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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 2021. Part 2 describes the Tier 4 and Tier 5 assessments, catch rate standardisations and other work contributing to the assessment and management of SESSF stocks in 2021.

Stock Assessment for the Southern and Eastern Scalefish and Shark Fishery 2020 and 2021

Part 2: 2021

G.N. Tuck
May 2022
Report 2019/0800

Australian Fisheries Management Authority

Stock Assessment for the Southern and Eastern Scalefish and Shark Fishery: 2021

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1. Non-Technical Summary

Stock Assessment for the Southern and Eastern Scalefish and Shark Fishery 2020 and 2021

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OBJECTIVES:

- Provide quantitative and qualitative species assessments in support of the four SESSFRAG assessment groups, including RBC calculations within the SESSF harvest strategy framework
- 2020: Provide Tier 1 assessments for Gummy Shark, Eastern Redfish and School Whiting; Tier 4 assessments for John Dory, Mirror Dory, Ocean Perch, OreoBasket, Ribaldo, Royal Red Prawn, Sawshark and Silver Trevally; and Tier 5 for Blue-eye Trevalla
- 2021: Provide Tier 1 assessments for Eastern Orange Roughy, Blue Grenadier, E/W Jackass Morwong and Silver Warehou; Tier 4 for Mirror Dory and Tier 5 for E/W Deepwater Shark

Outcomes Achieved - 2021

The 2021 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 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 summaries results and outlines any issues that were raised from the standardizations to 20 species and/or groups, corresponding to 41 different combinations of stocks and fisheries. The 20 species (or groups) assessed were Alfonsino (*Beryx splendens*), Bight Redfish (*Centroberyx gerrardi*), Blue-eye Trevalla (*Hyperoglyphe antarctica*), Blue Grenadier (*Macroronus novaezelandiae*), Blue Warehou (*Seriolella brama*), Deepwater Flathead (*Platycephalus conatus*), Flathead (*Neoplatycephalus richardsoni* and Platycephalidae), Gemfish (*Rexea solandri*), John Dory (*Zeus faber*), Jackass Morwong (*Nemadactylus macropterus*), Mirror Dory (*Zenopsis nebulosa*), Ocean Jackets (*Nelusetta ayraudi* and Balistidae, Monacanthidae - undifferentiated), Ocean Perch (*Helicolenus percoides*), Pink Ling (*Genypterus blacodes*), Redfish (*Centroberyx affinis*), Ribaldo (*Mora moro*), Royal Red Prawn (*Haliporoides sibogae*), School Whiting (*Sillago flindersi*), Silver Trevally (*Pseudocaranx dentex*) and Silver Warehou (*Seriolella punctata*).

Standardized CPUE has generally increased since about 2005 for Pink Ling west, and non-spawning Blue Grenadier has continued its increasing recent trend. Other species/stocks have shown shorter term increases over the last two to three years e.g., Pink Ling east, Ribaldo, Royal Red Prawn (a marked recent increase), offshore Ocean Perch, School Whiting (trawl) and Western Gemfish. Silver warehou east and west appear to have stabilised after at least a ten-year general decline. By contrast, standardized CPUE has declined for John Dory, Mirror Dory, Eastern Morwong, Tiger Flathead

(Danish seine), Ocean Jackets, and Silver Trevally. There are some recent positive signs for Eastern Gemfish. The results from the standardisations are a key input to Tier 4 and Tier 1 assessments.

Blue-eye catch rate standardisation

This chapter updates standardized CPUE indices for Blue-eye Trevalla (*Hyperoglyphe antarctica*) to 2020, by combining standardized CPUE series of two different line gears (drop-line and auto-line) to obtain a single CPUE series for the line sector from zones 20, 30, 40, 50 (z2050) and 83, 84 and 85 (Great Australian Bight; GAB). A downward trend is apparent in the standardized CPUE series over the 2018-2020 period. All analyses have limited numbers of observations and hence are relatively uncertain.

Deepwater species catch rate standardisation

Catches of eastern Deepwater Sharks declined steadily from 1996 to a low in 2007 when the 700 m closure was introduced. Since the borders of this closure were modified in 2009 (and 2016) catches have increased again to reach an average of 36 t per annum with fewer vessels contributing significantly to this fishery relative to the 1990's. Nevertheless, fishing appears to be consistent and the standardized CPUE trend has been essentially low and flat since 2010, despite an increase in 2020 relative to the previous year. The removal of catch from the 700 m closure made minimal differences to standardized CPUE compared to CPUE indices which included the closure in analyses.

As with the eastern Deepwater Sharks, catches of western Deepwater Sharks decreased from a high in 1998 of 406 t to a low in 2007 of 9 t after the introduction of the 700 m closure, picking up again after the modifications in 2009 and 2016, with a mean of 86 t over the last five years. Standardized CPUE has been approximately cyclic since about 2007 with lows over the 2012-2014 period and has returned to the long-term average since 2016. The removal of catch from the 700 m closure made minimal differences to standardized CPUE compared to CPUE indices which included the closure in the analyses, except for the most recent year, where the index increased compared with the previous year.

Catches of Mixed Oreos declined from 1995 - 2002 and have remained relatively low since the 700 m closure in 2007 (i.e., mean ~71 t between 2007-2012), but have increased to a mean of 115 t from 2013 - 2020 perhaps due to the introduction of electronic monitoring over this period. Standardized CPUE has been essentially flat over the 1995 – 2019 period, but below the long-term average and increased to the long-term average in 2020.

Shark species catch rate standardisation

This chapter summarizes catches and catch-per-unit (CPUE) for Gummy Shark (*Mustelus antarcticus*), School Shark (*Galeorhinus galeus*), Sawshark (*Pristiophorus cirratus*, *P. nudipinnis*, *P. spp* and Pristiophoridae) and Elephant Fish (*Callorhinchus milii*) in Australia's Gillnet Hook and Trap sector.

Recorded catch of School Shark by trawl in 2019 (i.e., 29 t) is the largest since 1996, and those from trawling do not appear to be targeted, as evidenced by the large proportion of < 30 kg shots present in the logbook data. Also, there was a 10 t decrease of trawl caught school shark in 2020 compared with 2019.

There was an increase in recorded gillnet catch of Gummy Shark in 2017 relative to 2016 in South Australia and Bass Strait. However, there was a 54% drop in recorded gillnet catch in 2019 relative 2018 in South Australia. The 2020 catch was almost the same as the 2019 catch (i.e., 65 t in 2019 and

63 t in 2020). Standardized catch per netlength (CPUN; kg/m) in South Australia increased from 2013 to 2016 and decreased to below the long-term average in 2020. By contrast, gillnet standardized CPUN in Bass Strait is cyclic and has increased above the long-term average in 2020. Standardized CPUN of gillnet caught Gummy Shark around Tasmania remained noisy and flat with increases in the last two years.

Recorded logbook trawl catch of Gummy Shark has been greater than 100 t per annum since 2018, the first time since 2011. Also, the 117 t recorded in 2019 is the largest in the time series. Annual standardized CPUE has been mostly flat and below the long-term average between 1997 and 2007 and has increased above the long-term average since 2012. Similarly, standardized CPUE in both South Australia and Tasmania have mostly increased and above the long-term average since at least 2014. By contrast, standardized CPUE in Bass Strait has been mostly flat and above the long-term average since 2008. Standardized CPUE for bottom line has remained mostly flat and noisy, with 2018 – 2020 period mostly exceeding the long-term average.

For Sawshark, standardized CPUN for gillnets exhibits a steady decline since about 2001, with small increases in recent years, except in 2017. Trawl caught Sawshark standardized CPUE exhibit a noisy but flat trend. Sawshark standardized CPUE by Danish seine (which has the highest proportion of shots < 30 kg among methods) has remained either consistently below or at the long-term average since 2001.

Like School Shark, Elephantfish (*Callorhinchus milii*) are a non-targeted species, as indicated by the large proportion of small shots (i.e., < 30 kg). Gillnet standardized CPUN is flat and noisy, and below the long-term average since about 2013. In recent years discard rates have been very high, which may imply that their CPUE is in fact increasing.

Catch Histories

Catch history time series have been developed for this year's Tier 4 assessments for the following four species: Silver Trevally (*Pseudocaranx dentex*), John Dory (*Zeus faber*), Mirror Dory (*Zenopsis nebulosa*) East and West separately and Blue-eye Trevalla (*Hyperoglyphe antarctica*). It is proposed that these series are employed in this year's Tier 4 assessments, with the hope that any remaining data issues relating to potential double reporting/counting of some catch in both NSW and Commonwealth waters may be clearly resolved in the future.

Tier 4

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. In 2021, five Tier 4 assessments were performed for the following species and/or fisheries: Silver Trevally (*Pseudocaranx dentex*), Mirror Dory East (*Zenopsis nebulosa*), Mirror Dory West (*Zenopsis nebulosa*), John Dory (*Zeus faber*) and Blue-eye Trevalla slope (*Hyperoglyphe antarctica*).

For Silver Trevally, the 2021 estimated RBC was approximately 178.85 t, an approximate 190.84 t decrease compared to the 2020 estimated RBC (369.69 t). This decrease in RBC can be mostly attributed to a drop in the most recent standardized CPUE (including discards). For Mirror Dory – East, the 2021 estimated RBC was 112.93 t, a decrease of 32.76 t compared to the 2020 estimated RBC (145.69 t). For Mirror Dory – West, the 2021 estimated RBC was 56.18 t, a decrease of 5.39 t compared to the 2020 estimated RBC (61.57 t). For John Dory, the 2021 estimated RBC was 0 t compared to the 2017 estimated RBC (485 t). For Blue eye Trevalla, the 2021 RBC was approximately 349.32 t, corresponding to a 122.29 t increase compared to the 2020 RBC, i.e., 227.03 t. This 54% increase in RBC between assessments can be mostly attributed the use of the new standardized CPUE series which resulted in a higher most recent four-year average compared with the corresponding average standardized CPUE from the previous assessment.

Deepwater Shark Data

The Deepwater Shark basket consists of 18 species belonging to the families of sleeper sharks (Somniosidae), gulper sharks (Centrophoridae), dogfish (Squalidae), kitefin sharks (Dalatiidae) and lantern sharks (Etmopteridae). Assessment is applied separately to stocks east and west of 148ºS Longitude. Of these 18 species, Longsnout Dogfish (*Deania quadrispinosa*) was found to be 'high risk,' and Black Shark (*Dalatias licha*) was found to be 'medium risk' by the most recent ERA for the trawl sub-fishery (Sporcic et al 2021). This ERA, unlike earlier work, accounted for cumulative spatial fishing effort and has assigned fewer deepwater shark species to the 'high risk' category. Existing deepwater closures and gulper closures are likely to be providing some level of protection for Deepwater Shark.

This chapter explored the Logbook and Observer data available for the Deepwater Shark basket, and to discuss possible options for a Tier 5 (data limited) assessment. We also present discard estimates for two sub-sets of the basket of species, consisting of those thought to be more often, and those less often, discarded.

Few logbook records identify Deepwater Shark to species or even family level. Those records that do not use a high-level group code most commonly use the code 'platypus shark,' which groups two species (Longsnout Dogfish and Brier Shark). Less often, the individual species codes for Longsnout Dogfish and Brier Shark are recorded. This is at odds with observer records where Black Sharks predominate along with Brier Sharks. Observers typically report Deepwater Shark to species level for those caught in waters deeper than 600m but less often for shallower waters. Discard rates are high and estimates have high CVs, so that landed catches are likely to be a poor reflection of total catch. Separating the Deepwater shark basket into 'byproduct' and 'bycatch' groups does lower this CV somewhat and is therefore to be recommended. Landings of Deepwater Shark are greater in the west than the east, both historically and currently, with landings increasing steadily in the west since the mid-2000s. Landed catches in both regions were highest in the late 1990s. In deep waters, Deepwater Shark are primarily caught with Orange Roughy and Oreos. In shallower waters in the east, they used to be primarily caught with Redfish but as Redfish catches have declined, they are now primarily caught with Pink Ling, Tiger Flathead and a mixture of other eastern shelf species. In shallower waters in the east, Deepwater Shark are primarily caught with Pink Ling, Blue Grenadier, Blue-eye Trevalla and Silver Warehou.

Currently, neither CPUE nor total catch (landings plus discards) information can be relied on for assessment of Deepwater Sharks, quantitative assessment methods are therefore not applicable, and indicators of stock health must be used instead. Due to their low reproductive rates, deepwater shark are a vulnerable group that, despite likely protection from current closures, should be subject to improved future data collection.

Tier 5 for Blue-eye Trevalla

This chapter conducts a Tier 5 assessment for Blue-eye Trevalla, updating the Tier 5 of 2018, making some additional assumptions, and use a Tier 1-like Harvest Control Rule for the age structured Stock Reduction Analysis model. We considered three alternative stock definitions: Tasmantid (eastern) seamounts only (essentially the definition used by Haddon and Sporcic, 2018), Tasmantid seamounts plus Lord Howe Rise, and Tasmantid plus Lord Howe Rise plus Gascoyne seamount.

The C-MSY model aims to generate an approximate estimate of MSY (productivity) but does not provide a valid estimate of current depletion or of the sustainable catch at the current stock status. The method provides a range of possible levels of current stock status that are not inconsistent with the catch data. It is important to note that, in the case of the C-MSY analysis, updating the analysis using the same catch series plus recent managed catches, would not be a valid application of the method as it would operate either to ratchet the catches down or up. If catch-MSY (or any catch-only method) is all that can be used, then an RBC could be set once but should remain fixed into the future because updating the analysis when one only has new catch data is invalid. The geometric mean values of MSY range from 96t to 105t (if Gascoyne is not considered, as we recommend). The age-structured SRA model is very sensitive to the form of the selectivity function that is chosen, and to the upper limit for the harvest rate imposed. Across the range of values for natural mortality, steepness, upper harvest rate and stock definition (catch time series) RBCs range from 0t to 176t.

Ignoring models that include catches from the Gascoyne, an annual catch in the range of 30-40t (which includes the 36t per annum currently allowed) appears likely to be sustainable, even somewhat conservative, for the majority of models considered. The collection of data that can serve as an index of abundance is strongly encouraged.

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 water species)
- Shark Resource Assessment Group (shark species)
- Great Australian Bight Resource Assessment Group (GAB species)

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 4 and 5. 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 a description of the SESSFRAG agreed changes to the assessment schedule and may differ from the objectives in the original contract:

- Provide quantitative and qualitative species assessments in support of the four SESSFRAG assessment groups, including RBC calculations within the SESSF harvest strategy framework

- 2020: Provide Tier 1 assessments for Gummy Shark, Eastern Redfish and School Whiting; Tier 4 assessments for John Dory, Mirror Dory, Ocean Perch, OreoBasket, Ribaldo, Royal Red Prawn, Sawshark and Silver Trevally; and Tier 5 for Blue-eye Trevalla

- 2021: Provide Tier 1 assessments for Eastern Orange Roughy, Blue Grenadier, E/W Jackass Morwong and Silver Warehou; Tier 4 for Mirror Dory and Tier 5 for E/W Deepwater shark

5. Executive Summary: CPUE standardizations for selected SESSF Species (data to 2020)

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5.1 Summary

This document outlines any issues that were raised from the standardizations corresponding to the 41 different combinations of stocks and fisheries in Sporcic (2021). Visual summaries of all optimum statistical models, along with tables of the properties of each dataset are presented in Sporcic (2021). In addition, this document estimates the root mean squared error (RMSE) of the loess fit to the standardized catch-per-unit-effort (CPUE) for 20 species and/or groups, corresponding to 41 different combinations of stocks and fisheries from Sporcic (2021).

The 20 species (or groups) assessed were Alfonsino (*Beryx splendens*), Bight Redfish (*Centroberyx gerrardi*), Blue-eye Trevalla (*Hyperoglyphe antarctica*), Blue Grenadier (*Macroronus novaezelandiae*), Blue Warehou (*Seriolella brama*), Deepwater Flathead (*Platycephalus conatus*), Flathead (*Neoplatycephalus richardsoni* and Platycephalidae), Gemfish (*Rexea solandri*), John Dory (*Zeus faber*), Jackass Morwong (*Nemadactylus macropterus*), Mirror Dory (*Zenopsis nebulosa*), Ocean Jackets (*Nelusetta ayraudi* and Balistidae, Monacanthidae - undifferentiated), Ocean Perch (*Helicolenus percoides*), Pink Ling (*Genypterus blacodes*), Redfish (*Centroberyx affinis*), Ribaldo (*Mora moro*), Royal Red Prawn (*Haliporoides sibogae*), School Whiting (*Sillago flindersi*), Silver Trevally (*Pseudocaranx dentex*) and Silver Warehou (*Seriolella punctata*).

Fishing depths have been (i) recorded as single values or (ii) recorded at more than one constant value across different operations in the Commonwealth logbook database for certain vessels since about 2016. These fishing depths have been modified based on positional bathymetry and used in this year's standardization analyses, as agreed by SESSFRAG in 2020 and by AFMA in 2021. This is likely to have influenced standardized CPUE indices for inshore Ocean Perch, Flathead - Danish seine (zones 20 and 60), Royal Red Prawn and School Whiting in recent years.

Loess fits of annual standardized CPUE are illustrated for all 41 stocks and fisheries. These smooth fits are indicative of potential trends. In addition, the root mean square error (RMSE) of the Loess fits to standardized CPUE series of 41 combinations of stocks and fisheries were also estimated. Blue Warehou (Trawl; east) had the largest RMSE, followed by Blue Warehou (Trawl; west), Blue-eye Trevalla (Trawl; zones 20, 30), Jackass Morwong (Trawl; zone 30), Blue-eye trevalla (Trawl; zone 40, 50) and Redfish (zone 10) across Tier levels.

The Tier 1 species with the largest RMSE were Jackass Morwong (Trawl; zone 30), followed by Redfish (zone 10), Deepwater Flathead, eastern Gemfish (spawning) and Redfish (zone 10, 20). By contrast, the Tier 1 species with the lowest RMSE were Pink Ling (Trawl; east) followed by both Jackass Morwong (Trawl; zone 10, 20) and Flathead (Trawl; zones 10, 20) and Pink Ling (Trawl; west).

5.2 Introduction

The CPUE standardization document (Sporcic, 2021) has been produced to provide 41 standardized CPUE across 20 SESSF species which are used in Tier 1 and Tier 4 stock assessments. This report estimates the root mean square error (RMSE) of the Loess fit to each of the 41 standardized CPUE series, which are used in Tier 1 stock assessments. It also summarizes the results within (Sporcic 2021) across all species and issues raised by the data from particular species.

5.3 Methods

Outputs from Sporcic (2021) includes a table of the optimum standardized CPUE indices for each fishery. A Loess curve was fitted to the 41 annual CPUE series. The root mean square error (RMSE), sometimes referred to as the root mean squared deviation (RMSD), of the Loess fit of the annual CPUE estimates was calculated to provide an indication of how variable the mean annual estimates are around the central trend line (Table 5.1). Essentially this attempts to measure the average difference between two time series, i.e., the CPUE series and the central trend line. The equation used for the RMSE was:

$$RSME = \sqrt{\frac{\sum_{i=1}^{n}\left(\hat{I}_i - \hat{L}_i\right)^2}{n}}$$

where $\hat{I}_i$ is the expected mean CPUE in year *i*, $\hat{L}_i$ is the predicted Loess trend value for year *i*, and *n* is the number of years. The *loess* function in **R** was used for the calculations (R Core Team, 2021).

To provide a visual summary of these outcomes, all 41 CPUE series are individually plotted. Two forms of the same data were plotted; the first with a constant y-axis scale to provide a visual impression of the variation of CPUE through time in each fishery relative to every other fishery (Figure 5.1), and a second where each plot is given its own y-axis scale to maximize the vertical contrast and of any trends that exist (Figure 5.2).

The Action Items and Issues section from each fishery's analyses is extracted and printed to be considered for further action. Where a fishery/species is listed with no action items below it this implies none were written in the original document (Sporcic, 2021). The intent of this section is to highlight to the RAG and other stakeholders potential issues that could receive further attention to resolve.

5.4 Action Items and Issues by Fishery

5.4.1 *JohnDory1020*

A potential change in fishing behaviour is suggested to have occurred since about 2014, which is evidenced by changes in the distribution of log-transformed CPUE each year. From 2014 a number of widely spread spikes in the histograms have become apparent, especially between 2015 and 2020. The underlying driver for these changes is not immediately apparent.

5.4.2 *SchoolWhiting60*

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. 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.

5.4.3 *SchoolWhitingTW*

The last three years 2017 - 2019 appear to have exhibited a change in fishing behaviour as evidenced by the changing distributions of records at depth. Why this has occurred in the last three years remains unknown.

5.4.4 *SchoolWhitingTW1020*

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

5.4.5 *MirrorDory1030*

No issues identified.

5.4.6 *MirrorDory4050*

It is recommended that the CPUE time-series only be used from 1995 onwards because catches before then are relatively minor. From 1990 the CPUE trend for r splabel appears to be relatively flat and noisy around the long-term average with periods above and below.

5.4.7 *JackassMorwong30*

With only 68 records and 30 t of reported catch in 1986, it is recommended that the standardization analysis should begin in 1987 or 1988.

5.4.8 *JackassMorwong1020*

The structural adjustment altered the effect of the vessel factor on the standardized result. However, log(CPUE) has also changed in character from 2014 - 2020, with spikes of low CPUE arising.

5.4.9 *JackassMorwong4050*

The depth factor changed its influence from 2001-2019 reflecting the increase in catches from 2001 and suggesting the fishery changed remarkably at that time. The reasons behind this change should be explored in more detail.

5.4.10 *SilverWarehou4050*

Annual Silver Warehou catches in the west were high (i.e., 1680 t - 2945 t per annum) for the period around 1999 - 2006. Vessels that contributed to these high catches left the fishery after the structural adjustment. This suggests that there have been transitional periods in the time-series of CPUE. This needs more attention because this may imply that CPUE may no longer be acting as a valid index of relative abundance through time.

5.4.11 *SilverWarehou1030*

Annual Silver Warehou catches in the east were relatively high for the period around 1992 - 2006, with specific vessels contributing to these large catches. This suggests that there have been transitional periods in the time-series of CPUE and needs more attention because of the potential implications this has for the index of relative abundance through time.

5.4.12 *FlatheadTW30*

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

5.4.13 *FlatheadTW1020*

After consideration of 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.

5.4.14 *FlatheadDS2060*

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

5.4.15 *Redfish1020*

After consideration of Redfish catches in zones 10 and 20 by year and vessel, the period around 1993 - 2006 appears to be different from the catches by vessel from 2007. This suggests that there have been transitional periods in the time-series of CPUE. This needs more attention because of the potential implications this has for the index of relative abundance through time.

5.4.16 *BlueEyeTW2030*

Given the ongoing low catches (with the lowest in the series in 2020), 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 CPUE and the standardized CPUE it is questionable whether this time-series of standardized CPUE is indicative in any useful way of the relative abundance of Blue-eye Trevalla. Whether this analysis should be continued should be considered.

5.4.17 *BlueEyeTW4050*

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

5.4.18 *BlueGrenadierNS*

It is recommended that alternate statistical distributions be considered.

5.4.19 *PinkLing1030*

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

5.4.20 *PinkLing4050*

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

5.4.21 *OceanPerchOffshore1020*

No issues identified.

5.4.22 *OceanPerchOffshore1050*

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

5.4.23 *OceanPerchInshore1020*

Fishing depths have been (i) recorded as single values or (ii) recorded at more than one constant value across different operations in the Commonwealth logbook database for certain vessels since about 2016. These fishing depths have been modified based on positional bathymetry and have been used in the standardization analysis presented here, as agreed by SESSFRAG in 2020. Differences between this year's standardized CPUE (i.e., 1986 - 2020) compared with last year's standardized CPUE (i.e., 1986 - 2019) are likely due to these modified fishing depths. As the discarding rate continues to be very high (up to ~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.

5.4.24 *OceanJackets1050*

No issues identified.

5.4.25 *OceanJacketsGAB*

No issues identified.

5.4.26 *gemfish4050*

No issues identified.

5.4.27 *gemfish4050GAB*

This analysis is recommended to be abandoned as it combines data from two biological stocks.

5.4.28 *gemfishGAB*

No issues identified.

5.4.29 *bluewarehou1030*

No issues identified.

5.4.30 *bluewarehou4050*

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

5.4.31 *deepwaterflathead*

It is recommended that alternate statistical distributions be considered.

5.4.32 *bightredfish*

It is recommended that alternate statistical distributions be considered.

5.4.33 *RibaldoTW*

It is recommended that the geographical distribution of catches be explored to determine the representativeness of the entire stock's distribution during the early years. It is also recommended that alternate statistical distributions be considered.

5.4.34 *RibaldoAL*

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

5.4.35 *SilverTrevally1020*

Further exploration of the reasons behind the recent deviation of the standardized time-series from the nominal geometric mean are required to provide a more detailed explanation for these changed dynamics.

5.4.36 *SilverTrevally1020nompa*

Further exploration of the reasons behind the recent deviation of the standardized time-series from the nominal geometric mean are required to provide a more detailed explanation for these changed dynamics.

5.4.37 *RoyalRedPrawn*

It is recommended that alternate statistical distributions be considered.

5.4.38 *EasternGemfishNonSp*

No issues identified.

5.4.39 *EasternGemfishSp*

No issues identified.

5.4.40 *Alfonsino*

No issues identified.

5.4.41 *Redfish10*

After consideration of Redfish catches in zones 10 and 20 by year and vessel, the period around 1993 - 2006 appears to be different from the catches by vessel from 2007. This suggests that there have been transitional periods in the time-series of CPUE. This needs more attention because of the potential implications this has for the index of relative abundance through time.

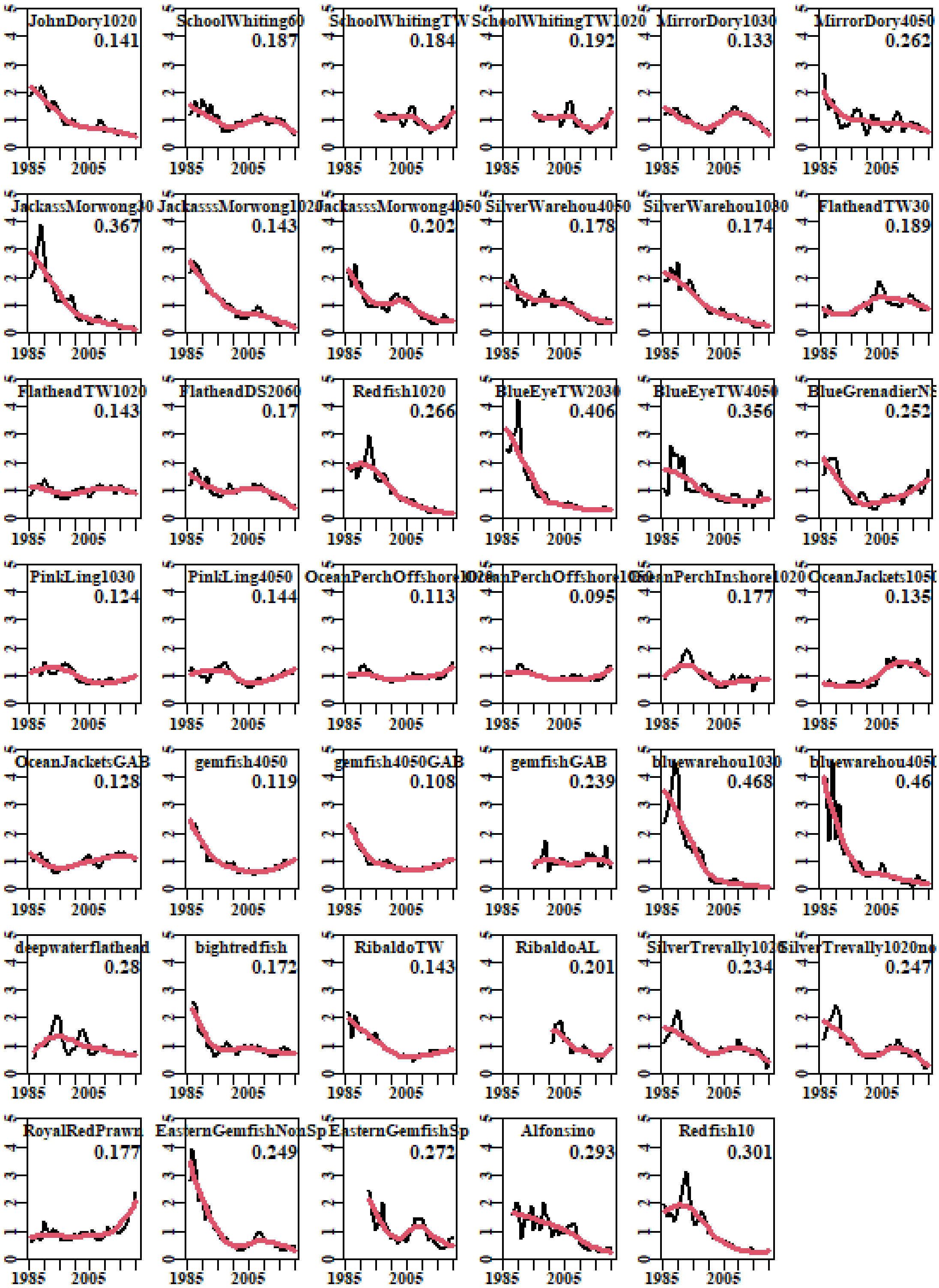

Figure 5.1. The optimal standardized CPUE trend for each fishery analysed. In each case, the black line represents the standardization, and the red line is a loess best fitting trend. The title in each plot is the fishery and the number at top right is the root mean squared deviation. All y-axes have a maximum of 5.0.

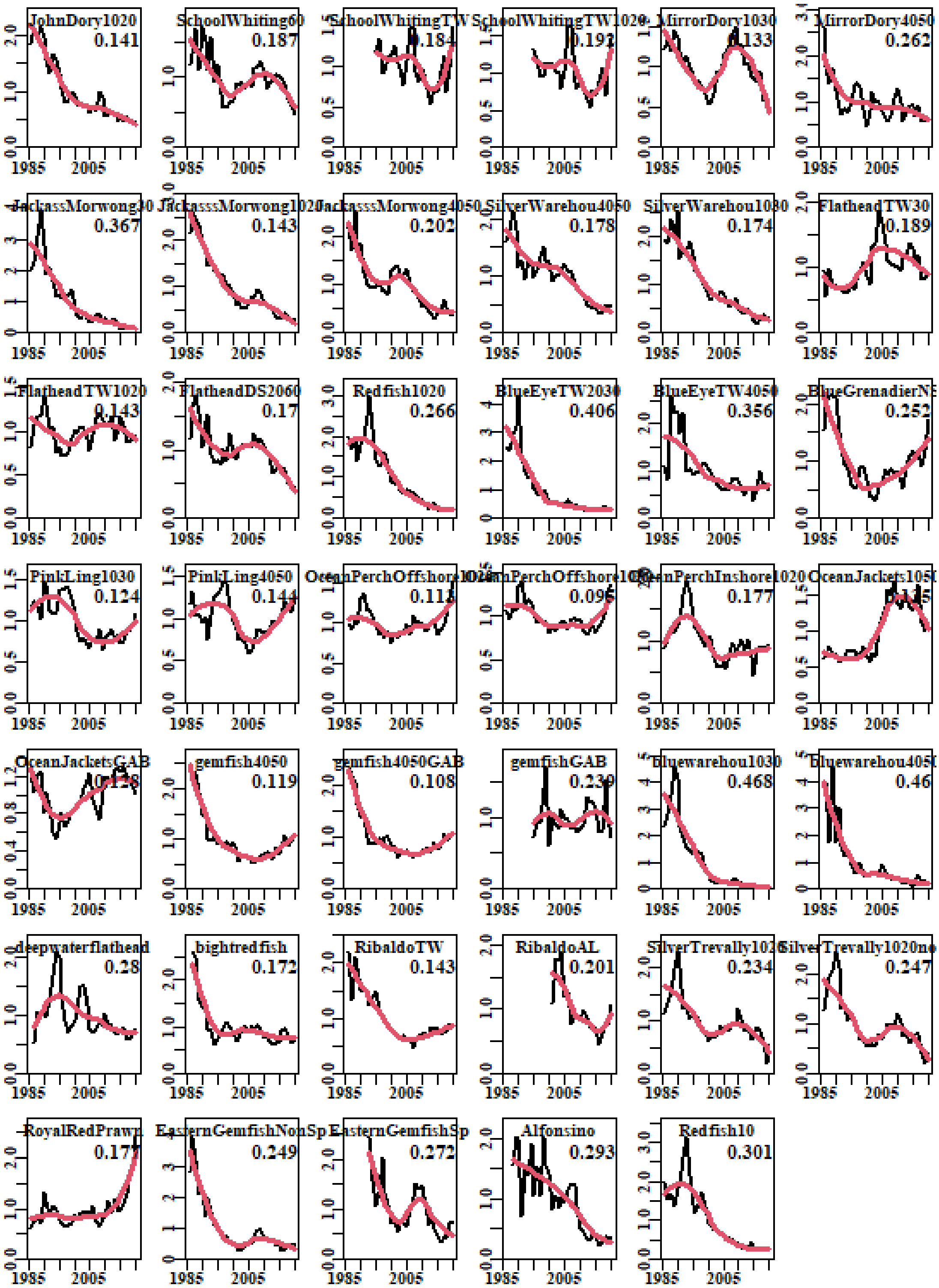

Figure 5.2. The optimal standardized CPUE trend for each fishery analysed. In each case, the black line represents the standardization, and the red line is a loess best fitting trend. The title in each plot is the fishery and the number at top right is the root mean squared deviation. All y-axes have individual scales.

Table 5.1. The basic properties of each dataset, including the number of observations (Nobs) used in the optimum analysis, the number of parameters fitted in the optimum model (Npars), and the proportion of the total variation the model accounted for (Adj_R2), and the shallowest (Ldepth; m) and deepest (Udepth; m) depths. RMSE: root mean square error.

	Nobs	Npars	Adj_r2	Ldepth (m)	Udepth (m)	RMSE
JohnDory1020	150140	240	25.73	0	200	0.141
SchoolWhiting60	97455	146	13.95	0	100	0.187
SchoolWhitingTW	23682	262	40.77	0	140	0.184
SchoolWhitingTW1020	16322	150	44.41	0	140	0.192
MirrorDory1030	102671	279	35.57	0	600	0.133
MirrorDory4050	35284	177	32.97	0	600	0.262
JackassMorwong30	23163	158	38.14	60	300	0.367
JackasssMorwong1020	120984	254	28.16	60	300	0.143
JackasssMorwong4050	14963	167	36.82	60	360	0.202
SilverWarehou4050	67541	177	24.63	0	600	0.178
SilverWarehou1030	78307	269	22.76	0	600	0.174
FlatheadTW30	29675	305	20.50	0	300	0.189
FlatheadTW1020	295137	278	16.80	0	400	0.143
FlatheadDS2060	247092	127	38.46	0	200	0.170
Redfish1020	104161	241	31.65	0	400	0.266
BlueEyeTW2030	13282	213	55.84	0	1000	0.406
BlueEyeTW4050	13815	175	44.43	0	1000	0.356
BlueGrenadierNS	152441	325	36.11	100	1000	0.252
PinkLing1030	107798	279	29.13	250	600	0.124
PinkLing4050	86410	192	29.17	200	780	0.144
OceanPerchOffshore1020	87749	244	29.89	200	700	0.113
OceanPerchOffshore1050	122898	323	35.76	200	700	0.095
OceanPerchInshore1020	17116	240	34.73	0	200	0.177
OceanJackets1050	96899	278	27.03	0	300	0.135
OceanJacketsGAB	59578	114	26.72	0	300	0.128
gemfish4050	36379	166	43.46	100	700	0.119
gemfish4050GAB	48094	233	45.67	100	650	0.108
gemfishGAB	10256	109	52.89	100	650	0.239
bluewarehou1030	38047	256	39.86	0	400	0.468
bluewarehou4050	13553	169	31.37	0	600	0.460
deepwaterflathead	84846	159	36.00	50	350	0.280
bightredfish	57179	146	29.92	50	300	0.172
RibaldoTW	25328	250	30.96	0	1000	0.143
RibaldoAL	6391	134	41.65	0	950	0.201
SilverTrevally1020	59780	229	30.76	0	200	0.234
SilverTrevally1020nompa	40314	227	32.62	0	200	0.247
RoyalRedPrawn	26245	277	43.81	200	680	0.177
EasternGemfishNonSp	41021	300	40.26	0	600	0.249
EasternGemfishSp	16555	163	30.05	300	500	0.272
Alfonsino	4556	239	54.16	0	950	0.293
Redfish10	75966	215	25.14	0	400	0.301

5.5 Acknowledgements

Thanks goes to the CSIRO database team for their preliminary processing of the catch and effort data as received from the Australian Fisheries management Authority. Geoff Tuck (CSIRO) is thanked for his helpful comments.

5.6 References

Sporcic, M. (2021). CPUE standardizations for selected SESSF Species (data to 2020). CSIRO Oceans and Atmosphere, Hobart. 341 p.

R Core Team (2021). *R: A language and environment for statistical computing.* R Foundation for Statistical Computing, Vienna, Austria. URL https://www.R-project.org/.

6. Statistical CPUE standardizations for selected SESSF Species (data to 2020)

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6.1 Introduction

Commercial catch-per-unit-effort (CPUE) data are used in many fishery stock assessments in Australia as an index of relative abundance. This assumes there is a direct relationship between CPUE and exploitable biomass. However, many other factors can influence CPUE, including vessel, gear, depth, season, area and time of fishing (e.g. day or night). The use of CPUE as an index of relative abundance requires the removal of the effects of variation due to changes in these factors on the assumption that what remains will provide a better estimate of the underlying biomass 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 statistical modelling procedures that focus attention on 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 Southern and Eastern Scalefish and Shark Fishery (SESSF) 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 CPUE indices (based on data to 2020 inclusive) for over 40 different (non shark) stocks within Australia’s SESSF.

6.1.1 *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 various 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.

There may be situations where fishers report the need to avoid catching certain species, 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 ongoing introduction of numerous area closures imposed for a range of different reasons.

6.2 Methods

6.2.1 CPUE Standardization

6.2.1.1 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 CPUE 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, 2018) 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 6.1) within the years specified for each analysis.

6.2.1.2 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 and 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:

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

where $Ln(\text{CPUE}_i)$ is the natural logarithm of the CPUE (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.)

6.2.1.3 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 CPUE changes.

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

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

6.2.1.4 Model Development and Selection

In each case, an array of statistical models were 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.

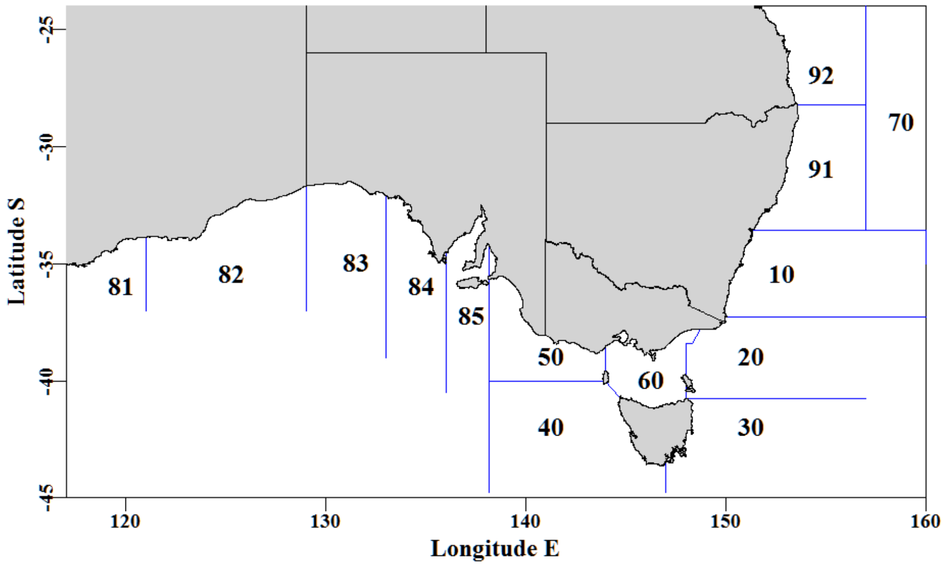

Figure 6.1. The statistical reporting zones in the SESSF

6.3 John Dory 10 20

For John Dory (DOJ– 37264004 – *Zeus faber*) have been primarily caught by trawl in zones 10 and 20 between the years 1986 - 2020. Small catches have also been recorded by gillnet and Danish seine. Initial data selection was based on criteria provided in Table 6.1 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.

6.3.1 *Inferences*

A significant proportion of shots each year were < 30 kg, which suggests this is rarely a targeted species (Figure 6.3).

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 6.5). The qqplot suggests the assumed Normal distribution is valid, with small deviations at the upper tail of the distribution (Figure 6.5).

Standardized CPUE has been below the long-term average since 1997. Also, there has been a gradually declining trend since at least 1996 (Figure 6.2).

6.3.2 *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, especially between 2015 and 2020. The underlying driver for these changes is not immediately apparent.

Table 6.1. 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, OTB
years	1986 - 2020

Table 6.2. 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

Year	Total	N	Catch	Vess	GeoM	Opt	StDev	C<30Kg	P<30Kg
1986	231.7	6414	202.1	90	12.1	1.8554	0.000	66.553	0.329
1987	206.1	4638	180.9	78	14.5	2.1476	0.021	43.254	0.239
1988	182.0	4532	161.2	73	13.5	1.9816	0.021	45.311	0.281
1989	217.9	4786	186.9	70	14.2	2.1681	0.021	49.093	0.263
1990	167.9	3674	135.7	60	13.0	1.9777	0.023	39.868	0.294
1991	172.3	4009	125.4	53	11.9	1.5727	0.023	43.685	0.348
1992	130.9	3890	107.9	49	9.6	1.3261	0.023	42.938	0.398
1993	240.5	5354	179.1	55	11.6	1.6703	0.022	57.565	0.321
1994	267.9	6508	207.7	55	11.1	1.5778	0.021	72.330	0.348
1995	185.7	6033	167.1	52	10.1	1.3403	0.021	68.473	0.410
1996	160.8	6339	145.0	58	8.4	1.0521	0.021	67.184	0.463
1997	87.8	4386	77.9	60	6.2	0.8144	0.023	43.209	0.555
1998	109.1	5080	98.2	53	6.9	0.8468	0.022	52.297	0.532
1999	132.8	5534	120.1	56	7.7	0.9977	0.022	57.792	0.481
2000	164.1	6956	146.6	59	7.2	0.9201	0.021	66.796	0.456
2001	129.3	6612	116.1	50	5.8	0.7737	0.021	61.573	0.530
2002	151.0	6663	135.9	49	6.7	0.7553	0.021	58.195	0.428
2003	156.9	6518	136.7	51	6.7	0.7348	0.021	59.400	0.434
2004	166.0	7051	147.0	51	6.8	0.7732	0.021	65.525	0.446
2005	107.4	4894	88.0	48	5.7	0.6387	0.022	41.054	0.466
2006	85.4	3706	71.0	43	5.8	0.7143	0.024	34.230	0.482
2007	62.5	2823	51.3	23	5.9	0.6454	0.026	25.596	0.499
2008	116.8	3800	102.1	26	8.8	0.9802	0.024	37.392	0.366
2009	91.7	3097	79.0	23	8.4	0.9084	0.025	31.271	0.396
2010	62.0	2953	51.1	24	5.4	0.5777	0.026	27.968	0.548
2011	74.8	3338	56.3	22	5.4	0.6039	0.025	31.361	0.557
2012	67.1	3336	55.9	22	5.4	0.5988	0.025	31.500	0.563
2013	63.5	2659	48.5	22	5.7	0.6244	0.026	24.778	0.511
2014	46.6	2637	35.3	23	3.8	0.4657	0.027	21.683	0.614
2015	73.6	2789	54.6	29	5.7	0.5930	0.026	24.484	0.448
2016	66.9	2226	39.3	24	5.4	0.4855	0.028	18.782	0.477
2017	68.6	1959	39.7	22	6.2	0.5467	0.029	17.737	0.447
2018	57.8	1985	33.1	21	4.7	0.4648	0.030	17.492	0.528
2019	55.9	1663	27.7	20	4.5	0.4362	0.031	13.841	0.499
2020	58.4	1298	24.1	19	4.6	0.4305	0.034	9.962	0.414

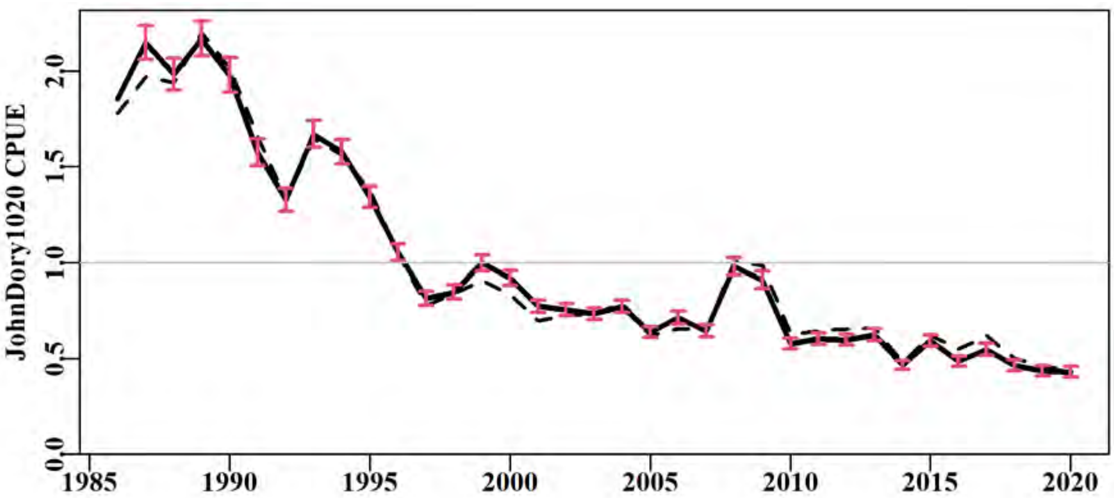

Figure 6.2. JohnDory1020 standardization. The dashed black line represents the geometric mean CPUE, solid black line the standardized CPUE. The red bars are the 95% confidence intervals about the mean estimates. The graph scales both time-series of standardized CPUE relative to the mean of each time-series.

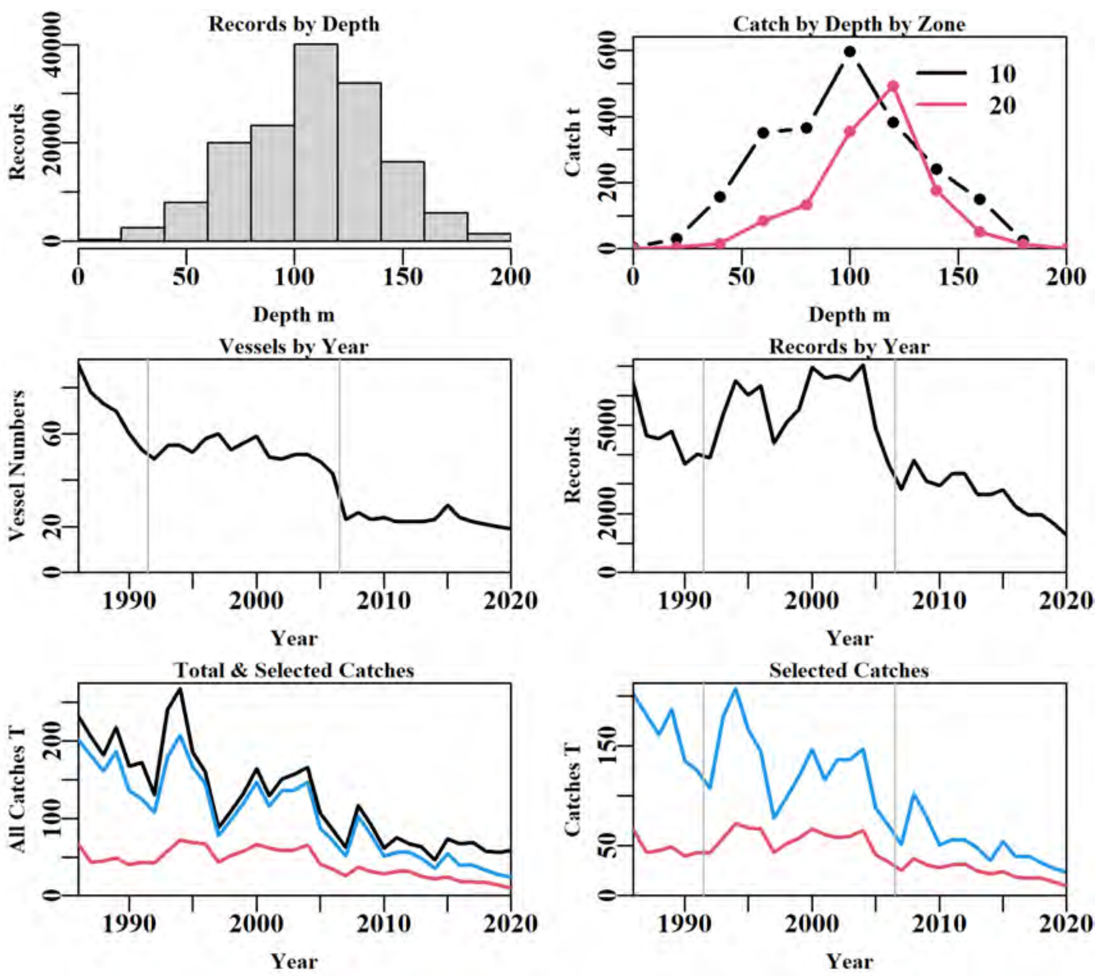

Figure 6.3. JohnDory1020 fishery details. The bottom left plot depicts all known catches (top black line), and all selected catches used in the analysis (middle blue line); the lower red line: selected catches < 30 kg).

Table 6.3. 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	249550	227932	221810	219125	181040	150261	150140
Difference	0	21618	6122	2685	38085	30779	121
Catch	4480	4345	4202	4145	3790	3637	3635
Difference	0	135	142	58	354	154	2

Table 6.4. 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 6.5. 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

Term	AIC	RSS	MSS	Nobs	Npars	adj_r2	%Change
Year	33985	188191	29488	150140	35	13.5	0
Vessel	17979	168776	48903	150140	206	22.4	8.83
DayNight	15531	166040	51640	150140	209	23.6	1.26
DepCat	13793	164107	53573	150140	219	24.5	0.88
Month	12586	162769	54910	150140	230	25.1	0.61
Zone	12557	162735	54945	150140	231	25.1	0.02
Zone:Month	11985	162093	55587	150140	242	25.4	0.29
Zone:DepCat	11342	161404	56275	150140	240	25.7	0.61

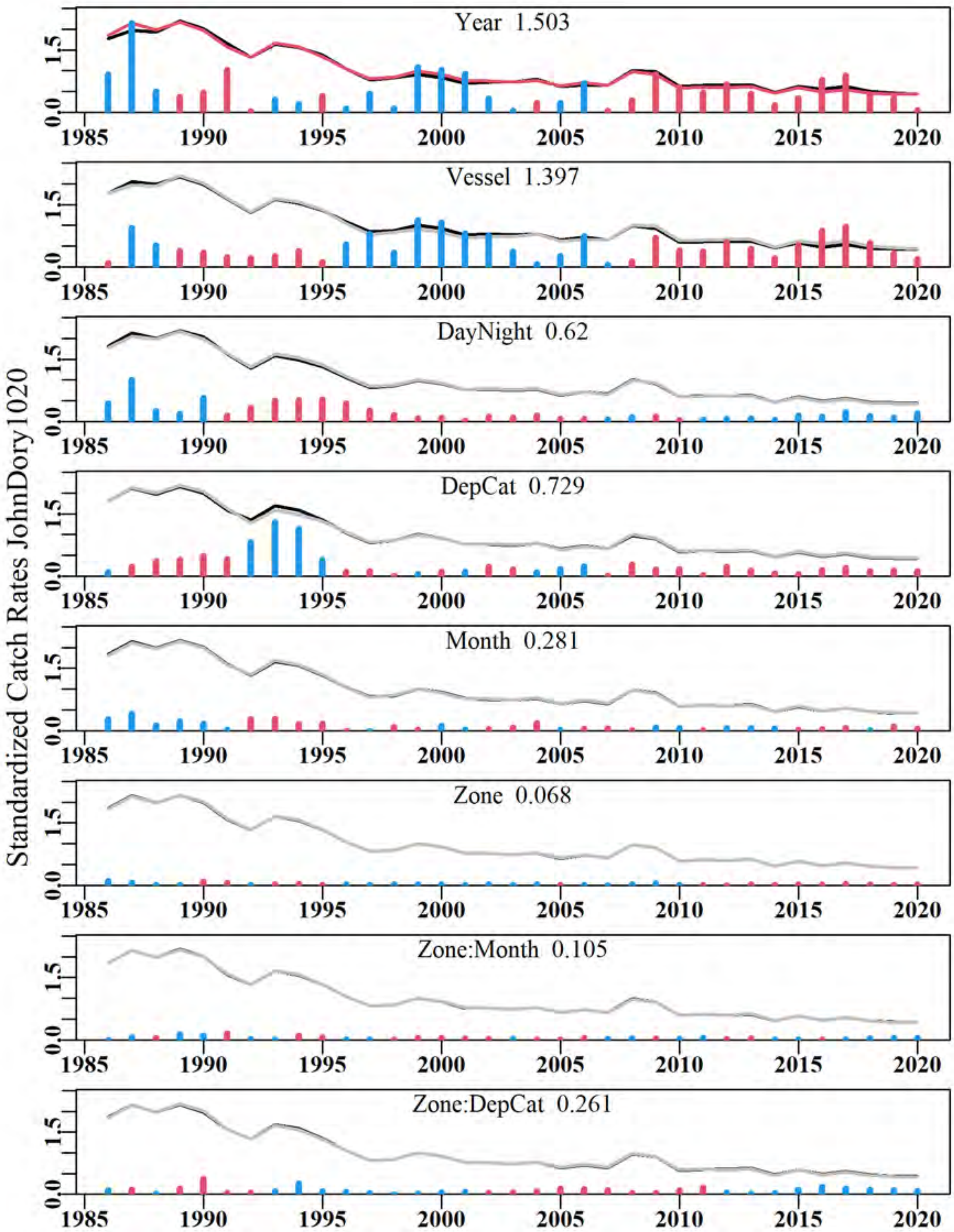

Figure 6.4. JohnDory1020. The influence of each factor on the optimal standardization. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by vertical bars with blue bars indicating the optimum model is higher than the geometric 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.

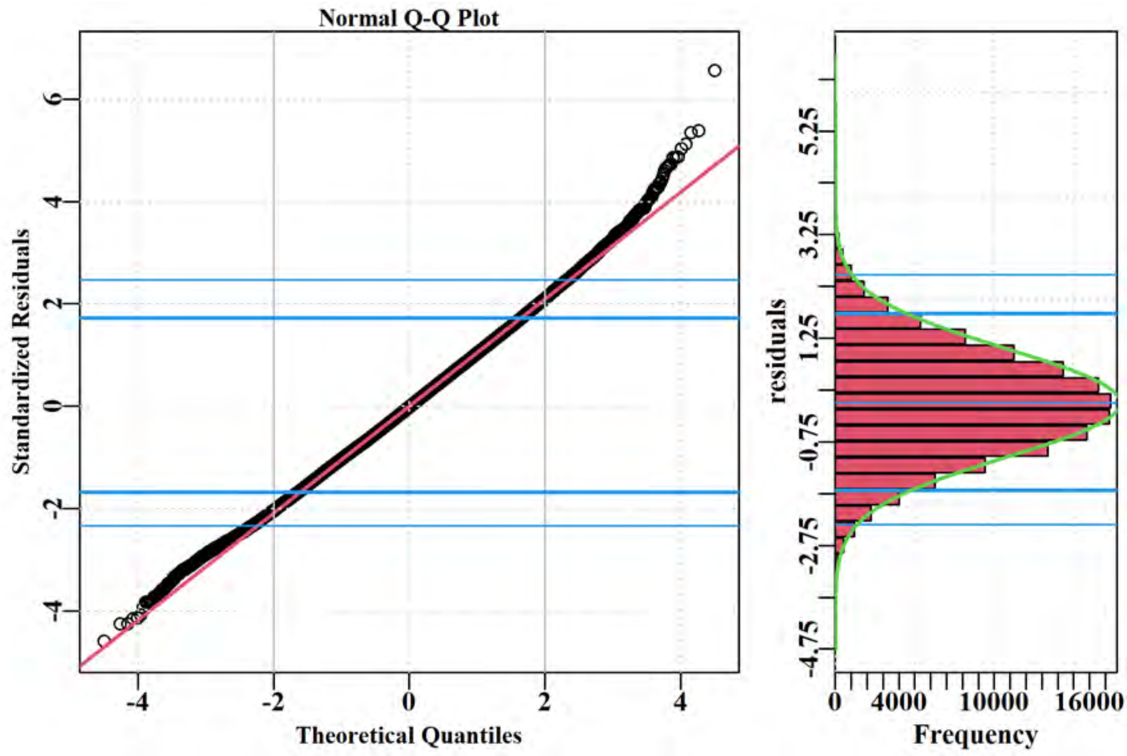

Figure 6.5. JohnDory1020. diagnostic plots. The distribution of residuals from the optimum fit. The qqplot indicates the fit to the expected normality, while the histogram of residuals illustrates the 90% quantiles to indicate the intensity of any lack of fit at the margins of the distribution.

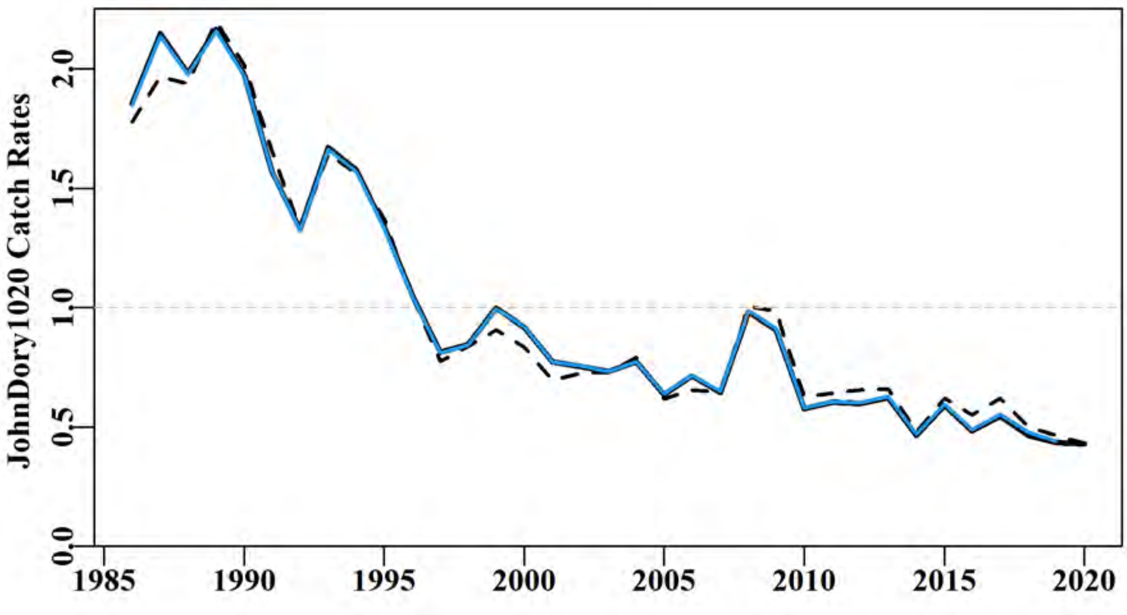

Figure 6.6. JohnDory1020. A comparison of the previous year's standardization (blue line) with this year's. They should lie on top of each other, although small deviations may relate to data adjustments, particularly in very recent years.

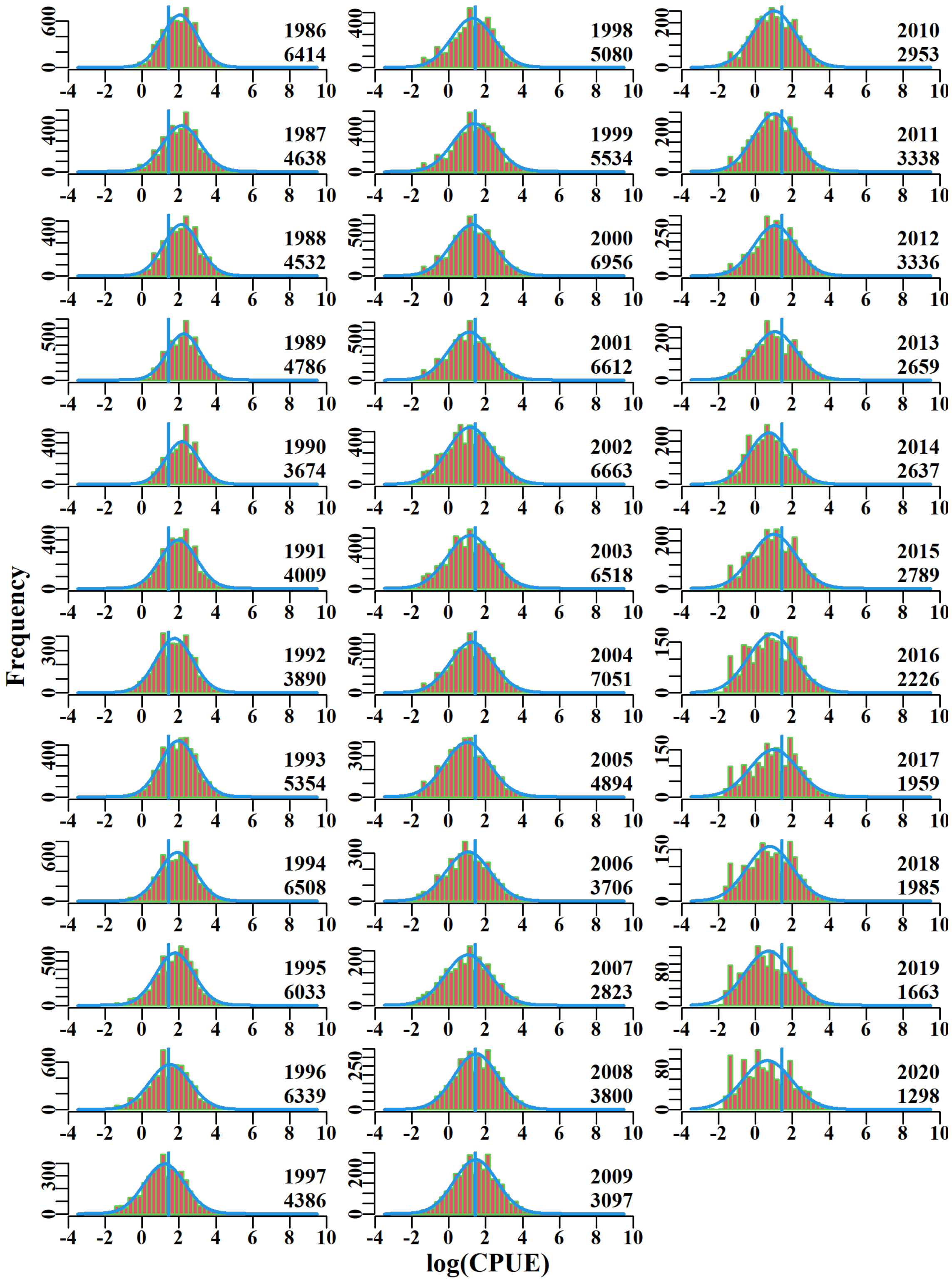

Figure 6.7. JohnDory1020. The natural log(CPUE) for each year of data available the blue lines are normal distributions fitted to the histogram frequencies. The numbers in each plot are the year and number of records.

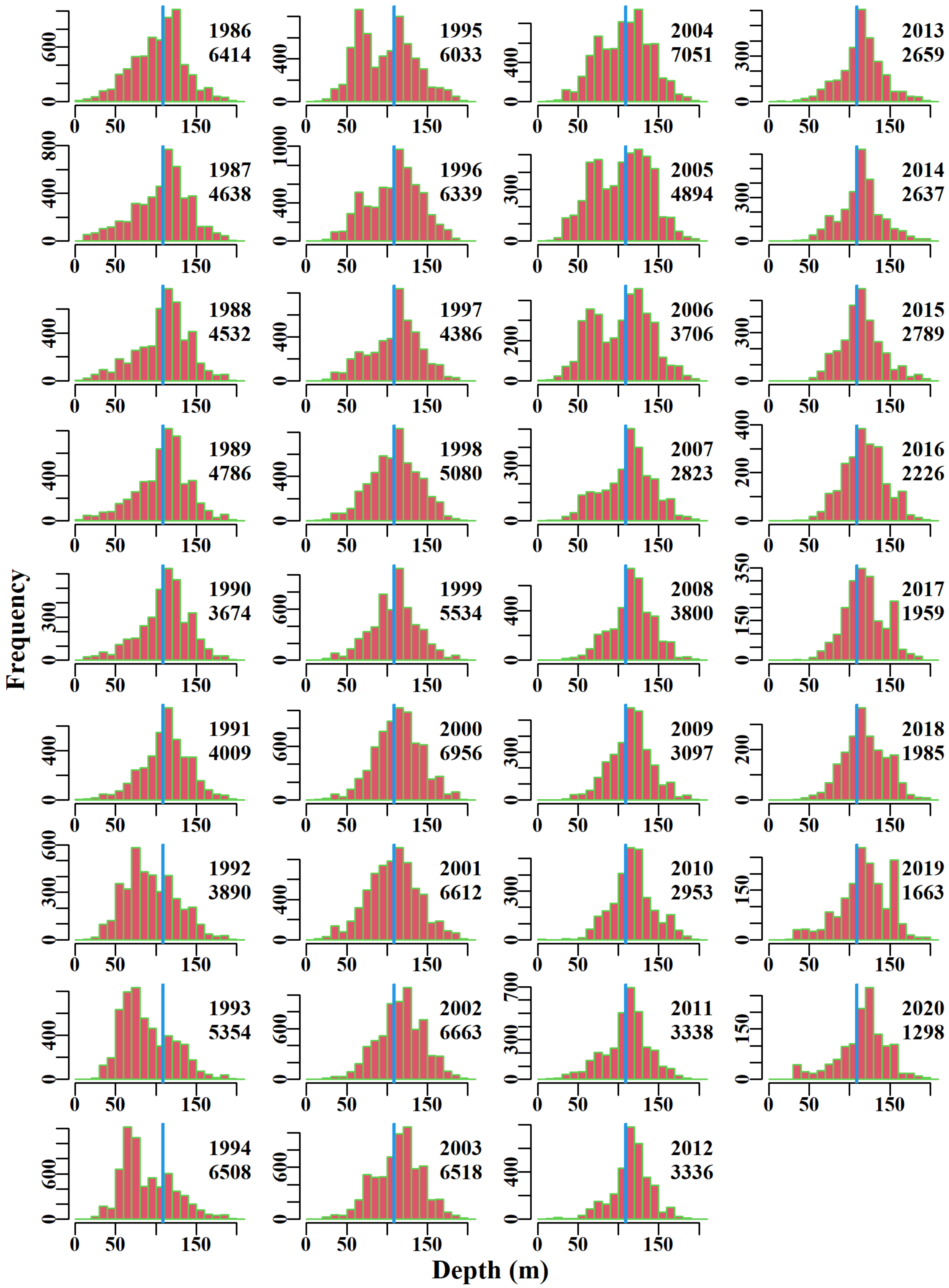

Figure 6.8. JohnDory1020. The average Depth of fishing for each year of data available to illustrate the development of the fishery through time. The numbers in each plot are the year and number of records.

6.4 School Whiting DS 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 up to 100 m. All vessels and all records were included in the analysis. CPUE was expressed as the natural log of catch per shot (catch/shot). The years used in the analysis were 1986 - 2020. Initial data selection was based on criteria provided in Table 6.6 from the Commonwealth logbook database. A total of 8 statistical models were fitted sequentially to the available data, and the order of the non-interaction terms added based on the relative contribution of each term to model fit.

6.4.1 *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, CPUE have been slowly rising and at approximately 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 6.10). Since 2013, there has been fewer catches in deeper waters (i.e., greater than 50 m). Standardized CPUE exhibits a flat trend over 2012-17 and has declined and dropped below the long-term average since 2017, based on 95% confidence intervals (Figure 6.9). The catch of 393.8 t in 2020 is the lowest since 2013.

6.4.2 *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 6.12). 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 vessels fishing changed in about 2003 onwards and this was reinforced by the DayNight term. The vessel effect also changed dramatically since 2014, at which time the distribution of catches among the vessels participating became more even than previously.

Fishing depths have been (i) recorded as single values or (ii) recorded at more than one constant value across different operations in the Commonwealth logbook database for certain vessels since about 2016. These fishing depths have been modified based on positional bathymetry and have been used in the standardization analysis presented here, as agreed by SESSFRAG in 2020.

Table 6.6. 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 - 2020

Table 6.7. 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

Year	Total	N	Catch	Vess	GeoM	Opt	StDev	C<30Kg	P<30Kg
1986	1302.4	5616	1167.1	26	262.4	1.1895	0.000	18.476	0.016
1987	996.0	4058	909.2	23	271.6	1.3204	0.029	12.131	0.013
1988	1256.2	3768	1158.2	25	375.7	1.6847	0.030	10.303	0.009
1989	1061.5	4421	989.1	26	260.6	1.1192	0.029	14.045	0.014
1990	1930.4	6082	1803.1	24	351.5	1.7280	0.027	15.136	0.008
1991	1630.3	4645	1456.3	26	407.7	1.5169	0.029	10.954	0.008
1992	854.1	2906	751.3	23	362.0	1.1033	0.033	8.103	0.011
1993	1696.0	4810	1512.2	24	444.7	1.5784	0.029	9.958	0.007
1994	946.2	4407	864.8	23	273.8	0.9250	0.029	12.619	0.015
1995	1212.6	4198	1050.0	21	337.1	1.1740	0.030	9.197	0.009
1996	898.2	4126	692.3	22	223.6	0.7731	0.030	13.981	0.020
1997	697.4	3066	442.1	20	202.5	0.5832	0.032	11.232	0.025
1998	594.2	2913	447.6	20	211.5	0.5615	0.033	10.661	0.024
1999	681.3	1870	411.5	21	345.1	0.6430	0.039	6.013	0.015
2000	701.0	1917	344.0	18	266.8	0.6701	0.038	7.058	0.021
2001	890.9	1990	424.6	19	296.0	0.9230	0.039	6.779	0.016
2002	788.3	2186	428.2	20	258.4	0.8955	0.037	7.753	0.018
2003	866.2	2338	460.0	20	275.4	0.9368	0.037	7.942	0.017
2004	604.9	1751	332.0	20	264.4	0.8496	0.040	6.951	0.021
2005	662.7	1562	296.4	20	255.6	0.9456	0.041	4.883	0.016
2006	667.5	1404	263.4	18	258.3	0.8565	0.043	5.336	0.020
2007	535.4	1469	343.1	14	330.0	1.1362	0.042	4.479	0.013
2008	502.2	1248	313.7	15	370.2	1.1256	0.045	4.280	0.014
2009	462.6	1548	347.6	15	309.7	1.2211	0.042	5.171	0.015
2010	408.9	1167	270.8	15	339.6	1.0639	0.046	4.199	0.016
2011	373.9	1564	257.2	14	198.8	0.8508	0.042	6.430	0.025
2012	435.8	1562	302.3	14	262.7	0.9141	0.042	5.604	0.019
2013	510.6	1765	336.1	14	249.9	0.9535	0.040	6.569	0.020
2014	698.8	2047	480.8	14	336.2	1.0429	0.039	6.106	0.013
2015	741.1	2449	563.7	14	327.5	1.0175	0.037	7.530	0.013
2016	698.7	2334	557.6	15	303.8	0.9901	0.037	7.843	0.014
2017	743.3	2381	631.9	16	378.2	0.9181	0.037	6.235	0.010
2018	589.4	2643	509.5	17	242.1	0.7007	0.036	9.530	0.019
2019	479.1	2783	401.3	17	175.4	0.6035	0.035	10.814	0.027
2020	511.3	2461	393.8	18	215.6	0.4847	0.037	11.283	0.029

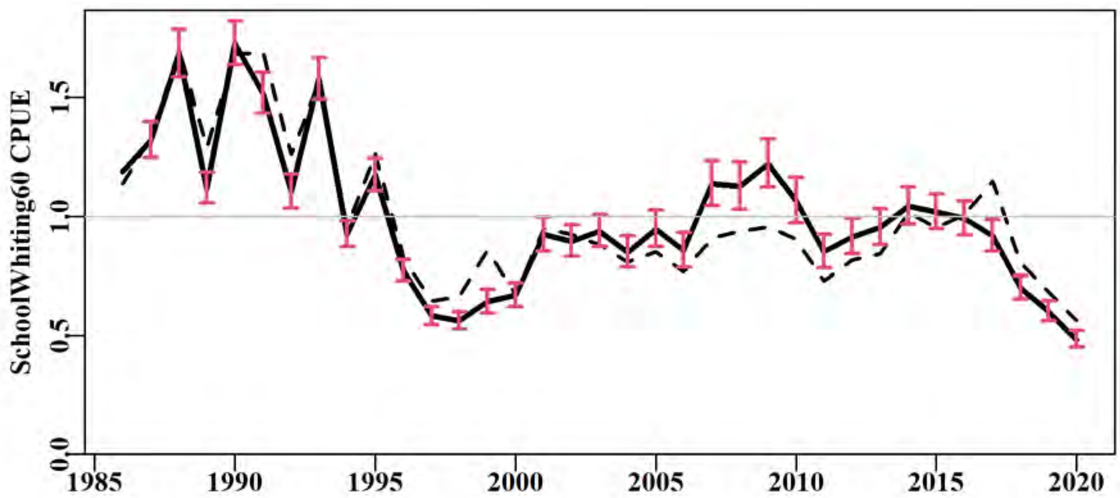

Figure 6.9. SchoolWhiting60 standardization. The dashed black line represents the geometric mean CPUE, solid black line the standardized CPUE. The red bars are the 95% confidence intervals about the mean estimates. The graph scales both time-series of standardized CPUE relative to the mean of each time-series.

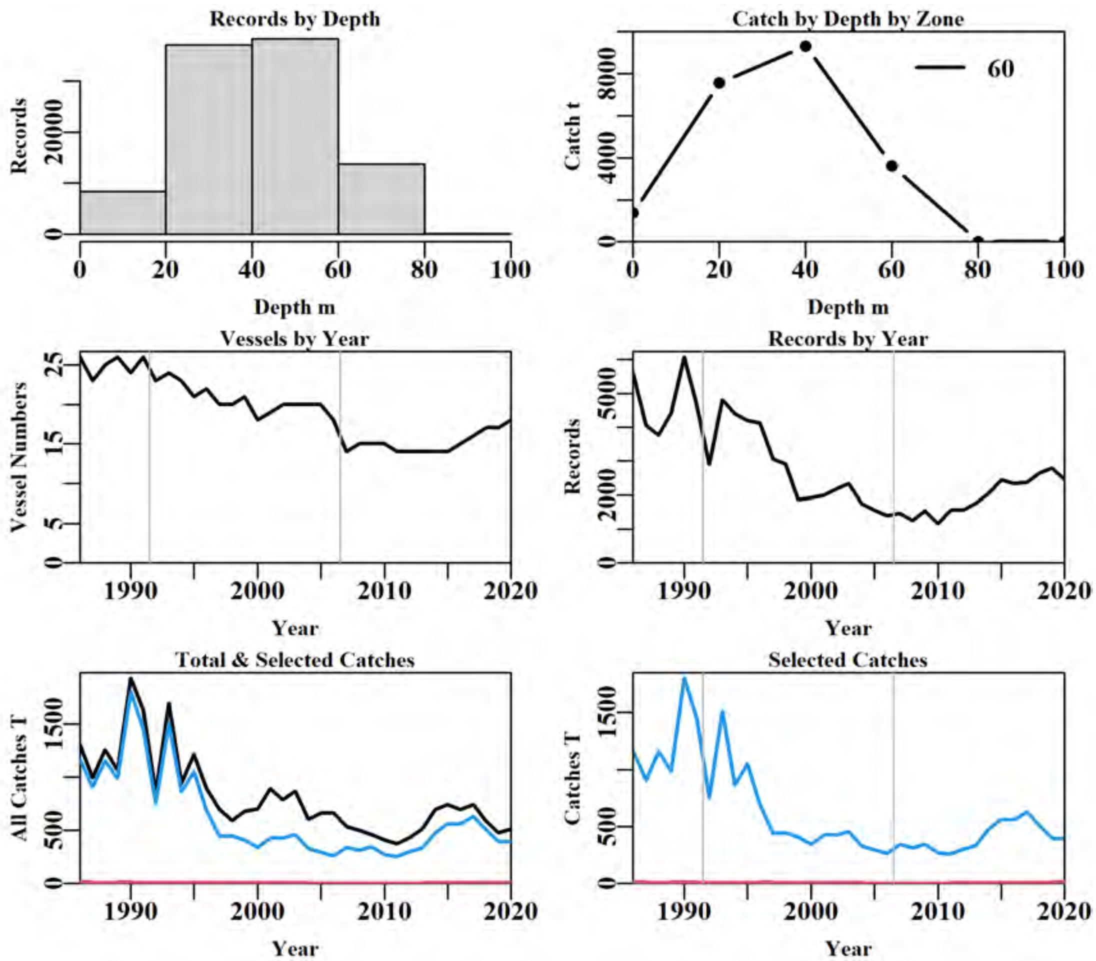

Figure 6.10. SchoolWhiting60 fishery details. The bottom left plot depicts all known catches (top black line), and all selected catches used in the analysis (middle blue line); the lower red line: selected catches < 30 kg).

Table 6.8. 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	151730	143025	138056	136002	103193	100430	97455
Difference	0	8705	4969	2054	32809	2763	2975
Catch	28996	28996	28262	27899	23036	22618	21913
Difference	0	0	734	363	4863	418	705

Table 6.9. 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 6.10. 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

Term	AIC	RSS	MSS	Nobs	Npars	adj_r2	%Change
Year	71619	203073	9421	97455	35	4.4	0
DayNight	67605	194867	17627	97455	38	8.3	3.86
Vessel	63819	187245	25249	97455	89	11.8	3.54
Month	62694	185055	27439	97455	100	12.8	1.02
DepCat	62141	183988	28506	97455	105	13.3	0.50
DayNight:DepCat	61968	183621	28872	97455	116	13.5	0.16
DepCat:Month	61474	182581	29913	97455	146	13.9	0.63
DayNight:Month	61878	183369	29125	97455	138	13.6	0.26

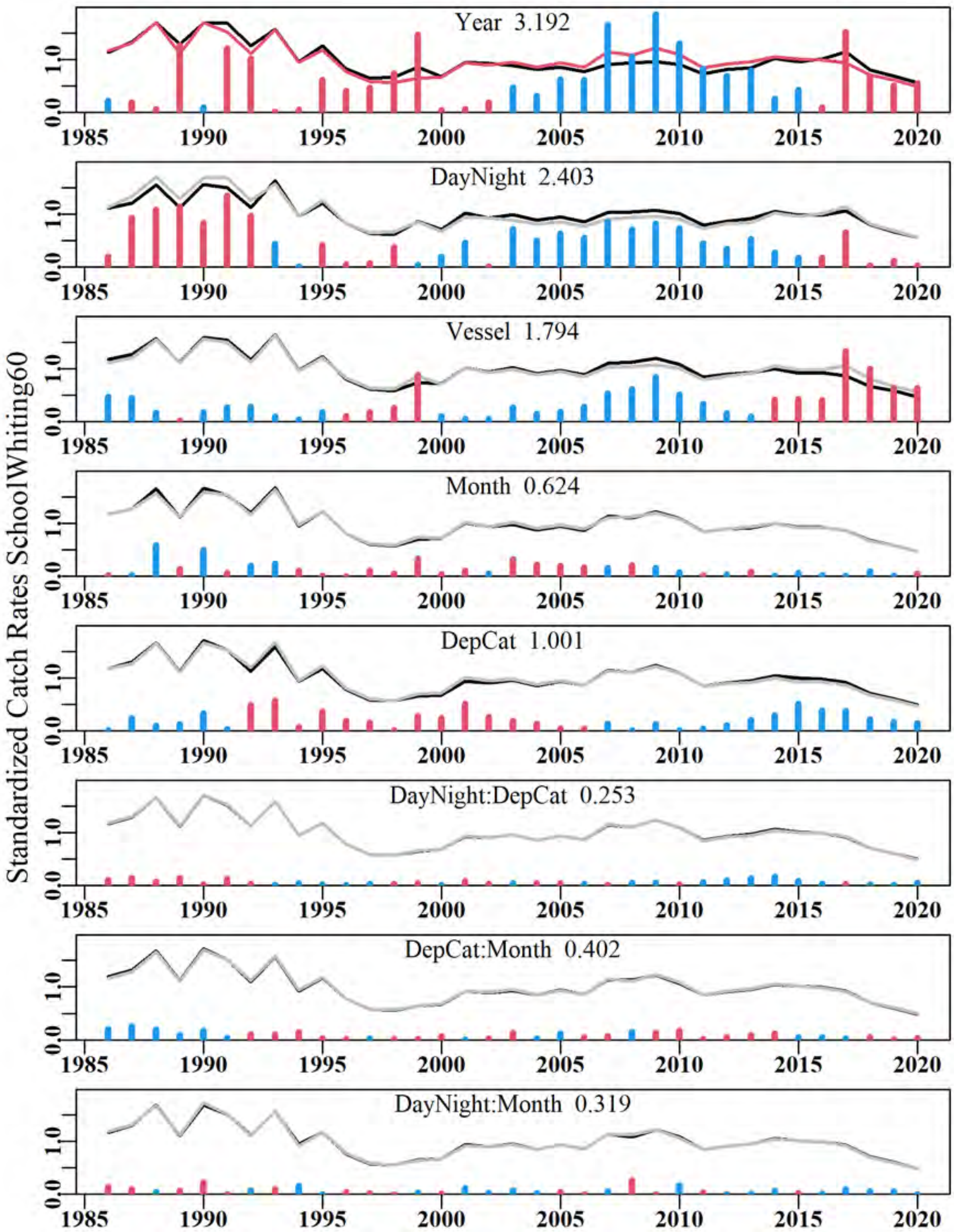

Figure 6.11. SchoolWhiting60. The influence of each factor on the optimal standardization. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by vertical bars with blue bars indicating the optimum model is higher than the 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.

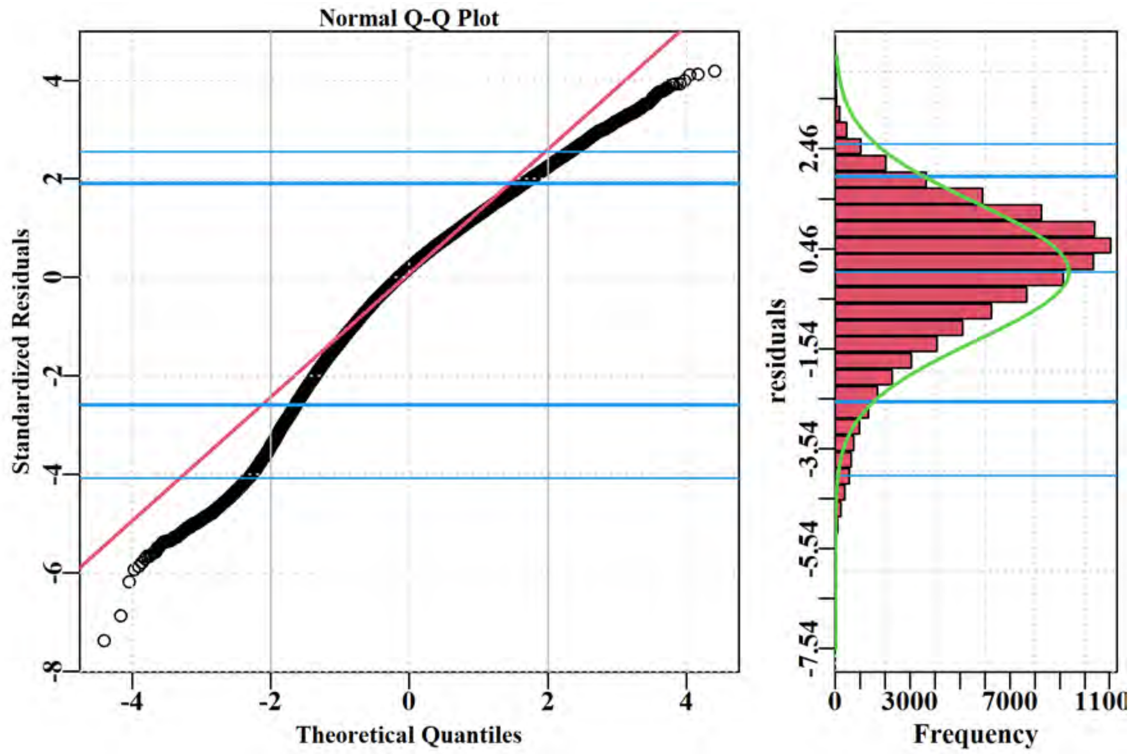

Figure 6.12. SchoolWhiting60. diagnostic plots. The distribution of residuals from the optimum fit. The qqplot indicates the fit to the expected normality, while the histogram of residuals illustrates the 90% quantiles to indicate the intensity of any lack of fit at the margins of the distribution.

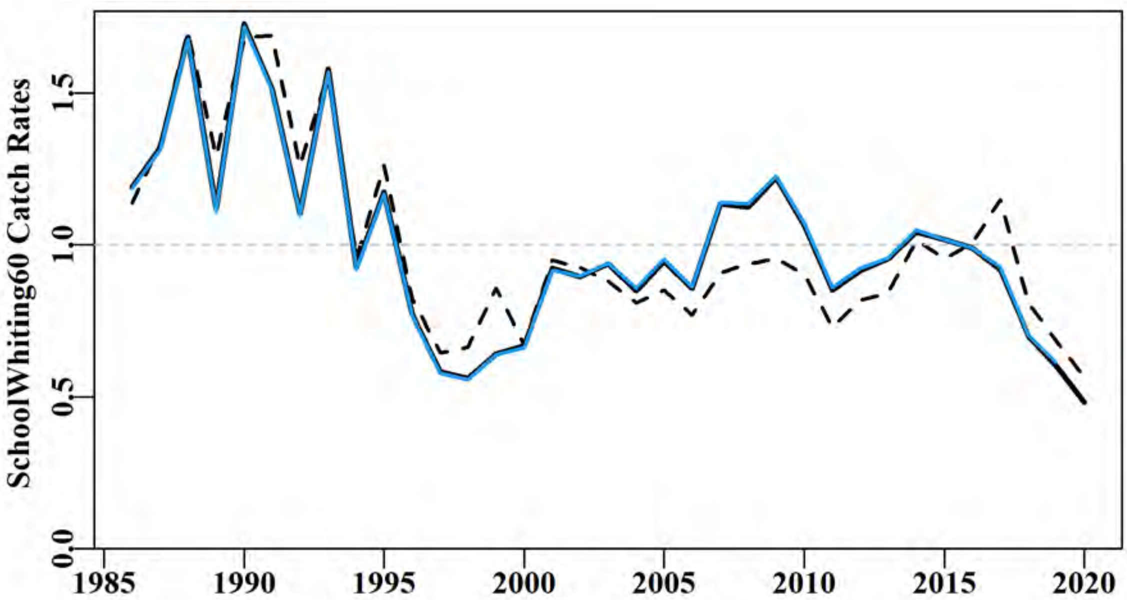

Figure 6.13. SchoolWhiting60. A comparison of the previous year's standardization (blue line) with this year's. They should lie on top of each other, although small deviations may relate to data adjustments, particularly in very recent years.

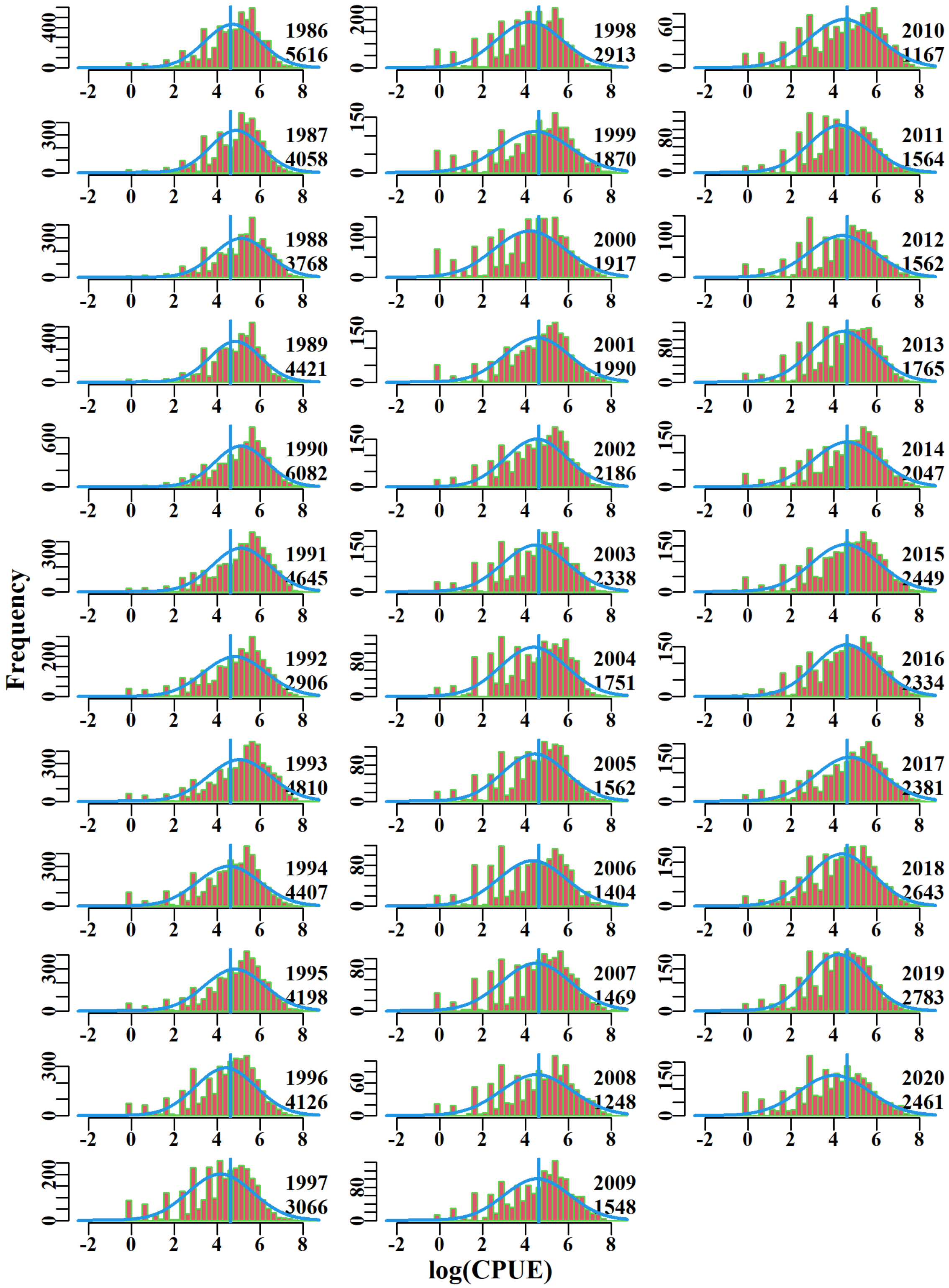

Figure 6.14. SchoolWhiting60. The natural log(CPUE) for each year of data available the blue lines are normal distributions fitted to the histogram frequencies. The numbers in each plot are the year and number of records.

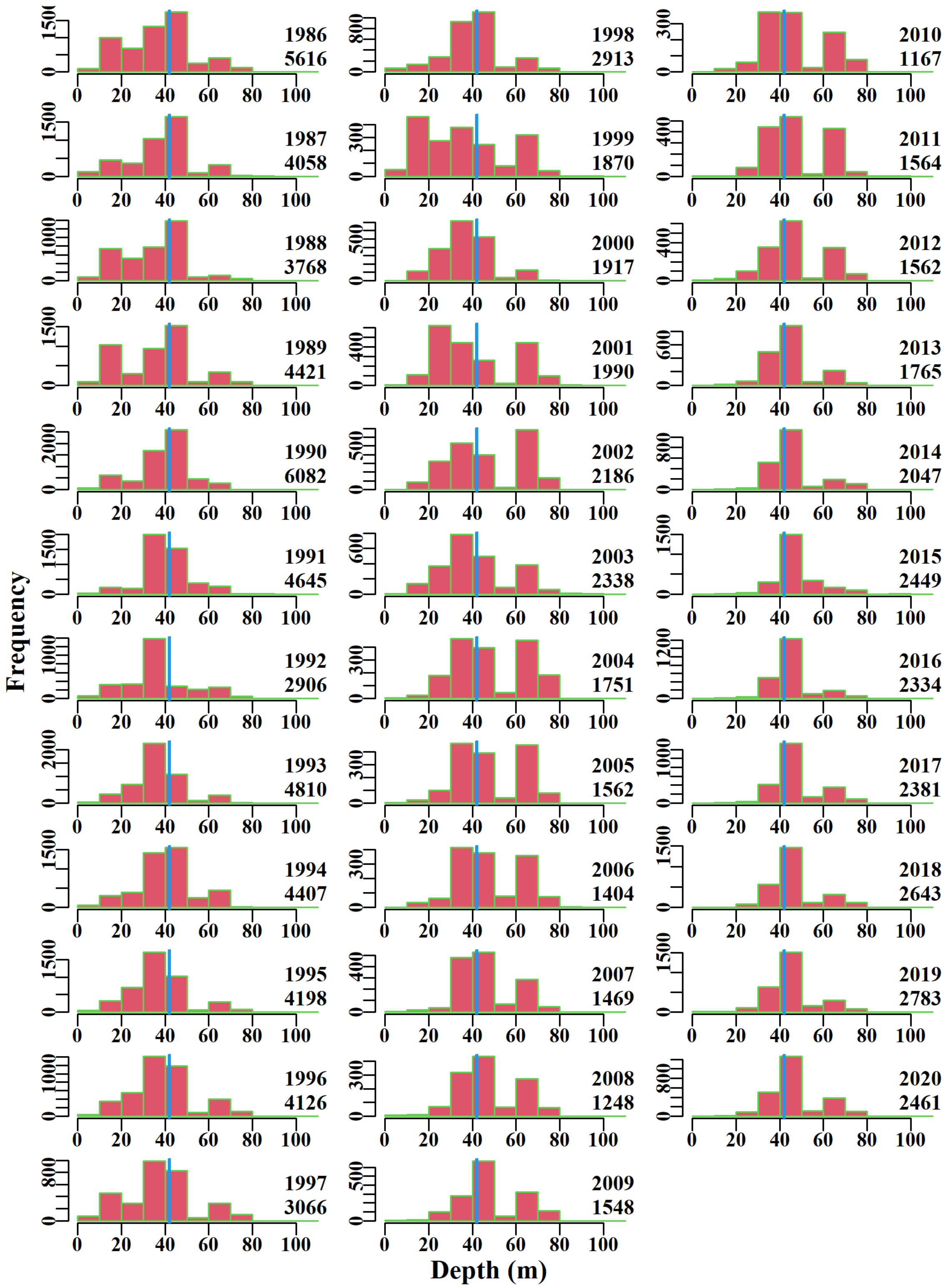

Figure 6.15. SchoolWhiting60. The average Depth of fishing for each year of data available to illustrate the development of the fishery through time. The numbers in each plot are the year and number of records.

6.5 School Whiting Trawl 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 - 2020. CPUE was 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.

6.5.1 *Inferences*

Most trawl caught school whiting occur between approximately 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 6.15). The qqplot suggests that the assumed Normal distribution is valid, with small deviations at the tails (Figure 6.19).

Standardized CPUE has exceeded the long-term average in 2016, 2017, 2019 and 2020 based on the 95% confidence intervals (Figure 6.16). Also, there has been a relative increase in standardized CPUE over the last three years.

6.5.2 *Action Items and Issues*

The last three years 2017 - 2019 appear to have exhibited a change in fishing behaviour as evidenced by the changing distributions of records at depth, why this has occurred in the last three years remains unknown.

Fishing depths have been (i) recorded as single values or (ii) recorded at more than one constant value across different operations in the Commonwealth logbook database for certain vessels since about 2016. These fishing depths have been modified based on positional bathymetry and have been used in the standardization analysis presented here, as agreed by SESSFRAG in 2020. Differences between this year's standardized CPUE (i.e., 1986 – 2020) compared with last year's standardized CPUE (i.e., 1986 – 2019) are likely due to these modified fishing depths.

Table 6.11. 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, OTB
years	1995 - 2020

Table 6.12. 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

Year	Total	N	Catch	Vess	GeoM	Opt	StDev	C<30Kg	P<30Kg
1995	1212.6	277	40.7	16	64.8	1.1957	0.000	1.046	0.026
1996	898.2	437	75.1	21	83.2	1.3256	0.094	0.806	0.011
1997	697.4	824	97.0	23	68.0	0.9173	0.085	2.771	0.029
1998	594.2	710	81.1	25	54.6	0.9372	0.087	2.844	0.035
1999	681.3	886	107.1	27	63.2	1.1295	0.085	2.809	0.026
2000	701.0	1229	154.4	30	69.6	1.1308	0.082	3.735	0.024
2001	890.9	2101	309.2	34	92.7	1.2459	0.079	7.896	0.026
2002	788.3	1662	172.1	36	73.2	1.0363	0.081	6.024	0.035
2003	866.2	2426	291.3	40	68.7	0.9786	0.079	9.290	0.032
2004	604.9	2037	186.2	39	48.0	0.7578	0.079	9.837	0.053
2005	662.7	1953	250.4	37	71.4	1.0660	0.080	7.556	0.030
2006	667.5	1437	225.6	28	75.4	1.4658	0.081	5.825	0.026
2007	535.4	495	86.7	15	105.5	1.4752	0.094	2.110	0.024
2008	502.2	841	107.4	15	68.1	0.9380	0.086	3.724	0.035
2009	462.6	444	36.8	17	46.7	0.8065	0.095	2.629	0.071
2010	408.9	463	47.6	17	60.4	0.9658	0.095	2.282	0.048
2011	373.9	494	64.5	15	83.4	0.8323	0.094	2.313	0.036
2012	435.8	509	45.3	16	49.7	0.6123	0.093	3.115	0.069
2013	510.6	663	57.0	14	44.4	0.5450	0.089	4.006	0.070
2014	698.8	815	71.4	18	52.2	0.7477	0.087	4.168	0.058
2015	741.1	767	55.2	18	36.7	0.6817	0.088	4.944	0.090
2016	698.7	618	66.6	14	64.9	0.9281	0.091	3.387	0.051
2017	743.3	391	45.8	12	65.7	1.1211	0.099	2.252	0.049
2018	589.4	406	28.7	15	30.3	0.6874	0.101	2.421	0.084
2019	479.1	377	33.2	6	48.3	0.9820	0.101	1.424	0.043
2020	511.3	420	58.9	8	74.7	1.4903	0.101	1.577	0.027

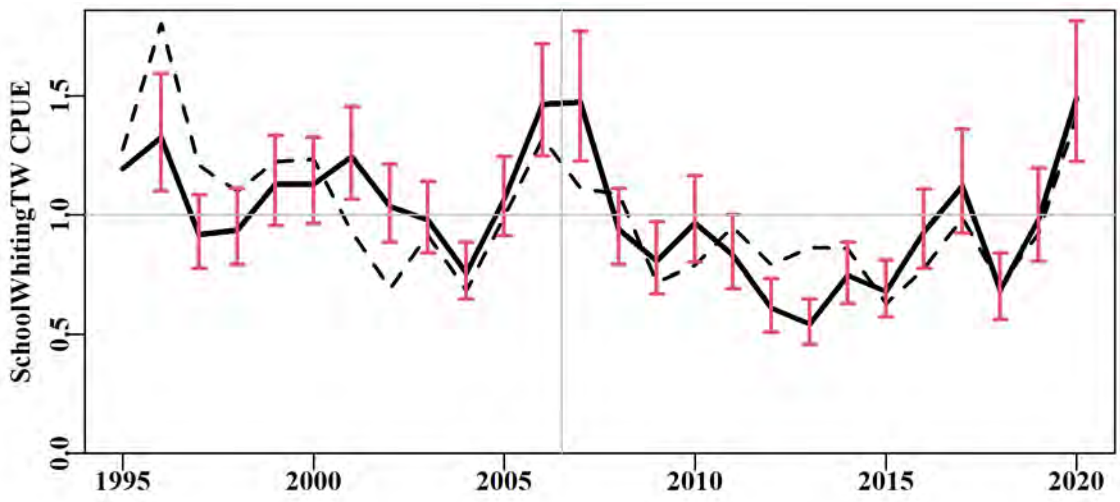

Figure 6.16. SchoolWhitingTW standardization. The dashed black line represents the geometric mean CPUE, solid black line the standardized CPUE. The red bars are the 95% confidence intervals about the mean estimates. The graph scales both time-series of standardized CPUE relative to the mean of each time-series.

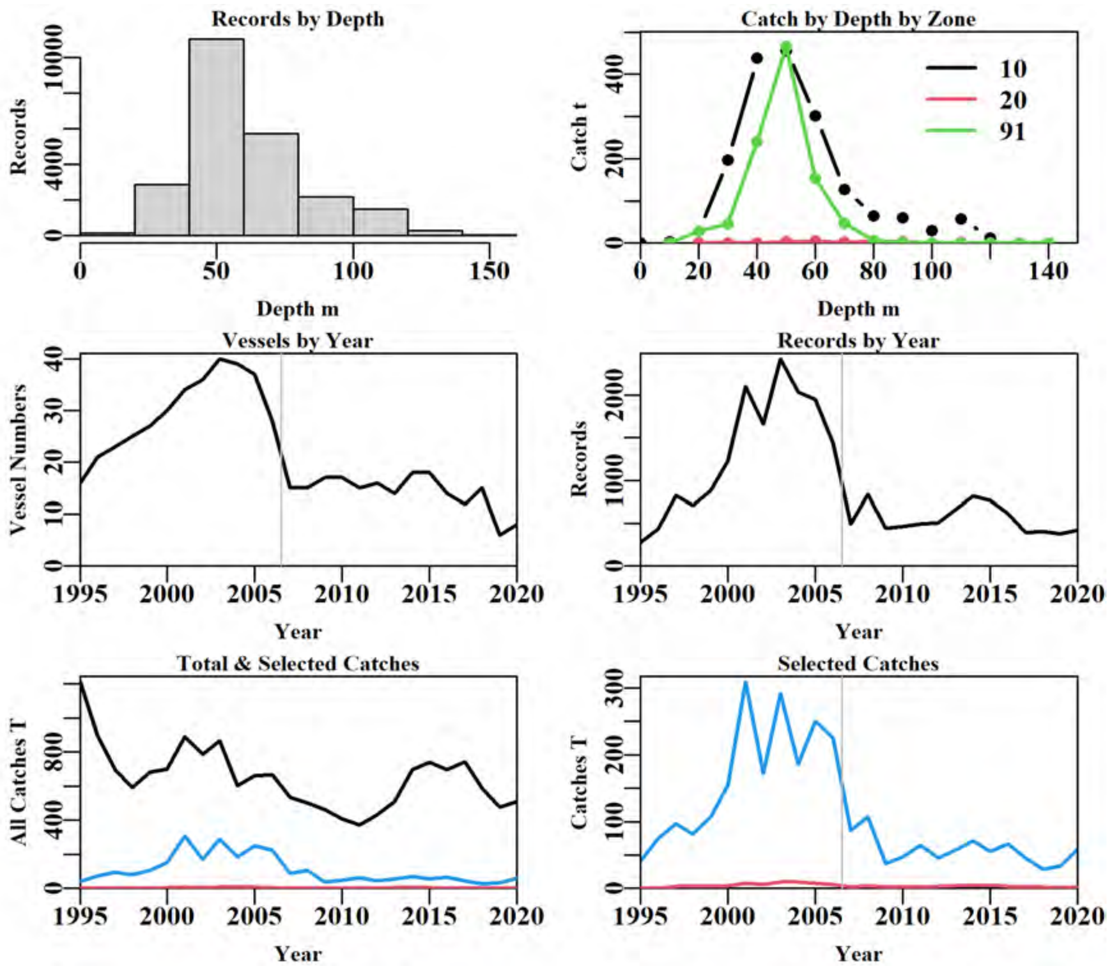

Figure 6.17. SchoolWhitingTW fishery details. The bottom left plot depicts all known catches (top black line), and all selected catches used in the analysis (middle blue line); the lower red line: selected catches < 30 kg).

Table 6.13. 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	151730	117962	116011	72615	25165	23709	23682
Difference	0	33768	1951	43396	47450	1456	27
Catch	28996	24032	23624	12784	3016	2797	2795
Difference	0	4964	408	10840	9768	219	2

Table 6.14. 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 6.15. 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

Term	AIC	RSS	MSS	Nobs	Npars	adj_r2	%Change
Year	20774	56812	1329	23682	26	2.2	0
Vessel	12563	39932	18209	23682	95	31.0	28.86
DayNight	10310	36299	21842	23682	98	37.3	6.27
DepCat	9390	34875	23266	23682	112	39.7	2.42
Month	9323	34743	23397	23682	123	39.9	0.20
DayNight:DepCat	9027	34235	23906	23682	150	40.7	0.81
DepCat:Month	9127	34055	24086	23682	262	40.8	0.84
DayNight:Month	9247	34562	23578	23682	147	40.2	0.25

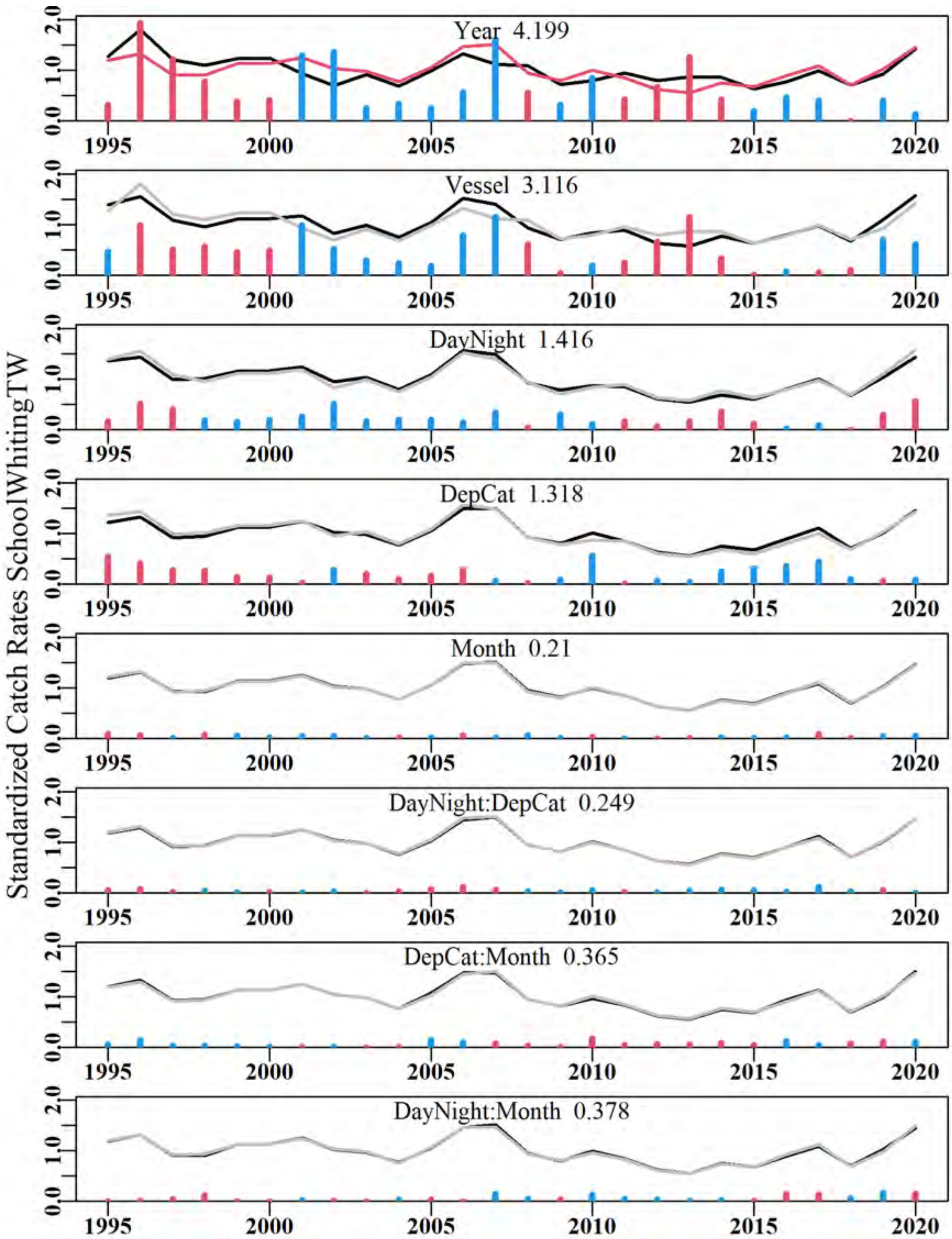

Figure 6.18. SchoolWhitingTW. The influence of each factor on the optimal standardization. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by vertical bars with blue bars indicating the optimum model is higher than the 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.

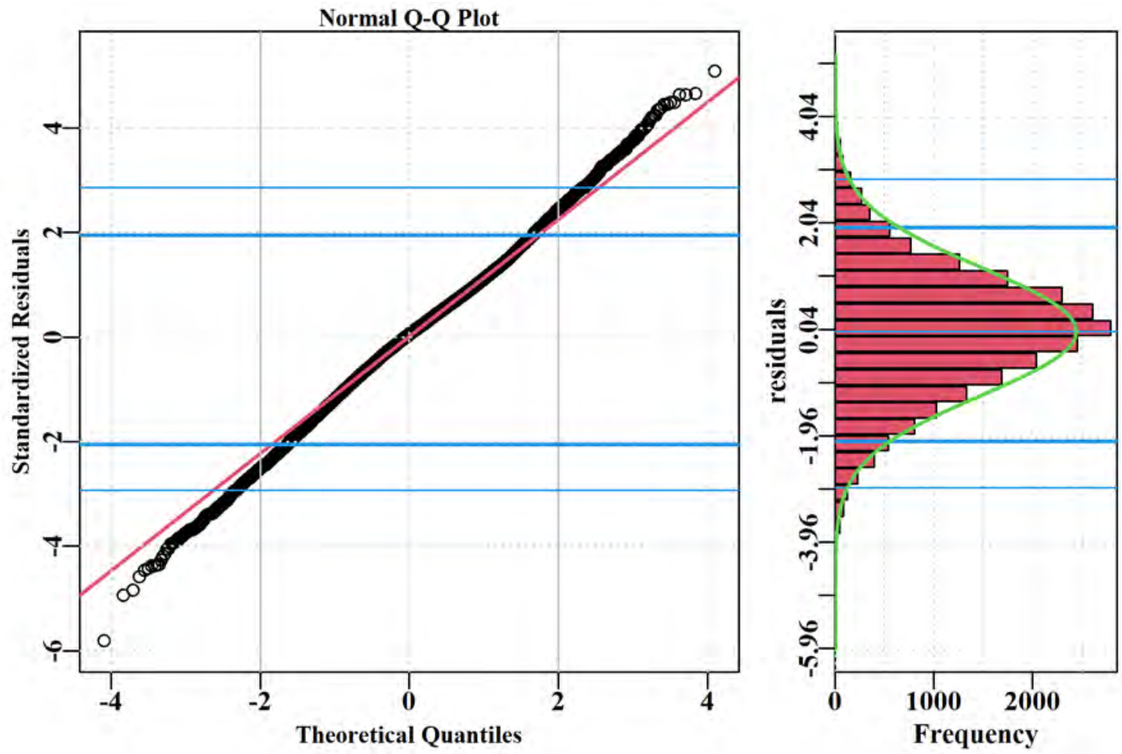

Figure 6.19. SchoolWhitingTW. diagnostic plots. The distribution of residuals from the optimum fit. The qqplot indicates the fit to the expected normality, while the histogram of residuals illustrates the 90% quantiles to indicate the intensity of any lack of fit at the margins of the distribution.

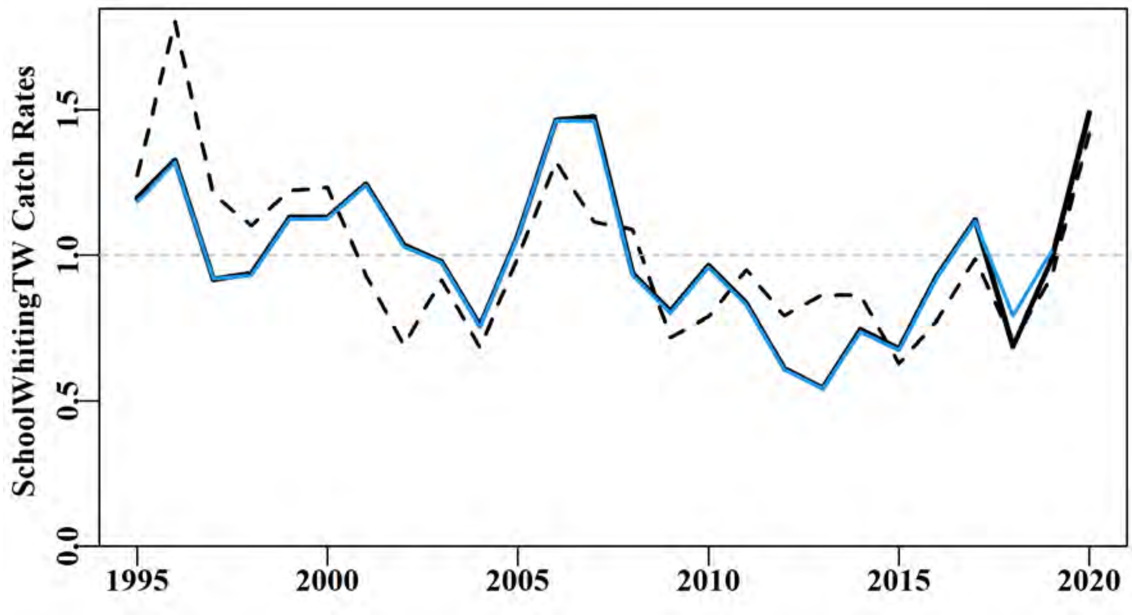

Figure 6.20. SchoolWhitingTW. A comparison of the previous year's standardization (blue line) with this year's. They should lie on top of each other, although small deviations may relate to data adjustments, particularly in very recent years.

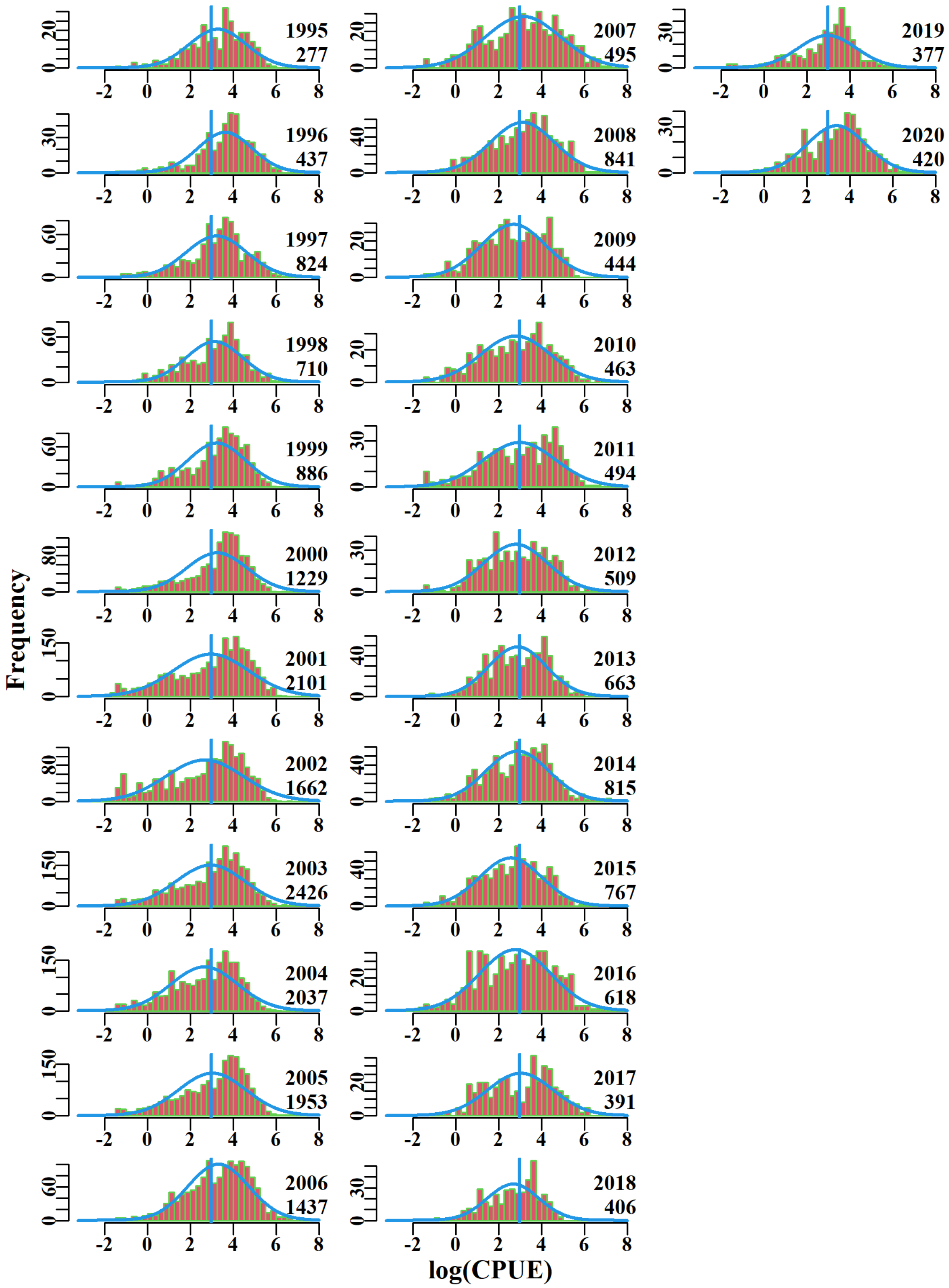

Figure 6.21. SchoolWhitingTW. The natural log(CPUE) for each year of data available the blue lines are normal distributions fitted to the histogram frequencies. The numbers in each plot are the year and number of records.

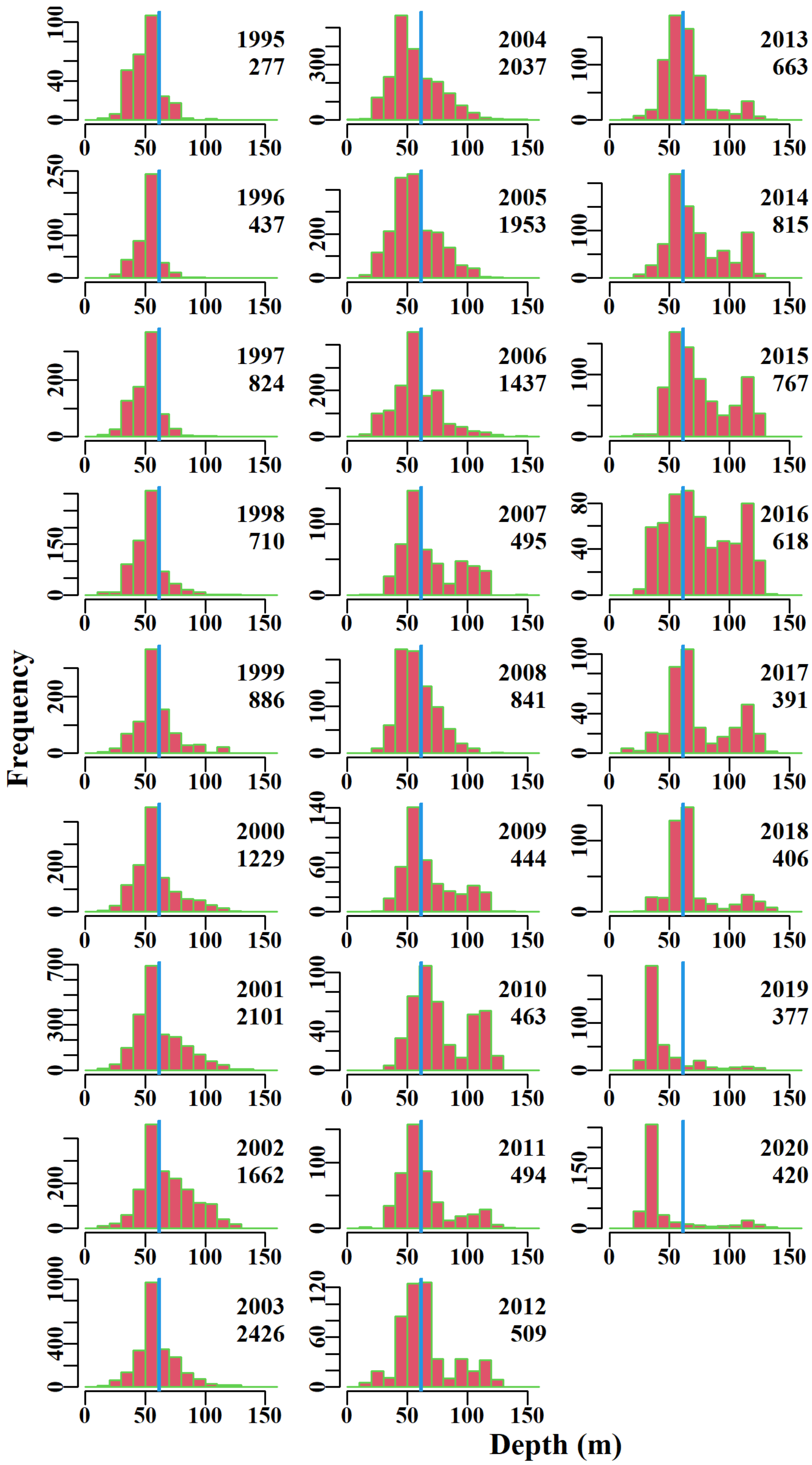

Figure 6.22. SchoolWhitingTW. The average Depth of fishing for each year of data available to illustrate the development of the fishery through time. The numbers in each plot are the year and number of records.

6.6 School Whiting Trawl 10 20

6.6.1 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 - 2020. Catch rates were expressed as the natural log of catch per hour (catch/hr). Initial data selection was based on criteria provided in Table 6.16 from the Commonwealth logbook database. This analysis omits zone 91, which, even though the fishery is a clear and natural extension of the Commonwealth fishery (as evidenced by plotting the location of each shot) being State waters and catches they are omitted from the standardization for comparison with the complete analysis. A total of 8 statistical models were fitted sequentially to the available data, and the order of the non-interaction terms added based on the relative contribution of each term to model fit.

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

Standardized CPUE is relatively noisy and flat except between 2006 - 2007 (i.e. around the time of the structural adjustment) (Figure 6.23).

6.6.2 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.

Fishing depths have been (i) recorded as single values or (ii) recorded at more than one constant value across different operations in the Commonwealth logbook database for certain vessels since about 2016. These fishing depths have been modified based on positional bathymetry and have been used in the standardization analysis presented here, as agreed by SESSFRAG in 2020. Differences between this year's standardized CPUE (i.e., 1986 – 2020) compared with last year's standardized CPUE (i.e., 1986 – 2019) are likely due to these modified fishing depths.

Table 6.16. 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, OTB
years	1995 - 2020

Table 6.17. 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

Year	Total	N	Catch	Vess	GeoM	Opt	StDev	C<30Kg	P<30Kg
1995	1212.6	153	23.3	13	94.2	1.3202	0.000	0.689	0.030
1996	898.2	142	27.7	17	170.6	1.1824	0.154	0.393	0.014
1997	697.4	438	58.2	21	119.6	0.9555	0.124	1.951	0.033
1998	594.2	313	32.7	25	70.8	0.9519	0.129	1.685	0.051
1999	681.3	486	51.5	27	72.0	1.1280	0.123	2.083	0.040
2000	701.0	794	98.9	30	89.8	1.1107	0.117	2.765	0.028
2001	890.9	1453	178.9	34	87.0	1.1312	0.114	6.864	0.038
2002	788.3	1302	128.3	36	78.6	1.0224	0.114	4.992	0.039
2003	866.2	1638	192.6	38	79.1	0.9999	0.113	7.165	0.037
2004	604.9	1281	90.8	38	40.5	0.7880	0.114	7.119	0.078
2005	662.7	1254	132.9	37	65.0	1.0180	0.114	6.453	0.049
2006	667.5	948	140.3	28	79.7	1.6083	0.116	4.665	0.033
2007	535.4	434	80.5	15	122.5	1.6187	0.125	1.835	0.023
2008	502.2	522	68.3	15	81.5	0.8689	0.122	2.344	0.034
2009	462.6	376	30.3	17	46.1	0.7864	0.127	2.204	0.073
2010	408.9	385	37.8	17	55.6	0.9466	0.128	2.137	0.057
2011	373.9	422	50.0	15	84.5	0.7886	0.126	1.941	0.039
2012	435.8	426	40.0	16	57.1	0.6489	0.125	2.445	0.061
2013	510.6	505	45.4	14	50.1	0.5256	0.123	2.810	0.062
2014	698.8	693	63.4	18	58.3	0.7591	0.120	3.551	0.056
2015	741.1	647	47.6	18	39.0	0.6914	0.121	4.158	0.087
2016	698.7	544	58.2	14	66.4	0.8733	0.123	3.137	0.054
2017	743.3	323	37.9	12	67.9	1.0685	0.132	2.077	0.055
2018	589.4	265	16.5	15	27.1	0.7035	0.139	1.691	0.102
2019	479.1	258	23.1	6	51.6	1.0555	0.138	1.103	0.048
2020	511.3	320	47.1	8	84.6	1.4485	0.135	1.517	0.032

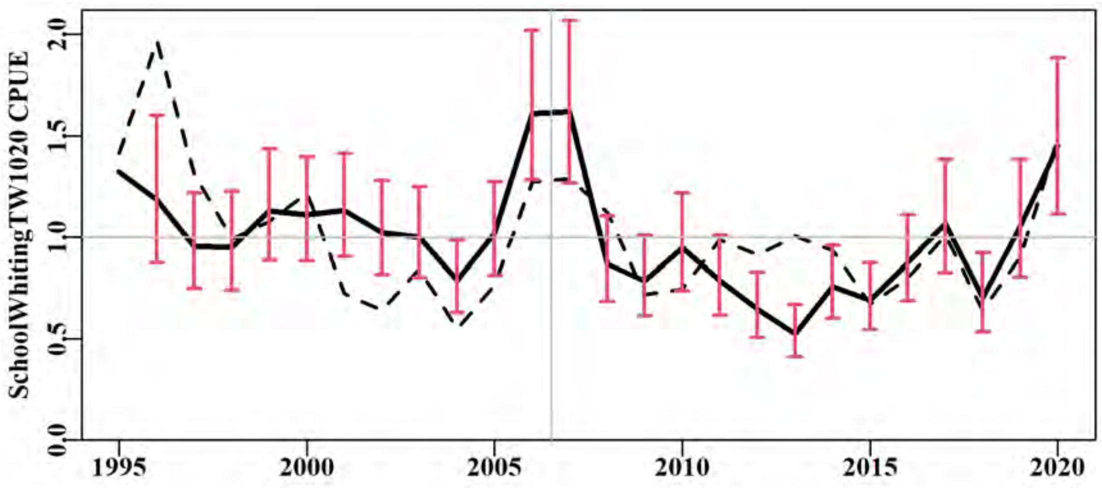

Figure 6.23. SchoolWhitingTW1020 standardization. The dashed black line represents the geometric mean CPUE, solid black line the standardized CPUE. The red bars are the 95% confidence intervals about the mean estimates. The graph scales both time-series of standardized CPUE relative to the mean of each time-series.

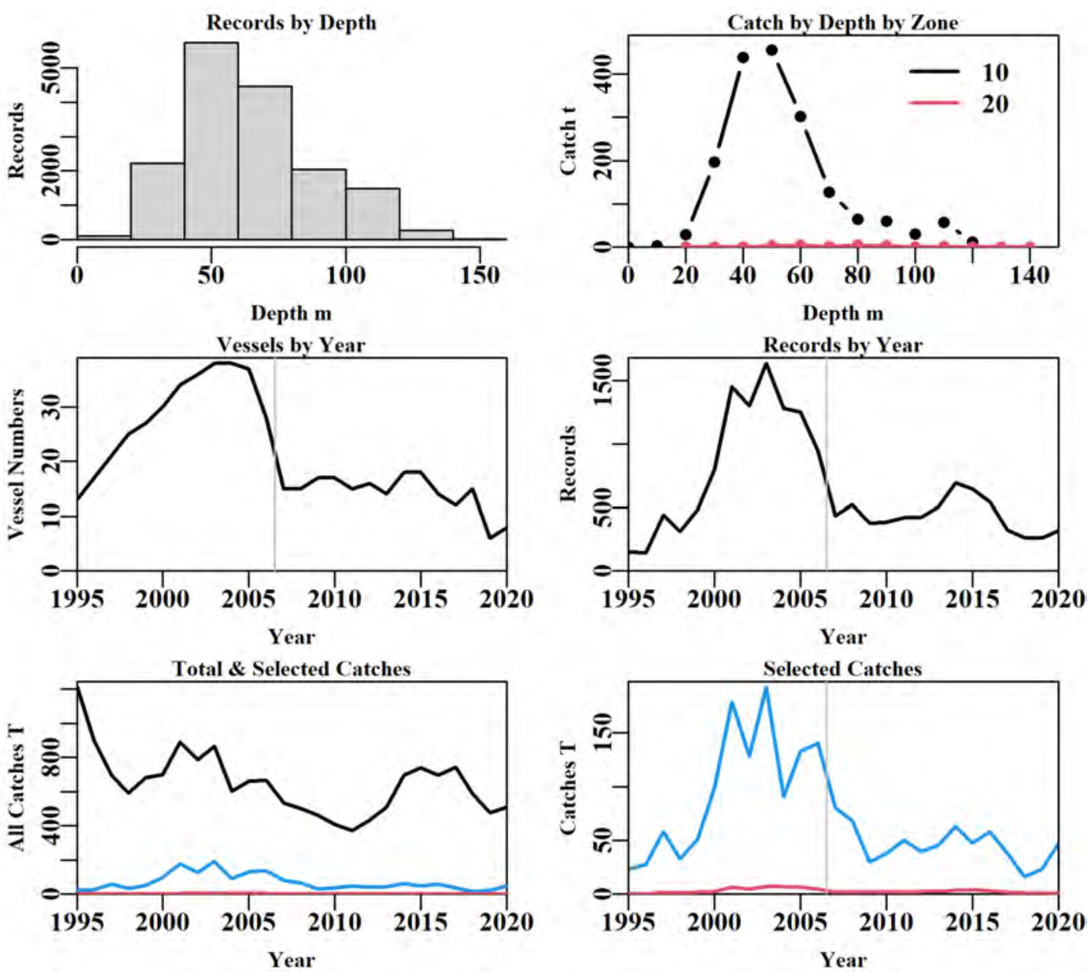

Figure 6.24. SchoolWhitingTW1020 fishery details. The bottom left plot depicts all known catches (top black line), and all selected catches used in the analysis (middle blue line); the lower red line: selected catches < 30 kg).

Table 6.18. 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	151730	117962	116011	72615	17801	16349	16322
Difference	0	33768	1951	43396	54814	1452	27
Catch	28996	24032	23624	12784	2023	1805	1802
Difference	0	4964	408	10840	10761	218	2

Table 6.19. 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 6.20. 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

Term	AIC	RSS	MSS	Nobs	Npars	adj_r2	%Change
Year	17418	47299	1232	16322	26	2.4	0
Vessel	11414	32466	16065	16322	95	32.7	30.33
DayNight	9535	28924	19607	16322	98	40.0	7.33
DepCat	8732	27489	21042	16322	112	43.0	2.92
Month	8667	27343	21188	16322	123	43.2	0.26
DayNight:DepCat	8352	26731	21800	16322	150	44.4	1.18
DepCat:Month	8559	26707	21824	16322	261	44.1	0.84
DayNight:Month	8624	27191	21340	16322	147	43.5	0.23

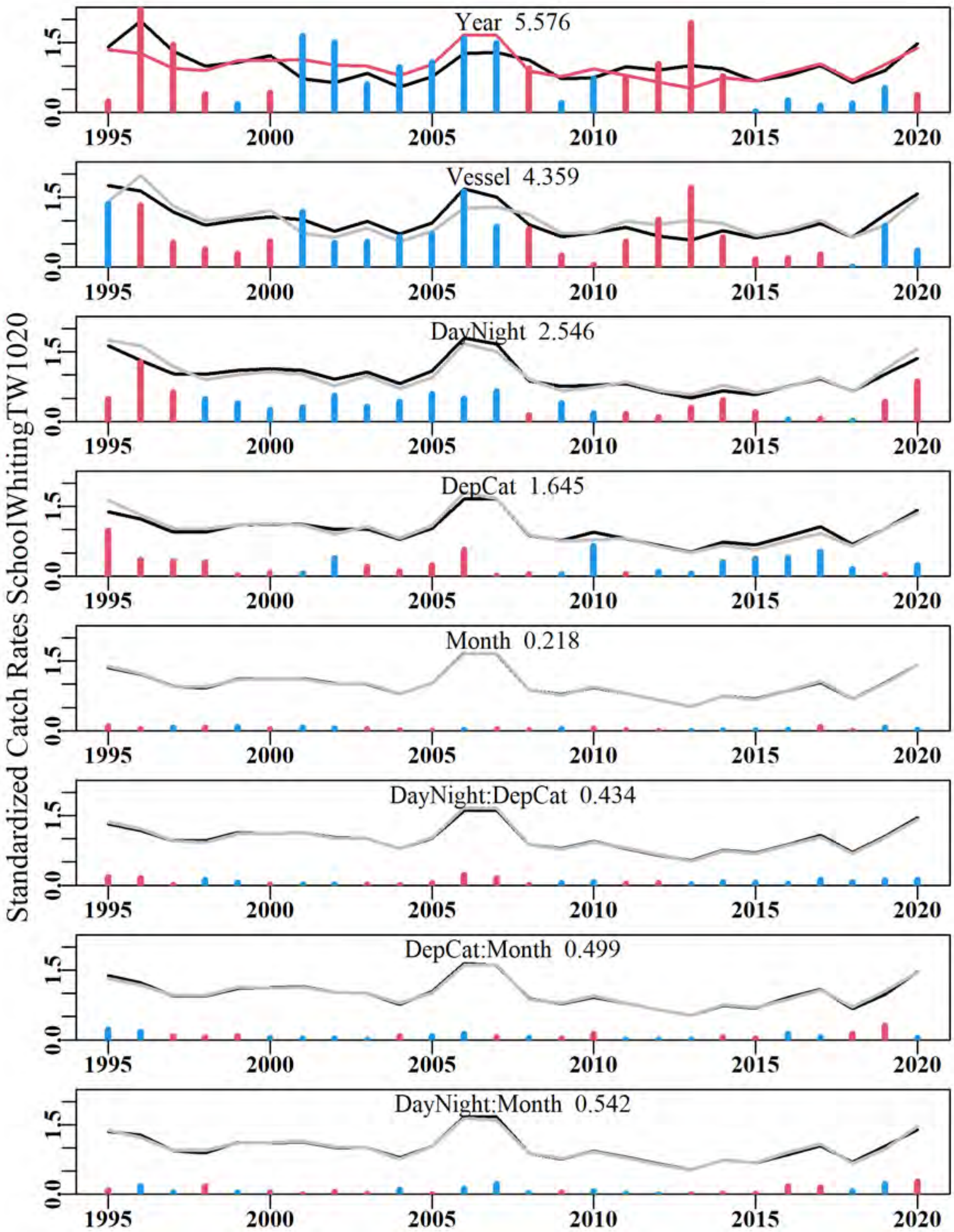

Figure 6.25. SchoolWhitingTW1020. The influence of each factor on the optimal standardization. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by vertical bars with blue bars indicating the optimum model is higher than 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.

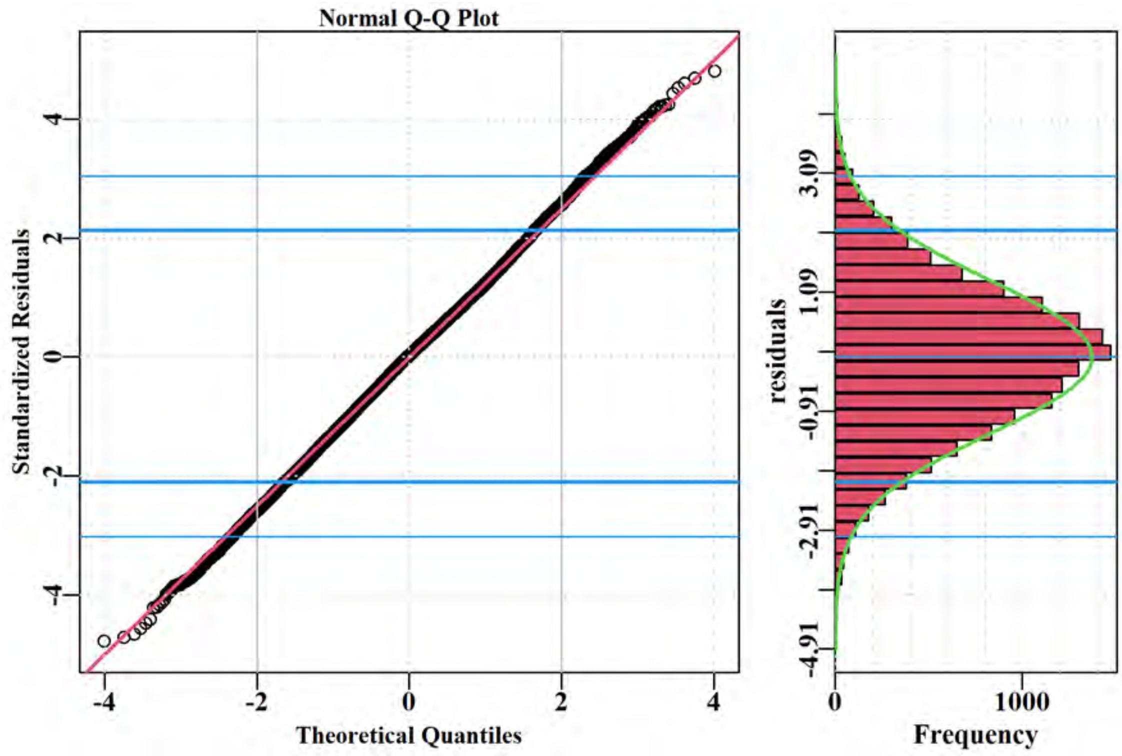

Figure 6.26. SchoolWhitingTW1020. diagnostic plots. The distribution of residuals from the optimum fit. The qqplot indicates the fit to the expected normality, while the histogram of residuals illustrates the 90% quantiles to indicate the intensity of any lack of fit at the margins of the distribution.

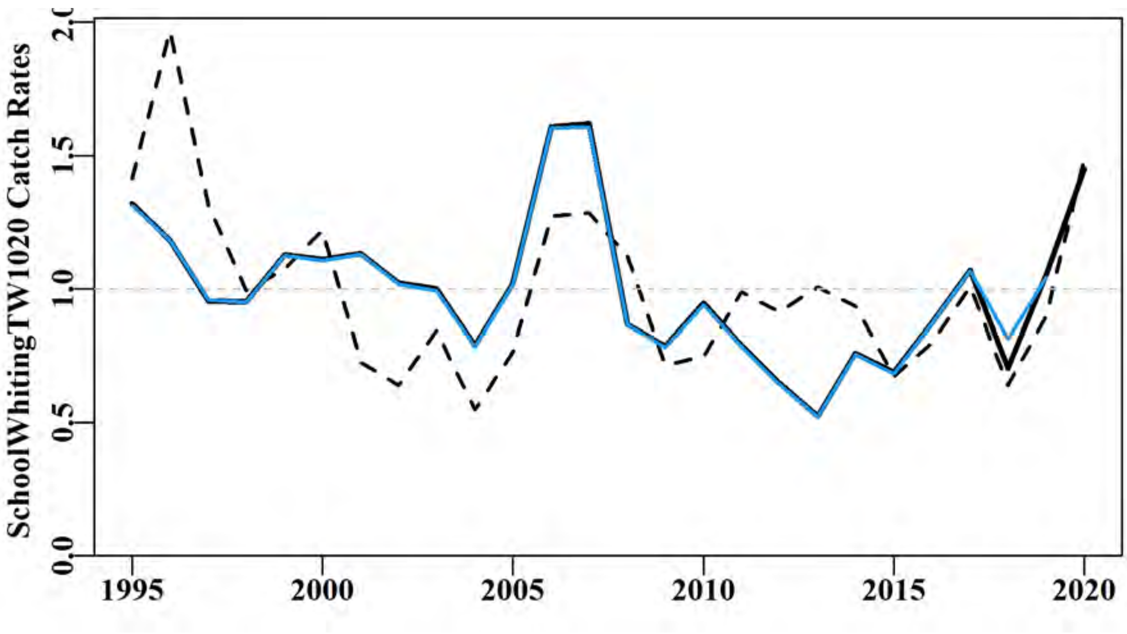

Figure 6.27. SchoolWhitingTW1020. A comparison of the previous year's standardization (blue line) with this year's. They should lie on top of each other, although small deviations may relate to data adjustments, particularly in very recent years.

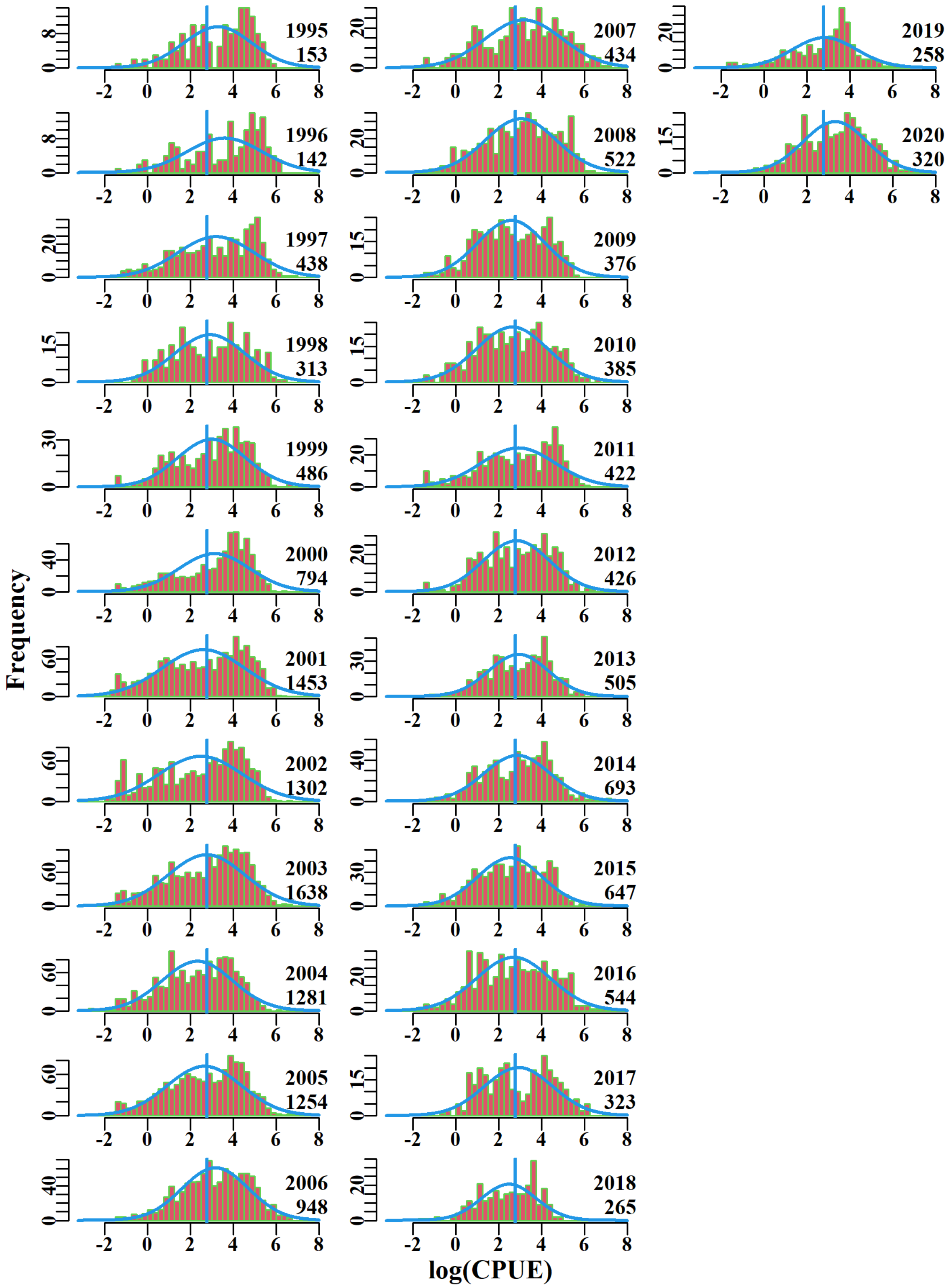

Figure 6.28. SchoolWhitingTW1020. The natural log(CPUE) for each year of data available the blue lines are normal distributions fitted to the histogram frequencies. The numbers in each plot are the year and number of records.

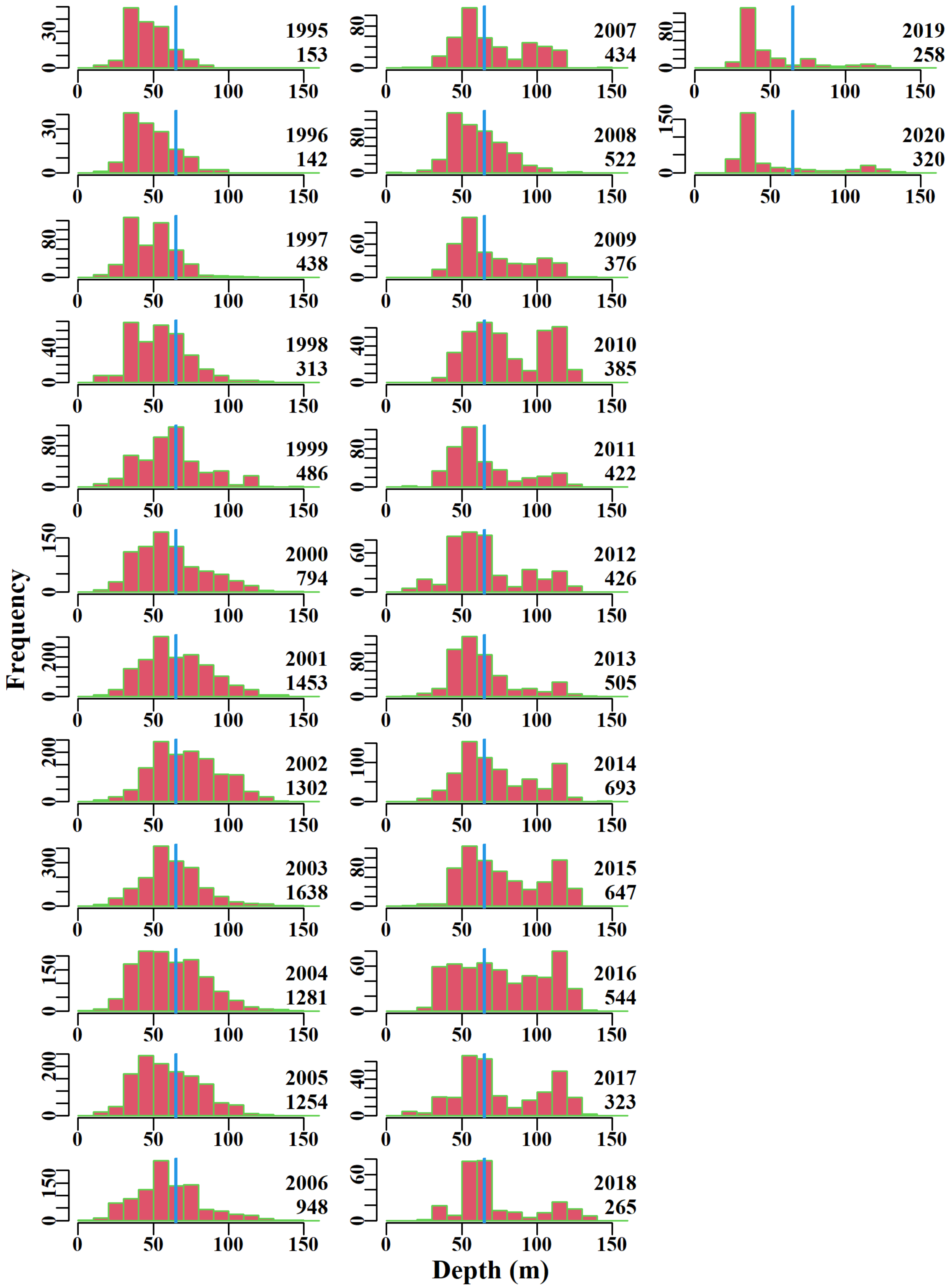

Figure 6.29. SchoolWhitingTW1020. The average Depth of fishing for each year of data available to illustrate the development of the fishery through time. The numbers in each plot are the year and number of records.

6.7 Mirror Dory 10 – 30

Mirror Dory (DOM – 37264003 – *Zenopsis nebulosa*) has a long history within the SESSF with catches being taken widely and by multiple methods. Records corresponding to the trawl fishery based on methods TW, TDO, TMO, OTT, OTB, in zones 10, 20, 30, and depths 0 to 600 m within the SET fishery for the period 1986 - 2020 were used were used in the analysis. Initial data selection was based on criteria provided in Table 6.21 from the Commonwealth logbook database.

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

6.7.1 *Inferences*

The terms Year, Vessel, DepCat, and Month had the greatest contribution to model fit, based on the AIC and R^2 statistics (Table 6.25). The qqplot suggests that the assumed Normal distribution is valid (Figure 6.33).

The Mirror Dory fishery in zones 10 - 30 exhibits large scale, apparently cyclical changes in CPUE. It appears that 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 < 30 kg (Figure 6.31), which is suggestive of either low availability or high levels of small fish. Standardized CPUE has declined on average from 2009 to 2016. It differs from unstandardized CPUE early in the fishery (1986 - 1990), in the second half of the fishery (2000 - 2007) and over the 2014 - 2017 period. The most recent changes appear strongly correlated with changes in the average depth of fishing with a shift to more relatively shallow water fishing, compared to the second half of the fishery. Standardized CPUE marginally decreased in 2020 relative to the previous year and has been below the long-term average and relatively stable for the past three years.

6.7.2 *Action Items and Issues*

No issues identified.

Table 6.21. 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, OTB
years	1986 - 2020

Table 6.22. 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

Year	Total	N	Catch	Vess	GeoM	Opt	StDev	C<30Kg	P<30Kg
1986	402.1	3140	367.9	80	39.2	1.2202	0.000	16.353	0.044
1987	450.8	2953	412.9	70	40.7	1.3323	0.033	15.129	0.037
1988	346.0	3065	313.1	77	33.7	1.2062	0.033	19.277	0.062
1989	591.6	2992	513.4	70	54.5	1.4505	0.033	15.795	0.031
1990	295.8	1801	253.5	61	36.5	1.3763	0.039	10.132	0.040
1991	240.3	2003	168.7	68	27.0	1.2078	0.038	16.089	0.095
1992	167.0	2032	140.4	57	22.3	1.0542	0.038	17.959	0.128
1993	306.2	2997	265.7	62	32.4	1.1436	0.034	21.976	0.083
1994	297.3	3482	260.5	62	25.9	1.0125	0.033	30.013	0.115
1995	244.9	3495	196.0	58	21.7	0.9106	0.033	33.141	0.169
1996	352.7	4377	211.5	68	16.7	0.7966	0.032	43.254	0.205
1997	459.6	4757	287.1	65	19.5	0.8473	0.032	45.256	0.158
1998	355.8	4093	230.1	55	19.4	0.7555	0.033	38.934	0.169
1999	309.5	4211	234.2	59	19.3	0.6693	0.033	39.603	0.169
2000	171.1	4593	142.5	64	11.3	0.5307	0.032	46.471	0.326
2001	243.4	4533	128.7	54	10.0	0.5332	0.033	46.396	0.361
2002	449.6	5032	194.3	53	14.0	0.6666	0.032	44.433	0.229
2003	613.9	5333	403.8	58	29.9	0.9532	0.032	40.852	0.101
2004	507.4	4256	291.0	57	25.8	0.9060	0.033	32.430	0.111
2005	579.9	4356	420.4	55	37.4	1.1646	0.033	30.059	0.071
2006	419.6	3214	296.4	44	35.4	1.1736	0.035	23.588	0.080
2007	289.6	2210	201.1	22	33.6	1.2673	0.038	16.397	0.082
2008	396.3	2477	316.9	26	48.0	1.4099	0.037	17.554	0.055
2009	476.5	2191	333.9	27	55.9	1.5057	0.038	15.733	0.047
2010	580.0	2068	378.3	25	71.5	1.2616	0.039	13.158	0.035
2011	514.5	2208	339.2	26	64.0	1.2841	0.038	14.273	0.042
2012	365.5	1712	281.3	24	66.7	1.0204	0.041	10.981	0.039
2013	279.9	1633	206.6	24	55.6	1.0595	0.041	10.502	0.051
2014	190.0	1732	112.4	25	24.7	0.8823	0.041	15.045	0.134
2015	240.4	2126	163.5	27	31.8	0.8626	0.039	17.175	0.105
2016	249.4	2060	202.2	26	42.2	0.8138	0.039	13.167	0.065
2017	224.3	1410	163.3	22	51.0	0.9426	0.043	11.205	0.069
2018	96.6	1214	58.0	18	18.9	0.5889	0.046	12.155	0.210
2019	104.4	1588	65.8	20	15.2	0.6330	0.043	15.839	0.241
2020	90.6	1327	50.4	18	14.5	0.5574	0.044	11.585	0.230

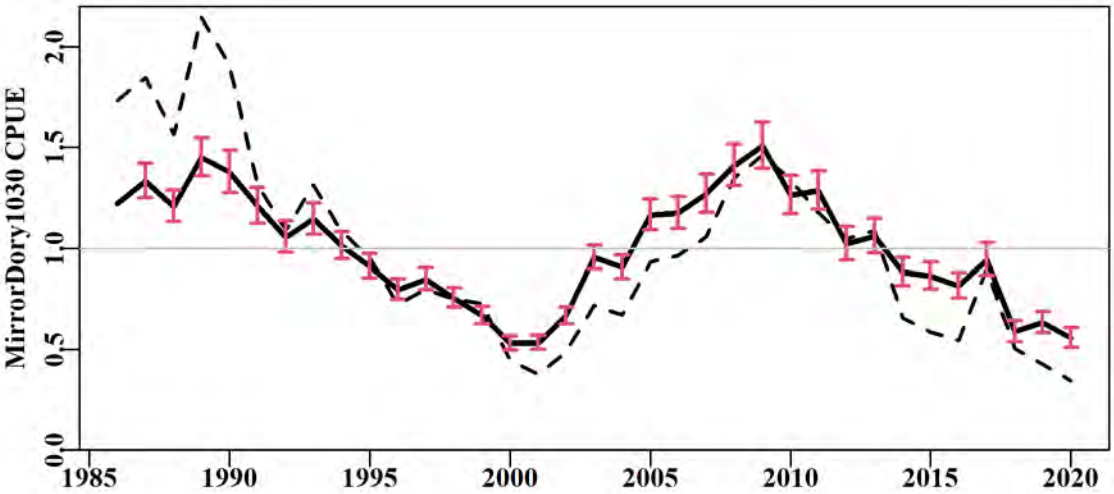

Figure 6.30. MirrorDory1030 standardization. The dashed black line represents the geometric mean CPUE, solid black line the standardized CPUE. The red bars are the 95% confidence intervals about the mean estimates. The graph scales both time-series of standardized CPUE relative to the mean of each time-series.

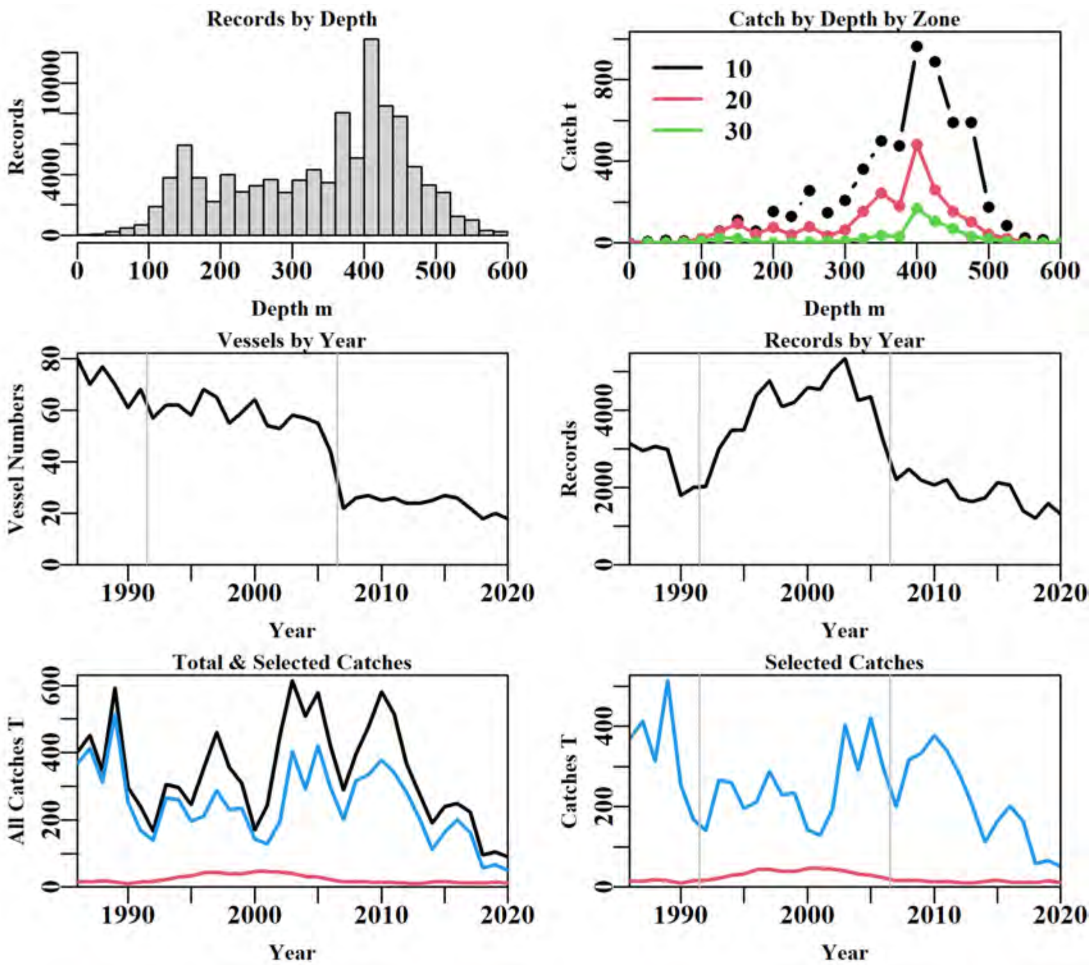

Figure 6.31. MirrorDory1030 fishery details. The bottom left plot depicts all known catches (top black line), and all selected catches used in the analysis (middle blue line); the lower red line: selected catches < 30 kg).

Table 6.23. 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	151829	147770	145773	145194	105703	102721	102671
Difference	0	4059	1997	579	39491	2982	50
Catch	11939	11811	11639	11605	8677	8608	8605
Difference	0	128	172	34	2928	69	3

Table 6.24. 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 6.25. 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

Term	AIC	RSS	MSS	Nobs	Npars	adj_r2	%Change
Year	76482	216107	21835	102671	35	9.1	0
Vessel	58815	181300	56642	102671	217	23.6	14.50
DepCat	47203	161836	76105	102671	241	31.8	8.18
Month	45155	158606	79336	102671	252	33.2	1.35
Zone	44213	157151	80790	102671	254	33.8	0.61
DayNight	43340	155812	82129	102671	257	34.4	0.56
Zone:Month	41443	152894	85047	102671	279	35.6	1.22
Zone:DepCat	42945	155072	82869	102671	304	34.6	0.28

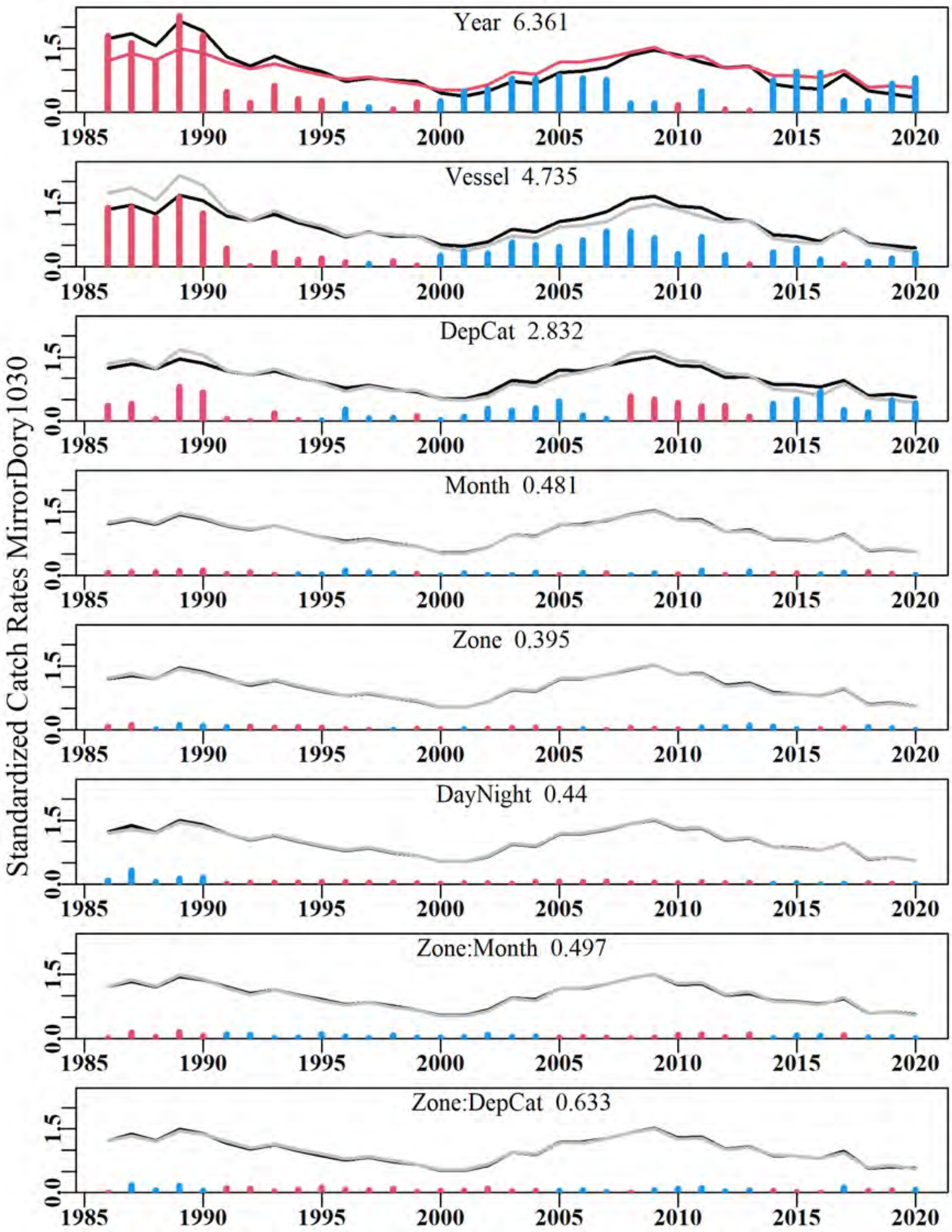

Figure 6.32. MirrorDory1030. The influence of each factor on the optimal standardization. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by vertical bars with blue bars indicating the optimum model is higher than the 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.

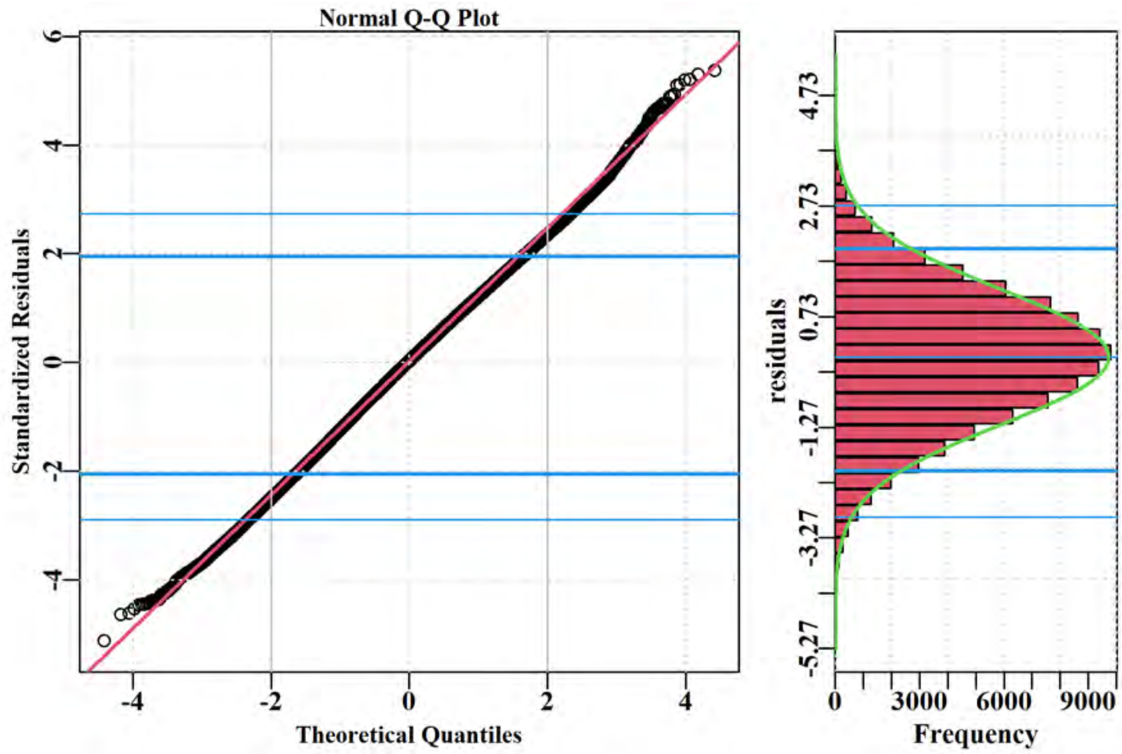

Figure 6.33. MirrorDory1030. diagnostic plots. The distribution of residuals from the optimum fit. The qqplot indicates the fit to the expected normality, while the histogram of residuals illustrates the 90% quantiles to indicate the intensity of any lack of fit at the margins of the distribution.

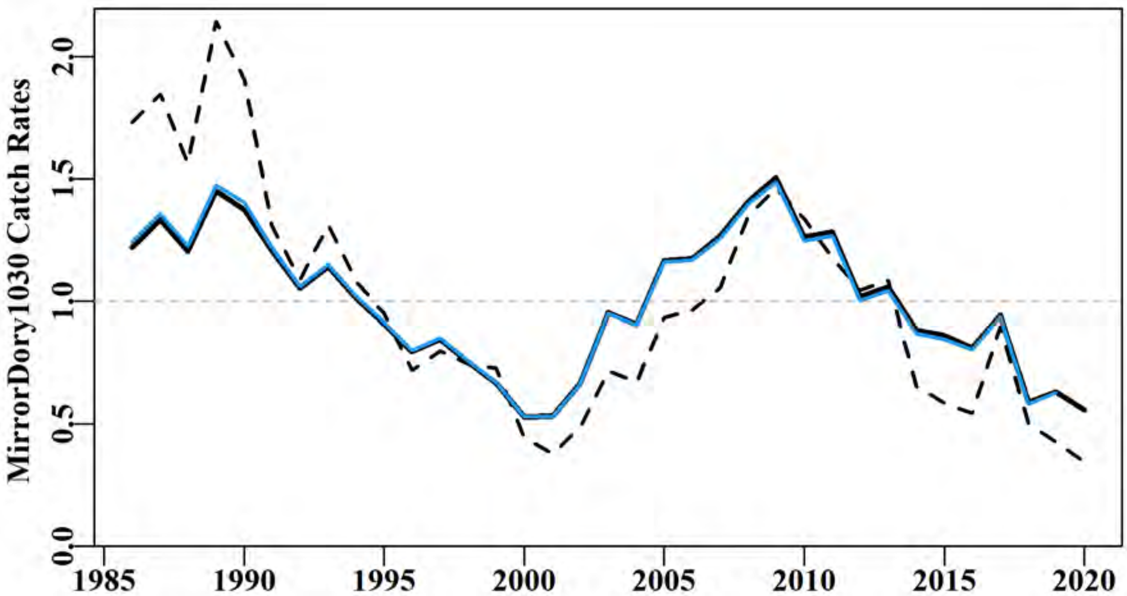

Figure 6.34. MirrorDory1030. A comparison of the previous year's standardization (blue line) with this year's. They should lie on top of each other, although small deviations may relate to data adjustments, particularly in very recent years.

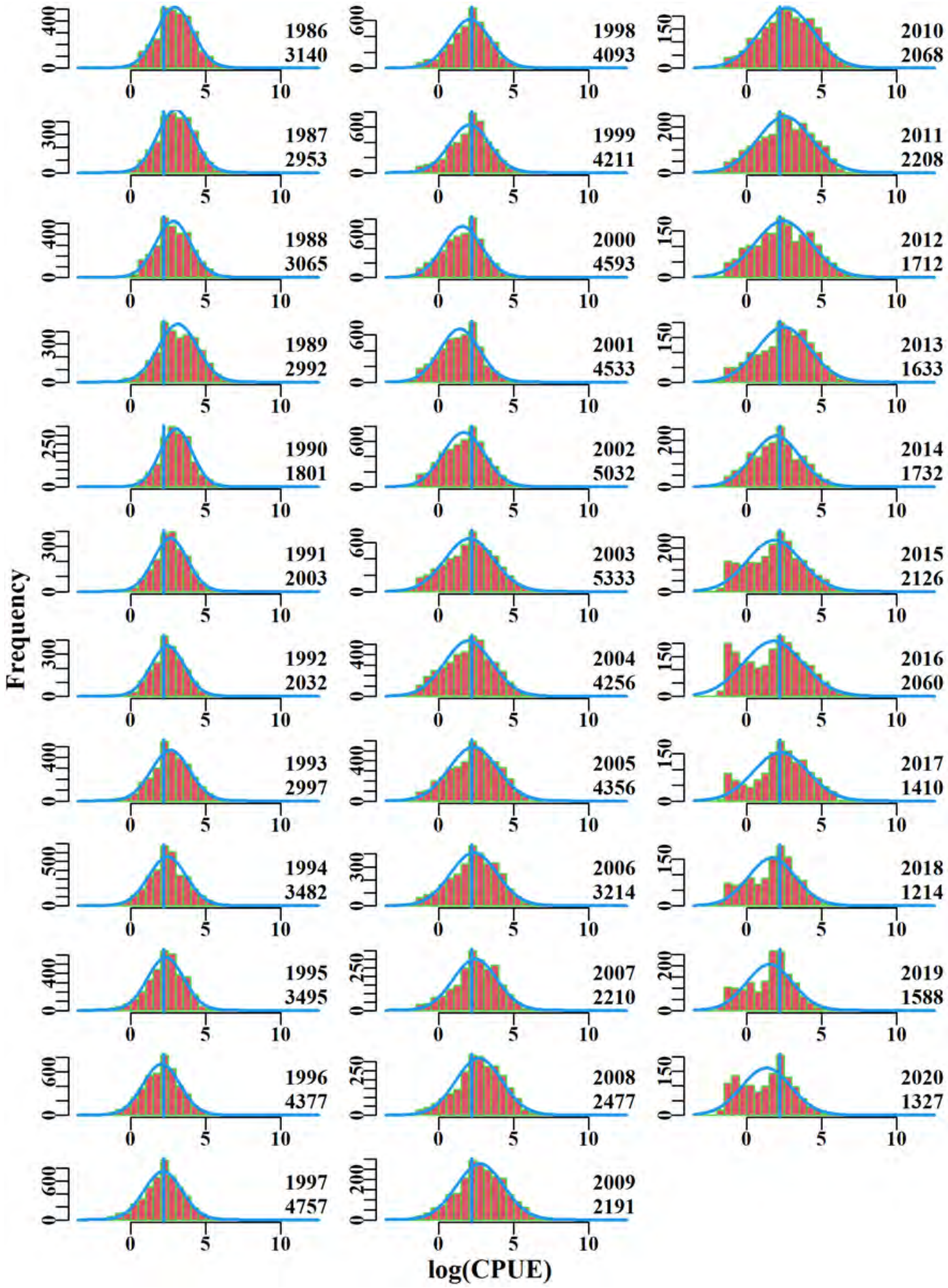

Figure 6.35. MirrorDory1030. The natural log(CPUE) for each year of data available the blue lines are normal distributions fitted to the histogram frequencies. The numbers in each plot are the year and number of records.

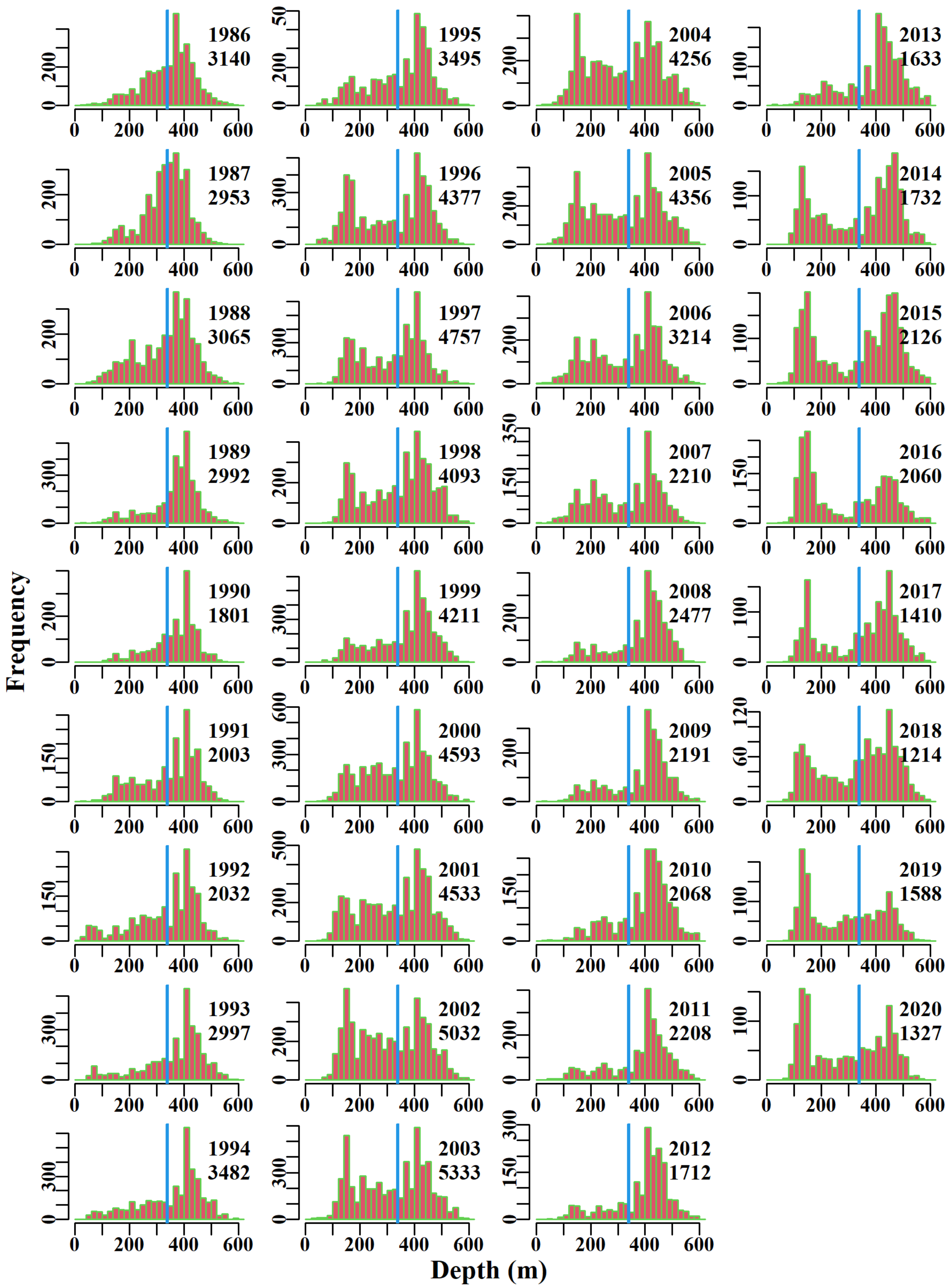

Figure 6.36. MirrorDory1030. The average Depth of fishing for each year of data available to illustrate the development of the fishery through time. The numbers in each plot are the year and number of records.

6.8 Mirror Dory 40 50

Trawl caught Mirror Dory (DOM – 37264003 – *Zenopsis nebulosa*) using methods TW, TDO, TMO, OTT, OTB, in zones 40, 50, and depths 0 to 600 m within the SET fishery for the years 1986 - 2020 were analysed. These constitute the criteria used to select data from the Commonwealth logbook database (Table 6.26).

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.

6.8.1 *Inferences*

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

The amount of catch remains minor until about 1995 (Table 6.27) 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. From 1990 the CPUE trend for Mirror Dory in the west appears to be relatively periodic and noisy around the long-term average with periods above and below.

6.8.2 *Action Items and Issues*

It is recommended that the CPUE time-series only be used from 1995 onwards (Figure 6.37) because catches before then are relatively minor.

Table 6.26. 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, OTB
years	1986 - 2020

Table 6.27. 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

Year	Total	N	Catch	Vess	GeoM	Opt	StDev	C<30Kg	P<30Kg
1986	402.1	58	7.4	11	37.2	2.6380	0.000	0.390	0.053
1987	450.8	142	15.5	23	36.1	1.7658	0.186	0.929	0.060
1988	346.0	122	15.0	17	37.2	1.3922	0.195	0.940	0.063
1989	591.6	71	11.1	15	45.3	1.7357	0.207	0.545	0.049
1990	295.8	95	10.0	14	37.9	1.2270	0.211	0.505	0.051
1991	240.3	208	12.8	17	17.8	0.8904	0.184	2.642	0.207
1992	167.0	206	8.3	20	14.6	0.7189	0.186	1.870	0.225
1993	306.2	278	18.1	18	16.7	0.8519	0.181	3.207	0.177
1994	297.3	330	18.2	20	14.8	0.7780	0.179	4.166	0.229
1995	244.9	704	37.9	23	15.4	1.0216	0.176	7.882	0.208
1996	352.7	1433	115.0	26	23.4	1.3653	0.176	12.869	0.112
1997	459.6	1903	148.2	24	24.5	1.3844	0.175	16.696	0.113
1998	355.8	1468	116.2	20	27.5	1.3076	0.176	12.717	0.109
1999	309.5	1316	63.2	23	17.0	0.8506	0.176	13.721	0.217
2000	171.1	975	22.4	31	7.9	0.4699	0.177	11.410	0.510
2001	243.4	2461	105.8	29	14.1	0.8120	0.175	28.871	0.273
2002	449.6	3151	240.2	28	24.8	1.2034	0.175	27.990	0.117
2003	613.9	2420	154.2	28	20.7	1.0007	0.175	20.528	0.133
2004	507.4	2201	159.4	25	20.3	0.9964	0.175	16.778	0.105
2005	579.9	1761	99.7	23	15.2	0.7894	0.176	15.640	0.157
2006	419.6	1053	64.8	19	15.7	0.6543	0.177	8.754	0.135
2007	289.6	1160	63.1	16	14.3	0.5878	0.176	11.733	0.186
2008	396.3	873	57.4	17	16.1	0.6979	0.177	8.632	0.150
2009	476.5	1331	123.0	14	20.0	1.0623	0.176	9.533	0.078
2010	580.0	1582	177.0	14	26.5	1.2959	0.176	9.483	0.054
2011	514.5	1648	157.3	16	21.8	0.9851	0.176	9.446	0.060
2012	365.5	993	69.6	15	16.9	0.5776	0.177	7.420	0.107
2013	279.9	635	54.4	15	20.8	0.7780	0.178	5.055	0.093
2014	190.0	832	67.3	14	19.6	0.8949	0.177	6.618	0.098
2015	240.4	945	70.6	13	17.4	0.9254	0.177	6.928	0.098
2016	249.4	622	41.4	13	16.5	0.6796	0.179	4.790	0.116
2017	224.3	700	57.7	11	16.0	0.9067	0.178	5.651	0.098
2018	96.6	529	31.0	11	10.8	0.5708	0.180	4.534	0.146
2019	104.4	574	33.9	14	12.0	0.6075	0.179	4.821	0.142
2020	90.6	506	28.1	14	9.5	0.5771	0.180	5.009	0.178

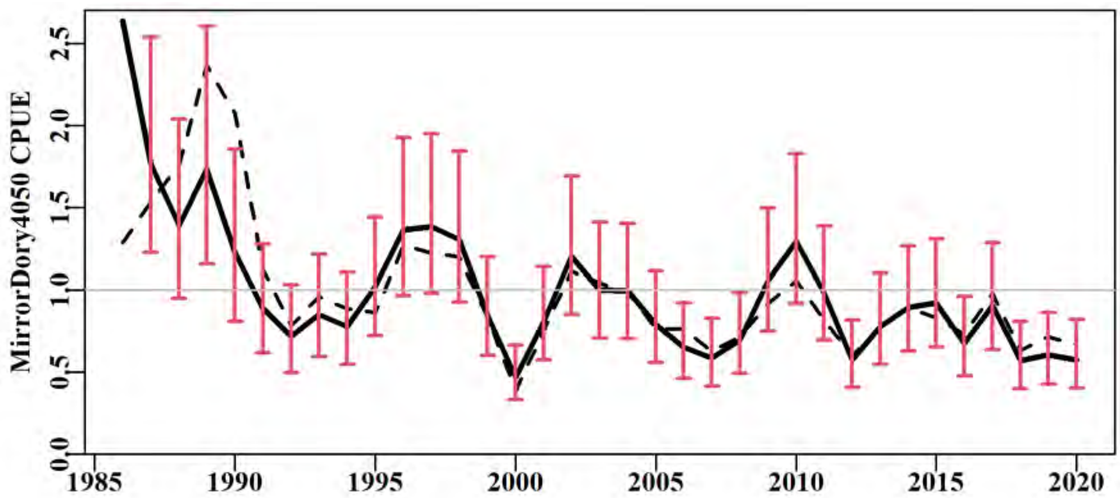

Figure 6.37. MirrorDory4050 standardization. The dashed black line represents the geometric mean CPUE, solid black line the standardized CPUE. The red bars are the 95% confidence intervals about the mean estimates. The graph scales both time-series of standardized CPUE relative to the mean of each time-series.

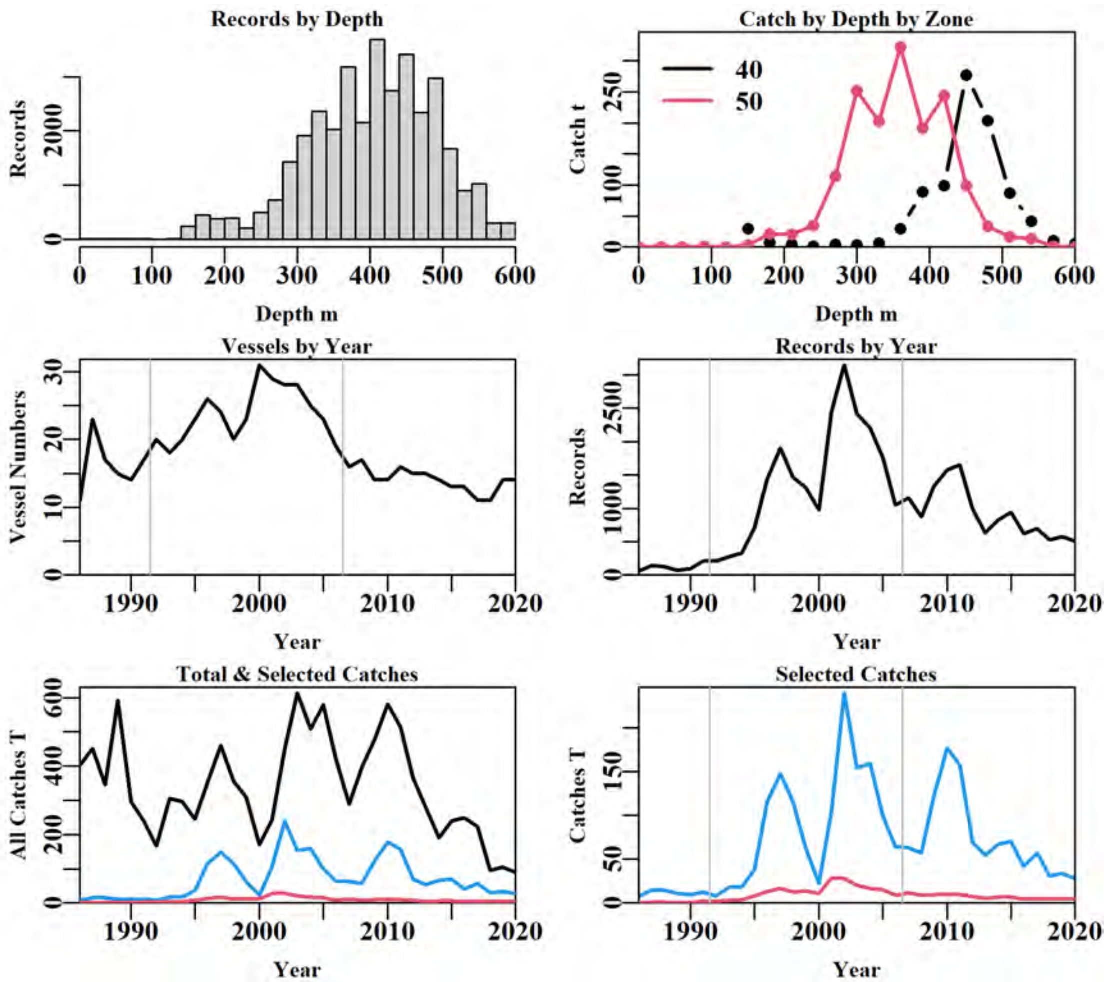

Figure 6.38. MirrorDory4050 fishery details. The bottom left plot depicts all known catches (top black line), and all selected catches used in the analysis (middle blue line); the lower red line: selected catches < 30 kg).

Table 6.28. 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	151829	147770	145773	145194	35515	35342	35286
Difference	0	4059	1997	579	109679	173	56
Catch	11939	11811	11639	11605	2486	2479	2475
Difference	0	128	172	34	9119	7	4

Table 6.29. 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 6.30. 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

Term	AIC	RSS	MSS	Nobs	Npars	adj_r2	%Change
Year	11268	48465	2398	35286	35	4.62	0
Vessel	4596	39896	10967	35284	131	21.27	16.649
Month	2916	38017	12846	35284	142	24.96	3.684
DepCat	976	35943	14921	35284	162	29.01	4.054
DayNight	-243	34716	16147	35284	165	31.43	2.417
Zone	-638	34327	16536	35284	166	32.19	0.766
Zone:Month	-1036	33921	16942	35284	177	32.97	0.781
Zone:DepCat	-704	34224	16639	35284	186	32.36	0.164

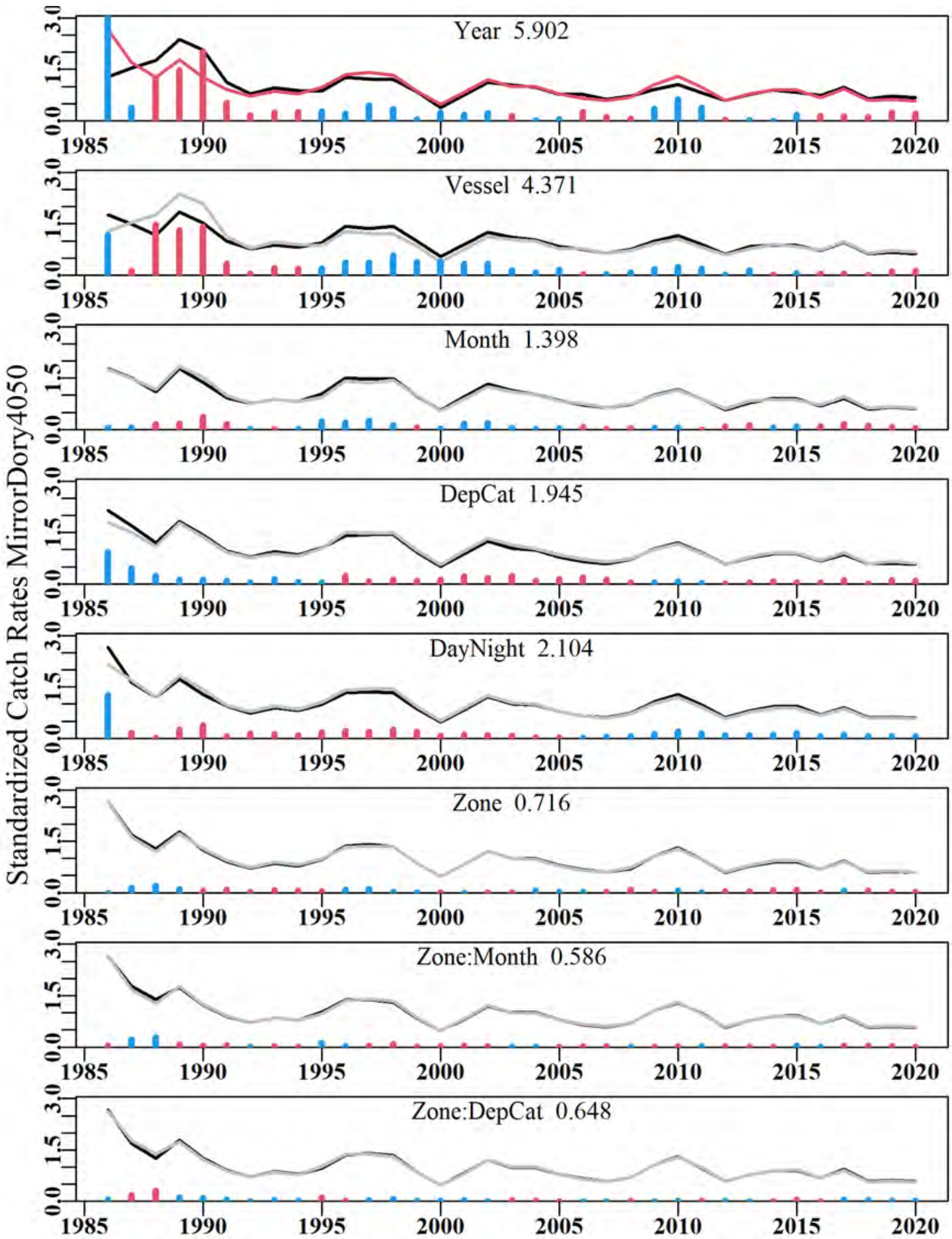

Figure 6.39. MirrorDory4050. The influence of each factor on the optimal standardization. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by vertical bars with blue bars indicating the optimum model is higher than the 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.

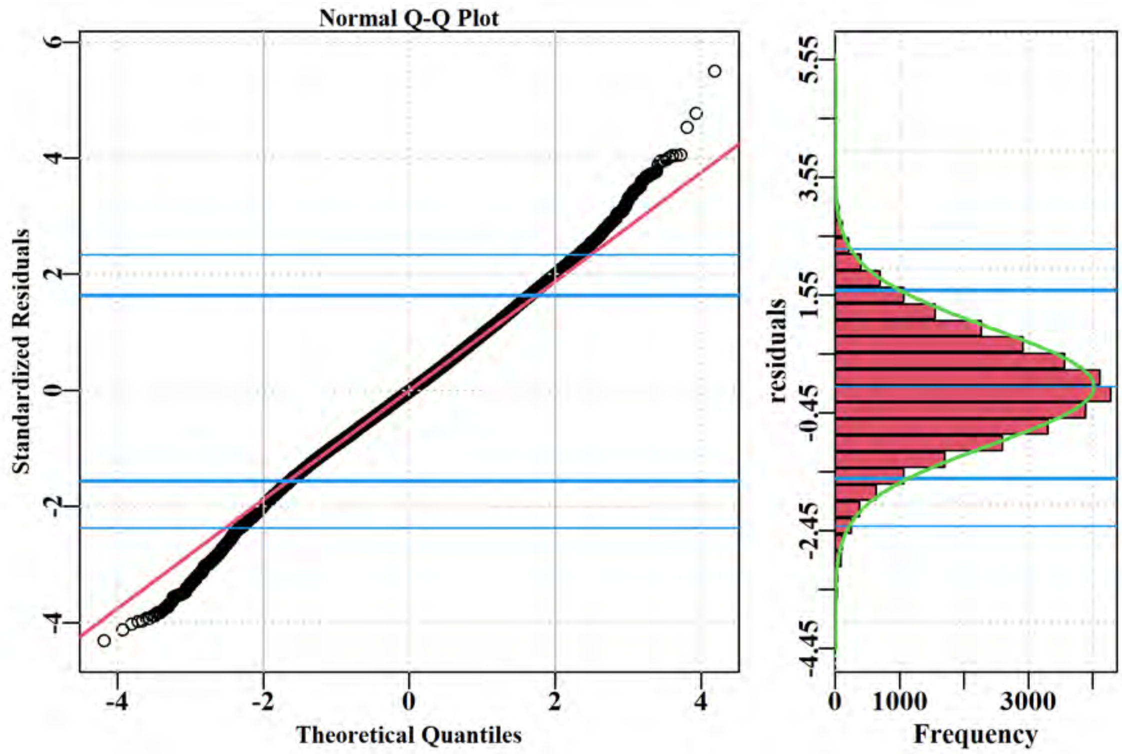

Figure 6.40. MirrorDory4050. diagnostic plots. The distribution of residuals from the optimum fit. The qqplot indicates the fit to the expected normality, while the histogram of residuals illustrates the 90% quantiles to indicate the intensity of any lack of fit at the margins of the distribution.

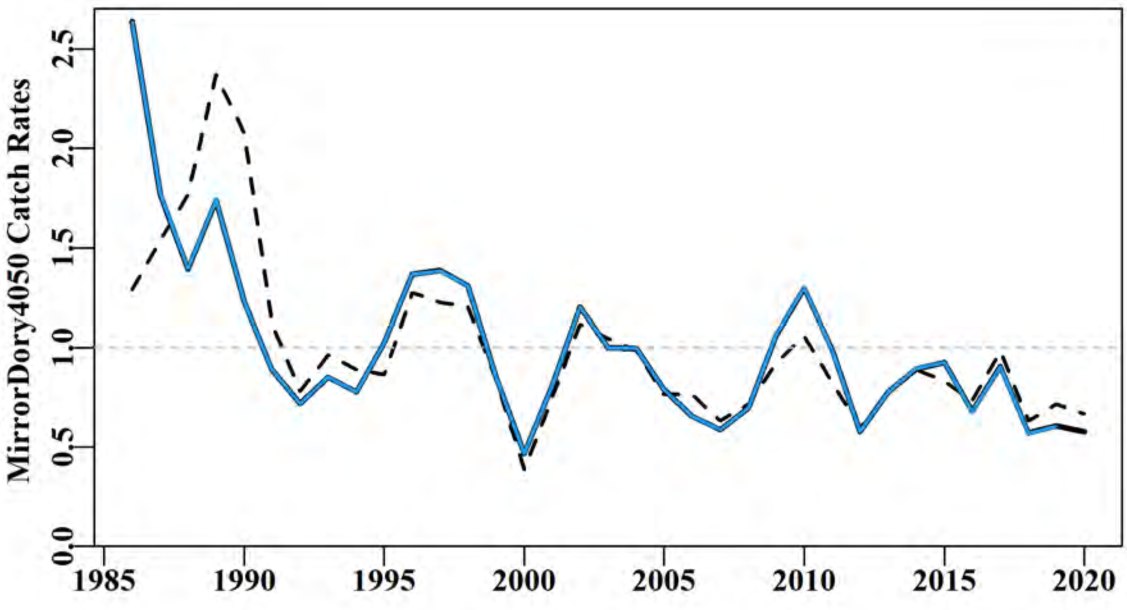

Figure 6.41. MirrorDory4050. A comparison of the previous year's standardization (blue line) with this year's. They should lie on top of each other, although small deviations may relate to data adjustments, particularly in very recent years.

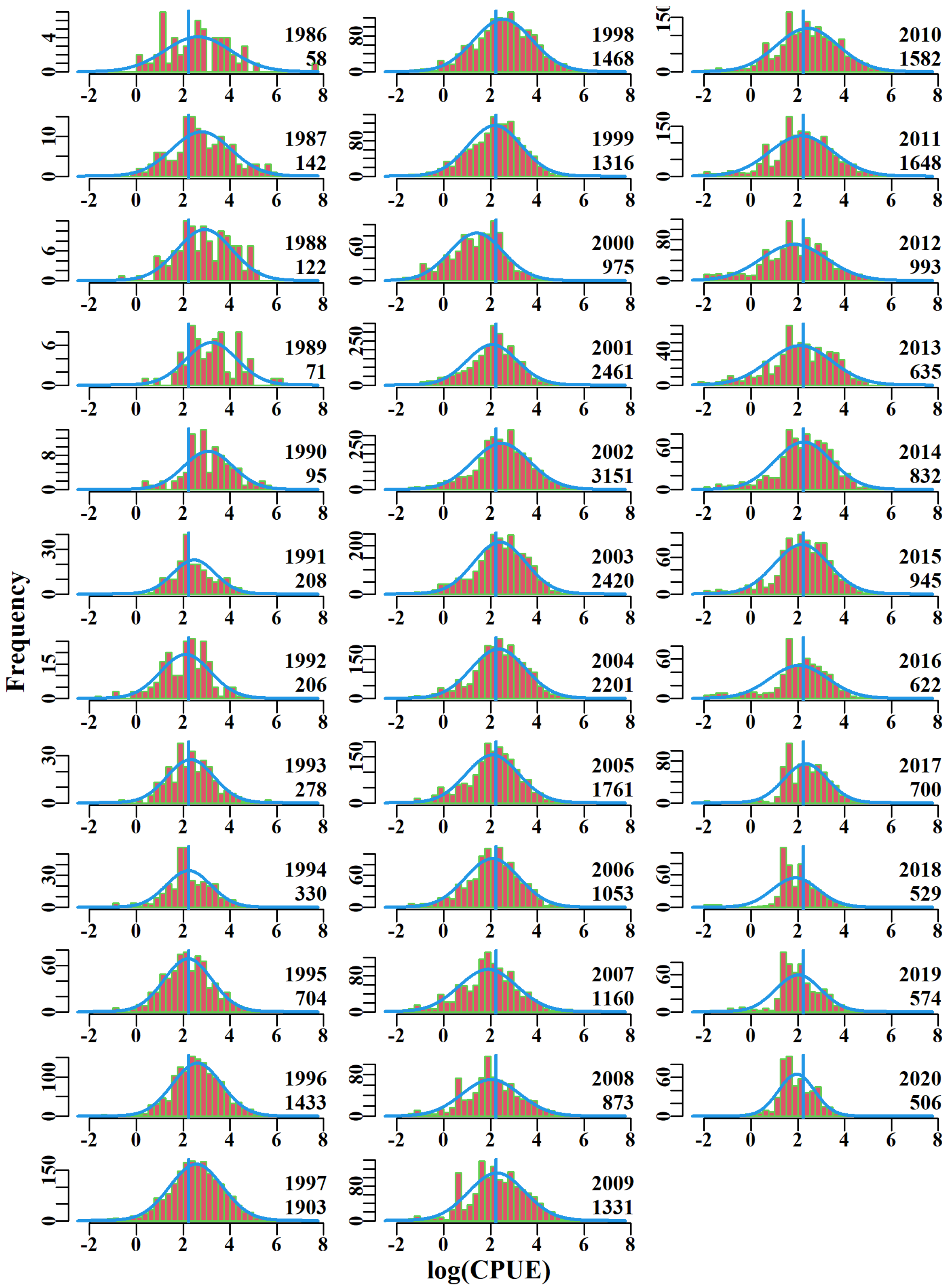

Figure 6.42. MirrorDory4050. The natural log(CPUE) for each year of data available the blue lines are normal distributions fitted to the histogram frequencies. The numbers in each plot are the year and number of records.

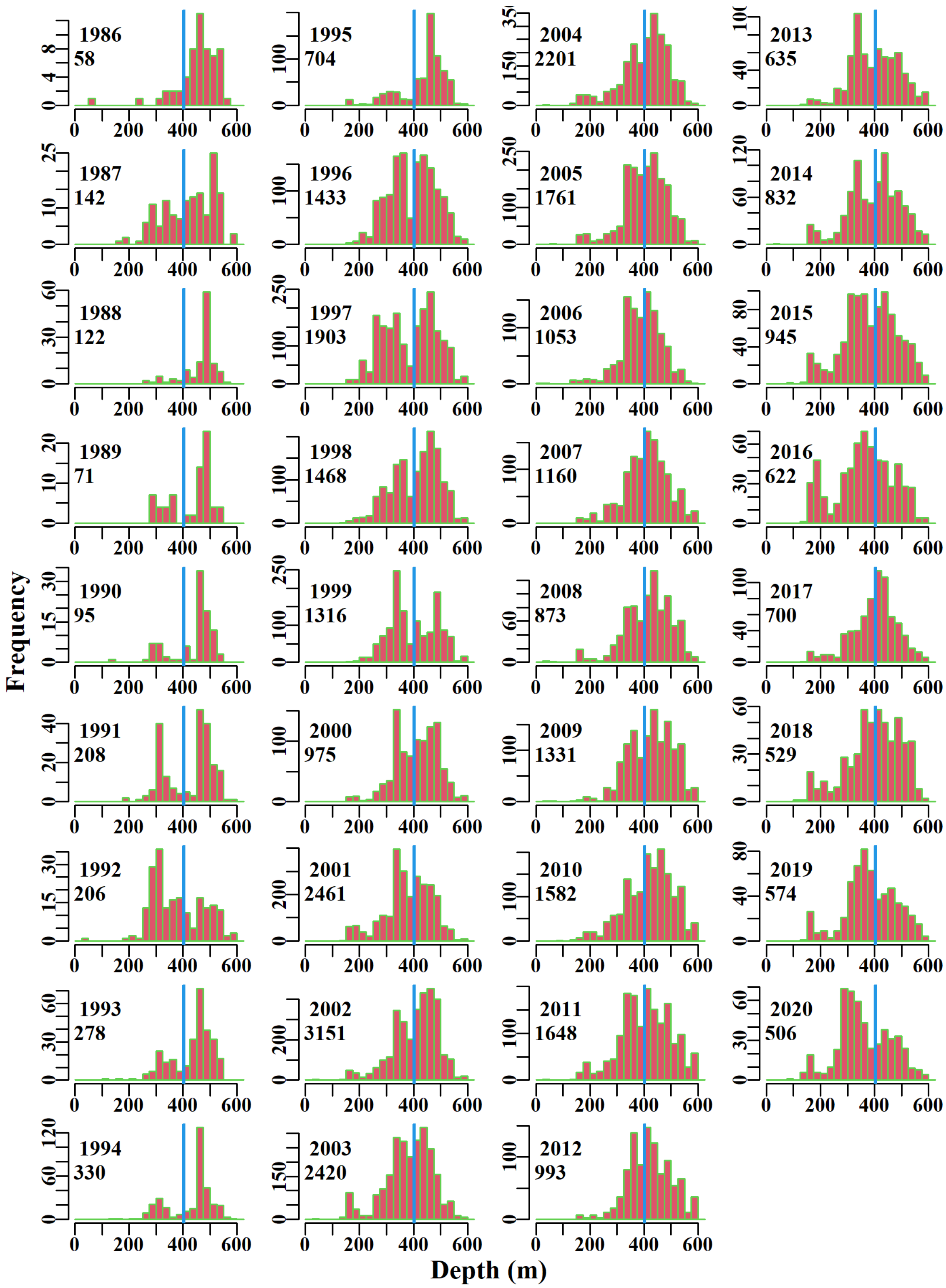

Figure 6.43. MirrorDory4050. The average Depth of fishing for each year of data available to illustrate the development of the fishery through time. The numbers in each plot are the year and number of records

6.9 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, OTB, in zones 30, and depths 70 to 300 m within the SET fishery for the years 1986 - 2020 (Table 6.31). 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.

6.9.1 *Inferences*

The terms Year, Month, Vessel, DepCat 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 6.35). The qqplot suggests that the assumed Normal distribution is valid, with small deviations at the tails of the distribution (Figure 6.47).

Annual standardized CPUE has been below the long-term average since about 2001. More recently, the relative CPUE trend has been flat since at least 2015 (i.e., not statistically different from each other over the last seven years) (Figure 6.44). The recorded catch of 54 t in 2019 was the highest since 2013 (102.9 t). By contrast, the recorded catch (21.1 t) in 2020 was the lowest in the series.

6.9.2 *Action Items and Issues*

With only 68 records and 30 t of reported catch in 1986, it is recommended that the standardization analysis should begin in 1987 or 1988 (Table 6.32).

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 m 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 6.31. 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, OTB
years	1986 - 2020

Table 6.32. 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

Year	Total	N	Catch	Vess	GeoM	Opt	StDev	C<30Kg	P<30Kg
1986	982.8	68	29.8	6	166.0	2.0092	0.000	0.255	0.009
1987	1087.7	205	57.0	13	104.4	2.2481	0.181	0.695	0.012
1988	1483.5	282	207.7	13	272.2	3.0639	0.180	0.684	0.003
1989	1667.5	687	475.0	19	231.9	3.8837	0.173	0.775	0.002
1990	1001.4	379	140.2	26	146.8	2.8045	0.173	0.901	0.006
1991	1138.1	408	184.4	29	154.7	1.8887	0.171	1.060	0.006
1992	758.4	333	106.7	18	109.0	2.0968	0.176	1.050	0.010
1993	1016.0	1031	322.3	27	104.7	1.6788	0.166	2.433	0.008
1994	818.6	759	179.1	22	71.2	1.1626	0.167	2.130	0.012
1995	789.8	821	183.7	19	68.6	1.1525	0.168	4.244	0.023
1996	827.3	889	161.4	19	54.5	1.0970	0.167	5.219	0.032
1997	1063.4	939	202.3	15	71.6	1.1971	0.167	3.427	0.017
1998	876.5	768	190.7	15	74.4	1.1760	0.167	2.123	0.011
1999	961.5	854	246.9	17	91.6	1.4012	0.168	2.310	0.009
2000	945.2	548	123.4	23	66.5	0.8618	0.170	2.126	0.017
2001	790.2	807	110.3	19	43.2	0.5452	0.166	5.349	0.049
2002	811.2	1039	108.3	15	34.7	0.4471	0.165	6.333	0.058
2003	774.6	1121	186.2	19	59.8	0.5955	0.165	5.933	0.032
2004	765.5	1494	200.8	15	41.6	0.4464	0.164	8.776	0.044
2005	784.2	1136	135.6	17	35.0	0.3376	0.165	7.263	0.054
2006	811.3	1112	152.8	14	40.5	0.4155	0.166	5.253	0.034
2007	607.9	705	110.6	8	49.8	0.5881	0.168	2.355	0.021
2008	700.4	752	117.2	9	51.2	0.5973	0.168	2.573	0.022
2009	454.4	456	53.4	10	37.8	0.4153	0.172	1.849	0.035
2010	380.1	340	54.9	9	48.8	0.4593	0.175	1.468	0.027
2011	428.0	444	47.4	8	34.6	0.3135	0.172	2.027	0.043
2012	395.6	518	88.8	8	56.1	0.4145	0.171	1.761	0.020
2013	323.9	595	102.9	10	57.8	0.4556	0.170	2.670	0.026
2014	216.6	360	53.3	9	38.8	0.2398	0.174	2.274	0.043
2015	152.5	455	30.4	11	18.5	0.1466	0.172	3.163	0.104
2016	183.4	768	48.3	10	19.6	0.1609	0.168	5.918	0.123
2017	246.2	611	37.9	9	21.3	0.1764	0.170	4.605	0.121
2018	209.7	468	26.4	9	18.2	0.1376	0.172	3.327	0.126
2019	161.9	623	54.0	12	29.4	0.2468	0.170	4.113	0.076
2020	99.1	388	21.1	8	18.2	0.1390	0.174	3.300	0.156

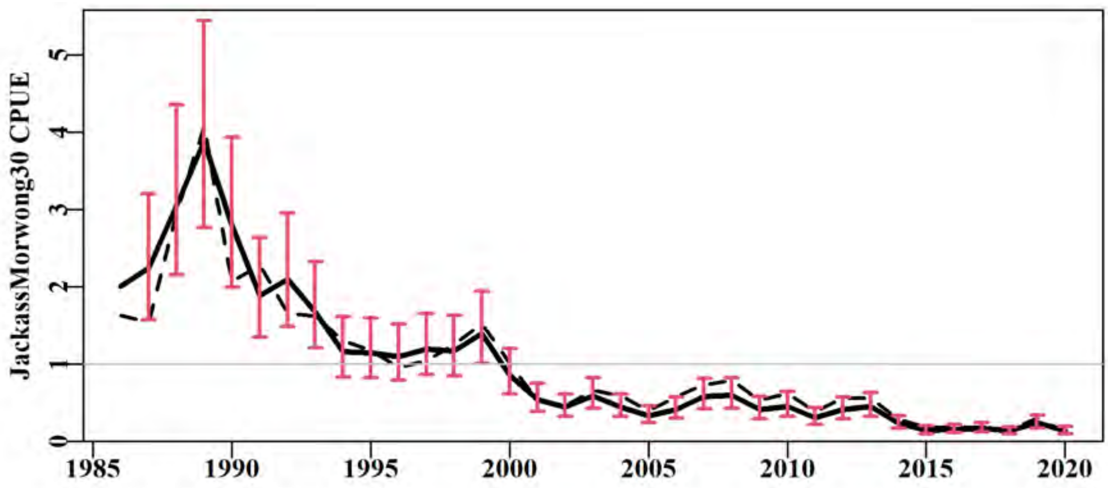

Figure 6.44. JackassMorwong30 standardization. The dashed black line represents the geometric mean CPUE, solid black line the standardized CPUE. The red bars are the 95% confidence intervals about the mean estimates. The graph scales both time-series of standardized CPUE relative to the mean of each time-series.

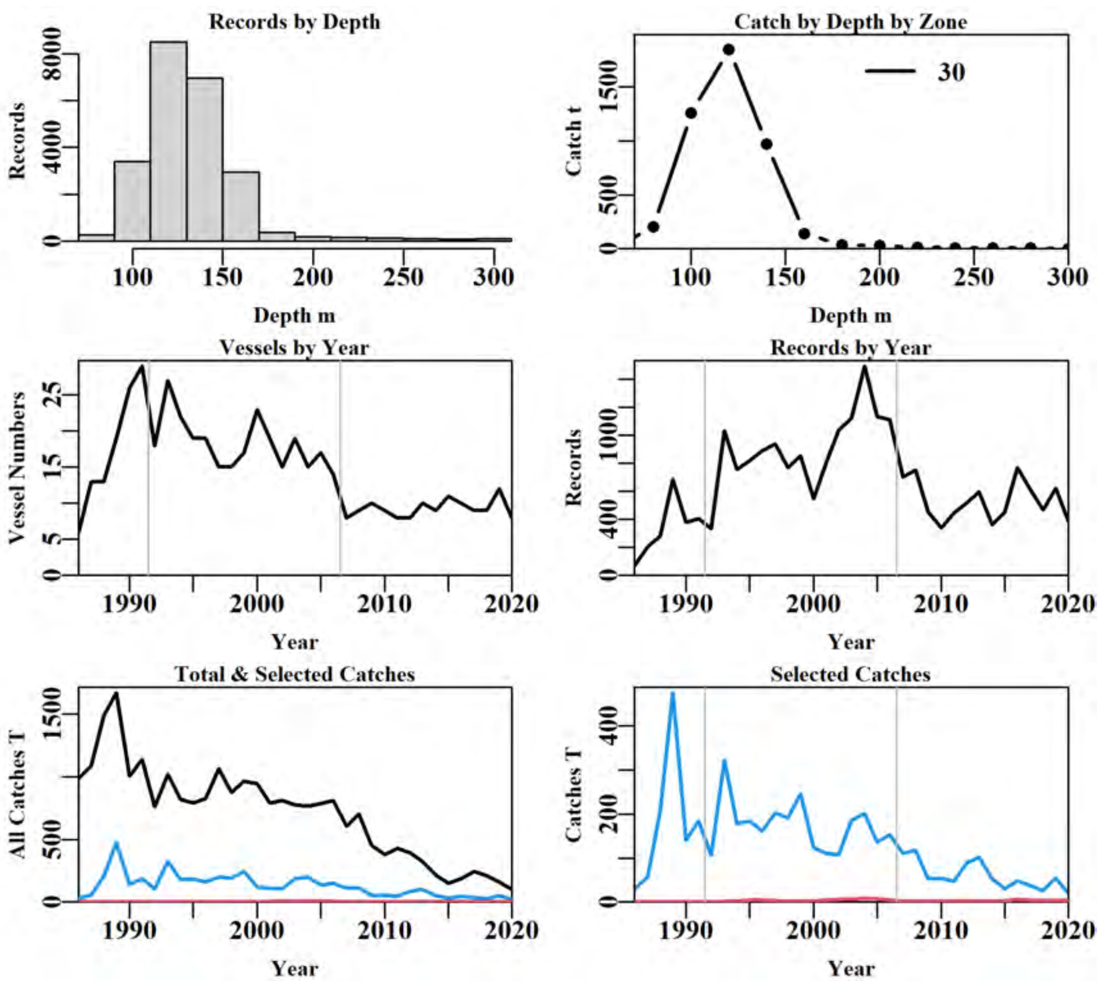

Figure 6.45. JackassMorwong30 fishery details. The bottom left plot depicts all known catches (top black line), and all selected catches used in the analysis (middle blue line); the lower red line: selected catches < 30 kg).

Table 6.33. 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	267032	244420	215233	211719	23667	23166	23163
Difference	0	22612	29187	3514	188052	501	3
Catch	25405	24443	22968	22395	4617	4551	4551
Difference	0	962	1475	573	17778	66	0

Table 6.34. 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 6.35. 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

Term	AIC	RSS	MSS	Nobs	Npars	adj_r2	%Change
Year	13922	42122	13642	23163	35	24.4	0
Month	12069	38847	16917	23163	46	30.2	5.85
Vessel	10460	35937	19827	23163	143	35.2	4.96
DepCat	9751	34819	20945	23163	155	37.1	1.98
DayNight	9382	34259	21505	23163	158	38.1	1.00
Zone:Month	9382	34259	21505	23163	158	38.1	0.00
Zone:DepCat	9382	34259	21505	23163	158	38.1	0.00

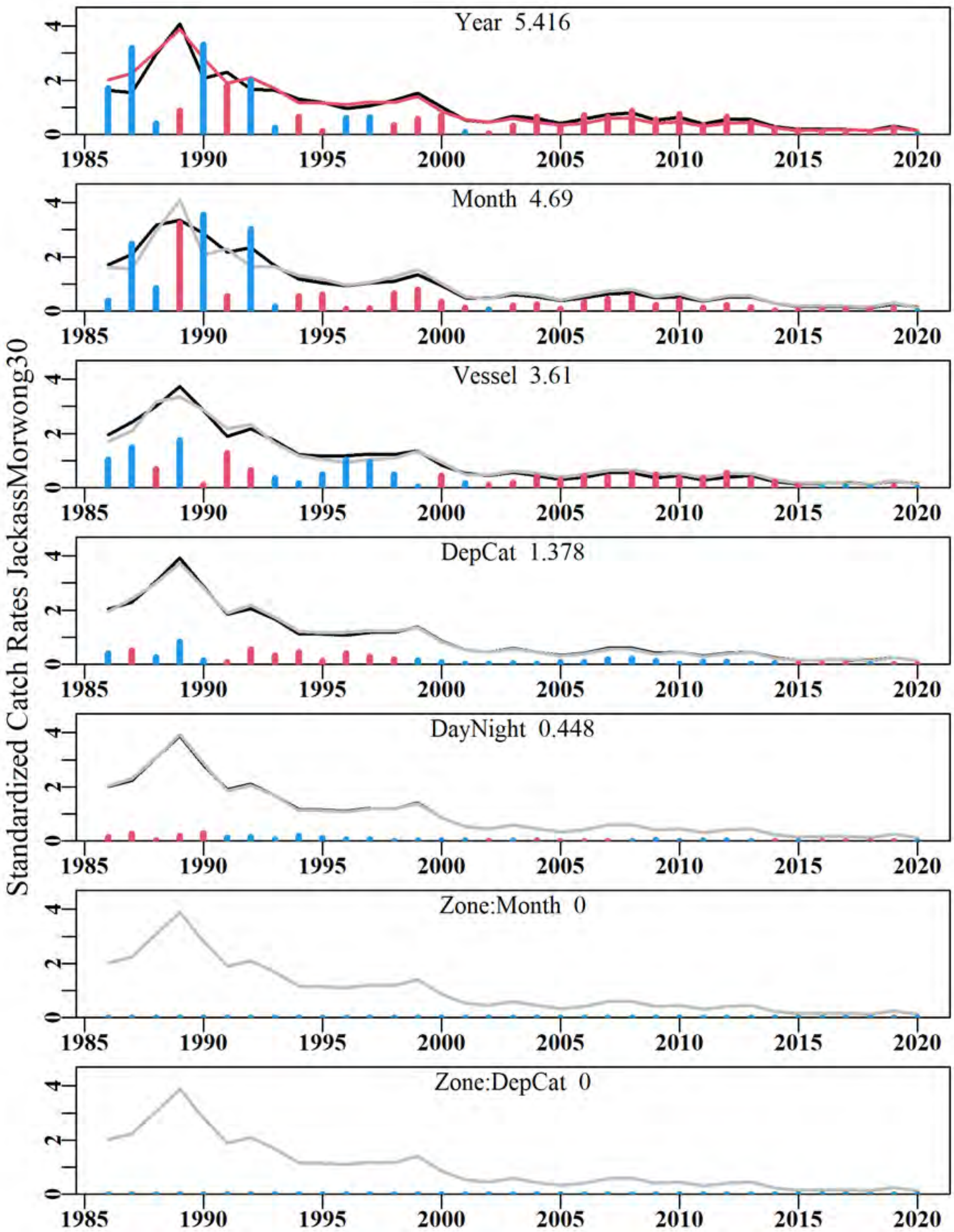

Figure 6.46. JackassMorwong30. The influence of each factor on the optimal standardization. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by vertical bars with blue bars indicating the optimum model is higher than the 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.

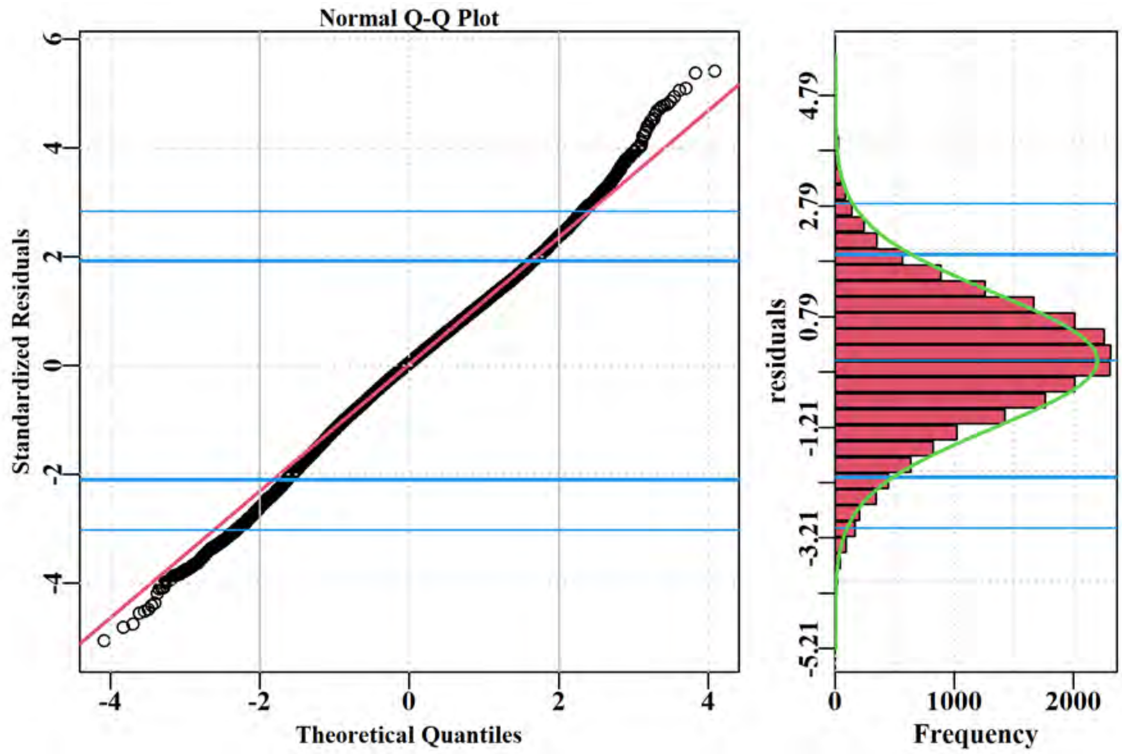

Figure 6.47. JackassMorwong30. diagnostic plots. The distribution of residuals from the optimum fit. The qqplot indicates the fit to the expected normality, while the histogram of residuals illustrates the 90% quantiles to indicate the intensity of any lack of fit at the margins of the distribution.

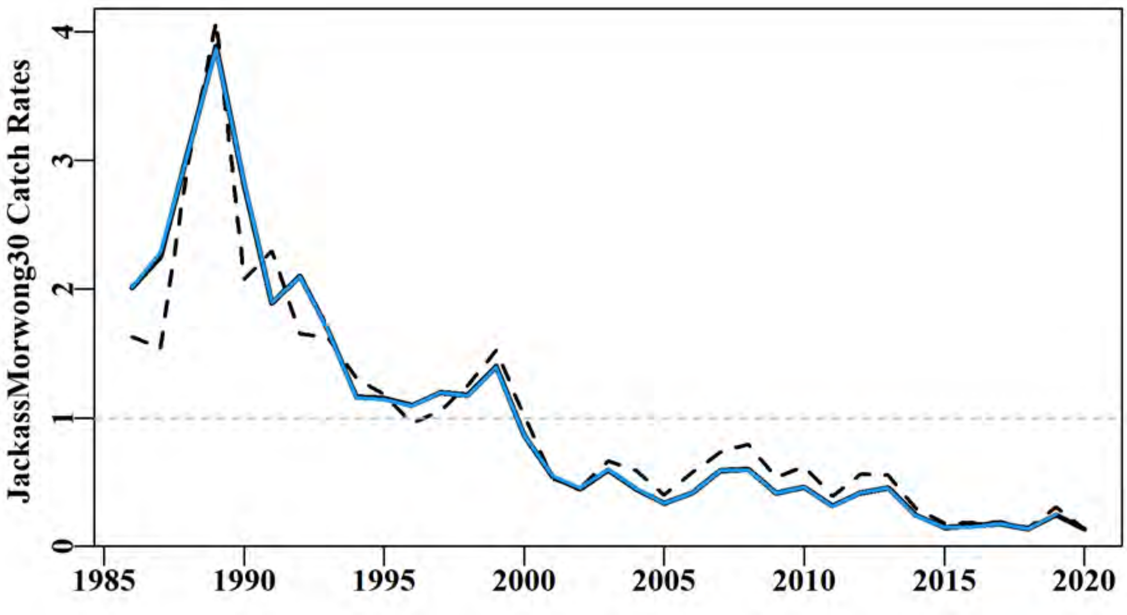

Figure 6.48. JackassMorwong30. A comparison of the previous year's standardization (blue line) with this year's. They should lie on top of each other, although small deviations may relate to data adjustments, particularly in very recent years.

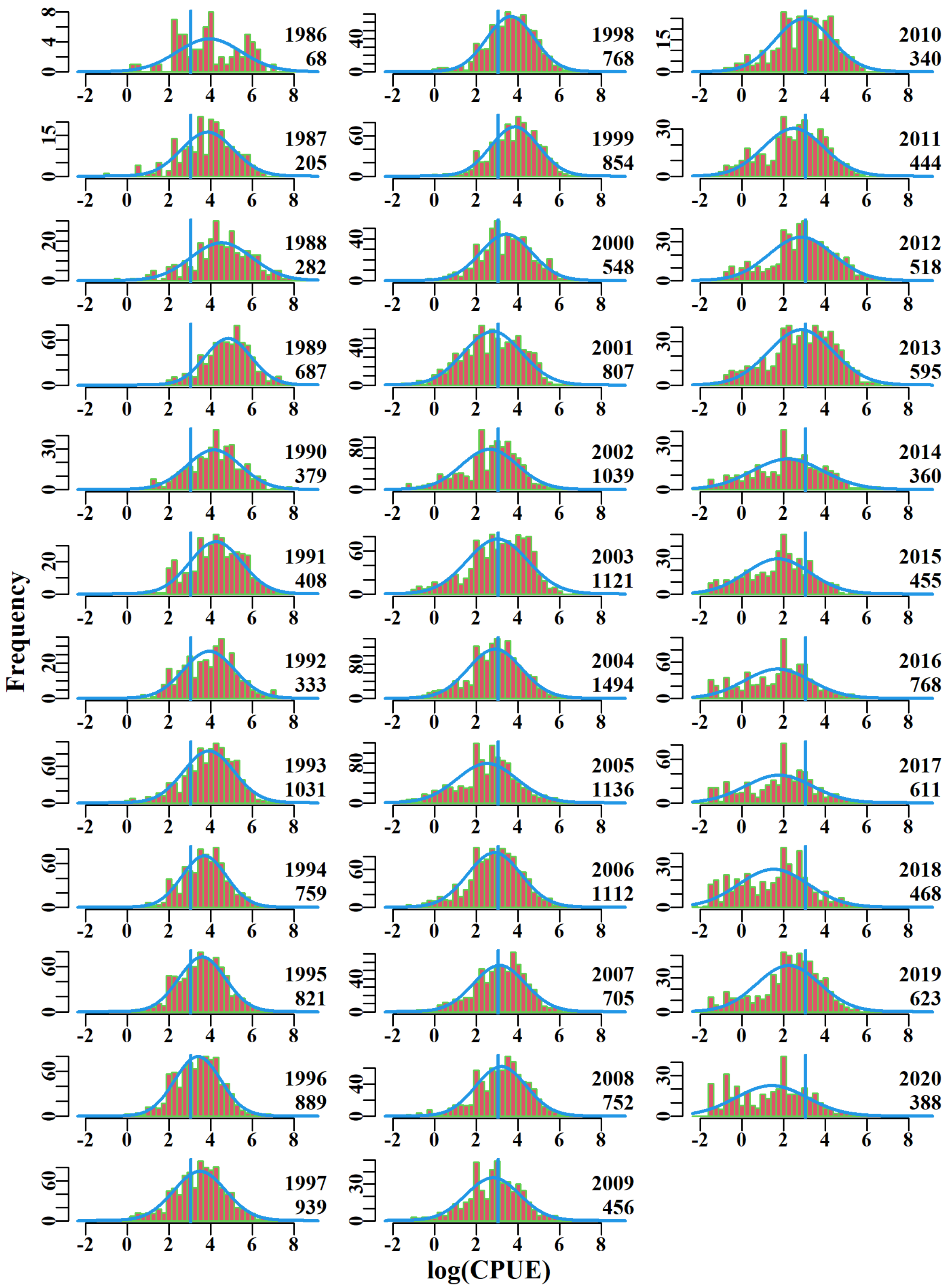

Figure 6.49. JackassMorwong30. The natural log(CPUE) for each year of data available the blue lines are normal distributions fitted to the histogram frequencies. The numbers in each plot are the year and number of records.

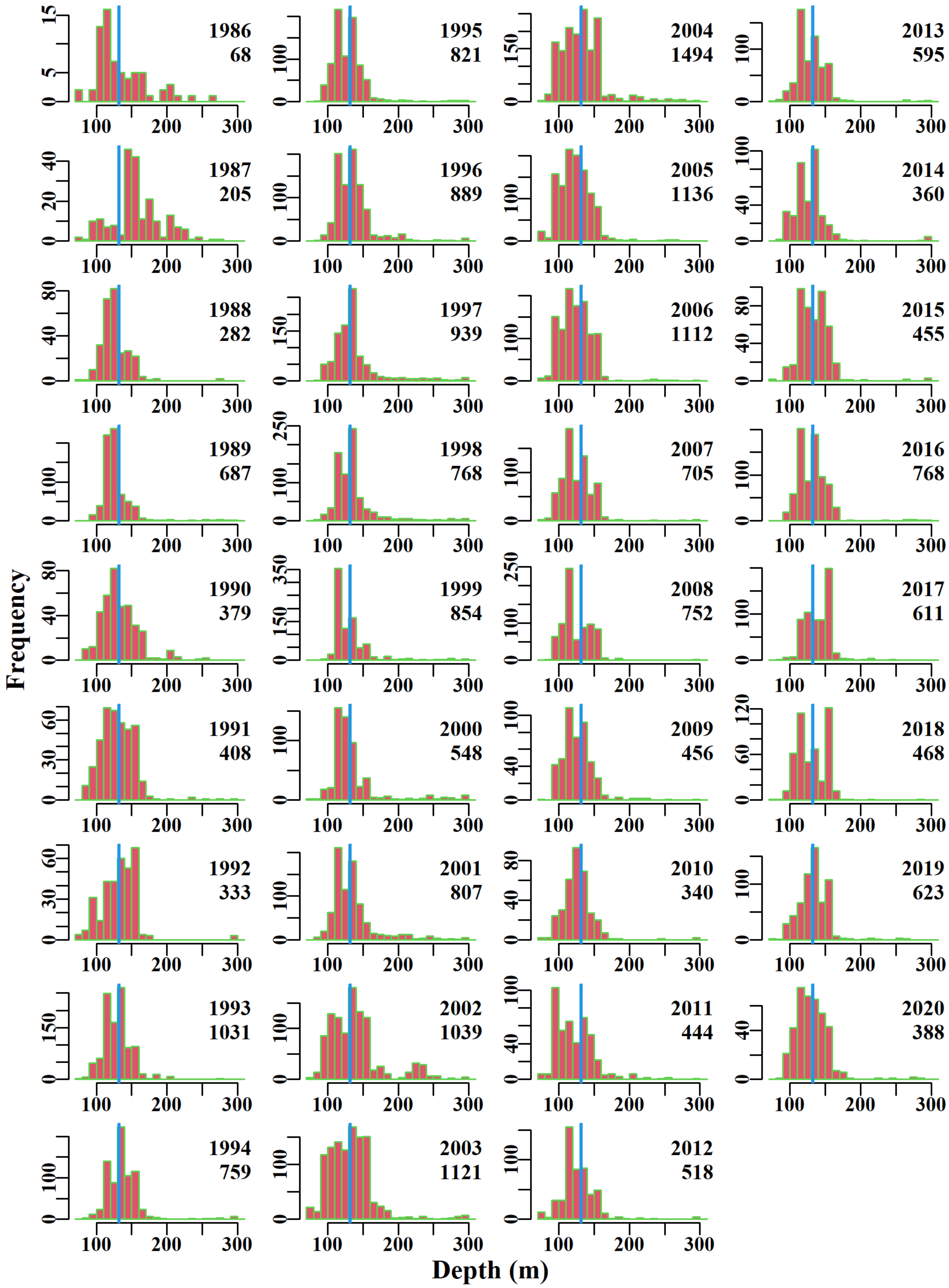

Figure 6.50. JackassMorwong30. The average Depth of fishing for each year of data available to illustrate the development of the fishery through time. The numbers in each plot are the year and number of records.

6.10 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, OTB, in zones 10, 20 and depths 70 to 300 m within the SET fishery for the years 1986 - 2020 (Table 6.36). 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.

6.10.1 *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 6.40). The qqplot suggests that the assumed Normal distribution is valid, with small deviations at the upper tail of the distribution (Figure 6.54).

Most catch was reported in zone 20 in less than 200 m. Annual standardized CPUE has been below the long-term average since about 2000 with apparent periodicity (Figure 6.51). Both the recorded catch (36.6 t) and number of records (956) in 2020 were the lowest in the series.

6.10.2 *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 - 2020, with spikes of low CPUE arising.

Table 6.36. 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, OTB
years	1986 - 2020

Table 6.37. 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

Year	Total	N	Catch	Vess	GeoM	Opt	StDev	C<30Kg	P<30Kg
1986	982.8	5041	685.5	87	50.9	2.1589	0.000	28.043	0.041
1987	1087.7	4231	851.6	79	69.6	2.6176	0.030	20.466	0.024
1988	1483.5	5127	1020.0	79	65.0	2.4573	0.029	25.887	0.025
1989	1667.5	4305	924.2	65	72.2	2.3341	0.030	19.307	0.021
1990	1001.4	4090	593.5	59	49.2	1.9628	0.031	21.795	0.037
1991	1138.1	4398	651.3	55	54.3	1.7997	0.031	26.145	0.040
1992	758.4	2829	377.5	47	48.6	1.4609	0.034	17.346	0.046
1993	1016.0	3322	463.0	49	45.6	1.5581	0.033	21.593	0.047
1994	818.6	4419	469.2	49	38.6	1.3561	0.031	29.317	0.062
1995	789.8	4576	433.9	47	31.6	1.2441	0.031	33.286	0.077
1996	827.3	6181	541.8	50	29.0	1.1279	0.029	45.827	0.085
1997	1063.4	5994	669.8	52	38.6	1.2514	0.030	38.284	0.057
1998	876.5	4773	435.1	46	32.0	1.0089	0.031	36.545	0.084
1999	961.5	4409	446.6	50	36.3	1.0125	0.032	31.411	0.070
2000	945.2	5615	477.9	55	29.5	0.8627	0.030	40.940	0.086
2001	790.2	4793	251.5	46	18.5	0.5940	0.031	36.983	0.147
2002	811.2	5700	328.2	44	20.4	0.6643	0.031	45.985	0.140
2003	774.6	4555	236.4	47	17.6	0.5280	0.032	35.723	0.151
2004	765.5	4178	219.7	52	17.2	0.5227	0.033	31.301	0.142
2005	784.2	4320	258.8	39	19.4	0.6332	0.032	35.033	0.135
2006	811.3	3388	273.8	36	25.2	0.7735	0.034	27.137	0.099
2007	607.9	2413	211.2	20	31.6	0.7491	0.037	17.187	0.081
2008	700.4	3106	313.1	25	30.5	0.9480	0.035	23.478	0.075
2009	454.4	2400	223.7	19	28.2	0.8600	0.037	18.584	0.083
2010	380.1	2478	184.9	19	24.5	0.5873	0.037	19.898	0.108
2011	428.0	2291	161.6	18	24.2	0.5869	0.038	17.187	0.106
2012	395.6	2111	169.7	19	27.9	0.5744	0.039	14.445	0.085
2013	323.9	1394	96.6	15	25.0	0.4769	0.044	10.082	0.104
2014	216.6	1515	76.2	17	17.2	0.3551	0.043	11.597	0.152
2015	152.5	1094	42.3	20	14.3	0.2977	0.048	8.727	0.206
2016	183.4	1145	70.8	16	24.2	0.3423	0.048	7.792	0.110
2017	246.2	1230	72.6	16	23.4	0.4056	0.046	9.147	0.126
2018	209.7	1396	77.6	16	18.9	0.3330	0.046	10.764	0.139
2019	161.9	1211	52.2	14	14.5	0.2723	0.047	9.681	0.186
2020	99.1	956	36.6	13	12.6	0.2829	0.050	7.859	0.215

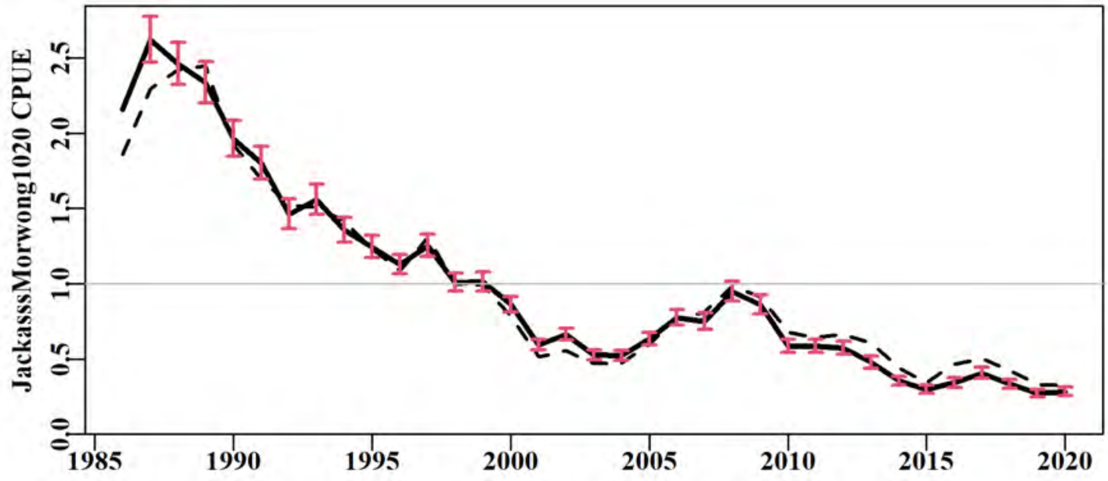

Figure 6.51. JackasssMorwong1020 standardization. The dashed black line represents the geometric mean CPUE, solid black line the standardized CPUE. The red bars are the 95% confidence intervals about the mean estimates. The graph scales both time-series of standardized CPUE relative to the mean of each time-series.

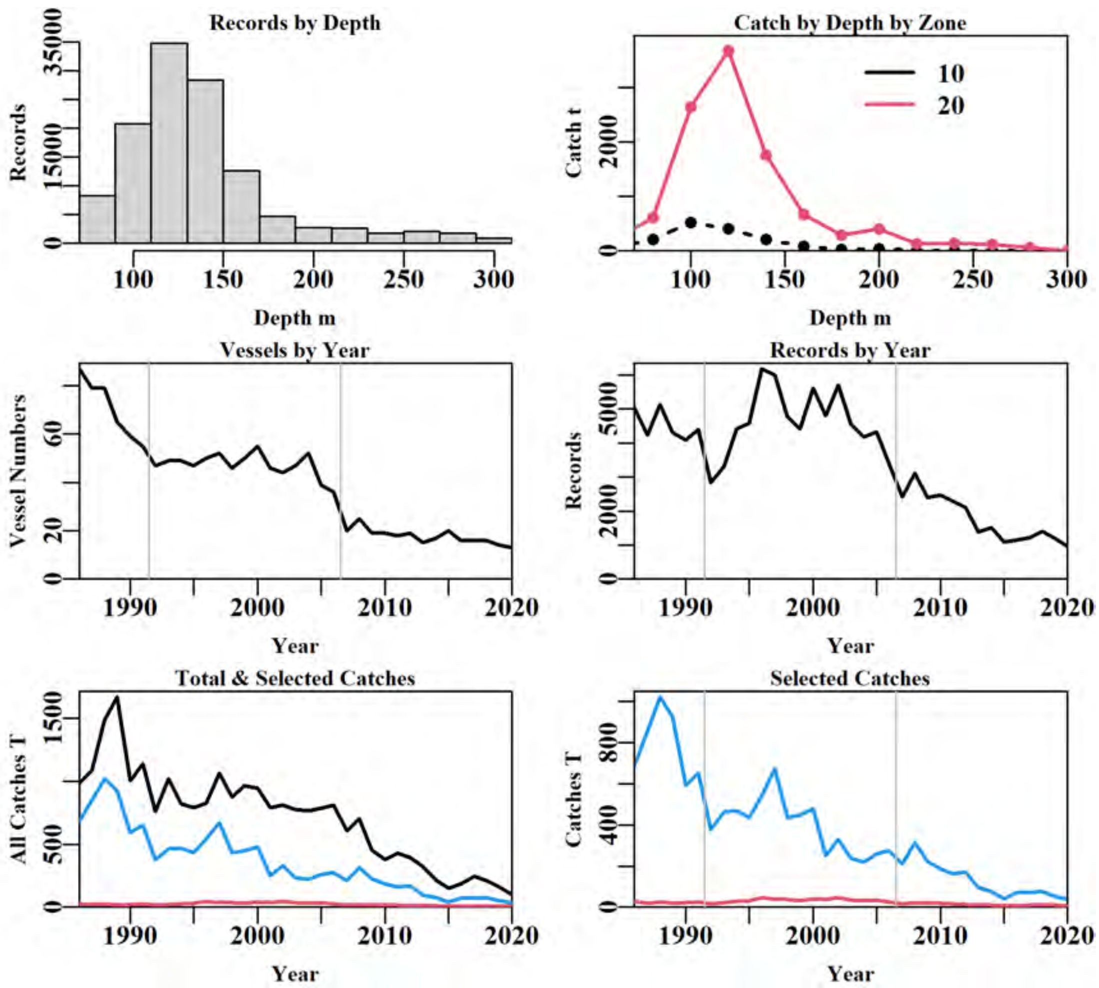

Figure 6.52. JackasssMorwong1020 fishery details. The bottom left plot depicts all known catches (top black line), and all selected catches used in the analysis (middle blue line); the lower red line: selected catches < 30 kg).

Table 6.38. 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	267032	244420	215233	211719	137332	121080	120984
Difference	0	22612	29187	3514	74387	16252	96
Catch	25405	24443	22968	22395	12900	12407	12399
Difference	0	962	1475	573	9495	493	8

Table 6.39. 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 6.40. 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

Term	AIC	RSS	MSS	Nobs	Npars	adj_r2	%Change
Year	89522	253415	37109	120984	35	12.7	0
Vessel	75510	225027	65498	120984	216	22.4	9.66
Month	72315	219122	71403	120984	227	24.4	2.03
Zone	70102	215147	75378	120984	228	25.8	1.37
DepCat	68761	212732	77792	120984	240	26.6	0.83
DayNight	67160	209926	80599	120984	243	27.6	0.97
Zone:Month	66234	208288	82236	120984	254	28.2	0.56
Zone:DepCat	66848	209344	81181	120984	255	27.8	0.19

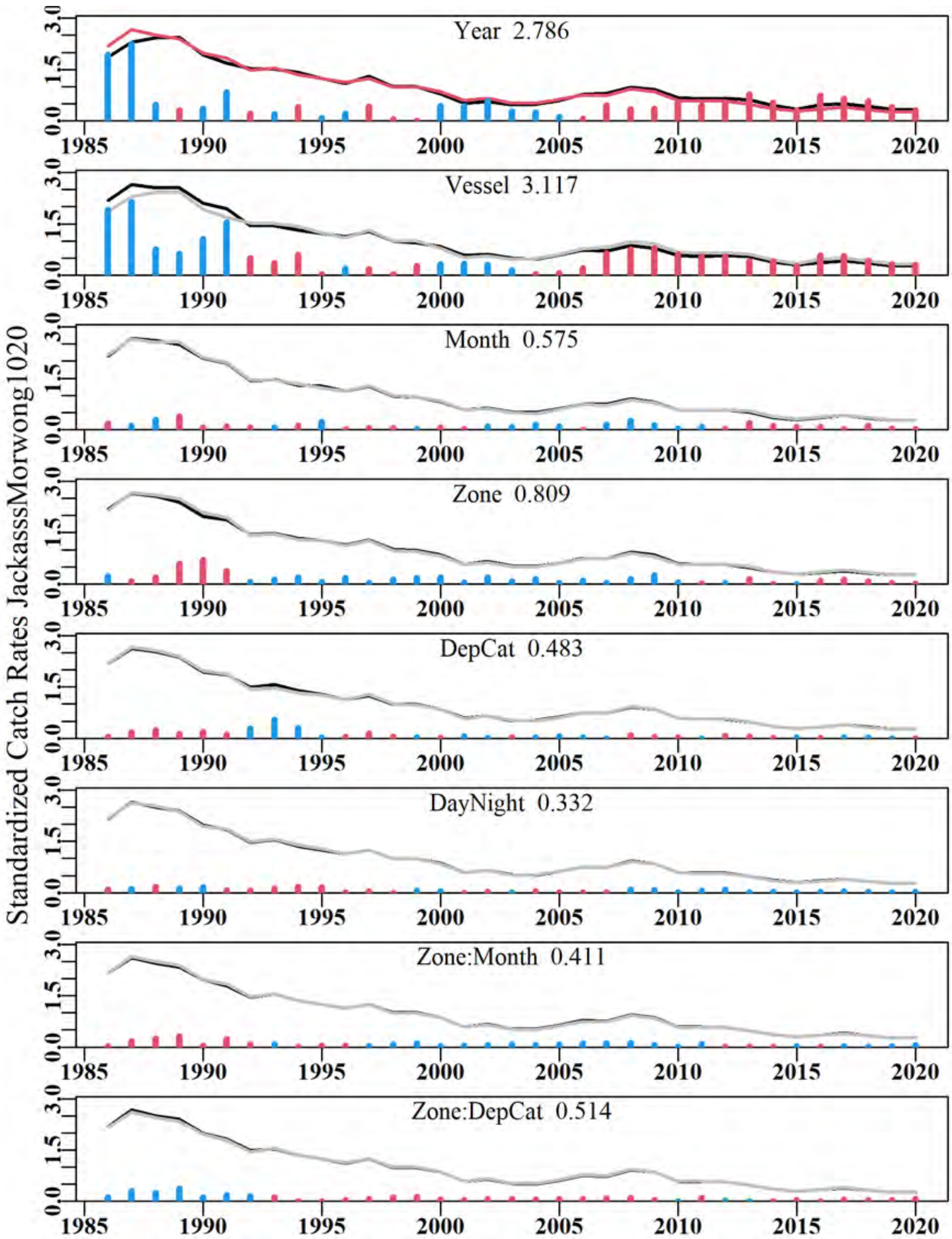

Figure 6.53. JackasssMorwong1020. The influence of each factor on the optimal standardization. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by vertical bars with blue bars indicating the optimum model is higher than 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.

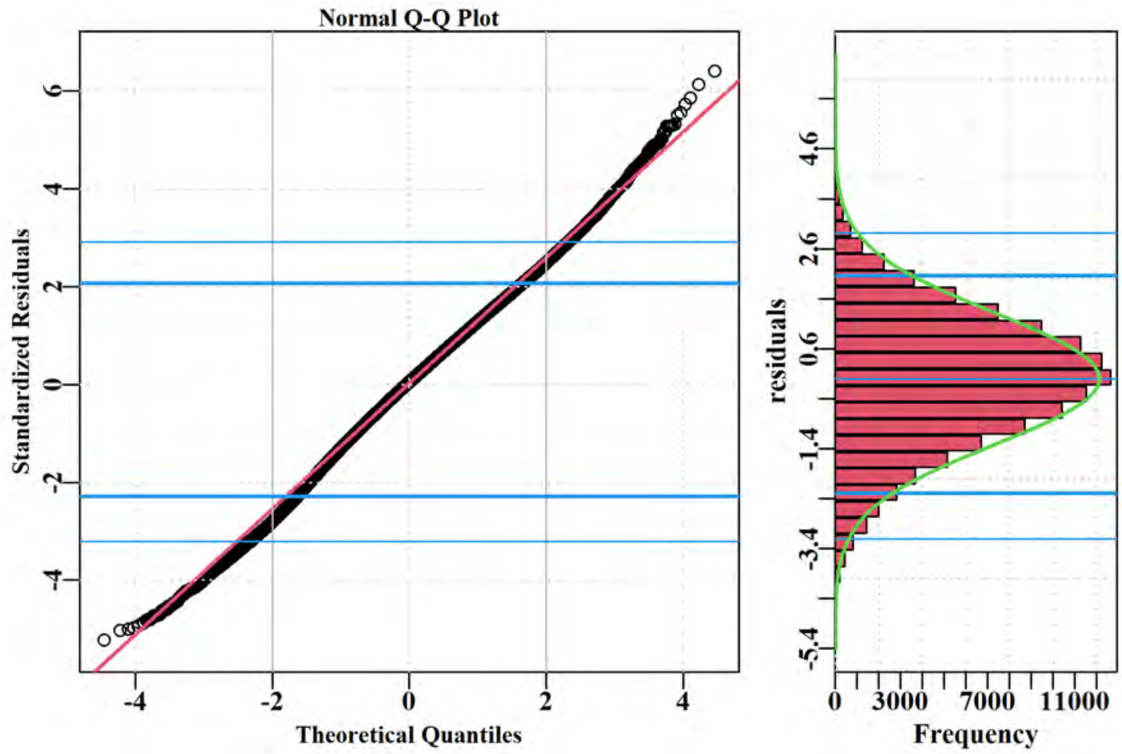

Figure 6.54. JackasssMorwong1020. diagnostic plots. The distribution of residuals from the optimum fit. The qqplot indicates the fit to the expected normality, while the histogram of residuals illustrates the 90% quantiles to indicate the intensity of any lack of fit at the margins of the distribution.

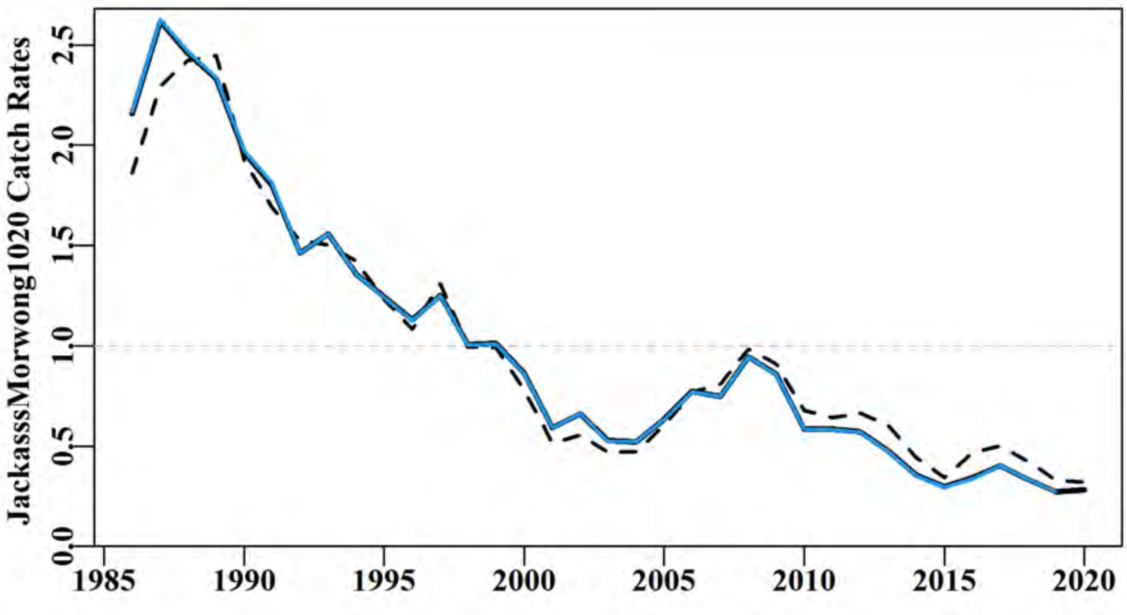

Figure 6.55. JackasssMorwong1020. A comparison of the previous year's standardization (blue line) with this year's. They should lie on top of each other, although small deviations may relate to data adjustments, particularly in very recent years.

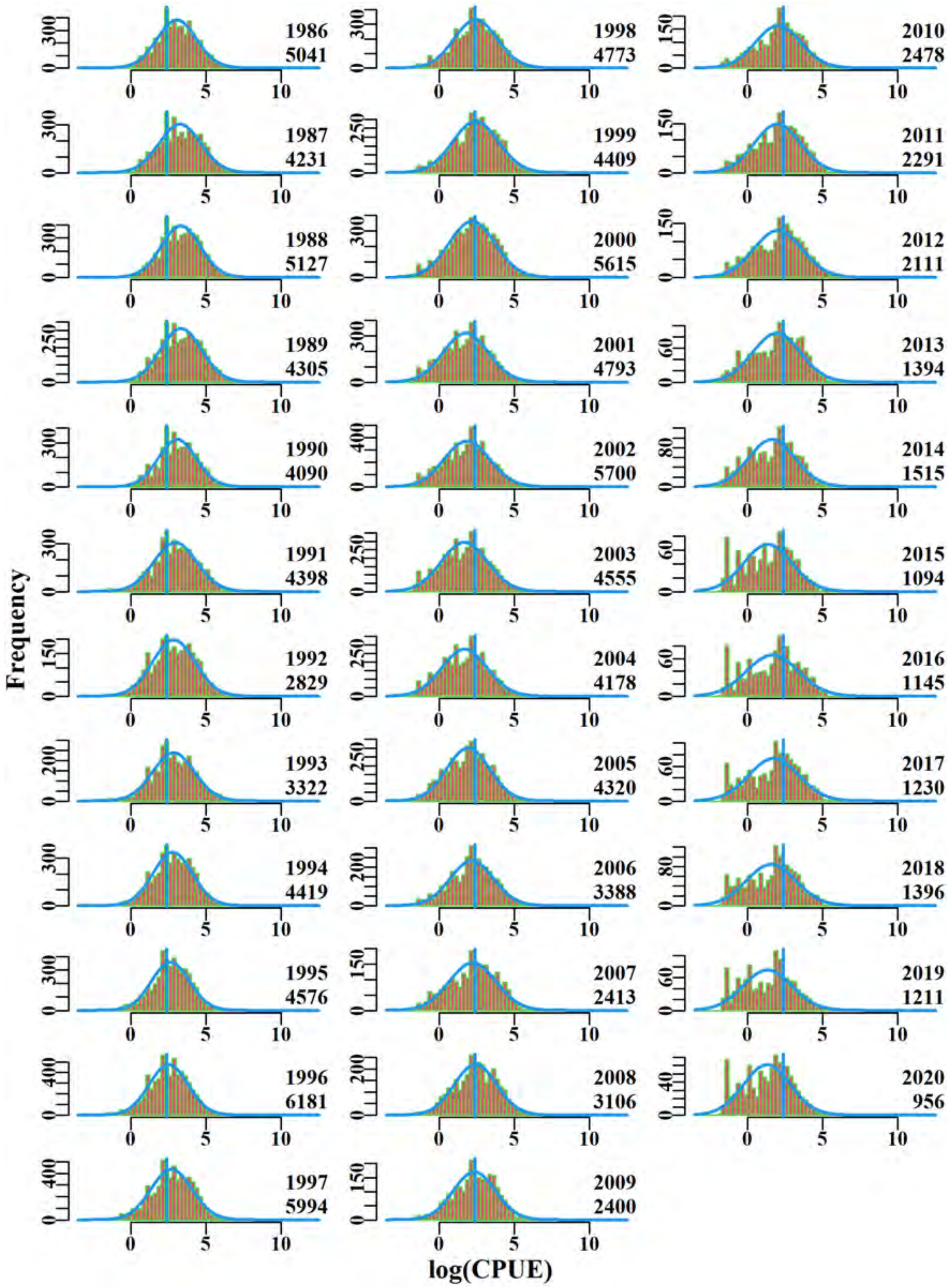

Figure 6.56. JackasssMorwong1020. The natural log(CPUE) for each year of data available the blue lines are normal distributions fitted to the histogram frequencies. The numbers in each plot are the year and number of records.

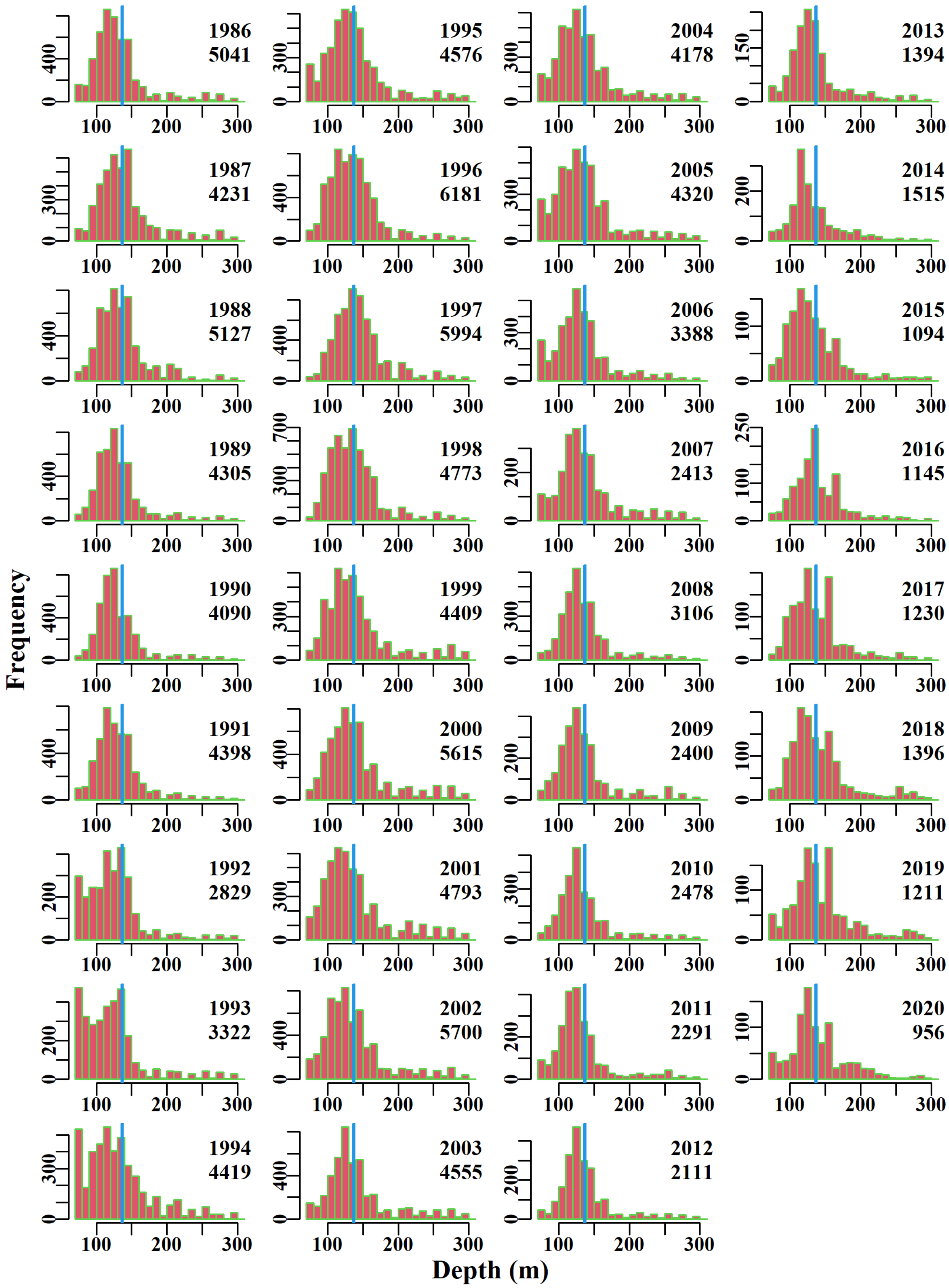

Figure 6.57. JackasssMorwong1020. The average Depth of fishing for each year of data available to illustrate the development of the fishery through time. The numbers in each plot are the year and number of records.

6.11 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, OTB, in zones 40, 50, and depths 70 to 360 m within the SET fishery for years 1986 - 2020 (Table 6.41). 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.

6.11.1 *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 6.45). The qqplot suggests a possible departure from Normality, as depicted by the tails of the distribution (Figure 6.61).

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, decreased to 2014, increased to 2017 and decreased in 2018, 2019 and 2020 (Figure 6.58). The recorded catch (7.8 t) and number of records (128) in 2020 was the lowest since 2016.

6.11.2 *Action Items and Issues*

The depth factor changed its influence from 2001-2019 reflecting the increase in catches from 2001 and suggesting the fishery changed remarkably at that time. The reasons behind this change should be explored in more detail.

Table 6.41. 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, OTB
years	1986 - 2020

Table 6.42. 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

Year	Total	N	Catch	Vess	GeoM	Opt	StDev	C<30Kg	P<30Kg
1986	982.8	550	149.1	19	114.8	2.1605	0.000	1.928	0.013
1987	1087.7	349	58.4	21	61.0	1.6923	0.086	2.079	0.036
1988	1483.5	401	65.4	19	66.0	2.4957	0.086	1.803	0.028
1989	1667.5	345	83.2	21	74.7	1.8129	0.091	2.283	0.027
1990	1001.4	410	80.3	22	77.2	1.8357	0.092	2.303	0.029
1991	1138.1	279	40.3	26	39.8	1.2321	0.097	1.790	0.044
1992	758.4	249	28.6	14	33.0	1.0129	0.099	2.122	0.074
1993	1016.0	248	25.0	17	29.6	0.9564	0.101	2.247	0.090
1994	818.6	309	22.5	16	22.9	0.9326	0.094	2.725	0.121
1995	789.8	292	77.0	17	63.2	0.9719	0.095	2.405	0.031
1996	827.3	345	36.1	17	31.3	1.0807	0.092	2.869	0.079
1997	1063.4	489	53.9	20	26.8	0.8567	0.085	4.823	0.090
1998	876.5	266	54.6	19	42.7	0.8689	0.098	2.825	0.052
1999	961.5	382	76.9	17	42.5	0.7885	0.090	3.711	0.048
2000	945.2	429	118.9	29	79.8	1.2628	0.090	3.723	0.031
2001	790.2	920	276.8	25	104.8	1.3491	0.079	5.171	0.019
2002	811.2	850	249.4	21	95.2	1.3625	0.079	4.464	0.018
2003	774.6	649	170.7	24	85.9	1.1560	0.083	3.106	0.018
2004	765.5	674	174.5	25	77.1	1.2271	0.082	2.843	0.016
2005	784.2	717	188.5	21	77.7	1.3269	0.081	3.105	0.016
2006	811.3	799	178.3	19	57.6	1.0466	0.080	3.293	0.018
2007	607.9	585	114.2	15	44.8	0.8704	0.083	2.758	0.024
2008	700.4	466	101.5	16	55.7	0.9032	0.086	1.491	0.015
2009	454.4	409	58.3	13	34.1	0.7207	0.089	2.178	0.037
2010	380.1	409	38.2	13	20.6	0.5311	0.089	2.589	0.068
2011	428.0	621	82.8	14	27.6	0.5624	0.083	2.709	0.033
2012	395.6	341	34.5	14	23.1	0.4212	0.092	2.604	0.076
2013	323.9	463	35.7	13	15.7	0.3891	0.087	3.435	0.096
2014	216.6	252	10.1	13	8.8	0.3024	0.100	2.484	0.245
2015	152.5	154	7.0	9	8.3	0.3862	0.114	1.297	0.185
2016	183.4	255	25.0	11	18.1	0.4577	0.099	1.601	0.064
2017	246.2	495	79.8	12	29.6	0.6900	0.088	2.386	0.030
2018	209.7	224	44.4	10	33.6	0.5467	0.104	1.047	0.024
2019	161.9	209	22.3	10	18.0	0.4135	0.107	1.271	0.057
2020	99.1	128	7.8	10	10.9	0.3765	0.126	0.732	0.094

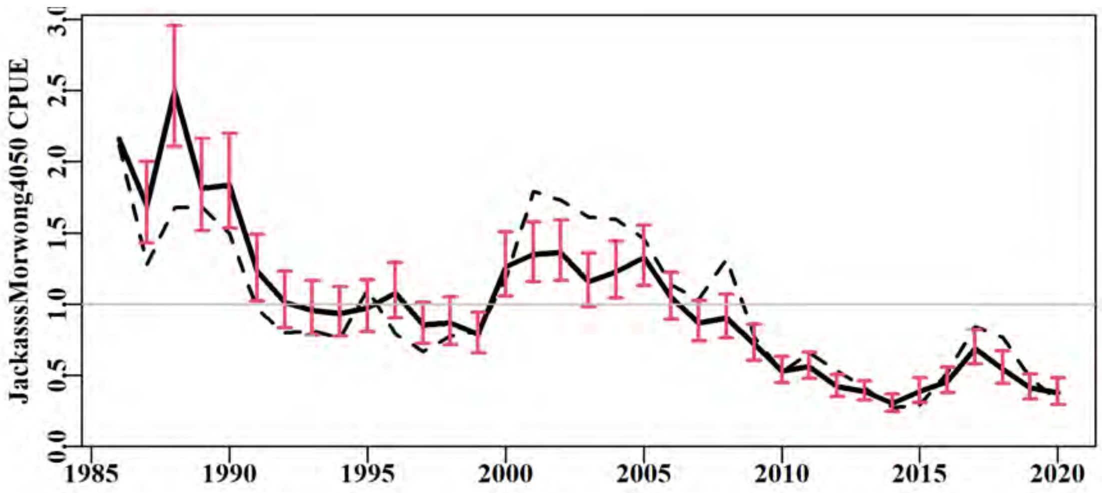

Figure 6.58. JackasssMorwong4050 standardization. The dashed black line represents the geometric mean CPUE, solid black line the standardized CPUE. The red bars are the 95% confidence intervals about the mean estimates. The graph scales both time-series of standardized CPUE relative to the mean of each time-series.

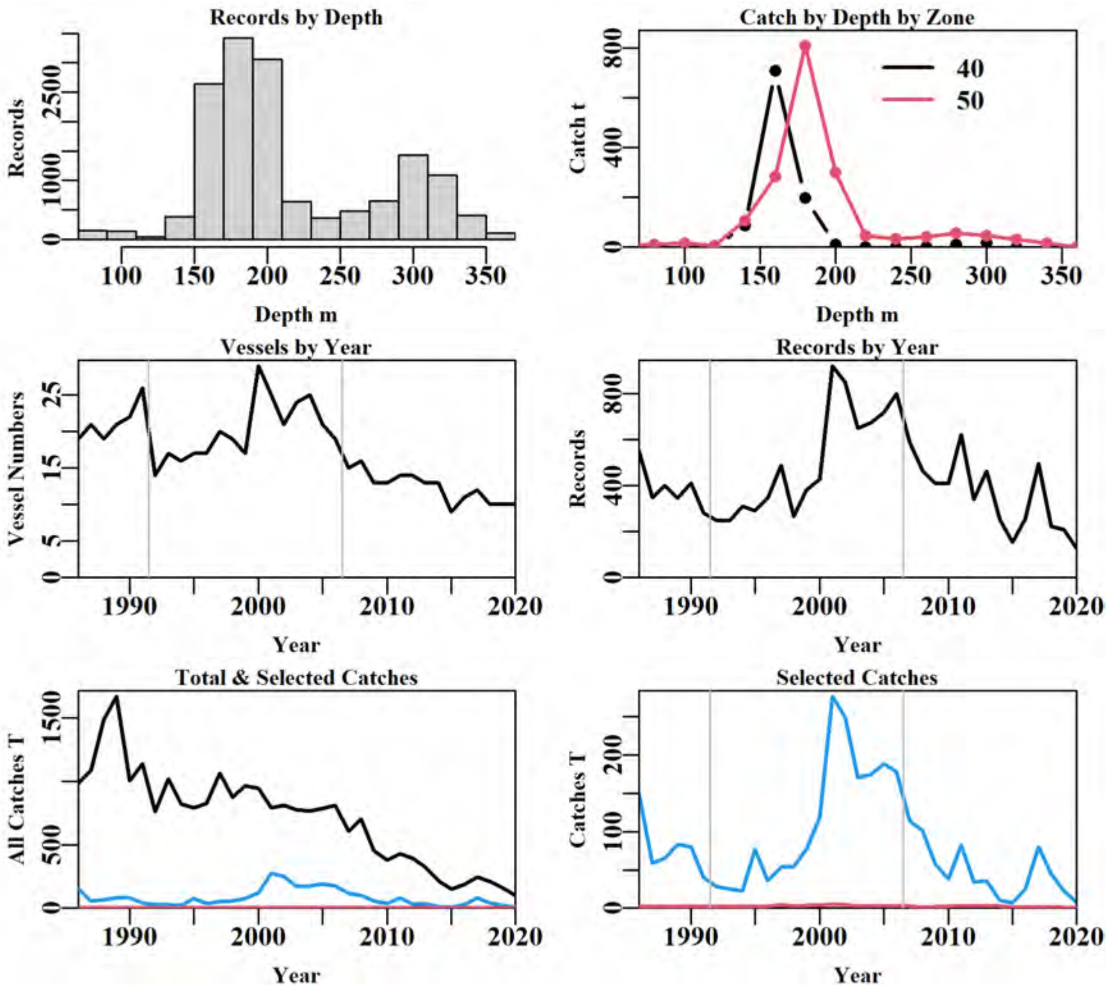

Figure 6.59. JackasssMorwong4050 fishery details. The bottom left plot depicts all known catches (top black line), and all selected catches used in the analysis (middle blue line); the lower red line: selected catches < 30 kg).

Table 6.43. 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	267032	244420	220938	217355	15571	14998	14963
Difference	0	22612	23482	3583	201784	573	35
Catch	25405	24443	23304	22722	2914	2879	2870
Difference	0	962	1140	581	19808	35	9

Table 6.44. 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 6.45. 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

Term	AIC	RSS	MSS	Nobs	Npars	adj_r2	%Change
Year	8325	25979	3687	14963	35	12.2	0
DepCat	5995	22188	7478	14963	50	25.0	12.73
Month	4698	20316	9350	14963	61	31.2	6.28
Vessel	3980	19130	10535	14963	152	34.9	3.62
DayNight	3801	18895	10771	14963	155	35.6	0.79
Zone	3680	18741	10925	14963	156	36.2	0.52
Zone:Month	3536	18534	11132	14963	167	36.8	0.66
Zone:DepCat	3584	18585	11080	14963	170	36.6	0.47

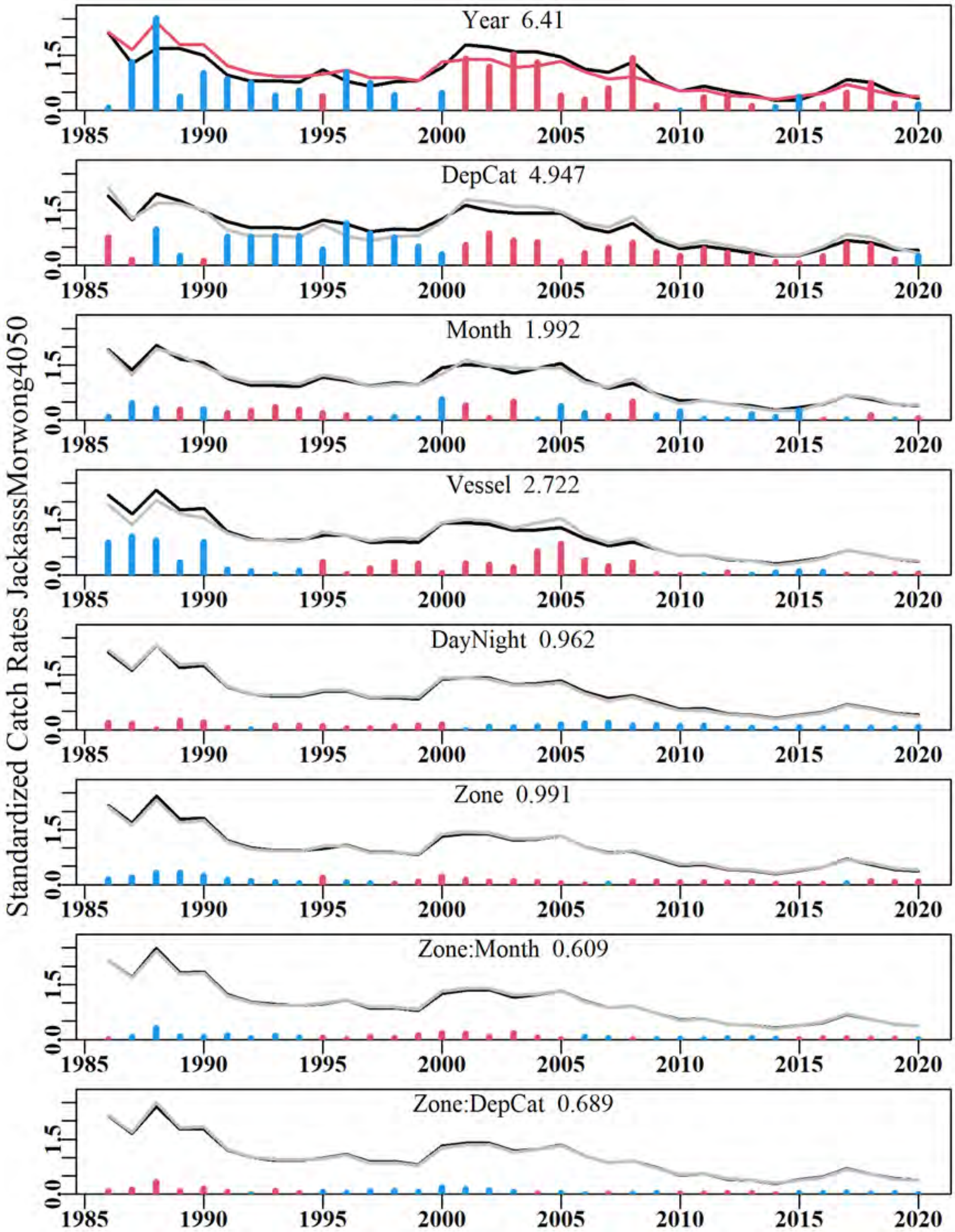

Figure 6.60. JackasssMorwong4050. The influence of each factor on the optimal standardization. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by vertical bars with blue bars indicating the optimum model is higher than 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.

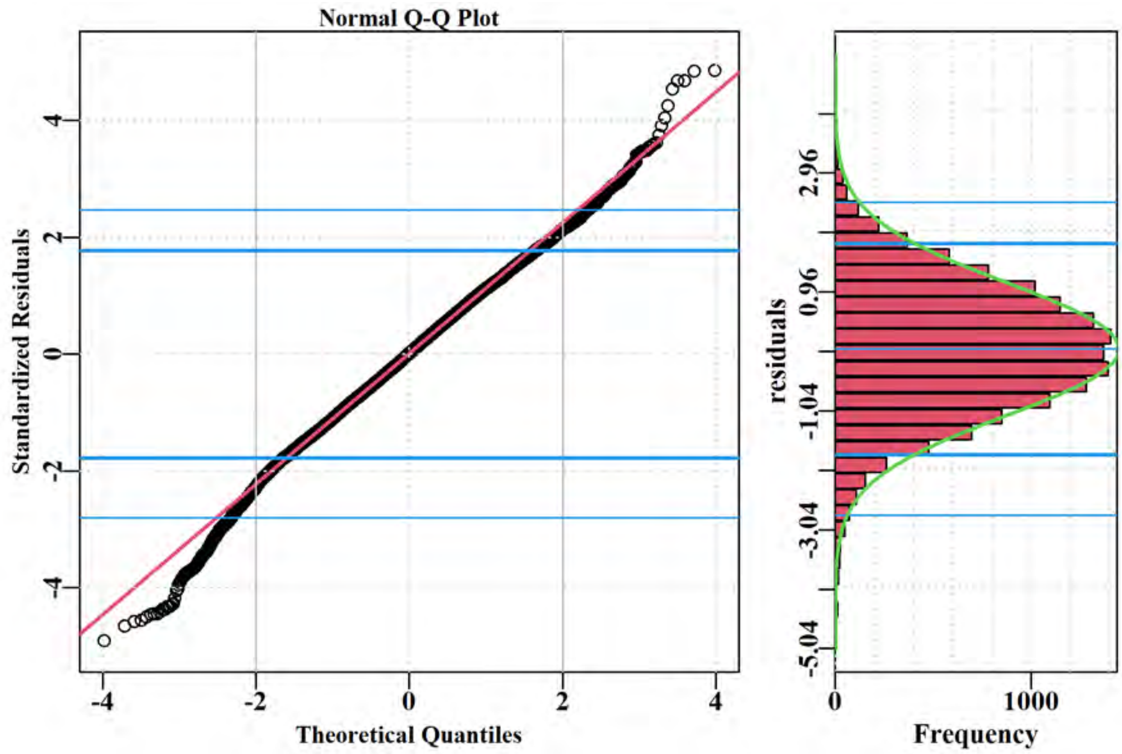

Figure 6.61. JackasssMorwong4050. diagnostic plots. The distribution of residuals from the optimum fit. The qqplot indicates the fit to the expected normality, while the histogram of residuals illustrates the 90% quantiles to indicate the intensity of any lack of fit at the margins of the distribution.

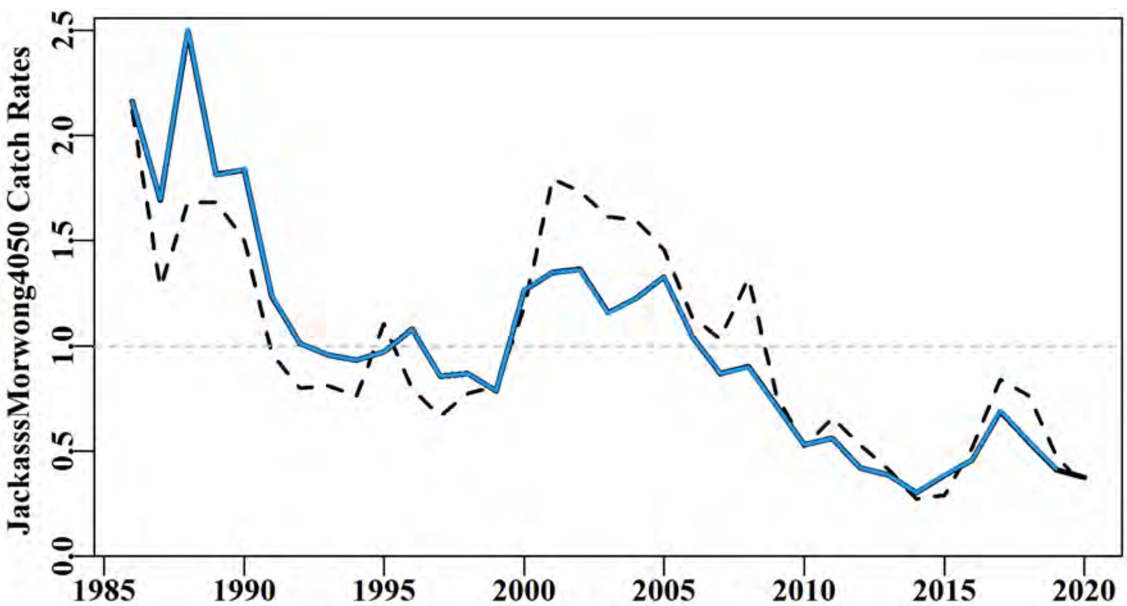

Figure 6.62. JackasssMorwong4050. A comparison of the previous year's standardization (blue line) with this year's. They should lie on top of each other, although small deviations may relate to data adjustments, particularly in very recent years.

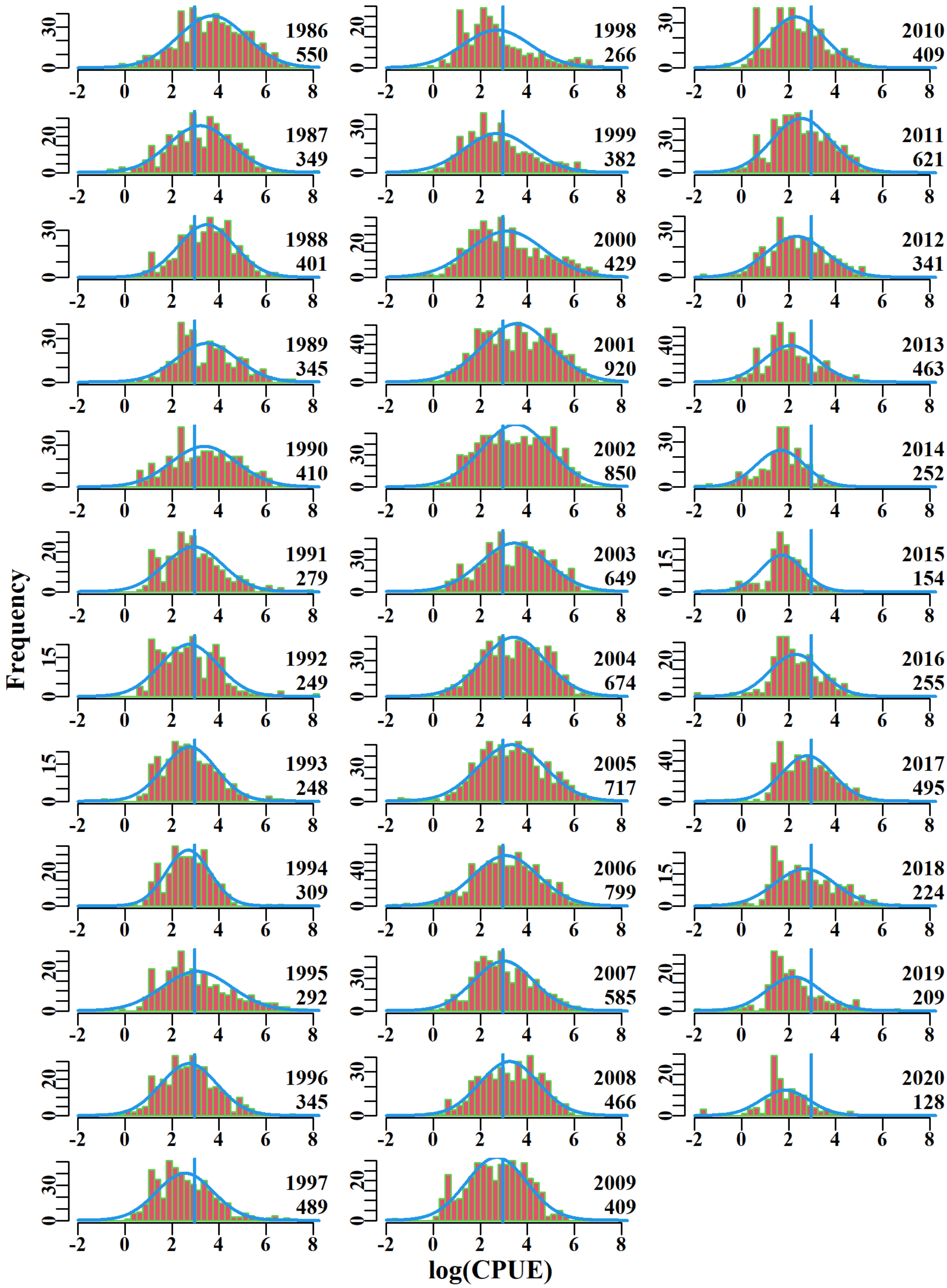

Figure 6.63. JackasssMorwong4050. The natural log(CPUE) for each year of data available the blue lines are normal distributions fitted to the histogram frequencies. The numbers in each plot are the year and number of records.

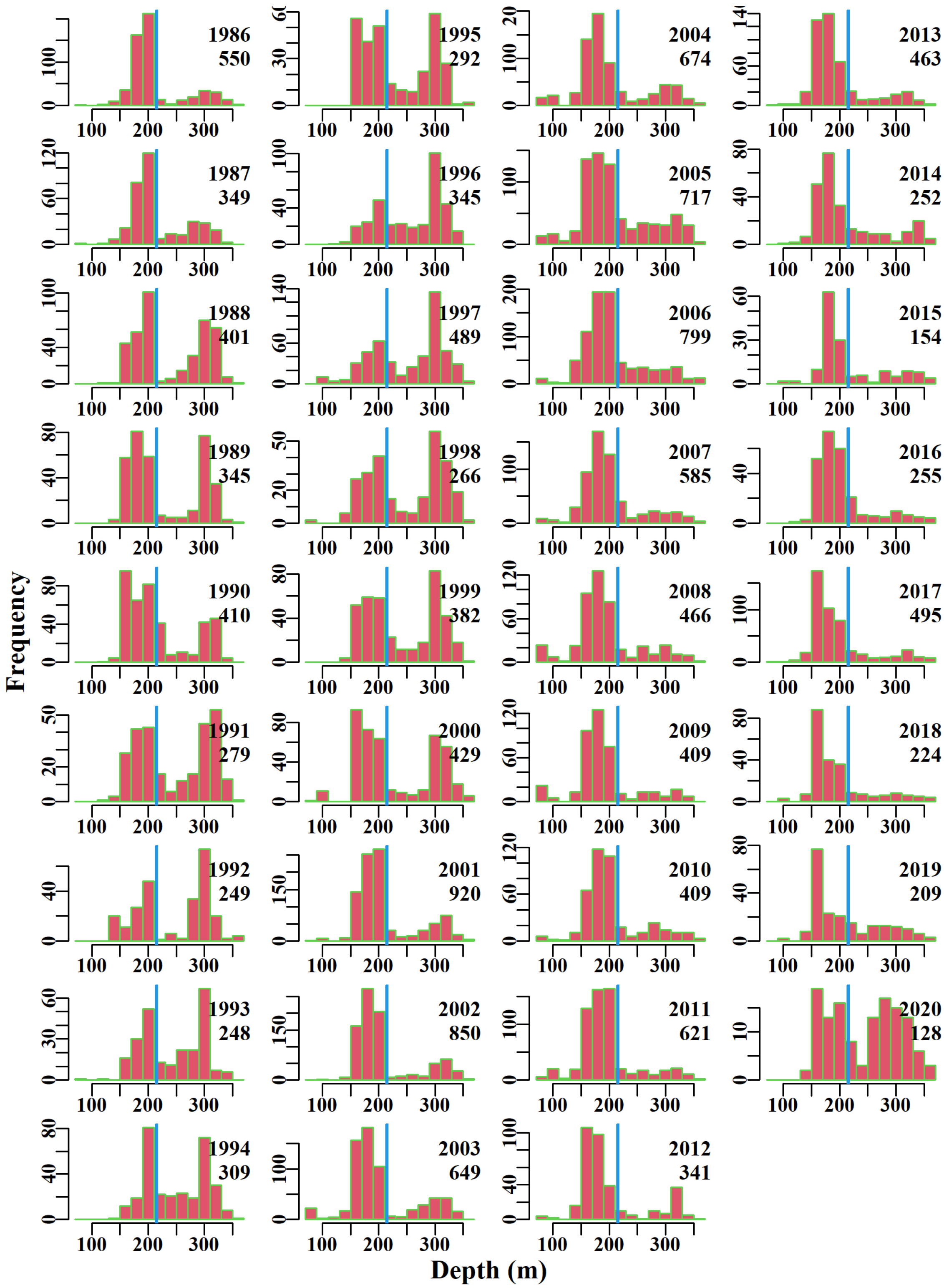

Figure 6.64. JackasssMorwong4050. The average Depth of fishing for each year of data available to illustrate the development of the fishery through time. The numbers in each plot are the year and number of records.

6.12 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, OTB, in zones 40, 50, and depths 0 to 600 m within the SET fishery for years 1986 - 2020 (Table 6.46). 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.

6.12.1 *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 6.50). The qqplot suggests that the assumed Normal distribution is valid (Figure 6.68).

Annual standardized CPUE has declined since 2005, and since 2008 have been below the long-term average (Figure 6.65). The influence of the vessel factor was high from 1999 to about 2006 after which it was less influential. The 2020 catch (163.5 t) of Silver Warehou in the west was the lowest in the series (i.e., since 1986).

6.12.2 *Action Items and Issues*

Annual Silver Warehou catches in the west were high (i.e., 1680 t – 2945 t per annum) for the period around 1999 - 2006. Vessels that contributed to these high catches left the fishery after the structural adjustment. This suggests that there have been transitional periods in the time-series of CPUE. This needs more attention because this may imply that CPUE may no longer be acting as a valid index of relative abundance through time.

Table 6.46. 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, OTB
years	1986 - 2020

Table 6.47. 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:DepCat

Year	Total	N	Catch	Vess	GeoM	Opt	StDev	C<30Kg	P<30Kg
1986	1156.5	1118	643.2	23	201.2	1.5956	0.000	4.167	0.006
1987	782.2	723	490.0	26	279.5	1.7840	0.082	2.368	0.005
1988	1646.2	574	684.4	27	553.8	2.1273	0.087	2.295	0.003
1989	926.3	649	569.0	27	287.0	1.8019	0.089	2.663	0.005
1990	1346.6	565	296.6	26	197.1	1.1632	0.088	2.986	0.010
1991	1453.2	691	623.8	29	267.7	1.2672	0.085	3.180	0.005
1992	733.8	582	185.4	21	98.1	0.9513	0.087	3.330	0.018
1993	1815.8	1541	749.3	23	151.0	1.3076	0.072	6.998	0.009
1994	2309.5	1639	753.6	26	155.7	1.1894	0.070	7.735	0.010
1995	2003.8	1673	771.7	24	147.2	0.9838	0.070	8.958	0.012
1996	2188.5	1551	1016.2	26	209.0	1.0985	0.071	8.450	0.008
1997	2562.0	1874	1261.4	24	210.8	1.3293	0.070	9.427	0.007
1998	2166.0	1848	1196.4	22	221.7	1.5251	0.070	7.985	0.007
1999	2834.1	2735	1772.1	24	241.8	1.2796	0.067	11.412	0.006
2000	3401.6	3557	2568.9	31	321.2	1.2416	0.066	15.063	0.006
2001	2970.4	4177	2170.7	29	193.7	0.9206	0.065	20.784	0.010
2002	3841.4	4421	2944.8	27	249.0	0.9878	0.065	20.321	0.007
2003	2910.1	3398	2199.3	28	256.8	1.0193	0.066	14.878	0.007
2004	3202.4	4241	2534.7	25	164.8	1.1147	0.065	14.503	0.006
2005	2648.0	3065	2100.2	24	220.2	1.2195	0.067	11.833	0.006
2006	2191.2	2682	1680.0	21	187.2	1.0816	0.068	10.636	0.006
2007	1816.6	2764	1360.1	16	144.6	1.0697	0.067	10.282	0.008
2008	1381.2	2056	870.0	17	105.7	0.8704	0.069	9.048	0.010
2009	1285.3	2042	719.9	13	73.2	0.7623	0.069	9.352	0.013
2010	1189.4	2319	782.7	14	64.7	0.6883	0.069	11.517	0.015
2011	1108.8	2889	818.3	17	57.4	0.6578	0.067	11.542	0.014
2012	781.2	1846	546.4	15	57.3	0.4901	0.071	10.147	0.019
2013	584.1	1513	342.2	16	48.6	0.4497	0.073	8.189	0.024
2014	356.9	1540	244.0	14	29.2	0.4262	0.072	8.700	0.036
2015	368.4	1381	268.0	13	34.2	0.4623	0.074	6.637	0.025
2016	331.5	1102	172.1	13	25.2	0.3377	0.076	6.353	0.037
2017	325.7	1246	218.5	12	29.3	0.3773	0.075	5.926	0.027
2018	357.6	1236	266.8	12	32.2	0.5013	0.076	3.922	0.015
2019	304.0	1243	226.4	15	31.1	0.4460	0.076	5.133	0.023
2020	261.8	1083	163.5	14	26.7	0.4721	0.079	5.024	0.031

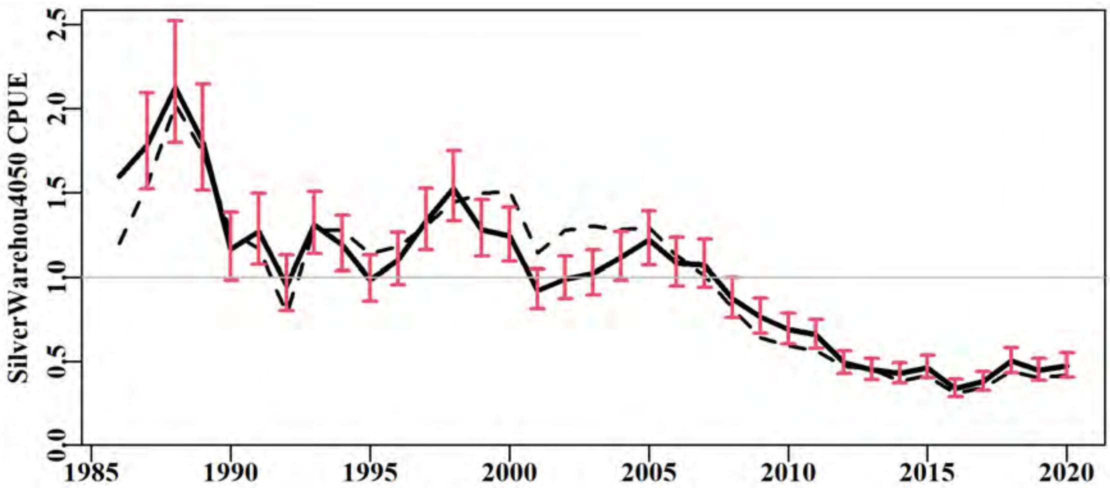

Figure 6.65. SilverWarehou4050 standardization. The dashed black line represents the geometric mean CPUE, solid black line the standardized CPUE. The red bars are the 95% confidence intervals about the mean estimates. The graph scales both time-series of standardized CPUE relative to the mean of each time-series.

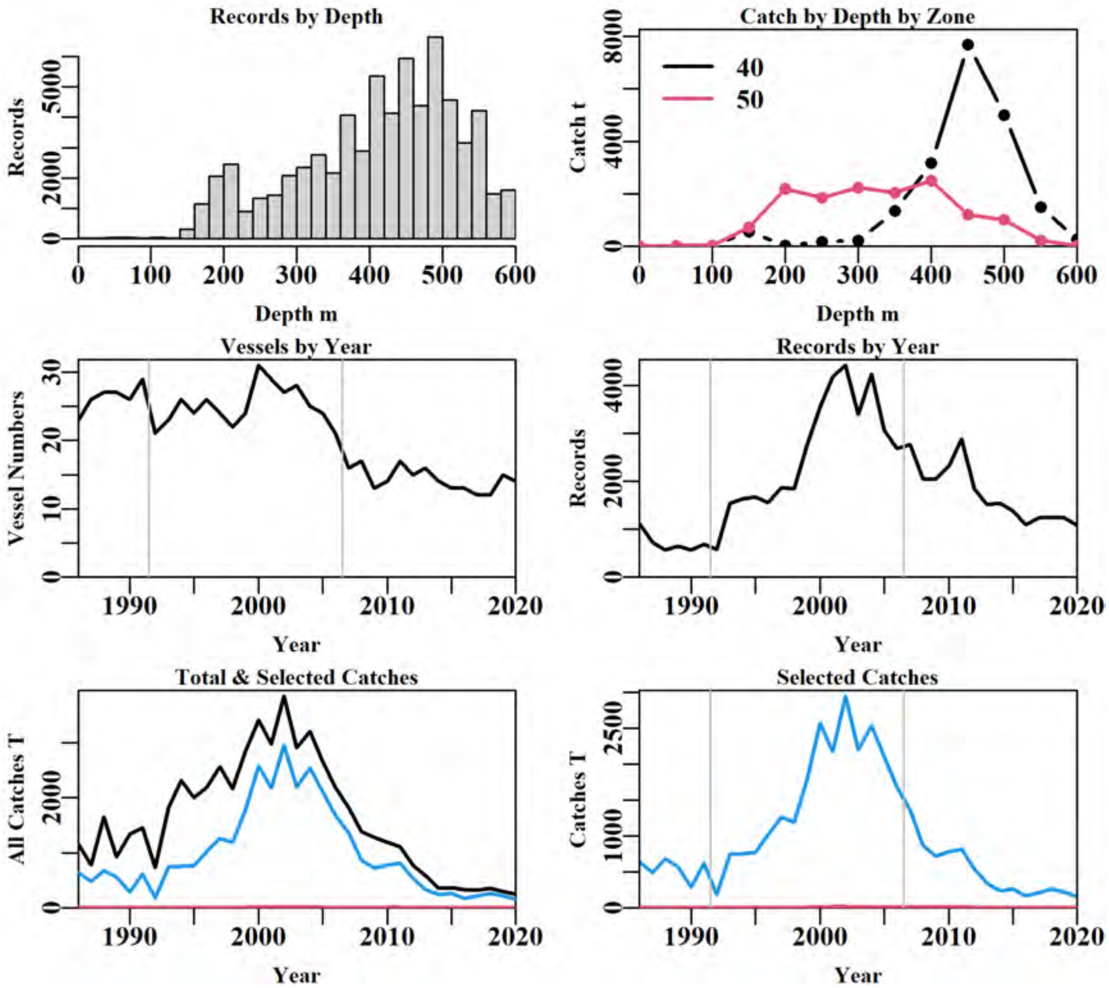

Figure 6.66. SilverWarehou4050 fishery details. The bottom left plot depicts all known catches (top black line), and all selected catches used in the analysis (middle blue line); the lower red line: selected catches < 30 kg).

Table 6.48. 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	161630	155857	151451	150399	67907	67688	67564
Difference	0	5773	4406	1052	82492	219	124
Catch	55941	55451	53735	53341	34389	34340	34211
Difference	0	490	1717	393	18953	49	129

Table 6.49. 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 6.50. 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:DepCat

Term	AIC	RSS	MSS	Nobs	Npars	adj_r2	%Change
Year	69655	189234	15457	67564	35	7.50	0
Vessel	61769	167871	36820	67541	138	17.80	10.293
Month	58603	160130	44560	67541	149	21.58	3.777
DepCat	57444	157350	47340	67541	161	22.92	1.348
Zone	56507	155179	49512	67541	162	23.99	1.063
DayNight	56175	154404	50286	67541	165	24.36	0.376
Zone:Month	55964	153872	50818	67541	176	24.61	0.248
Zone:DepCat	55949	153832	50858	67541	177	24.63	0.266

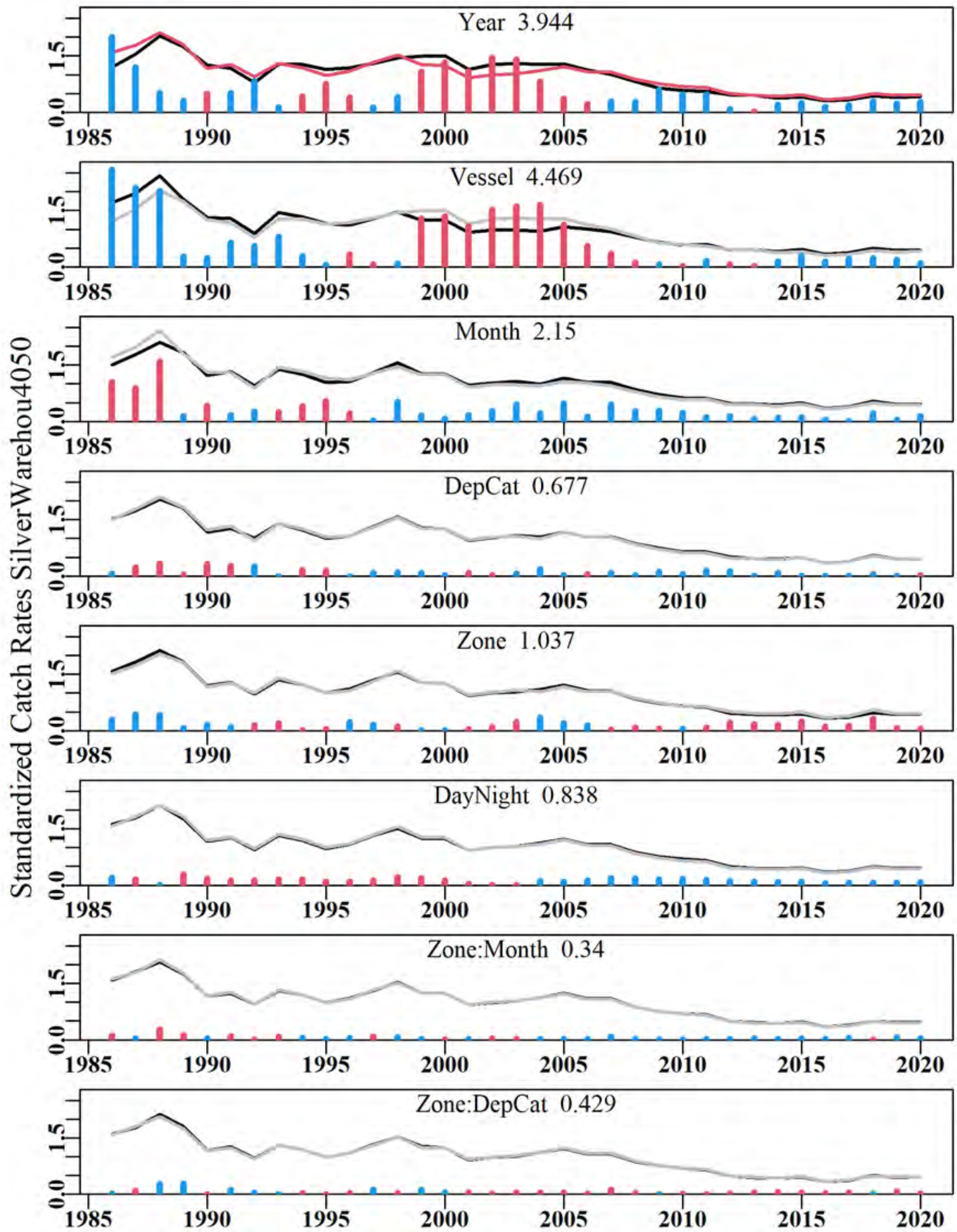

Figure 6.67. SilverWarehou4050. The influence of each factor on the optimal standardization. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by vertical bars with blue bars indicating the optimum model is higher than the 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.

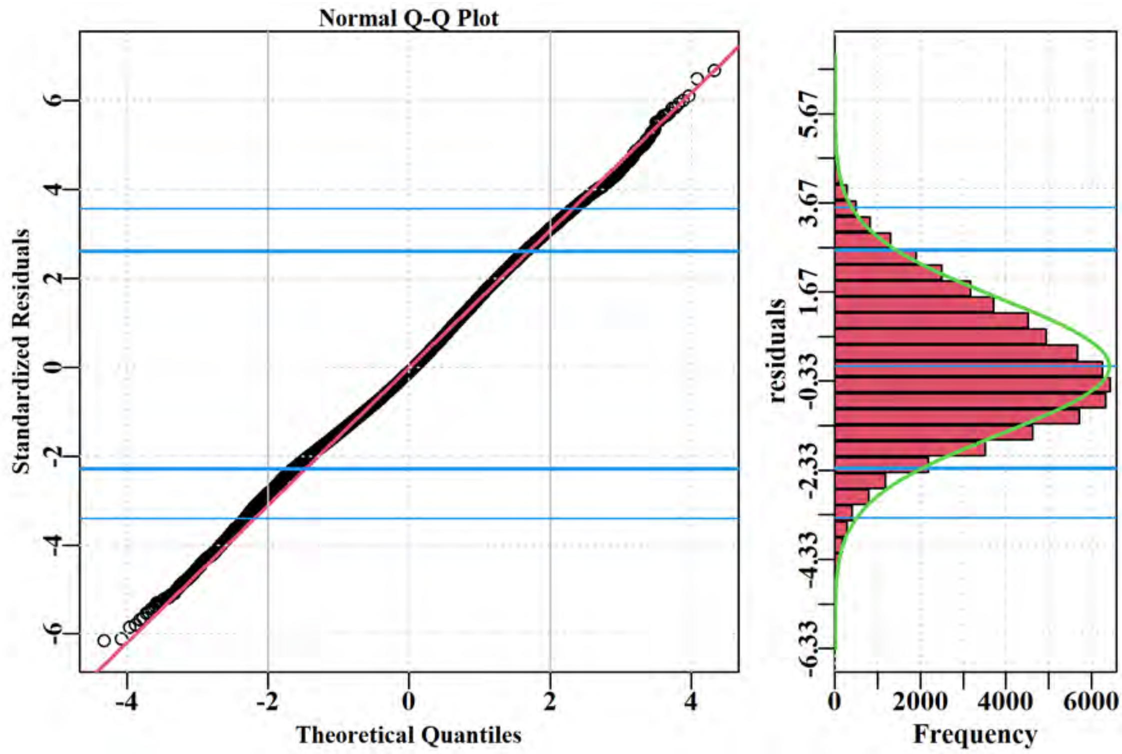

Figure 6.68. SilverWarehou4050. diagnostic plots. The distribution of residuals from the optimum fit. The qqplot indicates the fit to the expected normality, while the histogram of residuals illustrates the 90% quantiles to indicate the intensity of any lack of fit at the margins of the distribution.

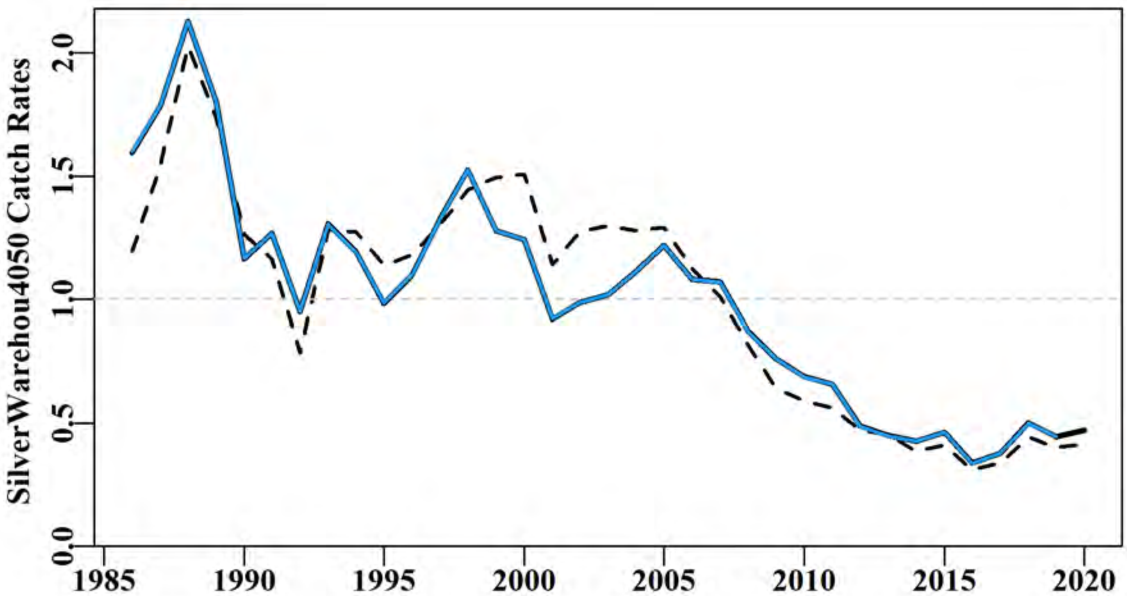

Figure 6.69. SilverWarehou4050. A comparison of the previous year's standardization (blue line) with this year's. They should lie on top of each other, although small deviations may relate to data adjustments, particularly in very recent years.

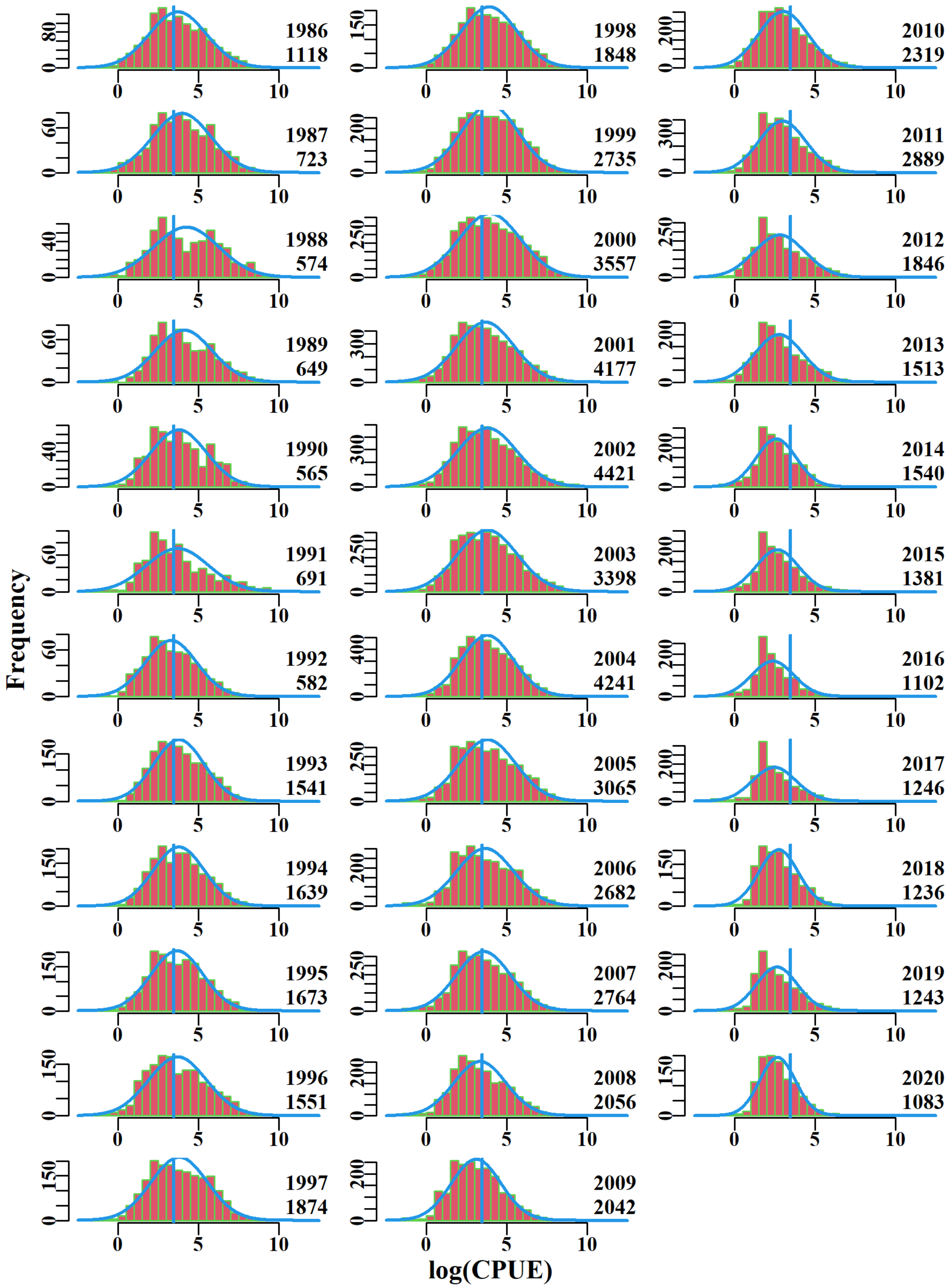

Figure 6.70. SilverWarehou4050. The natural log(CPUE) for each year of data available the blue lines are normal distributions fitted to the histogram frequencies. The numbers in each plot are the year and number of records.

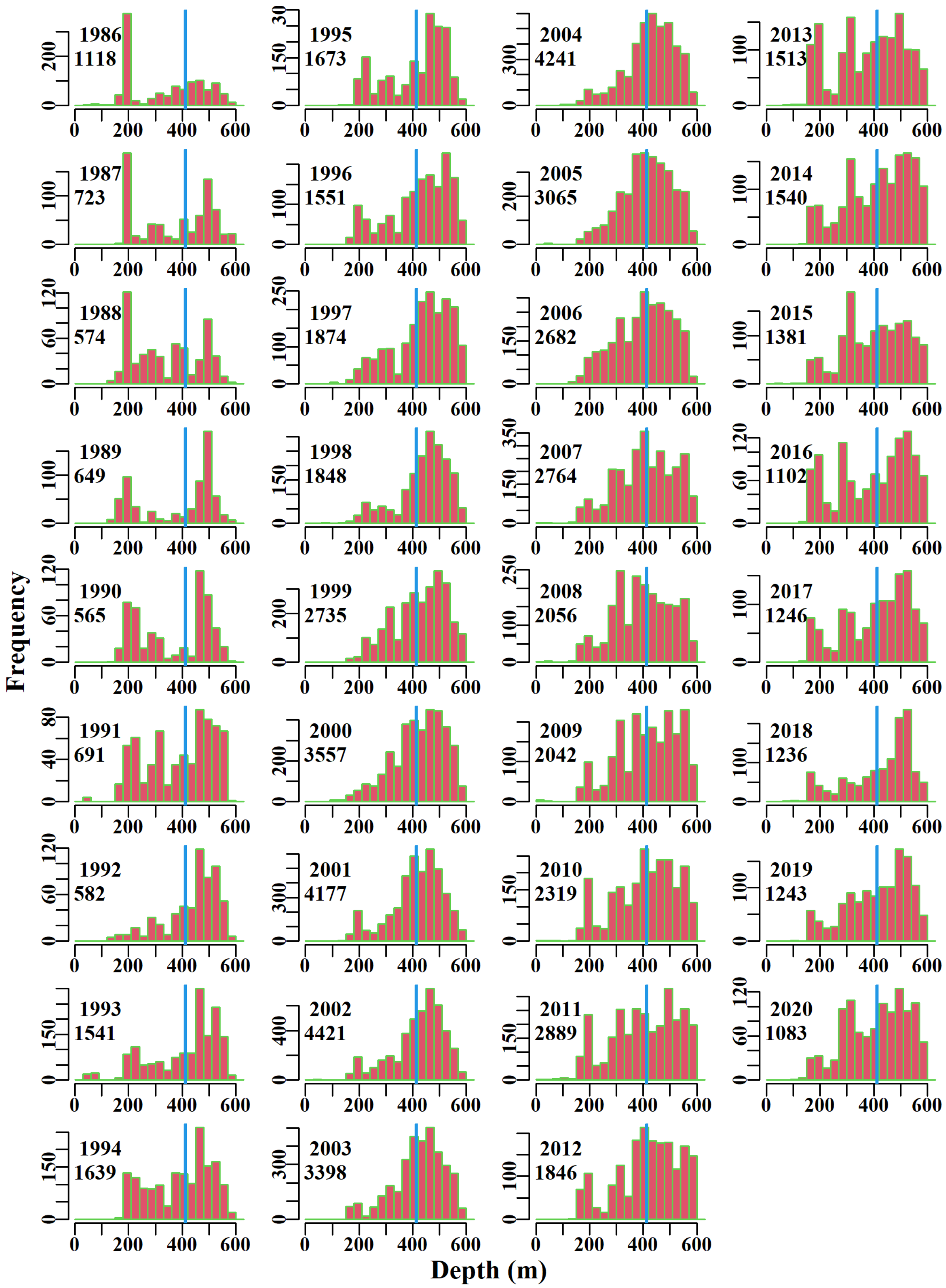

Figure 6.71. SilverWarehou4050. The average Depth of fishing for each year of data available to illustrate the development of the fishery through time. The numbers in each plot are the year and number of records.

6.13 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, OTB, in zones 10, 20, 30, and depths 0 to 600 m within the SET fishery for years 1986 - 2020 (Table 6.51).

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.

6.13.1 *Inferences*

Most Silver Warehou in the east have been caught in zone 20 across the specified depth range between 1986 - 2020. 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, based on the AIC and R^2 statistics (Table 6.55). The qqplot suggests that the assumed Normal distribution is valid (Figure 6.75).

Annual standardized CPUE has declined since 1994 and have been below average since 2000 (Figure 6.72).

6.13.2 *Action Items and Issues*

Annual Silver Warehou catches in the east were relatively high for the period around 1992 – 2006, with specific vessels contributing to these large catches. This suggests that there have been transitional periods in the time-series of CPUE and needs more attention because of the potential implications this has for the index of relative abundance through time.

Table 6.51. 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, OTB
years	1986 - 2020

Table 6.52. 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

Year	Total	N	Catch	Vess	GeoM	Opt	StDev	C<30Kg	P<30Kg
1986	1156.5	1318	491.7	66	113.2	1.9333	0.000	6.906	0.014
1987	782.2	778	264.8	56	112.0	1.8568	0.078	4.472	0.017
1988	1646.2	1668	926.1	69	172.0	2.3774	0.066	8.485	0.009
1989	926.3	1394	336.7	63	62.3	1.9777	0.070	9.172	0.027
1990	1346.6	1398	972.3	59	256.2	2.5230	0.071	5.674	0.006
1991	1453.2	1572	576.6	63	117.7	1.5289	0.071	9.864	0.017
1992	733.8	1256	423.8	41	110.1	1.7356	0.073	7.415	0.017
1993	1815.8	2289	970.5	49	129.5	1.7175	0.066	14.634	0.015
1994	2309.5	2852	1535.2	46	186.7	1.9018	0.065	16.832	0.011
1995	2003.8	3317	1186.1	45	112.5	1.6083	0.064	22.666	0.019
1996	2188.5	4508	1115.4	53	72.4	1.3028	0.062	32.860	0.029
1997	2562.0	3877	1036.3	48	81.8	1.2935	0.064	26.098	0.025
1998	2166.0	2847	777.6	43	72.9	1.0672	0.065	21.294	0.027
1999	2834.1	2398	905.7	43	113.2	0.9324	0.067	17.189	0.019
2000	3401.6	3160	722.0	50	79.2	0.7470	0.065	21.600	0.030
2001	2970.4	3151	637.1	40	72.1	0.7015	0.065	21.675	0.034
2002	3841.4	3981	707.8	42	60.5	0.8129	0.064	27.884	0.039
2003	2910.1	3967	567.6	50	48.1	0.7359	0.064	28.176	0.050
2004	3202.4	3570	487.0	46	43.0	0.8635	0.065	25.638	0.053
2005	2648.0	3791	429.8	42	33.9	0.8047	0.064	30.420	0.071
2006	2191.2	2948	388.7	35	33.2	0.6806	0.066	24.183	0.062
2007	1816.6	1864	274.8	23	44.4	0.5319	0.070	14.426	0.052
2008	1381.2	2301	397.8	24	43.8	0.6251	0.068	19.377	0.049
2009	1285.3	2285	366.4	23	50.0	0.7106	0.068	17.169	0.047
2010	1189.4	2085	282.0	20	40.1	0.5261	0.069	15.392	0.055
2011	1108.8	1983	215.2	22	30.5	0.4564	0.070	15.878	0.074
2012	781.2	1834	188.8	20	33.0	0.4169	0.070	14.161	0.075
2013	584.1	1448	158.9	21	37.9	0.5204	0.073	11.465	0.072
2014	356.9	1344	89.2	22	21.7	0.3564	0.074	11.540	0.129
2015	368.4	1288	64.8	22	16.2	0.2455	0.074	11.574	0.179
2016	331.5	1337	100.1	22	19.5	0.2051	0.074	9.449	0.094
2017	325.7	1069	96.0	18	39.4	0.2909	0.077	7.021	0.073
2018	357.6	1183	84.5	19	24.0	0.3674	0.076	9.122	0.108
2019	304.0	1180	69.5	19	23.6	0.2967	0.077	10.480	0.151
2020	261.8	1066	90.4	16	29.2	0.3481	0.078	9.374	0.104

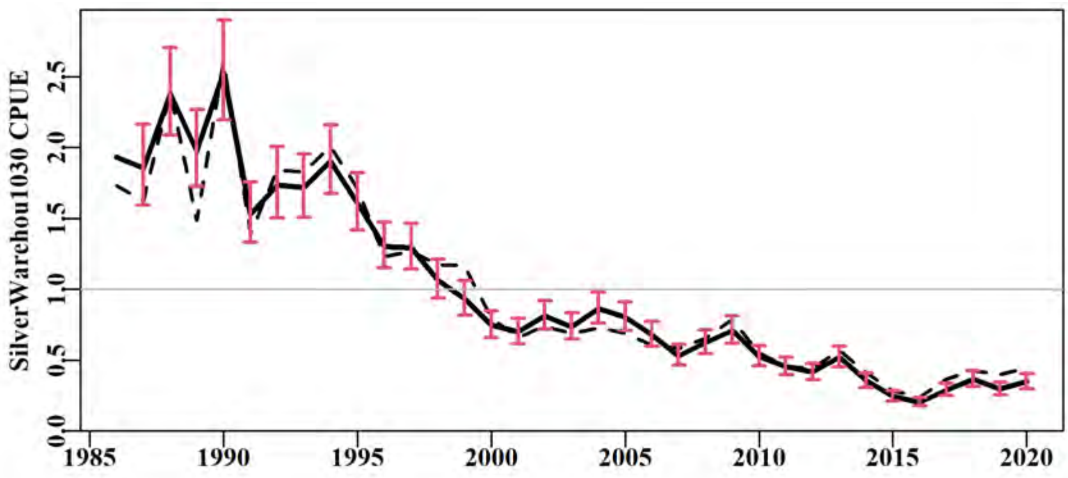

Figure 6.72. SilverWarehou1030 standardization. The dashed black line represents the geometric mean CPUE, solid black line the standardized CPUE. The red bars are the 95% confidence intervals about the mean estimates. The graph scales both time-series of standardized CPUE relative to the mean of each time-series.

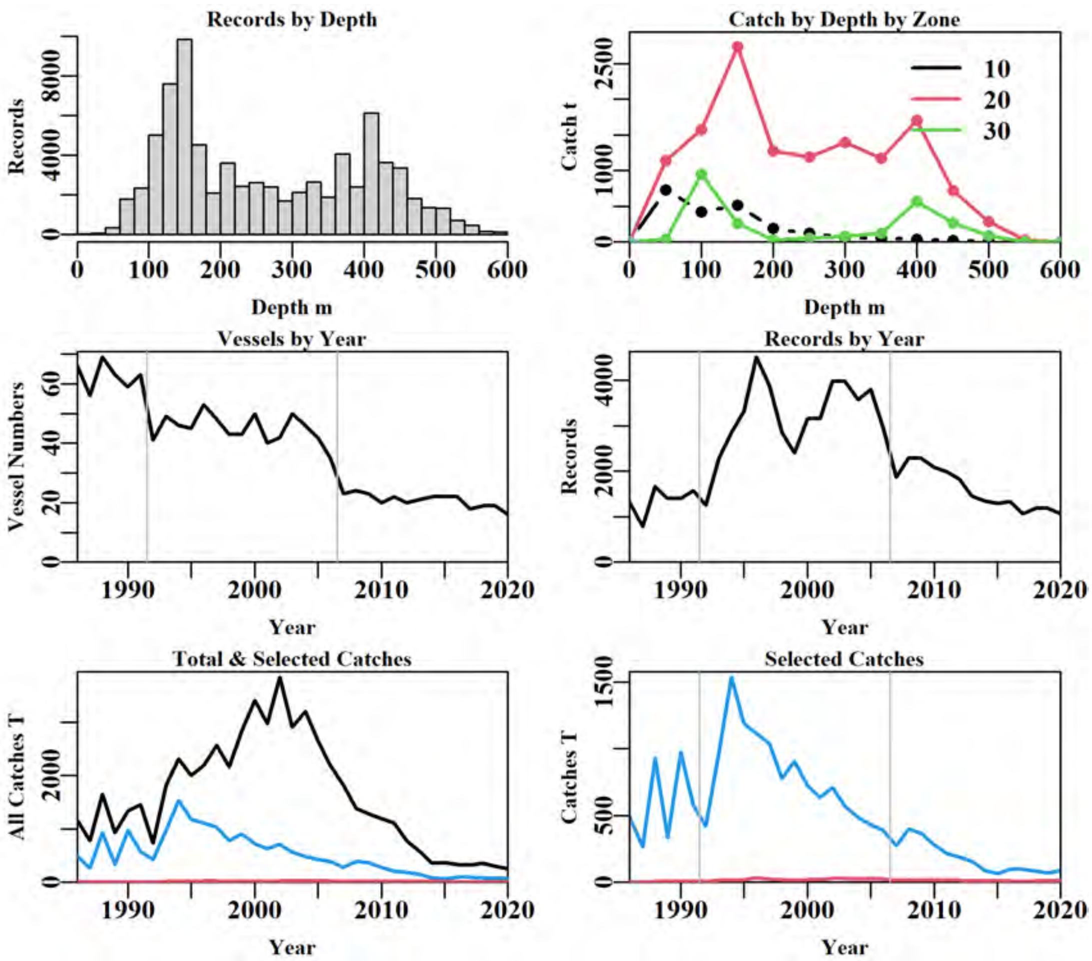

Figure 6.73. SilverWarehou1030 fishery details. The bottom left plot depicts all known catches (top black line), and all selected catches used in the analysis (middle blue line); the lower red line: selected catches < 30 kg).

Table 6.53. 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	161630	155857	151451	150399	79863	78406	78307
Difference	0	5773	4406	1052	70536	1457	99
Catch	55941	55451	53735	53341	18428	17958	17937
Difference	0	490	1717	393	34913	470	21

Table 6.54. 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 6.55. 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

Term	AIC	RSS	MSS	Nobs	Npars	adj_r2	%Change
Year	87271	238464	23354	78307	35	8.9	0
Vessel	80742	218365	43452	78307	218	16.4	7.48
Month	77024	208181	53637	78307	229	20.3	3.89
DepCat	75848	205015	56803	78307	241	21.5	1.20
Zone	75619	204406	57411	78307	243	21.7	0.23
DayNight	75614	204377	57440	78307	246	21.7	0.01
Zone:Month	74658	201782	60035	78307	268	22.7	0.97
Zone:DepCat	74563	201534	60283	78307	269	22.8	1.07

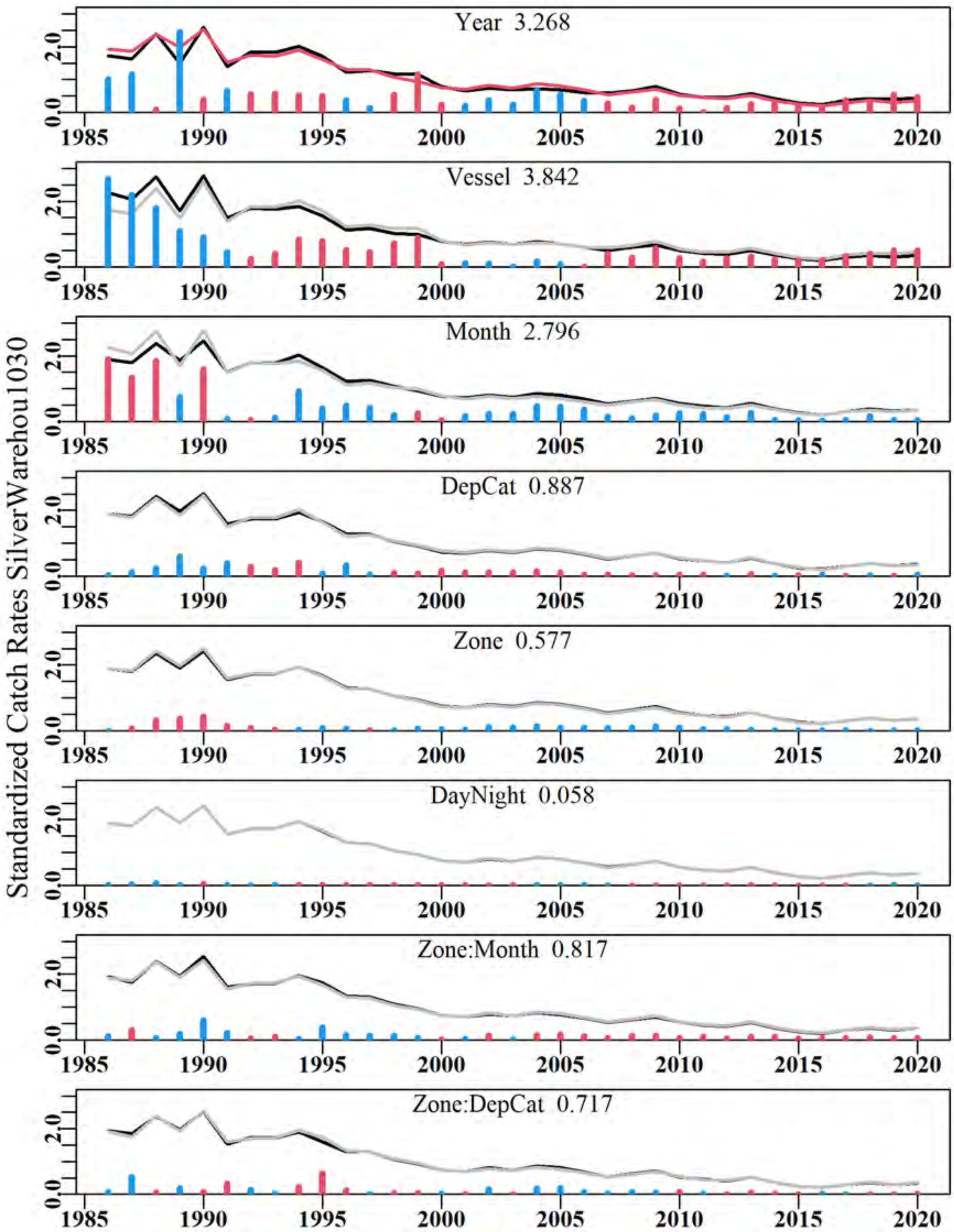

Figure 6.74. SilverWarehou1030. The influence of each factor on the optimal standardization. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by vertical bars with blue bars indicating the optimum model is higher than the 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.

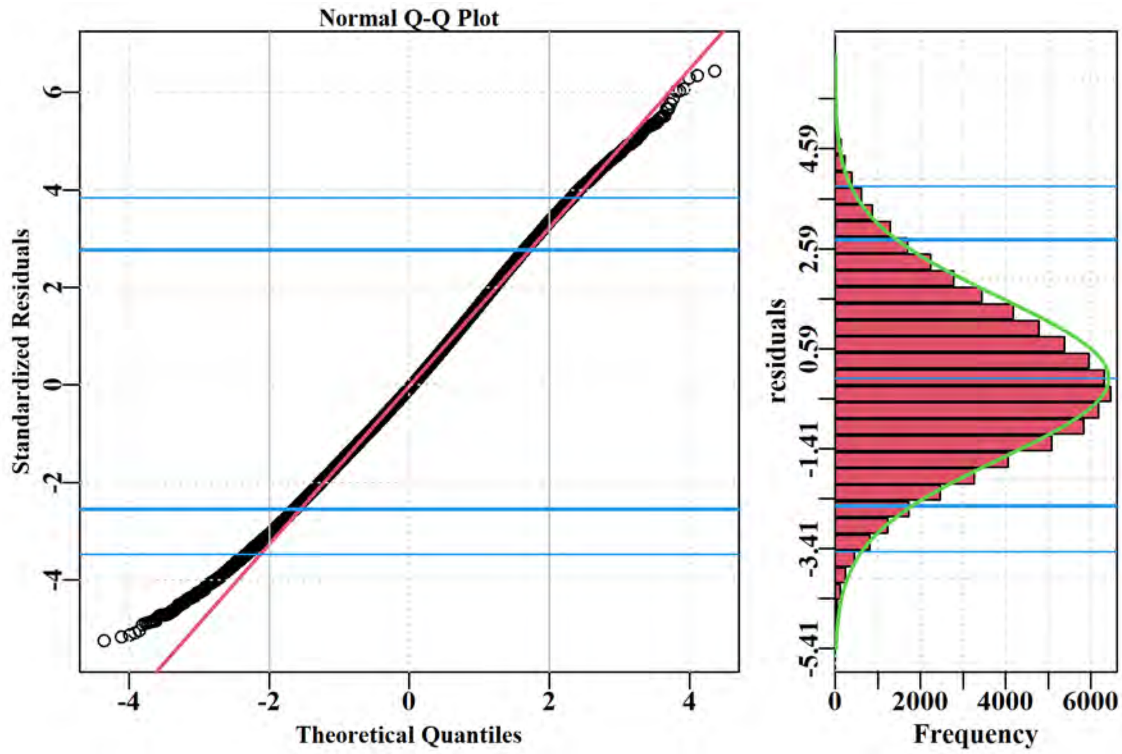

Figure 6.75. SilverWarehou1030. diagnostic plots. The distribution of residuals from the optimum fit. The qqplot indicates the fit to the expected normality, while the histogram of residuals illustrates the 90% quantiles to indicate the intensity of any lack of fit at the margins of the distribution.

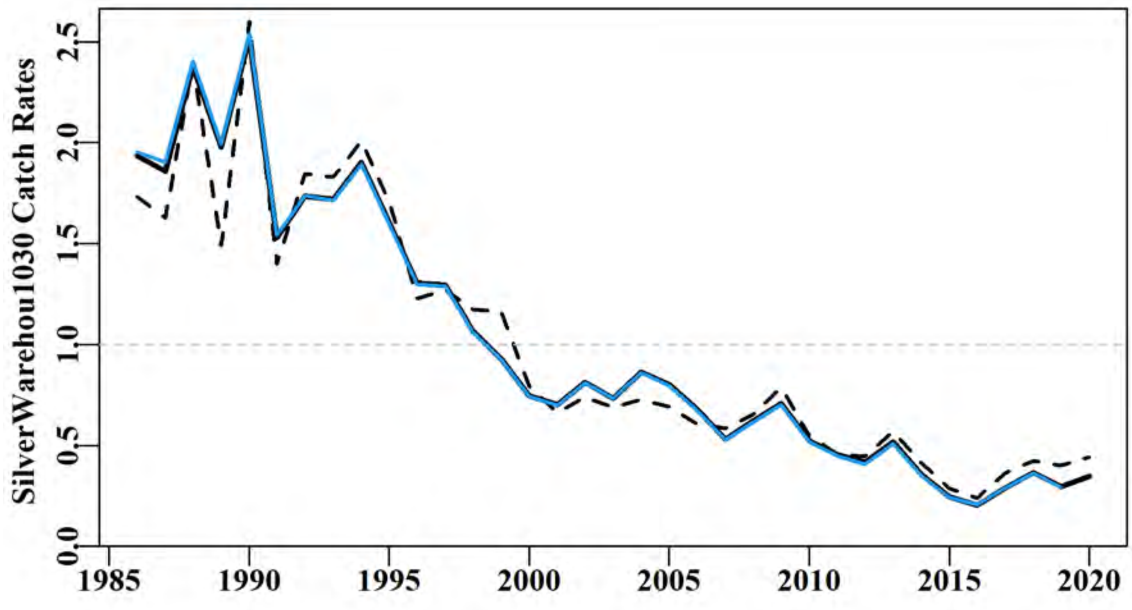

Figure 6.76. SilverWarehou1030. A comparison of the previous year's standardization (blue line) with this year's. They should lie on top of each other, although small deviations may relate to data adjustments, particularly in very recent years.

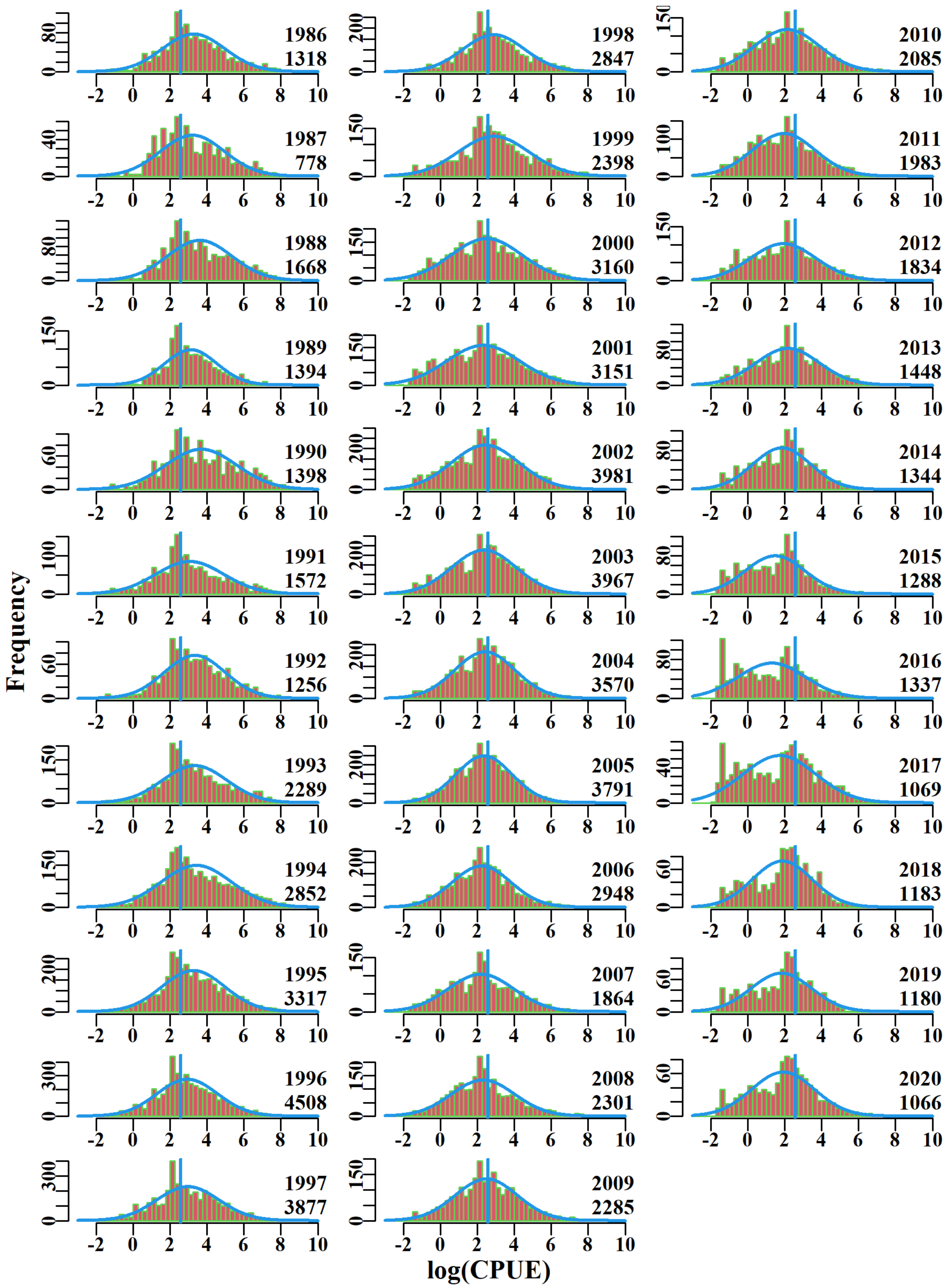

Figure 6.77. SilverWarehou1030. The natural log(CPUE) for each year of data available the blue lines are normal distributions fitted to the histogram frequencies. The numbers in each plot are the year and number of records.

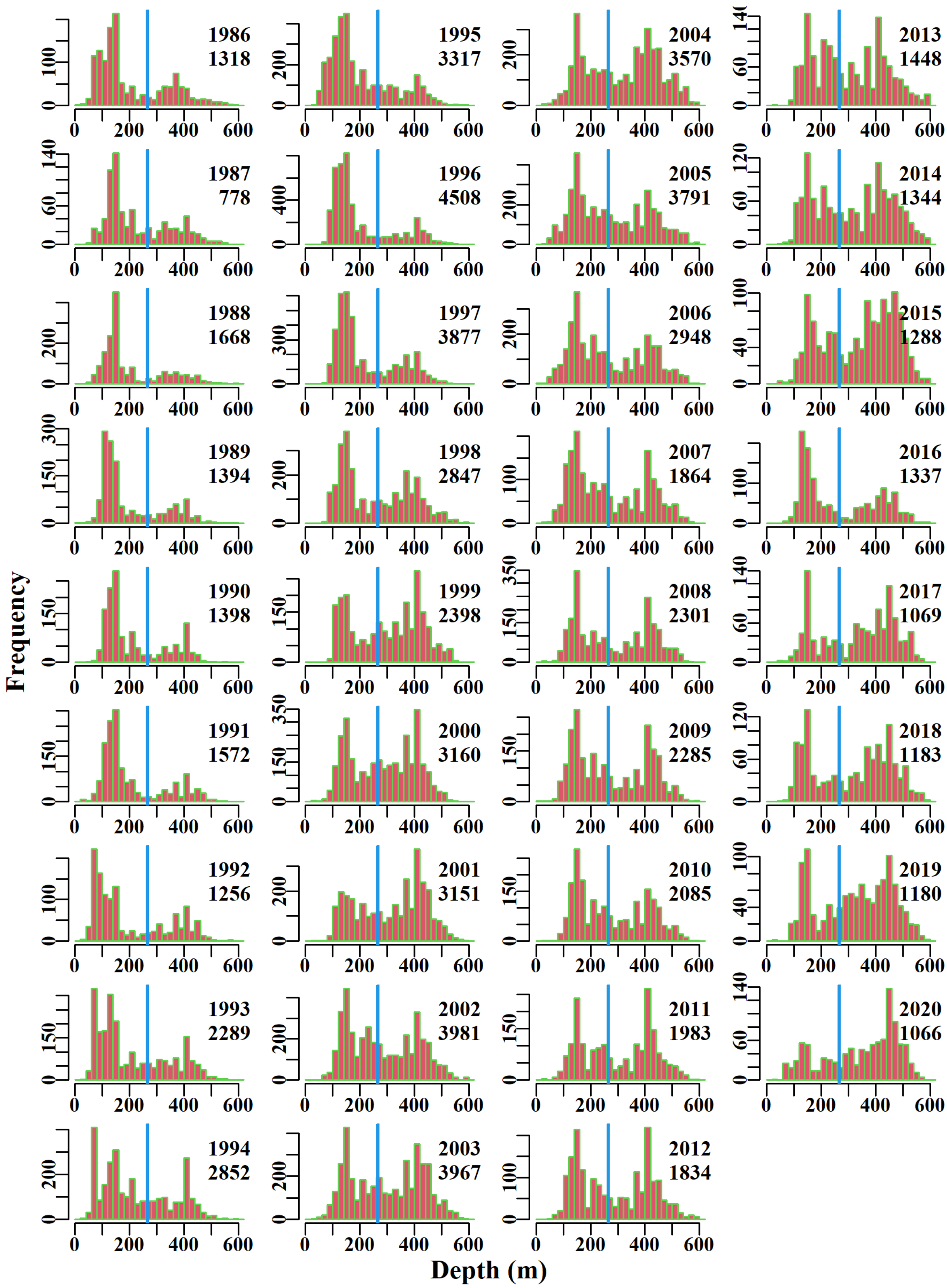

Figure 6.78. SilverWarehou1030. The average Depth of fishing for each year of data available to illustrate the development of the fishery through time. The numbers in each plot are the year and number of records.

6.14 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 due to a change in recording Tiger Flathead as 37296000 (Platycephalidae) in electronic logbooks since 2013. Trawl caught Flathead based on methods TW, TDO, OTB, TMO, in zones 30, and depths 0 to 300 within the SET fishery for the years 1986 - 2020 were analysed (Table 6.56). 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.

6.14.1 *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, 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 2020 (Figure 6.79). Annual catches have increased again in more recent years.

6.14.2 *Action Items and Issues*

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

Table 6.56. 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, OTB, TMO
years	1986 - 2020

Table 6.57. 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

Year	Total	N	Catch	Vess	GeoM	Opt	StDev	C<30Kg	P<30Kg
1986	1892.2	70	16.7	6	67.0	0.9589	0.000	0.571	0.034
1987	2461.3	87	5.0	9	18.5	0.5620	0.190	0.985	0.196
1988	2469.5	191	39.9	9	53.1	0.9849	0.172	1.272	0.032
1989	2599.1	515	48.4	19	29.4	0.7217	0.164	3.760	0.078
1990	2032.4	248	23.4	27	34.0	0.7263	0.166	1.925	0.082
1991	2230.2	302	32.0	29	28.2	0.6821	0.162	2.614	0.082
1992	2375.6	267	33.5	15	37.6	0.6524	0.166	1.428	0.043
1993	1879.3	891	91.1	24	30.3	0.6081	0.158	6.341	0.070
1994	1710.7	608	64.2	17	31.6	0.6355	0.159	4.671	0.073
1995	1800.7	690	71.0	17	31.4	0.7174	0.159	6.187	0.087
1996	1880.1	714	61.5	17	26.8	0.6519	0.159	6.916	0.112
1997	2356.0	878	104.6	14	42.8	0.8053	0.158	5.263	0.050
1998	2306.4	700	118.2	14	55.9	0.9640	0.158	2.918	0.025
1999	3118.1	769	174.8	17	68.3	1.0797	0.159	3.464	0.020
2000	2946.0	512	83.6	20	50.1	0.8747	0.160	2.501	0.030
2001	2599.7	927	102.3	17	31.6	0.7383	0.157	4.949	0.048
2002	2876.3	1360	211.6	15	46.8	1.3196	0.156	5.332	0.025
2003	3230.0	1443	237.2	21	47.2	1.3586	0.155	3.920	0.017
2004	3222.8	1913	475.7	15	80.2	1.8548	0.155	3.784	0.008
2005	2844.2	1508	383.5	18	77.8	1.6896	0.156	3.731	0.010
2006	2586.1	1299	285.1	13	60.3	1.3682	0.156	2.395	0.008
2007	2648.4	808	170.3	8	64.1	1.1167	0.158	1.834	0.011
2008	2912.3	851	165.9	10	60.3	1.0469	0.158	2.624	0.016
2009	2460.5	590	98.9	10	49.9	1.0185	0.159	1.393	0.014
2010	2502.8	499	101.8	10	58.5	1.0148	0.160	1.737	0.017
2011	2465.9	614	128.8	9	64.5	0.9582	0.159	1.478	0.011
2012	2780.9	702	151.5	9	58.9	1.2184	0.158	1.048	0.007
2013	1941.0	828	190.8	11	65.6	1.1774	0.158	2.406	0.013
2014	2369.9	751	180.0	11	67.5	1.3689	0.158	1.213	0.007
2015	2667.9	1159	290.8	13	69.3	1.2842	0.157	2.088	0.007
2016	2775.6	1555	329.9	12	59.7	1.0493	0.156	6.682	0.020
2017	2311.7	1293	290.2	10	62.3	1.1820	0.157	3.304	0.011
2018	2000.8	1188	212.8	12	46.2	0.8325	0.157	3.601	0.017
2019	1938.1	1615	252.1	13	41.4	0.8498	0.156	5.267	0.021
2020	1990.2	1330	228.4	9	44.5	0.9287	0.157	3.691	0.016

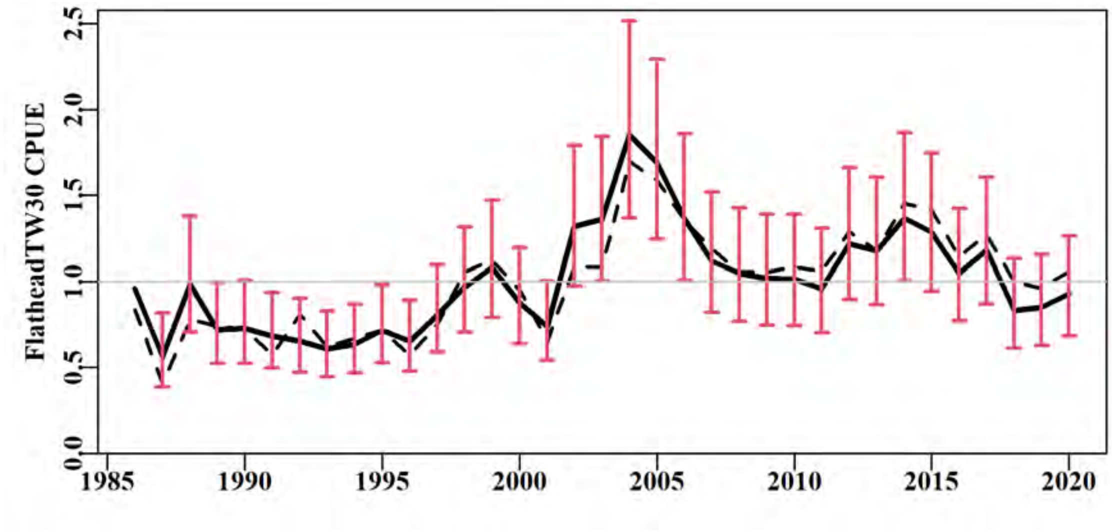

Figure 6.79. FlatheadTW30 standardization. The dashed black line represents the geometric mean CPUE, solid black line the standardized CPUE. The red bars are the 95% confidence intervals about the mean estimates. The graph scales both time-series of standardized CPUE relative to the mean of each time-series.

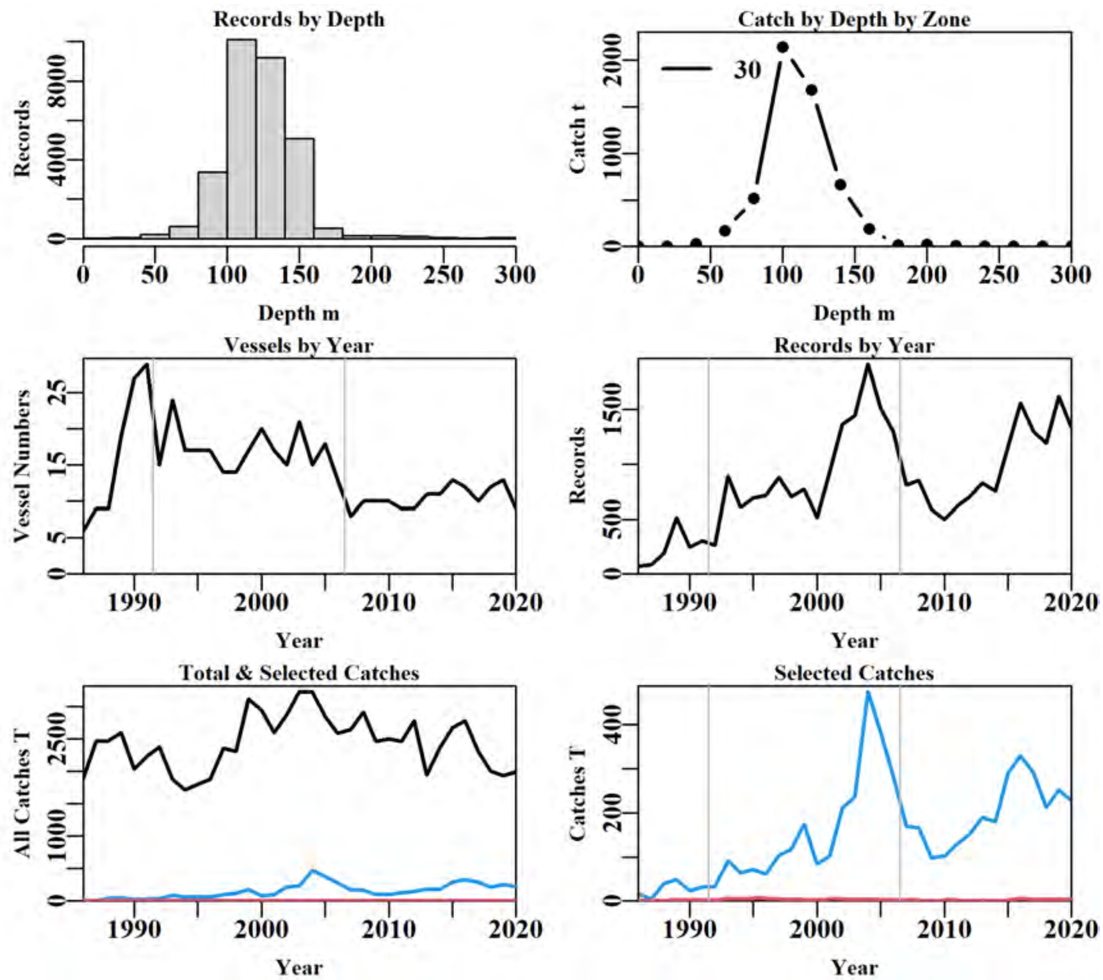

Figure 6.80. FlatheadTW30 fishery details. The bottom left plot depicts all known catches (top black line), and all selected catches used in the analysis (middle blue line); the lower red line: selected catches < 30 kg).

Table 6.58. 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	666789	575039	561392	553157	32509	29678	29675
Difference	0	91750	13647	8235	520648	2831	3
Catch	86135	75764	74434	73494	6042	5456	5456
Difference	0	10372	1330	940	67452	586	0

Table 6.59. 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 6.60. 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

Term	AIC	RSS	MSS	Nobs	Npars	adj_r2	%Change
Year	3417	33218	2478	29675	35	6.8	0
Vessel	1373	30807	4889	29675	131	13.3	6.48
DepCat	185	29568	6128	29675	146	16.8	3.44
DayNight	-14	29364	6331	29675	149	17.3	0.56
Month	-346	29017	6679	29675	160	18.3	0.95
Month:DepCat	-1022	28087	7608	29675	305	20.5	2.23
DayNight:Month	-413	28904	6792	29675	184	18.5	0.25

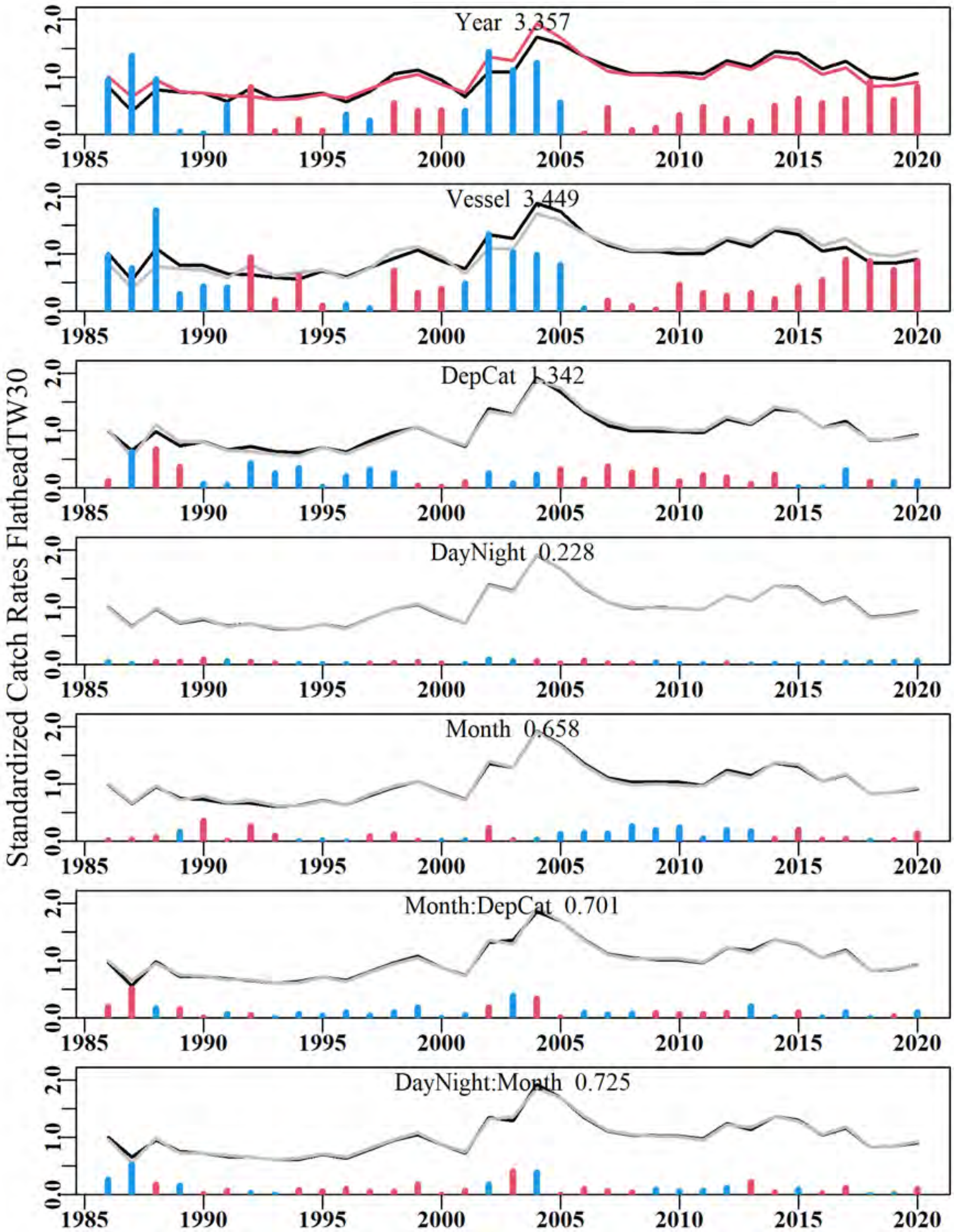

Figure 6.81. FlatheadTW30. The influence of each factor on the optimal standardization. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by vertical bars with blue bars indicating the optimum model is higher than the geometric 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.

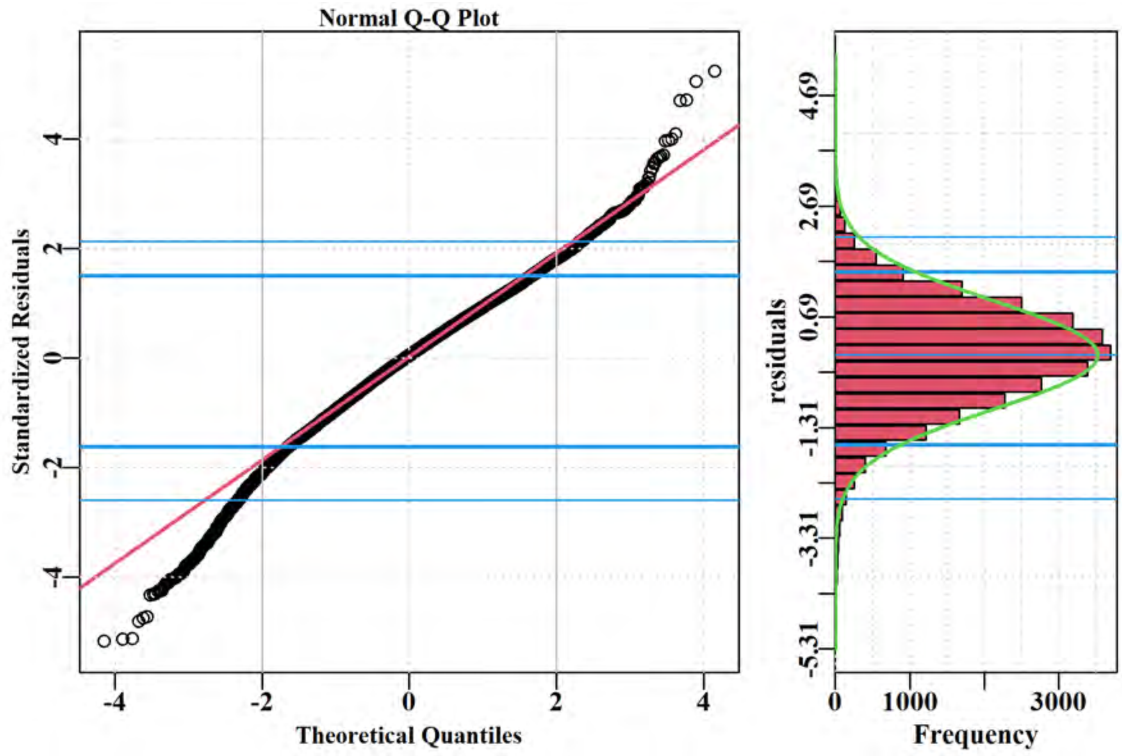

Figure 6.82. FlatheadTW30. diagnostic plots. The distribution of residuals from the optimum fit. The qqplot indicates the fit to the expected normality, while the histogram of residuals illustrates the 90% quantiles to indicate the intensity of any lack of fit at the margins of the distribution.

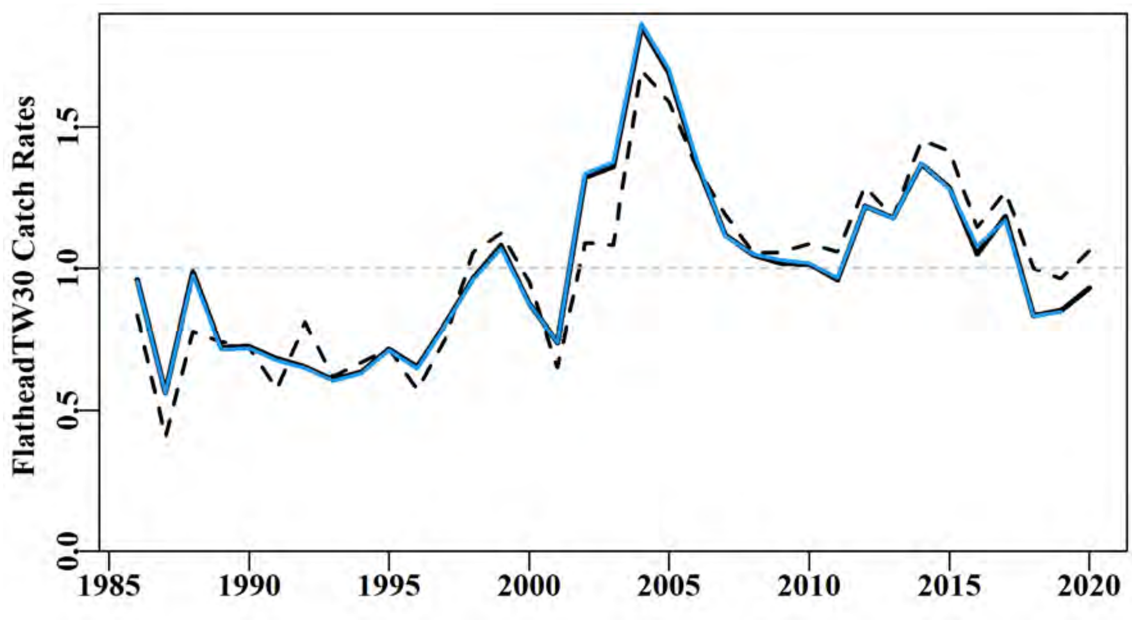

Figure 6.83. FlatheadTW30. A comparison of the previous year's standardization (blue line) with this year's. They should lie on top of each other, although small deviations may relate to data adjustments, particularly in very recent years.

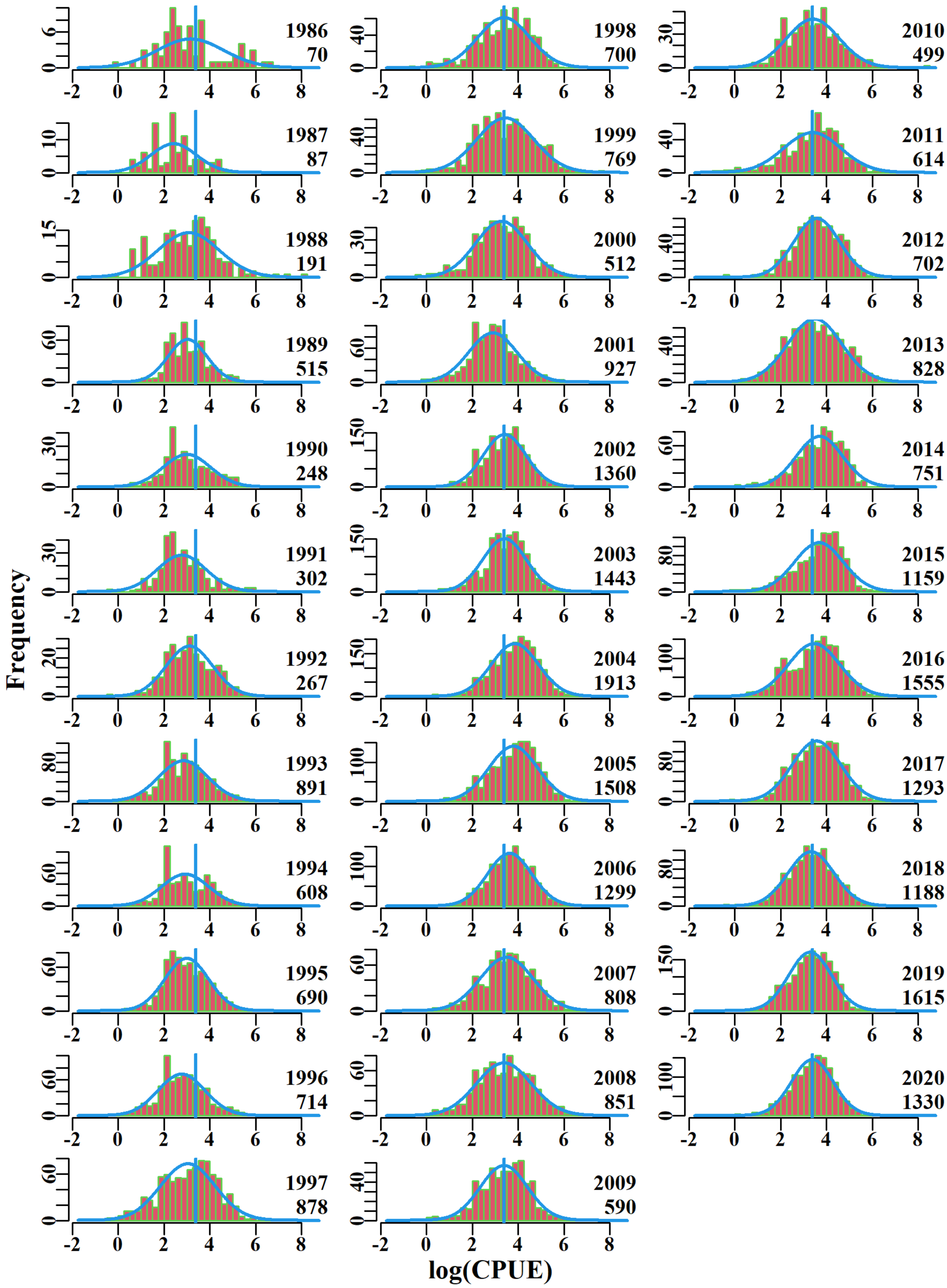

Figure 6.84. FlatheadTW30. The natural log(CPUE) for each year of data available the blue lines are normal distributions fitted to the histogram frequencies. The numbers in each plot are the year and number of records.

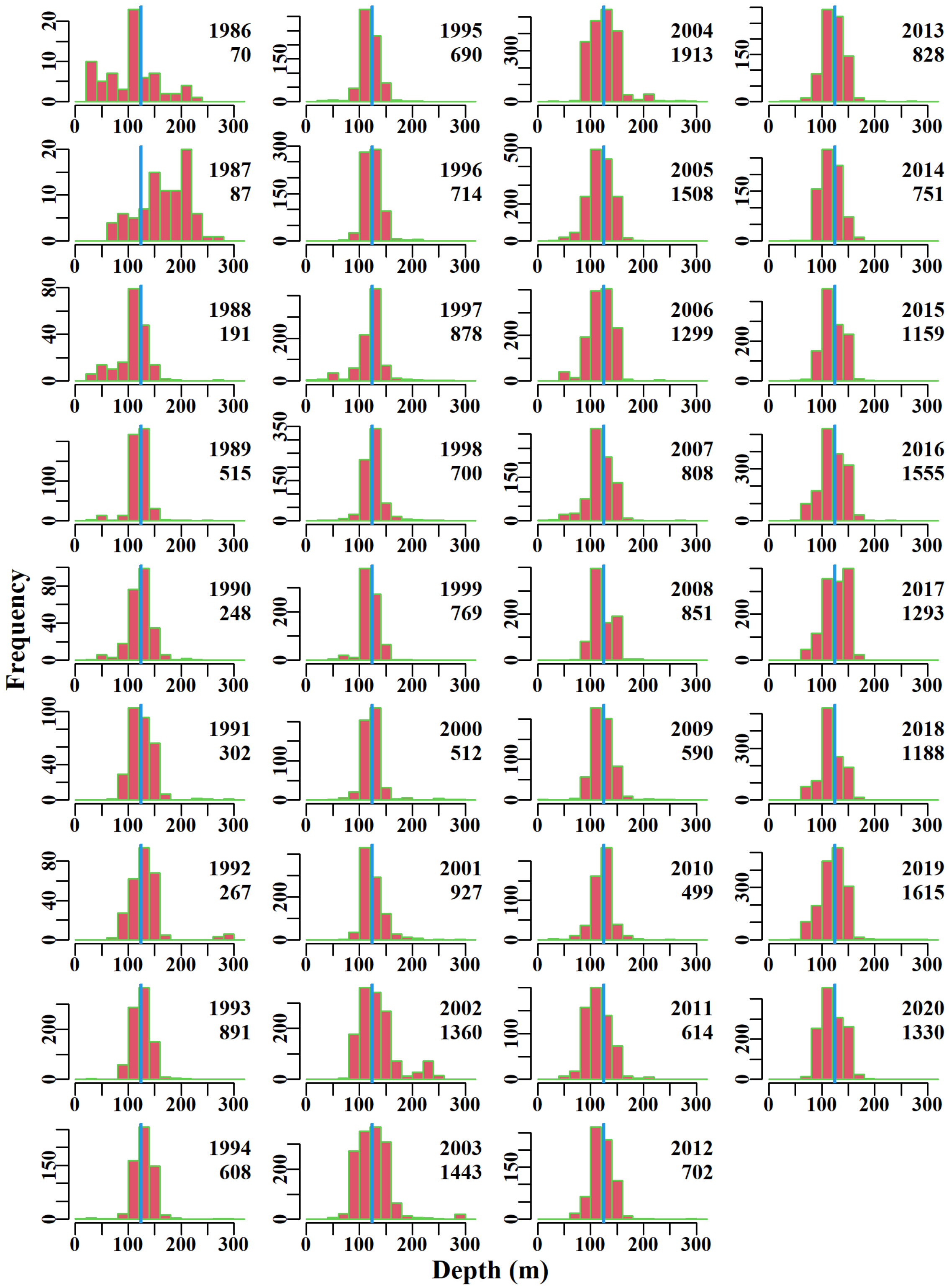

Figure 6.85. FlatheadTW30. The average Depth of fishing for each year of data available to illustrate the development of the fishery through time. The numbers in each plot are the year and number of records.

6.15 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, OTB, TMO, in zones 10, 20, and depths 0 to 400 m within the SET fishery for the years 1986 - 2020 were analysed (Table 6.61). 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.

6.15.1 *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 total Flathead catch (614 t) and corresponding number of vessels (21) from zones 10 and 20 in 2019 are the lowest in the series.

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 6.89).

Annual standardized CPUE appears cyclical above and below average, has remained below average in 2017-2018 and increased to the long-term average in 2019 and 2020, based on the 95% confidence intervals (Figure 6.86). 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.

6.15.2 *Action Items and Issues*

After consideration of 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 6.61. 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, OTB, TMO
years	1986 - 2020

Table 6.62. 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

Year	Total	N	Catch	Vess	GeoM	Opt	StDev	C<30Kg	P<30Kg
1986	1892.2	10185	962.2	94	31.6	0.8046	0.000	64.431	0.067
1987	2461.3	8056	1004.2	86	41.6	1.0722	0.016	43.737	0.044
1988	2469.5	9149	1169.2	86	42.2	1.1740	0.016	47.288	0.040
1989	2599.1	8803	1206.1	74	44.8	1.1741	0.016	46.430	0.038
1990	2032.4	7702	1212.0	64	52.3	1.3964	0.017	27.684	0.023
1991	2230.2	7750	1136.6	57	52.0	1.3118	0.017	30.402	0.027
1992	2375.6	6865	895.2	54	43.9	1.0357	0.017	29.894	0.033
1993	1879.3	8642	982.4	57	38.8	1.0502	0.016	38.124	0.039
1994	1710.7	10193	894.9	55	29.9	0.7624	0.016	62.717	0.070
1995	1800.7	10233	985.3	54	31.5	0.8049	0.016	65.863	0.067
1996	1880.1	10984	952.3	58	29.3	0.7196	0.016	75.637	0.079
1997	2356.0	10265	988.7	61	31.2	0.7199	0.016	64.965	0.066
1998	2306.4	9954	996.8	52	32.5	0.7611	0.016	63.038	0.063
1999	3118.1	10340	1125.1	57	36.3	0.9197	0.016	56.814	0.050
2000	2946.0	12861	1641.9	59	51.9	1.0110	0.015	62.611	0.038
2001	2599.7	11661	1307.5	52	39.4	0.9704	0.016	52.699	0.040
2002	2876.3	12364	1447.6	49	39.3	1.0535	0.015	55.469	0.038
2003	3230.0	12794	1583.8	52	41.4	1.0396	0.015	58.188	0.037
2004	3222.8	12155	1336.5	52	36.4	0.9042	0.016	62.850	0.047
2005	2844.2	10588	1143.5	49	34.2	0.7789	0.016	62.412	0.055
2006	2586.1	9073	1138.3	45	40.2	0.9428	0.016	43.946	0.039
2007	2648.4	6281	1067.3	25	55.1	1.1483	0.018	21.708	0.020
2008	2912.3	7194	1307.6	27	56.3	1.2105	0.017	26.303	0.020
2009	2460.5	6214	1037.7	26	51.4	1.1215	0.018	22.375	0.022
2010	2502.8	6686	1086.7	25	49.2	1.0799	0.018	25.093	0.023
2011	2465.9	6606	1070.4	24	52.4	1.0645	0.018	23.787	0.022
2012	2780.9	6795	1149.3	25	54.6	1.1676	0.018	25.865	0.023
2013	1941.0	5587	682.8	24	37.4	0.8824	0.019	25.723	0.038
2014	2369.9	6337	943.4	25	46.0	1.0361	0.018	22.647	0.024
2015	2667.9	6358	983.6	30	48.4	1.1682	0.018	15.754	0.016
2016	2775.6	5907	888.7	27	49.1	1.0666	0.019	16.011	0.018
2017	2311.7	5346	714.0	24	43.0	0.8804	0.019	19.043	0.027
2018	2000.8	5556	748.8	25	40.2	0.8825	0.019	18.178	0.024
2019	1938.1	4950	615.6	21	36.0	0.9411	0.020	16.259	0.026
2020	1990.2	4703	603.2	19	37.4	0.9436	0.020	15.508	0.026

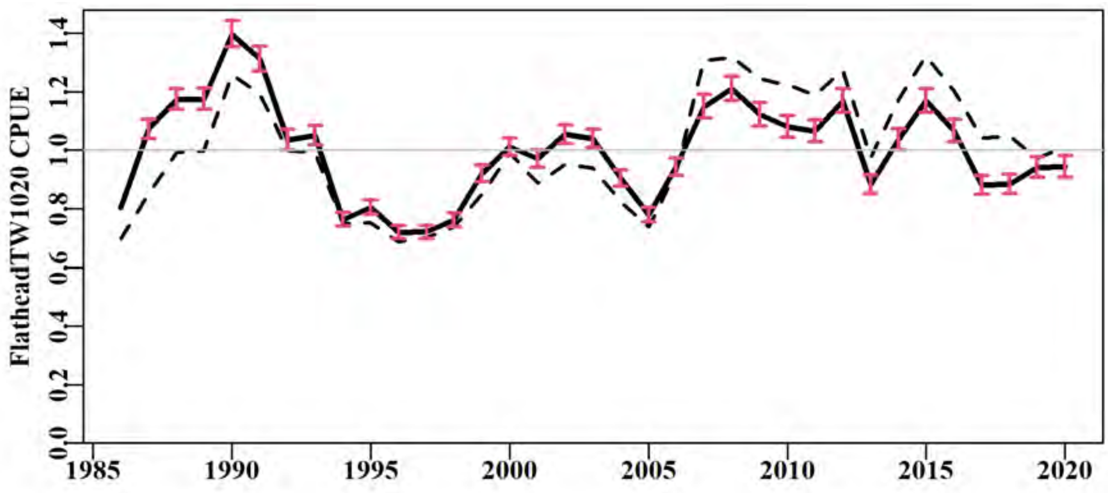

Figure 6.86. FlatheadTW1020 standardization. The dashed black line represents the geometric mean CPUE, solid black line the standardized CPUE. The red bars are the 95% confidence intervals about the mean estimates. The graph scales both time-series of standardized CPUE relative to the mean of each time-series.

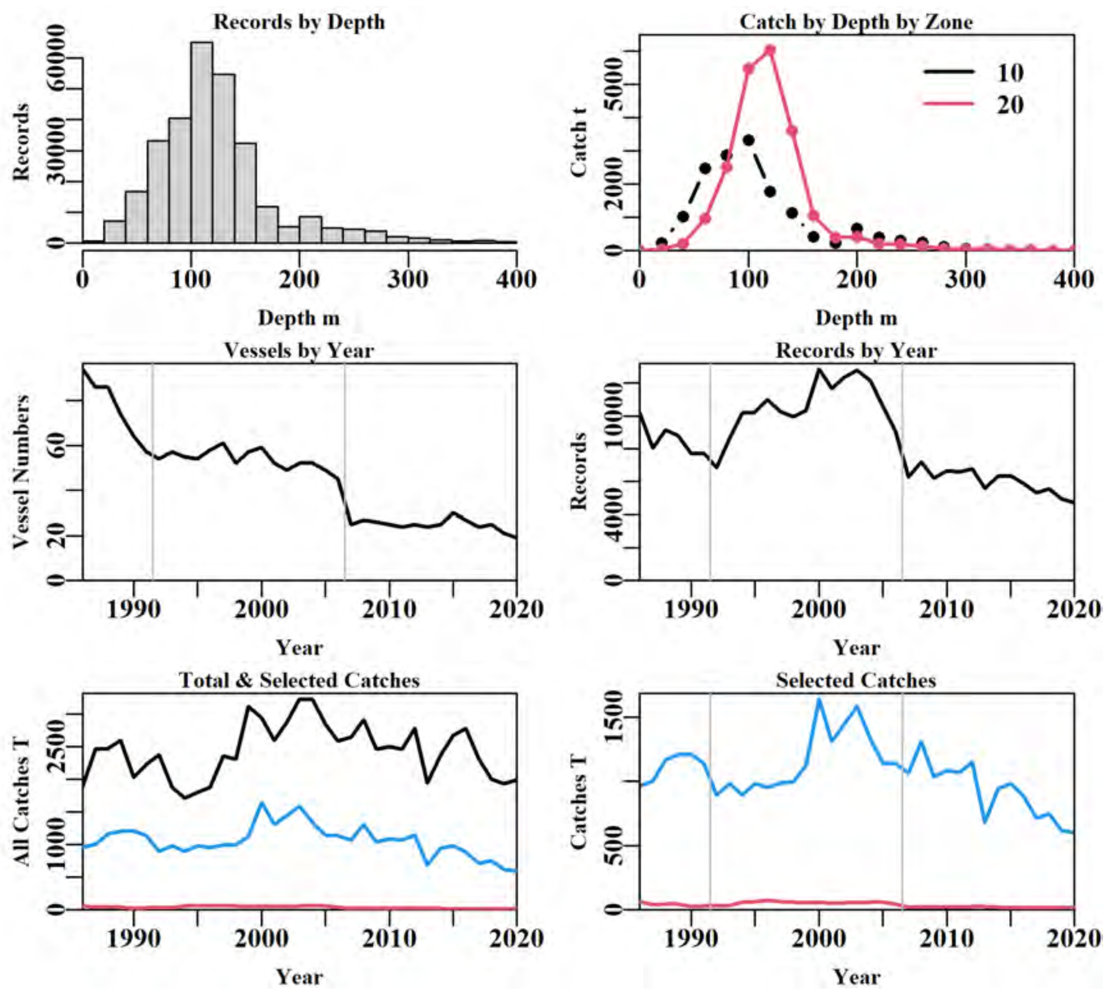

Figure 6.87. FlatheadTW1020 fishery details. The bottom left plot depicts all known catches (top black line), and all selected catches used in the analysis (middle blue line); the lower red line: selected catches < 30 kg).

Table 6.63. 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	666789	575039	568106	559779	383566	295441	295137
Difference	0	91750	6933	8327	176213	88125	304
Catch	86135	75764	74903	73957	55566	37045	37009
Difference	0	10372	861	945	18392	18521	36

Table 6.64. 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 6.65. 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

Term	AIC	RSS	MSS	Nobs	Npars	adj_r2	%Change
Year	43236	341619	11789	295137	35	3.3	0
Vessel	12393	307329	46079	295137	223	13.0	9.65
DepCat	3654	298322	55086	295137	243	15.5	2.54
Month	2715	297353	56055	295137	254	15.8	0.27
DayNight	2211	296839	56569	295137	257	15.9	0.14
Zone	2129	296754	56653	295137	258	16.0	0.02
Zone:Month	-227	294373	59035	295137	269	16.6	0.67
Zone:DepCat	-838	293746	59662	295137	278	16.8	0.85

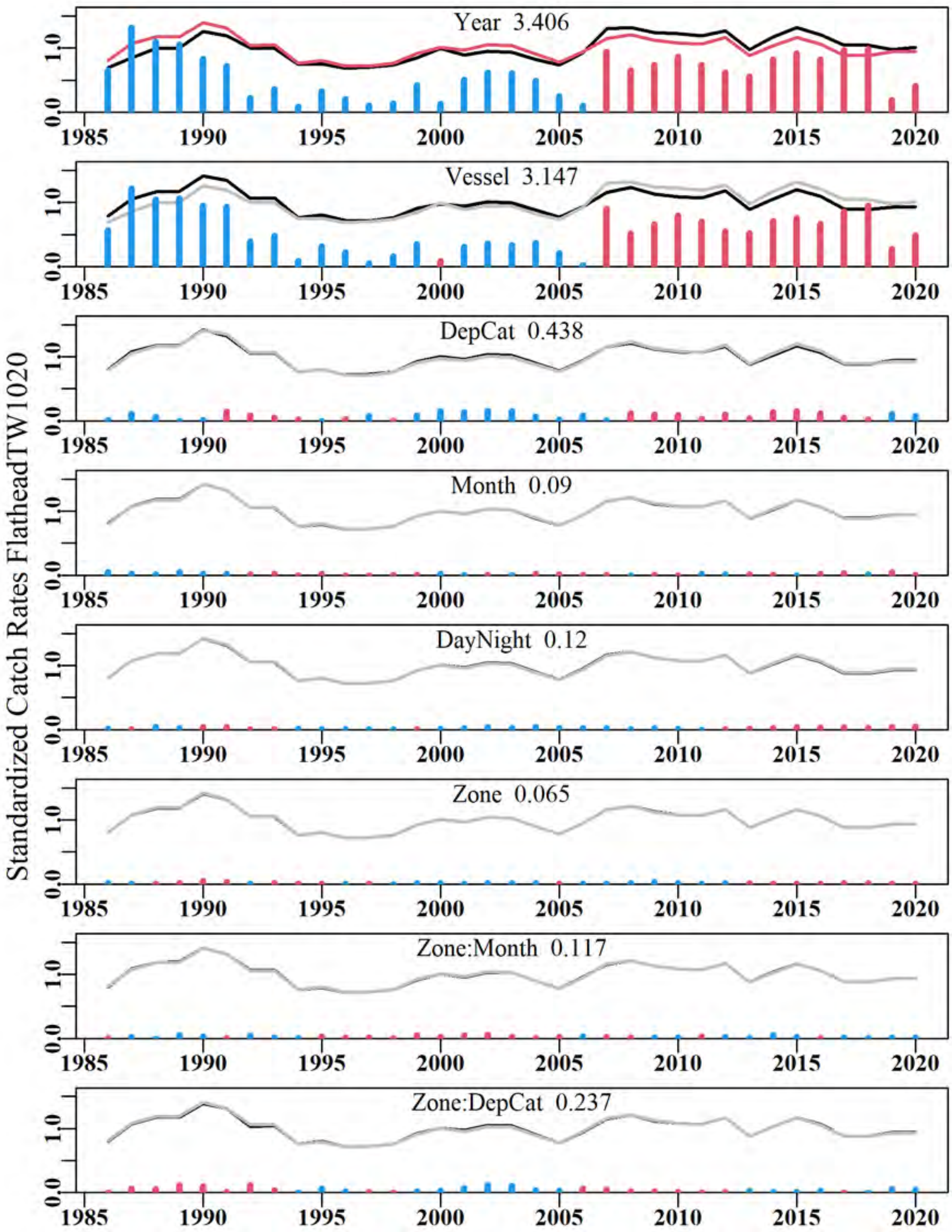

Figure 6.88. FlatheadTW1020. The influence of each factor on the optimal standardization. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by vertical bars with blue bars indicating the optimum model is higher than the 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.

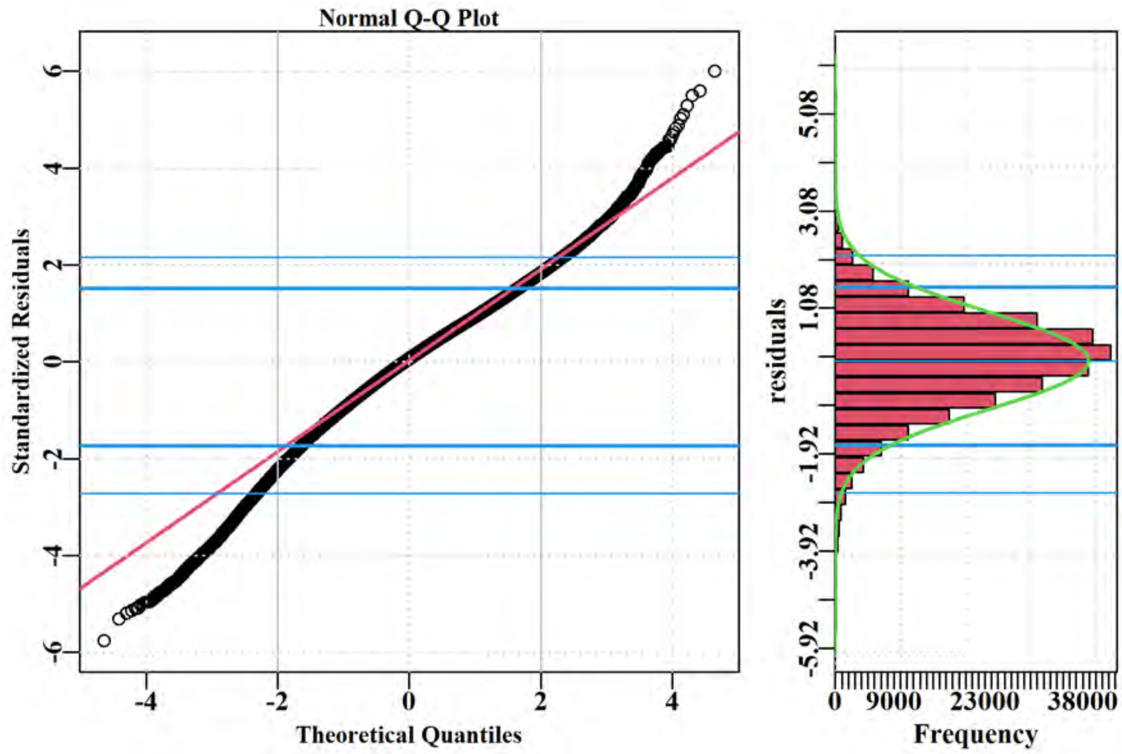

Figure 6.89. FlatheadTW1020. diagnostic plots. The distribution of residuals from the optimum fit. The qqplot indicates the fit to the expected normality, while the histogram of residuals illustrates the 90% quantiles to indicate the intensity of any lack of fit at the margins of the distribution.

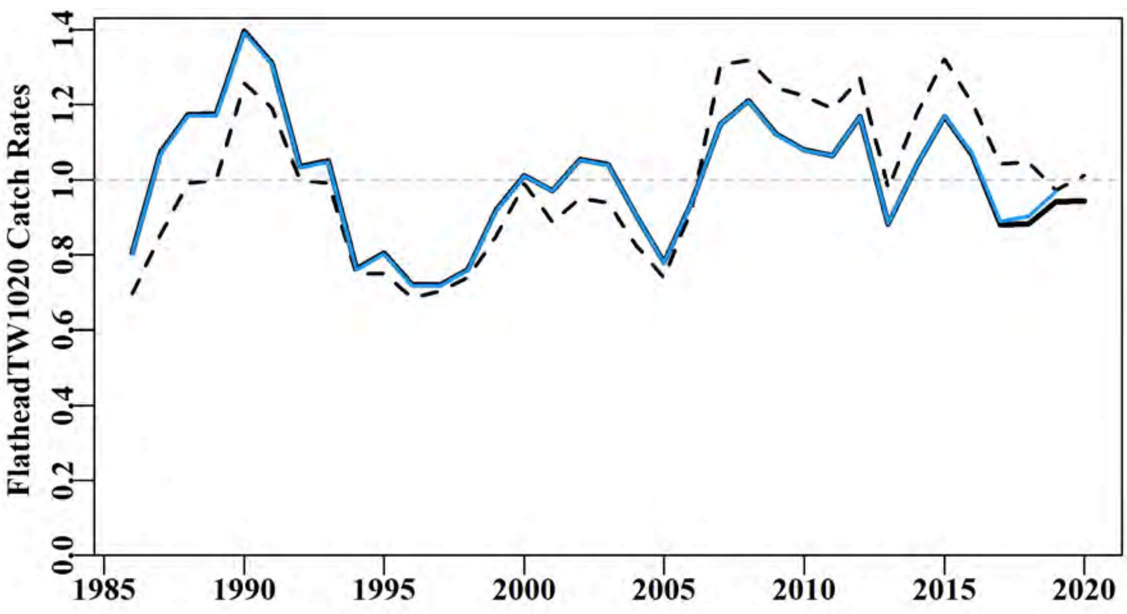

Figure 6.90. FlatheadTW1020. A comparison of the previous year's standardization (blue line) with this year's. They should lie on top of each other, although small deviations may relate to data adjustments, particularly in very recent years.

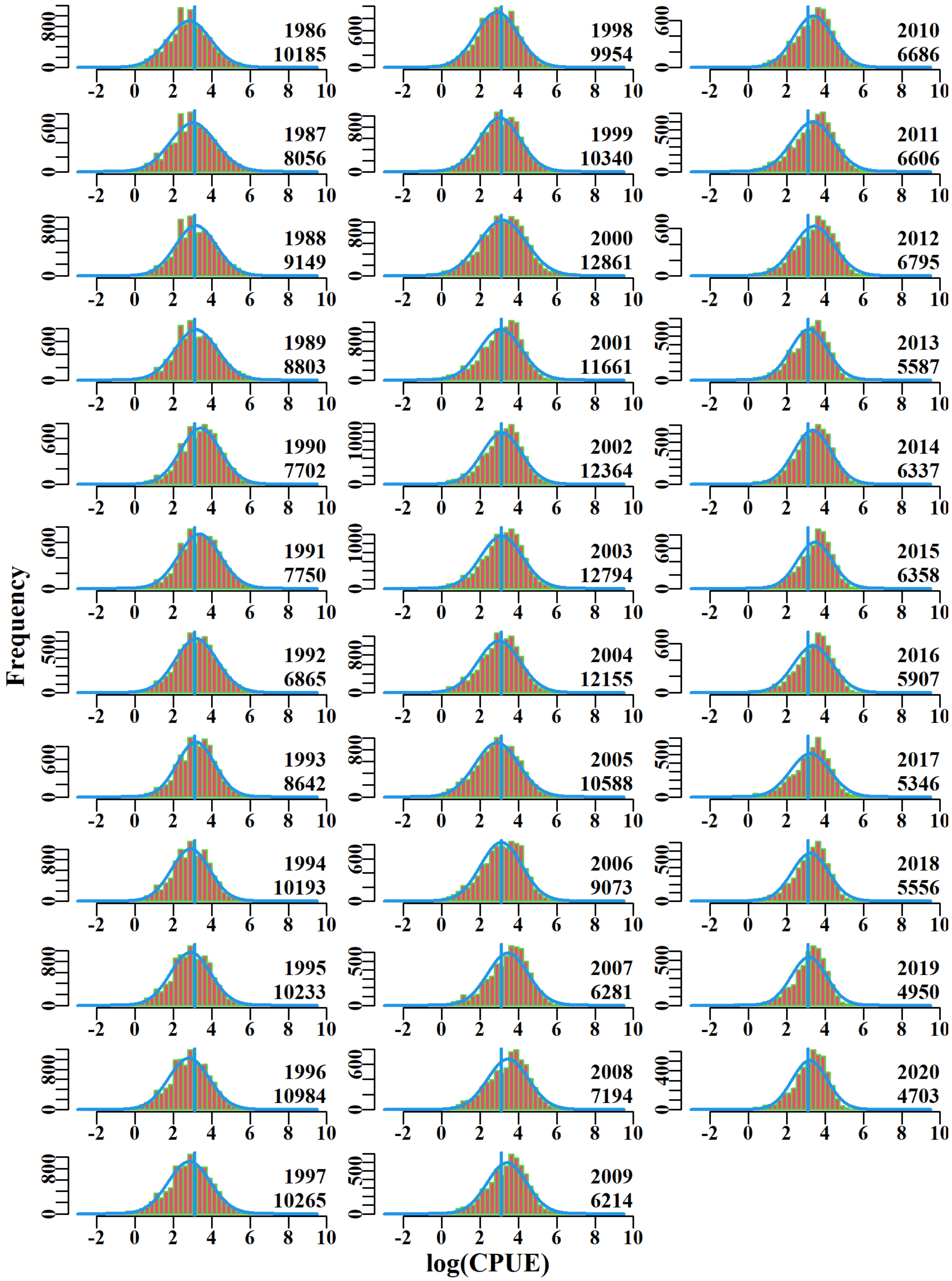

Figure 6.91. FlatheadTW1020. The natural log(CPUE) for each year of data available the blue lines are normal distributions fitted to the histogram frequencies. The numbers in each plot are the year and number of records.

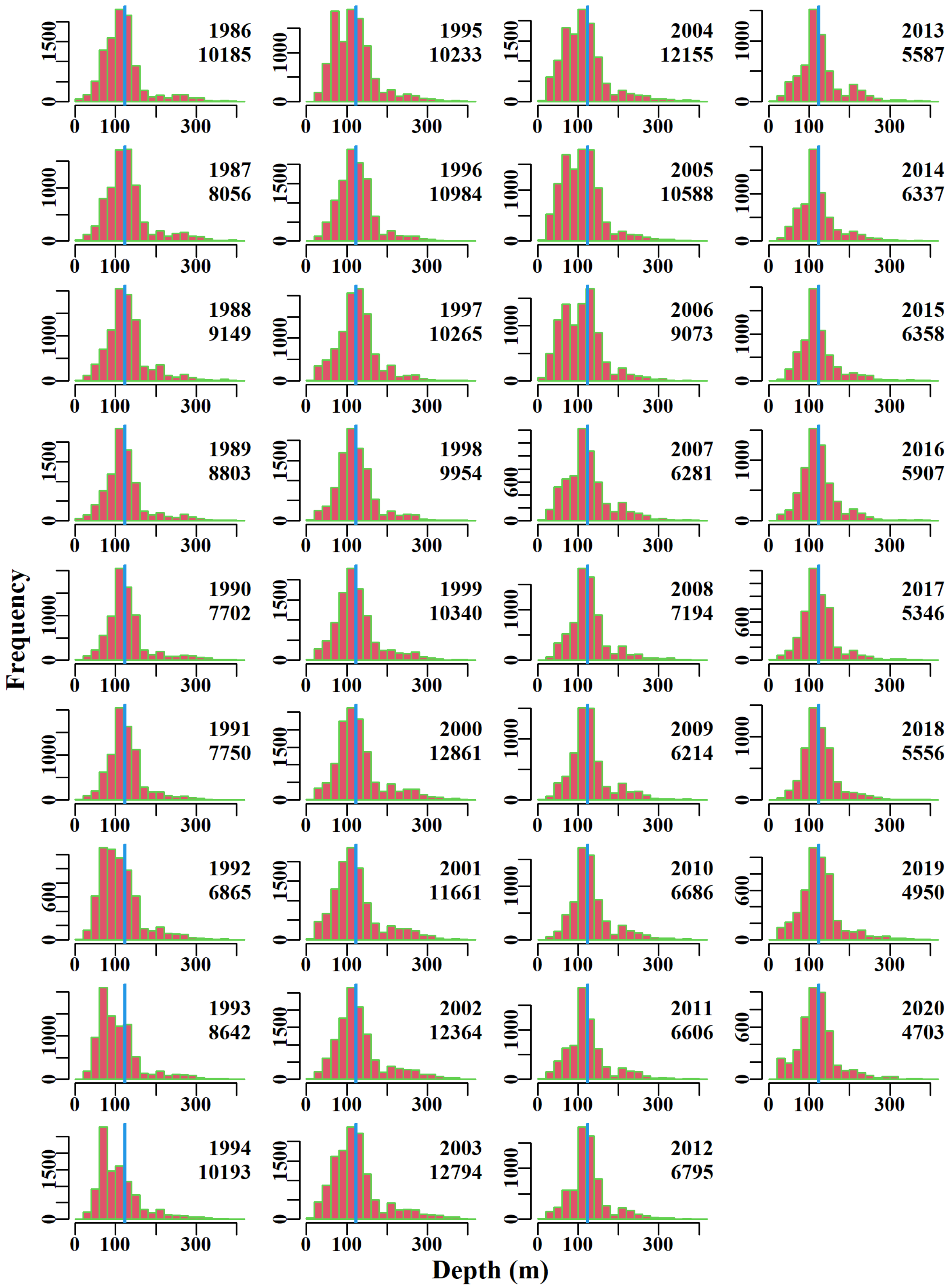

Figure 6.92. FlatheadTW1020. The average Depth of fishing for each year of data available to illustrate the development of the fishery through time. The numbers in each plot are the year and number of records.

6.16 Flathead DS 20 60

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, SSC, in zones 20, 60 and depths 0 m to 200 m within the SET fishery for the years 1986 - 2020 were analysed (Table 6.66). 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.

6.16.1 *Inferences*

Flathead (*Neoplatycephalus richardsoni* and Platycephalidae) taken by Danish seine are caught in shallower depths in zone 60 compared to zone 20 (Figure 6.94), 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 2012 (Figure 6.93). There has also been an overall decrease over the 2007-2020 period. The 2020 catch (791.2 t) by Danish seine in zones 20 and 60 is the second lowest since 1997.

6.16.2 *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 of mostly flathead compared to shots of mostly School Whiting). This will be important for determining whether estimated annual indices adequately reflect stock abundance.

Fishing depths have been (i) recorded as single values or (ii) recorded at more than one constant value across different operations in the Commonwealth logbook database for certain vessels since about 2016. These fishing depths have been modified based on positional bathymetry and have been used in the standardization analysis presented here, as agreed by SESSFRAG in 2020.

Table 6.66. 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, SSC
years	1986 - 2020

Table 6.67. 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

Year	Total	N	Catch	Vess	GeoM	Opt	StDev	C<30Kg	P<30Kg
1986	1892.2	5469	759.8	26	207.0	1.1600	0.000	26.255	0.035
1987	2461.3	5532	1340.9	23	352.7	1.6316	0.024	25.075	0.019
1988	2469.5	5745	1074.7	25	268.3	1.7890	0.024	21.449	0.020
1989	2599.1	5384	1138.0	27	297.1	1.5506	0.024	27.184	0.024
1990	2032.4	4462	568.1	24	157.2	1.0414	0.025	28.665	0.050
1991	2230.2	4463	746.5	28	215.7	1.4126	0.025	24.633	0.033
1992	2375.6	6504	1197.0	23	233.5	1.5151	0.023	27.718	0.023
1993	1879.3	5954	532.9	25	113.2	0.9376	0.024	40.678	0.076
1994	1710.7	7164	633.0	24	124.9	0.8076	0.023	40.569	0.064
1995	1800.7	5420	648.6	21	204.7	0.8295	0.024	24.806	0.038
1996	1880.1	7509	742.8	22	139.0	0.7771	0.023	44.616	0.060
1997	2356.0	8279	1136.0	20	192.2	1.0101	0.022	37.876	0.033
1998	2306.4	9800	1126.5	21	147.9	0.8502	0.022	48.033	0.043
1999	3118.1	8670	1679.4	23	269.0	1.2371	0.022	25.637	0.015
2000	2946.0	7297	1080.0	19	199.3	0.9221	0.023	32.454	0.030
2001	2599.7	7781	1066.4	19	196.4	0.8649	0.023	32.654	0.031
2002	2876.3	8124	1130.0	22	182.0	1.0208	0.023	31.327	0.028
2003	3230.0	8872	1186.7	23	168.5	1.0597	0.023	30.001	0.025
2004	3222.8	7645	1234.5	22	194.6	1.0418	0.023	25.002	0.020
2005	2844.2	7009	1105.1	22	184.3	1.0551	0.024	22.184	0.020
2006	2586.1	5461	950.5	21	233.5	1.0383	0.025	15.784	0.017
2007	2648.4	5472	1160.9	15	293.4	1.2495	0.025	14.892	0.013
2008	2912.3	6118	1261.6	15	280.1	1.1203	0.024	18.042	0.014
2009	2460.5	5433	1153.0	15	318.0	1.1575	0.025	17.949	0.016
2010	2502.8	5997	1159.0	15	274.1	1.0486	0.024	15.542	0.013
2011	2465.9	6788	1105.0	14	207.9	0.9719	0.024	20.671	0.019
2012	2780.9	7156	1371.1	14	299.4	0.9248	0.024	19.403	0.014
2013	1941.0	7196	929.3	14	168.9	0.6676	0.024	30.599	0.033
2014	2369.9	8326	1160.1	14	186.4	0.7186	0.023	32.787	0.028
2015	2667.9	8618	1311.2	15	196.1	0.7132	0.023	39.398	0.030
2016	2775.6	9257	1468.4	16	205.5	0.7418	0.023	40.877	0.028
2017	2311.7	8603	1108.1	17	164.6	0.7159	0.023	42.413	0.038
2018	2000.8	7941	833.6	18	126.1	0.5127	0.023	45.256	0.054
2019	1938.1	8097	771.7	19	114.7	0.4662	0.023	45.188	0.059
2020	1990.2	9546	791.2	19	106.6	0.4392	0.023	52.815	0.067

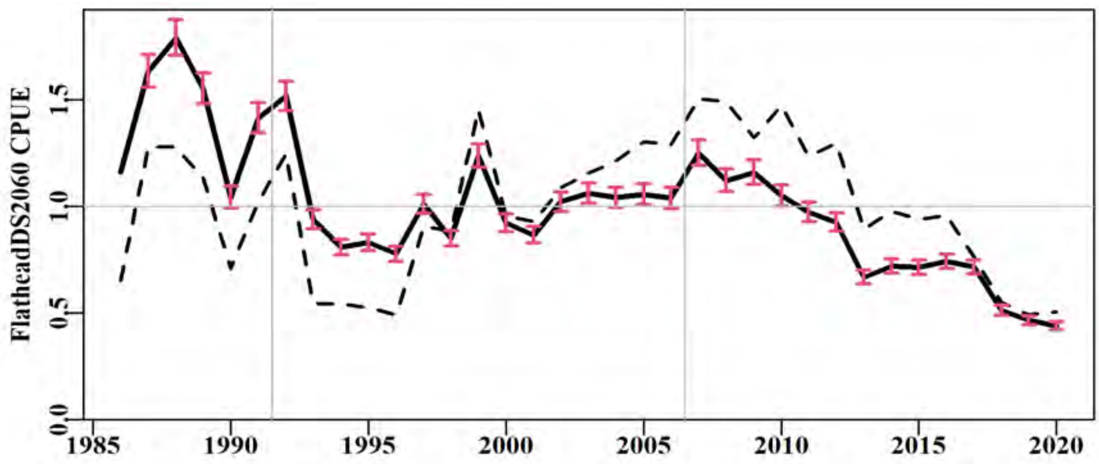

Figure 6.93. FlatheadDS2060 standardization. The dashed black line represents the geometric mean CPUE, solid black line the standardized CPUE. The red bars are the 95% confidence intervals about the mean estimates. The graph scales both time-series of standardized CPUE relative to the mean of each time-series.

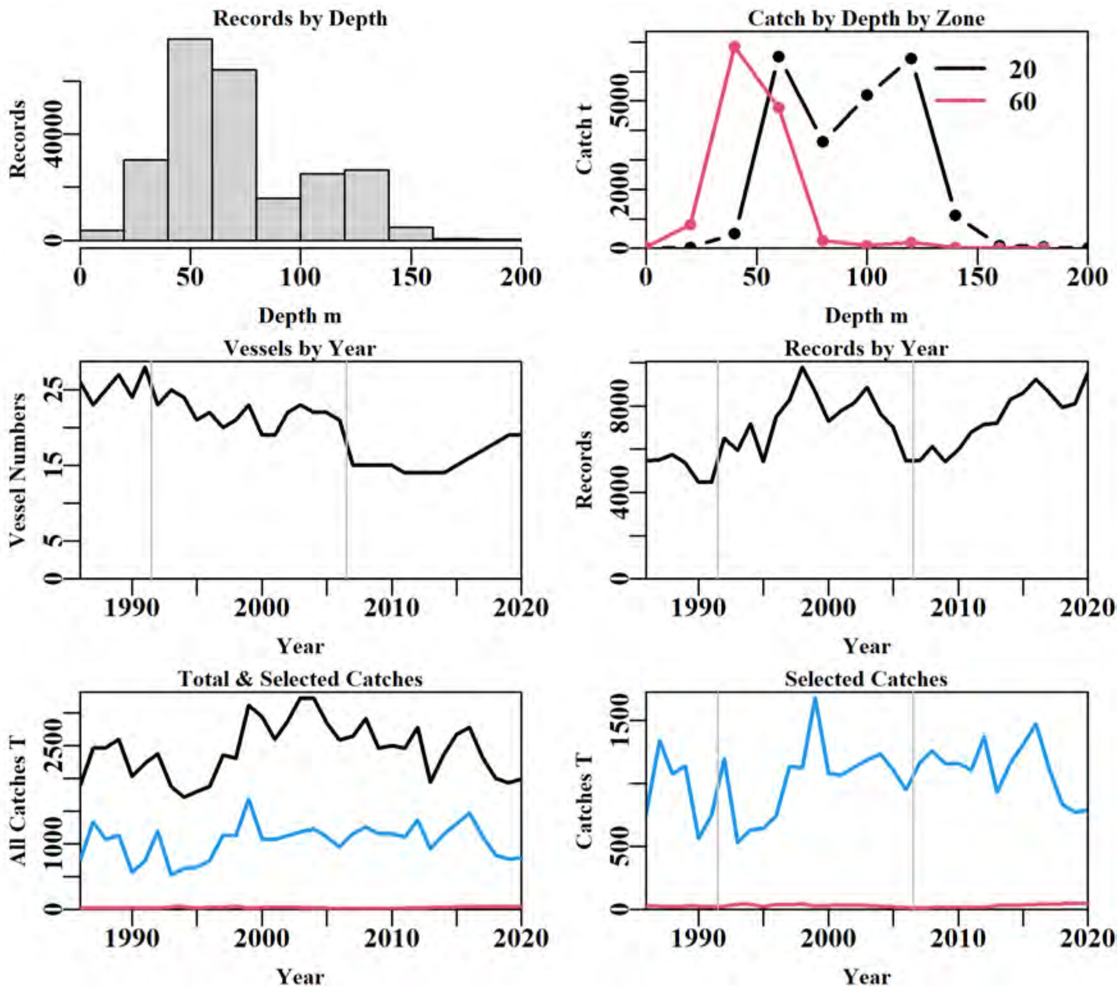

Figure 6.94. FlatheadDS2060 fishery details. The bottom left plot depicts all known catches (top black line), and all selected catches used in the analysis (middle blue line); the lower red line: selected catches < 30 kg).

Table 6.68. 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	666789	650736	606136	597957	385095	249009	247092
Difference	0	16053	44600	8179	212862	136086	1917
Catch	86135	86135	81363	80437	57881	36731	36662
Difference	0	0	4772	927	22556	21150	69

Table 6.69. 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 6.70. 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

Term	AIC	RSS	MSS	Nobs	Npars	adj_r2	%Change
Year	192917	539276	31027	247092	35	5.4	0
DepCat	123877	407784	162519	247092	45	28.5	23.06
Month	111283	387486	182817	247092	56	32.0	3.56
Vessel	97177	365819	204484	247092	112	35.8	3.79
DayNight	92790	359372	210931	247092	115	37.0	1.13
Zone	90866	356581	213722	247092	116	37.4	0.49
Zone:Month	86822	350762	219540	247092	127	38.5	1.02
Zone:DepCat	90564	356121	214182	247092	125	37.5	0.08

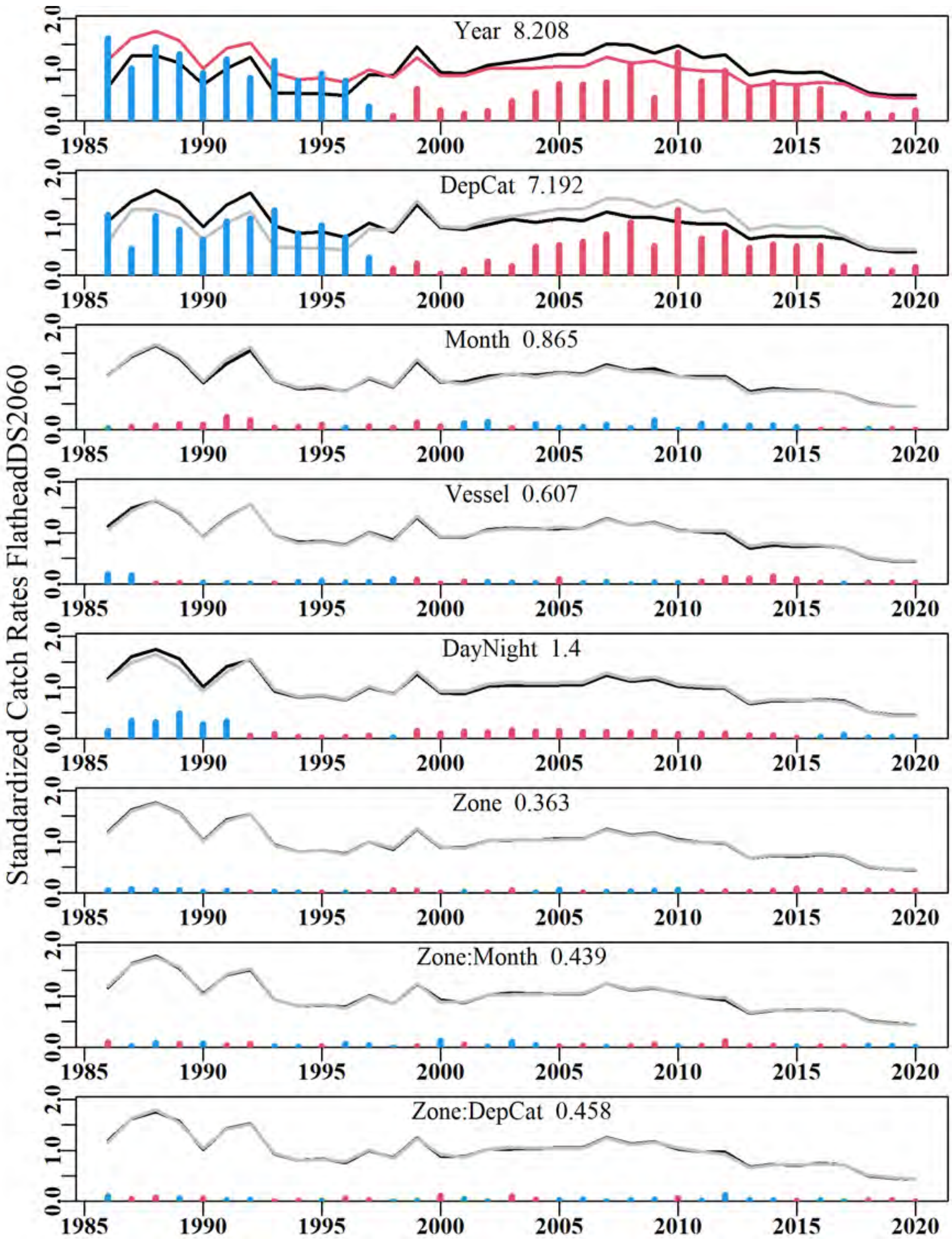

Figure 6.95. FlatheadDS2060. The influence of each factor on the optimal standardization. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by vertical bars with blue bars indicating the optimum model is higher than the 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.

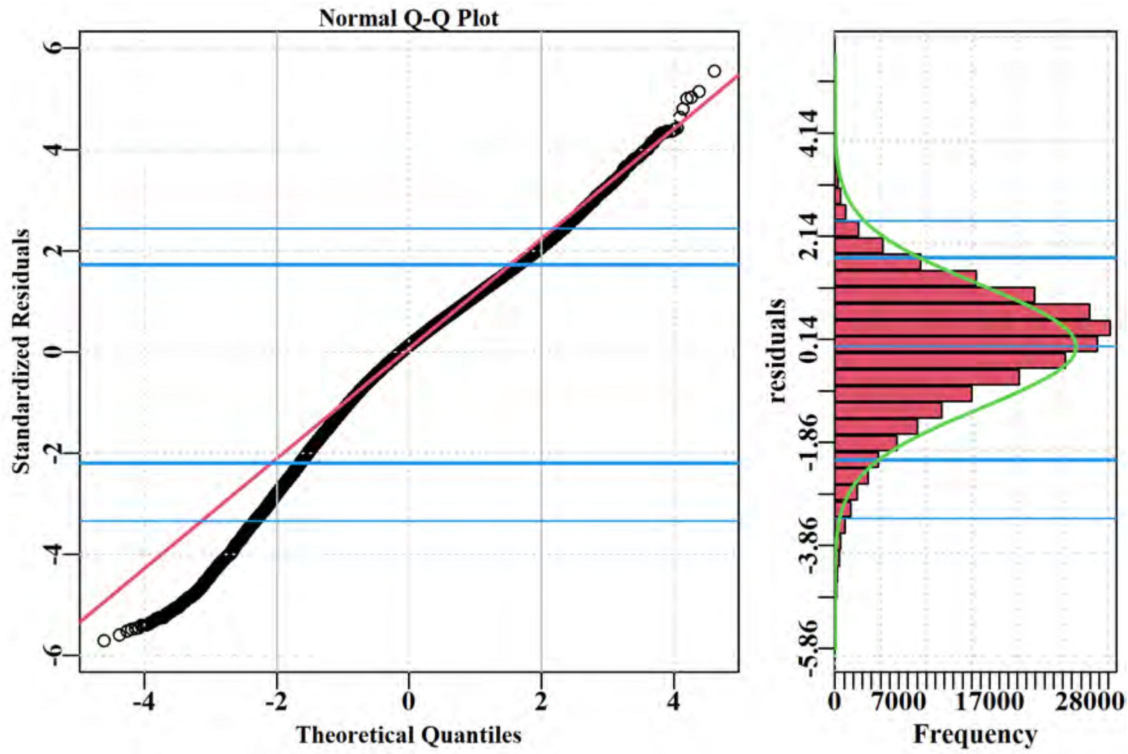

Figure 6.96. FlatheadDS2060. diagnostic plots. The distribution of residuals from the optimum fit. The qqplot indicates the fit to the expected normality, while the histogram of residuals illustrates the 90% quantiles to indicate the intensity of any lack of fit at the margins of the distribution.

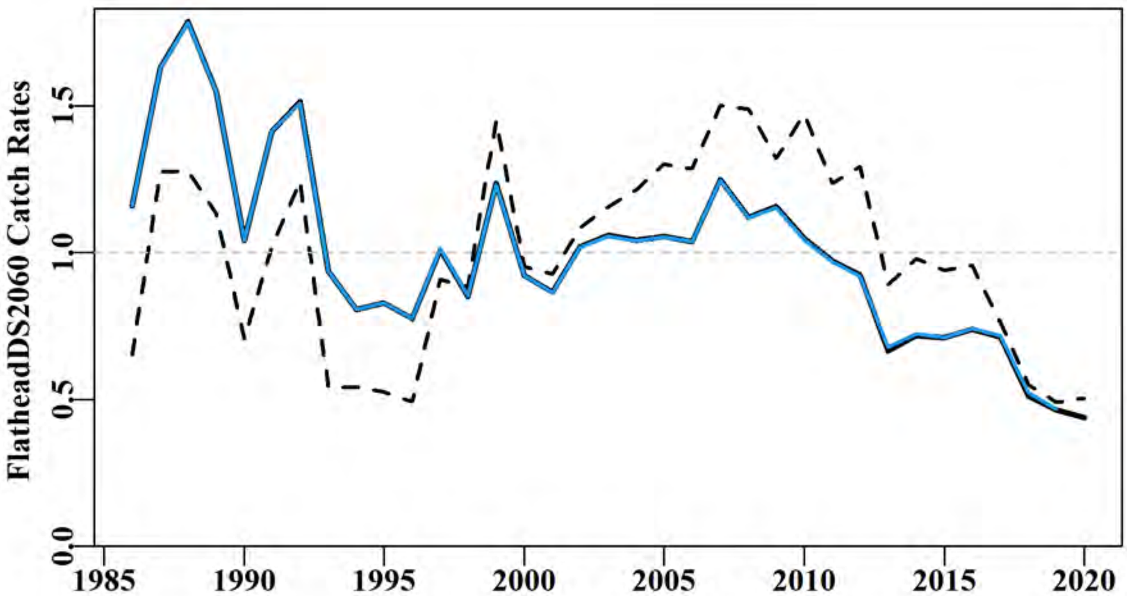

Figure 6.97. FlatheadDS2060. A comparison of the previous year's standardization (blue line) with this year's. They should lie on top of each other, although small deviations may relate to data adjustments, particularly in very recent years.

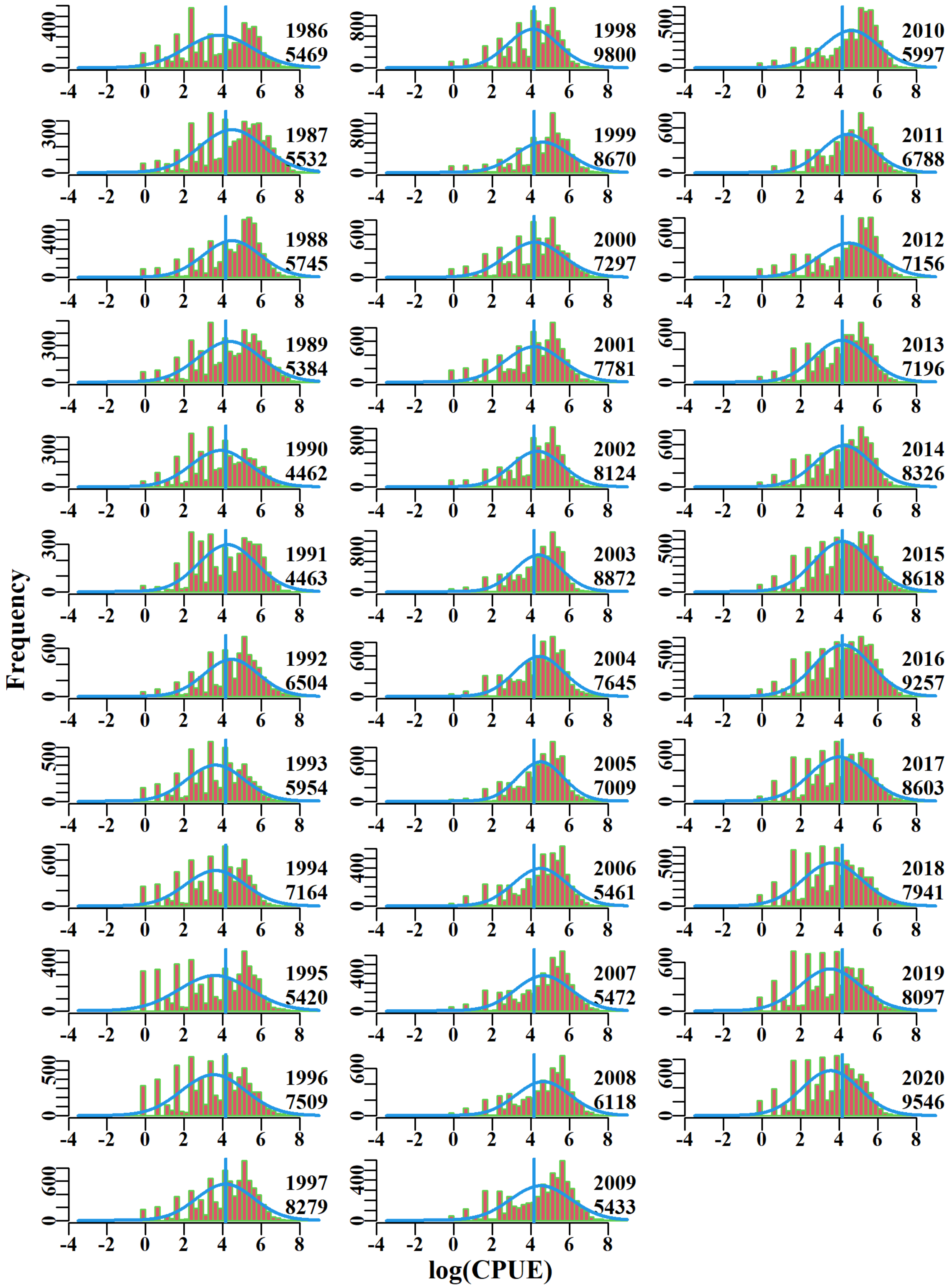

Figure 6.98. FlatheadDS2060. The natural log(CPUE) for each year of data available the blue lines are normal distributions fitted to the histogram frequencies. The numbers in each plot are the year and number of records.

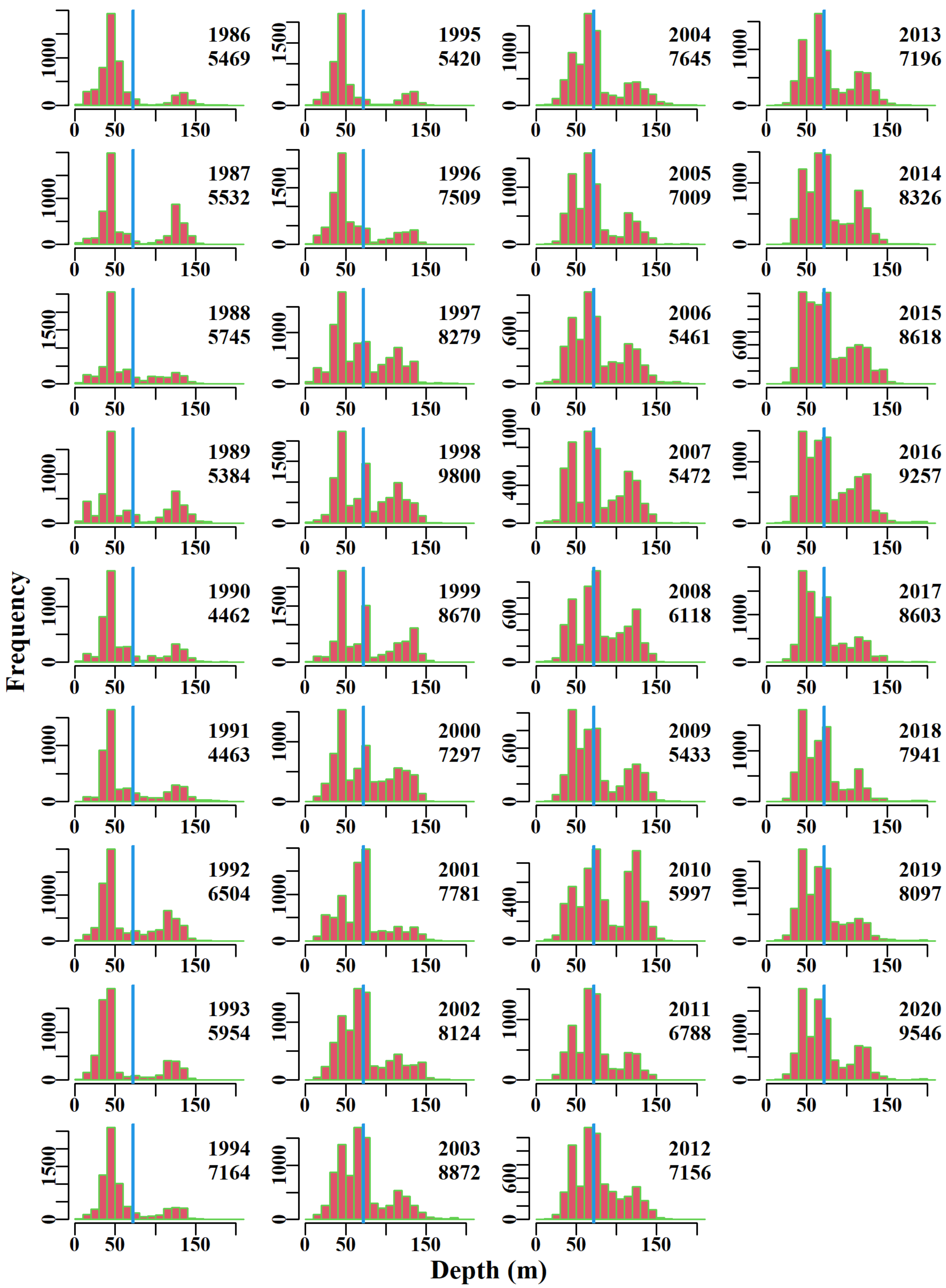

Figure 6.99. FlatheadDS2060. The average Depth of fishing for each year of data available to illustrate the development of the fishery through time. The numbers in each plot are the year and number of records.

6.17 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, OTB, in zones 10, 20, and depths 0 to 400 m within the SET fishery for the years 1986 - 2020 were used in the analysis (Table 6.71). 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.

6.17.1 *Inferences*

Most trawl caught Redfish has occurred in zone 10 across the analysis period. The total annual redfish catch in 2019 (20 t) and 2020 (20.7 t) employed in the analysis are the lowest recorded in the series (between 1986 - 2020). Large scale changes in CPUE have occurred zones 10 and 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 6.75). The qqplot suggests that the assumed Normal distribution is valid (Figure 6.103).

Annual standardized CPUE has declined since 1994 (relative to the previous year) and have been below average since 2000 (Figure 6.100).

6.17.2 *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 from the catches by vessel from 2007. This suggests that there have been transitional periods in the time-series of CPUE. This needs more attention because of the potential implications this has for the index of relative abundance through time.

Table 6.71. 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, OTB
years	1986 - 2020

Table 6.72. 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

Year	Total	N	Catch	Vess	GeoM	Opt	StDev	C<30Kg	P<30Kg
1986	1687.5	5336	1598.0	87	119.3	1.9749	0.000	23.159	0.014
1987	1252.7	3903	1181.8	79	121.1	1.6962	0.034	17.828	0.015
1988	1125.5	3966	1078.0	75	95.2	1.9057	0.034	17.697	0.016
1989	714.3	2710	641.2	72	80.1	1.4057	0.038	15.566	0.024
1990	931.4	2573	785.7	58	104.9	1.7757	0.039	11.772	0.015
1991	1570.6	3330	1231.1	52	140.8	1.9653	0.037	14.904	0.012
1992	1636.7	3175	1514.1	48	198.6	2.4741	0.038	14.286	0.009
1993	1921.4	3755	1754.8	53	205.4	2.9679	0.036	16.091	0.009
1994	1487.8	5440	1329.2	53	111.4	2.1853	0.034	28.214	0.021
1995	1240.6	5675	1188.8	52	82.3	1.4160	0.033	34.359	0.029
1996	1344.0	5775	1297.5	55	90.4	1.2845	0.033	33.779	0.026
1997	1397.3	4363	1340.7	58	138.4	1.3472	0.035	25.498	0.019
1998	1555.2	4297	1527.5	49	187.2	1.5842	0.035	23.599	0.015
1999	1116.5	3934	1089.3	53	145.2	1.3235	0.036	21.181	0.019
2000	758.5	4661	734.3	53	80.4	0.8897	0.035	28.968	0.039
2001	742.5	4560	718.5	47	75.8	0.8478	0.035	29.022	0.040
2002	807.1	5188	770.8	49	69.5	0.7921	0.034	32.706	0.042
2003	615.6	4096	553.9	51	62.6	0.6780	0.036	27.500	0.050
2004	475.2	3951	447.7	50	52.0	0.6026	0.036	27.007	0.060
2005	483.5	3768	451.1	46	47.4	0.6674	0.037	26.639	0.059
2006	325.5	2573	302.3	42	46.5	0.6214	0.040	19.702	0.065
2007	216.3	1871	208.1	23	46.8	0.6165	0.045	13.427	0.065
2008	183.8	1922	179.3	25	35.2	0.5415	0.045	15.446	0.086
2009	160.5	1602	153.6	23	33.5	0.4618	0.047	12.758	0.083
2010	152.8	1839	146.2	24	28.8	0.4514	0.045	15.982	0.109
2011	87.3	1397	82.8	22	21.8	0.3306	0.050	10.828	0.131
2012	66.4	1345	61.9	21	18.2	0.2326	0.050	11.194	0.181
2013	62.7	1129	60.3	20	20.1	0.2917	0.053	9.787	0.162
2014	86.9	1411	82.6	22	25.9	0.3864	0.049	11.904	0.144
2015	52.2	1192	50.0	22	17.5	0.2384	0.052	10.106	0.202
2016	38.4	959	35.8	21	15.3	0.1976	0.057	7.646	0.214
2017	25.4	606	22.0	18	16.4	0.1956	0.068	5.182	0.235
2018	29.9	740	27.4	17	13.8	0.1852	0.065	5.389	0.197
2019	26.7	570	20.0	16	14.0	0.2191	0.071	4.973	0.249
2020	47.0	549	20.7	15	15.1	0.2462	0.072	4.834	0.233

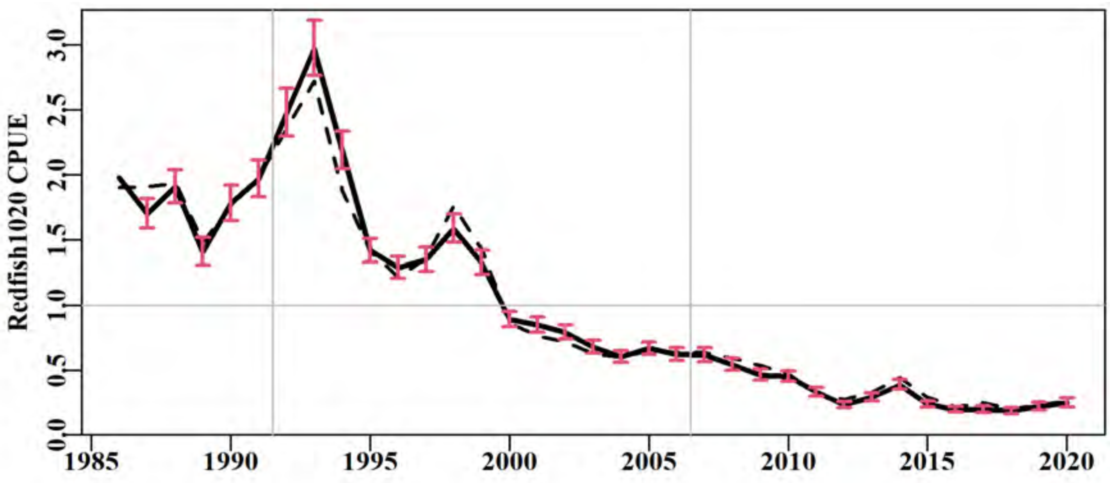

Figure 6.100. Redfish1020 standardization. The dashed black line represents the geometric mean CPUE, solid black line the standardized CPUE. The red bars are the 95% confidence intervals about the mean estimates. The graph scales both time-series of standardized CPUE relative to the mean of each time-series.

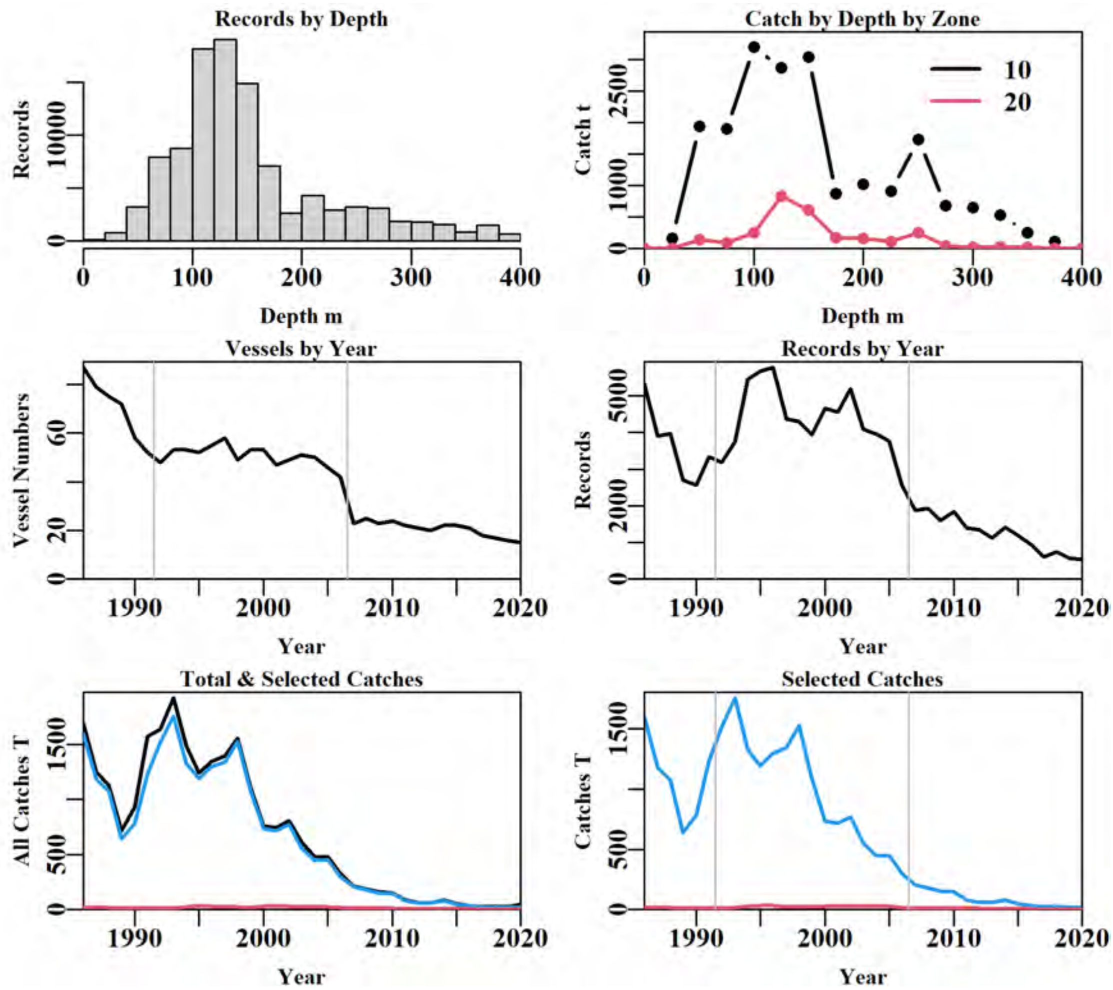

Figure 6.101. Redfish1020 fishery details. The bottom left plot depicts all known catches (top black line), and all selected catches used in the analysis (middle blue line); the lower red line: selected catches < 30 kg).

Table 6.73. 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	122039	116414	113200	112169	105297	104224	104161
Difference	0	5625	3214	1031	6872	1073	63
Catch	24592	24094	23695	23538	22845	22689	22687
Difference	0	498	399	157	693	156	2

Table 6.74. 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 6.75. 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

Term	AIC	RSS	MSS	Nobs	Npars	adj_r2	%Change
Year	112902	307718	42067	104161	35	12.0	0
Vessel	94833	257922	91863	104161	194	26.1	14.13
DepCat	89545	245081	104704	104161	210	29.8	3.67
Zone	88220	241977	107808	104161	211	30.7	0.89
DayNight	87546	240403	109381	104161	214	31.1	0.45
Month	87187	239526	110259	104161	225	31.4	0.24
Zone:Month	87059	239181	110603	104161	236	31.5	0.09
Zone:DepCat	86782	238522	111263	104161	241	31.7	0.28

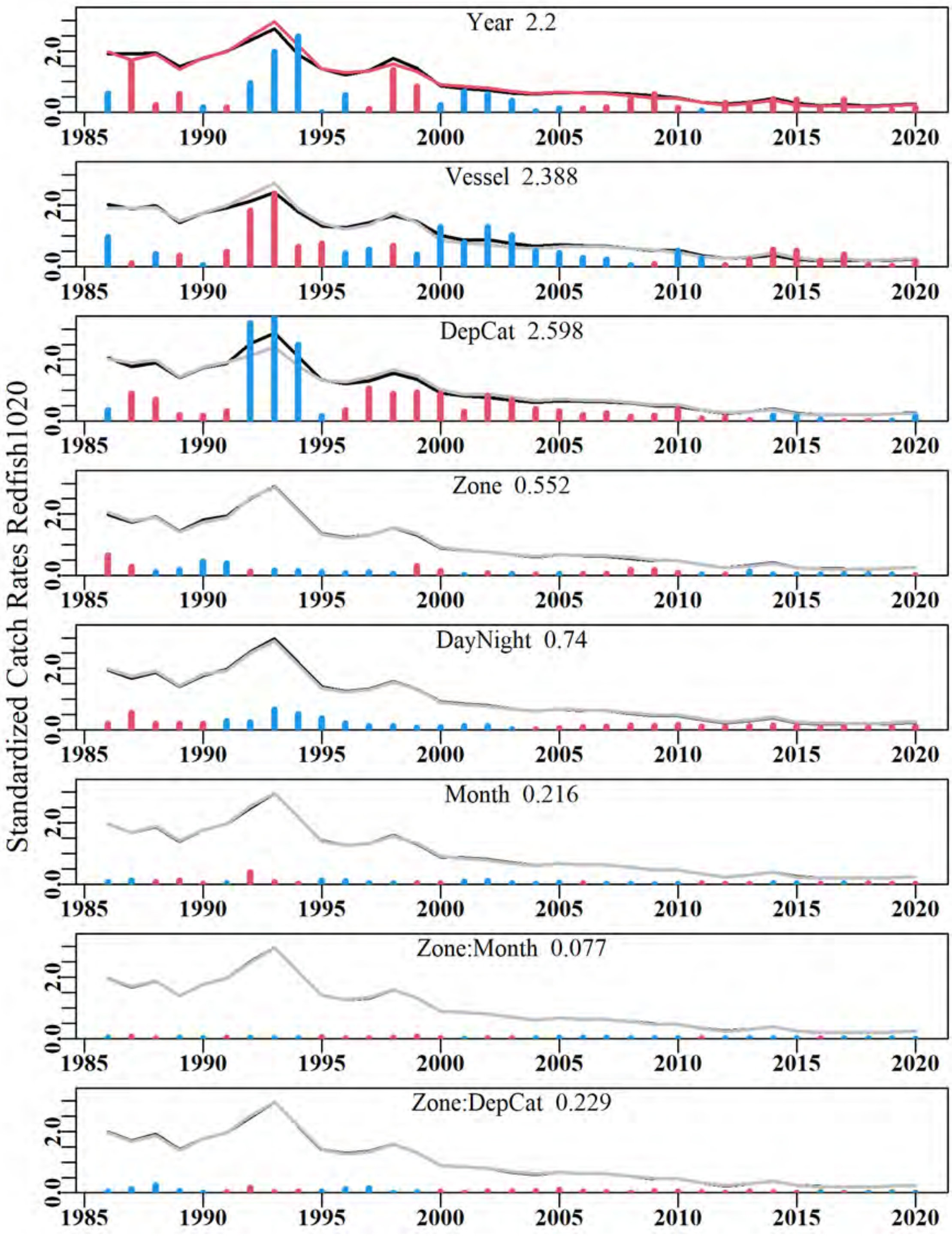

Figure 6.102. Redfish1020. The influence of each factor on the optimal standardization. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by vertical bars with blue bars indicating the optimum model is higher than the geometric 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.

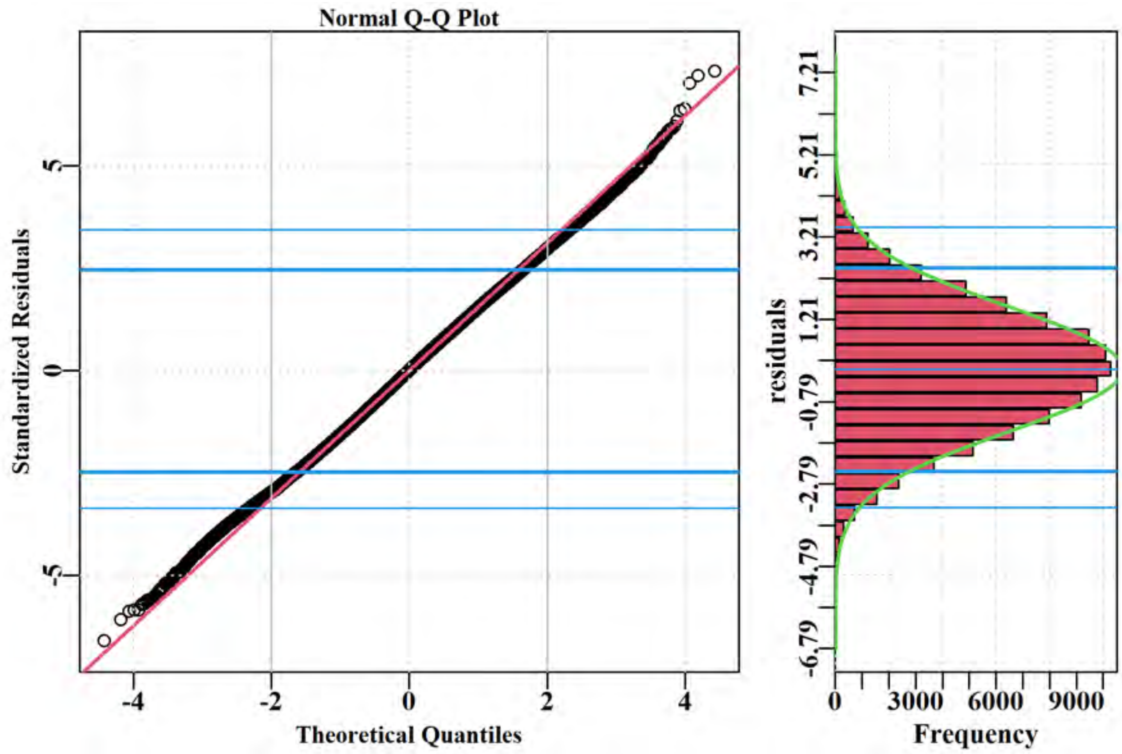

Figure 6.103. Redfish1020. diagnostic plots. The distribution of residuals from the optimum fit. The qqplot indicates the fit to the expected normality, while the histogram of residuals illustrates the 90% quantiles to indicate the intensity of any lack of fit at the margins of the distribution.

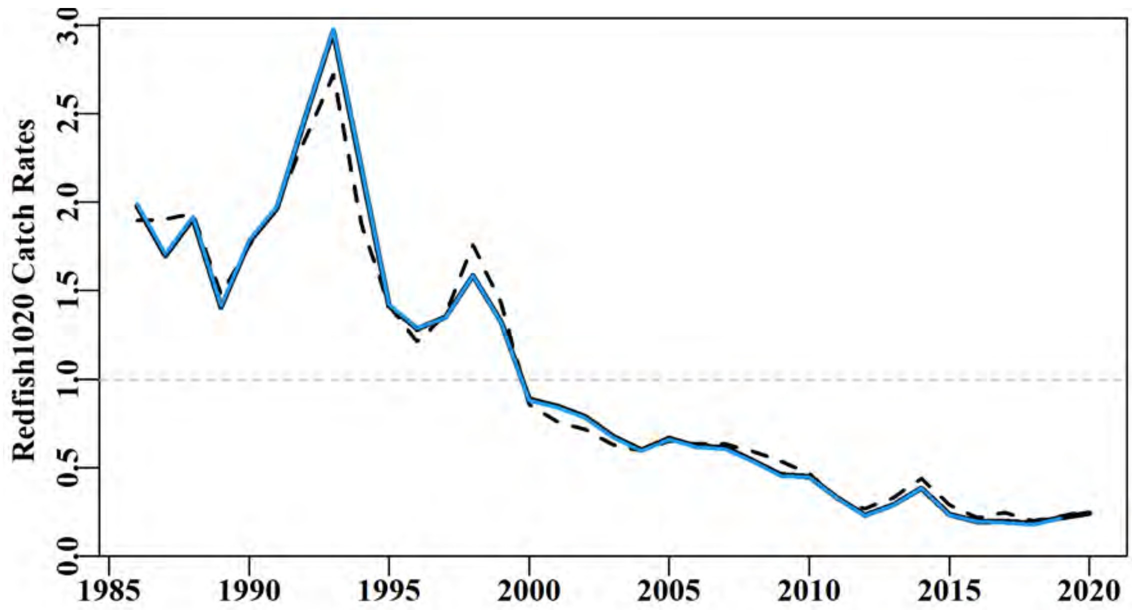

Figure 6.104. Redfish1020. A comparison of the previous year's standardization (blue line) with this year's. They should lie on top of each other, although small deviations may relate to data adjustments, particularly in very recent years.

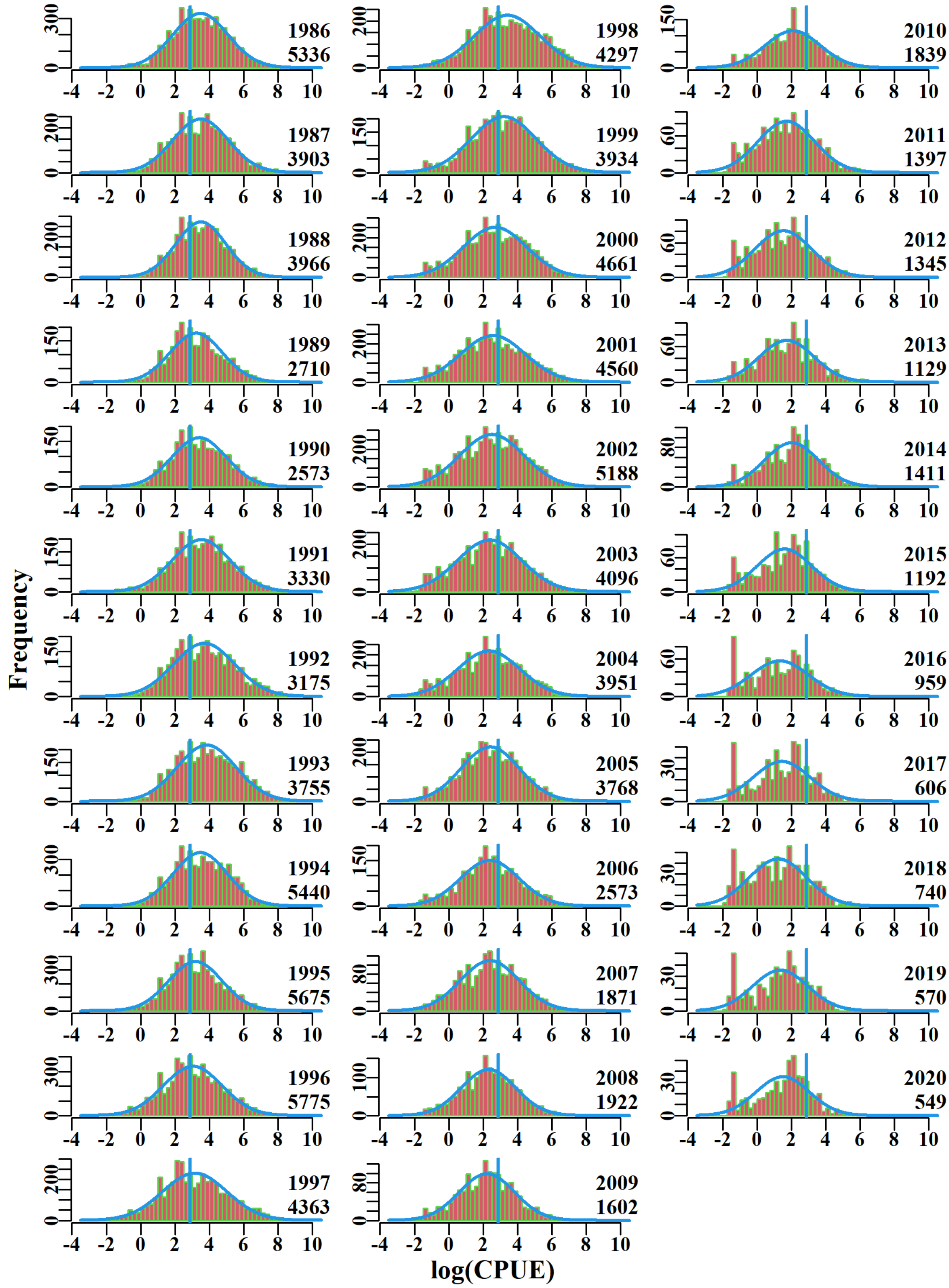

Figure 6.105. Redfish1020. The natural log(CPUE) for each year of data available the blue lines are normal distributions fitted to the histogram frequencies. The numbers in each plot are the year and number of records.

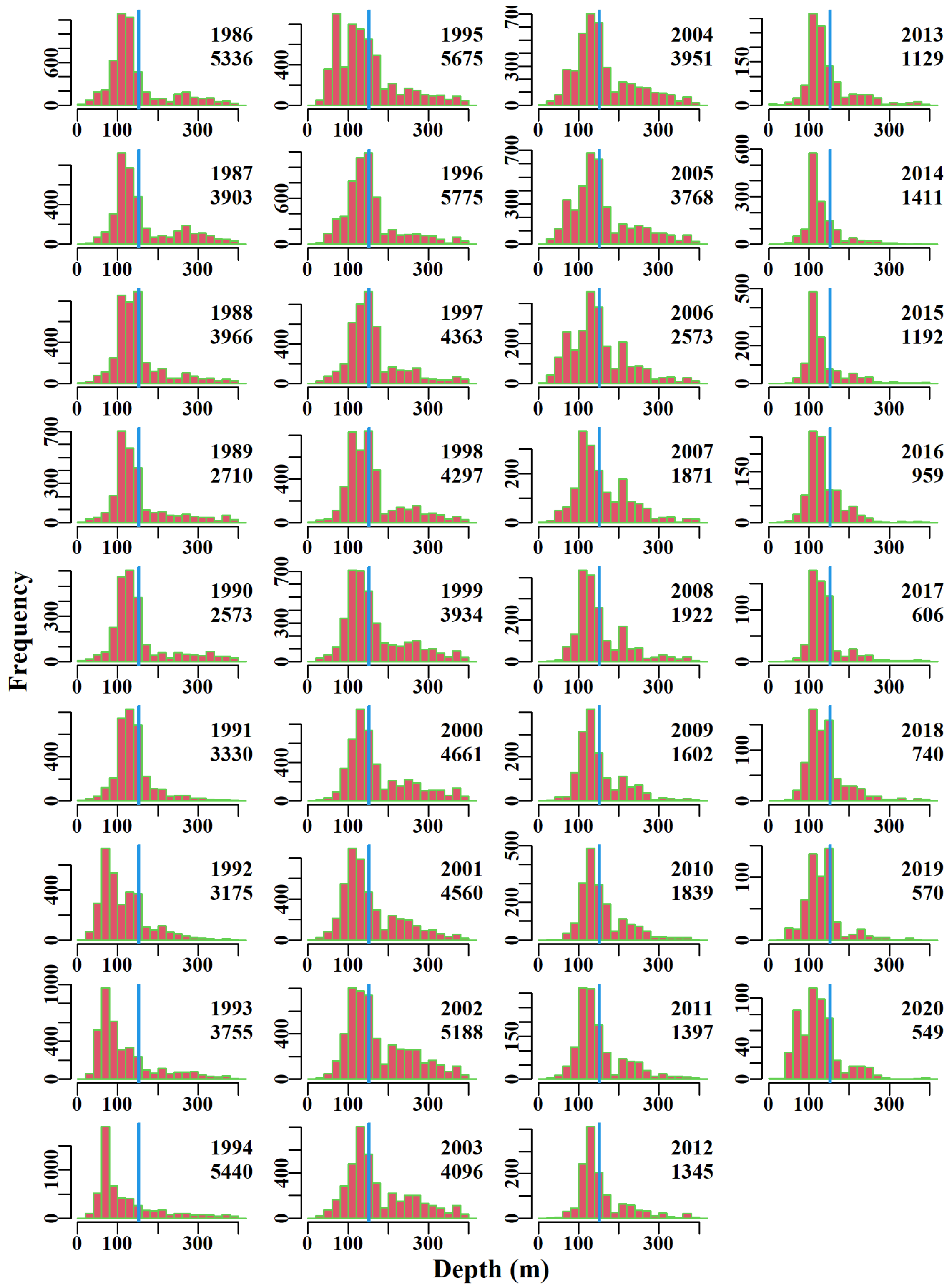

Figure 6.106. Redfish1020. The average Depth of fishing for each year of data available to illustrate the development of the fishery through time. The numbers in each plot are the year and number of records.

6.18 Blue-eye Trevala TW 20 30

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, OTB, TMO, in zones 20, 30, and depths 0 to 1000 m within the SET fishery for the years 1986 - 2020 were used in the analysis. Recently, Ocean Blue-Eye Trevalla (37445014 - *Schedophilus labyrinthicus*) was also included in this analysis. These constitute the criteria used to select data from the Commonwealth logbook database (Table 6.76). Standardized CPUE based on line caught Blue-Eye Trevalla can be found in Sporcic (2021a,b).

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.

6.18.1 *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 < 30 kg (Figure 6.108), 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 6.80). The qqplot suggests a departure from the assumed Normal distribution as depicted by the tails of the distribution (Figure 6.110).

Annual standardized CPUE has been below average since about 1996 and shows a relatively flat trend (Figure 6.107).

6.18.2 *Action Items and Issues*

Given the ongoing low catches (with the lowest in the series in 2020), 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 CPUE and the standardized CPUE it is questionable whether this time-series of standardized 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 6.76. 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, OTB, TMO
years	1986 - 2020

Table 6.77. 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

Year	Total	N	Catch	Vess	GeoM	Opt	StDev	C<30Kg	P<30Kg
1986	38.0	166	9.1	17	21.9	2.4781	0.000	1.453	0.159
1987	15.5	189	10.0	14	17.6	2.3578	0.137	1.769	0.177
1988	105.2	305	19.3	21	22.7	2.9095	0.130	3.404	0.176
1989	88.1	313	33.3	32	38.2	3.2371	0.133	2.849	0.086
1990	79.3	263	39.8	36	89.5	4.2690	0.135	1.574	0.040
1991	76.0	473	29.2	37	20.9	2.2305	0.127	5.507	0.189
1992	49.3	310	13.8	23	16.5	1.6694	0.134	3.321	0.241
1993	59.7	725	37.4	31	19.8	1.3755	0.124	7.126	0.190
1994	110.0	853	89.0	33	41.6	1.5524	0.124	7.877	0.089
1995	58.6	485	28.2	29	17.6	1.0358	0.128	6.015	0.213
1996	71.7	643	35.3	29	16.4	0.8405	0.126	6.625	0.188
1997	471.5	602	19.9	31	10.7	0.7724	0.128	6.481	0.326
1998	476.0	471	18.7	24	11.3	0.8970	0.130	5.166	0.277
1999	575.0	631	41.7	27	9.2	0.9165	0.127	6.515	0.156
2000	671.4	656	35.7	35	7.6	0.5652	0.125	5.636	0.158
2001	648.3	699	25.2	24	4.6	0.4967	0.125	6.042	0.240
2002	843.9	701	33.7	28	12.0	0.4893	0.127	5.847	0.173
2003	605.3	721	13.6	25	6.0	0.4882	0.127	5.454	0.401
2004	612.3	622	15.2	28	11.6	0.4811	0.128	4.486	0.296
2005	755.3	486	17.4	26	16.5	0.4890	0.131	3.086	0.178
2006	573.7	326	36.8	17	67.9	0.5977	0.135	2.087	0.057
2007	937.1	246	10.6	11	9.7	0.4961	0.141	1.652	0.156
2008	398.9	429	13.4	15	26.3	0.4597	0.135	2.720	0.203
2009	521.0	240	22.8	14	90.1	0.4344	0.142	1.294	0.057
2010	437.4	190	10.7	13	32.3	0.3020	0.148	0.979	0.091
2011	554.2	214	7.2	12	12.7	0.3105	0.144	1.192	0.166
2012	463.8	149	1.3	11	2.7	0.2858	0.154	0.924	0.694
2013	398.4	146	4.1	11	25.9	0.2487	0.156	0.921	0.224
2014	460.5	120	20.6	11	337.4	0.3337	0.162	0.554	0.027
2015	305.4	185	22.1	14	368.3	0.3244	0.151	0.833	0.038
2016	332.7	140	9.5	12	82.5	0.2702	0.157	0.775	0.082
2017	385.3	187	34.4	11	592.4	0.3745	0.150	0.840	0.024
2018	345.9	189	33.8	10	574.1	0.3840	0.150	0.703	0.021
2019	303.7	111	9.6	13	74.0	0.3087	0.168	0.567	0.059
2020	231.7	96	2.1	12	9.0	0.3190	0.172	0.647	0.304

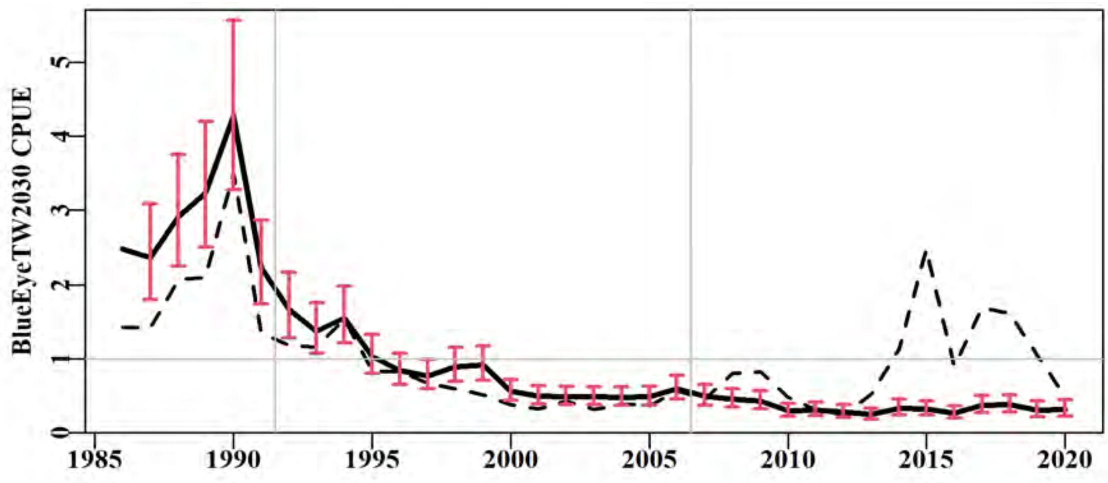

Figure 6.107. BlueEyeTW2030 standardization. The dashed black line represents the geometric mean CPUE, solid black line the standardized CPUE. The red bars are the 95% confidence intervals about the mean estimates. The graph scales both time-series of standardized CPUE relative to the mean of each time-series.

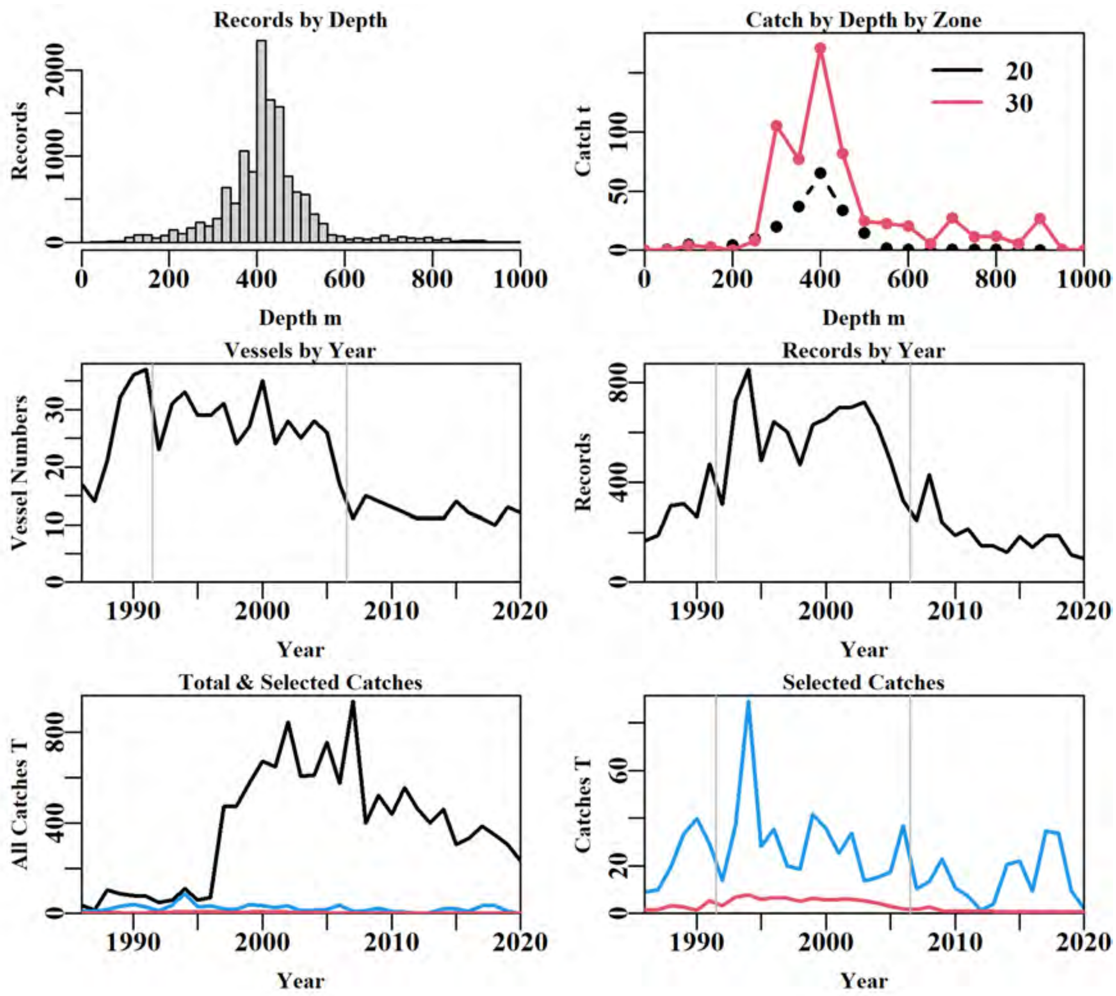

Figure 6.108. BlueEyeTW2030 fishery details. The bottom left plot depicts all known catches (top black line), and all selected catches used in the analysis (middle blue line); the lower red line: selected catches < 30 kg).

Table 6.78. 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	57647	36559	36324	36134	15398	13292	13282
Difference	0	21088	235	190	20736	2106	10
Catch	13144	5295	5270	5188	1588	809	805
Difference	0	7850	25	81	3600	779	4

Table 6.79. 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 6.80. 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

Term	AIC	RSS	MSS	Nobs	Npars	adj_r2	%Change
Year	13124	35491	5399	13282	35	13.0	0
Vessel	4994	18887	22003	13282	159	53.3	40.27
Zone	4586	18313	22576	13282	160	54.7	1.42
DepCat	4529	18180	22710	13282	180	54.9	0.26
Month	4502	18113	22777	13282	191	55.1	0.13
DayNight	4471	18063	22827	13282	194	55.2	0.11
Zone:DepCat	4291	17768	23122	13282	213	55.8	0.67
Zone:Month	4432	17980	22910	13282	205	55.3	0.17

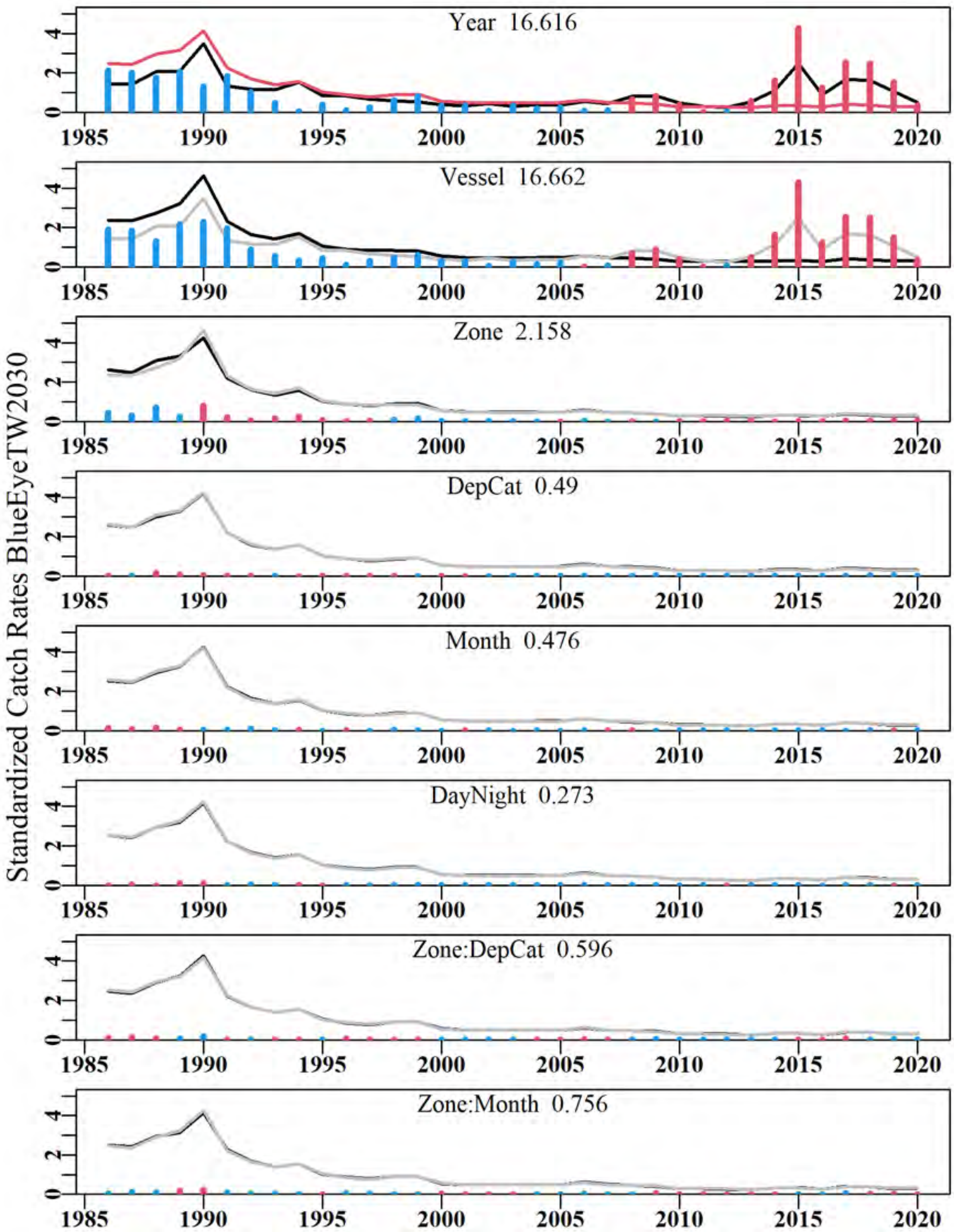

Figure 6.109. BlueEyeTW2030. The influence of each factor on the optimal standardization. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by vertical bars with blue bars indicating the optimum model is higher than the 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.

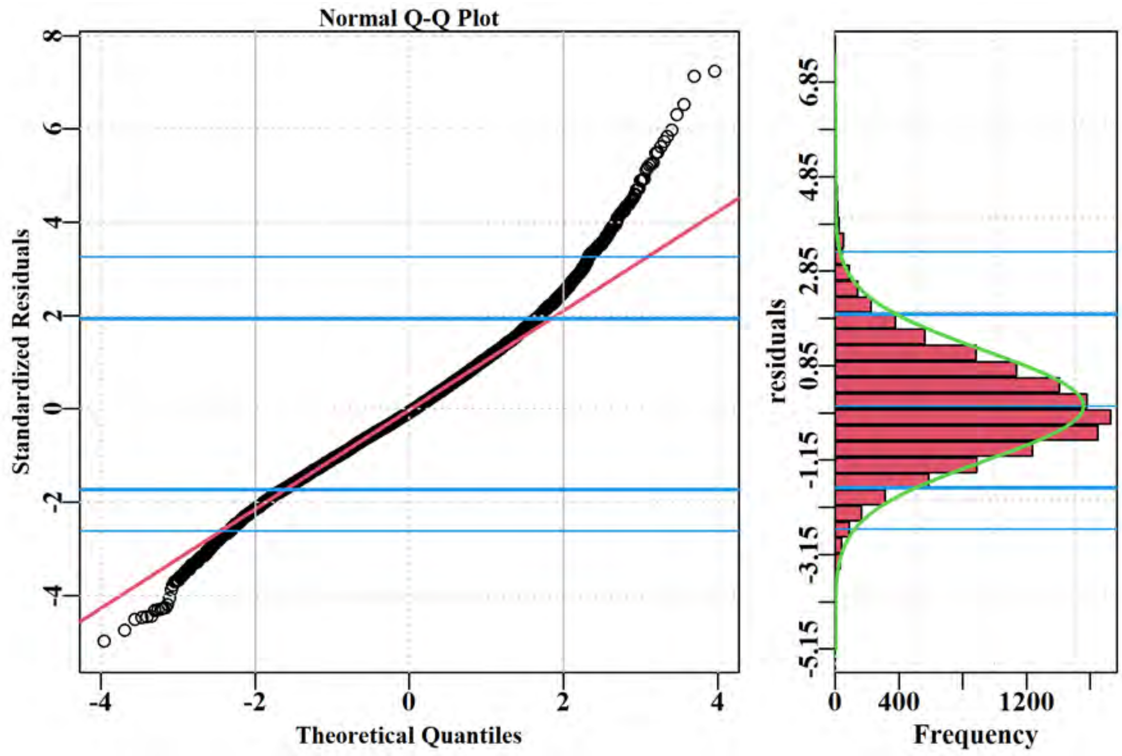

Figure 6.110. BlueEyeTW2030. diagnostic plots. The distribution of residuals from the optimum fit. The qqplot indicates the fit to the expected normality, while the histogram of residuals illustrates the 90% quantiles to indicate the intensity of any lack of fit at the margins of the distribution.

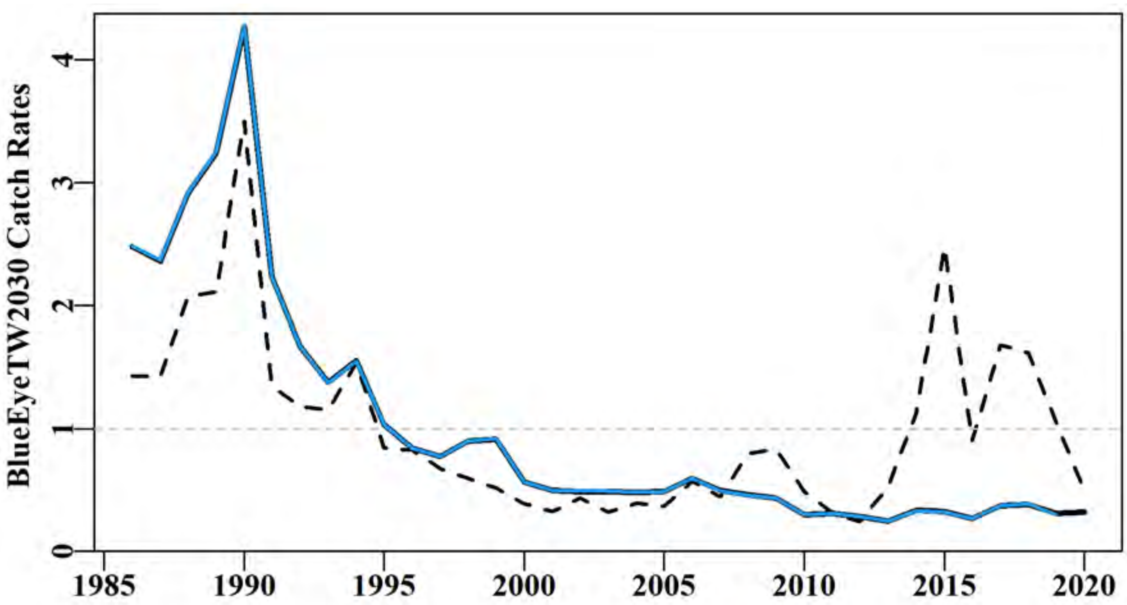

Figure 6.111. BlueEyeTW2030. A comparison of the previous year's standardization (blue line) with this year's. They should lie on top of each other, although small deviations may relate to data adjustments, particularly in very recent years.

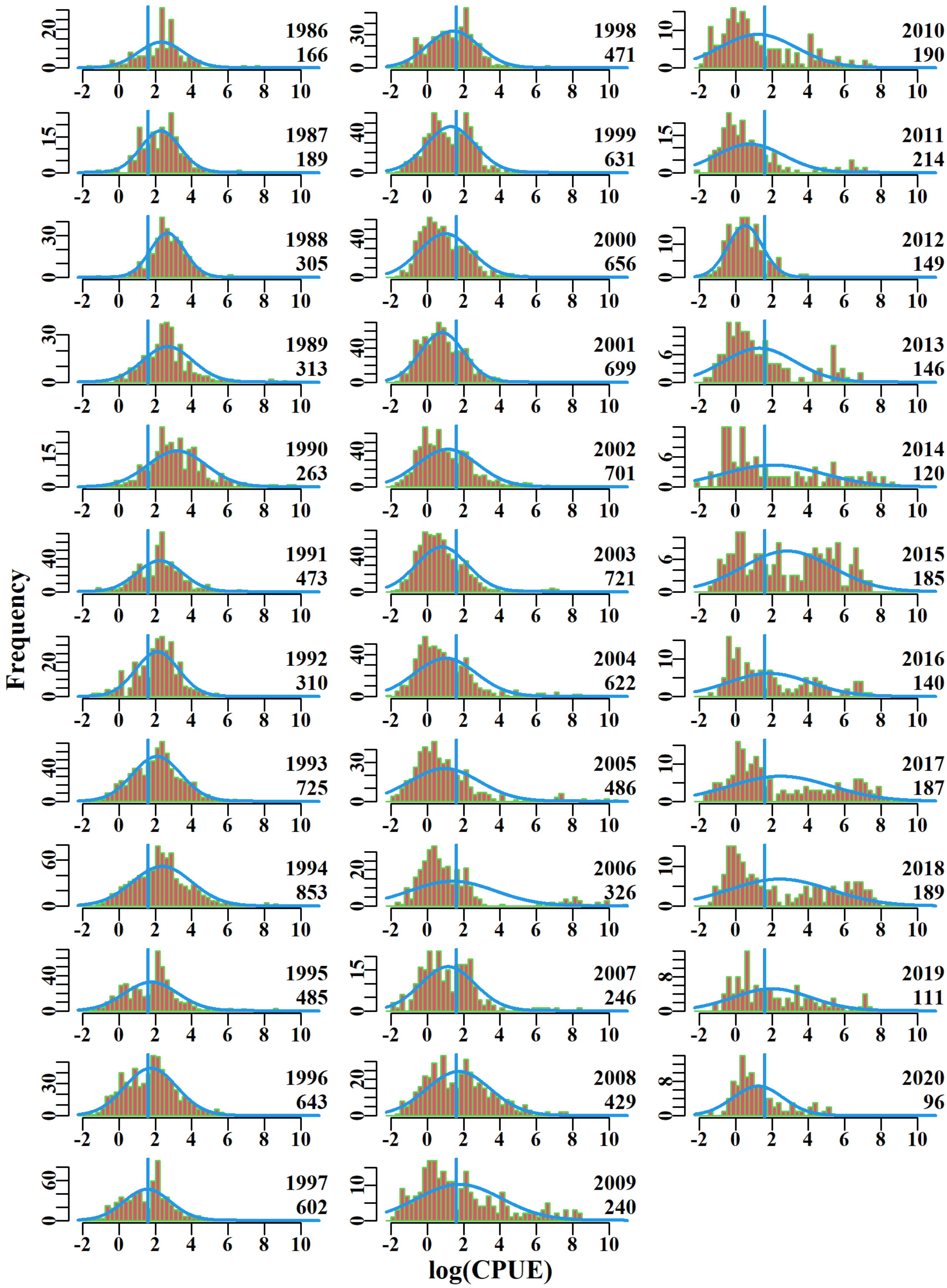

Figure 6.112. BlueEyeTW2030. The natural log(CPUE) for each year of data available the blue lines are normal distributions fitted to the histogram frequencies. The numbers in each plot are the year and number of records.

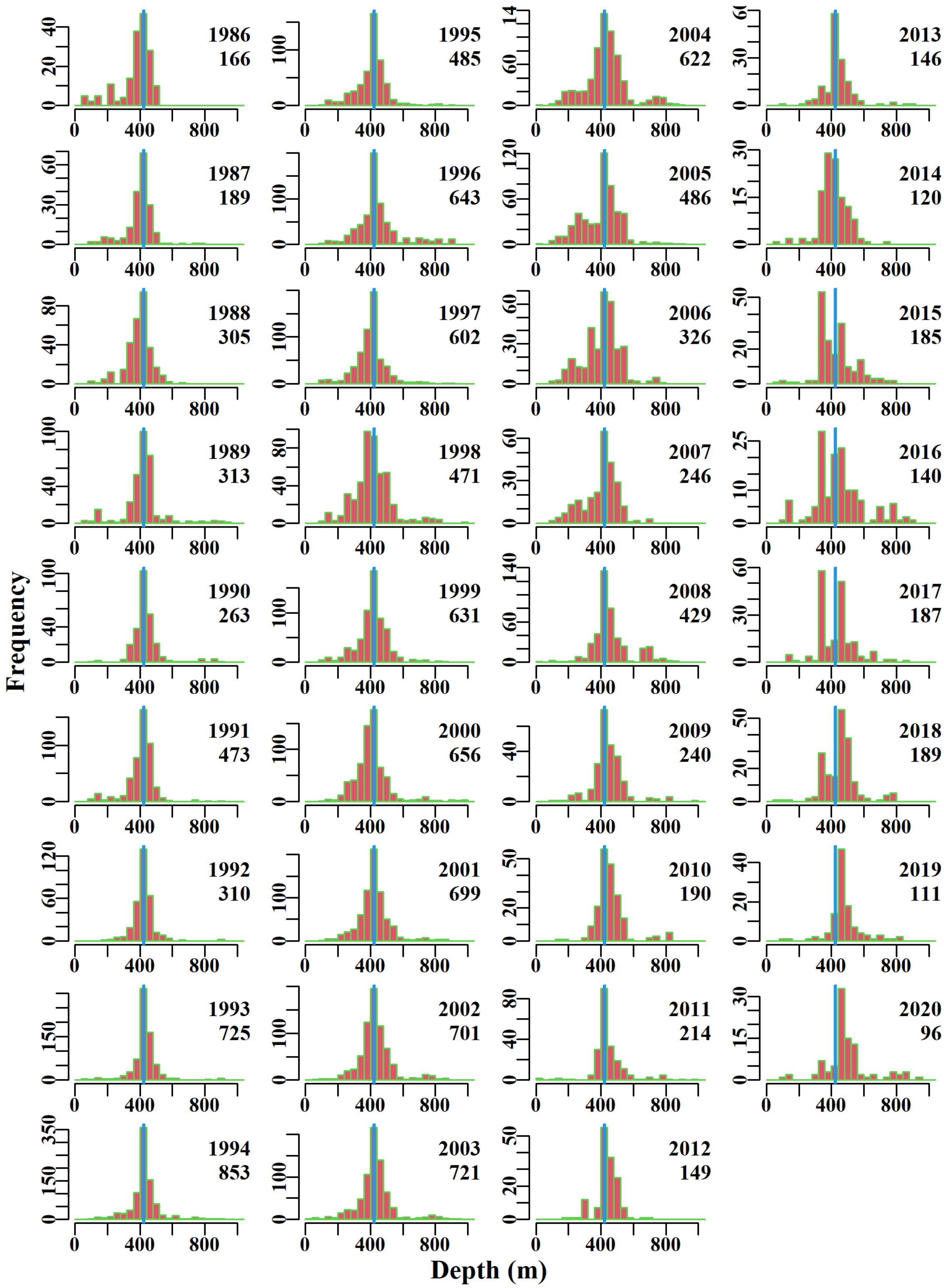

Figure 6.113. BlueEyeTW2030. The average Depth of fishing for each year of data available to illustrate the development of the fishery through time. The numbers in each plot are the year and number of records.

6.19 Blue-Eye Trevalla TW 40 50

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, TMO, in zones 40, 50, and depths 0 to 1000 m within the SET fishery for the years 1986 - 2020 were used in the analysis. Recently, Ocean Blue-Eye Trevalla (37445014 - *Schedophilus labyrinthicus*) was also included in this analysis. These constitute the criteria used to select data from the Commonwealth logbook database (Table 6.81). Standardized CPUE based on line caught Blue-Eye Trevalla can be found in Sporcic (2021a,b).

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

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

6.19.1 *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 1992 - 2006) there was an increase in small shots of < 30 kg, which suggests that these are merely bycatch to the usual fishing practices (Figure 6.115).

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 6.85). The qqplot suggests a departure from the assumed Normal distribution as depicted by the tails of the distribution (Figure 6.117). Annual standardized CPUE has been below average since about 1996 and relatively flat trend (Figure 6.114). CPUE are consistent from 1988 - 1991 (i.e., before the introduction of quotas in 1992) but are double that following the introduction of quota. Very few vessels now contribute to significant catches.

6.19.2 *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 6.81. 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, TMO
years	1986 - 2020

Table 6.82. 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

Year	Total	N	Catch	Vess	GeoM	Opt	StDev	C<30Kg	P<30Kg
1986	38.0	194	16.0	18	26.9	1.0880	0.000	1.602	0.100
1987	15.5	56	3.1	14	19.8	0.8308	0.178	0.356	0.113
1988	105.2	142	76.4	15	474.9	2.5866	0.157	0.716	0.009
1989	88.1	238	44.0	24	93.5	2.2443	0.138	2.149	0.049
1990	79.3	156	30.9	15	65.7	2.2468	0.159	1.840	0.060
1991	76.0	125	18.6	18	35.4	1.8071	0.159	1.149	0.062
1992	49.3	129	28.6	15	620.9	2.2480	0.157	0.908	0.032
1993	59.7	289	18.1	19	16.3	1.0075	0.140	3.992	0.220
1994	110.0	348	16.3	19	14.0	1.0200	0.136	5.148	0.316
1995	58.6	498	26.3	21	12.3	0.9137	0.133	6.648	0.253
1996	71.7	521	30.0	24	17.8	0.9617	0.133	6.277	0.209
1997	471.5	788	82.4	18	22.3	0.9770	0.130	7.718	0.094
1998	476.0	778	58.9	19	14.6	1.1563	0.131	8.746	0.148
1999	575.0	875	46.2	19	15.5	1.1720	0.130	9.412	0.204
2000	671.4	1104	44.6	25	13.1	1.0151	0.129	11.127	0.249
2001	648.3	966	43.4	26	15.0	0.9786	0.131	10.771	0.248
2002	843.9	803	32.3	26	13.6	0.8140	0.131	8.786	0.272
2003	605.3	389	11.0	25	8.5	0.7151	0.138	3.775	0.344
2004	612.3	848	31.2	24	10.0	0.6287	0.131	7.179	0.230
2005	755.3	507	12.7	22	7.5	0.6035	0.135	4.366	0.343
2006	573.7	527	16.2	17	7.3	0.5961	0.134	3.967	0.245
2007	937.1	530	26.1	16	12.9	0.6397	0.134	3.655	0.140
2008	398.9	321	16.4	14	14.9	0.8555	0.140	2.685	0.164
2009	521.0	342	15.8	13	10.6	0.8064	0.139	2.540	0.161
2010	437.4	423	30.9	14	15.6	0.8213	0.137	2.775	0.090
2011	554.2	379	14.7	14	6.5	0.6353	0.138	3.017	0.205
2012	463.8	251	9.0	11	4.7	0.4754	0.146	1.736	0.194
2013	398.4	202	18.7	15	10.8	0.6151	0.148	1.585	0.085
2014	460.5	216	8.7	13	6.6	0.5810	0.148	2.118	0.243
2015	305.4	106	2.7	9	5.3	0.3713	0.168	0.745	0.281
2016	332.7	92	3.3	13	7.1	0.6184	0.171	0.842	0.255
2017	385.3	228	17.3	10	18.1	1.0062	0.152	2.029	0.117
2018	345.9	193	8.4	10	6.9	0.6374	0.153	2.098	0.248
2019	303.7	181	9.0	9	12.5	0.7250	0.152	1.572	0.175
2020	231.7	71	3.9	10	11.6	0.6011	0.187	0.676	0.173

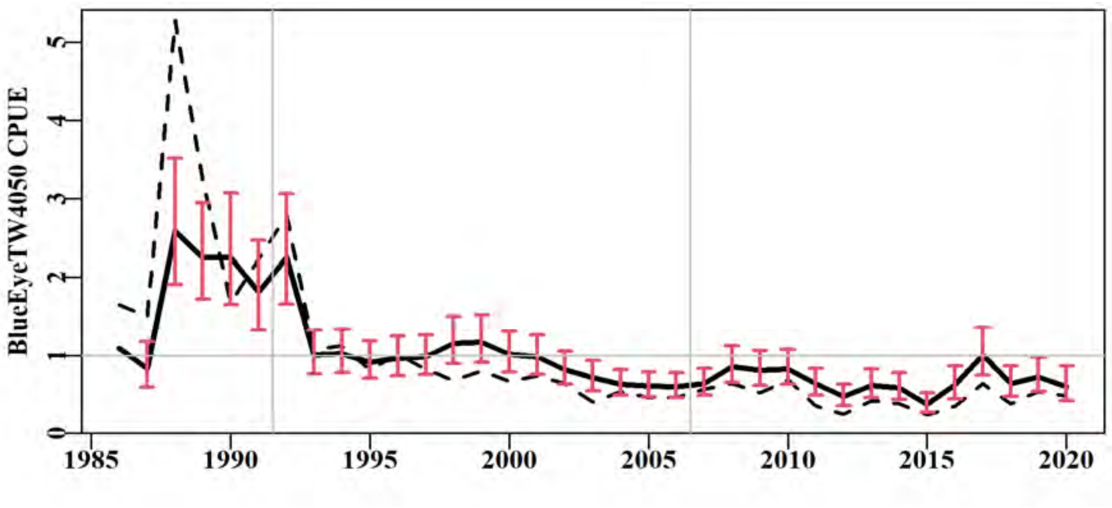

Figure 6.114. BlueEyeTW4050 standardization. The dashed black line represents the geometric mean CPUE, solid black line the standardized CPUE. The red bars are the 95% confidence intervals about the mean estimates. The graph scales both time-series of standardized CPUE relative to the mean of each time-series.

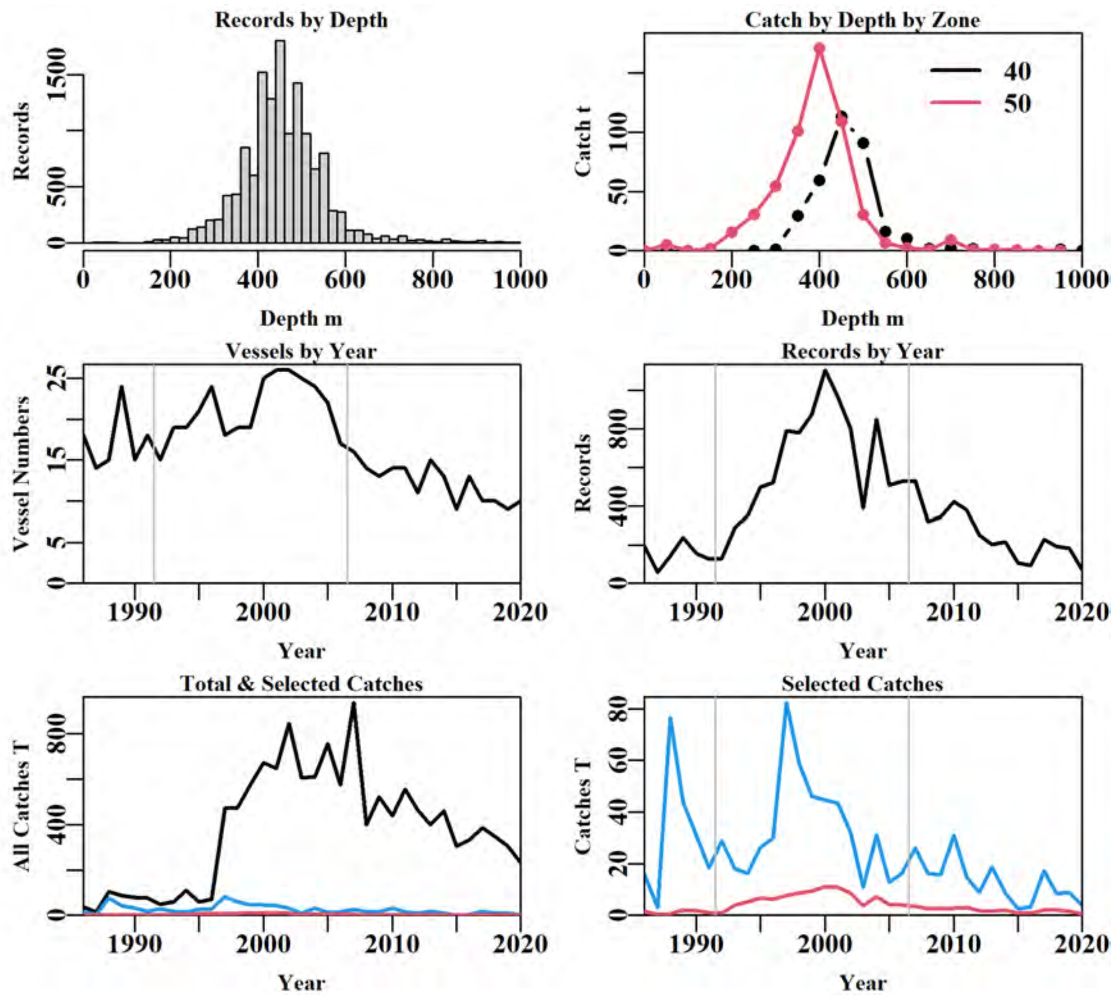

Figure 6.115. BlueEyeTW4050 fishery details. The bottom left plot depicts all known catches (top black line), and all selected catches used in the analysis (middle blue line); the lower red line: selected catches < 30 kg).

Table 6.83. 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	57647	36559	36324	36134	15171	13840	13816
Difference	0	21088	235	190	20963	1331	24
Catch	13144	5295	5270	5188	1345	873	872
Difference	0	7850	25	81	3843	472	1

Table 6.84. 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 6.85. 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

Term	AIC	RSS	MSS	Nobs	Npars	adj_r2	%Change
Year	9102	26565	3374	13816	35	11.1	0
Vessel	3466	17441	12498	13815	123	41.2	30.17
DepCat	3069	16898	13041	13815	143	43.0	1.75
Zone	2991	16800	13139	13815	144	43.3	0.33
DayNight	2859	16634	13305	13815	147	43.8	0.55
Month	2758	16486	13453	13815	158	44.3	0.46
Zone:DepCat	2742	16427	13512	13815	175	44.4	0.13
Zone:Month	2758	16460	13479	13815	169	44.3	0.04

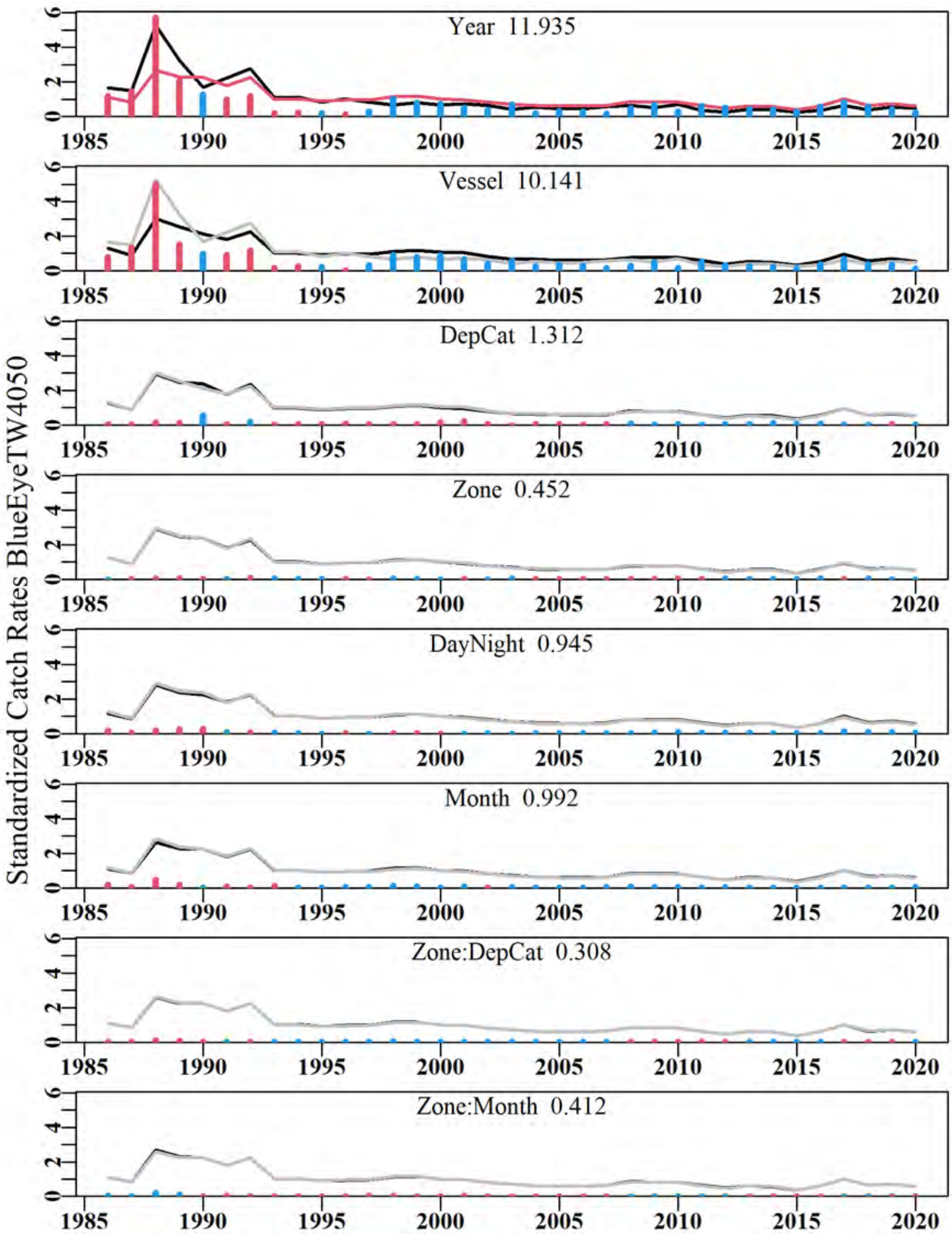

Figure 6.116. BlueEyeTW4050. The influence of each factor on the optimal standardization. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by vertical bars with blue bars indicating the optimum model is higher than the 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.

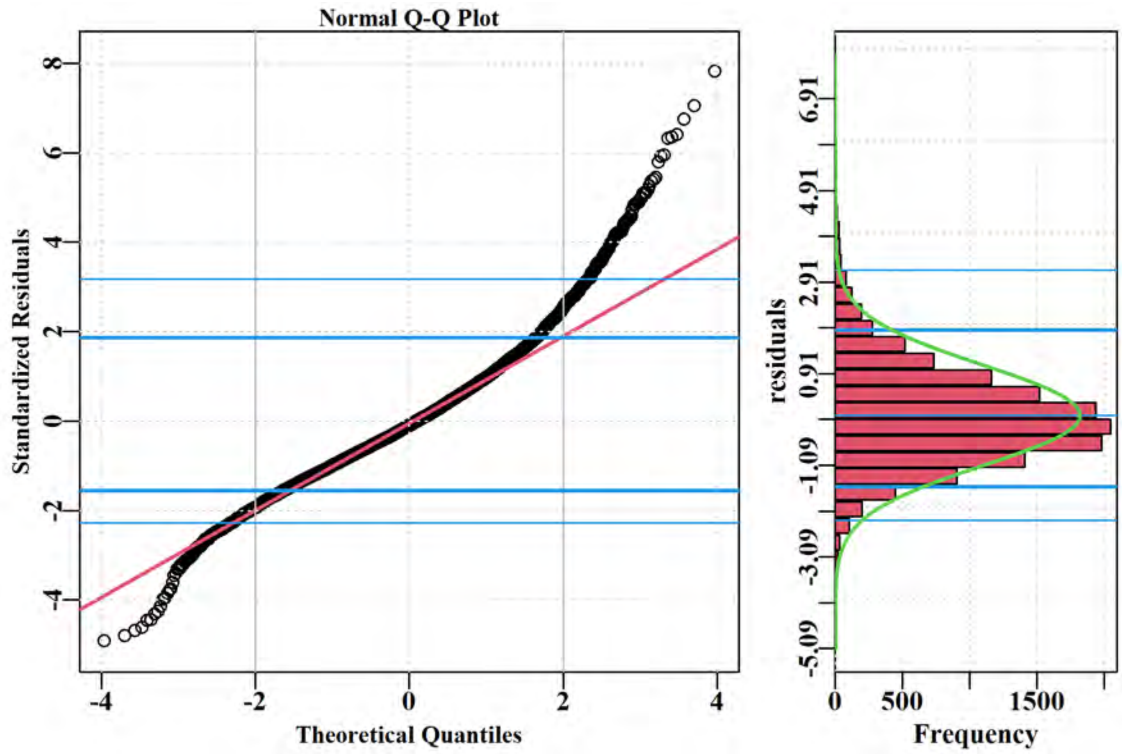

Figure 6.117. BlueEyeTW4050. diagnostic plots. The distribution of residuals from the optimum fit. The qqplot indicates the fit to the expected normality, while the histogram of residuals illustrates the 90% quantiles to indicate the intensity of any lack of fit at the margins of the distribution.

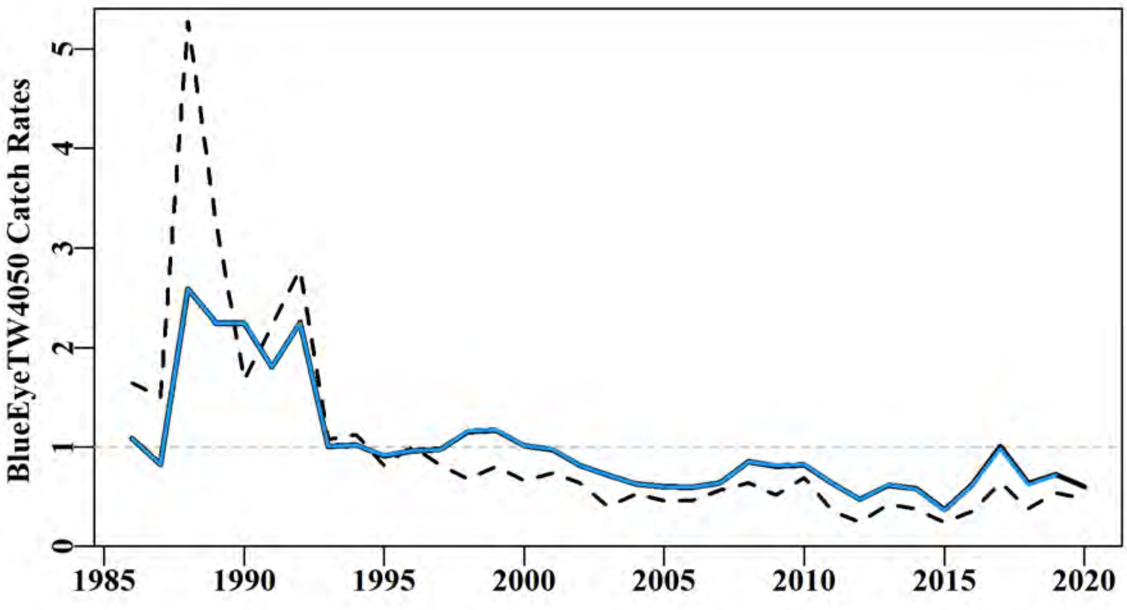

Figure 6.118. BlueEyeTW4050. A comparison of the previous year's standardization (blue line) with this year's. They should lie on top of each other, although small deviations may relate to data adjustments, particularly in very recent years.

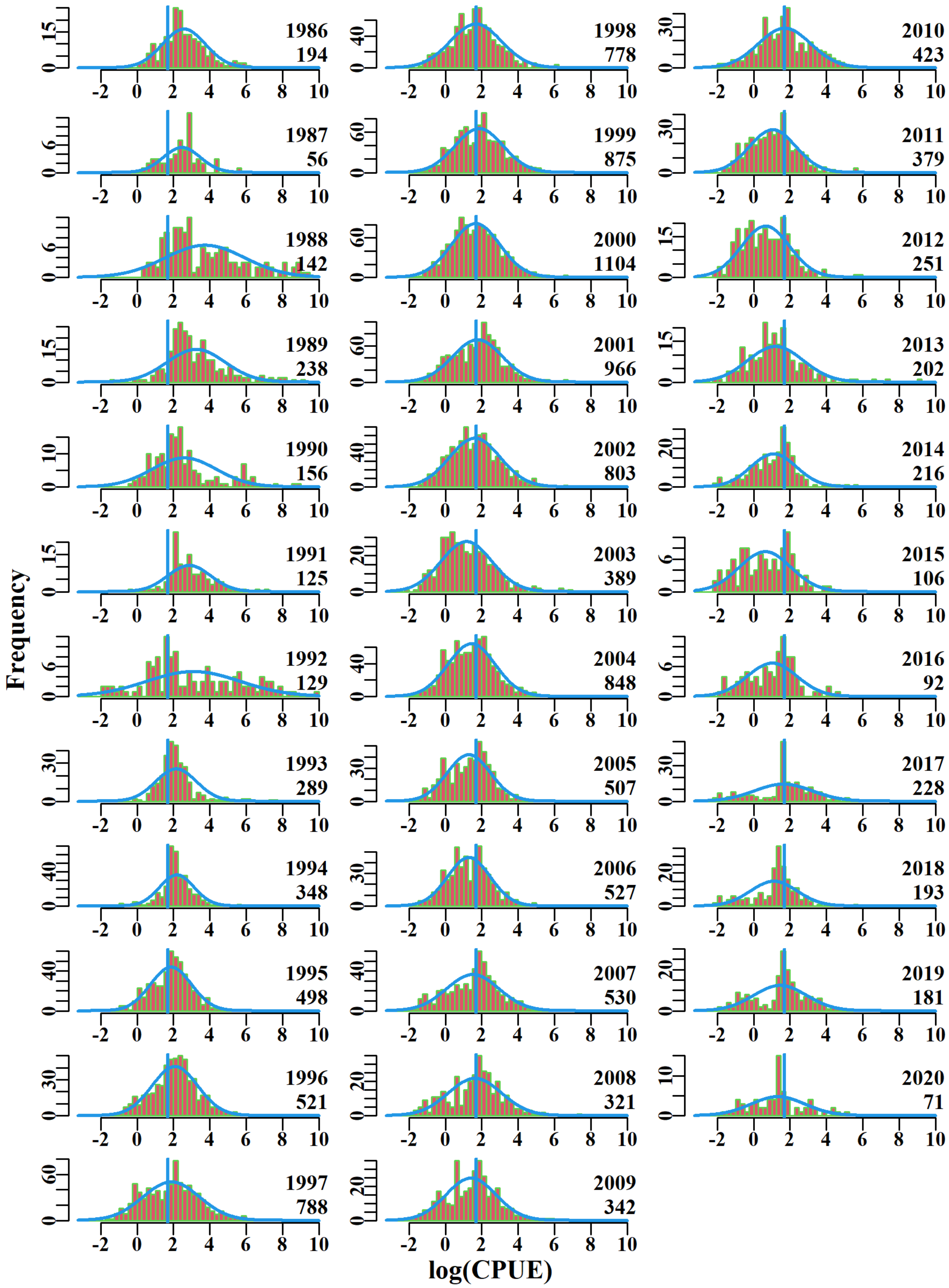

Figure 6.119. BlueEyeTW4050. The natural log(CPUE) for each year of data available the blue lines are normal distributions fitted to the histogram frequencies. The numbers in each plot are the year and number of records.

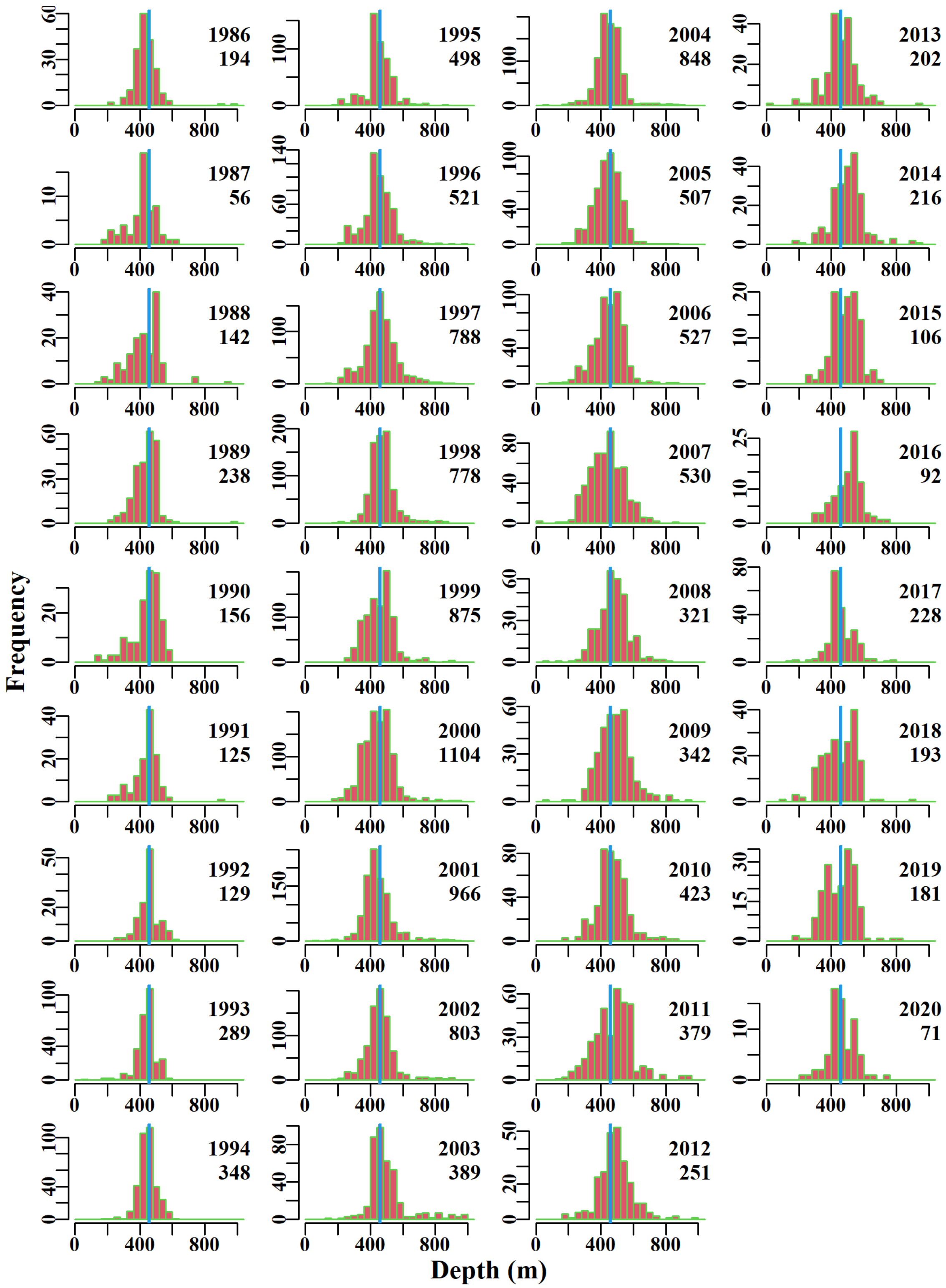

Figure 6.120. BlueEyeTW4050. The average Depth of fishing for each year of data available to illustrate the development of the fishery through time. The numbers in each plot are the year and number of records.

6.20 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, OTB, TMO, in zones 10, 20, 30, 40, 50, 60 and depths 100 to 1000 m within the SET fishery for the years 1986 - 2020 were used in the analysis (Table 6.86).

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.

6.20.1 *Inferences*

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

The terms Year, Vessel, DayNight, DepCat, Zone and Month 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 6.90). The qqplot suggests a slight departure from the assumed Normal distribution as depicted by the upper tail of the distribution (Figure 6.124).

Annual standardized CPUE have been below average between 1993 - 2013, with two apparent cycles, each peaking in 1999 and 2008 respectively. Between 2014 to 2017, these indices were above average and on average in 2018. Also, there has been a consistent increase since 2018 (Figure 6.121).

6.20.2 *Action Items and Issues*

It is recommended that alternate statistical distributions be considered.

Table 6.86. 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, OTB, TMO
years	1986 - 2020

Table 6.87. 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

Year	Total	N	Catch	Vess	GeoM	Opt	StDev	C<30Kg	P<30Kg
1986	1205.6	3189	1183.2	92	141.8	1.5312	0.000	12.995	0.011
1987	1462.5	3561	1434.5	91	135.0	1.9494	0.034	14.597	0.010
1988	1530.1	3952	1469.1	102	129.2	2.1329	0.034	17.925	0.012
1989	1855.2	4303	1812.1	99	151.3	2.1313	0.034	18.000	0.010
1990	1710.8	3520	1468.5	92	149.1	2.1103	0.036	12.473	0.008
1991	2780.7	4244	2334.0	86	206.1	1.5098	0.034	15.704	0.007
1992	1760.8	3232	1505.6	62	178.1	1.2214	0.037	12.483	0.008
1993	1670.0	4190	1615.4	63	125.4	0.9287	0.035	19.071	0.012
1994	1341.2	4469	1306.7	66	94.2	0.8412	0.035	22.544	0.017
1995	1020.1	5059	1012.7	61	58.6	0.5802	0.034	32.505	0.032
1996	1092.7	5352	1054.4	72	56.4	0.5262	0.034	38.052	0.036
1997	1032.0	6175	993.4	73	43.8	0.5464	0.033	45.709	0.046
1998	1488.4	6585	1450.6	65	74.9	0.8818	0.033	41.062	0.028
1999	2113.3	8032	2043.8	65	89.6	0.9257	0.032	47.051	0.023
2000	1768.0	7667	1747.4	74	73.4	0.6643	0.033	49.517	0.028
2001	1062.1	7325	1020.8	60	40.3	0.3828	0.033	56.149	0.055
2002	1151.4	6331	1124.3	57	54.9	0.3794	0.034	40.900	0.036
2003	707.8	5652	667.5	56	33.7	0.3171	0.034	36.211	0.054
2004	1444.4	6362	1198.8	56	56.1	0.5326	0.034	23.385	0.020
2005	1626.7	5283	1164.8	54	65.9	0.6428	0.034	18.083	0.016
2006	1486.5	4317	1292.9	42	84.6	0.8564	0.036	11.037	0.009
2007	1312.0	3619	1193.3	27	86.6	0.7622	0.037	10.146	0.009
2008	1312.5	3365	1254.7	26	110.9	0.8386	0.037	8.968	0.007
2009	1151.2	3389	1112.8	23	89.2	0.7778	0.037	9.648	0.009
2010	1167.6	3266	1130.8	25	81.9	0.7805	0.037	8.044	0.007
2011	923.1	3907	882.3	26	49.4	0.6370	0.036	9.375	0.011
2012	645.7	3116	602.4	29	41.6	0.5080	0.038	9.802	0.016
2013	774.5	3031	733.8	26	58.0	0.9059	0.038	7.204	0.010
2014	994.1	3038	921.3	28	78.6	1.0920	0.038	6.127	0.007
2015	1070.1	2964	1047.1	29	105.3	1.1867	0.038	8.165	0.008
2016	981.4	2527	964.8	24	111.0	1.0000	0.040	5.583	0.006
2017	1279.9	2953	1240.6	24	116.8	1.1183	0.039	4.753	0.004
2018	1087.2	2838	1055.1	23	99.6	0.8990	0.039	5.080	0.005
2019	1442.7	2984	1371.7	22	134.8	1.1917	0.039	4.240	0.003
2020	1540.8	2644	1364.5	22	136.7	1.7107	0.040	2.210	0.002

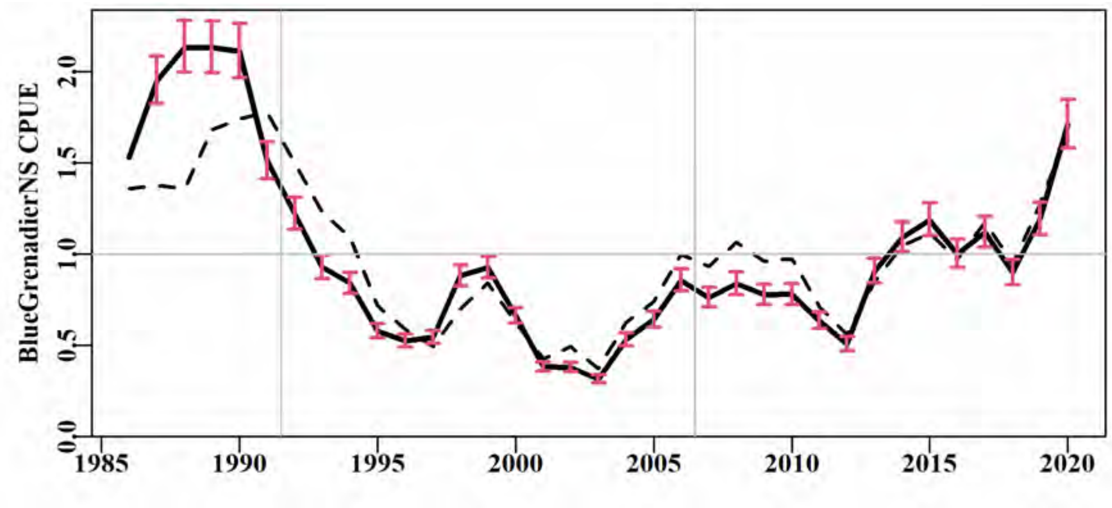

Figure 6.121. BlueGrenadierNS standardization. The dashed black line represents the geometric mean CPUE, solid black line the standardized CPUE. The red bars are the 95% confidence intervals about the mean estimates. The graph scales both time-series of standardized CPUE relative to the mean of each time-series.

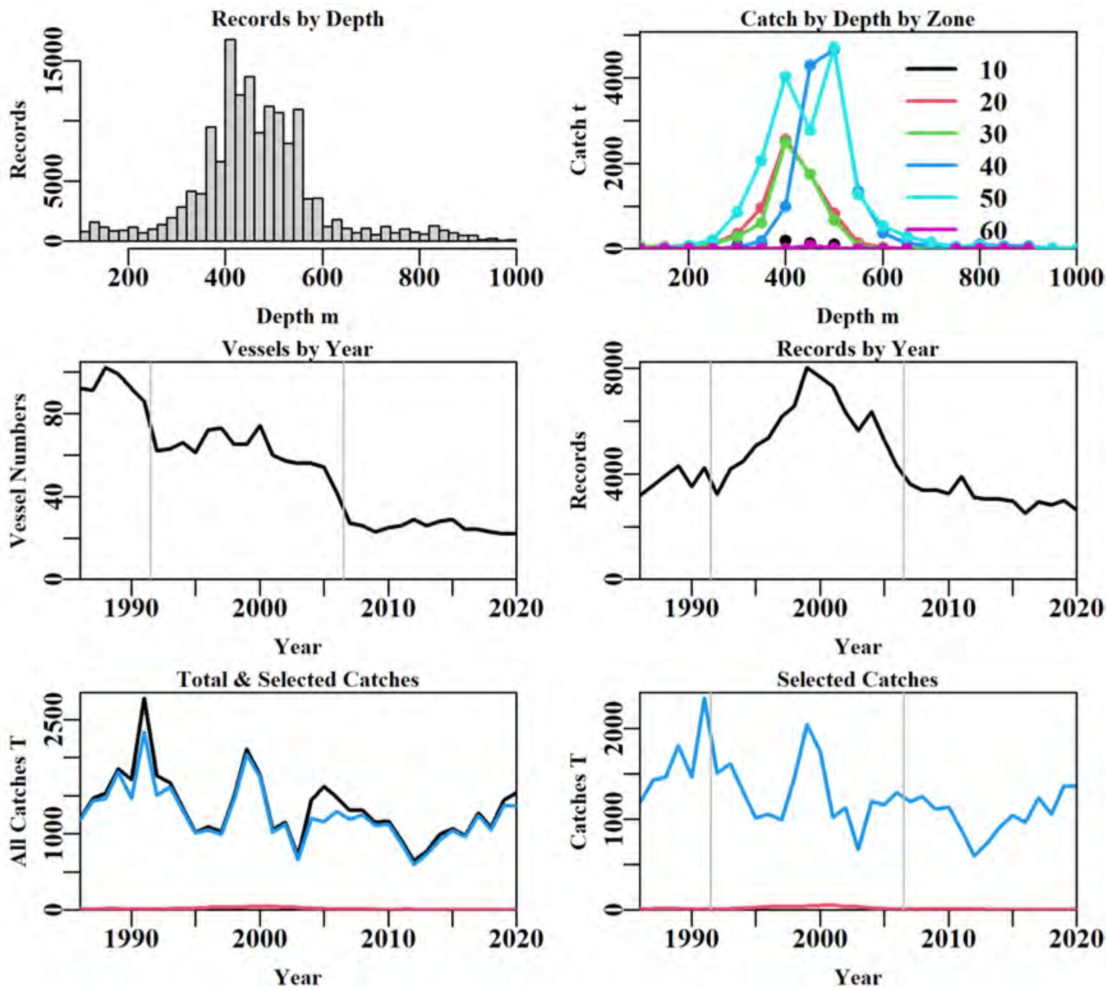

Figure 6.122. BlueGrenadierNS fishery details. The bottom left plot depicts all known catches (top black line), and all selected catches used in the analysis (middle blue line); the lower red line: selected catches < 30 kg).

Table 6.88. 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	178364	162050	160404	158793	154580	152559	152441
Difference	0	16314	1646	1611	4213	2021	118
Catch	47568	46945	46431	45857	44292	43795	43776
Difference	0	623	514	574	1565	498	19

Table 6.89. 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 6.90. 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

Term	AIC	RSS	MSS	Nobs	Npars	adj_r2	%Change
Year	140401	382734	27458	152441	35	6.7	0
Vessel	115745	324719	85472	152441	236	20.7	14.04
DayNight	105616	303831	106360	152441	239	25.8	5.10
DepCat	95998	285188	125004	152441	257	30.4	4.54
Zone	91036	276036	134156	152441	262	32.6	2.23
Month	86447	267810	142382	152441	273	34.6	2.00
Zone:DepCat	84819	264675	145517	152441	357	35.3	0.73
Zone:Month	82930	261525	148667	152441	325	36.1	1.51

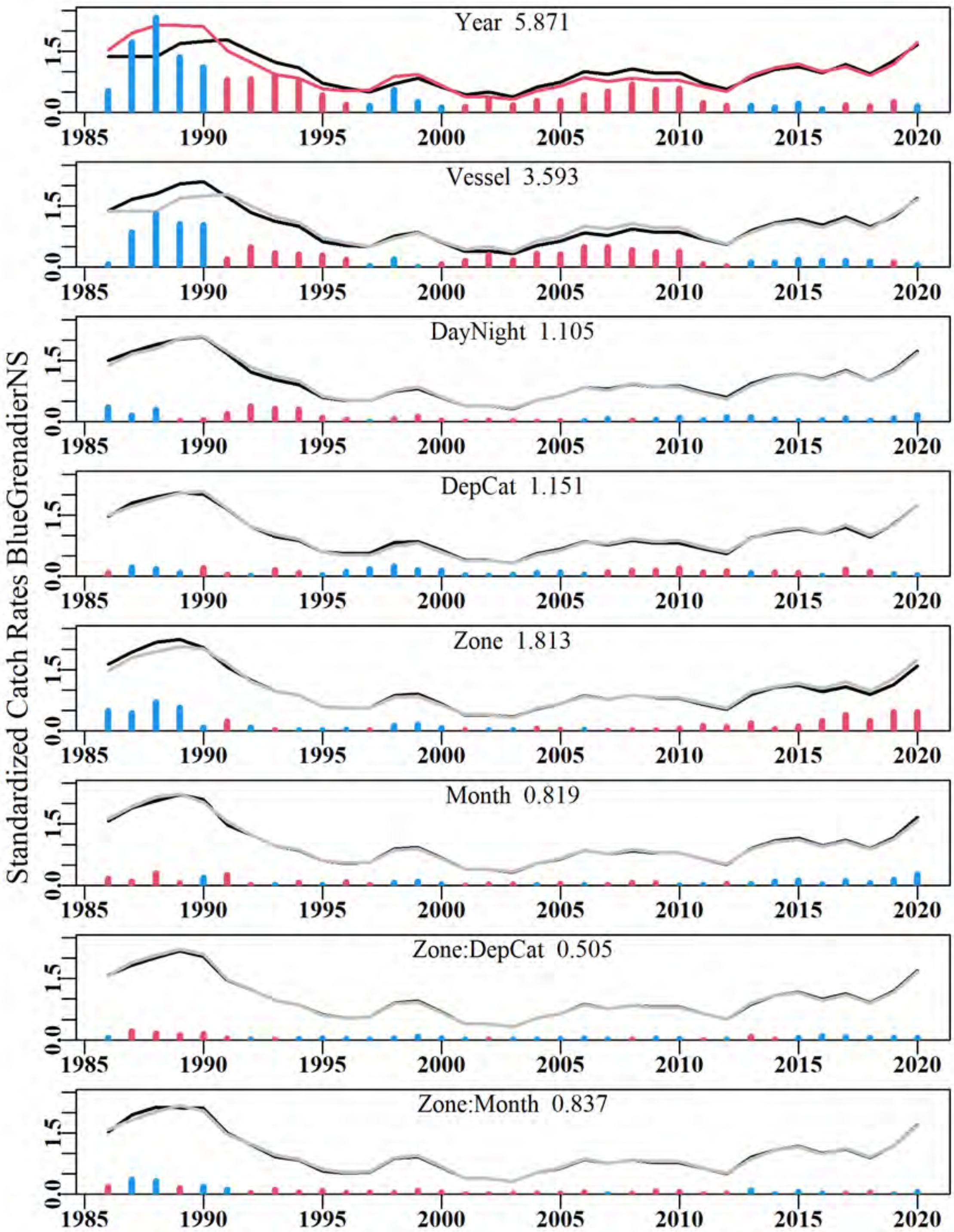

Figure 6.123. BlueGrenadierNS. The influence of each factor on the optimal standardization. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by vertical bars with blue bars indicating the optimum model is higher than the 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.

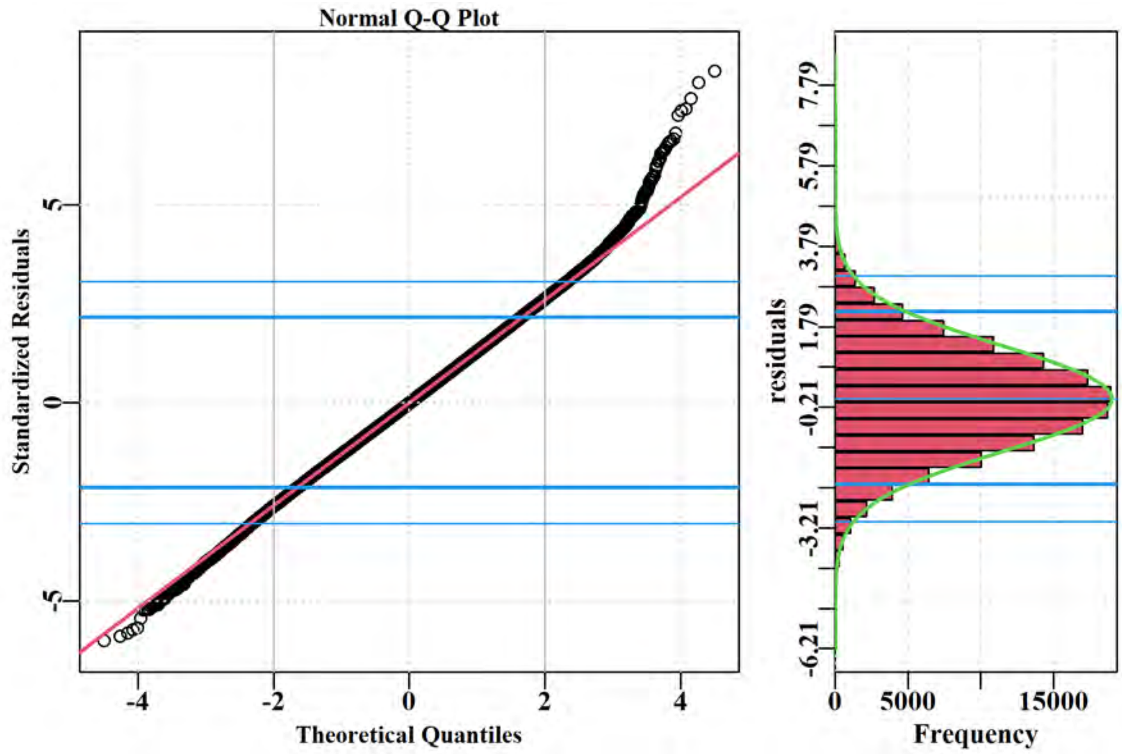

Figure 6.124. BlueGrenadierNS. diagnostic plots. The distribution of residuals from the optimum fit. The qqplot indicates the fit to the expected normality, while the histogram of residuals illustrates the 90% quantiles to indicate the intensity of any lack of fit at the margins of the distribution.

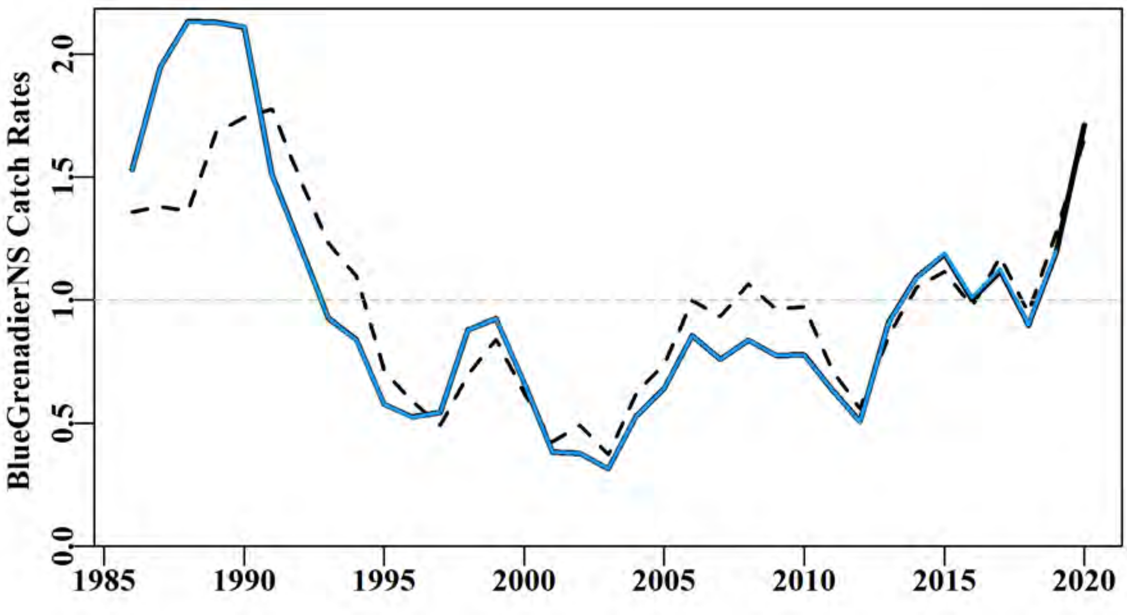

Figure 6.125. BlueGrenadierNS. A comparison of the previous year's standardization (blue line) with this year's. They should lie on top of each other, although small deviations may relate to data adjustments, particularly in very recent years.

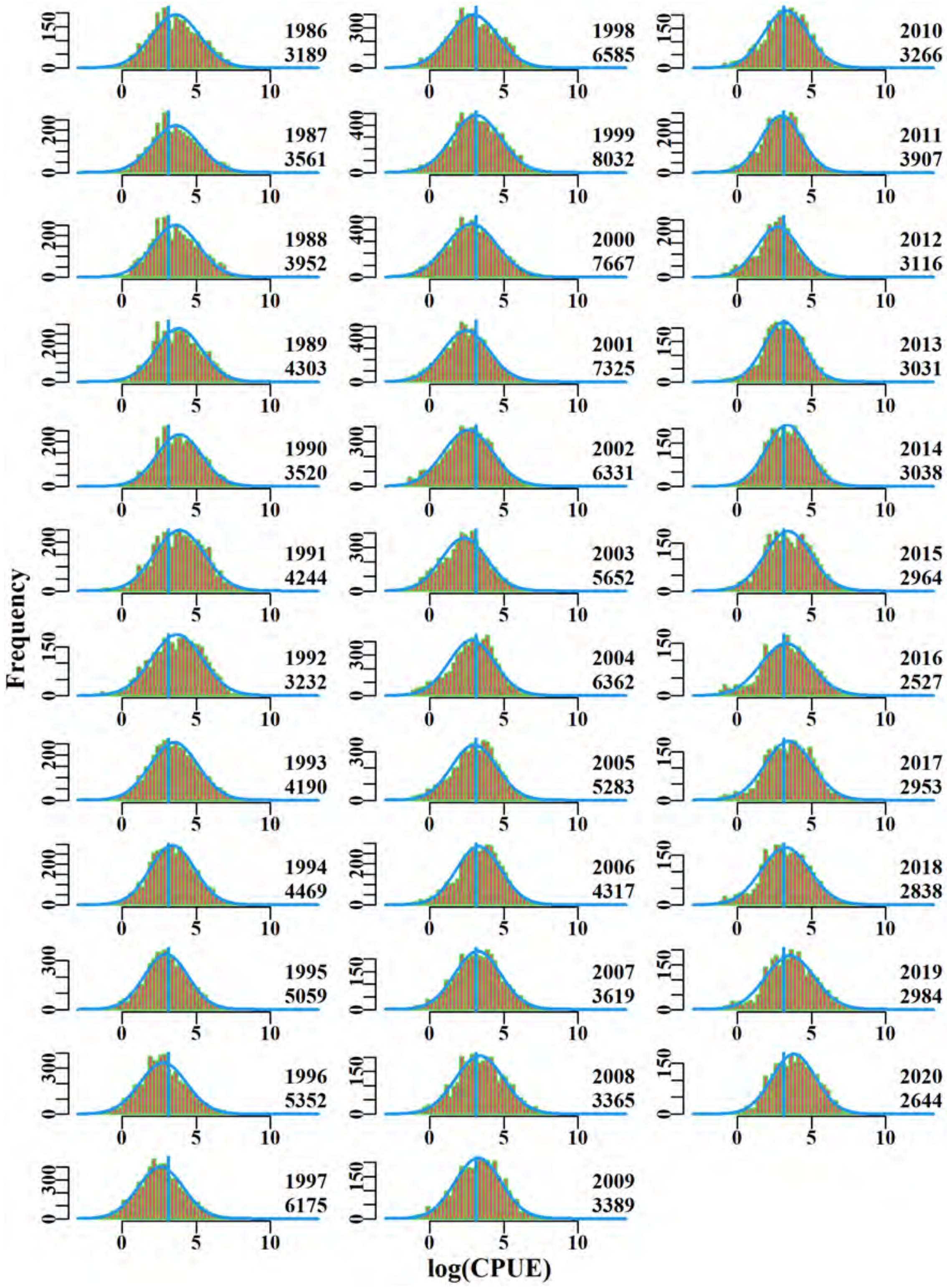

Figure 6.126. BlueGrenadierNS. The natural log(CPUE) for each year of data available the blue lines are normal distributions fitted to the histogram frequencies. The numbers in each plot are the year and number of records.

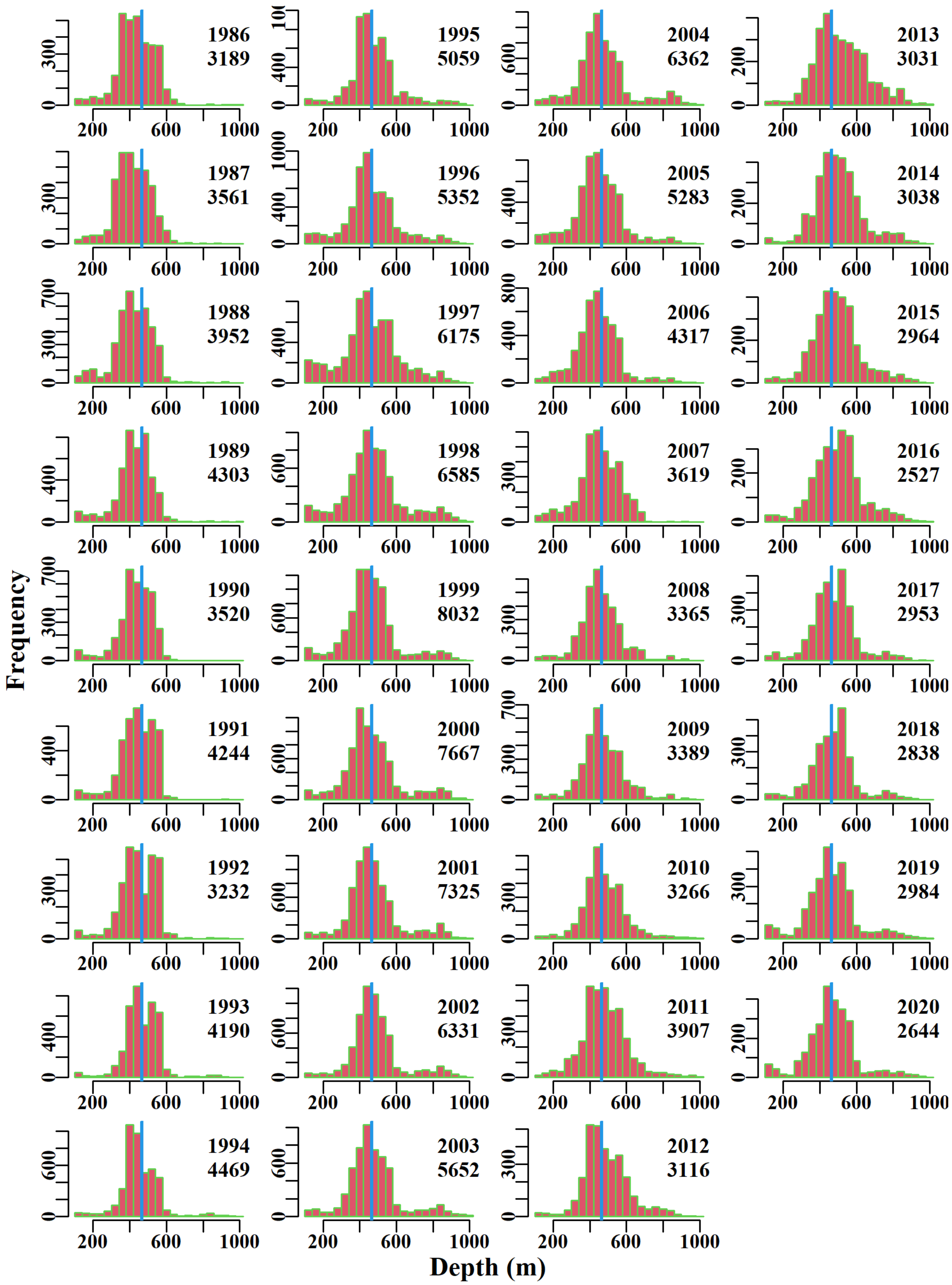

Figure 6.127. BlueGrenadierNS. The average Depth of fishing for each year of data available to illustrate the development of the fishery through time. The numbers in each plot are the year and number of records.

6.21 Pink Ling TW 10 – 30

Pink Ling (LIG – 37228002 –*Genypterus blacodes*) was one of the 16 species first included in the quota system in 1992, which reflects its long history within the SESSF. Pink Ling caught by trawl based on methods TW, TDO, TMO, OTB, in zones 10, 20, 30, and depths 250 to 600 m within the SET fishery for the years 1986 - 2020 were used in the analysis (Table 6.91). 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.

6.21.1 *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 6.95). The qqplot suggests a departure from the assumed Normal distribution as depicted by both tails of the distribution (Figure 6.131).

Annual standardized CPUE has been below average corresponding to a relatively flat trend over the 2001-19 period, with the most recent estimate exceeding the long-term average, based on 95% confidence intervals (Figure 6.128). More recently, CPUE has increased since 2015. The structural adjustment had a major effect upon the influence of the vessel factor from 2006 or 2007 onwards.

6.21.2 *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 6.91. 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, TMO, OTB
years	1986 - 2020

Table 6.92. 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

Year	Total	N	Catch	Vess	GeoM	Opt	StDev	C<30Kg	P<30Kg
1986	679.1	4512	498.3	80	44.9	1.1586	0.000	24.955	0.050
1987	765.1	4251	491.4	77	46.0	1.2241	0.022	22.694	0.046
1988	583.1	3603	398.3	77	40.5	1.1768	0.024	17.925	0.045
1989	678.9	3870	421.3	76	39.9	1.0190	0.023	20.150	0.048
1990	674.5	2768	411.6	67	52.7	1.4684	0.026	11.056	0.027
1991	736.8	2903	366.0	71	46.2	1.4371	0.026	13.338	0.036
1992	568.3	2417	329.4	58	45.9	1.1293	0.027	11.224	0.034
1993	892.8	3471	500.7	58	50.3	1.0817	0.025	16.847	0.034
1994	895.4	4036	468.4	62	42.7	1.1053	0.024	21.041	0.045
1995	1208.9	4346	585.6	57	49.3	1.3805	0.023	21.920	0.037
1996	1233.4	4254	666.7	63	56.2	1.3756	0.023	17.576	0.026
1997	1696.8	4772	730.9	61	52.0	1.4001	0.023	19.670	0.027
1998	1592.4	4883	728.3	56	53.1	1.3879	0.023	22.477	0.031
1999	1651.6	5934	831.1	59	48.8	1.2635	0.022	27.979	0.034
2000	1507.5	5100	658.8	62	46.3	1.1067	0.023	24.500	0.037
2001	1393.0	4555	484.9	52	38.0	0.8656	0.024	24.294	0.050
2002	1330.3	3882	360.3	52	35.2	0.7576	0.025	22.555	0.063
2003	1353.3	4278	444.4	57	38.6	0.7918	0.024	19.522	0.044
2004	1522.9	3328	345.6	54	37.1	0.7093	0.026	14.208	0.041
2005	1204.6	3370	324.5	51	32.6	0.6614	0.026	13.679	0.042
2006	1069.2	2566	321.1	38	42.1	0.7949	0.027	6.841	0.021
2007	876.0	1628	202.8	23	42.0	0.7563	0.032	4.517	0.022
2008	980.3	2342	325.4	24	46.7	0.9001	0.029	5.268	0.016
2009	775.0	1886	208.3	27	34.7	0.6467	0.030	5.024	0.024
2010	906.2	1923	265.5	23	47.0	0.8004	0.030	4.976	0.019
2011	1081.9	2122	287.3	22	46.7	0.8423	0.029	4.720	0.016
2012	1030.9	1919	268.1	24	49.5	0.9000	0.030	4.917	0.018
2013	752.9	1565	184.8	22	40.8	0.7458	0.032	4.498	0.024
2014	861.2	1642	234.9	24	49.1	0.8362	0.032	5.039	0.021
2015	722.1	1650	188.9	24	41.1	0.7233	0.032	5.273	0.028
2016	736.0	1515	192.7	25	42.0	0.7400	0.033	4.896	0.025
2017	896.7	1862	276.1	22	53.4	0.8711	0.031	5.064	0.018
2018	874.0	1603	226.6	20	48.3	0.8953	0.032	3.764	0.017
2019	799.2	1718	227.9	19	49.8	0.9685	0.032	4.393	0.019
2020	801.4	1324	201.1	17	56.1	1.0787	0.034	2.263	0.011

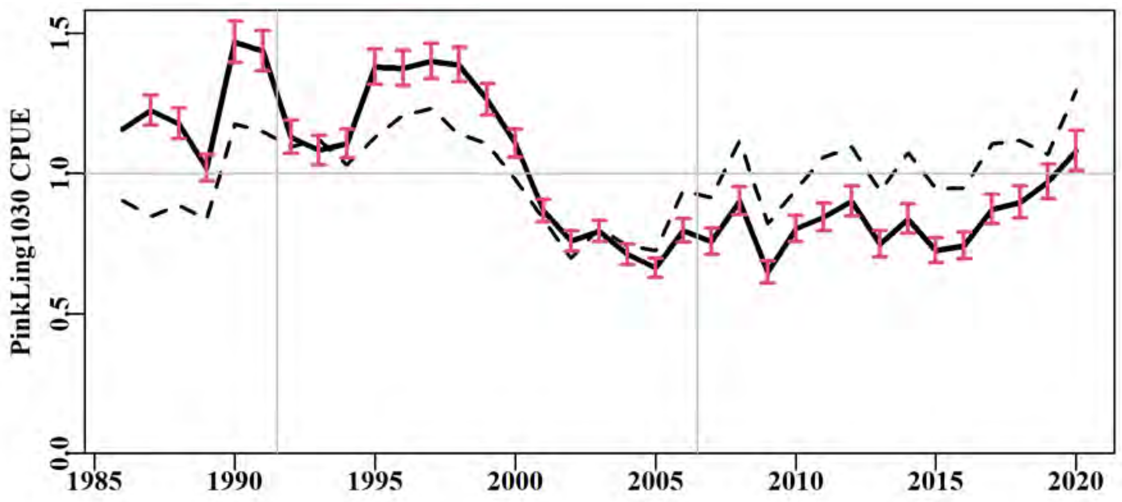

Figure 6.128. PinkLing1030 standardization. The dashed black line represents the geometric mean CPUE, solid black line the standardized CPUE. The red bars are the 95% confidence intervals about the mean estimates. The graph scales both time-series of standardized CPUE relative to the mean of each time-series.

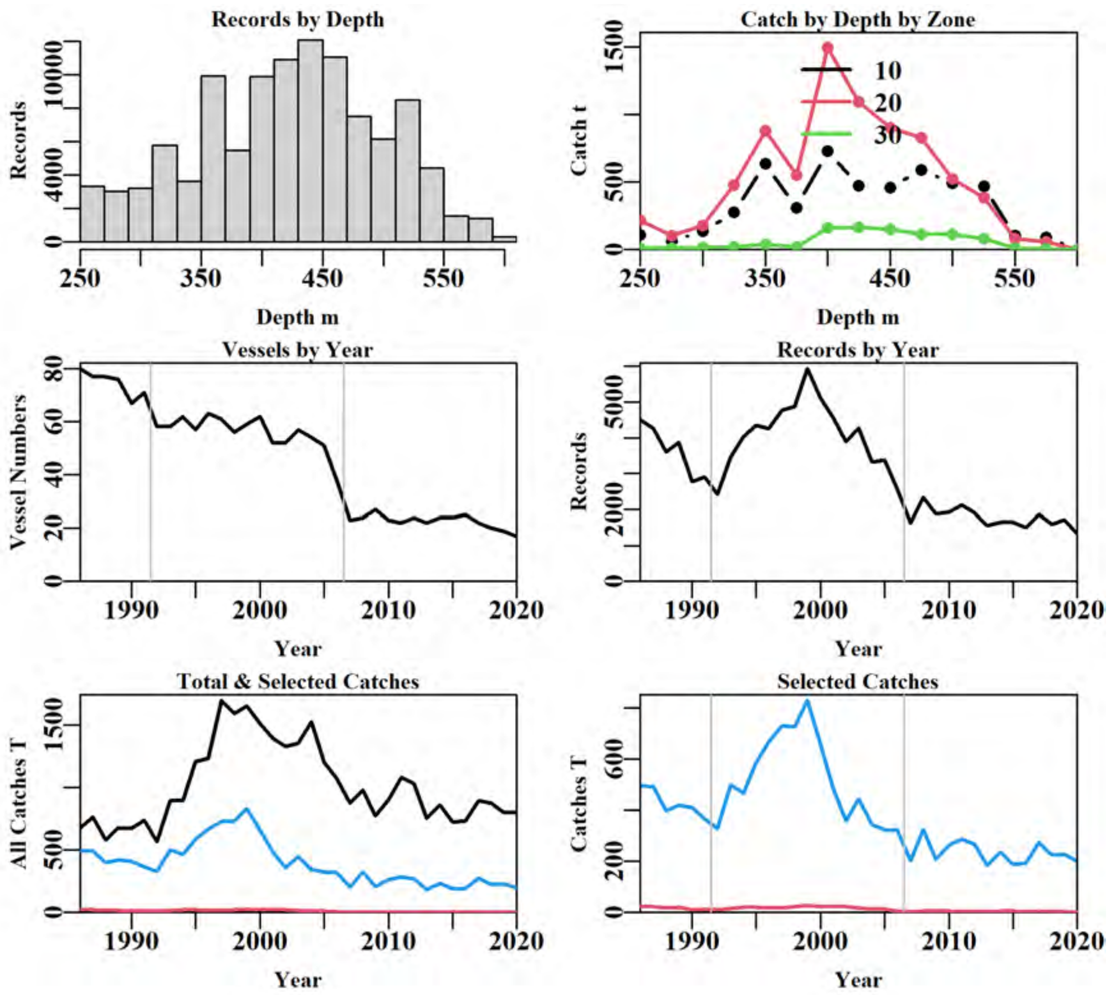

Figure 6.129. PinkLing1030 fishery details. The bottom left plot depicts all known catches (top black line), and all selected catches used in the analysis (middle blue line); the lower red line: selected catches < 30 kg).

Table 6.93. 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	323807	295660	197583	195437	110197	107840	107798
Difference	0	28147	98077	2146	85240	2357	42
Catch	35666	28511	25086	24778	14145	13667	13658
Difference	0	7156	3425	308	10633	478	9

Table 6.94. 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 6.95. 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

Term	AIC	RSS	MSS	Nobs	Npars	adj_r2	%Change
Year	34833	148820	2895	107798	35	1.9	0
Vessel	16808	125471	26244	107798	221	17.1	15.25
DepCat	5974	113445	38270	107798	235	25.1	7.93
Month	2036	109354	42362	107798	246	27.8	2.70
Zone	1473	108779	42936	107798	248	28.1	0.38
DayNight	1285	108584	43131	107798	251	28.3	0.13
Zone:DepCat	0	107242	44474	107798	279	29.1	0.87
Zone:Month	207	107460	44255	107798	273	29.0	0.73

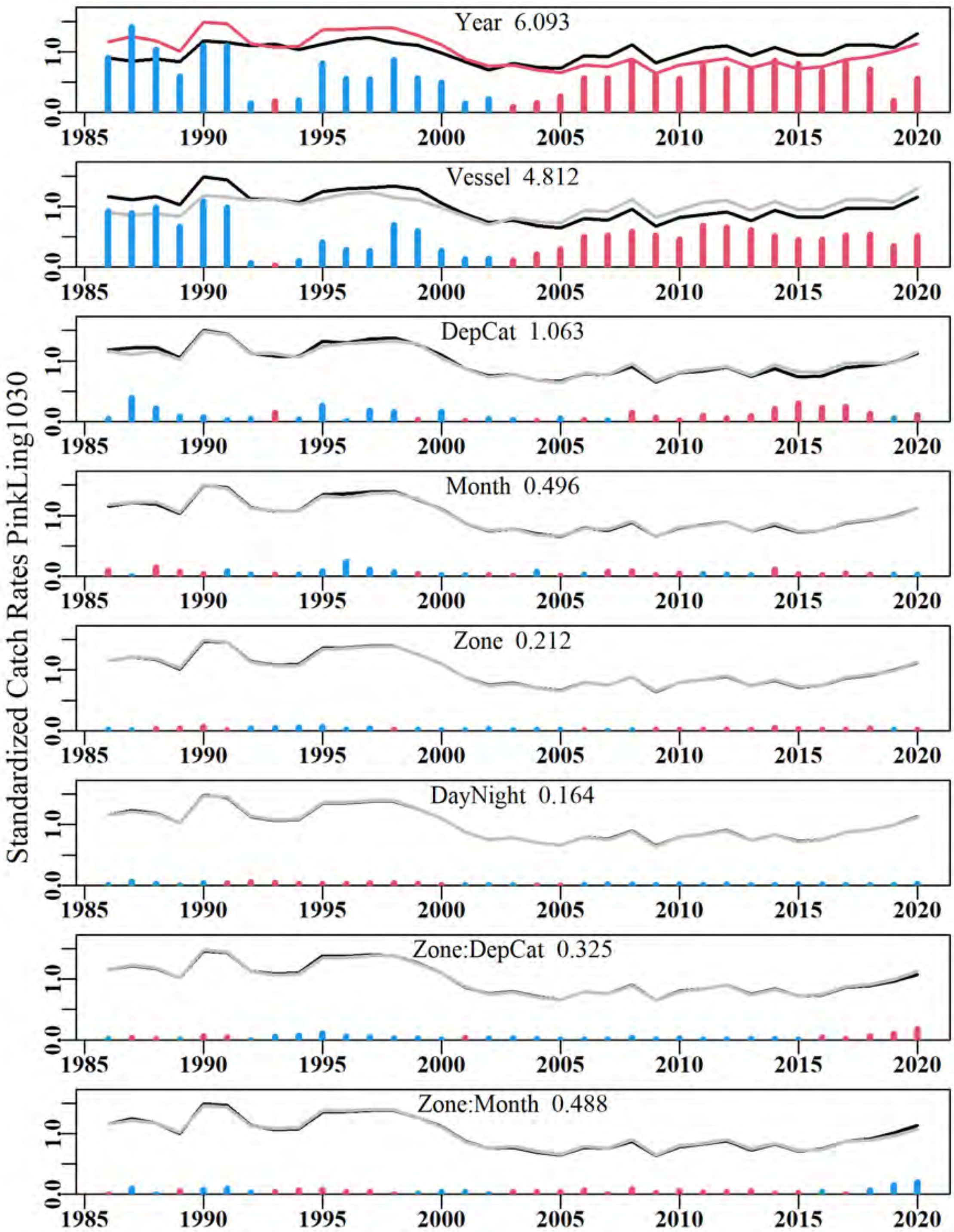

Figure 6.130. PinkLing1030. The influence of each factor on the optimal standardization. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by vertical bars with blue bars indicating the optimum model is higher than the geometric 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.

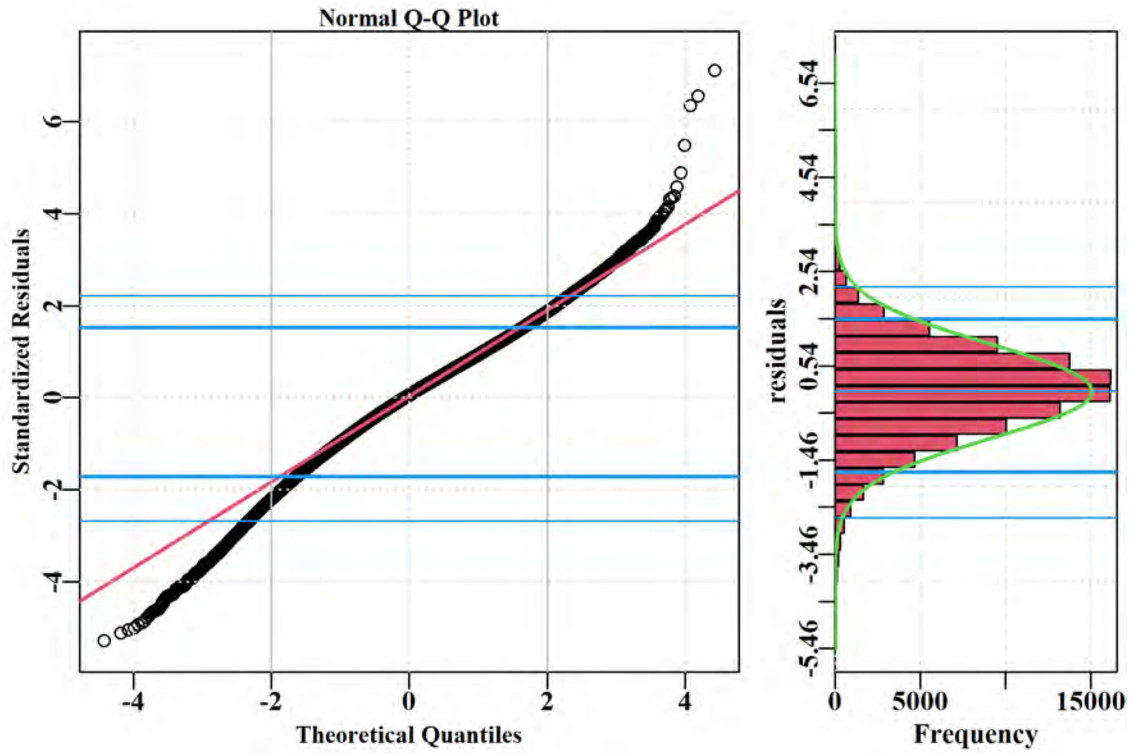

Figure 6.131. PinkLing1030. diagnostic plots. The distribution of residuals from the optimum fit. The qqplot indicates the fit to the expected normality, while the histogram of residuals illustrates the 90% quantiles to indicate the intensity of any lack of fit at the margins of the distribution.

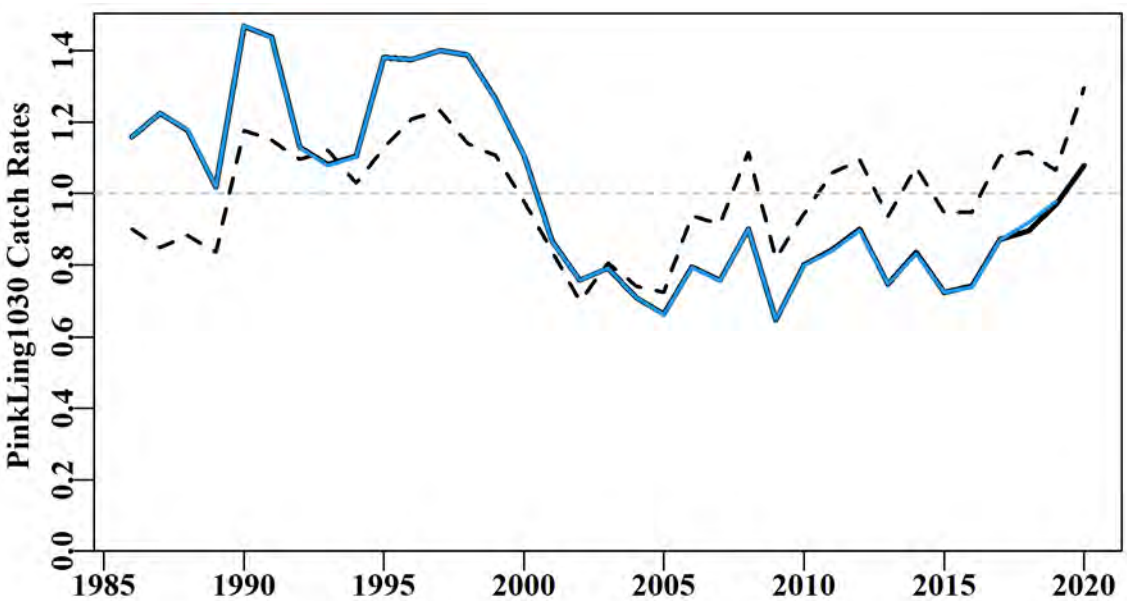

Figure 6.132. PinkLing1030. A comparison of the previous year's standardization (blue line) with this year's. They should lie on top of each other, although small deviations may relate to data adjustments, particularly in very recent years.

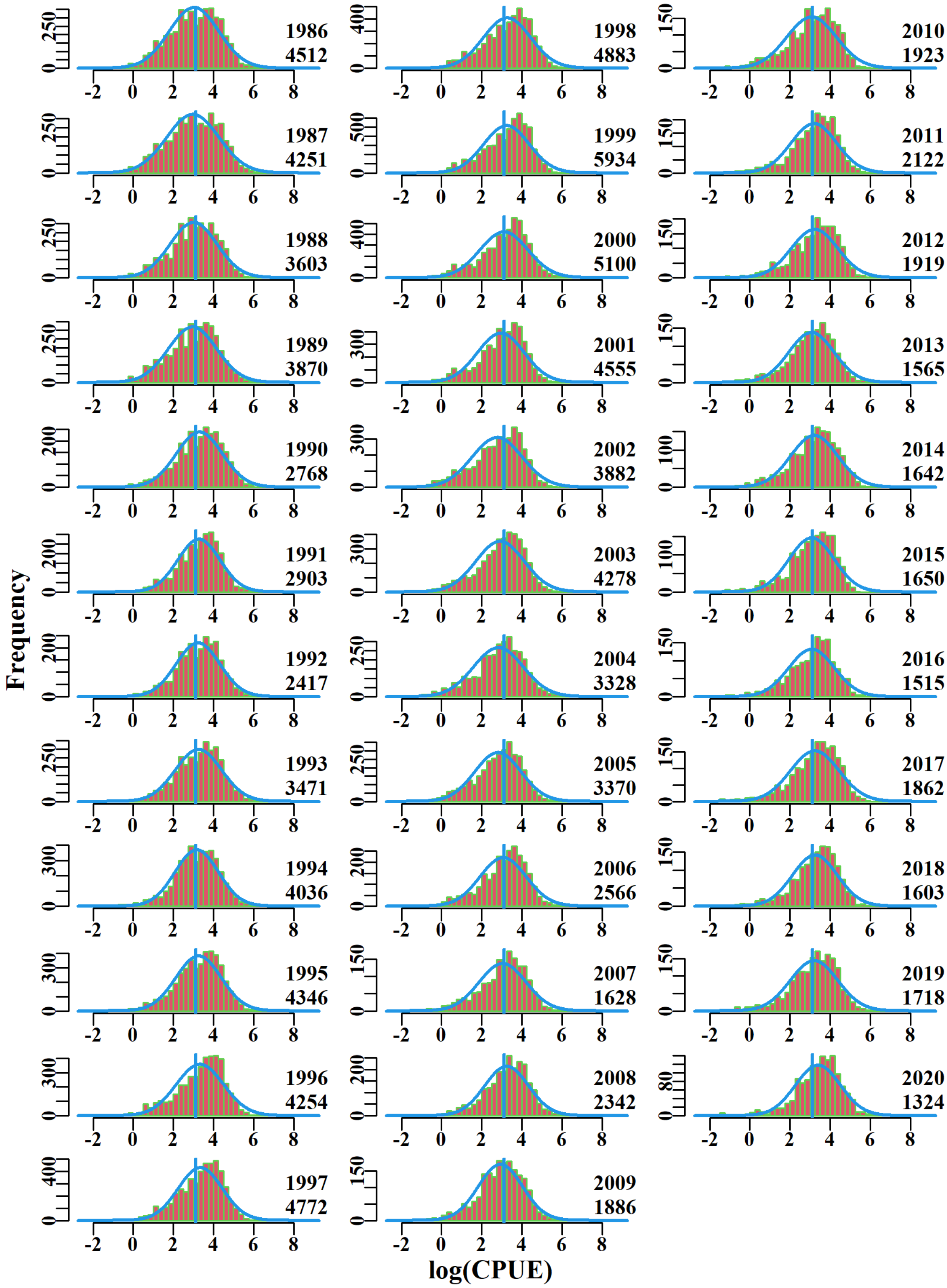

Figure 6.133. PinkLing1030. The natural log(CPUE) for each year of data available the blue lines are normal distributions fitted to the histogram frequencies. The numbers in each plot are the year and number of records.

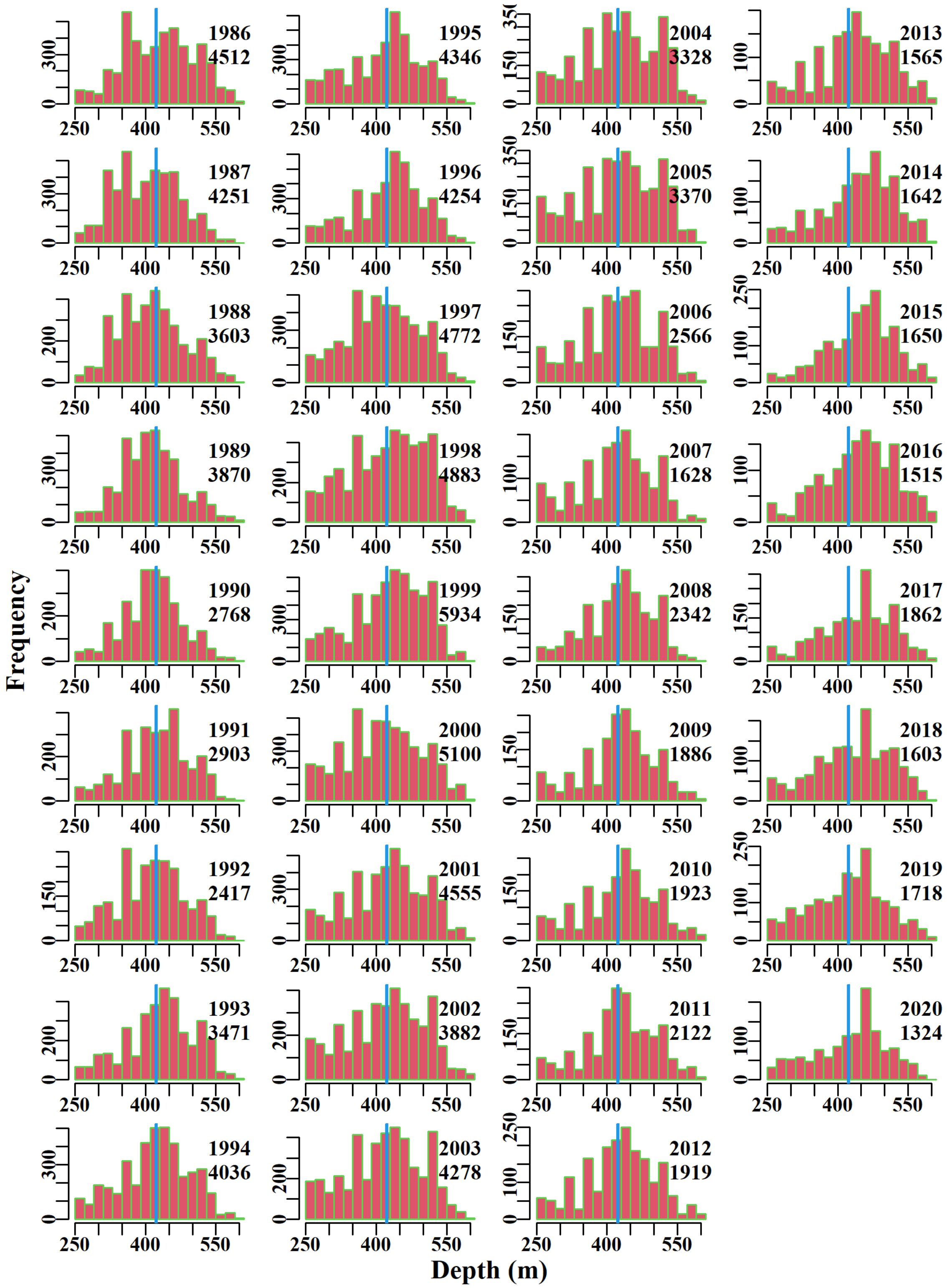

Figure 6.134. PinkLing1030. The average Depth of fishing for each year of data available to illustrate the development of the fishery through time. The numbers in each plot are the year and number of records.

6.22 Pink Ling TW 40 50

Pink Ling (LIG – 37228002 – *Genypterus blacodes*) was one of the 16 species first included in the quota system in 1992. Pink Ling based on methods TW, TDO, TMO, OTB, in zones 40, 50, and depths 200 to 800 m within the SET fishery for the years 1986 - 2020 were used in the analysis (Table 6.96).

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.

6.22.1 *Inferences*

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

The terms Year, DepCat, Vessel, Month, Zone 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 6.100). The qqplot suggests a departure from the assumed Normal distribution as depicted by both tails of the distribution (Figure 6.138).

Annual standardized CPUE reached to a minimum in 2005 and increased since then to the long-term average from 2013 to 2016, increased to above average in 2017 to 2018, decreased to the long-term average in 2019 and then increased above the long-term average in 2020 based on the 95% confidence intervals (Figure 6.135). Also, there has been an overall increase in CPUE since 2005 (i.e., the lowest CPUE index).

6.22.2 *Action Items and Issues*

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

Table 6.96. 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, TMO, OTB
years	1986 - 2020

Table 6.97. 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

Year	Total	N	Catch	Vess	GeoM	Opt	StDev	C<30Kg	P<30Kg
1986	679.1	1265	112.9	23	27.8	1.1716	0.000	6.366	0.056
1987	765.1	1306	205.7	28	52.0	1.3242	0.037	5.740	0.028
1988	583.1	1025	95.5	32	28.0	1.0326	0.040	6.722	0.070
1989	678.9	1466	182.8	34	36.2	1.0600	0.038	8.690	0.048
1990	674.5	1483	135.2	32	26.7	0.9525	0.038	11.943	0.088
1991	736.8	1874	194.8	37	25.6	1.0193	0.037	11.915	0.061
1992	568.3	1629	101.9	24	17.0	0.7592	0.038	12.661	0.124
1993	892.8	2249	235.2	24	26.6	1.0265	0.036	15.744	0.067
1994	895.4	2096	246.1	24	30.8	1.2534	0.036	12.093	0.049
1995	1208.9	3504	425.5	25	31.9	1.2987	0.034	21.955	0.052
1996	1233.4	3385	446.1	26	33.1	1.3640	0.034	22.301	0.050
1997	1696.8	3716	572.2	24	37.2	1.4303	0.034	21.065	0.037
1998	1592.4	3705	555.3	21	38.2	1.4152	0.034	19.120	0.034
1999	1651.6	3784	426.2	24	30.4	1.1172	0.034	23.836	0.056
2000	1507.5	4642	508.4	31	28.6	0.9737	0.034	31.181	0.061
2001	1393.0	5084	500.3	28	24.5	0.8635	0.034	36.867	0.074
2002	1330.3	4619	428.9	27	21.5	0.7474	0.034	36.499	0.085
2003	1353.3	3807	358.5	27	20.5	0.7517	0.034	26.224	0.073
2004	1522.9	3880	302.7	25	17.7	0.7059	0.034	17.723	0.059
2005	1204.6	2651	195.0	23	15.6	0.5885	0.036	11.283	0.058
2006	1069.2	2298	207.9	21	17.9	0.6217	0.036	6.710	0.032
2007	876.0	2505	284.5	16	21.7	0.6822	0.036	7.621	0.027
2008	980.3	1777	211.8	17	24.5	0.8776	0.037	4.357	0.021
2009	775.0	1956	258.3	13	24.6	0.8519	0.037	4.144	0.016
2010	906.2	2316	268.9	14	20.9	0.8318	0.036	4.801	0.018
2011	1081.9	2772	355.3	16	21.6	0.8312	0.035	5.216	0.015
2012	1030.9	2264	333.0	14	25.8	0.8783	0.036	4.383	0.013
2013	752.9	1757	278.2	17	27.9	0.9829	0.038	3.547	0.013
2014	861.2	1944	284.6	15	24.8	0.9624	0.037	3.547	0.012
2015	722.1	1639	238.6	13	25.1	0.9428	0.038	2.734	0.011
2016	736.0	1582	232.0	13	27.5	1.0312	0.038	3.653	0.016
2017	896.7	1768	294.1	12	28.7	1.2011	0.038	1.999	0.007
2018	874.0	1689	318.4	12	31.3	1.1449	0.038	1.716	0.005
2019	799.2	1538	238.1	13	24.8	1.0694	0.039	2.556	0.011
2020	801.4	1436	254.1	12	29.7	1.2352	0.039	3.076	0.012

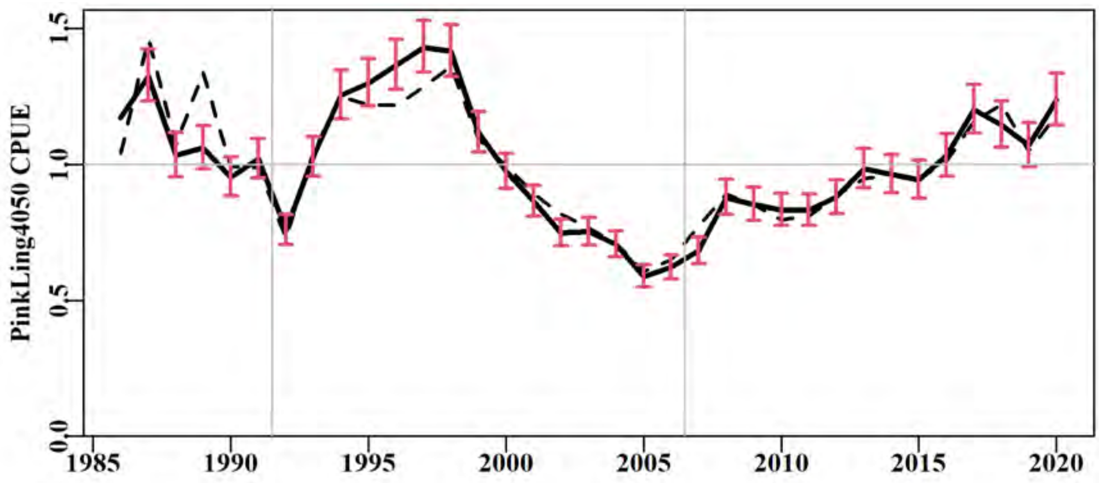

Figure 6.135. PinkLing4050 standardization. The dashed black line represents the geometric mean CPUE, solid black line the standardized CPUE. The red bars are the 95% confidence intervals about the mean estimates. The graph scales both time-series of standardized CPUE relative to the mean of each time-series.

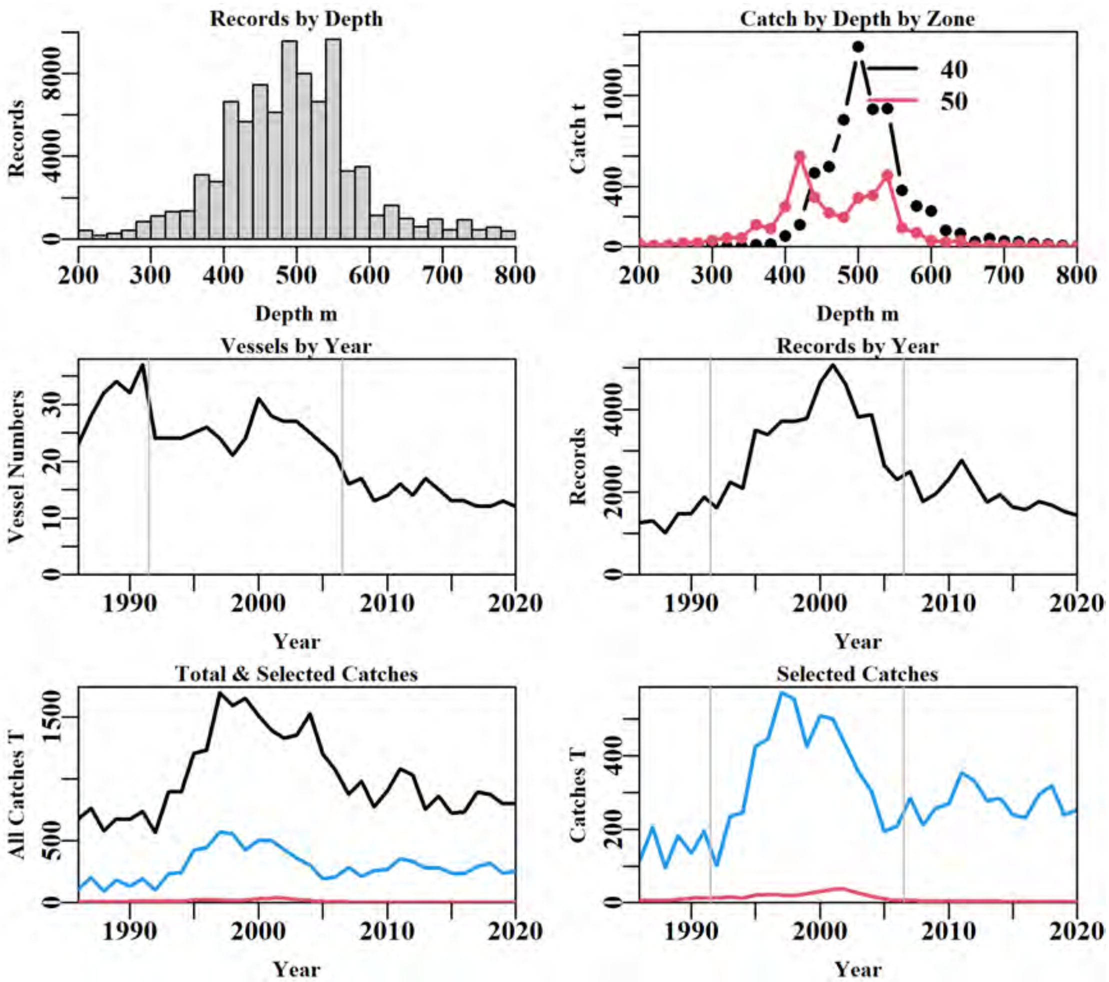

Figure 6.136. PinkLing4050 fishery details. The bottom left plot depicts all known catches (top black line), and all selected catches used in the analysis (middle blue line); the lower red line: selected catches < 30 kg).

Table 6.98. 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	323807	295660	219066	216762	87726	86495	86411
Difference	0	28147	76594	2304	129036	1231	84
Catch	35666	28511	26625	26301	10896	10291	10287
Difference	0	7156	1885	324	15405	605	5

Table 6.99. 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 6.100. 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

Term	AIC	RSS	MSS	Nobs	Npars	adj_r2	%Change
Year	-1133	85216	4103	86411	35	4.6	0
DepCat	-13898	73462	15857	86411	65	17.7	13.14
Vessel	-20863	67614	21705	86410	166	24.2	6.46
Month	-23882	65276	24043	86410	177	26.8	2.61
Zone	-25034	64410	24909	86410	178	27.7	0.97
DayNight	-25079	64372	24947	86410	181	27.8	0.04
Zone:DepCat	-25990	63653	25667	86410	211	28.6	0.78
Zone:Month	-26753	63121	26198	86410	192	29.2	1.39

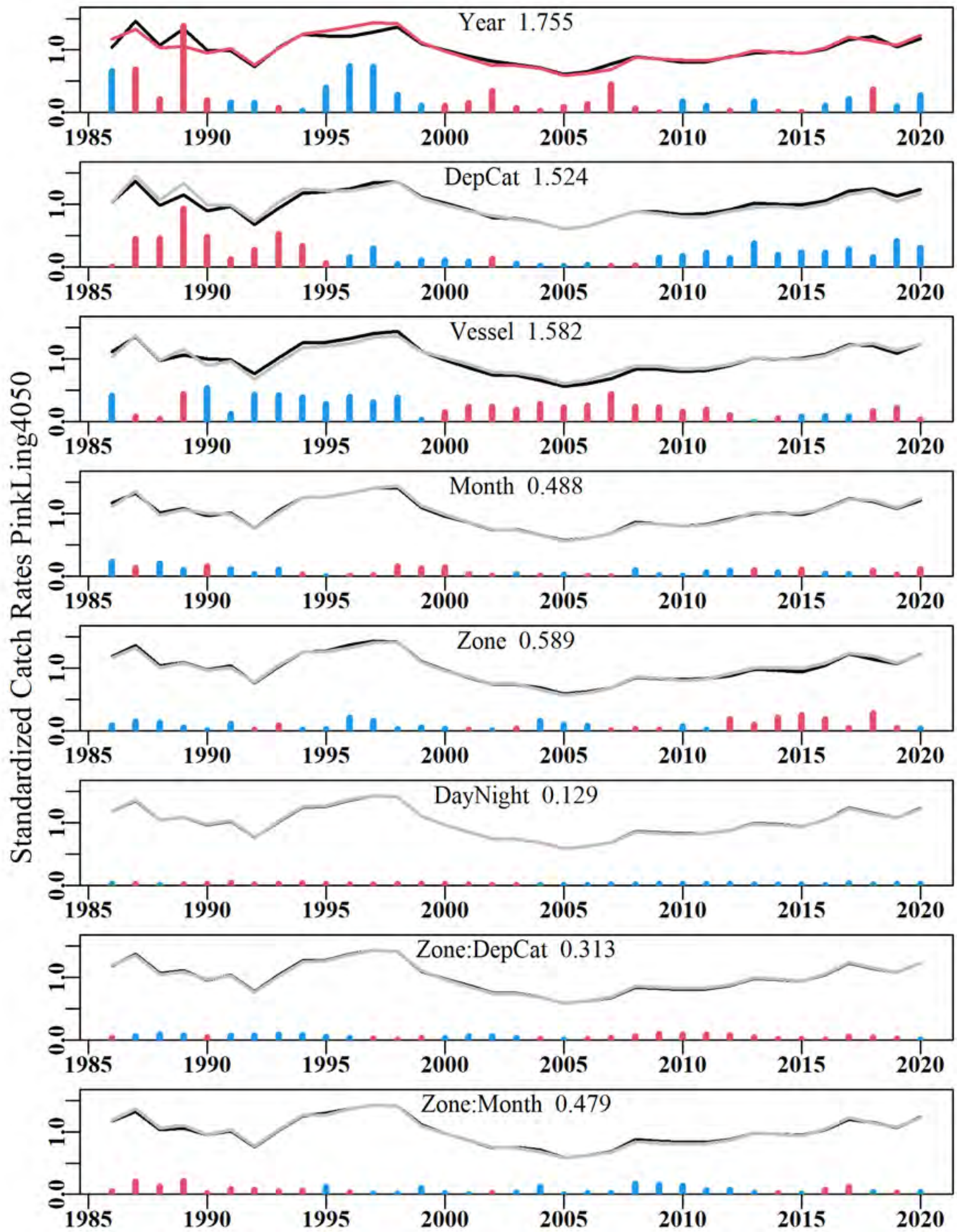

Figure 6.137. PinkLing4050. The influence of each factor on the optimal standardization. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by vertical bars with blue bars indicating the optimum model is higher than the geometric 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.

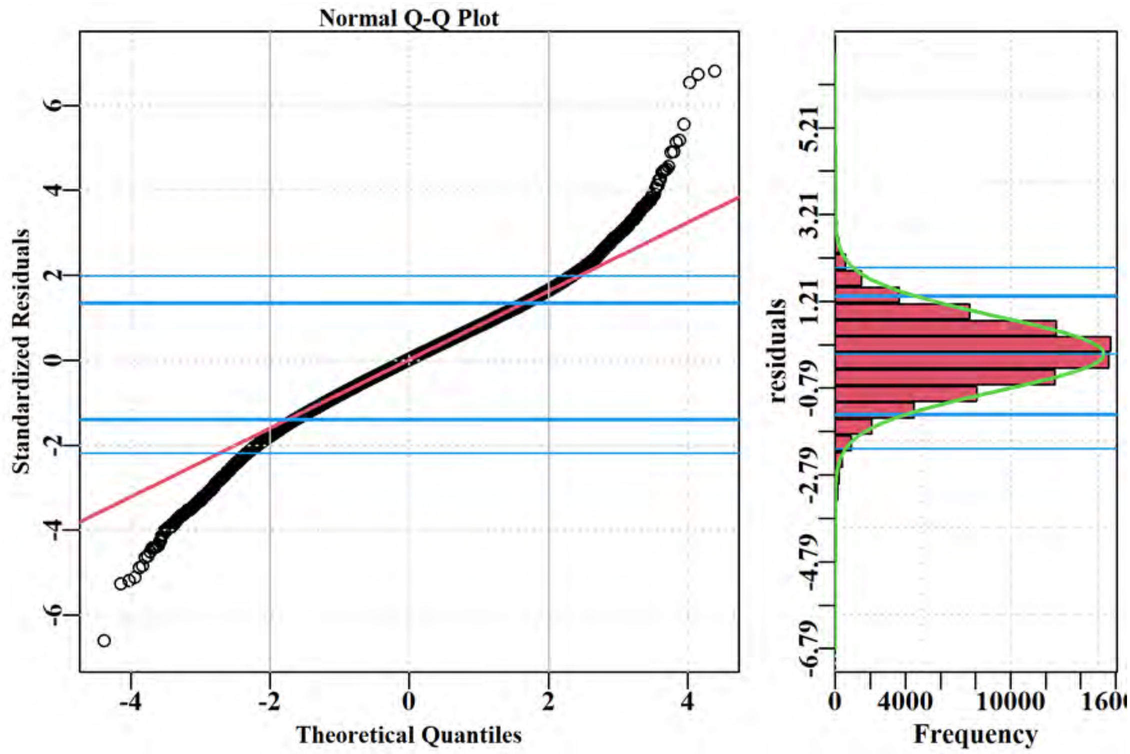

Figure 6.138. PinkLing4050. diagnostic plots. The distribution of residuals from the optimum fit. The qqplot indicates the fit to the expected normality, while the histogram of residuals illustrates the 90% quantiles to indicate the intensity of any lack of fit at the margins of the distribution.

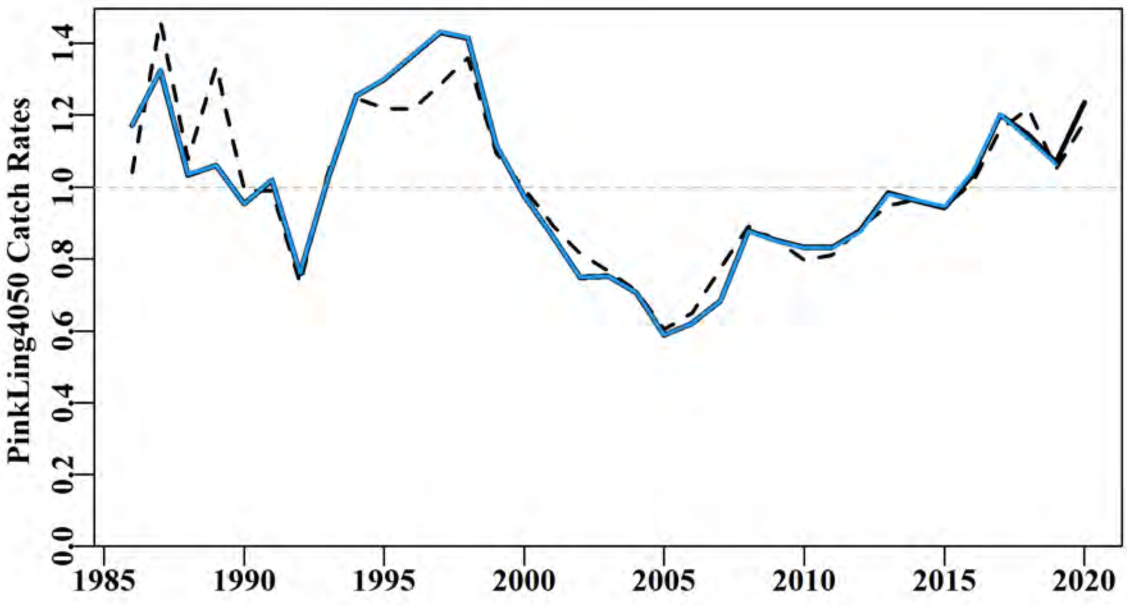

Figure 6.139. PinkLing4050. A comparison of the previous year's standardization (blue line) with this year's. They should lie on top of each other, although small deviations may relate to data adjustments, particularly in very recent years.

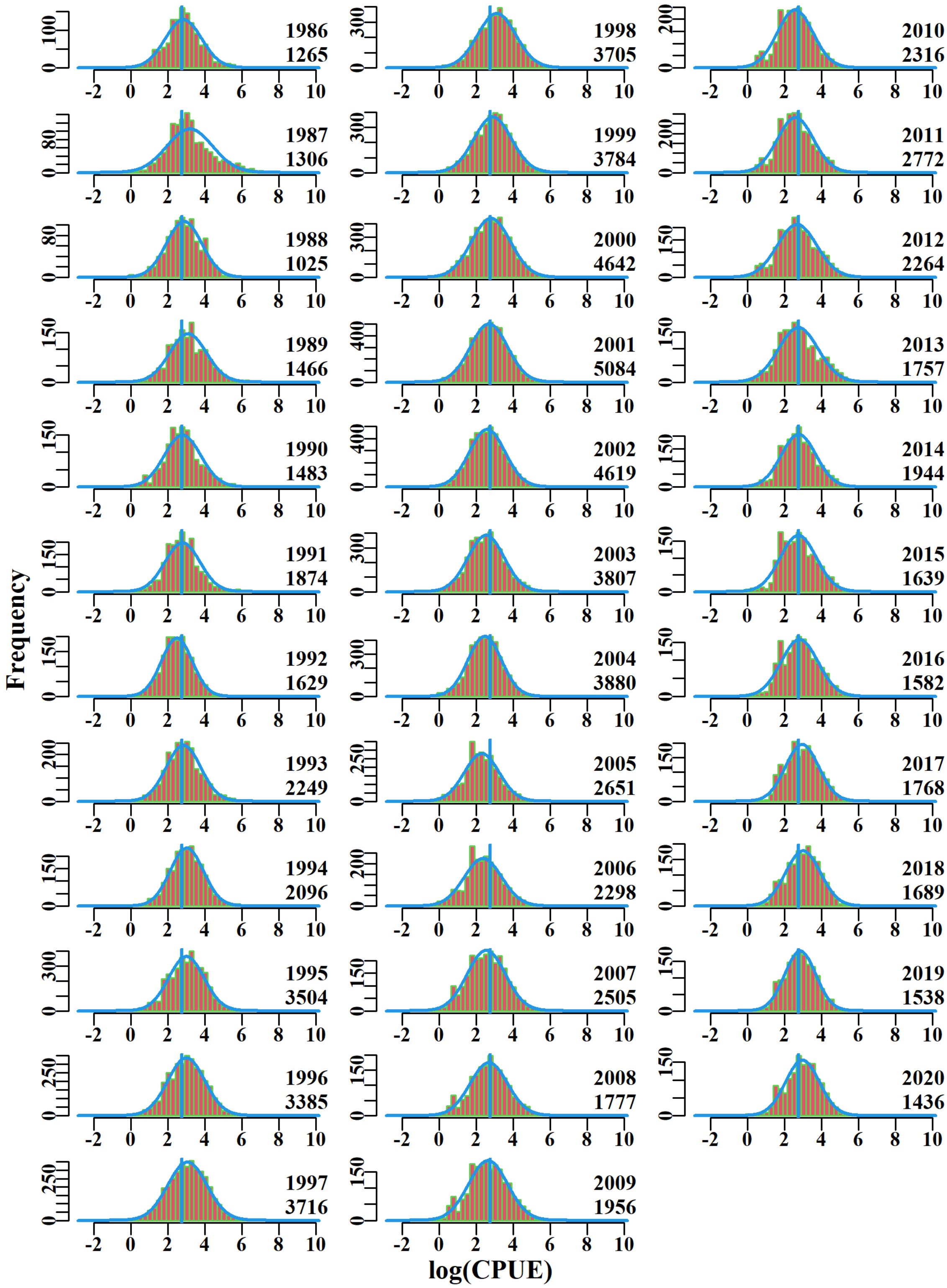

Figure 6.140. PinkLing4050. The natural log(CPUE) for each year of data available the blue lines are normal distributions fitted to the histogram frequencies. The numbers in each plot are the year and number of records.

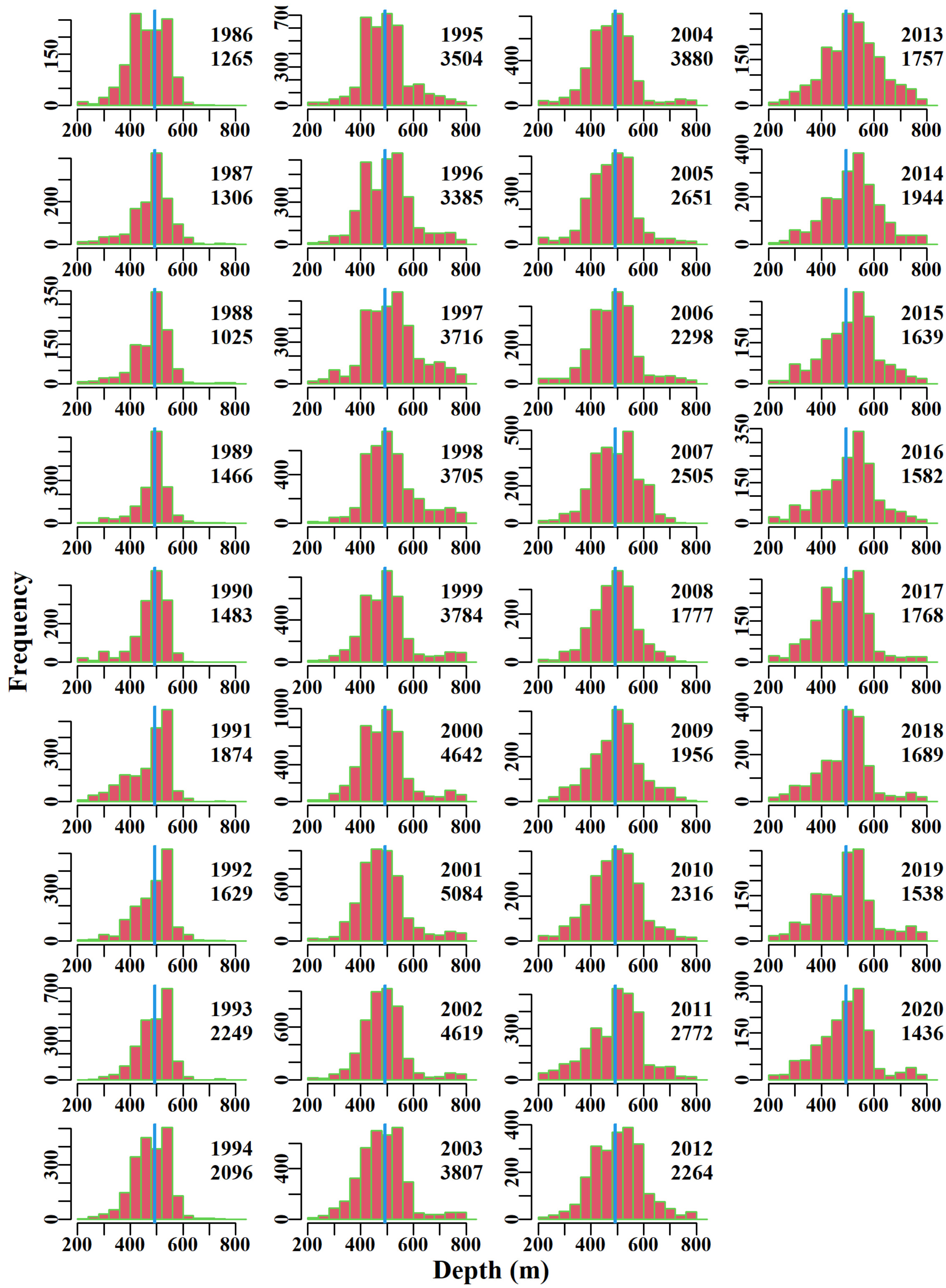

Figure 6.141. PinkLing4050. The average Depth of fishing for each year of data available to illustrate the development of the fishery through time. The numbers in each plot are the year and number of records.

6.23 Ocean Perch Offshore 10 20

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, OTB, in zones 10, 20, and depths 200 to 700 m within the SET fishery for the years 1986 - 2020 were used in the analysis (Table 6.101).

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.

6.23.1 *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 shots of < 30 kg (Figure 6.143), which is suggestive of either low availability or high levels of small fish.

The terms Year, Month, Vessel, 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 6.105). The qqplot suggests a slight departure from the assumed Normal distribution as depicted by both tails of the distribution (Figure 6.145).

Annual standardized CPUE has been below average and relatively flat between 1995 and 2006. The trend from 2007 has also been relatively flat and mostly just above average, apart from 2019 and 2020 which was increasing and above average (Figure 6.142). Also, CPUE has increased since 2015.

6.23.2 *Action Items and Issues*

No issues identified.

Table 6.101. 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, OTB
years	1986 - 2020

Table 6.102. 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

Year	Total	N	Catch	Vess	GeoM	Opt	StDev	C<30Kg	P<30Kg
1986	262.5	3479	207.4	77	21.5	0.9837	0.000	27.384	0.132
1987	198.4	3137	132.8	70	15.8	0.9116	0.026	27.705	0.209
1988	188.4	2806	150.7	73	18.6	1.0166	0.027	23.405	0.155
1989	209.2	3029	159.6	67	19.6	0.9765	0.027	24.547	0.154
1990	181.7	1958	115.3	57	20.6	1.2995	0.030	15.715	0.136
1991	223.6	2073	138.0	53	24.5	1.3644	0.030	16.912	0.123
1992	169.7	1850	114.2	48	20.4	1.1613	0.031	16.166	0.142
1993	259.6	2905	197.4	52	21.7	1.1635	0.027	25.126	0.127
1994	257.3	3000	179.9	49	22.0	1.0851	0.027	26.269	0.146
1995	240.0	3138	150.0	50	18.1	0.9600	0.027	31.852	0.212
1996	263.9	3402	176.2	53	17.8	0.8578	0.026	31.446	0.178
1997	298.8	3707	192.6	53	17.2	0.9041	0.026	35.444	0.184
1998	295.0	3837	194.0	49	17.3	0.8047	0.026	36.497	0.188
1999	295.8	4398	218.4	52	16.8	0.8967	0.025	42.854	0.196
2000	270.2	4168	180.7	53	14.9	0.7551	0.026	40.560	0.224
2001	281.6	4050	184.5	43	16.7	0.8727	0.026	38.378	0.208
2002	255.3	3631	150.2	45	15.9	0.8137	0.027	32.844	0.219
2003	322.8	3945	184.5	53	17.3	0.8637	0.026	35.037	0.190
2004	316.3	3111	149.7	46	17.9	0.8741	0.028	25.834	0.173
2005	316.9	3041	167.5	46	19.9	0.9875	0.028	26.055	0.156
2006	237.6	2309	112.7	38	15.6	0.8575	0.030	22.962	0.204
2007	180.6	1519	94.7	22	20.2	1.0993	0.033	14.042	0.148
2008	184.4	1831	101.6	23	17.5	0.9987	0.032	16.250	0.160
2009	173.9	1662	98.9	23	20.0	0.9989	0.033	15.540	0.157
2010	195.6	1726	117.2	21	22.7	0.9748	0.032	14.324	0.122
2011	186.9	1843	115.5	22	23.4	0.8986	0.032	15.249	0.132
2012	183.9	1673	113.4	22	26.2	0.9479	0.033	13.219	0.117
2013	171.2	1277	102.4	20	30.1	1.0089	0.035	9.188	0.090
2014	174.4	1522	115.9	21	29.9	0.9991	0.033	10.421	0.090
2015	150.9	1404	104.9	22	31.5	0.8612	0.034	9.146	0.087
2016	132.1	1144	93.4	23	31.1	0.9288	0.037	6.982	0.075
2017	155.7	1390	107.6	19	29.7	0.9873	0.035	8.647	0.080
2018	151.8	1290	102.3	17	28.3	1.0715	0.036	8.103	0.079
2019	165.5	1293	105.0	18	28.2	1.3069	0.036	8.596	0.082
2020	141.7	1201	85.9	16	24.7	1.5081	0.037	8.837	0.103

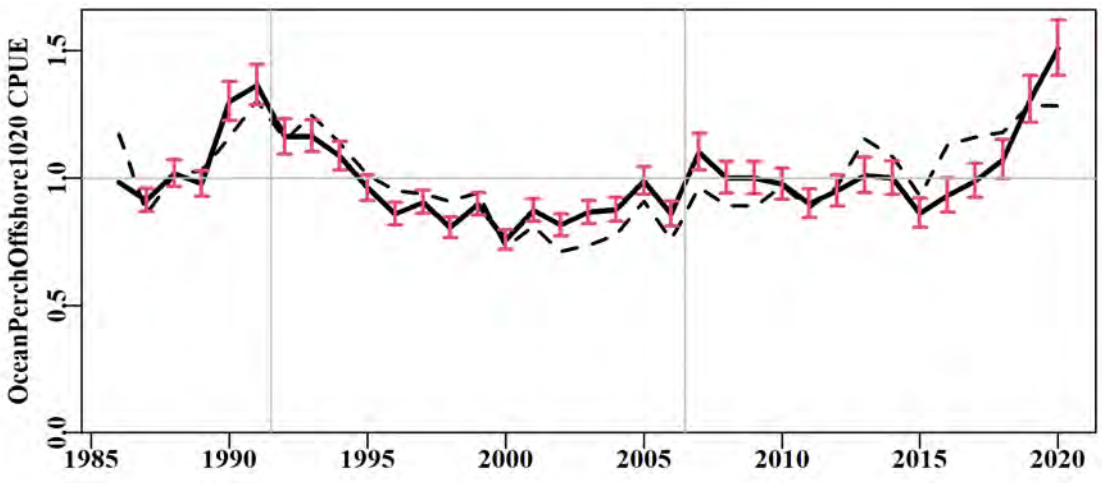

Figure 6.142. OceanPerchOffshore1020 standardization. The dashed black line represents the geometric mean CPUE, solid black line the standardized CPUE. The red bars are the 95% confidence intervals about the mean estimates. The graph scales both time-series of standardized CPUE relative to the mean of each time-series.

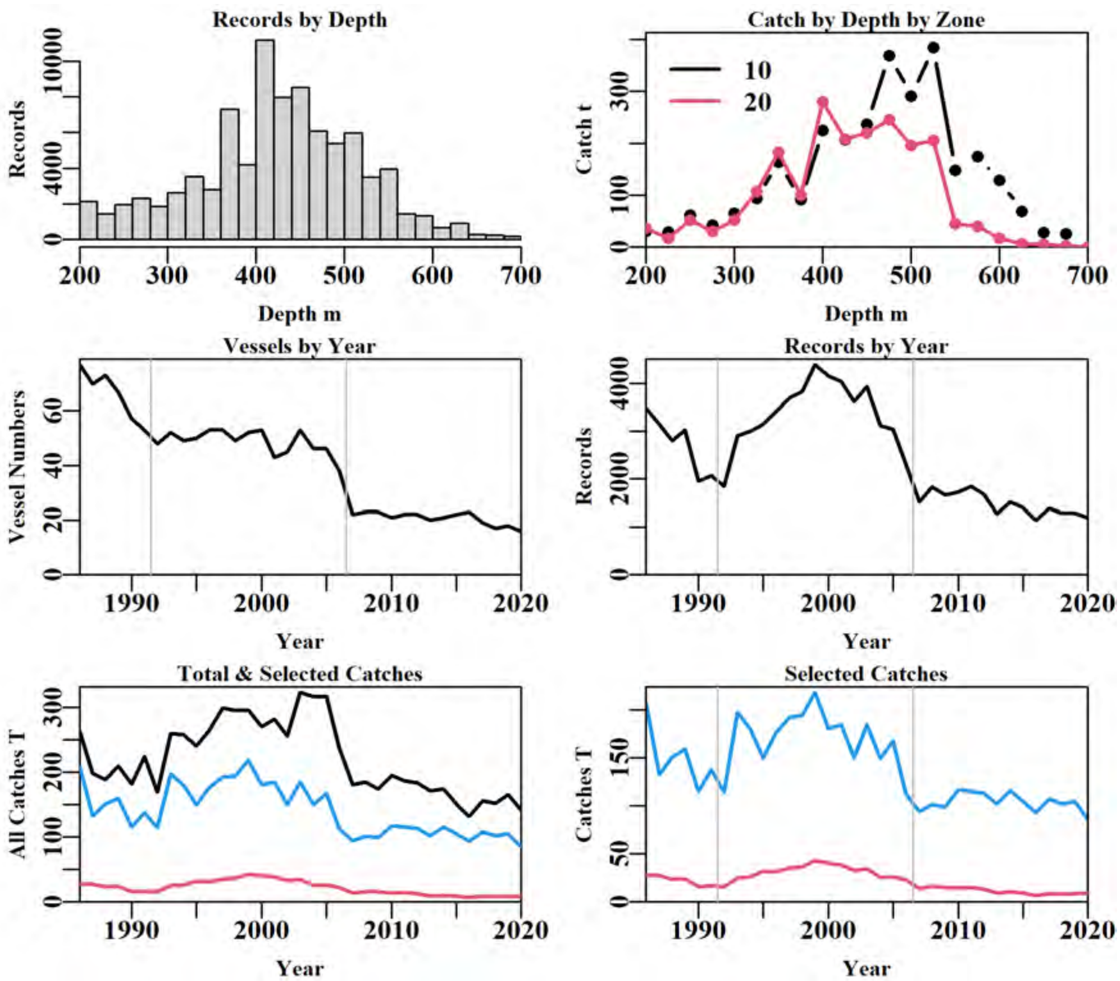

Figure 6.143. OceanPerchOffshore1020 fishery details. The bottom left plot depicts all known catches (top black line), and all selected catches used in the analysis (middle blue line); the lower red line: selected catches < 30 kg).

Table 6.103. 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	179725	161058	131021	129434	88617	87793	87749
Difference	0	18667	30037	1587	40817	824	44
Catch	7833	7201	6326	6193	4976	4918	4915
Difference	0	631	876	133	1217	57	3

Table 6.104. 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 6.105. 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

Term	AIC	RSS	MSS	Nobs	Npars	adj_r2	%Change
Year	27905	120505	2584	87749	35	2.1	0
Month	26484	118540	4549	87749	46	3.6	1.58
Vessel	12239	100403	22686	87749	209	18.2	14.59
DepCat	1490	88787	34302	87749	229	27.7	9.44
DayNight	893	88179	34910	87749	232	28.2	0.49
Zone	861	88145	34945	87749	233	28.2	0.03
Zone:Month	-1213	86064	37025	87749	244	29.9	1.69
Zone:DepCat	387	87630	35459	87749	253	28.6	0.40

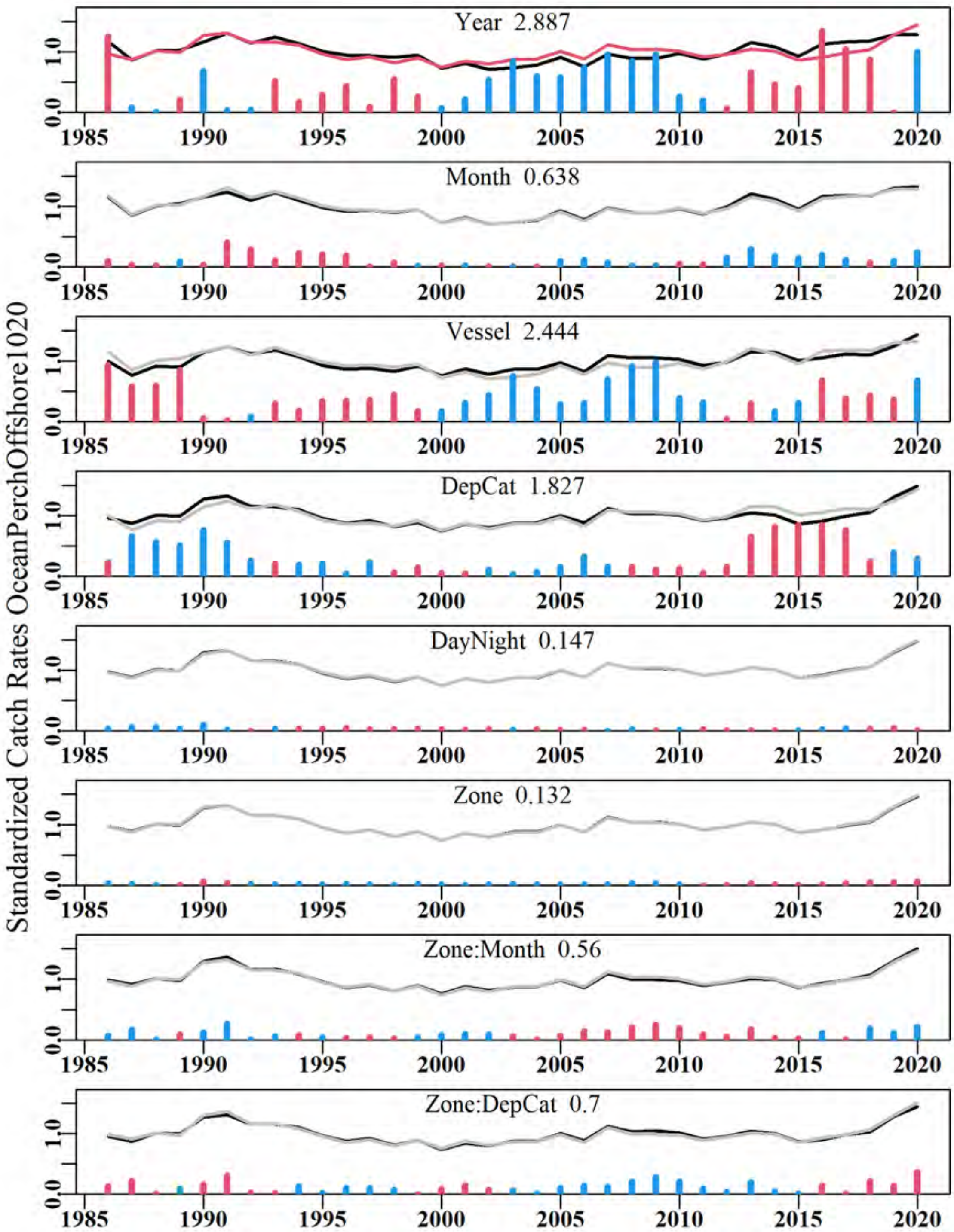

Figure 6.144. OceanPerchOffshore1020. The influence of each factor on the optimal standardization. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by vertical bars with blue bars indicating the optimum model is higher 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.

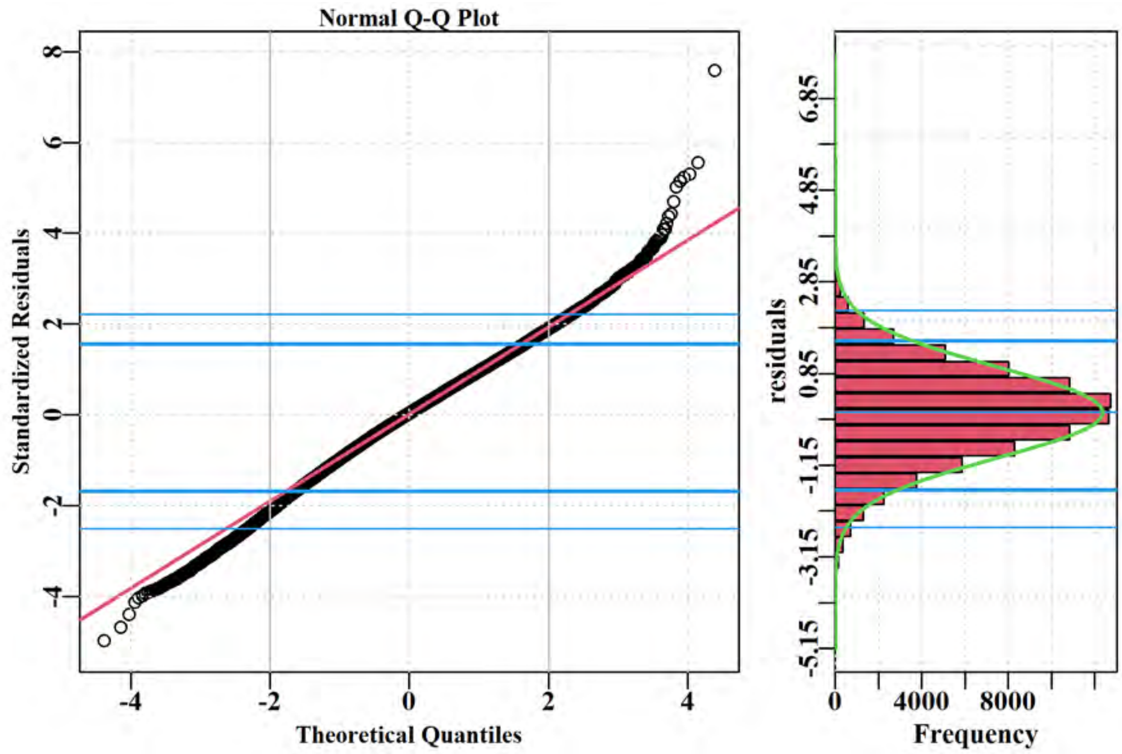

Figure 6.145. OceanPerchOffshore1020. diagnostic plots. The distribution of residuals from the optimum fit. The qqplot indicates the fit to the expected normality, while the histogram of residuals illustrates the 90% quantiles to indicate the intensity of any lack of fit at the margins of the distribution.

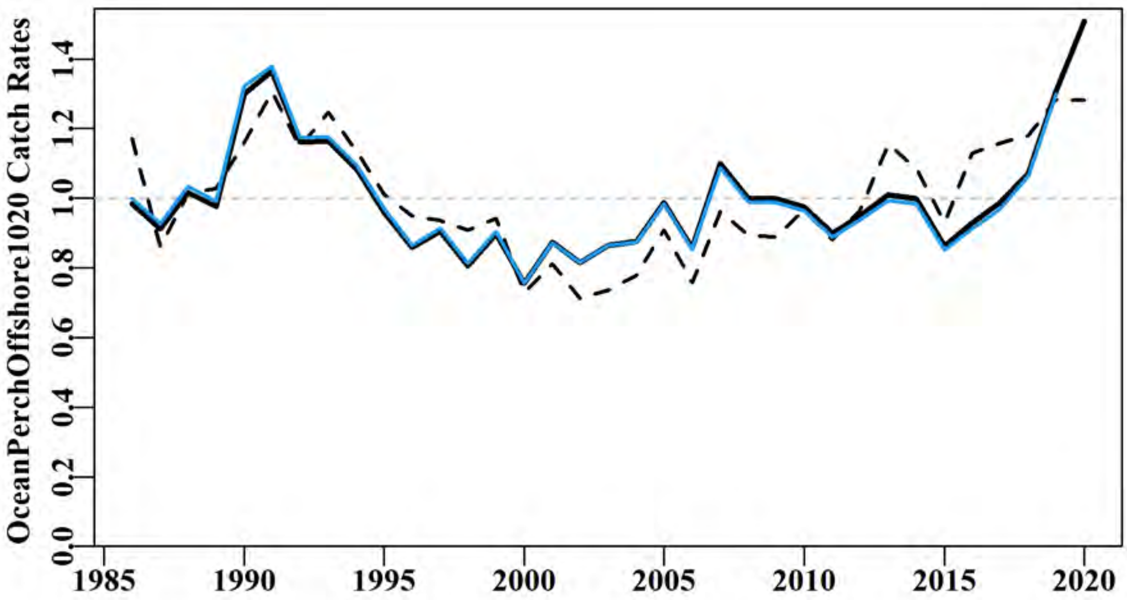

Figure 6.146. OceanPerchOffshore1020. A comparison of the previous year's standardization (blue line) with this year's. They should lie on top of each other, although small deviations may relate to data adjustments, particularly in very recent years.

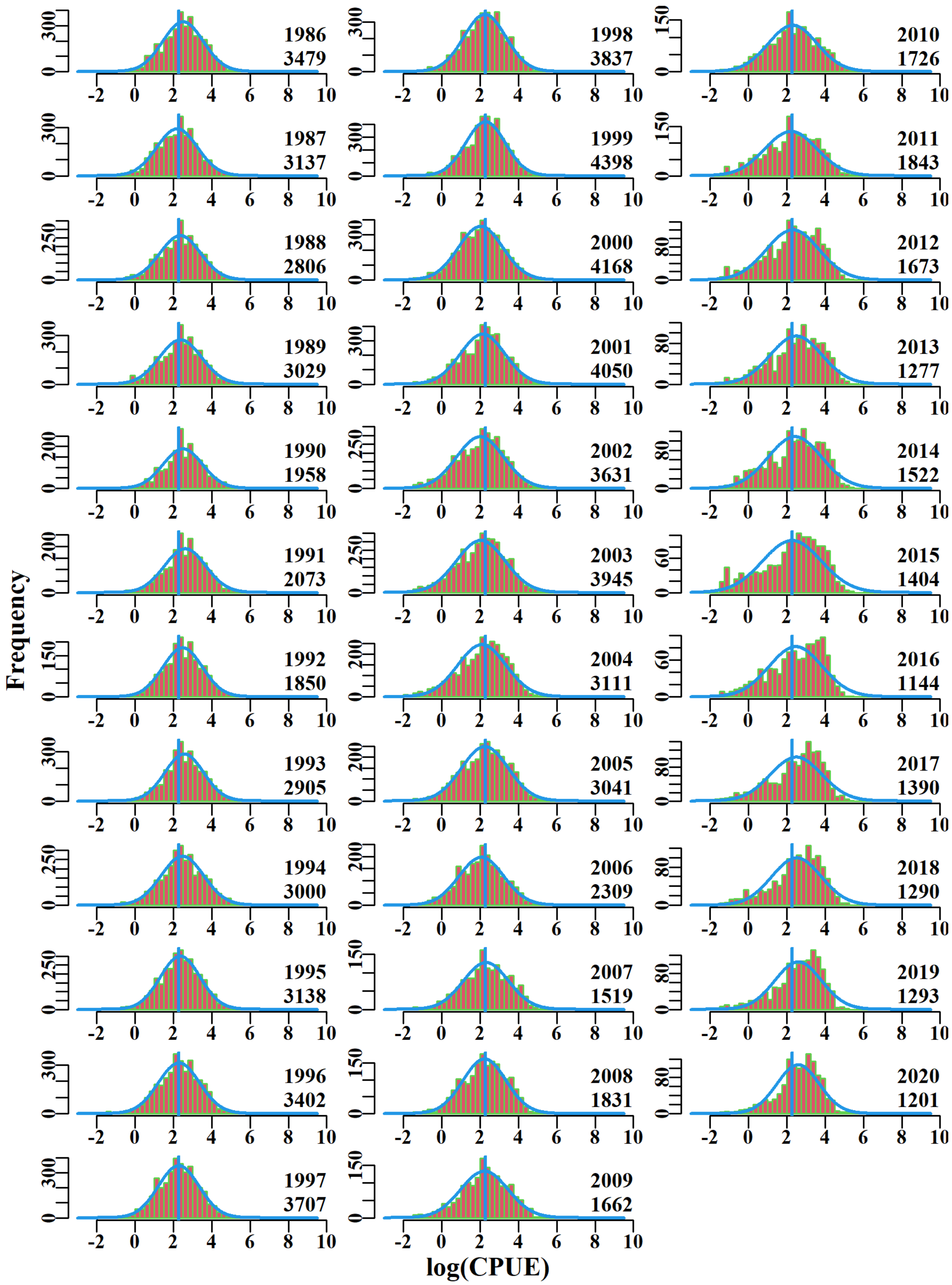

Figure 6.147. OceanPerchOffshore1020. The natural log(CPUE) for each year of data available the blue lines are normal distributions fitted to the histogram frequencies. The numbers in each plot are the year and number of records.

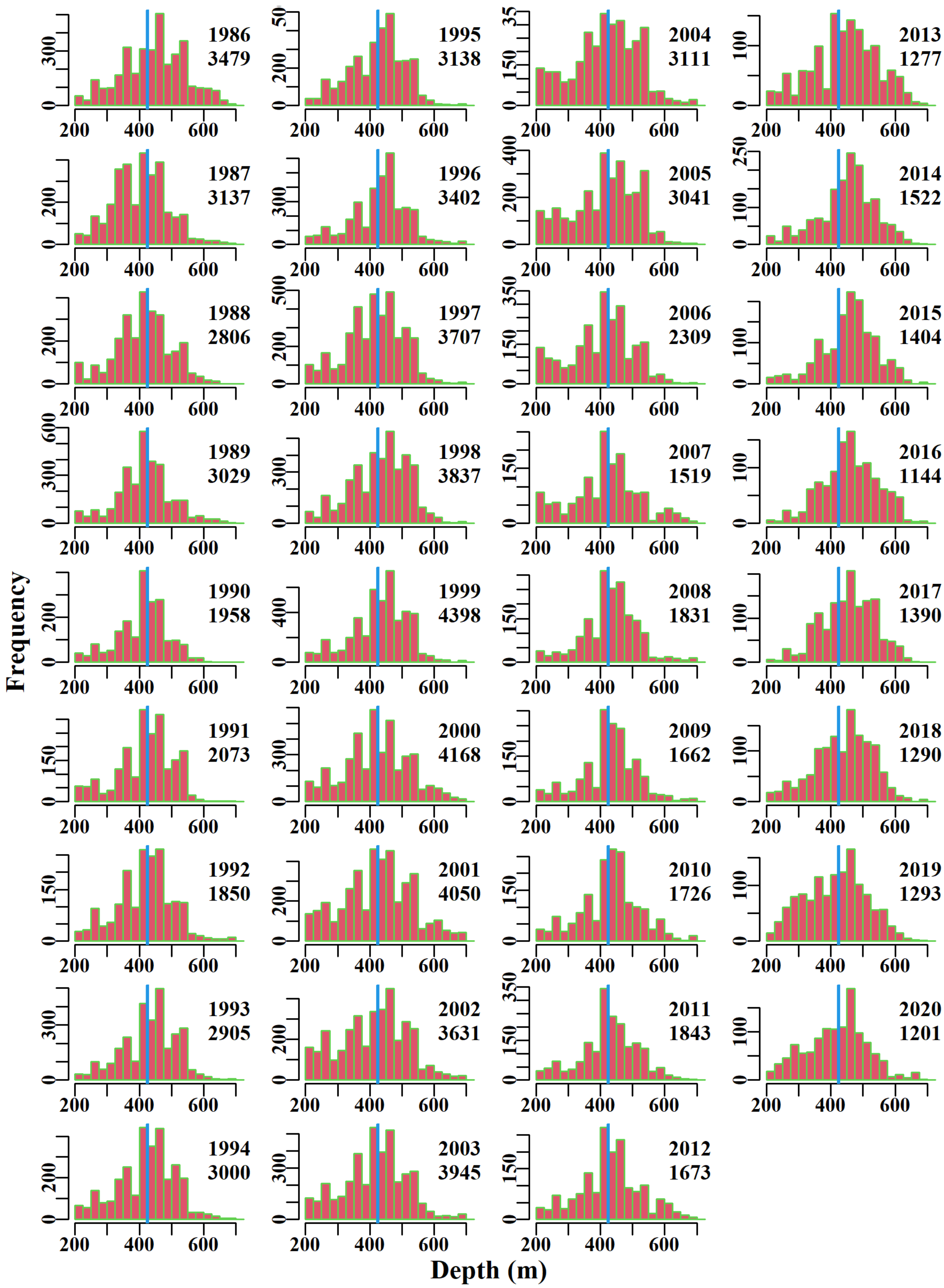

Figure 6.148. OceanPerchOffshore1020. The average Depth of fishing for each year of data available to illustrate the development of the fishery through time. The numbers in each plot are the year and number of records.

6.24 Ocean Perch Offshore 10-50

Offshore Ocean Perch (REG - 37287001 - *Helicolenus percoides*) caught by trawl based on methods TW, TDO, OTB, TMO, in zones 10, 20, 30, 40, 50, and depths 200 to 700 m within the SET fishery for the years 1986 - 2020 were used in the analysis (Table 6.106).

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

6.24.1 *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 shots of < 30kg (Figure 6.150), which is suggestive of either low availability or high levels of small fish.

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

Annual standardized CPUE has been below average and relatively flat between 1995 and 2006. The trend from 2007 to 2010 has also been relatively flat and on average, below average and flat between 2011 to 2016 and increasing to either on average or just above average since 2017 (Figure 6.149). Also, CPUE has increased since 2015.

6.24.2 *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 CPUE in those zones would seem to be more indicative of the main location for the stock.

Table 6.106. 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, OTB, TMO
years	1986 - 2020

Table 6.107. 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

Year	Total	N	Catch	Vess	GeoM	Opt	StDev	C<30Kg	P<30Kg
1986	262.5	3728	220.7	92	20.9	1.0647	0.000	29.840	0.135
1987	198.4	3409	144.5	93	15.7	0.9744	0.024	30.071	0.208
1988	188.4	3097	161.3	93	18.4	1.0981	0.025	26.371	0.163
1989	209.2	3412	173.2	86	18.8	1.0679	0.025	29.526	0.170
1990	181.7	2423	131.5	80	18.6	1.3501	0.027	22.128	0.168
1991	223.6	2853	169.5	87	21.3	1.3958	0.026	26.864	0.159
1992	169.7	2375	130.3	70	17.7	1.1486	0.027	22.496	0.173
1993	259.6	3644	221.9	68	19.2	1.1862	0.024	35.361	0.159
1994	257.3	3782	208.3	66	19.1	1.1378	0.024	38.140	0.183
1995	240.0	4437	191.0	69	15.2	1.0542	0.024	50.683	0.265
1996	263.9	4849	213.9	76	14.5	0.9378	0.023	53.199	0.249
1997	298.8	5594	246.5	71	13.8	0.9767	0.023	59.734	0.242
1998	295.0	5326	240.5	67	14.6	0.9036	0.023	55.634	0.231
1999	295.8	5776	255.7	72	14.8	0.9398	0.023	61.811	0.242
2000	270.2	5686	217.7	80	12.9	0.8114	0.023	59.058	0.271
2001	281.6	5960	228.9	68	13.4	0.8760	0.023	63.067	0.276
2002	255.3	5596	195.1	69	12.4	0.8345	0.023	57.058	0.292
2003	322.8	5777	231.2	66	13.4	0.9030	0.023	57.363	0.248
2004	316.3	5099	202.2	68	12.9	0.9226	0.024	50.046	0.248
2005	316.9	4505	201.2	64	14.9	0.9452	0.024	42.533	0.211
2006	237.6	3337	137.9	52	12.4	0.8445	0.026	34.920	0.253
2007	180.6	2609	121.6	33	13.6	0.9736	0.027	26.037	0.214
2008	184.4	2666	124.7	32	13.8	0.9724	0.027	25.722	0.206
2009	173.9	2705	128.7	32	13.9	0.9537	0.027	27.628	0.215
2010	195.6	2892	150.7	32	14.4	0.9701	0.027	29.748	0.197
2011	186.9	3107	146.6	30	14.6	0.8256	0.026	29.911	0.204
2012	183.9	2755	135.9	30	16.9	0.8005	0.027	23.894	0.176
2013	171.2	2304	126.2	29	17.4	0.8542	0.028	19.494	0.154
2014	174.4	2402	136.8	30	18.8	0.9063	0.028	20.537	0.150
2015	150.9	2172	124.2	31	19.8	0.8039	0.029	17.125	0.138
2016	132.1	1714	109.0	30	21.3	0.8947	0.031	12.294	0.113
2017	155.7	1943	121.8	26	22.9	0.9590	0.030	14.726	0.121
2018	151.8	1629	112.3	25	23.3	1.0804	0.031	11.054	0.098
2019	165.5	1768	120.4	24	21.7	1.2784	0.031	13.207	0.110
2020	141.7	1567	97.5	22	20.1	1.3540	0.032	12.575	0.129

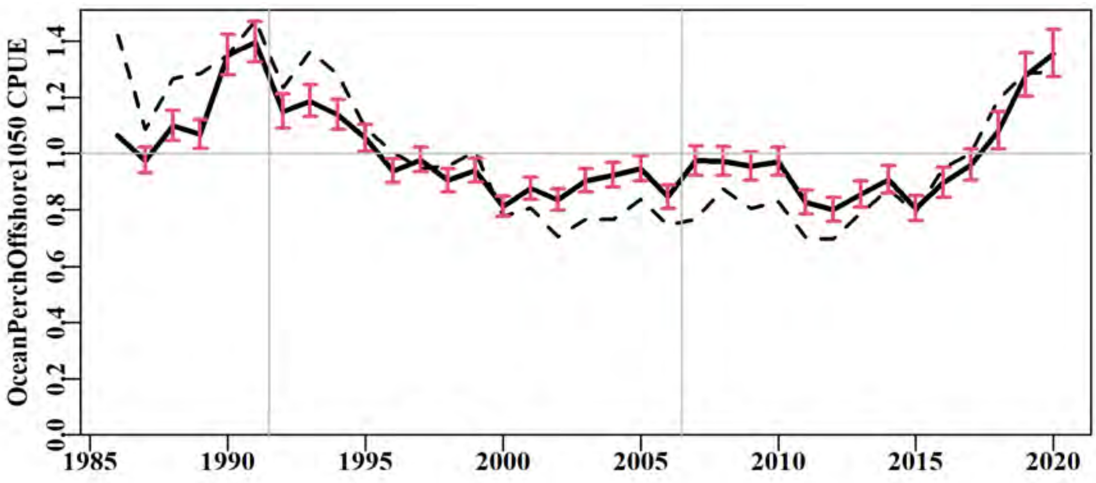

Figure 6.149. OceanPerchOffshore1050 standardization. The dashed black line represents the geometric mean CPUE, solid black line the standardized CPUE. The red bars are the 95% confidence intervals about the mean estimates. The graph scales both time-series of standardized CPUE relative to the mean of each time-series.

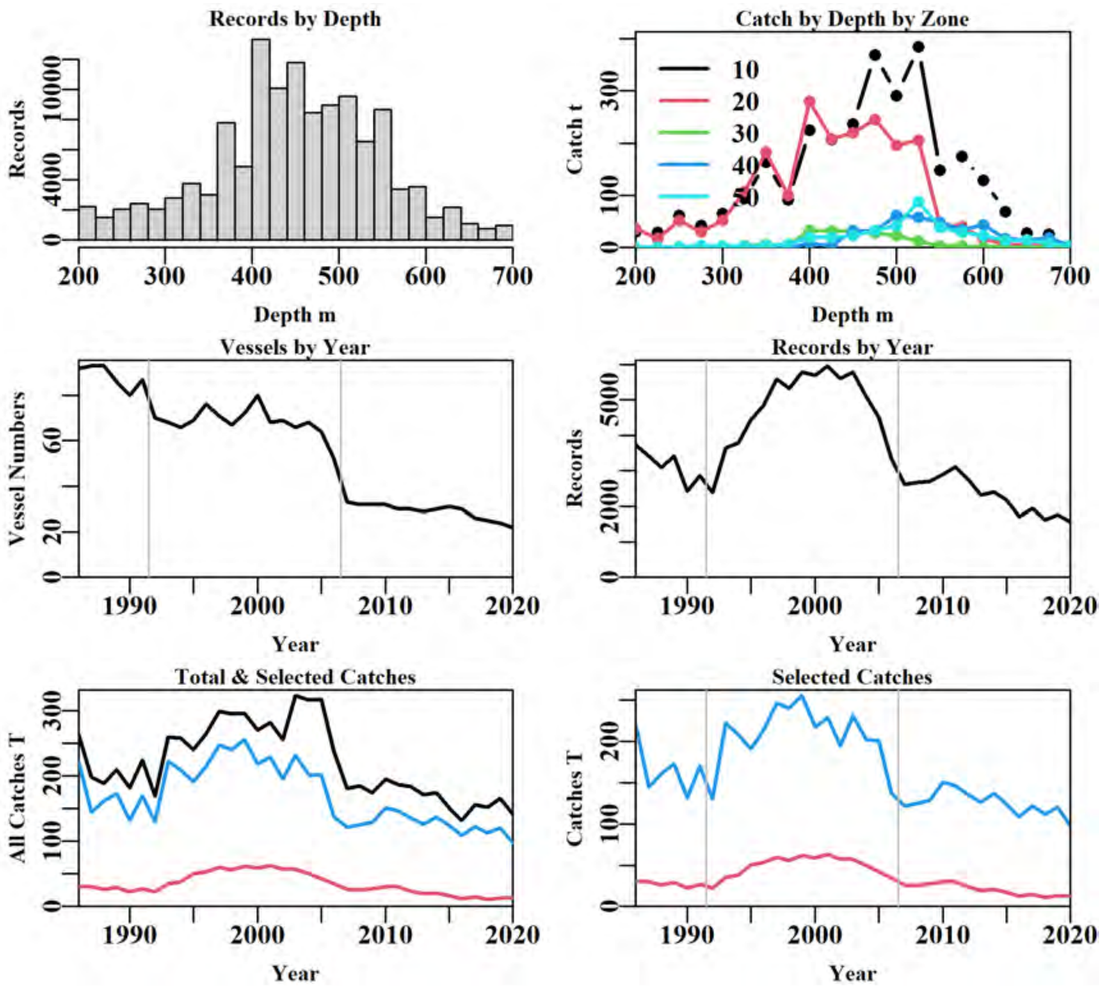

Figure 6.150. OceanPerchOffshore1050 fishery details. The bottom left plot depicts all known catches (top black line), and all selected catches used in the analysis (middle blue line); the lower red line: selected catches < 30 kg).

Table 6.108. 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 6.109. 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

Term	AIC	RSS	MSS	Nobs	Npars	adj_r2	%Change
Year	40425	170667	6242	122898	35	3.5	0
Month	39900	169910	6999	122898	46	3.9	0.42
Vessel	11094	133958	42951	122898	252	24.1	20.20
DepCat	2537	124907	52002	122898	272	29.2	5.12
DayNight	1166	123516	53393	122898	275	30.0	0.79
Zone	-6612	115933	60976	122898	279	34.3	4.29
Zone:Month	-9302	113342	63567	122898	323	35.8	1.44
Zone:DepCat	-8417	114094	62815	122898	359	35.3	1.00

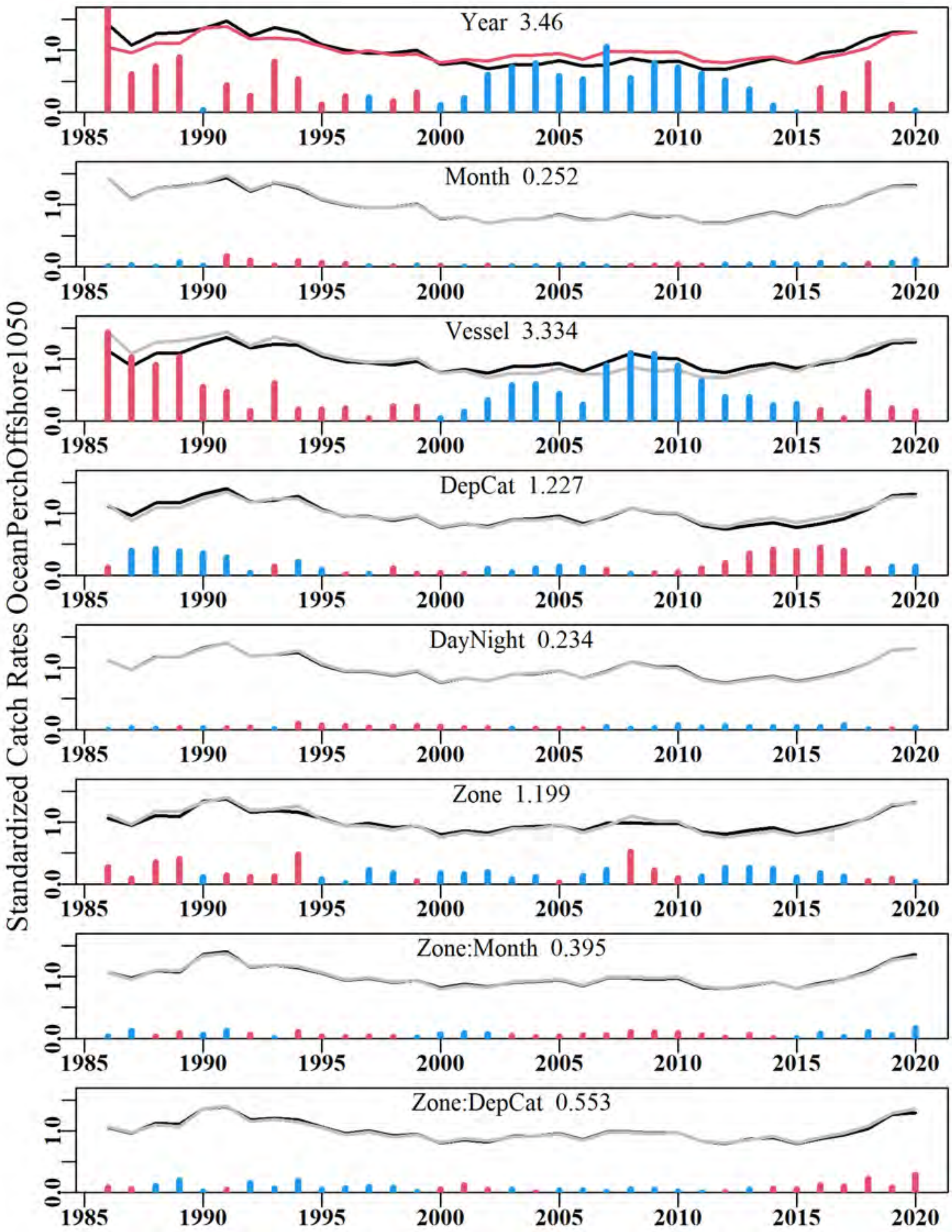

Figure 6.151. OceanPerchOffshore1050. The influence of each factor on the optimal standardization. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by vertical bars with blue bars indicating the optimum model is higher 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.

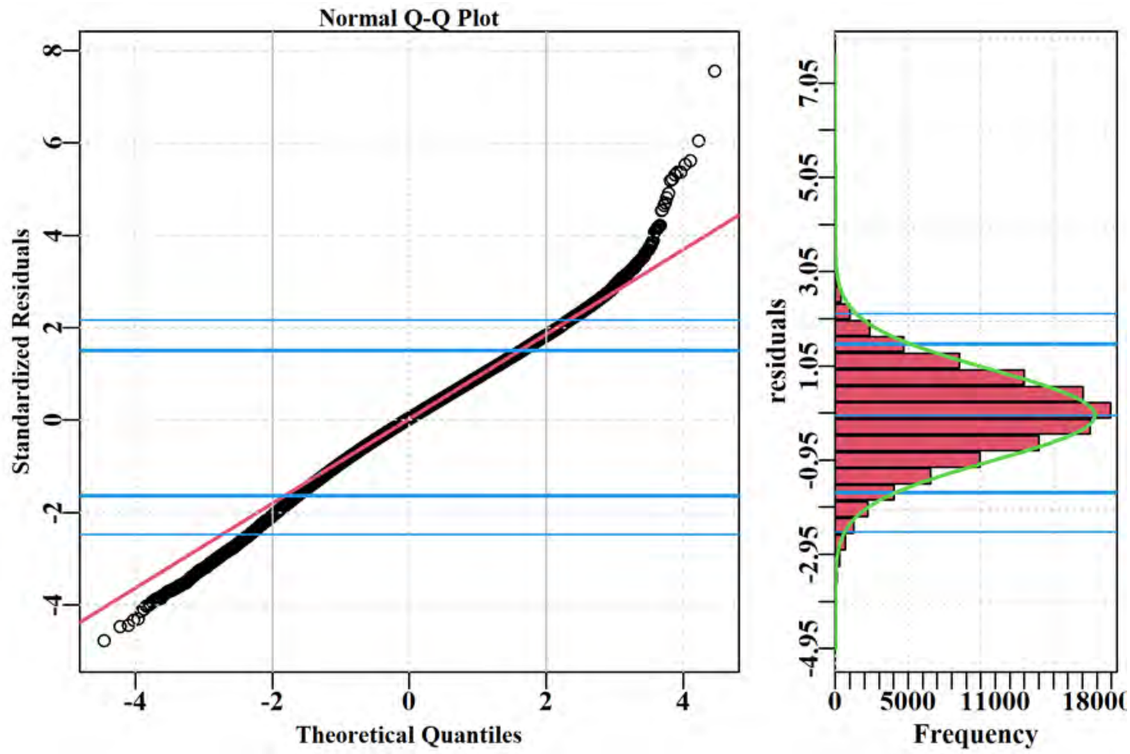

Figure 6.152. OceanPerchOffshore1050. diagnostic plots. The distribution of residuals from the optimum fit. The qqplot indicates the fit to the expected normality, while the histogram of residuals illustrates the 90% quantiles to indicate the intensity of any lack of fit at the margins of the distribution.

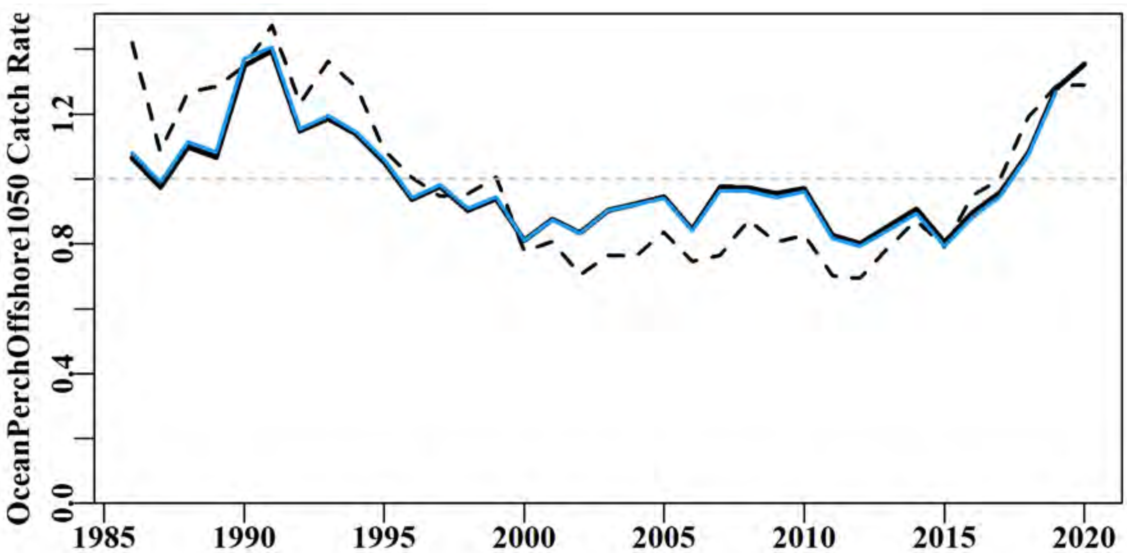

Figure 6.153. OceanPerchOffshore1050. A comparison of the previous year's standardization (blue line) with this year's. They should lie on top of each other, although small deviations may relate to data adjustments, particularly in very recent years.

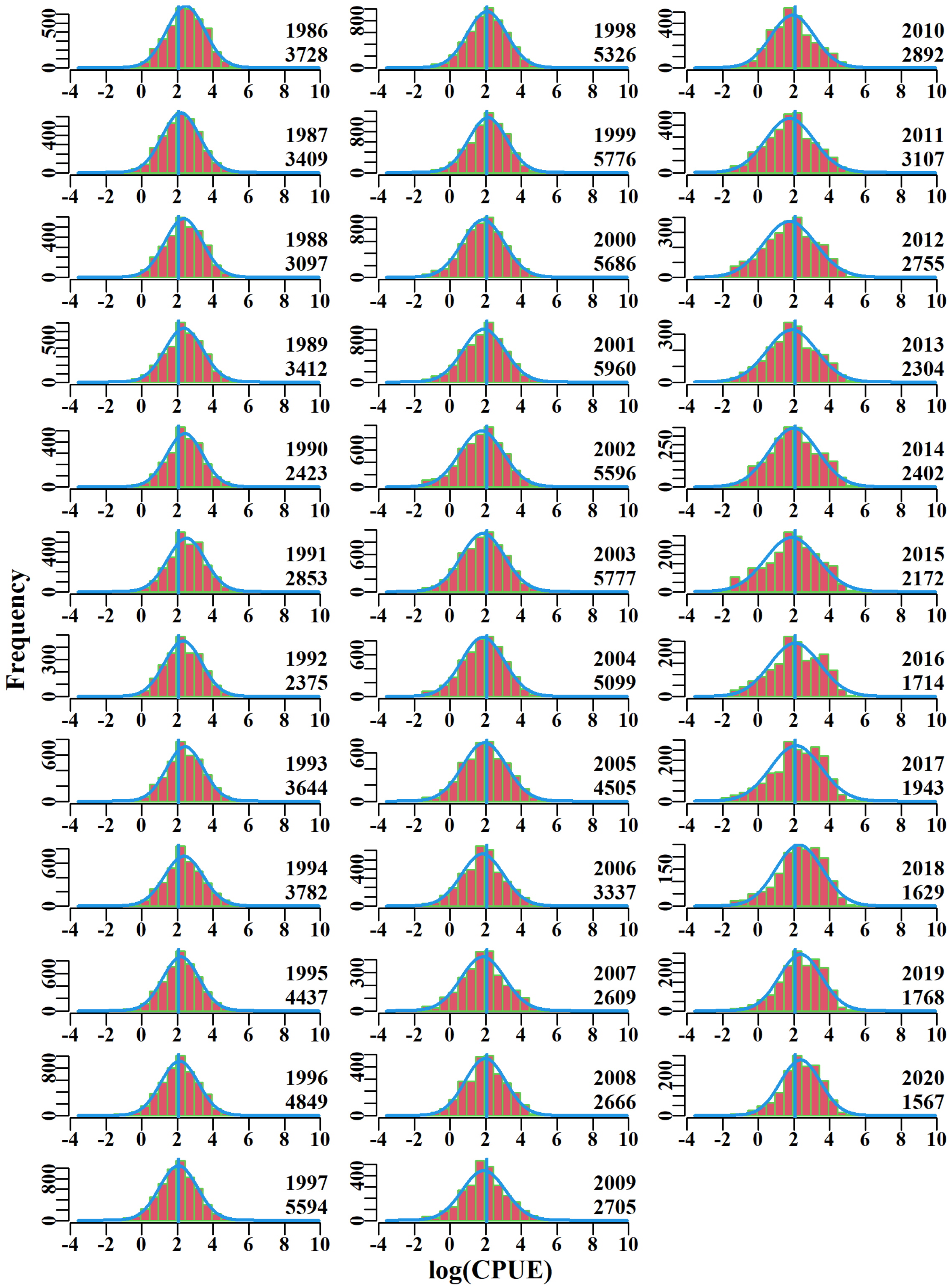

Figure 6.154. OceanPerchOffshore1050. The natural log(CPUE) for each year of data available the blue lines are normal distributions fitted to the histogram frequencies. The numbers in each plot are the year and number of records.

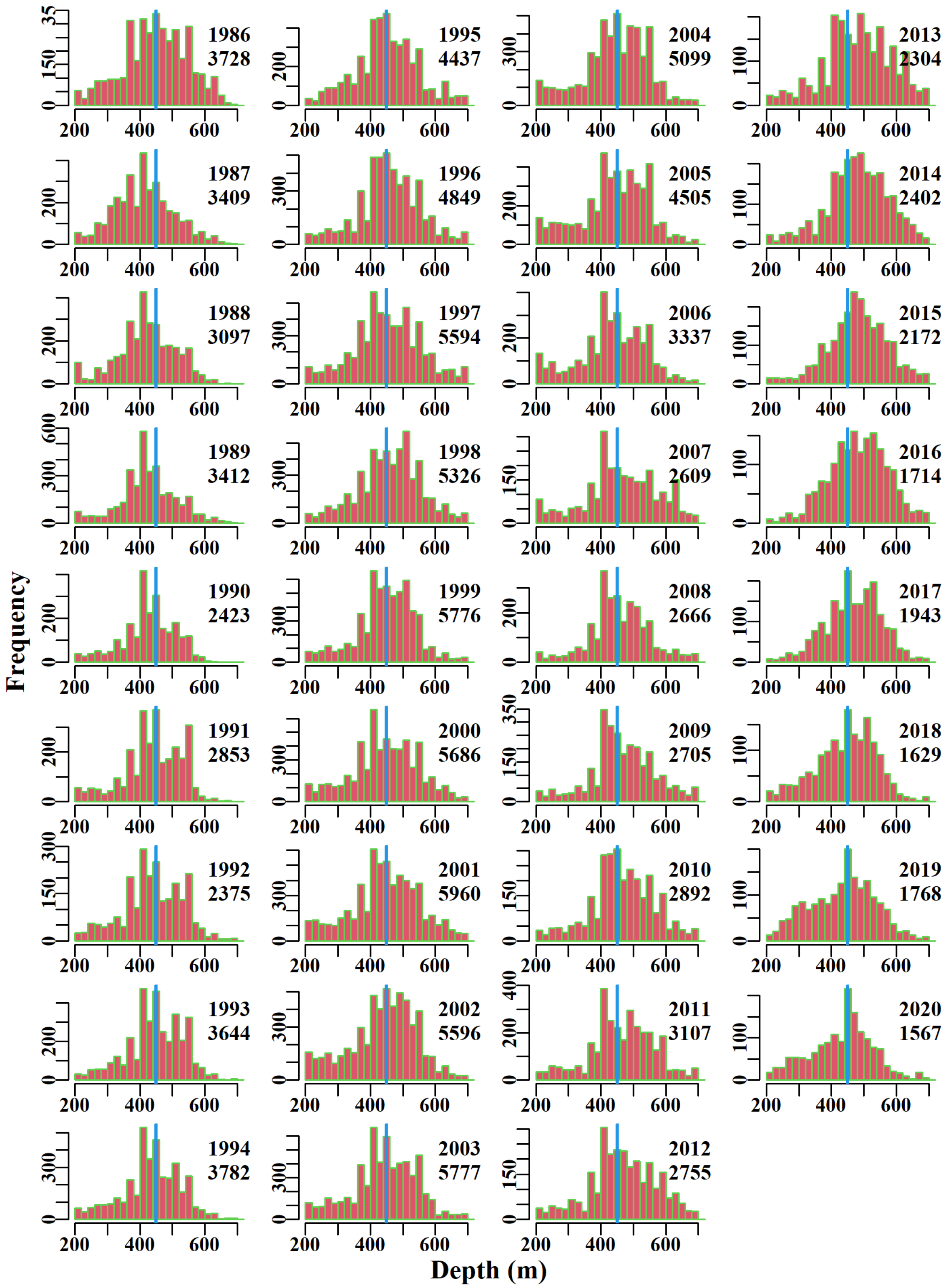

Figure 6.155. OceanPerchOffshore1050. The average Depth of fishing for each year of data available to illustrate the development of the fishery through time. The numbers in each plot are the year and number of records.

6.25 Comparison of Zones 10:20 and 10:50

Table 6.110. 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 due to the inclusion of the catches reported in zones 30, 40, and 50.

Year	10	10	20	20	30	30	40	40	50	50
1986	156.970	2761	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	11.762	255	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	110.359	2074	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	22.658	691
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	92.558	2252	12.500	336	19.829	825	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	48.573	705	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	9.238	322
2010	69.609	770	47.630	956	5.069	146	14.458	494	13.930	526
2011	63.509	712	51.962	1131	4.392	180	11.866	594	14.840	490
2012	72.051	722	41.315	951	3.957	183	10.137	594	8.406	305
2013	58.325	517	44.041	760	4.180	181	7.537	391	12.128	455
2014	68.110	586	47.750	936	1.389	60	9.121	415	10.476	405
2015	61.210	531	43.673	873	4.408	139	6.570	349	8.310	280
2016	61.392	508	32.052	636	1.870	83	6.810	290	6.868	197
2017	51.956	531	55.607	859	3.137	141	4.555	238	6.551	174
2018	40.587	418	61.761	872	2.691	101	2.611	108	4.686	130
2019	46.771	438	58.179	855	4.922	198	3.395	101	7.162	176
2020	31.395	313	54.524	888	3.430	149	2.358	60	5.794	157

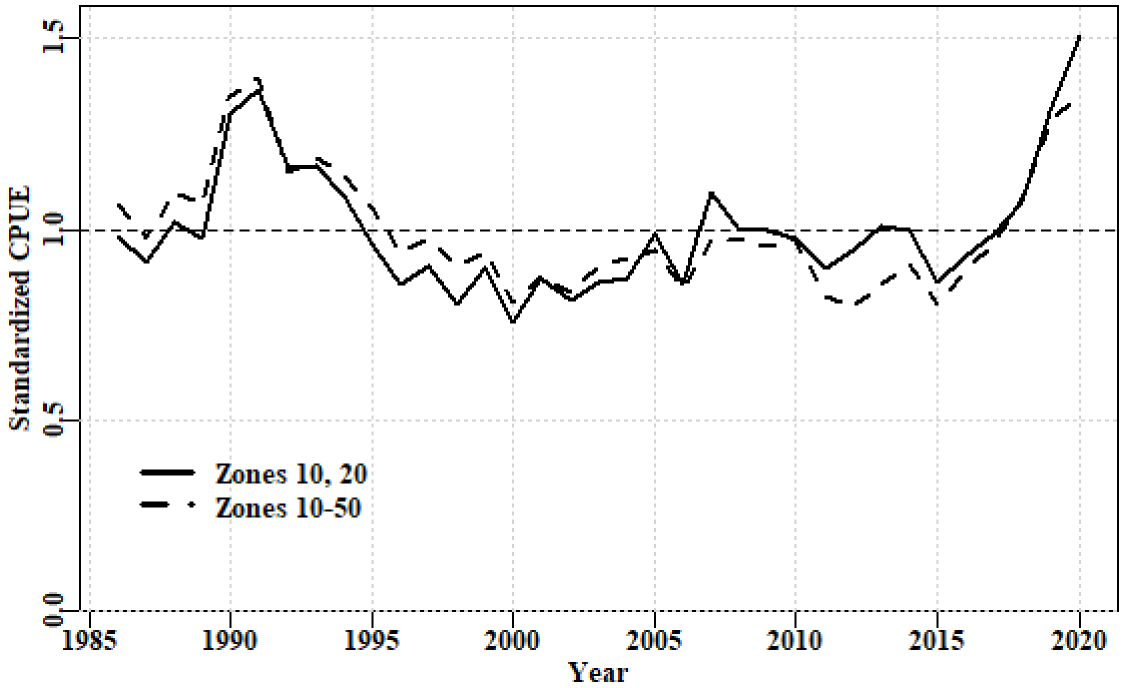

Figure 6.156. A comparison of the optimum standardization for Offshore Ocean Perch when using just Zones 10 and 20 and when including records from zones 30, 40 and 50.

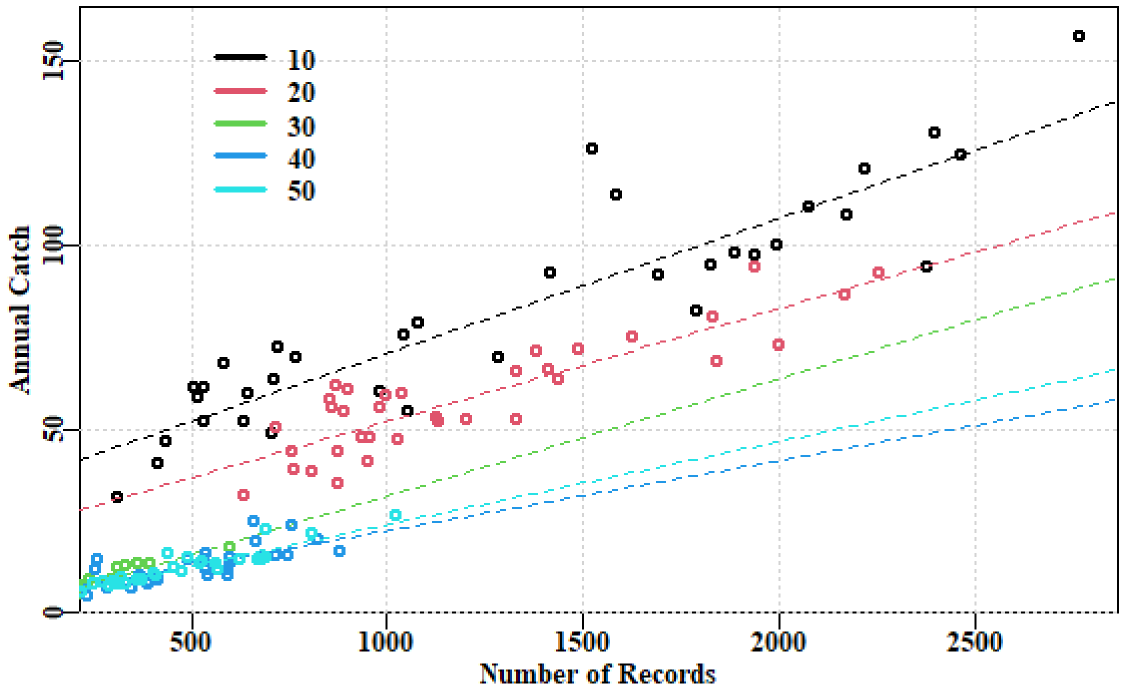

Figure 6.157. A plot of the different reported Catch vs reported number of records for each zone from 10 to 50 for Offshore Ocean Perch. The dotted lines are the linear regressions in each case illustrating the different average ratio CPUE for each zone and that fact that CPUE in zones 30 - 50 is generally lower for the same effort than in zones 10 and 20.

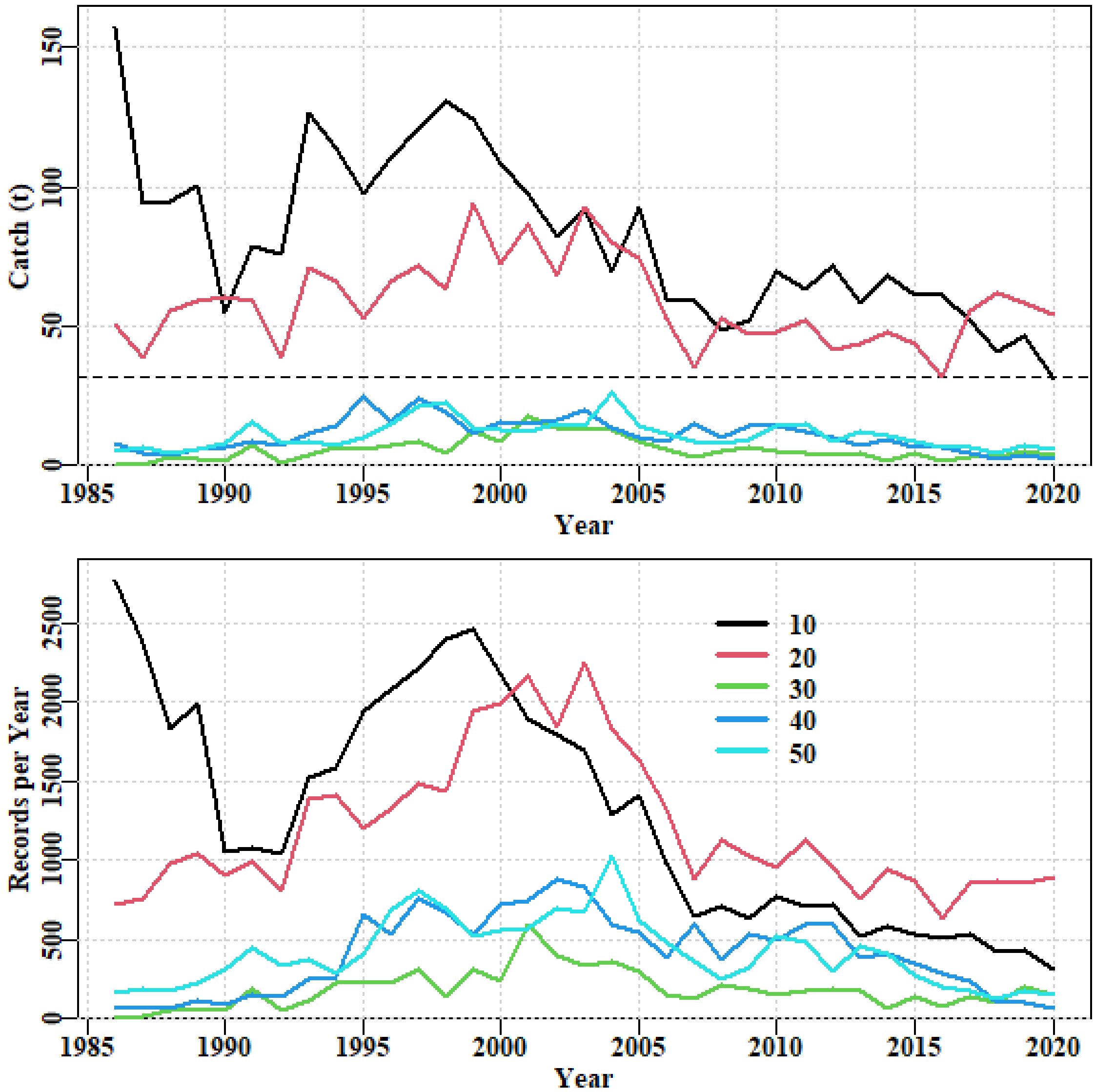

Figure 6.158. Catch and Records by Zone through time illustrating that catches in 30 to 50 have never been as great as those in zones 10 and 20 although the number of records can be relatively high.

6.26 Ocean Perch Inshore 10 20

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, OTB, in zones 10, 20, and depths 0 to 200 m within the SET fishery for the years 1986 - 2020 were analysed (Table 6.111). 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.

6.26.1 *Inferences*

The majority of catch of this species occurred in zone 10 followed by zone 20. Small shots < 30 kg appear throughout the analysis period. Also, there was an increase in small shots of < 30 kg over the 1992 - 2006 period, which is suggestive of either low availability or high levels of small fish (Figure 6.160).

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 6.115). The qqplot suggests a small departure from the assumed Normal distribution as depicted by both tails of the distribution (Figure 6.162).

Annual standardized CPUE has been relatively flat in the last five years based on the 95% confidence intervals (Figure 6.159).

6.26.2 *Action Items and Issues*

Fishing depths have been (i) recorded as single values or (ii) recorded at more than one constant value across different operations in the Commonwealth logbook database for certain vessels since about 2016. These fishing depths have been modified based on positional bathymetry and have been used in the standardization analysis presented here, as agreed by SESSFRAG in 2020. Differences between this year's standardized CPUE (i.e., 1986 – 2020) compared with last year's standardized CPUE (i.e., 1986 – 2019) are likely due to these modified fishing depths. As the discarding rate continues to be very high (up to ~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 6.111. 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, OTB
years	1986 - 2020

Table 6.112. 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

Year	Total	N	Catch	Vess	GeoM	Opt	StDev	C<30Kg	P<30Kg
1986	262.5	338	15.2	50	11.9	0.8837	0.000	3.786	0.248
1987	198.4	403	11.9	58	10.7	1.0293	0.092	4.053	0.340
1988	188.4	517	16.5	58	11.6	1.1836	0.089	5.689	0.345
1989	209.2	436	15.0	52	12.4	1.1384	0.093	4.817	0.322
1990	181.7	438	15.0	43	11.9	1.2283	0.094	4.444	0.297
1991	223.6	480	19.4	42	16.9	1.3154	0.093	4.962	0.255
1992	169.7	261	14.0	26	19.7	1.7393	0.105	2.624	0.187
1993	259.6	446	23.3	33	20.5	1.9411	0.097	3.858	0.166
1994	257.3	544	22.3	32	15.6	1.7918	0.094	6.112	0.274
1995	240.0	592	20.8	32	13.4	1.3512	0.091	7.659	0.368
1996	263.9	679	20.6	39	11.0	1.2167	0.090	8.841	0.429
1997	298.8	554	15.2	39	10.3	1.1422	0.093	6.486	0.427
1998	295.0	633	15.0	38	9.3	1.0058	0.092	8.329	0.554
1999	295.8	666	15.3	38	8.8	0.9009	0.091	8.525	0.558
2000	270.2	1316	30.4	37	8.8	1.0663	0.086	15.227	0.501
2001	281.6	1034	23.1	34	8.7	1.0339	0.088	10.701	0.462
2002	255.3	1405	24.7	34	6.5	0.7425	0.087	12.224	0.495
2003	322.8	1069	17.0	37	5.9	0.5756	0.088	9.449	0.555
2004	316.3	944	14.7	38	6.1	0.5822	0.090	7.482	0.509
2005	316.9	850	17.3	39	7.0	0.6543	0.090	7.912	0.459
2006	237.6	585	8.9	34	4.7	0.5501	0.093	4.704	0.531
2007	180.6	386	8.6	20	9.5	0.7931	0.100	4.281	0.500
2008	184.4	317	7.6	20	8.9	0.9682	0.103	3.388	0.448
2009	173.9	259	6.0	21	8.2	0.8275	0.107	2.847	0.471
2010	195.6	275	6.3	21	8.3	0.8791	0.105	3.098	0.494
2011	186.9	244	5.2	19	7.8	1.0153	0.108	2.414	0.464
2012	183.9	372	7.3	20	7.4	0.8467	0.100	3.514	0.481
2013	171.2	218	4.9	14	7.7	1.0085	0.110	2.815	0.575
2014	174.4	152	3.0	15	6.4	0.7362	0.121	1.724	0.572
2015	150.9	119	2.5	14	6.6	0.4482	0.129	1.049	0.416
2016	132.1	96	2.5	13	8.7	0.8115	0.140	1.014	0.405
2017	155.7	80	2.1	12	7.7	0.9048	0.145	1.035	0.504
2018	151.8	95	4.8	10	16.8	0.8864	0.144	1.103	0.229
2019	165.5	172	5.5	14	11.3	0.8987	0.120	2.003	0.365
2020	141.7	141	4.6	14	12.7	0.9032	0.125	1.385	0.300

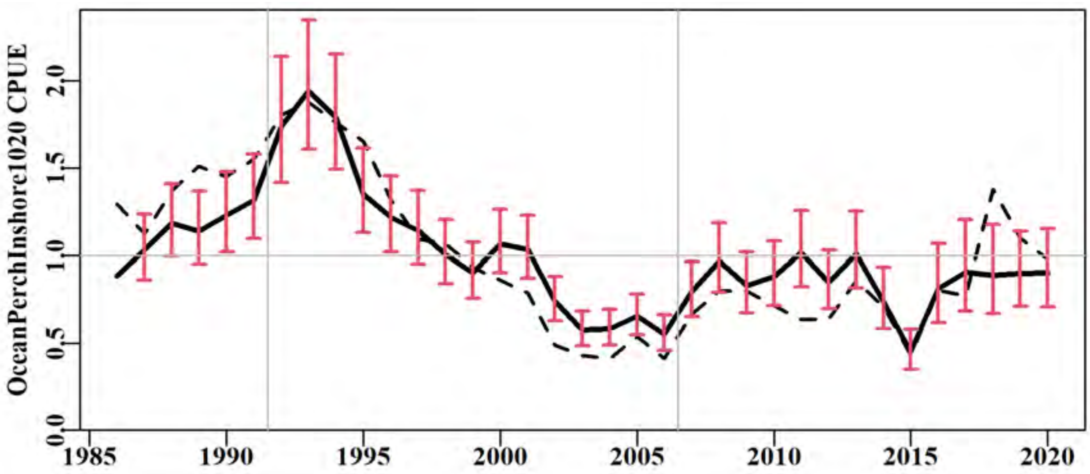

Figure 6.159. OceanPerchInshore1020 standardization. The dashed black line represents the geometric mean CPUE, solid black line the standardized CPUE. The red bars are the 95% confidence intervals about the mean estimates. The graph scales both time-series of standardized CPUE relative to the mean of each time-series.

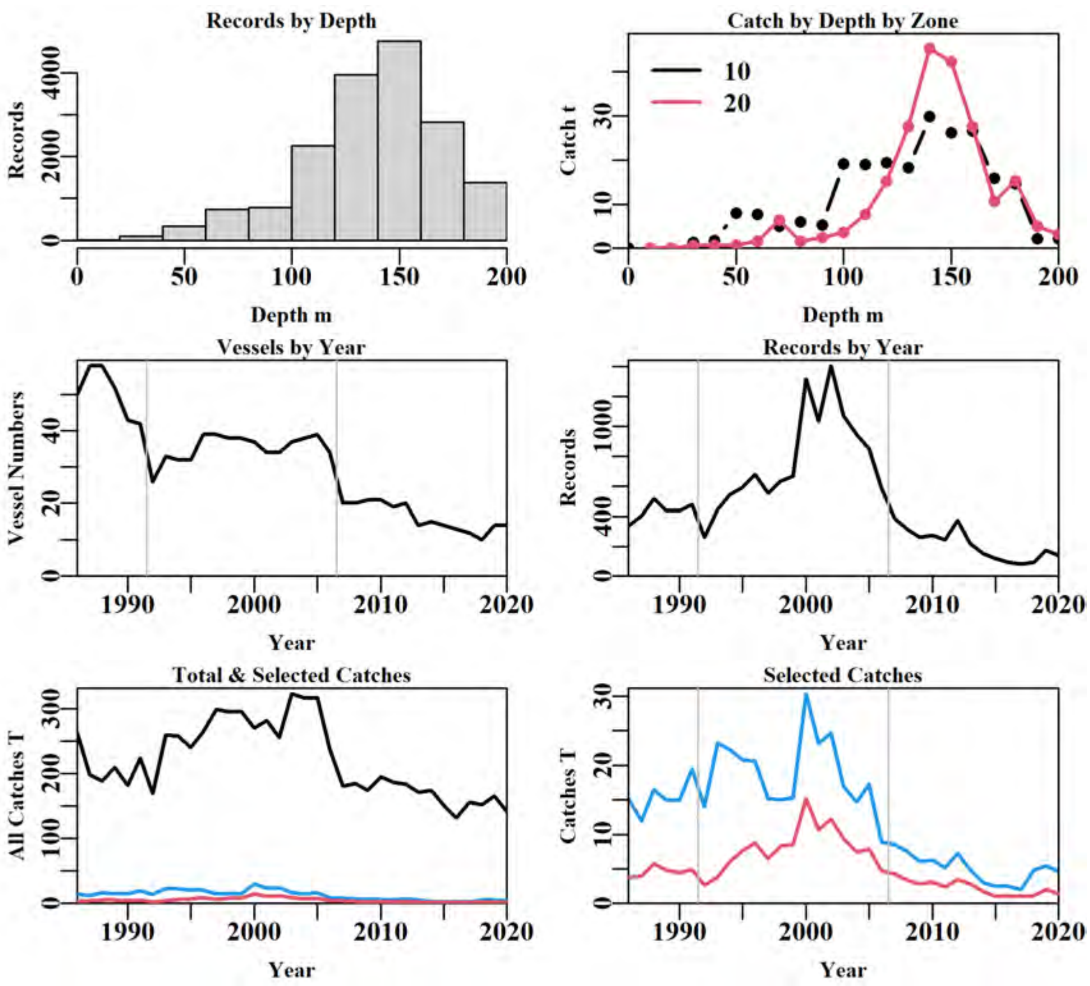

Figure 6.160. OceanPerchInshore1020 fishery details. The bottom left plot depicts all known catches (top black line), and all selected catches used in the analysis (middle blue line); the lower red line: selected catches < 30 kg).

Table 6.113. 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	179725	161058	25048	24843	17475	17139	17116
Difference	0	18667	136010	205	7368	336	23
Catch	7833	7201	666	660	452	447	446
Difference	0	631	6535	7	208	4	1

Table 6.114. 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 6.115. 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

Term	AIC	RSS	MSS	Nobs	Npars	adj_r2	%Change
Year	6007	24213	3926	17116	35	13.8	0
Month	5704	23758	4381	17116	46	15.3	1.57
Vessel	2307	19140	8999	17116	197	31.2	15.85
DepCat	1688	18417	9722	17116	217	33.7	2.52
DayNight	1618	18335	9804	17116	220	34.0	0.28
Zone	1557	18268	9872	17116	221	34.2	0.24
Zone:Month	1553	18240	9899	17116	232	34.3	0.06
Zone:DepCat	1446	18110	10030	17116	240	34.7	0.50

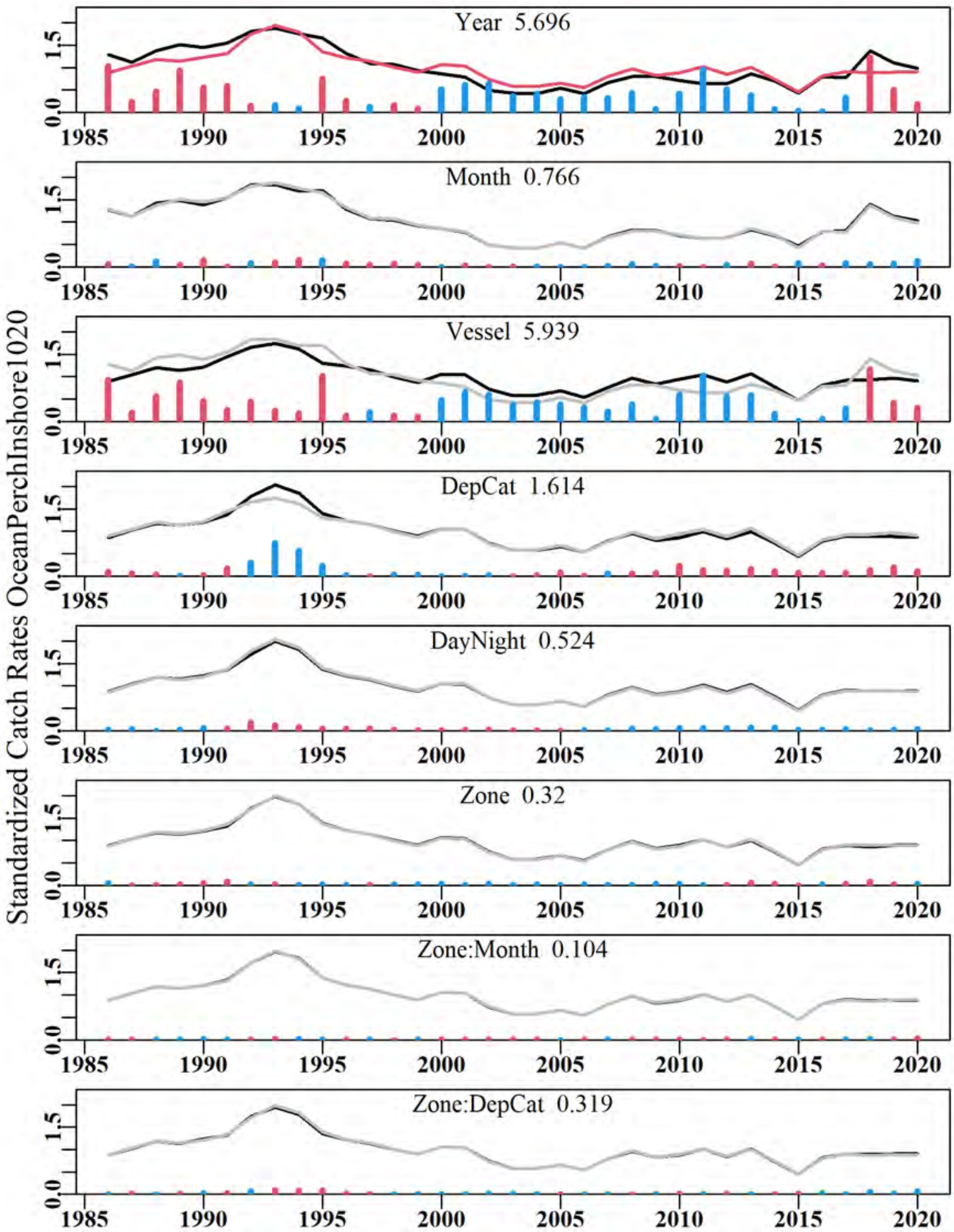

Figure 6.161. OceanPerchInshore1020. The influence of each factor on the optimal standardization. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by vertical bars with blue bars indicating the optimum model is higher than 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.

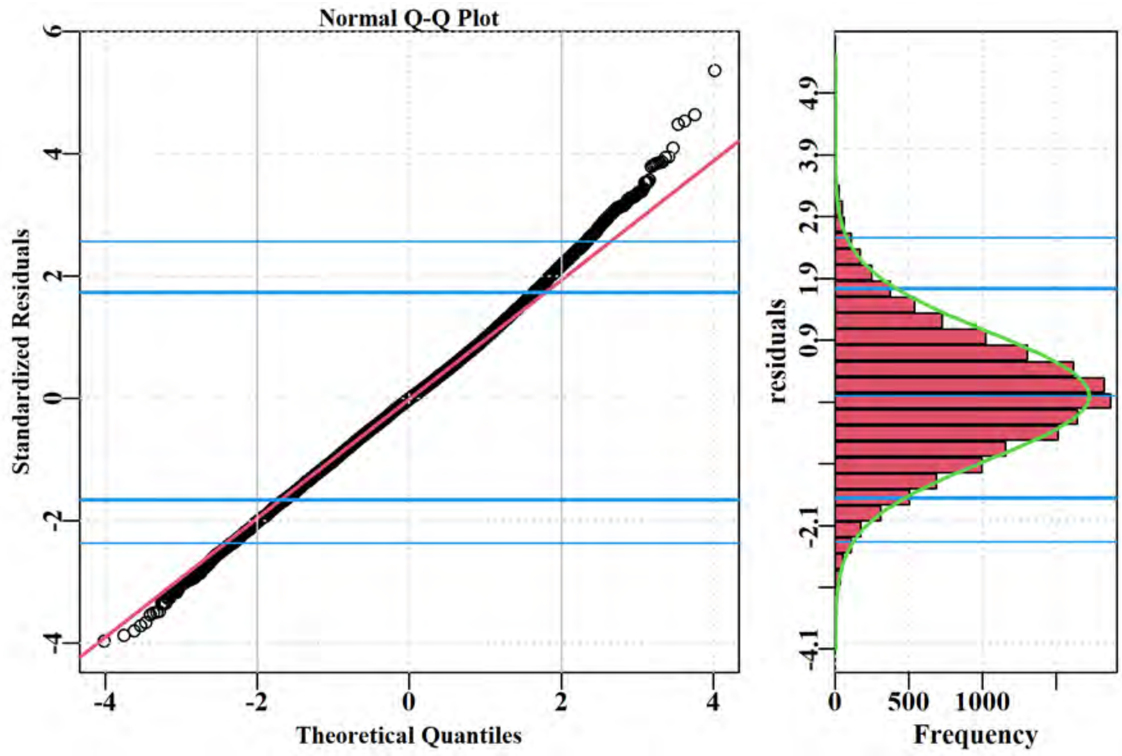

Figure 6.162. OceanPerchInshore1020. diagnostic plots. The distribution of residuals from the optimum fit. The qqplot indicates the fit to the expected normality, while the histogram of residuals illustrates the 90% quantiles to indicate the intensity of any lack of fit at the margins of the distribution.

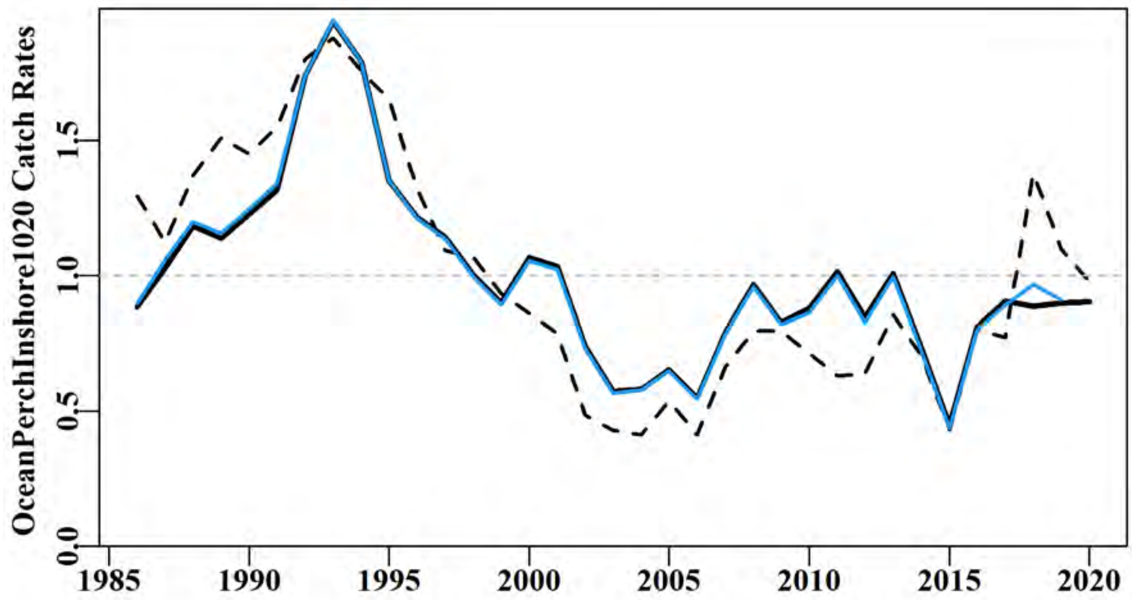

Figure 6.163. OceanPerchInshore1020. A comparison of the previous year's standardization (blue line) with this year's. They should lie on top of each other, although small deviations may relate to data adjustments, particularly in very recent years.

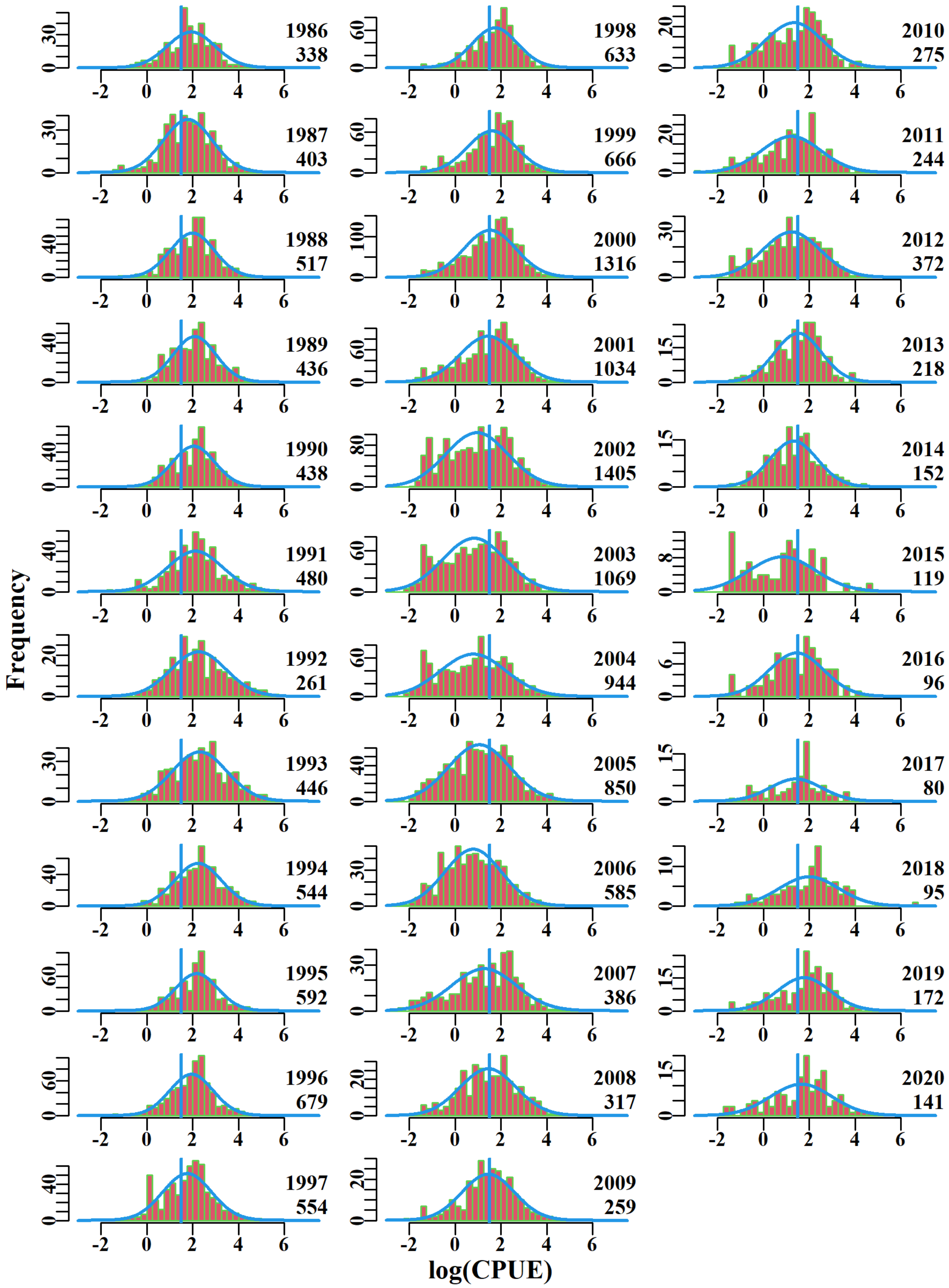

Figure 6.164. OceanPerchInshore1020. The natural log(CPUE) for each year of data available the blue lines are normal distributions fitted to the histogram frequencies. The numbers in each plot are the year and number of records.

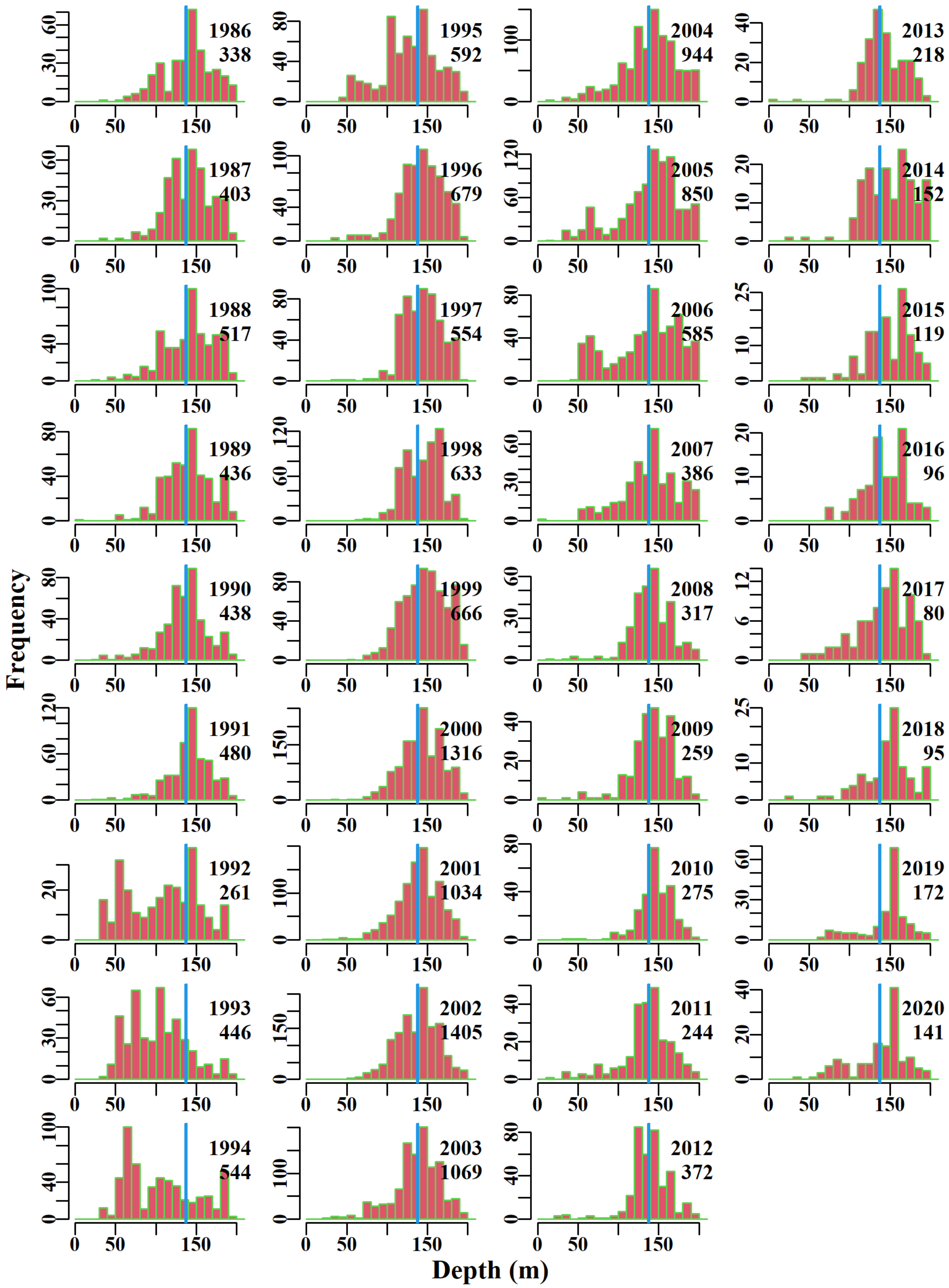

Figure 6.165. OceanPerchInshore1020. The average Depth of fishing for each year of data available to illustrate the development of the fishery through time. The numbers in each plot are the year and number of records.

6.27 Ocean Jackets 10-50

Ocean Jackets (LTC – 37465006 – *Nelusetta ayraudi* and Leather Jackets LTH – 37465000). Trawl caught Ocean Jackets based on methods TW, TDO, OTB, in zones 10, 20, 30, 40, 50, and depths 0 to 300 m within the SET fishery for the years 1986 - 2020 were analysed (Table 6.116). 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.

6.27.1 *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 throughout the analysis period. There was an increase in small shots of < 30 kg over the 1992 - 2006 period, which is suggestive of either low availability or high levels of small fish (Figure 6.167).

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 6.120). The qqplot suggests a small departure from the assumed Normal distribution as depicted by both tails of the distribution (Figure 6.169).

Annual standardized CPUE are relatively flat and below average between 1986-2003 reflecting the relatively low catches at the time. It increased rapidly along with catches from 2004 - 2007 after which it has continued to be relatively high (declining slightly from 2007 - 2016), decreased from 2017 to just above average in 2018, further decreased to the long-term average in 2019 and increased to above average in 2020 based on the 95% confidence intervals (Figure 6.166). The 2019 catch of 123.4 t corresponding to 18 vessels is the lowest since 2002.

6.27.2 *Action Items and Issues*

No issues identified.

Table 6.116. 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, OTB
years	1986 - 2020

Table 6.117. 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

Year	Total	N	Catch	Vess	GeoM	Opt	StDev	C<30Kg	P<30Kg
1986	56.4	2471	44.7	75	7.3	0.6191	0.000	26.955	0.603
1987	53.4	1432	28.0	61	7.6	0.6584	0.038	16.203	0.579
1988	66.3	1905	45.6	66	8.8	0.7927	0.035	22.651	0.497
1989	71.8	1800	32.6	65	6.9	0.6804	0.036	20.112	0.617
1990	91.0	1542	33.0	46	7.6	0.6725	0.038	16.489	0.499
1991	170.5	1325	24.7	46	6.7	0.5855	0.040	15.249	0.618
1992	88.9	1190	24.5	41	6.7	0.5986	0.041	14.472	0.591
1993	71.9	1326	29.0	42	6.9	0.6492	0.040	16.816	0.581
1994	74.5	1437	34.5	45	8.3	0.7340	0.039	19.276	0.559
1995	140.2	2216	58.9	41	9.0	0.7204	0.035	27.382	0.465
1996	199.6	2553	71.5	53	9.9	0.7451	0.034	30.221	0.423
1997	177.4	1993	52.1	51	9.5	0.6799	0.036	21.864	0.420
1998	189.9	2480	67.7	44	9.4	0.6749	0.035	27.242	0.402
1999	202.8	2682	88.0	52	10.6	0.7923	0.034	31.123	0.354
2000	198.8	2983	73.2	53	7.7	0.6400	0.034	37.471	0.512
2001	222.6	3195	64.4	55	6.5	0.5698	0.033	37.882	0.588
2002	378.5	4865	199.1	61	10.8	0.6821	0.031	52.170	0.262
2003	482.3	5464	185.8	58	9.8	0.6480	0.031	54.008	0.291
2004	692.6	6200	311.4	60	16.0	1.0581	0.031	56.415	0.181
2005	890.6	5131	341.2	54	21.1	1.1948	0.031	39.369	0.115
2006	741.5	4599	300.1	50	21.2	1.3256	0.032	34.980	0.117
2007	564.8	3073	284.1	27	31.3	1.5805	0.034	19.766	0.070
2008	490.4	3519	316.3	29	28.9	1.5010	0.034	23.006	0.073
2009	610.0	3229	374.2	28	36.6	1.6806	0.034	19.665	0.053
2010	484.0	3202	294.2	29	30.5	1.3777	0.034	20.507	0.070
2011	487.4	3192	274.6	29	30.0	1.3098	0.034	21.184	0.077
2012	519.7	3405	340.4	30	33.6	1.4905	0.034	21.441	0.063
2013	488.6	2816	262.7	27	28.7	1.4910	0.035	16.442	0.063
2014	512.0	3362	273.0	28	24.5	1.3355	0.034	21.360	0.078
2015	414.9	3066	248.0	31	25.7	1.2881	0.034	19.929	0.080
2016	467.1	2599	238.5	28	29.8	1.3389	0.036	16.962	0.071
2017	424.9	1854	219.6	25	44.1	1.6371	0.038	7.889	0.036
2018	306.5	1643	146.9	24	30.7	1.1123	0.039	9.211	0.063
2019	258.6	1779	125.5	19	23.6	1.0097	0.039	11.831	0.094
2020	288.5	1371	128.7	22	28.2	1.1259	0.041	9.066	0.070

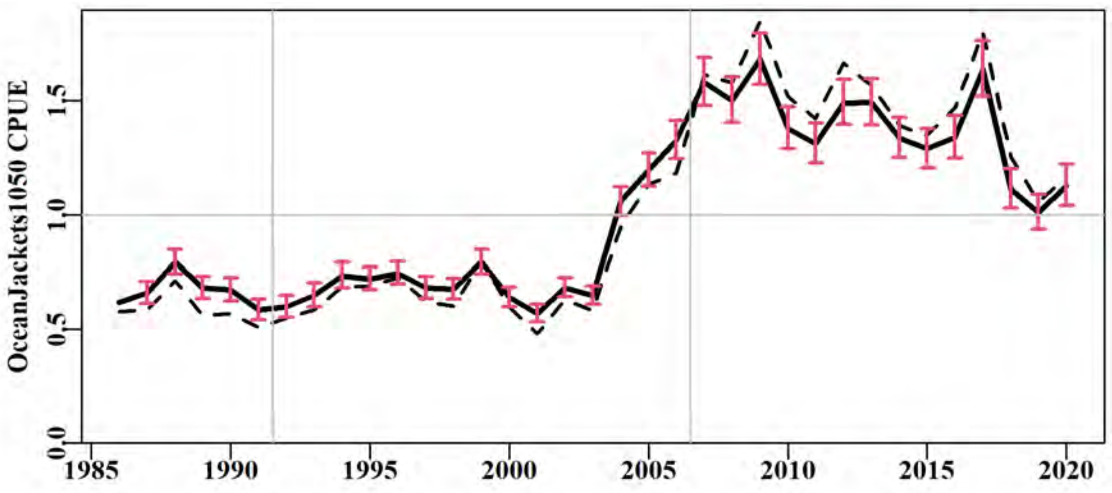

Figure 6.166. OceanJackets1050 standardization. The dashed black line represents the geometric mean CPUE, solid black line the standardized CPUE. The red bars are the 95% confidence intervals about the mean estimates. The graph scales both time-series of standardized CPUE relative to the mean of each time-series.

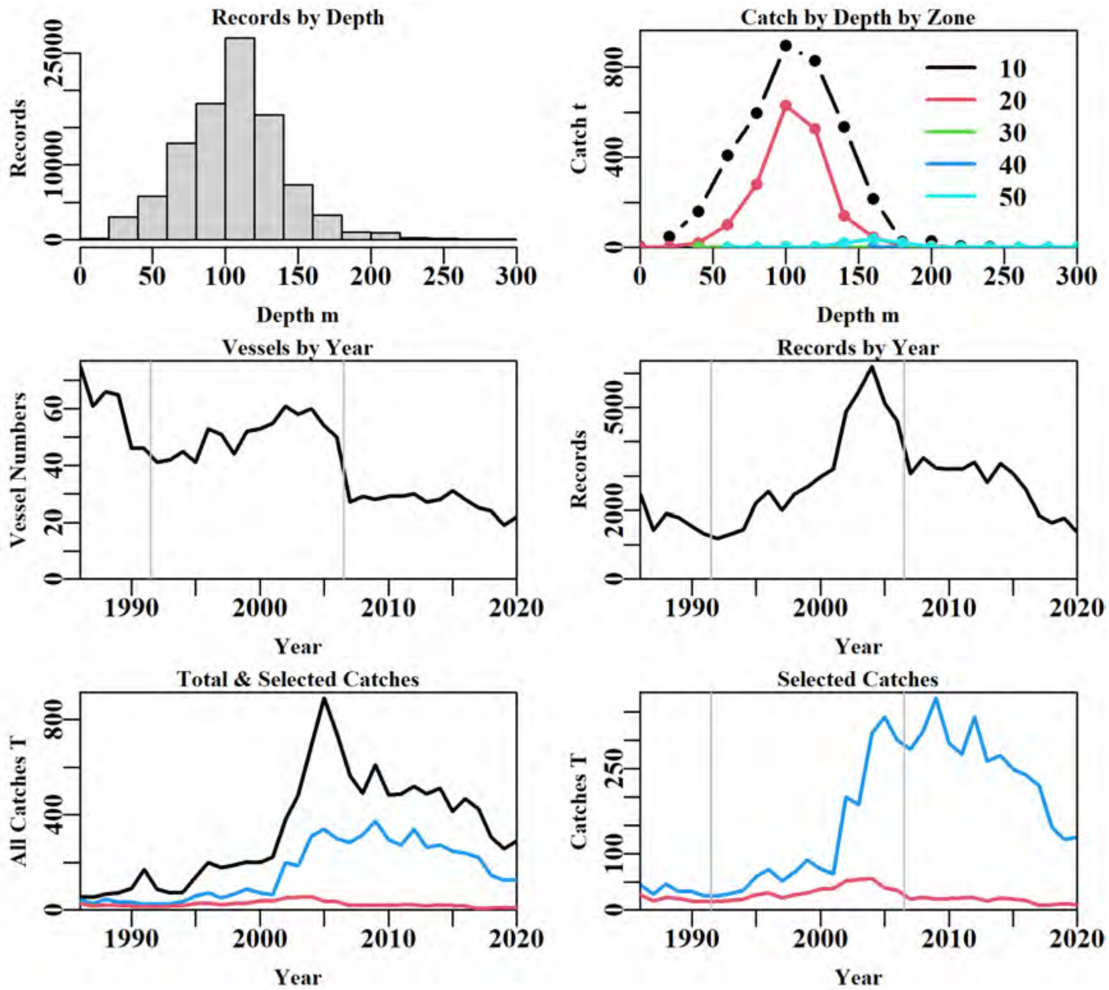

Figure 6.167. OceanJackets1050 fishery details. The bottom left plot depicts all known catches (top black line), and all selected catches used in the analysis (middle blue line); the lower red line: selected catches < 30 kg).

Table 6.118. 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	191116	176472	174663	170825	102774	97074	96899
Difference	0	14644	1809	3838	68051	5700	175
Catch	12143	12003	11868	11332	5727	5651	5636
Difference	0	141	135	536	5605	76	14

Table 6.119. 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 6.120. 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

Term	AIC	RSS	MSS	Nobs	Npars	adj_r2	%Change
Year	26385	127134	17900	96899	35	12.3	0
Vessel	12682	109973	35061	96899	209	24.0	11.70
DepCat	12050	109224	35810	96899	224	24.5	0.51
Month	10983	108003	37031	96899	235	25.4	0.83
Zone	9989	106892	38142	96899	239	26.1	0.76
DayNight	9859	106742	38292	96899	242	26.2	0.10
Zone:Month	9632	106407	38627	96899	281	26.4	0.20
Zone:DepCat	8823	105529	39505	96899	278	27.0	0.81

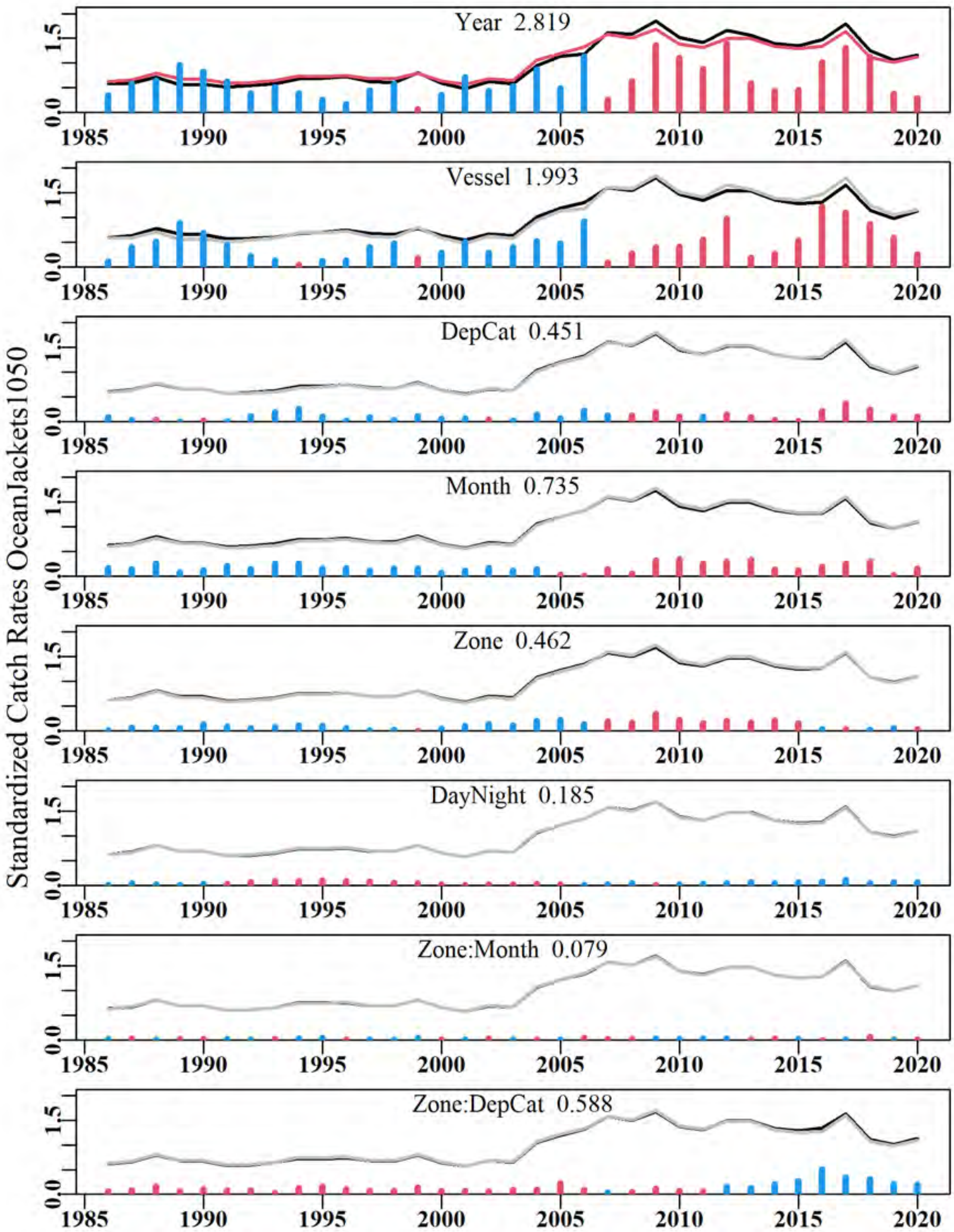

Figure 6.168. OceanJackets1050. The influence of each factor on the optimal standardization. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by vertical bars with blue bars indicating the optimum model is higher than the 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.

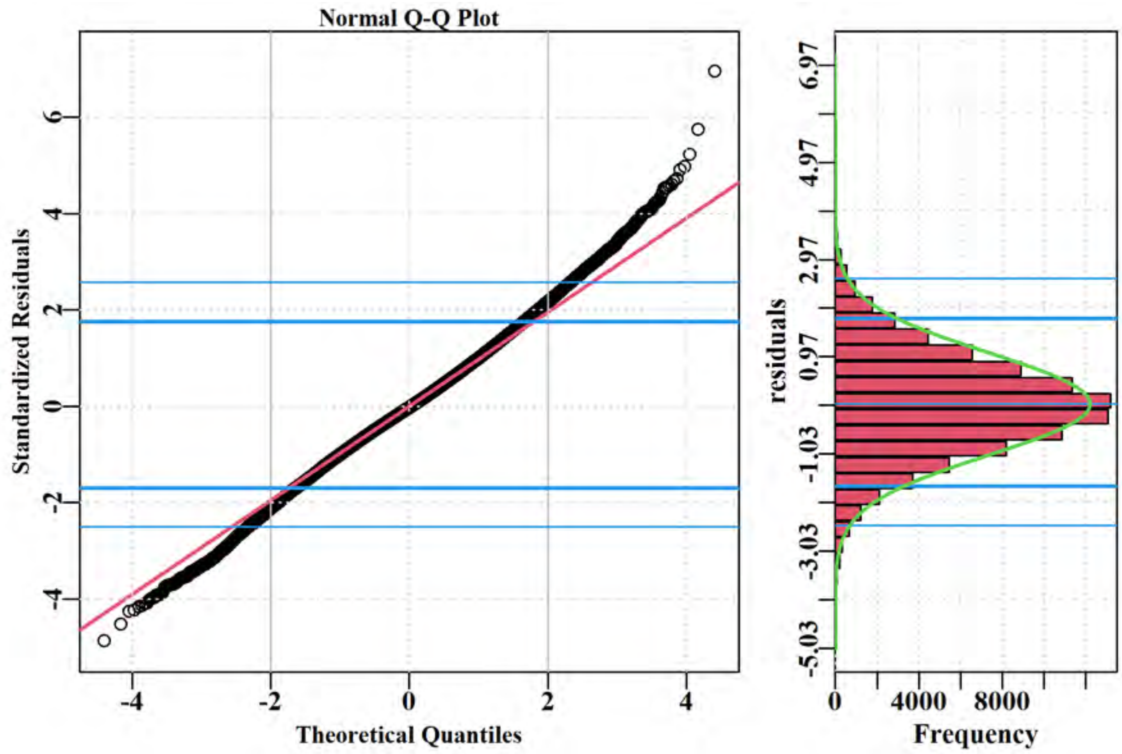

Figure 6.169. OceanJackets1050. diagnostic plots. The distribution of residuals from the optimum fit. The qqplot indicates the fit to the expected normality, while the histogram of residuals illustrates the 90% quantiles to indicate the intensity of any lack of fit at the margins of the distribution.

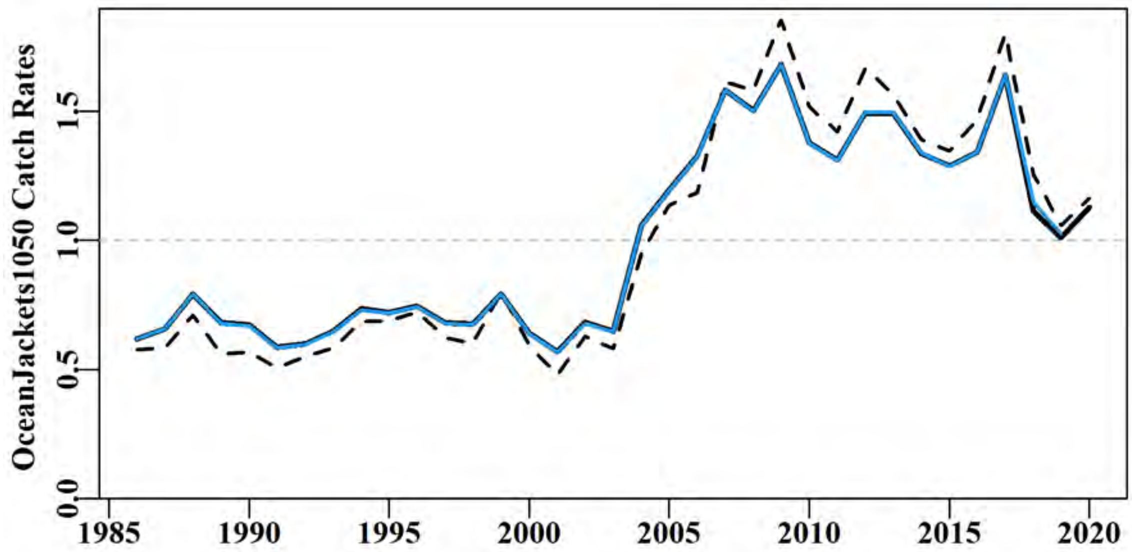

Figure 6.170. OceanJackets1050. A comparison of the previous year's standardization (blue line) with this year's. They should lie on top of each other, although small deviations may relate to data adjustments, particularly in very recent years.

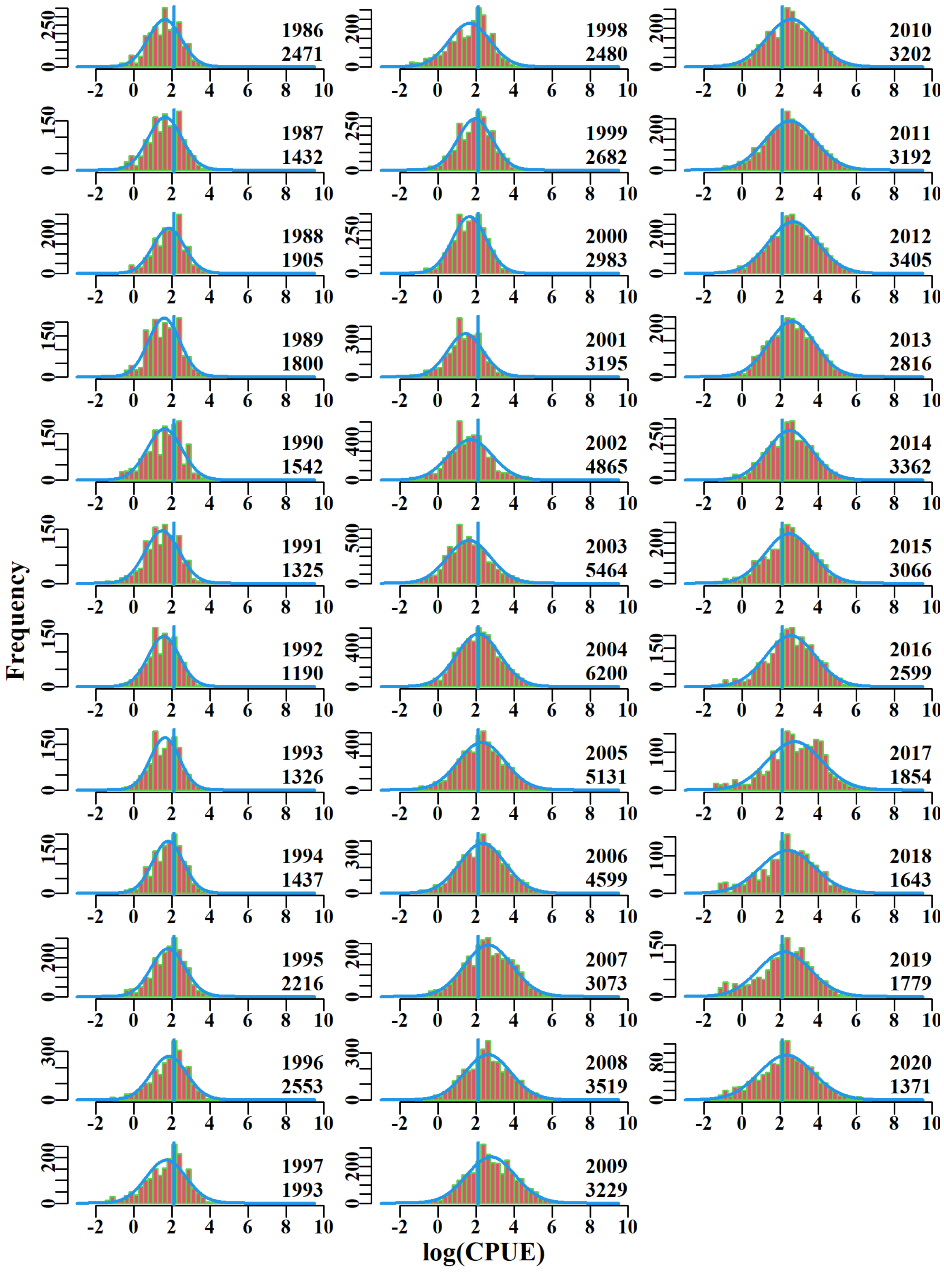

Figure 6.171. OceanJackets1050. The natural log(CPUE) for each year of data available the blue lines are normal distributions fitted to the histogram frequencies. The numbers in each plot are the year and number of records.

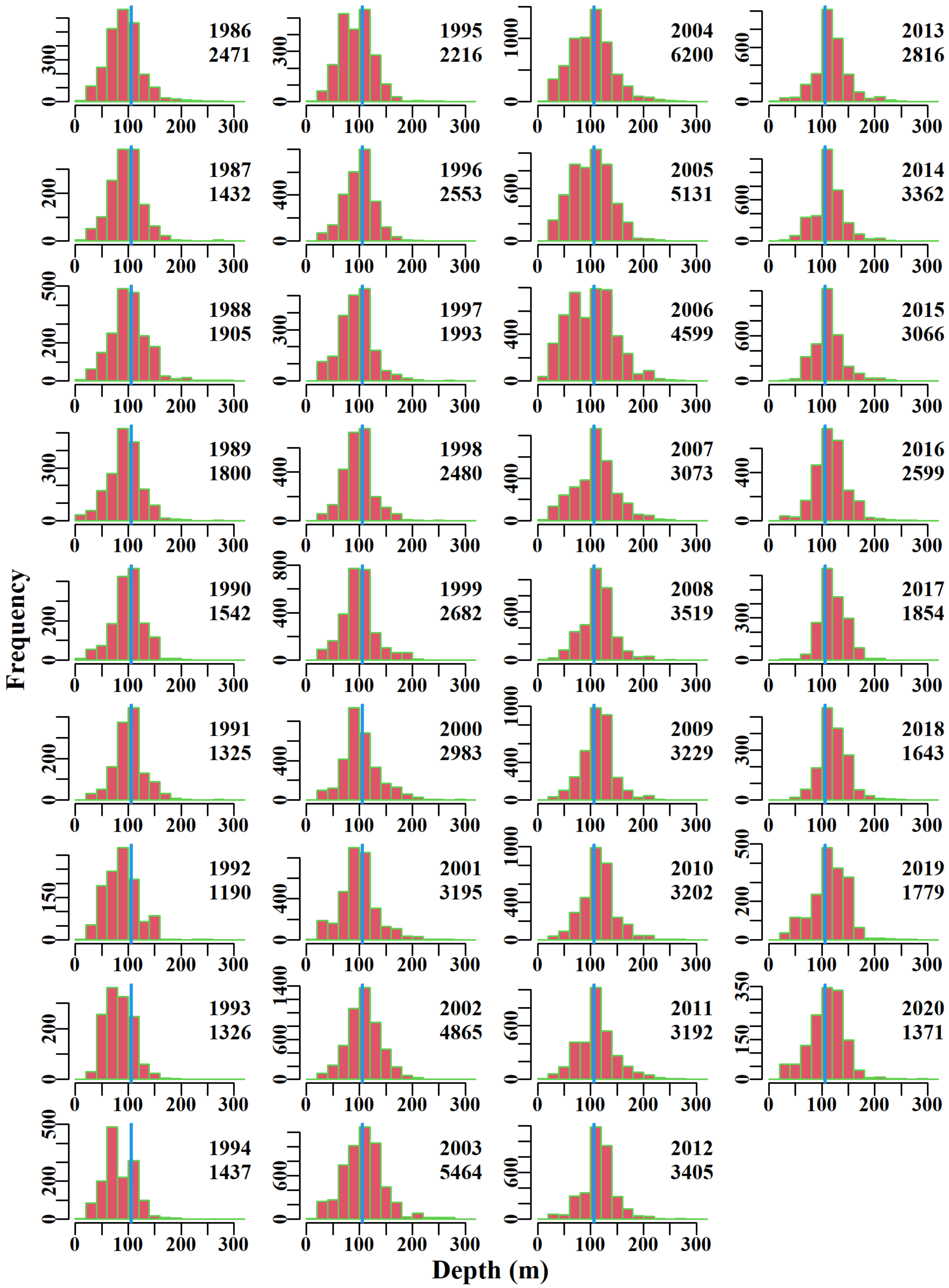

Figure 6.172. OceanJackets1050. The average Depth of fishing for each year of data available to illustrate the development of the fishery through time. The numbers in each plot are the year and number of records.

6.28 Ocean Jackets GAB

Ocean Jackets (LTC – 37465006 – *Nelusetta ayraudi* and Leather Jackets LTH – 37465000). Trawl caught Ocean Jackets based on methods TW, TDO, OTT, TMO, PTB, in zones 82, 83, and depths 0 to 300 m within the GAB fishery for the years 1986 - 2020 were analysed. These constitute the criteria used to select data from the Commonwealth logbook database (Table 6.121).

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.

6.28.1 *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 total catch of 120.4 t in 2019 is the lowest since 2000.

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 126). The qqplot suggests a small departure from the assumed Normal distribution as depicted by both tails of the distribution (Figure 6.176).

Annual standardized CPUE are noisy and flat across the 1986 - 2020 period (Figure 6.173) but catches and numbers were low from 1986 – 1989.

6.28.2 *Action Items and Issues*

No issues identified.

Table 6.121. 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, OTT, TMO, PTB
years	1986 - 2020

Table 6.122. 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

Year	Total	N	Catch	Vess	GeoM	Opt	StDev	C<30Kg	P<30Kg
1986	56.4	137	8.0	1	15.1	1.2439	0.000	2.520	0.317
1987	53.4	206	21.7	3	22.9	1.0208	0.105	2.270	0.105
1988	66.3	244	15.6	7	20.8	1.2171	0.184	1.603	0.103
1989	71.8	571	34.6	7	18.0	1.2389	0.182	4.168	0.120
1990	91.0	916	51.2	11	15.7	0.8122	0.179	8.675	0.169
1991	170.5	1248	139.2	8	26.8	1.0336	0.179	6.470	0.046
1992	88.9	923	57.5	7	14.1	0.8830	0.179	9.354	0.163
1993	71.9	813	38.4	4	9.9	0.6001	0.179	9.442	0.246
1994	74.5	736	36.1	5	10.6	0.5324	0.179	7.495	0.208
1995	140.2	1311	78.0	5	12.9	0.6944	0.178	12.907	0.165
1996	199.6	1712	122.3	6	14.9	0.8130	0.178	15.049	0.123
1997	177.4	2123	119.5	9	11.8	0.6688	0.178	21.575	0.180
1998	189.9	1787	115.6	9	13.8	0.7226	0.178	16.270	0.141
1999	202.8	1573	108.4	7	13.6	0.8219	0.178	12.140	0.112
2000	198.8	1567	123.4	5	17.3	0.8438	0.178	11.452	0.093
2001	222.6	1992	146.1	6	15.5	0.8759	0.178	12.521	0.086
2002	378.5	1793	148.1	6	16.3	0.9338	0.178	11.991	0.081
2003	482.3	2791	275.1	9	19.3	1.0611	0.178	11.385	0.041
2004	692.6	3399	360.3	9	20.9	1.1603	0.178	13.172	0.037
2005	890.6	4288	519.8	10	23.8	1.2298	0.178	14.612	0.028
2006	741.5	3573	405.1	11	21.4	0.9514	0.178	11.905	0.029
2007	564.8	2591	248.8	8	19.8	0.8533	0.178	10.479	0.042
2008	490.4	2314	144.0	6	12.9	0.7414	0.178	14.610	0.101
2009	610.0	2139	218.4	4	20.9	1.0380	0.178	11.145	0.051
2010	484.0	1777	167.1	4	19.0	1.1853	0.178	5.245	0.031
2011	487.4	1881	192.4	4	21.0	1.1775	0.178	5.756	0.030
2012	519.7	1725	156.0	5	17.3	1.1453	0.178	3.236	0.021
2013	488.6	2222	205.0	6	17.4	1.2578	0.178	1.018	0.005
2014	512.0	2051	209.9	6	18.3	1.2889	0.178	0.332	0.002
2015	414.9	1569	148.5	3	18.4	1.2449	0.179	0.893	0.006
2016	467.1	1656	203.3	4	23.8	1.2976	0.179	4.774	0.023
2017	424.9	1623	183.7	4	21.8	1.1934	0.179	10.354	0.056
2018	306.5	1515	149.7	4	19.8	1.1451	0.179	10.383	0.069
2019	258.6	1400	121.4	3	17.8	1.0680	0.179	7.588	0.062
2020	288.5	1412	122.8	3	16.7	1.0046	0.179	9.504	0.077

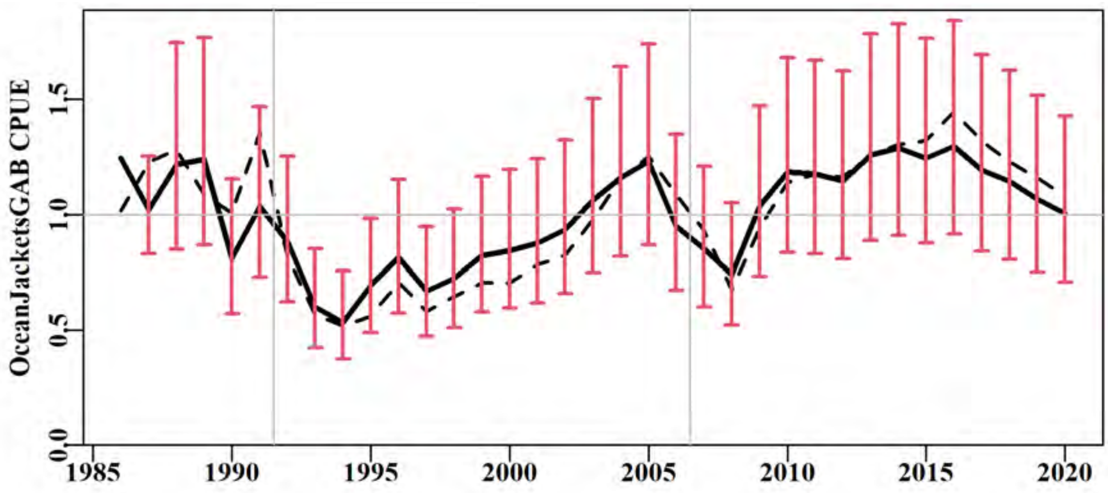

Figure 6.173. OceanJacketsGAB standardization. The dashed black line represents the geometric mean CPUE, solid black line the standardized CPUE. The red bars are the 95% confidence intervals about the mean estimates. The graph scales both time-series of standardized CPUE relative to the mean of each time-series.

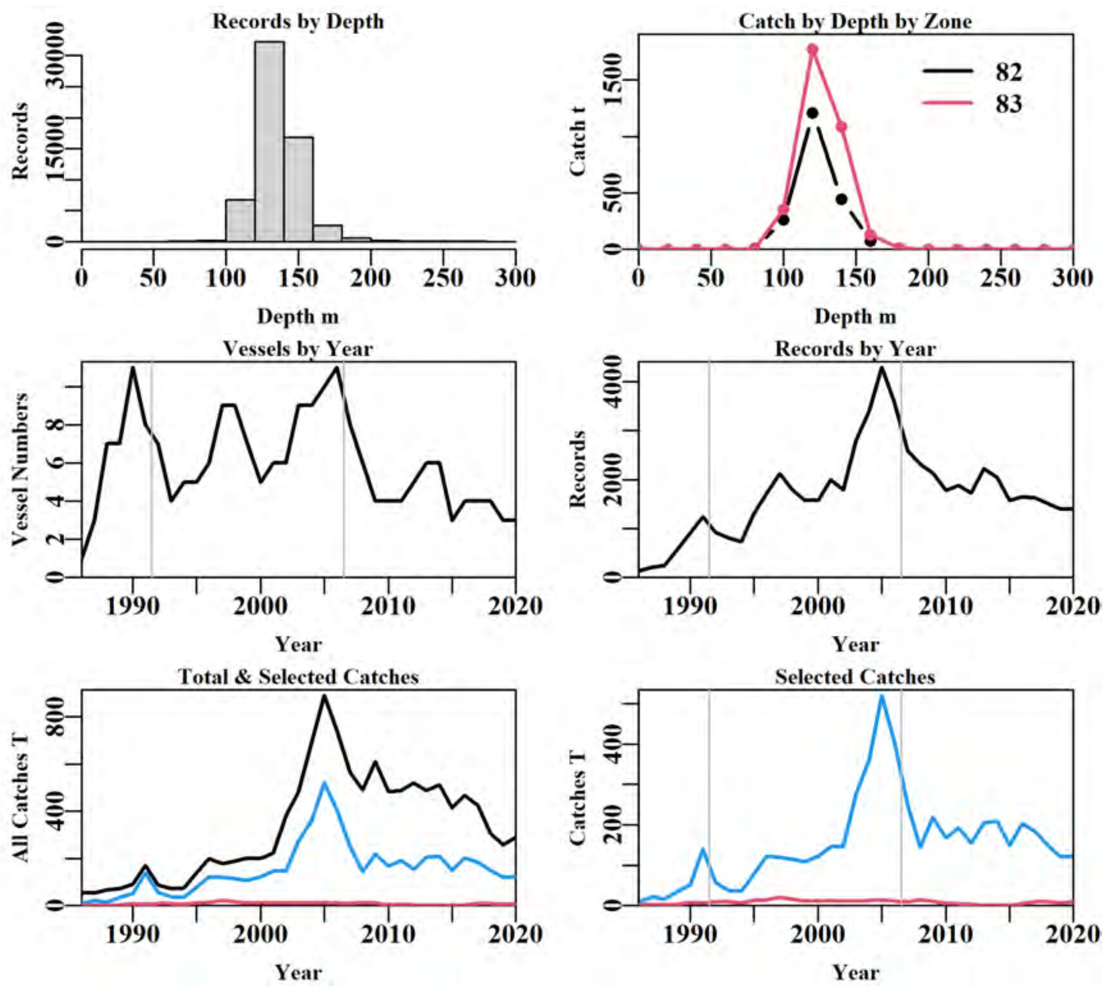

Figure 6.174. OceanJacketsGAB fishery details. The bottom left plot depicts all known catches (top black line), and all selected catches used in the analysis (middle blue line); the lower red line: selected catches < 30 kg).

Table 6.123. 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	191116	176715	174892	171052	61975	59593	59578
Difference	0	14401	1823	3840	109077	2382	15
Catch	12143	12004	11869	11334	5415	5395	5395
Difference	0	139	135	536	5918	20	1

Table 6.124. 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 6.125. 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

Term	AIC	RSS	MSS	Nobs	Npars	adj_r2	%Change
Year	489	59999	4557	59578	35	7.0	0
DayNight	-6082	53727	10829	59578	38	16.7	9.72
Vessel	-8878	51199	13357	59578	76	20.6	3.87
DepCat	-12128	48456	16100	59578	91	24.8	4.23
Month	-13420	47399	17157	59578	102	26.5	1.63
Zone	-13420	47398	17158	59578	103	26.5	0.00
Zone:Month	-13622	47220	17336	59578	114	26.7	0.26
Zone:DepCat	-13450	47350	17206	59578	118	26.5	0.06

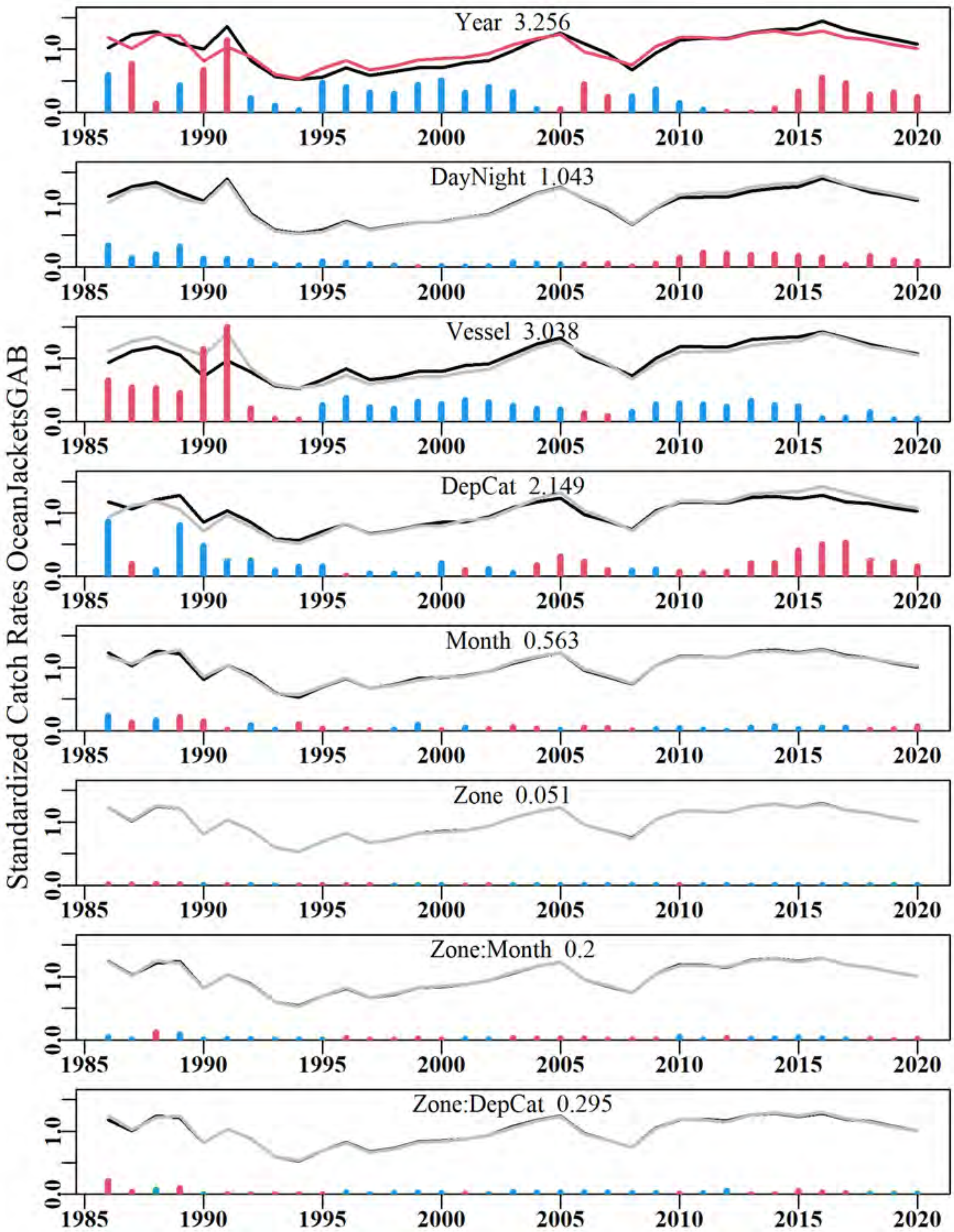

Figure 6.175. OceanJacketsGAB. The influence of each factor on the optimal standardization. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by vertical bars with blue bars indicating the optimum model is higher than the 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.

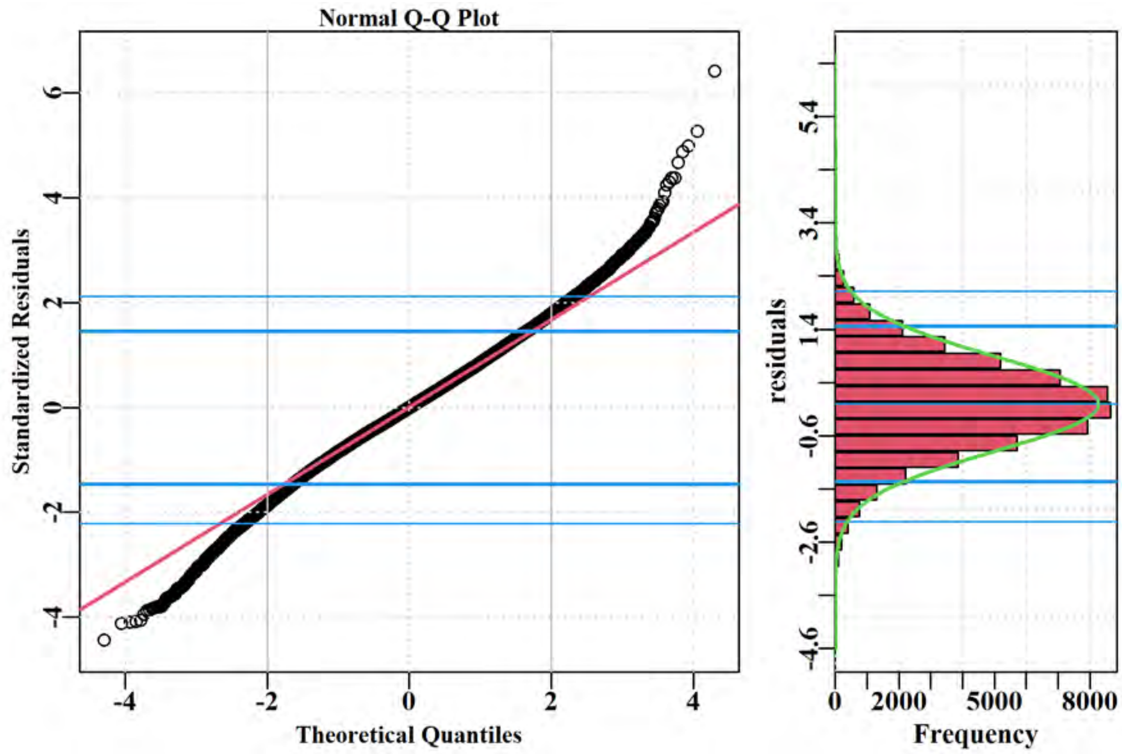

Figure 6.176. OceanJacketsGAB. diagnostic plots. The distribution of residuals from the optimum fit. The qqplot indicates the fit to the expected normality, while the histogram of residuals illustrates the 90% quantiles to indicate the intensity of any lack of fit at the margins of the distribution.

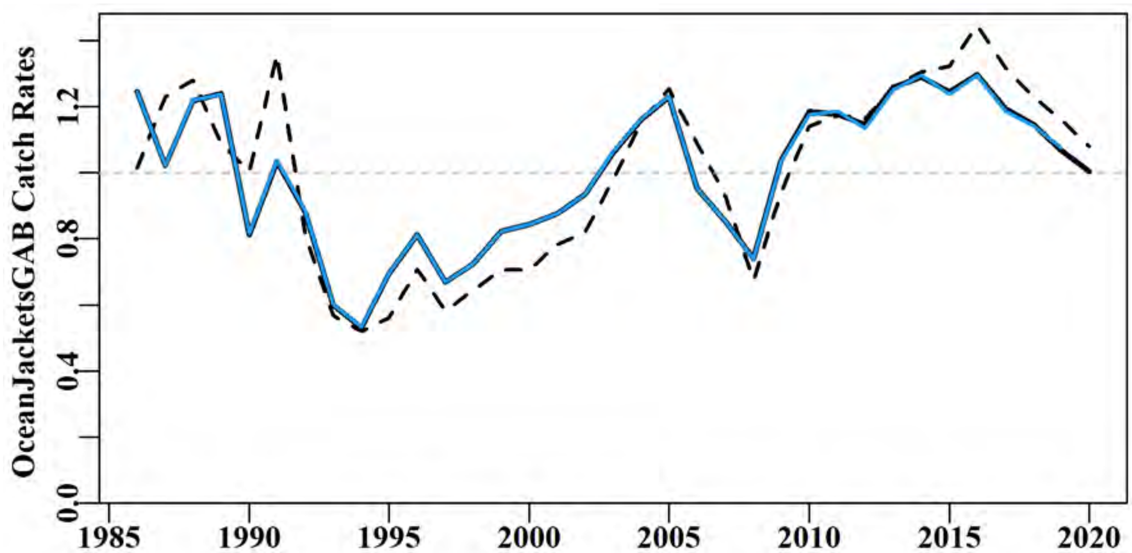

Figure 6.177. OceanJacketsGAB. A comparison of the previous year's standardization (blue line) with this year's. They should lie on top of each other, although small deviations may relate to data adjustments, particularly in very recent years.

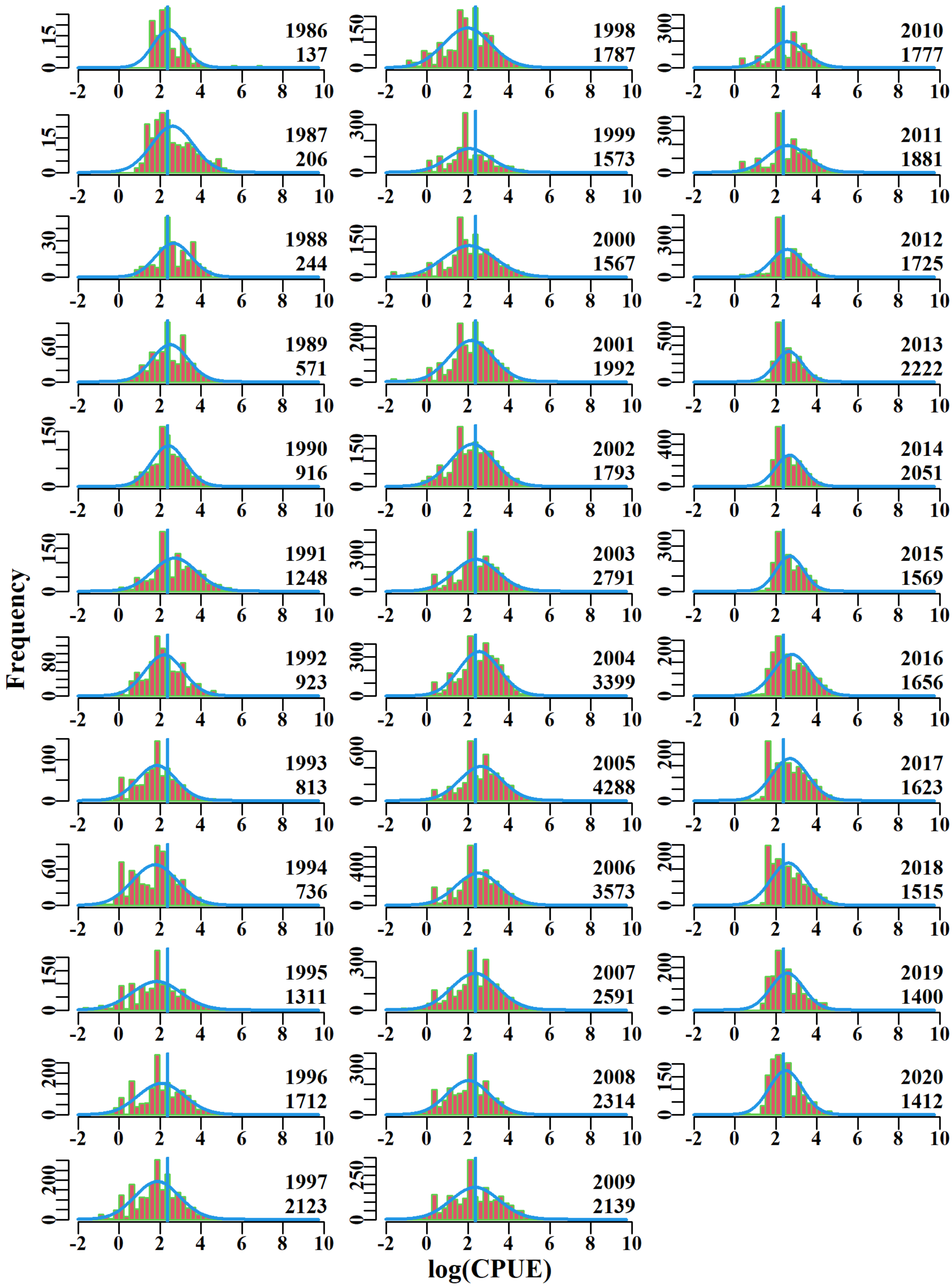

Figure 6.178. OceanJacketsGAB. The natural log(CPUE) for each year of data available the blue lines are normal distributions fitted to the histogram frequencies. The numbers in each plot are the year and number of records.

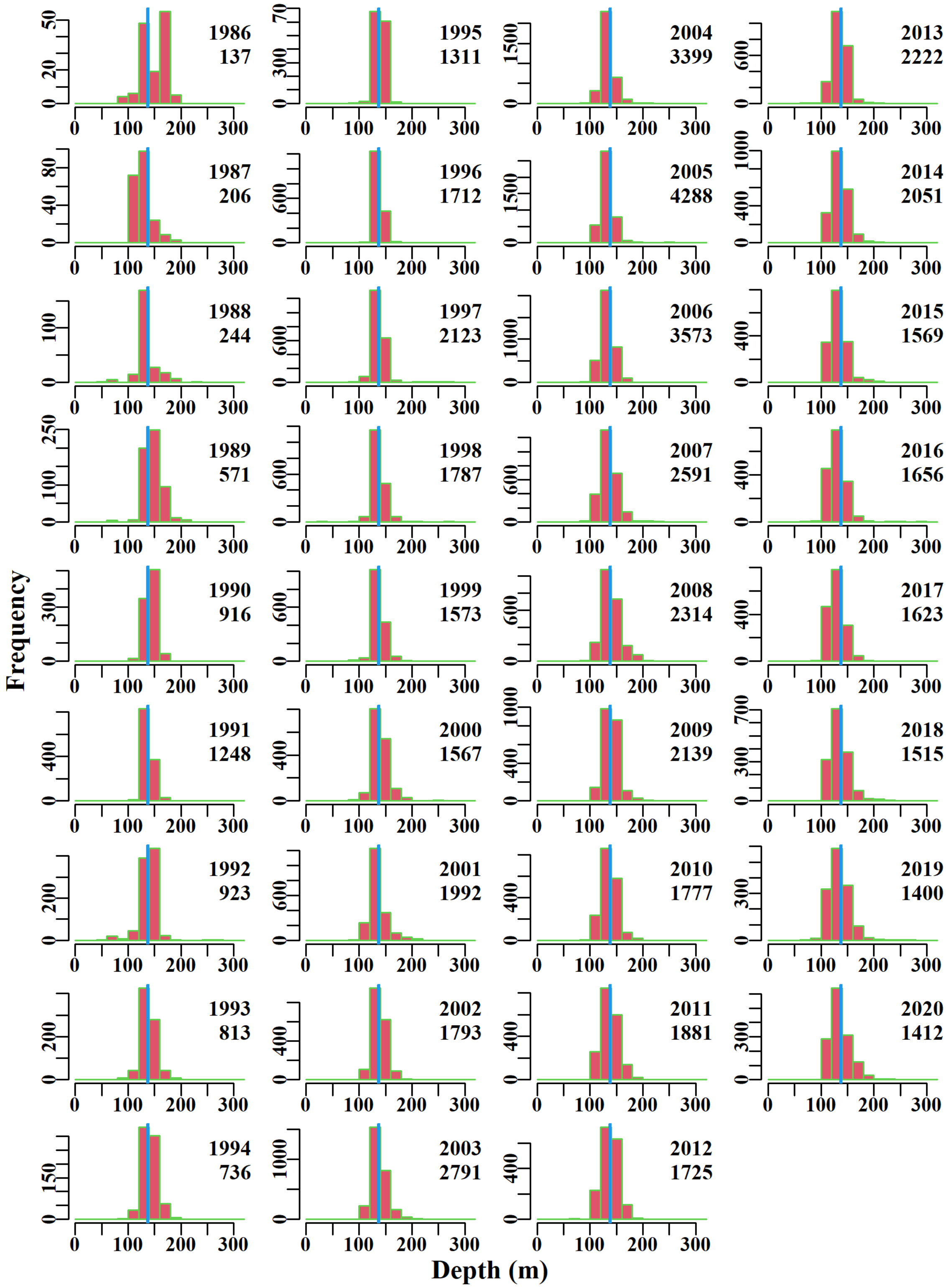

Figure 6.179. OceanJacketsGAB. The average Depth of fishing for each year of data available to illustrate the development of the fishery through time. The numbers in each plot are the year and number of records.

6.29 Western Gemfish 40 50

For western Gemfish (GEM– 37439002 – *Rexea solandri*) in zones 40 and 50, initial data selection was conducted according to the details given in Table 6.126.

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.

6.29.1 *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 6.130). The qqplot suggests a small departure from the assumed Normal distribution as depicted by the upper tail of the distribution (Figure 6.183).

Annual standardized CPUE are noisy and flat since 1992 and consistently mostly below average since 2001 (Figure 6.180). However, there has been an overall increase in CPUE (to the long-term average) since 2007.

6.29.2 *Action Items and Issues*

No issues identified.

Table 6.126. 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, TMO
years	1986 - 2020

Table 6.127. 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

Year	Total	N	Catch	Vess	GeoM	Opt	StDev	C<30Kg	P<30Kg
1986	307.7	1681	306.8	24	63.5	2.4387	0.000	5.837	0.019
1987	250.2	1210	248.2	26	68.3	2.3026	0.045	4.464	0.018
1988	223.4	1204	220.5	27	63.1	2.3021	0.047	6.723	0.030
1989	156.7	1076	156.6	28	50.0	1.9388	0.049	6.139	0.039
1990	135.2	1023	134.4	24	44.1	1.4745	0.053	8.274	0.062
1991	268.5	1353	247.4	25	57.4	1.4629	0.050	7.115	0.029
1992	89.7	661	80.7	15	43.1	0.9927	0.057	4.224	0.052
1993	101.8	711	101.4	16	40.0	0.9675	0.057	5.646	0.056
1994	96.0	825	95.0	18	33.5	1.0366	0.054	5.739	0.060
1995	84.2	962	84.0	21	29.1	0.9128	0.052	8.373	0.100
1996	142.9	1130	142.5	26	44.2	0.9725	0.050	9.811	0.069
1997	152.9	1373	152.3	21	42.6	0.8695	0.048	11.465	0.075
1998	122.4	1255	121.9	20	40.2	0.9220	0.050	10.284	0.084
1999	176.9	1685	175.5	18	37.2	0.8740	0.047	14.406	0.082
2000	231.9	1904	229.0	28	57.3	0.9512	0.047	14.844	0.065
2001	168.5	1668	168.2	26	45.0	0.7575	0.048	13.752	0.082
2002	85.9	1395	85.1	23	19.9	0.5691	0.049	13.044	0.153
2003	122.7	1045	121.5	23	41.0	0.6643	0.052	7.667	0.063
2004	107.1	1212	105.2	22	25.4	0.6243	0.052	8.132	0.077
2005	116.1	1053	114.1	18	32.9	0.6569	0.053	5.770	0.051
2006	104.7	882	101.6	17	25.5	0.5360	0.056	4.491	0.044
2007	60.0	688	57.2	14	20.1	0.5046	0.058	3.687	0.064
2008	55.4	747	52.8	13	14.9	0.5953	0.057	4.709	0.089
2009	60.0	926	56.2	12	12.9	0.6502	0.054	6.100	0.108
2010	90.1	1364	86.1	14	12.9	0.7046	0.050	8.024	0.093
2011	55.2	1063	53.5	12	10.1	0.7143	0.053	6.881	0.129
2012	49.6	710	46.4	13	13.6	0.6783	0.058	4.037	0.087
2013	42.2	571	37.8	14	13.2	0.6029	0.062	3.080	0.081
2014	70.5	669	68.9	14	25.2	0.8455	0.060	2.098	0.030
2015	48.7	654	46.3	12	17.2	0.7042	0.061	2.060	0.045
2016	53.3	658	50.6	13	17.8	0.7938	0.060	2.161	0.043
2017	82.9	853	81.5	10	20.3	1.0751	0.058	1.039	0.013
2018	44.3	623	43.9	10	12.7	0.8660	0.062	1.084	0.025
2019	94.3	865	93.8	12	20.8	0.9822	0.057	1.220	0.013
2020	61.6	683	60.3	12	18.8	1.0563	0.061	1.426	0.024

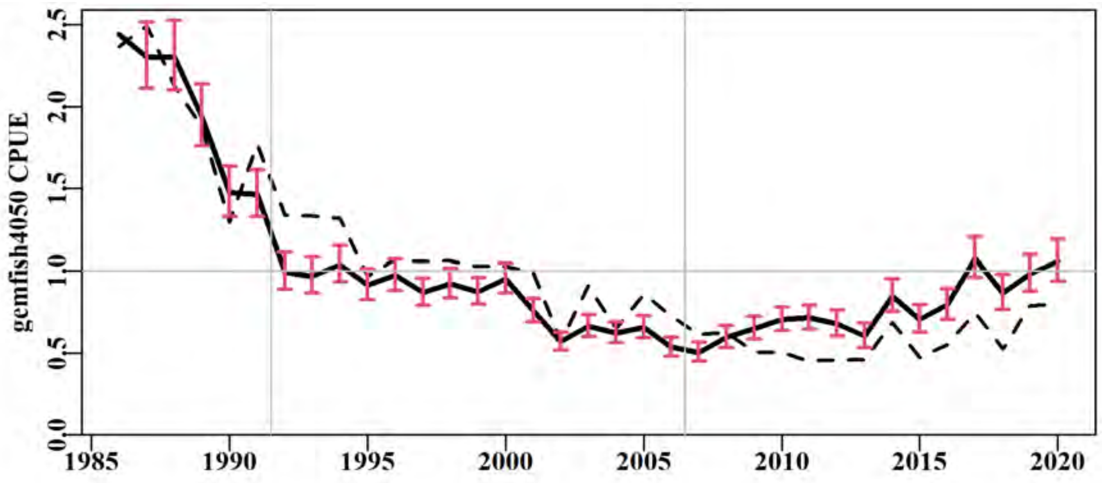

Figure 6.180. gemfish4050 standardization. The dashed black line represents the geometric mean CPUE, solid black line the standardized CPUE. The red bars are the 95% confidence intervals about the mean estimates. The graph scales both time-series of standardized CPUE relative to the mean of each time-series.

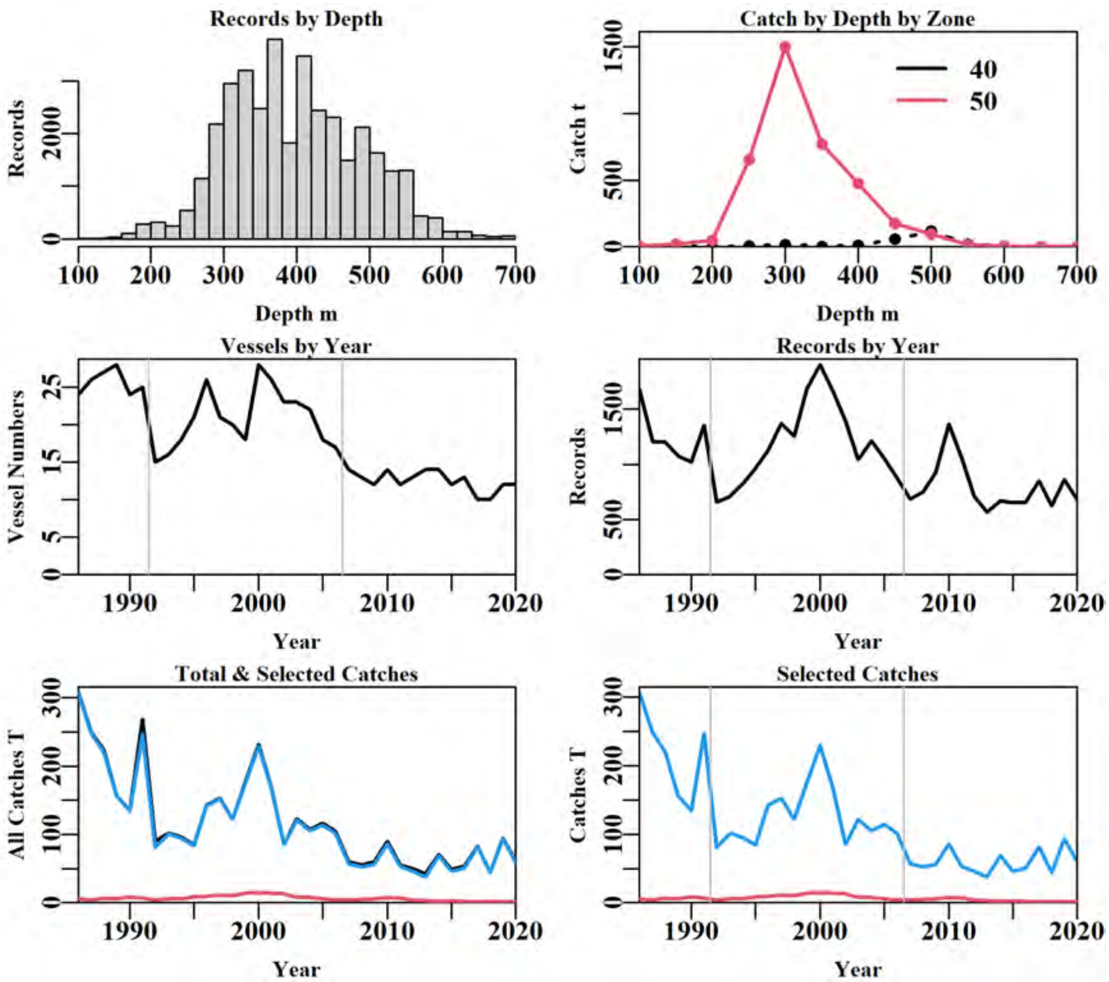

Figure 6.181. gemfish4050 fishery details. The bottom left plot depicts all known catches (top black line), and all selected catches used in the analysis (middle blue line); the lower red line: selected catches < 30 kg).

Table 6.128. 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	40098	37877	37531	36771	36771	36425	36382
Difference	0	2221	346	760	0	346	43
Catch	4264	4225	4205	4054	4054	4029	4027
Difference	0	39	21	151	0	25	2

Table 6.129. 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 6.130. 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

Term	AIC	RSS	MSS	Nobs	Npars	adj_r2	%Change
Year	23926	70089	8706	36382	35	11.0	0
DepCat	14646	54274	24521	36382	47	31.0	20.07
Vessel	9037	46280	32515	36379	140	41.0	10.00
Zone	8936	46149	32647	36379	141	41.2	0.17
DayNight	8235	45261	33534	36379	144	42.3	1.13
Month	7870	44781	34014	36379	155	42.9	0.59
Zone:Month	7533	44342	34454	36379	166	43.5	0.54
Zone:DepCat	7795	44663	34133	36379	166	43.1	0.13

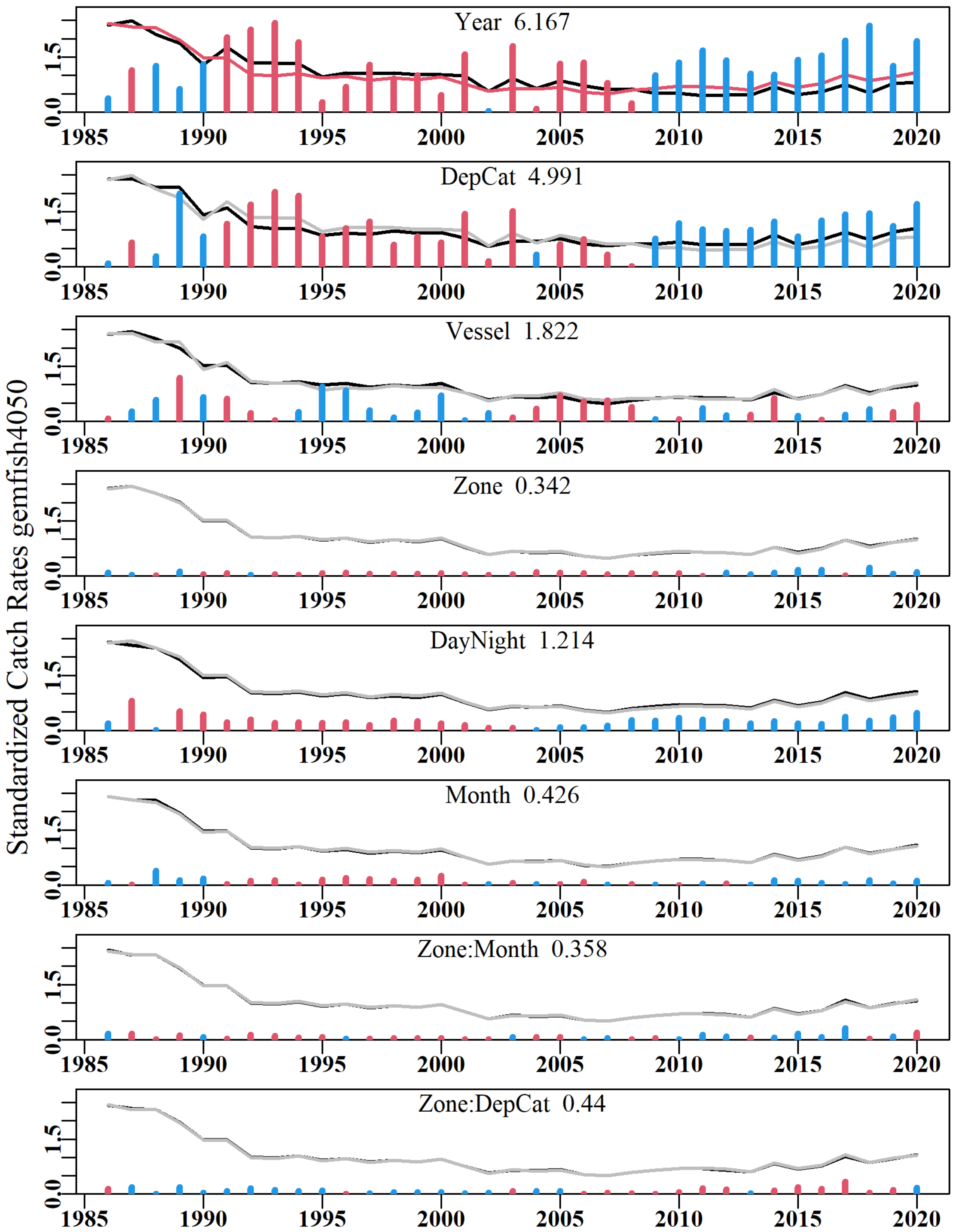

Figure 6.182. gemfish4050. The influence of each factor on the optimal standardization. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by vertical bars with blue bars indicating the optimum model is higher than the geometric 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.

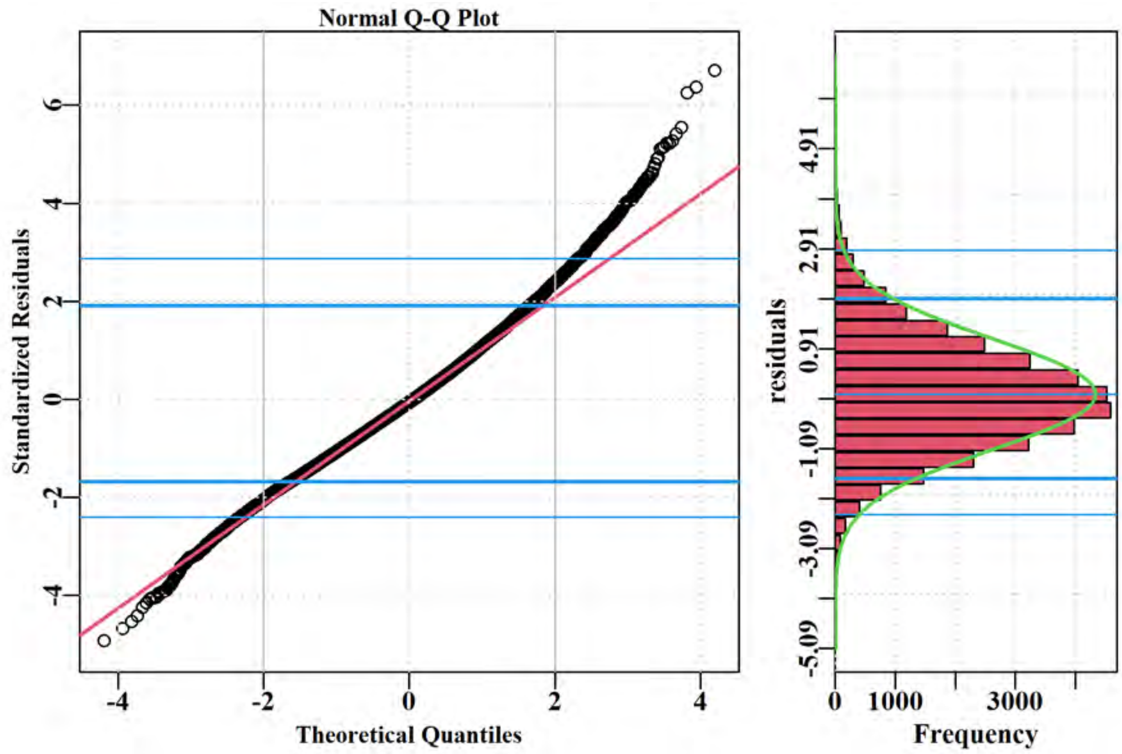

Figure 6.183. gemfish4050. diagnostic plots. The distribution of residuals from the optimum fit. The qqplot indicates the fit to the expected normality, while the histogram of residuals illustrates the 90% quantiles to indicate the intensity of any lack of fit at the margins of the distribution.

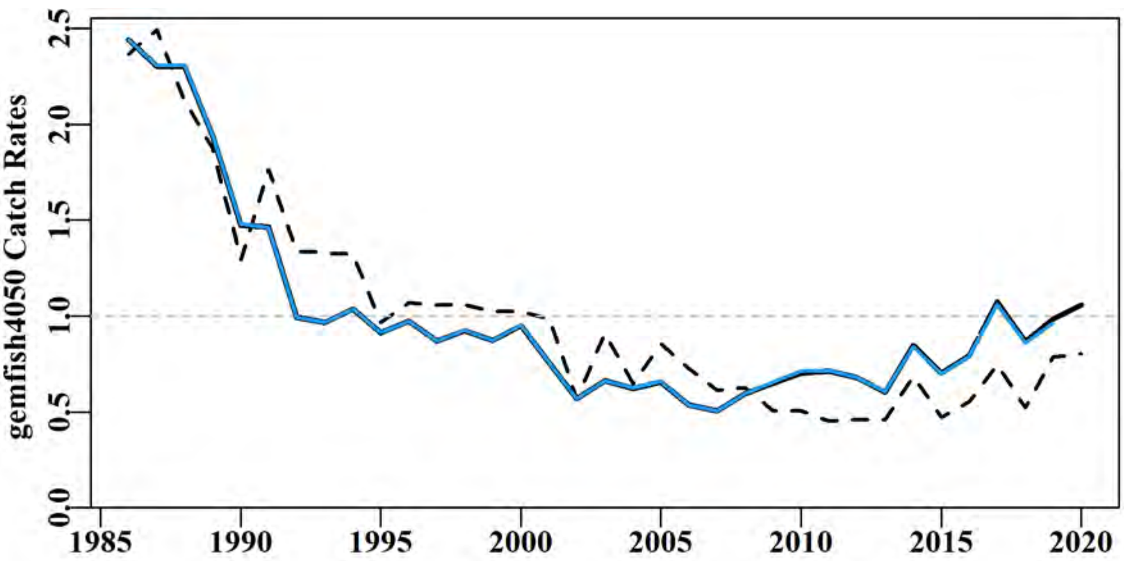

Figure 6.184. gemfish4050. A comparison of the previous year's standardization (blue line) with this year's. They should lie on top of each other, although small deviations may relate to data adjustments, particularly in very recent years.

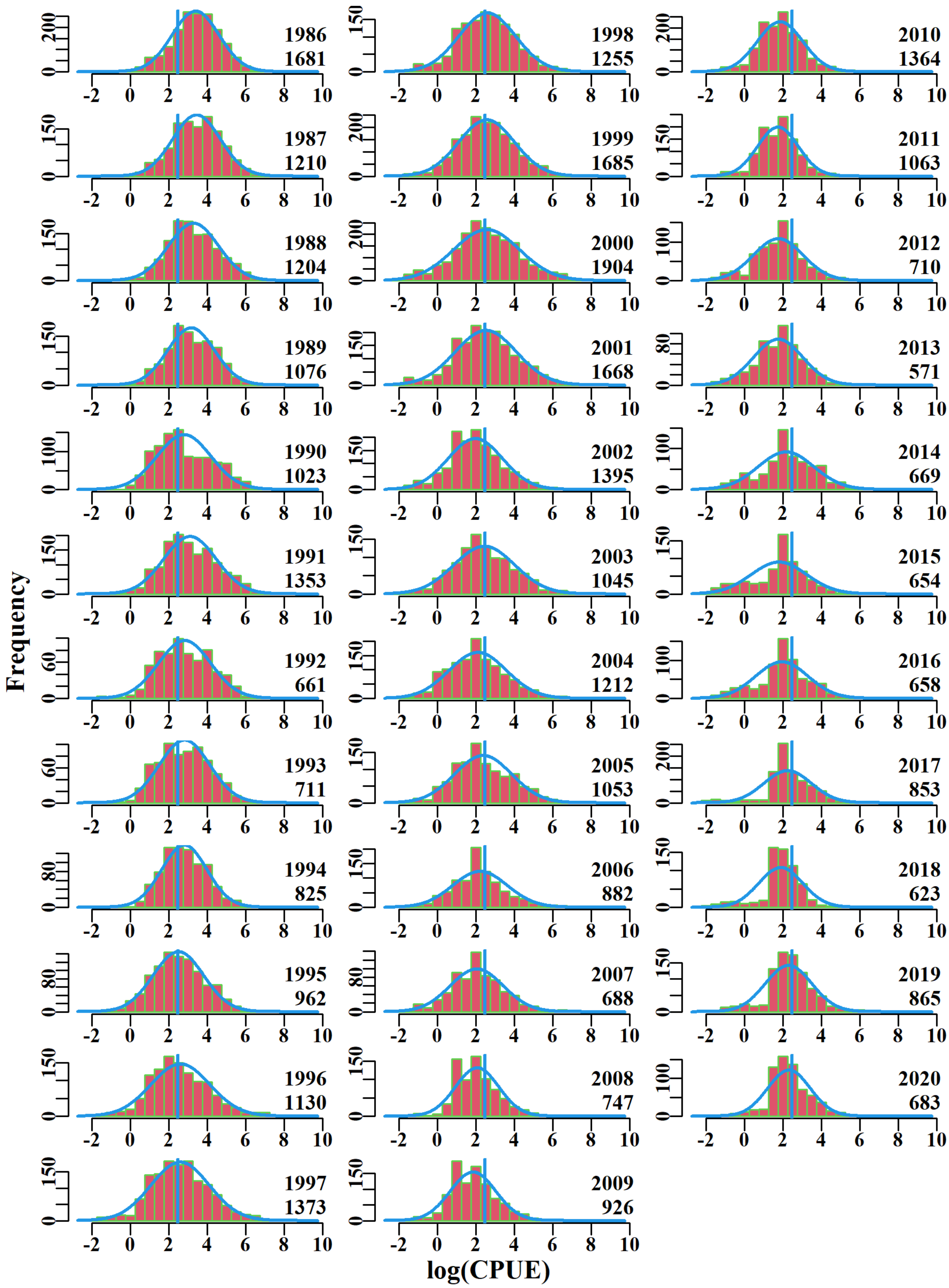

Figure 6.185. gemfish4050. The natural log(CPUE) for each year of data available the blue lines are normal distributions fitted to the histogram frequencies. The numbers in each plot are the year and number of records.

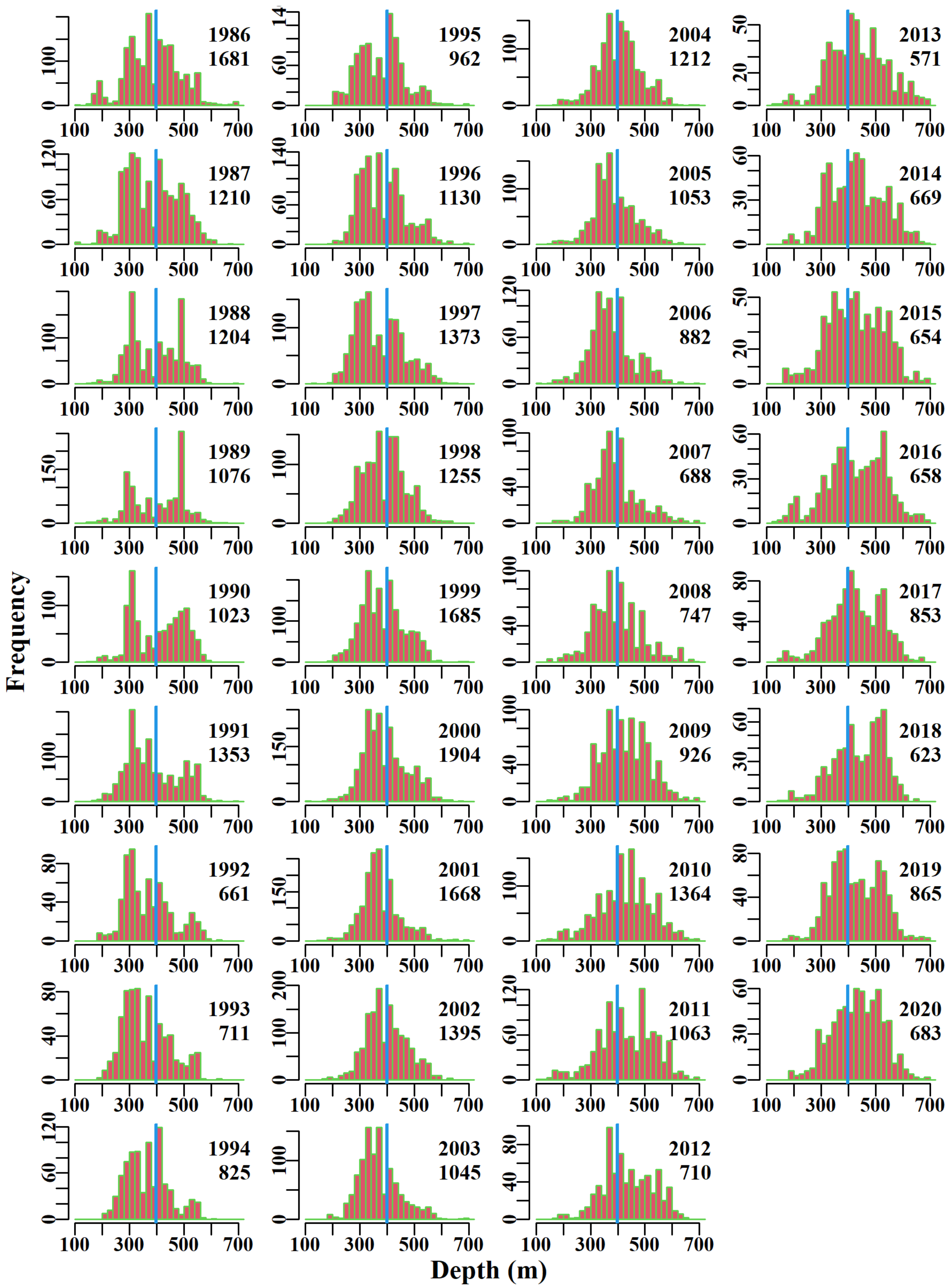

Figure 6.186. gemfish4050. The average Depth of fishing for each year of data available to illustrate the development of the fishery through time. The numbers in each plot are the year and number of records.

6.30 Western Gemfish 40 50 GAB

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 6.131.

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.

6.30.1 *Inferences*

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

The terms Year, DepCat, Vessel, Zone and DayNight 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 6.135). The qqplot suggests the assumed Normal distribution is valid with a slight departure as depicted by the tails of the distribution (Figure 6.190).

Annual standardized CPUE has been consistently below average and flat since 1999, with small overall increases in annual CPUE (to the long-term average) in 2020 (Figure 6.187). 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.

6.30.2 *Action Items and Issues*

This analysis is recommended to be abandoned as it combines data from two biological stocks.

Table 6.131. 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, TMO
years	1986 - 2020

Table 6.132. 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

Year	Total	N	Catch	Vess	GeoM	Opt	StDev	C<30Kg	P<30Kg
1986	308.9	1700	306.5	25	62.3	2.3569	0.000	6.369	0.021
1987	263.8	1283	261.5	29	67.9	2.1830	0.046	5.264	0.020
1988	260.2	1399	254.9	36	63.3	2.0801	0.048	8.098	0.032
1989	185.3	1397	184.8	37	45.6	1.6227	0.049	8.774	0.047
1990	146.2	1231	145.2	35	38.5	1.3941	0.053	10.504	0.072
1991	300.0	1560	278.4	32	56.2	1.3813	0.050	8.992	0.032
1992	105.7	797	96.7	21	41.4	1.0177	0.056	5.404	0.056
1993	108.7	892	108.2	20	35.4	0.8557	0.056	7.358	0.068
1994	110.8	1037	109.8	24	33.3	0.8758	0.053	7.391	0.067
1995	107.1	1285	106.9	26	27.1	0.8536	0.051	11.458	0.107
1996	162.9	1576	161.7	32	30.7	0.9640	0.049	15.841	0.098
1997	214.8	2090	214.1	28	32.8	0.8610	0.047	19.333	0.090
1998	208.1	1964	207.2	26	35.9	0.9939	0.048	16.454	0.079
1999	323.9	2324	320.4	24	42.6	1.0030	0.046	17.891	0.056
2000	264.1	2331	261.2	32	52.9	0.8527	0.047	17.644	0.068
2001	259.9	2333	258.6	30	47.1	0.7962	0.047	17.391	0.067
2002	129.7	1748	128.5	28	20.4	0.6083	0.049	15.336	0.119
2003	207.5	1605	200.9	33	34.3	0.6679	0.050	11.011	0.055
2004	488.2	1942	480.3	30	48.1	0.7122	0.049	11.003	0.023
2005	389.6	1871	378.4	27	50.5	0.7215	0.050	8.591	0.023
2006	463.3	1614	437.1	26	56.6	0.6724	0.051	6.624	0.015
2007	426.7	1398	416.6	20	63.7	0.6089	0.052	5.950	0.014
2008	169.0	1237	155.7	18	19.5	0.6556	0.053	7.665	0.049
2009	113.5	1266	104.9	16	13.7	0.6795	0.052	8.242	0.079
2010	139.6	1700	128.4	18	12.7	0.7395	0.050	10.095	0.079
2011	87.3	1285	74.8	16	10.4	0.7589	0.052	8.266	0.110
2012	108.2	1044	102.1	18	16.4	0.8129	0.055	5.473	0.054
2013	55.9	707	47.2	20	13.2	0.6967	0.060	3.150	0.067
2014	97.7	838	89.1	17	24.5	0.9135	0.058	2.300	0.026
2015	57.0	717	50.2	14	16.5	0.7587	0.061	2.257	0.045
2016	55.8	678	51.2	15	17.2	0.8493	0.061	2.312	0.045
2017	86.0	933	83.7	13	18.8	1.0633	0.058	1.277	0.015
2018	46.9	699	46.2	13	11.9	0.9217	0.062	1.507	0.033
2019	95.4	897	94.4	14	20.3	1.0023	0.058	1.434	0.015
2020	62.9	719	61.1	15	18.0	1.0653	0.062	1.679	0.027

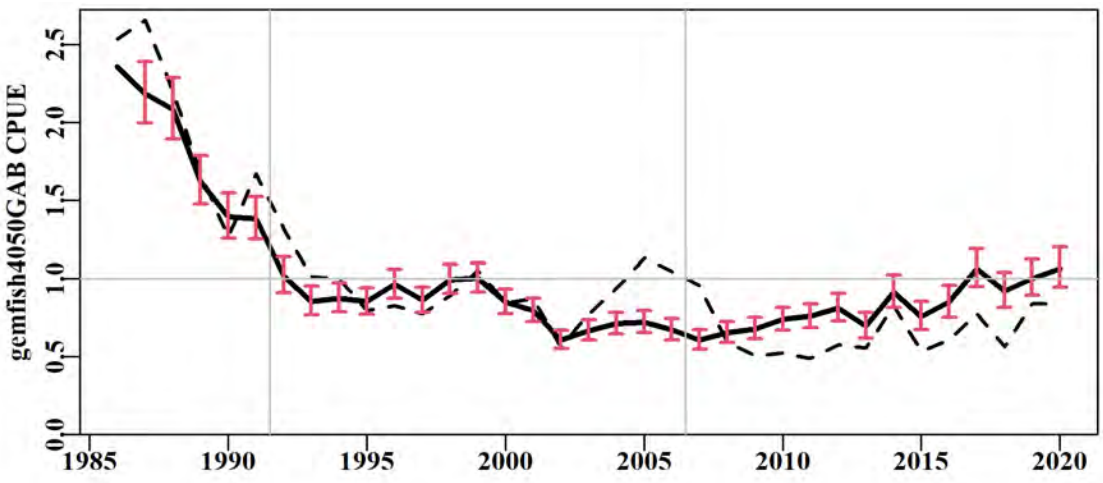

Figure 6.187. gemfish4050GAB standardization. The dashed black line represents the geometric mean CPUE, solid black line the standardized CPUE. The red bars are the 95% confidence intervals about the mean estimates. The graph scales both time-series of standardized CPUE relative to the mean of each time-series.

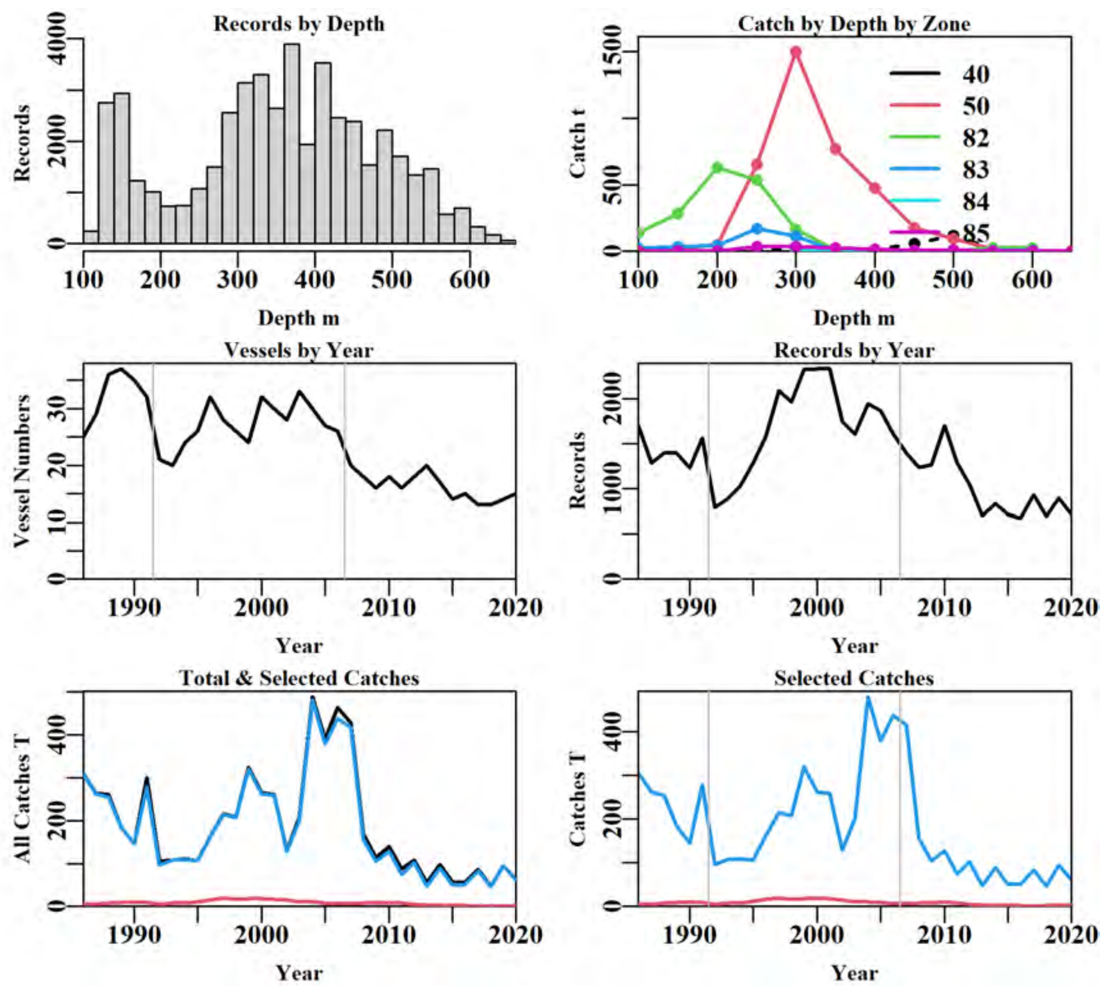

Figure 6.188. gemfish4050GAB fishery details. The bottom left plot depicts all known catches (top black line), and all selected catches used in the analysis (middle blue line); the lower red line: selected catches < 30 kg).

Table 6.133. 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	55095	53148	52169	51186	51186	48142	48097
Difference	0	1947	979	983	0	3044	45
Catch	6803	6775	6711	6544	6544	6409	6407
Difference	0	29	64	167	0	135	2

Table 6.134. 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 6.135. 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

Term	AIC	RSS	MSS	Nobs	Npars	adj_r2	%Change
Year	39307	108745	8989	48097	35	7.6	0
DepCat	25516	81599	36135	48097	46	30.6	23.06
Vessel	17212	68333	49401	48094	160	41.8	11.14
Zone	16386	67156	50578	48094	165	42.8	1.00
DayNight	15263	65597	52136	48094	168	44.1	1.32
Month	15052	65280	52454	48094	179	44.3	0.26
Zone:Month	13945	63651	54083	48094	233	45.7	1.33
Zone:DepCat	14583	64507	53227	48094	231	44.9	0.60

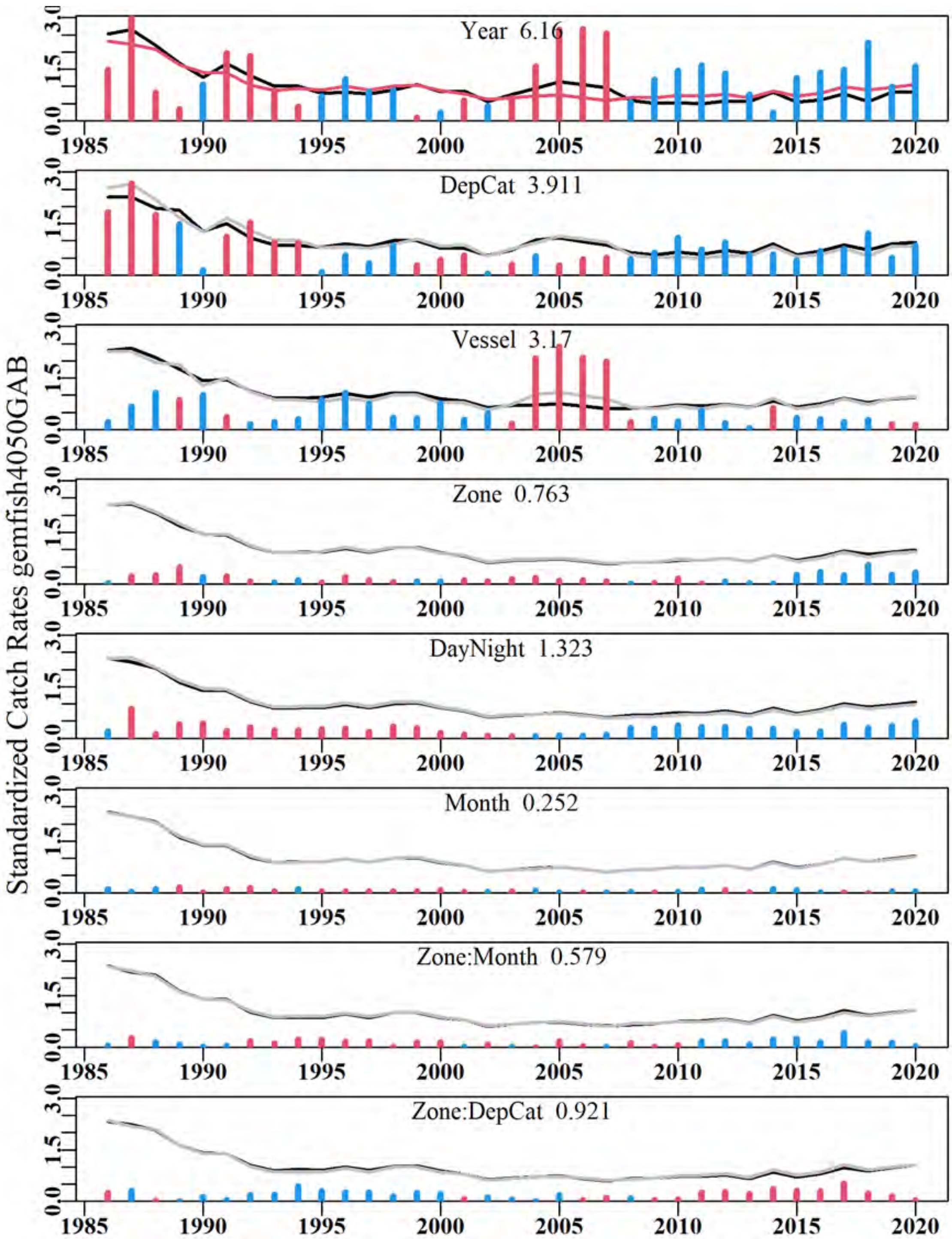

Figure 6.189. gemfish4050GAB. The influence of each factor on the optimal standardization. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by vertical bars with blue bars indicating the optimum model is higher than the 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.

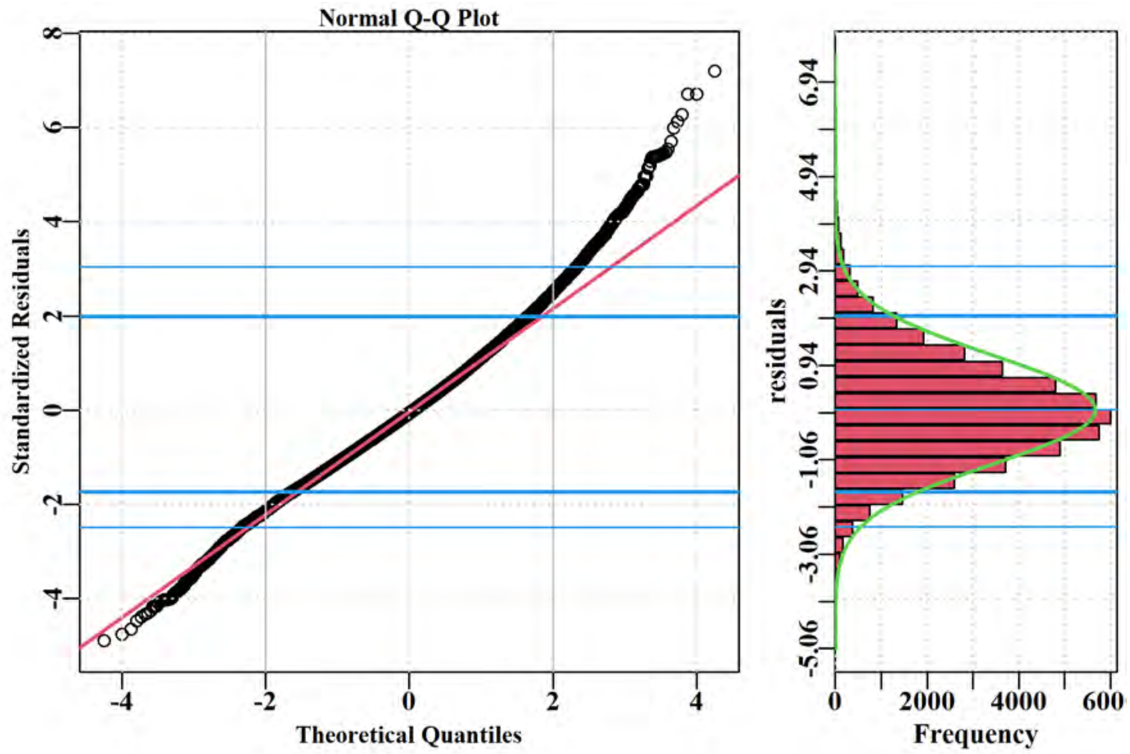

Figure 6.190. gemfish4050GAB. diagnostic plots. The distribution of residuals from the optimum fit. The qqplot indicates the fit to the expected normality, while the histogram of residuals illustrates the 90% quantiles to indicate the intensity of any lack of fit at the margins of the distribution.

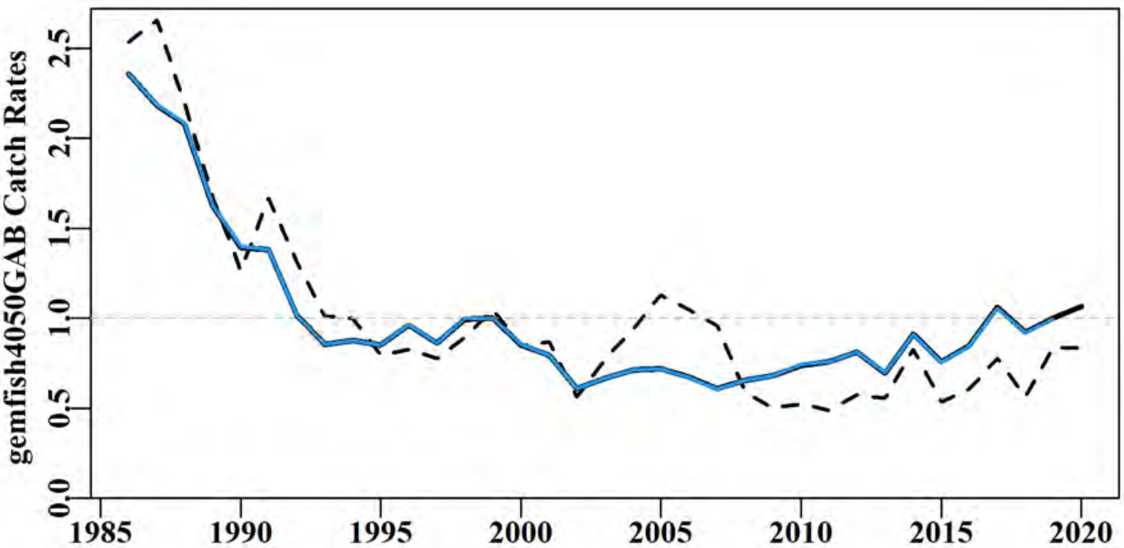

Figure 6.191. gemfish4050GAB. A comparison of the previous year's standardization (blue line) with this year's. They should lie on top of each other, although small deviations may relate to data adjustments, particularly in very recent years.

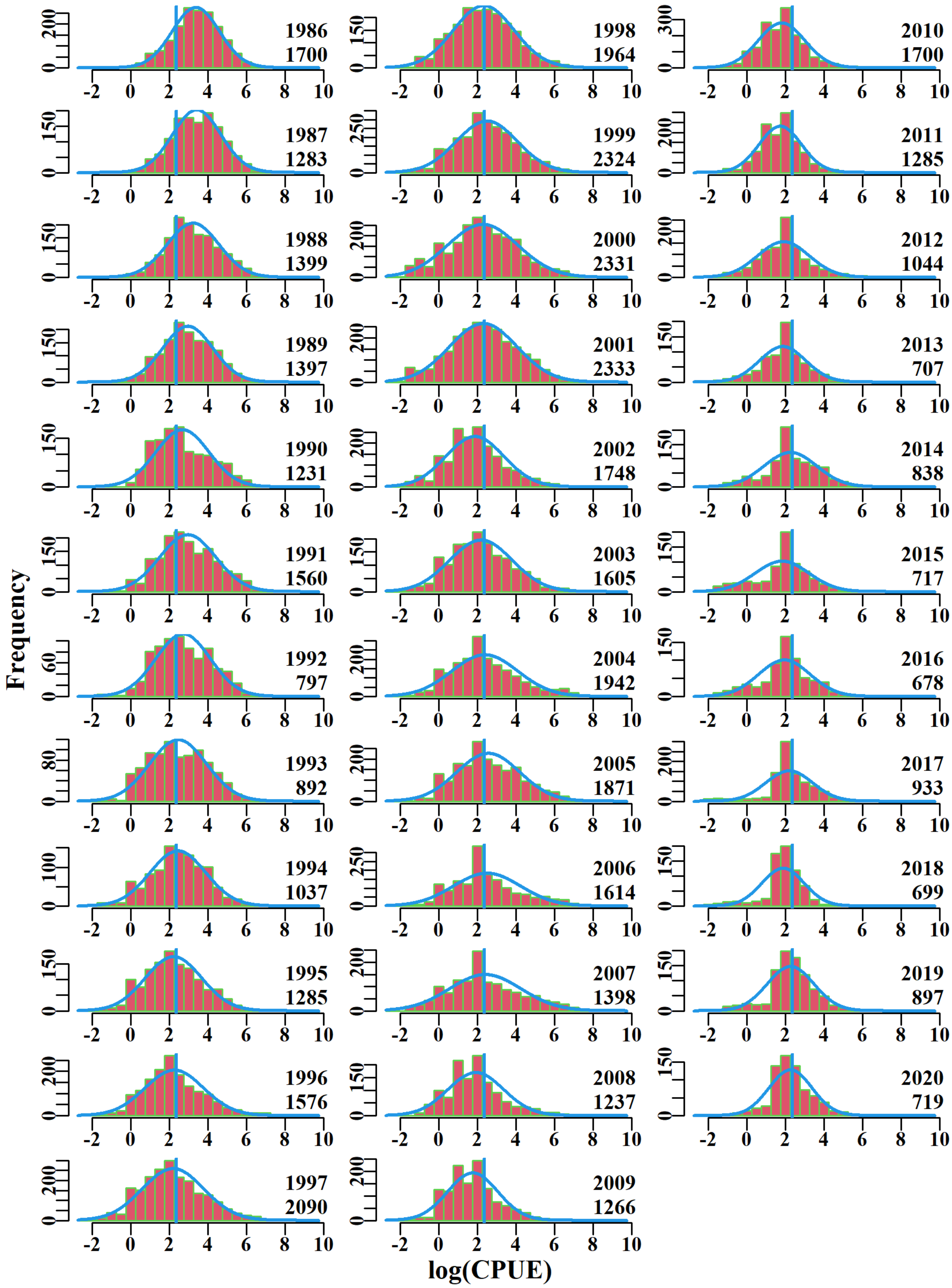

Figure 6.192. gemfish4050GAB. The natural log(CPUE) for each year of data available the blue lines are normal distributions fitted to the histogram frequencies. The numbers in each plot are the year and number of records.

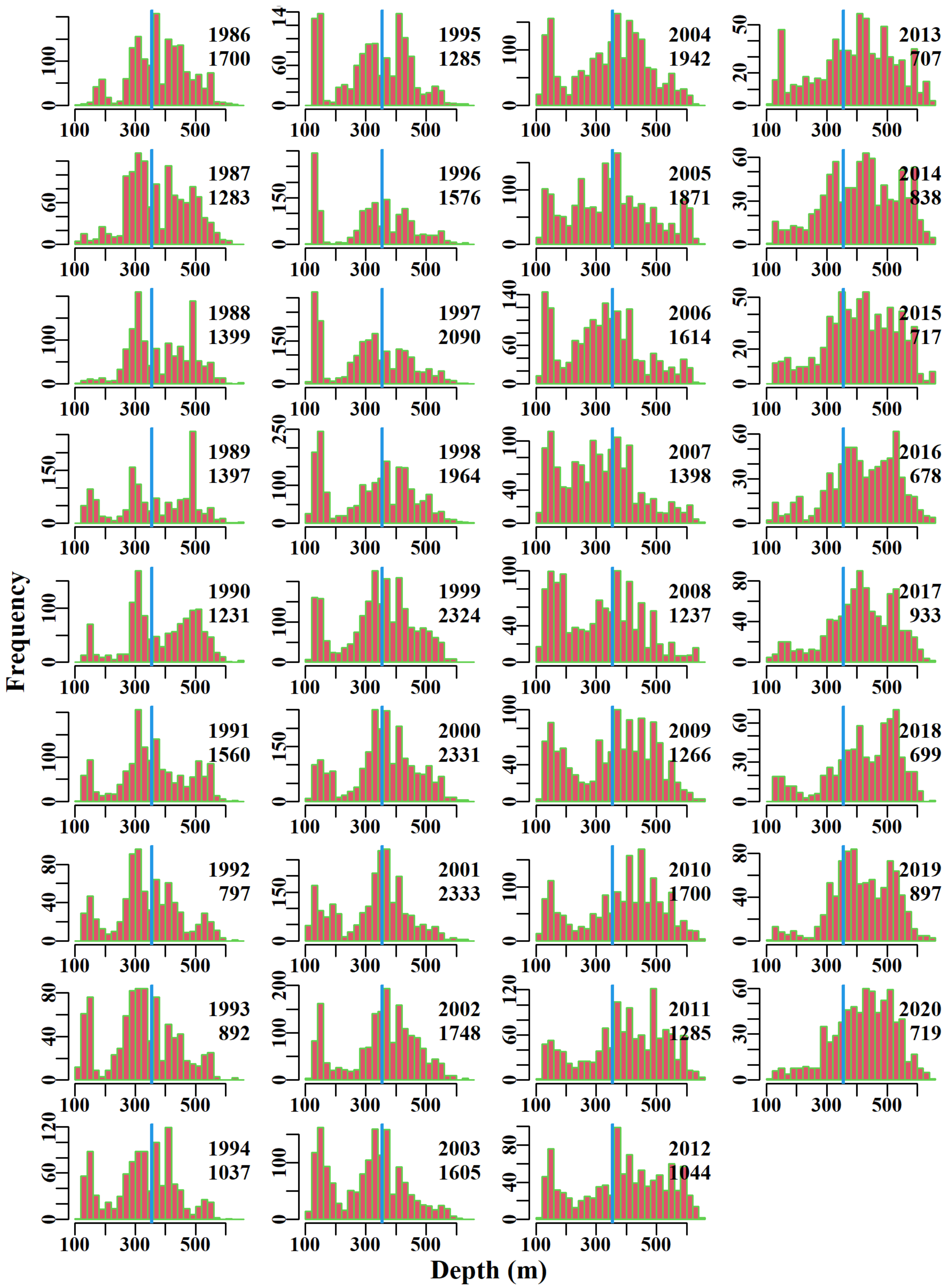

Figure 6.193. gemfish4050GAB. The average Depth of fishing for each year of data available to illustrate the development of the fishery through time. The numbers in each plot are the year and number of records

6.31 Western Gemfish GAB

For western Gemfish (GEM – 37439002 – *Rexea solandri*) in zones in the GAB, initial data selection was conducted according to the details given in Table 6.136.

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.

6.31.1 *Inferences*

The majority of catch of this species occurred in zone 82 followed by zone 83 with minimal catches in the remaining GAB zones. There were a small number of records (30) and corresponding catch (0.7 t) in 2016 across these zones. Similarly, there were only 39 records accounting for 0.9 t in 2019 and only 40 records accounting for 0.9 t in 2020 across these two zones. There were very high catches between 2004-2007.

The terms Year, DepCat, Vessel, Zone, DayNight, 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 6.140). The qqplot suggests a small departure from the assumed Normal distribution as depicted by the upper tail (Figure 6.197).

Annual standardized CPUE are noisy and flat across the years analysed (Figure 6.194), with the effect of the exceptional vessel being accounted for in the standardization.

6.31.2 *Action Items and Issues*

No issues identified.

Table 6.136. 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 - 2020

Table 6.137. 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

Year	Total	N	Catch	Vess	GeoM	Opt	StDev	C<30Kg	P<30Kg
1995	181.9	324	22.5	5	13.2	0.7326	0.000	3.093	0.138
1996	382.2	448	19.2	7	7.1	0.9374	0.093	6.034	0.314
1997	572.0	718	61.7	9	12.9	0.9276	0.089	7.883	0.128
1998	404.8	708	85.3	8	24.8	1.4018	0.090	6.170	0.072
1999	448.7	643	144.9	7	59.0	1.7033	0.093	3.520	0.024
2000	336.5	428	32.2	6	14.6	0.5939	0.098	2.805	0.087
2001	331.5	670	90.3	7	42.9	0.9986	0.092	3.634	0.040
2002	195.9	351	43.2	6	20.7	0.8847	0.102	2.283	0.053
2003	268.0	559	79.2	10	20.7	0.8407	0.097	3.308	0.042
2004	569.0	732	375.2	10	116.2	1.1128	0.097	2.901	0.008
2005	511.8	818	264.3	10	83.4	0.9923	0.097	2.821	0.011
2006	544.9	732	335.7	11	133.6	0.9532	0.097	2.133	0.006
2007	599.1	713	359.6	9	174.3	0.8344	0.095	2.271	0.006
2008	294.9	494	103.2	7	28.0	0.8656	0.097	2.975	0.029
2009	194.9	347	48.9	4	15.2	0.8016	0.104	2.161	0.044
2010	220.7	345	42.7	4	11.7	0.8401	0.104	2.100	0.049
2011	147.7	229	21.5	4	12.4	0.8913	0.115	1.421	0.066
2012	168.6	334	55.8	5	23.0	1.2850	0.107	1.437	0.026
2013	103.8	148	9.7	6	11.6	1.1970	0.132	0.154	0.016
2014	130.3	176	20.2	5	20.7	1.2130	0.133	0.246	0.012
2015	86.7	68	4.1	2	10.5	1.1353	0.174	0.209	0.051
2016	74.6	30	0.7	3	7.4	0.7865	0.245	0.196	0.273
2017	119.2	85	2.6	4	7.8	0.8155	0.160	0.312	0.120
2018	74.3	77	2.3	4	6.9	1.5221	0.167	0.423	0.184
2019	158.1	39	0.9	2	8.1	1.0121	0.217	0.237	0.257
2020	121.4	40	0.9	3	5.2	0.7216	0.215	0.333	0.372

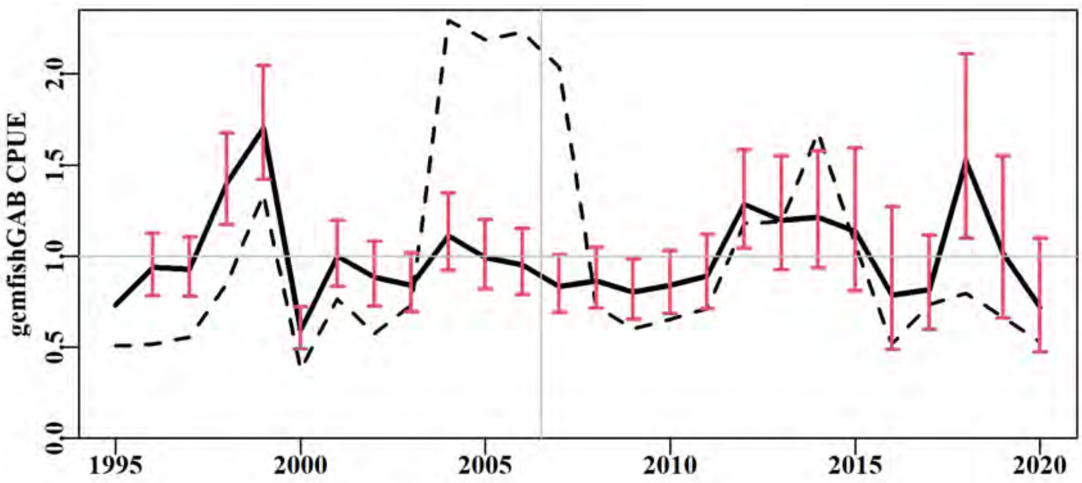

Figure 6.194. gemfishGAB standardization. The dashed black line represents the geometric mean CPUE, solid black line the standardized CPUE. The red bars are the 95% confidence intervals about the mean estimates. The graph scales both time-series of standardized CPUE relative to the mean of each time-series.

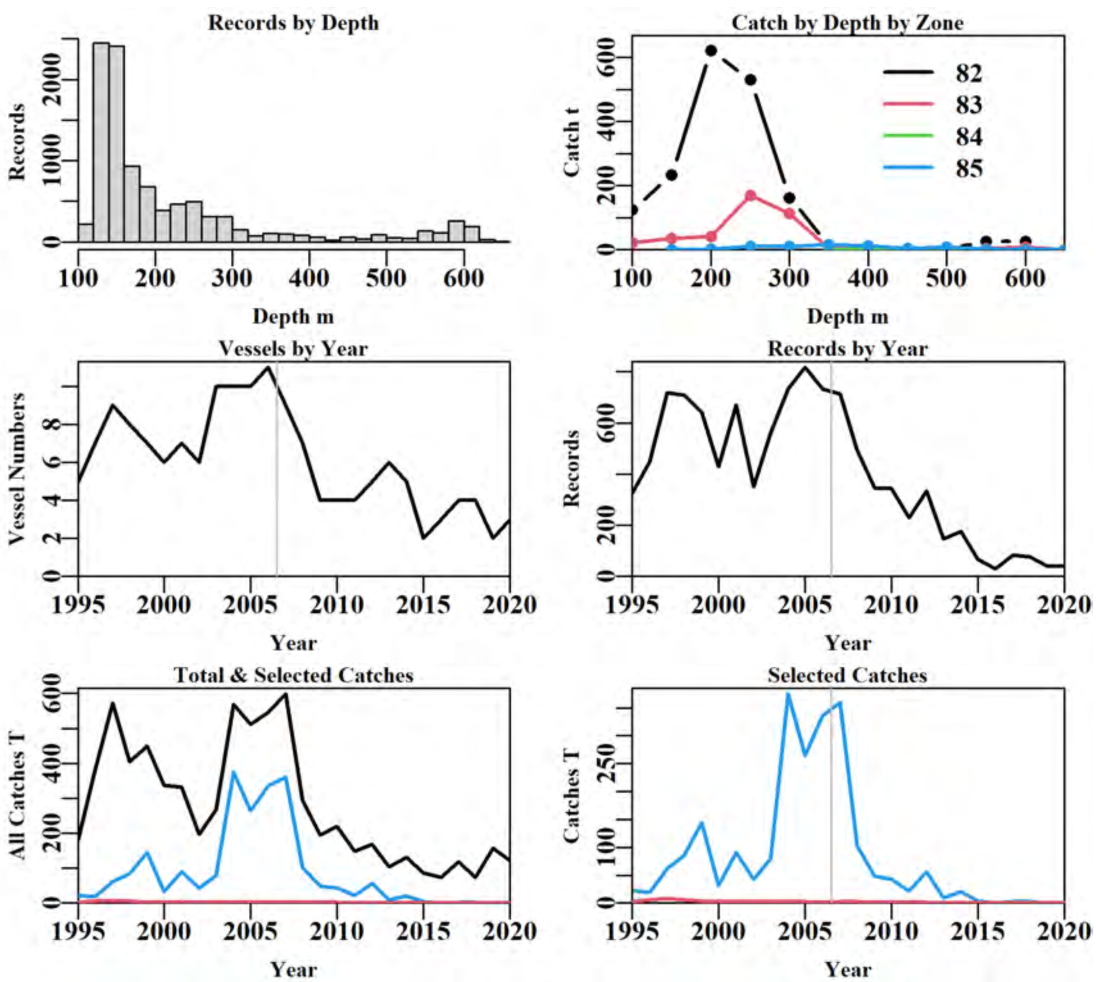

Figure 6.195. gemfishGAB fishery details. The bottom left plot depicts all known catches (top black line), and all selected catches used in the analysis (middle blue line); the lower red line: selected catches < 30 kg).

Table 6.138. 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	137853	129681	127268	89102	12183	10270	10256
Difference	0	8172	2413	38166	76919	1913	14
Catch	24002	23764	23533	7141	2317	2228	2227
Difference	0	238	232	16392	4824	89	1

Table 6.139. 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 6.140. 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

Term	AIC	RSS	MSS	Nobs	Npars	adj_r2	%Change
Year	11149	30261	3467	10256	26	10.1	0
DepCat	7479	21113	12616	10256	37	37.2	27.12
Vessel	5929	18069	15659	10256	60	46.1	8.93
Zone	5546	17398	16330	10256	63	48.1	1.99
DayNight	5181	16779	16949	10256	66	49.9	1.83
Month	4884	16266	17463	10256	77	51.4	1.48
Zone:Month	4599	15721	18007	10256	109	52.9	1.48
Zone:DepCat	4807	16060	17669	10256	104	51.9	0.49

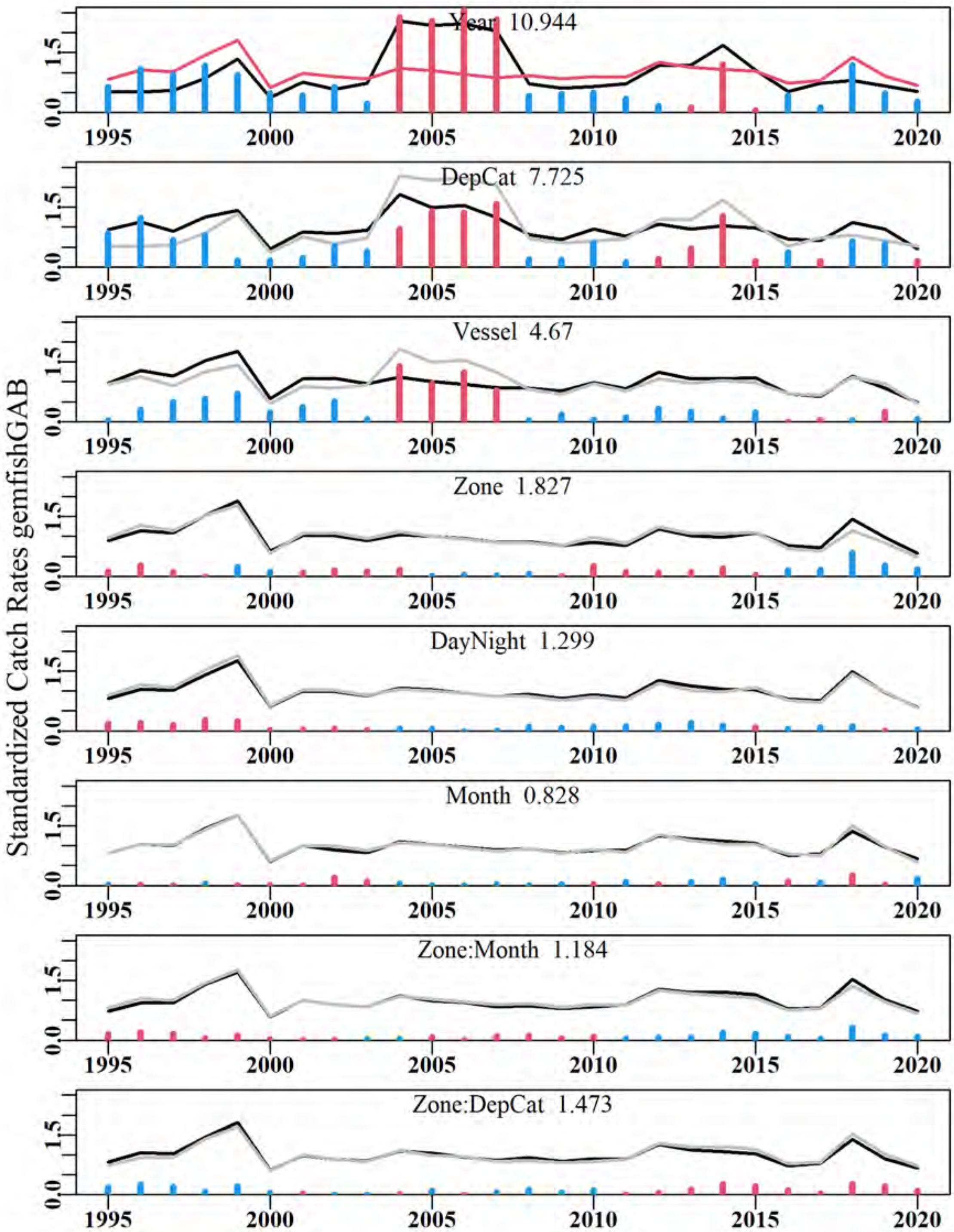

Figure 6.196. gemfishGAB. The influence of each factor on the optimal standardization. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by vertical bars with blue bars indicating the optimum model is higher than the geometric 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.

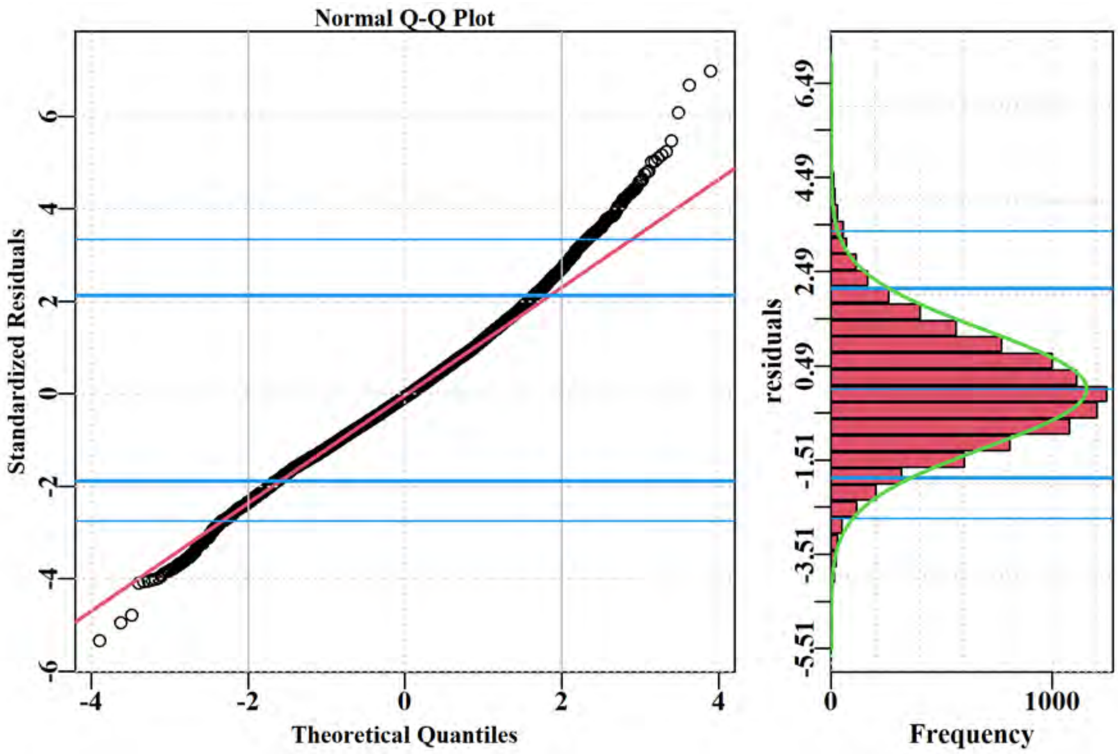

Figure 6.197. gemfishGAB. diagnostic plots. The distribution of residuals from the optimum fit. The qqplot indicates the fit to the expected normality, while the histogram of residuals illustrates the 90% quantiles to indicate the intensity of any lack of fit at the margins of the distribution.

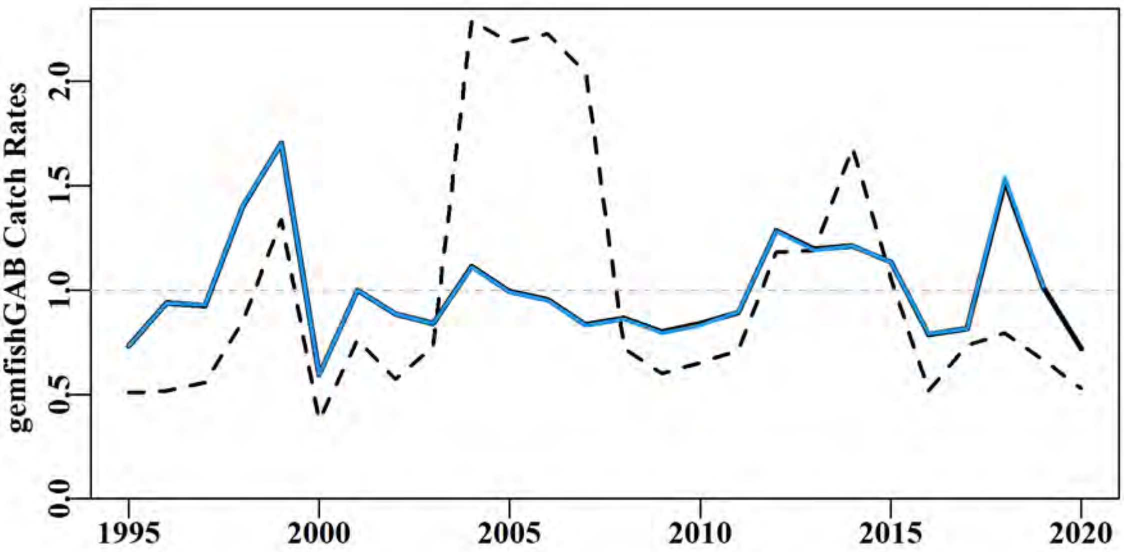

Figure 6.198. gemfishGAB. A comparison of the previous year's standardization (blue line) with this year's. They should lie on top of each other, although small deviations may relate to data adjustments, particularly in very recent years.

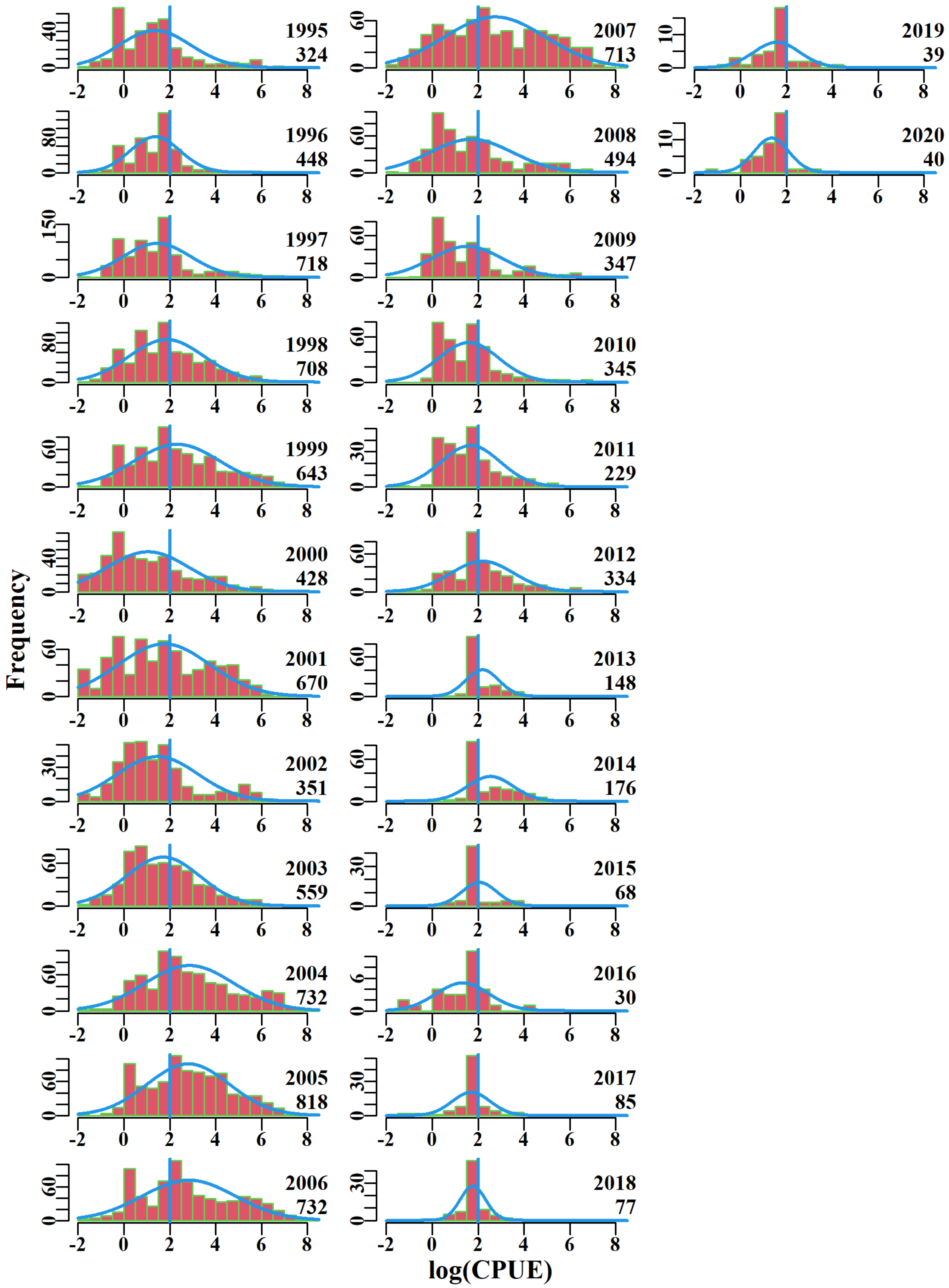

Figure 6.199. gemfishGAB. The natural log(CPUE) for each year of data available the blue lines are normal distributions fitted to the histogram frequencies. The numbers in each plot are the year and number of records.

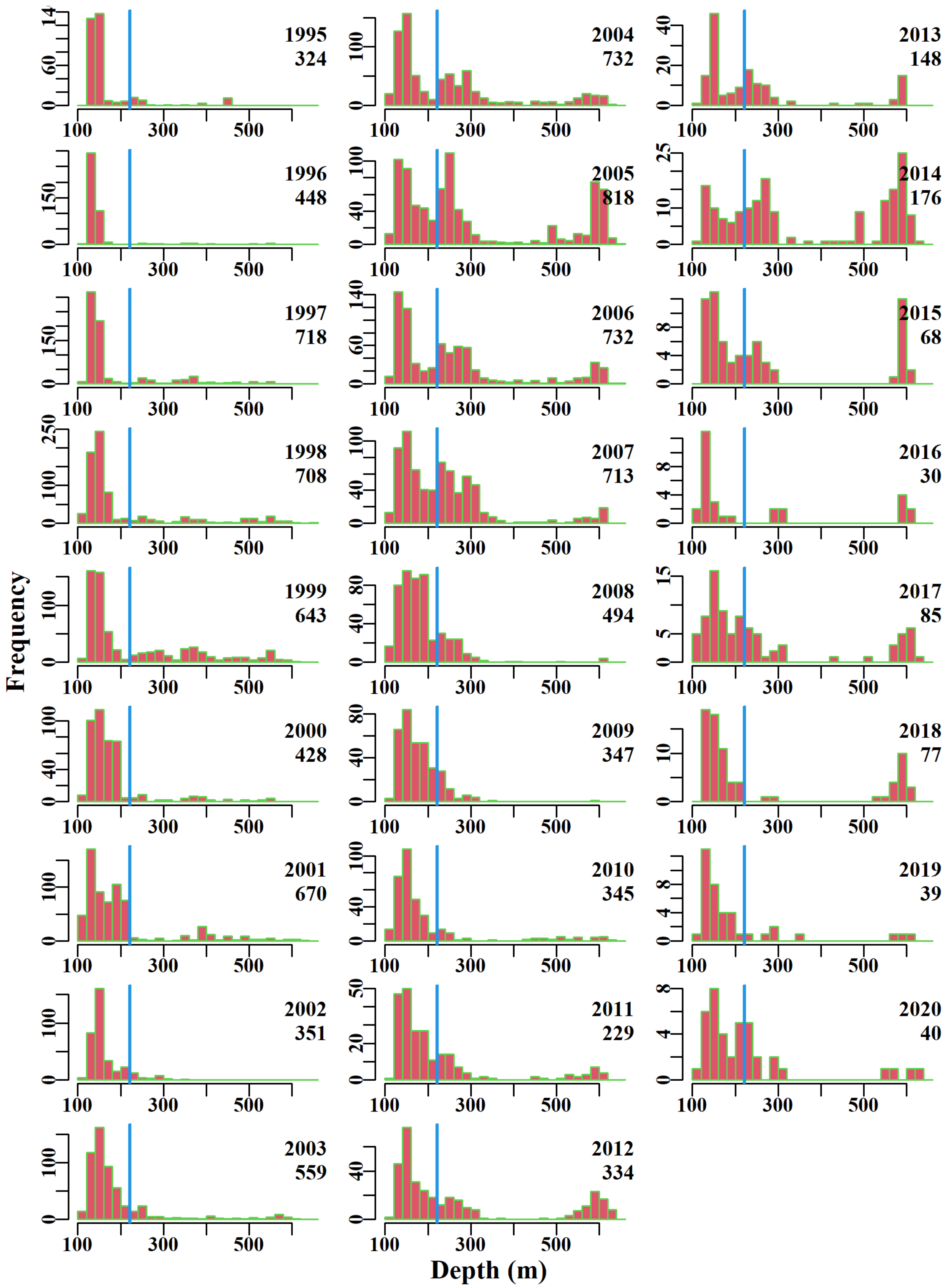

Figure 6.200. gemfishGAB. The average Depth of fishing for each year of data available to illustrate the development of the fishery through time. The numbers in each plot are the year and number of records.

6.32 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 6.141.

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.

6.32.1 *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 6.145). The qqplot suggests that the assumed Normal distribution is valid as depicted with slight departures from the tails of the distribution (Figure 6.204).

Annual standardized CPUE trend is flat since 1992 and consistently below average since 1999 (Figure 6.201).

6.32.2 *Action Items and Issues*

No issues identified.

Table 6.141. 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, OTB
years	1986 - 2020

Table 6.142. 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

Year	Total	N	Catch	Vess	GeoM	Opt	StDev	C<30Kg	P<30Kg
1986	211.9	700	138.7	40	69.8	2.3543	0.000	3.563	0.026
1987	405.9	457	168.2	40	84.9	2.7779	0.105	2.506	0.015
1988	544.0	772	333.6	33	122.0	3.4804	0.095	3.566	0.011
1989	776.0	1172	654.9	41	180.8	4.5728	0.092	4.010	0.006
1990	881.4	816	504.6	41	182.2	4.1323	0.097	3.118	0.006
1991	1284.2	1557	462.9	54	99.8	2.3265	0.092	8.997	0.019
1992	934.4	1331	401.4	40	96.0	1.9524	0.093	8.172	0.020
1993	829.6	2174	428.5	45	61.2	1.5279	0.089	14.159	0.033
1994	944.8	2429	469.7	43	63.7	1.4517	0.088	16.820	0.036
1995	815.4	2631	467.1	44	59.6	1.3053	0.088	19.900	0.043
1996	724.5	3544	530.8	48	53.9	1.4336	0.087	26.062	0.049
1997	935.2	2467	403.0	42	57.3	1.3905	0.090	16.367	0.041
1998	903.2	2552	457.2	39	65.4	1.2713	0.089	17.177	0.038
1999	591.1	1640	131.6	39	27.2	0.6847	0.092	12.412	0.094
2000	470.5	2221	185.7	41	25.1	0.5854	0.090	15.442	0.083
2001	285.5	1469	57.3	33	11.1	0.3453	0.094	10.220	0.178
2002	290.5	1854	62.9	36	8.1	0.2629	0.092	12.452	0.198
2003	234.0	1311	40.8	38	6.1	0.2010	0.095	8.270	0.203
2004	232.4	1243	51.8	38	11.5	0.2736	0.097	8.430	0.163
2005	289.1	820	21.2	33	5.6	0.1903	0.101	4.649	0.219
2006	379.5	772	25.6	28	8.3	0.2177	0.102	4.635	0.181
2007	177.8	577	16.5	14	5.8	0.2266	0.107	3.838	0.233
2008	163.3	730	26.5	18	8.7	0.3128	0.103	5.475	0.207
2009	135.2	443	35.7	15	21.6	0.3927	0.112	2.854	0.080
2010	129.3	361	11.7	15	7.6	0.2400	0.117	2.212	0.189
2011	103.3	427	9.6	13	5.0	0.1993	0.114	2.601	0.270
2012	52.3	346	9.8	14	5.8	0.1620	0.119	1.872	0.192
2013	68.0	163	3.7	17	5.8	0.1520	0.147	0.934	0.255
2014	15.3	88	1.8	12	3.7	0.1018	0.183	0.376	0.211
2015	5.4	55	1.6	9	8.0	0.1191	0.223	0.302	0.190
2016	18.8	190	6.8	14	8.0	0.1062	0.142	0.992	0.147
2017	16.4	280	3.9	12	2.6	0.0498	0.127	1.085	0.280
2018	39.0	230	3.9	9	4.1	0.0709	0.134	1.320	0.336
2019	17.8	169	7.7	12	13.3	0.0871	0.155	0.995	0.130
2020	2.7	56	0.4	6	1.6	0.0416	0.221	0.293	0.765

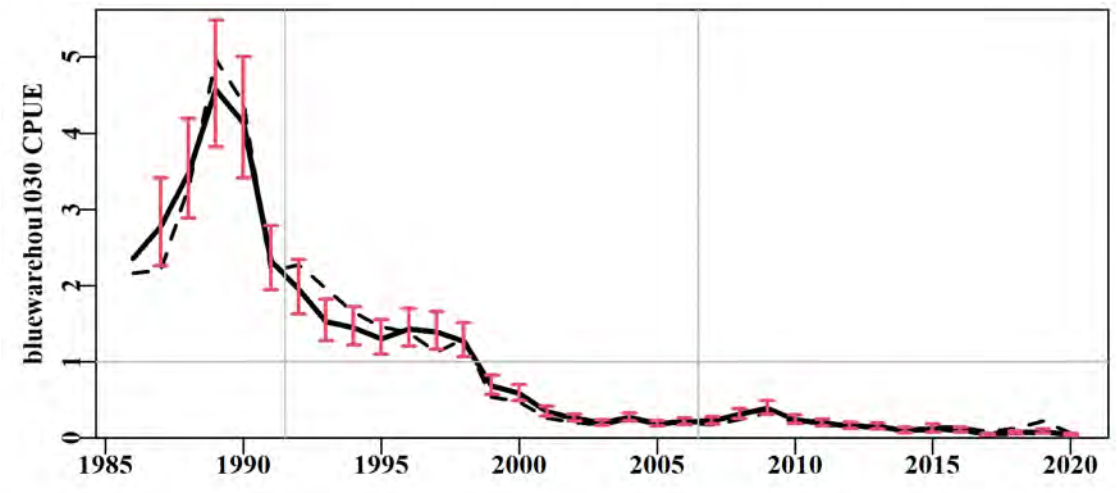

Figure 6.201. bluewarehou1030 standardization. The dashed black line represents the geometric mean CPUE, solid black line the standardized CPUE. The red bars are the 95% confidence intervals about the mean estimates. The graph scales both time-series of standardized CPUE relative to the mean of each time-series.

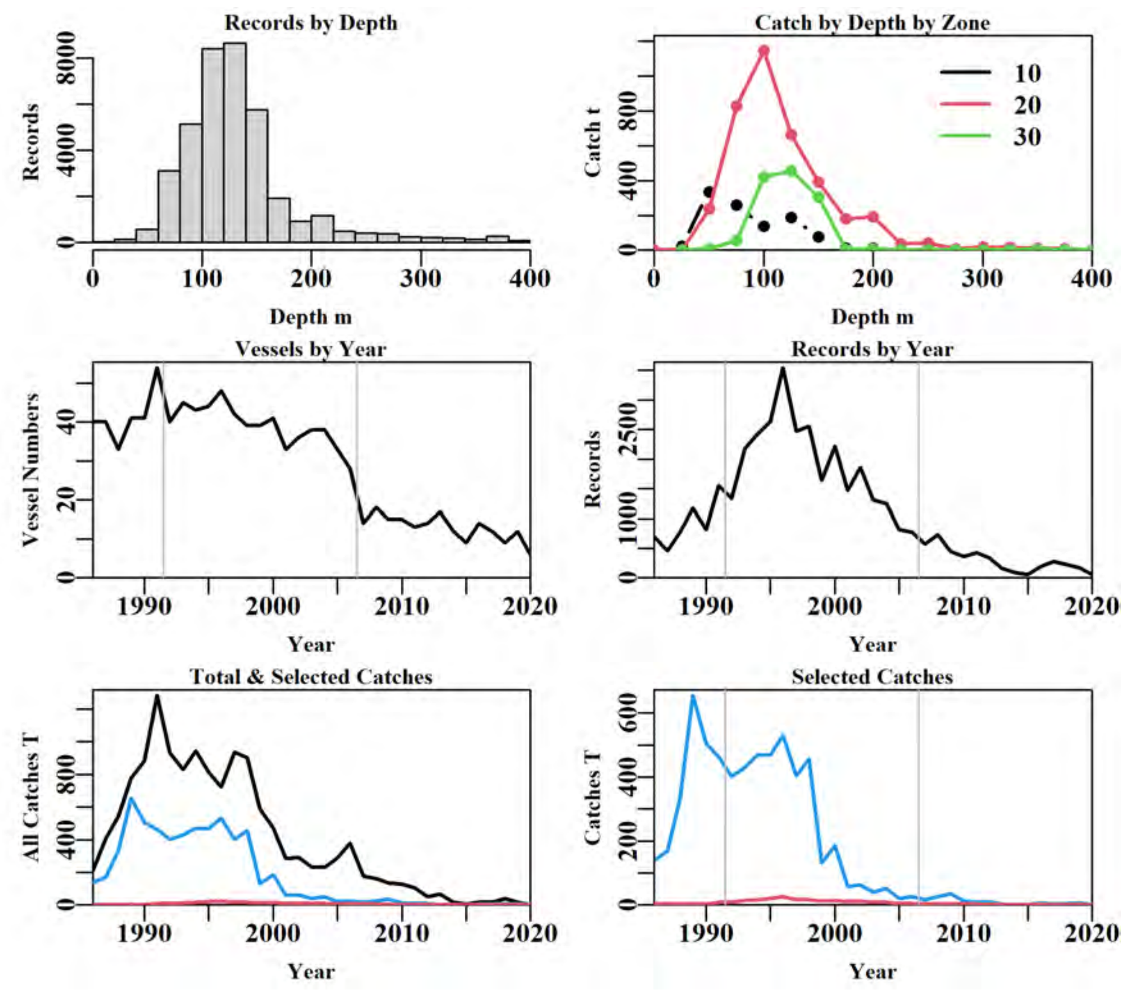

Figure 6.202. bluewarehou1030 fishery details. The bottom left plot depicts all known catches (top black line), and all selected catches used in the analysis (middle blue line); the lower red line: selected catches < 30 kg).

Table 6.143. 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	68429	62225	59372	59164	41143	38104	38047
Difference	0	6204	2853	208	18021	3039	57
Catch	13976	13589	12855	12811	6725	6139	6137
Difference	0	387	734	44	6086	586	2

Table 6.144. 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 6.145. 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

Term	AIC	RSS	MSS	Nobs	Npars	adj_r2	%Change
Year	38069	103291	41676	38047	35	28.7	0
Vessel	33249	90207	54761	38047	202	37.4	8.76
DepCat	32778	89021	55947	38047	218	38.2	0.80
Month	32589	88530	56438	38047	229	38.6	0.32
Zone	32190	87597	57371	38047	231	39.2	0.64
DayNight	32104	87385	57583	38047	234	39.3	0.14
Zone:Month	31804	86598	58370	38047	256	39.9	0.51
Zone:DepCat	31857	86683	58285	38047	264	39.8	0.44

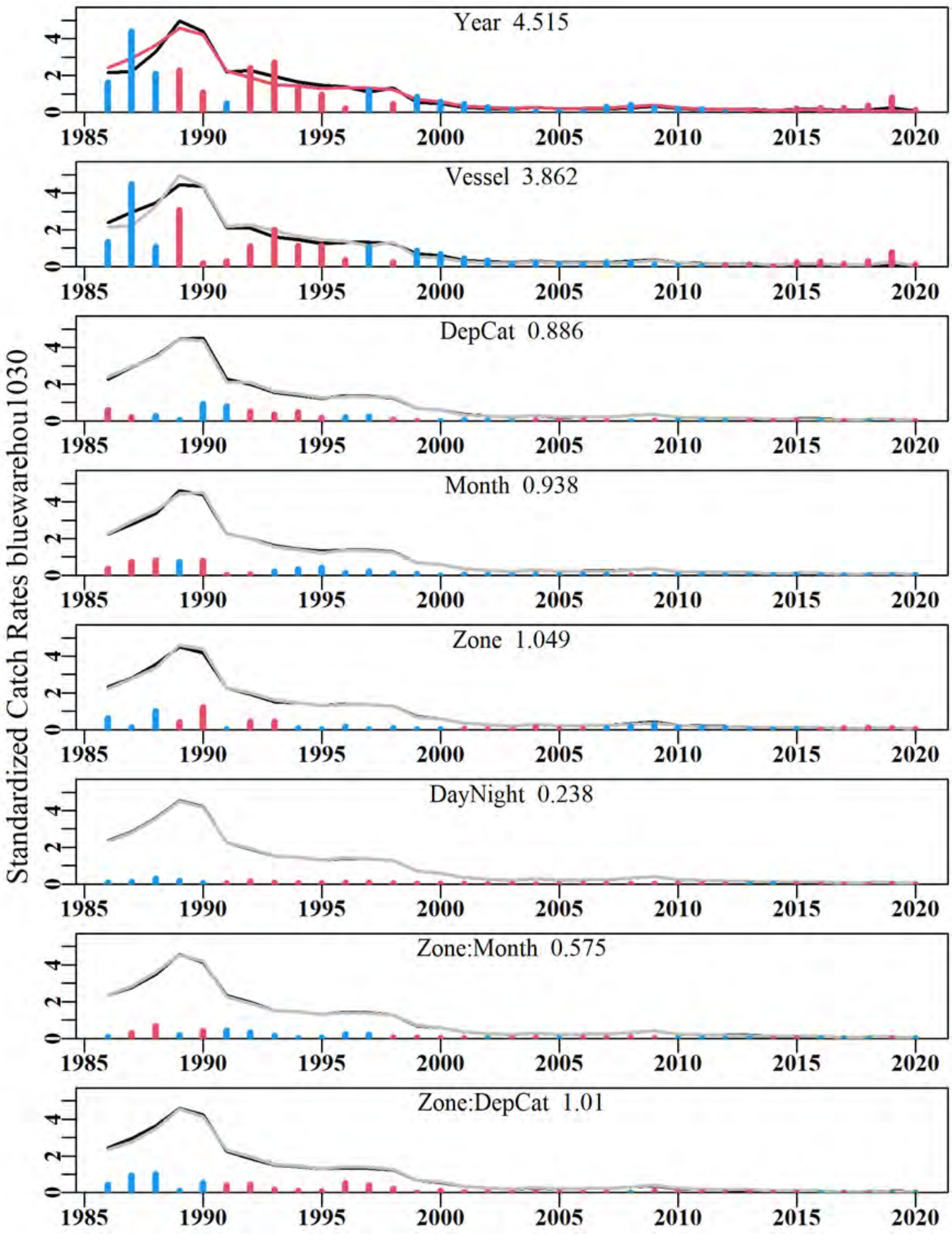

Figure 6.203. bluewarehou1030. The influence of each factor on the optimal standardization. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by vertical bars with blue bars indicating the optimum model is higher than the 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.

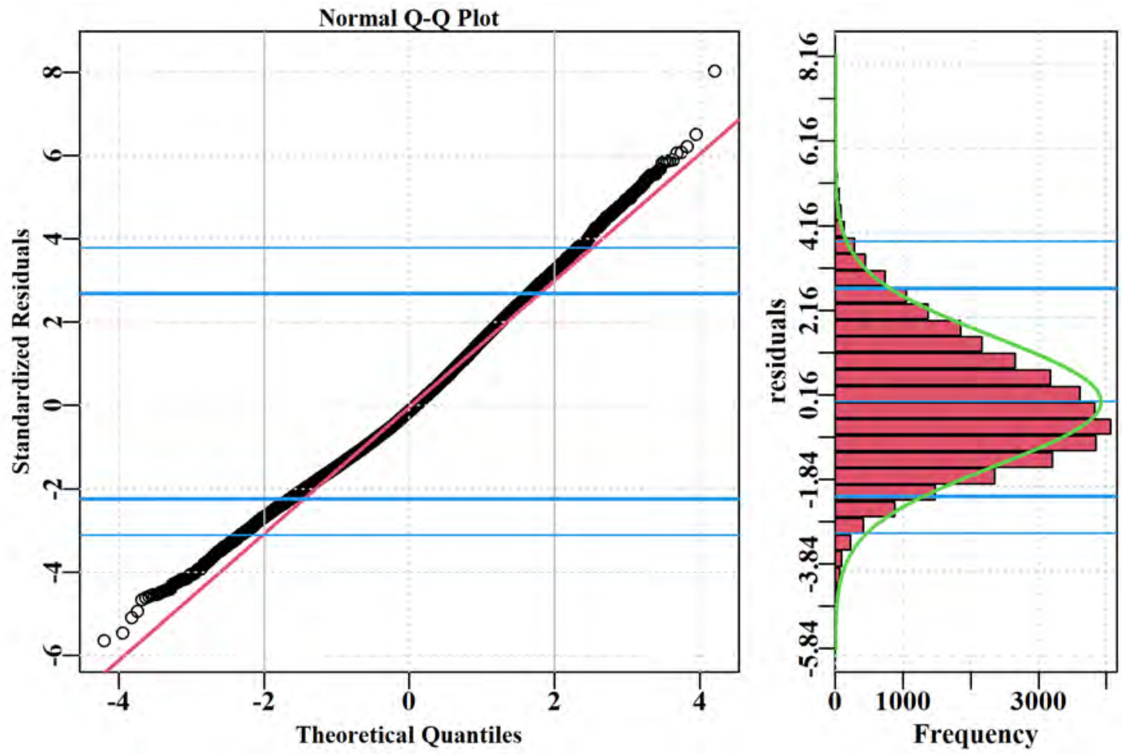

Figure 6.204. bluewarehou1030. diagnostic plots. The distribution of residuals from the optimum fit. The qqplot indicates the fit to the expected normality, while the histogram of residuals illustrates the 90% quantiles to indicate the intensity of any lack of fit at the margins of the distribution.

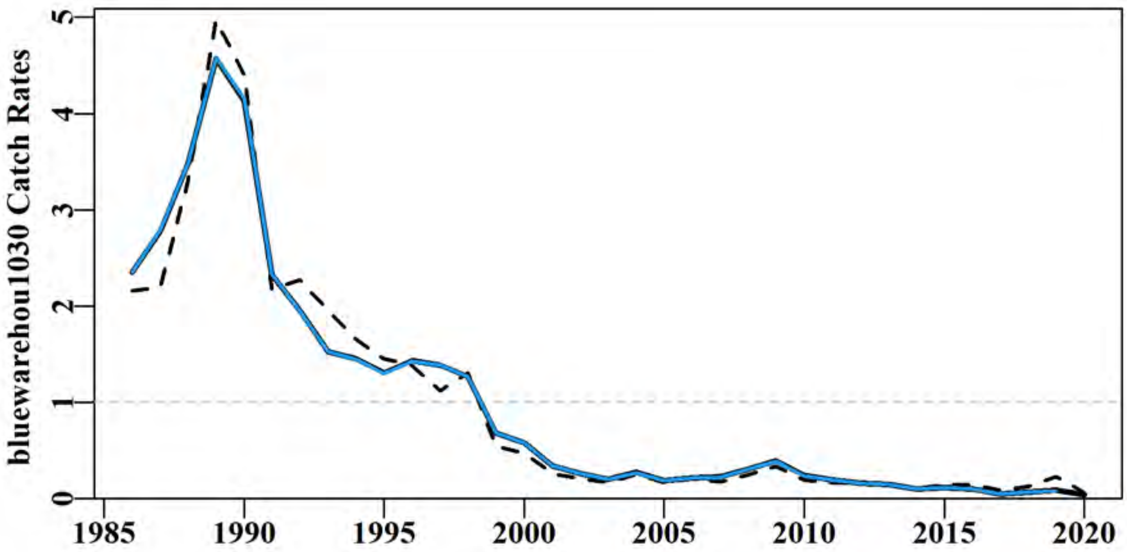

Figure 6.205. bluewarehou1030. A comparison of the previous year's standardization (blue line) with this year's. They should lie on top of each other, although small deviations may relate to data adjustments, particularly in very recent years.

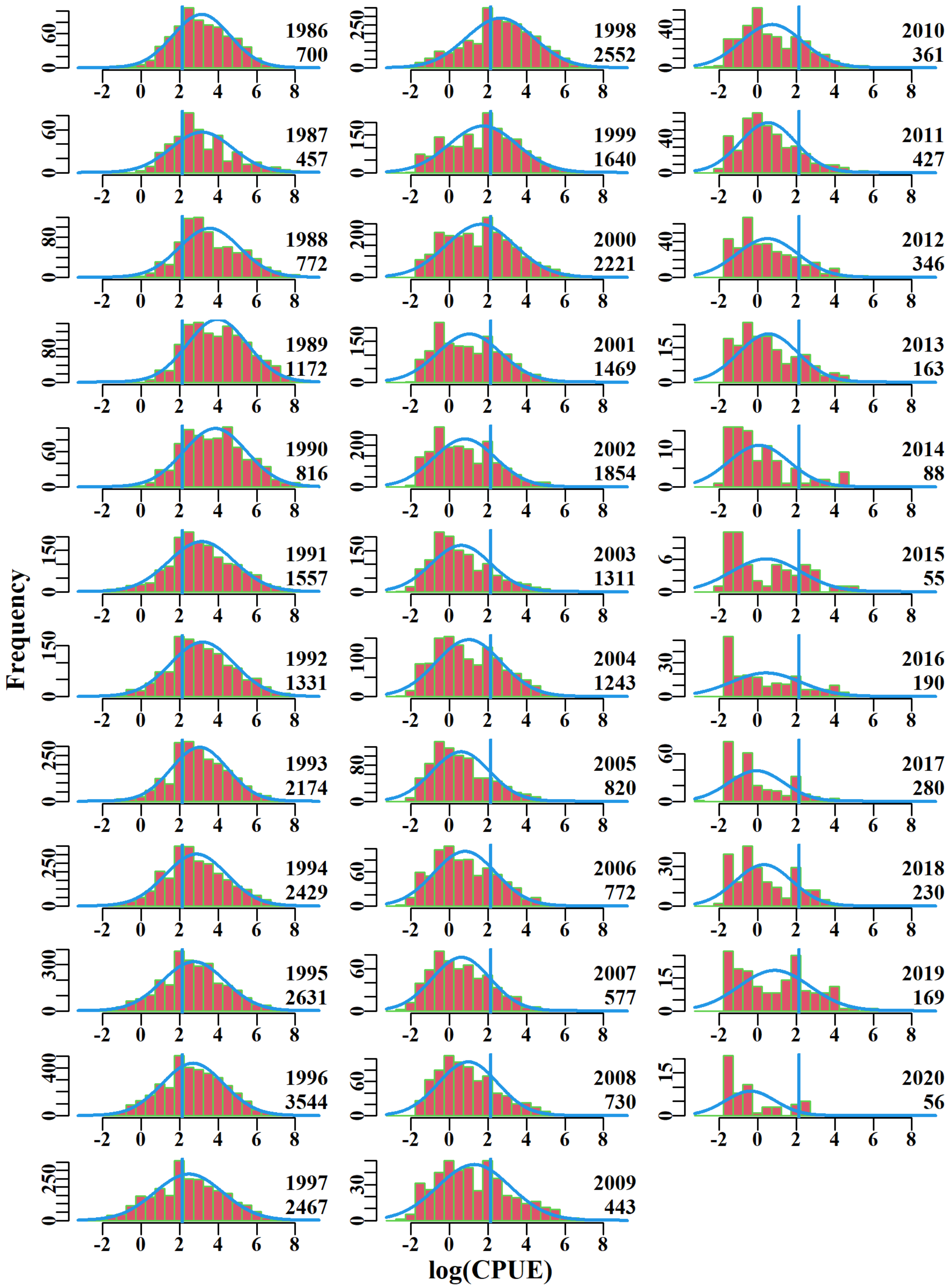

Figure 6.206. bluewarehou1030. The natural log(CPUE) for each year of data available the blue lines are normal distributions fitted to the histogram frequencies. The numbers in each plot are the year and number of records.

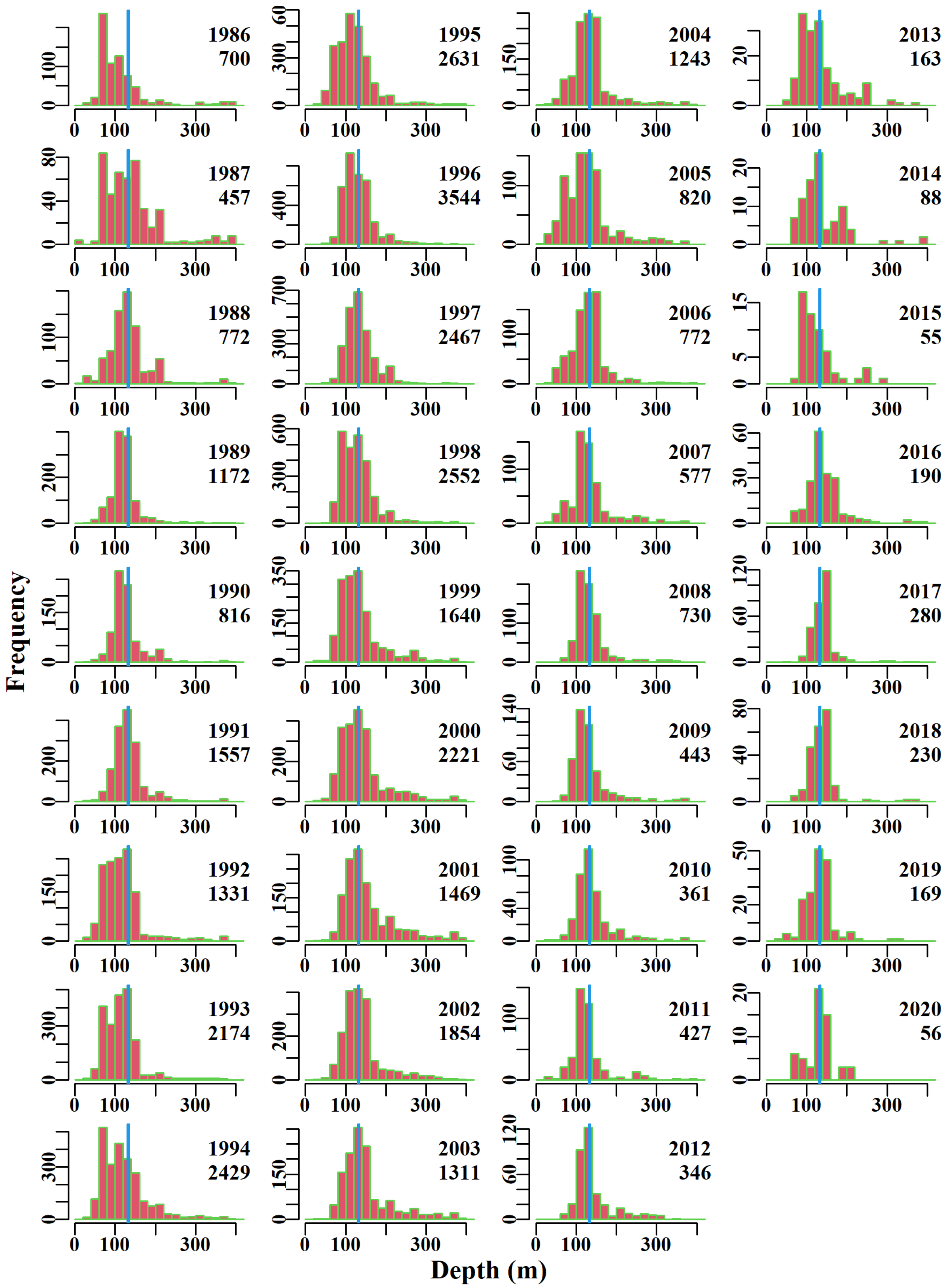

Figure 6.207. bluewarehou1030. The average Depth of fishing for each year of data available to illustrate the development of the fishery through time. The numbers in each plot are the year and number of records.

6.33 Blue Warehou 40 50

For Blue Warehou (TRT – 37445005 – *Seriolella brama*) in zones 40 and 50, initial data selection was conducted according to the details given in Table 6.146.

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

6.33.1 *Inferences*

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

The terms Year, Vessel, Month and DepCat had the greatest contribution to model fit, with the remaining terms each explaining < 1% of the overall variation in CPUE, based on the AIC and R^2 statistics (Table 6.150). The qqplot suggests that the assumed Normal distribution is valid with a slight departure in the lower tail of the distribution (Figure 6.211).

Annual standardized CPUE trend is flat since 1992 and mostly below average (Figure 6.208). 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.

6.33.2 *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 6.146. 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
years	1986 - 2020

Table 6.147. 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

Year	Total	N	Catch	Vess	GeoM	Opt	StDev	C<30Kg	P<30Kg
1986	211.9	159	71.4	14	162.6	3.7787	0.000	0.759	0.011
1987	405.9	183	215.6	10	635.9	4.0197	0.241	0.334	0.002
1988	544.0	179	198.0	12	566.9	1.7336	0.249	0.700	0.004
1989	776.0	56	81.3	13	562.1	4.5488	0.309	0.235	0.003
1990	881.4	439	298.1	13	341.8	1.7677	0.234	2.210	0.007
1991	1284.2	595	647.1	18	850.7	2.9946	0.232	1.060	0.002
1992	934.4	536	429.7	17	473.1	1.6018	0.234	1.733	0.004
1993	829.6	494	362.7	21	413.0	1.2355	0.235	1.700	0.005
1994	944.8	820	444.1	21	245.7	1.3532	0.230	2.525	0.006
1995	815.4	820	323.6	22	155.8	0.9204	0.228	4.180	0.013
1996	724.5	696	180.9	24	87.2	0.6127	0.230	4.248	0.023
1997	935.2	430	243.5	23	354.0	0.6495	0.235	3.038	0.012
1998	903.2	582	354.5	19	459.4	1.0015	0.234	2.728	0.008
1999	591.1	687	169.4	19	122.7	0.5535	0.233	4.505	0.027
2000	470.5	651	203.6	24	157.7	0.4407	0.233	3.736	0.018
2001	285.5	685	194.0	23	98.5	0.4535	0.232	4.249	0.022
2002	290.5	528	217.9	23	184.0	0.5776	0.235	2.977	0.014
2003	234.0	361	172.4	19	185.9	0.5281	0.240	2.421	0.014
2004	232.4	430	158.8	21	136.3	0.5790	0.237	2.276	0.014
2005	289.1	457	257.4	18	333.5	0.9170	0.238	1.735	0.007
2006	379.5	693	337.5	16	212.7	0.6200	0.234	3.736	0.011
2007	177.8	462	147.7	16	116.3	0.5193	0.237	2.541	0.017
2008	163.3	349	117.0	12	88.9	0.4266	0.240	2.016	0.017
2009	135.2	308	89.0	11	70.1	0.3133	0.243	1.337	0.015
2010	129.3	407	105.3	12	52.7	0.3691	0.238	1.833	0.017
2011	103.3	517	77.8	14	31.2	0.3425	0.236	2.225	0.029
2012	52.3	254	30.7	14	22.3	0.1937	0.247	1.654	0.054
2013	68.0	304	57.9	13	37.3	0.2683	0.243	1.522	0.026
2014	15.3	60	11.6	9	48.9	0.1878	0.303	0.457	0.039
2015	5.4	17	0.6	5	5.9	0.0810	0.438	0.049	0.085
2016	18.8	42	2.6	8	11.6	0.2829	0.332	0.243	0.094
2017	16.4	85	7.3	8	14.4	0.5057	0.286	0.617	0.084
2018	39.0	164	25.2	8	21.9	0.2711	0.257	0.464	0.018
2019	17.8	86	7.3	8	16.4	0.2386	0.283	0.258	0.035
2020	2.7	17	0.8	4	8.5	0.1130	0.455	0.079	0.094

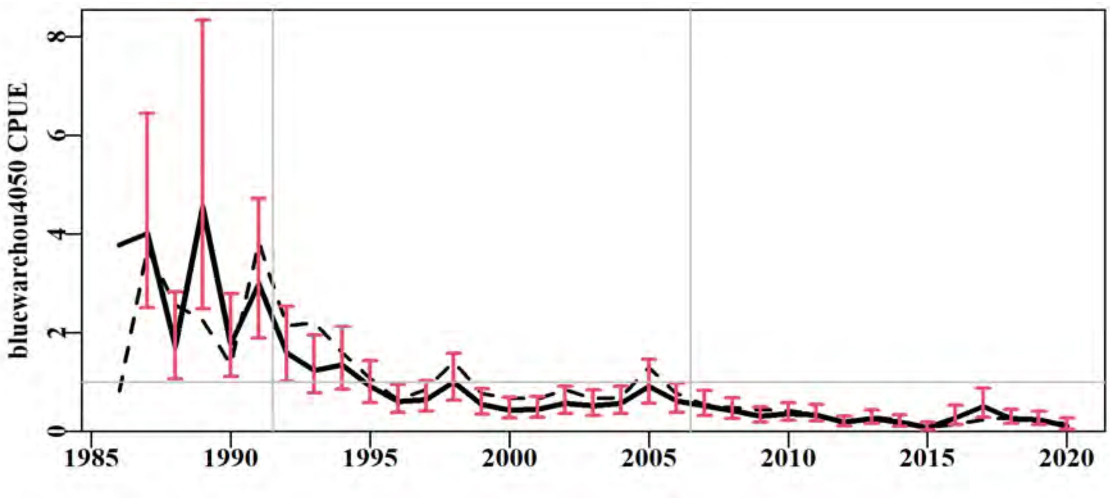

Figure 6.208. bluewarehou4050 standardization. The dashed black line represents the geometric mean CPUE, solid black line the standardized CPUE. The red bars are the 95% confidence intervals about the mean estimates. The graph scales both time-series of standardized CPUE relative to the mean of each time-series.

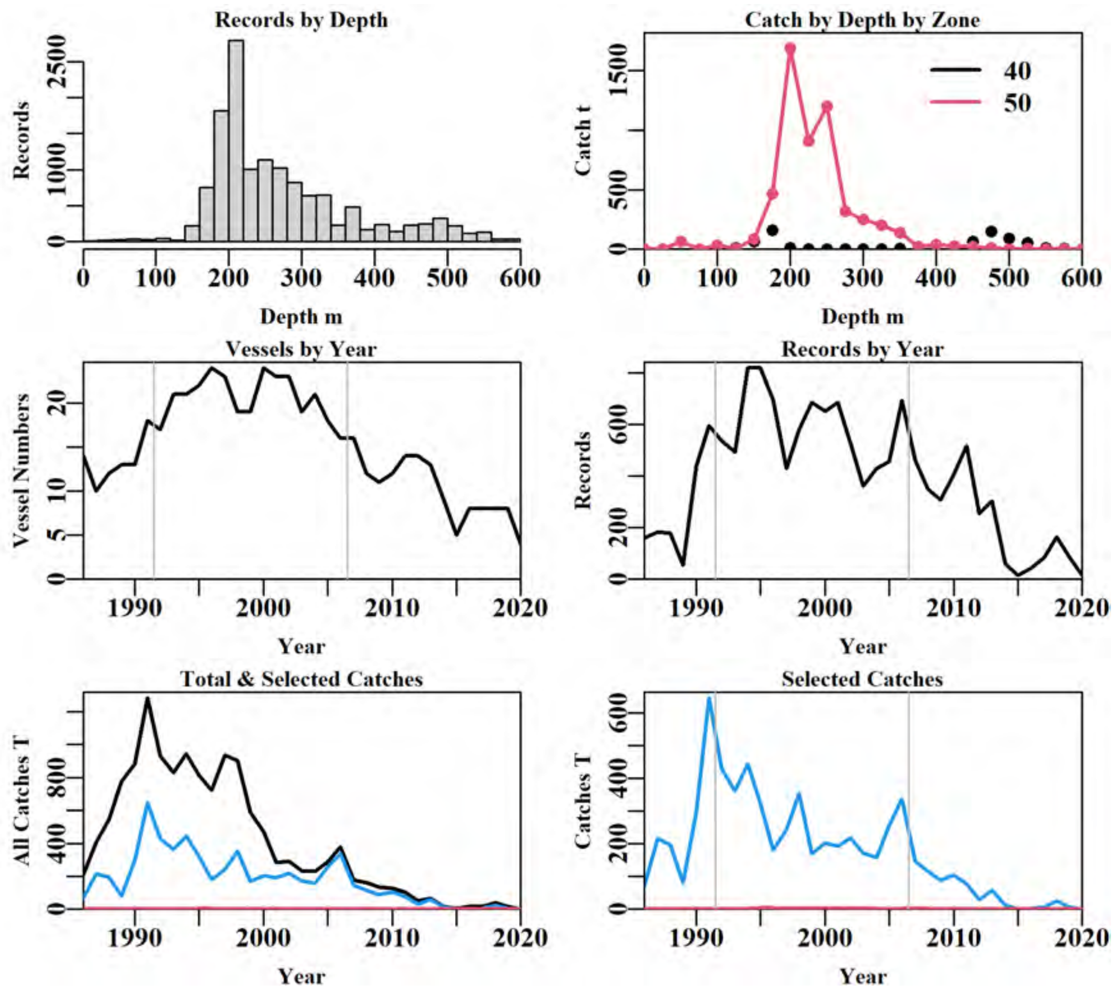

Figure 6.209. bluewarehou4050 fishery details. The bottom left plot depicts all known catches (top black line), and all selected catches used in the analysis (middle blue line); the lower red line: selected catches < 30 kg).

Table 6.148. 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	68429	62225	61718	61482	14331	13574	13553
Difference	0	6204	507	236	47151	757	21
Catch	13976	13589	13491	13423	6385	6246	6242
Difference	0	387	99	68	7038	139	3

Table 6.149. 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 6.150. 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

Term	AIC	RSS	MSS	Nobs	Npars	adj_r2	%Change
Year	14793	40163	6533	13553	35	13.8	0
Vessel	13617	36371	10325	13553	119	21.4	7.65
Month	12598	33681	13015	13553	130	27.2	5.75
DepCat	11921	31927	14768	13553	154	30.8	3.67
Zone	11920	31920	14776	13553	155	30.9	0.01
DayNight	11868	31784	14911	13553	158	31.1	0.28
Zone:Month	11833	31652	15044	13553	169	31.4	0.23
Zone:DepCat	11864	31677	15018	13553	179	31.3	0.12

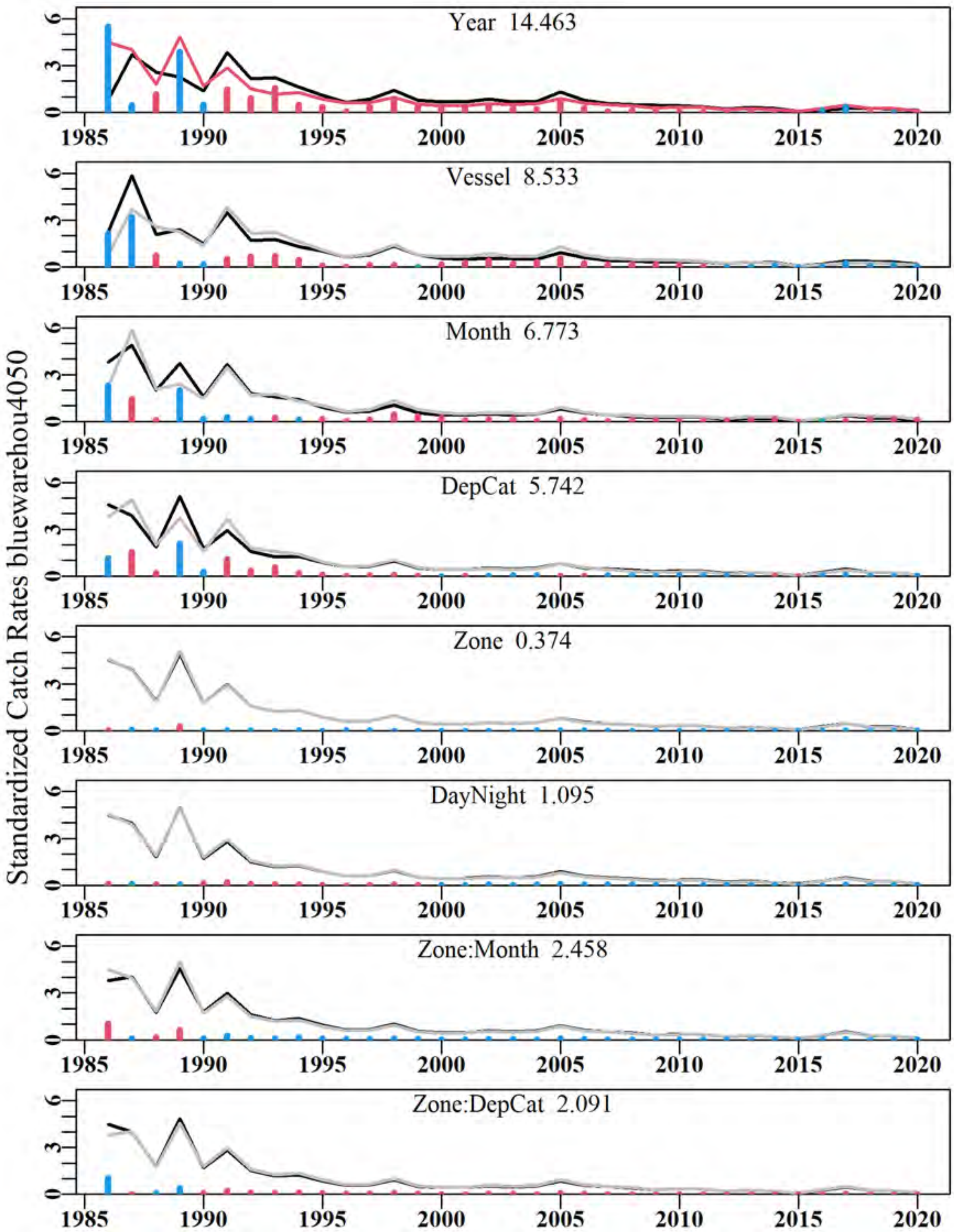

Figure 6.210. bluewarehou4050. The influence of each factor on the optimal standardization. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by vertical bars with blue bars indicating the optimum model is higher than the 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.

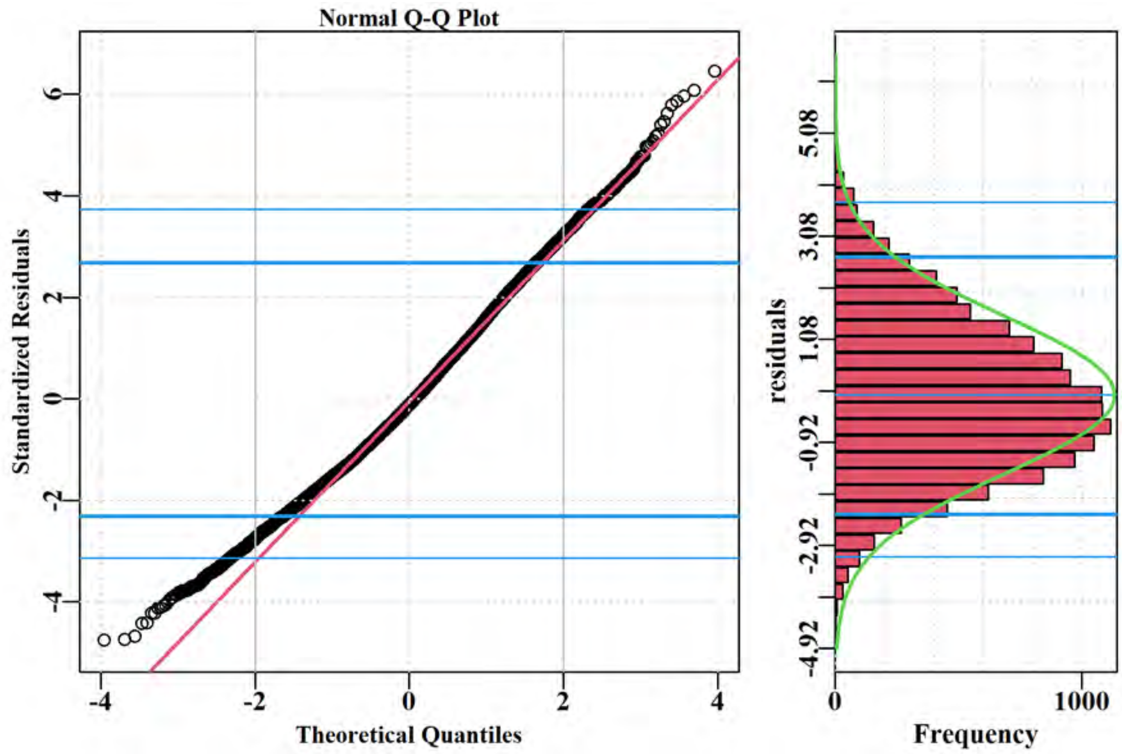

Figure 6.211. bluewarehou4050. diagnostic plots. The distribution of residuals from the optimum fit. The qqplot indicates the fit to the expected normality, while the histogram of residuals illustrates the 90% quantiles to indicate the intensity of any lack of fit at the margins of the distribution.

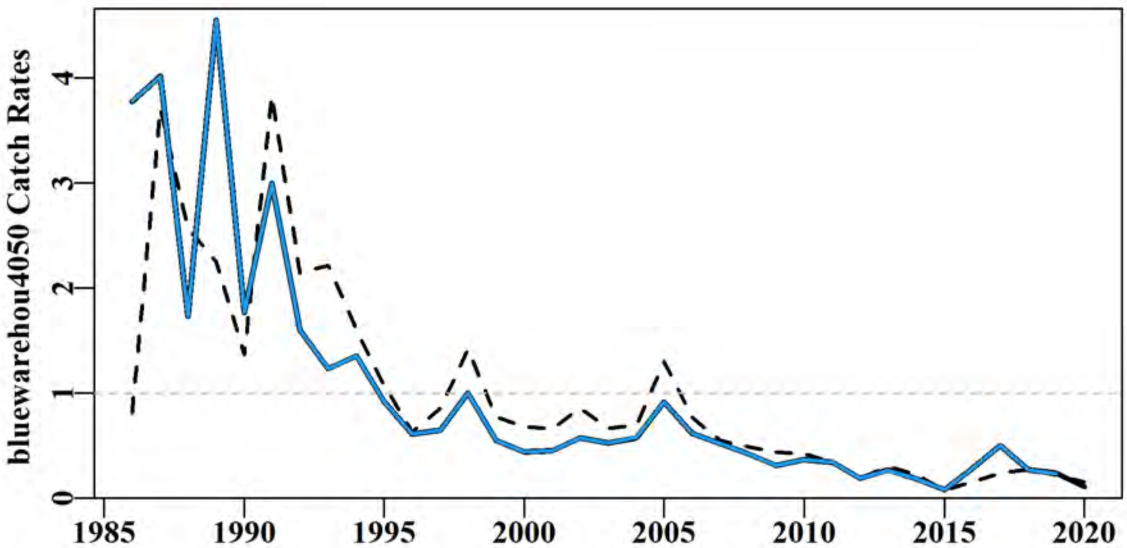

Figure 6.212. bluewarehou4050. A comparison of the previous year's standardization (blue line) with this year's. They should lie on top of each other, although small deviations may relate to data adjustments, particularly in very recent years.

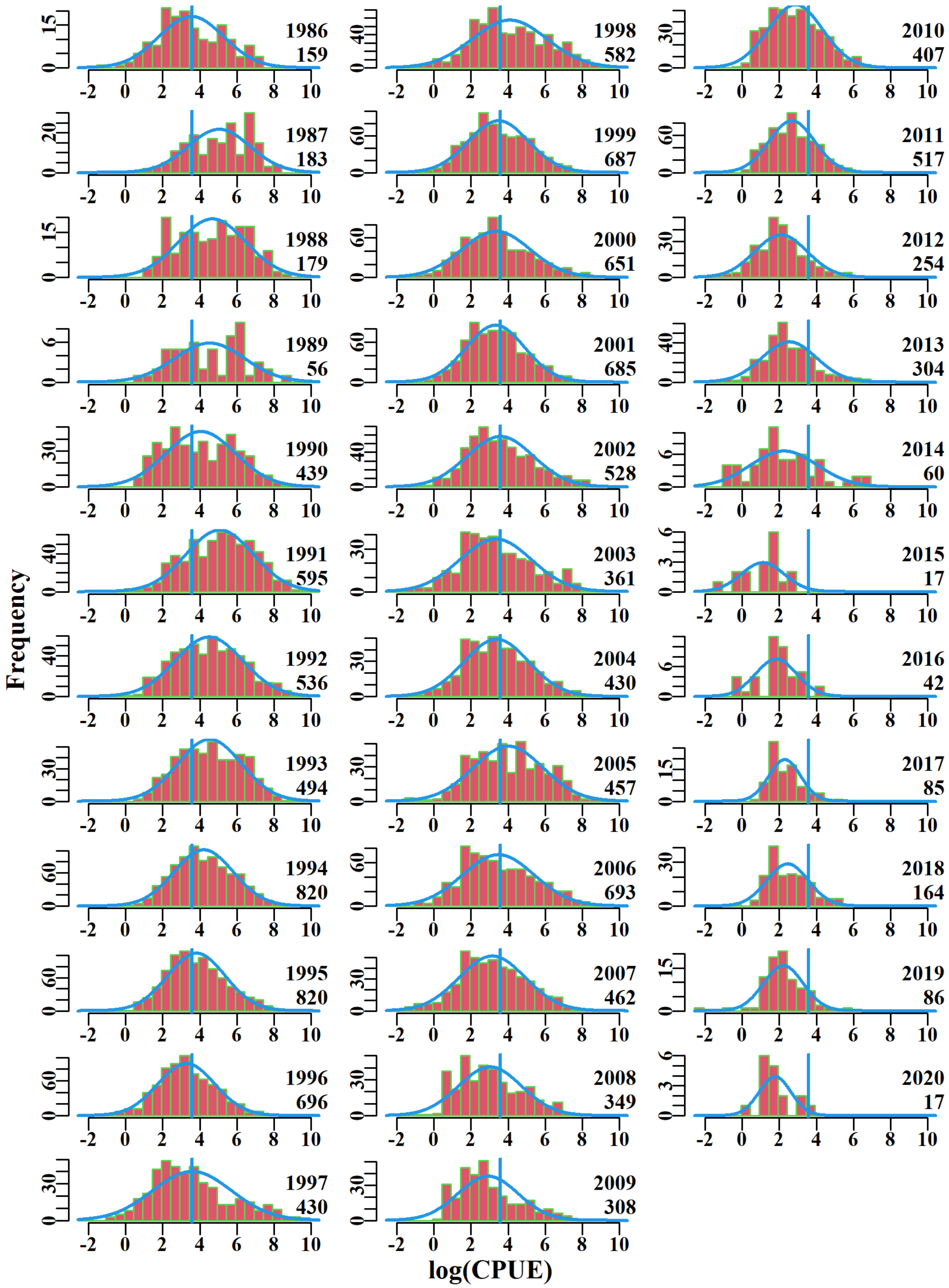

Figure 6.213. bluewarehou4050. The natural log(CPUE) for each year of data available the blue lines are normal distributions fitted to the histogram frequencies. The numbers in each plot are the year and number of records.

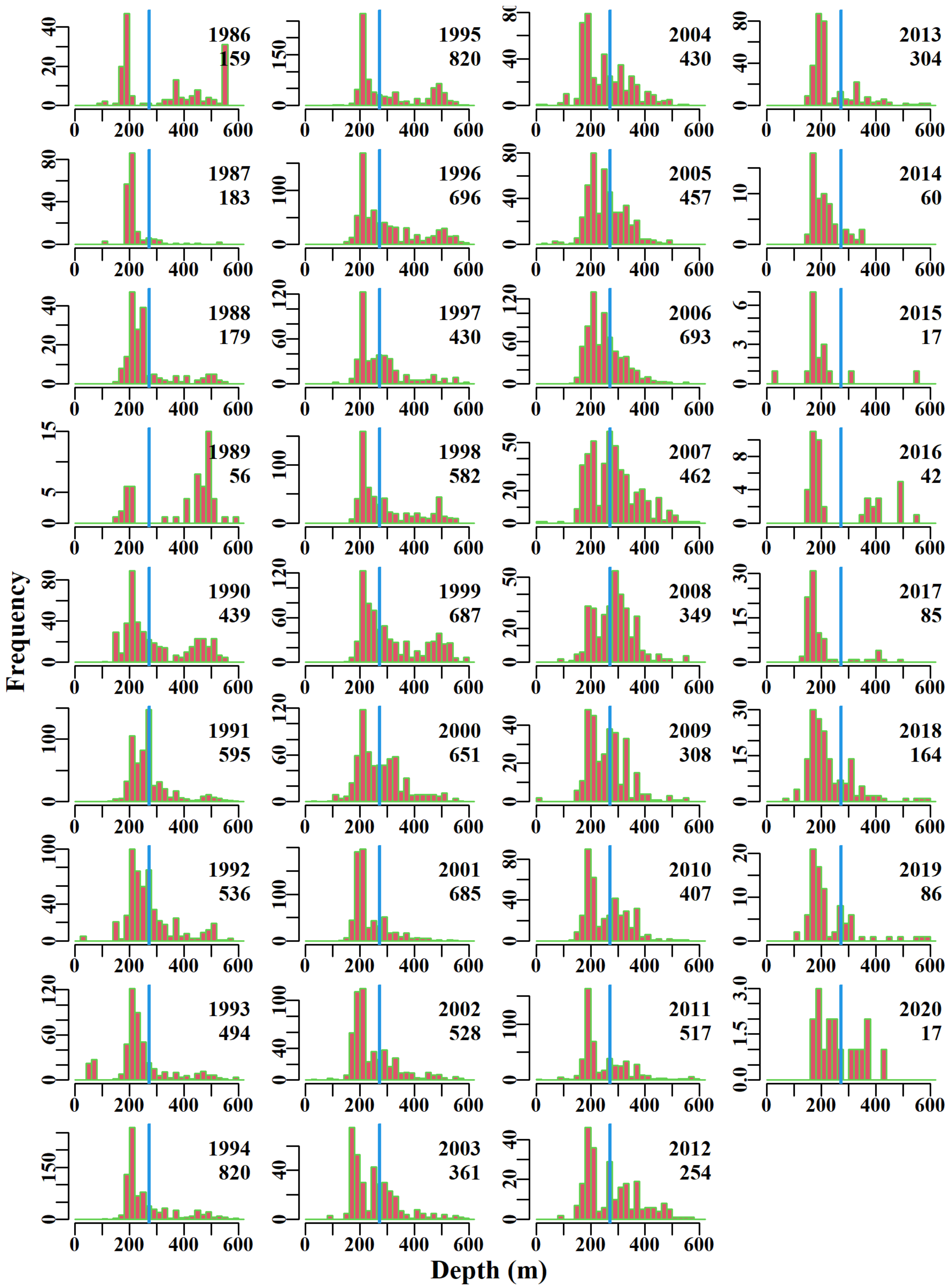

Figure 6.214. bluewarehou4050. The average Depth of fishing for each year of data available to illustrate the development of the fishery through time. The numbers in each plot are the year and number of records.

6.34 Deepwater Flathead

The initial data selection for Deepwater Flathead (FLD – 37296002 – *Platycephalus conatus*) in the GAB was conducted according to the details given in Table 6.151.

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.

6.34.1 *Inferences*

The majority of catch of this species occurred in longitude 129-130 (degrees longitude - takes 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 6.155). The qqplot suggests a departure from the assumed Normal distribution as depicted by the tails of the distribution (Figure 6.218).

Annual standardized CPUE has been cyclical in the early years following the increases and decreases in catches (prior to 2007) and relatively flat and mostly below average since 2005 (Figure 6.215). The most recent catch of 285 t in 2020 is the lowest since 1989.

6.34.2 *Action Items and Issues*

It is recommended that alternate statistical distributions be considered.

Table 6.151. 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, TMO
years	1987 - 2020

Table 6.152. 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

Year	Total	N	Catch	Vess	GeoM	Opt	StDev	C<30Kg	P<30Kg
1987	80.3	229	44.3	3	62.5	0.5298	0.000	0.195	0.004
1988	319.5	533	262.9	4	197.6	1.0747	0.055	0.732	0.003
1989	402.6	944	345.6	6	100.3	1.0474	0.053	0.803	0.002
1990	430.2	1297	393.9	6	90.8	1.0257	0.052	0.900	0.002
1991	621.0	1468	514.4	8	85.4	0.9868	0.050	0.819	0.002
1992	524.1	958	499.5	3	117.9	1.2571	0.052	0.345	0.001
1993	593.1	881	580.7	5	149.5	1.6926	0.052	0.570	0.001
1994	1285.9	1684	1233.8	6	173.3	2.0874	0.050	0.327	0.000
1995	1585.1	1849	1552.3	5	176.6	1.9961	0.050	0.030	0.000
1996	1499.2	2726	1450.5	6	110.2	1.3282	0.049	0.405	0.000
1997	1030.0	2684	944.5	7	72.0	0.9204	0.049	1.340	0.001
1998	690.4	2401	669.2	7	57.0	0.7077	0.049	3.280	0.005
1999	571.0	2064	549.4	7	53.7	0.8389	0.051	1.530	0.003
2000	845.6	2378	773.9	5	67.5	0.9156	0.050	1.857	0.002
2001	973.1	2411	910.5	5	75.6	1.0991	0.050	1.207	0.001
2002	1708.9	3113	1613.1	8	103.5	1.5152	0.050	0.900	0.001
2003	2260.6	4468	2156.6	10	93.8	1.5093	0.049	0.387	0.000
2004	2155.6	5350	2054.6	9	74.5	1.1919	0.049	0.923	0.000
2005	1426.0	5014	1238.5	10	49.5	0.7579	0.049	1.642	0.001
2006	1014.2	4151	947.2	10	45.9	0.6947	0.050	1.667	0.002
2007	1039.9	3659	908.2	6	50.8	0.7729	0.050	2.978	0.003
2008	813.2	3086	766.5	4	50.6	0.9222	0.050	2.089	0.003
2009	849.4	3193	824.6	4	52.3	0.8171	0.050	2.793	0.003
2010	966.8	2803	927.0	4	67.8	1.0347	0.050	1.300	0.001
2011	963.2	3269	789.3	4	47.1	0.8261	0.050	1.490	0.002
2012	1020.0	3452	843.1	4	48.3	0.8258	0.050	1.724	0.002
2013	874.8	3234	649.6	4	39.1	0.7235	0.050	2.080	0.003
2014	588.6	2572	485.3	4	37.5	0.6688	0.050	2.314	0.005
2015	593.9	2248	472.0	3	42.2	0.7480	0.051	1.574	0.003
2016	737.3	2531	591.4	4	48.6	0.7887	0.050	2.013	0.003
2017	547.4	2486	435.5	3	36.5	0.5929	0.051	3.474	0.008
2018	522.5	2243	390.9	4	36.9	0.6052	0.051	2.925	0.007
2019	620.1	2159	485.2	3	45.1	0.7363	0.051	2.041	0.004
2020	352.6	1308	285.1	3	45.4	0.7614	0.052	1.214	0.004

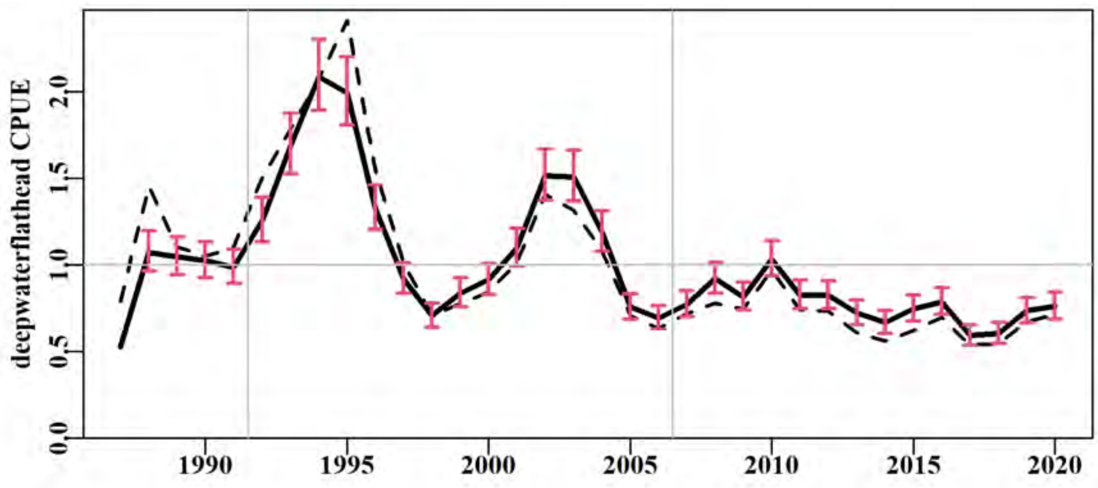

Figure 6.215. deepwaterflathead standardization. The dashed black line represents the geometric mean CPUE, solid black line the standardized CPUE. The red bars are the 95% confidence intervals about the mean estimates. The graph scales both time-series of standardized CPUE relative to the mean of each time-series.

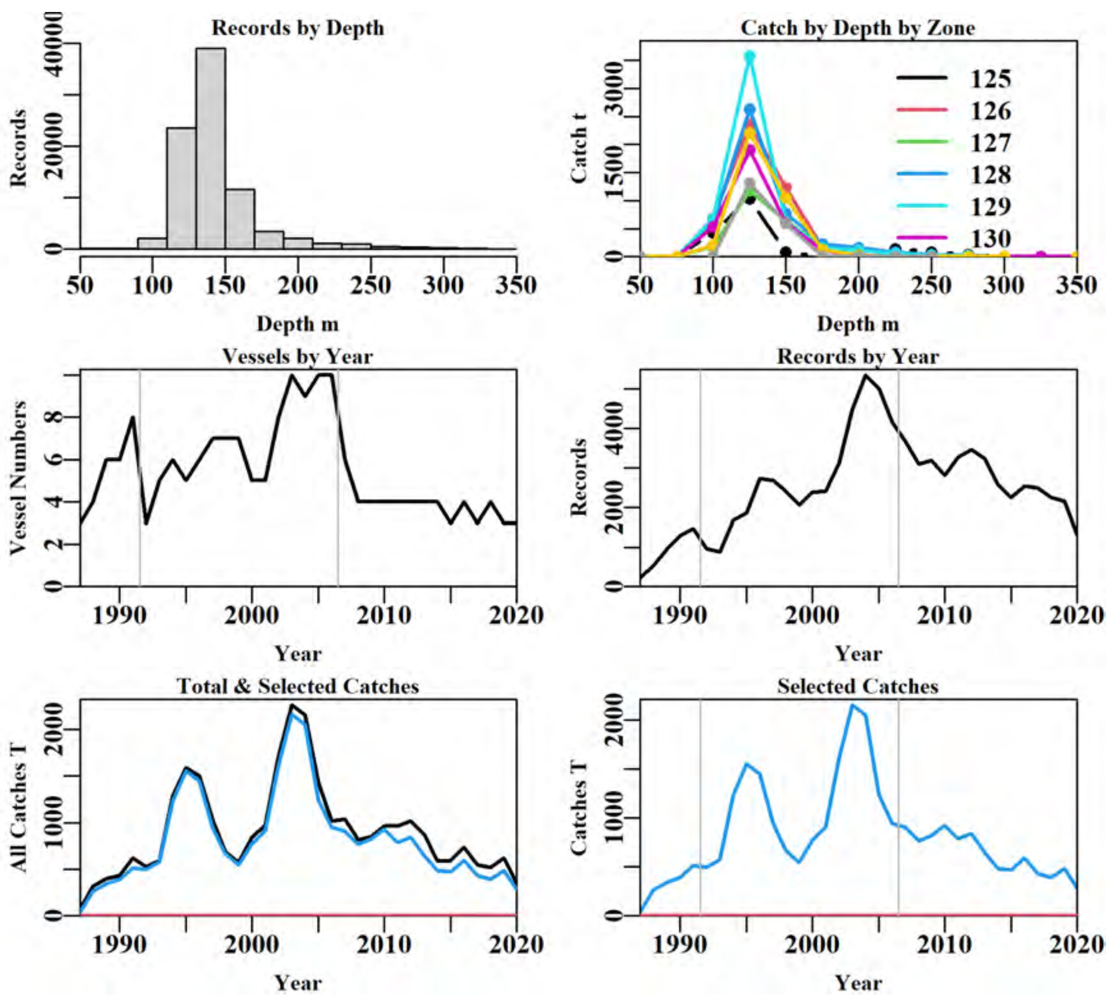

Figure 6.216. deepwaterflathead fishery details. The bottom left plot depicts all known catches (top black line), and all selected catches used in the analysis (middle blue line); the lower red line: selected catches < 30 kg).

Table 6.153. deepwaterflathead 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	68429	62225	61718	61482	14331	13574	13553
Difference	0	6204	507	236	47151	757	21
Catch	13976	13589	13491	13423	6385	6246	6242
Difference	0	387	99	68	7038	139	3

Table 6.154. 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 6.155. 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

Term	AIC	RSS	MSS	Nobs	Npars	adj_r2	%Change
Year	-41365	52065	10757	84846	34	17.1	0
Vessel	-47190	48590	14233	84846	53	22.6	5.52
Zone	-53803	44939	17884	84846	60	28.4	5.81
Month	-57504	43009	19813	84846	71	31.5	3.06
DepCat	-58822	42335	20488	84846	83	32.5	1.07
DayNight	-60756	41378	21445	84846	86	34.1	1.52
Zone:Month	-61988	40707	22115	84846	163	35.1	1.01
Zone:Vessel	-62881	40233	22589	84846	213	35.8	1.73
Zone:DepCat	-63208	40129	22693	84846	159	36.0	1.93

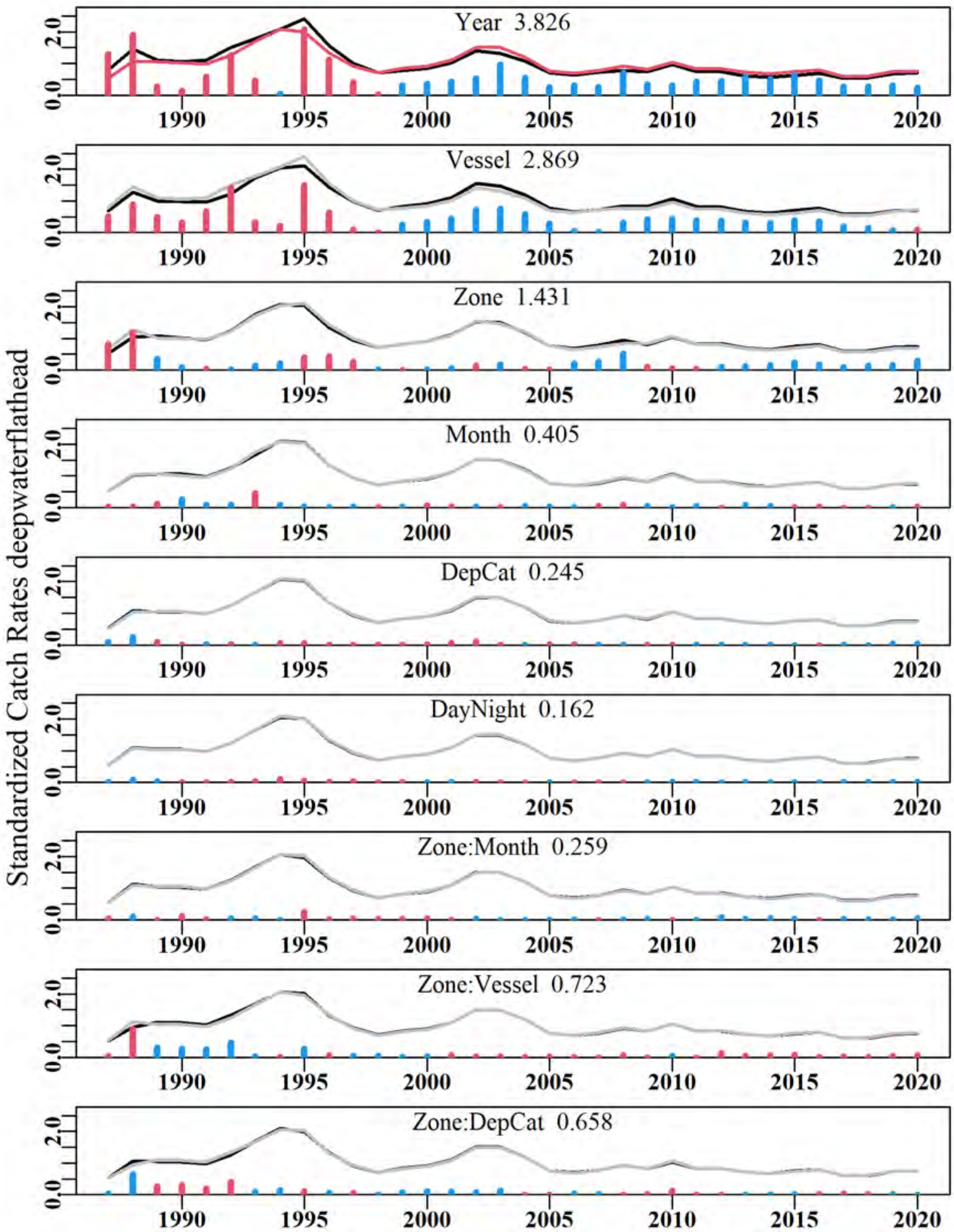

Figure 6.217. deepwaterflathead. The influence of each factor on the optimal standardization. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by vertical bars with blue bars indicating the optimum model is higher than 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.

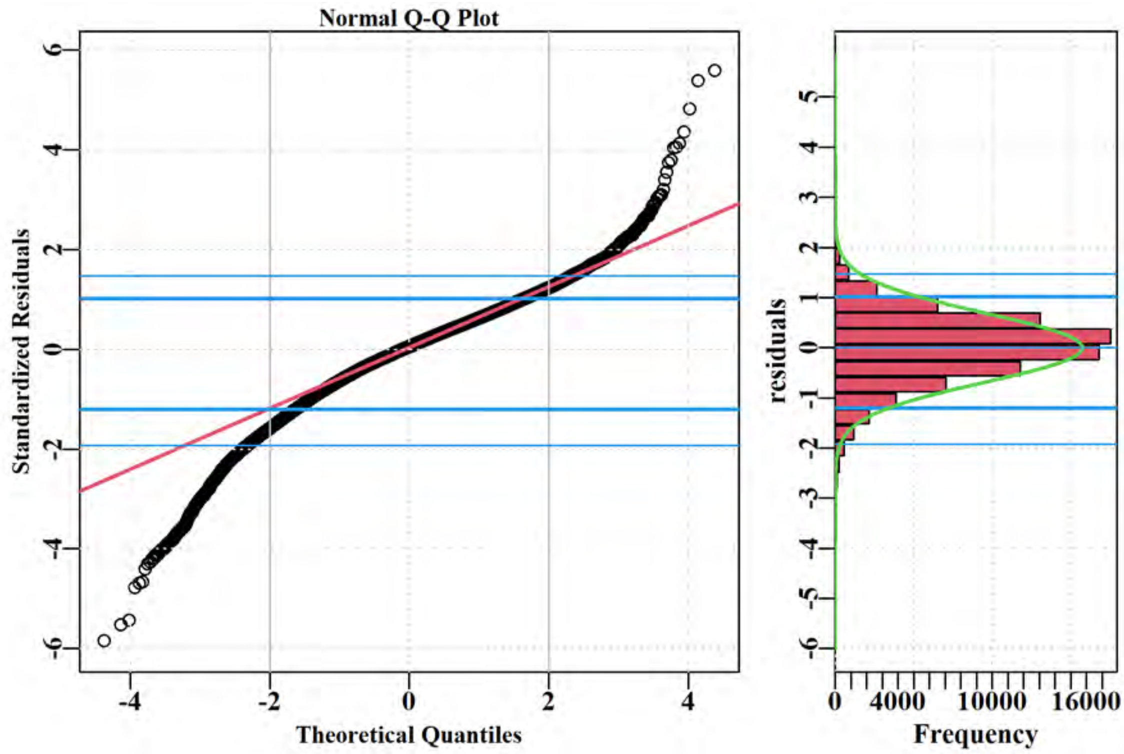

Figure 6.218. deepwaterflathead. diagnostic plots. The distribution of residuals from the optimum fit. The qqplot indicates the fit to the expected normality, while the histogram of residuals illustrates the 90% quantiles to indicate the intensity of any lack of fit at the margins of the distribution.

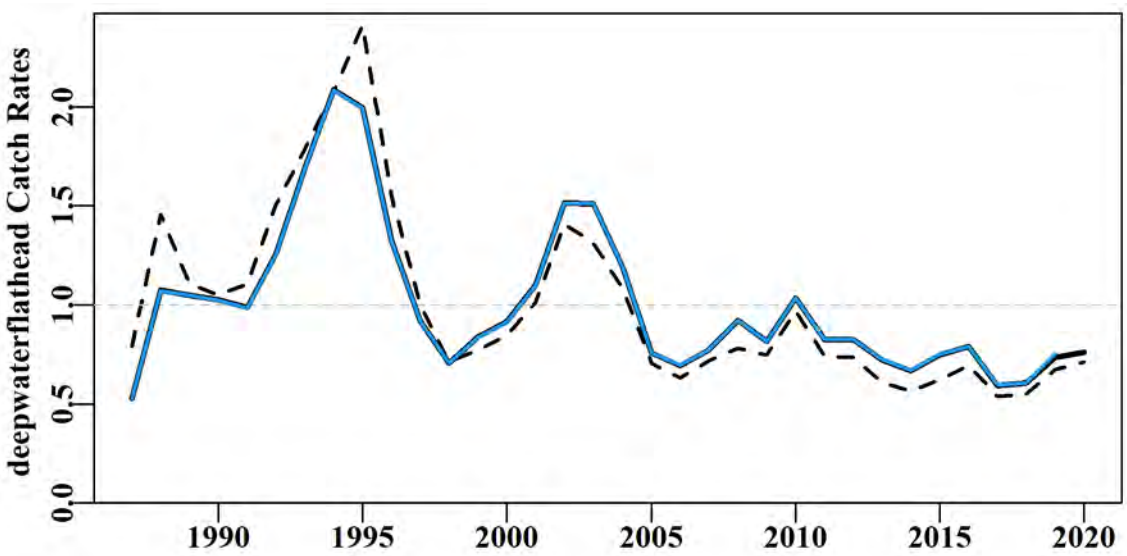

Figure 6.219. deepwaterflathead. A comparison of the previous year's standardization (blue line) with this year's. They should lie on top of each other, although small deviations may relate to data adjustments, particularly in very recent years.

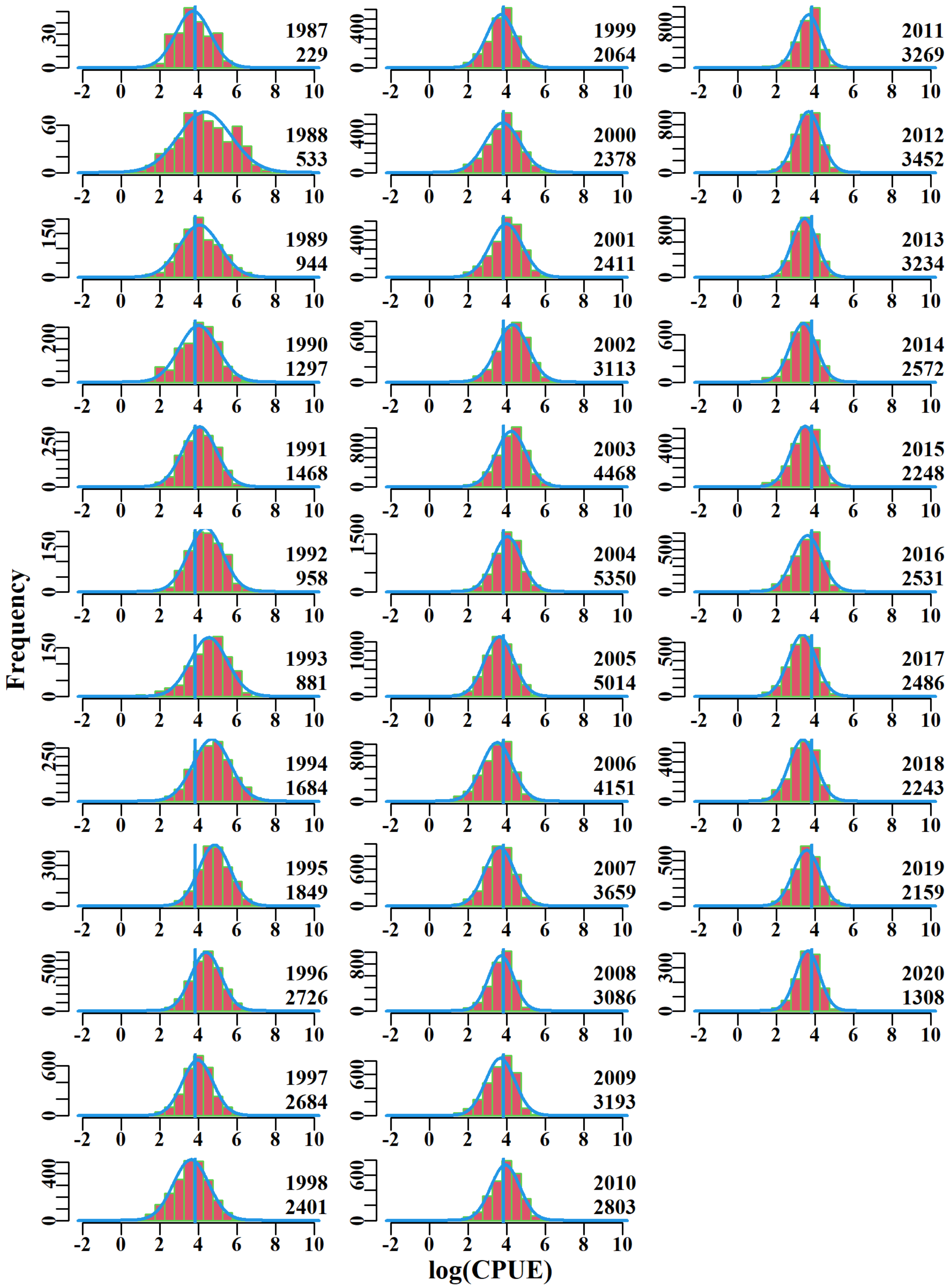

Figure 6.220. deepwaterflathead. The natural log(CPUE) for each year of data available the blue lines are normal distributions fitted to the histogram frequencies. The numbers in each plot are the year and number of records.

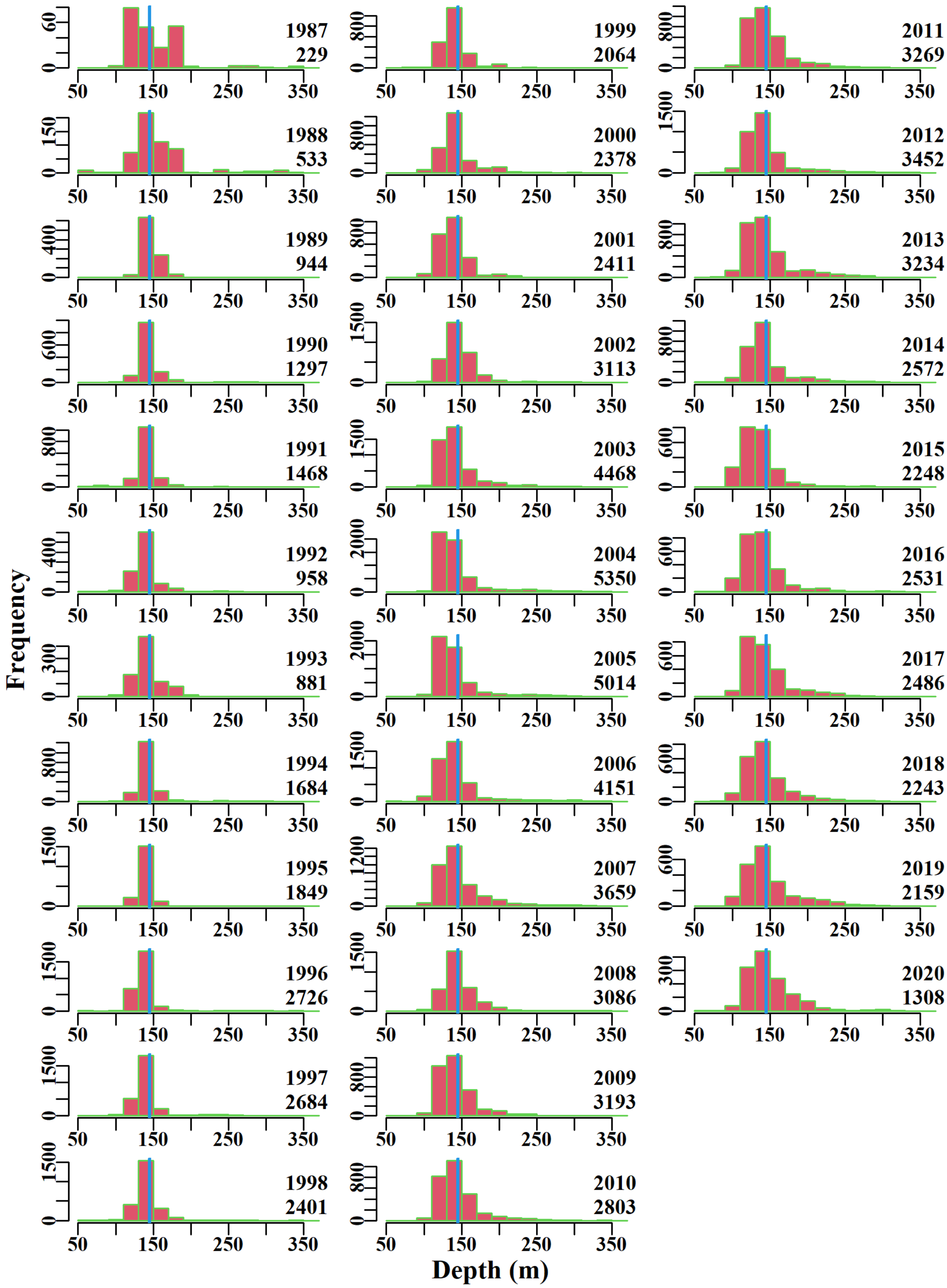

Figure 6.221. deepwaterflathead. The average Depth of fishing for each year of data available to illustrate the development of the fishery through time. The numbers in each plot are the year and number of records.

6.35 Bight Redfish

Initial data selection for Bight Redfish (FLD – 37258004 – *Centroberyx gerrardi*) in the GAB was conducted according to the details given in Table 6.156.

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.

6.35.1 *Inferences*

The majority of catch of this species occurred in zone 131, again with degree longitude taking the place of zones to provide more detail. The total catch of 104.1 t in 2020 is the lowest since 1989.

The terms Year, DayNight, Zone, Month, Vessel and interaction term Zone:DepCat had the greatest contribution to model fit, based on the AIC and R^2 statistics (Table 6.159). The qqplot suggests a departure from the assumed Normal distribution as depicted by the tails of the distribution (Figure 6.225).

Annual standardized CPUE trend is flat since 1992 and oscillating above and below average (Figure 6.222), and this is despite major changes in the distribution of the log(CPUE) from 2012 - 2020. 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.

6.35.2 *Action Items and Issues*

It is recommended that alternate statistical distributions be considered.

Table 6.156. 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 - 2020

Table 6.157. 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

Year	Total	N	Catch	Vess	GeoM	Opt	StDev	C<30Kg	P<30Kg
1987	47.4	152	24.6	3	51.6	2.5910	0.000	0.090	0.004
1988	88.0	404	68.1	4	60.9	2.4807	0.112	0.885	0.013
1989	173.6	737	148.2	6	62.1	1.5602	0.108	2.017	0.014
1990	290.1	1045	252.8	8	75.1	1.4281	0.106	2.220	0.009
1991	274.0	1018	221.8	7	58.8	1.3120	0.104	3.790	0.017
1992	132.1	719	117.0	3	39.7	0.9659	0.107	3.816	0.033
1993	108.7	688	105.9	5	37.2	0.9171	0.107	4.561	0.043
1994	163.6	1275	159.3	6	35.9	0.6257	0.103	7.128	0.045
1995	176.9	1396	175.4	5	30.2	0.7436	0.103	7.773	0.044
1996	334.1	2029	328.7	6	37.8	0.9090	0.102	10.358	0.032
1997	375.9	1922	366.0	7	46.2	0.9536	0.102	9.838	0.027
1998	442.2	1794	434.0	7	57.1	1.1168	0.102	8.723	0.020
1999	328.3	1495	327.2	7	51.8	0.9820	0.105	5.404	0.017
2000	397.5	1715	390.3	5	64.5	0.8733	0.104	6.689	0.017
2001	228.9	1641	227.7	5	34.9	0.6833	0.104	7.421	0.033
2002	374.5	2123	369.8	8	37.2	0.7315	0.103	9.152	0.025
2003	853.2	3144	845.0	10	57.8	1.0065	0.103	8.796	0.010
2004	882.2	3782	754.4	9	42.7	0.9770	0.102	15.491	0.021
2005	759.5	3532	718.2	10	43.0	0.9323	0.103	13.678	0.019
2006	958.4	3294	930.1	9	72.1	1.0194	0.103	10.318	0.011
2007	756.0	2744	683.8	6	67.8	0.9481	0.103	11.605	0.017
2008	661.5	2427	643.1	4	68.0	1.0153	0.104	9.294	0.014
2009	462.6	2307	453.4	4	48.4	0.9479	0.103	11.703	0.026
2010	285.3	1858	280.8	4	34.8	0.7582	0.104	10.622	0.038
2011	329.1	2184	321.2	4	30.7	0.7603	0.104	10.872	0.034
2012	266.4	1883	259.6	4	26.7	0.6837	0.104	14.541	0.056
2013	198.3	1520	191.5	4	22.9	0.6184	0.105	12.283	0.064
2014	238.1	1428	235.6	4	32.1	0.6710	0.106	8.433	0.036
2015	173.6	1193	170.5	3	29.8	0.6608	0.107	5.431	0.032
2016	437.8	1800	434.4	4	39.6	0.9169	0.105	8.295	0.019
2017	281.2	1443	279.5	3	45.6	0.9454	0.106	5.984	0.021
2018	214.5	1226	211.7	4	40.0	0.8473	0.106	6.867	0.032
2019	153.3	1052	149.7	3	30.5	0.6732	0.107	5.863	0.039
2020	105.6	701	104.1	3	31.5	0.7445	0.110	4.835	0.046

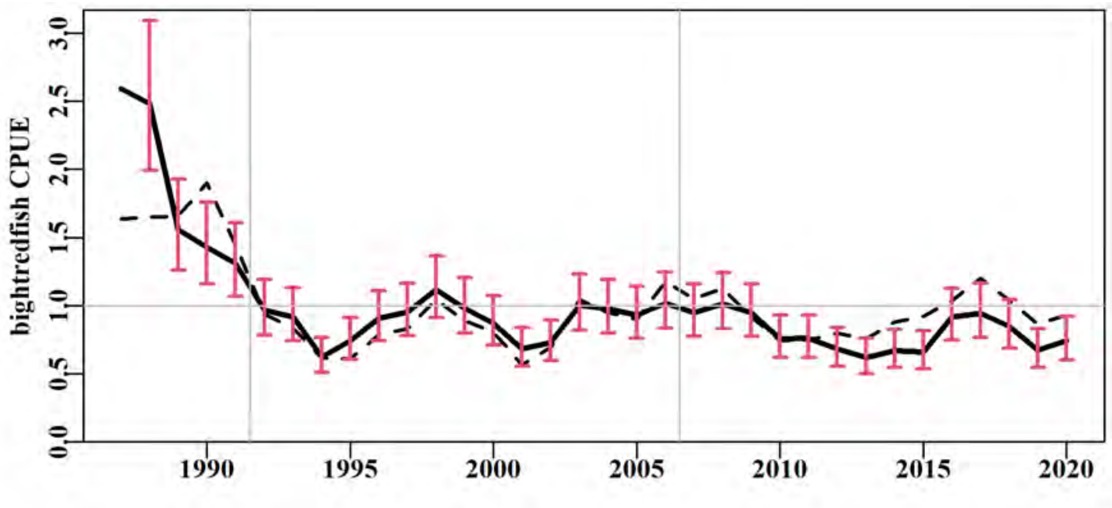

Figure 6.222. bightredfish standardization. The dashed black line represents the geometric mean CPUE, solid black line the standardized CPUE. The red bars are the 95% confidence intervals about the mean estimates. The graph scales both time-series of standardized CPUE relative to the mean of each time-series.

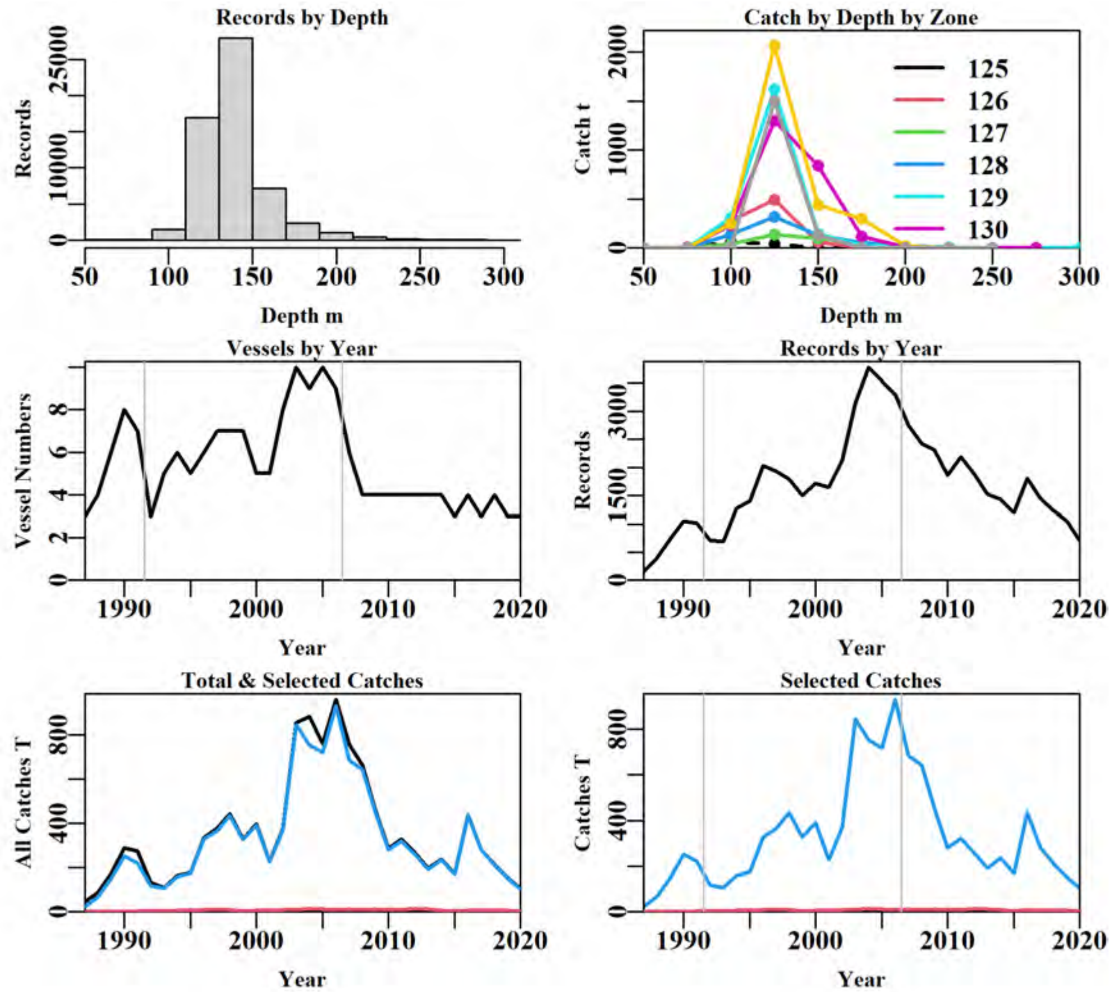

Figure 6.223. bightredfish fishery details. The bottom left plot depicts all known catches (top black line), and all selected catches used in the analysis (middle blue line); the lower red line: selected catches < 30 kg).

Table 6.158. 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 6.159. 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

Term	AIC	RSS	MSS	Nobs	Npars	adj_r2	%Change
Year	34249	103956	3129	57179	34	2.9	0
DayNight	28793	94486	12599	57179	37	11.7	8.84
Zone	22977	85327	21758	57179	44	20.3	8.55
Month	18698	79144	27941	57179	55	26.0	5.76
Vessel	17491	77440	29645	57179	74	27.6	1.57
DepCat	17264	77106	29979	57179	84	27.9	0.30
Zone:Month	16313	75630	31455	57179	161	29.2	1.28
Zone:Vessel	16583	75855	31230	57179	211	28.9	1.01
Zone:DepCat	15692	74853	32232	57179	146	29.9	2.03

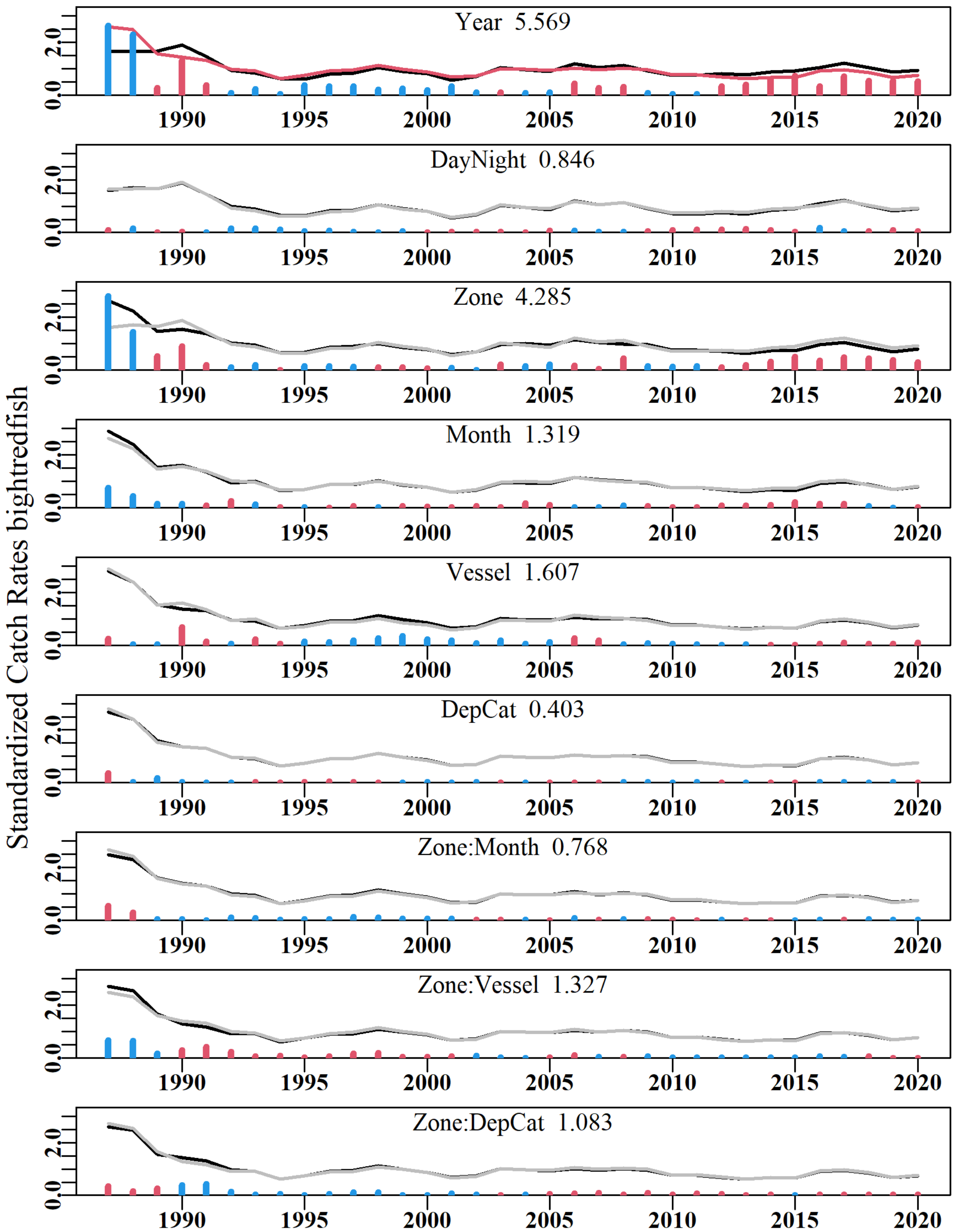

Figure 6.224. bightredfish. The influence of each factor on the optimal standardization. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by vertical bars with blue bars indicating the optimum model is higher than the geometric 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.

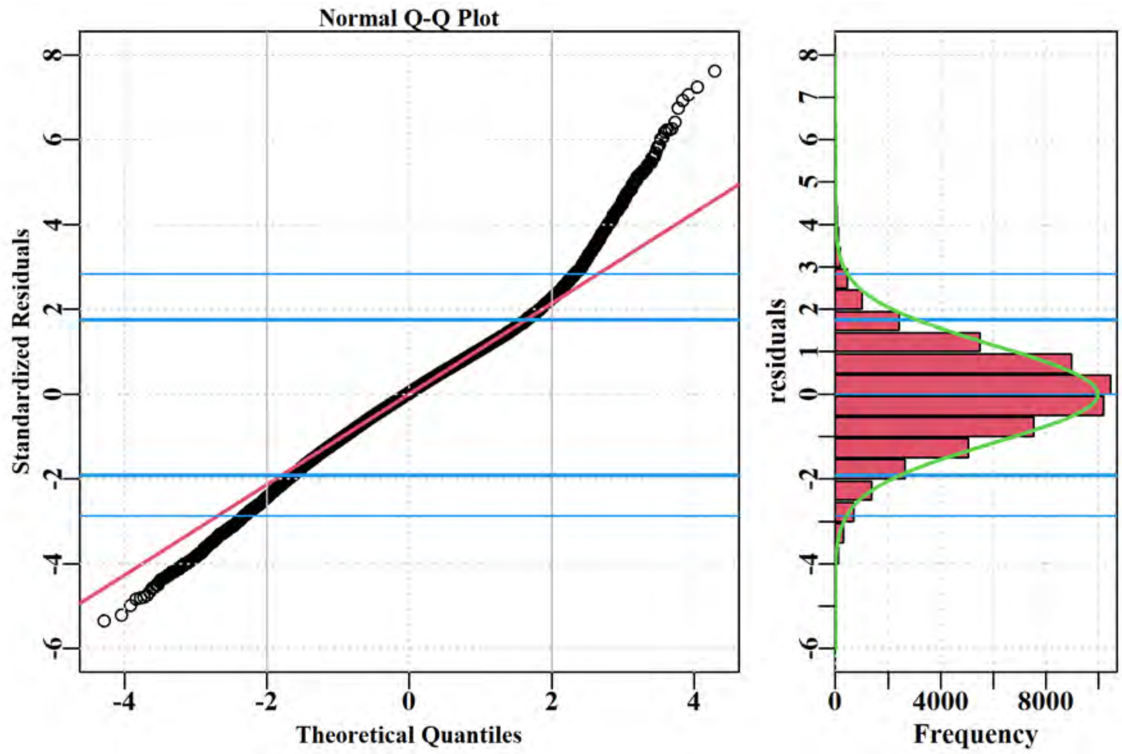

Figure 6.225. bightredfish. diagnostic plots. The distribution of residuals from the optimum fit. The qqplot indicates the fit to the expected normality, while the histogram of residuals illustrates the 90% quantiles to indicate the intensity of any lack of fit at the margins of the distribution.

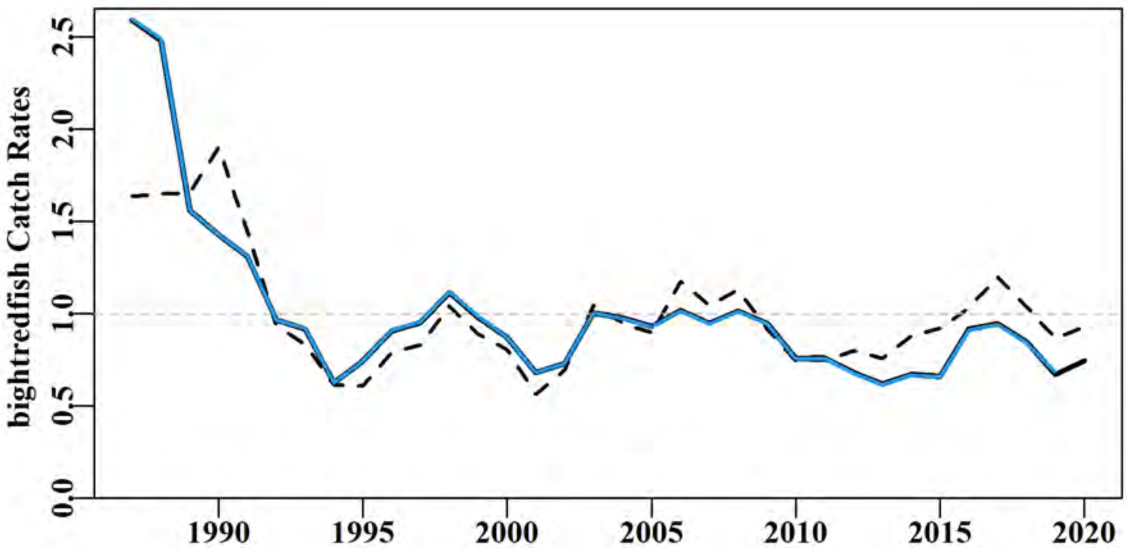

Figure 6.226. bightredfish. A comparison of the previous year's standardization (blue line) with this year's. They should lie on top of each other, although small deviations may relate to data adjustments, particularly in very recent years.

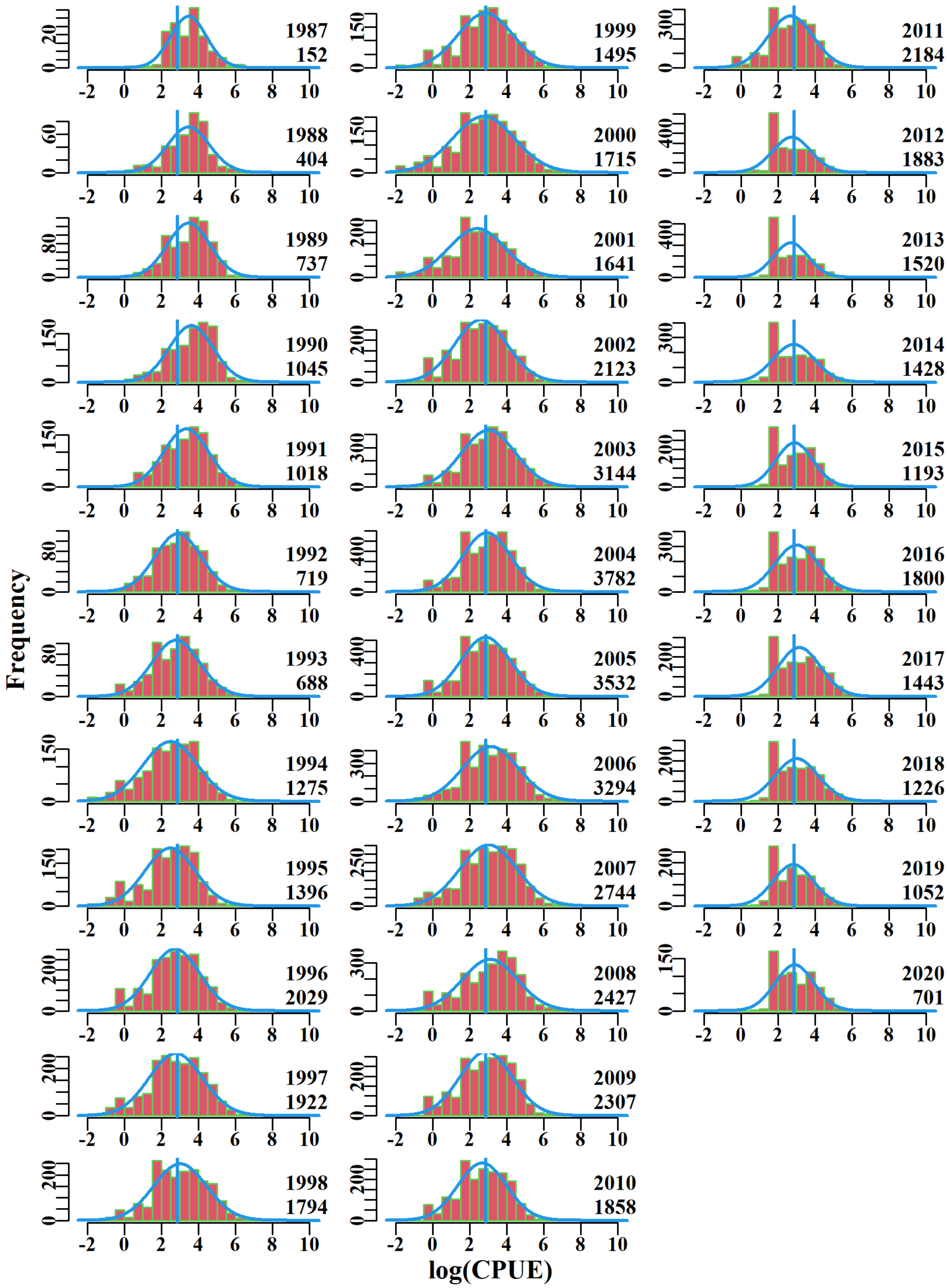

Figure 6.227. bightredfish. The natural log(CPUE) for each year of data available the blue lines are normal distributions fitted to the histogram frequencies. The numbers in each plot are the year and number of records.

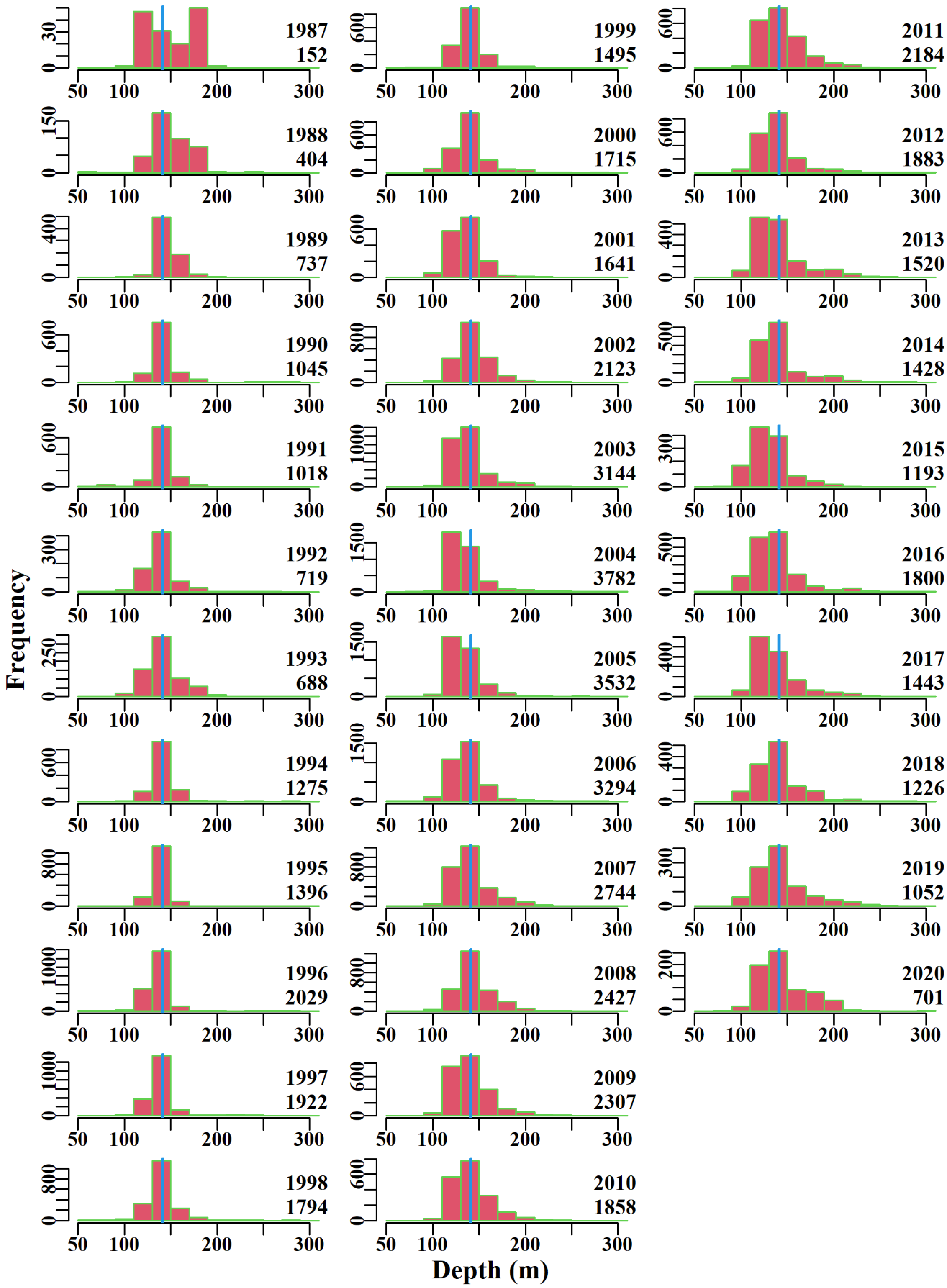

Figure 6.228. bightredfish. The average Depth of fishing for each year of data available to illustrate the development of the fishery through time. The numbers in each plot are the year and number of records.

6.36 Ribaldo 10-50

Initial data selection for Ribaldo (RBD – 37224002 – *Mora moro*) in the SET was conducted according to the details given in Table 6.160.

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.

6.36.1 *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, Month and interaction term Zone:Month had the greatest contribution to model fit, based on the AIC and R^2 statistics (Table 6.164). The qqplot suggests a departure from the assumed Normal distribution as depicted by the tails of the distribution (Figure 6.232).

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 6.229).

6.36.2 *Action Items and Issues*

It is recommended that the geographical distribution of catches be explored to determine the representativeness of the entire stock's distribution during the early years. It is also recommended that alternate statistical distributions be considered.

Table 6.160. 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, OTB, TMO
years	1986 - 2020

Table 6.161. 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

Year	Total	N	Catch	Vess	GeoM	Opt	StDev	C<30Kg	P<30Kg
1986	4.1	72	3.5	11	24.3	2.1908	0.000	0.655	0.186
1987	7.9	158	7.3	14	16.5	1.3175	0.140	1.509	0.207
1988	10.9	122	7.9	22	25.7	2.1028	0.156	0.855	0.108
1989	11.3	136	7.7	14	30.2	1.9184	0.154	1.114	0.144
1990	3.7	58	2.3	11	14.0	1.5183	0.175	0.648	0.287
1991	7.8	145	5.2	22	11.9	1.4979	0.153	1.697	0.329
1992	13.3	226	11.7	26	16.1	1.4811	0.144	1.982	0.170
1993	22.8	330	19.8	37	18.8	1.2511	0.144	3.424	0.173
1994	41.9	423	23.6	30	18.5	1.3591	0.142	4.945	0.209
1995	90.3	1139	85.9	26	18.9	1.4918	0.138	10.299	0.120
1996	82.3	1483	76.6	32	15.0	1.1365	0.138	14.889	0.194
1997	103.1	1708	96.2	30	14.0	0.9789	0.137	16.008	0.166
1998	100.0	1666	91.9	33	13.6	0.9288	0.137	16.781	0.183
1999	72.1	1132	59.7	32	12.6	0.8406	0.138	13.618	0.228
2000	66.8	1173	53.8	42	10.5	0.7685	0.138	12.935	0.240
2001	82.5	1129	52.6	37	9.9	0.7118	0.138	12.191	0.232
2002	157.8	1139	57.0	30	10.0	0.6545	0.138	11.246	0.197
2003	180.8	1302	65.6	35	10.0	0.6285	0.138	12.107	0.184
2004	181.1	1253	66.1	33	11.1	0.6841	0.138	7.617	0.115
2005	90.4	649	28.4	32	9.5	0.6081	0.140	3.891	0.137
2006	122.6	619	31.2	34	11.5	0.6320	0.140	3.234	0.104
2007	78.3	398	15.3	24	8.6	0.4566	0.143	2.556	0.167
2008	78.5	356	16.9	24	9.9	0.6010	0.144	2.272	0.134
2009	105.0	554	31.9	20	11.9	0.6675	0.141	3.169	0.099
2010	91.9	672	36.6	22	11.6	0.6989	0.140	5.060	0.138
2011	93.9	849	44.1	20	9.9	0.7006	0.139	4.554	0.103
2012	107.2	707	39.8	19	11.7	0.6952	0.140	3.542	0.089
2013	122.7	916	68.4	23	14.5	0.8475	0.139	3.885	0.057
2014	138.2	855	59.9	22	12.5	0.8144	0.139	4.387	0.073
2015	99.8	743	50.8	25	13.3	0.8143	0.140	3.530	0.070
2016	66.6	599	40.2	20	12.6	0.7240	0.141	3.272	0.081
2017	80.9	596	42.1	18	15.1	0.7902	0.141	2.719	0.065
2018	94.0	627	43.7	17	14.1	0.7438	0.141	3.181	0.073
2019	122.3	731	66.2	21	17.0	0.9070	0.140	3.372	0.051
2020	135.9	663	51.6	19	15.0	0.8380	0.140	3.090	0.060

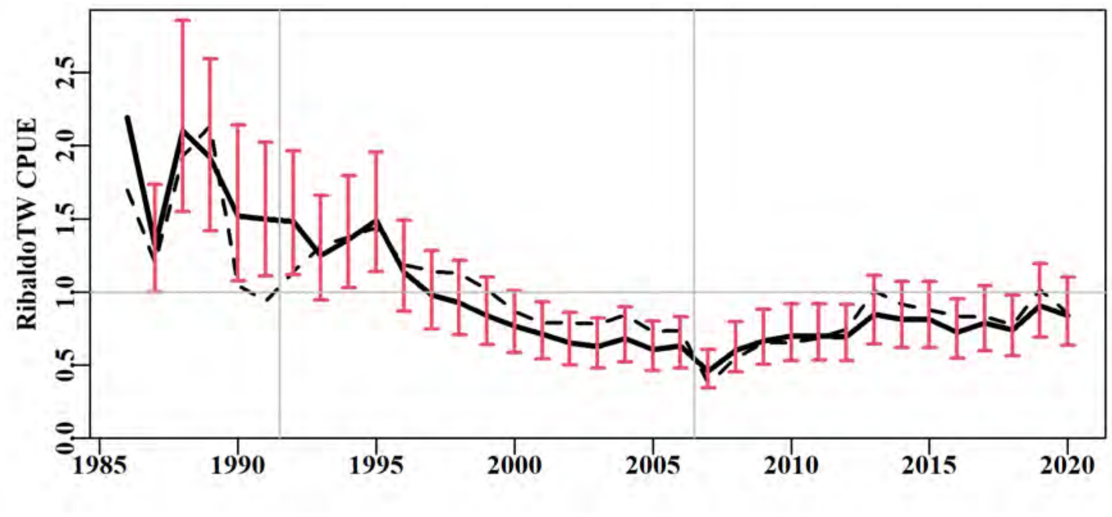

Figure 6.229. RibaldoTW standardization. The dashed black line represents the geometric mean CPUE, solid black line the standardized CPUE. The red bars are the 95% confidence intervals about the mean estimates. The graph scales both time-series of standardized CPUE relative to the mean of each time-series.

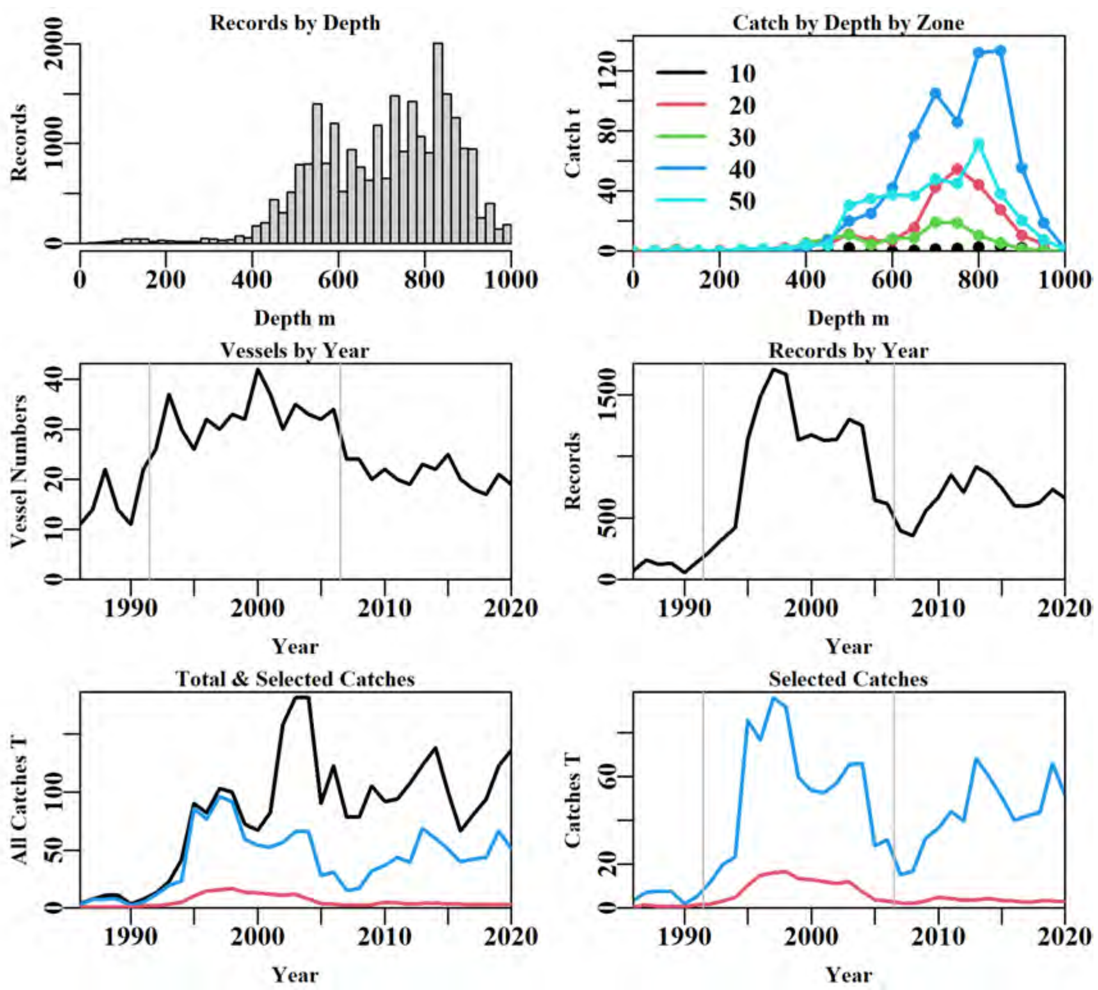

Figure 6.230. RibaldoTW fishery details. The bottom left plot depicts all known catches (top black line), and all selected catches used in the analysis (middle blue line); the lower red line: selected catches < 30 kg).

Table 6.162. 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	38044	29846	28827	28579	26276	25338	25328
Difference	0	8198	1019	248	2303	938	10
Catch	2899	1871	1821	1790	1598	1462	1461
Difference	0	1028	51	30	192	136	1

Table 6.163. 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 6.164. 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

Term	AIC	RSS	MSS	Nobs	Npars	adj_r2	%Change
Year	-542	24724	1681	25328	35	6.2	0
Vessel	-3066	22144	4260	25328	168	15.6	9.34
DepCat	-6645	19196	7209	25328	188	26.8	11.18
Zone	-7294	18704	7700	25328	192	28.6	1.86
DayNight	-7432	18599	7806	25328	195	29.0	0.40
Month	-7504	18530	7875	25328	206	29.3	0.23
Zone:Month	-8079	18051	8354	25328	250	31.0	1.71
Zone:DepCat	-8027	18044	8361	25328	281	30.9	1.65

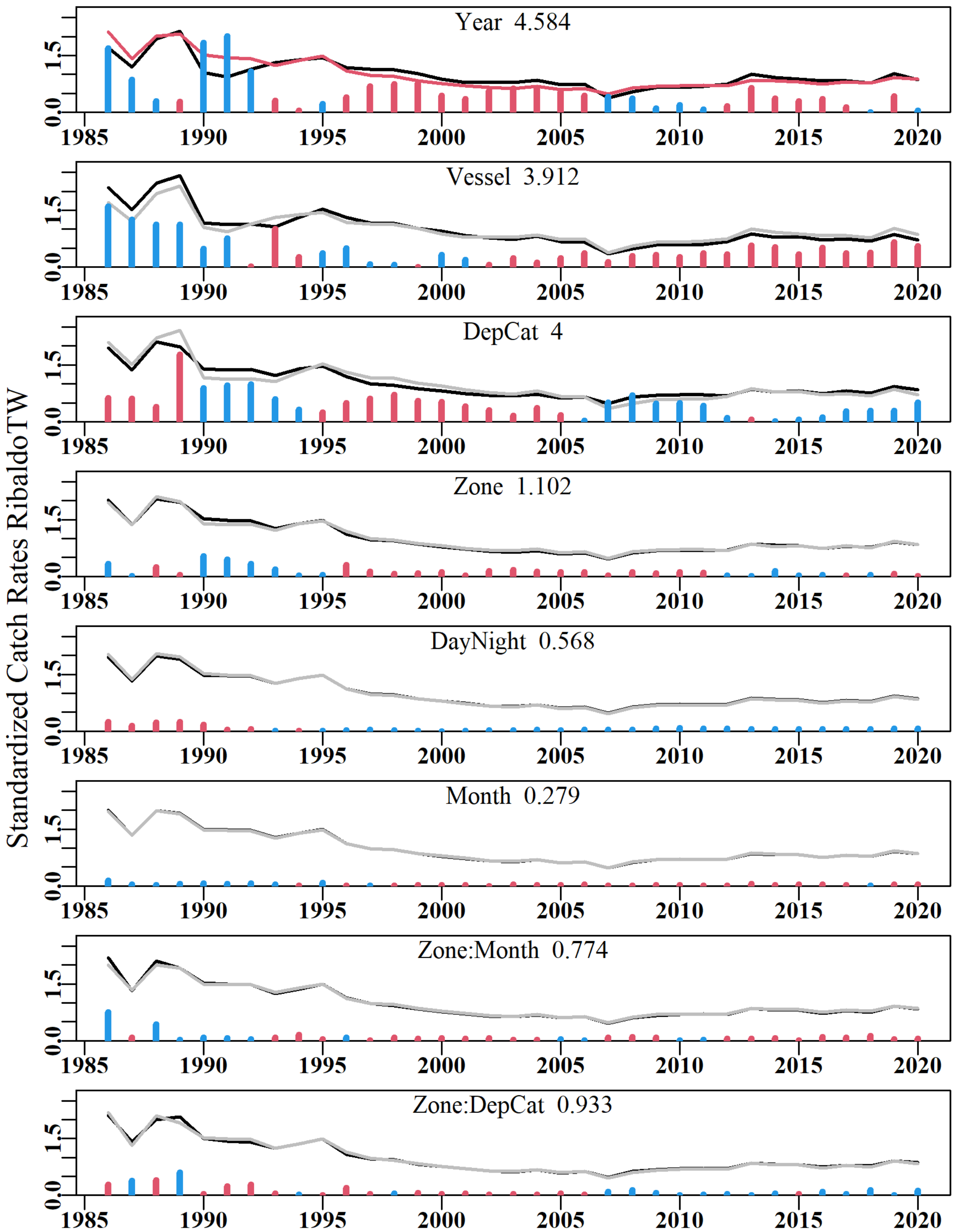

Figure 6.231. RibaldoTW. The influence of each factor on the optimal standardization. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by vertical bars with blue bars indicating the optimum model is higher than the geometric 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.

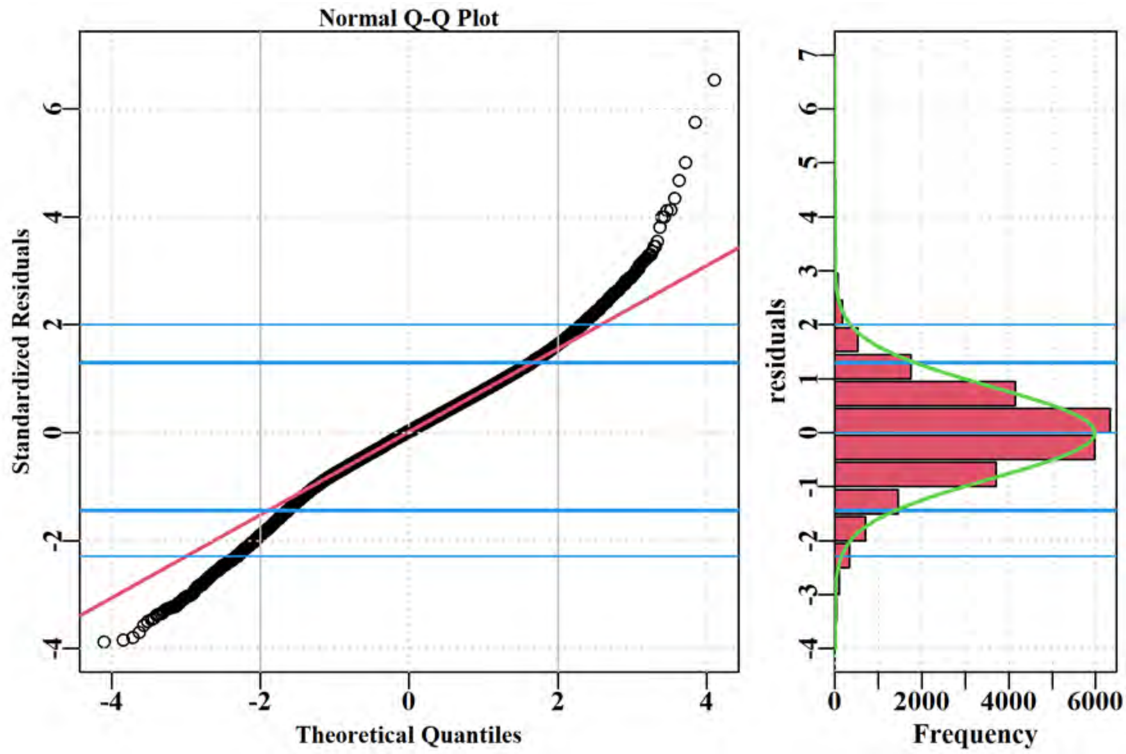

Figure 6.232. RibaldoTW. diagnostic plots. The distribution of residuals from the optimum fit. The qqplot indicates the fit to the expected normality, while the histogram of residuals illustrates the 90% quantiles to indicate the intensity of any lack of fit at the margins of the distribution.

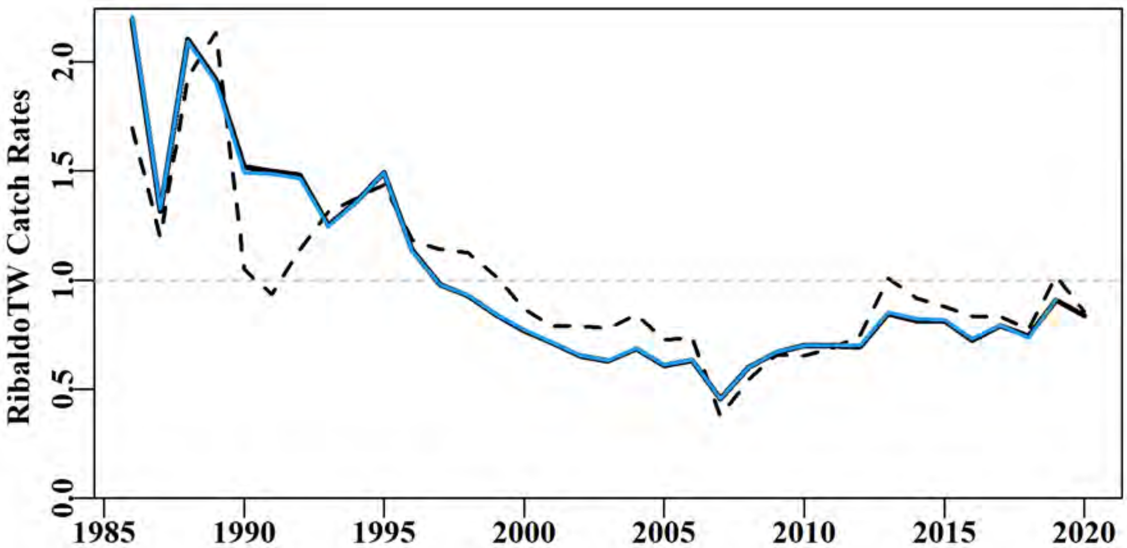

Figure 6.233. RibaldoTW. A comparison of the previous year's standardization (blue line) with this year's. They should lie on top of each other, although small deviations may relate to data adjustments, particularly in very recent years.

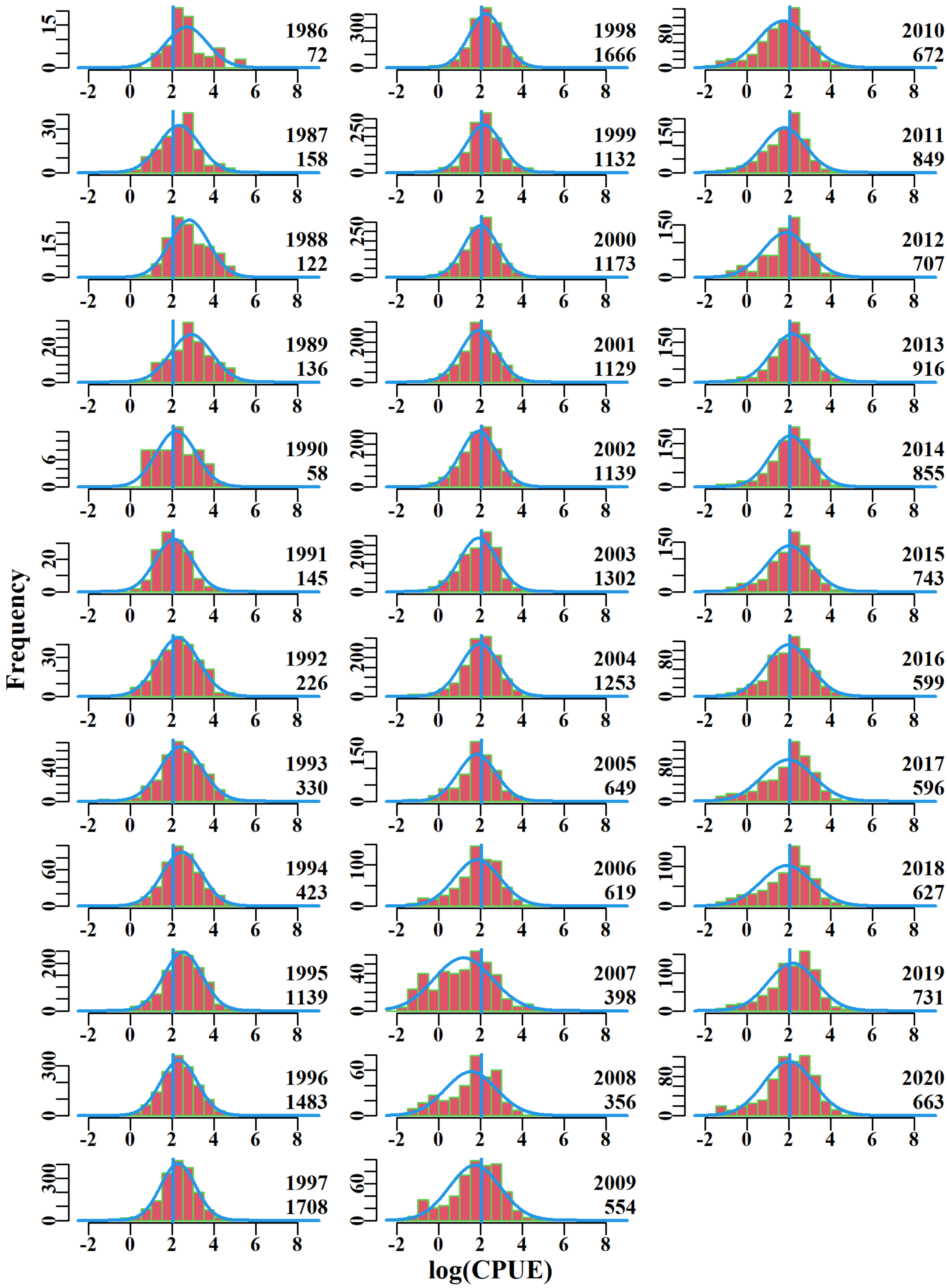

Figure 6.234. RibaldoTW. The natural log(CPUE) for each year of data available the blue lines are normal distributions fitted to the histogram frequencies. The numbers in each plot are the year and number of records.

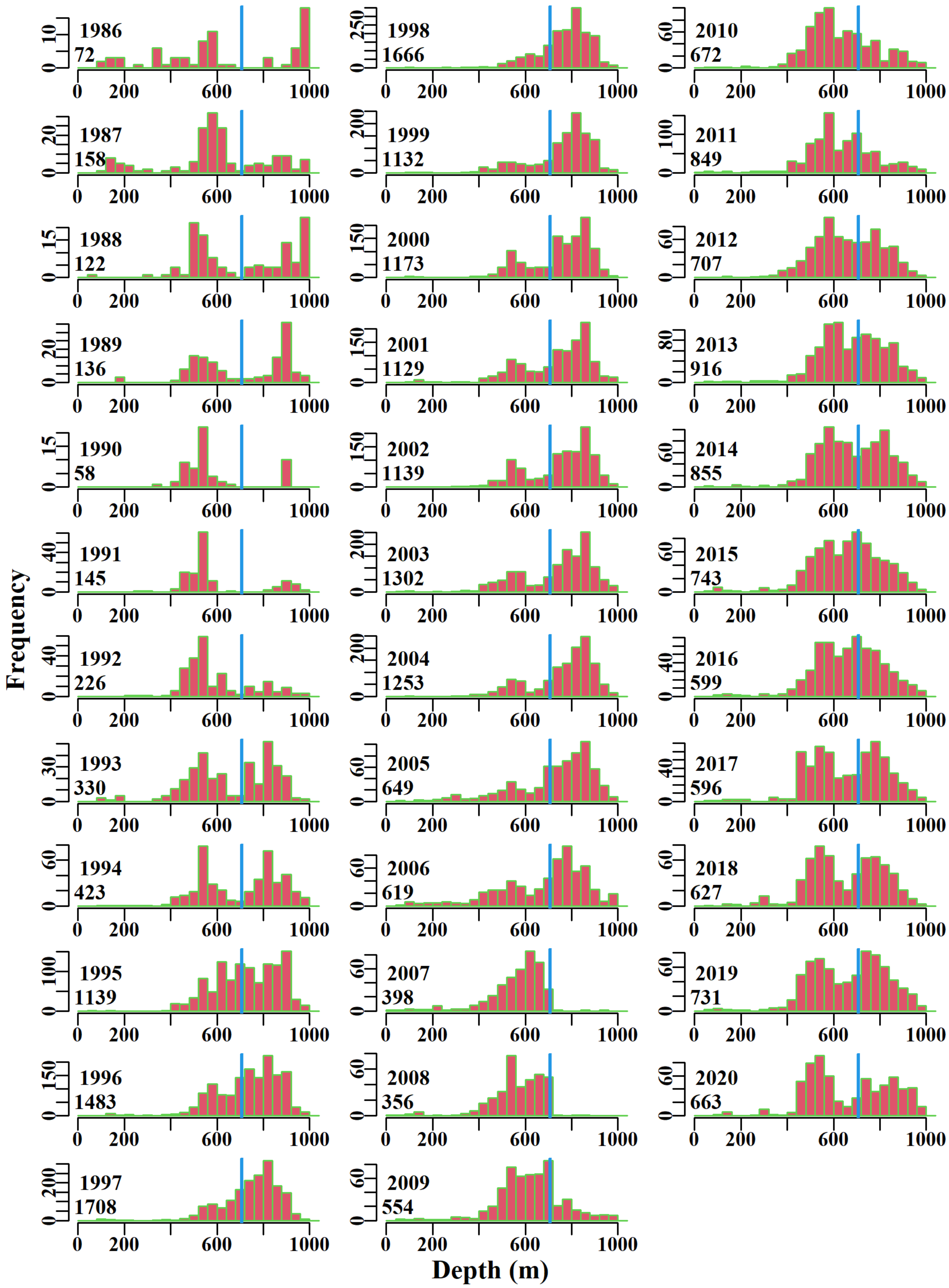

Figure 6.235. RibaldoTW. The average Depth of fishing for each year of data available to illustrate the development of the fishery through time. The numbers in each plot are the year and number of records.

6.37 RibaldoAL

Initial data selection for Ribaldo (RBD – 37224002 – *Mora moro*) in the SEN and GHT was conducted according to the detials given in Table 6.165.

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.

6.37.1 *Inferences*

Most of the catch occurred in zone 30, followed by zone 40, 20 and 50.

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 6.169). 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 6.239).

Annual standardized CPUE trend is noisy and relatively flat since about 2005 and mostly below average (Figure 6.236).

6.37.2 *Action Items and Issues*

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

Table 6.165. 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, ALL
years	2001 - 2020

Table 6.166. 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

Year	Total	N	Catch	Vess	GeoM	Opt	StDev	C<30Kg	P<30Kg
2001	82.5	61	15.5	1	276.7	1.0797	0.000	0.205	0.013
2002	157.8	177	87.0	3	620.4	1.7775	0.206	0.384	0.004
2003	180.8	221	95.5	6	539.8	1.7636	0.199	0.785	0.008
2004	181.1	604	92.2	10	143.7	1.8799	0.188	4.580	0.050
2005	90.4	258	34.4	6	138.7	1.1883	0.193	1.973	0.057
2006	122.6	605	65.4	8	123.5	1.2763	0.184	3.488	0.053
2007	78.3	386	27.8	6	73.2	0.7715	0.187	2.580	0.093
2008	78.5	401	56.8	6	168.8	0.9211	0.185	2.130	0.038
2009	105.0	432	68.3	6	218.5	0.8702	0.183	2.266	0.033
2010	91.9	381	51.7	5	175.7	0.8263	0.185	1.811	0.035
2011	93.9	354	46.3	5	163.8	0.9945	0.186	1.871	0.040
2012	107.2	293	58.4	6	282.2	0.8827	0.188	1.228	0.021
2013	122.7	275	49.8	5	241.2	0.7085	0.189	1.143	0.023
2014	138.2	265	66.0	4	506.8	0.7483	0.190	0.853	0.013
2015	99.8	196	35.0	3	270.3	0.6822	0.194	0.865	0.025
2016	66.6	238	23.2	3	129.5	0.4563	0.192	1.365	0.059
2017	80.9	295	36.8	3	150.3	0.6089	0.188	1.459	0.040
2018	94.0	291	47.6	3	220.2	0.7656	0.189	1.309	0.028
2019	122.3	295	45.9	2	218.1	0.7373	0.189	1.266	0.028
2020	135.9	363	77.5	2	337.6	1.0610	0.185	1.324	0.017

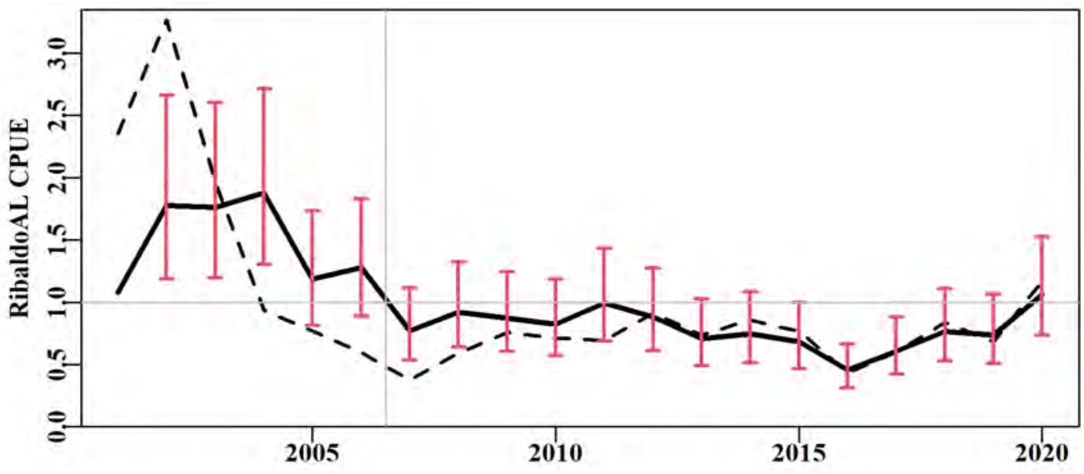

Figure 6.236. RibaldoAL standardization. The dashed black line represents the geometric mean CPUE, solid black line the standardized CPUE. The red bars are the 95% confidence intervals about the mean estimates. The graph scales both time-series of standardized CPUE relative to the mean of each time-series.

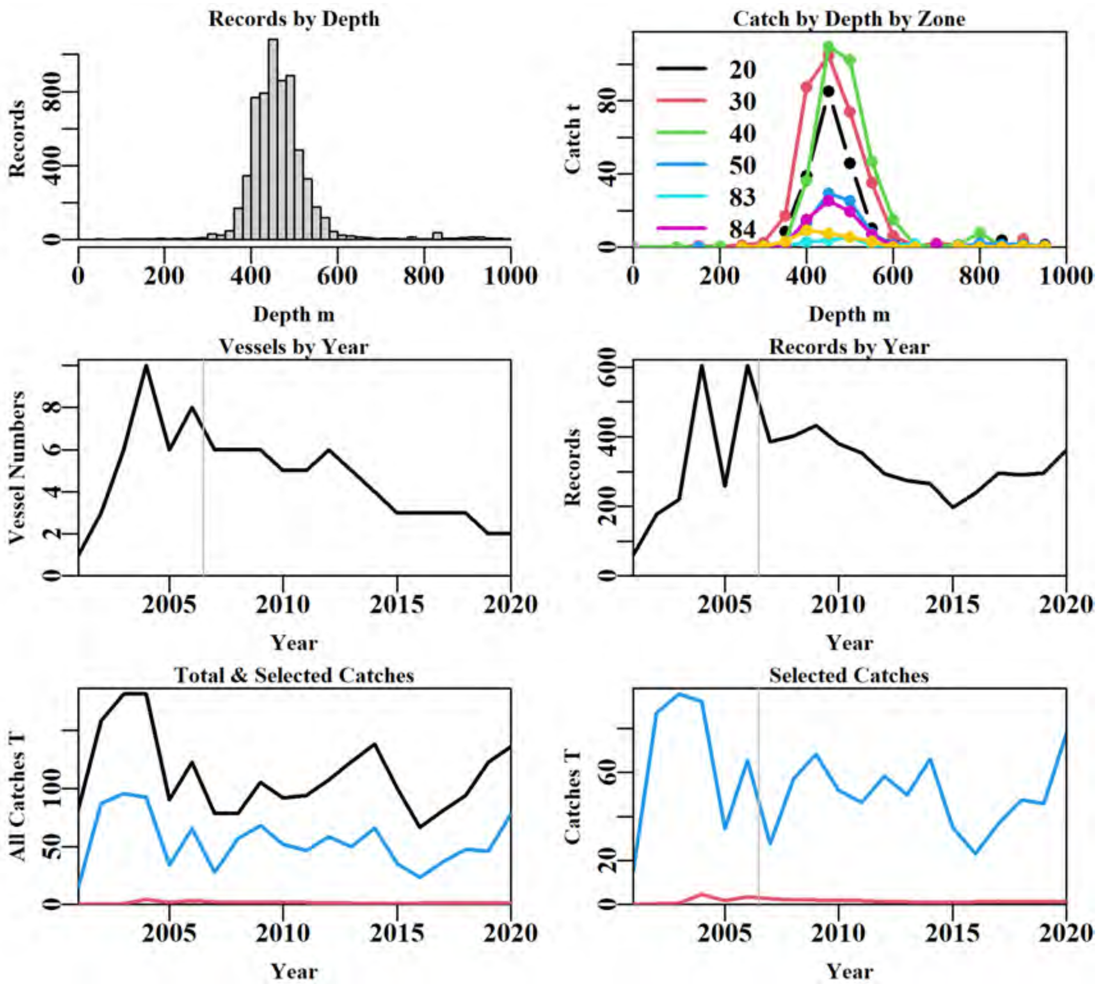

Figure 6.237. RibaldoAL fishery details. The bottom left plot depicts all known catches (top black line), and all selected catches used in the analysis (middle blue line); the lower red line: selected catches < 30 kg)

Table 6.167. 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	38044	37135	36049	24500	23430	6416	6391
Difference	0	909	1086	11549	1070	17014	25
Catch	2899	2899	2835	2186	2074	1084	1081
Difference	0	0	65	648	112	990	3

Table 6.168. 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 6.169. 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

Term	AIC	RSS	MSS	Nobs	Npars	adj_r2	%Change
Year	6285	16980	1115	6391	20	5.9	0
Vessel	4282	12361	5734	6391	33	31.3	25.47
DepCat	3749	11307	6787	6391	51	37.0	5.67
Zone	3525	10898	7196	6391	57	39.2	2.22
Month	3495	10810	7285	6391	68	39.6	0.39
Zone:Month	3342	10339	7756	6391	134	41.6	2.02
Zone:DepCat	3467	10533	7562	6391	137	40.5	0.90

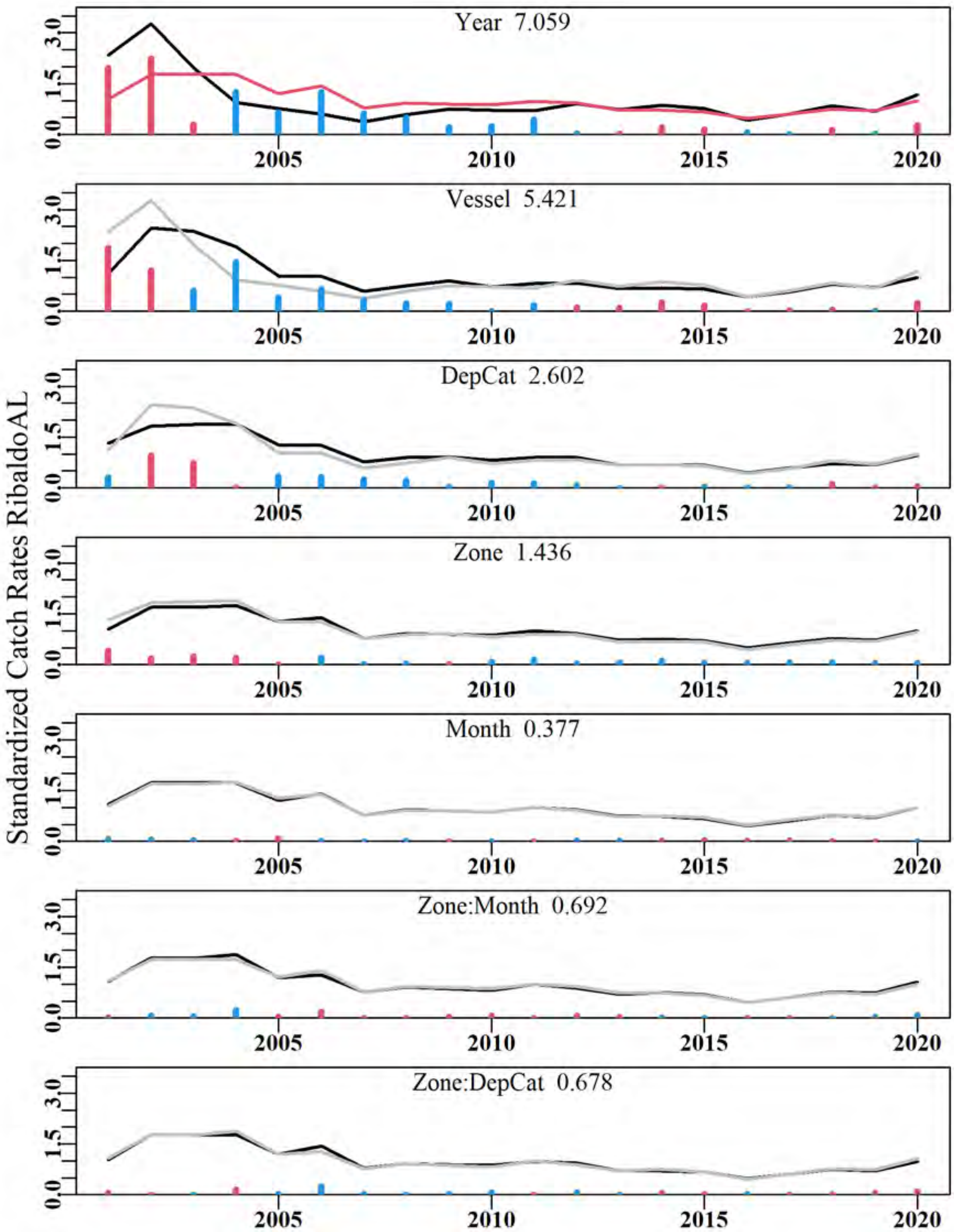

Figure 6.238. RibaldoAL. The influence of each factor on the optimal standardization. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by vertical bars with blue bars indicating the optimum model is higher than the geometric 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.

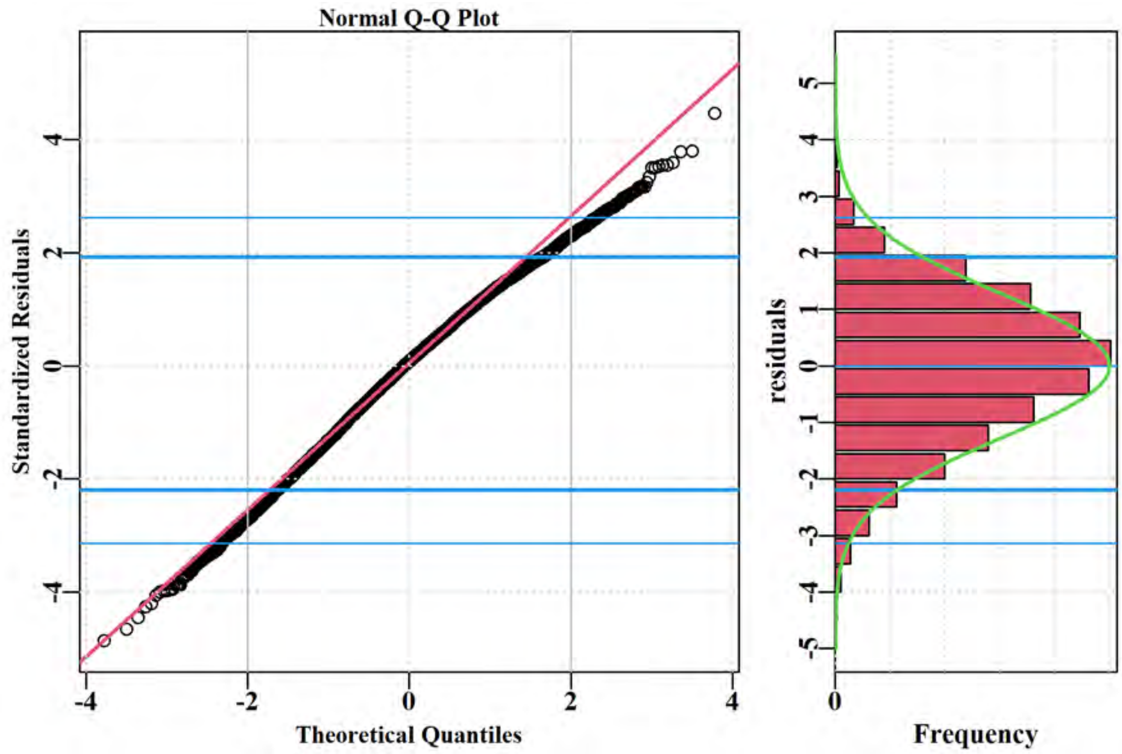

Figure 6.239. RibaldoAL. diagnostic plots. The distribution of residuals from the optimum fit. The qqplot indicates the fit to the expected normality, while the histogram of residuals illustrates the 90% quantiles to indicate the intensity of any lack of fit at the margins of the distribution.

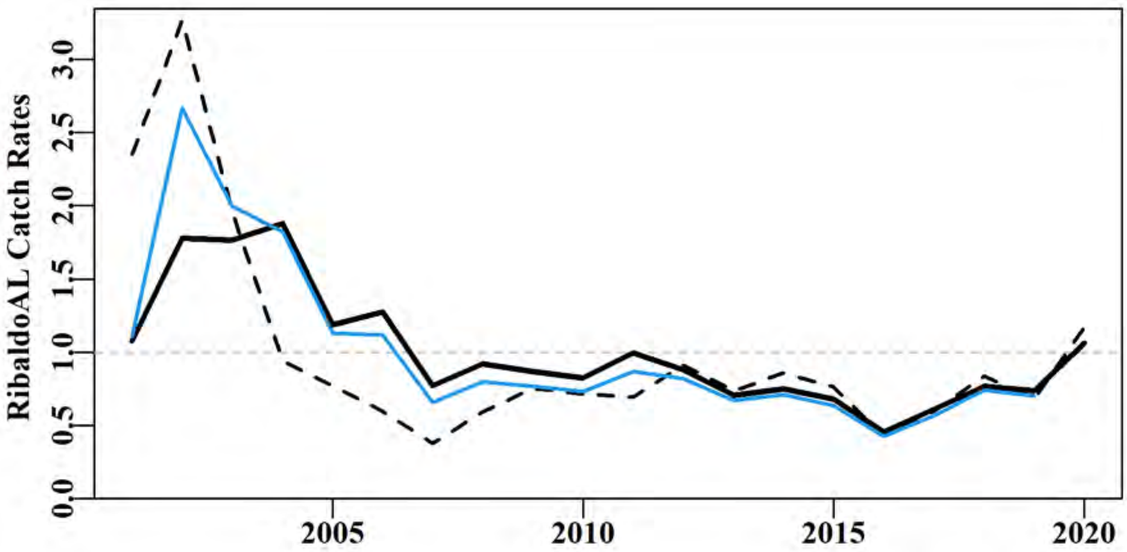

Figure 6.240. RibaldoAL. A comparison of the previous year's standardization (blue line) with this year's. They should lie on top of each other, although small deviations may relate to data adjustments, particularly in very recent years.

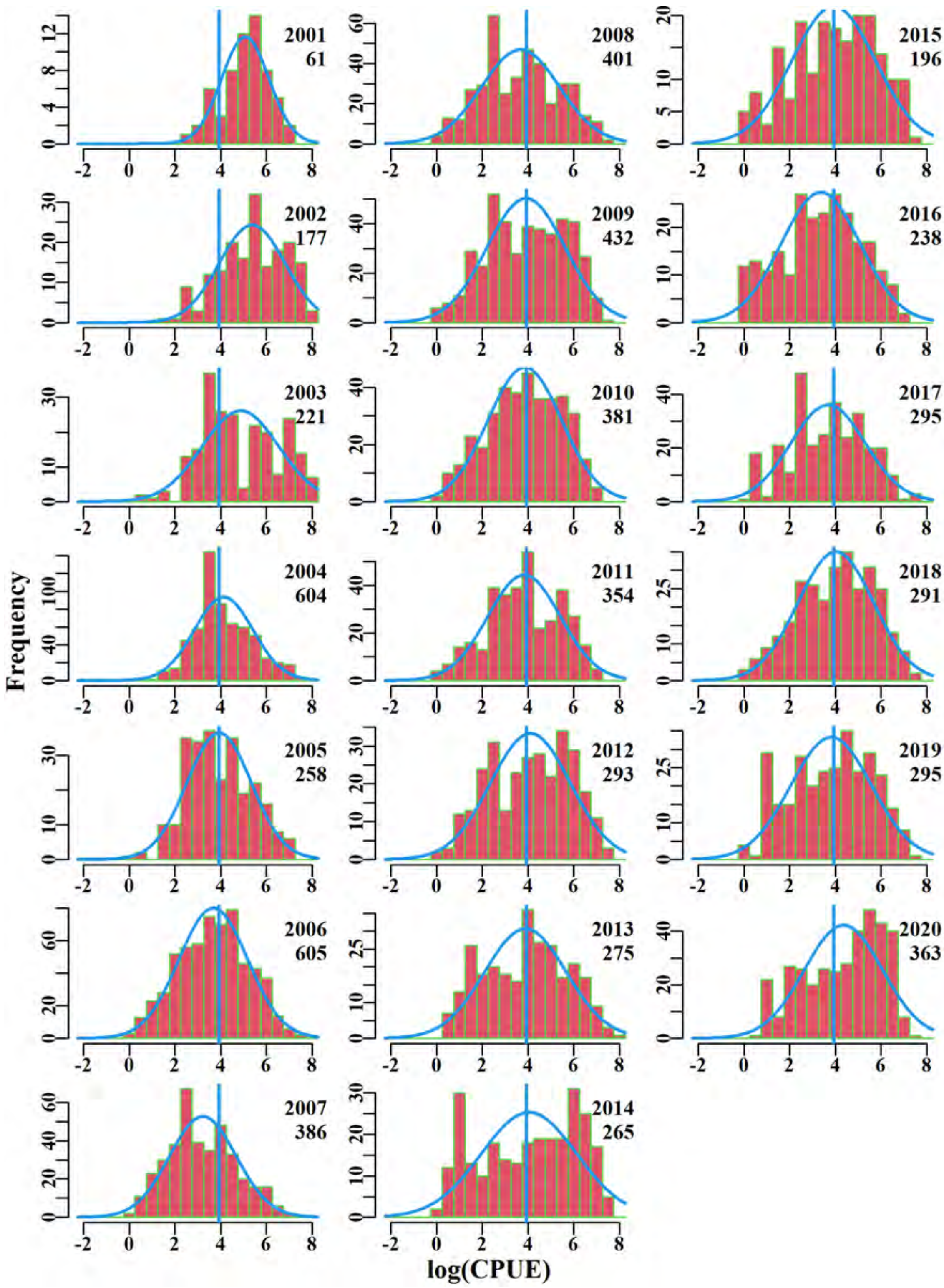

Figure 6.241. RibaldoAL. The natural log(CPUE) for each year of data available the blue lines are normal distributions fitted to the histogram frequencies. The numbers in each plot are the year and number of records.

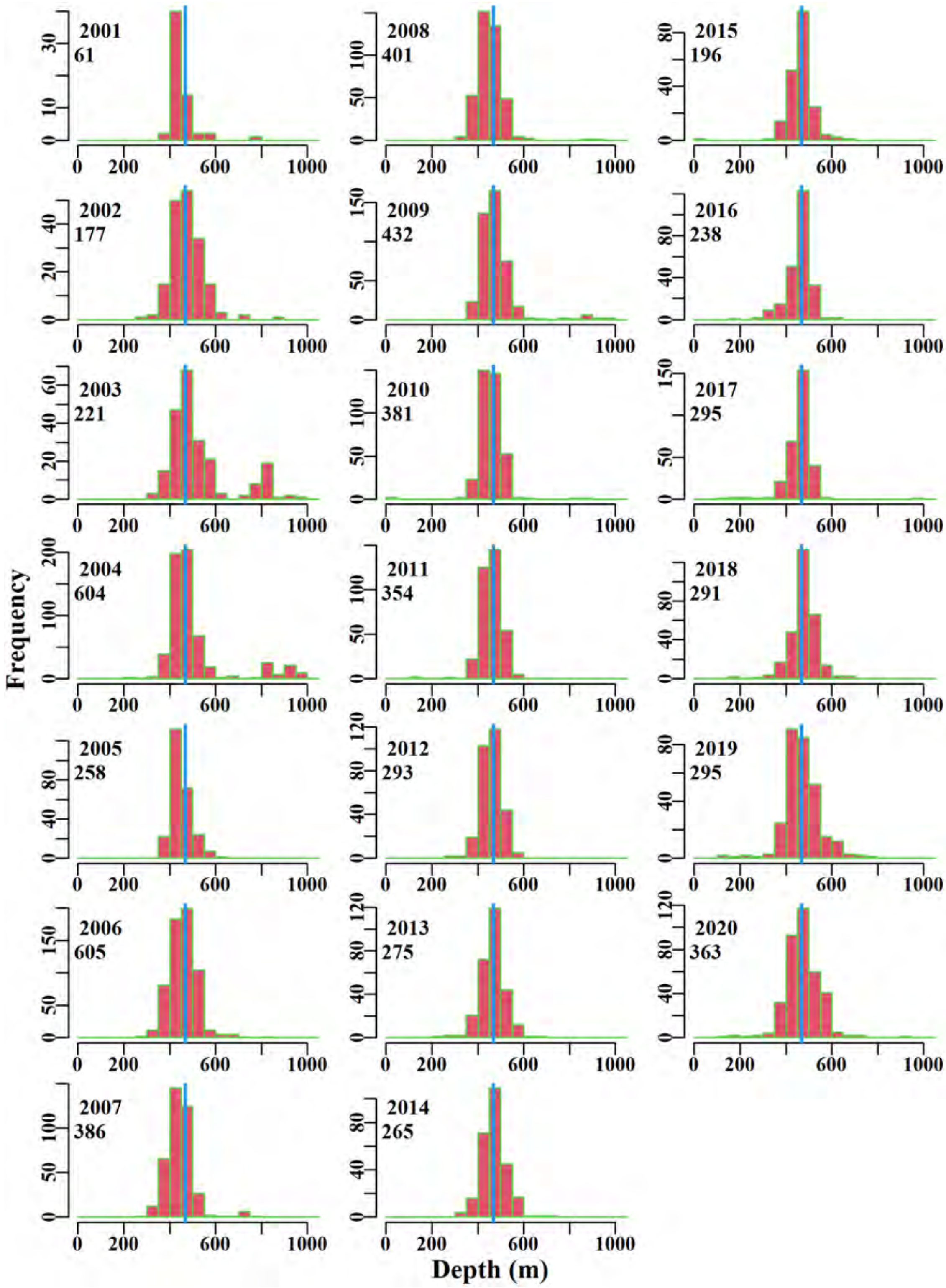

Figure 6.242. RibaldoAL. The average Depth of fishing for each year of data available to illustrate the development of the fishery through time. The numbers in each plot are the year and number of records.

6.38 Silver Trevally 10 20

Initial data selection for Silver Trevally (TRE – 37337062 – *Pseudocaranx dentex*) in the SET was conducted according to the details given in Table 6.170.

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.

6.38.1 *Inferences*

Most of the catch 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 6.174). The qqplot suggests that the assumed Normal distribution is valid with a slight departure as depicted at the lower tail of the distribution (Figure 6.246).

Annual standardized CPUE trend is noisy and relatively flat since about 1992 and has remained below average since 2012 (Figure 6.243). There was an increase in CPUE in 2020 relative to the previous year. 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 CPUE. Seven vessels operated in 2019 contributing to a total of only 1.9 t, the lowest in the series.

6.38.2 *Actin 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 6.170. 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, OTB
years	1986 - 2020

Table 6.171. 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

Year	Total	N	Catch	Vess	GeoM	Opt	StDev	C<30Kg	P<30Kg
1986	469.5	1976	306.3	74	49.4	1.1387	0.000	14.045	0.046
1987	198.5	1253	133.7	64	43.6	1.3294	0.057	9.101	0.068
1988	278.5	1581	244.0	56	51.4	1.5389	0.052	12.112	0.050
1989	376.2	2193	332.7	62	60.6	1.9610	0.048	13.682	0.041
1990	450.6	2082	344.4	53	59.7	2.2928	0.050	11.655	0.034
1991	340.7	2216	251.4	50	43.8	1.9926	0.050	14.239	0.057
1992	296.5	1692	249.2	45	40.8	1.2302	0.053	11.785	0.047
1993	377.7	2265	281.1	49	42.6	1.2372	0.050	16.104	0.057
1994	392.9	3283	360.1	48	38.8	1.0490	0.047	24.712	0.069
1995	413.4	3347	383.2	48	44.6	1.1826	0.046	25.171	0.066
1996	340.6	3208	315.3	53	39.8	1.0704	0.047	24.514	0.078
1997	328.8	2815	292.9	56	53.7	1.0440	0.048	19.728	0.067
1998	210.1	2287	177.6	46	39.0	0.7986	0.049	17.833	0.100
1999	166.1	1859	114.5	45	31.9	0.7821	0.052	13.541	0.118
2000	154.8	2011	122.9	49	26.3	0.6053	0.051	14.723	0.120
2001	270.2	3255	229.0	45	36.3	0.7340	0.046	21.930	0.096
2002	232.8	2776	209.6	44	38.3	0.6894	0.048	17.710	0.085
2003	337.9	2732	277.9	49	59.7	0.7359	0.048	16.611	0.060
2004	458.2	3316	365.1	45	64.3	0.9002	0.047	19.378	0.053
2005	291.1	2301	240.1	43	59.0	0.7820	0.050	13.644	0.057
2006	247.3	1684	209.0	39	82.8	0.8483	0.053	9.278	0.044
2007	172.7	832	115.4	22	89.2	0.8250	0.064	4.408	0.038
2008	128.4	1054	95.8	23	49.0	0.9546	0.060	6.864	0.072
2009	164.1	1142	135.3	23	57.8	0.9597	0.059	6.689	0.049
2010	240.2	1231	191.3	24	99.9	1.2194	0.058	6.212	0.032
2011	193.5	1103	175.3	20	112.9	1.0422	0.059	5.548	0.032
2012	139.7	954	129.0	21	99.1	0.8162	0.062	5.062	0.039
2013	122.8	720	112.9	19	97.4	0.8682	0.067	3.918	0.035
2014	107.0	887	97.8	20	62.4	0.6635	0.063	5.216	0.053
2015	79.5	570	73.1	22	69.7	0.6887	0.073	2.914	0.040
2016	52.4	388	49.5	18	109.4	0.8645	0.084	1.858	0.038
2017	52.9	399	45.0	15	77.7	0.7954	0.083	2.192	0.049
2018	37.7	207	30.0	14	119.9	0.6090	0.111	1.269	0.042
2019	3.8	43	1.9	7	22.7	0.1996	0.225	0.234	0.121
2020	39.4	118	22.8	12	263.1	0.5513	0.145	0.480	0.021

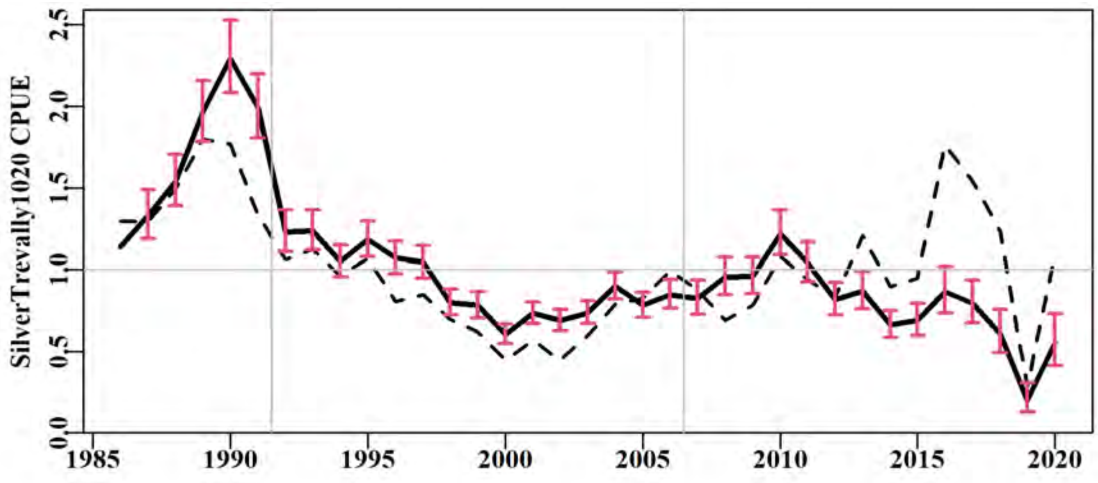

Figure 6.243. SilverTrevally1020 standardization. The dashed black line represents the geometric mean CPUE, solid black line the standardized CPUE. The red bars are the 95% confidence intervals about the mean estimates. The graph scales both time-series of standardized CPUE relative to the mean of each time-series.

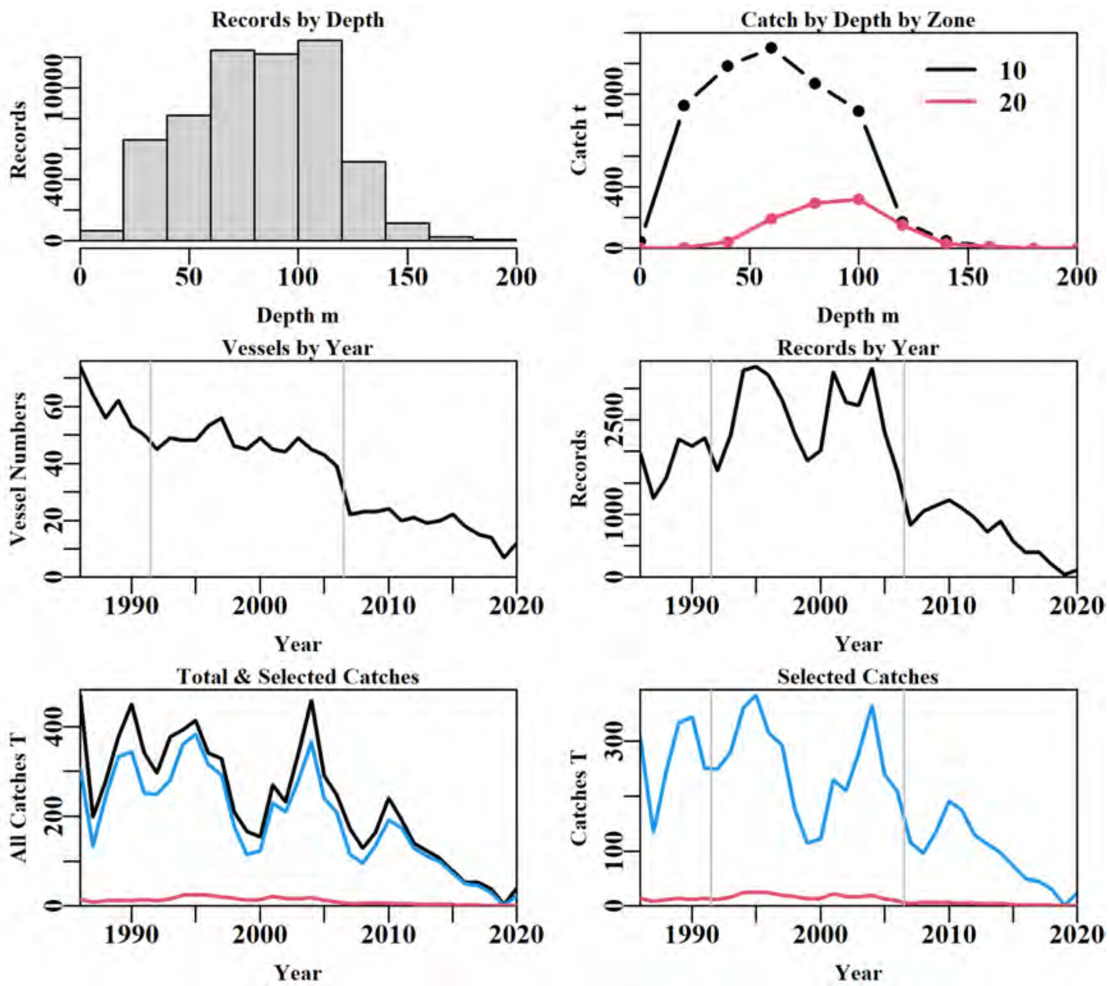

Figure 6.244. SilverTrevally1020 fishery details. The bottom left plot depicts all known catches (top black line), and all selected catches used in the analysis (middle blue line); the lower red line: selected catches < 30 kg).

Table 6.172. 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	76615	73414	71811	70924	61237	59836	59780
Difference	0	3201	1603	887	9687	1401	56
Catch	8326	8150	7862	7703	6761	6722	6715
Difference	0	176	288	159	941	39	7

Table 6.173. 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 6.174. 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

Term	AIC	RSS	MSS	Nobs	Npars	adj_r2	%Change
Year	62902	171011	8069	59780	35	4.5	0
Vessel	48907	134604	44476	59780	193	24.6	20.14
DepCat	45587	127290	51790	59780	203	28.7	4.09
Month	44861	125707	53373	59780	214	29.6	0.87
DayNight	44011	123918	55161	59780	217	30.6	1.00
Zone	43981	123853	55227	59780	218	30.6	0.04
Zone:Month	43841	123518	55562	59780	229	30.8	0.18
Zone:DepCat	43956	123764	55316	59780	227	30.6	0.04

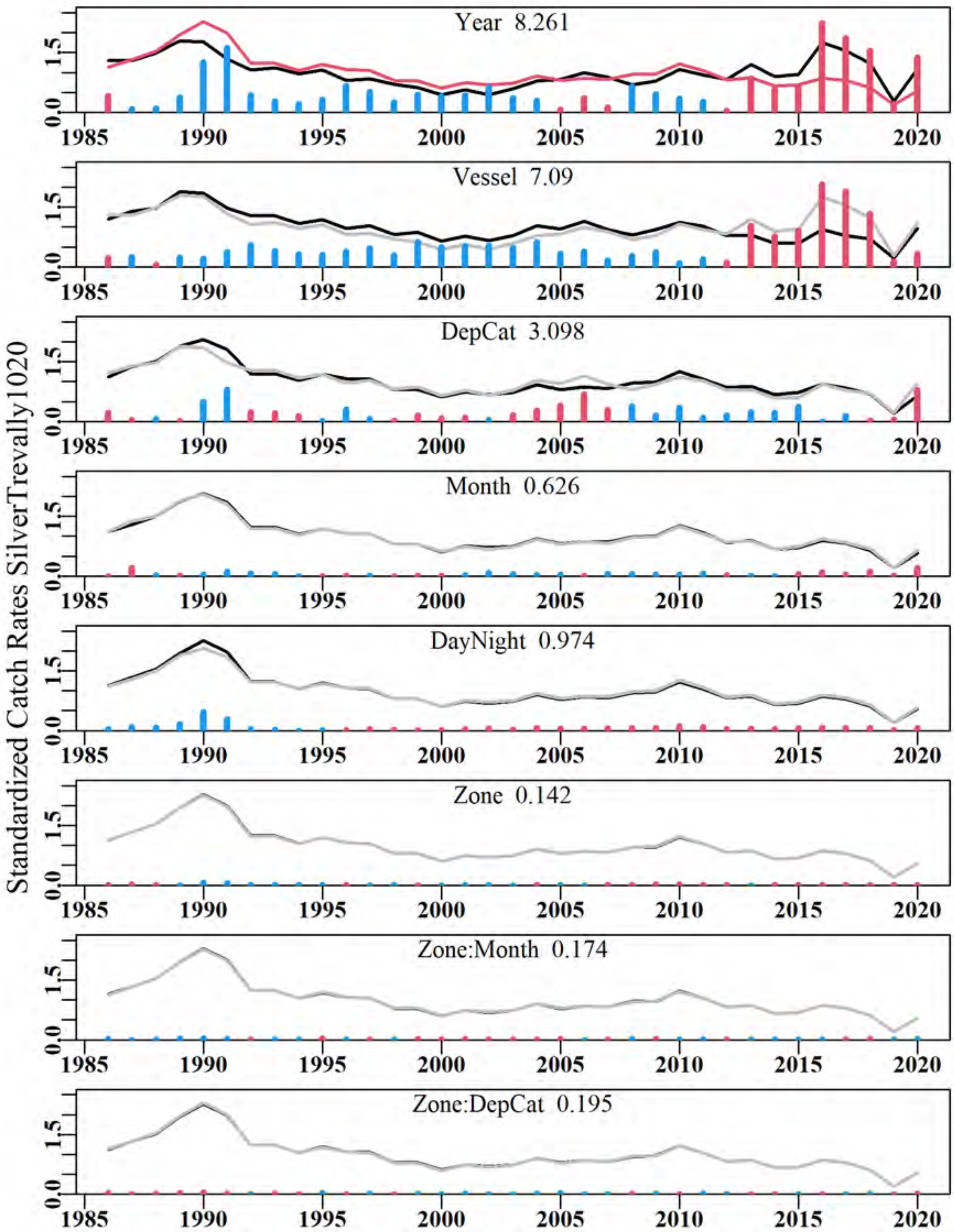

Figure 6.245. SilverTrevally1020. The influence of each factor on the optimal standardization. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by vertical bars with blue bars indicating the optimum model is higher than 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.

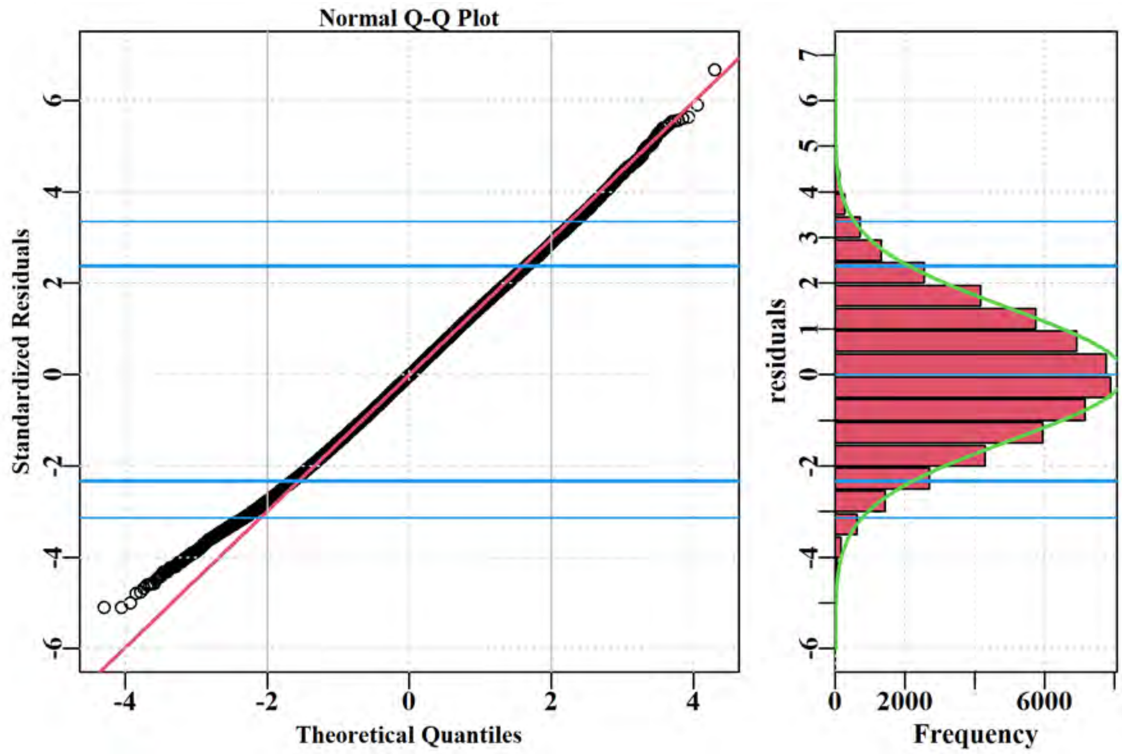

Figure 6.246. SilverTrevally1020. diagnostic plots. The distribution of residuals from the optimum fit. The qqplot indicates the fit to the expected normality, while the histogram of residuals illustrates the 90% quantiles to indicate the intensity of any lack of fit at the margins of the distribution.

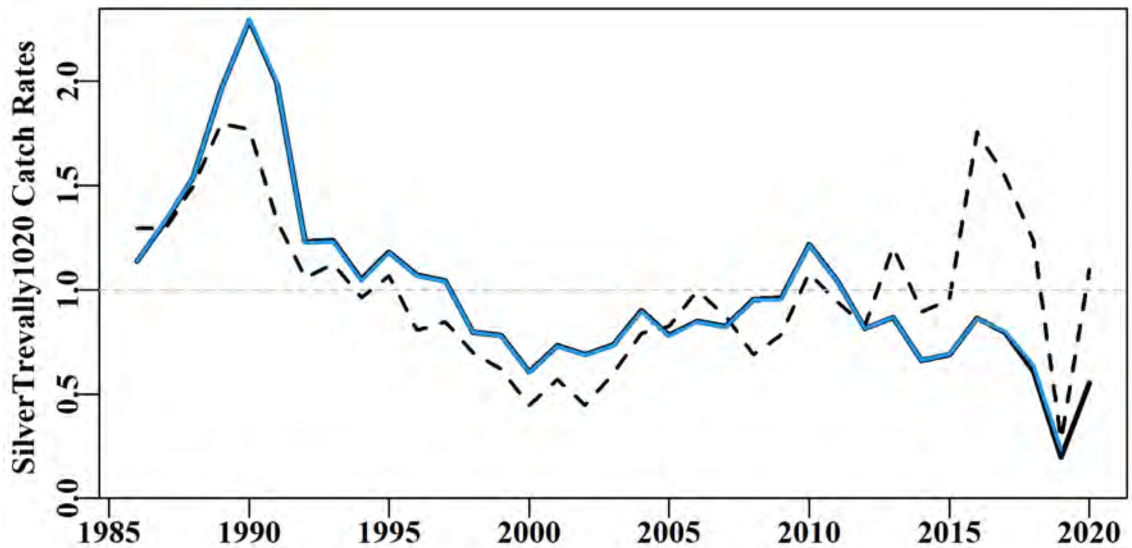

Figure 6.247. SilverTrevally1020. A comparison of the previous year's standardization (blue line) with this year's. They should lie on top of each other, although small deviations may relate to data adjustments, particularly in very recent years.

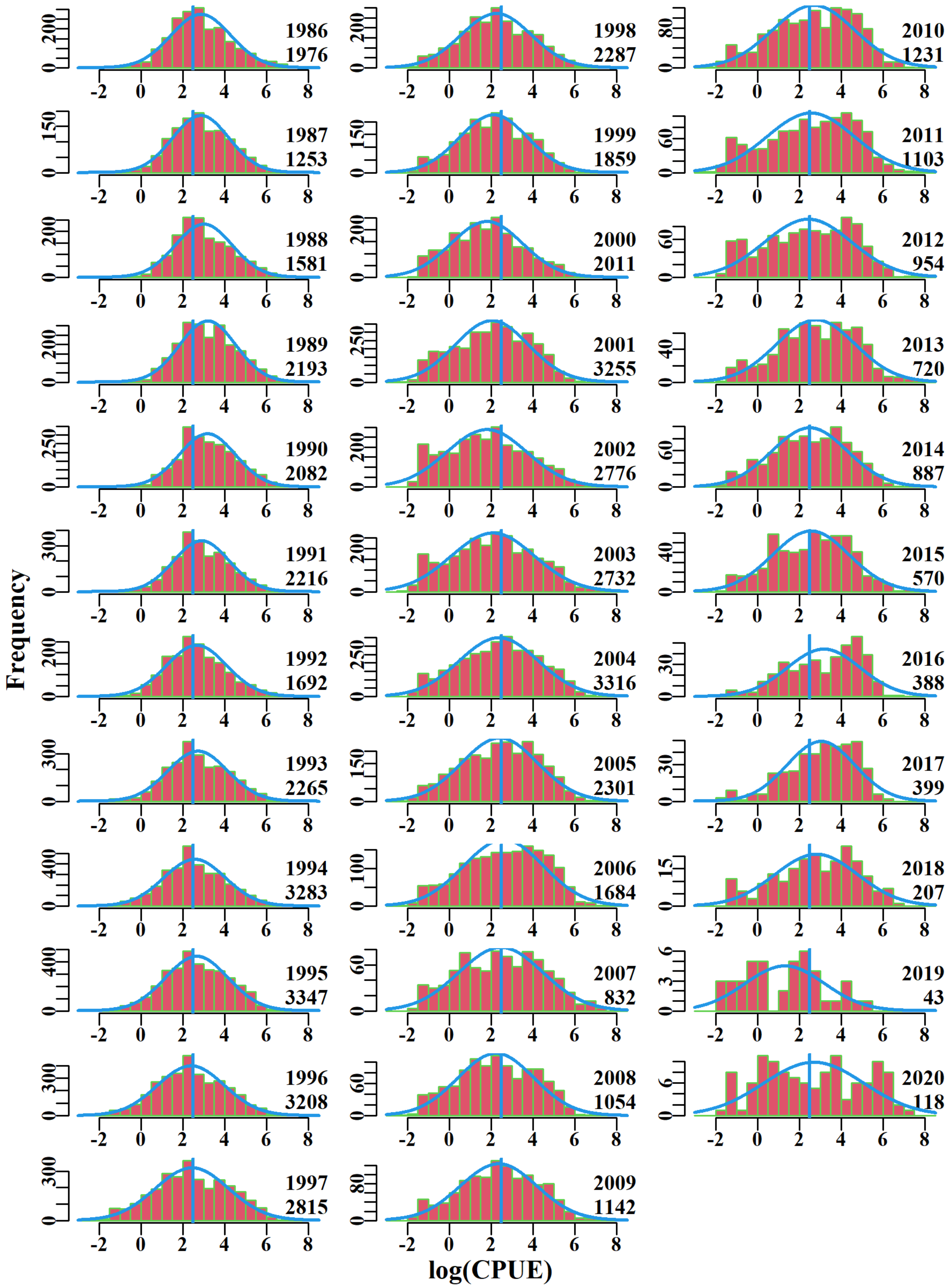

Figure 6.248. SilverTrevally1020. The natural log(CPUE) for each year of data available the blue lines are normal distributions fitted to the histogram frequencies. The numbers in each plot are the year and number of records.

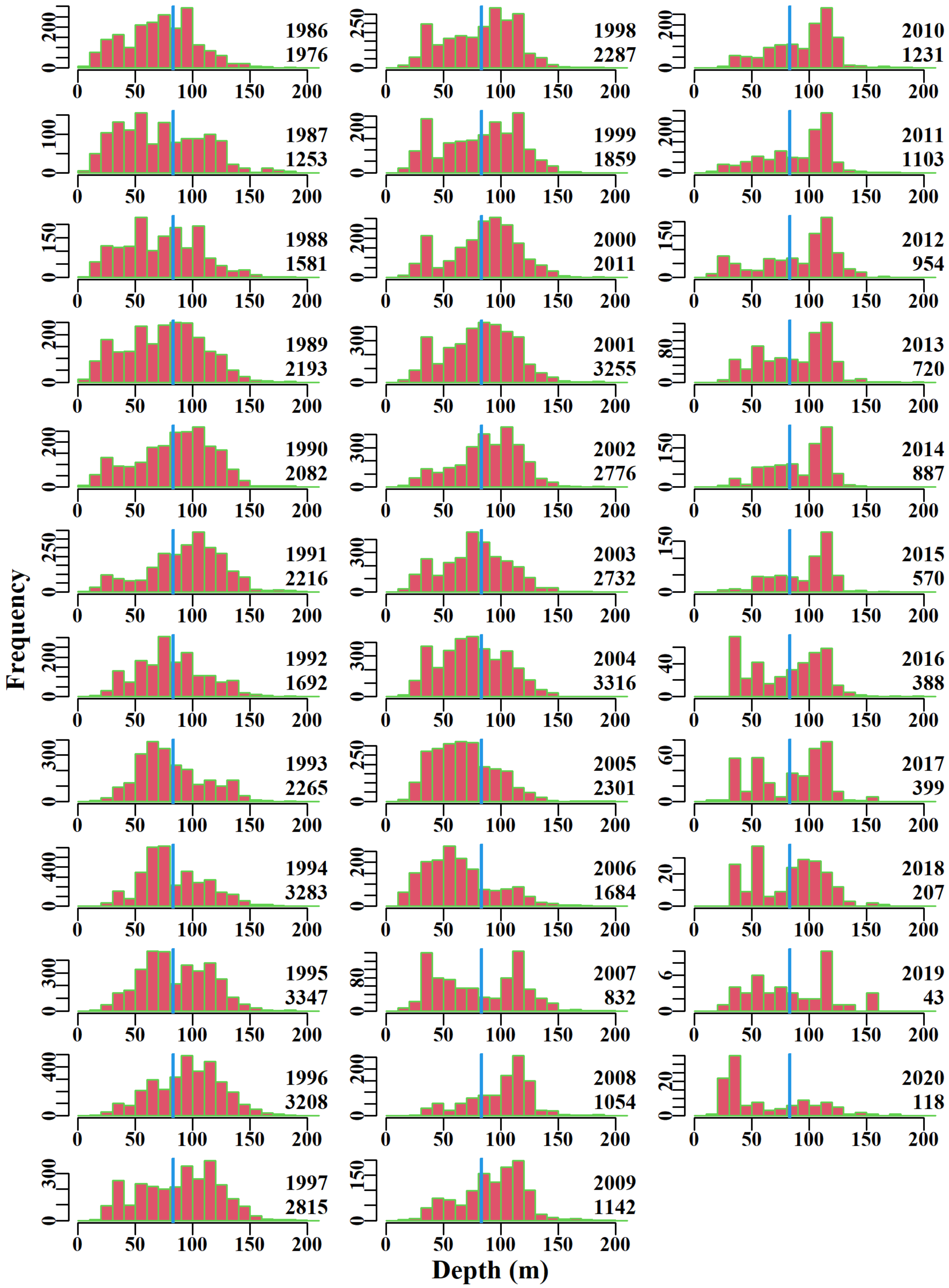

Figure 6.249. SilverTrevally1020. The average Depth of fishing for each year of data available to illustrate the development of the fishery through time. The numbers in each plot are the year and number of records.

6.39 Silver Trevally 10 20 – No MPA

Initial data selection for Silver Trevally (TRE - 37337062 - *Pseudocaranx dentex*) in the SET was conducted according to the details given in Table 6.175and 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.

6.39.1 *Inferences*

Most of the catch of this species occurred in zone 10, followed by 20.

The terms Year, Vessel, DepCat, Month 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. The qqplot suggests that the assumed Normal distribution is valid with a slight departure as depicted at the lower tail of the distribution (Figure 6.253).

Annual standardized CPUE trend is noisy and relatively flat since about 2012 and below average (Figure 6.250). A deviation similar to that in the 'include MPA' scenario is apparent where the standardized trend deviates markedly from the nominal geometric mean trend from 2013 - 2017 and for the same reasons of changes in vessels fishing, low numbers of significantly contributing vessels, changes in the depth distribution of fishing and lower catches and numbers of records.

6.39.2 *Action Items and Issues*

Further exploration of the reasons behind the recent deviation of the standardized time-series from the nominal geometric mean are required to provide a more detailed explanation for these changed dynamics.

Table 6.175. 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, OTB
years	1986 - 2020

Table 6.176. 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

Year	Total	N	Catch	Vess	GeoM	Opt	StDev	C<30Kg	P<30Kg
1986	469.5	1765	285.3	74	49.0	1.2567	0.000	12.762	0.045
1987	198.5	1077	120.9	62	45.8	1.4998	0.061	7.630	0.063
1988	278.5	1258	226.7	53	59.1	1.9314	0.056	9.599	0.042
1989	376.2	1846	282.5	62	56.2	2.0670	0.051	12.318	0.044
1990	450.6	1835	292.1	52	55.1	2.4282	0.052	10.697	0.037
1991	340.7	1957	218.8	49	42.5	2.1418	0.053	12.580	0.057
1992	296.5	1359	170.8	45	34.5	1.3136	0.057	9.782	0.057
1993	377.7	1408	152.3	48	35.2	1.3495	0.057	10.929	0.072
1994	392.9	2074	176.9	47	28.2	1.0723	0.053	16.809	0.095
1995	413.4	1942	179.2	44	31.5	1.2040	0.053	16.202	0.090
1996	340.6	2179	177.6	49	27.6	1.0426	0.053	18.281	0.103
1997	328.8	1647	115.7	49	24.9	0.9766	0.056	13.637	0.118
1998	210.1	1226	64.0	42	19.4	0.6936	0.059	10.434	0.163
1999	166.1	1023	49.0	40	17.2	0.7021	0.062	8.026	0.164
2000	154.8	1245	54.5	46	13.8	0.5411	0.059	9.610	0.176
2001	270.2	2024	121.5	43	23.7	0.6648	0.053	13.786	0.113
2002	232.8	1812	97.7	39	19.0	0.5355	0.055	11.638	0.119
2003	337.9	1526	89.8	49	21.9	0.5469	0.056	9.592	0.107
2004	458.2	1868	151.7	43	36.8	0.7858	0.054	11.342	0.075
2005	291.1	1013	98.7	41	41.5	0.6798	0.062	6.210	0.063
2006	247.3	695	79.3	37	59.7	0.8631	0.069	4.529	0.057
2007	172.7	557	79.2	21	92.1	0.9926	0.075	2.895	0.037
2008	128.4	887	80.6	22	46.9	0.9597	0.065	5.931	0.074
2009	164.1	933	107.0	23	55.7	0.9548	0.064	5.623	0.053
2010	240.2	1011	152.6	24	89.7	1.2151	0.063	5.213	0.034
2011	193.5	910	149.6	20	113.8	1.0458	0.065	4.590	0.031
2012	139.7	733	97.6	21	72.6	0.7542	0.069	4.241	0.043
2013	122.8	520	72.4	19	70.9	0.8303	0.076	2.924	0.040
2014	107.0	673	66.7	20	51.2	0.6259	0.070	4.127	0.062
2015	79.5	473	61.2	21	67.6	0.6956	0.079	2.422	0.040
2016	52.4	288	33.6	18	89.7	0.7966	0.095	1.528	0.045
2017	52.9	291	33.4	15	69.8	0.8001	0.095	1.634	0.049
2018	37.7	132	14.7	14	58.5	0.4165	0.135	0.926	0.063
2019	3.8	39	1.8	7	21.1	0.2128	0.232	0.196	0.111
2020	39.4	88	10.4	12	81.2	0.4037	0.164	0.382	0.037

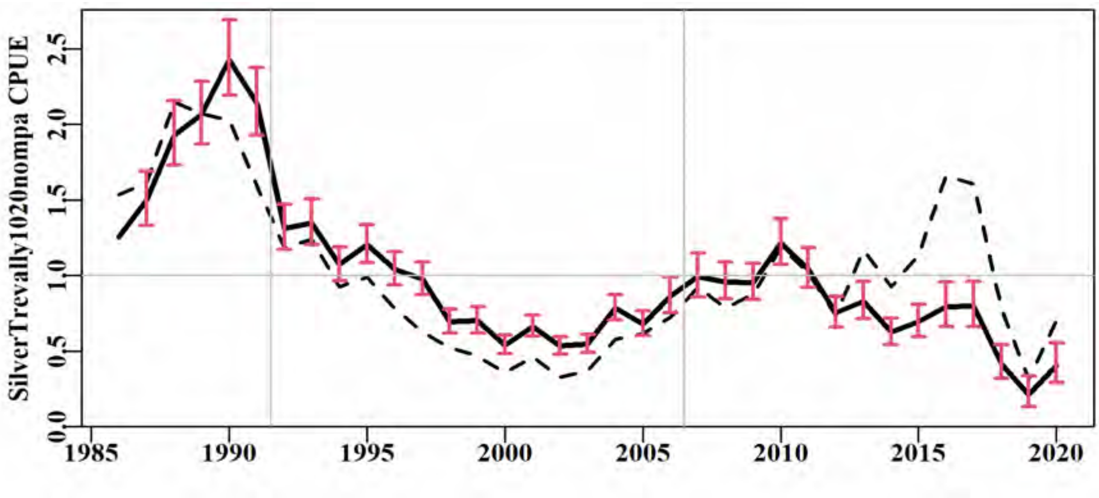

Figure 6.250. SilverTrevally1020nompa standardization. The dashed black line represents the geometric mean CPUE, solid black line the standardized CPUE. The red bars are the 95% confidence intervals about the mean estimates. The graph scales both time-series of standardized CPUE relative to the mean of each time-series.

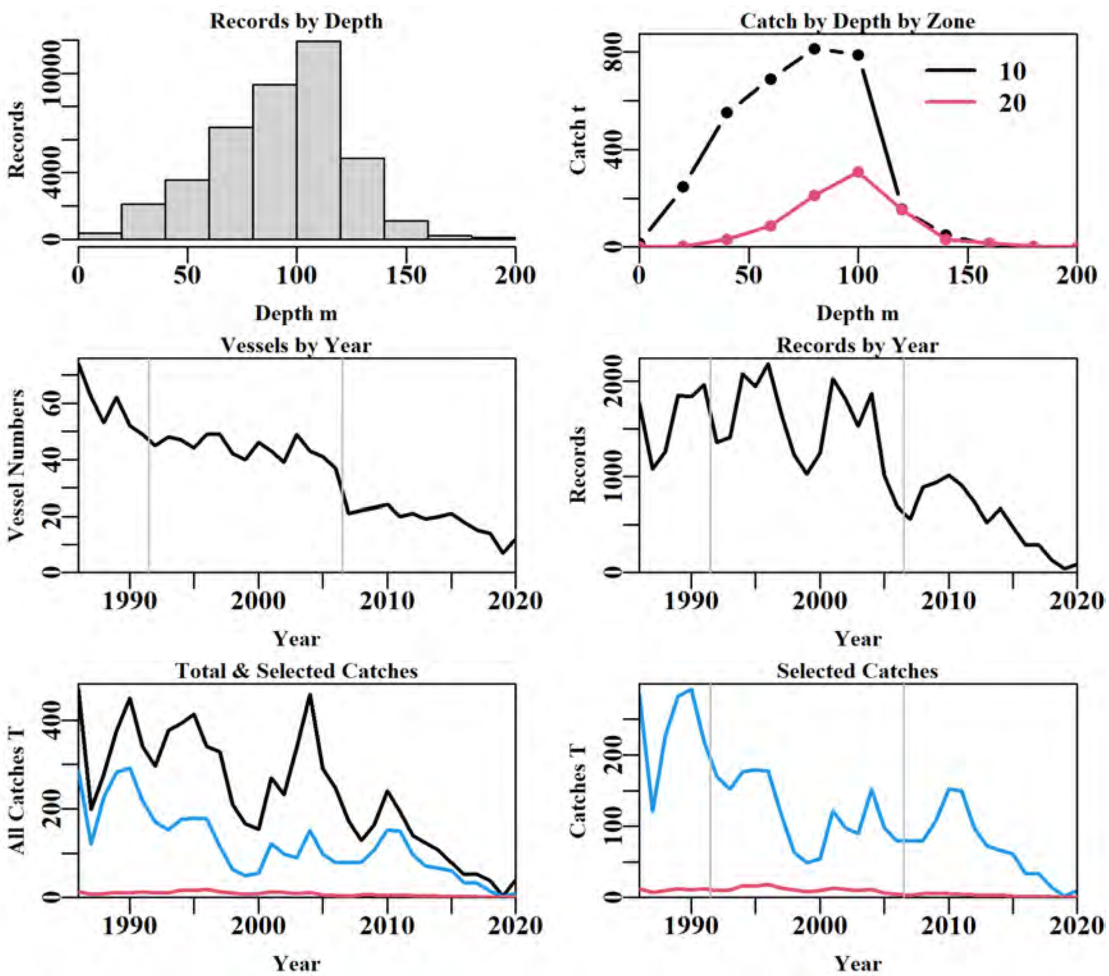

Figure 6.251. SilverTrevally1020nompa fishery details. The bottom left plot depicts all known catches (top black line), and all selected catches used in the analysis (middle blue line); the lower red line: selected catches < 30 kg).

Table 6.177. 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	76615	73414	71811	70924	61237	59836	59780	40314
Difference	0	3201	1603	887	9687	1401	56	19466
Catch	8326	8150	7862	7703	6761	6722	6715	0
Difference	0	176	288	159	941	39	7	0

Table 6.178. 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 6.179. 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

Term	AIC	RSS	MSS	Nobs	Npars	adj_r2	%Change
Year	39676	107678	12277	40314	35	10.2	0
Vessel	30961	86075	33879	40314	191	27.9	17.75
DepCat	29795	83580	36374	40314	201	30.0	2.07
Month	29049	82002	37952	40314	212	31.3	1.30
DayNight	28414	80710	39245	40314	215	32.4	1.08
Zone	28360	80596	39358	40314	216	32.5	0.09
Zone:Month	28268	80370	39584	40314	227	32.6	0.17
Zone:DepCat	28339	80518	39436	40314	225	32.5	0.05

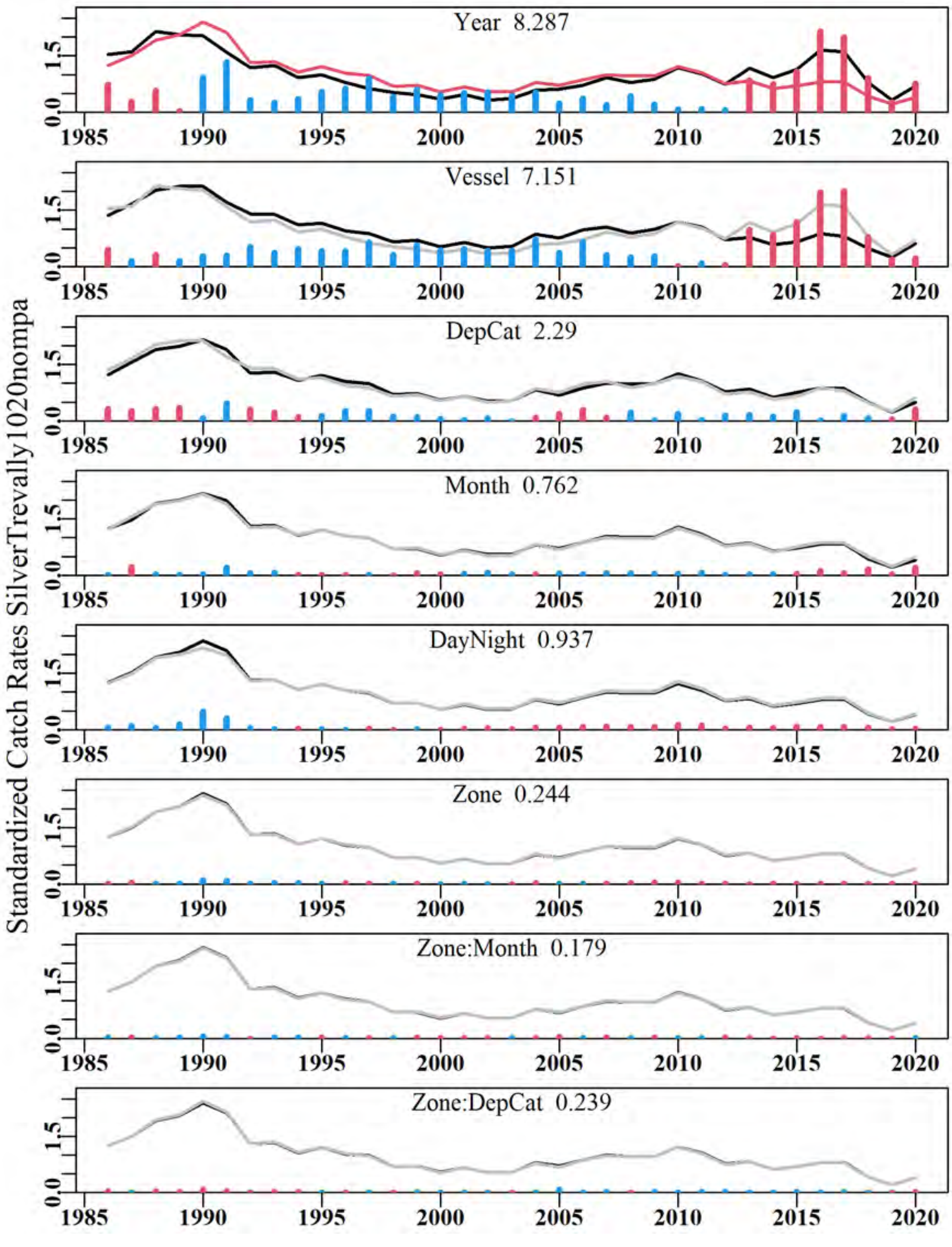

Figure 6.252. SilverTrevally1020nompa. The influence of each factor on the optimal standardization. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by vertical bars with blue bars indicating the optimum model is higher 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.

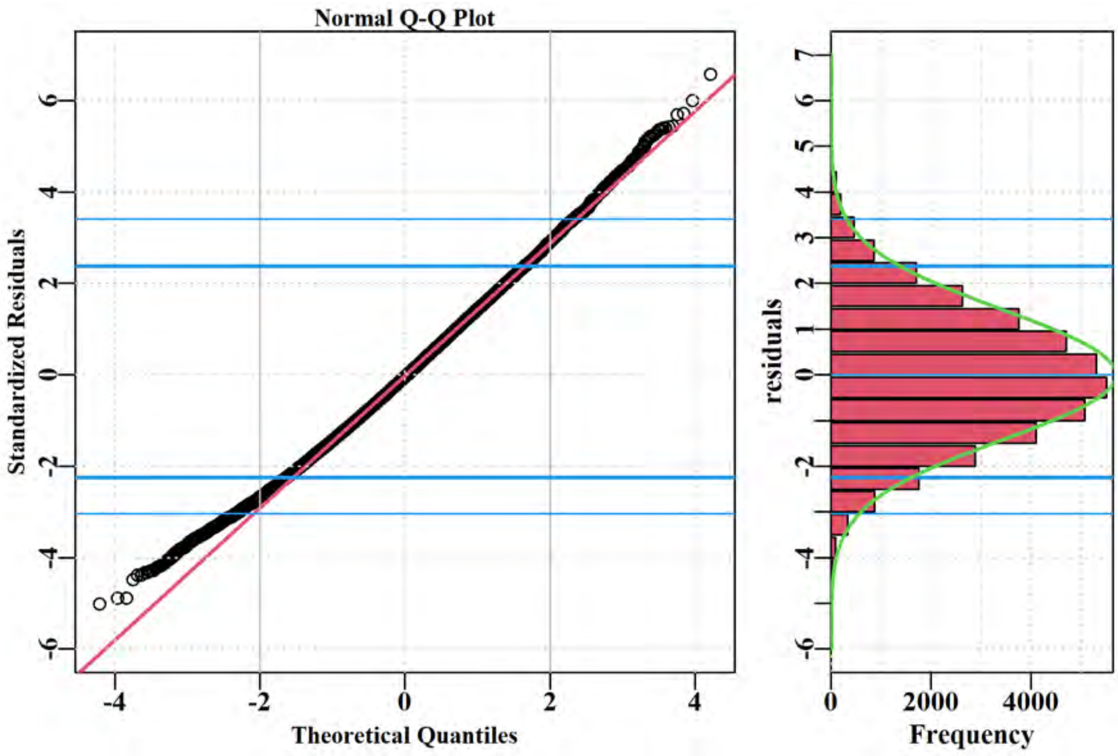

Figure 6.253. SilverTrevally1020nompa. diagnostic plots. The distribution of residuals from the optimum fit. The qqplot indicates the fit to the expected normality, while the histogram of residuals illustrates the 90% quantiles to indicate the intensity of any lack of fit at the margins of the distribution.

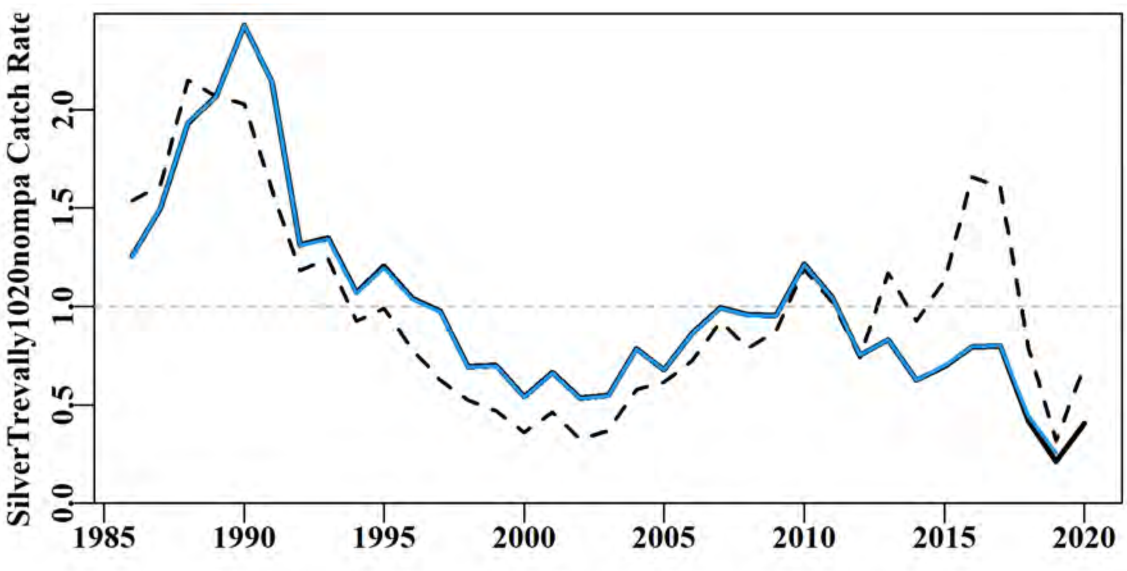

Figure 6.254. SilverTrevally1020nompa. A comparison of the previous year's standardization (blue line) with this year's. They should lie on top of each other, although small deviations may relate to data adjustments, particularly in very recent years.

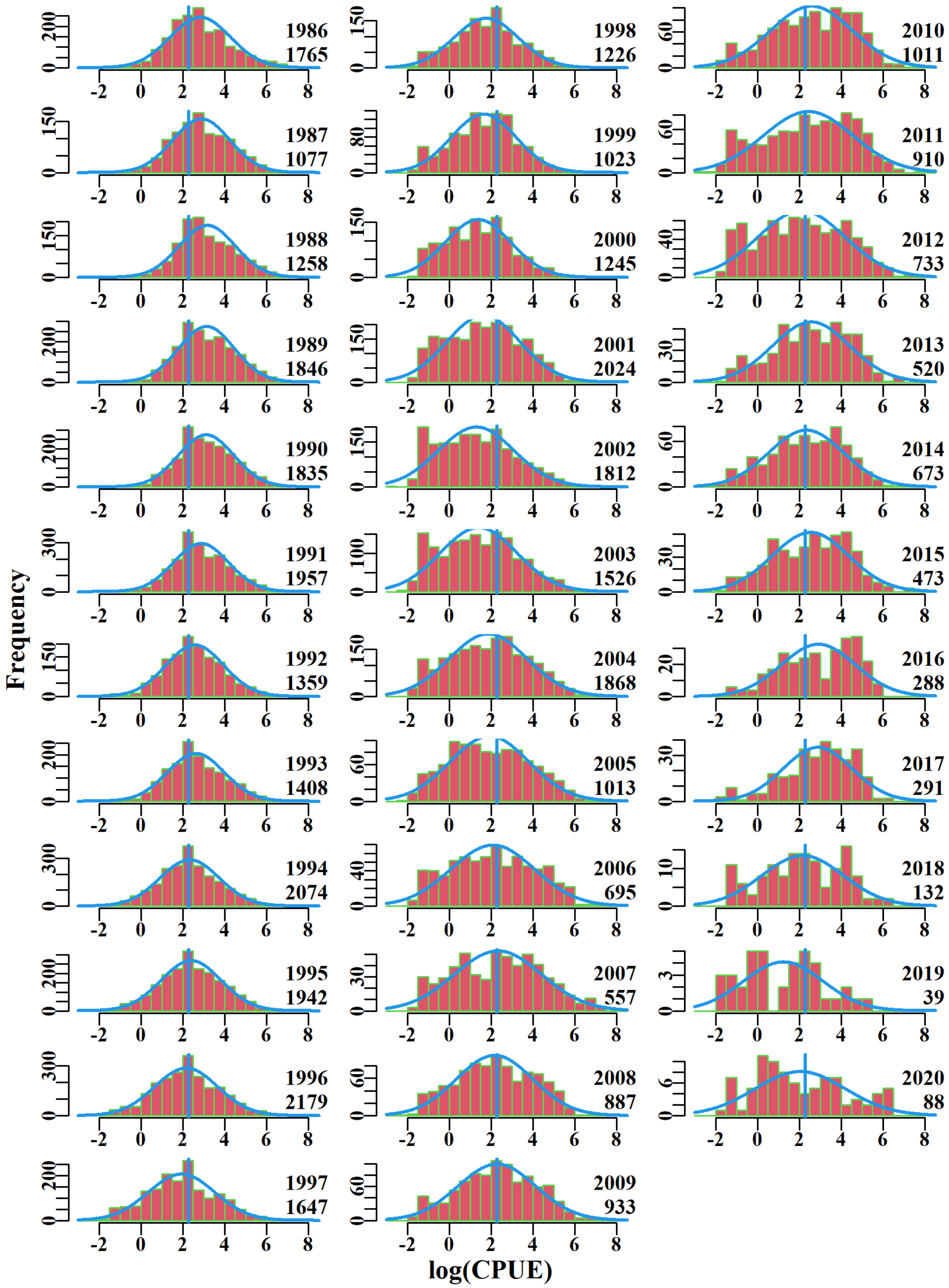

Figure 6.255. SilverTrevally1020nompa. The natural log(CPUE) for each year of data available the blue lines are normal distributions fitted to the histogram frequencies. The numbers in each plot are the year and number of records.

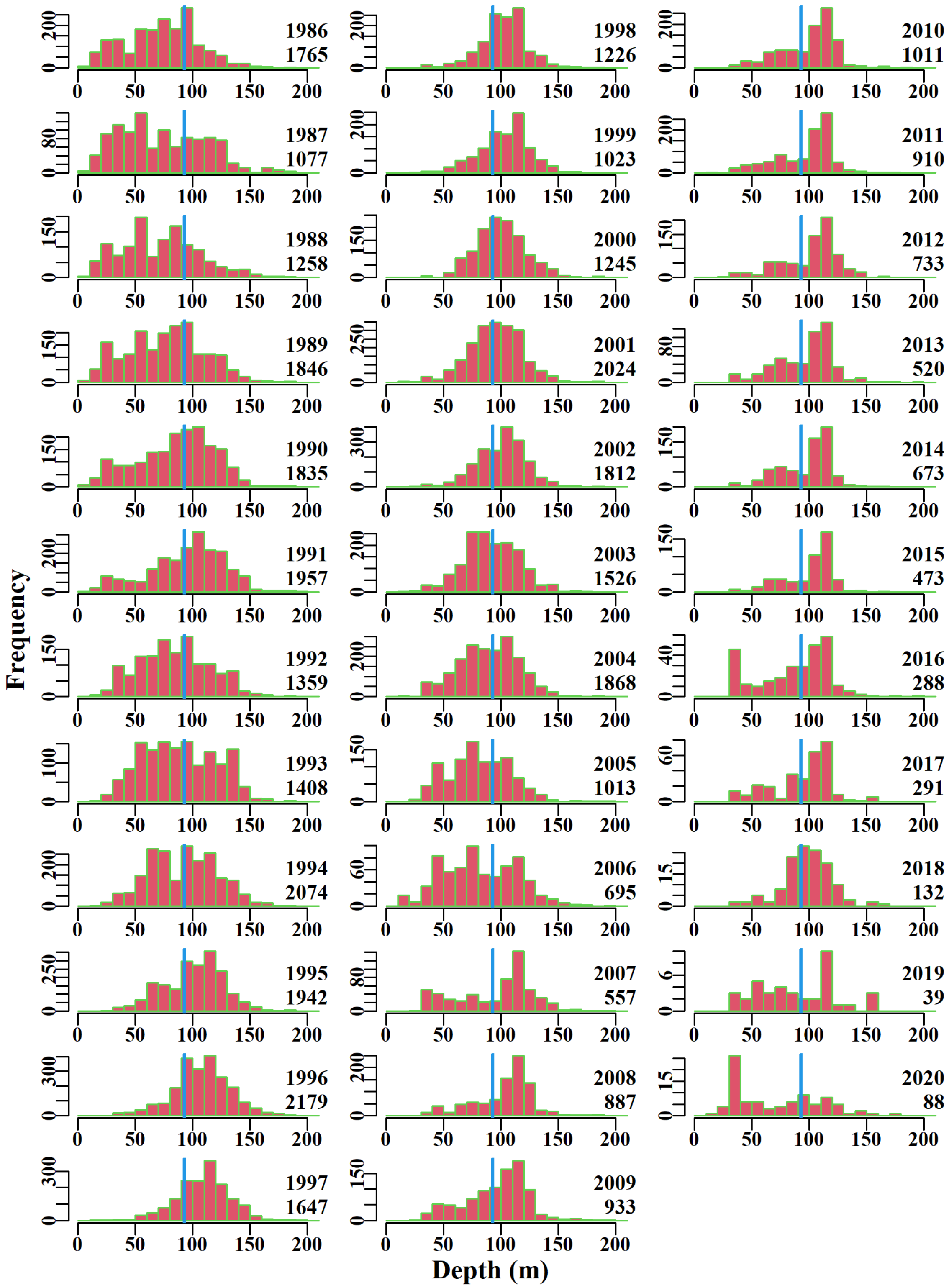

Figure 6.256. SilverTrevally1020nompa. The average Depth of fishing for each year of data available to illustrate the development of the fishery through time. The numbers in each plot are the year and number of records.

6.40 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 6.180.

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.

6.40.1 *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 6.184). The qqplot suggests a departure from the assumed Normal distribution as depicted at the lower tail (<5% of records) of the distribution (Figure 6.260).

Annual standardized CPUE trend is noisy and relatively flat across the years analysed, except from 2017 onwards, where the trend is increasing and above the long-term average (Figure 6.257). From 2013 - 2016 the standardized trend deviates from the nominal geometric mean trend such that the trend stays on the long-term average CPUE while the geometric mean appears to rise well above it. There are now very few vessels contributing to this fishery and it appears that fishing is more focused at different depths in the last two years compared with previous years. 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.

Fishing depths have been (i) recorded as single values or (ii) recorded at more than one constant value across different operations in the Commonwealth logbook database for certain vessels since about 2016. These fishing depths have been modified based on positional bathymetry and have been used in the standardization analysis presented here, as agreed by SESSFRAG in 2020. Differences between this year's standardized CPUE (i.e., 1986 – 2020) compared with last year's standardized CPUE (i.e., 1986 – 2019) are likely due to these modified fishing depths.

6.40.2 *Action Items and Issues*

It is recommended that alternate statistical distributions be considered.

Table 6.180. 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, OTB
years	1986 - 2020

Table 6.181. 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

Year	Total	N	Catch	Vess	GeoM	Opt	StDev	C<30Kg	P<30Kg
1986	278.2	1592	232.2	47	71.8	0.6002	0.000	6.689	0.029
1987	351.3	1763	324.7	47	93.0	0.7506	0.038	4.739	0.015
1988	362.5	1392	343.3	41	124.5	0.8211	0.041	3.627	0.011
1989	329.3	1143	310.8	39	139.3	0.6996	0.043	3.462	0.011
1990	337.1	719	308.6	25	175.4	1.3224	0.050	0.615	0.002
1991	334.1	728	296.3	29	183.2	1.1671	0.051	1.447	0.005
1992	166.9	426	142.3	19	164.7	0.8786	0.059	0.728	0.005
1993	298.8	671	232.1	21	172.6	1.0423	0.050	1.377	0.006
1994	359.8	650	234.3	26	169.5	0.9809	0.050	1.308	0.006
1995	335.6	1066	252.3	25	105.3	0.7912	0.044	1.862	0.007
1996	360.8	1212	272.1	24	95.5	0.7014	0.043	1.653	0.006
1997	252.7	850	165.2	21	86.8	0.6519	0.047	1.309	0.008
1998	233.3	1228	190.0	23	67.7	0.6869	0.043	2.549	0.013
1999	367.0	1579	342.8	25	84.5	0.7087	0.041	2.569	0.007
2000	434.9	1537	398.2	26	127.1	0.8983	0.041	3.619	0.009
2001	276.8	1313	228.9	22	75.7	0.7675	0.043	3.874	0.017
2002	484.2	1735	415.8	23	131.5	0.9176	0.040	4.529	0.011
2003	230.8	796	161.8	26	114.9	0.9320	0.049	3.164	0.020
2004	193.9	569	167.4	22	206.8	0.9666	0.054	2.108	0.013
2005	173.9	587	152.8	21	149.1	0.8860	0.054	2.192	0.014
2006	192.3	453	177.3	17	295.8	1.0583	0.058	1.714	0.010
2007	121.5	323	115.7	9	249.3	0.7476	0.066	1.480	0.013
2008	75.8	252	70.6	8	220.9	0.6587	0.073	1.340	0.019
2009	68.8	248	67.3	9	159.3	0.8257	0.078	0.647	0.010
2010	96.8	343	82.8	9	138.1	0.8040	0.066	1.561	0.019
2011	110.9	288	107.9	8	207.2	1.1650	0.070	0.510	0.005
2012	126.5	359	120.5	9	167.3	0.9156	0.064	1.002	0.008
2013	212.2	416	198.1	9	280.6	1.1939	0.067	0.643	0.003
2014	121.7	348	118.3	11	178.1	0.9488	0.065	0.535	0.005
2015	126.5	345	119.8	8	219.9	0.9771	0.066	0.723	0.006
2016	145.3	323	136.9	9	273.9	1.0992	0.066	0.733	0.005
2017	137.1	308	133.2	8	270.3	1.3034	0.069	0.490	0.004
2018	164.5	304	159.4	4	356.4	1.7672	0.072	0.708	0.004
2019	146.6	244	142.2	5	374.3	1.9577	0.078	0.615	0.004
2020	98.6	135	92.5	3	436.6	2.4068	0.104	0.238	0.003

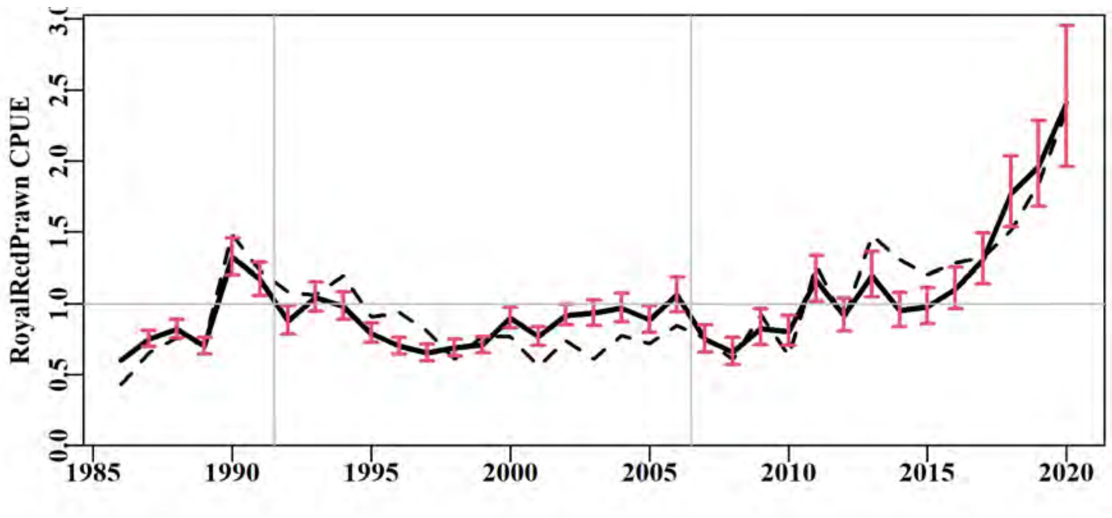

Figure 6.257. RoyalRedPrawn standardization. The dashed black line represents the geometric mean CPUE, solid black line the standardized CPUE. The red bars are the 95% confidence intervals about the mean estimates. The graph scales both time-series of standardized CPUE relative to the mean of each time-series.

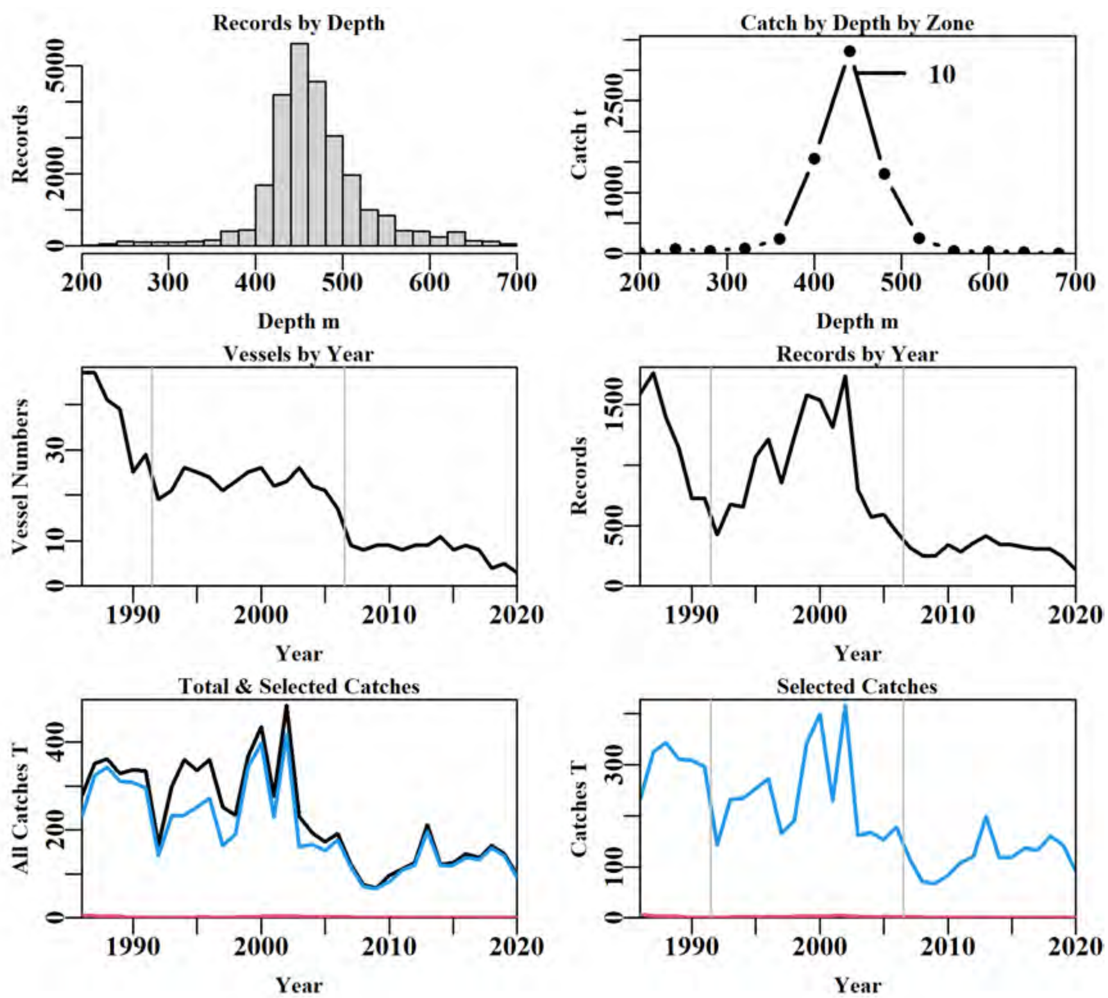

Figure 6.258. RoyalRedPrawn fishery details. The bottom left plot depicts all known catches (top black line), and all selected catches used in the analysis (middle blue line); the lower red line: selected catches < 30 kg).

Table 6.182. 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	41872	34359	33853	33326	26370	26245	26245
Difference	0	7513	506	527	6956	125	0
Catch	8164	8071	7966	7910	7053	7014	7014
Difference	0	93	105	56	857	38	0

Table 6.183. 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 6.184. 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

Term	AIC	RSS	MSS	Nobs	Npars	adj_r2	%Change
Year	15167	46652	2688	26245	35	5.3	0
DepCat	10605	39172	10168	26245	47	20.5	15.14
Vessel	4195	30481	18860	26245	134	37.9	17.44
Month	2418	28462	20879	26245	145	42.0	4.09
DayNight	2207	28227	21113	26245	148	42.5	0.47
DayNight:DepCat	2090	28031	21309	26245	181	42.8	0.33
Month:DepCat	1717	27434	21907	26245	277	43.8	1.34
DayNight:Month	2202	28154	21187	26245	180	42.5	0.08

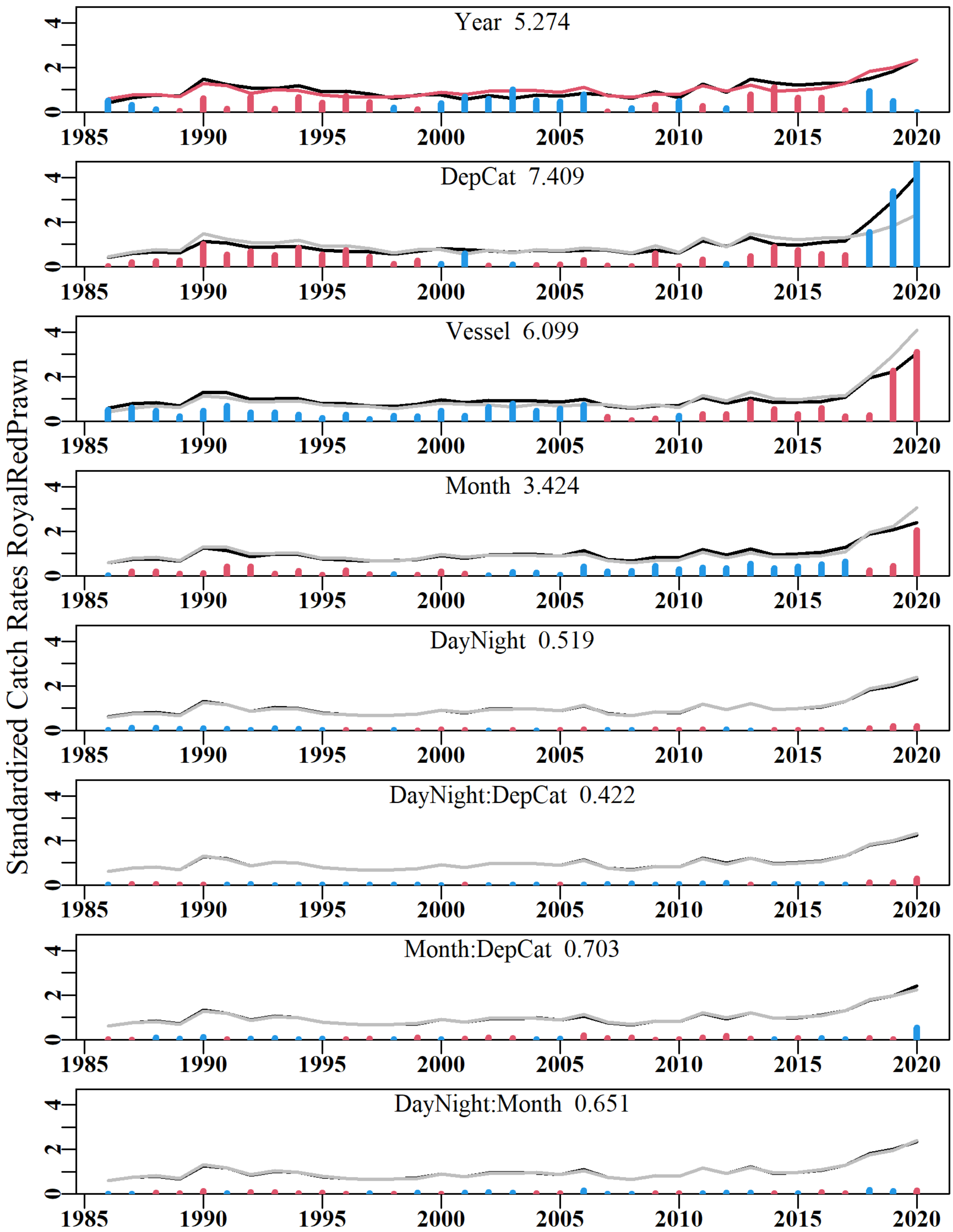

Figure 6.259. RoyalRedPrawn. The influence of each factor on the optimal standardization. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by vertical bars with blue bars indicating the optimum model is higher than the 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.

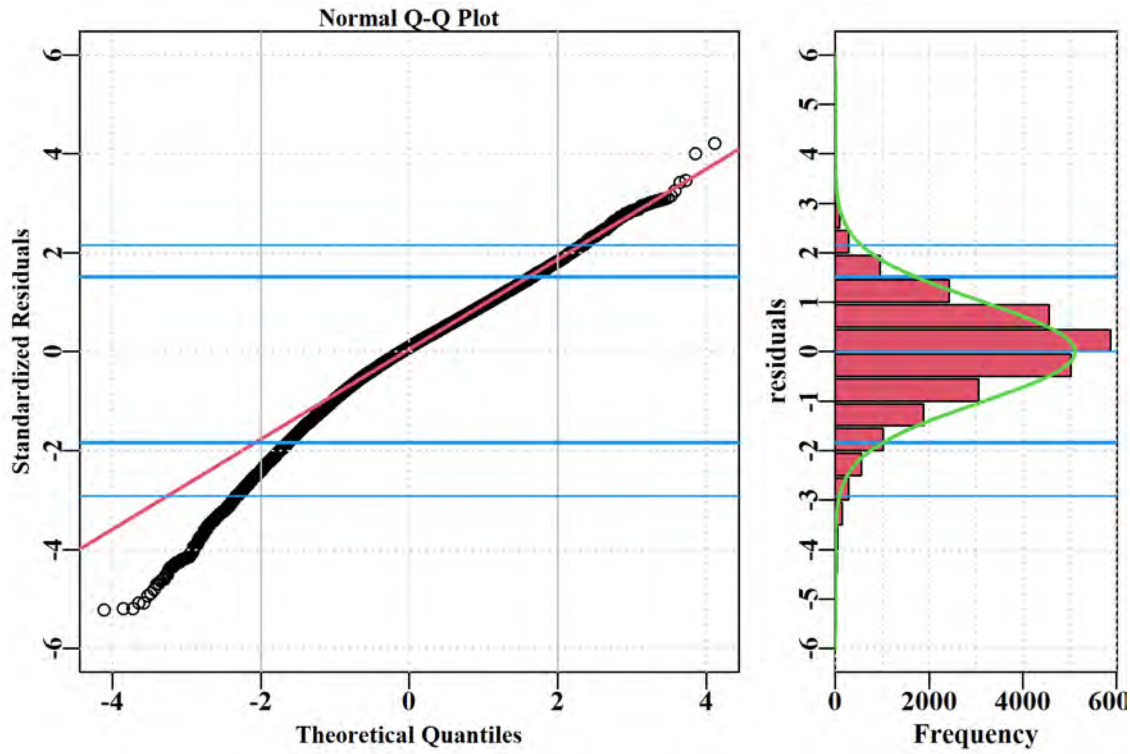

Figure 6.260. RoyalRedPrawn. diagnostic plots. The distribution of residuals from the optimum fit. The qqplot indicates the fit to the expected normality, while the histogram of residuals illustrates the 90% quantiles to indicate the intensity of any lack of fit at the margins of the distribution.

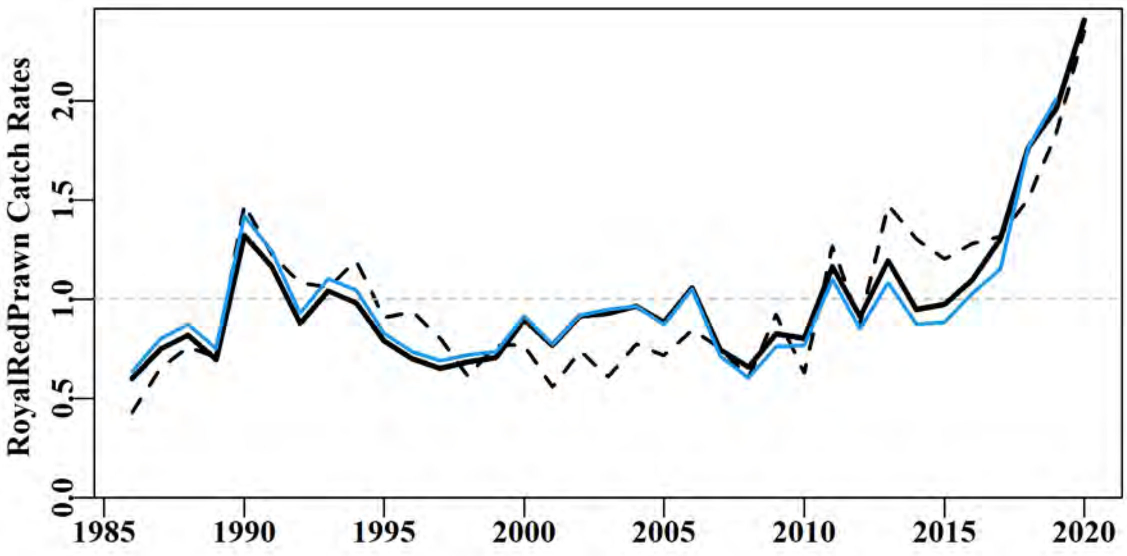

Figure 6.261. RoyalRedPrawn. A comparison of the previous year's standardization (blue line) with this year's. They should lie on top of each other, although small deviations may relate to data adjustments, particularly in very recent years.

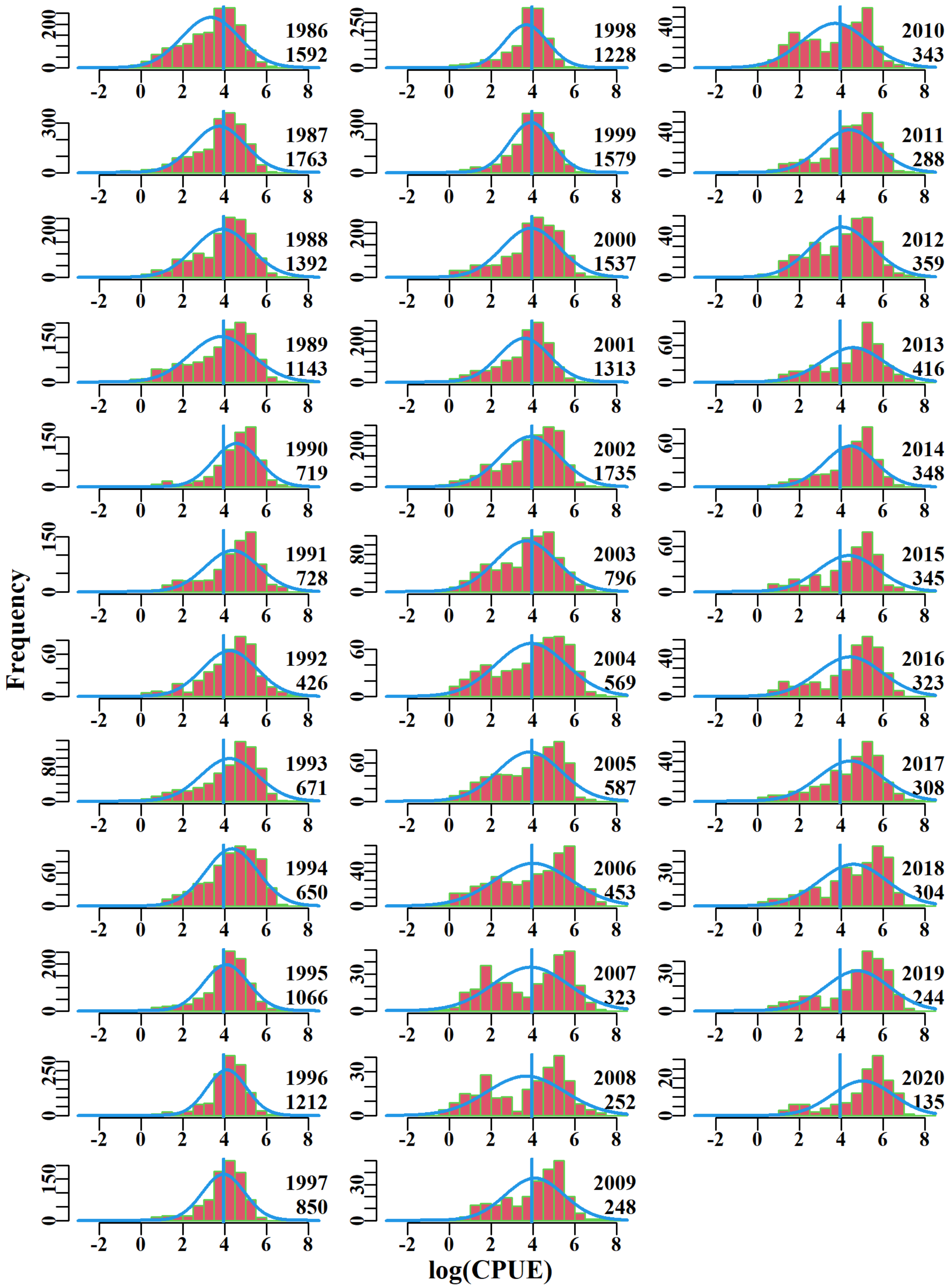

Figure 6.262. RoyalRedPrawn. The natural log(CPUE) for each year of data available the blue lines are normal distributions fitted to the histogram frequencies. The numbers in each plot are the year and number of records.

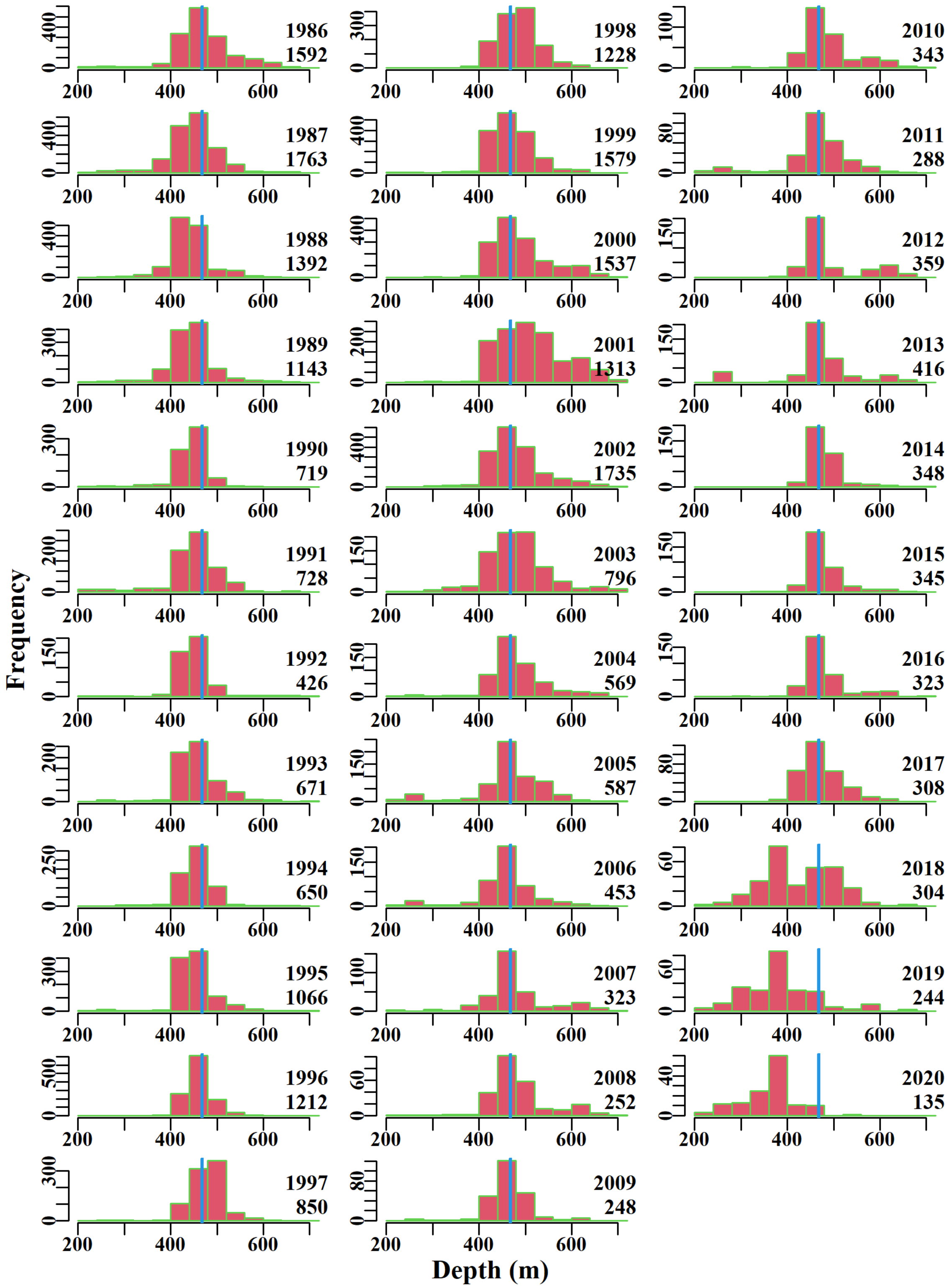

Figure 6.263. RoyalRedPrawn. The average Depth of fishing for each year of data available to illustrate the development of the fishery through time. The numbers in each plot are the year and number of records.

6.41 Eastern Gemfish NonSpawning

For non-spawning eastern Gemfish (GEM – 37439002 – *Rexea solandri*) in the SET, initial data selection was conducted according to the details given in Table 6.185.

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.

6.41.1 *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 up to 1% of the overall variation in CPUE, based on the AIC and R^2 statistics (Table 6.189). The qqplot suggests that the assumed Normal distribution is valid with a slight depature as depicted at the lower tail of the distribution (Figure 6.267).

Following a large spike in standardized CPUE 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 appears to be a 14 - 15 year cycle of rise and fall (Figure 6.264). 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 means that the most recent CPUE, from about 2013, will not be representative of even the depleted stock state.

6.41.2 *Action Items and Issues*

No issues identified.

Table 6.185. 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, OTB, TMO
years	1986 - 2020

Table 6.186. 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

Year	Total	N	Catch	Vess	GeoM	Opt	StDev	C<30Kg	P<30Kg
1986	647.9	2028	389.4	85	50.9	2.8315	0.000	13.705	0.035
1987	1027.6	1882	761.6	74	121.6	3.9150	0.043	9.656	0.013
1988	744.5	2187	497.2	77	64.7	3.2262	0.043	13.954	0.028
1989	306.7	1427	143.5	69	29.5	2.1008	0.048	13.936	0.097
1990	251.0	745	87.3	68	35.6	2.1029	0.058	5.730	0.066
1991	367.6	719	63.3	71	23.6	1.4060	0.059	7.059	0.111
1992	243.5	682	134.6	50	41.0	1.9676	0.060	4.859	0.036
1993	183.3	1521	93.7	58	20.2	1.5597	0.048	14.627	0.156
1994	148.2	1820	63.1	55	12.9	1.0798	0.046	18.222	0.289
1995	137.9	1683	49.9	54	11.5	0.9690	0.047	18.718	0.375
1996	223.7	1938	55.5	61	9.8	0.7547	0.046	18.655	0.336
1997	265.6	1775	65.3	58	9.5	0.7874	0.049	18.355	0.281
1998	238.8	1241	45.5	49	9.9	0.7403	0.051	12.901	0.283
1999	318.2	1342	30.3	53	7.2	0.5439	0.051	12.684	0.419
2000	248.6	1713	32.2	58	6.2	0.4853	0.048	15.019	0.466
2001	239.3	1636	32.1	50	4.7	0.3880	0.049	12.320	0.384
2002	146.9	1612	19.0	50	3.0	0.3009	0.049	10.864	0.571
2003	205.5	1574	20.0	48	3.7	0.3262	0.050	10.222	0.512
2004	454.9	1759	38.4	54	6.9	0.4595	0.049	12.383	0.322
2005	436.3	1711	40.4	48	7.3	0.4944	0.049	12.613	0.312
2006	425.7	1316	32.0	43	7.1	0.5243	0.052	10.140	0.317
2007	495.6	779	28.0	22	10.2	0.6931	0.059	5.844	0.209
2008	203.9	828	34.7	26	14.6	0.9253	0.058	6.769	0.195
2009	146.9	501	25.3	27	24.6	0.9601	0.068	3.767	0.149
2010	150.5	680	21.9	23	10.0	0.6903	0.061	5.334	0.244
2011	101.2	776	21.8	22	8.4	0.6228	0.060	5.621	0.258
2012	130.2	697	21.7	23	9.4	0.6028	0.062	4.916	0.227
2013	80.4	585	23.2	23	14.8	0.6861	0.066	4.098	0.177
2014	104.5	516	9.6	23	6.0	0.4180	0.068	3.437	0.356
2015	68.7	619	16.1	24	10.3	0.4520	0.065	3.447	0.214
2016	52.8	412	7.4	23	6.4	0.2944	0.074	2.664	0.358
2017	102.5	556	19.0	21	15.0	0.3299	0.067	3.257	0.171
2018	56.8	516	15.7	20	14.3	0.4324	0.069	3.059	0.195
2019	121.2	743	26.7	20	14.6	0.4436	0.064	4.652	0.174
2020	87.7	502	23.1	17	13.2	0.4857	0.070	2.934	0.127

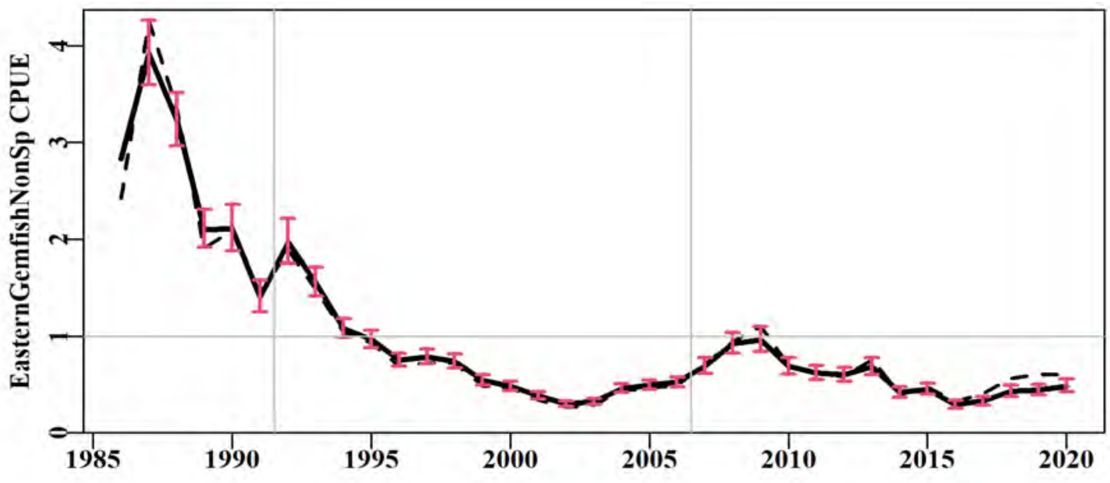

Figure 6.264. EasternGemfishNonSp standardization. The dashed black line represents the geometric mean CPUE, solid black line the standardized CPUE. The red bars are the 95% confidence intervals about the mean estimates. The graph scales both time-series of standardized CPUE relative to the mean of each time-series.

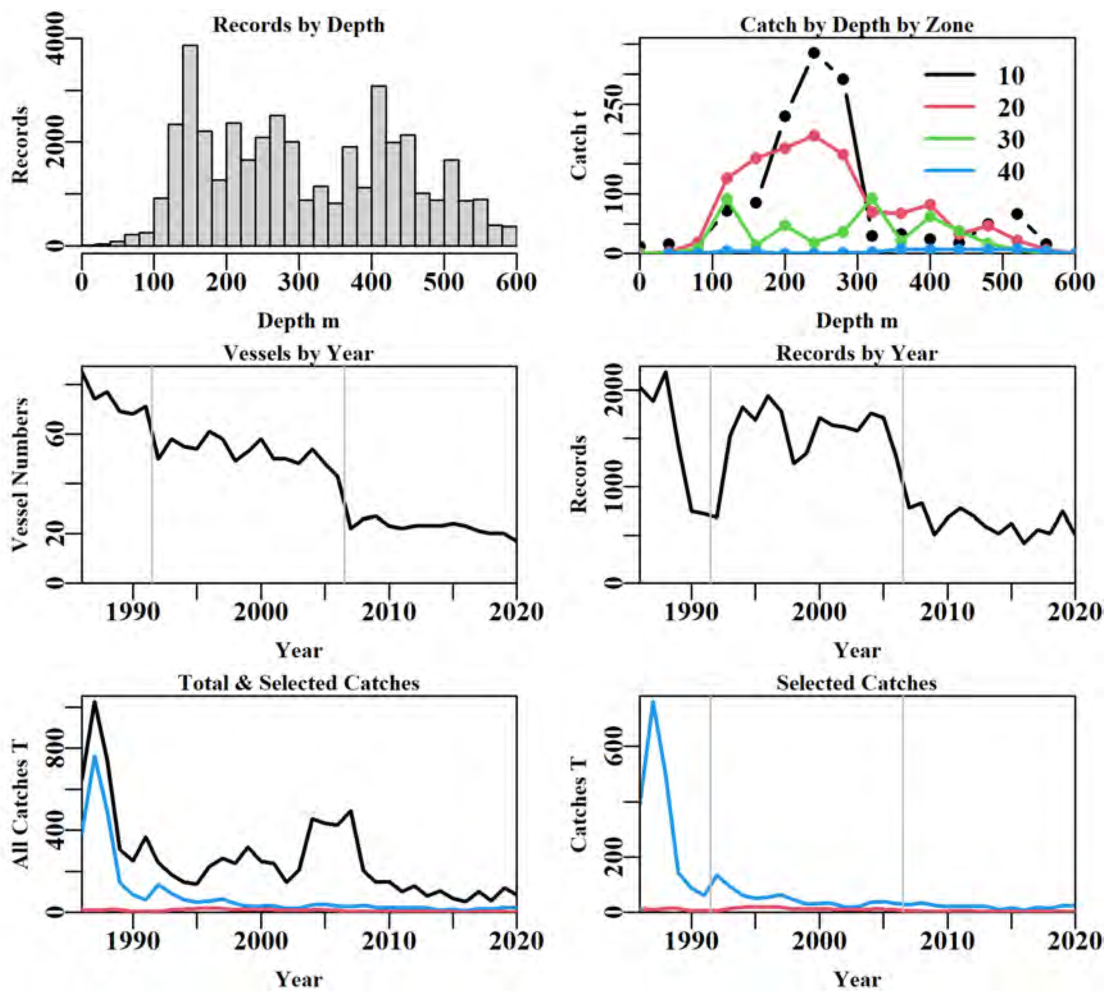

Figure 6.265. EasternGemfishNonSp fishery details. The bottom left plot depicts all known catches (top black line), and all selected catches used in the analysis (middle blue line); the lower red line: selected catches < 30 kg).

Table 6.187. 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	97216	85394	83361	81491	42109	41076	41021
Difference	0	11822	2033	1870	39382	1033	55
Catch	9444	9184	8979	8712	3059	3000	2989
Difference	0	260	205	268	5652	59	11

Table 6.188. 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 6.189. 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

Term	AIC	RSS	MSS	Nobs	Npars	adj_r2	%Change
Year	27538	80133	23933	41021	35	22.9	0
Vessel	20987	67679	36387	41021	224	34.6	11.68
DepCat	19284	64880	39186	41021	239	37.3	2.68
Month	18748	64004	40062	41021	250	38.1	0.83
DayNight	18401	63455	40611	41021	253	38.6	0.53
Zone	17999	62826	41240	41021	256	39.3	0.60
Zone:DepCat	17358	61720	42346	41021	300	40.3	1.00
Zone:Month	17661	62211	41855	41021	289	39.8	0.55

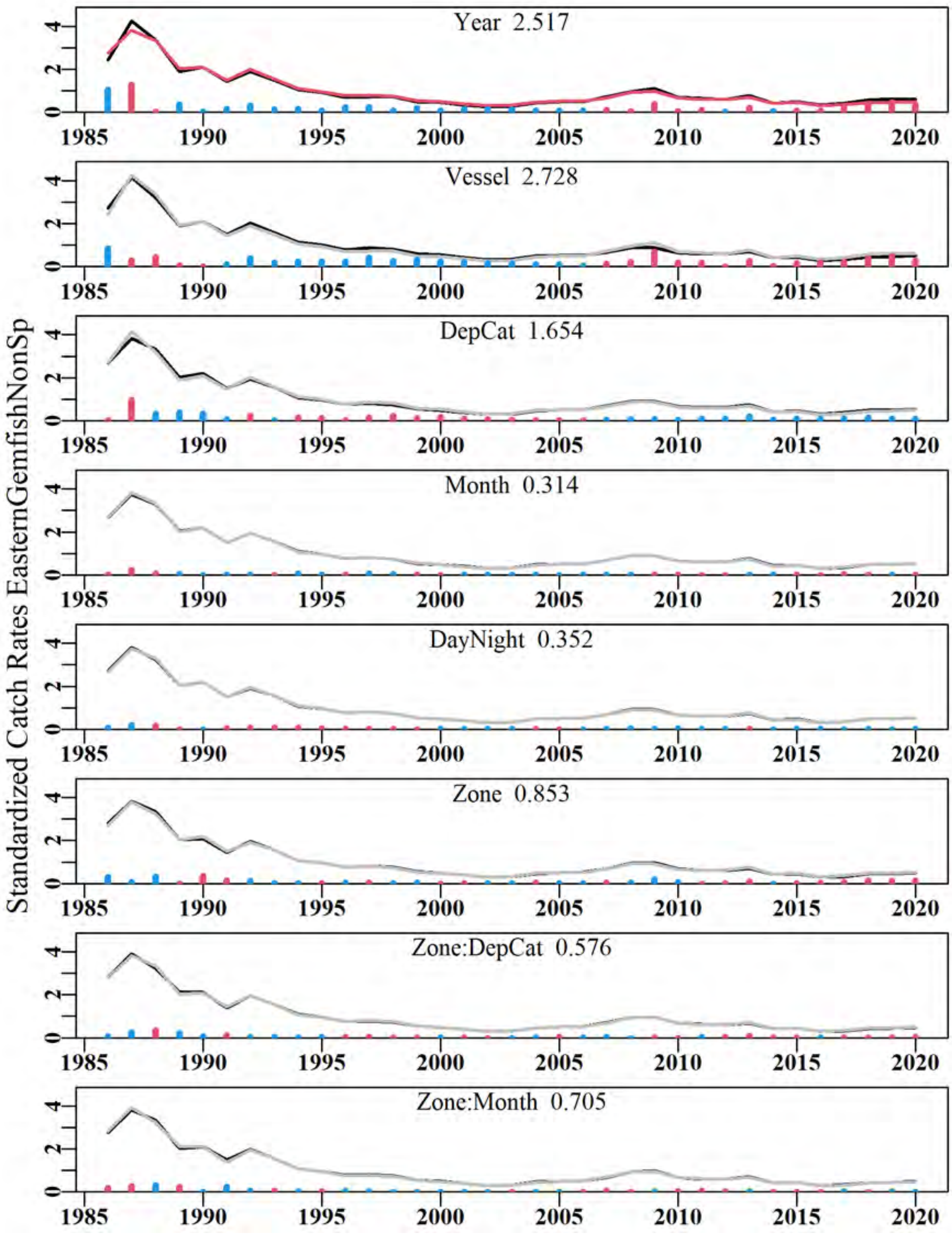

Figure 6.266. EasternGemfishNonSp. The influence of each factor on the optimal standardization. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by vertical bars with blue bars indicating the optimum model is higher than 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.

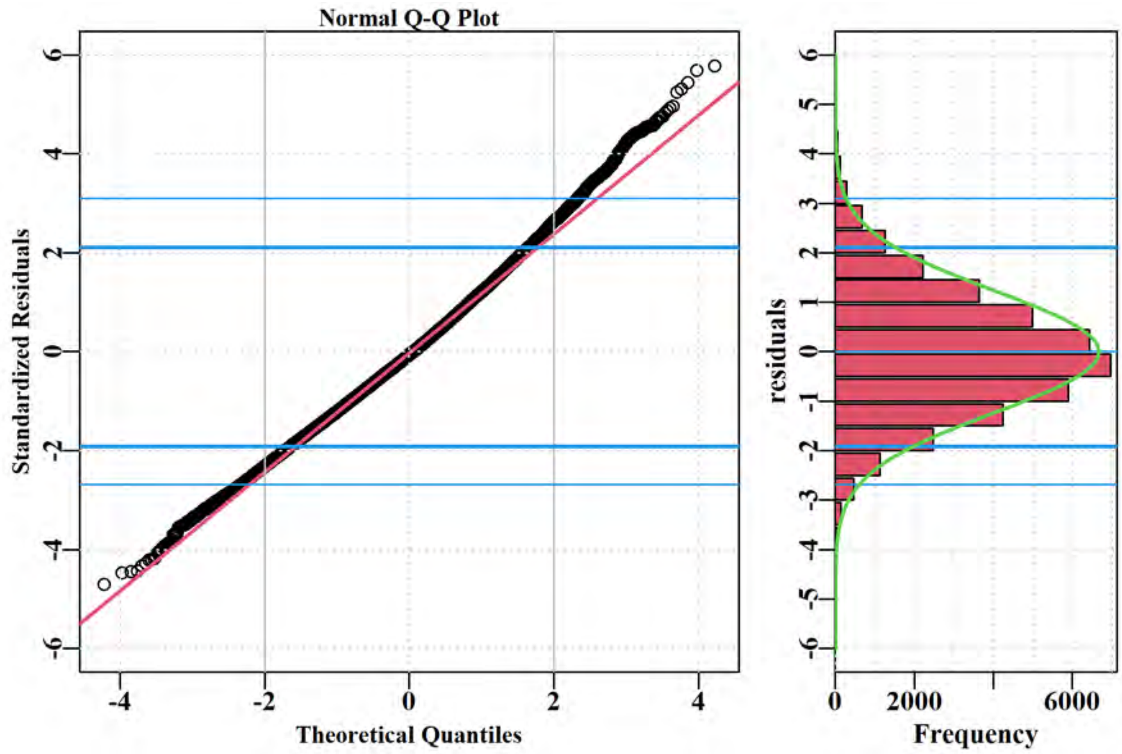

Figure 6.267. EasternGemfishNonSp. diagnostic plots. The distribution of residuals from the optimum fit. The qqplot indicates the fit to the expected normality, while the histogram of residuals illustrates the 90% quantiles to indicate the intensity of any lack of fit at the margins of the distribution.

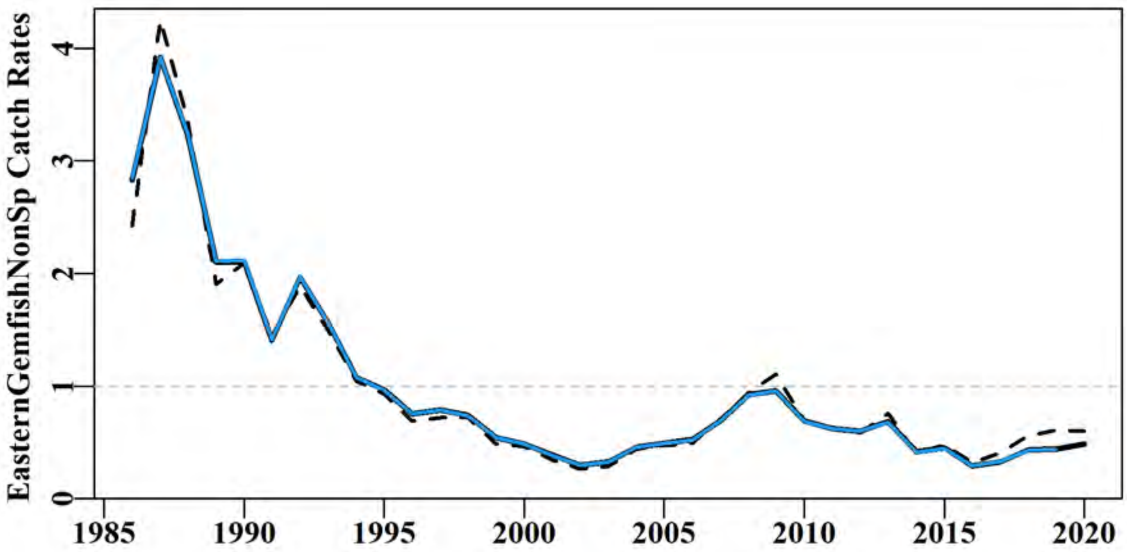

Figure 6.268. EasternGemfishNonSp. A comparison of the previous year's standardization (blue line) with this year's. They should lie on top of each other, although small deviations may relate to data adjustments, particularly in very recent years.

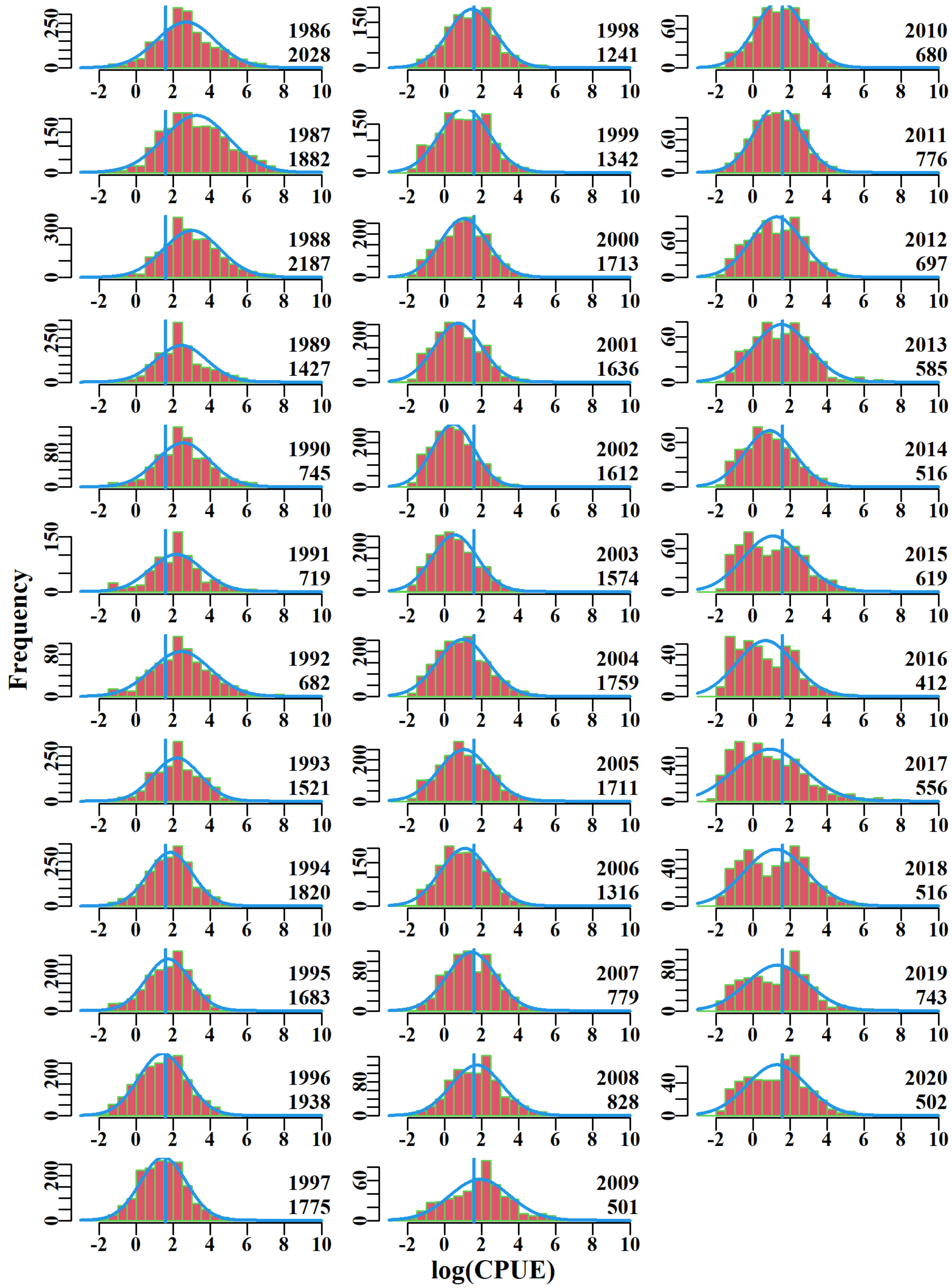

Figure 6.269. EasternGemfishNonSp. The natural log(CPUE) for each year of data available the blue lines are normal distributions fitted to the histogram frequencies. The numbers in each plot are the year and number of records.

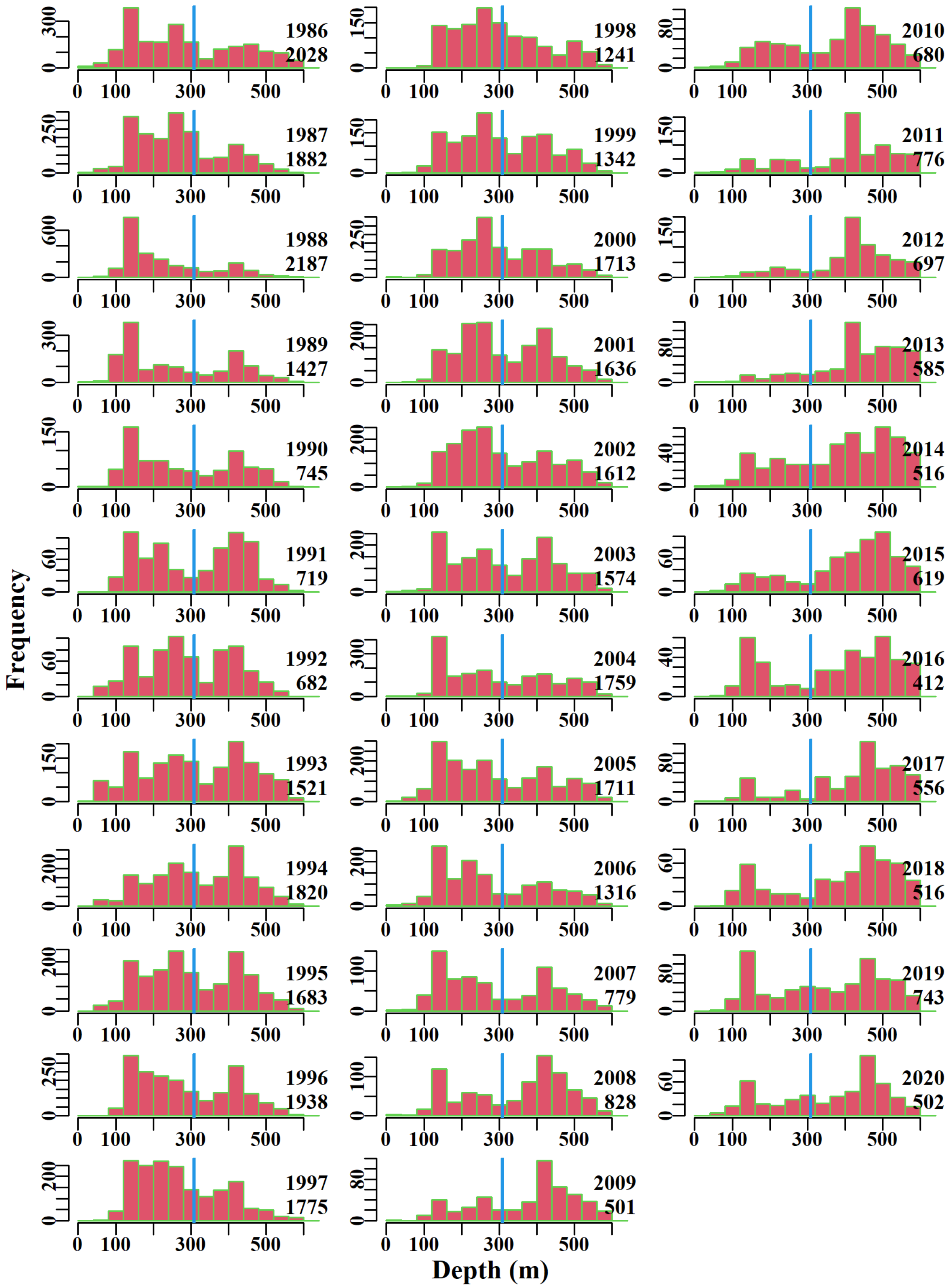

Figure 6.270. EasternGemfishNonSp. The average Depth of fishing for each year of data available to illustrate the development of the fishery through time. The numbers in each plot are the year and number of records.

6.42 Eastern Gemfish Spawning

Initial data selection for the eastern Gemfish spawning run fishery (GEM – 37439002 - *Rexea solandri*) in the SET was conducted according to the details given in Table 6.190. 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.

6.42.1 *Inferences*

The majority of catch of this species occurred in zone 10, followed by 20 and minimal catches in the remaining zones. Even though survey vessel data were removed there were still increased catches in 1996, 1997 and 1998, but after that catches have been less than 42 t since 2000.

The terms Year, Vessel, Month, DepCat, Month and one interaction term Zone:Month had the greatest contribution to model fit, based on the AIC and R^2 statistics (Table 6.194). The qqplot suggests that the assumed Normal distribution is valid with a slight depature as depicted at the upper tail of the distribution (Figure 6.274).

Annual standardized CPUE trend has declined since 2010 and remained below average since 2011 (Figure 6.271). This reflects what appears to be a longer term cycle of CPUE values, which suggests that CPUE values would soon be expected to rise, which occurred in 2019 and 2020. However, the very low catches since the past six years indicate that industry avoidance strategies are effective, and this means the recent CPUE may not provide an unbiased representation of the stock status.

6.42.2 *Action Items and Issues*

No issues identified.

Table 6.190. 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, OTB, TMO
years	1993 - 2020

Table 6.191. 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

Year	Total	N	Catch	Vess	GeoM	Opt	StDev	C<30Kg	P<30Kg
1993	205.9	819	132.9	50	40.2	2.4352	0.000	5.357	0.040
1994	97.2	814	48.6	47	22.1	1.5968	0.063	7.120	0.146
1995	57.2	657	21.9	48	12.1	1.0670	0.066	7.390	0.338
1996	197.6	768	135.1	49	35.3	1.3427	0.064	6.914	0.051
1997	342.5	1225	268.0	47	62.6	2.0126	0.059	7.393	0.028
1998	188.9	879	144.6	46	40.5	1.3400	0.063	7.610	0.053
1999	168.5	1064	87.9	45	21.7	1.0979	0.062	10.350	0.118
2000	103.4	1176	37.0	44	9.9	0.7358	0.062	11.959	0.323
2001	102.6	853	32.7	47	11.7	0.7401	0.065	8.229	0.252
2002	54.1	922	22.4	42	7.3	0.5357	0.065	8.882	0.396
2003	75.1	960	31.6	48	10.7	0.7528	0.064	8.531	0.270
2004	220.2	625	19.7	44	9.8	0.7164	0.071	5.296	0.269
2005	143.2	635	21.4	40	10.2	0.6435	0.070	5.958	0.278
2006	228.1	567	34.6	35	18.3	1.0060	0.072	4.245	0.123
2007	132.8	305	25.3	19	25.0	1.2304	0.087	1.730	0.068
2008	65.1	441	34.9	23	23.1	1.5009	0.079	3.376	0.097
2009	63.1	404	35.2	22	26.5	1.4058	0.081	3.176	0.090
2010	77.8	378	41.0	24	31.1	1.4689	0.081	2.484	0.061
2011	47.1	408	26.7	21	17.2	1.0608	0.080	3.392	0.127
2012	41.8	379	28.0	21	18.3	0.6831	0.083	3.279	0.117
2013	33.9	290	16.0	20	18.2	0.8649	0.089	2.873	0.179
2014	30.8	368	11.2	19	8.7	0.6209	0.083	3.000	0.267
2015	18.8	320	7.8	20	8.0	0.4795	0.087	2.591	0.333
2016	18.8	304	5.4	21	5.2	0.3519	0.088	2.395	0.440
2017	16.0	212	5.2	18	7.9	0.4391	0.100	1.551	0.298
2018	14.0	208	6.9	17	9.9	0.4022	0.102	1.695	0.246
2019	31.9	303	14.5	18	15.6	0.7271	0.091	2.386	0.165
2020	35.9	271	11.4	15	13.8	0.7419	0.095	2.049	0.180

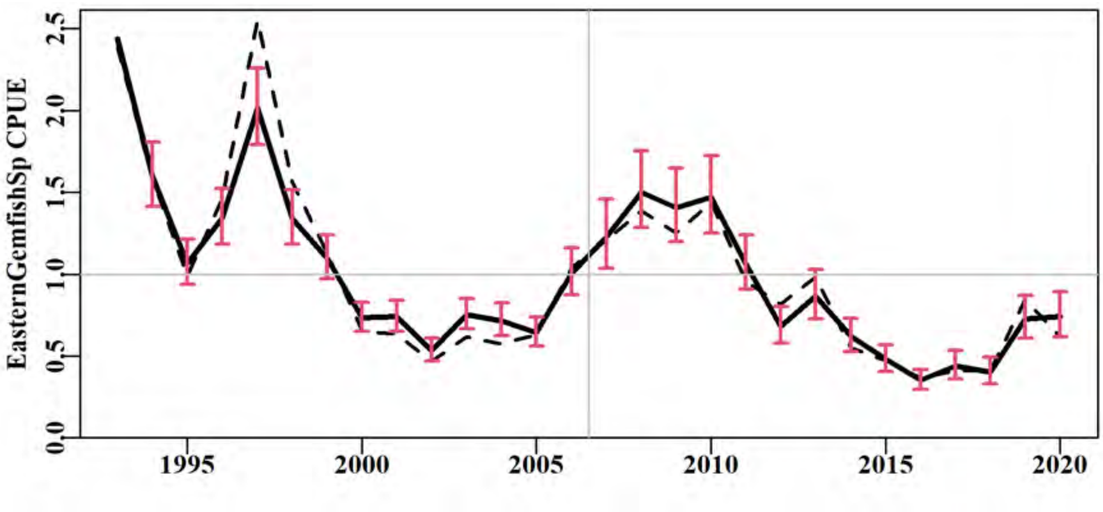

Figure 6.271. EasternGemfishSp standardization. The dashed black line represents the geometric mean CPUE, solid black line the standardized CPUE. The red bars are the 95% confidence intervals about the mean estimates. The graph scales both time-series of standardized CPUE relative to the mean of each time-series.

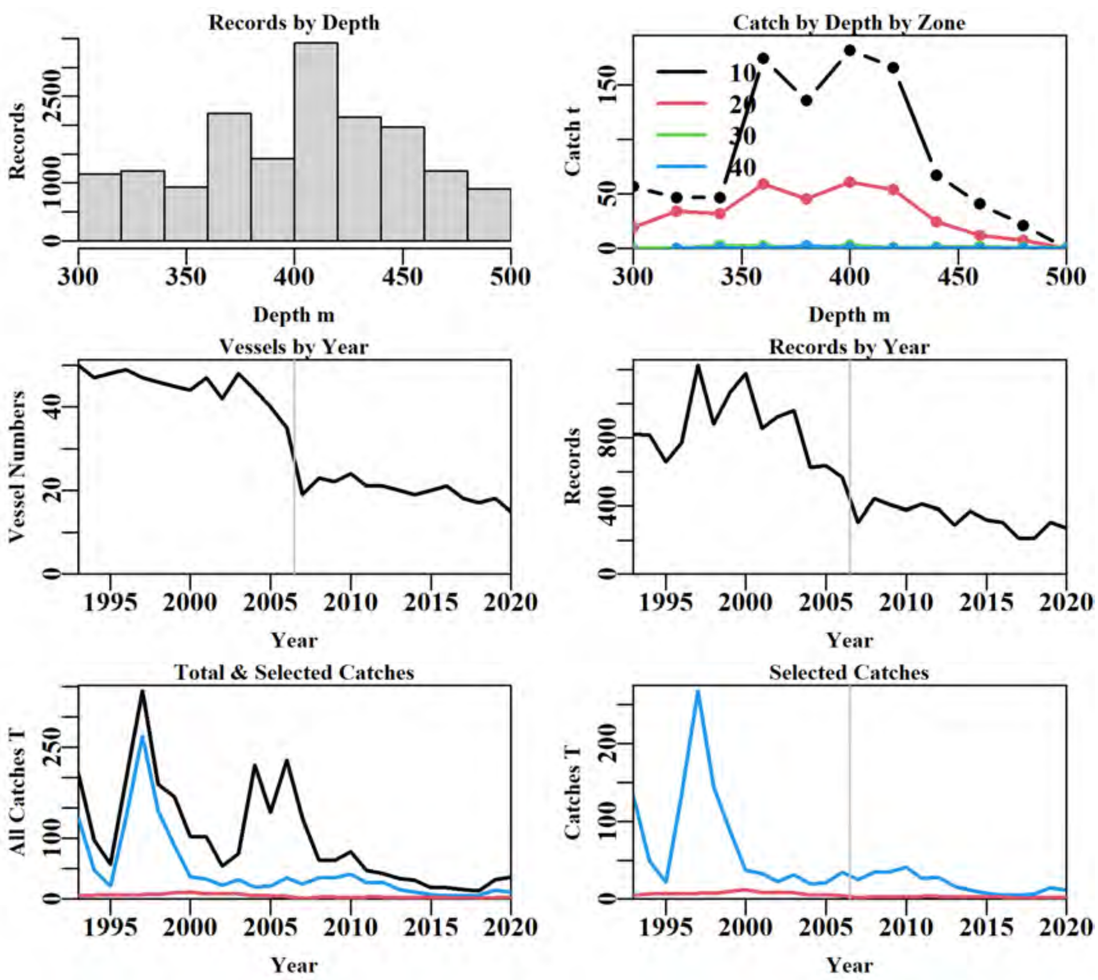

Figure 6.272. EasternGemfishSp fishery details. The bottom left plot depicts all known catches (top black line), and all selected catches used in the analysis (middle blue line); the lower red line: selected catches < 30 kg).

Table 6.192. 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	52498	46656	32578	21774	16722	16555	16555
Difference	0	5842	14078	10804	5052	167	0
Catch	16395	16140	14137	2084	1333	1308	1308
Difference	0	255	2003	12054	751	25	0

Table 6.193. 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 6.194. 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

Term	AIC	RSS	MSS	Nobs	Npars	adj_r2	%Change
Year	9681	29609	4786	16555	28	13.8	0
Vessel	7908	26260	8135	16555	135	23.0	9.25
Month	7075	24963	9433	16555	138	26.8	3.79
DepCat	6714	24395	10001	16555	148	28.4	1.62
DayNight	6612	24236	10159	16555	151	28.9	0.45
Zone	6605	24217	10178	16555	154	28.9	0.04
Zone:Month	6351	23823	10572	16555	163	30.1	1.12
Zone:DepCat	6577	24095	10300	16555	182	29.2	0.24

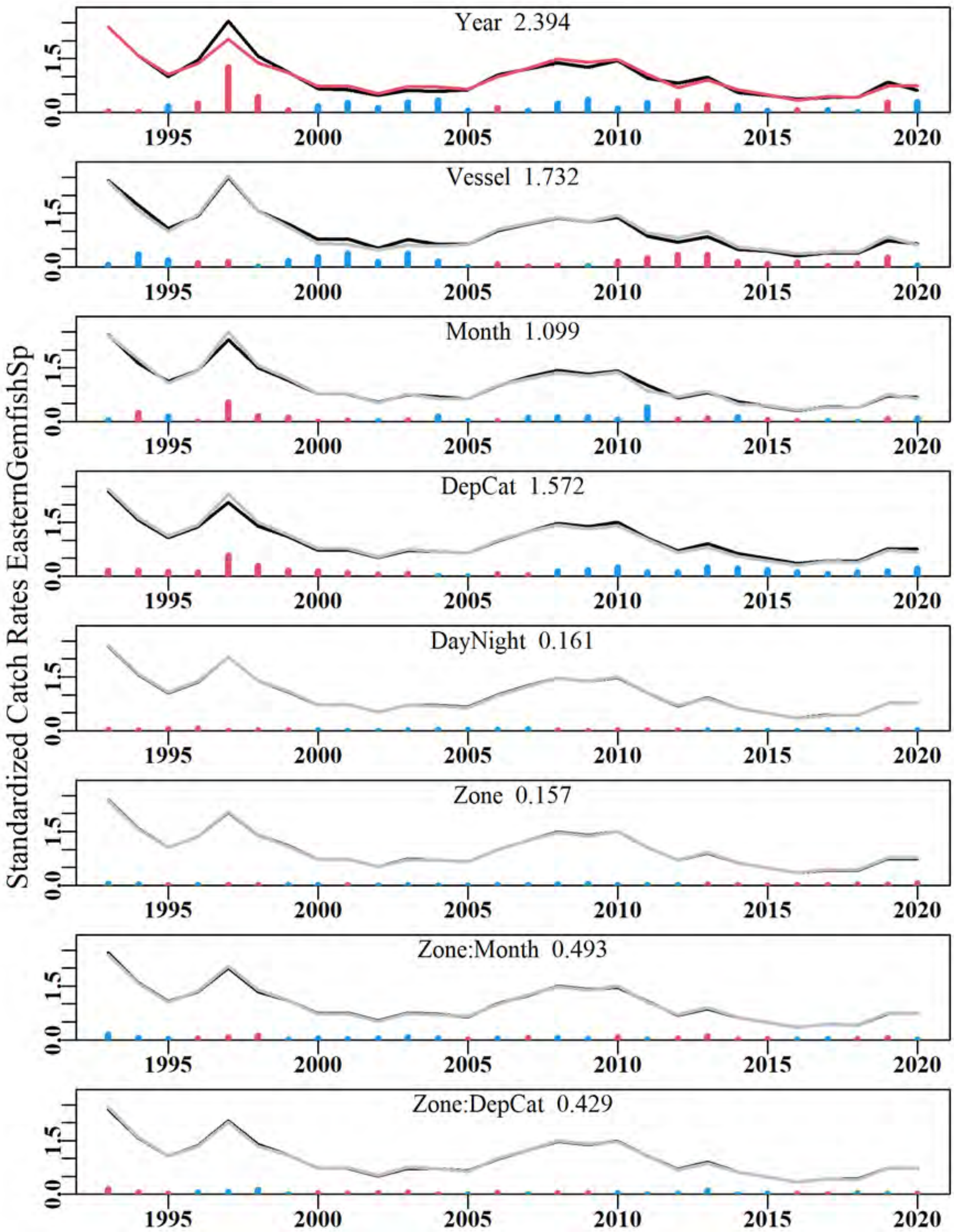

Figure 6.273. EasternGemfishSp. The influence of each factor on the optimal standardization. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by vertical bars with blue bars indicating the optimum model is higher than the 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.

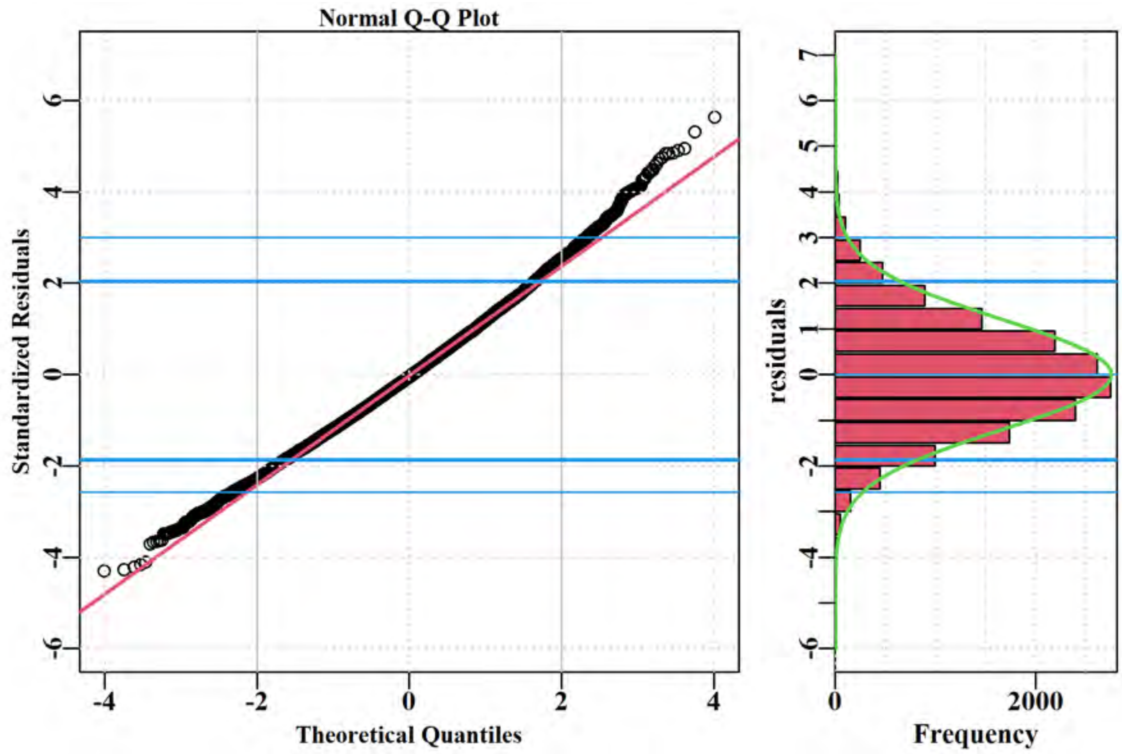

Figure 6.274. EasternGemfishSp. diagnostic plots. The distribution of residuals from the optimum fit. The qqplot indicates the fit to the expected normality, while the histogram of residuals illustrates the 90% quantiles to indicate the intensity of any lack of fit at the margins of the distribution.

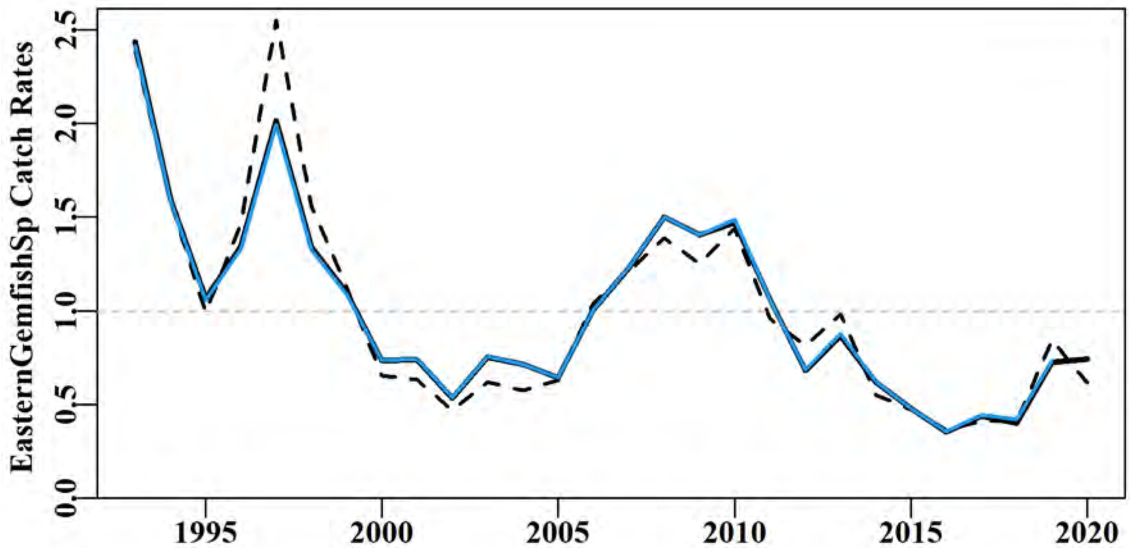

Figure 6.275. EasternGemfishSp. A comparison of the previous year's standardization (blue line) with this year's. They should lie on top of each other, although small deviations may relate to data adjustments, particularly in very recent years.

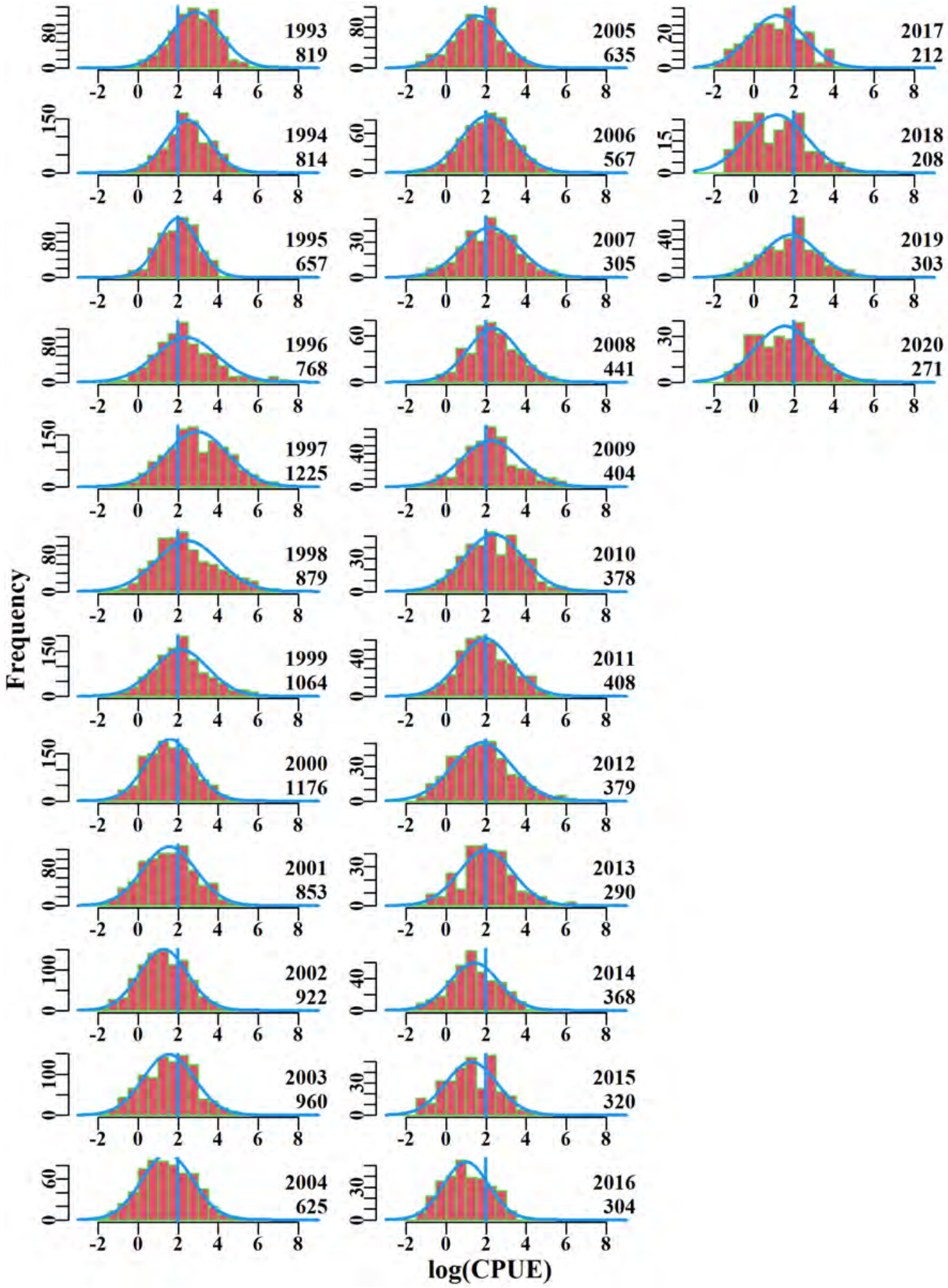

Figure 6.276. EasternGemfishSp. The natural log(CPUE) for each year of data available the blue lines are normal distributions fitted to the histogram frequencies. The numbers in each plot are the year and number of records.

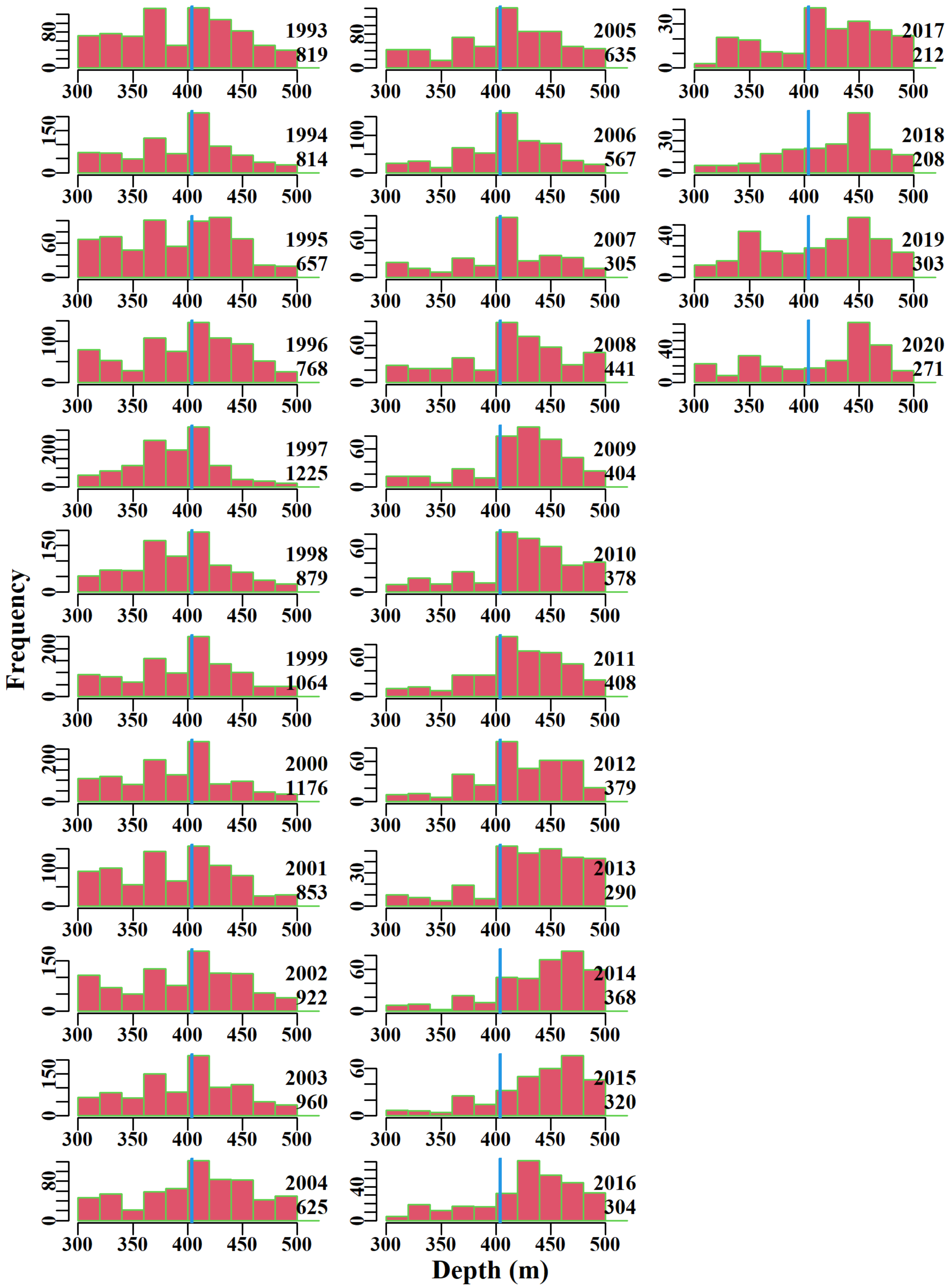

Figure 6.277. EasternGemfishSp. The average Depth of fishing for each year of data available to illustrate the development of the fishery through time. The numbers in each plot are the year and number of records.

6.43 Alfonsino

Initial data selection for Alfonsino (ALF - 37258002 - *Beryx splendens*) in the SET was conducted according to the details given in Table 6.195.

A total of 7 statistical models were fitted sequentially to the available data.

6.43.1 *Inferences*

The terms Year, Vessel, Zone, DepCat and one interaction term 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. The qqplot indicates that less than 5% of records, those in the lower tail of the distribution, deviate from the Normality assumption.

Annual standardized CPUE trend is noisy and relatively flat across the years analysed (Figure 6.278). From 2013 - 2015 the standardized trend deviates from the nominal geometric mean trend such that the trend stays on the long-term average CPUE while the geometric mean appears to rise well above it. There are now very few vessels contributing to this fishery and it appears that fishing is 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.

6.43.2 *Action Items and Issues*

No issues identified.

Table 6.195. 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, OTB, TMO
years	1986 - 2020

Table 6.196. 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

Year	Total	N	Catch	Vess	GeoM	Opt	StDev	C<30Kg	P<30Kg
1988	0.5	8	0.5	2	52.7	1.5759	0.000	0.138	0.257
1989	2.6	11	2.3	5	62.0	2.0214	0.655	0.120	0.052
1990	3.6	31	3.6	12	33.7	1.9835	0.596	0.352	0.097
1991	5.7	68	5.3	22	30.9	0.7181	0.568	0.962	0.182
1992	18.7	72	17.8	18	96.6	1.4762	0.532	0.565	0.032
1993	5.2	68	5.0	15	25.3	1.3877	0.551	0.826	0.164
1994	15.6	100	7.8	22	40.1	1.9133	0.550	1.137	0.146
1995	8.6	72	7.4	16	36.6	1.0500	0.561	0.834	0.113
1996	12.4	63	12.0	14	51.5	1.5352	0.566	0.727	0.061
1997	11.8	65	7.5	16	24.5	1.0530	0.568	0.805	0.107
1998	6.8	62	3.4	11	22.9	2.0199	0.574	0.501	0.146
1999	55.0	163	8.3	20	22.1	1.5690	0.552	1.971	0.238
2000	504.6	177	35.3	21	88.3	1.4279	0.555	2.463	0.070
2001	337.9	144	5.6	24	17.3	0.8226	0.556	1.948	0.350
2002	2643.0	222	24.9	31	153.3	1.0621	0.552	1.786	0.072
2003	1819.6	126	6.0	24	18.0	0.8504	0.557	1.589	0.264
2004	1411.3	172	16.1	27	19.7	1.0130	0.554	1.448	0.090
2005	445.2	161	7.9	24	23.6	0.9474	0.552	1.366	0.174
2006	458.4	223	11.0	22	29.8	1.1407	0.550	1.893	0.172
2007	530.3	206	8.5	13	15.4	1.2417	0.551	1.804	0.212
2008	260.2	359	48.2	13	37.6	1.2277	0.546	3.158	0.065
2009	98.8	336	15.3	14	24.2	0.8855	0.547	3.030	0.197
2010	57.9	261	8.8	16	10.1	0.5280	0.549	1.798	0.204
2011	807.2	229	4.3	15	4.6	0.4504	0.550	1.712	0.401
2012	616.1	131	1.9	14	4.3	0.3522	0.556	0.826	0.436
2013	225.6	95	3.7	14	8.5	0.3163	0.560	0.793	0.214
2014	85.0	100	5.9	12	85.4	0.4508	0.559	0.703	0.120
2015	76.2	178	13.5	13	120.1	0.3993	0.552	0.731	0.054
2016	23.3	96	3.2	10	18.9	0.2197	0.561	0.321	0.100
2017	8.2	136	6.1	12	27.8	0.2948	0.556	0.740	0.122
2018	8.4	151	5.3	12	21.2	0.3712	0.555	0.843	0.160
2019	34.5	158	7.6	15	10.6	0.3462	0.553	0.853	0.112
2020	5.3	112	3.1	14	6.3	0.3487	0.559	0.812	0.260

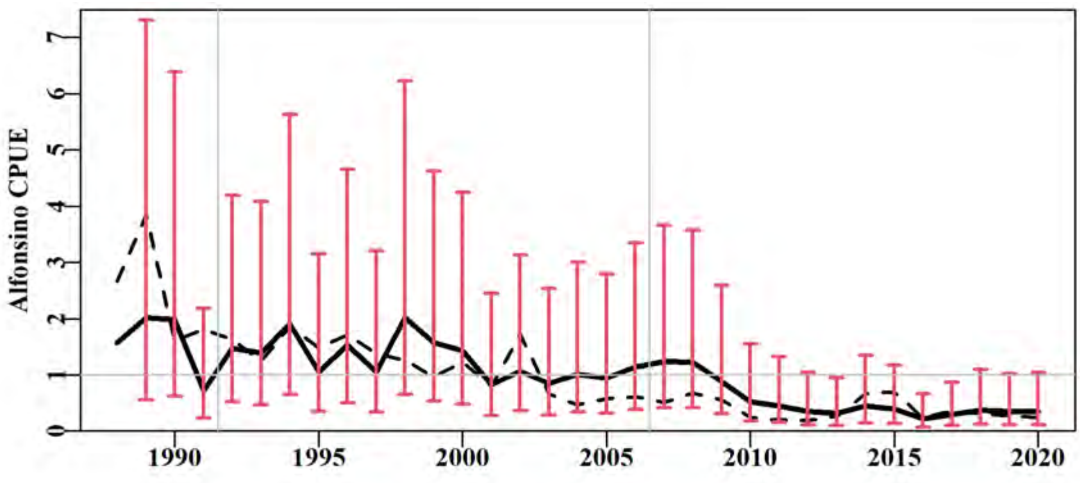

Figure 6.278. Alfonsino standardization. The dashed black line represents the geometric mean CPUE, solid black line the standardized CPUE. The red bars are the 95% confidence intervals about the mean estimates. The graph scales both time-series of standardized CPUE relative to the mean of each time-series.

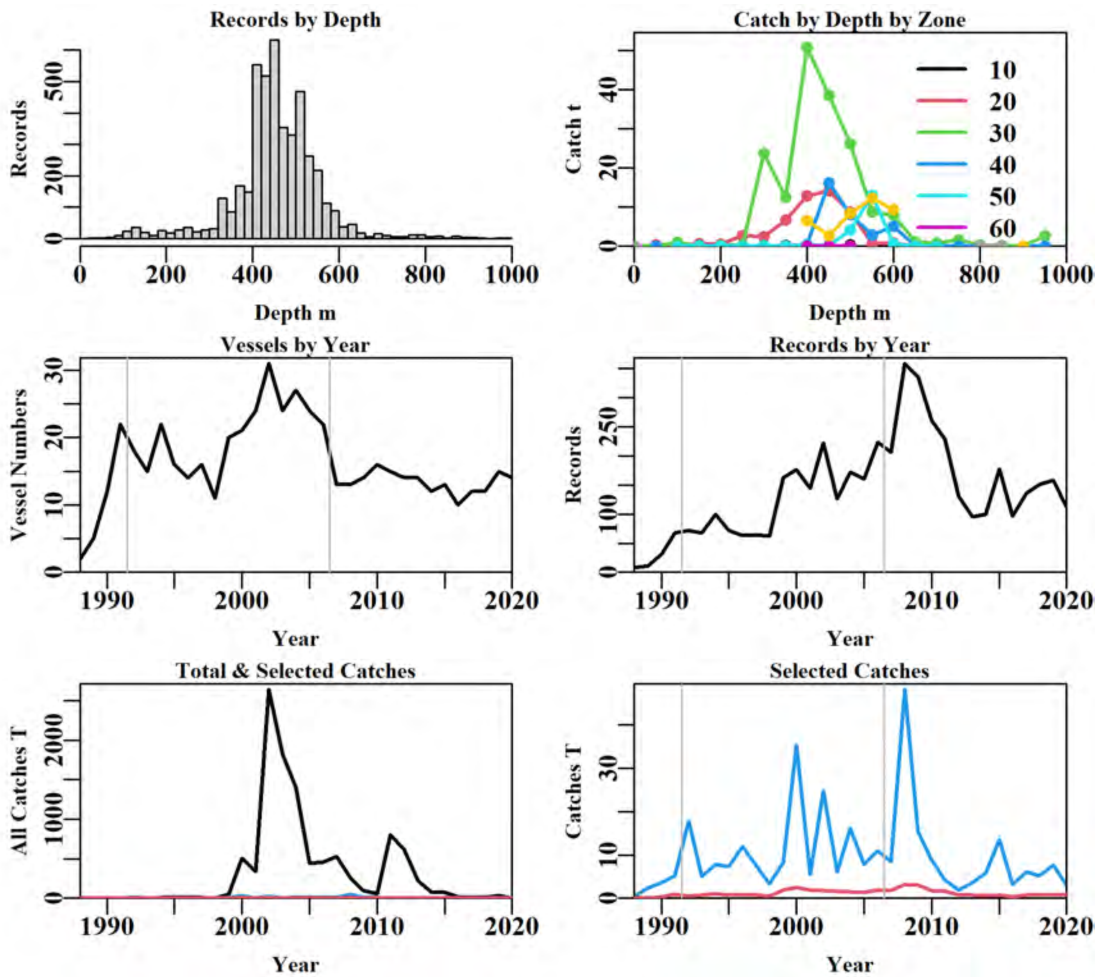

Figure 6.279. Alfonsino fishery details. The bottom left plot depicts all known catches (top black line), and all selected catches used in the analysis (middle blue line); the lower red line: selected catches < 30 kg).

Table 6.197. 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	14303	10469	10359	10284	6954	6214	4556
Difference	0	3834	110	75	3330	740	1658
Catch	10606	10521	10410	10408	1940	1928	323
Difference	0	85	111	2	8468	13	1604

Table 6.198. 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 6.199. 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

Term	AIC	RSS	MSS	Nobs	Npars	adj_r2	%Change
Year	5432	14795	2098	4556	33	11.8	0
Vessel	3069	8403	8491	4556	140	48.7	36.90
DepCat	3020	8244	8650	4556	159	49.4	0.75
Zone	2818	7863	9031	4556	166	51.7	2.26
DayNight	2777	7785	9109	4556	168	52.2	0.46
Month	2719	7650	9243	4556	179	52.9	0.71
Zone:DepCat	2651	7340	9554	4556	239	54.2	1.28

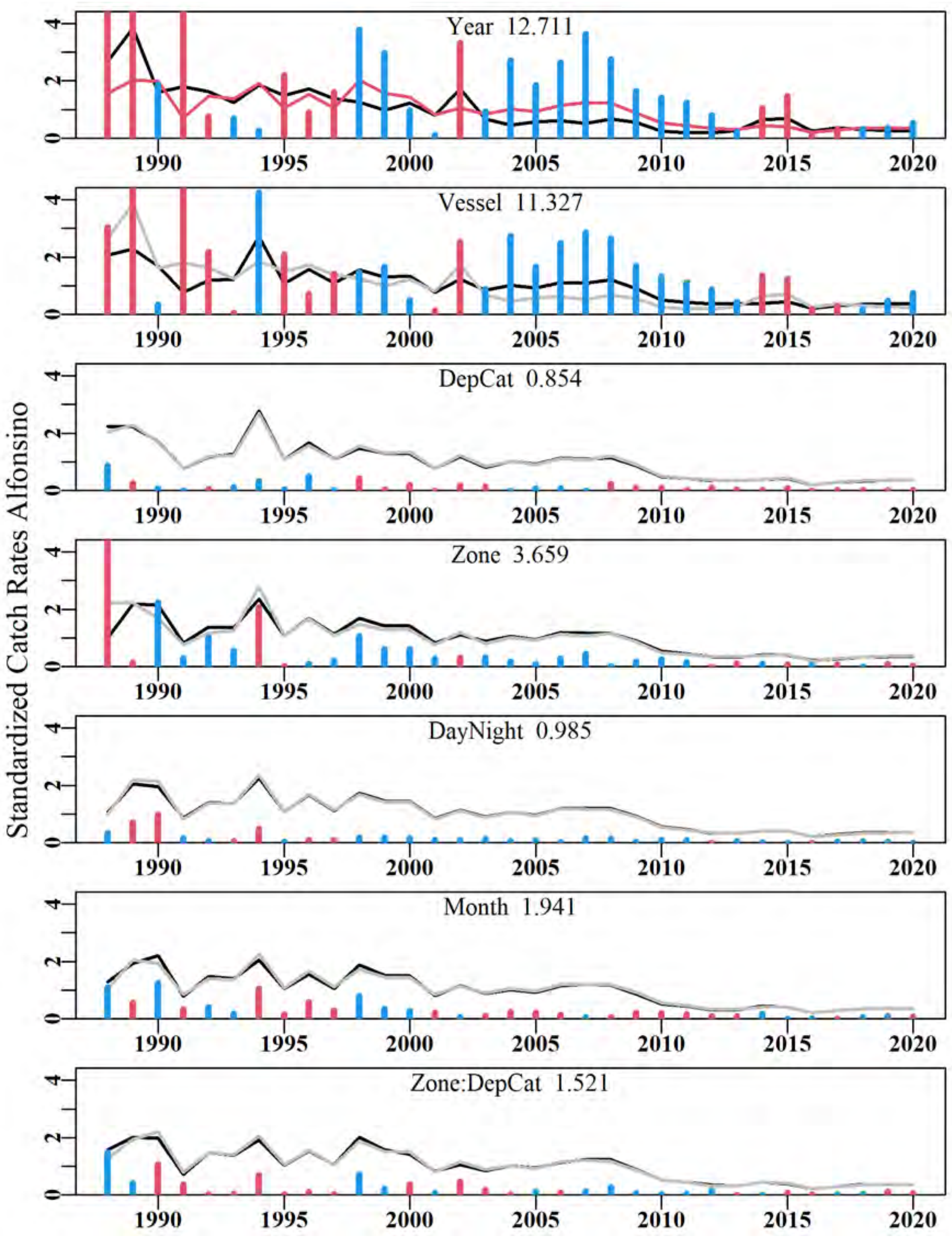

Figure 6.280. Alfonsino. The influence of each factor on the optimal standardization. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by vertical bars with blue bars indicating the optimum model is higher than the geometric 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.

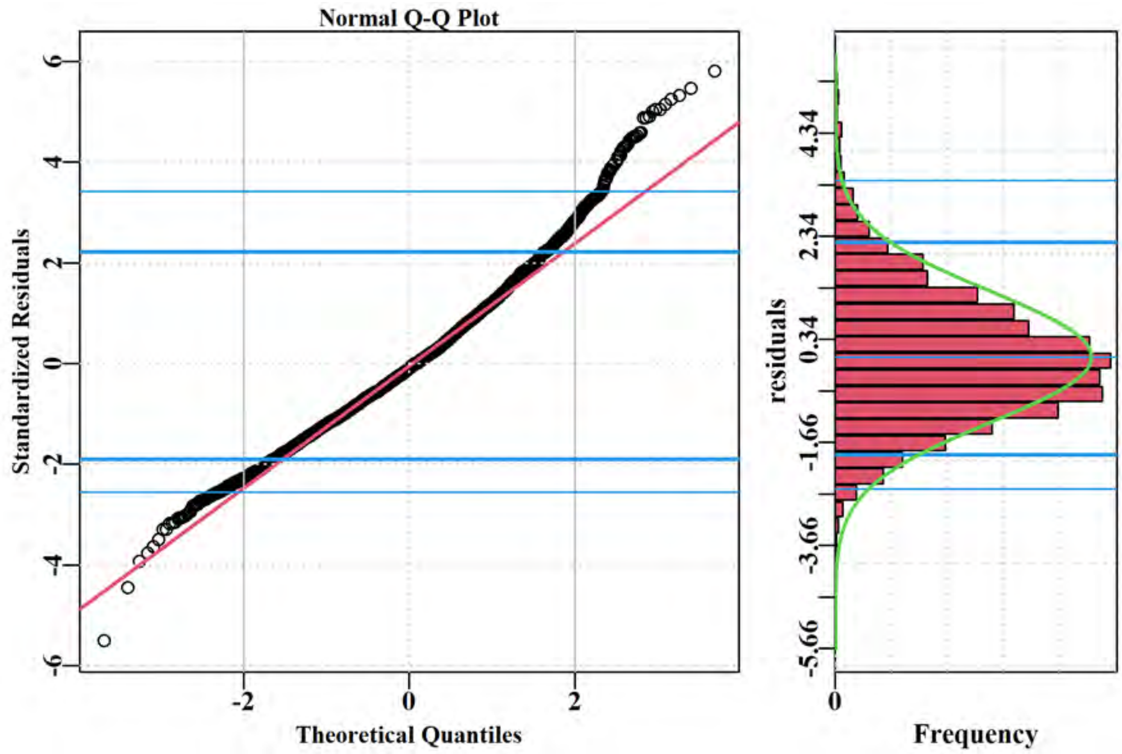

Figure 6.281. Alfonsino. diagnostic plots. The distribution of residuals from the optimum fit. The qqplot indicates the fit to the expected normality, while the histogram of residuals illustrates the 90% quantiles to indicate the intensity of any lack of fit at the margins of the distribution.

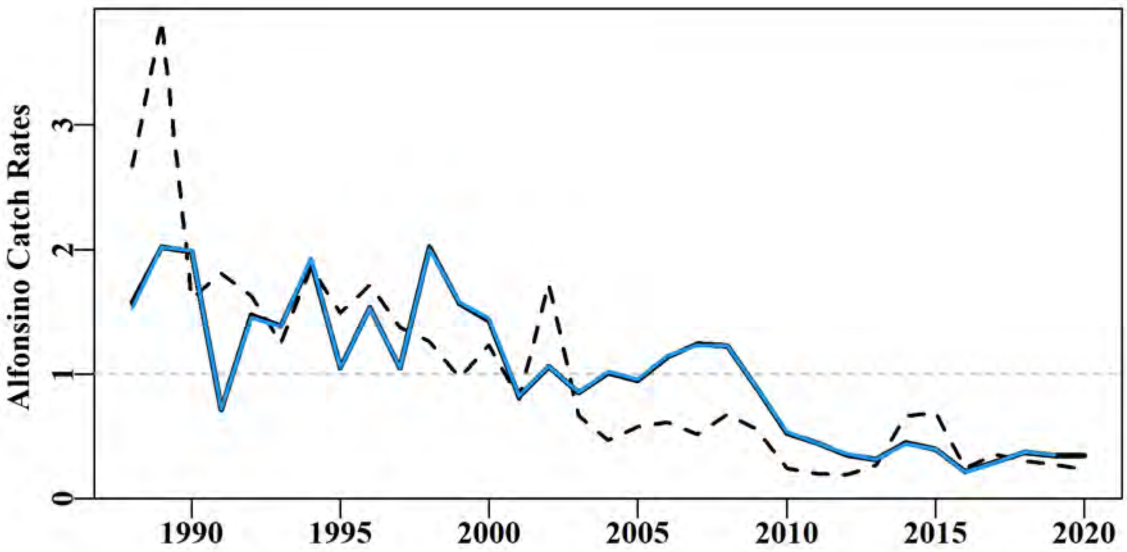

Figure 6.282. Alfonsino. A comparison of the previous year's standardization (blue line) with this year's. They should lie on top of each other, although small deviations may relate to data adjustments, particularly in very recent years.

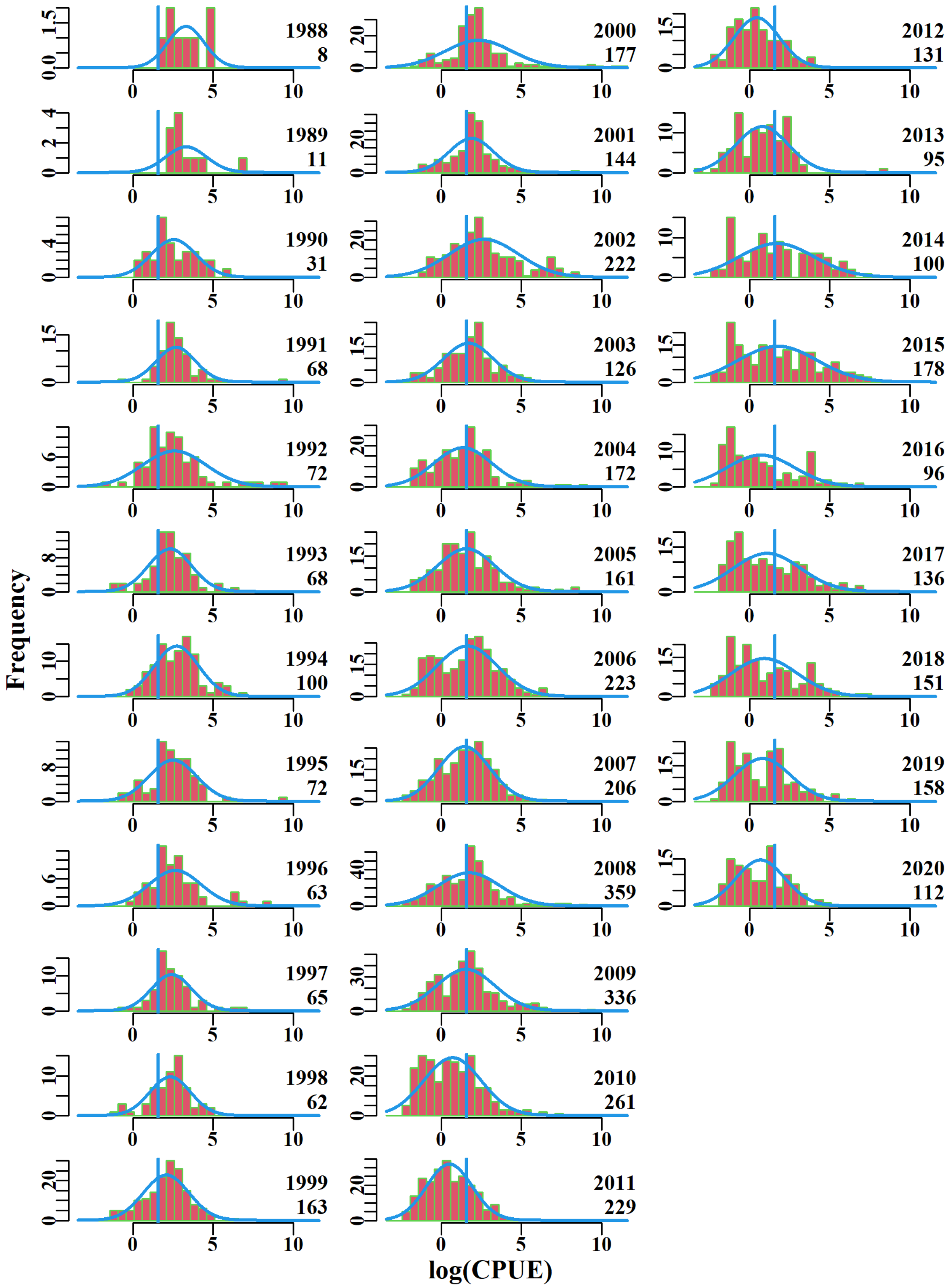

Figure 6.283. Alfonsino. The natural log(CPUE) for each year of data available the blue lines are normal distributions fitted to the histogram frequencies. The numbers in each plot are the year and number of records.

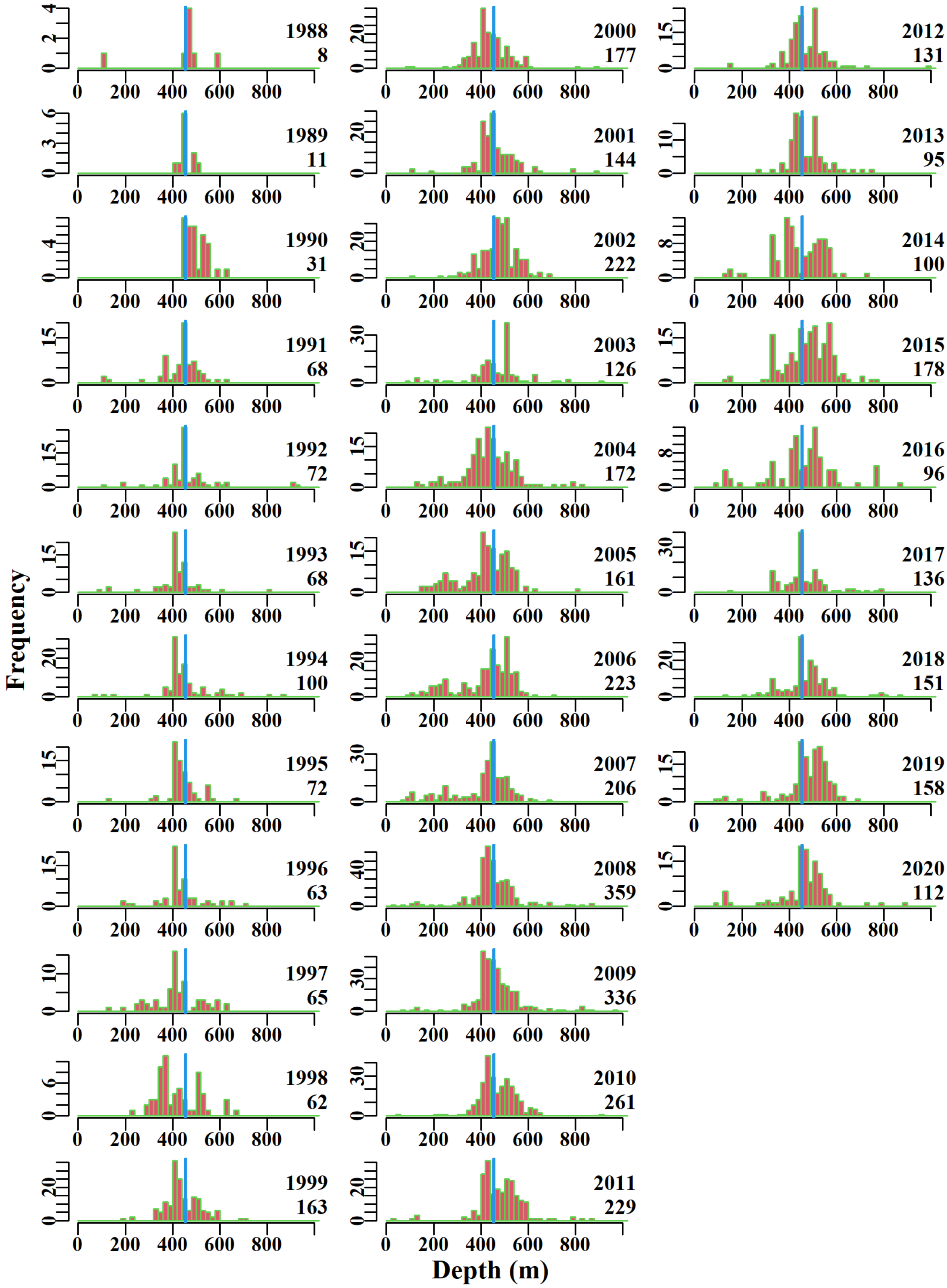

Figure 6.284. Alfonsino. The average Depth of fishing for each year of data available to illustrate the development of the fishery through time. The numbers in each plot are the year and number of records.

6.44 Redfish 10

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, OTB, in zones 10, and depths 0 to 400 m within the SET fishery for the years 1986 - 2020 were used in the analysis (Table 6.200). 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.

6.44.1 *Inferences*

The total annual redfish catch in 2019 (17.1 t) and 2020 (19.5 t) employed in the analysis are the lowest recorded in the series (i.e., between 1986 - 2020). Large scale changes in CPUE have occurred zone 10.

The terms Year, Vessel, DepCat 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 6.204). The qqplot suggests that the assumed Normal distribution is valid (Figure 6.288).

Annual standardized CPUE has declined since 1994 (relative to the previous year) and have been below average since 2000 (Figure 6.285).

6.44.2 *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 from the catches by vessel from 2007. This suggests that there have been transitional periods in the time-series of CPUE. This needs more attention because of the potential implications this has for the index of relative abundance through time.

Table 6.200. Redfish10. The data selection criteria used to specify and identify the fishery data to be included in the analysis.

Property	Value
label	Redfish10
csirocode	37258003
fishery	SET
depthrange	0 - 400
depthclass	25
zones	10
methods	TW, TDO, OTB
years	1986 - 2020

Table 6.201. Redfish10. 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

Year	Total	N	Catch	Vess	GeoM	Opt	StDev	C<30Kg	P<30Kg
1986	1687.5	4504	1528.6	81	143.1	1.9761	0.000	18.299	0.012
1987	1252.7	3366	1111.6	73	141.0	1.5569	0.037	14.700	0.013
1988	1125.5	2964	903.8	70	116.2	1.6580	0.039	12.169	0.013
1989	714.3	2148	586.3	64	100.0	1.3530	0.043	11.362	0.019
1990	931.4	1883	691.5	49	137.1	1.7958	0.045	8.111	0.012
1991	1570.6	2453	1051.4	44	165.0	1.9048	0.042	10.458	0.010
1992	1636.7	2492	1414.9	42	265.9	2.6093	0.042	9.890	0.007
1993	1921.4	2983	1598.1	47	253.0	3.1259	0.040	11.246	0.007
1994	1487.8	4217	1130.3	49	130.0	2.1684	0.037	20.580	0.018
1995	1240.6	4397	1023.3	46	92.7	1.4124	0.037	23.928	0.023
1996	1344.0	4057	1097.0	49	116.5	1.2093	0.037	22.841	0.021
1997	1397.3	2937	1154.4	50	202.4	1.4028	0.040	14.685	0.013
1998	1555.2	3106	1371.1	43	259.2	1.7252	0.040	13.289	0.010
1999	1116.5	3005	969.2	44	166.1	1.3894	0.040	14.534	0.015
2000	758.5	3290	639.9	49	99.8	0.9453	0.039	18.241	0.029
2001	742.5	3212	604.0	41	96.4	0.8993	0.039	19.138	0.032
2002	807.1	3453	598.4	44	86.1	0.7358	0.039	19.599	0.033
2003	615.6	2665	477.2	43	90.9	0.7294	0.041	15.409	0.032
2004	475.2	2696	388.5	44	69.7	0.6126	0.041	17.164	0.044
2005	483.5	2419	359.6	41	61.8	0.6244	0.043	14.484	0.040
2006	325.5	1753	255.5	34	58.9	0.5941	0.047	11.515	0.045
2007	216.3	1200	148.4	18	50.3	0.5305	0.054	7.909	0.053
2008	183.8	1388	154.8	22	41.9	0.4982	0.052	10.088	0.065
2009	160.5	1161	123.1	20	35.7	0.3909	0.055	8.969	0.073
2010	152.8	1210	112.0	19	32.3	0.3763	0.054	10.241	0.091
2011	87.3	861	57.0	17	27.9	0.3000	0.061	6.378	0.112
2012	66.4	968	54.5	17	22.5	0.2491	0.058	8.376	0.154
2013	62.7	761	51.5	18	25.1	0.2981	0.063	6.980	0.136
2014	86.9	1093	75.7	19	29.0	0.4224	0.056	9.408	0.124
2015	52.2	936	47.2	19	18.9	0.2763	0.059	8.546	0.181
2016	38.4	659	31.1	19	18.3	0.2289	0.068	6.080	0.195
2017	25.4	438	20.5	15	18.5	0.2387	0.080	4.334	0.211
2018	29.9	495	23.0	16	17.8	0.2079	0.079	3.970	0.173
2019	26.7	382	17.1	13	17.0	0.2418	0.088	3.592	0.210
2020	47.0	414	19.5	14	16.3	0.3125	0.085	4.076	0.209

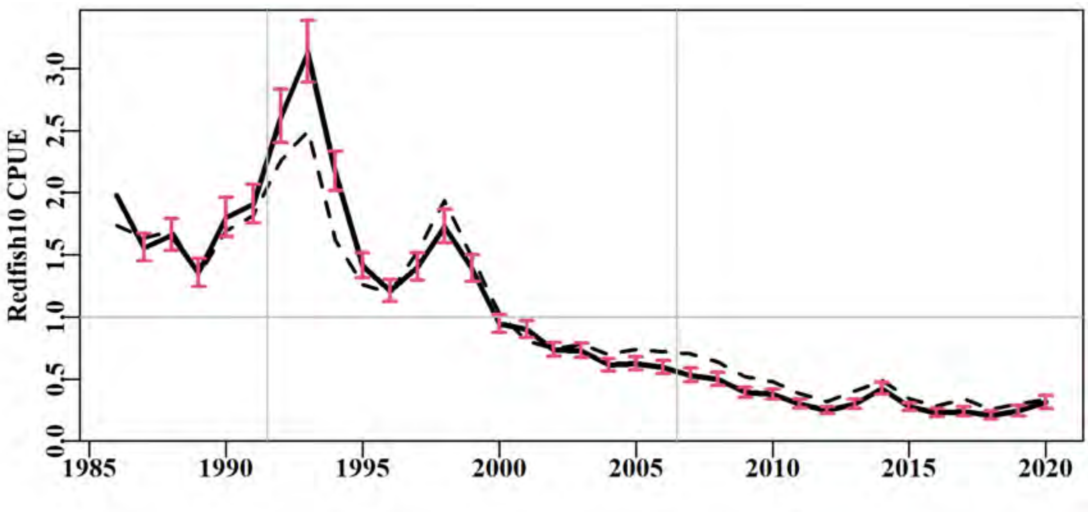

Figure 6.285. Redfish10 standardization. The dashed black line represents the geometric mean CPUE, solid black line the standardized CPUE. The red bars are the 95% confidence intervals about the mean estimates. The graph scales both time-series of standardized CPUE relative to the mean of each time-series.

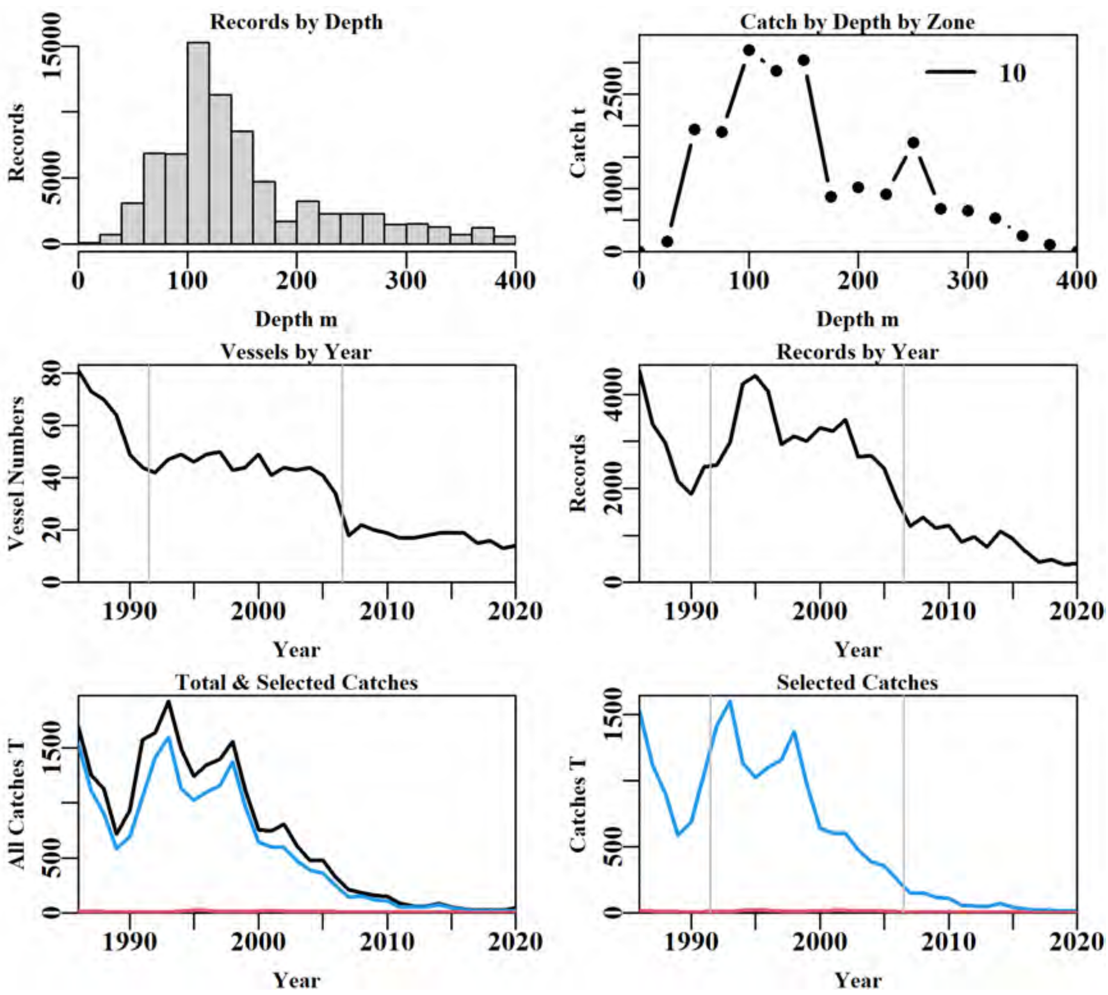

Figure 6.286. Redfish10 fishery details. The bottom left plot depicts all known catches (top black line), and all selected catches used in the analysis (middle blue line); the lower red line: selected catches < 30 kg).

Table 6.202. Redfish10 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	122039	116414	113200	112169	76462	75988	75966
Difference	0	5625	3214	1031	35707	474	22
Catch	24592	24094	23695	23538	20019	19892	19890
Difference	0	498	399	157	3519	128	2

Table 6.203. The models used to analyse data for Redfish10

	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 + Zone:Month
Model7	Year + Vessel + DepCat + DayNight + Month + Zone:DepCat

Table 6.204. Redfish10. 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

Term	AIC	RSS	MSS	Nobs	Npars	adj_r2	%Change
Year	78545	213432	22569	75966	35	9.5	0
Vessel	69997	189966	46035	75966	185	19.3	9.79
DepCat	65461	178879	57122	75966	201	24.0	4.69
DayNight	64460	176523	59478	75966	204	25.0	1.00
Month	64329	176169	59832	75966	215	25.1	0.14
Zone:Month	64329	176169	59832	75966	215	25.1	0.00
Zone:DepCat	64329	176169	59832	75966	215	25.1	0.00

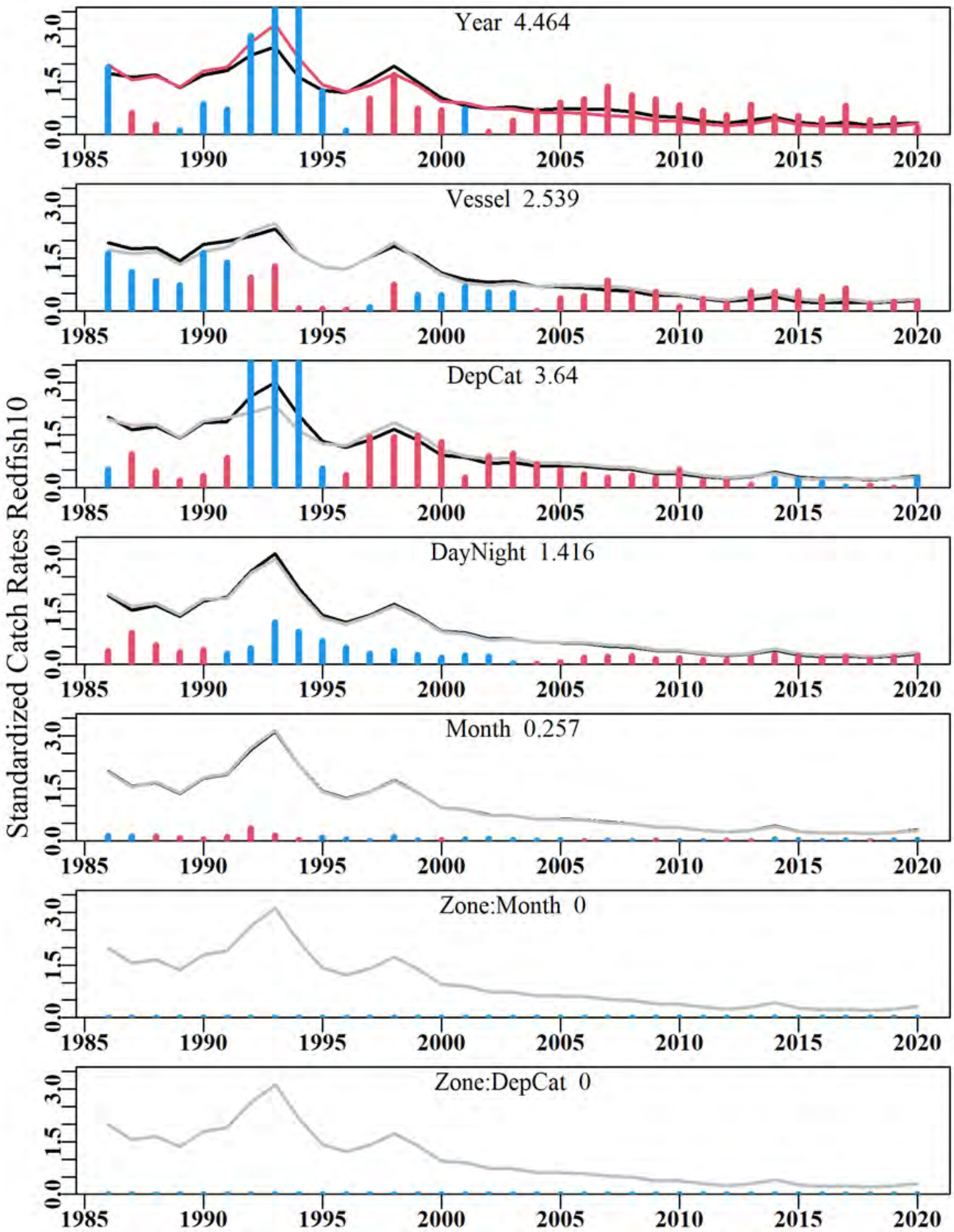

Figure 6.287. Redfish10. The influence of each factor on the optimal standardization. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by vertical bars with blue bars indicating the optimum model is higher than the geometric 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.

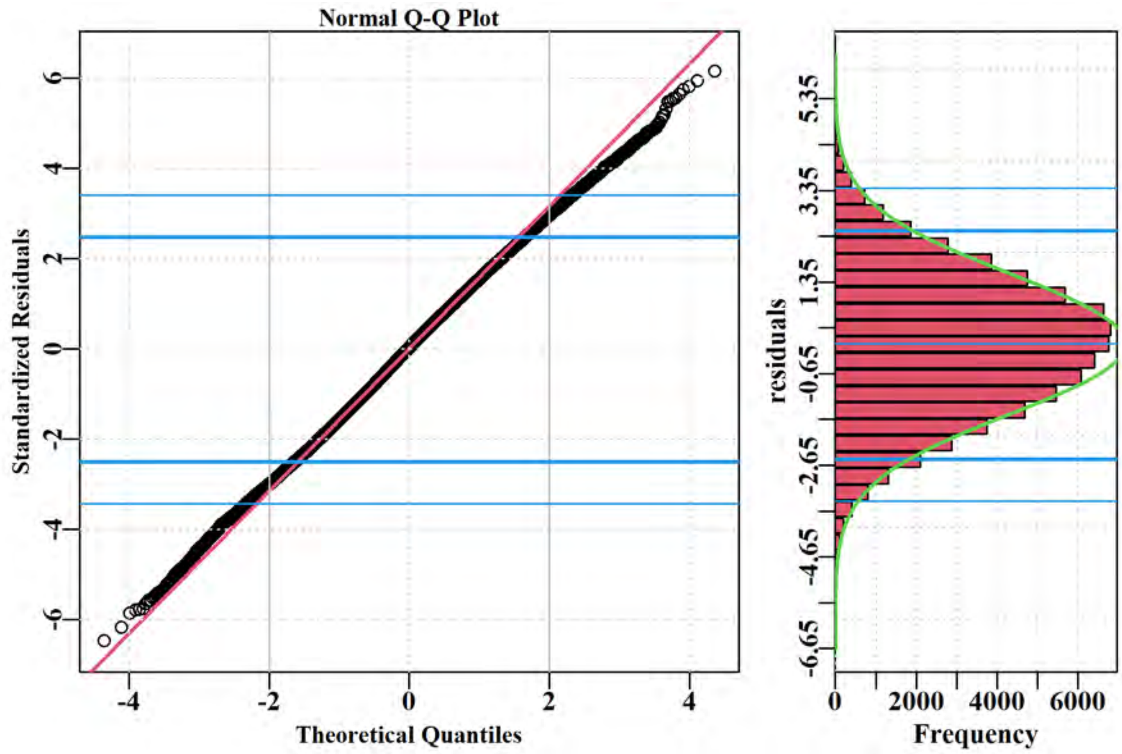

Figure 6.288. Redfish10. diagnostic plots. The distribution of residuals from the optimum fit. The qqplot indicates the fit to the expected normality, while the histogram of residuals illustrates the 90% quantiles to indicate the intensity of any lack of fit at the margins of the distribution.

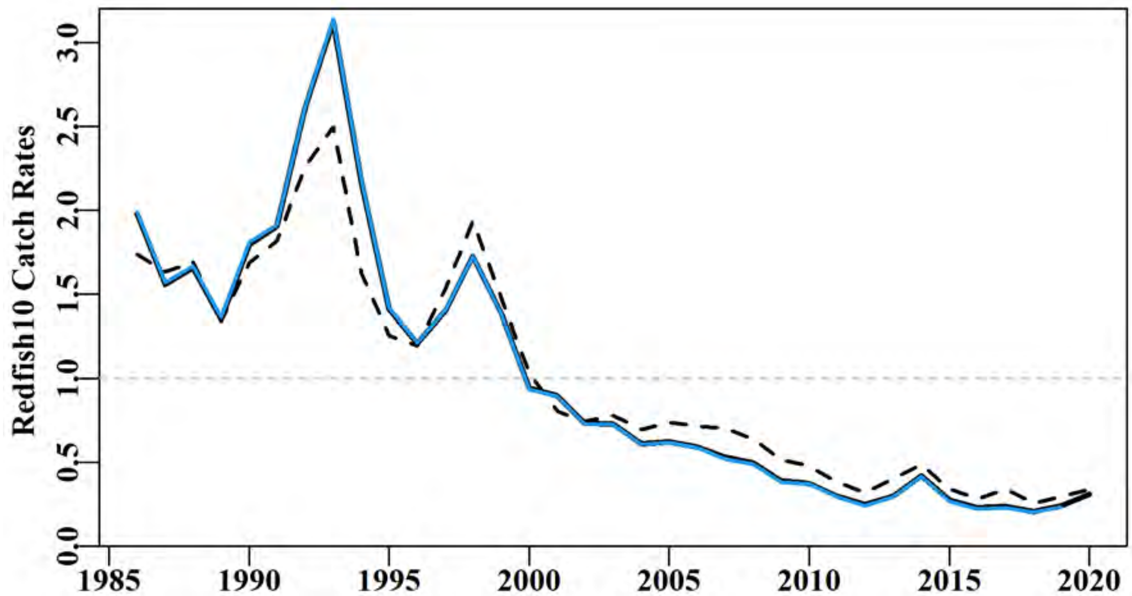

Figure 6.289. Redfish10. A comparison of the previous year's standardization (blue line) with this year's. They should lie on top of each other, although small deviations may relate to data adjustments, particularly in very recent years.

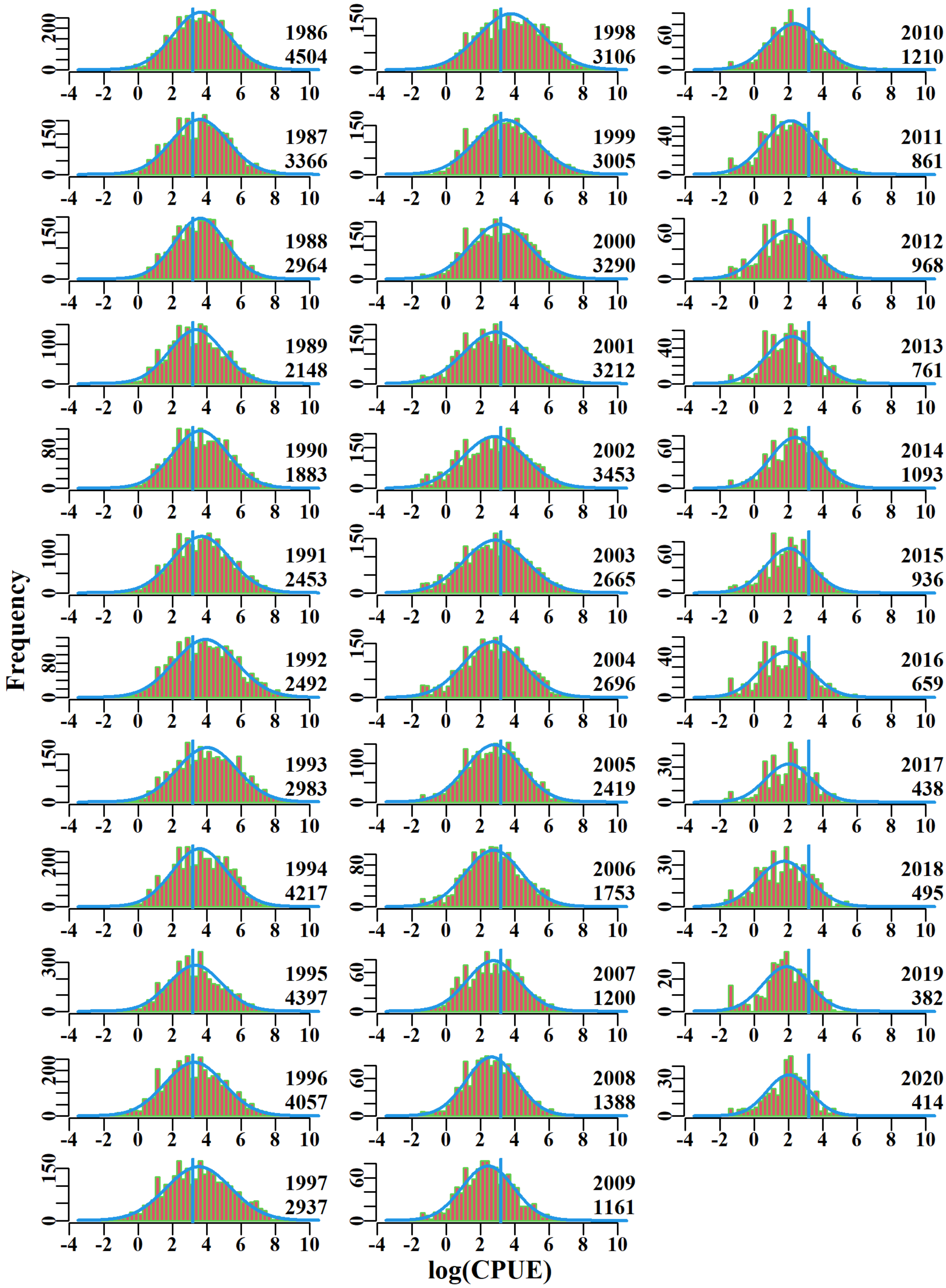

Figure 6.290. Redfish10. The natural log(CPUE) for each year of data available the blue lines are normal distributions fitted to the histogram frequencies. The numbers in each plot are the year and number of records.

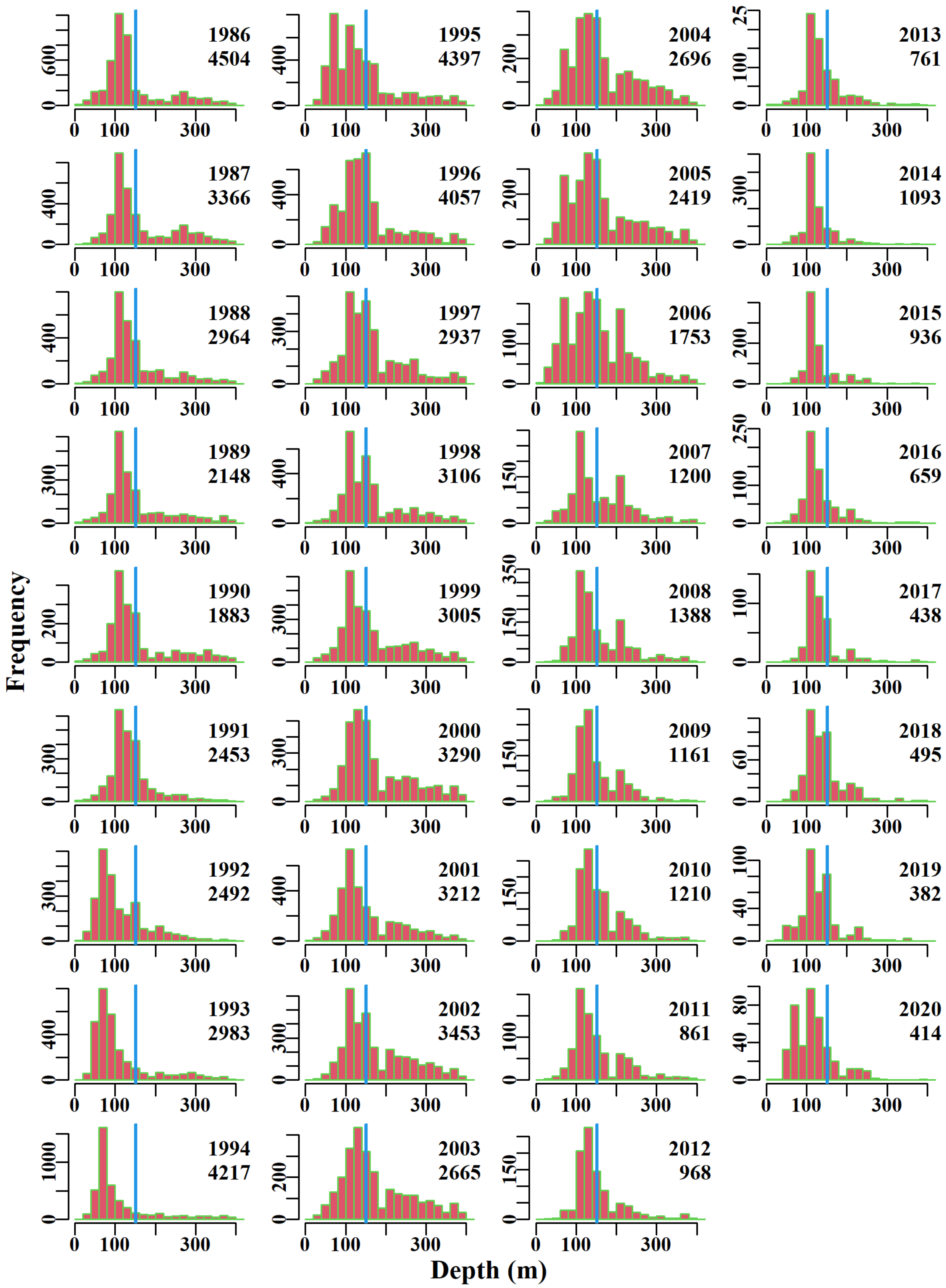

Figure 6.291. Redfish10. The average Depth of fishing for each year of data available to illustrate the development of the fishery through time. The numbers in each plot are the year and number of records.

6.45 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. Geoff Tuck and Jemery Day (CSIRO) are also thanked for their helpful comments on this report.

6.46 References

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7. Update Part 1: Statistical CPUE (catch-per-hook) Standardizations for Blue-eye Trevalla (Auto-line and Drop-line) in the SESSF (data to 2020)

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7.1 Executive Summary

This report updates standardized catch-per-unit (CPUE; catch per hook) indices for Blue-eye Trevalla (*Hyperoglyphe antarctica*) to 2020, based on the method used in Haddon and Sporcic (2017), by combining standardized CPUE series of two different line gears (drop-line and auto-line) to obtain a single CPUE series for the line sector for zones 20-50 only. These two time-series of standardized CPUE from drop-line and auto-line were combined using catch weighting and scaled the two series to the same mean CPUE of 1.0 for the period of 2002 - 2006, which was the period of overlap (as agreed by SERAG).

There is a downward trend over the analysis period for both combined standardized catch-per-hook and catch-per-day CPUE. Since 2014 a downward trend is apparent for the combined standardized CPUE despite a slight increase in the most recent index compared with the previous one. All analyses have limited numbers of observations and hence are relatively uncertain. There was a 64 t decrease (i.e., 50%; from ~ 131 t to ~ 66 t) in logbook catch by both auto-line and drop-line in the west (zone 40, 50) in 2019 relative to 2018, followed by a 9 t increase in catch (14%; from 66 t to 75 t) in 2019 relative to 2020. By contrast, there was a 48 t increase (95%; from ~51 t to 99 t) in the Great Australian Bight (GAB) in 2019 relative to the previous year, followed by a 36 t decrease in 2019 (36%; 99 t to 63 t) relative to 2020. Also, an average of 71 t per year has been recorded in logbooks, by both auto-line and drop-line in the east (zones 10, 20, 30) since 2017.

7.2 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 (e.g. Figure 7.5), although its juvenile stages are widely dispersed. Not only is it patchily distributed but the fishery differs markedly by area through the application of different methods and histories of exploitation. The differences in exploitation history along with sampling different areas in different years may have been sufficient to have led to the appearance of heterogeneity in the biological characteristics of different populations. There is little consistency between consecutive years in the age structure and length structure of samples (Figure 7.1); 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 Trevalla and has made the application of the Tier 3 catch-curve approach equally problematic (Fay, 2007a, b). Such spatial heterogeneity has been reviewed and further evidence presented, all of which supported the notion that there were spatially structured differences between Blue-eye Trevalla populations between regions around the south-east of Australia (Williams et al., 2016).

Table 7.1. 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 - 2020. Data filters were restricted to fisheries SET, GAB, SEN, GHT, SSF, SSG, and SSH. Methods were limited to AL, DL, TW, and TDO. Only CAAB code = 37445001 that identifies *Hyperoglyphe antarctica* were included.

Year	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	90.932	93	384.409	1078	95.042	1893
2001	47.884	76	335.872	799	90.218	1809
2002	134.067	234	223.074	619	67.998	1548
2003	219.676	487	221.649	587	28.920	1211
2004	329.608	1345	158.491	520	48.767	1559
2005	301.453	1151	93.779	368	42.969	1169
2006	354.593	1099	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	52.839	101	25.128	301
2016	190.073	305	91.297	139	12.871	244
2017	250.218	344	65.524	183	52.961	425
2018	218.140	392	57.346	192	42.332	387
2019	223.649	444	33.076	171	18.931	304
2020	188.235	482	20.637	130	6.149	201

While there is a long history of catches by trawl in the Blue-eye Trevalla fishery, most catch has always been taken by line-methods (generally less than 13% of catches are taken by trawl since 2003; Table 7.1). Unfortunately, fisheries data from line methods, in the Gillnet Hook and Trap (GHT) fishery, only began to be collected comprehensively from late in 1997 onwards (Table 7.1). 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 7.1, Figure 7.2). 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 7.2; Table 7.1).

In the two years, 2013 - 2014, drop-line catches dropped to 10 t or less while auto-line catches continue to dominate the fishery. However, in 2015, drop-line catches increased by about 43 t (i.e., from 10 t to 53 t), while auto-line catches dropped by about 34 t (i.e., from 227 t to 193 t) from the previous year (Table 7.1; Figure 7.2).

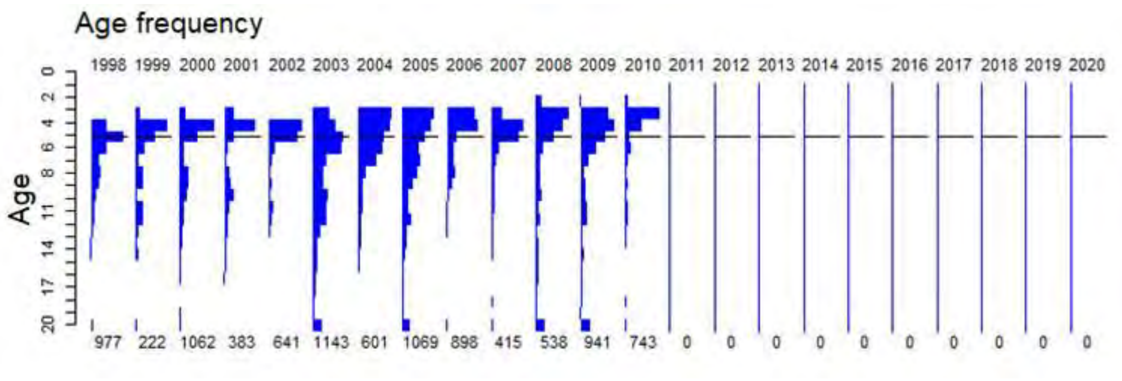

Figure 7.1. Age distributions sampled from the catches of Blue-eye Trevalla (*Hyperoglyphe antarctica*) for the years 1995 - 2020 (Bessell-Browne et al., 2021). The sample sizes in the bottom row of numbers should be sufficient to provide a good representation if the stock were homogeneous in its properties.

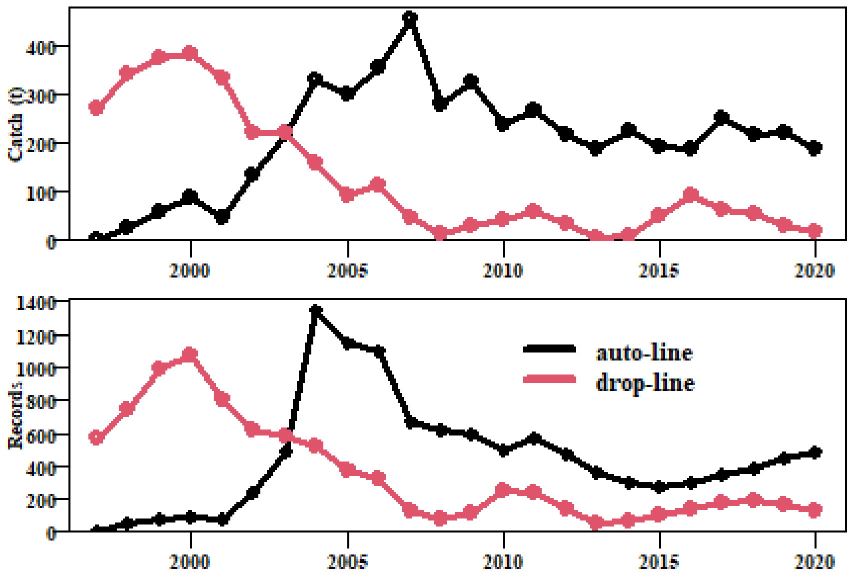

Figure 7.2. The trends in the number of records and catch of Blue-eye Trevalla from 1997-2020 by the two main line methods (Table 7.1). Most catches are now taken by auto-line.

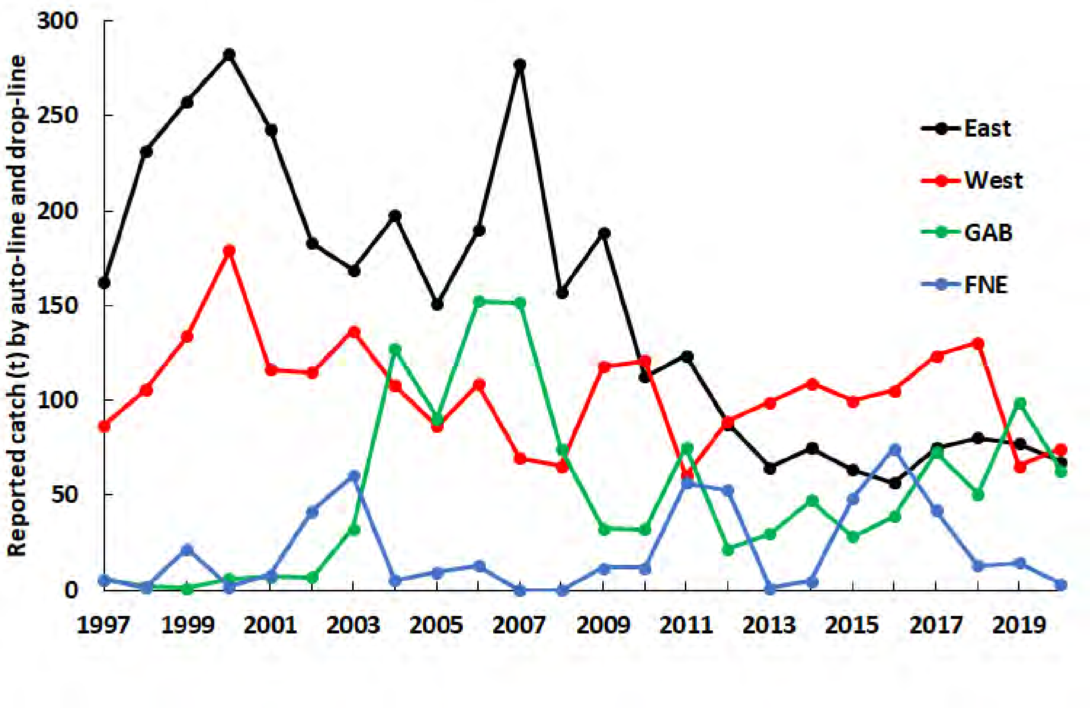

Figure 7.3. The total reported catches from 1997 - 2020 taken by auto-line and drop-line combined across the east (zones 20, 30), the west (zones 40, 50), the GAB (zones 83, 84, 85) and the far north east (zones 91, 92).

There was a 64 t decrease (i.e., 50%; from ~ 131 t to ~ 66 t) in logbook catch by both auto-line and drop-line in the west (zone 40, 50) in 2019 relative to 2018, followed by a 9 t increase in catch (14%; from 66 t to 75 t) in 2019 relative to 2020. By contrast, there was a 48 t increase (95%; from ~51 t to 99 t) in the Great Australian Bight (GAB) in 2019 relative to the previous year, followed by a 36 t decrease in 2019 (36%; 99 t to 63 t) relative to 2020. Also, an average of 71 t per year has been recorded in logbooks, since 2017 in the east (zones 10, 20, 30) (Table 7.2; Figure 7.3).

7.2.1 *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 Trevalla 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 assessment 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 Trevalla fishery but the time series of significant catches by that method was relatively short (only six years from 2002 - 2007; Table 7.1 and Figure 7.2). At that time some way of extending the time series was required to allow for the application of the Tier 4 methodology. Unfortunately, in the logbook records there was, and sometimes still is, often confusion in how to record effort (in terms of number of lines and number of hooks per line, or number of line drops, or length of main line) so it was not feasible at that time to estimate CPUE as a catch-per-hook. Instead CPUE was based on catch-per-record, which was equivalent to catch-per-day. The CPUE standardization conducted in 2008 on data from 1997 - 2007 (Haddon, 2009) was the first time that the catch-per-day data from drop-line was combined with auto-line catch-per-day data, with a justification presented to the RAGs. This was followed in 2009 by a summary of the separate auto-line and drop-line CPUE and a more detailed 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 extend the time series of line-caught Blue-eye Trevalla back to 1997 rather than 2002. Despite this extension of time, the early Tier 4 Blue-eye Trevalla 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 Trevalla was assessed using a standardized CPUE time series from the combined auto-line and drop-line fisheries, which combined data from the two methods from 8 zones (SESSF zone 10 - 50 with 83 - 85; Figure 7.4). 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 catch-per-day was analysis repeated in 2014 (Sporcic and Haddon, 2014), however, because of the unaccounted influences of issues such as (i) a restriction of fishing location options due to an increase in the number of marine closures (i.e., all methods and solely for auto-line) over known Blue-eye Trevalla fishing grounds, (ii) a reported expansion of depredations by whales on auto-line catches in association with changed behaviour of fishing vessels in the presence of whales, (iii) a movement of fishing effort much further north off the east coast of New South Wales and Queensland and (iv) ignoring 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 Trevalla fishery. It as therefore necessary 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 7.2. Blue-eye Trevalla catch by SESSF zone. Data filtered on species, fisheries and are limited to catches by auto-line and drop-line. Only zones 20, 30, 40, 50, 83, 84, 85, 91, and 92 have significant catches.

Year	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	69.568	137.520	94.846	50.728	12.610	61.083	53.409	5.045	0.180
2005	85.138	103.016	59.675	43.673	19.478	29.313	41.815	4.881	4.700
2006	67.365	122.376	80.766	27.767	31.416	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	51.836	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	14.158	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	38.237	10.147
2016	7.557	49.054	69.982	35.283		29.283	9.576	42.901	31.805
2017	9.615	65.340	83.638	39.839	1.800	58.788	11.969	27.845	14.390
2018	16.657	63.644	86.034	44.675	7.499	30.869	12.575	6.915	6.035
2019	10.216	67.136	39.130	26.444	54.461	34.022	10.656	9.207	5.452
2020	7.000	60.836	45.221	29.392	30.498	23.149	9.407	2.370	0.840

7.2.2 *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 7.5) 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 Trevalla 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 was repeated to include data to 2019.

7.2.3 *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 are 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.

7.2.4 *Report Structure*

There are three 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.

7.2.5 *CPUE Standardization*

7.2.5.1 Data Selection

Blue-eye Trevalla catches were selected by method and area for CPUE analyses. CPUE from these specific areas (Figure 7.4) were standardized using the methods described below and reported elsewhere.

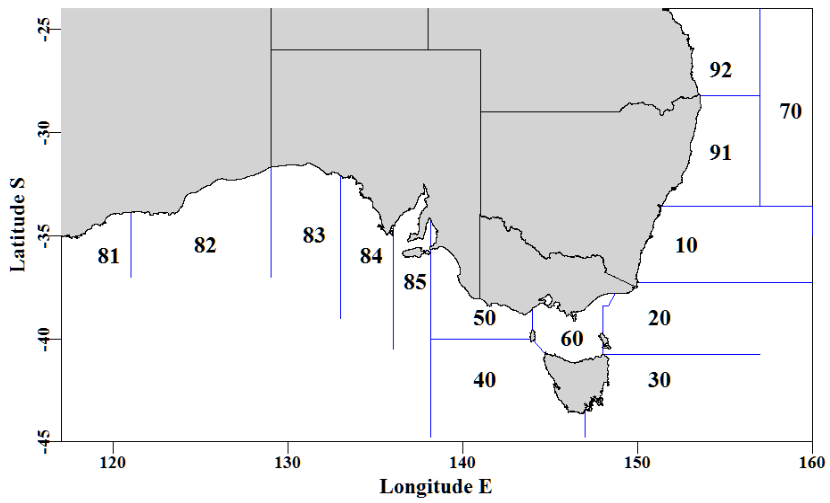

Figure 7.4. A schematic diagram depicting the statistical reporting zones in the SESSF, as used in this document. The GAB fishery is to the west of Zone 50. The main SESSF trawl zones are zones 10 - 50. Each zone extends out to the boundary of the EEZ, except for zones 50 and 60, and for zones 92 and 91, which are bounded by zone 70.

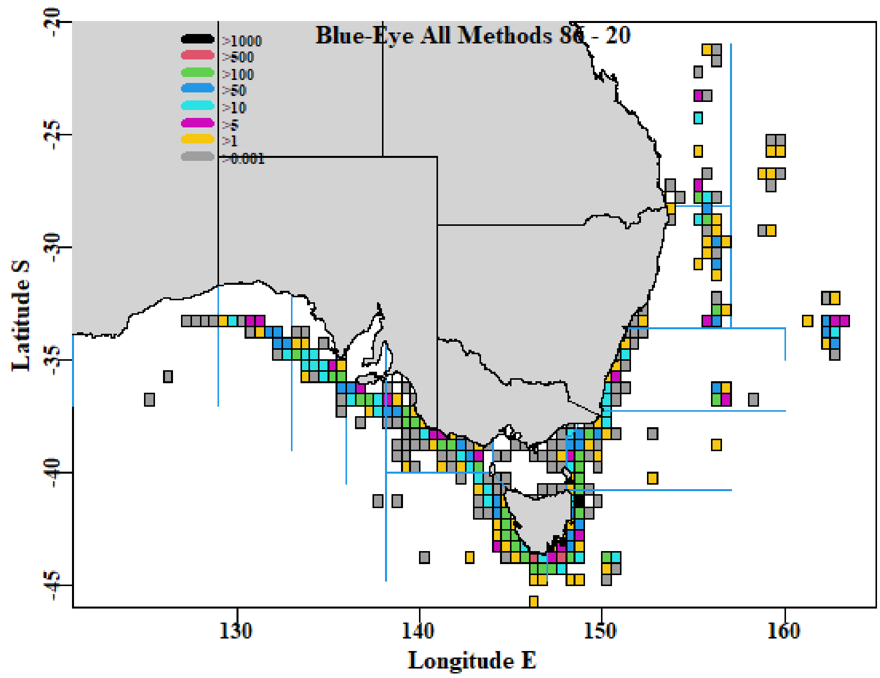

Figure 7.5. All reported catches of Blue-eye Trevalla by all methods from 1986 - 2019 in 0.5 degree squares. At least two records per square were required for inclusion in the map (all data were used in the analyses). The legend units are in tonnes summed across all years.

7.2.6 *General Linear Modelling*

Where trawling was the method used, CPUE was 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. CPUE was 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 and 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 $\mathrm{Ln}(CPUE_i)$ is the natural logarithm of the CPUE (either kg/hr, 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.).

7.2.6.1 The Year Effect

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

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

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

7.3 Results

7.3.1 *Reported Catches*

Blue-eye Trevalla 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 7.5). 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 7.3. 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 Trevalla.

	Total	Method	Depth	Years	Zones	Fishery
Records	56604	11706	11047	10916	10342	10304
Difference	0	44898	659	131	574	38
Catch	11815.77	5323.48	5039.07	4963.12	4654.41	4632.95
DeltaC	0	6492.29	284.41	75.95	308.70	21.47
%DiffC	00	54.95	5.34	1.51	6.22	0.46

Table 7.4. Blue-eye Trevalla catch by SESSF zone taken by auto-line. Total is all Blue-eye Trevalla 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 zones 20 - 85 taken by auto-line.

Year	Total	Other	AL	20	30	40	50	83	84	85
1997	464.069	463.802	0.267			0.267				
1998	444.979	429.990	14.989		0.033	14.956				
1999	546.140	499.471	46.670	35.575	1.725	9.370				
2000	657.408	629.109	28.299	12.210	6.061	10.028				
2001	580.054	539.822	40.232	2.000	23.634	14.598				
2002	462.267	330.901	131.366	2.640	65.100	42.326	21.300			
2003	561.989	405.003	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	441.340	143.057	298.283	84.748	59.833	57.312	37.012	19.058	5.185	35.135
2006	534.272	189.853	344.418	67.075	66.585	78.303	25.309	31.128	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	27.542	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	116.669	182.530	6.620	35.462	68.554	33.036		29.283	9.576
2017	380.850	134.126	246.724	9.615	45.621	83.106	35.824	1.800	58.788	11.969
2018	338.247	125.443	212.804	8.720	40.499	77.118	35.620	7.499	30.869	12.480
2019	292.713	76.453	216.260	8.597	51.605	36.710	20.209	54.461	34.022	10.656
2020	219.360	38.248	181.112	6.705	53.093	37.833	23.724	30.197	22.597	6.963

Table 7.5. 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			

7.3.2 *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 7.6). 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 7.7). This source of confusion appears to have propagated confusion in the logbook entries for a number of years following the changes and is the main reason this data needs review.

Table 7.6. 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	10175

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 7.6). 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 7.7. 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			298.283	0	0	1136
2006			344.418	0	0	1075
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			219.554	0	0	291
2015			183.735	0	0	251
2016			182.530	0	0	289
2017			246.724	0	0	338
2018			212.789	0	0	378
2019			216.260	0	0	425
2020			181.112	0	0	468

7.3.2.1 Vessels per Year

A total of 14 vessels have reported catches of Blue-eye Trevalla using auto-line since 1997, although a maximum of 11 reported in any single year (Figure 7.6). The active fleet expanded between 2002 - 2004. The structural adjustment occurred from November 2005 to November 2006 and that (along with TAC changes) appears to have stabilized numbers at about six vessels, with only three or four contributing in recent years. However, the four lowest catching vessels, across all years 1997 - 2016, have only landed totals of either 0.815, 3.55, 6.0, or 6.256 t of Blue-eye Trevalla in between one and six 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 7.6). However, for the standardization analysis, no selection on minimum catch was made.

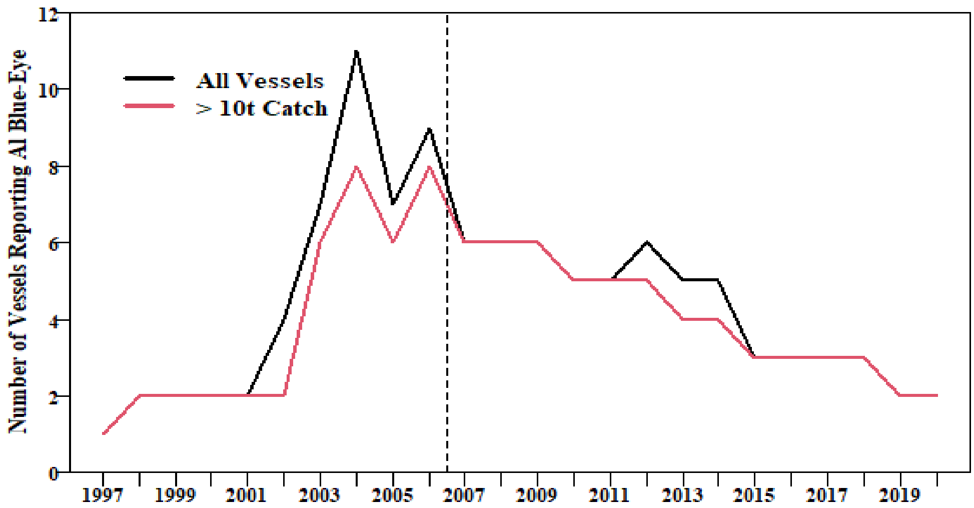

Figure 7.6. The number of auto-line vessels reporting Blue-eye Trevalla catches per year of the fishery compared with the number of vessels that caught more than a total of 10 tonnes over the 20 years from 1997 - 2019. Vertical dashed line is 2006.5, identifying the structural adjustment.

7.3.2.2 Catch-per-Hook

Table 7.8. 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 7.9. The sequence of data selection and editing and their effects on the amount of Blue-eye Trevalla catch and number of records. The manipulation codes are described in Table 7.8. DeltaC: change in catch; %DiffC: percentage change of each term.

	Records	Difference	Catch	DeltaC	%DiffC
Total	56604	0	11815.766	0	0
Method	11706	44898	5323.478	6492.289	100.00
Depth	11047	659	5039.071	284.407	94.66
Years	10916	131	4963.118	75.953	93.23
Zones	10342	574	4654.413	308.704	87.43
Fishery	10304	38	4632.945	21.468	87.03
U-THS	10304	0	4632.945	0	87.03
9798SUV	10304	0	4632.945	0	87.03
H0-SUVgt0	10304	0	4632.945	0	87.03
noEffort	10222	82	4626.443	6.502	86.91
SUVgtUV	10222	0	4626.443	0	86.91
CEgt10	10211	11	4615.517	10.925	86.70
Hlt1000	10170	41	4598.500	17.018	86.38

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 7.7).

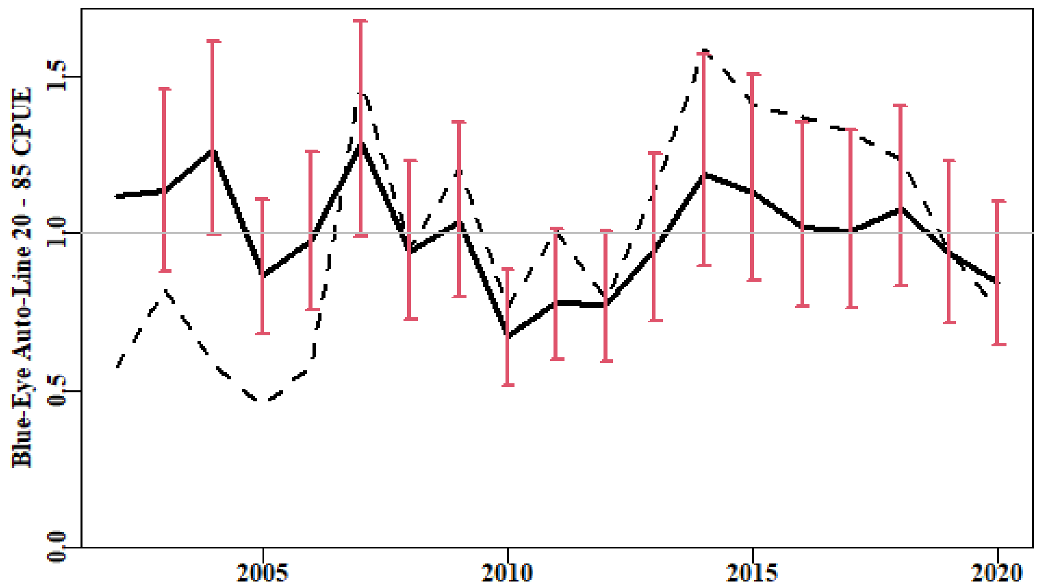

Figure 7.7. Standardized CPUE for Blue-eye Trevalla taken by auto-line from 2002 - 2020 from zones 20, 30, 40, 50, 83, 84, and 85. While the error bars are wide note the relative flattening of the trend in the solid standardized trend compared to the increasing trend in the unstandardized geometric mean (dashed line) over the 2010-14 period.

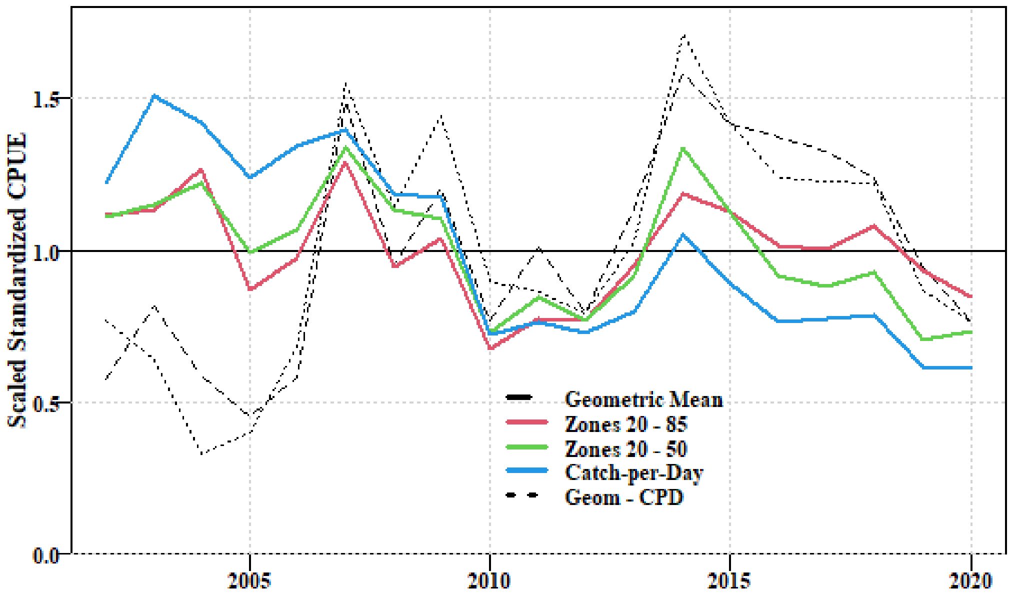

Figure 7.8. A comparison of the standardized CPUE for auto-line vessels using catch-per-day (blue line and dotted black line), and catch-per-hook (red, green, and dashed black line). All three main lines have high levels of uncertainty (e.g. Figure 7.6), but the relative flattening of the catch-per-hook trajectory is clear. All trends were scaled to an average of 1.0.

The optimum statistical model fitted to the available data from 2002 - 2020 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 7.10; Figure 7.8). 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.

7.3.3 *Combine Drop-Line with Auto-Line*

With a standardized drop-line CPUE index available for 1997 - 2006, and an auto-line index from 2002 - 2020 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 a catch-weighted average of the two lines over the overlapping period is provided (Figure 7.9; Table 7.11).

Table 7.10. 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 Trevalla catches as catch-per-hook (cph) from zones 20 - 85 (z2085), zones 20 - 50 (z2050), and as catch-per-day (cpd) for zones 20 - 50 (ceCPD). 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	0.5743	0.7693	1.1161	1.1096	1.2189	131.366
2003	0.8191	0.6425	1.1332	1.1507	1.5081	156.966
2004	0.5861	0.3326	1.2655	1.2180	1.4207	265.447
2005	0.4537	0.4009	0.8680	0.9917	1.2404	297.580
2006	0.5805	0.6820	0.9759	1.0675	1.3424	344.019
2007	1.4880	1.5480	1.2888	1.3394	1.3947	445.329
2008	0.9525	1.1457	0.9446	1.1301	1.1858	275.976
2009	1.2046	1.4455	1.0391	1.1043	1.1759	302.036
2010	0.7689	0.8988	0.6757	0.7312	0.7240	228.394
2011	1.0084	0.8643	0.7772	0.8431	0.7625	223.640
2012	0.7932	0.7933	0.7713	0.7717	0.7297	179.075
2013	1.1366	1.0252	0.9504	0.9160	0.7998	184.360
2014	1.5847	1.7123	1.1869	1.3356	1.0500	219.558
2015	1.4117	1.4176	1.1287	1.1247	0.8924	183.373
2016	1.3727	1.2382	1.0160	0.9137	0.7610	182.530
2017	1.3232	1.2252	1.0054	0.8834	0.7763	246.724
2018	1.2377	1.2219	1.0793	0.9299	0.7856	210.824
2019	0.9424	0.8704	0.9350	0.7052	0.6192	216.260
2020	0.7617	0.7662	0.8430	0.7342	0.6125	180.866

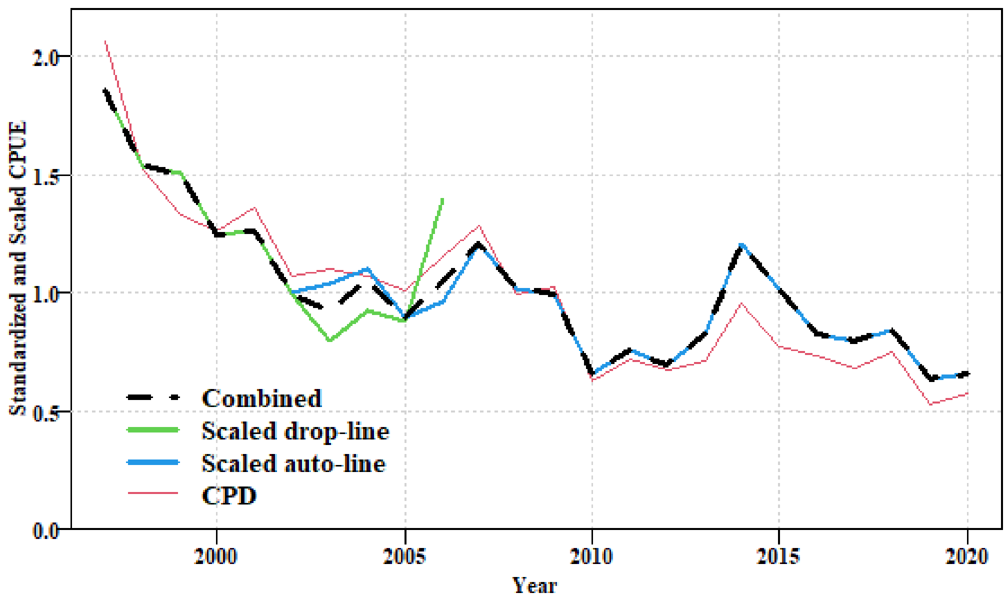

Figure 7.9. A comparison of Blue-eye Trevalla standardized catch-per-hook estimates for drop-line and auto-line catches of Blue-eye Trevalla from zones 20 - 50. A catch-weighted average of the lines from the two methods leads to a compromise in the years 2002 - 2006. If the 2001 auto-line estimates had been included this would have raised the average in 2001 slightly but at that point in time drop-line catches still dominated (Table 7.1). Catch-per-day (CPD) is included as a red line.

Table 7.11. 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. Relative catches by method are in alC (auto-line) and dlC (drop-line). ceCPD is the optimum standardized CPUE as measured by catch-per-day.

Year	ceDL	ceAL	scaleDL	scaleAL	combined	ceCPD	alC	dlC
1997	1.4977		1.8588		1.8588	2.0635	0.267	242.435
1998	1.2406		1.5397		1.5397	1.5257	14.989	318.441
1999	1.2115		1.5036		1.5036	1.3300	46.670	336.133
2000	1.0037		1.2457		1.2457	1.2604	28.299	372.543
2001	1.0179		1.2633		1.2633	1.3628	40.232	311.101
2002	0.8013	1.1096	0.9945	1.0019	0.9977	1.0738	131.366	173.513
2003	0.6441	1.1507	0.7994	1.0390	0.9282	1.1034	156.986	135.032
2004	0.7456	1.2180	0.9254	1.0998	1.0532	1.0754	230.575	84.059
2005	0.7079	0.9917	0.8786	0.8955	0.8926	1.0090	238.905	48.581
2006	1.1297	1.0675	1.4021	0.9639	1.0472	1.1527	237.272	55.729
2007		1.3394		1.2094	1.2094	1.2844	307.310	38.766
2008		1.1301		1.0204	1.0204	0.9981	205.017	15.299
2009		1.1043		0.9971	0.9971	1.0226	281.002	17.818
2010		0.7312		0.6603	0.6603	0.6277	202.140	24.755
2011		0.8431		0.7613	0.7613	0.7175	151.900	30.748
2012		0.7717		0.6968	0.6968	0.6748	158.120	17.928
2013		0.9160		0.8271	0.8271	0.7118	156.342	7.003
2014		1.3356		1.2059	1.2059	0.9538	176.813	3.853
2015		1.1247		1.0155	1.0155	0.7774	159.096	1.727
2016		0.9137		0.8250	0.8250	0.7375	143.672	14.368
2017		0.8834		0.7977	0.7977	0.6828	174.167	22.810
2018		0.9299		0.8396	0.8396	0.7521	161.957	43.889
2019		0.7052		0.6368	0.6368	0.5270	117.121	18.465
2020		0.7342		0.6629	0.6629	0.5757	121.354	15.621

7.4 Discussion

7.4.1 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 CPUE 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 CPUE as are the recent reductions in TAC, which mostly coincide with the introduction of important Blue-eye Trevalla closures on the east coast of Tasmania. In addition, there would appear to have been large and sudden changes in 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 be confused for a change in the stock. CPUE 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.

7.4.2 *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 favoured fishing grounds then there will undoubtedly be a change in fishing behaviour (which, in the case of Blue-eye Trevalla 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 Trevalla 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 Trevalla 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 seamounts and offshore 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 (< 20 t) throughout that period.

7.4.3 *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 onwards, other changes include the first gear limitation (to 15,000 hooks maximum) in 2001 and the rapid expansion of the auto-line fleet from 2002 onwards. The data up to 2000/2001 are not widely distributed spatially each year and are not distributed among many vessels. For this reason, it is difficult to justify using the auto-line data before 2002.

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 Trevalla 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 Trevalla 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.

7.5 Conclusions

The diversity of methods used to fish for Blue-eye Trevalla 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 handling 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 CPUE estimates in terms of kg/hook for both methods have been generated.
- As has been done previously, the two series were combined, using a catch weighted approach over the overlap period. There is a downward trend over the analysis period for both combined catch-per-hook and catch-per-day CPUE. However, since 2014 a steeper downward trend is apparent for the combined standardized CPUE than the catch-per-day CPUE.

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 assessment (see Sporcic, 2021). This would be more representative of the current fishery as it is presently pursued than restricting the series to zones 20 - 50 only.

7.6 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. Thanks also goes to Geoff Tuck (CSIRO) for his helpful comments on this report.

7.7 References

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8. Update Part 2: Statistical CPUE (catch-per-hook) standardizations for Blue-eye Trevalla (Auto-line and Drop-line) in the SESSF (data to 2020)

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8.1 Executive Summary

This report provides standardized catch-per-unit (CPUE; catch per hook) series for Blue-eye Trevalla (*Hyperoglyphe antarctica*) to 2020, by combining standardized CPUE series of two different line gears (drop-line and auto-line) to obtain a single CPUE series for the line sector from zones 20, 30, 40, 50 (z2050) and 83, 84 and 85 (Great Australian Bight; GAB), here within termed z2085. This contrasts the regular updated standardized CPUE series, which to date are based on zones 20-50 only (Sporcic, 2021). A downward trend is apparent in the z2085 standardized CPUE series over the 2018-2020 period. Since 2016, standardized z2085 CPUE indices are greater than the z2050 CPUE indices. All analyses have limited numbers of observations and hence are relatively uncertain.

There was a 64 t decrease (i.e., 50%; from ~ 131 t to ~ 66 t) in logbook catch by both auto-line and drop-line in the west (zone 40, 50) in 2019 relative to 2018, followed by a 9 t increase in catch (14%; from 66 t to 75 t) in 2019 relative to 2020. By contrast, there was a 48 t increase (95%; from ~51 t to 99 t) in the Great Australian Bight (GAB) in 2019 relative to the previous year, followed by a 36 t decrease in 2019 (36%; 99 t to 63 t) relative to 2020. Also, an average of 71 t per year has been recorded in logbooks, by both auto-line and drop-line in the east (zones 10, 20, 30) since 2017.

8.2 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 (e.g. Figure 8.5), although its juvenile stages are widely dispersed. Not only is it patchily distributed but the fishery differs markedly by area through the application of different methods and histories of exploitation. The differences in exploitation history along with sampling different areas in different years may have been sufficient to have led to the appearance of heterogeneity in the biological characteristics of different populations. There is little consistency between consecutive years in the age structure and length structure of samples (Figure 8.1); 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 Trevalla and has made the application of the Tier 3 catch-curve approach equally problematic (Fay, 2007a, b). Such spatial heterogeneity has been reviewed and further evidence presented, all of which supported the notion that there were spatially structured differences between Blue-eye Trevalla populations between regions around the south-east of Australia (Williams et al., 2016).

Table 8.1. 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 - 2020. Data filters were restricted the fisheries SET, GAB, SEN, GHT, SSF, SSG, and SSH. Methods were limited to AL, DL, TW, and TDO. Only CAAB code = 37445001 that identifies *Hyperoglyphe antarctica* were included.

Year	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	90.932	93	384.409	1078	95.042	1893
2001	47.884	76	335.872	799	90.218	1809
2002	134.067	234	223.074	619	67.998	1548
2003	219.676	487	221.649	587	28.920	1211
2004	329.608	1345	158.491	520	48.767	1559
2005	301.453	1151	93.779	368	42.969	1169
2006	354.593	1099	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	52.839	101	25.128	301
2016	190.073	305	91.297	139	12.871	244
2017	250.218	344	65.524	183	52.961	425
2018	218.140	392	57.346	192	42.332	387
2019	223.649	444	33.076	171	18.931	304
2020	188.235	482	20.637	130	6.149	201

While there is a long history of catches by trawl in the Blue-eye Trevalla fishery, most catch has always been taken by line-methods (generally less than 13% of catches are taken by trawl since 2003; Table 8.1). Unfortunately, fisheries data from line methods, in the Gillnet Hook and Trap (GHT) fishery, only began to be collected comprehensively from late in 1997 onwards (Table 8.1). 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 8.1, Figure 8.2). 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 8.2; Table 8.1).

In the two years, 2013 - 2014, drop-line catches dropped to 10 t or less while auto-line catches continue to dominate the fishery. However, in 2015, drop-line catches increased by about 43 t (i.e., from 10 t to 53 t), while auto-line catches dropped by about 34 t (i.e., from 227 t to 193 t) from the previous year (Table 8.1; Figure 8.2).

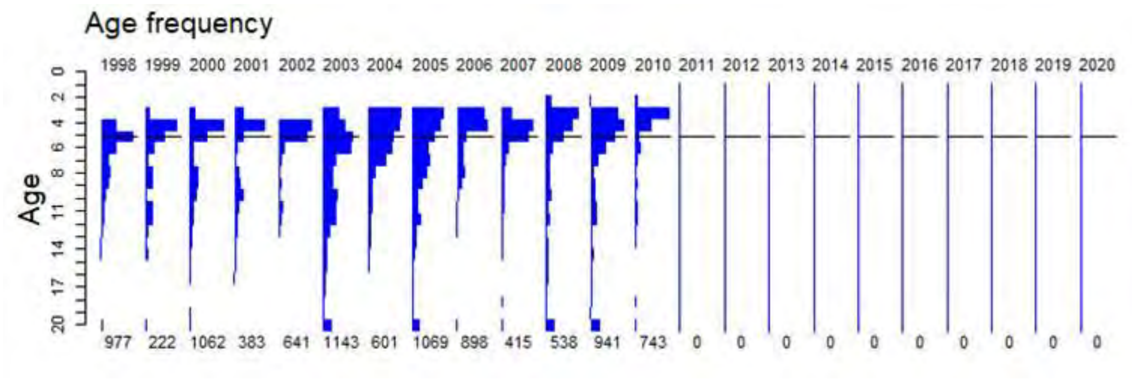

Figure 8.1. Age distributions sampled from the catches of Blue-eye Trevalla (*Hyperoglyphe antarctica*) for the years 1995 - 2020 (Bessell-Browne et al., 2021). The sample sizes in the bottom row of numbers should be sufficient to provide a good representation if the stock were homogeneous in its properties.

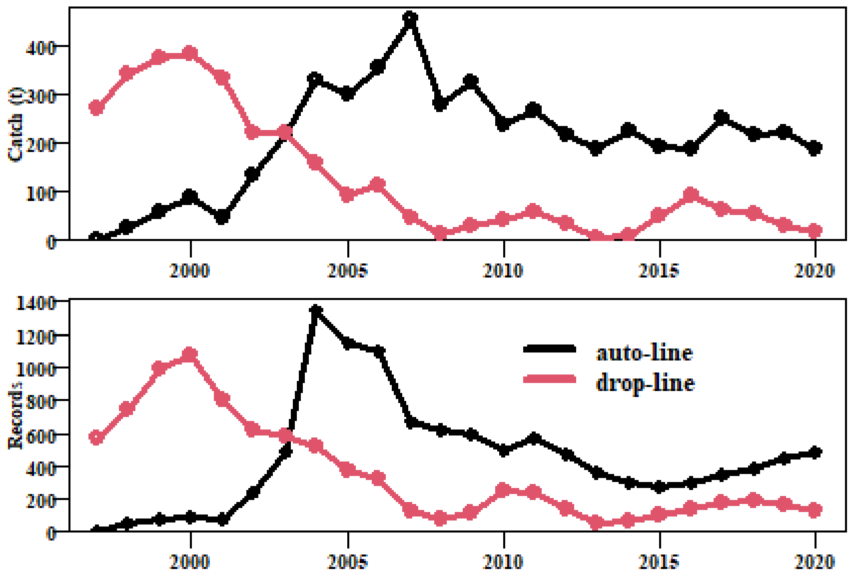

Figure 8.2. The trends in the number of records and the catches of Blue-eye Trevalla from 1997 - 2020 by the two main line methods (Table 8.1); most catches are now taken by auto-line.

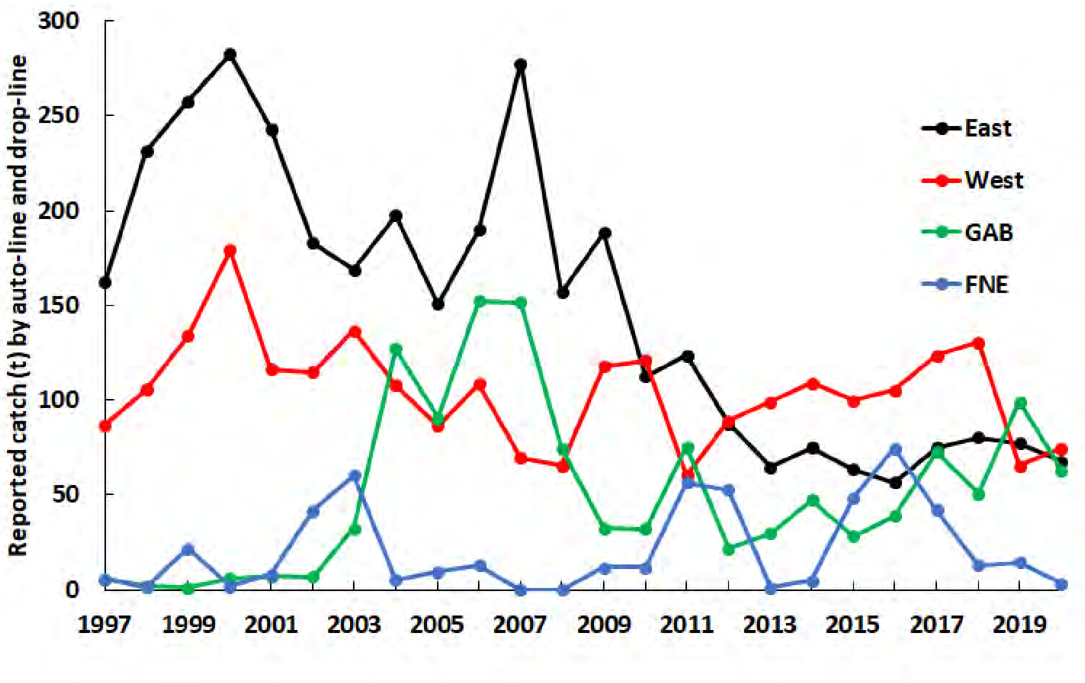

Figure 8.3. The total reported catches from 1997 - 2020 taken by auto-line and drop-line combined across the east (zones 20, 30), the west (zones 40, 50), the GAB (zones 83, 84, 85) and the far north east (zones 91, 92).

There was a 64 t decrease (i.e., 50%; from ~ 131 t to ~ 66 t) in logbook catch by both auto-line and drop-line in the west (zone 40, 50) in 2019 relative to 2018, followed by a 9 t increase in catch (14%; from 66 t to 75 t) in 2019 relative to 2020. By contrast, there was a 48 t increase (95%; from ~51 t to 99 t) in the Great Australian Bight (GAB) in 2019 relative to the previous year, followed by a 36 t decrease in 2019 (36%; 99 t to 63 t) relative to 2020. Also, an average of 71 t per year has been recorded in logbooks, since 2017 in the east (zones 10, 20, 30) (Table 8.2; Figure 8.3).

8.2.1 *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 Trevalla 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 Trevalla fishery but the time series of significant catches by that method was relatively short (only six years from 2002 - 2007; Table 8.1 and Figure 8.2). At that time some way of extending the time series was required to allow for the application of the Tier 4 methodology. Unfortunately, in the logbook records there was, and sometimes still is, often confusion in how to record effort (in terms of number of lines and number of hooks per line, or number of line drops, or length of main line) so it was not feasible at that time to estimate CPUE as a catch-per-hook. Instead CPUE was based on catch-per-record, which was equivalent to catch-per-day. The CPUE standardization conducted in 2008 on data from 1997 - 2007 (Haddon, 2009) was the first time that the catch-per-day data from drop-line was combined with auto-line catch-per-day data, with a justification presented to the RAGs. This was followed in 2009 by a summary of the separate auto-line and drop-line CPUE and a more detailed 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 extend the time series of line-caught Blue-eye Trevalla back to 1997 rather than 2002. Despite this extension of time, the early Tier 4 Blue-eye Trevalla 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 Trevalla was assessed using a standardized CPUE time series from the combined auto-line and drop-line fisheries, which combined data from the two methods from 8 zones (SESSF zone 10 - 50 with 83 - 85; Figure 8.4). 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 catch-per-day was analysis repeated in 2014 (Sporcic and Haddon, 2014), however, because of the unaccounted influences of issues such as (i) a restriction of fishing location options due to an increase in the number of marine closures (i.e., all methods and solely for auto-line) over known Blue-eye Trevalla fishing grounds, (ii) a reported expansion of depredations by whales on auto-line catches in association with changed behaviour of fishing vessels in the presence of whales, (iii) a movement of fishing effort much further north off the east coast of New South Wales and Queensland and (iv) ignoring 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 Trevalla fishery. It as therefore necessary 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 8.2. Blue-eye Trevalla catch by SESSF zone. Data filtered on species, fisheries and are limited to catches by auto-line and drop-line. Only zones 20, 30, 40, 50, 83, 84, 85, 91, and 92 have significant catches.

Year	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	69.568	137.520	94.846	50.728	12.610	61.083	53.409	5.045	0.180
2005	85.138	103.016	59.675	43.673	19.478	29.313	41.815	4.881	4.700
2006	67.365	122.376	80.766	27.767	31.416	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	51.836	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	14.158	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	38.237	10.147
2016	7.557	49.054	69.982	35.283		29.283	9.576	42.901	31.805
2017	9.615	65.340	83.638	39.839	1.800	58.788	11.969	27.845	14.390
2018	16.657	63.644	86.034	44.675	7.499	30.869	12.575	6.915	6.035
2019	10.216	67.136	39.130	26.444	54.461	34.022	10.656	9.207	5.452
2020	7.000	60.836	45.221	29.392	30.498	23.149	9.407	2.370	0.840

8.2.2 *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 8.5) 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 Trevalla 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 was repeated to include data to 2020.

8.2.3 *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 are 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.

8.2.4 *Report Structure*

There are three 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.

8.2.5 *CPUE Standardization*

8.2.5.1 Data Selection

Blue-eye Trevalla catches were selected by method and area for CPUE analyses. CPUE from these specific areas (Figure 8.4) were standardized using the methods described below and reported elsewhere.

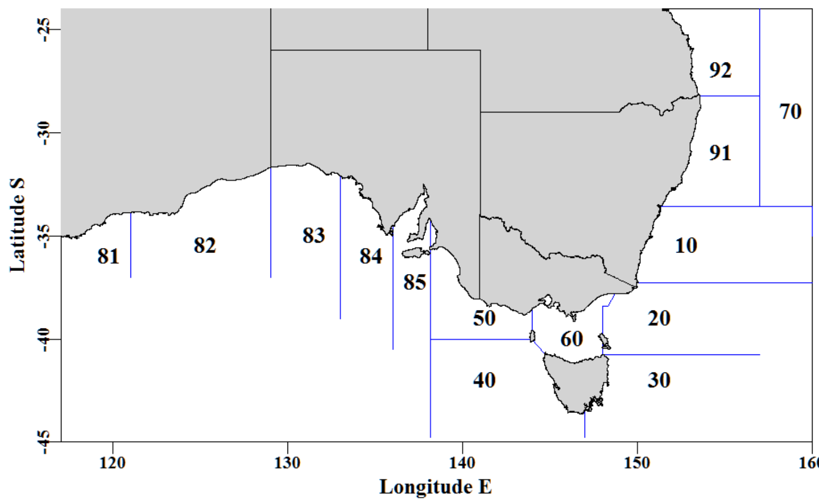

Figure 8.4. A schematic diagram depicting the statistical reporting zones in the SESSF, as used in this document. The GAB fishery is to the west of Zone 50. The main SESSF trawl zones are zones 10 - 50. Each zone extends out to the boundary of the EEZ, except for zones 50 and 60, and for zones 92 and 91, which are bounded by zone 70.

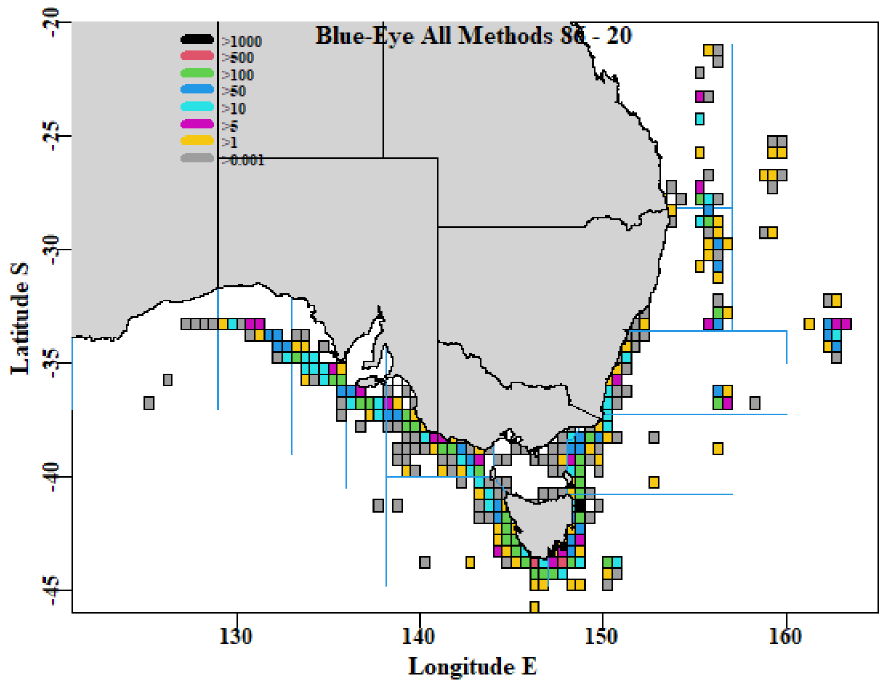

Figure 8.5. All reported catches of Blue-eye Trevalla by all methods from 1986 - 2020 in 0.5 degree squares. At least two records per square were required for inclusion in the map (all data were used in the analyses). The legend units are in tonnes summed across all years.

8.2.6 *General Linear Modelling*

Where trawling was the method used, CPUE was 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. CPUE was 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 and 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 CPUE (either kg/hr, 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.).

8.2.6.1 The Year Effect

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

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

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

8.3.1 Reported Catches

Blue-eye Trevalla 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 8.5). 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 8.3. 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 Trevalla.

	Total	Method	Depth	Years	Zones	Fishery
Records	56604	11706	11047	10916	10342	10304
Difference	0	44898	659	131	574	38
Catch	11815.77	5323.48	5039.07	4963.12	4654.41	4632.95
DeltaC	0	6492.29	284.41	75.95	308.70	21.47
%DiffC	0	54.95	5.34	1.51	6.22	0.46

Table 8.4. Blue-eye Trevalla catch by SESSF zone taken by auto-line. Total is all Blue-eye Trevalla 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 zones 20 - 85 taken by auto-line.

Year	Total	Other	AL	20	30	40	50	83	84	85
1997	464.069	463.802	0.267			0.267				
1998	444.979	429.990	14.989		0.033	14.956				
1999	546.140	499.471	46.670	35.575	1.725	9.370				
2000	657.408	629.109	28.299	12.210	6.061	10.028				
2001	580.054	539.822	40.232	2.000	23.634	14.598				
2002	462.267	330.901	131.366	2.640	65.100	42.326	21.300			
2003	561.989	405.003	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	441.340	143.057	298.283	84.748	59.833	57.312	37.012	19.058	5.185	35.135
2006	534.272	189.853	344.418	67.075	66.585	78.303	25.309	31.128	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	27.542	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	116.669	182.530	6.620	35.462	68.554	33.036		29.283	9.576
2017	380.850	134.126	246.724	9.615	45.621	83.106	35.824	1.800	58.788	11.969
2018	338.247	125.443	212.804	8.720	40.499	77.118	35.620	7.499	30.869	12.480
2019	292.713	76.453	216.260	8.597	51.605	36.710	20.209	54.461	34.022	10.656
2020	219.360	38.248	181.112	6.705	53.093	37.833	23.724	30.197	22.597	6.963

Table 8.5. 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			

8.3.2 *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 8.6). 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 8.7). This source of confusion appears to have propagated confusion in the logbook entries for a number of years following the changes and is the main reason this data needs review.

Table 8.6. 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	10175

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 8.6). 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 8.7. 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			298.283	0	0	1136
2006			344.418	0	0	1075
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			219.554	0	0	291
2015			183.735	0	0	251
2016			182.530	0	0	289
2017			246.724	0	0	338
2018			212.789	0	0	378
2019			216.260	0	0	425
2020			181.112	0	0	468

8.3.2.1 Vessels per Year

A total of 14 vessels have reported catches of Blue-eye Trevalla using auto-line since 1997, although a maximum of 11 reported in any single year (Figure 8.6). The active fleet expanded between 2002 - 2004. The structural adjustment occurred from November 2005 to November 2006 and that (along with TAC changes) appears to have stabilized numbers at about six vessels, with only three or four contributing in recent years. However, the four lowest catching vessels, across all years 1997 - 2016, have only landed totals of either 0.815, 3.55, 6.0, or 6.256 t of Blue-eye Trevalla in between one and six 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 8.6). However, for the standardization analysis, no selection on minimum catch was made.

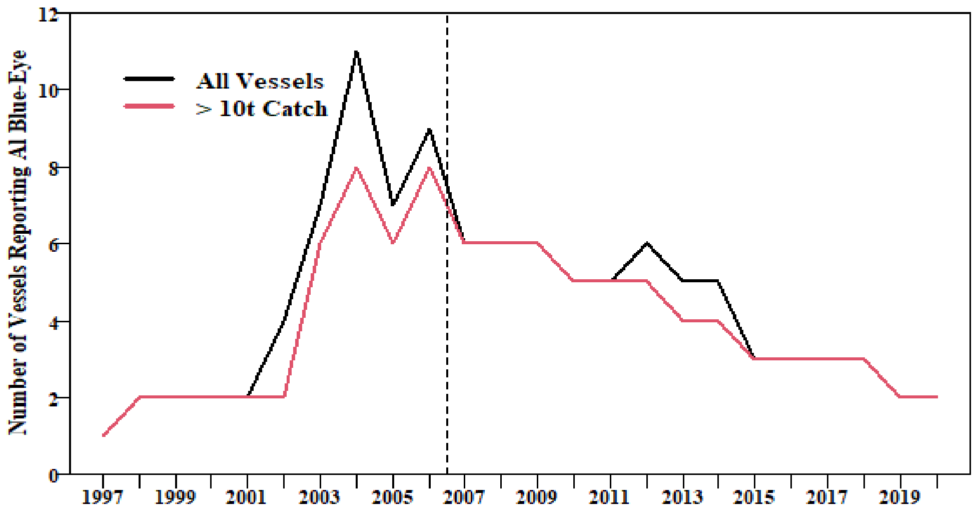

Figure 8.6. The number of auto-line vessels reporting Blue-eye Trevalla catches per year of the fishery compared with the number of vessels that caught more than a total of 10 tonnes over the 20 years from 1997 - 2020. Vertical dashed line is 2006.5, identifying the structural adjustment.

8.3.2.2 Catch-per-Hook

Table 8.8. 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 8.9. The sequence of data selection and editing and their effects on the amount of Blue-eye Trevalla catch and number of records. The manipulation codes are described in Table 8.8. DeltaC: change in catch; %DiffC: percentage change of each term.

	Records	Difference	Catch	DeltaC	%DiffC
Total	56604	0	11815.766	0.000	0.00
Method	11706	44898	5323.478	6492.289	100.00
Depth	11047	659	5039.071	284.407	94.66
Years	10916	131	4963.118	75.953	93.23
Zones	10342	574	4654.413	308.704	87.43
Fishery	10304	38	4632.945	21.468	87.03
U-THS	10304	0	4632.945	0.000	87.03
9798SUV	10304	0	4632.945	0.000	87.03
H0-SUVgt0	10304	0	4632.945	0.000	87.03
noEffort	10222	82	4626.443	6.502	86.91
SUVgtUV	10222	0	4626.443	0.000	86.91
CEgt10	10211	11	4615.517	10.925	86.70
Hlt1000	10170	41	4598.500	17.018	86.38

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 8.7).

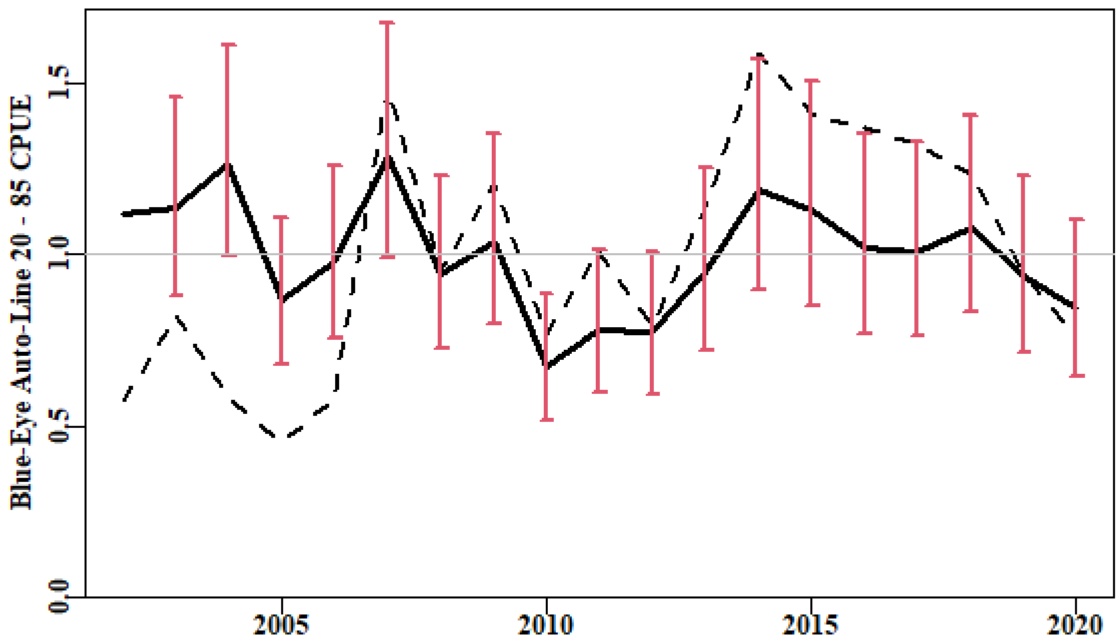

Figure 8.7. Standardized CPUE for Blue-eye Trevalla taken by auto-line from 2002 - 2020 from zones 20, 30, 40, 50, 83, 84, and 85. While the error bars are wide note the relative flattening of the trend in the solid standardized trend compared to the increasing trend in the unstandardized geometric mean (dashed line) over the 2010-14 period.

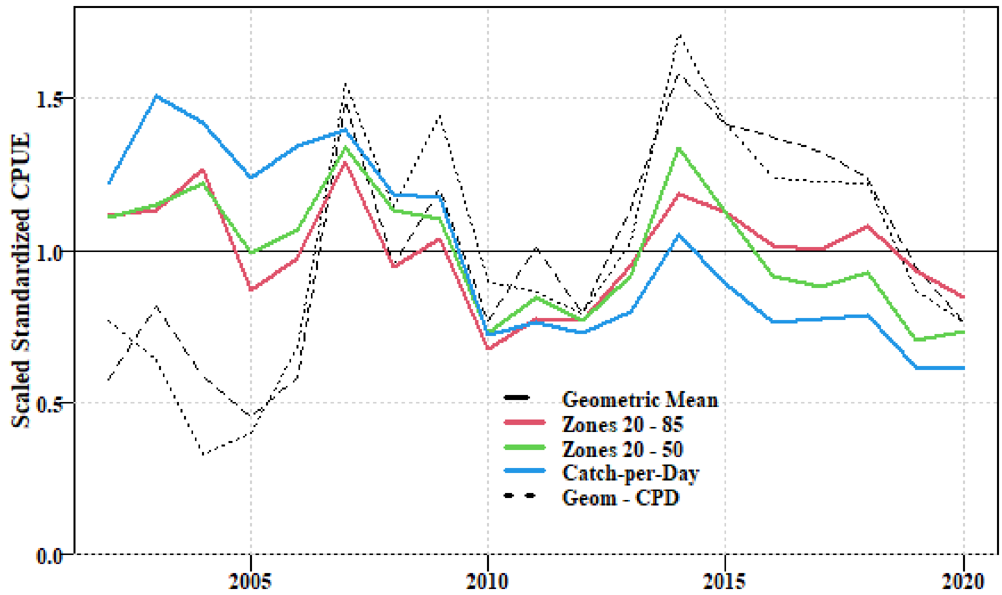

Figure 8.8. A comparison of the standardized CPUE for auto-line vessels using catch-per-day (blue line and dotted black line), and catch-per-hook (red, green, and dashed black line). All three main lines have high levels of uncertainty (e.g. Figure 8.7), but the relative flattening of the catch-per-hook trajectory is clear. All trends were scaled to an average of 1.0.

The optimum statistical model fitted to the available data from 2002 - 2020 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 8.10; Figure 8.8). 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.

8.3.3 *Combine Drop-Line with Auto-Line*

With a standardized drop-line CPUE index available for 1997 - 2006, and an auto-line index from 2002 - 2020 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. A catch-weighted average of the two lines over the overlapping period is provided for the provision of management advice (Figure 8.9; Table 8.11). This combined standardized CPUE series was based on data from zones 20, 30, 40, 50 (z2050) and 83, 84 and 85 (Great Australian Bight; GAB), here within termed z2085. A downward trend is apparent in the z2085 standardized CPUE series over the 2018-2020 period. Also, since 2016, standardized z2085 CPUE indices are greater than the z2050 CPUE indices (Figure 8.10).

Table 8.10. 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 Trevalla catches as catch-per-hook (cph) from zones 20 - 85 (z2085), zones 20 - 50 (z2050), and as catch-per-day (cpd) for zones 20 - 50 (ceCPD). 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	0.5743	0.7693	1.1161	1.1096	1.2189	131.366
2003	0.8191	0.6425	1.1332	1.1507	1.5081	156.966
2004	0.5861	0.3326	1.2655	1.2180	1.4207	265.447
2005	0.4537	0.4009	0.8680	0.9917	1.2404	297.580
2006	0.5805	0.6820	0.9759	1.0675	1.3424	344.019
2007	1.4880	1.5480	1.2888	1.3394	1.3947	445.329
2008	0.9525	1.1457	0.9446	1.1301	1.1858	275.976
2009	1.2046	1.4455	1.0391	1.1043	1.1759	302.036
2010	0.7689	0.8988	0.6757	0.7312	0.7240	228.394
2011	1.0084	0.8643	0.7772	0.8431	0.7625	223.640
2012	0.7932	0.7933	0.7713	0.7717	0.7297	179.075
2013	1.1366	1.0252	0.9504	0.9160	0.7998	184.360
2014	1.5847	1.7123	1.1869	1.3356	1.0500	219.558
2015	1.4117	1.4176	1.1287	1.1247	0.8924	183.373
2016	1.3727	1.2382	1.0160	0.9137	0.7610	182.530
2017	1.3232	1.2252	1.0054	0.8834	0.7763	246.724
2018	1.2377	1.2219	1.0793	0.9299	0.7856	210.824
2019	0.9424	0.8704	0.9350	0.7052	0.6192	216.260
2020	0.7617	0.7662	0.8430	0.7342	0.6125	180.866

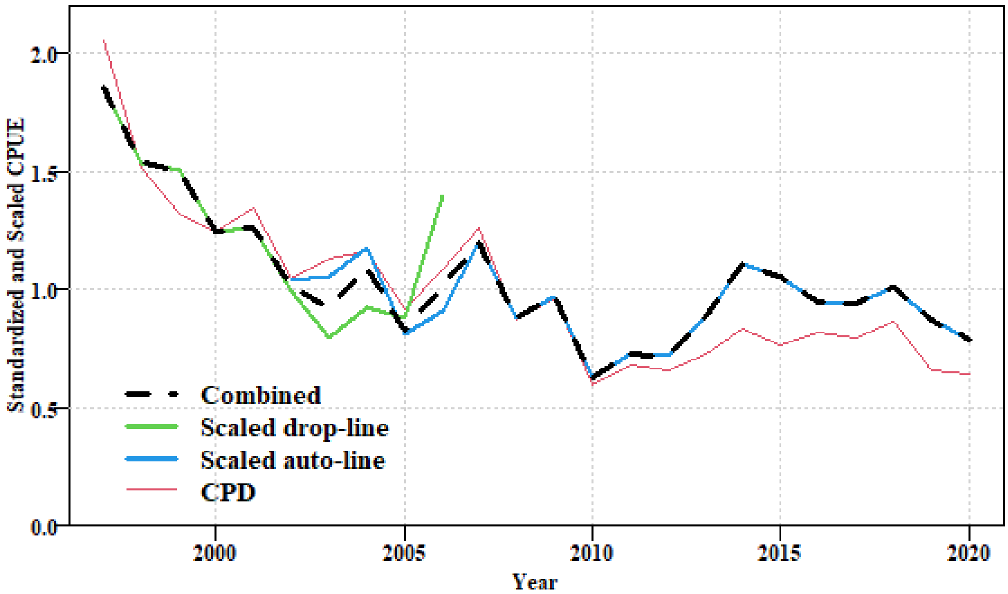

Figure 8.9. A comparison of Blue-eye Trevalla standardized catch-per-hook estimates for drop-line and auto-line catches of Blue-eye Trevalla from zones 20 - 85. A catch-weighted average of the lines from the two methods leads to a compromise in the years 2002 - 2006. If the 2001 auto-line estimates had been included this would have raised the average in 2001 slightly but at that point in time drop-line catches still dominated (Table 8.1). Catch-per-day (CPD) is included as a red line.

Table 8.11. The optimum standardized CPUE (scaled to a mean of 1.0) for both drop-line, ceDL, and auto-line, ceAL, all for zones 20 - 85. 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. Relative catches by method are in alC (auto-line) and dlC (drop-line). ceCPD is the optimum standardized CPUE as measured by catch-per-day.

Year	ceDL	ceAL	scaleDL	scaleAL	combined	ceCPD	alC	dlC
1997	1.4977		1.8588		1.8588	2.0552	0.267	248.213
1998	1.2406		1.5397		1.5397	1.5148	14.989	320.409
1999	1.2115		1.5036		1.5036	1.3235	46.670	337.105
2000	1.0037		1.2457		1.2457	1.2499	28.299	378.109
2001	1.0179		1.2633		1.2633	1.3440	40.232	317.550
2002	0.8013	1.1161	0.9945	1.0414	1.0143	1.0472	131.366	180.154
2003	0.6441	1.1332	0.7994	1.0574	0.9243	1.1324	156.986	167.220
2004	0.7456	1.2655	0.9254	1.1808	1.0915	1.1628	269.751	144.982
2005	0.7079	0.8680	0.8786	0.8099	0.8243	0.9152	298.283	79.309
2006	1.1297	0.9759	1.4021	0.9105	1.0213	1.0862	344.418	100.149
2007		1.2888		1.2025	1.2025	1.2661	446.738	45.123
2008		0.9446		0.8814	0.8814	0.8759	277.900	15.399
2009		1.0391		0.9696	0.9696	0.9620	312.829	17.818
2010		0.6757		0.6305	0.6305	0.5985	229.942	28.964
2011		0.7772		0.7252	0.7252	0.6837	225.541	32.368
2012		0.7713		0.7197	0.7197	0.6620	180.025	17.928
2013		0.9504		0.8868	0.8868	0.7294	185.985	7.228
2014		1.1869		1.1075	1.1075	0.8331	219.558	7.947
2015		1.1287		1.0532	1.0532	0.7688	183.735	4.871
2016		1.0160		0.9480	0.9480	0.8199	182.530	14.368
2017		1.0054		0.9381	0.9381	0.8005	246.724	22.810
2018		1.0793		1.0071	1.0071	0.8617	212.804	43.889
2019		0.9350		0.8724	0.8724	0.6614	216.260	18.465
2020		0.8430		0.7865	0.7865	0.6456	181.112	16.734

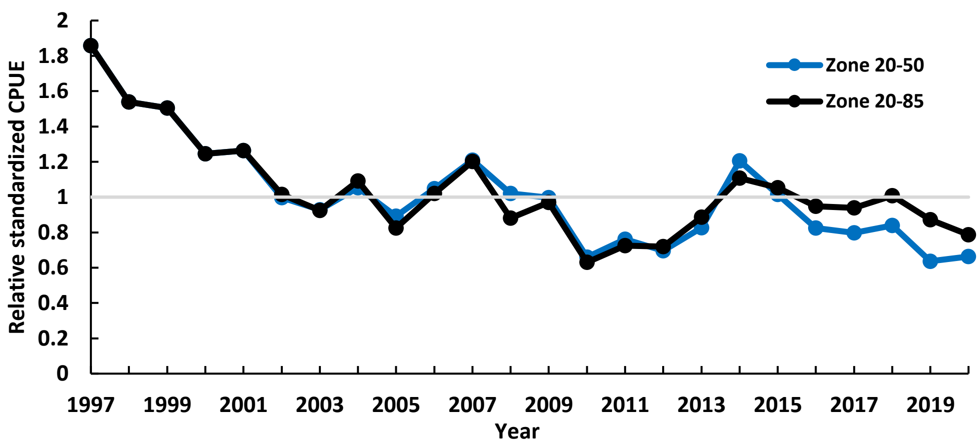

Figure 8.10. Combined Blue-eye Trevalla standardized catch-per-hook estimates for drop-line and auto-line catches of Blue-eye Trevalla from (i) zones 20 – 50 (blue line; see also Sporcic 2021 for details and (ii) zones 20 – 50 and the GAB (black line).

8.4 Discussion

8.4.1 *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 CPUE 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 CPUE as are the recent reductions in TAC, which mostly coincide with the introduction of important Blue-eye Trevalla 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 be confused for a change in the stock. CPUE 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.

8.4.2 *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 favoured fishing grounds then there will undoubtedly be a change in fishing behaviour (which, in the case of Blue-eye Trevalla 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 Trevalla 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 Trevalla 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 seamounts and offshore 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 (< 20 t) throughout that period.

8.4.3 *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 Trevalla and decisions concerning where to fish presumably entail a consideration of all areas available to be fished. This Tier 4 assessment uses the standardization from zones 20 – 50 and the GAB (zones 83, 84 and 85). The inclusion of GAB catches in the analysis of catch-per-hook does not alter the trend in standardized CPUE in major way. However, it may influence the estimated RBC from a Tier 4 assessment, given that the standardized indices are higher (and closer to the long-term average) in the most recent years compared with the standardized CPUE series that excludes the GAB catches.

8.5 Conclusions

The diversity of methods used to fish for Blue-eye Trevalla 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.

1. 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.
2. Separate and different algorithms for handling 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.
3. Using those algorithms the drop-line and auto-line data have again been re-structured and CPUE estimates in terms of kg/hook for both methods have been generated.
4. As has been done previously, the two series were combined, using a catch weighted approach over the overlap period. There is a downward trend over the analysis period for both combined catch-per-hook and catch-per-day CPUE. However, since 2014 a steeper downward trend is apparent for the combined standardized CPUE than the catch-per-day CPUE.

Given the current structure of the auto-line fishery and significant catches from GAB zones which dominate recent catches, the standardized CPUE series provided in this report employed data from zones 20, 30, 40, 50, 83, 84, and 85. It is thought to be more representative of the current fishery than restricting the series to zones 20 - 50 only.

8.6 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. Thanks also goes to Geoff Tuck (CSIRO) for reviewing this report.

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9. Statistical CPUE standardizations for selected deepwater SESSF Species (data to 2020)

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9.1 Executive Summary

This report summarizes catches and standardized catch-per-unit (CPUE) for Deepwater Sharks in Australia's Southern and Eastern Scalefish and Shark Fishery (SESSF). It focuses on data mostly from years 1995 - 2020 available in the Commonwealth logbook database. This database contains catch and effort records relating to all fishing methods and zones and allows for a detailed CPUE standardization analysis, which is required to provide a complete view of the current state of the fishery.

Catches of eastern Deepwater Sharks declined steadily from 1996 to a low in 2007 when the 700 m closure was introduced. Since the borders of this closure were modified in 2009 (and 2016) catches have increased again to reach an average of 36 t per annum with fewer vessels contributing significantly to this fishery relative to the 1990's. Nevertheless, fishing appears to be consistent and the standardized CPUE trend has been essentially low and flat since 2010, despite an increase in 2020 relative to the previous year. The removal of catch from the 700 m closure made minimal differences to standardized CPUE compared to CPUE indices which included the closure in analyses.

As with the eastern Deepwater Sharks, catches of western Deepwater Sharks decreased from a high in 1998 of 406 t to a low in 2007 of 9 t after the introduction of the 700 m closure, picking up again after the modifications in 2009 and 2016, with a mean of 86 t over the last five years. Standardized CPUE has been approximately cyclic since about 2007 with lows over the 2012-2014 period and has returned to the long-term average since 2016. The removal of catch from the 700 m closure made minimal differences to standardized CPUE compared to CPUE indices which included the closure in the analyses, except for the most recent year, where the index increased compared with the previous year.

Catches of Mixed Oreos declined from 1995 - 2002 and have remained relatively low since the 700 m closure in 2007 (i.e., mean ~71 t between 2007-2012), but have increased to a mean of 115 t from 2013 - 2020 perhaps due to the introduction of electronic monitoring over this period. Standardized CPUE has been essentially flat over the 1995 – 2019 period, but below the long-term average and increased to the long-term average in 2020.

9.2 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 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 annual 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 statistical modelling procedures that focus attention on 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 Southern and Eastern Scalefish and Shark Fishery (SESSF) 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 2020 inclusive) for selected deepwater species groups within Australia's SESSF. The species groups considered here are eastern Deepwater Sharks, western Deepwater Sharks and mixed Oreos. It also provides additional analyses for eastern and western Deepwater Sharks which either include or exclude closures.

9.2.1 *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 South East Scalefish and Shark Fishery (SESSF) including the introduction of the quota management system in 1992 and that of the Harvest Strategy Policy (HSP) and associated structural adjustment in 2005 - 2007. The combination of limited quotas and the HSP is now controlling catches in such a way that many fishers have been altering their fishing behaviour to take into account the availability of quota and their own access to quota needed to land the species taken in the mixed species SESSF.

There may be situations where fishers report the need to avoid catching certain species, 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.

9.3 Methods

9.3.1 *CPUE Standardization*

9.3.1.1 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 CPUE 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, 2018) 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.

9.3.1.2 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 and 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:

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

where $Ln(CPUE_i)$ is the natural logarithm of CPUE (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.).

9.3.1.3 The Mean Yyear 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 CPUE 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

9.3.1.4 Model Development and Selection

In each case an array of statistical models were 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.

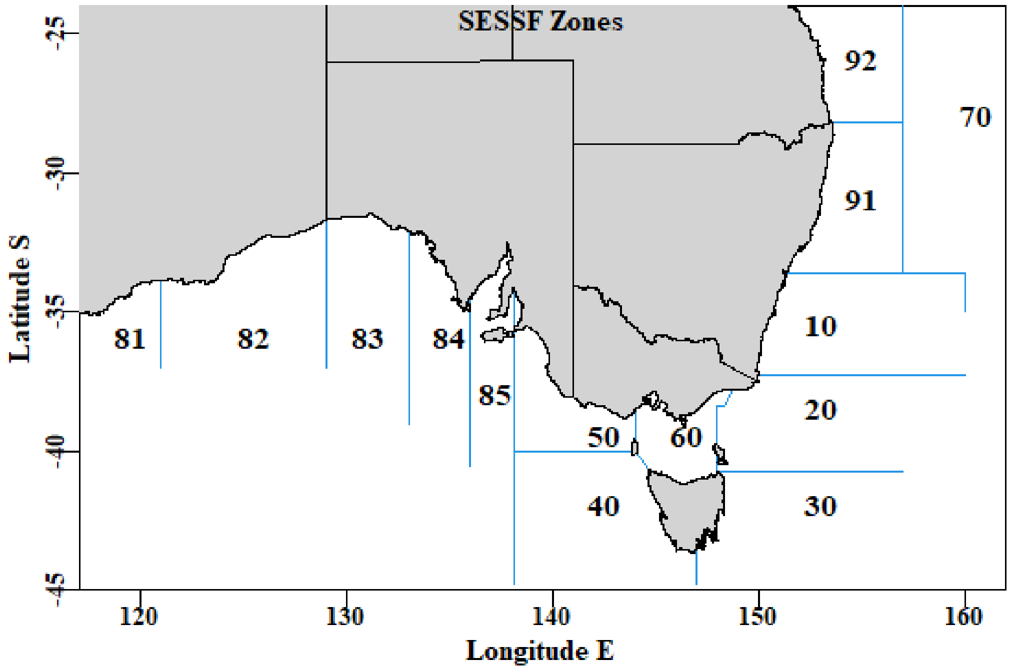

Figure 9.1. The statistical reporting zones in the SESSF.

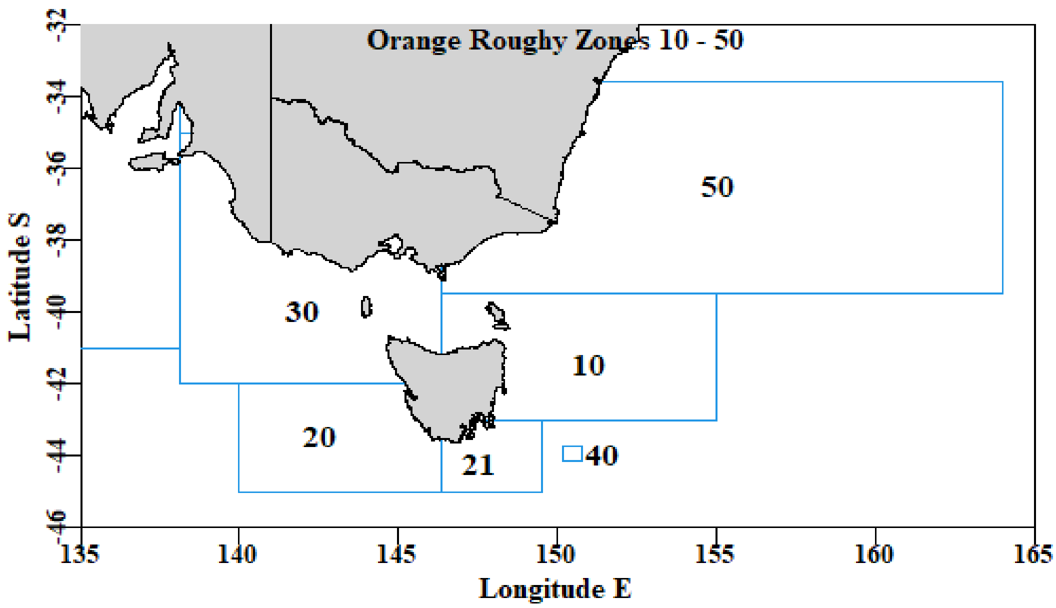

Figure 9.2. The Orange Roughy zones used to describe the deepwater fisheries.

9.4 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 for eastern Deepwater Shark declined steadily from 1996 to a low in 2007 when the 700 m closure was introduced. Since the borders of this closure were modified in 2009 (and 2016) catches have increased again to reach an average of 36 t per annum with fewer vessels contributing significantly to this fishery relative to the 1990's. The 49 t catch in 2019 was the highest recorded since 2006. 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. CPUE was expressed as the natural log of catch per hour (catch/hr). The years analysed were 1995 - 2020 (Table 9.1). A total of eight 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.

9.4.1 *Inferences*

This remains a locally important but minor fishery. There were high catches in the first two years and this corresponded to relatively unusual effort distributions 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). Most 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 R^2 statistics (Table 9.5). 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 9.6). Standardized CPUE exhibits a flat trend below the long-term average since 2010 (Figure 9.3).

9.4.2 *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 9.1. 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, OTB, TMO
years	1995 - 2020

Table 9.2. 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

Year	Total	N	Catch	Vess	GeoM	Opt	StDev	C<30Kg	P<30Kg
1995	595.4	553	178.7	17	213.2	2.9176	0.000	1.602	0.009
1996	834.2	1095	348.3	25	113.6	2.8107	0.064	2.980	0.009
1997	851.0	997	206.2	25	62.2	1.7390	0.063	3.610	0.018
1998	838.5	1203	221.1	24	53.4	1.4958	0.063	5.039	0.023
1999	731.3	1078	167.1	24	43.8	1.2412	0.064	4.500	0.027
2000	683.6	904	177.6	37	54.7	1.3128	0.067	3.152	0.018
2001	572.8	954	144.9	28	49.9	1.1637	0.069	4.746	0.033
2002	516.0	932	156.3	26	48.8	1.1434	0.069	4.419	0.028
2003	360.8	999	125.9	24	37.4	0.8192	0.069	5.953	0.047
2004	377.7	706	96.1	26	34.9	0.8330	0.073	3.886	0.040
2005	202.8	427	62.7	13	38.8	0.8344	0.080	2.274	0.036
2006	178.1	373	38.0	19	32.6	0.7957	0.084	3.046	0.080
2007	56.4	49	2.9	13	12.8	0.6779	0.171	0.418	0.147
2008	51.8	79	10.5	8	25.4	0.9915	0.140	0.434	0.041
2009	83.1	183	27.6	11	36.3	0.9221	0.102	0.892	0.032
2010	77.4	212	20.3	11	21.6	0.5674	0.097	1.445	0.071
2011	78.9	165	16.2	13	21.4	0.5458	0.105	0.849	0.052
2012	82.8	231	21.7	13	21.3	0.5379	0.098	1.380	0.063
2013	105.5	213	17.9	10	20.8	0.5438	0.098	1.640	0.092
2014	134.3	374	38.7	12	18.0	0.5457	0.085	2.239	0.058
2015	118.5	401	33.1	12	22.0	0.5469	0.085	2.554	0.077
2016	122.6	299	34.0	14	25.0	0.5539	0.093	1.581	0.046
2017	125.7	327	35.5	12	23.0	0.5623	0.091	1.680	0.047
2018	114.1	403	37.5	14	25.3	0.5879	0.091	1.993	0.053
2019	163.5	522	48.8	13	25.3	0.5806	0.087	2.155	0.044
2020	154.2	383	25.9	11	24.3	0.7297	0.107	0.964	0.037

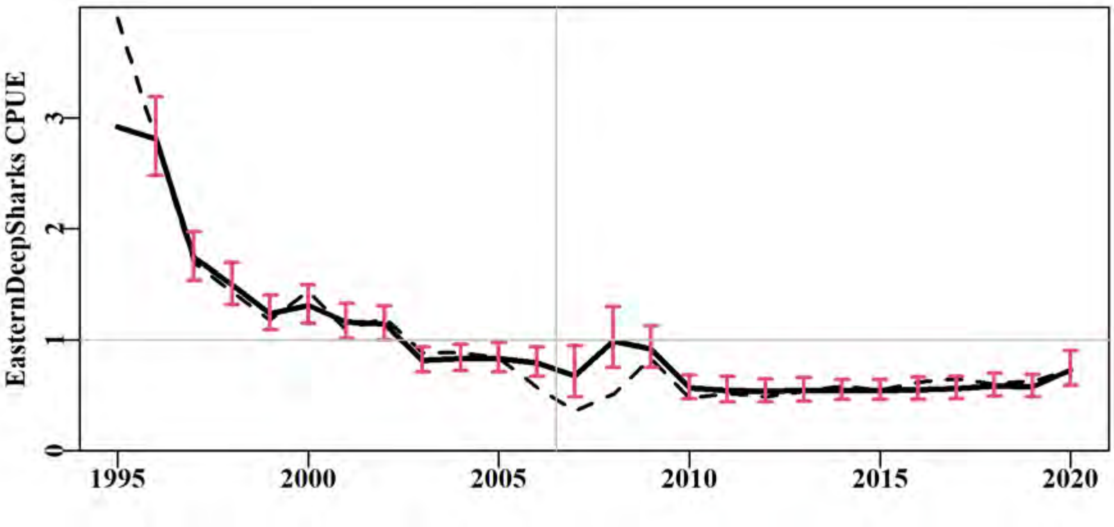

Figure 9.3. EasternDeepSharks standardization. The dashed black line represents the geometric mean CPUE, solid black line the standardized CPUE. The red bars are the 95% confidence intervals about the mean estimates. The graph scales both time-series of standardized CPUE relative to the mean of each time-series.

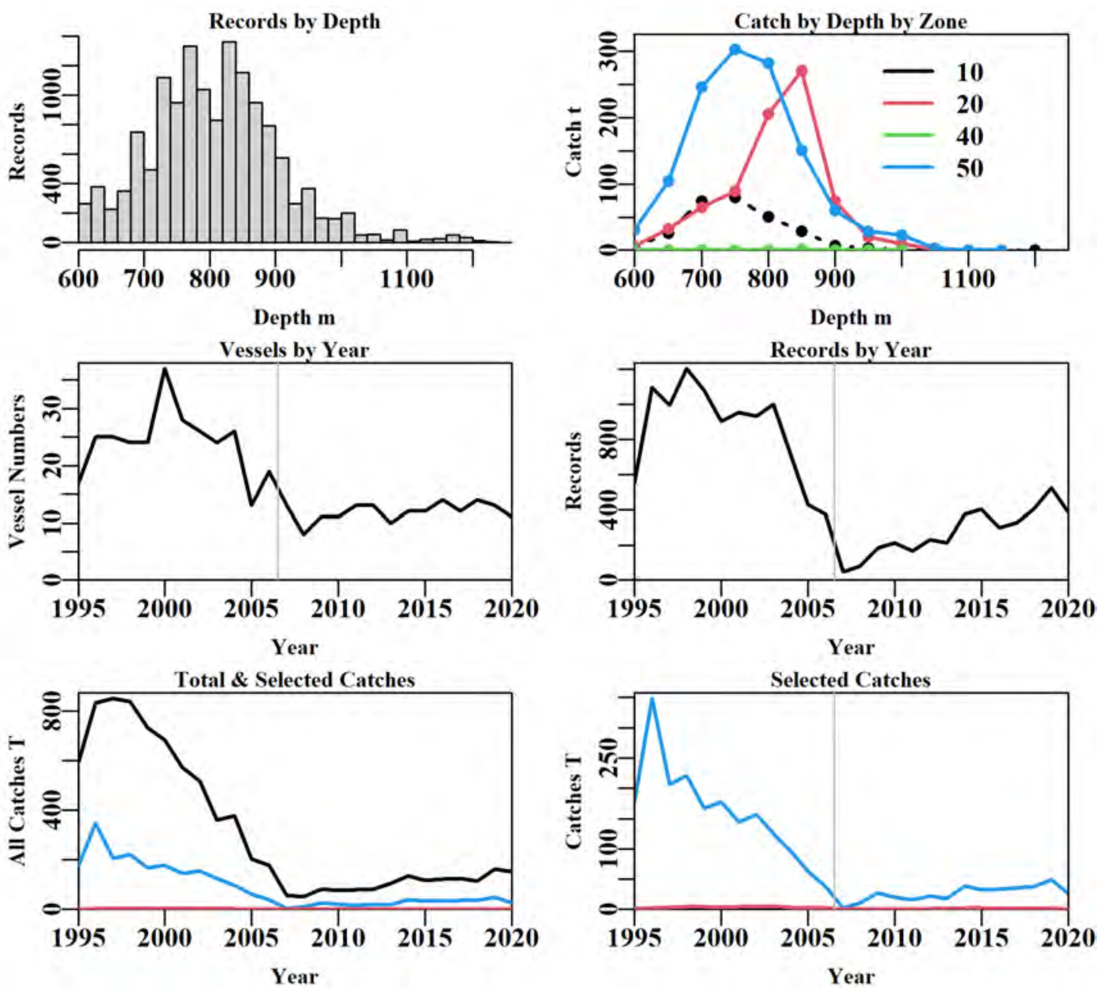

Figure 9.4. EasternDeepSharks fishery details. The bottom left plot depicts all known catches (top black line), and all selected catches used in the analysis (middle blue line); the lower red line: selected catches < 30 kg).

Table 9.3. 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	370489	239950	102210	57367	57056	14062	13383
Difference	0	130539	137740	44843	311	42994	679

Table 9.4. 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 9.5. 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

Term	AIC	RSS	MSS	Nobs	Npars	adj_r2	%Change
Year	4943	19287	3810	13383	26	16.3	0.00
Vessel	3409	17012	6085	13383	99	25.8	9.46
DepCat	2529	15900	7196	13383	111	30.6	4.78
Month	2502	15843	7253	13383	122	30.8	0.19
DayNight	2479	15811	7285	13383	124	30.9	0.13
ORzone	2346	15647	7449	13383	127	31.6	0.70
ORzone:DepCat	2208	15420	7677	13383	156	32.5	0.85
ORzone:Month	2275	15500	7597	13383	155	32.1	0.50

Table 9.6. 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	615.74
Black	37020002	85.10
Brier	37020003	108.37
Platypus	37020004	130.84
Plunket	37020013	0.236
Pearl	37020905	578.06
Roughskin	37020906	225.52
Lantern	37020907	9.5
OtherSharks	37990003	532.11

Table 9.7. EasternDeepSharks. Annual catch (t) by CAAB code for a basket species.

Year	37020000	37020002	37020003	37020004	37020013	37020905	37020906	37020907	37990003
1995	87.80								89.81
1996	161.61								186.33
1997	97.41	8.74							100.06
1998	117.50	27.91							74.80
1999	97.05	25.26							44.78
2000	40.94	1.59		11.86		64.21	45.59		13.41
2001	10.55		11.75	25.50		58.15	29.35		8.87
2002	0.98		22.88	25.87	0.06	72.08	27.10		6.58
2003	0.57		14.55	18.10		59.78	32.70		0.07
2004	0.02		14.27	16.83		40.53	21.34	2.0	0.24
2005			6.24	11.03		28.69	8.96	7.5	0.25
2006	0.03		3.88	7.74		18.85	6.87		0.19
2007	0.06			0.40		1.64	0.48		0.27
2008	0.20			0.83		6.83	2.61		
2009	0.05		0.21	0.13		14.08	12.81		0.04
2010	0.75		0.02	1.07		12.68	5.08		0.01
2011	0.00			0.26	0.04	8.74	6.86		0.03
2012	0.03		0.50	1.51		10.38	9.02		
2013		0.03	1.93	1.45		9.03	5.44		
2014		3.73	4.55	1.39		23.26	4.57		1.04
2015	0.04	3.37	6.05	3.81		16.59	1.62		1.10
2016	0.00	2.41	6.10	1.09	0.06	20.62	2.74		0.93
2017	0.00	2.03	6.28	1.99		22.22	2.03		0.82
2018	0.02	2.50	4.30		0.06	29.01	0.35		1.22
2019	0.11	4.36	3.57			39.28			1.23
2020		3.17	1.29		0.02	21.42			0.01

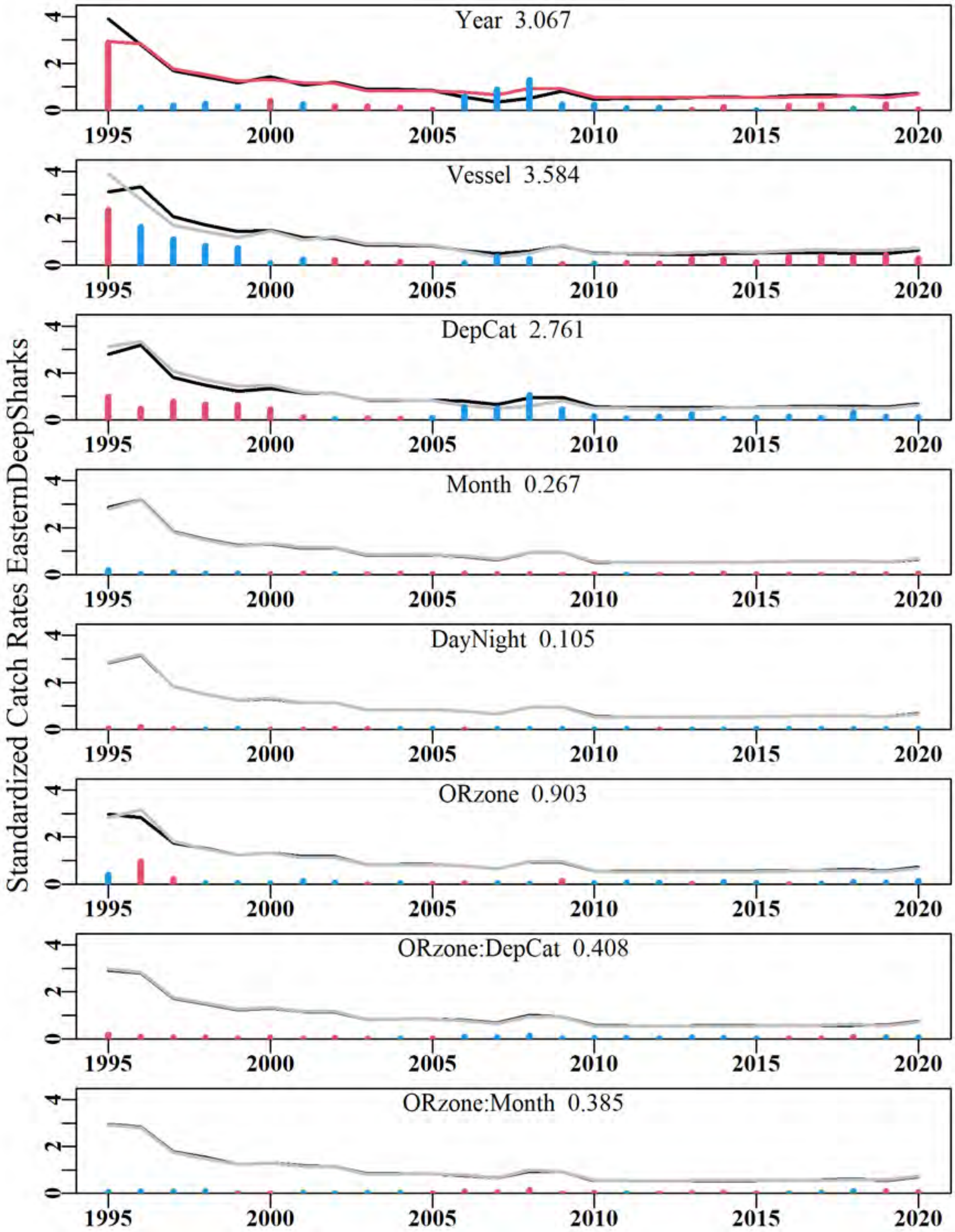

Figure 9.5. EasternDeepSharks. The influence of each factor on the optimal standardization. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by vertical bars with blue bars indicating the optimum model is higher than the 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.

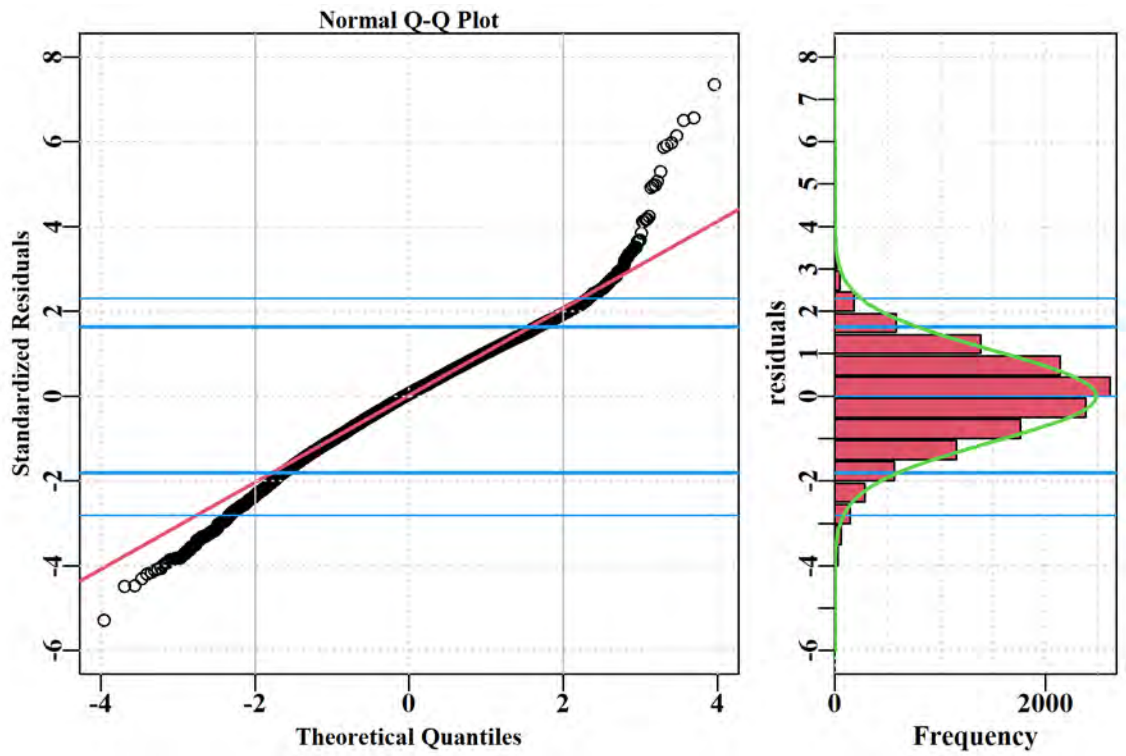

Figure 9.6. EasternDeepSharks. Diagnostic plots. The distribution of residuals from the optimum fit. The qqplot indicates the fit to the expected normality, while the histogram of residuals also illustrates the 1%, 5%, 95% and 99% quantiles to indicate the intensity of any lack of fit at the margins of the distribution (reflected also in the qqplot).

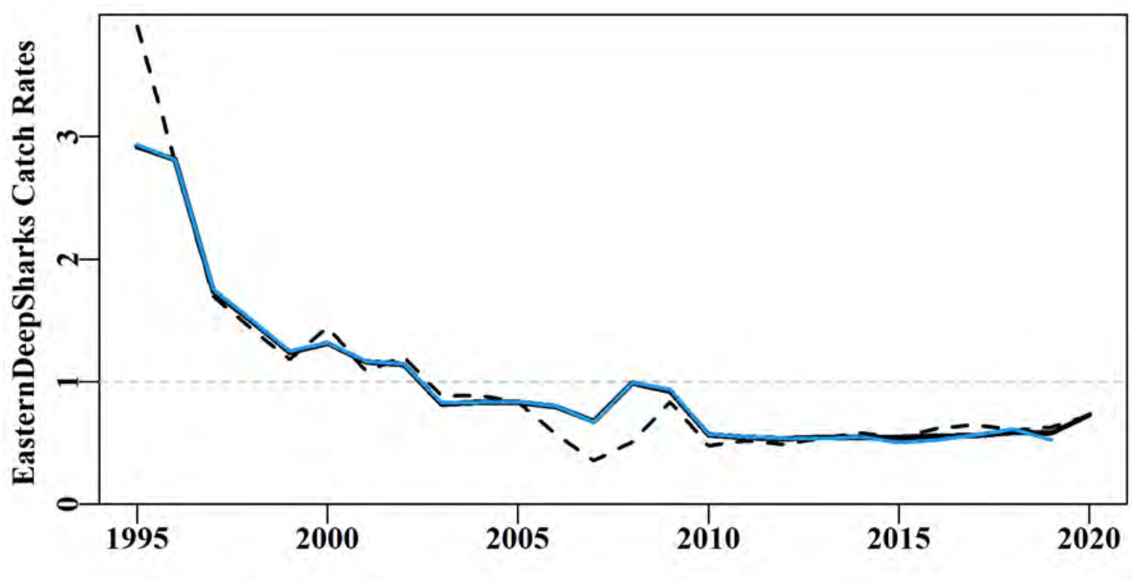

Figure 9.7. EasternDeepSharks. A comparison of the previous year's standardization (blue line) with this year's (black line). They should lie on top of each other, although small deviations may relate to data adjustments, particularly in very recent years. The geometric mean corresponds to the back dashed line.

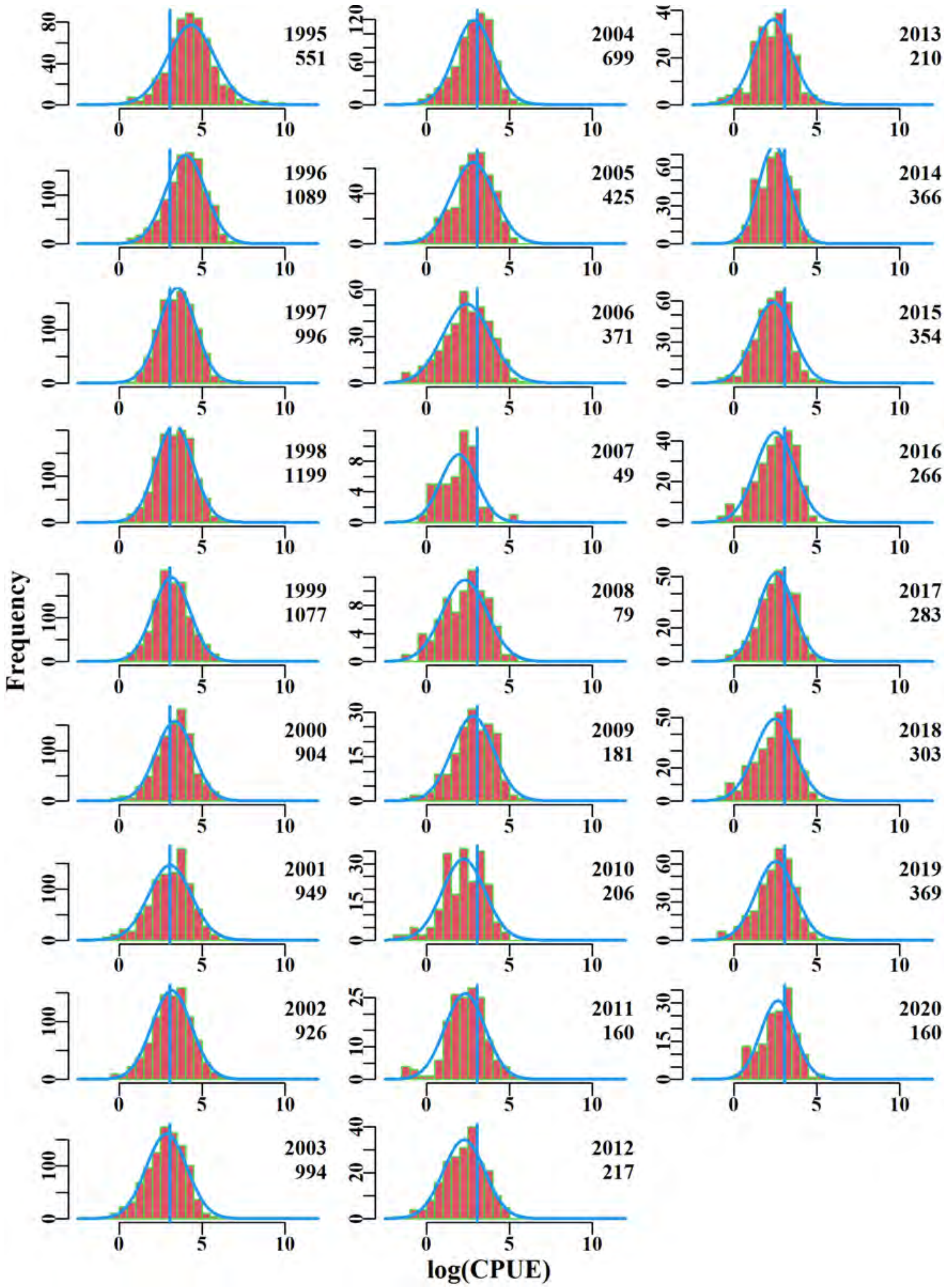

Figure 9.8. EasternDeepSharks. The natural log(CPUE) for each year of data available the blue lines are normal distributions fitted to the histogram frequencies. The numbers in each plot are the year and number of records. The vertical blue line is the average across all years.

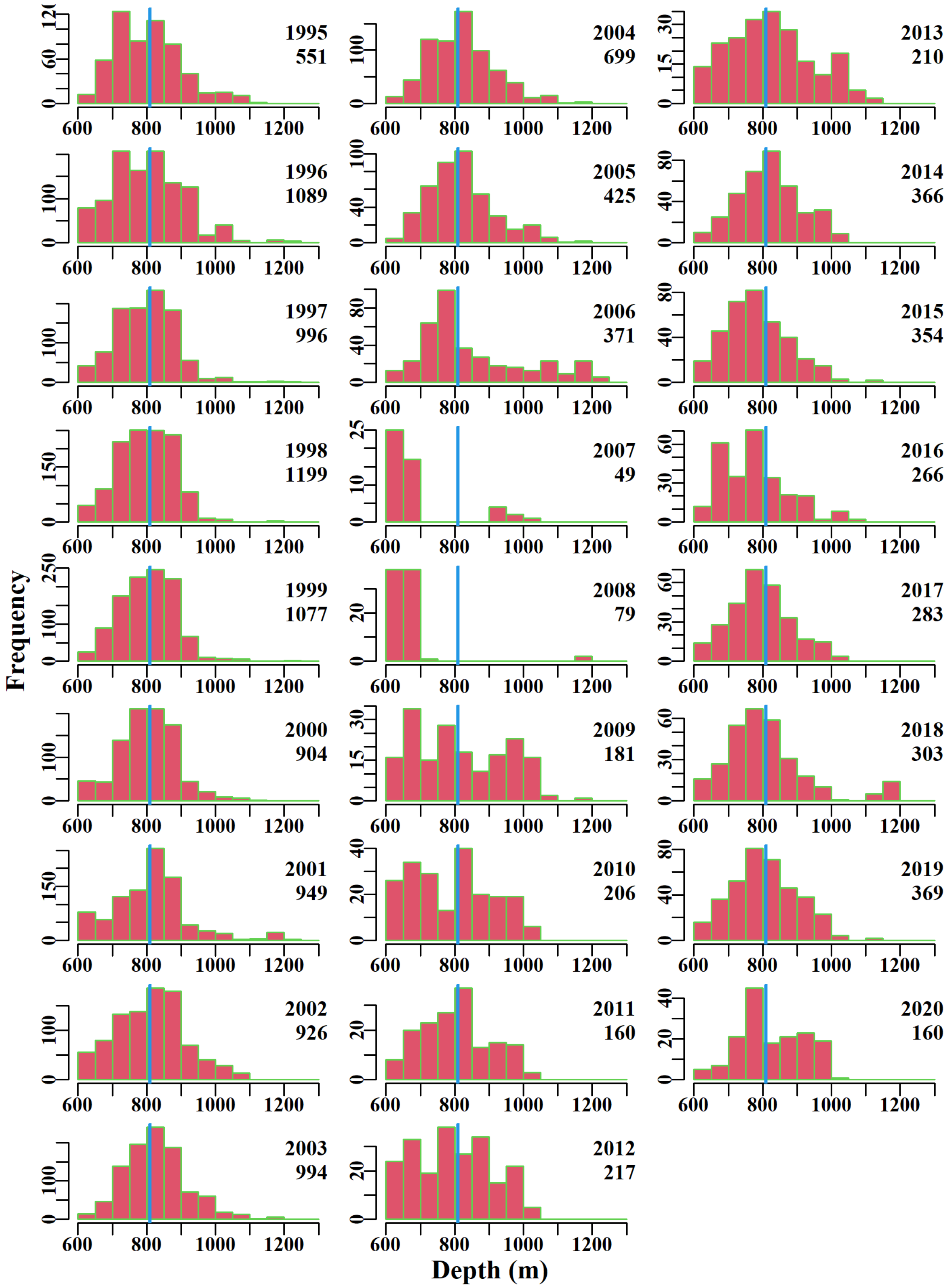

Figure 9.9. EasternDeepSharks. Frequency distribution of fishing depth (m) for each year of data available to illustrate the development of the fishery through time. The numbers in each plot are the year and number of records. The vertical blue line is the average across all years.

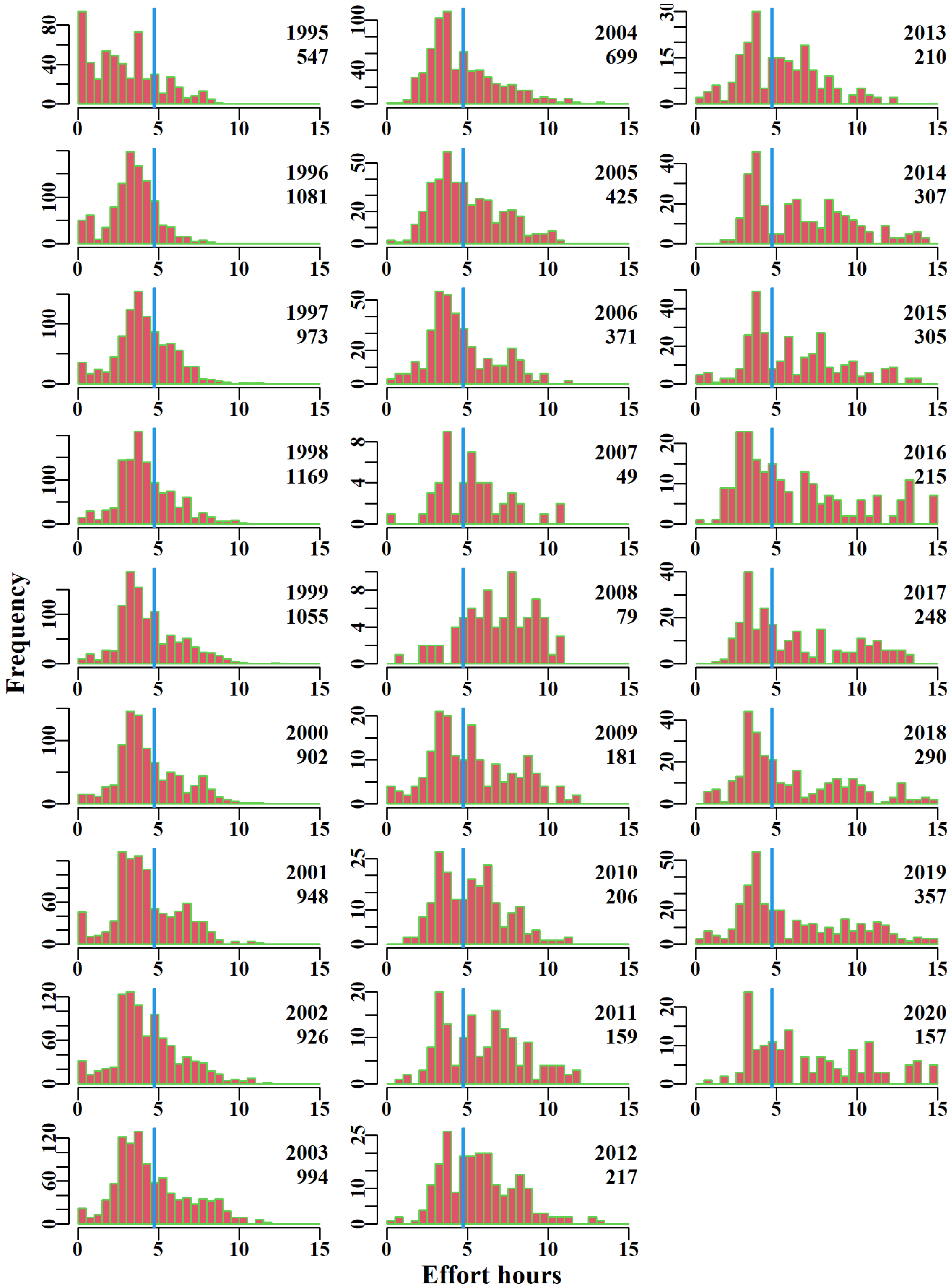

Figure 9.10. EasternDeepSharks. Frequency distribution of effort (hours) each year for the available data. The numbers in each plot are the year and number of records. The vertical blue line is the average across all years.

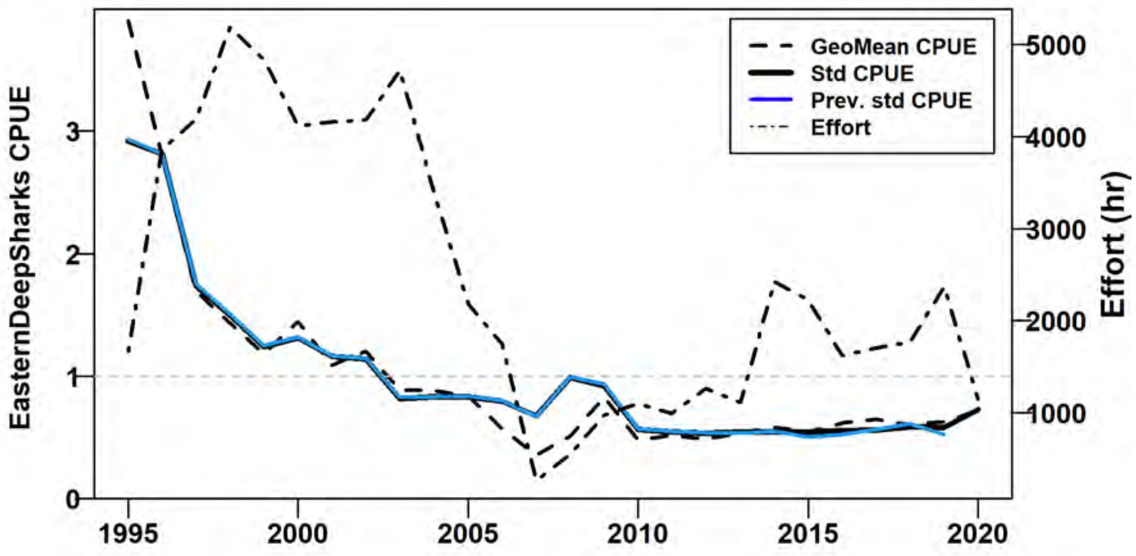

Figure 9.11. Annual standardised CPUE (blue), geometric mean CPUE (dashed line) and effort (dot-dash line).

9.5 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. CPUE was expressed as the natural log of catch per hour (catch/hr). The years analysed were 1995 - 2020 (Table 9.8). In addition, catches corresponding to closures were omitted from analyses.

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

9.5.1 *Inferences*

The removal of catches from closures throughout the time series resulted in a further 1967 observations omitted from analyses. Most catch occurred in ORzone 50, 20 followed by 10 (Figure 9.13).

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 9.12). 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 9.15).

Standardized CPUE exhibits a relatively flat trend and below the long-term average since 2010 (Figure 9.12).

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

9.5.2 *Action Items and Issues*

See Actions and Issues for eastern Deepwater Shark with closures.

Table 9.8. 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, OTB, TMO
years	1995 - 2020

Table 9.9. 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

Year	Total	N	Catch	Vess	GeoM	Opt	StDev	C<30Kg	P<30Kg
1995	595.4	279	82.2	16	123.5	2.6717	0.000	0.612	0.007
1996	834.2	873	287.9	23	106.7	2.7995	0.080	1.980	0.007
1997	851.0	790	157.2	24	52.7	1.7207	0.078	2.613	0.017
1998	838.5	1051	192.4	23	52.0	1.4435	0.077	4.611	0.024
1999	731.3	946	146.6	22	43.8	1.2130	0.077	4.131	0.028
2000	683.6	774	154.4	36	54.3	1.2892	0.081	2.631	0.017
2001	572.8	790	119.5	27	46.0	1.1960	0.084	4.042	0.034
2002	516.0	788	130.8	25	46.5	1.2114	0.083	3.934	0.030
2003	360.8	808	97.9	22	34.0	0.8208	0.084	4.643	0.047
2004	377.7	596	77.1	25	32.7	0.8495	0.087	3.228	0.042
2005	202.8	340	43.6	12	33.8	0.8143	0.096	1.818	0.042
2006	178.1	276	30.4	17	29.9	0.8096	0.100	2.130	0.070
2007	56.4	49	2.9	13	12.8	0.7603	0.174	0.418	0.147
2008	51.8	75	9.4	8	23.9	1.0213	0.148	0.434	0.046
2009	83.1	180	27.1	11	36.5	0.9745	0.111	0.892	0.033
2010	77.4	203	19.1	11	21.5	0.5921	0.107	1.391	0.073
2011	78.9	156	14.7	13	20.2	0.5228	0.115	0.837	0.057
2012	82.8	221	21.5	13	21.9	0.5721	0.108	1.302	0.061
2013	105.5	196	17.0	10	21.3	0.5566	0.109	1.408	0.083
2014	134.3	372	38.4	12	18.1	0.5493	0.095	2.239	0.058
2015	118.5	379	32.2	11	21.7	0.5587	0.097	2.504	0.078
2016	122.6	299	34.0	14	25.0	0.5535	0.102	1.581	0.046
2017	125.7	320	34.2	12	23.0	0.5768	0.101	1.680	0.049
2018	114.1	395	36.4	13	25.2	0.6032	0.101	1.993	0.055
2019	163.5	506	48.8	12	25.3	0.5858	0.098	2.130	0.044
2020	154.2	281	25.9	11	24.4	0.7338	0.116	0.953	0.037

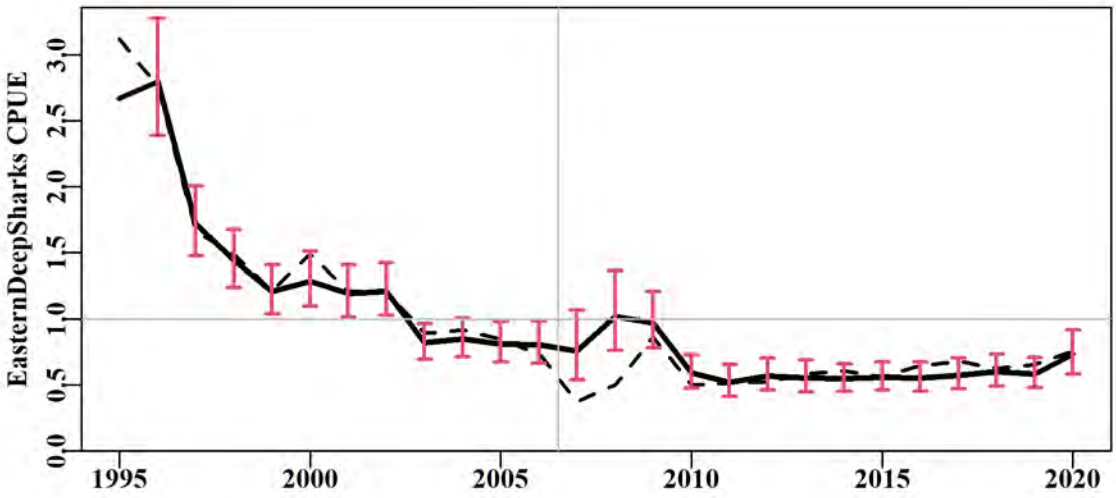

Figure 9.12. EasternDeepSharks standardization. The dashed black line represents the geometric mean CPUE, solid black line the standardized CPUE. The red bars are the 95% confidence intervals about the mean estimates. The graph scales both time-series of standardized CPUE relative to the mean of each time-series.

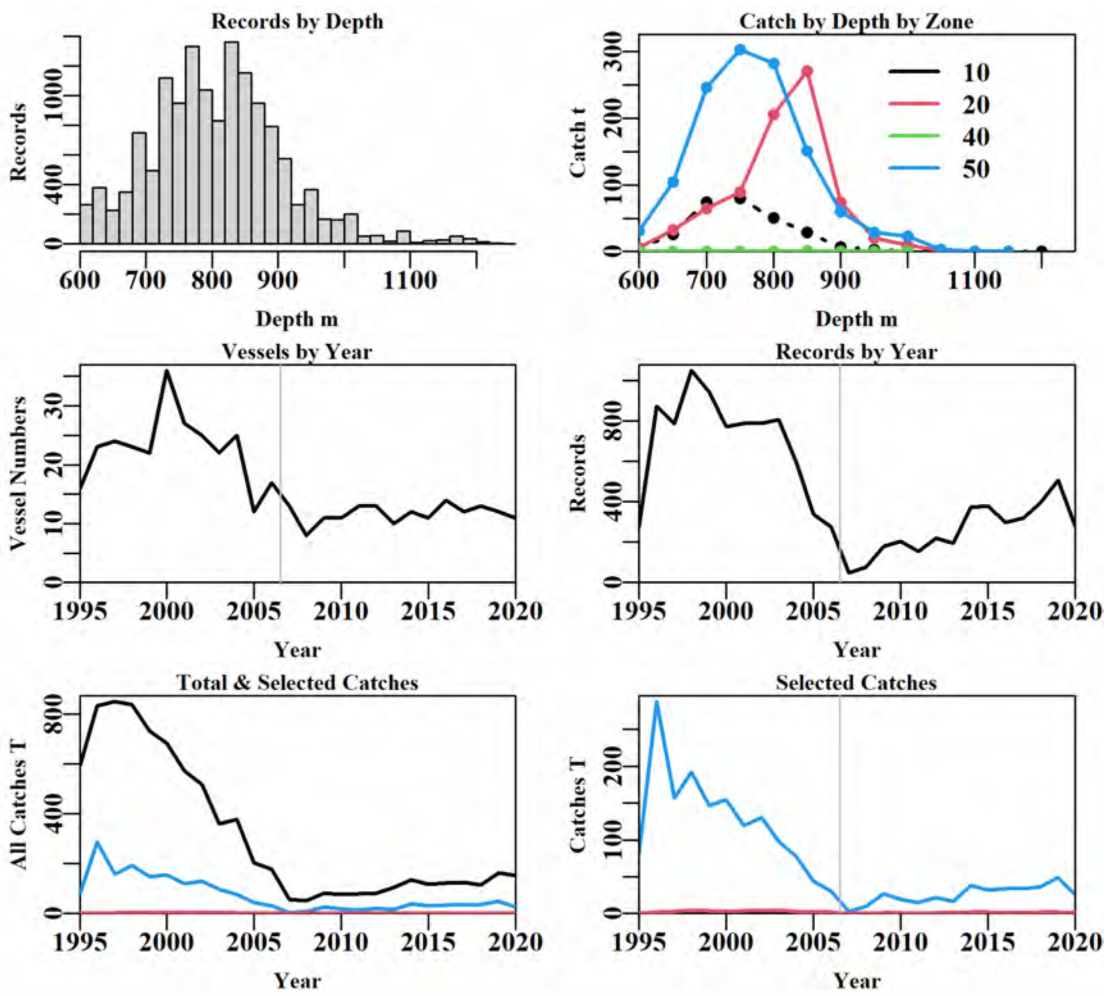

Figure 9.13. EasternDeepSharks fishery details. The bottom left plot depicts all known catches (top black line), and all selected catches used in the analysis (middle blue line); the lower red line: selected catches < 30 kg).

Table 9.10. 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	370489	239950	102210	57367	57056	14062	13383	11408
Difference	0	130539	137740	44843	311	42994	679	1975

Table 9.11. 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 9.12. 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

Term	AIC	RSS	MSS	Nobs	Npars	adj_r2	%Change
Year	3382	15276	2640	11408	26	14.6	0.00
Vessel	2240	13649	4267	11408	97	23.2	8.62
DepCat	1768	13068	4848	11408	109	26.4	3.19
Month	1744	13016	4900	11408	120	26.6	0.22
DayNight	1734	13000	4916	11408	122	26.7	0.08
ORzone	1591	12833	5083	11408	124	27.6	0.93
ORzone:DepCat	1493	12674	5242	11408	146	28.3	0.76
ORzone:Month	1542	12729	5187	11408	146	28.0	0.44

Table 9.13. EasternDeepSharks. Total catch (t) in the fishery under each separate CAAB code included in the basket species.

Name	CAAB Code	Total Catch (t)
Dogfishes	37020000	474.15
Black	37020002	71.89
Brier	37020003	96.51
Platypus	37020004	102.95
Plunket	37020013	0.236
Pearl	37020905	515.47
Roughskin	37020906	187.13
OtherSharks	37990003	426.99

Table 9.14. EasternDeepSharks. Annual catch (t) by CAAB code for a basket species.

Year	37020000	37020002	37020003	37020004	37020013	37020905	37020906	37990003
1995	43.61							38.64
1996	123.33							164.32
1997	65.57	5.93						85.66
1998	105.44	21.19						64.86
1999	84.39	21.84						40.42
2000	39.12	1.59		10.97		54.91	35.87	11.96
2001	10.04		11.33	16.18		51.15	22.99	7.11
2002	0.98		19.58	22.57	0.06	58.59	21.74	6.57
2003	0.57		12.37	12.98		47.86	23.85	0.07
2004	0.02		10.87	13.45		32.82	18.91	0.22
2005			4.48	8.00		23.27	7.63	0.24
2006			3.08	5.66		16.10	5.03	0.19
2007	0.06			0.40		1.64	0.48	0.27
2008				0.83		6.58	2.02	
2009	0.05		0.21	0.13		13.84	12.61	0.04
2010	0.75		0.02	1.02		11.70	4.89	0.01
2011	0.00			0.26	0.04	7.95	6.10	0.03
2012	0.03		0.50	1.51		10.19	8.94	
2013		0.03	1.93	1.45		8.60	4.97	
2014		3.73	4.55	1.39		22.98	4.57	1.04
2015	0.04	3.22	6.05	3.52		16.43	1.59	1.10
2016	0.00	2.41	6.10	1.09	0.06	20.62	2.74	0.93
2017	0.00	1.96	6.28	1.57		21.54	1.92	0.82
2018	0.02	2.47	4.30		0.06	28.01	0.30	1.22
2019	0.11	4.36	3.57			39.25		1.23
2020		3.16	1.29		0.02	21.42		0.01

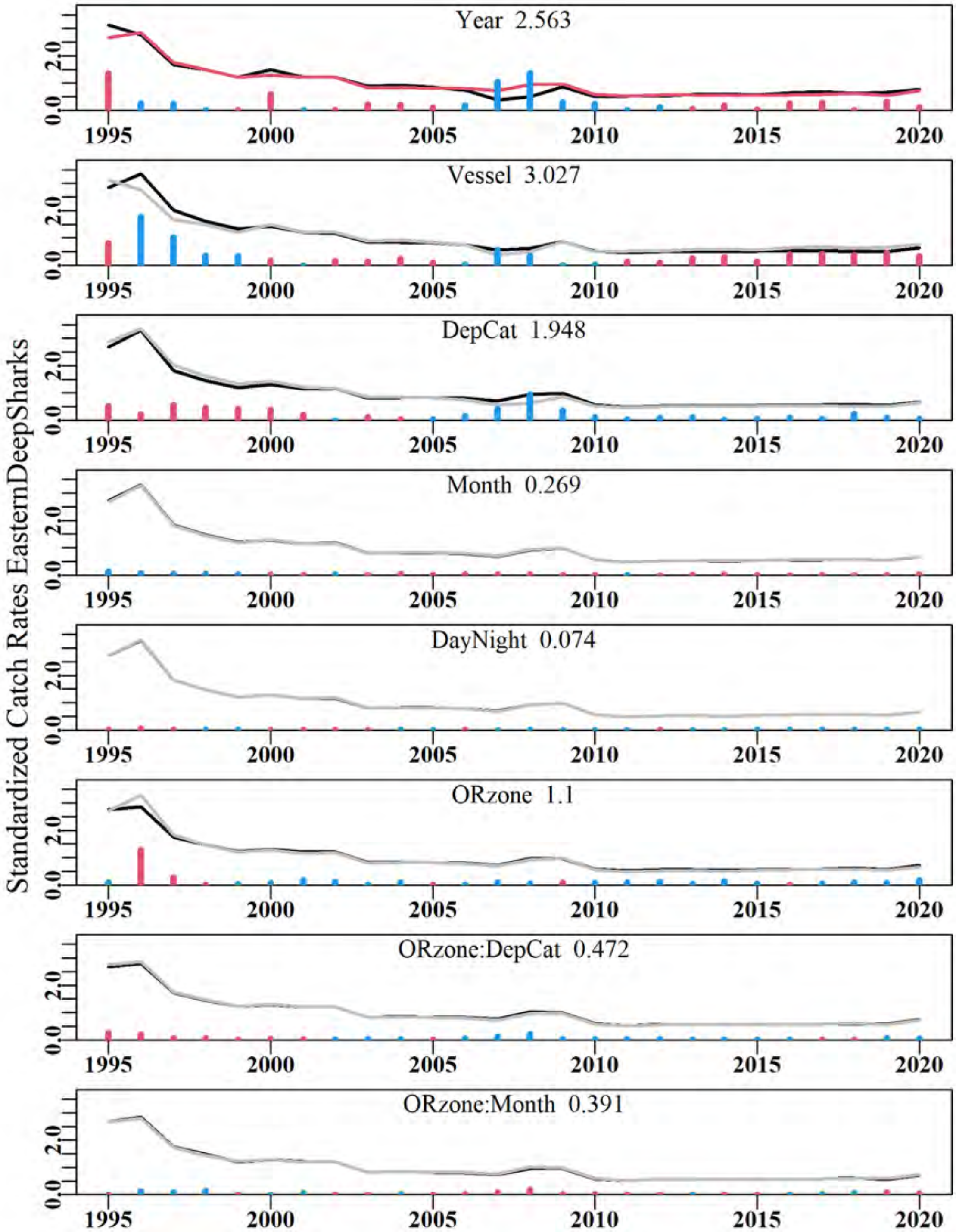

Figure 9.14. EasternDeepSharks. The influence of each factor on the optimal standardization. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by vertical bars with blue bars indicating the optimum model is higher than the 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.

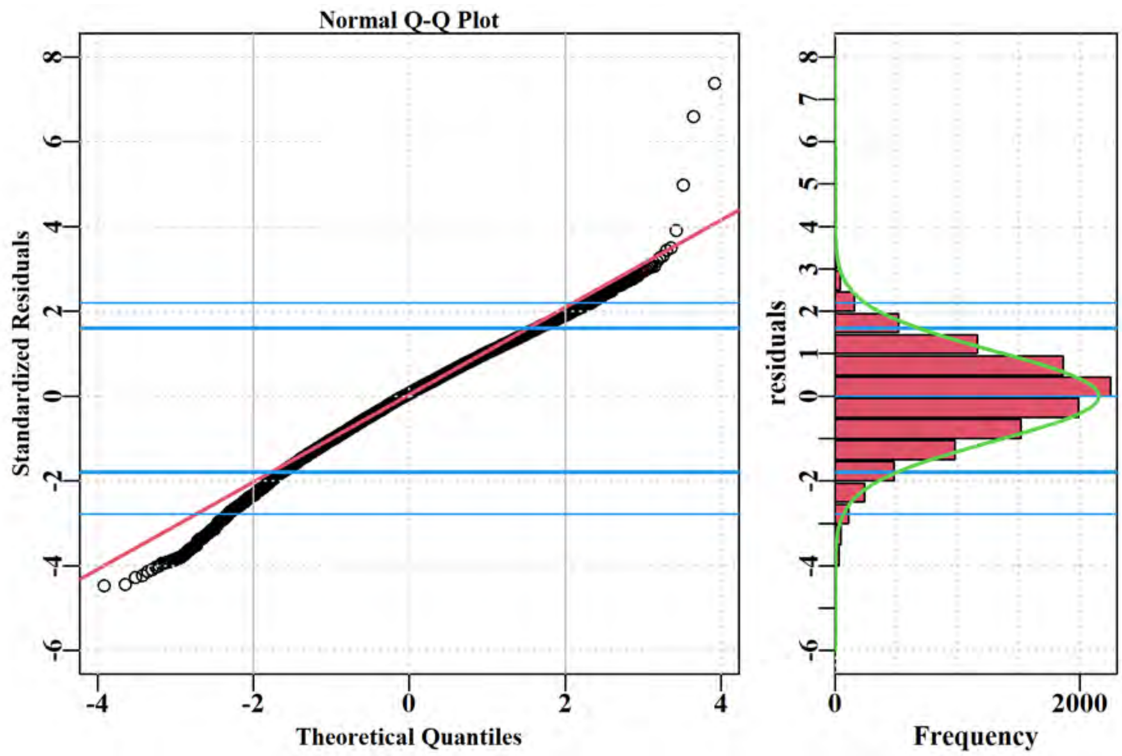

Figure 9.15. EasternDeepSharks. Diagnostic plots. The distribution of residuals from the optimum fit. The qqplot indicates the fit to the expected normality, while the histogram of residuals also illustrates the 1%, 5%, 95% and 99% quantiles to indicate the intensity of any lack of fit at the margins of the distribution (reflected also in the qqplot).

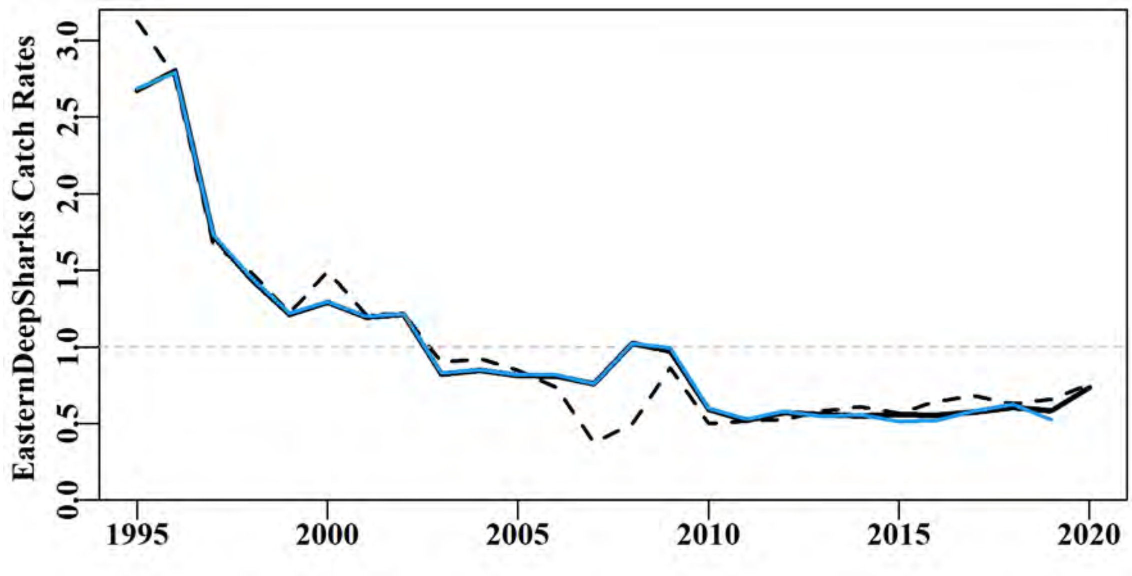

Figure 9.16. EasternDeepSharks. A comparison of the previous year's standardization (blue line) with this year's (black line). They should lie on top of each other, although small deviations may relate to data adjustments, particularly in very recent years. The geometric mean corresponds to the back dashed line.

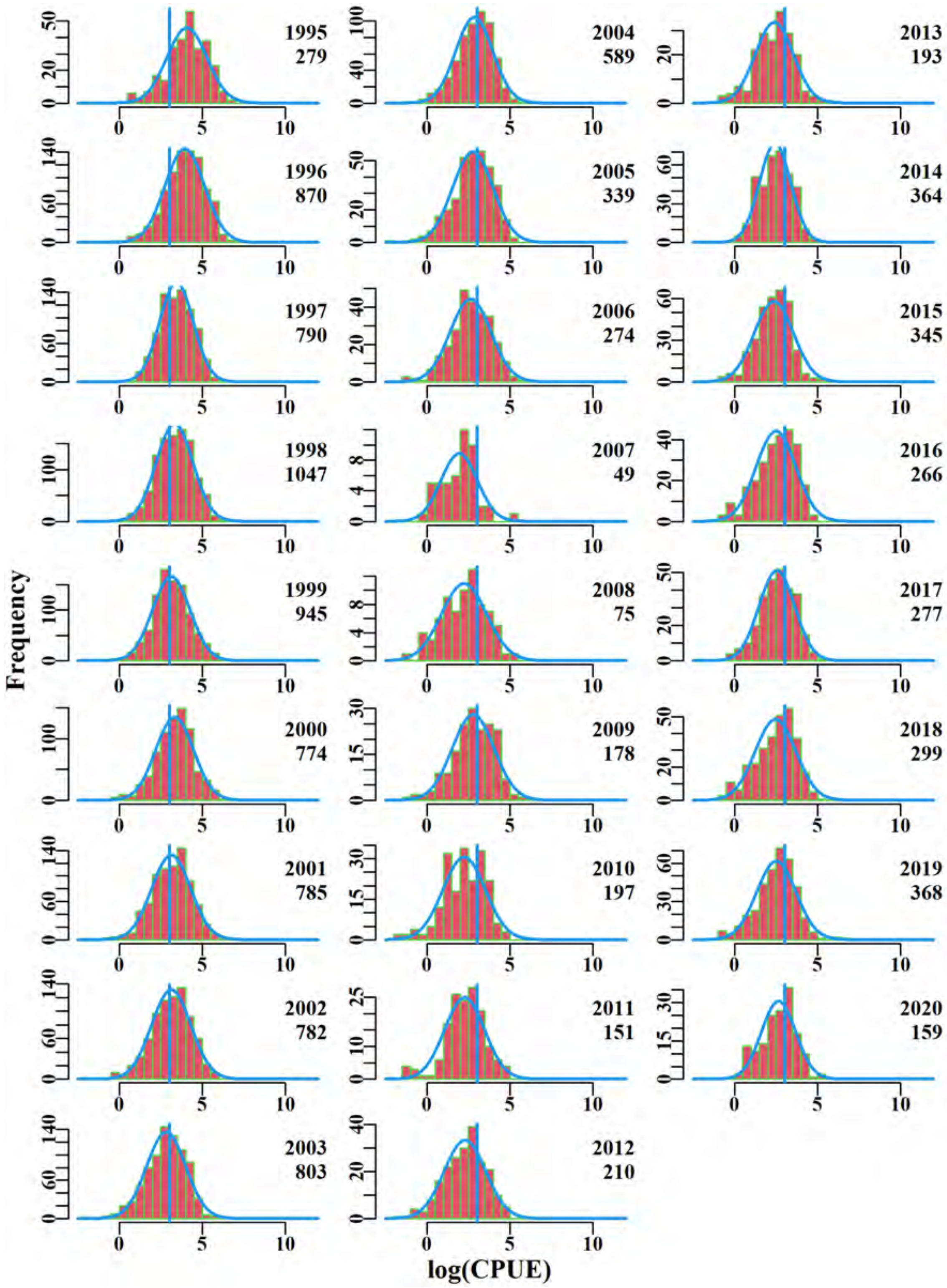

Figure 9.17. EasternDeepSharks. The natural log(CPUE) for each year of data available the blue lines are normal distributions fitted to the histogram frequencies. The numbers in each plot are the year and number of records. The vertical blue line is the average across all years.

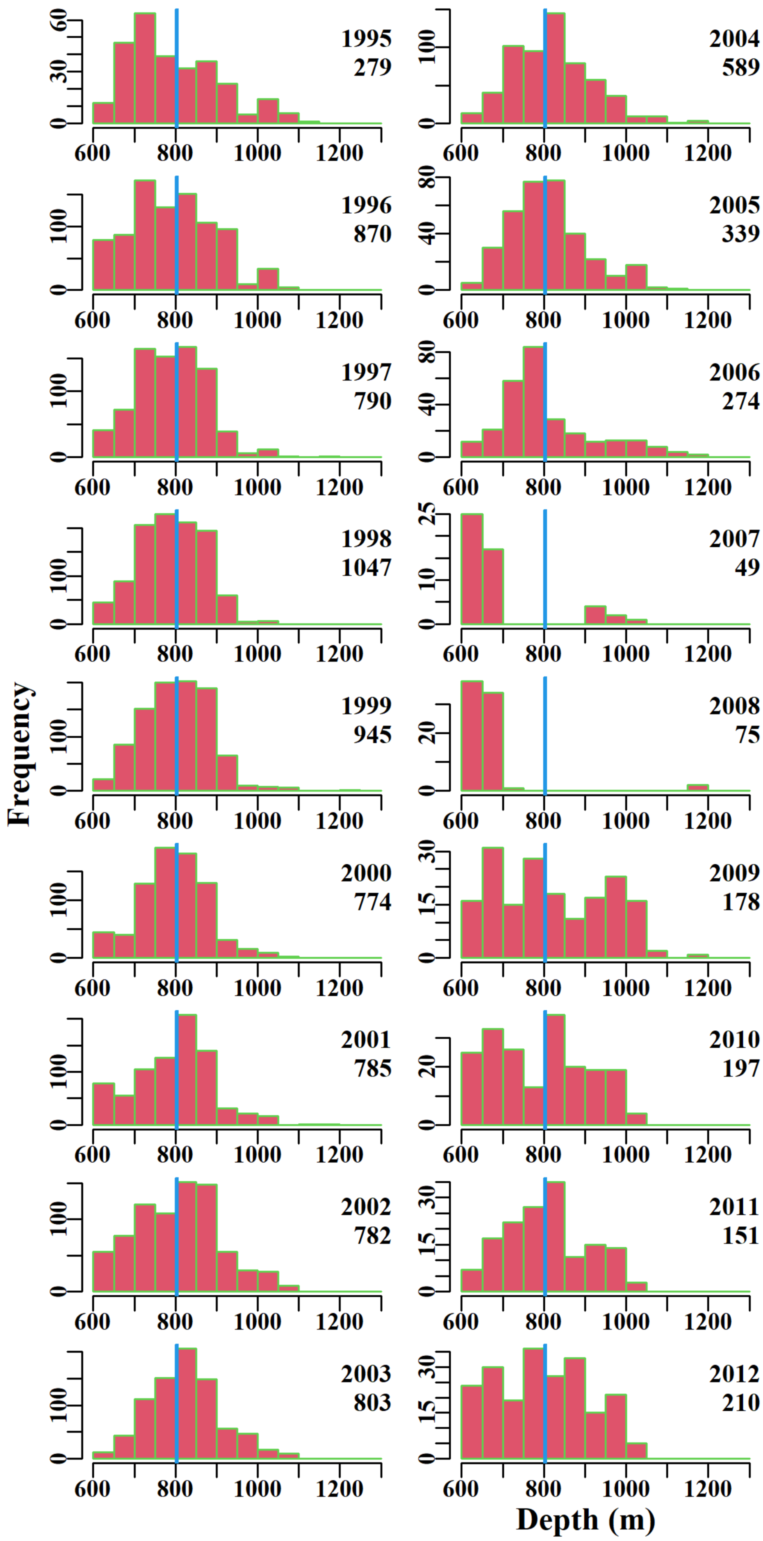

Figure 9.18. EasternDeepSharks. Frequency distribution of fishing depth (m) for each year of data available to illustrate the development of the fishery through time. The numbers in each plot are the year and number of records. The vertical blue line is the average across all years.

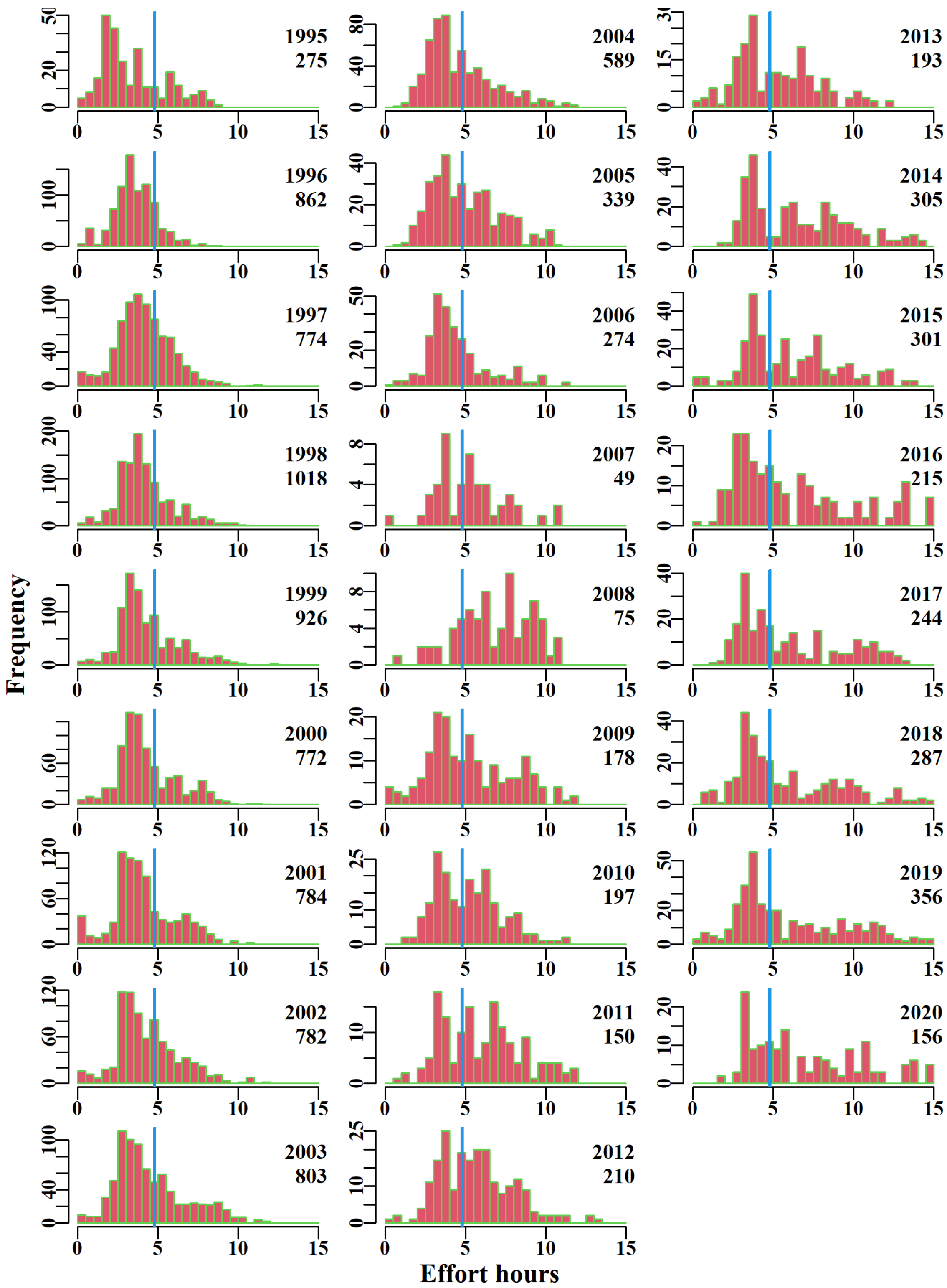

Figure 9.19. EasternDeepSharks. Frequency distribution of effort (hours) each year for the available data. The numbers in each plot are the year and number of records. The vertical blue line is the average across all years.

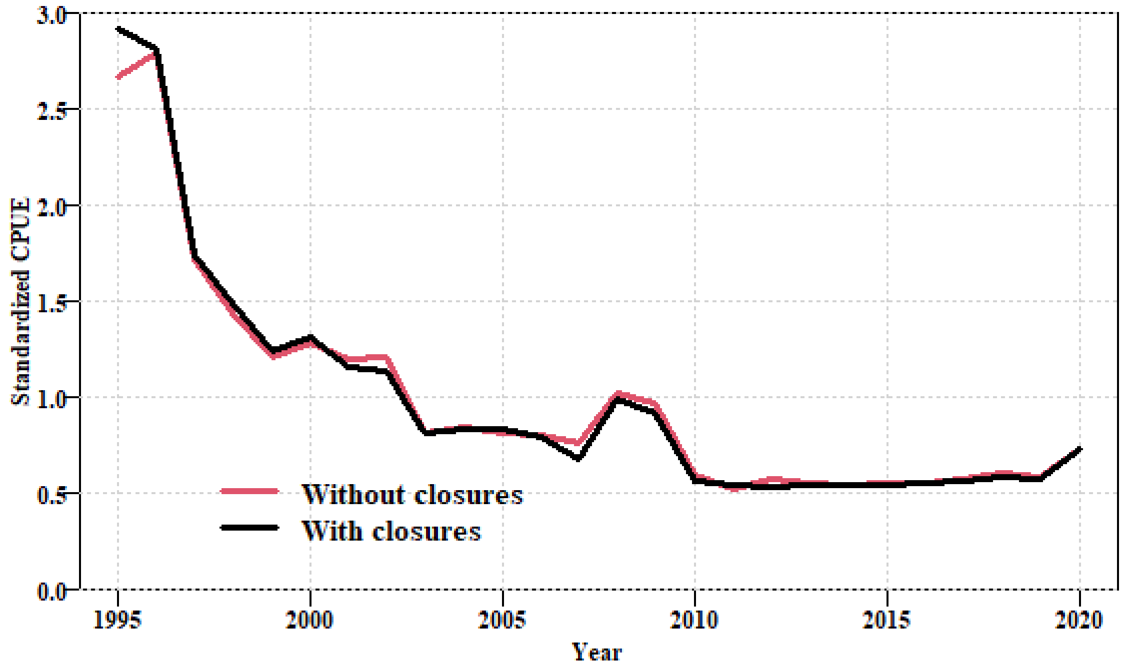

Figure 9.20. Standardized CPUE indices with and without closures.

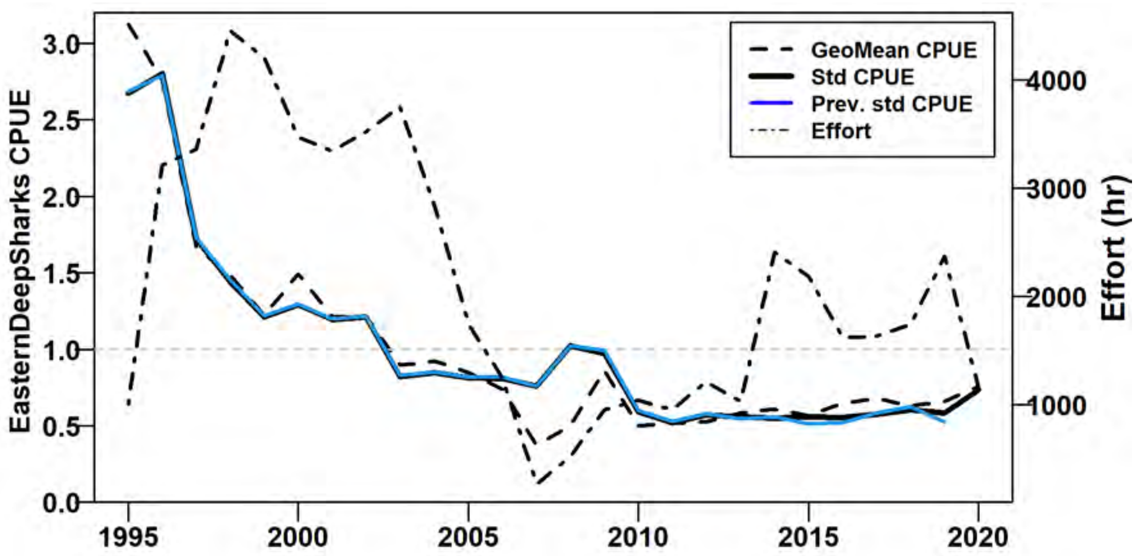

Figure 9.21. Annual standardised CPUE (blue), geometric mean CPUE (dashed line) and effort (dot-dash line).

9.6 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. CPUE was expressed as the natural log of catch per hour (catch/hr). The years analysed were 1995 - 2020 (Table 9.15).

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

9.6.1 *Inferences*

As with the eastern Deepwater Sharks, catches of western Deepwater Sharks decreased from a high in 1997 and 1998 to a low in 2007 after the introduction of the 700 m closure, picking up again after the modifications in 2009 and 2016, with an average of 86 t over the last five years. The 100 t catch in 2019 was the highest recorded since 2005.

The terms Year, Vessel and DepCat had the greatest contribution to model fit, based on the AIC and R^2 statistics (Table 9.19). 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 9.25).

Standardized CPUE has been approximately cyclic since about 2007 with lows over 2012-2014 period, but has returned to the long-term average since 2016, based on 95% confidence intervals (Figure 9.22). Generally, there is an increasing trend since 2012, although the 2019 and 2020 estimate decreased relative to 2018.

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.

9.6.2 *Action Items and Issues*

No issues identified.

Table 9.15. 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, OTB, TMO
years	1995 - 2020

Table 9.16. 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

Year	Total	N	Catch	Vess	GeoM	Opt	StDev	C<30Kg	P<30Kg
1995	595.4	694	103.2	11	43.0	1.6945	0.000	3.683	0.036
1996	834.2	1347	189.9	25	38.6	1.8082	0.047	8.613	0.045
1997	851.0	2322	339.9	22	37.0	1.4885	0.044	12.084	0.036
1998	838.5	3235	405.9	19	29.2	1.1564	0.043	17.624	0.043
1999	731.3	2449	321.4	22	28.8	1.1281	0.044	13.384	0.042
2000	683.6	2031	318.5	22	34.0	1.2736	0.046	8.361	0.026
2001	572.8	1929	244.3	20	27.3	0.9981	0.046	10.879	0.045
2002	516.0	1675	251.0	18	28.5	1.0508	0.047	7.883	0.031
2003	360.8	1459	167.7	18	20.9	0.8032	0.047	8.009	0.048
2004	377.7	1819	212.8	15	22.4	0.8184	0.047	10.673	0.050
2005	202.8	862	84.1	13	20.5	0.7213	0.052	6.061	0.072
2006	178.1	616	69.4	13	22.3	0.8398	0.056	3.798	0.055
2007	56.4	111	8.8	9	20.7	0.8721	0.102	0.611	0.070
2008	51.8	118	15.5	8	25.1	1.1331	0.101	0.312	0.020
2009	83.1	226	33.4	10	25.8	1.1725	0.078	1.032	0.031
2010	77.4	274	36.0	9	25.7	1.0496	0.073	1.886	0.052
2011	78.9	309	38.0	11	22.4	0.9071	0.069	1.479	0.039
2012	82.8	379	35.4	10	15.7	0.6119	0.067	2.740	0.077
2013	105.5	683	69.2	12	14.9	0.5958	0.058	4.108	0.059
2014	134.3	772	74.0	9	13.2	0.5521	0.057	4.673	0.063
2015	118.5	579	70.9	8	17.2	0.6774	0.060	2.636	0.037
2016	122.6	563	75.9	10	23.1	0.8979	0.062	2.621	0.035
2017	125.7	628	76.7	10	24.4	0.8911	0.061	3.369	0.044
2018	114.1	479	67.8	10	26.3	1.0622	0.066	1.766	0.026
2019	163.5	698	100.0	9	22.6	0.9153	0.060	2.572	0.026
2020	154.2	832	107.1	9	22.3	0.8809	0.057	4.246	0.040

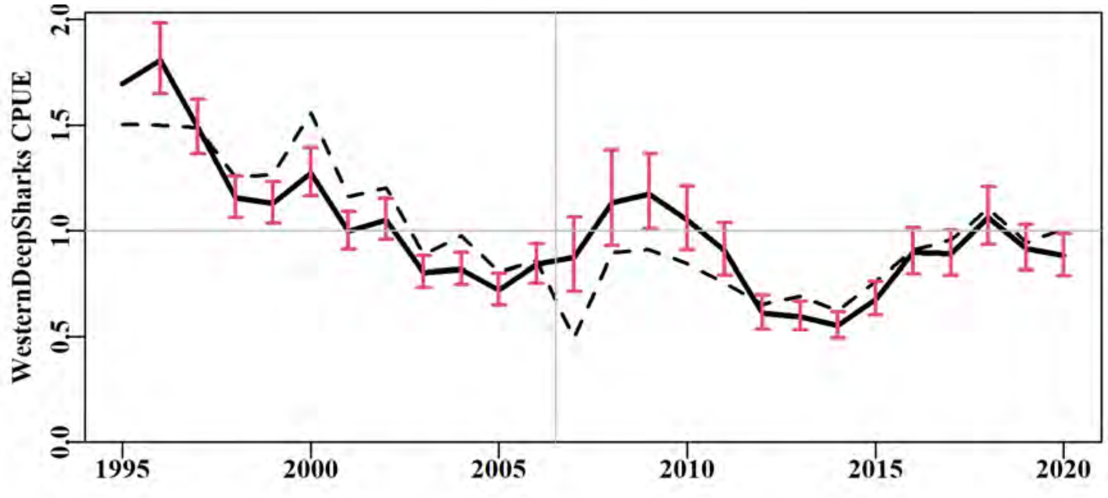

Figure 9.22. WesternDeepSharks standardization. The dashed black line represents the geometric mean CPUE, solid black line the standardized CPUE. The red bars are the 95% confidence intervals about the mean estimates. The graph scales both time-series of standardized CPUE relative to the mean of each time-series.

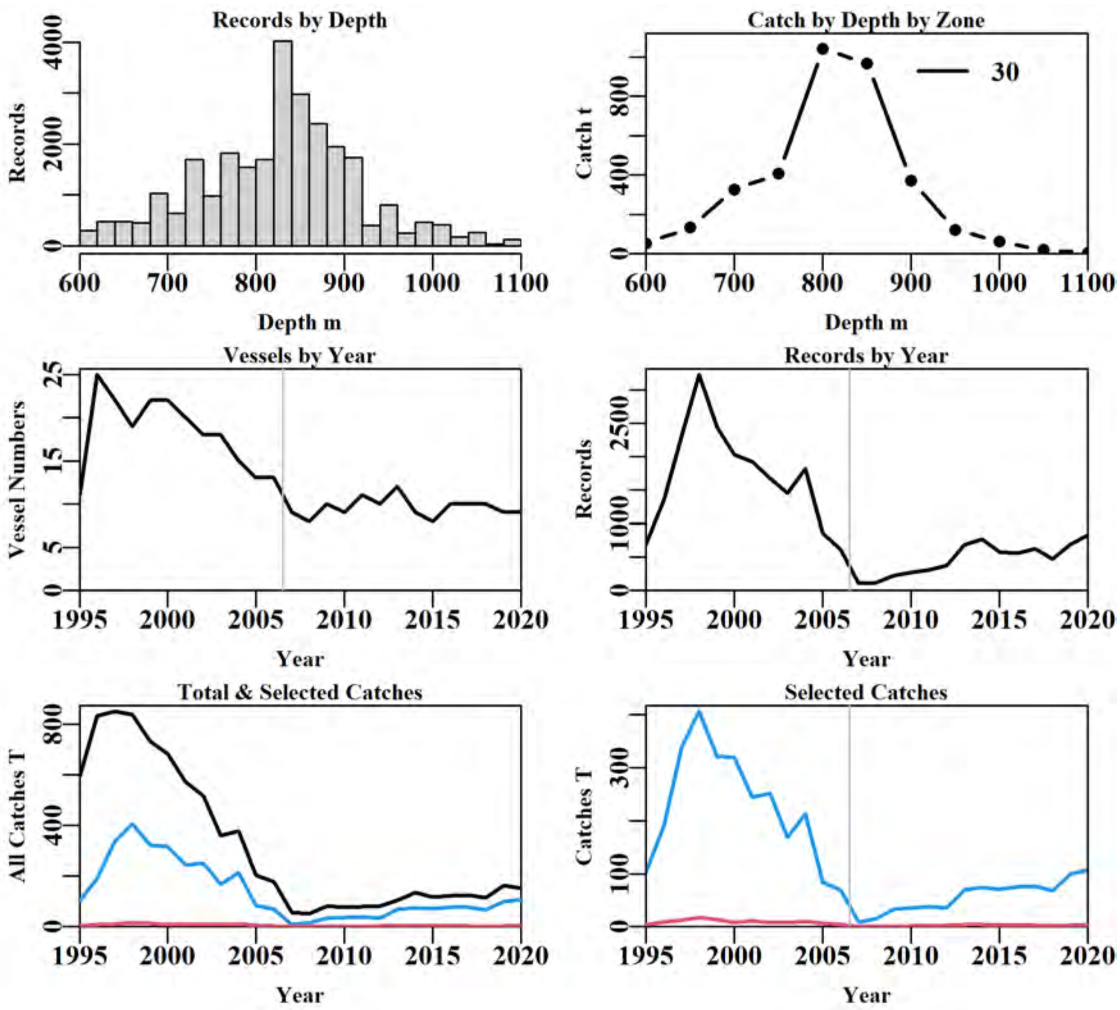

Figure 9.23. WesternDeepSharks fishery details. The bottom left plot depicts all known catches (top black line), and all selected catches used in the analysis (middle blue line); the lower red line: selected catches < 30 kg).

Table 9.17. 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	370489	239950	102210	34743	34727	27089	26431
Difference	0	130539	137740	67467	16	7638	658

Table 9.18. 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 9.19. 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

Term	AIC	RSS	MSS	Nobs	Npars	adj_r2	%Change
Year	1567	27990	1739	26431	26	5.8	0.00
Vessel	135	26422	3307	26431	72	10.9	5.12
DepCat	-2363	24021	5708	26431	82	19.0	8.07
Month	-2493	23884	5845	26431	93	19.4	0.43
DayNight	-2575	23804	5925	26431	96	19.6	0.26
inout	-2634	23749	5980	26431	97	19.8	0.18
Vessel:DepCat	-3450	22547	7181	26431	375	23.1	3.24
Vessel:Month	-2871	22927	6802	26431	444	21.6	1.74

Table 9.20. 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	513.88
Black	37020002	352.58
Platypus	37020004	271.62
Plunket	37020013	0.224
Pearl	37020905	1193.20
Roughskin	37020906	564.37
Lantern	37020907	0
OtherSharks	37990003	620.69

Table 9.21. WesternDeepSharks. Annual catch (t) by CAAB code for a basket species.

Year	37020000	37020002	37020004	37020013	37020905	37020906	37020907	37990003
1995	49.07							54.10
1996	96.15							93.75
1997	122.53	34.69						182.67
1998	124.31	148.12						133.44
1999	95.57	120.26						105.55
2000	19.48	12.93	16.29		105.25	135.17		29.35
2001	0.12		26.18		107.18	103.62		7.20
2002	0.05		36.77		146.99	63.59		3.58
2003	0.05		20.42		87.11	59.16		0.96
2004	0.10		20.87		117.34	74.35		0.11
2005	1.09		11.04		46.33	22.98		2.67
2006	0.38		9.55		41.51	17.95		
2007	1.59		0.30		5.68	1.21		
2008	0.71		2.52		6.82	5.36		0.12
2009	1.03		2.11		14.54	15.72		
2010	0.18		3.39		12.02	20.44		
2011	0.36		3.08		18.18	14.95		1.46
2012	0.40		4.21		24.37	6.34		0.03
2013	0.36	2.28	25.54		26.04	15.01		
2014	0.20	5.70	28.67		32.13	4.10		3.18
2015	0.09	4.28	28.35		33.77	2.30		2.07
2016	0.00	3.77	23.41		47.25	1.12		0.39
2017	0.00	3.68	3.07	0.22	69.12	0.54		0.05
2018	0.06	2.78	1.35		63.46	0.12		0.00
2019		5.27	3.31		91.24	0.18	0	0.00
2020		8.83	1.18		96.89	0.16	0	0.00

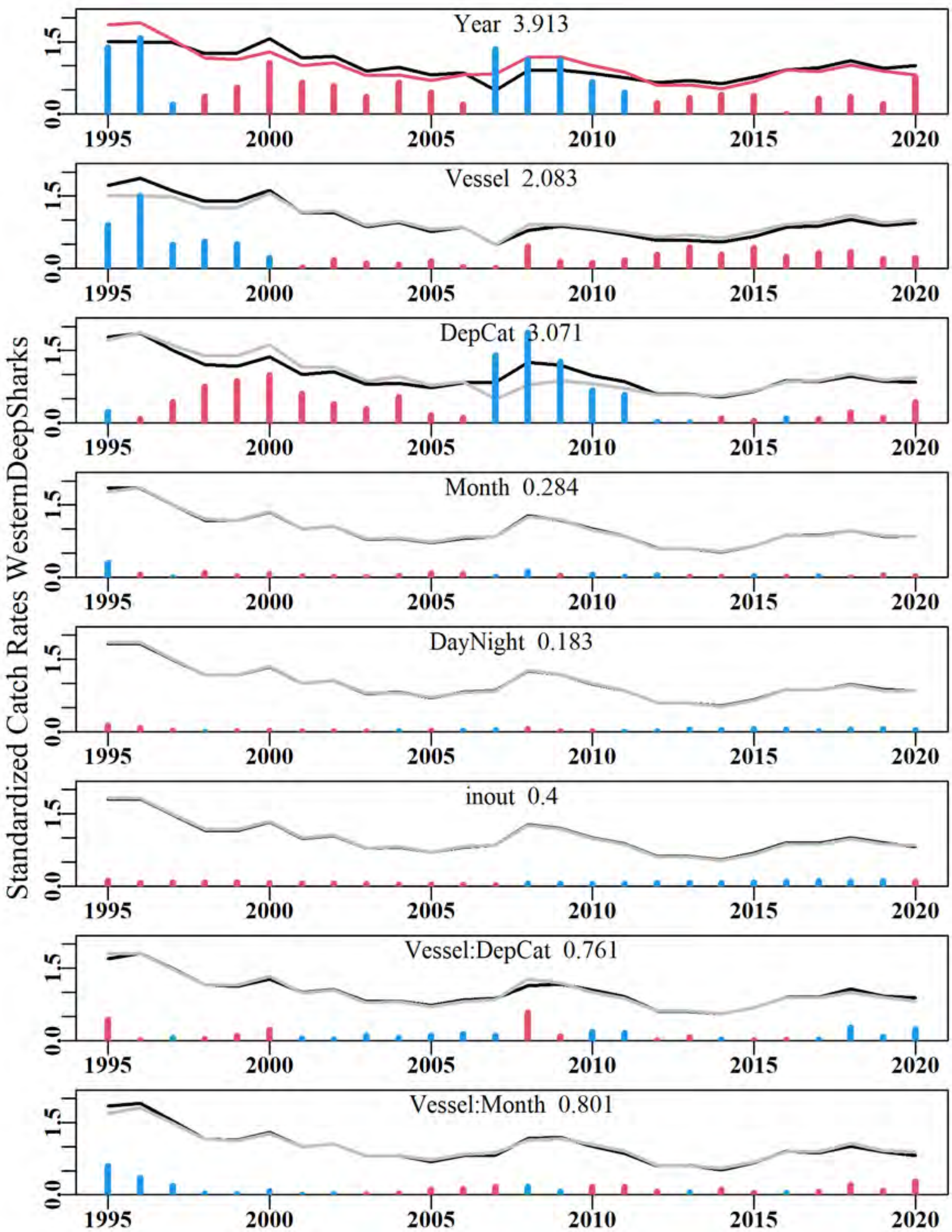

Figure 9.24. WesternDeepSharks. The influence of each factor on the optimal standardization. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by vertical bars with blue bars indicating the optimum model is higher than the 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.

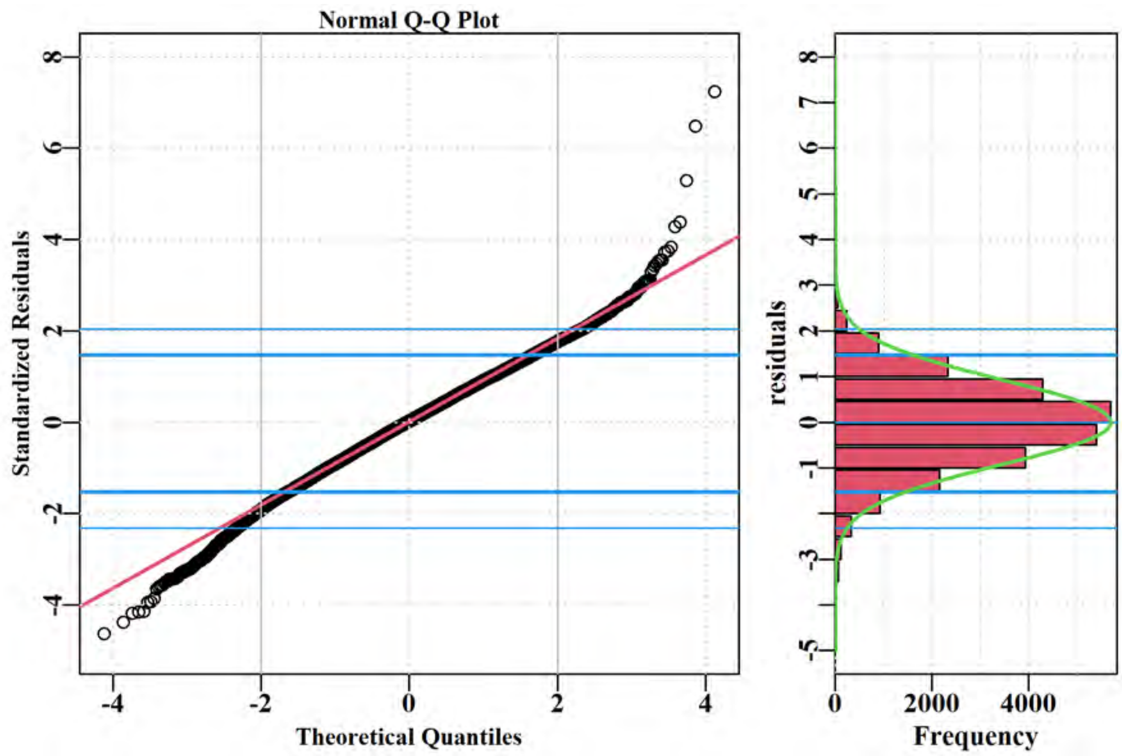

Figure 9.25. WesternDeepSharks. Diagnostic plots. The distribution of residuals from the optimum fit. The qqplot indicates the fit to the expected normality, while the histogram of residuals also illustrates the 1%, 5%, 95% and 99% quantiles to indicate the intensity of any lack of fit at the margins of the distribution (reflected also in the qqplot).

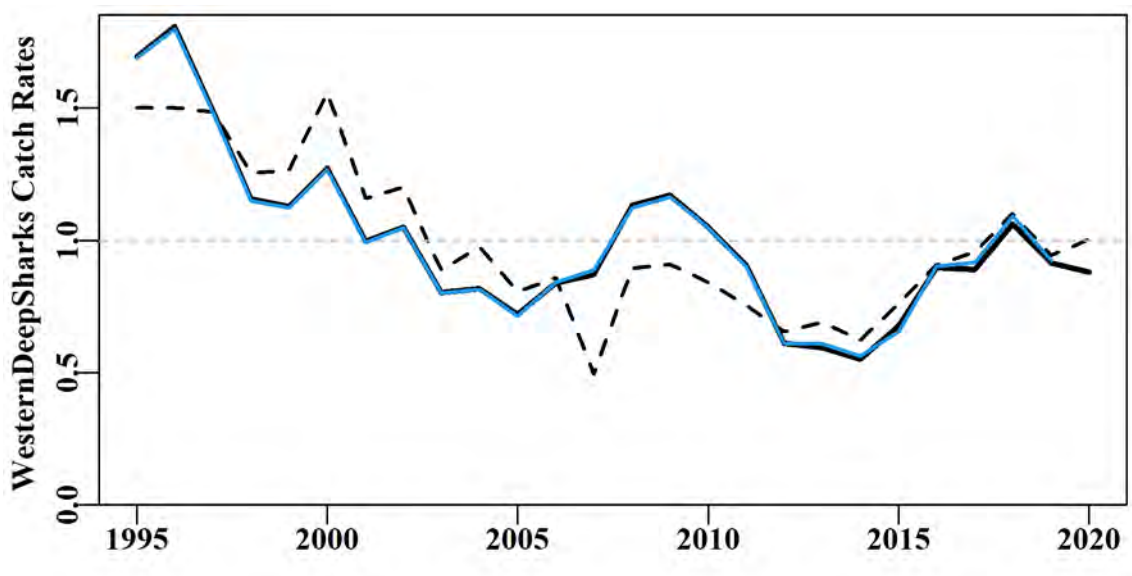

Figure 9.26. WesternDeepSharks. A comparison of the previous year's standardization (blue line) with this year's (black line). They should lie on top of each other, although small deviations may relate to data adjustments, particularly in very recent years. The geometric mean corresponds to the back dashed line.

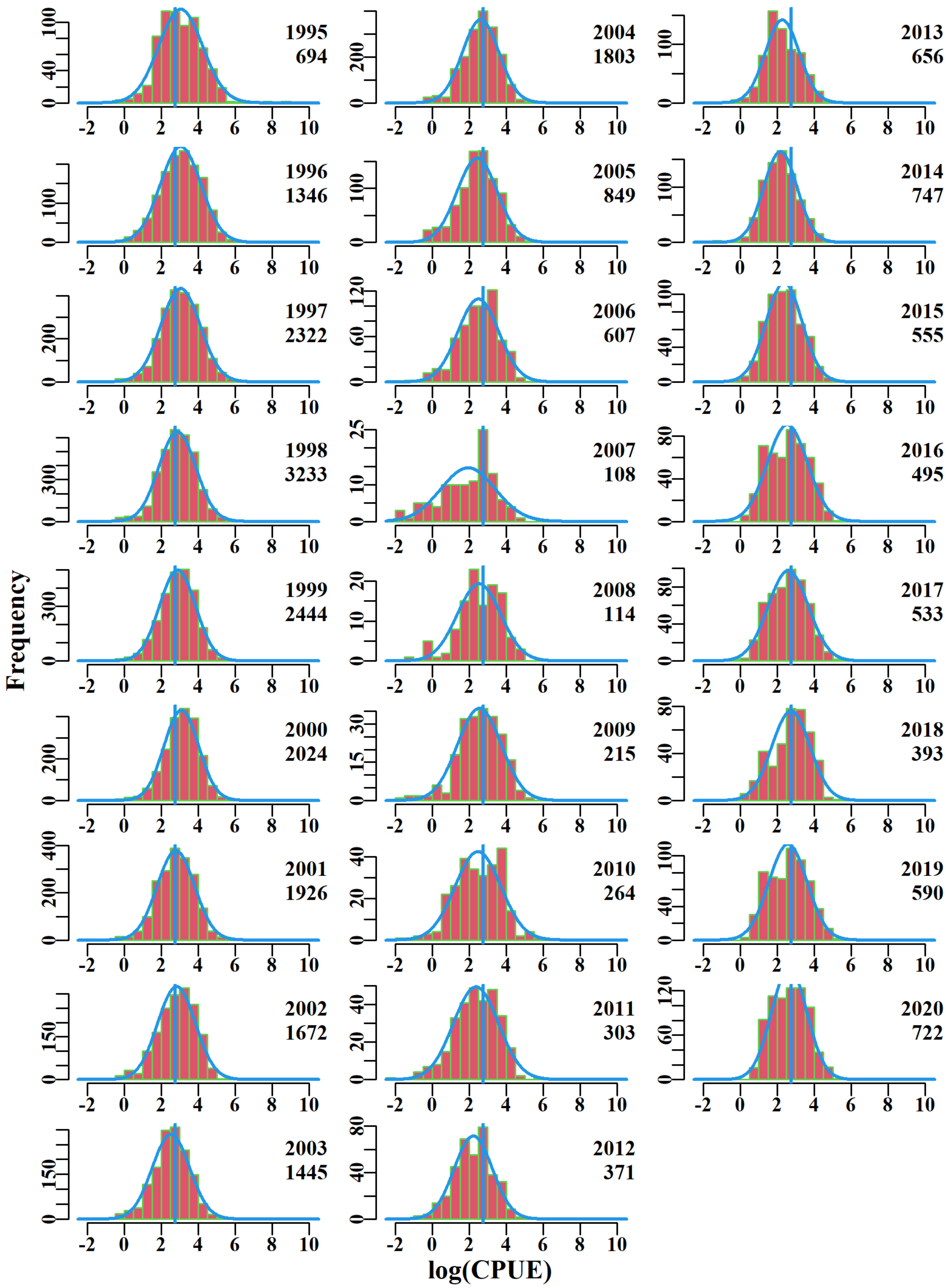

Figure 9.27. WesternDeepSharks. The natural log(CPUE) for each year of data available the blue lines are normal distributions fitted to the histogram frequencies. The numbers in each plot are the year and number of records. The vertical blue line is the average across all years.

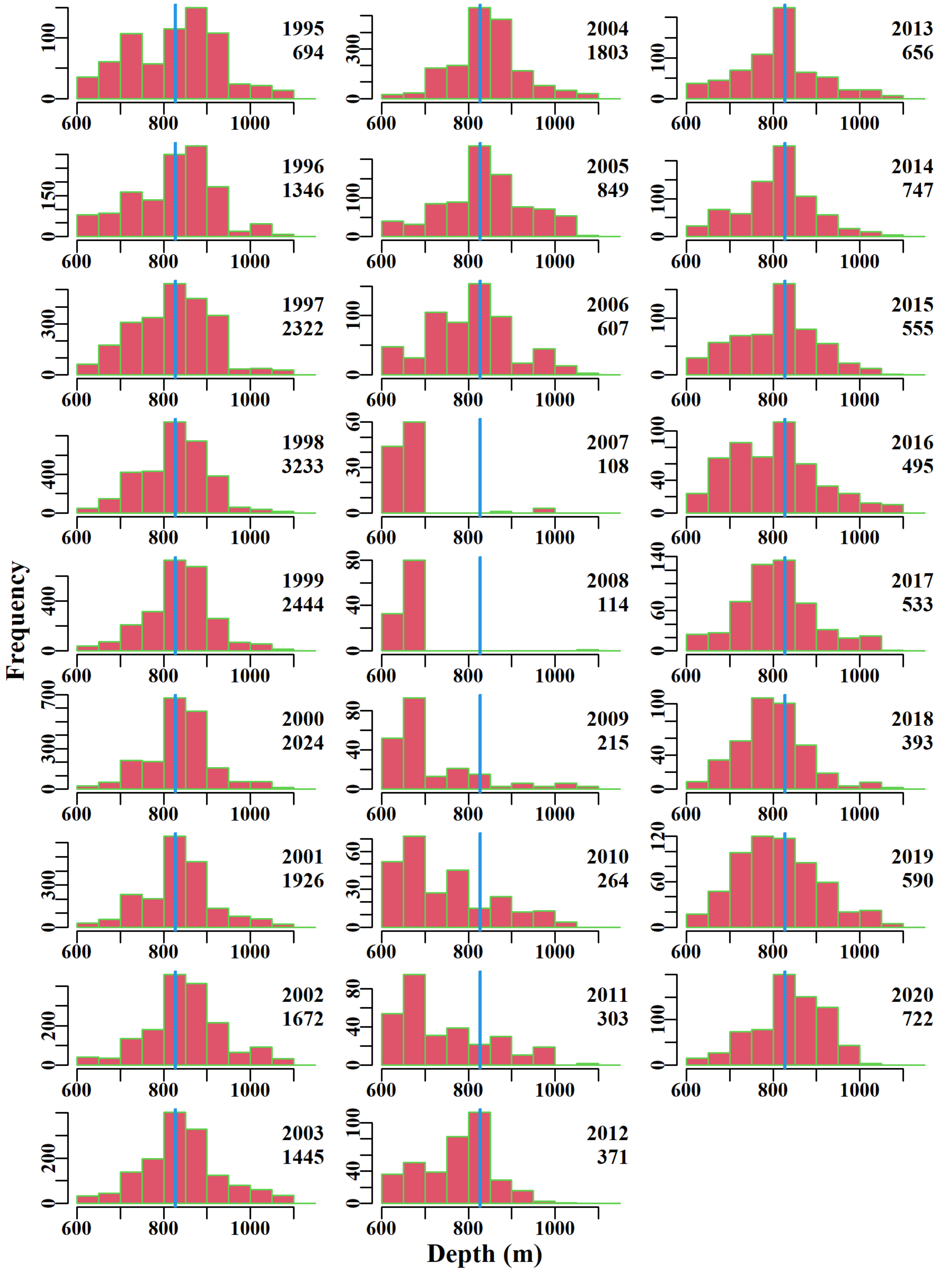

Figure 9.28. WesternDeepSharks. Frequency distribution of fishing depth (m) for each year of data available to illustrate the development of the fishery through time. The numbers in each plot are the year and number of records. The vertical blue line is the average across all years.

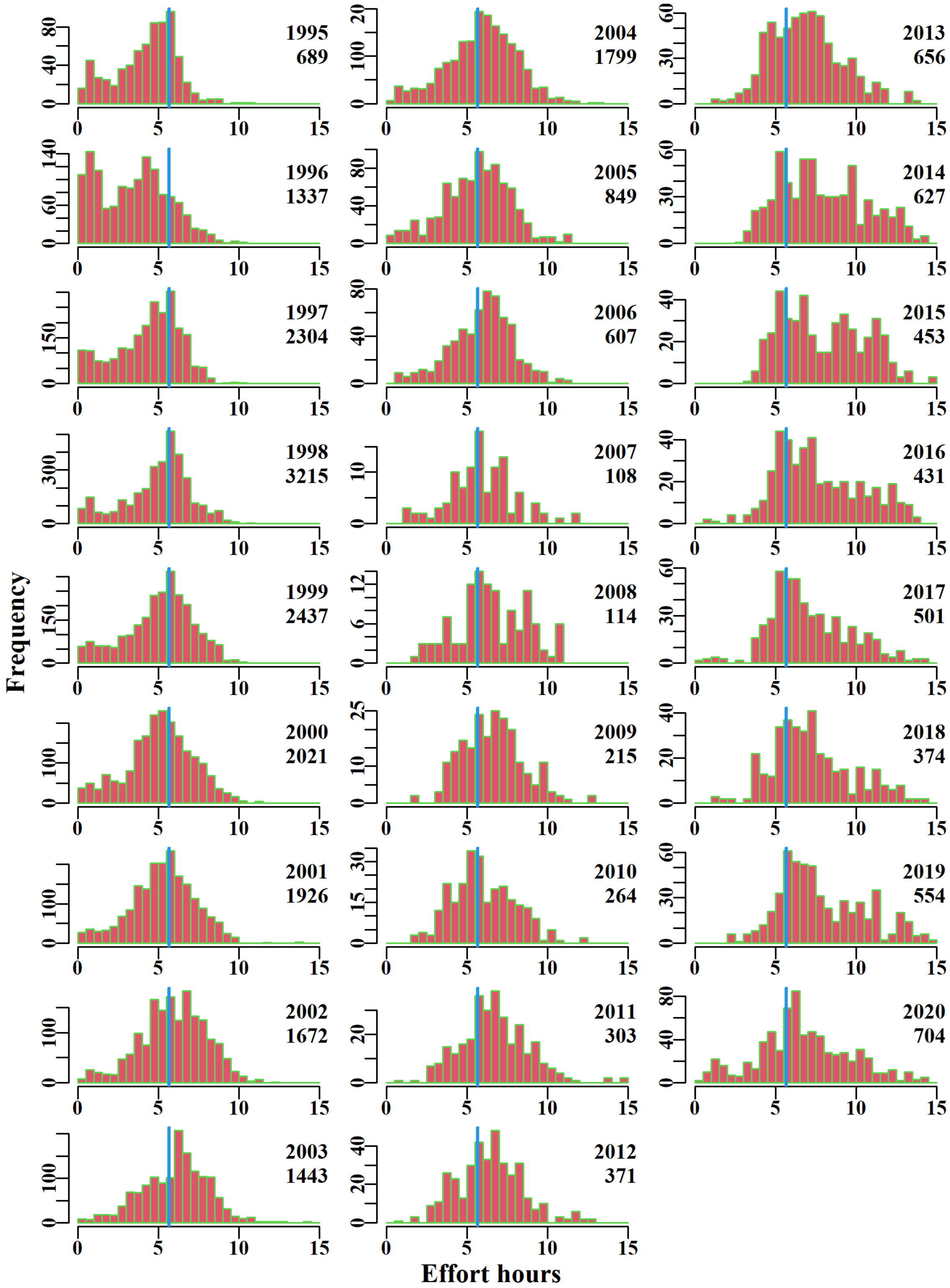

Figure 9.29. WesternDeepSharks. Frequency distribution of effort (hours) each year for the available data. The numbers in each plot are the year and number of records. The vertical blue line is the average across all years.

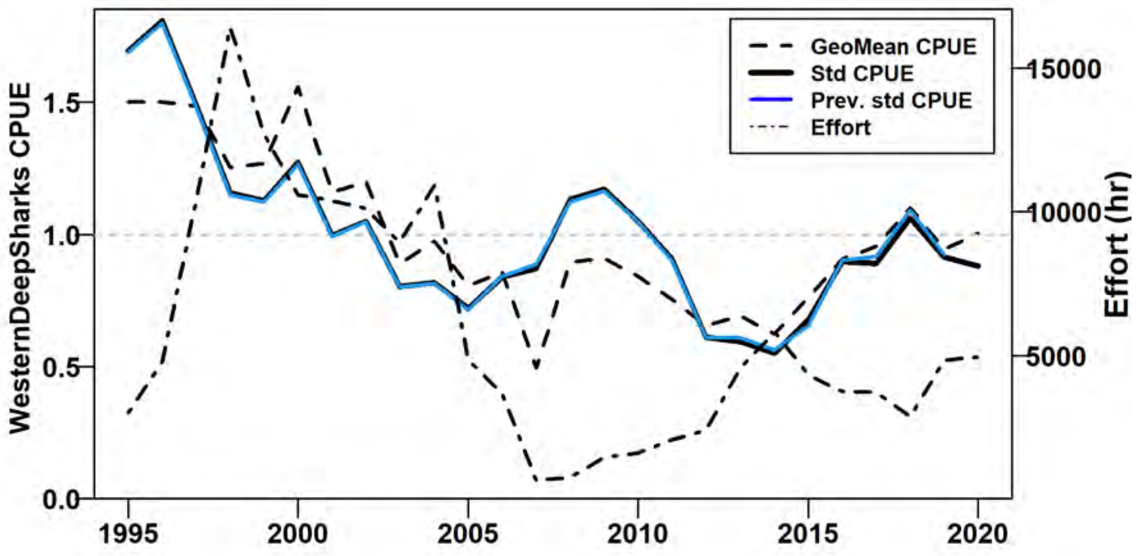

Figure 9.30. Annual standardised CPUE (blue), geometric mean CPUE (dashed line) and effort (dot-dash line).

9.7 *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. CPUE was expressed as the natural log of catch per hour (catch/hr). The years analysed were 1995 – 2020 (Table 9.22). Also, the 700 m closure was omitted from analyses.

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

9.7.1 *Inferences*

The terms Year, Vessel and DepCat and one interaction (Vessel:DepCat) had the greatest contribution to model fit, based on the AIC and R^2 statistics (Table 9.26). The qqplot suggests that the assumed Normal distribution of the log-transformed CPUE, is valid, with slight deviations as depicted from both tails (Figure 9.34).

Standardized CPUE has been approximately cyclic since about 2007 with lows over 2012-2014 period, and since then, there has been an overall increasing trend reaching the long-term average based on 95% confidence intervals (Figure 9.31).

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

9.7.2 *Action Items and Issues*

No issues identified.

Table 9.22. 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, OTB, TMO
years	1995 - 2020

Table 9.23. 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

Year	Total	N	Catch	Vess	GeoM	Opt	StDev	C<30Kg	P<30Kg
1995	595.4	485	75.2	9	37.0	1.6021	0.000	2.431	0.032
1996	834.2	877	143.2	22	40.1	1.8433	0.058	4.821	0.034
1997	851.0	1632	253.3	20	37.1	1.5083	0.053	7.097	0.028
1998	838.5	2213	273.8	19	28.7	1.1629	0.052	11.071	0.040
1999	731.3	1654	201.9	21	25.2	1.0730	0.053	8.653	0.043
2000	683.6	1369	210.9	22	31.5	1.2757	0.055	5.361	0.025
2001	572.8	1307	165.2	19	25.8	1.0176	0.055	6.746	0.041
2002	516.0	1093	167.6	17	30.1	1.0973	0.056	4.977	0.030
2003	360.8	997	113.5	16	20.0	0.8528	0.057	5.266	0.046
2004	377.7	1225	144.8	14	22.4	0.8356	0.056	7.545	0.052
2005	202.8	573	56.4	13	20.2	0.7312	0.063	3.984	0.071
2006	178.1	438	52.0	13	23.3	0.9137	0.067	2.530	0.049
2007	56.4	98	7.9	9	19.0	0.8439	0.111	0.548	0.069
2008	51.8	114	15.1	8	25.6	1.1999	0.107	0.312	0.021
2009	83.1	212	31.7	9	26.2	1.1964	0.084	0.942	0.030
2010	77.4	256	33.4	9	25.0	1.0373	0.080	1.776	0.053
2011	78.9	293	35.5	11	22.0	0.8926	0.075	1.404	0.040
2012	82.8	370	34.4	10	15.7	0.5995	0.074	2.684	0.078
2013	105.5	659	66.6	12	14.9	0.5931	0.065	3.969	0.060
2014	134.3	758	72.7	9	13.3	0.5306	0.064	4.610	0.063
2015	118.5	570	69.3	8	17.0	0.6522	0.067	2.611	0.038
2016	122.6	540	71.0	10	22.8	0.8467	0.069	2.521	0.036
2017	125.7	619	73.1	10	24.0	0.8527	0.068	3.369	0.046
2018	114.1	472	66.6	10	26.3	0.9989	0.072	1.766	0.027
2019	163.5	680	96.3	9	22.4	0.8585	0.067	2.498	0.026
2020	154.2	418	67.0	9	25.7	0.9842	0.073	1.556	0.023

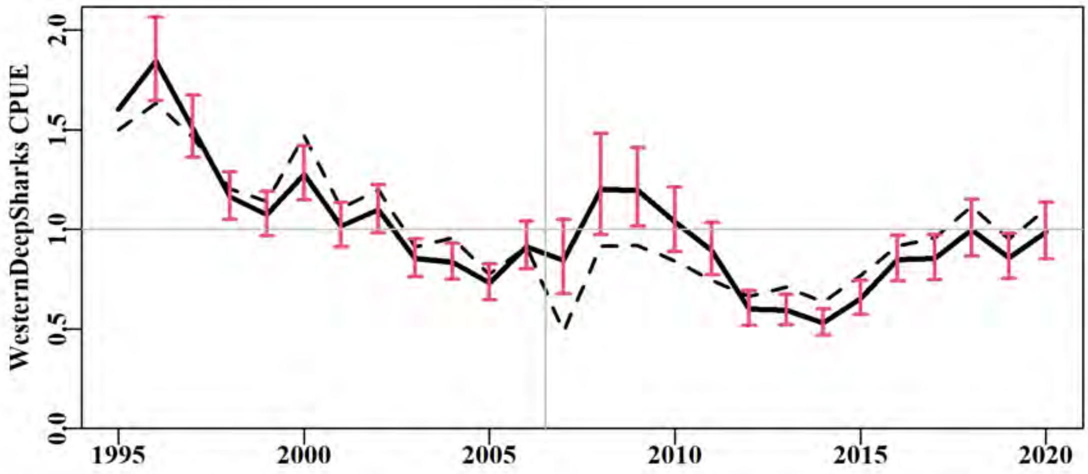

Figure 9.31. WesternDeepSharks standardization. The dashed black line represents the geometric mean CPUE, solid black line the standardized CPUE. The red bars are the 95% confidence intervals about the mean estimates. The graph scales both time-series of standardized CPUE relative to the mean of each time-series.

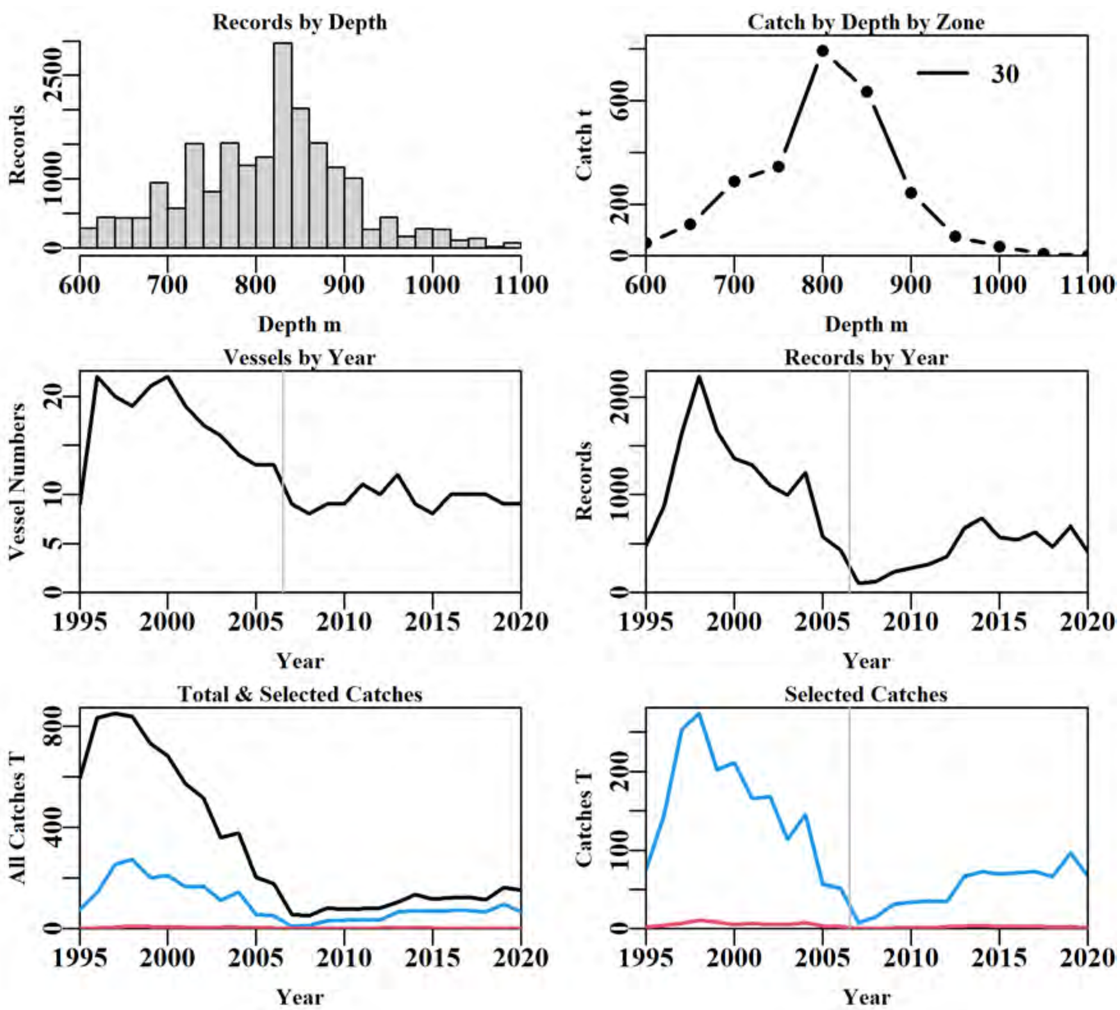

Figure 9.32. WesternDeepSharks fishery details. The bottom left plot depicts all known catches (top black line), and all selected catches used in the analysis (middle blue line); the lower red line: selected catches < 30 kg).

Table 9.24. 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	370489	239950	102210	34743	34727	27089	26431	19345
Difference	0	130539	137740	67467	16	7638	658	7086

Table 9.25. 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 9.26. 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

Term	AIC	RSS	MSS	Nobs	Npars	adj_r2	%Change
Year	1492	20840	1267	19345	26	5.6	0.00
Vessel	368	19572	2535	19345	71	11.1	5.54
DepCat	-1599	17661	4445	19345	81	19.8	8.63
Month	-1708	17543	4564	19345	92	20.3	0.49
DayNight	-1760	17492	4615	19345	94	20.5	0.22
Vessel:DepCat	-2169	16675	5432	19345	352	23.2	2.68
Vessel:Month	-1770	16884	5222	19345	431	21.9	1.39

Table 9.27. 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	379.63
Black	37020002	217.25
Platypus	37020004	254.23
Plunket	37020013	0.224
Pearl	37020905	911.43
Roughskin	37020906	386.73
Lantern	37020907	0
OtherSharks	37990003	448.97

Table 9.28. WesternDeepSharks. Annual catch (t) by CAAB code for a basket species.

Year	37020000	37020002	37020004	37020013	37020905	37020906	37020907	37990003
1995	36.76							38.46
1996	76.24							67.00
1997	95.35	26.40						131.57
1998	88.21	87.06						98.51
1999	62.16	65.60						74.17
2000	14.44	8.74	13.97		71.03	79.98		22.78
2001	0.10		22.57		71.37	66.33		4.87
2002	0.05		34.76		89.01	40.49		3.29
2003	0.05		17.99		54.93	39.63		0.93
2004	0.10		18.32		76.03	50.35		0.05
2005	1.06		10.19		30.88	13.62		0.64
2006	0.22		8.19		30.35	13.25		
2007	1.52		0.25		5.26	0.86		
2008	0.71		2.33		6.67	5.33		0.09
2009	1.03		2.11		13.63	14.91		
2010	0.18		3.06		10.79	19.36		
2011	0.36		2.95		17.15	14.04		0.96
2012	0.40		4.21		23.62	6.16		0.03
2013	0.36	2.28	25.10		24.60	14.26		
2014	0.20	5.65	28.51		31.31	3.87		3.18
2015	0.09	4.23	28.13		32.57	2.27		2.01
2016		3.37	23.32		42.88	1.04		0.39
2017	0.00	3.28	3.07	0.22	65.91	0.54		0.05
2018	0.03	2.78	0.98		62.64	0.12		0.00
2019		5.01	3.06		88.02	0.16	0	0.00
2020		2.85	1.18		62.78	0.16	0	0.00

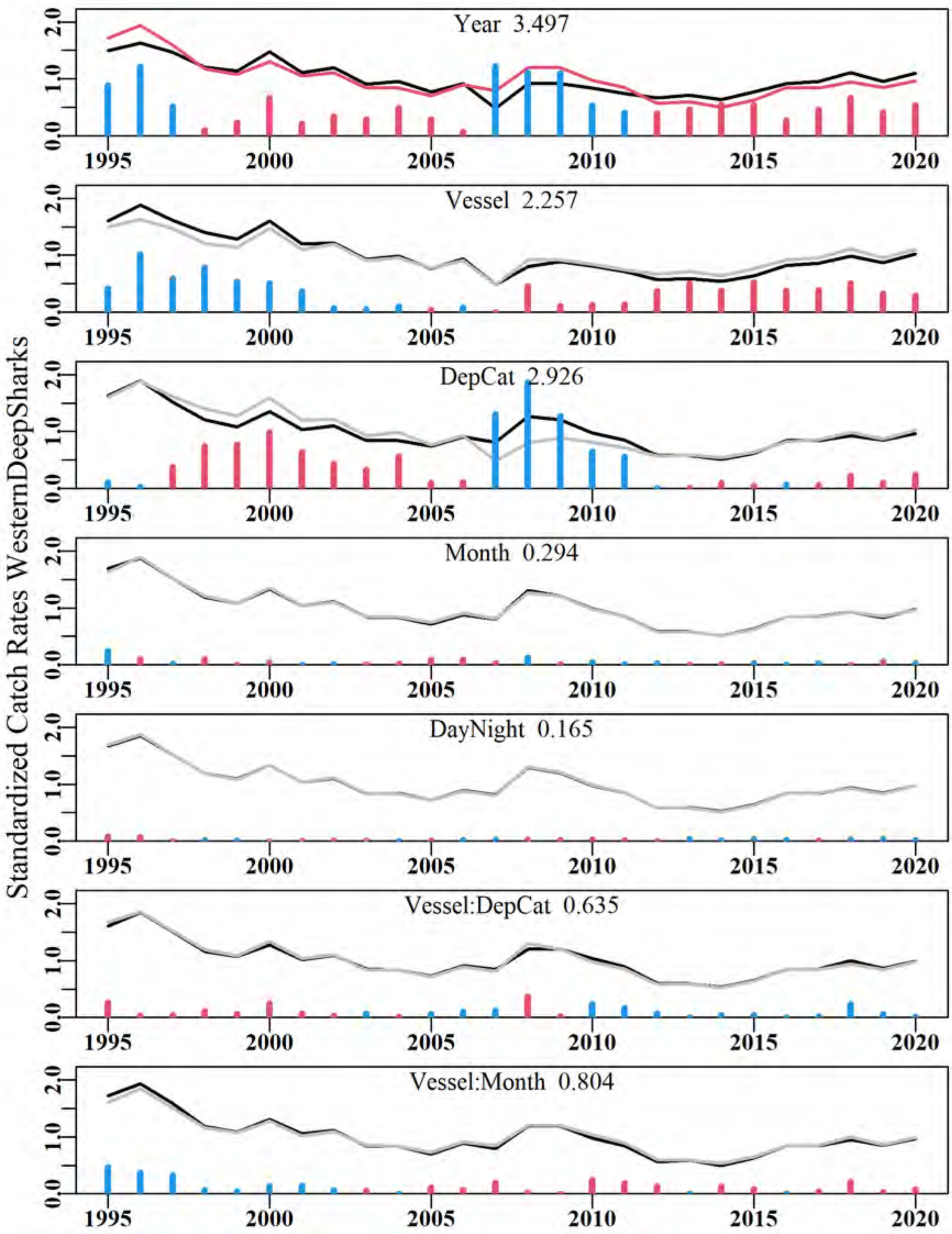

Figure 9.33. WesternDeepSharks. The influence of each factor on the optimal standardization. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by vertical bars with blue bars indicating the optimum model is higher than the 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.

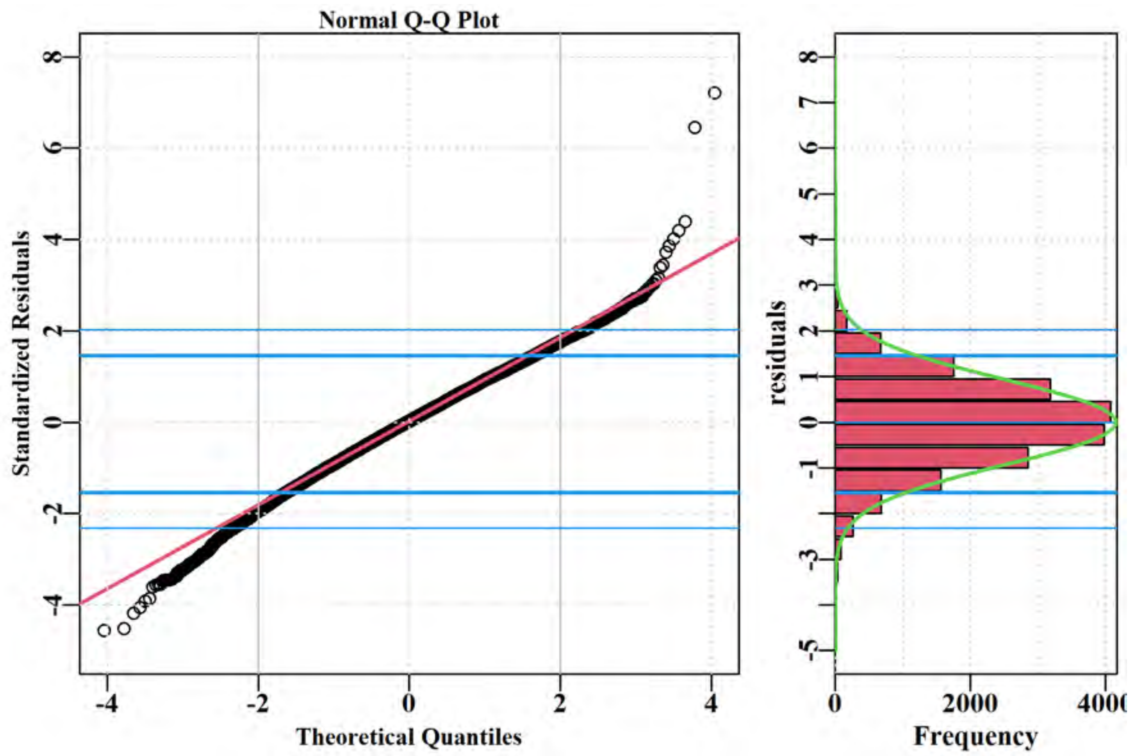

Figure 9.34. WesternDeepSharks. Diagnostic plots. The distribution of residuals from the optimum fit. The qqplot indicates the fit to the expected normality, while the histogram of residuals also illustrates the 1%, 5%, 95% and 99% quantiles to indicate the intensity of any lack of fit at the margins of the distribution (reflected also in the qqplot).

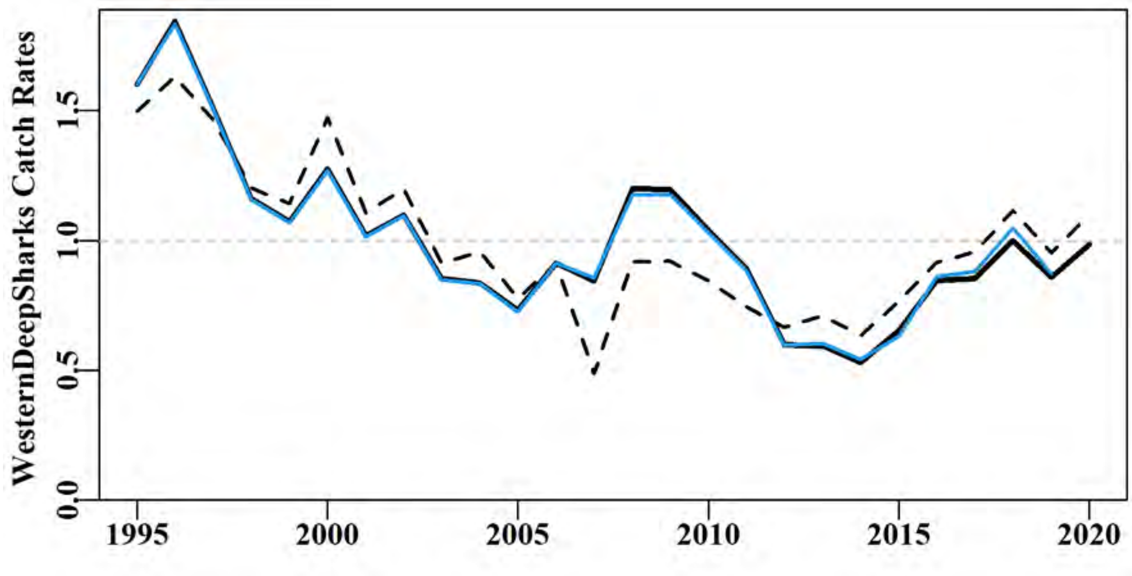

Figure 9.35. WesternDeepSharks. A comparison of the previous year's standardization (blue line) with this year's (black line). They should lie on top of each other, although small deviations may relate to data adjustments, particularly in very recent years. The geometric mean corresponds to the back dashed line.

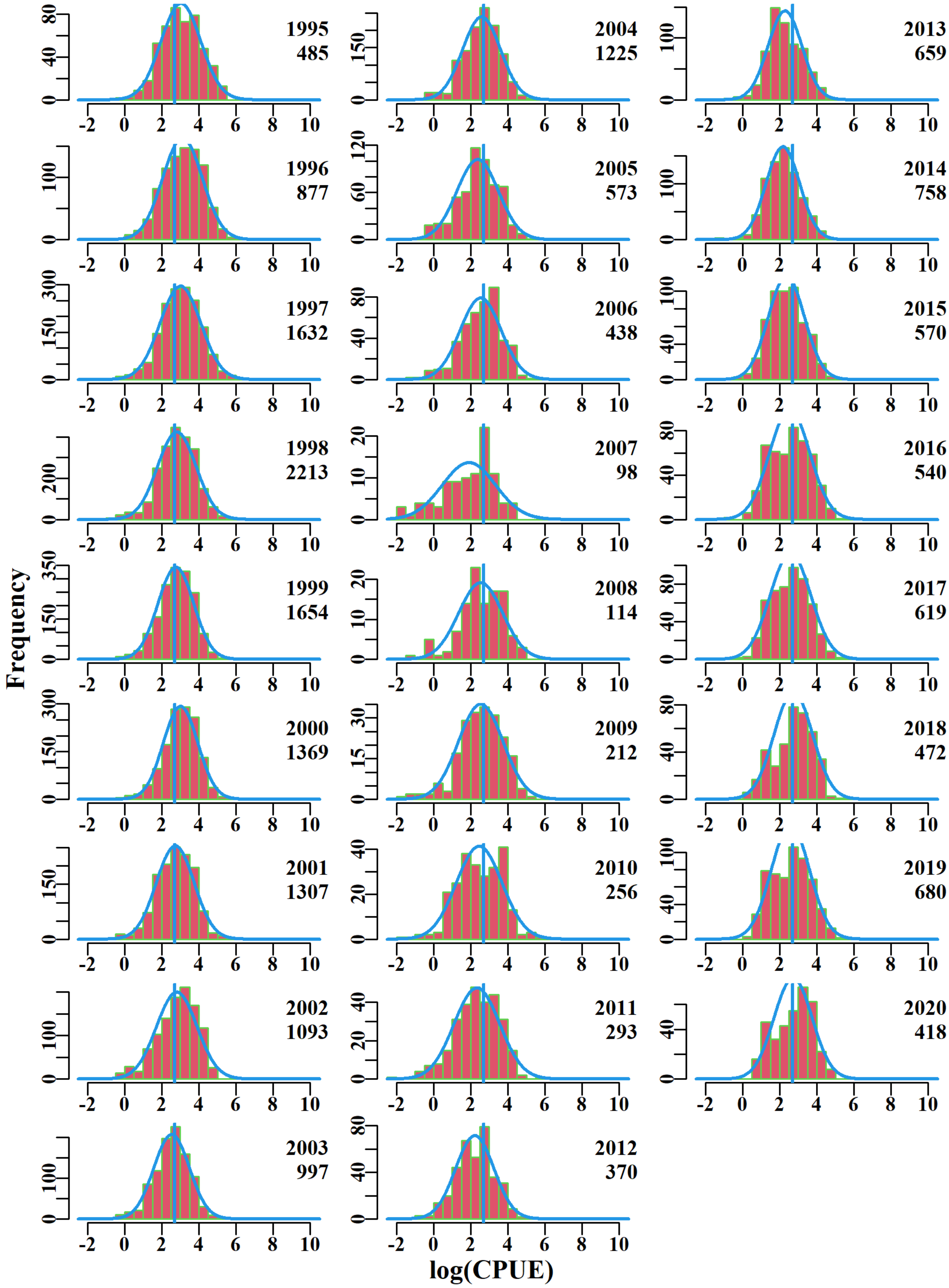

Figure 9.36. WesternDeepSharks. The natural log(CPUE) for each year of data available the blue lines are normal distributions fitted to the histogram frequencies. The numbers in each plot are the year and number of records. The vertical blue line is the average across all years.

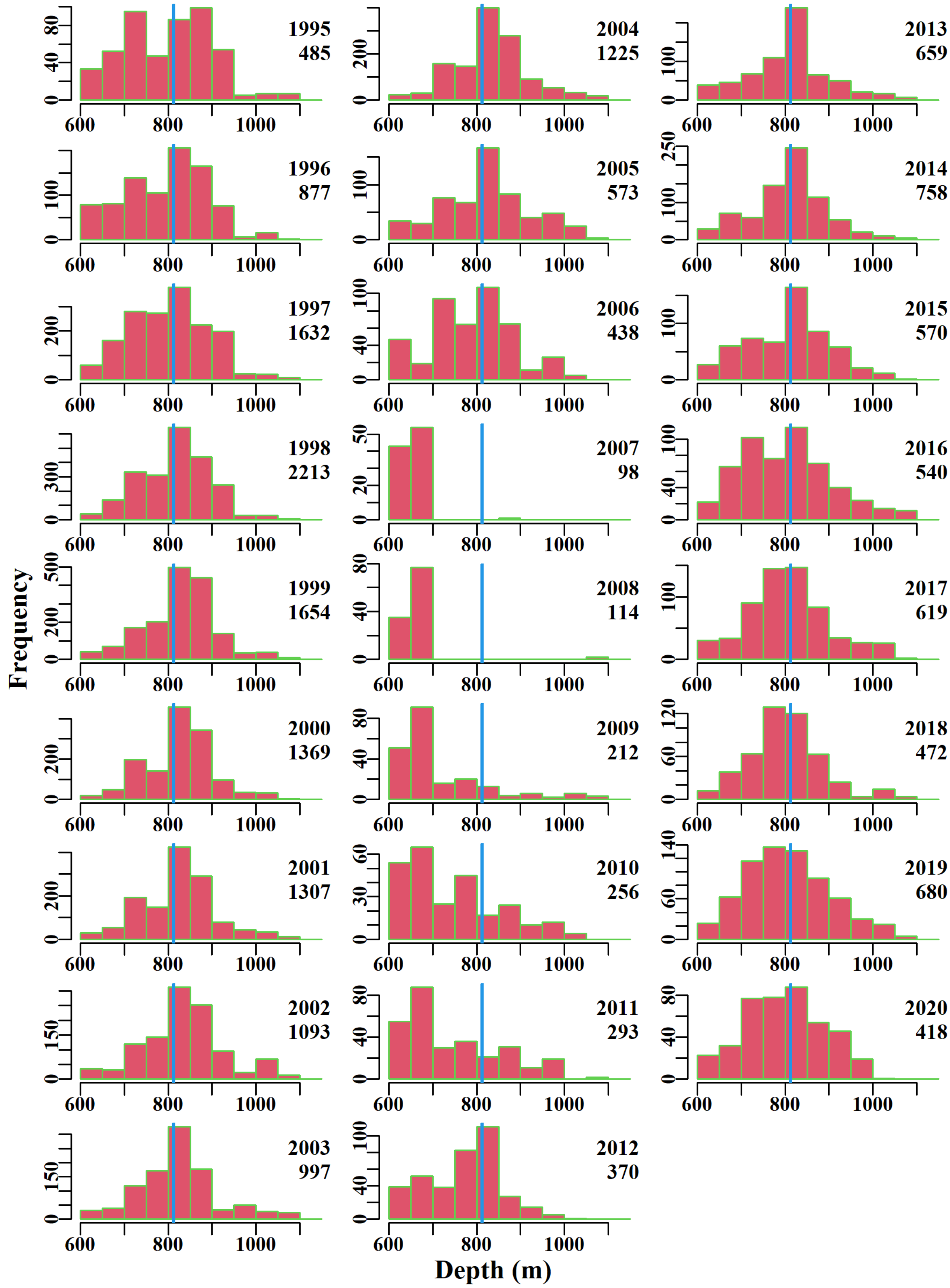

Figure 9.37. WesternDeepSharks. Frequency distribution of fishing depth (m) for each year of data available to illustrate the development of the fishery through time. The numbers in each plot are the year and number of records. The vertical blue line is the average across all years.

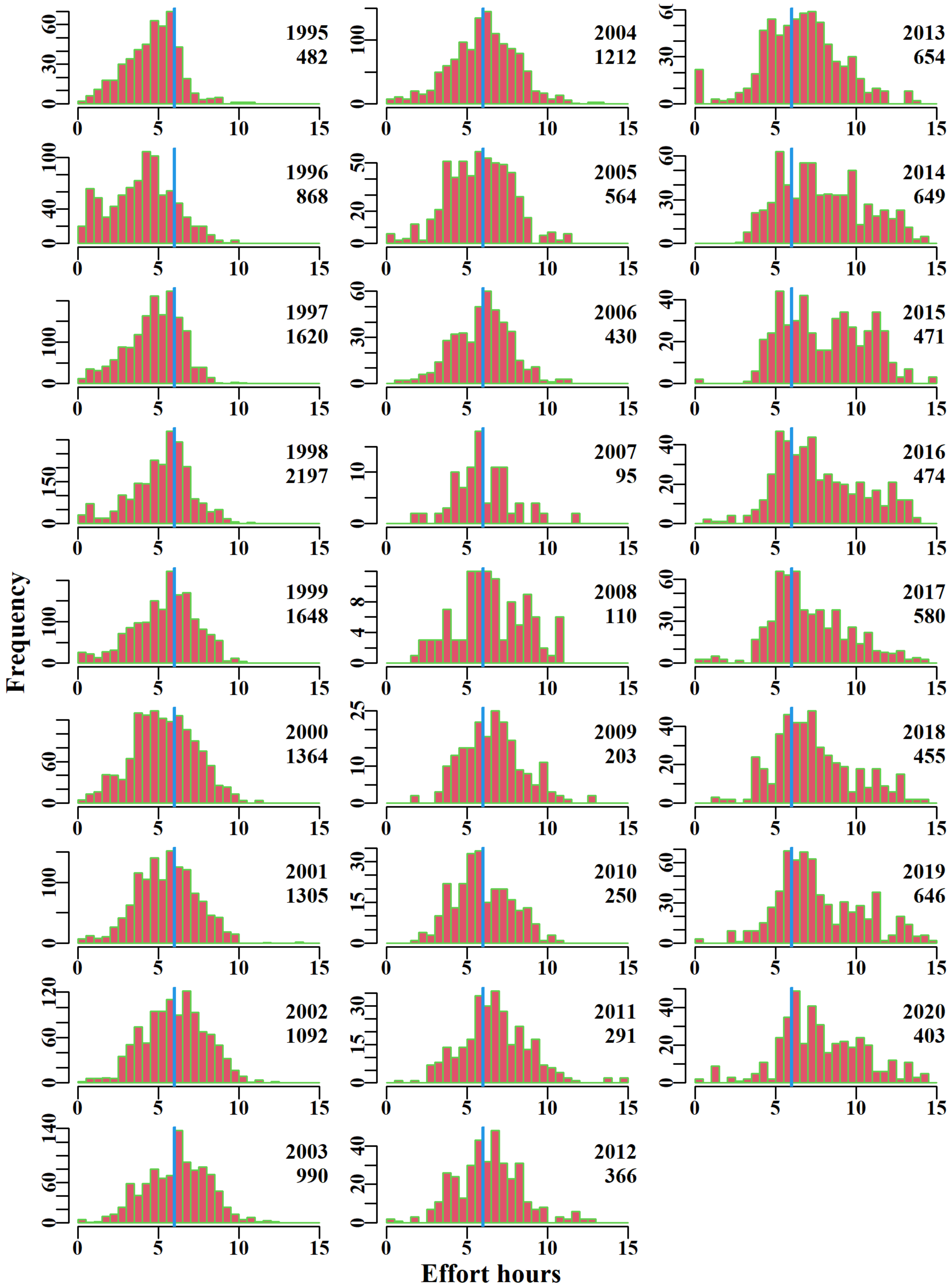

Figure 9.38. WesternDeepSharks. Frequency distribution of effort (hours) each year for the available data. The numbers in each plot are the year and number of records. The vertical blue line is the average across all years.

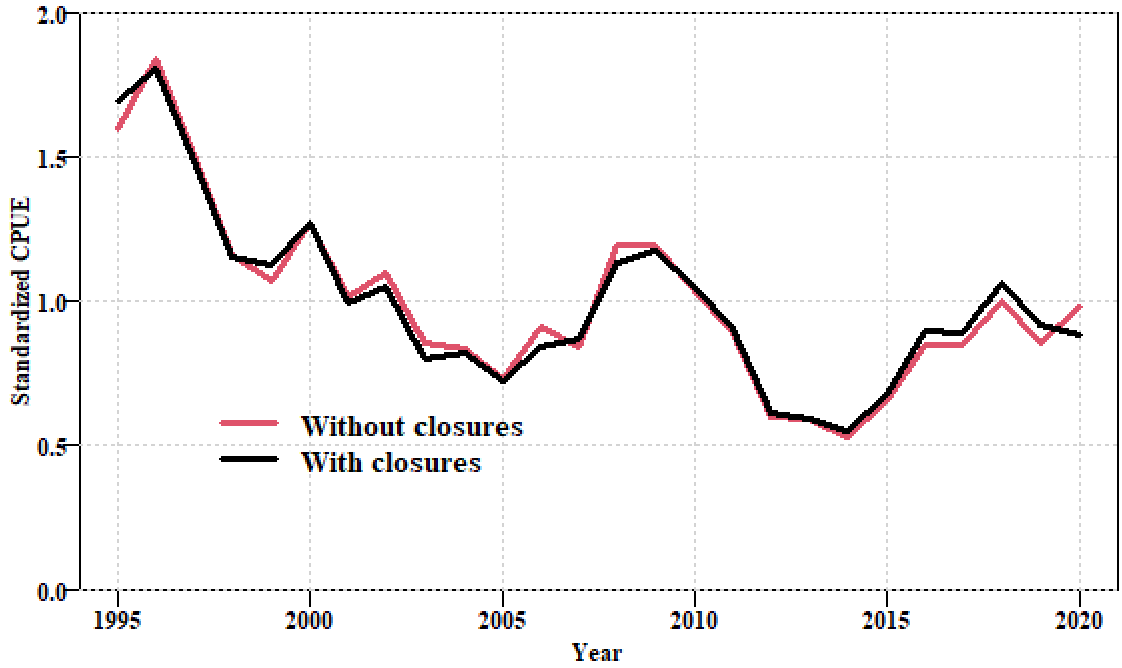

Figure 9.39. Standardized CPUE indices with (red) and without (black) closures.

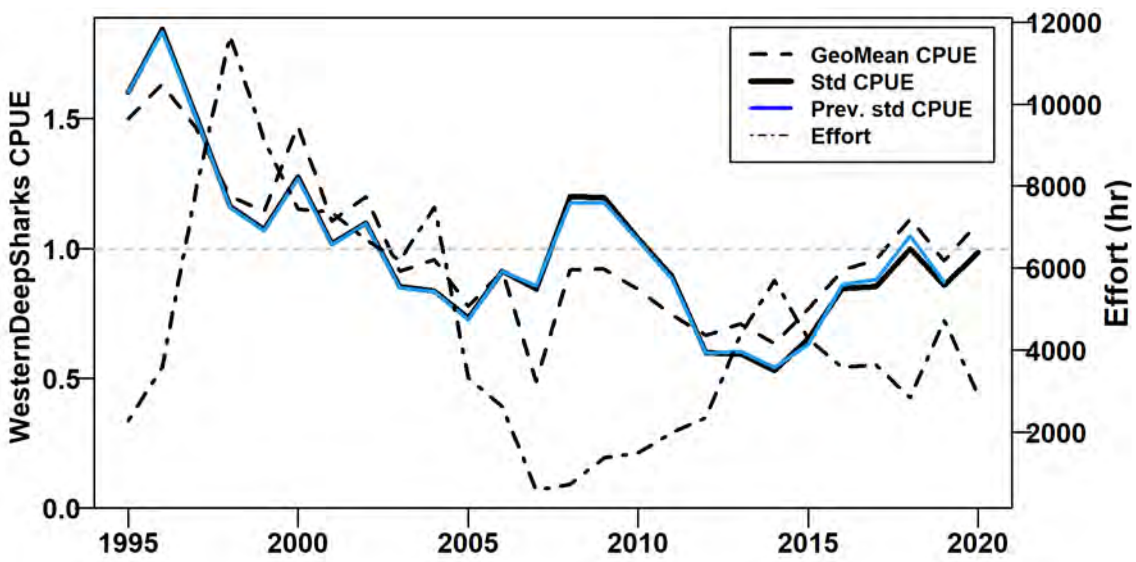

Figure 9.40. Annual standardised CPUE (blue), geometric mean CPUE (dashed line) and effort (dot-dash line).

9.8 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. CPUE was expressed as the natural log of catch per hour (catch/hr). The years analysed were 1986 - 2020 (Table 9.29).

A total of nine 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.

9.8.1 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 115 t from 2013 - 2020. Most 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 R^2 statistics (Table 9.33). 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 9.44).

After an initial period of great volatility between 1986 - 1994, standardized CPUE has been essentially flat and stable since 2000 (Figure 9.41).

9.8.2 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 were less than or equal to 1.5 hours whereas from 1995 onwards almost all effort has been for longer than 2 hours. Since 2015, the occurrence of less than or equal to one hour shots returned in noticeable numbers.

Table 9.29. 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, OTB, TMO
years	1986 - 2020

Table 9.30. 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

Year	Total	N	Catch	Vess	GeoM	Opt	StDev	C<30Kg	P<30Kg
1986	56.6	191	54.2	12	168.5	1.1205	0.000	0.974	0.018
1987	90.2	242	73.6	21	194.4	2.1152	0.142	1.123	0.015
1988	157.2	257	43.3	17	102.9	1.7324	0.145	1.468	0.034
1989	749.2	480	216.7	26	1429.3	3.0907	0.127	1.948	0.009
1990	1100.4	461	258.4	30	5108.2	5.0226	0.136	0.650	0.003
1991	1136.2	340	87.2	35	437.6	1.6436	0.137	0.912	0.010
1992	3354.0	626	611.8	32	4715.6	3.4242	0.119	2.503	0.004
1993	1097.4	841	283.7	39	519.0	1.8346	0.119	4.188	0.015
1994	1112.3	1095	284.2	34	266.2	1.2397	0.117	7.405	0.026
1995	1027.7	1768	498.0	30	96.4	1.1392	0.114	10.328	0.021
1996	785.3	2101	417.9	33	77.1	0.8066	0.114	12.888	0.031
1997	2091.1	2281	575.7	34	69.0	0.8467	0.114	11.973	0.021
1998	2042.4	2354	667.0	33	87.6	1.0525	0.114	11.177	0.017
1999	905.8	1915	441.8	34	72.3	0.8766	0.115	10.149	0.023
2000	1059.7	1727	376.5	43	63.2	0.6457	0.115	10.109	0.027
2001	1140.3	1947	403.0	38	63.7	0.6466	0.115	10.745	0.027
2002	857.2	1459	213.3	37	41.8	0.4549	0.116	9.990	0.047
2003	886.0	1455	228.4	30	43.8	0.4443	0.116	8.497	0.037
2004	639.8	1445	180.7	31	36.9	0.4286	0.116	10.134	0.056
2005	503.1	847	101.4	22	36.5	0.3601	0.119	5.384	0.053
2006	214.3	703	88.2	27	43.1	0.3885	0.121	5.310	0.060
2007	135.2	402	68.0	19	74.6	0.4499	0.128	2.466	0.036
2008	78.4	298	48.4	16	37.2	0.3370	0.133	1.784	0.037
2009	191.2	501	73.4	18	35.2	0.3500	0.124	3.926	0.053
2010	238.0	504	76.3	15	33.7	0.3184	0.124	3.874	0.051
2011	107.0	593	86.0	19	29.7	0.3260	0.122	4.555	0.053
2012	82.9	526	71.3	16	29.4	0.2953	0.124	4.318	0.061
2013	165.3	770	152.0	19	36.2	0.3927	0.121	6.013	0.040
2014	151.1	724	130.6	17	32.3	0.4595	0.121	3.913	0.030
2015	136.1	715	110.4	17	68.0	0.4897	0.122	3.809	0.035
2016	148.7	645	114.1	18	93.0	0.4647	0.123	2.950	0.026
2017	157.5	595	80.8	18	60.0	0.4099	0.122	3.456	0.043
2018	152.0	589	93.2	16	73.9	0.4189	0.123	3.266	0.035
2019	182.9	679	103.5	18	61.0	0.3699	0.122	3.663	0.035
2020	201.7	644	133.5	19	81.1	0.6043	0.123	3.445	0.026

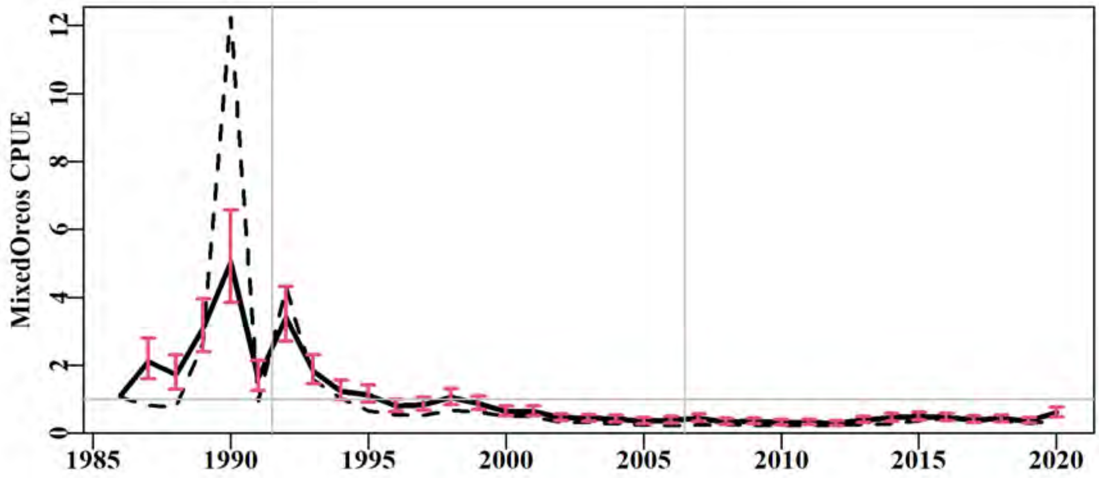

Figure 9.41. MixedOreos standardization. The dashed black line represents the geometric mean CPUE, solid black line the standardized CPUE. The red bars are the 95% confidence intervals about the mean estimates. The graph scales both time-series of standardized CPUE relative to the mean of each time-series.

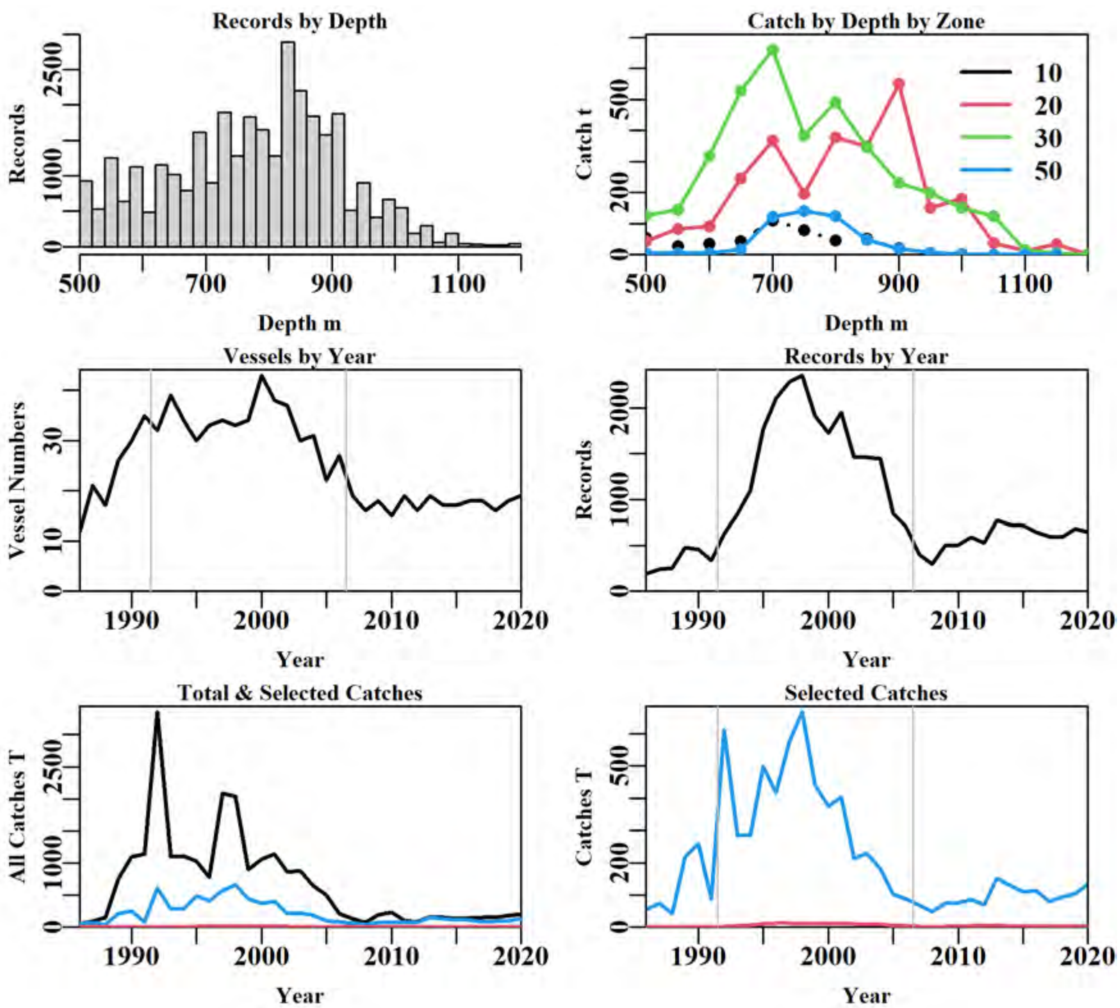

Figure 9.42. MixedOreos fishery details. The bottom left plot depicts all known catches (top black line), and all selected catches used in the analysis (middle blue line); the lower red line: selected catches < 30 kg).

Table 9.31. 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	59650	57718	57534	45717	45684	42939	41531	31593
Difference	0	1932	184	11817	33	2745	1408	9938

Table 9.32. 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 9.33. 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

Term	AIC	RSS	MSS	Nobs	Npars	adj_r2	%Change
Year	23264	65831	13533	31593	35	17.0	0.00
Vessel	18054	55403	23962	31593	154	29.9	12.89
DepCat	15974	51828	27537	31593	168	34.3	4.50
ORzone	14861	50025	29340	31593	171	36.6	2.28
DayNight	13724	48247	31118	31593	174	38.9	2.25
Month	13118	47297	32067	31593	185	40.1	1.18
inout	13021	47148	32216	31593	186	40.2	0.19
ORzone:DepCat	12537	46311	33053	31593	227	41.2	0.98
DepCat:Month	12722	46278	33087	31593	331	41.1	0.83

Table 9.34. 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	6164.898775
Oxeye	37266002	277.737
Warty	37266004	262.83
Black	37266005	23.604
OreoDory	37266902	645.9484

Table 9.35. MixedOreos. Annual catch (t) by CAAB code for a basket species.

Year	37266001	37266002	37266004	37266005	37266006	37266902
1986	19.27	3.21	31.70			
1987	40.57	13.81	19.18			
1988	13.71	9.53	20.03			
1989	175.80	27.47	13.44			
1990	252.55	3.56	2.26			
1991	84.00	2.68	0.53			
1992	599.04	11.70	1.05			
1993	277.04	3.61	3.03			
1994	262.49	3.10	18.62			
1995	466.52	17.16	14.32			
1996	401.70	0.55	15.61			
1997	550.60	4.92	20.19			
1998	641.87	0.34	24.81			
1999	430.50	0.08	11.21			
2000	345.46	0.03	30.99			
2001	396.49	0.40	6.06			
2002	211.64	0.10	1.59			
2003	228.08		0.30			
2004	179.07	0.06	1.54			
2005	92.24	1.68				7.51
2006	36.56	8.73				42.88
2007	11.31	9.88				46.77
2008	6.98	0.95				40.52
2009	6.85	1.39				65.15
2010	8.06	0.66				67.54
2011	6.80	7.88				71.30
2012	8.24	13.50				49.59
2013	18.11	14.14				119.75
2014	56.38	22.34	2.90	0.00		49.00
2015	71.65	19.15	0.00	0.00		19.56
2016	57.08	25.40		0.00	0	31.65
2017	48.17	8.06		0.20		24.33
2018	60.36	11.96	0.88	7.84		12.19
2019	65.53	18.56	8.44	8.94	0	2.06
2020	92.04	15.93	17.39	6.62		1.50

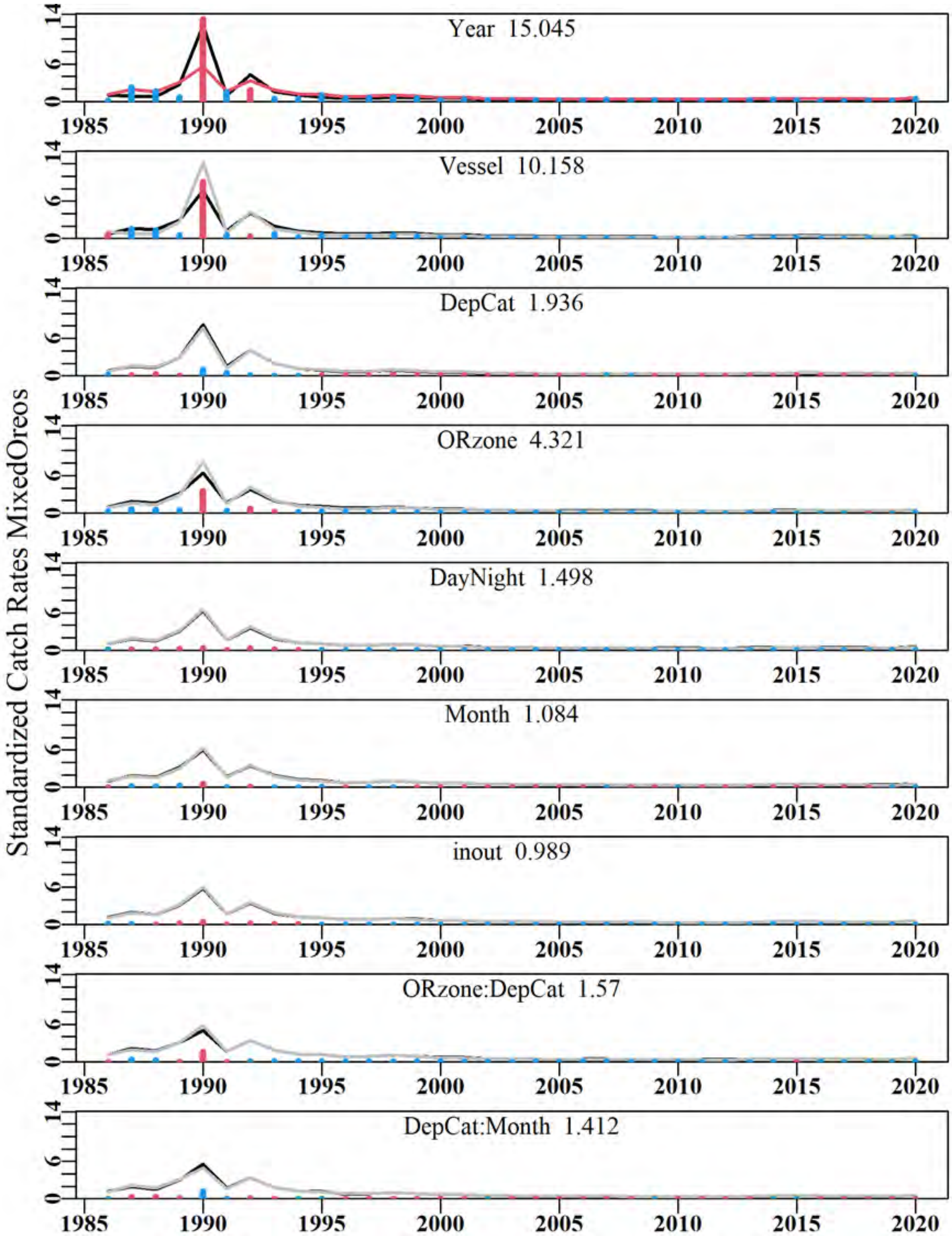

Figure 9.43. MixedOreos. The influence of each factor on the optimal standardization. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by vertical bars with blue bars indicating the optimum model is higher than the geometric 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.

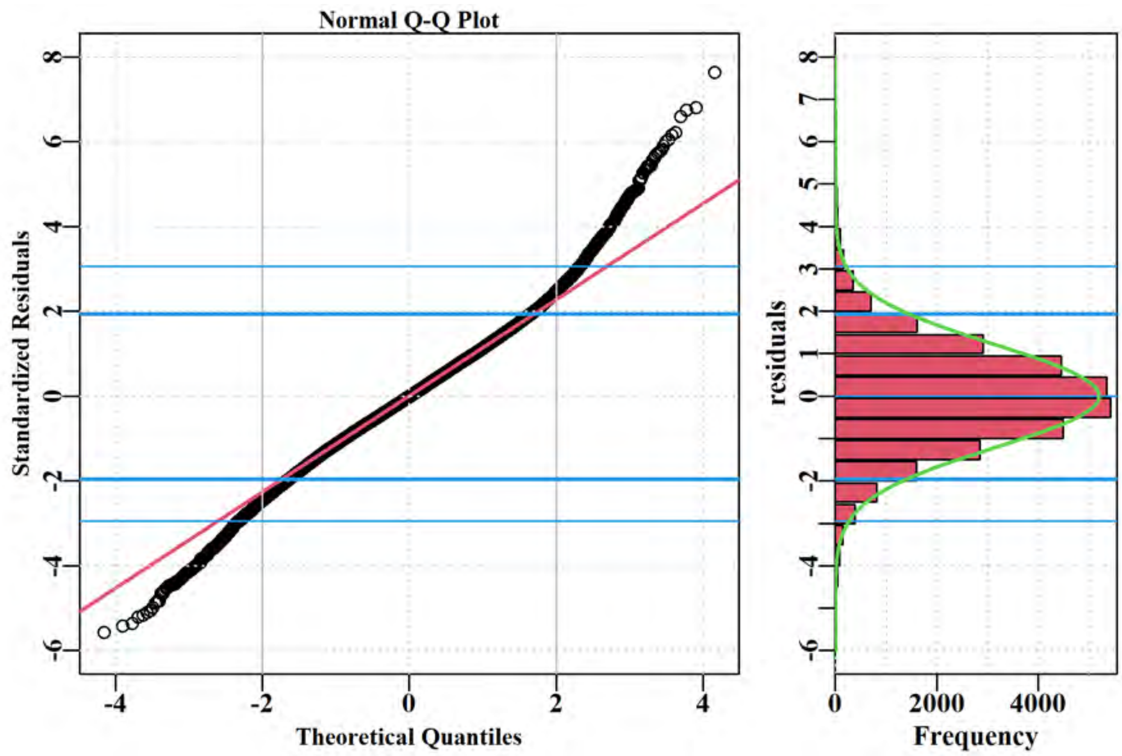

Figure 9.44. MixedOreos. Diagnostic plots. The distribution of residuals from the optimum fit. The qqplot indicates the fit to the expected normality, while the histogram of residuals also illustrates the 1%, 5%, 95% and 99% quantiles to indicate the intensity of any lack of fit at the margins of the distribution (reflected also in the qqplot).

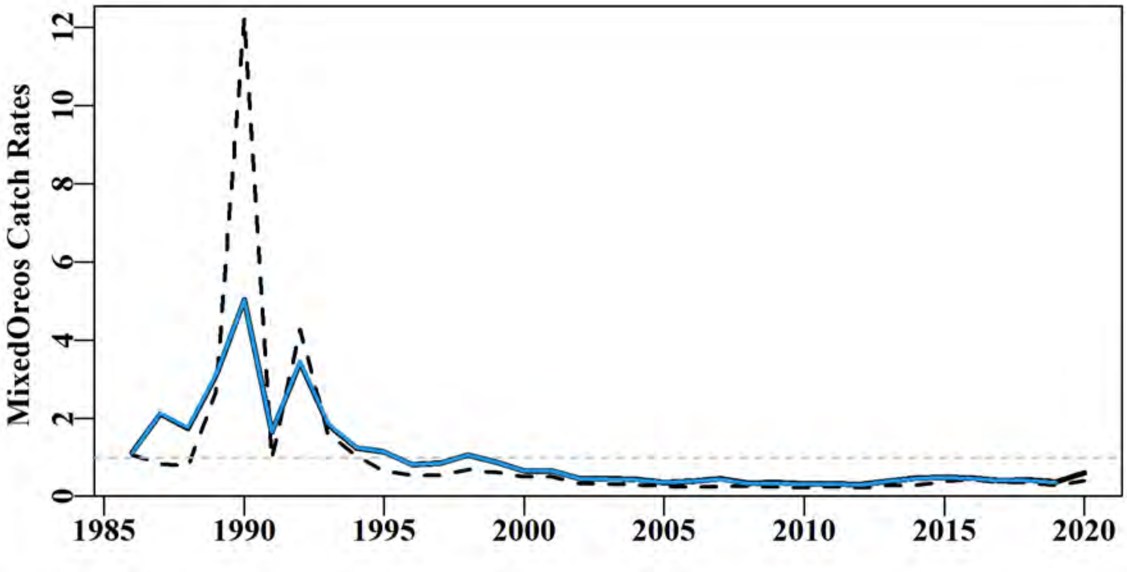

Figure 9.45. MixedOreos. A comparison of the previous year's standardization (blue line) with this year's (black line). They should lie on top of each other, although small deviations may relate to data adjustments, particularly in very recent years. The geometric mean corresponds to the back dashed line.

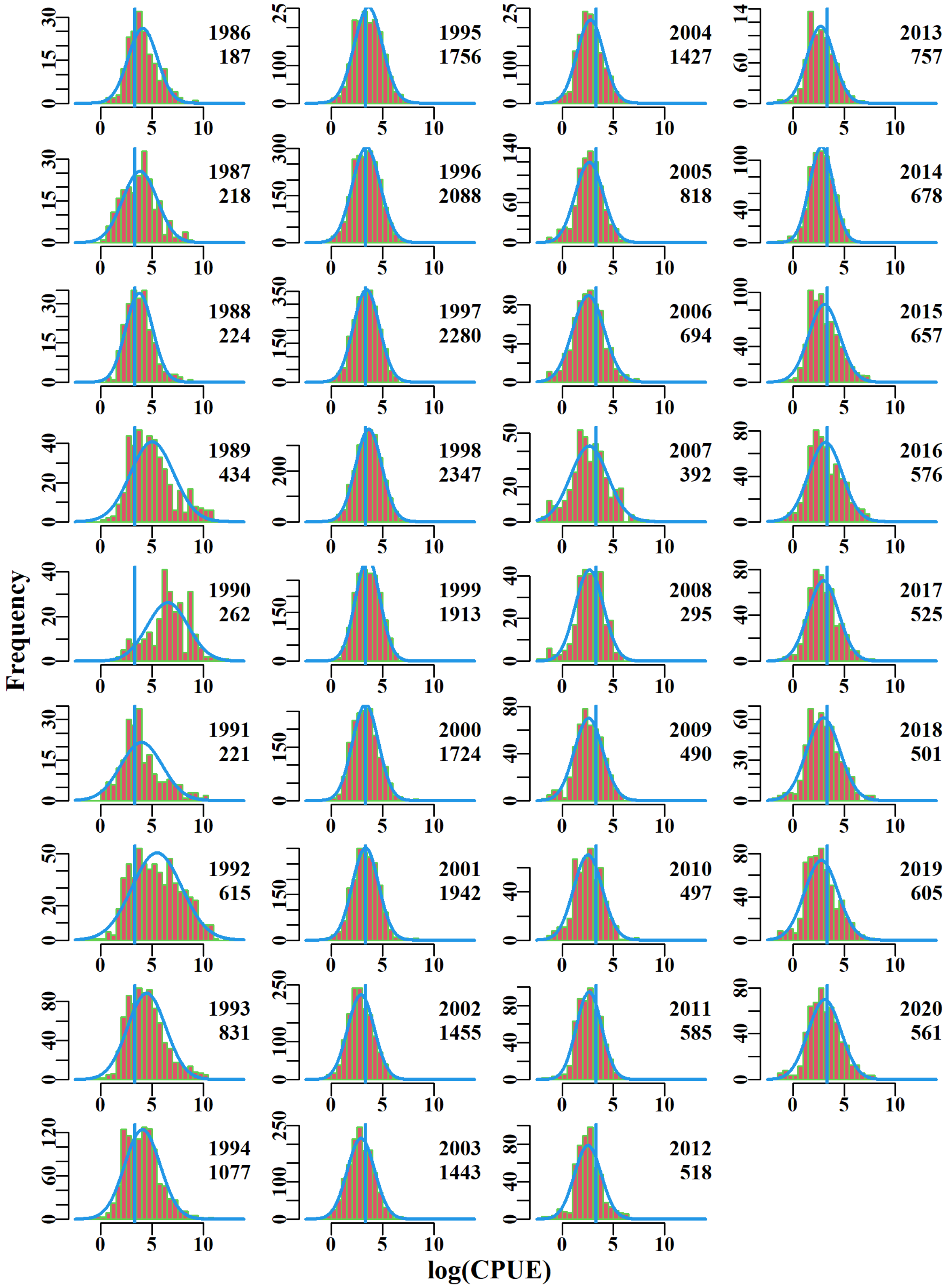

Figure 9.46. MixedOreos. The natural log(CPUE) for each year of data available the blue lines are normal distributions fitted to the histogram frequencies. The numbers in each plot are the year and number of records. The vertical blue line is the average across all years.

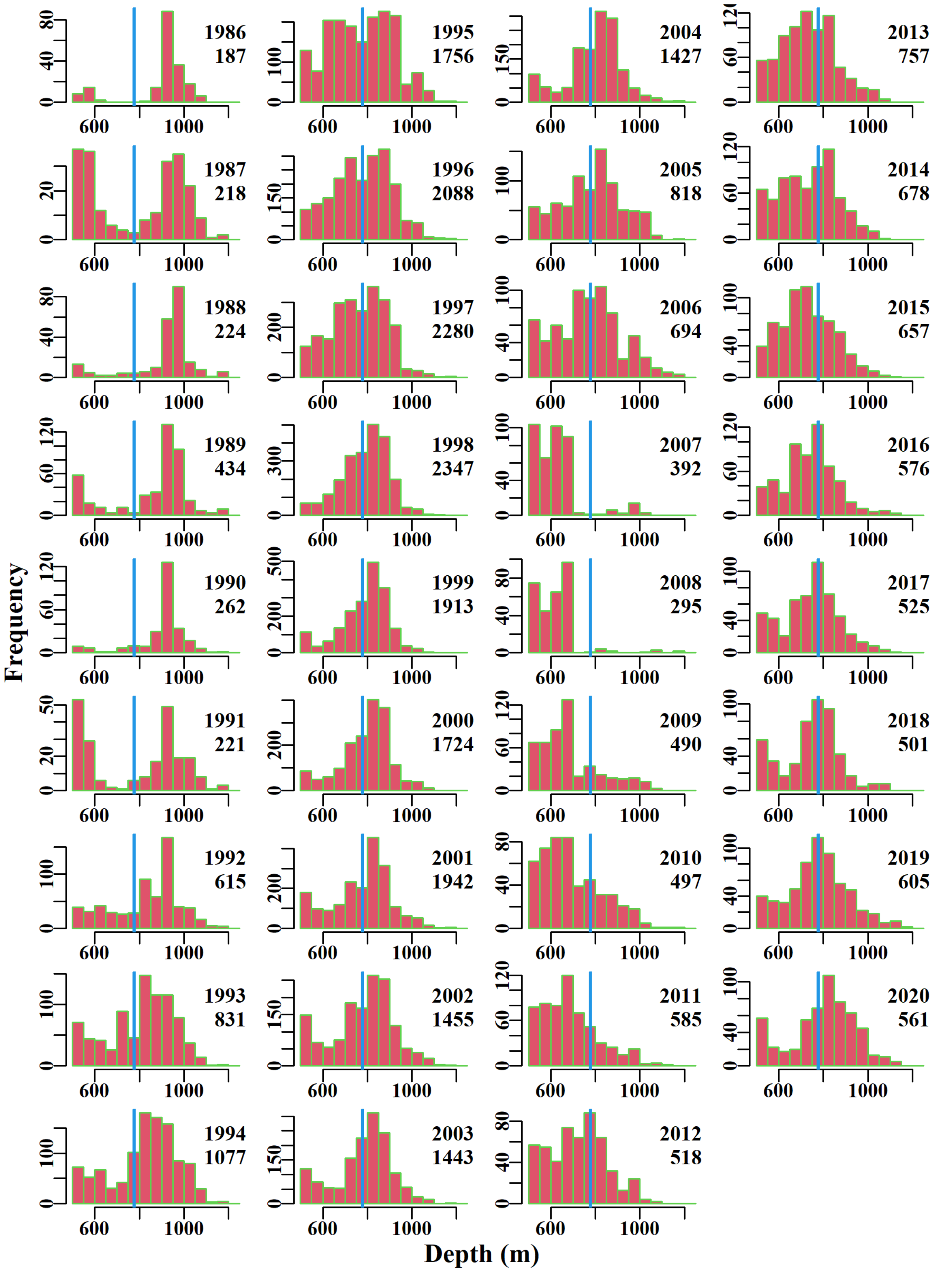

Figure 9.47. MixedOreos. Frequency distribution of fishing depth (m) for each year of data available to illustrate the development of the fishery through time. The numbers in each plot are the year and number of records. The vertical blue line is the average across all years.

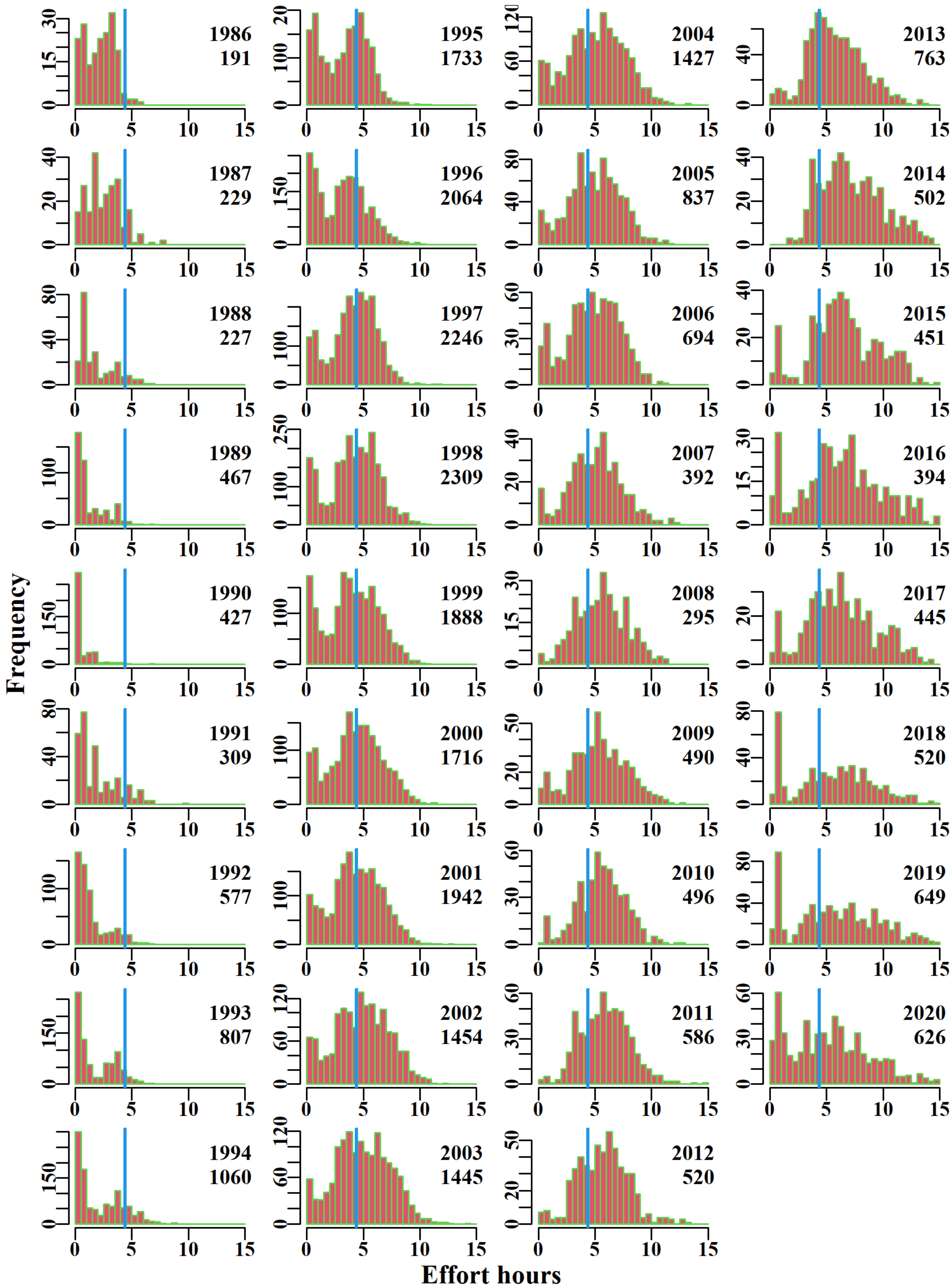

Figure 9.48. MixedOreos. Frequency distribution of effort (hours) each year for the available data. The numbers in each plot are the year and number of records. The vertical blue line is the average across all years.

9.9 Mixed Oreos 95

The analysis in this section uses data over a shorter time series, i.e., between 1995 – 2020, unlike the previous section which used data between 1986-2020 for the same species group. 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. CPUE was expressed as the natural log of catch per hour (catch/hr). The years analysed were 1995 - 2020 (Table 9.36).

A total of nine 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.

9.9.1 *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 97 t from 2013 - 2020 perhaps due to the introduction of electronic monitoring over this period. Most 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 R^2 statistics (Table 9.40). The qqplot suggests that the assumed Normal distribution of the log-transformed CPUE, may be valid, with slight deviations as depicted from both tails of the distribution (Figure 9.52).

tandardized CPUE has been essentially flat, below the long-term average and stable between 2002-2019 with a marked increase in CPUE to the long-term average in 2020.

9.9.2 *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 9.36. 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, OTB, TMO
years	1995 - 2020

Table 9.37. 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

Year	Total	N	Catch	Vess	GeoM	Opt	StDev	C<30Kg	P<30Kg
1995	1027.7	1292	431.16	24	75.59	2.6626	0.000	6.020	0.014
1996	785.3	1460	364.82	32	60.08	1.7988	0.043	7.537	0.021
1997	2091.1	1940	496.66	29	56.58	1.7470	0.041	8.388	0.017
1998	2042.4	1949	627.12	29	71.72	2.0576	0.042	6.666	0.011
1999	905.8	1550	419.37	30	57.75	1.7252	0.043	6.168	0.015
2000	1059.7	1476	335.44	40	47.25	1.3128	0.044	7.805	0.023
2001	1140.3	1687	349.51	36	44.53	1.2654	0.044	8.657	0.025
2002	857.2	1293	200.98	32	30.31	0.8827	0.046	8.291	0.041
2003	886.0	1325	207.50	27	31.31	0.8644	0.046	7.526	0.036
2004	639.8	1284	165.58	28	24.55	0.7442	0.047	8.842	0.053
2005	503.1	772	94.99	21	26.45	0.6711	0.053	4.942	0.052
2006	214.3	617	82.49	25	28.66	0.6587	0.056	4.514	0.055
2007	135.2	366	64.07	19	46.59	0.7243	0.067	2.208	0.034
2008	78.4	288	48.02	16	36.70	0.6135	0.073	1.711	0.036
2009	191.2	452	68.78	18	28.83	0.6753	0.062	3.370	0.049
2010	238.0	476	67.37	15	26.64	0.6049	0.061	3.796	0.056
2011	107.0	579	83.55	19	27.59	0.6177	0.058	4.447	0.053
2012	82.9	502	67.72	15	24.47	0.5733	0.062	4.098	0.061
2013	165.3	731	145.24	19	31.32	0.6824	0.056	5.689	0.039
2014	151.1	711	129.47	17	31.11	0.8447	0.057	3.775	0.029
2015	136.1	596	87.34	17	26.42	0.7264	0.060	3.313	0.038
2016	148.7	486	81.14	18	30.87	0.6660	0.065	2.339	0.029
2017	157.5	484	62.66	18	24.77	0.6512	0.065	2.673	0.043
2018	152.0	471	73.01	15	30.01	0.6368	0.067	2.468	0.034
2019	182.9	560	86.31	18	27.05	0.5969	0.063	2.877	0.033
2020	201.7	519	111.64	17	46.51	0.9960	0.064	2.568	0.023

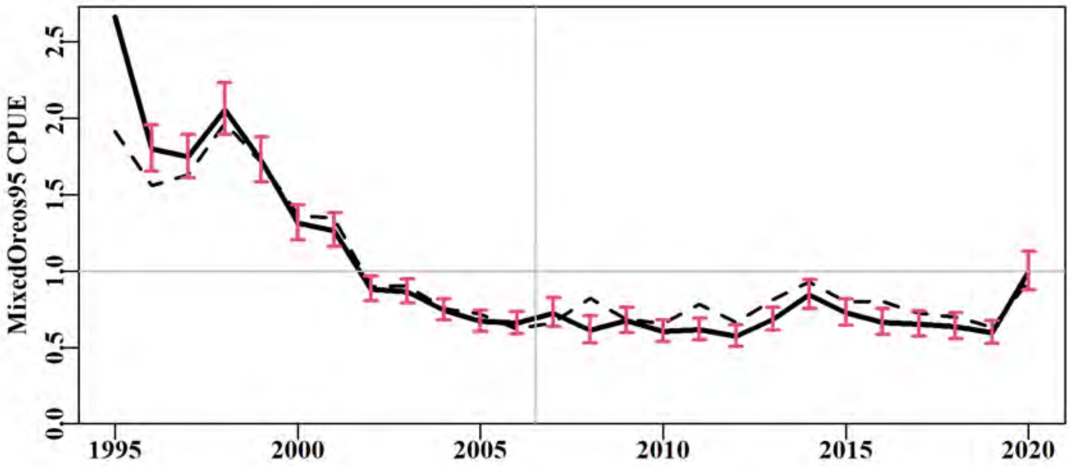

Figure 9.49. MixedOreos95 standardization. The dashed black line represents the geometric mean CPUE, solid black line the standardized CPUE. The red bars are the 95% confidence intervals about the mean estimates. The graph scales both time-series of standardized CPUE relative to the mean of each time-series.

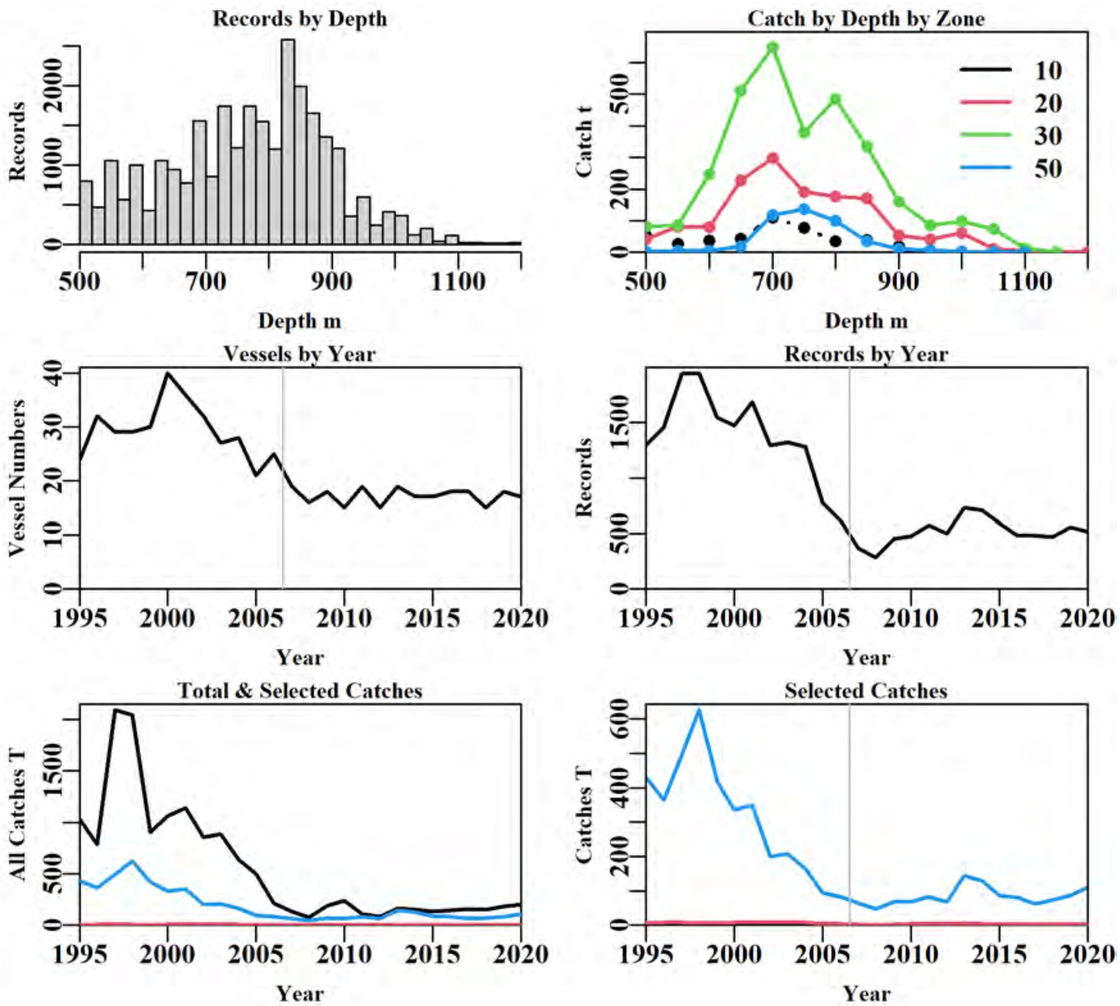

Figure 9.50. MixedOreos95 fishery details. The bottom left plot depicts all known catches (top black line), and all selected catches used in the analysis (middle blue line); the lower red line: selected catches < 30 kg).

Table 9.38. 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	59650	57718	44114	35487	35454	33264	28187	27524	23444
Difference	0	1932	13604	8627	33	2190	5077	663	4080

Table 9.39. 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 9.40. 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

Term	AIC	RSS	MSS	Nobs	Npars	adj_r2	%Change
Year	9833	35581	3655	23444	26	9.2	0.00
Vessel	7919	32580	6656	23444	102	16.6	7.39
DepCat	5188	28962	10274	23444	116	25.8	9.22
ORzone	4734	28400	10835	23444	119	27.2	1.43
DayNight	3558	27006	12230	23444	121	30.8	3.57
Month	2868	26198	13038	23444	132	32.9	2.04
inout	2868	26196	13040	23444	133	32.9	0.00
ORzone:DepCat	2399	25594	13642	23444	171	34.3	1.44
DepCat:Month	2457	25432	13804	23444	274	34.4	1.56

Table 9.41. 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	4099.65
Oxeye	37266002	176.45
Warty	37266004	90.48
Black	37266005	1.03
OreoDory	37266902	584.37

Table 9.42. MixedOreos95. Annual catch (t) by CAAB code for a basket species.

Year	37266001	37266002	37266004	37266005	37266006	37266902
1995	414.89	4.47	11.80			
1996	350.68	0.43	13.71			
1997	481.83	4.92	9.90			
1998	614.68	0.24	12.20			
1999	411.35	0.08	7.94			
2000	333.41	0.03	2.00			
2001	347.61	0.40	1.50			
2002	199.84	0.10	1.04			
2003	207.25		0.25			
2004	164.01	0.03	1.54			
2005	86.80	0.95				7.24
2006	32.43	8.44				41.62
2007	9.79	9.88				44.40
2008	6.92	0.95				40.15
2009	6.18	1.39				61.21
2010	6.41	0.66				60.31
2011	6.80	7.88				68.88
2012	8.07	11.85				47.80
2013	17.63	13.44				114.17
2014	56.27	21.91	2.90	0.00		48.40
2015	59.23	16.41	0.00	0.00		11.70
2016	45.67	19.50		0.00	0	15.97
2017	44.92	8.05		0.00		9.69
2018	50.96	11.56	0.88			9.62
2019	57.47	18.56	8.44		0	1.84
2020	78.53	14.33	16.38	1.03		1.38

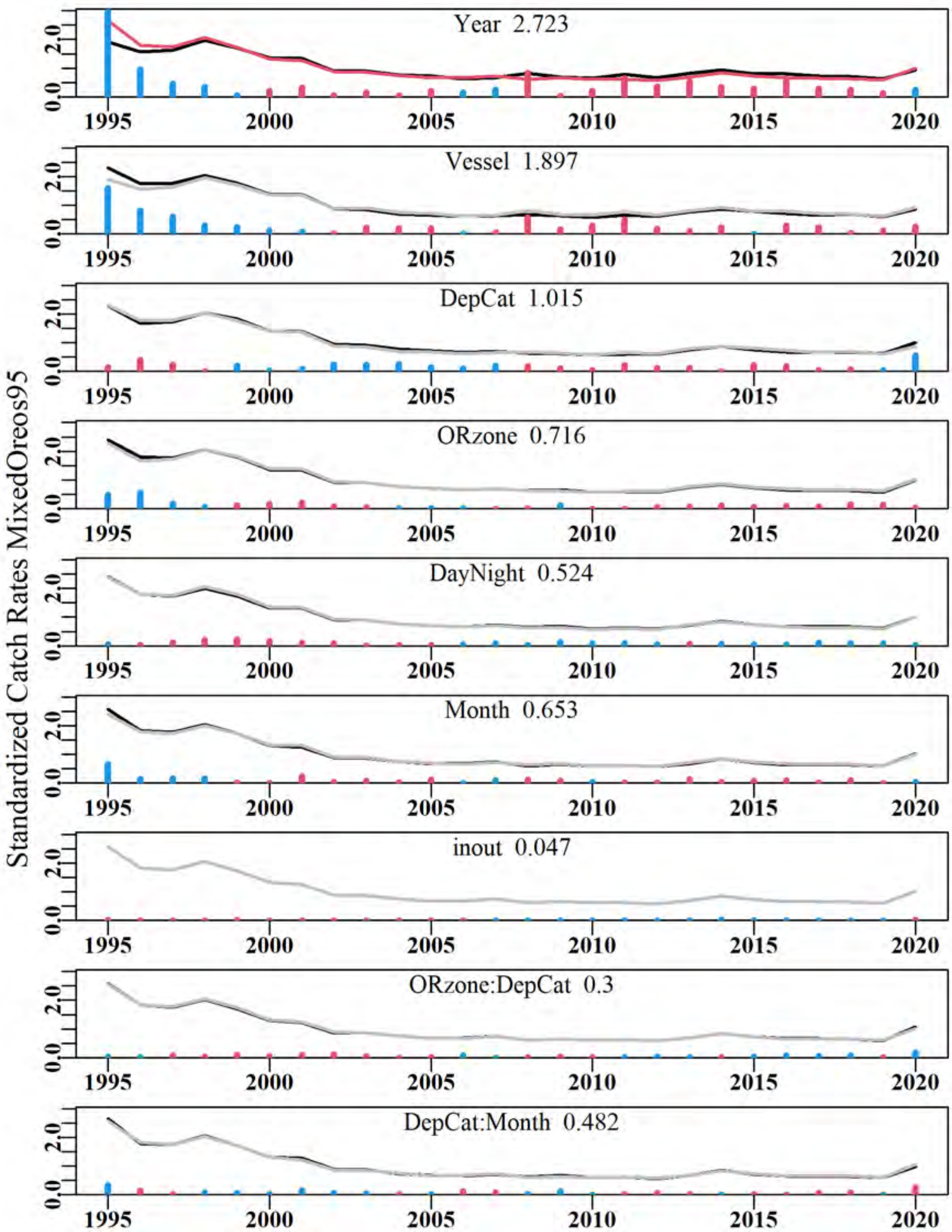

Figure 9.51. MixedOreos95. The influence of each factor on the optimal standardization. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by vertical bars with blue bars indicating the optimum model is higher than the geometric 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.

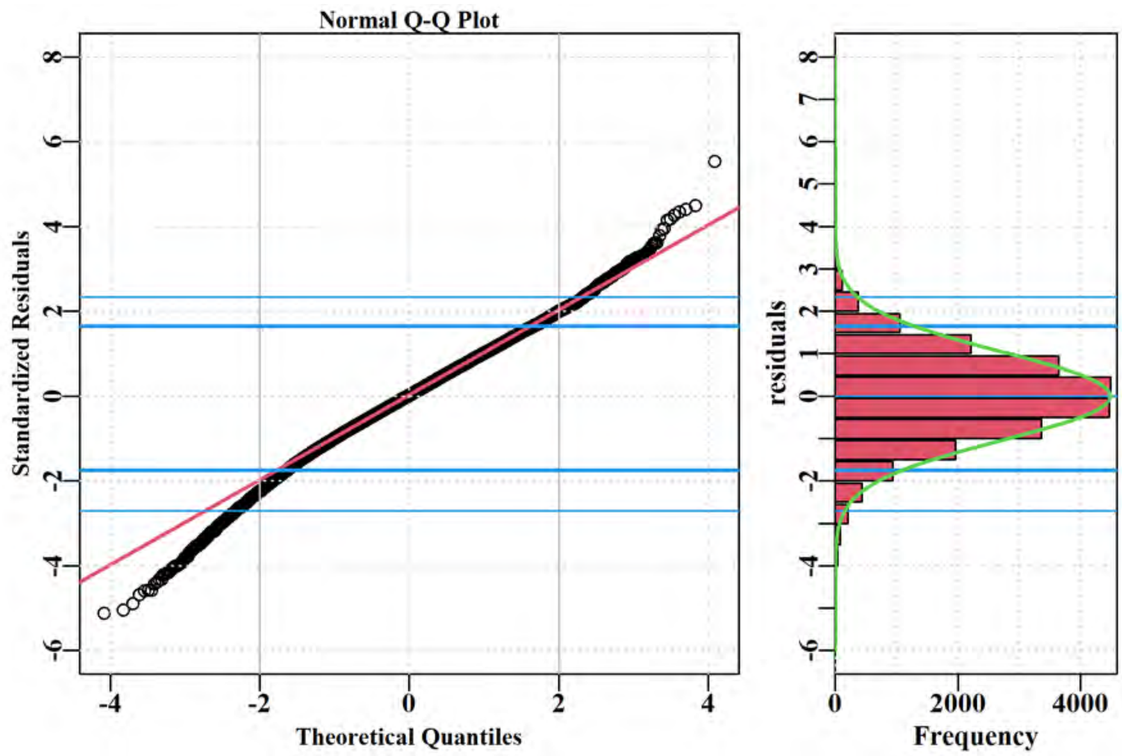

Figure 9.52. MixedOreos95. Diagnostic plots. The distribution of residuals from the optimum fit. The qqplot indicates the fit to the expected normality, while the histogram of residuals also illustrates the 1%, 5%, 95% and 99% quantiles to indicate the intensity of any lack of fit at the margins of the distribution (reflected also in the qqplot).

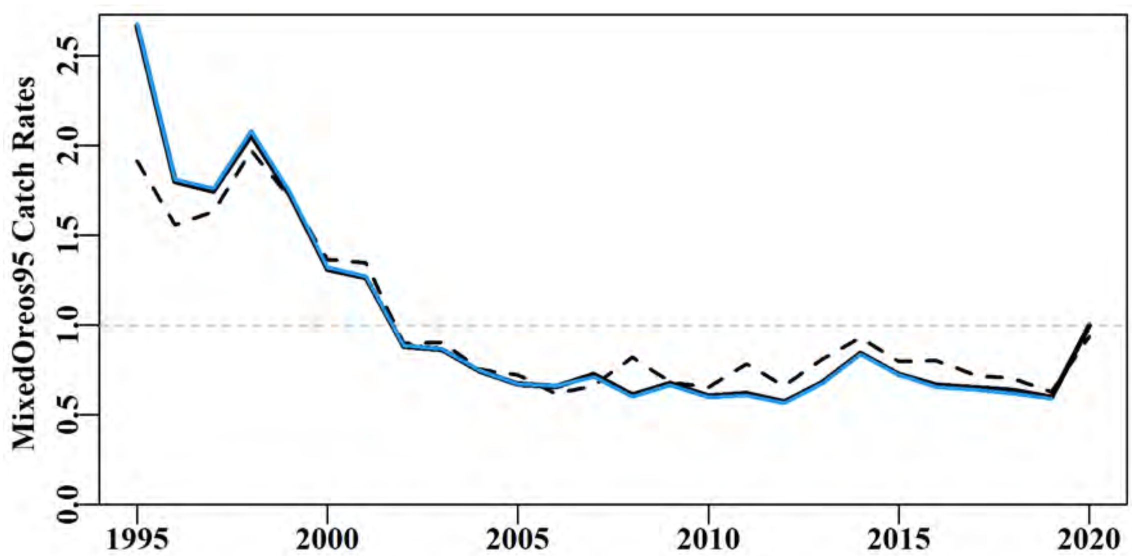

Figure 9.53. MixedOreos95. A comparison of the previous year's standardization (blue line) with this year's (black line). They should lie on top of each other, although small deviations may relate to data adjustments, particularly in very recent years. The geometric mean corresponds to the back dashed line.

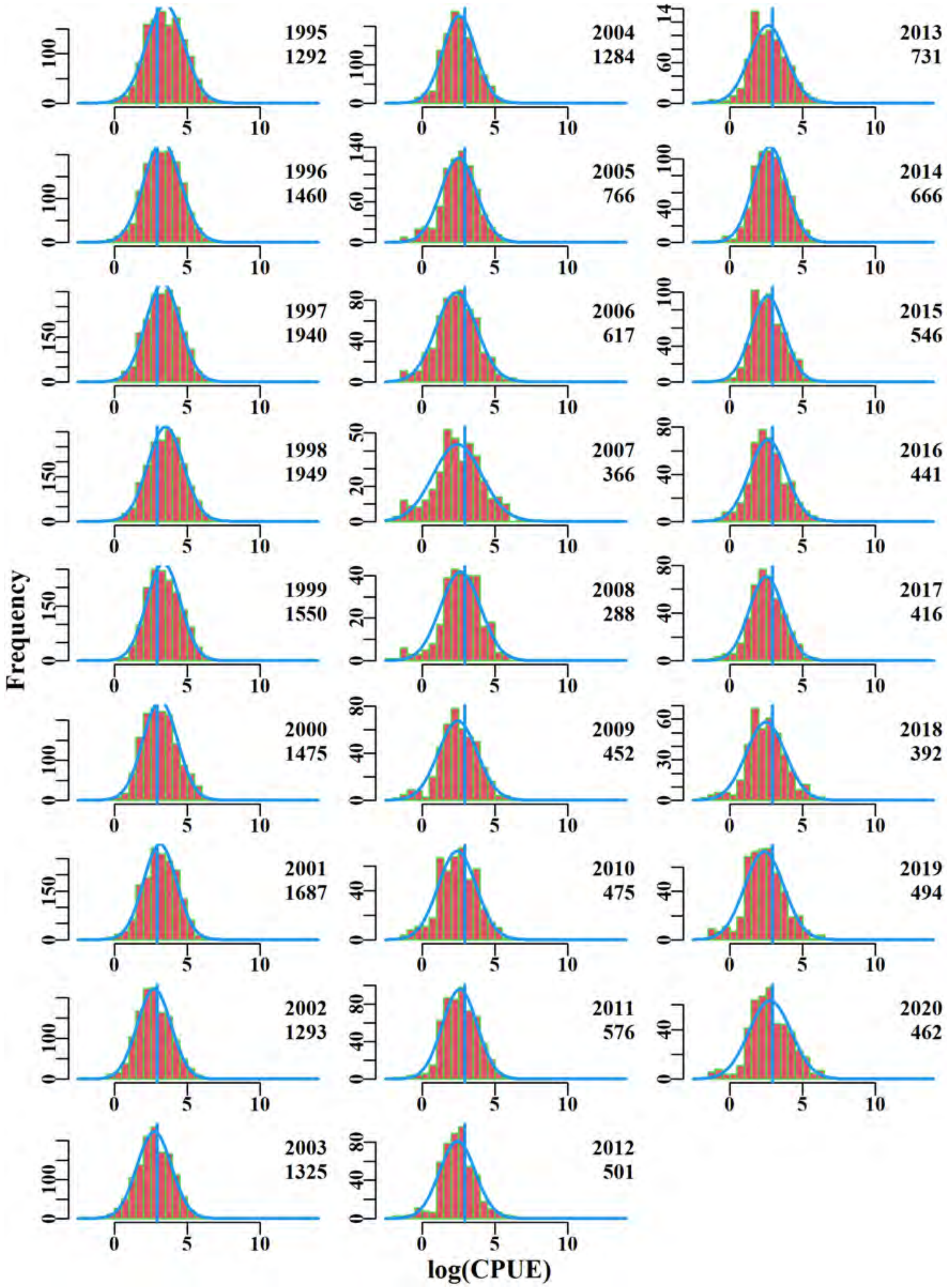

Figure 9.54. MixedOreos95. The natural log(CPUE) for each year of data available the blue lines are normal distributions fitted to the histogram frequencies. The numbers in each plot are the year and number of records. The vertical blue line is the average across all years.

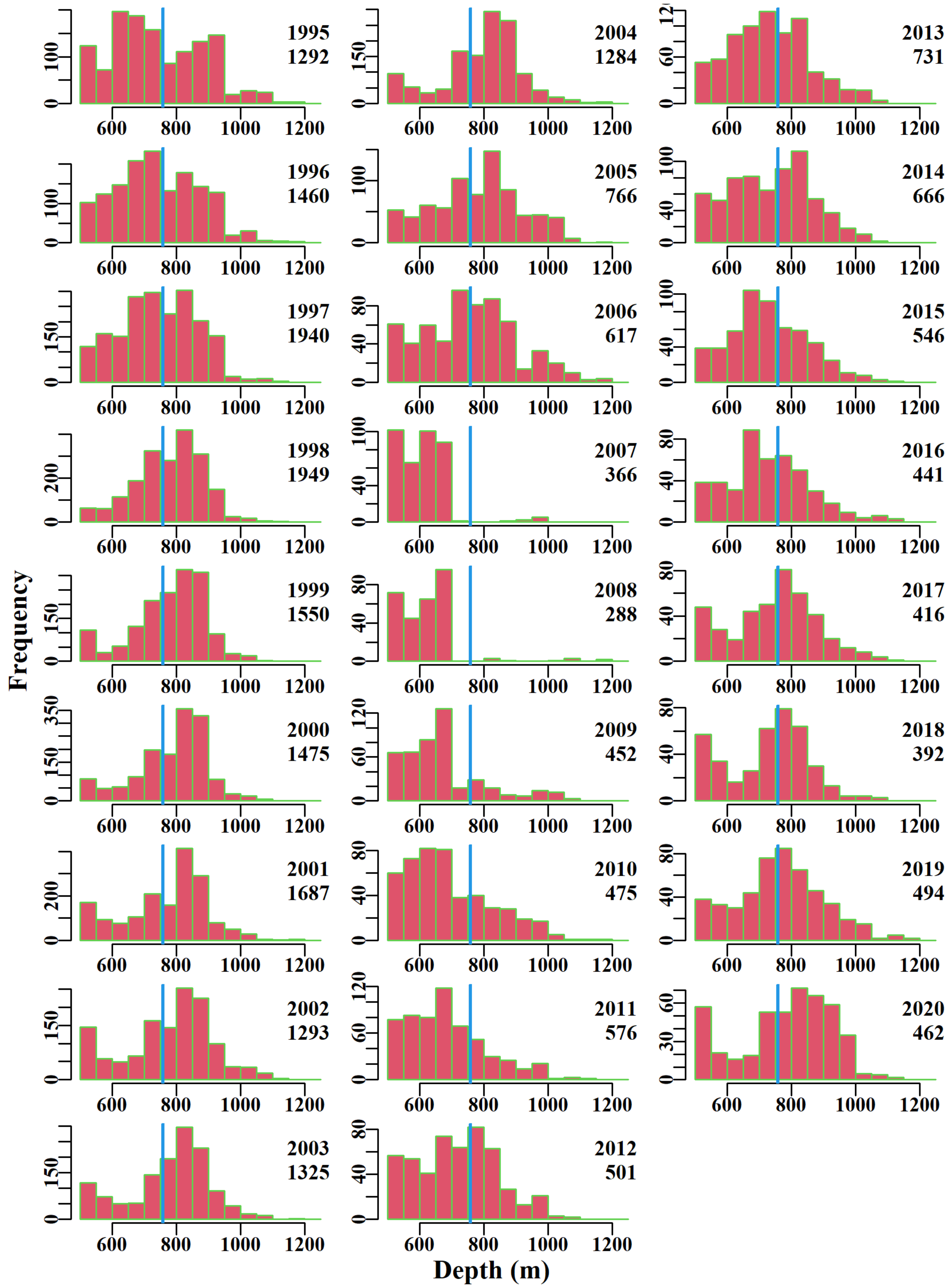

Figure 9.55. MixedOreos95. Frequency distribution of fishing depth (m) for each year of data available to illustrate the development of the fishery through time. The numbers in each plot are the year and number of records. The vertical blue line is the average across all years.

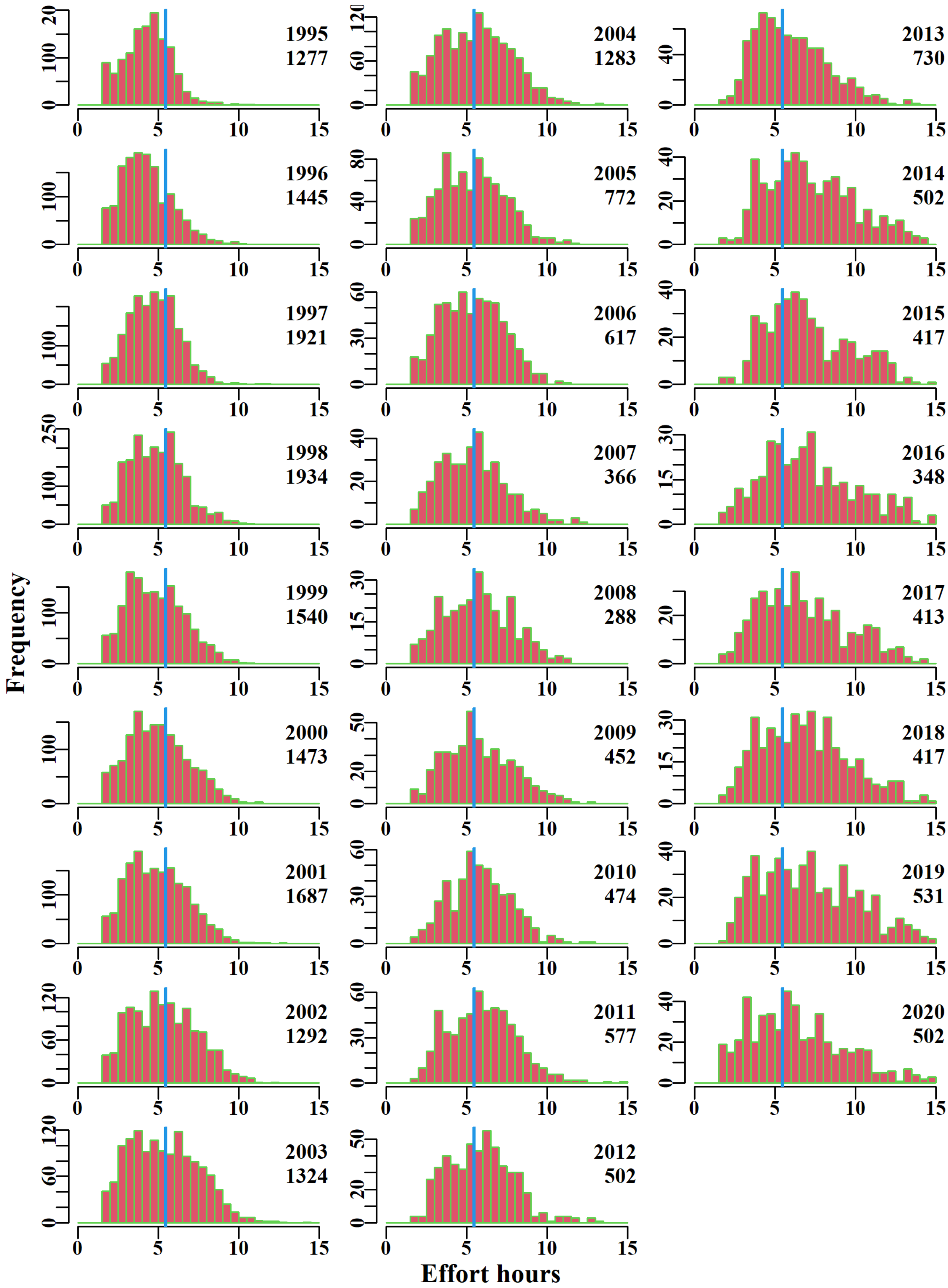

Figure 9.56. MixedOreos95. Frequency distribution of effort (hours) each year for the available data. The numbers in each plot are the year and number of records. The vertical blue line is the average across all years.

9.10 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. Geoff Tuck (CSIRO) is also thanked for his helpful comments on this report.

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10. CPUE standardizations for selected shark SESSF species (data to 2019)

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10.1 Executive Summary

This report summarizes catches and catch-per-unit (CPUE) for Gummy Shark (*Mustelus antarcticus*), School Shark (*Galeorhinus galeus*), Sawshark (*Pristiophorus cirratus*, *P. nudipinnis*, *P. spp* and Pristiophoridae) and Elephantfish (*Callorhinchus milii*) in Australia's Gillnet Hook and Trap Sector of the Southern and Eastern Scalefish and Shark Fishery (SESSF). It focuses on data over years 1995 - 2020 available in the Commonwealth logbook database. This database contains catch and effort records relating to all fishing methods and zones and allows for detailed CPUE standardization analyses, which is required to provide a complete view of the current state of the fishery.

Recorded catch of School Shark (*Galeorhinus galeus*) by trawl in 2019 (i.e., 29 t) is the largest since 1996, and those from trawling do not appear to be targeted, as evidenced by the large proportion of < 30 kg shots present in the logbook data. Also, there was a 10 t decrease of trawl caught school shark in 2020 compared with 2019. Nevertheless, the areas where they are caught have not changed greatly and yet the standardized catch-per-unit effort (CPUE) has generally increased, except in 2014, 2019 and 2020.

There was an increase in recorded gillnet catch of Gummy Shark (*Mustelus antarcticus*) in 2017 relative to 2016 in South Australia and Bass Strait. However, there was a 54% drop in recorded gillnet catch in 2019 relative 2018 in South Australia. The 2020 catch was almost the same as the 2019 catch (i.e., 65 t in 2019 and 63 t in 2020). Standardized catch per netlength (CPUN; kg/m) in South Australia increased from 2013 to 2016 and decreased to below the long-term average in 2020. By contrast, gillnet standardized CPUN in Bass Strait is cyclic and has increased above the long-term average in 2020. Standardized CPUN of gillnet caught Gummy Shark around Tasmania remained noisy and flat with increases in the last two years.

Recorded logbook trawl catch of Gummy Shark has been greater than 100 t per annum since 2018, the first time since 2011. Also, the 117 t recorded in 2019 is the largest in the time series. Annual standardized CPUE has been mostly flat and below the long-term average between 1997 and 2007 and has increased above the long-term average since 2012. Similarly, standardized CPUE in both South Australia and Tasmania have mostly increased and above the long-term average since at least 2014. By contrast, standardized CPUE in Bass Strait has been mostly flat and above the long-term average since 2008.

Non-zero catches per shot were employed in the statistical standardization analyses for gummy shark caught by bottom line. A detailed analysis of these effort units should be investigated to determine whether one effort unit or some combination could be used as an alternative effort unit in the standardization analyses. Standardized CPUE for trawl caught Gummy Shark has increased steadily since 2012, remaining above the long-term average, despite the small decreases in the last two years. By contrast, standardized CPUE for bottom line have remained mostly flat and noisy, with 2018 –

2020 period mostly exceeding the long-term average (based on 95% confidence intervals). Also, the 405 t of Gummy Shark caught by bottom line recorded in 2019 is the largest in the time series. To date, standardization analyses have not been conducted for Gummy Shark pertaining to the auto-line sector. With an increase of Gummy Shark caught by auto-line in recent years, there is a need to investigate whether there is enough information to allow for an auto-line CPUE standardization and/or a combined analysis for the line sector (i.e., bottom line and auto-line).

Gummy shark caught by Danish seine is not primarily targeted, based on the high proportion of small catches (less than 30 kg). The annual standardized CPUE has been mostly increasing and above the long-term average since about 2010.

Sawshark are considered as a bycatch group which is supported by the high proportion of < 30 kg catches that are reported by both gillnets, trawls and Danish seine. Standardized CPUN for gillnets exhibits a steady decline since about 2001, with small increases in recent years, except in 2017. Trawl caught Sawshark standardized CPUE exhibit a noisy but flat trend, with decreases to below the long-term average in 2016 and 2020, and small increases to the long-term average between that period.

By contrast, Sawshark standardized CPUE by Danish seine (which has the highest proportion of shots < 30 kg among methods) has remained either consistently below or at the long-term average since 2001. However, this species group is also discarded (e.g., 12% to 28%; discarded for 2011-2019) which may artificially inflate these estimates.

Like School Shark, Elephantfish (*Callorhinchus milii*) are a non-targeted species, as indicated by the large proportion of small shots (i.e., < 30 kg). Gillnet standardized CPUN is flat and noisy, and below the long-term average since about 2013. However, this analysis ignores discarding (e.g., ~39% in 2019) and uses number of shots instead of net length as a unit of effort. In recent years discard rates 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.

10.2 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 CPUE and exploitable biomass. However, many other factors can influence CPUE, including vessel, gear, depth, season, area and time of fishing (e.g. day or night). The use of CPUE as an index of relative abundance requires the removal of the effects of variation due to changes in these factors on the assumption that what remains will provide a better estimate of the underlying biomass 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 Southern and Eastern Scalefish and Shark Fishery (SESSF) 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 CPUE indices (based on data to 2020 inclusive) for Gummy Shark (South Australia-gillnet; Bass Strait-gillnet; Tasmania gillnet; South Australia-trawl; Bass Strait-trawl; Tasmania-trawl; Danish Seine; bottom line), School Shark (Trawl), Sawshark (gillnet; trawl; Danish seine) and Elephantfish (gillnet) within Australia's SESSF.

10.2.1 *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 account for the availability of quota and their own access to quota needed to land the species taken in the mixed species SESSF.

There may be situations where fishers report the need to avoid catching certain species, 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 ongoing introduction of numerous area closures imposed for a range of different reasons.

10.3 Methods

10.3.1 *CPUE Standardization*

10.3.1.1 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 CPUE 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, 2018) 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.

10.3.1.2 General Linear Modelling

In each case, CPUE, generally as kilograms per hour fished, kilograms per shot or kilograms per metre 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 and 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:

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

where $Ln(\text{CPUE}_i)$ 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.).

10.3.1.3 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:

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

here 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 CPUE changes.

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

where CPUE_t is the yearly coefficients from the standardization, $(\sum \text{CPUE}_t)/n$ 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.

10.3.1.4 Model Development and Selection

In each case an array of statistical models were 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.

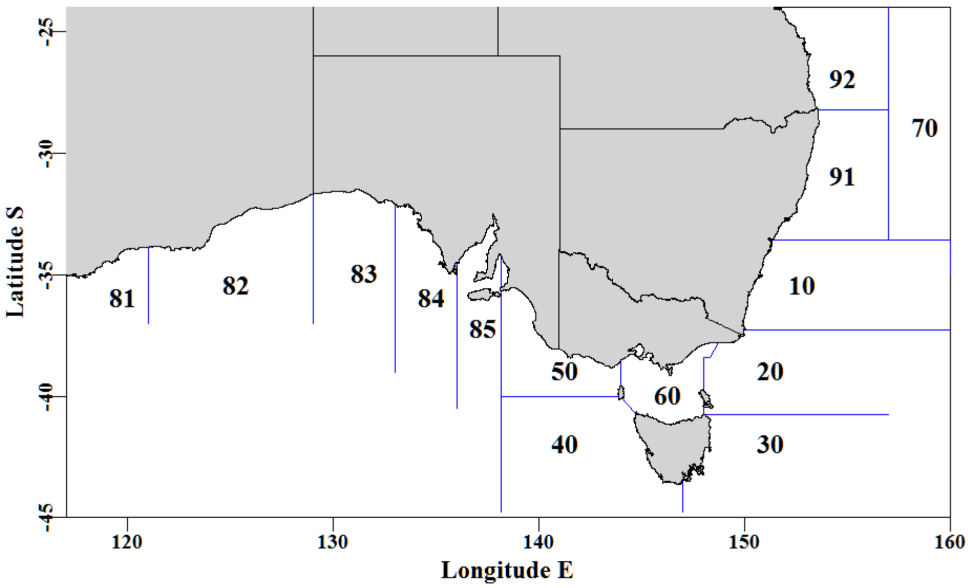

Figure 10.1. The statistical reporting zones in the SESSF.

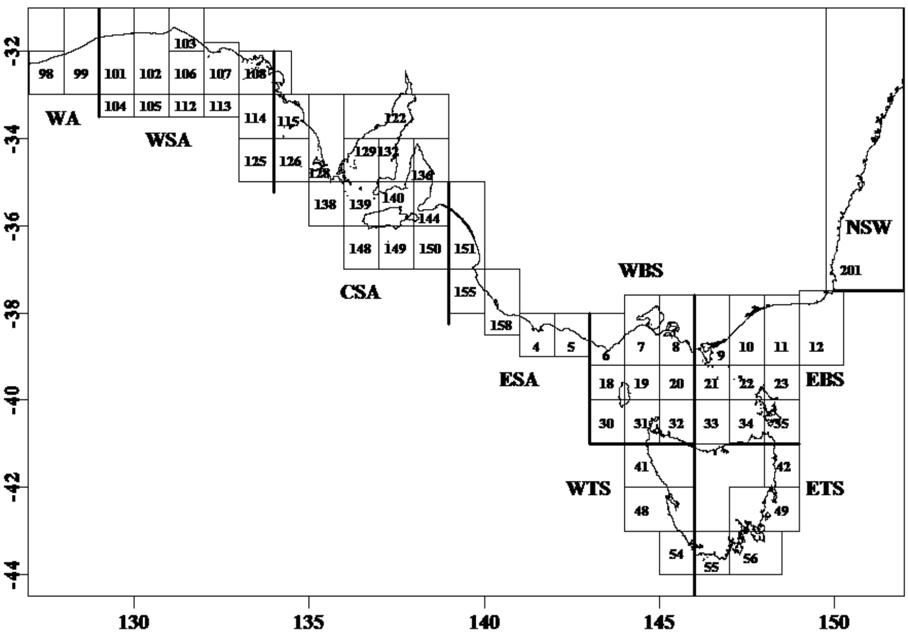

Figure 10.2. Shark statistical reporting areas and statistical regions. WA is Western Australia, WSA is Western South Australia, CSA is Central South Australia, ESA is Eastern South Australia (sometimes known as SAV - South Australia Victoria), WBS is Western Bass Strait, EBS is Eastern Bass Strait, NSW is New South Wales, ETS is Eastern Tasmania and WTS is Western Tasmania

10.4 Gummy shark: Gillnet South Australia

Positive non-zero records of catch per shot were employed in the statistical standardization analyses for Gummy Shark caught by gillnets.

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.

10.4.1 *Inferences*

Most catch occurred in Shark region 2, followed by 1, 9 and 3. There was a 54% drop in recorded gillnet catch in 2019 relative 2018 (ie., from 141 t to 65 t) in South Australia. The 2020 catch was almost the same as the 2019 catch (i.e., 65 t in 2019 and 63 t in 2020).

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 10.5). The qqplot suggests that the assumed Normal distribution is valid, with slight deviations as depicted by both tails of the distribution (Figure 10.6). Standardized CPUE exhibits a positive trend from 2012 to 2017 and has been above the long-term average since 2016. Since then, it has deceased to the long-term average in 2019 and to below the long-term average in 2020 (Figure 10.4).

10.4.2 *Action Items and Issues*

Further consideration of whether to consider the CPUE time-series as a valid index of relative abundance for Gummy Shark needs to be explored.

Table 10.1. 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, GNS
years	1997 - 2020

Table 10.2. GummySharkSA. Total catch (Total; t) is the total reported in the database, number of records used in the analysis (N), reported catch (Catch; t) in the area and depth used in the analysis and number of vessels used in the analysis (Vess). GeoM is the geometric mean of catch rates (kg/shot), standard deviation (StDev) relates to the optimum model. C<30Kg denotes the amount of catch in shots of <30kg, and P<30Kg is the proportion of total. The optimum model was SharkRegion:DepCat

Year	Total	N	Catch	Vess	GeoM	Opt	StDev	C<30Kg	P<30Kg
1997	952.1	4828	432.0	56	96.2	1.0997	0.000	27.199	0.063
1998	1401.2	7367	521.1	53	72.6	0.8818	0.022	50.807	0.097
1999	1923.8	6843	648.7	49	100.1	1.0600	0.023	38.965	0.060
2000	2436.9	6072	875.6	37	160.3	1.5212	0.024	24.242	0.028
2001	1703.3	5541	414.7	35	81.6	0.8248	0.025	30.145	0.073
2002	1527.2	5847	437.3	32	80.5	0.8884	0.025	35.877	0.082
2003	1653.4	5943	495.9	37	93.6	0.9610	0.025	33.592	0.068
2004	1670.4	5655	476.8	40	95.4	0.9860	0.026	30.295	0.064
2005	1573.3	5137	483.7	29	104.4	1.0598	0.027	27.698	0.057
2006	1577.1	5968	548.7	28	100.6	1.0886	0.026	31.127	0.057
2007	1575.0	4550	438.5	29	107.0	1.1452	0.027	22.012	0.050
2008	1727.9	4907	543.5	23	122.4	1.3408	0.027	21.515	0.040
2009	1500.9	5157	418.2	23	87.4	1.0238	0.027	30.674	0.073
2010	1404.9	5259	389.8	28	79.6	0.8961	0.027	32.880	0.084
2011	1364.7	3273	229.0	19	78.3	0.7900	0.030	21.029	0.092
2012	1304.4	1371	83.0	15	62.3	0.5921	0.039	10.043	0.121
2013	1307.7	800	60.5	18	77.6	0.6299	0.047	5.370	0.089
2014	1389.1	1461	126.0	19	96.5	0.8367	0.040	7.559	0.060
2015	1545.1	1544	151.6	15	105.7	1.0126	0.040	7.796	0.051
2016	1586.5	1062	134.5	11	132.4	1.2339	0.047	3.783	0.028
2017	1561.4	898	110.2	13	134.8	1.2549	0.051	2.647	0.024
2018	1560.1	1364	141.4	12	112.2	1.0740	0.047	4.841	0.034
2019	1709.7	885	64.6	11	76.2	0.9374	0.057	4.854	0.075
2020	1840.5	795	63.3	9	87.1	0.8614	0.057	4.429	0.070

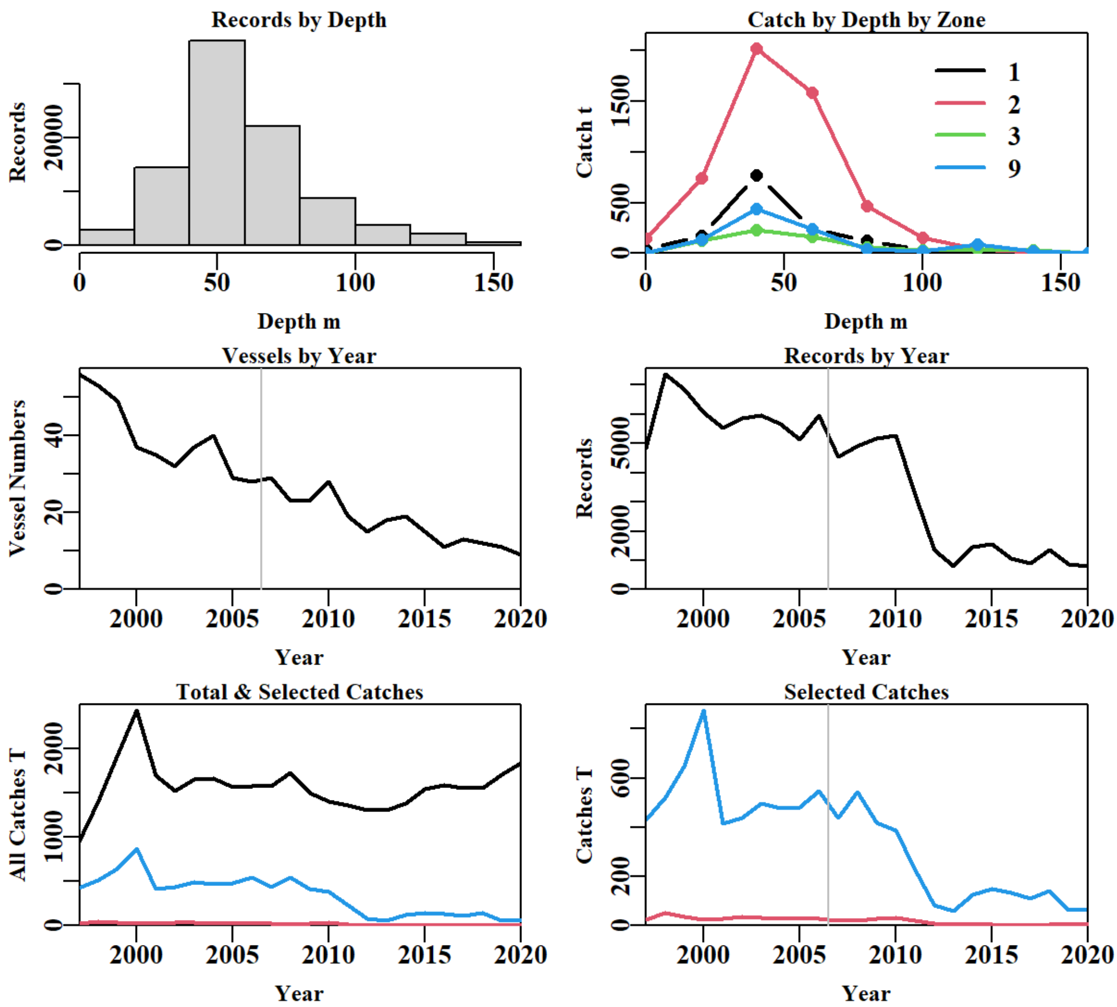

Figure 10.3. GummySharkSA fishery details. The bottom left plot depicts all known catches (top black line), and all selected catches used in the analysis (middle blue line); the lower red line: selected catches < 30 kg).

Table 10.3. 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	440781	0	38380.76	0
NoCE	425158	15623	38380.76	0
Depth	394618	30540	37204.21	1176.56
Years	383447	11171	36688.05	516.16
Zones	132174	251273	11224.05	25464.00
Method	92528	39646	8288.84	2935.21
Fishery	92527	1	8288.81	0.03

Table 10.4. 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 10.5. 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

Term	AIC	RSS	MSS	Nobs	Npars	adj_r2	%Change
Year	29498	127203	3701	92527	24	2.8	0
Vessel	25172	121023	9881	92527	165	7.4	4.58
DepCat	24304	119873	11031	92527	173	8.3	0.87
SharkRegion	24017	119494	11410	92527	176	8.5	0.29
Month	22773	117870	13034	92527	187	9.8	1.23
SharkRegion:DepCat	21795	116570	14334	92527	211	10.7	0.97
SharkRegion:Month	22369	117273	13631	92527	220	10.2	0.42

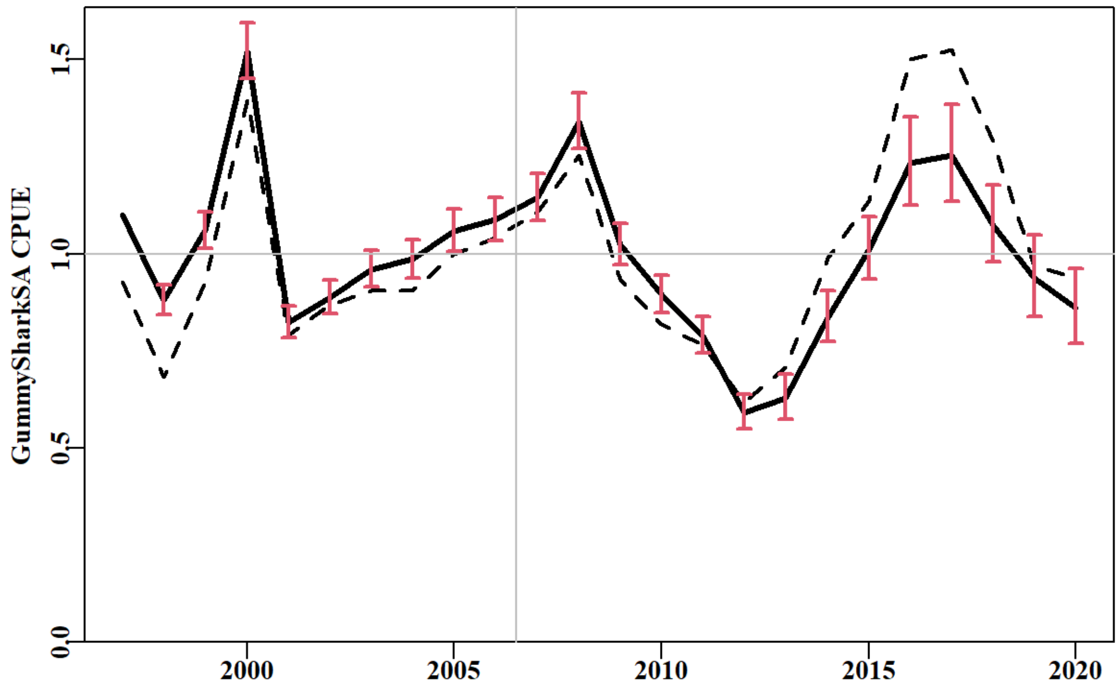

Figure 10.4. GummySharkSA standardization. The dashed black line represents the geometric mean catch rate, solid black line the standardized catch rates. The red bars are the 95% confidence intervals about the mean estimates. The graph scales both time-series of standardized catch rates relative to the mean of each time-series.

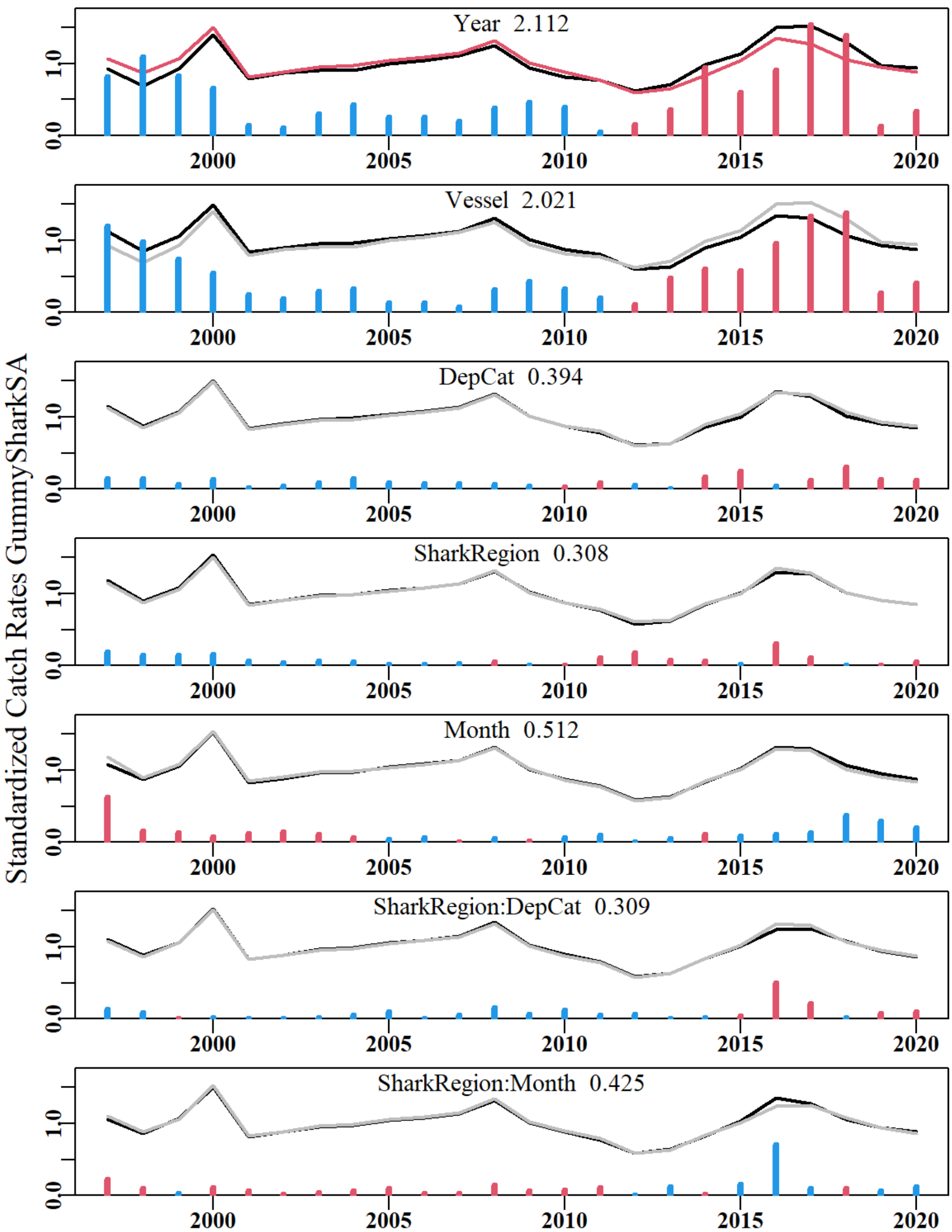

Figure 10.5. GummySharkSA. The influence of each factor on the optimal standardization. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by vertical bars with blue bars indicating the optimum model is higher than the geometric 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.

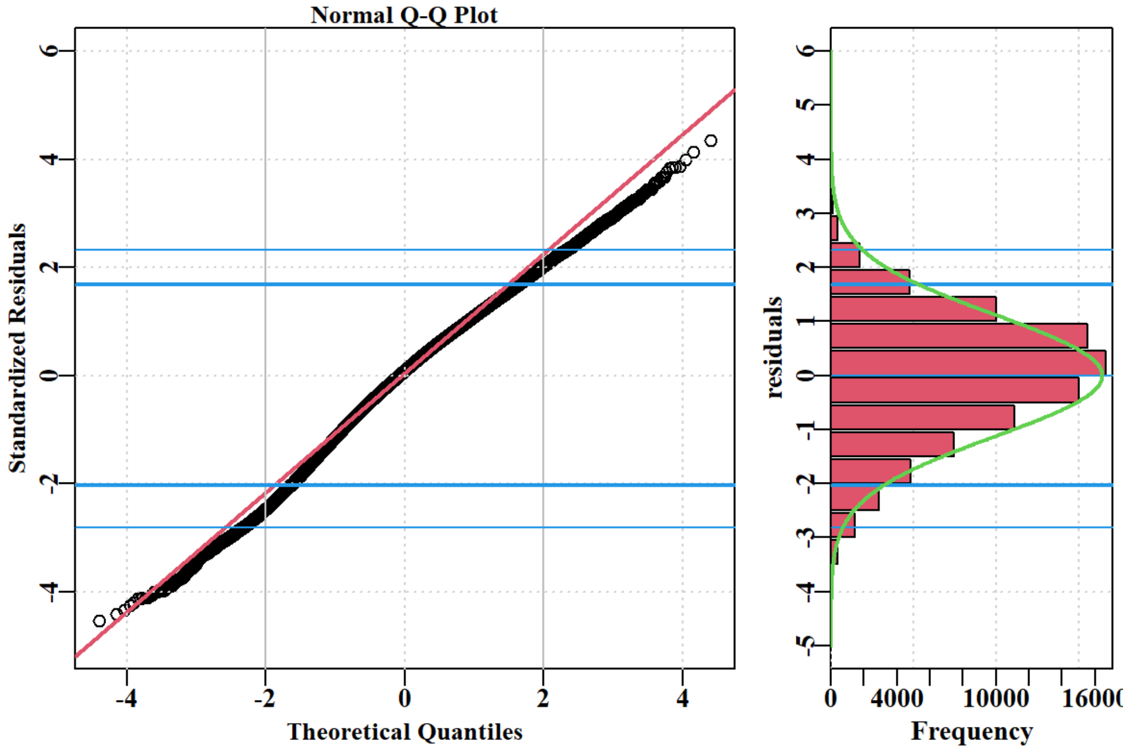

Figure 10.6. GummySharkSA. Diagnostic plots. The distribution of residuals from the optimum fit. The qqplot indicates the fit to the expected normality, while the histogram of residuals also illustrates the 1%, 5%, 95% and 99% quantiles to indicate the intensity of any lack of fit at the margins of the distribution (reflected also in the qqplot).

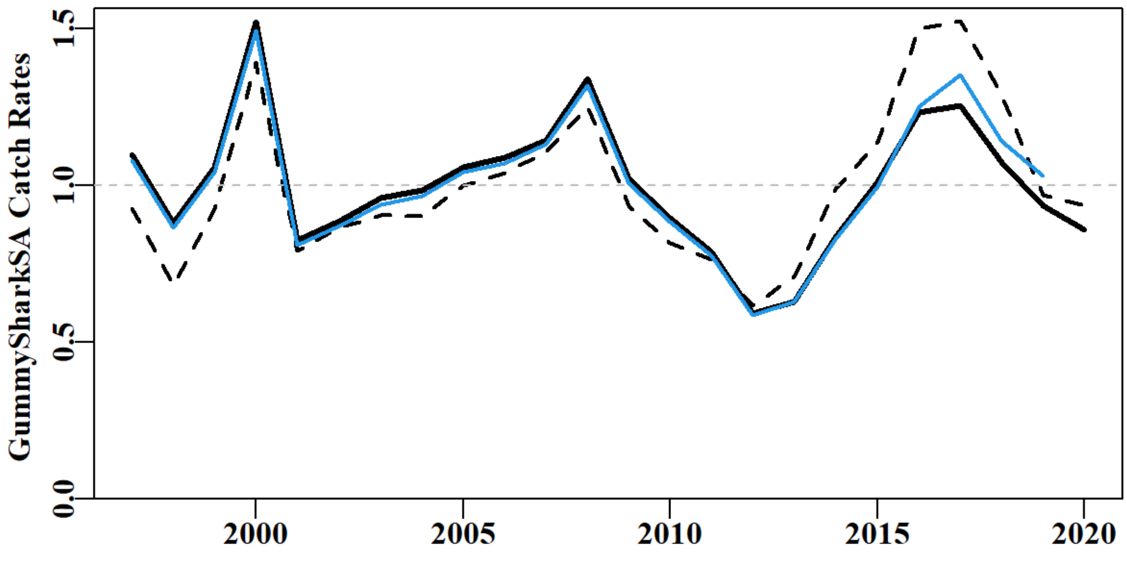

Figure 10.7. GummySharkSA. A comparison of the previous year's standardization (blue line) with this year's. They should lie on top of each other, although small deviations may relate to data adjustments, particularly in very recent years.

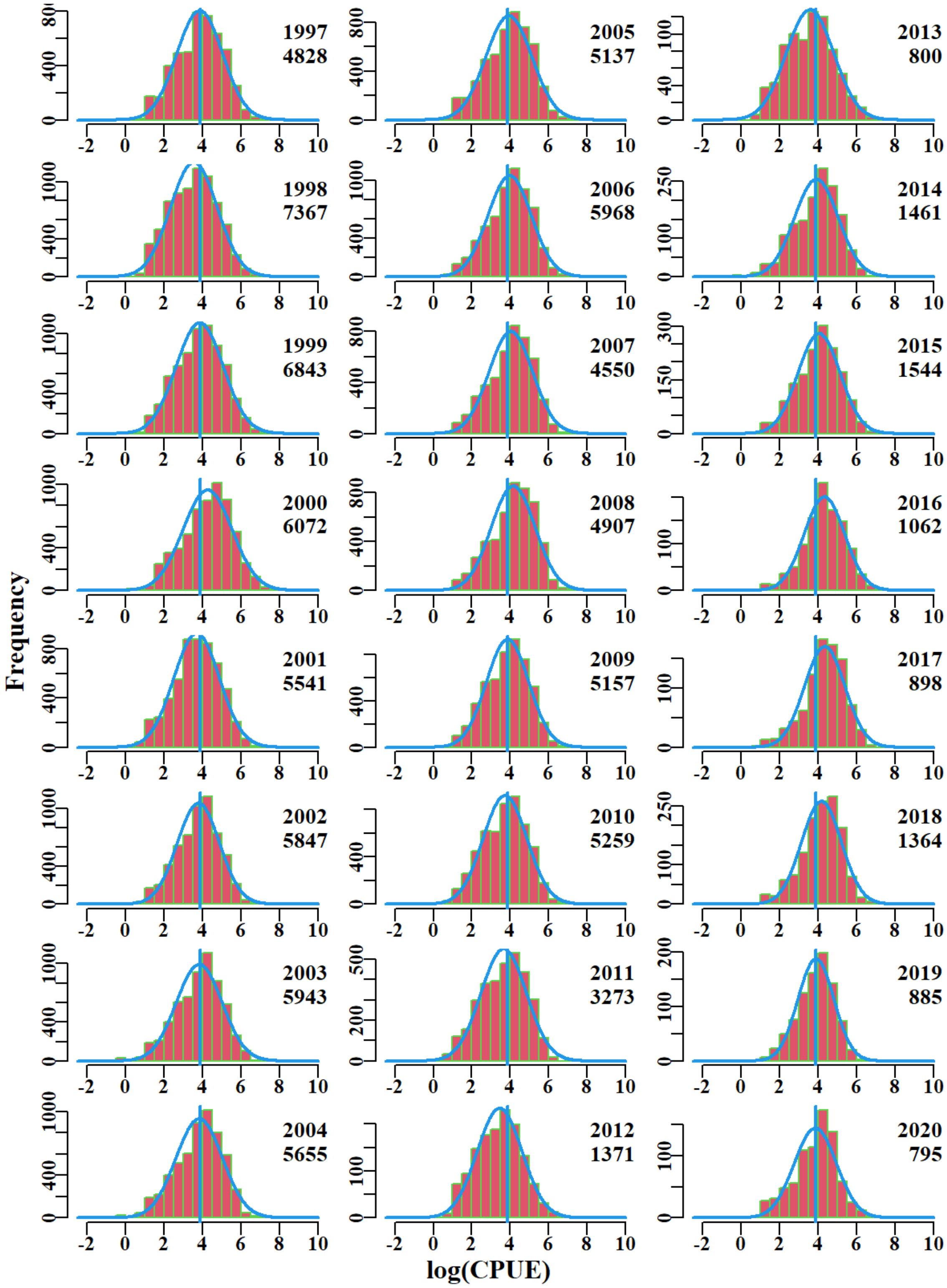

Figure 10.8. GummySharkSA. The natural log(CPUE) for each year of data available the blue lines are normal distributions fitted to the histogram frequencies. The numbers in each plot are the year and number of records. The vertical blue line is the average across all years.

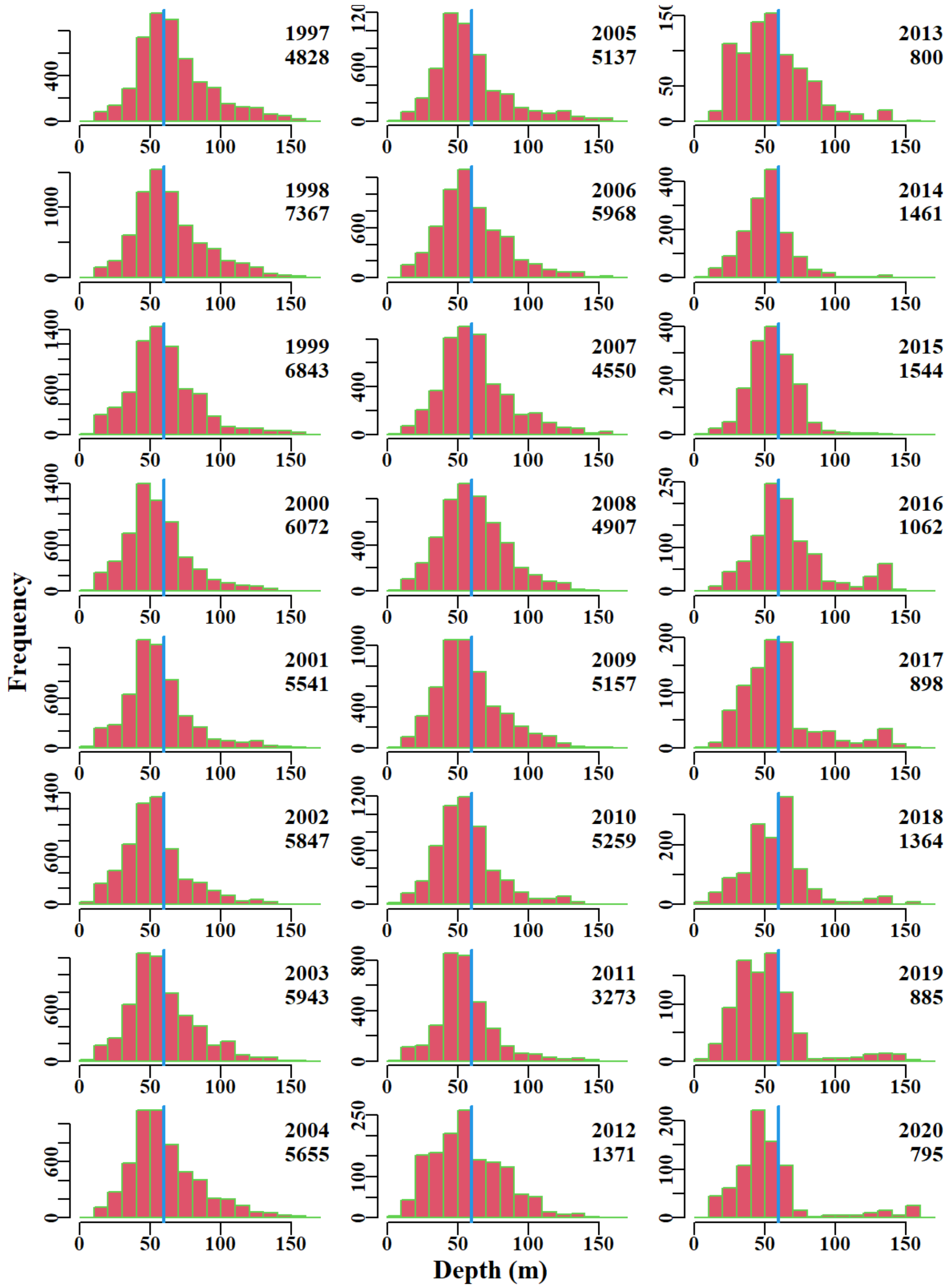

Figure 10.9. GummySharkSA. The average Depth of fishing for each year of data available to illustrate the development of the fishery through time. The numbers in each plot are the year and number of records. The vertical blue line is the average across all years.

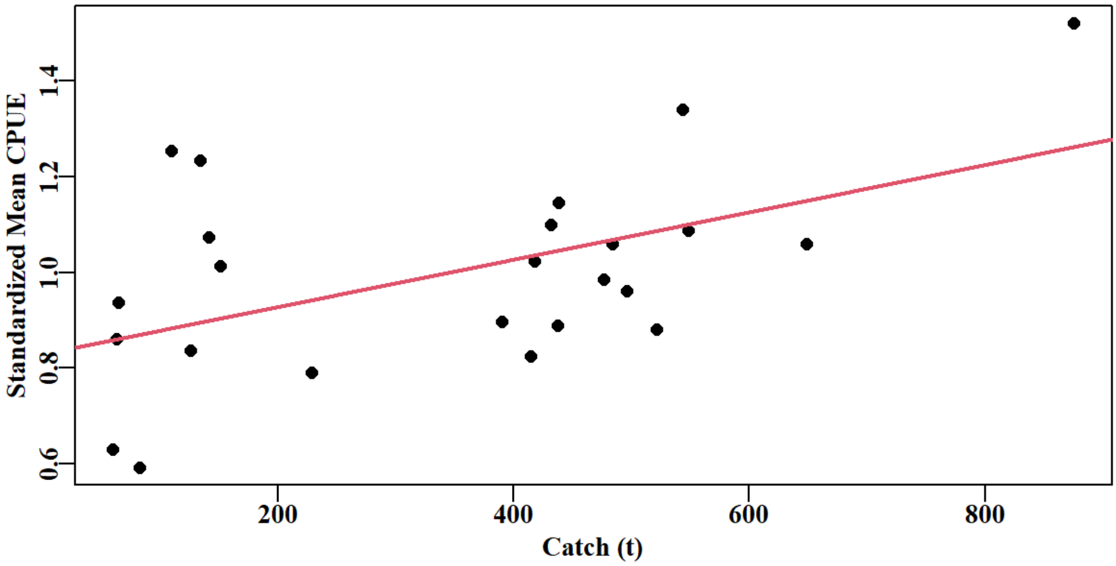

Figure 10.10. GummySharkSA. The linear relationship between annual mean CPUE and annual Catch.

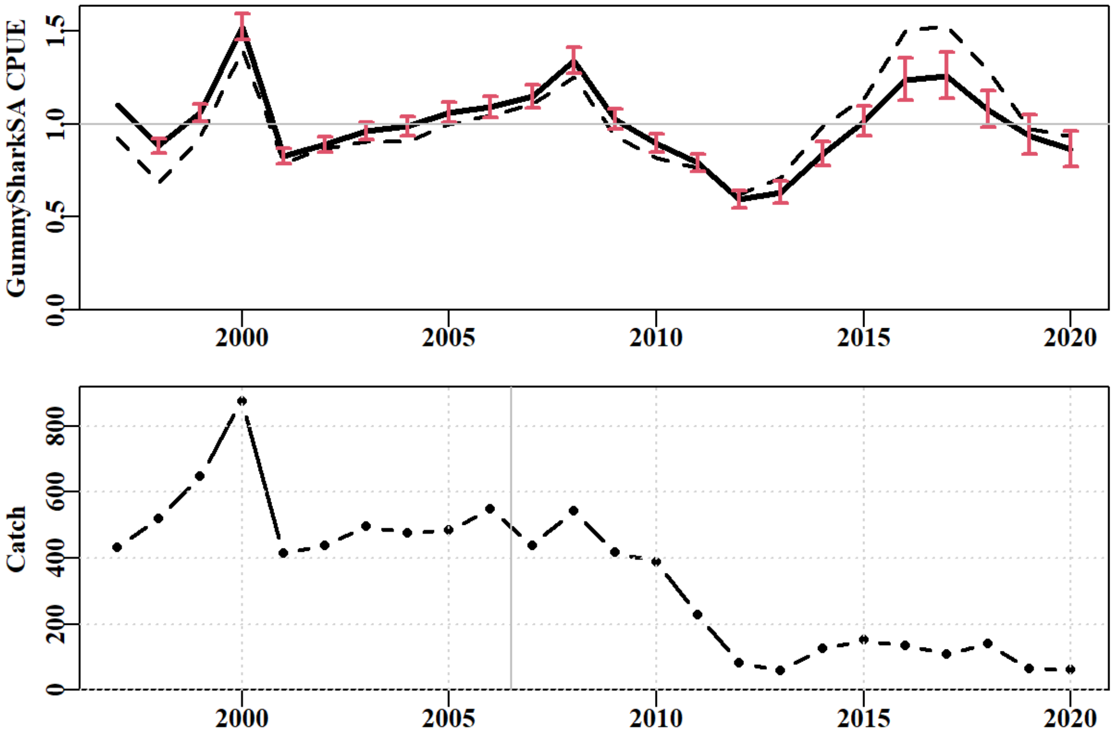

Figure 10.11. GummySharkSA. CPUE is correlated with catches through time. CPUE in the top plot and annual catch (t) in the lower plot.

10.5 Gummy shark: Gillnet Bass Strait

Positive non-zero records of catch per shot were employed in the statistical standardization analyses for Gummy Shark caught by gillnets.

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.

10.5.1 *Inferences*

Most catch occurred in Shark region 5 followed by 4.

The terms Year, Vessel, DepCat, Month, SharkRegion and one interaction (SharkRegion:Month) had the greatest contribution to model fit based on the AIC and R^2 statistics (Table 10.10), with the first two terms Year and Vessel contributing the most to the overall model fit. The qqplot suggests a slight departure from the assumed Normal distribution, as depicted by both tails of the distribution (Figure 10.15). CPUE is cyclical over the series, increased in 2016 (relative to 2015), dropped just below the long-term average in 2017 and increased thereafter (Figure 10.13).

10.5.2 *Action Items and Issues*

Further consideration of whether to consider the CPUE time-series as a valid index of relative abundance for Gummy Shark needs to be explored.

Table 10.6. 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, GNS
years	1997 - 2020

Table 10.7. GummySharkBS. Total catch (Total; t) is the total reported in the database, number of records used in the analysis (N), reported catch (Catch; t) in the area and depth used in the analysis and number of vessels used in the analysis (Vess). GeoM is the geometric mean of catch rates (kg/shot), standard deviation (StDev) relates to the optimum model. C<30Kg denotes the amount of catch in shots of <30kg, and P<30Kg is the proportion of total. The optimum model was SharkRegion:Month

Year	Total	N	Catch	Vess	GeoM	Opt	StDev	C<30Kg	P<30Kg
1997	952.1	4397	417.0	50	103.8	0.6368	0.000	23.872	0.057
1998	1401.2	5949	705.9	51	132.5	0.7791	0.024	26.642	0.038
1999	1923.8	6666	1030.9	57	176.6	1.0240	0.024	25.060	0.024
2000	2436.9	6922	1257.5	49	211.5	1.1179	0.024	22.653	0.018
2001	1703.3	6318	1051.1	47	202.3	0.9908	0.025	20.486	0.019
2002	1527.2	6299	833.8	47	157.5	0.8118	0.025	24.050	0.029
2003	1653.4	6628	883.6	44	160.0	0.8027	0.025	25.951	0.029
2004	1670.4	6290	880.2	41	162.6	0.8707	0.025	21.121	0.024
2005	1573.3	5280	811.4	39	171.0	0.9611	0.026	15.256	0.019
2006	1577.1	4064	727.6	33	201.4	1.0926	0.027	10.785	0.015
2007	1575.0	3479	873.9	25	291.6	1.3427	0.028	7.472	0.009
2008	1727.9	3672	954.7	26	301.8	1.4342	0.028	7.287	0.008
2009	1500.9	4089	831.5	28	233.8	1.2516	0.028	9.391	0.011
2010	1404.9	4408	738.0	31	191.3	0.9985	0.027	13.268	0.018
2011	1364.7	5171	797.9	32	173.6	0.9009	0.026	18.833	0.024
2012	1304.4	5442	780.2	37	162.2	0.8636	0.026	19.117	0.025
2013	1307.7	5345	757.6	36	160.6	0.8278	0.026	20.983	0.028
2014	1389.1	5246	810.0	36	175.5	0.8765	0.026	18.070	0.022
2015	1545.1	4924	973.8	30	233.0	1.0702	0.027	13.152	0.014
2016	1586.5	5052	1086.3	31	249.6	1.1949	0.027	12.938	0.012
2017	1561.4	5801	937.5	30	184.0	0.9116	0.026	17.749	0.019
2018	1560.1	5106	785.4	31	174.2	0.9237	0.027	16.305	0.021
2019	1709.7	4926	899.1	33	199.8	1.0842	0.027	12.430	0.014
2020	1840.5	4713	989.8	26	238.6	1.2323	0.028	10.635	0.011

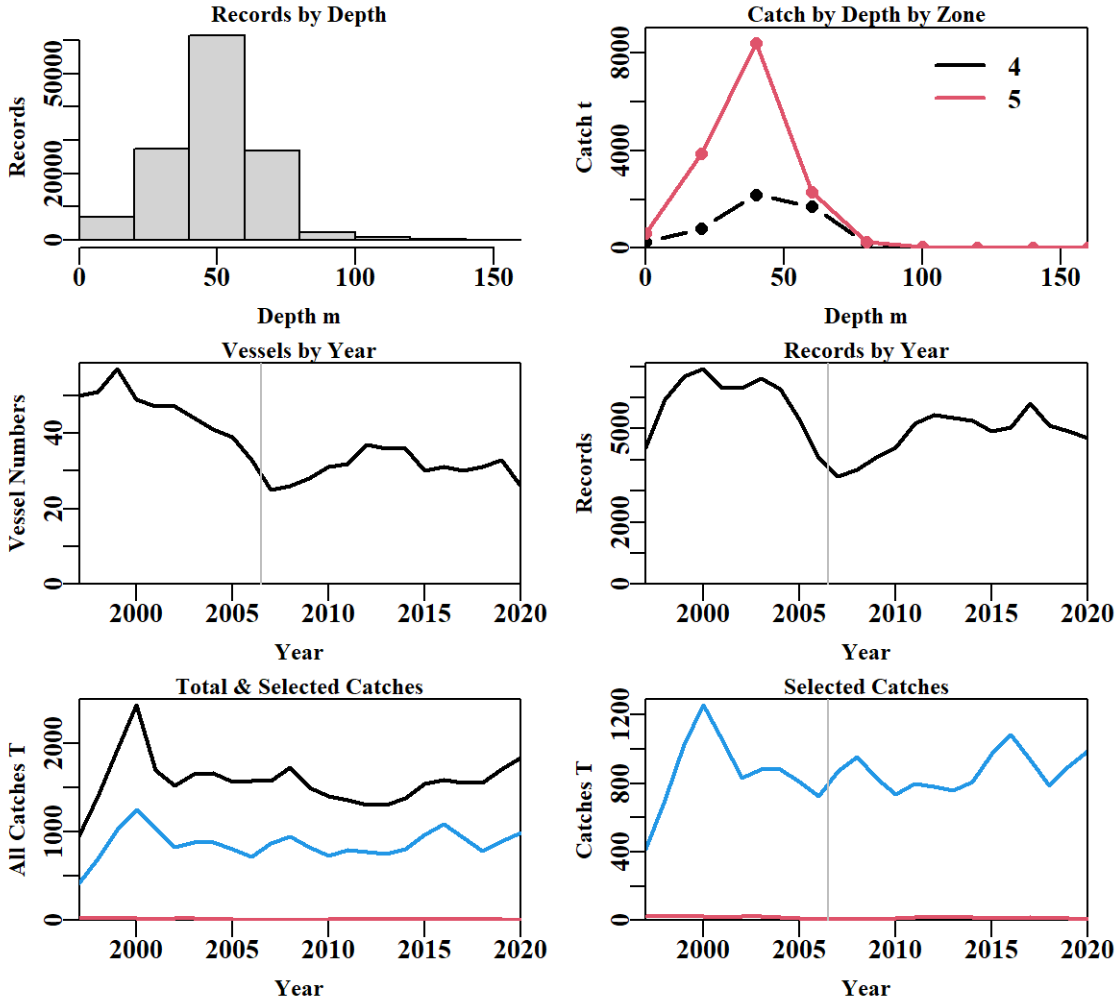

Figure 10.12. GummySharkBS fishery details. The bottom left plot depicts all known catches (top black line), and all selected catches used in the analysis (middle blue line); the lower red line: selected catches < 30 kg).

Table 10.8. 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	440781	0	38380.76	0
NoCE	425158	15623	38380.76	0
Depth	394618	30540	37204.21	1176.56
Years	383447	11171	36688.05	516.16
Zones	200143	183304	22383.07	14304.98
Method	126191	73952	20814.97	1568.10
Fishery	126187	4	20814.51	0.46

Table 10.9. 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 10.10. 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:Month

Term	AIC	RSS	MSS	Nobs	Npars	adj_r2	%Change
Year	49450	186655	6116	126187	24	3.2	0
Vessel	40679	173775	18997	126187	150	9.7	6.59
DepCat	39765	172499	20272	126187	158	10.4	0.66
SharkRegion	39754	172480	20291	126187	159	10.4	0.01
Month	38917	171310	21461	126187	170	11.0	0.60
SharkRegion:DepCat	38800	171133	21639	126187	177	11.1	0.09
SharkRegion:Month	38585	170830	21941	126187	181	11.3	0.24

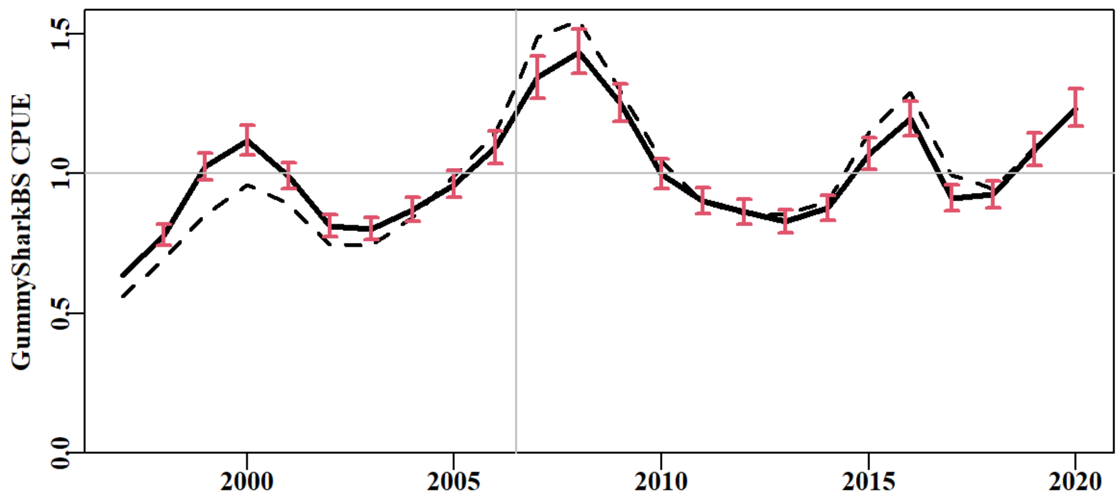

Figure 10.13. GummySharkBS standardization. The dashed black line represents the geometric mean catch rate, solid black line the standardized catch rates. The red bars are the 95% confidence intervals about the mean estimates. The graph scales both time-series of standardized catch rates relative to the mean of each time-series.

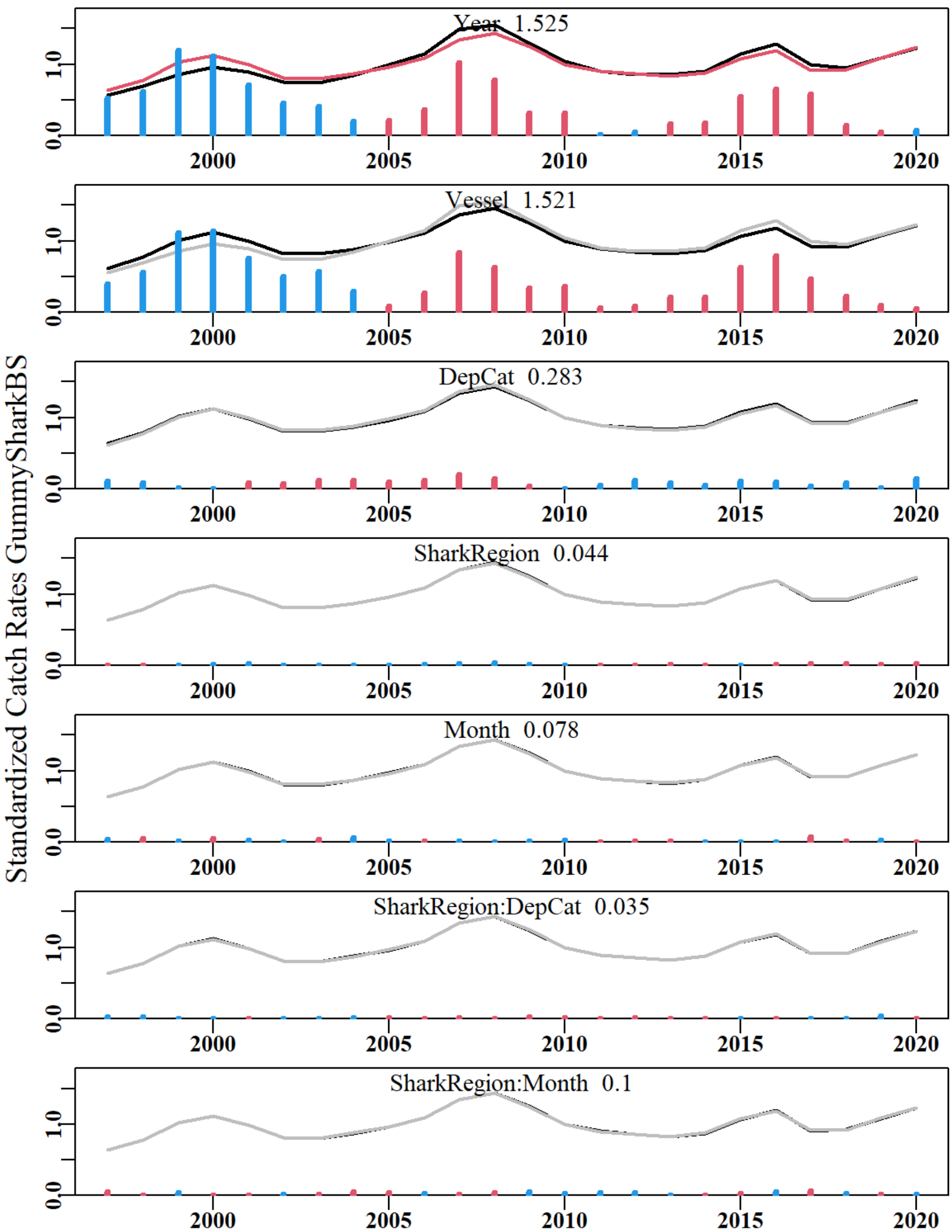

Figure 10.14. GummySharkBS. The influence of each factor on the optimal standardization. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by vertical bars with blue bars indicating the optimum model is higher than the geometric 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.

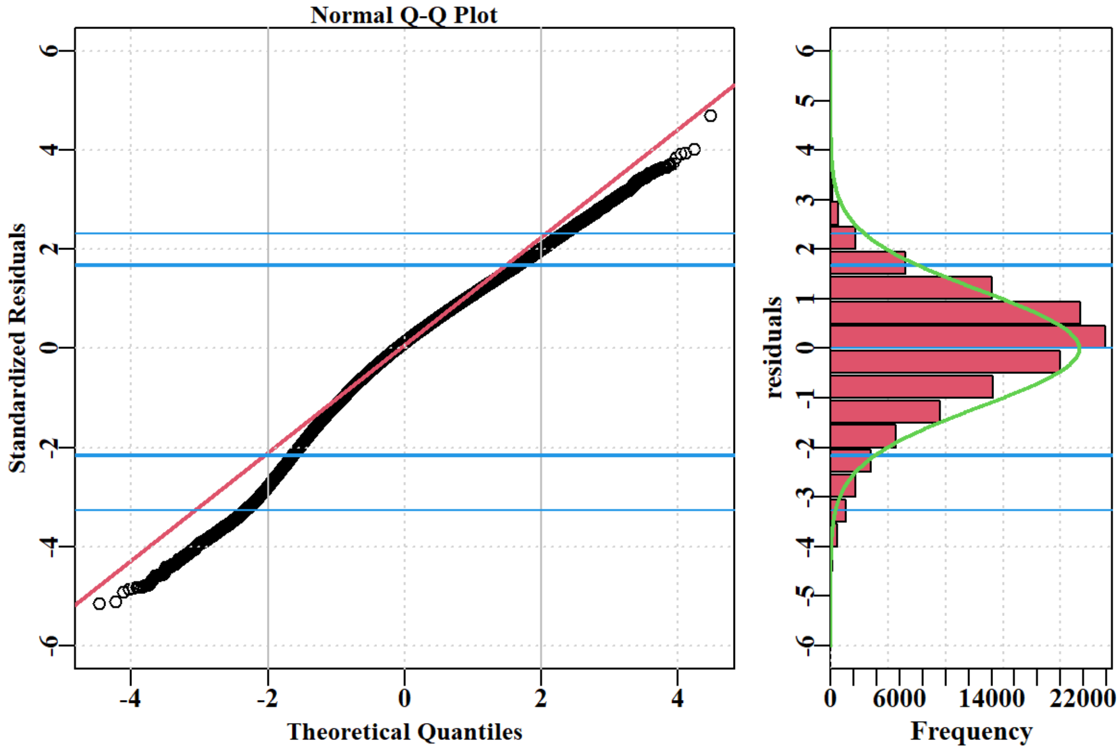

Figure 10.15. GummySharkBS. Diagnostic plots. The distribution of residuals from the optimum fit. The qqplot indicates the fit to the expected normality, while the histogram of residuals also illustrates the 1%, 5%, 95% and 99% quantiles to indicate the intensity of any lack of fit at the margins of the distribution (reflected also in the qqplot).

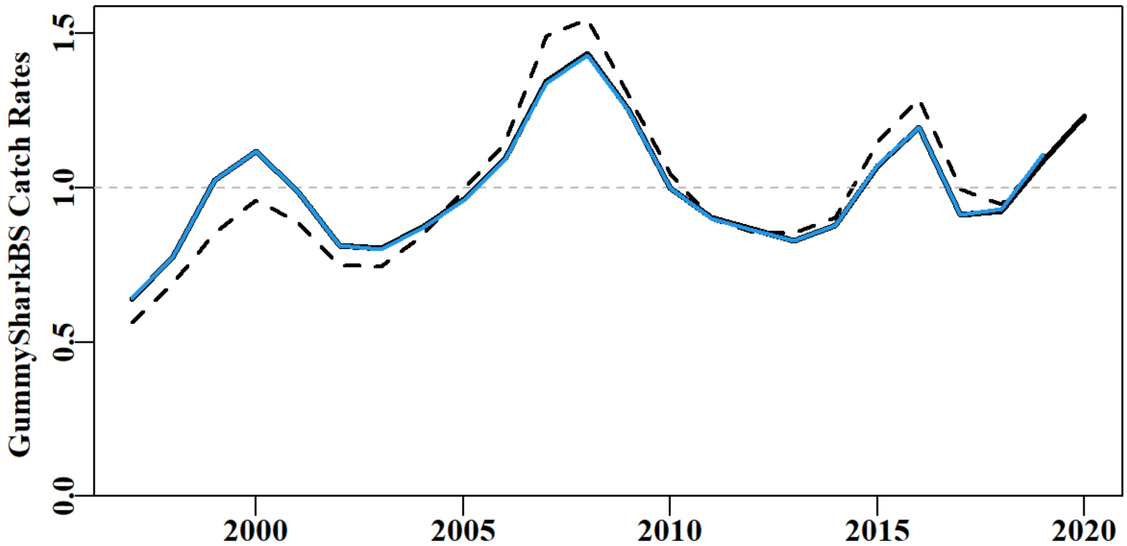

Figure 10.16. GummySharkBS. A comparison of the previous year's standardization (blue line) with this year's. They should lie on top of each other, although small deviations may relate to data adjustments, particularly in very recent years.

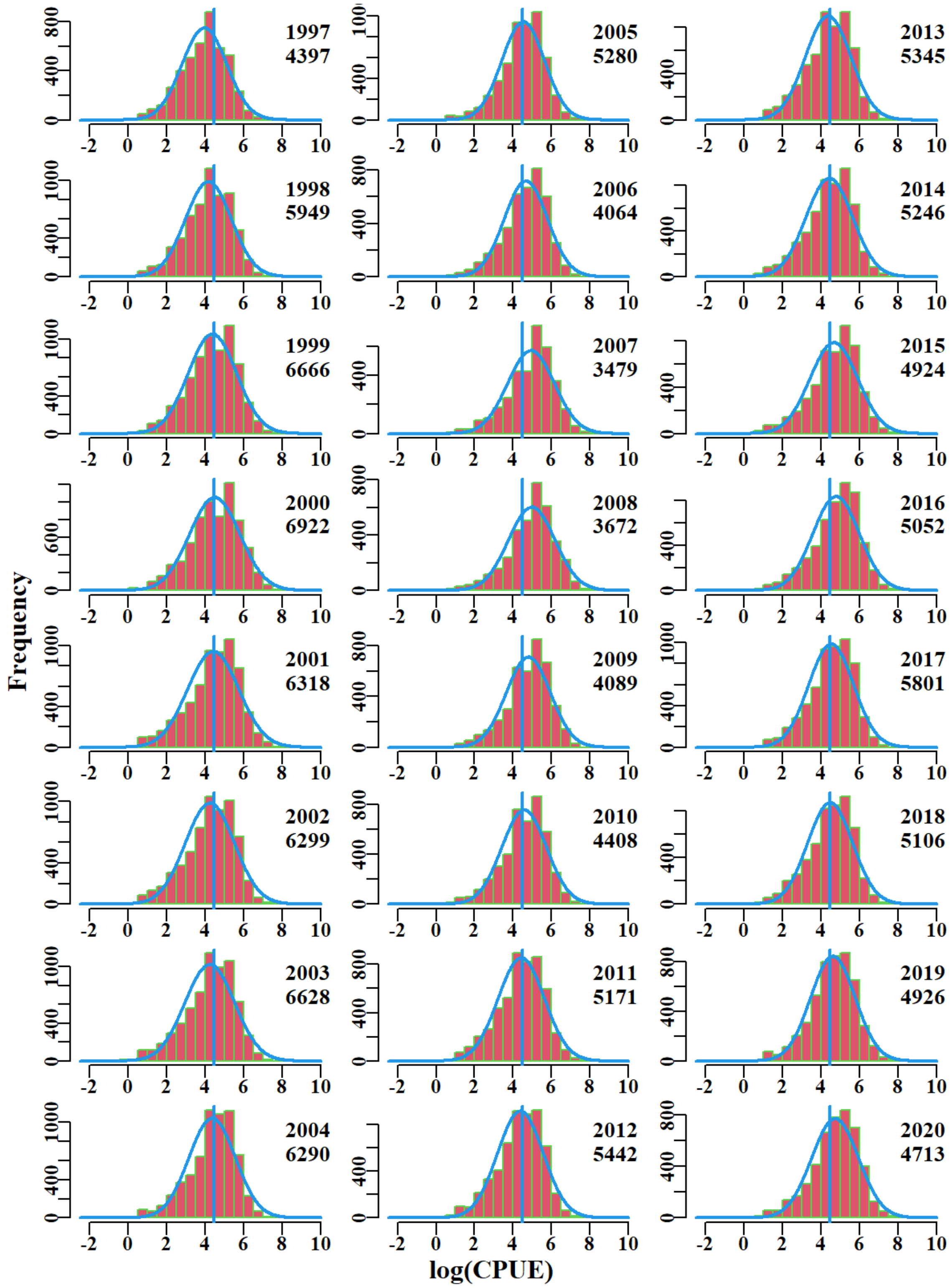

Figure 10.17. GummySharkBS. A comparison of the previous year's standardization (blue line) with this year's. They should lie on top of each other, although small deviations may relate to data adjustments, particularly in very recent years.

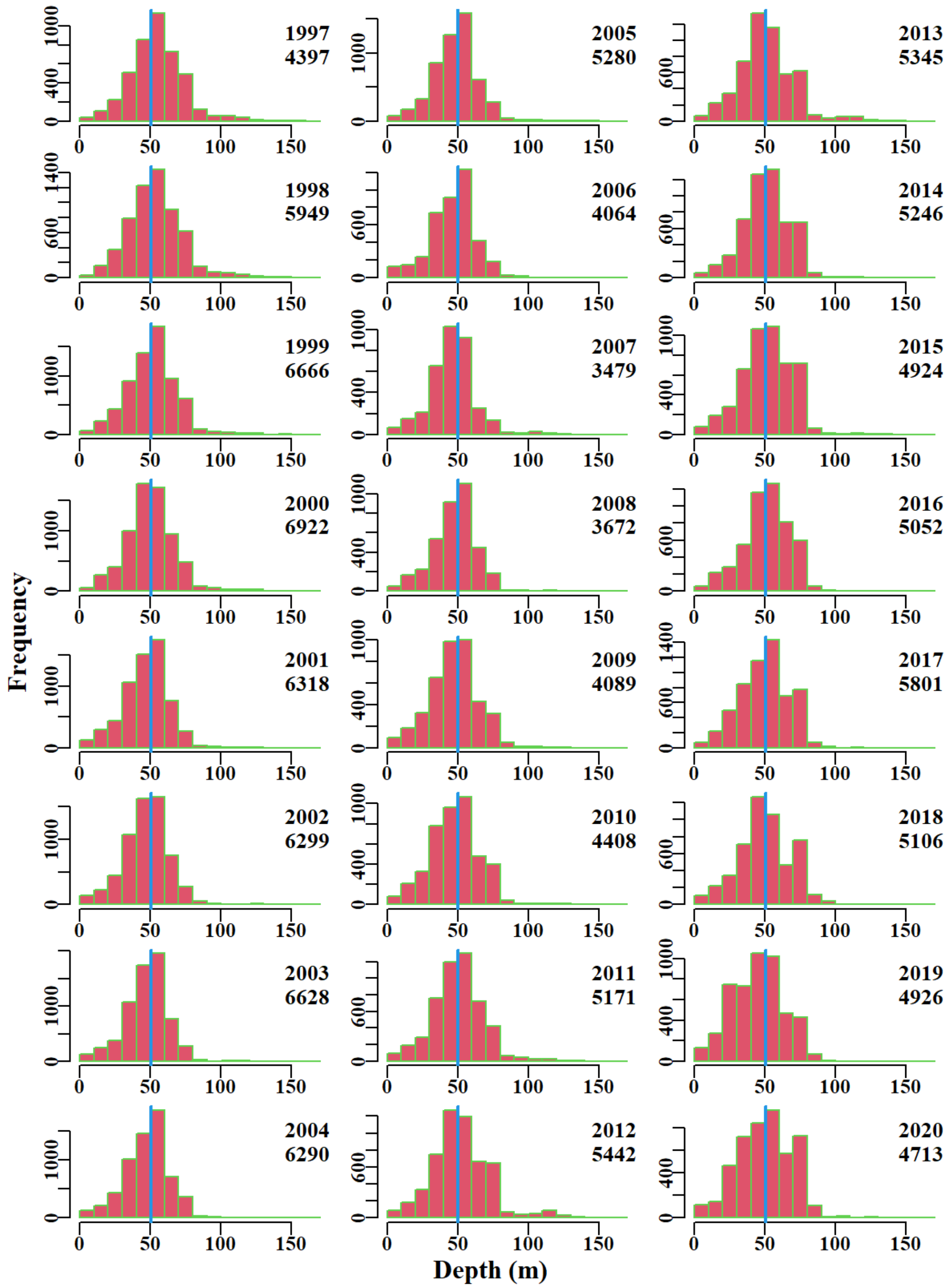

Figure 10.18. GummySharkBS. The average Depth of fishing for each year of data available to illustrate the development of the fishery through time. The numbers in each plot are the year and number of records. The vertical blue line is the average across all years.

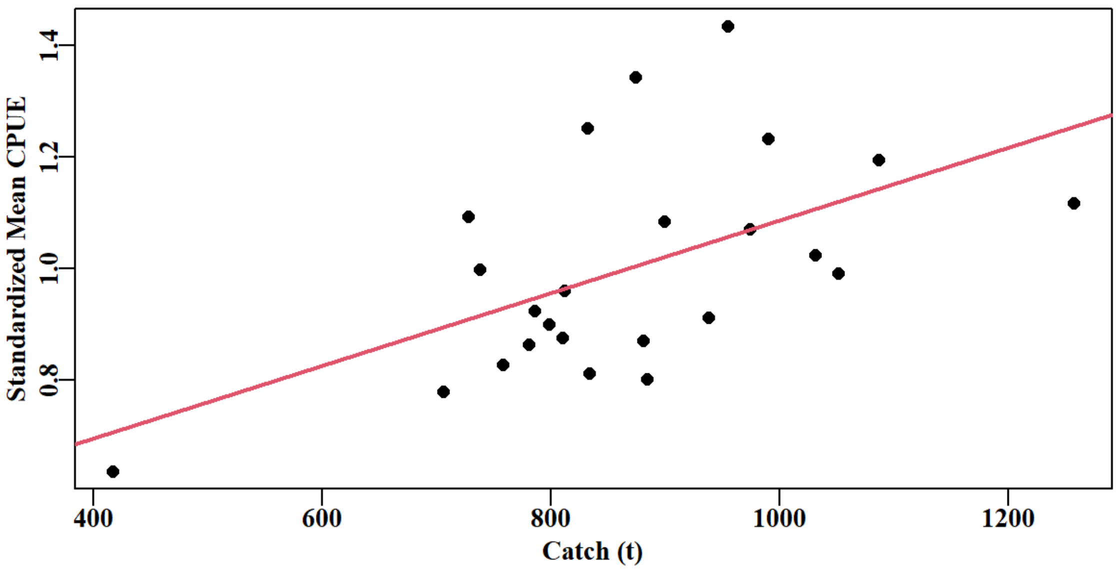

Figure 10.19. GummySharkBS. The linear relationship between annual mean CPUE and annual Catch.

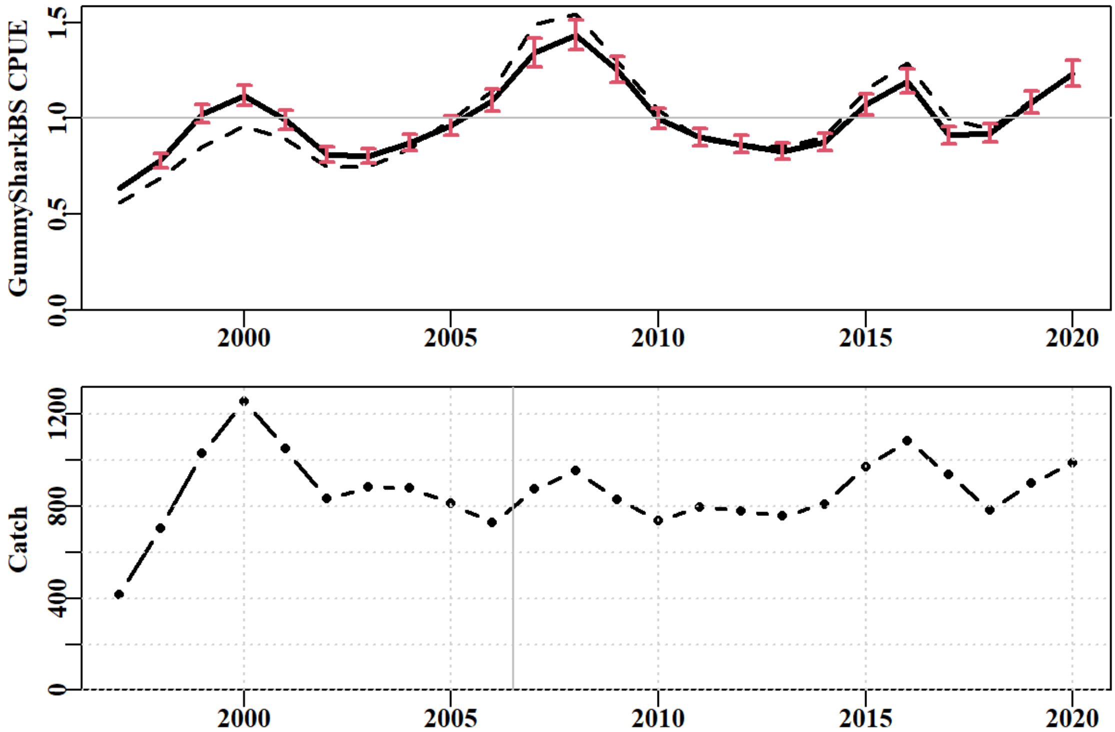

Figure 10.20. GummySharkBS. CPUE is correlated with catches through time. CPUE in the top plot and annual catch (t) in the lower plot.

10.6 Gummy shark: Gillnet Tasmania

Positive non-zero records of catch per shot were employed in the statistical standardization analyses for Gummy Shark caught by gillnets.

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.

10.6.1 *Inferences*

Most catch occurred in Shark region 7 followed by 6.

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 10.15), with the first two terms Year and Vessel contributing the most to the overall model fit. The qqplot suggests a slight departure from the assumed Normal distribution, as depicted by the lower tail of the distribution (Figure 10.24). Standardized CPUE (including corresponding 95% confidence intervals) has been mostly flat and at the long-term average since 1999 and slightly below the long-term average in three years (i.e., 1998, 2014 and 2015) (Figure 10.22).

10.6.2 *Action Items and Issues*

Further consideration of whether to consider the CPUE time-series as a valid index of relative abundance for Gummy Shark needs to be explored.

Table 10.11. 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, GMS
years	1997 - 2020

Table 10.12. GummySharkTA. Total catch (Total; t) is the total reported in the database, number of records used in the analysis (N), reported catch (Catch; t) in the area and depth used in the analysis and number of vessels used in the analysis (Vess). GeoM is the geometric mean of catch rates (kg/shot), standard deviation (StDev) relates to the optimum model. C<30Kg denotes the amount of catch in shots of <30kg, and P<30Kg is the proportion of total. The optimum model was SharkRegion:Month

Year	Total	N	Catch	Vess	GeoM	Opt	StDev	C<30Kg	P<30Kg
1997	952.1	203	17.3	14	96.0	0.7724	0.000	1.231	0.071
1998	1401.2	529	55.3	14	122.1	0.7154	0.107	3.061	0.055
1999	1923.8	854	102.0	19	134.8	0.9900	0.105	3.926	0.038
2000	2436.9	544	82.6	18	169.2	1.2152	0.112	1.909	0.023
2001	1703.3	600	65.1	21	125.2	1.2545	0.115	2.672	0.041
2002	1527.2	781	100.4	26	159.5	1.1632	0.115	3.399	0.034
2003	1653.4	873	90.5	23	118.0	1.2933	0.116	4.674	0.052
2004	1670.4	917	120.9	26	169.0	1.2274	0.115	3.893	0.032
2005	1573.3	657	85.8	15	157.2	1.1080	0.118	2.646	0.031
2006	1577.1	697	116.8	15	191.0	1.2436	0.117	2.334	0.020
2007	1575.0	835	95.3	14	135.6	1.0583	0.116	4.041	0.042
2008	1727.9	636	61.9	14	109.9	0.9175	0.118	3.464	0.056
2009	1500.9	527	67.2	14	160.0	1.0824	0.123	2.199	0.033
2010	1404.9	534	75.5	14	172.2	1.0815	0.123	2.089	0.028
2011	1364.7	687	102.7	13	178.8	0.8996	0.125	2.212	0.022
2012	1304.4	1119	130.0	18	126.8	0.9492	0.121	5.852	0.045
2013	1307.7	910	96.6	15	111.5	0.7875	0.125	4.804	0.050
2014	1389.1	482	65.1	13	144.0	0.7248	0.132	2.146	0.033
2015	1545.1	359	53.4	11	166.6	0.7116	0.132	1.439	0.027
2016	1586.5	344	68.1	7	235.9	0.9787	0.132	0.952	0.014
2017	1561.4	497	85.1	13	198.2	1.0131	0.128	1.258	0.015
2018	1560.1	362	46.2	9	135.8	0.7694	0.133	1.714	0.037
2019	1709.7	586	74.2	11	138.3	0.9815	0.132	1.842	0.025
2020	1840.5	458	84.9	6	201.5	1.0619	0.135	1.043	0.012

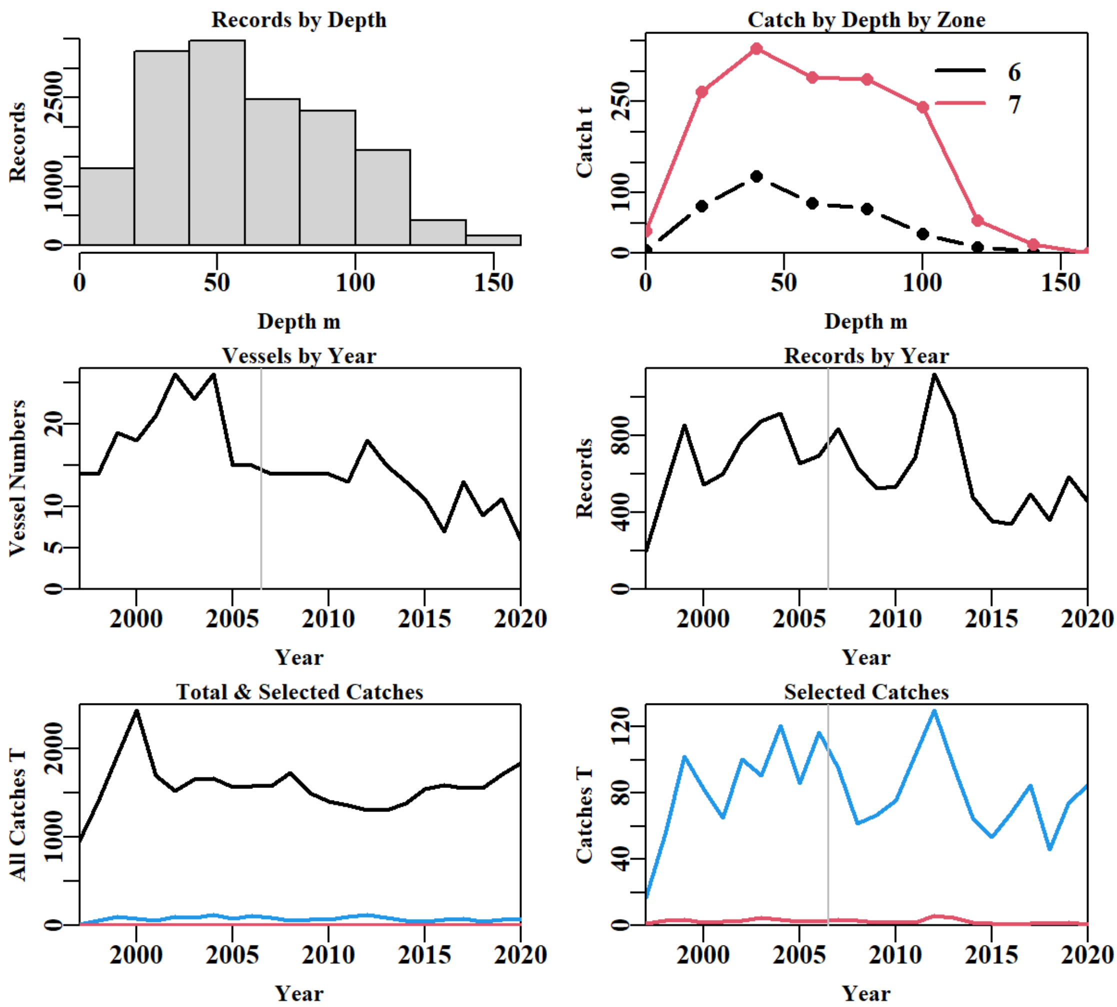

Figure 10.21. GummySharkTA fishery details. The bottom left plot depicts all known catches (top black line), and all selected catches used in the analysis (middle blue line); the lower red line: selected catches < 30 kg).

Table 10.13. 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	440781	0	38380.76	0
NoCE	425158	15623	38380.76	0
Depth	394618	30540	37204.21	1176.56
Years	383447	11171	36688.05	516.16
Zones	26014	357433	2396.96	34291.09
Method	14991	11023	1942.82	454.14
Fishery	14991	0	1942.82	0.00

Table 10.14. 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 10.15. 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

Term	AIC	RSS	MSS	Nobs	Npars	adj_r2	%Change
Year	7166	24102	876	14991	24	3.4	0
Vessel	1637	16475	8503	14991	111	33.6	30.19
DepCat	1604	16421	8557	14991	119	33.7	0.19
SharkRegion	1605	16421	8557	14991	120	33.7	0.00
Month	1243	16005	8973	14991	131	35.4	1.63
SharkRegion:DepCat	1197	15941	9037	14991	138	35.6	0.23
SharkRegion:Month	1185	15919	9059	14991	142	35.7	0.30

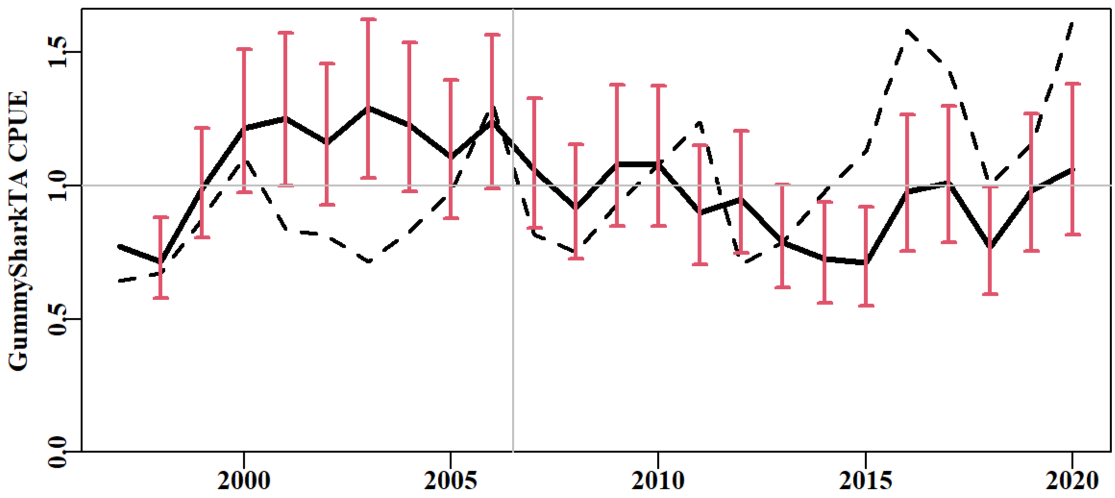

Figure 10.22. GummySharkTA standardization. The dashed black line represents the geometric mean catch rate, solid black line the standardized catch rates. The red bars are the 95% confidence intervals about the mean estimates. The graph scales both time-series of standardized catch rates relative to the mean of each time-series.

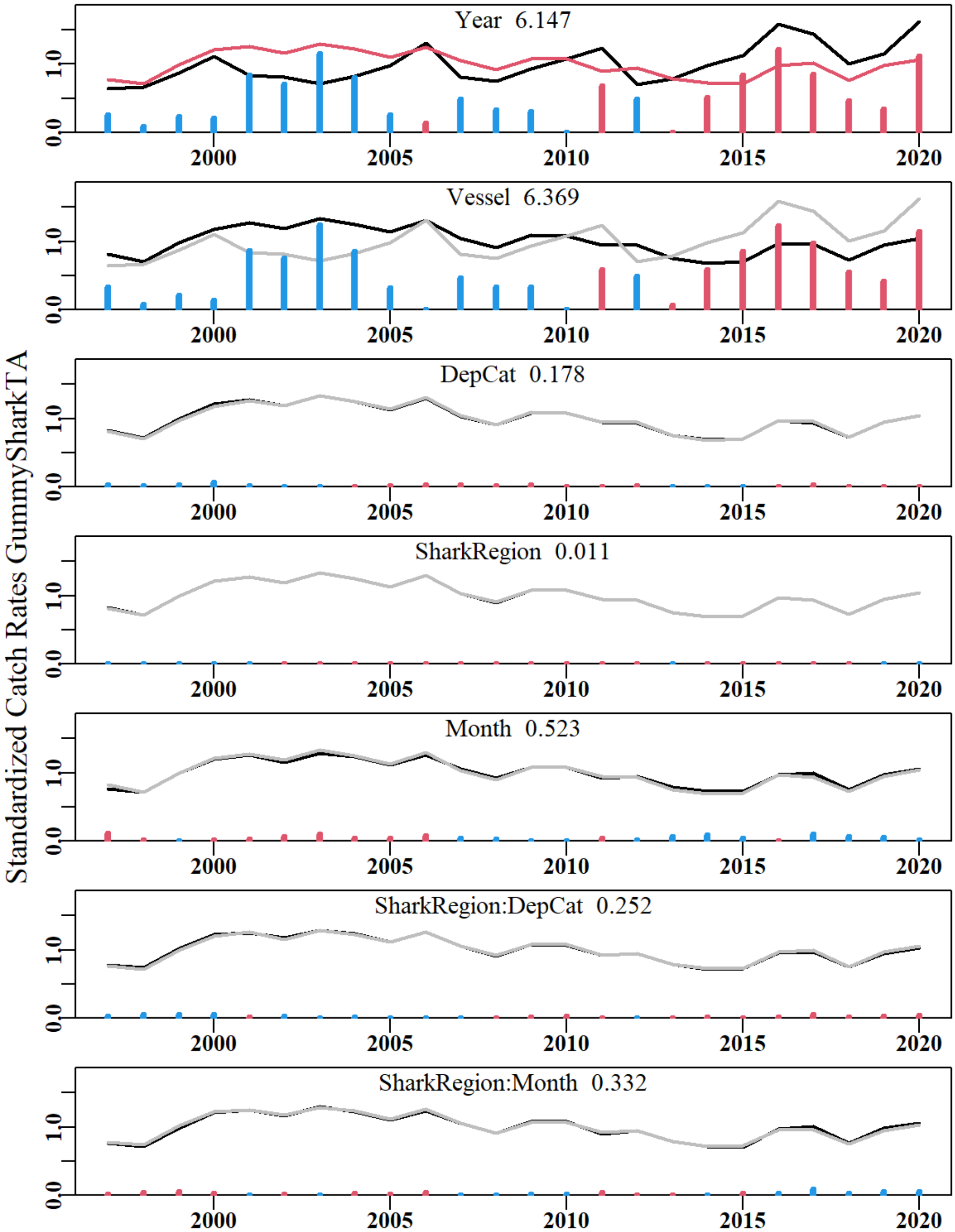

Figure 10.23. GummySharkTA. The influence of each factor on the optimal standardization. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by vertical bars with blue bars indicating the optimum model is higher than the geometric 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.

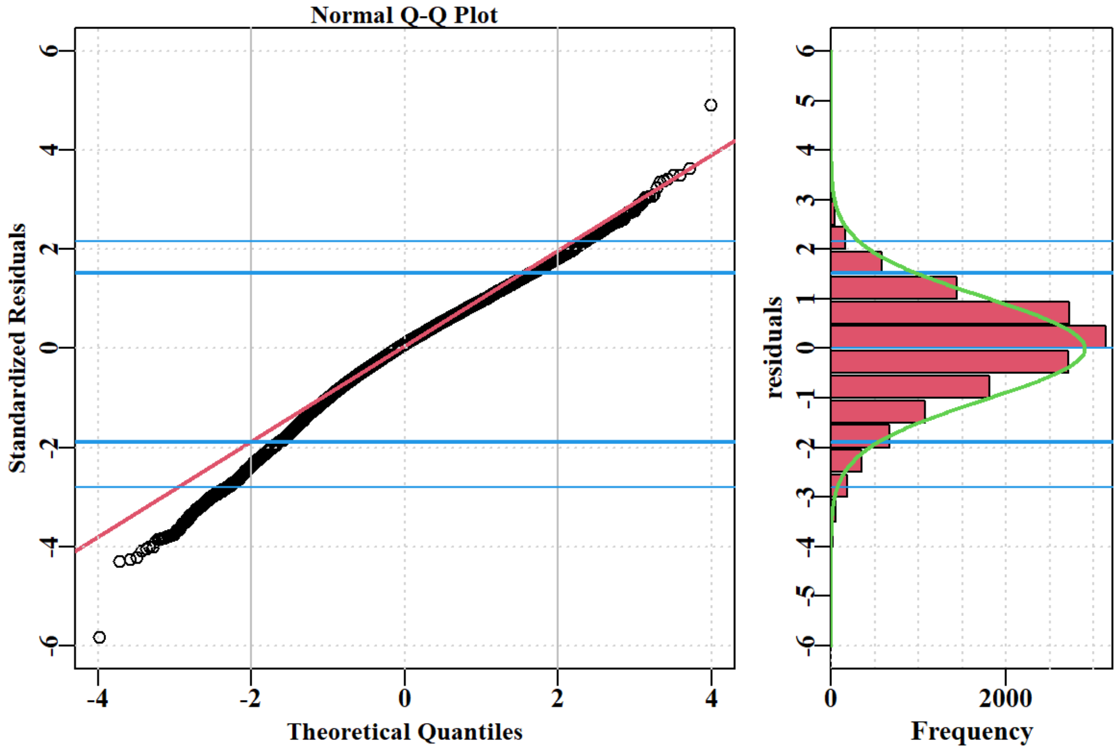

Figure 10.24. GummySharkTA. Diagnostic plots. The distribution of residuals from the optimum fit. The qqplot indicates the fit to the expected normality, while the histogram of residuals also illustrates the 1%, 5%, 95% and 99% quantiles to indicate the intensity of any lack of fit at the margins of the distribution (reflected also in the qqplot).

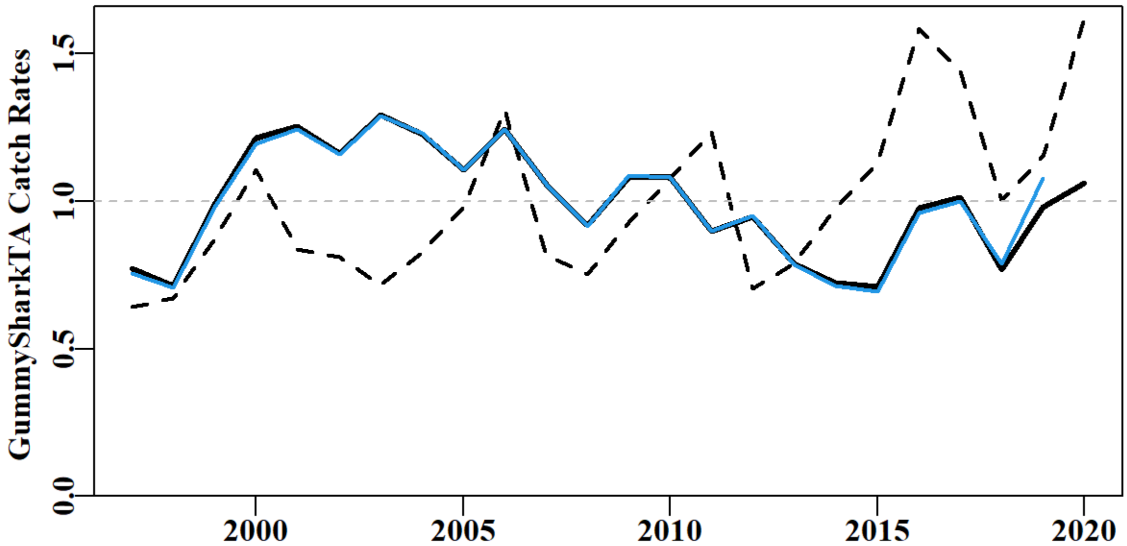

Figure 10.25. GummySharkTA. A comparison of the previous year's standardization (blue line) with this year's. They should lie on top of each other, although small deviations may relate to data adjustments, particularly in very recent years.

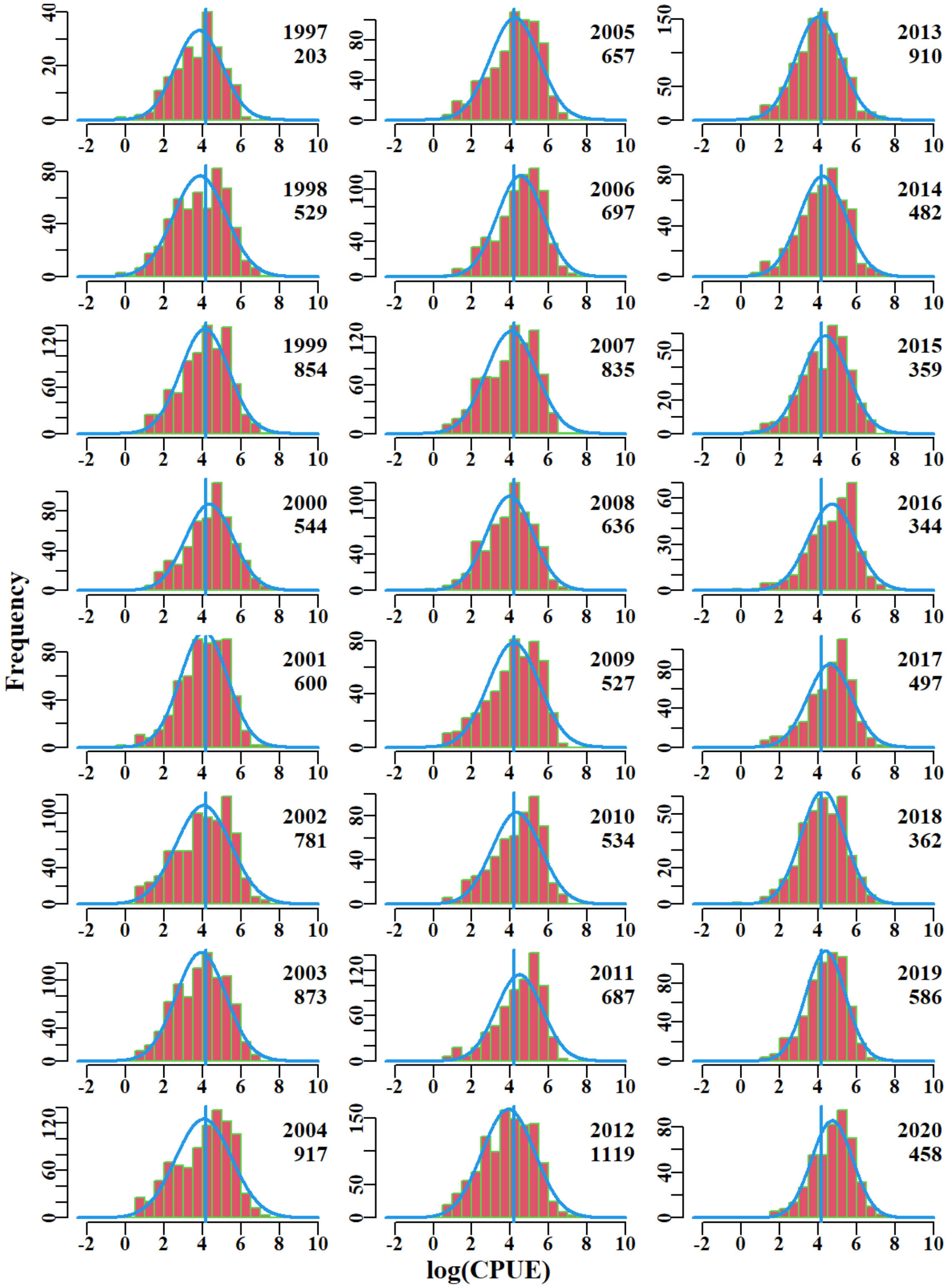

Figure 10.26. GummySharkTA. The natural log(CPUE) for each year of data available the blue lines are normal distributions fitted to the histogram frequencies. The numbers in each plot are the year and number of records. The vertical blue line is the average across all years.

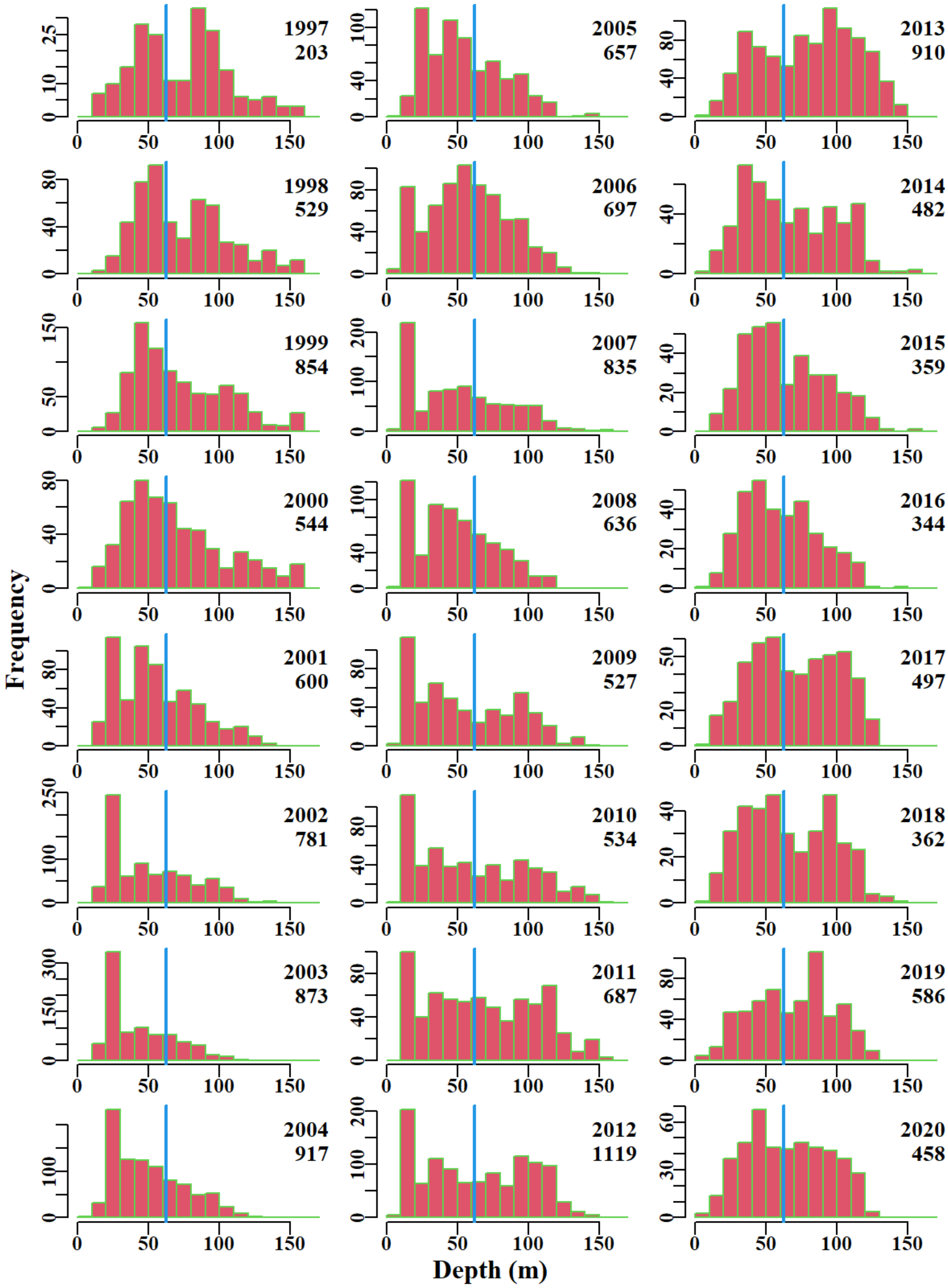

Figure 10.27. GummySharkTA. The average Depth of fishing for each year of data available to illustrate the development of the fishery through time. The numbers in each plot are the year and number of records. The vertical blue line is the average across all years.

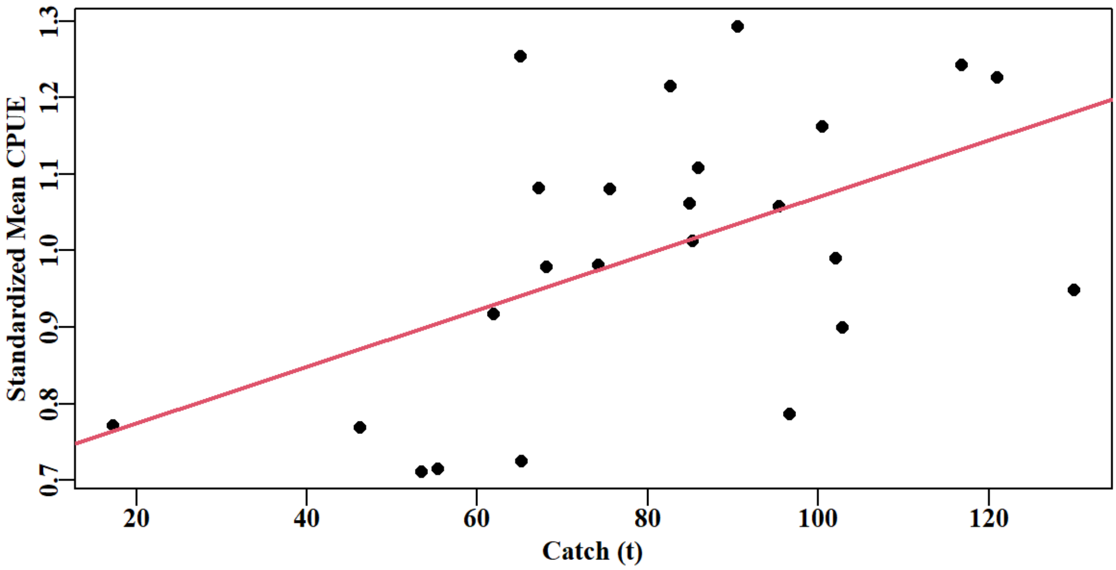

Figure 10.28. GummySharkTA. The linear relationship between annual mean CPUE and annual Catch.

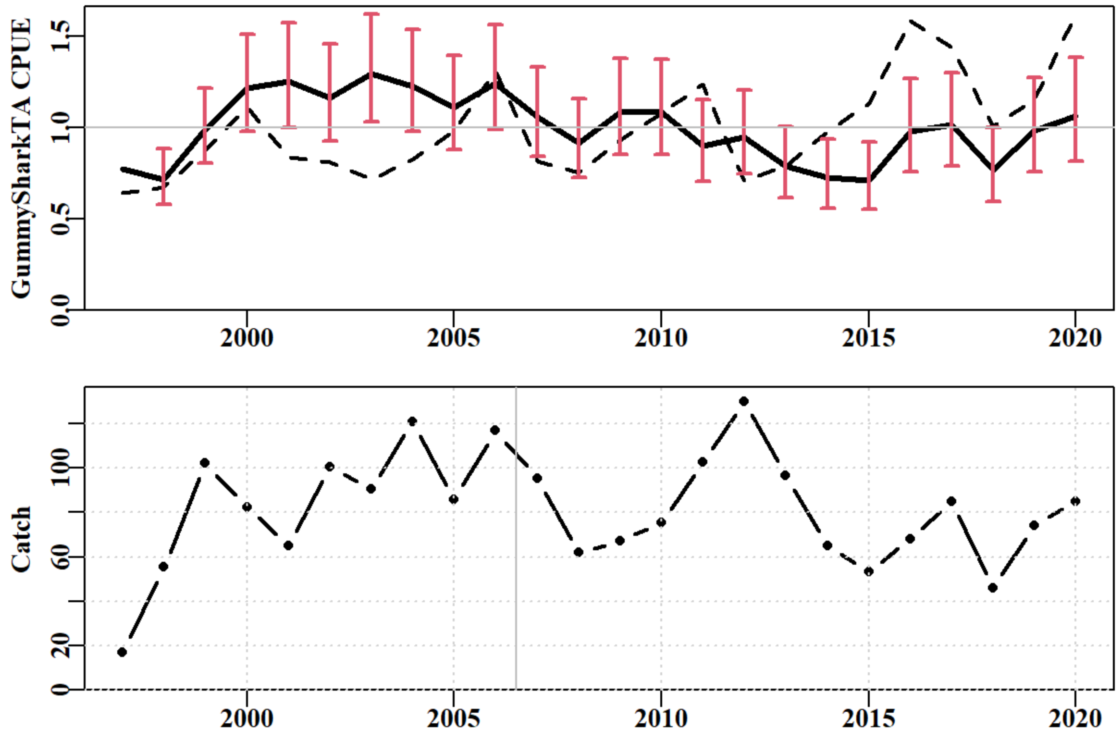

Figure 10.29. GummySharkTA. CPUE is correlated with catches through time. CPUE in the top plot and annual catch (t) in the lower plot.

10.7 Gummy shark: Gillnet South Australia – kg/m

Positive non-zero records of catch (kg) per netlength (m) were employed in the statistical standardization analyses for Gummy shark caught by gillnets from 1997 to 2020 inclusive.

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.

10.7.1 *Inferences*

Most catch occurred in Shark region 2, followed by 1, 9 and 3.

The terms Year, Vessel, Month, DepCat, SharkRegion and one interaction (SharkRegion:DepCat) had the greatest contribution to model fit based on the AIC and R^2 statistics (Table 10.19). The qqplot suggests a departure of the assumed Normal distribution, with slight deviations as depicted by the upper tail of the distribution (Figure 10.33). Overall, annual standardized CPUE using netlength (hereforth refer to as CPUN; black line) is similar in overall shape compared with catch-per-shot standardized CPUE (hereforth refer to as CPS; see earlier section). Also, CPUN (kg/m) indices are below the long-term average in five of the seven years since 2014 (i.e., 2014, 2015, 2018, 2019, 2020) and exhibits an apparent negative trend since 2016 (Figure 10.31).

Table 10.16. GummySharkSA_GN_ALL. The data selection criteria used to specify and identify the fishery data to be included in the analysis.

Property	Value
label	GummySharkSA_GN_ALL
csirocode	37017001
fishery	GHT_SEN_SSF_SSG_SSH
depthrange	0 - 160
depthclass	20
zones	1, 2, 3, 9
methods	GN, GNS
years	1997 - 2020

Table 10.17. GummySharkSA_GN_ALL. 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/m), 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

Year	Total	N	Catch	Vess	GeoM	Opt	StDev	C<30Kg	P<30Kg
1997	952.1	4310	386.2	52	0.030	1.1790	0.000	24.374	0.063
1998	1401.2	7351	520.2	53	0.023	0.9617	0.023	50.664	0.097
1999	1878.5	6491	608.9	49	0.032	1.1677	0.024	37.543	0.062
2000	2349.6	5344	797.0	37	0.059	1.7757	0.026	20.909	0.026
2001	1669.8	5150	383.6	35	0.030	0.9529	0.026	28.135	0.073
2002	1495.0	5388	406.0	32	0.029	0.9730	0.026	33.085	0.081
2003	1618.6	5538	462.9	37	0.032	0.9940	0.027	31.523	0.068
2004	1656.9	5597	472.5	40	0.032	1.0258	0.027	29.896	0.063
2005	1570.5	5109	482.4	29	0.030	1.0986	0.028	27.492	0.057
2006	1577.1	5968	548.7	28	0.028	1.0960	0.027	31.127	0.057
2007	1575.0	4550	438.5	29	0.033	1.1862	0.028	22.012	0.050
2008	1727.9	4907	543.5	23	0.035	1.3611	0.028	21.515	0.040
2009	1500.9	5157	418.2	23	0.029	1.1169	0.028	30.674	0.073
2010	1404.9	5259	389.8	28	0.025	0.9268	0.028	32.880	0.084
2011	1364.7	3273	229.0	19	0.023	0.7943	0.031	21.029	0.092
2012	1304.4	1371	83.0	15	0.019	0.6428	0.040	10.043	0.121
2013	1307.7	800	60.5	18	0.023	0.6875	0.048	5.370	0.089
2014	1389.1	1461	126.0	19	0.026	0.8249	0.041	7.559	0.060
2015	1545.1	1544	151.6	15	0.029	0.9172	0.041	7.796	0.051
2016	1586.5	1062	134.5	11	0.037	1.1503	0.048	3.783	0.028
2017	1561.4	898	110.2	13	0.031	1.0516	0.052	2.647	0.024
2018	1560.1	1365	141.4	12	0.023	0.7749	0.048	4.870	0.034
2019	1709.7	888	65.0	11	0.019	0.7424	0.059	4.854	0.075
2020	1840.5	796	63.5	9	0.019	0.5989	0.059	4.399	0.069

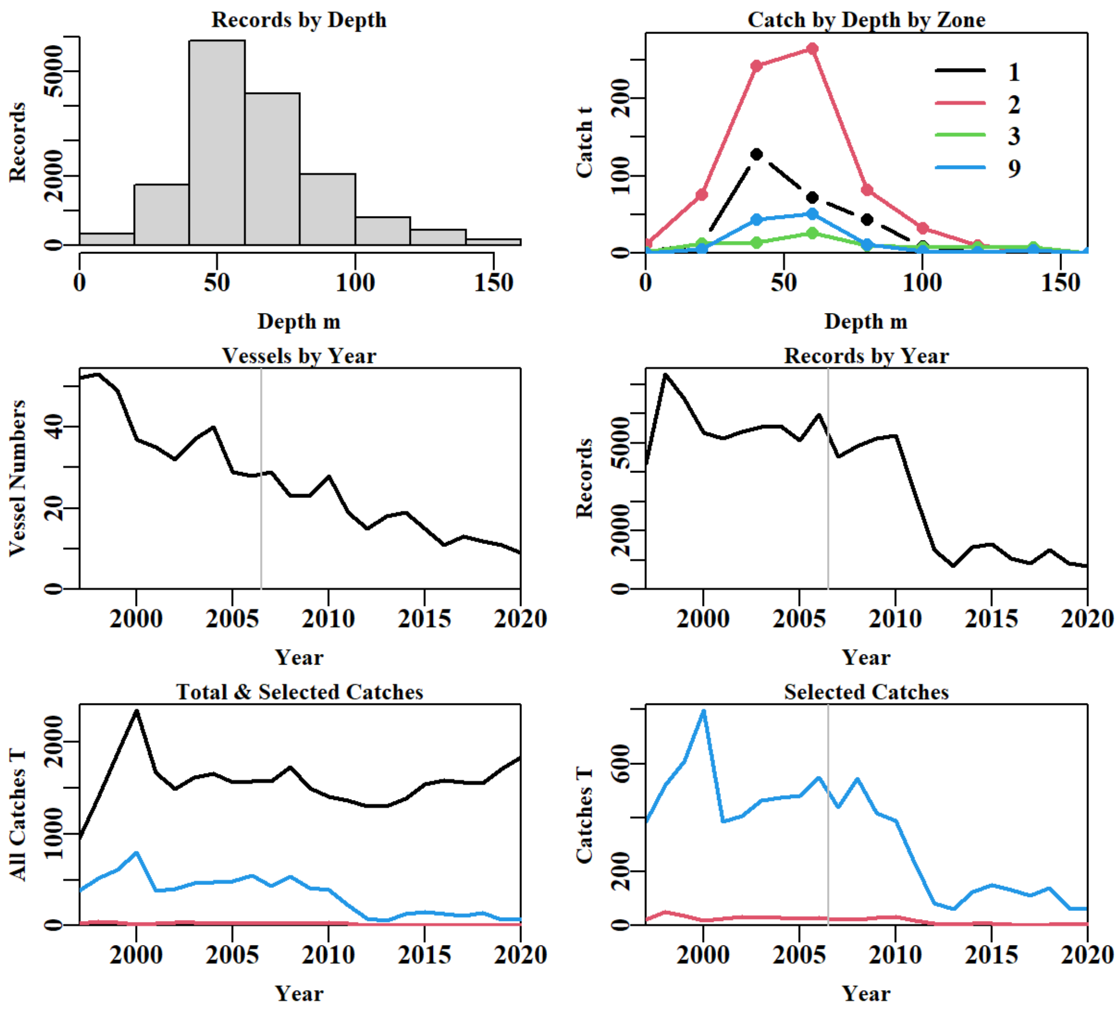

Figure 10.30. GummySharkSA_GN_ALL fishery details. The bottom left plot depicts all known catches (top black line), and all selected catches used in the analysis (middle blue line); the lower red line: selected catches < 30 kg).

Table 10.18. The models used to analyse data for GummySharkSA_GN_ALL

	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 10.19. GummySharkSA_GN_ALL. 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

Term	AIC	RSS	MSS	Nobs	Npars	adj_r2	%Change
Year	32038	127997	3277	89546	24	2.5	0
Vessel	26595	120074	11200	89546	163	8.4	5.89
DepCat	25594	118718	12556	89546	171	9.4	1.03
SharkRegion	25309	118333	12941	89546	174	9.7	0.29
Month	23907	116466	14808	89546	185	11.1	1.41
SharkRegion:DepCat	22693	114836	16438	89546	209	12.3	1.22
SharkRegion:Month	23458	115799	15475	89546	218	11.6	0.48

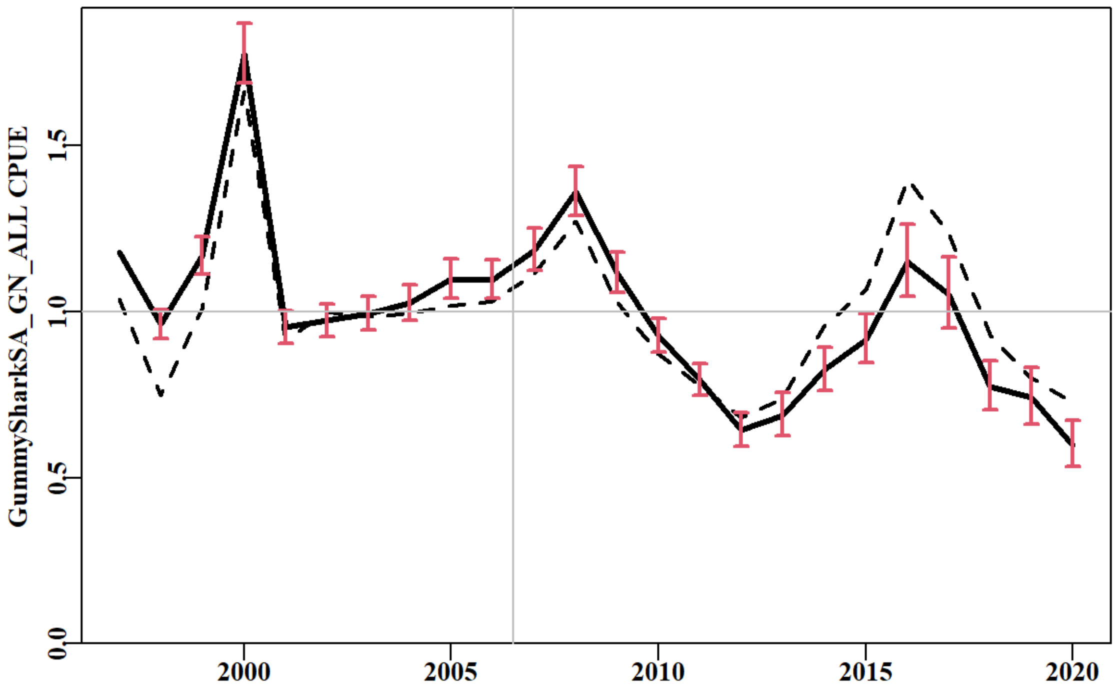

Figure 10.31. GummySharkSA_GN_ALL standardization. The dashed black line represents the geometric mean catch rate, solid black line the standardized catch rates. The red bars are the 95% confidence intervals about the mean estimates. The graph scales both time-series of standardized catch rates relative to the mean of each time-series.

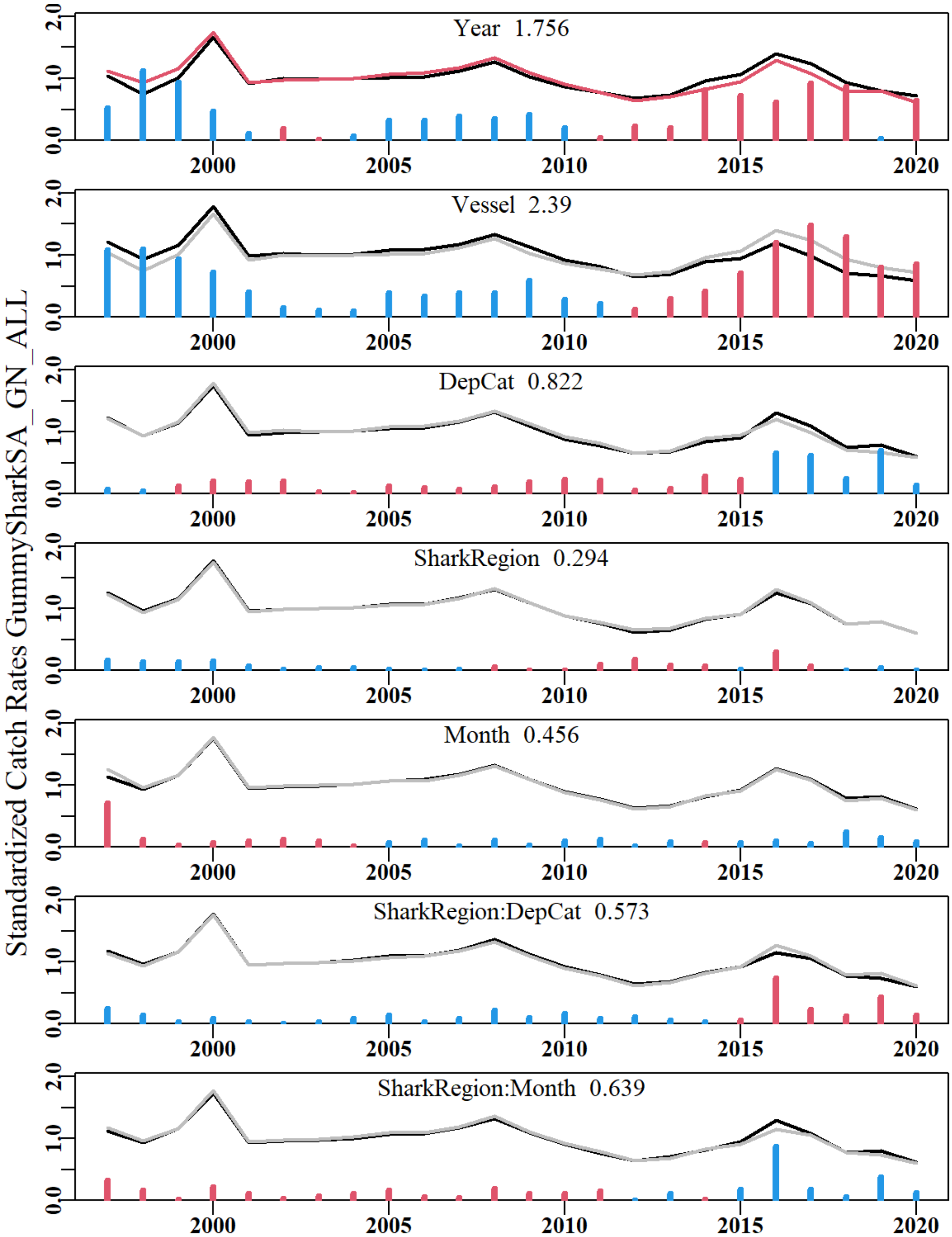

Figure 10.32. GummySharkSA_GN_ALL. The influence of each factor on the optimal standardization. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by vertical bars with blue bars indicating the optimum model is higher than 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.

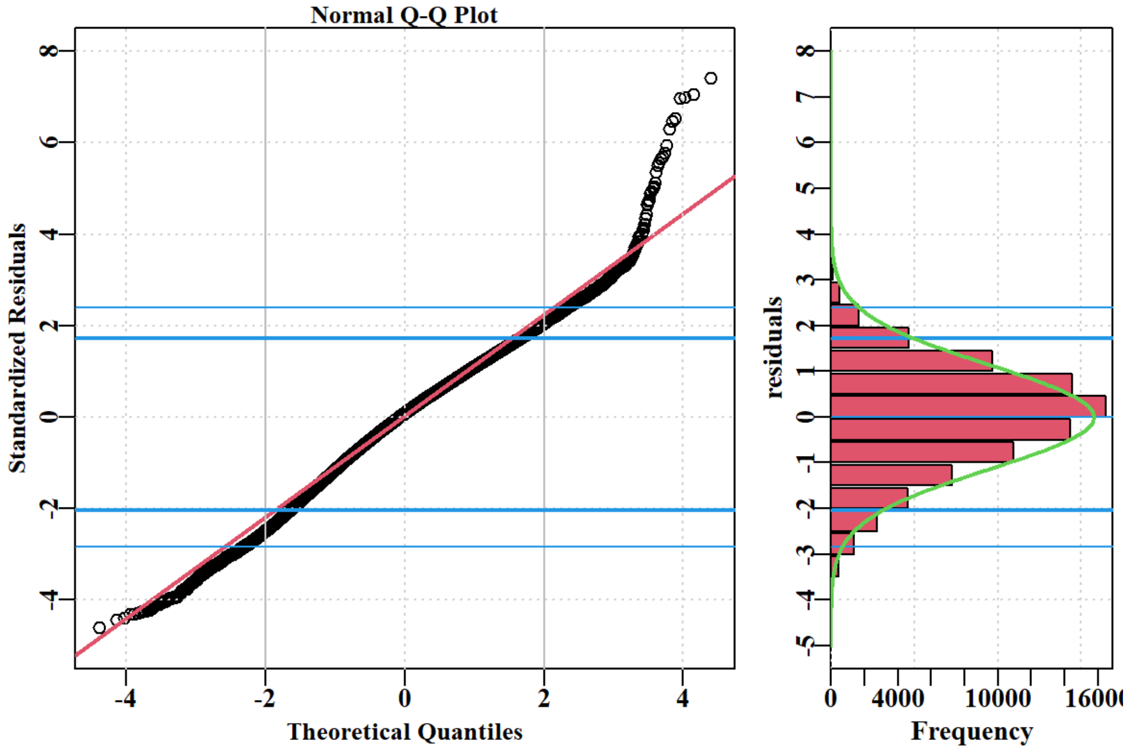

Figure 10.33. GummySharkSA_GN_ALL. Diagnostic plots. The distribution of residuals from the optimum fit. The qqplot indicates the fit to the expected normality, while the histogram of residuals also illustrates the 1%, 5%, 95% and 99% quantiles to indicate the intensity of any lack of fit at the margins of the distribution (reflected also in the qqplot).

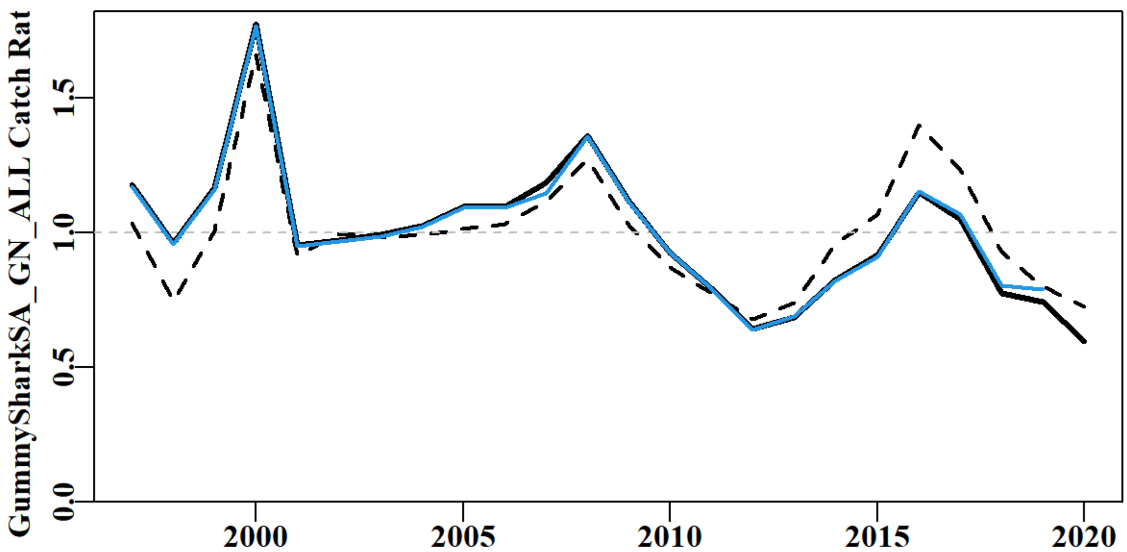

Figure 10.34. GummySharkSA_GN_ALL. A comparison of the previous year's standardization (blue line) with this year's. They should lie on top of each other, although small deviations may relate to data adjustments, particularly in very recent years.

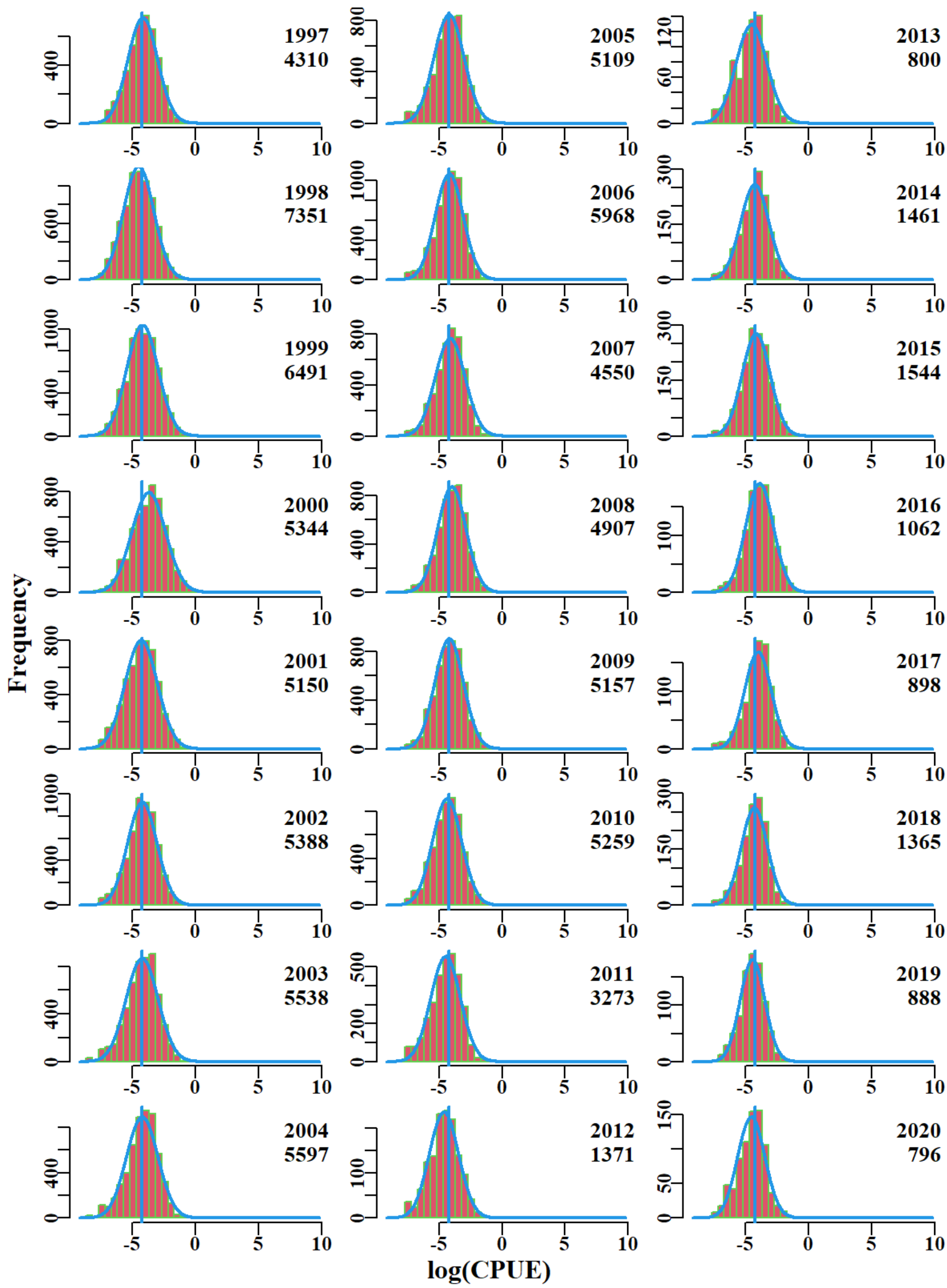

Figure 10.35. GummySharkSA_GN_ALL. The natural log(CPUE) for each year of data available the blue lines are normal distributions fitted to the histogram frequencies. The numbers in each plot are the year and number of records. The vertical blue line is the average across all years.

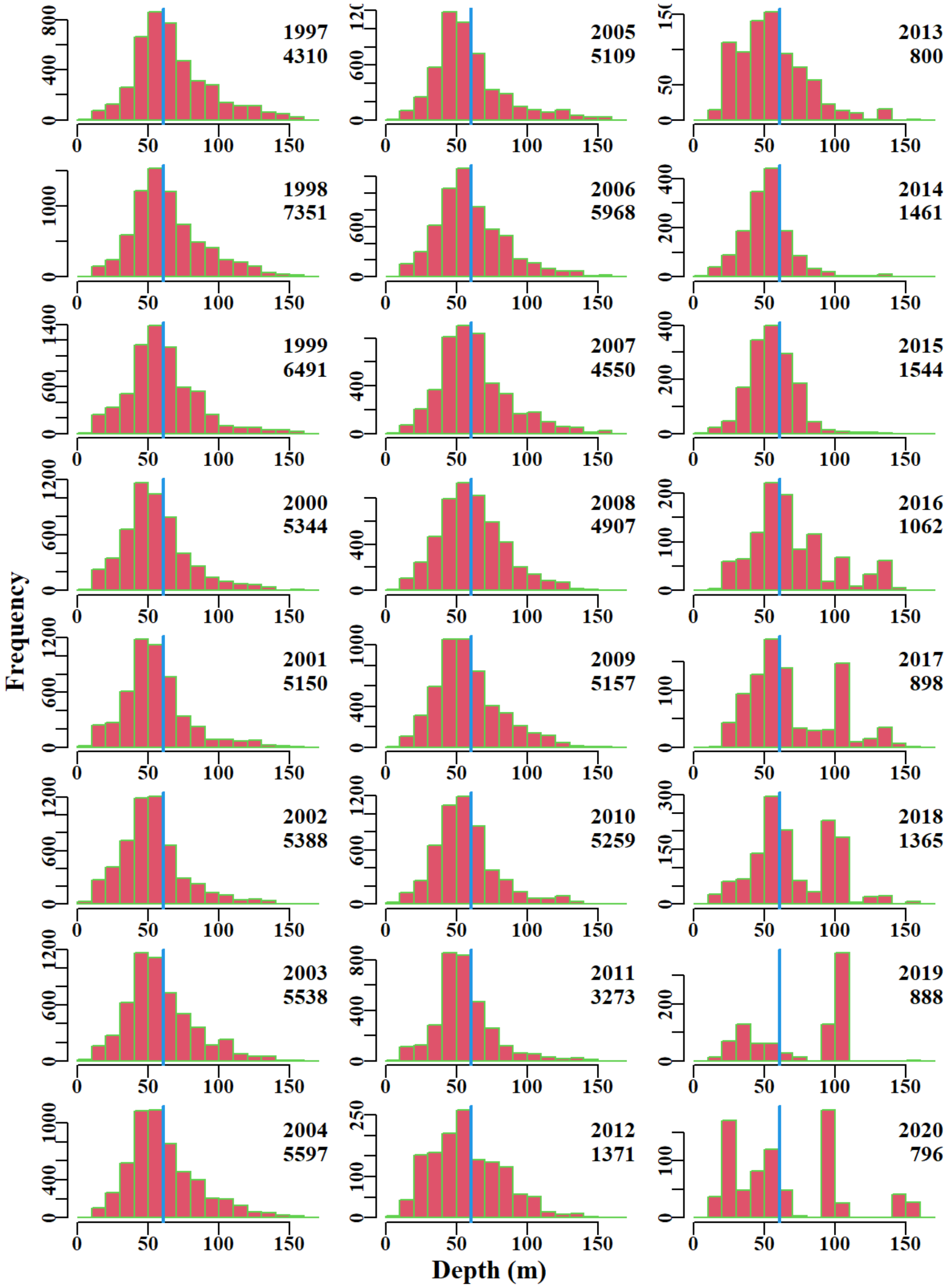

Figure 10.36. GummySharkSA_GN_ALL. The average Depth of fishing for each year of data available to illustrate the development of the fishery through time. The numbers in each plot are the year and number of records. The vertical blue line is the average across all years.

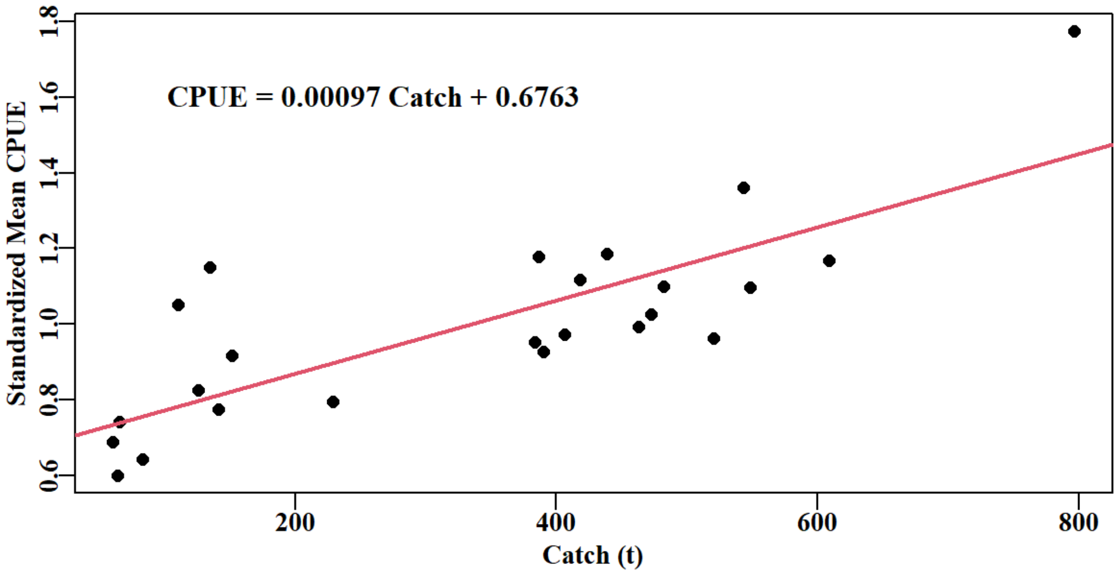

Figure 10.37. GummySharkSA_GN_ALL. The linear relationship between annual mean CPUE and annual Catch.

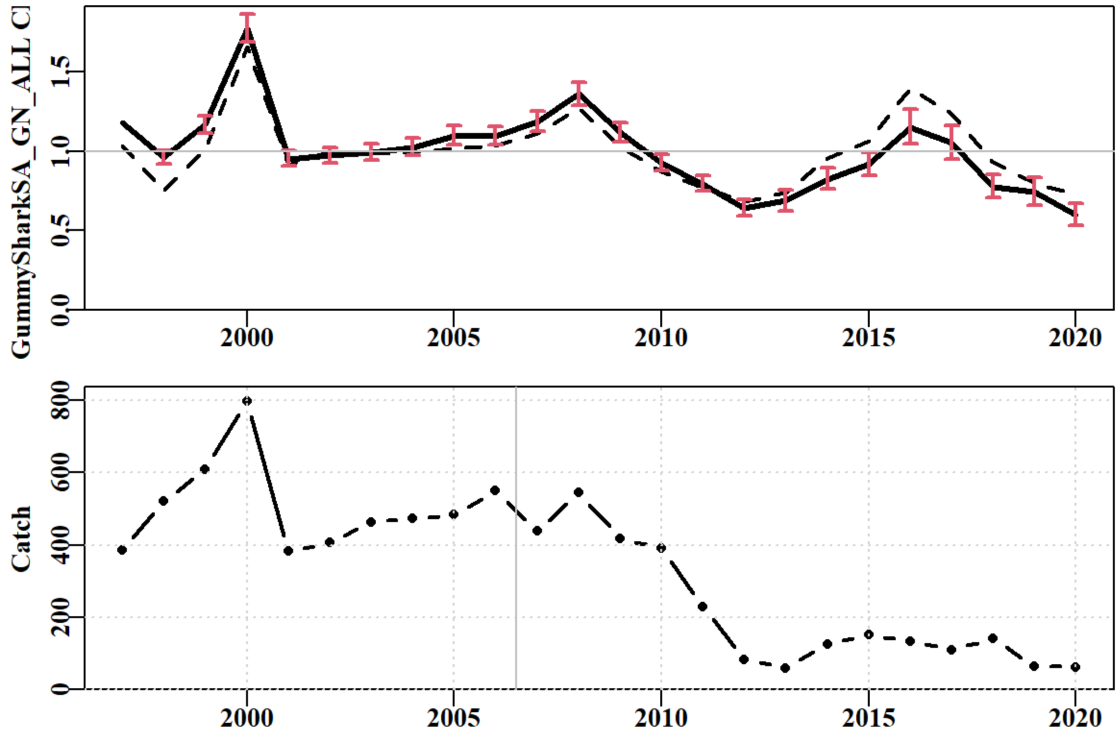

Figure 10.38. GummySharkSA_GN_ALL. CPUE is correlated with catches through time. CPUE in the top plot and annual catch (t) in the lower plot.

10.8 Gummy shark: Gillnet Bass Strait – kg/m

Positive non-zero records of catch (kg) per netlength (m) were employed in the statistical standardization analyses for Gummy shark caught by gillnets.

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.

10.8.1 *Inferences*

Most catch occurred in Shark region 5 followed by 4.

The terms Year, Vessel, DepCat, Month and one interaction (SharkRegion:Month) had the greatest contribution to model fit based on the AIC and R^2 statistics (Table 10.23). 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 by both tails of the distribution (Figure 10.42). Standardized CPUN is cyclical over the series, with the 2020 estimate reaching the long-term average (Figure 10.40).

Table 10.20. GummySharkBS_ALL. The data selection criteria used to specify and identify the fishery data to be included in the analysis.

Property	Value
label	GummySharkBS_ALL
csirocode	37017001
fishery	GHT_SEN_SSF_SSG_SSH
depthrange	0 - 160
depthclass	20
zones	4, 5
methods	GN, GNS
years	1997 - 2020

Table 10.21. GummySharkBS_ALL. 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/m), 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

Year	Total	N	Catch	Vess	GeoM	Opt	StDev	C<30Kg	P<30Kg
1997	952.1	4009	389.8	49	0.029	0.7409	0.000	21.177	0.054
1998	1401.2	5935	704.4	51	0.037	0.8787	0.025	26.555	0.038
1999	1878.5	6616	1025.8	57	0.052	1.1604	0.025	24.771	0.024
2000	2349.6	6870	1253.2	49	0.058	1.2251	0.025	22.361	0.018
2001	1669.8	6310	1050.6	47	0.055	1.0744	0.025	20.440	0.019
2002	1495.0	6299	833.8	47	0.042	0.8495	0.026	24.050	0.029
2003	1618.6	6626	883.4	44	0.043	0.8444	0.025	25.951	0.029
2004	1656.9	6278	879.2	41	0.043	0.8952	0.026	21.080	0.024
2005	1570.5	5273	810.8	38	0.044	0.9933	0.027	15.256	0.019
2006	1577.1	4064	727.6	33	0.052	1.1328	0.028	10.785	0.015
2007	1575.0	3479	873.9	25	0.071	1.3755	0.029	7.472	0.009
2008	1727.9	3672	954.7	26	0.074	1.4871	0.029	7.287	0.008
2009	1500.9	4089	831.5	28	0.057	1.2700	0.028	9.391	0.011
2010	1404.9	4408	738.0	31	0.047	1.0264	0.028	13.268	0.018
2011	1364.7	5166	797.2	32	0.042	0.9336	0.027	18.833	0.024
2012	1304.4	5442	780.2	37	0.038	0.8692	0.027	19.117	0.025
2013	1307.7	5273	746.6	36	0.035	0.7713	0.027	20.650	0.028
2014	1389.1	4990	766.4	36	0.037	0.7988	0.027	17.257	0.023
2015	1545.1	4770	940.6	30	0.049	0.9821	0.028	12.894	0.014
2016	1586.5	5055	1086.9	31	0.053	1.0865	0.027	12.938	0.012
2017	1561.4	5801	937.5	30	0.041	0.8535	0.027	17.749	0.019
2018	1560.1	5111	785.7	31	0.034	0.7962	0.027	16.337	0.021
2019	1709.7	4931	899.9	33	0.039	0.9156	0.028	12.436	0.014
2020	1840.5	4716	990.5	26	0.046	1.0393	0.029	10.635	0.011

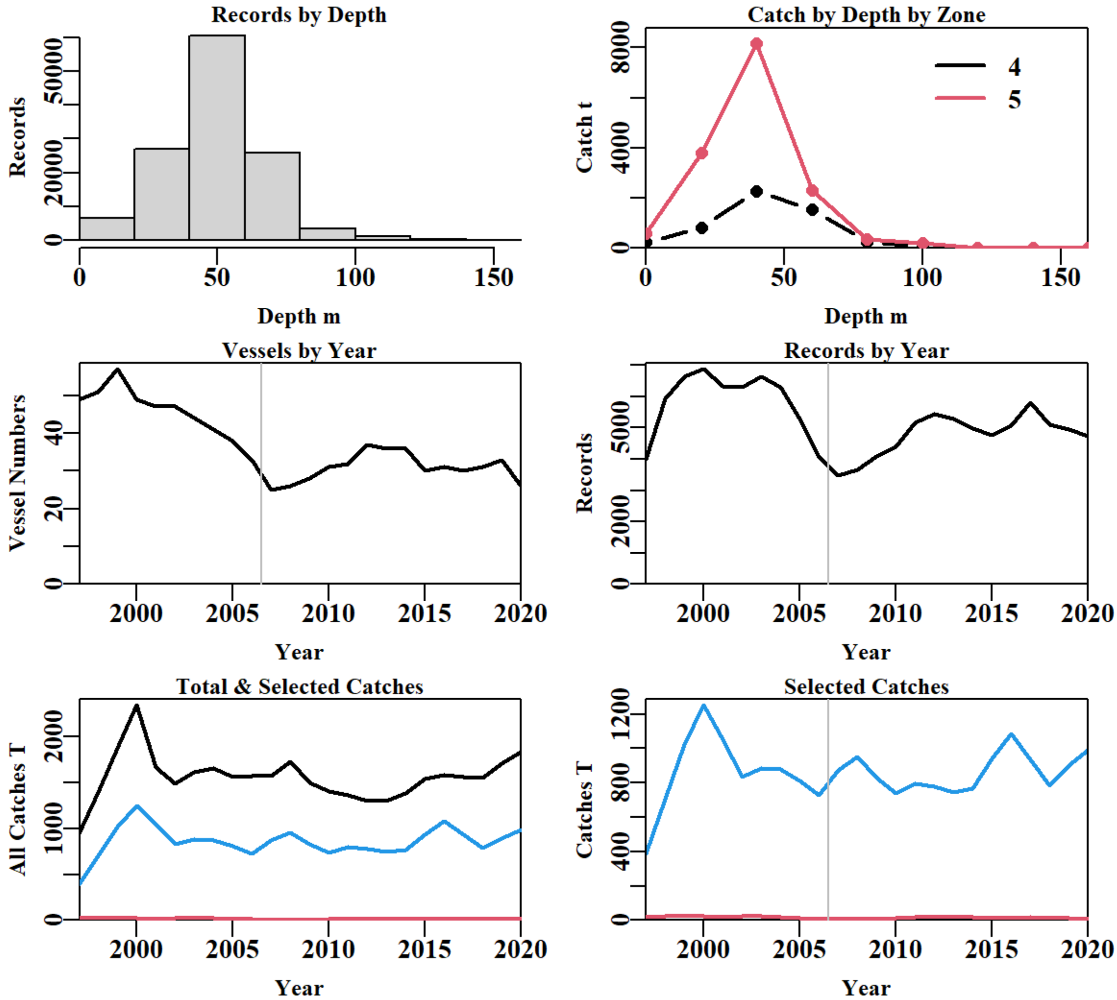

Figure 10.39. GummySharkBS_ALL fishery details. The bottom left plot depicts all known catches (top black line), and all selected catches used in the analysis (middle blue line); the lower red line: selected catches < 30 kg).

Table 10.22. The models used to analyse data for GummySharkBS_ALL

	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 10.23. GummySharkBS_ALL. 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

Term	AIC	RSS	MSS	Nobs	Npars	adj_r2	%Change
Year	46107	180857	4501	125183	24	2.4	0
Vessel	39423	171114	14243	125183	148	7.6	5.17
DepCat	38609	169985	15373	125183	156	8.2	0.60
SharkRegion	38605	169976	15382	125183	157	8.2	0.00
Month	37784	168836	16522	125183	168	8.8	0.61
SharkRegion:DepCat	37714	168721	16636	125183	175	8.8	0.06
SharkRegion:Month	37484	168401	16957	125183	179	9.0	0.23

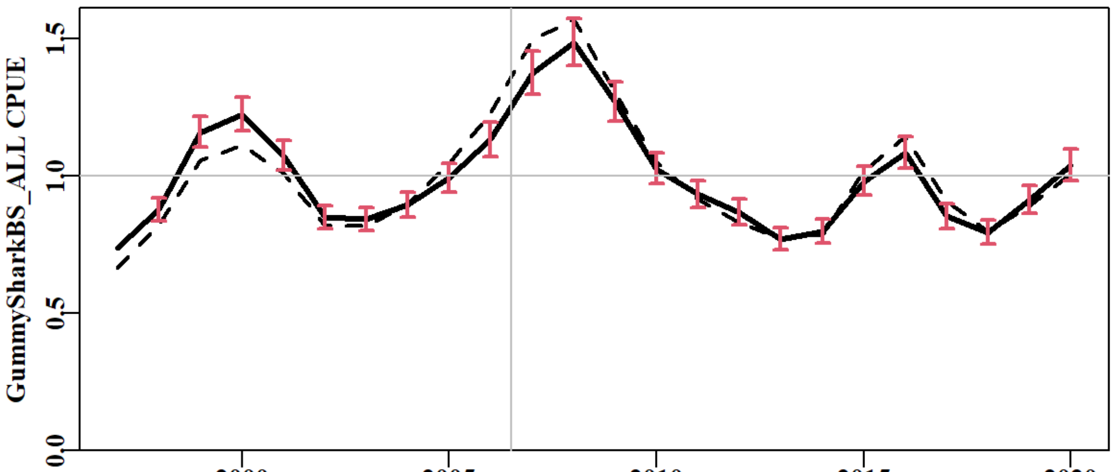

Figure 10.40. GummySharkBS_ALL standardization. The dashed black line represents the geometric mean catch rate, solid black line the standardized catch rates. The red bars are the 95% confidence intervals about the mean estimates. The graph scales both time-series of standardized catch rates relative to the mean of each time-series.

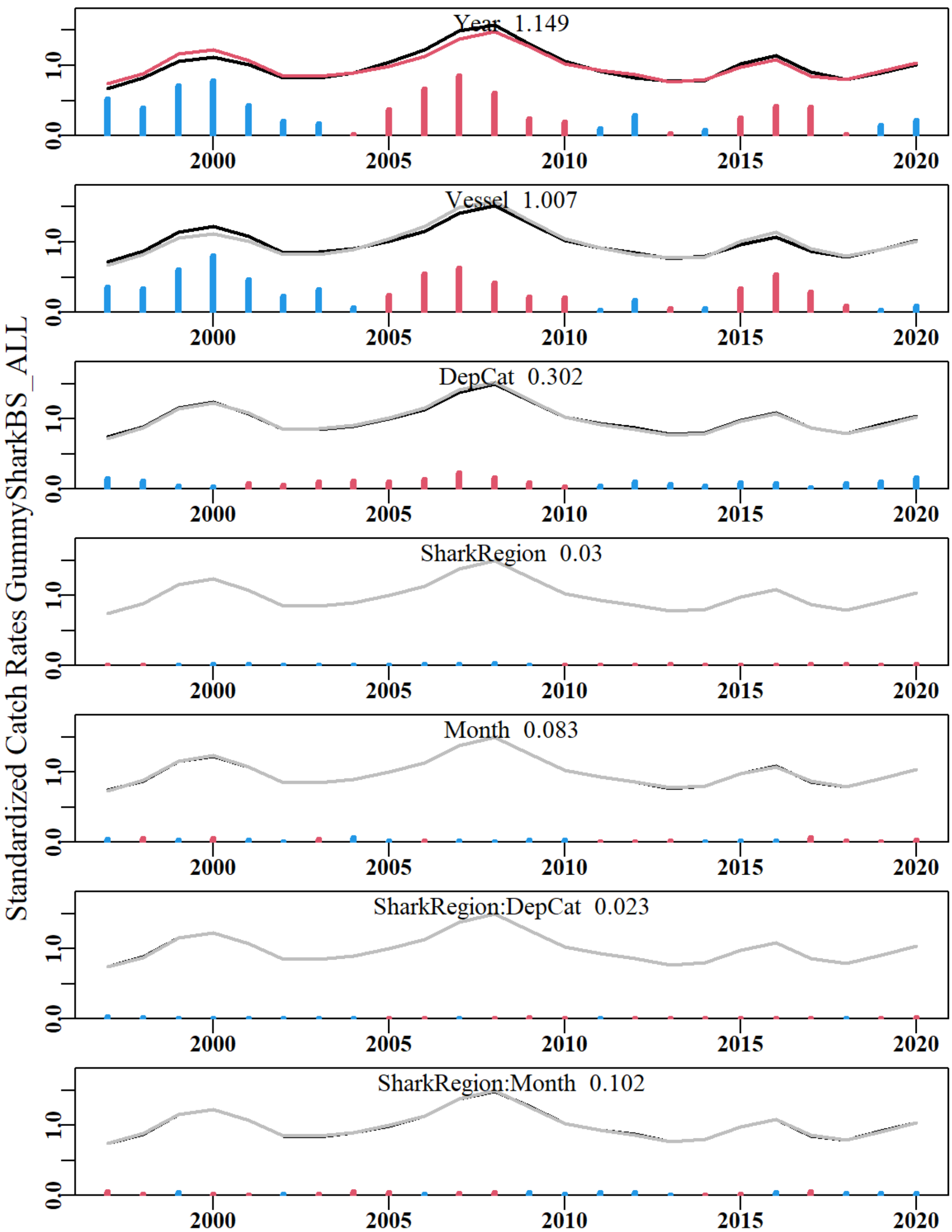

Figure 10.41. GummySharkBS_ALL. The influence of each factor on the optimal standardization. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by vertical bars with blue bars indicating the optimum model is higher than the 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.

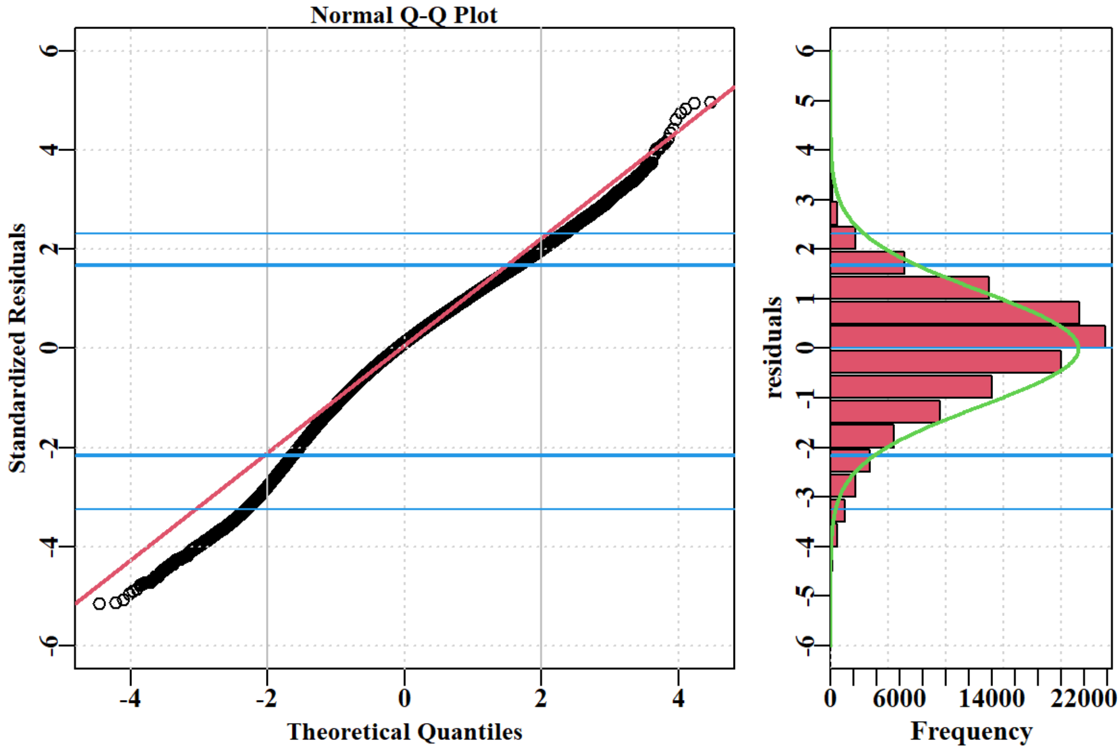

Figure 10.42. GummySharkBS_ALL. Diagnostic plots. The distribution of residuals from the optimum fit. The qqplot indicates the fit to the expected normality, while the histogram of residuals also illustrates the 1%, 5%, 95% and 99% quantiles to indicate the intensity of any lack of fit at the margins of the distribution (reflected also in the qqplot).

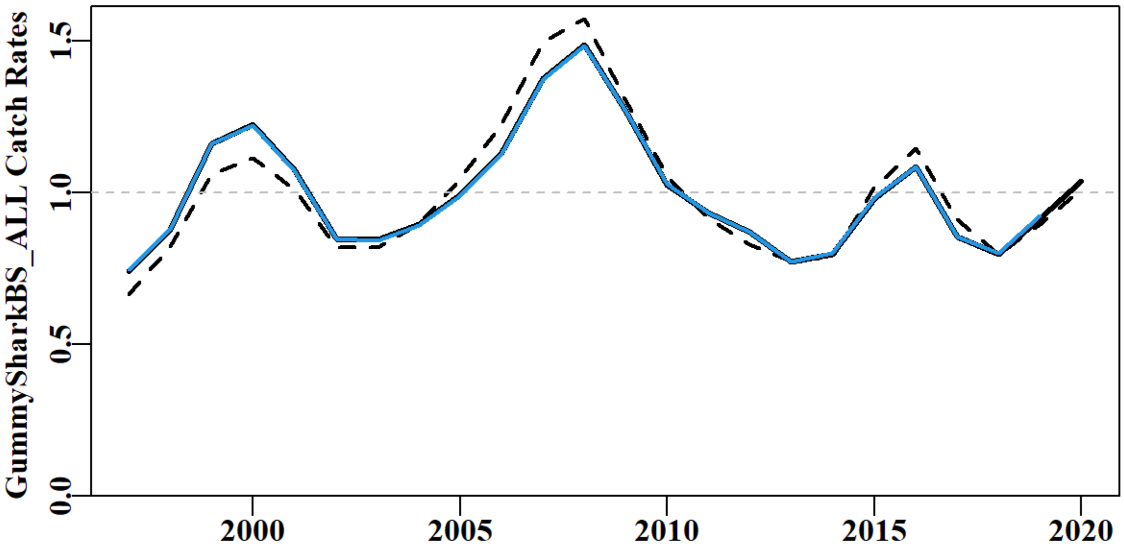

Figure 10.43. GummySharkBS_ALL. A comparison of the previous year's standardization (blue line) with this year's. They should lie on top of each other, although small deviations may relate to data adjustments, particularly in very recent years.

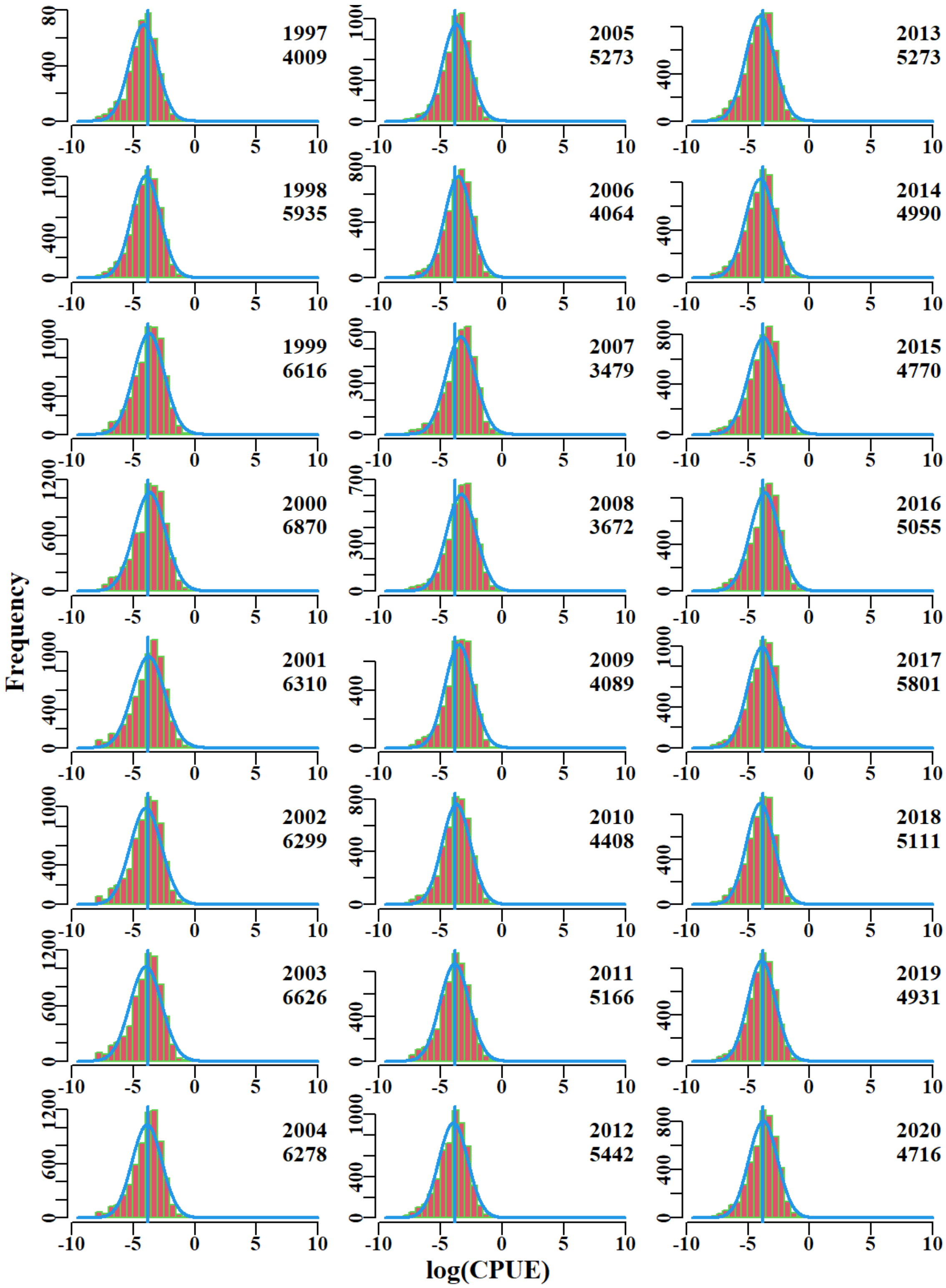

Figure 10.44. GummySharkBS_ALL. The natural log(CPUE) for each year of data available the blue lines are normal distributions fitted to the histogram frequencies. The numbers in each plot are the year and number of records. The vertical blue line is the average across all years.

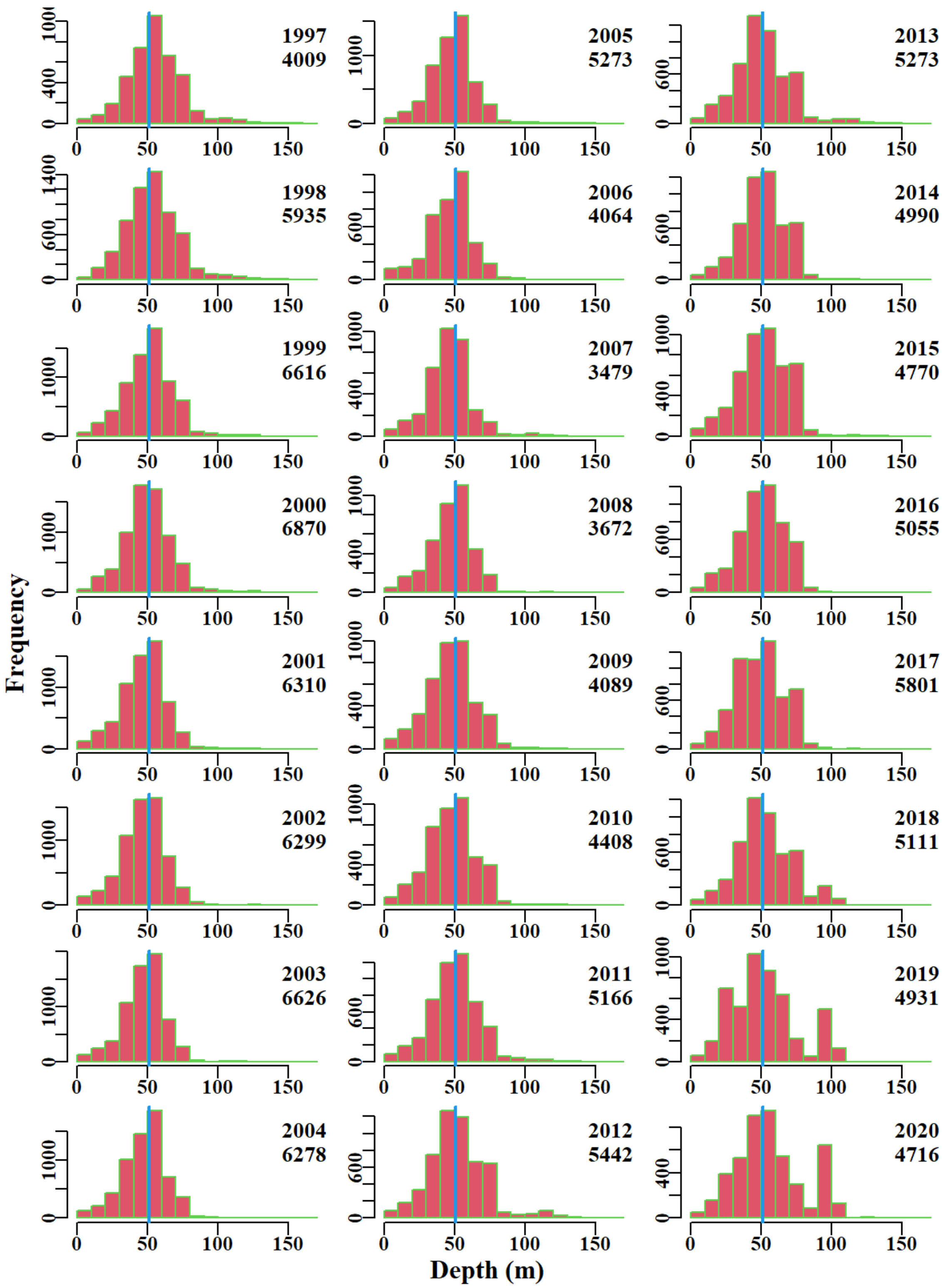

Figure 10.45. GummySharkBS_ALL. The average Depth of fishing for each year of data available to illustrate the development of the fishery through time. The numbers in each plot are the year and number of records. The vertical blue line is the average across all years.

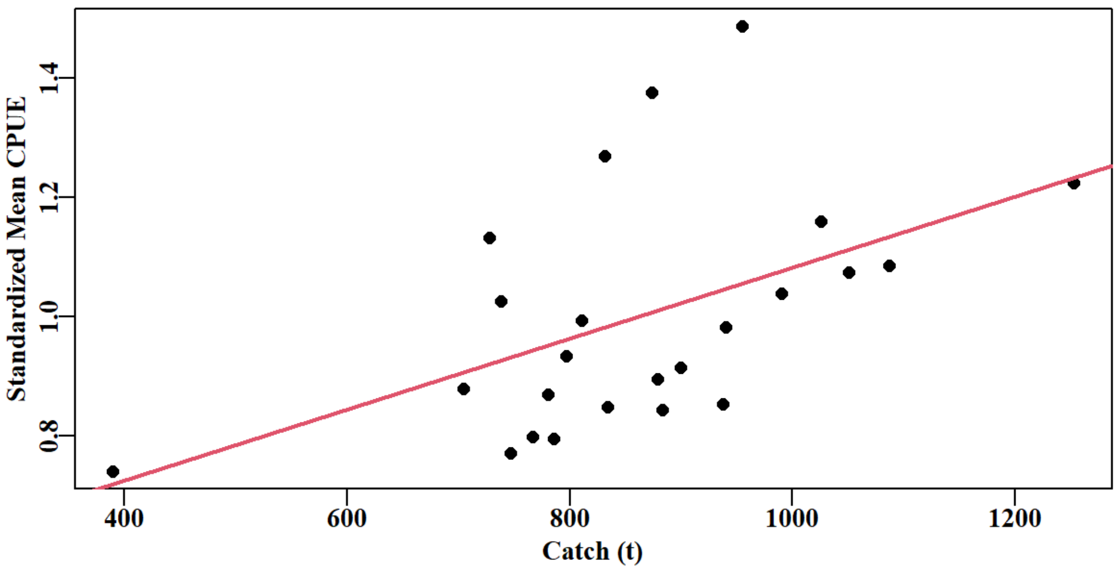

Figure 10.46. GummySharkBS_ALL. The linear relationship between annual mean CPUE and annual Catch.

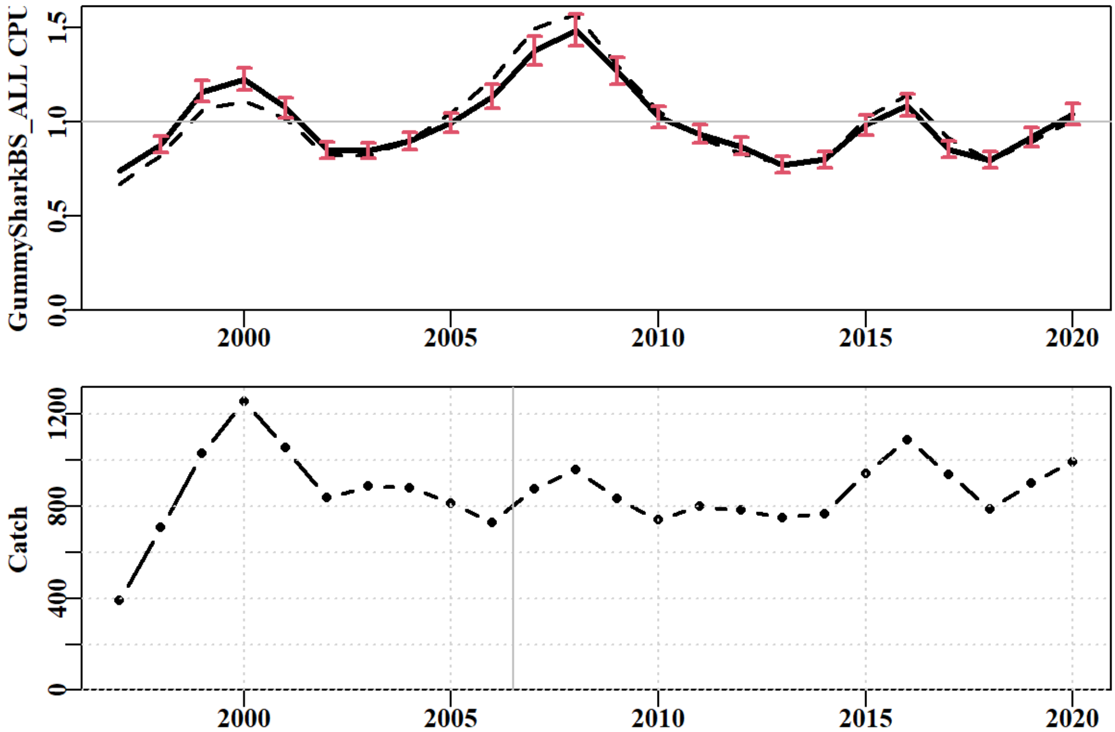

Figure 10.47. GummySharkBS_ALL. CPUE is correlated with catches through time. CPUE in the top plot and annual catch (t) in the lower plot.

10.9 Gummy shark: Gillnet Tasmania – kg/m

Positive non-zero records of catch (kg) per netlength (m) were employed in the statistical standardization analyses for Gummy shark caught by gillnets.

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.

10.9.1 *Inferences*

Most catch occurred in Shark region 7 followed by 6.

The terms Year, Vessel, DepCat, Month and one interaction (SharkRegion:Month) had the greatest contribution to model fit based on the AIC and R^2 statistics (Table 10.27). 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 by the lower tail of the distribution (Figure 10.51).

Standardized CPUN (i.e., catch-per-unit-netlength; kg/m) has been mostly flat between 1999 - 2012 and below the long-term average between 2013-2015 and in 2018 (Figure 10.49). Overall, annual standardized CPUN (black line) shows a similar overall shape to standardized CPS (i.e., catch-per-shot CPS; see earlier section).

Table 10.24. GummySharkTA_ALL. The data selection criteria used to specify and identify the fishery data to be included in the analysis.

Property	Value
label	GummySharkTA_ALL
csirocode	37017001
fishery	GHT_SEN_SSF_SSG_SSH
depthrange	0 - 160
depthclass	20
zones	6, 7
methods	GN, GNS
years	1997 - 2020

Table 10.25. GummySharkTA_ALL. 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/m), 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

Year	Total	N	Catch	Vess	GeoM	Opt	StDev	C<30Kg	P<30Kg
1997	952.1	191	16.0	13	0.025	0.8581	0.000	1.231	0.077
1998	1401.2	526	54.9	14	0.040	0.7863	0.108	3.061	0.056
1999	1878.5	794	97.1	19	0.047	1.0960	0.106	3.492	0.036
2000	2349.6	512	79.3	18	0.059	1.3343	0.114	1.759	0.022
2001	1669.8	573	63.3	21	0.050	1.3591	0.118	2.565	0.041
2002	1495.0	778	99.9	26	0.055	1.2063	0.117	3.377	0.034
2003	1618.6	812	89.1	23	0.042	1.4282	0.118	4.030	0.045
2004	1656.9	917	120.9	26	0.054	1.3574	0.116	3.893	0.032
2005	1570.5	656	85.3	15	0.046	1.1284	0.119	2.646	0.031
2006	1577.1	697	116.8	15	0.055	1.2663	0.119	2.334	0.020
2007	1575.0	835	95.3	14	0.036	1.0548	0.118	4.041	0.042
2008	1727.9	636	61.9	14	0.031	0.9073	0.120	3.464	0.056
2009	1500.9	527	67.2	14	0.042	1.0834	0.125	2.199	0.033
2010	1404.9	534	75.5	14	0.042	1.0601	0.124	2.089	0.028
2011	1364.7	687	102.7	13	0.044	0.8886	0.127	2.212	0.022
2012	1304.4	1119	130.0	18	0.034	0.9325	0.123	5.852	0.045
2013	1307.7	907	96.4	14	0.027	0.7012	0.126	4.794	0.050
2014	1389.1	482	65.1	13	0.034	0.6373	0.133	2.146	0.033
2015	1545.1	359	53.4	11	0.039	0.6279	0.133	1.439	0.027
2016	1586.5	344	68.1	7	0.057	0.9036	0.133	0.952	0.014
2017	1561.4	497	85.1	13	0.048	0.9352	0.129	1.258	0.015
2018	1560.1	362	46.2	9	0.031	0.6885	0.134	1.714	0.037
2019	1709.7	586	74.2	11	0.034	0.8439	0.134	1.839	0.025
2020	1840.5	461	85.0	7	0.047	0.9153	0.136	1.061	0.012

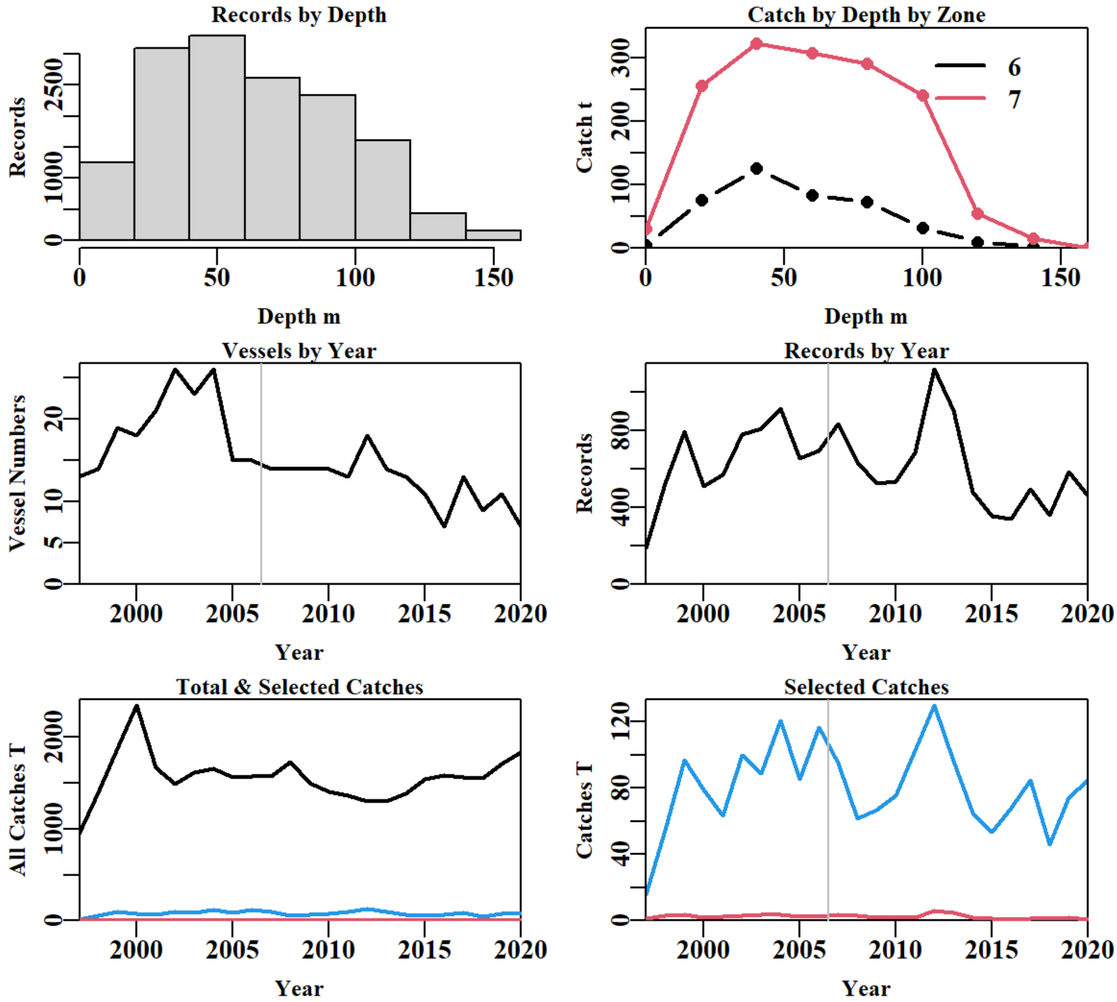

Figure 10.48. GummySharkTA_ALL fishery details. The bottom left plot depicts all known catches (top black line), and all selected catches used in the analysis (middle blue line); the lower red line: selected catches < 30 kg).

Table 10.26. The models used to analyse data for GummySharkTA_ALL

	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 10.27. GummySharkTA_ALL. 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

Term	AIC	RSS	MSS	Nobs	Npars	adj_r2	%Change
Year	5578	21498	597	14792	24	2.6	0
Vessel	1704	16353	5742	14792	110	25.4	22.89
DepCat	1674	16302	5793	14792	118	25.6	0.19
SharkRegion	1675	16302	5794	14792	119	25.6	0.00
Month	1327	15898	6197	14792	130	27.4	1.79
SharkRegion:DepCat	1277	15830	6265	14792	137	27.7	0.28
SharkRegion:Month	1267	15811	6284	14792	141	27.8	0.35

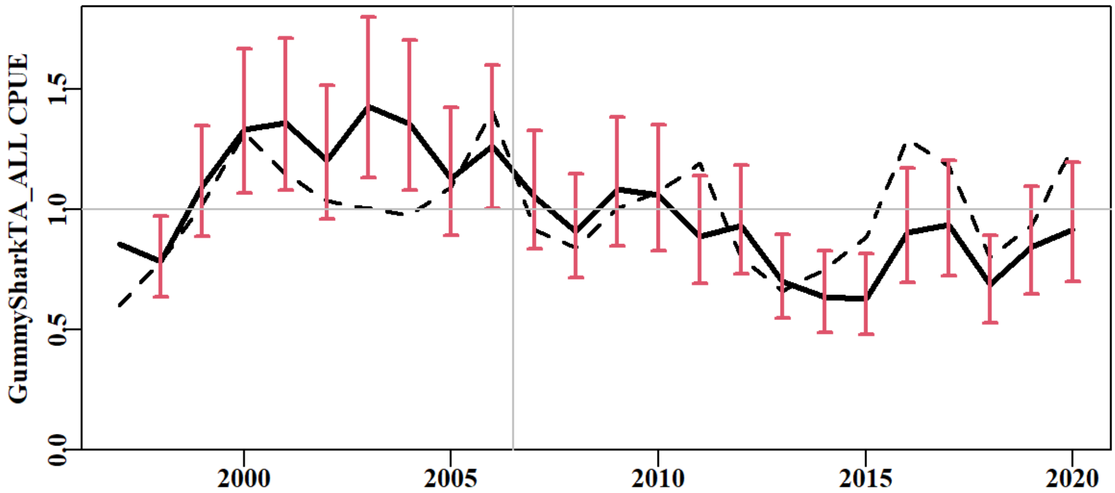

Figure 10.49. GummySharkTA_ALL standardization. The dashed black line represents the geometric mean catch rate, solid black line the standardized catch rates. The red bars are the 95% confidence intervals about the mean estimates. The graph scales both time-series of standardized catch rates relative to the mean of each time-series.

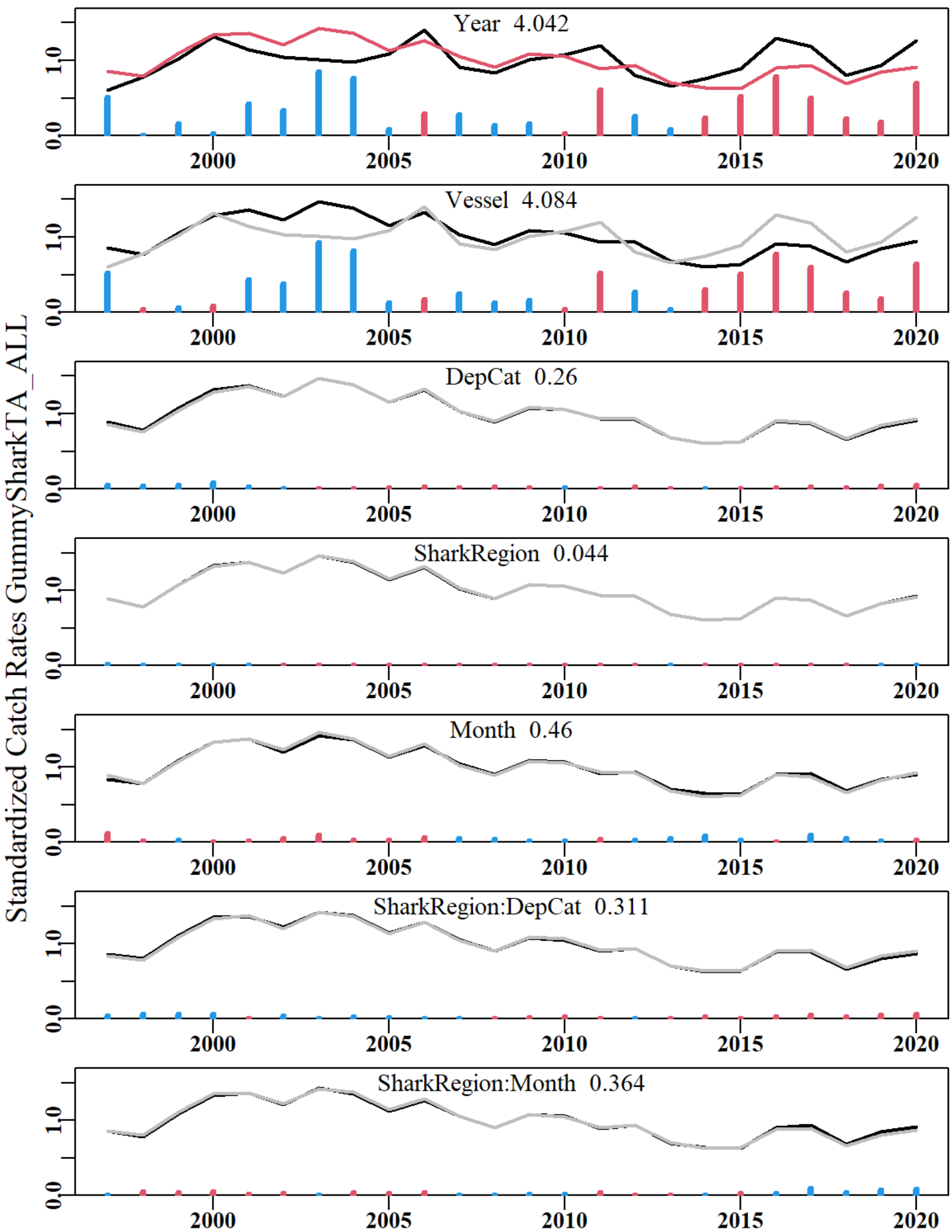

Figure 10.50. GummySharkTA_ALL. The influence of each factor on the optimal standardization. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by vertical bars with blue bars indicating the optimum model is higher than the 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.

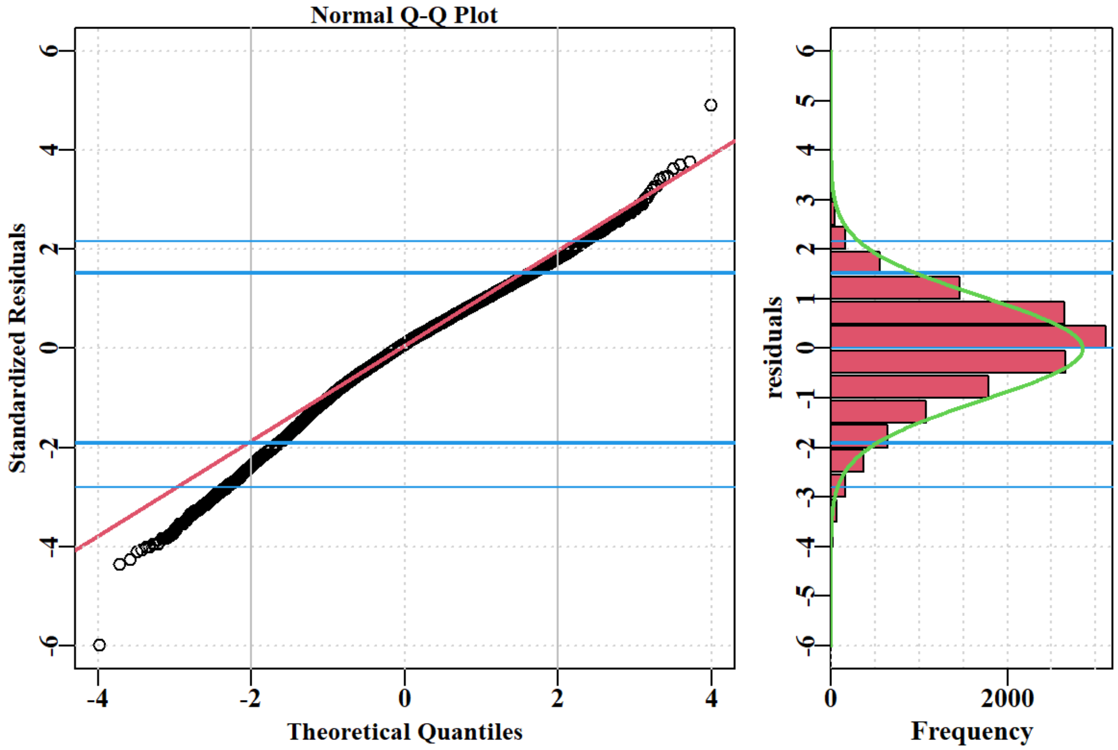

Figure 10.51. GummySharkTA_ALL. Diagnostic plots. The distribution of residuals from the optimum fit. The qqplot indicates the fit to the expected normality, while the histogram of residuals also illustrates the 1%, 5%, 95% and 99% quantiles to indicate the intensity of any lack of fit at the margins of the distribution (reflected also in the qqplot).

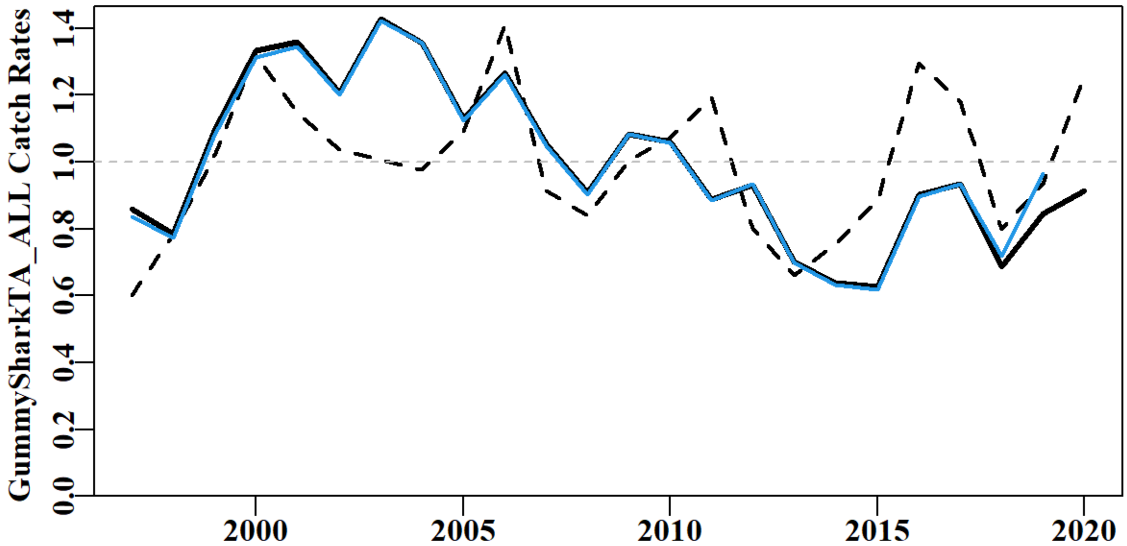

Figure 10.52. GummySharkTA_ALL. A comparison of the previous year's standardization (blue line) with this year's. They should lie on top of each other, although small deviations may relate to data adjustments, particularly in very recent years.

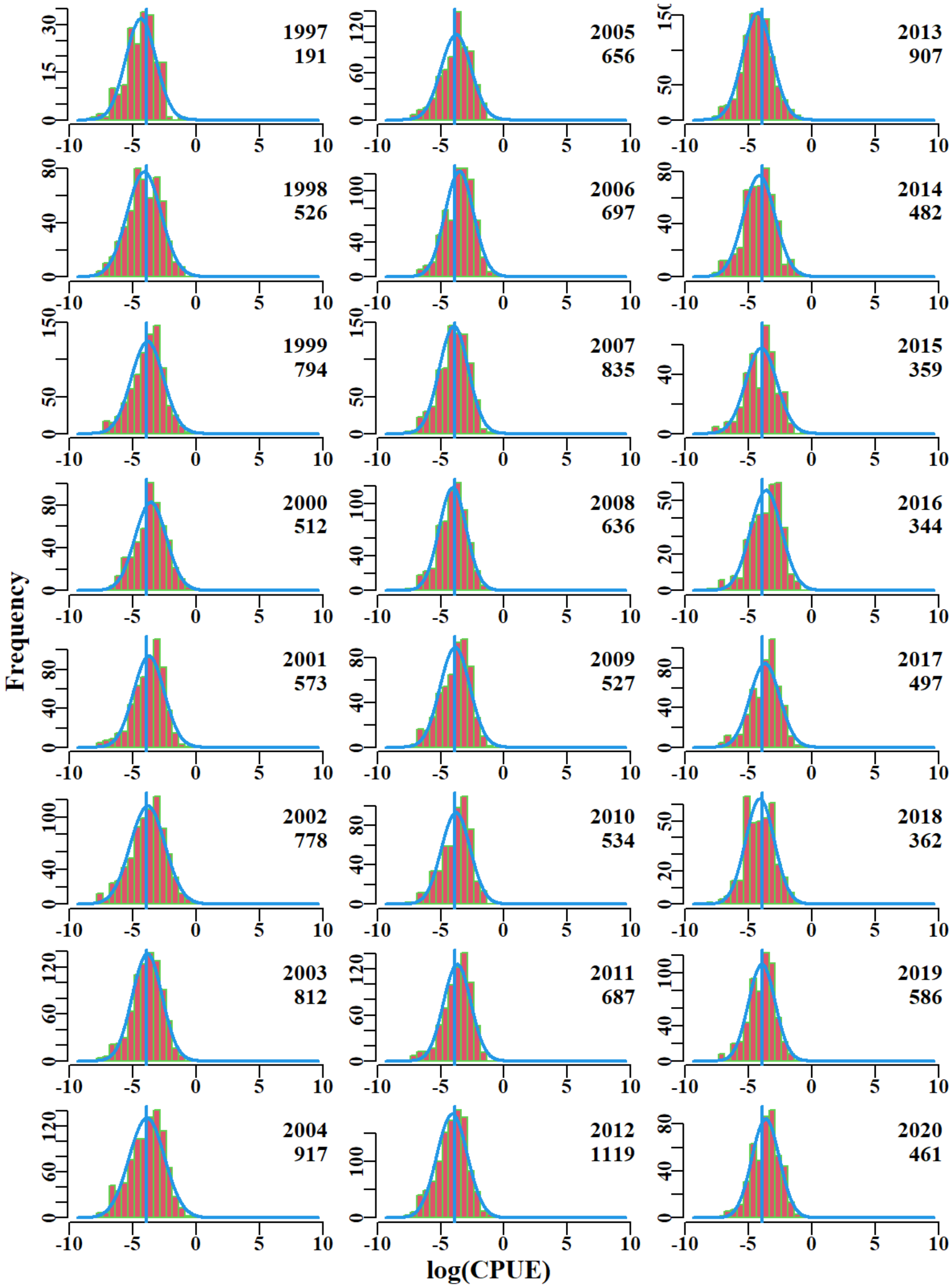

Figure 10.53. GummySharkTA_ALL. The natural log(CPUE) for each year of data available the blue lines are normal distributions fitted to the histogram frequencies. The numbers in each plot are the year and number of records. The vertical blue line is the average across all years.

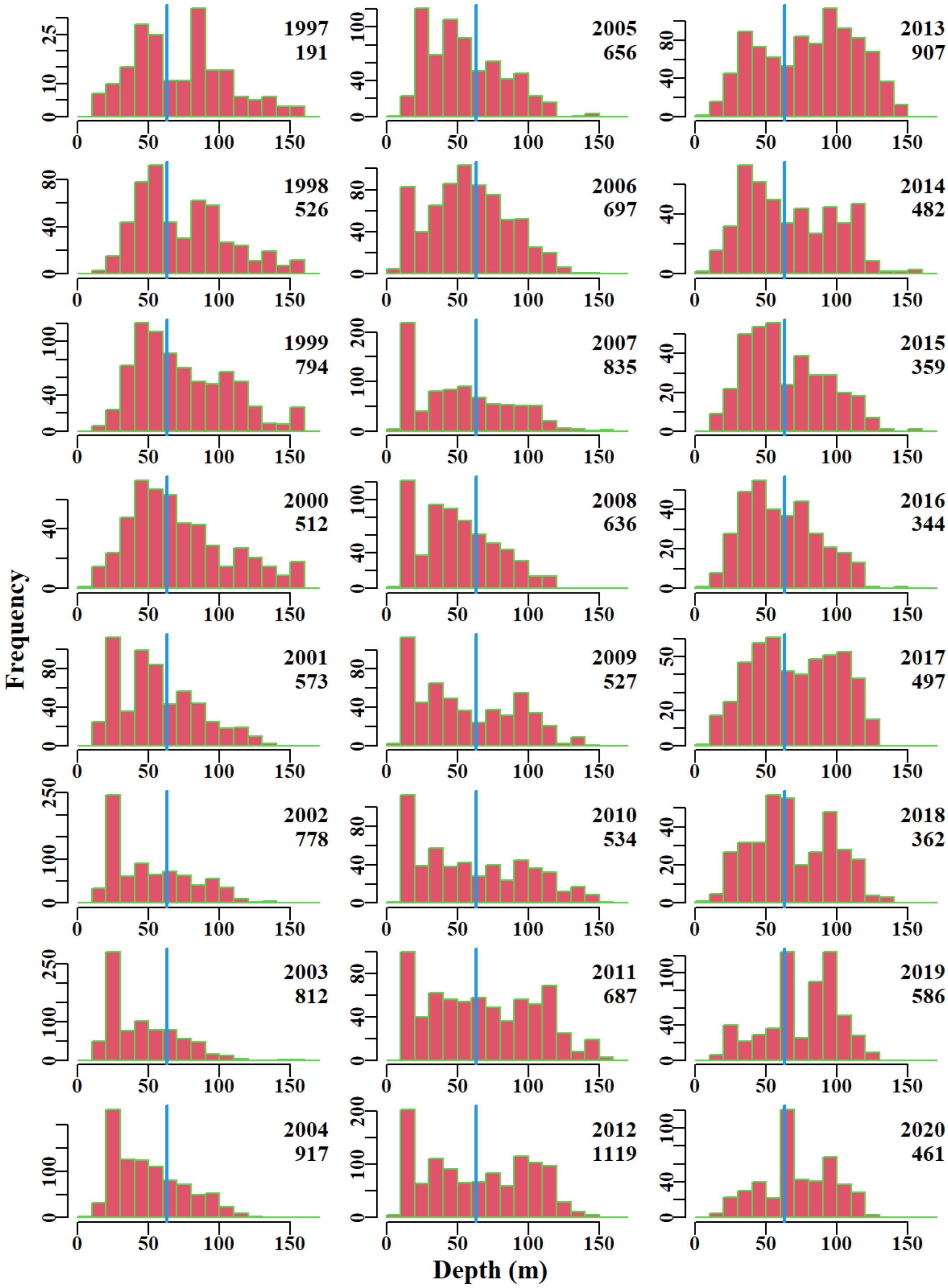

Figure 10.54. GummySharkTA_ALL. The average Depth of fishing for each year of data available to illustrate the development of the fishery through time. The numbers in each plot are the year and number of records. The vertical blue line is the average across all years.

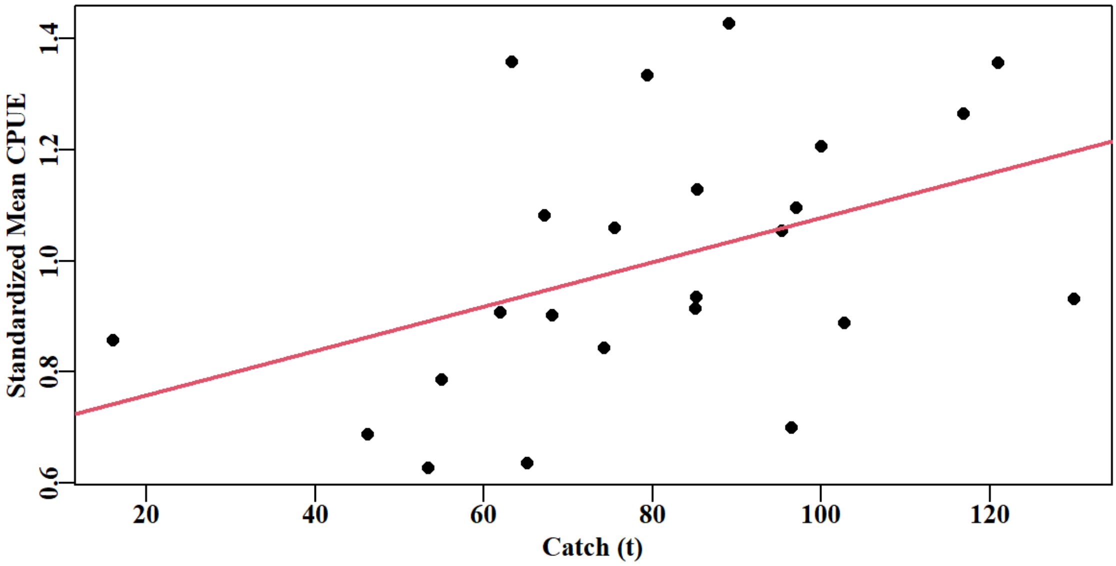

Figure 10.55. GummySharkTA_ALL. The linear relationship between annual mean CPUE and annual Catch.

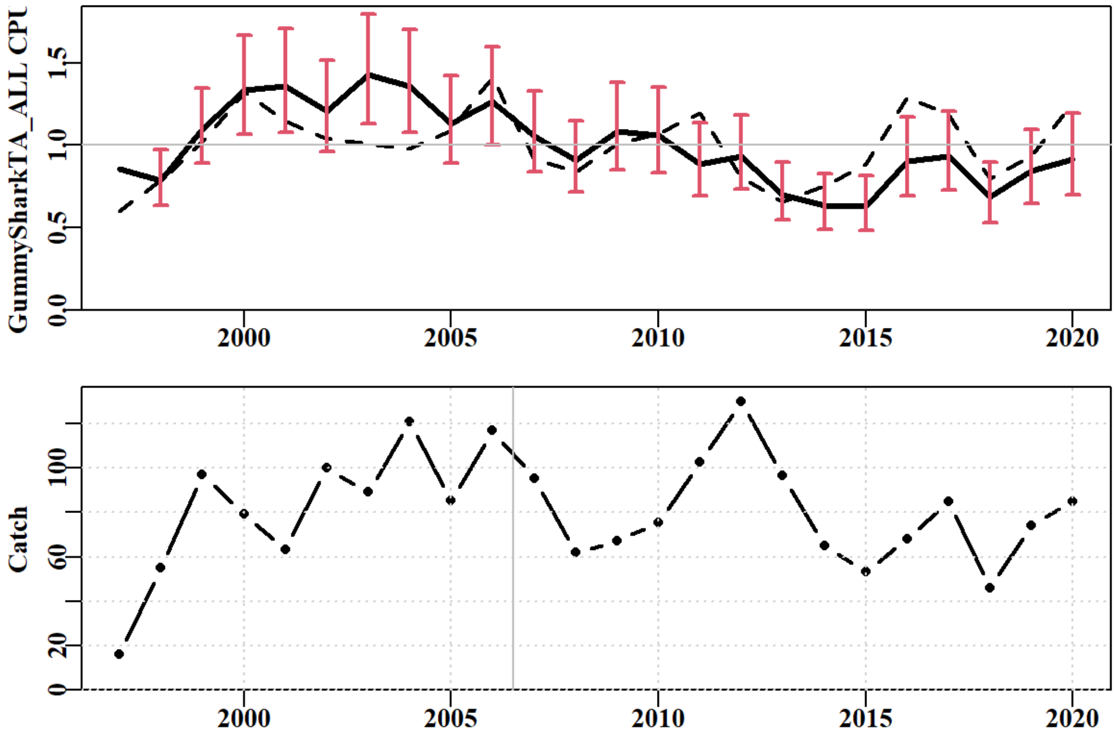

Figure 10.56. GummySharkTA_ALL. CPUE is correlated with catches through time. CPUE in the top plot and annual catch (t) in the lower plot.

10.10 Gummy shark: Trawl

CPUE (catch/hour) analysis used shots that reported catches of Gummy Shark (non zero shots). 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 this 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.

10.10.1 *Inferences*

Most catch occurred in Shark region 2, followed by 1 and 5. Recorded logbook catch has been greater than 100 t per annum since 2018, the first time since 2011. Also, the 117 t recorded in 2019 is the largest in the time series.

The terms Year, Vessel, Month, DepCat, DayNight, SharkRegion and one interaction (SharkRegion:Month) had the greatest contribution to model fit based on the AIC and R^2 statistics (Table 10.32). The qqplot suggests a slight departure from the assumed Normal distribution, as depicted by the upper tail of the distribution (Figure 10.60). Annual standardized CPUE has been mostly flat and below the long-term average between 1997 and 2007 and has increased above the long-term average since 2012 (Figure 10.58).

10.10.2 *Action Items and Issues*

Further consideration of whether to consider the CPUE time-series as a valid index of relative abundance for Gummy Shark needs to be explored.

Table 10.28. 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, TMO, OTB
years	1996 - 2020

Table 10.29. 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

Year	Total	N	Catch	Vess	GeoM	Opt	StDev	C<30Kg	P<30Kg
1996	49.4	2234	40.5	72	5.2	0.9502	0.000	24.951	0.616
1997	952.1	2778	43.6	77	4.5	0.8423	0.028	28.084	0.643
1998	1401.2	2462	39.2	62	4.5	0.8310	0.029	27.357	0.698
1999	1923.8	2396	38.2	69	4.7	0.8658	0.030	23.236	0.609
2000	2436.9	3141	50.4	76	4.8	0.7575	0.029	29.821	0.591
2001	1703.3	3356	56.5	63	4.6	0.7446	0.028	30.465	0.539
2002	1527.2	3994	61.2	67	4.1	0.7026	0.027	34.926	0.571
2003	1653.4	4572	80.4	73	4.4	0.7608	0.027	40.661	0.506
2004	1670.4	4789	89.5	73	4.6	0.7745	0.027	43.556	0.487
2005	1573.3	5057	95.9	70	4.6	0.7857	0.027	48.256	0.503
2006	1577.1	4896	102.1	62	5.0	0.8100	0.027	43.956	0.431
2007	1575.0	3598	84.9	37	5.6	0.8208	0.028	34.984	0.412
2008	1727.9	3769	86.3	36	5.4	0.9714	0.028	38.720	0.448
2009	1500.9	3492	87.6	31	5.8	1.0569	0.028	37.903	0.432
2010	1404.9	3640	90.2	33	5.9	1.0511	0.028	39.510	0.438
2011	1364.7	4289	100.7	32	5.5	0.9695	0.027	43.337	0.430
2012	1304.4	3820	101.9	31	6.2	1.0810	0.028	40.840	0.401
2013	1307.7	3514	96.9	33	6.6	1.2092	0.028	43.299	0.447
2014	1389.1	3159	91.3	34	6.9	1.1837	0.029	37.298	0.408
2015	1545.1	2941	83.0	36	6.9	1.1490	0.029	35.147	0.423
2016	1586.5	2847	86.8	34	7.7	1.1862	0.030	32.255	0.371
2017	1561.4	2873	90.4	33	8.0	1.2681	0.030	32.797	0.363
2018	1560.1	2855	105.7	31	9.4	1.4288	0.030	28.497	0.270
2019	1709.7	3230	116.8	29	9.4	1.4033	0.029	34.812	0.298
2020	1840.5	3185	112.7	30	8.9	1.3962	0.029	34.229	0.304

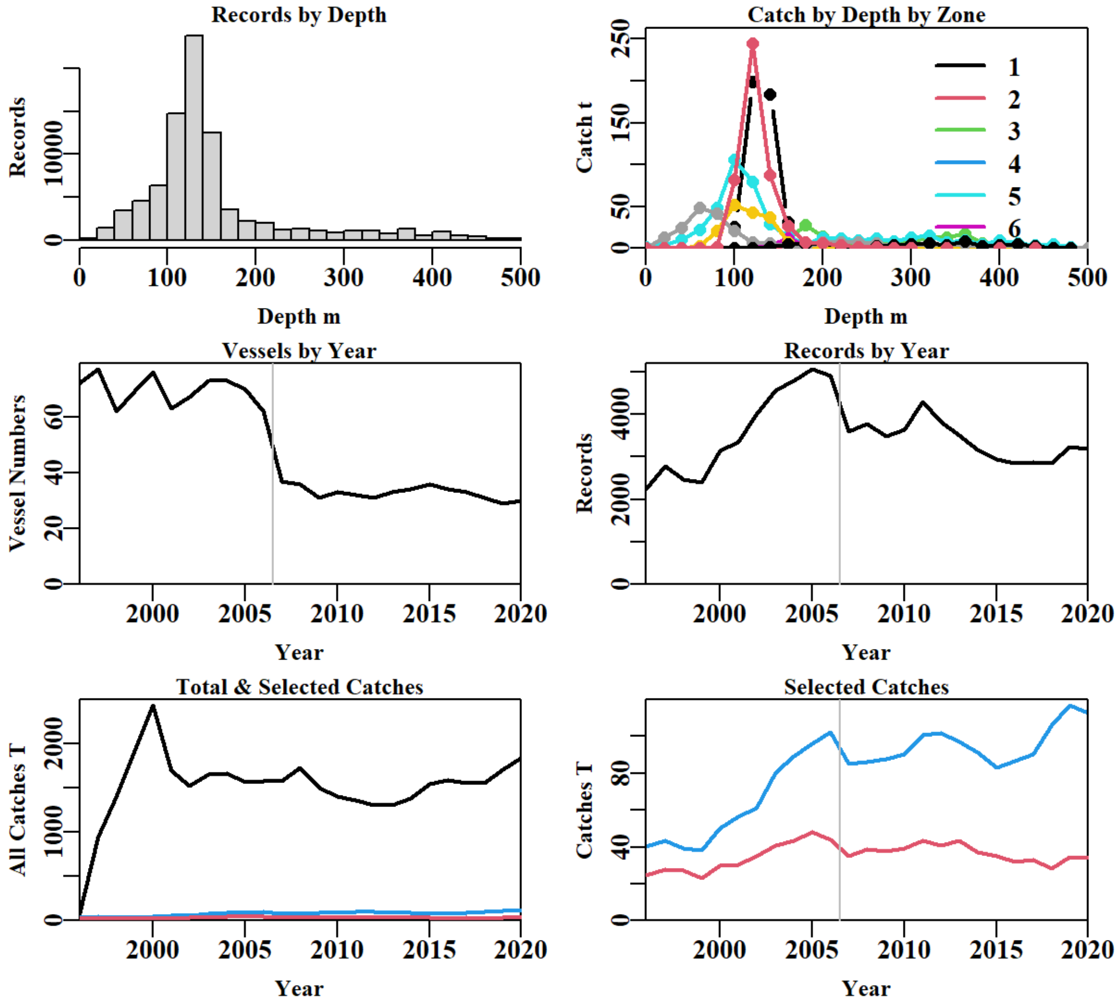

Figure 10.57. GummySharkTW fishery details. The bottom left plot depicts all known catches (top black line), and all selected catches used in the analysis (middle blue line); the lower red line: selected catches < 30 kg).

Table 10.30. 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	440781	0	38380.76	0
NoCE	292807	147974	24403.69	13977.07
Depth	290364	2443	24246.85	156.84
Years	281876	8488	23773.33	473.53
Zones	280885	991	23712.91	60.42
Method	87155	193730	2034.84	21678.07
Fishery	86887	268	2032.77	2.07

Table 10.31. The models used to analyse data for GummySharkTW

Term	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 10.32. 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	12924	100764	4159	86887	25	3.9	0.00
Vessel	-1166	85414	19510	86887	160	18.4	14.51
DepCat	-2852	83724	21199	86887	185	20.0	1.59
SharkRegion	-3688	82905	22018	86887	194	20.8	0.77
Month	-5474	81198	23725	86887	205	22.4	1.62
DayNight	-6680	80073	24850	86887	208	23.5	1.07
SharkRegion:DepCat	-8354	78210	26713	86887	394	25.1	1.62
SharkRegion:Month	-7409	79223	25700	86887	307	24.2	0.73

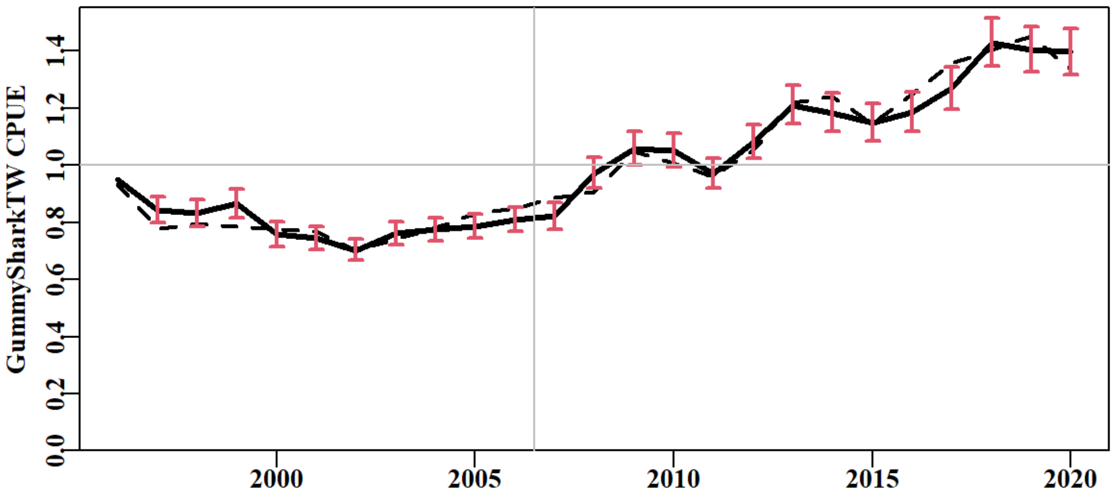

Figure 10.58. GummySharkTW standardization. The dashed black line represents the geometric mean catch rate, solid black line the standardized catch rates. The red bars are the 95% confidence intervals about the mean estimates. The graph scales both time-series of standardized catch rates relative to the mean of each time-series.

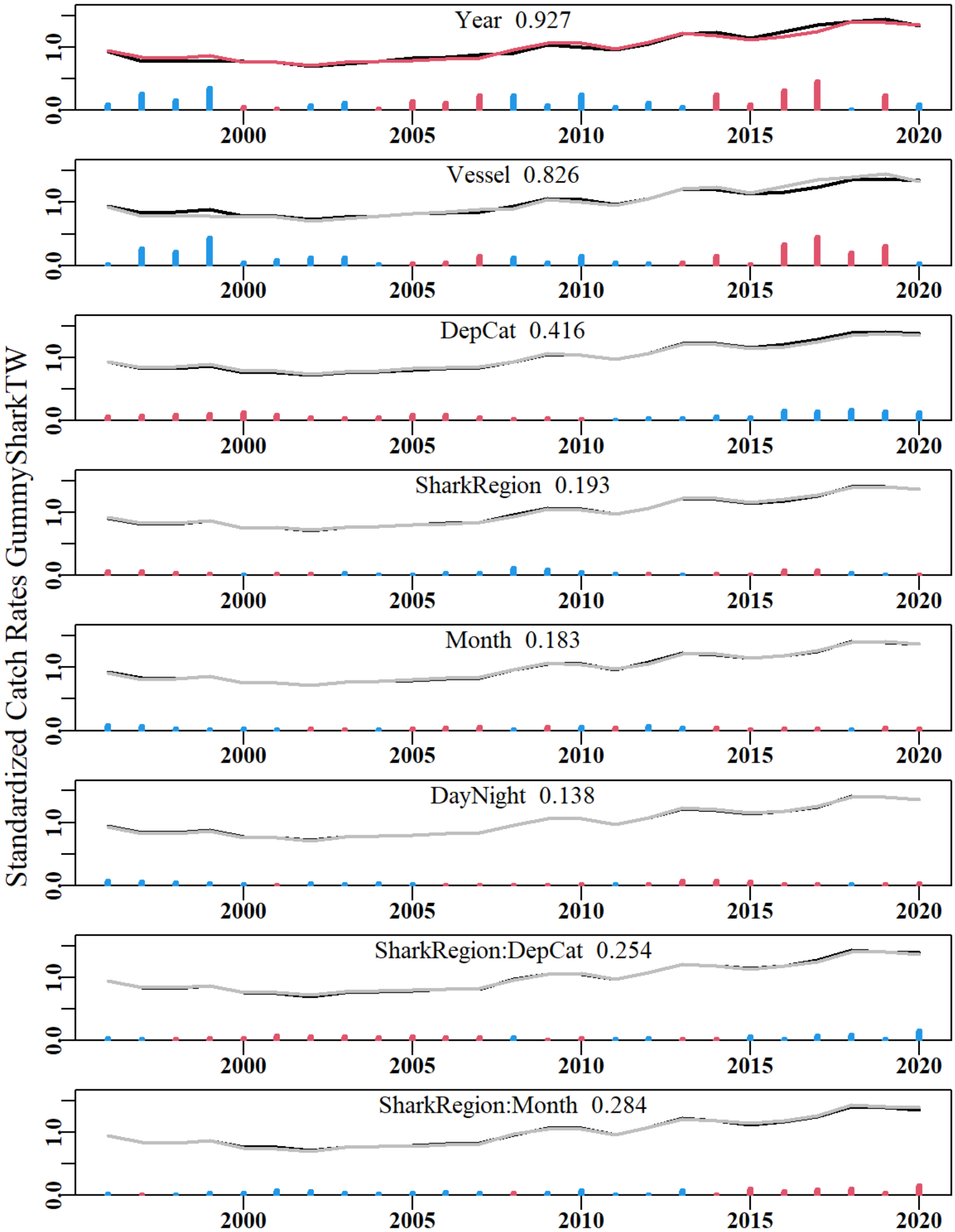

Figure 10.59. GummySharkTW. The influence of each factor on the optimal standardization. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by vertical bars with blue bars indicating the optimum model is higher than the geometric 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.

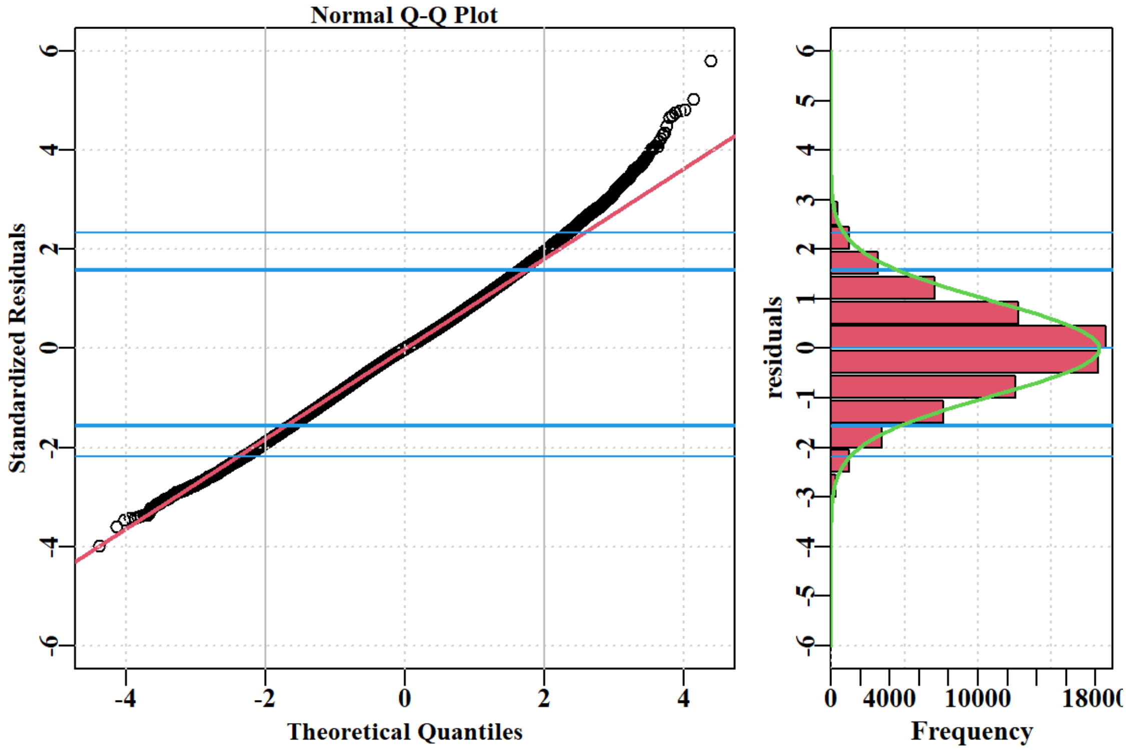

Figure 10.60. GummySharkTW. Diagnostic plots. The distribution of residuals from the optimum fit. The qqplot indicates the fit to the expected normality, while the histogram of residuals also illustrates the 1%, 5%, 95% and 99% quantiles to indicate the intensity of any lack of fit at the margins of the distribution (reflected also in the qqplot).

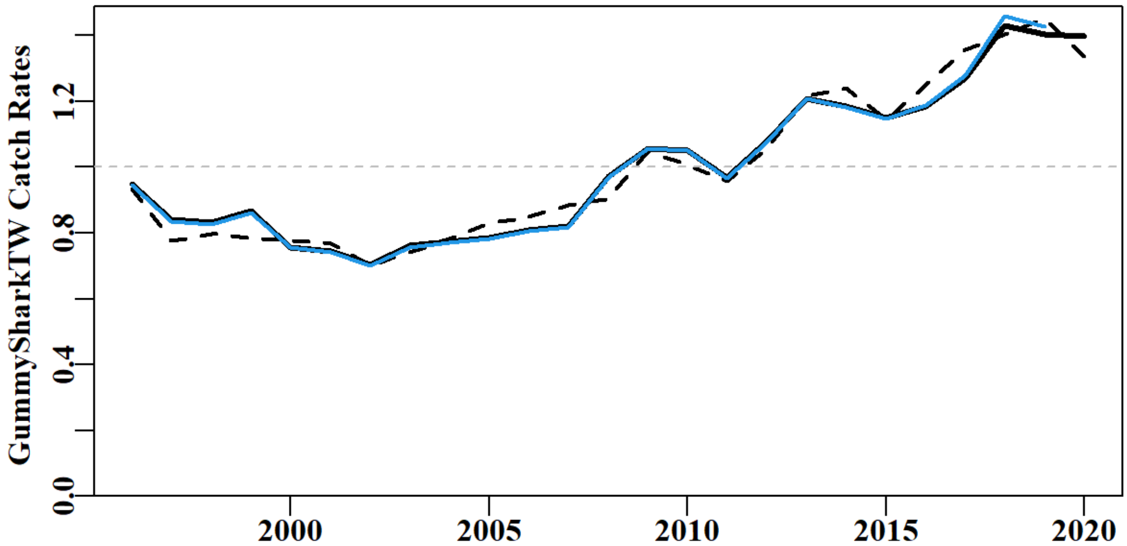

Figure 10.61. GummySharkTW. A comparison of the previous year's standardization (blue line) with this year's. They should lie on top of each other, although small deviations may relate to data adjustments, particularly in very recent years.

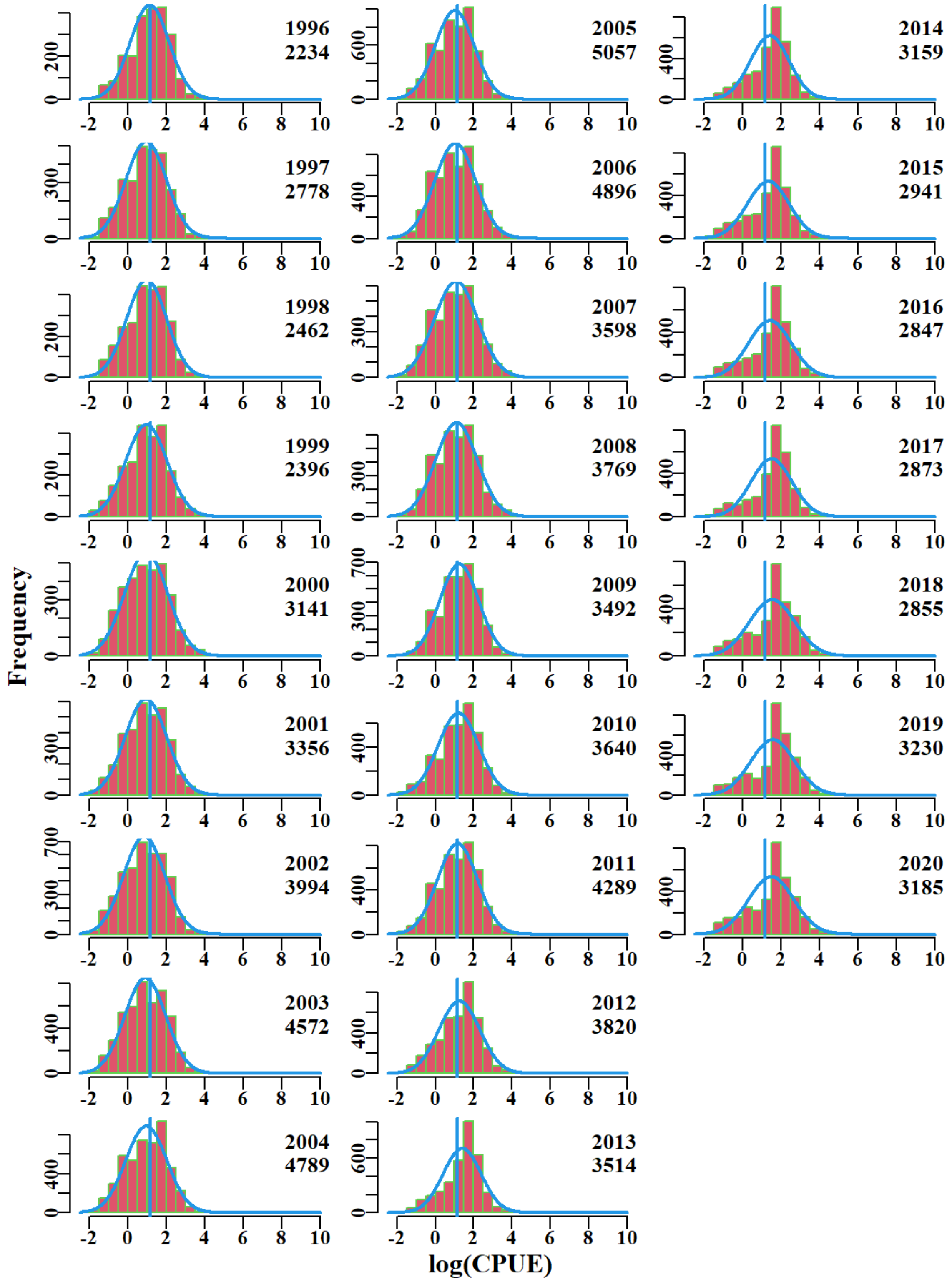

Figure 10.62. GummySharkTW. The natural log(CPUE) for each year of data available the blue lines are normal distributions fitted to the histogram frequencies. The numbers in each plot are the year and number of records. The vertical blue line is the average across all years.

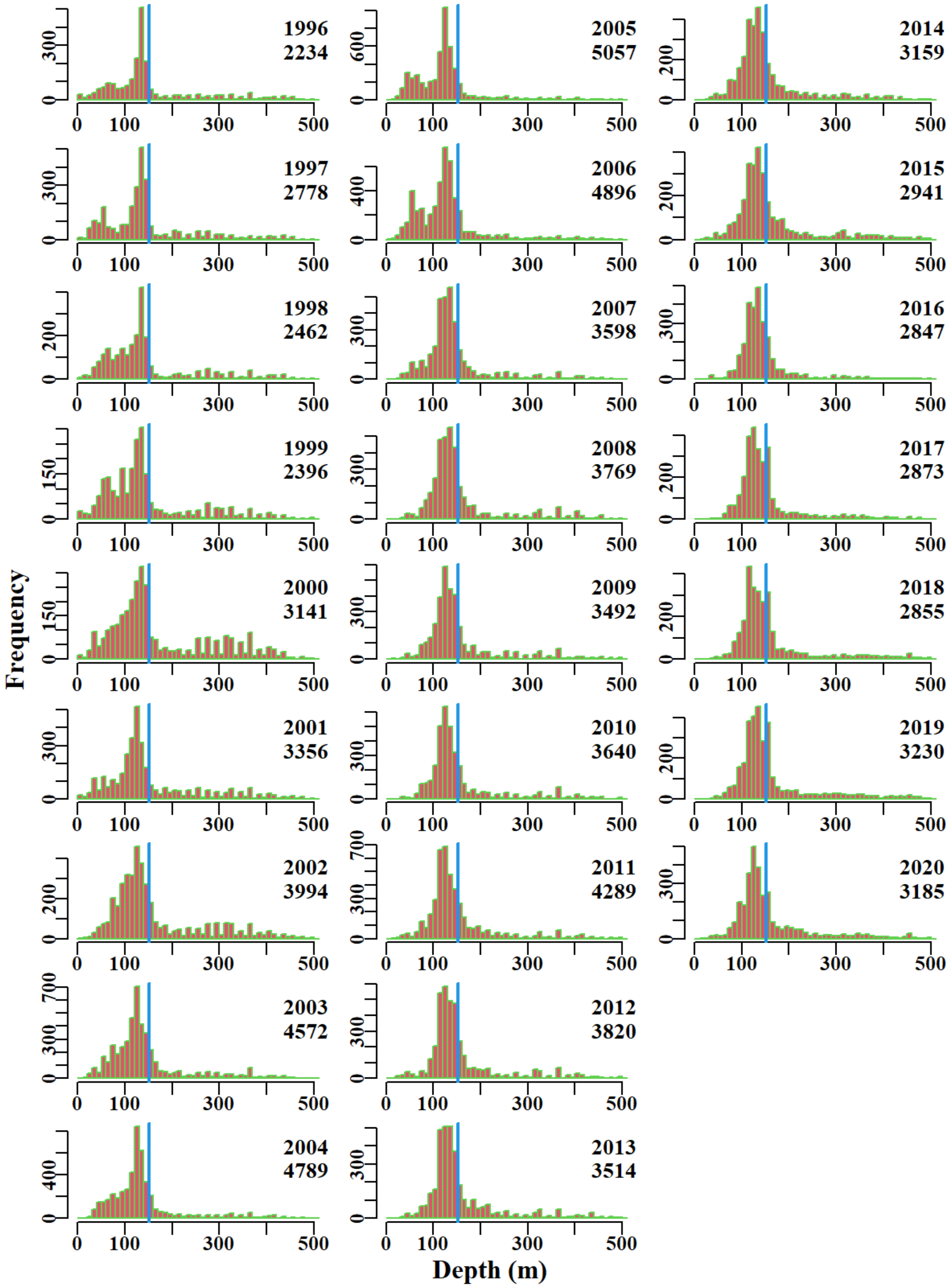

Figure 10.63. GummySharkTW. The average Depth of fishing for each year of data available to illustrate the development of the fishery through time. The numbers in each plot are the year and number of records. The vertical blue line is the average across all years.

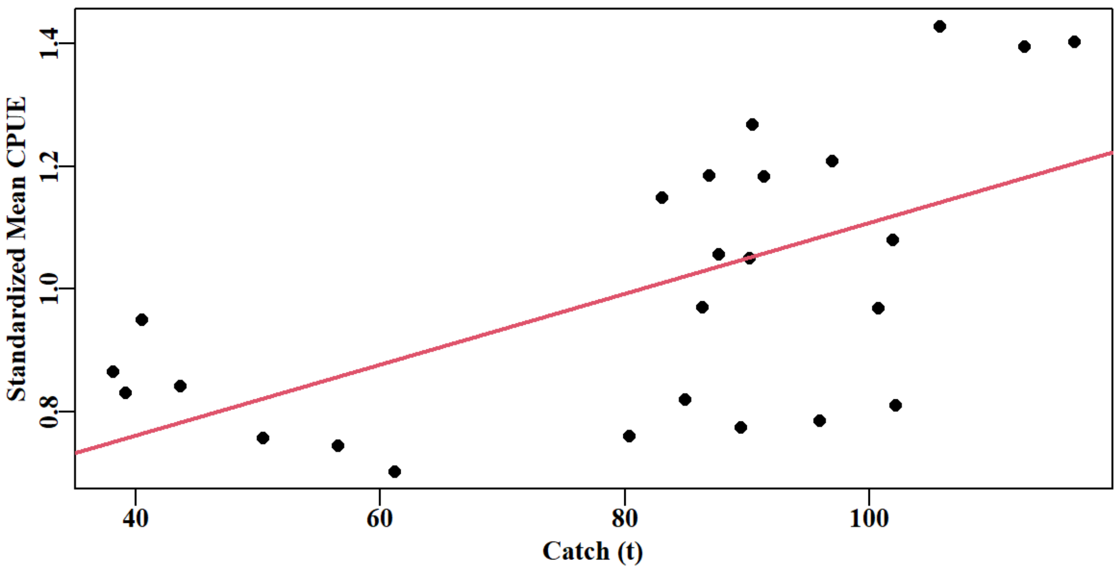

Figure 10.64. GummySharkTW. The linear relationship between annual mean CPUE and annual Catch.

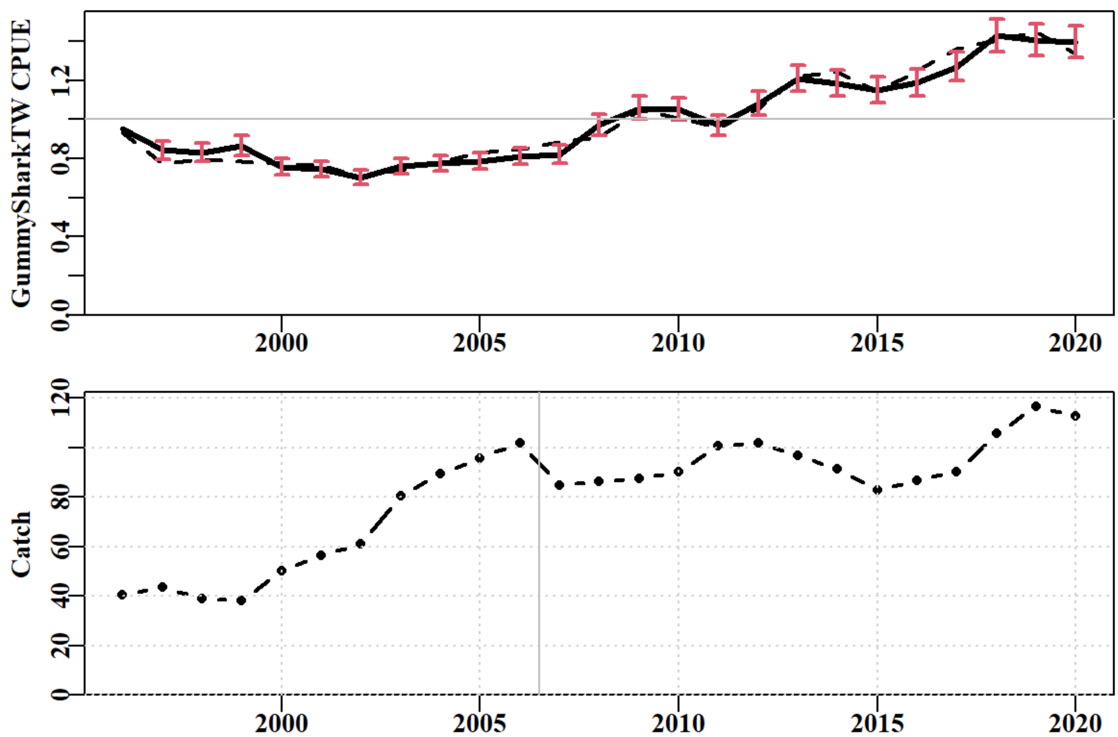

Figure 10.65. GummySharkTW. CPUE is correlated with catches through time. CPUE in the top plot and annual catch (t) in the lower plot.

10.11 Gummy shark: Trawl, South Australia

CPUE (catch/hour) analysis used shots that reported catches of Gummy Shark (non zero shots). Since Gummy Shark are not targeted by trawl vessels, it is inappropriate to include zero catches in this 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.

10.11.1 *Inferences*

Most catch occurred in Shark region 1, followed by 3. Recorded logbook catch has been greater than 30 t per annum since 2017. Also, the 37 t recorded in 2019 is the largest in the time series.

The terms Year, Vessel, Month, DepCat, DayNight, SharkRegion and one interaction (SharkRegion:Month) had the greatest contribution to model fit based on the AIC and R^2 statistics (Table 10.37). The qqplot suggests a slight departure from the assumed Normal distribution, as depicted by the lower and upper tails of the distribution (Figure 10.69). Overall, the annual standardized CPUE has increased and above the long-term average since 2012, despite the decrease in the most recent year (2020) (Figure 10.67).

10.11.2 *Action Items and Issues*

Further consideration of whether to consider the CPUE time-series as a valid index of relative abundance for Gummy Shark needs to be explored.

Table 10.33. GummySharkTWSA. The data selection criteria used to specify and identify the fishery data to be included in the analysis.

Property	Value
label	GummySharkTWSA
csirocode	37017001
fishery	SET_GAB
depthrange	0 - 500
depthclass	20
zones	1, 2, 3, 9
methods	TW, TDO, OTT
years	1996 - 2020

Table 10.34. GummySharkTWSA. 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

Year	Total	N	Catch	Vess	GeoM	Opt	StDev	C<30Kg	P<30Kg
1996	49.4	511	12.0	18	5.4	0.7751	0.000	7.000	0.582
1997	952.1	689	13.3	21	4.6	0.7472	0.046	9.355	0.706
1998	1401.2	531	10.8	18	4.7	0.6589	0.049	7.225	0.669
1999	1923.8	499	12.6	17	6.2	0.7657	0.050	4.914	0.390
2000	2436.9	695	19.6	23	7.0	0.7190	0.048	8.457	0.430
2001	1703.3	787	19.6	20	6.0	0.7529	0.047	8.286	0.423
2002	1527.2	660	15.5	20	5.3	0.6772	0.048	6.869	0.443
2003	1653.4	1010	25.6	25	5.0	0.7870	0.046	8.982	0.351
2004	1670.4	1137	29.8	26	5.3	0.8174	0.045	11.915	0.400
2005	1573.3	1227	30.1	23	4.9	0.8156	0.045	13.781	0.458
2006	1577.1	1429	33.2	22	4.7	0.6868	0.044	14.933	0.450
2007	1575.0	1178	27.4	18	4.7	0.7091	0.045	13.839	0.505
2008	1727.9	1251	25.9	16	4.2	0.7144	0.045	15.097	0.583
2009	1500.9	1184	32.2	14	5.1	0.8832	0.045	13.934	0.432
2010	1404.9	1016	27.5	14	5.2	0.9935	0.046	14.571	0.531
2011	1364.7	1263	33.9	14	5.2	0.9429	0.045	14.681	0.433
2012	1304.4	1195	39.3	14	6.0	1.0697	0.046	15.714	0.400
2013	1307.7	1178	39.2	16	6.3	1.3027	0.046	17.339	0.442
2014	1389.1	959	33.3	14	6.6	1.3016	0.047	14.234	0.428
2015	1545.1	821	30.9	11	6.8	1.2563	0.048	12.492	0.405
2016	1586.5	783	27.2	12	6.5	1.2548	0.048	11.796	0.434
2017	1561.4	916	32.4	11	6.8	1.3701	0.047	12.252	0.379
2018	1560.1	804	36.7	11	8.6	1.7041	0.048	9.518	0.260
2019	1709.7	830	35.5	9	8.2	1.6974	0.048	9.697	0.273
2020	1840.5	765	34.4	9	8.1	1.5974	0.049	8.709	0.253

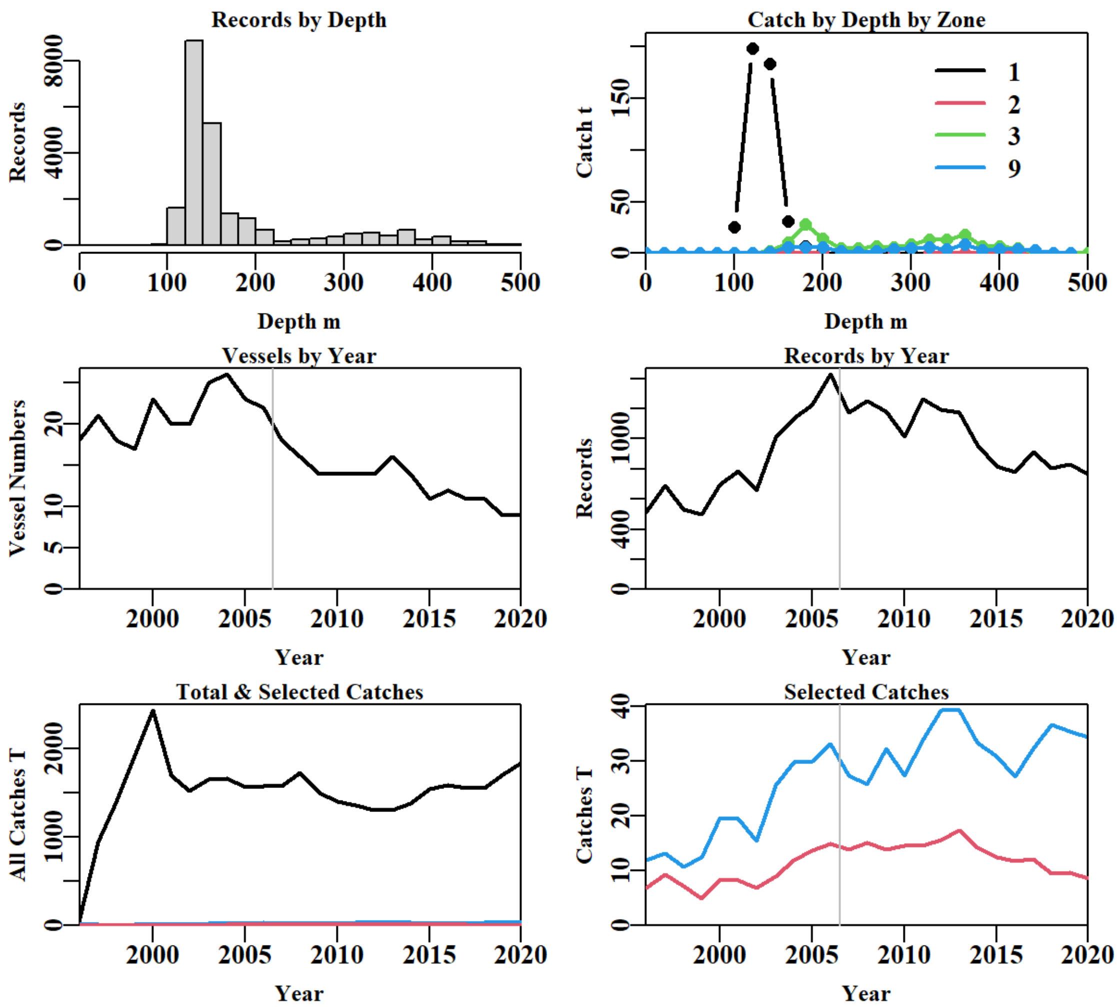

Figure 10.66. GummySharkTWSA fishery details. The bottom left plot depicts all known catches (top black line), and all selected catches used in the analysis (middle blue line); the lower red line: selected catches < 30 kg).

Table 10.35. GummySharkTWSA 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	440781	0	38380.76	0
NoCE	292807	147974	24403.69	13977.07
Depth	290364	2443	24246.85	156.84
Years	281876	8488	23773.33	473.53
Zones	81953	199923	5955.46	17817.86
Method	23323	58630	677.85	5277.62
Fishery	23318	5	677.80	0.05

Table 10.36. The models used to analyse data for GummySharkTWSA

	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 10.37. GummySharkTWSA. 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

Term	AIC	RSS	MSS	Nobs	Npars	adj_r2	%Change
Year	-9066	15773	1632	23318	25	9.3	0
Vessel	-12603	13486	3920	23318	83	22.2	12.96
DepCat	-12776	13357	4048	23318	108	22.9	0.66
SharkRegion	-13152	13140	4265	23318	111	24.1	1.24
Month	-13991	12664	4741	23318	122	26.9	2.71
DayNight	-14451	12413	4992	23318	125	28.3	1.44
SharkRegion:DepCat	-14593	12277	5129	23318	183	28.9	0.61
SharkRegion:Month	-14673	12261	5144	23318	158	29.1	0.78

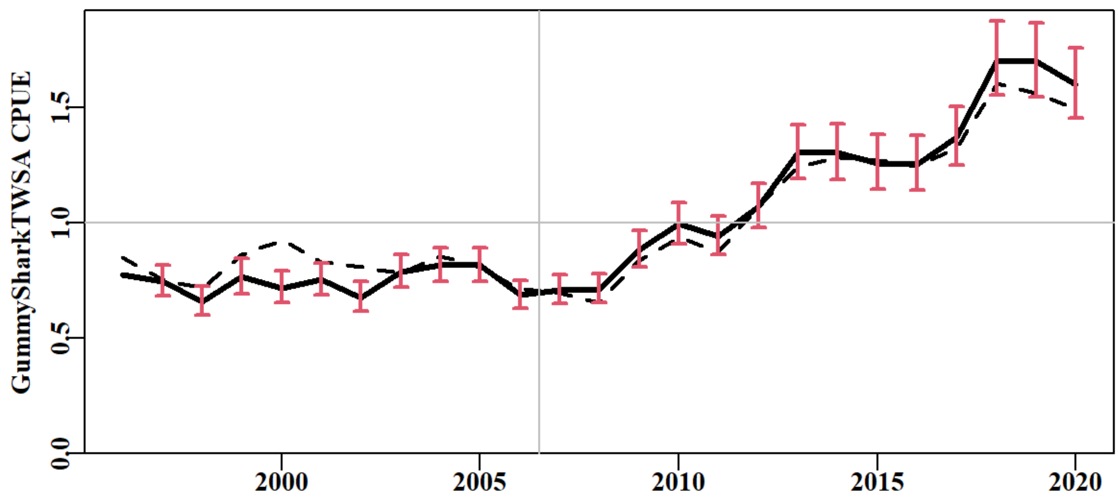

Figure 10.67. GummySharkTWSA standardization. The dashed black line represents the geometric mean catch rate, solid black line the standardized catch rates. The red bars are the 95% confidence intervals about the mean estimates. The graph scales both time-series of standardized catch rates relative to the mean of each time-series.

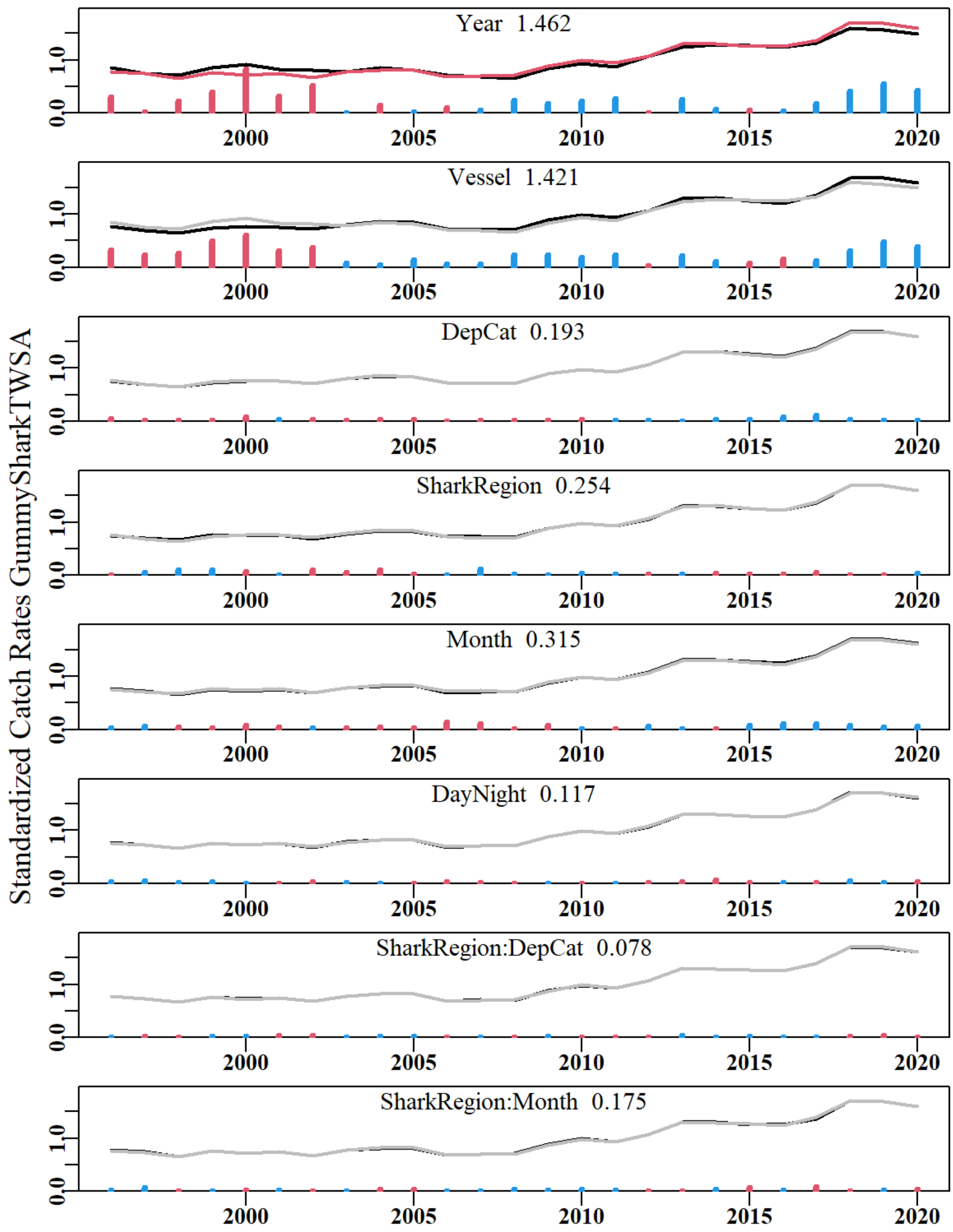

Figure 10.68. GummySharkTWSA. The influence of each factor on the optimal standardization. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by vertical bars with blue bars indicating the optimum model is higher than the 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.

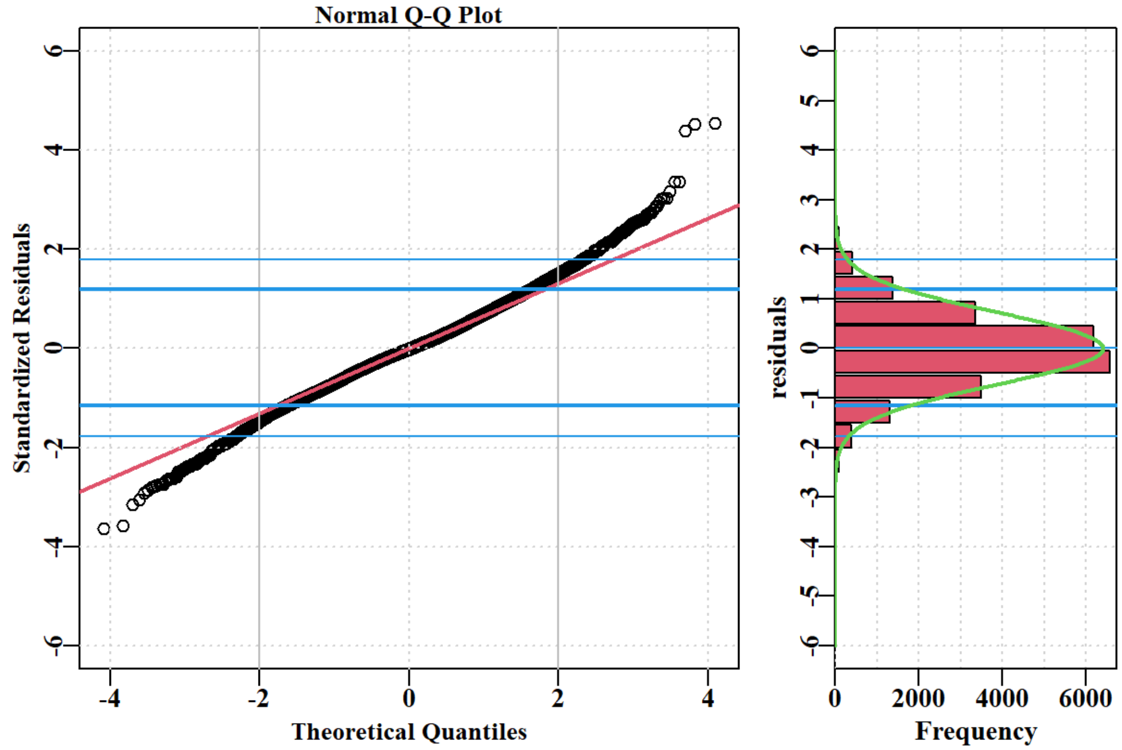

Figure 10.69. GummySharkTWSA. Diagnostic plots. The distribution of residuals from the optimum fit. The qqplot indicates the fit to the expected normality, while the histogram of residuals also illustrates the 1%, 5%, 95% and 99% quantiles to indicate the intensity of any lack of fit at the margins of the distribution (reflected also in the qqplot).

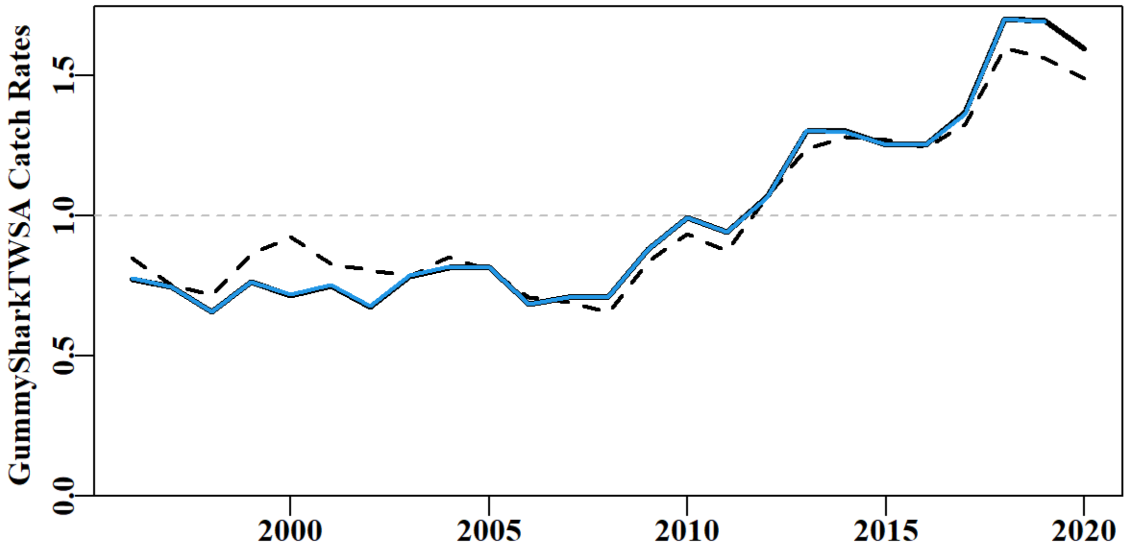

Figure 10.70. GummySharkTWSA. A comparison of the previous year's standardization (blue line) with this year's. They should lie on top of each other, although small deviations may relate to data adjustments, particularly in very recent years.

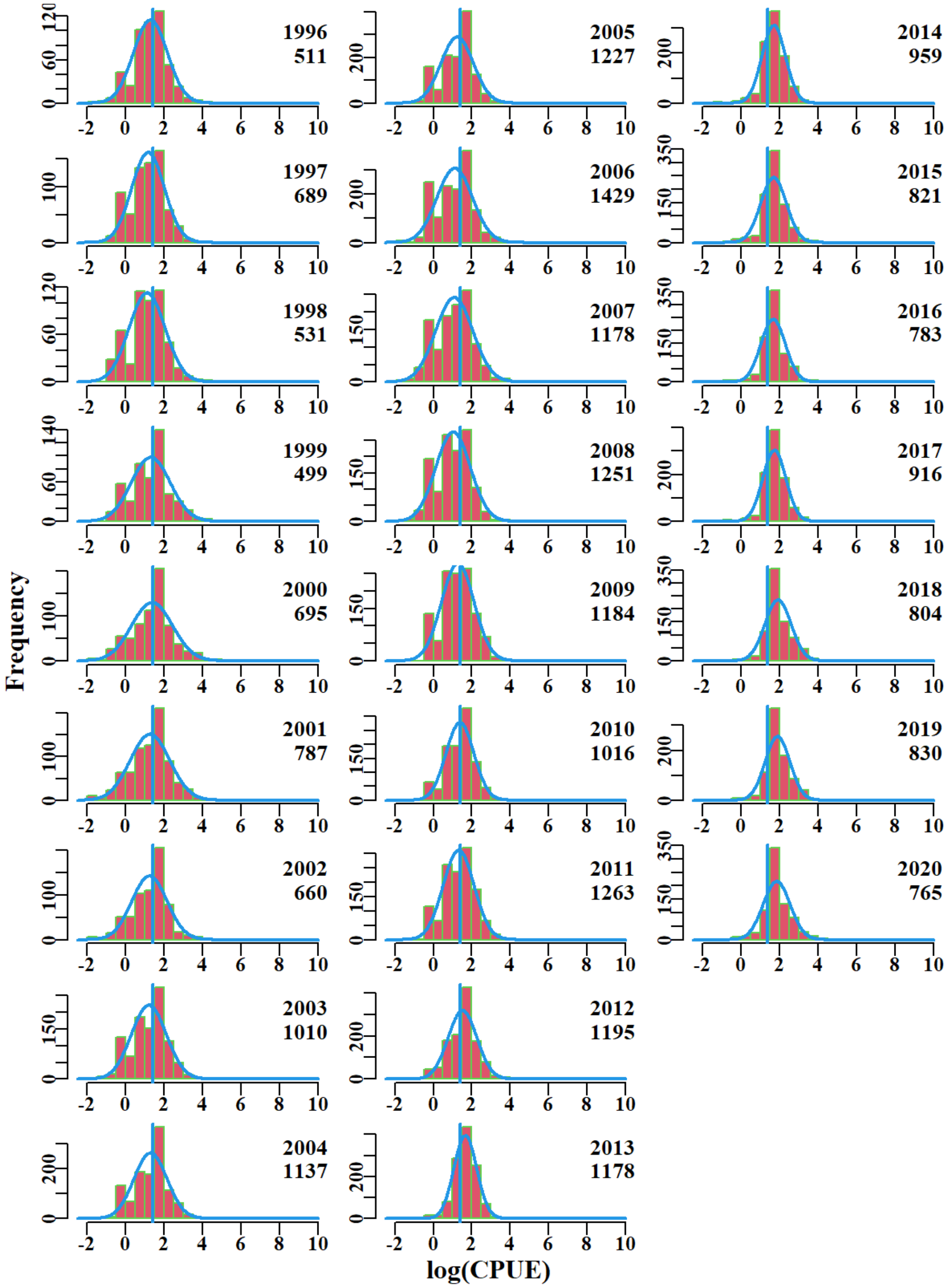

Figure 10.71. GummySharkTWSA. The natural log(CPUE) for each year of data available the blue lines are normal distributions fitted to the histogram frequencies. The numbers in each plot are the year and number of records. The vertical blue line is the average across all years.

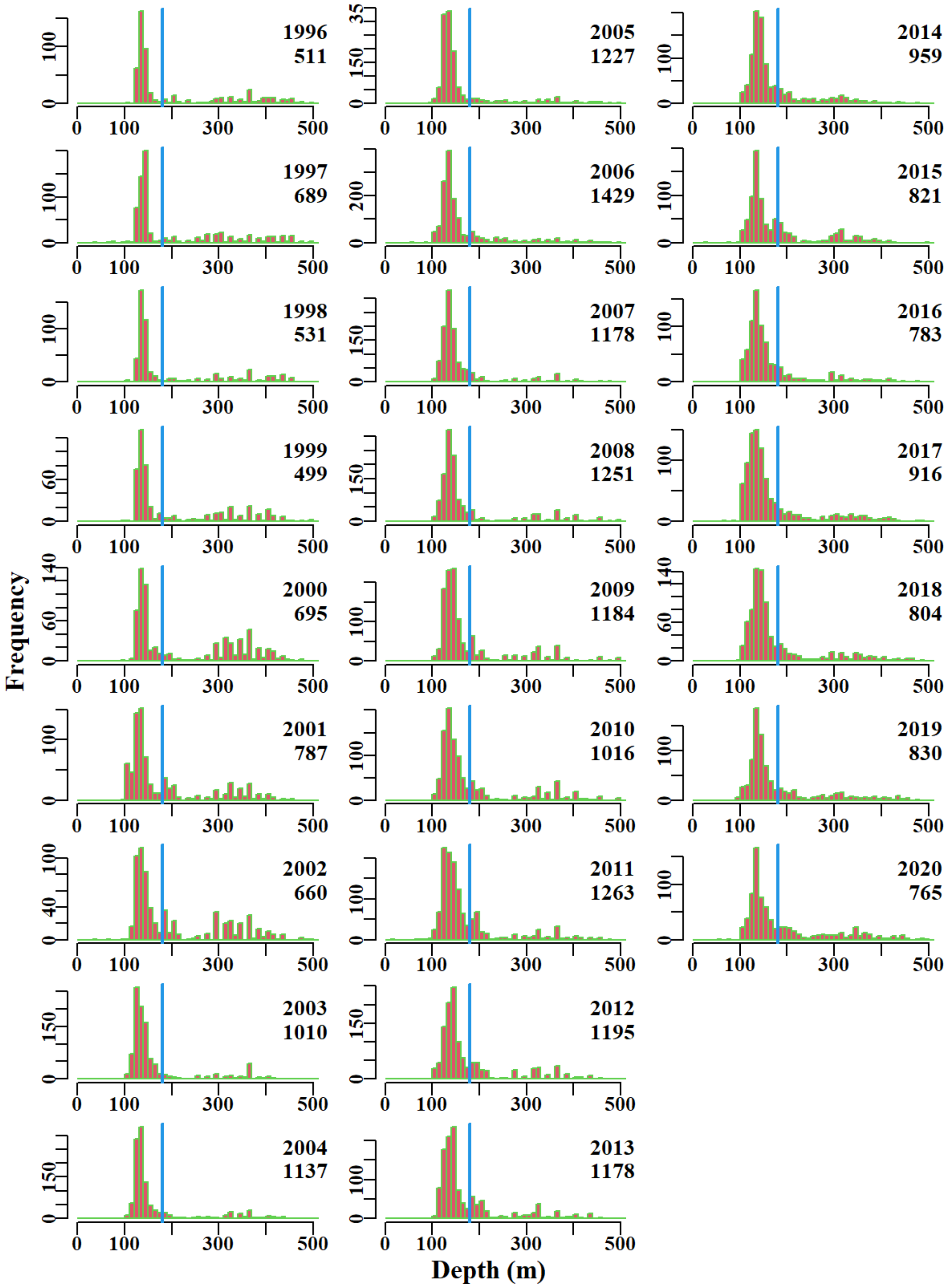

Figure 10.72. GummySharkTWSA. The average Depth of fishing for each year of data available to illustrate the development of the fishery through time. The numbers in each plot are the year and number of records. The vertical blue line is the average across all years.

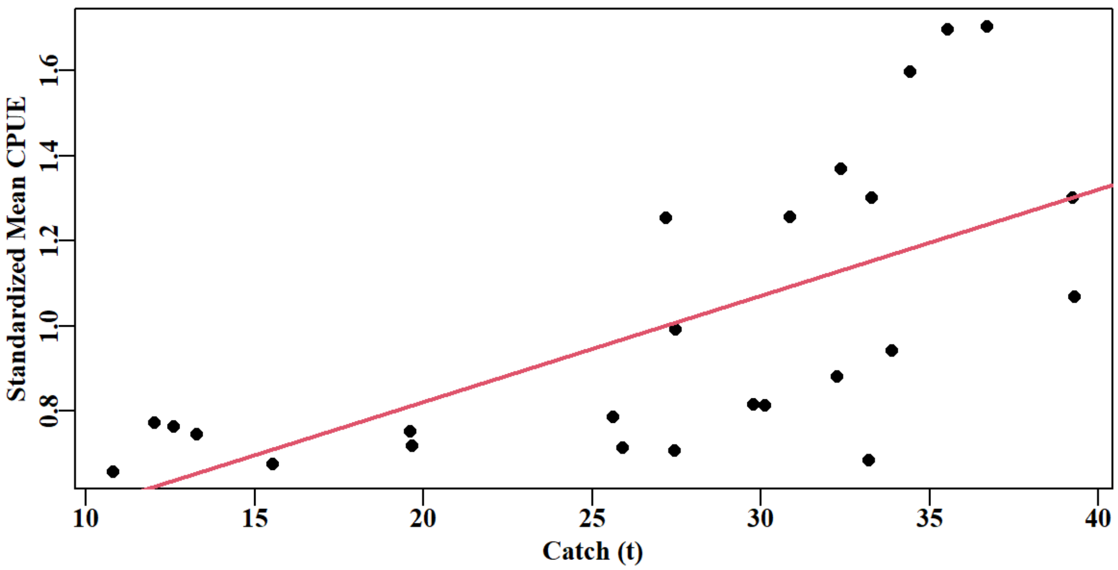

Figure 10.73. GummySharkTWSA. The linear relationship between annual mean CPUE and annual Catch.

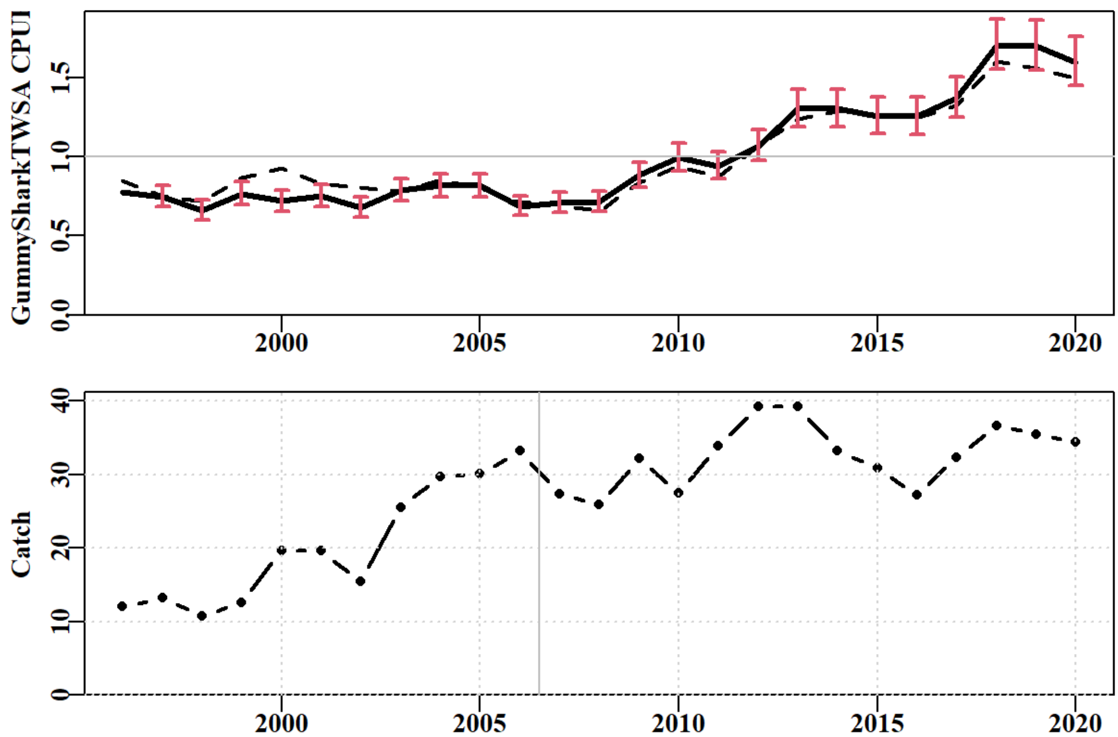

Figure 10.74. GummySharkTWSA. CPUE is correlated with catches through time. CPUE in the top plot and annual catch (t) in the lower plot.

10.12 Gummy shark: Trawl, Bass Strait

CPUE (catch/hour) analysis used shots that reported catches of Gummy Shark (non zero shots). Since Gummy Shark are not targeted by trawl vessels, it is inappropriate to include zero catches in this 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.

10.12.1 *Inferences*

Most catch occurred in Shark region 5, followed by 4.

The terms Year, Vessel, Month, DepCat, DayNight and one interaction (SharkRegion:DepCat) had the greatest contribution to model fit based on the AIC and R^2 statistics (Table 10.42). The qqplot suggests a slight departure from the assumed Normal distribution, as depicted by the lower tail of the distribution (Figure 10.78). Annual standardized CPUE has been mostly flat and above the long-term average since 2008 (Figure 10.76).

10.12.2 *Action Items and Issues*

Further consideration of whether to consider the CPUE time-series as a valid index of relative abundance for Gummy Shark needs to be explored.

Table 10.38. GummySharkTWBS. The data selection criteria used to specify and identify the fishery data to be included in the analysis.

Property	Value
label	GummySharkTWBS
csirocode	37017001
fishery	SET_GAB
depthrange	0 - 250
depthclass	20
zones	4, 5
methods	TW, TDO, OTT
years	1996 - 2020

Table 10.39. GummySharkTWBS. 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

Year	Total	N	Catch	Vess	GeoM	Opt	StDev	C<30Kg	P<30Kg
1996	49.4	486	5.3	23	3.5	0.9197	0.000	4.313	0.811
1997	952.1	755	6.0	24	2.5	0.6900	0.067	4.761	0.792
1998	1401.2	749	7.3	20	3.3	0.8612	0.068	6.229	0.853
1999	1923.8	885	9.0	25	3.4	0.9120	0.066	7.514	0.834
2000	2436.9	1042	9.6	32	3.7	0.7280	0.066	7.969	0.829
2001	1703.3	897	9.9	23	3.3	0.7495	0.068	7.022	0.708
2002	1527.2	919	8.8	21	2.5	0.6426	0.068	6.714	0.760
2003	1653.4	908	10.0	22	2.7	0.6669	0.069	7.220	0.719
2004	1670.4	968	9.7	21	2.7	0.6092	0.068	6.660	0.687
2005	1573.3	1019	8.9	22	2.5	0.5902	0.067	6.756	0.759
2006	1577.1	1115	11.1	21	2.7	0.7065	0.066	7.989	0.719
2007	1575.0	735	12.4	12	4.2	0.8441	0.072	5.965	0.479
2008	1727.9	980	21.5	15	5.4	1.2999	0.069	9.374	0.436
2009	1500.9	778	17.1	12	5.6	1.4264	0.072	8.349	0.487
2010	1404.9	939	19.8	12	5.6	1.2819	0.070	9.180	0.463
2011	1364.7	1049	20.6	12	5.1	1.1887	0.069	9.699	0.471
2012	1304.4	1017	22.2	13	5.9	1.3358	0.069	8.893	0.400
2013	1307.7	919	19.4	12	5.8	1.3045	0.070	8.852	0.455
2014	1389.1	924	23.7	14	6.3	1.2300	0.070	9.007	0.381
2015	1545.1	814	18.6	13	6.3	1.2050	0.071	8.165	0.440
2016	1586.5	687	18.8	14	7.8	1.2073	0.074	5.836	0.310
2017	1561.4	642	13.7	16	6.5	1.1268	0.075	6.965	0.509
2018	1560.1	706	16.1	14	6.5	1.1131	0.074	6.987	0.433
2019	1709.7	726	15.4	13	6.1	1.0489	0.074	7.228	0.469
2020	1840.5	844	21.3	12	7.3	1.3118	0.072	9.020	0.424

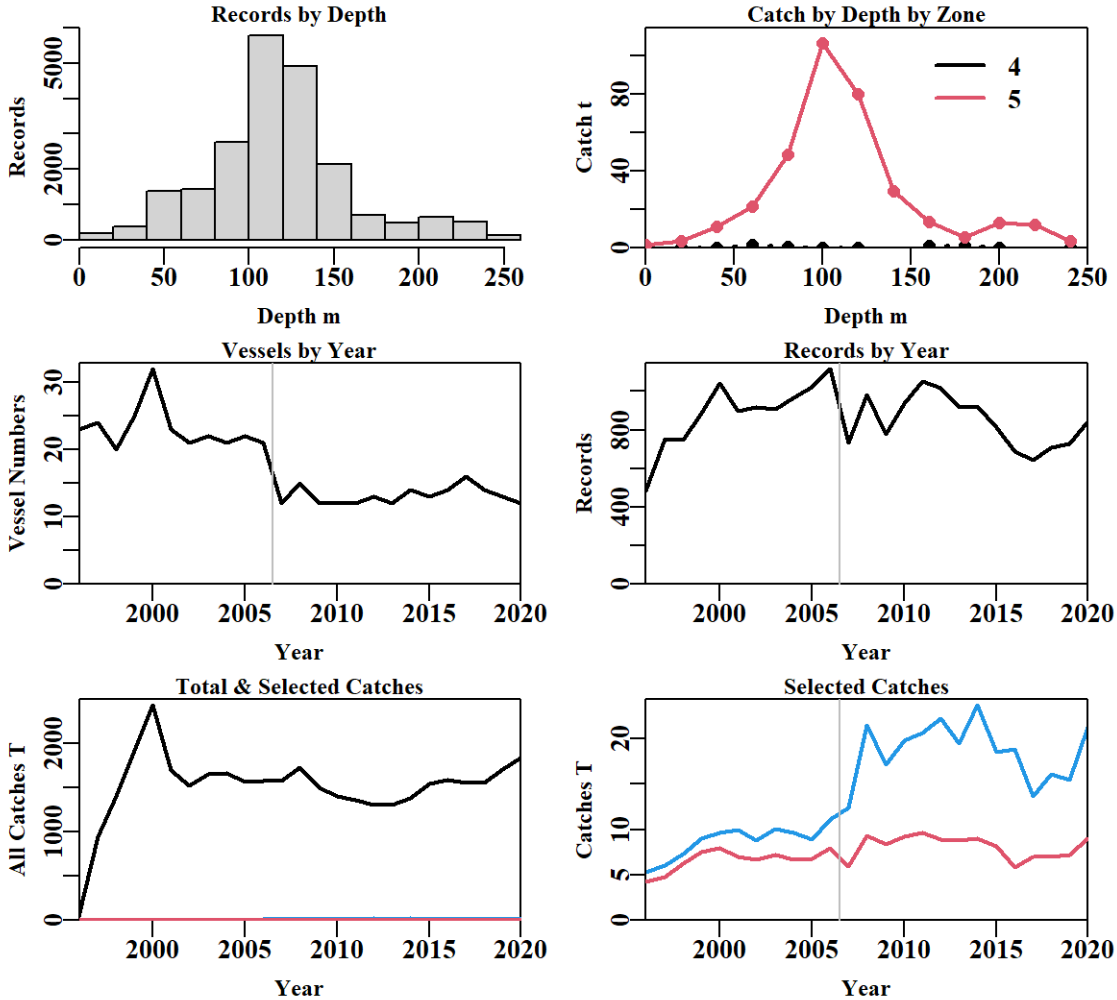

Figure 10.75. GummySharkTWBS fishery details. The bottom left plot depicts all known catches (top black line), and all selected catches used in the analysis (middle blue line); the lower red line: selected catches < 30 kg).

Table 10.40. GummySharkTWBS 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	440781	0	38380.76	0
NoCE	292807	147974	24403.69	13977.07
Depth	278435	14372	23887.02	516.67
Years	270694	7741	23438.00	449.02
Zones	144398	126296	15325.04	8112.96
Method	21738	122660	358.25	14966.78
Fishery	21503	235	356.48	1.77

Table 10.41. The models used to analyse data for GummySharkTWBS

	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 10.42. GummySharkTWBS. 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

Term	AIC	RSS	MSS	Nobs	Npars	adj_r2	%Change
Year	7886	30957	1444	21503	25	4.3	0
Vessel	5426	27427	4974	21503	97	15.0	10.62
DepCat	5050	26921	5480	21503	109	16.5	1.52
SharkRegion	5036	26902	5499	21503	110	16.5	0.06
Month	4235	25891	6510	21503	121	19.6	3.09
DayNight	3990	25590	6811	21503	124	20.6	0.92
SharkRegion:DepCat	3950	25523	6877	21503	132	20.7	0.18
SharkRegion:Month	3987	25561	6840	21503	135	20.6	0.05

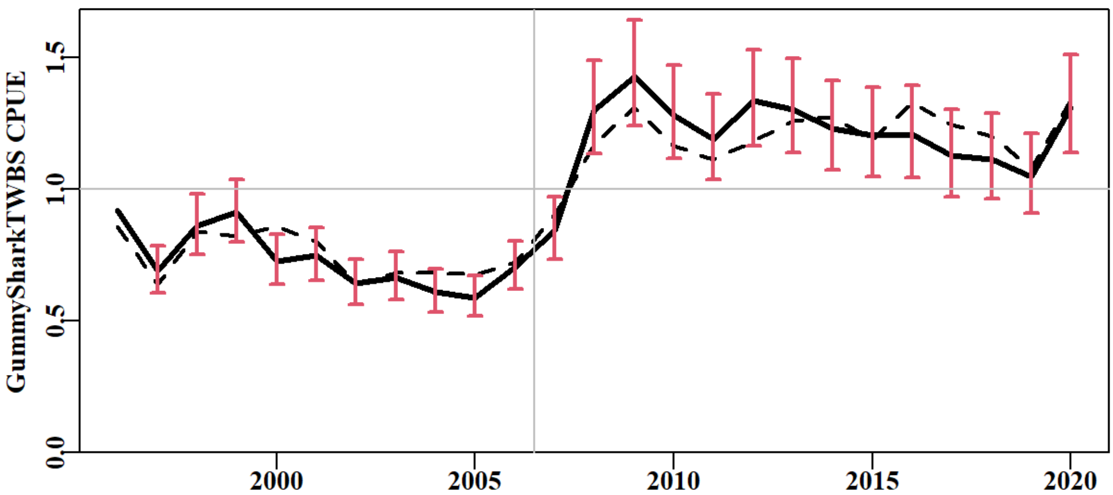

Figure 10.76. GummySharkTWBS standardization. The dashed black line represents the geometric mean catch rate, solid black line the standardized catch rates. The red bars are the 95% confidence intervals about the mean estimates. The graph scales both time-series of standardized catch rates relative to the mean of each time-series.

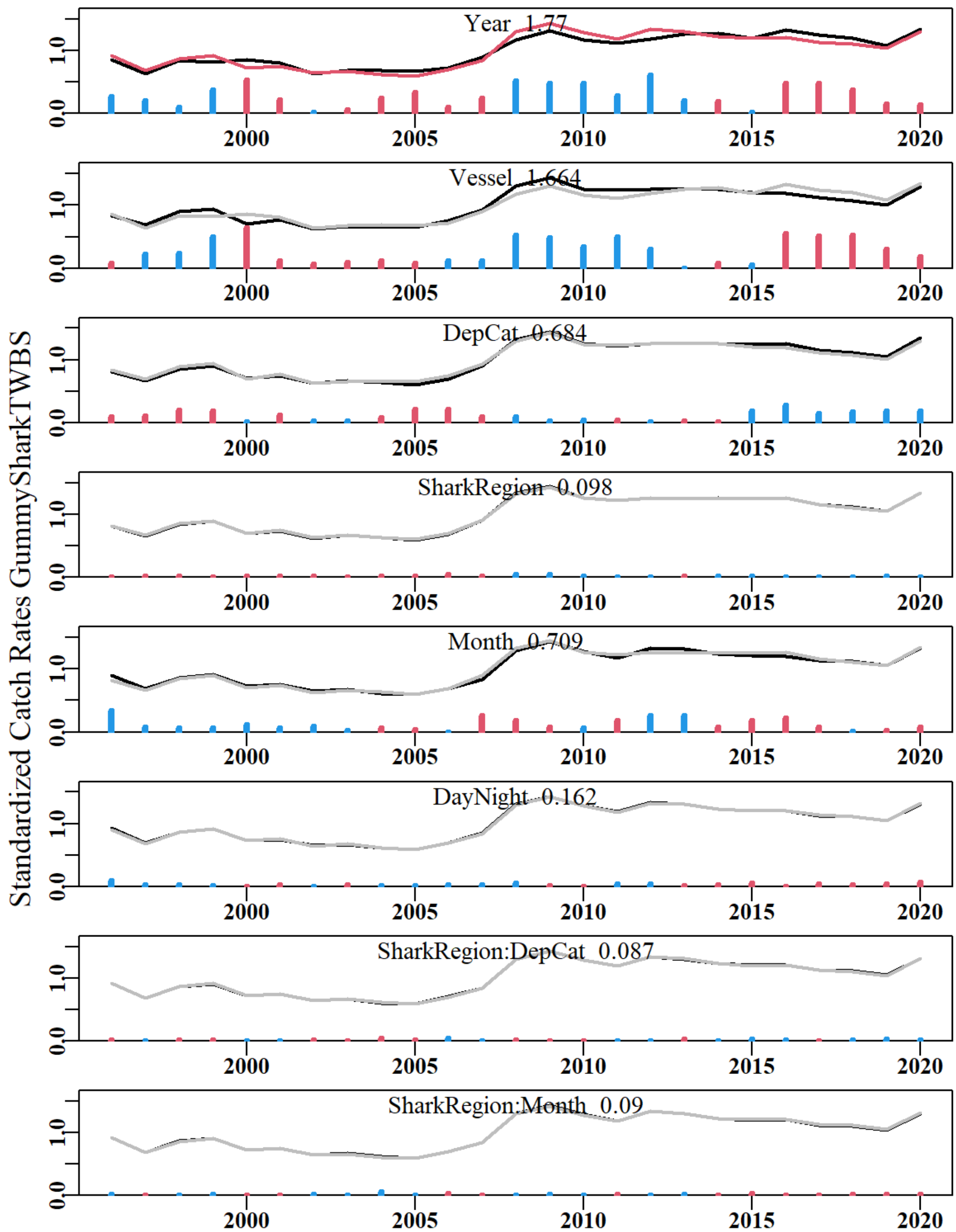

Figure 10.77. GummySharkTWBS. The influence of each factor on the optimal standardization. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by vertical bars with blue bars indicating the optimum model is higher than the 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.

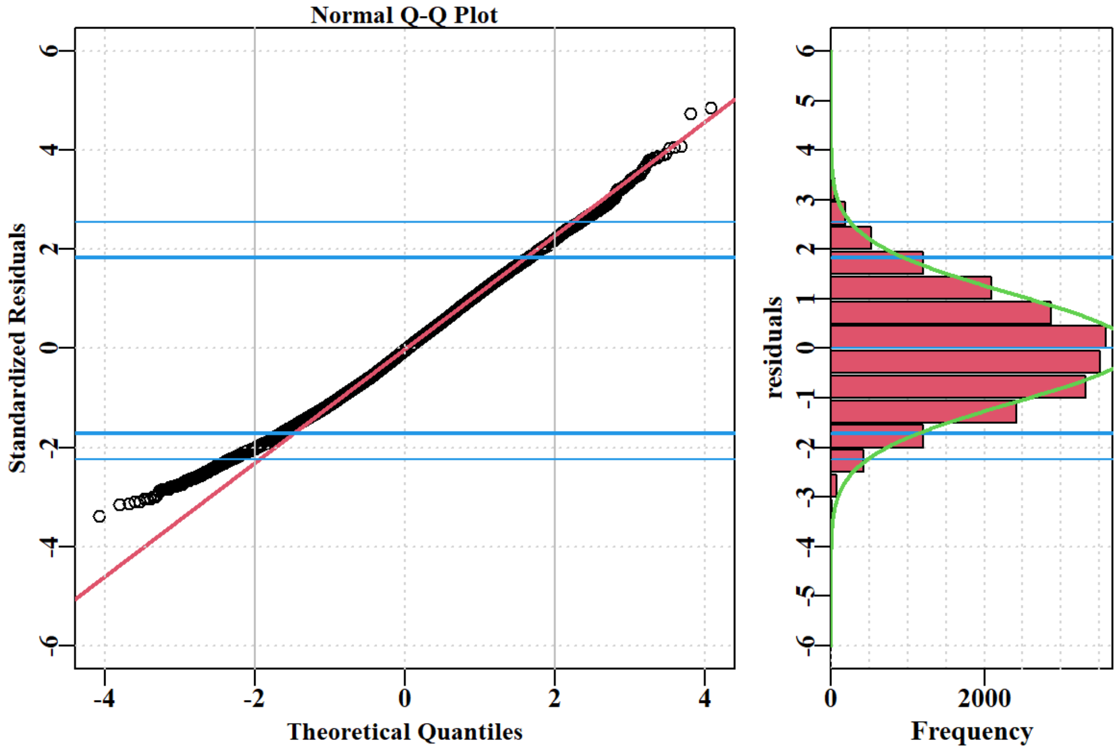

Figure 10.78. GummySharkTWBS. Diagnostic plots. The distribution of residuals from the optimum fit. The qqplot indicates the fit to the expected normality, while the histogram of residuals also illustrates the 1%, 5%, 95% and 99% quantiles to indicate the intensity of any lack of fit at the margins of the distribution (reflected also in the qqplot).

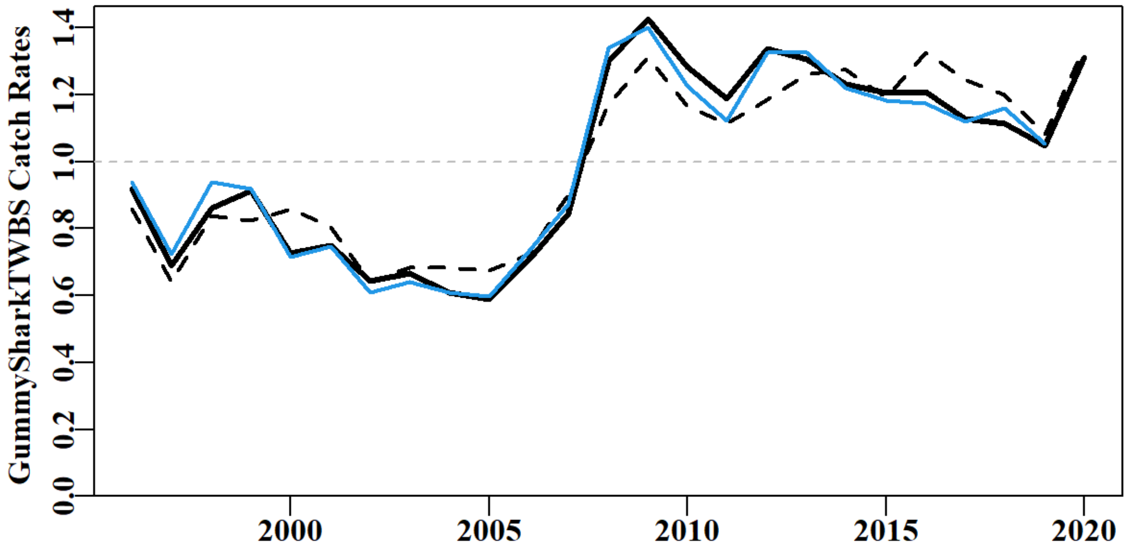

Figure 10.79. GummySharkTWBS. A comparison of the previous year's standardization (blue line) with this year's. They should lie on top of each other, although small deviations may relate to data adjustments, particularly in very recent years.

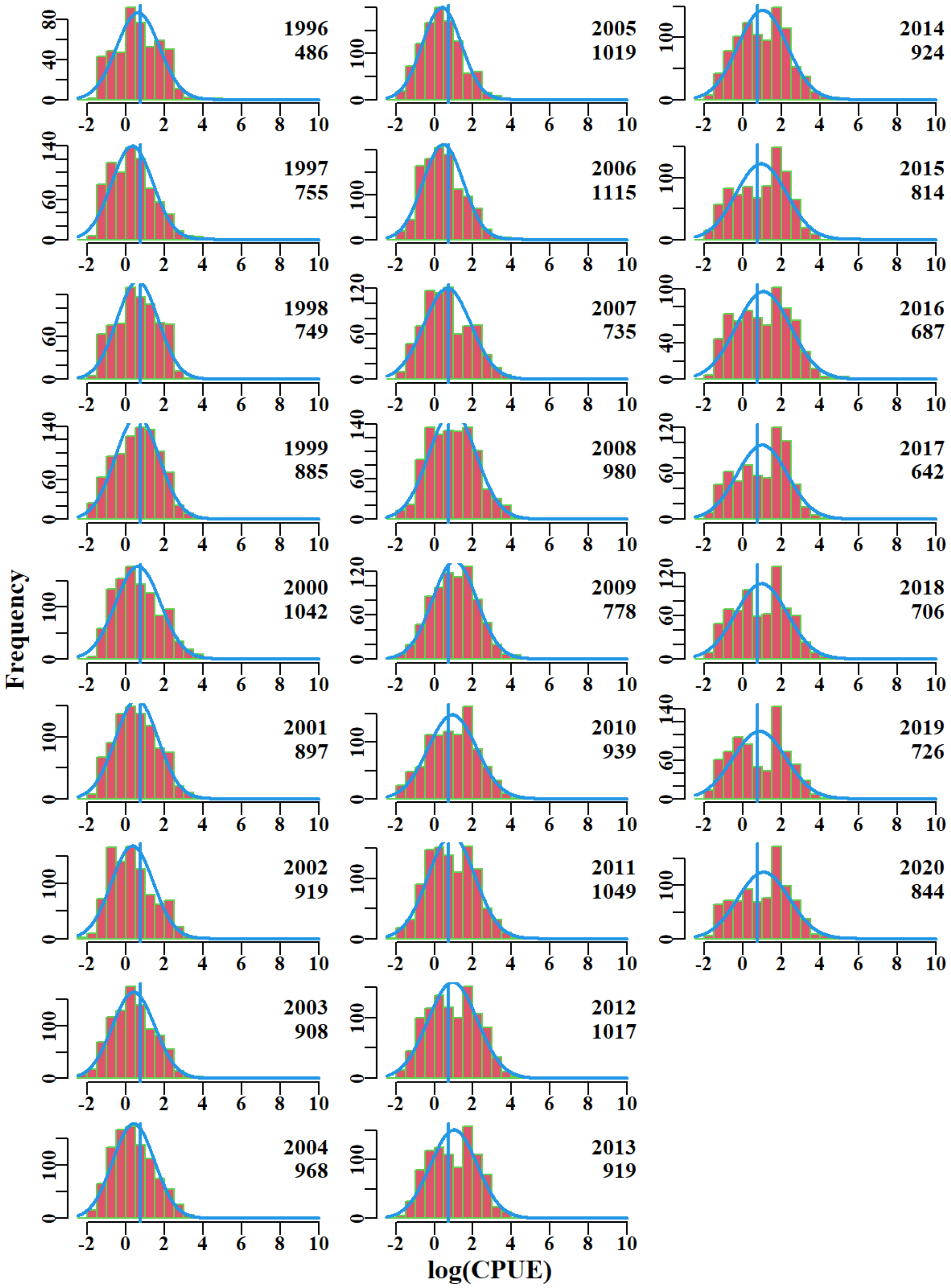

Figure 10.80. GummySharkTWBS. The natural log(CPUE) for each year of data available the blue lines are normal distributions fitted to the histogram frequencies. The numbers in each plot are the year and number of records. The vertical blue line is the average across all years.

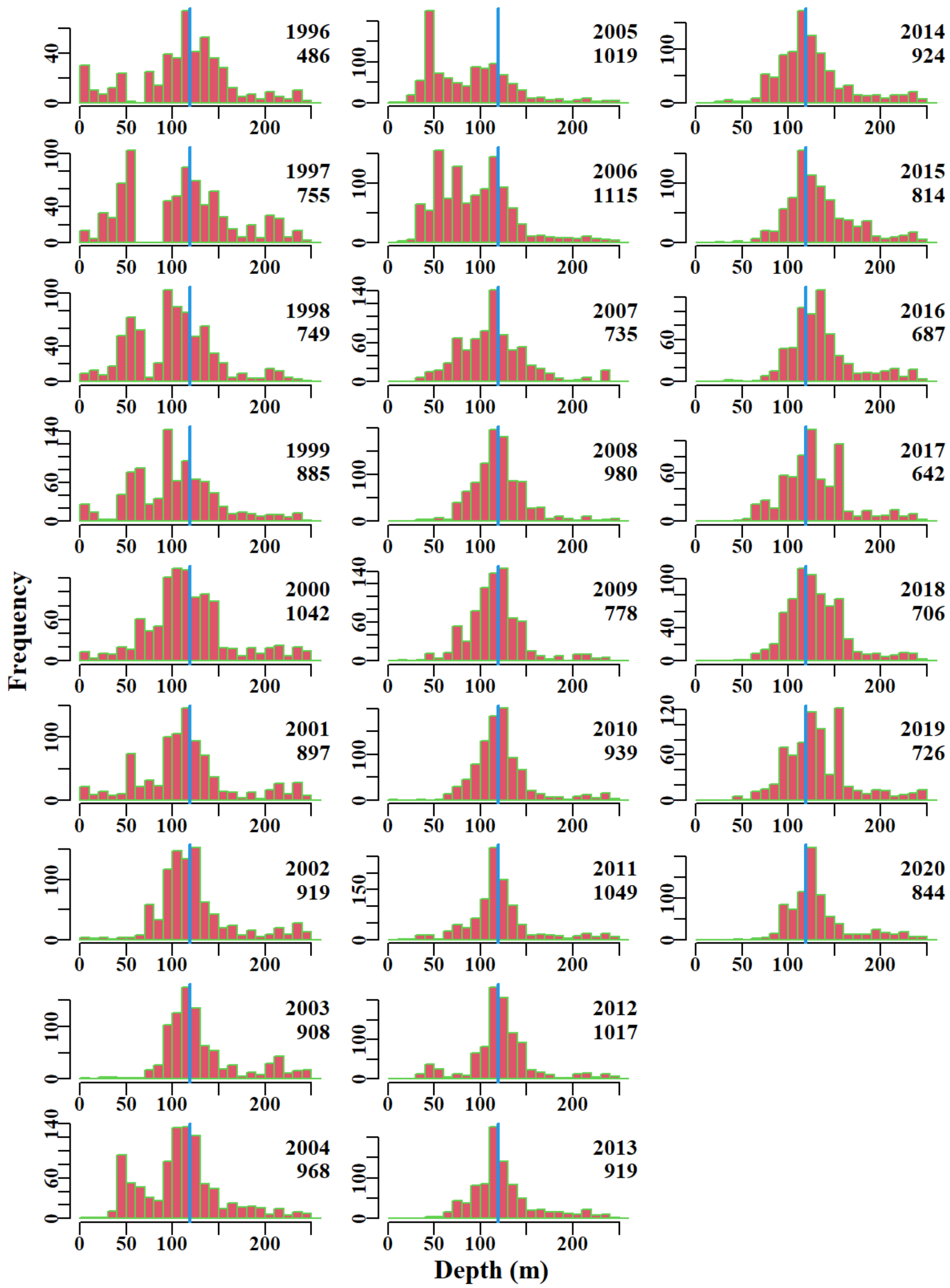

Figure 10.81. GummySharkTWBS. The average Depth of fishing for each year of data available to illustrate the development of the fishery through time. The numbers in each plot are the year and number of records. The vertical blue line is the average across all years.

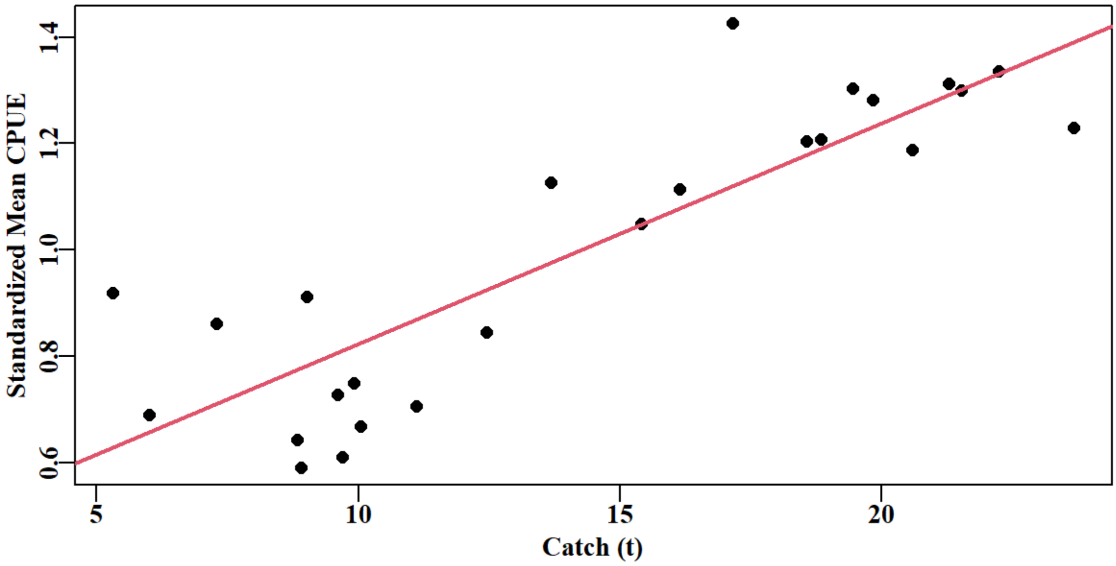

Figure 10.82. GummySharkTWBS. The linear relationship between annual mean CPUE and annual Catch.

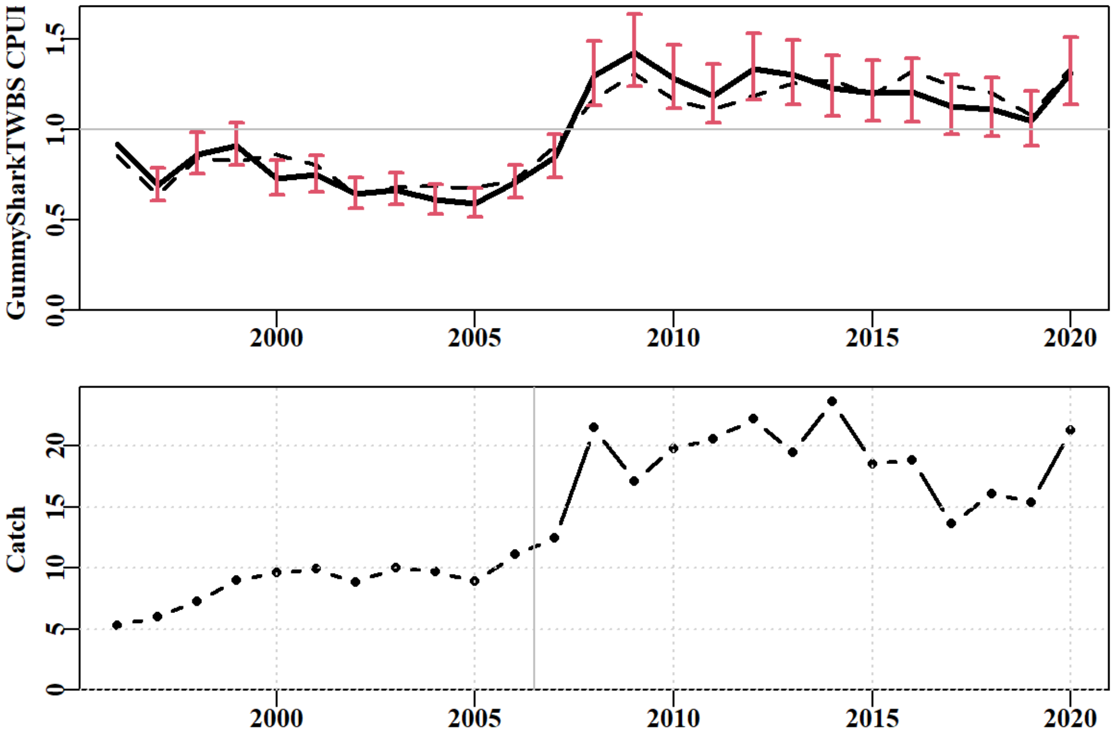

Figure 10.83. GummySharkTWBS. CPUE is correlated with catches through time. CPUE in the top plot and annual catch (t) in the lower plot.

10.13 Gummy shark: Trawl Tasmania: 1996 – 2020

CPUE (catch/hour) analysis used shots that reported catches of Gummy Shark (non zero shots). Since Gummy Shark are not targeted by trawl vessels, it is inappropriate to include zero catches in this 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.

10.13.1 *Inferences*

Most catch occurred in Shark region 7 followed by 6. Recorded logbook catch has been greater than 10 t per annum since 2016, the first time since 2005.

The terms Year, Vessel, Month, DepCat, DayNight and one interaction (SharkRegion:DepCat) had the greatest contribution to model fit based on the AIC and R^2 statistics (Table 10.47). The qqplot suggests a slight departure from the assumed Normal distribution, as depicted by the upper tail of the distribution (Figure 10.87). Annual standardized CPUE has been mostly noisy and flat and has increased above the long-term average since 2019, based on the 95% confidence intervals (Figure 10.85).

10.13.2 *Action Items and Issues*

Further consideration of whether to consider the CPUE time-series as a valid index of relative abundance for Gummy Shark needs to be explored.

Table 10.43. GummySharkTWTAS. The data selection criteria used to specify and identify the fishery data to be included in the analysis.

Property	Value
label	GummySharkTWTAS
csirocode	37017001
fishery	SET_GAB
depthrange	0 - 500
depthclass	20
zones	6, 7
methods	TW, TDO, OTT, OTB, TMO
years	1996 - 2020

Table 10.44. GummySharkTWTAS. 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

Year	Total	N	Catch	Vess	GeoM	Opt	StDev	C<30Kg	P<30Kg
1996	49.4	60	1.3	10	7.1	0.8550	0.000	1.235	0.954
1997	952.1	120	1.6	11	4.4	0.8442	0.159	1.268	0.813
1998	1401.2	64	1.0	12	4.5	0.6018	0.169	0.768	0.803
1999	1923.8	85	1.2	12	4.5	0.7267	0.169	1.070	0.870
2000	2436.9	151	2.3	16	4.3	0.7156	0.162	1.854	0.818
2001	1703.3	290	4.1	15	4.1	0.6314	0.161	3.138	0.767
2002	1527.2	605	10.2	16	4.9	0.7664	0.158	6.648	0.655
2003	1653.4	754	11.5	19	4.3	0.7507	0.158	8.762	0.761
2004	1670.4	656	10.1	17	4.5	0.7455	0.159	7.495	0.744
2005	1573.3	654	10.0	16	4.5	0.8361	0.159	6.138	0.616
2006	1577.1	554	9.8	13	4.8	0.8628	0.160	4.784	0.486
2007	1575.0	372	6.4	11	5.1	0.9517	0.162	3.187	0.497
2008	1727.9	374	5.4	10	4.2	0.8650	0.163	3.041	0.564
2009	1500.9	327	5.8	10	5.2	0.9629	0.163	2.637	0.453
2010	1404.9	272	6.8	10	6.9	1.2658	0.165	2.362	0.348
2011	1364.7	419	9.4	10	6.0	1.0303	0.162	3.738	0.400
2012	1304.4	374	7.4	9	5.4	0.9129	0.163	2.948	0.400
2013	1307.7	369	7.0	11	5.5	1.0112	0.163	3.334	0.474
2014	1389.1	310	7.7	11	6.7	1.0395	0.164	2.016	0.263
2015	1545.1	395	9.8	13	6.2	1.1389	0.162	4.280	0.436
2016	1586.5	594	15.7	12	7.6	1.3522	0.160	6.151	0.392
2017	1561.4	518	14.5	10	8.7	1.5263	0.161	5.341	0.367
2018	1560.1	501	12.7	12	6.9	1.3888	0.161	4.876	0.384
2019	1709.7	613	17.9	13	8.0	1.6892	0.160	8.401	0.469
2020	1840.5	502	13.2	10	7.3	1.5291	0.161	5.845	0.443

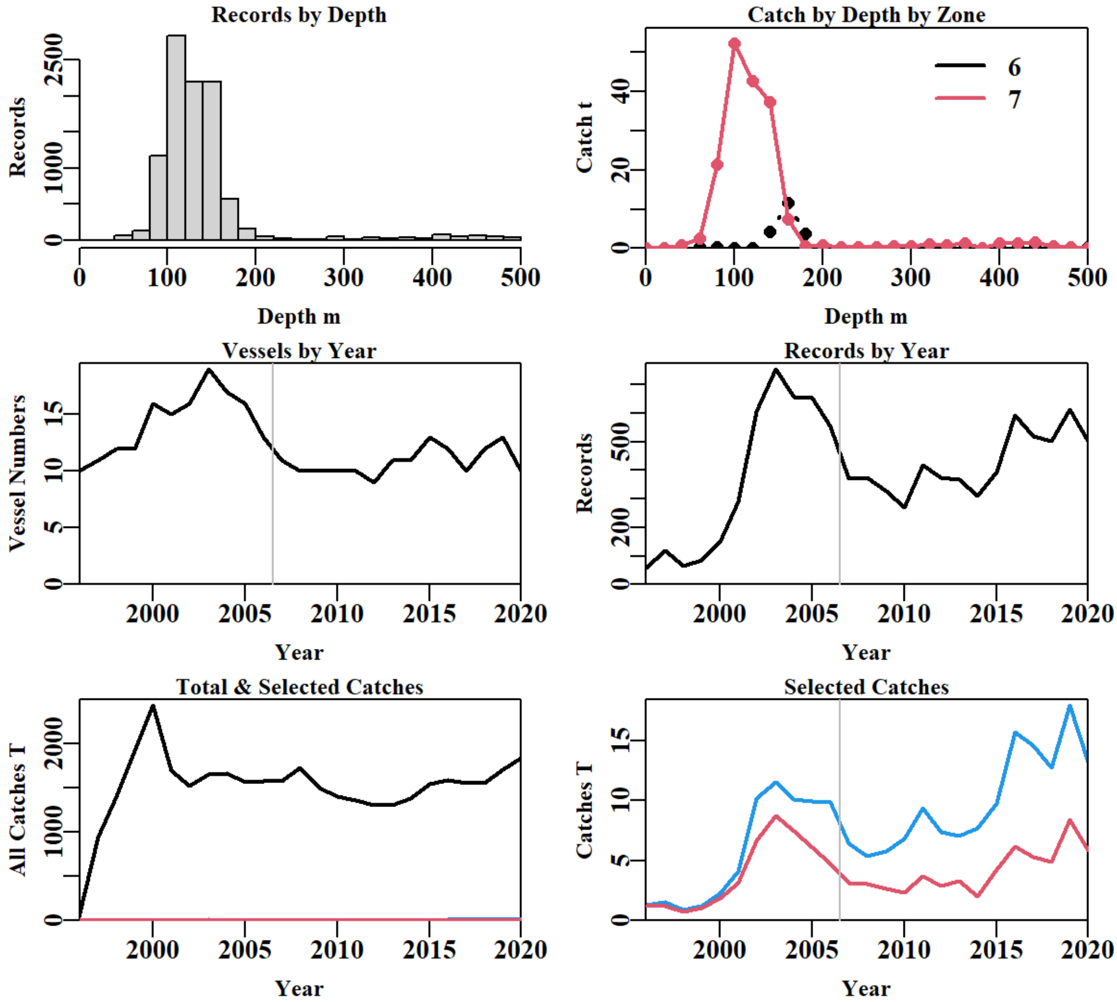

Figure 10.84. GummySharkTWTAS fishery details. The bottom left plot depicts all known catches (top black line), and all selected catches used in the analysis (middle blue line); the lower red line: selected catches < 30 kg).

Table 10.45. GummySharkTWTAS 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	440781	0	38380.76	0
NoCE	292807	147974	24403.69	13977.07
Depth	290364	2443	24246.85	156.84
Years	281876	8488	23773.33	473.53
Zones	20841	261035	1591.67	22181.65
Method	9933	10908	202.59	1389.08
Fishery	9933	0	202.59	0.00

Table 10.46. The models used to analyse data for GummySharkTWTAS

	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 10.47. GummySharkTWTAS. 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

Term	AIC	RSS	MSS	Nobs	Npars	adj_r2	%Change
Year	1002	10933	380	9933	25	3.1	0.00
Vessel	-1999	8002	3311	9933	74	28.7	25.61
DepCat	-1995	7965	3348	9933	99	28.9	0.15
SharkRegion	-2005	7956	3357	9933	100	29.0	0.08
Month	-2141	7830	3482	9933	111	30.0	1.04
DayNight	-2310	7695	3618	9933	113	31.2	1.20
SharkRegion:DepCat	-2320	7657	3656	9933	133	31.4	0.20
SharkRegion:Month	-2324	7667	3646	9933	124	31.4	0.17

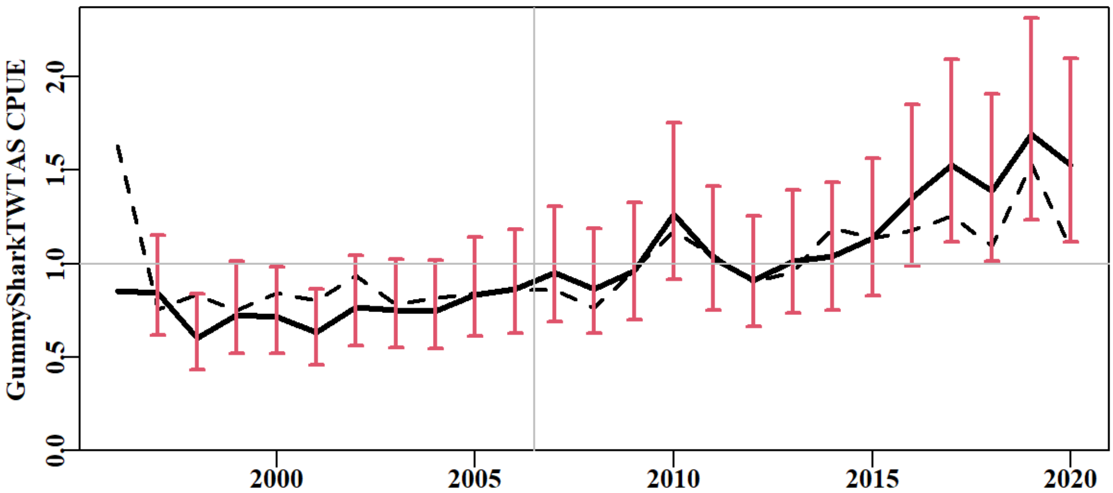

Figure 10.85. GummySharkTWTAS standardization. The dashed black line represents the geometric mean catch rate, solid black line the standardized catch rates. The red bars are the 95% confidence intervals about the mean estimates. The graph scales both time-series of standardized catch rates relative to the mean of each time-series.

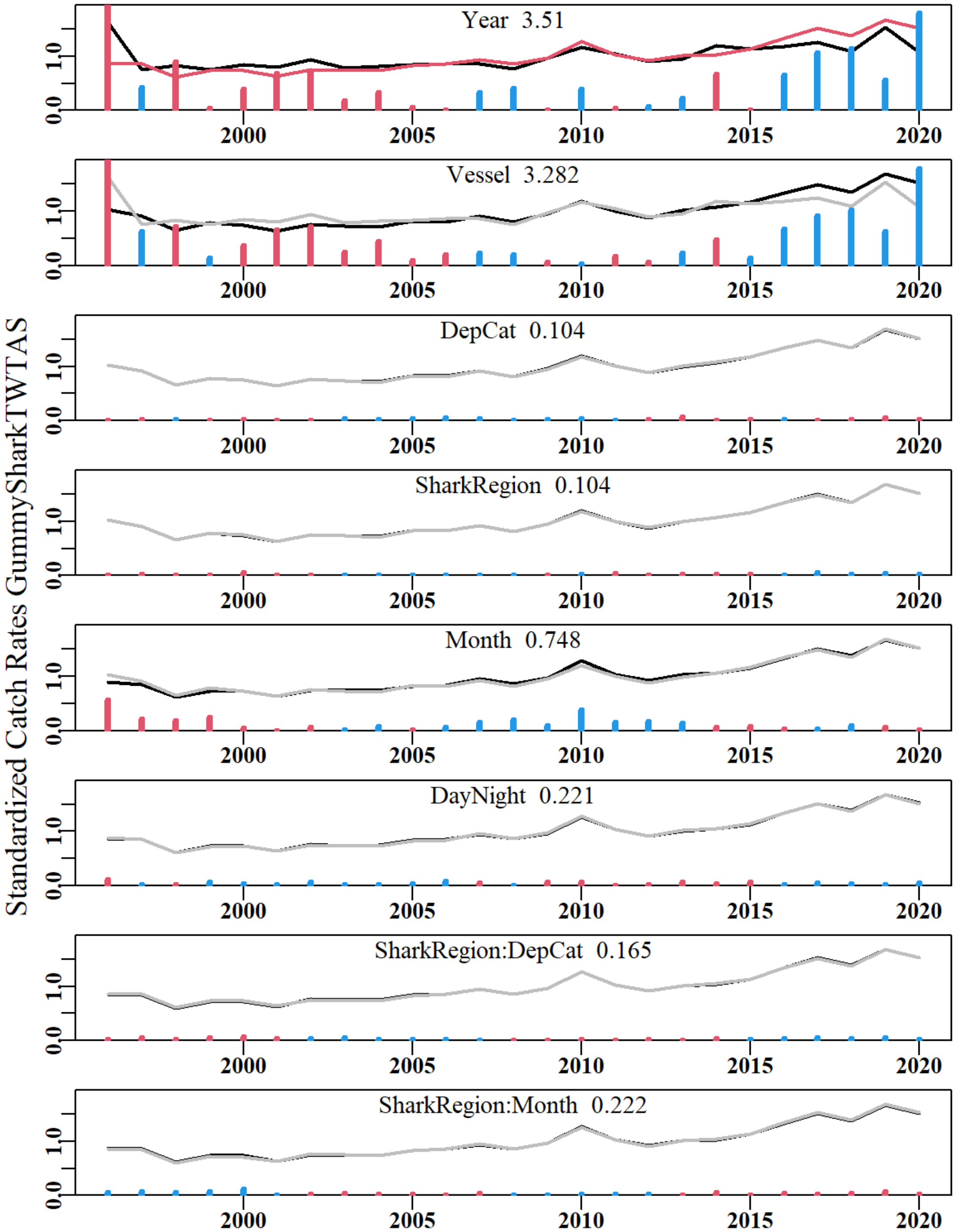

Figure 10.86. GummySharkTWTAS. The influence of each factor on the optimal standardization. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by vertical bars with blue bars indicating the optimum model is higher than the 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.

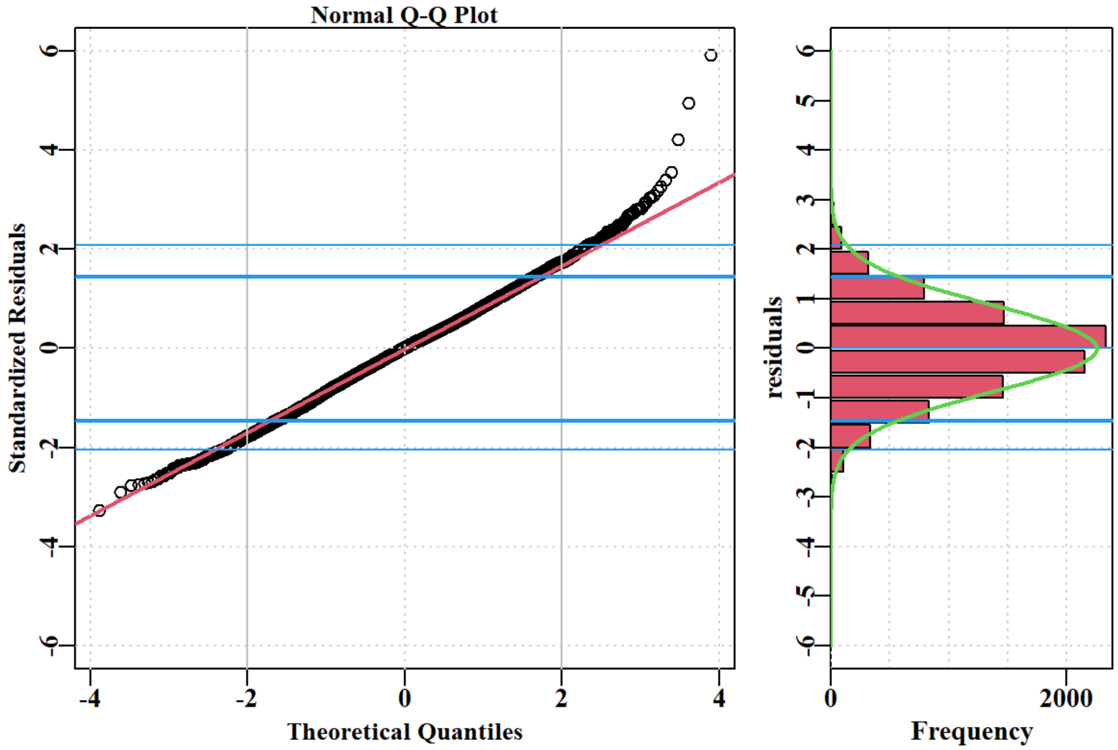

Figure 10.87. GummySharkTWTAS. Diagnostic plots. The distribution of residuals from the optimum fit. The qqplot indicates the fit to the expected normality, while the histogram of residuals also illustrates the 1%, 5%, 95% and 99% quantiles to indicate the intensity of any lack of fit at the margins of the distribution (reflected also in the qqplot).

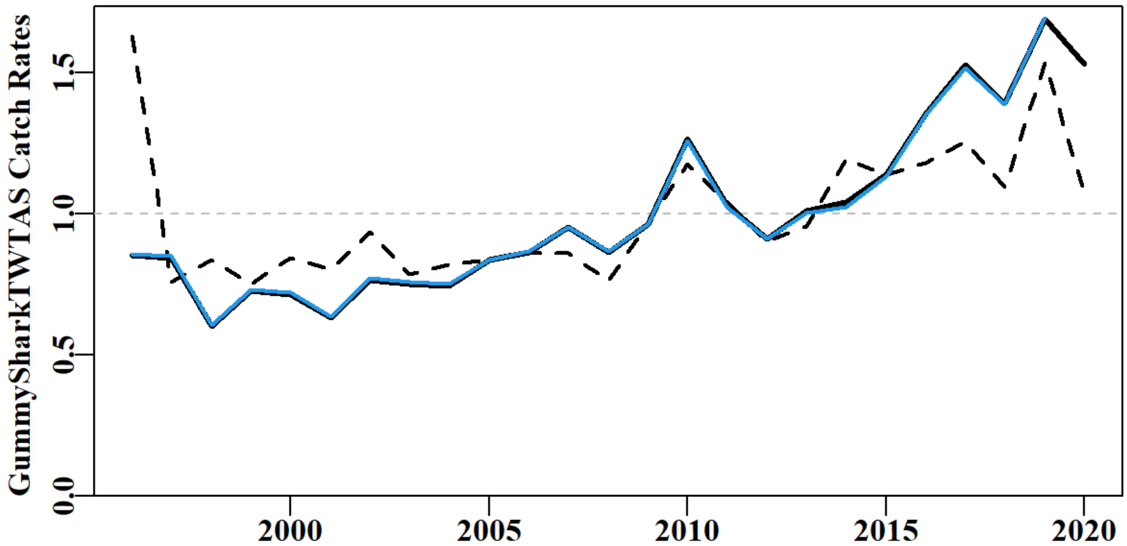

Figure 10.88. GummySharkTWTAS. A comparison of the previous year's standardization (blue line) with this year's. They should lie on top of each other, although small deviations may relate to data adjustments, particularly in very recent years.

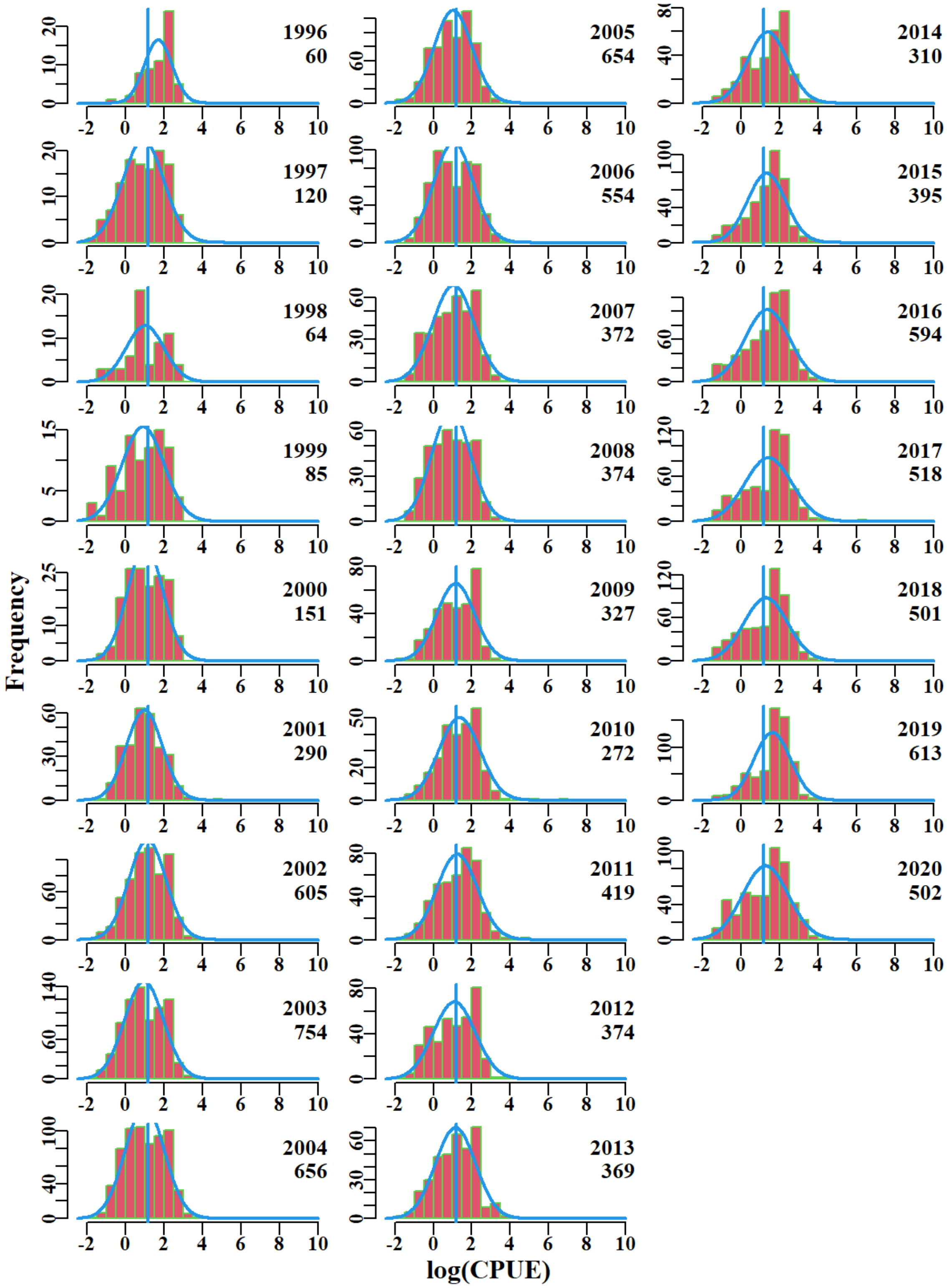

Figure 10.89. GummySharkTWTAS. The natural log(CPUE) for each year of data available the blue lines are normal distributions fitted to the histogram frequencies. The numbers in each plot are the year and number of records. The vertical blue line is the average across all years.

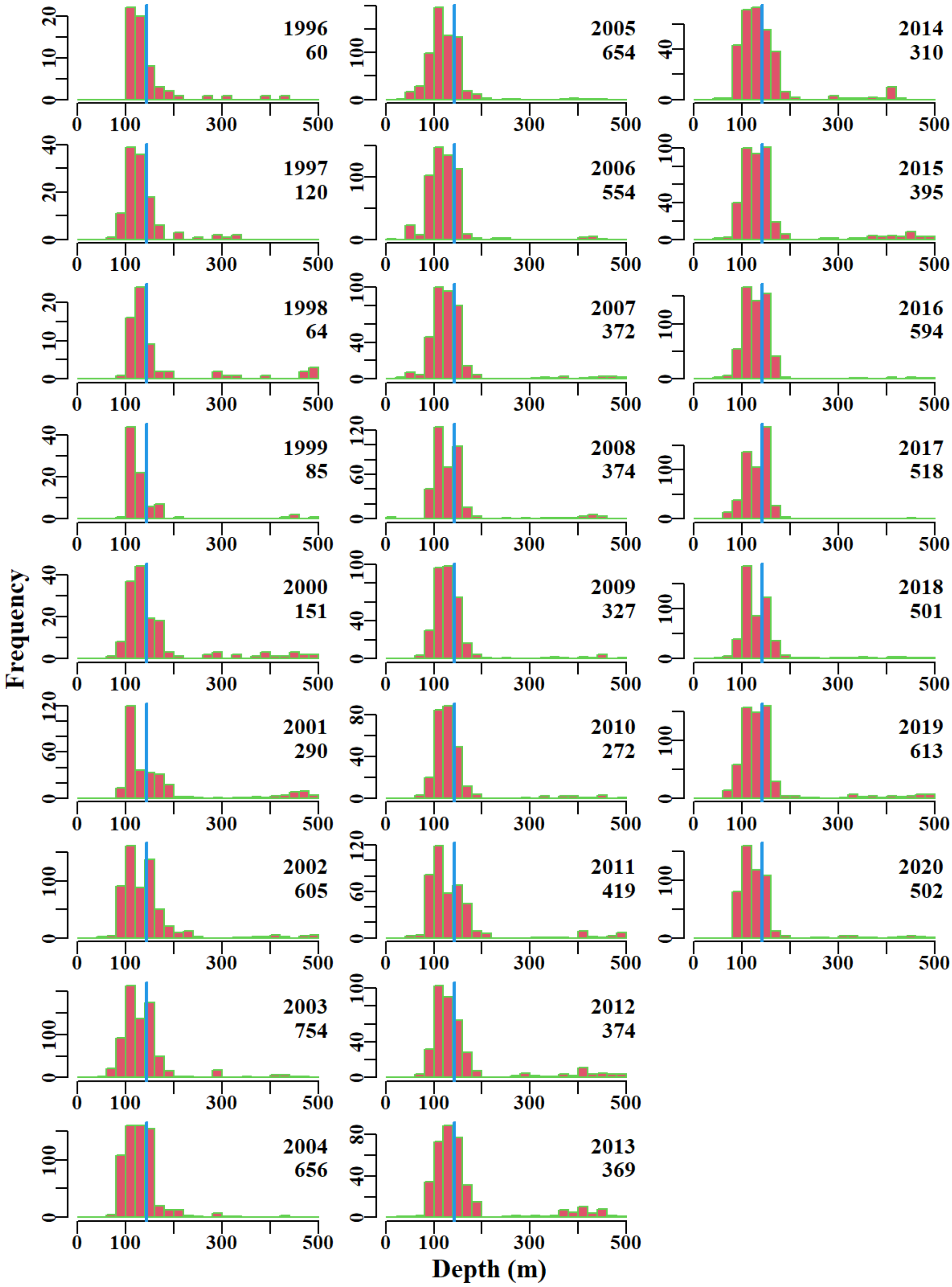

Figure 10.90. GummySharkTWTAS. The average Depth of fishing for each year of data available to illustrate the development of the fishery through time. The numbers in each plot are the year and number of records. The vertical blue line is the average across all years.

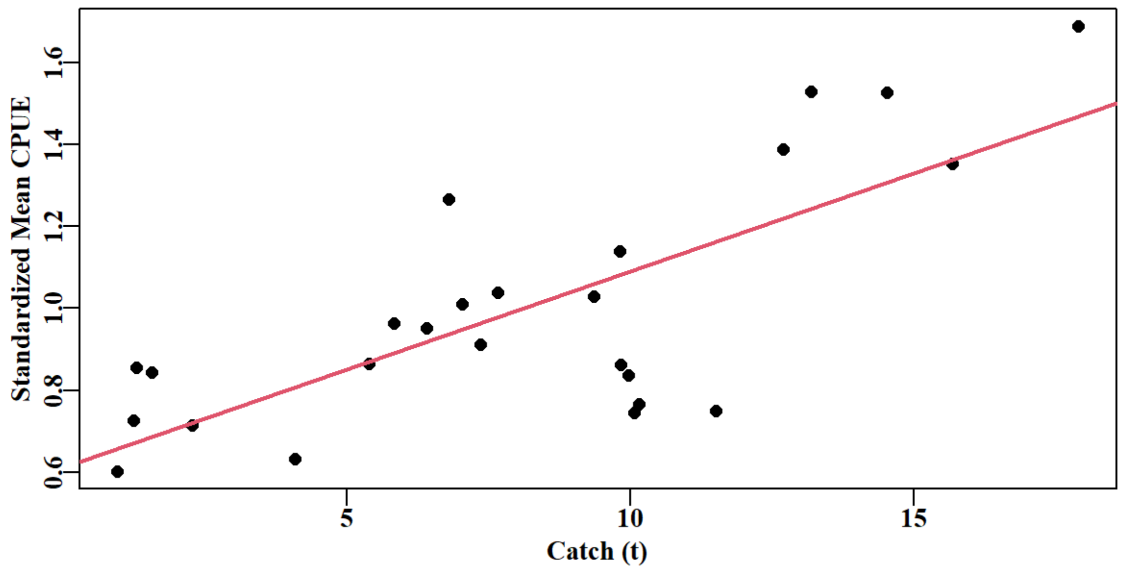

Figure 10.91. GummySharkTWTAS. The linear relationship between annual mean CPUE and annual Catch.

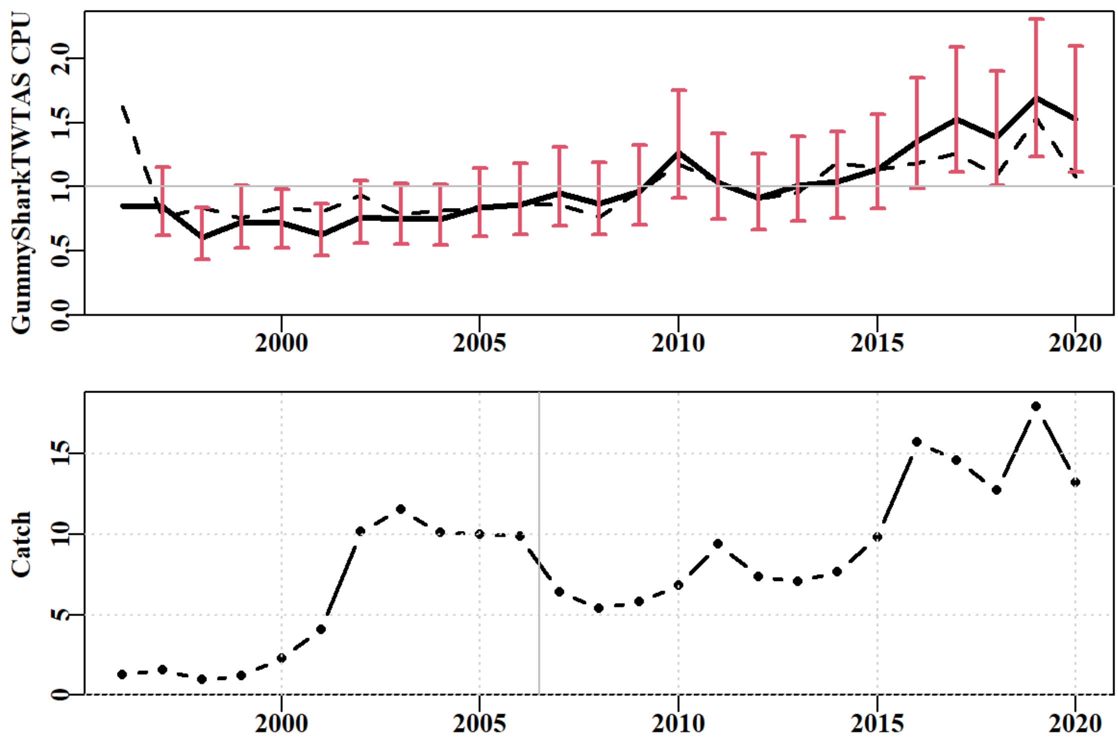

Figure 10.92. GummySharkTWTAS. CPUE is correlated with catches through time. CPUE in the top plot and annual catch (t) in the lower plot.

10.14 Gummy shark: Trawl Tasmania 2022 – 2020

CPUE (catch/hour) analysis used shots that reported catches of Gummy Shark (non zero shots). Since Gummy Shark are not targeted by trawl vessels, it is inappropriate to include zero catches in the analysis. Annual catches between 1996 and 2001 are small (between approximately 1 t to 4 t). Therefore, this series analysed from 2002 onwards.

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.

10.14.1 *Inferences*

Most catch occurred in Shark region 7 followed by 6. Recorded logbook catch has been greater than 10 t per annum since 2016, the first time since 2005.

The terms Year, Vessel, Month, DepCat, DayNight and one interaction (SharkRegion:DepCat) had the greatest contribution to model fit based on the AIC and R^2 statistics (Table 10.52). The qqplot suggests a slight departure from the assumed Normal distribution, as depicted by the upper tail of the distribution (Figure 10.96). Annual standardized CPUE has mostly increased since about 2014 and has been above the long-term average since 2016 (accounting for the 95% confidence intervals) (Figure 10.94).

10.14.2 *Action Items and Issues*

Further consideration of whether to consider the CPUE time-series as a valid index of relative abundance for Gummy Shark needs to be explored.

Table 10.48. GummySharkTWTAS. The data selection criteria used to specify and identify the fishery data to be included in the analysis.

Property	Value
label	GummySharkTWTAS
csirocode	37017001
fishery	SET
depthrange	0 - 500
depthclass	20
zones	6, 7
methods	TW, TDO, OTT, OTB, TMO
years	2002 - 2020

Table 10.49. GummySharkTWTAS. 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

Year	Total	N	Catch	Vess	GeoM	Opt	StDev	C<30Kg	P<30Kg
2002	1527.2	605	10.2	16	4.9	0.6883	0.000	6.648	0.655
2003	1653.4	754	11.5	19	4.3	0.6690	0.053	8.762	0.761
2004	1670.4	656	10.1	17	4.5	0.6681	0.054	7.495	0.744
2005	1573.3	654	10.0	16	4.5	0.7550	0.055	6.138	0.616
2006	1577.1	554	9.8	13	4.8	0.7866	0.058	4.784	0.486
2007	1575.0	372	6.4	11	5.1	0.8683	0.064	3.187	0.497
2008	1727.9	374	5.4	10	4.2	0.7945	0.064	3.041	0.564
2009	1500.9	327	5.8	10	5.2	0.8861	0.067	2.637	0.453
2010	1404.9	272	6.8	10	6.9	1.1798	0.072	2.362	0.348
2011	1364.7	419	9.4	10	6.0	0.9563	0.063	3.738	0.400
2012	1304.4	374	7.4	9	5.4	0.8484	0.064	2.948	0.400
2013	1307.7	369	7.0	11	5.5	0.9353	0.065	3.334	0.474
2014	1389.1	310	7.7	11	6.7	0.9498	0.069	2.016	0.263
2015	1545.1	395	9.8	13	6.2	1.0493	0.064	4.280	0.436
2016	1586.5	594	15.7	12	7.6	1.2461	0.057	6.151	0.392
2017	1561.4	518	14.5	10	8.7	1.4177	0.060	5.341	0.367
2018	1560.1	501	12.7	12	6.9	1.2943	0.061	4.876	0.384
2019	1709.7	613	17.9	13	8.0	1.5706	0.059	8.401	0.469
2020	1840.5	502	13.2	10	7.3	1.4366	0.062	5.845	0.443

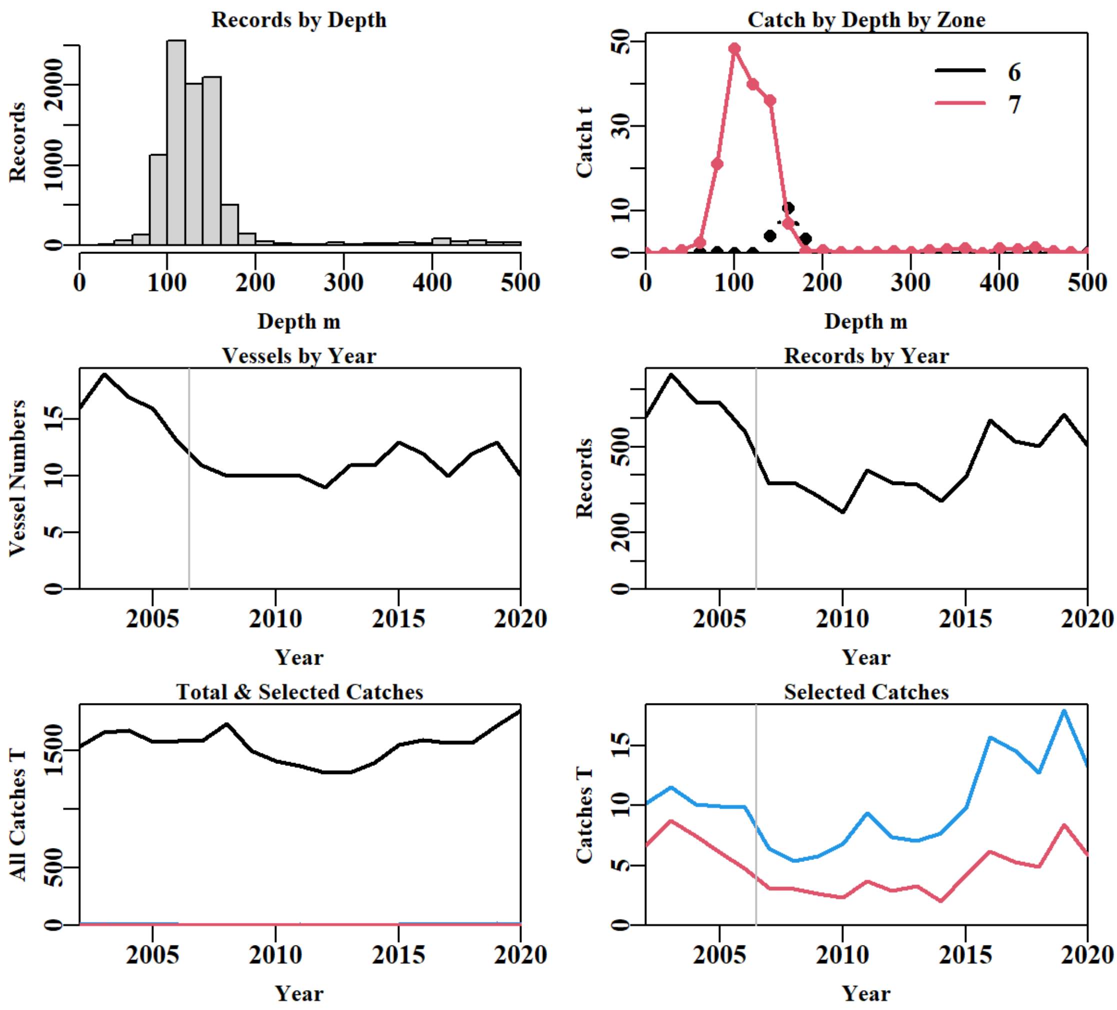

Figure 10.93. GummySharkTWTAS fishery details. The bottom left plot depicts all known catches (top black line), and all selected catches used in the analysis (middle blue line); the lower red line: selected catches < 30 kg).

Table 10.50. GummySharkTWTAS 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.

Term	Records	Difference	Catch	Difference
Total	440781	0	38380.76	0
NoCE	292807	147974	24403.69	13977.07
Depth	290364	2443	24246.85	156.84
Years	220466	69898	20294.61	3952.24
Zones	18822	201644	1462.81	18831.80
Method	9163	9659	191.20	1271.62
Fishery	9163	0	191.20	0.00

Table 10.51. The models used to analyse data for GummySharkTWTAS

	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 10.52. GummySharkTWTAS. 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

Term	AIC	RSS	MSS	Nobs	Npars	adj_r2	%Change
Year	1040	10222	331	9163	19	2.9	0
Vessel	-1827	7419	3134	9163	54	29.3	26.34
DepCat	-1826	7379	3173	9163	79	29.5	0.18
SharkRegion	-1837	7369	3184	9163	80	29.6	0.09
Month	-1978	7239	3313	9163	91	30.7	1.16
DayNight	-2144	7106	3447	9163	93	32.0	1.26
SharkRegion:DepCat	-2139	7079	3474	9163	113	32.1	0.11
SharkRegion:Month	-2157	7079	3474	9163	104	32.2	0.18

Figure 10.94. GummySharkTWTAS 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.

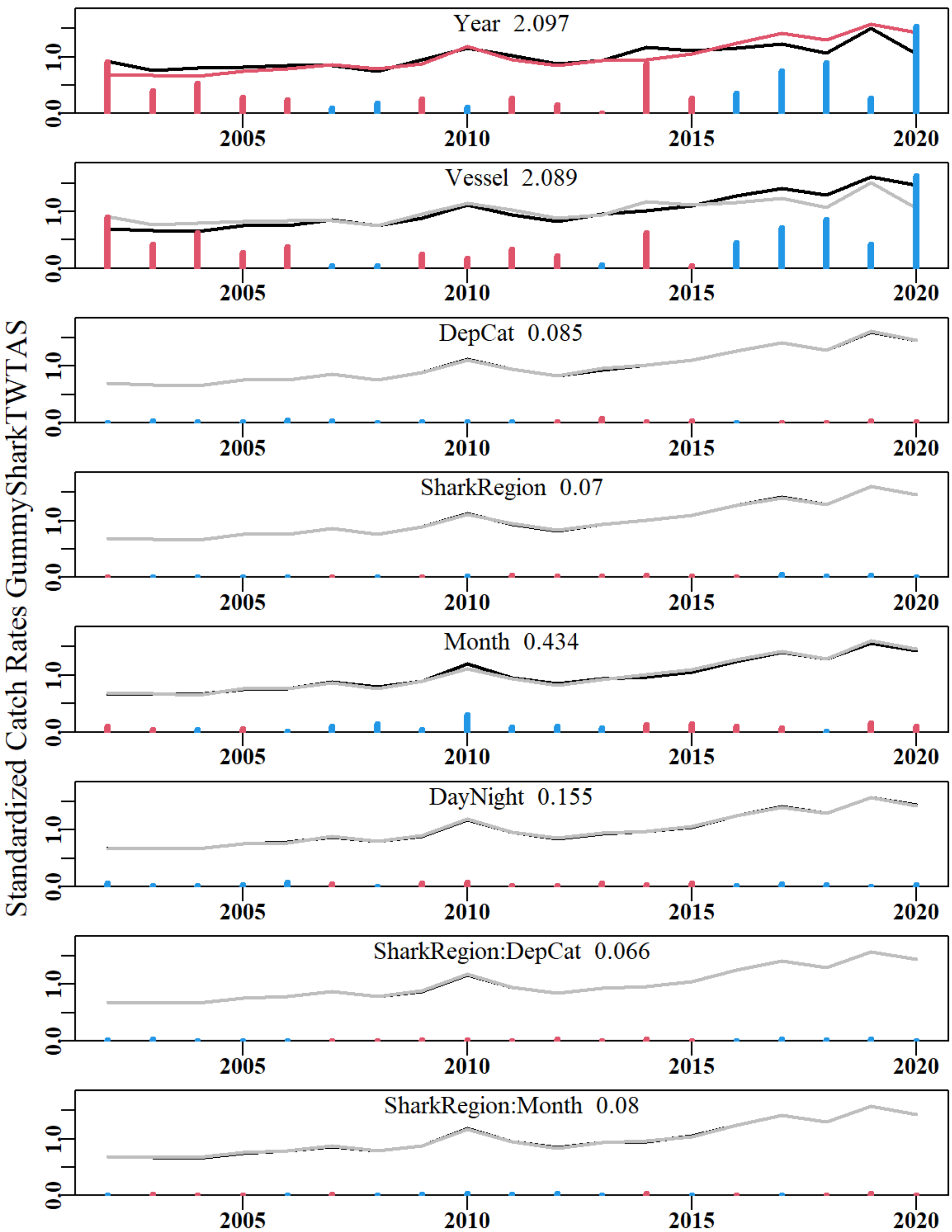

Figure 10.95. GummySharkTWTAS. The influence of each factor on the optimal standardization. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by vertical bars with blue bars indicating the optimum model is higher than the 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.

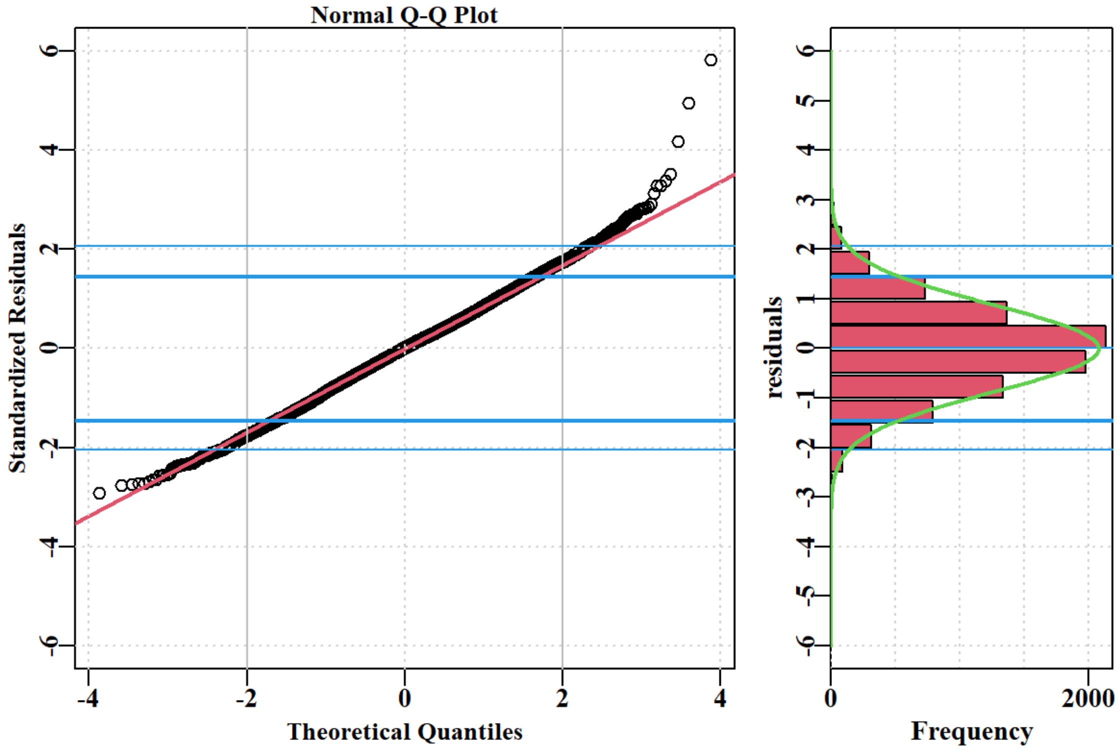

Figure 10.96. GummySharkTWTAS. Diagnostic plots. The distribution of residuals from the optimum fit. The qqplot indicates the fit to the expected normality, while the histogram of residuals also illustrates the 1%, 5%, 95% and 99% quantiles to indicate the intensity of any lack of fit at the margins of the distribution (reflected also in the qqplot).

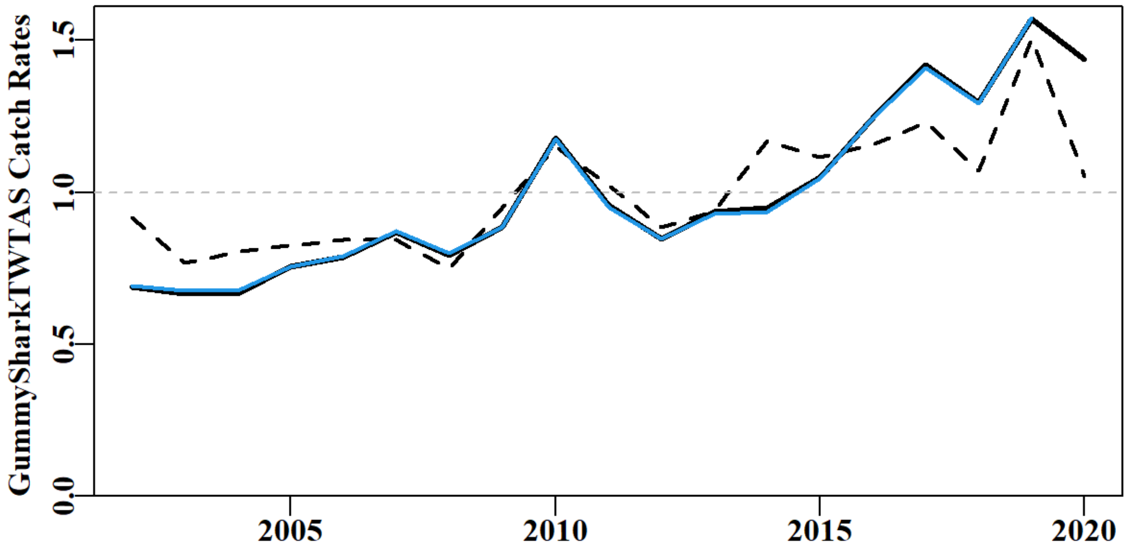

Figure 10.97. GummySharkTWTAS. A comparison of the previous year's standardization (blue line) with this year's. They should lie on top of each other, although small deviations may relate to data adjustments, particularly in very recent years.

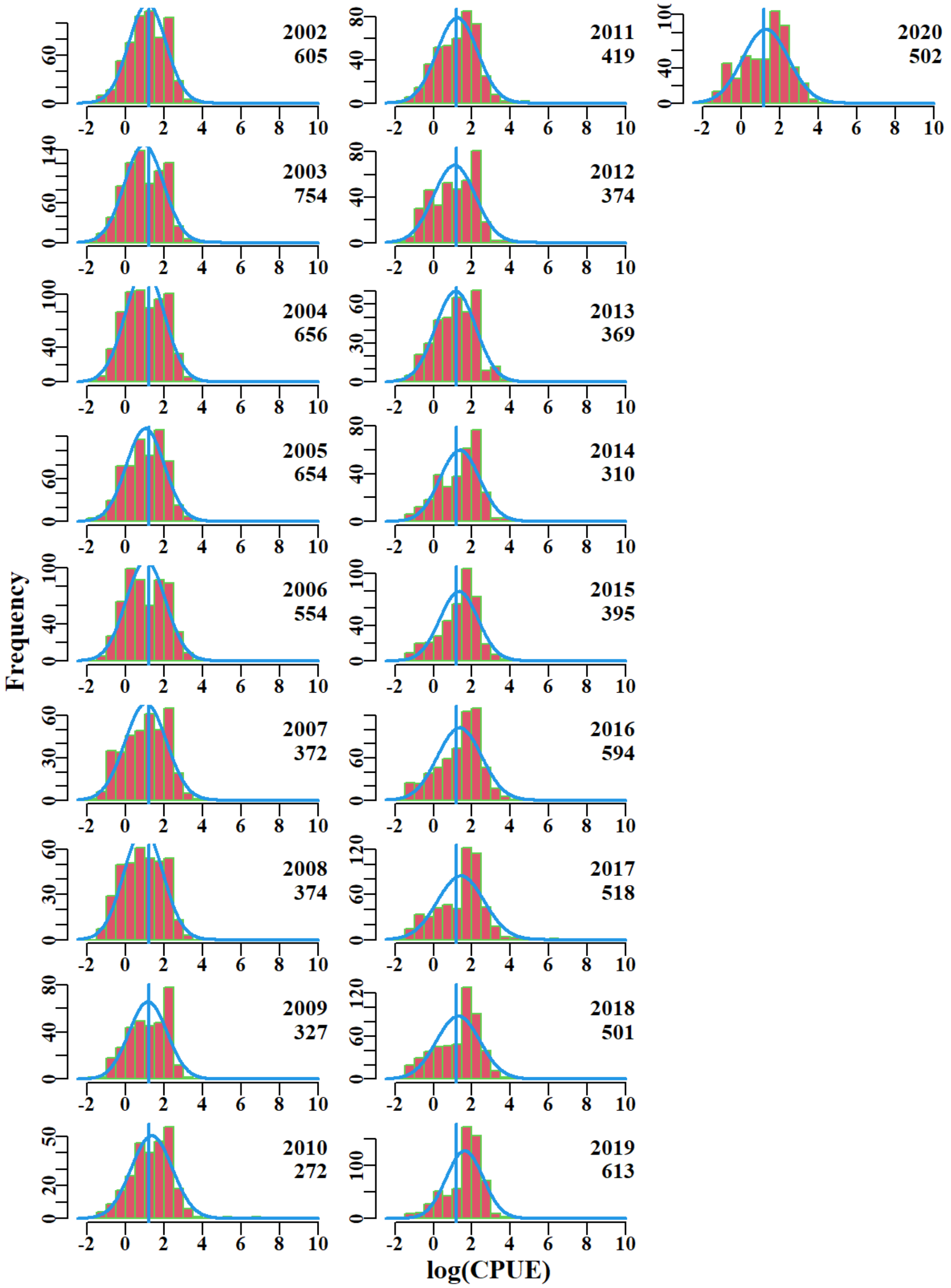

Figure 10.98. GummySharkTWTAS. The natural log(CPUE) for each year of data available the blue lines are normal distributions fitted to the histogram frequencies. The numbers in each plot are the year and number of records. The vertical blue line is the average across all years.

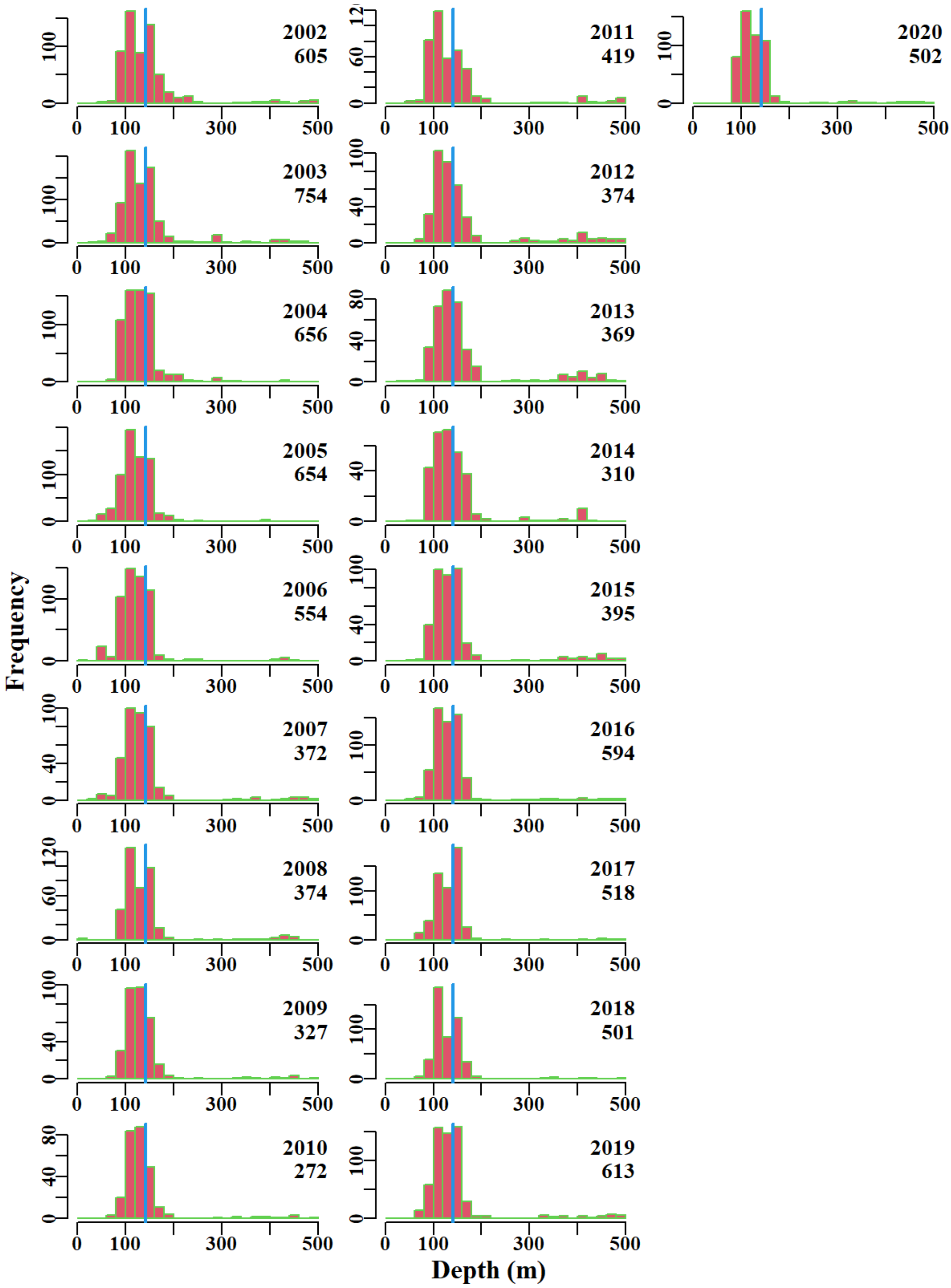

Figure 10.99. GummySharkTWTAS. The average Depth of fishing for each year of data available to illustrate the development of the fishery through time. The numbers in each plot are the year and number of records. The vertical blue line is the average across all years.

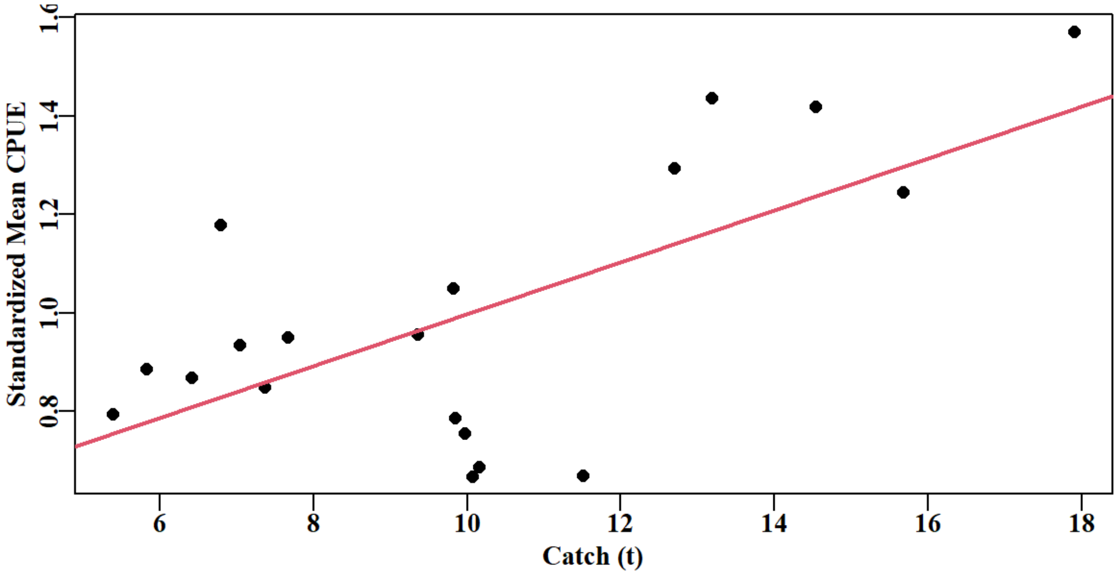

Figure 10.100. GummySharkTWTAS. The linear relationship between annual mean CPUE and annual Catch.

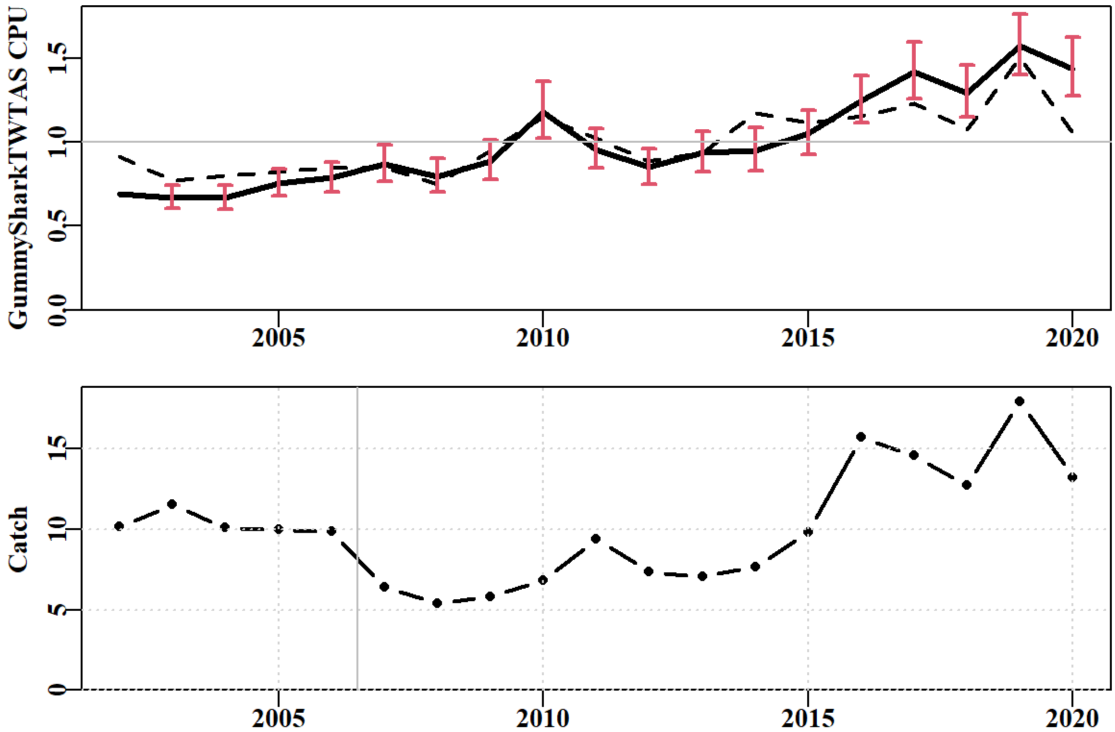

Figure 10.101. GummySharkTWTAS. CPUE is correlated with catches through time. CPUE in the top plot and annual catch (t) in the lower plot.

10.15 Gummy shark Bottom Line

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) one effort unit (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.

10.15.1 *Inferences*

Most catch occurred in Shark region 2, followed by 5 and 3. Recorded catch of Gummy Shark by bottom line used in analysis decreased between 2013 – 2016 (i.e., 229 t to 154 t) and has increased since then. Also, the 405 t recorded in 2019 is the largest in the time series.

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 10.57). The qqplot suggests a slight departure from the assumed Normal distribution, as depicted by both tails of the distribution (Figure 10.105). Annual standardized CPUE has been noisy and mostly flat since the start of the time series (Figure 10.103).

10.15.2 *Action Items and Issues*

Further consideration of whether to consider the CPUE time-series as a valid index of relative abundance for Gummy Shark needs to be explored. Also, a detailed analysis of effort units pertaining to line methods should be investigated to determine whether (i) one effort unit (iii) or some combination could be used as an alternative effort unit in the standardization analyses.

Table 10.53. 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, LLD
years	1998 - 2020

Table 10.54. 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/shot), standard deviation (StDev) relates to the optimum model. C<30Kg denotes the amount of catch in shots of <30kg, and P<30Kg is the proportion of total. The optimum model was SharkRegion:Month

Year	Total	N	Catch	Vess	GeoM	Opt	StDev	C<30Kg	P<30Kg
1998	1401.2	72	8.5	3	123.8	0.6296	0.000	0.180	0.021
1999	1923.8	333	46.7	13	150.8	0.8342	0.152	0.656	0.014
2000	2436.9	481	111.4	14	276.2	1.0906	0.166	0.927	0.008
2001	1703.3	541	58.7	23	130.4	0.6618	0.166	2.494	0.043
2002	1527.2	495	59.0	21	136.5	0.7417	0.167	2.242	0.038
2003	1653.4	619	64.5	27	120.3	0.8021	0.153	2.949	0.046
2004	1670.4	640	66.9	24	119.8	0.8318	0.152	2.912	0.044
2005	1573.3	578	59.6	24	117.9	0.9884	0.155	2.713	0.046
2006	1577.1	495	48.7	19	105.5	1.0638	0.157	2.909	0.060
2007	1575.0	625	54.4	19	88.9	0.9393	0.156	4.651	0.085
2008	1727.9	599	50.1	16	91.8	0.6965	0.158	4.368	0.087
2009	1500.9	819	67.0	15	86.4	0.8009	0.156	5.516	0.082
2010	1404.9	684	72.0	19	119.4	0.9490	0.157	3.713	0.052
2011	1364.7	1048	87.6	28	96.5	1.0284	0.156	5.974	0.068
2012	1304.4	1407	124.2	24	97.8	1.0474	0.156	7.392	0.060
2013	1307.7	2700	248.2	28	101.9	1.1759	0.155	14.130	0.057
2014	1389.1	3106	248.0	30	86.9	0.9602	0.155	20.085	0.081
2015	1545.1	2420	231.3	29	99.9	1.2091	0.155	13.932	0.060
2016	1586.5	1421	153.5	27	122.7	1.0439	0.156	7.420	0.048
2017	1561.4	1896	289.6	33	183.0	1.2292	0.155	8.014	0.028
2018	1560.1	2241	357.8	39	186.1	1.4283	0.155	9.700	0.027
2019	1709.7	2832	405.4	48	163.3	1.5346	0.155	11.598	0.029
2020	1840.5	3074	392.3	42	137.7	1.3133	0.156	15.670	0.040

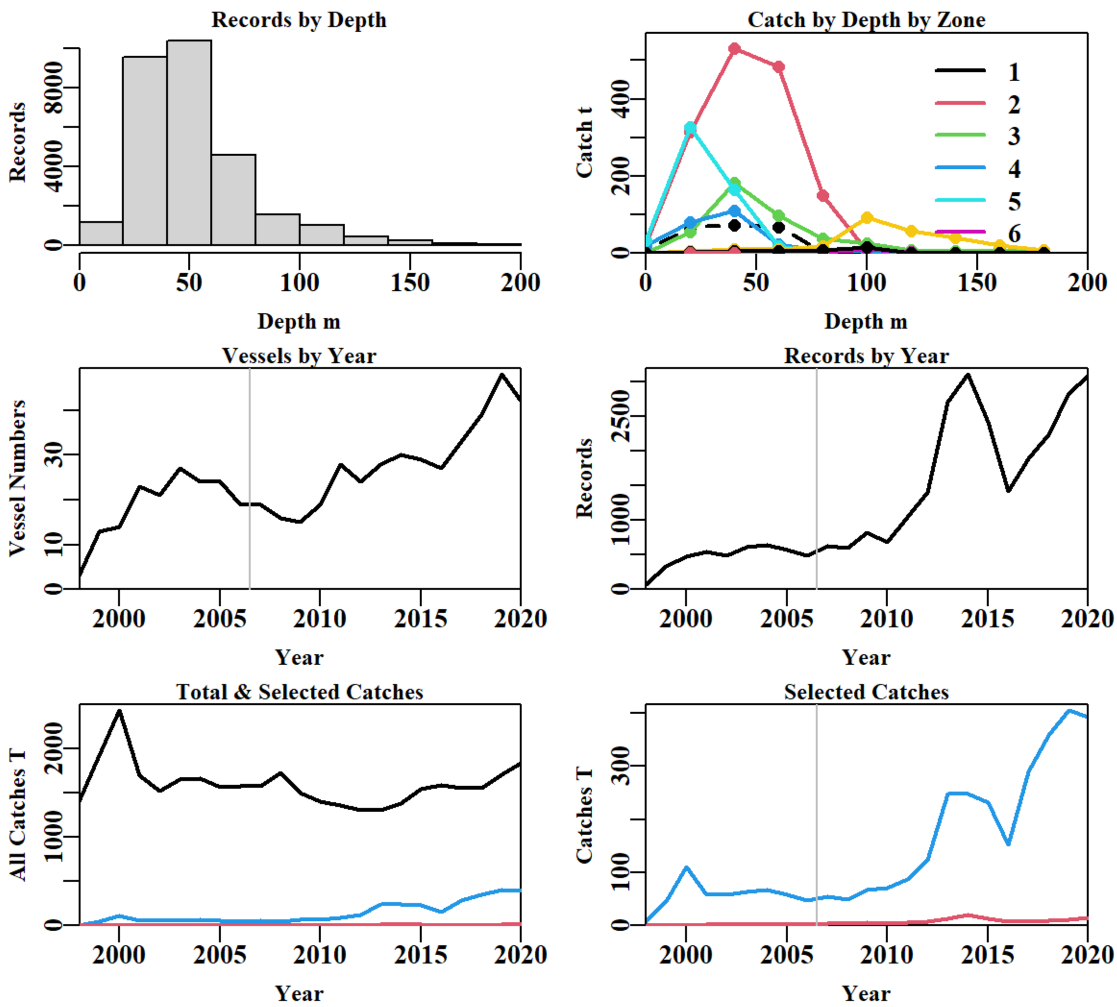

Figure 10.102. GummySharkBL fishery details. The bottom left plot depicts all known catches (top black line), and all selected catches used in the analysis (middle blue line); the lower red line: selected catches < 30 kg).

Table 10.55. 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	440781	0	38380.76	0
NoCE	425158	15623	38380.76	0
Depth	401666	23492	37436.40	944.37
Years	375581	26085	35974.25	1462.15
Zones	375056	525	35910.52	63.73
Method	29542	345514	3355.48	32555.04
Fishery	29126	416	3305.44	50.04

Table 10.56. 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 10.57. 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

Term	AIC	RSS	MSS	Nobs	Npars	adj_r2	%Change
Year	11737	43511	2142	29126	23	4.6	0
Vessel	1232	29841	15812	28972	188	34.0	29.42
DepCat	879	29461	16192	28972	197	34.9	0.82
SharkRegion	736	29298	16355	28972	206	35.2	0.34
Month	676	29215	16438	28972	217	35.4	0.16
DayNight	658	29190	16463	28972	220	35.4	0.05
SharkRegion:DepCat	562	28978	16675	28972	278	35.7	0.34
SharkRegion:Month	389	28756	16897	28972	303	36.2	0.78

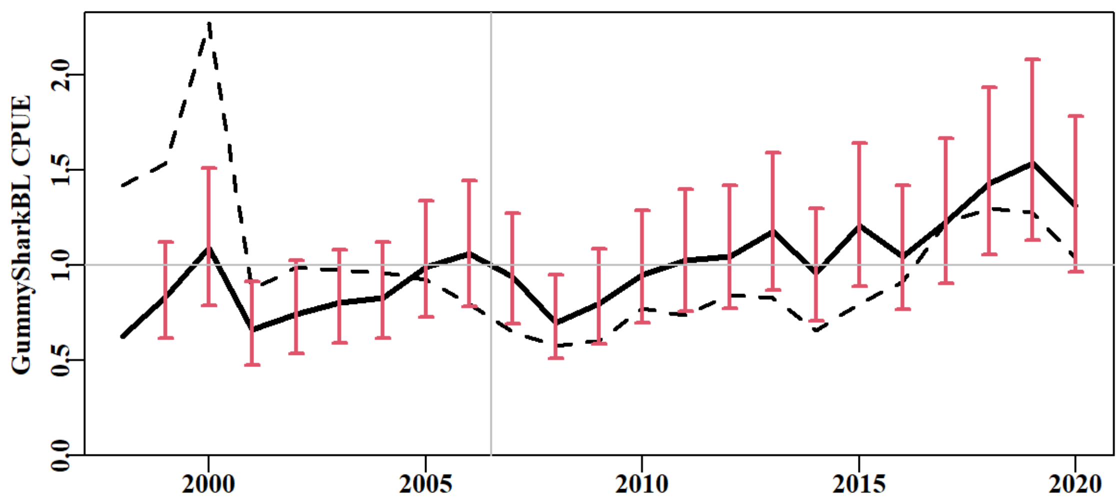

Figure 10.103. GummySharkBL standardization. The dashed black line represents the geometric mean catch rate, solid black line the standardized catch rates. The red bars are the 95% confidence intervals about the mean estimates. The graph scales both time-series of standardized catch rates relative to the mean of each time-series.

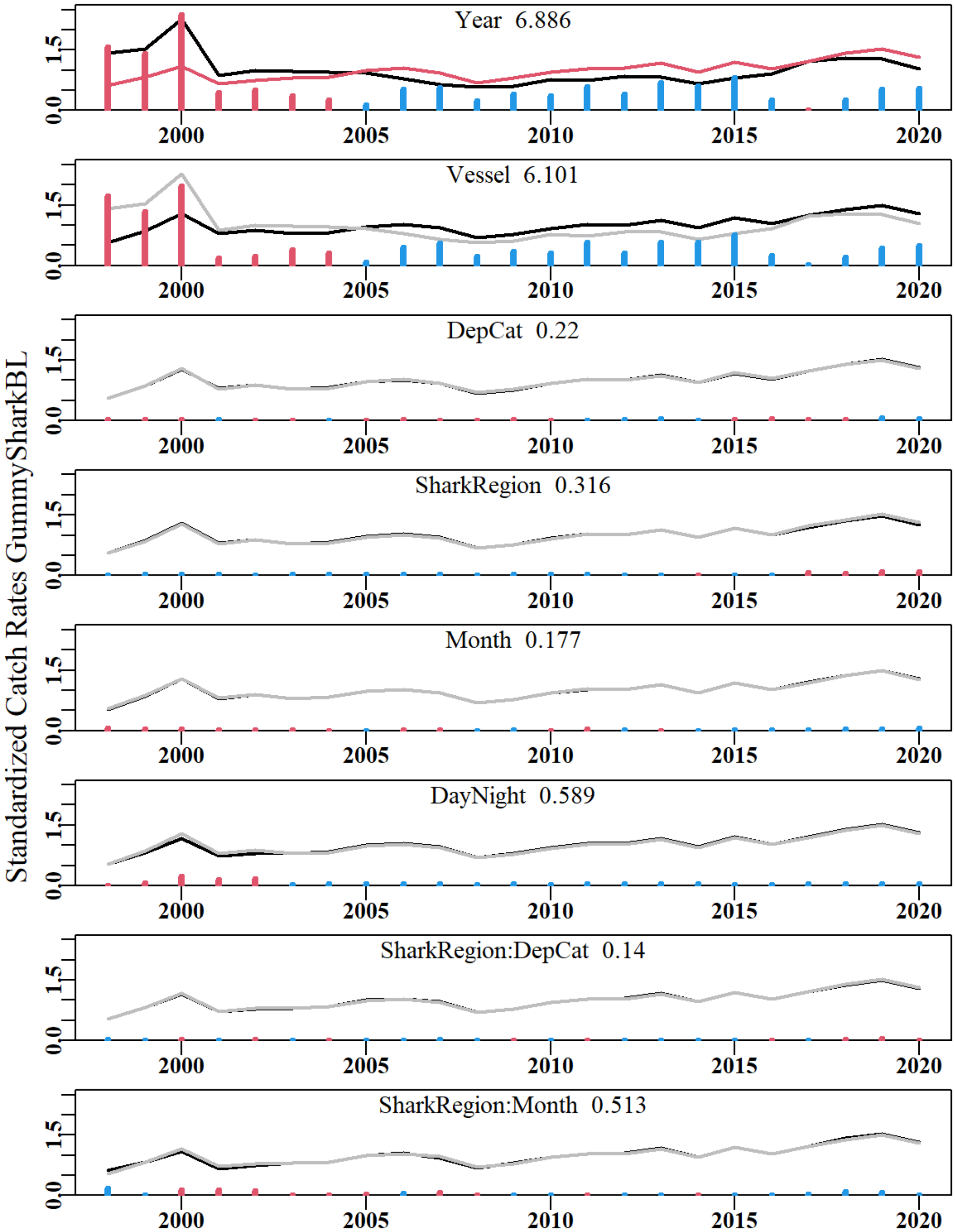

Figure 10.104. GummySharkBL. The influence of each factor on the optimal standardization. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by vertical bars with blue bars indicating the optimum model is higher than the 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.

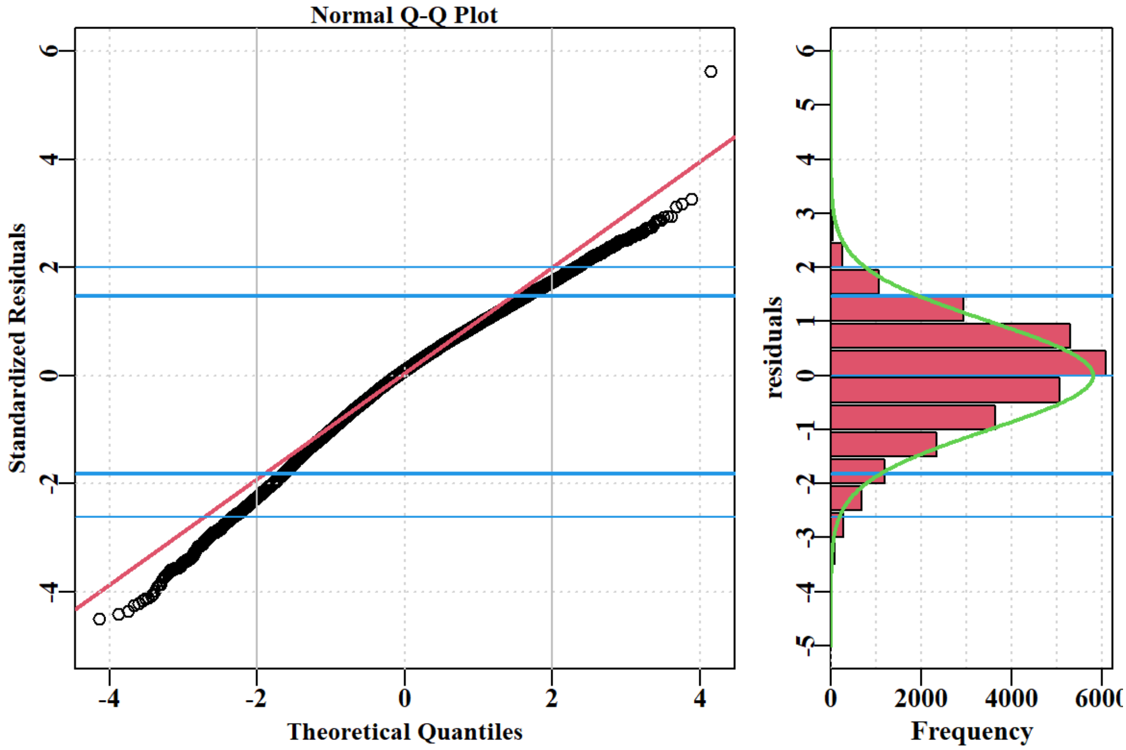

Figure 10.105. GummySharkBL. Diagnostic plots. The distribution of residuals from the optimum fit. The qqplot indicates the fit to the expected normality, while the histogram of residuals also illustrates the 1%, 5%, 95% and 99% quantiles to indicate the intensity of any lack of fit at the margins of the distribution (reflected also in the qqplot).

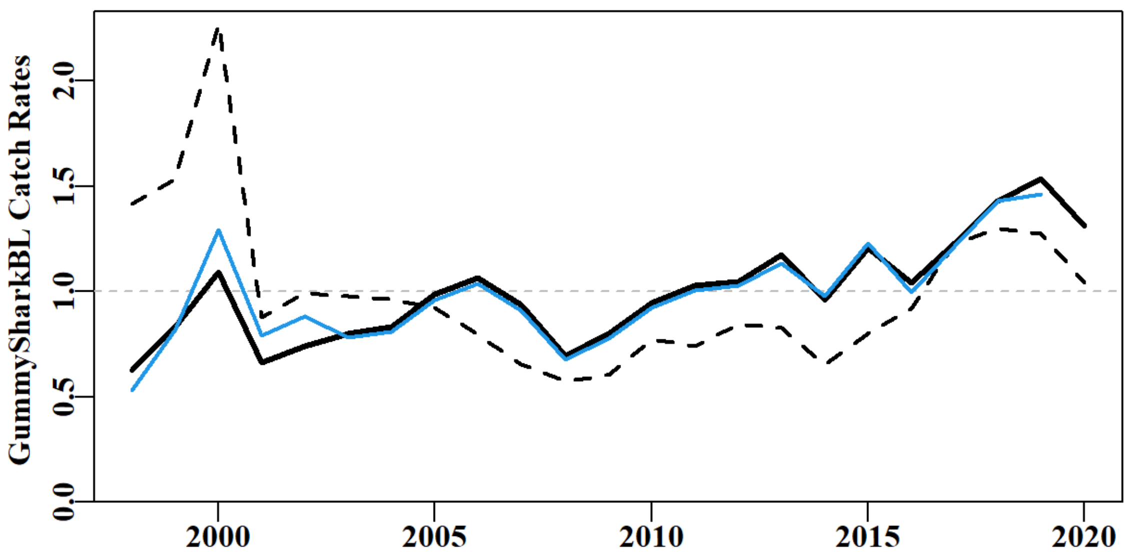

Figure 10.106. GummySharkBL. A comparison of the previous year’s standardization (blue line) with this year’s. They should lie on top of each other, although small deviations may relate to data adjustments, particularly in very recent years.

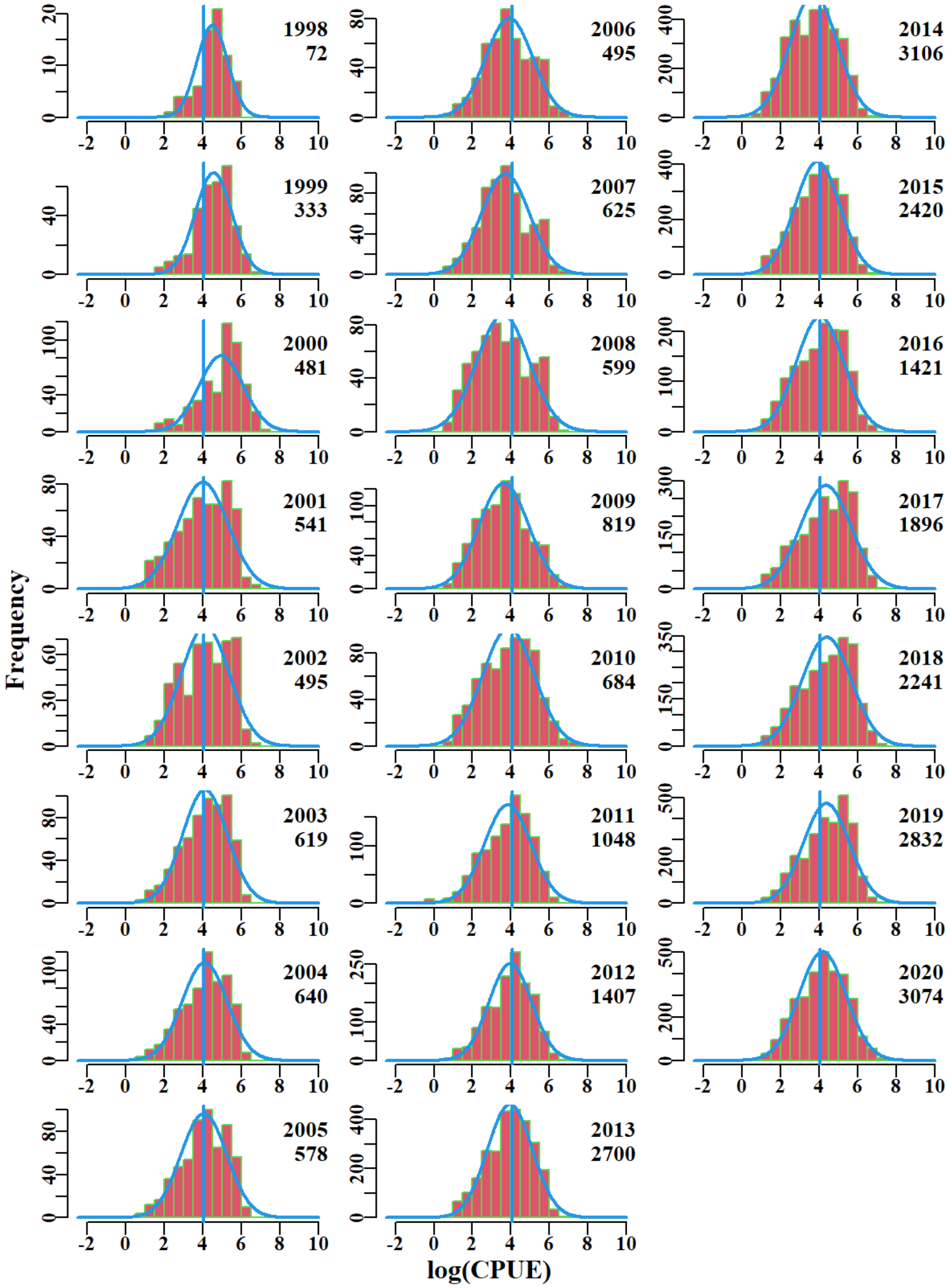

Figure 10.107. GummySharkBL. The natural log(CPUE) for each year of data available the blue lines are normal distributions fitted to the histogram frequencies. The numbers in each plot are the year and number of records. The vertical blue line is the average across all years.

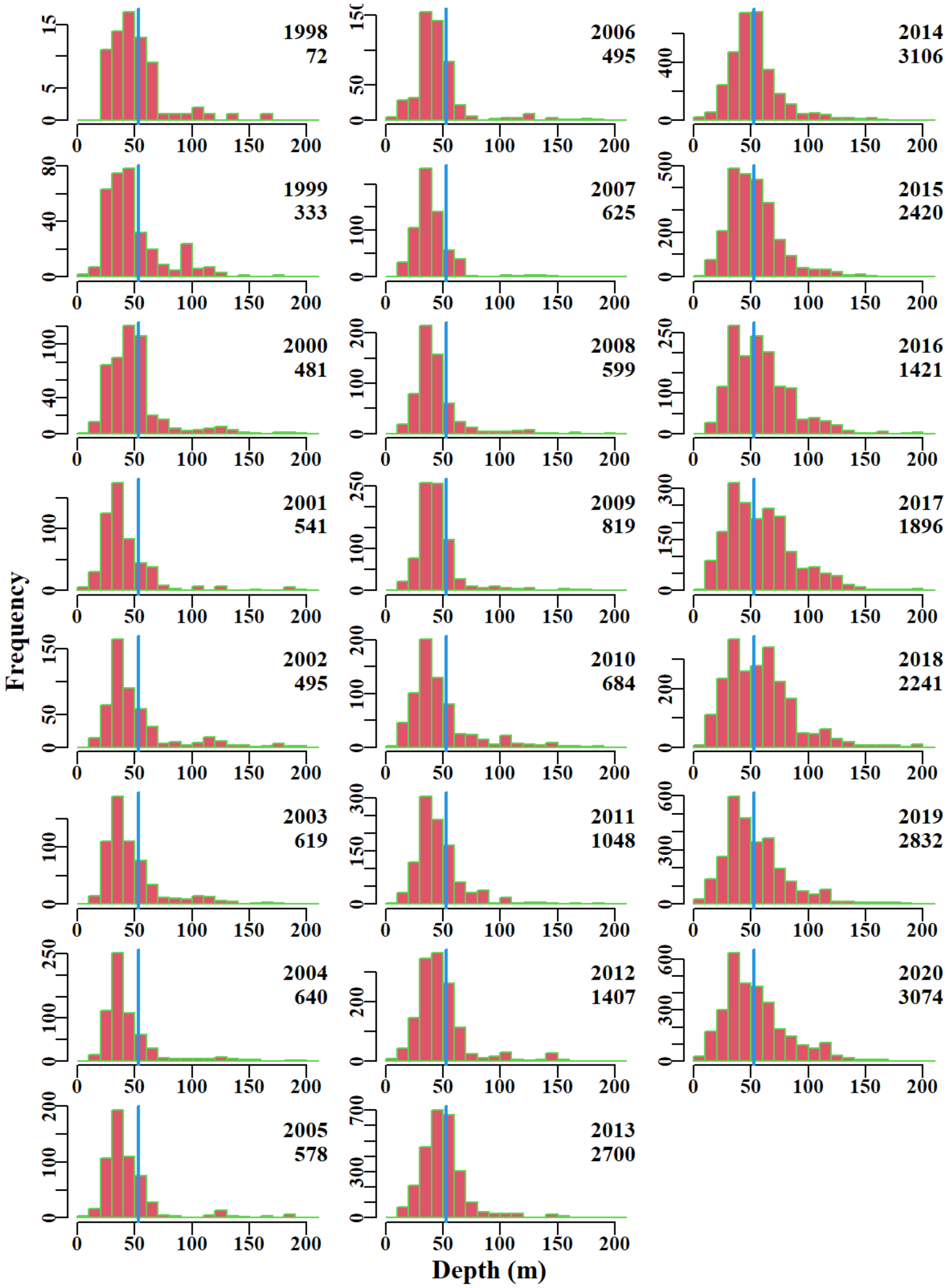

Figure 10.108. GummySharkBL. The average Depth of fishing for each year of data available to illustrate the development of the fishery through time. The numbers in each plot are the year and number of records. The vertical blue line is the average across all years.

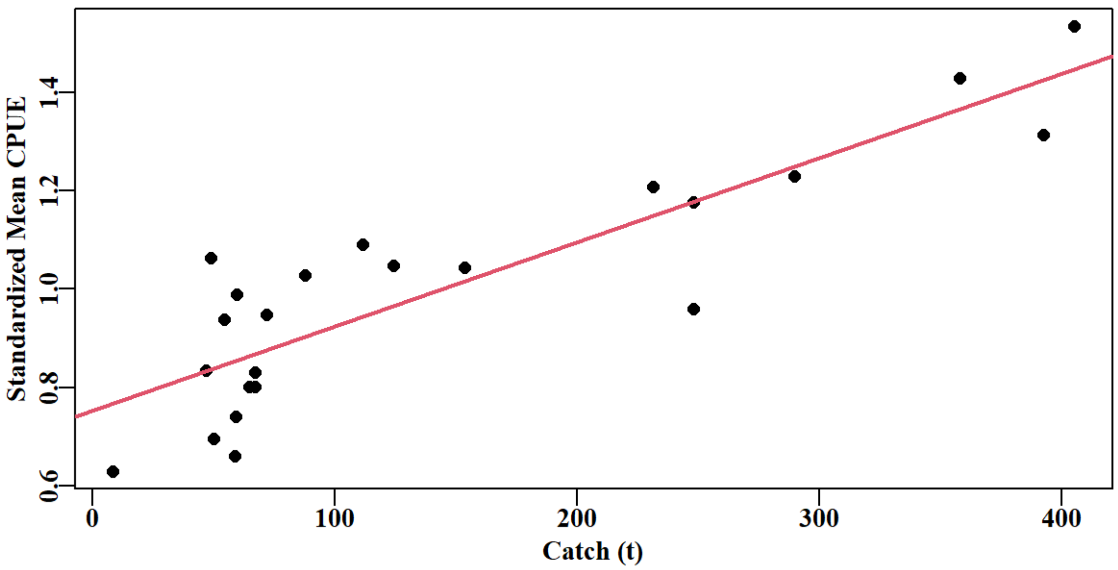

Figure 10.109. GummySharkBL. The linear relationship between annual mean CPUE and annual Catch.

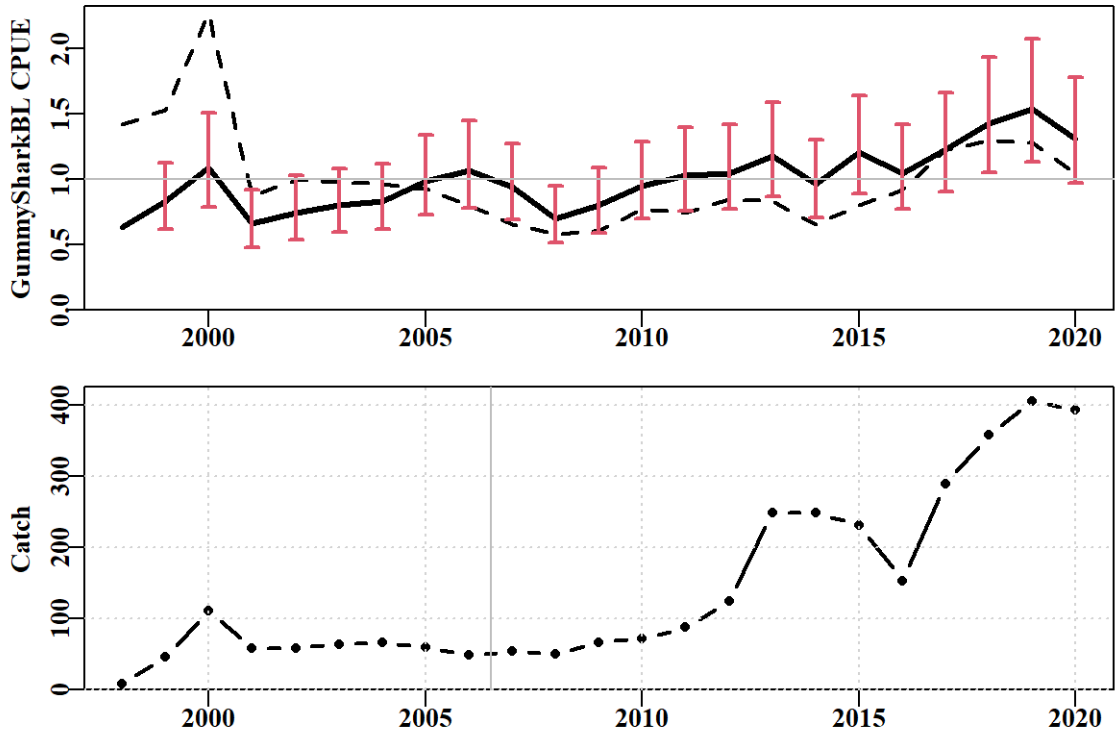

Figure 10.110. GummySharkBL. CPUE is correlated with catches through time. CPUE in the top plot and annual catch (t) in the lower plot.

10.16 Gummy shark Danish Seine BS and Vic

A large proportion of records contain missing effort entries, so CPUE used in the analysis was kg/shot.

The proportion of catches recording < 30 kg is relatively high, indicating that this species is not primary targeted by this gear (Figure 10.111).

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.

10.16.1 *Inferences*

Most catch occurred in Shark region 5 followed by 4. The 30 t recorded in 2020 is the largest in the time series.

The terms Year, Vessel, Month, DepCat, SharkRegion and one interaction (SharkRegion:DepCat) had the greatest contribution to model fit based on the AIC and R^2 statistics (Table 10.62). The qqplot suggests a slight departure from the assumed Normal distribution, as depicted by the upper tail of the distribution (Figure 10.114). Annual standardized CPUE has been mostly increasing and has been above the long-term average between since about 2010 (Figure 10.112).

10.16.2 *Action Items and Issues*

Further consideration of whether to consider the CPUE time-series as a valid index of relative abundance for Gummy Shark needs to be explored.

Table 10.58. GummySharkDSBS. The data selection criteria used to specify and identify the fishery data to be included in the analysis.

Property	Value
label	GummySharkDSBS
csirocode	37017001
fishery	SET_GHT
depthrange	0 - 250
depthclass	20
zones	4, 5
methods	DS, SSC
years	1996 - 2020

Table 10.59. GummySharkDSBS. Total catch (Total; t) is the total reported in the database, number of records used in the analysis (N), reported catch (Catch; t) in the area and depth used in the analysis and number of vessels used in the analysis (Vess). GeoM is the geometric mean of catch rates (kg/shot), standard deviation (StDev) relates to the optimum model. C<30Kg denotes the amount of catch in shots of <30kg, and P<30Kg is the proportion of total. The optimum model was SharkRegion:DepCat

Year	Total	N	Catch	Vess	GeoM	Opt	StDev	C<30Kg	P<30Kg
1996	49.4	1784	7.3	22	3.6	0.5846	0.000	6.428	0.882
1997	952.1	2410	8.7	20	3.3	0.5367	0.030	8.254	0.954
1998	1401.2	2601	11.2	20	3.9	0.6274	0.030	10.283	0.920
1999	1923.8	2400	13.0	23	4.8	0.7332	0.031	11.005	0.845
2000	2436.9	1800	10.8	19	4.9	0.7351	0.033	8.094	0.752
2001	1703.3	2451	13.9	19	5.0	0.6846	0.031	11.300	0.814
2002	1527.2	2312	12.3	21	4.9	0.6988	0.031	10.543	0.855
2003	1653.4	1678	7.8	22	4.3	0.6785	0.034	7.210	0.926
2004	1670.4	2013	10.7	22	5.1	0.7357	0.032	9.911	0.923
2005	1573.3	1576	15.0	22	6.3	0.8505	0.034	7.728	0.514
2006	1577.1	1305	8.2	19	5.6	0.8419	0.036	6.242	0.760
2007	1575.0	1278	11.5	15	7.7	0.9511	0.036	6.917	0.603
2008	1727.9	1558	14.6	15	7.9	1.0463	0.035	9.164	0.627
2009	1500.9	1681	13.0	15	6.9	1.0122	0.034	9.636	0.744
2010	1404.9	1948	13.2	15	6.5	1.0741	0.033	11.843	0.895
2011	1364.7	2468	23.2	14	8.2	1.1584	0.031	15.428	0.664
2012	1304.4	2415	24.0	14	9.3	1.2525	0.031	16.418	0.685
2013	1307.7	2620	23.6	14	8.3	1.1860	0.031	17.335	0.736
2014	1389.1	2064	16.5	14	7.6	1.1154	0.033	12.743	0.771
2015	1545.1	1982	20.6	15	9.6	1.3559	0.033	13.929	0.675
2016	1586.5	1842	22.4	15	10.5	1.4421	0.034	12.398	0.553
2017	1561.4	2001	20.7	16	9.3	1.3774	0.033	13.864	0.669
2018	1560.1	1829	20.3	17	9.5	1.3609	0.033	12.739	0.627
2019	1709.7	2112	29.3	18	12.0	1.4981	0.033	14.499	0.494
2020	1840.5	2418	30.1	19	11.6	1.4624	0.032	17.042	0.566

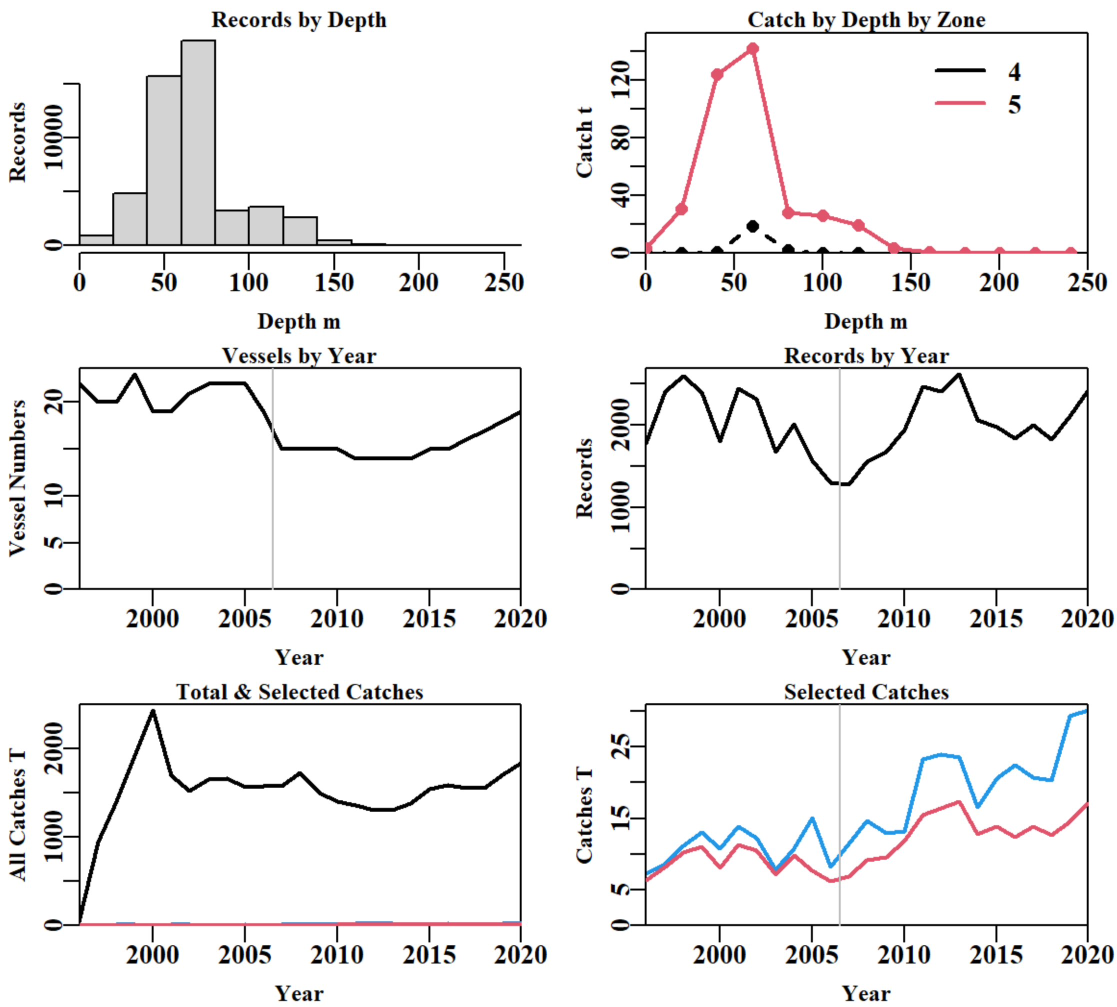

Figure 10.111. GummySharkDSBS fishery details. The bottom left plot depicts all known catches (top black line), and all selected catches used in the analysis (middle blue line); the lower red line: selected catches < 30 kg).

Table 10.60. GummySharkDSBS 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	440781	0	38380.76	0
NoCE	425158	15623	38380.76	0
Depth	406359	18799	37568.06	812.71
Years	398077	8282	37070.01	498.04
Zones	205217	192860	22447.31	14622.71
Method	50913	154304	405.19	22042.12
Fishery	50546	367	402.01	3.18

Table 10.61. The models used to analyse data for GummySharkDSBS

	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 10.62. GummySharkDSBS. 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

Term	AIC	RSS	MSS	Nobs	Npars	adj_r2	%Change
Year	-162	50335	4808	50546	25	8.7	0
Vessel	-2882	47628	7515	50546	62	13.5	4.85
DepCat	-3130	47372	7771	50546	74	14.0	0.44
SharkRegion	-3624	46910	8233	50546	75	14.8	0.84
Month	-4217	46342	8801	50546	86	15.8	1.01
DayNight	-4214	46339	8803	50546	89	15.8	0.00
SharkRegion:DepCat	-4246	46298	8845	50546	96	15.9	0.06
SharkRegion:Month	-4232	46302	8840	50546	100	15.9	0.05

Figure 10.112. GummySharkDSBS 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.

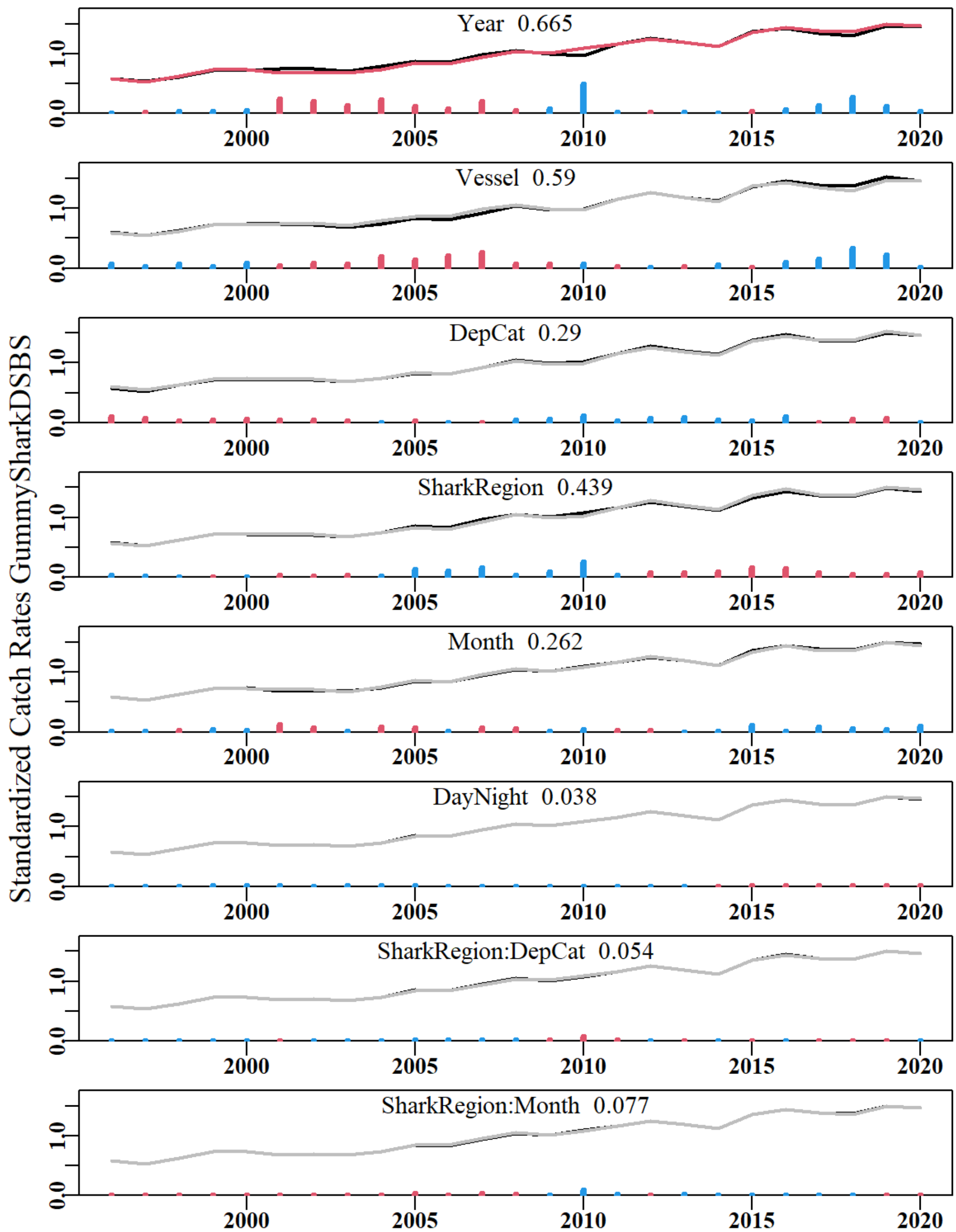

Figure 10.113. GummySharkDSBS. The influence of each factor on the optimal standardization. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by vertical bars with blue bars indicating the optimum model is higher than the 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.

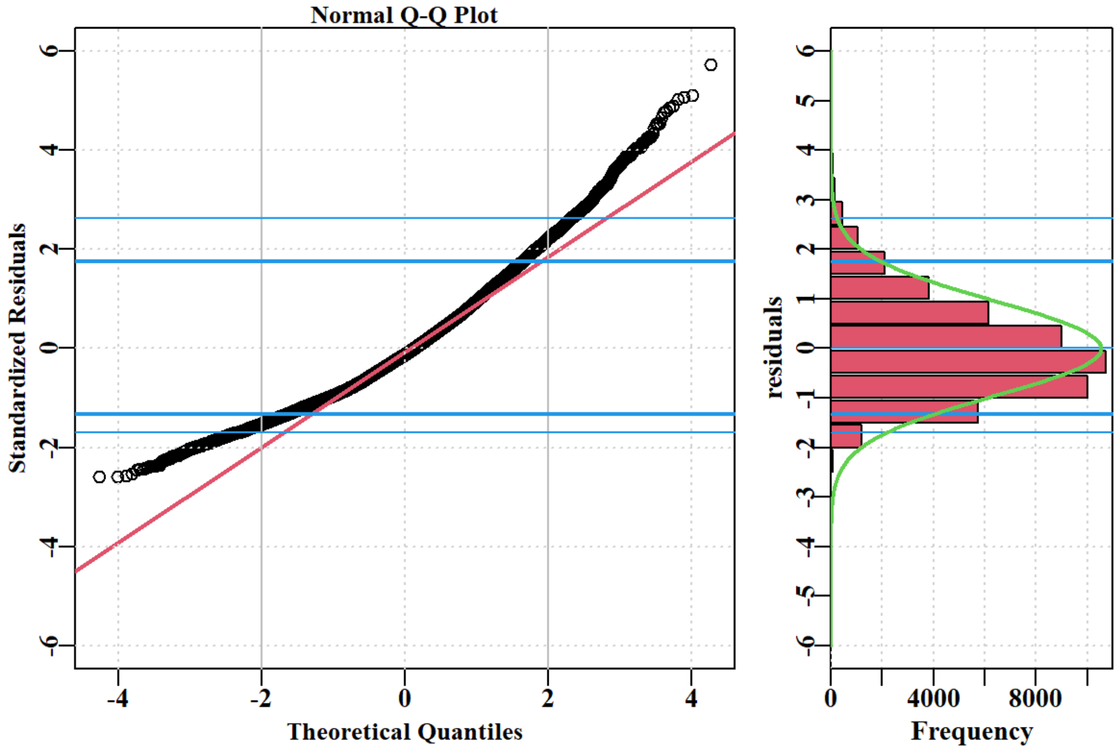

Figure 10.114. GummySharkDSBS. Diagnostic plots. The distribution of residuals from the optimum fit. The qqplot indicates the fit to the expected normality, while the histogram of residuals also illustrates the 1%, 5%, 95% and 99% quantiles to indicate the intensity of any lack of fit at the margins of the distribution (reflected also in the qqplot).

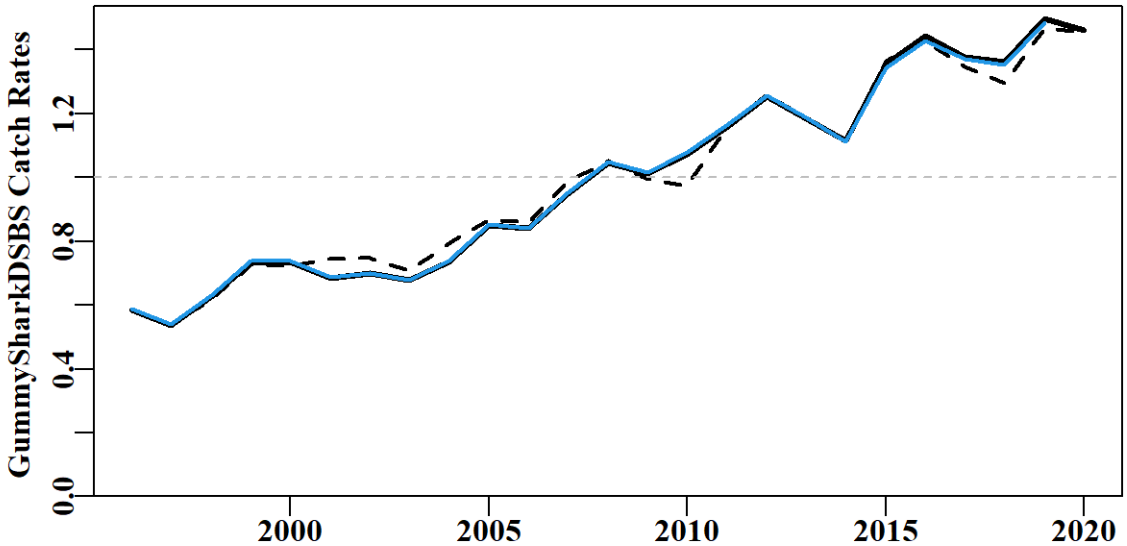

Figure 10.115. GummySharkDSBS. A comparison of the previous year's standardization (blue line) with this year's. They should lie on top of each other, although small deviations may relate to data adjustments, particularly in very recent years.

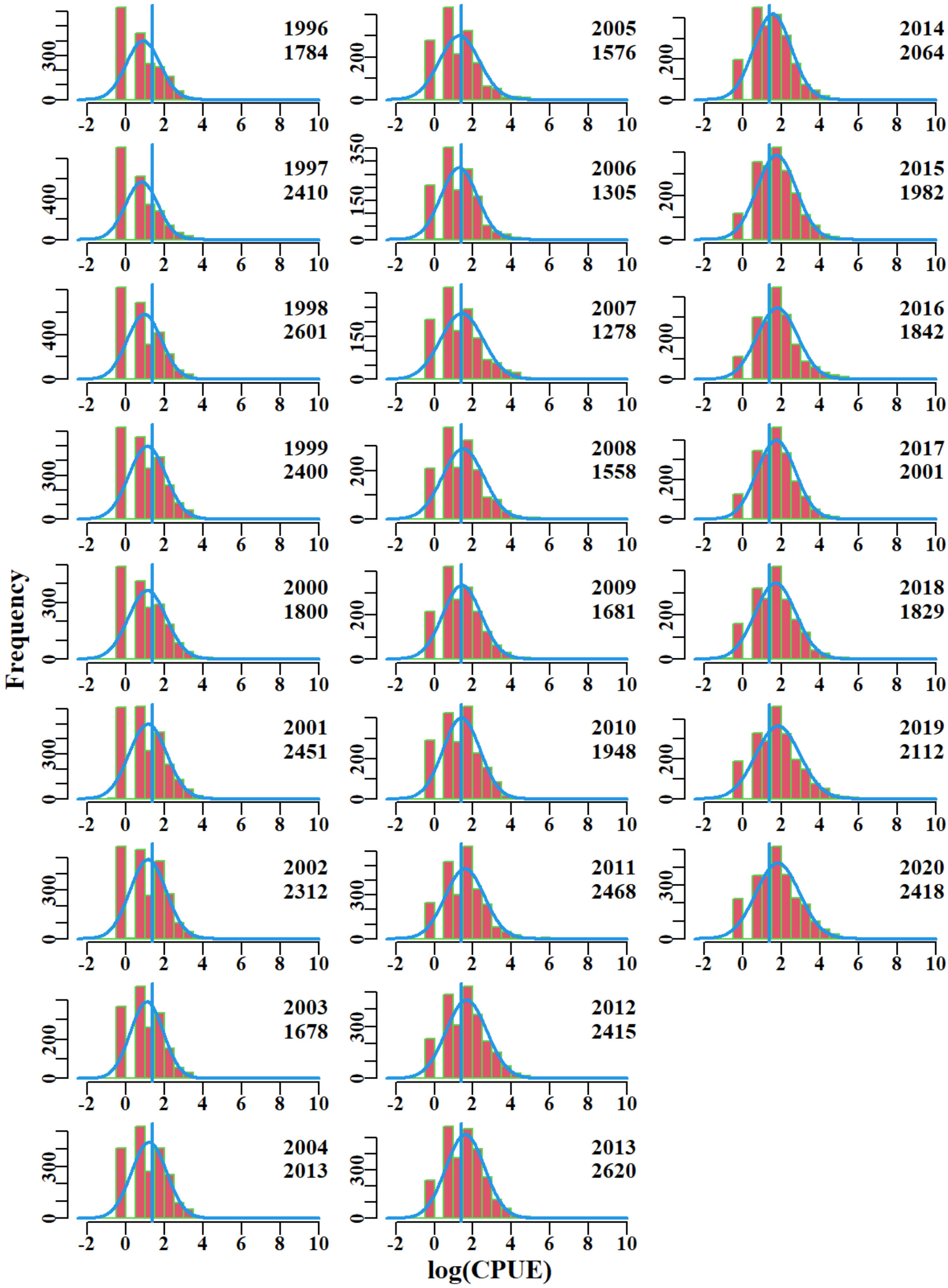

Figure 10.116. GummySharkDSBS. The natural log(CPUE) for each year of data available the blue lines are normal distributions fitted to the histogram frequencies. The numbers in each plot are the year and number of records. The vertical blue line is the average across all years.

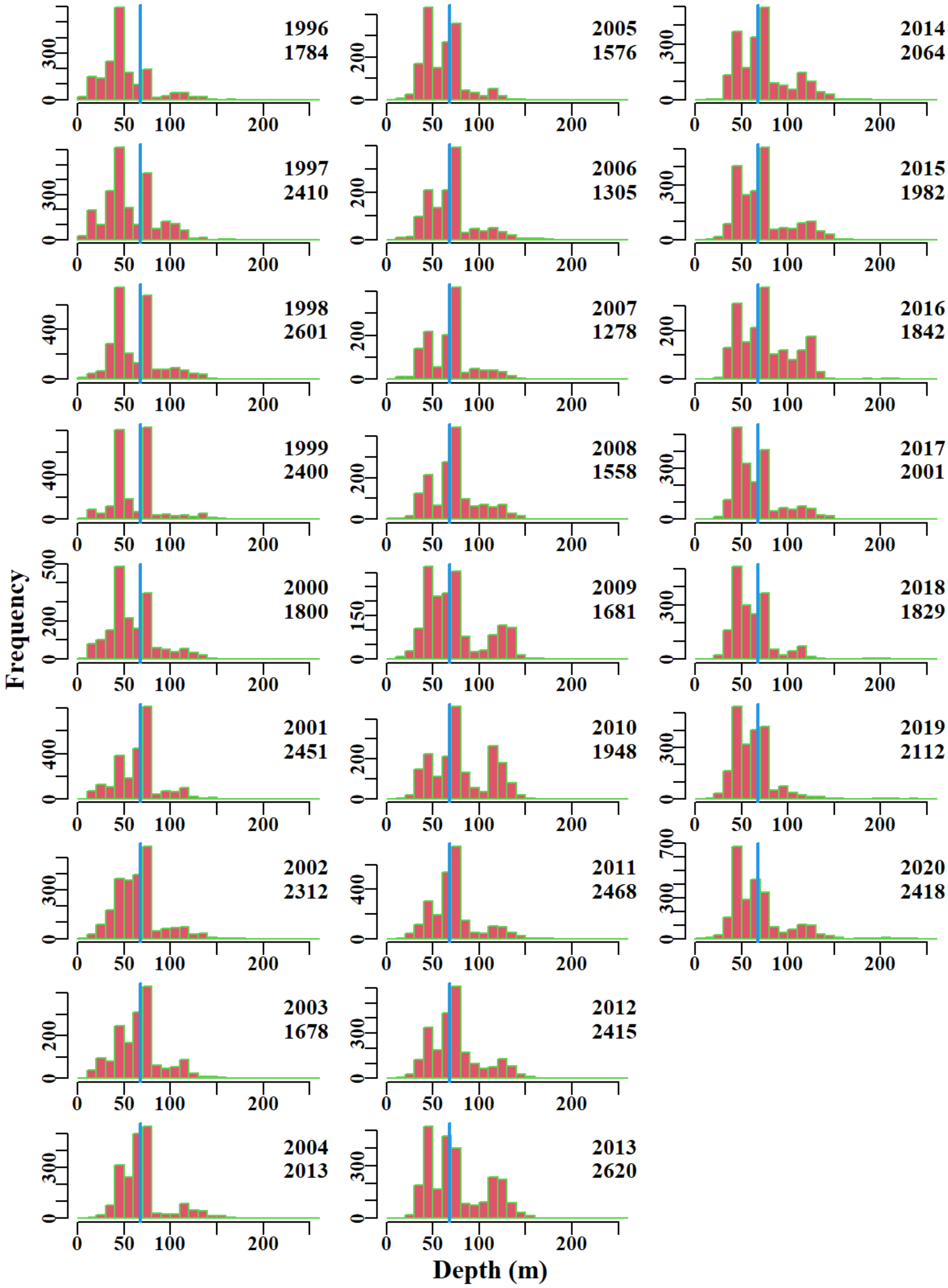

Figure 10.117. GummySharkDSBS. The average Depth of fishing for each year of data available to illustrate the development of the fishery through time. The numbers in each plot are the year and number of records. The vertical blue line is the average across all years.

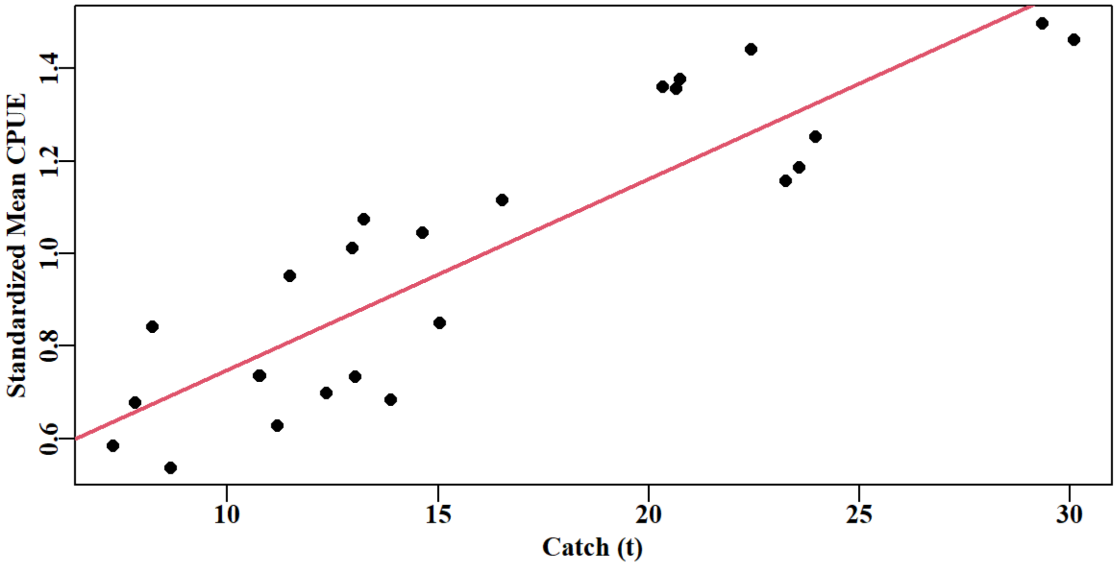

Figure 10.118. GummySharkDSBS. The linear relationship between annual mean CPUE and annual Catch.

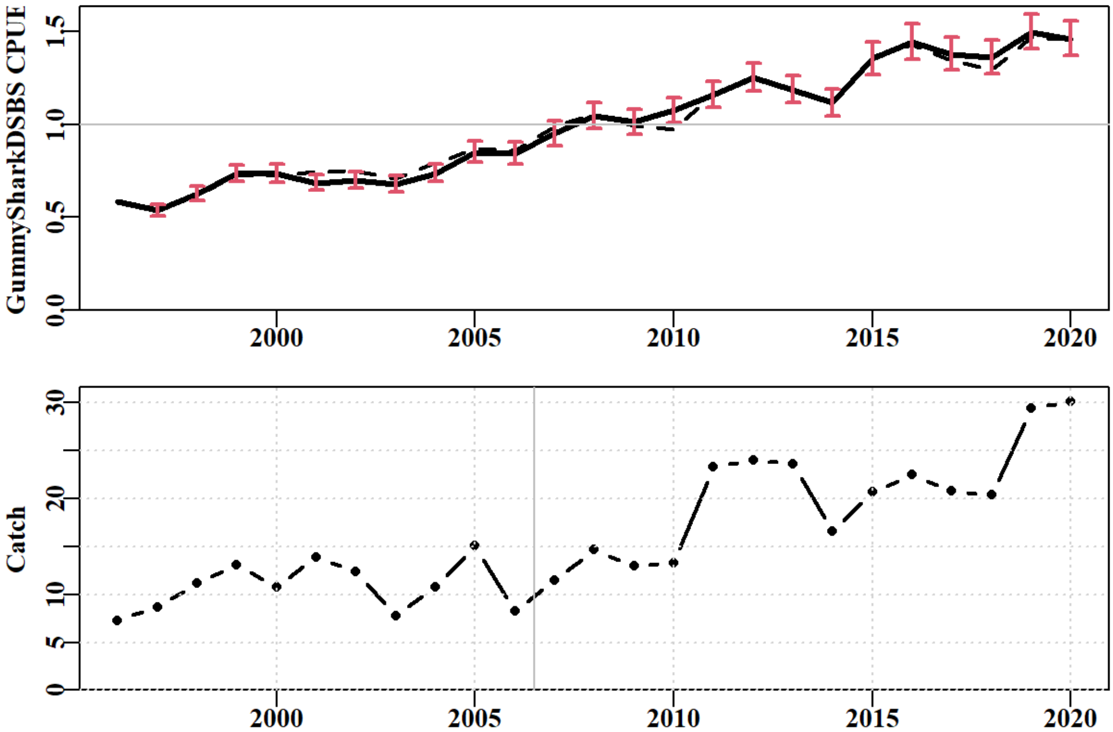

Figure 10.119. GummySharkDSBS. CPUE is correlated with catches through time. CPUE in the top plot and annual catch (t) in the lower plot.

10.17 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.

10.17.1 *Inferences*

Most catch occurred in Shark region 6. The 29 t recorded in 2019 is the largest in the series.

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 10.67). The first two terms had the greatest contribution to model fit. The qqplot suggests a slight departure from the assumed Normal distribution, as depicted by the upper tail of the distribution (Figure 10.123). 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 2020 relative to 2019 (Figure 10.121).

10.17.2 *Action Items and Issues*

None identified.

Table 10.63. 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, OTB, TMO
years	1996 - 2020

Table 10.64. 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

Year	Total	N	Catch	Vess	GeoM	Opt	StDev	C<30Kg	P<30Kg
1996	29.1	922	24.4	67	7.6	1.1765	0.000	11.882	0.486
1997	457.0	1187	23.7	60	6.4	1.0351	0.043	13.246	0.560
1998	562.0	957	19.8	51	6.0	0.9602	0.046	10.817	0.546
1999	490.6	759	14.1	51	5.4	0.8785	0.050	9.078	0.644
2000	464.9	919	16.6	70	5.0	0.7517	0.049	8.720	0.524
2001	190.6	859	15.7	47	5.2	0.7338	0.049	8.919	0.568
2002	219.5	943	16.9	57	5.2	0.7705	0.049	9.283	0.550
2003	218.3	767	13.2	59	4.8	0.7074	0.052	7.482	0.568
2004	200.4	697	13.3	54	4.5	0.7325	0.053	6.954	0.521
2005	210.3	517	8.3	45	4.2	0.7590	0.057	4.784	0.577
2006	212.0	570	10.9	47	4.9	0.7576	0.056	5.154	0.474
2007	197.8	348	7.3	32	5.9	0.8080	0.065	3.469	0.474
2008	234.4	404	9.0	30	5.7	0.9702	0.061	3.817	0.425
2009	253.2	439	13.8	28	6.8	1.0392	0.059	4.440	0.323
2010	180.2	428	12.6	26	7.2	0.9919	0.060	4.007	0.318
2011	182.4	449	13.8	28	6.8	0.9661	0.059	4.004	0.290
2012	136.1	342	10.9	26	8.2	1.0423	0.065	2.979	0.274
2013	150.0	372	18.3	32	12.2	1.1134	0.064	3.218	0.176
2014	200.0	394	11.2	26	7.1	1.0821	0.062	3.829	0.341
2015	146.9	333	12.3	26	8.1	1.1272	0.065	3.557	0.290
2016	133.9	363	14.1	26	8.7	1.2977	0.063	4.188	0.297
2017	225.6	544	20.8	22	8.5	1.2994	0.059	5.831	0.280
2018	153.5	525	23.9	25	9.4	1.3553	0.059	5.545	0.232
2019	201.8	654	28.6	23	10.0	1.3416	0.056	5.868	0.205
2020	128.6	511	19.1	19	7.5	1.3027	0.060	5.234	0.275

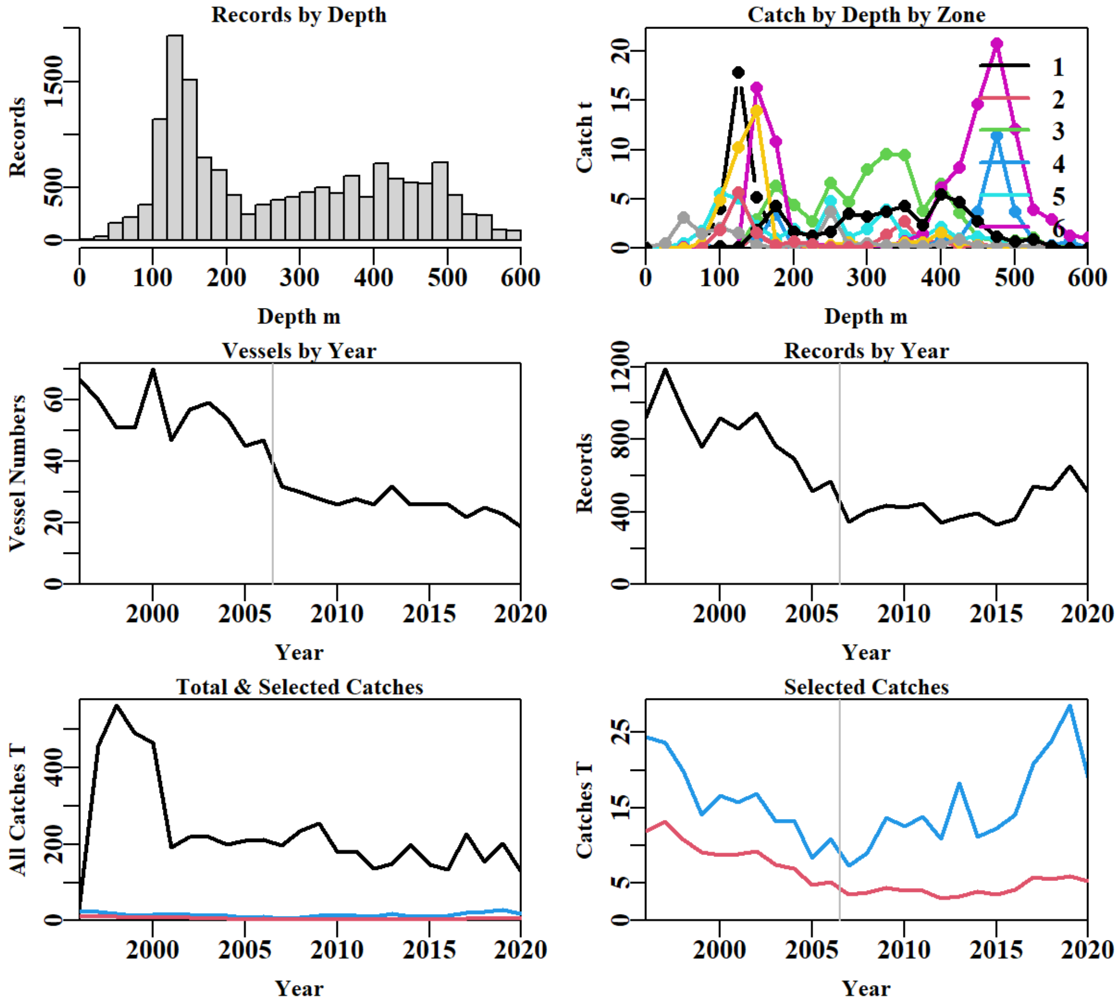

Figure 10.120. SchoolSharkTW fishery details. The bottom left plot depicts all known catches (top black line), and all selected catches used in the analysis (middle blue line); the lower red line: selected catches < 30 kg).

Table 10.65. 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	124238	0	5988.55	0
NoCE	77427	46811	3737.60	2250.95
Depth	76644	783	3698.65	38.95
Years	71963	4681	3513.55	185.10
Zones	71672	291	3506.86	6.70
Method	15204	56468	392.49	3114.37
Fishery	15203	1	392.48	0.01

Table 10.66. 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 10.67. 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

Term	AIC	RSS	MSS	Nobs	Npars	adj_r2	%Change
Year	3650	19265	572	15203	25	2.7	0
Vessel	-47	14834	5003	15203	163	24.4	21.68
DepCat	-810	14064	5773	15203	187	28.2	3.81
SharkRegion	-1544	13385	6451	15203	196	31.6	3.42
Month	-1645	13277	6560	15203	207	32.1	0.50
DayNight	-1708	13217	6620	15203	210	32.4	0.29
SharkRegion:DepCat	-1928	12745	7092	15203	377	34.1	1.68
SharkRegion:Month	-2013	12789	7048	15203	308	34.2	1.76

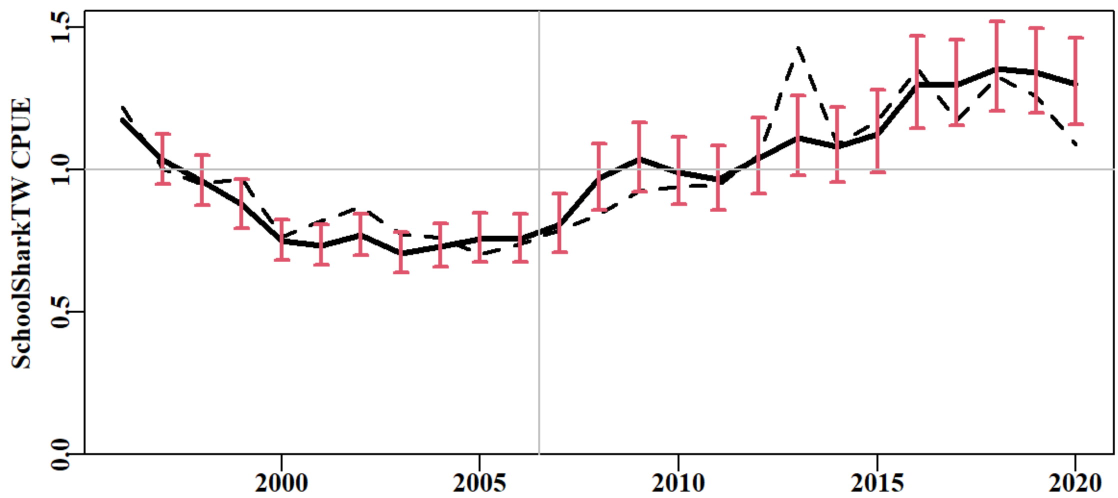

Figure 10.121. SchoolSharkTW standardization. The dashed black line represents the geometric mean catch rate, solid black line the standardized catch rates. The red bars are the 95% confidence intervals about the mean estimates. The graph scales both time-series of standardized catch rates relative to the mean of each time-series.

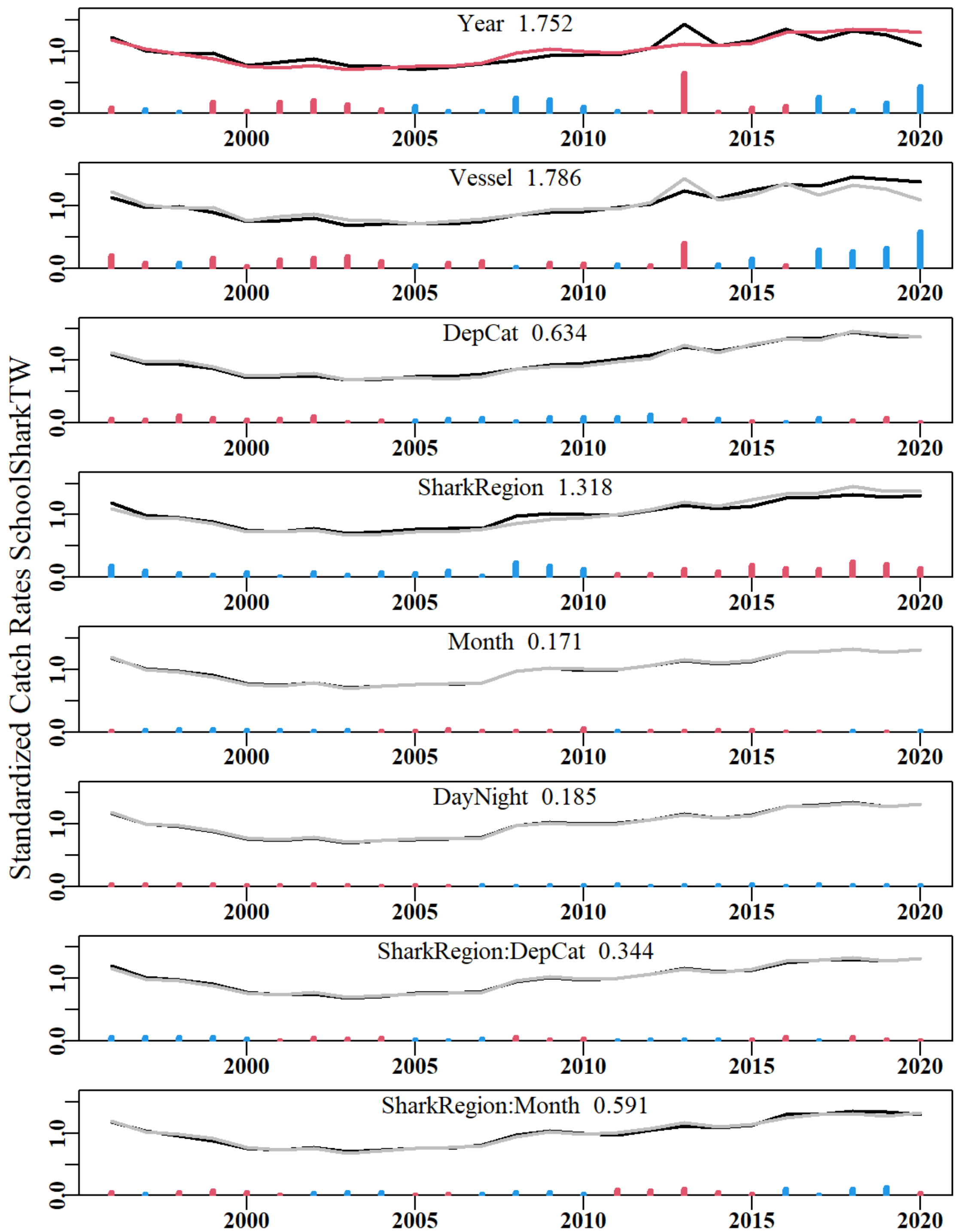

Figure 10.122. SchoolSharkTW. The influence of each factor on the optimal standardization. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by vertical bars with blue bars indicating the optimum model is higher than the 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.

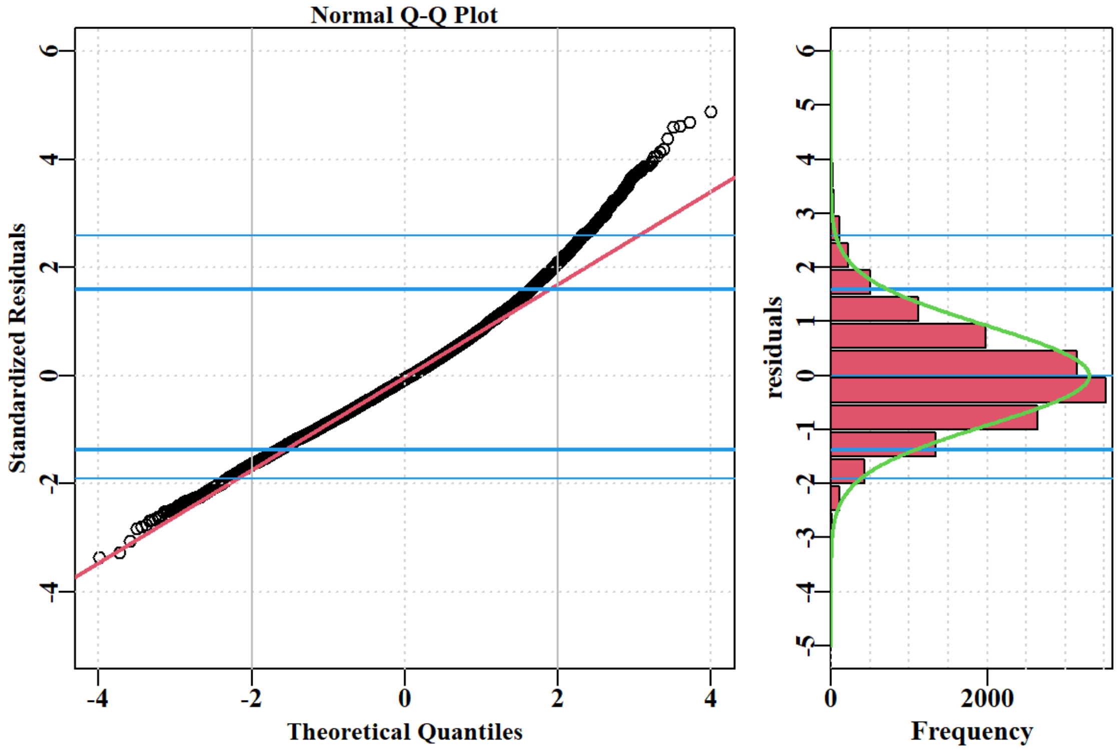

Figure 10.123. SchoolSharkTW. Diagnostic plots. The distribution of residuals from the optimum fit. The qqplot indicates the fit to the expected normality, while the histogram of residuals also illustrates the 1%, 5%, 95% and 99% quantiles to indicate the intensity of any lack of fit at the margins of the distribution (reflected also in the qqplot).

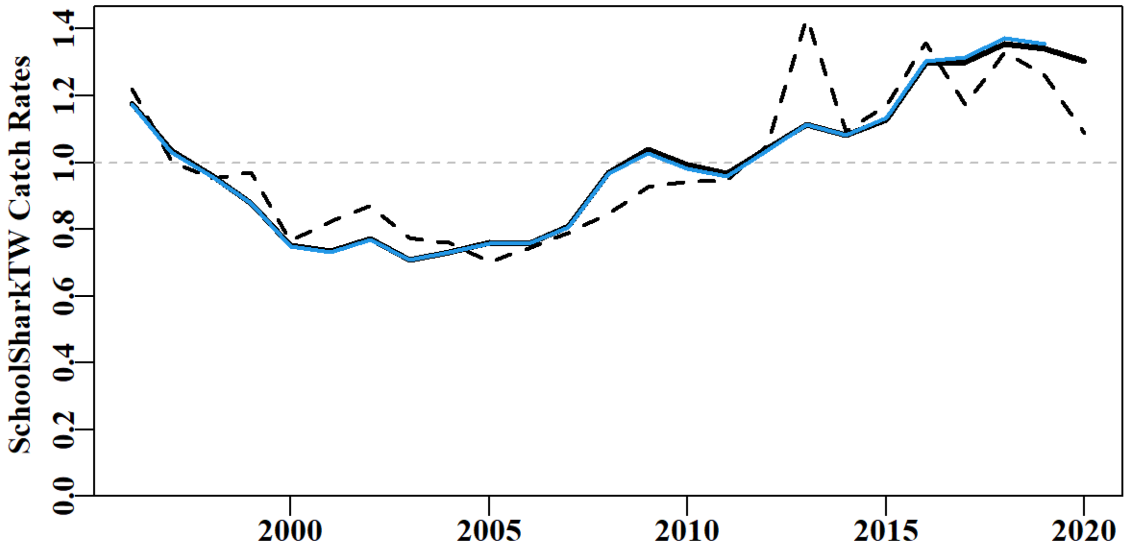

Figure 10.124. SchoolSharkTW. A comparison of the previous year's standardization (blue line) with this year's. They should lie on top of each other, although small deviations may relate to data adjustments, particularly in very recent years.

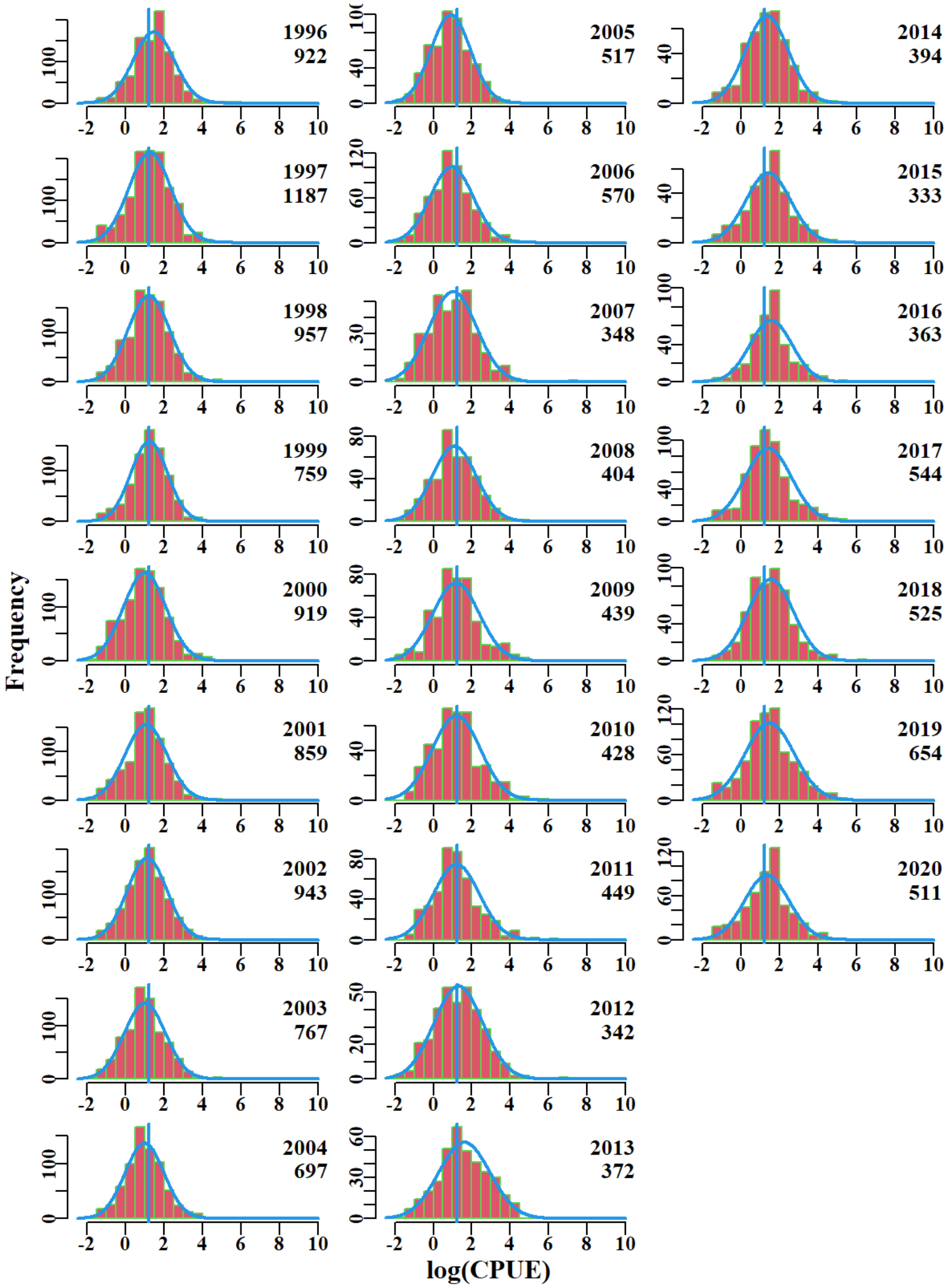

Figure 10.125. SchoolSharkTW. The natural log(CPUE) for each year of data available the blue lines are normal distributions fitted to the histogram frequencies. The numbers in each plot are the year and number of records. The vertical blue line is the average across all years.

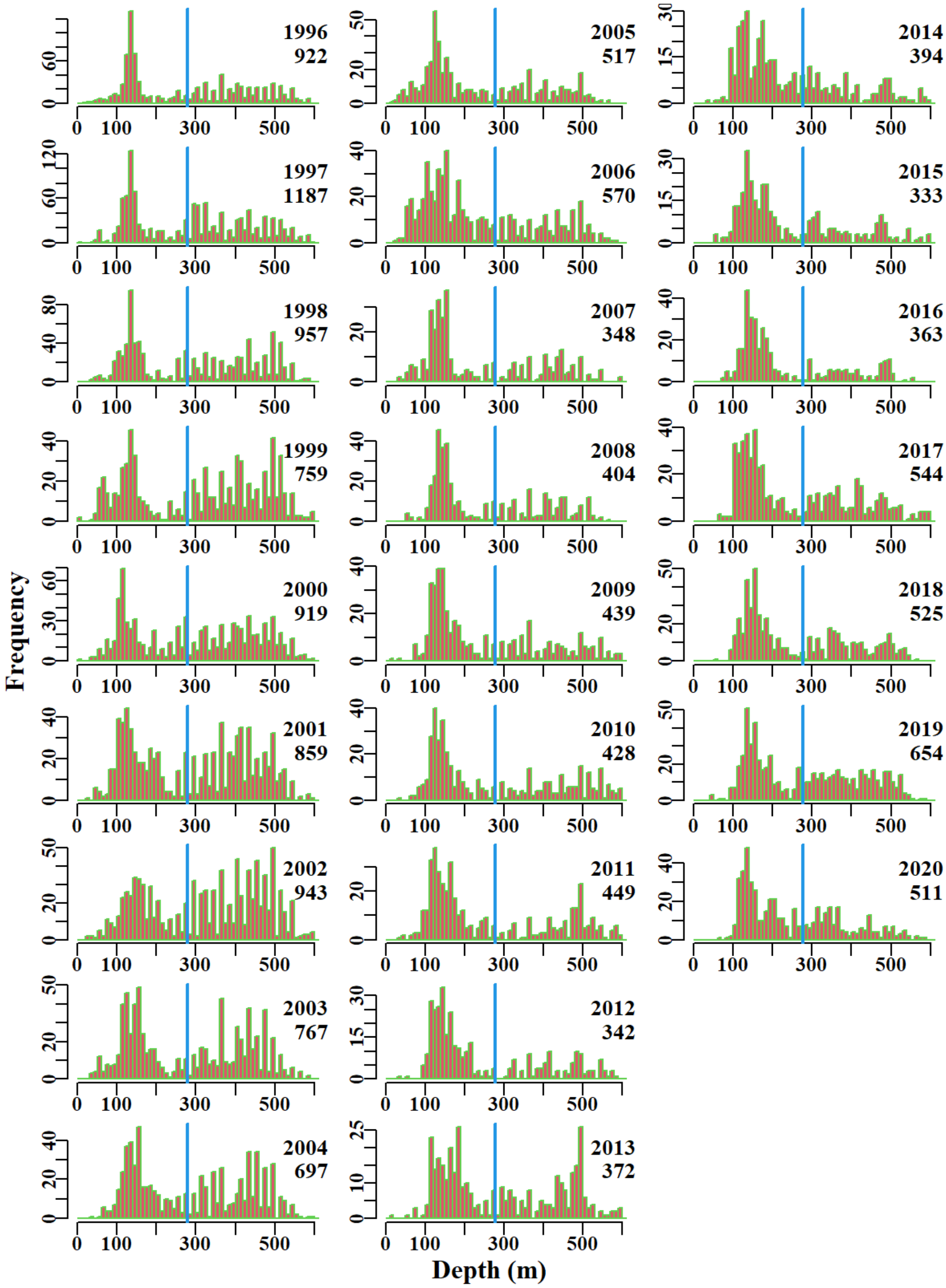

Figure 10.126. SchoolSharkTW. The average Depth of fishing for each year of data available to illustrate the development of the fishery through time. The numbers in each plot are the year and number of records. The vertical blue line is the average across all years.

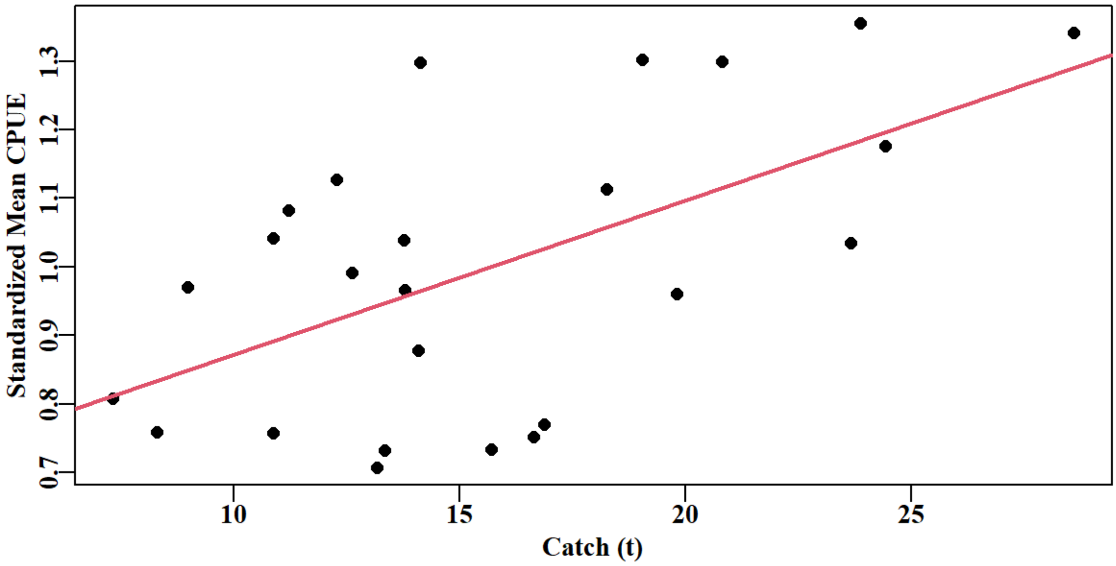

Figure 10.127. SchoolSharkTW. The linear relationship between annual mean CPUE and annual Catch.

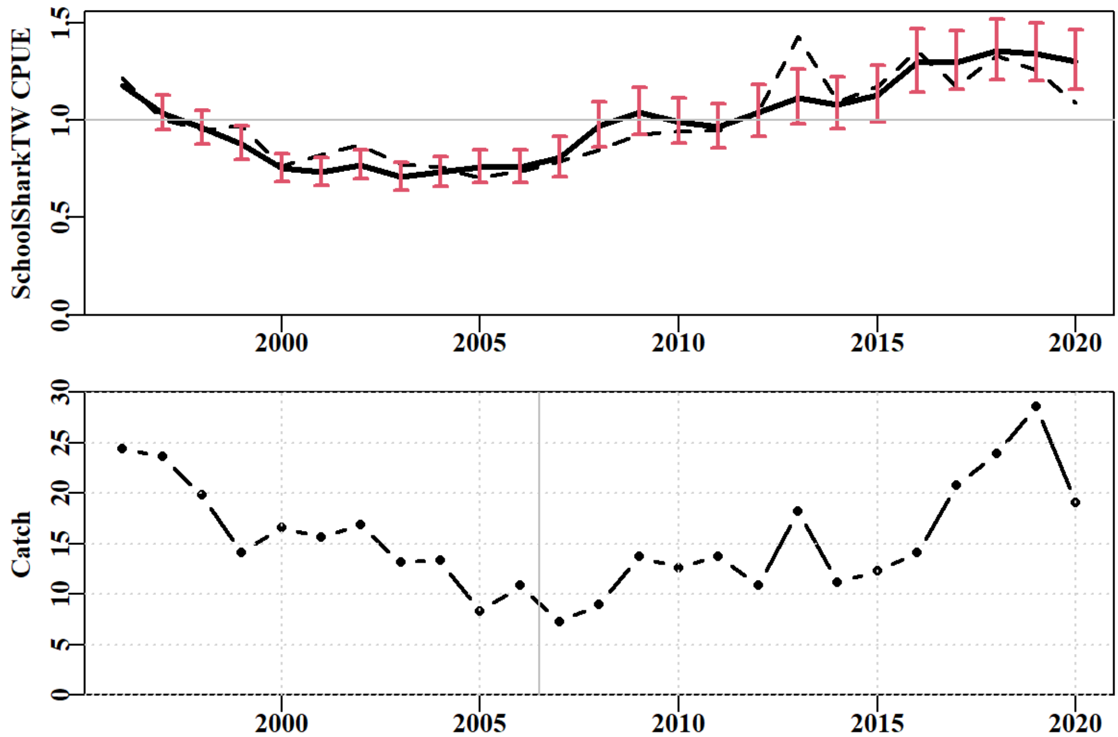

Figure 10.128. SchoolSharkTW. CPUE is correlated with catches through time. CPUE in the top plot and annual catch (t) in the lower plot.

10.18 Sawshark Gillnet

Sawshark are considered as 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 based on the number of fishing operations available. Positive non-zero records of catch per shot were employed in the statistical standardization analyses for Sawshark caught by gillnets.

10.18.1 *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 < 30 kg indicates the by-product nature of this fishery (confirmed by the large proportion of discards from this fishery). Most catch occurred in Shark region 5, followed by 4.

The terms Year, Vessel, DepCat, SharkRegion, Month and one interaction (SharkRegion:Month) had the greatest contribution to model fit based on the AIC and R^2 statistics (Table 10.72). The qqplot suggests the assumed Normal distribution is valid, with a slight deviation as depicted by both tails of the distribution (Figure 10.132). Annual standardized CPUE has been below the long-term average since 2009, with minor increases over the 2015-2016 and 2017-20 periods (Figure 10.130).

10.18.2 *Action Items and Issues*

Further consideration of whether to consider the CPUE time-series as a valid index of relative abundance for Sawshark needs to be explored.

Table 10.68. SawSharkGN. The data selection criteria used to specify and identify the fishery data to be included in the analysis.

Property	Value
label	SawSharkGN
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, GNS
years	1997 - 2020

Table 10.69. SawSharkGN. Total catch (Total; t) is the total reported in the database, number of records used in the analysis (N), reported catch (Catch; t) in the area and depth used in the analysis and number of vessels used in the analysis (Vess). GeoM is the geometric mean of catch rates (kg/shot), standard deviation (StDev) relates to the optimum model. C<30Kg denotes the amount of catch in shots of <30kg, and P<30Kg is the proportion of total. The optimum model was SharkRegion:Month

Year	Total	N	Catch	Vess	GeoM	Opt	StDev	C<30Kg	P<30Kg
1997	214.2	4722	146.9	81	32.8	1.2791	0.000	40.042	0.273
1998	284.2	6876	225.0	81	33.7	1.2764	0.023	49.272	0.219
1999	295.6	7638	229.4	86	31.3	1.3645	0.023	58.951	0.257
2000	361.8	7192	275.4	76	39.4	1.7447	0.023	56.498	0.205
2001	340.7	6483	260.1	80	41.7	1.8134	0.024	48.260	0.186
2002	256.6	6251	157.3	77	26.7	1.1051	0.024	47.071	0.299
2003	319.9	6958	190.6	81	29.4	1.1312	0.024	48.471	0.254
2004	314.9	6560	190.8	73	30.7	1.1773	0.024	47.709	0.250
2005	296.7	5783	169.8	62	29.9	1.0747	0.025	42.053	0.248
2006	317.7	5270	155.6	58	30.6	1.0793	0.025	34.869	0.224
2007	214.5	4710	105.9	44	22.3	0.9265	0.026	29.244	0.276
2008	211.7	4652	114.4	44	26.2	1.0687	0.026	30.927	0.270
2009	191.5	4872	88.5	44	18.6	0.9049	0.026	34.081	0.385
2010	192.5	5080	91.4	47	18.7	0.8767	0.026	36.924	0.404
2011	197.1	5332	102.4	46	18.9	0.8447	0.025	38.476	0.376
2012	158.6	4606	73.8	42	16.0	0.6738	0.026	32.666	0.443
2013	165.7	4352	70.6	39	16.4	0.6366	0.027	34.764	0.492
2014	167.2	4174	80.7	38	19.3	0.6884	0.027	32.190	0.399
2015	164.2	4062	75.6	35	19.0	0.6865	0.027	31.248	0.413
2016	164.6	4333	94.5	33	22.2	0.7413	0.027	34.150	0.361
2017	178.8	5050	96.8	35	19.0	0.6534	0.026	38.320	0.396
2018	169.9	4584	85.5	33	18.2	0.7114	0.027	34.811	0.407
2019	163.0	4377	85.2	34	19.0	0.7506	0.027	30.972	0.363
2020	163.0	4247	98.0	26	23.0	0.7907	0.027	31.397	0.320

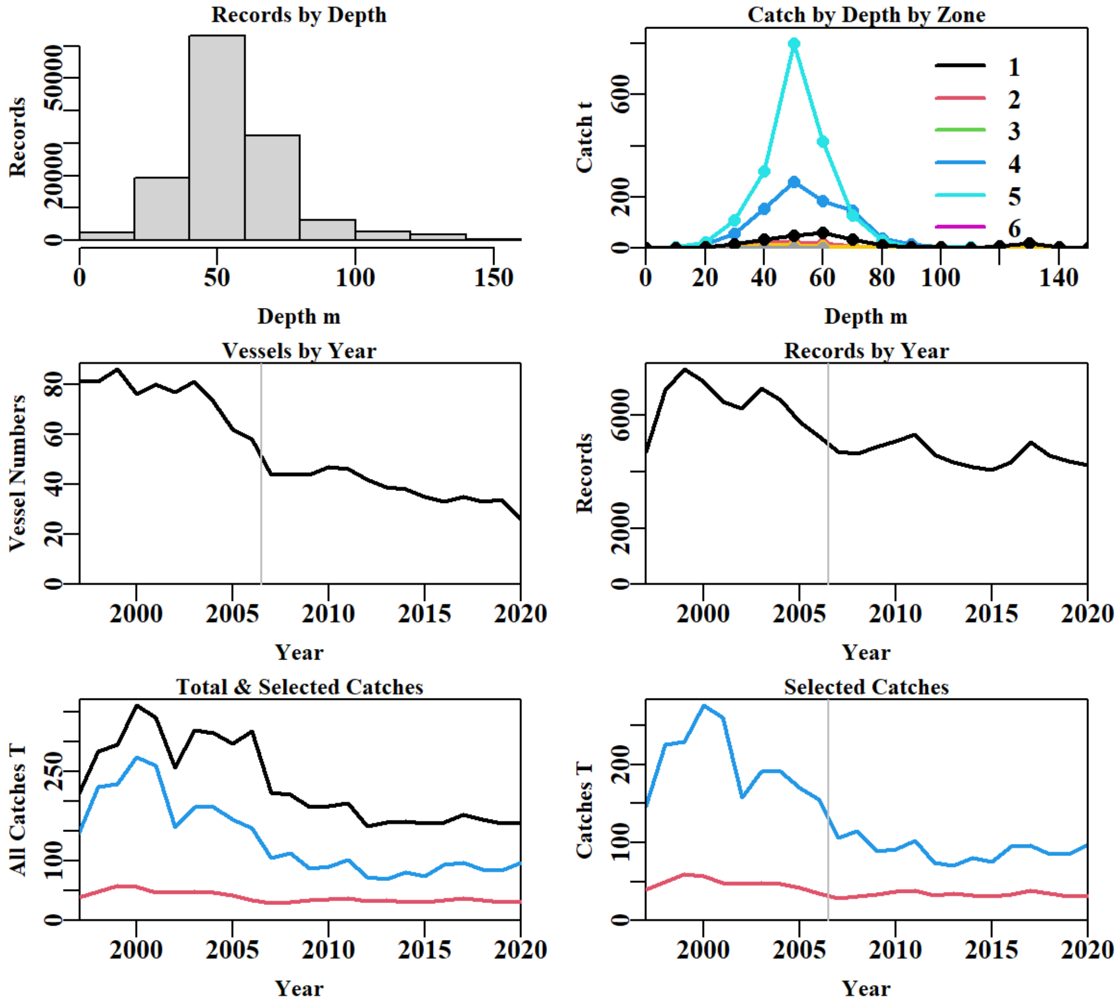

Figure 10.129. SawSharkGN fishery details. The bottom left plot depicts all known catches (top black line), and all selected catches used in the analysis (middle blue line); the lower red line: selected catches < 30 kg).

Table 10.70. SawSharkGN 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	274139	0	5982.57	0
NoCE	265699	8440	5982.57	0
Depth	236530	29169	4859.17	1123.41
Years	222332	14198	4527.39	331.78
Zones	217055	5277	4371.26	156.13
Method	128168	88887	3264.37	1106.89
Fishery	128164	4	3264.26	0.11

Table 10.71. The models used to analyse data for SawSharkGN

	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 10.72. SawSharkGN. 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

Term	AIC	RSS	MSS	Nobs	Npars	adj_r2	%Change
Year	77715	234935	8280	128164	24	3.4	0
Vessel	52799	192836	50379	128164	220	20.6	17.19
DepCat	44888	181250	61964	128164	235	25.3	4.76
SharkRegion	38967	173046	70169	128164	243	28.7	3.38
Month	36429	169624	73591	128164	254	30.1	1.40
SharkRegion:DepCat	32794	164600	78615	128164	363	32.1	2.01
SharkRegion:Month	31549	163065	80150	128164	341	32.8	2.66

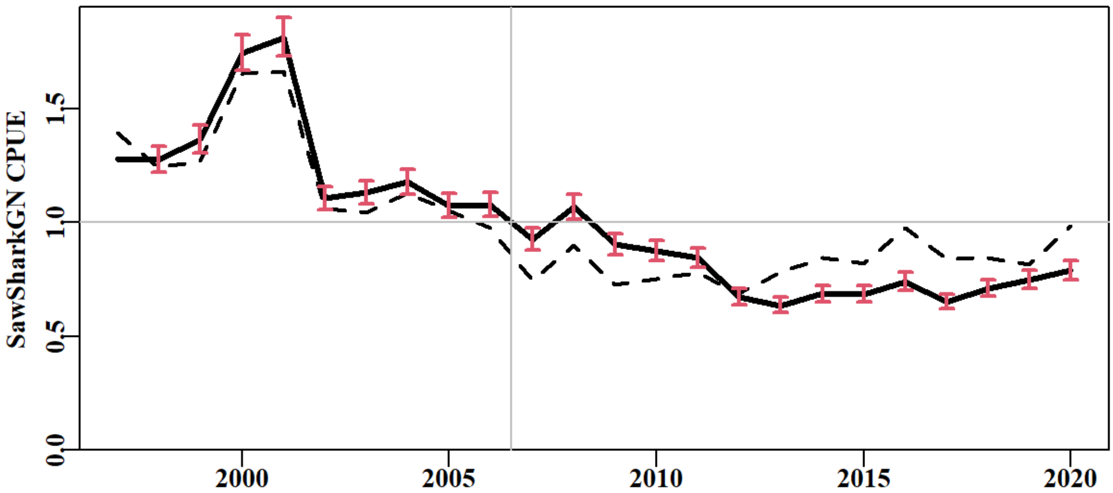

Figure 10.130. SawSharkGN standardization. The dashed black line represents the geometric mean catch rate, solid black line the standardized catch rates. The red bars are the 95% confidence intervals about the mean estimates. The graph scales both time-series of standardized catch rates relative to the mean of each time-series.

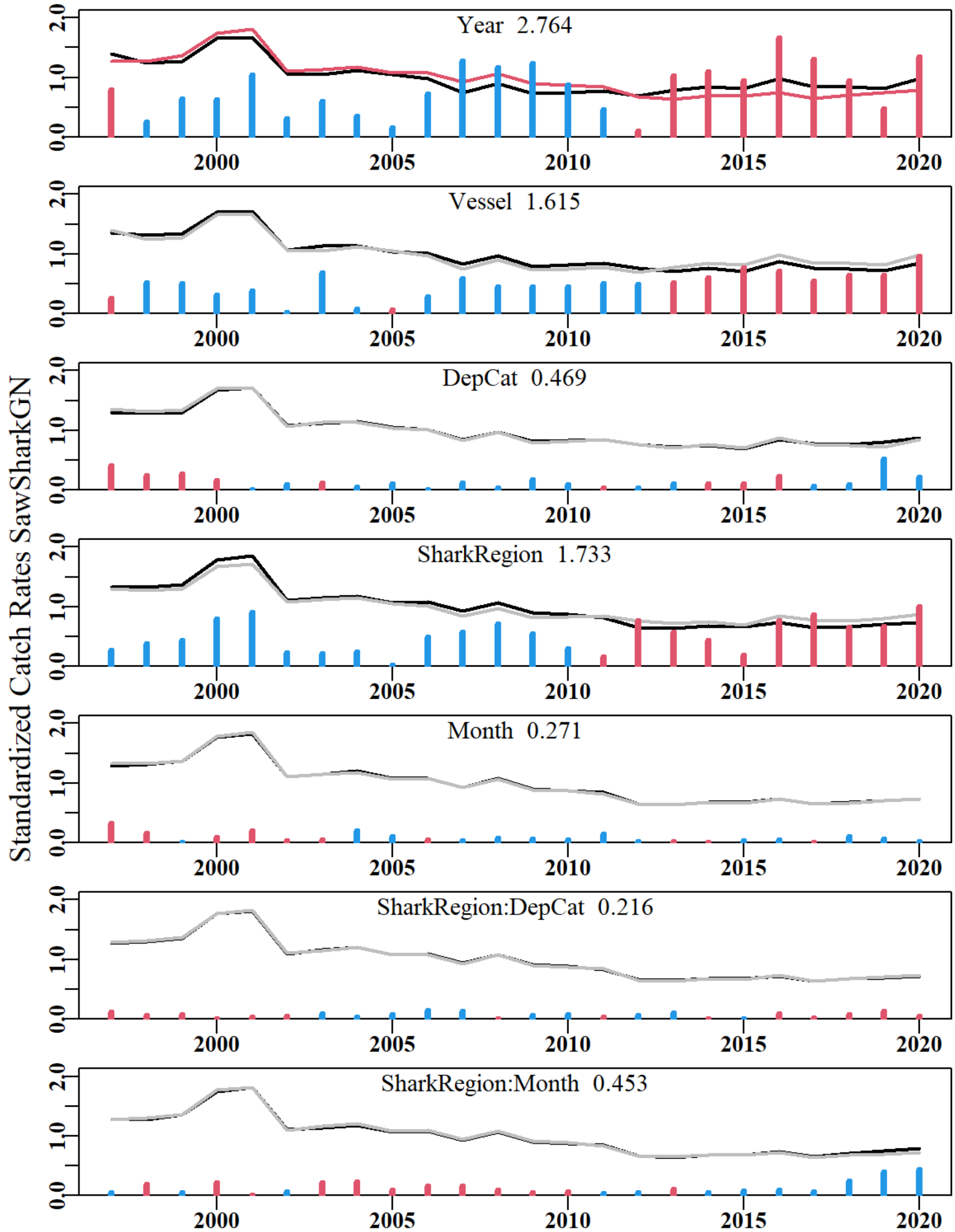

Figure 10.131. SawSharkGN. The influence of each factor on the optimal standardization. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by vertical bars with blue bars indicating the optimum model is higher than the geometric 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.

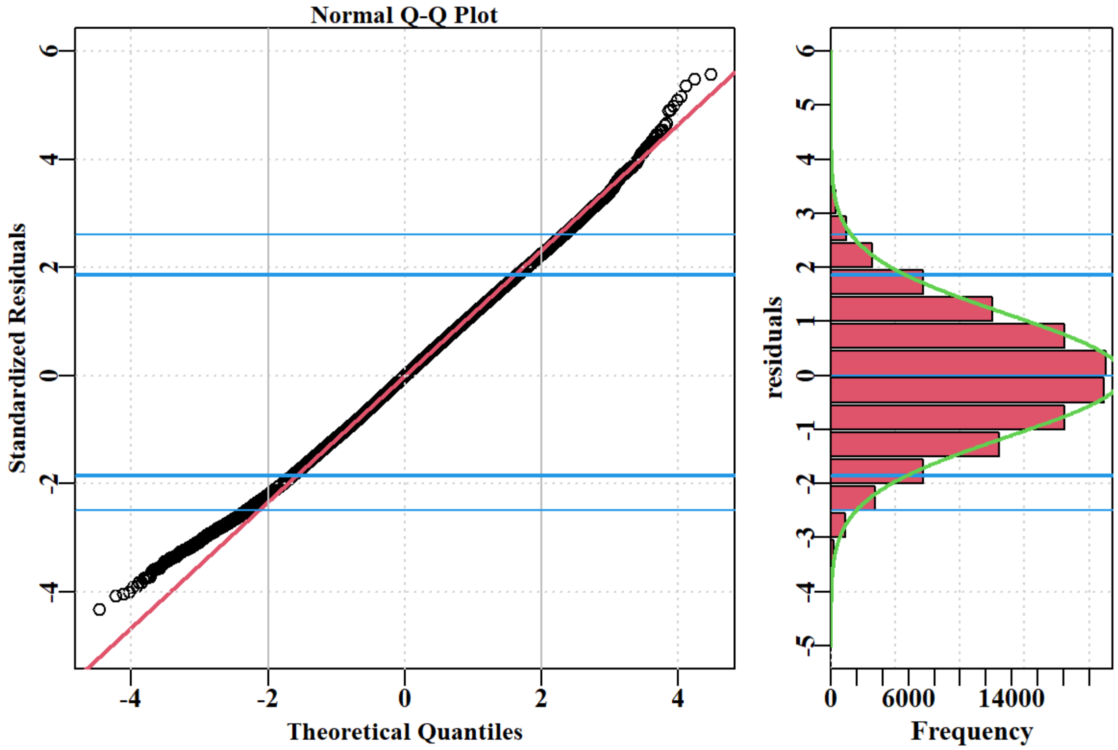

Figure 10.132. SawSharkGN. Diagnostic plots. The distribution of residuals from the optimum fit. The qqplot indicates the fit to the expected normality, while the histogram of residuals also illustrates the 1%, 5%, 95% and 99% quantiles to indicate the intensity of any lack of fit at the margins of the distribution (reflected also in the qqplot).

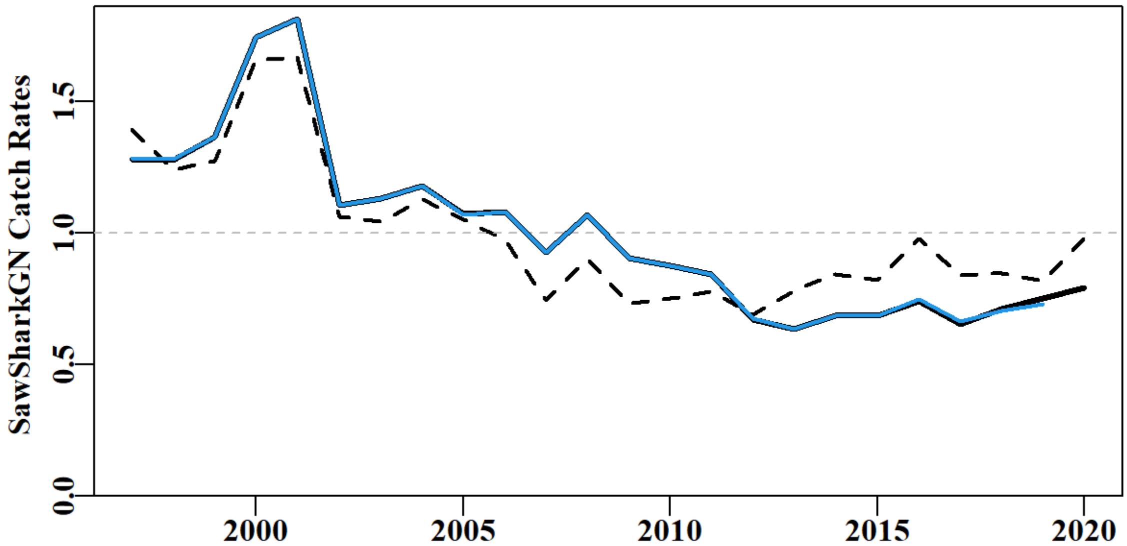

Figure 10.133. SawSharkGN. A comparison of the previous year's standardization (blue line) with this year's. They should lie on top of each other, although small deviations may relate to data adjustments, particularly in very recent years.

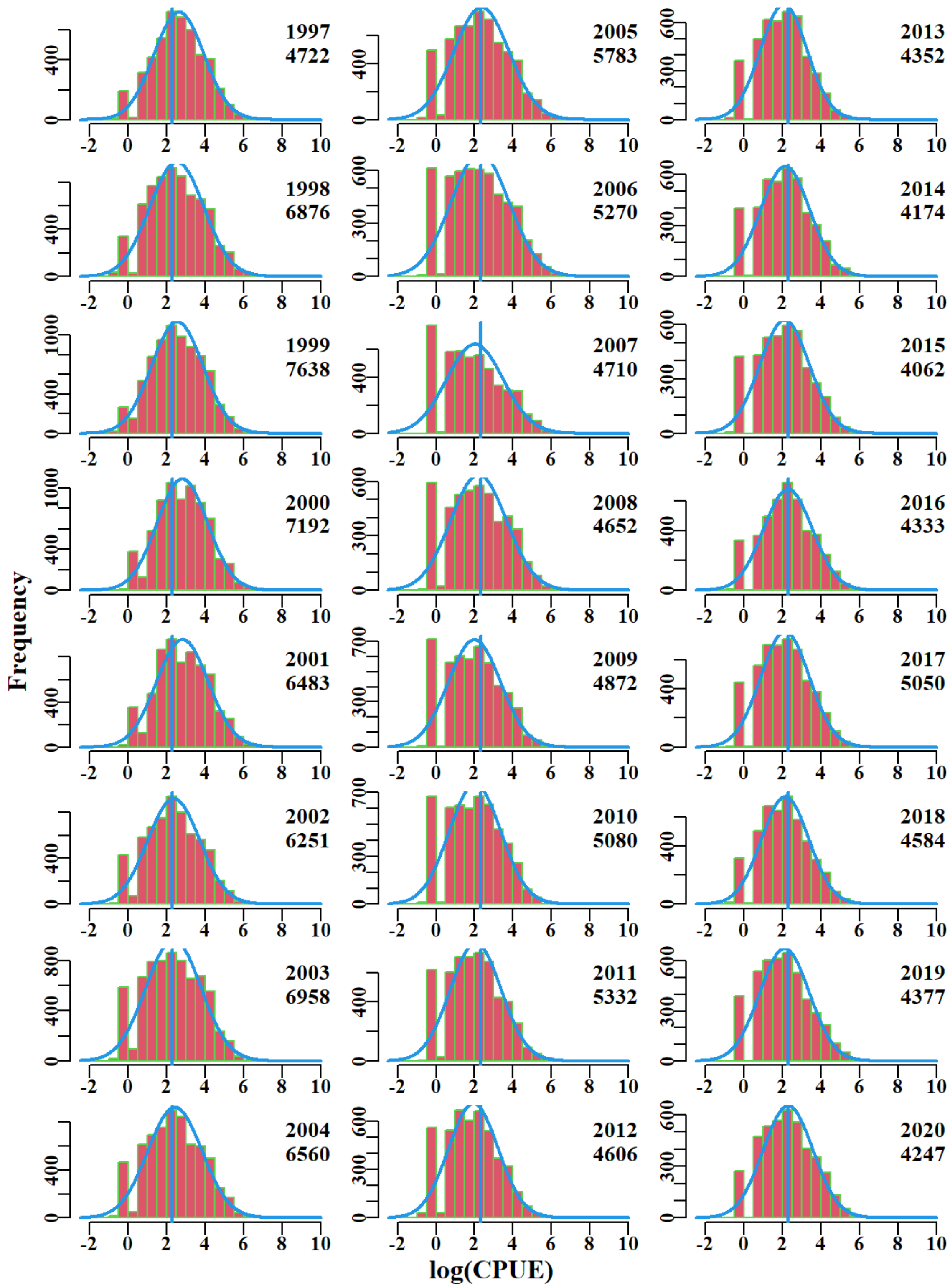

Figure 10.134. SawSharkGN. The natural log(CPUE) for each year of data available the blue lines are normal distributions fitted to the histogram frequencies. The numbers in each plot are the year and number of records. The vertical blue line is the average across all years.

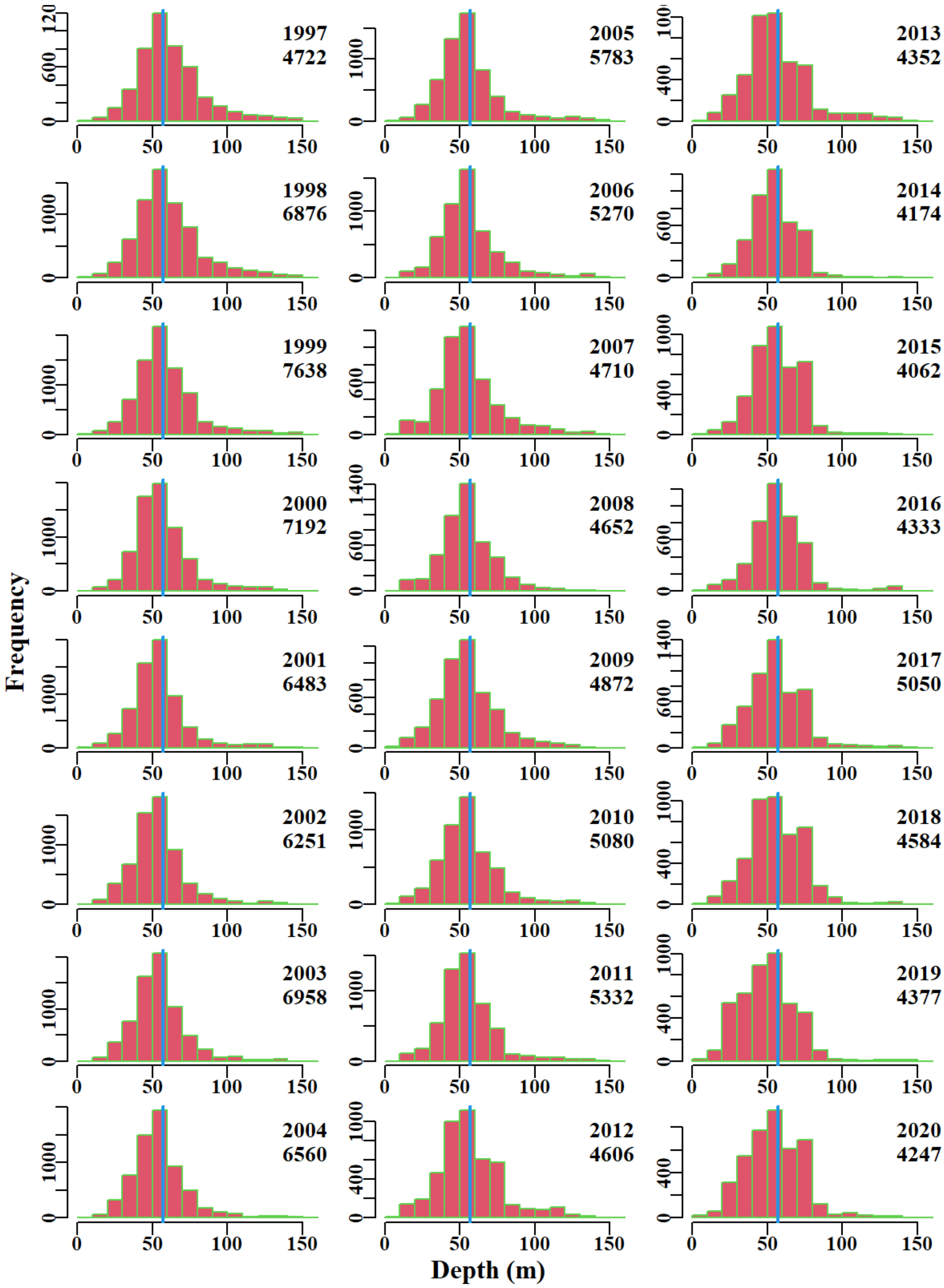

Figure 10.135. SawSharkGN. The average Depth of fishing for each year of data available to illustrate the development of the fishery through time. The numbers in each plot are the year and number of records. The vertical blue line is the average across all years.

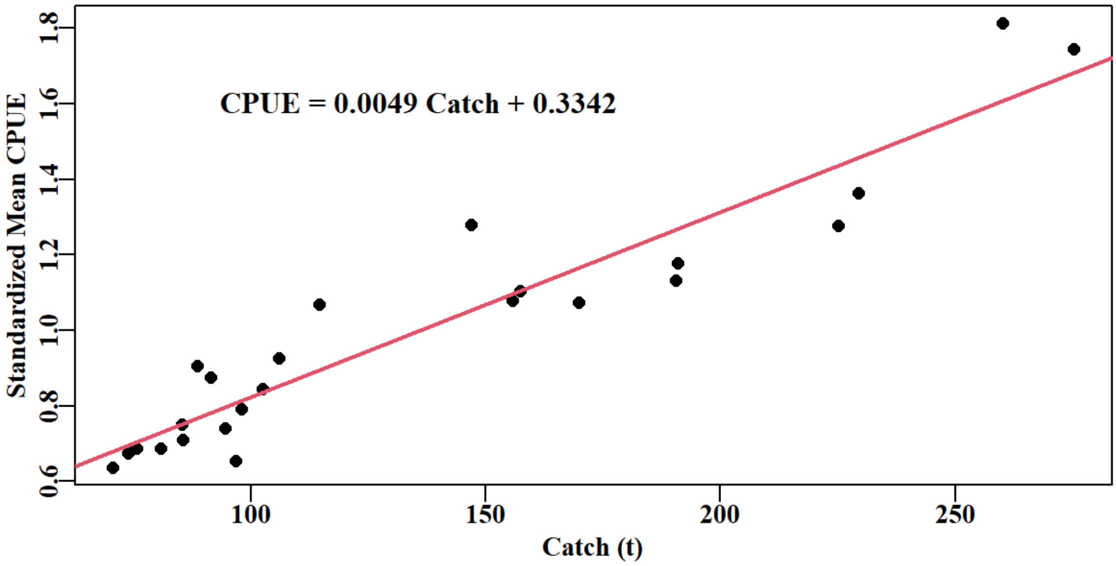

Figure 10.136. SawSharkGN. The linear relationship between annual mean CPUE and annual Catch.

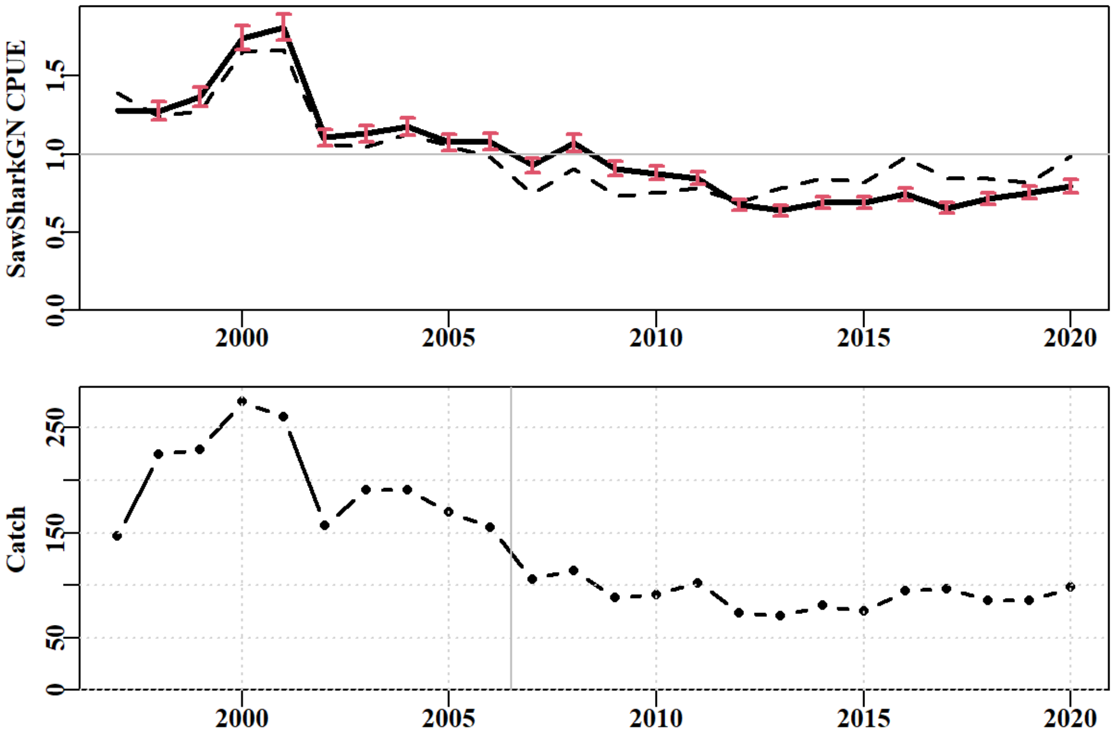

Figure 10.137. SawSharkGN. CPUE is correlated with catches through time. CPUE in the top plot and annual catch (t) in the lower plot.

10.19 Sawshark Gillnet kg/m

Sawshark are considered primarily as a bycatch species and are taken mostly by gillnets, trawl and Danish seine. Positive non-zero records of catch (kg) per netlength (m) were employed in the statistical standardization analyses for Sawshark caught by gillnets.

Gillnet effort was recorded as total length of shot (TLS) between 1997 and 1999. Part way through mid-1999, this was replaced with gillnet netlength (GNL). These two gillnet netlengths were combined into the one series for analysis and relevant depths and shark zones were selected based on the number of available fishing operations.

10.19.1 *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). Most catch occurred in Shark region 5, followed by 4.

The terms Year, Vessel, DepCat, SharkRegion, Month and one interaction (SharkRegion:Month) had the greatest contribution to model fit based on the AIC and R^2 statistics (Table 10.76). The qqplot suggests the assumed Normal distribution is valid, with slight deviations as depicted by both tails of the distribution (Figure 10.141).

Annual standardized CPUN (i.e., catch-per-unit-netlength; kg/m) has been flat, close to the long-term average between 2002-2008 and flat and below the long-term average since 2009, with minor increases over the 2014-2016 and 2018-2020 periods (Figure 10.139). Overall, annual standardized CPUN (black line) is similar in overall shape compared to standardized CPS (i.e., catch-per-shot CPS; see earlier section).

Table 10.73. SawShark_GN. The data selection criteria used to specify and identify the fishery data to be included in the analysis.

Property	Value
label	SawShark_GN
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, GNS
years	1997 - 2020

Table 10.74. SawShark_GN. 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/m), 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

Year	Total	N	Catch	Vess	GeoM	Opt	StDev	C<30Kg	P<30Kg
1997	214.2	4399	133.7	78	0.009	1.3755	0.000	36.614	0.274
1998	284.2	6862	224.6	80	0.010	1.3993	0.023	49.103	0.219
1999	292.1	7453	225.8	86	0.010	1.5019	0.024	57.666	0.255
2000	352.4	6883	268.2	76	0.012	1.8786	0.024	54.048	0.201
2001	338.2	6387	257.6	80	0.012	1.9483	0.025	47.267	0.183
2002	255.8	6167	156.6	77	0.008	1.1382	0.025	46.280	0.296
2003	319.0	6842	189.7	81	0.008	1.1637	0.025	47.715	0.252
2004	314.7	6536	190.6	73	0.008	1.1931	0.025	47.586	0.250
2005	296.7	5775	169.7	62	0.008	1.0866	0.026	41.991	0.247
2006	317.7	5270	155.6	58	0.008	1.0984	0.026	34.869	0.224
2007	214.5	4700	105.9	44	0.005	0.9334	0.027	29.199	0.276
2008	211.7	4652	114.4	44	0.006	1.0681	0.027	30.927	0.270
2009	191.5	4872	88.5	44	0.005	0.9220	0.027	34.081	0.385
2010	192.5	5080	91.4	47	0.005	0.8921	0.027	36.924	0.404
2011	197.1	5332	102.4	46	0.005	0.8561	0.026	38.476	0.376
2012	158.6	4606	73.8	42	0.004	0.6660	0.027	32.666	0.443
2013	165.7	4310	69.9	39	0.004	0.5617	0.028	34.378	0.492
2014	167.2	3969	77.1	38	0.004	0.6199	0.028	30.529	0.396
2015	164.2	3947	73.4	35	0.004	0.6191	0.028	30.202	0.411
2016	164.6	4335	94.5	33	0.005	0.6729	0.028	34.166	0.361
2017	178.8	5050	96.8	35	0.004	0.6012	0.027	38.320	0.396
2018	169.9	4591	85.6	33	0.004	0.5768	0.028	34.859	0.407
2019	163.0	4382	85.4	34	0.004	0.5874	0.028	31.004	0.363
2020	163.0	4251	98.1	26	0.004	0.6399	0.028	31.430	0.321

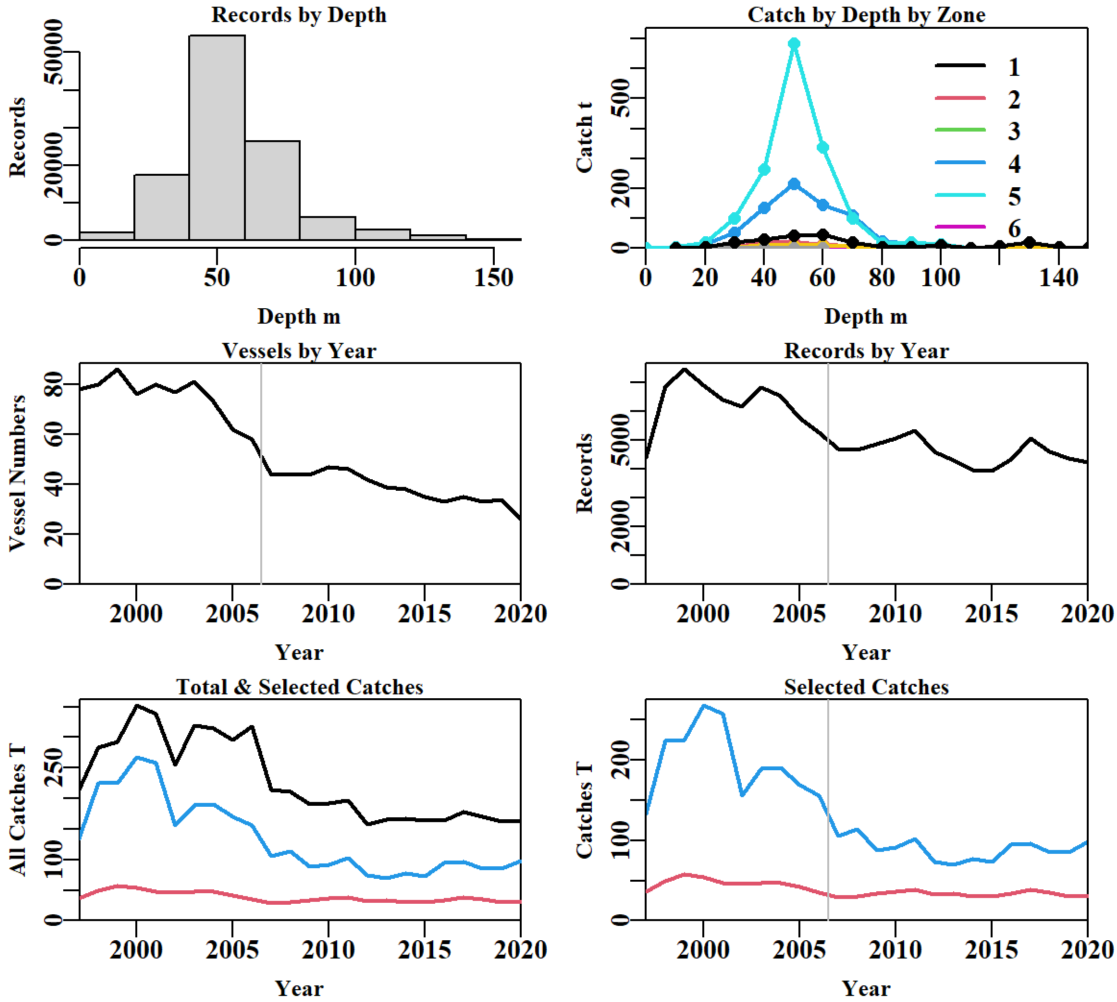

Figure 10.138. SawShark_GN fishery details. The bottom left plot depicts all known catches (top black line), and all selected catches used in the analysis (middle blue line); the lower red line: selected catches < 30 kg).

Table 10.75. The models used to analyse data for SawShark_GN

	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 10.76. SawShark_GN. 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

Term	AIC	RSS	MSS	Nobs	Npars	adj_r2	%Change
Year	74994	228878	16026	126651	24	6.5	0
Vessel	52850	191582	53322	126651	216	21.6	15.11
DepCat	47729	183970	60934	126651	223	24.7	3.11
SharkRegion	42785	176904	67999	126651	231	27.6	2.89
Month	40360	173519	71385	126651	242	29.0	1.38
SharkRegion:DepCat	37815	169924	74979	126651	295	30.5	1.44
SharkRegion:Month	35262	166444	78460	126651	329	31.9	2.85

Figure 10.139. SawShark_GN 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.

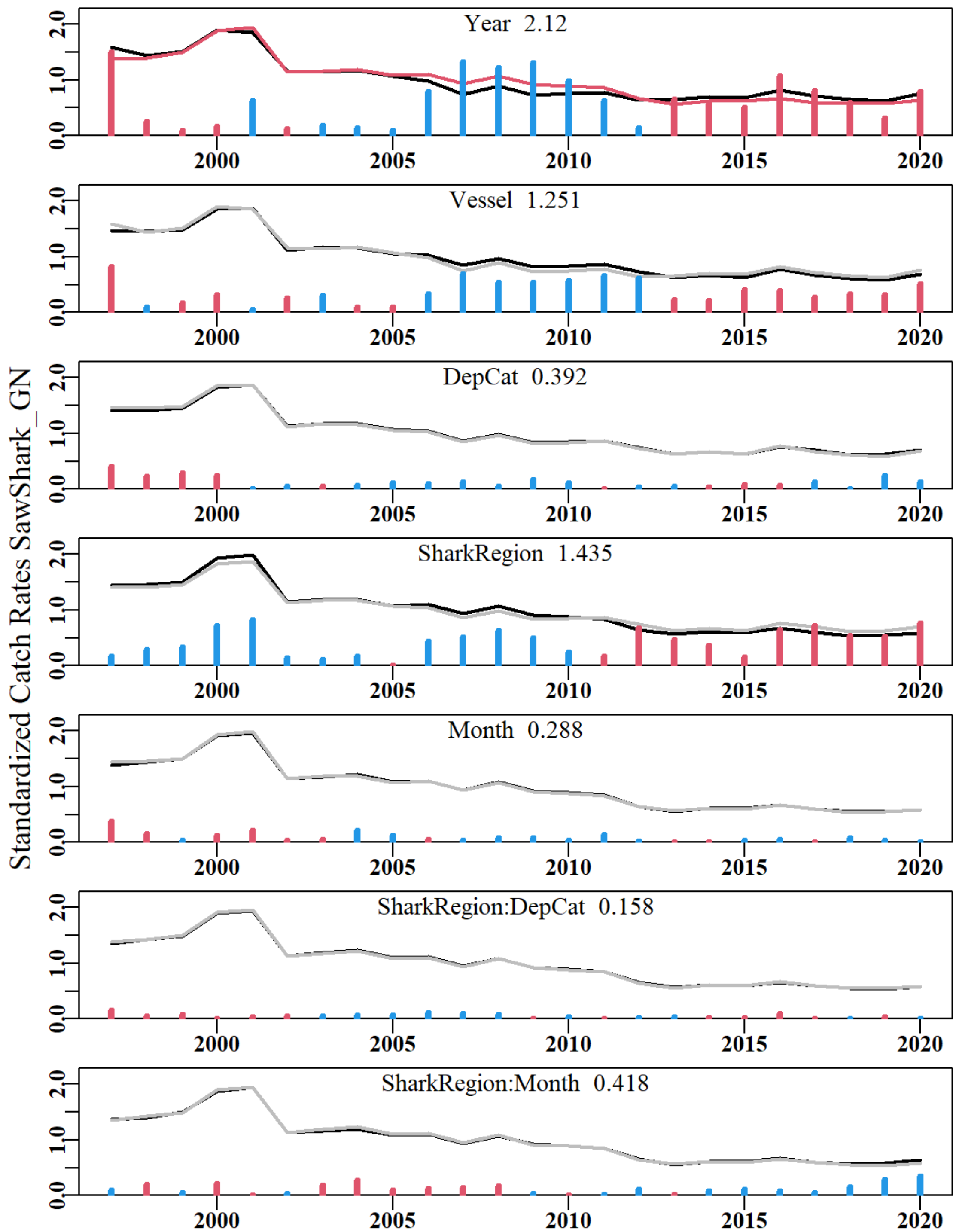

Figure 10.140. SawShark_GN. The influence of each factor on the optimal standardization. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by vertical bars with blue bars indicating the optimum model is higher than the geometric 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.

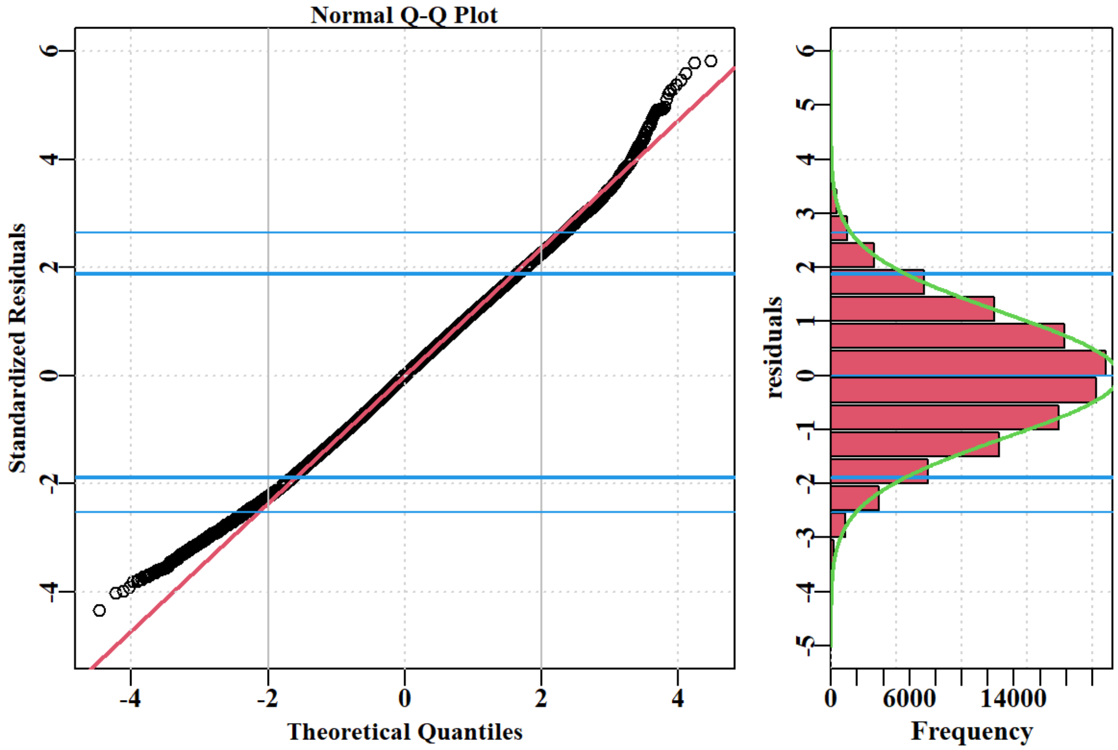

Figure 10.141. SawShark_GN. Diagnostic plots. The distribution of residuals from the optimum fit. The qqplot indicates the fit to the expected normality, while the histogram of residuals also illustrates the 1%, 5%, 95% and 99% quantiles to indicate the intensity of any lack of fit at the margins of the distribution (reflected also in the qqplot).

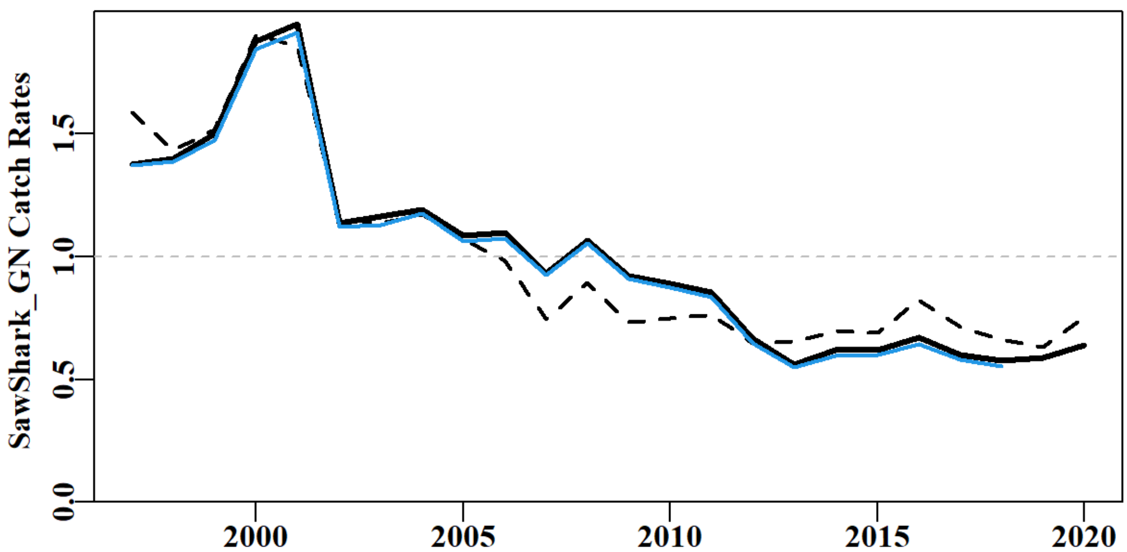

Figure 10.142. SawShark_GN. A comparison of the previous year's standardization (blue line) with this year's. They should lie on top of each other, although small deviations may relate to data adjustments, particularly in very recent years.

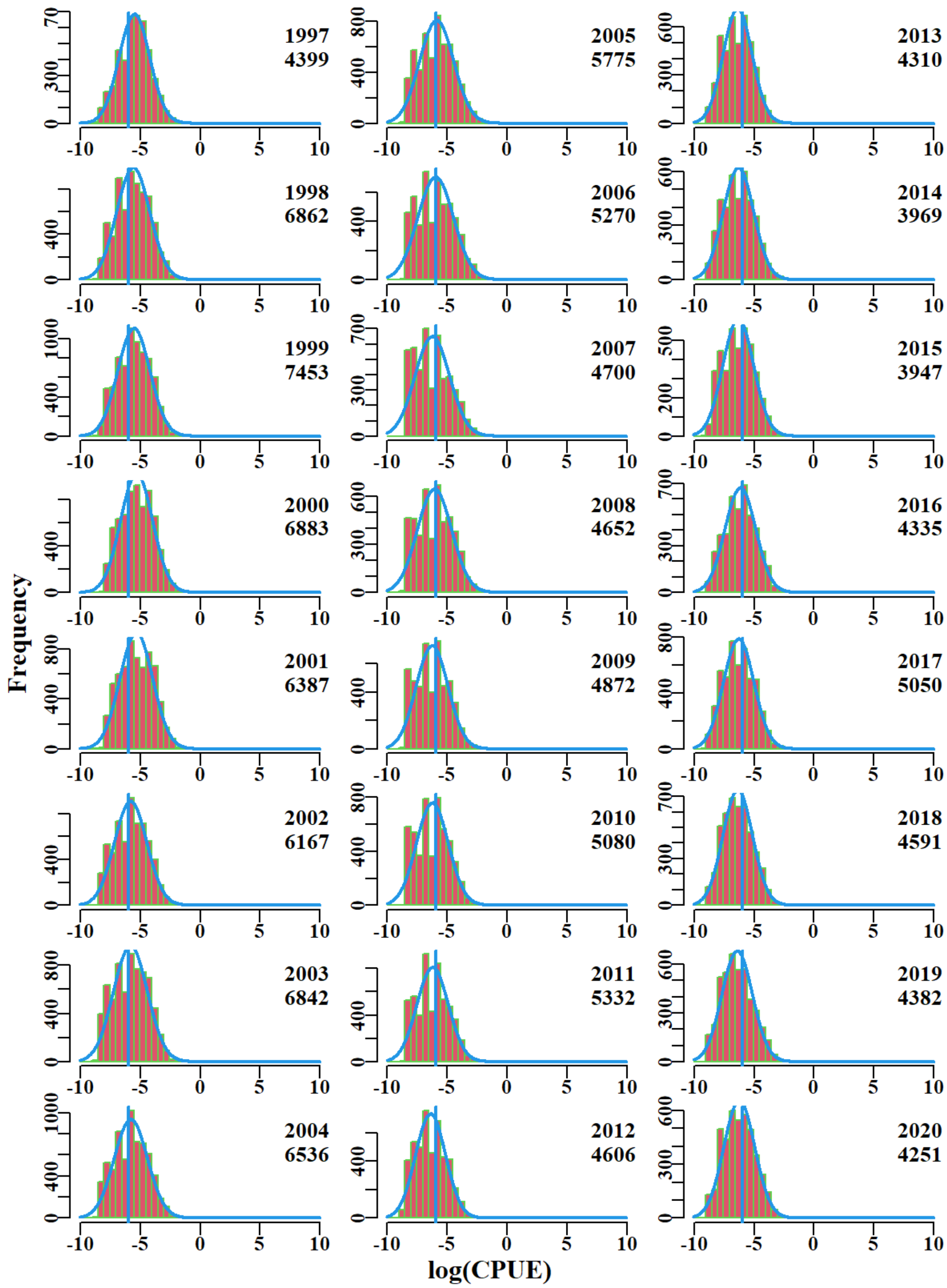

Figure 10.143. SawShark_GN. The natural log(CPUE) for each year of data available the blue lines are normal distributions fitted to the histogram frequencies. The numbers in each plot are the year and number of records. The vertical blue line is the average across all years.

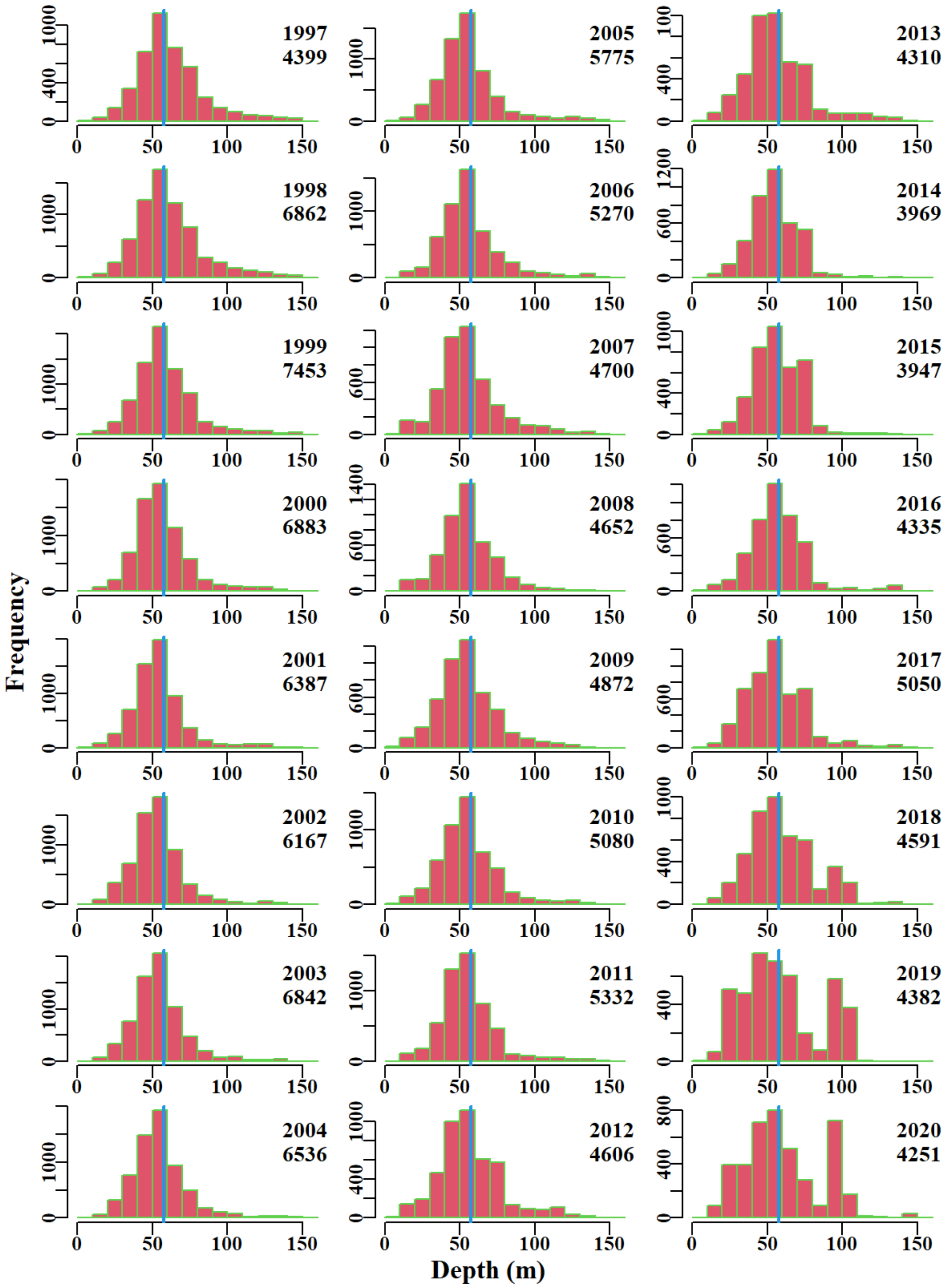

Figure 10.144. SawShark_GN. The average Depth of fishing for each year of data available to illustrate the development of the fishery through time. The numbers in each plot are the year and number of records. The vertical blue line is the average across all years.

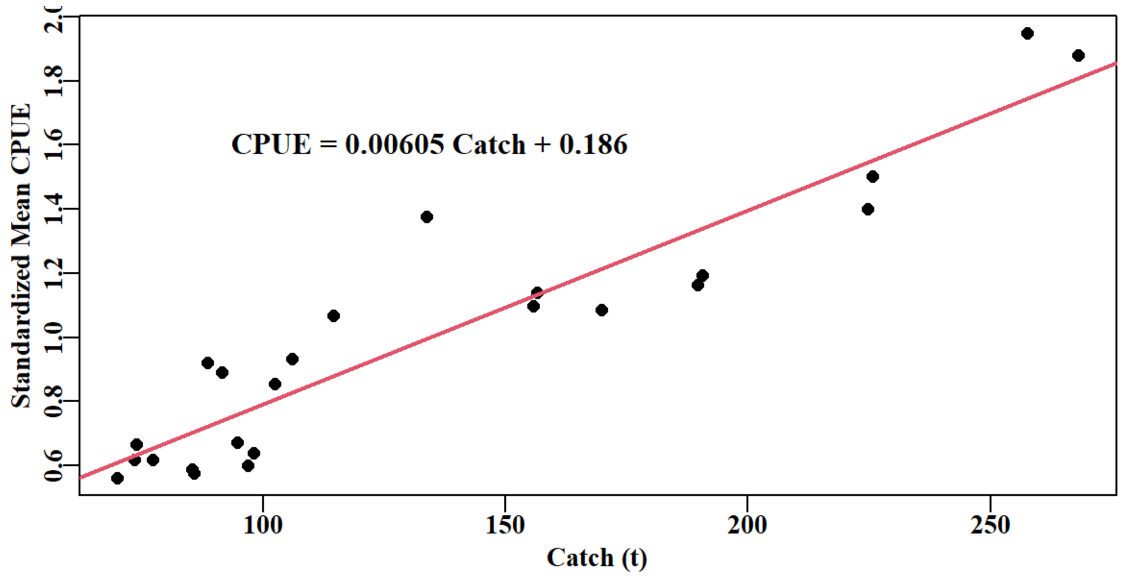

Figure 10.145. SawShark_GN. The linear relationship between annual mean CPUE and annual Catch.

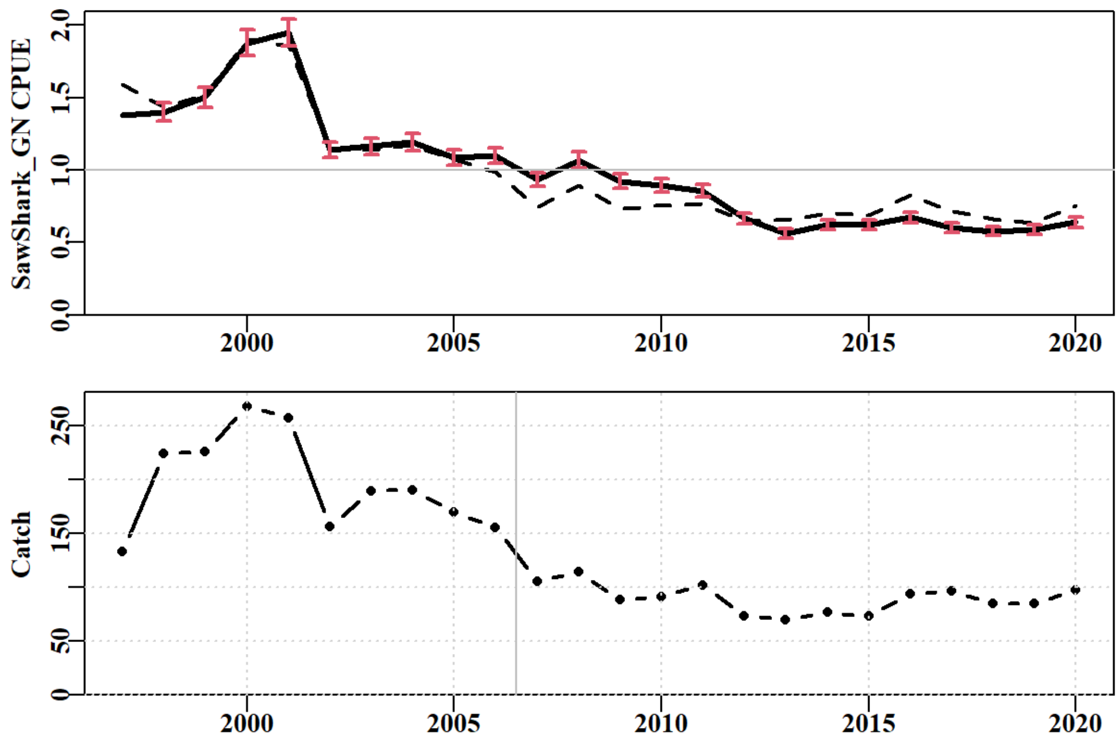

Figure 10.146. SawShark_GN. CPUE is correlated with catches through time. CPUE in the top plot and annual catch (t) in the lower plot.

10.20 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.

10.20.1 *Inferences*

Most catch occurred in Shark region 1, followed by 2 and 5.

The terms Year, Vessel, DepCat, SharkRegion, Month and one interaction (SharkRegion:DepCat) had the greatest contribution to model fit based on the AIC and R^2 statistics (Table 10.81). The qqplot suggests the assumed Normal distribution is valid, with a slight deviation as depicted by the upper tail of the distribution (Figure 10.150). Annual standardized CPUE has increased, reached the long-term average over the 2017-2019 period, and decreased in 2020, based on 95% confidence intervals (Figure 10.148).

10.20.2 *Action Items and Issues*

Further consideration of whether to consider the CPUE time-series as a valid index of relative abundance for Sawshark needs to be explored.

Table 10.77. 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, OTB, TMO
years	1995 - 2020

Table 10.78. 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:DepCat

Year	Total	N	Catch	Vess	GeoM	Opt	StDev	C<30Kg	P<30Kg
1995	57.1	1764	51.7	54	7.9	1.3163	0.000	17.727	0.343
1996	67.5	1992	59.9	60	8.1	1.3338	0.035	19.324	0.323
1997	214.2	2443	59.4	60	6.5	1.1915	0.035	24.417	0.411
1998	284.2	1694	47.9	54	6.8	1.0903	0.038	16.888	0.353
1999	295.6	1813	51.2	50	7.6	1.2463	0.037	17.384	0.339
2000	361.8	2361	69.0	64	10.2	1.0876	0.036	23.081	0.335
2001	340.7	2556	68.1	54	6.9	1.0614	0.036	23.634	0.347
2002	256.6	3298	70.8	68	5.9	0.9450	0.034	28.762	0.406
2003	319.9	4401	100.8	75	5.7	0.8693	0.033	34.953	0.347
2004	314.9	4271	95.4	76	6.3	0.8514	0.033	33.848	0.355
2005	296.7	4932	104.6	71	5.7	0.8543	0.033	40.170	0.384
2006	317.7	4625	137.2	64	7.4	0.9432	0.033	33.402	0.243
2007	214.5	2561	82.0	39	7.4	0.8140	0.036	20.114	0.245
2008	211.7	2891	71.6	40	5.6	0.8603	0.035	24.796	0.346
2009	191.5	2806	78.4	34	6.7	1.0880	0.035	25.884	0.330
2010	192.5	3138	80.4	37	5.9	0.9852	0.035	29.956	0.373
2011	197.1	2914	66.8	36	5.5	0.8862	0.035	25.062	0.375
2012	158.6	2426	60.5	36	6.2	0.8841	0.036	21.854	0.361
2013	165.7	2526	70.0	36	6.7	1.0319	0.036	26.220	0.375
2014	167.2	2261	70.1	36	7.5	1.0347	0.037	24.565	0.351
2015	164.2	2213	59.4	36	7.0	0.9418	0.037	22.834	0.385
2016	164.6	1977	47.2	37	6.7	0.8654	0.038	19.457	0.412
2017	178.8	1978	59.8	33	7.9	0.9376	0.038	19.320	0.323
2018	169.9	2100	59.3	32	7.8	0.9691	0.038	20.628	0.348
2019	163.0	1998	56.2	29	7.6	1.0155	0.038	18.574	0.330
2020	163.0	1563	40.9	27	6.7	0.8959	0.040	15.176	0.371

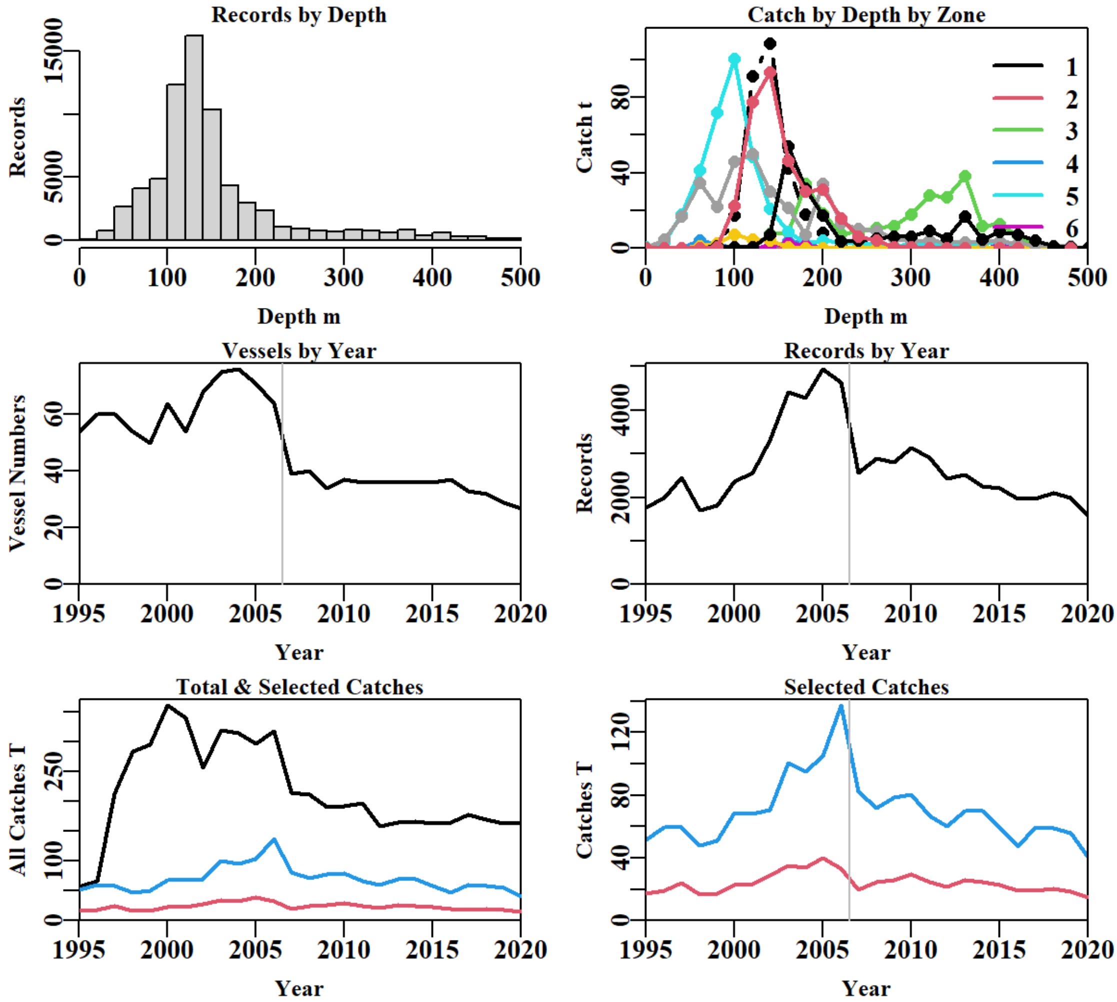

Figure 10.147. SawSharkTrawl fishery details. The bottom left plot depicts all known catches (top black line), and all selected catches used in the analysis (middle blue line); the lower red line: selected catches < 30 kg).

Table 10.79. 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	274139	0	5982.57	0
NoCE	203098	71041	4431.88	1550.69
Depth	201285	1813	4392.61	39.27
Years	188973	12312	4052.04	340.57
Zones	188566	407	4043.20	8.84
Method	69591	118975	1820.05	2223.14
Fishery	69502	89	1818.67	1.38

Table 10.80. 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 10.81. 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:DepCat

Term	AIC	RSS	MSS	Nobs	Npars	adj_r2	%Change
Year	32778	111300	1112	69502	26	1.0	0
Vessel	12026	82247	30165	69502	162	26.7	25.71
DepCat	9911	79724	32688	69502	187	28.9	2.22
SharkRegion	7590	77085	35327	69502	196	31.2	2.34
Month	5958	75273	37139	69502	207	32.8	1.61
DayNight	5871	75172	37240	69502	210	32.9	0.09
SharkRegion:DepCat	4440	73239	39173	69502	400	34.5	1.55
SharkRegion:Month	3740	72695	39717	69502	309	35.0	2.12

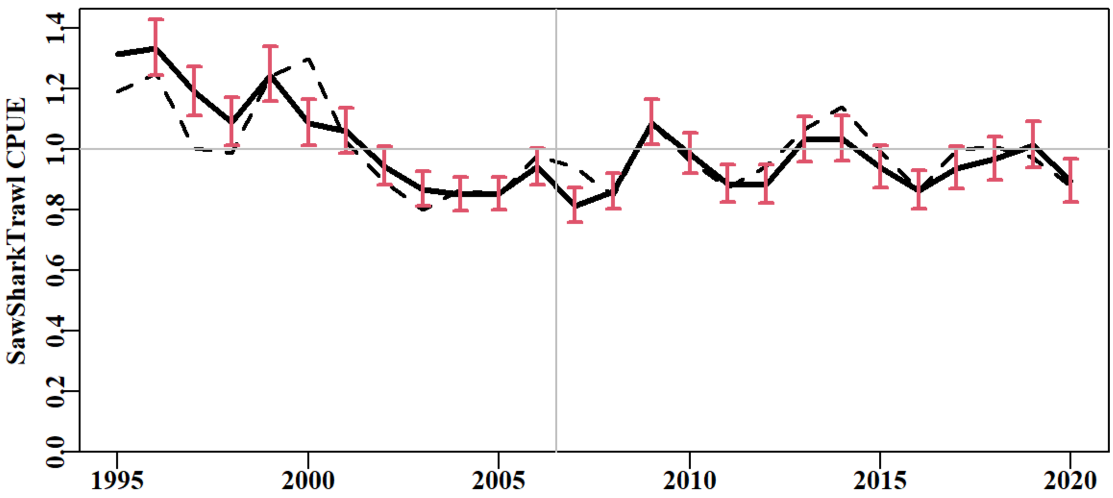

Figure 10.148. SawSharkTrawl standardization. The dashed black line represents the geometric mean catch rate, solid black line the standardized catch rates. The red bars are the 95% confidence intervals about the mean estimates. The graph scales both time-series of standardized catch rates relative to the mean of each time-series.

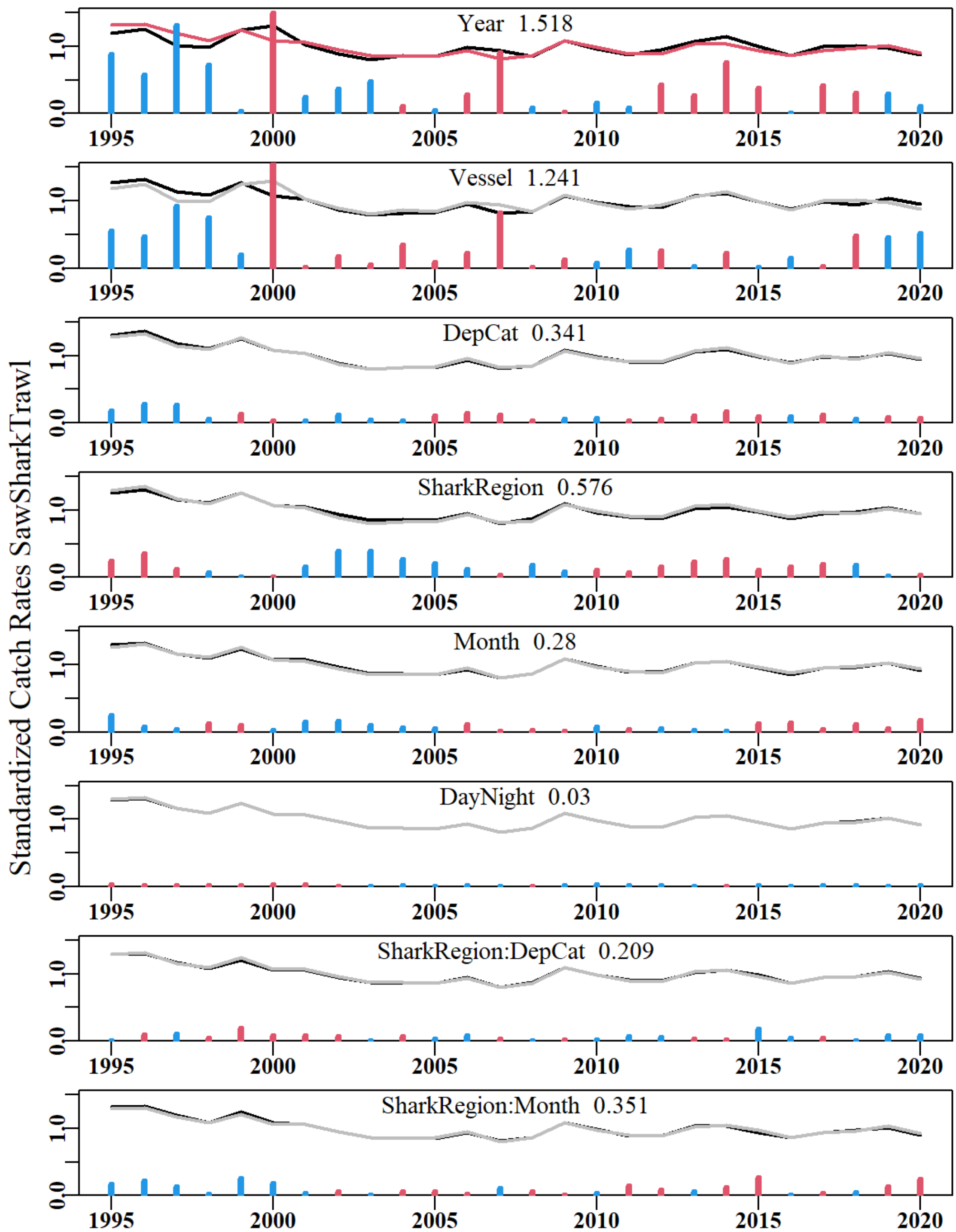

Figure 10.149. SawSharkTrawl. The influence of each factor on the optimal standardization. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by vertical bars with blue bars indicating the optimum model is higher than the 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.

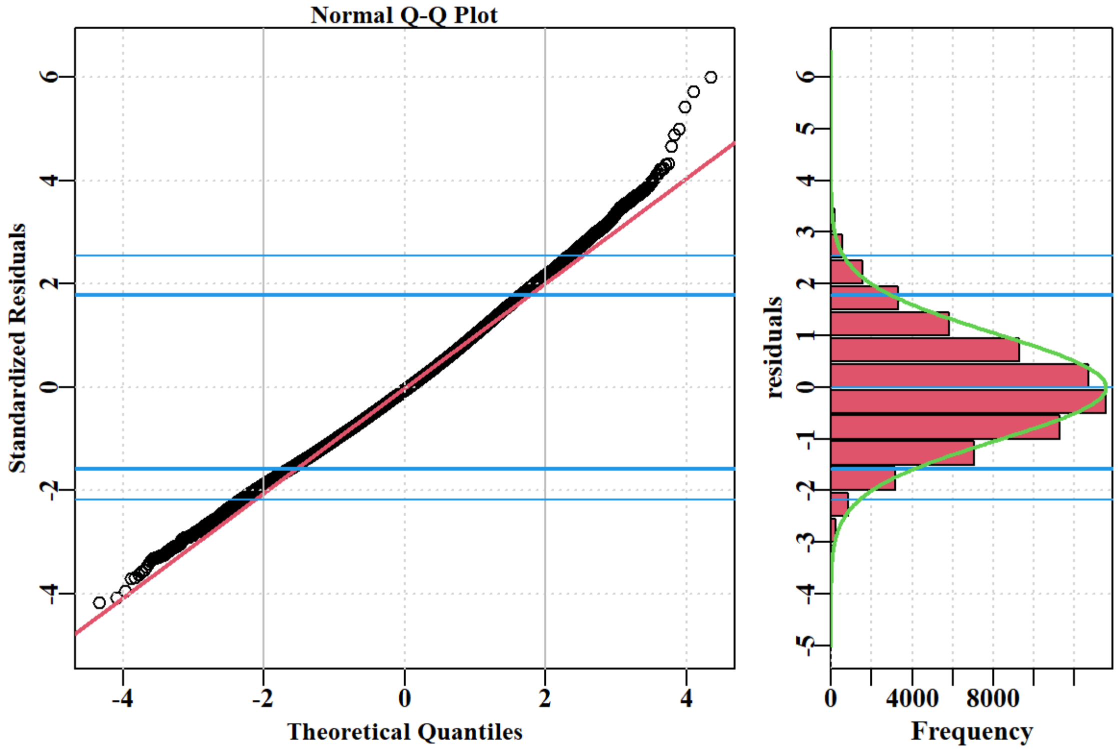

Figure 10.150. SawSharkTrawl. Diagnostic plots. The distribution of residuals from the optimum fit. The qqplot indicates the fit to the expected normality, while the histogram of residuals also illustrates the 1%, 5%, 95% and 99% quantiles to indicate the intensity of any lack of fit at the margins of the distribution (reflected also in the qqplot).

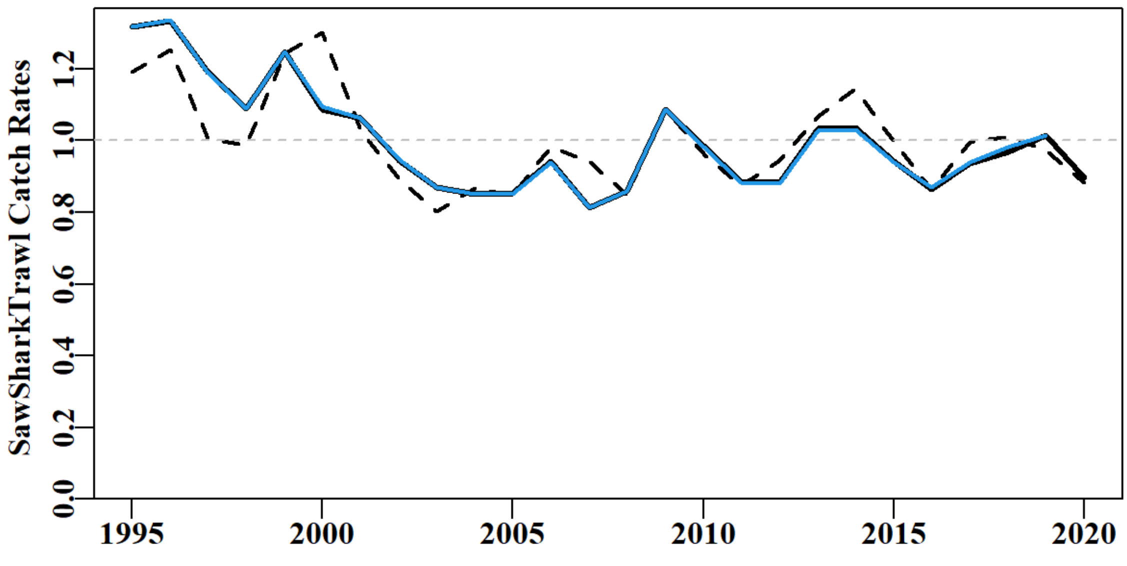

Figure 10.151. SawSharkTrawl. A comparison of the previous year's standardization (blue line) with this year's. They should lie on top of each other, although small deviations may relate to data adjustments, particularly in very recent years.

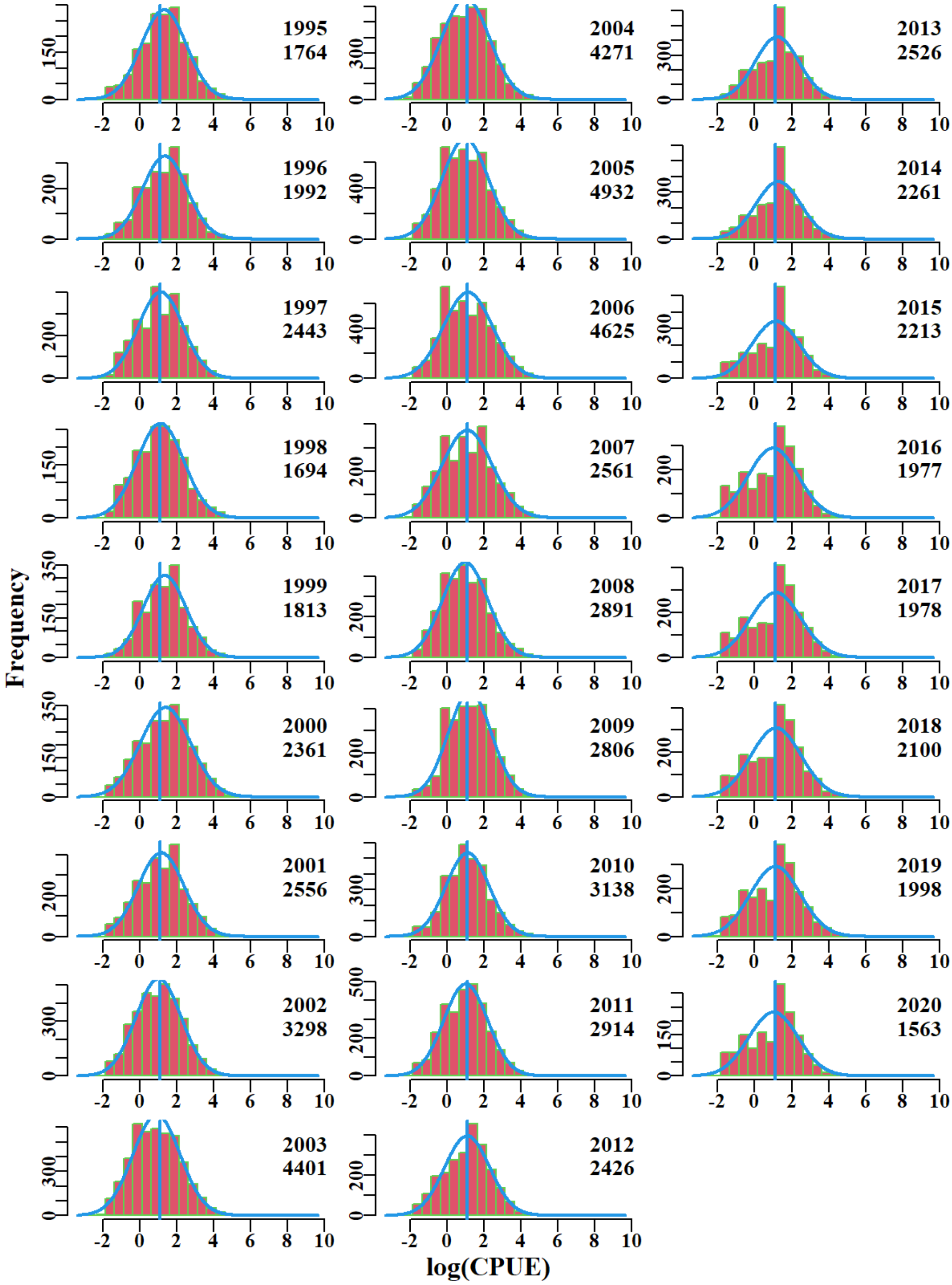

Figure 10.152. SawSharkTrawl. The natural log(CPUE) for each year of data available the blue lines are normal distributions fitted to the histogram frequencies. The numbers in each plot are the year and number of records. The vertical blue line is the average across all years.

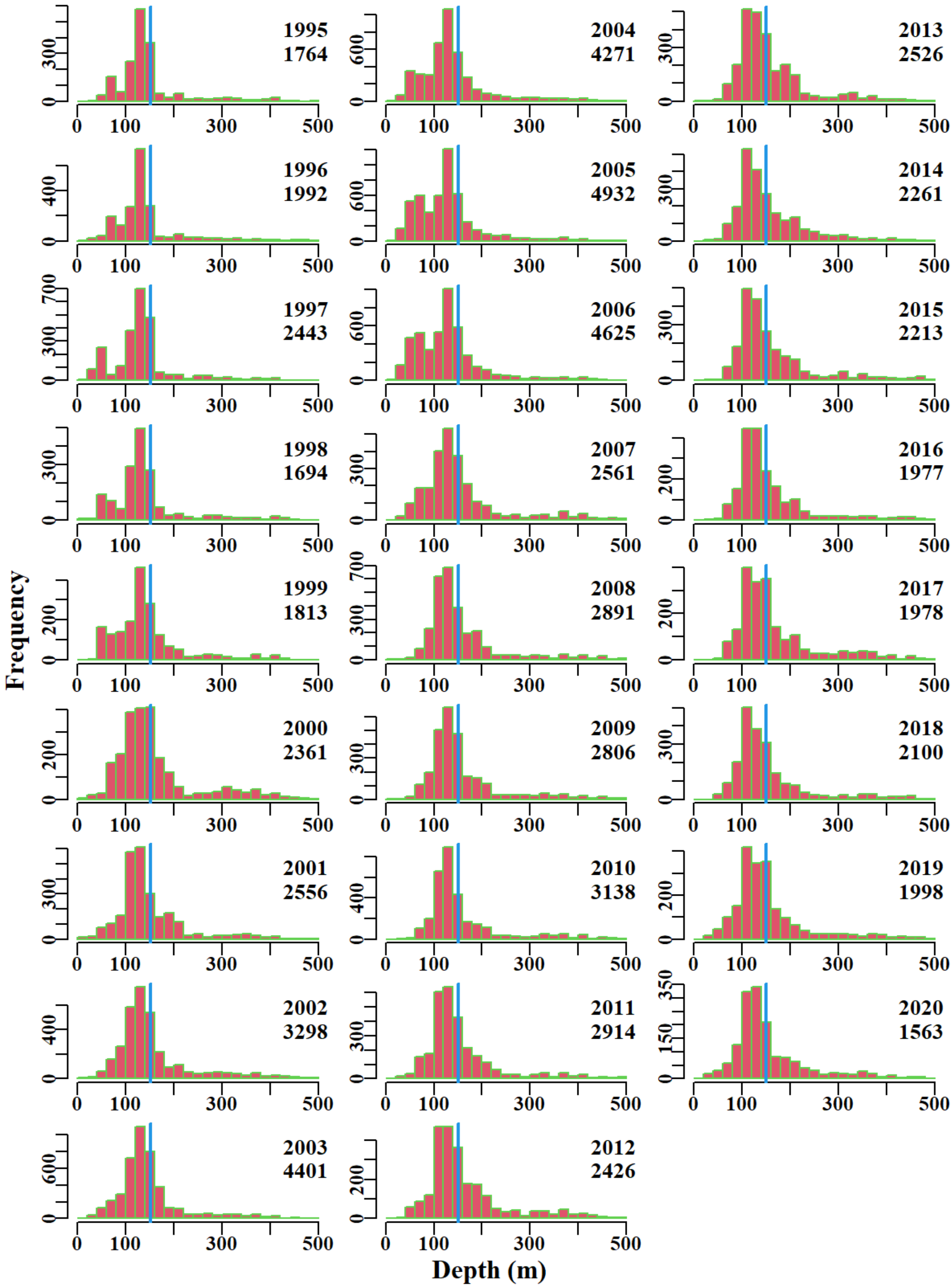

Figure 10.153. SawSharkTrawl. The average Depth of fishing for each year of data available to illustrate the development of the fishery through time. The numbers in each plot are the year and number of records. The vertical blue line is the average across all years.

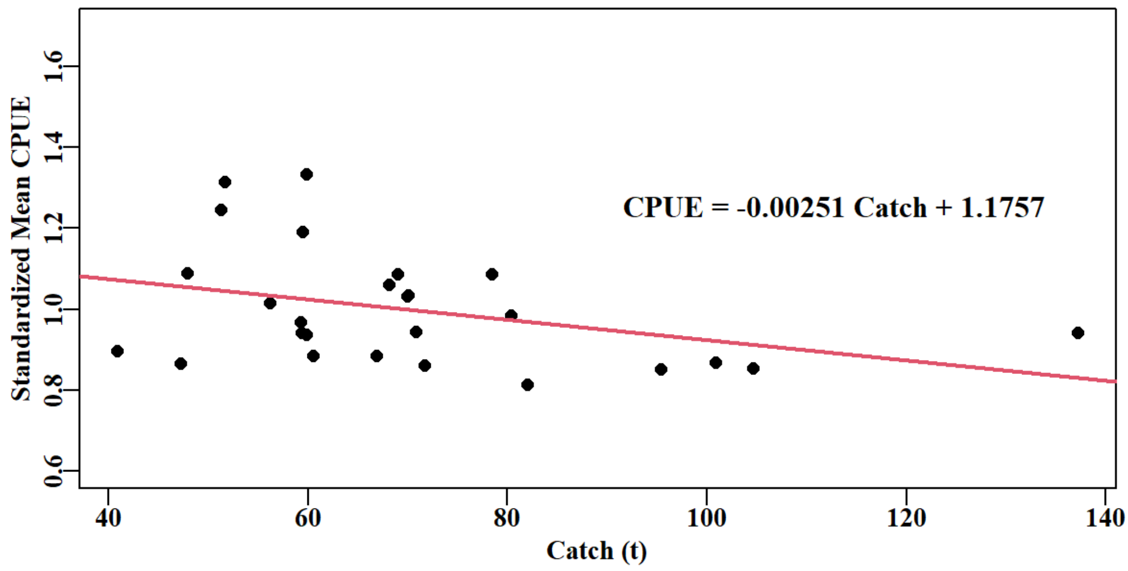

Figure 10.154. SawSharkTrawl. The linear relationship between annual mean CPUE and annual Catch.

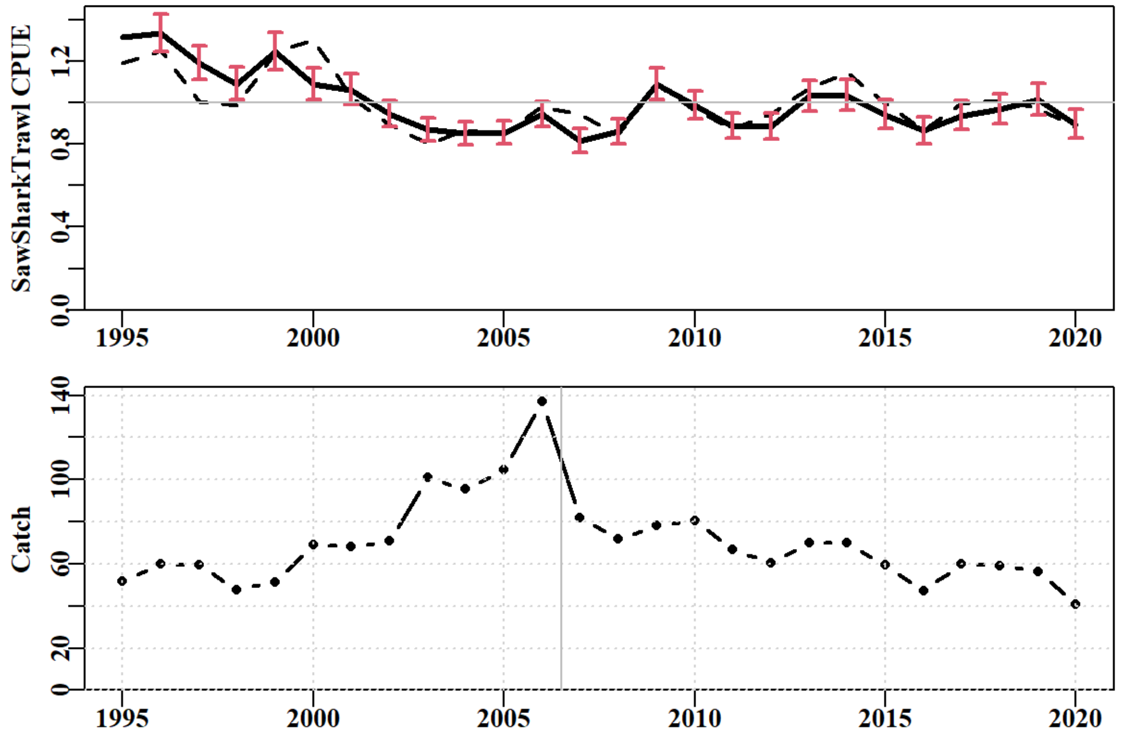

Figure 10.155. SawSharkTrawl. CPUE is correlated with catches through time. CPUE in the top plot and annual catch (t) in the lower plot.

10.21 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 regions 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.

10.21.1 *Inferences*

Most catch occurred in Shark region 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 10.86). The qqplot suggests the assumed Normal distribution may be invalid, as depicted by both tails of the distribution (Figure 10.159). Annual standardized CPUE has remained consistently below or at the long-term average since 2001 (Figure 10.157).

10.21.2 *Action Items and Issues*

Further consideration of whether to consider the CPUE time-series as a valid index of relative abundance for Saw shark 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 10.82. 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, SSC
years	1997 - 2020

Table 10.83. SawShark_DS. Total catch (Total; t) is the total reported in the database, number of records used in the analysis (N), reported catch (Catch; t) in the area and depth used in the analysis and number of vessels used in the analysis (Vess). GeoM is the geometric mean of catch rates (kg/shot), standard deviation (StDev) relates to the optimum model. C<30Kg denotes the amount of catch in shots of <30kg, and P<30Kg is the proportion of total. The optimum model was SharkRegion:Month

Year	Total	N	Catch	Vess	GeoM	Opt	StDev	C<30Kg	P<30Kg
1997	214.2	428	4.0	13	9.2	1.4277	0.000	3.588	0.904
1998	284.2	481	6.7	12	13.9	1.6467	0.068	4.918	0.732
1999	295.6	611	6.4	13	10.0	1.2955	0.065	4.834	0.752
2000	361.8	397	7.2	11	16.9	1.9412	0.073	3.548	0.496
2001	340.7	504	7.0	12	13.2	1.0935	0.071	4.367	0.626
2002	256.6	2646	23.5	22	8.4	0.9152	0.057	16.749	0.712
2003	319.9	2971	21.5	22	6.8	0.8052	0.057	17.384	0.807
2004	314.9	3124	23.5	22	6.7	0.7448	0.057	16.101	0.685
2005	296.7	2557	16.9	22	5.7	0.6614	0.058	12.223	0.725
2006	317.7	2189	17.4	19	7.2	0.7759	0.059	12.134	0.698
2007	214.5	2194	20.9	15	8.5	0.8691	0.059	12.614	0.603
2008	211.7	2406	21.9	15	8.4	0.9119	0.058	14.783	0.675
2009	191.5	2793	20.8	15	6.6	0.8767	0.058	14.690	0.707
2010	192.5	2334	16.7	15	6.7	0.8996	0.059	13.214	0.791
2011	197.1	2795	24.6	14	8.3	0.8721	0.058	17.446	0.709
2012	158.6	2164	20.0	14	8.6	0.8530	0.059	13.778	0.688
2013	165.7	2485	20.5	14	7.7	0.8690	0.058	15.294	0.747
2014	167.2	1706	13.1	14	6.9	0.7727	0.060	9.634	0.736
2015	164.2	2102	23.6	15	10.3	1.0537	0.059	13.525	0.572
2016	164.6	1862	18.9	15	9.1	1.0022	0.060	11.702	0.619
2017	178.8	1710	15.9	16	8.2	0.9807	0.060	9.717	0.610
2018	169.9	1883	20.1	17	9.1	0.9739	0.060	10.731	0.534
2019	163.0	1924	17.2	18	7.9	0.8919	0.060	10.643	0.620
2020	163.0	1639	16.6	19	8.9	0.8666	0.061	9.210	0.554

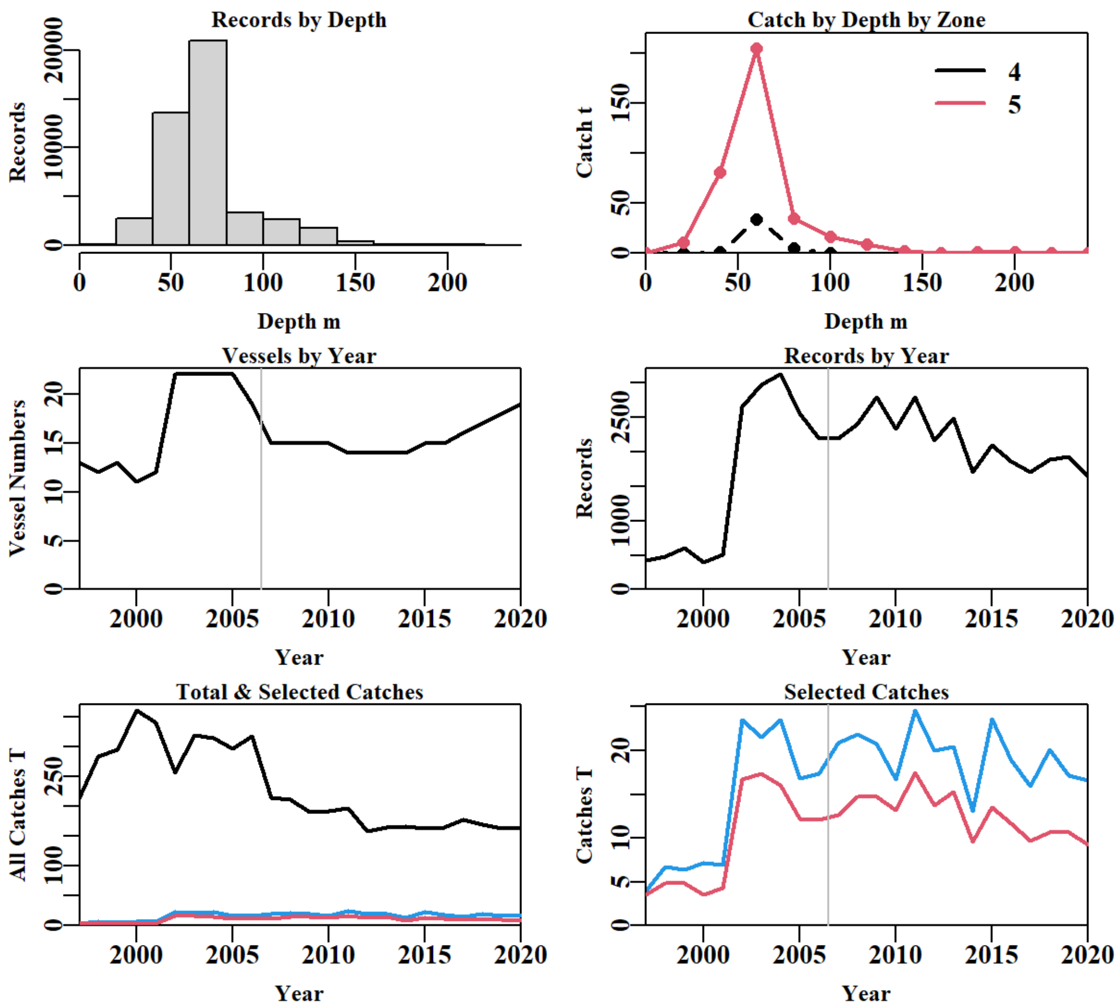

Figure 10.156. SawShark_DS fishery details. The bottom left plot depicts all known catches (top black line), and all selected catches used in the analysis (middle blue line); the lower red line: selected catches < 30 kg).

Table 10.84. 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	274139	0	5982.57	0
NoCE	265699	8440	5982.57	0
Depth	254059	11640	5509.42	473.16
Years	237915	16144	5096.07	413.35
Zones	157856	80059	3413.50	1682.56
Method	46292	111564	406.98	3006.53
Fishery	45905	387	404.87	2.11

Table 10.85. 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 10.86. 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

Term	AIC	RSS	MSS	Nobs	Npars	adj_r2	%Change
Year	6943	53344	1496	45905	24	2.7	0
Vessel	4690	50712	4128	45905	59	7.4	4.73
DepCat	2111	47917	6924	45905	71	12.5	5.08
SharkRegion	1819	47611	7229	45905	72	13.0	0.56
Month	1366	47121	7719	45905	83	13.9	0.87
DayNight	1263	47009	7831	45905	86	14.1	0.20
SharkRegion:DepCat	1072	46802	8039	45905	92	14.5	0.37
SharkRegion:Month	1069	46788	8052	45905	97	14.5	0.38

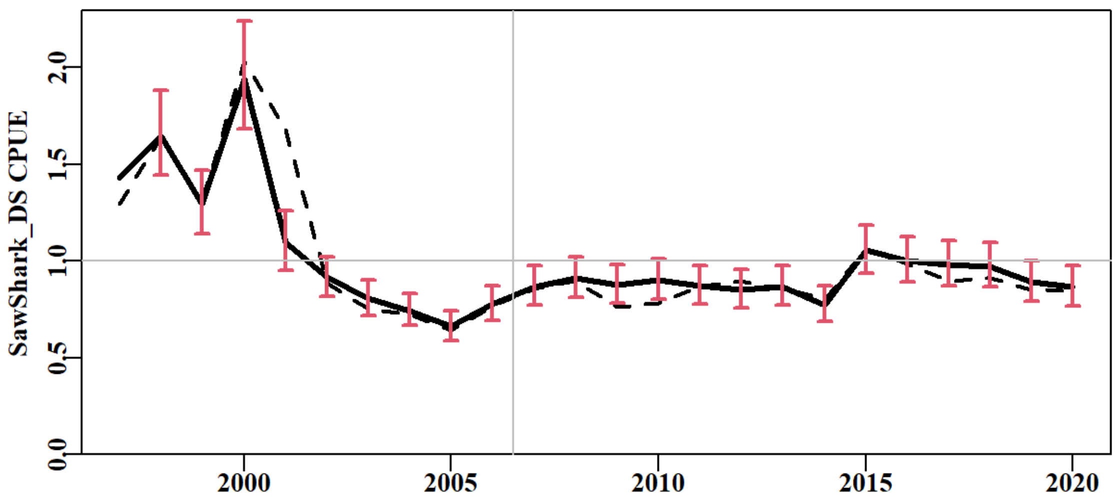

Figure 10.157. SawShark_DS standardization. The dashed black line represents the geometric mean catch rate, solid black line the standardized catch rates. The red bars are the 95% confidence intervals about the mean estimates. The graph scales both time-series of standardized catch rates relative to the mean of each time-series.

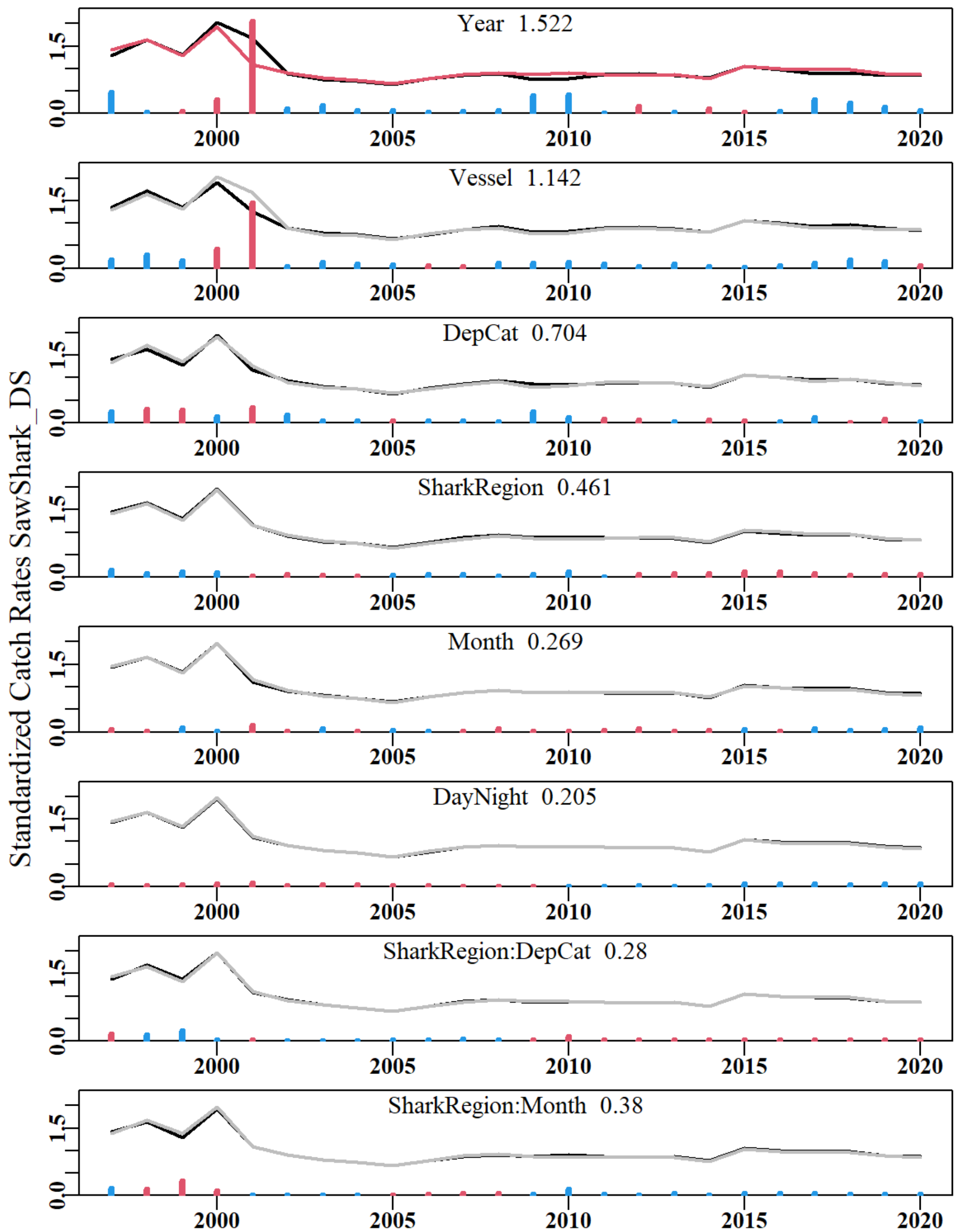

Figure 10.158. SawShark_DS. The influence of each factor on the optimal standardization. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by vertical bars with blue bars indicating the optimum model is higher than the geometric 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.

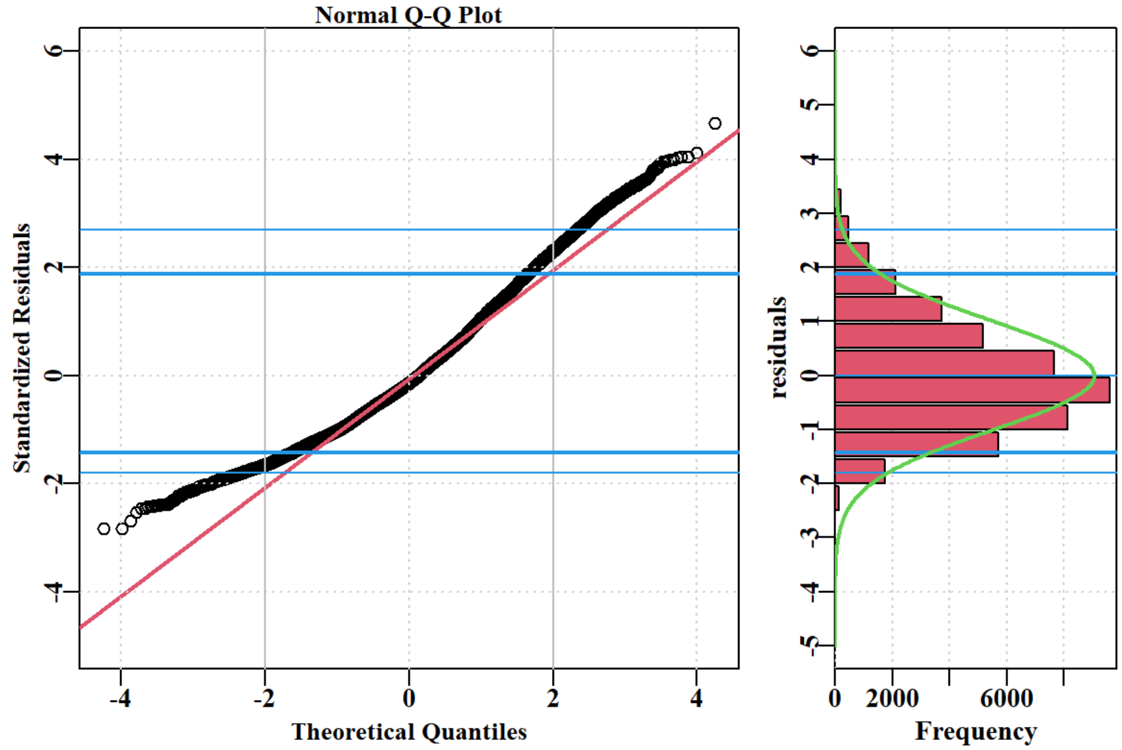

Figure 10.159. SawShark_DS. Diagnostic plots. The distribution of residuals from the optimum fit. The qqplot indicates the fit to the expected normality, while the histogram of residuals also illustrates the 1%, 5%, 95% and 99% quantiles to indicate the intensity of any lack of fit at the margins of the distribution (reflected also in the qqplot).

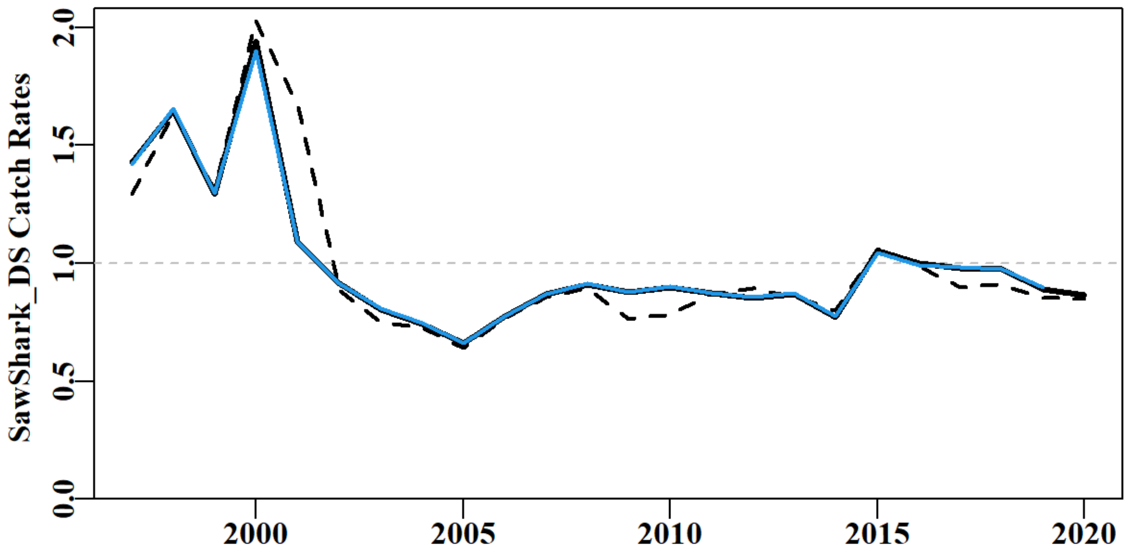

Figure 10.160. SawShark_DS. A comparison of the previous year's standardization (blue line) with this year's. They should lie on top of each other, although small deviations may relate to data adjustments, particularly in very recent years.

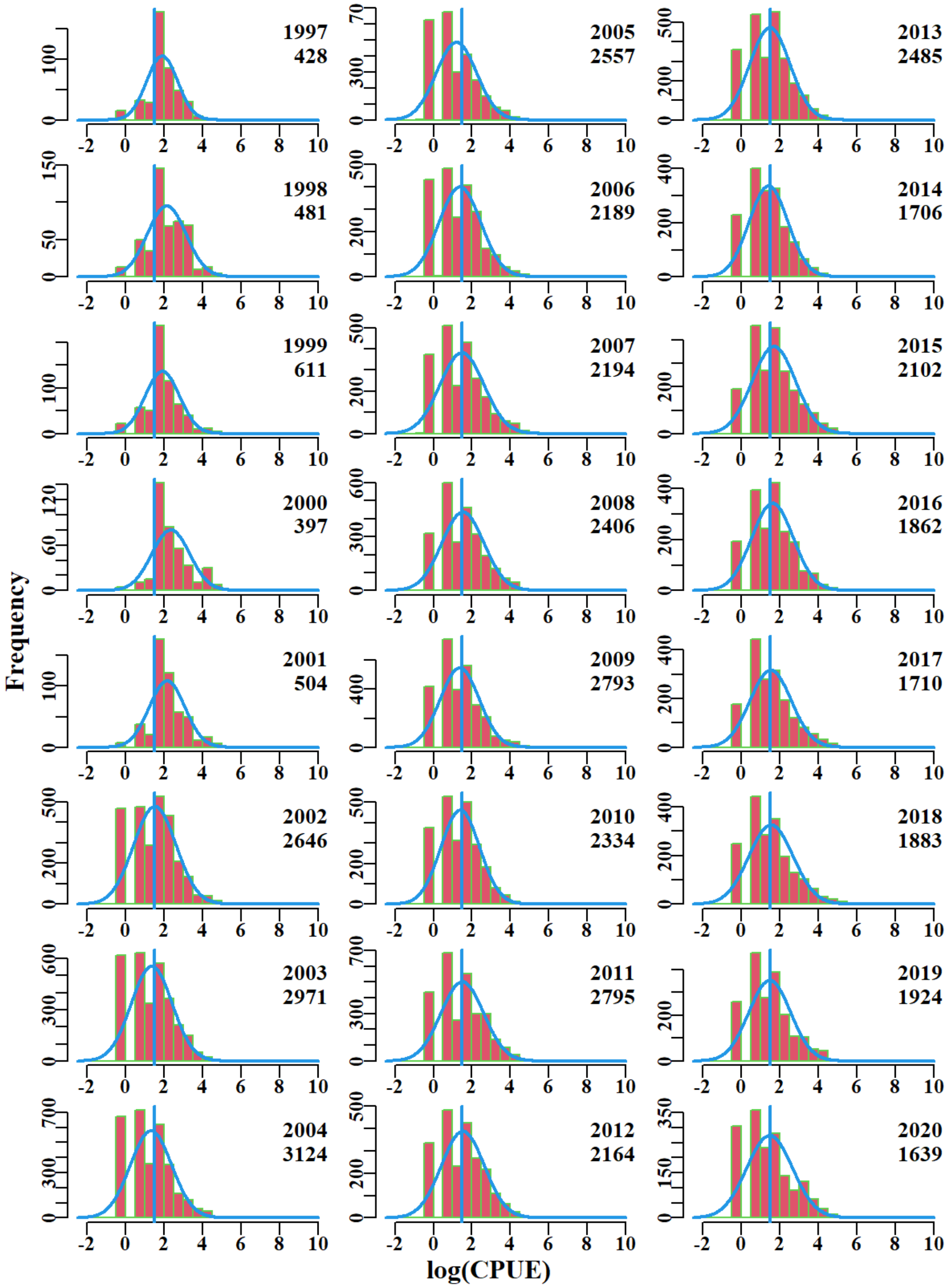

Figure 10.161. SawShark_DS. The natural log(CPUE) for each year of data available the blue lines are normal distributions fitted to the histogram frequencies. The numbers in each plot are the year and number of records. The vertical blue line is the average across all years.

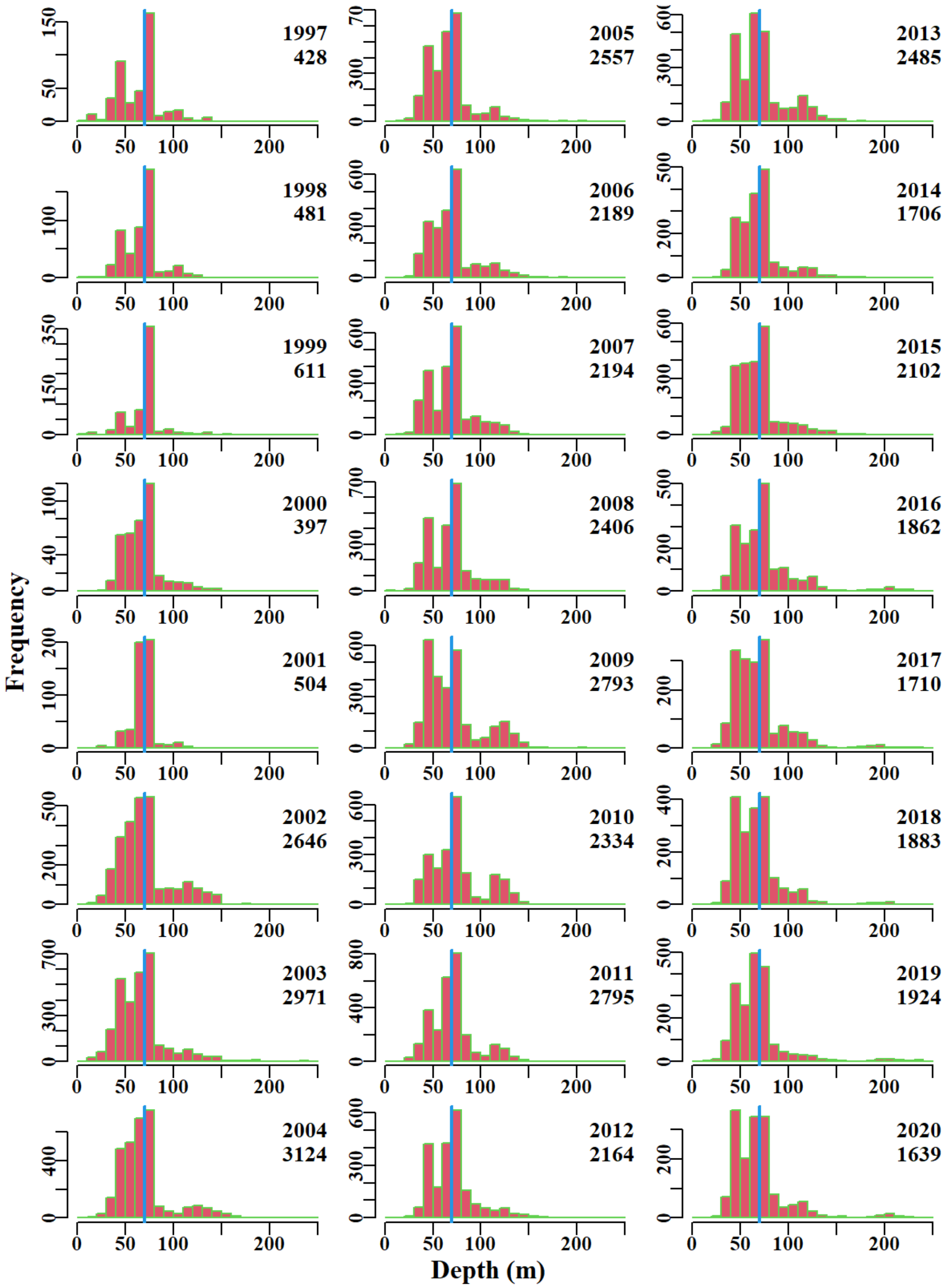

Figure 10.162. SawShark_DS. The average Depth of fishing for each year of data available to illustrate the development of the fishery through time. The numbers in each plot are the year and number of records. The vertical blue line is the average across all years.

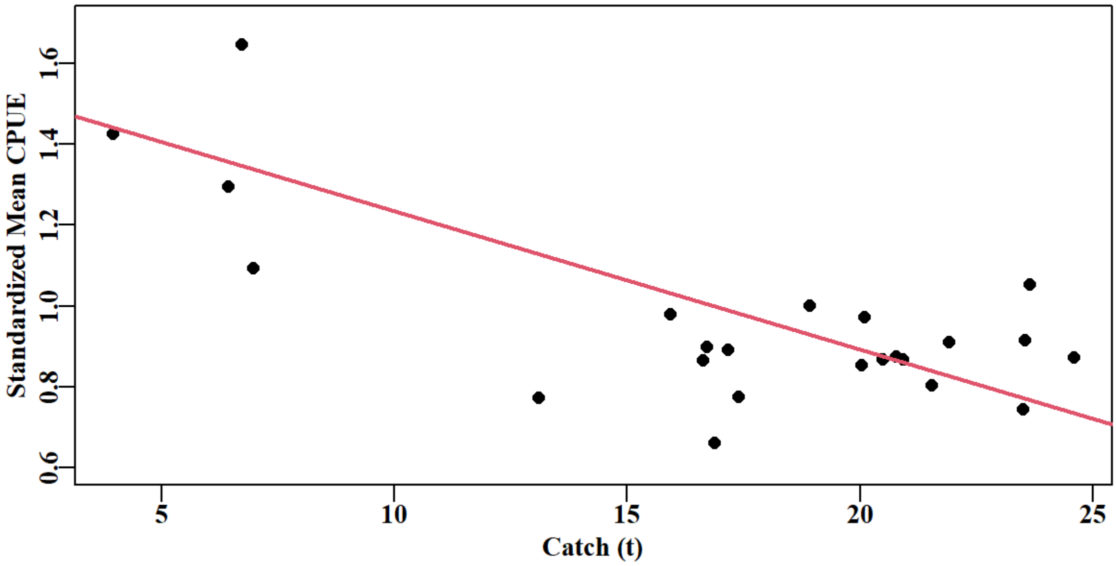

Figure 10.163. The linear relationship between annual mean CPUE and annual Catch.

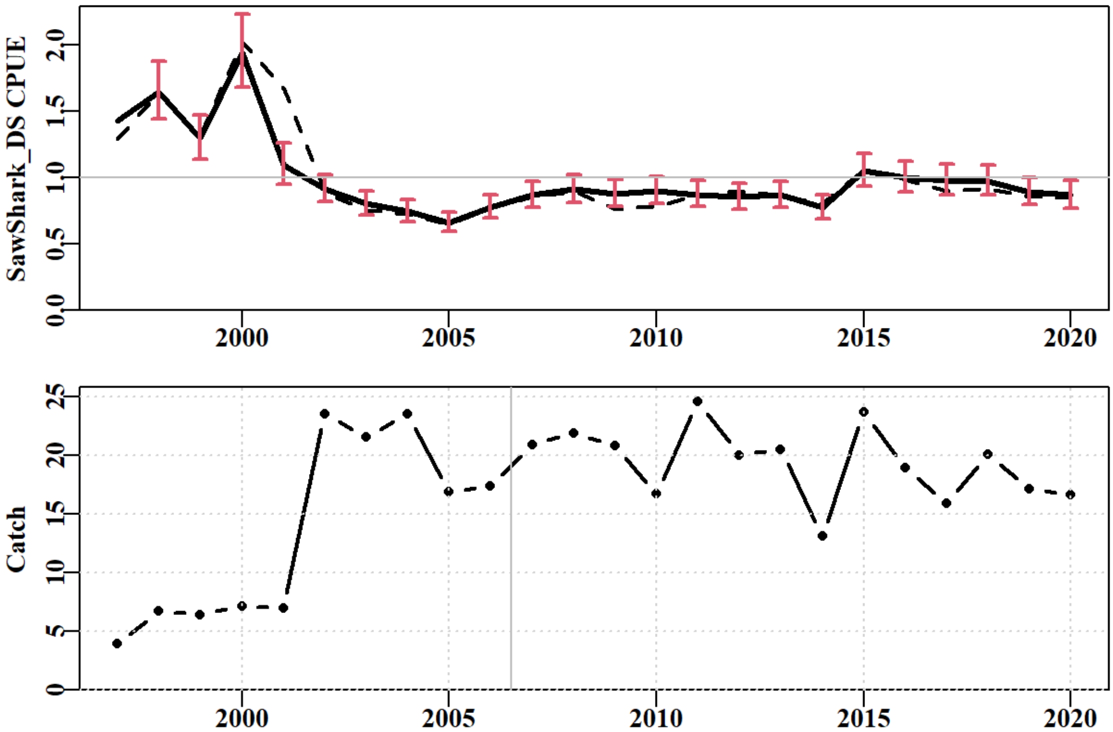

Figure 10.164. SawShark_DS. CPUE is correlated with catches through time. CPUE in the top plot and annual catch (t) in the lower plot.

10.22 Elephantfish: Gillnet

The proportion of catches recording < 30 kg is relatively high in Elephantfish reports, indicating that they are not a primary target species and tend to be caught in small numbers and weights in each shot (Figure 10.165). The preliminary estimate of the proportion discarded for 2019 is 0.39, corresponding to 27.9 t (Althaus et al. 2020). 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.

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.

10.22.1 *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).

Most catch occurred in Shark region 5, followed by 4.

The terms Year, Vessel, Month, DepCat, SharkRegion and one interaction (SharkRegion:Month) had the greatest contribution to model fit based on the AIC and R^2 statistics (Table 10.91). The qqplot suggests the assumed Normal distribution may be valid, with a slight deviation as depicted by the lower tail of the distribution (Figure 10.168). Annual standardized CPUE has remained below the long-term average since 2014, with a slight increase in 2018 (relative to 2017) followed by a decrease in 2019 and no depreciable difference in 2020 (Figure 10.166).

10.22.2 *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 10.87. 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, GNS
years	1997 - 2020

Table 10.88. ElephantFishGN. Total catch (Total; t) is the total reported in the database, number of records used in the analysis (N), reported catch (Catch; t) in the area and depth used in the analysis and number of vessels used in the analysis (Vess). GeoM is the geometric mean of catch rates (kg/shot), standard deviation (StDev) relates to the optimum model. C<30Kg denotes the amount of catch in shots of <30kg, and P<30Kg is the proportion of total. The optimum model was SharkRegion:Month

Year	Total	N	Catch	Vess	GeoM	Opt	StDev	C<30Kg	P<30Kg
1997	32.0	1441	25.3	56	15.8	0.9863	0.000	9.166	0.362
1998	52.0	2111	41.4	57	16.1	0.9143	0.047	12.658	0.306
1999	69.0	2772	54.5	66	17.4	1.0705	0.047	17.654	0.324
2000	78.7	2708	62.0	57	18.5	1.3273	0.047	19.903	0.321
2001	88.8	2746	71.2	62	22.6	1.3678	0.047	19.152	0.269
2002	59.4	2100	36.9	61	16.0	0.9869	0.049	13.464	0.365
2003	71.2	2152	41.8	60	15.8	0.9758	0.050	12.994	0.311
2004	64.8	1746	30.2	51	14.7	0.9432	0.052	10.598	0.351
2005	66.4	1845	32.1	40	16.0	0.9738	0.051	11.385	0.355
2006	53.3	1638	30.8	42	16.0	1.0497	0.053	9.758	0.317
2007	51.7	1737	32.2	38	16.9	1.1184	0.052	11.584	0.360
2008	61.5	1989	38.1	34	18.1	1.1803	0.051	13.550	0.355
2009	65.3	2072	42.8	35	21.2	1.3754	0.051	15.337	0.358
2010	56.7	2223	33.9	35	14.6	1.0852	0.051	14.395	0.425
2011	50.5	2637	33.3	35	11.4	0.9178	0.050	17.380	0.522
2012	66.0	2626	43.2	38	15.6	1.0650	0.050	17.456	0.404
2013	61.9	2406	36.1	34	14.4	0.9933	0.050	17.439	0.483
2014	47.4	2153	29.1	31	12.8	0.8885	0.051	15.168	0.521
2015	49.3	1772	27.5	27	14.1	0.8306	0.052	10.971	0.399
2016	49.0	1999	34.2	27	14.8	0.8496	0.051	12.238	0.358
2017	40.8	1947	24.7	24	11.1	0.7050	0.052	11.650	0.472
2018	43.4	1933	25.9	27	12.0	0.8200	0.052	11.308	0.437
2019	44.5	1979	28.0	27	11.9	0.7828	0.053	11.300	0.403
2020	37.7	1681	23.4	20	12.5	0.7925	0.055	9.336	0.400

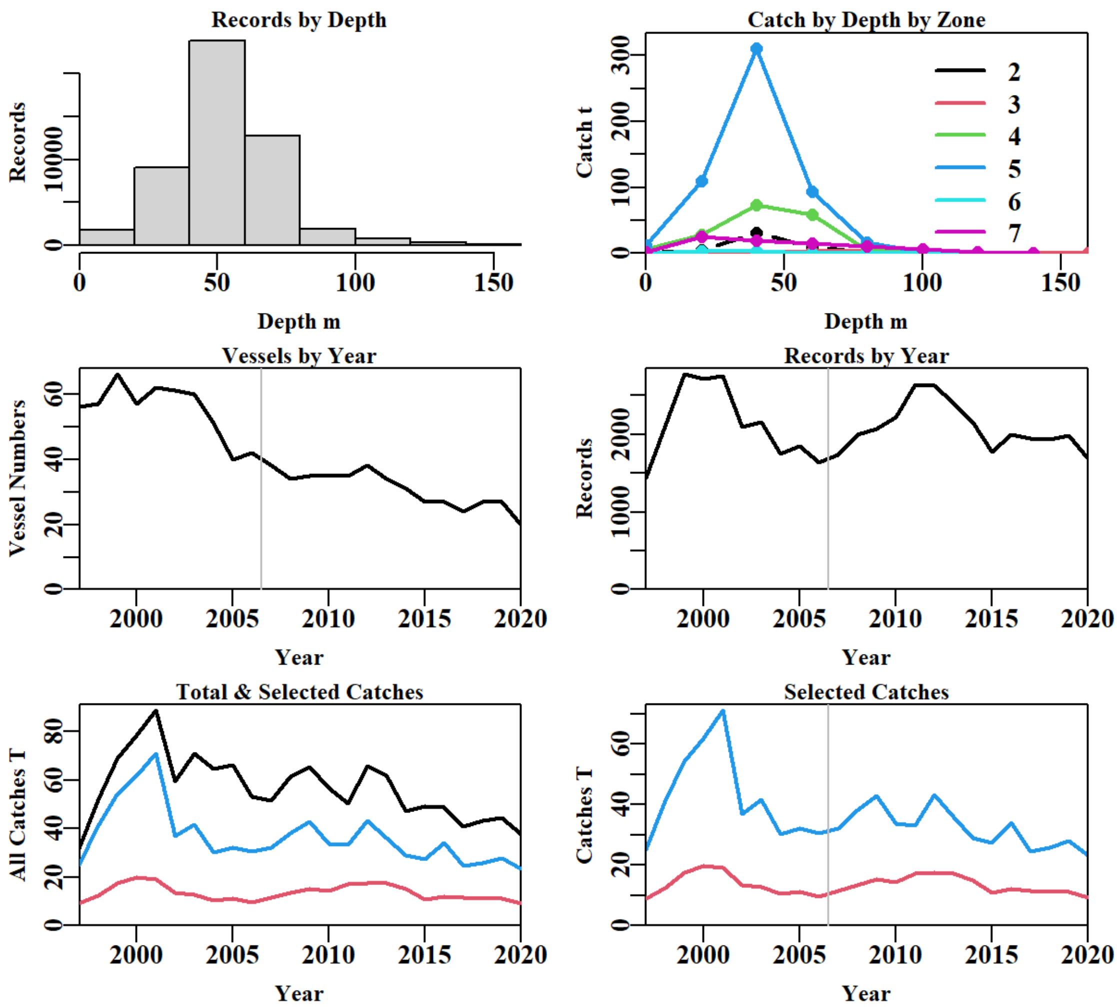

Figure 10.165. ElephantFishGN fishery details. The bottom left plot depicts all known catches (top black line), and all selected catches used in the analysis (middle blue line); the lower red line: selected catches < 30 kg).

Table 10.89. 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	98729	0	1413.58	0.00
NoCE	88225	10504	1413.58	0.00
Depth	80556	7669	1319.16	94.43
Years	79064	1492	1283.96	35.19
Zones	75611	3453	1217.43	66.54
Method	50415	25196	878.42	339.01
Fishery	50413	2	878.41	0.01

Table 10.90. 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 10.91. 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

Term	AIC	RSS	MSS	Nobs	Npars	adj_r2	%Change
Year	29001	89529	1253	50413	24	1.3	0
Vessel	25879	83613	7168	50413	186	7.6	6.22
Month	25683	83253	7528	50413	197	7.9	0.38
DepCat	25669	83203	7578	50413	205	8.0	0.04
SharkRegion	25410	82761	8020	50413	210	8.5	0.48
SharkRegion:DepCat	25180	82273	8508	50413	244	8.9	0.48
SharkRegion:Month	25002	81915	8866	50413	265	9.3	0.84

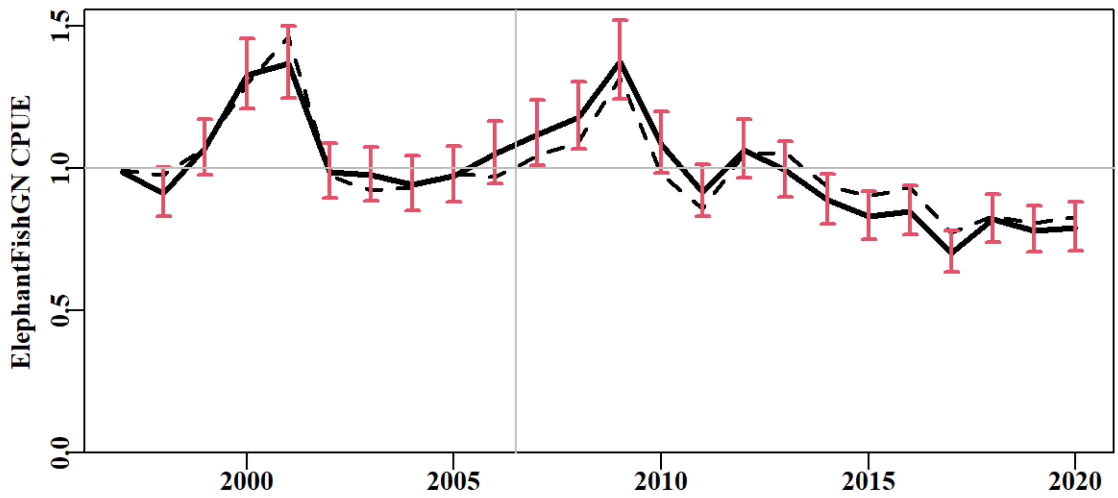

Figure 10.166. ElephantFishGN standardization. The dashed black line represents the geometric mean catch rate, solid black line the standardized catch rates. The red bars are the 95% confidence intervals about the mean estimates. The graph scales both time-series of standardized catch rates relative to the mean of each time-series.

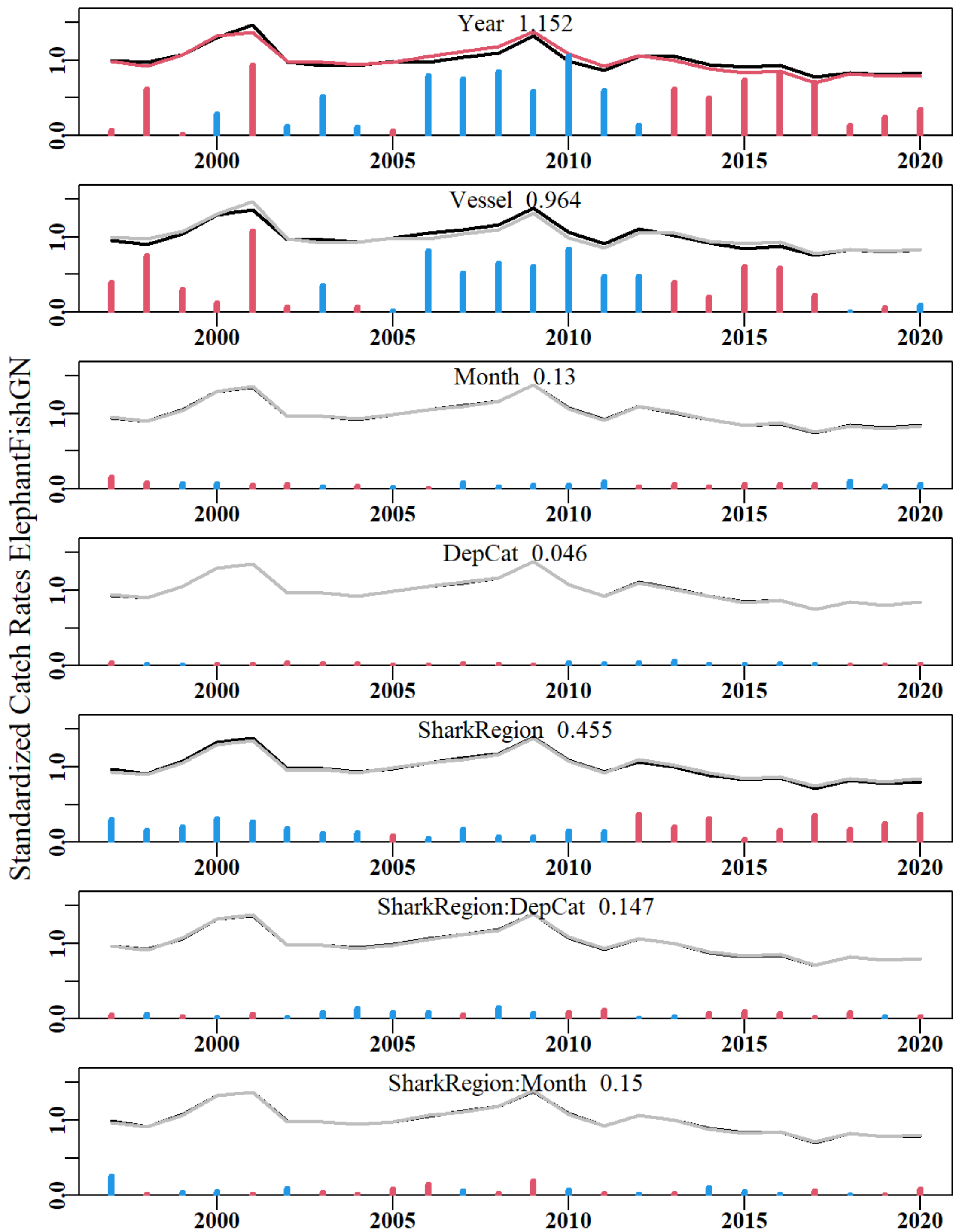

Figure 10.167. ElephantFishGN. The influence of each factor on the optimal standardization. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by vertical bars with blue bars indicating the optimum model is higher than the 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.

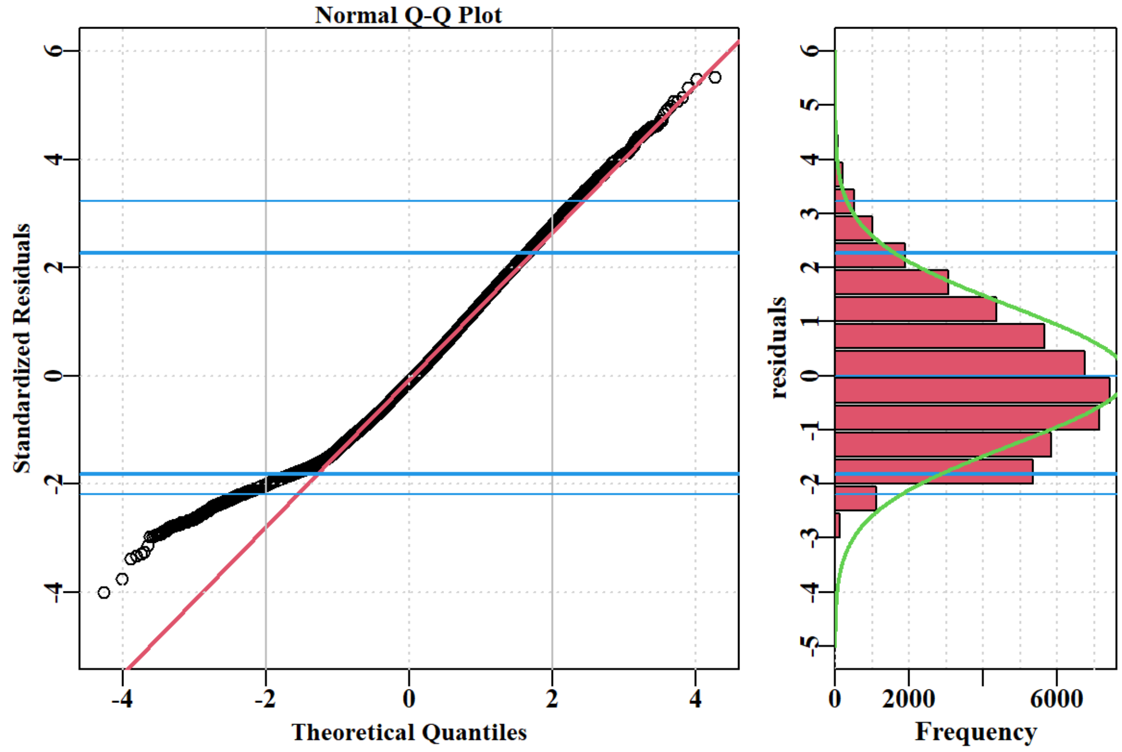

Figure 10.168. ElephantFishGN. Diagnostic plots. The distribution of residuals from the optimum fit. The qqplot indicates the fit to the expected normality, while the histogram of residuals also illustrates the 1%, 5%, 95% and 99% quantiles to indicate the intensity of any lack of fit at the margins of the distribution (reflected also in the qqplot).

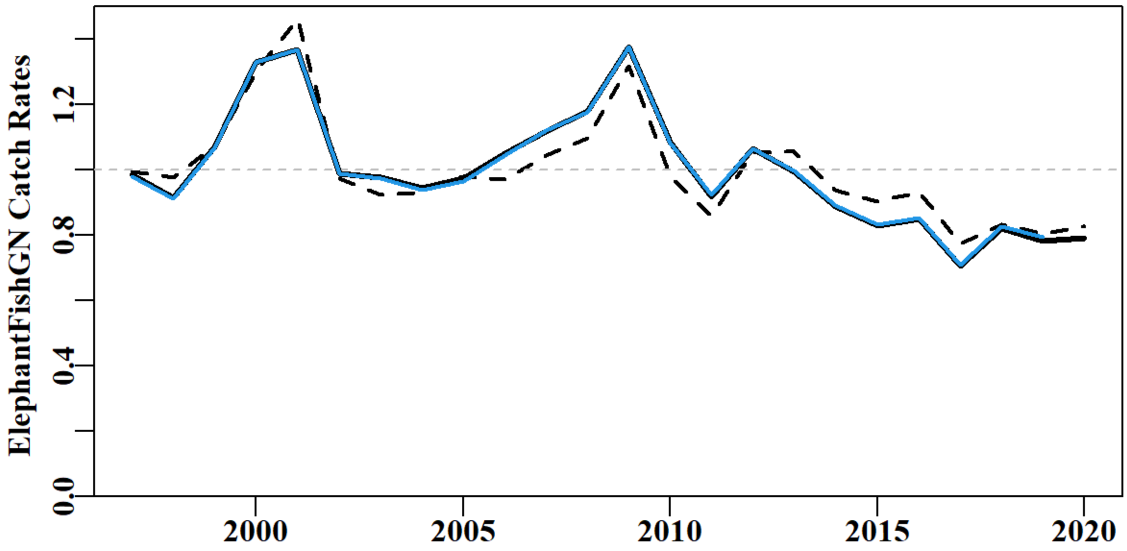

Figure 10.169. ElephantFishGN. A comparison of the previous year's standardization (blue line) with this year's. They should lie on top of each other, although small deviations may relate to data adjustments, particularly in very recent years.

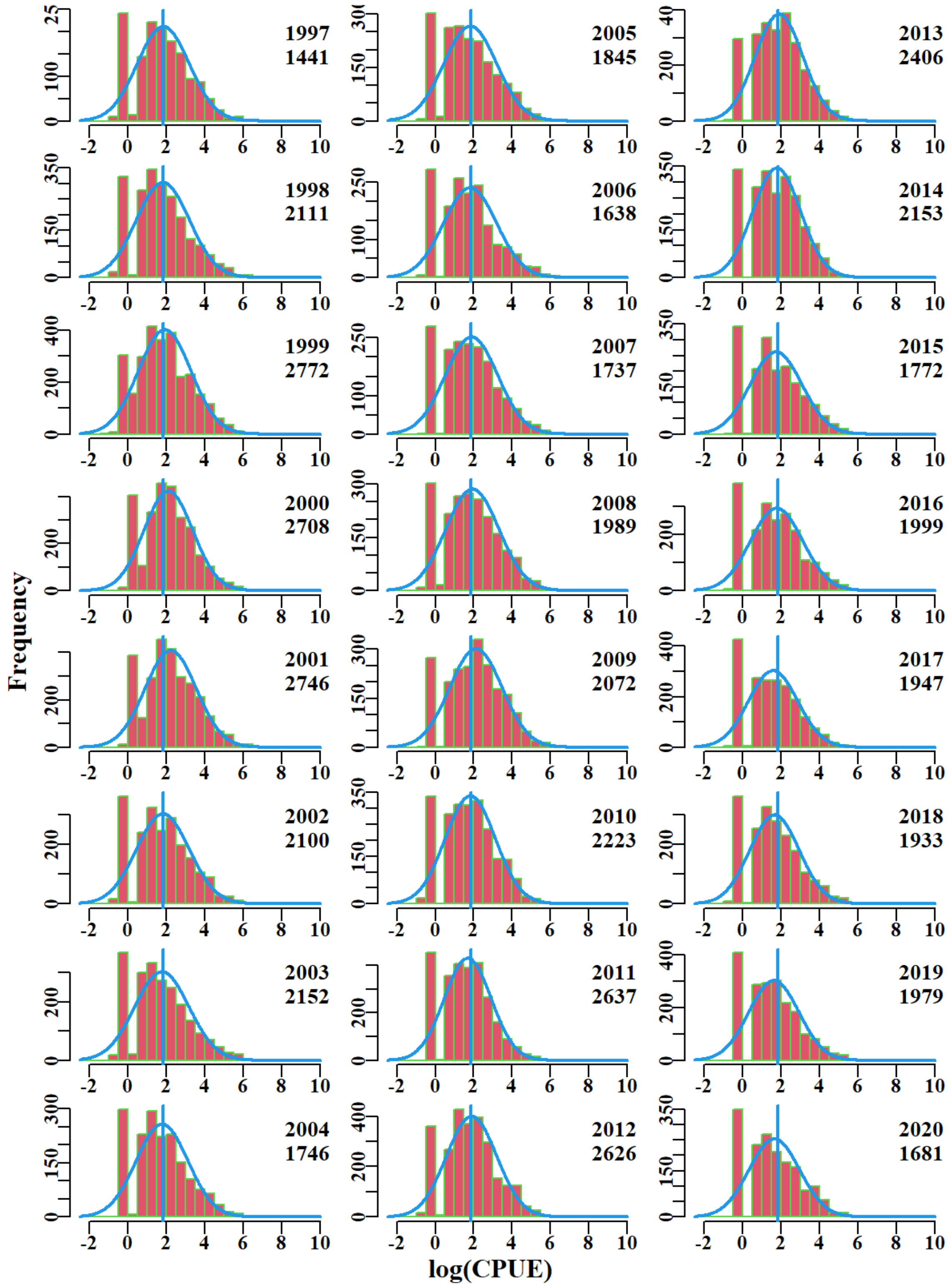

Figure 10.170. ElephantFishGN. The natural log(CPUE) for each year of data available the blue lines are normal distributions fitted to the histogram frequencies. The numbers in each plot are the year and number of records. The vertical blue line is the average across all years.

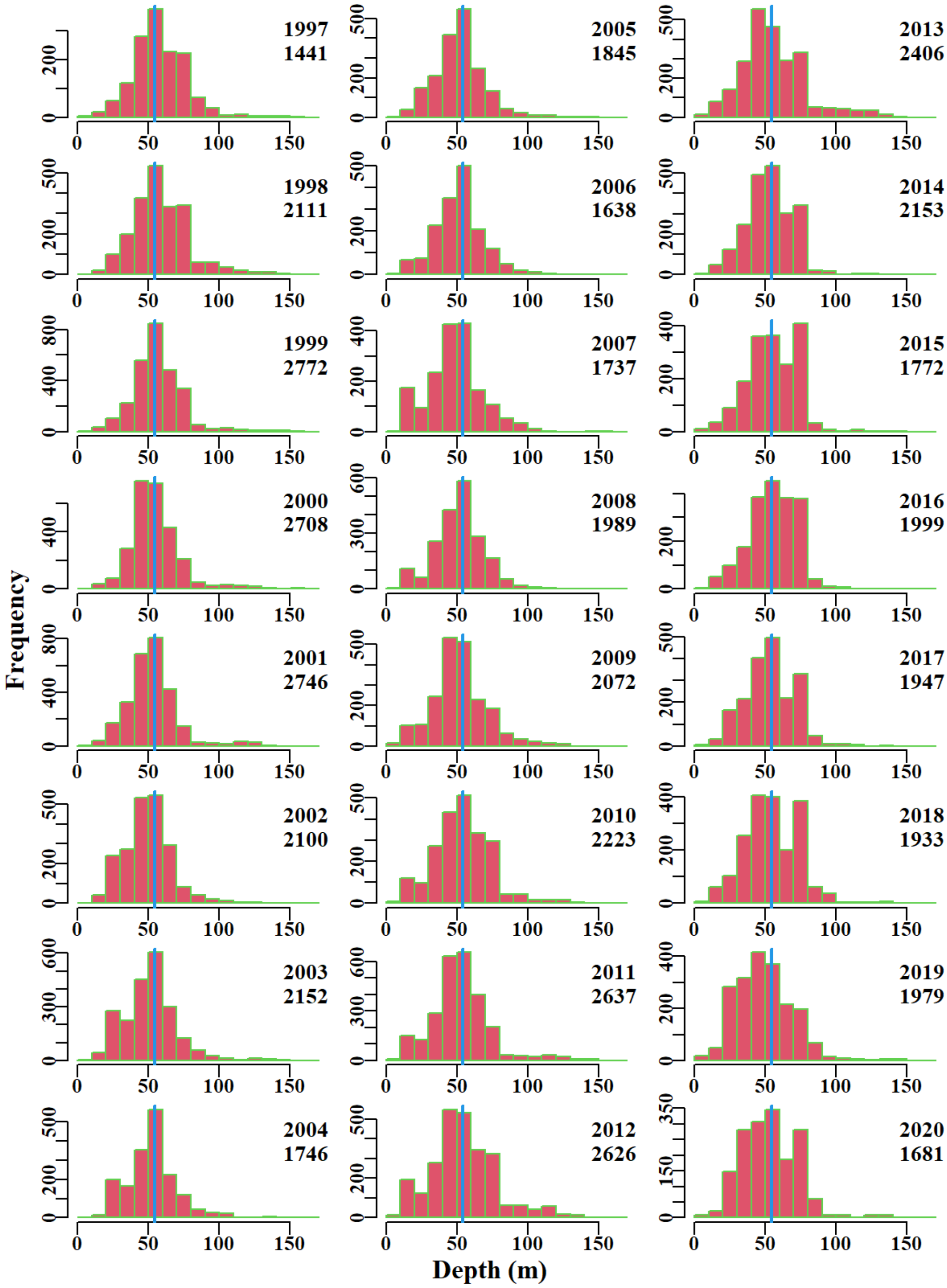

Figure 10.171. ElephantFishGN. The average Depth of fishing for each year of data available to illustrate the development of the fishery through time. The numbers in each plot are the year and number of records. The vertical blue line is the average across all years.

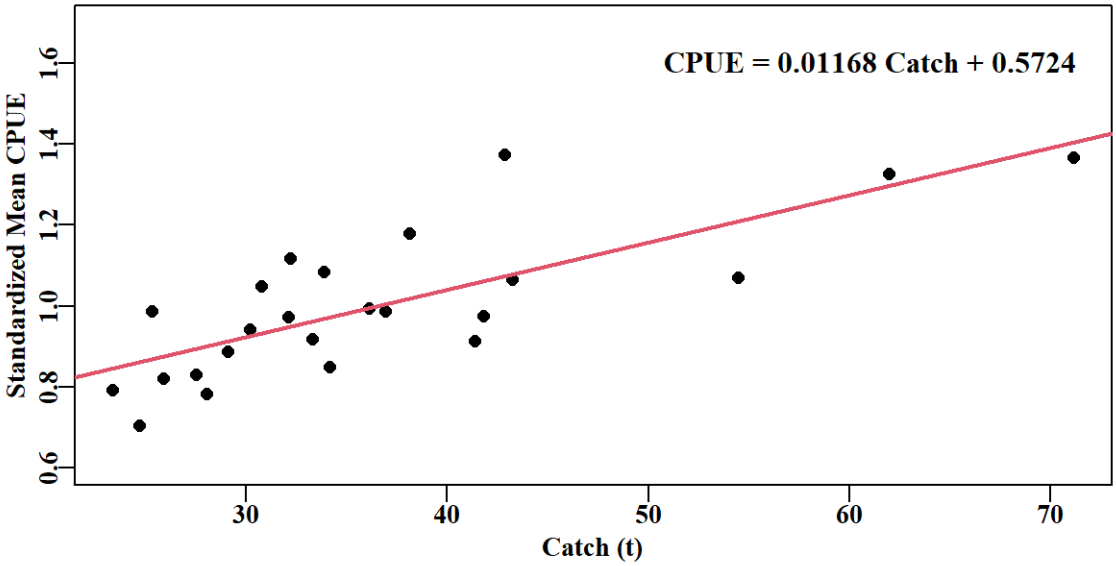

Figure 10.172. ElephantFishGN. The linear relationship between annual mean CPUE and annual Catch.

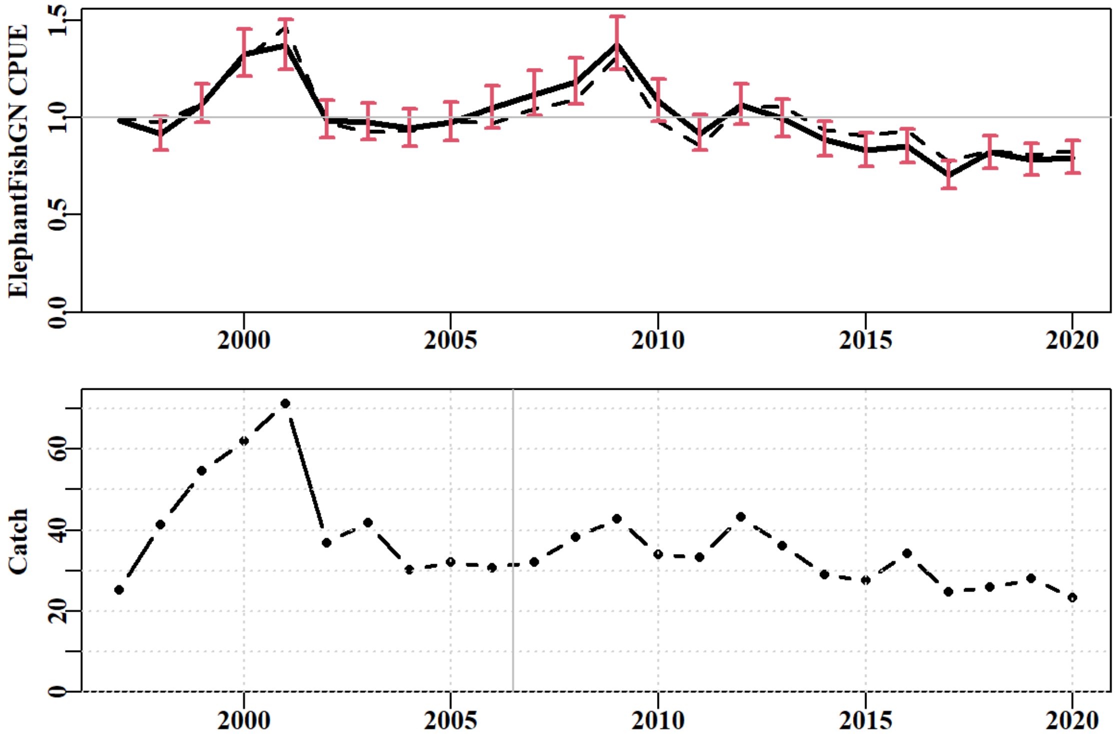

Figure 10.173. ElephantFishGN. CPUE is correlated with catches through time. CPUE in the top plot and annual catch (t) in the lower plot.

10.23 Elephantfish Gillnet kg/m

The proportion of catches recording < 30 kg is relatively high in Elephantfish reports, indicating that Elephantfish are not a primary target species and tend to be caught in small numbers and weights in each shot (Figure 10.174). Estimates of the proportion discarded annually has been high. Given the high proportion of discards, it is questionable as to whether an analysis including zero catches would be valid, but could be explored. Therefore, only non-zero shots were analysed. The use of effort in units of net length was investigated in this analysis. Exploratory analyses shows inconsistency in the recording of gillnet effort units in the logbook database, particularly in 1997, 1998 and part 1999 compared to later years. A detailed effort analysis was conducted and utilized in this standardization (see also Sporcic, 2020).

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.

10.23.1 *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).

Most catch occurred in Shark region 5, followed by 4.

The terms Year, Vessel, Month, SharkRegion, DepCat and one interaction (SharkRegion:Month) had the greatest contribution to model fit based on the AIC and R^2 statistics (Table 10.93). The terms Year and Vessel had the greatest contribution to model fit. The qqplot suggests the assumed Normal distribution may be invalid, as depicted by the lower tail of the distribution (Figure 10.177).

Annual standardized CPUN (i.e., catch-per-netlength; catch per m) has remained below the long-term average since about 2013. Also, it has been essentially flat since 2017, despite the slight increase in 2018 relative to 2017 (Figure 10.175).

Overall, annual standardized CPUN (black line) shows a similar overall shape to standardized CPS (i.e., catch-per-shot CPS; blue line; see also Sporcic, 2020).

Table 10.92. 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	1, 2, 3, 4, 5, 6, 7, 8, 9
methods	GN, GNS
years	1997 - 2020

Table 10.93. 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/m), 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

Year	Total	N	Catch	Vess	GeoM	Opt	StDev	C<30Kg	P<30Kg
1997	32.0	1420	24.6	51	0.005	1.0296	0.000	8.880	0.362
1998	52.0	2203	42.3	57	0.005	0.9901	0.048	13.394	0.317
1999	67.7	2908	58.3	66	0.006	1.1903	0.048	18.698	0.321
2000	77.5	2825	66.3	54	0.006	1.4456	0.048	20.703	0.312
2001	87.7	2833	75.1	62	0.007	1.4895	0.048	19.775	0.263
2002	59.3	2154	38.9	60	0.005	1.0240	0.050	14.005	0.360
2003	70.6	2174	45.4	58	0.005	1.0297	0.051	13.142	0.290
2004	64.8	1843	32.7	51	0.005	0.9938	0.052	11.061	0.339
2005	66.4	1955	34.0	39	0.004	1.0269	0.052	12.069	0.355
2006	53.3	1679	31.6	39	0.004	1.1010	0.054	10.167	0.322
2007	51.7	1793	33.9	36	0.005	1.1472	0.053	12.031	0.355
2008	61.5	2052	39.8	33	0.005	1.2075	0.052	14.058	0.353
2009	65.3	2126	43.9	34	0.005	1.3957	0.052	15.583	0.355
2010	56.7	2258	34.7	34	0.004	1.0973	0.052	14.697	0.423
2011	50.5	2590	33.4	34	0.003	0.9347	0.051	17.210	0.516
2012	66.0	2689	44.7	37	0.004	1.0344	0.051	17.920	0.401
2013	61.9	2484	38.2	33	0.003	0.9106	0.051	18.030	0.473
2014	47.4	2121	29.8	31	0.003	0.8102	0.052	15.195	0.511
2015	49.3	1780	28.0	27	0.003	0.7396	0.053	11.044	0.394
2016	49.0	2025	35.2	27	0.003	0.7577	0.052	12.489	0.355
2017	40.8	1986	25.5	23	0.003	0.6524	0.053	11.949	0.468
2018	43.4	1917	26.3	27	0.002	0.6867	0.053	11.547	0.439
2019	44.5	1891	28.3	27	0.003	0.6544	0.055	11.117	0.393
2020	37.7	1626	24.3	20	0.003	0.6514	0.056	9.345	0.385

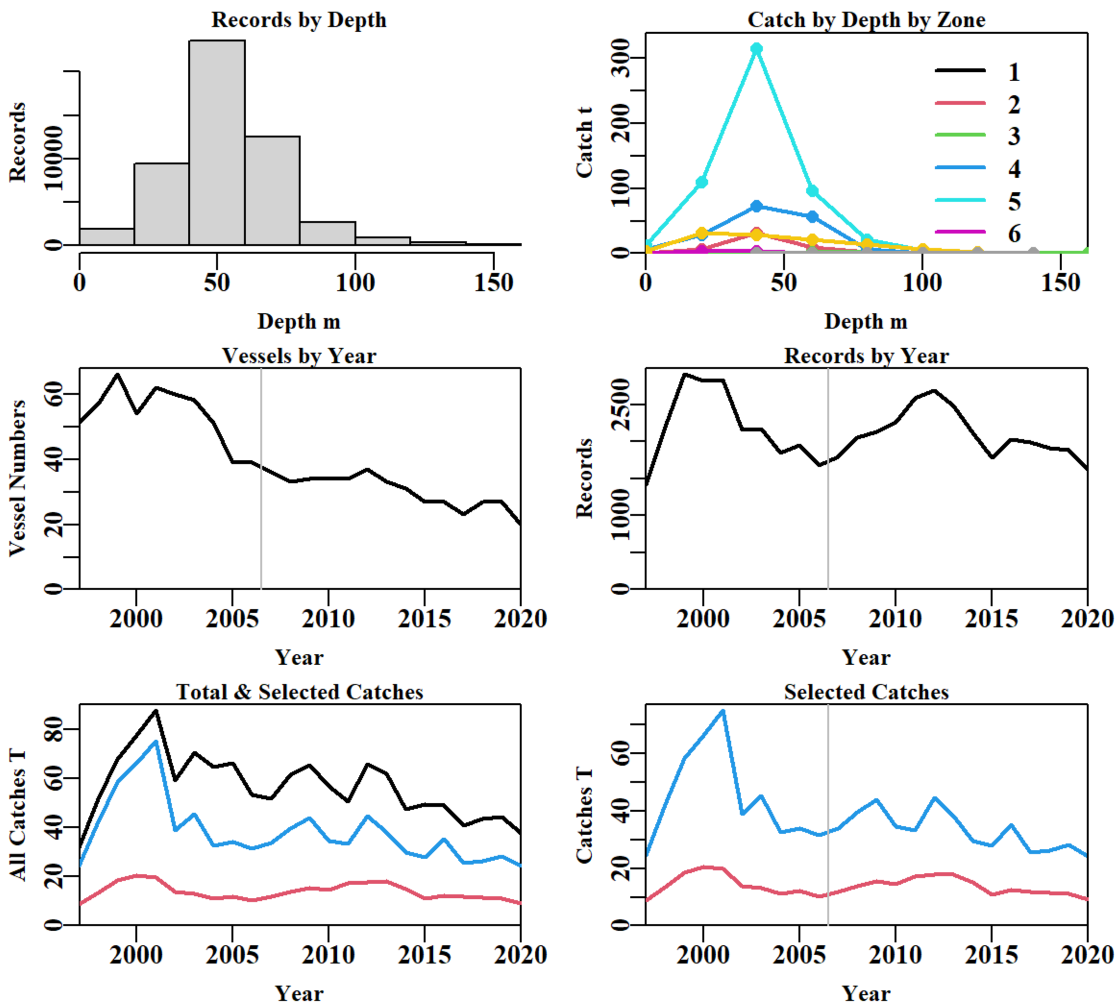

Figure 10.174. ElephantFishGN fishery details. The bottom left plot depicts all known catches (top black line), and all selected catches used in the analysis (middle blue line); the lower red line: selected catches < 30 kg).

Table 10.94. The models used to analyse data for ElephantFishGN

	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 10.95. 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

Term	AIC	RSS	MSS	Nobs	Npars	adj_r2	%Change
Year	30797	93411	3461	51291	24	3.5	0
Vessel	27222	86588	10284	51291	182	10.3	6.77
DepCat	27178	86486	10387	51291	190	10.4	0.09
SharkRegion	26954	86086	10787	51291	197	10.8	0.40
Month	26820	85825	11048	51291	208	11.0	0.25
SharkRegion:DepCat	26648	85407	11465	51291	247	11.4	0.36
SharkRegion:Month	26424	84949	11923	51291	273	11.8	0.80

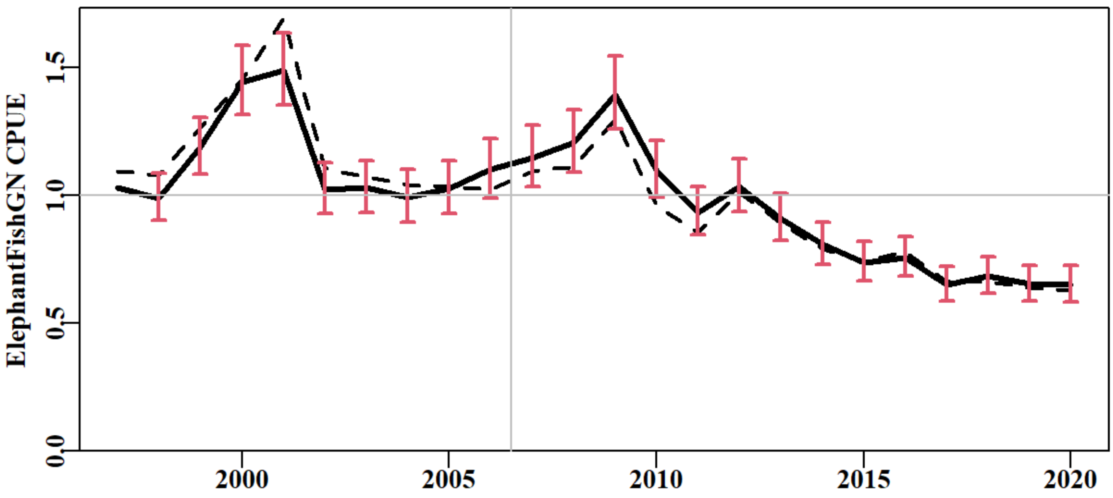

Figure 10.175. ElephantFishGN standardization. The dashed black line represents the geometric mean catch rate, solid black line the standardized catch rates. The red bars are the 95% confidence intervals about the mean estimates. The graph scales both time-series of standardized catch rates relative to the mean of each time-series.

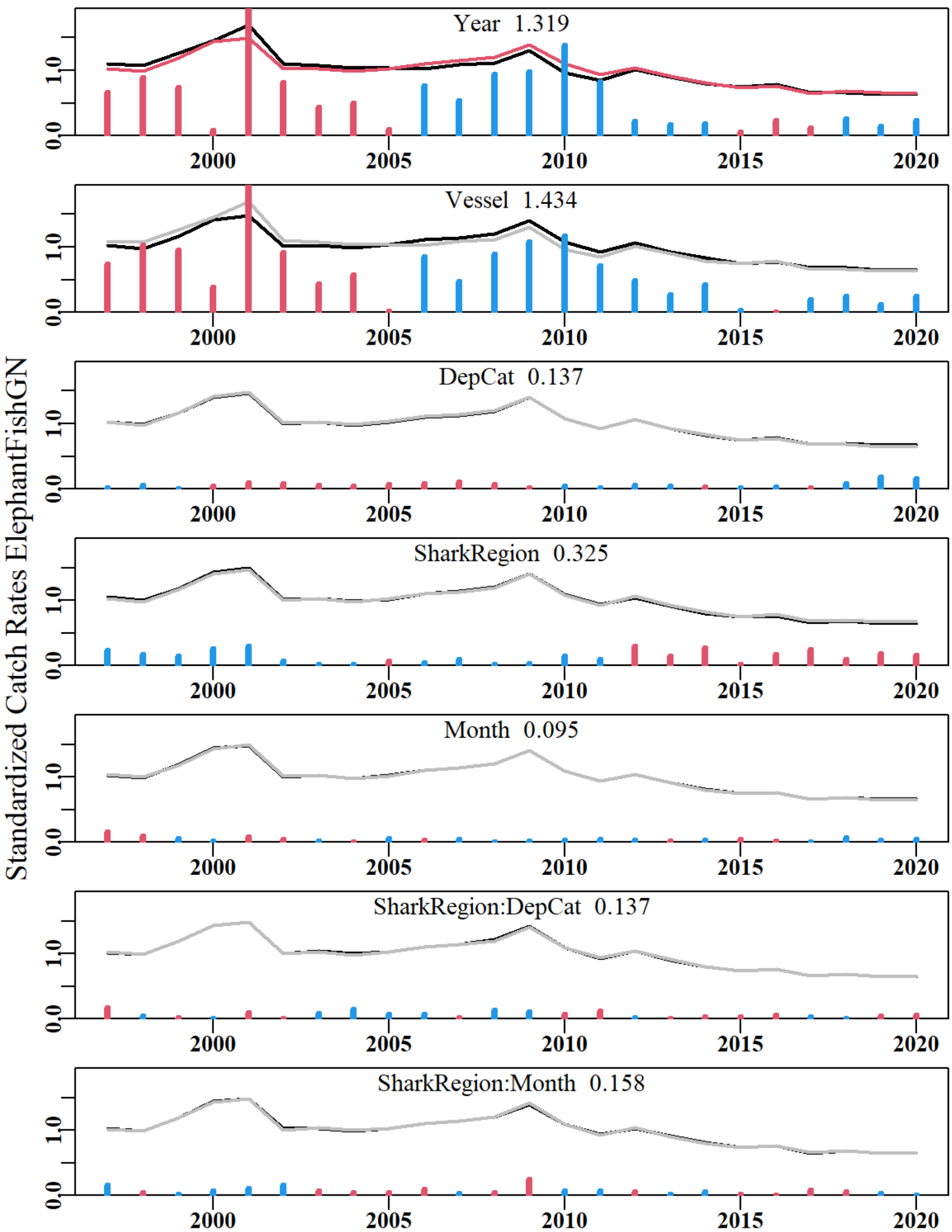

Figure 10.176. ElephantFishGN. The influence of each factor on the optimal standardization. The top graph depicts the geometric mean (black line) and the optimum model (red line). The difference between them is illustrated by vertical bars with blue bars indicating the optimum model is higher than the 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.

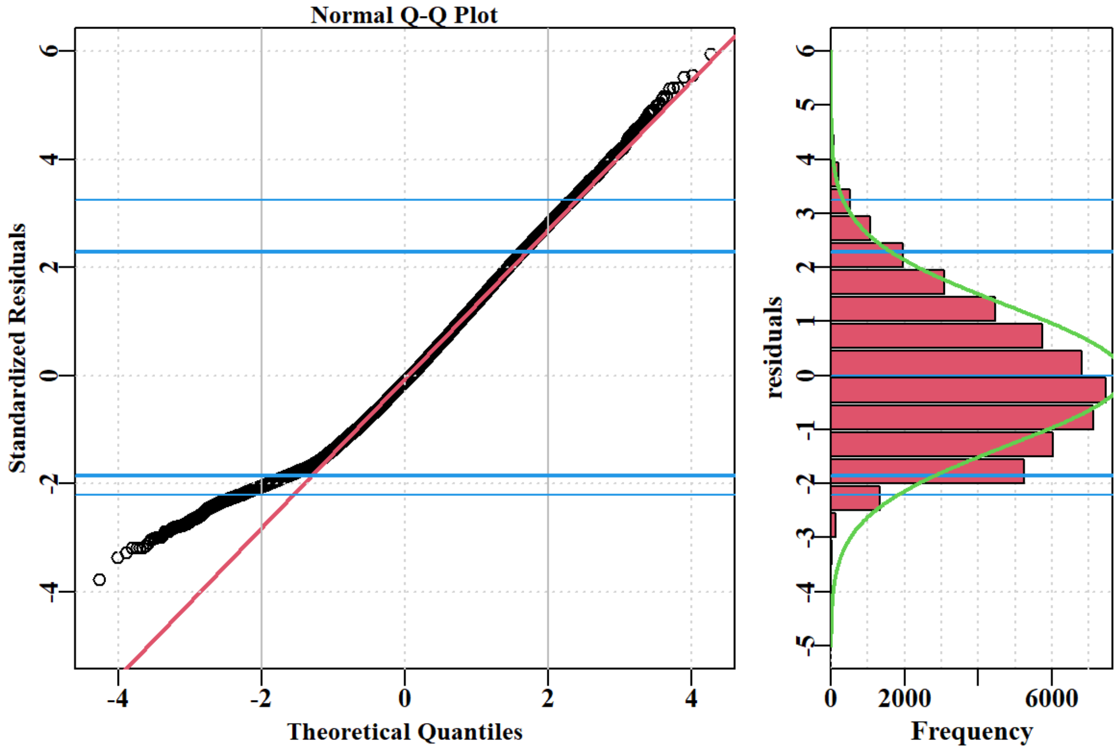

Figure 10.177. ElephantFishGN. Diagnostic plots. The distribution of residuals from the optimum fit. The qqplot indicates the fit to the expected normality, while the histogram of residuals also illustrates the 1%, 5%, 95% and 99% quantiles to indicate the intensity of any lack of fit at the margins of the distribution (reflected also in the qqplot).

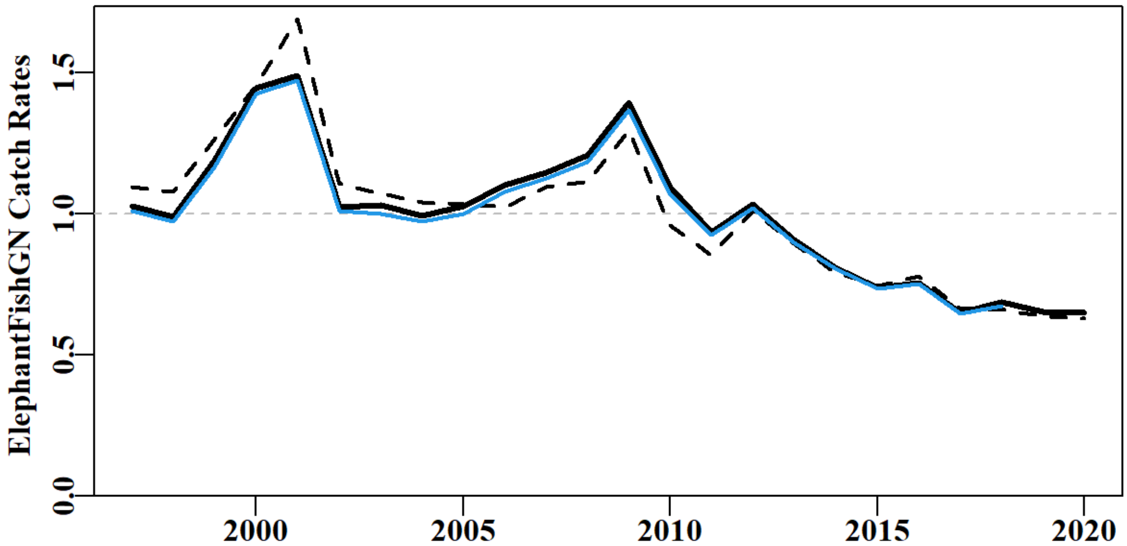

Figure 10.178. ElephantFishGN. A comparison of the previous year's standardization (blue line) with this year's. They should lie on top of each other, although small deviations may relate to data adjustments, particularly in very recent years.

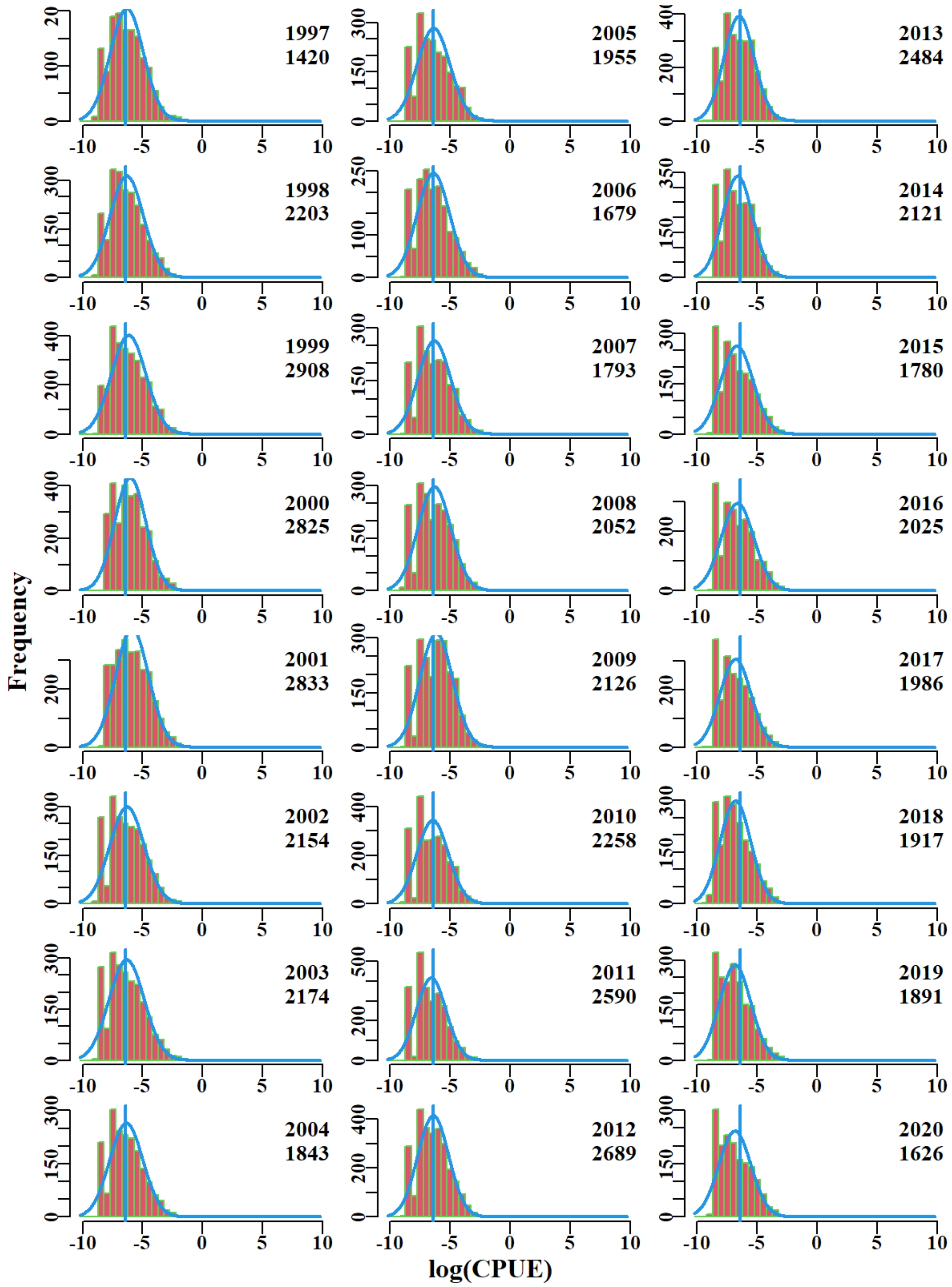

Figure 10.179. ElephantFishGN. The natural log(CPUE) for each year of data available the blue lines are normal distributions fitted to the histogram frequencies. The numbers in each plot are the year and number of records. The vertical blue line is the average across all years.

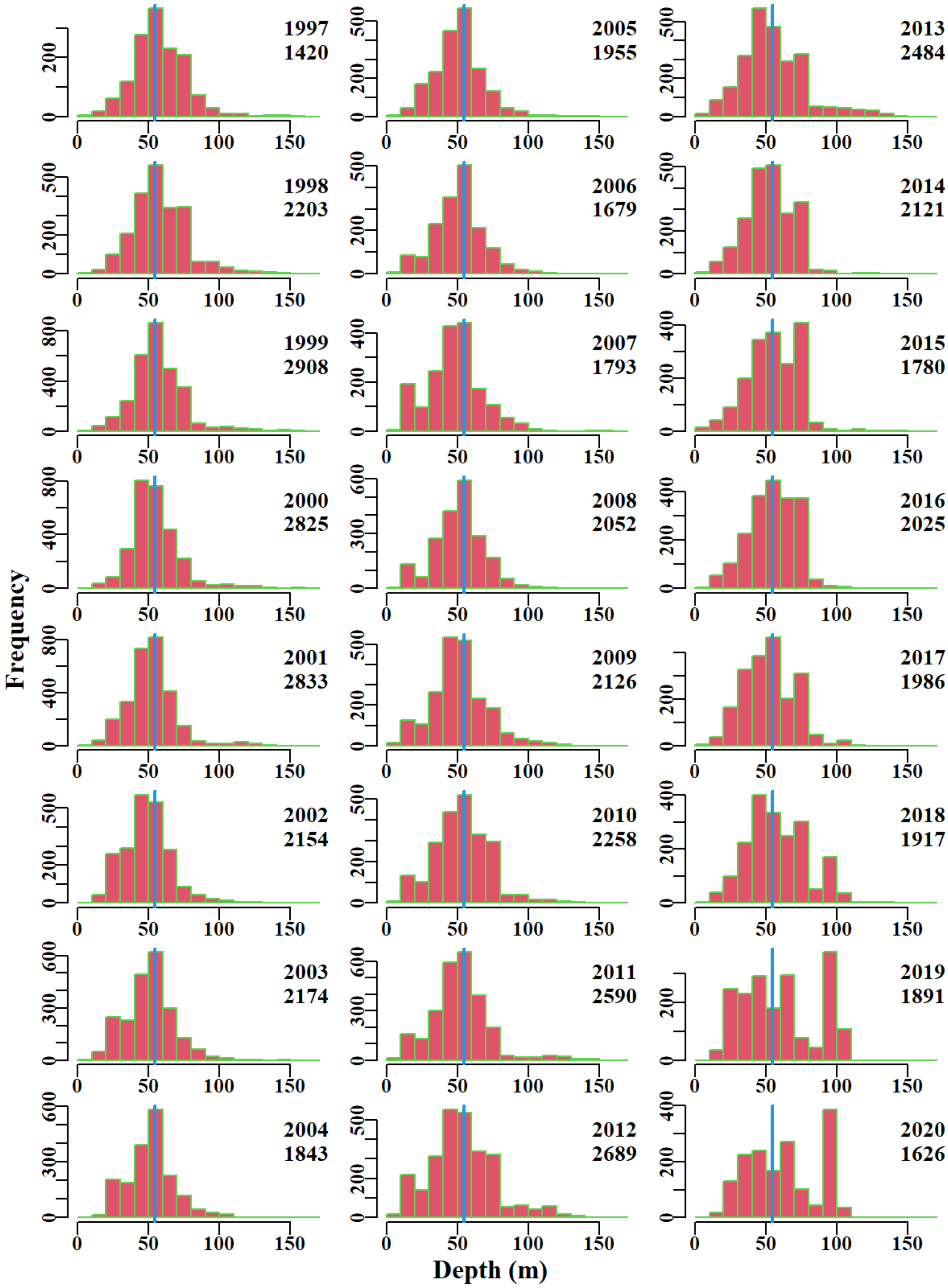

Figure 10.180. ElephantFishGN. The average Depth of fishing for each year of data available to illustrate the development of the fishery through time. The numbers in each plot are the year and number of records. The vertical blue line is the average across all years.

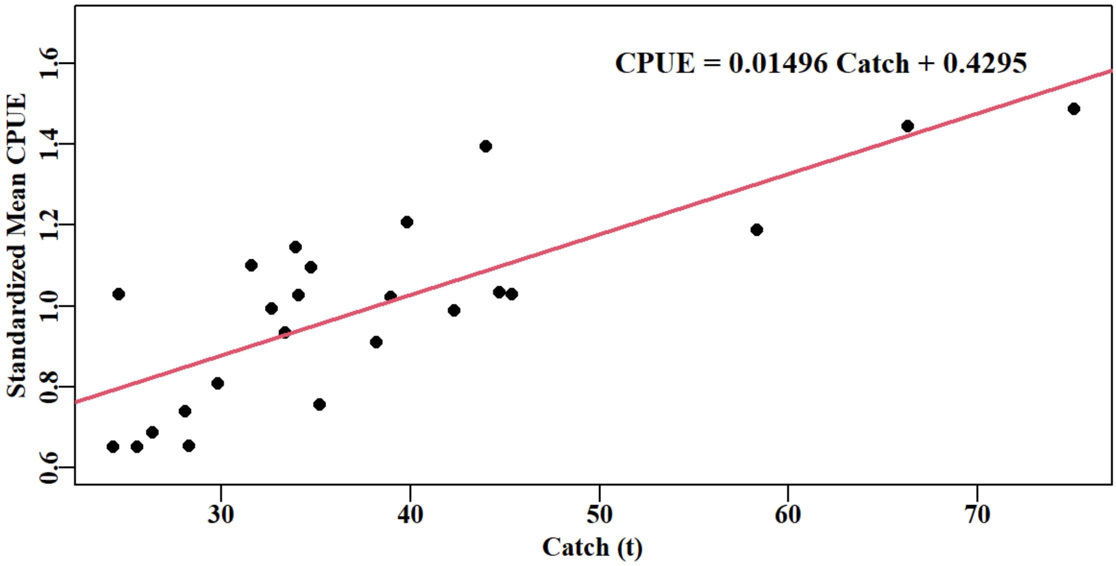

Figure 10.181. ElephantFishGN. The linear relationship between annual mean CPUE and annual Catch.

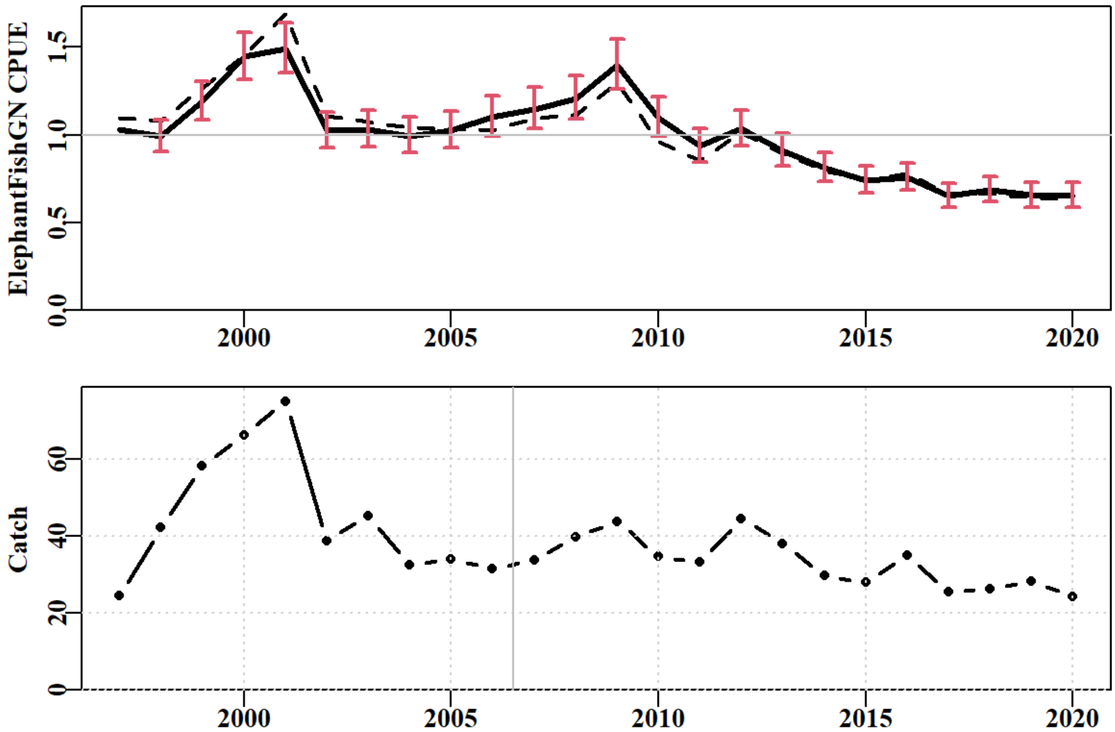

Figure 10.182. ElephantFishGN. CPUE is correlated with catches through time. CPUE in the top plot and annual catch (t) in the lower plot.

10.24 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). Geoff Tuck (CSIRO) is also thanked for his helpful comments on this report.

10.25 References

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11. Catch history time series for selected Tier 4 SESSF species (data to 2020)

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11.1 Executive Summary

Catch history time series have been developed for this year's Tier 4 assessments for the following four species: Silver Trevally (*Pseudocaranx dentex*), John Dory (*Zeus faber*), Mirror Dory (*Zenopsis nebulosa*) East and West separately and Blue-eye Trevalla (*Hyperoglyphe antarctica*). It is proposed that these series are employed in this year's Tier 4 assessments, with the hope that any remaining data issues relating to potential double reporting/counting of some catch in both NSW and Commonwealth waters may be clearly resolved in the future.

While there are unresolved data issues relating to these catch histories, they are the best available given limited time and resources to check both the original sources and previous RAG decisions and to produce a proposed catch history for SERAG consideration, and to potentially use in the upcoming 2021 Tier 4 assessments.

11.2 Background

This report produces an updated catch history series for four SESSF Tier 4 species: Silver Trevally, John Dory, Mirror Dory and Blue-eye Trevalla Slope using different data sources, which could be subject to change in the future.

The proposed catch history series for these four species uses data from different sources spanning the 1986 – 2020 period. Catch data from both State and Commonwealth sources were compiled in a RAG agreed data file (an MS Excel spreadsheet referred to as the "colourful spreadsheet" herein) for the period 1986-2013. This catch history was originally compiled by PIRVic and an initial version was provided to CSIRO by Matt Koopman in August 2007. This file was subsequently revised and/or updated annually at CSIRO up until 2013. The most recent version was last produced in October 2013. This document (relabelled as "Agenda Item 1.4 - Action Items - Attachment A - Catch Histories for Tier 3-4 Draft_29Oct13.xlsx") was distributed to the SESSFRAG data meeting, as one of the agenda papers, in August 2018.

An effort was made by the RAGs in 2006 (mostly at ShelfRAG as this issue almost exclusively applied to shelf species) to correct existing historical catch history for the various Commonwealth quota species by correctly accounting for state catches (Neil Klaer pers. comm., 2021). State scientists were tasked with compiling best estimates of catches for many species that correctly accounted for additional catch made by the states ("Matt Koopman to develop tables for each species including Commonwealth/state landed & discarded and RBC", ShelfRAG 3/2006). This task was undertaken by Matt Koopman (former PIRVic) for Victoria, Kevin Rowling (former NSW Fisheries) for NSW and Jeremy Lyle (former IMAS) for Tasmanian state catch.

While this spreadsheet lists logbook catches (SEF1) from 1985 and Commonwealth catch disposal Records (CDRs) from as early as 1992 for some species, the state catch columns were checked and adjusted, covering the period 1985-2000, at some stage in the years leading up to 2008 in an attempt to remove double reporting/counting. The NSW state column is believed to exclude catches already listed in the Commonwealth logbook (SEF1) and CDR (SEF2) columns in this spreadsheet (Kevin Rowling, Neil Klaer, Matt Koopman, pers. comm., 2021). However, the list of species and methods used to remove this historical double reporting/counting is not currently documented. There are indications that "process corrected summaries" were produced by Kevin Rowling in February 2006 (Kevin Rowling, pers. comm., 2021), for all the relevant species affected, and it appears that the process involved an attempt to remove double counted catches from vessels that were dual registered (i.e., Commonwealth and State). Further documentation may be available in future but is currently inaccessible due to the current COVID-19 lockdown in Sydney (Kevin Rowling, pers. comm., 2021).

Care should be taken to ensure that any potential modifications to data in the period 1985-2000 are done consistently, and that any data that is replaced represents the same data type. In particular, the NSW state catch data supplied by Kevin Rowling from 1985-2000, should only be replaced by NSW state catch data that excludes that component of the catch already reported to the Commonwealth in some form (either through CDRs or logbook records). Alternative methods of removing this double reporting/counting could be considered in future, if possible, in consultation with predecessors (e.g., Kevin Rowling) before any replacement of this RAG agreed catch series across the 1985-2000 period, and a clear justification as to why the new method is preferable to the current method. Clearly this is a difficult job while the documentation on the current method is incomplete.

In addition to data sourced from the colourful spreadsheet, more recent NSW state data used in this report is based on updates provided by Geoff Liggins (NSW Fisheries) in July 2021. Updates to the NSW state catch from Geoff Liggins were only applied from 2011 onwards, replacing the last two years of NSW state catch (2011 and 2012) in the colourful spreadsheet, as this most recent data is often revised. Annual NSW catch up to 2010 were sourced from the RAG agreed colourful spreadsheet.

The most recent NSW update provided by Geoff Liggins (20 Aug 2021) was not included in the proposed catch series for the four species in this report, as recommended by SESSFRAG in August 2020. Any revisions to the NSW state catch histories that address the double reporting/counting issue may require further attention which would involve a detailed comparison of individual vessel/operator Commonwealth and NSW catch records.

Commonwealth landings data (CDRs) used were either based on the colourful spreadsheet prior to 1998 or from Commonwealth logbook data (in the absence of CDR data over this 1986-1997 period, or if logbook data were greater than CDRs). CDRs from 1998 onwards are not controversial.

Annual discards were obtained from Althaus et al. 2021 with modifications to the forward-filled and backward-filled missing data fields, based on detailed recommendations discussed and agreed by SERAG in September 2020.

The Fishery Assessment Report (FAR) is an additional potential data source for catch histories (Smith and Wayte, 2004), but is considered less reliable than the colourful spreadsheet (Sally Wayte, pers. comm., 2021).

11.3 Silver Trevally (Pseudocaranx dentex)

Annual catch of Silver Trevally (TRE – 37337062 – *Pseudocaranx dentex*) over the 1986-2020 period was constructed as follows:

Table 11.1. Silver Trevally: Data particulars used to derive the catch history series (1986-2020) for use in the 2021 Tier 4 assessment. CWTH: Commonwealth.

Item No.	Jurisdictional component	Jurisdictional sub-component	Years	Data
1.	State	Vic, Tas	1986-1991	Colourful spreadsheet
2.	State	Vic, Tas	1992-2020	CSIRO database, excluding auto-fill
3.	State	NSW	1986-2010	Colourful spreadsheet. Note: this data originated from Kevin Rowling (pers. comm., 2021)
4.	State	NSW	2011-2020	Geoff Liggins July 2021 update
5.	CWTH	-	1986-1991	Colourful spreadsheet: SEF1^
6.	CWTH	-	1992-1997	Colourful spreadsheet: SEF2^
7.	CWTH	-	1998 - 2020	AFMA landings

^: This was used to create a catch history used in the proposed Tier 1 assessment (as agreed by ShelfRAG in 2006; Day et al. 2006).

Annual discards were based on estimates from Althaus et al. 2021, with the following modifications requested by SERAG in 2020 (see Proportion Discard in Table 11.2):

- Use mean discard estimates from 1998-2001 to backfill discard estimates from 1986-1997, excluding forward fills.
- Forward fill missing discard data entries in the catch time series from previous years. Include in table where this occurred (2016-2020).

An alternate catch series for Victoria exists between 1986-93, which has not been used in this series.

Table 11.2. Silver Trevally annual catch (t), discards (t) and State catch (t). Catch (t) includes State catch. Auto-filled proportion discard were based on (i) Althaus et al. (2021) and (ii) recommendations by SERAG (2020) which are highlighted (blue).

YEAR	CATCH (t)	DISCARDS (t)	TOTAL (t)	STATE (t)	PROPORTION DISCARD
1986	1166.6	5.27	1171.86	1052.1	0.0045
1987	1142.28	5.16	1147.43	1134.51	0.0045
1988	1226.55	5.54	1232.08	1221.3	0.0045
1989	1394.18	6.29	1400.47	1374.4	0.0045
1990	1587.73	7.17	1594.89	1515.81	0.0045
1991	990.05	4.47	994.52	922.74	0.0045
1992	947.23	4.28	951.51	740.44	0.0045
1993	1029.86	4.65	1034.5	870.29	0.0045
1994	835.82	3.77	839.59	697.27	0.0045
1995	995.63	4.49	1000.12	793.66	0.0045
1996	1018.88	4.6	1023.48	803.54	0.0045
1997	784.69	3.54	788.24	617.6	0.0045
1998	616.8	0.01	616.81	516.57	0.00001
1999	479.71	1.97	481.68	406.78	0.0041
2000	491.15	0.005	491.16	398.28	0.00001
2001	641.17	9.01	650.18	484.55	0.0139
2002	517.88	1.1	518.99	356.51	0.0021
2003	523.36	1.51	524.87	397.6	0.0029
2004	654.5	7.47	661.97	514.09	0.0113
2005	509.39	0.1	509.5	412.72	0.0002
2006	422.97	1.87	424.84	351.78	0.0044
2007	361.03	1.6	362.63	294.22	0.0044
2008	286.05	2.37	288.42	174.75	0.0082
2009	316.46	0.003	316.46	159.71	0.00001
2010	393.26	0.16	393.42	169.63	0.0004
2011	384.98	13.9	398.87	179.39	0.0348
2012	307.89	1.17	309.06	179.34	0.0038
2013	329.71	0.82	330.54	197.13	0.0025
2014	318.86	11.48	330.33	204.03	0.0347
2015	208.7	31.46	240.16	128.42	0.131
2016	201.1	30.32	231.42	144.81	0.131
2017	187.53	28.27	215.8	135.78	0.131
2018	138.72	20.91	159.64	105	0.131
2019	86.22	13	99.22	83.17	0.131
2020	109.18	16.46	125.64	72.84	0.131

11.4 John Dory (Zeus faber)

Annual catch of John Dory (DOJ– 37264004 – *Zeus faber*) over the 1986-2020 period (see Table 11.4) was constructed as follows:

Table 11.3. John Dory: Data particulars used to derive the catch history series (1986-2020) for use in the 2021 Tier 4 assessment. CWTH: Commonwealth.

Item No.	Jurisdictional component	Jurisdictional sub-component	Years	Data
1.	State	Vic, Tas	1986-2012	Colourful spreadsheet
2.	State	Vic, Tas	2013-2020	CSIRO database, excluding auto-fill
3.	State	NSW	1986-2010	Colourful spreadsheet. Note: this data originated from Kevin Rowling (pers. comm., 2021)
4.	State	NSW	2011-2019	Geoff Liggins July 2021 update
5.	State	NSW	2020	Geoff Liggins July 2021 update
6.	CWTH	-	1986-1991	Colourful spreadsheet: SEF1
7.	CWTH	-	1992-1997	Colourful spreadsheet: SEF2
8.	CWTH	-	1998 - 2020	AFMA landings

Annual discards were based on estimates from Althaus et al. 2021, with the following modifications requested by SERAG in 2020 (see Proportion Discard in Table 11.4):

- Use mean discard estimate from 1998-2006 to back fill discard estimates (1986-1997).
- Forward fill missing discard data entry in the catch time series repeating 2019 discard data in 2020.

Table 11.4. John Dory annual catch (t), discards (t) and State catch (t). Catch (t) includes State catch. Auto-filled proportion discard were based on (i) Althaus et al. (2021) and (ii) recommendations by SERAG (2020) which are highlighted (blue).

YEAR	CATCH (t)	DISCARDS (t)	TOTAL (t)	STATE (t)	PROPORTION DISCARD
1986	301.39	7.35	308.74	274.99	0.0238
1987	239.53	5.84	245.37	215.53	0.0238
1988	226.43	5.52	231.95	195.23	0.0238
1989	251.86	6.14	258.01	205.06	0.0238
1990	212.13	5.17	217.3	167.73	0.0238
1991	236.74	5.77	242.52	192.34	0.0238
1992	239.53	5.84	245.37	148.33	0.0238
1993	398.45	9.72	408.17	297.65	0.0238
1994	409.52	9.99	419.5	296.56	0.0238
1995	282.37	6.89	289.26	167.97	0.0238
1996	248.39	6.06	254.45	113.5	0.0238
1997	119.32	2.91	122.23	29.58	0.0238
1998	155.55	3.37	158.92	40.25	0.0212
1999	173.75	2.92	176.67	35.54	0.0165
2000	209.4	17.03	226.42	39.5	0.0752
2001	165.61	6.04	171.65	29.72	0.0352
2002	184.71	1.68	186.39	19.69	0.009
2003	193.24	3.2	196.44	28.25	0.0163
2004	193.68	1.74	195.41	27.68	0.0089
2005	131.99	3.54	135.52	29.22	0.0261
2006	107.13	0.64	107.76	23.48	0.0059
2007	82.54	1.36	83.9	13.82	0.0162
2008	177.18	0.6	177.79	41.01	0.0034
2009	127.52	4.34	131.86	19.66	0.0329
2010	86.71	2.96	89.66	14.28	0.033
2011	125.45	8.45	133.9	33.17	0.0631
2012	97.16	1.26	98.42	18.19	0.0128
2013	101.28	1.23	102.51	22.99	0.012
2014	70.54	5.52	76.06	9.78	0.0726
2015	106.44	0.32	106.76	14.33	0.003
2016	85.56	1.78	87.34	7.03	0.0204
2017	90.54	3.1	93.64	9.43	0.0331
2018	72.18	1.19	73.37	4.33	0.0162
2019	72.93	8.33	81.26	6.15	0.1025
2020	75.69	8.64	84.34	7	0.1025

11.5 Mirror Dory East (*Zenopsis nebulosa*)

Annual catch of Mirror Dory East (DOME– 37264003 – *Zenopsis nebulosa*) over the 1986-2020 period (see Table 11.6) was constructed as follows:

Table 11.5. Mirror Dory East: Data particulars used to derive the catch history series (1986-2020) for use in the 2021 Tier 4 assessment. CWTH: Commonwealth.

Item No.	Jurisdictional component	Jurisdictional sub-component	Years	Data
1.	State	Vic, Tas	1986 - 1991	No catch
2.	State	Tas	1992, 1993	No catch
3.	State	Vic	1992, 1993	Colourful spreadsheet apportioned by the Vic catch split: 20:**80** East and West respectively
4.	State	Vic, Tas	1994-2020	CSIRO database, excluding auto-fill. Tas catch split: 1:1; Vic catch split: 20:**80** East and West respectively
5.	State	NSW	1986-2010	Colourful spreadsheet. Note: this data originated from Kevin Rowling (pers. comm., 2021)
6.	State	NSW	2011-2020	Geoff Liggins July 2021 update
7.	CWTH	-	1986 - 1991	Colourful spreadsheet: SEF1 proportioned by the ratio of East to West logbook catch to the East
8.	CWTH	-	1992 - 1997	Colourful spreadsheet: SEF2 The ratio of East to West logbook catch was used to apportion CDR to the East
9.	CWTH	-	1998 - 2020	AFMA landings

Annual discards were based on estimates from Althaus et al. 2021, with the following modifications requested by SERAG in 2020 (see Proportion Discard in Table 11.6):

- Use mean discard estimates from years where data exists (over the 1998 – 2020 period) to backfill discard estimates (1986-1997).
- The same average discard estimates will also be used to forward fill any missing years, i.e., 2011-2014, 2016 and 2018.

Table 11.6. Mirror Dory East annual catch (t), discards (t) and State catch (t). Catch (t) includes State catch. Auto-filled proportion discard were based on (i) Althaus et al. (2021) and (ii) recommendations by SERAG (2020) which are highlighted (blue).

YEAR	CATCH (t)	DISCARDS (t)	TOTAL (t)	STATE (t)	PROPORTION DISCARD
1986	335.7	79.74	415.45	276.9	0.1925
1987	341.01	80.7	421.71	272.61	0.1925
1988	372.64	87.93	460.56	297.04	0.1925
1989	542.26	128.6	670.85	398.26	0.1925
1990	267.95	63.4	331.35	211.55	0.1925
1991	276.86	64.34	341.19	170.06	0.1925
1992	343.51	82.34	425.85	152.01	0.1925
1993	513.83	123.16	636.99	220.85	0.1925
1994	459.1	109.45	568.55	175.1	0.1925
1995	383.92	91.55	475.47	158.77	0.1925
1996	417.45	99.52	516.97	166.13	0.1925
1997	421.23	100.43	521.66	68.77	0.1925
1998	303.19	79.34	382.53	26.99	0.2074
1999	310.38	42.24	352.62	36.88	0.1198
2000	189.54	81.08	270.61	11.04	0.2996
2001	172.72	164.43	337.14	10.35	0.4877
2002	257.16	45.7	302.86	21.65	0.1509
2003	563.09	124.88	687.97	68.35	0.1815
2004	451.86	122.59	574.45	106.34	0.2134
2005	557.39	44.29	601.68	73.36	0.0736
2006	426.57	23.35	449.92	85.42	0.0519
2007	264.52	50.84	315.35	28.71	0.1612
2008	390.33	75.46	465.79	22.08	0.162
2009	416.2	273.9	690.11	34.93	0.3969
2010	428.74	186.82	615.56	12.02	0.3035
2011	391.4	93.29	484.69	6.09	0.1925
2012	339.26	80.87	420.13	5.63	0.1925
2013	246.88	58.85	305.73	3.65	0.1925
2014	137.89	32.87	170.75	1.79	0.1925
2015	183.12	1.11	184.23	0.6	0.006
2016	230.47	54.93	285.41	5.71	0.1925
2017	183.76	4.55	188.31	0.32	0.0242
2018	69.85	16.65	86.5	0.06	0.1925
2019	80.21	42.72	122.93	0.01	0.3476
2020	70.45	6.54	76.99	0.003	0.085

11.6 Mirror Dory West (Zenopsis nebulosa)

Annual catch of Mirror Dory West (DOME– 37264003 – *Zenopsis nebulosa*) over the 1986-2020 period (see Table 11.8) was constructed as follows:

Table 11.7. Mirror Dory West: Data particulars used to derive the catch history series (1986-2020) for use in the 2021 Tier 4 assessment. CWTH: Commonwealth.

Item No.	Jurisdictional component	Jurisdictional sub-component	Years	Data
1.	State	Vic, Tas	1986-1991	No catch
2.	State	Tas	1992, 1993	No catch
3.	State	Vic	1992, 1993	Colourful spreadsheet apportioned by the Vic catch split: **20**:80 East and West respectively
4.	State	Vic, Tas	1994-2020	CSIRO database, excluding auto-fill. Tas catch split: 1:1; Vic catch split: **20**:80 East and West respectively
5.	CWTH	-	1986-1991	Colourful spreadsheet: SEF1 proportioned by the ratio of East to West logbook catch to the West
6.	CWTH	-	1992-1997	AFMA logbook^
7.	CWTH	-	1998-2020	AFMA landings

^: AFMA logbook used as the CDR data apportioned to the West was less than the total reported in logbooks for each year in this period (1992-1997).

Discards are not used in the Tier 4 assessment for Mirror Dory West.

Table 11.8. Mirror Dory West annual catch (t) and State catch (t). Catch (t) includes State catch.

YEAR	CATCH (t)	STATE (t)
1986	7.8	
1987	16.12	
1988	17.1	
1989	11.23	
1990	10.15	
1991	14.93	
1992	9.77	0.48
1993	19.33	0.72
1994	18.65	0.334
1995	39.3	0.738
1996	117.41	0.238
1997	150	0.138
1998	136.18	0.001
1999	71.68	0.007
2000	27.79	0.001
2001	133.76	
2002	287.99	0.003
2003	174.93	0.061
2004	175.91	0.025
2005	106.58	0.039
2006	64.65	0.005
2007	71.39	0.005
2008	74.12	0.014
2009	144.96	
2010	204.2	
2011	177.02	0.001
2012	82.14	
2013	65.2	0.001
2014	76.92	
2015	77.27	
2016	46.37	
2017	64.53	
2018	37.39	
2019	41.46	
2020	33.93	

11.7 Bue-eye Trevalla (Hyperoglyphe antarctica)

Annual catch of Blue-eye Trevalla (TBE– 37445001 – *Hyperoglyphe antarctica*) over the 1997-2020 period for the slope (see Table 11.10) was constructed as follows:

Table 11.9. Blue-eye Trevalla: Data particulars used to derive the catch history series (1997-2020) for use in the 2021 Tier 4 assessment. CWTH: Commonwealth.

Item No.	Jurisdictional component	Jurisdictional sub-component	Years	Data
1.	State	Vic, Tas	1997-2020	CSIRO database^
2.	State	NSW	1997-1998	Geoff Liggins July 2021 update minus Seamount Line (Rowling 2006)
3.	State	NSW	1999-2020	Geoff Liggins NSW July 2021 update
4.	CWTH	-	1997-2020	AFMA landings^^

^ the 7.1 t Tasmanian catch reported in 2015 (see Althaus et al. 2021) was not used in this series, as there is considerable uncertainty with this estimate; ^^ includes ECDW CDRs

Separate NSW catch series for slope (1985-2004) and seamounts (1984-1998) from line methods have been produced by Rowling 2006. Annual seamount line catch (Rowling 2006) was subtracted from the Geoff Liggins July 2021 update to estimate the annual NSW slope catch for first two years of the assessment period (1997-1998). The NSW slope catch (i.e., Geoff Liggins July 2021 update) was used from 1999 onwards. There is some uncertainty whether part of the annual catch over the 1999-2020 period could also include seamounts.

Table 11.10. Blue-eye Trevalla annual catch (t) and State catch (t). Catch (t) includes State catch.

YEAR	CATCH (t)	STATE (t)
997	821.73	620.21
1998	595.45	121.36
1999	676.58	132.61
2000	747.77	89.46
2001	653.47	78.18
2002	553.9	102.36
2003	555.19	55.73
2004	693.34	66.87
2005	543.71	62.94
2006	593.84	45.61
2007	643.24	57.79
2008	411.15	37.78
2009	467.25	38.76
2010	430.73	47.86
2011	422.53	46.25
2012	293.34	34.52
2013	287.9	24.05
2014	339.64	21.15
2015	259.4	23.68
2016	253.36	16.7
2017	374.91	19.32
2018	361.39	23.85
2019	299.42	9.4
2020	225.09	9.42

11.8 Ackowledgements

Thanks go to Geoff Tuck (CSIRO) for discussion and useful comments on an earlier version of this report. Also, Robin Thomson is thanked for clarifying the Mirror Dory East and West split that is applied to Catch Disposal Records (CDRs).

11.9 References

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12. Tier 4 assessments for selected SESSF species (data to 2020)

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12.1 Executive Summary

Four Tier 4 assessments were performed for the following species and/or fisheries:

- Silver Trevally (*Pseudocaranx dentex*)
- Mirror Dory East (*Zenopsis nebulosa*)
- Mirror Dory West (*Zenopsis nebulosa*)
- John Dory (*Zeus faber*)

Silver Trevally: The 2021 estimated RBC was approximately 178.85 t, an approximate 190.84 t decrease compared to the 2020 estimated RBC (369.69 t). This decrease in RBC can be mostly attributed to a drop in the most recent standardized CPUE (including discards) and hence the mean CPUE of the most recent four-years which are used to calculate the RBC. The 2021 RBC is greater than the reported catch of approximately 125.64 t in 2020 for this species.

Mirror Dory - East: The 2021 estimated RBC was 112.93 t, a decrease of 32.76 t compared to the 2020 estimated RBC (145.69 t). Note that the 2021 RBC is greater than the reported catch of approximately 77 t in 2020 for this species. The decrease in RBC of approximately 33 t can be mostly attributed to a decrease in the most recent CPUE (including discards) and hence the most recent four-year average which is used to calculate the RBC. Also, the CPUE in 2020 (0.49) is at the CPUE limit based on the Tier 4 harvest control rule (0.49).

Mirror Dory - West: The 2021 estimated RBC was 56.18 t, a decrease of 5.39 t compared to the 2020 estimated RBC (61.57 t). The decrease in RBC of approximately 5.4 t can be attributed to a decrease in the most recent four-year average CPUE which is used to calculate the RBC. The 2021 RBC is greater than the reported catch of approximately 34 t in 2020 for this species.

John Dory: The 2021 estimated RBC was 0 t compared to the 2017 estimated RBC (485 t). Note that the 2021 RBC is less than the reported catch of approximately 75.7 t in 2020 (excluding discards) for this species (Total = 84.34 t including discards).

12.2 Introduction

12.2.1 *Tier 4 Harvest Control Rule*

The Tier 4 harvest control rules are the default procedure applied to species which only have catches and catch per unit effort (CPUE) data available; specifically, there is no other reliable information on either current biomass levels or current exploitation rates.

Ideally, in line with the notion of being more precautionary in the absence of information, the outcome from these analyses should be more conservative than those available from higher Tier analyses; this is now explicitly implemented by imposing a 15% discount factor on the Tier 4 RBC as a precautionary measure unless there are good reasons for not imposing such a discount on particular species. The application of the discount factor will occur unless RAGs generate explicit advice that alternative equivalent precautionary measures are in place (such as spatial or temporal closures) or that there is evidence of historical stability of the stock at current catch levels (AFMA, 2009).

Tier 4 analyses require as a minimum, a time series of total catches and of standardized CPUE, along with an agreed reference period and reference points.

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

12.2.2 *Tier 4 Assumptions*

12.2.2.1 Informative CPUE

There is a linear relationship between CPUE and exploitable biomass. If there is hyper-stability (CPUE remain stable while stock size changes) or hyper-depletion (CPUE decline much faster than stock size changes) then the standard Tier 4 analysis would provide biased results.

12.2.2.2 Consistent CPUE Through Time

The character of the estimated CPUE 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 CPUE 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 CPUE are extremely variable through time, such that mean estimates become unreliable measures of stock status, then the Tier 4 approach cannot be validly applied.

12.2.2.3 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 CPUE 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 $B_{48\%}$.

12.2.2.4 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.

12.2.2.5 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.

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.

12.3 Silvery Trevally Discard

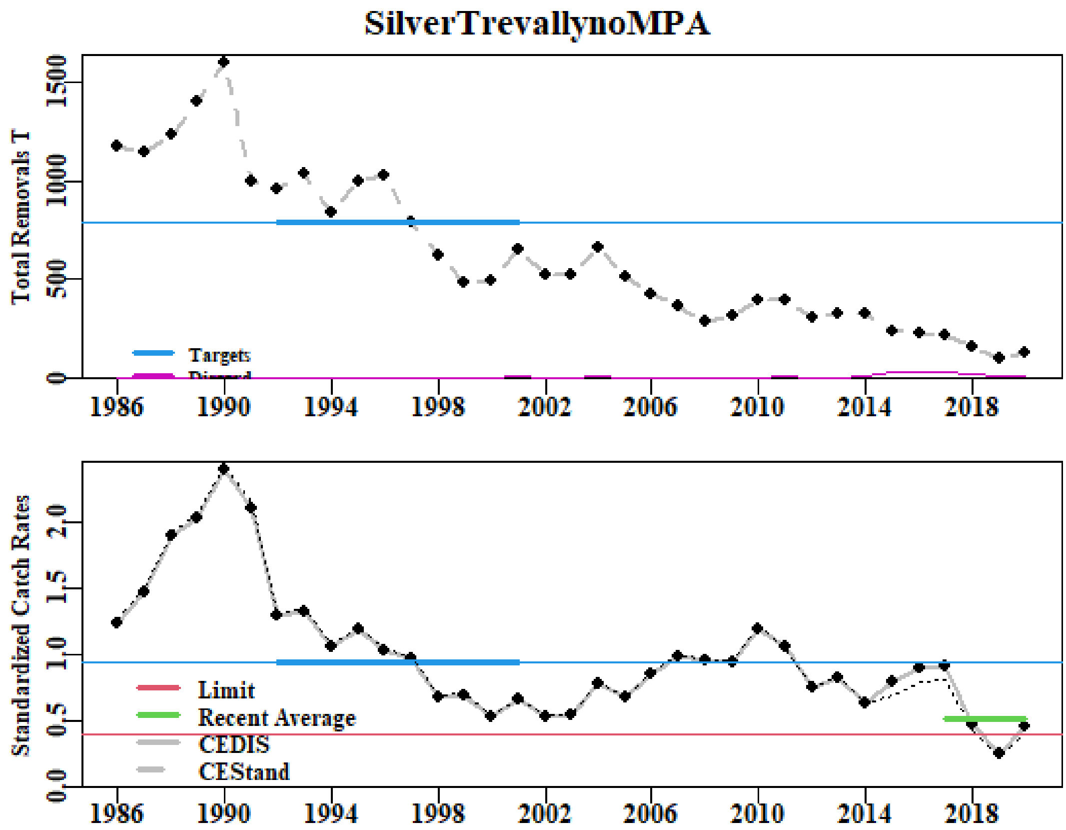

Figure 12.1. Silver Trevally Discard. Top plot is the total removals with the fine line illustrating the target catch. Bottom plot represents the standardized CPUE with the upper fine line representing the target CPUE and the lower line the limit CPUE. Thickened lines represent the reference period for catches, CPUE, and the recent average CPUE. The thin black dotted line is the unmodified standardized CPUE before the inclusion of discards.

Table 12.1. Silver Trevally Discard RBC calculations. C_{targ} and $CPUE_{targ}$ (CE_Target) are targets identified in the above figure, $CPUE_{Lim}$ is 20% of the B_0 proxy (which relate to the $CPUE_{targ}$), and the most recent CPUE is the average CPUE over the last four years (CE_Recent). 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	1992 - 2001	|	Scaling	0.227
CE_Target	0.9418	|	Previous TAC (t)	289
CE_Limit	0.3924	|	C_{targ}	787.726
CE_Recent	0.5172	|	RBC	178.853
Wt_Discard	16.917	|		

Table 12.2. Silver Trevally 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 CPUE (Sporcic, 2021). Discards (D) are estimates from 1986 to present (see details in Sporcic and Day 2021).

Year	Catch	Discards	Total	(D/C)+1	CE	DiscCE	TAC	State
1986	1166.6	5.265	1171.864	1.005	1.2567	1.2380	-	1052.095
1987	1142.3	5.155	1147.432	1.005	1.4998	1.4775	-	1134.513
1988	1226.5	5.536	1232.083	1.005	1.9314	1.9026	-	1221.298
1989	1394.2	6.292	1400.470	1.005	2.0670	2.0362	-	1374.397
1990	1587.7	7.166	1594.892	1.005	2.4282	2.3920	-	1515.806
1991	990.1	4.468	994.519	1.005	2.1418	2.1099	-	922.743
1992	947.2	4.275	951.506	1.005	1.3136	1.2940	-	740.440
1993	1029.9	4.648	1034.505	1.005	1.3495	1.3294	500	870.292
1994	835.8	3.772	839.587	1.005	1.0723	1.0563	500	697.273
1995	995.6	4.493	1000.121	1.005	1.2040	1.1861	500	793.656
1996	1018.9	4.598	1023.478	1.005	1.0426	1.0271	500	803.543
1997	784.7	3.541	788.235	1.005	0.9766	0.9621	500	617.604
1998	616.8	0.006	616.811	1.000	0.6936	0.6802	500	516.569
1999	479.7	1.972	481.680	1.004	0.7021	0.6914	500	406.778
2000	491.2	0.005	491.156	1.000	0.5411	0.5306	500	398.277
2001	641.2	9.010	650.184	1.014	0.6648	0.6611	450	484.553
2002	517.9	1.102	518.986	1.002	0.5355	0.5263	360	356.505
2003	523.4	1.509	524.866	1.003	0.5469	0.5379	320	397.604
2004	654.5	7.470	661.973	1.011	0.7858	0.7794	320	514.086
2005	509.4	0.101	509.496	1.000	0.6798	0.6668	320	412.717
2006	423.0	1.875	424.841	1.004	0.8631	0.8502	270	351.778
2007	361.0	1.600	362.632	1.004	0.9926	0.9777	191	294.224
2008	286.0	2.371	288.420	1.008	0.9597	0.9490	296	174.746
2009	316.5	0.003	316.463	1.000	0.9548	0.9364	360	159.714
2010	393.3	0.163	393.421	1.000	1.2151	1.1921	360	169.633
2011	385.0	13.897	398.873	1.036	1.0458	1.0626	540	179.389
2012	307.9	1.170	309.055	1.004	0.7542	0.7424	540	179.338
2013	329.7	0.823	330.535	1.002	0.8303	0.8163	588	197.128
2014	318.9	11.479	330.335	1.036	0.6259	0.6359	588	204.027
2015	208.7	31.461	240.161	1.151	0.6956	0.7850	588	128.417
2016	201.1	30.316	231.420	1.151	0.7966	0.8990	588	144.806
2017	187.5	28.270	215.803	1.151	0.8001	0.9029	613	135.779
2018	138.7	20.912	159.637	1.151	0.4165	0.4700	307	105.000
2019	86.2	12.997	99.217	1.151	0.2128	0.2401	292	83.169
2020	109.2	16.459	125.641	1.151	0.4037	0.4556	289	72.836

12.3.1 *Discussion*

This assessment excluded data from within the Bateman's Bay MPA. The large closure over the previously preferred fishing areas may have had an unknown but depressing effect on the commercial fishery. While Silver Trevally are relatively mobile fish they can still be expected to stay mostly over their preferred habitat, much of which lies within the Bateman's Bay MPA. But given their mobility and the uncertainties relating to their actual movements it is currently not possible to conclude that the MPA affects anything other than fisher behaviour. In addition, the catch time series used in this assessment was derived from Sporcic and Day (2021), which incorporated the July 2021 revised NSW estimates and endorsed by SERAG (28-29 September 2021). There has been an overall decrease in the total annual catch (one order of magnitude) since the start of this series, despite relatively small increases between some years (Table 12.2). However, the 2020 annual catch increased relative to the previous year (109.2 t *vs* 86.2 t excluding discards; Table 12.2).

The 2021 estimated RBC was approximately 178.85 t (Table 12.1), an approximate 190.84 t decrease compared to the 2020 estimated RBC (369.69 t). This decrease in RBC can be mostly attributed to a drop in the most recent standardized CPUE (including discards) and hence the mean CPUE of the most recent four-years which are used to calculate the RBC. The 2021 RBC is greater than the reported catch of approximately 125.64 t in 2020 for this species (Table 12.2).

12.4 Mirror Dory East Discard

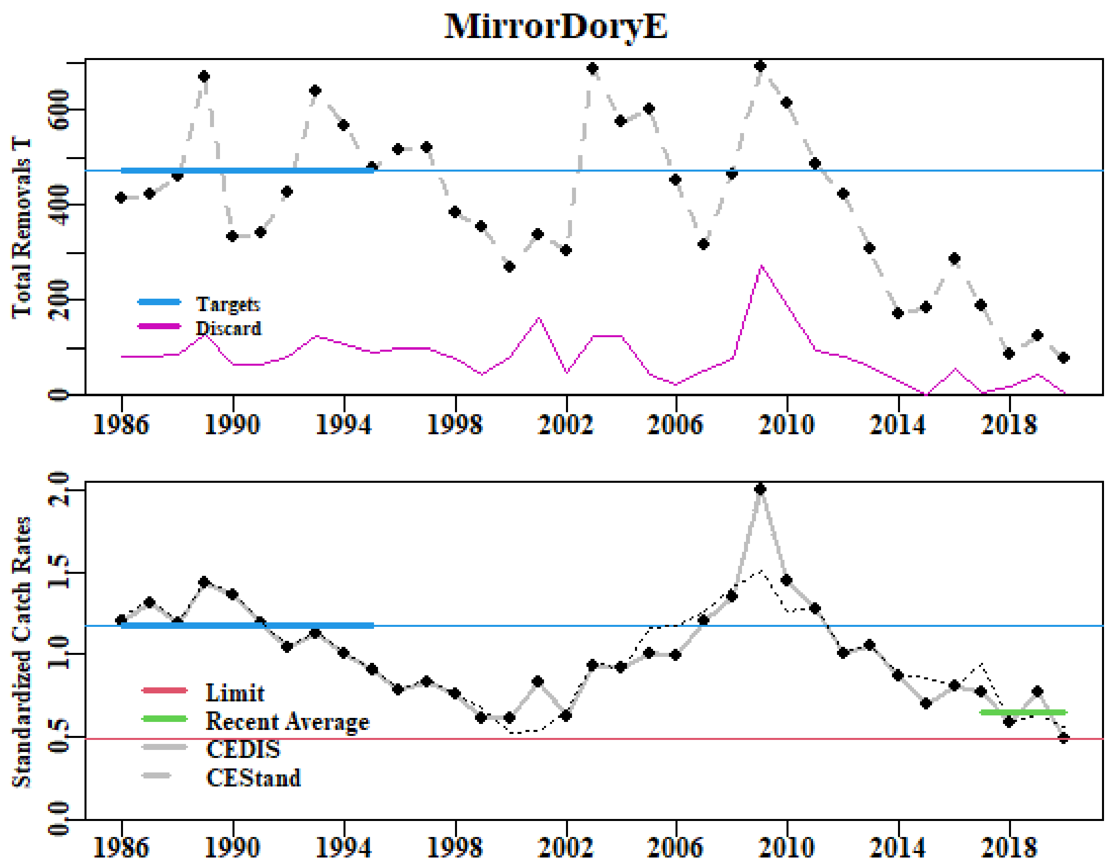

Figure 12.2. Mirror Dory 10 - 30 Discard. Top plot is the total removals with the fine line illustrating the target catch. Bottom plot represents the standardized CPUE with the upper fine line representing the target CPUE and the lower line the limit CPUE. Thickened lines represent the reference period for catches, CPUE, and the recent average CPUE. The thin black dotted line is the unmodified standardized CPUE before the inclusion of discards.

Table 12.3. Mirror Dory 10 - 30 Discard RBC calculations. C_{targ} and $CPUE_{targ}$ (CE_Target) are the targets identified in the above figure, $CPUE_{Lim}$ is 20% of the B_0 proxy (which relate to the $CPUE_{targ}$), and the most recent CPUE is the average CPUE over the last four years (CE_Recent). The RBC calculation does not account for predicted discards of predicted State catches. Wt_Discard is the weighted average discards from the last four years. E: east; W: west.

Parameter	Value	Parameter	Value
Reference_Years	1986 - 1995	Scaling	0.2378
CE_Target	1.178	Previous combined (E + W) TAC (t)	137
CE_Limit	0.4908	C_{targ}	474.797
CE_Recent	0.6543	RBC	112.925
Wt_Discard	17.407		

Table 12.4. 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 CPUE (Sporcic, 2021). Discards (D) are estimates from 1986 to present (see details in Sporcic and Day 2021). Total Allowable Catch (TAC) are combined east and west.

Year	Catch	Discards	Total	(D/C)+1	CE	DiscCE	TAC	State
1986	335.7	79.744	415.447	1.238	1.2202	1.2068	0	276.903
1987	341.0	80.697	421.709	1.237	1.3323	1.3167	0	272.612
1988	372.6	87.926	460.564	1.236	1.2062	1.1915	0	297.038
1989	542.3	128.595	670.851	1.237	1.4505	1.4342	0	398.256
1990	267.9	63.404	331.351	1.237	1.3763	1.3602	0	211.547
1991	276.9	64.336	341.191	1.232	1.2078	1.1896	0	170.055
1992	343.5	82.335	425.849	1.240	1.0542	1.0445	0	152.007
1993	513.8	123.160	636.991	1.240	1.1436	1.1330	800	220.856
1994	459.1	109.448	568.547	1.238	1.0125	1.0021	800	175.100
1995	383.9	91.553	475.474	1.238	0.9106	0.9013	800	158.769
1996	417.4	99.519	516.966	1.238	0.7966	0.7884	800	166.133
1997	421.2	100.435	521.664	1.238	0.8473	0.8386	800	68.767
1998	303.2	79.336	382.526	1.262	0.7555	0.7618	800	26.987
1999	310.4	42.245	352.622	1.136	0.6693	0.6077	800	36.879
2000	189.5	81.075	270.611	1.428	0.5307	0.6056	800	11.043
2001	172.7	164.425	337.144	1.952	0.5332	0.8318	800	10.346
2002	257.2	45.702	302.862	1.178	0.6666	0.6274	640	21.645
2003	563.1	124.877	687.967	1.222	0.9532	0.9307	576	68.347
2004	451.9	122.593	574.451	1.271	0.9060	0.9205	576	106.337
2005	557.4	44.287	601.681	1.079	1.1646	1.0047	700	73.364
2006	426.6	23.351	449.922	1.055	1.1736	0.9893	634	85.425
2007	264.5	50.836	315.355	1.192	1.2673	1.2075	788	28.711
2008	390.3	75.461	465.793	1.193	1.4099	1.3446	634	22.076
2009	416.2	273.903	690.105	1.658	1.5057	1.9953	718	34.930
2010	428.7	186.822	615.559	1.436	1.2616	1.4476	718	12.019
2011	391.4	93.292	484.688	1.238	1.2841	1.2709	718	6.090
2012	339.3	80.865	420.130	1.238	1.0204	1.0099	718	5.630
2013	246.9	58.845	305.726	1.238	1.0595	1.0486	1077	3.649
2014	137.9	32.866	170.755	1.238	0.8823	0.8732	808	1.787
2015	183.1	1.105	184.228	1.006	0.8626	0.6936	437	0.595
2016	230.5	54.935	285.408	1.238	0.8138	0.8054	325	5.715
2017	183.8	4.549	188.309	1.025	0.9426	0.7720	235	0.322
2018	69.8	16.649	86.497	1.238	0.5889	0.5828	253	0.056
2019	80.2	42.725	122.931	1.533	0.6330	0.7754	188	0.006
2020	70.4	6.545	76.993	1.093	0.5574	0.4869	137	0.003

12.4.1 *Discussion*

The 2020 catch and standardized CPUE have decreased relative to the previous year respectively. The catch time series used in this assessment was derived from Sporcic and Day (2021), which incorporated the July 2021 revised NSW estimates and endorsed by SERAG (28-29 September 2021). Discard estimates were based on Althaus et al. (2021) and modifications requested by SERAG in 2020 (see details in Sporcic and Day 2021).

The 2021 estimated RBC was 112.93 t (Table 12.3), a decrease of 32.76 t compared to the 2020 estimated RBC (145.69 t; Sporcic 2020). The 2021 RBC is greater than the reported catch of approximately 77 t (i.e., including discards) in 2020 for this species (Table 12.4). The decrease in RBC of approximately 33 t can be mostly attributed to a decrease in the most recent CPUE (including discards) and hence the most recent four-year average which is used to calculate the RBC. Also, the CPUE in 2020 (0.49; Table 12.4) is at the CPUE limit based on the Tier 4 harvest control rule (0.49; Table 12.3).

12.5 Mirror Dory West

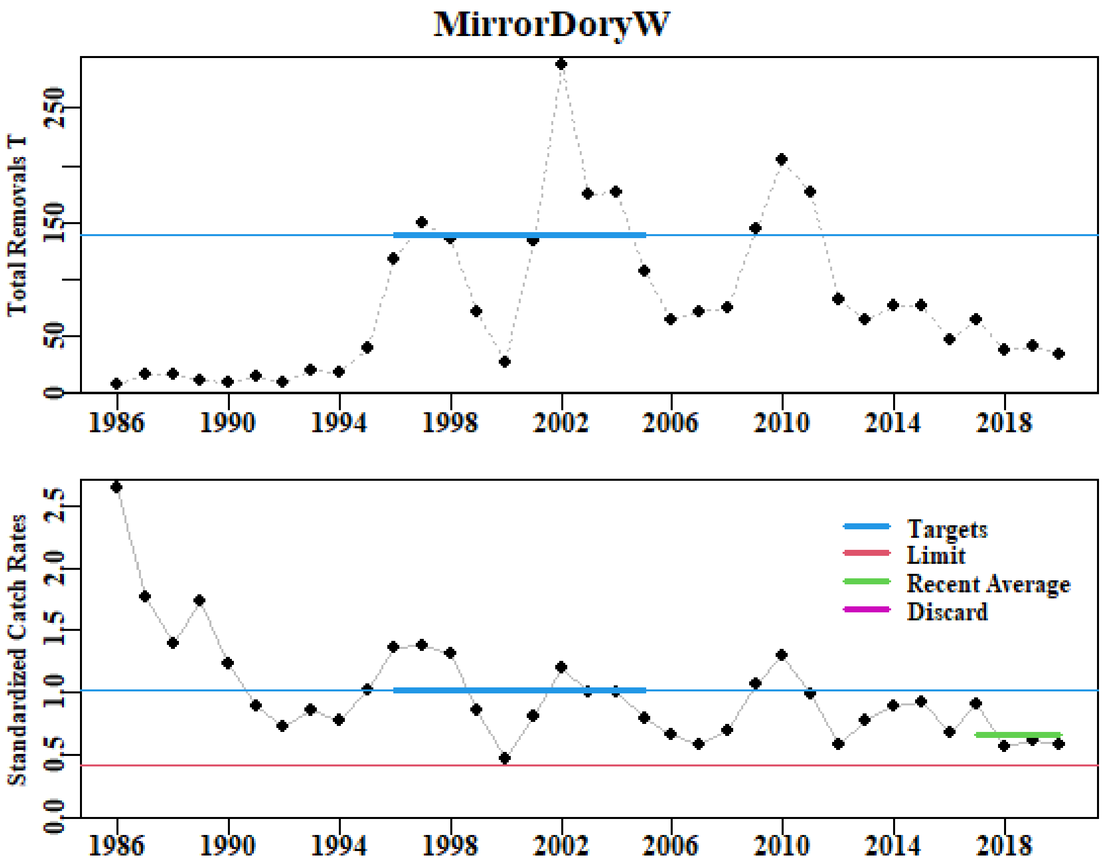

Figure 12.3. Mirror Dory 40 - 50. Top plot is the total removals with the fine line illustrating the target catch. Bottom plot represents the standardized CPUE with the upper fine line representing the target CPUE and the lower line the limit CPUE. Thickened lines represent the reference period for catches, CPUE, and the recent average CPUE.

Table 12.5. Mirror Dory 40 - 50 RBC calculations. C_{targ} and $CPUE_{targ}$ (CE_Target) are the targets identified in the figure above, $CPUE_{Lim}$ is 20% of the B_0 proxy (which relate to the $CPUE_{targ}$), and the most recent CPUE is the average CPUE over the last four years (CE_Recent). The RBC calculation does not account for predicted discards of predicted State catches. Wt_Discard is the weighted average discards from the last four years. E: east; W: west.

Parameter	Value		Parameter	Value
Reference_Years	1996 - 2005	|	Scaling	0.4065
CE_Target	1.018	|	Previous TAC (t)	137
CE_Limit	0.4242	|	C_{targ}	138.224
CE_Recent	0.6655	|	RBC	56.184
Wt_Discard		|		

Table 12.6. 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 CPUE (Sporcic, 2021). GeoMean is the geometric mean CPUE. Total Allowable Catch (TAC) are combined east and west.

Year	Catch	Discards	Total	State	CE	GeoMean	TAC
1986	8		7.800		2.6380	1.8026	0
1987	16		16.123		1.7658	1.7493	0
1988	17		17.104		1.3922	1.8026	0
1989	11		11.227		1.7357	2.1951	0
1990	10		10.151		1.2270	1.8365	0
1991	15		14.928		0.8904	0.8625	0
1992	10		9.770	0.480	0.7189	0.7075	0
1993	19		19.330	0.720	0.8519	0.8092	800
1994	19		18.646	0.334	0.7780	0.7172	800
1995	39		39.305	0.738	1.0216	0.7462	800
1996	117		117.407	0.238	1.3653	1.1339	800
1997	150		150.000	0.138	1.3844	1.1872	800
1998	136		136.183	0.000	1.3076	1.3325	800
1999	72		71.677	0.006	0.8506	0.8238	800
2000	28		27.792	0.001	0.4699	0.3828	800
2001	134		133.762		0.8120	0.6832	800
2002	288		287.994	0.002	1.2034	1.2017	640
2003	175		174.927	0.060	1.0007	1.0030	576
2004	176		175.911	0.024	0.9964	0.9837	576
2005	107		106.584	0.039	0.7894	0.7365	700
2006	65		64.651	0.005	0.6543	0.7608	634
2007	71		71.390	0.005	0.5878	0.6929	788
2008	74		74.123	0.014	0.6979	0.7801	634
2009	145		144.958		1.0623	0.9691	718
2010	204		204.199		1.2959	1.2841	718
2011	177		177.025	0.001	0.9851	1.0563	718
2012	82		82.141		0.5776	0.8189	718
2013	65		65.201	0.001	0.7780	1.0079	1077
2014	77		76.918		0.8949	0.9497	808
2015	77		77.272		0.9254	0.8431	437
2016	46		46.370		0.6796	0.7995	325
2017	65		64.531		0.9067	0.7753	235
2018	37		37.387		0.5708	0.5233	253
2019	41		41.458		0.6075	0.5815	188
2020	34		33.929		0.5771	0.4603	137

12.5.1 *Discussion*

With the fishery only beginning to report significant catches from about 1996 onwards the reference period used is relatively recent. Nevertheless, there are now 11 years between the reference period and the start of the most recent four years used to denote the current state of the fishery. The catch time series used was derived from Sporcic and Day (2021). The 2020 catch and standardized CPUE have decreased relative to the previous year respectively.

The 2021 estimated RBC was 56.18 t (Table 12.5), a decrease of 5.39 t compared to the 2020 estimated RBC (61.57 t; Sporcic 2020). The decrease in RBC of approximately 5.4 t can be attributed to a decrease in the most recent four-year average CPUE which is used to calculate the RBC. The 2021 RBC is greater than the reported catch of approximately 34 t in 2020 for this species (Table 12.6).

12.6 John Dory

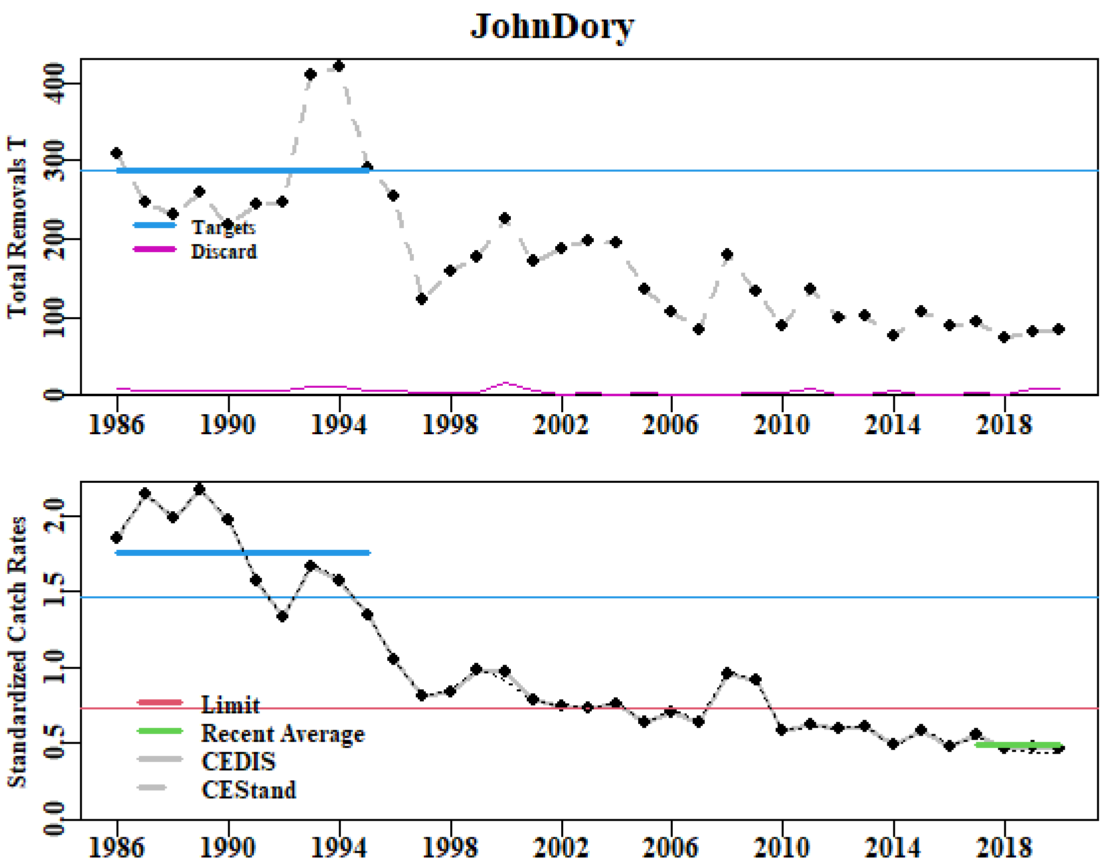

Figure 12.4. John Dory Discard. Top plot is the total removals with the fine line illustrating the target catch. Bottom plot represents the standardized CPUE with the upper fine line representing the target CPUE and the lower line the limit CPUE. Thickened lines represent the reference period for catches, CPUE, and the recent average CPUE. The thin black dotted line is the unmodified standardized CPUE before the inclusion of discards.

Table 12.7. John Dory Discard RBC calculations. C_{targ} and $CPUE_{targ}$ (CE_Target) are the targets identified in the above figure, $CPUE_{Lim}$ is 20% of the B_0 proxy (which relate to the $CPUE_{targ}$), and the most recent CPUE is the average CPUE over the last four years (CE_Recent). 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
CE_Target	1.464	|	Previous TAC (t)	452
CE_Limit	0.732	|	C_{targ}	286.619
CE_Recent	0.4695	|	RBC	0
Wt_Discard	7.196	|		

Table 12.8. John Dory 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 CPUE (Sporcic, 2021). Discards (D) are estimates from 1986 to present (see details in Sporcic and Day 2021).

Year	Catch	Discards	Total	(D/C)+1	CE	DiscCE	TAC	State
1986	301.4	7.351	308.741	1.024	1.8554	1.8502	-	274.990
1987	239.5	5.843	245.373	1.024	2.1476	2.1416	-	215.530
1988	226.4	5.523	231.950	1.024	1.9816	1.9760	-	195.227
1989	251.9	6.143	258.007	1.024	2.1681	2.1620	-	205.064
1990	212.1	5.174	217.303	1.024	1.9777	1.9721	-	167.729
1991	236.7	5.775	242.517	1.024	1.5727	1.5683	-	192.342
1992	239.5	5.842	245.367	1.024	1.3261	1.3224	240	148.325
1993	398.4	9.719	408.167	1.024	1.6703	1.6656	240	297.648
1994	409.5	9.989	419.505	1.024	1.5778	1.5734	240	296.555
1995	282.4	6.888	289.263	1.024	1.3403	1.3365	240	167.970
1996	248.4	6.059	254.451	1.024	1.0521	1.0491	240	113.496
1997	119.3	2.911	122.235	1.024	0.8144	0.8121	240	29.579
1998	155.5	3.369	158.915	1.022	0.8468	0.8422	240	40.245
1999	173.8	2.915	176.667	1.017	0.9977	0.9875	240	35.542
2000	209.4	17.027	226.422	1.081	0.9201	0.9685	240	39.502
2001	165.6	6.042	171.653	1.036	0.7737	0.7806	240	29.721
2002	184.7	1.677	186.389	1.009	0.7553	0.7419	240	19.694
2003	193.2	3.202	196.440	1.017	0.7348	0.7271	240	28.248
2004	193.7	1.739	195.415	1.009	0.7732	0.7594	240	27.679
2005	132.0	3.537	135.523	1.027	0.6387	0.6384	240	29.218
2006	107.1	0.636	107.764	1.006	0.7143	0.6995	190	23.481
2007	82.5	1.359	83.899	1.016	0.6454	0.6386	178	13.819
2008	177.2	0.604	177.788	1.003	0.9802	0.9574	190	41.012
2009	127.5	4.338	131.862	1.034	0.9084	0.9144	190	19.660
2010	86.7	2.959	89.664	1.034	0.5777	0.5815	221	14.280
2011	125.5	8.451	133.901	1.067	0.6039	0.6275	221	33.170
2012	97.2	1.259	98.421	1.013	0.5988	0.5904	221	18.186
2013	101.3	1.229	102.514	1.012	0.6244	0.6152	221	22.993
2014	70.5	5.519	76.060	1.078	0.4657	0.4888	221	9.778
2015	106.4	0.320	106.762	1.003	0.5930	0.5790	169	14.334
2016	85.6	1.785	87.340	1.021	0.4855	0.4825	167	7.030
2017	90.5	3.099	93.637	1.034	0.5467	0.5504	175	9.432
2018	72.2	1.189	73.374	1.016	0.4648	0.4599	263	4.327
2019	72.9	8.328	81.256	1.114	0.4362	0.4731	395	6.148
2020	75.7	8.644	84.338	1.114	0.4305	0.4669	452	7.002

12.6.1 *Discussion*

This is the first Tier 4 assessment for John Dory, as it was previously a Tier 3 assessment (Castillo-Jordán 2017). Total annual catch peaked in 1994 and CPUE has been below the reference target level since 1995 within this assessment period (1986-2020). The catch time series used was derived in Sporcic and Day (2021), which incorporated the July 2021 revised NSW estimates and was endorsed by SERAG (28-29 September 2021). Discard estimates were based on Althaus et al. (2021) and modifications requested by SERAG in 2020 (see details in Sporcic and Day 2021).

The 2021 estimated RBC was 0 t compared to the 2017 estimated RBC (485 t) (Table 12.7). Note that the 2021 RBC is less than the reported catch of approximately 75.7 t in 2020 (excluding discards) for this species (Total = 84.34 t including discards; Table 12.8). Also, annual standardized CPUE has been below the CPUE limit since 2010 (Figure 12.4; Table 12.8).

12.7 Ackowledgements

Thanks goes to the CSIRO database team for their processing of the catch and effort (CPUE) and Catch Disposal Record (CDR) data as received from the Australian Fisheries Management Authority. Thanks also goes to Dr Geoff Liggins (NSW Department of Primary Industries) for providing revised NSW catch series for the assessed species. Both Geoff Tuck (CSIRO) and Jemery Day (CSIRO) are also thanked for reviewing this report.

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12.9 Appendix A: Methods

12.9.1 *Tier 4 Harvest Control Rule*

The data required are time series of catches and standardized CPUE. The analyses have been conducted on total catches across the entire SESSF (including State catches, SEF2 landing records, and any discards). For some species, where there is only a single stock and a single primary fishing method, analyses are presented using standardized CPUE data (e.g., Haddon, 2014). For other species, there may be multiple stocks or areas or multiple methods and selecting which time series of CPUE to use in the analyses is not always straightforward. In those cases, the standardized CPUE time series for the method now accounting for most 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 CPUE 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 (2021), 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 CPUE 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 CPUE 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. $CPUE_{\text{targ}}$ is the target CPUE for the species,
3. $CPUE_{\text{lim}}$ is the limit CPUE for the species = 0.4 * $CPUE_{\text{targ}}$,
4. $\overline{CPUE}$ is the average CPUE over the past *m* years; *m* tends to be the most recent four years,
5. C_{targ} is a catch target derived from a period of historical catch that has been identified as a desirable target in terms of CPUE, catches and status of the fishery, e.g. 1986 – 1995. This is an average of the total removals for the selected reference period, including any discards.

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

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 CPUE in year y, $yr2$ and $yr1$ represent the last and the first years in the reference period respectively.

Percent discards are estimated from ISMP observations from 1998 to the current year. Discards for earlier years, prior to ISMP sampling, are generally estimated by taking the overall average percent discard from 1998 to the 2006 and applying that discard rate to the reported landings for the earlier years. The year 2006 was selected as the final year as discarding practices altered at about that time following the structural adjustment and the introduction of the Harvest Strategy Policy. For Eastern Gemfish the average discard rate was determined for 1998-2002 to allow for the non-target nature of the fishery following 2002. The calculation of the earlier discards is done so that the total catches can be estimated even though only the landed catches are available. To calculate the discards for a given year we used:

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

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

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

where D_{CUR} is the estimated discard rate for the coming year y, D_{y-1} is the discards rate in year $y-1$. The discard rate in year y is the ratio of discards to the sum of landed catches plus those discards (this can vary between 0 – 100%):

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

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

Plots are given of the total removals illustrating the target catch level. In addition, the standardized CPUE are illustrated with the target CPUE and the limit CPUE. Finally, where the data are available, plots are given of the Total removals contrasted with State removals, and of discards and non-trawl catches.

12.9.2 *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 CPUE relate only to the estimated landed weights. In those species where discarding makes up a significant proportion of the catch (in some years more redfish were discarded than landed and more inshore ocean perch tend to be discarded than landed) it is reasonable to ask how the discards would have affected CPUE. This is an important question because standardized commercial CPUE are used in Australian stock assessments as an index of relative abundance (e.g., Haddon, 2014); if ignoring discards leads to a consistent bias this could affect the outcome of the assessments and thus, the assessments should become aware of the effects of discards.

Standardized CPUE are used in assessments as an index of relative abundance through time and it is the trends exhibited by the CPUE 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 CPUE 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 CPUE 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 CPUE should be examined each year as a sensitivity analysis to contrast with the outcome from the unaugmented CPUE (Haddon, 2010).

12.9.2.1 Analyses Including Discards

Discard rates cannot simply be added to known catches on the way to calculating CPUE. The standardized CPUE are estimated from individual catch and effort records but the estimates of discards are summary estimates for each fishery. While a method for incrementing the standardized CPUE has been developed it should be noted that this ignores all complications relating to unknown aspects of discarding behaviour (e.g., Is the discard rate constant across all catch sizes, across all vessels, across all areas?). This means that including discard catches into the annual CPUE estimates introduces an unknown amount of uncertainty into the analysis. It should also be noted that the discard estimates are highly variable from year to year and derive from relatively small samples of all trips contributing to catches.

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

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

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

where $\hat{I}_{R,t}$ is the ratio mean CPUE for year *t*, $\sum C_t$ is the sum of landed catches in year *t*, and $\sum E_t$ is the sum of effort (as hours trawled) in year *t*. If $\sum D_t$ is the sum of discards in year *t* then the discard incremented ratio mean CPUE would be:

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

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

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

where I_t is the CPUE estimate to be modified by the inclusion of discards. If this is the ratio mean then the augmented CPUE would be identical to the first equation dealing with $\sum D_t$. In practice, the CPUE used with the multiplier are the standardized CPUE (e.g. Haddon, 2014; Sporcic 2021).

12.9.2.2 The Limitations of Including Discards

The discard rates are estimated as the proportion of the total catch (= landed catch plus discards), which means that discard proportions greater than 0.5 imply that more fish are discarded than landed. To calculate the discarded catches from a discard rate and the landed catches we use:

$$D_t = \left(\frac{C_t}{1 - P_t}\right) - C_t$$

where D_t is the discarded catches in year *t*, C_t is the total landed catches in year *t*, and P_t is the proportion of discards in year *t*. Because the divisor is $1 - P_t$ as P_t tends to 1.0 the divisor becomes very small and hence acts as a multiplier on total landed catch C_t. The effect of this is that when P_t is estimated to be above 0.5 the multiplying effect in the calculation of discards becomes grossly exaggerated (Figure A12.1).

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.

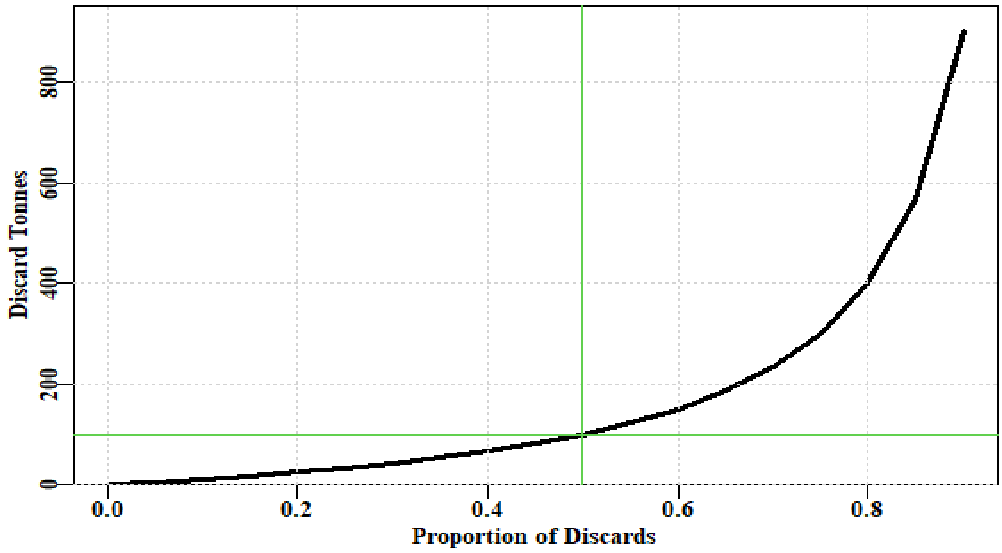

Figure A 12.1. The influence of the proportion discarded on estimates of discarded catches. As the proportion of discards approaches 1.0 the multiplying effect in the estimation of discard amounts becomes greatly amplified.

12.9.3 *Selection of Reference Periods*

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

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

To select a reference period requires a time series of comparable CPUE. For this reason the use of standardized CPUE should be an improvement over using, for example, the observed arithmetic or geometric mean CPUE. CPUE data is available in the SESSF for all targeted species from 1986 - 2011, although it needs to be noted that the character of the fishery has changed markedly during that period. Little et al. (2009) provide a discussion on how reference periods might be selected. They proposed a default 10 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 CPUE. 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 CPUE, $CPUE_{targ}$, was divided by two as a proxy for expected changes to CPUE as the fishery develops and the resource stock size declines towards the assumed proxy target for 48% unfished biomass.

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

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

12.10 Appendix B: Alternative CPUE standardizations for Silver Trevally and John Dory

AFMA have requested the following CPUE standardizations to be undertaken in addition to the regular updates to CPUE standardizations for both John Dory and Silver Trevally. The resulting standardized CPUE series are based on methods reported in Sporcic (2021).

1. **John Dory:** Produce a standardized CPUE series that excludes all vessels that left the fishery (i.e., due the structural adjustment i.e., from 2006-07) in earlier past of the series.
2. **Silver Trevally:** Produce a standardized CPUE series that excludes vessels targeting.

12.10.1 *Silver Trevally (Pseudocaranx)*

An alternative standardized CPUE series was produced for silver trevally as requested by AFMA in 2021. This series, unlike the series produced in Sporcic (2021) excluded the top four vessels corresponding to the greatest number of shots of at least 30 kg (Figure B 12.1).

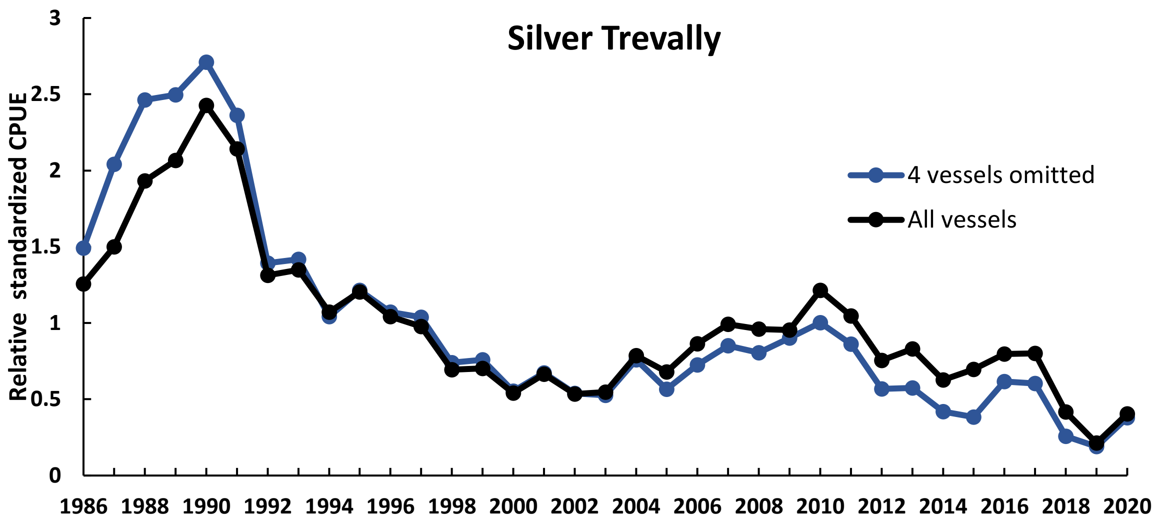

Figure B 12.1. Relative standardized CPUE for silver trevally. Standardized CPUE estimated in Sporcic 2021 (blue line); and standardized CPUE omitting the top four vessels corresponding to the greatest number of shots of at least 30 kg.

12.10.2 *John Dory (Zeus faber)*

An alternative standardized CPUE series was produced, as requested by the AFMA in 2021. This series, unlike the series produced by Sporcic (2021) excluded vessels that contributed to the fishery prior to the structural adjustment i.e., part way through 2006 and 2007 and therefore were no longer active in the fishery after the structural adjustment (Figure B 12.2, Figure B 12.3).

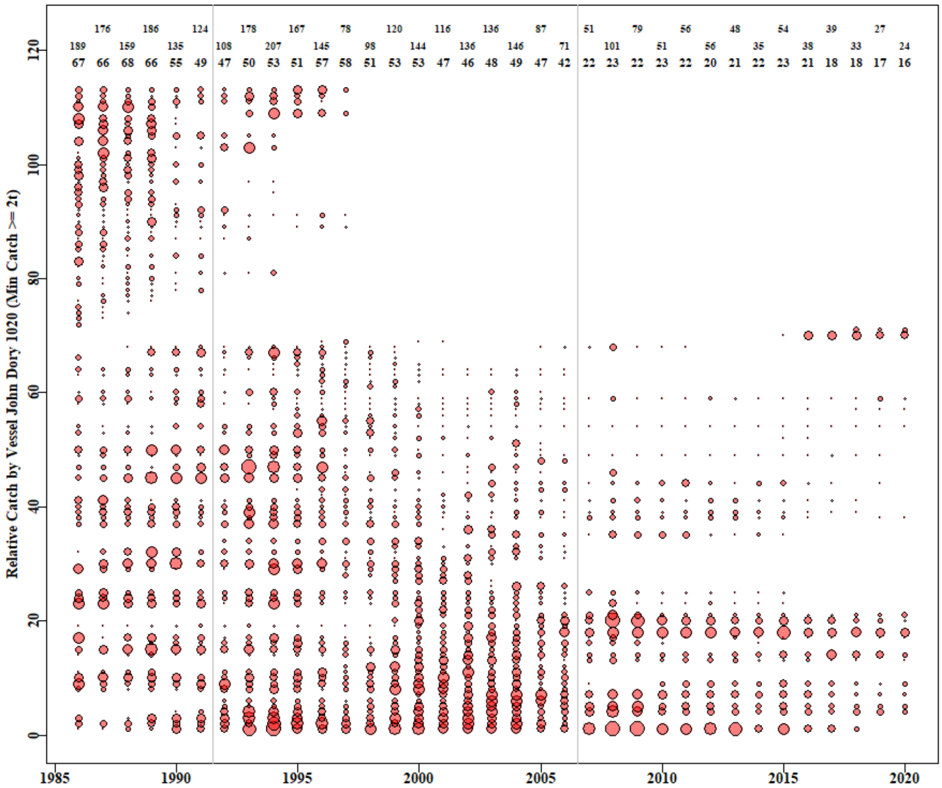

Figure B 12.2. Relative catch (t) of John Dory by vessel number.

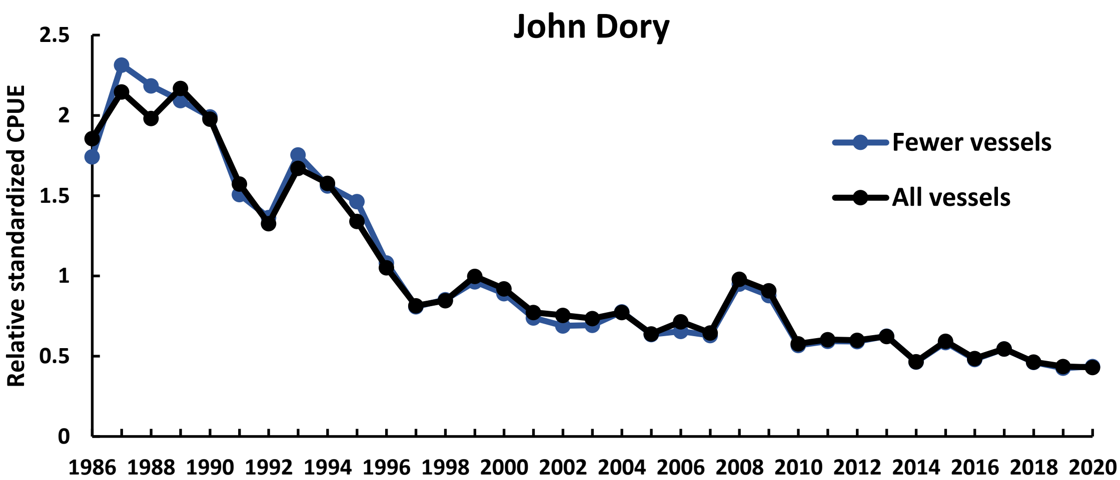

Figure B 12.3. Relative standardized CPUE corresponding to all vessels (black line; see also Sporcic 2021) and corresponding to vessels that left the fishery following the structural adjustment.

13. Tier 4 assessments for Blue-eye Trevalla (*Hyperoglyphe antarctica*) slope (data to 2020)

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13.1 Executive Summary

A Tier 4 assessment was performed for the following species:

- Blue-eye Trevalla slope (*Hyperoglyphe antarctica*)

The catch-time series used in this assessment was derived from Sporcic and Day (2021). Furthermore, as requested by SERAG in 2020, the standardized CPUE series was based on data corresponding to SESSF zones 20-50 and the Great Australian Bight (GAB) (Sporcic 2021). However, the standardized CPUE series used in the previous Tier 4 assessment was based on SESSF zones 20-50 only, i.e., excluding the GAB (Sporcic 2020).

The 2021 RBC was approximately 349.32 t, corresponding to a 122.29 t increase compared to the 2020 RBC, i.e., 227.03 t (Sporcic 2020). This 54% increase in RBC between assessments can be mostly attributed the use of the new standardized CPUE series which resulted in a higher most recent four-year average compared with the corresponding average standardized CPUE from the previous assessment. The scaling factor of approximately 54% which is applied to the target catch reflects this RBC-increase. The 2021 estimated RBC (i.e., for the 2022 fishing season) is greater than the reported catch of approximately 225.1 t in 2020 for this species.

13.2 Introduction

13.2.1 *Tier 4 Harvest Control Rule*

The Tier 4 harvest control rules are the default procedure applied to species which only have catches and catch per unit effort (CPUE) data available; specifically, there is no other reliable information on either current biomass levels or current exploitation rates.

Ideally, in line with the notion of being more precautionary in the absence of information, the outcome from these analyses should be more conservative than those available from higher Tier analyses; this is now explicitly implemented by imposing a 15% discount factor on the Tier 4 RBC as a precautionary measure unless there are good reasons for not imposing such a discount on particular species. The application of the discount factor will occur unless RAGs generate explicit advice that alternative equivalent precautionary measures are in place (such as spatial or temporal closures) or that there is evidence of historical stability of the stock at current catch levels (AFMA, 2009).

Tier 4 analyses require as a minimum, a time series of total catches and of standardized CPUE, along with an agreed reference period and reference points.

The current Tier 4 analysis and control rule underwent Management Strategy Evaluation (Wayte, 2009; Little et al., 2011a), which demonstrated its advantages over an earlier implementation used in 2007 and 2008. Further work has since demonstrated that if 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).

13.2.2 *Tier 4 Assumptions*

13.2.2.1 Informative CPUE

There is a linear relationship between CPUE and exploitable biomass. If there is hyper-stability (CPUE remain stable while stock size changes) or hyper-depletion (CPUE decline much faster than stock size changes) then the standard Tier 4 analysis would provide biased results.

13.2.2.2 Consistent CPUE Through Time

The character of the estimated CPUE 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 CPUE 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 CPUE are extremely variable through time, such that mean estimates become unreliable measures of stock status, then the Tier 4 approach cannot be validly applied.

13.2.2.3 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 CPUE 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 $B_{48\%}$.

13.2.2.4 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 number of fish killed remains.

13.2.2.5 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.

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.

13.3 Blue-eye Trevalla

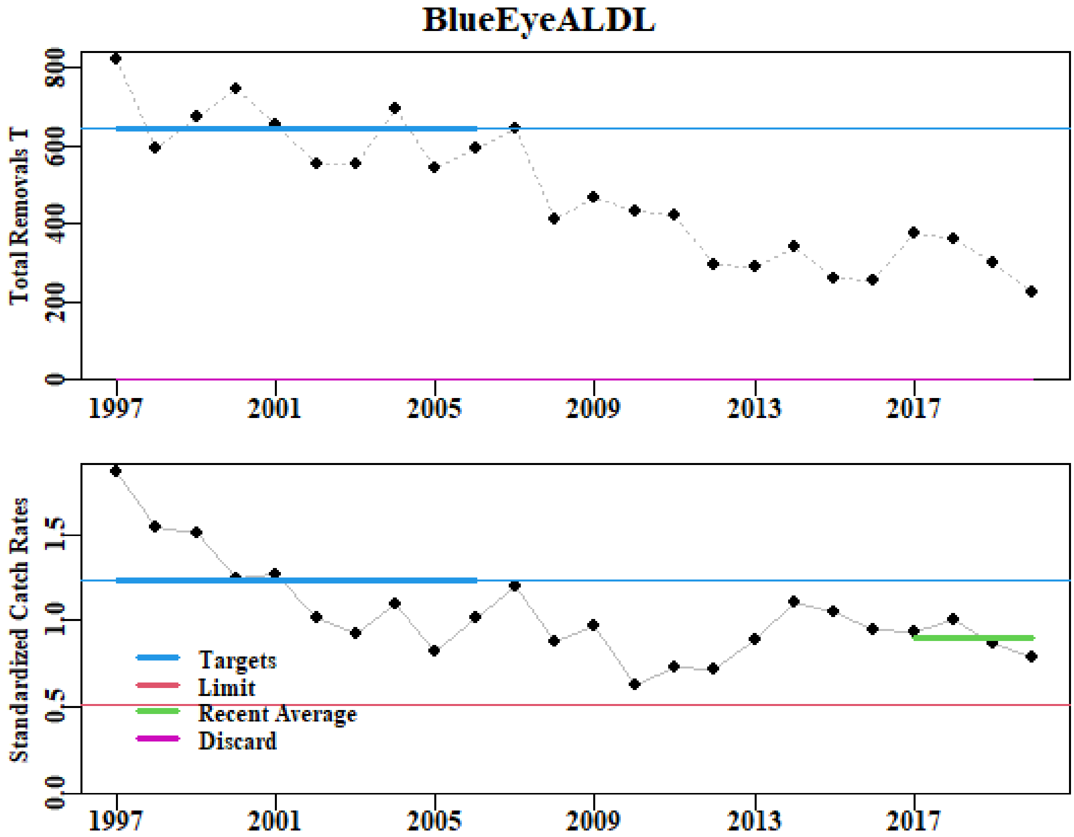

Figure 13.1. Blue-eye Trevalla. Top plot is the total removals with the fine line illustrating the target catch. Bottom plot represents the standardized CPUE with the upper fine line representing the target CPUE and the lower line the limit CPUE. Thickened lines represent the reference period for catches, CPUE, and the recent average CPUE. The thin black dotted line is the unmodified standardized CPUE. Discards are assumed to be.

Table 13.1. Blue-eye Trevalla RBC calculations. C_{targ} and $CPUE_{targ}$ (CE_Target) are the targets identified in the figure above, $CPUE_{Lim}$ is 20% of the B0 proxy (which relate to the $CPUE_{targ}$), and the most recent CPUE is the average CPUE over the last four years (CE_Recent). The RBC calculation does not account for predicted discards of predicted State catches.

Parameter	Value		Parameter	Value
Reference_Years	1997 - 2006	|	Scaling	0.5428
CE_Target	1.2287	|	Previous TAC (t)	448
CE_Limit	0.512	|	C_{targ}	643.497
CE_Recent	0.901	|	RBC	349.321
Wt_Discard	-	|		

Table 13.2. Blue-eye Trevalla data for the Tier 4 calculations. Total (t) is the sum of State, Non-Trawl and SEF2 catches. All values in Tonnes. CE is the standardized CPUE corresponding to zones 20-50 and the Great Australian Bight (Sporcic, 2021).

Year	Catch	Total	State	Non-Trawl	CE	TAC
1997	821.73	821.73	620.21	205.86	1.8588	125
1998	595.45	595.45	121.36	380.44	1.5397	630
1999	676.58	676.58	132.61	464.66	1.5036	630
2000	747.77	747.77	89.46	567.19	1.2457	630
2001	653.47	653.47	78.18	478.40	1.2633	630
2002	553.90	553.90	102.36	427.97	1.0143	630
2003	555.19	555.19	55.73	556.56	0.9243	690
2004	693.34	693.34	66.87	566.92	1.0915	621
2005	543.71	543.71	62.94	449.20	0.8243	621
2006	593.84	593.84	45.61	496.74	1.0213	560
2007	643.24	643.24	57.79	536.28	1.2025	785
2008	411.15	411.15	37.78	338.85	0.8814	560
2009	467.25	467.25	38.76	404.11	0.9696	560
2010	430.73	430.73	47.86	358.81	0.6305	428
2011	422.53	422.53	46.25	430.06	0.7252	326
2012	293.34	293.34	34.52	307.37	0.7197	388
2013	287.90	287.90	24.05	252.18	0.8868	388
2014	339.64	339.64	21.15	292.21	1.1075	335
2015	259.40	259.40	23.68	267.52	1.0532	335
2016	253.36	253.36	16.70	310.36	0.9480	410
2017	374.91	374.91	19.32	355.62	0.9381	458
2018	361.39	361.39	23.85	305.37	1.0071	462
2019	299.42	299.42	9.40	277.61	0.8724	458
2020	225.09	225.09	9.42	211.26	0.7865	448

13.3.1 *Discussion*

The catch-time series used in this assessment (Table 13.1) was derived from Sporcic and Day (2021). Furthermore, as requested by SERAG in 2020, the standardized CPUE series was based on data corresponding to SESSF zones 20-50 and the Great Australian Bight (GAB) (Table 13.1; Sporcic 2021). However, the standardized CPUE series used in the previous Tier 4 assessment was based on SESSF zones 20-50 only, i.e., excluding the GAB (Sporcic 2020).

The 2021 RBC was approximately 349.32 t (Table 13.1), corresponding to a 122.29 t increase compared to the 2020 RBC, i.e., 227.03 t (Sporcic 2020). This 54% increase in RBC between assessments can be mostly attributed the use of the new standardized CPUE series which resulted in a higher most recent four-year average compared with the corresponding average standardized CPUE from the previous assessment. The scaling factor of approximately 54% which is applied to the target catch reflects this RBC-increase. The 2021 estimated RBC (i.e., for the 2022 fishing season) is greater than the reported catch of approximately 225.1 t in 2020 for this species.

13.4 Ackowledgements

Thanks goes to the CSIRO database team for their processing of the catch and effort (CPUE) and Catch Disposal Record (CDR) data as received from the Australian Fisheries Management Authority. Thanks also goes to Dr Geoff Liggins (NSW Department of Primary Industries) for providing revised NSW catch series for the assessed species. Geoff Tuck (CSIRO) and Jemery Day (CSIRO) are also thanked for reviewing this report.

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13.6 Appendix A: Methods

13.6.1 Tier 4 Harvest Control Rule

The data required are time series of catches and standardized CPUE. The analyses have been conducted on total catches across the entire SESSF (including State catches, SEF2 landing records, and any discards). For some species, where there is only a single stock and a single primary fishing method, analyses are presented using standardized CPUE data (e.g., Haddon, 2014). For other species, there may be multiple stocks or areas or multiple methods and selecting which time series of CPUE to use in the analyses is not always straightforward. In those cases, the standardized CPUE time series for the method now accounting for the majority of current catch was used.

All 2010 data relating to catches and discards, from both State waters and SEF2 data sets, were provided by AFMA, with initial processing by N. Klaer and J. Upston of CSIRO. All CPUE 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 (2021), which provided the tables and graphs required for the Tier 4 assessments. The data and results for each analysis are presented for transparency. The Tier 4 harvest control rule formulation essentially uses a ratio of current CPUE with respect to the selected limit and target reference points to calculate a scaling factor 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 CPUE then the RBC could undergo large changes. Such changes are constrained by the following limits:

$$RBC_y = 1.5RBC_{y-1} \quad RBC_y > 1.5RBC_{y-1}$$
$$RBC_y = 0.5RBC_{y-1} \quad RBC_y < 0.5RBC_{y-1}$$

where

1. RBC_y is the RBC in year y,
2. $CPUE_{\text{targ}}$ is the target CPUE for the species,
3. $CPUE_{\text{lim}}$ is the limit CPUE for the species = 0.4 * $CPUE_{\text{targ}}$,
4. $\overline{CPUE}$ is the average CPUE over the past *m* years; *m* tends to be the most recent four years,
5. C_{targ} is a catch target derived from a period of historical catch that has been identified as a desirable target in terms of CPUE, catches and status of the fishery, e.g. 1986 – 1995. This is an average of the total removals for the selected reference period, including any discards.

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

where L_y represents the landings in year y.

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

where $CPUE_y$ is the CPUE in year y, $yr2$ and $yr1$ represent the last and the first years in the reference period respectively.

Percent discards are estimated from ISMP observations from 1998 to the current year. Discards for earlier years, prior to ISMP sampling, are generally estimated by taking the overall average percent discard from 1998 to the 2006 and applying that discard rate to the reported landings for the earlier years. The year 2006 was selected as the final year as discarding practices altered at about that time following the structural adjustment and the introduction of the Harvest Strategy Policy. For Eastern Gemfish the average discard rate was determined for 1998-2002 to allow for the non-target nature of the fishery following 2002. The calculation of the earlier discards is done so that the total catches can be estimated even though only the landed catches are available. To calculate the discards for a given year we used:

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

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

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

where D_{CUR} is the estimated discard rate for the coming year y, D_{y-1} is the discards rate in year $y-1$. The discard rate in year y is the ratio of discards to the sum of landed catches plus those discards (this can vary between 0 – 100 %):

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

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

Plots are given of the total removals illustrating the target catch level. In addition, the standardized CPUE are illustrated with the target CPUE and the limit CPUE. Finally, where the data are available, plots are given of the Total removals contrasted with State removals, and of discards and non-trawl catches.

13.6.2 *The Inclusion of Discards*

Some species, especially redfish (*Centroberyx affinis*) and inshore Ocean Perch (*Helicolenus percoides*), have experienced high levels of discarding but the reported CPUE relate only to the estimated landed weights. In those species where discarding makes up a significant proportion of the catch (in some years more redfish were discarded than landed and more inshore ocean perch tend to be discarded than landed) it is reasonable to ask how the discards would have affected CPUE. This is an important question because standardized commercial CPUE are used in Australian stock assessments as an index of relative abundance (e.g., Haddon, 2014); if ignoring discards leads to a consistent bias this could affect the outcome of the assessments and thus, the assessments should become aware of the effects of discards.

CPUE are used in assessments as an index of relative abundance through time and it is the trends exhibited by the CPUE 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 CPUE 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 CPUE 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 CPUE should be examined each year as a sensitivity analysis to contrast with the outcome from the un-augmented CPUE (Haddon, 2010).

13.6.2.1 Analsyes Including Discards

Discard rates cannot simply be added to known catches on the way to calculating CPUE. The standardized CPUE are estimated from individual catch and effort records but the estimates of discards are summary estimates for each fishery. While a method for incrementing the standardized CPUE has been developed it should be noted that this ignores all complications relating to unknown aspects of discarding behaviour (e.g., Is the discard rate constant across all catch sizes, across all vessels, across all areas?). This means that including discard catches into the annual CPUE estimates introduces an unknown amount of uncertainty into the analysis. It should also be noted that the discard estimates are highly variable from year to year and derive from relatively small samples of all trips contributing to catches.

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

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

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

where $\hat{I}_{R,t}$ is the ratio mean CPUE for year *t*, $\sum C_t$ is the sum of landed catches in year *t*, and $\sum E_t$ is the sum of effort (as hours trawled) in year *t*. If $\sum D_t$ is the sum of discards in year *t* then the discard incremented ratio mean CPUE would be:

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

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

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

where I_t is the CPUE estimate to be modified by the inclusion of discards. If this is the ratio mean, then the augmented CPUE would be identical to the first equation dealing with $\sum D_t$. In practice, the CPUE used with the multiplier are the standardized CPUE (e.g. Haddon, 2014; Sporcic, 2021).

13.6.2.2 The Limitations of Including Discards

The discard rates are estimated as the proportion of the total catch (= landed catch plus discards), which means that discard proportions greater than 0.5 imply that more fish are discarded than landed. To calculate the discarded catches from a discard rate and the landed catches we use:

$$D_t = \left(\frac{C_t}{1 - P_t}\right) - C_t$$

where D_t is the discarded catches in year *t*, C_t is the total landed catches in year *t*, and P_t is the proportion of discards in year *t*. Because the divisor is $1 - P_t$ as P_t tends to 1.0 the divisor becomes very small and hence acts as a multiplier on total landed catch C_t. The effect of this is that when P_t is estimated to be above 0.5 the multiplying effect in the calculation of discards becomes grossly exaggerated (Figure A13.1).

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.

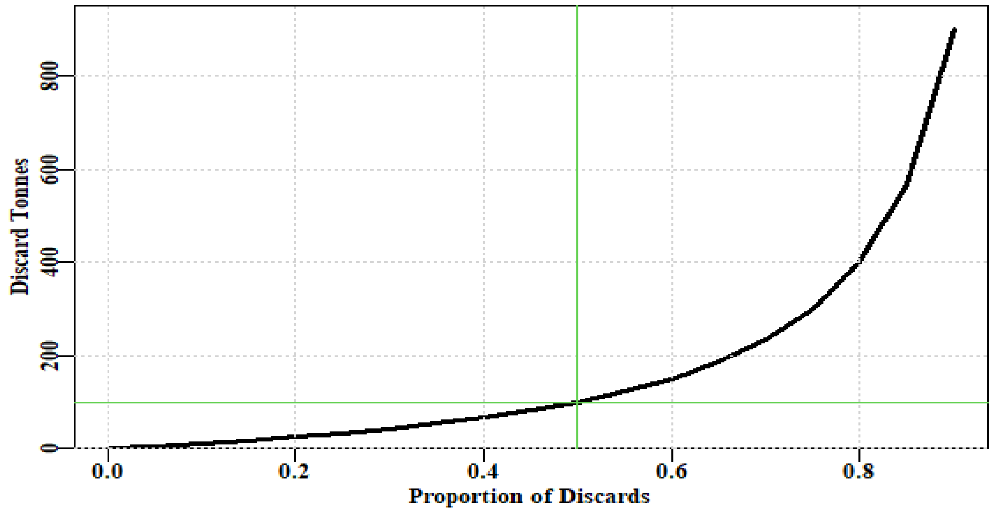

Figure A 13.1. The influence of the proportion discarded on estimates of discarded catches. As the proportion of discards approaches 1.0 the multiplying effect in the estimation of discard amounts becomes greatly amplified.

13.6.3 *Selection of Reference Periods*

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

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

To select a reference period requires a time series of comparable CPUE. For this reason the use of standardized CPUE should be an improvement over using, for example, the observed arithmetic or geometric mean CPUE. CPUE data is available in the SESSF for all targeted species from 1986 - 2011, although it needs to be noted that the character of the fishery has changed markedly during that period. Little et al. (2009) provide a discussion on how reference periods might be selected. They proposed a default 10-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 CPUE. 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 CPUE, $CPUE_{targ}$, was divided by two as a proxy for expected changes to CPUE as the fishery develops and the resource stock size declines towards the assumed proxy target for 48% unfished biomass.

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

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

14. Further exploration of data available for assessing the Deepwater Shark basket

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14.1 Executive Summary

The SESSF's Deepwater Shark basket consists of 18 species belonging to the families of sleeper sharks (Somniosidae), gulper sharks (Centrophoridae), dogfish (Squalidae), kitefin sharks (Dalatiidae) and lantern sharks (Etmopteridae). Assessment is applied separately to stocks east and west of 148ºS Longitude. Of these 18 species, Longsnout Dogfish (*Deania quadrispinosa*) was found to be 'high risk,' and Black Shark (*Dalatias licha*) was found to be 'medium risk' by the most recent ERA for the trawl sub-fishery (Sporcic et al 2021). This ERA, unlike earlier work, accounted for cumulative spatial fishing effort and has assigned fewer deepwater shark species to the 'high risk' category. Existing deepwater closures and gulper closures are likely to be providing some level of protection for Deepwater Shark.

The purpose of this report is to explore the Logbook and Observer data available for the Deepwater Shark basket, and to discuss possible options for a Tier 5 (data limited) assessment. We also present discard estimates for two sub-sets of the basket of species, consisting of those thought to be more often, and those less often, discarded.

Few logbook records identify Deepwater Shark to species or even family level. Those records that do not use a high-level group code most commonly use the code 'platypus shark,' which groups two species (Longsnout Dogfish and Brier Shark). Less often, the individual species codes for Longsnout Dogfish and Brier Shark are recorded. This is at odds with observer records where Black Sharks predominate along with Brier Sharks. Observers typically report Deepwater Shark to species level for those caught in waters deeper than 600m but less often for shallower waters. Discard rates are high and estimates have high CVs, so that landed catches are likely to be a poor reflection of total catch. Separating the Deepwater shark basket into 'byproduct' and 'bycatch' groups does lower this CV somewhat and is therefore to be recommended.

Landings of Deepwater Shark are greater in the west than the east, both historically and currently, with landings increasing steadily in the west since the mid-2000s. Landed catches in both regions were highest in the late 1990s. Landings from waters shallower than 600m, while lower than from deeper waters, are far from insignificant.

In deep waters, Deepwater Shark are primarily caught with Orange Roughy and Oreos. In shallower waters in the east, they used to be primarily caught with Redfish but as Redfish catches have declined, they are now primarily caught with Pink Ling, Tiger Flathead and a mixture of other eastern shelf species. In shallower waters in the east, Deepwater Shark are primarily caught with Pink Ling, Blue Grenadier, Blue-eye Trevalla and Silver Warehou.

Currently, neither CPUE nor total catch (landings plus discards) information can be relied on for assessment of Deepwater Sharks, quantitative assessment methods are therefore not applicable, and indicators of stock health must be used instead. Due to their low reproductive rates, deepwater shark are a vulnerable group that, despite likely protection from current closures, should be subject to improved future data collection. The following are strongly recommended in order to improve assessment and management for these species:

- compile currently available data into a single report,
- attempt to quantify the level of protection given by the closures by measuring the overlap between the fishery and the species distributions,
- apply quantitative assessment methods to Brier Shark (or to Brier and Longsnout Dogfish combined, if data are not available separately) as these are likely to be the most vulnerable of the deepwater shark basket species and also the most data-rich,
  - construct catch time series by identifying (from Observer data) the relationship between *Deania* catch and factors such as vessel, depth, time of fishing, location, and season - more than time series, that bracket uncertainty, might be necessary,
  - similarly, use a model-based method to calculate discard rates for *Deania*,
  - construct (if possible) a reliable CPUE time-series for *Deania* from vessels that specialise in deepwater shark fishing,
- apply model-based discard estimation to the deepwater shark group as a whole, or to subsets chosen to reflect fishing and discard patterns (ie more and less often discarded species),
- ensure that new Observers receive sufficient training in the identification of deepwater shark species

Until the work listed above is completed, management via adjustment of the TAC for this species (and, for the bycatch and byproduct component of fishing, of the TACs of companion species) could be via examination of indicators of stock health. Indicators of abundance that are available for these species are:

- landed catches, which declined abruptly but are now slowly increasing
- lengths for Brier Shark, which show no pattern of concern
- research surveys, which show no clear abundance change over time
- species composition over time shows patchiness, but shows possible decline of Owston's Dogfish in the West

Control rules that will allow the adjustment of RBCs for deepwater shark in the light of changes in indicators, are important if indicators are continued to be used for this group. That is, the indicators need to be operationalised in a way that services the control and management of the fishery. Alternatively, if data-limited, or even Tier 1 or 4 assessments of Brier Shark are developed, rules for translating those results to the whole basket will be needed.

14.2 Introduction

The SESSF Deepwater Shark basket consists of 18 species belonging to the families of sleeper sharks (Somniosidae), gulper sharks (Centrophoridae), dogfish (Squalidae), kitefin sharks (Dalatiidae) and lantern sharks (Etmopteridae), (Table 14.1). Of these 18 species, Longsnout Dogfish (*Deania quadrispinosa*) was found to be 'high risk,' and Black Shark (*Dalatias licha*) was found to be 'medium risk' by the ERA for the trawl sub-fishery. Sporcic et al (2021) state: "The Tier 4 high risk species Longsnout dogfish Deania quadrispinosa (part of a basket deepwater shark species) should be considered further with respect to sustainability, given the validity of assumption that CPUE indexes abundance in Tier 4 assessments is questionable."

Estimates of discarding rates for Deepwater Shark are typically well above 50%, meaning that CPUEs are likely to be inaccurate. Even total catch figures are likely to be inaccurate because the CVs associated with the discard estimates are typically over 100% and therefore cannot be used to adjust landed catch figures to reflect total removals.

The most recent assessment for Deepwater Shark (separated into east and west stocks) was performed in 2018 using the Tier 4 method. SERAG were concerned that because more than 50% of the catch is discarded, the CPUE might not index abundance. Deepwater Shark have therefore been moved to Tier 5, a relatively new category reserved for species that cannot be assessed at Tier 1 or Tier 4 level because of lack of appropriate data and, particularly, concerns that CPUE is not indexing abundance.

Haddon et al (2015) used Management Strategy Evaluation to test the efficacy of seven candidate data limited methods applied to two data rich SESSF species (Tiger Flathead and School Whiting). These seven methods were the median, average, and 3rd highest catch estimates (for stocks for which catch is the only data available), and model assisted catch-only methods that included the Depletion-Corrected Average Catch, the Depletion-Adjusted Catch Scalar, and the Depletion-Based Stock Reduction Analysis (which are aimed at species for which some biological information in addition to catch is available). However, to-date, only two methods (Catch-MSY and Age Structured Reduction Modelling) have been applied in a single completed SESSF Tier 5 analysis (for Blue-eye Trevalla, Haddon & Sporcic 2018a, 2018b). The array of data limited methods tested on Tiger Flathead and School Whiting by Haddon et al (2015) were applied to the data limited stock, Smooth Oreo, as part of exploratory work but were not used as an accepted Tier 5 analysis (Haddon 2015). Note that all of these methods assume that the catch time series reflects the underlying abundance of the stock, an assumption that does not hold for Deepwater Sharks, because of the high, unreported discard rates, and the spatio-temporal variability in discarding behaviour. Furthermore, these methods are intended for application to single biological stocks, whereas Deepwater Sharks consist of a basket of 18 species.

Deepwater Sharks are relatively slow growing, probably long-lived sharks that grow to 50-150cm long. They mature at 9-15 years old, and produce relatively small litters (2-20 pups; AFMA website). Their productivity, and consequently their resilience to fishing pressure, is therefore likely to be low (as found by Sporcic et al 2021). For reporting purposes, only those logbook catches of Deepwater Shark species caught in greater than 600m depths are classified as belonging to the 'Deepwater Shark' basket, but some of the species assigned to this basket are caught in relatively large numbers in shallower water (see this report). Catches of these species are deducted from quota regardless of the depths in which they were caught.

The purpose of this report is to explore the Logbook and Observer data available for the Deepwater Shark basket, and to discuss (broadly) possible options for a Tier 5 assessment, including the use of a suite of empirical indicators. We also present discard estimates for two sub-sets of the basket of species, consisting of those thought to be more often, and those less often, discarded (as classified by Dan Corrie and Tamre Sarhan, AFMA, pers. comm.) while noting that the ERA (Sporcic et al 2021) recognises two additional species from the deepwater shark basket as 'byproduct' species: Owston's Dogfish (*Centroscymnus owstonii*) and Portuguese Dogfish (*Centroscymnus coelolepis*). Further adjustment to the definitions of the 'bycatch' and 'byproduct' groups is discussed below.

The bulk of the catch (both landed and total) is Brier Shark, and most of this comes from just two vessels fishing in the west. A useable time series of length frequencies is available from onboard observers for just Brier Shark and this does not show any clear or concerning trend over time. Species composition of the catch, over time, from onboard Observer records does not show clear trends; Longsnout Dogfish are present in the observations in the East in some years but absent in others, and Golden Dogfish are present for most years during 2001-2016 inclusive (apart from a period when the Observer program was restarted) but rare or absent during 2017-2020.

Examination of fishery independent survey data also does not show concerning trends although it does show, and suffer from, great variability in the availability of Deepwater Sharks.

Large sections of deeper waters have been closed to fishing for at least some gears, or become temporarily closed once a gulper shark trigger limit has been reached. These closures are likely to be giving Deepwater Sharks some level of protection. As part of the ERA process, the 'susceptibility' of a species to fishing is measured as a combination of the fishery footprint, species distribution, fishing effort, along with 'encounterability' of the species with the gear, fishing selectivity and post-capture mortality (if available). Fishing effort for 2012-2016 was used when calculating this measure, implicitly allowing closures to influence the overall relatively low susceptibility scores for Black Shark, Brier Shark and Longsnout Dogfish (3.1 - 7.5%)., Table 2.32, Sporcic et al 2021).

POSSIBLE INDICATORS:

- Brier shark logbook catch time series (west)
- Brier shark length frequency time series
- Species composition within Deepwater Shark basket (observer records), including presence/absence of species in annual catches
- Fishery independent survey trends
- Overlap between fishing and species distribution

14.2.1 *Maps*

Maps showing the location of reported catch, by CAAB code are shown in Figures 14.1 to 14.9 below. Cells for which fewer than 5 vessels reported catches are masked. "East" and "West" are defined by Longitude 148°S which runs through the center of Tasmania.

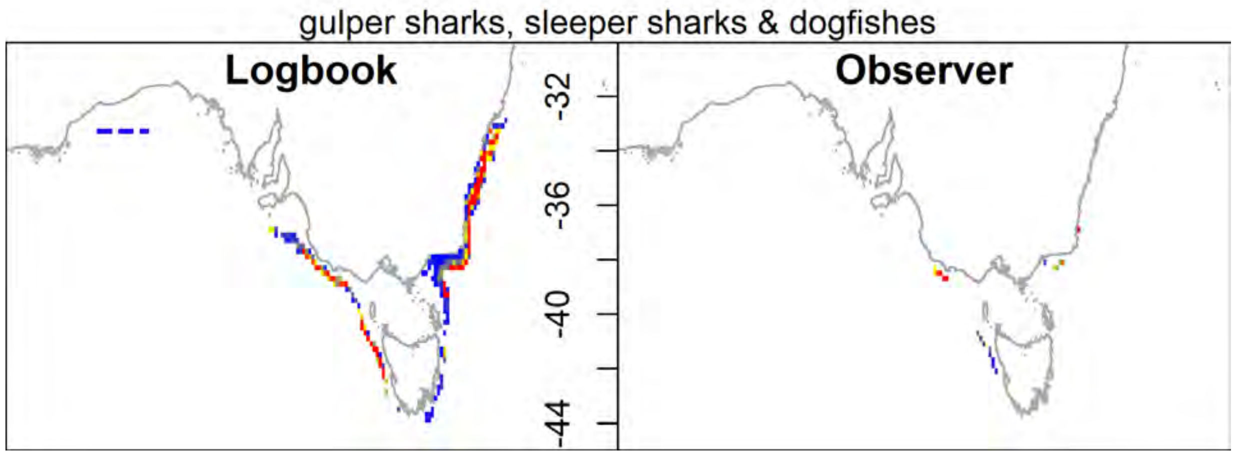

Figure 14.1. Maps showing the location of reported catch in logbooks (left plot) or by Observers (right plot) for gulper sharks, sleeper sharks & dogfishes (37020000, see Table 14.1). Red indicates high, yellow intermediate, and blue low catches (logbooks) or numbers of observations (Observer).

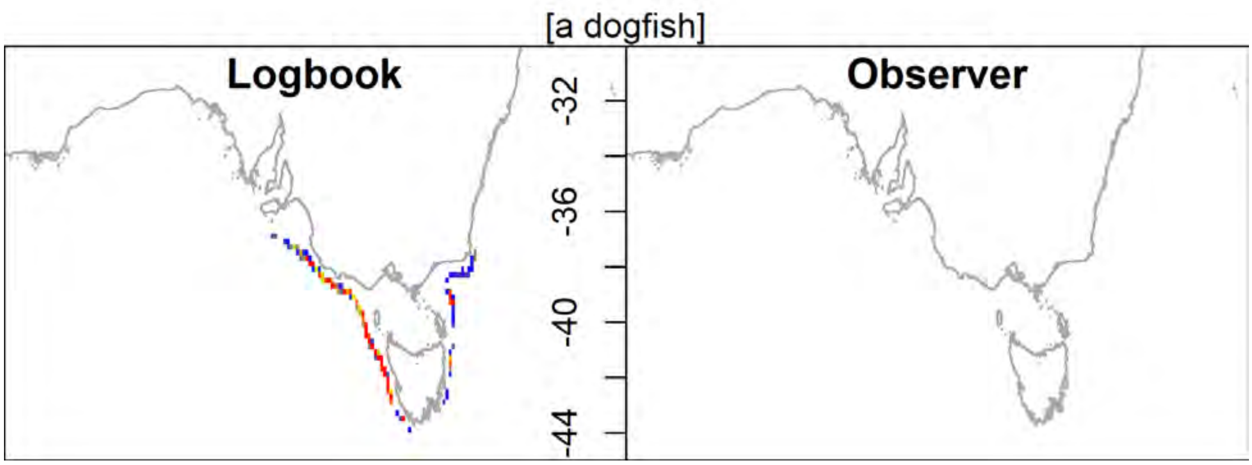

Figure 14.2. Maps showing the location of reported catch in logbooks (left plot) or by Observers (right plot) for [a dogfish] (37020906, see Table 14.1). Red indicates high, yellow intermediate, and blue low catches (logbooks) or numbers of observations (Observer).

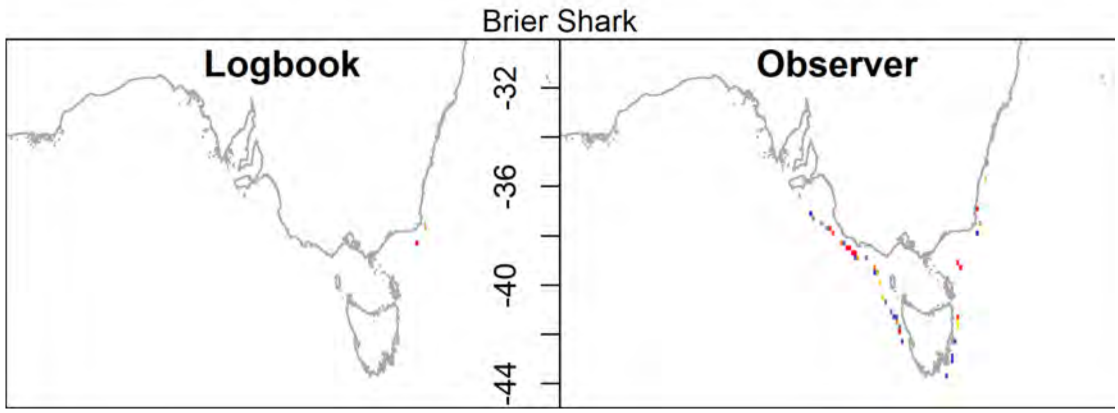

Figure 14.3. Maps showing the location of reported catch in logbooks (left plot) or by Observers (right plot) for Brier Shark (37020003, see Table 14.1). Red indicates high, yellow intermediate, and blue low catches (logbooks) or numbers of observations (Observer).

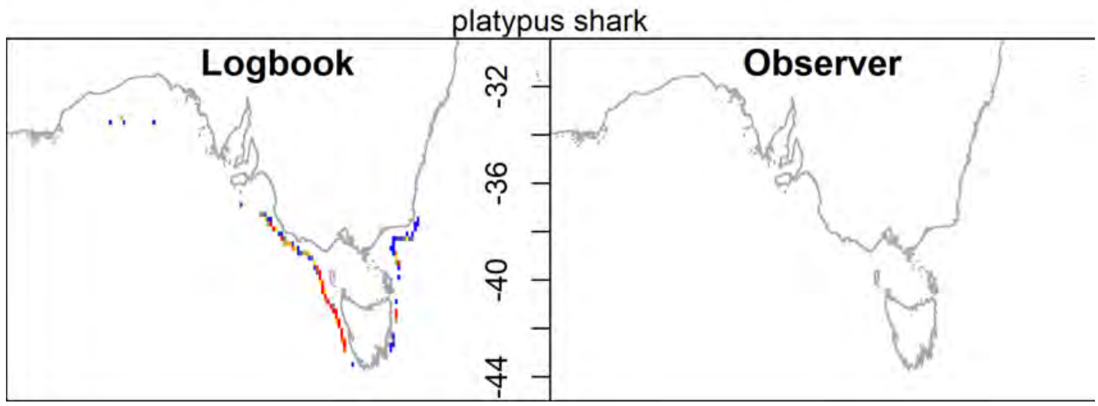

Figure 14.4. Maps showing the location of reported catch in logbooks (left plot) or by Observers (right plot) for platypus shark (37020905, see Table 14.1). Red indicates high, yellow intermediate, and blue low catches (logbooks) or numbers of observations (Observer).

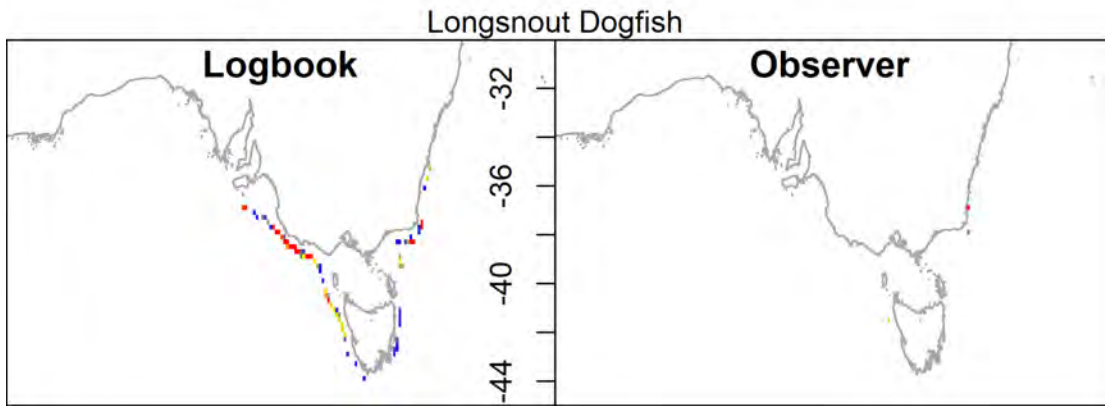

Figure 14.5. Maps showing the location of reported catch in logbooks (left plot) or by Observers (right plot) for Longsnout Dogfish (37020004, see Table 14.1). Red indicates high, yellow intermediate, and blue low catches (logbooks) or numbers of observations (Observer).

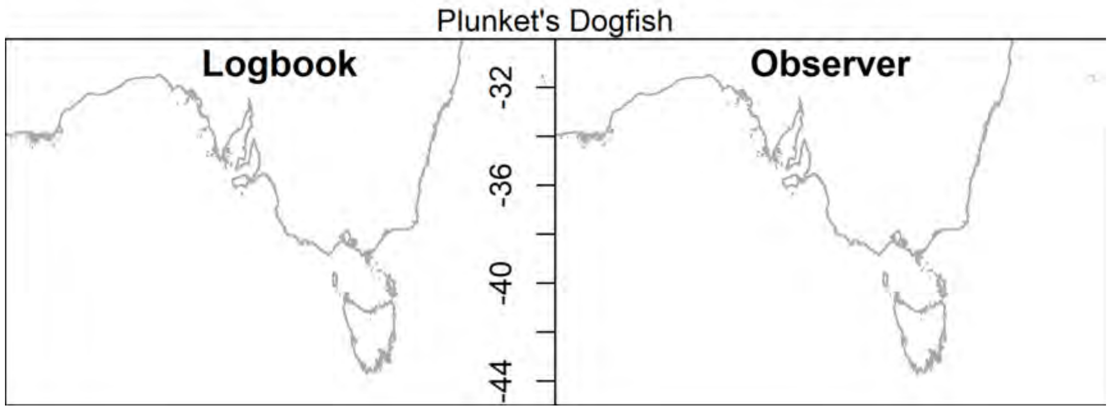

Figure 14.6. Maps showing the location of reported catch in logbooks (left plot) or by Observers (right plot) for Plunket's Dogfish (37020013, see Table 14.1). Red indicates high, yellow intermediate, and blue low catches (logbooks) or numbers of observations (Observer).

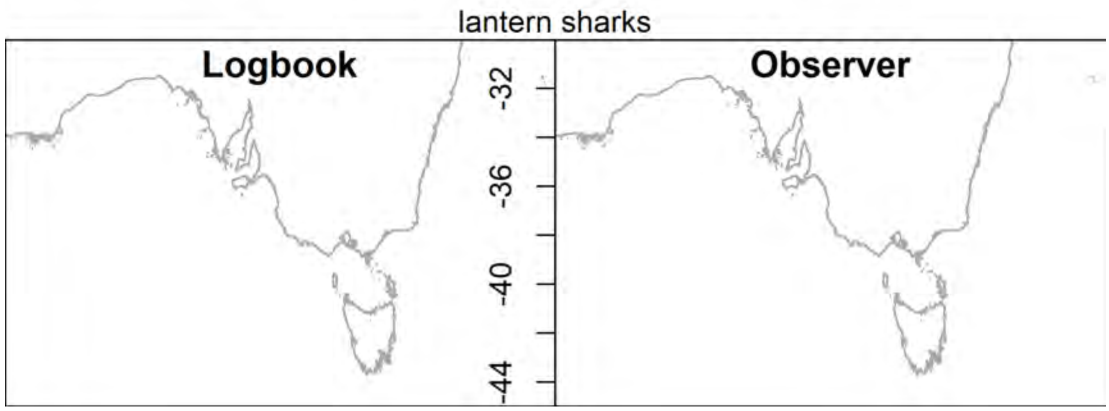

Figure 14.7. Maps showing the location of reported catch in logbooks (left plot) or by Observers (right plot) for lantern sharks (37020907, see Table 14.1). Red indicates high, yellow intermediate, and blue low catches (logbooks) or numbers of observations (Observer).

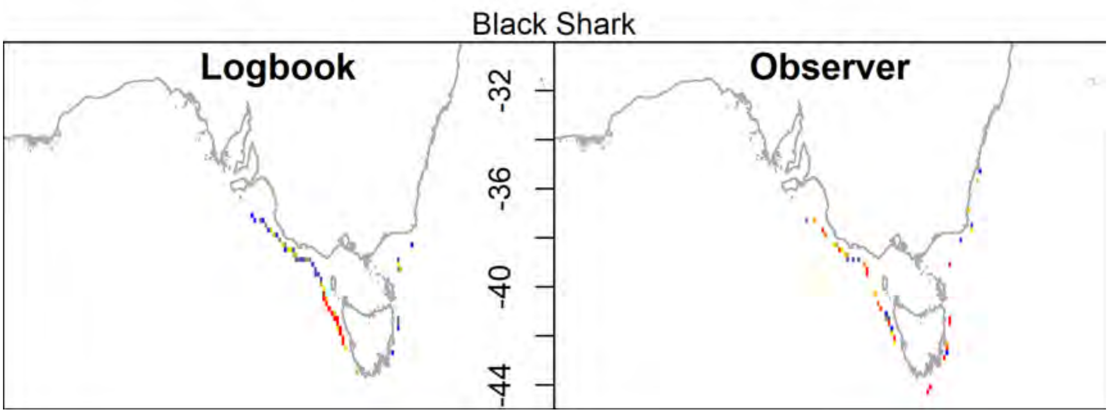

Figure 14.8. Maps showing the location of reported catch in logbooks (left plot) or by Observers (right plot) for Black Shark (37020002, see Table 14.1). Red indicates high, yellow intermediate, and blue low catches (logbooks) or numbers of observations (Observer).

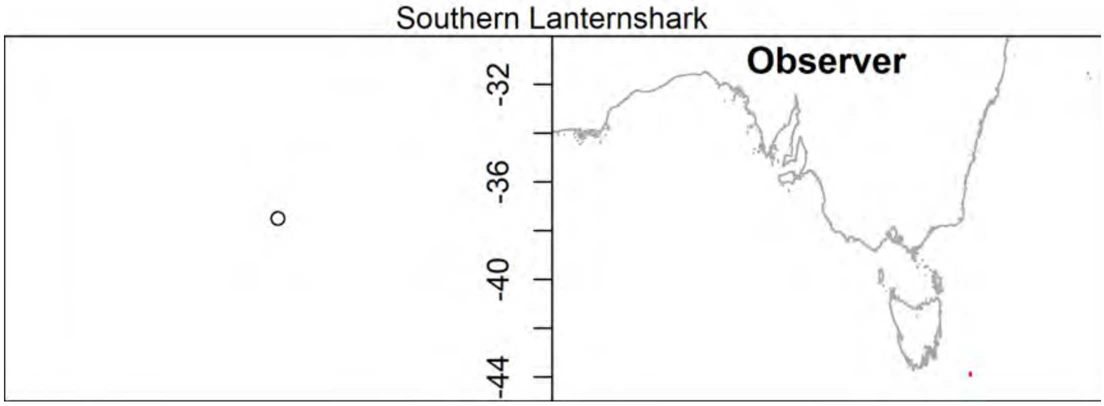

Figure 14.9. Maps showing the location of reported catch in logbooks (left plot) or by Observers (right plot) for Southern Lanternshark (37020021, see Table 14.1). Red indicates high, yellow intermediate, and blue low catches (logbooks) or numbers of observations (Observer).

14.3 Logbook and observer data

14.3.1 *Species identification and depth distribution*

The common and scientific names of the Deepwater Shark species that make up the basket are shown in Table 14.1 along with the common name of the family to which they belong. Deepwater Shark are most often reported, not to species, but rather to group level. The CAAB codes listed in Table 14.1 were used to extract Deepwater Shark information from the AFMA logbook and Observer databases.

The bulk of logbook catches are reported to a high-level group code rather than to a species code (Figure 14.10) although there are many reports of 'platypus shark' (a name embracing both Longsnout Dogfish and Brier Shark) and Longsnout Dogfish from logbooks. Deepwater Shark are more commonly reported to species level by observers. Observer records are very valuable for this group, because many species are highly discarded and therefore unlikely to be reported in logbooks. The highest level group code is prevalent in Observer records for catches made in waters shallower than 600m. Observers most frequently report Brier Shark or Black Shark, with Brier Shark dominating in the west. Smaller tonnages of 'platypus shark' and Longsnout Dogfish are reported by Observers, primarily in the west.

Reports of Deepwater Shark taken from depths shallower than 600m dominate in the east, where trawl grounds are shallower than they are in the west. Fewer Deepwater Shark catches are reported from waters shallower than 600m in the west (Figure 14.10).

Table 14.1. CAAB code, common, scientific, and family names for species and groups assigned to the Deepwater Shark quota basket. The 'DATASET' column indicates whether the CAAB code appears in just one, both, or neither of the logbook and observer datasets. The 'BYPROD?' column indicates whether the data were treated as 'byproduct' for the discard calculation and 'SPDISCRATE' column gives a crude overall observation of /% discarded.

CAAB	SPECIES	SCIENTIFIC	FAMILY	GROUP	DATASET	BYPROD?	SPDISCRATE
37,020,000	gulper sharks, sleeper sharks & dogfishes	Centrophoridae, Dalatiidae, Squalidae, Somniosidae & Etmopteridae - undifferentiated			Both		18
37,020,003	Brier Shark	Deania calceus	Centrophoridae	Gulper sharks	Both	Yes	79
37,020,004	Longsnout Dogfish	Deania quadrispinosa	Centrophoridae	Gulper sharks	Both	Yes	75
37,020,905	platypus shark	Deania calceus & Deania quadrispinosa	Centrophoridae	Gulper sharks	Both		86
37,020,002	Black Shark	Dalatias licha	Dalatiidae	Kitefin sharks	Both	Yes	34
37,020,005	Blackbelly Lanternshark	Etmopterus lucifer	Etmopteridae	Lantern sharks	Observer		
37,020,015	Slender Lanternshark	Etmopterus pusillus	Etmopteridae	Lantern sharks	Observer		
37,020,021	Southern Lanternshark	Etmopterus granulosus	Etmopteridae	Lantern sharks	Both		13
37,020,024	Bareskin Dogfish	Centroscyllium kamoharai	Etmopteridae	Lantern sharks	Neither		
37,020,027	Smooth Lanternshark	Etmopterus bigelowi	Etmopteridae	Lantern sharks	Observer		
37,020,028	Pygmy Lanternshark	Etmopterus fusus	Etmopteridae	Lantern sharks	Observer		
37,020,029	Pink Lanternshark	Etmopterus dianthus	Etmopteridae	Lantern sharks	Logbook		
37,020,030	Blackmouth Lanternshark	Etmopterus evansi	Etmopteridae	Lantern sharks	Neither		
37,020,031	Lined Lanternshark	Etmopterus dislineatus	Etmopteridae	Lantern sharks	Observer		
37,020,032	Short-tail Lanternshark	Etmopterus brachyurus	Etmopteridae	Lantern sharks	Observer		
37,020,033	Moller's Lanternshark	Etmopterus molleri	Etmopteridae	Lantern sharks	Observer		
37,020,907	lantern sharks	Etmopterus spp.	Etmopteridae	Lantern sharks	Both		1
37,020,012	Golden Dogfish	Centroselachus crepidater	Somniosidae	Sleeper sharks	Observer	Yes	
37,020,013	Plunket's Dogfish	Scymnodon plunketi	Somniosidae	Sleeper sharks	Both		62
37,020,019	Owston's Dogfish	Centroscymnus owstonii	Somniosidae	Sleeper sharks	Observer		
37,020,025	Portuguese Dogfish	Centroscymnus coelolepis	Somniosidae	Sleeper sharks	Observer	Yes	
37,020,906	[a dogfish]	Centroscymnus spp.	Somniosidae	Sleeper sharks	Both		28

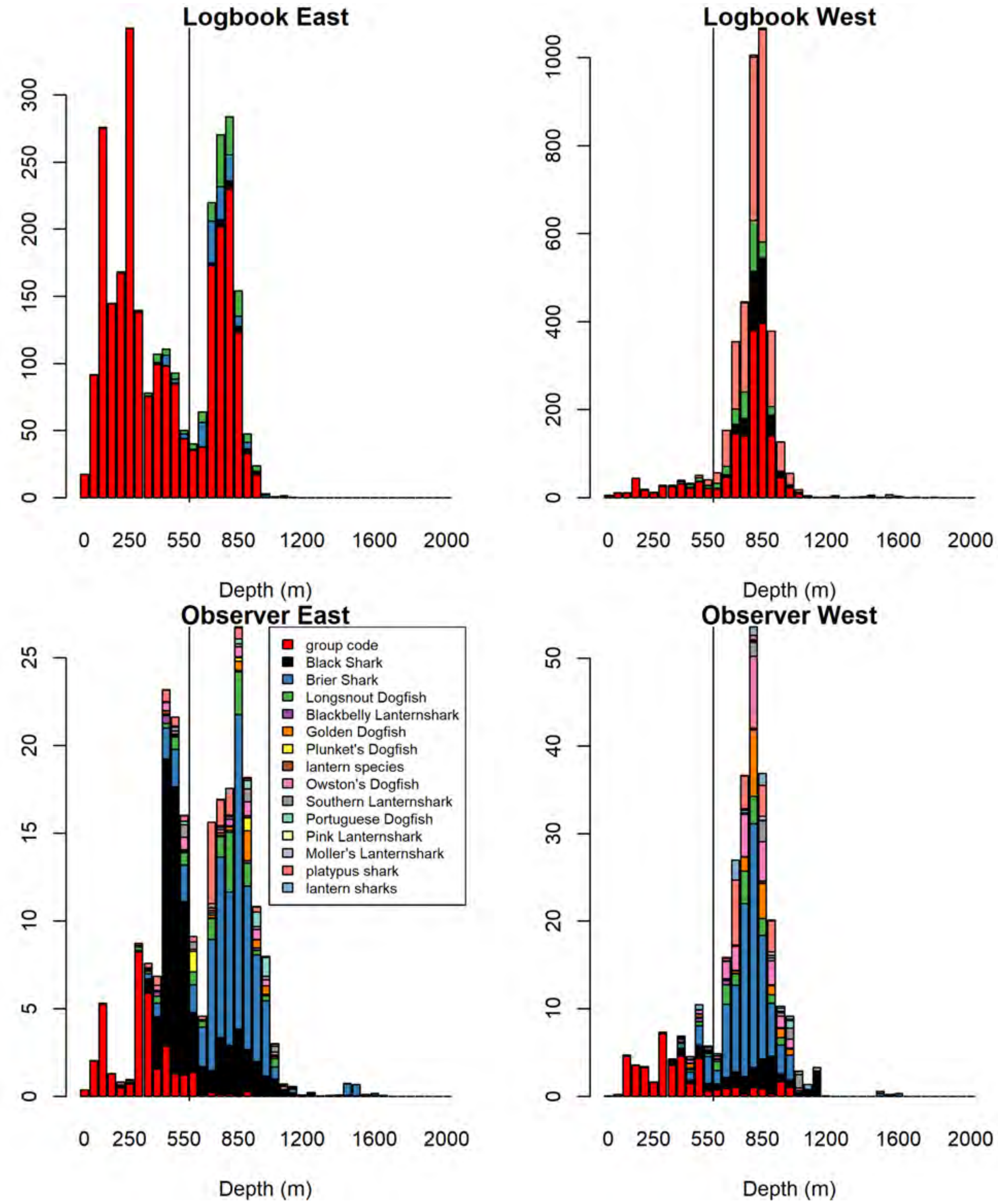

Figure 14.10. Reported weight (tonnes) at depth by species or group from logbook (upper plots) and observer (lower plots) datasets in the east (left) and west (right). The vertical line indicates the 600m depth. For parsimony, lanternsharks that were identified to species have been grouped as *lantern species* whereas *lantern sharks* were not reported to species. *group code* indicates both high-level CAAB codes 37020000 and 37020906.

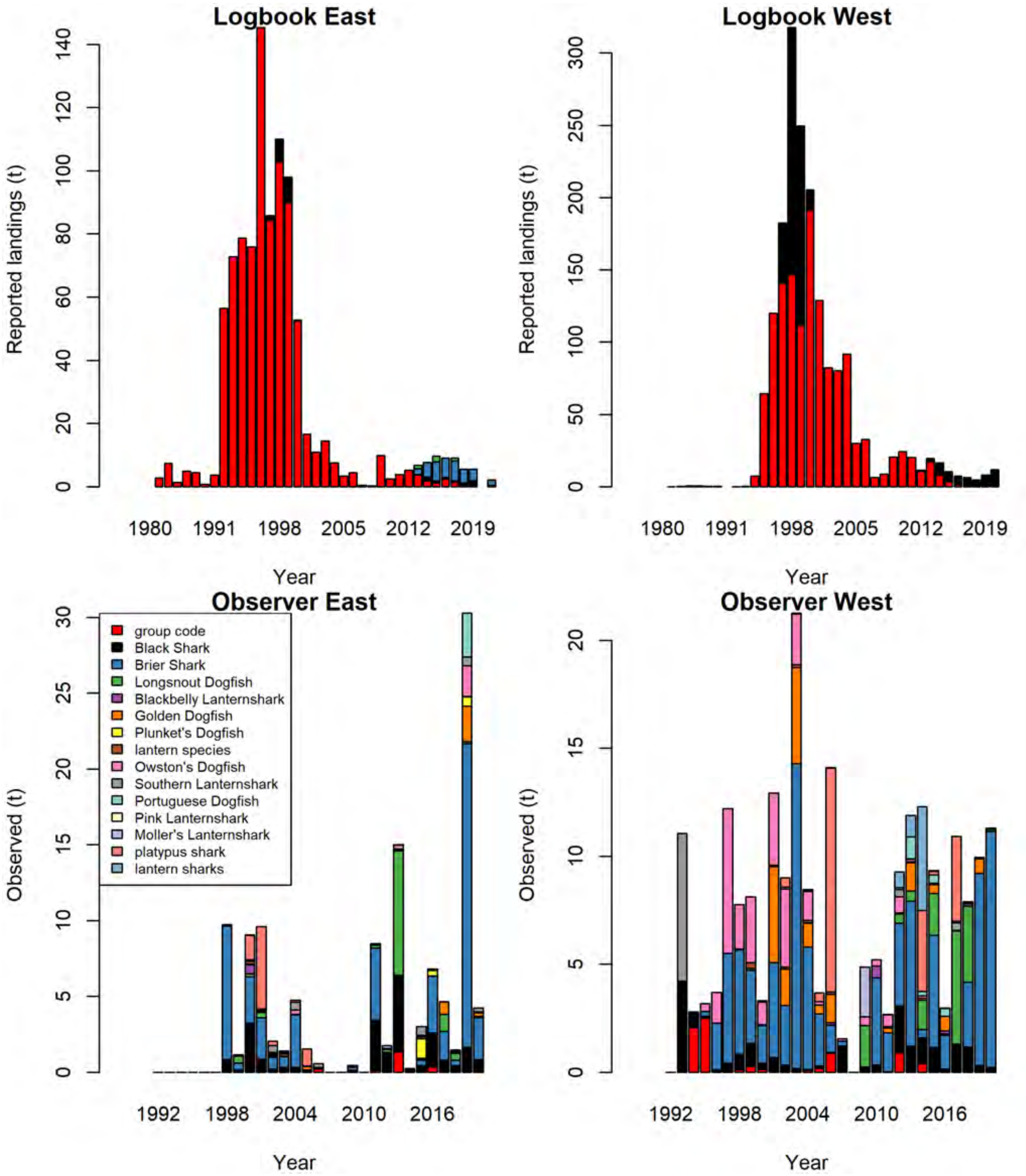

Figure 14.11. Logbook reported landings (upper plots) and observations (lower plots) in tonnes by year and species or group reported. For parsimony, most lanternsharks that were identified to species have been grouped as *lantern species* whereas *lantern sharks* were those not reported to species. *group code* indicates both high-level CAAB codes 37020000 and 37020906.

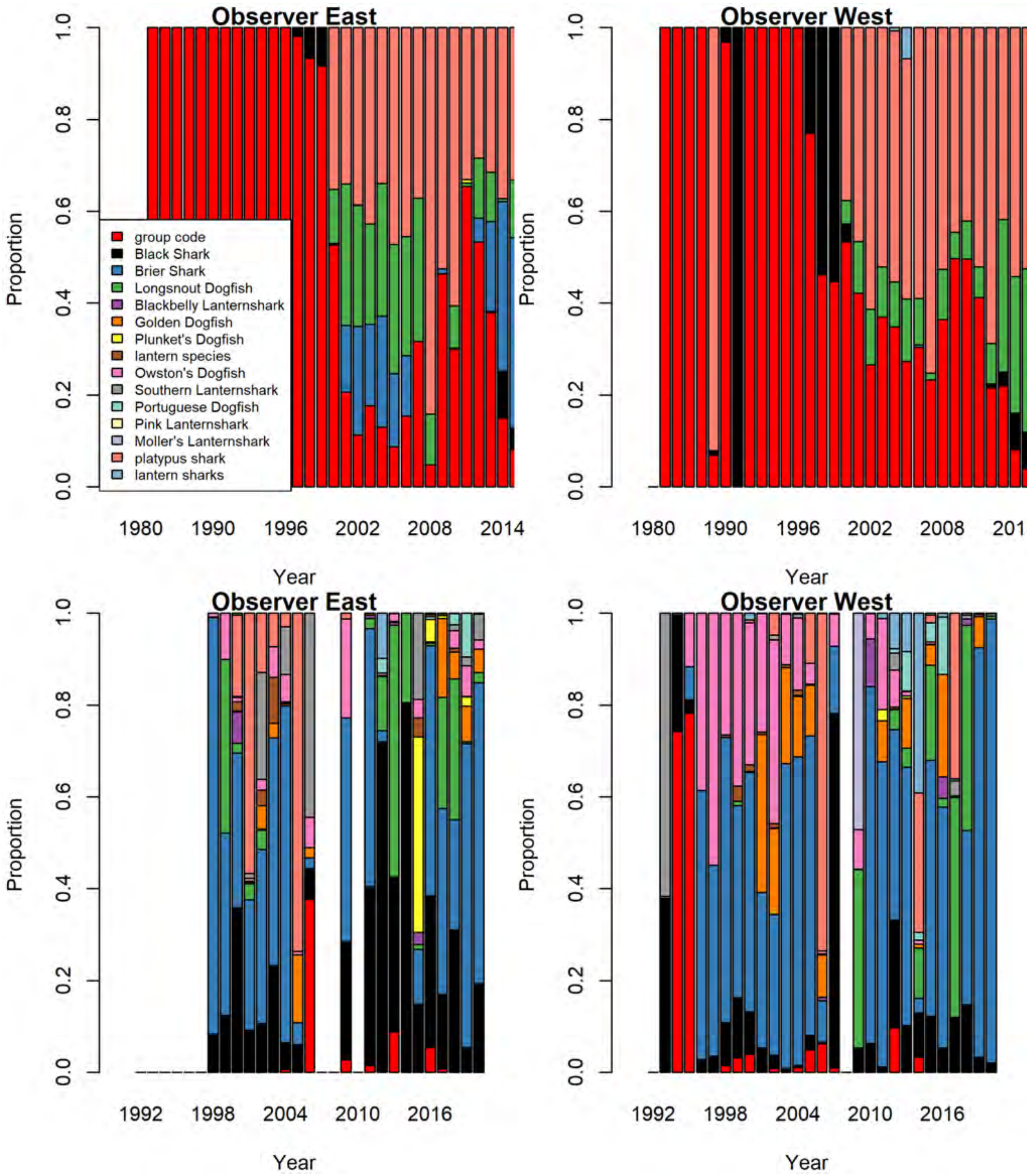

Figure 14.12. Proportion (by weight) species composition by year and species or group reported in logbooks (upper plots) and by onboard observers (lower plots) in the east (left plots) and west (right plots). For parsimony, most lanternsharks that were identified to species have been grouped as *lantern species* whereas *lantern sharks* were those not reported to species. *group code* indicates both high-level CAAB codes 37020000 and 37020906.

For the plots that follow, the number of species displayed was reduced (for clarity of presentation) by grouping the relatively small number of reports of a relatively large number of species of lanternshark into a single ‘lantern species’ category (apart from the more often reported Blackbelly Lanternshark), and the two high-level group codes (CAAB 37020000 and 37020906) were combined. Note that there is also a ‘lantern sharks’ category (CAAB 37020907) that is reported by Observers when identification was not made to species level.

Species level reporting in the logbooks greatly improved from the early 2000’s presumably in response to considerable work at that time to circulate identification sheets and hold face-to-face meetings with industry members (Figure 14.11 and Figure 14.12). The two *Deania* species (separately or as ‘platypus shark’) and Black shark (*Daliatias licha*) are the most reported species in logbooks. Relatively high levels of reporting of Black Shark immediately prior to the early 2000s is likely to be confusion between the use of the name, which has been used for *Daliatias licha* by researchers and as a generic name for Deepwater Shark by fishers (Daley et al 2002).

The percentage of observed catch associated with each deepwater CAAB code in the logbooks and Observer reports, by year, in the east and the west, is shown in Figure 14.12. For Observers, only years for which more than 20 observations are available, are shown.

Few or no records were made in the east prior to the 2000s and the first three years in the west show poor speciation. Both series show reduced data and alteration in reported species composition between 2006 and 2010, which could reflect the Observer program moving from Victoria to AFMA rather than a change in species composition of the catch.

Other than the early years of both the Victorian and AFMA observer programs, speciation seems equally good throughout the dataset. There is some patchiness in that, for example, Longsnout Dogfish occur in reasonable numbers in some years in the east and not at all in others; encouragingly, observers stopped reporting Platypus shark after 2007 instead reporting Longsnout Dogfish and Brier Shark. Golden dogfish (ignoring the upheavals of 2006-2010) are present every year in reasonable numbers during 2001-2016 inclusive, but are patchier from 2010 onwards. This might reflect reduction in sample size (including the removal, in mid-2015, of Observers from non-trawl vessels).

Of most concern is the apparent decline of Owston’s dogfish in the west. Owston’s is relatively abundant from the mid-1990s, declines thereafter, and is rare to absent from the mid-2010s. The introduction of extensive 700m depth closures from 2005 could explain shifts in species composition after that time. Interestingly, Longsnout Dogfish is hardly recorded in the West prior to 2009, but is relatively commonly reported thereafter - again, this might be due to Observer’s recognizing the species, or due to closures, or it might be a change in relative abundance.

Reporting of ‘platypus shark’ (which reflects uncertainty regarding whether the species is Brier Shark or Longsnout Dogfish) occurs in some years and then disappears, usually by the following year. This might reflect the arrival of new observers in the program going through a learning period, just as the whole Victorian and AFMA Observer programs did. That phenomenon might contribute somewhat to the ‘patchiness’ of some of the data. Notwithstanding, Daley et al (2002) indicate that the availability of deepwater sharks to capture is itself highly variable and patchy.

These plots do not account for potentially influential factors such as gear (note that observers were removed from line and gillnet vessels in mid-2015, however the vast bulk of the observations are from trawl), location, depth and size of the catches of companion species (e.g. Orange Roughy and Blue Grenadier are both companion species whose catch has varied considerably from year to year).

14.3.2 *Catch time series*

Deepwater Shark CDR records begin in 2005 (not shown) but there is considerable logbook reporting from the late 1990s (Figure 14.13) and from the mid 1980s in shallower waters in the east. In the west, reported catches peaked in the early 2000s, declined until 2008 and have slowly increased since then. In the west, there is little difference between the trend in reported catches from all depths compared with from only deeper than 600m. In the east, catches reported from shallower than 600m dominate during the 1980s and early 1990s but thereafter the trend for all depths is very similar to that for depths over 600m, reflecting lower catches in shallower waters. In both east and west, the vast majority of catches are reported by trawlers and only a small percentage from hook and line vessels in shallower depths. Like the west, the east shows a slow increase in reported catches from 2008 although the trend is less clear (Figure 14.13).

POSSIBLE INDICATOR:

- Total catch time series (east and west), albeit with unknown, large and variable discarding

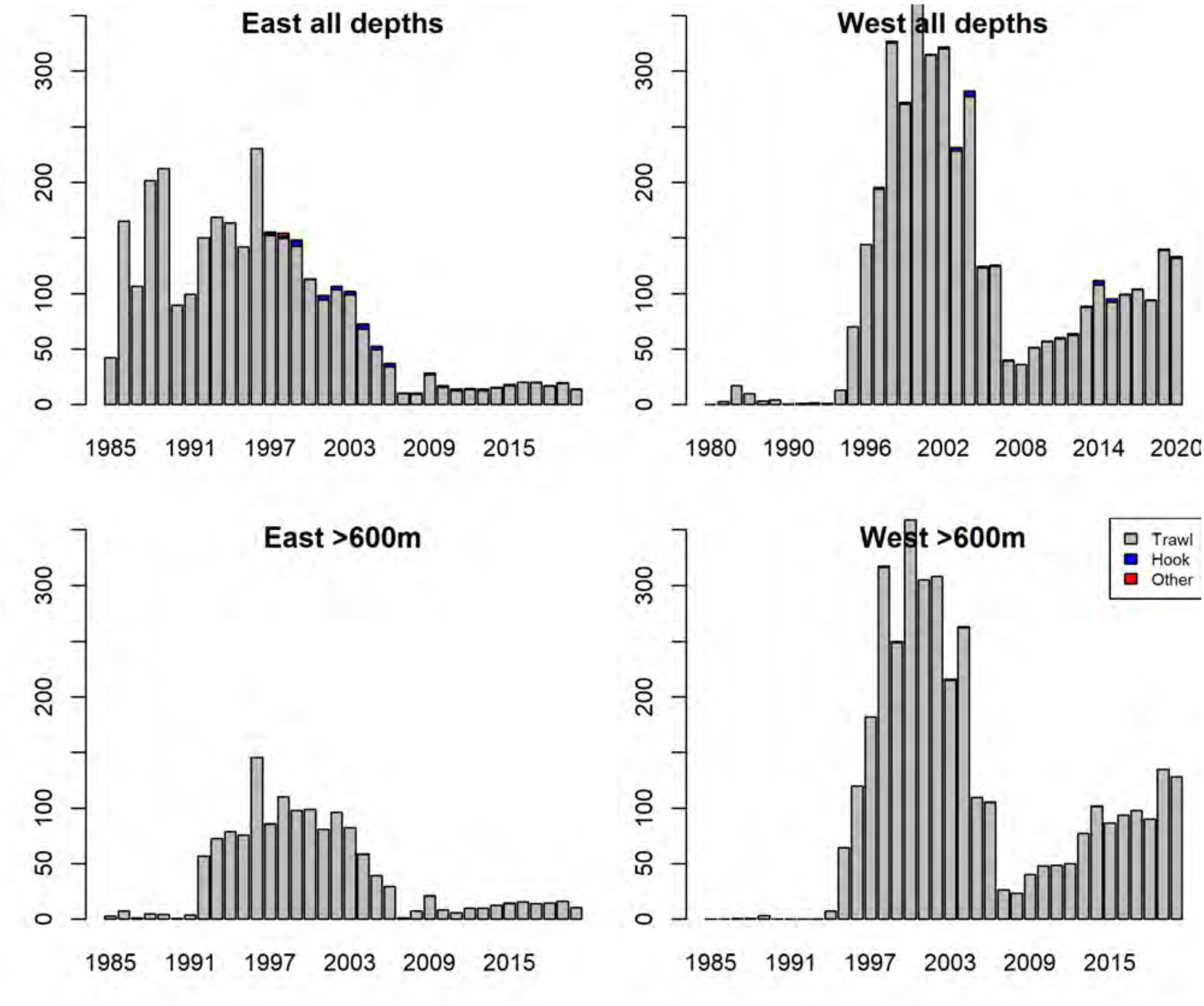

Figure 14.13. Logbook reported weight (tonnes) by year and gear for all depths (upper plots) or over 600m (lower plots) for east (left) and west (right).

14.3.3 *Companion species*

In depths shallower than 600m, Deepwater Shark make up a relatively small proportion of the total reported catch, whereas in deeper water they make up a much larger proportion of the logbook reported catch, at least prior to the late 2000s (Figure 14.14). In deeper waters, reported catches were greatest during the 1990s and early 2000s.

In the east, the primary companion species for Deepwater Shark in waters shallower than 600m are Redfish, Pink Ling, and Flathead with Redfish making up the largest proportion of the total landed catch, suggesting that Deepwater Shark are a byproduct of fishing targeting for Redfish (at least, during the 1980s and 1990s). In the west, shallower than 600m, the primary companion species are Pink Ling, Blue Grenadier, and Blue-eye Trevalla (Figure 14.14) and landings of Deepwater Shark constitute only 5% of the overall landings, suggesting that they are not targeted.

In waters deeper than 600m, Deepwater Shark generally have comprised the largest part of the landed catch of shots from which they were reported. This suggests that they are a target species group in deeper waters in both the east and west. In both regions the primary companion species are Orange Roughy, and Oreos along with Ribaldo in the east and Blue Grenadier in the west (Figure 14.14).

POSSIBLE INDICATOR:

- Catch percentage of Deepwater Shark basket relative to companion species, each of 4 zones

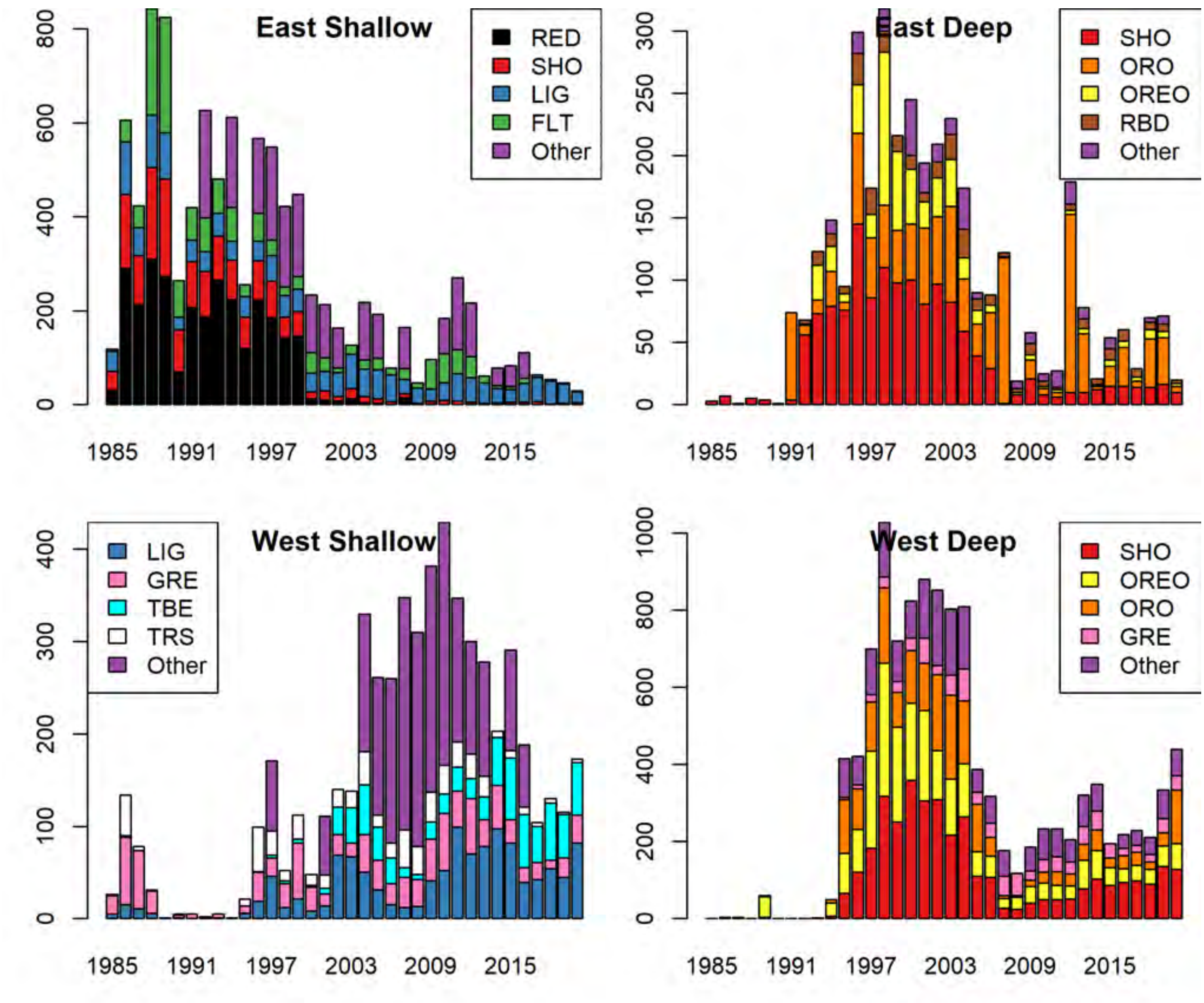

Figure 14.14. Primary companion species reported along with Deepwater Sharks shallower (upper plots) or deeper than 600m (lower plots) in the east (left) and west (right); SHO = Deepwater Shark, RED=Redfish, LIG=Pink Ling, FLT=Tiger Flathead, GRE=Blue Grenadier, TBE=Blue-eye Trevalla, TRS=Silver Trevally, ORO=Orange Roughy, OREO=Oreos, RBD=Ribaldo.

14.3.4 *Onboard Observer length frenquencies*

Length frequencies from onboard Observer records are shown in Figure 14.16 to Figure 14.19. Note that these are 'raw' length frequencies in that they simply present the numbers of sharks, by length bin, reported by Observers. Observed numbers have not been scaled, e.g. to represent the size of the shot from which they were taken, or the size of the reported catch by depth category for the year.

Observations of Brier Shark dominate the Observer length dataset (Figure 14.16). Other CAAB codes might have a useable length sample size for a single year or perhaps two years, but only Brier Shark has a useable time series (Figure 14.15). Examination of that time series shows no consistent trend in the median length over time although a long tail in the distribution (i.e. of smaller sharks) is present in earlier years but largely absent in the three most recent years (Figure 14.16). Splitting the length frequencies by zone (Figure 14.17), depth (Figure 14.18) and east/west (Figure 14.19) does not give rise to any obvious trends in time in the length data. The bulk of the brier shark data is from the west, specifically western Bass Strait (WBass) and Western Tasmania (WTas). The majority is from a single vessel (not shown).

POSSIBLE INDICATORS:

- Brier shark length frequency time series by region and depth
- Brier shark mean, median, percentile length
- Snapshot length-frequencies for various CAAB codes

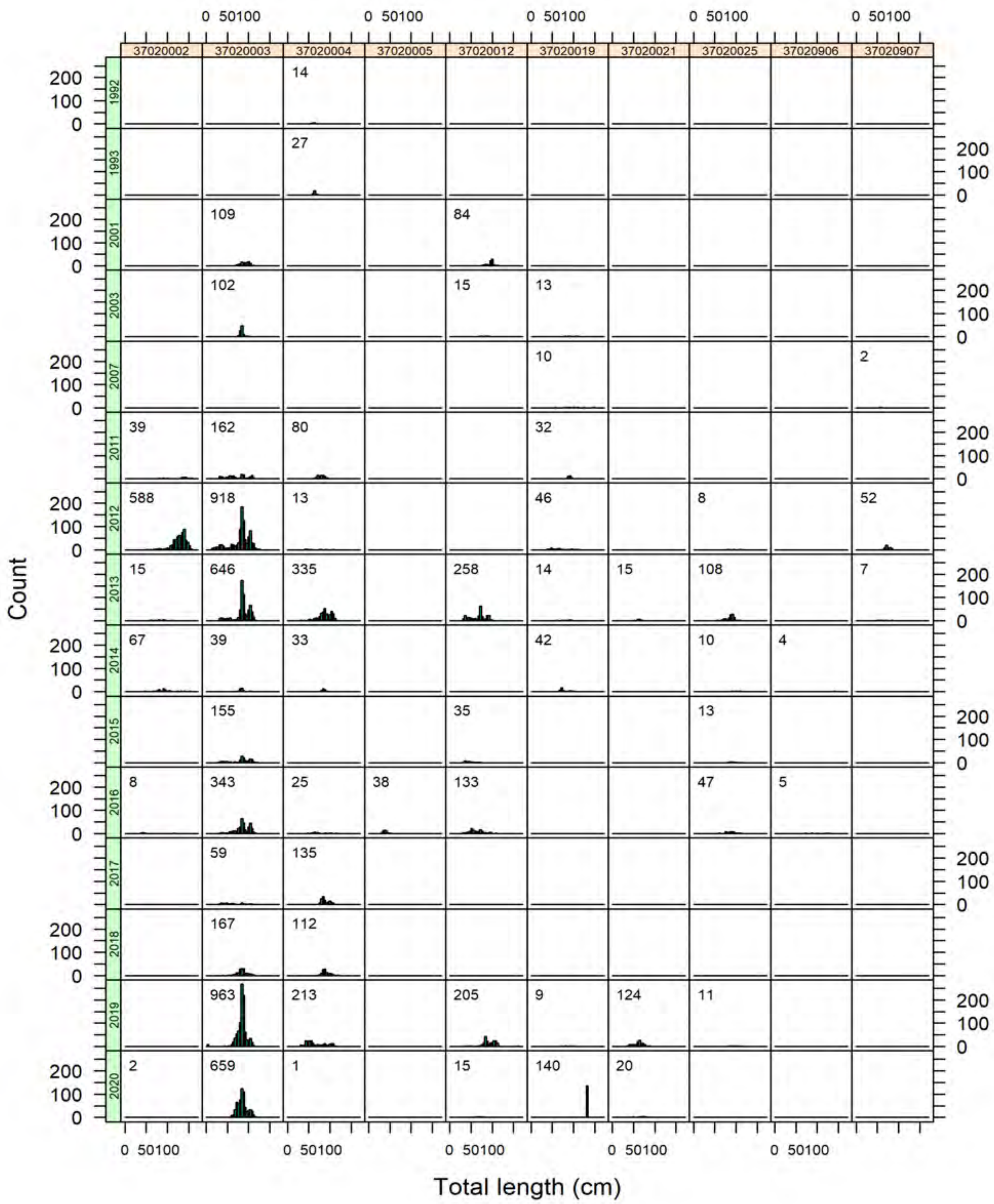

Figure 14.15. Unscaled length frequencies from onboard Observer records by deepwater shark CAAB code and year. Only trawl records, and total length measurements, are used. Inset numbers indicate total number of fish in each distribution. Species codes are: 37020002=Black Shark; 37020003=Brier Shark; 37020004=Longsnout Dogfish; 37020005=Blackbelly Lanternshark; 37020012=Golden Dogfish; 37020019=Owston's Dogfish; 37020021=Southern Lanternshark; 37020025=Portuguese Dogfish; 37020906=[a dogfish]; 37020907=lantern sharks.

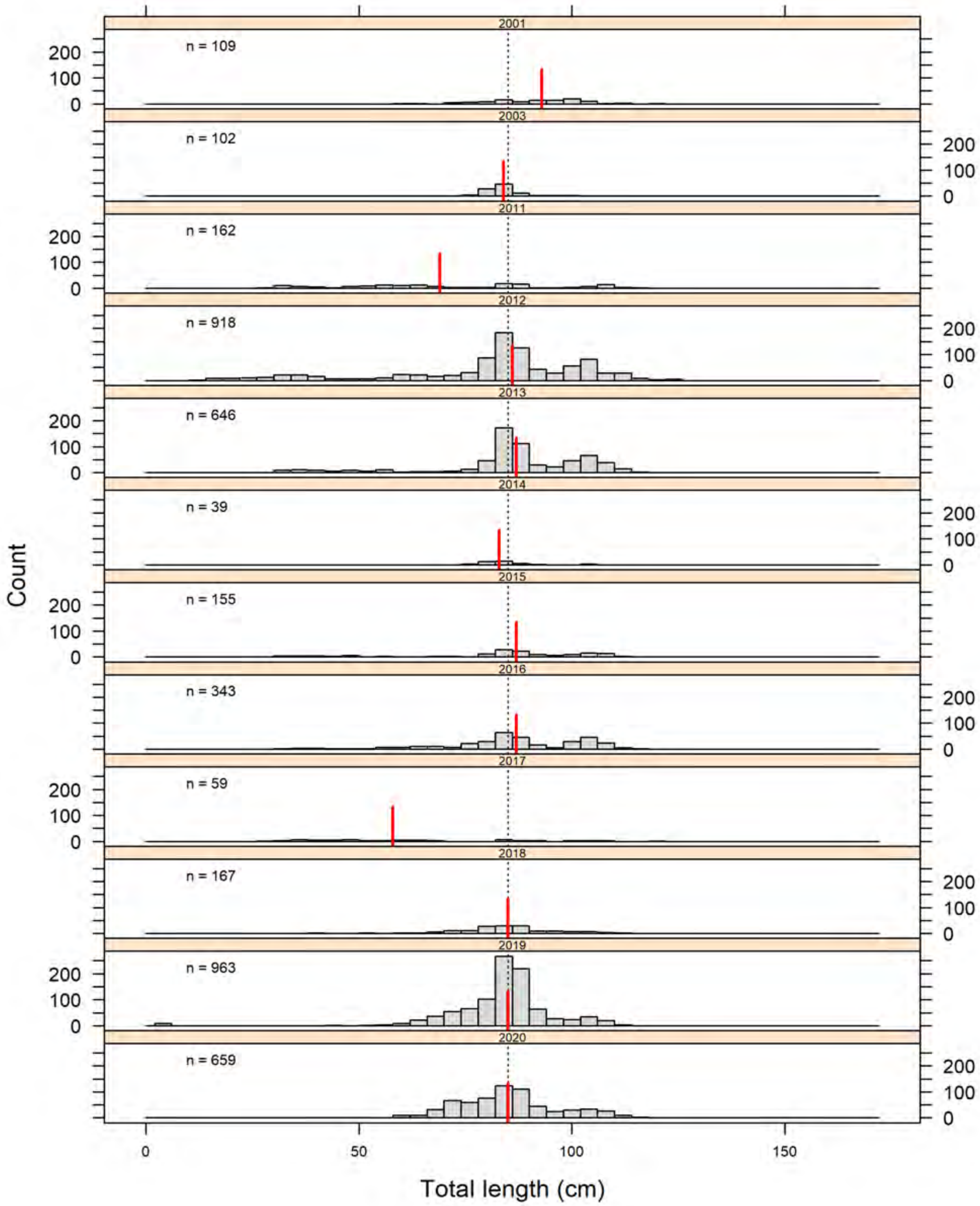

Figure 14.16. Unscaled annual length frequencies for Brier Shark CAAB=37020003 from onboard Observer records. Only trawl records, and total length measurements, are used. Inset numbers indicate total number of fish in each distribution. Red lines indicate the distribution median for each panel (only shown for n>10), while dotted lines show the median length for all observed Brier Sharks across all years.

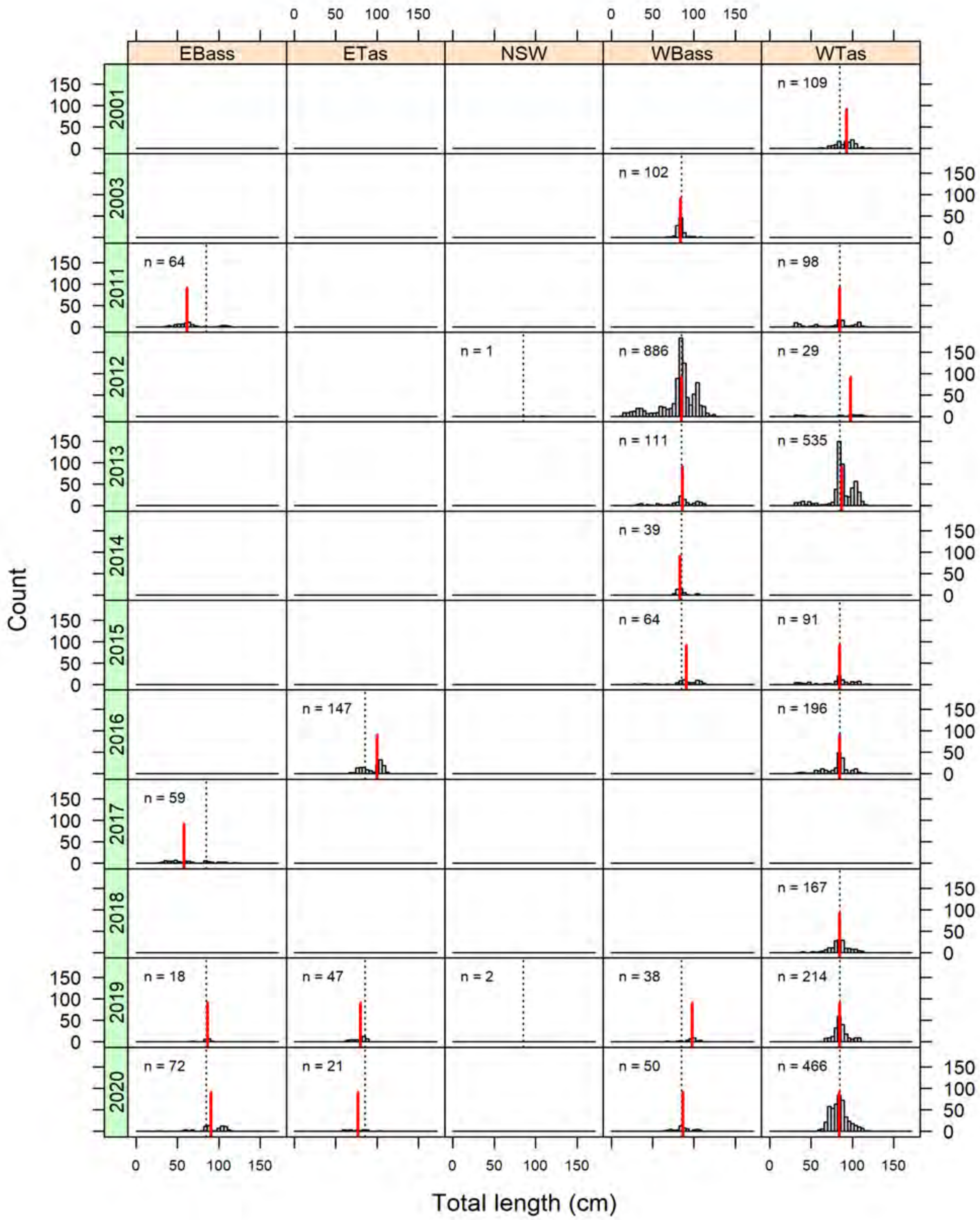

Figure 14.17. Unscaled annual length frequencies for Brier Shark CAAB=37020003 from onboard Observer records by SEF zone. Only trawl records, and total length measurements, are used. Inset numbers indicate total number of fish in each distribution. Red lines indicate the distribution median for each panel (only shown for n>10), while dotted lines show the median length for all observed Brier Sharks.

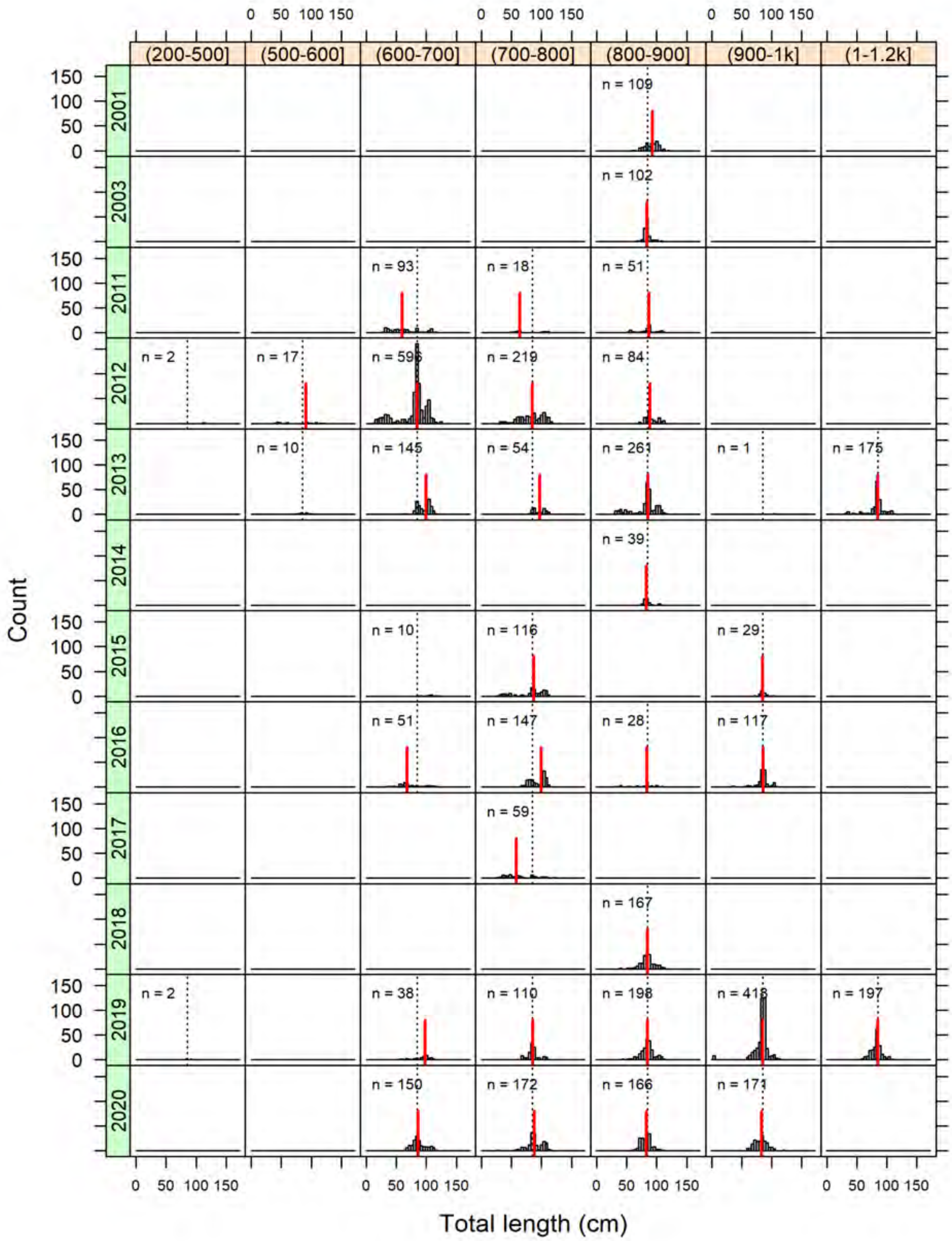

Figure 14.18. Unscaled annual length frequencies for Brier Shark CAAB=37020003 from onboard Observer records by depth bin. Only trawl records, and total length measurements, are used. Inset numbers indicate total number of fish in each distribution. Red lines indicate the distribution median for each panel (only shown for n>10), while dotted lines show the median length for all observed Brier Sharks.

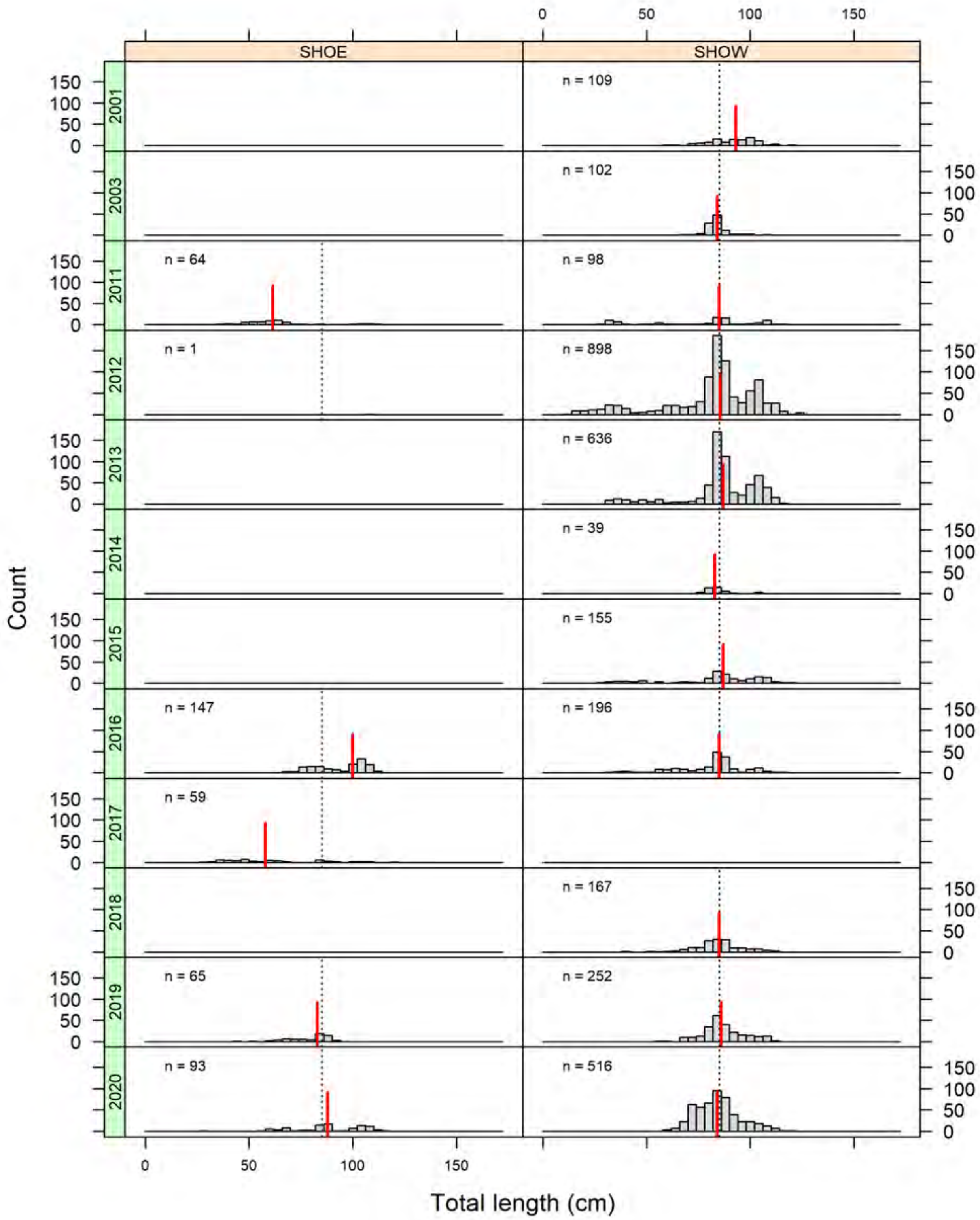

Figure 14.19. Unscaled annual length frequencies for Brier Shark CAAB=37020003 from onboard Observer records separately for the East (SHOE) and West (SHOW). Only trawl records, and total length measurements, are used. Inset numbers indicate total number of fish in each distribution. Red lines indicate the distribution median for each panel (only shown for n>10), while dotted lines show the median length for all observed Brier Sharks.

14.4 Discards

Some Deepwater Shark species are more likely to be retained (byproduct) than discarded (bycatch; see the 'BYPROD?' column of Table 14.1). Consequently, the variance of the overall discard estimate might be inflated when all Deepwater Shark species are combined and underlying trends might be obscured. The Bergh method was used to discard rates and CVs for all Deepwater Shark CAAB codes combined, for the east and west, and then for just those species thought to be more often retained or often discarded. Resulting time series are shown in the upper plots of Figure 14.4. Variances are large and are not shown separately (lower plots) for clarity. The majority of estimates have CVs over 100%, but there is a tendency towards lower CVs particularly for byproduct species, presumably because there is more data for those, more commonly caught, species.

The classification into 'byproduct' and 'bycatch' was made in consultation with Dan Corrie and Tamre Sarhan (AFMA, pers comm) and differs from that of the ERA (Sporcic et al 2021) which recognises two additional species from the deepwater shark basket as 'byproduct' species: Owston's Dogfish (*Centroscymnus owstonii*) and Portuguese Dogfish (*Centroscymnus coelolepis*). The 'platypus shark' group which comprises both *Deania* species was accidentally omitted from our calculation. In addition to applying the standard discard estimation method separately to these 'byproduct' and 'bycatch' groups, we calculated a crude estimate of discarding by simply summing the observed discard weight for each CAAB code, over all observations (i.e. over all years) and divided that by the observed total catch to obtain a CAAB-specific estimate of discarding (Table 14.1, 'SPDISCRATE' column). The result indicates that Owston's Dogfish is highly retained, however Portuguese Dogfish has a lower retention. In addition to Owston's dogfish, Slender Lanternshark and Plunkett's dogfish should be considered for inclusion in the 'byproduct' group for future estimation of discarding. This alteration is unlikely to have much influence on the results as these species are relatively rarely recorded by observers, however the change might improve the CV somewhat.

Post release survival rates have not been measured, but Deepwater Shark returned to the water are thought very unlikely to survive due, mainly, to temperature shock (Daley et al 2002).

POSSIBLE INDICATOR:

- Estimated discard rates could be applied to obtain estimates, and upper and lower bounds, of total removals, and hence a total catch time series, for "byproduct" and "bycatch" baskets

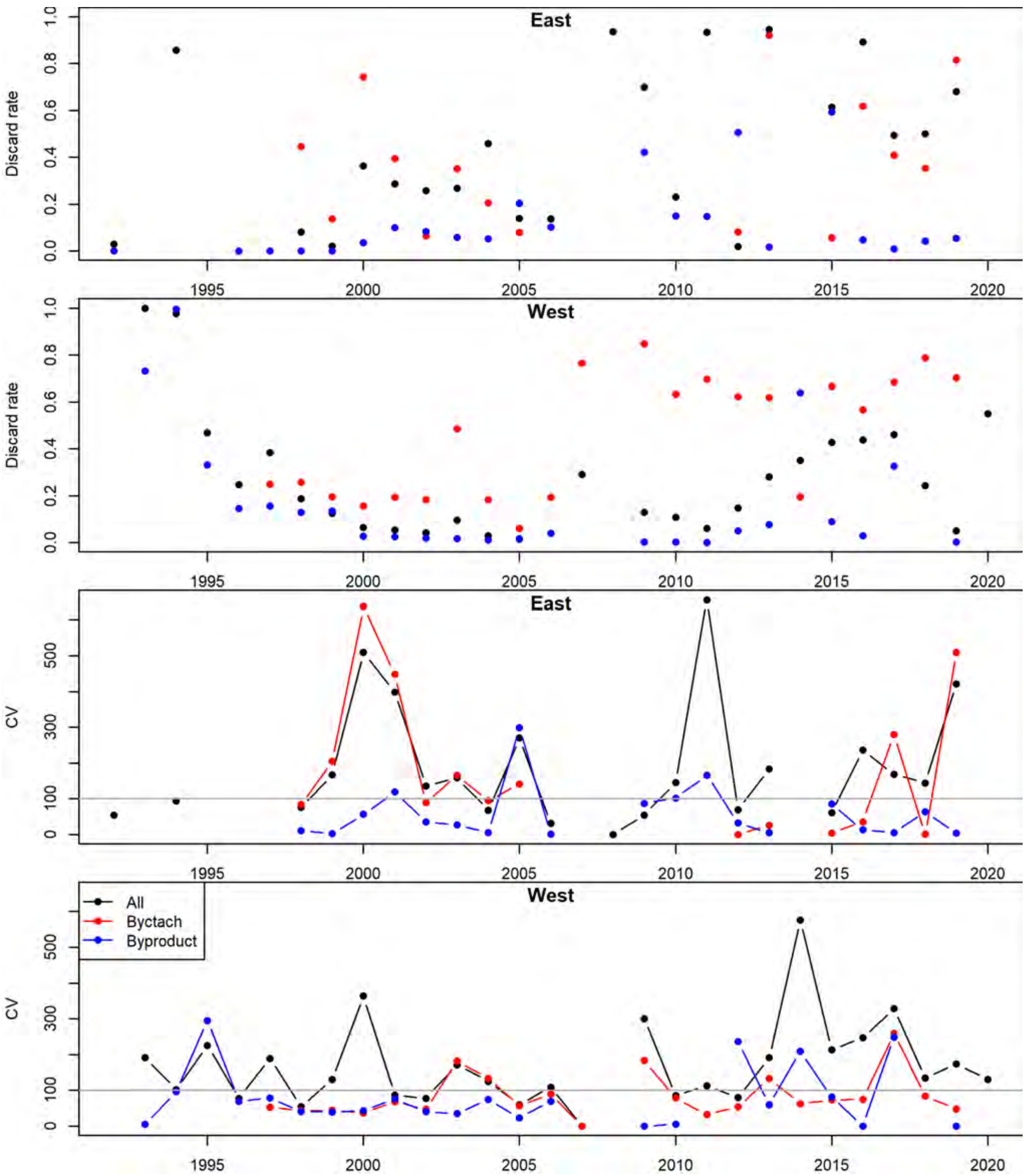

Figure 14.20. Discard rates (upper plots) and CVs (lower plots) for eastern or western Deepwater Shark for all species combined (black) or just bycatch (red), or byproduct (blue) species.

14.5 Other sources of data

14.5.1 *Research surveys*

Daley et al (2002) examined records of upper- and mid-slope dogfish from research survey data conducted using the FRV Kapala (1976-1997), Soela (1984-1989), Southern Surveyor (1991-1994) and a number of chartered SET vessels. While the Kapala surveys (conducted off NSW) show strong declines for upper-slope dogfish, no clear trends are visible for mid-slope dogfish from any research surveys. Daley et al's (2002) plots are not reproduced here as they consider many influential factors, such as location and depth, which resulted in a large number of plots, none of which showed any clear patterns. Daley et al (2002) point out that the research surveys were conducted for a range of reasons, none of which were specifically to monitor dogfish, and that they employed inconsistent methodologies. This reduced the power to detect trends in dogfish abundance using this data. Nevertheless, the dramatic reduction in abundance of some upper-slope dogfish that is clearly evident in the (relatively shallow) Kapala series ought to be visible, despite inconsistent methodology, in other surveys if it had occurred to mid-slope species, but this is not evident.

An additional source of survey data, collected using consistent methodology, is the Orange Roughy survey series (1987-2017) e.g. Kloser et al (2017). Small numbers of Deepwater Shark are collected during each survey. These are recorded to species level and, in most cases, a length and weight are recorded for each individual shark. During the 2017 survey the following Deepwater Shark total catch weight by species were recorded: Brier Shark (22kg), Longsnout Velvet Dogfish (48kg), and Plunket's Dogfish (66 kg). There might be some difficulties in interpreting common names i.e. is Longsnout Velvet Dogfish the Longsnout Dogfish (*Deania quadrispinosa*), the Velvet Dogfish (*Zameus squamulosus*) or (most likely) the Longnose Velvet Dogfish, *Centroselachus crepidater* aka Golden Dogfish. Also, the relatively small numbers of dogsharks caught while targeting Roughy will likely inflate the variance of these abundance data. Notwithstanding, the relatively long time series and consistent methodology make examination of this data worthwhile. Most of the bycatch data has yet to be made available, but CSIRO hopes to do that work over the next few months.

POTENTIAL INDICATORS:

- Fishery independent time series of Deepwater Shark catch but species

14.5.2 *Biological parameters*

Biological parameters have been compiled, where possible, for Deepwater Shark basket species as part of the ERA process (Sporcic et al 2021; see Table 14.2). In many cases the parameter values are averages over species belonging to the same family. Two natural mortality estimates (0.09 and 0.17) were taken from Fishbase. Growth parameters, and estimates relating to fecundity (such as litter size, gestation time, size and age at maturity) have also been compiled (Sporcic et al 2021). While these parameters are likely to be poorly estimated, particularly when they are drawn from related species and not the species of interest, they are likely to be indicative of the biology of Deepwater Shark and could be used to apply more reliable assessment methods than those based on catch alone. Selected values are shown in Table 14.2.

Table 14.2. Selected parameter values collected for use in SAFE or similar assessments as part of the ERA process.

SP NAME	SCI NAME	GROWTH	AGE MATURE	NUM PUPS	M
Brier Shark	Deania calceus	TRUE	15.50	9.0	0.17
Longsnout Dogfish	Deania quadrispinosa	TRUE	13.00	9.0	0.17
Black Shark	Dalatias licha	TRUE	25.75	15.0	0.09
Blackbelly Lanternshark	Etmopterus lucifer	TRUE	10.50	11.5	0.09
Slender Lanternshark	Etmopterus pusillus	TRUE	22.00	11.5	
Southern Lanternshark	Etmopterus granulosus	TRUE	10.00	11.5	0.09
Bareskin Dogfish	Centroscyllium kamoharai	FALSE			
Smooth Lanternshark	Etmopterus bigelowi	TRUE	14.70	11.5	
Pygmy Lanternshark	Etmopterus fusus	TRUE		11.5	
Pink Lanternshark	Etmopterus dianthus	FALSE			
Blackmouth Lanternshark	Etmopterus evansi	TRUE		11.5	
Lined Lanternshark	Etmopterus dislineatus	FALSE			
Short-tail Lanternshark	Etmopterus brachyurus	FALSE			
Moller's Lanternshark	Etmopterus molleri	FALSE			
Golden Dogfish	Centroselachus crepidater	TRUE	25.50	6.0	0.09
Plunket's Dogfish	Scymnodon plunketi	TRUE	23.50	24.5	
Owston's Dogfish	Centroscymnus owstonii	TRUE	25.50	21.0	
Portuguese Dogfish	Centroscymnus coelolepis	TRUE	25.50	17.0	

14.5.3 *IUCN Status*

The recently released ‘Action Plan for Australian Sharks and Rays’ (Kyne et al 2021) asseses the extinction risk for Australian Chondrichthyan species using the IUCN risk criteria. Two of the 18 deepwater shark basket species are listed as ‘Near Threatened’: Longsnout Dogfish and Owston’s Dogfish. All other deepwater basket species considered were listed as ‘Least Concern.’ These categories are described by Kyne et al (2021) as:

- Near threatened: a species does not qualify for CR, EN or VU now, but is close to qualifying for or is likely to qualify for a threatened category in the near future;
- Least Concern (LC): a species does not qualify for CR, EN, VU, or NT.

For those listed as least concern, the main reason given is that much of their range is outside of the region or depth of fishing including the protection afforded by the 700m depth closure.

Australia is regarded as a ‘lifeboat’ for two deepwater shark species that are more threatened elsewhere: Owston’s Dogfish, and Black Shark (*Dalatias licha*).

14.6 Data-limited methods

14.6.1 *Analytical (model-based) methods*

Catch-only methods, and any method that relies on a time series of catches are not appropriate for the Deepwater Shark quota basket because their high, spatially- and temporally-variable, and poorly estimated, discard rates mean that landed (reported) catch is a poor indication of total removals. Understanding discard rates is critical because post-release mortality is suspected to be almost 100% (Daley et al 2002). That stated, estimates of total discards have been made, and, although these are highly uncertain, they could tentatively be used to estimate a possible range for total removals. However, estimates of discarding are not species-specific, and catch-only methods apply only on a single species basis.

At best, an attempt could be made to apply catch-only methods to the Deepwater Shark species basket, assuming similar life history parameters and selectivities. Regardless, estimates of stock status arising from catch-only assessment methods, themselves inherently prone to bias, will be highly uncertain. If catch-only methods are considered, a range of such methods should be utilised to acknowledge this uncertainty and to determine whether results corroborate or contradict one another across different approaches. Care should be taken, when applying these methods, to examine the applicability of their assumptions, in particular where these have been developed in application to scalefish and not to sharks. Sharks typically have lower reproductive rates than scalefish, and require higher biomass reference points in relation to unfished biomass with consequent lower F-based reference points.

Catch rates are not likely to reliably index abundance, again because of high, spatially- and temporally-variable, and poorly estimated, discard rates. With the exception of the limited time series of fishery independent survey and observer data,no other indices of abundance are currently available. This severely limits the possibility of precise estimates of current abundance or depletion.

Biological information that could support model-based assessment methods is available for several Deepwater Shark species. The lack of accurate catch data would have to be overcome by assuming alternative catch time series, that bracket the range of possible catches, as described above. Results are likely to be a range of possible depletions rather than more precise estimates.

Alternatively, focussing on just Brier Shark, which forms the majority of the catch for which time series of lengths, as well as biological parameters, are available, and for which discarding is relatively low, might allow the implementation of quantitative methods, including length-only methods such as length-based spawner potential ratio (LB-SPR), or the length-based integrated mixed effects model (LIME), a more flexible model (that can account for variable recruitment and fishing mortality) which can also incorporate augmentary catch and CPUE data. Particularly in the west, management controls based on the assessment of Brier Shark could defensibly serve to vicariously manage the other Deepwater Shark species. Brier Shark is a strong candidate as a keystone species, because it is the most predominantly caught species in the west, and is one of the two most vulnerable species in the Deepwater Shark basket species group.

Methods ought to be applied to individual species (and, if relevant, stocks i.e. east vs west) rather than to the Deepwater Shark basket as a whole. It is therefore recommended to concentrate on the species for which most information is available. This will have the undesirable, but unavoidable, consequence that species that are naturally rare, or already greatly depleted, will therefore receive the least attention.

POTENTIAL INDICATORS:

- (from catch-only methods) Stock status (depletion) for Brier shark, or for a combined subset of species with similar life history + (from length-based methods) Estimates of spawner potential ratio (SPR) and fishing mortality rate

14.6.2 *Indicator-based frameworks*

In a data-limited context, indicators, both empirical (derived more-or-less directly from raw data) or model-based, can be used in combination to guide tactical decision making. Indicator-based frameworks (IBFs) that structure the integration and interpretation of indicators can be used when the application of more formal analytical assessments is not feasible, or where indicators in combination provide a greater insight into stock status. IBFs have the potential to enrich single indicator approaches such that they are more insightful and informative: they can be used to address limitations where a primary indicator does not provide complete information about resource state, where interpretation of a single indicator is ambiguous, or both. Within an IBF, combinations of performance measures (indicator values relative to reference points) result in a unique interpretations of overall status that are explicitly linked to decision (control) rules.

Throughout this report, potential performance indicators have been highlighted based on the appraisal of the available data sources. For the Deepwater Shark basket, while there may be no single reliable performance indicator, a range of indicators could potentially provide a set of checks and balances to identify changes in the state of the fishery that may be cause for concern, and invoke a corresponding management response.

Even where data-limited model-based assessment approaches, such as catch- or length-only methods, are able to be undertaken, there is inherent uncertainty in each. They also (should) only focus on only one species within the basket. Invoking decision rules in response to performance measures arising from such assessments therefore carries significant risk of failing to detect broader changes that may be of concern. For example, a species-specific catch-only assessment will not detect recruitment overfishing that may be detected by a length-only assessment, while neither will detect shifts in species composition, changes in overall total catch, or spatial contraction or expansion of fishing effort.

Incorporating the performance indicators arising from such assessments, together with additional empirical indicators, into a multi-indicator framework, enables all possible sources of information to be utilised in such a way that, if properly designed, should detect any changes that may warrant closer inspection and management intervention. Indicator-based frameworks can be structured to use different indicators simultaneously or sequentially.

There are various types of approaches used to integrate indicators into assessment-decision rule frameworks . These range from

- simple aggregates of indicators to achieve an overall qualitative performance (e.g., traffic light or CUSUM approaches)
- those that have unique interpretations based on combinations of indicator values (e.g., trigger systems)
- hierarchical decision trees, that use certain primary indicators to inform a control rule, and supplementary indicators to augment their interpretation and further adjust the management measure.

When initiating development of a multi-indicator framework, it is crucial to acknowledge that this is a challenging process, – not least because of the lack of a prescription for the design process, the common use of indirect proxy indicators, and, possibly, a lack of understanding as to how multiple indicators interact. Issues can arise due to IBFs typically classifying discrete resource states as triggers for adjustments to management measures. When the indicators are borderline between states, stakeholder disputes as to the "true" state, and indicator oscillation around (above and below) thresholds can occur, resulting in too frequent and unnecessary adjustments to management measures. This problem can be exacerbated by the imprecision of indicators, consequently affecting the frequency and magnitude of adjustments to management measures, raising concerns about whether management responses are tracking signals or chasing noise.

Additionally, problematic choices of reference points for indicators can sometimes lead to continual increases or decreases of catches, regardless of resource state, known as a ratchet effect (Klaer et al 2012). Likewise, time lags between changes to resource states and their subsequent detection by a "lag" indicator (one that detects a change long after it has taken place) can result in indicator frameworks that incorrectly delay necessary adjustments.

As such, it is strongly recommended that the performance of any IBF is subject to MSE testing. Nonetheless, IBFs provide a means to formally integrate multiple indicators in a weight-of-evidence approach to management, either in the absence of a model-based assessment, where there is uncertainty around model-based assessment outcomes, or given the inability of a single-species assessment to detect broader changes in a multi-species context.

14.7 Conclusions

- There is evidence of targeting of Deepwater Shark in waters deeper than 600m, where they form the greatest proportion of landings from shots that contain Deepwater Shark. This is particularly evident for two vessels that concentrate on fishing off the west coast of Tasmania and Western Bass Strait.
- Both catch and catch rate information are unreliable for most species in this group, but because of relatively low discarding rates, a catch time series might be constructed for Brier Shark.
- The absence of reliable catch rates (or other indices of abundance) means that current biomass and depletion cannot be estimated with precision, however it might be possible to construct a CPUE time series for Brier Shark using the main target vessels.
- The absence of reliable catch (and discard) information mean that catch-only methods are not recommended for this group (with the possible exception of Brier Shark, or where aggregated data is across species with similar life history and subject to similar selectivity).
- Some length data, and some biological parameters are available, so that length-based data limited methods or empirical indicators could be used, but these should be applied on a species (and stock) specific basis.
- Further work to understand how much protection is afforded by existing closures is recommended, on either a species-specific or family-specific basis. If such protection is substantive, this reduces the risk to the basket and, to an extent, affords a degree of vicarious passive management.
- As proposed by the October 2021 Tier 5 Workshop, it would be useful to prepare a report that synthesises the sizable set of reports and publications currently available for deepwater sharks, with an especial view to identifying potential performance indicators. This will better inform future discussions regarding the species group.
- Routine estimation of discards for deepwater dogshark should be applied separately to 'byproduct / targeted' and 'bycatch' species and the choice of species to include in each group should be made by a group of experts. Provisionally, we suggest that the first group should comprise: Platypus Shark, Brier Shark, Longsnout dogfish, Black Shark, Golden dogfish, Slender Lanternshark,

Golden dogfish, Plunkett's dogfish, Owston's dogfish but probably not Portuguese dogfish. A model-based discard calculation would help to account for sparce and unbalanced sampling across influential factors such as depth, zone, (possibly season); alteration in targeting of companion species could be accounted for as well as the strong vessel effect. Tentatively, a range of total removals could be estimated.

- The bulk of the retained (and likely the total catch) of deepwater shark is Brier shark (*Deania calceus*) together with Longsnout Dogfish (*Deana quadrispinosa*) this is also likely to be the most vulnerable species in terms of low reproductive output and consequent ability to recover from overexploitation. Future management of the deepwater shark group might be achieved by concentrating on quantitative assessment of either Brier shark or both *Deania* species together, using the health of these species as an indicator of overall health of the group.
- If indicators are continued to be used for this group (noting that these can include both model-based indicators for Brier Shark, and empirical indicators for the basket), these must be operationalised by linking them to dynamic control rules that allow the adjustment of RBCs for Deepwater Shark. Alternatively, if data-limited, or even Tier 1 or 4 assessments of Brier Shark are used in isolation, rules for translating those results to the whole basket, will be needed.

14.8 Ackowledgements

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15. Tier 5 analyses for seamount Blue-Eye Trevalla in 2021

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15.1 Executive Summary

Blue-eye Trevalla in the SESSF are assessed as two separate stocks, with a Tier 4 applied to the Slope stock and Tier 5 to the seamount stock. Recent catches on the seamounts have been relatively low (even including those in nearby international waters: 39t, 37t, 11t in 2018, 2019, 2020 respectively). The relatively sedentary nature of adult Blue-Eye Trevalla likely allows localised depletion to take place, so that it would be best to ensure that catches are spread across seamounts rather than allowing all catches to take place in a limited area.

The first data-limited (Tier 5) investigation of Blue-Eye Trevalla caught in the SESSF fishery's eastern seamount stock was performed by Haddon & Sporcic (2018) using two data-limited methods (Catch-MSY and an age structured Stock Reduction Analysis). We repeat their work, making some additional or alternative assumptions, and use a Tier 1-like Harvest Control Rule for the age structured Stock Reduction Analysis model. We considered three alternative stock definitions: Tasmantid (eastern) seamounts only (essentially the definition used by Haddon and Sporcic, 2018), Tasmantid seamounts plus Lord Howe Rise, and Tasmantid plus Lord Howe Rise plus Gascoyne seamount. Williams et al (2017) indicated that the Gascoyne seems to be a separate stock from the Tasmantids but that evidence for separation of Lord Howe Rise from the Tasmantids is present but weak. We present results for the scenario that includes the Gascoyne for interest only, but do not recommend using those for management of the seamount stock as Gascoyne is likely to be a separate stock and is also outside of the Australian EEZ. This collection of potential stock structures was used because, while juvenile fish are relatively mobile, once adult Blue-Eye Trevalla settle on a seamount they are generally assumed to remain on that seamount. Such sessile behaviour means that delineating stock structure becomes difficult because functionally separate populations with different dynamics and productivity may still have genetic similarities.

The C-MSY model aims to generate an approximate estimate of MSY (productivity) but does not provide a valid estimate of current depletion or of the sustainable catch at the current stock status. The method provides a range of possible levels of current stock status that are not inconsistent with the catch data, rather than an estimate of current stock status. Linking the output (an estimate of MSW) to a useful harvest control rule to produce a current sustainable catch level is therefore difficult. The range of values of current depletion that result from the method can be somewhat informative, depending on the nature of the catch time series, and the upper K value that corresponds with the lowest r in the chosen range. This is not the case for seamount Blue-Eye Trevalla, where the results reflect the full range of allowed depletion levels i.e. almost zero to almost 1.

It is important to note that, in the case of the C-MSY analysis, updating the analysis using the same catch series plus recent managed catches, would not be a valid application of the method as it would operate either to ratchet the catches down or up depending on whether the original catch levels were biased low or high relative to the actual productivity and unknown current status. If catch-MSY (or any catch-only method) is all that can be used, then an RBC could be set once but should remain fixed into the future because updating the analysis when one only has new catch data is invalid.

We present results using data to 2018, as well as updated catch time series resulting from alternative choices regarding stock definition. The geometric mean values of MSY range from 96t to 105t (if Gascoyne is not considered, as we recommend). Note that MSY would be a sustainable level of catch only if the stock remained at, or above, 50% of its unfished level.

The age-structured SRA model is very sensitive to the form of the selectivity function that is chosen, and to the upper limit for the harvest rate imposed. Across the range of values for natural mortality, steepness, upper harvest rate and stock definition (catch time series) RBCs range from 0t to 176t. All scenarios examined resulted in some combinations of parameter values that lead to a zero RBC. Scenarios that allow the fishery to take younger fish result in many more combinations that lead to zero RBCs as well as lower maximum RBC values.

Interpretation of the RBC values presented here must be done in the context of the stock definition used. For example, when using Tasmantid seamount and Lord Howe Rise catches in a model, the modelled RBCs relate to catches, some of which are not under quota, so that the TAC resulting from this RBC needs to be reduced by the proportion of catches that are under quota. When using only Tasmantid seamount catches, the RBC applies to a population a little smaller than that which is fished, because this assumes that the catches on the Lord Howe Rise are taken from a separate stock.

Data-limited methods such as those presented here are used in situations where there is no reliable index of abundance to give an indication of the response of a stock to fishing, as is the case for seamount Blue-Eye Trevalla. As such, current stock status is unknown and estimates of sustainable catches are very broad. Stock Reduction Analyses, which are not fitted to data, provide a range of plausible states of nature that are consistent with the catches that were taken. It is therefore invalid to use statistics such as the median, average, or mode to characterise the results. The extremes are as likely to be 'true' as the central value. For the C-MSY model, the geometric mean of the MSY values is used because that model makes use of the negative correlation between the r and K parameters, which results in the range of derived MSY values being tighter than the ranges of the separate r and K parameters. Nevertheless, it would be invalid to treat the set of biomass trajectories in the same fashion e.g., by reporting mean stock status in 2020.

As Haddon & Sporcic (2018a, b) clearly stated, it is essential to collect future data to allow the estimation of the impact of fishing on this stock because these data-limited methods cannot provide that evidence. The alternative is to treat this seamount fishery as a form of exploratory fishery, set a cautious TAC, encourage that the catches taken are spread over a large area, and monitor the fishery for any changes in either the spatial extent or intensity of the fishery through time.

Ignoring models that include catches from the Gascoyne, an annual catch in the range of 30-40t (which includes the 36t per annum currently allowed) appears likely to be sustainable, even somewhat conservative, for the majority of models considered. The collection of data that can serve as an index of abundance is strongly encouraged, although the difficulties involved in doing so for Blue-Eye Trevalla are acknowledged.

15.2 Introduction

Blue-Eye Trevalla are a high value species caught in the Southern and Eastern Scalefish and Shark Fishery (SESSF). Until recently, a single stock has been assumed and assessment has been conducted using the ‘Tier 4’ empirical method, which uses the ratio of recent to past catch rate (CPUE) to adjust catches. An investigation into Trevalla stock structure using a range of methods including spatial analysis of age and growth, otolith microchemistry, and ecological dispersal modelling, indicated clear stock separation between Trevalla on the seamounts and those on the continental slope (Williams et al 2017). Stock delineation amongst fish on the continental slope was less clear and AFMA’s SESSF RAG ‘RAG Chairs’ meeting chose to assess Blue-Eye Trevalla as two separate stocks: slope and seamount (AFMA 2018). The slope stock is assessed using Tier 4 but fishing on the seamounts has been sporadic and is complicated by the potential for localised depletion, so that Tier 4 is not an appropriate method.

The SESSF fishery has been managed using Tier 1 (full age-structure assessment models), Tier 3 (Catch Curves used to calculate current fishing mortality rates, coupled with Yield-per-Recruit models to establish F-based target and limit reference points), and Tier 4 (an empirical Harvest Control Rule that uses catches and standardised CPUE). However, Tier 3 was shown by simulation testing to be an unreliable method (Fay et al 2011, Fulton pers comm) and it became apparent that CPUE based on reported landed catches was not a reliable index of abundance for some stocks, particularly those that have high discard rates (not the case for Blue-Eye Trevalla), are no longer targeted, or that are only sporadically fished. As a method of last resort, ‘Tier 5’ is intended to draw on the burgeoning field of data-limited or data-poor methods (Haddon et al 2015).

Haddon et al (2015) used Management Strategy Evaluation to test the efficacy of seven candidate data-limited methods by applying those to two data rich SESSF species that have very different life histories: Tiger Flathead and School Whiting. These seven methods were the median, average, and third highest catch estimates (for stocks for which catch is the only data available), and model assisted catch-only methods that included the Depletion-Corrected Average Catch, the Depletion-Adjusted Catch Scalar, and the Depletion-Based Stock Reduction Analysis (which are aimed at species for which some biological information are available in addition to catch data).

Haddon & Sporcic (2018a, b) applied two data-limited methods (Catch-MSY and an Age Structured Stock Reduction Model) to seamount Blue-Eye Trevalla. This is currently the only Tier 5 assessment that has been used to set a TAC in the SESSF. The array of data-limited methods tested by Haddon et al (2015) were applied to the data-limited stock, Smooth Oreo, as part of exploratory work but were not used as an accepted Tier 5 analysis because the assumptions of the methods were not met by that stock (Haddon et al 2015).

Note the clear advice given by Haddon & Sporcic (repeated in both 2018a and 2018b): “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.” In other words, application of data-limited methods should only ever be considered a stop-gap measure pending collection and analysis of meaningful data to inform fishery dynamics.

The Tier 5 Harvest Control Rule Working Group (AFMA 2021) noted (at its March 2020 meeting) the importance of identifying a pathway out of Tier 5 assessments to allow species to be assessed at a higher Tier level, including data collection (i.e., age and length sampling, better estimates of CPUE) and monitoring. A subsequent meeting of that group (February 2021, AFMA 2021) emphasized the need to approach each new Tier 5 assessment by thoroughly exploring the data that are available, the potential for improving data collection, to identify data-limited methods that can appropriately be applied, and to consider appropriate harvest control rules perhaps with trigger limits. A decision support tool, such as FishPath, can help to identify the range of methods that can be used, and to easily access critical information on the assumptions, strengths, and limitations of each method. CSIRO's advice, ratified by the Working Group, is to apply, if at all possible, a range of methods, ideally using independent data sets and differing assumptions, to determine whether outcomes corroborate or contradict one another (AFMA 2021).

The outcomes of a FishPath evaluation of the seamount stock of Blue-Eye Trevalla have yet to be considered. This stock, along with the Slope stock, are the subject of a close kin mark recapture (CKMR) scoping study that might lead to a full CKMR assessment. Pending that work, we have repeated the Catch-MSY and age structured stock reduction analyses (SRA) of Haddon & Sporcic (2018a, b). We have used an alternative catch time series, one that considers catches from the Gascoyne seamount, which lies outside of the Australian EEZ. High seas catches are not routinely included in AFMA stock assessments but could be important in considering the biological stock as a whole. Additionally, for the age structured SRA, we have used an alternative growth curve and we explore an alternative selectivity curve. Our growth curve attempts to overcome the bias that results from recruitment to the fishery being a function of size instead of age.

15.3 Data

The data-limited methods used here rely heavily, or entirely, on the catches removed from the stock and should therefore consider all catches likely to have been taken from the biological stock. The purpose of this work is to provide advice to fisheries managers on the TAC for catches taken in regions, and by gears, for which Blue-Eye Trevalla are under quota. The biological stock, and the quota region, do not necessarily match. For example, in the East Coast Deep Water (ECDW) region of the SESSF, trawl catch are under quota but non-trawl catches are not. For the purpose of the work presented here, all catches that are taken from the biological stock under investigation must be included, but an adjustment might need to be made later to account for the component of the stock that is not under TAC. For example, if 80% of the catches were under TAC but the RBC applies to the whole stock, then only 80% of the RBC should be considered for TAC purposes.

15.3.1 *Catches*

The Tasmantid seamounts are a chain of extinct undersea volcanoes that parallel the continental shelf off Queensland and NSW (Figure 15.1). The southernmost seamount in this chain, Gascoyne seamount, is somewhat isolated towards the southern end of the chain and is the only Tasmantid seamount that falls outside of the Australian EEZ. For clarity of presentation, throughout this report we somewhat incorrectly use the term 'Tasmantid seamounts' to refer to the Tasmantid chain excluding Gascoyne seamount. Blue-Eye Trevalla catches are also made on other seamounts and undersea structures to the west of the Tasmantid chain, most notably the South Lord Howe Rise (Figure 15.1). Logbook reported catches are shown in (Figure 15.2).

Williams et al (2017) found clear stock separation between Blue-Eye Trevalla on the Tasmantid seamounts and the continental slope. They write that the "southernmost Gascoyne Seamount appears different to the remainder of the Tasmantid seamounts but is outside the Australian EZ." The implication being that because Gascoyne is outside the EEZ, catches from this region will not be considered by management. We include a scenario that includes Gascoyne catches, as an interesting illustration of the impact on model results of the relatively large catches that were taken from the Gascoyne during the early 2000s (Figure 15.3). However, we advise against using these results for management purposes because Gascoyne seems not to be part of the Tasmantid seamount stock.

Regarding the Lord Howe Rise, Williams et al (2017) write that “Growth of Blue-Eye Trevalla is significantly different on the Lord Howe Rise compared to all other areas, including seamounts … and there is limited connection with the seamounts … A boundary between the seamounts and Lord Howe is not suggested because ‘stock’ differences are not strong, and catches are small.” The Lord Howe Rise falls partly within and partly outside the EEZ (Figure 15.1).

The data-limited methods presented here rely on catches alone to make inference about stock status, therefore the inclusion or exclusion of catches from the Gascoyne and Lord Howe Rise greatly impacts results. The decision to exclude catches from the Gascoyne is a relatively easy one given Williams et al (2017)’s conclusion that that seamount population seems different from the rest, and that being outside the EEZ, that region is not part of the SESSF TAC decision. Alternatively, the Lord Howe Rise falls partly within the EEZ and partly outside, and although there is some evidence of stock separation between it and the Tasmantid seamount chain, that evidence is weak. We therefore consider two catch scenarios: (i) seamounts with Lord Howe Rise, (ii) seamounts and without Lord Howe Rise.

Historical catches prior to the start of the AFMA logbook time series were provided by Rowling (2006). These are almost identical to the historical catches used by Haddon & Sporcic (2018a, b) which were taken from Tilzey (1997); see Figure 15.3 for catches prior to 1998. Catches from 1998 onwards were taken from the AFMA logbook database. Haddon & Sporcic (2018a, b) defined the ‘seamount’ region as being north of latitude 28.2S (the ‘Barrenjoey line’ or northern limit of SET zone 10) thereby excluding catches from the Gascoyne seamount (Haddon & Sporcic 2018a, b) and likely including some of the Lord Howe Rise catches.

In this report, we use longitude 153ºE as the delineator between the ‘shelf’ and ‘seamount’ stocks of Blue-Eye Trevalla (Figure 15.2); longitude 160 ºE to separate Lord Howe Rise from Tasmantid seamounts, and Latitude 35ºS to distinguish Gascoyne seamount from the remainder of the Tasmantid seamounts. We do not distinguish between catches made under quota and those not under quota, i.e., non-trawl catches from the ECDW sector are included in our catch time series.

To account for the known downward bias in logbook reported catches, we applied a multiplier of 1.1 to these catches, reflecting the average ratio between CDR and associated logbook catches for this species (Althaus et al 2021). Post-1997 catches used in the present study are therefore slightly larger than those used by Haddon & Sporcic (2018a, b) (Figure 15.3). Discard rates for Blue-Eye Trevalla are typically below 1% (Althaus et al 2021) and were therefore ignored.

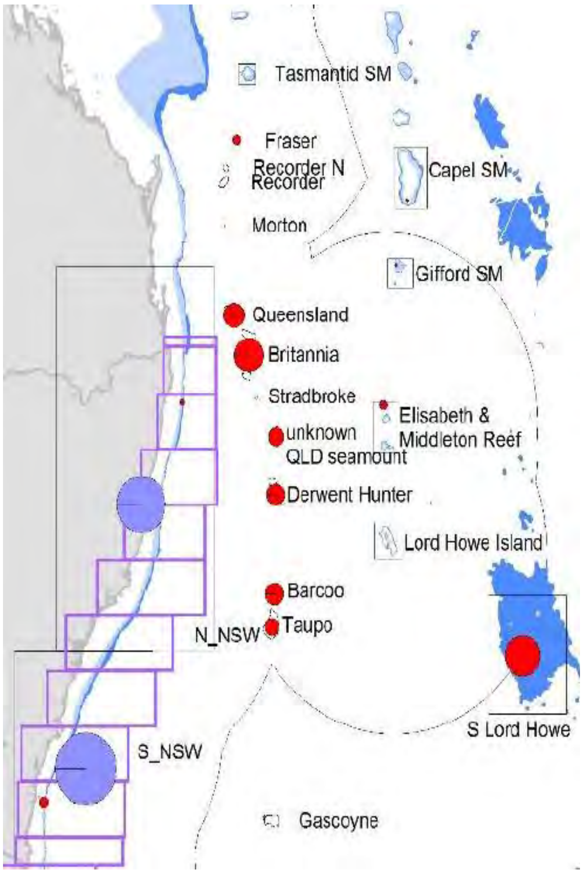

Figure 15.1. Location of Blue-Eye Trevalla fishing off eastern Australia, showing the Tasmantid seamount chain as well as other features to the west. Depth contours 200-700 m (light) and 700-1100 m (dark) are coloured in two shades of blue. Figure taken from Williams et al 2017.

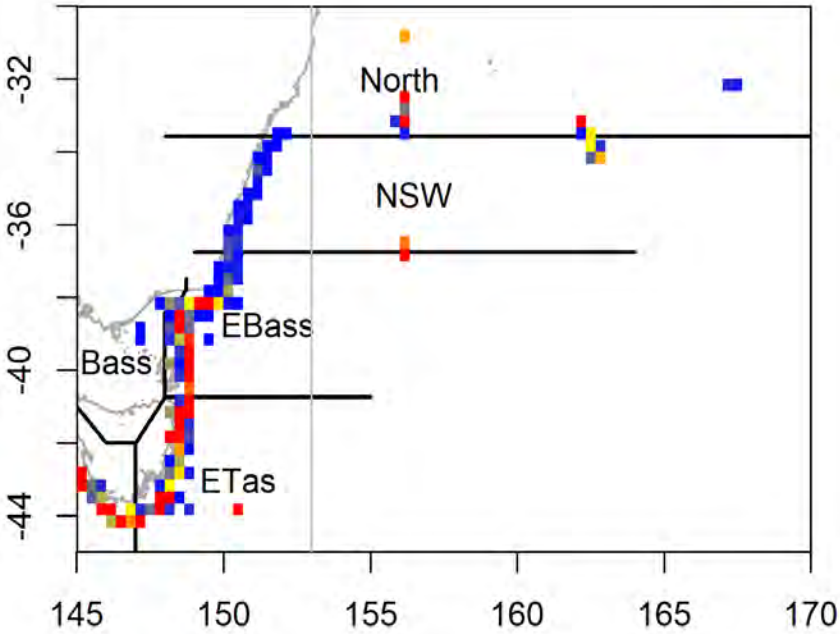

Figure 15.2. Location of logbook reported catches of Blue-Eye Trevalla, in third of a degree blocks. Blocks from which fewer than 5 vessels reported catches are not shown, resulting in the masking of blocks that together represent 13% of the total catch. Catches have been summed over all years; red represents highest, yellow intermediate, and blue lowest catches.

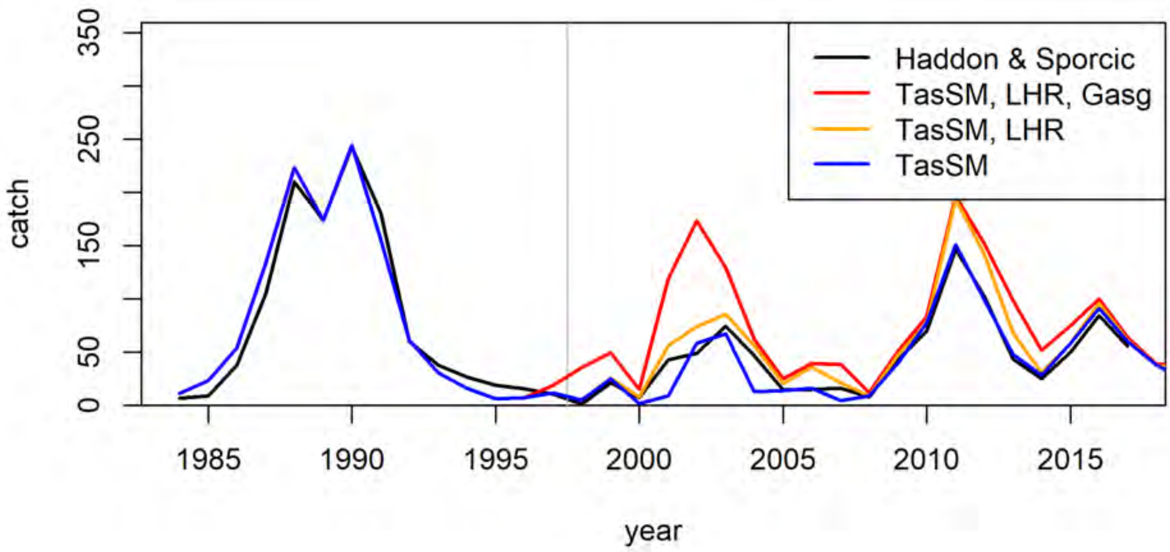

Figure 15.3. Blue-Eye Trevalla annual seamount catches used by Haddon & Sporcic (2018a, b) and by this report. A vertical grey line at 1997.5 demarcates the historical from the AFMA time series.

15.3.2 *Growth*

Young Blue-Eye Trevalla show considerable variation in growth rates during their early years. They settle into a benthic habitat (where they become vulnerable to fishing) at a relatively precise size of approximately 45cm rather than as a function of age. This is evident from a histogram of the lengths of all samples held in the Fish Ageing Services (FAS) database (Figure 15.4). Consequently, growth curves calculated from samples collected from the fishery are strongly biased by the absence of the slower growing fish that have not yet reached 45cm and the presence of the fastest growing fish that reached that size at a younger age (Thomson & Baelde 2002, Horn 2010). Horn used measurements of otolith radii to back-calculate the length at pre-capture ages of older fish and in so doing calculated growth curves for New Zealand caught Trevalla that showed much smaller median length-at-age for younger fish than those calculated in the conventional manner.

Not having access to otolith radius measurements, we were unable to apply Horn (2010)'s back-calculation method to our sample. We attempted to produce unbiased (or at least less biased) growth curves by (1) fixing the von Bertalanffy t_0 parameter at the value calculated by Horn (2010), t_0=-0.0627; and (b) restricting the sample used for the von Bertalanffy estimation to just those over the age of 5, which appears from Horn's work to be an age by which most fish have recruited to the fishery.

There are sex differences in growth of Blue-Eye Trevalla, with females attaining somewhat greater length than males, but the difference is small enough to ignore for a data-limited assessment where other uncertainties are much greater. We also ignore the considerable variability in growth rates amongst seamounts demonstrated by Williams et al (2017).

We therefore calculate a single growth curve for both sexes and all areas combined using data from the FAS database, this does not include data collected by Williams et al (2017). We used data for all 11,261 Blue-Eye Trevalla stored in the Fish Ageing Services (FAS) database, only one of which was recorded as having been collected in the ECDW fishery, the remainder being drawn from SESSF and GAB zones. Future work could include re-estimating the growth curve using data from the seamounts.

Growth curves that estimate t_0, whether applied to all samples or only to those over 5 years, are much flatter than those that fix t_0 at Horn's value (Figure 15.5). The curve that fixes t_0 but uses all samples provides a poor fit to older animals. The curve that fixes t_0 and uses only individuals over 5 years of age appears to be the most realistic, although it seems to under-estimate the size at age for the oldest animals. A Richard's growth curve might provide an improved fit overall, but would redefine the meaning of the t_0 parameter, making the use of Horn's value invalid. Ideally, Horn's back-calculation method would be applied to samples collected from Australian seamounts and von Bertalanffy and Richard's growth curves applied to those data.

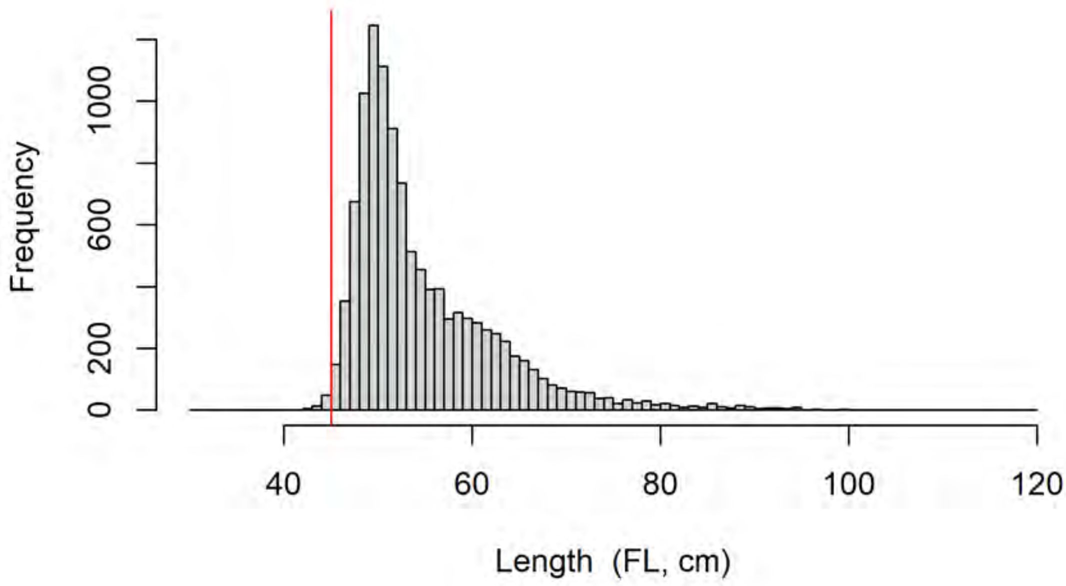

Figure 15.4. Histogram of lengths of all samples held in the Fish Ageing Services database. A red vertical line indicates 45cm.

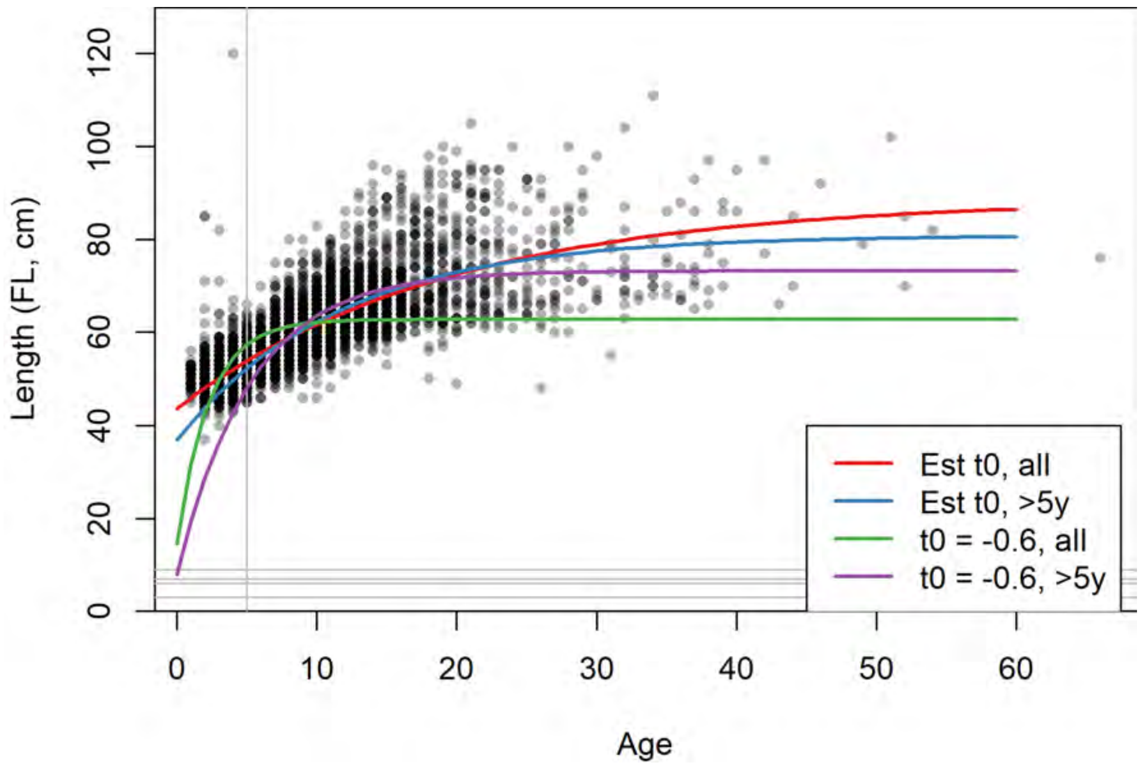

Figure 15.5. Age and length data for Blue-Eye Trevalla from the Fish Ageing Service database. Growth curves were fitted to all data *all* or just those over 5 years *> 5y* either estimating the t_0 parameter *Est* t_0 or fixing it $t_0 = -0.6$. Horizontal grey lines show the sizes of the smallest Blue-Eye ever collected.

15.3.3 *Selectivity and biological parameters*

Haddon & Sporcic (2018a)'s fishing selectivity function (which reflects both gear selectivity and availability) was chosen by examining the available data and choosing a relationship that seemed consistent with those data. The age at 50% selectivity is 10y, which corresponds with a mean length of 64cm (Figure 15.5). This age might seem high in light of the FAS length samples (Figure 15.4) but might be reasonable given that seamount Blue-Eye are likely to be typically larger than the shelf Blue-Eye in the FAS database. However, the sampled lengths rise rapidly from a little over 45cm to a peak at 50cm (Figure 15.4) and the mean length at age 8y is close to 50cm.

Klaer & Thomson (2005) assumed logistic, length-based selectivy for Trevalla, with 25% selectivity at 48cm and 50% selectivity at 50cm which implies 50% selectivity at age 5.4y given the growth curve presented in this report. However they do not discuss the origin of those figures and given the lengths and ages considered here, a higher age at 50% selectivity seems more feasable.

We therefore consider two alternative selectivity functions, that chosen by Haddon & Sporcic (2018a) that has an age at 50% selectivity of 10y, and another that uses 8y. We did not alter the selectivity parameter that defines how steeply selectivity increases with age. Note that spatial information is not considered here but that seamount fish were not included in the length-age dataset.

We use the parameter ranges chosen by Haddon & Sporcic (2018a) for natural mortality (M), steepness (h), and unfished recruitment ($R0$) as well as the fixed parameter values they used for the age of the plus group, and the length-weight and maturity relationships (fecundity is defined as weight multiplied by maturity). These parameter values, along with the new growth parameters, are shown in Table 15.1. The length-based biological relationships specified by these parameters are shown in Figure 15.6.

15.3.4 *Harvest rates*

To reduce the range of results from the models presented here, an upper limit is placed on the harvest rate (i.e. proportion of the stock that is available to the fishing gear that is removed) in any year. A range of upper harvest rate limits, from 0.25 to 0.5, was assumed. An upper limit of 0.5 is relatively large, suggesting that a fishing vessel might remove 50% of all available fish in a single year. The reason for using such a large value is the argument (Pascale Baelde, pers comm) that when resident fish are removed, younger fish that have not yet found suitable habitat in which to settle, will fill those spaces and hence higher harvest rates could be maintained for long periods. In the absence of further information on which to base this decision, a relatively large upper limit is a conservative assumption, at least for the age-structured SRA model.

Table 15.1. Parameter values, ranges, and increments used in the analyses presented here.

PARAMETER	VALUE	MIN	MAX	INC	EXPLANATION
Linf	73.175				Growth parameter
K	0.191				Growth parameter
t_0	-0.600				Growth parameter
a	0.018				Length-weight parameter
b	3.016				Length-weight parameter
M50	11.000				Age-Maturity parameter
dM	1.000				Age-Maturity parameter
S50		8.00	10.00		Age-selectivity parameter
dS	1.500				Age-selectivity parameter
aplus	56.000				Age of plus group
M		0.08	0.12	0.01	Natural mortality
h		0.60	0.80	0.10	Steepness
ln(R0)		9.50	12.50	0.01	Log unfished recruitment
maxH		0.25	0.50	0.25	Maximum allowed annual harvest rate

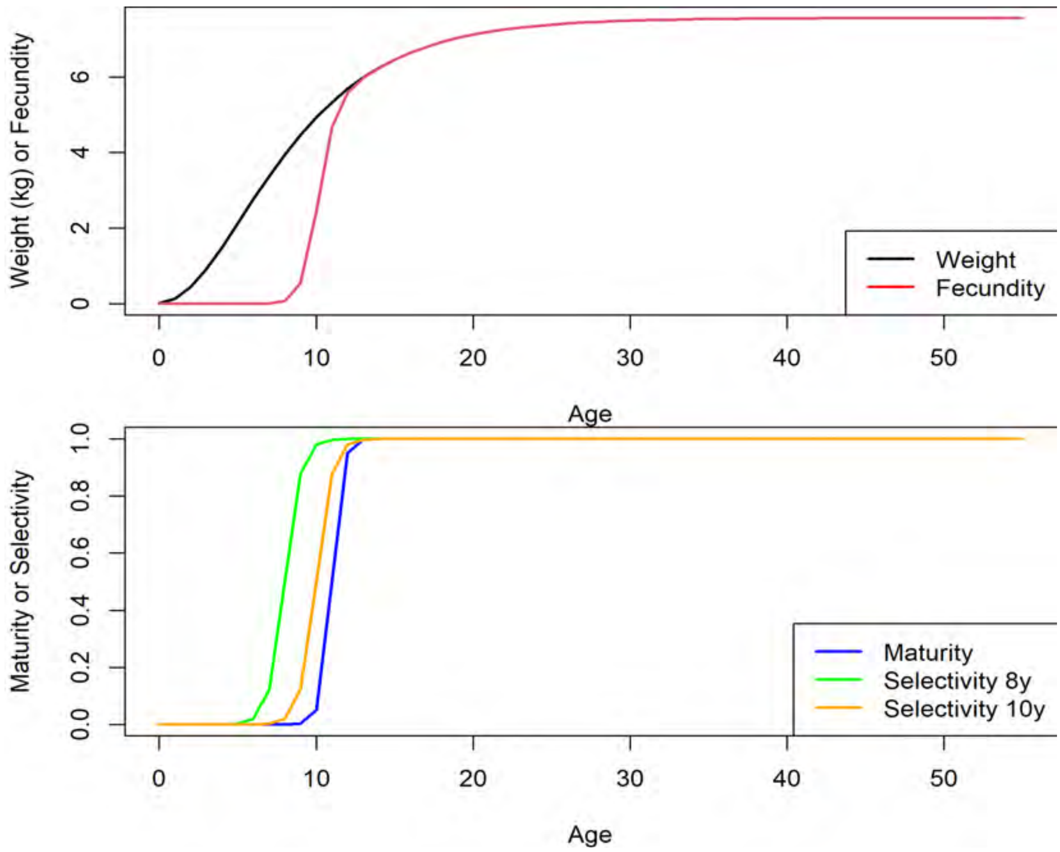

Figure 15.6. Biological and fishing relationships used in this analysis. The selectivity relationship reaches 0.5 at either age 8y or age 10y.

15.4 Methods

We repeat the work of Haddon & Sporcic (2018a, b) in applying two data-limited methods: Catch-MSY (C-MSY) and age structured Stock Reduction Analysis. When implementing a Stock Reduction Analysis (SRA), known catches are sequentially removed from a stock, typically assuming that the stock was pristine at the start of the catch time series. The model that is used can be an aggregated biomass model (such as a Schaefer production model), a full age-structured model, or anything in between. The defining feature of an SRA is that no index of abundance is available to tune the model.

See Martell & Froese (2013) and Haddon & Sporcic (2018b) for details on the catch-MSY and age-structured models used here.

15.4.1 *Catch-MSY (C-MSY)*

C-MSY, although not normally described as an SRA in the literature, involves no parameter estimation, only the removal of catches from a modelled population (Martell & Froese 2013). The model used is a Schaefer Surplus Production model. Plausible ranges are chosen for the parameters of that model: the intrinsic growth rate *r*, and unfished biomass *K*. Combinations of *r* and *K* that cannot support the catches that are known to have been taken, or that lead to biomass values above *K*, are trimmed from the parameter set, leaving a reduced set of possible pairings of *r* and *K*. The method cleverly exploits the intrinsic correlation between *r* and *K* in a Schaefer Surplus Production model in that the range of MSY values resulting from the trimmed set of *r*-*K* pairs is narrow relative to the range in each of the *r* and *K* sets. Martell & Froese (2013) recommend using the geometric mean of the resulting MSY values as an estimate of MSY for the stock. Note that MSY is an indication of the level of catch that would be expected to be sustainable only if the population is at or above B_{MSY}, which for a Schaefer model is 50% of the unfished biomass (*K*). If the stock is below that level, then catches must be below MSY to allow recovery to B_{MSY}. Martell & Froese (2013) suggest that stock status can be assessed using indicators (if available) such as changes in survey biomass, CPUE, changes in lengths over time, and whether past catches have exceeded MSY.

15.4.2 *Age-structured SRA*

The model that is used to remove catches from a stock that begins in an unfished state need not be a Production Model. If biological parameters (length-at-age, length-weight relationship, maturity-at-age) are available, and a guess can be made regarding the fishing selectivity-at-age, then a full age-structured model can be used instead. As Haddon & Sporcic (2018b) point out, the assumptions of a Production Model might not be adequately met for a long-lived species such as Trevalla, which can live to over 50 years. Like C-MSY, the application of an age-structured SRA involves choosing plausible ranges for parameters, removing known catches from a stock that is considered to be in an unfished equilibrium at the start of fishing (or making a guess at its stock status in that year), and trimming parameter combinations that lead to implausible or impossible biomass trajectories.

The most notable difference between the results of SRA and conventional stock assessment models is that SRA does not involve conditioning model parameters using an index of abundance i.e. there is no model fitting. Instead, there are pre-selected ranges of plausible parameter values that are trimmed by removing combinations of values that are not consistent with available information. The range of plausible trajectories (and the parameter combinations that gave rise to these) from an SRA can be further reduced based on external evidence of changes in abundance. This might include survey or CPUE data points for particular years, if any are available.

When the parameters of a model are tuned to available data, there will be a set of point estimates that are best supported by the data. The mode or median of a distribution of parameter estimates, and the stock status given by these, will be the 'best-fit' point. By contrast, the range of parameter values resulting from an SRA, and their associated biomass trajectories and stock status, are all equally probable - none have greater weight of evidence. It is therefore best to choose values that give conservative results, rather than values near the center of the range.

15.4.3 *Harvest Control Rule*

To convert the results of the age-structured SRA model to future catches, we use a Tier 1-like Harvest Control Rule (HCR) defined in terms of harvest rates instead of fishing mortality rates. The recommended harvest rate lies between zero and the harvest rate that would take a previously unexploited population to 48% stock status (H48). For each biomass trajectory calculated as part of the SRA modelling we calculate a harvest rate (Hnext) for the following year, based on the HCR and the stock status (depletion) in the most recent year (Dnow):

$$Hnext = 0 \qquad Dnow < 0.2$$
$$Hnext = H48 * (Dnow - 0.2)/(0.35 - 0.2) \qquad 0.2 < Dnow < 0.35$$
$$Hnext = H48 \qquad Dnow > 0.35$$

e apply the resulting harvest rate (Hnext) to the population calculated by the SRA (for the given set of assumed parameter values) to give a catch figure for the next year. Blue-Eye are a long-lived species that recruit to the fishery between 2 and 6 years old so expected changes in stock status over a three year period as a result of one year's altered catch is likely to be small in comparison to the much greater variation in model results from alternative values of natural mortality, steepness, and selectivity. For that reason, and to reduce complexity of presentation, we did not calculate longer time series of future catches from the HCR but only a single year.

15.5 Results

The inclusion of catches from Gascoyne seamount greatly increase the 'peak' in catches that occurred around 2001-2004. To a lesser extent, inclusion of Lord Howe Rise catches slightly inflate the 2011-2013 'peak.' SRA methods are most optimistic if high catches occurred early in the time series, followed by a relatively long period of low catches that allow time for the stock to build up a large biomass. Age structured SRA model results that use catches from the Gascoyne and Lord Howe Rise are therefore more pessimistic than those that, like Haddon & Sporcic (2018a), use catches from Tasmantid seamounts only.

15.5.1 *Catch MSY*

Haddon & Sporcic (2018b) accepted many of the default settings used by their implementation of the catch-MSY model. These include:

- an initial upper limit for K of 60 times the maximum catch in any year of the available catch time series, which is later reduced to the smallest K that provides an acceptable trajectory when assuming the lowest value of r (as recommended by Martell & Froese 2013),

- a stock status range in the first year for which catches are available, of 0.5 to 0.975 (provided catch in the very first year is less than a quarter of the maximum catch, which it is for all catch time series considered here),
- a stock status range in the final year for which catches are available, of 0.05 to 0.5 (provided catch in the very last year is less than half of the maximum catch, which it is for all catch time series considered here).

The behaviour of the C-MSY model implemented here can be seen by comparing the results from using the TLG (Tasmantid plus Lord Howe Rise plus Gascoyne) catches to the Tasmantid only catches (HS2018 and T series) (Figure 15.7). For the Tasmantid-only models, the lowest value of *r*, coupled with relatively low values of *K* (see the first bullet point above), can sustain the catches that were observed. However, to sustain larger catches after 1998, the lower *K* values are now rejected. This results, somewhat counterintuitively, in a higher geometric mean MSY value for the TLG model (69t) than any of the other models (50t - 58t).

Another reason for the rejection of higher *K* values from the T and TL models is the limit on stock status in the final year, which causes rejection of combinations of *r* and *K* values that lead to a very productive stock. However, the TLG catch time series, having larger catches in more recent years produces a more depleted stock in the final year (Figure 15.7) and therefore allows larger *r* and *K* values compared with the other models (Figure 15.8). The distribution of resulting MSY values is quite similar for all catch time series, although that for TLG is shifted slightly to the right (Figure 15.8).

The current status of Blue-Eye Trevalla on the eastern seamounts is unknown, given the absence of an index of abundance. It could perhaps be argued that the pseudo-rational harvesting across the array of seamounts should avoid the lower levels of depletion. To be conservative, we chose to allow the full possible range of depletion levels, from zero to 1. The stock status of Blue-Eye Trevalla on the eastern seamounts is unknown but is likely to have been close to unfished prior to the start of known fishing in the early 1980s. For these reasons, we changed the default stock status ranges

- from 0.5-0.975 to 0.8-1 in the initial year, and
- from 0.05-0.5 to 0.05-1 in the final year.

The tighter stock status range in the initial year does not offset the effect of the much wider range in the final year, so that the resulting range of acceptable *r* and *K* values is much broader (Figure 15.9 and Figure 15.10). The resulting geometric mean MSY estimates are consequently larger: 97t - 115t, Figure 15.10).

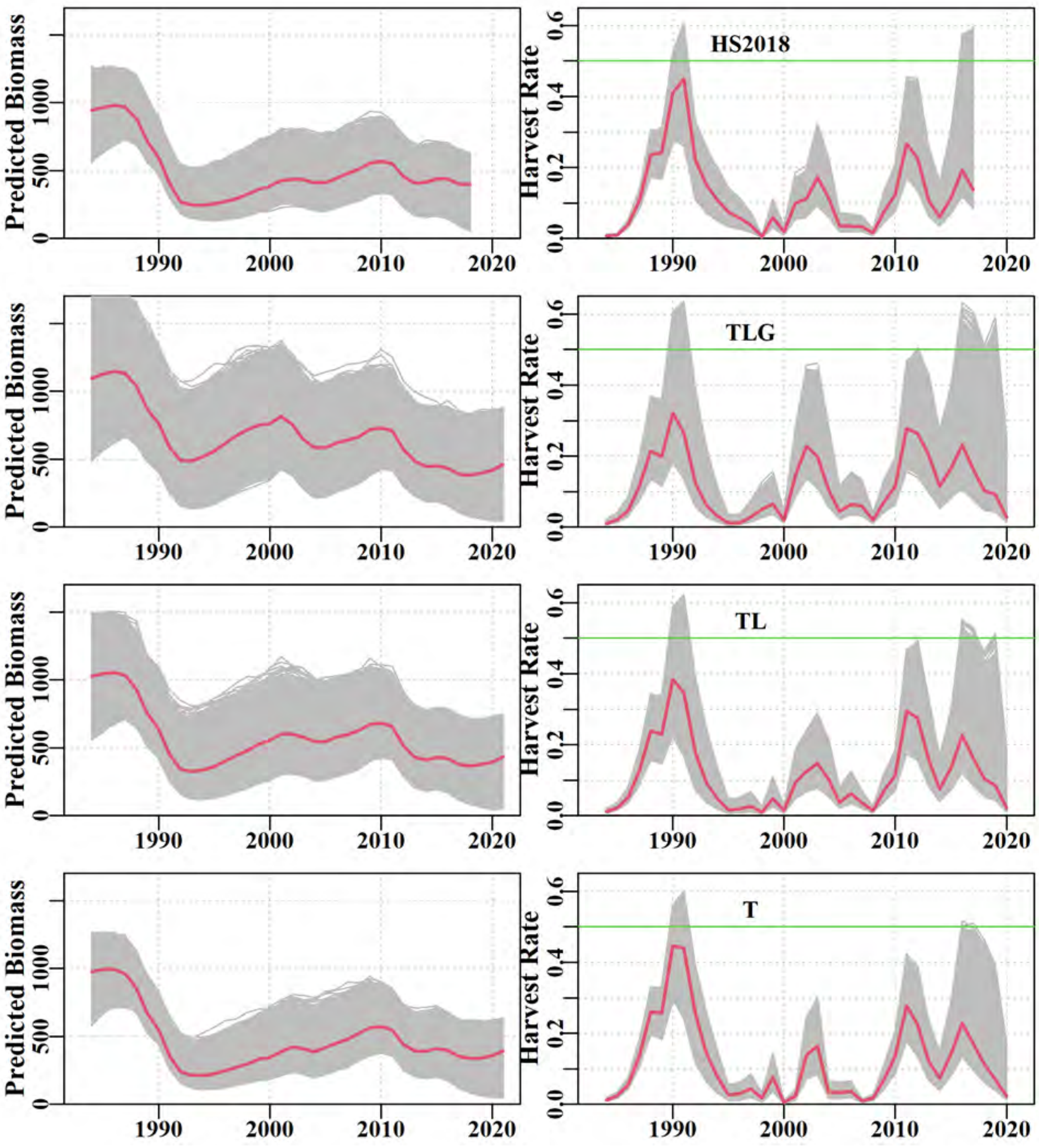

Figure 15.7. Stock biomass and implied harvest rates for C-MSY using Haddon & Sporcic (2018)'s catches (first row), new catches for all regions TLG (second row), without Gascoyne TL (third row) and Tasmantids only T (fourth row). Red lines join mean values from each year. Default stock status ranges were used for the initial and final years.

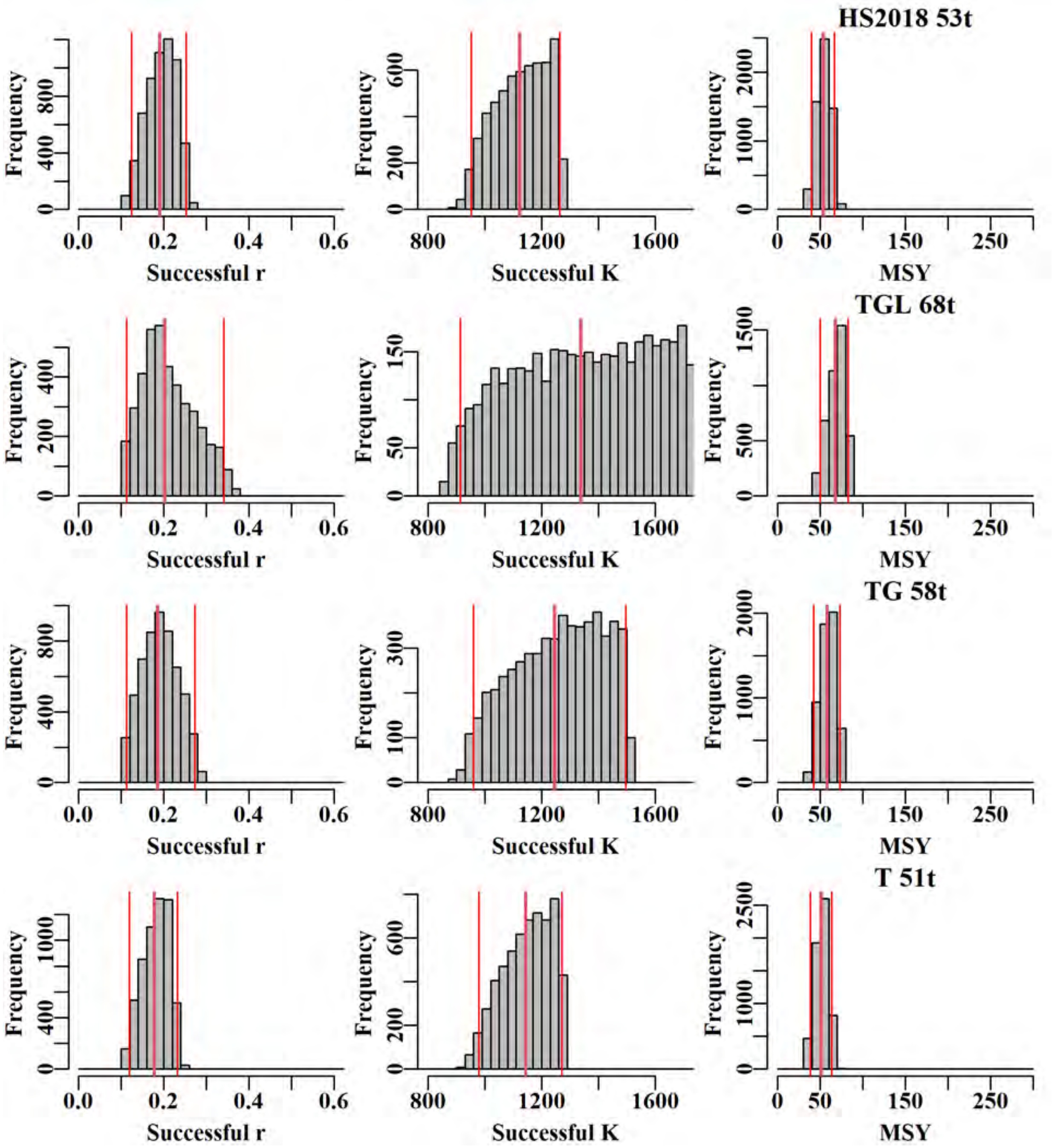

Figure 15.8. Histograms of accepted r, K, and resulting MSY values using Haddon & Sporcic's catches (first row), new catches for all regions TLG (second row), without Gascoyne TL (third row) and Tasmantids only T (fourth row). Default stock status ranges were used for the initial and final years. Geometric mean MSY rounded to the nearest tonne is shown.

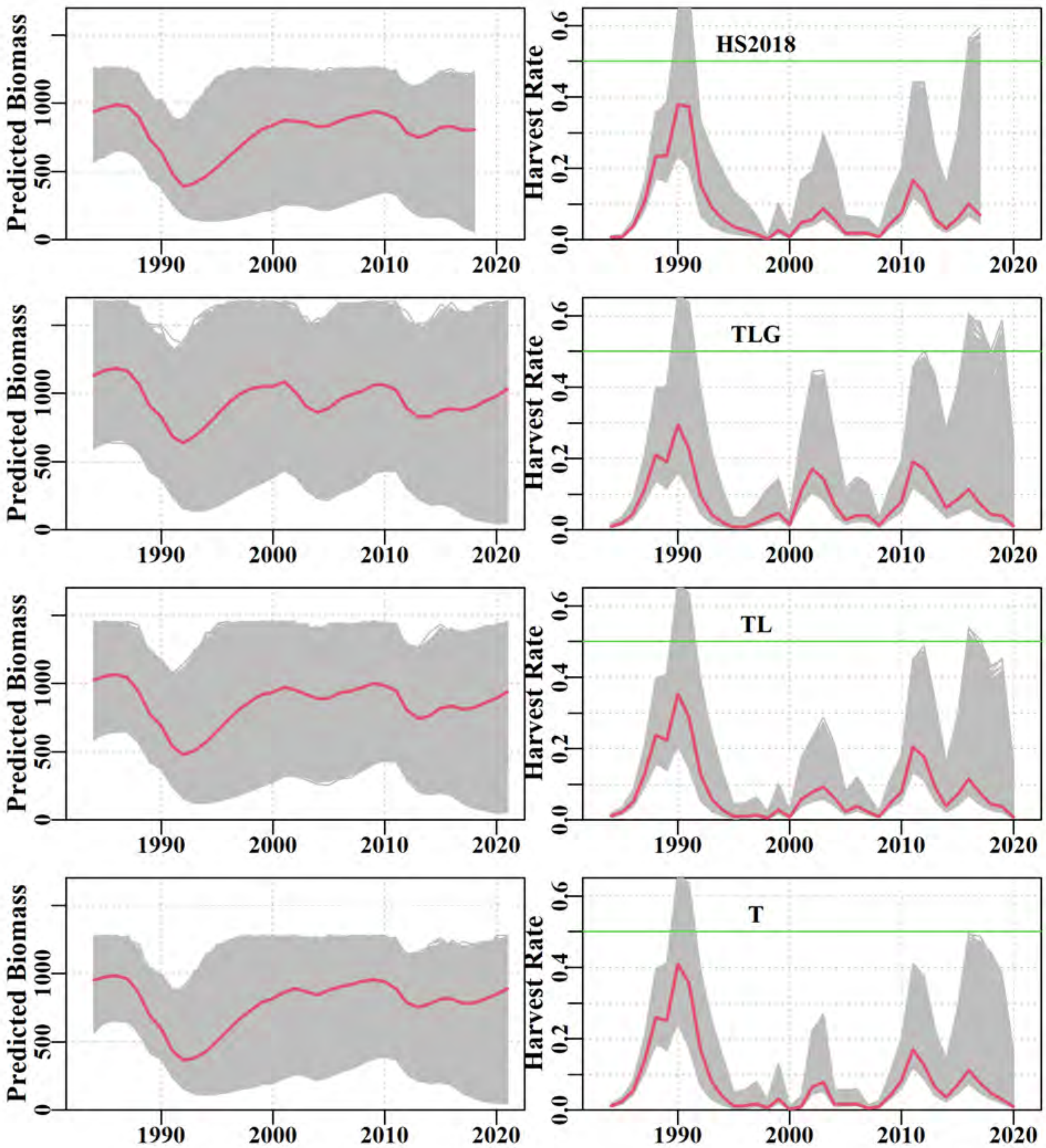

Figure 15.9. Stock biomass and implied harvest rates for C-MSY using Haddon & Sporcic (2018)'s catches (first row), new catches for all regions TLG (second row), without Gascoyne TL (third row) and Tasmantids only T (fourth row). Red lines join mean values from each year. Default stock status ranges were *not* used for the initial and final years.

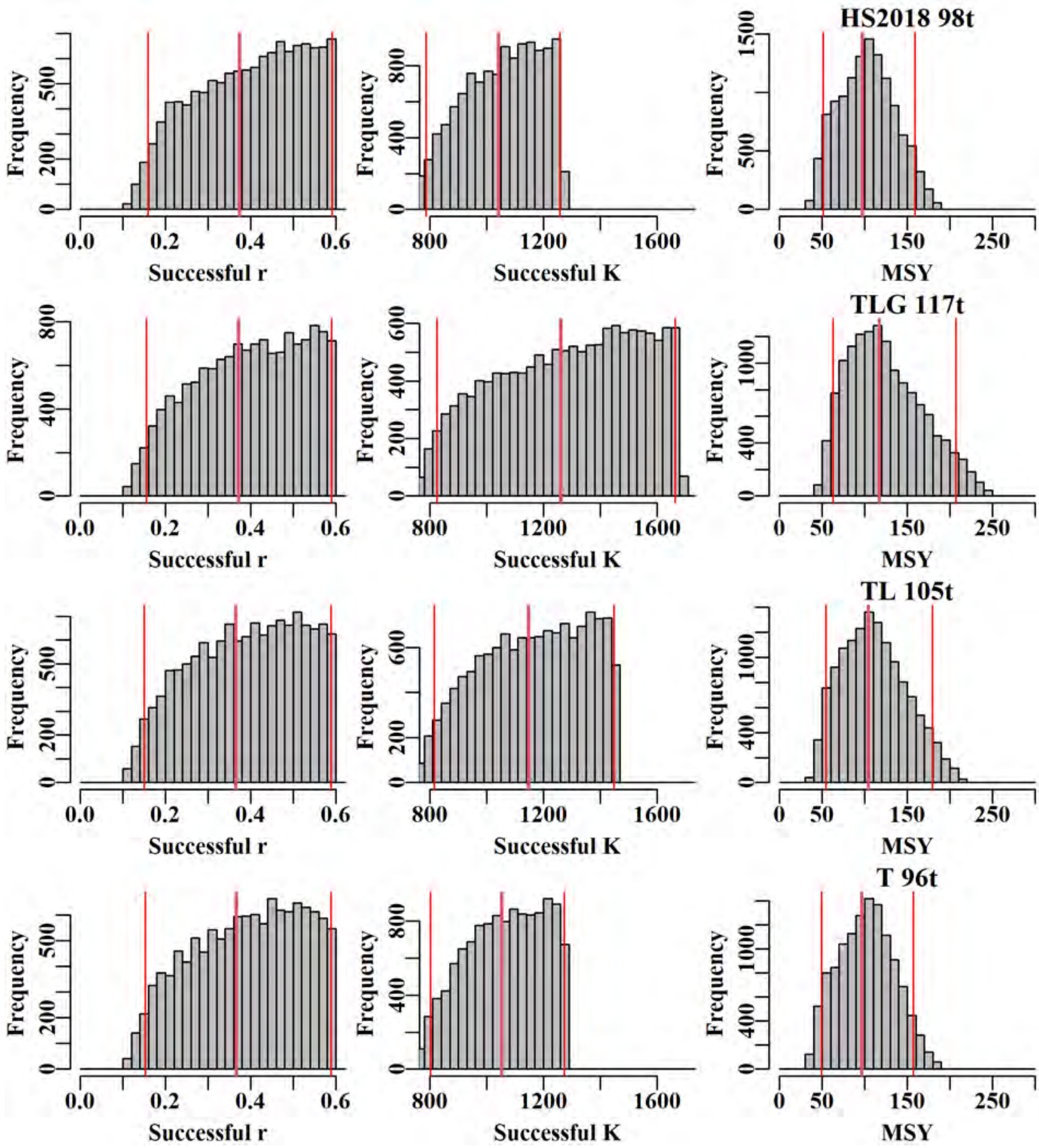

Figure 15.10. Histograms of accepted r, K, and resulting MSY values using Haddon & Sporcic (2018)'s catches (first row), new catches for all regions TLG (second row), without Gascoyne TL (third row) and Tasmantids only T (fourth row). Default stock status ranges were *not* used for the initial and final years. Geometric mean MSY rounded to the nearest tonne is shown.

15.5.2 *Age-structured SRA*

To examine the effect of each of the changes (new growth curve, altered catch time series, and alternative selectivity function) we introduced each change sequentially. Altering the growth curve has little influence because it primarily affects younger fish that have yet to recruit to the fishery (Figure 15.11). Allowing the Gascoyne and Lord Howe catches in addition to those from the Tasmantid seamount chain results in greater depletion in recent years primarily due to the large catches on the Gascoyne during the early 2000s which slow recovery from the catches during the 1980s and 1990s.

Results that include catches on Lord Howe are similar, but a little more depleted, than those that consider only the Tasmantid seamount chain (Figure 15.11). Allowing the fishery to catch younger fish (i.e. changing the age at 50%-selectivity from 10y to 8y) results in much lower stock status in the most recent years (Figure 15.12).

15.5.3 *Varifying parameter values*

Thus far, results have been shown for a single value of natural mortality and steepness in order to more easily age-structured SRA compare models that use alternative catch time series, growth curves, and selectivity curves. Now we investigate the effect of alternative values of natural mortality and steepness. Results are shown in terms of the estimated depletion in the most recent year, as was shown by Haddon & Sporcic (2018a), and also in terms of future catch from application of the HCR.

Stock status (Figure 15.13) and catch (Figure 15.14) results are shown for all natural mortality and steepness values, and both assumed selectivity curves for the lowest and highest extremes of the accepted set of ln(R0) values. Models that resulted in stock status below 0.2 (see horizontal red dotted line in Figure 15.13) result in zero RBC in Figure 15.14. The model that allows Trevalla to be selected at younger ages results in non-zero catches for only the highest R0 values with maximum exploitation rate of a relatively low 0.25.

Histograms of the RBC values resulting from each parameter combination of steepness, natural mortality, R0 and upper harvest rates are shown in Figure 15.15 for each model scenario (i.e., catch time series and selectivity curve).

15.6 Discussion and Conclusions

We have discussed the model results within the Results section; our conclusions and recommendations are captured in the Executive Summary and are not repeated here. Consideration of Future Work follows the figures below.

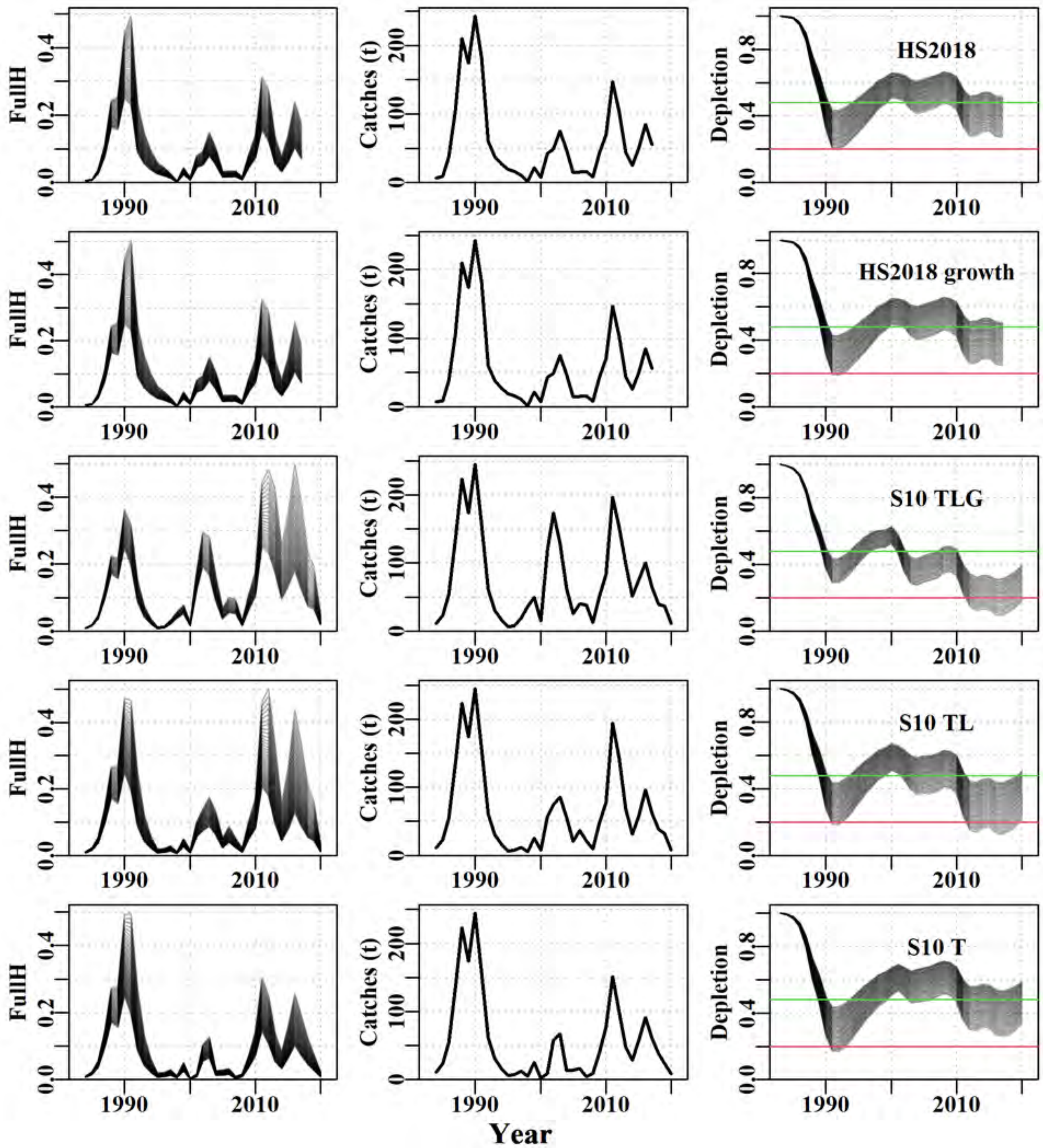

Figure 15.11. Harvest rate (left), annual catches (centre), and stock status (right) for the dataset used by Haddon & Sporcic (2018a) (first row), new growth curve (second row), Haddon & Sporcic's catches (first row), new growth curve 2018_growth (second row), new catches for all regions TLG (third row), without Gascoyne TL (fourth row) and without Lord Howe Rise T (fifth row). Results are shown for all parameter combinations that supported known catches. Values of M=0.1, and h=0.7 were used and all other parameter values or ranges are shown in Table 15.1.

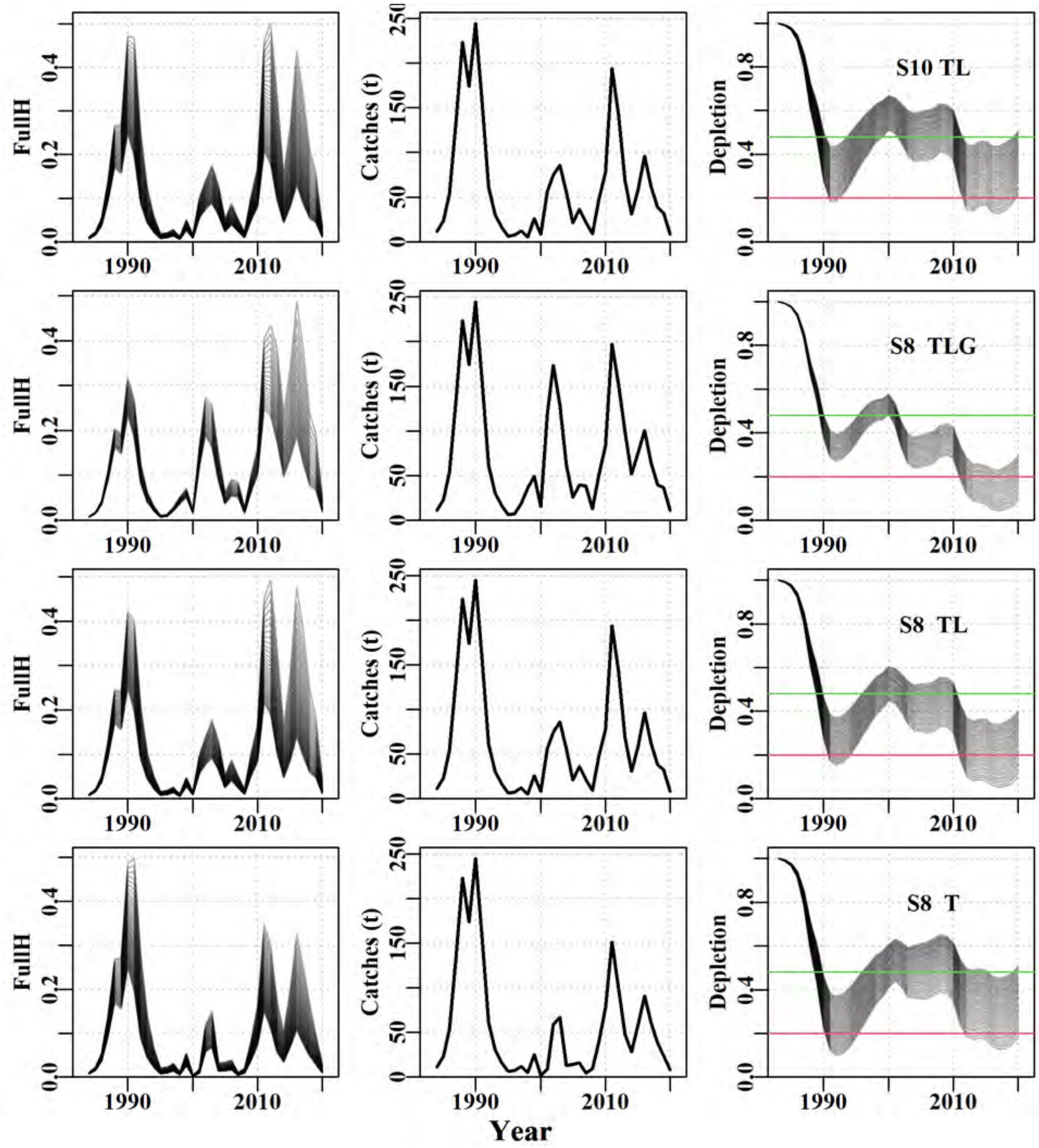

Figure 15.12. Harvest rate (left), annual catches (centre), and stock status (right) using 50% selectivity at 10y (first row), or 50% selectivity at 8y for all regions TLG (second row), without Gascoyne TL (third row) and without Lord Howe Rise T (fourth row). Values of *M*=0.1, and *h*=0.7 were used and all other parameter values or ranges are shown in Table 15.1.

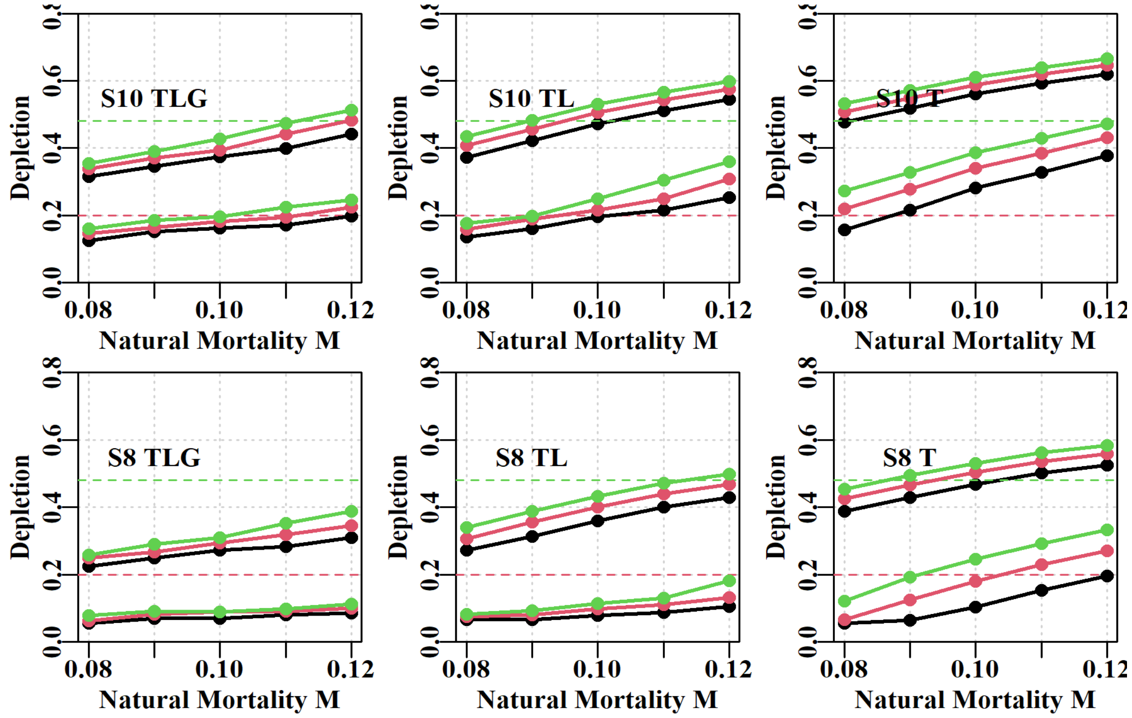

Figure 15.13. The stock depletion levels predicted at the lower and upper maximum harvest rates (H=0.25 - upper set, and H=0.5 - lower set). Results are shown for selectivity curves S50=10, S50=8 and implied stock structure TLG (Tasmantid plus Lord Howe Rise plus Gascoyne), then TL and T. The steepness values are 0.6 (black line), 0.7 (red line) and 0.8 (green line).

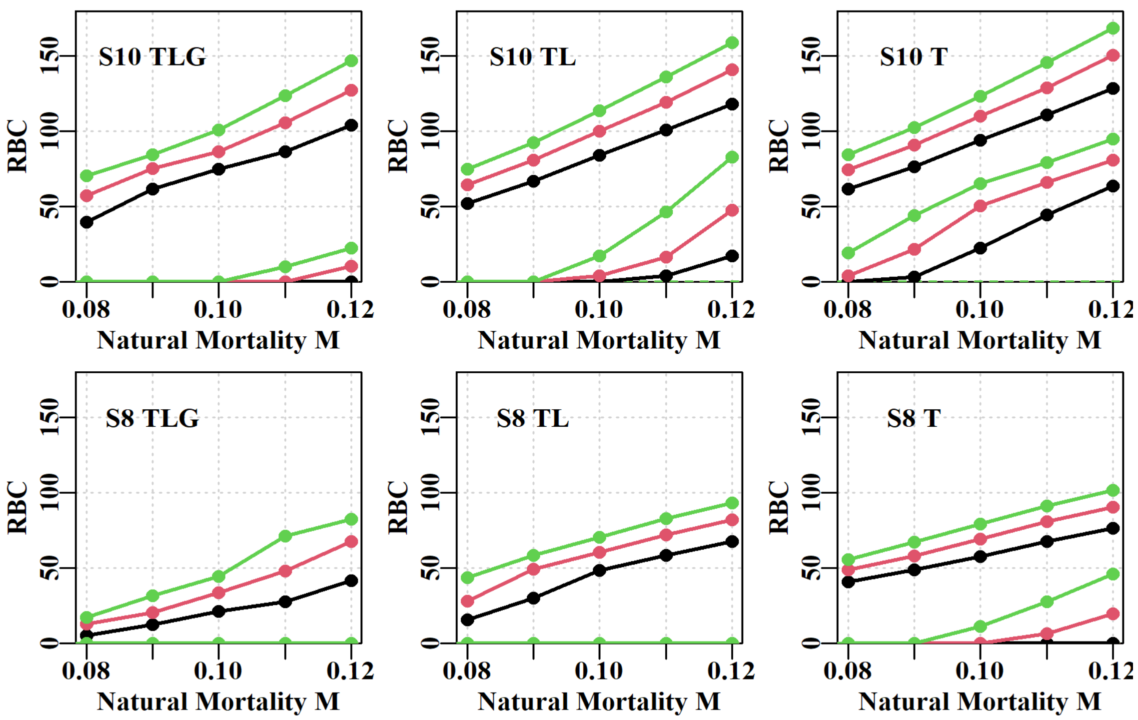

Figure 15.14. RBCs calculated from the Tier 1-like HCR at the lower and upper maximum harvest rates (H=0.25 - upper set, and H=0.5 - lower set). Results are shown for selectivity curves S50=10, S50=8 and implied stock structure TLG (Tasmantid plus Lord Howe Rise plus Gascoyne), then TL and T. The steepness values are 0.6 (black line), 0.7 (red line) and 0.8 (green line).

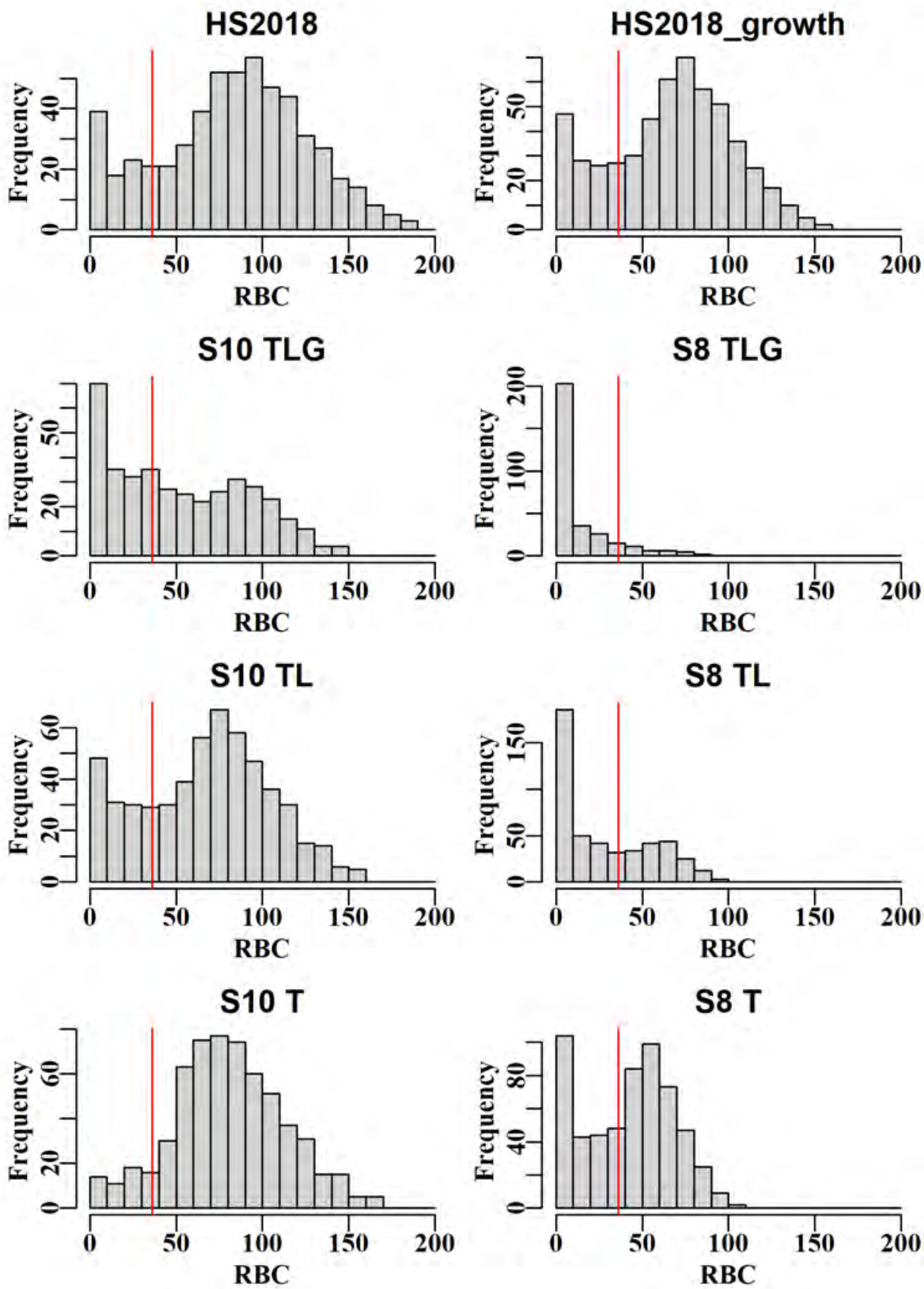

Figure 15.15. Histograms of RBC values resulting from the range of steepness *h*, natural mortality *M*, *R0* and maximum harvest rates for several alternative catch time series and two selectivity curves. RBCs were calculated from a Tier 1-like HCR (see text for details). The vertical red lines are show the current allowed annual take of 36t.

15.7 Future work

- The range of uncertainty in the results shown here could be somewhat narrowed by reducing parameter uncertainty i.e. by reducing the ranges considered for steepness and natural mortality. However, steepness is notoriously difficult to estimate; the 0.6-0.8 range used here is unlikely to be narrowed by meta-analysis. The range for natural mortality *might* somewhat narrowed by further investigation. The 'base case with sensitivities' approach typically used by SESSF Tier 1 assessments could be adopted, but that approach would ignore the true uncertainty in model results. The Tier 1 method has been MSE tested, which is not (perhaps yet) true for Tier 5 methods in the SESSF.
- Data-limited methods typically make strong assumptions therefore it is best to apply several methods of differing types, and to seek a consensus among those results. A decision support tool such as FishPath is a useful aid in choosing suitable data-limited methods. Two methods that could be considered are Froese et al (2017)'s CMSY method that addresses some of the shortcomings of the original Catch MSY method (Martel & Froese, 2013) and provides estimates of stock status. This method should be used with caution, however, as it some bias towards estimating higher productivity. Another method to consider is the Optimised Catch-Only method (OCOM, Zhou et al 2018) which uses SRA and also provides estimates of stock status. Length-only assessment methods could also be considered.
- The results of the age-structured model were very sensitive to the assumed selectivity curve, a choice that was made by eye. Blue-Eye length frequencies typically show a bimodal pattern in which fish are first caught when they settle at 65cm, grow for another 10cm and then become less available until they have grown sufficiently to once again become more prevalent in the catches at a larger size range (Thomson & Baelde 2002). More selectivity patterns, based on length rather than age, should be explored when age-structured SRA models are used. Dome-shaped selectivity (i.e. declining availability at largest sizes) is also a possibility (Thomson & Baelde, 2002) although must be used with care as it can lead to overconfidence through the estimation of an invisible 'cryptic biomass' of highly fecund mature fish that are not vulnerable to fishing pressure.
- Ultimately, the collection of data that can support assessments, in particular an index of abundance, would be of most benefit to sustainable management of this stock. Close Kin Mark Recapture might provide such an index but will not be available for several years (if at all).
- Further consideration of HCRs might lead to (MSE tested) rules that use less formal performance indicators than those used by Tier 1 assessments. These could be based on indicators e.g. catches as a proportion of TAC, length data (if available) and would also be useful for the setting of TACs for 'weight of evidence' species in the SESSF.

15.8 Ackowledgements

Natalie Dowling and Geoff Tuck (CSIRO) are thanked for useful comments on an earlier draft of this manuscript and for several informative conversations during the development of the Tier 5 approach this year. Dan Corrie, Sally Weekes and Lou Cathro (AFMA) provided insights in the data, fishery, and management of this stock as well as helping to make sense of the results from the data-limited methods. Members of SESSFRAG and SERAG provided input into the 2018 Tier 5 assessment process, much of which was repeated here.

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16. 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.

17. Conclusion

The 2021 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 (Blue Grenadier, Silver Warehou, Eastern Jackass Morwong and Eastern Zone Orange Roughy), projection updates for School Whiting and Tiger Flathead, as well as cpue standardisations for shelf, slope, deepwater and shark species, Tier 4 and Tier 5 analyses. Typical assessment outputs provided indications of current stock status and an application of the Commonwealth Harvest Strategy framework. This framework is based on a set of assessment methods and associated harvest control rules, with the decision to apply a particular combination dependent on the type and quality of information available to determine stock status (Tiers 1 to 5).

The assessment outputs from this project are a critical component of the management and TAC setting process for these fisheries. The results from these studies are being used by SESSFRAG, industry and management to help manage the fishery in accordance with agreed sustainability objectives.

Stock status and Recommended Biological Catch (RBC) conclusions (non-Tier 1):

Catch-per-unit-effort data is an important input to many of the stock assessments conducted within the SESSF, where it is used as an index of relative abundance through time. Summarized are the main findings regarding the standardization for 20 species, distributed across 41 different combinations of stocks and fisheries using statistical models customized to suit each set of circumstances. The results from the standardisations are a key input to Tier 4 and Tier 1 assessments.

Standardized CPUE has generally increased since about 2005 for Pink Ling west, and non-spawning Blue Grenadier has continued its increasing recent trend. Other species/stocks have shown shorter term increases over the last two to three years e.g., Pink Ling east, Ribaldo, Royal Red Prawn (a marked recent increase), offshore Ocean Perch, School Whiting (trawl) and Western Gemfish. Silver warehou east and west appear to have stabilised after at least a ten-year general decline. By contrast, standardized CPUE has declined for John Dory, Mirror Dory, Eastern Morwong, Tiger Flathead (Danish seine), Ocean Jackets, and Silver Trevally. There are some recent positive signs for Eastern Gemfish. For Blue-eye Trevalla (slope) a downward trend is apparent in the standardized CPUE series over the 2018-2020 period. For Eastern Deepwater Sharks, the standardized CPUE trend has been essentially low and flat since 2010, despite an increase in 2020 relative to the previous year. For Western Deepwater Sharks, standardized CPUE has been approximately cyclic since about 2007 with lows over the 2012-2014 period and has returned to the long-term average since 2016. For Mixed Oreos, standardized CPUE has been essentially flat over the 1995 – 2019 period, but below the long-term average and increased to the long-term average in 2020. For Gummy Shark, standardized catch per netlength (CPUN; kg/m) in South Australia increased from 2013 to 2016 and decreased to below the long-term average in 2020. By contrast, gillnet standardized CPUN in Bass Strait is cyclic and has increased above the long-term average in 2020. Standardized CPUN of gillnet caught Gummy Shark around Tasmania remained noisy and flat with increases in the last two years. For trawl, standardized CPUE in both South Australia and Tasmania have mostly increased and above the long-term average since at least 2014. By contrast, standardized CPUE in Bass Strait has been mostly flat and above the long-term average since 2008. Standardized CPUE for bottom line has remained mostly flat and noisy, with 2018 – 2020 period mostly exceeding the long-term average. For Sawshark, standardized CPUN for gillnets exhibits a steady decline since about 2001, with small increases in recent years, except in

2017. Trawl caught Sawshark standardized CPUE exhibit a noisy but flat trend. Sawshark standardized CPUE by Danish seine has remained either consistently below or at the long-term average since 2001. For Elephantfish, gillnet standardized CPUN is flat and noisy, and below the long-term average since about 2013. In recent years discard rates have been very high, which may imply that their CPUE is in fact increasing.

For the Tier 4 stocks, the 2021 estimated RBC for Silver Trevally was approximately 178.85 t, an approximate 190.84 t decrease compared to the 2020 estimated RBC (369.69 t). This decrease in RBC can be mostly attributed to a drop in the most recent standardized CPUE (including discards). For Mirror Dory – East, the 2021 estimated RBC was 112.93 t, a decrease of 32.76 t compared to the 2020 estimated RBC (145.69 t). For Mirror Dory – West, the 2021 estimated RBC was 56.18 t, a decrease of 5.39 t compared to the 2020 estimated RBC (61.57 t). For John Dory, the 2021 estimated RBC was 0 t compared to the 2017 estimated RBC (485 t). For Blue eye Trevalla, the 2021 RBC was approximately 349.32 t, corresponding to a 122.29 t increase compared to the 2020 RBC.

The Tier 5 assessment for Blue-eye Trevalla (seamounts) showed that if catch-MSY (or any catch-only method) is all that can be used, then an RBC could be set once but should remain fixed into the future because updating the analysis when one only has new catch data is invalid. The geometric mean values of MSY range from 96t to 105t (if Gascoyne is not considered, as we recommend). The age-structured SRA model is very sensitive to the form of the selectivity function that is chosen, and to the upper limit for the harvest rate imposed. Across the range of values for natural mortality, steepness, upper harvest rate and stock definition (catch time series) RBCs range from 0t to 176t. Ignoring models that include catches from the Gascoyne, an annual catch in the range of 30-40t (which includes the 36t per annum currently allowed) appears likely to be sustainable.

18. Appendix: Intellectual Property

No intellectual property has arisen from the project that is likely to lead to significant commercial benefits, patents or licenses.

19. Appendix: Project Staff

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