaldoAL. The influence of each factor on the optimal standardization. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by vertical bars with blue bars indicating the optimum model is higher than the geometric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

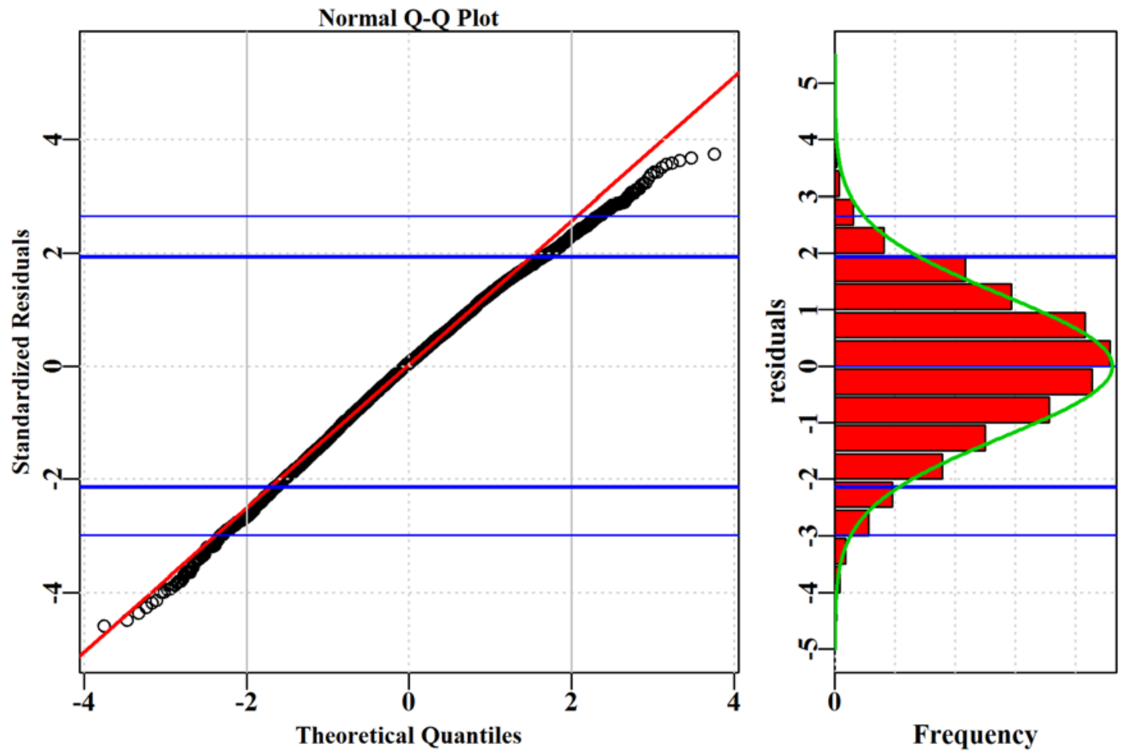


Figure 5.239. RibaldoAL. diagnostic plots. The distribution of residuals from the optimum fit. The qqplot indicates the fit to the expected normality, while the histogram of residuals illustrates the 90% quantiles to indicate the intensity of any lack of fit at the margins of the distribution.

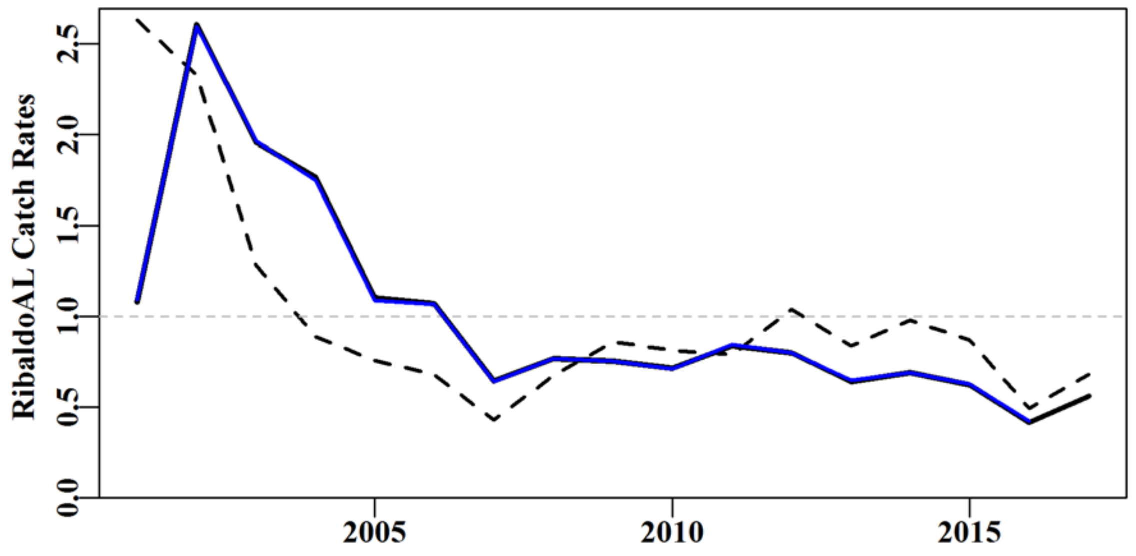


Figure 5.240. RibaldoAL. A comparison of the previous year's standardization (blue line) with this year's. They should lie on top of each other, although small deviations may relate to data adjustments, particularly in very recent years.

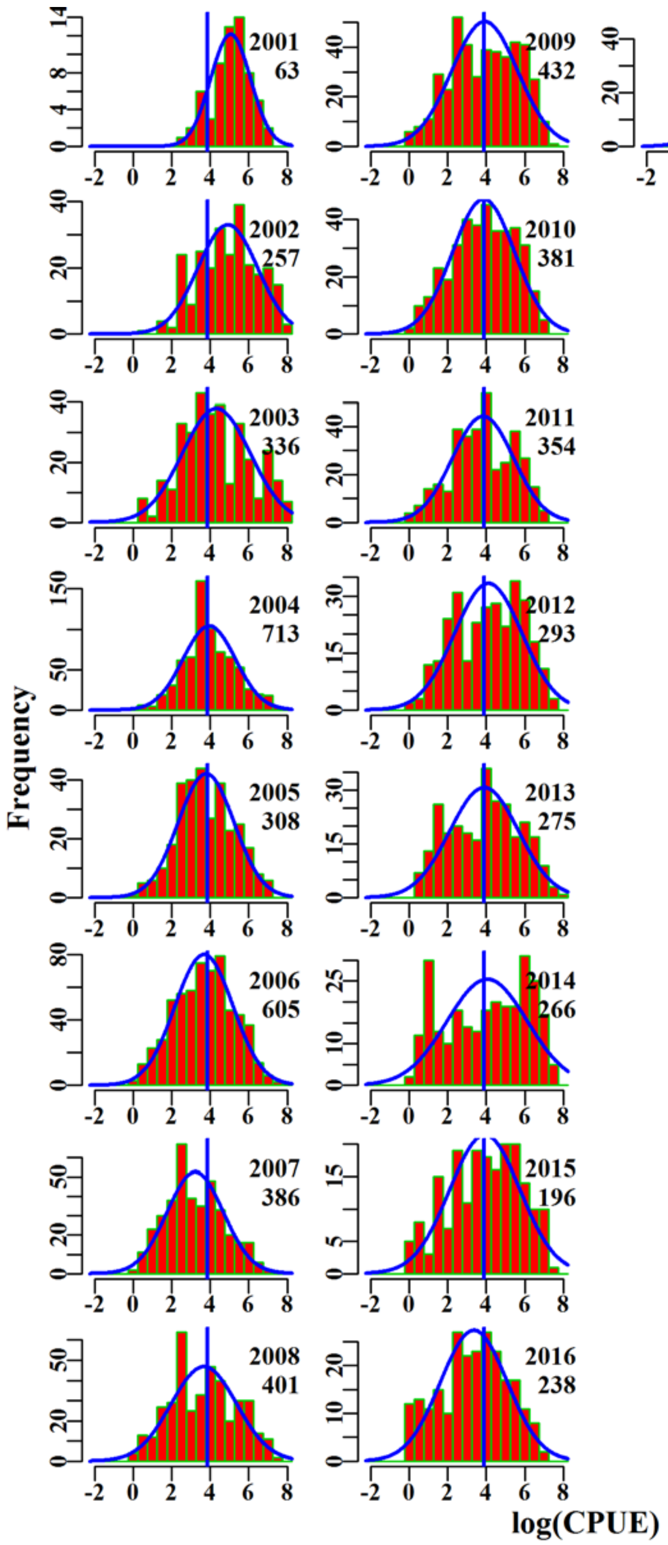


Figure 5.241. RibaldoAL. The log(CPUE) for each year of data available the blue lines are normal distributions fitted to the histogram frequencies. The numbers in each plot are the year and number of records.

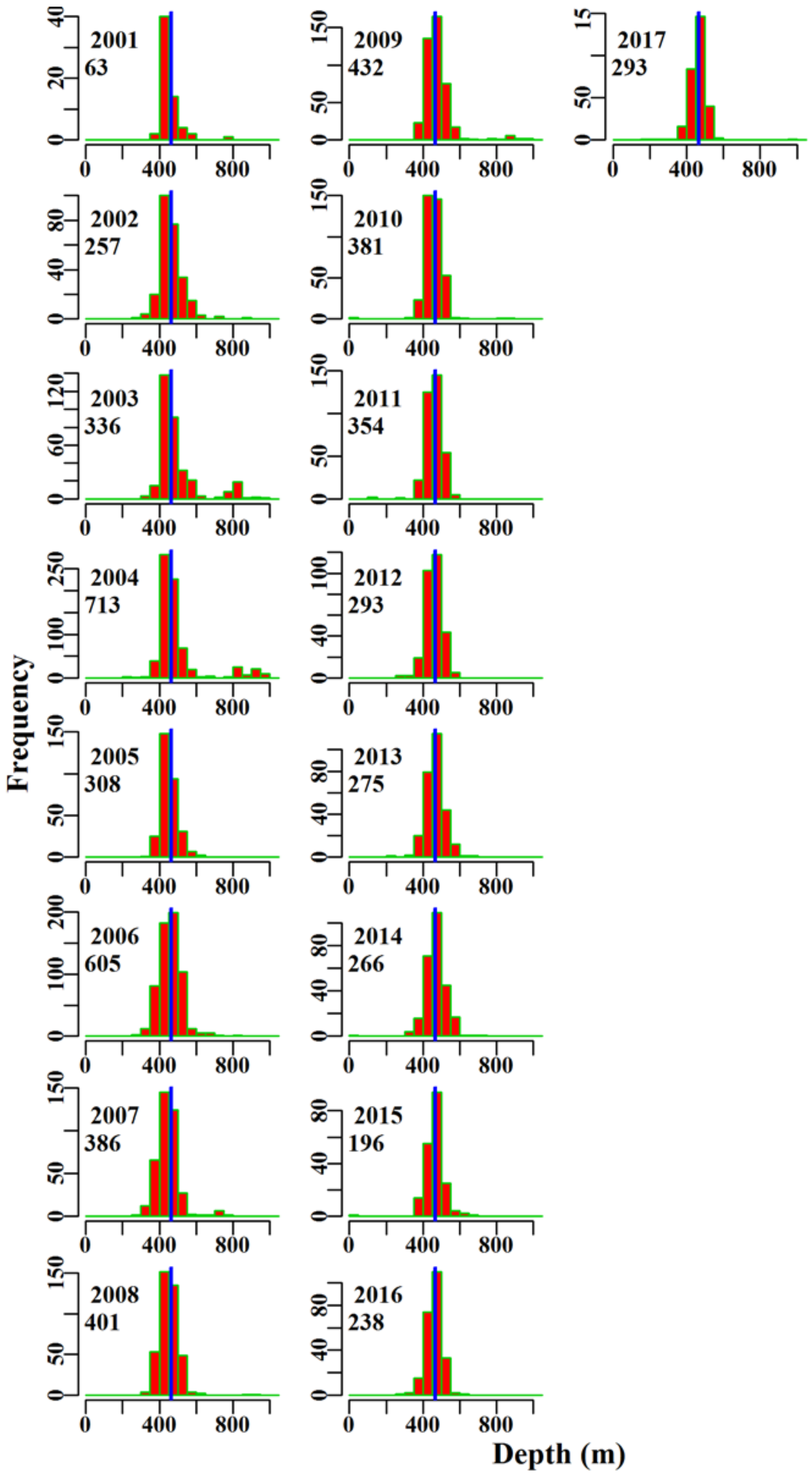


Figure 5.242. RibaldoAL. The average Depth of fishing for each year of data available to illustrate the development of the fishery through time. The numbers in each plot are the year and number of records.

5.39 Silver Trevally 1020

Initial data selection for Silver Trevally (TRE – 37337062 – *Pseudocaranx dentex*) in the SET was conducted according to the detials 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 departure 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 explanaiton 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 - 2017

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	1.0845	0.000	14.045	0.046
1987	198.5	1253	133.7	64	43.6	1.2749	0.057	9.101	0.068
1988	278.5	1581	244.0	56	51.4	1.4666	0.052	12.112	0.050
1989	376.2	2193	332.7	62	60.6	1.8650	0.048	13.682	0.041
1990	450.4	2081	344.2	53	59.7	2.1922	0.050	11.655	0.034
1991	340.7	2210	250.2	50	43.7	1.9049	0.050	14.181	0.057
1992	296.5	1688	249.0	45	40.9	1.1665	0.053	11.715	0.047
1993	377.7	2264	281.1	49	42.7	1.1732	0.050	16.074	0.057
1994	392.8	3282	360.0	48	38.8	0.9951	0.047	24.712	0.069
1995	413.4	3347	383.2	48	44.6	1.1209	0.046	25.171	0.066
1996	340.6	3208	315.3	53	39.8	1.0148	0.047	24.514	0.078
1997	328.8	2815	292.9	56	53.7	0.9914	0.048	19.728	0.067
1998	210.1	2287	177.6	46	39.0	0.7582	0.049	17.833	0.100
1999	166.1	1857	114.4	45	31.9	0.7431	0.052	13.539	0.118
2000	154.8	2010	122.9	49	26.3	0.5748	0.051	14.713	0.120
2001	270.2	3255	229.0	45	36.3	0.6958	0.046	21.930	0.096
2002	232.8	2776	209.6	44	38.3	0.6532	0.048	17.710	0.085
2003	337.9	2732	277.9	49	59.7	0.6975	0.048	16.611	0.060
2004	458.2	3316	365.1	45	64.3	0.8539	0.047	19.378	0.053
2005	291.1	2301	240.1	43	59.0	0.7429	0.050	13.644	0.057
2006	247.3	1684	209.0	39	82.8	0.8079	0.053	9.278	0.044
2007	172.7	832	115.4	22	89.2	0.7863	0.064	4.408	0.038
2008	128.4	1054	95.8	23	49.0	0.9061	0.060	6.864	0.072
2009	164.1	1142	135.3	23	57.8	0.9109	0.059	6.689	0.049
2010	240.2	1231	191.3	24	99.9	1.1590	0.058	6.212	0.032
2011	193.5	1103	175.3	20	112.9	0.9915	0.059	5.548	0.032
2012	139.7	954	129.0	21	99.1	0.7798	0.062	5.062	0.039
2013	122.8	720	112.9	19	97.4	0.8302	0.067	3.918	0.035
2014	106.9	885	97.8	20	62.6	0.6347	0.063	5.176	0.053
2015	79.5	570	73.1	22	69.7	0.6630	0.073	2.914	0.040
2016	52.4	337	39.2	18	113.7	0.8084	0.089	1.643	0.042
2017	52.9	324	35.3	14	86.0	0.7528	0.090	1.862	0.053

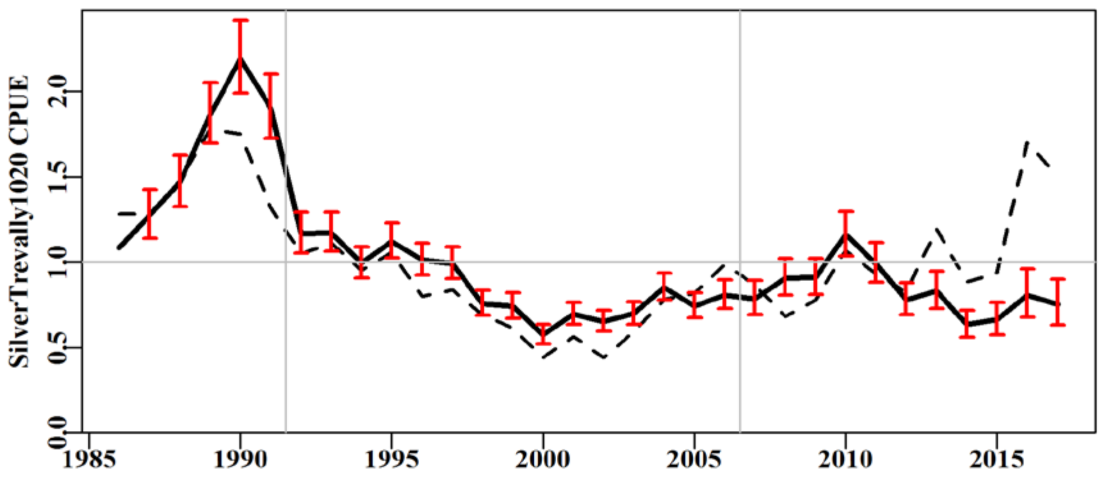


Figure 5.243. SilverTrevally1020 standardization. The dashed black line represents the geometric mean catch rate, solid black line the standardized catch rates. The red bars are the 95% confidence intervals about the mean estimates. The graph scales both time-series of standardized catch rates relative to the mean of each time-series.

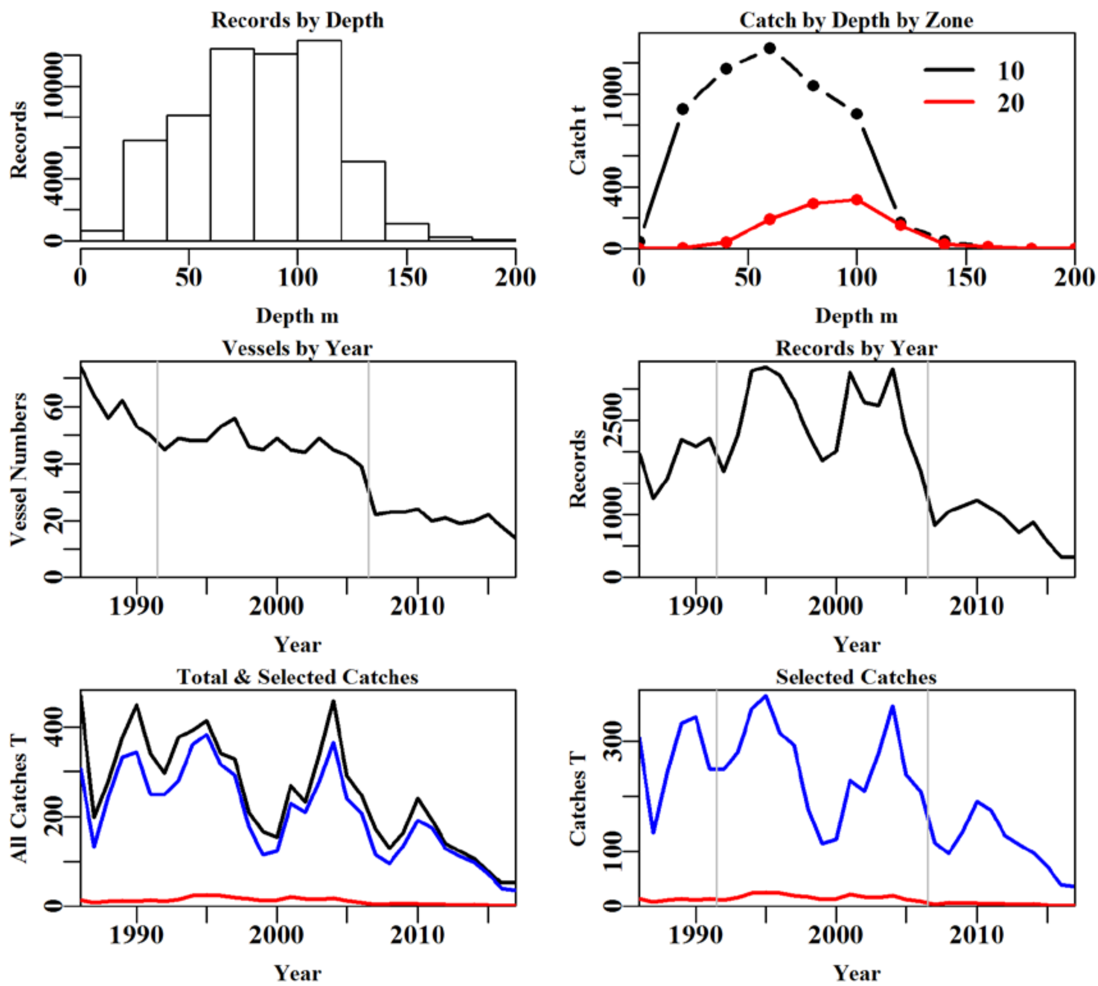


Figure 5.244. SilverTrevally1020 fishery details. The bottom left plot depicts all known catches (top black line), and all selected catches used in the analysis (middle blue line); the lower red line: selected catches < 30 kg).

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	75797	72657	70987	70078	60706	59324	59268
Difference	0	3140	1670	909	9372	1382	56
Catch	8255.543	8079.3989	7773.2194	7603.7339	6684.5922	6645.3013	6638.330
Difference	0.000	176.1438	306.1794	169.4855	919.1418	39.2909	6.971

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	62202	169102	7917	59268	32	4.4	0.00
Vessel	48324	133091	43927	59268	189	24.6	20.15
DepCat	45066	125931	51087	59268	199	28.6	4.05
Month	44352	124376	52643	59268	210	29.5	0.87
DayNight	43516	122621	54397	59268	213	30.5	0.99
Zone	43489	122563	54456	59268	214	30.5	0.03
Zone:Month	43346	122222	54796	59268	225	30.7	0.18
Zone:DepCat	43465	122475	54544	59268	223	30.6	0.04

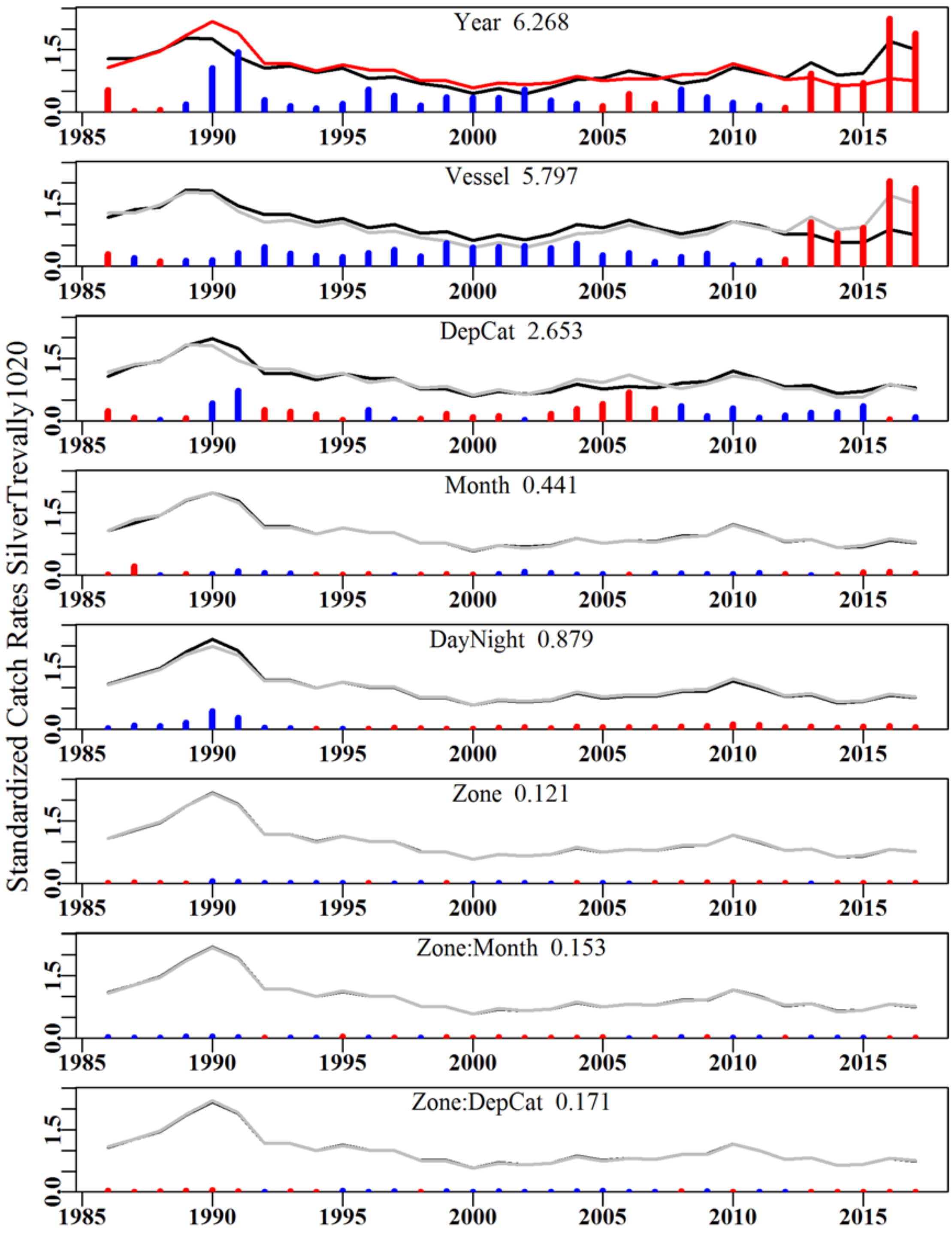


Figure 5.245. SilverTrevally1020. The influence of each factor on the optimal standardization. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by vertical bars with blue bars indicating the optimum model is higher than 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.

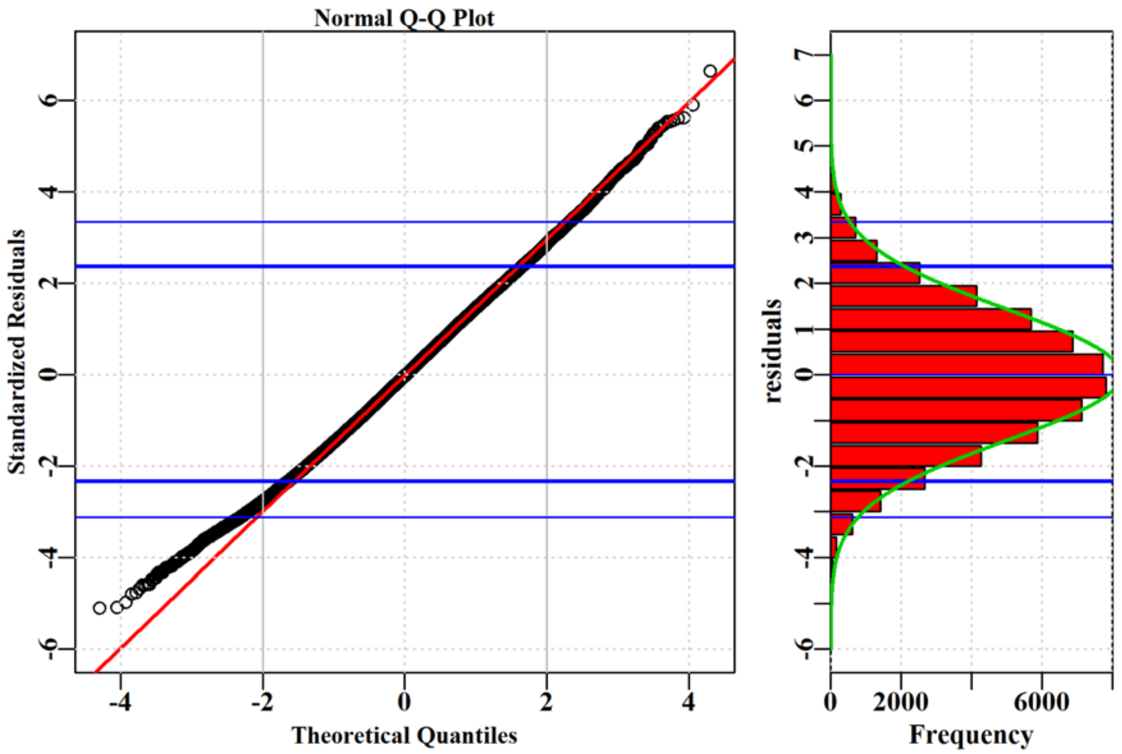


Figure 5.246. SilverTrevally1020. diagnostic plots. The distribution of residuals from the optimum fit. The qqplot indicates the fit to the expected normality, while the histogram of residuals illustrates the 90% quantiles to indicate the intensity of any lack of fit at the margins of the distribution.

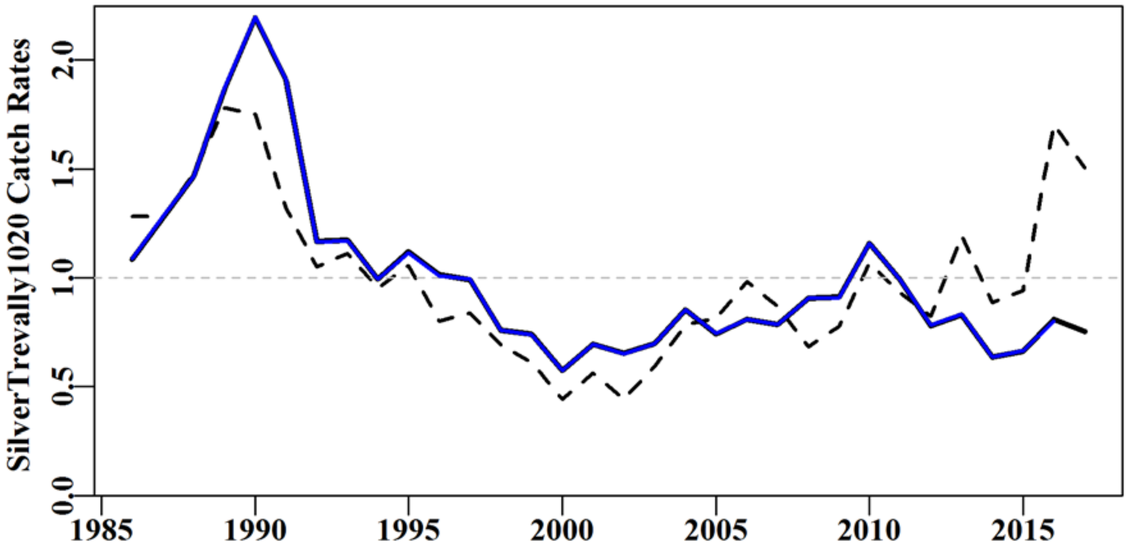


Figure 5.247. SilverTrevally1020. A comparison of the previous year's standardization (blue line) with this year's. They should lie on top of each other, although small deviations may relate to data adjustments, particularly in very recent years.

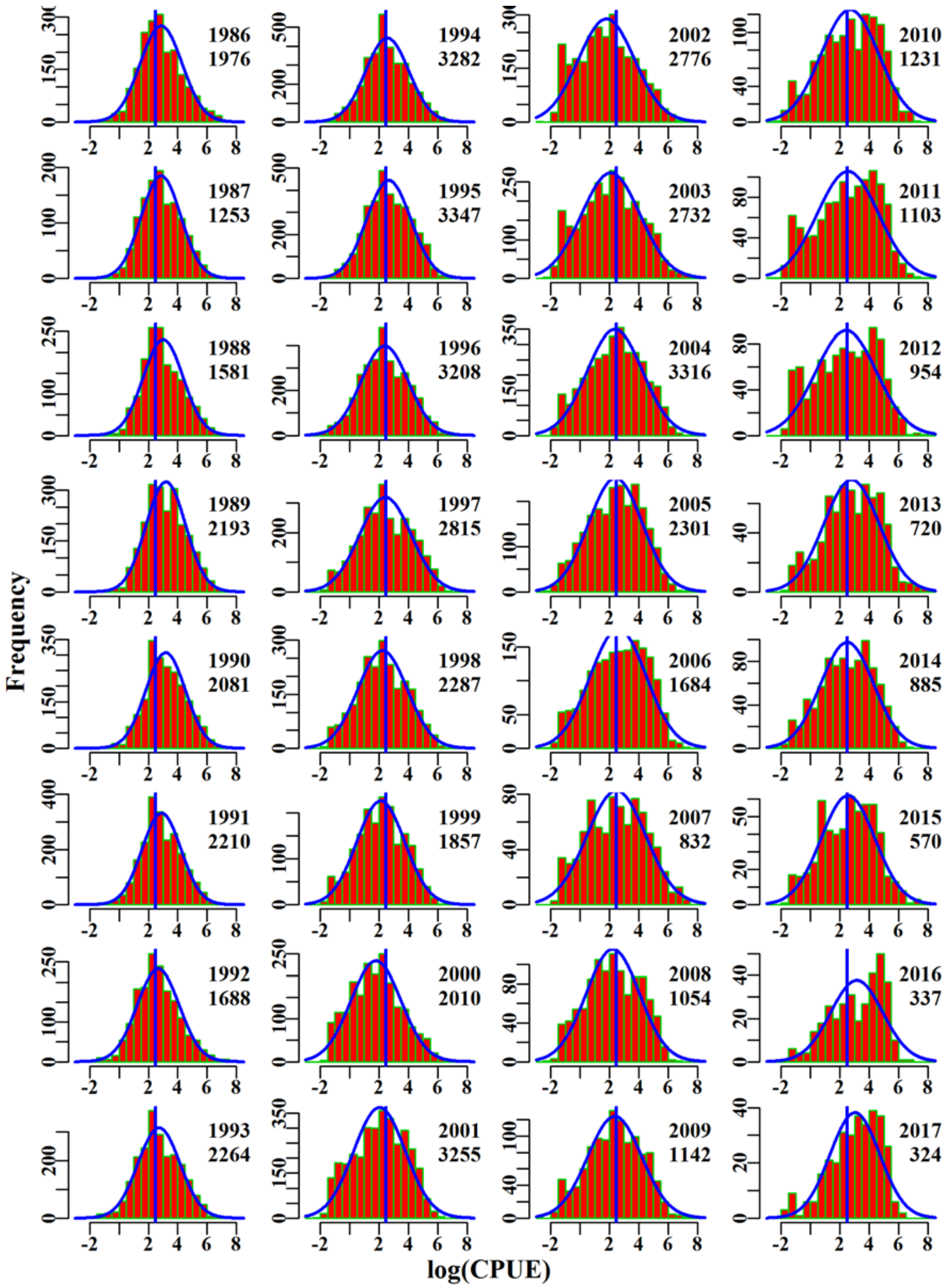


Figure 5.248. SilverTrevally1020. The log(CPUE) for each year of data available the blue lines are normal distributions fitted to the histogram frequencies. The numbers in each plot are the year and number of records.

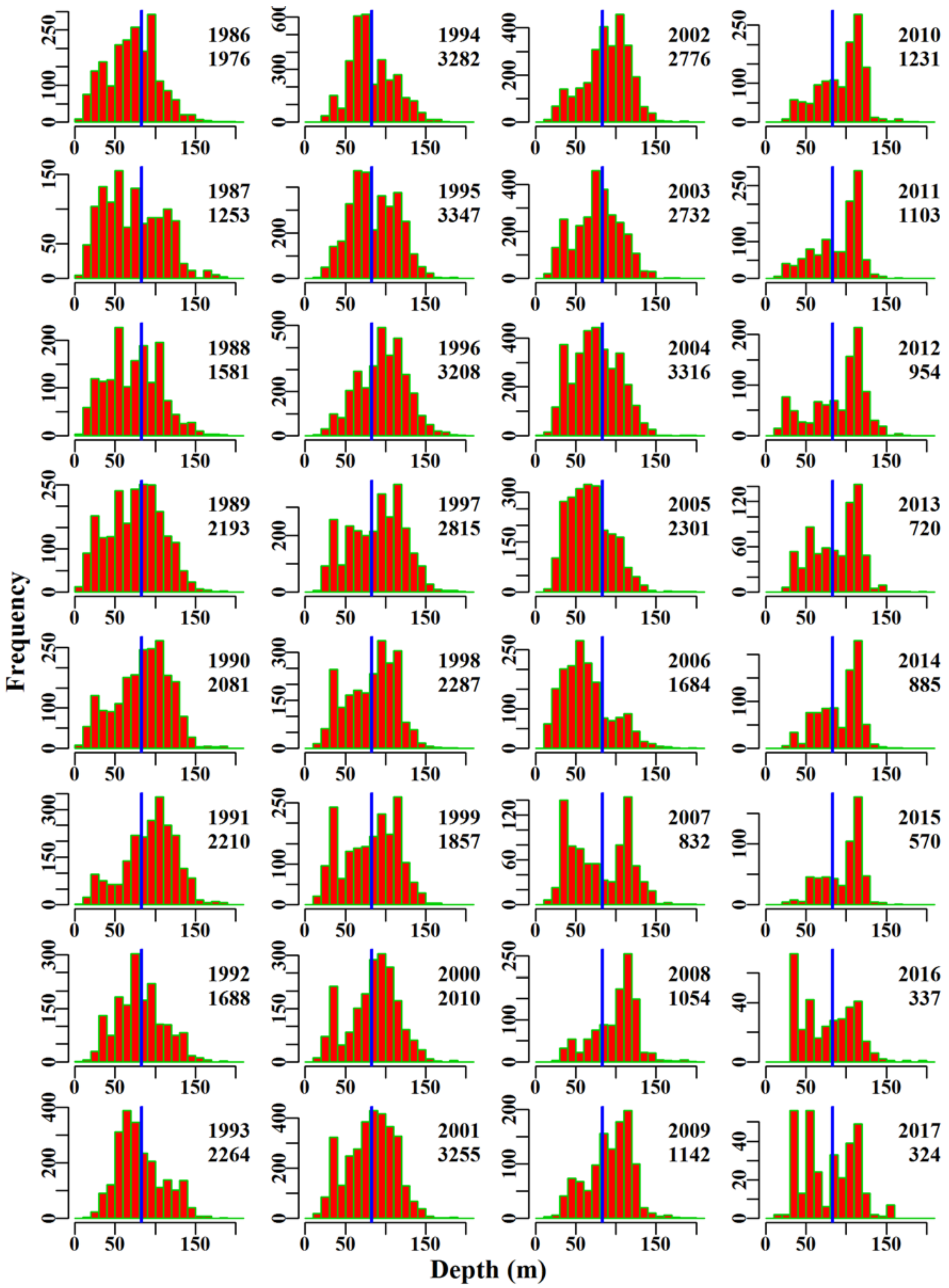


Figure 5.249. SilverTrevally1020. The average Depth of fishing for each year of data available to illustrate the development of the fishery through time. The numbers in each plot are the year and number of records.

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 - 2016 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 - 2017

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	1.1835	0.000	12.762	0.045
1987	198.5	1077	120.9	62	45.8	1.4185	0.061	7.630	0.063
1988	278.5	1258	226.7	53	59.1	1.8275	0.056	9.599	0.042
1989	376.2	1846	282.5	62	56.2	1.9481	0.051	12.318	0.044
1990	450.4	1834	292.0	52	55.1	2.2946	0.052	10.697	0.037
1991	340.7	1953	218.0	49	42.5	2.0246	0.053	12.522	0.057
1992	296.5	1356	170.7	45	34.6	1.2320	0.057	9.742	0.057
1993	377.7	1407	152.3	48	35.2	1.2658	0.057	10.899	0.072
1994	392.8	2073	176.8	47	28.2	1.0060	0.053	16.809	0.095
1995	413.4	1942	179.2	44	31.5	1.1273	0.053	16.202	0.090
1996	340.6	2179	177.6	49	27.6	0.9783	0.053	18.281	0.103
1997	328.8	1647	115.7	49	24.9	0.9180	0.056	13.637	0.118
1998	210.1	1226	64.0	42	19.4	0.6519	0.059	10.434	0.163
1999	166.1	1022	49.0	40	17.3	0.6608	0.062	8.024	0.164
2000	154.8	1244	54.5	46	13.9	0.5092	0.059	9.600	0.176
2001	270.2	2024	121.5	43	23.7	0.6239	0.053	13.786	0.113
2002	232.8	1812	97.7	39	19.0	0.5027	0.055	11.638	0.119
2003	337.9	1526	89.8	49	21.9	0.5129	0.056	9.592	0.107
2004	458.2	1868	151.7	43	36.8	0.7382	0.054	11.342	0.075
2005	291.1	1013	98.7	41	41.5	0.6397	0.062	6.210	0.063
2006	247.3	695	79.3	37	59.7	0.8129	0.069	4.529	0.057
2007	172.7	557	79.2	21	92.1	0.9401	0.075	2.895	0.037
2008	128.4	887	80.6	22	46.9	0.9051	0.065	5.931	0.074
2009	164.1	933	107.0	23	55.7	0.9014	0.064	5.623	0.053
2010	240.2	1011	152.6	24	89.7	1.1492	0.063	5.213	0.034
2011	193.5	910	149.6	20	113.8	0.9893	0.065	4.590	0.031
2012	139.7	733	97.6	21	72.6	0.7169	0.069	4.241	0.043
2013	122.8	520	72.4	19	70.9	0.7892	0.076	2.924	0.040
2014	106.9	672	66.7	20	51.4	0.5947	0.070	4.117	0.062
2015	79.5	473	61.2	21	67.6	0.6671	0.079	2.422	0.040
2016	52.4	237	23.3	18	89.2	0.7297	0.103	1.313	0.056
2017	52.9	216	23.7	14	77.6	0.7407	0.107	1.304	0.055

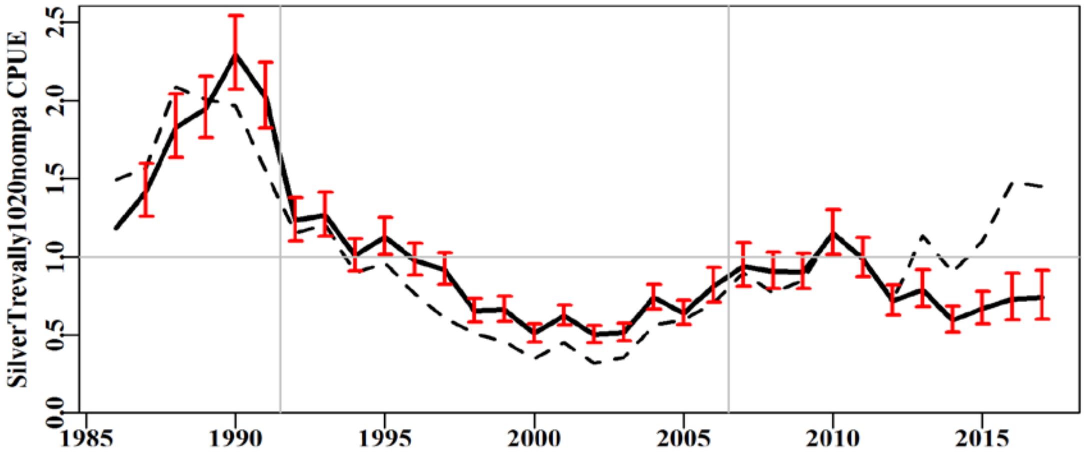


Figure 5.250. SilverTrevally1020nompa standardization. The dashed black line represents the geometric mean catch rate, solid black line the standardized catch rates. The red bars are the 95% confidence intervals about the mean estimates. The graph scales both time-series of standardized catch rates relative to the mean of each time-series.

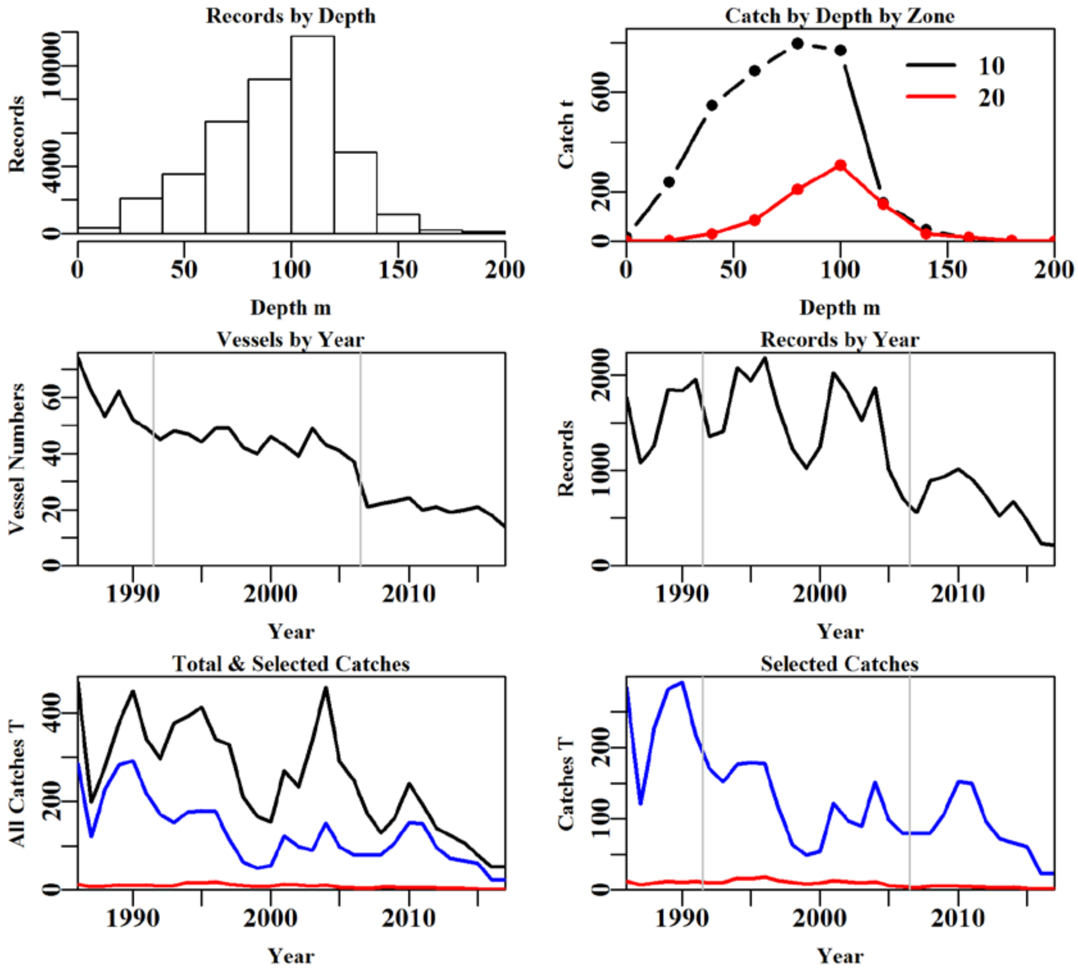


Figure 5.251. SilverTrevally1020nompa fishery details. The bottom left plot depicts all known catches (top black line), and all selected catches used in the analysis (middle blue line); the lower red line: selected catches < 30 kg).

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	75797	72657	70987	70078	60706	59324	59268	39916
Difference	0	3140	1670	909	9372	1382	56	19352
Catch	8255.543	8079.398	7773.2194	7603.7339	6684.5922	6645.3013	6638.330	0
Difference	0.000	176.1438	306.1794	169.4855	919.1418	39.2909	6.971	0

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	39182	106356	12131	39916	32	10.2	0.00
Vessel	30550	85010	33477	39916	187	27.9	17.75
DepCat	29404	82562	35925	39916	197	30.0	2.06
Month	28675	81024	37462	39916	208	31.3	1.28
DayNight	28053	79760	38727	39916	211	32.3	1.07
Zone	28003	79654	38832	39916	212	32.4	0.09
Zone:Month	27909	79423	39064	39916	223	32.6	0.18
Zone:DepCat	27981	79575	38912	39916	221	32.5	0.05

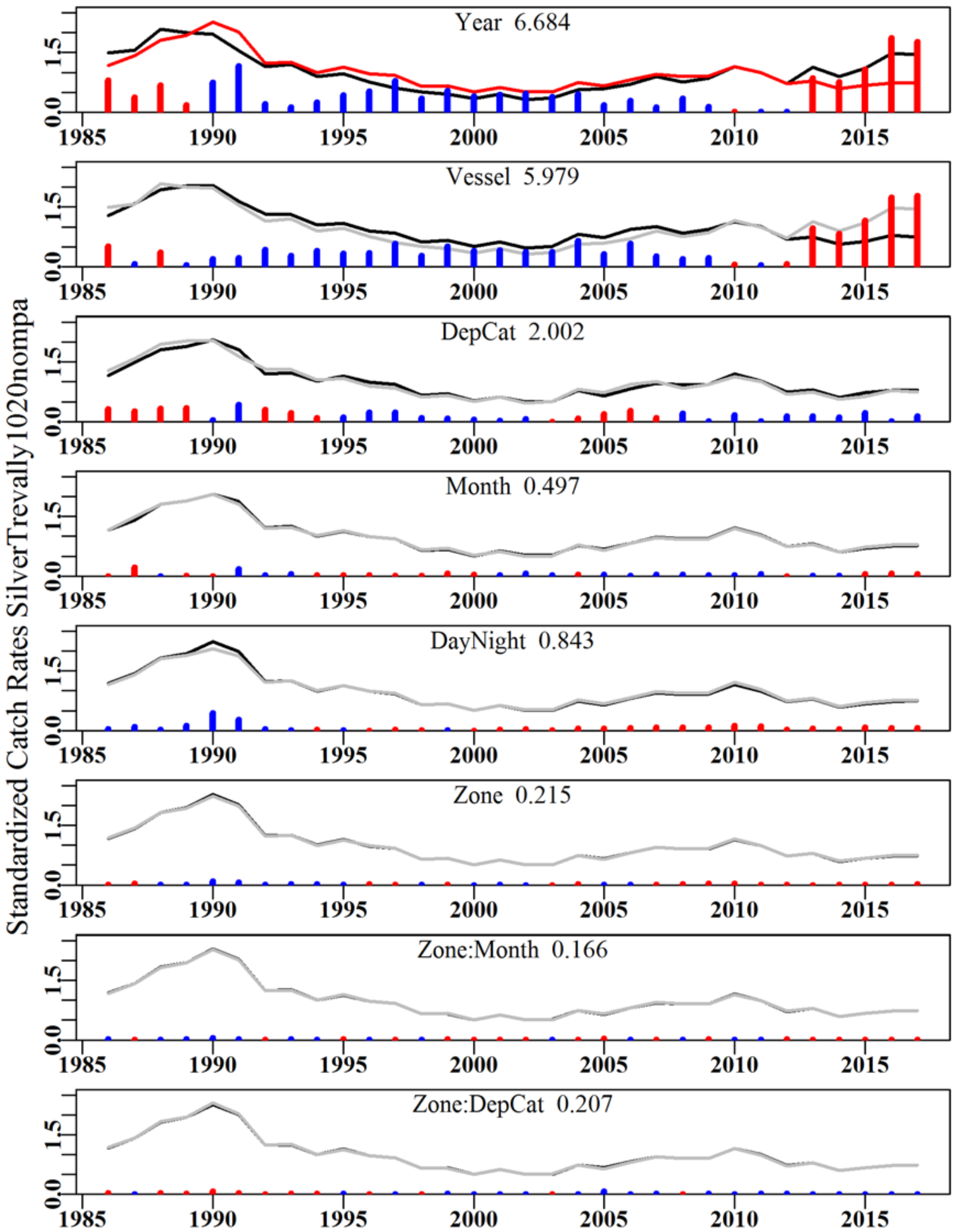


Figure 5.252. SilverTrevally1020nompa. The influence of each factor on the optimal standardization. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by vertical bars with blue bars indicating the optimum model is higher 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.

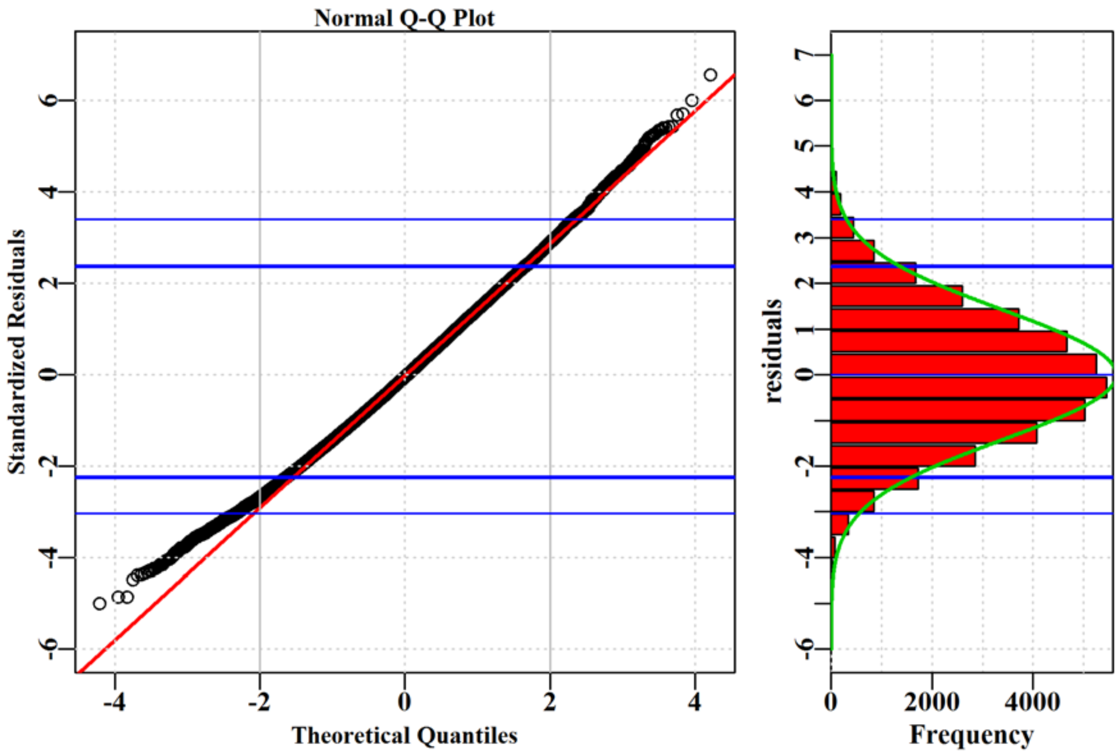


Figure 5.253. SilverTrevally1020nompa. diagnostic plots. The distribution of residuals from the optimum fit. The qqplot indicates the fit to the expected normality, while the histogram of residuals illustrates the 90% quantiles to indicate the intensity of any lack of fit at the margins of the distribution.

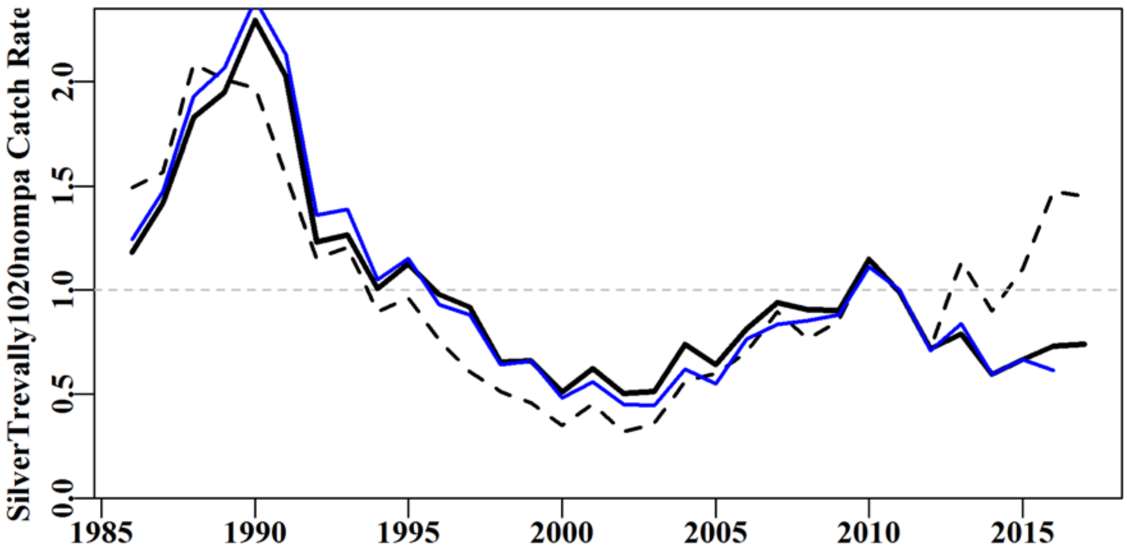


Figure 5.254. SilverTrevally1020nompa. A comparison of the previous year's standardization (blue line) with this year's. They should lie on top of each other, although small deviations may relate to data adjustments, particularly in very recent years.

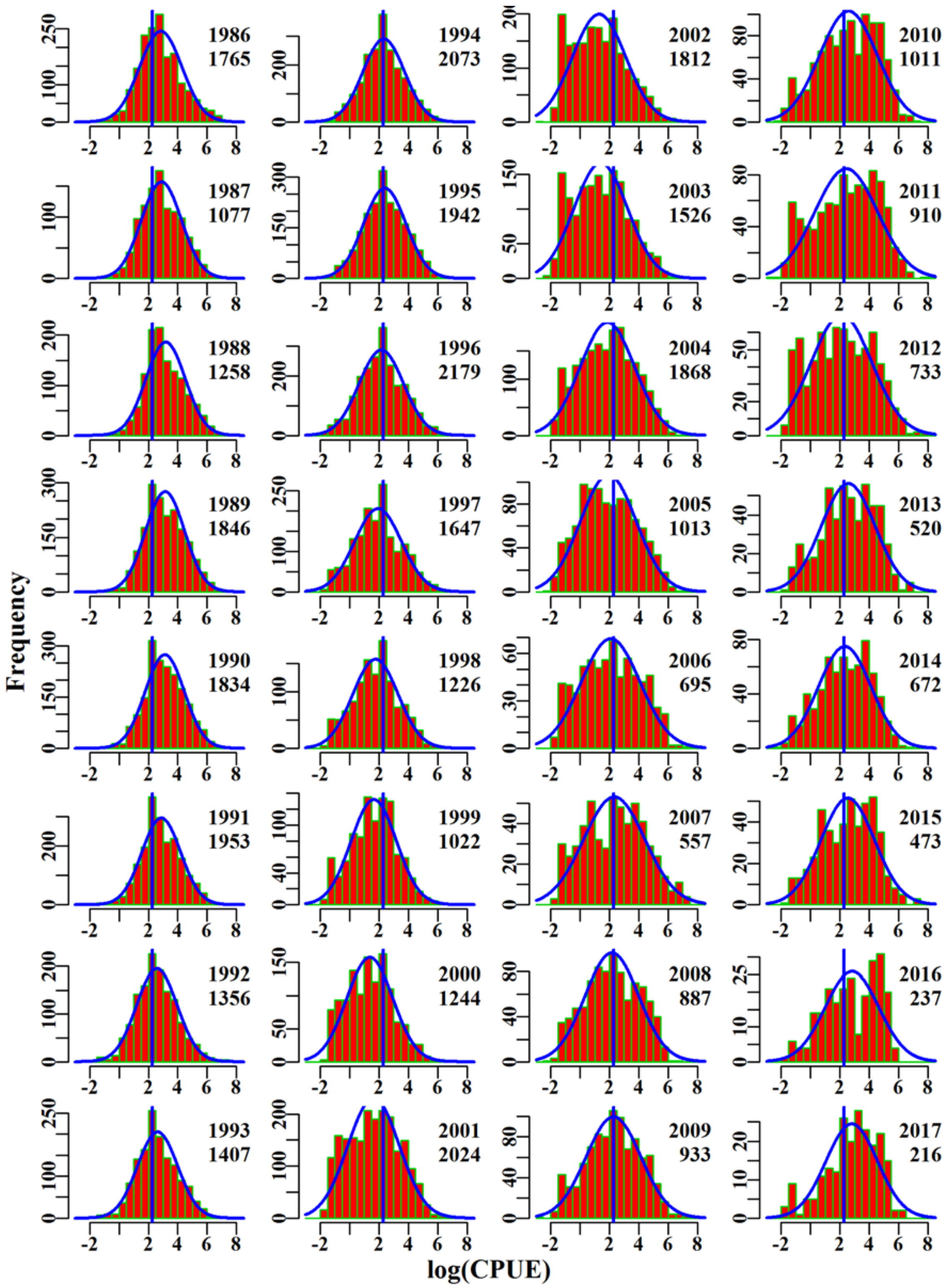


Figure 5.255. SilverTrevally1020nompa. The log(CPUE) for each year of data available the blue lines are normal distributions fitted to the histogram frequencies. The numbers in each plot are the year and number of records.

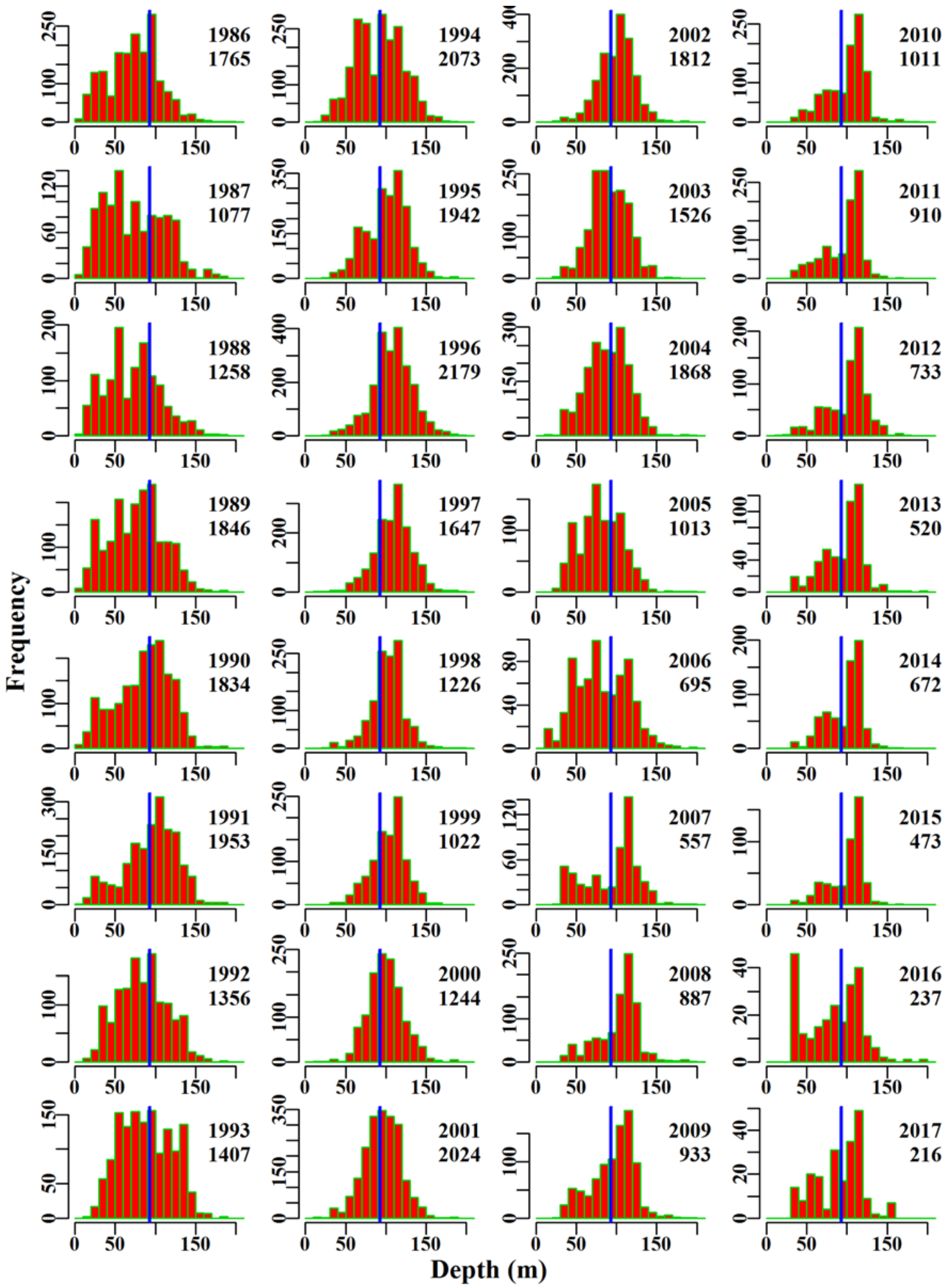


Figure 5.256. SilverTrevally1020nompa. The average Depth of fishing for each year of data available to illustrate the development of the fishery through time. The numbers in each plot are the year and number of records.

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*

No issues identified.

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 - 2017

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	0.6946	0.000	6.689	0.029
1987	351.3	1763	324.7	47	93.0	0.8775	0.038	4.739	0.015
1988	362.5	1392	343.3	41	124.5	0.9709	0.041	3.627	0.011
1989	329.3	1143	310.8	39	139.3	0.8312	0.043	3.462	0.011
1990	337.1	719	308.6	25	175.4	1.5687	0.049	0.615	0.002
1991	334.1	728	296.3	29	183.2	1.3755	0.050	1.447	0.005
1992	166.9	426	142.3	19	164.7	1.0196	0.058	0.728	0.005
1993	298.8	671	232.1	21	172.6	1.2134	0.050	1.377	0.006
1994	359.8	650	234.3	26	169.5	1.1495	0.050	1.308	0.006
1995	335.6	1066	252.3	25	105.3	0.9066	0.044	1.862	0.007
1996	360.8	1212	272.1	24	95.5	0.8020	0.042	1.653	0.006
1997	252.7	850	165.2	21	86.8	0.7511	0.047	1.309	0.008
1998	233.3	1228	190.0	23	67.7	0.7869	0.043	2.549	0.013
1999	367.0	1579	342.8	25	84.5	0.8038	0.041	2.569	0.007
2000	434.9	1537	398.2	27	127.1	1.0062	0.041	3.619	0.009
2001	276.8	1313	228.9	22	75.7	0.8483	0.043	3.874	0.017
2002	484.2	1735	415.8	23	131.5	1.0205	0.040	4.529	0.011
2003	230.8	796	161.8	26	114.9	1.0495	0.049	3.164	0.020
2004	193.9	569	167.4	22	206.8	1.0659	0.054	2.108	0.013
2005	173.9	587	152.8	21	149.1	0.9691	0.054	2.192	0.014
2006	192.3	453	177.3	17	295.8	1.1641	0.058	1.714	0.010
2007	121.5	323	115.7	9	249.3	0.8015	0.066	1.480	0.013
2008	75.8	252	70.6	8	220.9	0.6876	0.074	1.340	0.019
2009	68.8	248	67.3	9	159.3	0.8760	0.079	0.647	0.010
2010	96.8	343	82.8	9	138.1	0.8624	0.066	1.561	0.019
2011	110.9	288	107.9	8	207.2	1.2569	0.070	0.510	0.005
2012	126.5	359	120.5	9	167.3	0.9651	0.065	1.002	0.008
2013	212.2	416	198.1	9	280.6	1.2367	0.069	0.643	0.003
2014	121.7	348	118.3	11	178.1	0.9870	0.066	0.535	0.005
2015	126.5	345	119.8	8	219.9	0.9929	0.068	0.723	0.006
2016	145.3	323	136.9	9	273.9	1.1645	0.067	0.733	0.005
2017	137.1	308	133.2	8	270.3	1.2944	0.072	0.490	0.004

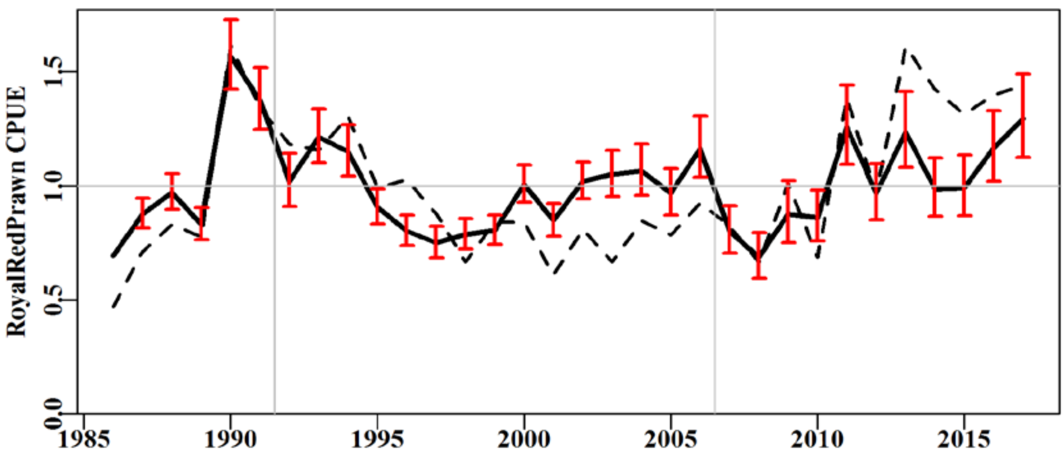


Figure 5.257. RoyalRedPrawn standardization. The dashed black line represents the geometric mean catch rate, solid black line the standardized catch rates. The red bars are the 95% confidence intervals about the mean estimates. The graph scales both time-series of standardized catch rates relative to the mean of each time-series.

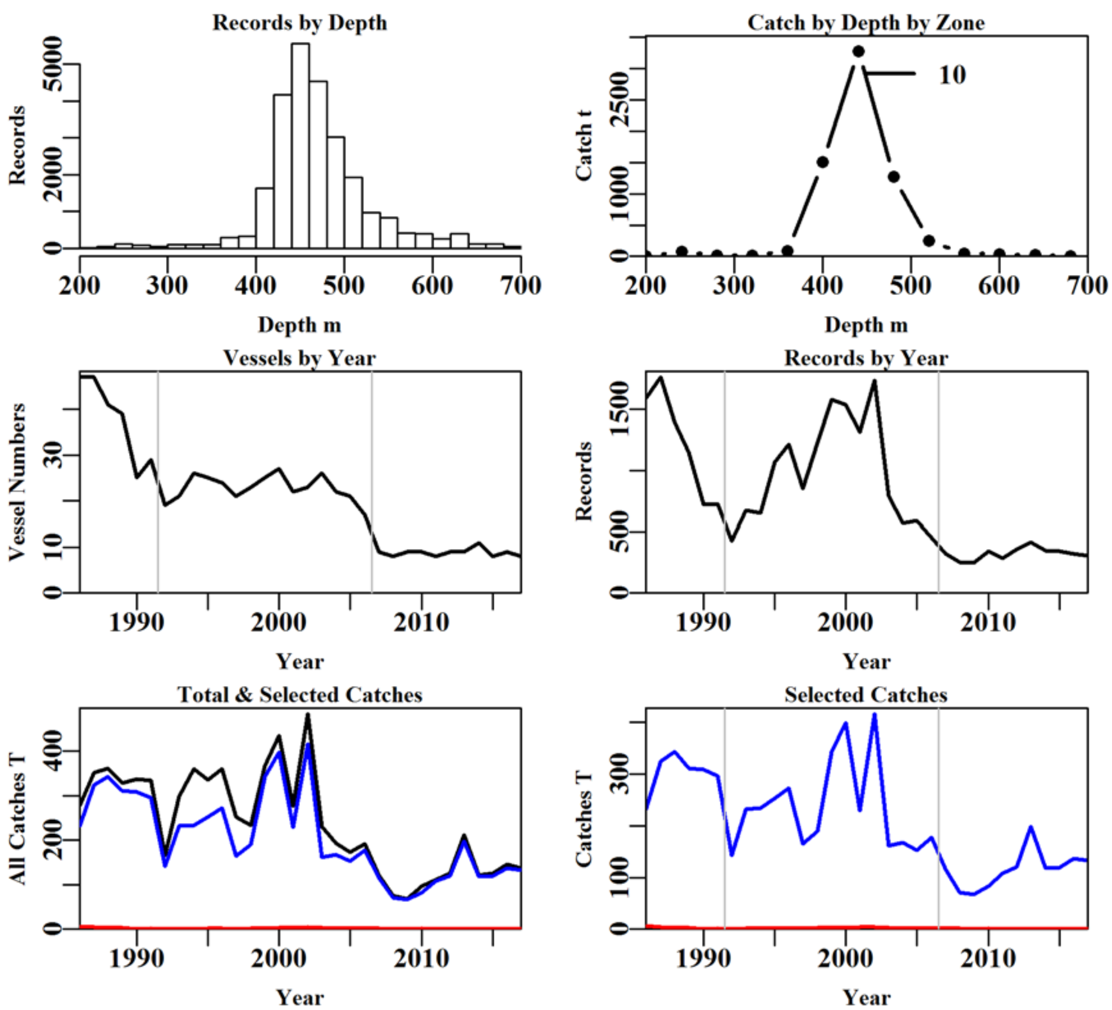


Figure 5.258. RoyalRedPrawn fishery details. The bottom left plot depicts all known catches (top black line), and all selected catches used in the analysis (middle blue line); the lower red line: selected catches < 30 kg).

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	40280	32848	32352	31875	25686	25561	25561
Difference	0	7432	496	477	6189	125	0
Catch	7797.921	7706.8508	7607.6469	7506.845	6658.0590	6619.644	6619.644
Difference	0.000	91.0706	99.2039	100.802	848.7859	38.415	0.000

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	14531	45017	2243	25561	32	4.6	0.00
DepCat	9703	37234	10026	25561	44	21.1	16.45
Vessel	3697	29238	18022	25561	131	37.8	16.74
Month	1974	27308	19952	25561	142	41.9	4.08
DayNight	1781	27096	20164	25561	145	42.3	0.44
DayNight:DepCat	1674	26913	20346	25561	178	42.7	0.31
Month:DepCat	1271	26297	20963	25561	273	43.8	1.42
DayNight:Month	1778	27025	20234	25561	177	42.4	0.08

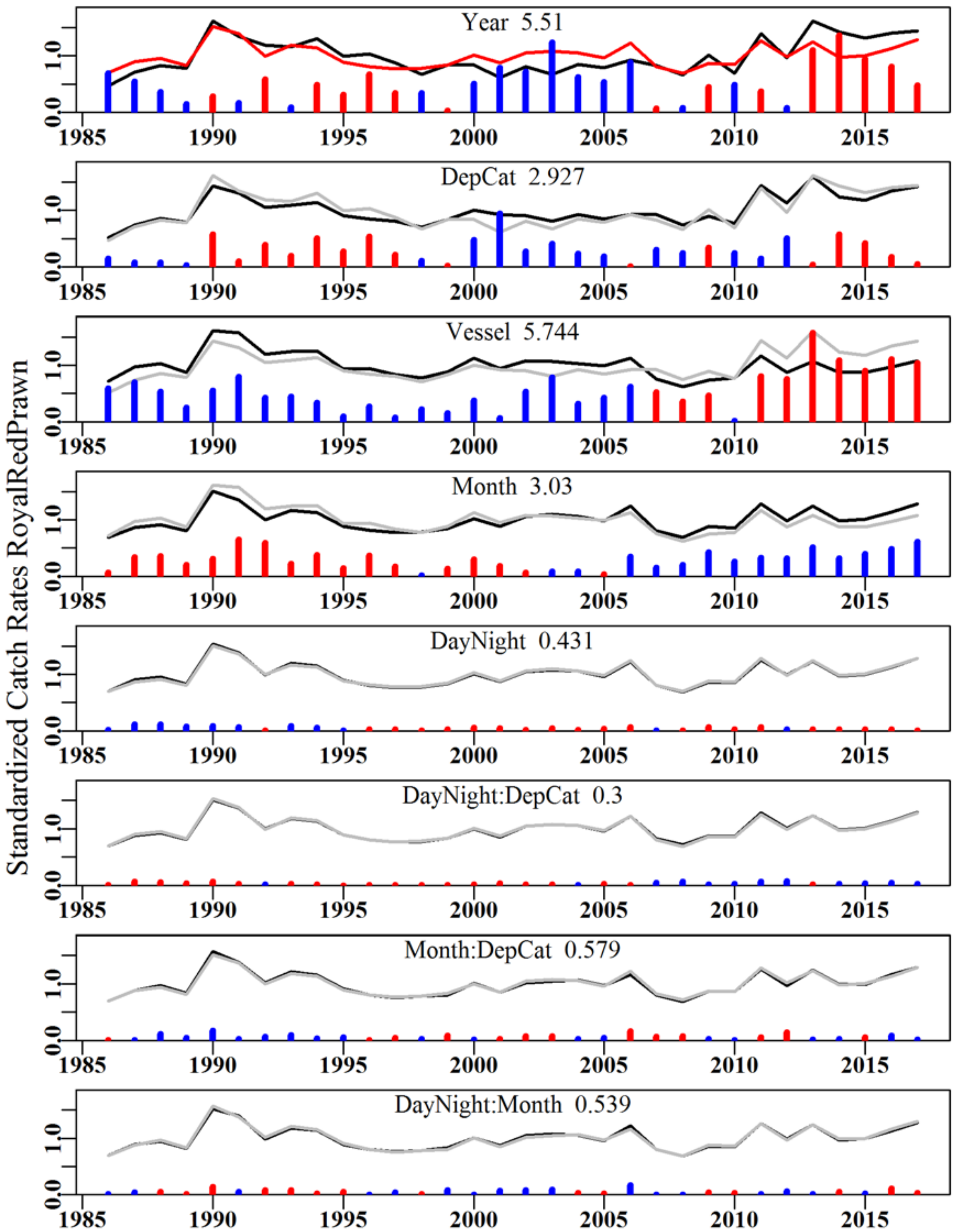


Figure 5.259. RoyalRedPrawn. The influence of each factor on the optimal standardization. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by vertical bars with blue bars indicating the optimum model is higher than the 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.

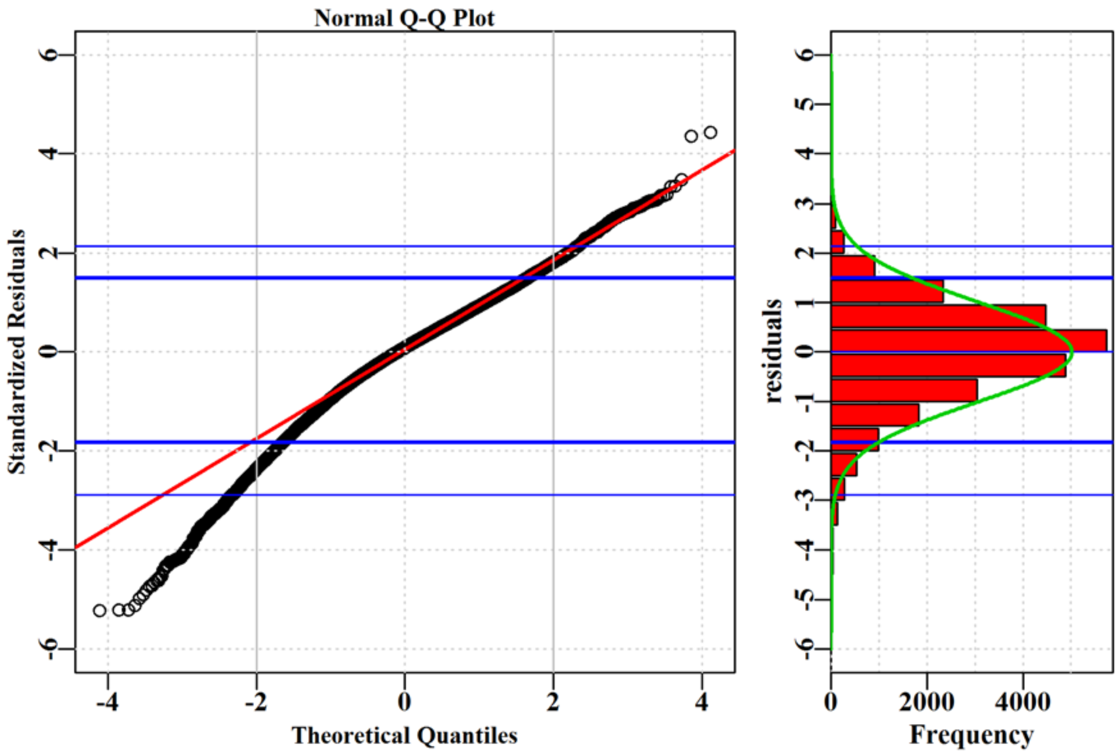


Figure 5.260. RoyalRedPrawn. diagnostic plots. The distribution of residuals from the optimum fit. The qqplot indicates the fit to the expected normality, while the histogram of residuals illustrates the 90% quantiles to indicate the intensity of any lack of fit at the margins of the distribution.

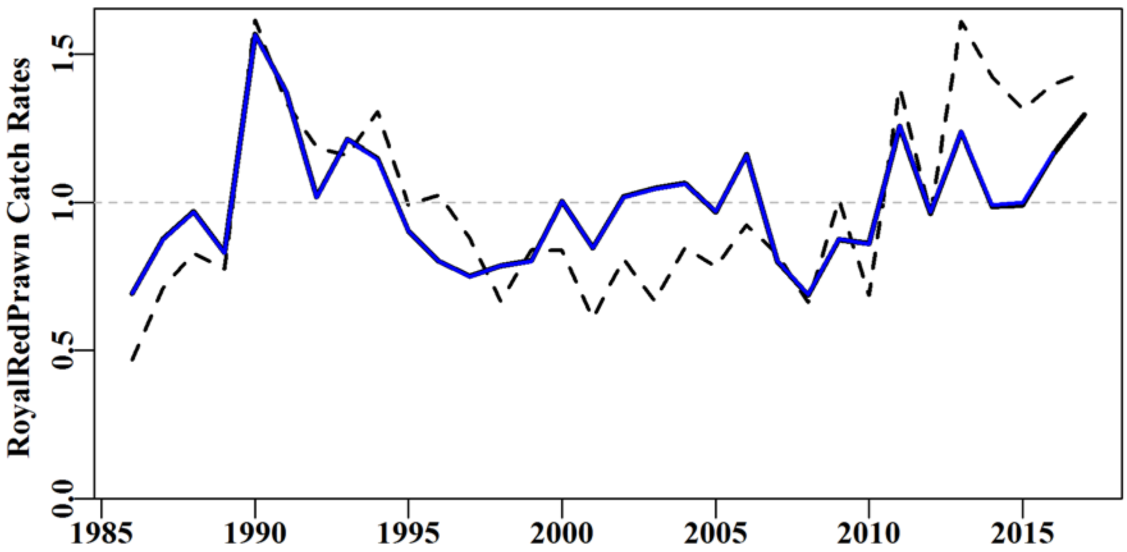


Figure 5.261. RoyalRedPrawn. A comparison of the previous year's standardization (blue line) with this year's. They should lie on top of each other, although small deviations may relate to data adjustments, particularly in very recent years.

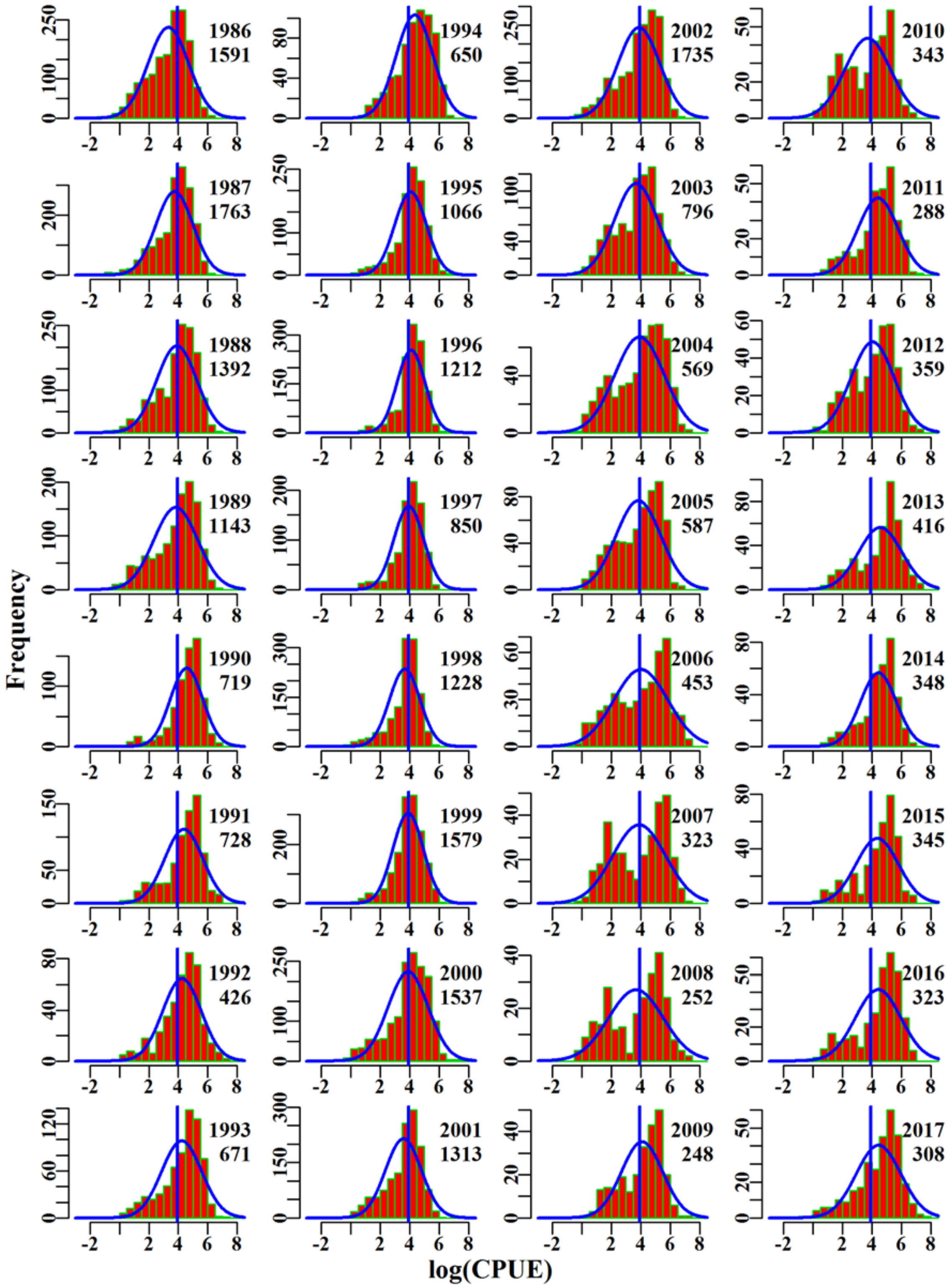


Figure 5.262. RoyalRedPrawn. The log(CPUE) for each year of data available the blue lines are normal distributions fitted to the histogram frequencies. The numbers in each plot are the year and number of records.

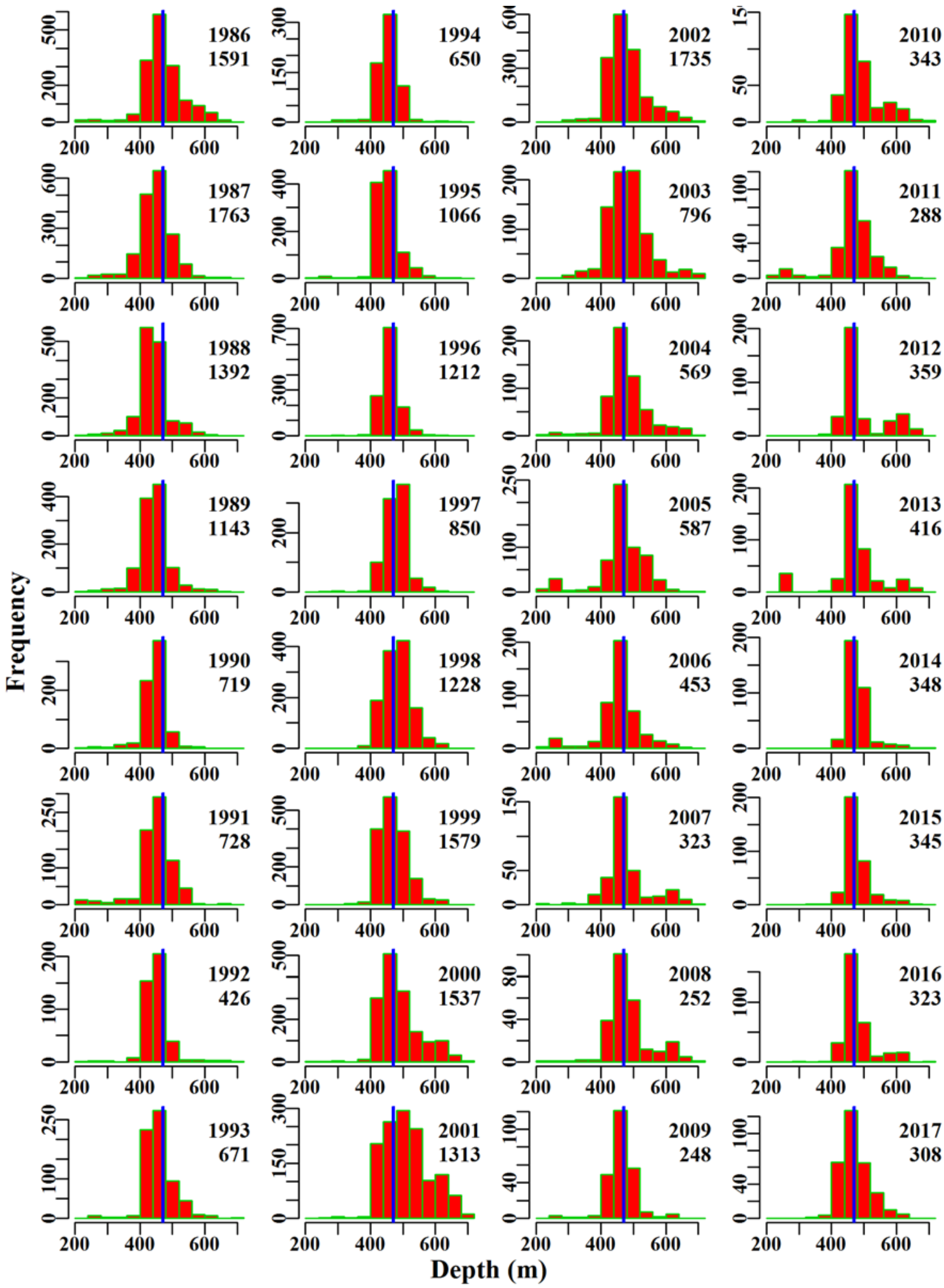


Figure 5.263. RoyalRedPrawn. The average Depth of fishing for each year of data available to illustrate the development of the fishery through time. The numbers in each plot are the year and number of records.

5.42 Eastern Gemfish NonSpawning

For non-spawning Eastern Gemfish (GEM – 37439002 – *Haliporoides sibogae*) in the SET, initial data selection was conducted according to the details 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 departure as depicted at the upper 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 - 2017

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	2.7126	0.000	13.705	0.035
1987	1027.6	1882	761.6	74	121.6	3.7294	0.043	9.656	0.013
1988	744.5	2187	497.2	77	64.7	3.0654	0.043	13.954	0.028
1989	306.7	1427	143.5	69	29.5	2.0137	0.048	13.936	0.097
1990	251.0	745	87.3	68	35.6	2.0249	0.058	5.730	0.066
1991	367.6	719	63.3	71	23.6	1.3483	0.059	7.059	0.111
1992	243.5	682	134.6	50	41.0	1.8660	0.060	4.859	0.036
1993	183.3	1521	93.7	58	20.2	1.4754	0.048	14.627	0.156
1994	148.2	1820	63.1	55	12.9	1.0234	0.046	18.222	0.289
1995	137.7	1683	49.9	54	11.5	0.9173	0.047	18.718	0.375
1996	223.7	1938	55.5	61	9.8	0.7143	0.046	18.655	0.336
1997	265.6	1775	65.3	58	9.5	0.7454	0.049	18.355	0.281
1998	238.8	1241	45.5	49	9.9	0.6991	0.051	12.901	0.283
1999	318.2	1342	30.3	53	7.2	0.5134	0.050	12.684	0.419
2000	248.6	1713	32.2	58	6.2	0.4610	0.048	15.019	0.466
2001	239.3	1636	32.1	50	4.7	0.3701	0.049	12.320	0.384
2002	146.9	1612	19.0	50	3.0	0.2859	0.049	10.864	0.571
2003	205.5	1574	20.0	48	3.7	0.3131	0.050	10.222	0.512
2004	454.9	1759	38.4	54	6.9	0.4396	0.049	12.383	0.322
2005	436.3	1711	40.4	48	7.3	0.4698	0.049	12.613	0.312
2006	425.6	1316	32.0	43	7.1	0.4953	0.052	10.140	0.317
2007	495.6	779	28.0	22	10.2	0.6608	0.059	5.844	0.209
2008	203.9	828	34.7	26	14.6	0.8836	0.058	6.769	0.195
2009	146.9	501	25.3	27	24.6	0.9141	0.068	3.767	0.149
2010	150.5	680	21.9	23	10.0	0.6585	0.061	5.334	0.244
2011	101.2	776	21.8	22	8.4	0.5987	0.060	5.621	0.258
2012	130.2	697	21.7	23	9.4	0.5706	0.062	4.917	0.227
2013	80.4	585	23.2	23	14.8	0.6443	0.066	4.098	0.177
2014	104.5	516	9.6	23	6.0	0.3788	0.068	3.437	0.356
2015	68.6	619	16.1	24	10.3	0.4202	0.065	3.447	0.214
2016	52.2	397	7.0	23	6.2	0.2750	0.075	2.472	0.355
2017	102.2	540	18.7	20	15.2	0.3118	0.069	3.037	0.162

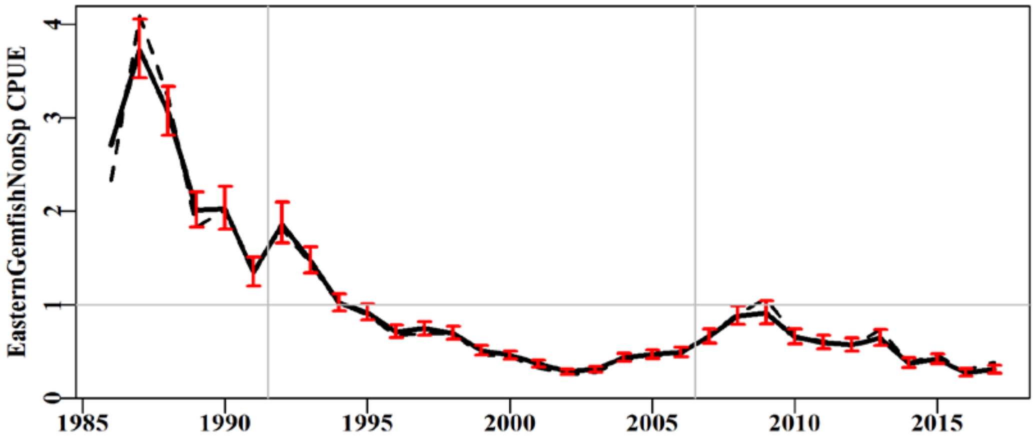


Figure 5.264. EasternGemfishNonSp standardization. The dashed black line represents the geometric mean catch rate, solid black line the standardized catch rates. The red bars are the 95% confidence intervals about the mean estimates. The graph scales both time-series of standardized catch rates relative to the mean of each time-series.

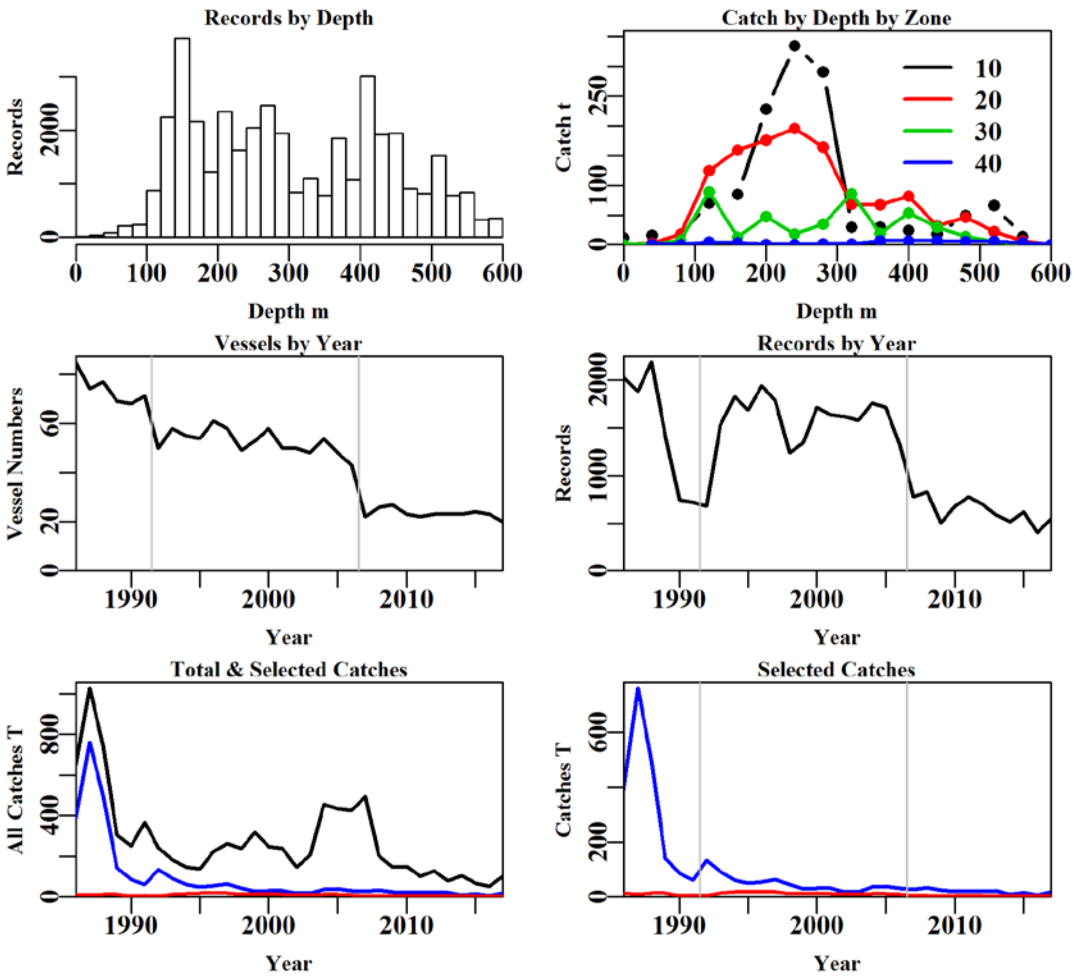


Figure 5.265. EasternGemfishNonSp fishery details. The bottom left plot depicts all known catches (top black line), and all selected catches used in the analysis (middle blue line); the lower red line: selected catches < 30 kg).

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	91917	81514	79587	77740	39982	39273	39229
Difference	0	10403	1927	1847	37758	709	44
Catch	9167.857	8911.1166	8710.6752	8453.909	2962.687	2924.96587	2922.3074
Difference	0.000	256.7401	200.4414	256.766	5491.222	37.72102	2.6585

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	25611	75238	23750	39229	32	23.9	0.00
Vessel	19647	64006	34982	39229	221	35.0	11.04
DepCat	17971	61282	37706	39229	236	37.7	2.74
Month	17450	60440	38547	39229	247	38.6	0.84
DayNight	17119	59923	39065	39229	250	39.1	0.52
Zone	16798	59426	39562	39229	253	39.6	0.50
Zone:DepCat	16253	58474	40513	39229	297	40.5	0.90
Zone:Month	16484	58852	40136	39229	286	40.1	0.53

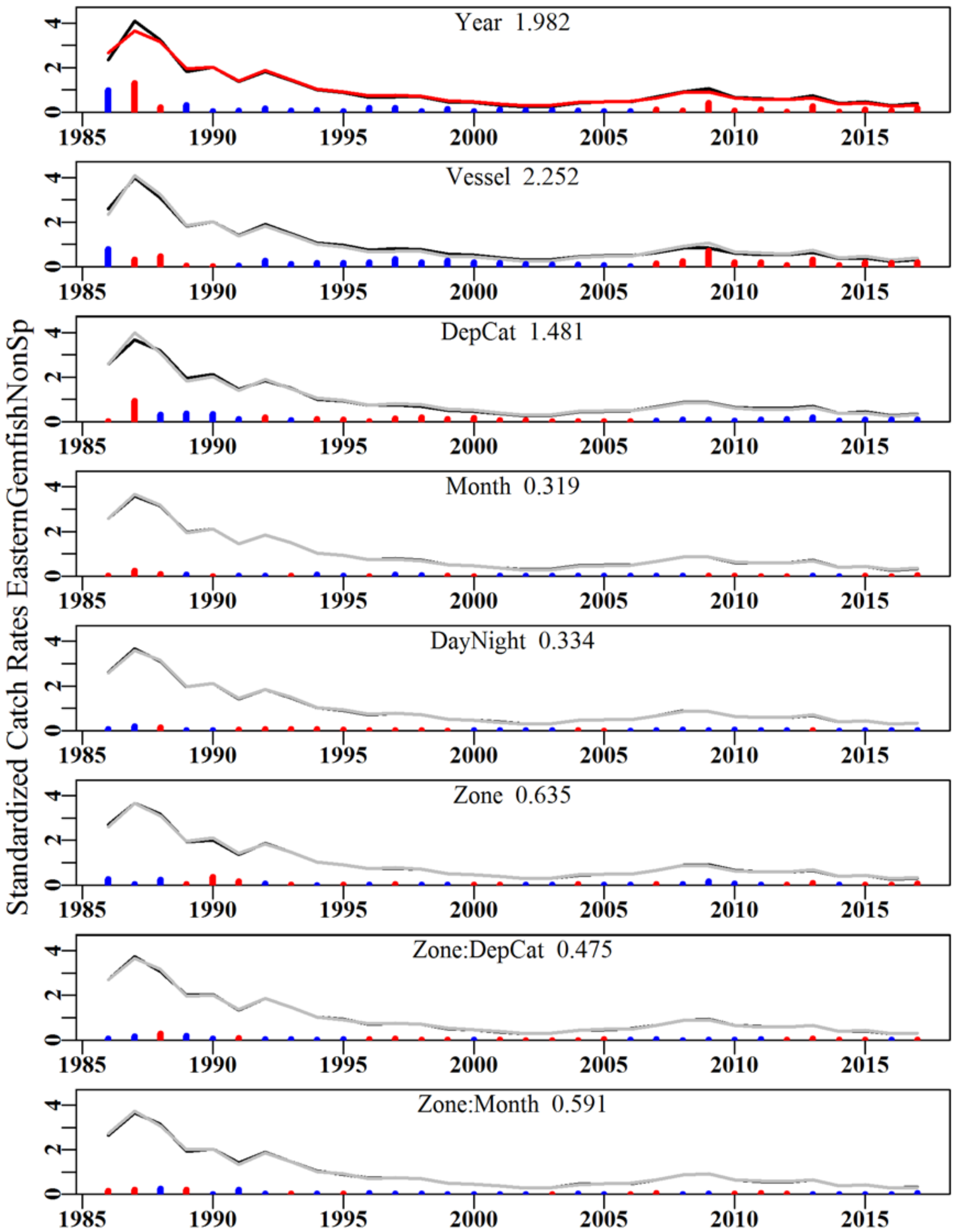


Figure 5.266. EasternGemfishNonSp. The influence of each factor on the optimal standardization. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by vertical bars with blue bars indicating the optimum model is higher than 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.

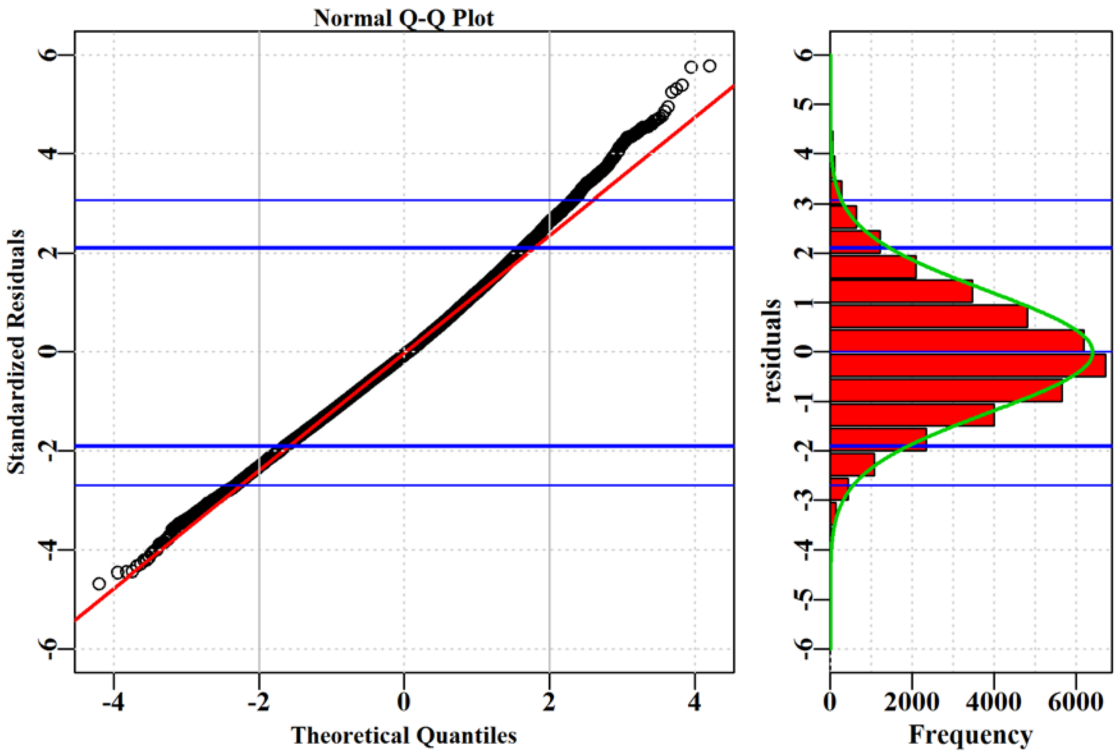


Figure 5.267. EasternGemfishNonSp. diagnostic plots. The distribution of residuals from the optimum fit. The qqplot indicates the fit to the expected normality, while the histogram of residuals illustrates the 90% quantiles to indicate the intensity of any lack of fit at the margins of the distribution.

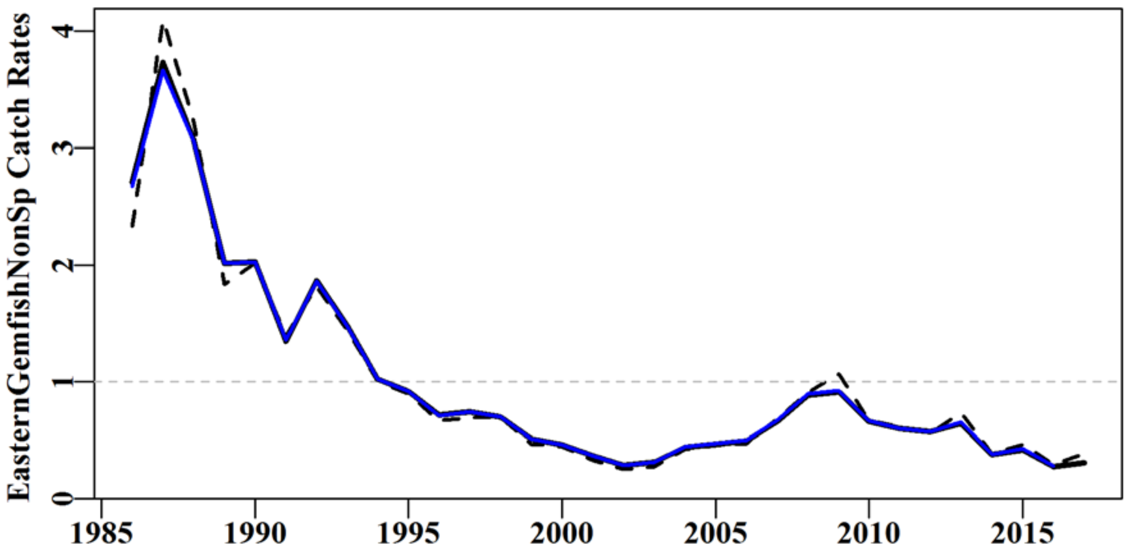


Figure 5.268. EasternGemfishNonSp. A comparison of the previous year's standardization (blue line) with this year's. They should lie on top of each other, although small deviations may relate to data adjustments, particularly in very recent years.

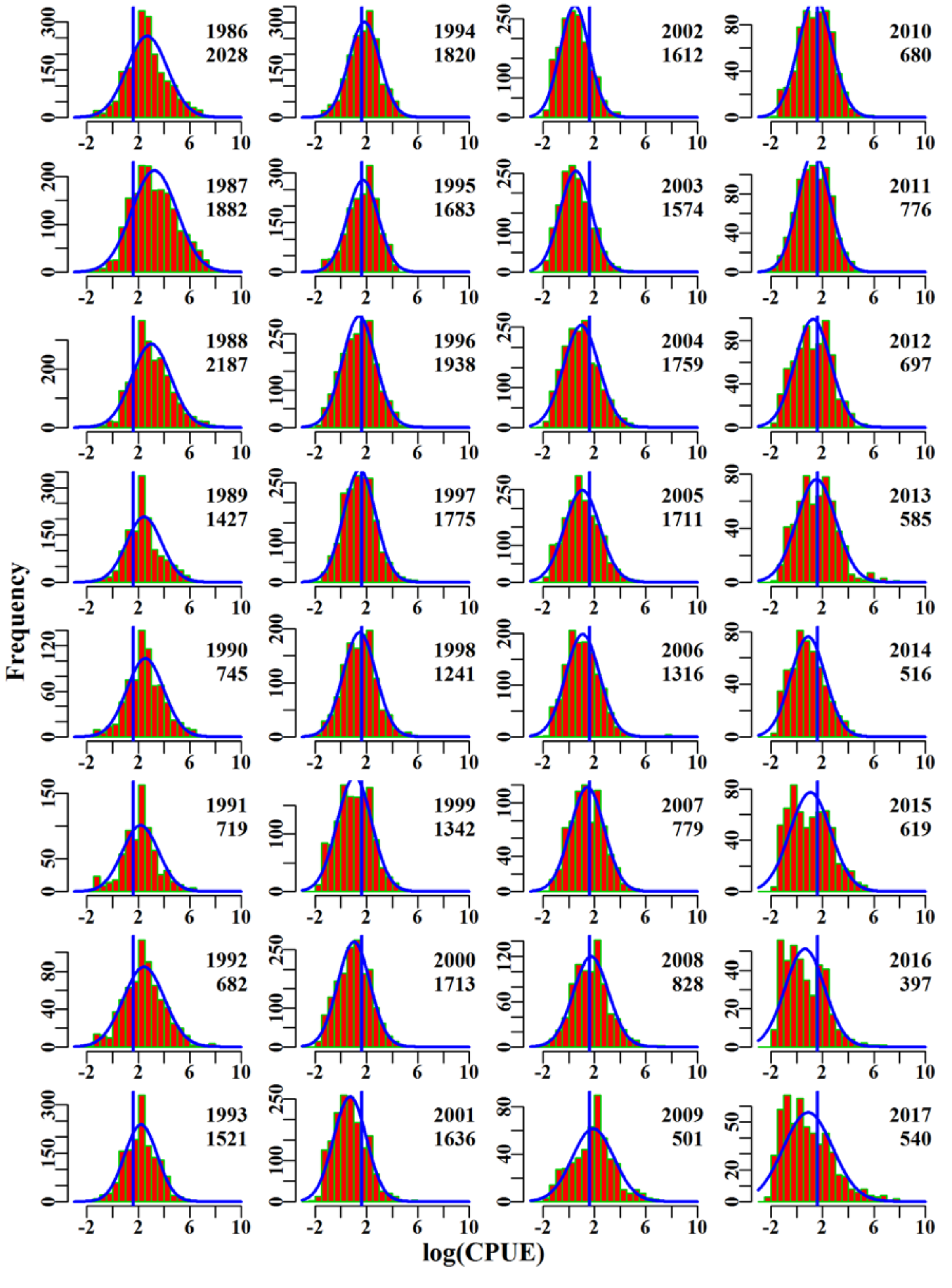


Figure 5.269. EasternGemfishNonSp. The log(CPUE) for each year of data available the blue lines are normal distributions fitted to the histogram frequencies. The numbers in each plot are the year and number of records.

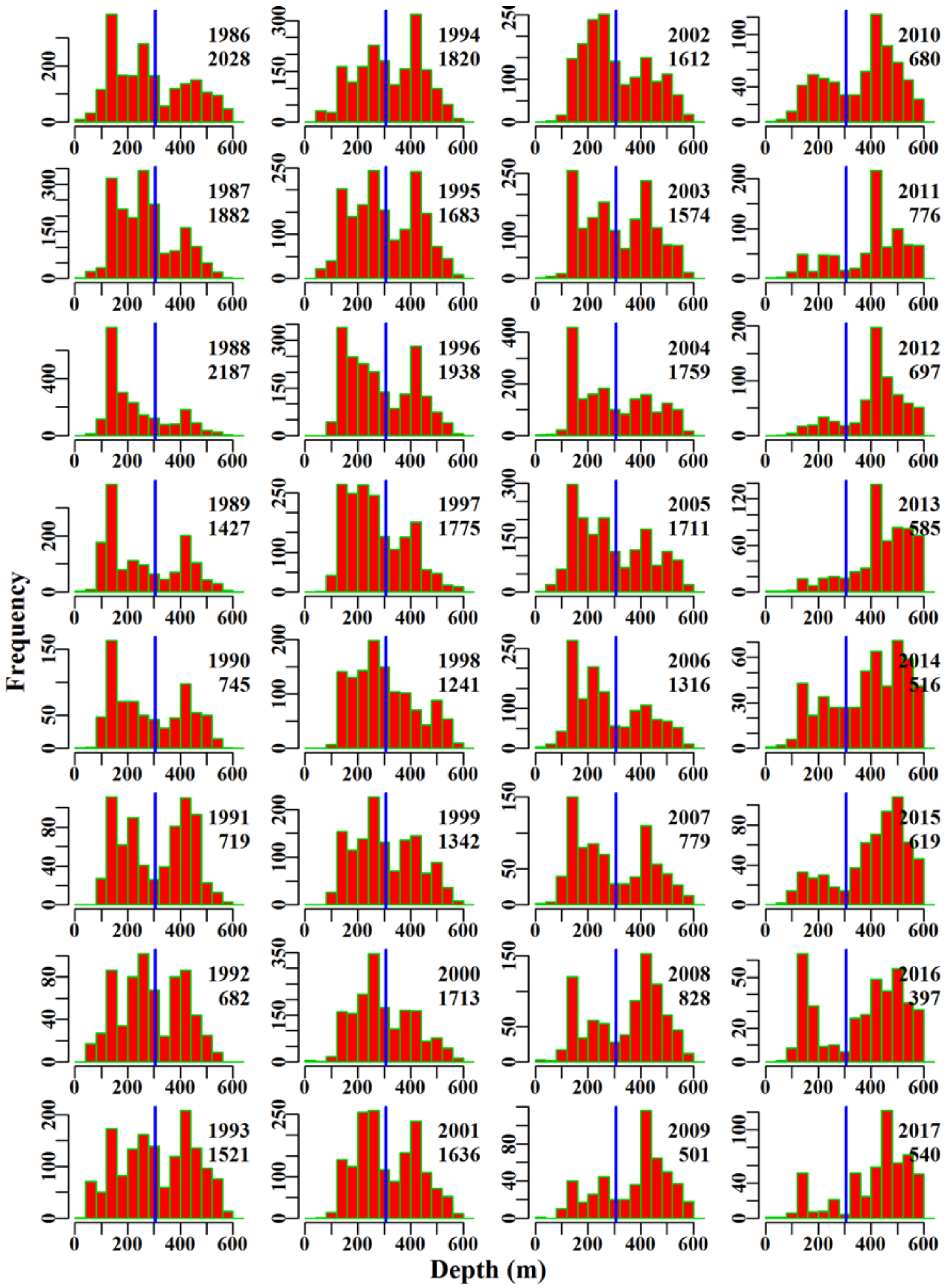


Figure 5.270. EasternGemfishNonSp. The average Depth of fishing for each year of data available to illustrate the development of the fishery through time. The numbers in each plot are the year and number of records.

5.43 Eastern Gemfish Spawning

Initial data selection for the Eastern Gemfish spawning run fishery (GEM - 37439002 - *Rexea collandri*) 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 2017 catch (5.6 t) corresponds to the lowest catch across the years analysed.

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 departure 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 2012 (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 sinse the past two years indicate, the 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 - 2017

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	2.3169	0.000	5.357	0.040
1994	97.2	814	48.6	47	22.1	1.5156	0.062	7.120	0.146
1995	57.2	657	21.9	48	12.1	1.0232	0.066	7.390	0.338
1996	197.6	768	135.1	49	35.3	1.2773	0.063	6.914	0.051
1997	342.5	1225	268.0	47	62.6	1.9094	0.059	7.393	0.028
1998	188.9	879	144.6	46	40.5	1.2713	0.063	7.610	0.053
1999	168.5	1064	87.9	45	21.7	1.0468	0.061	10.350	0.118
2000	103.4	1176	37.0	44	9.9	0.7076	0.061	11.959	0.323
2001	102.6	853	32.7	47	11.7	0.7169	0.065	8.229	0.252
2002	54.1	922	22.4	42	7.3	0.5185	0.064	8.882	0.396
2003	75.0	959	31.5	48	10.7	0.7293	0.063	8.516	0.270
2004	220.2	625	19.7	44	9.8	0.6921	0.071	5.296	0.269
2005	143.2	635	21.4	40	10.2	0.6158	0.069	5.958	0.278
2006	228.1	567	34.6	35	18.3	0.9622	0.072	4.245	0.123
2007	132.8	305	25.3	19	25.0	1.1824	0.087	1.730	0.068
2008	65.1	441	34.9	23	23.1	1.4382	0.079	3.376	0.097
2009	63.1	404	35.2	22	26.5	1.3330	0.080	3.176	0.090
2010	77.8	378	41.0	24	31.1	1.4382	0.081	2.484	0.061
2011	47.1	408	26.7	21	17.2	1.0142	0.079	3.392	0.127
2012	41.7	379	28.0	21	18.3	0.6601	0.083	3.279	0.117
2013	33.9	290	16.0	20	18.2	0.8393	0.088	2.873	0.179
2014	30.8	368	11.2	19	8.7	0.5945	0.082	3.000	0.267
2015	18.8	320	7.8	20	8.0	0.4552	0.087	2.591	0.333
2016	18.8	322	6.0	21	5.4	0.3384	0.087	2.635	0.439
2017	16.0	232	5.6	19	7.7	0.4033	0.098	1.825	0.328

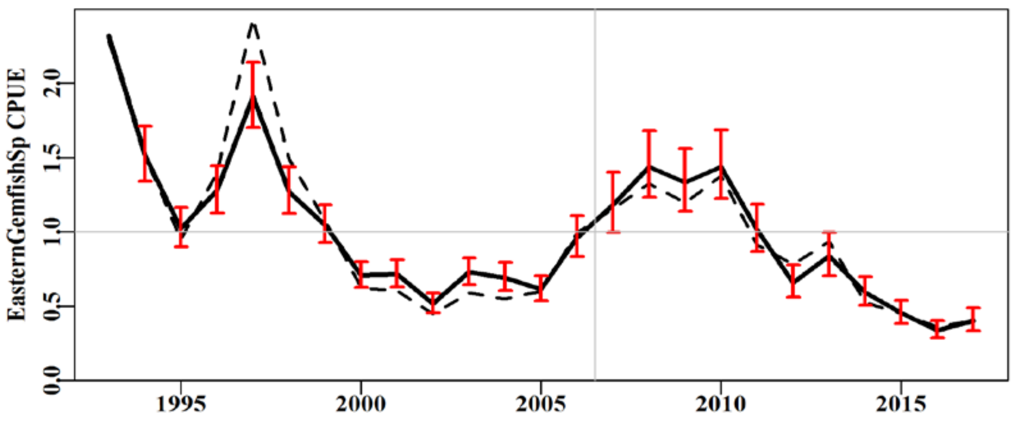


Figure 5.271. EasternGemfishSp standardization. The dashed black line represents the geometric mean catch rate, solid black line the standardized catch rates. The red bars are the 95% confidence intervals about the mean estimates. The graph scales both time-series of standardized catch rates relative to the mean of each time-series.

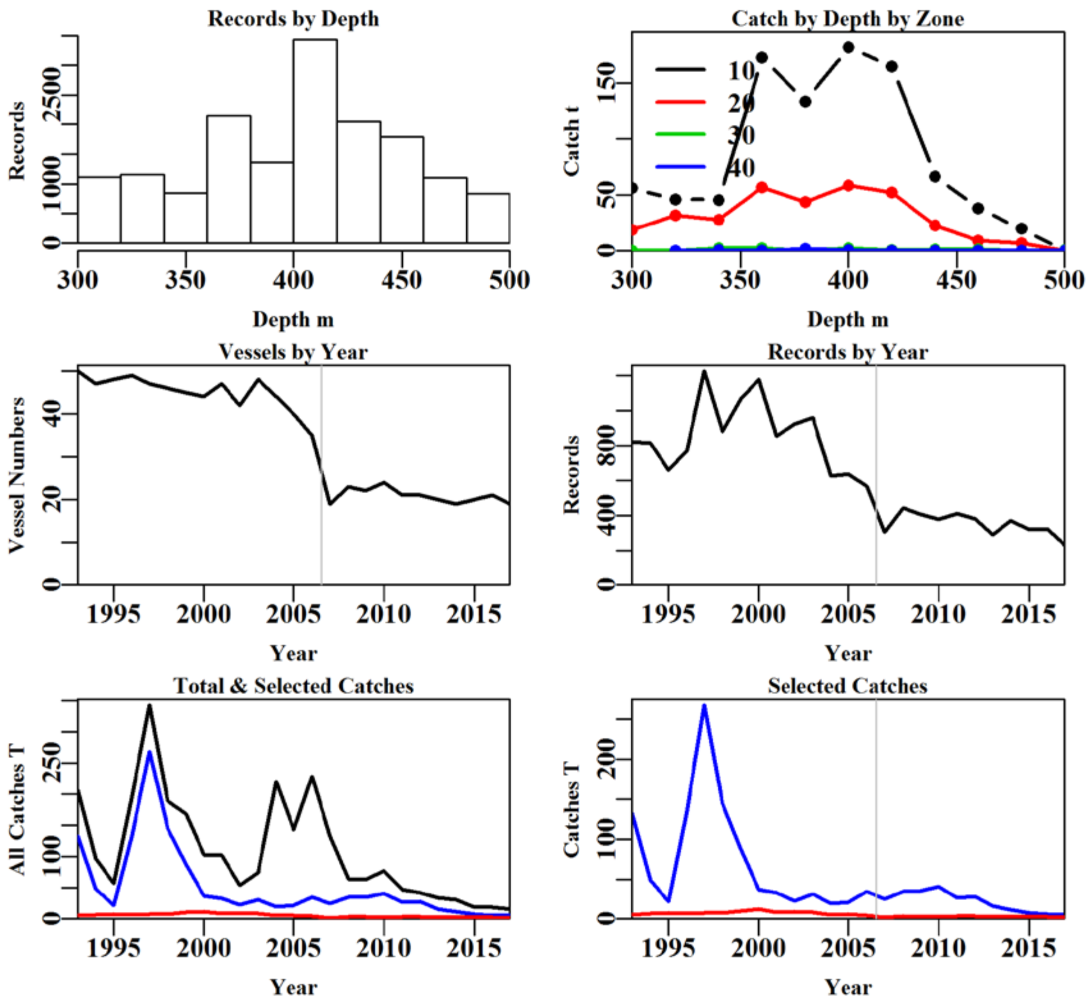


Figure 5.272. EasternGemfishSp fishery details. The bottom left plot depicts all known catches (top black line), and all selected catches used in the analysis (middle blue line); the lower red line: selected catches < 30 kg).

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	50325	45075	31543	20741	15940	15810	15810
Difference	0	5250	13532	10802	4801	130	0
Catch	16310.81	16056.2503	14078.487	2026.765	1295.5762	1276.04447	1276.044
Difference	0.00	254.5581	1977.763	12051.722	731.1889	19.53175	0.000

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	9095	28016	4561	15810	25	13.9	0.00
Vessel	7370	24781	7795	15810	132	23.3	9.42
Month	6511	23463	9114	15810	135	27.4	4.07
DepCat	6177	22942	9635	15810	145	28.9	1.57
DayNight	6073	22784	9793	15810	148	29.4	0.48
Zone	6070	22771	9806	15810	151	29.4	0.02
Zone:Month	5823	22393	10184	15810	160	30.6	1.13
Zone:DepCat	6061	22680	9897	15810	178	29.6	0.16

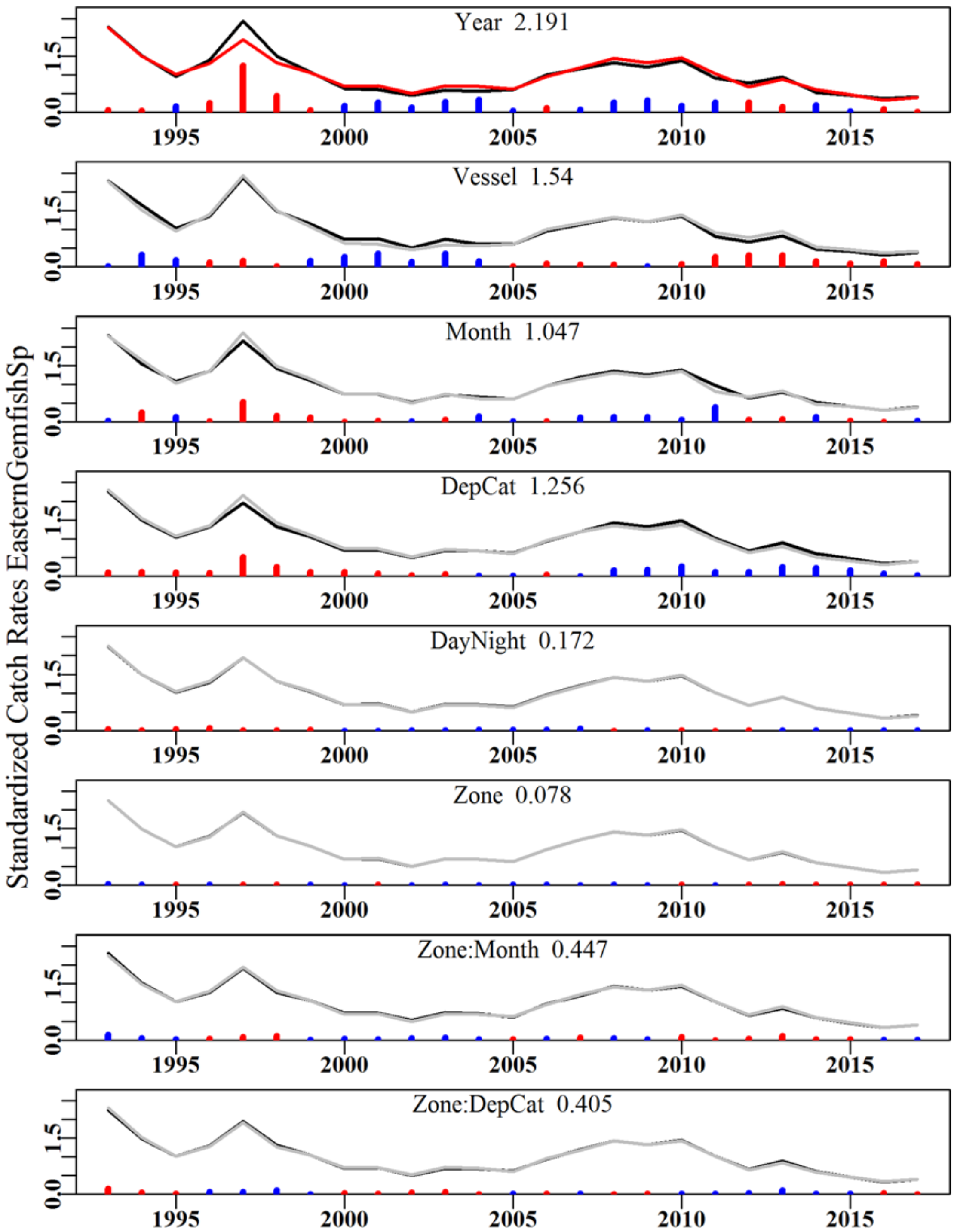


Figure 5.273. EasternGemfishSp. The influence of each factor on the optimal standardization. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by vertical bars with blue bars indicating the optimum model is higher than the 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.

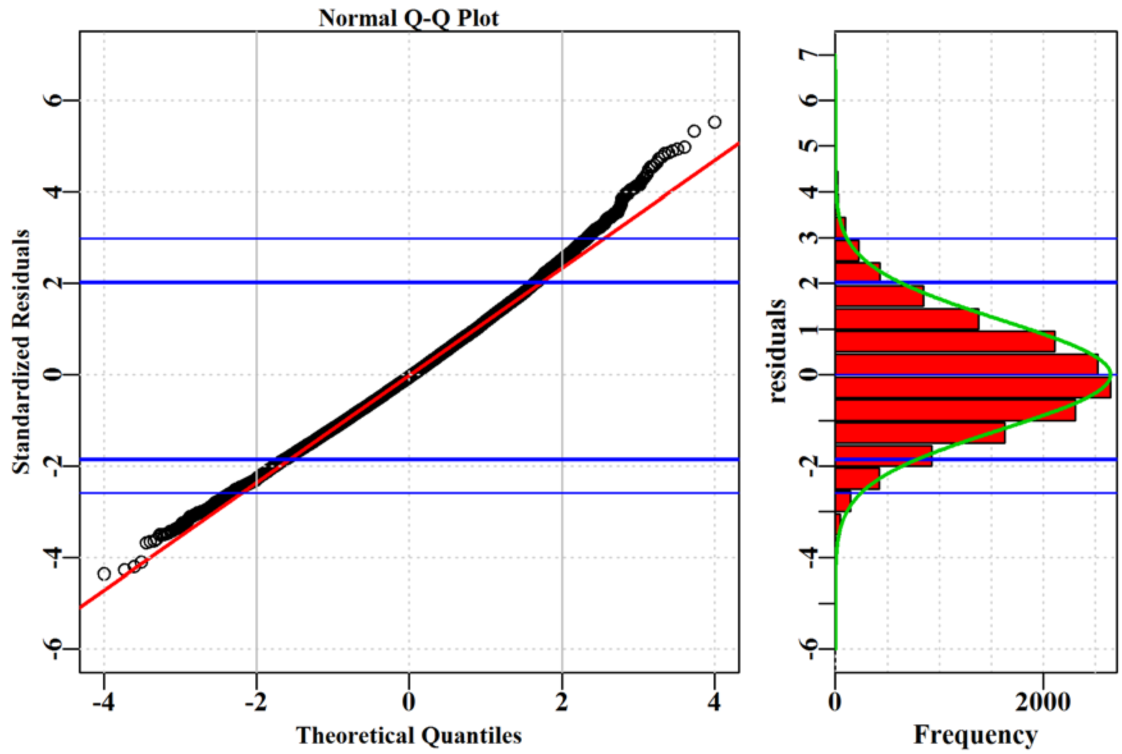


Figure 5.274. EasternGemfishSp. diagnostic plots. The distribution of residuals from the optimum fit. The qqplot indicates the fit to the expected normality, while the histogram of residuals illustrates the 90% quantiles to indicate the intensity of any lack of fit at the margins of the distribution.

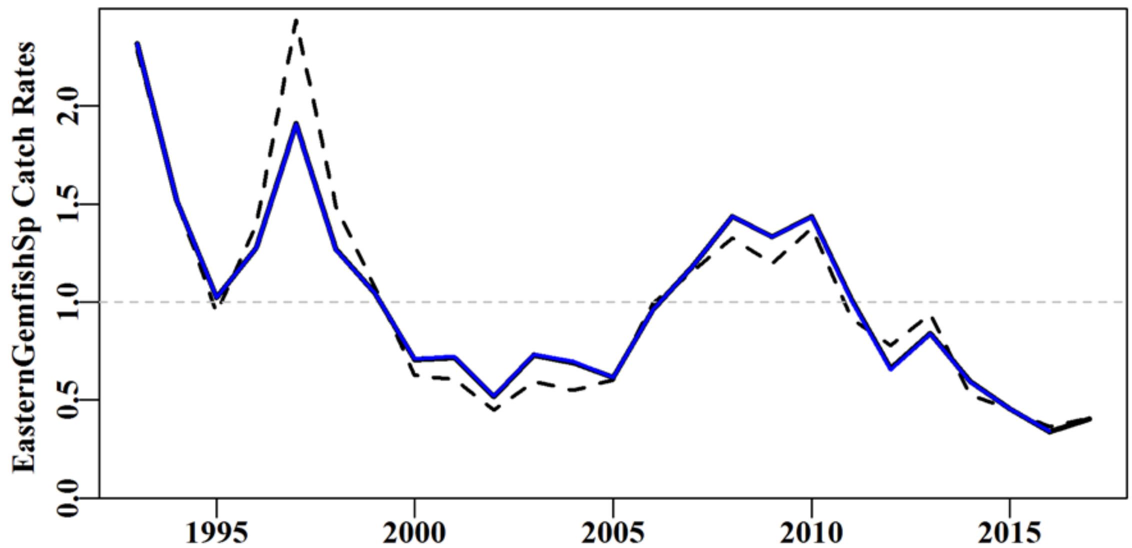


Figure 5.275. EasternGemfishSp. A comparison of the previous year's standardization (blue line) with this year's. They should lie on top of each other, although small deviations may relate to data adjustments, particularly in very recent years.

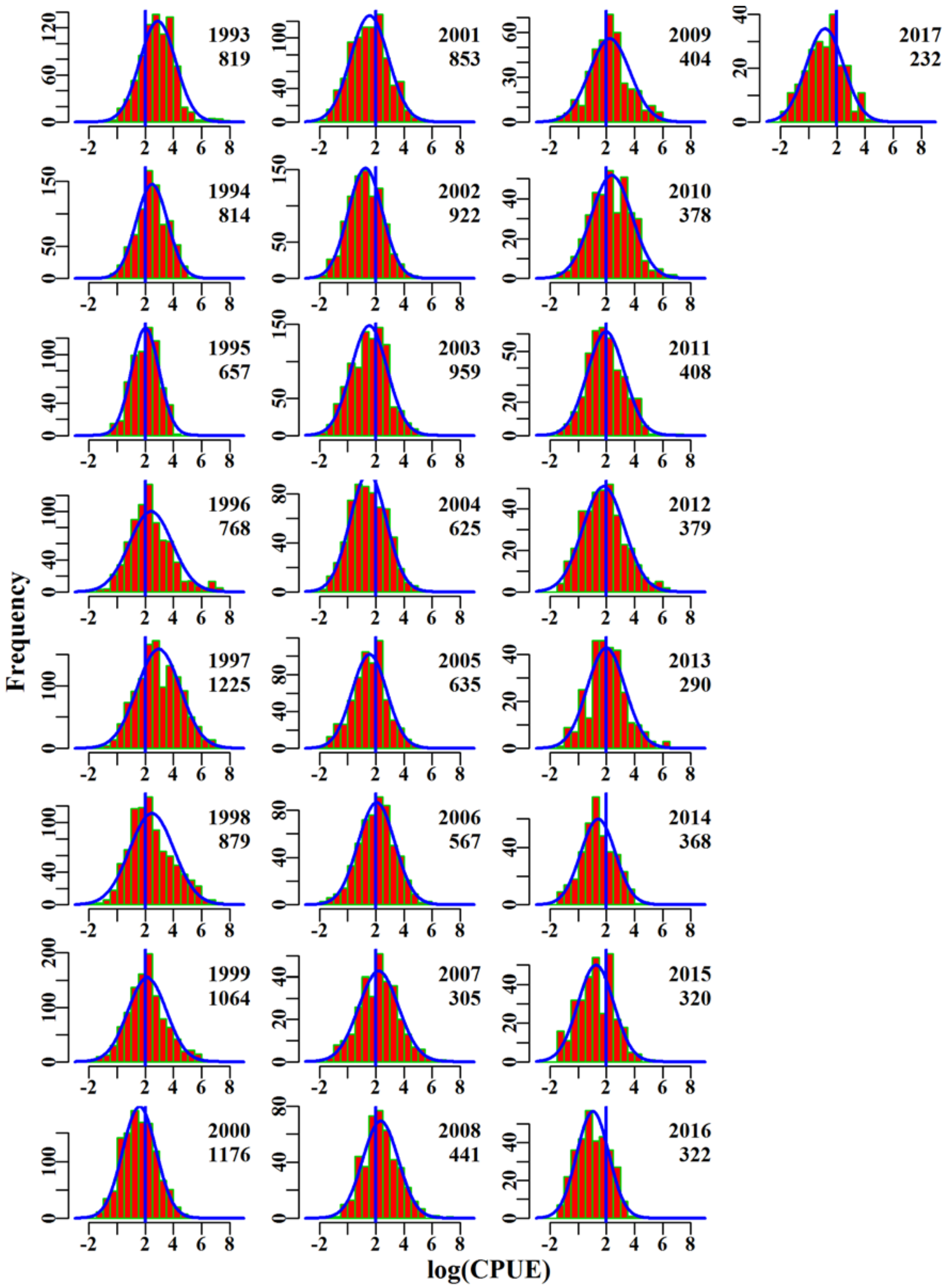


Figure 5.276. EasternGemfishSp. The log(CPUE) for each year of data available the blue lines are normal distributions fitted to the histogram frequencies. The numbers in each plot are the year and number of records.

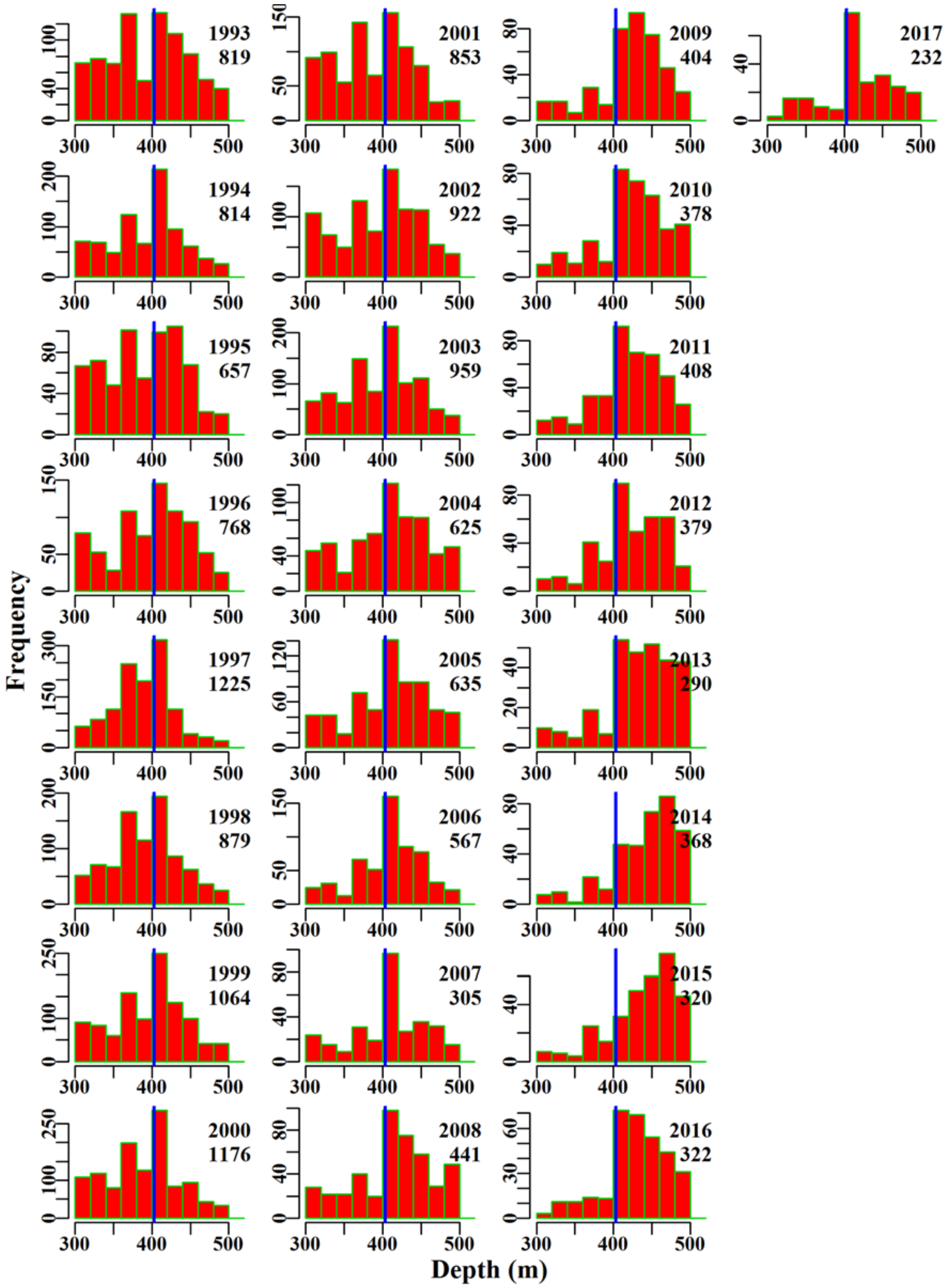


Figure 5.277. EasternGemfishSp. The average Depth of fishing for each year of data available to illustrate the development of the fishery through time. The numbers in each plot are the year and number of records.

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 majority of catch of this species occurred in zone 30, 20, 70, 40, 50 and minimal catches in the remaining zones.

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 upper 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 - 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. By contrast, both geometric mean and standardized CPUE in 2017 are similar. 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 - 2017

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	1.3664	0.000	0.138	0.257
1989	2.6	11	2.3	5	62.0	1.8266	0.650	0.120	0.052
1990	3.6	31	3.6	12	33.7	1.7393	0.593	0.352	0.097
1991	5.7	68	5.3	22	30.9	0.6650	0.564	0.962	0.182
1992	18.7	72	17.8	18	96.6	1.3503	0.529	0.565	0.032
1993	5.2	68	5.0	15	25.3	1.2644	0.548	0.826	0.164
1994	15.6	100	7.8	22	40.1	1.8819	0.547	1.137	0.146
1995	8.6	72	7.4	16	36.6	1.0084	0.558	0.834	0.113
1996	12.4	63	12.0	14	51.5	1.5024	0.563	0.727	0.061
1997	11.8	65	7.5	16	24.5	1.0377	0.565	0.805	0.107
1998	6.8	62	3.4	11	22.9	1.9339	0.571	0.501	0.146
1999	55.0	163	8.3	20	22.1	1.4885	0.549	1.971	0.238
2000	504.6	177	35.3	21	88.3	1.3632	0.553	2.463	0.070
2001	337.9	144	5.6	24	17.3	0.8036	0.553	1.948	0.350
2002	2643.0	222	24.9	31	153.3	1.0132	0.549	1.786	0.072
2003	1819.6	126	6.0	24	18.0	0.7940	0.554	1.589	0.264
2004	1411.3	172	16.1	27	19.7	0.9597	0.551	1.448	0.090
2005	445.2	161	7.9	24	23.6	0.8975	0.549	1.366	0.174
2006	458.4	223	11.0	22	29.8	1.0851	0.547	1.893	0.172
2007	530.2	205	8.5	13	15.4	1.1739	0.548	1.774	0.209
2008	260.2	359	48.2	13	37.6	1.1673	0.543	3.158	0.065
2009	98.8	336	15.3	14	24.2	0.8448	0.544	3.030	0.197
2010	57.9	261	8.8	16	10.1	0.5101	0.547	1.798	0.204
2011	807.2	229	4.3	15	4.6	0.4186	0.547	1.712	0.401
2012	616.1	131	1.9	14	4.3	0.3428	0.553	0.826	0.436
2013	225.6	95	3.7	14	8.5	0.2984	0.557	0.793	0.214
2014	85.0	100	5.9	12	85.4	0.3996	0.556	0.703	0.120
2015	76.2	178	13.5	13	120.1	0.3761	0.550	0.731	0.054
2016	23.3	96	3.2	10	18.9	0.2066	0.558	0.321	0.100
2017	8.2	136	6.1	12	27.8	0.2804	0.553	0.740	0.122

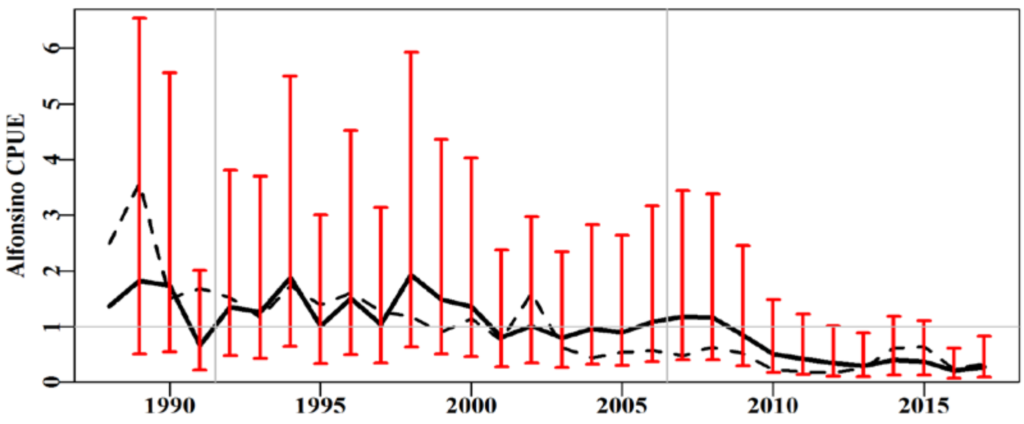


Figure 5.278. Alfonsino standardization. The dashed black line represents the geometric mean catch rate, solid black line the standardized catch rates. The red bars are the 95% confidence intervals about the mean estimates. The graph scales both time-series of standardized catch rates relative to the mean of each time-series.

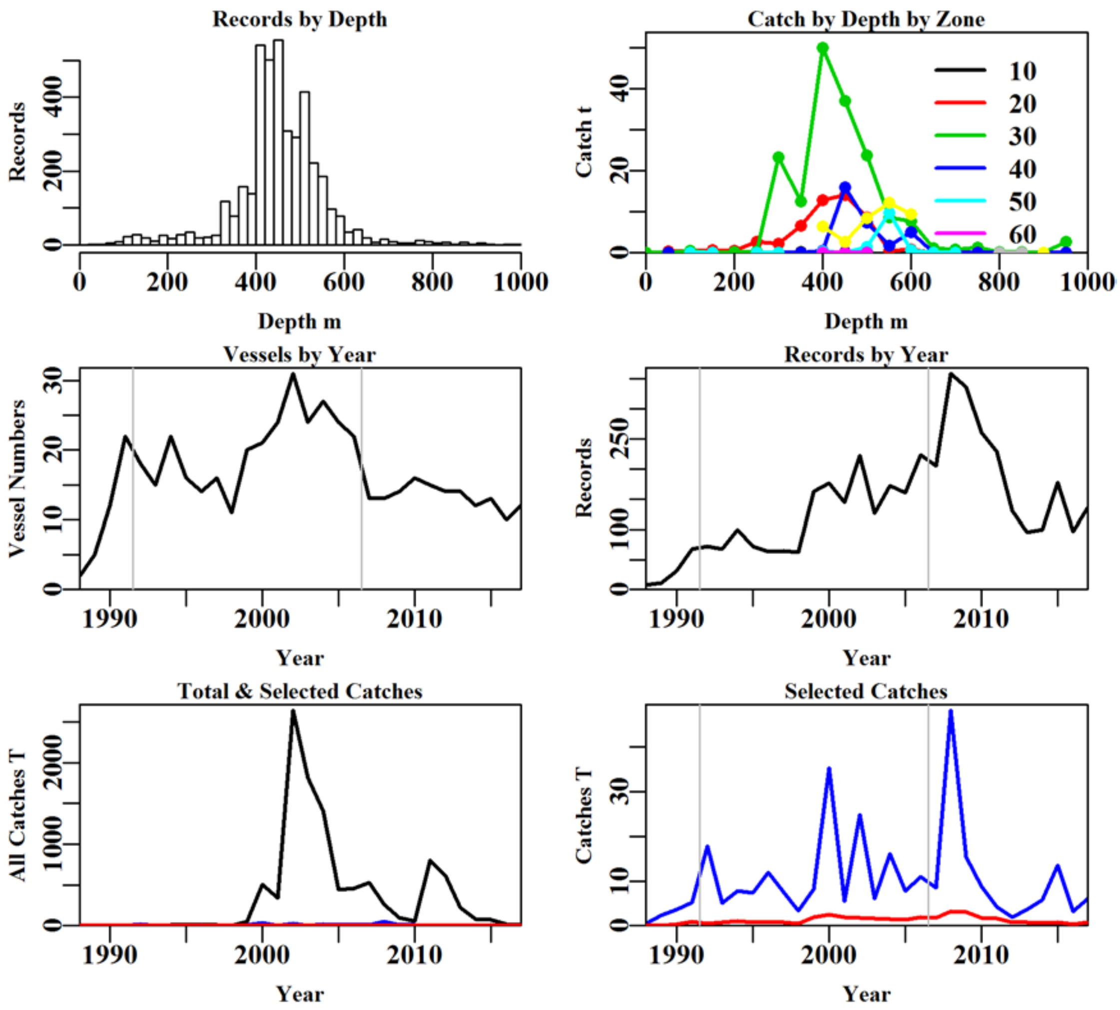


Figure 5.279. Alfonsino fishery details. The bottom left plot depicts all known catches (top black line), and all selected catches used in the analysis (middle blue line); the lower red line: selected catches < 30 kg).

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	13311	9577	9468	9421	6133	5756	4134
Difference	0	3734	109	47	3288	377	1622
Catch	10557.14	10472.63783	10361.8795	10360.770	1907.935	1899.3008	307.1445
Difference	0.00	84.49995	110.7583	1.109	8452.836	8.6337	1592.1563

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	4922	13402	1831	4134	30	11.4	0.00
Vessel	2724	7485	7748	4134	135	49.2	37.82
DepCat	2672	7323	7910	4134	154	50.1	0.86
Zone	2464	6941	8292	4134	161	52.6	2.52
DayNight	2437	6889	8344	4134	163	52.9	0.33
Month	2380	6759	8474	4134	174	53.7	0.76
Zone:DepCat	2338	6508	8725	4134	231	54.8	1.07

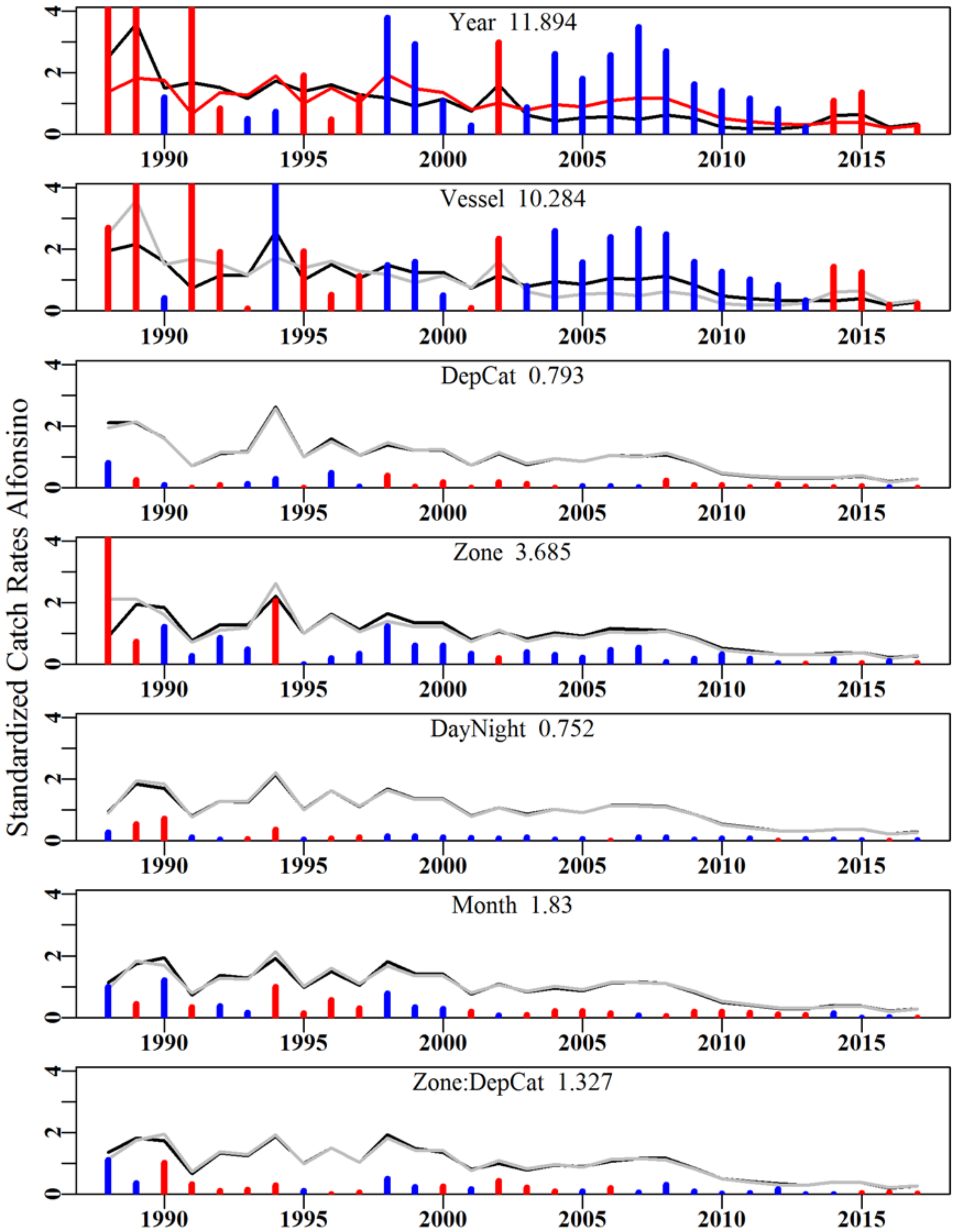


Figure 5.280. Alfonsino. The influence of each factor on the optimal standardization. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by vertical bars with blue bars indicating the optimum model is higher than the geometric 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.

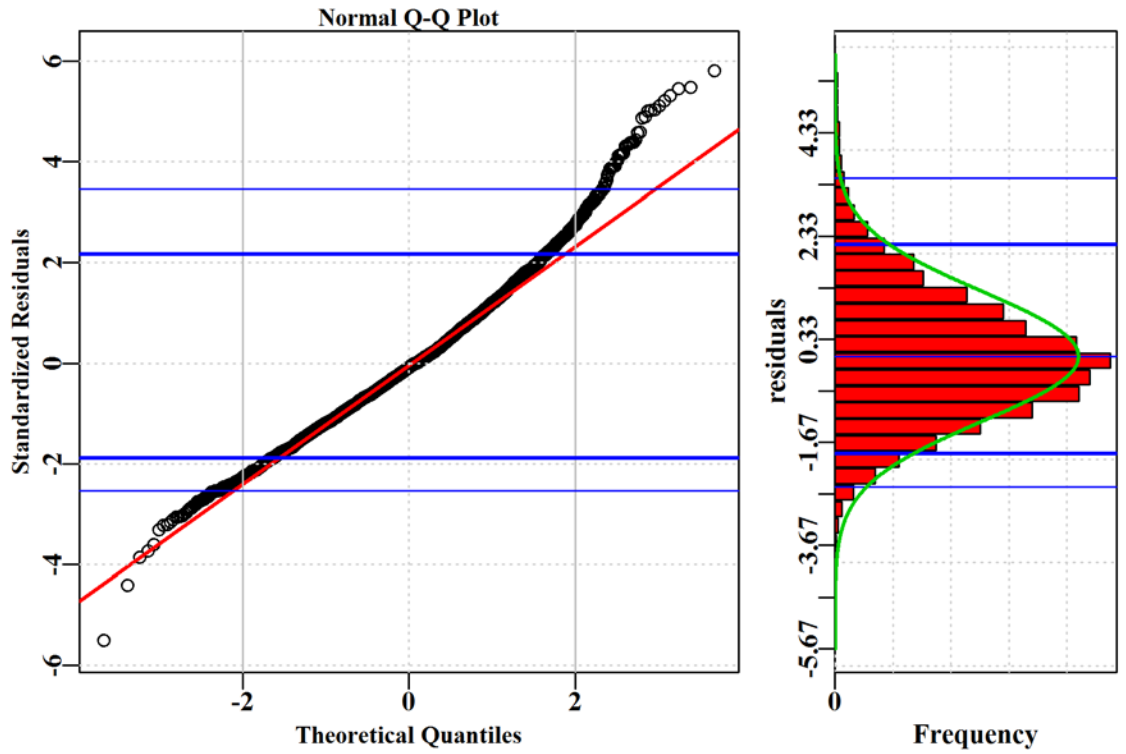


Figure 5.281. Alfonsino. diagnostic plots. The distribution of residuals from the optimum fit. The qqplot indicates the fit to the expected normality, while the histogram of residuals illustrates the 90% quantiles to indicate the intensity of any lack of fit at the margins of the distribution.

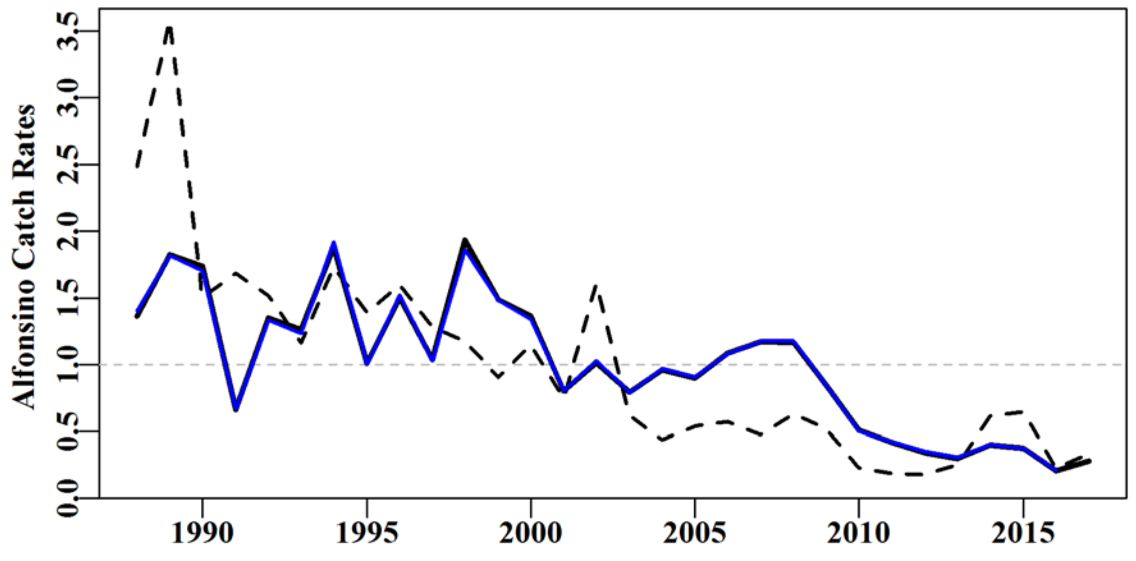


Figure 5.282. Alfonsino. A comparison of the previous year's standardization (blue line) with this year's. They should lie on top of each other, although small deviations may relate to data adjustments, particularly in very recent years.

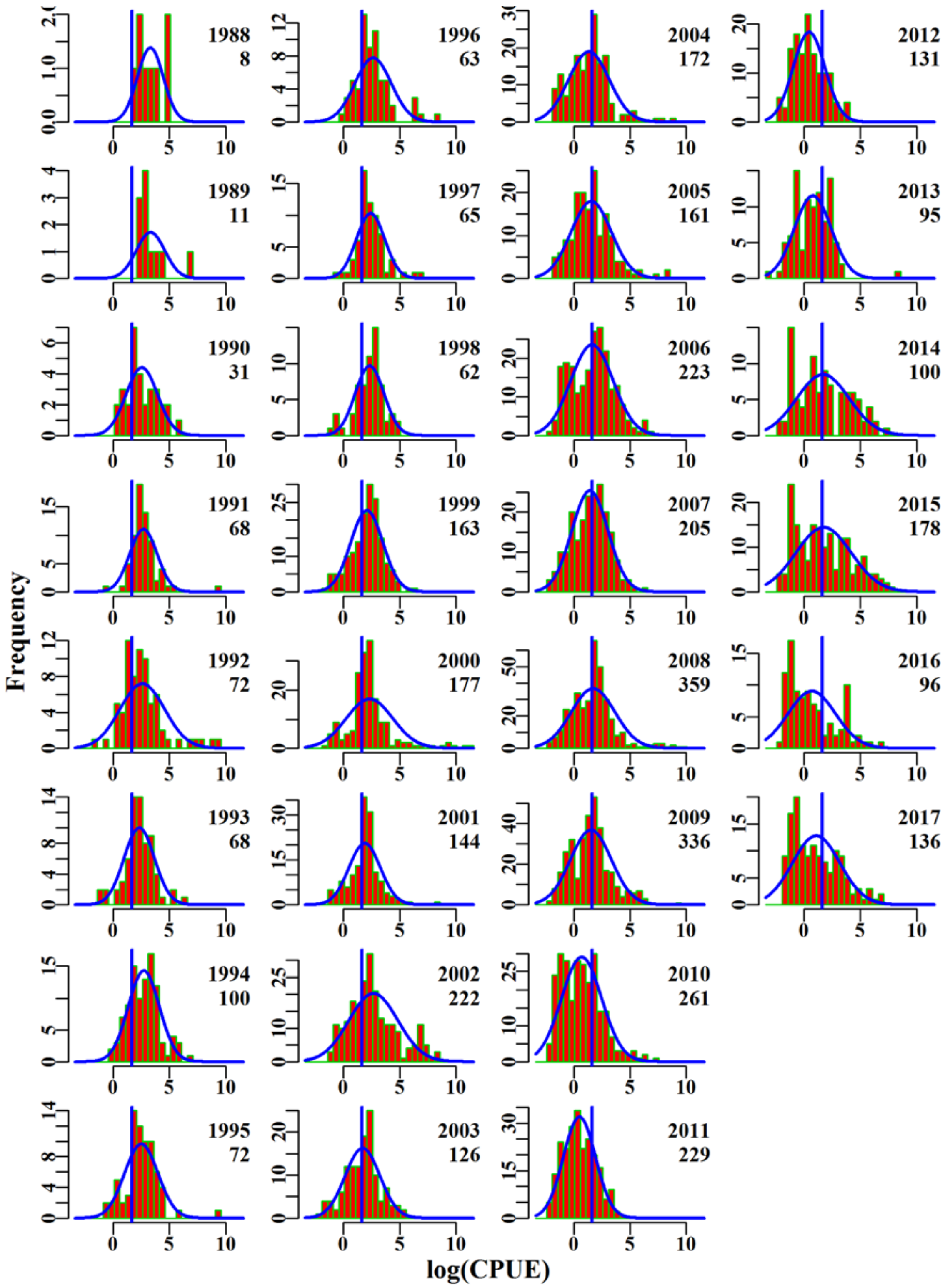


Figure 5.283. Alfonsino. The log(CPUE) for each year of data available the blue lines are normal distributions fitted to the histogram frequencies. The numbers in each plot are the year and number of records.

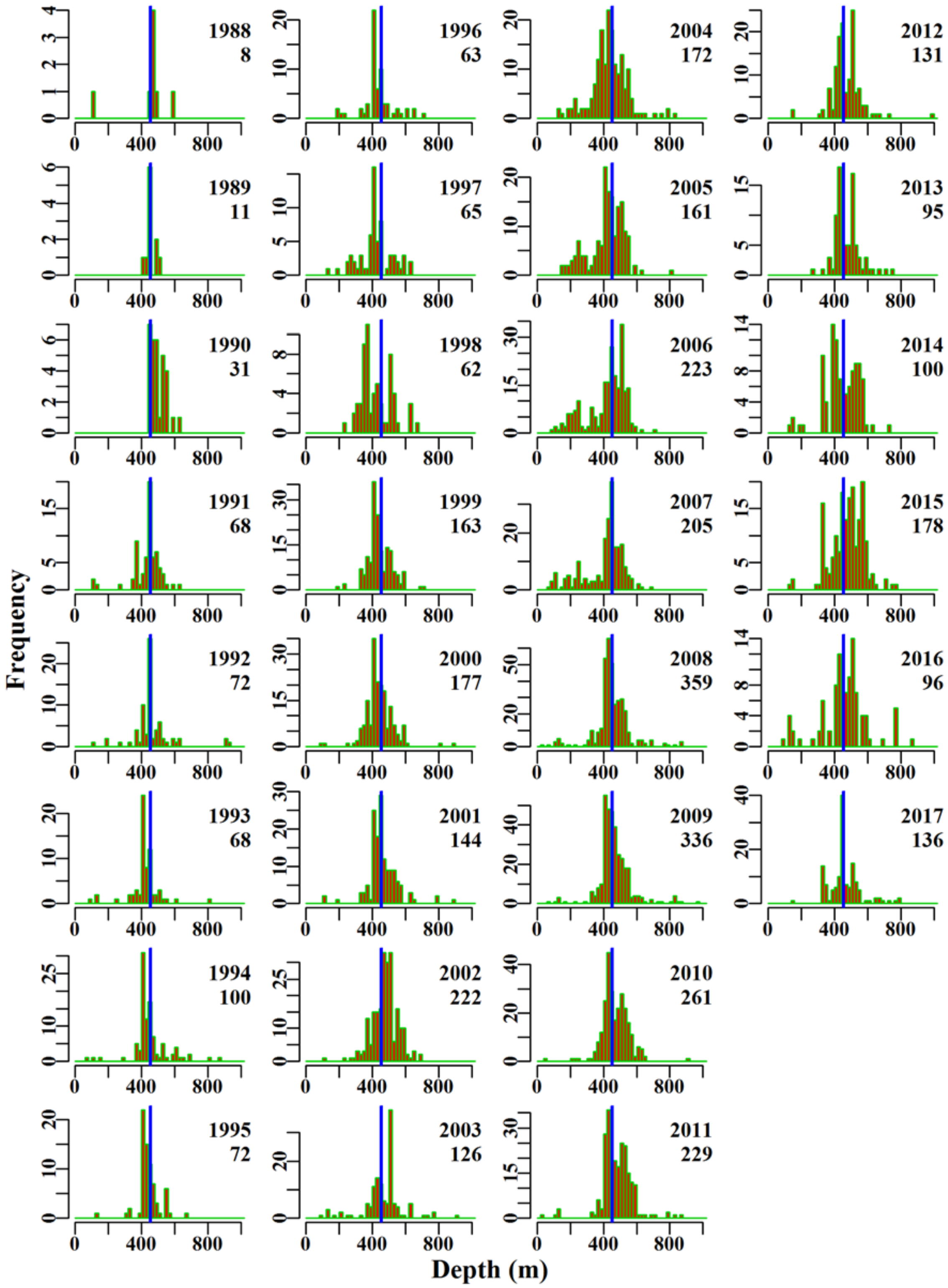


Figure 5.284. Alfonsino. The average Depth of fishing for each year of data available to illustrate the development of the fishery through time. The numbers in each plot are the year and number of records.

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.

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6. Statistical CPUE (catch-per-hook) Standardizations for Blue-Eye Trevalla (Auto-line and Drop line) in the SESSF (data to 2017)

Miriana Sporcic and Malcolm Haddon

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

6.1 Executive Summary

This report is an update of standardized CPUE (catch per hook) indices for Blue-Eye Trevalla which includes data in 2017 based on the same method proposed in Haddon and Sporcic (2017).

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 that depend 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 over-laps 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 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.

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 juveniles stages are widely dispersed. Not only is it patchily distributed but the fishery differs markedly by area through the application of different methods and histories of exploitation. The differences in exploitation history along with sampling different areas in different years may have been sufficient to have led to the appearance of heterogeneity in the biological characteristics of different populations. There is little consistency between consecutive years in the age structure and length structure of samples (Figure 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	249.571	342	61.503	171	52.961	425

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 (gen-erally 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).

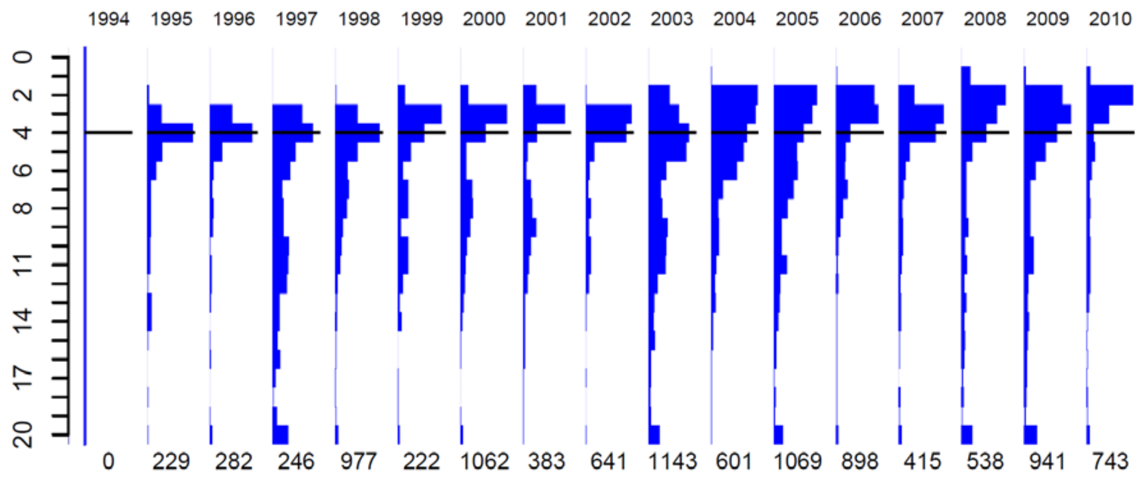

Figure 6.1. Age distributions sampled from the catches of Blue-Eye (*Hyperoglyphe antarctica*) for the years 1995 - 2010 (Thomson et al, 2016). The sample sizes in the bottom row of numbers should be sufficient to provide a good representation if the stock were homogeneous in its properties.

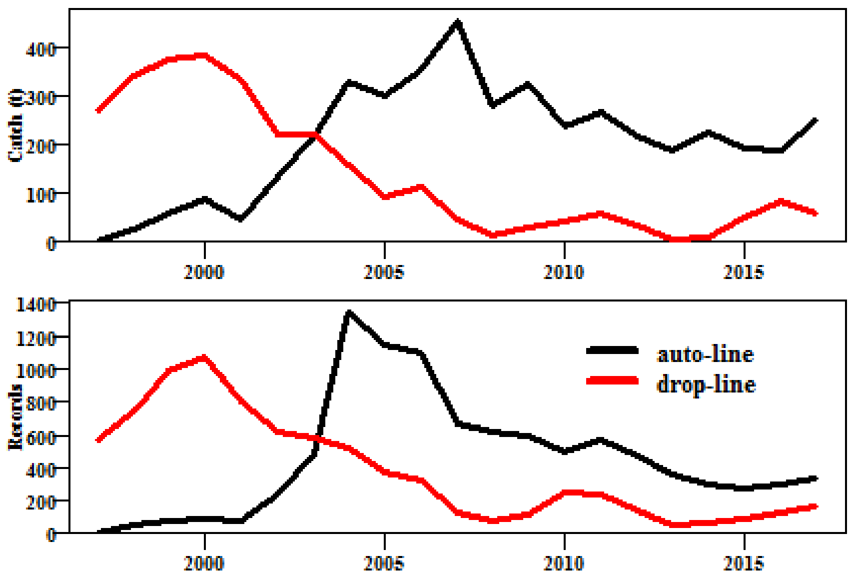

Figure 6.2. The trends in the number of records and the catches of Blue-Eye from 1997 - 2016 by the two main line methods (Table 1); most catches are now taken by auto-line.

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 in-creased 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 log-book 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 defense 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 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 combine validly. The method of processing the data and clarifying the database issues has now been worked through (Haddon, 2015b, 2016; Haddon and Sporcic (2017)).

Table 6.2. Catch by SESSF Zone of Blue-Eye (*Hyperoglyphe antarctica*). Data filtered on species, fisheries and are restrict 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	8.022	65.340	83.638	40.785	1.800	58.788	11.969	26.998	11.215

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 combined 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.

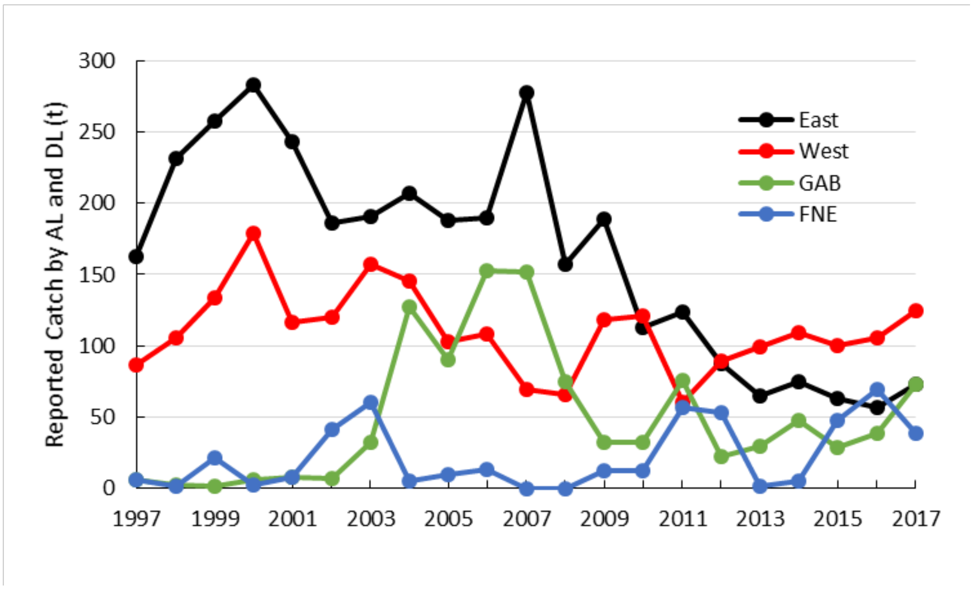

Figure 6.3. The total reported catches from 1997 - 2017 taken by auto-line and drop-line combined across the east (zones 20, 30), the west (zones 40, 50), the GAB (zones 83, 84, 85) and the far north east (zones 91, 92).

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 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).

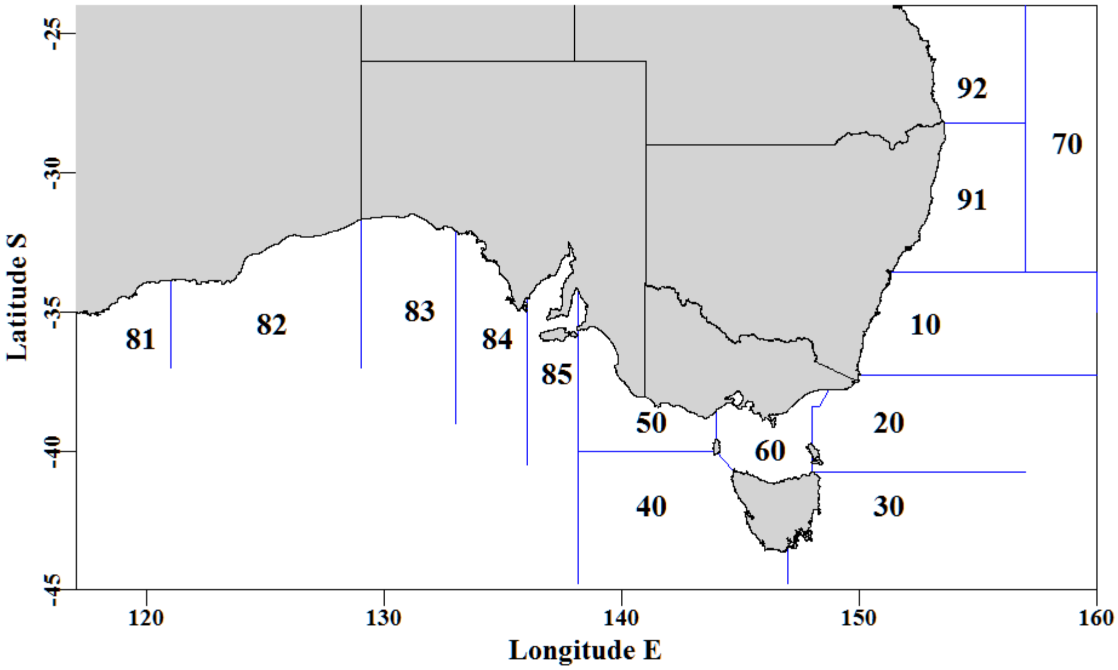

Figure 6.4. A schematic diagram depicting the statistical reporting zones in the SESSF, as used in this document. The GAB fishery is to the west of Zone 50. The main SESSF trawl zones are zones 10 - 50. Each zone extends out to the boundary of the EEZ, except for zones 50 and 60, and for zones 92 and 91, which are bounded by zone 70.

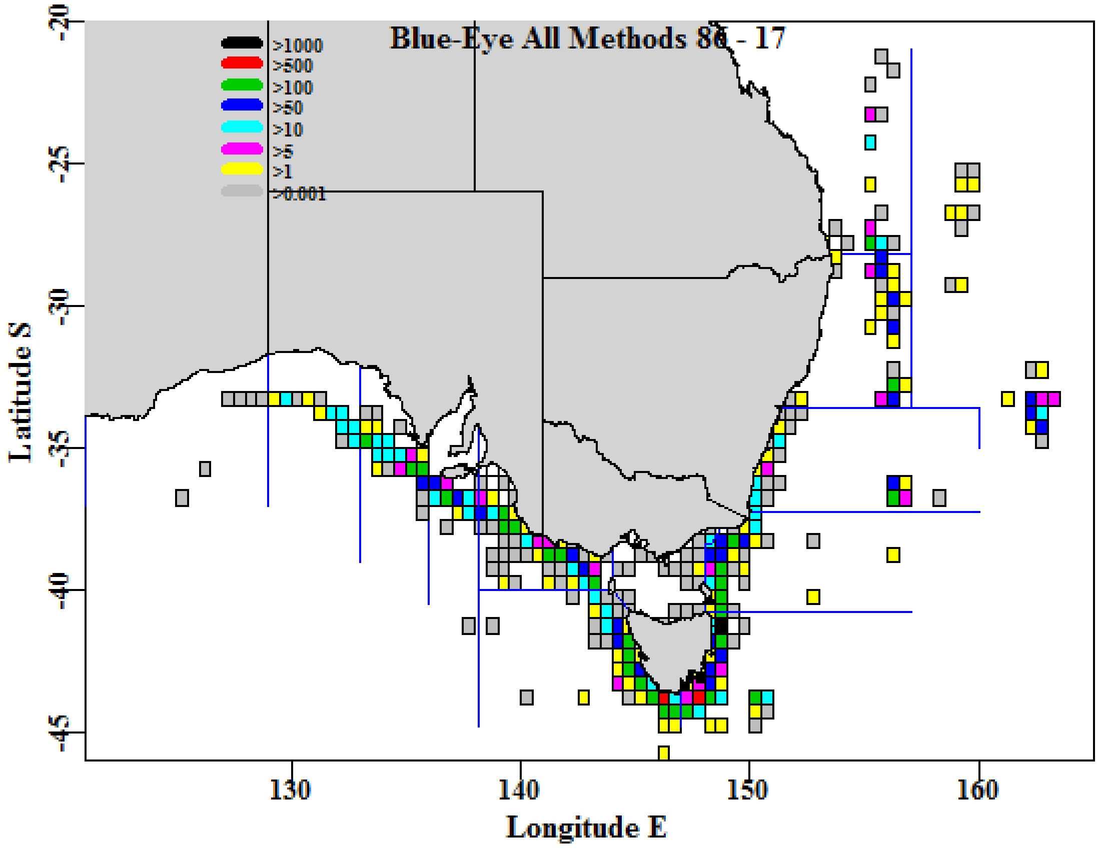

Figure 6.5. All reported catches of Blue-Eye by all methods from 1986 - 2016 in 0.5 degree squares. At least two records per square were required for inclusion in the map (all data were used in the analyses). The legend units are in tonnes summed across all years.

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:

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

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

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

where $CPUE_t$ is the yearly coefficients from the standardization, $\left(\sum CPUE_t\right)/n$ 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	53677.00	10287.000	9696.000	9570.000	9072.000	9031.000
Difference	0.00	43390.000	591.000	126.000	498.000	41.000
Catch	10980.43	4692.941	4428.372	4341.393	4045.163	4022.101
DeltaC	0.00	6287.492	264.570	86.979	296.231	23.061
%DiffC	0.00	57.261	5.638	1.964	6.823	0.570

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.

	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	134.723	246.097	8.022	45.641	83.106	36.770	1.800	58.788	11.969

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	381.509			

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	8903

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			245.151	0	0	336

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 6.5). 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 - 2016, 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 6.5). However, for the standardization analysis no selection on minimum catch was made.

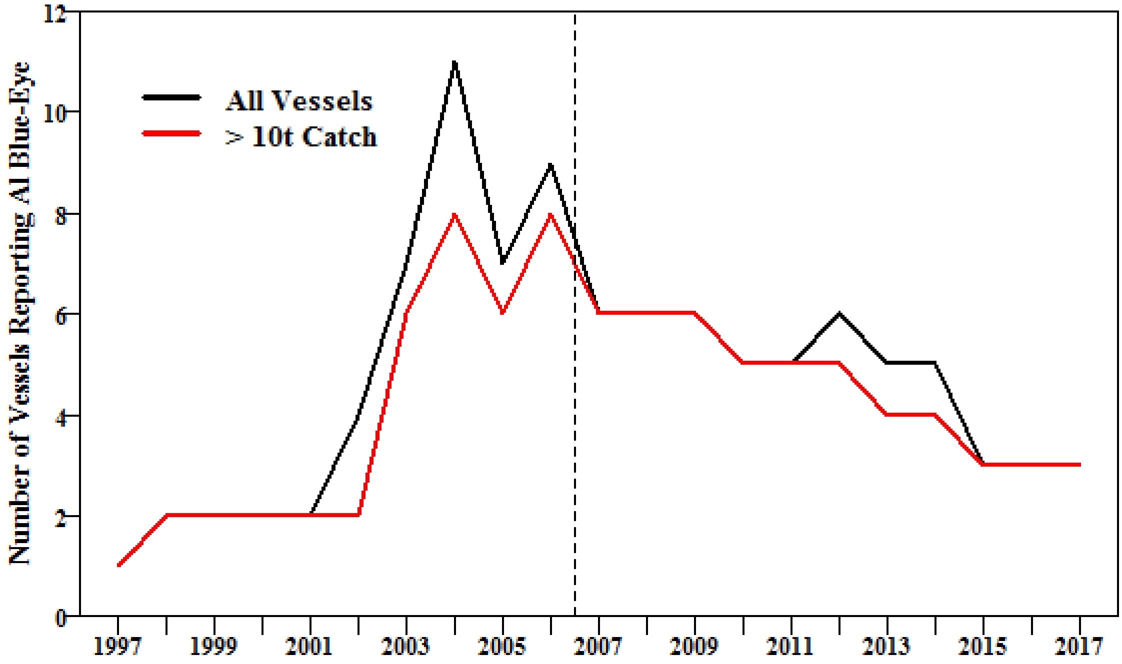

Figure 6.6. The number of auto-line vessels reporting Blue-Eye catches per year of the fishery compared with the number of vessels that caught more than a total of 10 tonnes over the 20 years from 1997 - 2016. Vertical dashed line is 2006.5, identifying the structural adjustment.

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 description of Step codes are described in Table 6.8.

Step	Records	Difference	Catch	DeltaC	%DiffC
Total	53677	0	10980.434	0.000	0.00
Method	10287	43390	4692.941	6287.492	100.00
Depth	9696	591	4428.372	264.570	94.36
Years	9570	126	4341.393	86.979	92.51
Zones	9072	498	4045.163	296.231	86.20
Fishery	9031	41	4022.101	23.061	85.71
U-THS	9031	0	4022.101	0.000	85.71
9798SUV	9031	0	4022.101	0.000	85.71
H0-SUVgt0	9031	0	4022.101	0.000	85.71
noEffort	8949	82	4015.599	6.502	85.57
SUVgtUV	8949	0	4015.599	0.000	85.57
CEgt10	8939	10	4004.919	10.680	85.34
Hlt1000	8902	37	3989.881	15.038	85.02

Once catch-per-hook CPUE data were available these could then be standardized using standard methods. Standardizations only begin in 2002 after which sufficient data to be representative are available.

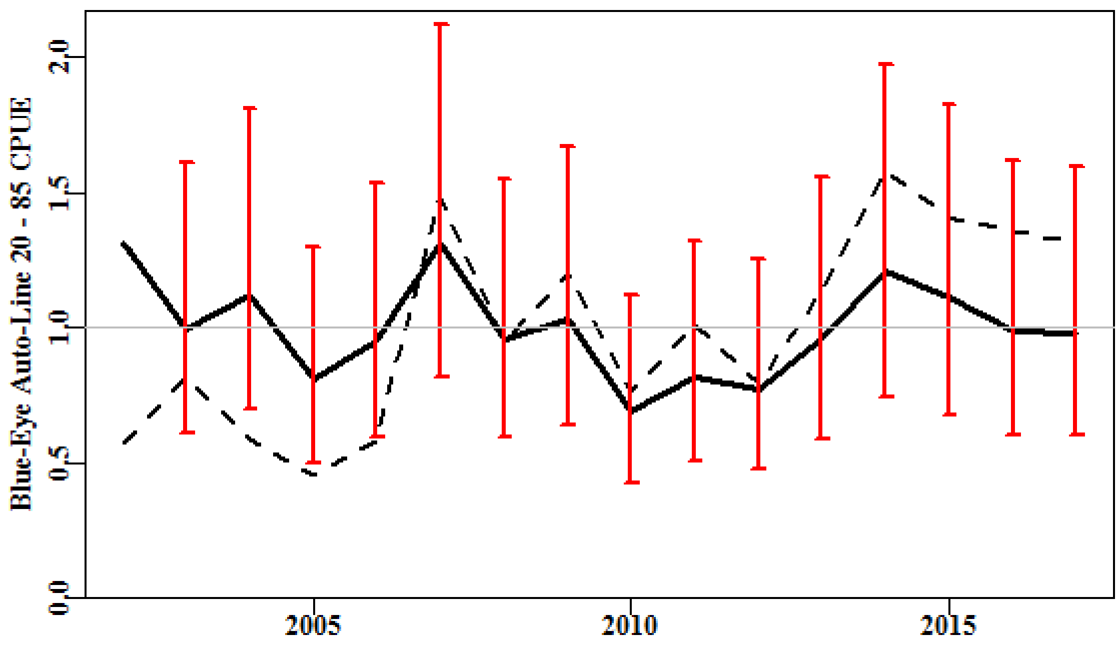

Figure 6.7. The standardized CPUE for Blue-Eye taken by auto-line from 2002 - 2016 from zones 20, 30, 40, 50, 83, 84, and 85. While the error bars are wide note the relative flattening of the trend in the solid standardized trend compared to the increasing trend in the unstandardized geometric mean (dashed line).

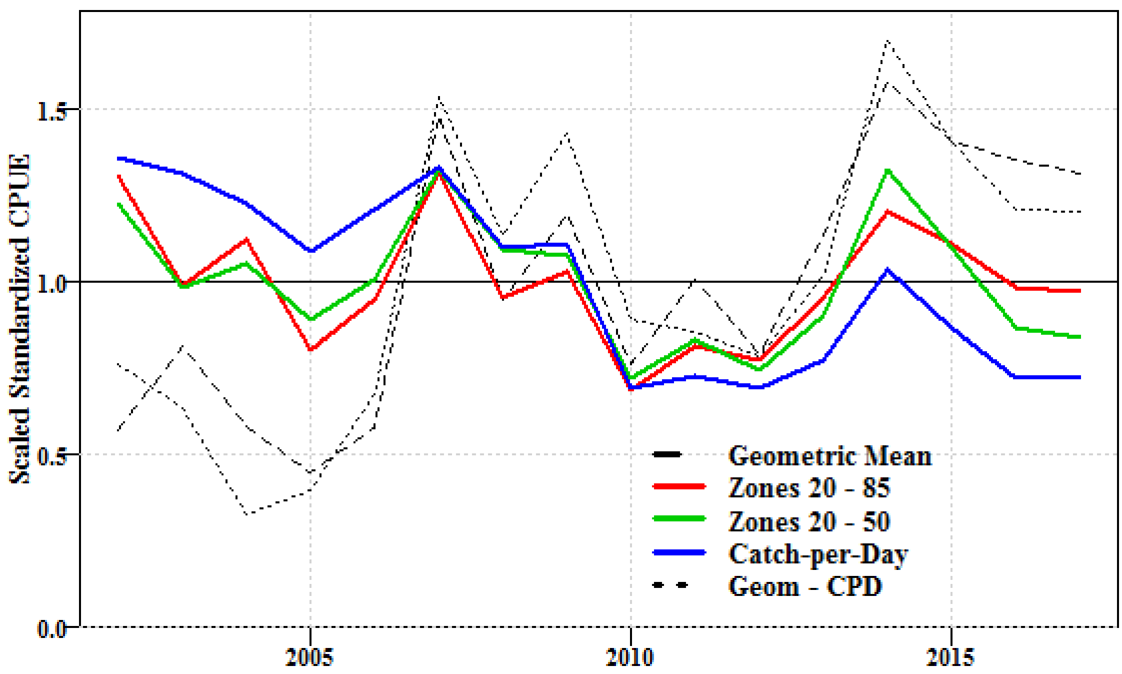

Figure 6.8. A comparison of the standardized catch rates for auto-line vessels using catch-per-day (blue line and dotted black line), and catch-per-hook (red, green, and dashed black line). All three main lines have high levels of uncertainty (e.g. Figure 6.6), but the relative flattening of the catch-per-hook trajectory is clear. All trends were scaled to an average of 1.0.

The optimum statistical model fitted to the available data from 2002 - 2016 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	0.5729	0.7638	1.3116	1.2284	1.3641	131.366
2003	0.8170	0.6379	0.9899	0.9834	1.3168	156.966
2004	0.5846	0.3302	1.1227	1.0573	1.2269	265.447
2005	0.4526	0.3978	0.8049	0.8924	1.0914	297.430
2006	0.5796	0.6771	0.9520	1.0054	1.2119	344.008
2007	1.4842	1.5369	1.3135	1.3261	1.3309	445.329
2008	0.9501	1.1375	0.9573	1.0932	1.1008	275.976
2009	1.2015	1.4351	1.0322	1.0758	1.1112	302.036
2010	0.7669	0.8924	0.6896	0.7236	0.6937	228.394
2011	1.0057	0.8581	0.8157	0.8310	0.7299	223.640
2012	0.7912	0.7876	0.7739	0.7477	0.6950	179.075
2013	1.1337	1.0178	0.9547	0.9048	0.7739	184.361
2014	1.5806	1.6999	1.2070	1.3278	1.0370	219.558
2015	1.4080	1.4074	1.1126	1.0989	0.8663	183.373
2016	1.3564	1.2128	0.9864	0.8659	0.7218	182.650
2017	1.3151	1.2077	0.9759	0.8383	0.7283	246.097

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 - 2016 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).

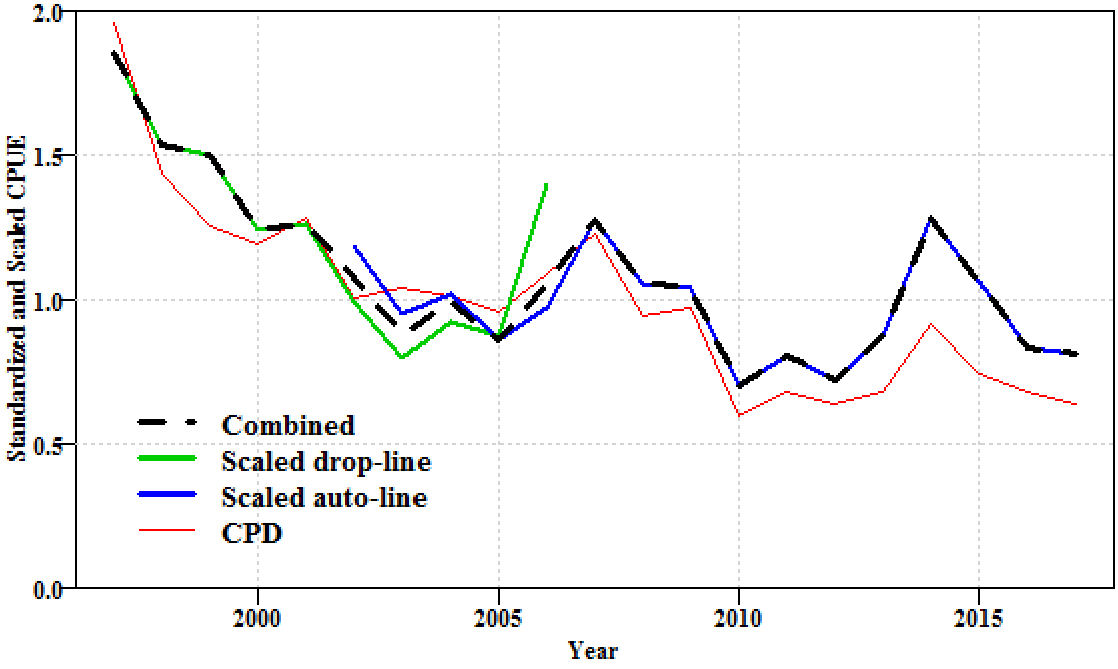

Figure 6.9. A comparison of Blue-Eye standardized catch-per-hook estimates for Drop-Line and Auto-Line catches of Blue-Eye from zones 20 - 50. A catch-weighted average of the lines from the two methods leads to a compromise in the years 2002 - 2006. If the 2001 auto-line estimates had been included this 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 (the columns with a scale postfix. 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.

	ceDL	ceAL	scaleDL	scaleAL	combined	ceCPD	alC	dlC
1997	1.4977		1.8588		1.8588	1.9580	0.267	242.435
1998	1.2406		1.5397		1.5397	1.4370	14.989	318.441
1999	1.2115		1.5036		1.5036	1.2597	46.670	336.133
2000	1.0037		1.2457		1.2457	1.1935	28.299	372.543
2001	1.0179		1.2633		1.2633	1.2839	40.232	311.101
2002	0.8013	1.2284	0.9945	1.1887	1.0782	1.0118	131.366	173.513
2003	0.6441	0.9834	0.7994	0.9516	0.8813	1.0417	156.986	135.032
2004	0.7456	1.0573	0.9254	1.0231	0.9970	1.0191	230.575	84.059
2005	0.7079	0.8924	0.8786	0.8636	0.8661	0.9614	238.755	48.581
2006	1.1297	1.0054	1.4021	0.9729	1.0545	1.0945	237.272	55.729
2007		1.3261		1.2832	1.2832	1.2298	307.310	38.766
2008		1.0932		1.0579	1.0579	0.9453	205.017	15.299
2009		1.0758		1.0410	1.0410	0.9723	281.002	17.818
2010		0.7236		0.7002	0.7002	0.6014	202.140	24.755
2011		0.8310		0.8042	0.8042	0.6822	151.900	30.748
2012		0.7477		0.7236	0.7236	0.6412	158.120	17.928
2013		0.9048		0.8756	0.8756	0.6795	156.342	7.003
2014		1.3278		1.2849	1.2849	0.9184	176.813	3.853
2015		1.0989		1.0634	1.0634	0.7452	159.096	1.727
2016		0.8659		0.8379	0.8379	0.6837	143.792	14.368
2017		0.8383		0.8112	0.8112	0.6402	173.540	22.810

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 behaviour may affect CPUE. Such things are confounded with stock size changes. That is, a change in the CPUE brought about by a management change, can easily be confused for a change in the stock. Catch rate standardization is a method of using statistical methods in an attempt to take account of such external factors, with common examples of important potentially influential factors being which vessel is fishing, where they are fishing, at what depth they are fishing, and what month they are fishing. The process of standardization is completely dependent upon the availability of quality data concerning the factors being considered.

6.5.2 *Other Factors Affecting CPUE*

There are some influential factors whose potential effects upon CPUE would be difficult to identify and isolate as a confounding effect with stock size. Any influence that occurs as 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 favored 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 continue to be used as still representing the fishery. Thus, if catch-per-record data is to continue being used for the provision of management advice then some extra data selection will need to be made to focus on those fishing events that are more typical of the fishery. 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.

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7. Statistical CPUE standardizations for selected deepwater SESSF Species (data to 2017).

Miriana Sporcic and Malcolm Haddon

CSIRO Oceans and Atmosphere, Castray Esplanade, Hobart TAS 7000, Australia

7.1 Introduction

Commercial catch per unit 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 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 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.

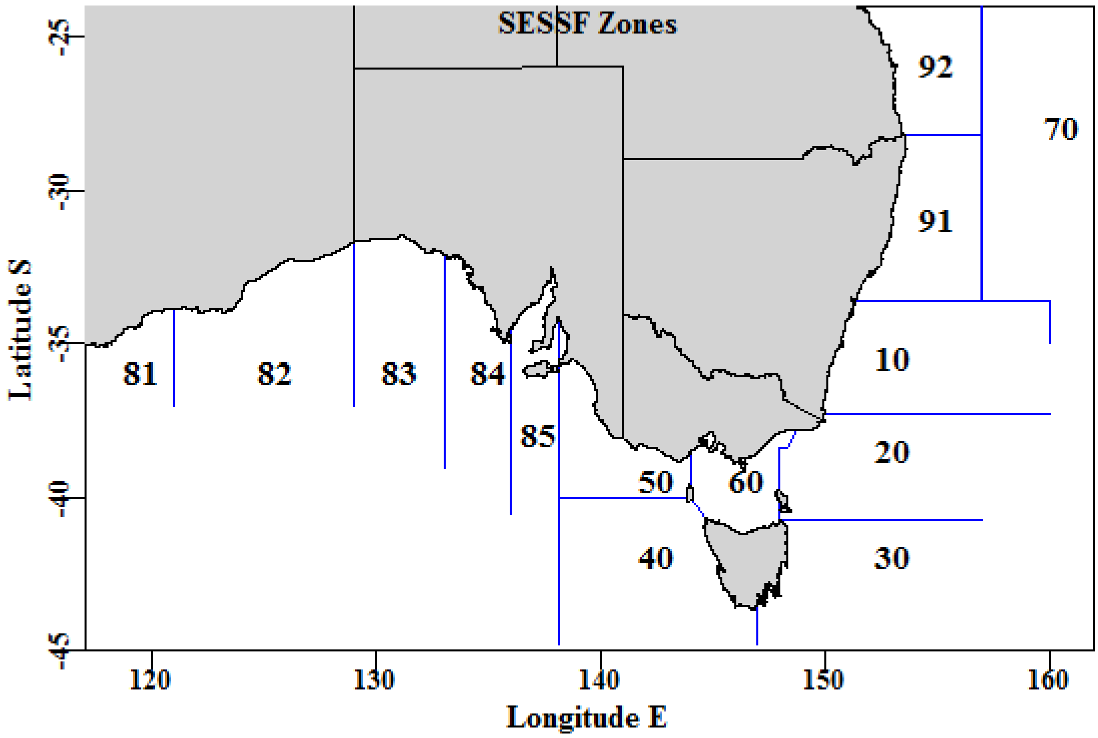

Figure 7.1. The statistical reporting zones in the SESSF.

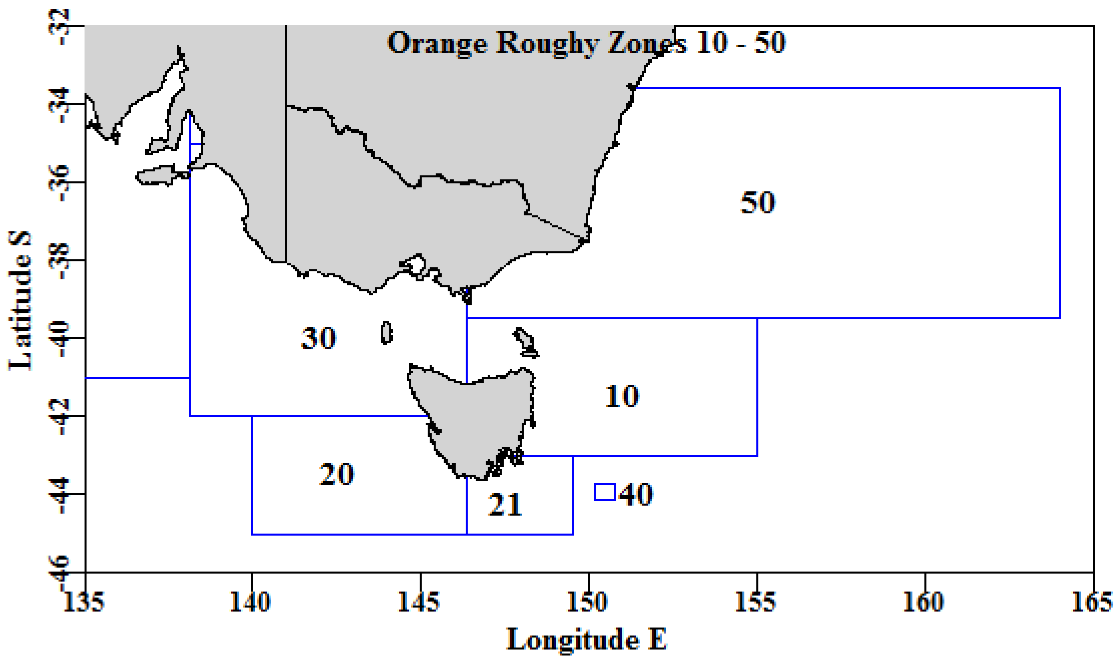

Figure 7.2 The Orange Roughy zones used to describe the deepwater fisheries.

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 - 2017 (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, 37020019, 37020021, 37020024, 37020025, 37020027, 37020028, 37020029, 37020030, 37020031, 37020032, 37020033, 37020905, 37020906, 37020907, 37990003
fishery	SET
depthrange	600 - 1250
depthclass	50
zones	10, 20, 21, 40, 50
methods	TW, TDO, OTT, PTB, TMO
years	1995 - 2017

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	2.7828	0.000	1.602	0.009
1996	834.2	1092	348.2	25	113.6	2.6904	0.065	2.975	0.009
1997	851.0	997	206.2	25	62.2	1.6581	0.064	3.610	0.018
1998	838.5	1203	221.1	24	53.4	1.4260	0.063	5.039	0.023
1999	731.3	1078	167.1	24	43.8	1.1848	0.064	4.500	0.027
2000	683.5	904	177.6	37	54.7	1.2476	0.067	3.152	0.018
2001	572.8	954	144.9	28	49.9	1.0932	0.070	4.746	0.033
2002	516.0	931	155.9	26	48.8	1.0765	0.069	4.419	0.028
2003	360.8	999	125.9	24	37.4	0.7865	0.070	5.953	0.047
2004	377.7	706	96.1	26	34.9	0.7854	0.073	3.886	0.040
2005	202.8	427	62.7	13	38.8	0.7830	0.081	2.274	0.036
2006	178.1	373	38.0	19	32.6	0.7486	0.085	3.046	0.080
2007	56.4	49	2.8	13	12.8	0.6450	0.172	0.418	0.147
2008	51.8	79	10.5	8	25.4	0.9529	0.141	0.434	0.041
2009	83.1	183	27.6	11	36.3	0.9020	0.102	0.892	0.032
2010	77.4	212	20.3	11	21.6	0.5560	0.097	1.445	0.071
2011	78.9	165	16.2	13	21.4	0.5329	0.106	0.849	0.052
2012	82.8	231	21.7	13	21.3	0.5287	0.098	1.380	0.063
2013	102.2	213	17.1	10	20.5	0.5176	0.100	1.640	0.096
2014	104.8	374	29.3	12	19.0	0.5388	0.092	1.581	0.054
2015	86.7	401	23.7	12	23.4	0.5164	0.094	1.916	0.081
2016	93.0	299	25.6	14	26.9	0.4962	0.102	1.206	0.047
2017	97.4	309	27.5	11	25.5	0.5505	0.106	0.954	0.035

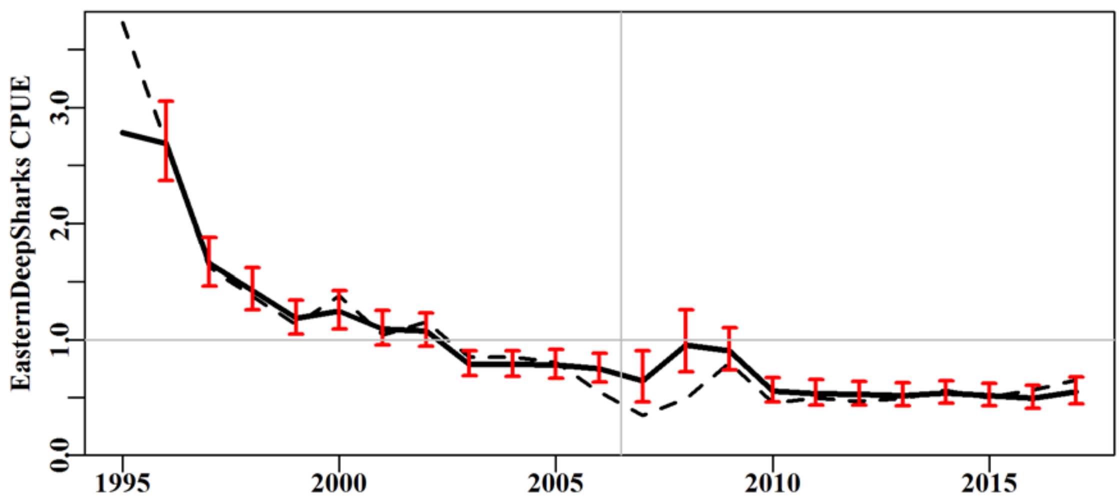

Figure 7.3. EasternDeepSharks standardization. The dashed black line represents the geometric mean catch rate, solid black line the standardized catch rates. The red bars are the 95% confidence intervals about the mean estimates. The graph scales both time-series of standardized catch rates relative to the mean of each time-series.

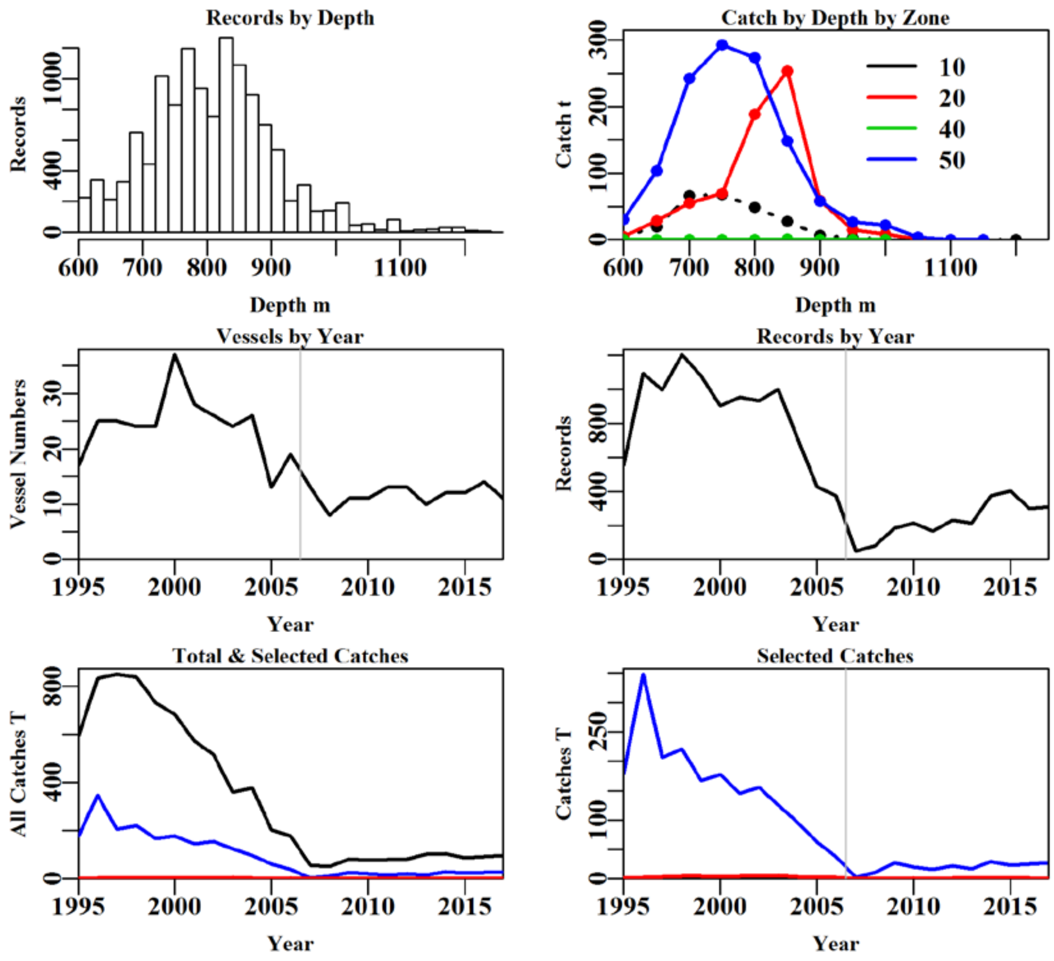

Figure 7.4. EasternDeepSharks fishery details. The bottom left plot depicts all known catches (top black line), and all selected catches used in the analysis (middle blue line); the lower red line: selected catches < 30 kg).

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	352955	229176	91215	53135	52876	12732	12174
Difference	0	123779	137961	38080	259	40144	558

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	4682	17816	3398	12174	23	15.9	0.00
Vessel	3147	15521	5693	12174	95	26.3	10.40
DepCat	2342	14500	6715	12174	107	31.1	4.78
Month	2318	14444	6770	12174	118	31.3	0.20
DayNight	2299	14418	6796	12174	120	31.4	0.11
ORzone	2177	14267	6947	12174	123	32.1	0.70
ORzone:DepCat	2039	14039	7175	12174	152	33.0	0.92
ORzone:Month	2105	14117	7097	12174	151	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	615.571
Black	37020002	73.0186
Brier	37020003	90.437
Platypus	37020004	129.434
Plunket	37020013	0.16
Pearl	37020905	467.2853
Roughskin	37020906	225.113
Lantern	37020907	9.5
OtherSharks	37990003	526.6475

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	161.580								186.264
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	0.06	71.731	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	0.04	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	0.06	15.831	2.738		
2017	0.005	1.898	4.030	1.986		16.635	2.029		0.825

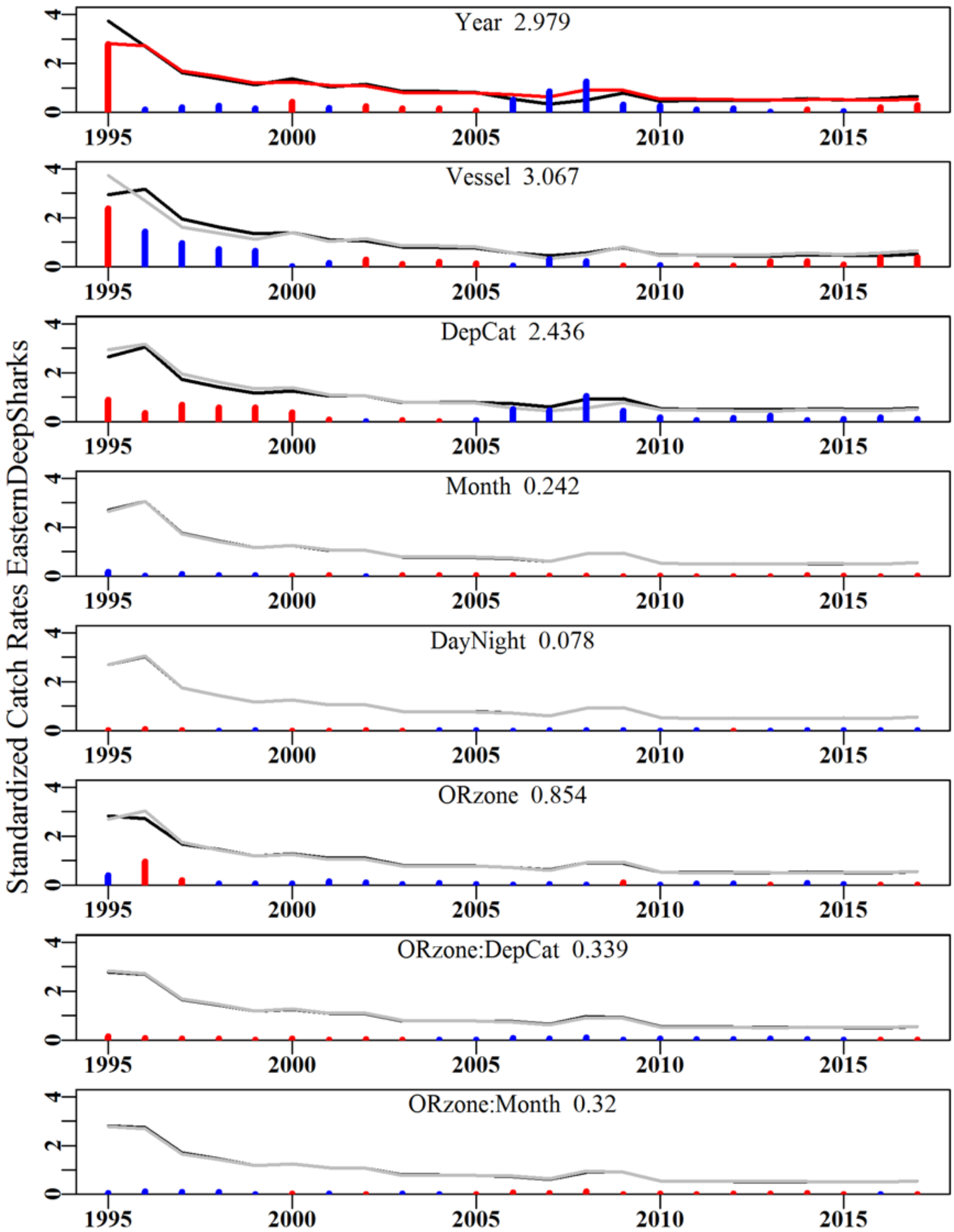

Figure 7.5. EasternDeepSharks. The influence of each factor on the optimal standardization. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by vertical bars with blue bars indicating the optimum model is higher than the 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.

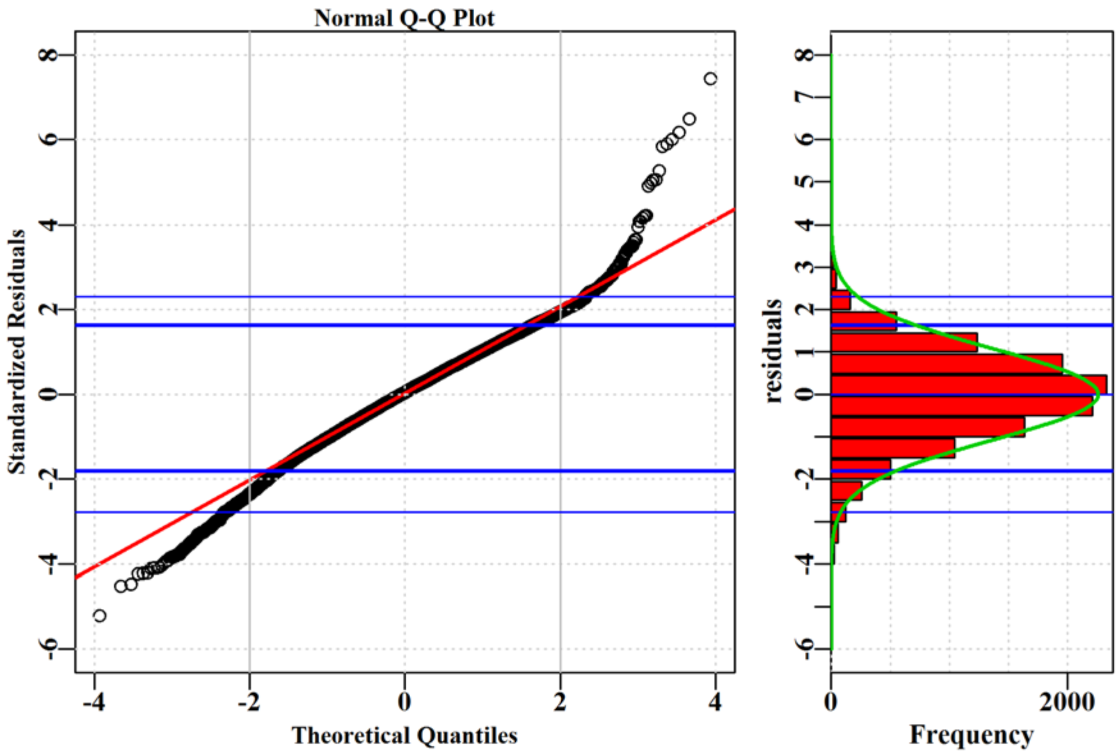

Figure 7.6. EasternDeepSharks. Diagnostic plots. The distribution of residuals from the optimum fit. The qqplot indicates the fit to the expected normality, while the histogram of residuals also illustrates the 1%, 5%, 95% and 99% quantiles to indicate the intensity of any lack of fit at the margins of the distribution (reflected also in the qqplot).

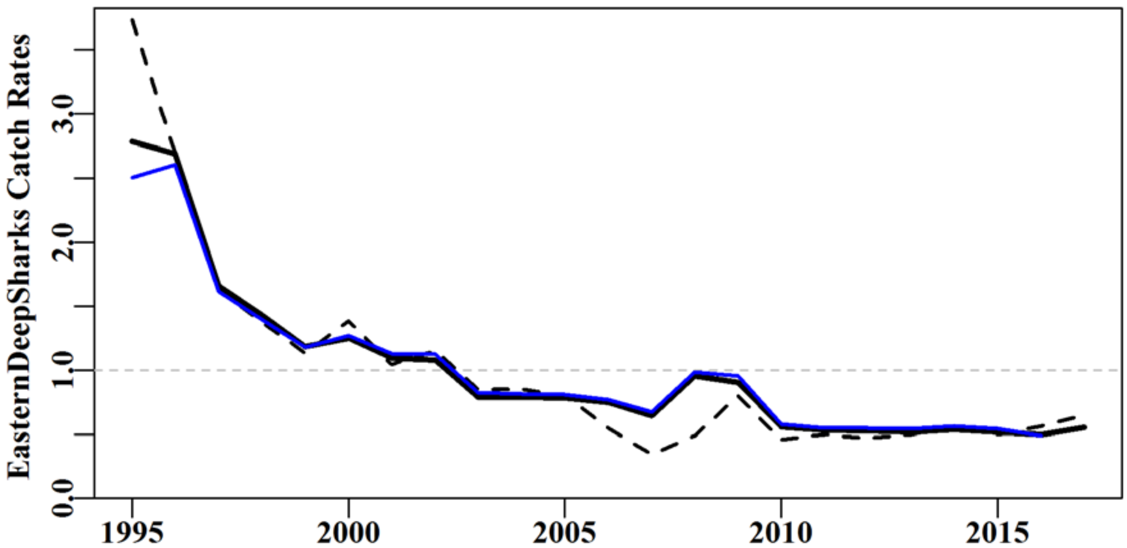

Figure 7.7. EasternDeepSharks. A comparison of the previous year's standardization (blue line) with this year's. They should lie on top of each other, although small deviations may relate to data adjustments, particularly in very recent years.

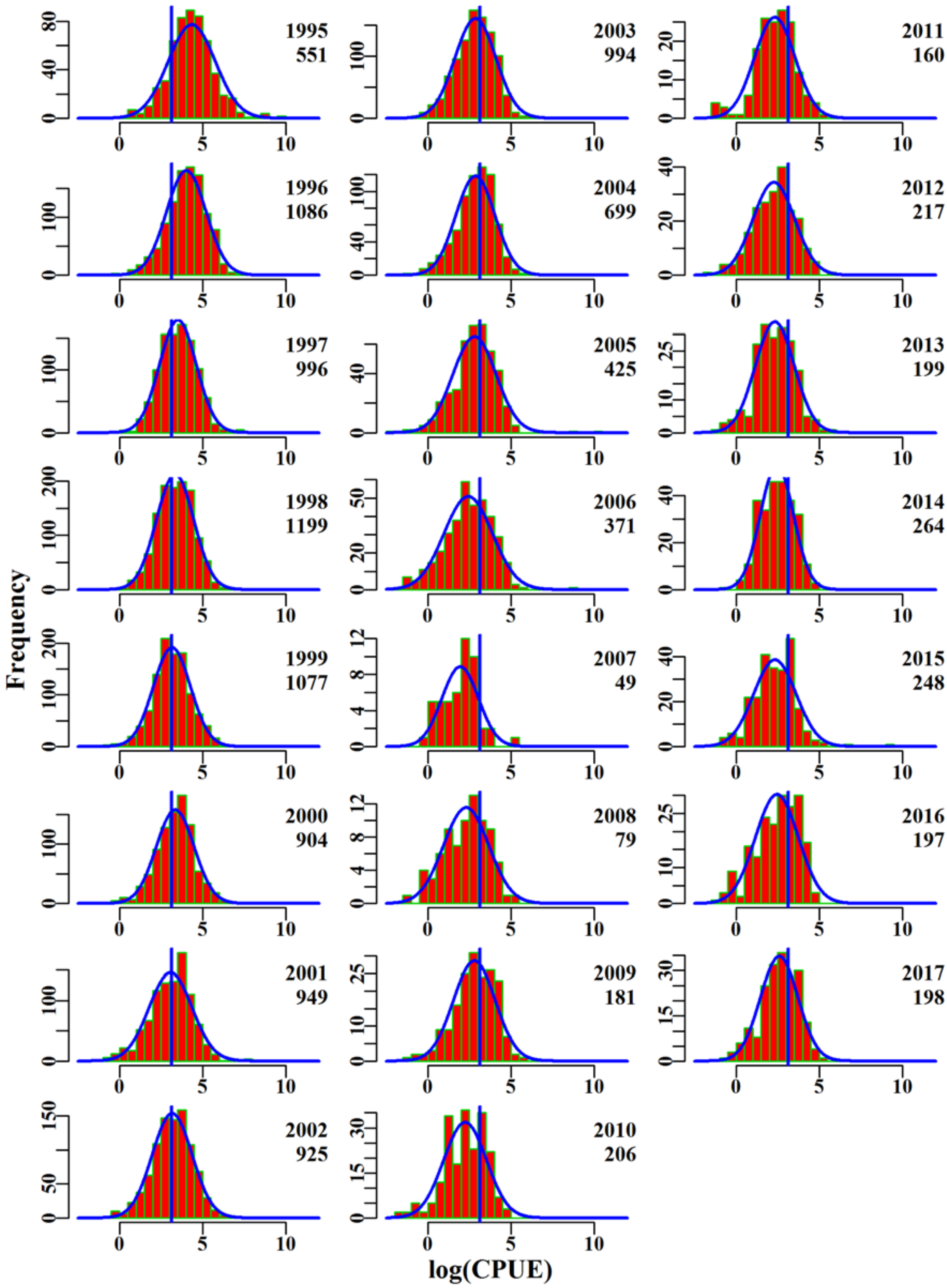

Figure 7.8. EasternDeepSharks. The log(CPUE) for each year of data available the blue lines are normal distributions fitted to the histogram frequencies. The numbers in each plot are the year and number of records. The vertical blue line is the average across all years.

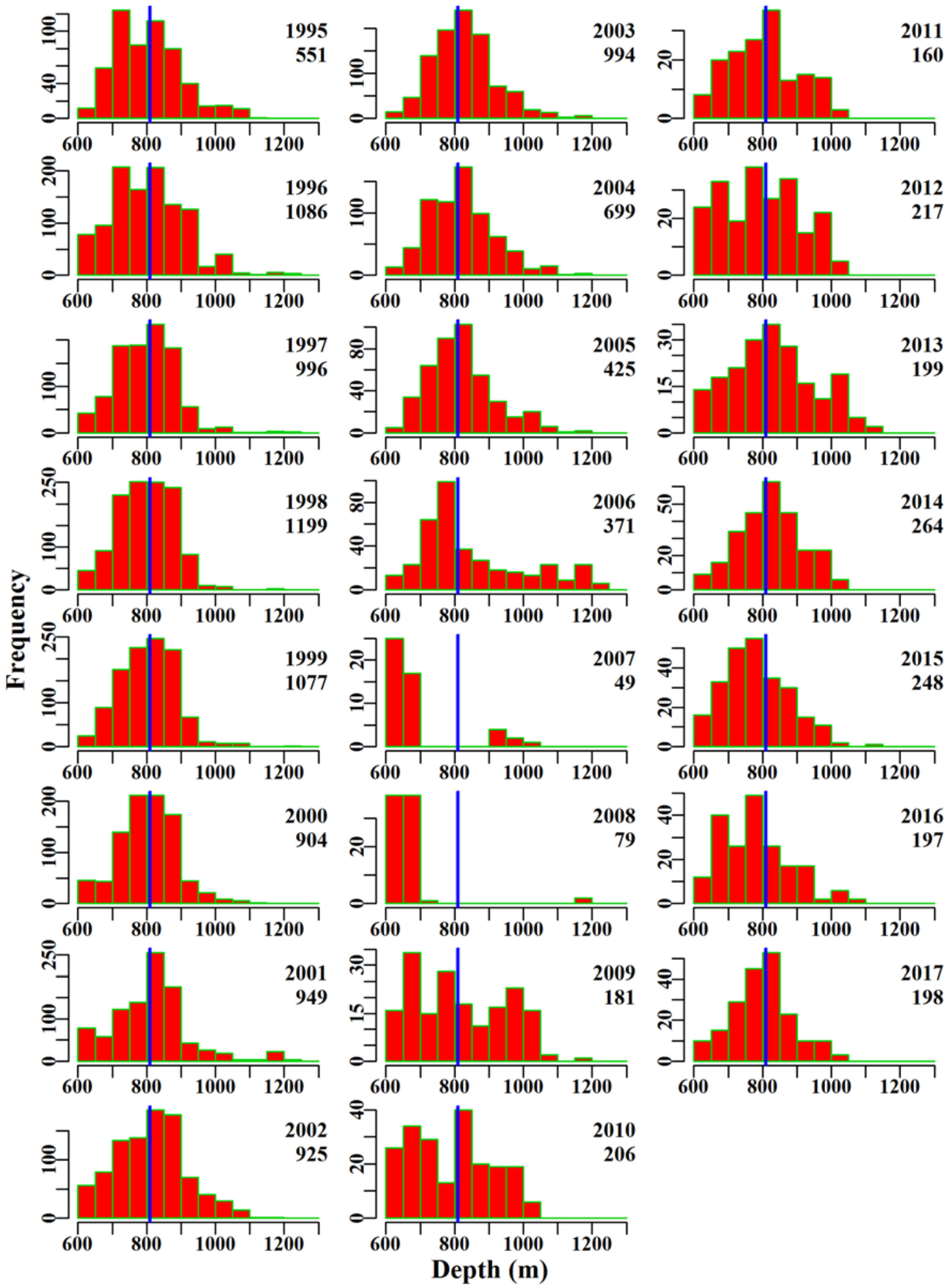

Figure 7.9. EasternDeepSharks. The average Depth of fishing for each year of data available to illustrate the development of the fishery through time. The numbers in each plot are the year and number of records. The vertical blue line is the average across all years.

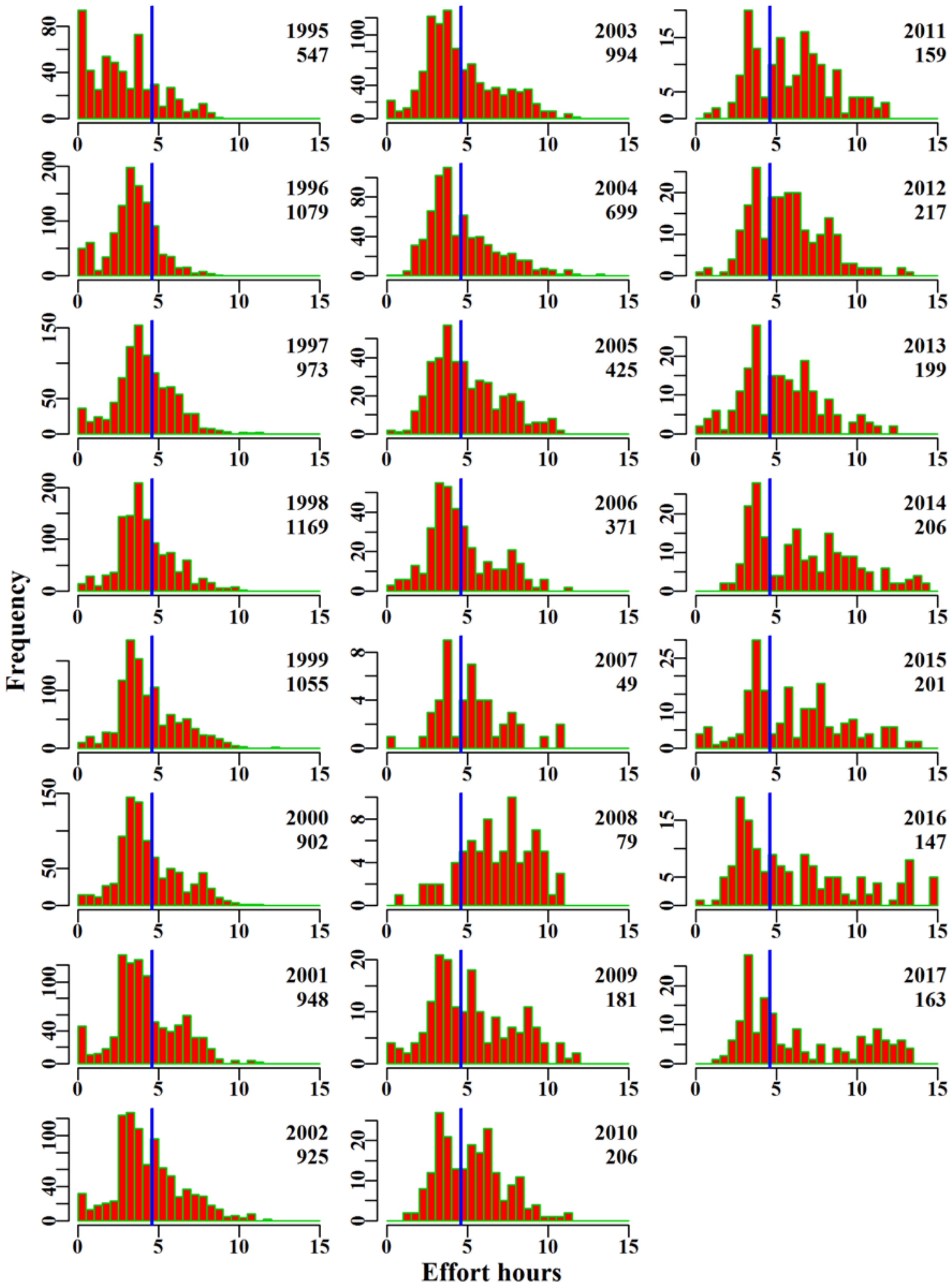

Figure 7.10. EasternDeepSharks. The frequency distribution of effort each year for the available data. The numbers in each plot are the year and number of records. The vertical blue line is the average across all years.

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 – 2017 (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 throughout 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 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 (Figure 7.19).

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, 37020019, 37020021, 37020024, 37020025, 37020027, 37020028, 37020029, 37020030, 37020031, 37020032, 37020033, 37020905, 37020906, 37020907, 37990003
fishery	SET
depthrange	600 - 1250
depthclass	50
zones	10, 20, 21, 40, 50
methods	TW, TDO, OTT, PTB, TMO
years	1995 - 2017

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	553	178.7	17	213.2	2.5450	0.000	1.602	0.009
1996	834.2	1092	348.2	25	113.6	2.6525	0.081	2.975	0.009
1997	851.0	997	206.2	25	62.2	1.6361	0.078	3.610	0.018
1998	838.5	1203	221.1	24	53.4	1.3747	0.077	5.039	0.023
1999	731.3	1078	167.1	24	43.8	1.1579	0.077	4.500	0.027
2000	683.5	904	177.6	37	54.7	1.2259	0.081	3.152	0.018
2001	572.8	954	144.9	28	49.9	1.1293	0.084	4.746	0.033
2002	516.0	931	155.9	26	48.8	1.1450	0.084	4.419	0.028
2003	360.8	999	125.9	24	37.4	0.7970	0.084	5.953	0.047
2004	377.7	706	96.1	26	34.9	0.8075	0.087	3.886	0.040
2005	202.8	427	62.7	13	38.8	0.7704	0.096	2.274	0.036
2006	178.1	373	38.0	19	32.6	0.7674	0.100	3.046	0.080
2007	56.4	49	2.8	13	12.8	0.7296	0.175	0.418	0.147
2008	51.8	79	10.5	8	25.4	0.9746	0.149	0.434	0.041
2009	83.1	183	27.6	11	36.3	0.9569	0.112	0.892	0.032
2010	77.4	212	20.3	11	21.6	0.5852	0.107	1.445	0.071
2011	78.9	165	16.2	13	21.4	0.5148	0.116	0.849	0.052
2012	82.8	231	21.7	13	21.3	0.5673	0.108	1.380	0.063
2013	102.2	213	17.1	10	20.5	0.5297	0.111	1.640	0.096
2014	104.8	374	29.3	12	19.0	0.5460	0.102	1.581	0.054
2015	86.7	401	23.7	12	23.4	0.5298	0.104	1.916	0.081
2016	93.0	299	25.6	14	26.9	0.4928	0.110	1.206	0.047
2017	97.4	309	27.5	11	25.5	0.5644	0.115	0.954	0.035

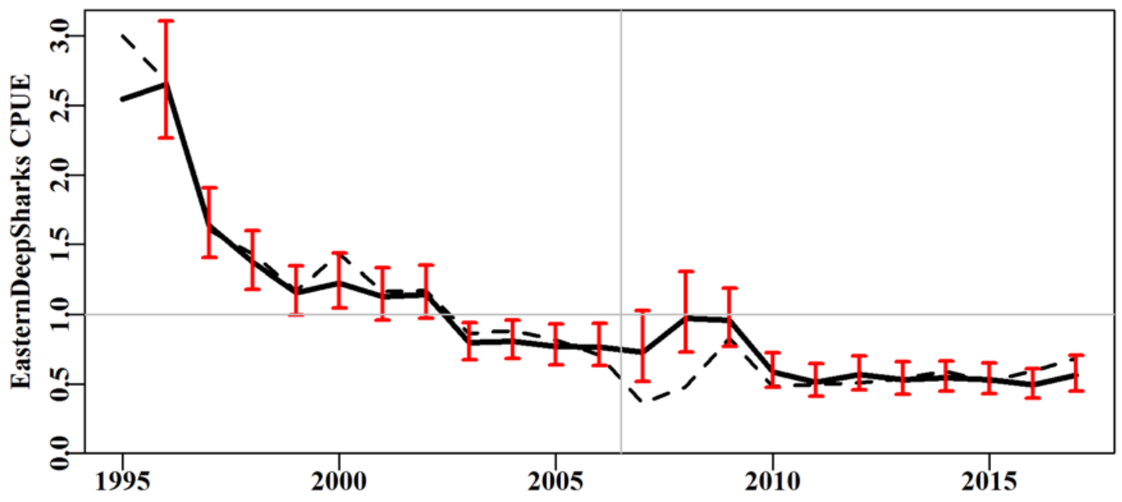

Figure 7.11. EasternDeepSharks standardization. The dashed black line represents the geometric mean catch rate, solid black line the standardized catch rates. The red bars are the 95% confidence intervals about the mean estimates. The graph scales both time-series of standardized catch rates relative to the mean of each time-series.

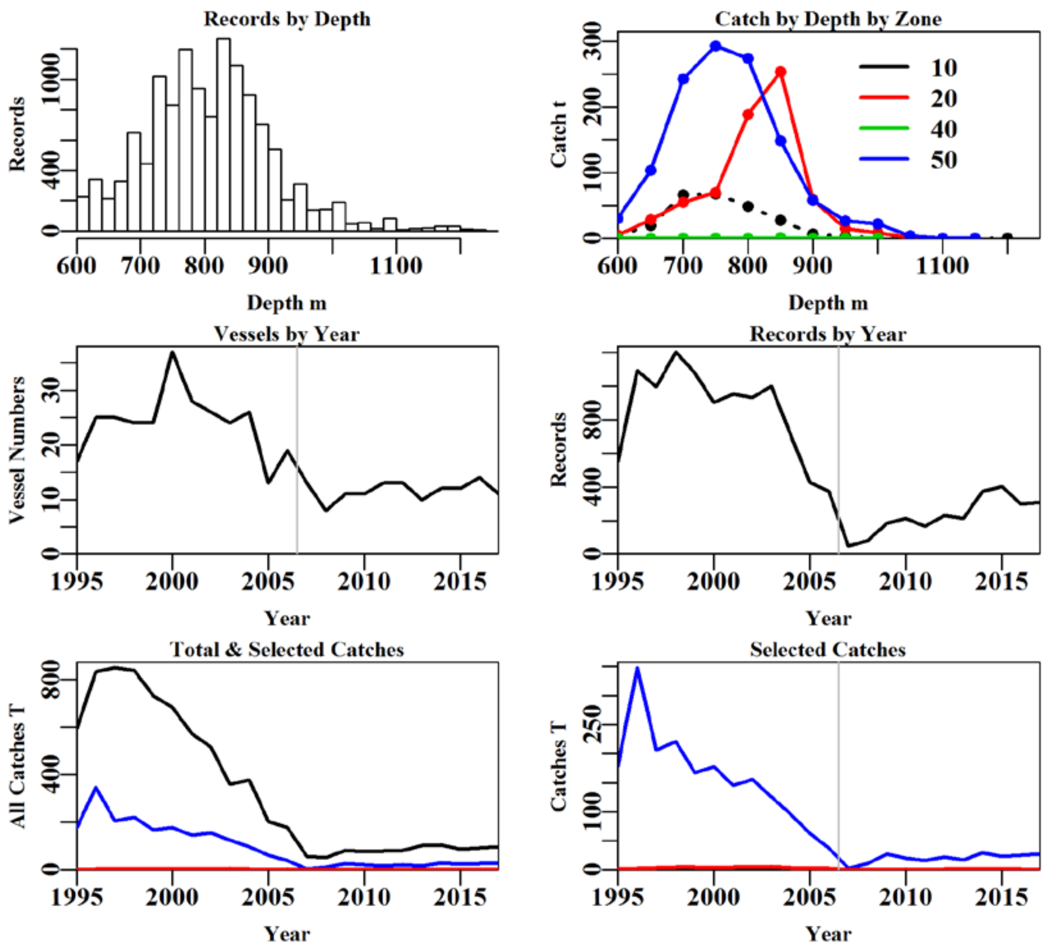

Figure 7.12. EasternDeepSharks fishery details. The bottom left plot depicts all known catches (top black line), and all selected catches used in the analysis (middle blue line); the lower red line: selected catches < 30 kg).

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	352955	229176	91215	53135	52876	12732	12174	10207
Difference	0	123779	137961	38080	259	40144	558	1967

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	3134	13813	2313	10207	23	14.2	0.00
Vessel	1985	12174	3952	10207	93	23.8	9.67
DepCat	1590	11685	4441	10207	105	26.8	2.97
Month	1571	11638	4488	10207	116	27.0	0.22
DayNight	1564	11625	4500	10207	118	27.1	0.07
ORzone	1430	11469	4657	10207	120	28.0	0.97
ORzone:DepCat	1326	11304	4822	10207	142	28.9	0.88
ORzone:Month	1378	11362	4764	10207	142	28.6	0.52

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	473.98
Black	37020002	59.8496
Brier	37020003	78.577
Platypus	37020004	101.543
Plunket	37020013	0.16
Pearl	37020905	405.8313
Roughskin	37020906	186.771
OtherSharks	37990003	421.5295

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	123.303							164.253
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	0.06	58.241	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	0.04	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	0.06	15.831	2.738	
2017	0.005	1.832	4.030	1.566		15.960	1.917	0.825

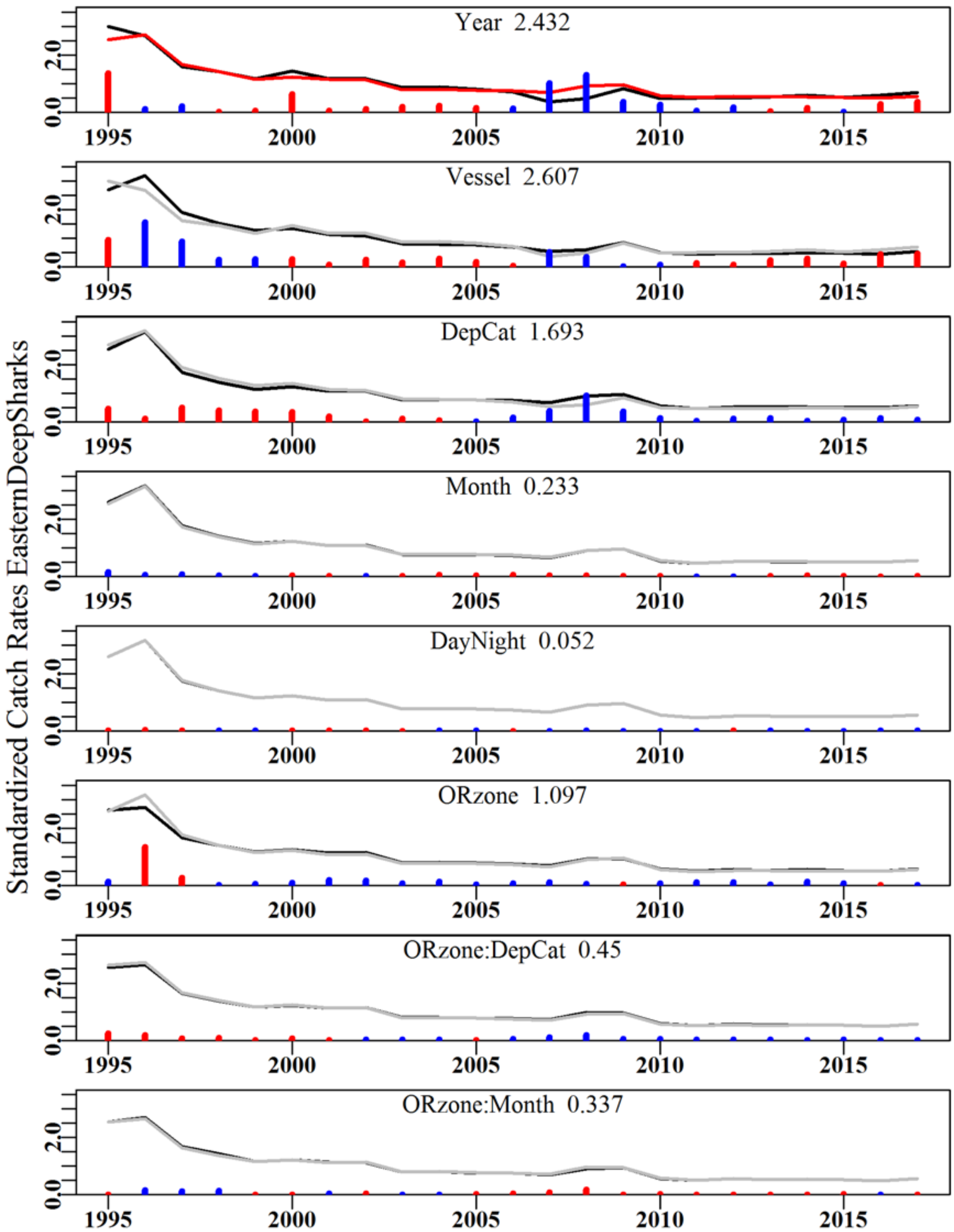

Figure 7.13. EasternDeepSharks. The influence of each factor on the optimal standardization. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by vertical bars with blue bars indicating the optimum model is higher than the 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.

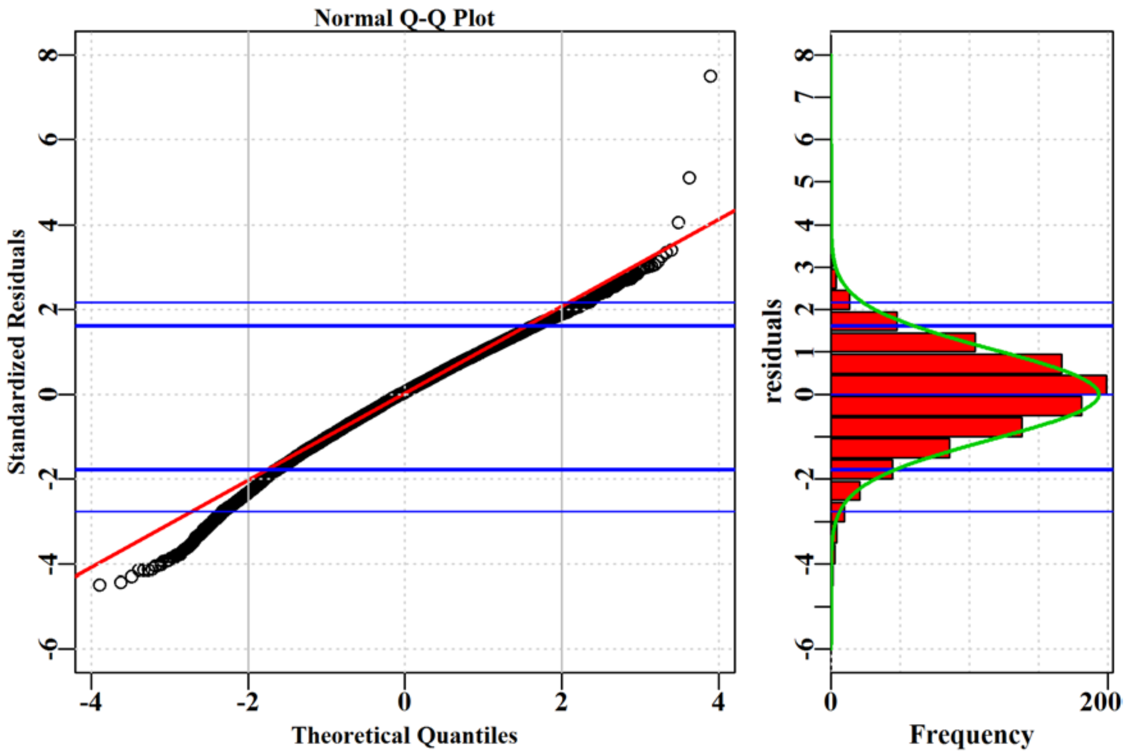

Figure 7.14. EasternDeepSharks. Diagnostic plots. The distribution of residuals from the optimum fit. The qqplot indicates the fit to the expected normality, while the histogram of residuals also illustrates the 1%, 5%, 95% and 99% quantiles to indicate the intensity of any lack of fit at the margins of the distribution (reflected also in the qqplot).

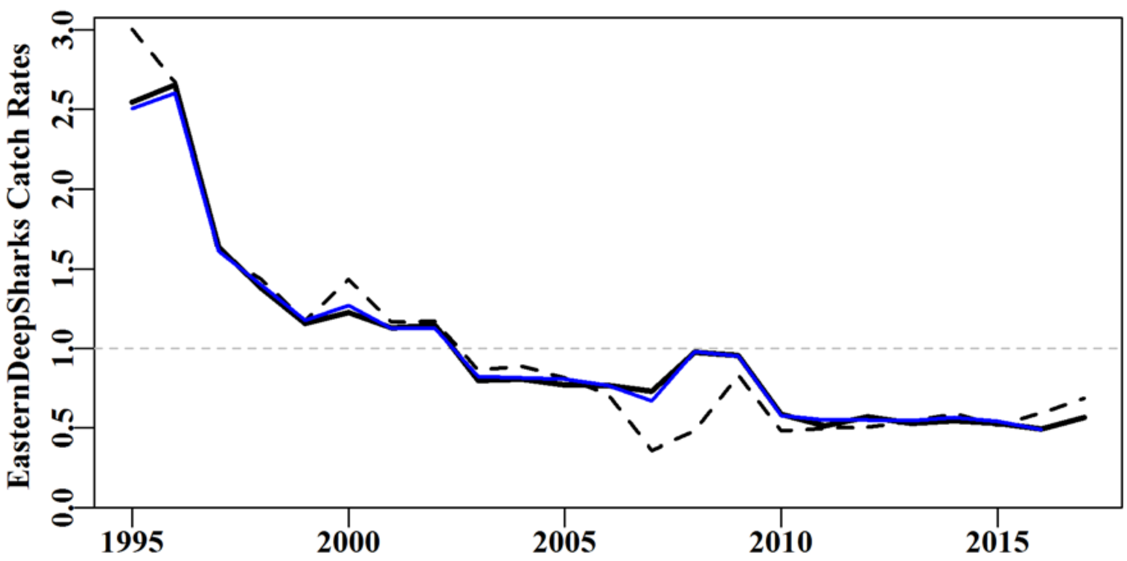

Figure 7.15. EasternDeepSharks. A comparison of the previous year's standardization (blue line) with this year's. They should lie on top of each other, although small deviations may relate to data adjustments, particularly in very recent years.

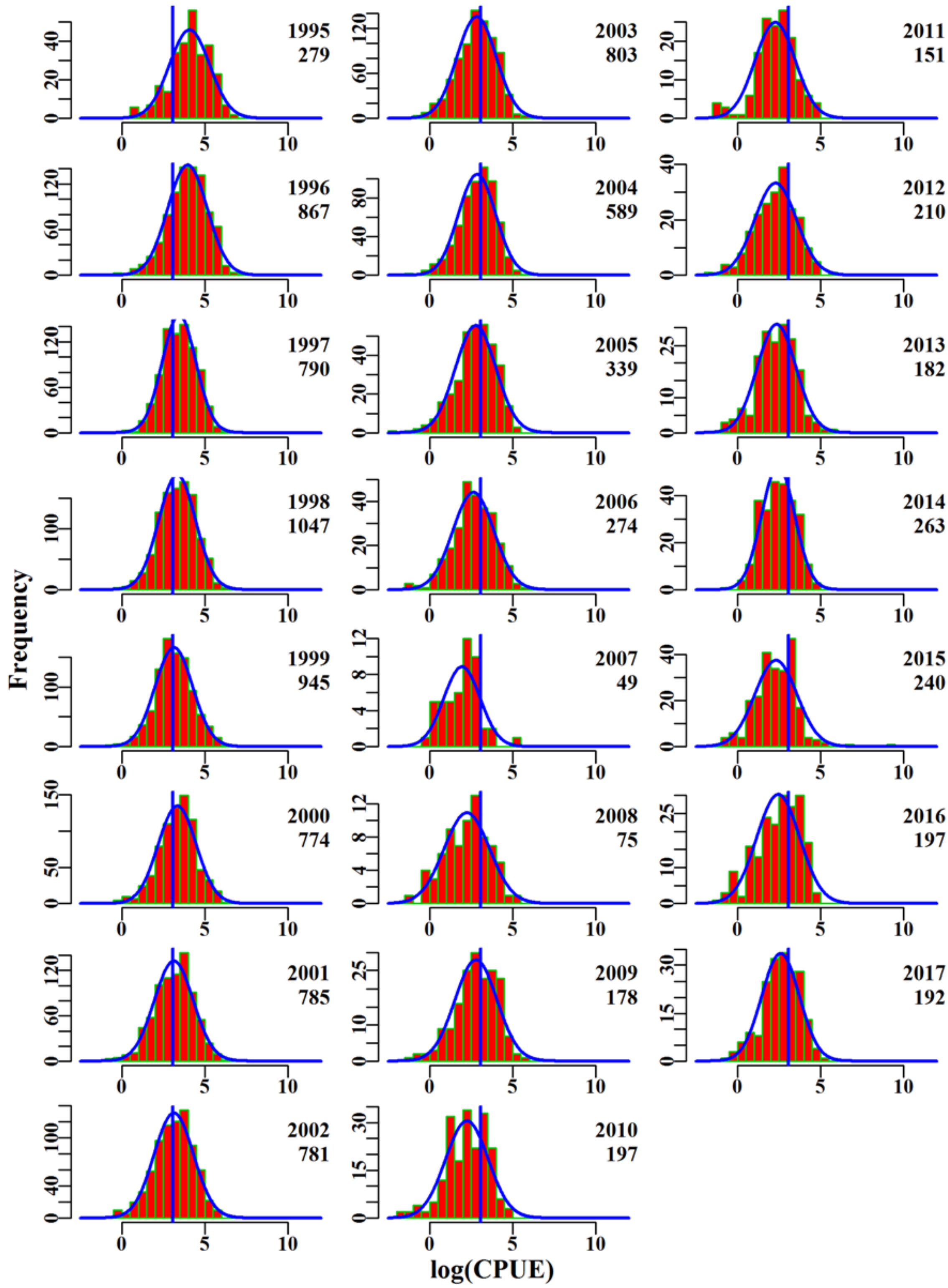

Figure 7.16. EasternDeepSharks. The log(CPUE) for each year of data available the blue lines are normal distributions fitted to the histogram frequencies. The numbers in each plot are the year and number of records. The vertical blue line is the average across all years.

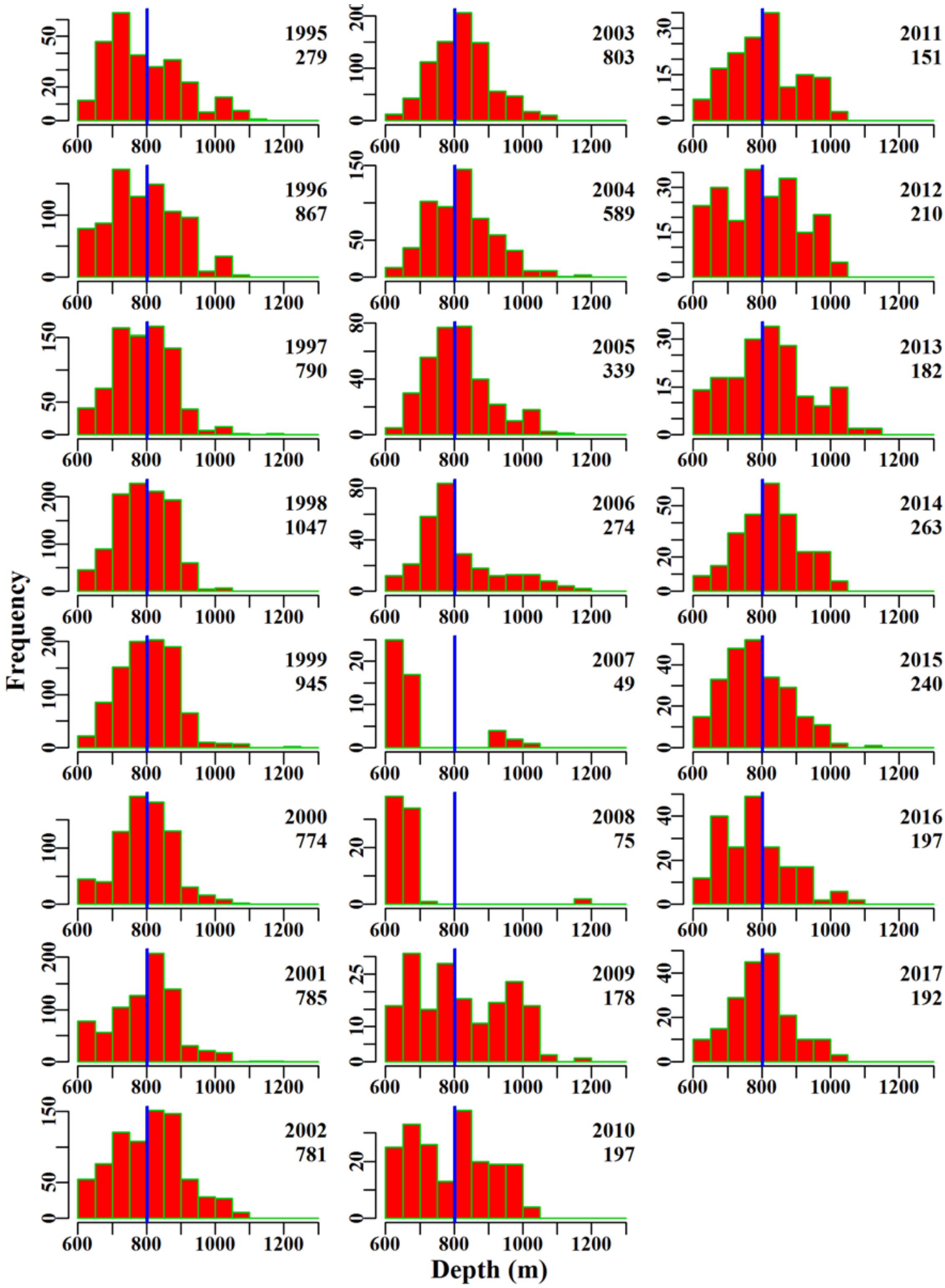

Figure 7.17. EasternDeepSharks. The average Depth of fishing for each year of data available to illustrate the development of the fishery through time. The numbers in each plot are the year and number of records. The vertical blue line is the average across all years.

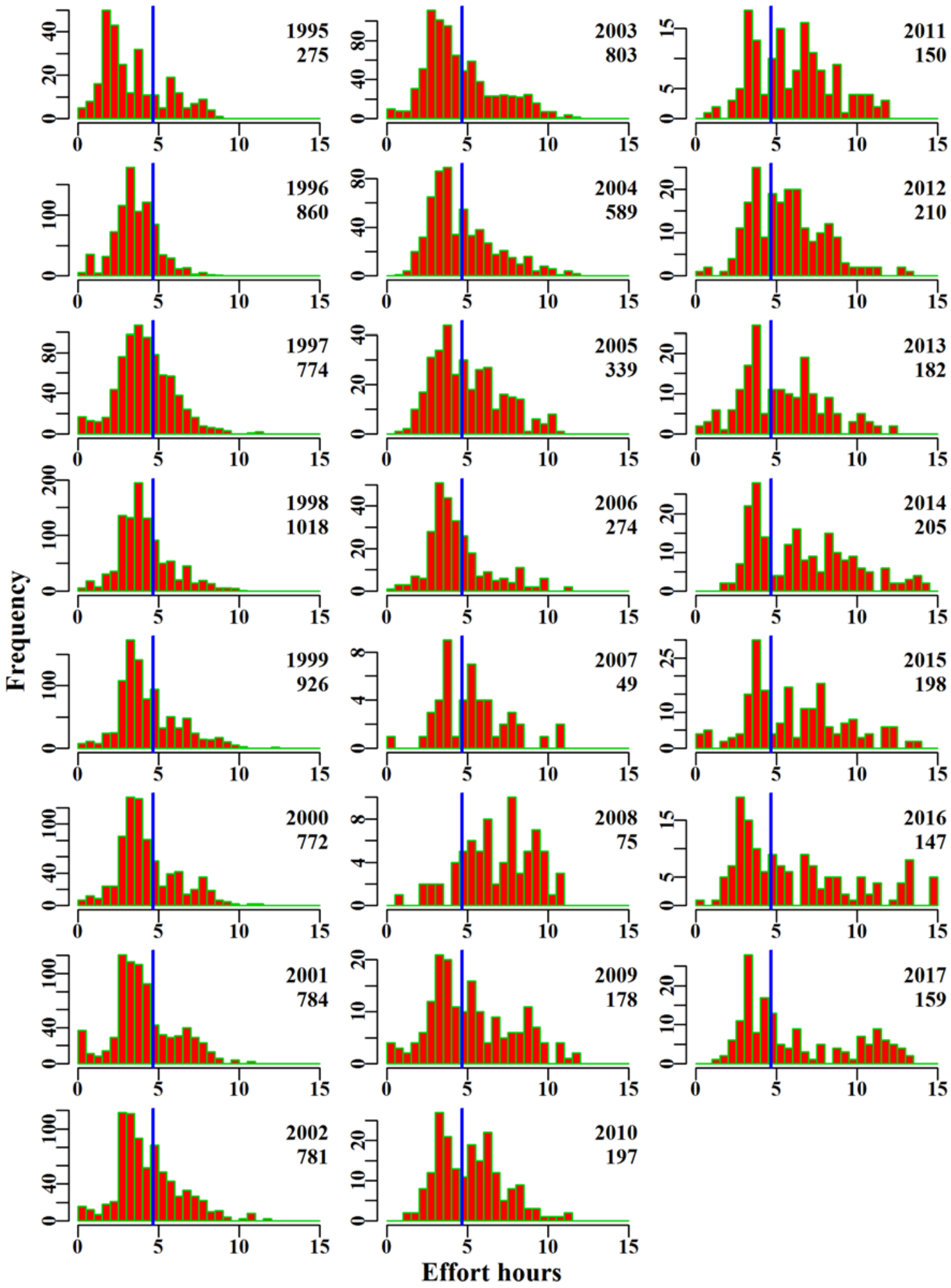

Figure 7.18. EasternDeepSharks. The frequency distribution of effort each year for the available data. The numbers in each plot are the year and number of records. The vertical blue line is the average across all years.

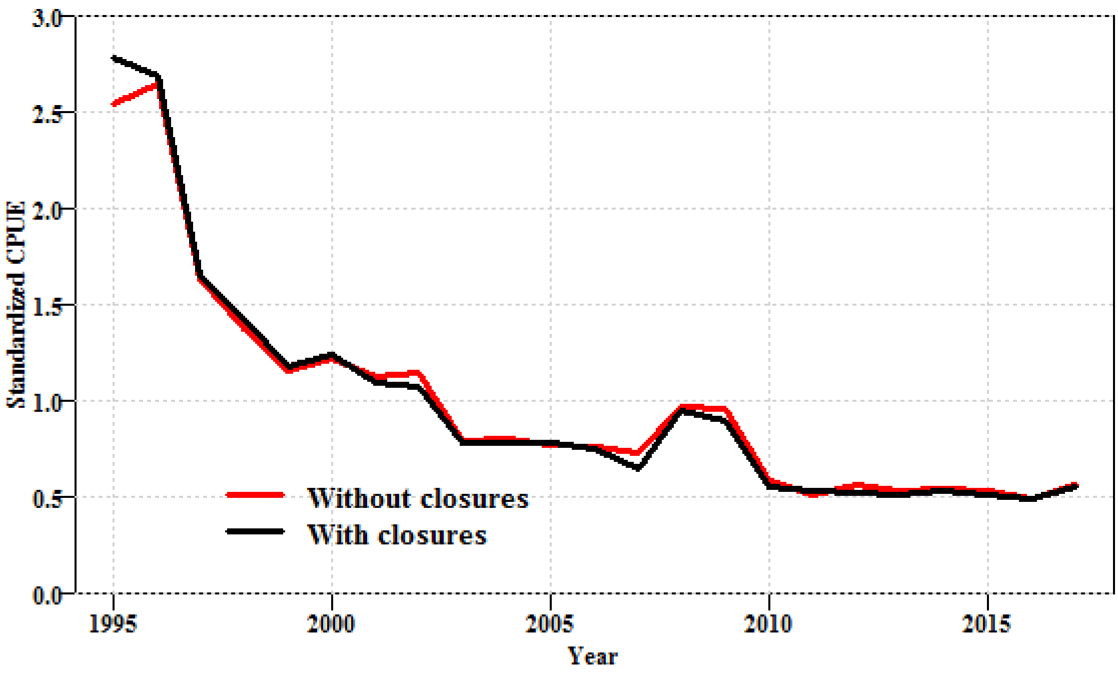

Figure 7.19. EasternDeepSharks. Standardized CPUE indices with and without closures.

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 – 2017 (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 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 2008-2010 and has almost returned to the long term average in 2017 (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 - 2017

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	1.6754	0.000	3.683	0.036
1996	834.2	1347	189.9	25	38.6	1.7839	0.047	8.613	0.045
1997	851.0	2322	339.9	22	37.0	1.4679	0.044	12.084	0.036
1998	838.5	3234	405.9	19	29.2	1.1388	0.043	17.614	0.043
1999	731.3	2449	321.4	22	28.8	1.1145	0.044	13.384	0.042
2000	683.5	2029	318.4	21	34.0	1.2589	0.046	8.331	0.026
2001	572.8	1929	244.3	20	27.3	0.9870	0.046	10.879	0.045
2002	516.0	1673	250.7	18	28.5	1.0423	0.047	7.883	0.031
2003	360.8	1457	167.3	18	20.8	0.7938	0.047	8.009	0.048
2004	377.7	1815	212.4	15	22.4	0.8130	0.047	10.673	0.050
2005	202.8	862	84.1	13	20.5	0.7117	0.052	6.061	0.072
2006	178.1	616	69.4	13	22.3	0.8472	0.056	3.798	0.055
2007	56.4	111	8.8	9	20.7	0.8941	0.102	0.611	0.070
2008	51.8	118	15.5	8	25.1	1.1023	0.102	0.312	0.020
2009	83.1	226	33.4	10	25.8	1.1574	0.078	1.032	0.031
2010	77.4	274	36.0	9	25.7	1.0420	0.073	1.886	0.052
2011	78.9	309	38.0	11	22.4	0.8908	0.069	1.479	0.039
2012	82.8	379	35.4	10	15.7	0.6146	0.068	2.740	0.077
2013	102.2	683	66.7	12	15.2	0.6132	0.059	4.098	0.061
2014	104.8	772	55.3	9	13.9	0.5648	0.061	3.797	0.069
2015	86.7	579	49.1	8	17.3	0.6568	0.066	2.150	0.044
2016	93.0	563	55.6	10	25.2	0.9137	0.069	1.881	0.034
2017	97.4	628	57.3	10	26.4	0.9159	0.068	2.495	0.044

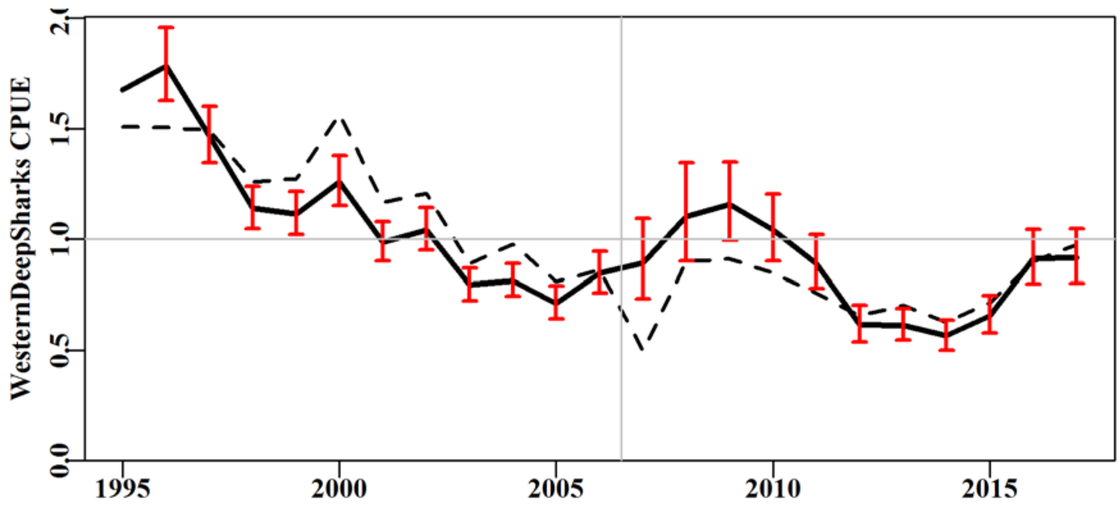

Figure 7.20. WesternDeepSharks standardization. The dashed black line represents the geometric mean catch rate, solid black line the standardized catch rates. The red bars are the 95% confidence intervals about the mean estimates. The graph scales both time-series of standardized catch rates relative to the mean of each time-series.

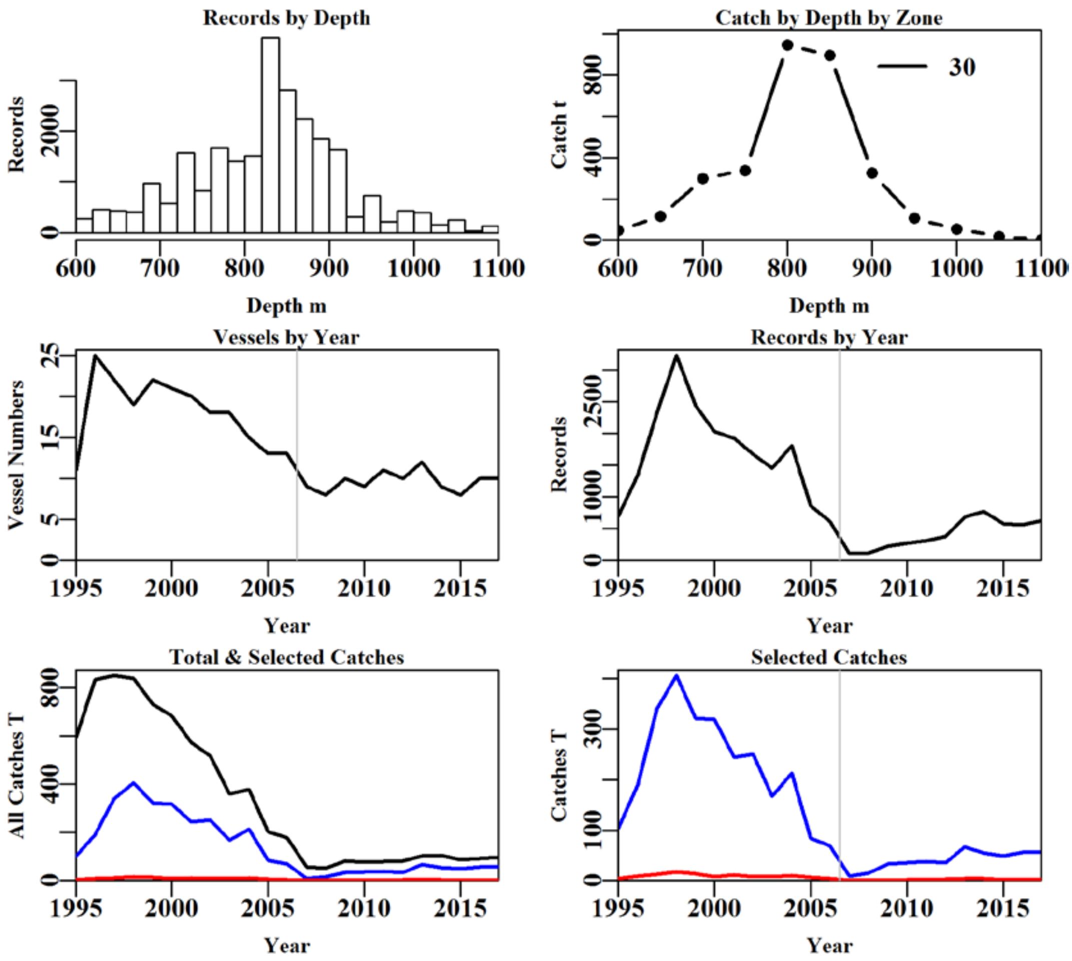

Figure 7.21. WesternDeepSharks fishery details. The bottom left plot depicts all known catches (top black line), and all selected catches used in the analysis (middle blue line); the lower red line: selected catches < 30 kg).

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	352955	229176	91215	30440	30424	25069	24000
Difference	0	123779	137961	60775	16	5355	1069

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	1760	25777	1614	24000	23	5.8	0.00
Vessel	334	24198	3193	24000	68	11.4	5.60
DepCat	-2092	21854	5537	24000	78	20.0	8.55
Month	-2245	21696	5695	24000	89	20.5	0.54
DayNight	-2323	21620	5771	24000	92	20.8	0.27
inout	-2403	21546	5845	24000	93	21.0	0.27
Vessel:DepCat	-3140	20431	6960	24000	362	24.3	3.23
Vessel:Month	-2575	20811	6580	24000	423	22.7	1.63

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	513.803
Black	37020002	333.543
Platypus	37020004	241.932
Plunket	37020013	0.224
Pearl	37020905	889.366
Roughskin	37020906	563.588
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	16.259		105.249	135.090	29.349
2001	0.125		26.184		107.183	103.619	7.196
2002	0.050		36.770		146.838	63.497	3.585
2003	0.050		20.295		86.814	59.161	0.964
2004	0.100		20.811		117.189	74.203	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

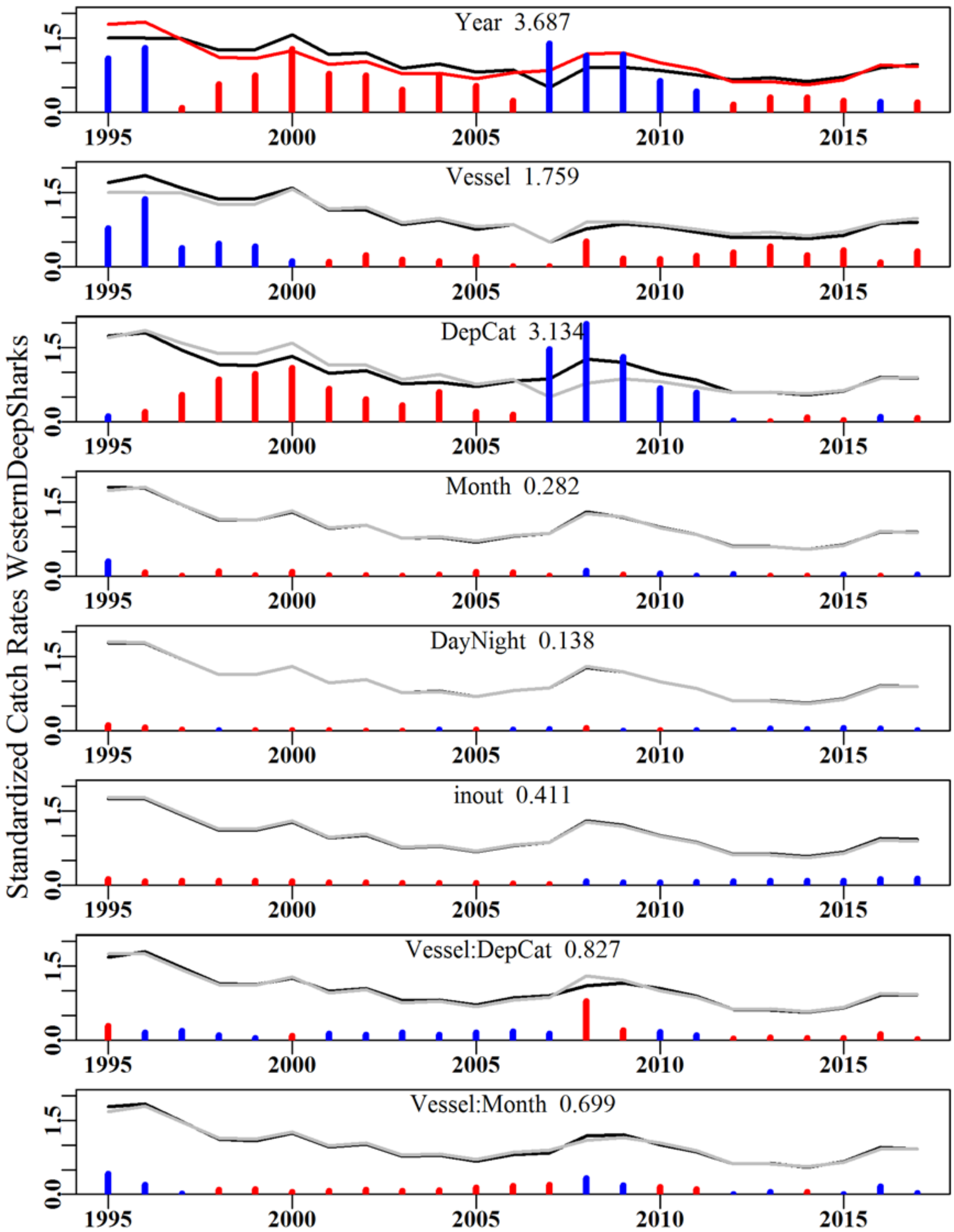

Figure 7.22. WesternDeepSharks. The influence of each factor on the optimal standardization. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by vertical bars with blue bars indicating the optimum model is higher than the 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.

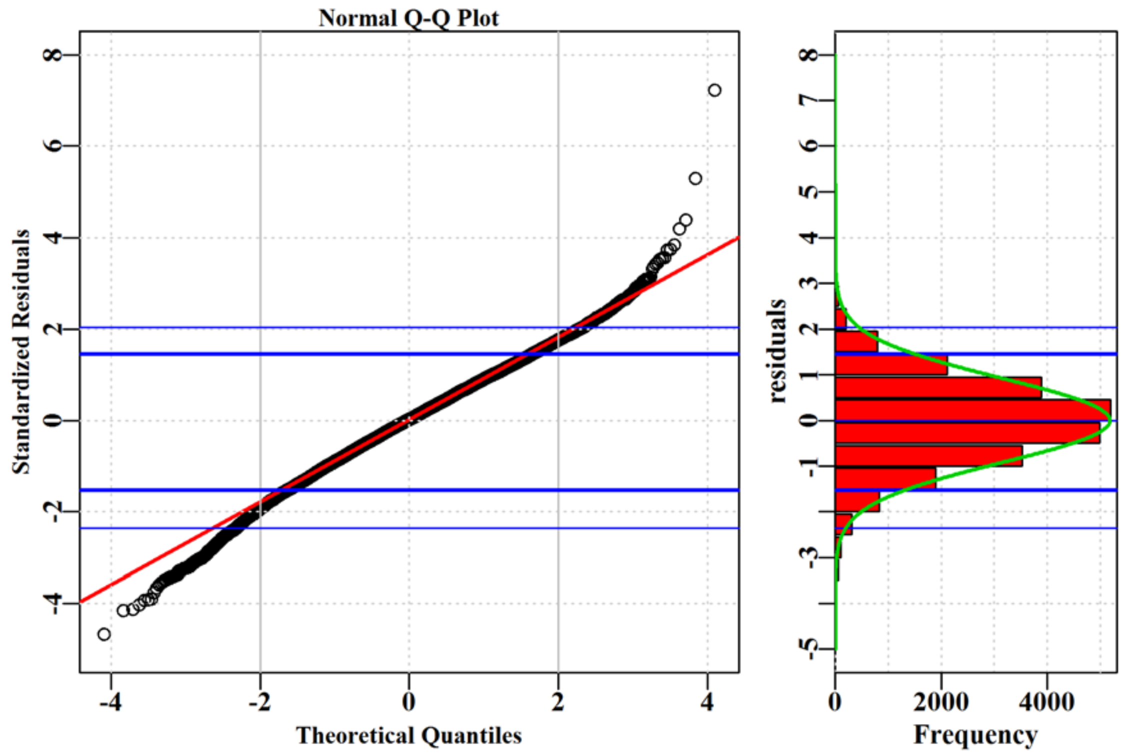

Figure 7.23. WesternDeepSharks. Diagnostic plots. The distribution of residuals from the optimum fit. The qqplot indicates the fit to the expected normality, while the histogram of residuals also illustrates the 1%, 5%, 95% and 99% quantiles to indicate the intensity of any lack of fit at the margins of the distribution (reflected also in the qqplot).

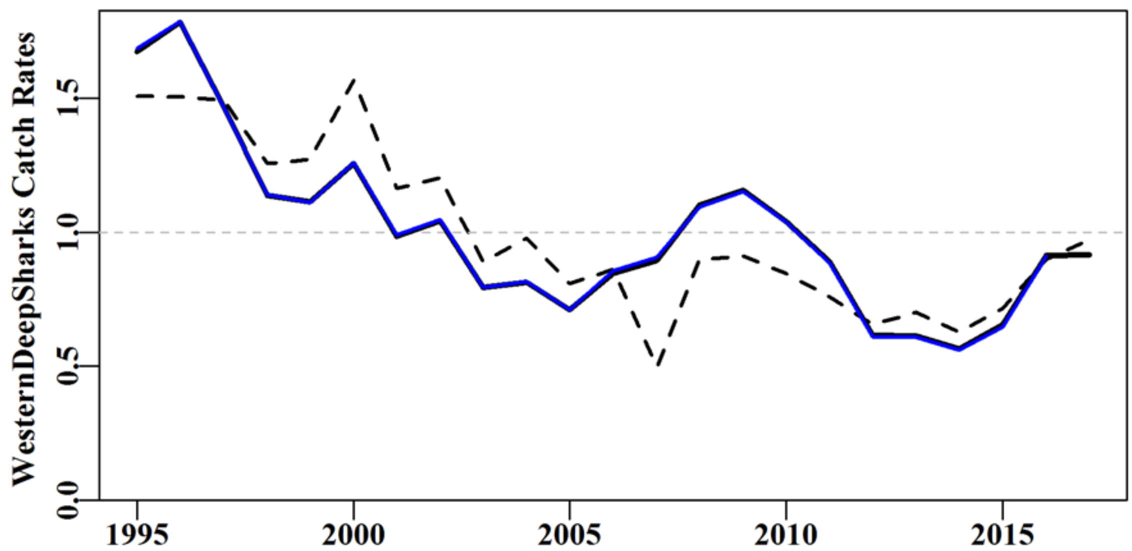

Figure 7.24. WesternDeepSharks. A comparison of the previous year's standardization (blue line) with this year's. They should lie on top of each other, although small deviations may relate to data adjustments, particularly in very recent years.

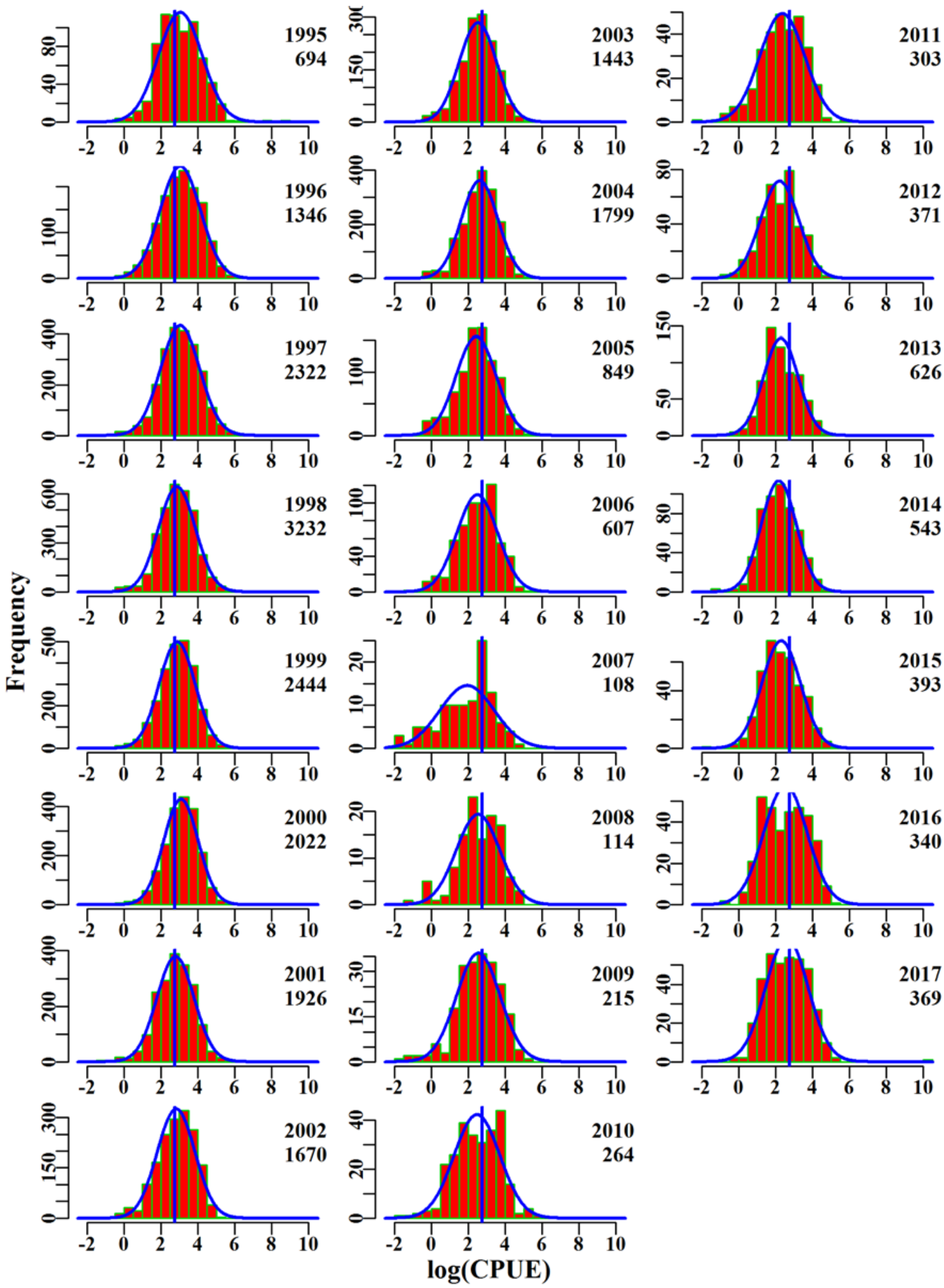

Figure 7.25. WesternDeepSharks. The log(CPUE) for each year of data available the blue lines are normal distributions fitted to the histogram frequencies. The numbers in each plot are the year and number of records. The vertical blue line is the average across all years.

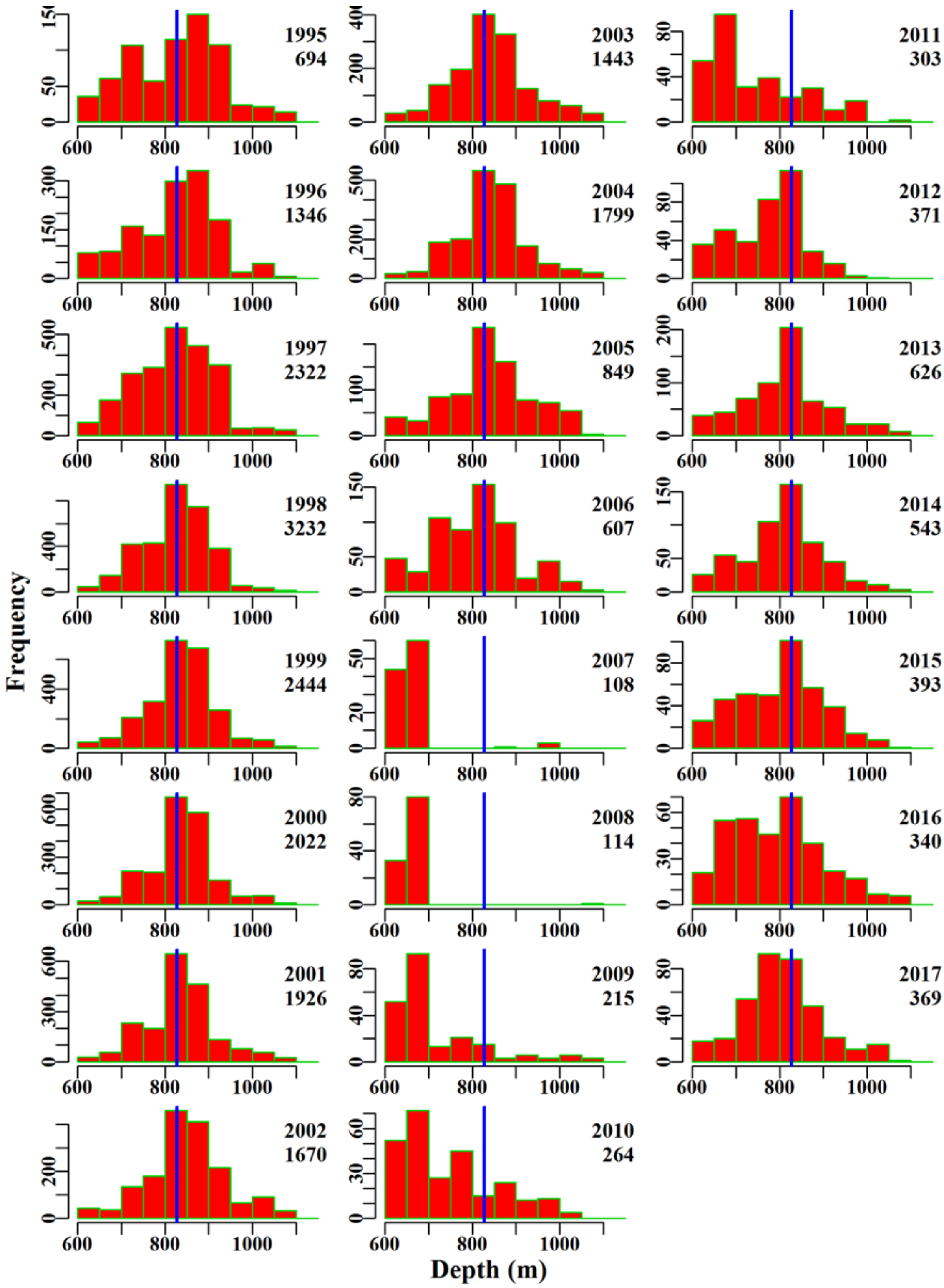

Figure 7.26. WesternDeepSharks. The average Depth of fishing for each year of data available to illustrate the development of the fishery through time. The numbers in each plot are the year and number of records. The vertical blue line is the average across all years.

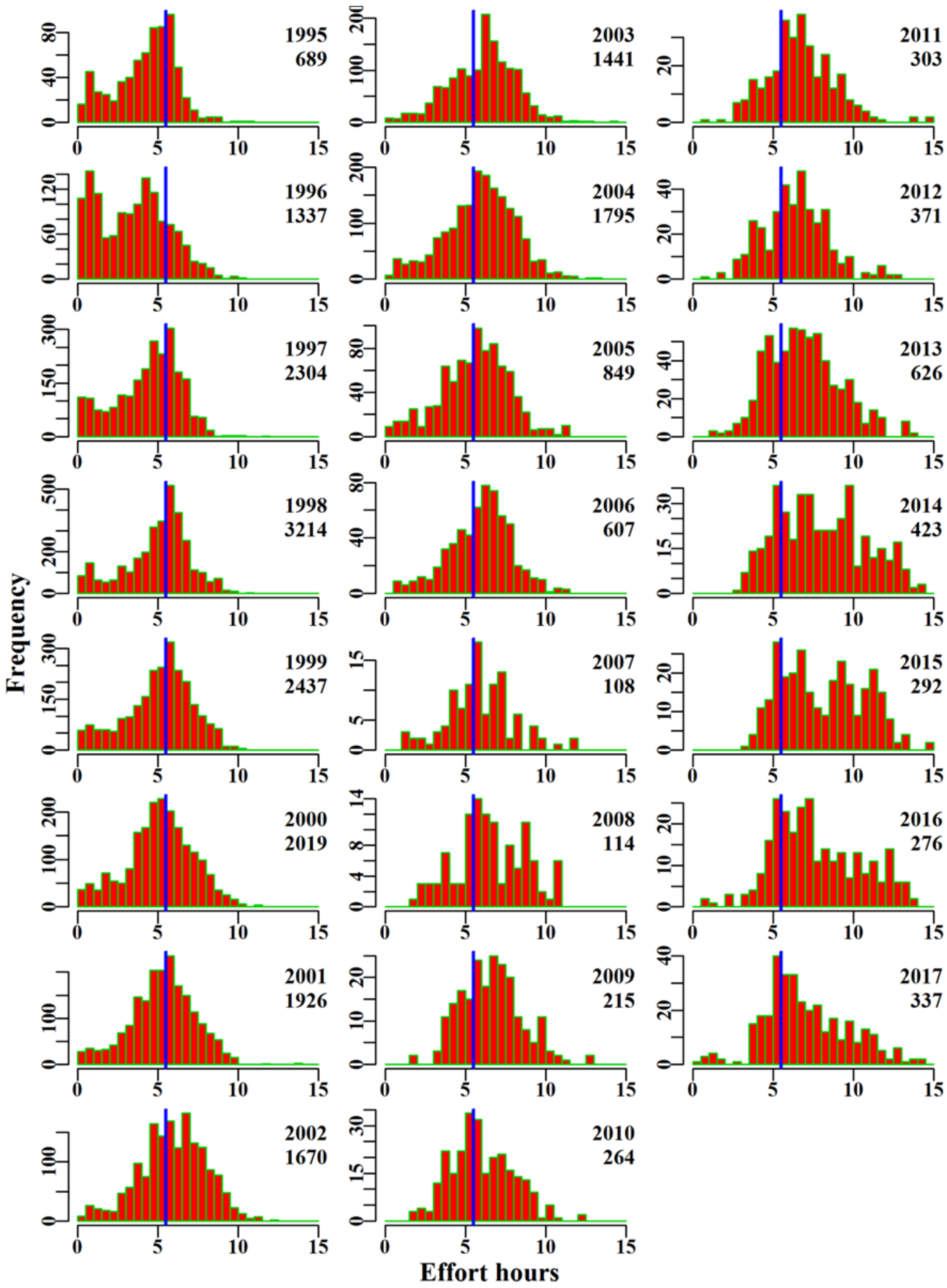

Figure 7.27. WesternDeepSharks. The frequency distribution of effort each year for the available data. The numbers in each plot are the year and number of records. The vertical blue line is the average across all years.

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 - 2017 (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 7.28).

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 almost returned to the long term average in 2017 (Figure 7.20).

The removal of catch from the 700 m closure, made minimal differences to standardized CPUE compared to CPUE indices which included them in analyses (Figure 7.36).

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, 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 - 2017

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	1.5918	0.000	2.431	0.032
1996	834.2	877	143.2	22	40.1	1.8222	0.058	4.821	0.034
1997	851.0	1632	253.3	20	37.1	1.4908	0.053	7.097	0.028
1998	838.5	2212	273.8	19	28.7	1.1480	0.052	11.061	0.040
1999	731.3	1654	201.9	21	25.2	1.0615	0.053	8.653	0.043
2000	683.5	1367	210.8	21	31.6	1.2627	0.055	5.331	0.025
2001	572.8	1307	165.2	19	25.8	1.0079	0.055	6.746	0.041
2002	516.0	1091	167.4	17	30.1	1.0901	0.056	4.977	0.030
2003	360.8	995	113.1	16	19.9	0.8407	0.057	5.266	0.047
2004	377.7	1221	144.5	14	22.4	0.8300	0.056	7.545	0.052
2005	202.8	573	56.4	13	20.2	0.7222	0.063	3.984	0.071
2006	178.1	438	52.0	13	23.3	0.9179	0.067	2.530	0.049
2007	56.4	98	7.9	9	19.0	0.8644	0.112	0.548	0.069
2008	51.8	114	15.1	8	25.6	1.1553	0.108	0.312	0.021
2009	83.1	212	31.7	9	26.2	1.1731	0.084	0.942	0.030
2010	77.4	256	33.4	9	25.0	1.0267	0.080	1.776	0.053
2011	78.9	293	35.5	11	22.0	0.8750	0.075	1.404	0.040
2012	82.8	370	34.4	10	15.7	0.5968	0.074	2.684	0.078
2013	102.2	659	64.0	12	15.3	0.6061	0.067	3.959	0.062
2014	104.8	758	54.2	9	13.9	0.5405	0.068	3.734	0.069
2015	86.7	570	48.0	8	17.2	0.6318	0.072	2.125	0.044
2016	93.0	540	52.0	10	25.1	0.8702	0.076	1.781	0.034
2017	97.4	619	54.8	10	26.1	0.8744	0.075	2.495	0.046

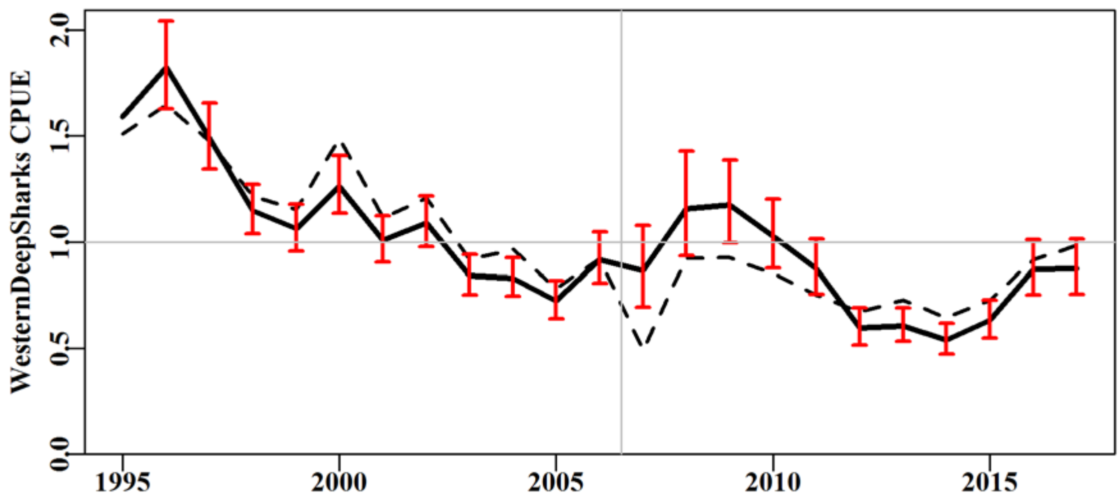

Figure 7.28. WesternDeepSharks standardization. The dashed black line represents the geometric mean catch rate, solid black line the standardized catch rates. The red bars are the 95% confidence intervals about the mean estimates. The graph scales both time-series of standardized catch rates relative to the mean of each time-series.

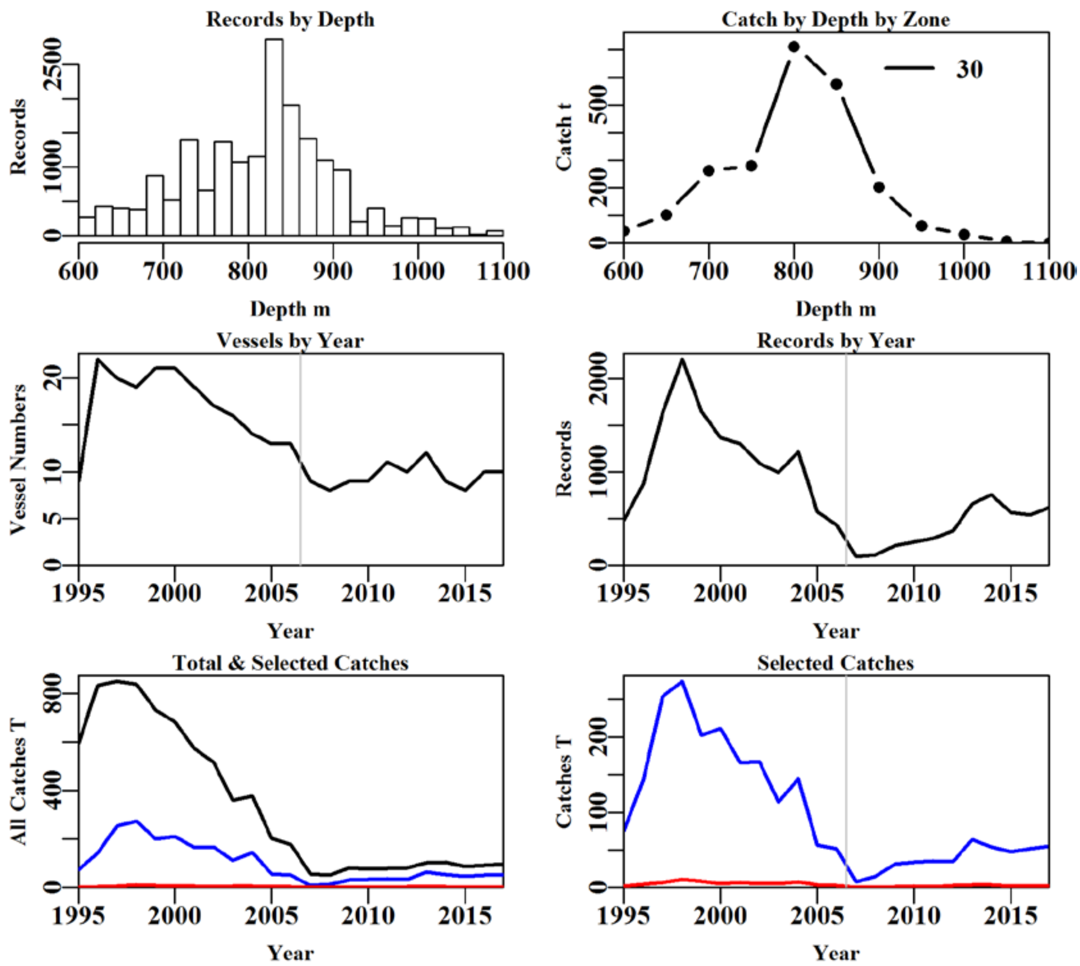

Figure 7.29. WesternDeepSharks fishery details. The bottom left plot depicts all known catches (top black line), and all selected catches used in the analysis (middle blue line); the lower red line: selected catches < 30 kg).

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	352955	229176	91215	30440	30424	25069	24000	17308
Difference	0	123779	137961	60775	16	5355	1069	6692

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	1609	18944	1182	17308	23	5.8	0.00
Vessel	519	17698	2428	17308	67	11.7	5.98
DepCat	-1344	15873	4253	17308	77	20.8	9.05
Month	-1471	15737	4389	17308	88	21.4	0.63
DayNight	-1519	15690	4436	17308	90	21.6	0.23
Vessel:DepCat	-1918	14898	5228	17308	339	24.5	2.87
Vessel:Month	-1475	15157	4969	17308	411	22.9	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	379.587
Black	37020002	204.454
Platypus	37020004	225.168
Plunket	37020013	0.224
Pearl	37020905	648.711
Roughskin	37020906	385.968
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	13.944		71.028	79.899	22.779
2001	0.100		22.569		71.369	66.330	4.866
2002	0.050		34.762		88.858	40.402	3.285
2003	0.050		17.858		54.630	39.630	0.934
2004	0.095		18.256		75.880	50.201	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

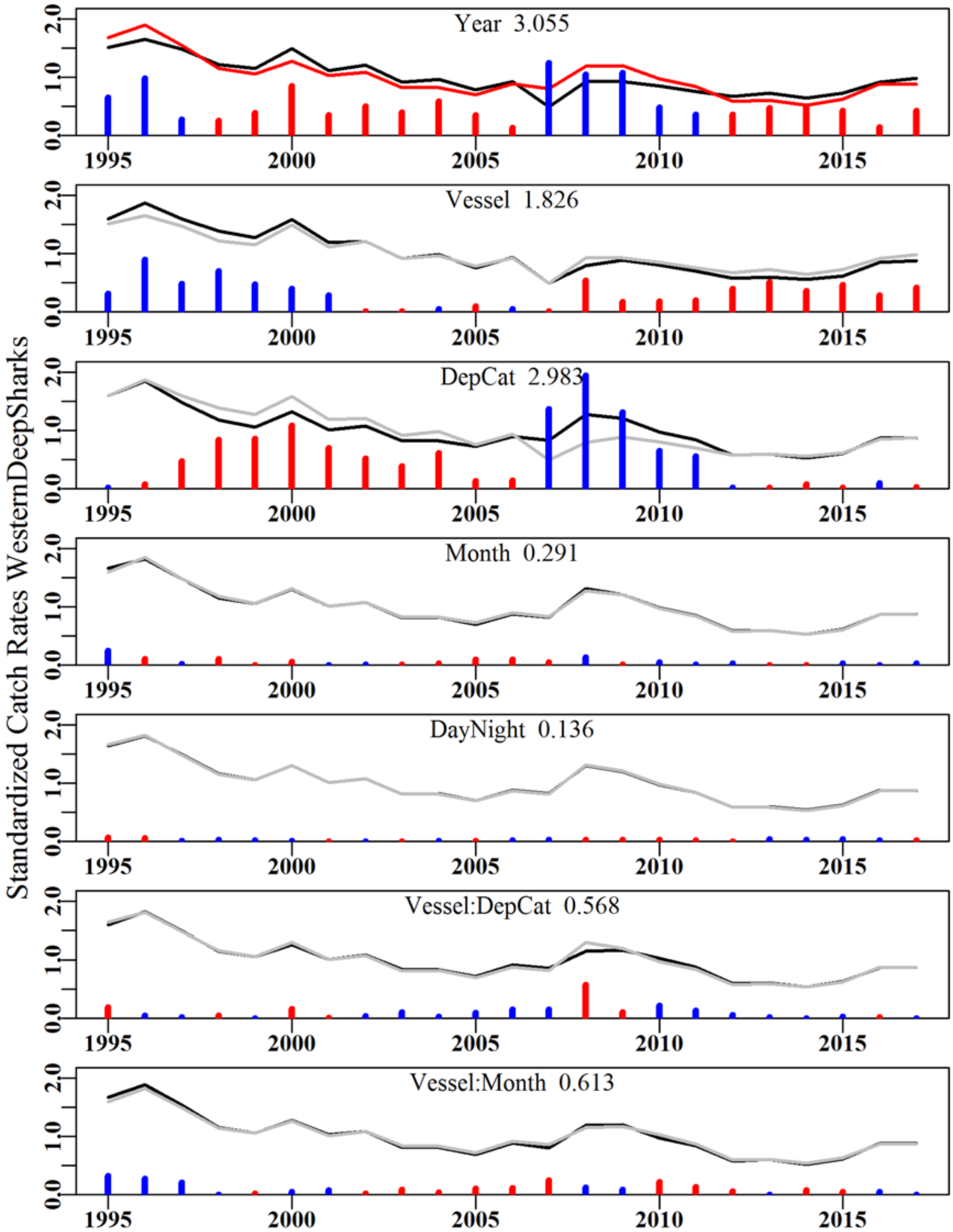

Figure 7.30. WesternDeepSharks. The influence of each factor on the optimal standardization. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by vertical bars with blue bars indicating the optimum model is higher than the 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.

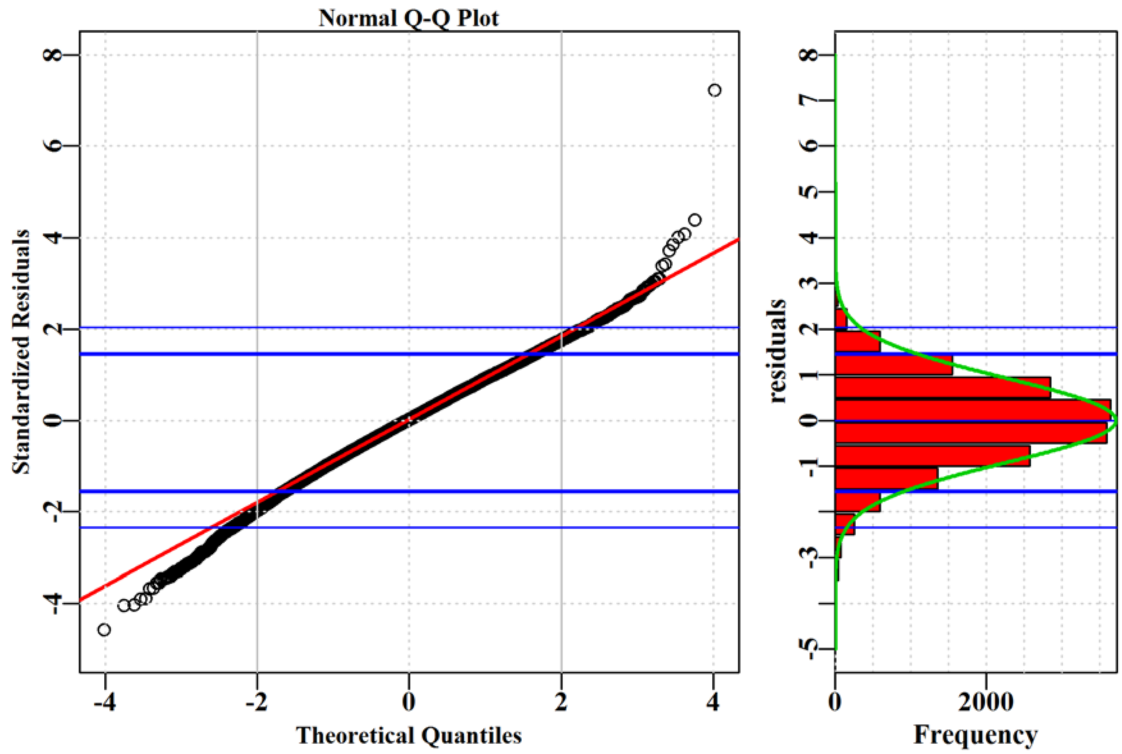

Figure 7.31. WesternDeepSharks. Diagnostic plots. The distribution of residuals from the optimum fit. The qqplot indicates the fit to the expected normality, while the histogram of residuals also illustrates the 1%, 5%, 95% and 99% quantiles to indicate the intensity of any lack of fit at the margins of the distribution (reflected also in the qqplot).

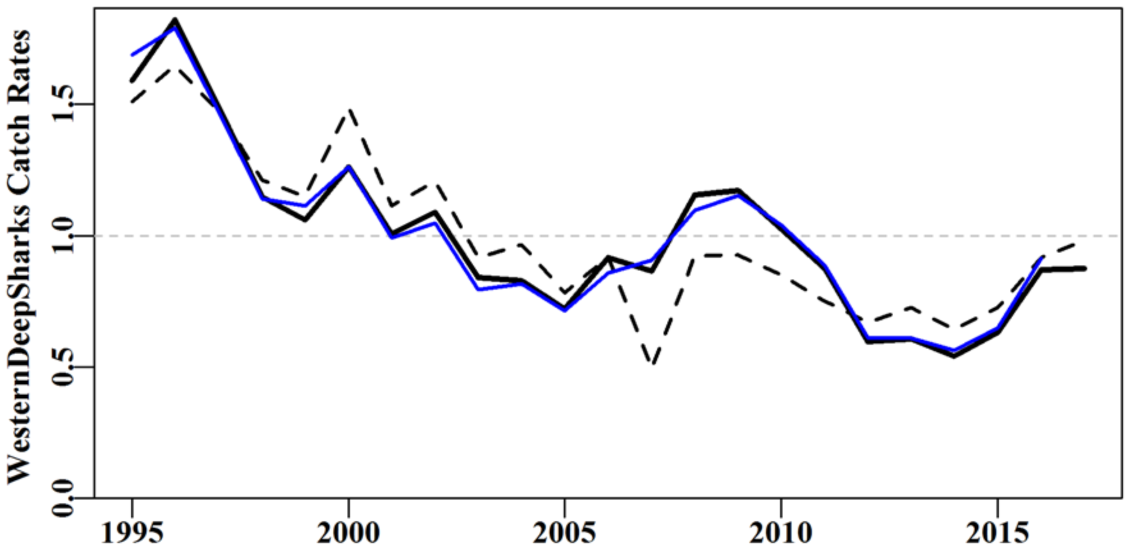

Figure 7.32. WesternDeepSharks. A comparison of the previous year's standardization (blue line) with this year's. They should lie on top of each other, although small deviations may relate to data adjustments, particularly in very recent years.

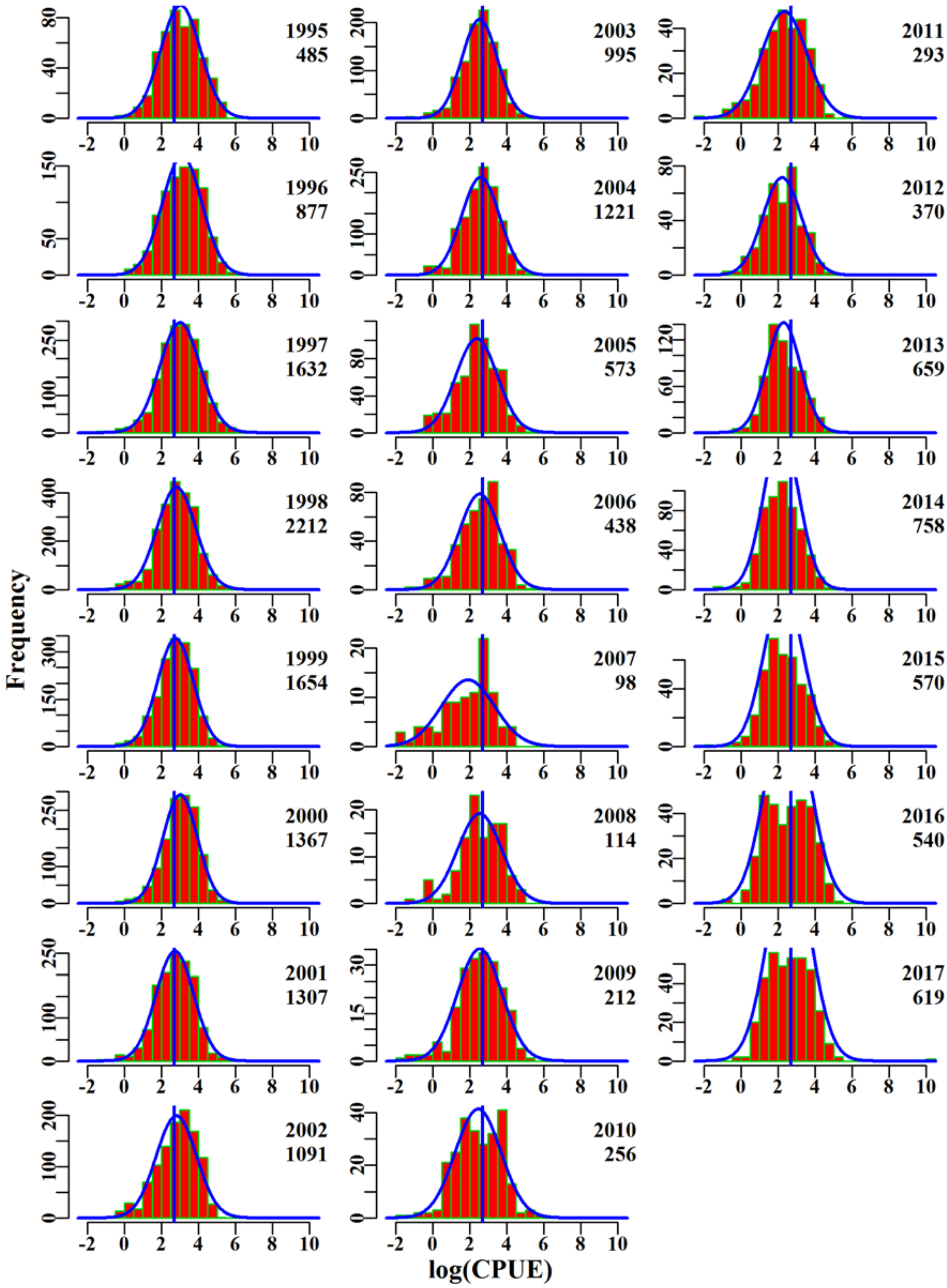

Figure 7.33. WesternDeepSharks. The log(CPUE) for each year of data available the blue lines are normal distributions fitted to the histogram frequencies. The numbers in each plot are the year and number of records. The vertical blue line is the average across all years.

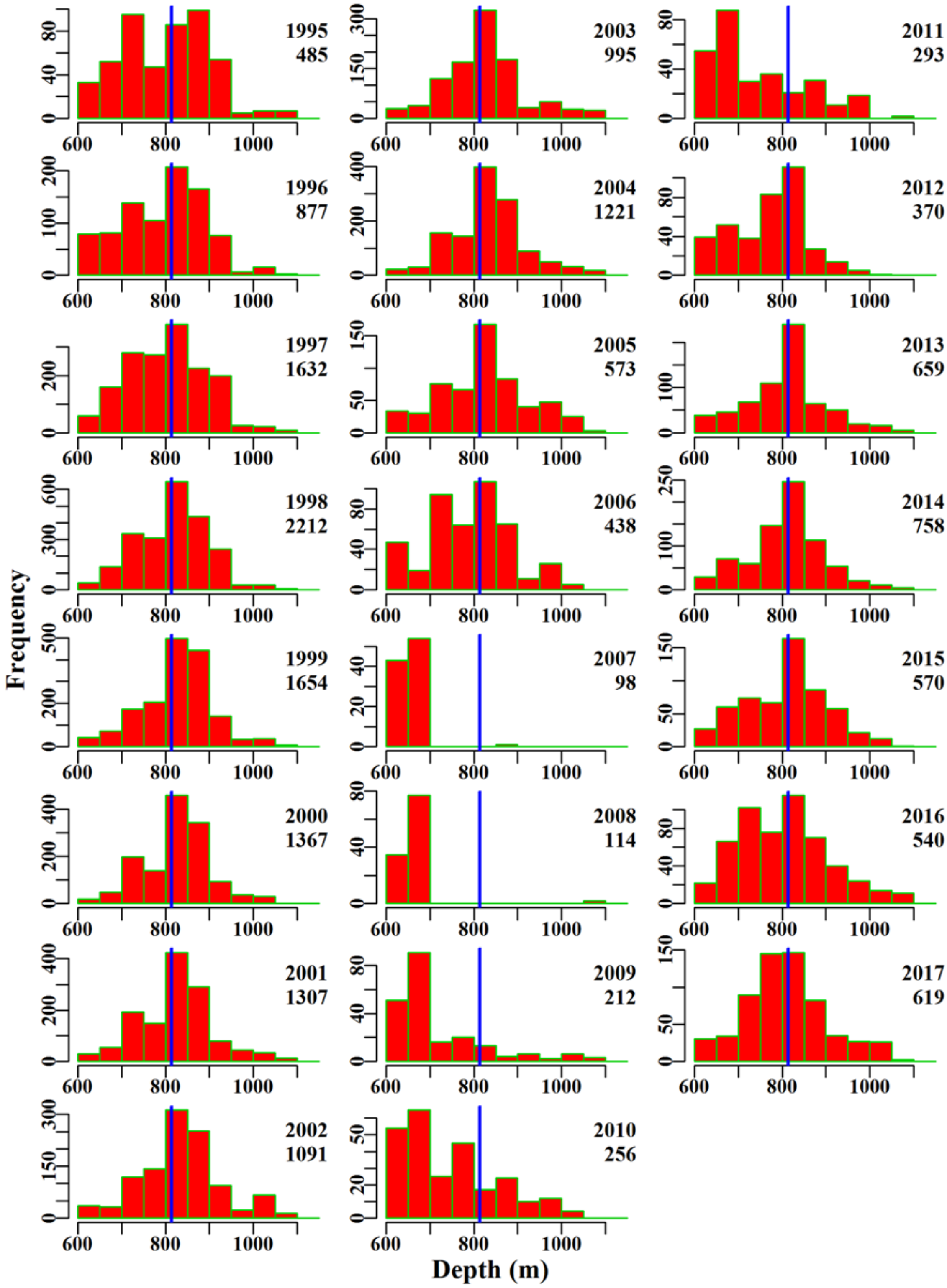

Figure 7.34. WesternDeepSharks. The average Depth of fishing for each year of data available to illustrate the development of the fishery through time. The numbers in each plot are the year and number of records. The vertical blue line is the average across all years.

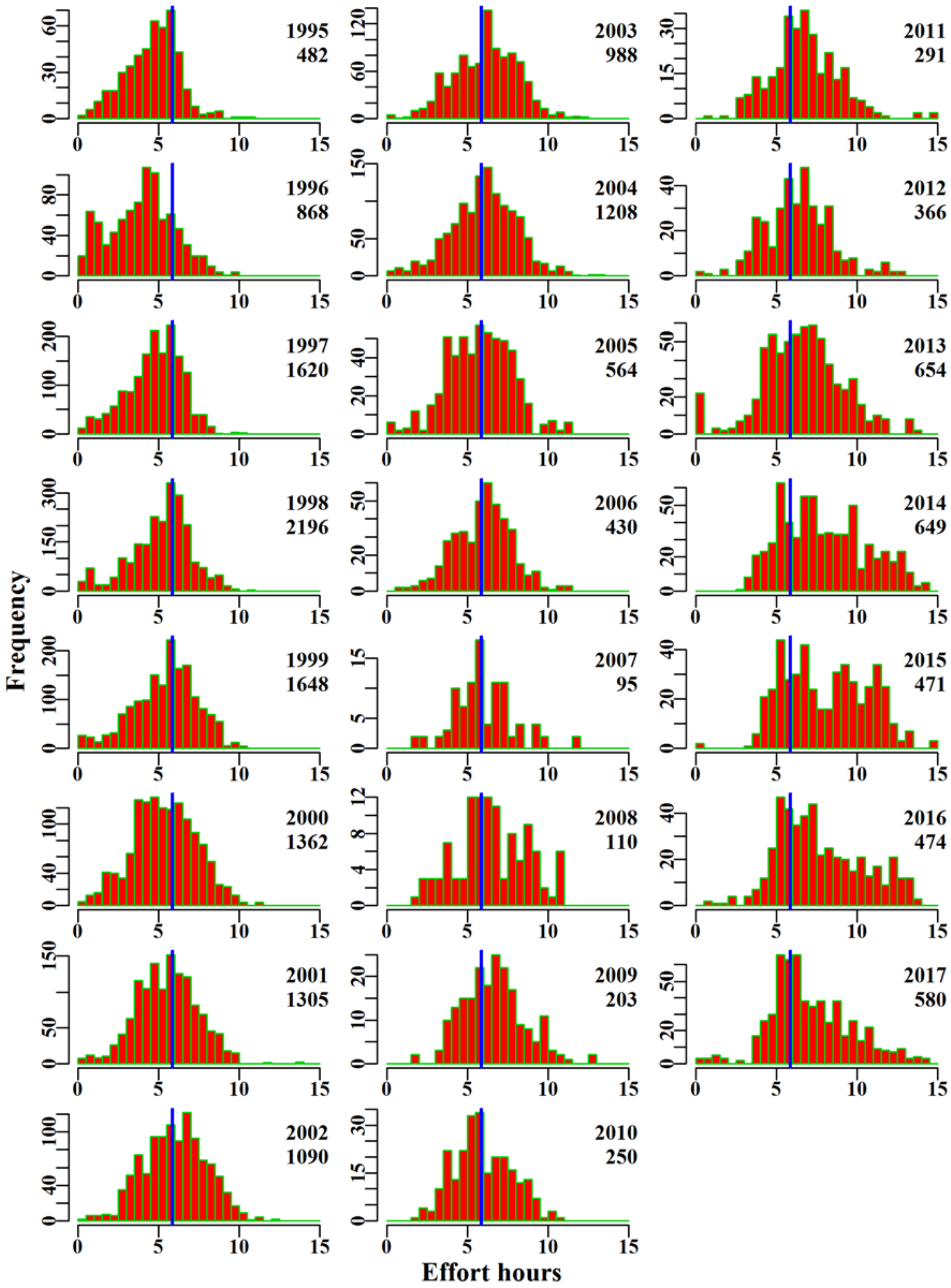

Figure 7.35. WesternDeepSharks. The frequency distribution of effort each year for the available data. The numbers in each plot are the year and number of records. The vertical blue line is the average across all years.

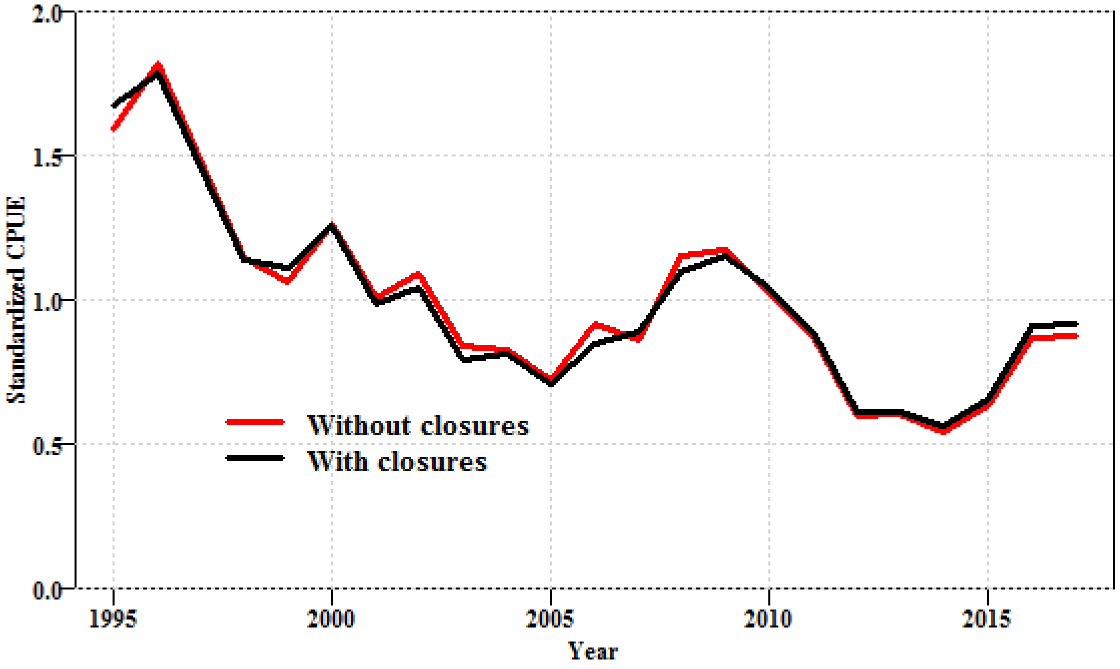

Figure 7.36. WesternDeepSharks. Standardized CPUE indices with and without closures.

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 – 2017 (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 117 t from 2013 - 2017. 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 - 2017

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	1.0239	0.000	0.974	0.018
1987	90.2	242	73.6	21	194.4	2.0335	0.142	1.123	0.015
1988	157.2	257	43.3	17	102.9	1.6814	0.146	1.468	0.034
1989	749.2	480	216.7	26	1429.3	2.9864	0.128	1.948	0.009
1990	1100.4	461	258.4	30	5108.2	4.7656	0.137	0.650	0.003
1991	1136.2	339	87.2	35	441.7	1.6169	0.138	0.892	0.010
1992	3354.0	624	606.8	32	4715.6	3.2915	0.120	2.493	0.004
1993	1097.4	839	282.5	39	516.5	1.7753	0.120	4.188	0.015
1994	1112.3	1094	283.2	34	262.7	1.1891	0.118	7.405	0.026
1995	1027.7	1768	498.0	30	96.4	1.0801	0.115	10.328	0.021
1996	785.3	2101	417.9	33	77.1	0.7677	0.115	12.888	0.031
1997	2091.1	2281	575.7	34	69.0	0.8001	0.115	11.973	0.021
1998	2042.3	2353	666.9	33	87.6	0.9941	0.115	11.177	0.017
1999	905.8	1915	441.8	34	72.3	0.8251	0.116	10.149	0.023
2000	1059.7	1726	376.3	42	63.2	0.6068	0.116	10.109	0.027
2001	1140.0	1946	402.7	38	63.7	0.6072	0.116	10.745	0.027
2002	857.2	1457	213.2	37	41.9	0.4253	0.117	9.960	0.047
2003	886.0	1452	228.0	30	43.8	0.4158	0.117	8.497	0.037
2004	639.8	1443	180.5	31	36.9	0.3996	0.118	10.133	0.056
2005	503.1	847	101.4	22	36.5	0.3346	0.121	5.384	0.053
2006	214.3	703	88.2	27	43.1	0.3634	0.122	5.310	0.060
2007	135.2	402	68.0	19	74.6	0.4187	0.129	2.466	0.036
2008	78.4	298	48.4	16	37.2	0.3098	0.134	1.784	0.037
2009	191.2	501	73.4	18	35.2	0.3264	0.126	3.926	0.053
2010	238.0	504	76.3	15	33.7	0.2981	0.125	3.874	0.051
2011	107.0	593	86.0	19	29.7	0.3006	0.124	4.555	0.053
2012	82.9	526	71.3	16	29.4	0.2752	0.125	4.317	0.061
2013	165.3	770	152.0	19	36.2	0.3606	0.122	6.013	0.040
2014	151.1	724	130.6	17	32.3	0.4273	0.123	3.913	0.030
2015	136.1	715	110.4	17	68.0	0.4641	0.123	3.809	0.035
2016	148.7	645	114.1	18	93.0	0.4470	0.124	2.950	0.026
2017	157.5	588	80.1	18	61.1	0.3892	0.123	3.406	0.043

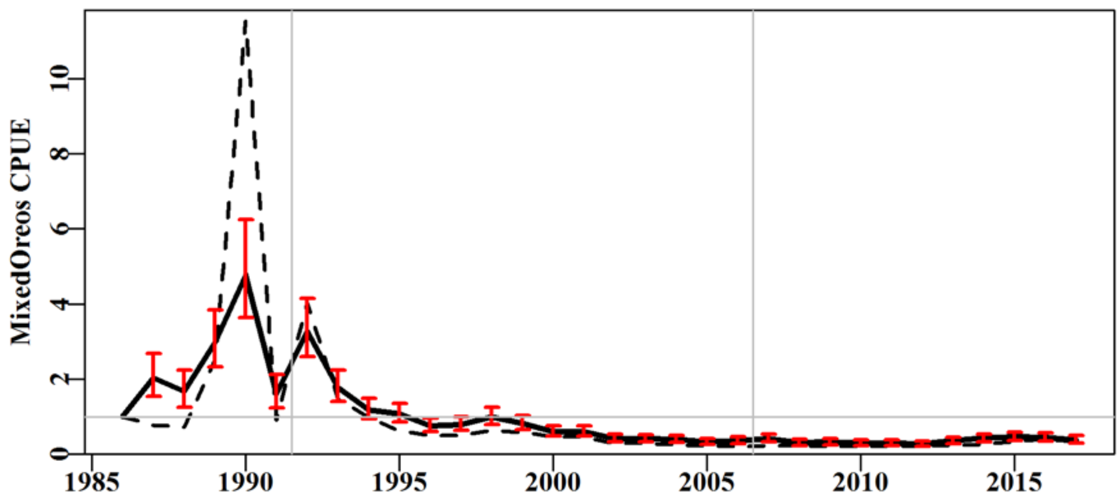

Figure 7.37. MixedOreos standardization. The dashed black line represents the geometric mean catch rate, solid black line the standardized catch rates. The red bars are the 95% confidence intervals about the mean estimates. The graph scales both time-series of standardized catch rates relative to the mean of each time-series.

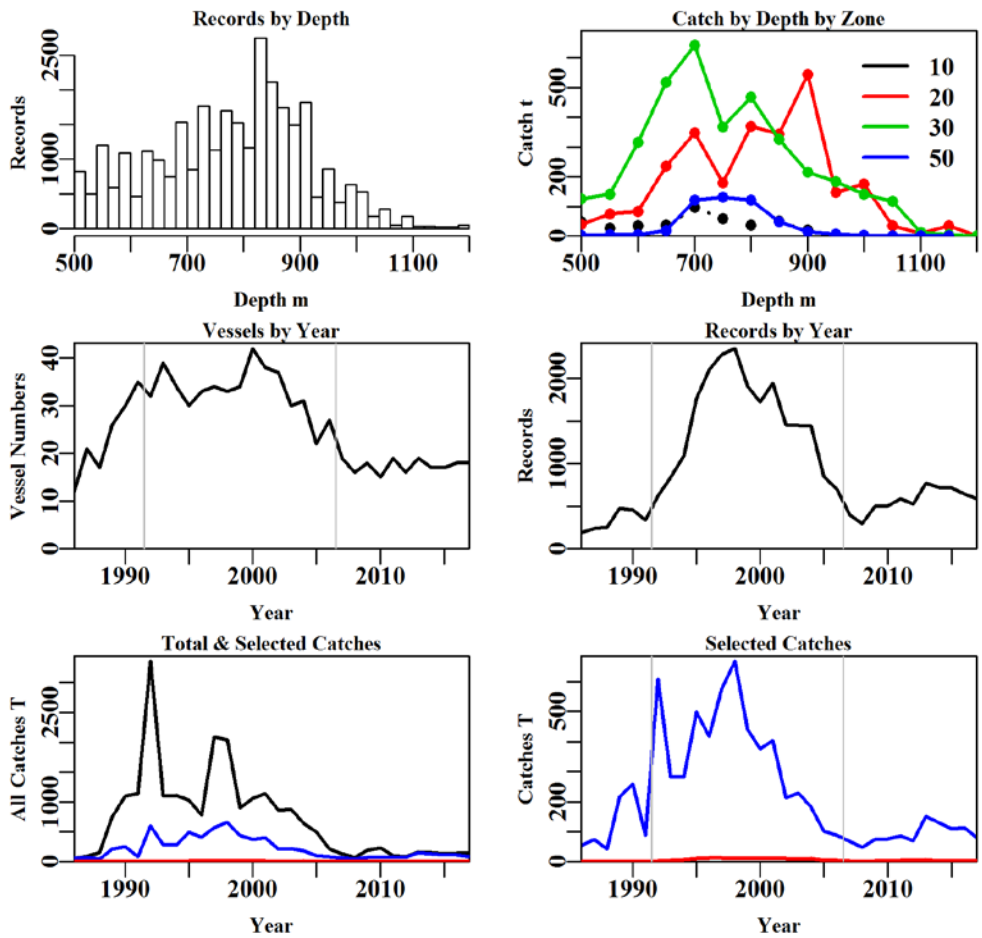

Figure 7.38. MixedOreos fishery details. The bottom left plot depicts all known catches (top black line), and all selected catches used in the analysis (middle blue line); the lower red line: selected catches < 30 kg).

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	56848	55298	55070	43443	43410	40807	39679	29905
Difference	0	1550	228	11627	33	2603	1128	9774

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	21573	61392	13216	29905	32	17.6	0.00
Vessel	16978	52237	22372	29905	149	29.6	12.01
DepCat	15040	48914	25694	29905	163	34.1	4.44
ORzone	13956	47163	27445	29905	166	36.4	2.35
DayNight	12922	45550	29058	29905	169	38.6	2.17
Month	12321	44612	29997	29905	180	39.8	1.24
inout	12258	44515	30093	29905	181	40.0	0.13
ORzone:DepCat	11755	43652	30956	29905	222	41.1	1.08
DepCat:Month	11952	43637	30972	29905	326	40.9	0.90

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	5944.597775
Oxeye	37266002	231.172
Warty	37266004	236.117
Black	37266005	0.2
OreoDory	37266902	630.4984

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	83.981	2.682	0.528			
1992	594.026	11.695	1.050			
1993	275.884	3.610	3.031			
1994	261.489	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	345.327	0.030	30.987			
2001	396.244	0.400	6.060			
2002	211.511	0.095	1.595			
2003	227.654		0.300			
2004	178.891	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	0.0		48.998
2015	71.652	19.153	0.000	0.0		19.559
2016	57.079	25.402		0.0	0	31.654
2017	47.625	7.939		0.2		24.331

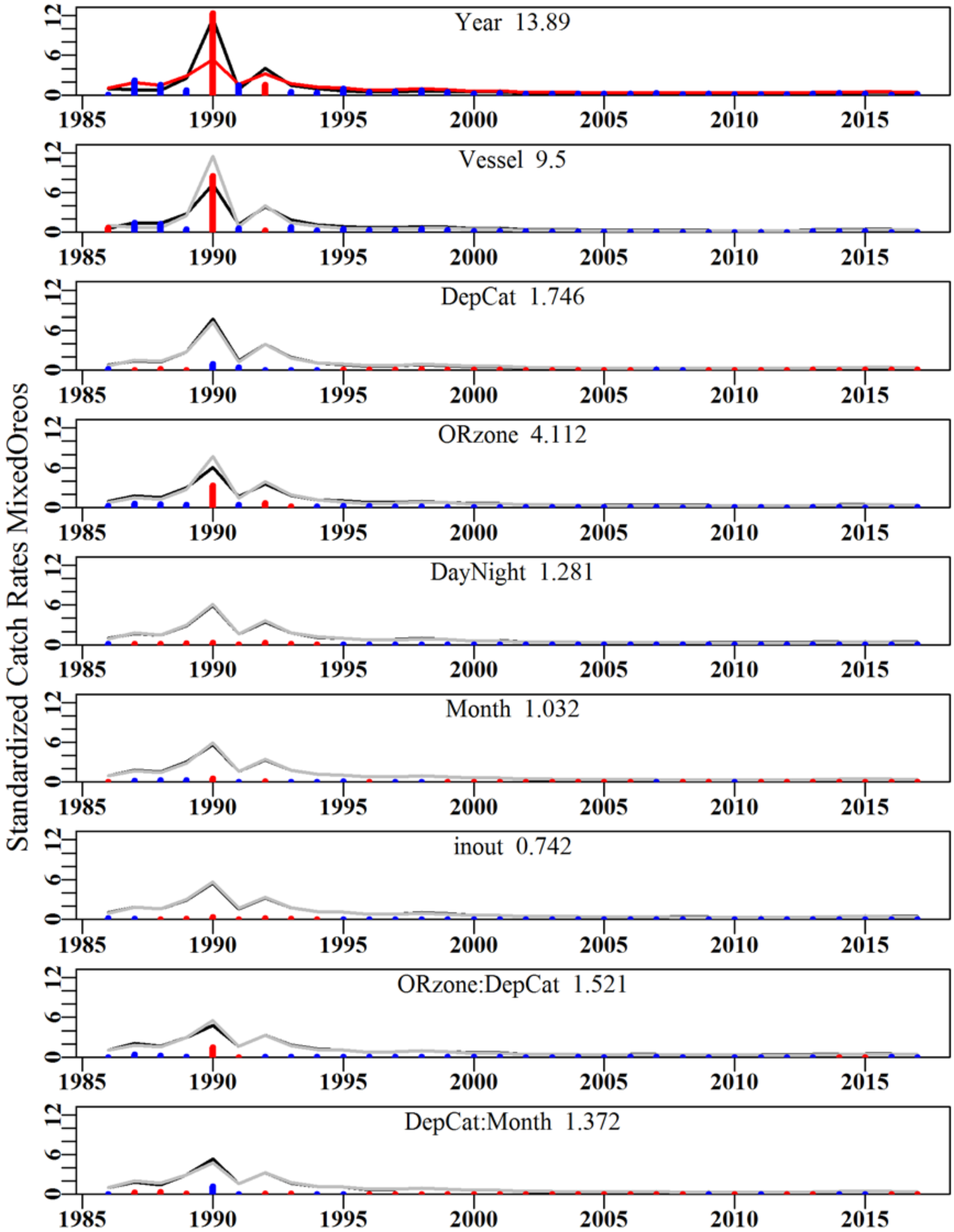

Figure 7.39. MixedOreos. The influence of each factor on the optimal standardization. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by vertical bars with blue bars indicating the optimum model is higher than the geometric 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.

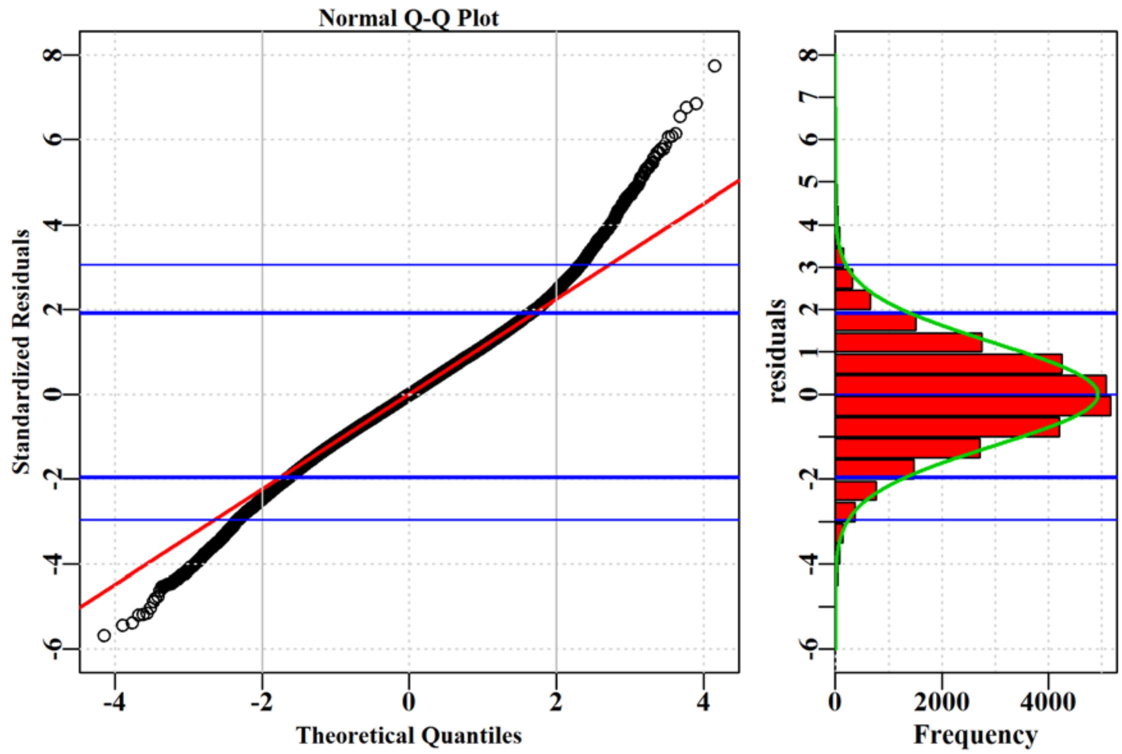

Figure 7.40. MixedOreos. Diagnostic plots. The distribution of residuals from the optimum fit. The qqplot indicates the fit to the expected normality, while the histogram of residuals also illustrates the 1%, 5%, 95% and 99% quantiles to indicate the intensity of any lack of fit at the margins of the distribution (reflected also in the qqplot).

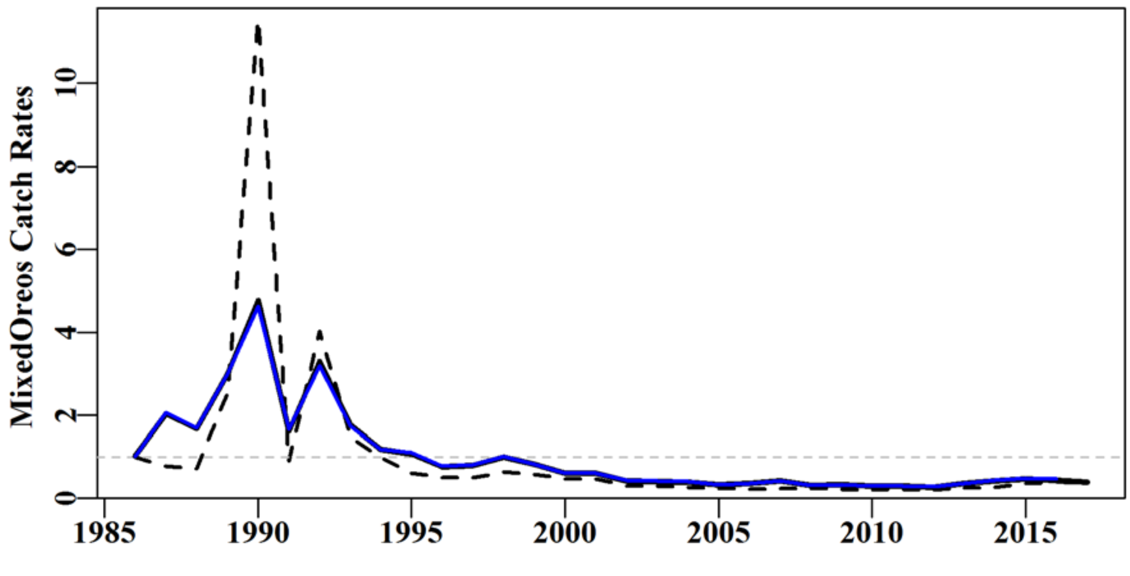

Figure 7.41. MixedOreos. A comparison of the previous year's standardization (blue line) with this year's. They should lie on top of each other, although small deviations may relate to data adjustments, particularly in very recent years.

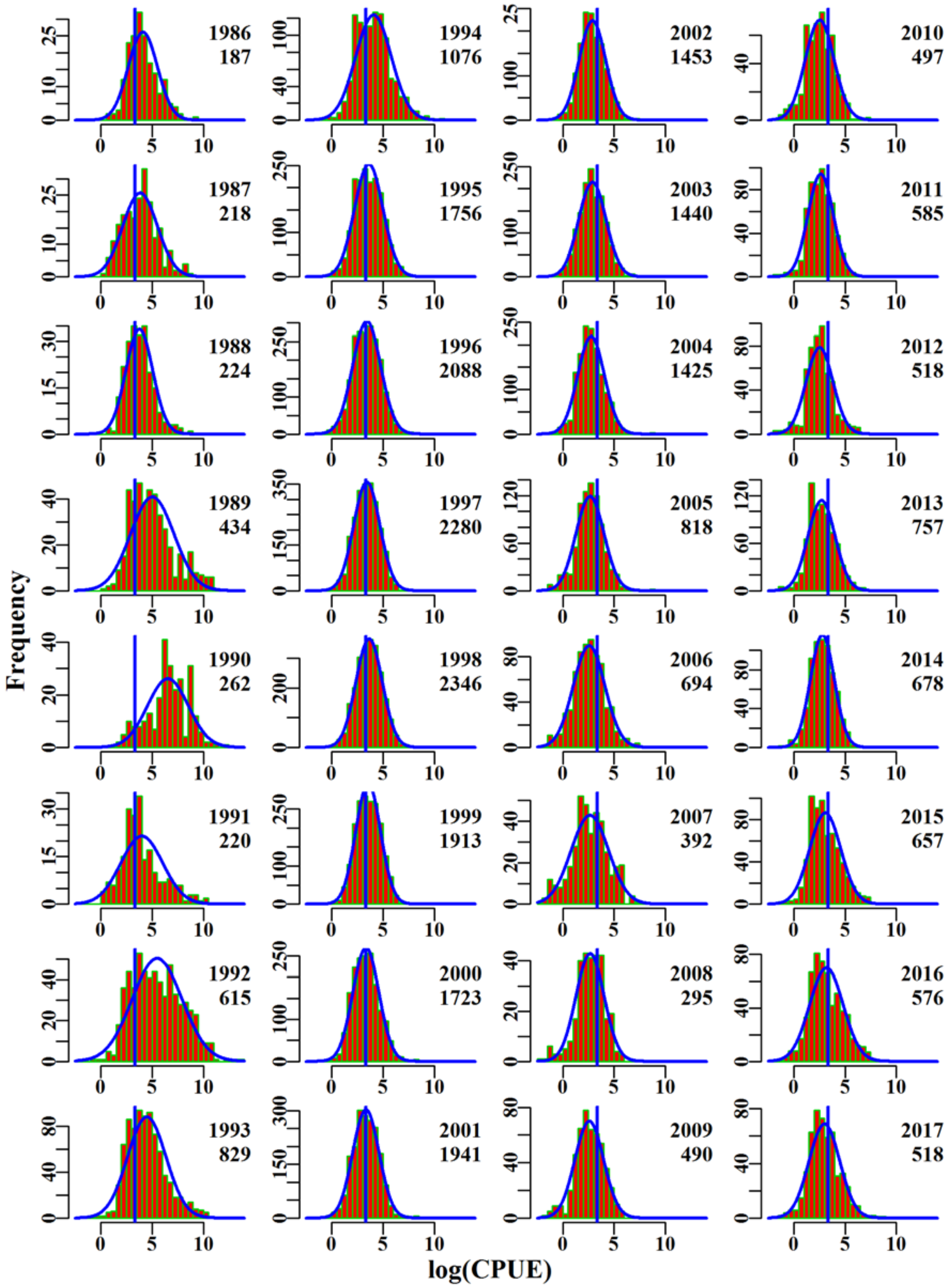

Figure 7.42. MixedOreos. The log(CPUE) for each year of data available the blue lines are normal distributions fitted to the histogram frequencies. The numbers in each plot are the year and number of records. The vertical blue line is the average across all years.

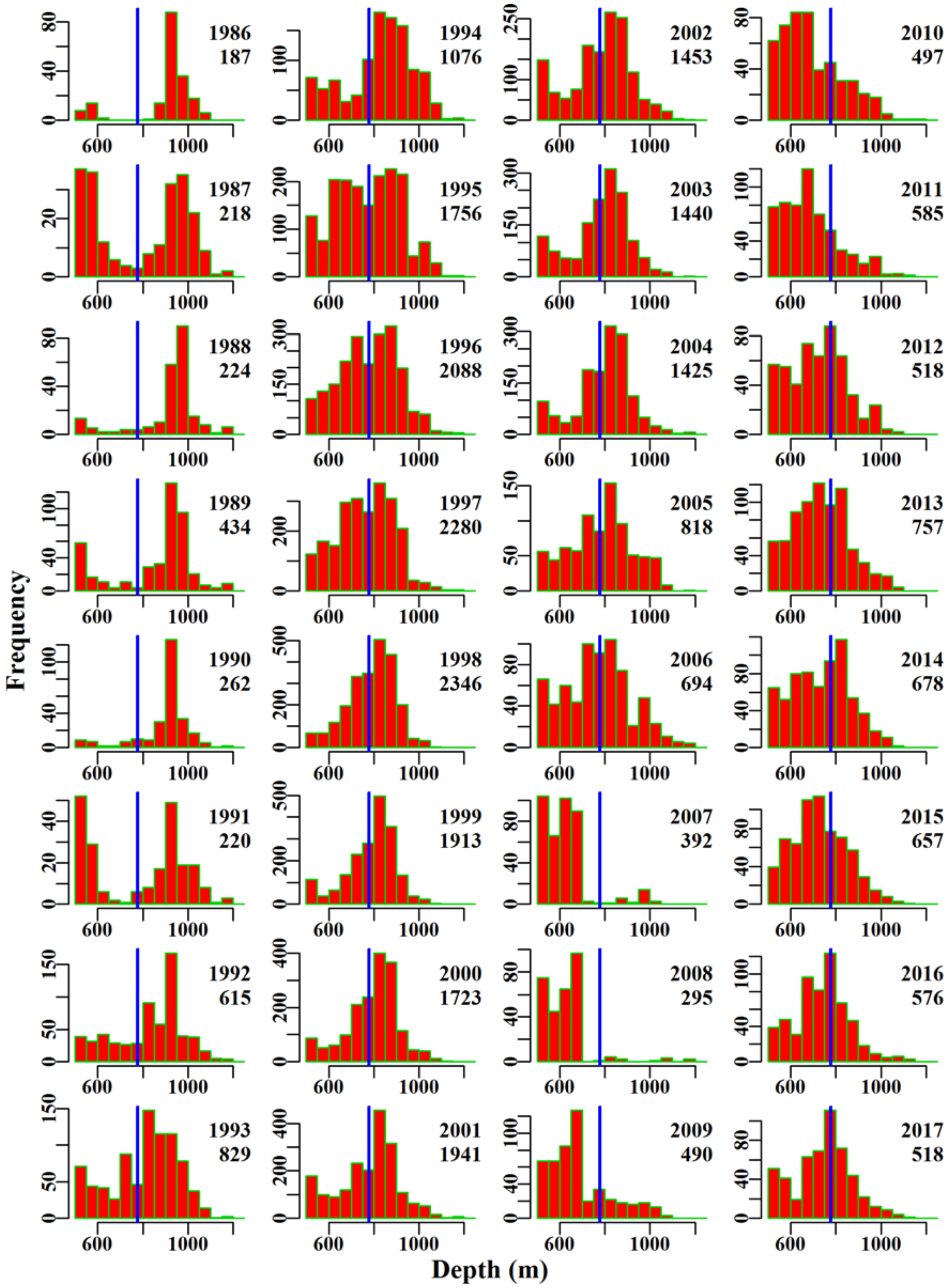

Figure 7.43. MixedOreos. The average Depth of fishing for each year of data available to illustrate the development of the fishery through time. The numbers in each plot are the year and number of records. The vertical blue line is the average across all years.

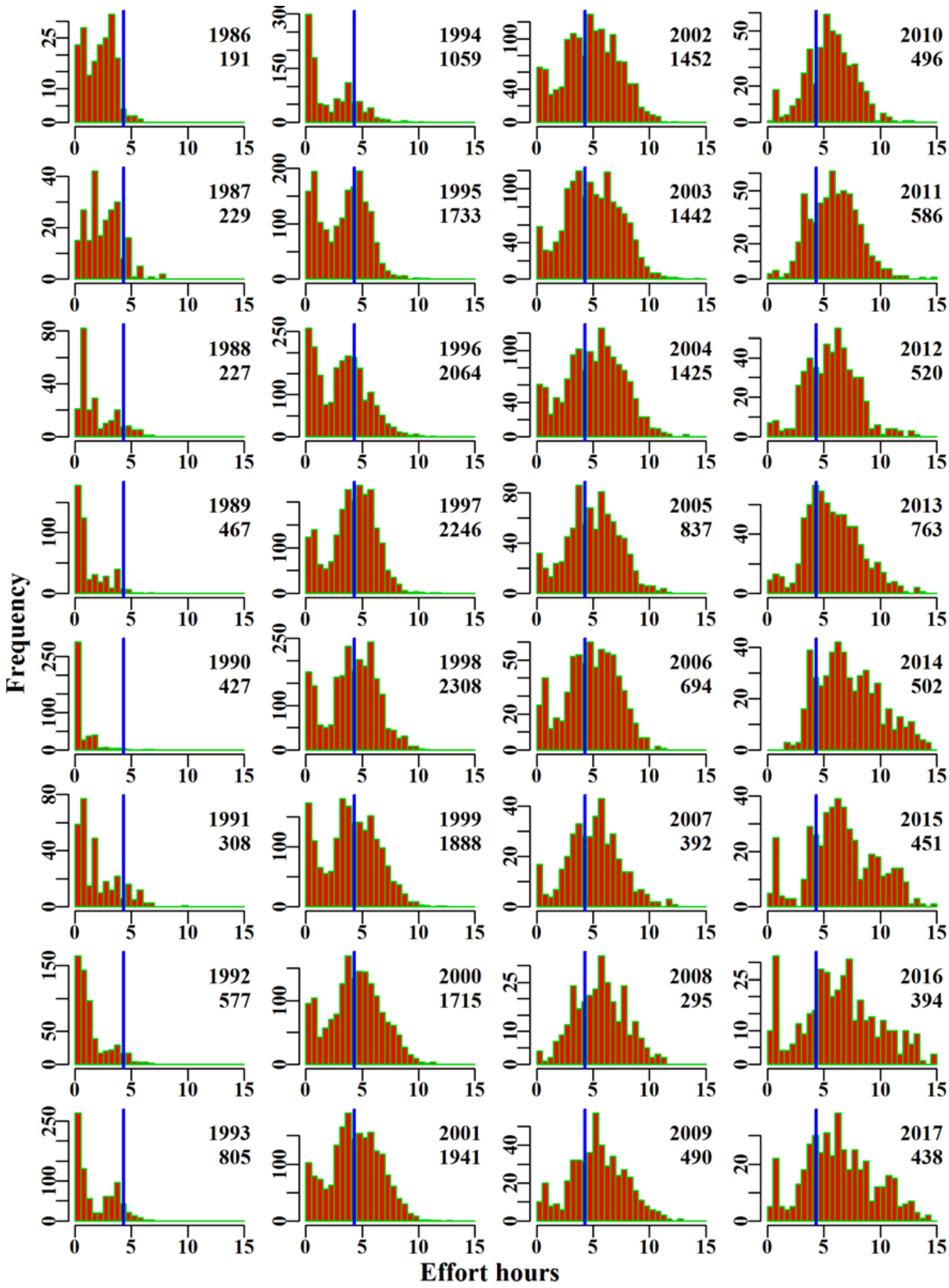

Figure 7.44. MixedOreos. The frequency distribution of effort each year for the available data. The numbers in each plot are the year and number of records. The vertical blue line is the average across all years.

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 – 2017 (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 101 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 7.33). 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).

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 - 2017

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	2.5790	0.000	6.020	0.014
1996	785.3	1460	364.82	32	60.08	1.7384	0.043	7.537	0.021
1997	2091.1	1940	496.66	29	56.58	1.6921	0.041	8.388	0.017
1998	2042.3	1948	627.02	29	71.75	2.0009	0.041	6.666	0.011
1999	905.8	1550	419.37	30	57.75	1.6747	0.043	6.168	0.015
2000	1059.7	1475	335.31	39	47.27	1.2794	0.044	7.805	0.023
2001	1140.0	1687	349.51	36	44.53	1.2300	0.044	8.657	0.025
2002	857.2	1291	200.85	32	30.35	0.8527	0.046	8.261	0.041
2003	886.0	1322	207.07	27	31.30	0.8409	0.046	7.526	0.036
2004	639.8	1282	165.40	28	24.55	0.7222	0.047	8.842	0.053
2005	503.1	772	94.99	21	26.45	0.6482	0.052	4.942	0.052
2006	214.3	617	82.49	25	28.66	0.6373	0.056	4.514	0.055
2007	135.2	366	64.07	19	46.59	0.6888	0.066	2.208	0.034
2008	78.4	288	48.02	16	36.70	0.5842	0.073	1.711	0.036
2009	191.2	452	68.78	18	28.83	0.6476	0.062	3.370	0.049
2010	238.0	476	67.37	15	26.64	0.5806	0.061	3.796	0.056
2011	107.0	579	83.55	19	27.59	0.5899	0.057	4.447	0.053
2012	82.9	502	67.72	15	24.47	0.5534	0.061	4.098	0.061
2013	165.3	731	145.24	19	31.32	0.6583	0.055	5.689	0.039
2014	151.1	711	129.47	17	31.11	0.8167	0.057	3.775	0.029
2015	136.1	596	87.34	17	26.42	0.7092	0.060	3.313	0.038
2016	148.7	486	81.14	18	30.87	0.6467	0.065	2.339	0.029
2017	157.5	477	61.99	18	25.04	0.6286	0.065	2.623	0.042

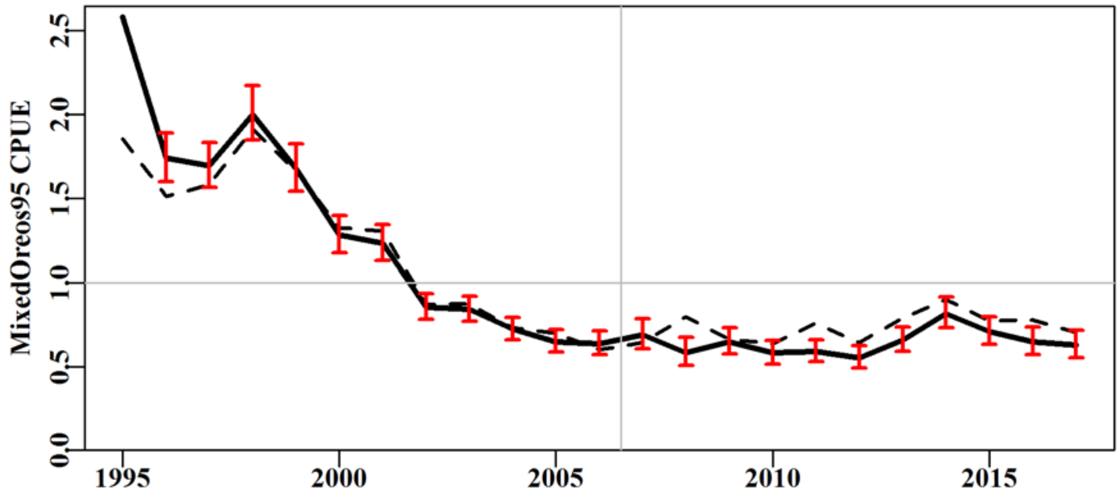

Figure 7.45. MixedOreos95 standardization. The dashed black line represents the geometric mean catch rate, solid black line the standardized catch rates. The red bars are the 95% confidence intervals about the mean estimates. The graph scales both time-series of standardized catch rates relative to the mean of each time-series.

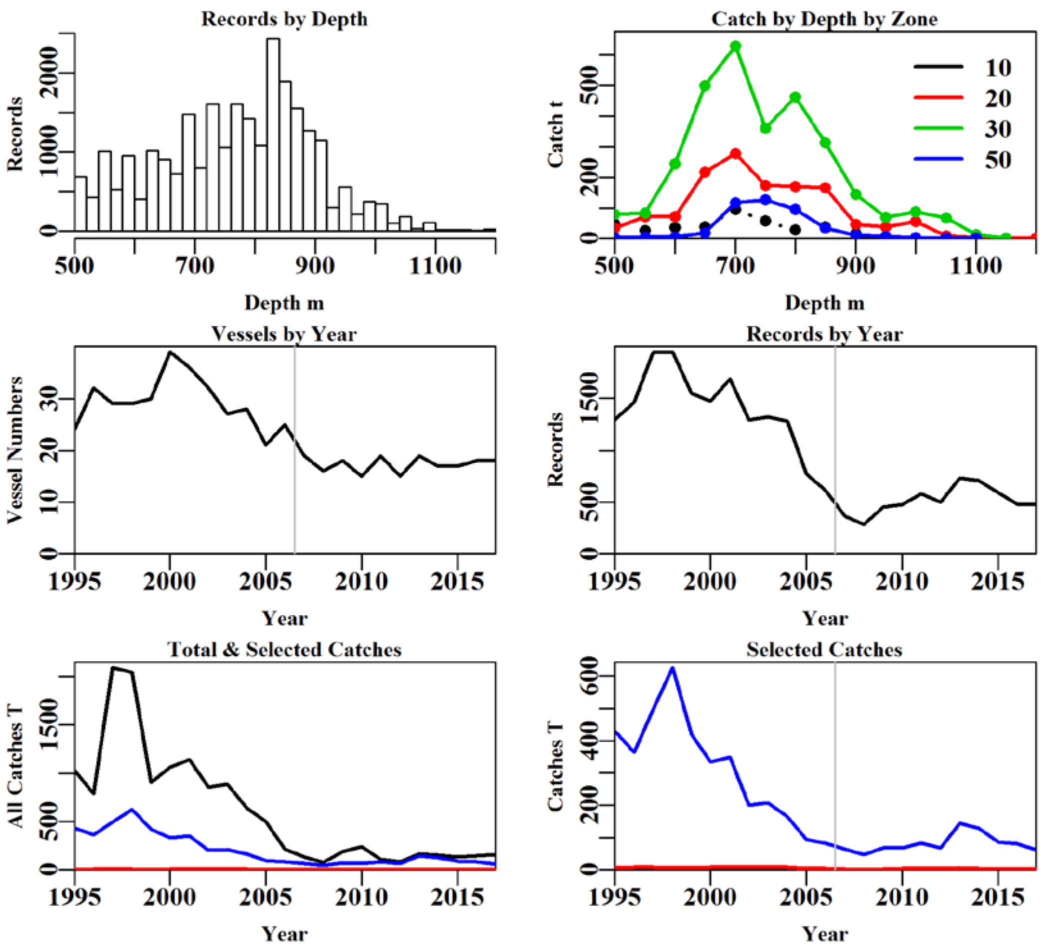

Figure 7.46. MixedOreos95 fishery details. The bottom left plot depicts all known catches (top black line), and all selected catches used in the analysis (middle blue line); the lower red line: selected catches < 30 kg).

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	56848	55298	41650	33221	33188	31139	26258	25840	22080
Difference	0	1550	13648	8429	33	2049	4881	418	3760

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	8903	32977	3382	22080	23	9.2	0.00
Vessel	7182	30304	6055	22080	96	16.3	7.08
DepCat	4553	26867	9491	22080	110	25.7	9.44
ORzone	4127	26346	10012	22080	113	27.2	1.43
DayNight	3020	25054	11305	22080	115	30.7	3.57
Month	2329	24258	12100	22080	126	32.9	2.17
inout	2330	24257	12102	22080	127	32.9	0.00
ORzone:DepCat	1893	23699	12659	22080	165	34.3	1.43
DepCat:Month	1932	23521	12838	22080	268	34.5	1.62

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	3911.1707
Oxeye	37266002	131.878
Warty	37266004	64.782
OreoDory	37266902	571.5379

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	333.281	0.030	1.997			
2001	347.609	0.400	1.505			
2002	199.714	0.095	1.040			
2003	206.820		0.250			
2004	163.834	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	0		48.403
2015	59.225	16.415	0.000	0		11.699
2016	45.674	19.496		0	0	15.972
2017	44.375	7.929		0		9.691

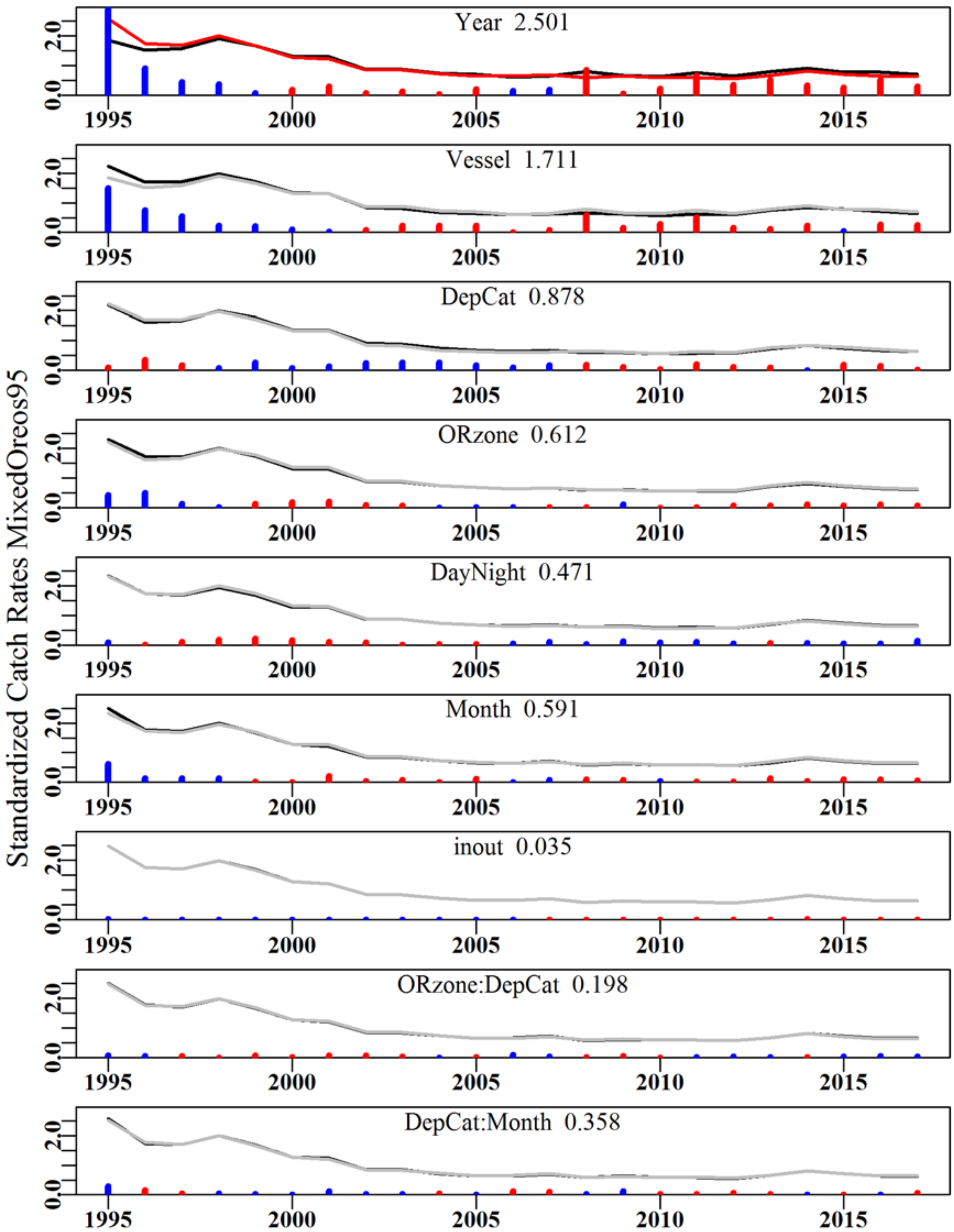

Figure 7.47. MixedOreos95. The influence of each factor on the optimal standardization. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by vertical bars with blue bars indicating the optimum model is higher than the geometric 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.

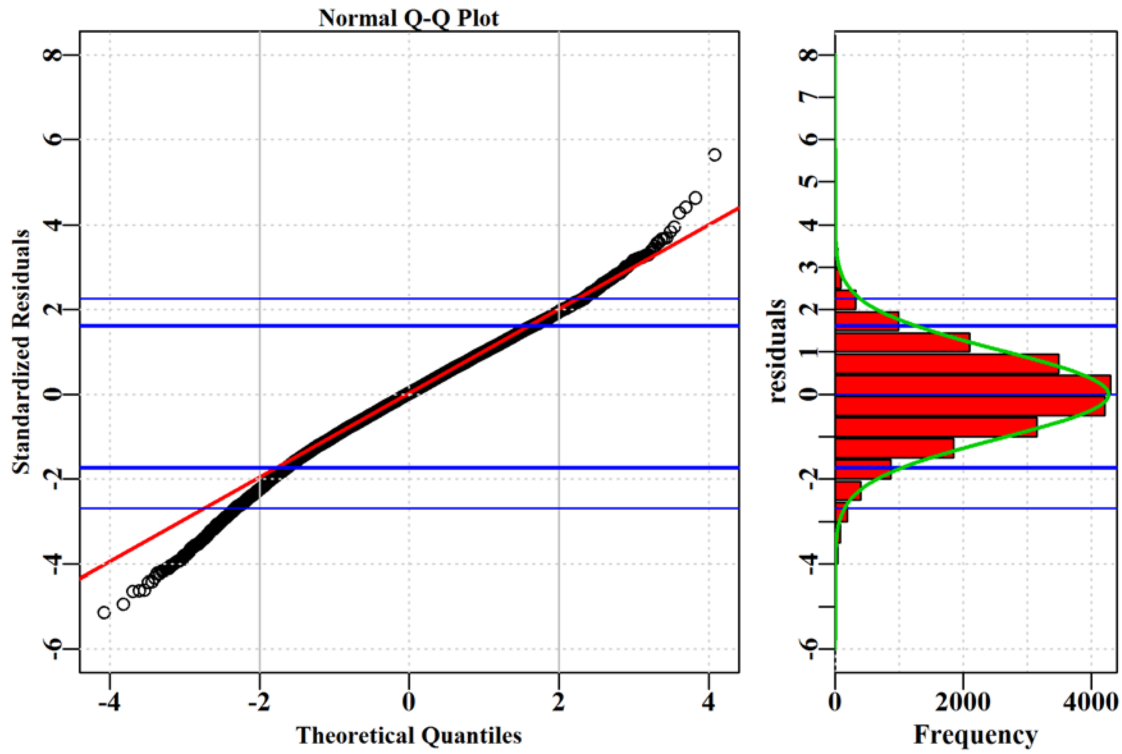

Figure 7.48. MixedOreos95. Diagnostic plots. The distribution of residuals from the optimum fit. The qqplot indicates the fit to the expected normality, while the histogram of residuals also illustrates the 1%, 5%, 95% and 99% quantiles to indicate the intensity of any lack of fit at the margins of the distribution (reflected also in the qqplot).

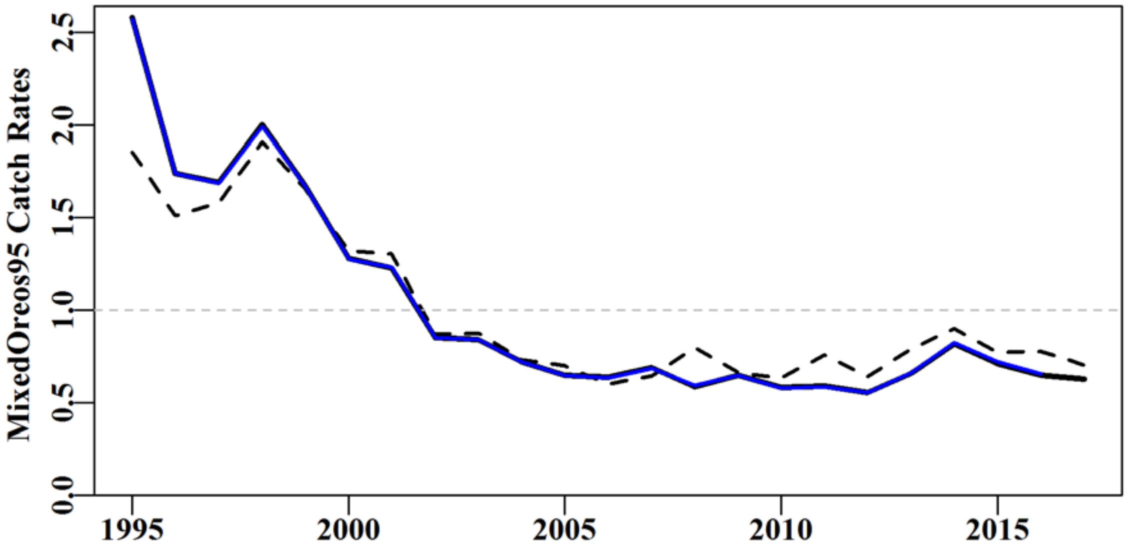

Figure 7.49. MixedOreos95. A comparison of the previous year's standardization (blue line) with this year's. They should lie on top of each other, although small deviations may relate to data adjustments, particularly in very recent years.

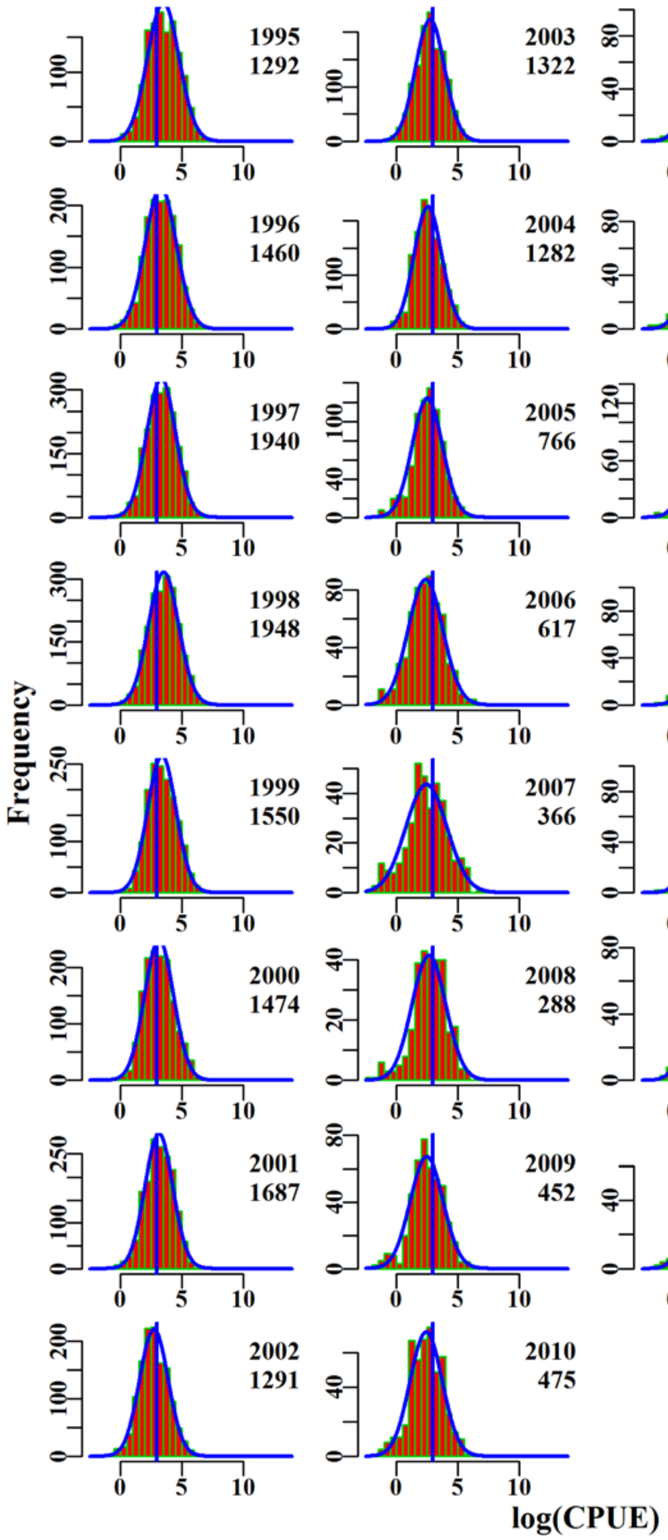

Figure 7.50. MixedOreos95. The log(CPUE) for each year of data available the blue lines are normal distributions fitted to the histogram frequencies. The numbers in each plot are the year and number of records. The vertical blue line is the average across all years.

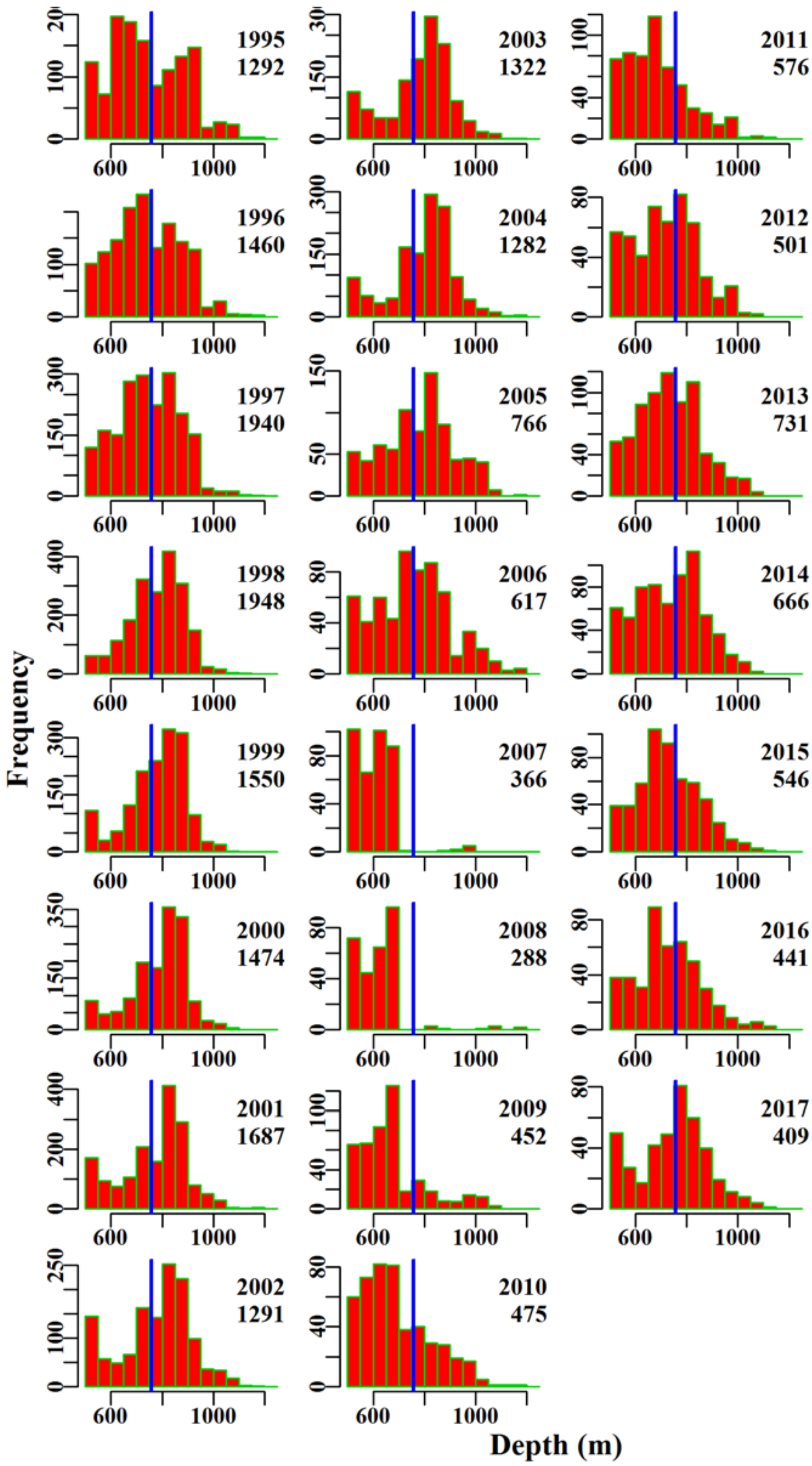

Figure 7.51. MixedOreos95. The average Depth of fishing for each year of data available to illustrate the development of the fishery through time. The numbers in each plot are the year and number of records. The vertical blue line is the average across all years.

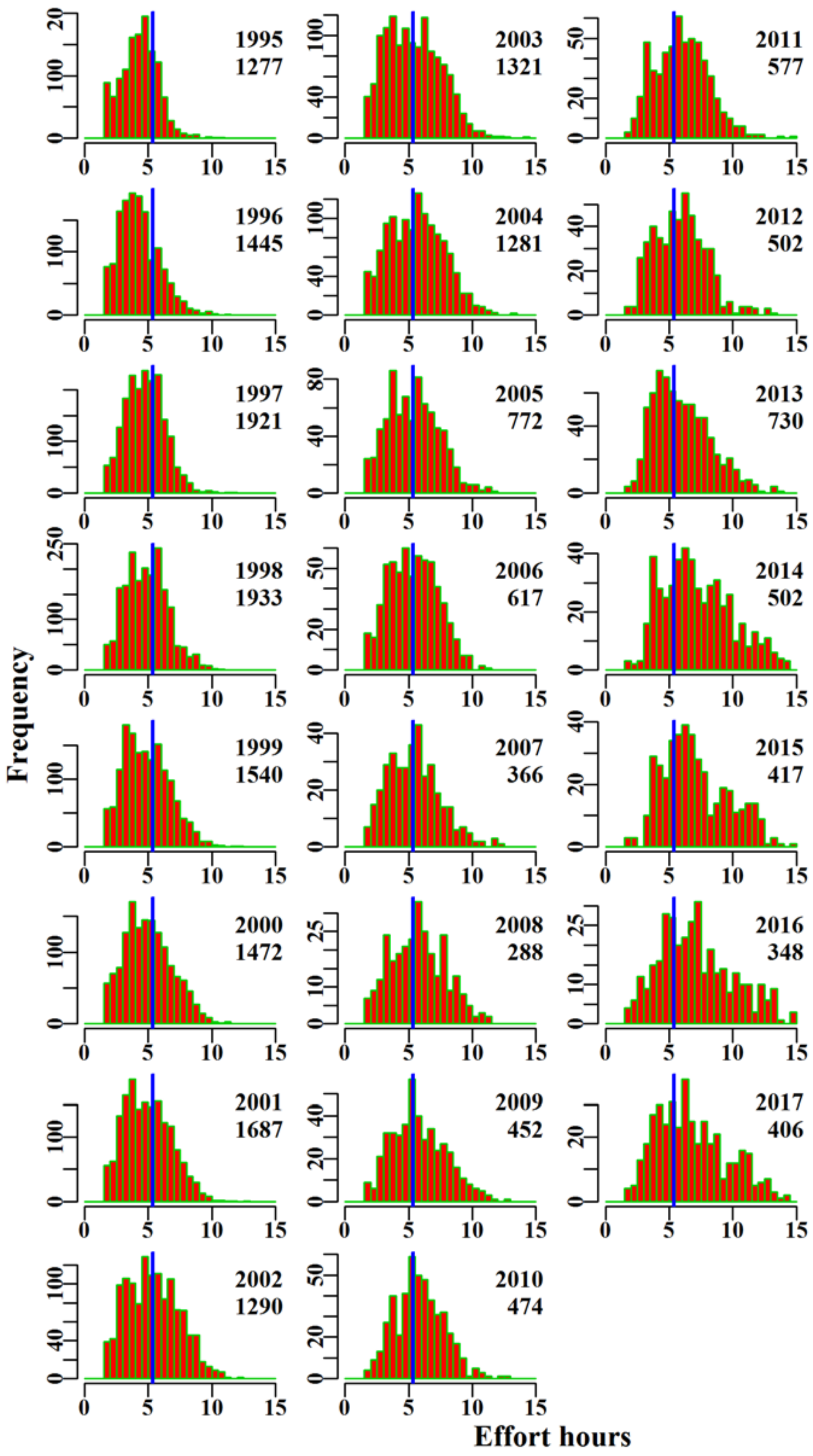

Figure 7.52. MixedOreos95. The frequency distribution of effort each year for the available data. The numbers in each plot are the year and number of records. The vertical blue line is the average across all years.

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. In addition, one author (MH) 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.

7.10 General References

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8. Statistical CPUE standardizations for selected shark species in the SESSF (data to 2017)

Miriana Sporcic and Malcolm Haddon

CSIRO Oceans and Atmosphere, Castray Esplanade, Hobart 7000, Australia

8.1 Executive Summary

This report focuses on data from years 1995 - 2017 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. Trawl caught school shark do not appear to be targeted, as evidenced by the large proportion of < 30 kg shots present in 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, with the exception of 2014 and 2017.

There has been a decrease in reported gillnet catches of gummy shark in 2017 in South Australia and Bass Strait. However, standardized CPUE in South Australia has increased since 2013, and has dropped to the long term average in 2017 in Bass Strait. By contrast, standardized CPUE of gillnet caught gummy shark around Tasmania remained flat since 2014 and increasing to the long term average in 2016 and 2017. Reported catch by bottom line was 229 t in 2013 and 225 t in 2014, dropped to 187 t in 2015, dropped to 147 t in 2016 and increased to 289 t in 2017. Also, there was a drop of ~5 t reported (i.e. 87 t to 83 t) in 2016 relative to 2015 and an decrease of ~3 t reported (i.e. 90 t to 87 t) in 2017 relative to 2016 for trawl. Standardized CPUE for trawl have increased steadily since 2012, remaining 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, 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 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. 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. By contrast, sawshark standardized CPUE by Danish seine (which has the highest proportion of shots < 30 kg among methods) has been flat since 2006 and increased above the long-term average in 2015, although not significantly so, and decreased to below the long term average in 2017. 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 and decreased in 2017. However this analysis ignores discarding (~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, $(\sum CPUE_t)/n$ 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.

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.

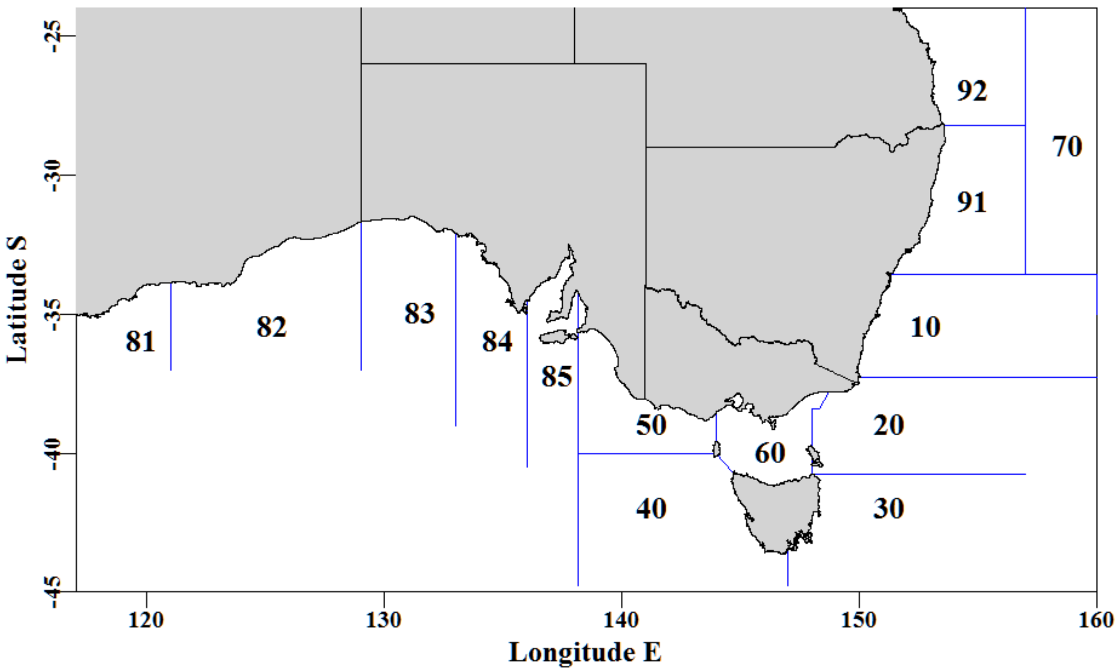

Figure 8.1. The statistical reporting zones in the SESSF.

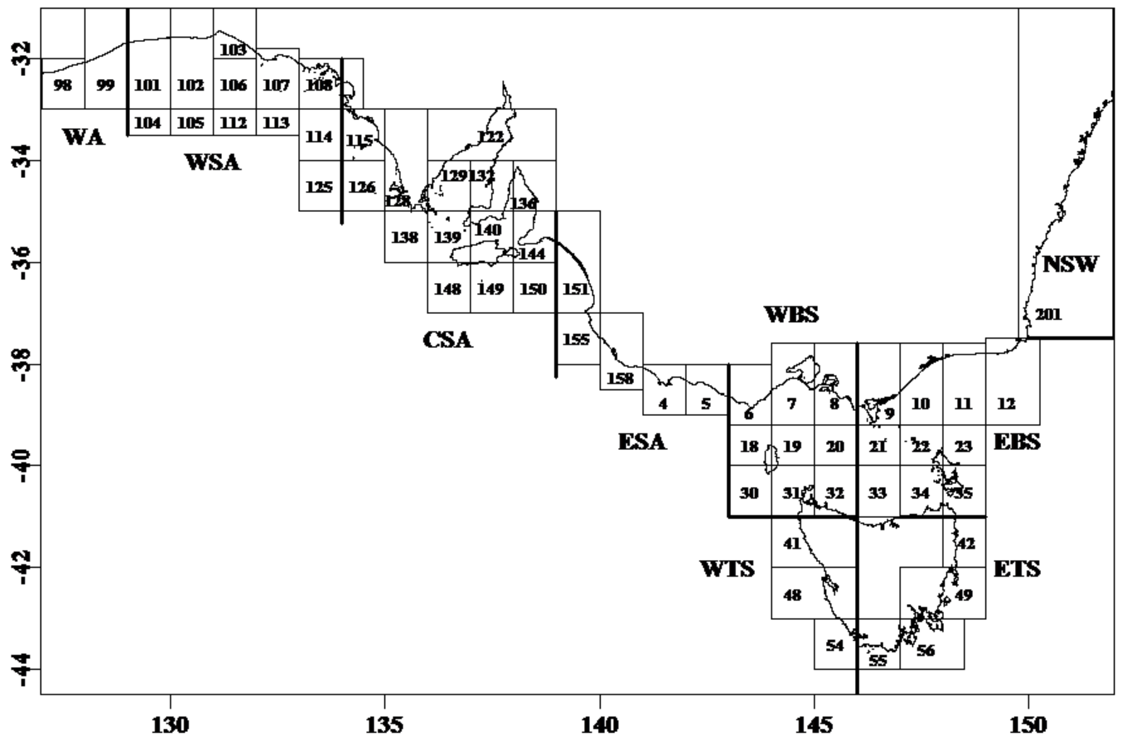

Figure 8.2. Shark statistical reporting areas and statistical regions. WA is Western Australia, WSA is Western South Australia, CSA is Central South Australia, ESA is Eastern South Australia (sometimes known as SAV - South Australia Victoria), WBS is Western Bass Strait, EBS is Eastern Bass Strait, NSW is New South Wales, ETS is Eastern Tasmania and WTS is Western Tasmania.

Box 1. Shark regions and zones employed in analyses.

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

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. 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 (zones) 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 R^2 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 positive 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 - 2017

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/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
1997	952.1	4826	431.9	56	96.2	1.0947	0.000	27.199	0.063
1998	1401.1	7367	521.1	53	72.6	0.8781	0.022	50.807	0.097
1999	1923.8	6842	648.7	49	100.1	1.0569	0.023	38.963	0.060
2000	2436.9	6072	875.6	37	160.3	1.5155	0.024	24.242	0.028
2001	1703.3	5541	414.7	35	81.6	0.8219	0.025	30.145	0.073
2002	1527.1	5846	437.3	32	80.5	0.8842	0.025	35.877	0.082
2003	1653.0	5943	495.9	37	93.6	0.9551	0.025	33.592	0.068
2004	1669.9	5654	476.6	40	95.4	0.9801	0.026	30.295	0.064
2005	1573.2	5137	483.7	29	104.4	1.0553	0.027	27.698	0.057
2006	1577.1	5968	548.7	28	100.6	1.0854	0.026	31.127	0.057
2007	1575.0	4549	438.5	29	107.0	1.1421	0.027	22.012	0.050
2008	1727.7	4907	543.5	23	122.4	1.3340	0.027	21.515	0.040
2009	1500.9	5157	418.2	23	87.4	1.0190	0.027	30.674	0.073
2010	1404.8	5258	389.8	28	79.6	0.8920	0.027	32.880	0.084
2011	1364.7	3272	229.0	19	78.3	0.7836	0.031	21.004	0.092
2012	1304.2	1371	83.0	15	62.3	0.5876	0.039	10.043	0.121
2013	1307.6	800	60.5	18	77.6	0.6263	0.048	5.370	0.089
2014	1389.1	1462	126.0	19	96.5	0.8312	0.040	7.559	0.060
2015	1545.1	1544	151.6	15	105.7	0.9890	0.040	7.796	0.051
2016	1586.5	1062	134.5	11	132.4	1.2037	0.048	3.783	0.028
2017	1561.3	898	110.2	13	134.8	1.2643	0.054	2.647	0.024

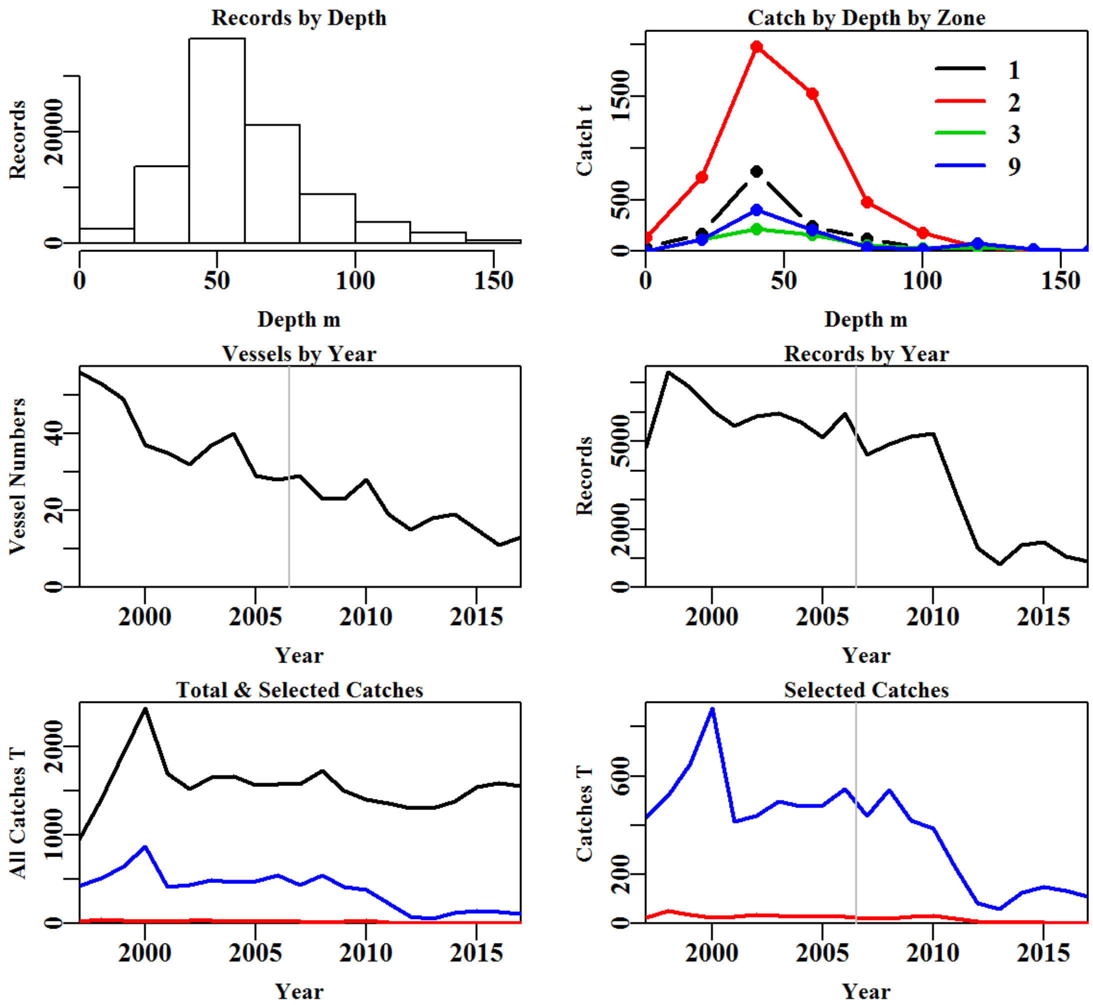

Figure 8.3. GummySharkSA fishery details. The bottom left plot depicts all known catches (top black line), and all selected catches used in the analysis (middle blue line); the lower red line: selected catches < 30 kg). Refer to Box 1 for names which correspond to zone numbers.

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	386988	0	33240.551	0.000
NoCE	379828	7160	33240.551	0.000
Depth	353045	26783	32283.687	956.864
Years	340890	12155	31793.418	490.270
Zones	120694	220196	9791.822	22001.596
Method	89476	31218	8019.100	1772.722
Fishery	89476	0	8019.100	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	29222	123977	3568	89476	21	2.8	0.00
Vessel	25083	118002	9543	89476	161	7.3	4.54
DepCat	24229	116860	10684	89476	169	8.2	0.89
SharkRegion	23921	116451	11094	89476	172	8.5	0.32
Month	22698	114842	12703	89476	183	9.8	1.25
SharkRegion:DepCat	21779	113608	13937	89476	207	10.7	0.95
SharkRegion:Month	22297	114245	13300	89476	216	10.2	0.44

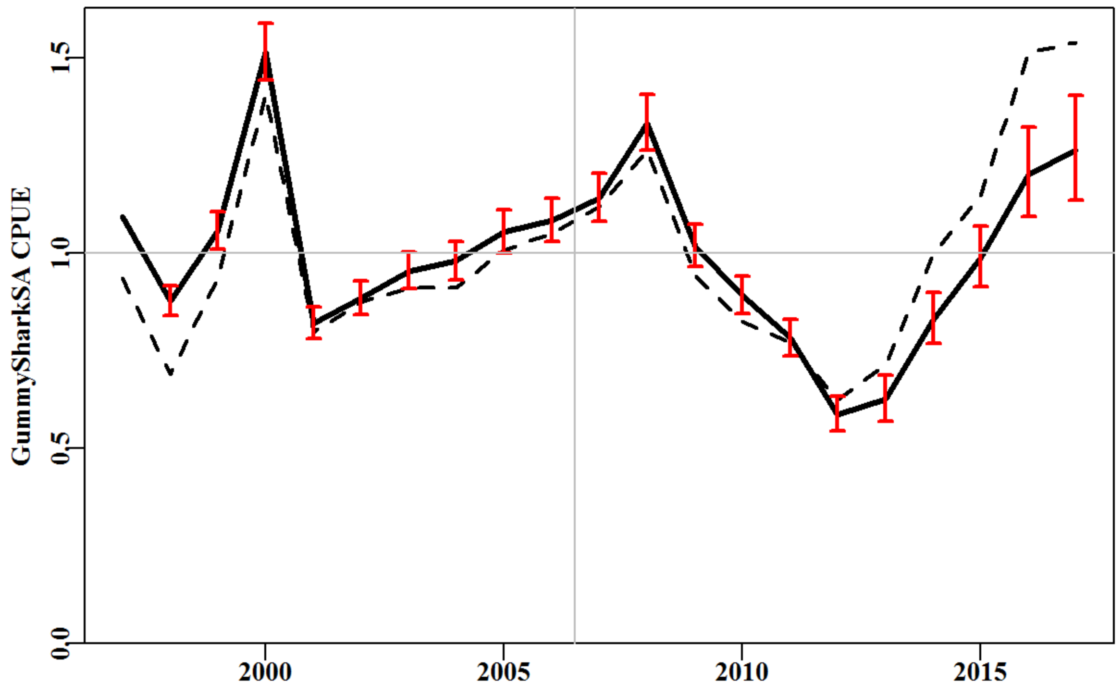

Figure 8.4. GummySharkSA standardization. The dashed black line represents the geometric mean catch rate, solid black line the standardized catch rates. The red bars are the 95% confidence intervals about the mean estimates. The graph scales both time-series of standardized catch rates relative to the mean of each time-series.

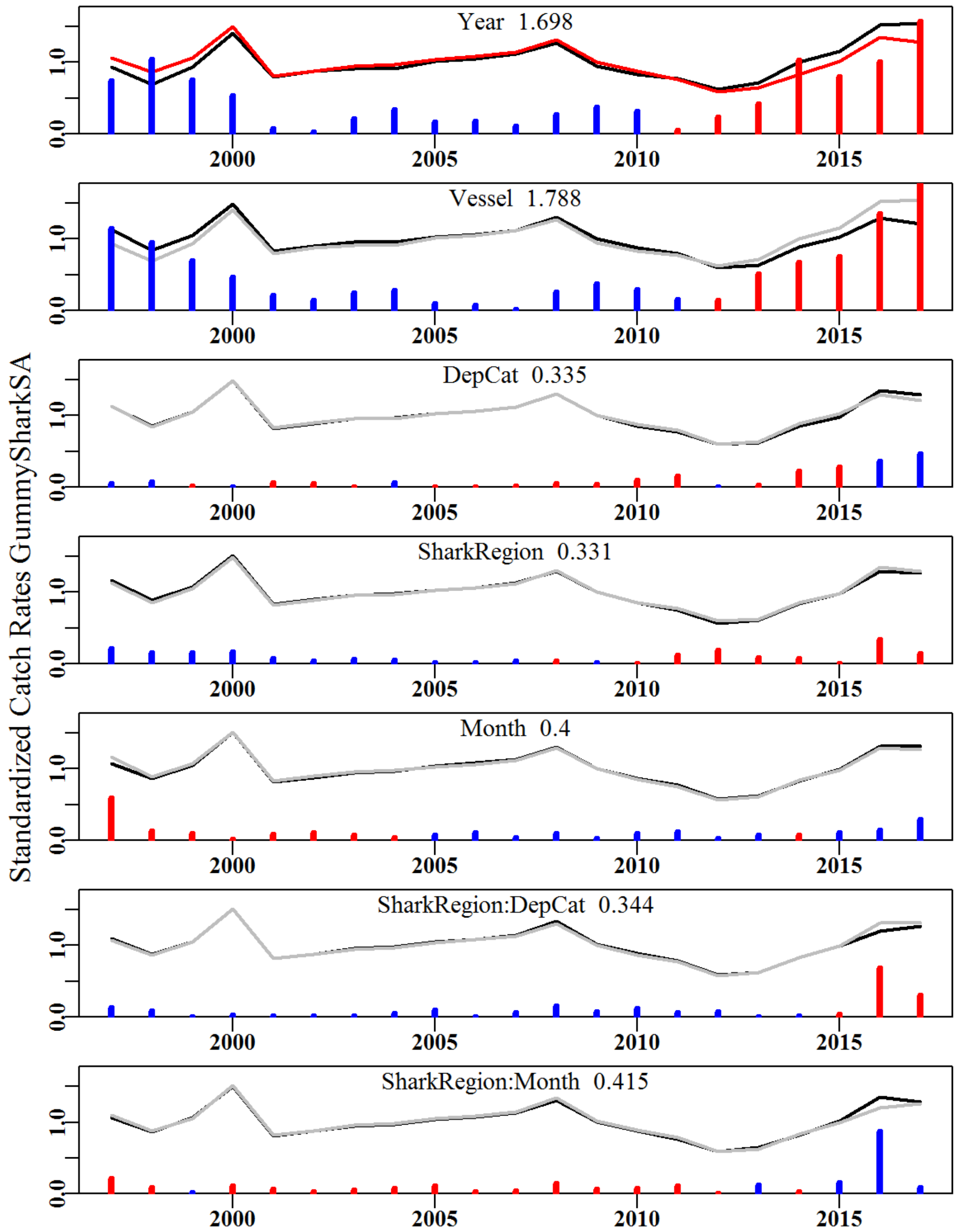

Figure 8.5. GummySharkSA. The influence of each factor on the optimal standardization. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by vertical bars with blue bars indicating the optimum model is higher than the geometric 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.

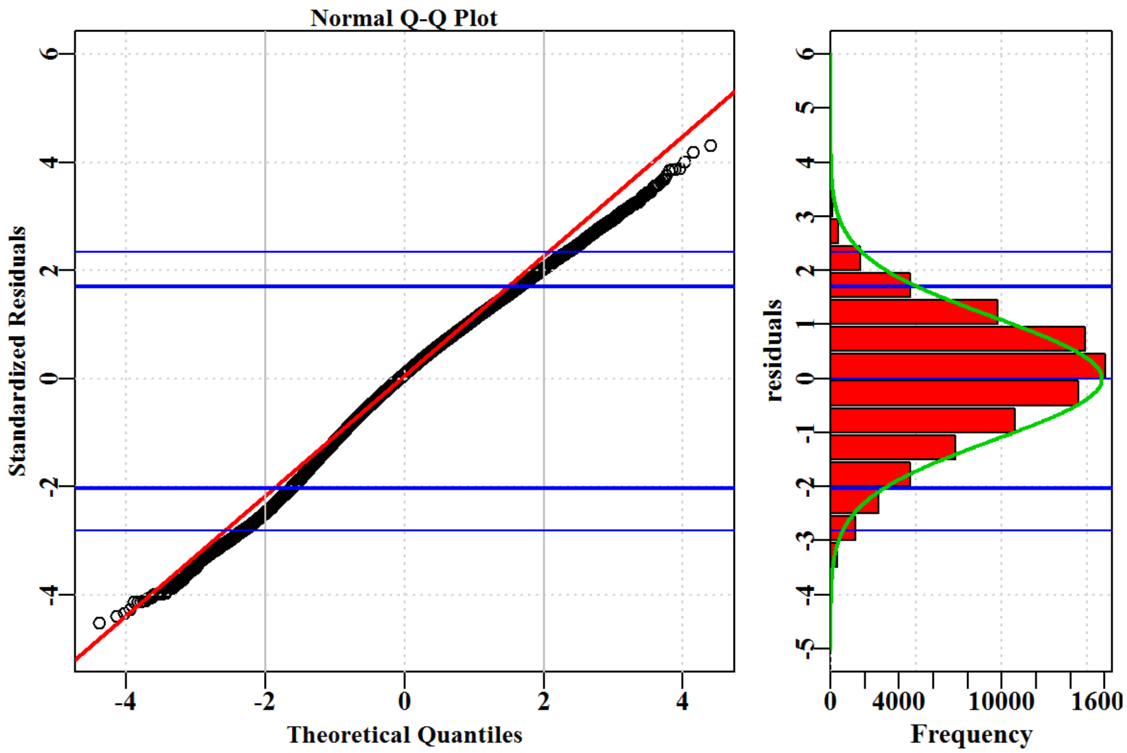

Figure 8.6. GummySharkSA. Diagnostic plots. The distribution of residuals from the optimum fit. The qqplot indicates the fit to the expected normality, while the histogram of residuals also illustrates the 1%, 5%, 95% and 99% quantiles to indicate the intensity of any lack of fit at the margins of the distribution (reflected also in the qqplot.

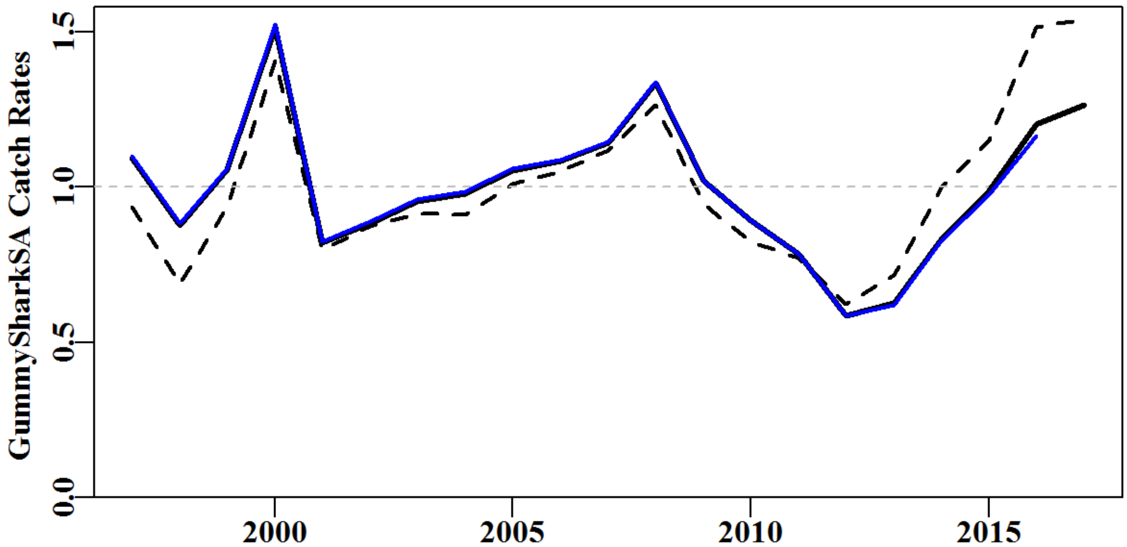

Figure 8.7. GummySharkSA. A comparison of the previous year's standardization (blue line) with this year's. They should lie on top of each other, although small deviations may relate to data adjustments, particularly in very recent years.

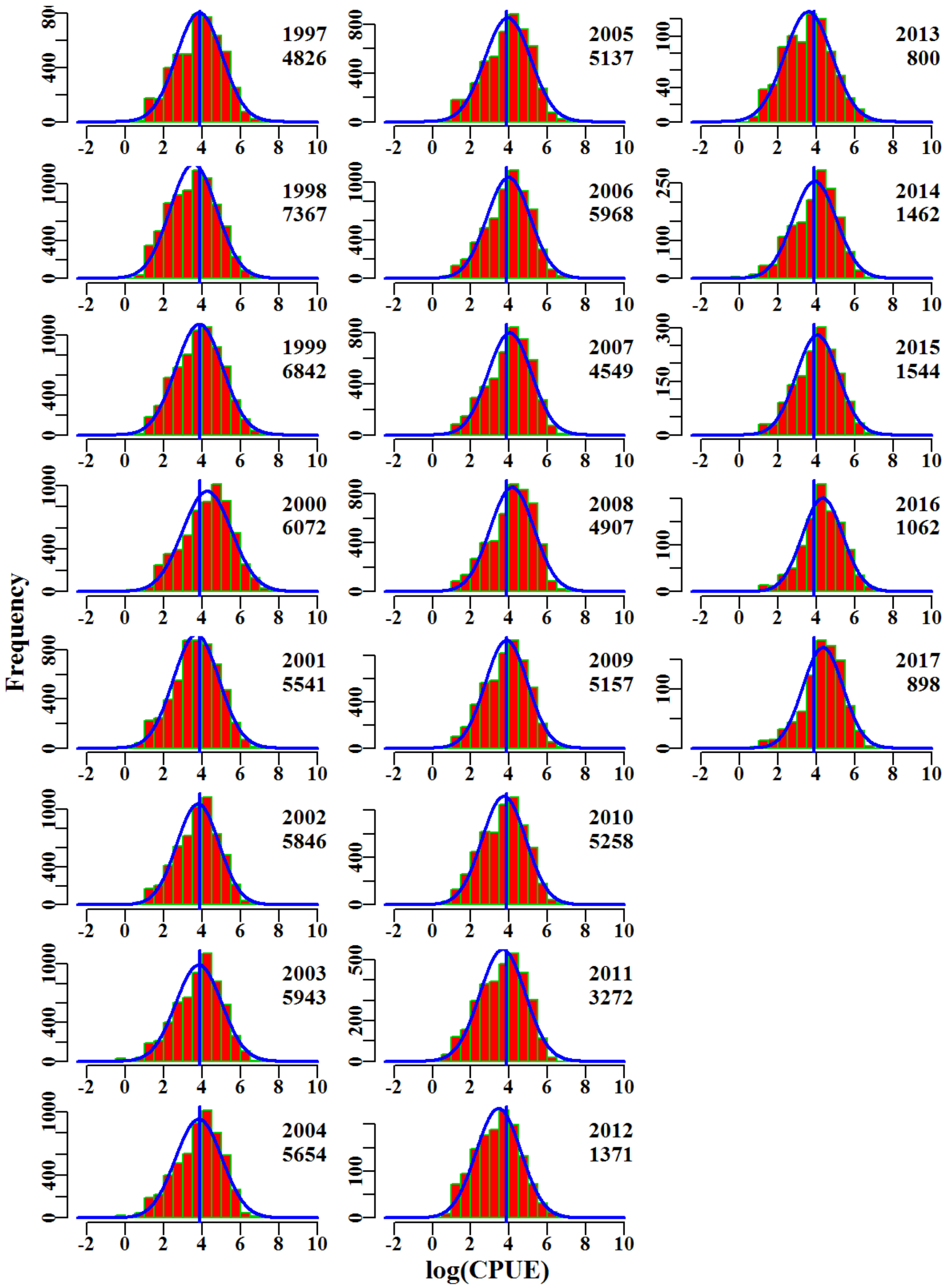

Figure 8.8. GummySharkSA. The $\log_e$(CPUE) for each year of data available the blue lines are normal distributions fitted to the histogram frequencies. The numbers in each plot are the year and number of records. The vertical blue line is the average across all years.

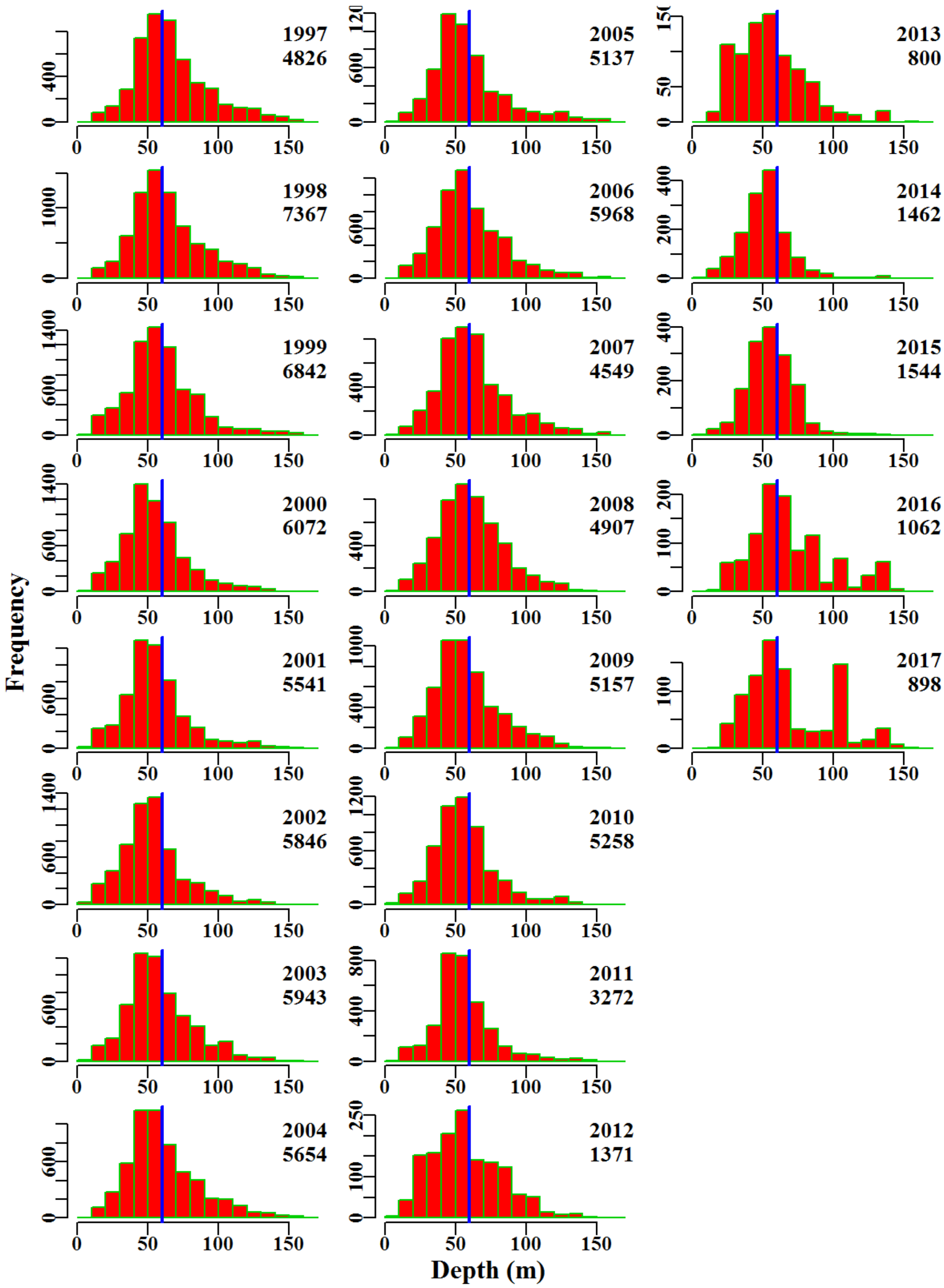

Figure 8.9. GummySharkSA. The average Depth of fishing for each year of data available to illustrate the development of the fishery through time. The numbers in each plot are the year and number of records. The vertical blue line is the average across all years.

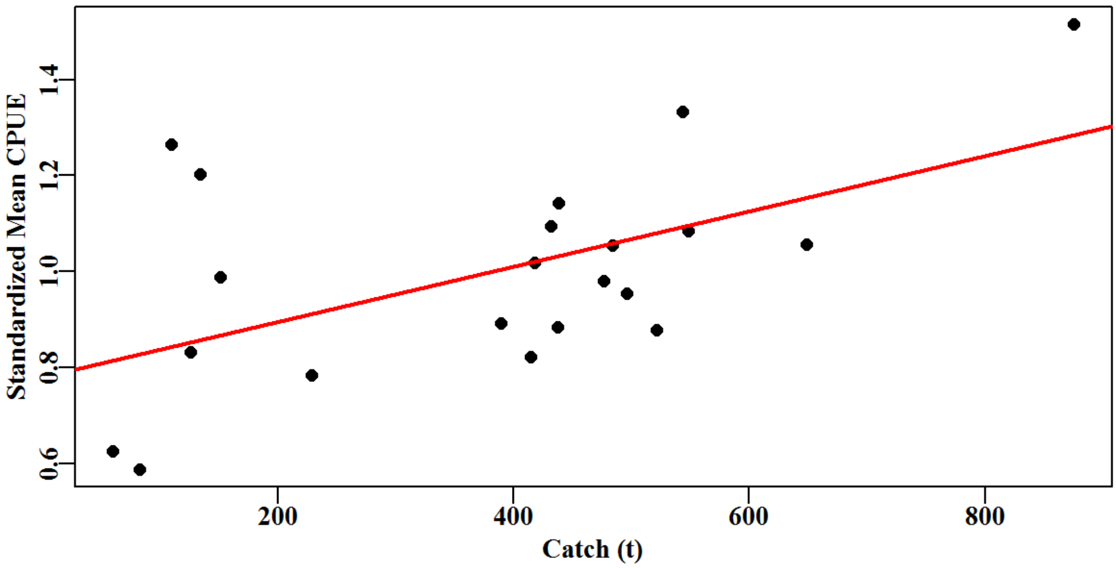

Figure 8.10. GummySharkSA. The linear relationship between Annual mean CPUE and Annual Catch.

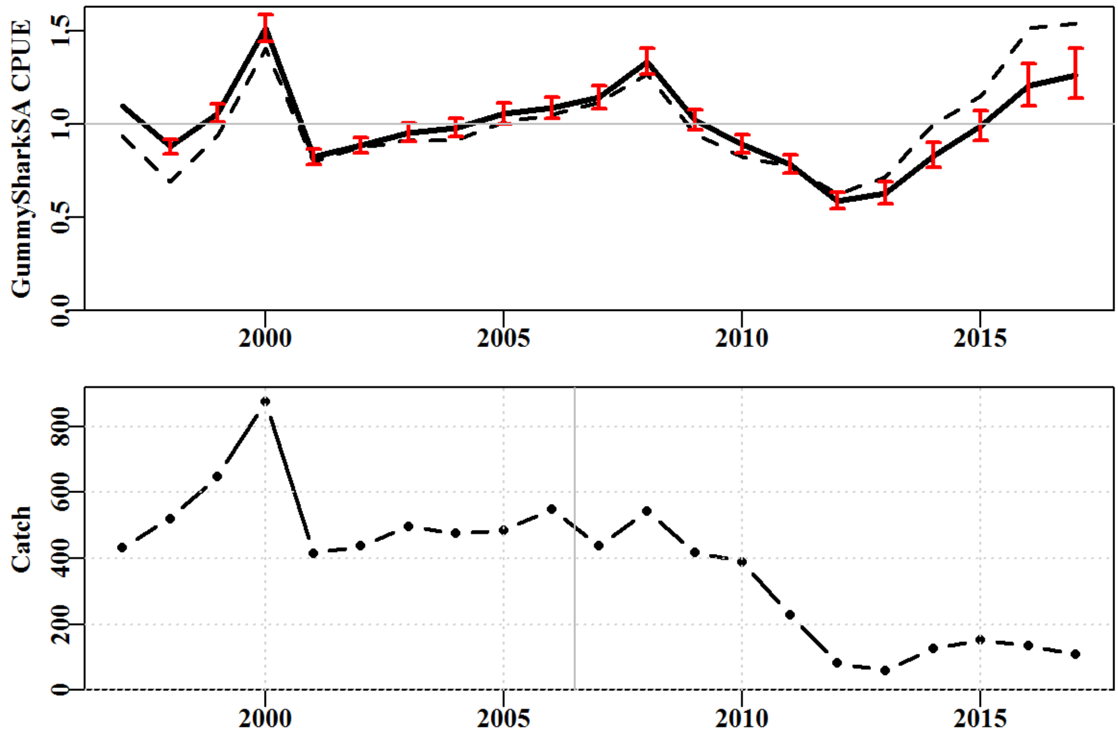

Figure 8.11. GummySharkSA. CPUE is correlated with catches through time. CPUE in the top plot and annual catch (t) in the lower plot.

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 (zones) 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 R^2 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 - 2017

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/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
1997	952.1	4397	417.0	50	103.8	0.6513	0.000	23.872	0.057
1998	1401.1	5947	704.8	51	132.4	0.7898	0.024	26.642	0.038
1999	1923.8	6666	1030.9	56	176.6	1.0342	0.024	25.060	0.024
2000	2436.9	6922	1257.5	49	211.5	1.1225	0.024	22.653	0.018
2001	1703.3	6318	1051.1	47	202.3	0.9964	0.024	20.486	0.019
2002	1527.1	6299	833.8	47	157.5	0.8145	0.025	24.050	0.029
2003	1653.0	6626	883.3	44	159.9	0.8063	0.024	25.951	0.029
2004	1669.9	6289	879.9	41	162.5	0.8726	0.025	21.121	0.024
2005	1573.2	5280	811.4	39	171.0	0.9692	0.026	15.256	0.019
2006	1577.1	4064	727.6	33	201.4	1.1027	0.027	10.785	0.015
2007	1575.0	3479	873.9	25	291.6	1.3467	0.028	7.472	0.009
2008	1727.7	3671	954.6	26	301.9	1.4420	0.028	7.287	0.008
2009	1500.9	4089	831.5	28	233.8	1.2582	0.027	9.391	0.011
2010	1404.8	4408	738.0	31	191.3	1.0113	0.027	13.268	0.018
2011	1364.7	5171	797.9	32	173.6	0.9093	0.026	18.833	0.024
2012	1304.2	5441	780.2	37	162.2	0.8737	0.026	19.117	0.025
2013	1307.6	5347	757.9	36	160.6	0.8371	0.026	21.012	0.028
2014	1389.1	5261	813.4	36	175.7	0.8962	0.026	18.070	0.022
2015	1545.1	4945	979.5	30	233.4	1.0965	0.027	13.152	0.013
2016	1586.5	5124	1107.4	31	251.0	1.2271	0.027	13.045	0.012
2017	1561.3	5808	939.6	30	184.2	0.9424	0.026	17.749	0.019

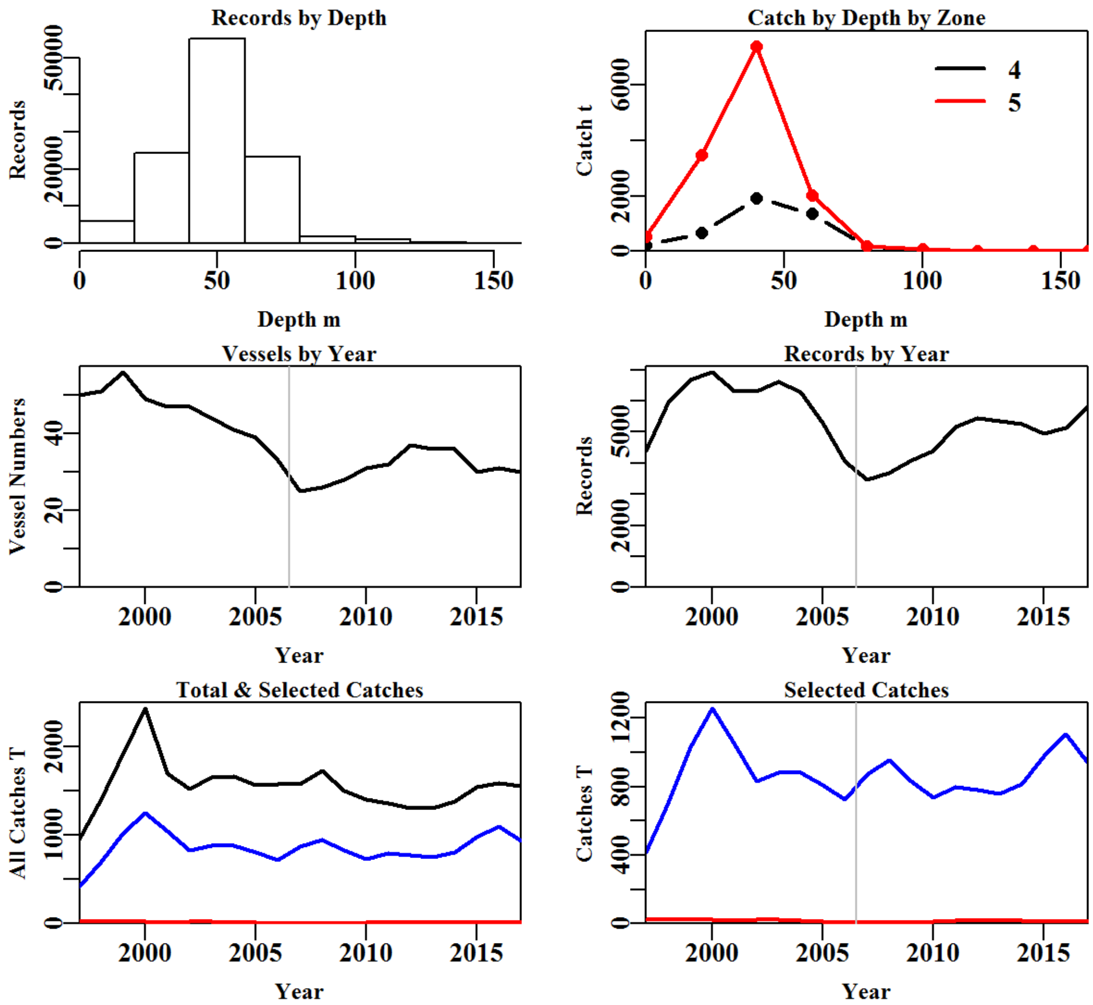

Figure 8.12. GummySharkBS fishery details. The bottom left plot depicts all known catches (top black line), and all selected catches used in the analysis (middle blue line); the lower red line: selected catches < 30 kg). Refer to Box 1 (p. 7) for names which correspond to zone numbers.

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	386988	0	33240.55	0.000
NoCE	379828	7160	33240.55	0.000
Depth	353045	26783	32283.69	956.864
Years	340890	12155	31793.42	490.270
Zones	175751	165139	19395.16	12398.261
Method	111552	64199	18171.08	1224.080
Fishery	111552	0	18171.08	0.000

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	44531	166219	5714	111552	21	3.3	0.00
Vessel	36303	154071	17863	111552	140	10.3	6.97
DepCat	35437	152858	19075	111552	148	11.0	0.70
SharkRegion	35430	152846	19087	111552	149	11.0	0.01
Month	34755	151893	20040	111552	160	11.5	0.55
SharkRegion:DepCat	34682	151776	20158	111552	167	11.6	0.06
SharkRegion:Month	34463	151467	20467	111552	171	11.8	0.24

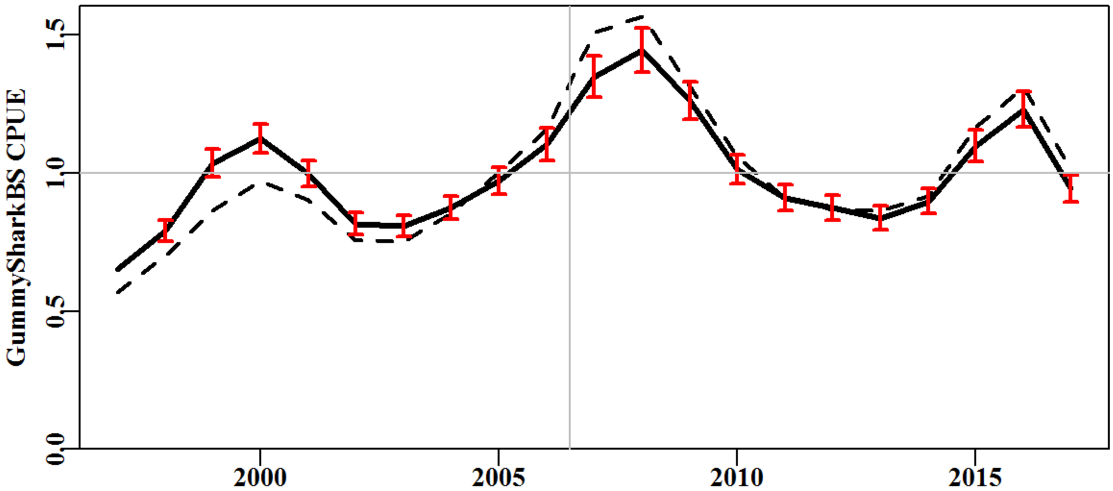

Figure 8.13. GummySharkBS standardization. The dashed black line represents the geometric mean catch rate, solid black line the standardized catch rates. The red bars are the 95% confidence intervals about the mean estimates. The graph scales both time-series of standardized catch rates relative to the mean of each time-series.

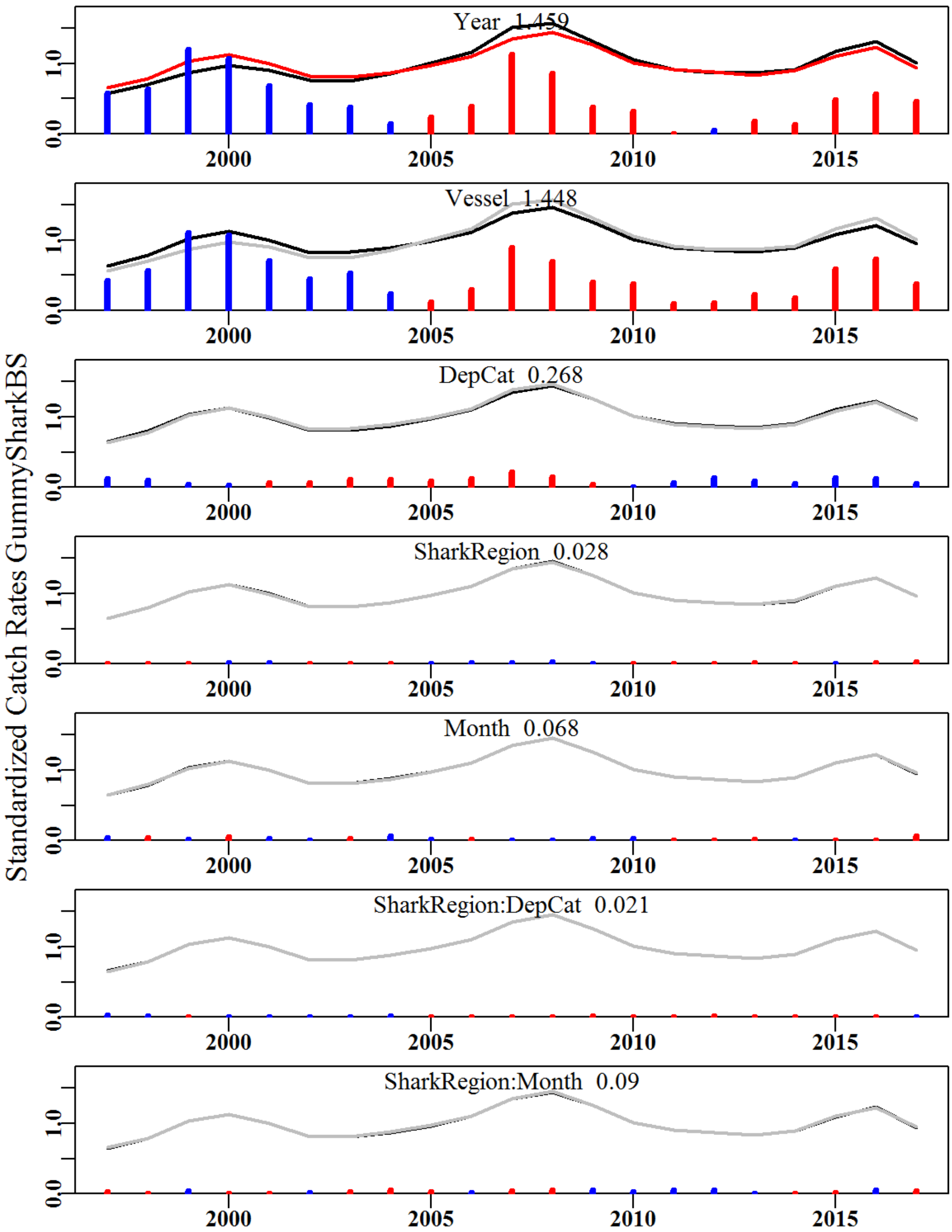

Figure 8.14. GummySharkBS. The influence of each factor on the optimal standardization. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by vertical bars with blue bars indicating the optimum model is higher than the geometric 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.

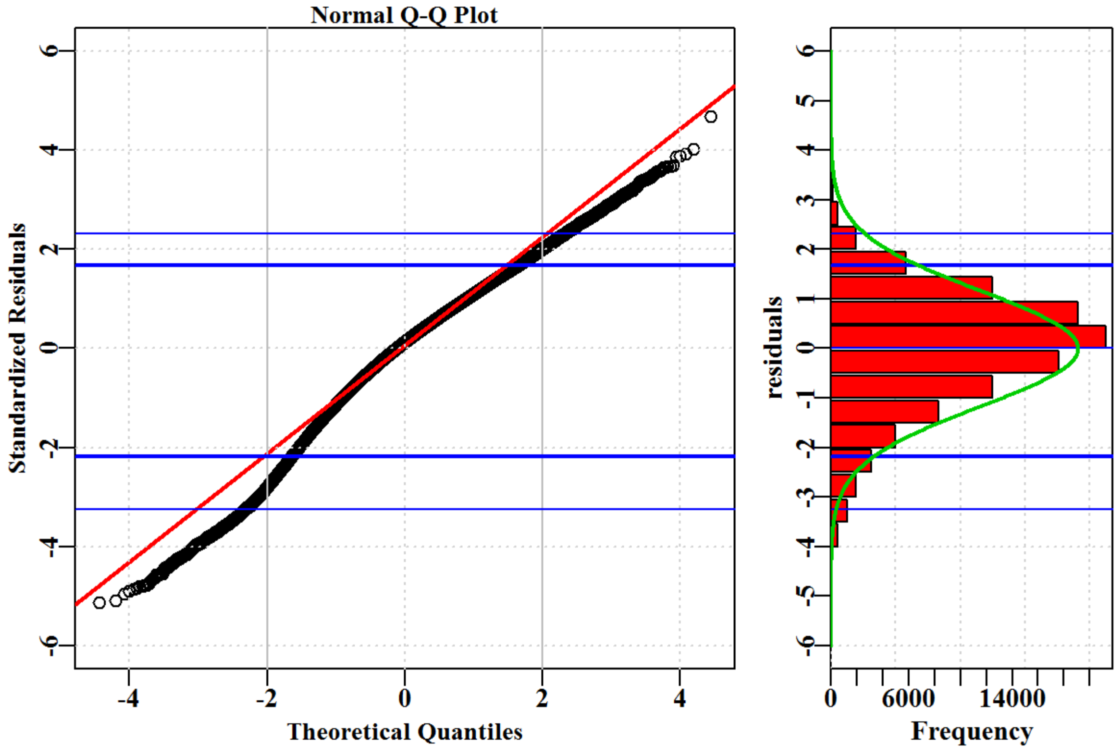

Figure 8.15. GummySharkBS. Diagnostic plots. The distribution of residuals from the optimum fit. The qqplot indicates the fit to the expected normality, while the histogram of residuals also illustrates the 1%, 5%, 95% and 99% quantiles to indicate the intensity of any lack of fit at the margins of the distribution (reflected also in the qqplot).

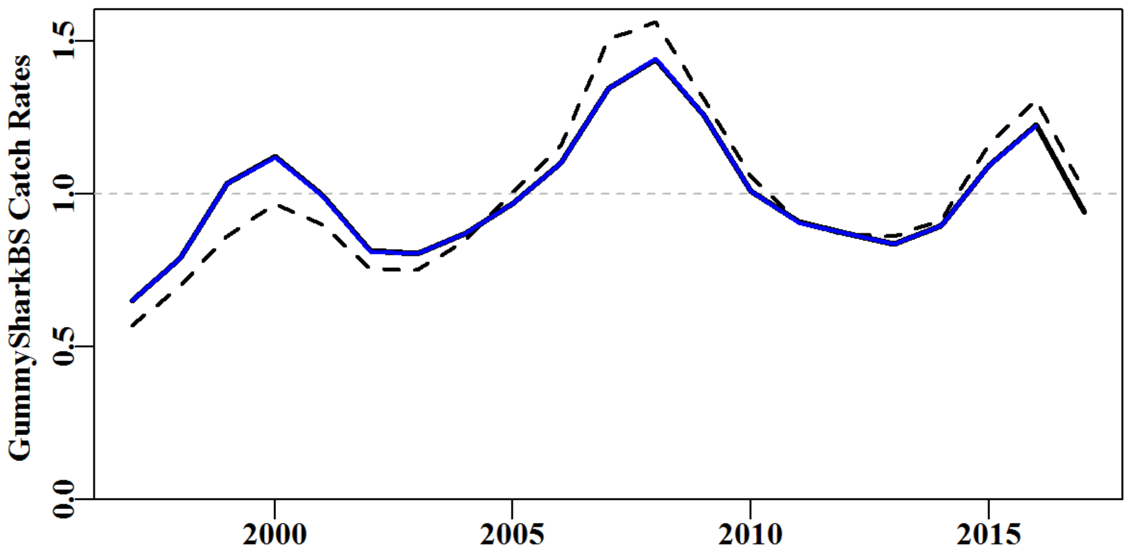

Figure 8.16. GummySharkBS. A comparison of the previous year's standardization (blue line) with this year's. They should lie on top of each other, although small deviations may relate to data adjustments, particularly in very recent years.

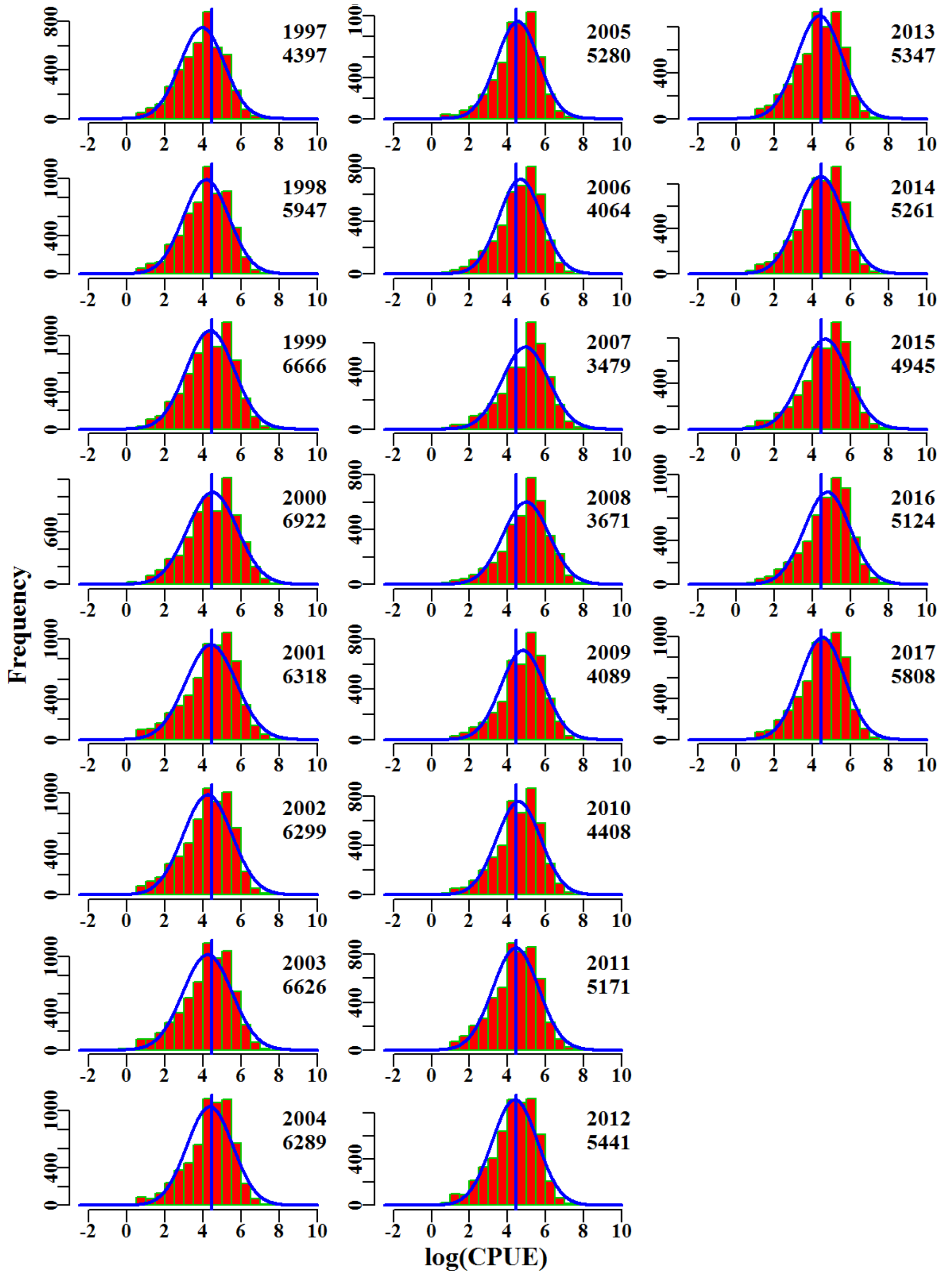

Figure 8.17. GummySharkBS. The $\log_e$(CPUE) for each year of data available the blue lines are normal distributions fitted to the histogram frequencies. The numbers in each plot are the year and number of records. The vertical blue line is the average across all years.

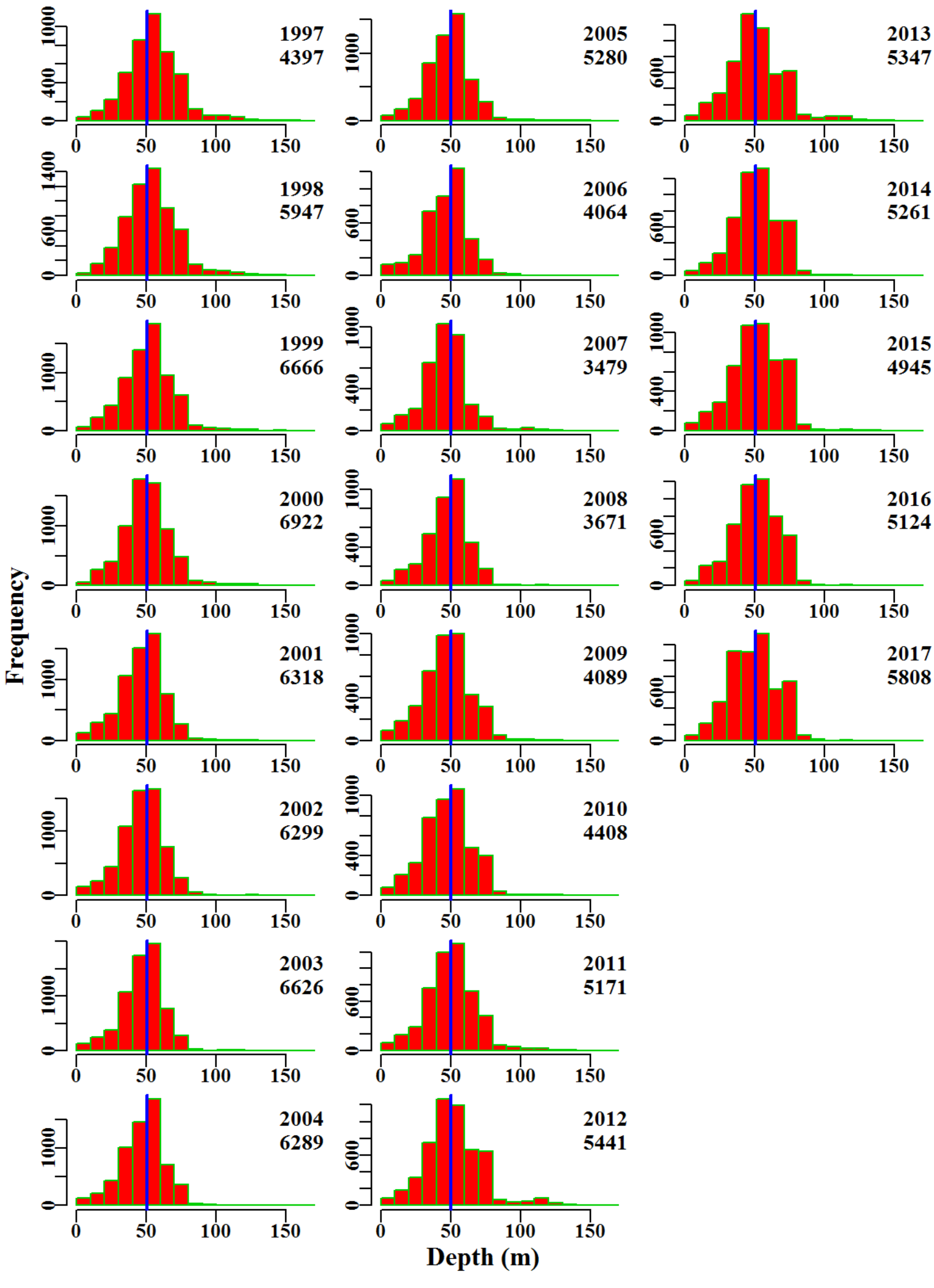

Figure 8.18. GummySharkBS. The average Depth of fishing for each year of data available to illustrate the development of the fishery through time. The numbers in each plot are the year and number of records. The vertical blue line is the average across all years.

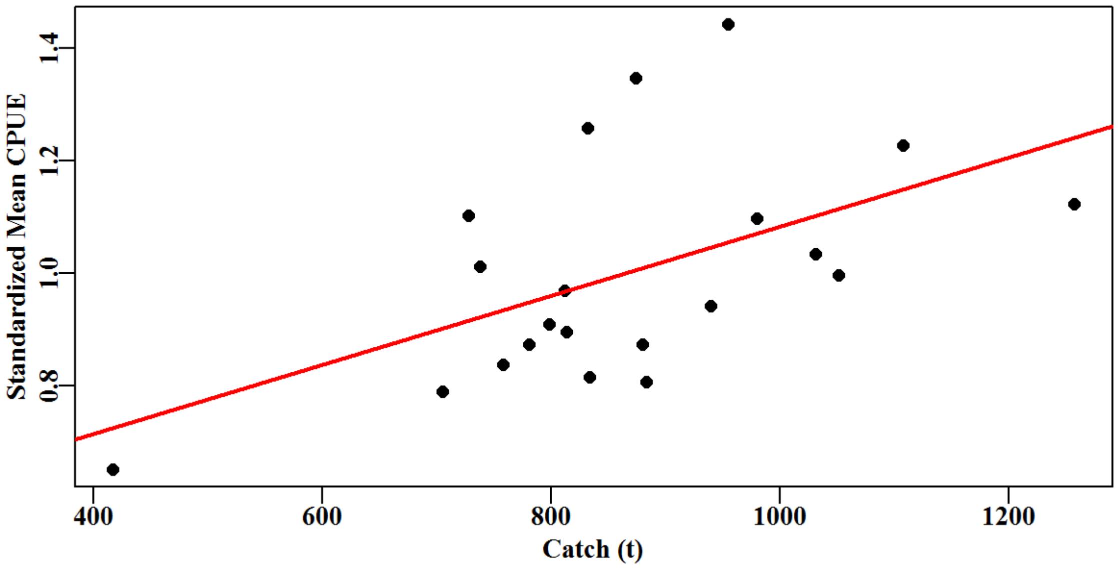

Figure 8.19. GummySharkBS. The linear relationship between Annual mean CPUE and Annual Catch.

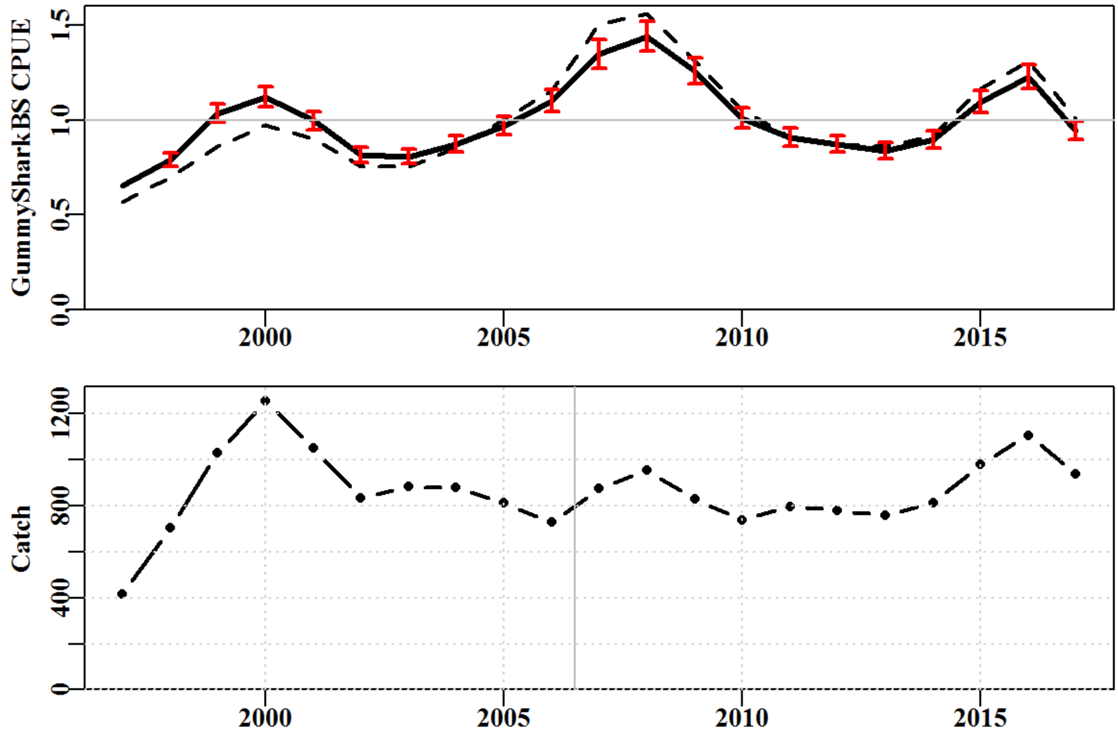

Figure 8.20. GummySharkBS. CPUE is correlated with catches through time. CPUE in the top plot and annual catch (t) in the lower plot.

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. 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 (zones) 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 R^2 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 slightly below the term average since 2016 (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 - 2017

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/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
1997	952.1	203	17.3	14	96.0	0.7512	0.000	1.231	0.071
1998	1401.1	529	55.3	14	122.1	0.7042	0.107	3.061	0.055
1999	1923.8	854	102.0	18	134.8	0.9790	0.105	3.926	0.038
2000	2436.9	544	82.6	18	169.2	1.1904	0.111	1.909	0.023
2001	1703.3	600	65.1	21	125.2	1.2301	0.115	2.672	0.041
2002	1527.1	781	100.4	26	159.5	1.1534	0.114	3.399	0.034
2003	1653.0	873	90.5	23	118.0	1.2816	0.115	4.674	0.052
2004	1669.9	917	120.9	26	169.0	1.2188	0.114	3.893	0.032
2005	1573.2	657	85.8	15	157.2	1.1071	0.117	2.646	0.031
2006	1577.1	697	116.8	15	191.0	1.2463	0.117	2.334	0.020
2007	1575.0	835	95.3	14	135.6	1.0587	0.116	4.041	0.042
2008	1727.7	635	61.8	14	109.9	0.9203	0.118	3.464	0.056
2009	1500.9	527	67.2	14	160.0	1.0950	0.123	2.199	0.033
2010	1404.8	534	75.5	14	172.2	1.0883	0.123	2.089	0.028
2011	1364.7	687	102.7	13	178.8	0.9000	0.125	2.212	0.022
2012	1304.2	1119	130.0	18	126.8	0.9561	0.121	5.852	0.045
2013	1307.6	910	96.6	15	111.5	0.7910	0.124	4.804	0.050
2014	1389.1	482	65.1	13	144.0	0.7058	0.132	2.146	0.033
2015	1545.1	359	53.4	11	166.6	0.6823	0.133	1.439	0.027
2016	1586.5	344	68.1	7	235.9	0.9553	0.133	0.952	0.014
2017	1561.3	497	85.1	13	198.2	0.9851	0.129	1.258	0.015

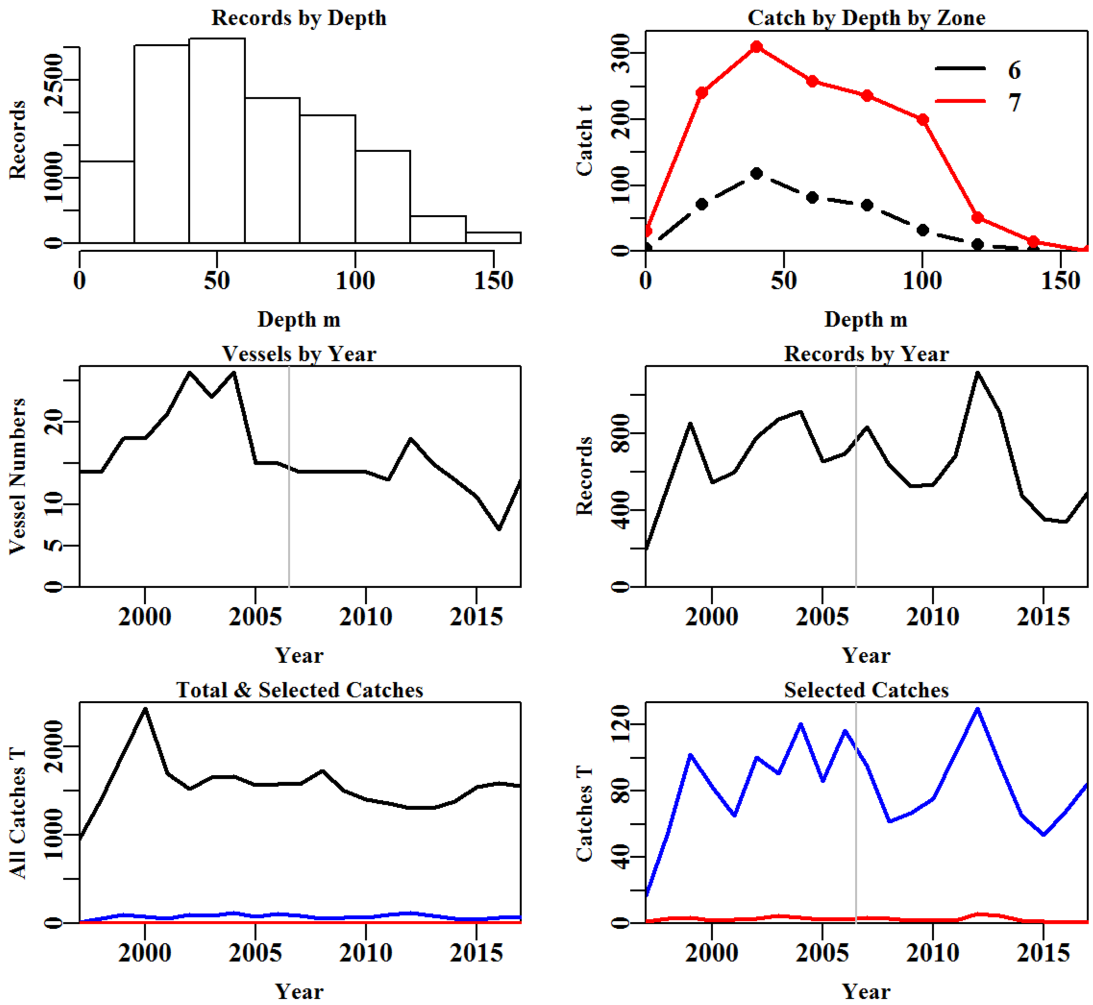

Figure 8.21. GummySharkTA fishery details. The bottom left plot depicts all known catches (top black line), and all selected catches used in the analysis (middle blue line); the lower red line: selected catches < 30 kg). Refer to Box 1 (p. 7) for names which correspond to zone numbers.

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	386988	0	33240.551	0.000
NoCE	379828	7160	33240.551	0.000
Depth	353045	26783	32283.687	956.864
Years	340890	12155	31793.418	490.270
Zones	22058	318832	2060.112	29733.306
Method	13584	8474	1737.516	322.596
Fishery	13584	0	1737.516	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	6886	22481	697	13584	21	2.9	0.00
Vessel	1548	14998	8180	13584	101	34.8	31.95
DepCat	1523	14954	8225	13584	109	35.0	0.16
SharkRegion	1522	14951	8227	13584	110	35.0	0.01
Month	1206	14583	8595	13584	121	36.5	1.55
SharkRegion:DepCat	1166	14525	8653	13584	128	36.7	0.22
SharkRegion:Month	1145	14494	8684	13584	132	36.9	0.34

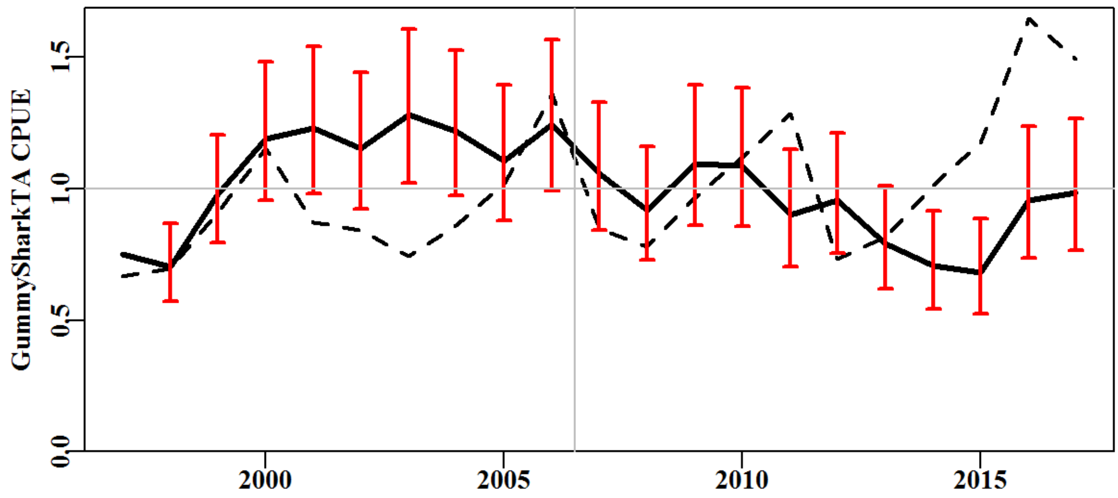

Figure 8.22. GummySharkTA standardization. The dashed black line represents the geometric mean catch rate, solid black line the standardized catch rates. The red bars are the 95% confidence intervals about the mean estimates. The graph scales both time-series of standardized catch rates relative to the mean of each time-series.

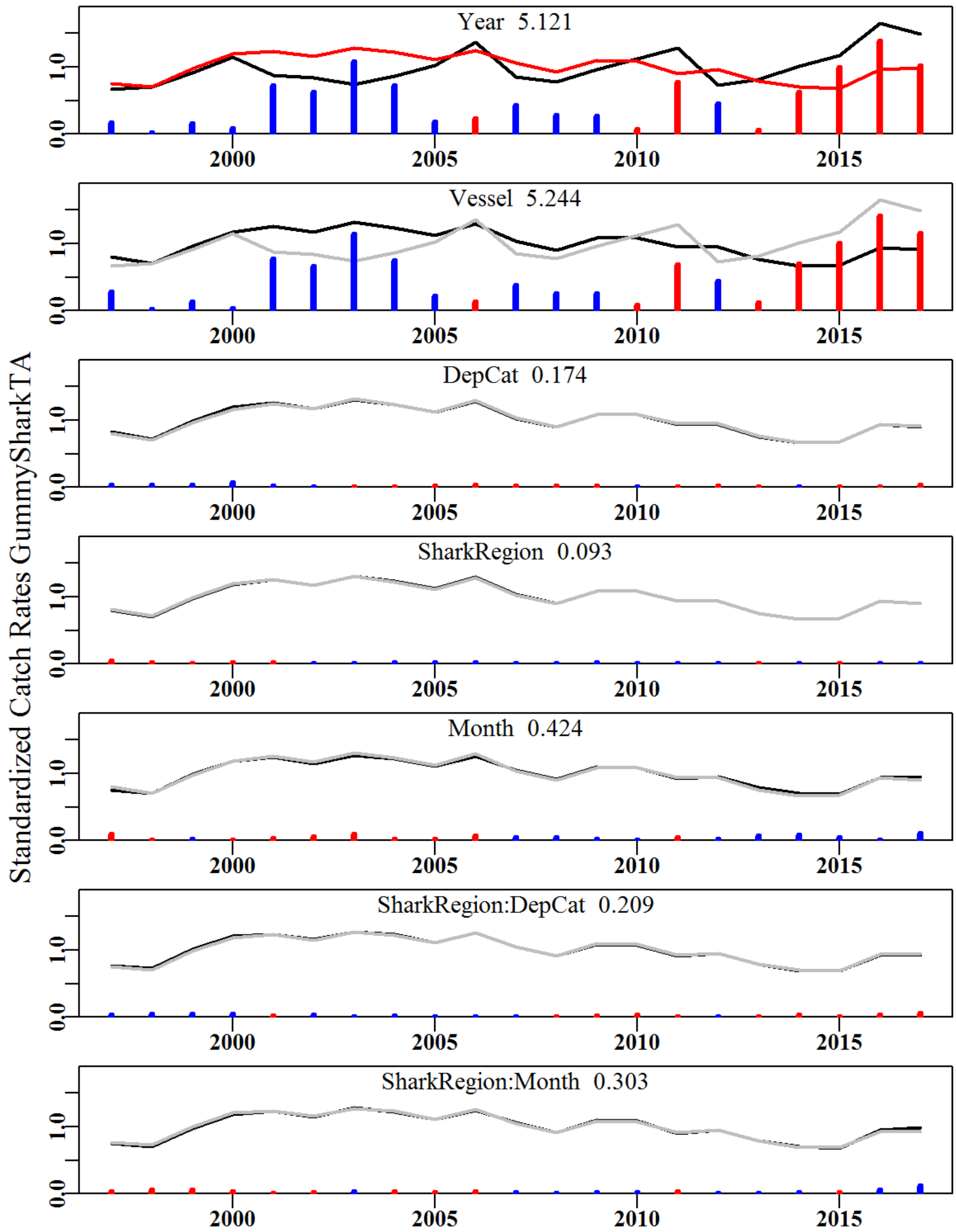

Figure 8.23. GummySharkTA. The influence of each factor on the optimal standardization. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by vertical bars with blue bars indicating the optimum model is higher than the geometric 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.

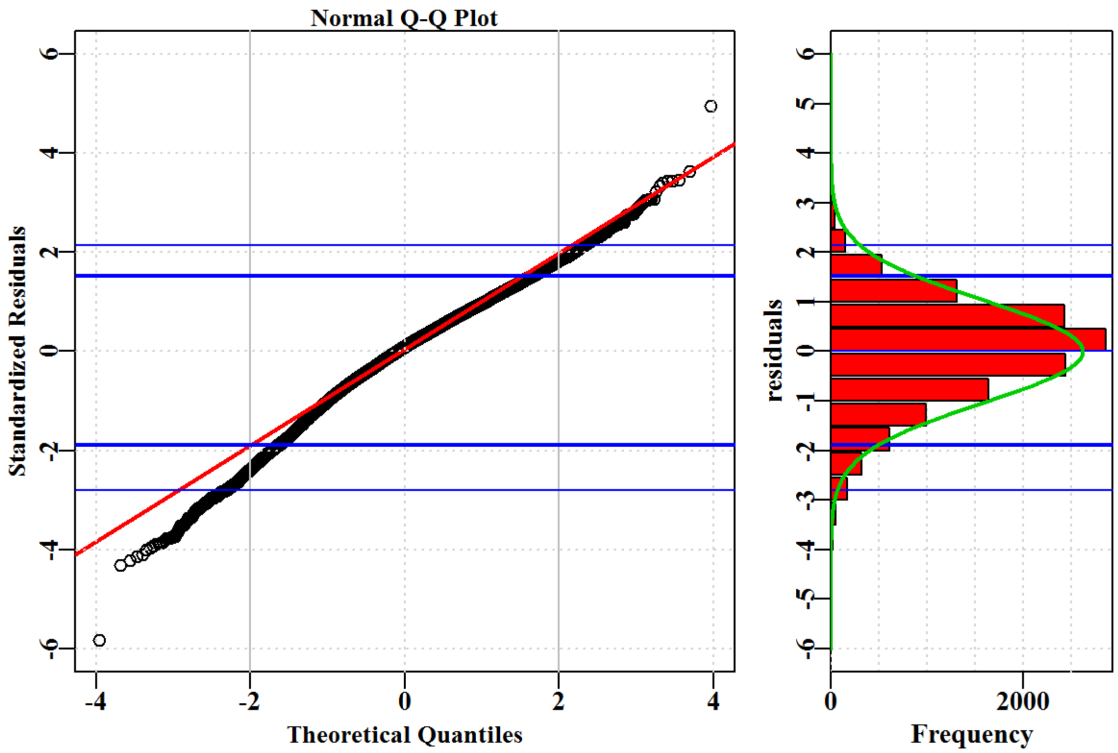

Figure 8.24. GummySharkTA. Diagnostic plots. The distribution of residuals from the optimum fit. The qqplot indicates the fit to the expected normality, while the histogram of residuals also illustrates the 1%, 5%, 95% and 99% quantiles to indicate the intensity of any lack of fit at the margins of the distribution (reflected also in the qqplot).

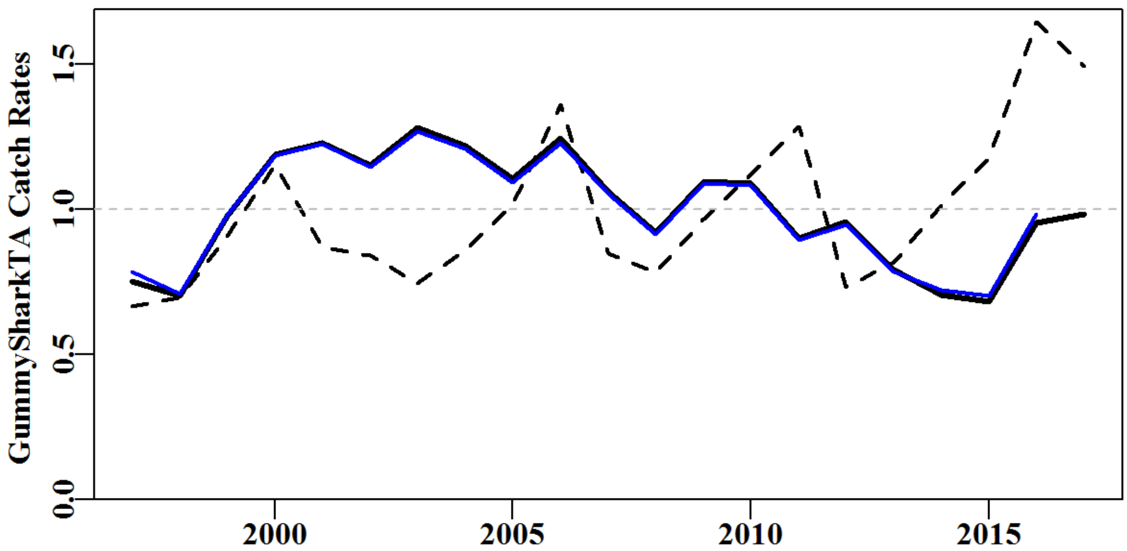

Figure 8.25. GummySharkTA. A comparison of the previous year's standardization (blue line) with this year's. They should lie on top of each other, although small deviations may relate to data adjustments, particularly in very recent years.

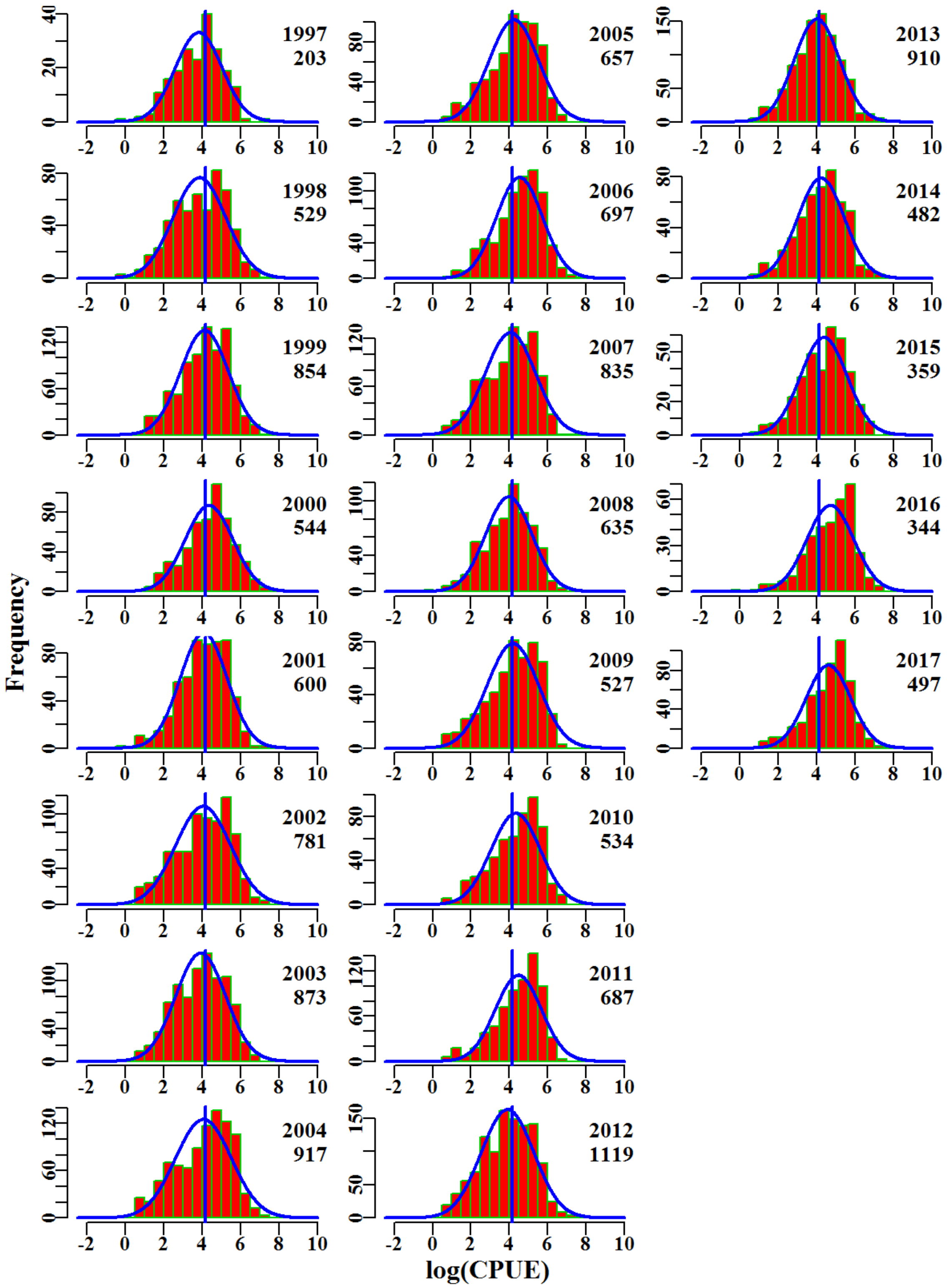

Figure 8.26. GummySharkTA. The $\log_e$(CPUE) for each year of data available the blue lines are normal distributions fitted to the histogram frequencies. The numbers in each plot are the year and number of records. The vertical blue line is the average across all years. The largest spike in 2016 corresponds to CPUE records between approximately 260-400 kg/shot. Similarly, the largest spike in 2017 corresponds to CPUE records between approximately 150-250 kg/shot.

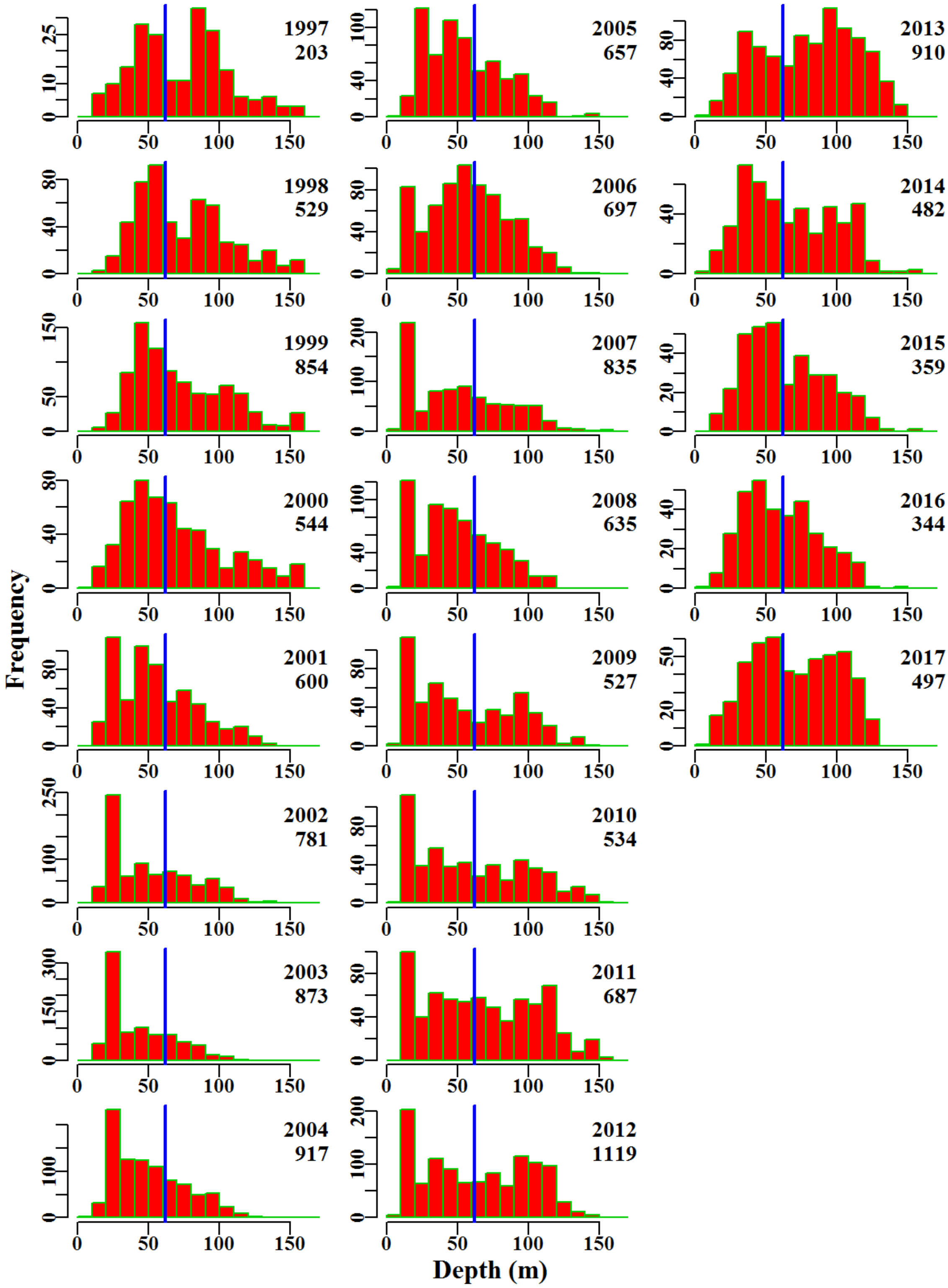

Figure 8.27. GummySharkTA. The average Depth of fishing for each year of data available to illustrate the development of the fishery through time. The numbers in each plot are the year and number of records. The vertical blue line is the average across all years.

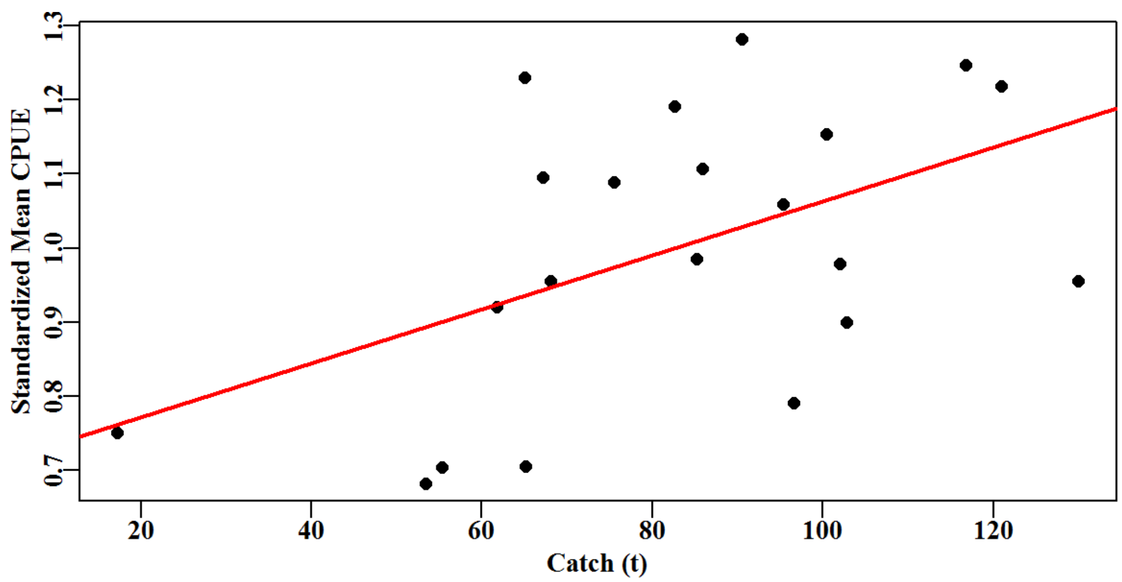

Figure 8.28. GummySharkTA. The linear relationship between Annual mean CPUE and Annual Catch.

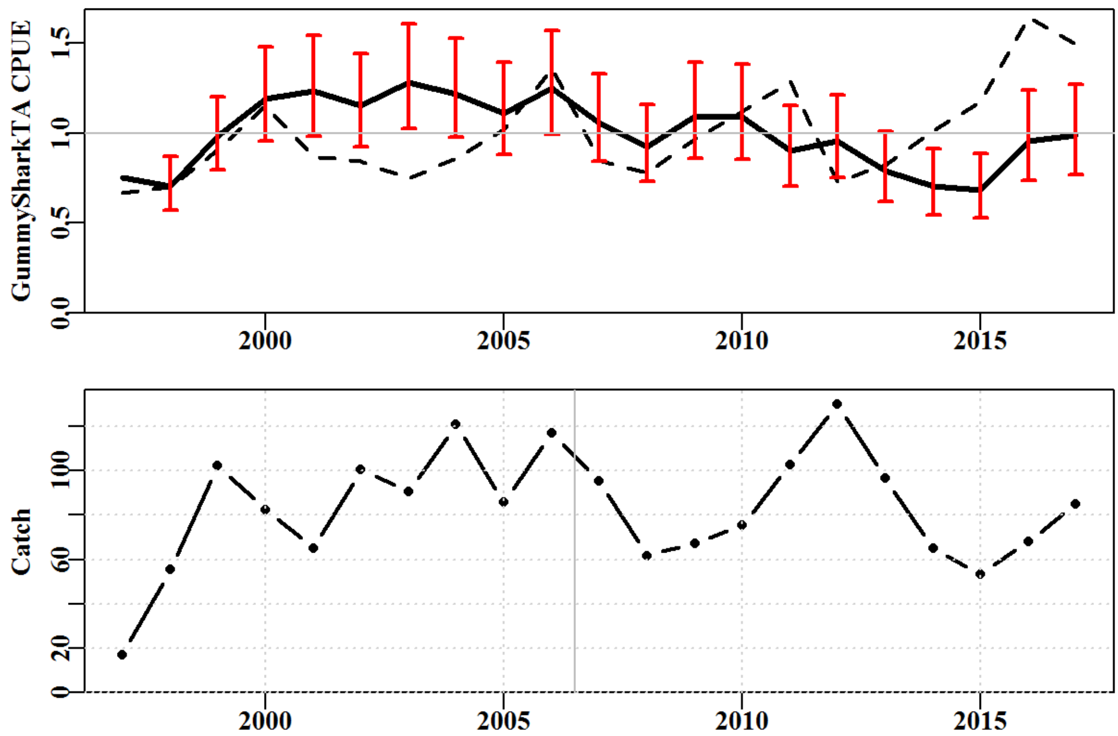

Figure 8.29. GummySharkTA. CPUE is correlated with catches through time. CPUE in the top plot and annual catch (t) in the lower plot.

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 (zones) 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 R^2 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 above the long term average since 2008 (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 - 2017

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	1.0097	0.000	24.951	0.616
1997	952.1	2778	43.6	77	4.5	0.8913	0.028	28.084	0.643
1998	1401.1	2462	39.2	62	4.5	0.8841	0.029	27.357	0.698
1999	1923.8	2395	38.2	69	4.7	0.9160	0.029	23.234	0.609
2000	2436.9	3141	50.4	76	4.8	0.8050	0.028	29.821	0.591
2001	1703.3	3355	56.5	63	4.6	0.7905	0.028	30.462	0.539
2002	1527.1	3994	61.2	67	4.1	0.7492	0.027	34.925	0.571
2003	1653.0	4572	80.4	73	4.4	0.8078	0.027	40.661	0.506
2004	1669.9	4788	89.4	73	4.6	0.8244	0.027	43.556	0.487
2005	1573.2	5056	95.9	70	4.6	0.8351	0.026	48.241	0.503
2006	1577.1	4896	102.1	62	5.0	0.8610	0.027	43.956	0.431
2007	1575.0	3598	84.9	37	5.6	0.8750	0.028	34.983	0.412
2008	1727.7	3769	86.3	36	5.4	1.0348	0.028	38.720	0.448
2009	1500.9	3492	87.6	31	5.8	1.1289	0.028	37.903	0.432
2010	1404.8	3640	90.2	33	5.9	1.1215	0.028	39.510	0.438
2011	1364.7	4289	100.7	32	5.5	1.0254	0.027	43.337	0.430
2012	1304.2	3816	101.8	31	6.2	1.1371	0.028	40.763	0.401
2013	1307.6	3513	96.9	33	6.6	1.2767	0.028	43.274	0.447
2014	1389.1	3159	91.3	34	6.9	1.2438	0.029	37.298	0.408
2015	1545.1	2939	82.9	36	6.9	1.2071	0.029	35.122	0.423
2016	1586.5	2844	86.7	34	7.7	1.2491	0.029	32.200	0.371
2017	1561.3	2860	90.0	33	8.0	1.3264	0.030	32.544	0.361

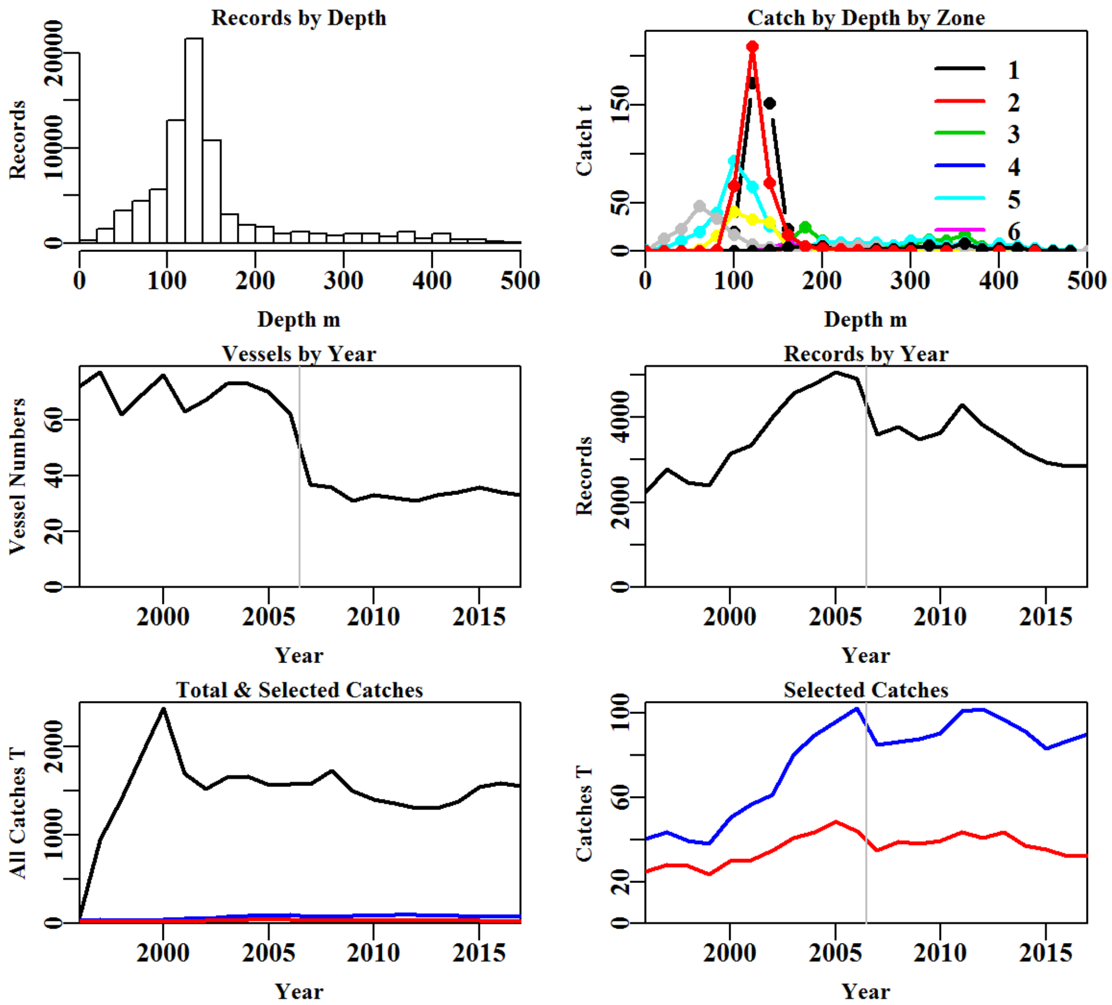

Figure 8.30. GummySharkTW fishery details. The bottom left plot depicts all known catches (top black line), and all selected catches used in the analysis (middle blue line); the lower red line: selected catches < 30 kg). Refer to Box 1 (p. 7) for names which correspond to zone numbers.

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	386988	0	33240.551	0.000
NoCE	254428	132560	20057.572	13182.979
Depth	252430	1998	19959.181	98.391
Years	242980	9450	19546.987	412.194
Zones	242291	689	19519.940	27.047
Method	77858	164433	1698.888	17821.052
Fishery	77590	268	1696.821	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	9756	87936	2680	77590	22	2.9	0.00
Vessel	-2444	74884	15731	77590	155	17.2	14.27
DepCat	-3890	73454	17161	77590	180	18.8	1.55
SharkRegion	-4673	72700	17915	77590	189	19.6	0.82
Month	-6523	70966	19649	77590	200	21.5	1.91
DayNight	-7654	69934	20681	77590	203	22.6	1.14
SharkRegion:DepCat	-9139	68282	22333	77590	388	24.3	1.65
SharkRegion:Month	-8260	69213	21402	77590	302	23.3	0.70

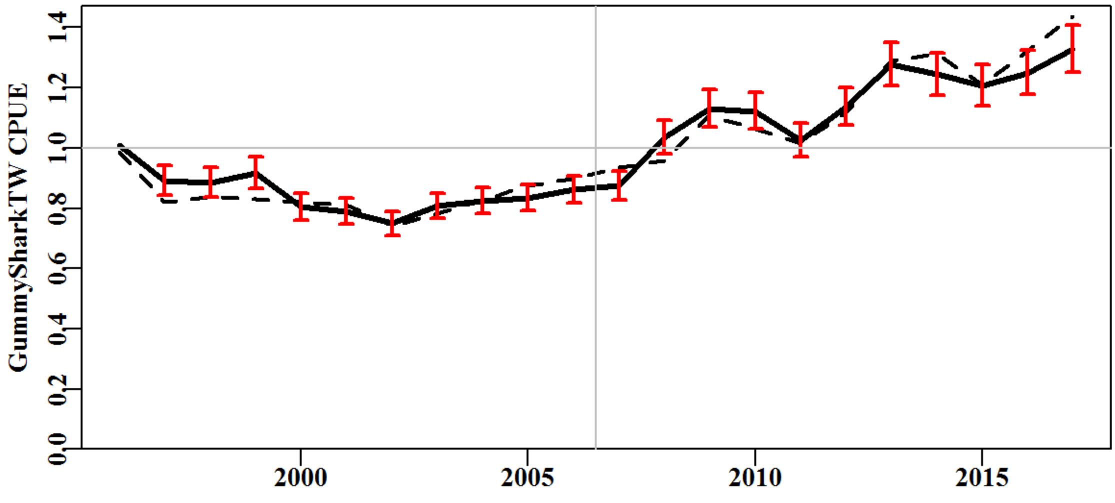

Figure 8.31. GummySharkTW standardization. The dashed black line represents the geometric mean catch rate, solid black line the standardized catch rates. The red bars are the 95% confidence intervals about the mean estimates. The graph scales both time-series of standardized catch rates relative to the mean of each time-series.

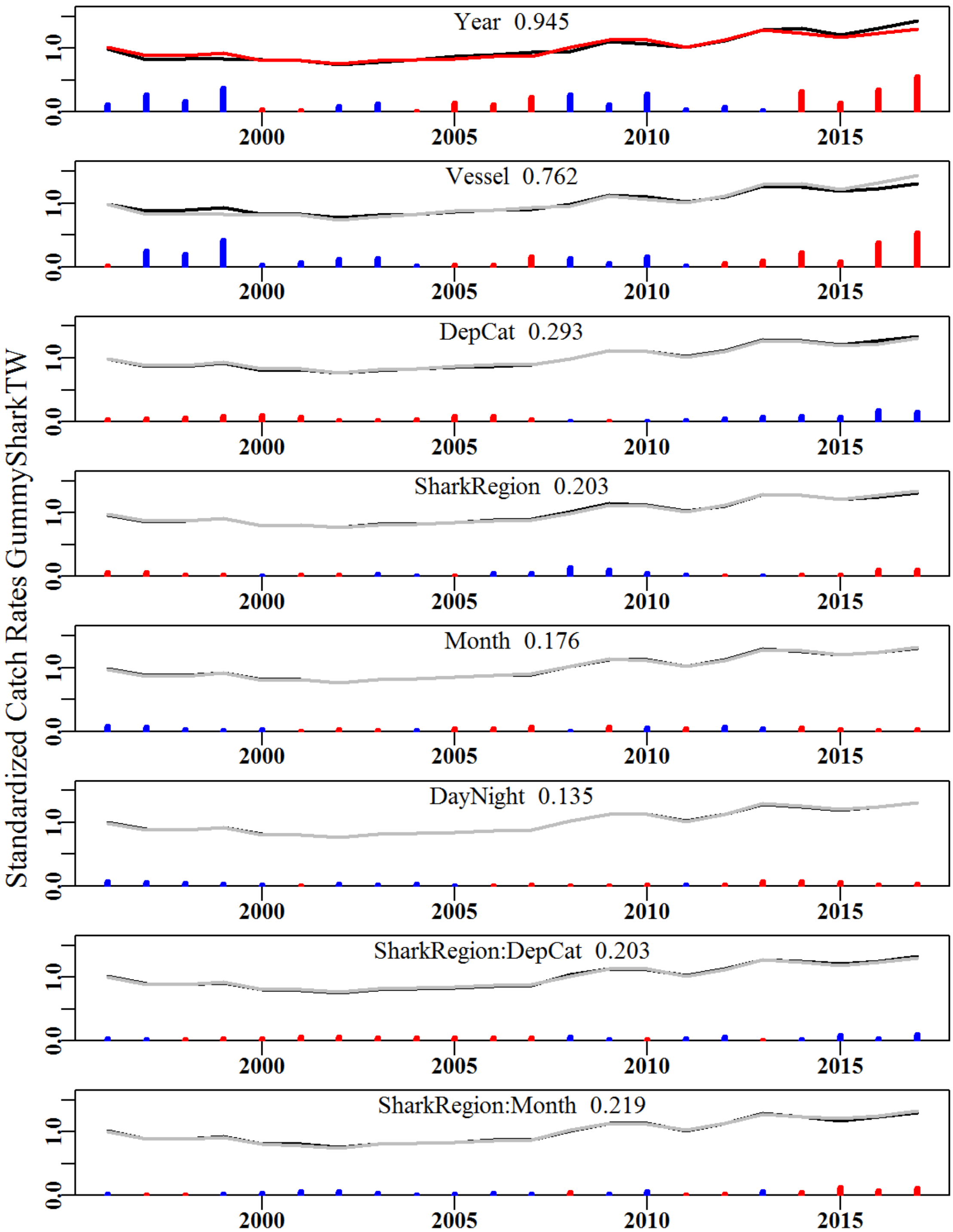

Figure 8.32. GummySharkTW. The influence of each factor on the optimal standardization. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by vertical bars with blue bars indicating the optimum model is higher than the geometric 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.

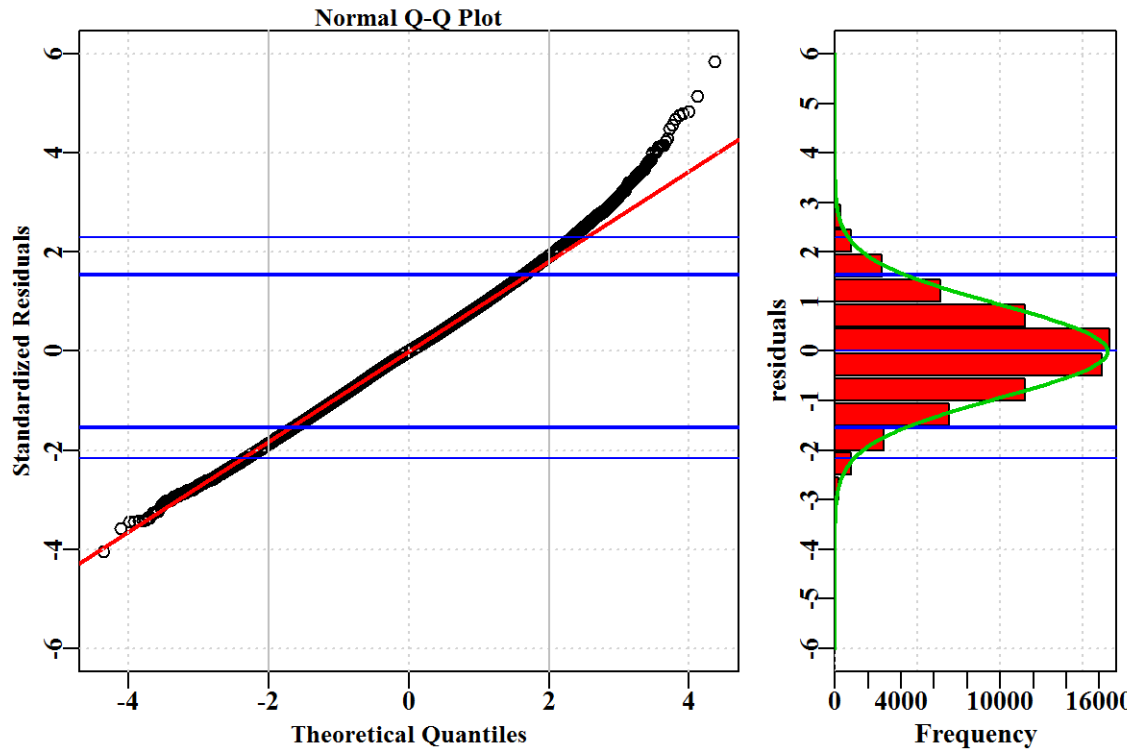

Figure 8.33. GummySharkTW. Diagnostic plots. The distribution of residuals from the optimum fit. The qqplot indicates the fit to the expected normality, while the histogram of residuals also illustrates the 1%, 5%, 95% and 99% quantiles to indicate the intensity of any lack of fit at the margins of the distribution (reflected also in the qqplot).

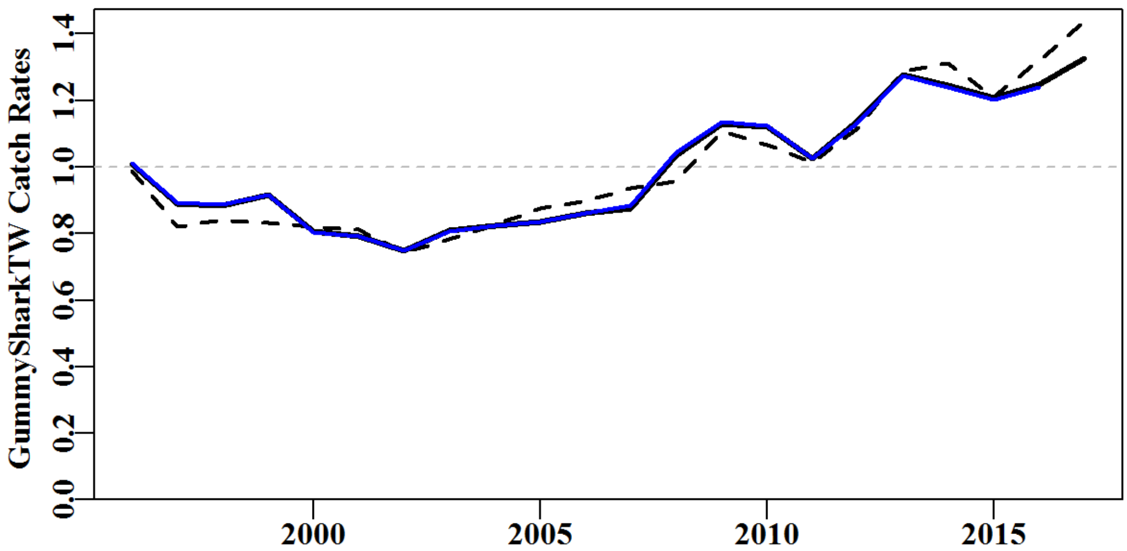

Figure 8.34. GummySharkTW. A comparison of the previous year's standardization (blue line) with this year's. They should lie on top of each other, although small deviations may relate to data adjustments, particularly in very recent years.

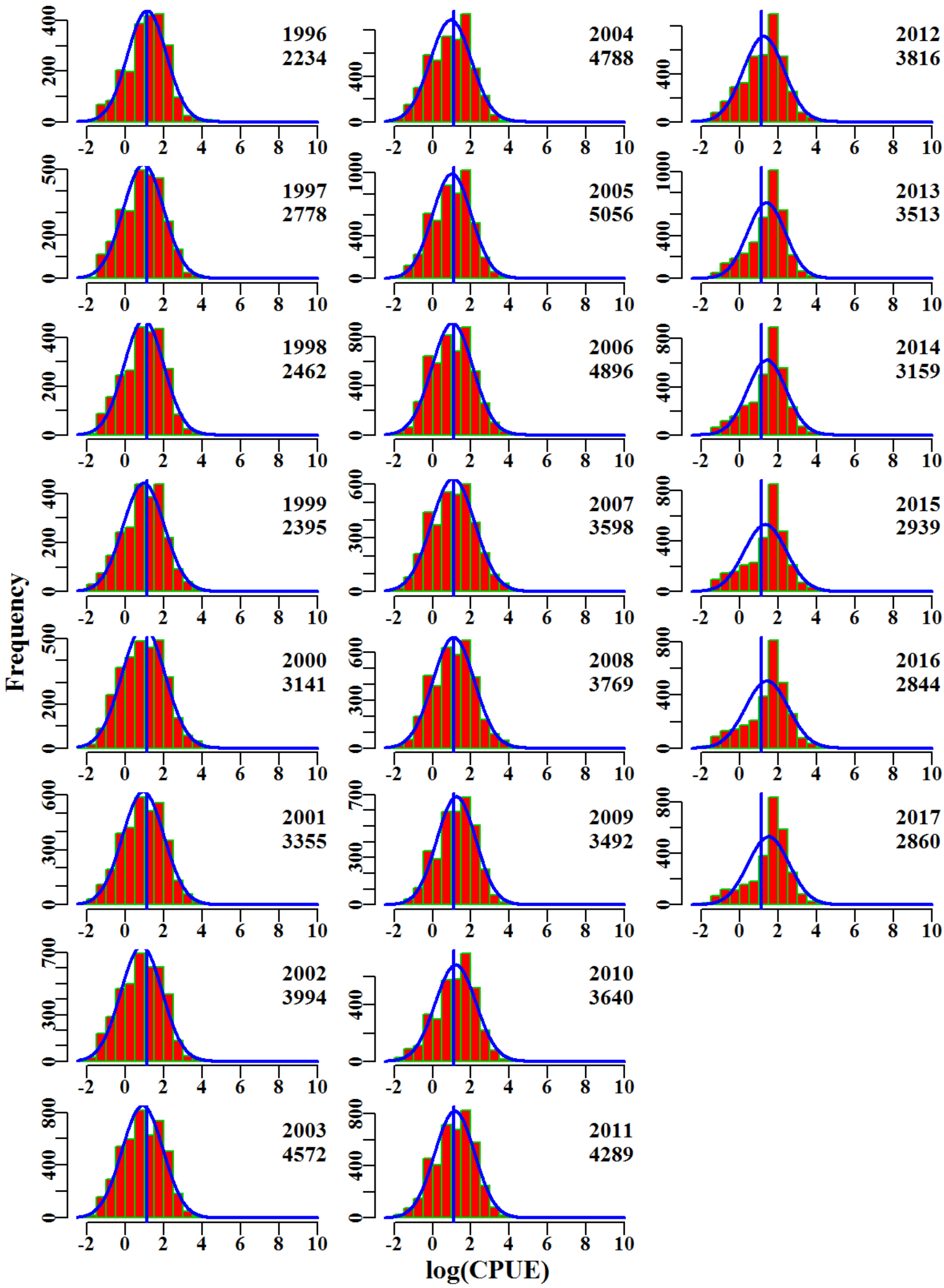

Figure 8.35. GummySharkTW. The $\log_e$(CPUE) for each year of data available the blue lines are normal distributions fitted to the histogram frequencies. The numbers in each plot are the year and number of records. The vertical blue line is the average across all years.

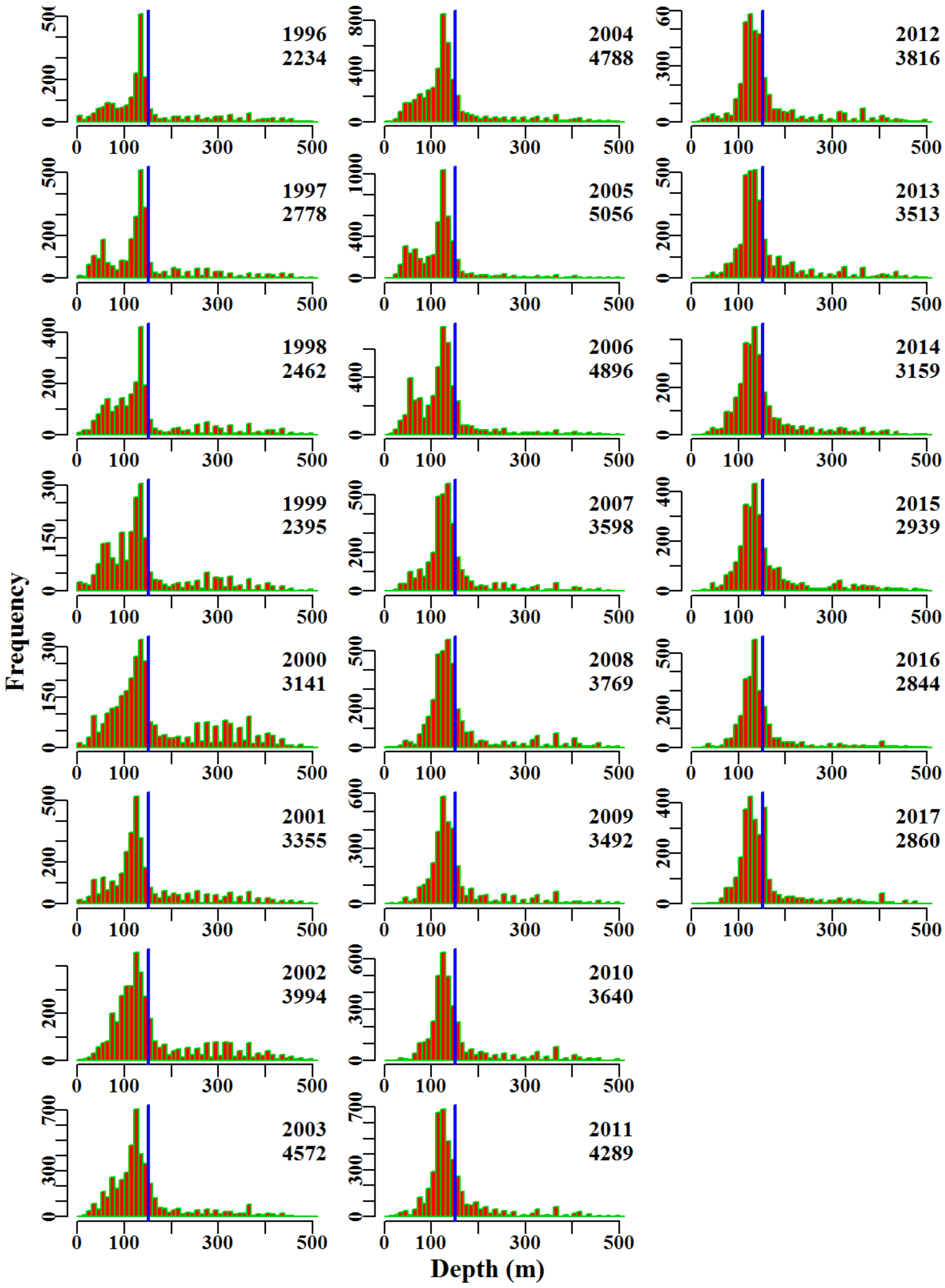

Figure 8.36. GummySharkTW. The average Depth of fishing for each year of data available to illustrate the development of the fishery through time. The numbers in each plot are the year and number of records. The vertical blue line is the average across all years.

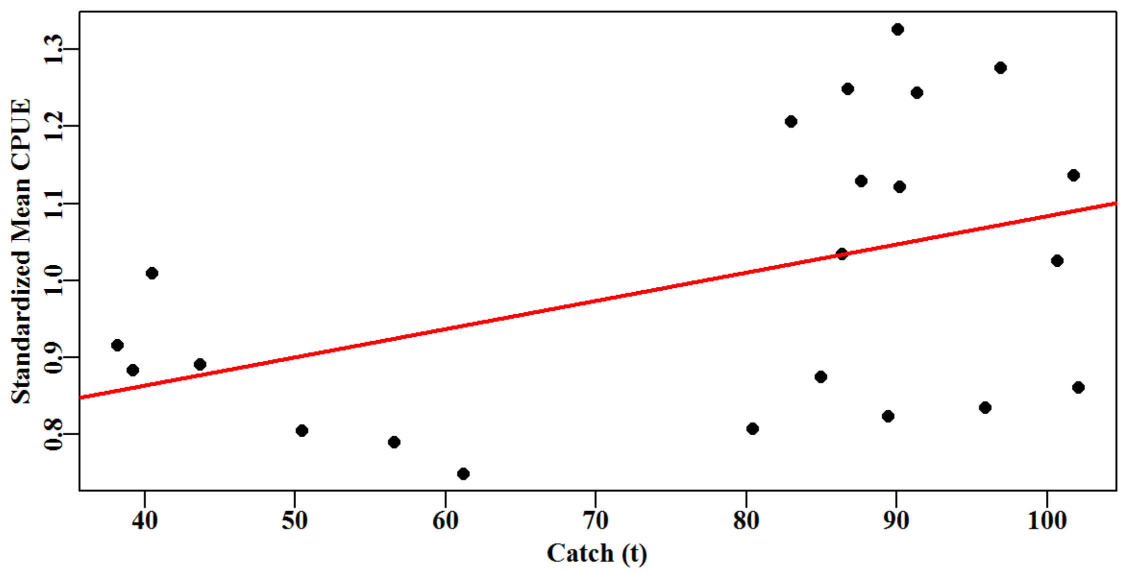

Figure 8.37. GummySharkTW. The linear relationship between Annual mean CPUE and Annual Catch.

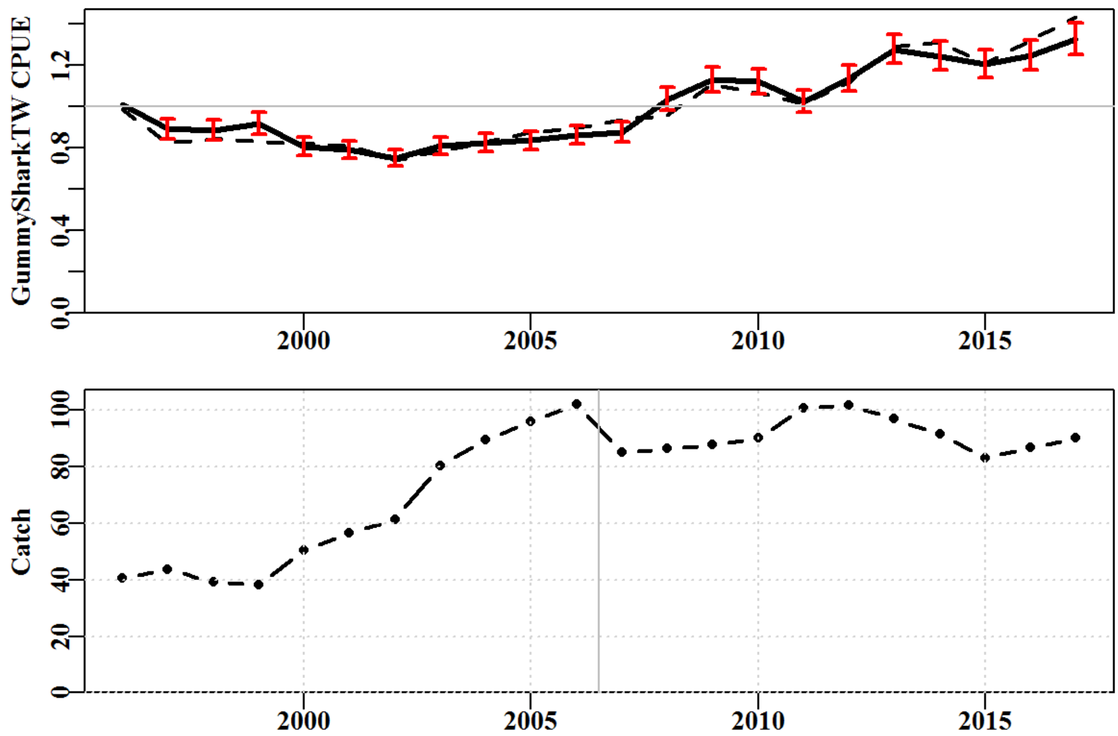

Figure 8.38. GummySharkTW. CPUE is correlated with catches through time. CPUE in the top plot and annual catch (t) in the lower plot.

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 (zones) 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 R^2 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 - 2017

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	0.9788	0.000	0.180	0.021
1999	1923.8	333	46.7	13	150.8	1.1551	0.158	0.656	0.014
2000	2436.9	481	111.4	14	276.2	1.3213	0.190	0.927	0.008
2001	1703.3	541	58.7	23	130.4	0.7879	0.193	2.494	0.043
2002	1527.1	495	59.0	21	136.5	0.8807	0.193	2.242	0.038
2003	1653.0	619	64.5	27	120.3	0.7664	0.193	2.949	0.046
2004	1669.9	640	66.9	24	119.8	0.8054	0.192	2.912	0.044
2005	1573.2	578	59.6	24	117.9	0.9506	0.194	2.713	0.046
2006	1577.1	495	48.7	19	105.5	1.0362	0.195	2.909	0.060
2007	1575.0	625	54.4	19	88.9	0.9236	0.194	4.651	0.085
2008	1727.7	599	50.1	16	91.8	0.6921	0.196	4.368	0.087
2009	1500.9	819	67.0	15	86.4	0.7943	0.194	5.516	0.082
2010	1404.8	684	72.0	19	119.4	0.9423	0.195	3.713	0.052
2011	1364.7	1045	87.2	28	96.2	1.0451	0.194	5.974	0.069
2012	1304.2	1407	124.2	24	97.8	1.0657	0.194	7.392	0.060
2013	1307.6	2515	229.1	27	100.5	1.1951	0.194	13.533	0.059
2014	1389.1	2758	225.7	29	89.6	1.0219	0.194	17.426	0.077
2015	1545.1	1948	187.3	28	106.9	1.3113	0.194	11.015	0.059
2016	1586.5	1388	147.4	25	120.1	1.0543	0.195	7.387	0.050
2017	1561.3	1876	289.3	32	184.5	1.2718	0.195	7.760	0.027

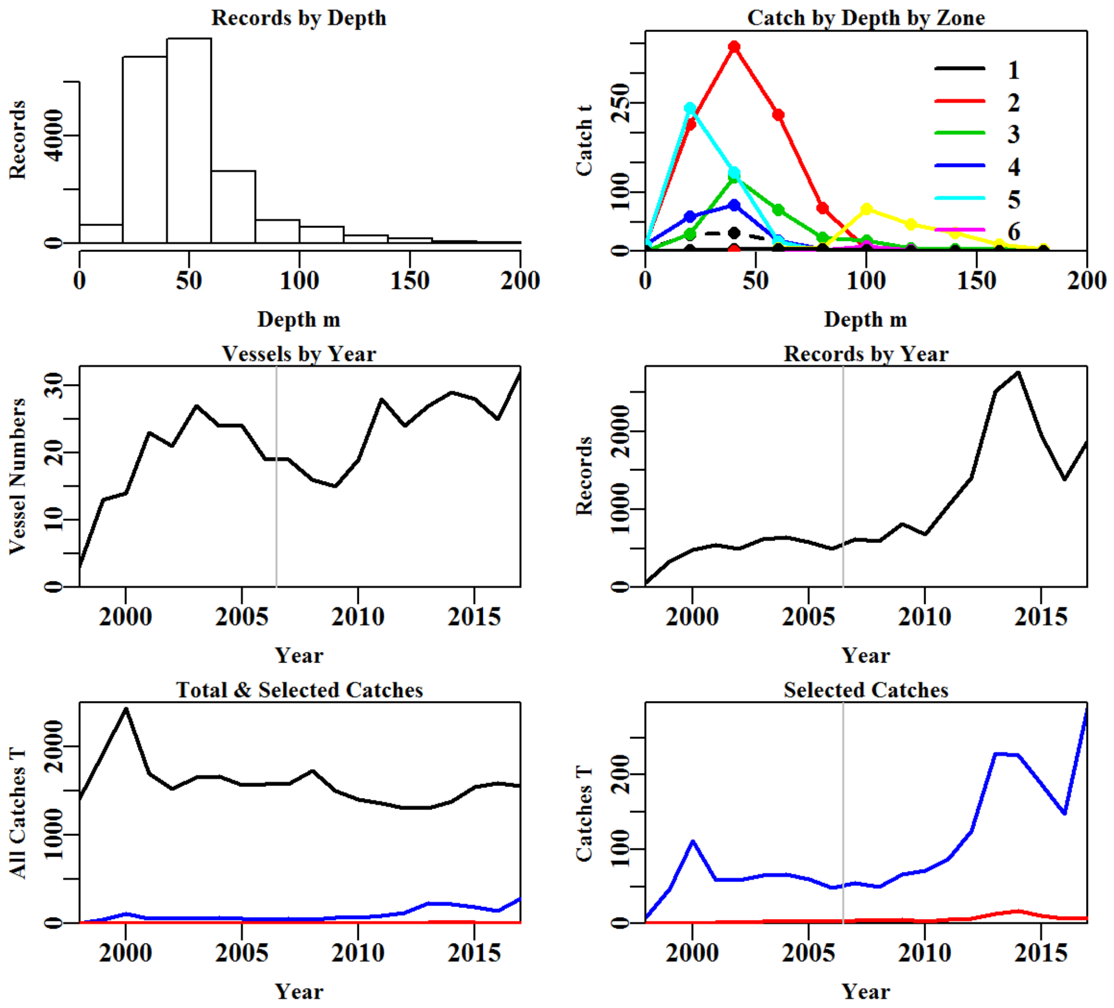

Figure 8.39. GummySharkBL fishery details. The bottom left plot depicts all known catches (top black line), and all selected catches used in the analysis (middle blue line); the lower red line: selected catches < 30 kg). Refer to Box 1for names which correspond to zone numbers.

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	386988	0	33240.551	0.000
NoCE	379828	7160	33240.551	0.000
Depth	359176	20652	32468.593	771.958
Years	332089	27087	31031.501	1437.092
Zones	331797	292	30999.782	31.718
Method	20297	311500	2097.459	28902.323
Fishery	19918	379	2057.732	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	8083	29828	1367	19918	20	4.3	0.00
Vessel	600	20212	10983	19918	154	34.7	30.41
DepCat	370	19962	11233	19918	163	35.5	0.78
SharkRegion	319	19893	11302	19918	172	35.7	0.20
Month	266	19819	11376	19918	183	35.9	0.20
DayNight	267	19813	11382	19918	186	35.9	0.01
SharkRegion:DepCat	221	19659	11536	19918	241	36.2	0.32
SharkRegion:Month	73	19470	11725	19918	263	36.8	0.86

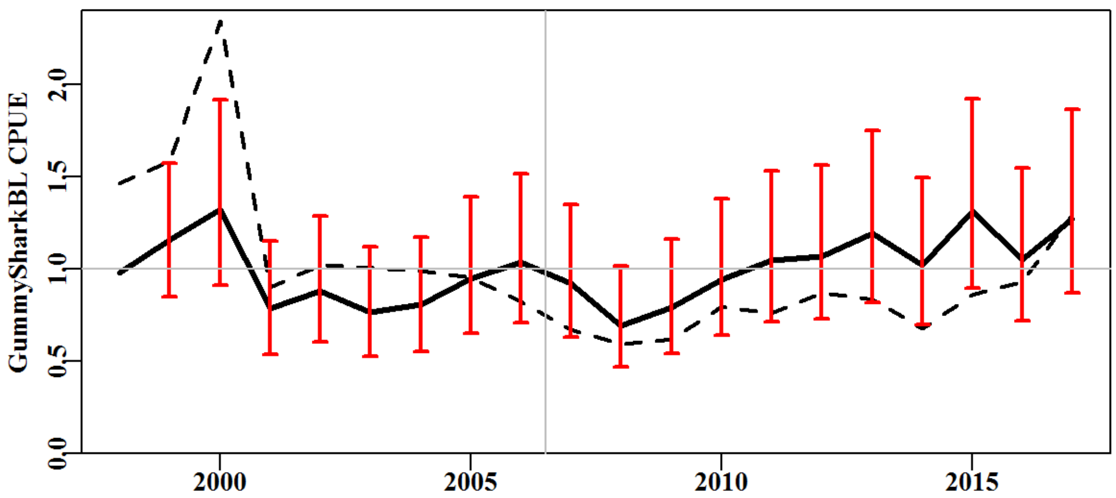

Figure 8.40. GummySharkBL standardization. The dashed black line represents the geometric mean catch rate, solid black line the standardized catch rates. The red bars are the 95% confidence intervals about the mean estimates. The graph scales both time-series of standardized catch rates relative to the mean of each time-series.

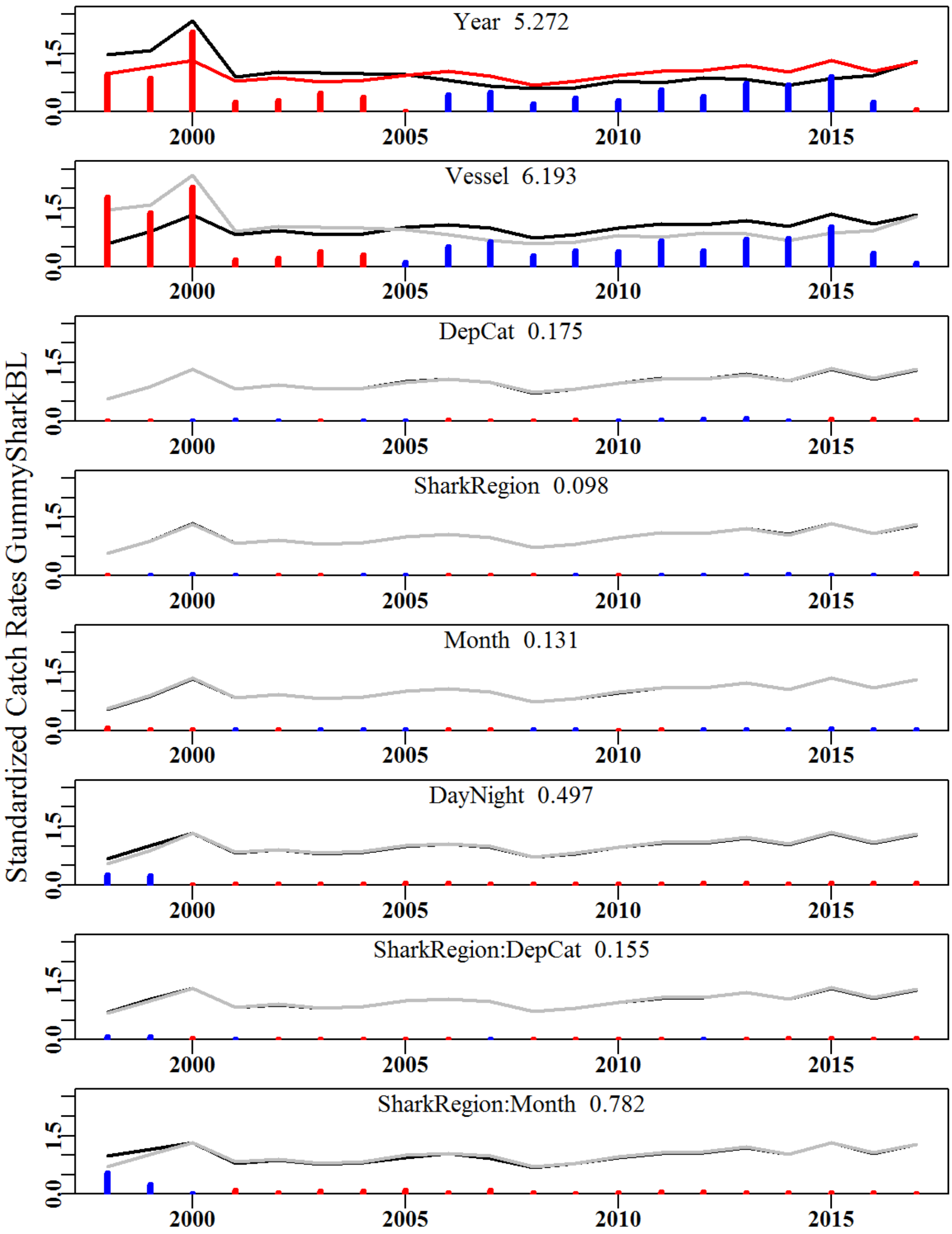

Figure 8.41. GummySharkBL. The influence of each factor on the optimal standardization. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by vertical bars with blue bars indicating the optimum model is higher than the geometric 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.

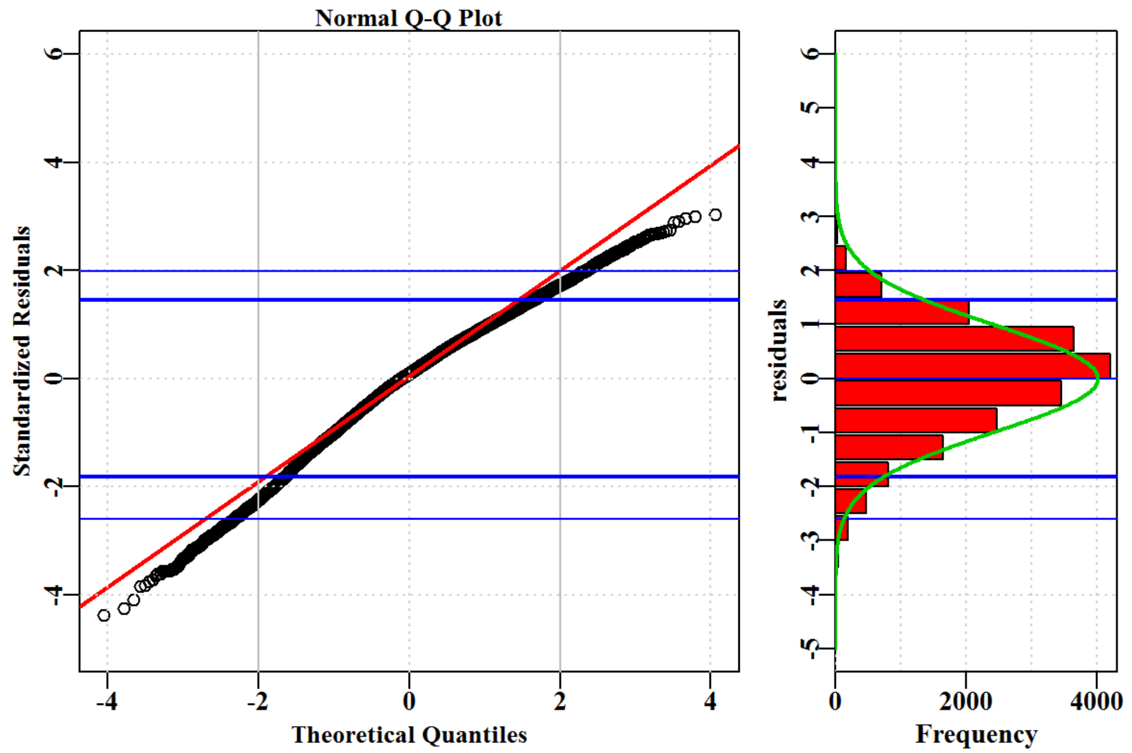

Figure 8.42. GummySharkBL. Diagnostic plots. The distribution of residuals from the optimum fit. The qqplot indicates the fit to the expected normality, while the histogram of residuals also illustrates the 1%, 5%, 95% and 99% quantiles to indicate the intensity of any lack of fit at the margins of the distribution (reflected also in the qqplot).

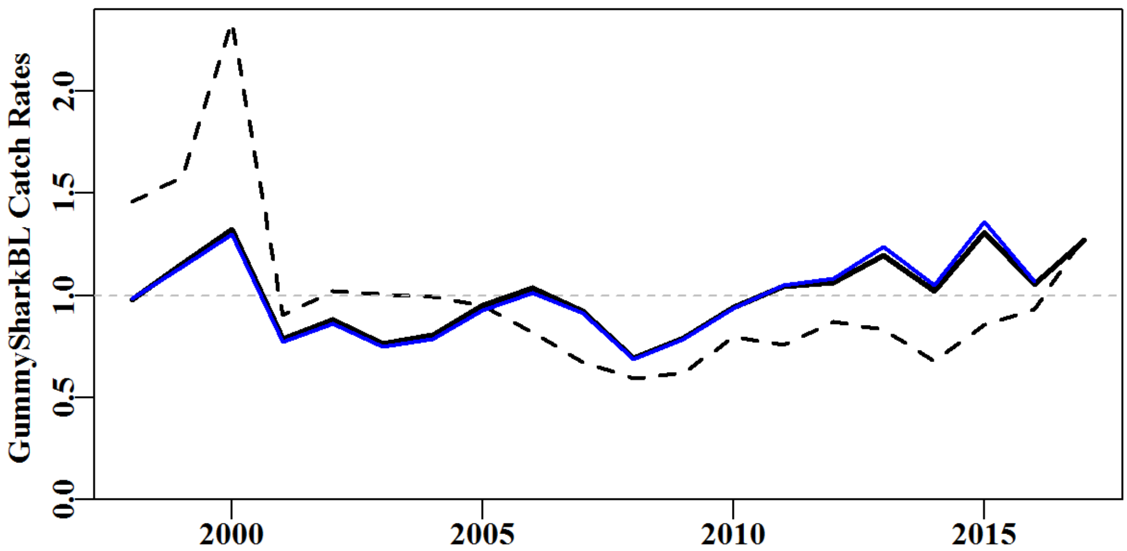

Figure 8.43. GummySharkBL. A comparison of the previous year's standardization (blue line) with this year's. They should lie on top of each other, although small deviations may relate to data adjustments, particularly in very recent years.

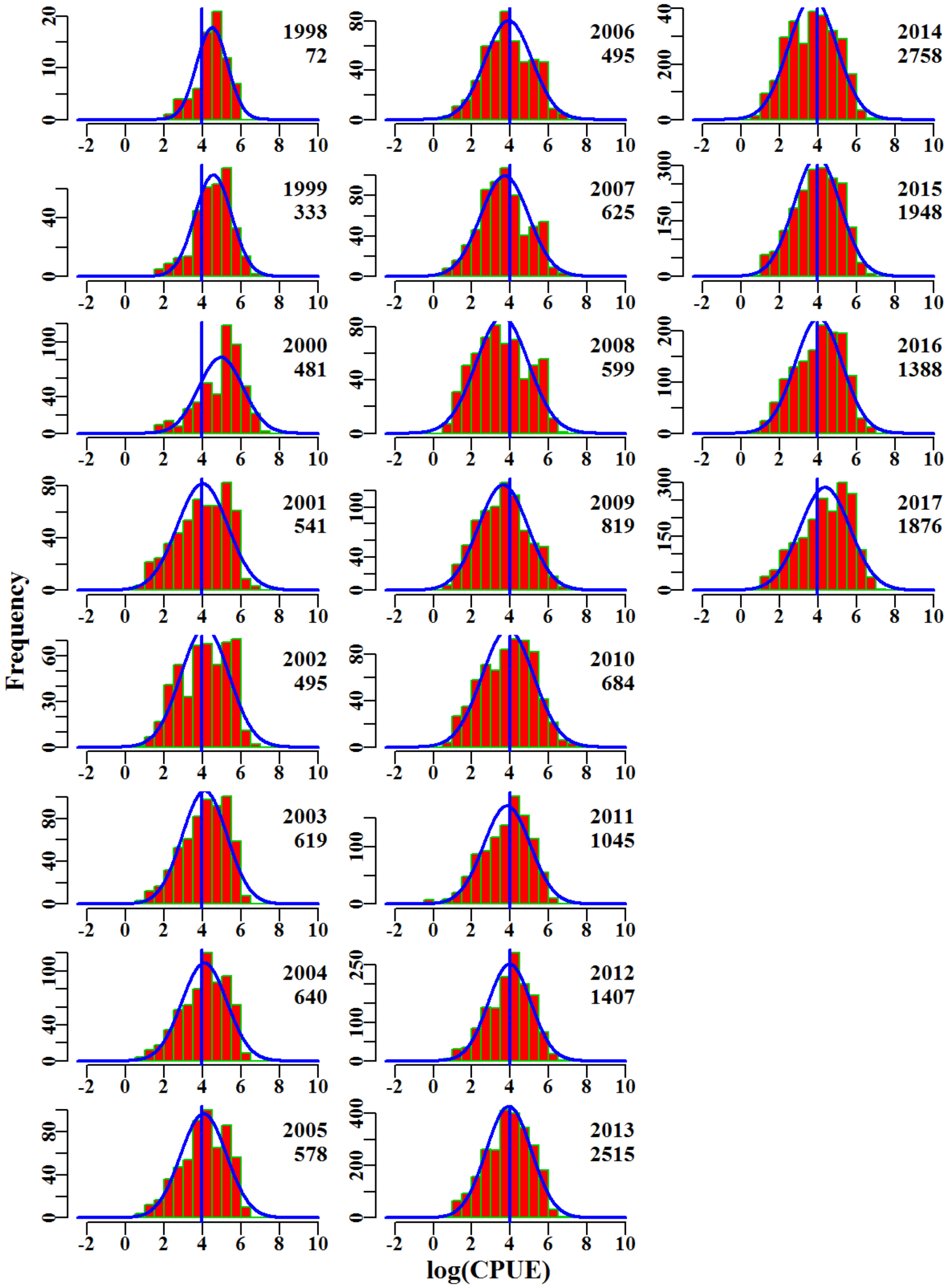

Figure 8.44. GummySharkBL. The $\log_e$(CPUE) for each year of data available the blue lines are normal distributions fitted to the histogram frequencies. The numbers in each plot are the year and number of records. The vertical blue line is the average across all years.

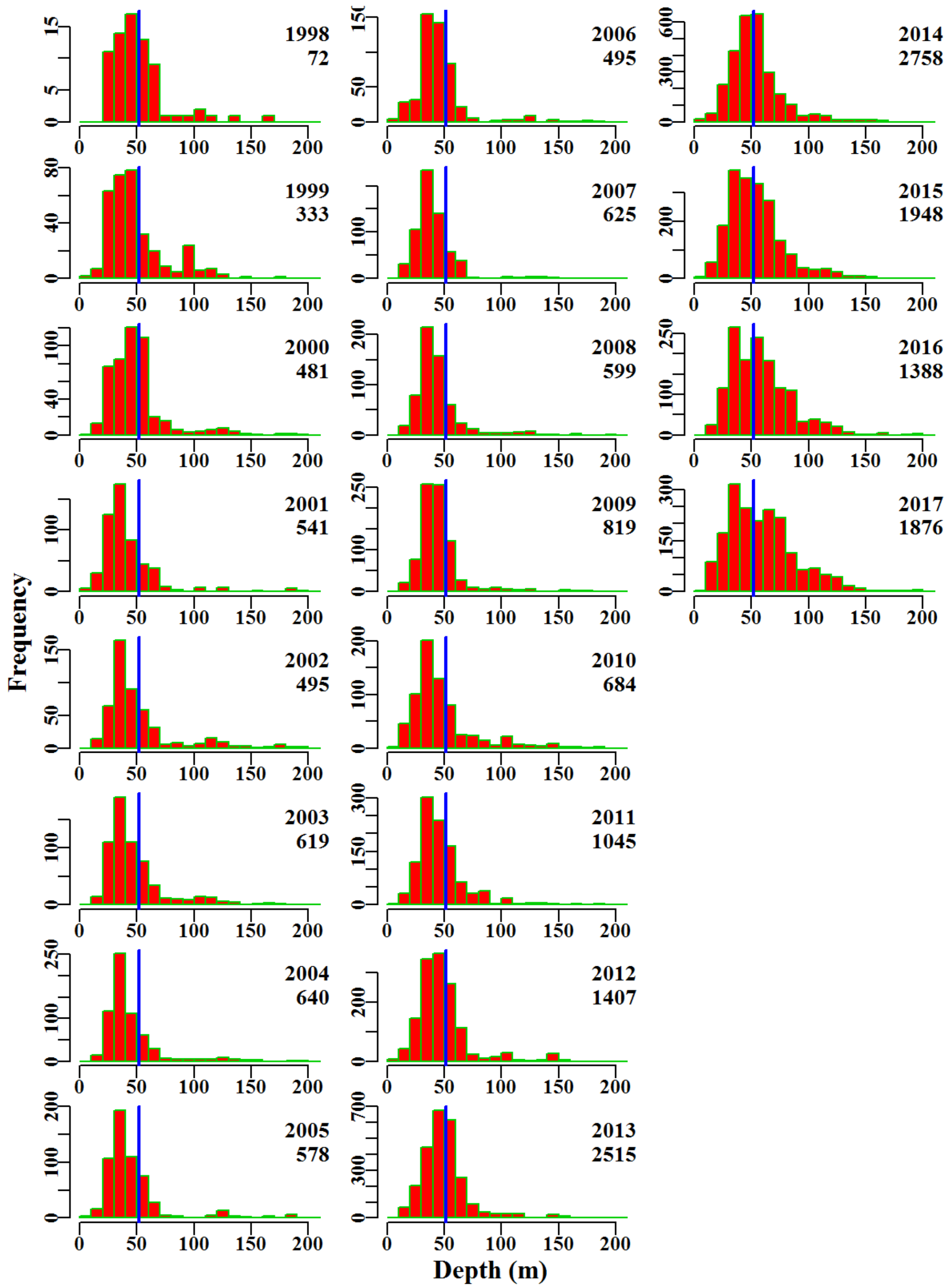

Figure 8.45. GummySharkBL. The average Depth of fishing for each year of data available to illustrate the development of the fishery through time. The numbers in each plot are the year and number of records. The vertical blue line is the average across all years.

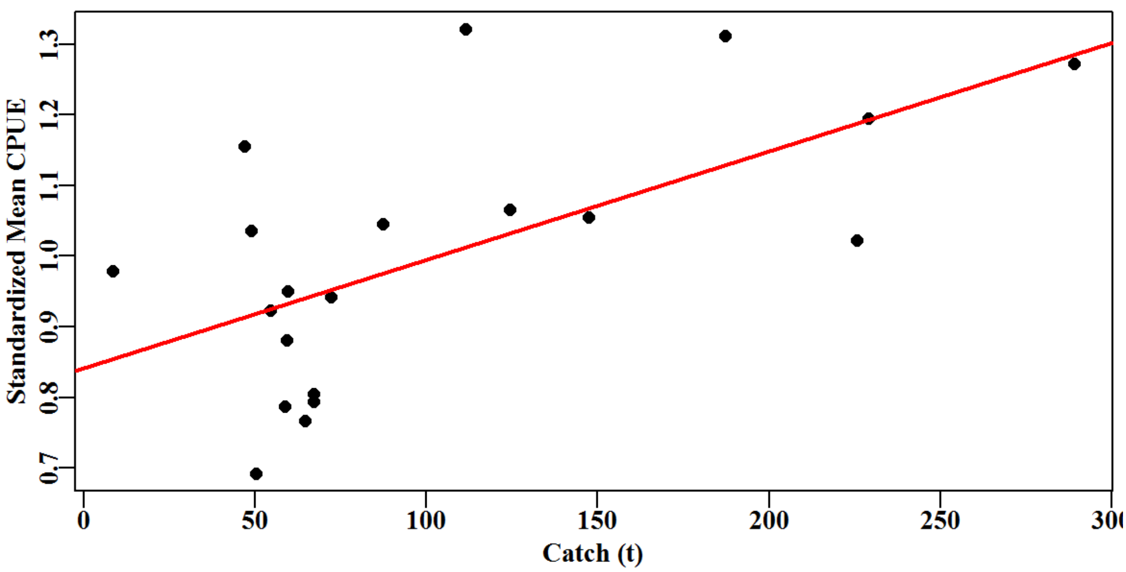

Figure 8.46. GummySharkBL. The linear relationship between Annual mean CPUE and Annual Catch.

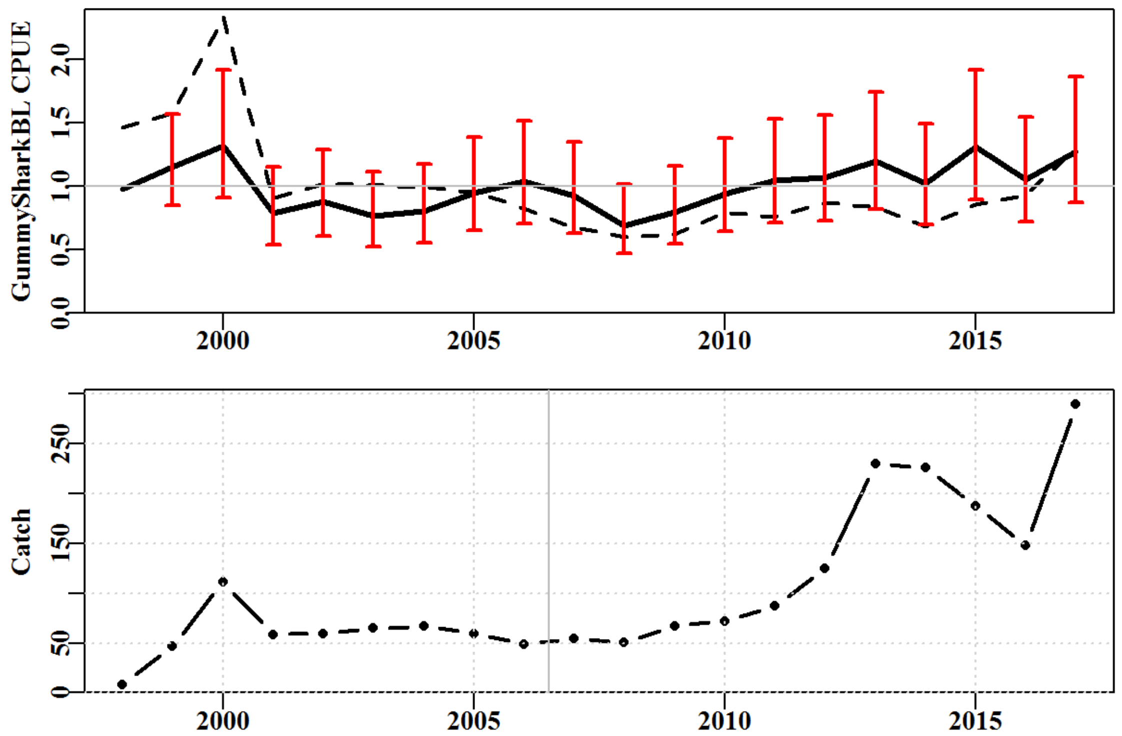

Figure 8.47. GummySharkBL. CPUE is correlated with catches through time. CPUE in the top plot and annual catch (t) in the lower plot.

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 (zone) 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 R^2 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 above the long term average since 2013, based on the 95% confidence intervals. There was a slight reduction 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 - 2017

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	1.2270	0.000	11.882	0.486
1997	457.0	1187	23.7	60	6.4	1.0678	0.043	13.246	0.560
1998	562.0	957	19.8	51	6.0	1.0049	0.045	10.817	0.546
1999	490.6	759	14.1	51	5.4	0.9176	0.049	9.078	0.644
2000	464.9	919	16.6	70	5.0	0.7852	0.048	8.720	0.524
2001	190.6	859	15.7	47	5.2	0.7743	0.049	8.919	0.568
2002	219.5	943	16.9	57	5.2	0.8147	0.048	9.283	0.550
2003	218.2	767	13.2	59	4.8	0.7501	0.051	7.482	0.568
2004	200.3	697	13.3	54	4.5	0.7715	0.052	6.954	0.521
2005	210.3	517	8.3	45	4.2	0.8012	0.056	4.784	0.577
2006	212.0	570	10.9	47	4.9	0.8047	0.055	5.154	0.474
2007	197.8	348	7.3	32	5.9	0.8419	0.064	3.469	0.474
2008	234.4	404	9.0	30	5.7	1.0089	0.060	3.817	0.425
2009	253.1	438	13.6	28	6.7	1.0764	0.058	4.441	0.326
2010	180.1	428	12.6	26	7.2	1.0141	0.060	4.007	0.318
2011	182.4	449	13.8	28	6.8	1.0024	0.059	4.004	0.290
2012	136.0	342	10.9	26	8.2	1.0750	0.064	2.979	0.274
2013	150.0	372	18.3	32	12.2	1.1874	0.063	3.218	0.176
2014	200.0	394	11.2	26	7.1	1.1322	0.061	3.829	0.341
2015	146.9	333	12.3	26	8.1	1.2060	0.064	3.557	0.290
2016	133.9	363	14.1	26	8.7	1.3855	0.063	4.188	0.297
2017	225.6	544	20.8	22	8.5	1.3511	0.061	5.831	0.280

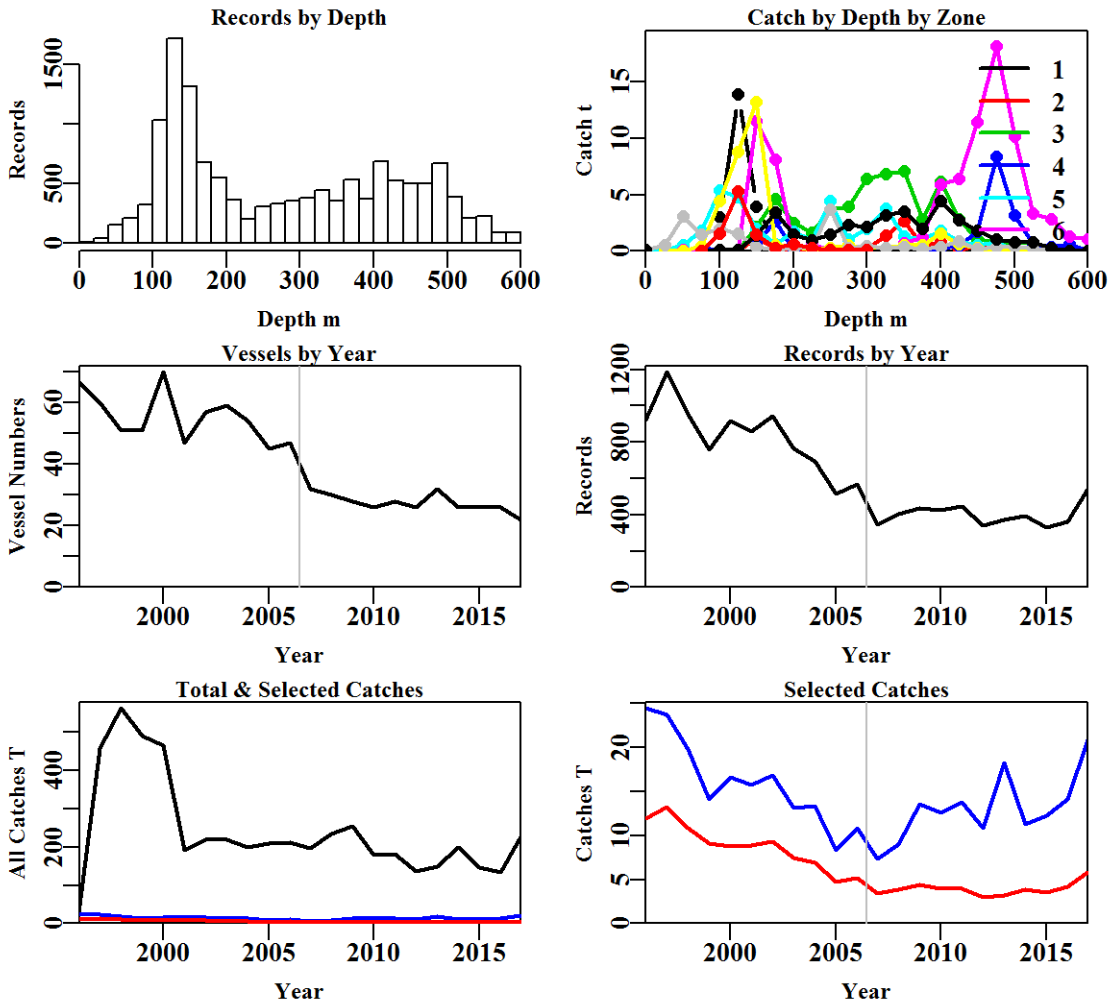

Figure 8.48. SchoolSharkTW fishery details. The bottom left plot depicts all known catches (top black line), and all selected catches used in the analysis (middle blue line); the lower red line: selected catches < 30 kg). Refer to Box 1 (p. 7) for names which correspond to zone numbers.

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	107933	0	5504.382	0.000
NoCE	67929	40004	3345.355	2159.027
Depth	67261	668	3311.830	33.525
Years	62556	4705	3127.691	184.139
Zones	62344	212	3124.387	3.304
Method	13513	48831	320.772	2803.615
Fishery	13512	1	320.762	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	2950	16755	448	13512	22	2.5	0.00
Vessel	-502	12721	4482	13512	157	25.2	22.74
DepCat	-1186	12049	5154	13512	181	29.0	3.82
SharkRegion	-1856	11451	5752	13512	190	32.5	3.48
Month	-1944	11358	5845	13512	201	33.0	0.49
DayNight	-2001	11306	5897	13512	204	33.3	0.29
SharkRegion:DepCat	-2169	10896	6306	13512	369	34.9	1.61
SharkRegion:Month	-2238	10949	6253	13512	302	34.9	1.62

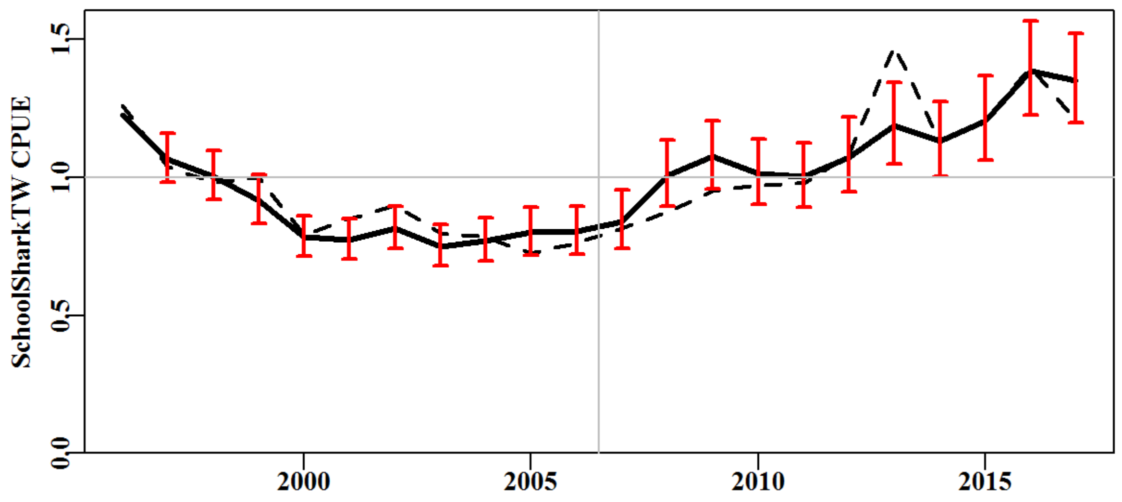

Figure 8.49. SchoolSharkTW standardization. The dashed black line represents the geometric mean catch rate, solid black line the standardized catch rates. The red bars are the 95% confidence intervals about the mean estimates. The graph scales both time-series of standardized catch rates relative to the mean of each time-series.

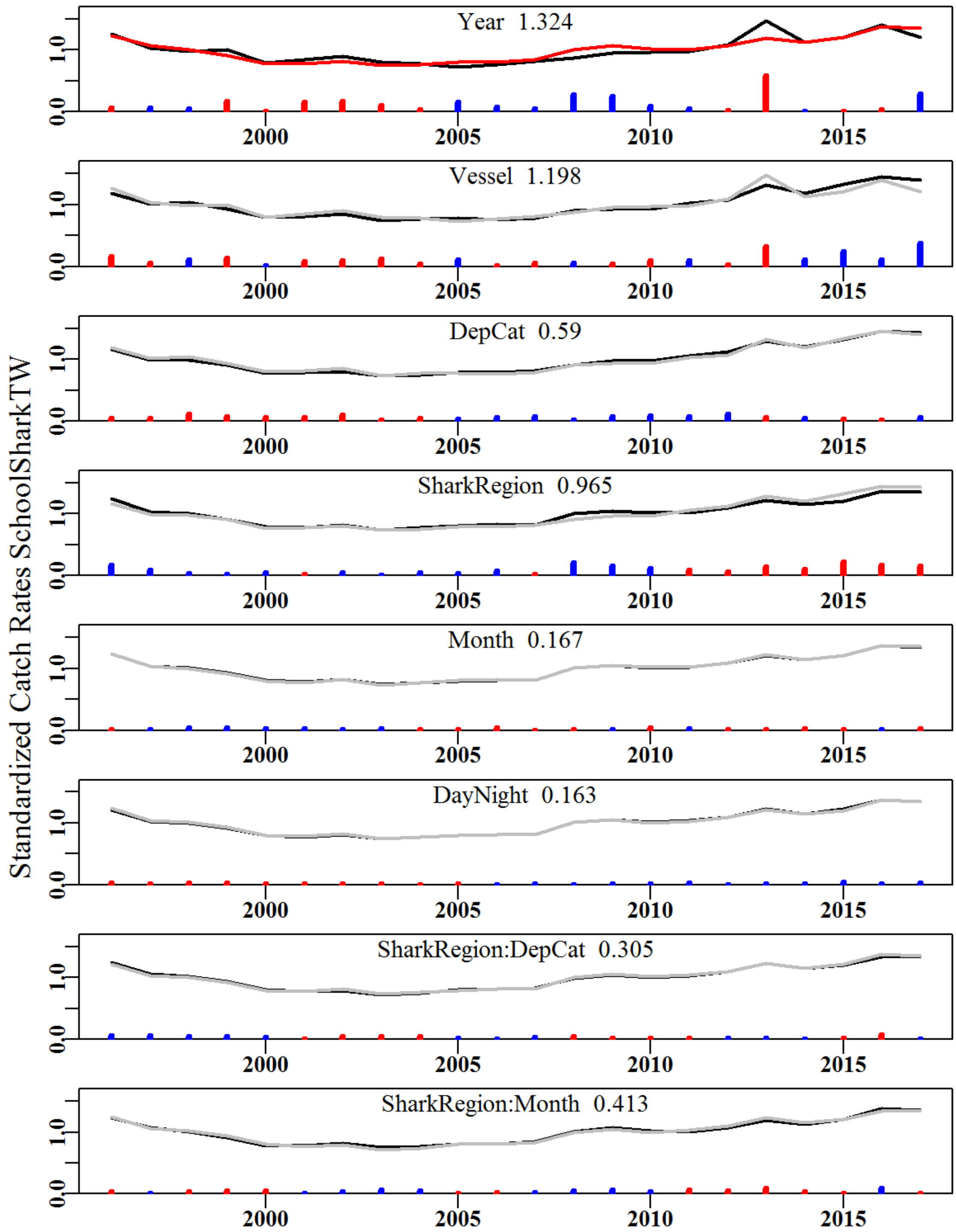

Figure 8.50. SchoolSharkTW. The influence of each factor on the optimal standardization. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by vertical bars with blue bars indicating the optimum model is higher than the geometric 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.

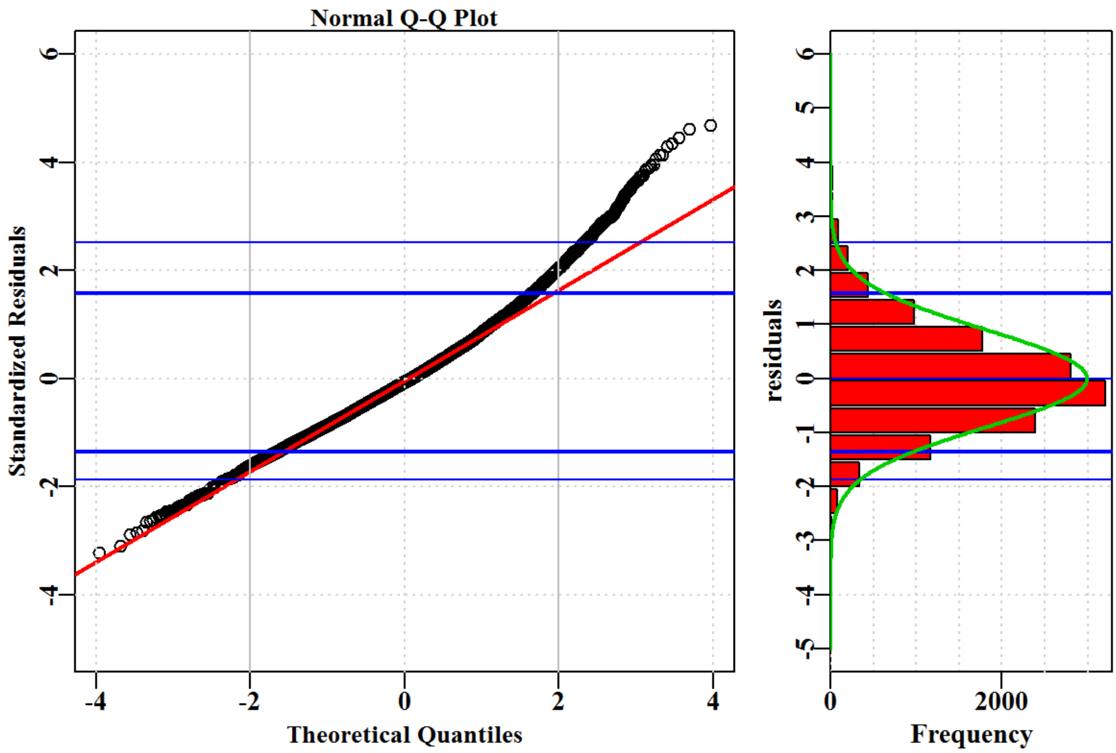

Figure 8.51. SchoolSharkTW. Diagnostic plots. The distribution of residuals from the optimum fit. The qqplot indicates the fit to the expected normality, while the histogram of residuals also illustrates the 1%, 5%, 95% and 99% quantiles to indicate the intensity of any lack of fit at the margins of the distribution (reflected also in the qqplot).

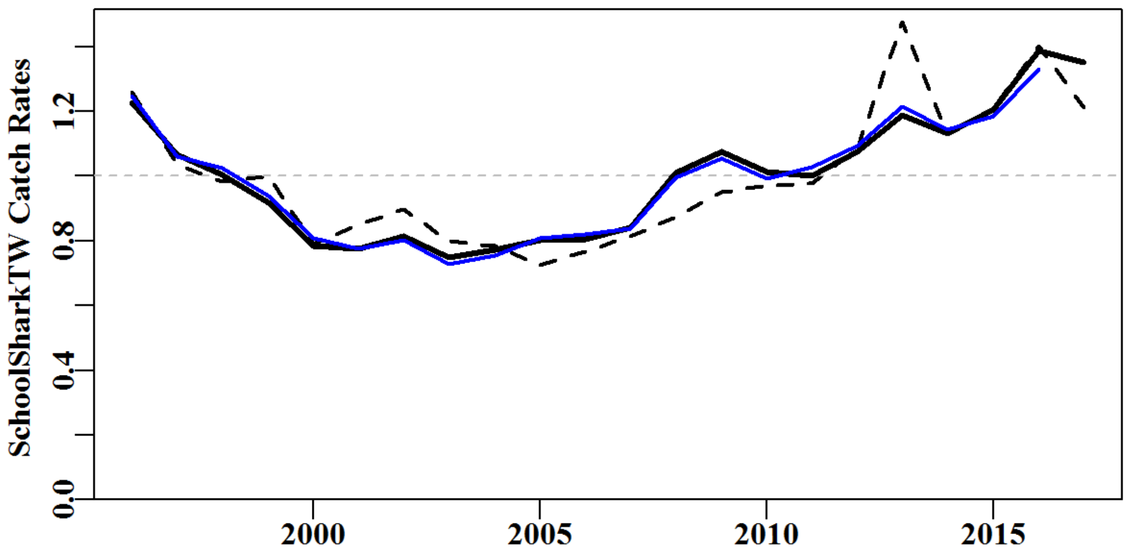

Figure 8.52. SchoolSharkTW. A comparison of the previous year's standardization (blue line) with this year's. They should lie on top of each other, although small deviations may relate to data adjustments, particularly in very recent years.

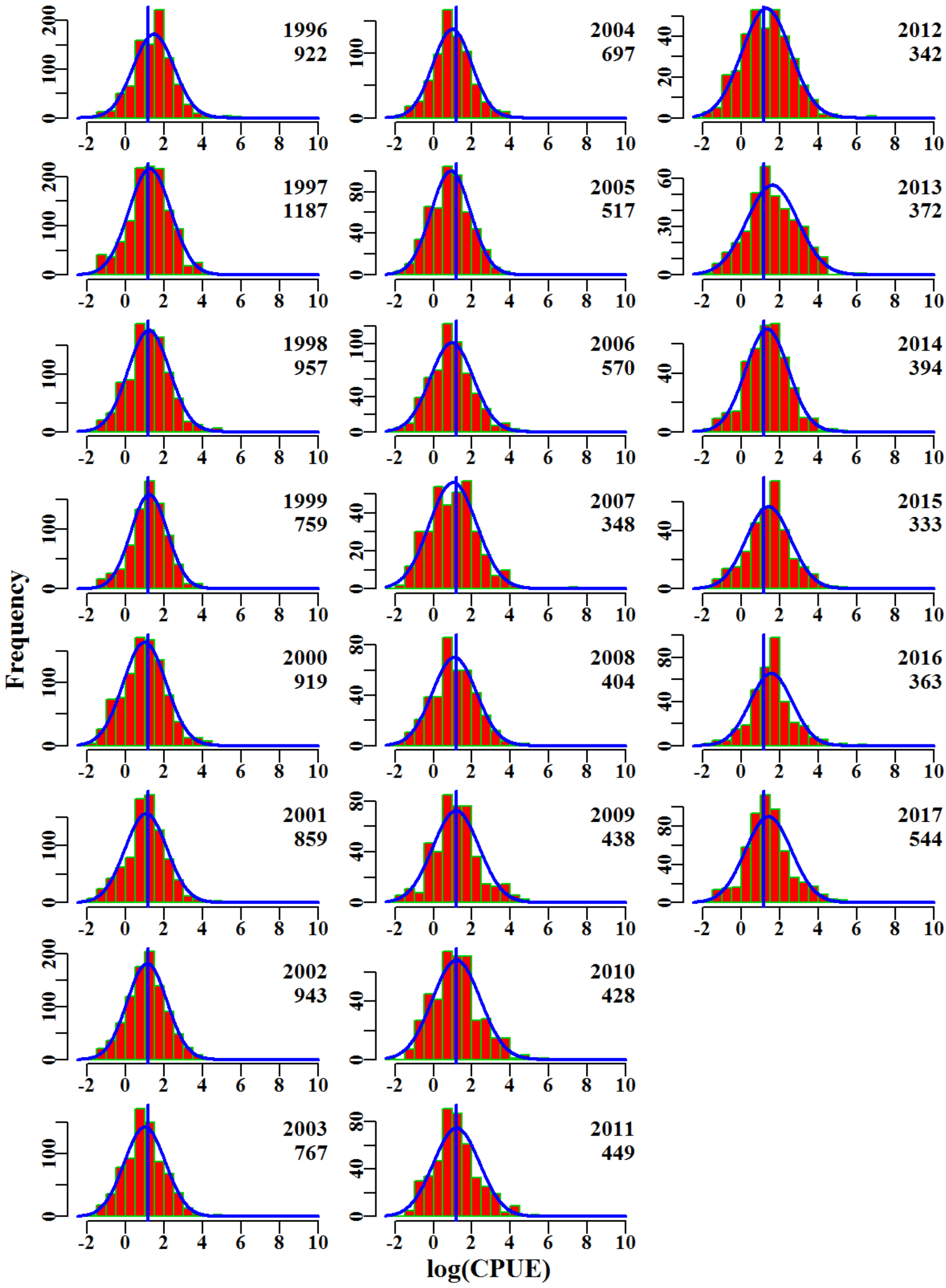

Figure 8.53. SchoolSharkTW. The log_e(CPUE) for each year of data available the blue lines are normal distributions fitted to the histogram frequencies. The numbers in each plot are the year and number of records. The vertical blue line is the average across all years.

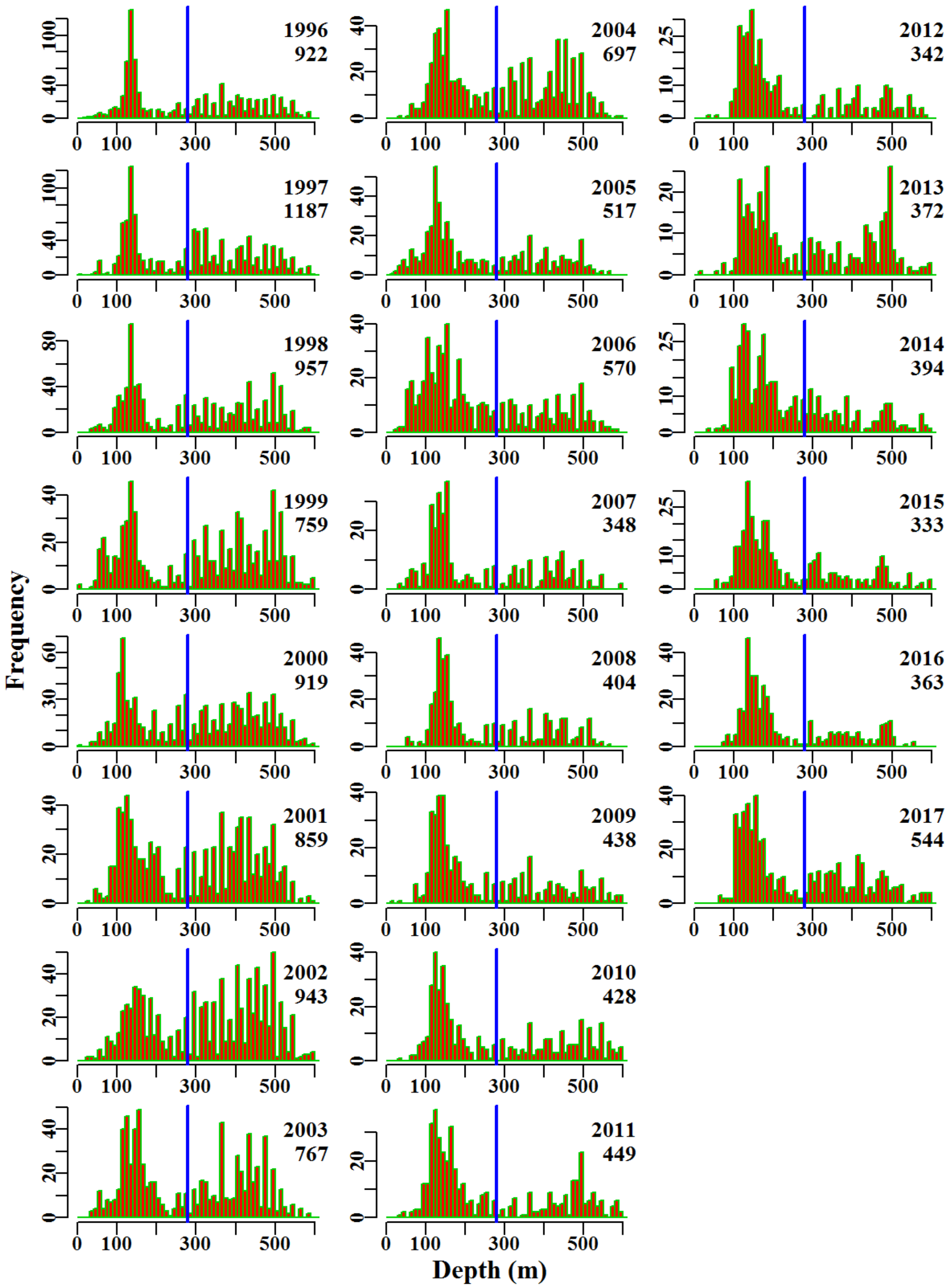

Figure 8.54. SchoolSharkTW. The average Depth of fishing for each year of data available to illustrate the development of the fishery through time. The numbers in each plot are the year and number of records. The vertical blue line is the average across all years.

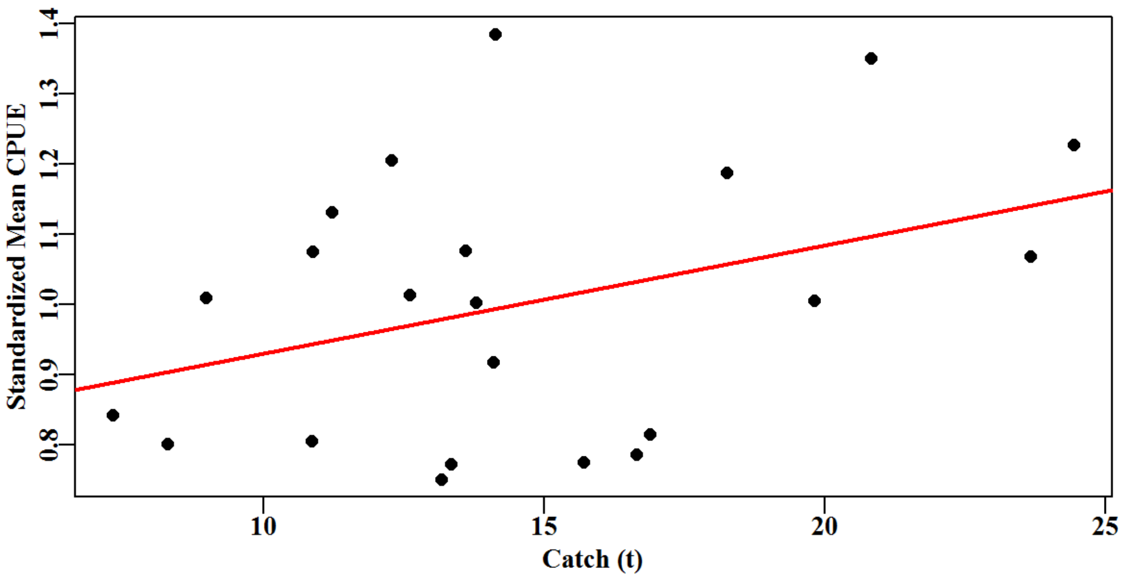

Figure 8.55. SchoolSharkTW. The linear relationship between Annual mean CPUE and Annual Catch.

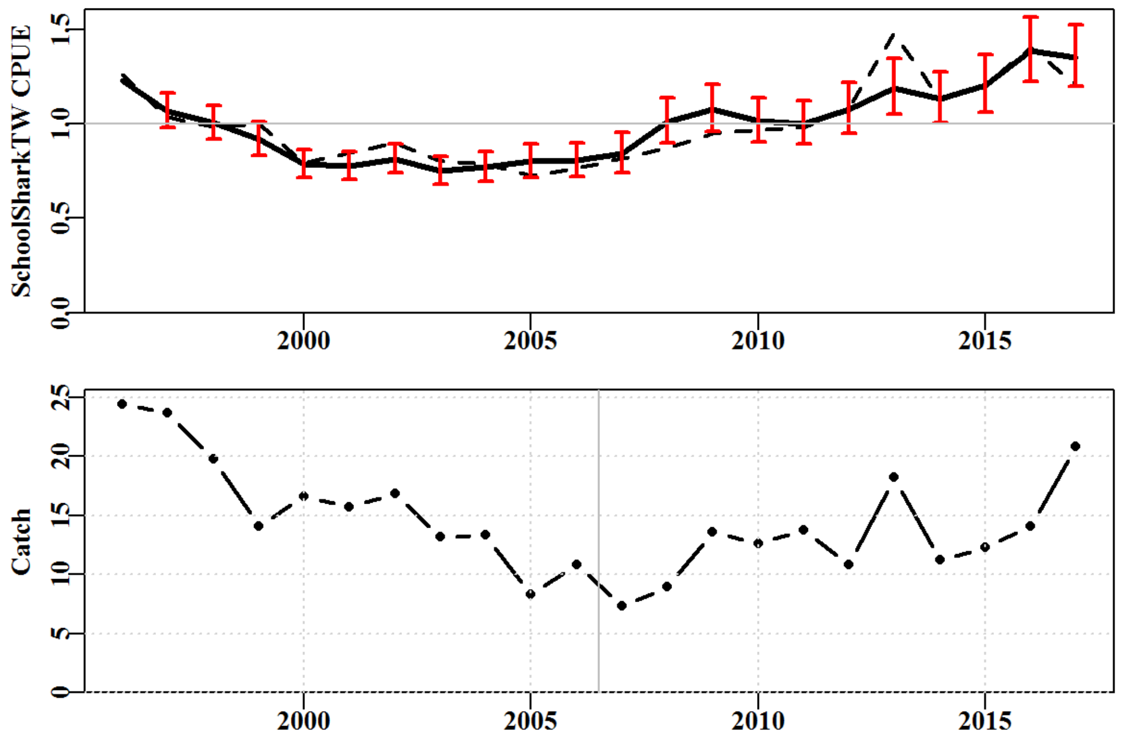

Figure 8.56. SchoolSharkTW. CPUE is correlated with catches through time. CPUE in the top plot and annual catch (t) in the lower plot.

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 (zone) 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 R^2 statistics (Table 8.35). The qqplot suggests the assumed Normal distribution is valid, with a 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 (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 - 2017

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/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
1997	214.2	4722	146.9	81	32.8	1.2345	0.000	40.042	0.273
1998	284.2	6875	225.0	81	33.7	1.2296	0.023	49.272	0.219
1999	295.6	7638	229.4	85	31.3	1.3173	0.022	58.951	0.257
2000	361.7	7192	275.4	76	39.4	1.6887	0.023	56.498	0.205
2001	340.7	6483	260.1	80	41.7	1.7573	0.023	48.260	0.186
2002	256.6	6251	157.3	77	26.7	1.0726	0.024	47.071	0.299
2003	319.7	6955	190.3	81	29.3	1.0956	0.023	48.450	0.255
2004	314.9	6560	190.8	73	30.7	1.1419	0.024	47.709	0.250
2005	296.7	5783	169.8	62	29.9	1.0326	0.024	42.053	0.248
2006	317.7	5270	155.6	58	30.6	1.0424	0.025	34.869	0.224
2007	214.5	4710	105.9	44	22.3	0.9029	0.026	29.244	0.276
2008	211.7	4651	114.4	44	26.2	1.0371	0.026	30.916	0.270
2009	191.5	4872	88.5	44	18.6	0.8793	0.026	34.081	0.385
2010	192.5	5080	91.4	47	18.7	0.8497	0.026	36.924	0.404
2011	197.0	5331	102.4	46	18.9	0.8106	0.025	38.456	0.376
2012	158.6	4606	73.8	42	16.0	0.6472	0.026	32.666	0.443
2013	165.7	4355	70.7	39	16.4	0.6073	0.027	34.782	0.492
2014	167.2	4179	80.7	38	19.3	0.6553	0.027	32.266	0.400
2015	164.2	4077	75.8	35	19.0	0.6547	0.027	31.405	0.414
2016	164.6	4382	95.5	33	22.2	0.7138	0.027	34.467	0.361
2017	178.8	5060	97.0	35	19.0	0.6295	0.026	38.468	0.397

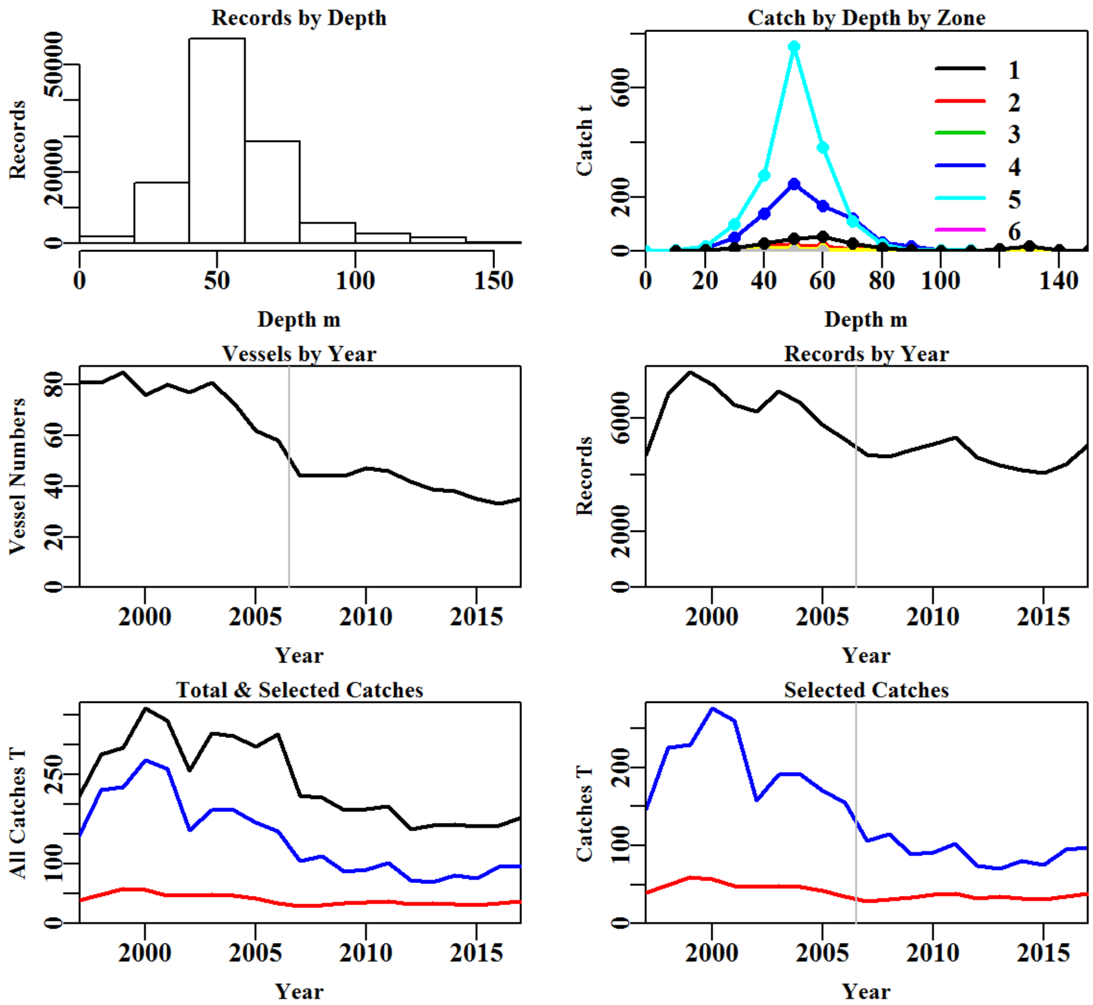

Figure 8.57. SawShark fishery details. The bottom left plot depicts all known catches (top black line), and all selected catches used in the analysis (middle blue line); the lower red line: selected catches < 30 kg). Refer to Box 1 (p. 7) for names which correspond to zone numbers.

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	245005	0	5492.345	0.000
NoCE	240744	4261	5492.345	0.000
Depth	214090	26654	4454.812	1037.533
Years	199311	14779	4119.738	335.074
Zones	194390	4921	3974.199	145.539
Method	115032	79358	2996.765	977.434
Fishery	115032	0	2996.765	0.000

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	71199	213534	7934	115032	21	3.6	0.00
Vessel	46861	172248	49221	115032	210	22.1	18.52
DepCat	39657	161749	59720	115032	225	26.8	4.74
SharkRegion	34371	154463	67006	115032	233	30.1	3.29
Month	32209	151558	69911	115032	244	31.4	1.31
SharkRegion:DepCat	28682	146708	74761	115032	351	33.6	2.13
SharkRegion:Month	27897	145761	75708	115032	331	34.0	2.57

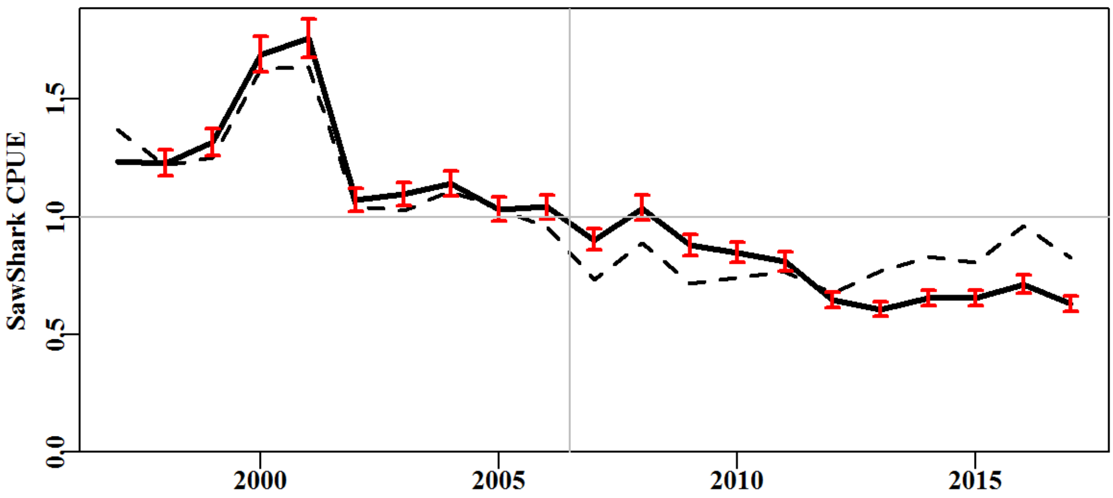

Figure 8.58. SawShark standardization. The dashed black line represents the geometric mean catch rate, solid black line the standardized catch rates. The red bars are the 95% confidence intervals about the mean estimates. The graph scales both time-series of standardized catch rates relative to the mean of each time-series.

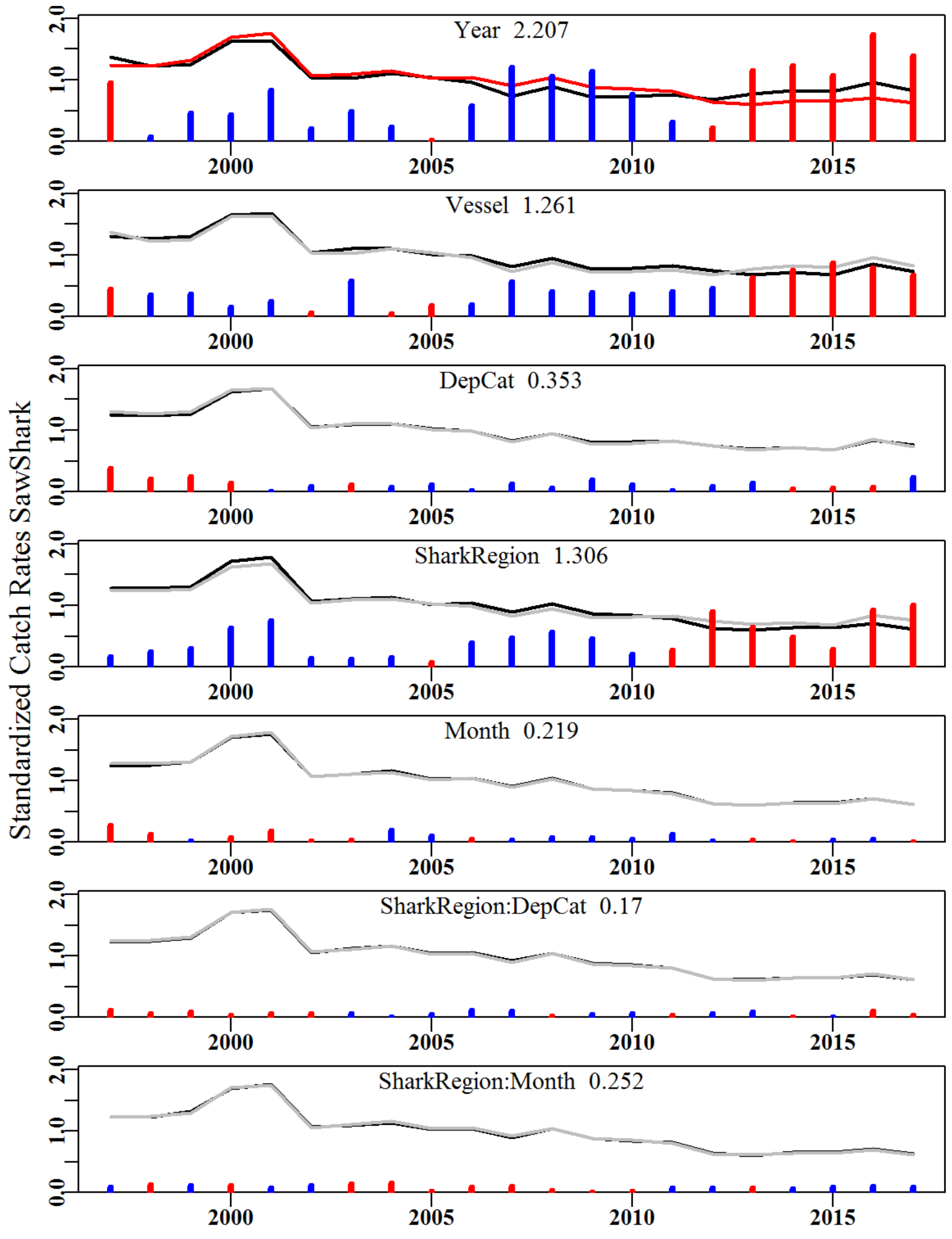

Figure 8.59. SawShark. The influence of each factor on the optimal standardization. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by vertical bars with blue bars indicating the optimum model is higher than the geometric 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.

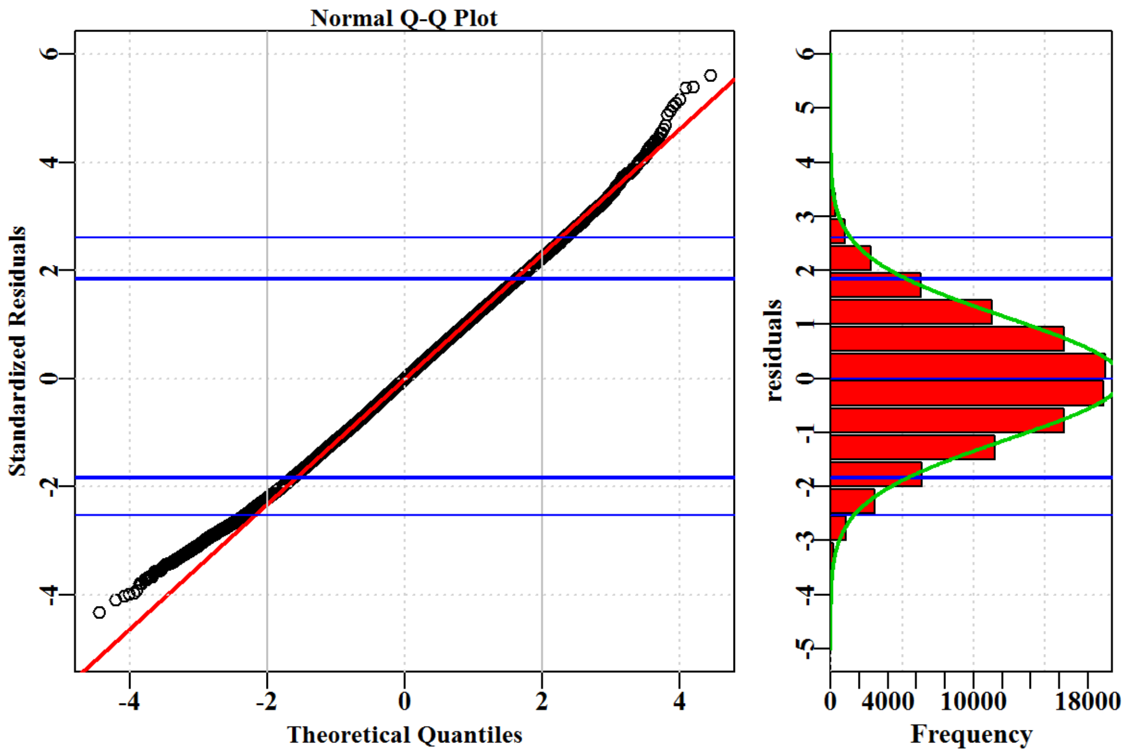

Figure 8.60. SawShark. Diagnostic plots. The distribution of residuals from the optimum fit. The qqplot indicates the fit to the expected normality, while the histogram of residuals also illustrates the 1%, 5%, 95% and 99% quantiles to indicate the intensity of any lack of fit at the margins of the distribution (reflected also in the qqplot).

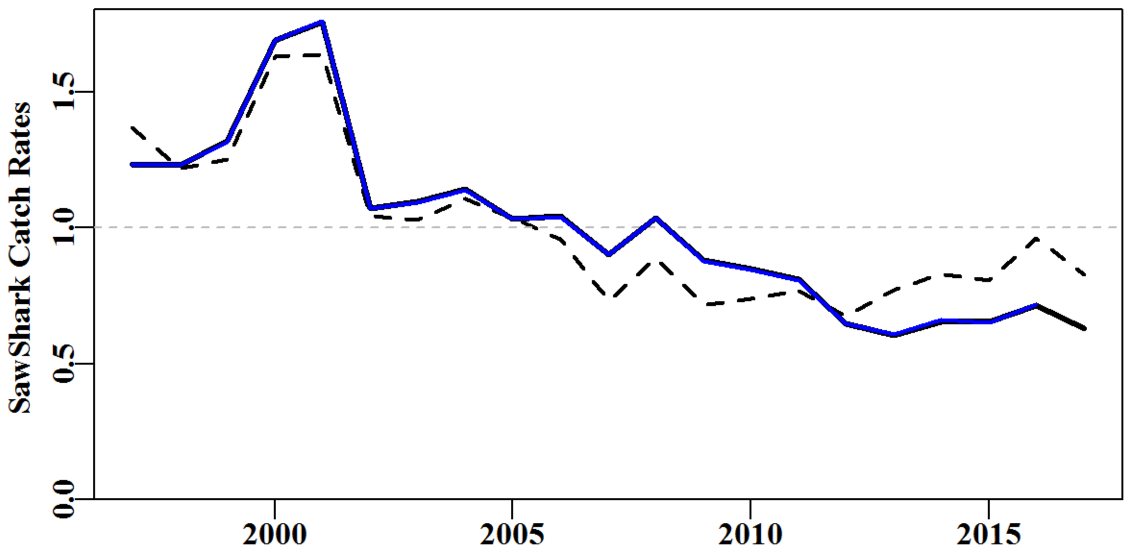

Figure 8.61. SawShark. A comparison of the previous year's standardization (blue line) with this year's. They should lie on top of each other, although small deviations may relate to data adjustments, particularly in very recent years.

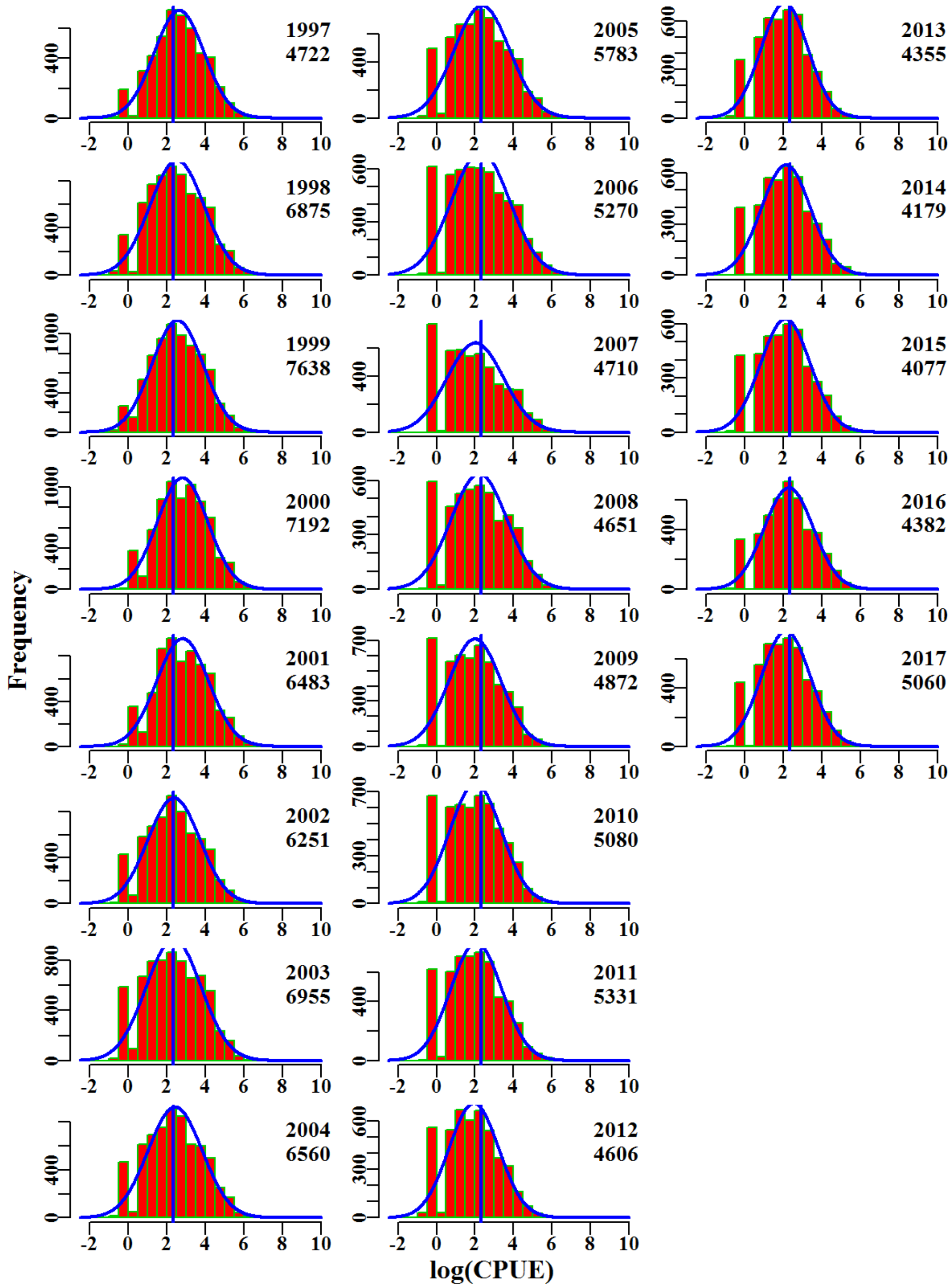

Figure 8.62. SawShark. The $\log_e$(CPUE) for each year of data available the blue lines are normal distributions fitted to the histogram frequencies. The numbers in each plot are the year and number of records. The vertical blue line is the average across all years.

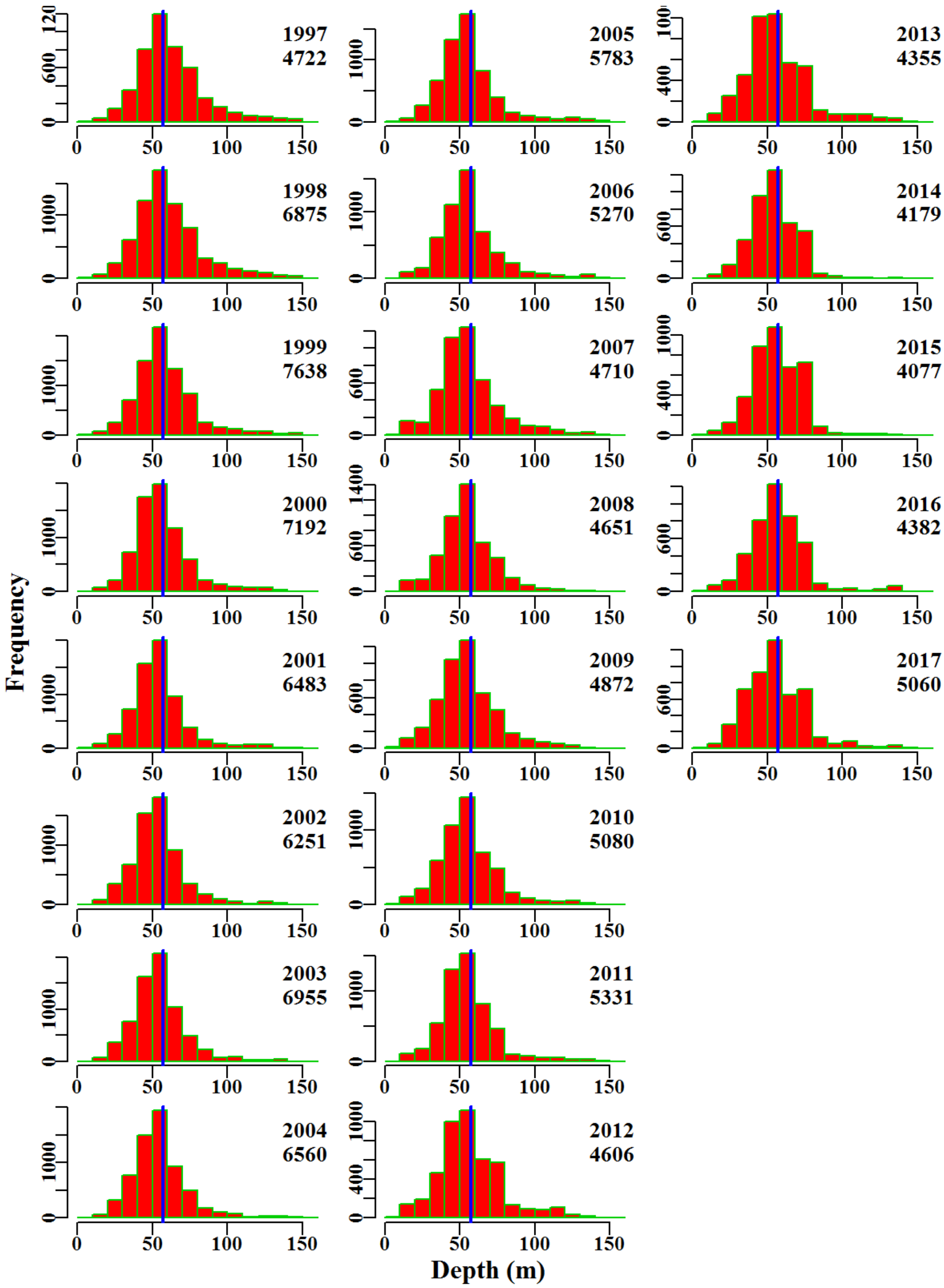

Figure 8.63. SawShark. The average Depth of fishing for each year of data available to illustrate the development of the fishery through time. The numbers in each plot are the year and number of records. The vertical blue line is the average across all years.

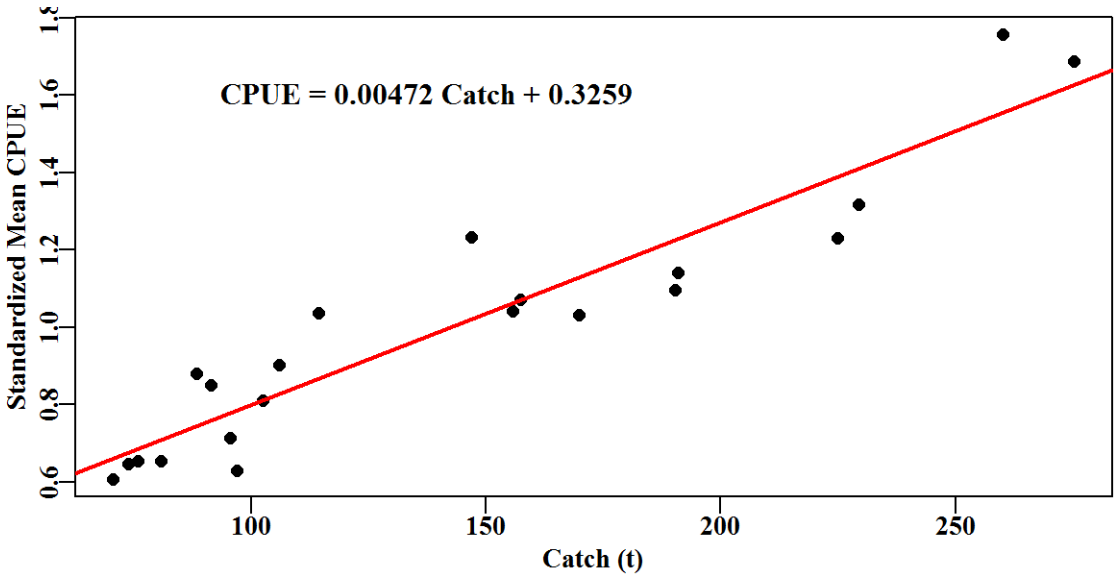

Figure 8.64. SawShark. The linear relationship between Annual mean CPUE and Annual Catch.

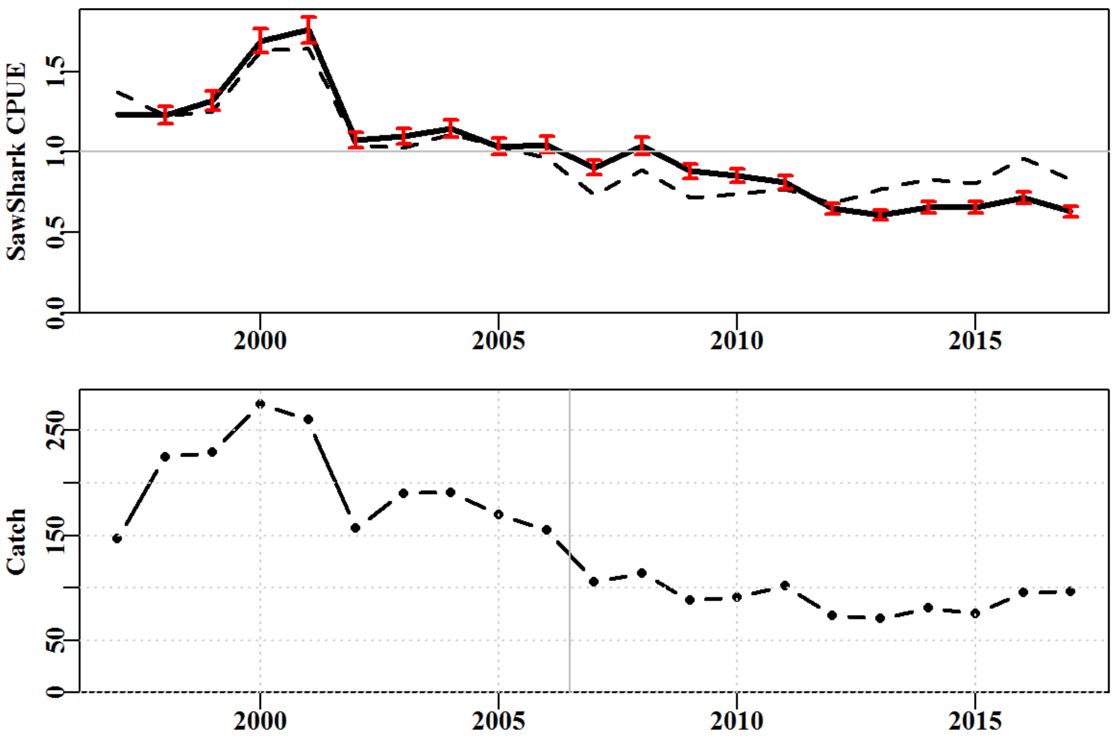

Figure 8.65. SawShark. CPUE is correlated with catches through time. CPUE in the top plot and annual catch (t) in the lower plot.

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 (zone) 1, 2 and 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 R^2 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 a 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).

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 - 2017

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	1.3149	0.000	17.727	0.343
1996	67.5	1992	59.9	60	8.1	1.3353	0.035	19.324	0.323
1997	214.2	2443	59.4	60	6.5	1.1871	0.035	24.417	0.411
1998	284.2	1694	47.9	54	6.8	1.0921	0.038	16.888	0.353
1999	295.6	1813	51.2	50	7.6	1.2502	0.037	17.384	0.339
2000	361.7	2361	69.0	65	10.2	1.0982	0.036	23.081	0.335
2001	340.7	2555	68.1	54	6.9	1.0652	0.036	23.629	0.347
2002	256.6	3298	70.8	68	5.9	0.9423	0.034	28.762	0.406
2003	319.7	4400	100.8	75	5.7	0.8619	0.033	34.943	0.347
2004	314.9	4270	95.4	76	6.3	0.8454	0.033	33.848	0.355
2005	296.7	4931	104.6	71	5.7	0.8495	0.033	40.154	0.384
2006	317.7	4625	137.2	64	7.4	0.9405	0.033	33.402	0.243
2007	214.5	2561	82.0	39	7.4	0.8122	0.036	20.114	0.245
2008	211.7	2891	71.6	40	5.6	0.8548	0.035	24.796	0.346
2009	191.5	2806	78.4	34	6.7	1.0875	0.035	25.884	0.330
2010	192.5	3138	80.4	37	5.9	0.9822	0.034	29.956	0.373
2011	197.0	2914	66.8	36	5.5	0.8795	0.035	25.062	0.375
2012	158.6	2426	60.5	36	6.2	0.8712	0.036	21.854	0.361
2013	165.7	2526	70.0	36	6.7	1.0163	0.036	26.220	0.375
2014	167.2	2261	70.1	36	7.5	1.0167	0.037	24.565	0.351
2015	164.2	2213	59.4	36	7.0	0.9326	0.037	22.834	0.385
2016	164.6	1977	47.2	37	6.7	0.8524	0.038	19.457	0.412
2017	178.8	1970	59.6	33	7.9	0.9119	0.038	19.137	0.321

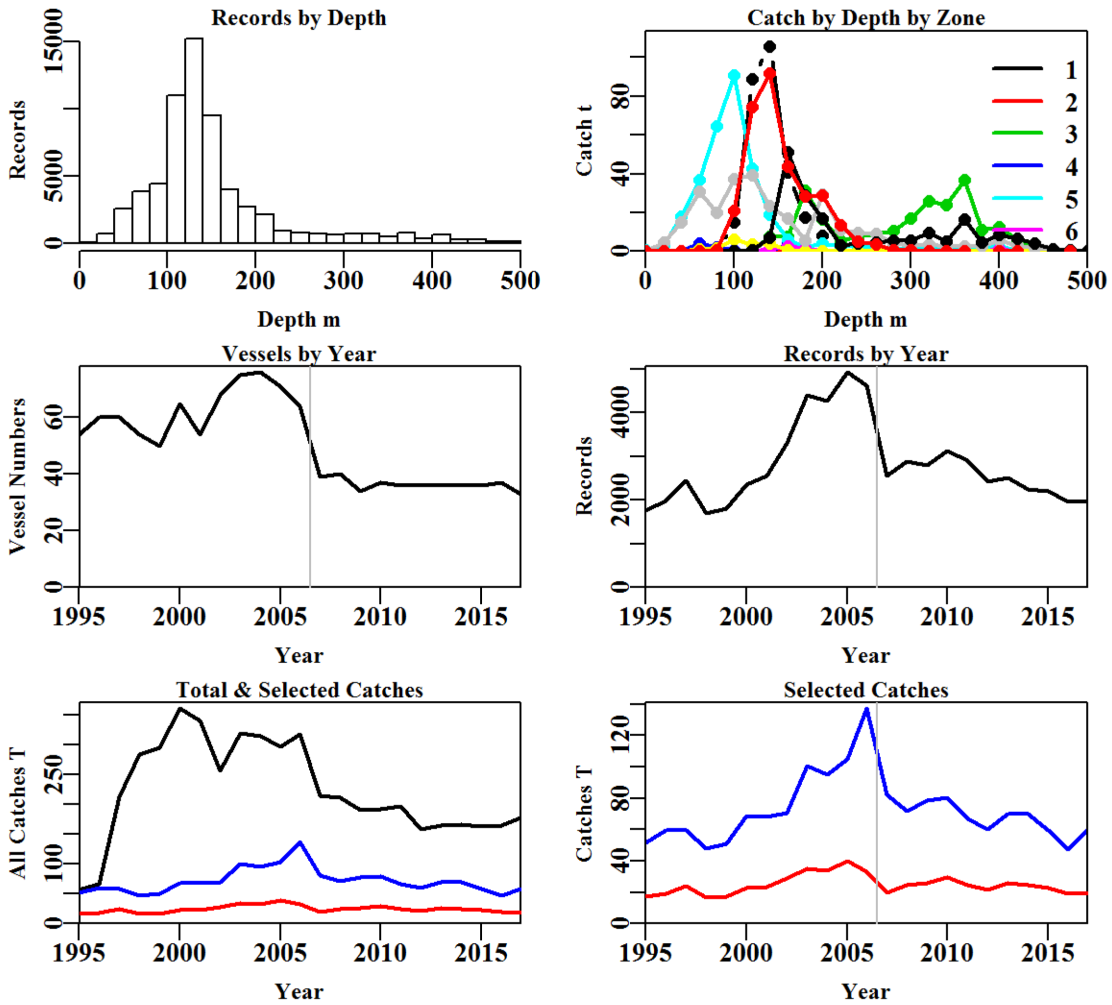

Figure 8.66. SawSharkTrawl fishery details. The bottom left plot depicts all known catches (top black line), and all selected catches used in the analysis (middle blue line); the lower red line: selected catches < 30 kg). Refer to Box 1 (p. 7) for names which correspond to zone numbers.

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	245005	0	5492.345	0.000
NoCE	178648	66357	3946.952	1545.393
Depth	177085	1563	3912.308	34.644
Years	164049	13036	3565.503	346.806
Zones	163786	263	3561.358	4.145
Method	63918	99868	1663.408	1897.949
Fishery	63829	89	1662.027	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	29296	100933	1094	63829	23	1.0	0.00
Vessel	10828	75257	26770	63829	158	26.1	25.02
DepCat	8833	72884	29144	63829	183	28.4	2.30
SharkRegion	6943	70736	31291	63829	192	30.5	2.10
Month	5402	69026	33001	63829	203	32.1	1.67
DayNight	5315	68926	33101	63829	206	32.2	0.10
SharkRegion:DepCat	4079	67203	34825	63829	396	33.7	1.50
SharkRegion:Month	3334	66612	35415	63829	305	34.4	2.17

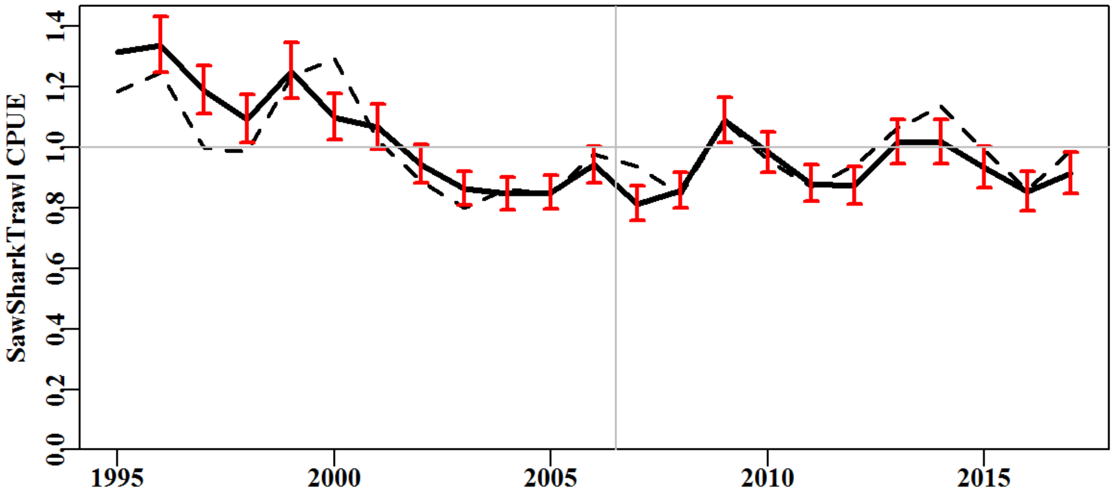

Figure 8.67. SawSharkTrawl standardization. The dashed black line represents the geometric mean catch rate, solid black line the standardized catch rates. The red bars are the 95% confidence intervals about the mean estimates. The graph scales both time-series of standardized catch rates relative to the mean of each time-series.

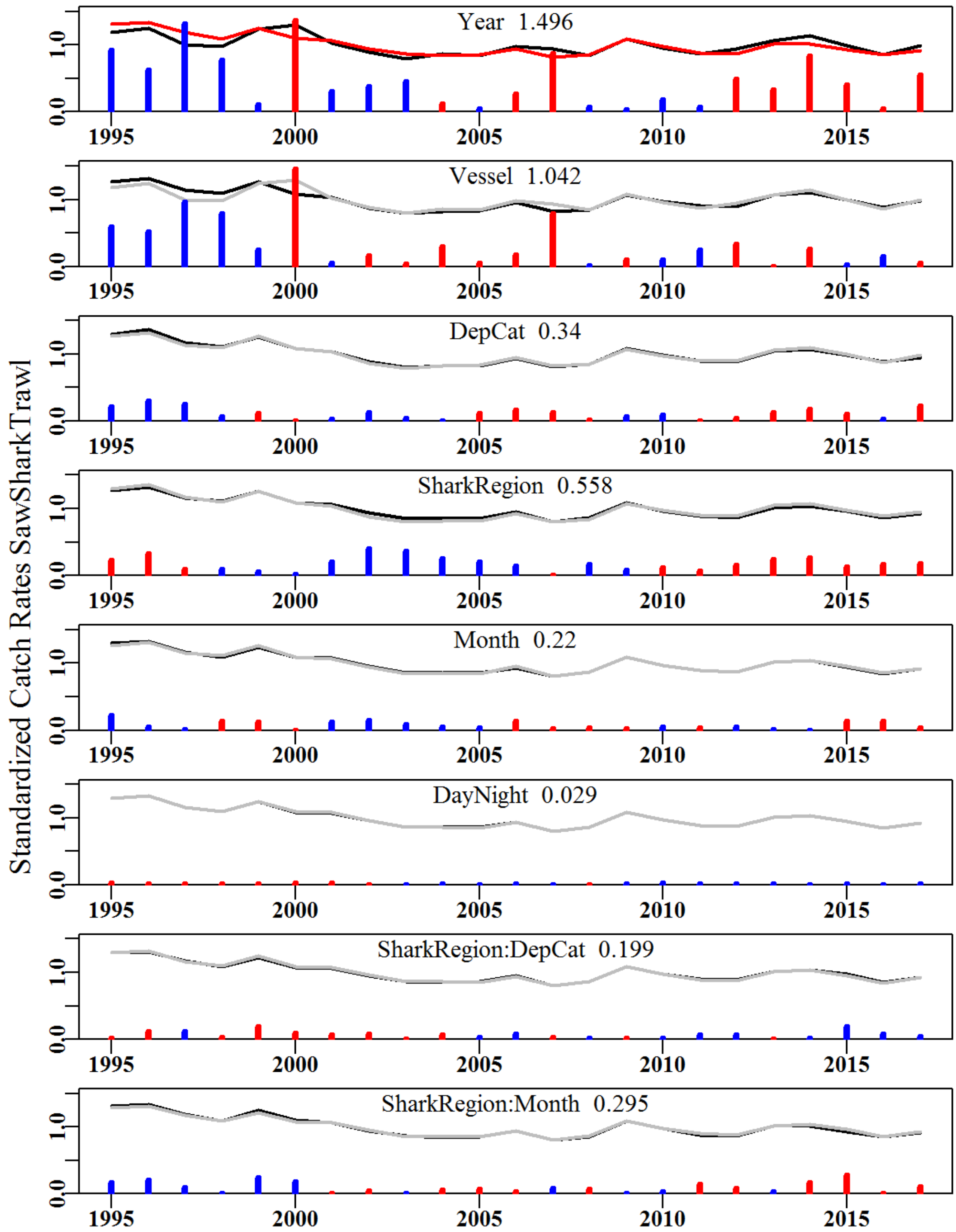

Figure 8.68. SawSharkTrawl. The influence of each factor on the optimal standardization. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by vertical bars with blue bars indicating the optimum model is higher than the geometric 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.

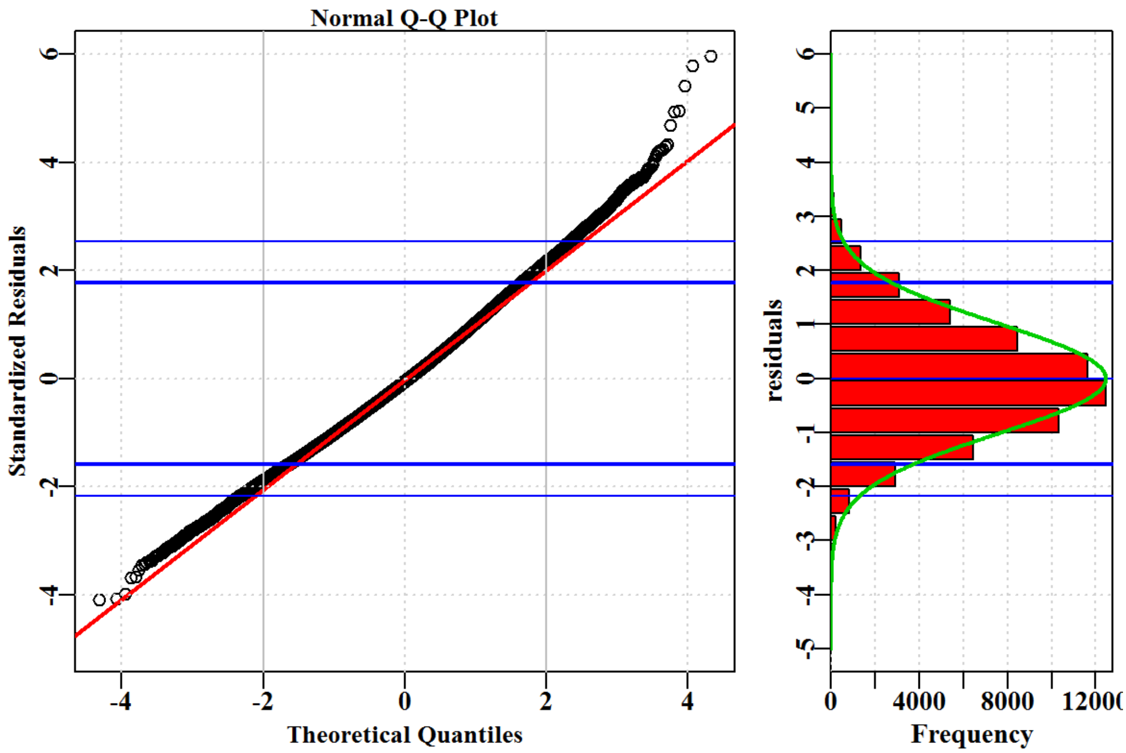

Figure 8.69. SawSharkTrawl. Diagnostic plots. The distribution of residuals from the optimum fit. The qqplot indicates the fit to the expected normality, while the histogram of residuals also illustrates the 1%, 5%, 95% and 99% quantiles to indicate the intensity of any lack of fit at the margins of the distribution (reflected also in the qqplot).

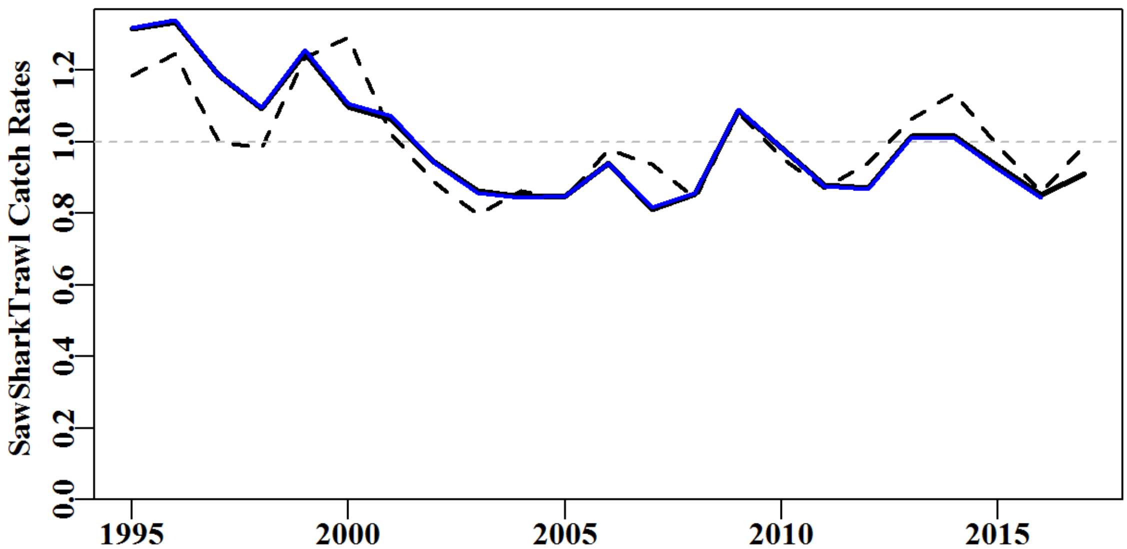

Figure 8.70. SawSharkTrawl. A comparison of the previous year's standardization (blue line) with this year's. They should lie on top of each other, although small deviations may relate to data adjustments, particularly in very recent years.

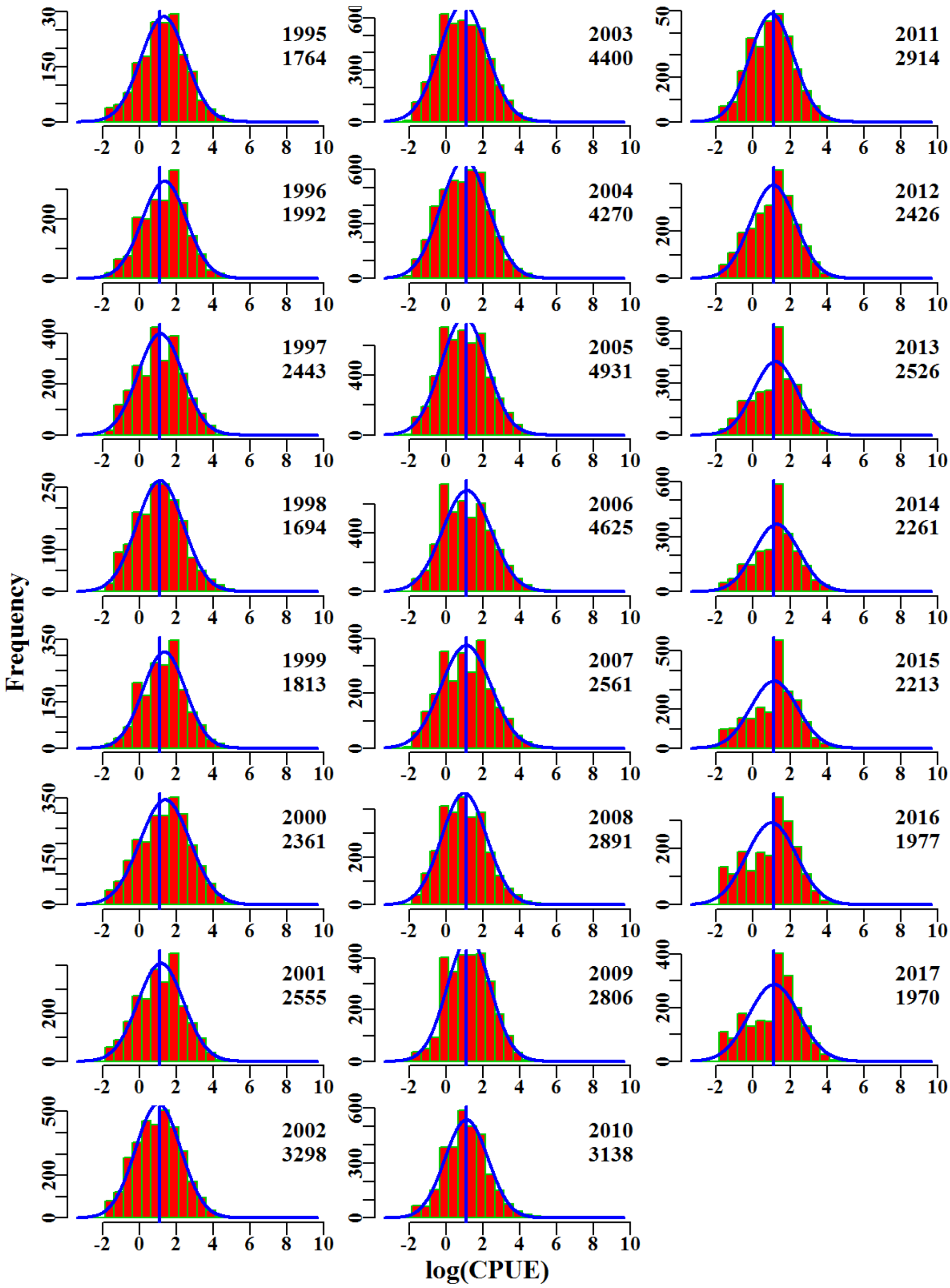

Figure 8.71. SawSharkTrawl. The $\log_e$(CPUE) for each year of data available the blue lines are normal distributions fitted to the histogram frequencies. The numbers in each plot are the year and number of records. The vertical blue line is the average across all years.

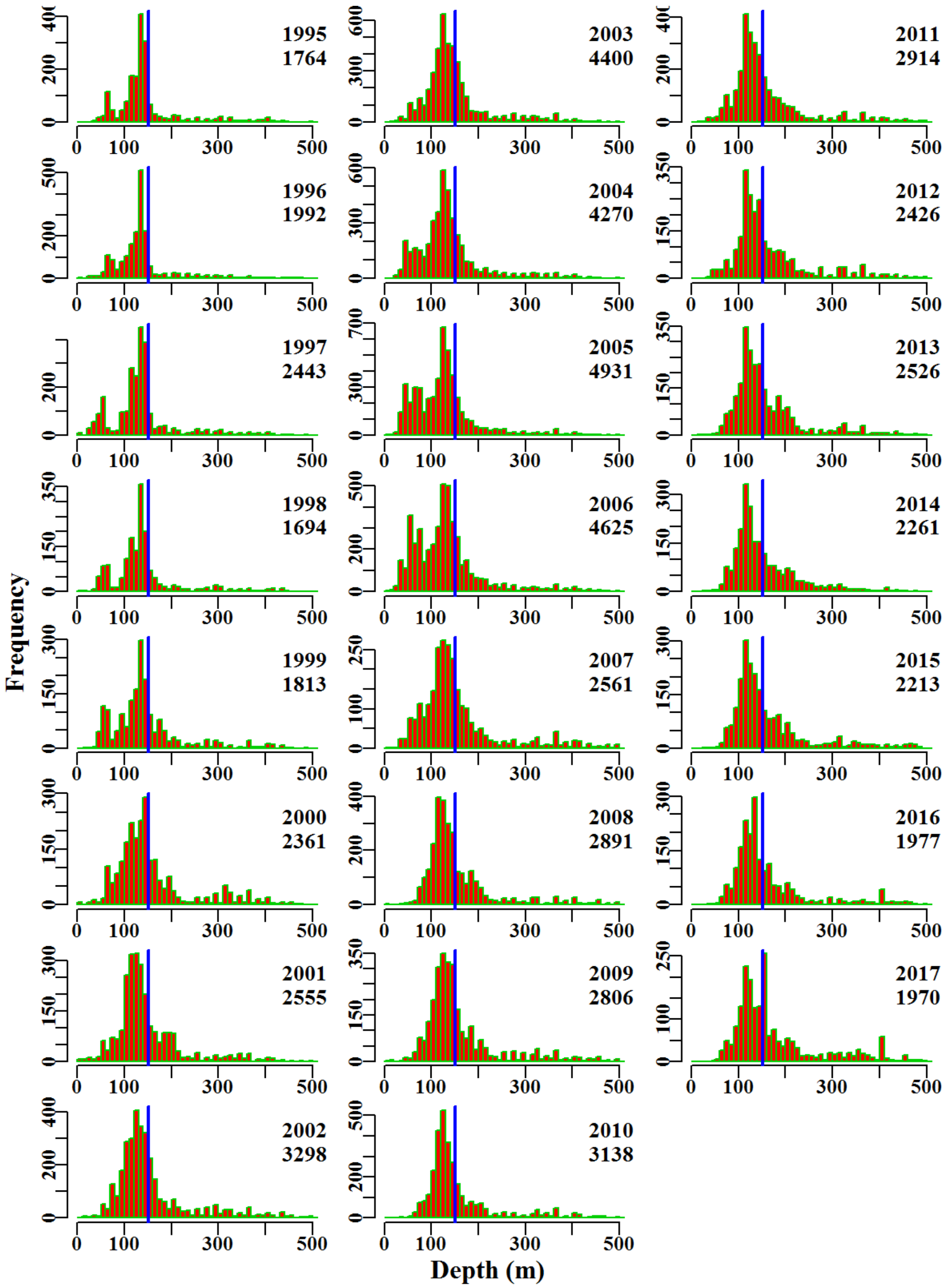

Figure 8.72. SawSharkTrawl. The average Depth of fishing for each year of data available to illustrate the development of the fishery through time. The numbers in each plot are the year and number of records. The vertical blue line is the average across all years.

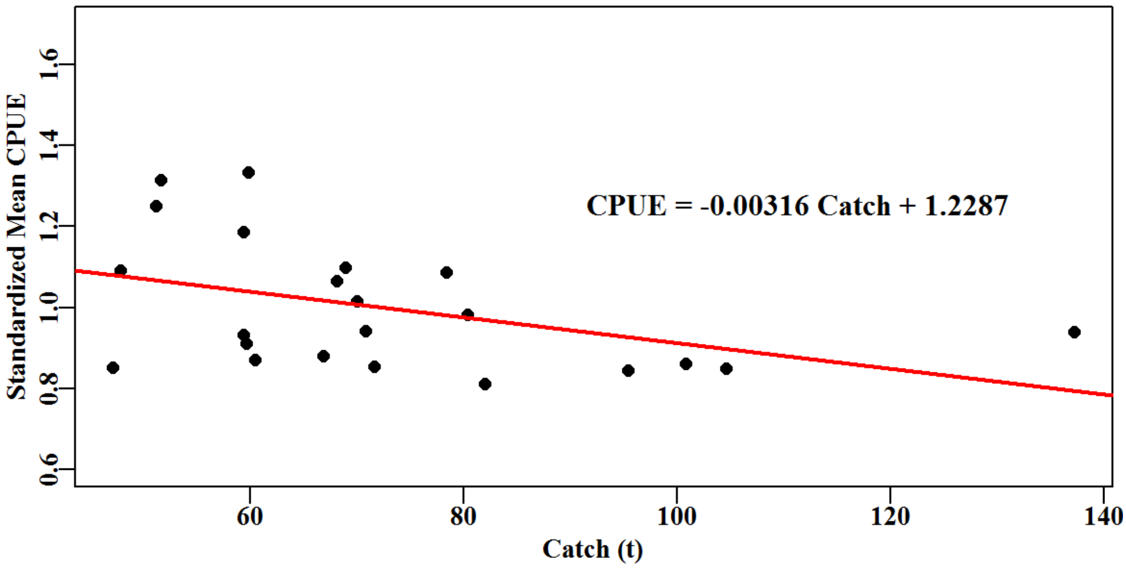

Figure 8.73. SawSharkTrawl The linear relationship between Annual mean CPUE and Annual Catch.

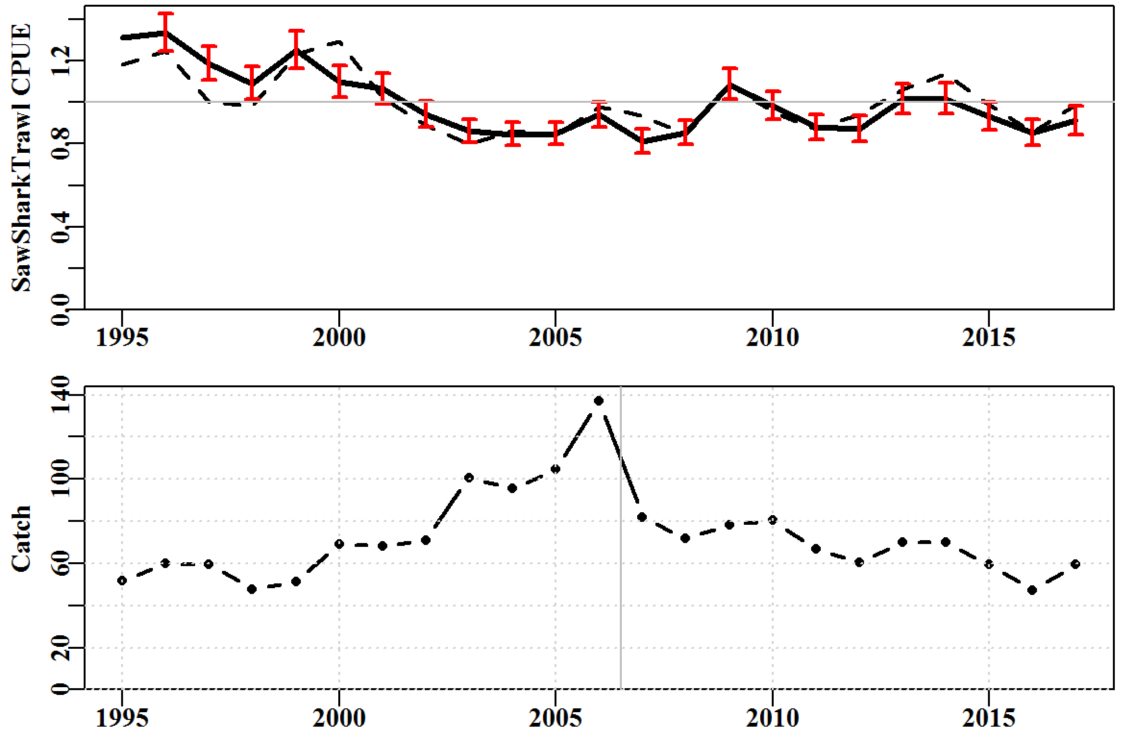

Figure 8.74. SawSharkTrawl. The linear relationship between Annual mean CPUE and Annual Catch.

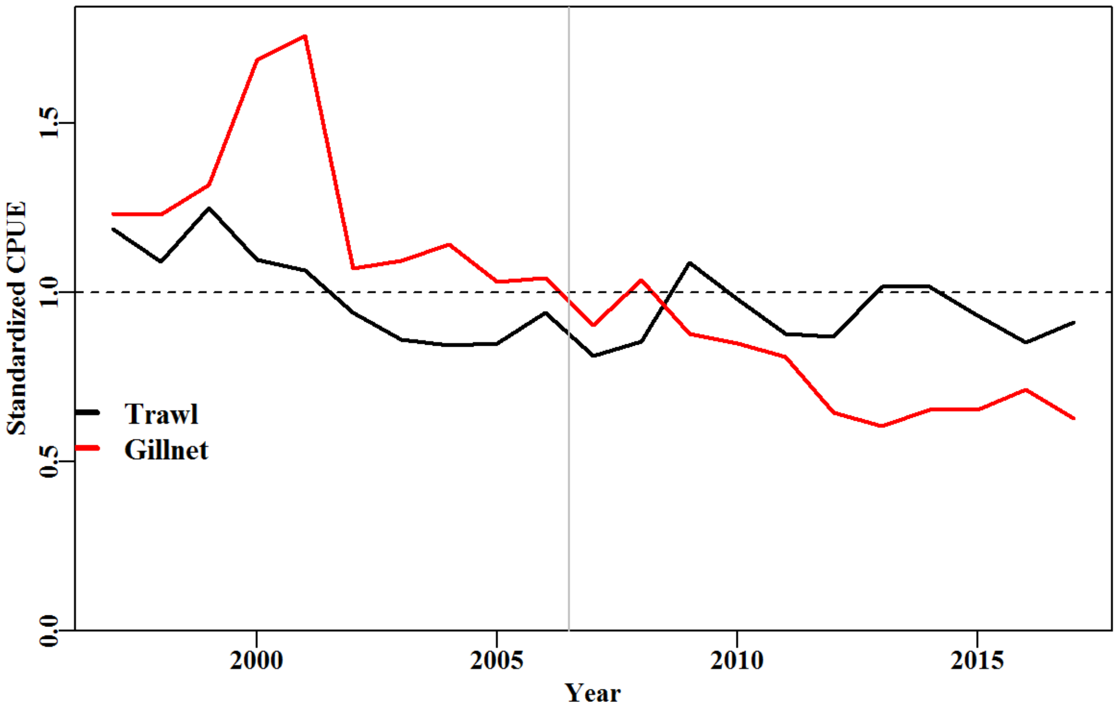

Figure 8.75. SawSharkTrawl. CPUE is correlated with catches through time. CPUE in the top plot and annual catch (t) in the lower plot.

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 (zone) 5, followed by 4.

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 R^2 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 a slight deviations as depicted from both tails of the distribution (Figure 8.79). Annual standardized CPUE has remained similar and at the long term average since 2015 (Figure 8.77).

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 - 2017

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/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
1997	214.2	428	4.0	13	9.2	1.3966	0.000	3.588	0.904
1998	284.2	481	6.7	12	13.9	1.6271	0.068	4.918	0.732
1999	295.6	611	6.4	13	10.0	1.2794	0.064	4.834	0.752
2000	361.7	396	7.1	11	16.9	1.8915	0.072	3.528	0.495
2001	340.7	504	7.0	12	13.2	1.0712	0.071	4.367	0.626
2002	256.6	2646	23.5	22	8.4	0.8944	0.057	16.749	0.712
2003	319.7	2971	21.5	22	6.8	0.7895	0.057	17.384	0.807
2004	314.9	3123	23.5	22	6.7	0.7317	0.057	16.076	0.685
2005	296.7	2556	16.8	22	5.7	0.6521	0.057	12.194	0.724
2006	317.7	2189	17.4	19	7.2	0.7646	0.058	12.133	0.698
2007	214.5	2194	20.9	15	8.5	0.8547	0.058	12.614	0.603
2008	211.7	2406	21.9	15	8.4	0.8994	0.058	14.783	0.675
2009	191.5	2793	20.8	15	6.6	0.8655	0.058	14.690	0.707
2010	192.5	2334	16.7	15	6.7	0.8886	0.058	13.213	0.791
2011	197.0	2795	24.6	14	8.3	0.8647	0.057	17.446	0.709
2012	158.6	2164	20.0	14	8.6	0.8443	0.058	13.778	0.688
2013	165.7	2486	20.5	14	7.7	0.8649	0.058	15.319	0.747
2014	167.2	1706	13.1	14	6.9	0.7682	0.060	9.634	0.736
2015	164.2	2103	23.7	15	10.3	1.0702	0.059	13.550	0.573
2016	164.6	1858	18.9	15	9.1	1.0097	0.060	11.673	0.618
2017	178.8	1711	15.9	16	8.2	0.9717	0.060	9.713	0.610

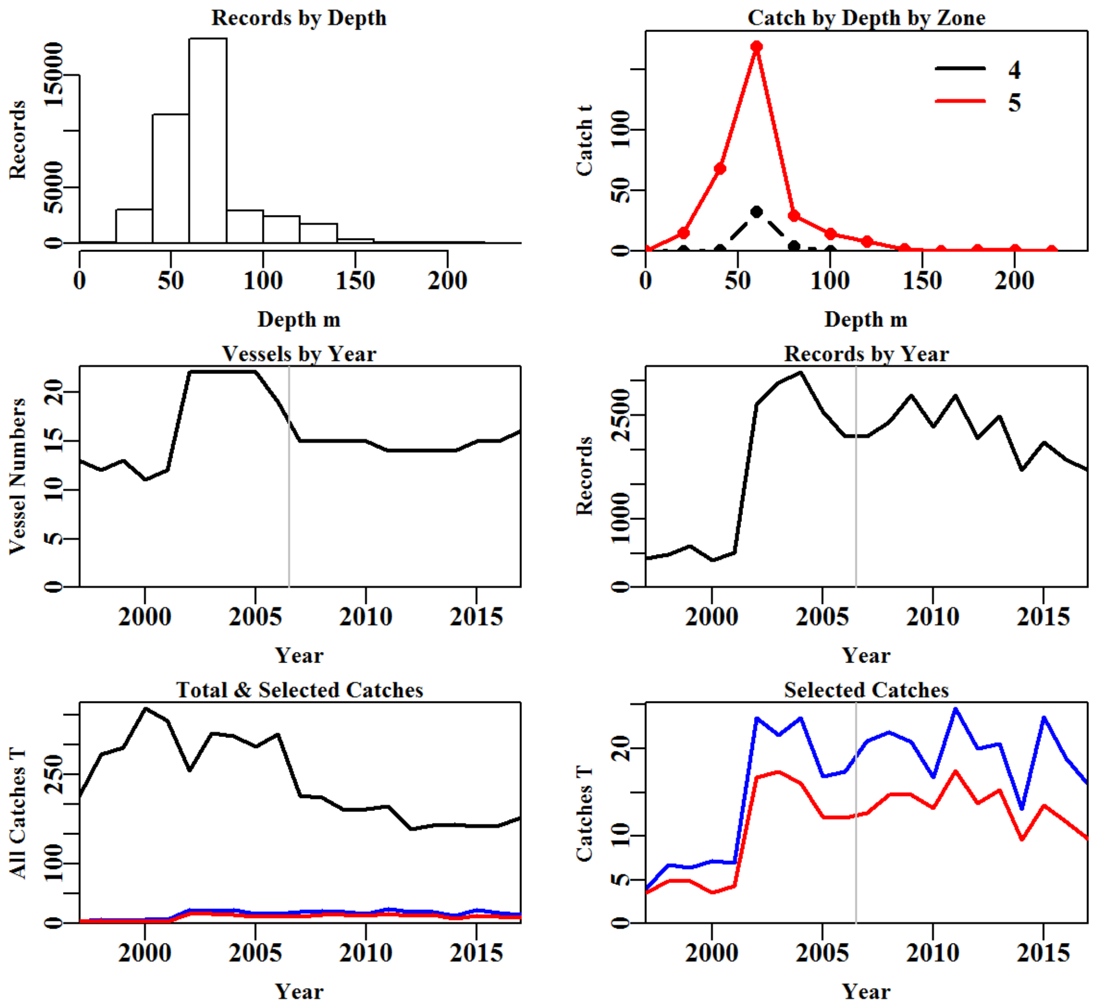

Figure 8.76. SawShark_DS fishery details. The bottom left plot depicts all known catches (top black line), and all selected catches used in the analysis (middle blue line); the lower red line: selected catches < 30 kg). Refer to Box 1 (p. 7) for names which correspond to zone numbers.

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	245005	0	5492.345	0.000
NoCE	240744	4261	5492.345	0.000
Depth	229966	10778	5048.775	443.570
Years	213178	16788	4632.421	416.354
Zones	139874	73304	3093.933	1538.488
Method	40832	99042	352.971	2740.962
Fishery	40455	377	350.936	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	5438	46228	1490	40455	21	3.1	0.00
Vessel	3508	44004	3713	40455	53	7.7	4.59
DepCat	1468	41817	5901	40455	64	12.2	4.57
SharkRegion	1209	41548	6169	40455	65	12.8	0.56
Month	738	41045	6672	40455	76	13.8	1.03
DayNight	623	40923	6795	40455	79	14.1	0.25
SharkRegion:DepCat	481	40767	6951	40455	85	14.4	0.31
SharkRegion:Month	410	40686	7032	40455	90	14.5	0.47

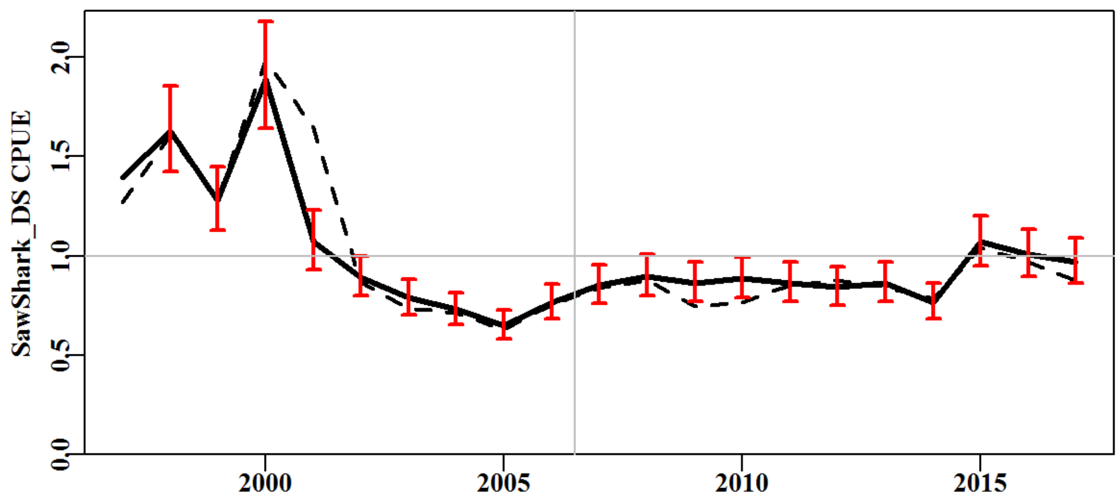

Figure 8.77. SawShark_DS standardization. The dashed black line represents the geometric mean catch rate, solid black line the standardized catch rates. The red bars are the 95% confidence intervals about the mean estimates. The graph scales both time-series of standardized catch rates relative to the mean of each time-series.

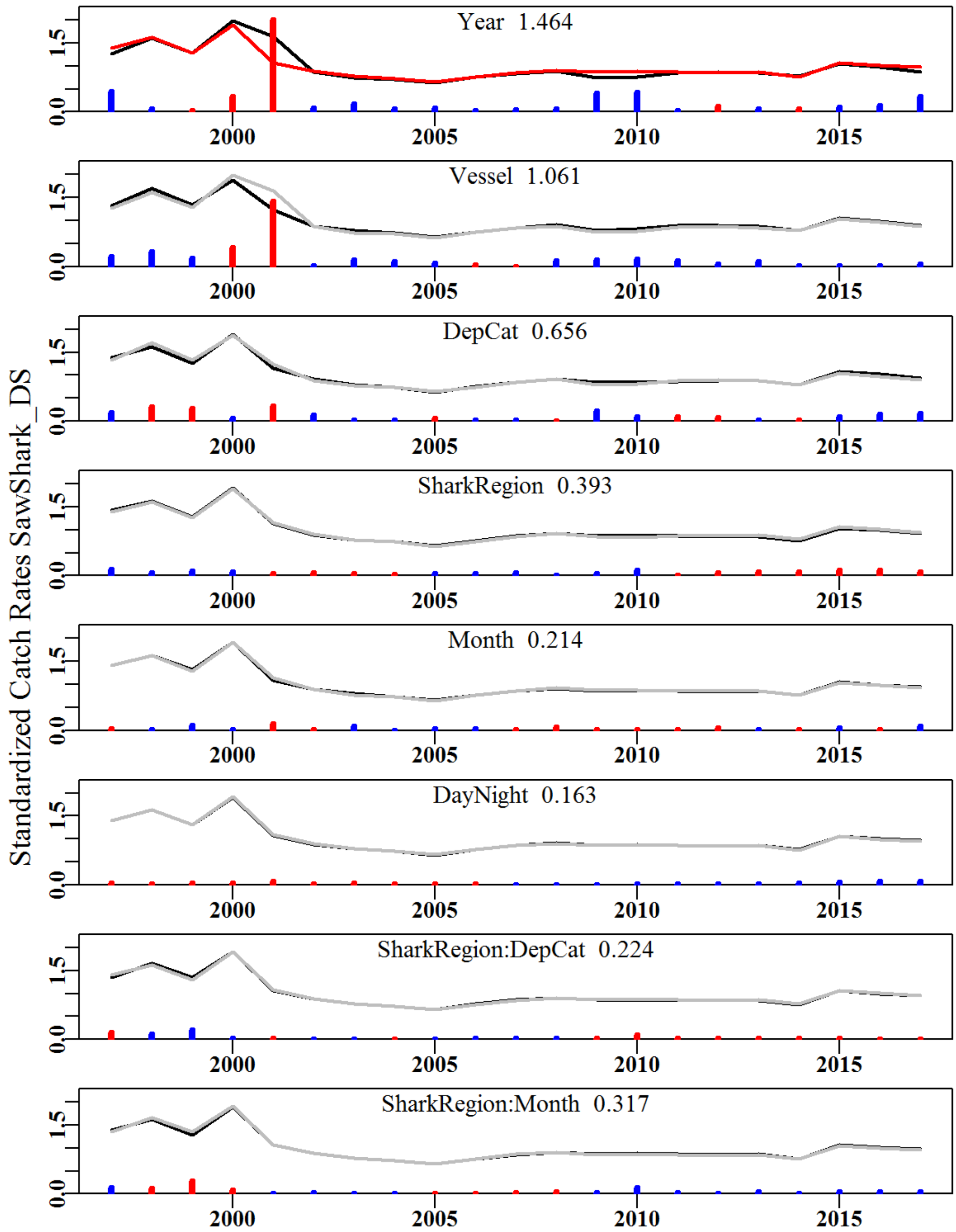

Figure 8.78. SawShark_DS. The influence of each factor on the optimal standardization. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by vertical bars with blue bars indicating the optimum model is higher than the geometric 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.

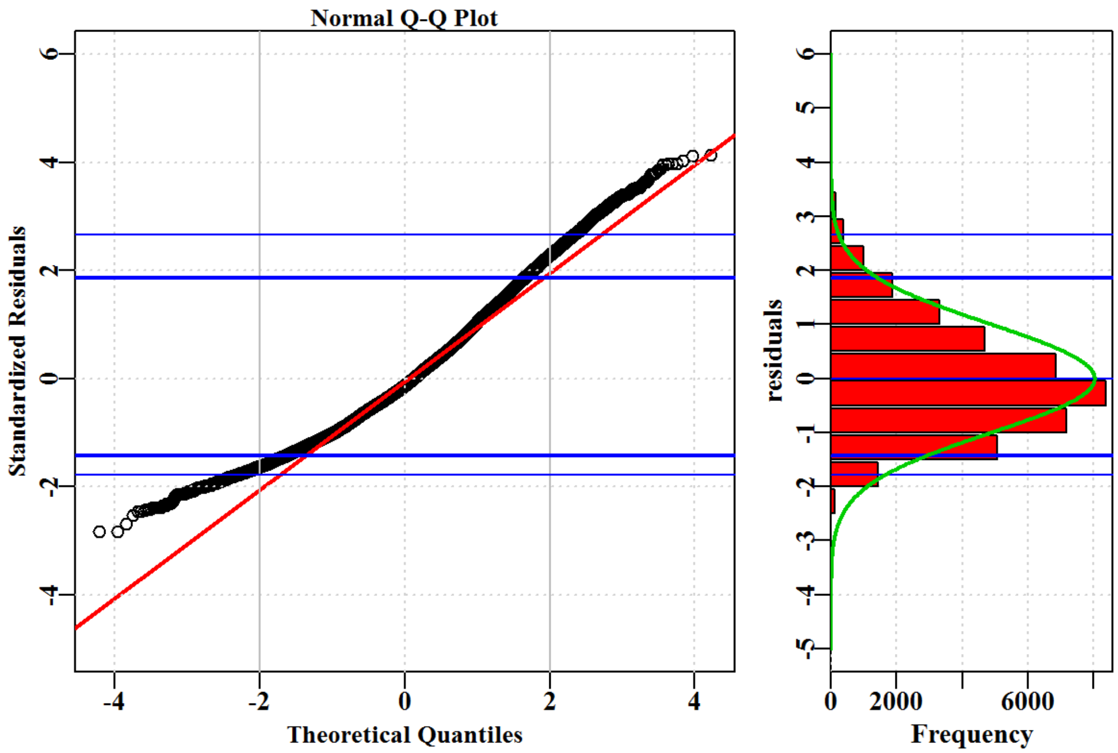

Figure 8.79. SawShark_DS. Diagnostic plots. The distribution of residuals from the optimum fit. The qqplot indicates the fit to the expected normality, while the histogram of residuals also illustrates the 1%, 5%, 95% and 99% quantiles to indicate the intensity of any lack of fit at the margins of the distribution (reflected also in the qqplot).

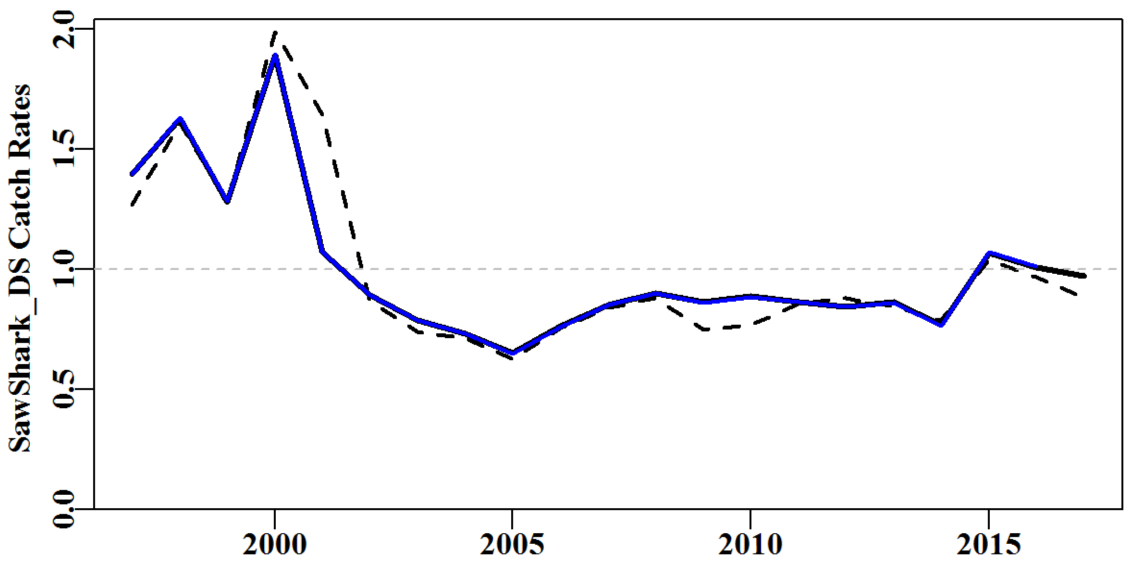

Figure 8.80. SawShark_DS. A comparison of the previous year's standardization (blue line) with this year's. They should lie on top of each other, although small deviations may relate to data adjustments, particularly in very recent years.

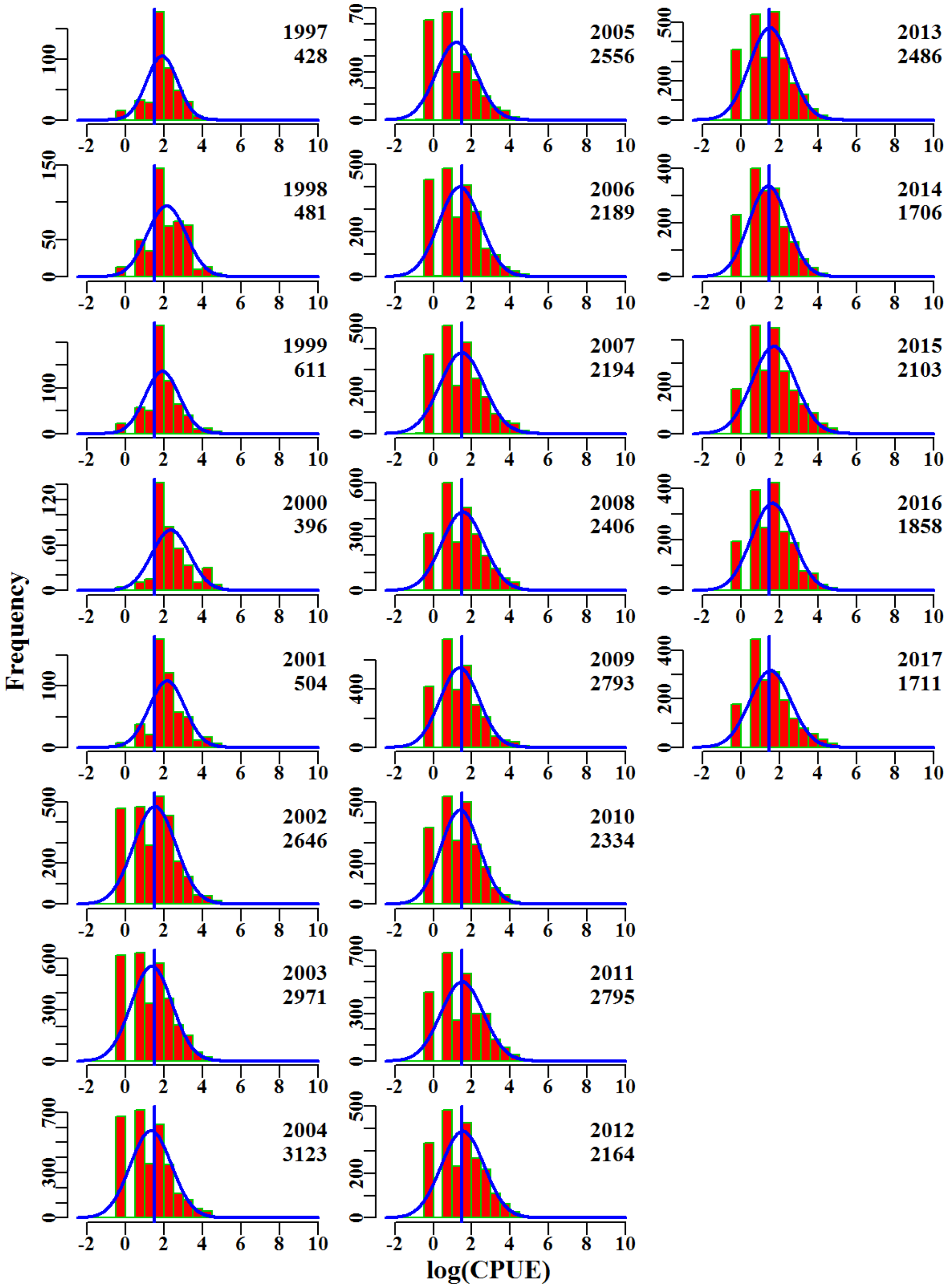

Figure 8.81. SawShark_DS. The $\log_e$(CPUE) for each year of data available the blue lines are normal distributions fitted to the histogram frequencies. The numbers in each plot are the year and number of records. The vertical blue line is the average across all years.

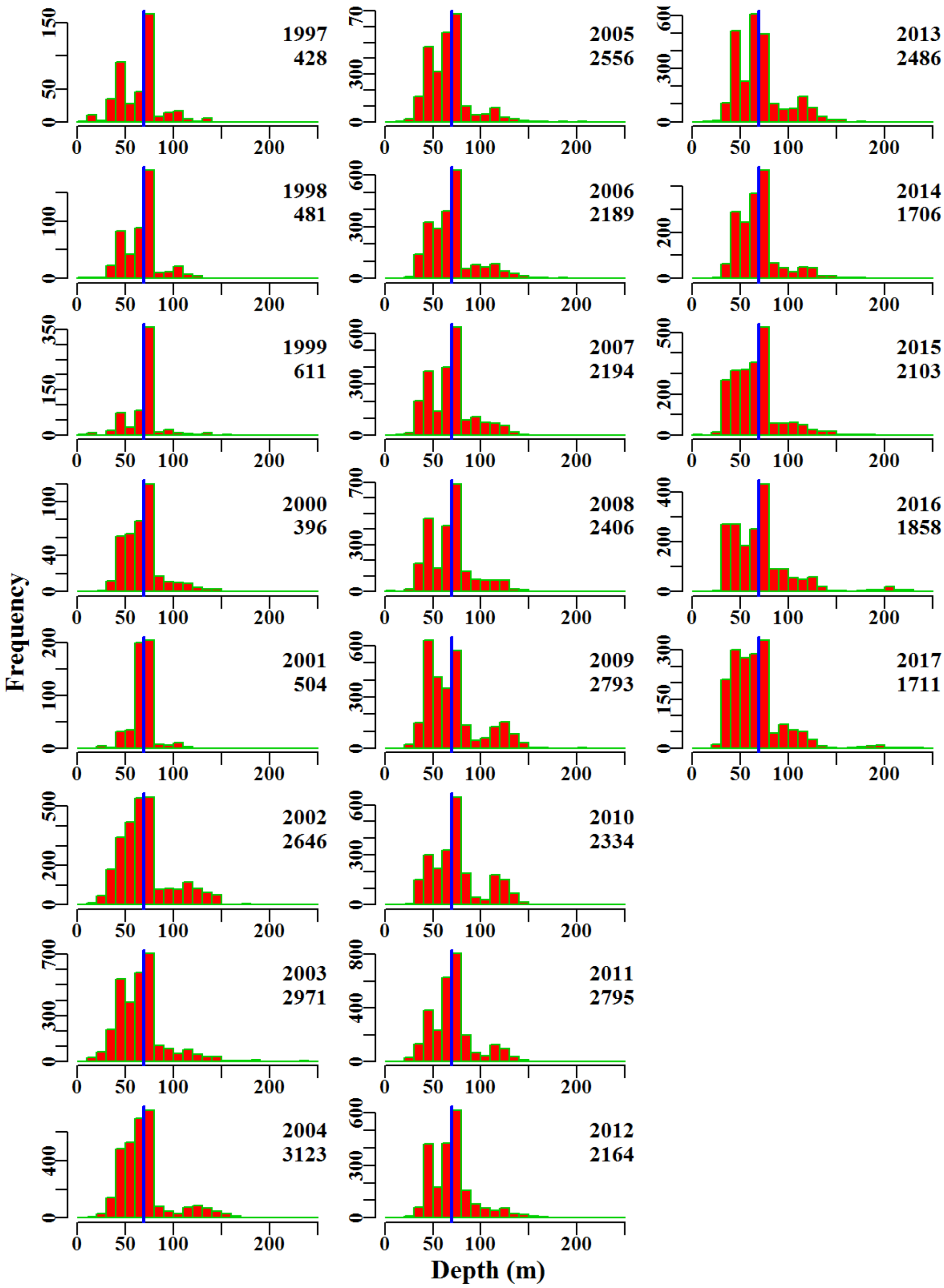

Figure 8.82. SawShark_DS. The average Depth of fishing for each year of data available to illustrate the development of the fishery through time. The numbers in each plot are the year and number of records. The vertical blue line is the average across all years.

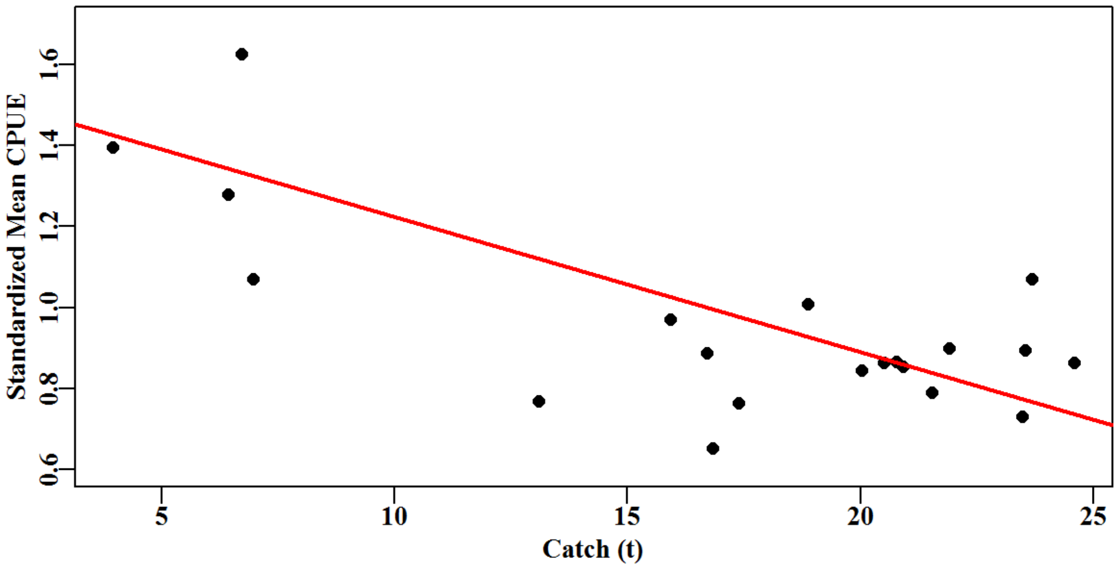

Figure 8.83. SawShark_DS. The linear relationship between Annual mean CPUE and Annual Catch.

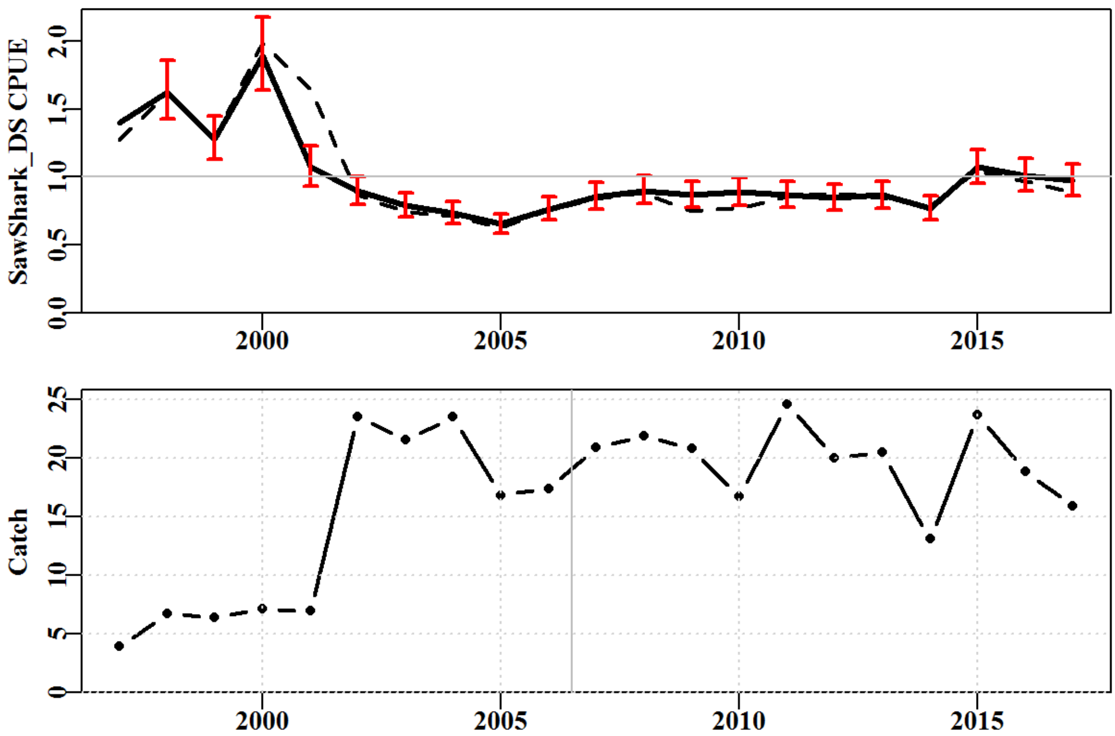

Figure 8.84. SawShark_DS. CPUE is correlated with catches through time. CPUE in the top plot and annual catch (t) in the lower plot.

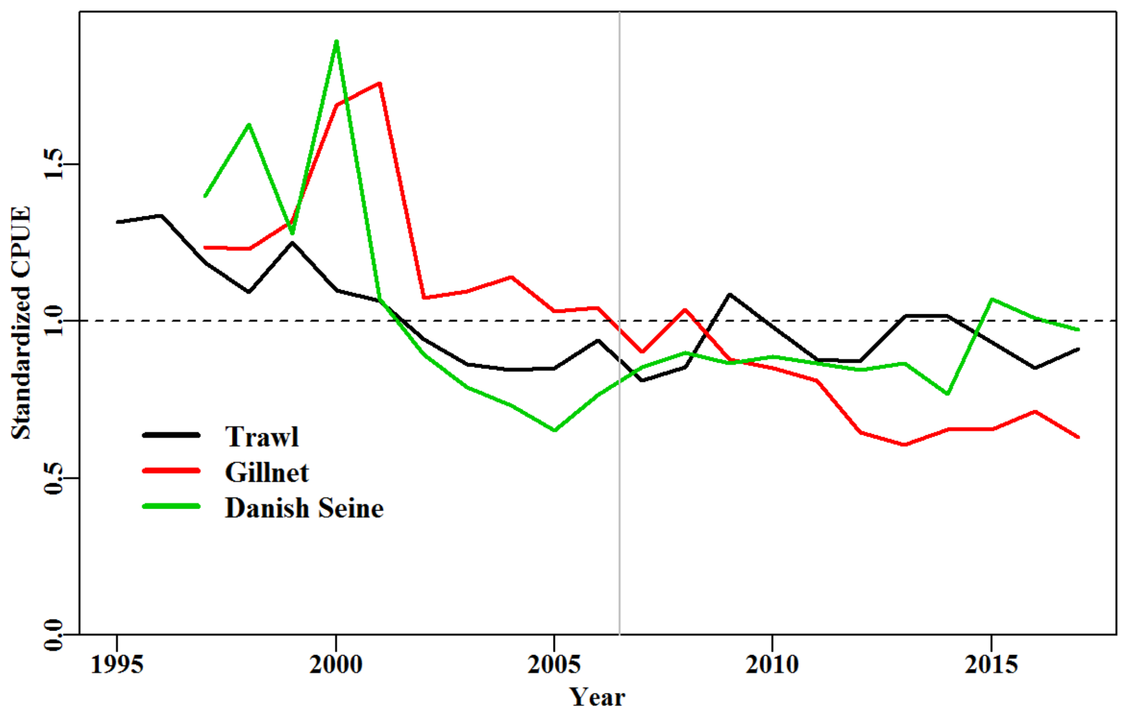

Figure 8.85. Sawshark CPUE from Trawl compared with that from Gillnet and Danish Seine.

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 23). 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 < 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 (zone) 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 R^2 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 (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 - 2017

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/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
1997	32.0	1441	25.3	56	15.8	0.9468	0.000	9.166	0.362
1998	51.9	2111	41.4	57	16.1	0.8829	0.047	12.658	0.306
1999	69.0	2772	54.5	65	17.4	1.0357	0.046	17.654	0.324
2000	78.7	2708	62.0	57	18.5	1.2972	0.046	19.903	0.321
2001	88.8	2746	71.2	62	22.6	1.3342	0.047	19.152	0.269
2002	59.4	2100	36.9	61	16.0	0.9646	0.049	13.464	0.365
2003	71.2	2151	41.8	60	15.8	0.9490	0.049	12.979	0.311
2004	64.8	1746	30.2	51	14.7	0.9110	0.051	10.598	0.351
2005	66.4	1845	32.1	40	16.0	0.9305	0.050	11.385	0.355
2006	53.3	1638	30.8	42	16.0	1.0127	0.052	9.758	0.317
2007	51.7	1737	32.2	38	16.9	1.0873	0.052	11.584	0.360
2008	61.4	1988	38.1	34	18.1	1.1481	0.050	13.550	0.356
2009	65.3	2072	42.8	35	21.2	1.3325	0.050	15.337	0.358
2010	56.7	2223	33.9	35	14.6	1.0366	0.050	14.395	0.425
2011	50.5	2637	33.3	35	11.4	0.8982	0.050	17.380	0.522
2012	65.9	2625	43.2	38	15.6	1.0442	0.049	17.456	0.404
2013	61.9	2409	36.2	34	14.4	0.9665	0.050	17.456	0.483
2014	47.4	2159	29.1	31	12.8	0.8716	0.050	15.225	0.522
2015	49.3	1784	27.6	27	14.1	0.8163	0.052	11.053	0.400
2016	49.0	2042	34.6	27	14.7	0.8373	0.051	12.489	0.361
2017	40.8	1954	25.0	24	11.2	0.6967	0.052	11.711	0.468

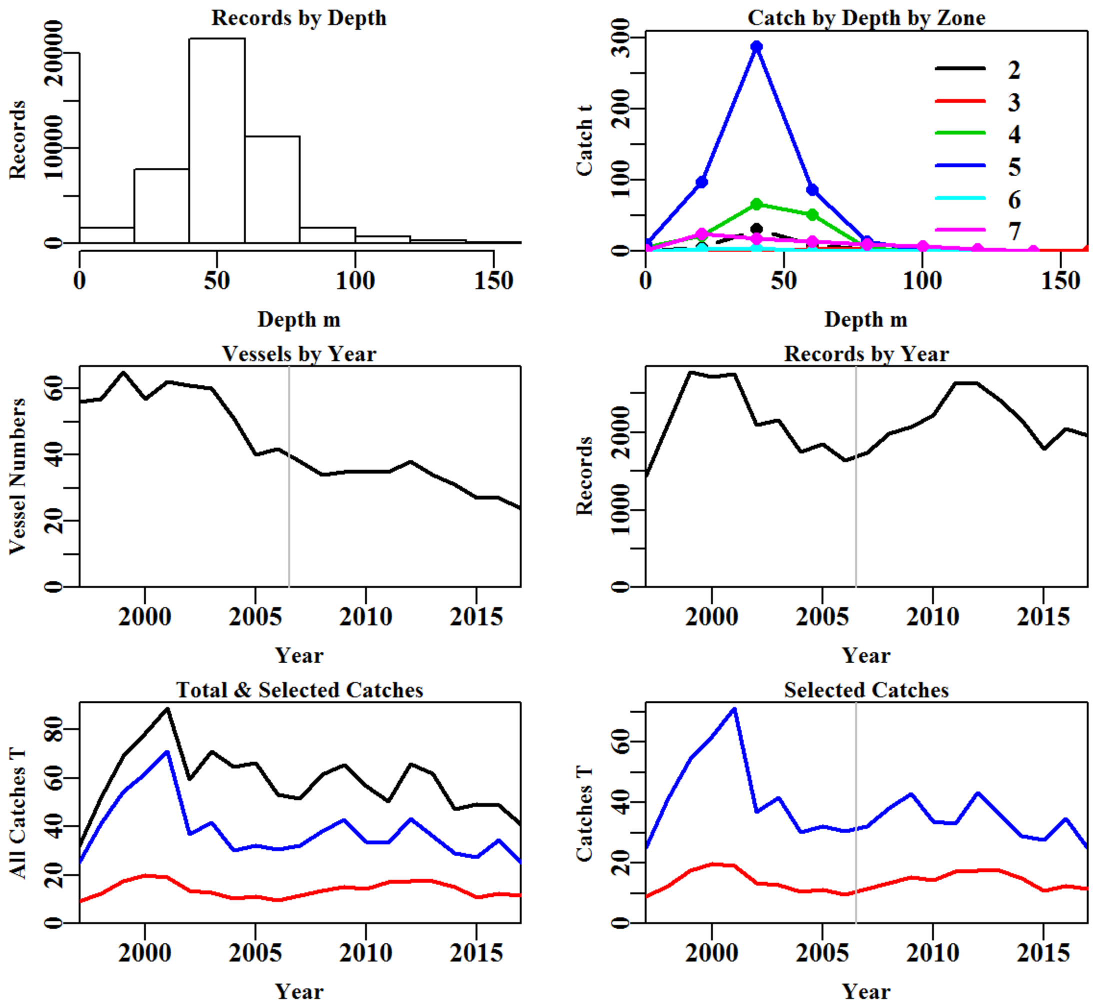

Figure 8.86. ElephantFishGN fishery details. The bottom left plot depicts all known catches (top black line), and all selected catches used in the analysis (middle blue line); the lower red line: selected catches < 30 kg). Refer to Box 1 (p. 7) for names which correspond to zone numbers.

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	85503	0	1294.638	0.000
NoCE	79763	5740	1294.638	0.000
Depth	72367	7396	1205.478	89.160
Years	70493	1874	1163.763	41.715
Zones	67245	3248	1101.266	62.497
Method	44888	22357	802.004	299.262
Fishery	44888	0	802.004	0.000

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	26048	80120	1008	44888	21	1.2	0.00
Vessel	22964	74285	6844	44888	176	8.1	6.88
Month	22751	73897	7231	44888	187	8.5	0.46
DepCat	22738	73850	7279	44888	195	8.6	0.04
SharkRegion	22548	73522	7607	44888	200	9.0	0.40
SharkRegion:DepCat	22329	73052	8076	44888	234	9.5	0.51
SharkRegion:Month	22118	72642	8486	44888	255	10.0	0.98

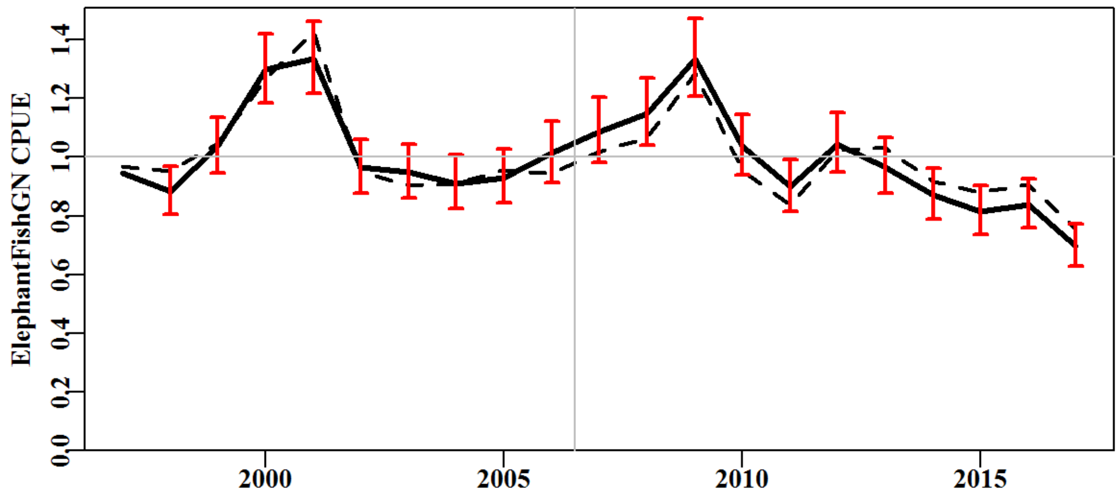

Figure 8.87. ElephantFishGN standardization. The dashed black line represents the geometric mean catch rate, solid black line the standardized catch rates. The red bars are the 95% confidence intervals about the mean estimates. The graph scales both time-series of standardized catch rates relative to the mean of each time-series.

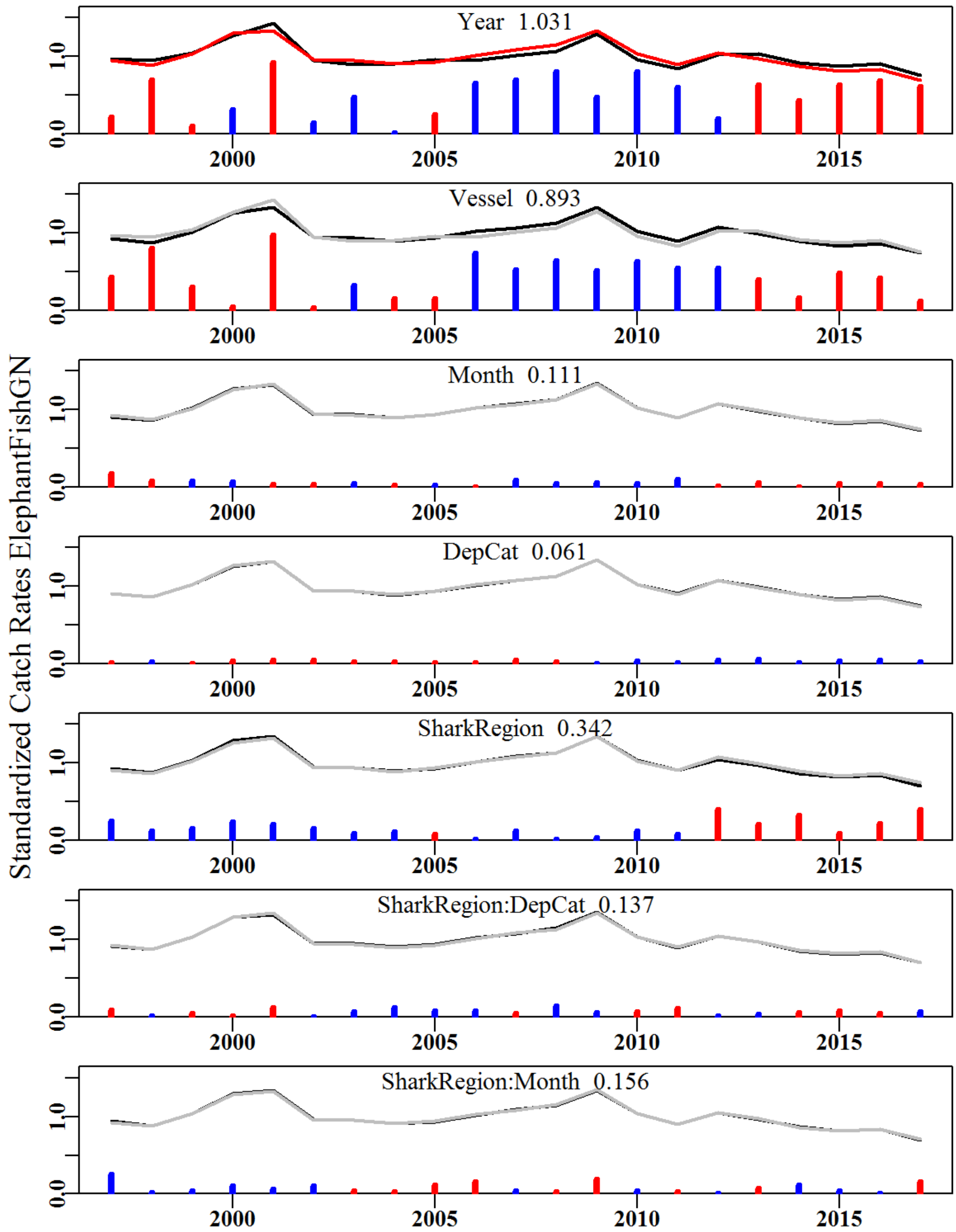

Figure 8.88. ElephantFishGN. The influence of each factor on the optimal standardization. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by vertical bars with blue bars indicating the optimum model is higher than the 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.

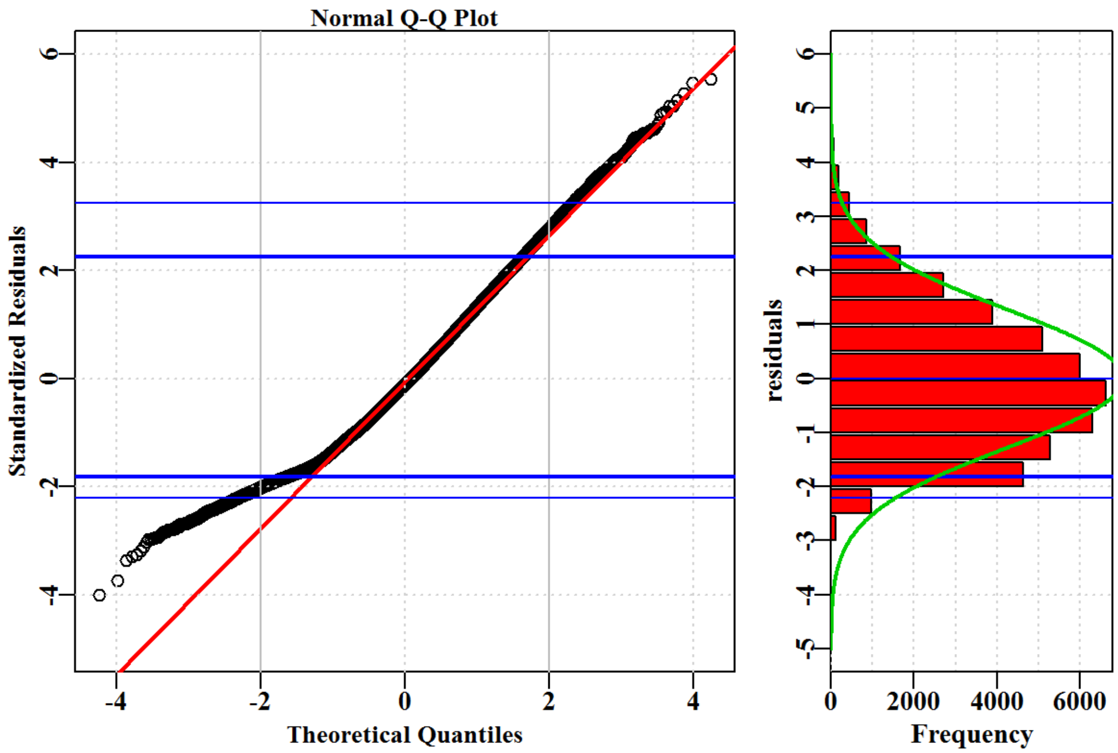

Figure 8.89. ElephantFishGN. Diagnostic plots. The distribution of residuals from the optimum fit. The qqplot indicates the fit to the expected normality, while the histogram of residuals also illustrates the 1%, 5%, 95% and 99% quantiles to indicate the intensity of any lack of fit at the margins of the distribution (reflected also in the qqplot).

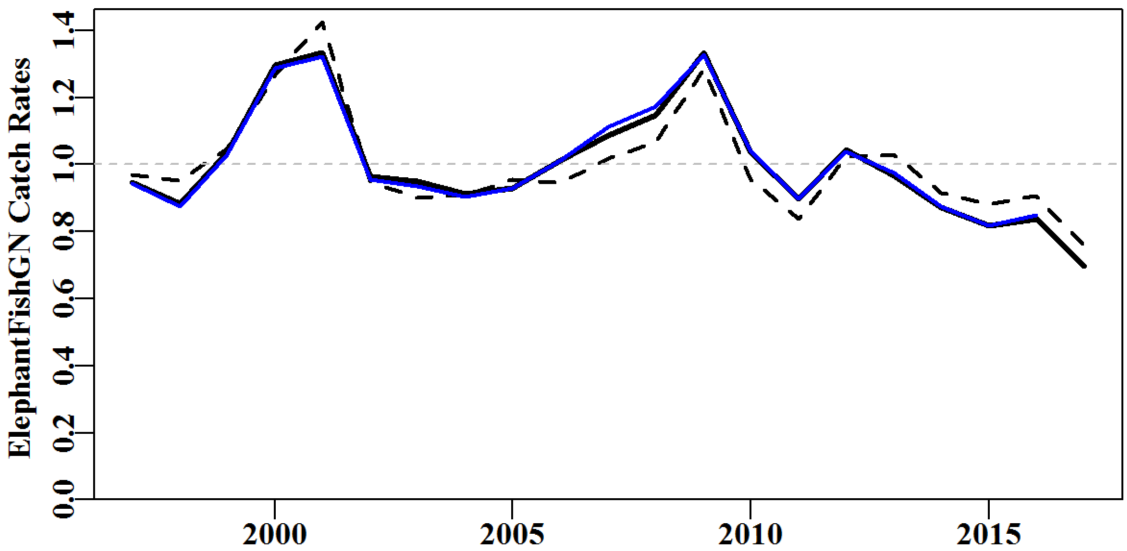

Figure 8.90. ElephantFishGN. A comparison of the previous year's standardization (blue line) with this year's. They should lie on top of each other, although small deviations may relate to data adjustments, particularly in very recent years.

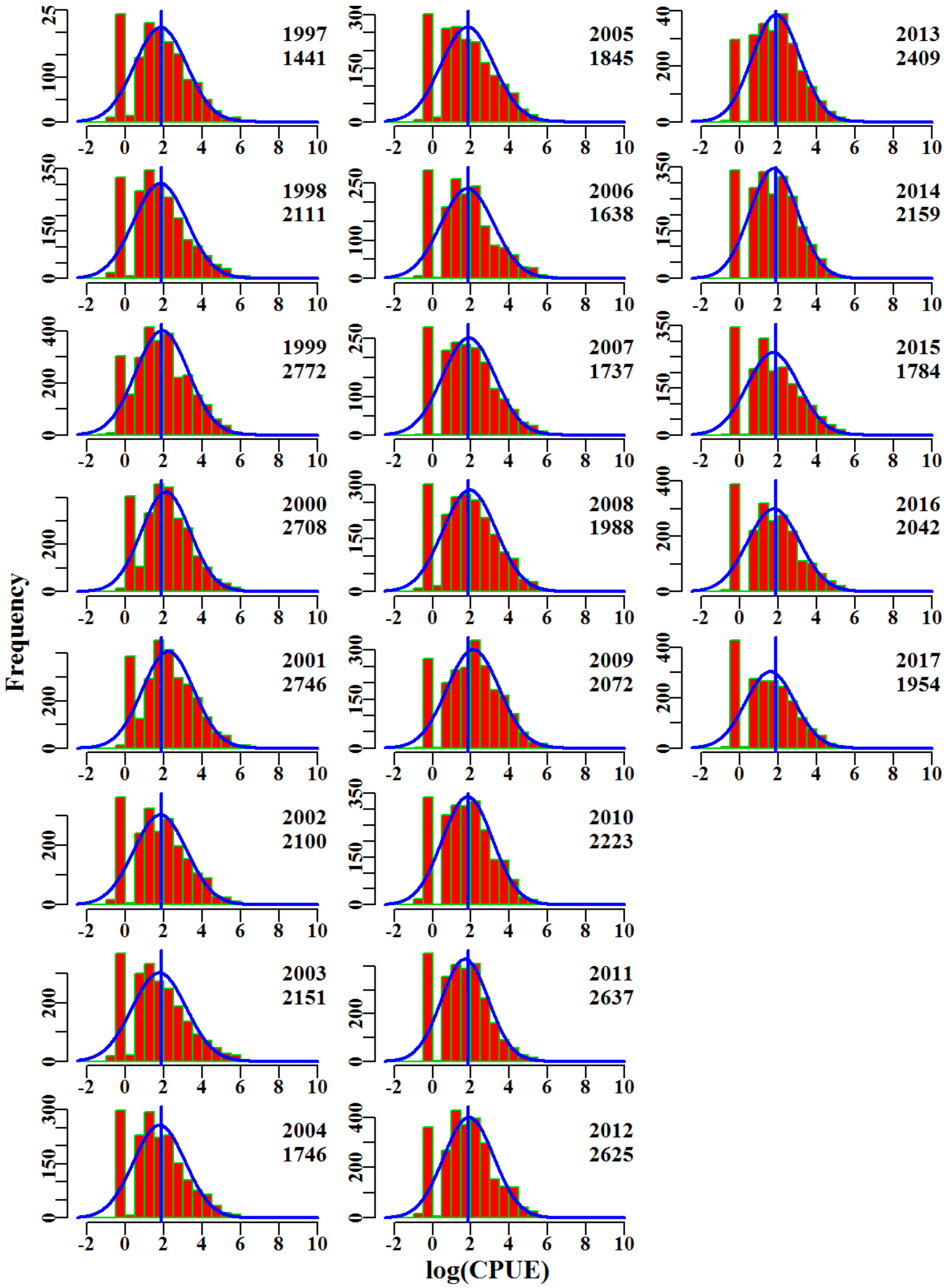

Figure 8.91. ElephantFishGN. The $\log_e$(CPUE) for each year of data available the blue lines are normal distributions fitted to the histogram frequencies. The numbers in each plot are the year and number of records. The vertical blue line is the average across all years.

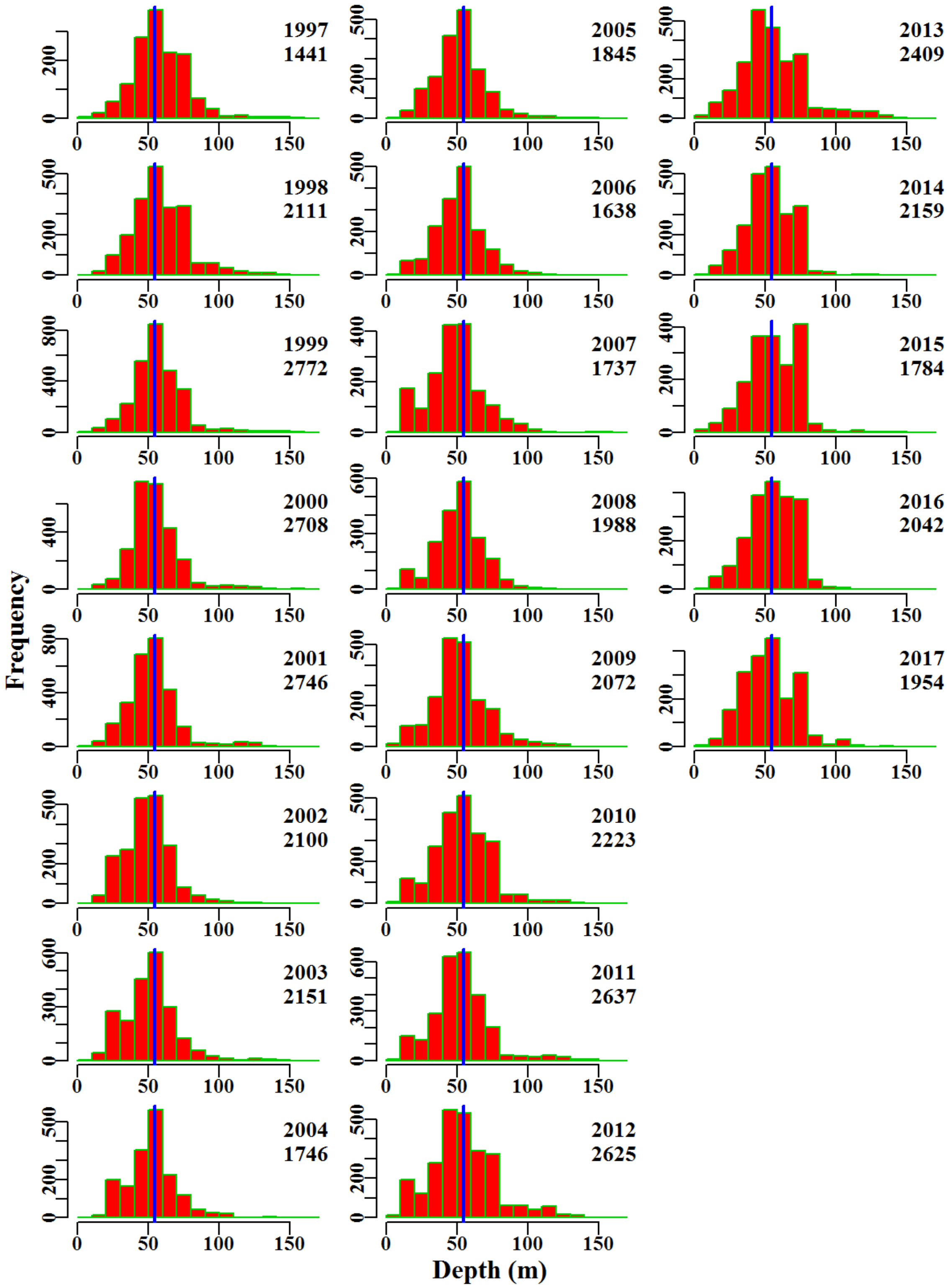

Figure 8.92. ElephantFishGN. The average Depth of fishing for each year of data available to illustrate the development of the fishery through time. The numbers in each plot are the year and number of records. The vertical blue line is the average across all years.

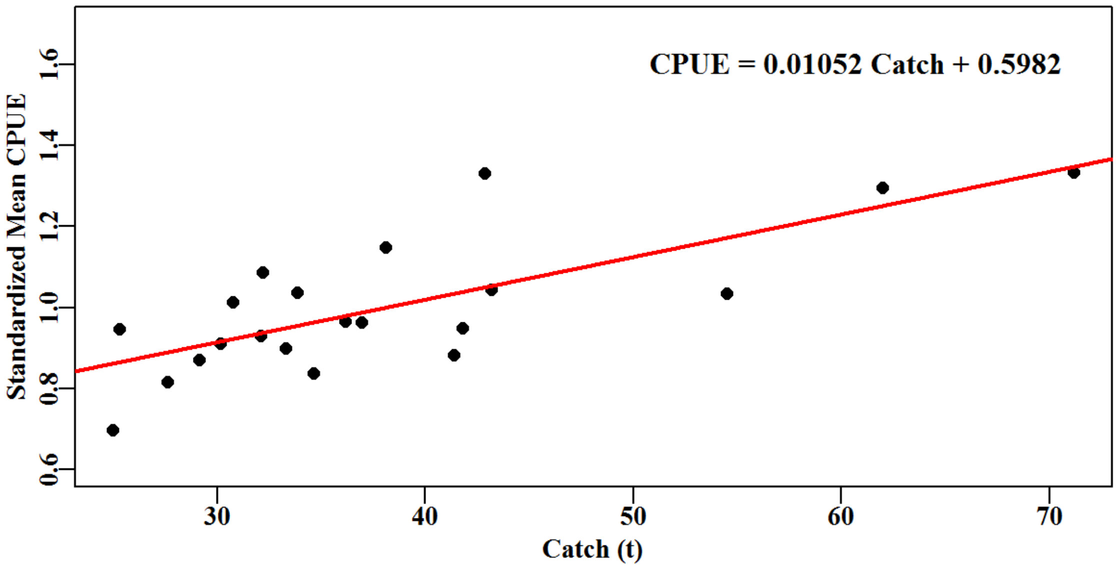

Figure 8.93. ElephantFishGN. The linear relationship between Annual mean CPUE and Annual Catch.

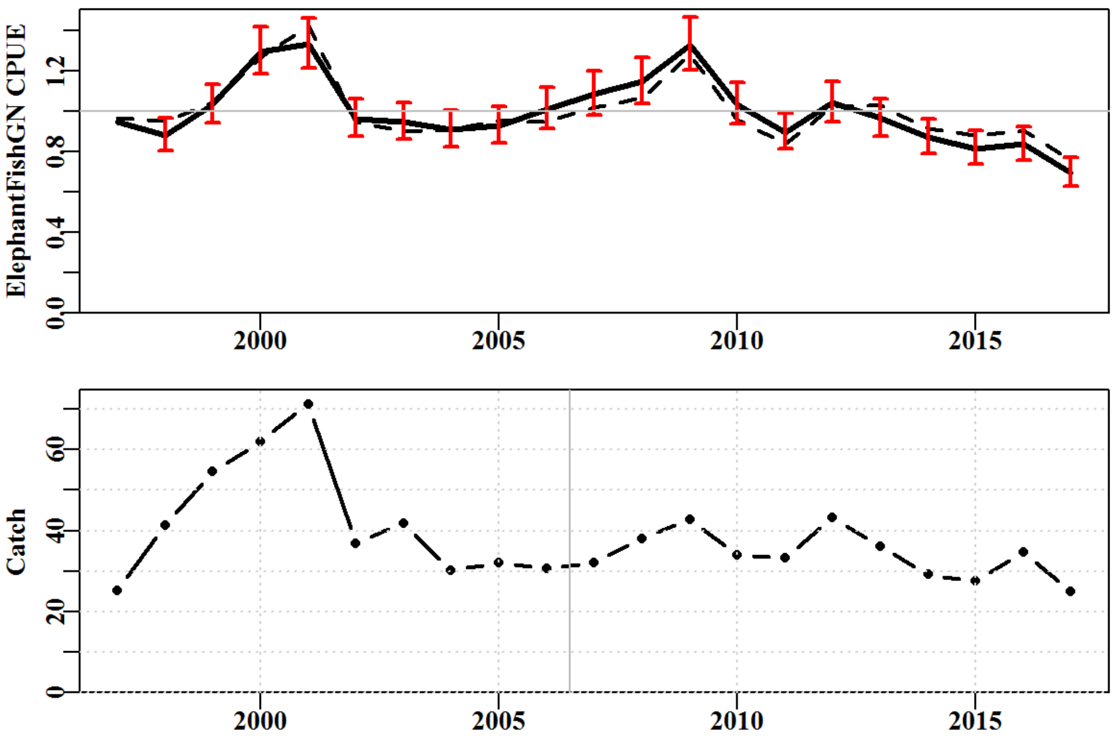

Figure 8.94. ElephantFishGN. CPUE is correlated with catches through time. CPUE in the top plot and annual catch (t) in the lower plot.

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 selected SESSF Species (data to 2017)

Miriana Sporcic

CSIRO Oceans and Atmosphere, Castray Esplanade, Hobart 7000, Australia

9.1 Background

Tier 4 analyses have been performed for the following species and/or species groups: mirror dory east, mirror dory west, eastern deepwater shark, western deepwater shark and blue eye trevalla (Zone 20 - 50).

Due to recent revisions to annual landed catch estimates (see Castillo-Jordán et al. (2018), page 7), the reported annual landed catch in this report differ from those used in previous Tier 4 analyses for all species. In addition, there have been considerable changes to estimated discards based on recent revisions (see Burch et al. 2018, pp 2-4). These estimates are currently being reviewed and therefore were not used in this report for species which include discards as agreed by SERAG (minutes; Assessment meeting 1, 19-21 September 2018). Instead, the accepted discard series was used.

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 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 RBC as a precautionary measure unless there are good reasons for not imposing such a discount on particular species. The application of the discount factor will occur unless RAGs generate explicit advice that alternative equivalent precautionary measures are in place (such as spatial or temporal closures) or that there is evidence of historical stability of the stock at current catch levels (AFMA, 2009).

In essence Tier 4 analyses require, as a minimum, a time series of total catches and of standardized catch rates.

The current Tier 4 analysis and control rule underwent Management Strategy Evaluation (Wayte, 2009, Little et al., 2011a), which demonstrated its advantages over an earlier implementation used in 2007 and 2008. Further work has since demonstrated that as long as there is a limit on increases and decreases to the RBC of no more than 50% then the notion of including a maximum RBC (at 1.25 times the target) is redundant (Little et al., 2011b).

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

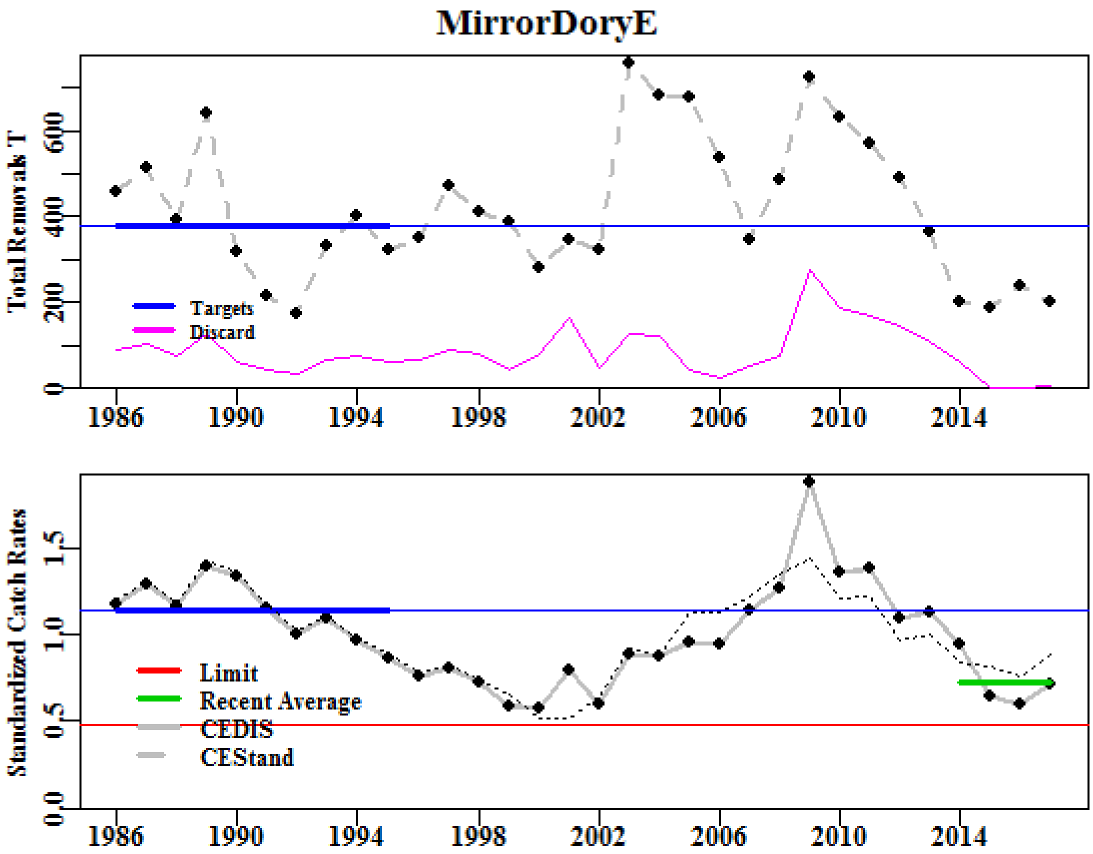

Figure 9.1. Mirror Dory 10 - 30 Discard. Top plot is the total removals with the fine line illustrating the target catch. Bottom plot represents the standardized catch rates with the upper fine line representing the target catch rate and the lower line the limit catch rate. Thickened lines represents 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.

Parameter	Value		Parameter	Value
Reference_Years	1986 - 1995	|	Scaling	0.3723
CE_Target	1.1408	|	Last Year's TAC	235
CE_Limit	0.4753	|	Ctarg	377.051
CE_Recent	0.723	|	RBC	140.378
Wt_Discard	7.086	|	-	-

Table 9.2. Mirror Dory 10 - 30 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 (Sporcic and Haddon, 2018a). GeoMean is the geometric mean catch rates. Discards (D) are estimates from 1998 to present. The ratio of discards to catch over the 1998 - 2006 period was used to estimate the discards between 1986 and 1997. TAC refers to the Total Allowable Catch (t).

Year	Catch (C)	Discards	Total	(D/C)+1	CE	DiscCE	TAC	State
1986	368	91.091	459.076	1.248	1.1982	1.1748	-	0.000
1987	414	102.375	515.946	1.248	1.3086	1.2831	-	0.000
1988	313	77.539	390.776	1.248	1.1832	1.1601	-	0.000
1989	514	127.170	640.906	1.248	1.4209	1.3932	-	0.000
1990	254	62.969	317.349	1.248	1.3546	1.3282	-	0.000
1991	171	42.318	213.272	1.248	1.1750	1.1521	-	0.000
1992	140	34.765	175.206	1.248	1.0219	1.0020	-	0.000
1993	267	66.116	333.207	1.248	1.1081	1.0865	800	0.000
1994	304	75.158	400.287	1.248	0.9811	0.9620	800	21.509
1995	243	60.097	324.483	1.248	0.8838	0.8666	800	21.609
1996	262	64.963	348.875	1.248	0.7751	0.7600	800	21.477
1997	361	89.460	472.447	1.248	0.8227	0.8066	800	21.590
1998	303	79.350	409.636	1.262	0.7330	0.7268	800	27.041
1999	310	42.255	389.673	1.136	0.6482	0.5788	800	36.959
2000	190	81.131	281.973	1.428	0.5122	0.5748	800	11.174
2001	173	164.476	347.647	1.952	0.5125	0.7862	800	10.399
2002	257	45.720	324.683	1.178	0.6427	0.5949	640	21.701
2003	563	124.887	756.542	1.222	0.9222	0.8855	576	68.462
2004	452	122.544	680.661	1.271	0.8755	0.8748	576	106.415
2005	557	44.291	675.235	1.079	1.1224	0.9522	700	73.457
2006	427	23.351	535.355	1.055	1.1291	0.9360	634	85.429
2007	265	50.836	344.076	1.192	1.2151	1.1385	788	28.716
2008	390	75.461	487.896	1.193	1.3502	1.2663	634	22.090
2009	416	274.025	725.525	1.658	1.4348	1.8698	718	35.112
2010	430	187.155	628.674	1.436	1.2021	1.3565	718	12.019
2011	391	170.552	568.040	1.436	1.2191	1.3756	718	6.091
2012	339	147.835	492.729	1.436	0.9633	1.0870	718	5.630
2013	249	108.442	362.938	1.436	1.0005	1.1290	1077	5.632
2014	138	60.090	199.778	1.436	0.8364	0.9438	808	1.787
2015	184	1.112	187.175	1.006	0.8165	0.6456	437	1.790
2016	230	1.623	237.621	1.007	0.7520	0.5952	325	5.717
2017	189	4.685	199.545	1.025	0.8789	0.7079	235	5.718

9.3.1 *Discussion*

While recent catches have stabilized at a low level, the most recent standardized CPUE has increased. Previously, CPUE has followed catches and so the CPUE may be expected to increase in coming years. Usually, the Mirror Dory East fishery is assessed using the Tier 4 method that includes discards in the catches and CPUE (see the Methods Appendix and the next analysis). However, for the past three years the discards of Mirror Dory in the east have been small (see Table 9.2). Such low estimated discards has the potential to distort the analysis (especially given the recent years' discards are weighted more heavily). It was decided by SERAG (see minutes 2018 Assessment Meeting 1, 19-21 September 2018) that the Tier 4 analysis to include discards.

9.4 Mirror Dory West

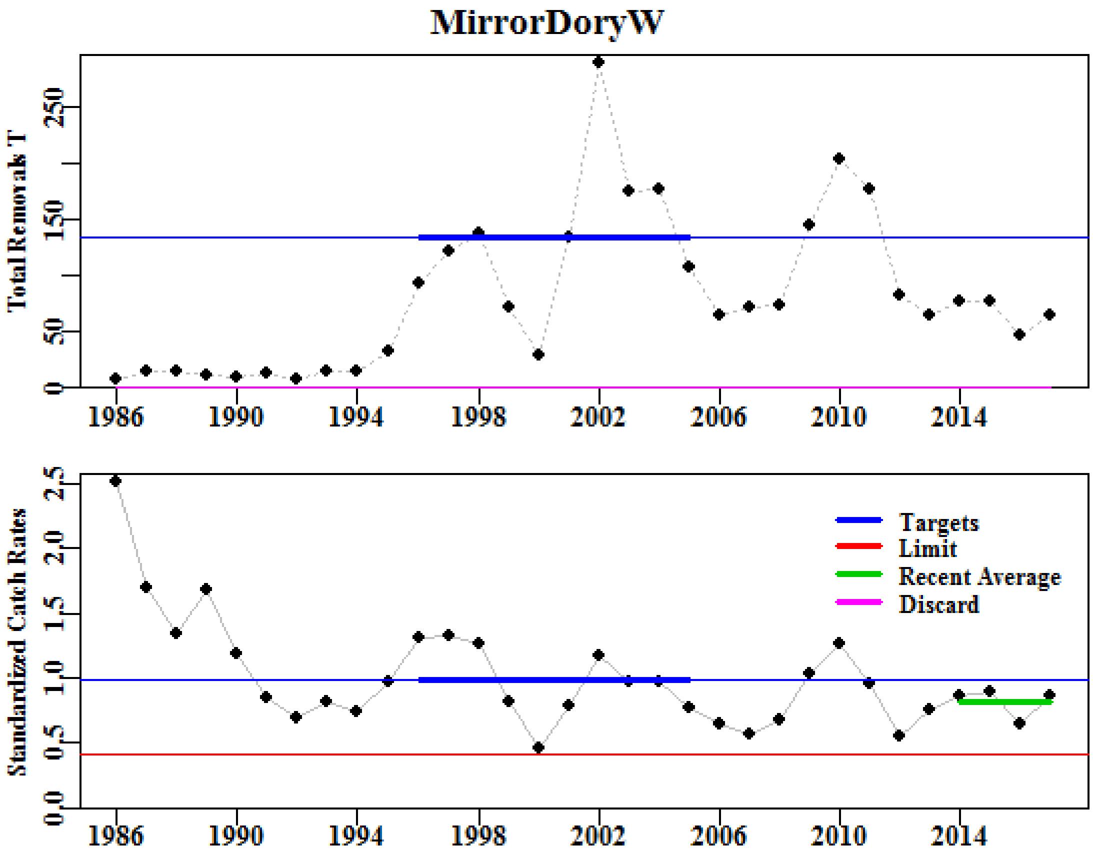

Figure 9.2. Mirror Dory 40 - 50. Top plot is the total removals with the fine line illustrating the target catch. Bottom plot represents the standardized catch rates with the upper fine line representing the target catch rate and the lower line the limit catch rate. Thickened lines represents the reference 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.

Parameter	Value		Parameter	Value
Reference_Years	1996 - 2005	|	Scaling	0.7114
CE_Target	0.9841	|	Last Year’s TAC	235
CE_Limit	0.41	|	Ctarg	133.2
CE_Recent	0.8184	|	RBC	94.76
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 and SEF2 catches. All values in Tonnes. CE is the standardized catch rate (Sporcic and Haddon, 2018a). GeoMean is the geometric mean catch rates. TAC refers to the Total Allowable Catch (t).

Year	Catch	Discards	Total	State	CE	GeoMean	TAC
1986	7	0	7.400		2.5065	1.7250	-
1987	16	0	15.500		1.6902	1.6740	-
1988	15	0	15.000		1.3418	1.7250	-
1989	11	0	11.100		1.6776	2.1006	-
1990	10	0	10.000		1.1809	1.7574	-
1991	13	0	12.800		0.8390	0.8254	-
1992	8	0	8.300	0.000	0.6899	0.6770	-
1993	15	0	14.753	0.000	0.8078	0.7790	800
1994	15	0	15.205	0.361	0.7446	0.6863	800
1995	31	0	31.613	0.765	0.9718	0.7141	800
1996	93	0	93.729	0.238	1.3141	1.0851	800
1997	120	0	120.546	0.350	1.3306	1.1361	800
1998	136	0	136.609	0.214	1.2597	1.2752	800
1999	72	0	72.108	0.220	0.8197	0.7883	800
2000	28	0	28.218	0.214	0.4551	0.3663	800
2001	134	0	134.192	0.215	0.7886	0.6538	800
2002	288	0	288.377	0.216	1.1661	1.1500	640
2003	175	0	175.424	0.274	0.9702	0.9599	576
2004	176	0	176.171	0.024	0.9700	0.9413	576
2005	107	0	106.623	0.039	0.7665	0.7048	700
2006	65	0	64.656	0.005	0.6387	0.7280	634
2007	71	0	71.395	0.005	0.5728	0.6631	788
2008	74	0	74.136	0.014	0.6743	0.7466	634
2009	145	0	144.954	0.000	1.0286	0.9274	718
2010	203	0	203.435	0.000	1.2548	1.2288	718
2011	177	0	177.026	0.001	0.9542	1.0109	718
2012	82	0	82.141	0.000	0.5584	0.7837	1077
2013	65	0	65.203	0.002	0.7540	0.9645	1077
2014	77	0	76.908	0.001	0.8673	0.9089	808
2015	77	0	77.321	0.002	0.8885	0.8068	437
2016	47	0	46.569	0.002	0.6516	0.7651	325
2017	65	0	64.549	0.002	0.8662	0.7419	235

9.4.1 *Discussion*

The 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 eight years between the reference period and the start of the most recent four years used to denote the current state of the fishery. CPUE in recent years is not as depressed in relative terms as on the east (Zone 10-30).

9.5 Eastern Deepwater Shark

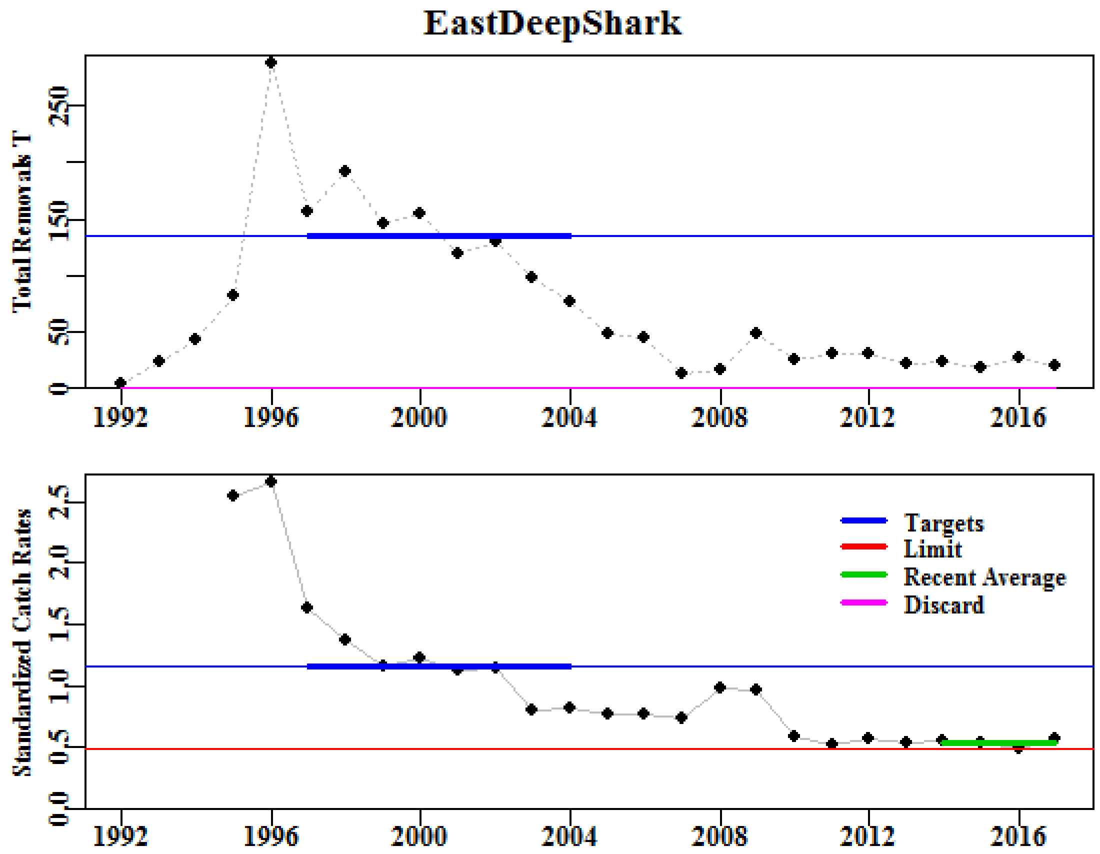

Figure 9.3. Eastern Deepwater Shark. Top plot is the total removals with the fine line illustrating the target catch. Bottom plot represents the standardized catch rates with the upper fine line representing the target catch rate and the lower line the limit catch rate. Thickened lines represents the reference period for catches, catch rates, and the recent average catch rate.

Table 9.5. Eastern Deepwater Shark 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.

Parameter	Value	Parameter	Value
Reference_Years	1997 - 2004	Scaling	0.0743
CE_Target	1.1592	Last Year's TAC	47
CE_Limit	0.483	Ctarg	134.443
CE_Recent	0.5332	RBC	9.993
Wt_Discard	0	-	-

Table 9.6. Eastern Deepwater Shark 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 (Sporcic and Haddon, 2018a). GeoMean is the geometric mean catch rates. TAC refers to the Total Allowable Catch (t).

Year	Catch	Discards	Total	State	CE	GeoMean	TAC
1992	4	0	4.232	0			-
1993	23	0	22.950	0			-
1994	43	0	42.750	0			-
1995	82	0	82.247	0	2.5450	4.7268	-
1996	288	0	287.778	0	2.6525	2.5186	-
1997	157	0	157.159	0	1.6361	1.3790	-
1998	192	0	192.378	0	1.3747	1.1839	-
1999	147	0	146.646	0	1.1579	0.9711	-
2000	154	0	154.416	0	1.2259	1.2127	-
2001	119	0	119.493	0	1.1293	1.1063	-
2002	130	0	130.456	0	1.1450	1.0819	-
2003	98	0	97.858	0	0.7970	0.8292	-
2004	77	0	77.136	0	0.8075	0.7738	-
2005	47	0	47.427	0	0.7704	0.8602	92
2006	45	0	45.358	0	0.7674	0.7228	92
2007	13	0	13.119	0	0.7296	0.2838	21
2008	17	0	16.590	0	0.9746	0.5631	50
2009	48	0	47.514	0	0.9569	0.8048	75
2010	26	0	25.668	0	0.5852	0.4789	85
2011	31	0	30.619	0	0.5148	0.4745	85
2012	30	0	30.179	0	0.5673	0.4722	85
2013	21	0	21.278	0	0.5297	0.4545	85
2014	23	0	23.021	0	0.5460	0.4212	47
2015	18	0	18.343	0	0.5298	0.5188	47
2016	26	0	26.216	0	0.4928	0.5964	47
2017	21	0	20.548	0	0.5644	0.5654	47

9.5.1 *Discussion*

The catch and effort database currently only has data for a limited number of the many species listed under the basket species in AFMA (2017). However, the listing omits important reporting codes (see Haddon and Sporcic, 2017) such as the 'Pearl Shark' (a combination of *Deania calcea* and *quadrispinosa* = 37020905) and the 'Black Shark - (roughskin)' (*Centroscymnus* spp. = 37020906). Even less specific are the codes 'dogfishes' (37020000) and 'Shark Other' (37990003), which were the primary reporting categories prior to 1995, which is the start year for the deepwater shark CPUE analyses, although those codes have been almost negligible since about 2003. The main species in the logbooks currently is still the 'Pearl Shark' code (37020905) which is specifically not included in the Management Arrangements booklet (AFMA, 2017). In previous years these composite codes for the logbooks were used in the standardizations and it would appear that they are accounted for in the catch disposal records as the end-of-season total catches can only be approximated by the log-books if the composite codes are included. For these reasons the standardizations were conducted including the composite codes and the CPUE document (Sporcic and Haddon, 2018a) should be inspected for details of these analyses. The current listing of deepwater shark species includes a number of *Etmopterus* species which have only recently been described beyond *Etmpoterus* A, B, C, D, and E. Given the difficulty in identifying such species it would appear ambitious to expect untrained commercial fishers to be able to identity these new species rather than use a generic 'Pearl' shark category. It is recommended that such details be clarified in future management arrangement booklets.

By contrast to previous Tier 4 analyses, catches in this analysis are based on open areas only. Catches of deepwater sharks in the east dropped rapidly in 2007 following the onset of the deepwater closure (Figure 9.3; Table 9.6). There was a temporary increase in 2009 when the 700 m boundary was revised to open a few parts of the closure, but catches remain low and are only increasing slowly. Given that the preferred depth of these target species can be greater than 700 m, the advent of the closure may have contributed greatly to the decline in CPUE apparent in the analysis (Figure 9.3; Table 9.6).

9.6 Western Deepwater Shark

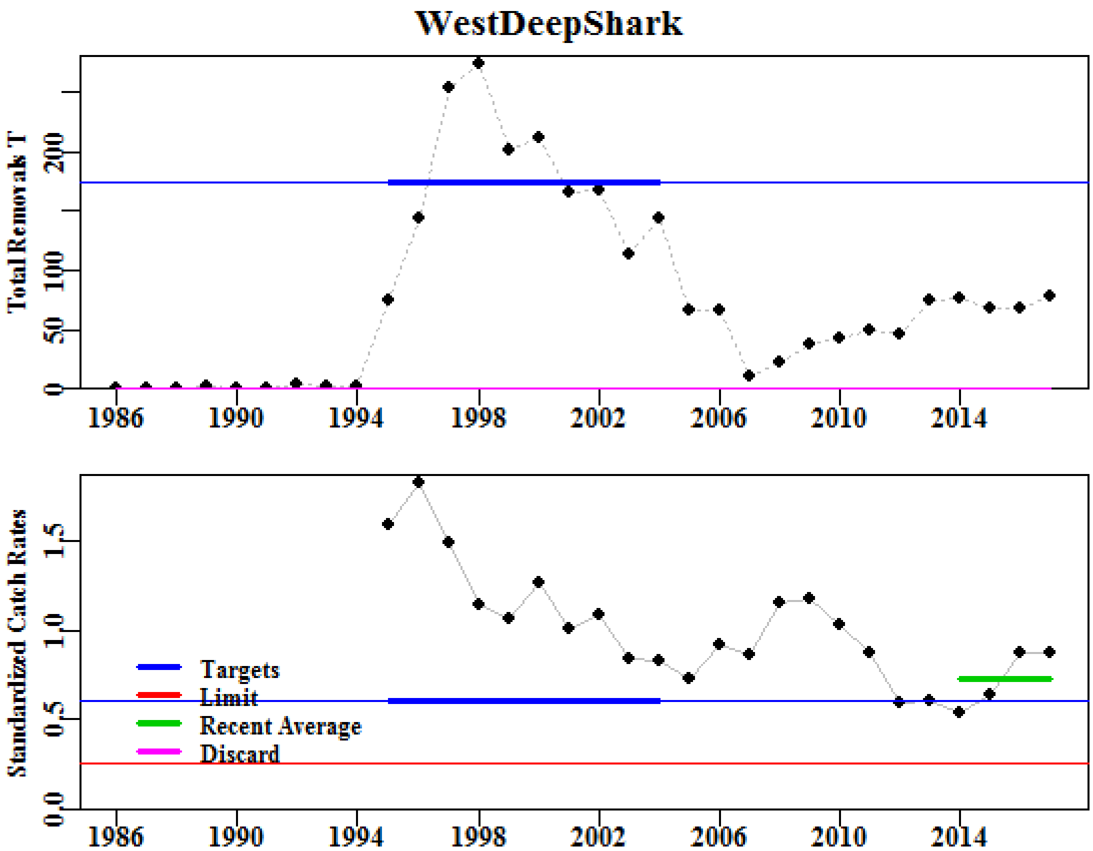

Figure 9.4. Western Deepater Shark. Top plot is the total removals with the fine line illustrating the target catch. Bottom plot represents the standardized catch rates with the upper fine line representing the target catch rate and the lower line the limit catch rate. Thickened lines represents the reference period for catches, catch rates, and the recent average catch rate.

Table 9.7. Western Deepater Shark 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.

Parameter	Value		Parameter	Value
Reference_Years	1995 - 2004	|	Scaling	1.3442
CE_Target	0.6073	|	Last Year's TAC	215
CE_Limit	0.253	|	Ctarg	174.849
CE_Recent	0.7292	|	RBC	235.036
Wt_Discard	0	|	-	-

Table 9.8. Western Deepater Shark 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 (Sporcic and Haddon, 2018a). GeoMean is the geometric mean catch rates. TAC refers to the Total Allowable Catch (t).

Year	Catch	Discards	Total	State	CE	GeoMean	TAC
1986	0.970	0	0.970	0			-
1987	0.545	0	0.545	0			-
1988	0.105	0	0.105	0			-
1989	1.490	0	1.490	0			-
1990	0.000	0	0.000	0			-
1991	0.480	0	0.480	0			-
1992	3.780	0	3.780	0			-
1993	1.995	0	1.995	0			-
1994	1.552	0	1.552	0			-
1995	75.219	0	75.219	0	1.5918	1.4865	-
1996	143.247	0	143.247	0	1.8222	1.6110	-
1997	253.317	0	253.317	0	1.4908	1.4905	-
1998	273.775	0	273.775	0	1.1480	1.1530	-
1999	201.927	0	201.927	0	1.0615	1.0124	-
2000	210.835	0	210.835	0	1.2627	1.2695	-
2001	165.234	0	165.234	0	1.0079	1.0365	-
2002	167.357	0	167.357	0	1.0901	1.2093	-
2003	113.102	0	113.102	0	0.8407	0.7995	-
2004	144.482	0	144.482	0	0.8300	0.8999	-
2005	66.806	0	66.806	0	0.7222	0.8115	108
2006	65.480	0	65.480	0	0.9179	0.9361	108
2007	10.261	0	10.261	0	0.8644	0.7633	10
2008	22.257	0	22.257	0	1.1553	1.0285	50
2009	37.634	0	37.634	0	1.1731	1.0526	63
2010	42.093	0	42.093	0	1.0267	1.0044	95
2011	49.623	0	49.623	0	0.8750	0.8838	143
2012	45.989	0	45.989	0	0.5968	0.6307	215
2013	75.439	0	75.439	0	0.6061	0.6147	215
2014	76.399	0	76.399	0	0.5405	0.5584	215
2015	67.885	0	67.885	0	0.6318	0.6910	215
2016	67.135	0	67.135	0	0.8702	1.0084	215
2017	78.757	0	78.757	0	0.8744	1.0486	215

9.6.1 *Discussion*

The western deepwater sharks have similar issues to the eastern deepwater sharks regarding the codes used to report their catches. Thus the primary species code used relates to 'Pearl Shark' (a combination of *Deania calcea* and *quadrispinosa* = 37020905) followed by the platypus shark (which, unlike the Pearl Shark, is on the Management Arrangements list). The Platypus shark is *Deania quadrispinosa*, which is included as one of the components of the 'Pearl Shark', which suggests that the reliability of the species identities may not be high (which is no insult to the commercial fishers as taxonomically separating these species is not always straightforward). When currently management does not require the separation of inshore and offshore Ocean Perch it would be oddly inconsistent to expect fishers to separate at least 18 different species of Lantern sharks.

By contrast to previous Tier 4 analyses, catches in this analysis are based on open areas only.

9.7 Blue Eye Non-Trawl

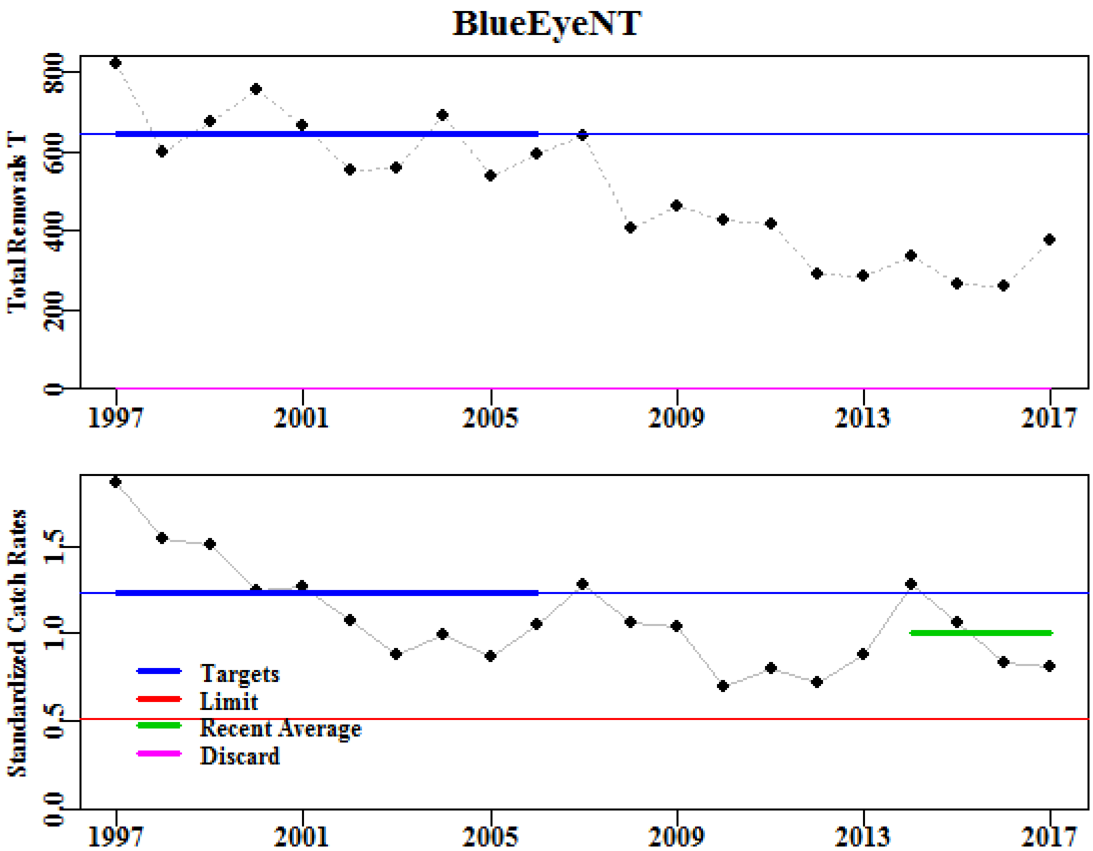

Figure 9.5. Blue-Eye. Top plot is the total removals with the fine line illustrating the target catch. Bottom plot represents the standardized catch rates with the upper fine line representing the target catch rate and the lower line the limit catch rate. Thickened lines represents the reference period for catches, catch rates, and the recent average catch rate.

Table 9.9. Blue-Eye 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.

Parameter	Value		Parameter	Value
Reference_Years	1997 - 2006	|	Scaling	0.6799
CE_Target	1.2288	|	Last Year's TAC	458
CE_Limit	0.512	|	Ctarg	645.263
CE_Recent	0.9994	|	RBC	438.697
Wt_Discard	0	|	-	-

Table 9.10. Blue-Eye data for the Tier 4 calculations. Total (t) is the sum of Discards, State (Vic, Tas and NSW), Non Trawl and SEF2 catches. All values in Tonnes. CE is the standardized catch rate (Sporcic and Haddon, 2018a). GeoMean is the geometric mean catch rates. TAC refers to the Total Allowable Catch (t).

Year	Catch	Discards	Total	State	CE	GeoMean	TAC
1997	202	0	821.654	620.141	1.8588		125
1998	474	0	597.101	123.012	1.5397		630
1999	544	0	676.578	132.608	1.5036		630
2000	658	0	757.291	98.983	1.2457		630
2001	575	0	662.430	87.133	1.2633		630
2002	453	0	555.398	102.362	1.0782		630
2003	508	0	559.752	51.704	0.8813		690
2004	627	0	691.737	64.538	0.9970		621
2005	483	0	538.353	55.638	0.8661		621
2006	548	0	592.332	44.095	1.0545		560
2007	585	0	638.553	53.102	1.2832		785
2008	373	0	408.359	34.980	1.0579		560
2009	428	0	463.579	35.090	1.0410		560
2010	383	0	426.149	43.287	0.7002		428
2011	376	0	418.651	42.377	0.8042		326
2012	259	0	290.136	31.317	0.7236		388
2013	264	0	285.982	22.135	0.8756		388
2014	318	0	337.104	18.619	1.2849		335
2015	236	0	263.983	27.591	1.0634		335
2016	242	0	257.269	15.708	0.8379		410
2017	360	0	375.817	15.708	0.8112		458

9.7.1 *Discussion*

This analysis (unlike the previous Tier 4 analysis), is based on landed catch corresponding to Zones 20 - 50, i.e., it excludes areas corresponding to seamounts. A separate seamount (Tier 5) analysis was conducted for this species.

9.8 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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9.10 Appendix: Methods

9.10.1 Tier 4 Harvest Control Rule

The data required are time series of catches and catch rates. The analyses have been conducted on total catches across the entire SESSF (including State catches, SEF2 landing records, and any discards). For some species, where there is only a single stock and a single primary fishing method, analyses are presented using standardized CPUE data (Haddon, 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 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 (2018), 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:

$$\begin{array}{ll} RBC_y = 1.5RBC_{y-1} & RBC_y > 1.5RBC_{y-1} \\ RBC_y = 0.5RBC_{y-1} & RBC_y < 0.5RBC_{y-1} \end{array}$$

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.

$$C_{\text{targ}} = \frac{\sum_{y=yr1} \; yr2L_y}{(yr2 - yr1 + 1)}$$

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%):

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

or 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, $CPUE_{targ}$, 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 standard-ized catch rates are illustrated with the target catch rate and the limit catch rate. Finally, where the data are available, plots are given of the Total removals contrasted with State removals, and of discards and non-trawl catches.

9.10.2 *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 catch rates. This is an important question because standardized commercial catch rates are used in Australian stock assessments as an index of relative abundance (Haddon, 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).

9.10.3 *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 catch rates has been developed it should be noted that this ignores all complications relating to unknown aspects of discarding behaviour (is the discard rate constant across all catch sizes, across all vessels, across all areas? etc). This means that including discard catches into the annual catch rate estimates introduces an unknown amount of uncertainty into the analysis. It should also be noted that the discard estimates are highly variable from year to year and derive from relatively small samples of all trips contributing to catches.

The method developed was to find the multiplier needed to adjust ratio mean catch rates and apply that to the standardized catch rates (Haddon, 2010). The ratio mean catch rates require the annual sum of catches for the fishery along with the sum of effort and ratio means calculated for each year. The discard estimates from the fishery can be added to the catch totals and new ratio means calculated and compared. The multiplier needed to make the same changes to the ratio mean catch rates can then be developed and applied to the standardized catch rates.

The ratio mean is simply the sum of all catches divided by the sum of effort

$$\hat{I}_{R,t} = \frac{\sum C_t}{\sum E_t}$$

where $\hat{I}_{R,t}$ is the ratio mean catch rate 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 catch rate 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 catch rate 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).

9.10.4 *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.

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.

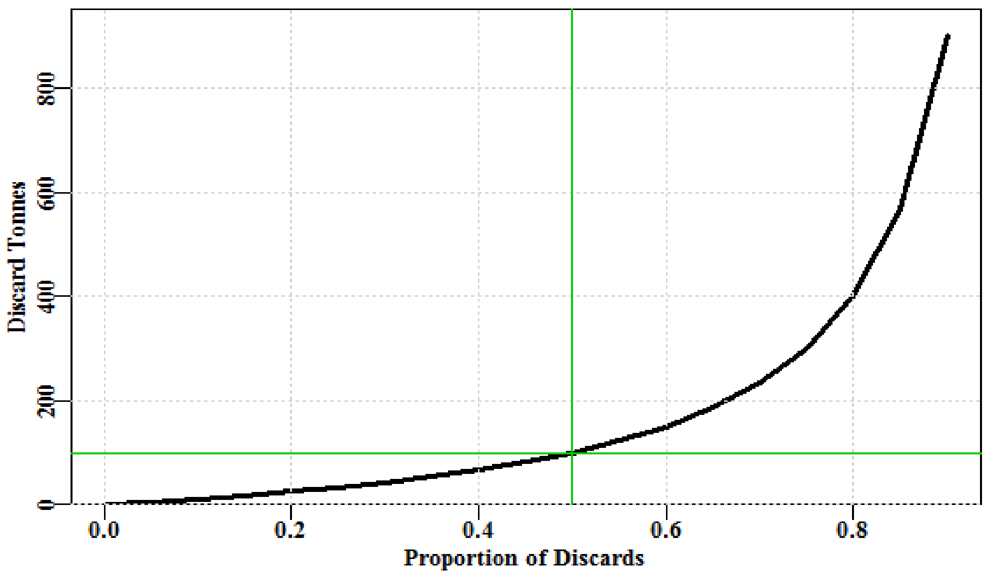

Figure 9.6. The influence of the proportion discarded on estimates of discarded catches. As the proportion of discards approaches 1.0 the multiplying effect in the estimation of discard amounts becomes greatly amplified.

9.10.5 *Selection of Reference Periods*

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

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

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

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

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

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

10. Blue-Eye Trevalla Tier 5 Eastern Seamount Assessment: Age-structured stock reduction analysis

Malcolm Haddon and Miriana Sporcic

CSIRO Oceans and Atmosphere, Castray Esplanade, Hobart 7000, Australia

10.1 Blue-Eye – Eastern Seamounts

10.1.1 *Summary*

An age-structured stock reduction analysis was conducted on the east coast seamount Blue-Eye data. However, uncertainty remains regarding many aspects of their biology and the fishery (e.g. selectivity and growth). The uncertainty regarding their natural mortality and steepness was covered by conducting a series of analyses using a matrix of values of ranging from 0.08 - 0.12 for natural mortality and 0.6 - 0.8 for steepness. For the sea-mounts all analyses were assumed to have started with an unfished stock. There was additional uncertainty associated with the value for maximum harvest rate. An array of values between 0.25 - 0.5 were all trialed with the full array of natural mortality and steepness combinations.

As there is no agreed harvest strategy or harvest control rule for Tier 5 assessments, the trajectories generated by the age-structured stock reduction analysis were each projected forward for 10 years under different constant catch regimes while searching for those catches that led to the trajectories being stable into the future. For those projections starting at less than the Commonwealth target reference depletion point it can be expected that any RBC from such analyses would be less than the constant catch that led to stability. How to select from teh range of possible constant catches that reflect the uncertainty over the maximum harvest rate remains a problem.

Constant catches leading to relative stability in depletion were estimated at about 25 t for lower productivity combinations of natural mortality and steepness (0.08, 0.6) and 48 t for higher productivity combinations (0.12, 0.8). This is comparable to the estimate of approximately 40 t from the catch-MSY analysis that was predicted to lead to the mean depletion remaining stable in the projections.

Fisheries that only have such catch data but that also require management advice are only marginally served by such ‘assessment’ methods. Such data-poor assessments are not usefully updated by including future catch levels if those catch levels came from the predictions of such an assessment. Rather, the application of such methods is effectively an admission that such a fishery should be classed exploratory. This implies that evidence needs to be gathered concerning any impact the exploratory fishing has upon the stock being fished.

10.1.2 *Introduction*

The array of fishing methods that have been used to catch Blue-Eye (*Hyperoglyphe antarcticus*) off the Australian east coast seamounts is diverse and exhibits no stable pattern of exploitation on any particular seamount (Haddon, 2014). Over the last five years the average catch was about 51 t with a minimum of 25 t and a maximum of 84 t (Table 10.1).

Table 10.1. Fishery data for Blue-eye. That from 1984 - 2016 is from the standard AFMA database, that from 1984 - 1996 derives from Tilzey (1997).

year	catch	year	catch	year	catch
1984	7	1996	16.000	2008	8.100
1985	9	1997	10.975	2009	43.003
1986	38	1998	1.590	2010	69.948
1987	105	1999	21.640	2011	147.192
1988	210	2000	7.258	2012	102.941
1989	174	2001	42.856	2013	43.887
1990	243	2002	48.983	2014	25.297
1991	181	2003	74.978	2015	50.385
1992	60	2004	47.021	2016	84.548
1993	38	2005	14.758	2017	55.603
1994	27	2006	15.431	.	.
1995	19	2007	16.174	.	.

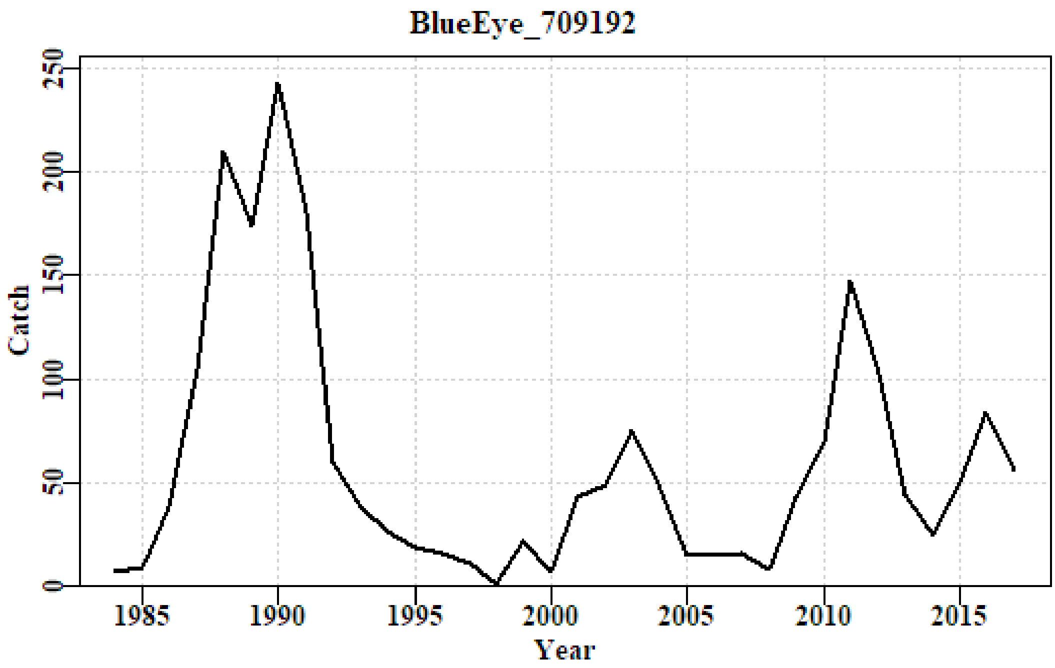

Figure 10.1. The catch history of the Blue-Eye fishery from the eastern seamount fishery.

It is possible to generate a sketch map of the distribution of the catches from the east coast seamounts, at least from 1997 to present where detailed data on location of catches is available.

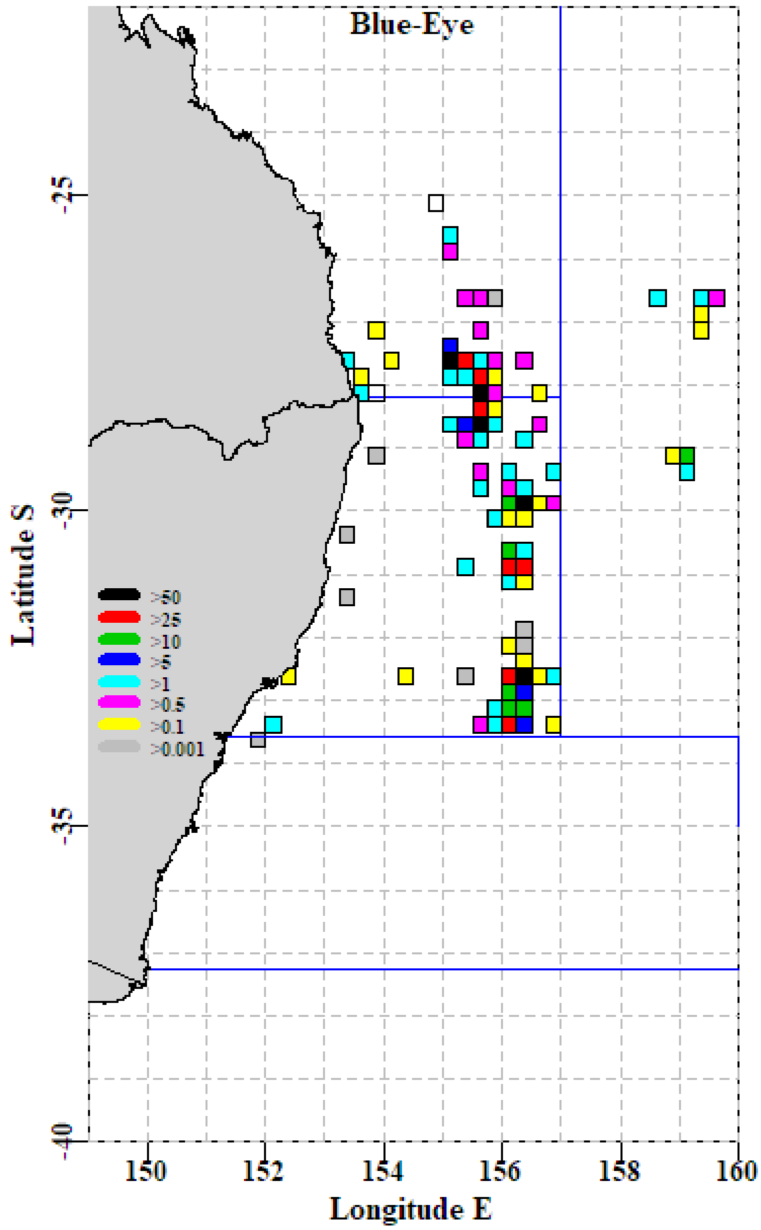

Figure 10.2. Schematic map of all Blue-Eye catches since 1997 off the east coast (zones 70, 90, and 91. The grid-scale is 1.0 and 0.25 degree and the catch-scale is tonnes.

10.1.3 *Catch by Gear*

Ten different gear types are recorded in AFMA's catch and effort database, although some appear to be erroneous or potential mis-attribution (e.g. LLP and PL; see Table 10.2). The methods that dominate in terms of total catch from 1997 - 2017 include auto-line, drop-line, hand-line, rod-and-reel and finally otter trawl. Only drop-line has a consistent catch history over the period 1997 - 2017 although in some years the amount of catch and number of records was insufficient to be representative. Some of the methods used in relatively recent years such as LDR and RR may be equivalent to hand-line (although often with hydraulic winching). Importantly for this current attempt at assessment no studies of the relative selectivity of these different gears have been conducted or are available for the east coast seamounts.

10.1.4 *Implications for Stock Assessment*

The only regularly available fisheries data available for the east coast seamounts are the commercial catches. Any recreational catches are unknown. There are no fully representative samples of age- or size- composition from the fishery although more restricted sampling of lengths and ages were made for the study by Williams *et al*. (2017). The multiple methods and episodic nature of the fishing on the eastern seamounts means there is no index of relative abundance available. This means the application of even simple surplus-production models or age-structured production models is not a viable option.

The catch-MSY method (Martell and Froese, 2013) has been implemented in a relatively simple to use R package (Haddon *et al*., 2018). This method implements a stock reduction analysis and uses a Schaefer surplus production model to simulate the underlying population dynamics and productivity. This approach has been implemented for the eastern seamounts Blue-Eye Fishery (Haddon and Sporcic, 2018). However, because Blue-Eye are relatively long-lived (~55 years or more) it can be argued that using a simple surplus production model to simulate the productivity of the stock ignores the age-structured dynamics expected for this species. To counter such an argument, this current document details an option for conducting a similar stock reduction approach but using an age-structured model for the underlying population dynamics.

Table 10.2. The catch by gear across the zones 90, 91, and 70 (the east coast above Barrenjoey and the eastern seamounts). AL - auto-line, BL - bottom-line, DL - drop-line, HL - hand-line, LDR - unknown, LLP - pelagic long-line, PL - pole-line, RR - rod-reel, TL - trot-line, and TW - otter trawl.

	AL	BL	DL	HL	LDR	LLP	PL	RR	TL	TW
1997	.	.	5.503	.	.	.	.	.	5.47	0.002
1998	.	.	1.590	.	.	.	.	.	.	.
1999	10.120	.	11.520	.	.	.	.	.	.	.
2000	1.330	.	0.520	.	.	.	.	.	.	5.408
2001	.	.	7.986	.	.	.	.	.	.	34.870
2002	2.100	.	44.114	.	.	.	.	.	.	2.769
2003	7.230	.	54.380	.	.	.	.	.	.	13.368
2004	6.080	.	5.165	.	.	.	.	.	.	35.776
2005	0.011	1.55	11.120	.	.	.	.	.	.	2.077
2006	5.555	.	9.860	.	.	0.016	.	.	.	.
2007	.	.	2.700	0.400	.	.	.	.	.	13.074
2008	.	.	8.100	.	.	.	.	.	.	.
2009	4.585	.	25.560	.	.	.	3.138	7.550	.	2.171
2010	.	.	13.160	.	.	.	.	56.788	.	.
2011	40.196	.	27.013	17.091	.	.	.	59.934	.	2.957
2012	36.777	.	16.179	21.171	.	.	.	14.782	.	14.031
2013	3.853	.	0.529	24.083	.	.	.	14.125	.	1.296
2014	4.505	.	0.510	19.932	.	.	.	0.350	.	.
2015	4.322	.	45.384	.	0.679	.	.	.	.	.
2016	5.308	.	69.647	4.000	5.593	.	.	.	.	.
2017	1.294	1.20	40.585	8.502	4.022	.	.	.	.	.
Total	133.266	2.75	401.125	95.179	10.294	0.016	3.138	153.529	5.47	127.799

10.2 Age-Structured Stock Reduction Modelling

10.2.1 *Introduction*

A stock reduction analysis uses a mathematical model to describe the dynamics of a fishery by simulating the stock dynamics and each year removes the known catches. The model used to simulate the dynamics needs to allow for changes in the stock biomass each year (natural mortality, fishing mortality, individual growth, and recruitment). It can do this with a simple or a more complex model. The stock may be assumed to start off in an unfished state or at some level of depletion. Essentially the model is used to simulate the stock productivity and its response to fishing pressure.

Using a surplus production model to describe the dynamics means there are few model parameters required (perhaps *r*, *K*, and *Binit*; see Haddon, 2018) along with the time-series of catches. Such an approach compresses the details of the stock dynamics into these simplified parameters, which for a long-lived species, might intuitively appear to be too great an approximation. Alternatively, one could use an age-structured production model. However, this would require more information, including a description of the growth (length-at-age and weight-at-age), maturity (maturity-at-age), a stock recruitment relationship (steepness and unfished recruitment), selectivity-at-age, and the natural mortality rate. As a minimum this entails many more parameters, which for a relatively data-poor species may not be well known or only known for stocks in different areas or countries. However the stock reduction is structured, the expected output is one or more stock biomass trajectories with associated harvest rates and depletion levels relative to unfished levels.

When the only data from a commercial fishery are the catches then any stock reduction can only provide an estimate of the minimum unfished biomass required to account for those known catches. With age-structured dynamics one would search for the unfished recruitment, log(*R0*), which would allow the catches to be taken without the stock going extinct (which is equivalent to the harvest rate reaching 1.0, implying 100% of exploitable fish are taken in a single year). In addition, if a plausible argument can be made, perhaps using a weight of evidence approach, for some other upper limit on the maximum harvest rate expected to have occurred. This can further constrain the lower limit of productivity and improve the plausibility of any result.

Unfortunately, without information concerning how a fishery may have influenced the stock (a trend in CPUE or survey abundance through time, the age- or length-composition of catches through time, or estimates of total mortality on the stock) then there remains no information on what the upper limit of unfished biomass may be. For example, 50 times the minimum unfished biomass would enable the same catches to be taken as 10 times the minimum unfished biomass, albeit at a different harvest rate, but without further information, which scenario is closer to reality would remain unknown. Thus a different strategy is required to set an upper limit on total productivity for a stock. Ideally, one would have available other constraints on the dynamics that could restrict the possible stock reduction trajectories, even if it were something simple such as the representative catch-rates in one year are known to have been much lower than in a different known year. Such constraints can be included in the analysis to eliminate what would become implausible stock reduction trajectories. Bentley and Langley (2012) adopt the phrase “thread the needle” to describe their ‘Feasible Stock Trajectories’ approach, which involves searching for stock reduction trajectories (threads) that meet or pass through an array of constraints (needles) in the process of eliminating implausible trajectories. This descriptive phrase derived from Walters *et al*. (2006) who used the phrase to relate to reconciling multiple sometimes inconsistent data sets within a stock reduction framework. Something like the Feasible Stock Trajectories (FST) approach seems the only approach applicable given the truly data-poor situations being considered in the eastern seamounts with respect to Blue-Eye.

10.2.2 *Possible Implementation*

One such approach is described briefly by Cordue (2018). For stocks with only commercial catch data, and in the context of some orange roughy (*Hoplostethus atlanticus*) fisheries, Cordue suggested that:

"A given catch history implies a minimum level of virgin biomass – the amount necessary to allow the catch to have been taken. Also, the catch cannot have reached 100% of the available biomass in any year as it is not physically possible for vessels to take every last fish. In these assessments three different levels of maximum exploitation rate (50%, 20%, 10%) were used to calculate a virgin biomass consistent with the maximum exploitation rate and the given catch history. A simple model with deterministic recruitment, a Beverton Holt stock recruitment relationship (steepness = 0.75), fixed natural mortality (0.045), and a single fishery (at the end of the year) on the spawning fish was used to do the calculations." (Cordue, 2018, p2)

Such an approach can generate time-series of harvest or exploitation rates, spawning biomass, exploitable biomass, and depletion relative to unfished biomass (*B0*). In the case described in the quotation above, however, the result would be a single set of such outputs for each stock examined. One major problem with this approach is it ignores the uncertainty that surrounds the adopted values for natural mortality and steepness (and the other biological properties used to set up the simple age-structured model). In addition, the selection of the plausible values of harvest rate appears limited and somewhat subjective when this are the only constraint imposed on the dynamics of the stock reduction.

What appears to be recommended is to use an age-structured model with deterministic dynamics based on the average recruitment predicted by a Beverton-Holt stock recruitment curve from a fixed natural mortality rate and a fixed steepness. This is to be applied to the known catches from defined fishing grounds. The only source of uncertainty that appears to be included is to assume a different fixed maximum possible level of harvest rate (exploitation rate) over the known catch history. Cordue (2018) implemented this procedure using CASAL (Bull *et al*., 2012) and, for each given maximum harvest rate, presumably searches for the unfished recruitment levels (log(*R0*)) that produce a productivity level for the stock that, when it has the known catches removed, leads to a maximum harvest rate in at least one year for each given stock.

Relying on selected single values for the variables that significantly influence productivity will likely provide an inadequate resolution of the potential variation in the population dynamics inherent to each stock being considered. Preferable to this restrictive methodology would be, as a minimum, to consider a grid of values across the natural mortality and the steepness with each combination being trialed over a range of maximum harvest rates. In most highly data-poor situations where only catches are known it would be unusual if the biological properties required to implement an age-structured production model were well known. So, in addition, alternative scenarios involving the growth and maturity characteristics could also be considered. Finally, the selectivity of fishing can be very difficult to characterize if there are multiple methods in a fishery, such as for Blue-Eye. This too may need to be considered and varied if the full uncertainty in the productivity is to be characterized. Here these extra sources of uncertainty are not considered and so the results produced must be considered in the light of the fact that not all sources of uncertainty have been explored.

10.3 Methods

A more general implementation of an age-structured stock reduction analysis can be made by using a simple age-structured model of population dynamics (see *Appendix 1:Age-Structured Model*

Equations). Akin to the catch-MSY approach, future versions of this age-structured stock reduction analysis could include a range of possible initial depletion levels, but for now the simplest case is where the stock concerned begins in an unfished state. In that way one only has to search for a value of unfished recruitment, log(*R0*), that generates stock dynamics that account for the known catches and maximum harvest rate assumed for the fishery. If any other constraints are known for the fishery these too could be included. However,given the multiple fishing methods used and the episodic nature of fishing for Blue-Eye on any single seamount the only fisheries data available for the eastern seamount Blue-Eye remains the catches (Table 10.1, Figure 10.1).

10.3.1 *Growth Characteristics*

The growth characteristics of Blue-Eye are known to vary by region (Williams et al, 2016, p38 - p59). Three sources of growth estimates and weight-at-age estimates were considered (Table 10.3).

Table 10.3. Alternative values for constants used to represent plausible values for different constants used to characterize the properties of the age-structured population.

	Tilzey, 1997	Smith and Wayte, 2004	Williams et al., 2016
Linf	92.950	92.950	88.826
K	0.080	0.080	0.183
t0	-5.555	-5.555	-2.370
WatAa	0.018	0.018	.
WatAb	3.016	3.016	.

The expected length-at-age parameters (L_∞, K, and t_0) differ by gender but average values can be used. From Tilzey (1997) to Smith and Wayte (2004) the same values were presented, later analyses used other values.

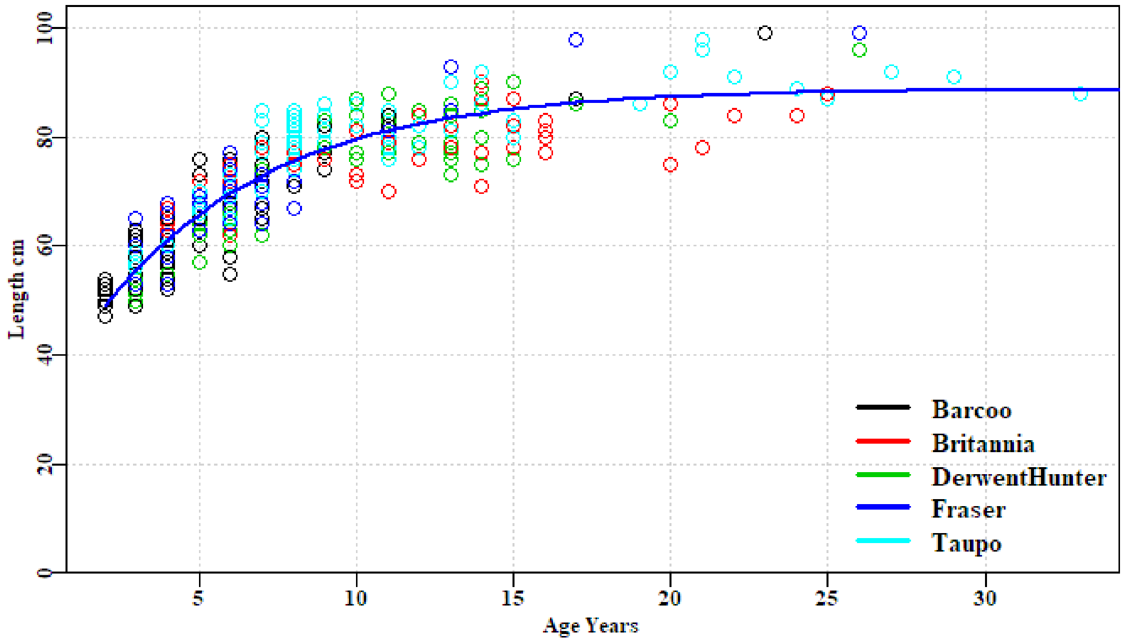

Figure 10.3. The length-at-age data for five seamounts with data ranging from 2 - 33 years of age and lengths 47 - 99. The optimum von Bertalanffy curve parameters were *Linf* = 88.8266, K = 0.18285, and t_0 = -2.3773. See Figure 2 for locations.

10.3.2 *Biological Properties*

Biological properties were obtained from earlier texts (Tilzey, 1997; Smith and Wayte, 2004) and were consistent through time although their origins were not always clear.

Table 10.4. The biological and fishery properties assumed to represent Blue-Eye taken in the south-east seamounts. The range of *M* and *h* are indicated by the low and high values with the increment in the inc column.

	Values	Low	High	inc
Natural Mortality M	0.1000	0.08	0.12	0.01
steepness h	0.7000	0.60	0.80	0.10
Linf	88.8260	.	.	.
K	0.1829	.	.	.
t0	-2.3700	.	.	.
weight-at-age a	0.0180	.	.	.
weight-at-age b	3.0160	.	.	.
Maturity A50	11.0000	.	.	.
deltaMat	1.0000	.	.	.
Selectivity A50	10.0000	.	.	.
delataSel	1.5000	.	.	.
maxage	55.0000	.	.	.

Table 10.5. The biological and fishery properties assumed to represent Blue-Eye taken in the south-east seamounts. The range of *M* and *h* used in the analyses are indicated by the low and high values with the increment in the inc column.

	Low	High	inc	Comment
log(R0)	9.5	11	0.01	Range of Unfished log(R0)
MaxH	0.25	0.5	0.01	The range of maximum harvest rates
steepness	0.6	0.8	0.1	Range of steepness

10.3.3 *The Algorithm Used*

The approach used is to step through the combinations of log(*R0*) and *h* (steepness), which directly affect the potential productivity of the modelled stock, plus any other variations one adopts, run the dynamics for each combination and then determine which combinations generate maximum harvest rates matching the constraints assumed. The combinations and constraints were defined in Table 10.5.

In this way the implications for depletion levels and stock status given the range of possible maximum harvest rates and range of productivity can be characterized. Combinations of variables that match the constraints can then have their dynamics projected forward under different conditions of constant catch to determine the expected effect of different levels of total catch. The usual harvest control rules can also be approximated. Because this approach merely puts bounds on what might be deemed possible it is uncertain in a different manner to more usual methods of stock assessment. Currently there are no harvest control rules defined for such approaches but, until a particular HCR is agreed, one can at least search for projected catches that generally lead to the lowest and highest assumed maximum harvest rate trajectories projecting forwards in an approximately stable manner. It can be expected that those trajectories that finish in a state depleted below the Commonwealth target of 0.48_B_0_ would lead to RBCs lower than the catches that lead to stability.

10.4 Results

10.4.1 *An Example Age-Structured Stock Reduction*

We have assumed the maximum harvest rate could lie anywhere between 0.25 and 0.5, which implies that across the time series of catches the maximum harvest rate could not be greater than the set of values between those limits. The steepness adopted in this first example was 0.6. For values of log(*R0*) between 9.5 - 10.5, in steps of 0.01, the dynamics were run and the summary results are given in Table 10.5.

```
inR0 <- seq(9.5,10.5,0.01)
limitH <- c(0.25,0.5)
glb$M <- 0.08
glb$steep <- 0.6
reduct <- asmreduction(inR0,fish,glb,props,limitH=limitH)
```

Table 10.6. Summary table of outputs for the array of initial recruitment levels log(*R0*), with a natural mortality of 0.08 and a steepness of 0.6. This table is the ‘pickR’ rows of the ‘answer’ object within the ‘reduct’ object.

logR0	B0	Bcurr	depl	MaxH	logR0	B0	Bcurr	depl	MaxH
9.64	998.671	89.0957	0.0892	0.51	9.82	1195.626	331.0968	0.28	0.324
9.65	1008.708	102.4478	0.1016	0.49	9.83	1207.642	344.8977	0.29	0.317
9.66	1018.846	115.7975	0.1137	0.48	9.84	1219.780	358.7652	0.29	0.312
9.67	1029.085	129.1409	0.1255	0.47	9.85	1232.039	372.7029	0.30	0.307
9.68	1039.428	142.4786	0.1371	0.45	9.86	1244.421	386.7143	0.31	0.302
9.69	1049.874	155.8132	0.1484	0.44	9.87	1256.927	400.8028	0.32	0.297
9.70	1060.425	169.1488	0.1595	0.43	9.88	1269.560	414.9717	0.33	0.293
9.71	1071.083	182.4902	0.1704	0.42	9.89	1282.319	429.2242	0.33	0.288
9.72	1081.847	195.8426	0.1810	0.41	9.90	1295.207	443.5632	0.34	0.284
9.73	1092.720	209.2113	0.1915	0.40	9.91	1308.224	457.9919	0.35	0.279
9.74	1103.702	222.6016	0.2017	0.39	9.92	1321.371	472.5132	0.36	0.275
9.75	1114.795	236.0188	0.2117	0.38	9.93	1334.651	487.1298	0.36	0.271
9.76	1125.998	249.4679	0.2216	0.37	9.94	1348.065	501.8446	0.37	0.267
9.77	1137.315	262.9538	0.2312	0.36	9.95	1361.613	516.6602	0.38	0.263
9.78	1148.745	276.4814	0.2407	0.35	9.96	1375.298	531.5793	0.39	0.259
9.79	1160.290	290.0551	0.2500	0.35	9.97	1389.120	546.6045	0.39	0.255
9.80	1171.951	303.6795	0.2591	0.34	9.98	1403.081	561.7384	0.40	0.251
9.81	1183.730	317.3587	0.2681	0.33	.	.	.	.	.

The fully selected harvest rate, the spawning biomass, and the stock depletion level are plotted for those trajectories whose maximum harvest rate lies between 0.25 and 0.5 (Figure 10.4).

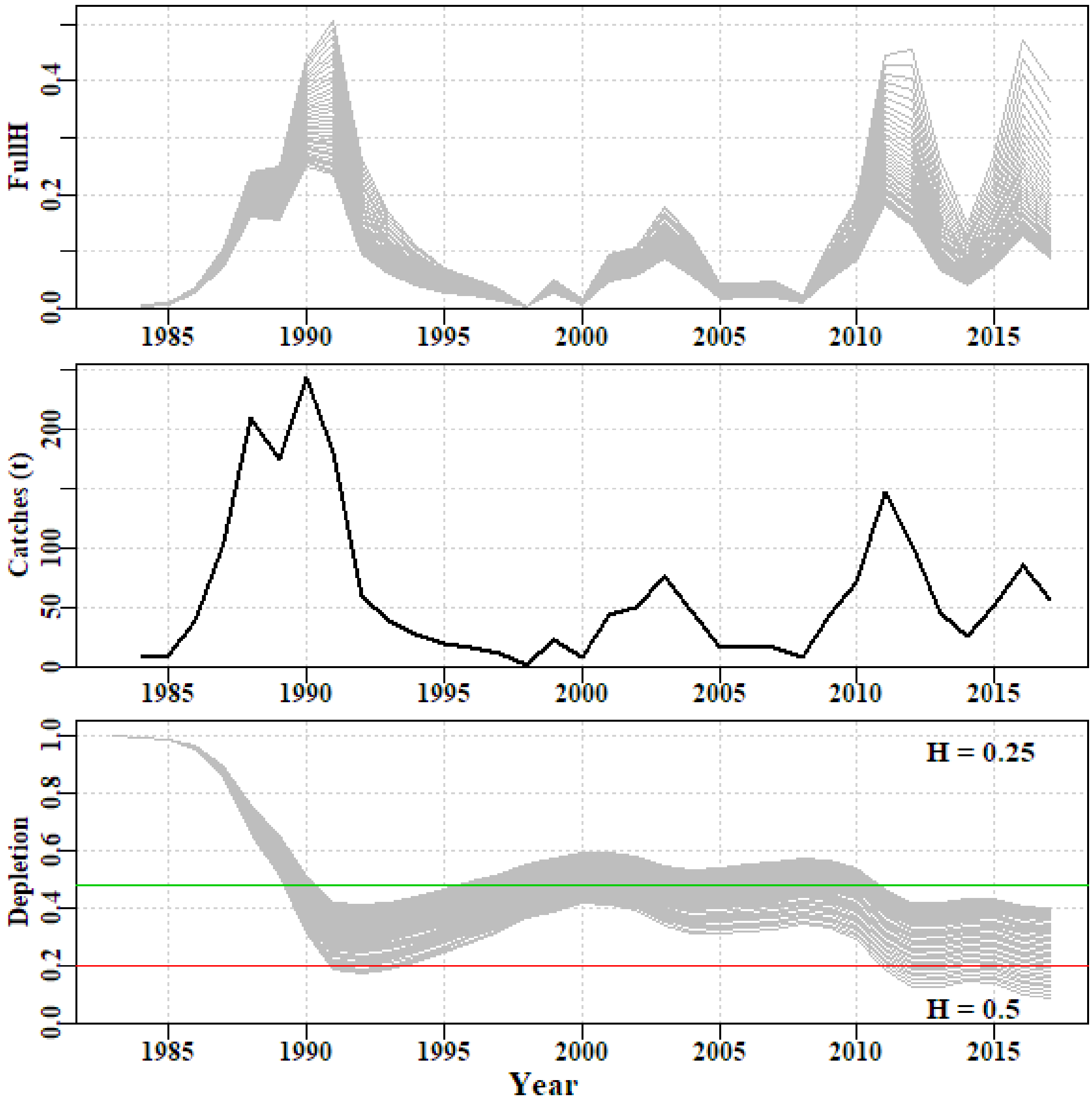

Figure 10.4. The stock reduction for east-coast seamounts using a natural mortality of 0.08 and steepness of 0.6. Each grey trajectory equates to a value of maximum harvest rate between 0.25 and 0.5 and represents a different unfished recruitment level *R0*.

Under the conditions of *M* = 0.08 and *h* = 0.6 (and all the other biological properties of growth, maturity, and selectivity, Table 10.4) the known catches lead to the stock being depleted to about 9%*B0* at an *MaxH* = 0.5. According to Table 10.5 the maximum harvest rate would need to be less than about 0.39 (39% of exploitable biomass per annum) for the stock not to be depleted below the limit reference point of 0.2 in the final year.

If the steepness, *h* is increased to 0.7 this increases the productivity but the *MaxH* = 0.5 still leads to a depletion level of about 14.5%*B0* in 2017. The *MaxH* would need to be less than about 0.41 (41%) for the stock to be above 20% in 2017. Finally, with a steepness of 0.8 as long as the *MaxH* is less than 0.5 then the catches imply that at worst, the stock is depleted to the 20%*B0* limit reference point, in 2017.

```
inR0 <- seq(9.5,10.5,0.01)
limitH <- c(0.25,0.5)
glb$M <- 0.08
glb$steep <- 0.8
reduct <- asmreduction(inR0,fish,glb,props,limitH=limitH)
```

Table 10.7. Summary table of outputs for the array of initial recruitment levels *R0*, with a natural mortality of 0.08 and a steepness of 0.8. This table is the ‘pickR’ rows of the ‘answer’ object within the ‘reduct’ object.

logR0	B0	Bcurr	depl	MaxH	logR0	B0	Bcurr	depl	MaxH
9.64	998.671	194.9038	0.1952	0.51	9.82	1195.626	420.1378	0.35	0.324
9.65	1008.708	207.1995	0.2054	0.49	9.83	1207.642	433.2096	0.36	0.317
9.66	1018.846	219.4804	0.2154	0.48	9.84	1219.780	446.3672	0.37	0.312
9.67	1029.085	231.7565	0.2252	0.47	9.85	1232.039	459.6134	0.37	0.307
9.68	1039.428	244.0371	0.2348	0.45	9.86	1244.421	472.9513	0.38	0.302
9.69	1049.874	256.3306	0.2442	0.44	9.87	1256.927	486.3836	0.39	0.297
9.70	1060.425	268.6447	0.2533	0.43	9.88	1269.560	499.9130	0.39	0.293
9.71	1071.083	280.9865	0.2623	0.42	9.89	1282.319	513.5420	0.40	0.288
9.72	1081.847	293.3624	0.2712	0.41	9.90	1295.207	527.2734	0.41	0.284
9.73	1092.720	305.7785	0.2798	0.40	9.91	1308.224	541.1094	0.41	0.279
9.74	1103.702	318.2402	0.2883	0.39	9.92	1321.371	555.0526	0.42	0.275
9.75	1114.795	330.7529	0.2967	0.38	9.93	1334.651	569.1053	0.43	0.271
9.76	1125.998	343.3213	0.3049	0.37	9.94	1348.065	583.2697	0.43	0.267
9.77	1137.315	355.9500	0.3130	0.36	9.95	1361.613	597.5482	0.44	0.263
9.78	1148.745	368.6431	0.3209	0.35	9.96	1375.298	611.9430	0.44	0.259
9.79	1160.290	381.4048	0.3287	0.35	9.97	1389.120	626.4561	0.45	0.255
9.80	1171.951	394.2387	0.3364	0.34	9.98	1403.081	641.0899	0.46	0.251
9.81	1183.730	407.1486	0.3440	0.33	.	.	.	.	.

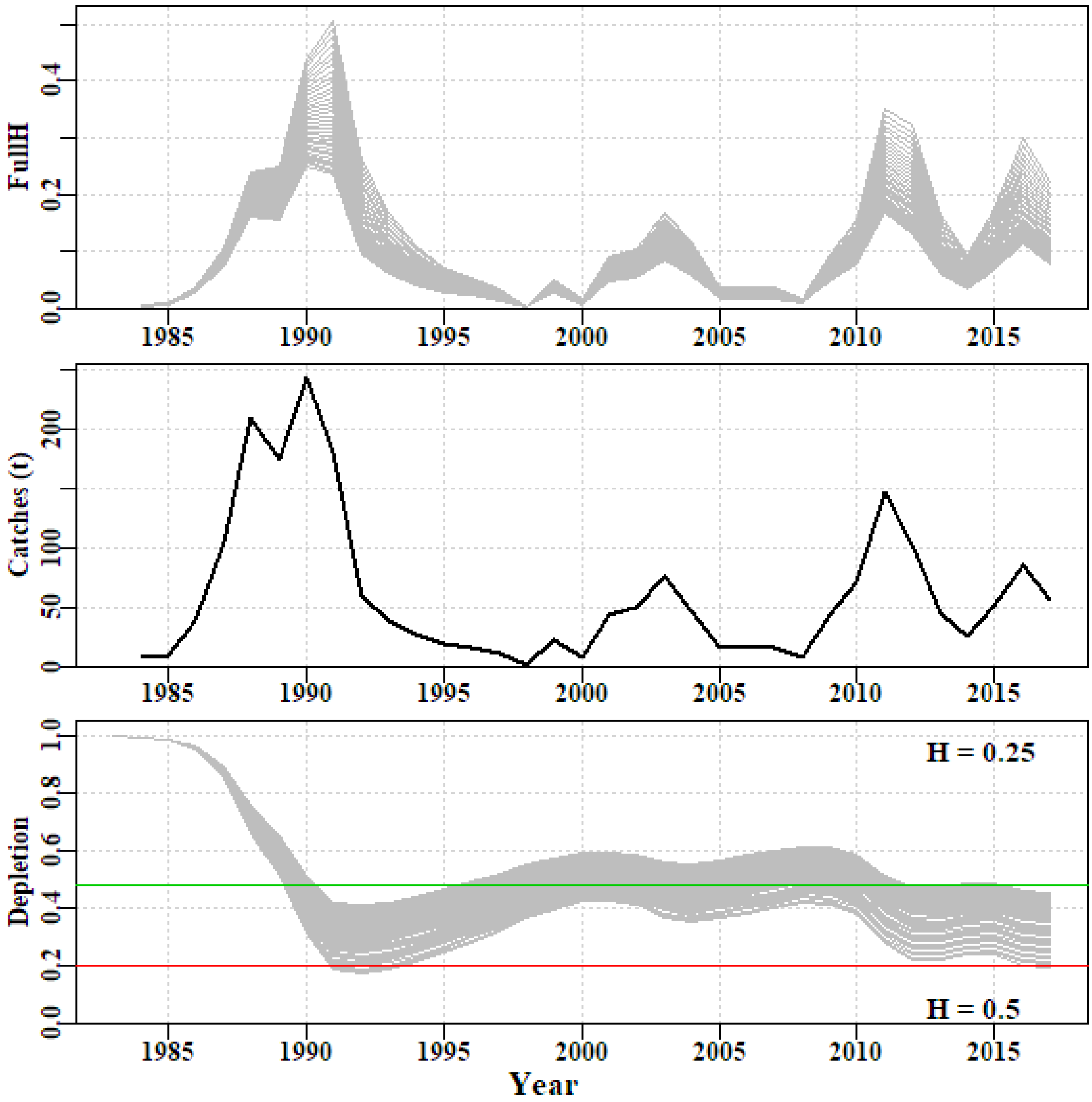

Figure 10.5. The stock reduction for east-coast seamounts using a natural mortality of 0.08 and steepness of 0.8. Each grey trajectory equates to a value of maximum harvest rate between 0.25 and 0.5 and represents a different unfished recruitment level *R0*. Note that the harvest rates at the end of the time series are lower than those seen in the lower productivity case represented by Figure 10.4.

The two spikes in harvest rate in the final years (2011 and 2016) relate to catches of 147 t and 84 t (Table 10.1). The decreases in spawning biomass and increases in depletion suggest that sustainable catches are likely to be less than such levels.

A comparison can be made of a search for the constant catch required for the two examples considered that would maintain each trajectory essentially in equilibrium (i.e. the depletion level and spawning biomass projected forward is flat). If projections of 10 years are made for the range of steepness considered at the natural mortality of 0.08 we can see that besides the lesser depletion level of the steepness at 0.8 the stock is naturally more productive and can withstand greater catches than the steepness of 0.6 (Figure 10.6).

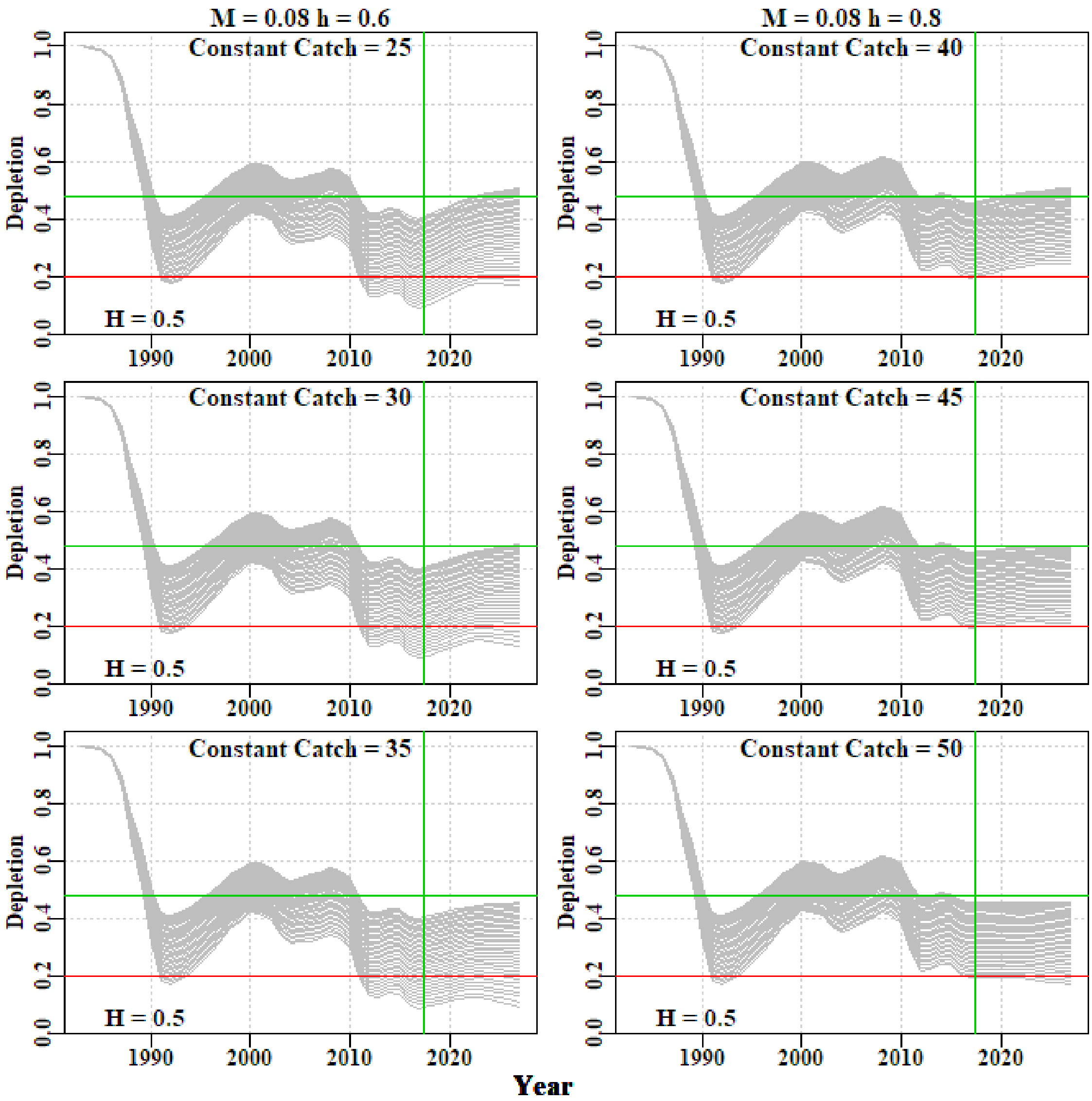

Figure 10.6. The stock reduction for east-coast seamounts using a natural mortality of 0.08 and steepness of 0.6 and 0.8 with different constant catch projections.

To obtain increases in biomass and reductions in the depletion level for all trajectories there is a distinct difference between the steepness of 0.6 and 0.8. With h = 0.6 even a constant projected catch of 30t leads to some of the trajectories for the higher *MaxH* values to decline after about 5 years of increase (middle panel Figure 10.6). So catches need to be as low as 25 t for all trajectories to increase, although this still leaves some trajectories below 20%*B0* after 10 years. With the h = 0.8 a constant projection catch of 40 t permits all trajectories to decrease the depletion level. This is partly the increased productivity implied by the higher steepness, and partly the lower level of depletion in 2017, which even for a *MaxH* of 0.5 is close to 20%*B0*. A steepness of 0.7 is in between these constant projected catches.

10.4.2 *h* vs *M* Scenarios

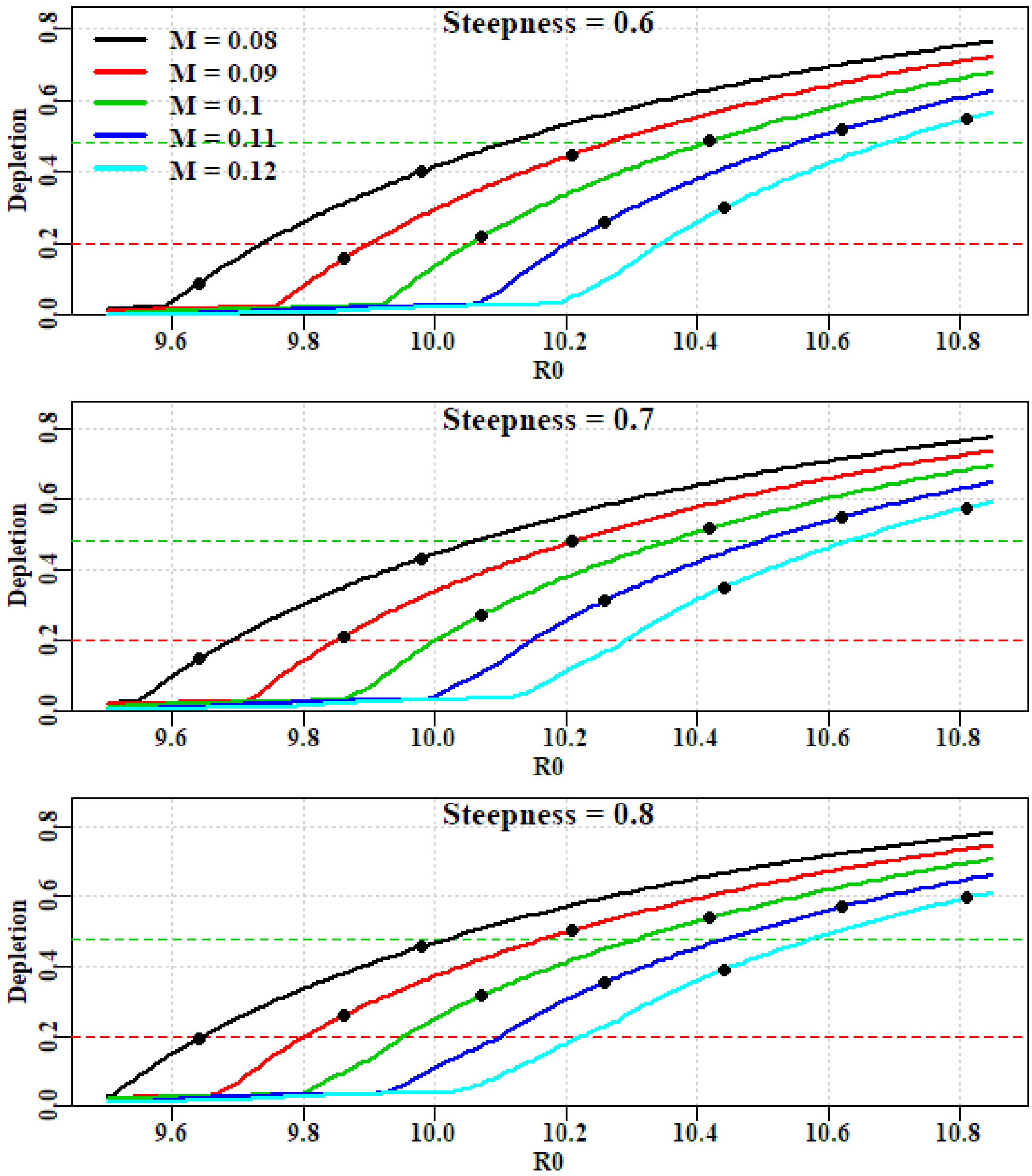

Figure 10.7. The stock depletion predicted for Age-Structured stock reductions of east-coast seamount Blue-Eye catches across the ranges of *M* and *h* depicted in Table 10.4.

The bottom set of points in Figure 10.7 along each of the different summary lines relate to the *MaxH* of 0.5 while the upper set of points in each plot relate to the implication of a maximum harvest rate of 0.25. If these points are extracted the implications for stock depletion of the range of maximum harvest rates can be made clearer.

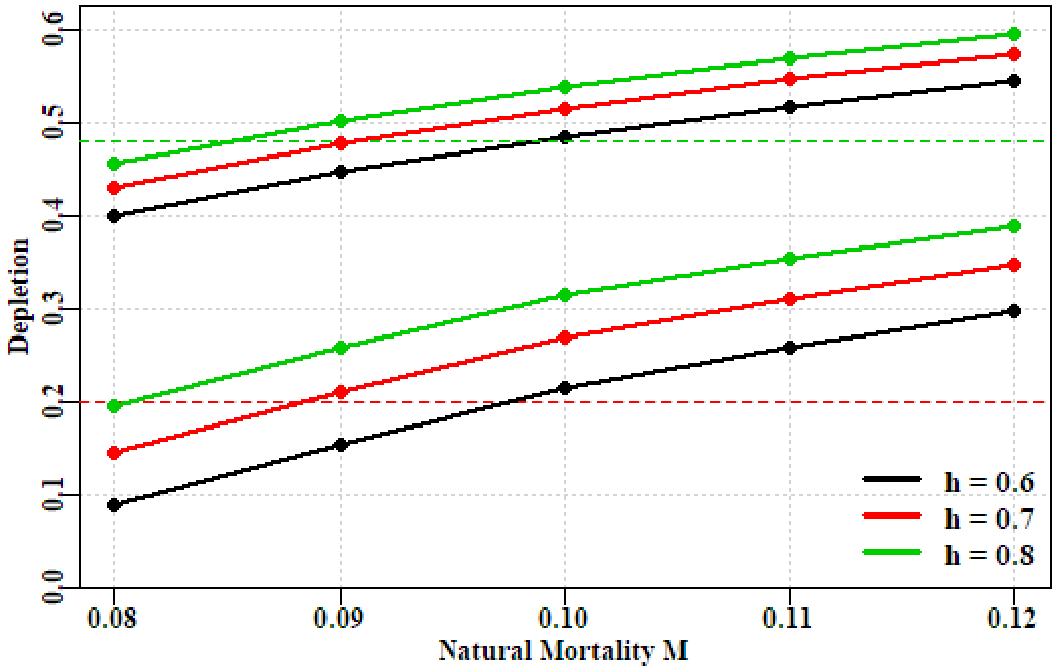

Figure 10.8. The stock depletion levels predicted for age-structured stock reductions of east-coast seamount Blue-Eye catches at the lower and upper maximum harvest rates (H=0.25 - upper set, and H=0.5 - lower set).

To ensure clarity a table of these figures is also presented Table 10.8.

Table 10.8. Summary table of predicted stock depletion levels in 2017 for different combinations of *M* and *h*. DeplHH stands for the lower depletion expected at the higher *MaxH* and DeplLH for the greater depletion at the lower *MaxH*. The *R0* are the values log(*R0*) that will permit the assumed maximum harvest rate given the known sequence of catches.

M	logR0	DeplHH	logR0	DeplLH	Steepness
0.08	9.64	0.0892	9.98	0.4004	0.6
0.09	9.86	0.1555	10.21	0.4483	0.6
0.1	10.07	0.2164	10.42	0.4858	0.6
0.11	10.26	0.2603	10.62	0.5187	0.6
0.12	10.44	0.2977	10.81	0.5471	0.6
0.08	9.64	0.1452	9.98	0.4317	0.7
0.09	9.86	0.2107	10.21	0.4788	0.7
0.1	10.07	0.2697	10.42	0.5154	0.7
0.11	10.26	0.3124	10.62	0.5474	0.7
0.12	10.44	0.3485	10.81	0.5746	0.7
0.08	9.64	0.1952	9.98	0.4569	0.8
0.09	9.86	0.2586	10.21	0.5030	0.8
0.1	10.07	0.3150	10.42	0.5388	0.8
0.11	10.26	0.3559	10.62	0.5698	0.8
0.12	10.44	0.3903	10.81	0.5960	0.8

10.4.3 *Projected Catches by Steepness and Natural Mortality*

Table 10.9. Table of catches at combinations of steepness (columns) and natural mortality (rows), which lead to slow increases in biomass and reductions in depletion level for all log(*R0*) trajectories.

	0.6	0.7	0.8
0.08	25	32	40
0.1	35	40	45
0.12	37	43	48

The catches that just lead to stock increases for all log(*R0*) trajectories are only estimated visually off of the plots (akin to Figure 10.6); hence they are only approximate. Before this approach can be used in practice it would be best to have some more formally agreed way of devising Recommended Biological Catch levels and subsequent TACs.

10.5 Discussion

The age-structured stock reduction approach described here, as applied to the east coast seamount Blue-Eye fishery, is a deterministic examination of the implications of an array of different assumptions concerning the fishery. Those assumptions principally revolve around the values taken for natural mortality and the steepness of the Beverton-Holt stock recruitment relationship. These two parameters (in combination with the estimates of growth and maturity) effectively determine the relative productivity of the stock in question. Instead of relying only on single values of steepness and natural mortality, neither of which is known with certainty, by exploring the implications of the exhaustive combinations of ranges of such values the sensitivity of the outcome (an approximate status quo catch-level) can be more fully characterized.

This method generates a table of potential catches that would seem likely to maintain the status quo or eventually lead to a slight increase in the stock size. Presumably for those combinations of parameters that predict the stock to be in a depleted state one would, in practice, recommend a lower catch than that which would lead to the status quo.

The available catches provide information regarding what the minimum biomass must have been to account for the catches for different combinations of the productivity parameters *M* and *h*. However, the catches do not provide useful information regarding what the upper bounds on stock size might be. To get any idea of what the upper bounds might be further constraints are required on what constitutes plausible outcomes from the modelling. Such constraints could take the form of some representative index of relative abundance across some years, or a time-series of lengths or ages. Such data are not available for the east coast seamount Blue-Eye fishery so instead a constraint on the maximum annual harvest rate of 0.5 was used. This seemed plausible as fewer than 50% of the seamounts were fished significantly in any one year (assuming the fishing records are spatially accurate). This upper limit is also intended to reflect the fact that fishing so far off-shore would need to maintain a relatively high catch rate to remain economic. To cover the possibility that the fishers would be more sensitive to declines in catch rate than in-shore fishers a lower limit to the maximum harvest rate of 0.25 was also used. Thus, the process involved searching for the unfished recruitment levels, log(*R0*), that would generate sufficient biomass that the catches removed would lead to a maximum harvest rate between the 0.25 - 0.5 annual maximum harvest rate.

One thing missing from such an assessment is an acceptable Harvest Control Rule (HCR). The generation of constant catches that should lead to status quo or slight stock increases over 10 years is merely indicative of the range of productivity expected; in this case from 25 t - 48 t.

Fisheries that only have such catch data but that also require management advice are only marginally served by such 'assessment' methods. Such assessments are not usefully updated by including future catch levels if those catch levels came from the predictions of such an assessment. Rather, the application of such methods is effectively an admission that such a fishery remains exploratory. This implies that evidence needs to be gathered concerning any impact the exploratory fishing has upon the stock being fished. At the very least, further constraints could be included into the stock reduction 'assessment'.

10.6 Acknowledgements

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10.8 Appendix 1: Age-Structured Model Equations

10.8.1 *Initiation of an Age-Structured Model*

At equilibrium, in an un-exploited population, the age-structure is assumed to be the result of natural mortality acting alone upon constant average unfished levels of recruitment. The equilibrium result would be a stable age distribution determined by those constant average recruitments and natural mortality. At the start of a time series, let us say in year 1, this is defined as:

Equ. 1:

$$N_{a,1} = \begin{cases} N_{0,1} = R_0 & a = 0 \\ N_{a-1,1}e^{-M} & 1 \le a < a_x \\ N_{a_x-1,1}e^{-M}/(1-e^{-M}) & a = a_x \end{cases}$$

where $N_{a,1}$ is the numbers of age a, in year 1, a_x is the maximum age modelled (the plus-group), and M is the instantaneous rate of natural mortality. In a pre-exploitation population there is no fishing mortality and the final component the above equation (where a = a_x), is referred to as the plus group because it is the series which combines ages a_x and all older ages that are not modelled explicitly. This requires the inclusion of the $(1-e^{-M})$ divisor to force the equation to be the sum of an exponential series. The $N_{0,1}$ is the constant unfished recruitment level, R_0. Sometimes this also has an e^{-M} term, depending on the timing of spawning. If the natural mortality term is included then the estimated R_0 value will be somewhat higher than if it is omitted (by $1/e^{-M}$), so it is usually simpler to omit it. This stable age distribution can also be obtained by first calculating the numbers-at-age for a recruitment of 1, or the numbers-at-age per recruit, and then multiplying that vectors of numbers by R_0., which is how it is implemented in *simpleSA::dynamics*

10.8.2 *Biological Characteristics*

Length-at-age of fish is defined by the von Bertalanffy growth function:

Equ. 2:

$$L_a = L_\infty(1 - e^{-k(a-t_0)})$$

where L_a is the mean length at age a, L_∞ is the asymptotic average maximum length, k is the grow rate coefficient, and t_0 is the length at age zero.

The mass-at-age relationship is defined as:

Equ. 3:

$$w_a = W_{aa}L^{W_{ab}}$$

where w_a is the mass at age a, and W_{aa} and W_{ab} are the coefficients that define the power relationship between length and mass.

10.8.3 *Spawning Stock Recruitment Relationship*

The biomass A_0 can be defined as the mature stock biomass that would develop given a constant recruitment level of one (i.e. $N_{0,1} = 1$ in the above equation). Thus, at a biomass of A_0, distributed across a stable age distribution, the resulting average recruitment level would be $R_0 = 1$. A_0 acts as a scaling factor in the recruitment equations by providing the link between R_0 and B_0

Equ. 4:

$$A_0 = \sum_{a=1}^{a_x} n_{a,1}\, m_a w_a$$

where m_i is the proportion mature at age a, $n_{a,1}$ is the virgin number of animals per recruit of age a in year 1, and w_a is the weight of an animal of age a. The average unfished recruitment level, R_0, is directly related to the virgin mature, or recruited, biomass, B_0

Equ. 5: $$R_0 = B_0/A_0$$

By determining A_0, from a constant recruitment level of one, the recruitment levels from realistic B_0 levels can be obtained by applying the above equation. Once R_0 has been determined the unfished number at age distribution can be obtained by substituting R_0 into the first equation. The spawning stock – recruitment relationship can be described by the deterministic form of the Beverton – Holt relationship:

Equ. 6: $$R_{y+1} = \frac{aB_y^{Sp}}{b+B_y^{Sp}}$$

where B_y^{Sp} is the mature, or spawning biomass in the in year y.

A re-parameterization of the Beverton-Holt parameters in terms of steepness, h, and B_0 is to specify a and b such that:

Equ. 7: $$a = \frac{4hR_0}{5h-1} \quad \text{and} \quad b = \frac{B_0(1-h)}{5h-1}$$

Using this re-parameterization the the number of recruits produced in year y from the spawning biomass in year $y-1$ is:

Equ. 8: $$N_{0,y} = \frac{4hR_0B_{y-1}^{Sp}}{(1-h)B_0+(5h-1)B_{y-1}^{Sp}}.$$

10.8.4 *Stock dynamics*

To describe the dynamics subsequent to population initiation (i.e. the generation of $N_{a,y}$, the number at age a in year y, for years other than 0), requires the inclusion of the stock recruitment relationship and the impact of fishing mortality. Not all age classes are necessarily fully selected, thus the fishing mortality term must be multiplied by the selectivity associated with the fishing gear for age a, s_a, described by a logistic curve:

Equ. 9: $$s_a = \frac{1}{\left(1+e^{\left(\frac{a-a_{50}}{\delta}\right)}\right)}$$

where a_{50} is the age at which 50% of individuals are selected by the fishing gear, and δ is a parameter that determines the width or steepness of the selectivity ogive. Such logistic curves are also used to describe the development of maturity within the population but in such a case the a_{50} refers to the age at 50% maturity.

A term is also needed for the recruitment in each year (stock-recruit relationship above), and this is assumed to be a function of the spawning biomass of the stock at the end of the previous year y, B_y^{Sp}.

The spawning biomass for a year y is:

Equ. 10: $$B_y^{Sp} = \sum_{a=0}^{a_x} w_a \, m_a N_{a,y}$$

If this is applied to the unfished stable age distribution this would provide an estimate of the unfished spawning biomass-per-recruit. When using difference equations (rather than continuous differential equations) the dynamics of the fishery, in terms of the order in which growth, natural, and fishing mortality occur, are important when defining how the numbers at age change. If the transition of numbers at age in year y into numbers at age in year $y+1$ is made in a number of steps this simplifies the calculation of internally consistent estimates of exploitable biomass, catch rates, and harvest rates. If it is assumed that the dynamics of a population entails that fish first grow from year $y-1$ to year y, then undergo half of natural mortality before they are fished and only then undergo the final half of natural mortality this would imply two steps to define the transition from one year to the next. The first step entails recruitment, growth from each age class to the next, and the application of the effect of half of natural mortality:

Equ. 11: $$N_{a,y^*} = \begin{cases} N_{0,y} & a = 0 \\ N_{a-1,y-1} e^{-M/2} & 1 \le a < a_x - 1 \\ \left(N_{a_x-1,y-1} + N_{a_x,y-1}\right) e^{-M/2} & a = a_x \end{cases}$$

where $N_{0,y}$ is defined by the stock - recruit relationship, ages 1 to a_x-1 are modelled by adding 1.0 to the previous year's ages 0 to $a_x - 2$ and imposing the survivorship from half the natural mortality, and the plus group (a_x) is modelled by adding 1.0 to the previous year's age a_x - 1 and adding those to the numbers in the previous year's age a_x and then applying the survivorship from half the natural mortality. The above equation thus leads to the mid-year exploitable biomass (mid-year being the reason for the $e^{-M/2}$) in year y being defined as:

Equ. 12: $$B_y^E = \sum_{a=0}^{a_x} w_a \, s_a N_{a,y^*}$$

The dynamics within any year are completed by the application of the survivorship following fishing mortality across all ages (expressed as an annual harvest rate), followed by the survivorship following the remainder of natural mortality. Natural mortality is not applied directly to the new recruits until they grow into the next year:

Equ. 13: $$N_{a,y} = \begin{cases} N_{0,y^*} & a = 0 \\ N_{a,y^*}\left(1 - s_a \hat{H}_y\right) e^{-M/2} & 1 \le a \le a_x \end{cases}$$

In the above equation, the $N_{a,y}$ refer the numbers in age a at the end of year y (i.e. after all the dynamics have occurred). The predicted harvest rate, ., given an observed or recommended catch level in year y, C_y, is estimated as

Equ. 14: $$\hat{H}_y = \frac{C_y}{B_y^E}$$

where B_y^E is defined above. The catch at age, in numbers, is therefore defined by:

Equ. 15: $$C_{a,y}^N = N_{a,y^*} s_a \hat{H}_y$$

and the total catch by mass is the sum of the separate catches at age multiplied by their respective average weights for all ages:

Equ. 16: $$C_y = \sum_{a=0}^{a_x} w_a \, C_{a,y}^N$$

Predicted catch rates also derive from the exploitable biomass and the average catchability coefficient, q:

Equ. 17: $$I_y = qB_y^E.$$

10.9 Appendix 2: R code for age-structured stock reduction

The following code is sourced into the R environment once the simpleSA R package is loaded as a library.

```
#' @title asmreduction conducts an age-structured stock reduction
#'
#' @description asmreduction conducts an age-structured stock
#'     reduction based on R functions out of the simpleSA package.
#'
#' @param inR0 the trial value of unfished recruitment R0
#' @param fish a data.frame containing the year and catch in each year
#' @param glb  the global variables defined in the data structures for
#'     simpleSA
#' @param props the biological properties of the species, including
#'     length-, weight-, maturity-, and selectivity-at-age
#' @param limitH a vecotr of two numbers denoting the lowest and
#'     highest values of the maximum harvest rate the stock is
#'     assumed to have experienced.
#' @param projyr number of years fo projecting at a constant catch. If
#'     set to 0 the contents of constC are ignored
#' @param constC the constant catch to apply in the projections
#'
#' @return a list containing a summary matrix, and the full results
#'     for fully selected harvets rate, the spawning biomass, the
#'     depletion, and the explotiable biomass in each trajectory.
#' @export
#'
#' @examples
#' \dontrun{
#' print("To be developed once an example dataset is included.")
#' }
asmreduction <- function(inR0,fish,glb,props,limitH=c(0,1),
                         projyr=0,constC=0.0) {
   steps <- length(inR0)
   year <- fish[,"year"]
   yrs <- c((year[1]-1),year)
   norigyr <- length(yrs)
   if (projyr > 0) {
      endyr <- tail(year,1)
      addyrs <- (endyr+1):(endyr+projyr)
      yrs <- c(yrs,addyrs)
      fish <- as.data.frame(cbind(year=yrs[2:length(yrs)],
                          catch=c(fish[,"catch"],rep(constC,projyr))))
   }
   nyrs <- length(yrs)
   columns <- c("R0","B0","depl","MaxH")
   answer <-
matrix(0,nrow=steps,ncol=length(columns),dimnames=list(inR0,columns))
   fullh <- matrix(0,nrow=nyrs,ncol=steps,dimnames=list(yrs,inR0))
   spawnb <- matrix(0,nrow=nyrs,ncol=steps,dimnames=list(yrs,inR0))
   exploitb <- matrix(0,nrow=nyrs,ncol=steps,dimnames=list(yrs,inR0))
   depl <- matrix(0,nrow=nyrs,ncol=steps,dimnames=list(yrs,inR0))
```

```
   for (i in 1:steps) { # step through inR0   i=1
      fishery <- dynamics(inR0[i],infish=fish,inglb=glb,inprops=props)
      answer[i,] <- c(inR0[i],getB0(exp(inR0[i]),glb,props),
                      fishery[35,"Deplete"],max(fishery[,"FullH"],na.rm=TRUE))
      fullh[,i] <- fishery[,"FullH"]
      spawnb[,i] <- fishery[,"SpawnB"]
      depl[,i] <- fishery[,"Deplete"]
      exploitb[,i] <- fishery[,"ExploitB"]
   }
   maxH <- apply(fullh[1:norigyr,],2,max,na.rm=TRUE) # max H in each
trajectory
   pickL <- which.closest(limitH[1],maxH)  # pick low H
   pickH <- which.closest(limitH[2],maxH)  # pick high H
   pickR <- pickH:pickL  # pick rows
   out <- list(answer=answer,fullh=fullh,spawnb=spawnb,depl=depl,
               pickR=pickR,yrs=yrs,inR0=inR0,limitH=limitH,
               projyr=projyr,constC=constC)
   return(out)
} # end of asmreduction

#' @title plotreduction generates a summary plot of a stock reduction
#'
#' @description plotreduction generates a summary plot of the output
#'     from an age-structured stock reduction produced by the
#'     asmreduction function, which in turn relies on the dynamics
#'     function from the aspm within the simpleSA package.
#'
#' @param inreduct the list object generates by asmreduction
#' @param defineplot boolean which determines whether a par statement
#'     is made or not. default = TRUE.
#'
#' @return nothing, but it does produce a 3,1 plot of FullH, spawning
#'     biomass, and depletion for the input stock reduction
#' @export
#'
#' @examples
#' \dontrun{
#' print("To be developed once an example dataset is included.")
#' }
plotreduction <- function(inreduct,defineplot=TRUE) {
   yrs <- inreduct$yrs
   nyrs <- length(yrs)
   pickR <- inreduct$pickR
   if (length(pickR) <= 1)
      stop("Lowest R0 value not low enough to achieve lowest limH \n")
   steps2 <- length(pickR)
   projyr <- inreduct$projyr
   if (defineplot) {
      par(mfrow=c(3,1),mai=c(0.25,0.45,0.05,0.05),oma=c(1.0,0,0.0,0.0))
      par(cex=0.85, mgp=c(1.35,0.35,0), font.axis=7,font=7,font.lab=7)
   }
   fullh2 <- inreduct$fullh[,pickR]
   ymax <- getmaxy(fullh2)
   plot(yrs,fullh2[,1],type="l",ylim=c(0,ymax),lwd=1,col="grey",
```

```
        ylab="FullH",panel.first=grid(),yaxs="i")
   for (i in 2:steps2) lines(yrs,fullh2[,i],lwd=1,col="grey")
   if (projyr > 0) abline(v=(inreduct$yrs[nyrs - projyr]+0.5),col=3)
   spawnb2 <- inreduct$spawnb[,pickR]
   ymax <- getmaxy(spawnb2)
   plot(yrs,spawnb2[,1],type="l",ylim=c(0,ymax),lwd=1,col="grey",
        ylab="Spawning Biomass (t)",panel.first=grid(),yaxs="i")
   for (i in 2:steps2) lines(yrs,spawnb2[,i],lwd=1,col="grey")
   if (projyr > 0) abline(v=(inreduct$yrs[nyrs - projyr]+0.5),col=3)
   depl2 <- inreduct$depl[,pickR]
   ymax <- getmaxy(depl2)
   plot(yrs,depl2[,1],type="l",ylim=c(0,ymax),lwd=1,col="grey",
        ylab="Depletion",panel.first=grid(),yaxs="i")
   for (i in 2:steps2) lines(yrs,depl2[,i],lwd=1,col="grey")
   abline(h=c(0.2,0.48),col=c(2,3))
   if (projyr > 0) abline(v=(inreduct$yrs[nyrs - projyr]+0.5),col=3)
   label <- paste0("H = ",inreduct$limitH[1])
   text(max(yrs)-5,0.9*ymax,label,pos=4,cex=1.1,font=7)
   label <- paste0("H = ",inreduct$limitH[2])
   text(max(yrs)-5,0.05*ymax,label,pos=4,cex=1.1,font=7)
   mtext("Year",side=1,outer=T,line=0.0,font=7,cex=1.1)
} # end of plotreduction
```

The formal structure of the output from *asmreduction* is:

```
## List of 13
##  $ answer : num [1:136, 1:5] 9.5 9.51 9.52 9.53 9.54 9.55 9.56 9.57 9.58 9.59
...
##   ..- attr(*, "dimnames")=List of 2
##   .. ..$ : chr [1:136] "9.5" "9.51" "9.52" "9.53" ...
##   .. ..$ : chr [1:5] "logR0" "B0" "Bcurr" "depl" ...
##  $ fullh  : num [1:35, 1:136] NA 0.00787 0.01019 0.04341 0.12486 ...
##   ..- attr(*, "dimnames")=List of 2
##   .. ..$ : chr [1:35] "1983" "1984" "1985" "1986" ...
##   .. ..$ : chr [1:136] "9.5" "9.51" "9.52" "9.53" ...
##  $ spawnb : num [1:35, 1:136] 868 862 853 818 721 ...
##   ..- attr(*, "dimnames")=List of 2
##   .. ..$ : chr [1:35] "1983" "1984" "1985" "1986" ...
##   .. ..$ : chr [1:136] "9.5" "9.51" "9.52" "9.53" ...
##  $ depl   : num [1:35, 1:136] 1 0.992 0.983 0.942 0.831 ...
##   ..- attr(*, "dimnames")=List of 2
##   .. ..$ : chr [1:35] "1983" "1984" "1985" "1986" ...
##   .. ..$ : chr [1:136] "9.5" "9.51" "9.52" "9.53" ...
##  $ pickR  : int [1:35] 15 16 17 18 19 20 21 22 23 24 ...
##  $ yrs    : num [1:35] 1983 1984 1985 1986 1987 ...
##  $ inR0   : num [1:136] 9.5 9.51 9.52 9.53 9.54 9.55 9.56 9.57 9.58 9.59 ...
##  $ limitH : num [1:2] 0.25 0.5
##  $ projyr : num 0
##  $ constC : num 0
##  $ M      : num 0.08
##  $ h      : num 0.6
##  $ catches: num [1:34] 7 9 38 105 210 174 243 181 60 38 ...
```

11. Blue-Eye Trevalla Tier 5 Eastern Seamount Assessment: catch-MSY analysis

Malcolm Haddon and Miriana Sporcic

CSIRO Oceans and Atmosphere, Castray Esplanade, Hobart 7000, Australia

11.1 Summary

While the catch-MSY analysis for the Blue-Eye from the eastern seamounts remains highly uncertain, it generates what appears to be a relatively robust estimate of MSY of about 46 - 50 t. The current depletion is estimated to be about 0.33_B_0_ although the uncertainty about that value is extreme.

Currently there is no accepted harvest strategy, or more specifically a harvest control rule (HCR) for such Tier 5 analyses, so generating an acceptable RBC cannot be done until such an HCR is agreed. A constant catch projection of about 40 t over a five year period leads to the predicted mean and median depletion levels staying stable, although the lowest and highest depletion levels continue to diverge. To allow for stock rebuilding, assuming the stock is close to or below the mean depletion level would presumably require a smaller RBC than 40 t, but such details need to be considered in the harvest strategy adopted for Tier 5 analyses.

This analysis assumes that the catch time series reflects changes in depletion of Blue-Eye. However, this may not be the case, as other factors unrelated to abundance can influence this (e.g. management changes - catch limits; marine closures; gear restrictions, fisher behaviour etc.). It also assumes that the fishery dynamics are adequately represented by the underlying model equations.

Fisheries that only have such catch data but that also require management advice are only marginally served by such ‘assessment’ methods. Such data-poor assessments are not usefully updated by including future catch levels if those catch levels came from the predictions of such an assessment. Rather, the application of such methods is effectively an admission that such a fishery should be classed exploratory. This implies that evidence needs to be gathered concerning any impact the exploratory fishing has upon the stock being fished.

11.2 Introduction

The methods used here are described in Haddon *et al* (2018) and relate specifically to the catch-MSY approach (Martell and Froese, 2013). The catch-MSY data-poor stock assessment method requires strong assumptions and a minimum amount and quality of data. If one has insufficient data, or only has data of poor and uncertain quality, then sometimes outcomes from a stock assessment are highly uncertain. The Blue-Eye fishery on the eastern seamounts is a difficult fishery to assess because of this.

11.3 Blue-Eye – Eastern Seamounts

11.3.1 *Introduction*

The array of fishing methods that have been used to catch Blue-Eye (*Hyperoglyphe antarcticus*) off the Australian east coast seamounts is diverse and exhibits no stable pattern of exploitation on any particular seamount (Haddon, 2014). Over the last five years the average catch was about 51 t with a minium of 25 t and a maximum of 84 t (Table 11.1).

Table 11.1. Fishery data for Blue-Eye. That from 1984 - 2016 is from the standard AFMA database, that from 1984 - 1996 derives from Tilzey (1997).

year	catch	year	catch	year	catch
1984	7	1996	16.000	2008	8.100
1985	9	1997	10.975	2009	43.003
1986	38	1998	1.590	2010	69.948
1987	105	1999	21.640	2011	147.192
1988	210	2000	7.258	2012	102.941
1989	174	2001	42.856	2013	43.887
1990	243	2002	48.983	2014	25.297
1991	181	2003	74.978	2015	50.385
1992	60	2004	47.021	2016	84.548
1993	38	2005	14.758	2017	55.603
1994	27	2006	15.431	.	.
1995	19	2007	16.174	.	.

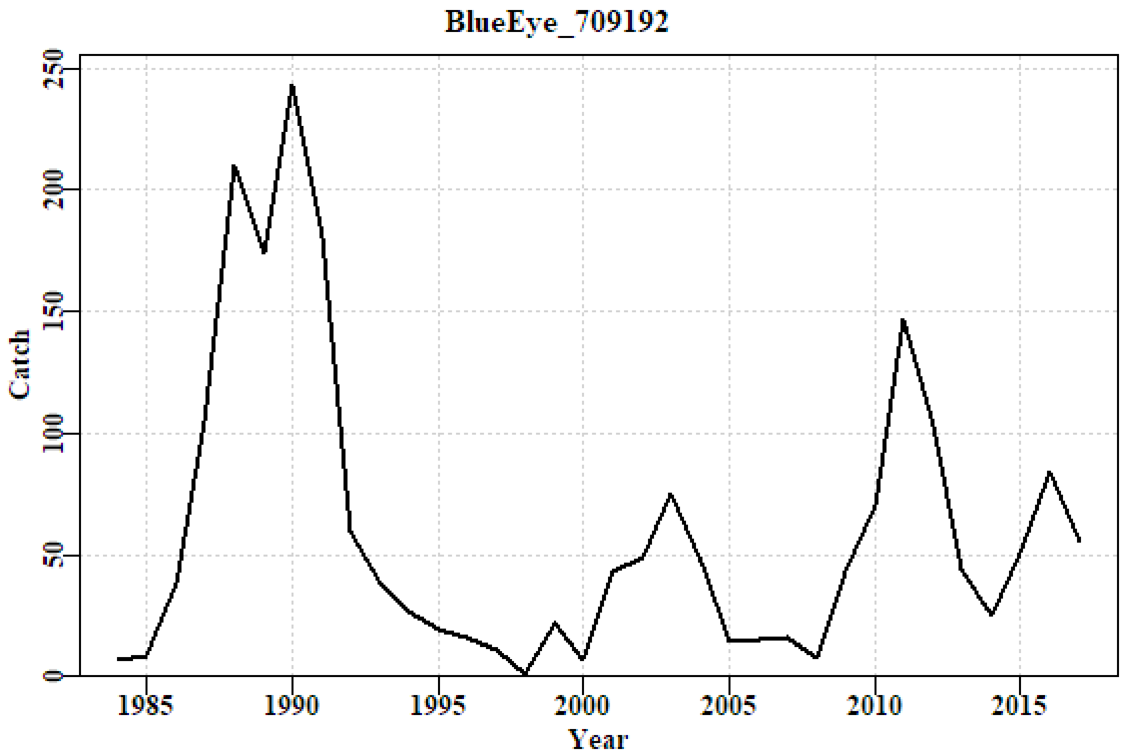


Figure 11.1. The catch (t) history of the Blue-Eye fishery from the Eastern Seamount fishery.

It is possible to generate a sketch map of the distribution of the catches from the eastern seamounts, at least from 1997 to present.

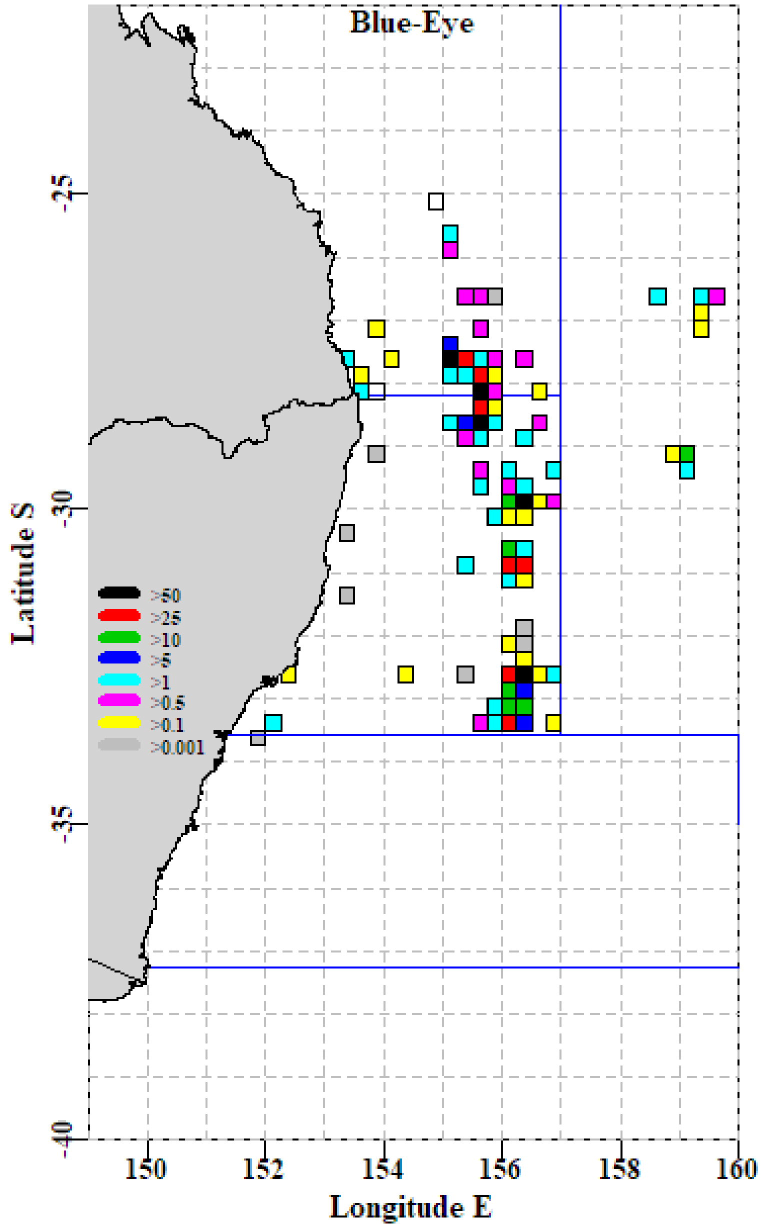


Figure 11.2. Schematic map of all Blue-Eye catches since 1997 off the east coast (zones 70, 90, and 91. The grid scale is 1.0 and 0.25 degree and the catch scale is in tonnes.

11.3.2 *Catch by Gear*

Table 11.2. The catch by gear across the zones 90, 91, and 70 (the east coast above Barrenjoey and the eastern Seamounts). AL - auto-line, BL - bottom-line, DL - drop-line, HL - hand-line, LDR - unknown, LLP - pelagic long-line, PL - pole-line, RR - rod-reel, TL - trot-line, and TW - otter trawl.

	AL	BL	DL	HL	LDR	LLP	PL	RR	TL	TW
1997	.	.	5.503	.	.	.	.	.	5.47	0.002
1998	.	.	1.590	.	.	.	.	.	.	.
1999	10.120	.	11.520	.	.	.	.	.	.	.
2000	1.330	.	0.520	.	.	.	.	.	.	5.408
2001	.	.	7.986	.	.	.	.	.	.	34.870
2002	2.100	.	44.114	.	.	.	.	.	.	2.769
2003	7.230	.	54.380	.	.	.	.	.	.	13.368
2004	6.080	.	5.165	.	.	.	.	.	.	35.776
2005	0.011	1.55	11.120	.	.	.	.	.	.	2.077
2006	5.555	.	9.860	.	.	0.016	.	.	.	.
2007	.	.	2.700	0.400	.	.	.	.	.	13.074
2008	.	.	8.100	.	.	.	.	.	.	.
2009	4.585	.	25.560	.	.	.	3.138	7.550	.	2.171
2010	.	.	13.160	.	.	.	.	56.788	.	.
2011	40.196	.	27.013	17.091	.	.	.	59.934	.	2.957
2012	36.777	.	16.179	21.171	.	.	.	14.782	.	14.031
2013	3.853	.	0.529	24.083	.	.	.	14.125	.	1.296
2014	4.505	.	0.510	19.932	.	.	.	0.350	.	.
2015	4.322	.	45.384	.	0.679	.	.	.	.	.
2016	5.308	.	69.647	4.000	5.593	.	.	.	.	.
2017	1.294	1.20	40.585	8.502	4.022	.	.	.	.	.

11.4 Methods

11.4.1 *Modified Catch-MSY*

The Catch-MSY method (Martell and Froese, 2013) could be termed a 'model-assisted' stock assessment method. It only requires a time-series of catches and a set of strong assumptions to conduct a stock assessment. As only a brief description of how it is considered to work is given here, it is recommended that users read the original paper to gain an understanding of what the method does and how it does it.

The underlying stock dynamics are described by the simple model used, which in the case implemented here is a Schaefer surplus production model with parameters r, the population growth rate, and K, the population carrying capacity or unfished biomass. The model uses ratios of the initial and final catches relative to the maximum catch to set up arrays of potential values for the initial and final depletion levels as well as for the potential range of r and K values (all of which are now modifiable by the user). The method sequentially steps through the years of the fishery by randomly selects pairs of r-K values from the wide initial ranges, which defines the initial biomass, subtracting the catches, and moving the population dynamics forward each year using the predictions from the simple model. Essentially this is a stock reduction that removes catches from a known set of dynamics. However, the very many r-K pairs used (at least 20000) are combined with a fixed set of initial depletion levels (about 20 steps between the minimum and maximum initial depletion set) to generate often 100,000s of possible stock reduction trajectories. Criteria are included (e.g. no trajectory is kept if it predicted zero biomass or biomass above *K*) that lead to numerous potential trajectories being rejected. Those that are left after all criteria for acceptance have been completed constitute the set of trajectories deemed to be consistent with the known catches. The implications of these successful trajectories are used to produce an assessment of the possible status of the stock.

The Catch-MSY method described here can be regarded as a model-assisted data-poor method. It uses a form of stock reduction analysis where the productivity of a given stock (its unfished biomass and its reproductive rate) is characterized within the parameters of a simple mathematical model, and how that modelled stock responds to the history of known catches (a stock reduction analysis) forms the basis of the alternative methods used to characterize productivity in management useable terms.

The Catch-MSY method (Martell and Froese, 2013) uses the relatively simple Schaefer surplus production model as the basis for describing the dynamics of the stock being described.

Equ. 1: $$B_{t+1} = B_t + rB_t\left(1 - \frac{B_t}{K}\right) - C_t$$

where B_t represents the stock biomass in year *t*, *r* represents a population growth rate that includes the balance between recruitment and natural mortality, *K* is the maximum population size (the carrying capacity), and C_t being the catch in year *t*. The $\left(1 - \frac{B_t}{K}\right)$ represents a density dependent term that trends linearly to zero as B_t tends towards *K*.

Importantly, for our purposes, one of the properties of the discrete Schaefer surplus production model is that MSY can be estimated very simply from the parameter estimates:

Equ. 2: $$MSY = \frac{rK}{4}$$

which reflects the symmetric production function implied by the model dynamics. A relatively simple future possible development would be to include the option of using Fox model dynamics instead of the Schaefer.

There are many fisheries within Australia that may only have a time-series of catches with only limited information related to a useable index of relative abundance. In addition, such catch time-series may not be available from the beginning of the fishery, which means that methods such as Depletion-Based Stock Reduction Analysis (Dick and MacCall, 2011) cannot be validly applied (although, as shown in Haddon et al, 2015, if sufficient years of catches are present (perhaps >25) then the method can still provide approximate estimates of management related parameters). Under such data-limited situations other catch-only based assessment methods can provide the required estimates of management interest.

11.4.2 *Stock Reduction Analyses*

As with many of the more capable catch-only data-poor approaches the Catch-MSY method evolved from the stock reduction analyses of Kimura and Tagart (1982), Kimura et al. (1984), and eventually Walters et al. (2006). It uses a discrete version of the Schaefer surplus production model (Schaefer, 1954, 1957) to describe the stock dynamics in each case. The Catch-MSY requires a time-series of total removals, prior ranges for the *r* and *K* parameters of the Schaefer model, and possible ranges of the relative stock size (depletion levels) in the first and last years of the time-series. As described by Martell and Froese (2013) the range of initial depletion levels can be divided into a set of initial values, and a stock reduction using the known total removals, applied to each of these multiple initial depletion levels combined with pairs of *r-K* parameters randomly drawn from uniform distributions across the prior ranges of those parameters. Each of these parameter pairs plus each of the initial depletion levels are projected using the total catch trajectory leading to a stock biomass trajectory which is either accepted or rejected depending on whether the stock collapses or exceeds the carrying capacity, and whether the final depletion level falls within the assumed final range.

The initial and final depletion ranges can be relatively broad. Other criteria can be included to further constrain the biomass trajectories if extra evidence is available. Such additional constraints are still under development. For example, in some of the examples you will notice that the annual harvest rates for some accepted trajectories can be very high (> 0.5), which for many (though not all) Australian species can be considered to be implausible. Now it is possible to conduct a sensitivity analysis where trajectories implying some pre-defined harvest rate will also be rejected. These high fishing mortality trajectories are only possible for the more productive parameter combinations so removing such trajectories will likely reduce the predicted MSY (maximum productivity).

11.4.3 *Results Catch-MSY*

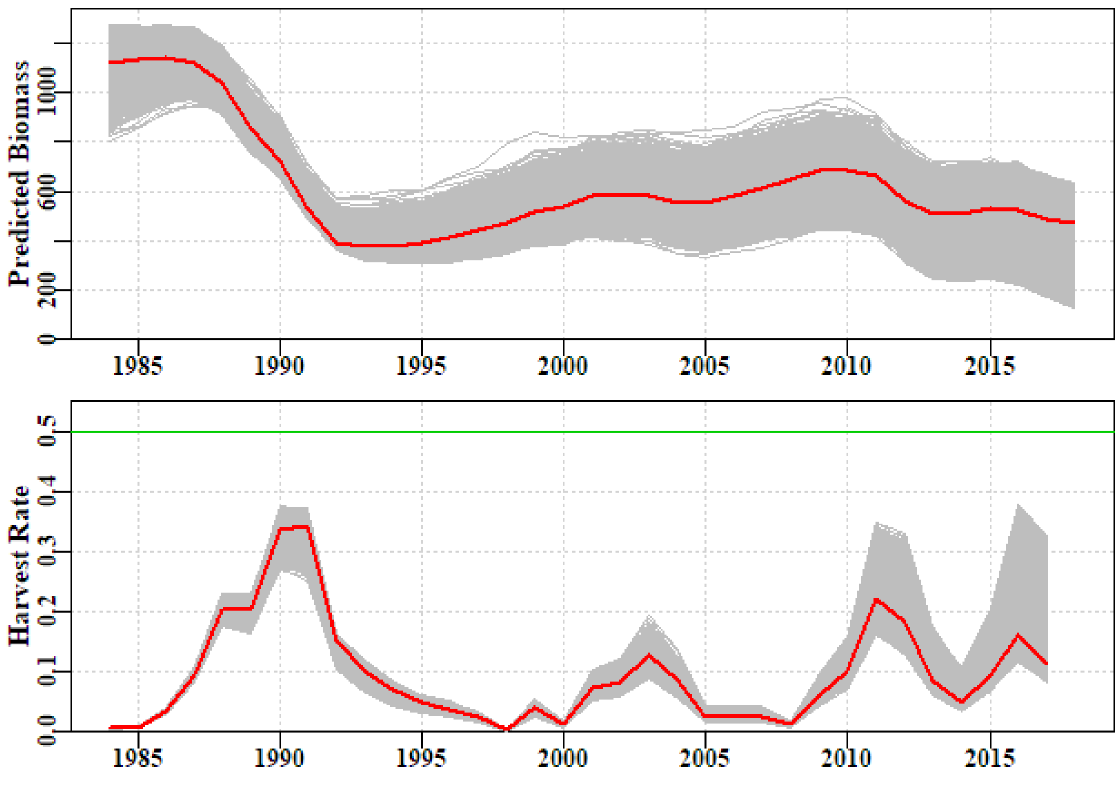


Figure 11.3. The estimated stock biomass and the implied harvest rates for the successful stock reduction analyses from the catch-MSY analysis for Blue-Eye on the eastern Seamounts. The maximum harvest rate in any one year is limited to 0.5, implying no more than 50% of exploitable Blue-eye could be taken in any single year (bottom plot). The top plot is of the successful biomass trajectories and the red line is the mean in each year.

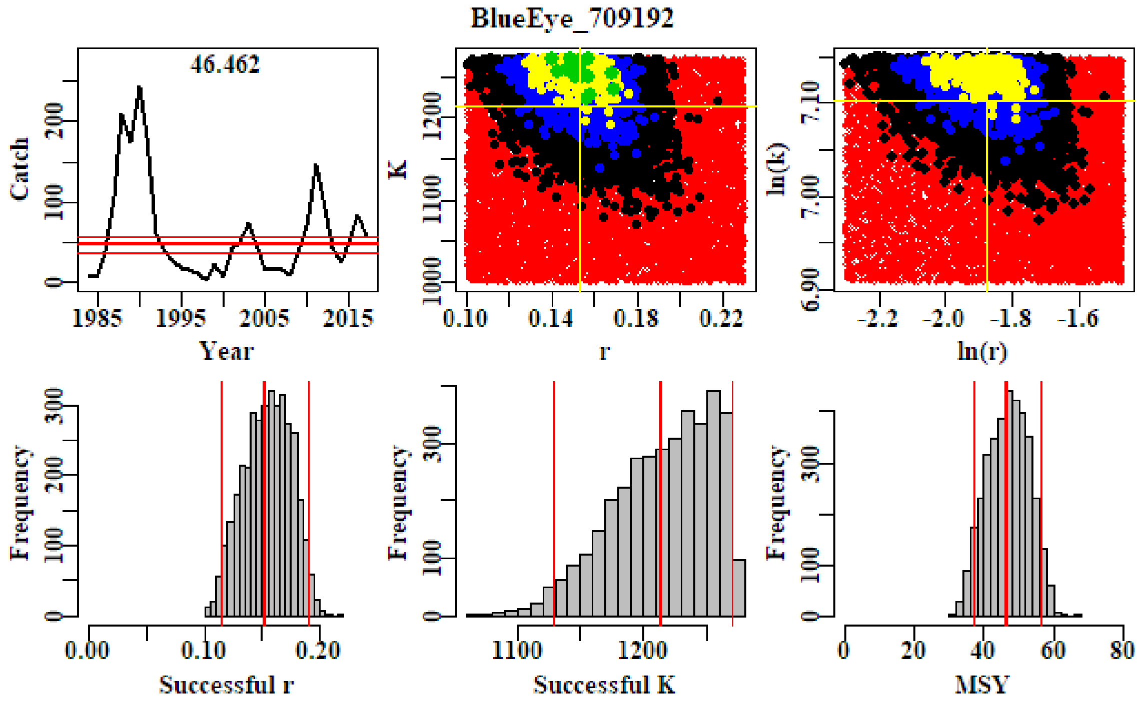


Figure 11.4. The catch-MSY analysis for Blue-Eye on the eastern Seamounts (Zones 70, 90, and 91). The ~46t is the approximate estimate of the MSY of the stock.

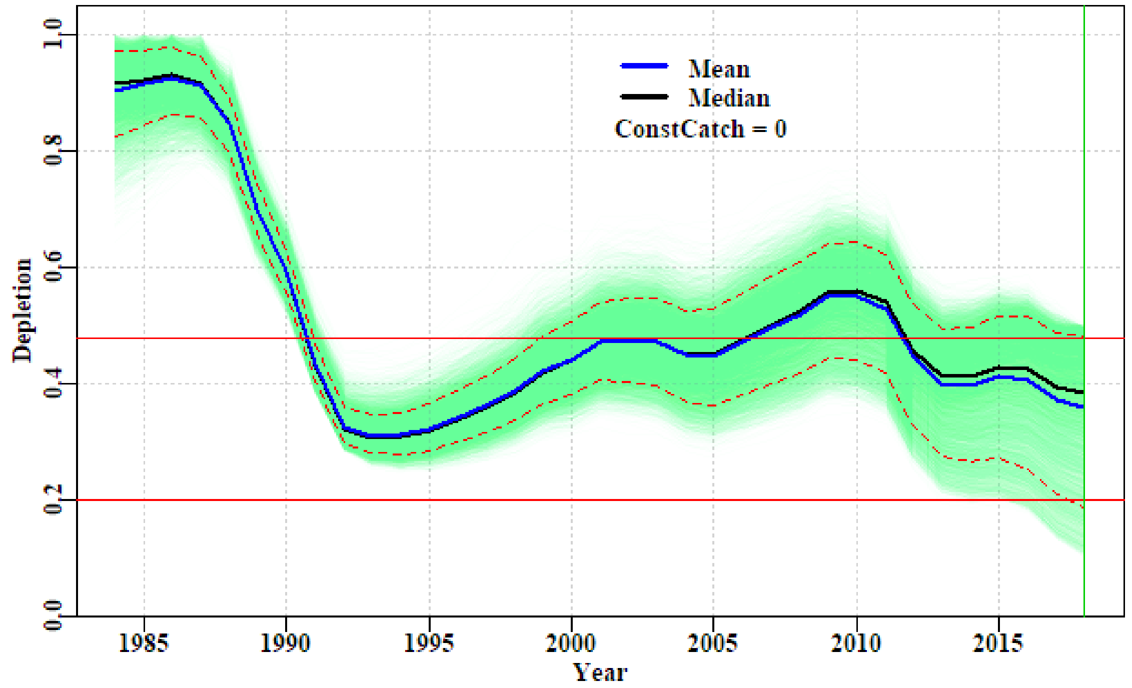


Figure 11.5. The catch-MSY analysis of stock depletion for Blue-Eye on the eastern Seamounts (Zones 70, 90, and 91). A plot of the successful depletion trajectories with the mean and median annual depletion marked with the density of trajectories represented by different intensity of colour. The lower red line is the default 0.2B0 limit reference point, while the upper is the input target reference point. Red dashed lines correspond to the 10% and 90% percentiles.

Conduct some forward projections under the assumed productivity from the catch-MSY analysis.

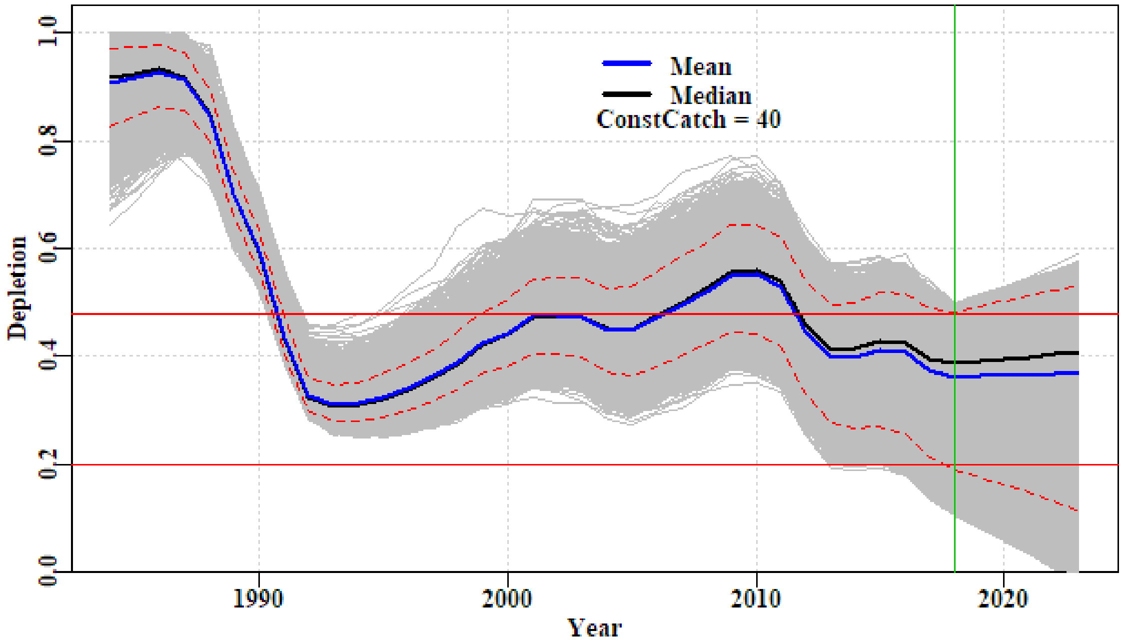
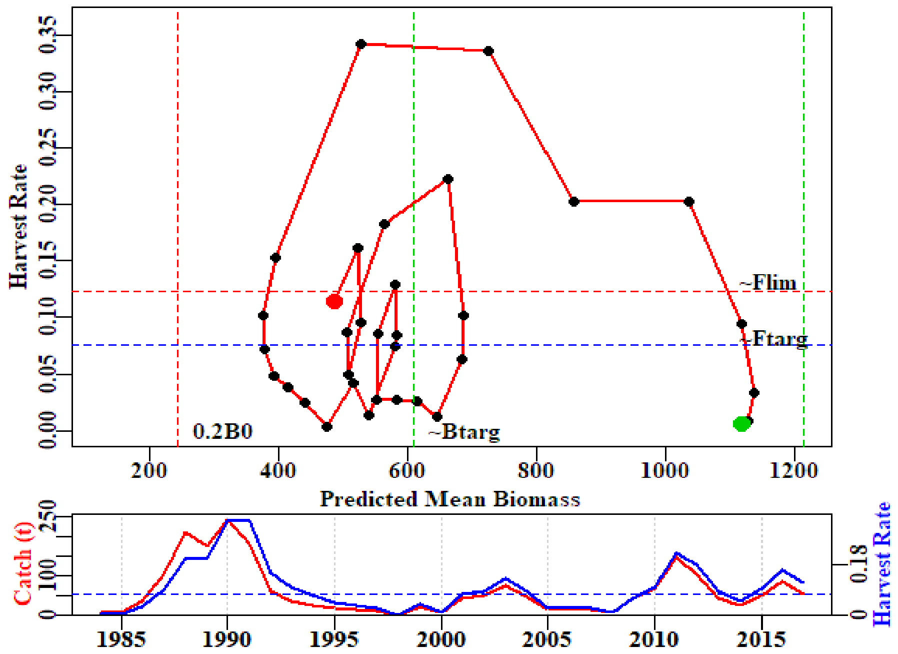


Figure 11.6. The catch-MSY analysis for Blue-Eye on the eastern seamounts (Zones 70, 90, and 91), with a projection forward for five years under a constant catch of 40 tonnes. The lower red line is the default 0.2B0 limit reference point, while the upper is the input target reference point 0.48B0. The green line denotes the end of the final year in which data are available.

11.4.4 *Phase Plot*

By plotting the predicted mean harvest rate against the mean biomass a phase plot providing a visual representation of the status of the stock is generated. While this looks convincing the high levels of uncertainty in this analysis must not be forgotten. The first year of data is a green point and the last a red point.



11.5 Discussion

Without extra information, such as some form of index of relative abundance, or estimate of abundance through time, the default assumptions of the catch-MSY lead to highly uncertain outcomes. In the base-case here it has been assumed that harvest rates never rose above 0.5 in any single year which adds a constraint to the analysis. This leads to an estimate of *MSY* of about 46t (Figure 11.4) and a maximum harvest rate in any one year of about 0.4. Because of the increased level of depletion implied by the catches, the harvest rates in 1990 and 1991 are about the same as in 2011 and 2012 and 2016 and 2017, despite the catches involved being rather smaller than those in the 1990s (Figure 11.3).

The predicted trajectory of stock depletion exhibits a strong decline in the late 1980s and early 1990s as a response to the relatively large catches taken at that time. Following that from about 1994 to 2010 the stock is predicted to have undergone some recovery such that the mean and median depletion rose above the target reference point of 0.48_B_0, *but then the catches from 2010 - 2012 and then in 2016 - 2017 decreased the stock size down to about 0.33_B_0*, with widely spread plausible trajectories and 90% percentile bounds from about 0.2 - 0.48_B_0_ (Figure 11.5).

Projecting the remaining trajectories forward under a constant catch of 40t leads to predicted stability in the mean and median depletion level (Figure 11.6). Currently, there is no accepted harvest strategy or harvest control rule for Tier 5 analyses but given the uncertainty of the analysis and the Commonwealth Harvest Strategy Policies objective of managing primary commercial stocks to a proxy of 0.48_B_0_ then presumably some level of catch less than 40t would need to be recommended. Once the SESSF RAG has recommended a harvest control rule then specific Recommended Biological Catch values could be estimated.

11.5.1 *Sensitivities*

The effect of assuming a maximum annual harvest rate of 0.5 is to lower the *MSY*, although only by between 6 - 7 t (see Appendix). The maximum harvest rate is approximately 0.6 when rather than about 0.4. Even the notion of the fishery taking 40% of all available Blue-Eye from all seamounts in particular years seems implausible for such a long lived species.

Many other sensitivities are possible (see Appendix), for example by changing the initial depletion of the seamount stock to somewhere between 0.9 and 1.0_B_0_ leads only to a slight decrease in productivity and no major change to the final depletion.

11.6 Acknowledgements

Thanks goes to the CSIRO database team for their preliminary processing of the catch data as received from the Australian Fisheries management Authority.

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11.8 Appendix: Additional Sensitivities

11.8.1 *No Maximum Harvest Rate*

The base-case assumes a maximum annual harvest rate of 0.5. A sensitivity can be conducted that examines the effect of this constraint by removing it.

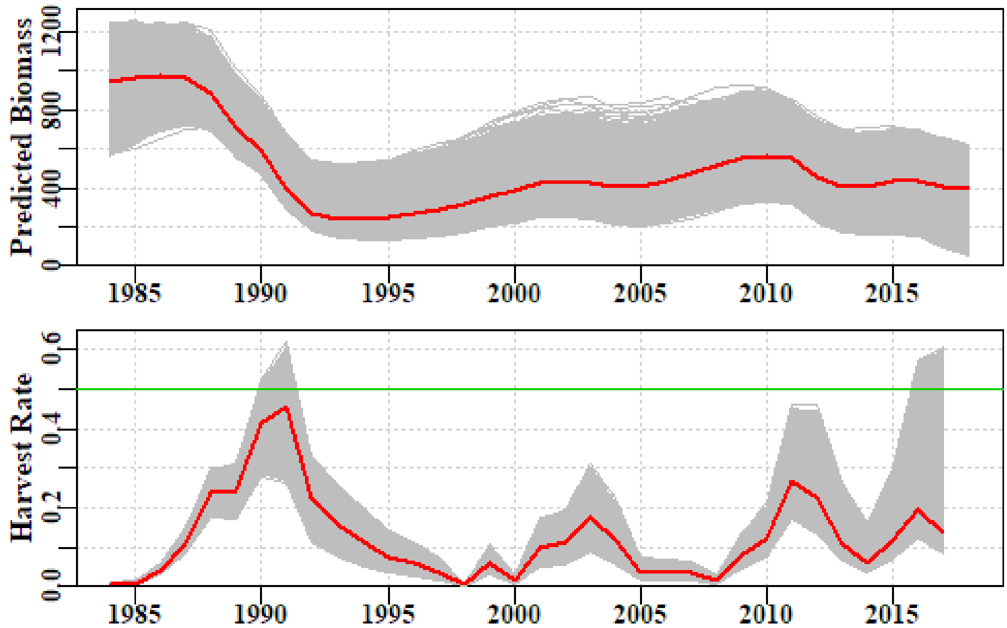

Figure 11.7. An alternative catch-MSY analysis removing the maximum harvest rate = 0.5 constraint so as to illustrate the impact of that assumption. Note the maximum harvest rate now reaches 0.6 in 1991, 2016, and 2017.

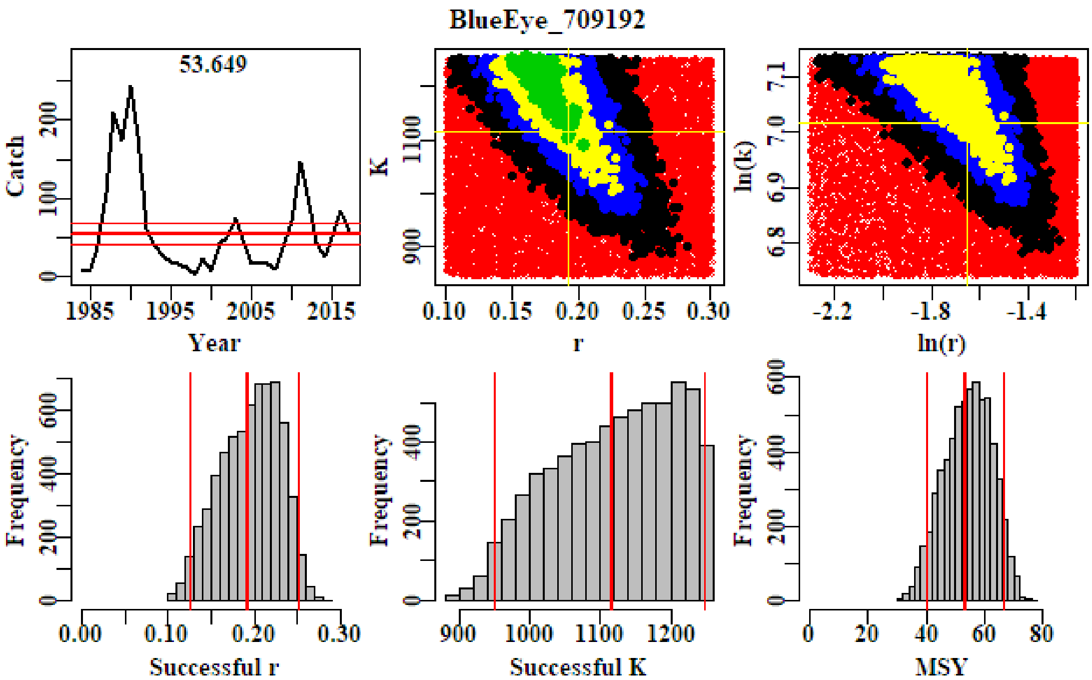

Figure 11.8. The catch-MSY analysis for Blue-Eye on the eastern Seamounts (Zones 70, 90, and 91). The ~53 t is the approximate estimate of the MSY of the stock.

11.8.2 *Initial Depletion between 0.9 – 1.0*

Rather than assume the default initial depletion level of between 0.7 - 0.95 it is simple to restrict the analysis to closer to the unfished state.

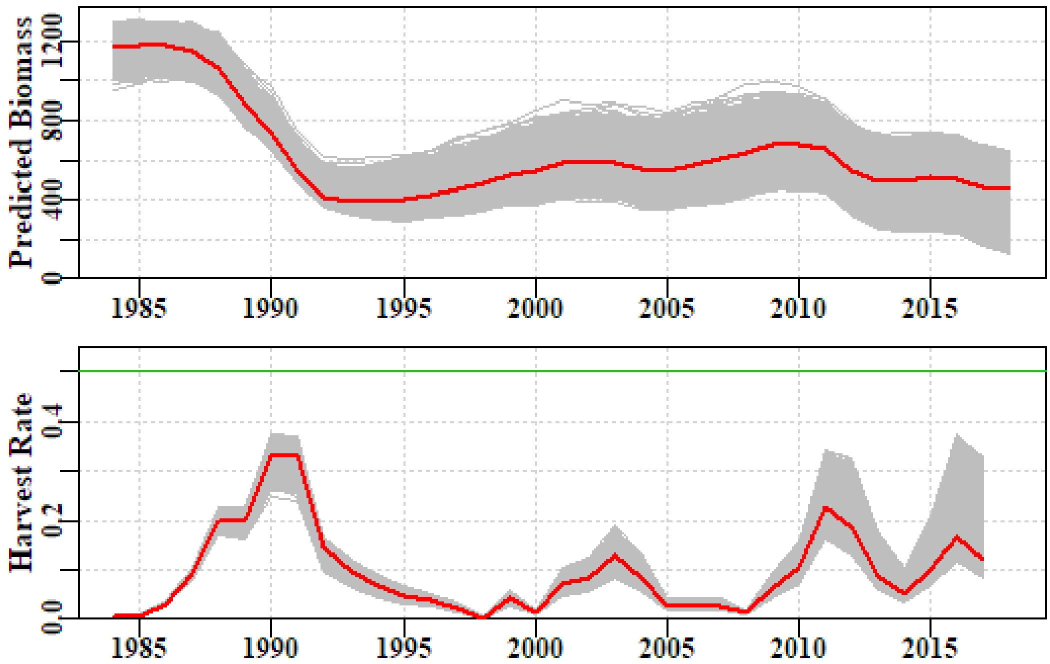

Figure 11.9. The estimated stock biomass and the implied harvest rates for the successful stock reduction analyses from the catch-MSY analysis for Blue-Eye on the eastern Seamounts with intiial depletion levels ranging fdrom 0.9 - 1.0 (although the assumed process error of 0.025 will alter these exact values).

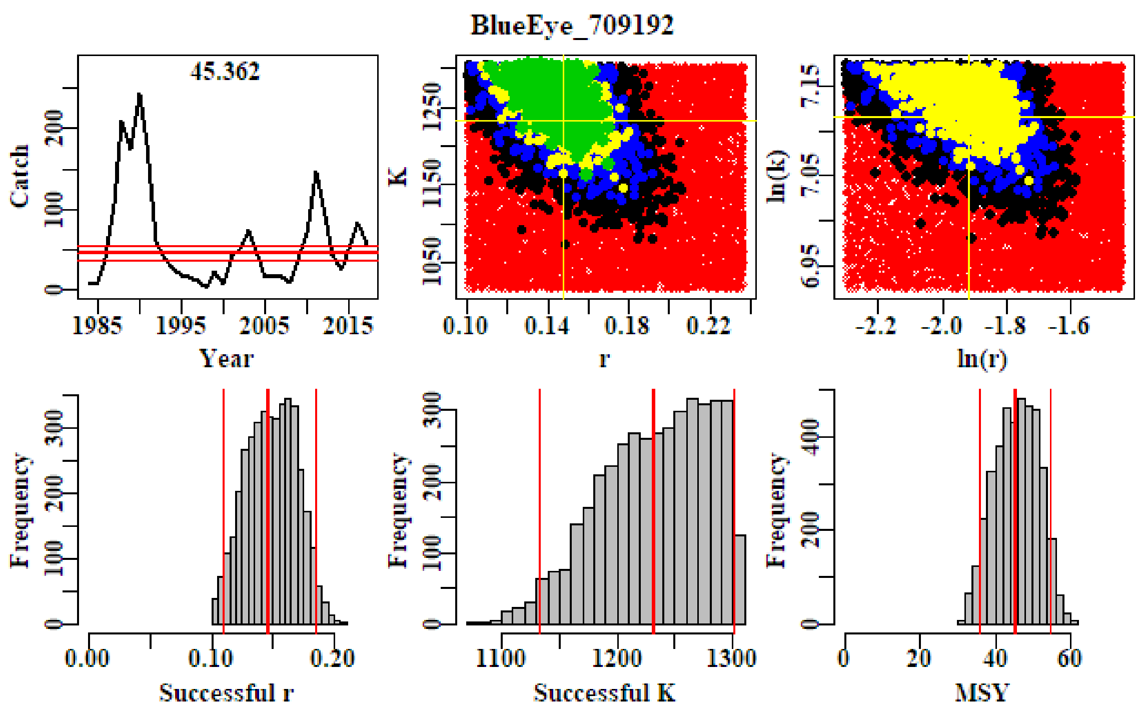

Figure 11.10. The catch-MSY analysis for Blue-Eye on the eastern seamounts (Zones 70, 90, and 91).

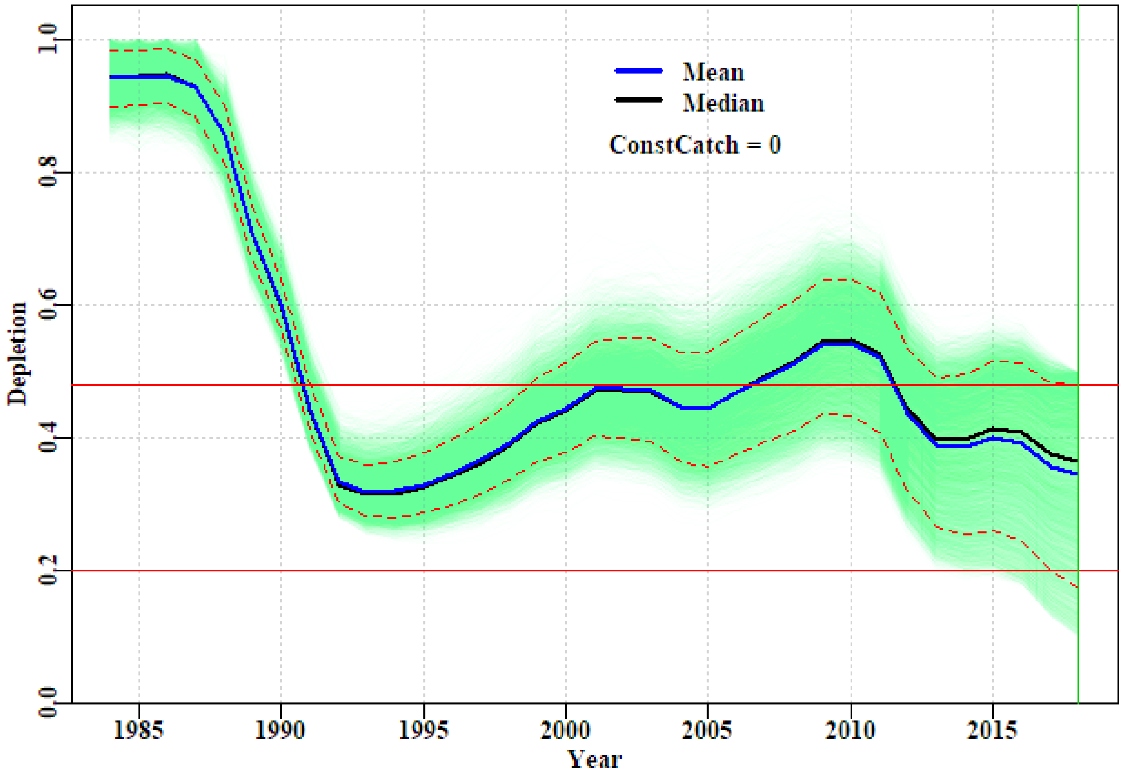

Figure 11.11. The catch-MSY analysis of stock depletion for Blue-Eye on the eastern Seamounts (Zones 70, 90, and 91) when starting from 0.9 - 1.0 depletion levels.The green line denotes the end of the final year in which data are available.

12. 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.

13. 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 2018 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 (school shark, jackass morwong (east and west), blue grenadier, silver warehou and an eastern orange roughy risk assessment, as well as cpue standardisations for shelf, slope, deepwater and shark species and Tier 4 analyses. Typical assessment outputs provide indications of current stock status and an application of the Commonwealth Harvest Strategy framework. This framework is based on a set of assessment methods and associated harvest control rules, with the decision to apply a particular combination dependent on the type and quality of information available to determine stock status (Tiers 1 to 4).

The assessment outputs from this project are a critical component of the management and TAC setting process for these fisheries. The results from these studies are being used by SESSFRAG, industry and management to help manage the fishery in accordance with agreed sustainability objectives.

Stock status and Recommended Biological Catch (RBC) conclusions (non-Tier 1):

Catch rates, as an index of abundance, were standardization for 21 species, distributed across 40 different combinations of stocks and fisheries using statistical models customized to suit each set of circumstances. Stocks included 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. Out of 40 stocks, there were eight whose standardized CPUE have increased over the last five years; 11 stocks where catch rates were stable and 20 stocks whose catch rates have declined over the last five years. In addition, there was an increase in standardized CPUE in 2017 from 2016 for 32 stocks/combinations of fisheries. The results from the standardisations are a key input to Tier 4 and Tier 1 assessments.

Separate analyses of catch rates were performed for blue-eye, deepwater species and sharks. For blue-eye the analysis using catch-per-hook exhibits a noisy but flat trajectory. For eastern deepwater sharks, the standardized CPUE exhibits a relatively flat trend below the long-term average 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 almost returned to the long-term average in 2017. For mixed oreos, after an initial period of great volatility between 1986 - 1994 the standardized CPUE has been essentially flat and stable since 2000. For school shark, the standardized CPUE has continued to increase, with the exception of 2014 and 2017. For gummy shark, standardized CPUE in South Australia has increased since 2013, and has dropped to the long-term average in 2017 in Bass Strait. By contrast, standardized CPUE of gillnet caught gummy shark around Tasmania remained flat since 2014 and increasing to the long-term average in 2016 and 2017. Standardized CPUE for trawl has increased steadily since 2012, remaining above the long-term average. By contrast, standardized CPUE for bottom line has remained flat and noisy since 2012. 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. By contrast, sawshark standardized CPUE by Danish seine has been flat since 2006 and increased above the long-term average in 2015. For elephant fish, gillnet standardized CPUE is flat and noisy, while decreased in 2015, increased in 2016 and decreased in 2017.

In 2018, Tier 4 analyses have been performed for the following species and/or species groups: mirror dory east, mirror dory west, eastern deepwater shark, western deepwater shark and blue eye trevalla (Zone 20 - 50). For mirror dory east (with discards), after a series of declining catch rates, the 2017 point increased. The RBC is 140 t. For mirror dory west, the catch rates are generally flat but cyclical. The RBC is 95 t. For eastern deepwater shark the catch rate trend is low and near the limit, but stable. The RBC is 10 t. For western deepwater shark the catch rate trend has seen an increase over the last 4 years and is above target. The RBC is 235 t. For blue-eye (non-trawl) the catch rate trend is relatively stable between the target and limit. The RBC is 439 t.

Two methods were used as Tier 5 assessments for blue-eye on the eastern seamounts. These were an age-structured stock reduction analysis and catch MSY. For the SRA model, constant catches leading to relative stability in depletion were estimated at about 25 t for lower productivity combinations of natural mortality and steepness (0.08, 0.6) and 48 t for higher productivity combinations (0.12, 0.8). This is comparable to the estimate of approximately 40 t from the catch MSY analysis that was predicted to lead to the mean depletion remaining stable in the projections.

14. Appendix: Intellectual Property

No intellectual property has arisen from the project that is likely to lead to significant commercial benefits, patents or licenses.

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. In 2018, Tier 4 analyses have been performed for the following species and/or species groups: mirror dory east, mirror dory west, eastern deepwater shark, western deepwater shark and blue eye trevalla (Zone 20 - 50). For mirror dory east (with discards), after a series of declining catch rates the 2017 point increased. The RBC is 140 t. For mirror dory west, the catch rates are generally flat but cyclical. The RBC is 95 t. For eastern deepwater shark the catch rate trend is low and near the limit, but stable. The RBC is 10 t. For western deepwater shark the catch rate trend has seen an increase over the last 4 years and is above target. The RBC is 235 t. For blue-eye (non-trawl) the catch rate trend is relatively stable between the target and limit. The RBC is 439 t.

Two methods were used as Tier 5 assessments for blue-eye on the eastern seamounts. These were an age-structured stock reduction analysis and catch MSY (cMSY). For the SRA, constant catches leading to relative stability in depletion were estimated at about 25 t for lower productivity combinations of natural mortality and steepness (0.08, 0.6) and 48 t for higher productivity combinations (0.12, 0.8). This is comparable to the estimate of approximately 40 t from the catch-MSY analysis that was predicted to lead to the mean depletion remaining stable in the projections. These analyses assume that the catch time series reflects changes in depletion of blue-eye. However, this may not be the case, as other factors unrelated to abundance can influence this (e.g. management changes; catch limits; marine closures; gear restrictions, fisher behaviour etc.).

15. Appendix: Project Staff

Franzis Althaus	CSIRO Oceans and Atmosphere, Hobart, Tasmania
Paul Burch	CSIRO Oceans and Atmosphere, Hobart, Tasmania
Claudio Castillo-Jordan	CSIRO Oceans and Atmosphere, Hobart, Tasmania
Jemery Day	CSIRO Oceans and Atmosphere, Hobart, Tasmania
Roy Deng	CSIRO Oceans and Atmosphere, Hobart, Tasmania
Mike Fuller	CSIRO Oceans and Atmosphere, Hobart, Tasmania
Malcolm Haddon	CSIRO Oceans and Atmosphere, Hobart, Tasmania
André Punt	CSIRO Oceans and Atmosphere, Hobart, Tasmania
Miriana Sporcic	CSIRO Oceans and Atmosphere, Hobart, Tasmania
Robin Thomson	CSIRO Oceans and Atmosphere, Hobart, Tasmania
Geoff Tuck	CSIRO Oceans and Atmosphere, Hobart, Tasmania