A re-examination of underlying model assumptions and resulting abundance indices of the Fishery Independent Survey (FIS) in Australia’s SESSF

Final Report

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Executive Summary

The model-based Fishery Independent Survey (FIS) for the Southern and Eastern Scalefish and Shark Fishery (SESSF) was developed in the lead up to the first survey in 2008 and is unique in a fisheries context in that it differs from a random stratified design, thereby allowing considerable flexibility in sampling station location and survey implementation for this complex multispecies fishery. However, the model required refinement to condition it on more recent and more relevant data from 2008 onwards and to account for considerable changes that occurred in the fishery following the structural adjustment. This project addressed these refinements, as outlined below.

Background

The original FIS statistical model was designed over ten years ago. The model was conditioned on Commonwealth logbook data over 2001 – 2005. Much has changed in the SESSF since 2005, such as marked changes to the fishing fleet resulting from the structural adjustment, and the potential for climate induced changes in fisheries and fish distribution. This is particularly relevant to the south-east of Australia which is a known climate hot-spot. The model may now be outdated since the initial conditioning due to potential changes to the relative abundance of different SESSF species and changes in species behaviour. In an effort to find efficiencies in the sampling design, it was timely to re-examine the underlying model assumptions (e.g., depth preference, day-night preference, and species range limits). This provided updated model-based CVs using more recent Commonwealth logbook data, and more reliable fishery independent abundance indices for selected SESSF species.
The FIS was originally intended to support the management of SESSF species, providing an abundance series that is independent of fisher behaviour, market forces, closed areas, management regulations and changes in gear used. Given the investment by the fishing industry and Government in the five completed surveys over the last 10 years, it is appropriate to consider how new FIS abundance indices can better inform SESSF stock assessments. To date, these indices have been incorporated in Tier 1 stock assessments for five species.

Aims/objectives

Objectives of this project are to:

1. re-examine some of the underlying assumptions of the survey;
2. update data that conditions the model and find efficiencies in sampling design; and,
3. use data simulation to examine the utility of the estimates given the process and sampling errors that have been observed.

Two additional objectives (outside the scope of this project) were also examined:

4. account for within-year variability to estimate FIS abundance indices, and
5. incorporate updated FIS abundance indices in seven Tier 1 stock assessments.

Methodology

Method 1: Station re-examination

Stations were identified with the least effect on precision of abundance indices. To maintain balanced sampling in real and covariate space, a metric based on the distance to nearest neighbouring stations was incorporated to select an ordered list of 12 stations that could potentially be relocated more efficiently for the four agreed key species (Tiger Flathead, Pink Ling, Blue Grenadier, Silver Warehou).

Method 2: 2018 reconditioned model (FIS2)

In order to update the data used to condition the model, Generalized Additive Model (GAM) assumptions were re-examined against newer logbook data and were re-run using Commonwealth logbook data from 2008 to 2016 (FIS2). Abundance indices and CVs were recalculated using revised model parameters for surveys in 2008, 2010, 2012, 2014 and 2016, for a variety of fleet configurations, either reflecting all zones, or matching the separate fleet definitions as used in the Tier 1 stock assessments.

Method 3: Data simulation using 2018 reconditioned model estimates

Abundance series were obtained from 100,000 simulations, showing the effect of sampling error for each key species. A statistical GAM model was then fitted to each, to estimate the process error given the model sampling error. This process error was then added to the sampling error to estimate the overall variance. Another 100,000 simulated series were sampled using the combined variance (sampling error and process error). These show how variable and uncertain the simulated series could potentially be, given the variation typically occurring in FIS observations.

Additional Method 4: Reconditioned model accounting for within-year variation (FIS3)

To explore the effect of within-year changes, a day-of-year model term was added to the existing GAM model used in FIS1 and FIS2 for each of the four agreed species. The logbook model was used to adjust for the limited within-year coverage of the FIS, by extrapolating the FIS abundance across the rest of the year. Abundance indices and CVs were calculated for surveys in 2008, 2010, 2012, 2014 and 2016.

Additional Method 5: Stock assessment scenario exploration

To examine the impacts of FIS abundance indices on stock assessments, a number of scenarios were explored using Stock Synthesis on seven stocks that were assessed in 2018. Comparisons were made between absolute and relative spawning biomass time series, recruitment time series and fits to both CPUE and FIS abundance indices for each scenario. This enabled an examination of the effect of different data sources on the assessment outputs, and gave an indication of differences in the assessment results and fits to abundance indices.

Results/key findings

Results 1: Station re-examination

Twelve candidate stations were selected from a group of 60 stations for potential design refinement, applied to the four agreed key species.

Results 2: 2018 reconditioned model (FIS2)

Spatial and depth bounds for all species were revised for FIS2. The FIS2 model predicted abundance series were mostly similar with those from FIS1. Differences in overall shape and apparent trend between FIS1 and FIS2 were greatest for Pink Ling. In most years and most stocks FIS2 abundance CVs were lower than FIS1 abundance CVs.

Results 3: Data simulation using 2018 reconditioned model (FIS2) estimates

When sampling and process error were considered, the potential range of results over all survey years was quite variable given the CVs observed for the stocks examined.

Results 4: Reconditioned model accounting for within-year variation (FIS3)

The transition from FIS2 to FIS3 resulted in generally greater changes to the shape and trend of the abundance series for all species/stocks examined, compared to the transition from FIS1 to FIS2. Generally, FIS3 CVs were lower than FIS2 CVs for the four key species examined. In all years, FIS3 abundance CVs were lower than FIS2 abundance CVs for Tiger Flathead – zone 10, 20, Blue Grenadier non-spawning, Pink Ling east and Pink Ling west. In most years, FIS3 CVs were lower than FIS2 CVs for Tiger Flathead – zone 30, Blue Grenadier spawning, Silver Warehou east and Silver Warehou west.

Results 5: Stock assessment scenario exploration

The inclusion of FIS abundance series in assessments generally did not lead to markedly different results with regard to key stock indicators, except for Pink Ling, or unless recent CPUE was excluded. This is partially due to the short FIS time series being less influential than the longer CPUE time series, but also because, for some species, the FIS series has little conflict with other data sources.

Implications for relevant stakeholders

Implications 1: Station re-examination

The framework developed could assist with any future refinements to the FIS design. The set of candidate stations is dependent on the species chosen, so a different set of key species would produce a different set of candidate stations for relocation.

Implications 2: 2018 reconditioned model (FIS2)

Software was updated. The reconditioning analyses led to a reduction in the CVs, increasing the utility and confidence in the FIS2 results.

Implications 3: Data simulation using 2018 reconditioned model estimates

Large variation was observed in possible trends from simulations using the calculated CVs for the five survey abundance estimates. Simulation analyses suggest that process error should be explicitly considered, as sampling error alone could not produce such variable results.

Implications 4: Reconditioned model accounting for within-year variation (FIS3)

Differences in seasonal patterns between years were accounted for which led to a further reduction in both abundance CVs and inter-survey variability, hence increasing the utility of the FIS3 results.

Implications 5: Stock assessment scenario exploration

Due to the relative length of the FIS abundance series compared to other data sources, the FIS series is likely to be too short to adequately assess the impact on stock assessment results in most scenarios explored.

Recommendations

Objective 1: Station re-examination

The list of species for which the design is sufficiently robust into the future should be reviewed. If required, the framework developed could be used to advise potential refinements of the FIS, further optimising the survey to estimate more reliable indices for the species selected. This in turn may reduce the reliability of indices for other species. For example, greater emphasis on deeper water may be desirable to improve the statistical balance of the survey design. However, for compatibility with the existing survey, it would be prudent to retain as much consistency as possible with previous surveys, by minimising the changes to station locations.

Objective 2: 2018 reconditioned model (FIS2)

As the reconditioned series (FIS2), used data after the structural adjustment to condition the model, which coincides with the collection of FIS data, it is recommended that the FIS2 abundance series be used in preference to the FIS1 series in the future, although FIS 3 should also be considered (see Additional Objective 4). The use of more recent data to condition the model is an improvement over the initial conditioning that used data from year 2001 to 2005. This was not possible when the FIS was initially implemented as these data were not available then.

Objective 3: Data simulation using 2018 reconditioned model estimates

This objective highlighted that the observed variation in the abundance series can lead to marked differences in resulting trends for the five years of the FIS. In order to provide greater confidence in the indices and consequent trend, a longer time series would be needed, as this will reduce the impact of variation (sampling and process error). Accounting for the process error would improve the utility of the FIS, as it would reduce one source of variation.

Additional Objective 4: Reconditioned model accounting for within-year variation (FIS3)

It is recommended that the FIS3 abundance series be used in preference to the FIS2 or FIS1 series in the future. Changes in fishing practice could influence the FIS3 abundance series via logbook data, either through conditioning or examining within-year variation. Consultation with industry, management and other key stakeholders would be beneficial to ensure that this variation is not a result of changes in fishing practice. Further work will be required to calculate FIS3 abundance indices for additional species, with careful examination of model fits and diagnostics for all species.

Additional Objective 5: Stock assessment scenario exploration

It is recommended that the effects of including the FIS3 abundance series are examined in stock assessments as additional scenario explorations. Given the varying results when the FIS2 series was included for different stocks, investigating the effects of including FIS3 on assessment outcomes could be informative.

Keywords

Model-based survey design, Generalized additive models, fishery independent survey, stock assessment, Tiger Flathead, Blue Grenadier, Jackass Morwong, Silver Warehou

1. Introduction

Selected species in the Commonwealth Southern and Eastern Scalefish and Shark Fishery (SESSF) rely on fishery-dependent catch-per-unit-effort (CPUE) data series as the main abundance index. These series are used as key inputs in the Tier 1 and Tier 4 assessments. To augment this fishery-dependent approach, a multi-species, fishery-independent survey (FIS) has been implemented biennially since 2008 for both quota and non-quota SESSF species (Knuckey et al., 2012; Peel et al., 2012; Knuckey et al., 2013; Upston et al., 2013; Day and Peel, 2015; Knuckey et al., 2015; Knuckey et al., 2017). Increasingly, FIS-abundance indices are being considered as additional inputs into Tier 1 stock assessments to support management.

The aim of the original FIS was to achieve reasonable precision of abundance indices (i.e., with coefficients of variation (CV) ≤ 0.3) for 11 SESSF species using annual surveys conducted in both summer and winter. Budget constraints limited the FIS implementation to biennial. For 2008, 2010 and 2012, separate surveys were conducted in summer and winter. Further budgetary constraints resulted in summer surveys being discontinued from 2014 onwards and subsequent FIS-abundance indices and corresponding CVs were based solely on biennial winter surveys in 2014 and 2016.

While the target CVs were set for 11 SESSF species, data collection included a broader suite of species, with abundance indices and CVs estimated for additional species, with some of these achieving the desired target.

The FIS design and analysis were based on an innovative model-based framework intended to allow flexibility to cope with foreseen and unforeseen logistical constraints, both before and after a survey (Peel et al., 2012). Furthermore, the FIS methodology relies on strength from the unbiased aspects of existing large sample-size logbook data, such as species depth preferences. This information is combined with the FIS to maintain its unbiased independent nature and provides better predictions than those provided by small FIS samples in isolation.

Results from the most recently available FIS estimates in the SESSF indicate that there is considerable inter-survey variation beyond biological feasibility (process error) and intra-annual variation (sampling error) in relative abundance indices for a number of key SESSF species (Knuckey et al. 2017; SMARP 2015). Examples of stocks that display substantial inter-annual variation beyond what would be considered to be biologically plausible include Silver Warehou (*Seriolella punctata*), Redfish (*Centroberyx affinis*), Jackass Morwong (*Nemadactylus macropterus*), and Blue Warehou (*Seriolella brama*), while others show a mostly biologically plausible trend. Relatively consistent FIS-abundance trends across all five years (2008, 2010, 2012, 2014, 2016) appear for Pink Ling (*Genypterus blacodes*), John Dory (*Zeus faber*) and Ribaldo (*Mora moro*), but for others the trend is likely beyond biologically feasible biomass increases or decreases (e.g. Gummy Shark (*Mustelus antarcticus*); School Shark (*Galeorhinus galeus*)).

To date, SESSF FIS-abundance indices corresponding to five species (i.e. Tiger Flathead (*Platycephalus richardsoni*), Jackass Morwong, Blue Grenadier *Macruronus novaezelandiae*), Silver Warehou and Pink Ling) have been incorporated into Tier 1 stock assessment models (Day 2017, Day and Castillo-Jordán 2018a, 2018b, Castillo-Jordán and Tuck 2018, Burch et al., 2019, Cordue 2018). By contrast, FIS-abundance indices have not been incorporated into Tier 1 stock assessments for a range of different reasons for Redfish, School Whiting, Gummy Shark and School Shark.

There is currently no accepted methodology to include FIS-abundance indices for Tier 4 species, as the method requires a long time series so that a reference period can be included. Also, for Tier 3 stocks, existing techniques do not use any abundance index to assess stock status. FIS-abundance indices are estimated for non-quota species, but have large estimated CVs and are not currently used to assess stock status.

In this project, some of the underlying assumptions of the survey design and sampling efficiencies will be re-examined, data used to condition the model updated and sampling and process error investigated in the context of observed CVs from the FIS. Two additional objectives (outside the scope of this project) will also be achieved by accounting for within-year variability to estimate FIS abundance indices and incorporating updated FIS abundance indices to seven Tier 1 stock assessments.

2. Objectives

Objectives of this project are to:

1. re-examine some of the underlying assumptions of the survey;
2. update data that conditions the model and find efficiencies in sampling design; and,
3. use data simulation to examine the utility of the estimates given the process and sampling errors that have been observed.

Two additional objectives (outside the scope of this project) were also examined:

4. account for within-year variability to estimate FIS abundance indices; and
5. incorporate updated FIS abundance indices in seven Tier 1 stock assessments.

3. Methods

3.1 Method 1: Station re-examination

The existing FIS analysis (FIS1) employs statistical Generalized Additive Models (GAMs) and a model-based design and analysis (Peel et al., 2012). Compared to traditional random stratified survey designs, this method allows more robustness to non-random sampling and changes in sampling design over time. Recent advances in the spatial modelling package in R (R Core Team, 2017) now allows the inclusion of random effects into the statistical model, which may allow identification of redundant or less informative sampling locations. This could potentially produce improved survey efficiencies by (i) modifying effort, (ii) reducing the number of stations or (iii) moving stations to under-sampled areas to reduce CVs.

A statistical model was fitted with station as a random effect as originally planned (Objective 1). However, the use of this approach made it difficult to select individual stations, hence making it sub-optimal as a means to identify stations that were less informative (i.e. increase design efficiency). Therefore we adopted a statistical Cross-Validation analysis by leaving out each station in turn and identifying stations for which the estimated design CV does not increase above a specified threshold (Figure 2).

The current model-based survey has approximately 200 survey stations positioned at different depths and locations across the area of the fishery, from which the catch composition of standardised trawl tows are determined. Initially, it was necessary to determine what constitutes a sample or station across years. This was more complex than just using the design stations implemented in the FIS, as the actual location of the station may deviate from the design location due to practicalities around localised conditions. Hence, realised samples from a particular station over time may overlap spatially with realised samples from a different station making station identification difficult from a single shot location alone. Therefore, the planned design locations were replaced with clusters of FIS samples based on their closeness in the model covariate space and physical location (i.e. distance along the coast, depth, longitude and latitude) and assigned a station identification to each cluster (Figure 1).

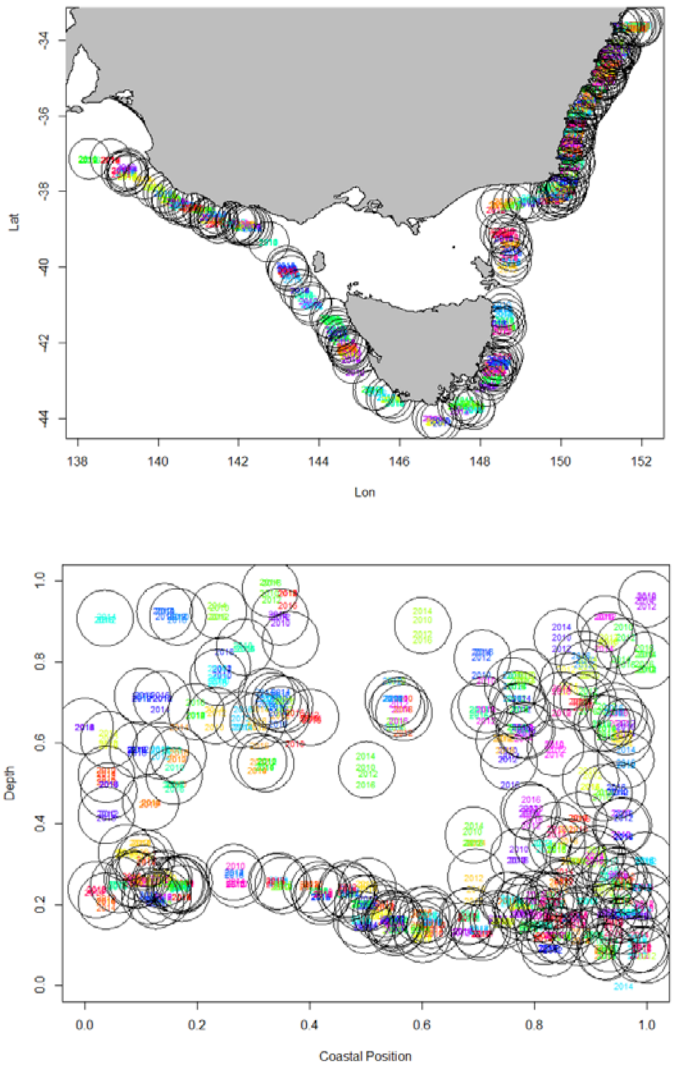

Figure 1. Clustering of FIS samples to generate stations. Colours within a circle represent the same station and numbers label the year to represent the location and depth for that year. This is represented geographically (upper plot) and in a depth and location (coastal position) co-ordinate space (lower plot).

The FIS model employs distance along coast and depth to determine a station, which is essentially physical location. However, in the model these are considered independently so the link to physical location is implicit. Therefore, we included actual spatial location (longitude, latitude) in the cluster analysis to group shots that had similar covariates and location. This will offer some protection in case there are some unknown environmental covariates excluded from the model because locations closer in physical location will tend to have similar covariates (Tobler's law: Tobler (1970)). In theory, clustering including physical location will result in samples within each cluster having less variation (similar covariate values) than samples between clusters.

The importance of a station, with respect to the CV of the abundance index, is species dependent. This approach identifies the stations which are least important for a chosen set of species. Four key species were agreed for use in this analysis (selected by the Steering Committee meeting, May 2018). The selection of these species was based on (i) economic importance to the SESSF (Gross Value of Production), (ii) variance in FIS abundances indices and (iii) representative depths and spatial range of species. The selected species were Tiger Flathead (*Platycephalus richardsoni*), Pink Ling (*Genypterus blacodes*), Blue Grenadier (*Macruronus novaezelandiae*) and Silver Warehou (*Seriolella punctata)*. A different set of least important stations will be identified if different species are chosen.

The approach identifies an ordered list of stations which are candidates for redesign for all agreed species according to the following algorithm and flowchart (Figure 2):

Set:
S = set of species to be assessed
P = the number of stations to be determined for potential redesign
tol = the tolerance $\in [0,1]$ for a CV to be considered unchanged by a station's removal (e.g. 0.001)

Identify stations outside bounds for all species *S* and remove from consideration

Set design D_1 as the design with all the remaining stations

For p = 1 to *P*

{

For each species *s* in *S*

{

Calculate $CV_{s,full}$ =precision current design D_p

For each station *i* in the design D_p

{
Calculate $CV_{s,i'}$ = precision of design D_p without station *i*
}

}

Identify set of stations Ω where $CV_{s,i'} < CV_{s,full} * (1+tol)$ for all $s \in S$ species

Calculate M_Ω = mean distance of each of the stations in Ω to its nearest 5 neighbouring stations in D_p

Determine A_p = the station from the selected stations Ω that has the closest neighbouring stations (i.e., the smallest M_Ω)

Remove station A_p from the current design D_p to form design D_{p+1}

}

Return the answer D_P *p=1,..,P*

Stations outside the chosen species range (coastal position and depth), were initially identified (Table 1 and Table 2). These stations would be ideal candidates for a potential redesign as they could potentially be removed. However, these were retained as (i) they may be of use for other species (ii) the chosen species range may change, and these stations may provide robustness and a way to detect and monitor such range changes.

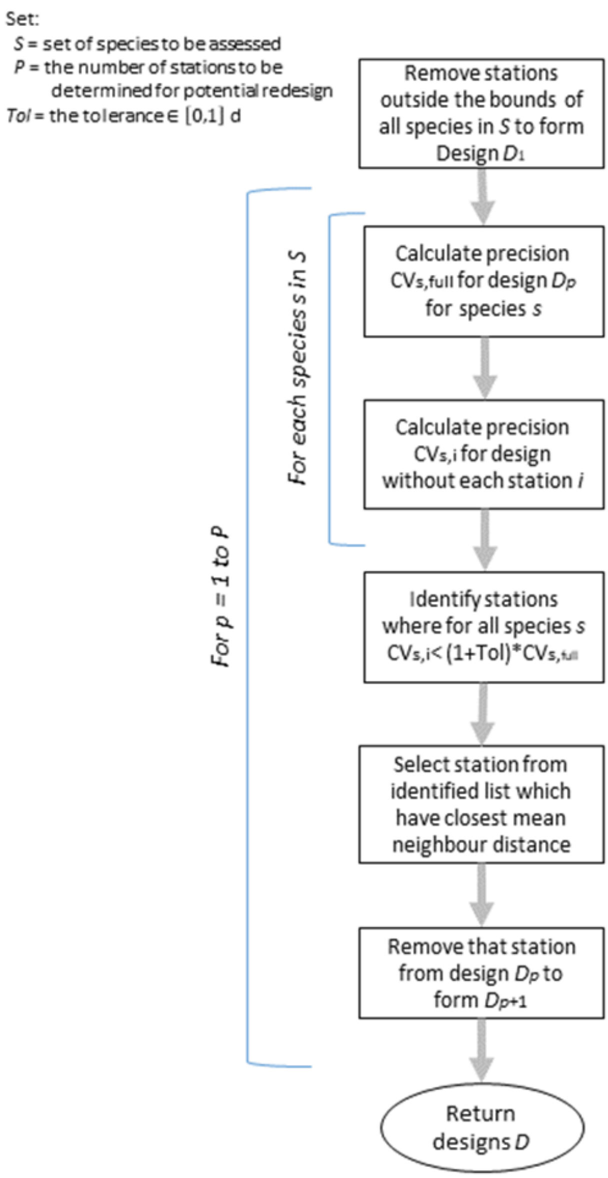

Figure 2. Flowchart of the process to identify stations for potential redesign.

To estimate the theoretical precision of the abundance index for each species based on Commonwealth logbook data from 2008-2016, CVs at each stage were calculated based on the same methodology as the initial FIS design (Peel et al., 2006) which used logbook data from an earlier period (2001-2005). Once the CVs were calculated for each species, the stations with the least effect on precision were identified in terms of the CV staying below a set threshold. These stations would therefore be good candidates for relocation. To maintain reasonably balanced sampling in real and covariate space, a metric based on the distance to nearest neighbouring stations was incorporated to select which of the identified list of potential stations to remove. Specifically, this prioritised stations which had close neighbours for potential removal. It also reduced the chance of excluding stations in sparsely sampled areas, in order to increase robustness by potentially accounting for future changes in species distribution. The selected station was removed, and the process repeated using the remaining stations to determine the next station to be dropped. This was continued until 12 candidate stations for redesign had been identified. The resulting list of candidate redesign stations was ordered and could not be subdivided, as each station was dependent on all other stations earlier in the list also being removed. The list could be shortened by systematically removing stations last added to the list, (i.e. to get a shorter list, stations removed from the list would be removed in reverse consecutive order). This process was employed using the four key species (Figure 2).

3.2 Method 2: 2018 reconditioned model (FIS2)

The existing FIS analysis (FIS1) employs statistical Generalized Additive Models (GAMs) and a model-based design and analysis (Peel et al., 2012) using R statistical software (version 3.5.0) and package (mgcv). A number of components in the FIS model, related to general species behaviour, are based on Commonwealth logbook data (e.g. species range limits, depth and day-night preference); components that are unlikely to reflect any bias by being based on fishery-dependent logbook data. Specifically, the model from Commonwealth logbook data was used to help interpolate FIS data to model densities between FIS sample locations. Commonwealth logbook data used in the original design was from 2001 to 2005. If there have been systematic changes in species or fisher/fleet behaviour since then, this could contribute to overall process error.

To address these issues, a 2018 reconditioned model (FIS2) was developed as follows. For selected species, models were re-examined/checked (i.e. species range limits and depth preferences) against newer logbook data, FIS data and statistical models re-analysed as required (Table 3). The geographical limits of a selected number of species was carefully examined, due to indices being unduly influenced by FIS shots from areas not representative of the fishery (e.g. small catches of Tiger Flathead along the west coast of Tasmania; Blue Grenadier catches outside Zone 40 during the spawning season). As well as improving the accuracy of current FIS outputs, this work may provide insight into any changes in species behaviour and/or distribution.

Abundance indices and CVs calculated for surveys in 2008, 2010, 2012, 2014 and 2016 using the 2018 reconditioned model (FIS2) were compared to the previous values conditioned on logbook data from 2001-2005 (FIS1; Table 5, Table 6; Upston et al., (2013), Day and Peel (2015), Knuckey et al., (2017)).

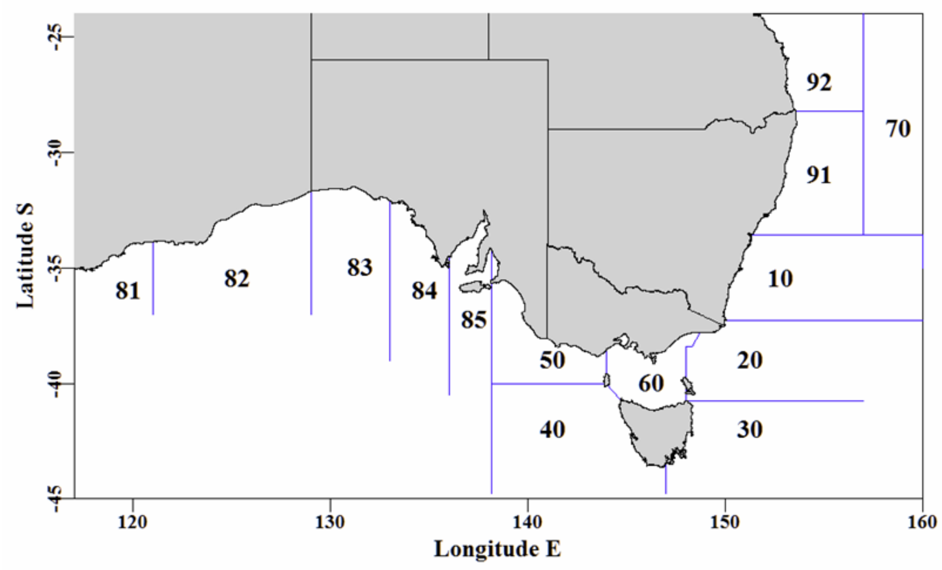

Figure 3. Statistical reporting zones in Australia's Southern and Eastern Scalefish and Shark Fishery (SESSF).

As has been done previously, FIS abundance indices were calculated for a variety of fleet configurations, either reflecting all zones, or matching the separate fleet definitions as used in the Tier 1 stock assessments (see Table 3 for fleet configurations for selected species). All analyses were conducted on winter survey data only, to enable use of the full five biennial surveys (2008, 2010, 2012, 2014, 2016), since the summer surveys stopped after 2012.

3.3 Method 3: Data simulation using 2018 reconditioned model estimates

One hundred thousand simulated abundance series were obtained by sampling from a log-Normal distribution using observed means and variances from the 2018 reconditioned model estimates (FIS2) for the four key species, for each fleet configuration, in each survey. However, this only shows the effect of sampling error for each key species.

A statistical GAM model was then fitted to each FIS2 series, to estimate the process error given the model sampling error. This process error was then added to the sampling error to estimate the overall variance. Another 100,000 simulated series were sampled from the log-Normal distribution using the realised mean from the reconditioned model and the combined variance (sampling error and process error). These show the effects of the combination of sampling error (within-year) and process error (between survey) for each key species, and how variable and uncertain the simulated series could potentially be, given the variation typically occurring in FIS observations.

3.4 Additional Method 4: Reconditioned model accounting for within-year variation (FIS3)

For some species the existing FIS series features changes in abundance that were greater than biologically feasible between surveys and greater than anticipated given the calculated precision (CVs). Some of this variation may be explained by looking at the temporal pattern of CPUE variation within a year, and which part of that pattern (peaks or troughs) the FIS observed in any given survey. If the seasonal pattern varies between surveys, this could introduce biases that the FIS1 and FIS2 models do not consider. For example, if a species abundance or availability is seasonal and reaches a peak as one year of the FIS is conducted, this is likely to produce biased results compared to another year of the FIS which happens to be conducted at a seasonal trough. If the peak coincided with the FIS in one year, this would result in a higher estimated FIS abundance compared to years when the peak occurred at a slightly different time of the year. Some protection was incorporated in the original design by having separate summer and winter surveys, but this protection no longer exists since the summer survey was discontinued from 2014 onwards.

To explore the effect of these within-year changes, a day-of-year model term was added to the existing GAM model used in FIS1 and FIS2 for each of the four agreed species. The logbook model was used to adjust for the limited within-year coverage of the FIS, by extrapolating the FIS abundance across the rest of the year.

3.5 Additional Method 5: Stock assessment scenario exploration

To examine the impacts of FIS abundance indices on recent SESSF stock assessments, a number of scenarios were explored using the Stock Synthesis (SS) assessment platform (Methot et al., 2018). Stock Synthesis models were run and re-balanced in each case with input data modified by including and excluding various FIS-related data sources. This was conducted on the following stocks (with associated assessment and FIS characteristics in brackets):

1. Jackass Morwong west (relatively short CPUE series, poor fit to CPUE, mostly moderate CVs on the FIS abundance series (FIS1: 0.25 - 0.34; FIS2: 0.23 – 0.47));

2. Jackass Morwong east (long CPUE series with good fits to CPUE and multiple abundance indices, high CVs on the FIS abundance series (FIS1East: 0.28 - 0.68; FIS2East: 0.32 - 0.93; FIS1Tas: 0.30 - 0.77; FIS2Tas: 0.41 - 1.03));

3. Blue Grenadier using the FIS from the non-spawning fleet, SESSF zones 10, 20, 30 and 50 (very high CVs on the FIS1 abundance series (FIS1: 0.34 - 2.3; FIS2: 0.11 – 0.28));

4. Blue Grenadier using the spawning fleet, SESSF zone 40 (moderate CVs on the FIS1 abundance series (FIS1: 0.26 – 0.59; FIS2: 0.16 – 0.21));

5. Silver Warehou (low-moderate CVs on the FIS1 abundance series (FIS1East: 0.18 - 0.28; FIS2East: 0.09 – 0.18; FIS1West: 0.15 - 0.35; FIS2West: 0.11 – 1.25) but high inter-survey variability due to infrequent very large catches of this schooling species);

6. Pink Ling west (good fit to CPUE series, low CVs on the FIS abundance series (FIS1: 0.18 - 0.22; FIS2: 0.18 – 0.21)) and

7. Pink Ling east (good fit to CPUE series, low CVs on the FIS abundance series (FIS1: 0.21 - 0.22; FIS2: 0.16 – 0.18)).

All of these species were assessed in 2018 (Day and Castillo-Jordán 2018a, 2018b, Castillo-Jordán and Tuck 2018, Burch et al., 2019, Cordue 2018) using Stock Synthesis or, for Pink Ling, CASAL (Bull et al., 2012). These assessments included FIS abundance indices either in the base case or as a sensitivity to the base case and, across assessments, feature a range of CVs for the associated FIS abundance indices.

The Pink Ling analysis (Additional Method 5) was based on a Stock Synthesis model updated from a previous assessment (Whitten et al., 2012) because the most recent Pink Ling assessments (Cordue 2015 and Cordue 2018) were conducted in CASAL and input files were not available. This Pink Ling model used very similar data to that used in the current accepted assessment (Cordue 2018), but with different treatment of CPUE standardisation and a different model platform (CASAL). The Pink Ling Stock Synthesis model was simply included in these analyses to illustrate potential differences due to inclusion of different FIS series and exclusion of recent CPUE data. The Pink Ling model here (Curin Osorio, pers. comm.), while a plausible model, is not intended to be used for management purposes and Stock Synthesis models of Pink Ling have not been used for management purposes since 2012 and are not the currently agreed assessment model. However, differences in model outputs (in depletion estimates for example) from the various FIS scenarios could point to important differences in the agreed CASAL Pink Ling assessment that should be explored in the future.

A number of scenarios were explored using the FIS data from the five surveys conducted between 2008 and 2016:

1. No FIS abundance indices
2. Including the FIS abundance indices used in the 2018 stock assessments (FIS1)
3. Scenario 2 with FIS length frequencies also included where available (only for eastern Jackass Morwong and western Jackass Morwong)
4. Scenario 2 with the commercial CPUE series truncated after 2006

Scenarios 2-4 were also repeated using the reconditioned FIS abundance indices obtained from Objective 2 from this project (FIS2) to examine differences in the stock assessment outcomes between using data from the original FIS abundance series (FIS1) and the reconditioned FIS abundance series (FIS2).

For each scenario, the modified assessment was iteratively reweighted after the input data was modified, following the same procedures used in the 2018 SESSF stock assessments (e.g. Day and Castillo-Jordán, 2018a).

For the stocks examined, comparisons were made between absolute and relative spawning biomass time series, recruitment time series and fits to both CPUE and FIS abundance indices for each scenario, to examine the effect of different data sources on these assessment outputs, and to give an indication of difference in the assessment results and fits to abundance indices. Time series were plotted together to enable easy comparison between scenarios for each stock.

4. Results

4.1 Objective 1 Results: Station re-examination

Five stations were identified as outside the species range (depth and coastal position) for all four key species (Table 1, Table 2). For Pink Ling, 88 of 192 stations had CVs below the threshold (i.e. the CV changed by less than 0.1 % from the CV of the full design; Figure 4). The collection of stations below the threshold for the three other key species resulted in 60 stations common to all four agreed key species (Tiger Flathead, Pink Ling, Blue Grenadier, Silver Warehou) for the first nearest neighbour mean distance selection (Figure 5). Twelve candidate stations were selected from this group of 60 stations. Other criteria could be used to choose stations such as cost or logistic difficulty in obtaining samples from stations, but only the lowest mean neighbour distance was used here.

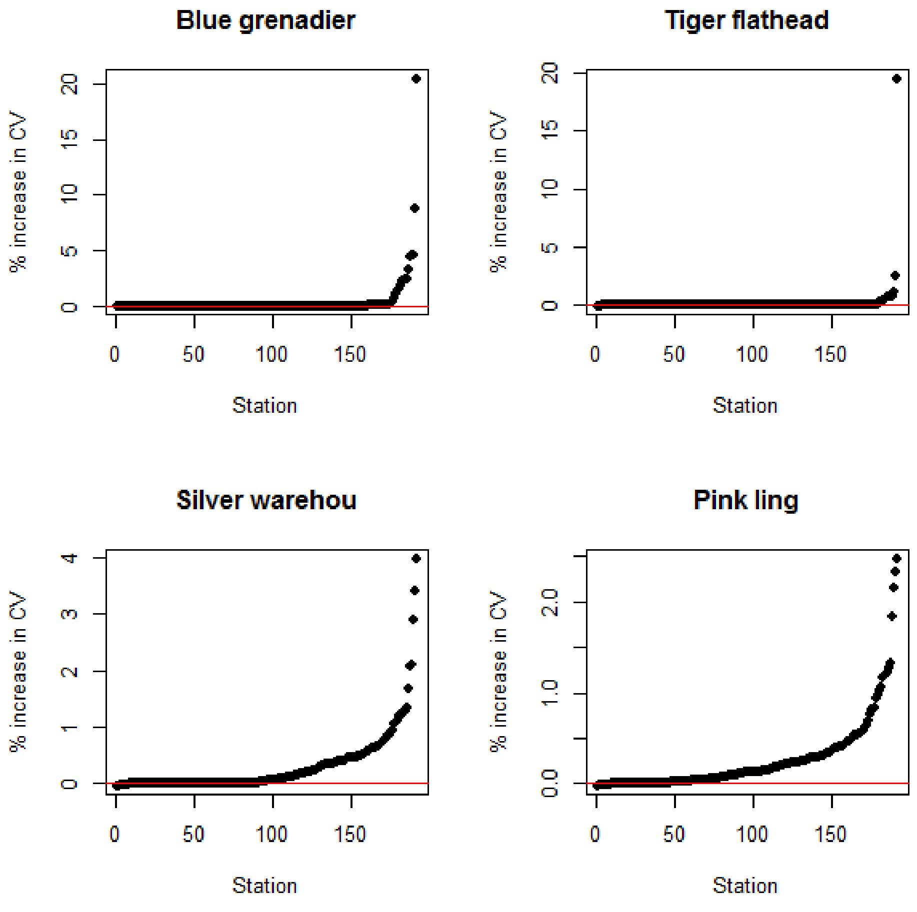

Figure 4. CV (% increase) by station (sorted) before the first station was selected for the four key species. The CV (% increase) for the full design (zero) is indicated by the red line.

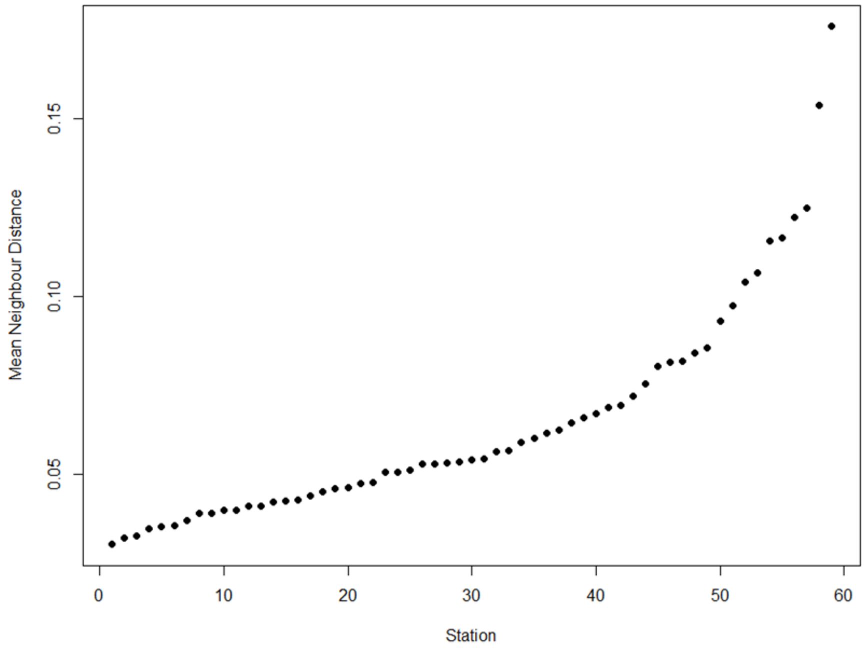

Figure 5. Mean distance (in normalised multi-dimensional space: coastal position x depth x latitude x longitude) between neighbours for the 59 sorted candidate stations before the first station was selected.

The 12 candidate stations for redesign are shown in Figure 6. Predominantly, these were stations in shallower water (<200 m) and more generally on the eastern half of the survey (Figure 6). As Blue Grenadier are rarely caught shallower than 200 m, the FIS catch was zero (2008-2016) for this species for all 12 candidate stations. By contrast, there were some catches from these 12 stations for the other three key species (Figure 7).

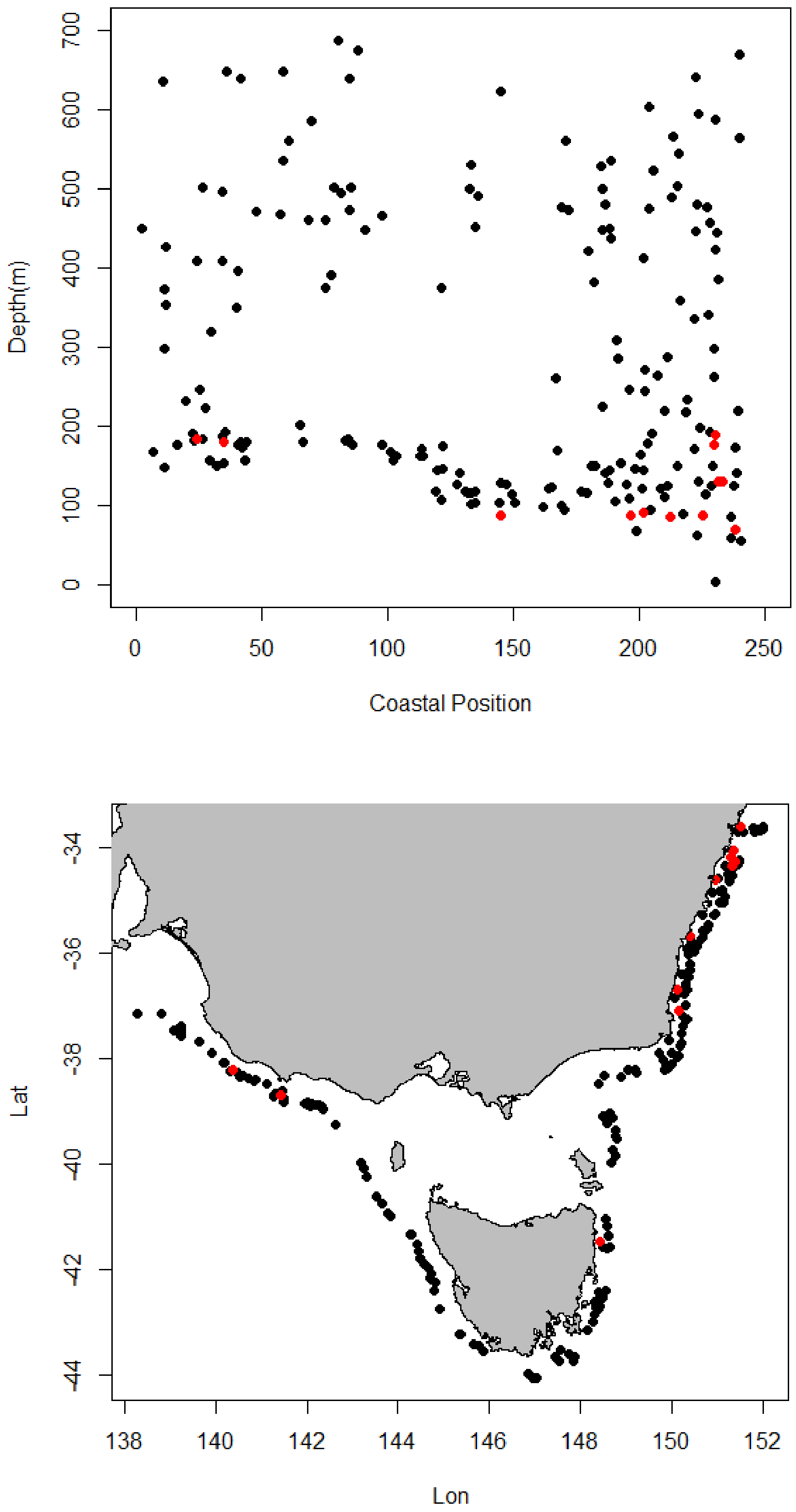

Figure 6. Candidate redesign stations (red) on covariate space (upper) and co-ordinate space (lower).

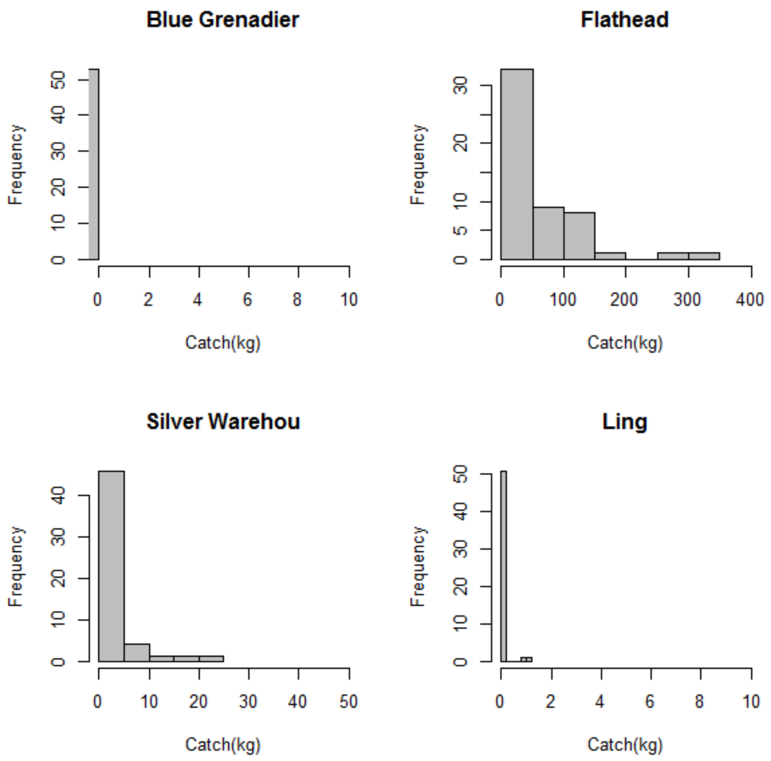

Figure 7. Distribution of catch (kg) corresponding to 12 candidate stations for the chosen species combined across years.

4.2 Objective 2 Results: 2018 reconditioned model (FIS2)

The spatial and depth bounds for all species were revised where appropriate for FIS2 (Table 1, Table 2). The spatial bounds were the same for Tiger Flathead and Redfish, increased for Silver Warehou, Blue-eye Trevalla and Jackass Morwong and decreased for Blue Grenadier and Ribaldo. The depth bounds were the same for Redfish, Ribaldo and Frostfish, broadened for Blue-eye Trevalla, narrowed for Silver Warehou, Ocean Jacket and School Shark, and reduced at both ends for Tiger Flathead and Jackass Morwong.

The FIS2 model predicted abundance series were mostly similar with those from FIS1 (Table 3 to Table 6; Figure 8 to Figure 25). For all species examined, there were changes in FIS2 abundance indices compared to FIS1 for each survey year (relative changes ranged from 0.5% to 181% (in magnitude), but with most over 20%; Table 7). Despite the size of these changes for some years, the differences in the apparent trends of the survey time series between FIS1 and FIS2 were relatively small for most species (Figure 26 to Figure 41).

Differences in overall shape and apparent trend between FIS1 and FIS2 were greatest for Pink Ling (Figure 33 and Figure 34). In particular, eastern Pink Ling changed from a dome shape (FIS1) to a declining series (FIS2) and western Pink Ling changed from an increasing abundance series (FIS1) to a relatively flat abundance series.

In most years, FIS2 CVs reduced compared with FIS1 CVs for Tiger Flathead, Pink Ling, Blue Grenadier, blue eye trevalla and Ribaldo (Table 3 to Table 6). There was little change in CVs for Redfish. Silver Warehou had mixed results, with CVs reduced in the east and increased in the west. By contrast, CVs for Jackass Morwong generally increased for all stocks, (with decreases for one survey each for west and east Jackass Morwong). Changes to CVs and CV ranges are summarised by species below (see also Table 7):

1. <u>Tiger Flathead – all Zones</u>: low CVs on the FIS abundance series (FIS1: 0.11 – 0.12; FIS2-: 0.09 – 0.11). CVs were similar between FIS1 and FIS2.
2. <u>Tiger Flathead – Zones 10, 20</u>: low CVs on the FIS abundance series (FIS1: 0.12 – 0.15; FIS2: 0.12 – 0.13). CVs increased in two surveys, with increases between 4% - 6%. For the remaining surveys, CVs decreased between 4% - 15%.
3. <u>Tiger Flathead – Zone 30</u>: low CVs on the FIS abundance series (FIS1: 0.18 – 0.20; FIS2: 0.13 – 0.19). CVs decreased in four surveys, with reductions between 9% - 29%. For the 2016 survey, the CV increased by 1%.
4. <u>Jackass Morwong – West:</u> mostly moderate CVs on the FIS abundance series (FIS1: 0.25 - 0.34; FIS2: 0.23 – 0.47). CVs increased in four out of five surveys, with two of these greater than 40%.
5. <u>Jackass Morwong – East</u>: high CVs on the FIS abundance series (FIS1East: 0.28 - 0.68; FIS2East: 0.32 - 0.93; FIS1Tas: 0.30 - 0.77; FIS2Tas: 0.41 - 1.03). CVs increased in four out of five surveys, with two of these greater than 25%.
6. <u>Blue Grenadier – Non-spawning</u>: very high CVs on the FIS1 abundance series (FIS1: 0.34 - 2.3; FIS2: 0.11 – 0.28). CVs decreased in all five surveys, with reductions between 23% - 93%, with four reductions greater than 80%.
7. <u>Blue Grenadier - Spawning</u>: moderate CVs on the FIS1 abundance series (FIS1: 0.26 – 0.59; FIS2: 0.16 – 0.21). CVs decreased in all five surveys, with reductions between 39% - 67%.
8. <u>Silver Warehou – East</u>: low-moderate CVs on the FIS1 abundance series (FIS1: 0.18 - 0.28; FIS2: 0.09 – 0.18) but high inter-survey variability due to infrequent very large catches of this schooling species. CVs decreased in all five surveys, with reductions between 36% - 57%.
9. <u>Silver Warehou – West</u>: low-moderate CVs on the FIS1 abundance series (FIS1: 0.15 - 0.35; FIS2: 0.11 – 1.25) but high inter-survey variability due to infrequent very large catches of this schooling species. CVs decreased in two surveys, with reductions between 37% - 39%. For the remaining surveys, CV's increased between 167% - 563%.
10. <u>Pink Ling – West:</u> low CVs on the FIS abundance series (FIS1: 0.18 - 0.22; FIS2: 0.18 – 0.21). CVs decreased in four out of five surveys, with reductions between 1% - 9%. The 2016 survey increased by 5%.
11. <u>Pink Ling – East</u>: low CVs on the FIS abundance series (FIS1: 0.21 - 0.22; FIS2: 0.16 – 0.18). CVs decreased in all five surveys, with reductions between 19% - 24%.
12. <u>Blue-eye Trevalla</u>: high CVs on the FIS abundance series (FIS1: 0.36 - 0.85; FIS2: 0.33 – 0.67) CVs reduced in FIS2 compared to FIS1. CVs decreased in all five surveys, with reductions between 2% - 21%.
13. <u>Redfish – Zones 10, 20, 30</u>: moderate CVs on the FIS abundance series (FIS1: 0.23 - 0.53; FIS2: 0.24 – 0.60) – similar CVs between FIS1 and FIS2. CVs increased in three out of five surveys, with increases between 9% - 12%. Note: FIS1 used all zones for Redfish, so results may not be directly comparable.
14. <u>Ribaldo</u>: moderate CVs on the FIS abundance series (FIS1: 0.39 - 0.57; FIS2: 0.26 – 0.32) – CVs reduced in FIS2 compared to FIS1. CVs decreased in all five surveys, with reductions between 33% - 47%.

Table 1. Coastal string used in updated (2018) and initial analysis (2006). Minimum (MIN); Maximum (MAX). Predicted biennial winter abundance indices (see Table 3) and corresponding coefficient of variation (CV; see Table 4) have been estimated for six species (bold).

COMMON NAME	SPECIES NAME	CAAB CODE	2018 MIN. COASTAL STRING	2018 MAX. COASTAL STRING	2006 MIN. COASTAL STRING	2006 MAX. COASTAL STRING
Agreed key species:						
Tiger Flathead	*Platycephalus richardsoni*	37296001	90	240	90	240
Pink Ling	*Genypterus blacodes*	37228002	0	230	0	230
Blue Grenadier	*Macruronus novaezelandiae*	37227001	0	220	0	240
Silver Warehou	*Seriolella punctata*	37445006	0	230	0	205
Additional species (outside the scope of this project):						
Blue-eye Trevalla	*Hyperoglyphe antarctica*	37445001	0	230	0	200
Redfish	*Centroberyx affinis*	37258003	183	240	183	240
Ribaldo	*Mora moro*	37224002	0	220	0	240
Jackass Morwong	*Nemadactylus macropterus*	37377003	0	230	5	210

Table 2. Species depth range (m) used in updated (2018) and initial analysis (2006). Minimum (MIN); Maximum (MAX). Predicted biennial winter abundance indices (see Table 3) and corresponding coefficient of variation (CV; see Table 4) have been estimated for six species (bold).

COMMON NAME	SPECIES NAME	CAAB CODE	2018 MIN. DEPTH (M)	2018 MAX. DEPTH (M)	2006 MIN. DEPTH (M)	2006 MAX. DEPTH (M)
Agreed key species:						
Tiger Flathead	*Platycephalus richardsoni*	37296001	20	250	50	700
Pink Ling	*Genypterus blacodes*	37228002	100	700	100	700
Blue Grenadier	*Macruronus novaezelandiae*	37227001	50	700	0	700
Silver Warehou	*Seriolella punctata*	37445006	0	700	100	700
Additional species (outside the scope of this project):						
Blue-eye Trevalla	*Hyperoglyphe antarctica*	37445001	0	700	150	700
Redfish	*Centroberyx affinis*	37258003	50	400	50	400
Ribaldo	*Mora moro*	37224002	0	700	0	700
Jackass Morwong	*Nemadactylus macropterus*	37377003	0	250	50	700

Table 3. Estimated biennial winter abundance indices based on the 2018 reconditioned model (FIS2). ZONE: see Figure 3 for the SESSF statistical reporting zones.

COMMON NAME	ZONE	2008	2010	2012	2014	2016
Tiger Flathead	All Zones	191.083	181.094	287.261	190.676	299.497
	10, 20	272.440	176.516	329.418	216.904	322.470
	30	133.113	174.318	212.919	212.227	392.341
Pink Ling	All Zones	17.739	15.100	15.371	9.577	12.775
	10, 20, 30	19.770	14.645	16.858	10.149	8.583
	40, 50	16.538	16.049	14.245	9.137	17.504
Blue Grenadier	All Zones	15.134	2.351	5.307	11.947	46.111
	Spawning: 40	19.674	6.300	6.908	25.374	172.968
	Non-spawning (10, 20, 30, 50)	11.642	0.752	4.657	7.362	3.688
Silver Warehou	All Zones	131.450	36.607	94.634	52.314	273.992
	10, 20, 30	117.213	40.749	153.404	26.798	480.101
	40, 50	169.863	30.019	45.299	82.409	165.298
Blue-eye Trevalla	All Zones	0.631	0.914	0.318	0.081	1.040
Redfish	10, 20, 30	11.477	31.864	3.241	8.952	9.166
Ribaldo	All Zones	13.762	9.334	13.945	42.746	17.449
Jackass Morwong	All Zones	77.438	42.732	56.361	15.978	12.547
	10, 20	11.695	10.471	7.695	4.854	6.452
	30	98.878	50.073	55.575	23.518	4.989
	40, 50	108.811	56.628	86.027	16.651	23.482

Table 4. Estimated coefficient of variation (CV) of biennial winter abundance indices based on the 2018 reconditioned model (FIS2). ZONE: see Figure 3 for the SESSF statistical reporting zones.

COMMON NAME	ZONE	2008	2010	2012	2014	2016
Tiger Flathead	All Zones	0.0999	0.1076	0.1019	0.0853	0.0963
	10, 20	0.1321	0.1287	0.1316	0.1198	0.1248
	30	0.1513	0.1805	0.1598	0.1273	0.1861
Pink Ling	All Zones	0.1262	0.1302	0.1321	0.1190	0.1229
	10, 20, 30	0.1632	0.1774	0.1733	0.1580	0.1582
	40, 50	0.2046	0.1956	0.2077	0.1835	0.1875
Blue Grenadier	All Zones	0.0940	0.1271	0.1040	0.1001	0.0741
	Spawning: 40	0.1937	0.2069	0.1838	0.1796	0.1612
	Non-spawning (10, 20, 30, 50)	0.1079	0.2843	0.1437	0.1524	0.2634
Silver Warehou	All Zones	0.0540	0.0670	0.1337	0.0633	0.0717
	10, 20, 30	0.0903	0.0901	0.1820	0.1043	0.0915
	40, 50	0.1128	0.4704	1.2164	0.0906	1.2514
Blue-eye Trevalla	All Zones	0.3323	0.3515	0.4047	0.6728	0.4711
Redfish	10, 20, 30	0.2265	0.2475	0.3398	0.2437	0.5948
Ribaldo	All Zones	0.3175	0.2926	0.3128	0.2622	0.2856
Jackass Morwong	All Zones	0.2351	0.2087	0.2218	0.2416	0.3762
	10, 20	0.3678	0.3117	0.4442	0.5095	0.9260
	30	0.4103	0.4105	0.4099	0.5143	1.0329
	40, 50	0.3961	0.2251	0.2608	0.2779	0.4745

Table 5. Estimated biennial winter abundance indices based on the 2006 model (FIS1). ZONE: see Figure 3 for the SESSF statistical reporting zones. A: from Upston et al. (2013); B: from Day and Peel (2015); C: from Knuckey et al. (2017).

COMMON NAME	ZONE	2008[A]	2010[A]	2012[A]	2014[B]	2016[C]
Tiger Flathead	All Zones	93.058	91.061	152.363	97.219	138.427
	10, 20	141.651	104.179	176.390	114.386	145.277
	30	81.641	112.717	123.092	102.058	177.275
Pink Ling	All Zones	18.163	19.722	18.750	21.890	20.456
	10, 20, 30	19.069	23.409	25.885	23.753	17.673
	40, 50	9.265	10.618	11.356	19.960	23.340
Blue Grenadier	All Zones	15.826	3.384	10.749	19.651	58.204
	Spawning: 40	65.055	17.968	15.123	44.523	211.293
	Non spawning (10, 20, 30, 50)	30.256	9.248	10.574	50.265	10.386
Silver Warehou	All Zones	106.690	32.873	114.796	24.119	155.675
	10, 20, 30	148.993	55.557	218.732	14.706	284.841
	40, 50	110.742	25.917	25.562	32.201	44.779
Blue-eye Trevalla	All Zones	1.260	1.662	0.652	0.297	1.351
Redfish	10, 20, 30	14.372	26.891	1.137	13.199	12.021
Ribaldo	All Zones	2.62	3.28	7.77	4.45	7.42
Jackass Morwong	All Zones	41.507	23.974	27.003	6.870	4.412
	10, 20	6.919	6.515	3.552	1.244	1.077
	30	52.425	31.536	34.725	15.084	3.318
	40, 50	51.564	25.525	39.263	7.269	7.031

Table 6. Estimated coefficient of variation (CV) of biennial winter abundance indices based on the 2006 model (FIS1). ZONE: see Figure 3 for the SESSF statistical reporting zones. A: from Upston et al. (2013); B: from Day and Peel (2015); C: from Knuckey et al. (2017).

COMMON NAME	ZONE	2008[A]	2010[A]	2012[A]	2014[B]	2016[C]
Tiger Flathead	All Zones	0.1121	0.1174	0.1070	0.1036	0.1220
	10, 20	0.1270	0.1321	0.1243	0.1249	0.1471
	30	0.1948	0.1985	0.1955	0.1801	0.1847
Pink Ling	All Zones	0.1537	0.1545	0.1699	0.1468	0.1364
	10, 20, 30	0.2059	0.2191	0.2219	0.2071	0.2064
	40, 50	0.2068	0.2100	0.2206	0.2009	0.1780
Blue Grenadier	All Zones	0.3030	0.2802	0.2342	0.2121	0.2333
	Spawning: 40	0.5945	0.3474	0.3386	0.3199	0.2639
	Non-spawning (10, 20, 30, 50)	0.5660	2.3087	0.9337	2.1856	0.3422
Silver Warehou	All Zones	0.1432	0.1358	0.2499	0.1323	0.1937
	10, 20, 30	0.2118	0.1788	0.2827	0.2113	0.1949
	40, 50	0.1803	0.1759	0.1836	0.1475	0.3549
Blue-eye Trevalla	All Zones	0.3890	0.3569	0.4990	0.8547	0.4845
Redfish	10, 20, 30	0.2279	0.2266	0.3058	0.2615	0.5318
Ribaldo	All Zones	0.52	0.46	0.57	0.39	0.54
Jackass Morwong	All Zones	0.2007	0.2069	0.2086	0.2353	0.3336
	10, 20	0.3928	0.2778	0.4372	0.4049	0.6804
	30	0.2957	0.3153	0.3065	0.3576	0.7690
	40, 50	0.2490	0.2609	0.2539	0.2707	0.3396

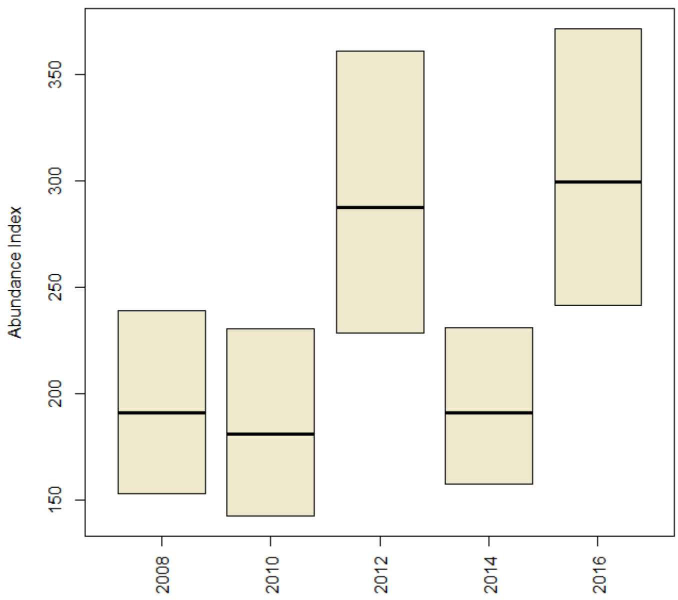

Figure 8. Tiger Flathead - All Zones: Model-predicted biennial winter abundance indices based on the 2018 reconditioned model (FIS2).

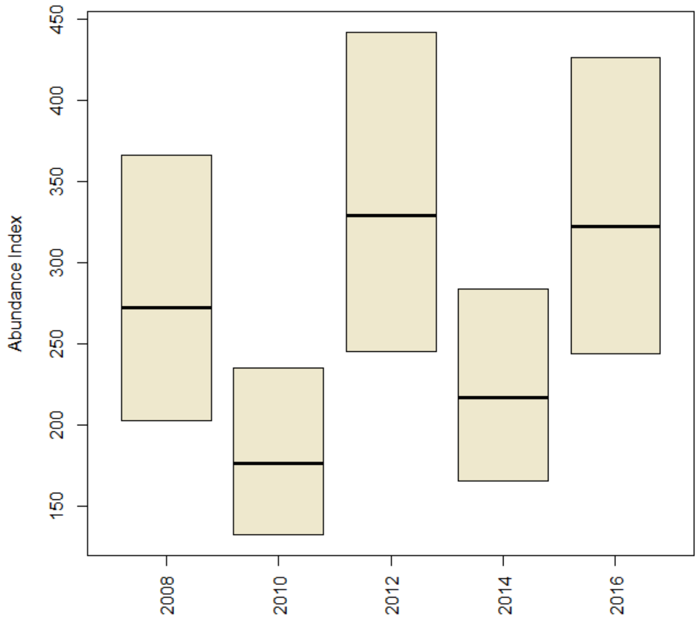

Figure 9. Tiger Flathead - Zones 10, 20: Model-predicted biennial winter abundance indices based on the 2018 reconditioned model (FIS2).

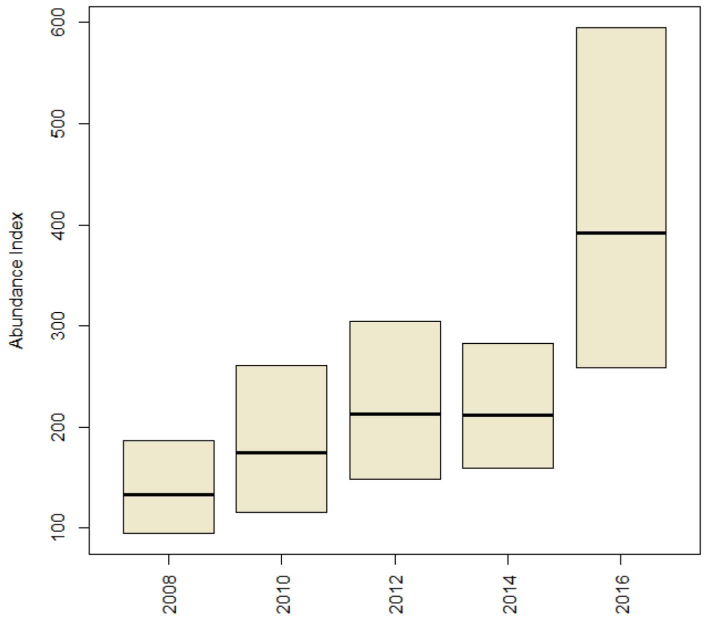

Figure 10. Tiger Flathead - Zone 30: Model-predicted biennial winter abundance indices based on the 2018 reconditioned model (FIS2).

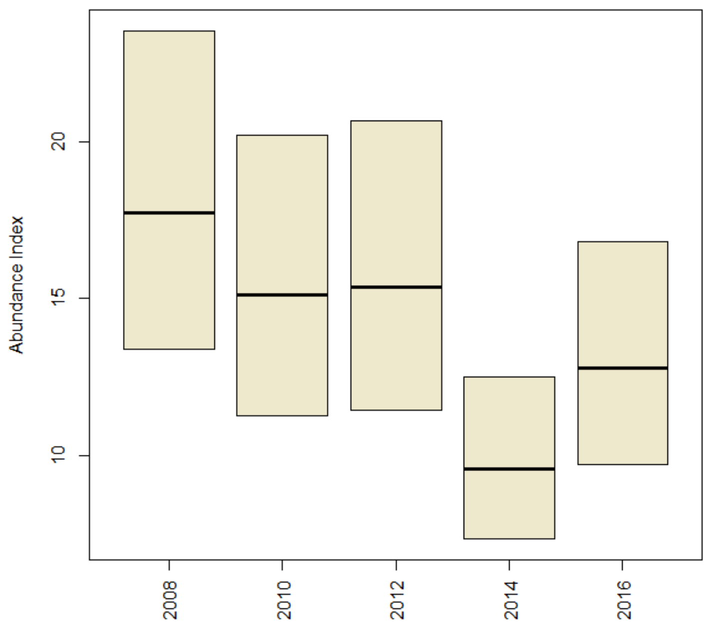

Figure 11. Pink Ling - All Zones: Model-predicted biennial winter abundance indices based on the 2018 reconditioned model (FIS2).

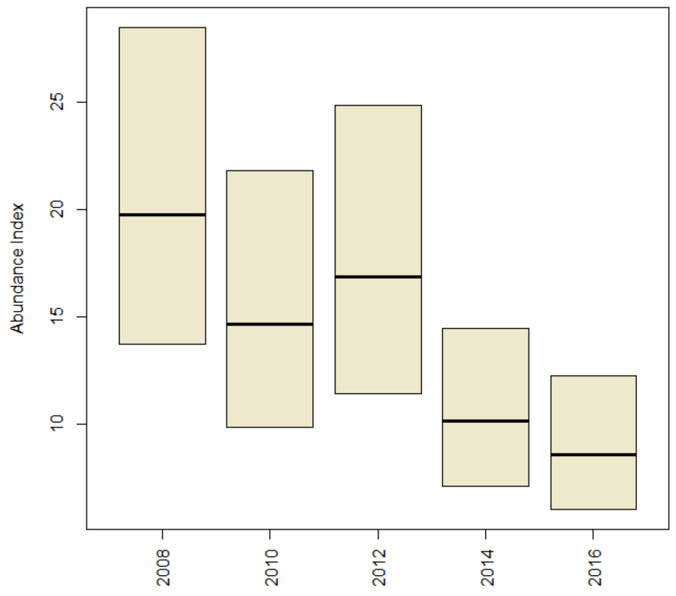

Figure 12. Pink Ling – East (Zones 10, 20, 30): Model-predicted biennial winter abundance indices based on the 2018 reconditioned model (FIS2).

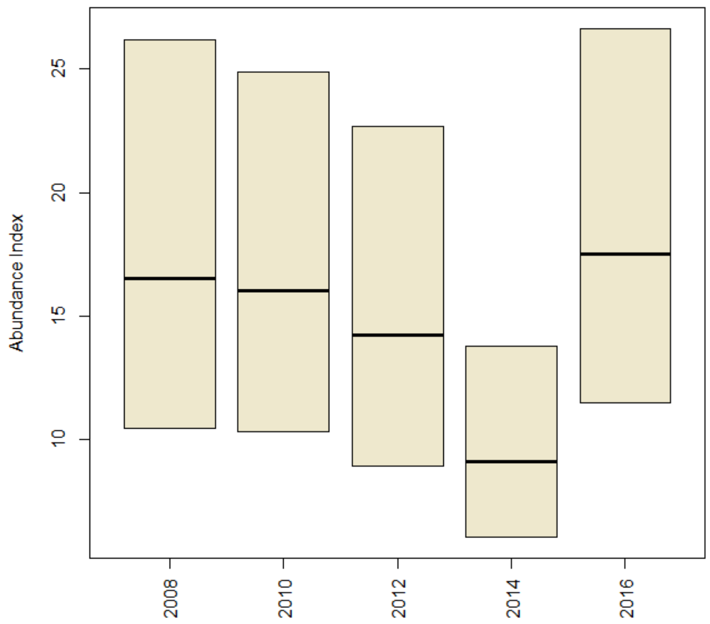

Figure 13. Pink Ling – West (Zones 40, 50): Model-predicted biennial winter abundance indices based on the 2018 reconditioned model (FIS2).

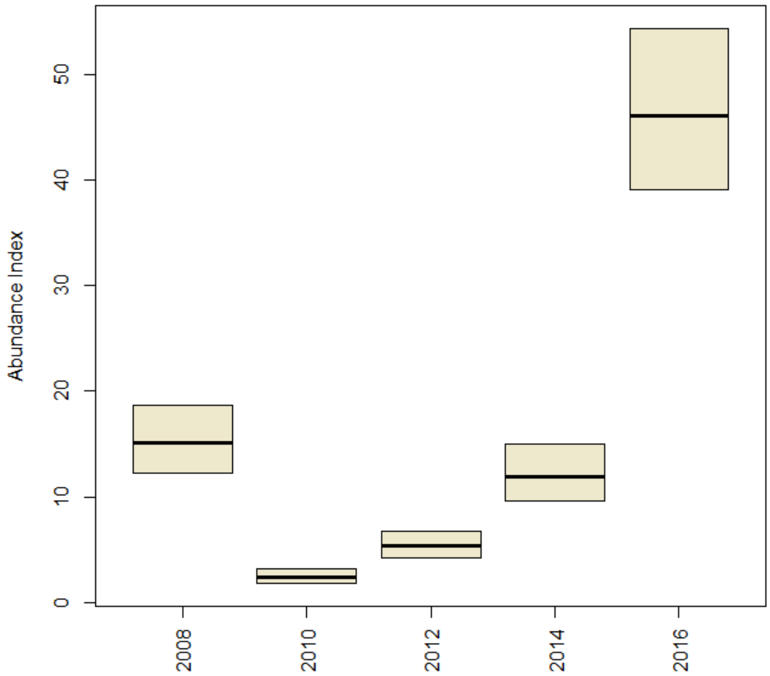

Figure 14. Blue Grenadier - All Zones: Model-predicted biennial winter abundance indices based on the 2018 reconditioned model (FIS2).

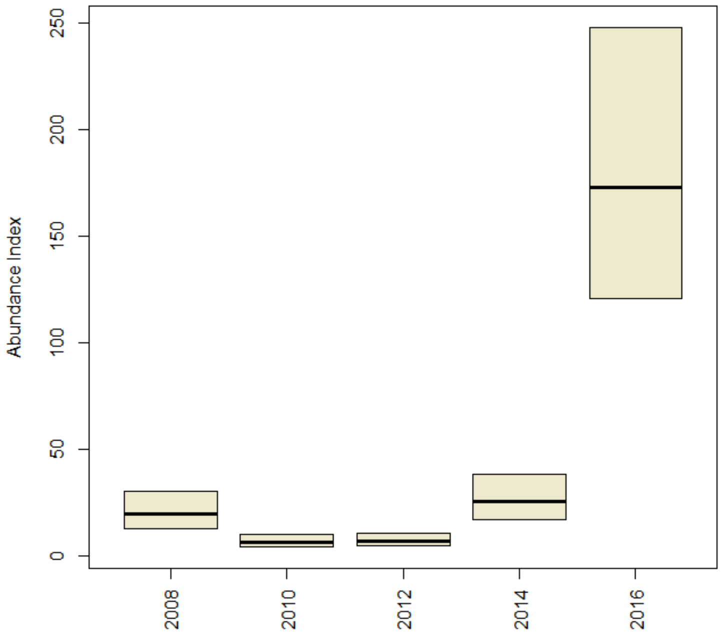

Figure 15. Blue Grenadier – Spawning (Zone 40): Model-predicted biennial winter abundance indices based on the 2018 reconditioned model (FIS2).

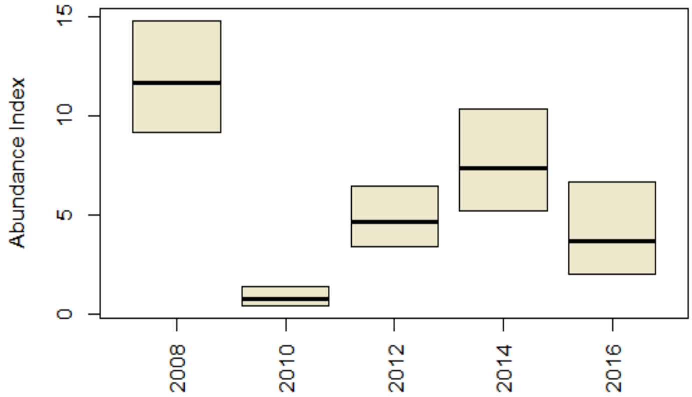

Figure 16. Blue Grenadier – Non-spawning (Zones 10, 20, 30, 50): Model-predicted biennial winter abundance indices based on the 2018 reconditioned model (FIS2).

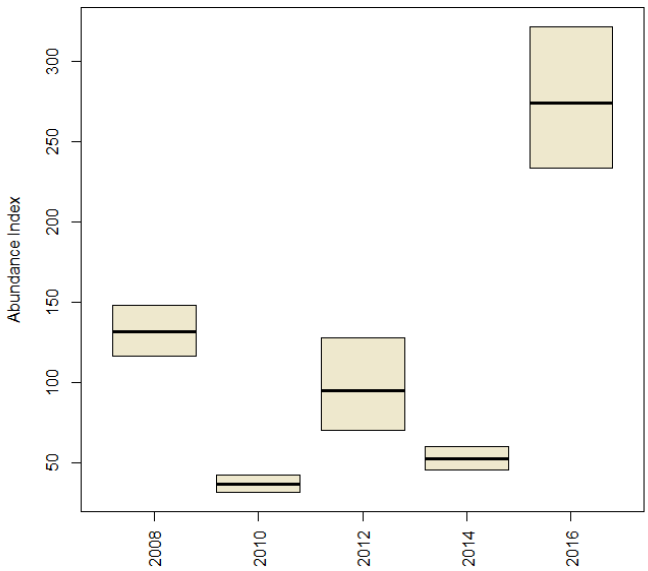

Figure 17. Silver Warehou – All Zones: Model-predicted biennial winter abundance indices based on the 2018 reconditioned model (FIS2).

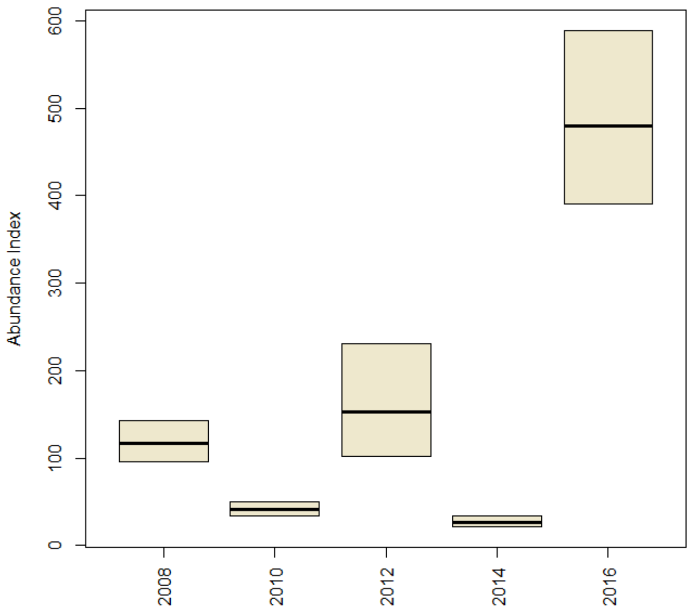

Figure 18. Silver Warehou – East (Zones 10, 20, 30): Model-predicted winter biennial abundance indices based on the 2018 reconditioned model (FIS2).

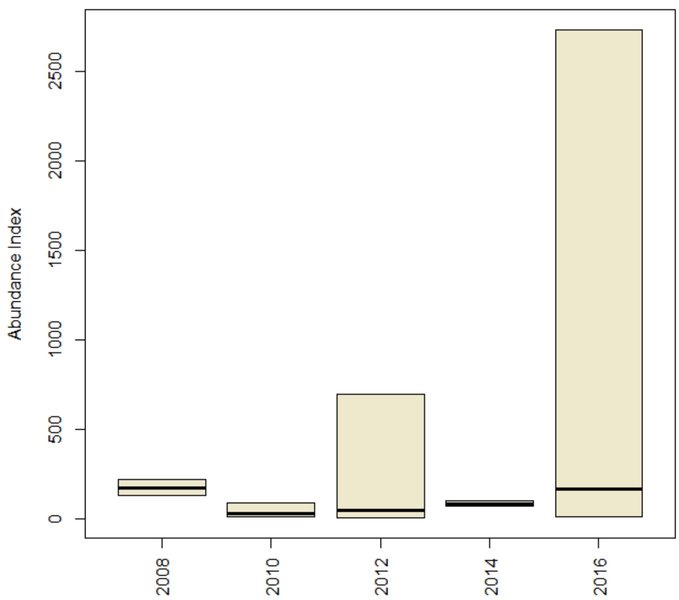

Figure 19. Silver Warehou – West (Zones 40, 50): Model-predicted biennial winter abundance indices based on the 2018 reconditioned model (FIS2).

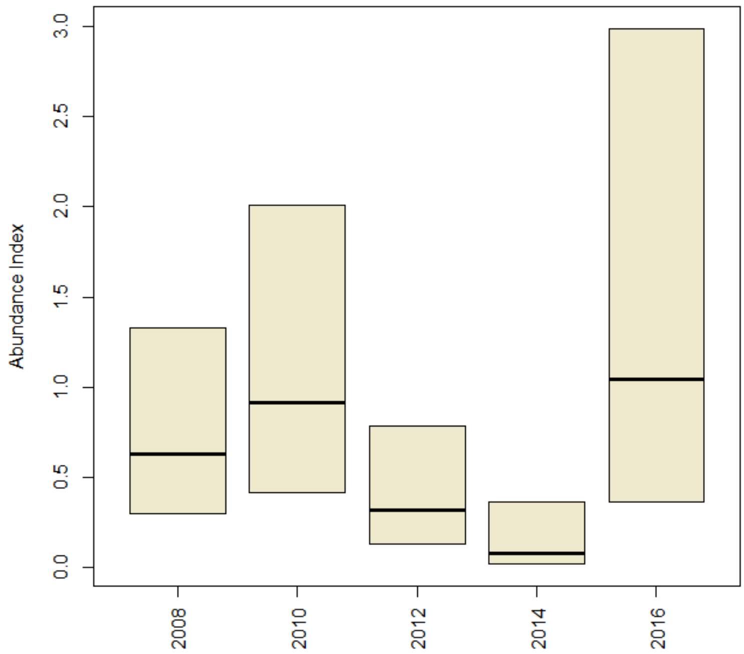

Figure 20. Blue-eye trevalla: Model-predicted biennial winter abundance indices based on the 2018 reconditioned model (FIS2).

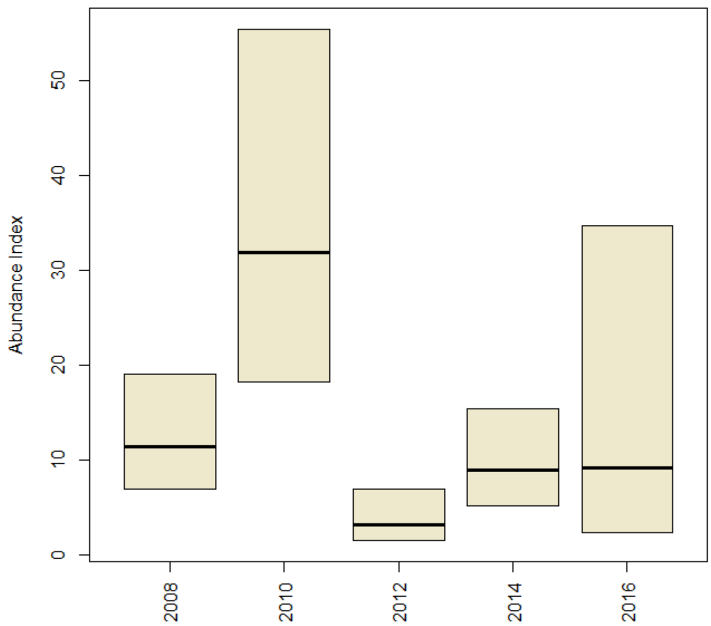

Figure 21. Redfish – East (Zones 10, 20, 30): Model-predicted biennial winter abundance indices based on the 2018 reconditioned model (FIS2).

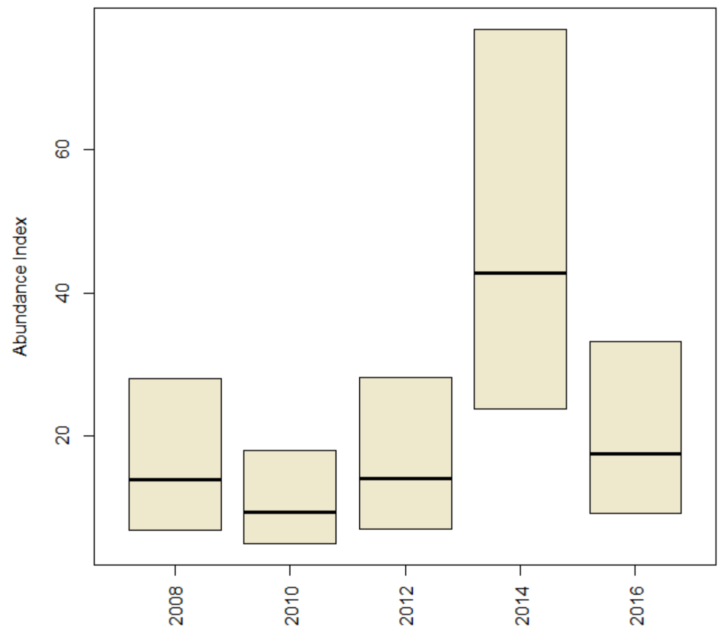

Figure 22. Ribaldo: Model-predicted biennial winter abundance indices based on the 2018 reconditioned model (FIS2).

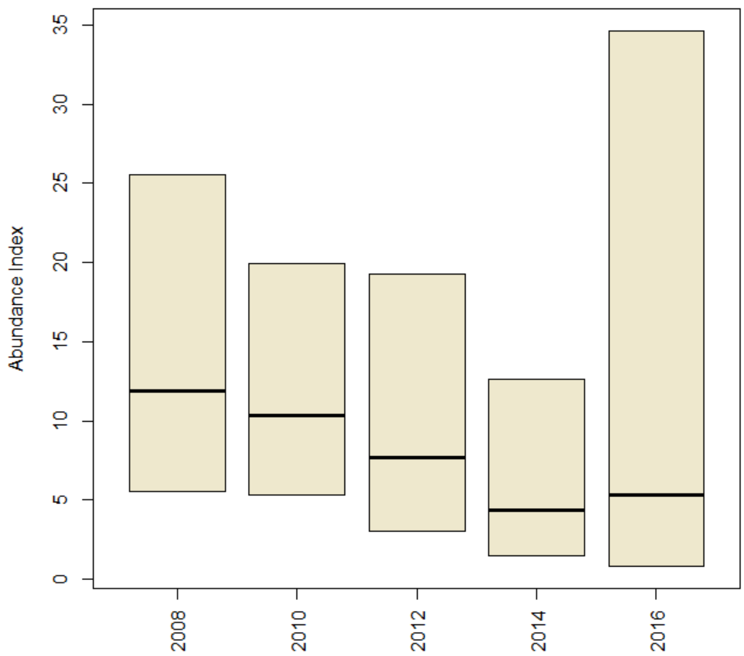

Figure 23. Jackass Morwong – Zone 10, 20: Model-predicted biennial winter abundance indices based on the 2018 reconditioned model (FIS2).

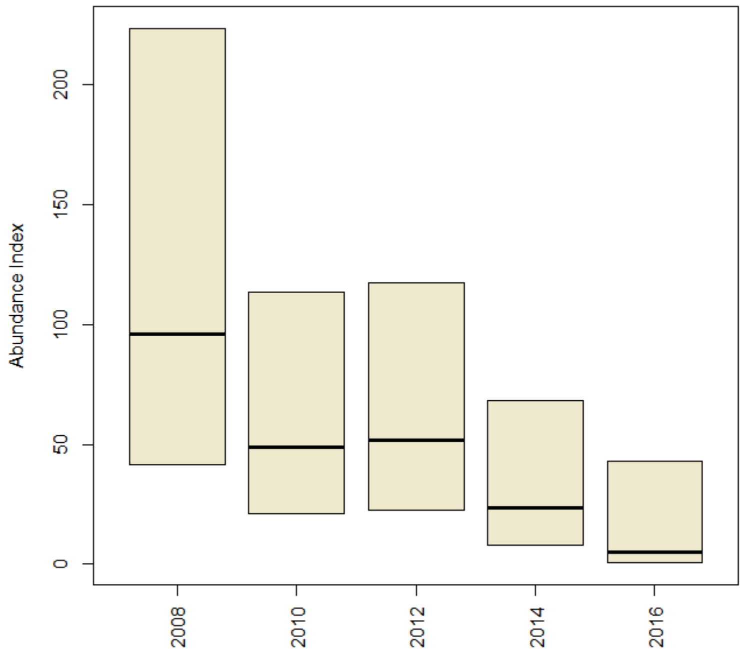

Figure 24. Jackass Morwong – Tas (Zone 30): Model-predicted biennial winter abundance indices based on the 2018 reconditioned model (FIS2).

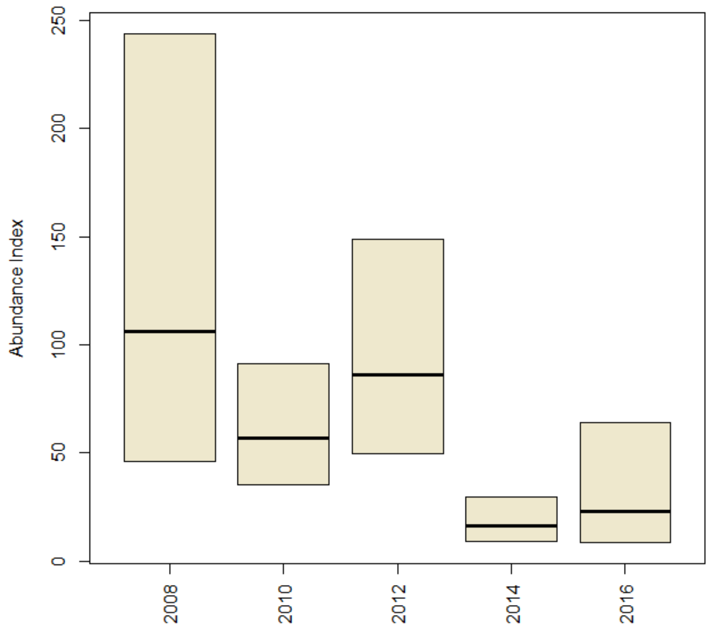

Figure 25. Jackass Morwong – West (Zones 40, 50): Model-predicted biennial winter abundance indices based on the 2018 reconditioned model (FIS2).

Table 7. Comparison of FIS1 and FIS2 relative abundance indices. Relative percent change of FIS2 compared to FIS1. CV: coefficient of variation; Min: minimum; Max: maximum.

COMMON NAME-FLEET CONFIGURATION	RELATIVE ABUNDANCE % CHANGE					CV % CHANGE					RELATIVE ABUNDANCE		CV	
	2008	2010	2012	2014	2016	2008	2010	2012	2014	2016	min	max	min	max
Blue Grenadier- all Zones	27.5	-7.4	-34.2	-18.9	5.6	-69.0	-54.6	-55.6	-52.8	-68.2	-34.2	27.5	-69.0	-52.8
Blue Grenadier-Non-spawning	51.6	-68.0	73.5	-42.3	39.9	-80.9	-87.7	-84.6	-93.0	-23.0	-68.0	73.5	-93.0	-23.0
Blue Grenadier-Spawning	-53.7	-46.3	-30.1	-12.8	25.3	-67.4	-40.4	-45.7	-43.9	-38.9	-53.7	25.3	-67.4	-38.9
Tiger Flathead – all Zones	2.2	-1.0	-6.2	-2.4	7.7	-10.9	-8.3	-4.8	-17.7	-21.1	-6.2	7.7	-21.1	-4.8
Tiger Flathead – Zones 10, 20	-0.5	-12.3	-3.4	-1.9	14.9	4.0	-2.6	5.9	-4.1	-15.1	-12.3	14.9	-15.1	5.9
Tiger Flathead – Zone 30	-13.5	-18.0	-8.2	10.3	17.4	-22.3	-9.1	-18.3	-29.3	0.8	-18.0	17.4	-29.3	0.8
Silver Warehou – all Zones	-9.2	-17.9	-39.2	59.9	29.7	-62.3	-50.7	-46.5	-52.2	-63.0	-39.2	59.9	-63.0	-46.5
Silver Warehou - East	-30.5	-35.2	-38.0	61.0	48.9	-57.4	-49.6	-35.6	-50.6	-53.0	-38.0	61.0	-57.4	-35.6
Silver Warehou - West	-25.6	-43.8	-14.0	24.2	79.1	-37.4	167.4	562.6	-38.6	252.6	-43.8	79.1	-38.6	562.6
Pink Ling – all Zones	37.0	7.4	15.0	-38.6	-12.4	-17.9	-15.7	-22.2	-18.9	-9.9	-38.6	37.0	-22.2	-9.9
Pink Ling – East	62.6	-1.9	2.1	-33.0	-23.8	-20.8	-19.1	-21.9	-23.7	-23.3	-33.0	62.6	-23.7	-19.1
Pink Ling – West	81.1	53.3	27.3	-53.6	-23.9	-1.1	-6.9	-5.8	-8.7	5.4	-53.6	81.1	-8.7	5.4
Jackass Morwong – Zones 10, 20	-20.7	-24.6	1.6	83.0	180.9	-6.4	12.2	1.6	25.8	36.1	-24.6	180.9	-6.4	36.1
Jackass Morwong – Zone 30	11.0	-6.6	-5.8	-8.3	-11.6	38.8	30.2	33.7	43.8	34.3	-11.6	11.0	30.2	43.8
Jackass Morwong – Zones 40, 50	-5.5	-0.6	-1.8	2.6	49.6	59.1	-13.7	2.7	2.7	39.7	-5.5	49.6	-13.7	59.1

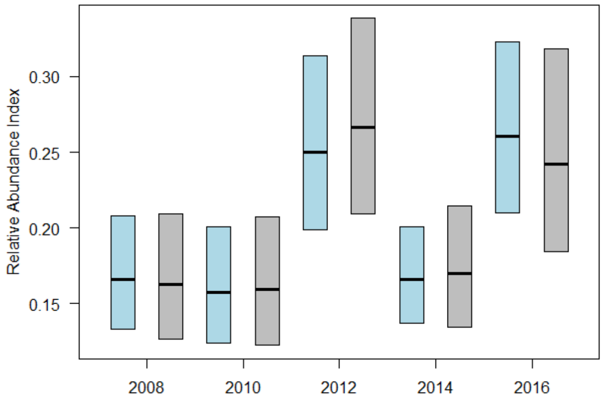

Figure 26. Flathead – All Zones: Relative biennial abundance indices for the 2018 reconditioned model (light blue; FIS2) and 2006 model (grey; FIS1).

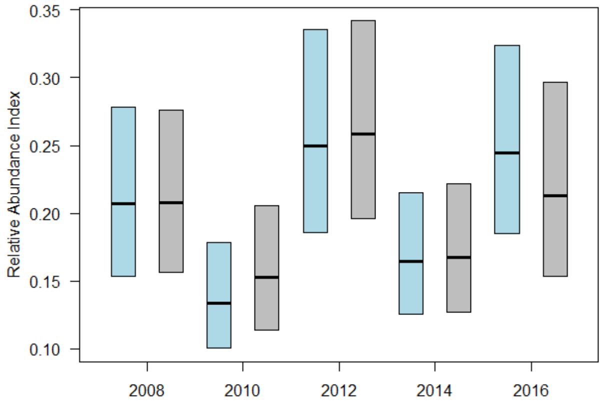

Figure 27. Flathead – Zones 10, 20: Relative biennial abundance indices for the 2018 reconditioned model (light blue; FIS2) and 2006 model (grey; FIS1).

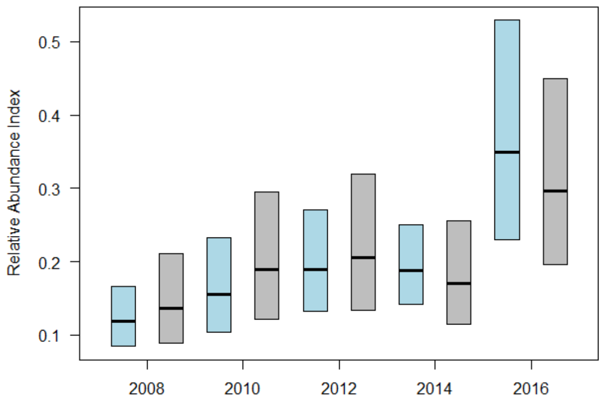

Figure 28. Flathead – Tas (Zone 30): Relative biennial abundance indices for the 2018 reconditioned model (light blue; FIS2) and 2006 model (grey; FIS1).

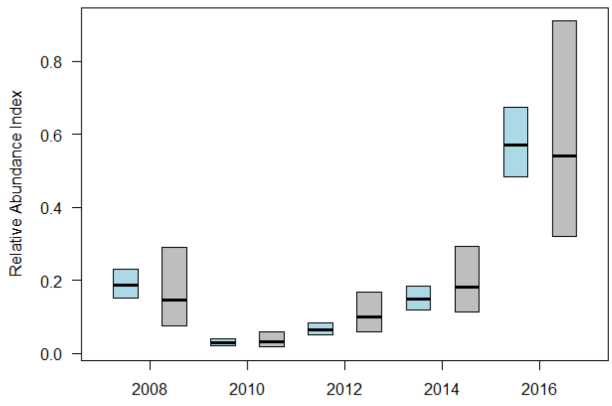

Figure 29. Blue Grenadier – All Zones: Relative biennial abundance indices for the 2018 reconditioned model (light blue; FIS2) and 2006 model (grey; FIS1).

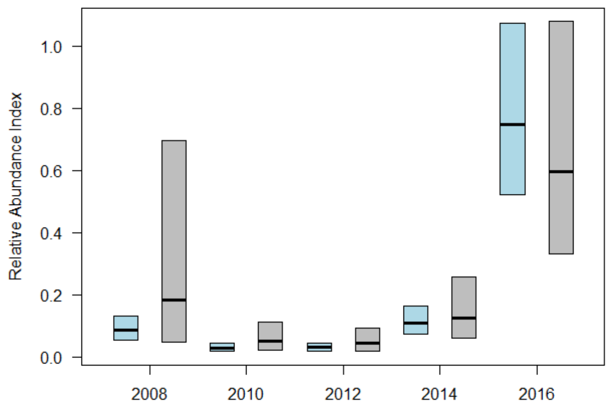

Figure 30. Blue Grenadier – Spawning (Zone 40): Relative biennial abundance indices for the 2018 reconditioned model (light blue; FIS2) and 2006 model (grey; FIS1).

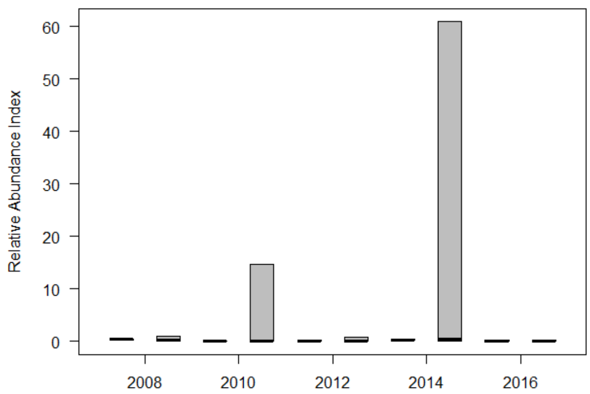

Figure 31. Blue Grenadier – Non-spawning (Zones 10, 20, 30, 50): Relative biennial abundance indices for the 2018 reconditioned model (light blue; FIS2) and 2006 model (grey; FIS1).

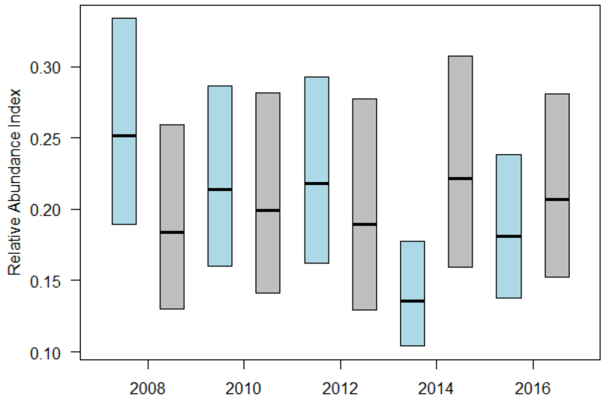

Figure 32. Pink Ling – All Zones: Relative biennial abundance indices for the 2018 reconditioned model (light blue; FIS2) and 2006 model (grey; FIS1).

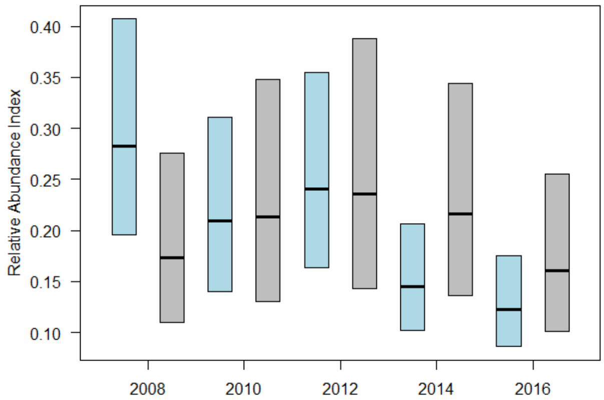

Figure 33. Pink Ling – East: Relative biennial abundance indices for the 2018 reconditioned model (light blue; FIS2) and 2006 model (grey; FIS1).

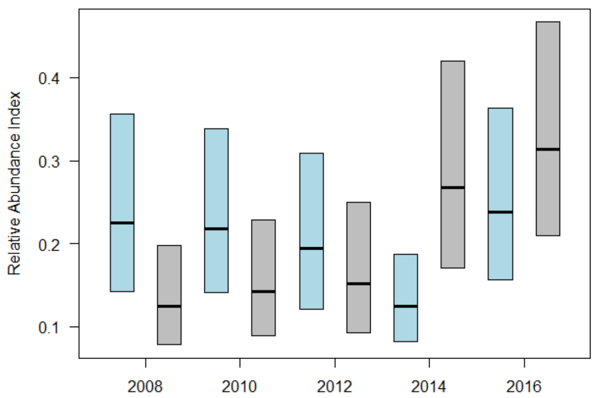

Figure 34. Pink Ling – West: Relative biennial abundance indices for the 2018 reconditioned model (light blue; FIS2) and 2006 model (grey; FIS1).

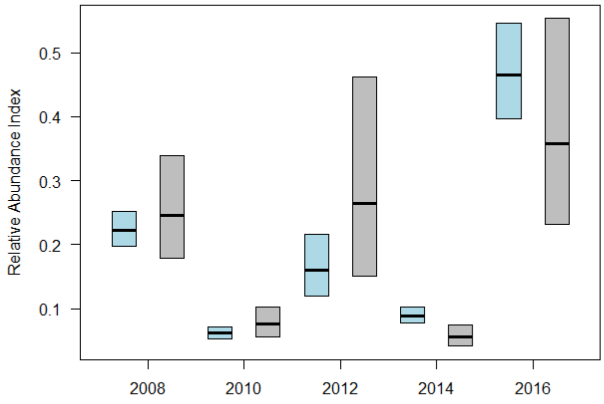

Figure 35. Silver Warehou – All Zones: Relative biennial abundance indices for the 2018 reconditioned model (light blue; FIS2) and 2006 model (grey; FIS1).

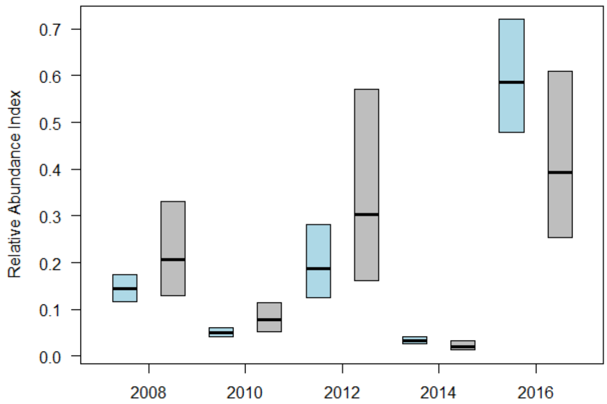

Figure 36. Silver Warehou – East: Relative biennial abundance indices for the 2018 reconditioned model (light blue; FIS2) and 2006 model (grey; FIS1).

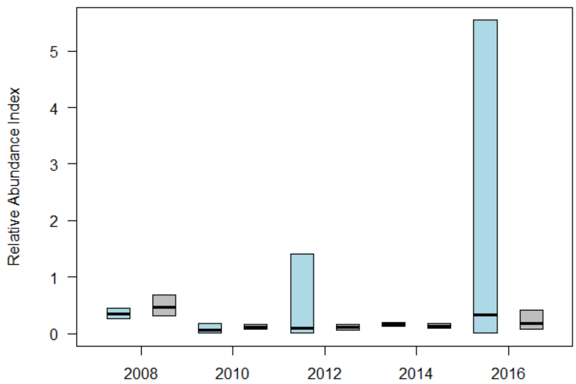

Figure 37. Silver Warehou – West: Relative biennial abundance indices for the 2018 reconditioned model (light blue; FIS2) and 2006 model (grey; FIS1).

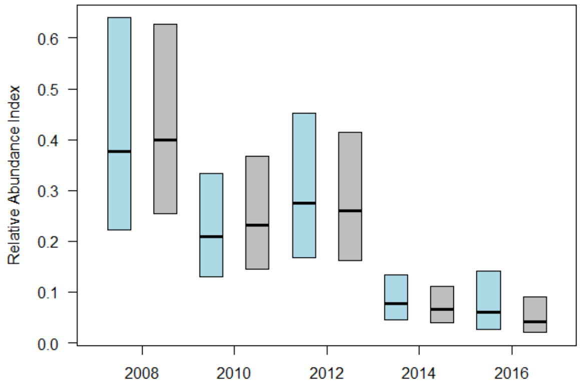

Figure 38. Jackass Morwong – All Zones: Relative biennial abundance indices for the 2018 reconditioned model (light blue; FIS2) and 2006 model (grey; FIS1).

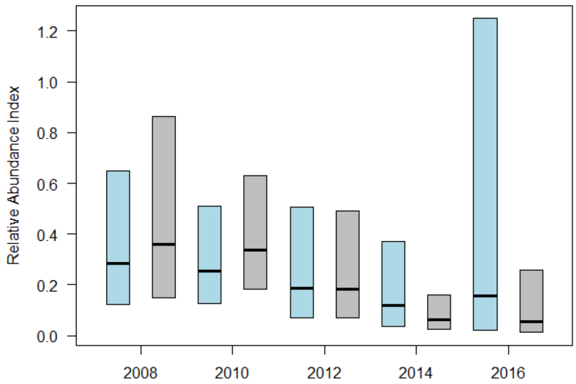

Figure 39. Jackass Morwong – East (Zone 10, 20): Relative biennial abundance indices for the 2018 reconditioned model (light blue; FIS2) and 2006 model (grey; FIS1).

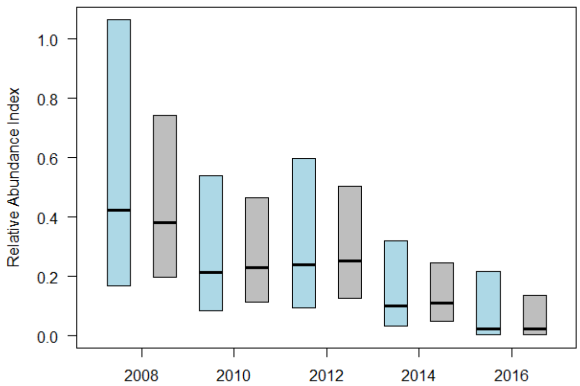

Figure 40. Jackass Morwong – Tas (Zone 30): Relative biennial abundance indices for the 2018 reconditioned model (light blue; FIS2) and 2006 model (grey; FIS1).

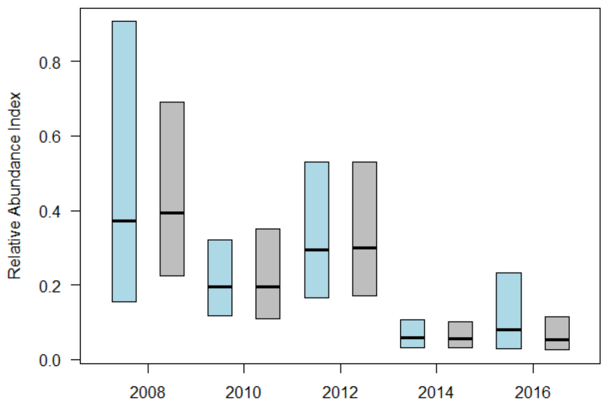

Figure 41. Jackass Morwong – West: Relative biennial abundance indices for the 2018 reconditioned model (light blue; FIS2) and 2006 model (grey; FIS1).

4.3 Objective 3 Results: Data simulation using 2018 reconditioned model estimates

A series of plots were produced for the four key species, to show both the FIS1 and FIS2 point estimates (predicted means), and the variation in the FIS2 series, realised from 200,000 simulations from each year (box and whisker plots). For each stock, the first plot shows simulated results incorporating within-year (sampling error) variation, for each year of the survey. The second plot combines within-year (sampling error) and between survey (process error) variation. The third plot shows 20 individual simulated trajectories, chosen at random, to illustrate the different possible trends that can arise from exactly the same sampling distributions generated from the means and CVs observed in the FIS.

In all cases the variation around the mean increased by adding process error. The increase was one order of magnitude for three of the four species, namely Silver Warehou - all zones (Figure 61), Silver Warehou - west (Figure 67), Tiger Flathead - east (Figure 58), Tiger Flathead - zone 30 (Figure 55) and Blue Grenadier - all zones (Figure 43). In one case the variation increased by two orders of magnitude, Silver Warehou - east (Figure 65). In the remaining cases increases were within the same order of magnitude.

Simulated trajectories from the Blue Grenadier non-spawning FIS had greatest variation, among the three Blue Grenadier fleet configurations (Figure 47). This is not surprising as the non-spawning FIS corresponds to the highest CVs (sampling error) across the configurations. All three configurations were constrained in 2010 (due to the low sampling error CV for that year) and had generally similar shape and trend, albeit with some variation between trajectories (Figure 44, Figure 47 and Figure 50).

For the three Tiger Flathead fleet configurations, there was considerable variation in trajectories with no consistent emerging trends or emerging patterns (Figure 53, Figure 56 and Figure 59). This variation was surprising given the relatively low estimated CVs (sampling error only).

Simulated trajectories for Silver Warehou were highly variable which was expected given the high CVs (sampling error), with less variation in 2010 and 2014. In addition to high sampling error, there was also very high process error for these series due to very large changes in the abundance indices between surveys. This combination of sampling and process error produced a broad range of different shapes and trends (Figure 62, Figure 65 and Figure 68) which appears to be largely driven by process error.

Similar to Tiger Flathead, the three Pink Ling fleet configurations had considerable variation in trajectories with no consistent emerging trends or emerging patterns (Figure 71, Figure 74 and Figure 77). This variation was surprising given the relatively low estimated CVs (sampling error only).

4.3.1 Blue Grenadier

Blue Grenadier – All Zones

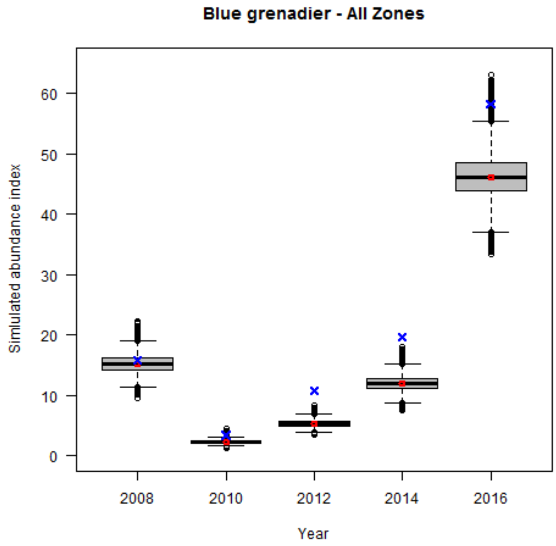

Figure 42. Blue Grenadier – All Zones: Boxplots (FIS2) of simulated biennial abundance indices and corresponding mean values of FIS1 (blue cross) and FIS2 (red circle) with sampling error only.

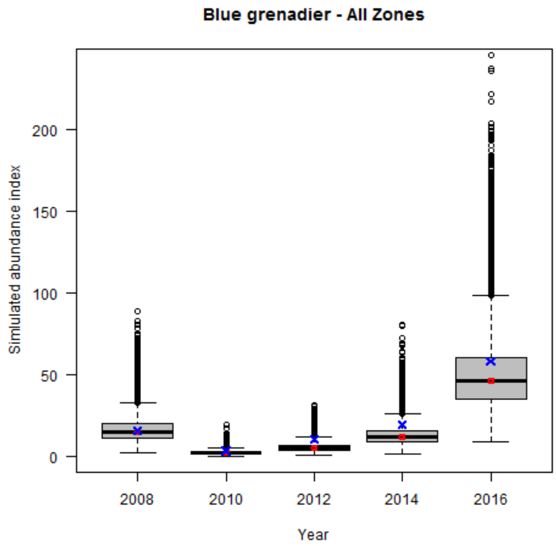

Figure 43. Blue Grenadier – All Zones: Boxplots (FIS2) of simulated biennial abundance indices and corresponding mean values of FIS1 (blue cross) and FIS2 (red circle) with both sampling and process error.

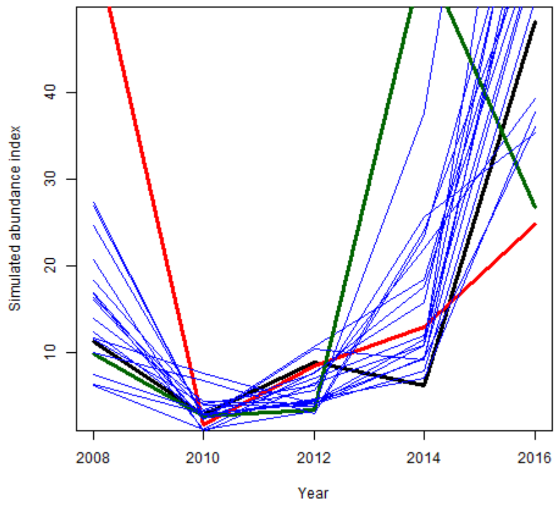

Figure 44. Blue Grenadier – All Zones: Twenty simulated relative biennial abundance indices for FIS2 with both sampling and process error. Coloured lines highlight contrast between different series.

Blue Grenadier – Non-spawning

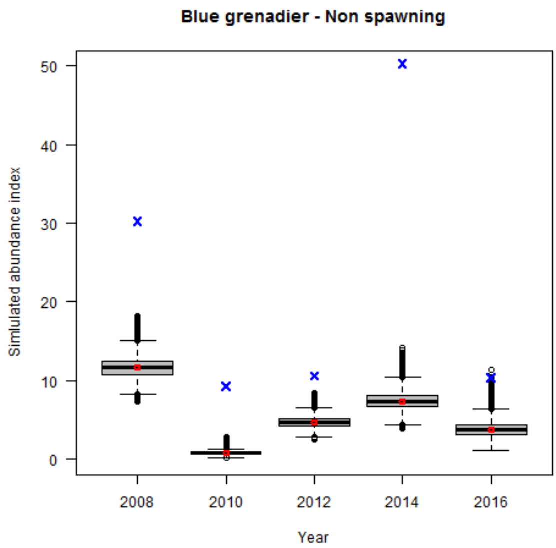

Figure 45. Blue Grenadier – Non-spawning: Boxplots (FIS2) of simulated biennial abundance indices and corresponding mean values of FIS1 (blue cross) and FIS2 (red circle) with sampling error only.

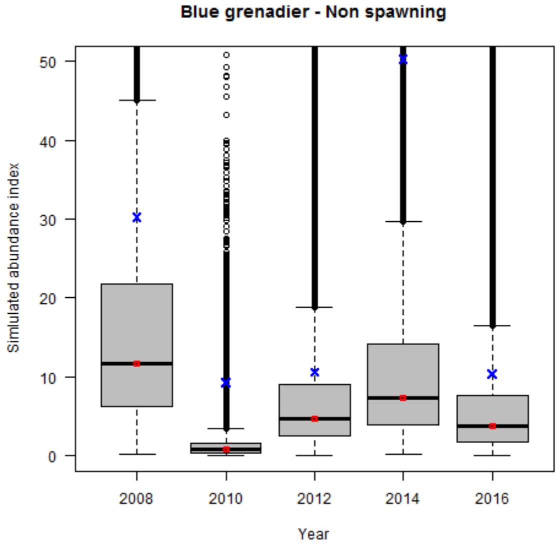

Figure 46. Blue Grenadier – Non-spawning: Boxplots (FIS2) of simulated biennial abundance indices and corresponding mean values of FIS1 (blue cross) and FIS2 (red circle) with both sampling and process error.

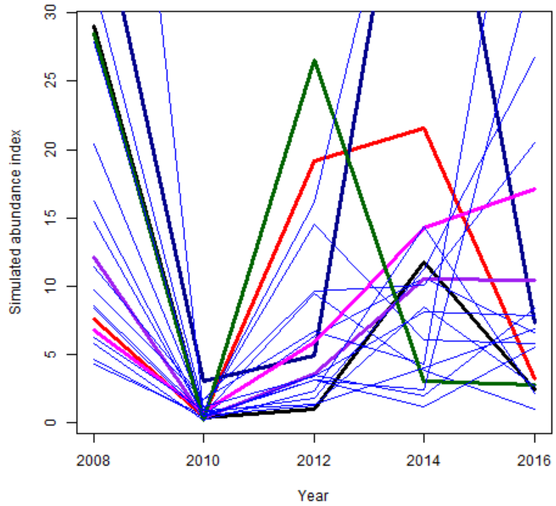

Figure 47. Blue Grenadier – Non-spawning: Twenty simulated relative biennial abundance indices for FIS2 with both sampling and process error. Coloured lines highlight contrast between different series.

Blue Grenadier – Zone 40 (Spawning)

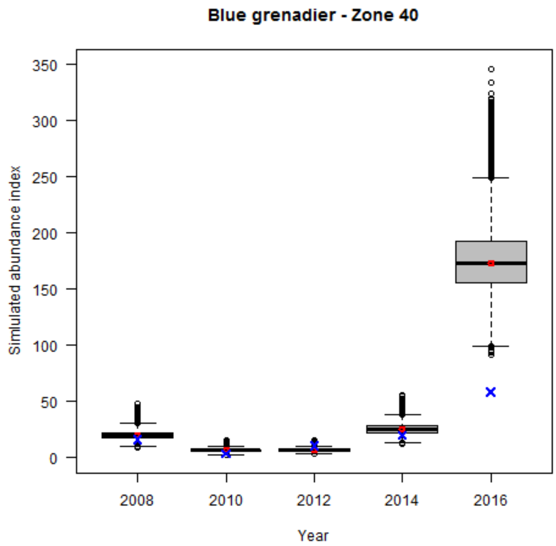

Figure 48. Blue Grenadier – Spawning: Boxplots (FIS2) of simulated biennial abundance indices and corresponding mean values of FIS1 (blue cross) and FIS2 (red circle) with sampling error only.

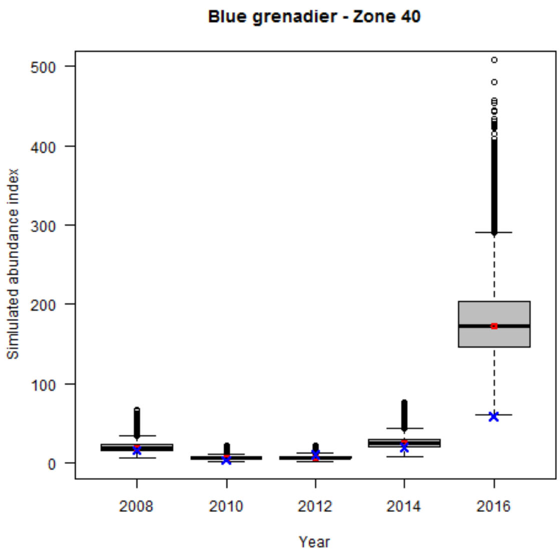

Figure 49. Blue Grenadier – Spawning: Boxplots (FIS2) of simulated biennial abundance indices and corresponding mean values of FIS1 (blue cross) and FIS2 (red circle) with both sampling and process error.

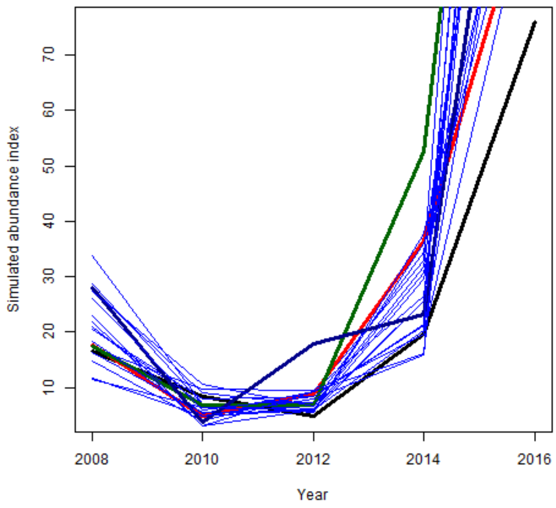

Figure 50. Blue Grenadier – Spawning: Twenty simulated relative biennial abundance indices for FIS2 with both sampling and process error. Coloured lines highlight contrast between different series.

4.3.2 Tiger Flathead

Tiger Flathead – All Zones

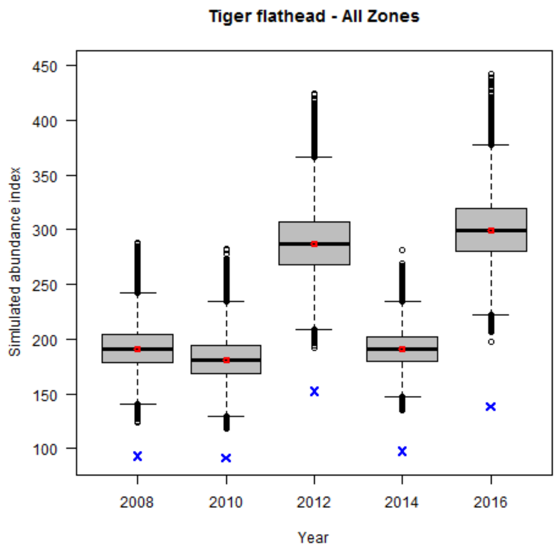

Figure 51. Tiger Flathead – All Zones: Boxplots (FIS2) of simulated biennial abundance indices and corresponding mean values of FIS1 (blue cross) and FIS2 (red circle) with sampling error only.

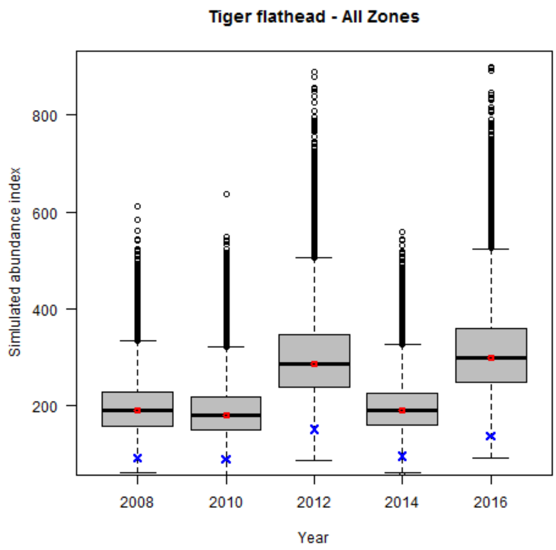

Figure 52. Tiger Flathead – All Zones: Boxplots (FIS2) of simulated biennial abundance indices and corresponding mean values of FIS1 (blue cross) and FIS2 (red circle) with both sampling and process error.

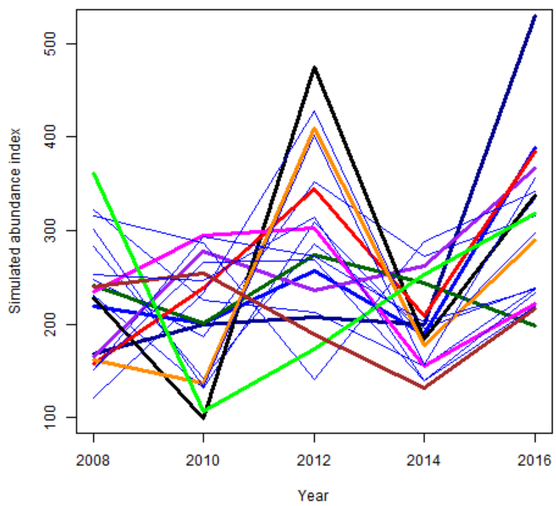

Figure 53. Tiger Flathead – All Zones: Twenty simulated relative biennial abundance indices for FIS2 with both sampling and process error. Coloured lines highlight contrast between different series.

Tiger Flathead – Tas (Zone 30)

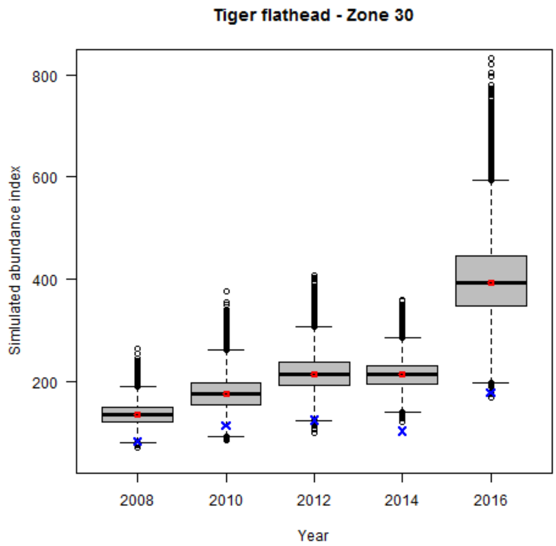

Figure 54. Tiger Flathead – Tas (Zone 30): Boxplots (FIS2) of simulated biennial abundance indices and corresponding mean values of FIS1 (blue cross) and FIS2 (red circle) with sampling error only.

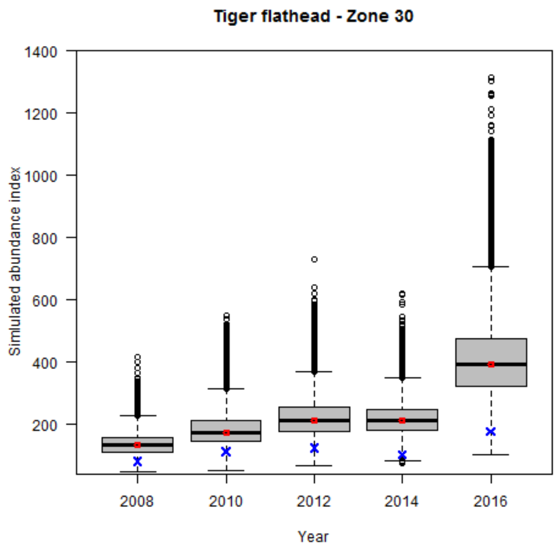

Figure 55. Tiger Flathead – Tas (Zone 30): Boxplots (FIS2) of simulated biennial abundance indices and corresponding mean values of FIS1 (blue cross) and FIS2 (red circle) with both sampling and process error.

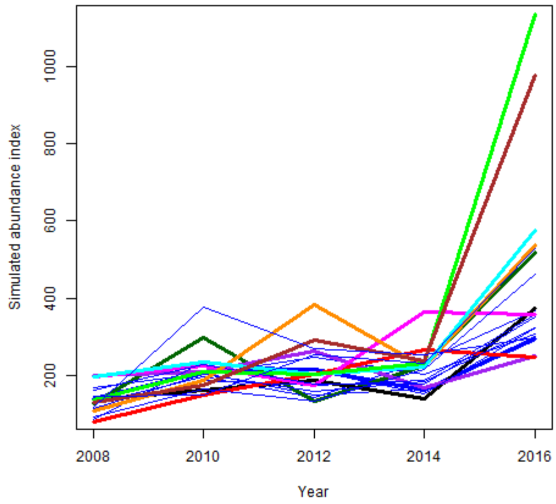

Figure 56. Tiger Flathead – Tas (Zone 30): Twenty simulated relative biennial abundance indices for FIS2 with both sampling and process error. Coloured lines highlight contrast between different series.

Tiger Flathead – Zone 10, 20

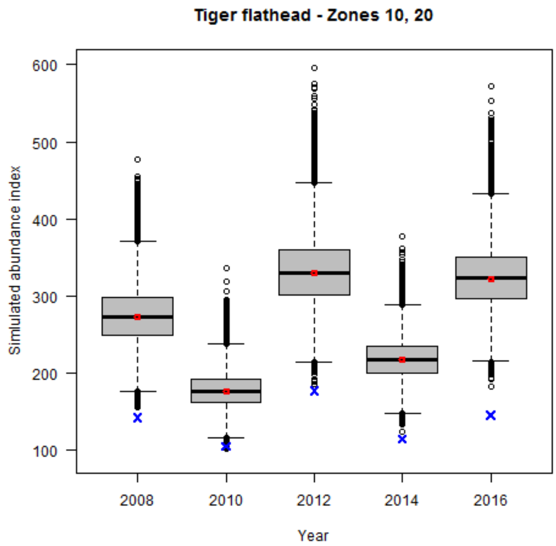

Figure 57. Tiger Flathead – Zone 10, 20: Boxplots (FIS2) of simulated biennial abundance indices and corresponding mean values of FIS1 (blue cross) and FIS2 (red circle) with sampling error only.

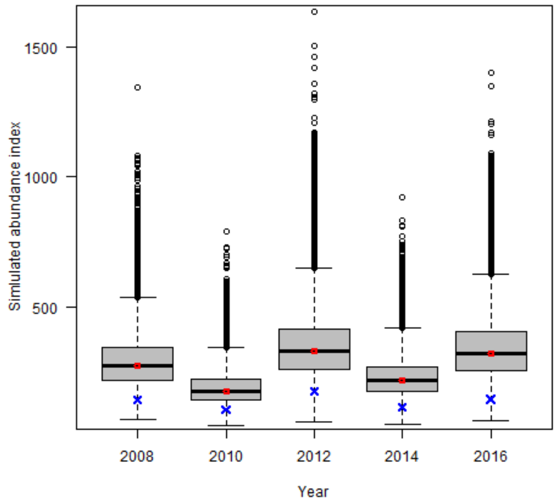

Figure 58. Tiger Flathead – Zone 10, 20: Boxplots (FIS2) of simulated biennial abundance indices and corresponding mean values of FIS1 (blue cross) and FIS2 (red circle) with both sampling and process error.

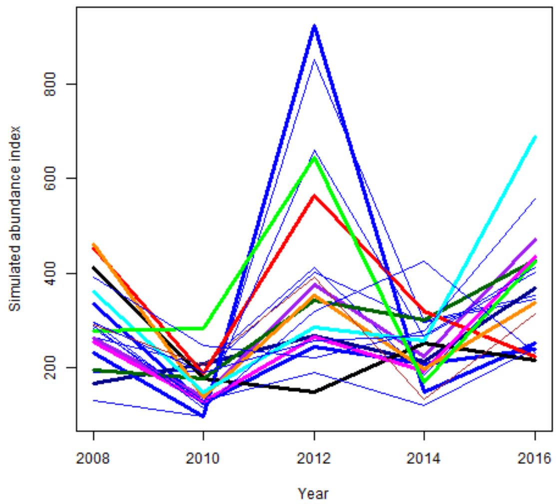

Figure 59. Tiger Flathead – Zone 10, 20: Twenty simulated relative biennial abundance indices for FIS2 with both sampling and process error. Coloured lines highlight contrast between different series.

4.3.3 Silver Warehou

Silver Warehou – All Zones

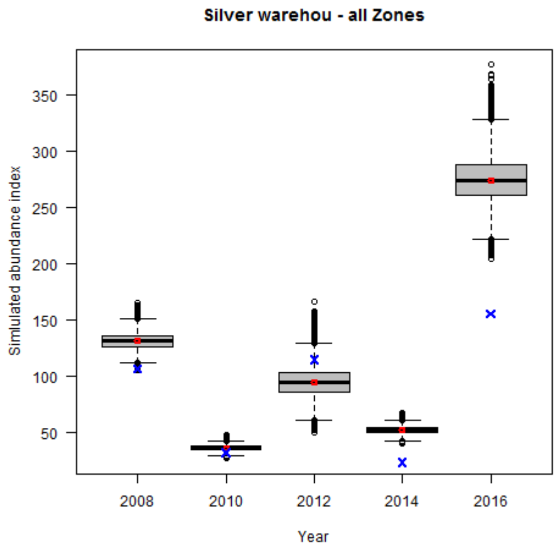

Figure 60. Silver Warehou – All Zones: Boxplots (FIS2) of simulated biennial abundance indices and corresponding mean values of FIS1 (blue cross) and FIS2 (red circle) with sampling error only.

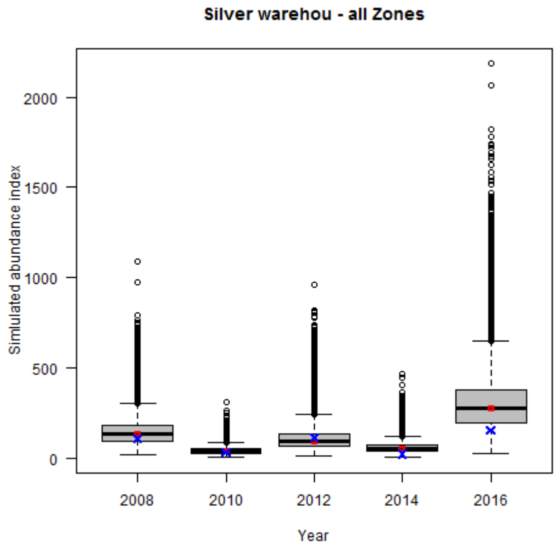

Figure 61. Silver Warehou – All Zones: Boxplots (FIS2) of simulated biennial abundance indices and corresponding mean values of FIS1 (blue cross) and FIS2 (red circle) with both sampling and process error.

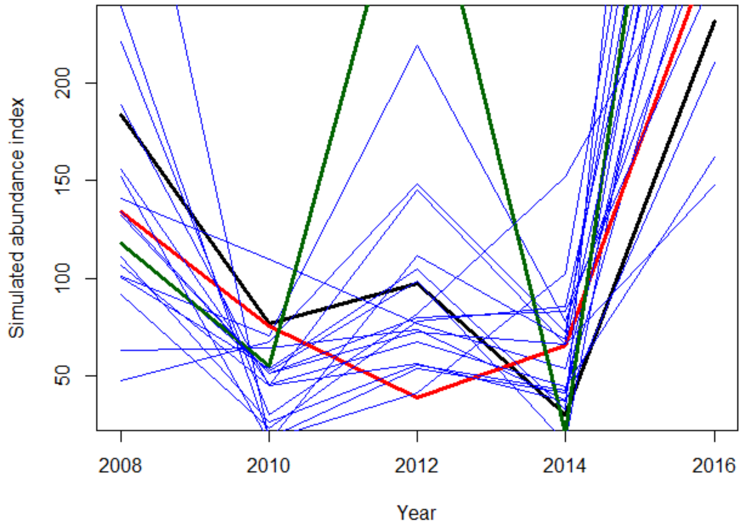

Figure 62. Silver Warehou – All Zones: Twenty simulated relative biennial abundance indices for FIS2 with both sampling and process error. Coloured lines highlight contrast between different series.

Silver Warehou – East

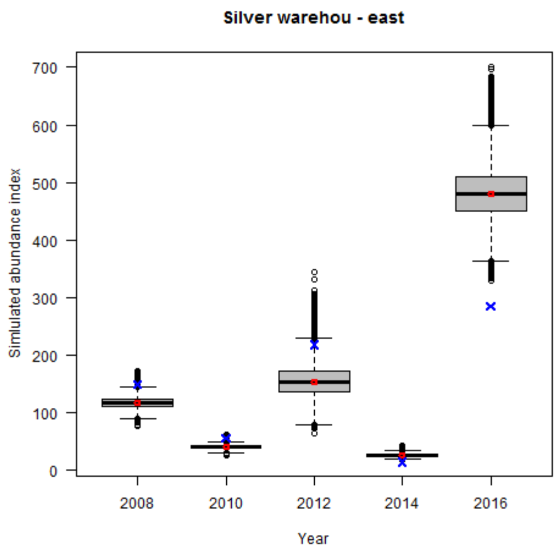

Figure 63. Silver Warehou – East: Boxplots (FIS2) of simulated biennial abundance indices and corresponding mean values of FIS1 (blue cross) and FIS2 (red circle) with sampling error only.

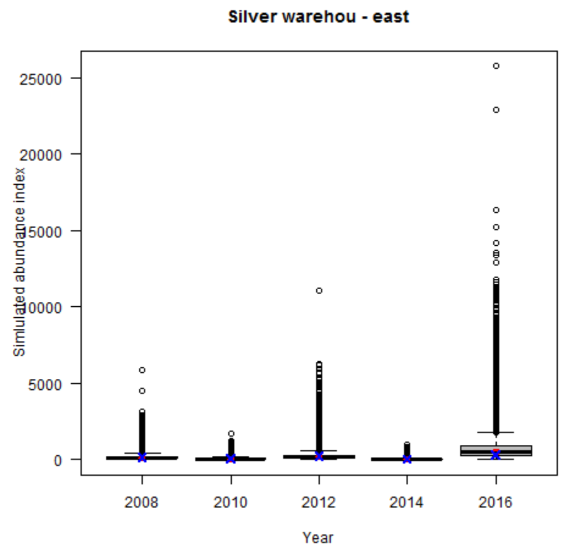

Figure 64. Silver Warehou – East: Boxplots (FIS2) of simulated biennial abundance indices and corresponding mean values of FIS1 (blue cross) and FIS2 (red circle) with both sampling and process error.

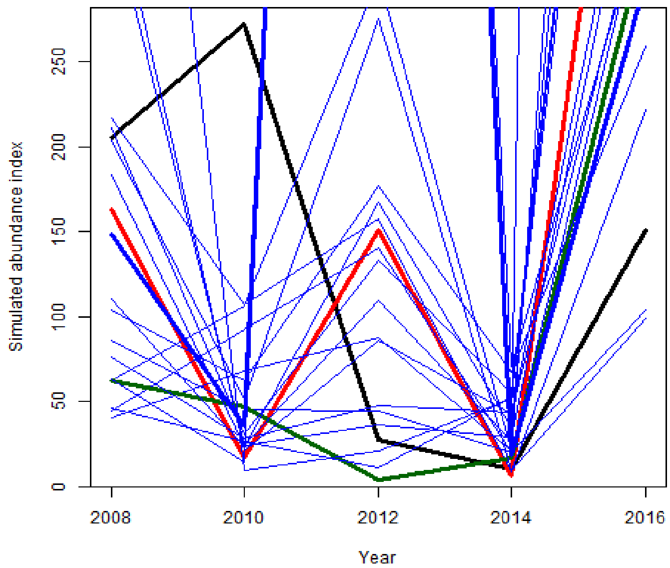

Figure 65. Silver Warehou – East: Twenty simulated relative biennial abundance indices for FIS2 with both sampling and process error. Coloured lines highlight contrast between different series.

Silver Warehou – West

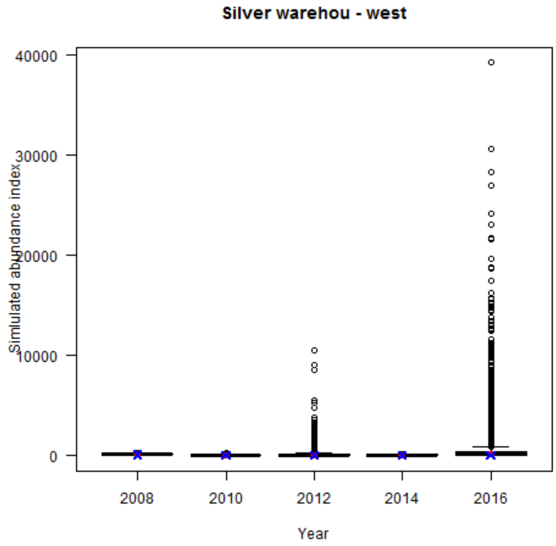

Figure 66. Silver Warehou – West: Boxplots (FIS2) of simulated biennial abundance indices and corresponding mean values of FIS1 (blue cross) and FIS2 (red circle) with sampling error only.

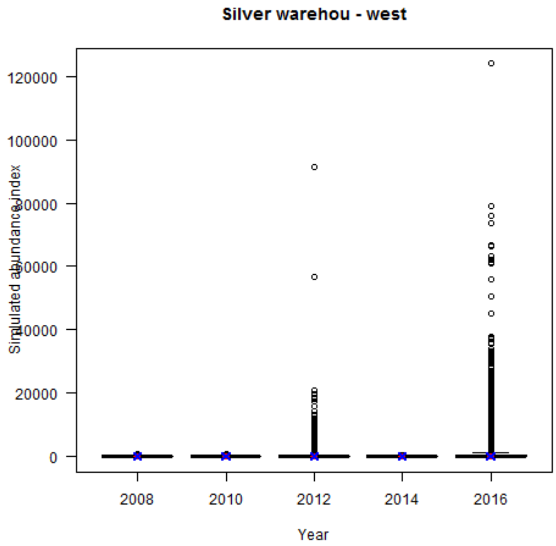

Figure 67. Silver Warehou – West: Boxplots (FIS2) of simulated biennial abundance indices and corresponding mean values of FIS1 (blue cross) and FIS2 (red circle) with both sampling and process error.

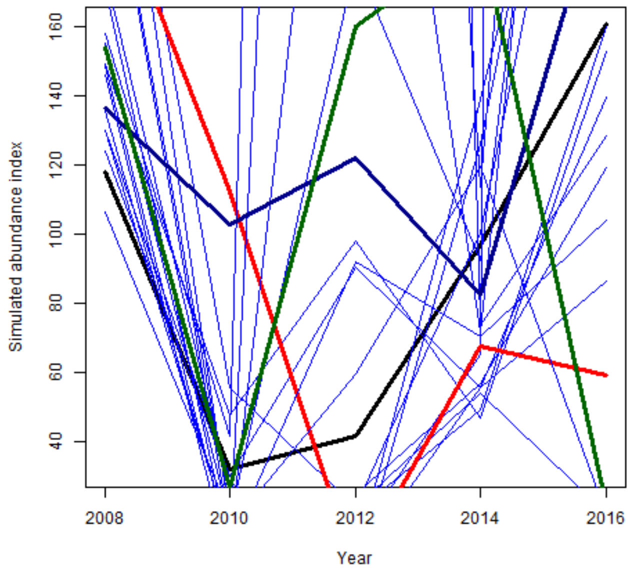

Figure 68. Silver Warehou – West: Twenty simulated relative biennial abundance indices for FIS2 with both sampling and process error. Coloured lines highlight contrast between different series.

4.3.4 Pink Ling

Pink Ling – All Zones

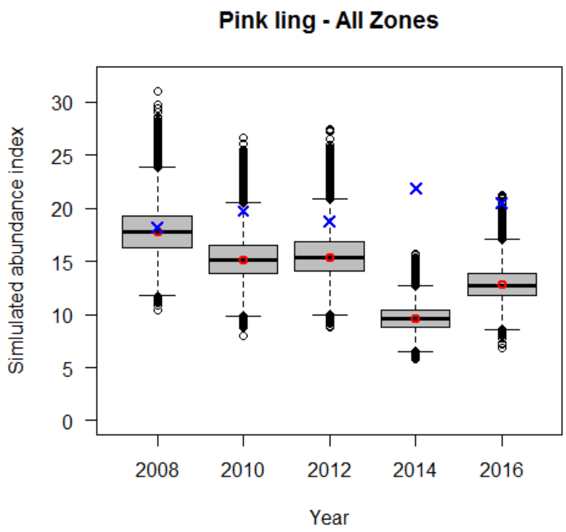

Figure 69. Pink Ling – All Zones: Boxplots (FIS2) of simulated biennial abundance indices and corresponding mean values of FIS1 (blue cross) and FIS2 (red circle) with sampling error only.

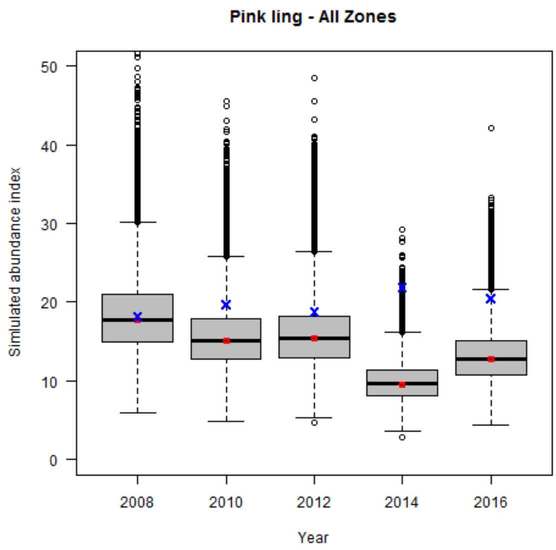

Figure 70. Pink Ling – All Zones: Boxplots (FIS2) of simulated biennial abundance indices and corresponding mean values of FIS1 (blue cross) and FIS2 (red circle) with both sampling and process error.

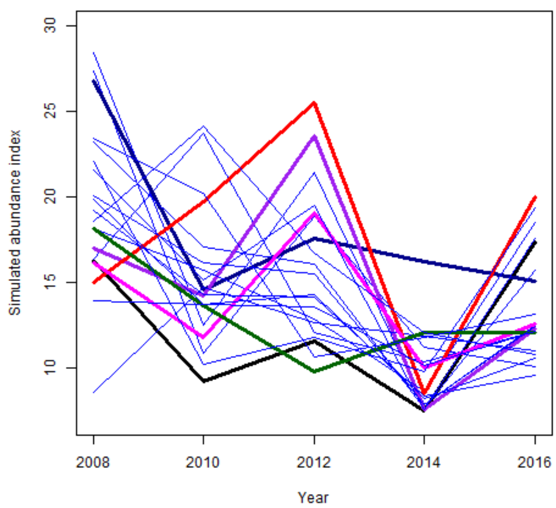

Figure 71. Pink Ling – All Zones: Twenty simulated relative biennial abundance indices for FIS2 with both sampling and process error. Coloured lines highlight contrast between different series.

Pink Ling – East

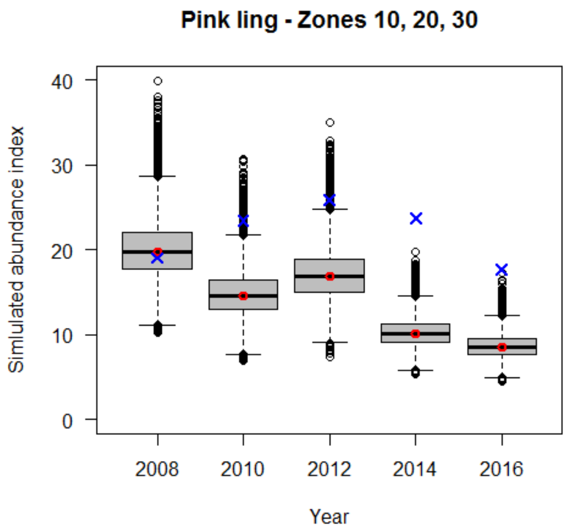

Figure 72. Pink Ling – East: Boxplots (FIS2) of simulated biennial abundance indices and corresponding mean values of FIS1 (blue cross) and FIS2 (red circle) with sampling error only.

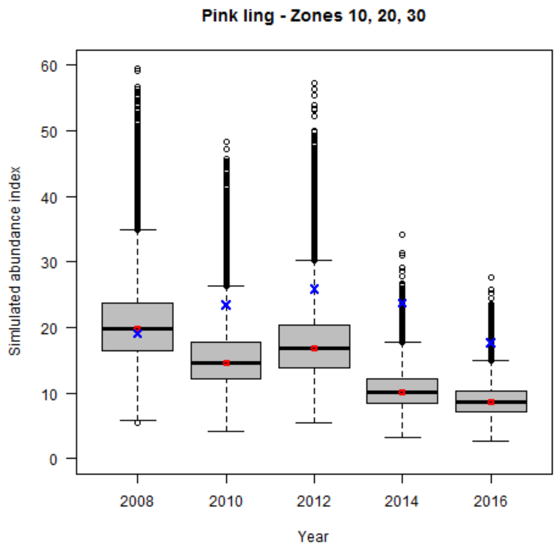

Figure 73. Pink Ling – East: Boxplots (FIS2) of simulated biennial abundance indices and corresponding mean values of FIS1 (blue cross) and FIS2 (red circle) with both sampling and process error.

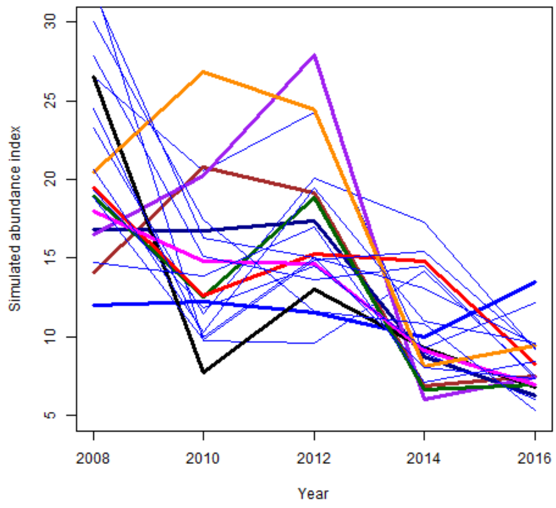

Figure 74. Pink Ling – East: Twenty simulated relative biennial abundance indices for FIS2 with both sampling and process error. Coloured lines highlight contrast between different series.

Pink Ling – West

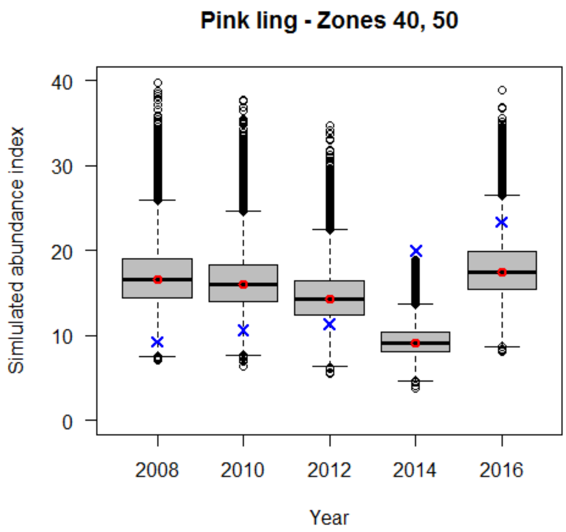

Figure 75. Pink Ling – West: Boxplots (FIS2) of simulated biennial abundance indices and corresponding mean values of FIS1 (blue cross) and FIS2 (red circle) with sampling error only.

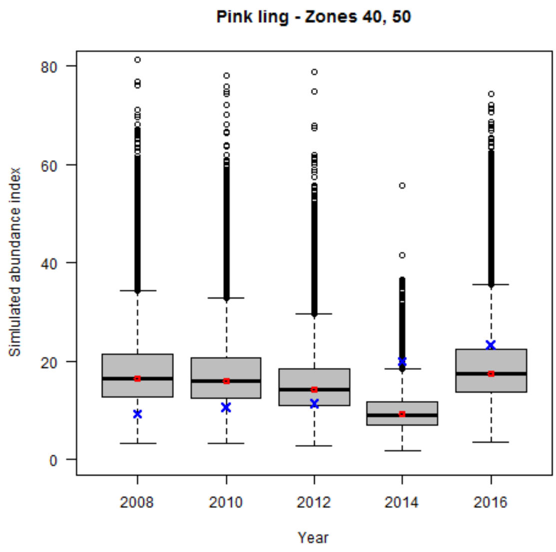

Figure 76. Pink Ling – West: Boxplots (FIS2) of simulated biennial abundance indices and corresponding mean values of FIS1 (blue cross) and FIS2 (red circle) with both sampling and process error.

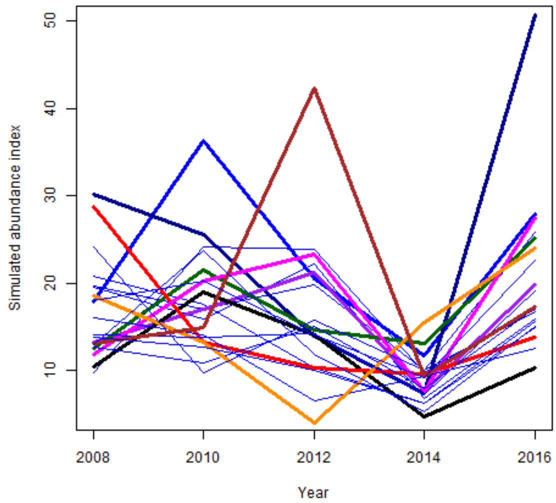

Figure 77. Pink Ling – West: Twenty simulated relative biennial abundance indices for FIS2 with both sampling and process error. Coloured lines highlight contrast between different series.

4.4 Additional Objective 4 Results: 2018 reconditioned model accounting for within-year variation (FIS3)

The transition from FIS2 to FIS3 resulted in generally greater changes to the shape and trend of the abundance series for all species/stocks examined, compared to the transition from FIS1 to FIS2 (Table 3, Table 8; Figure 78 to Figure 88). The relative changes between FIS2 and FIS3 ranged from 2% to 397% (in magnitude), with most over 20%, except for Tiger Flathead (most <20%; Table 10).

For Tiger Flathead (all zones and zone 10, 20), the overall shape was similar for the first four surveys for FIS2 and FIS3, followed by a relative reduction in the 2016 FIS3 abundance index compared to the 2016 FIS2 index (Figure 78 to Figure 80). This resulted in a difference in the overall apparent trend between FIS2 and FIS3. By contrast, the overall shape and apparent trend were similar between FIS2 and FIS3 for Tiger Flathead - zone 30. The relative reduction in the 2016 FIS3 abundance index occurred for all three fleet configurations for Tiger Flathead.

For Blue Grenadier (all zones and spawning), the overall shapes for FIS2 and FIS3 were similar for the first four surveys (and all five for spawning). This resulted in similar overall apparent trends between FIS2 and FIS3 (Figure 81 to Figure 83). The overall shape and apparent trend were contrasting between FIS2 and FIS3 for Blue Grenadier – non-spawning, with FIS2 decreasing and FIS3 increasing. In all three fleet configurations, the FIS3 relative abundance indices decreased from 2008 to 2012 (the first three surveys) relative to FIS2 and then increased in 2014 to 2016 (the last two surveys). In FIS2, there was a distinct difference in the shape of the abundance series between the all zones model and the spawning series (declining initially followed by a rapid increase, especially in 2016, a J-curve) and non-spawning series (decreasing with noise). The shape of the revised non-spawning series (FIS3) changed to a J-curve, now consistent with the other two fleet configurations.

For both east and west Pink Ling, the FIS3 relative abundance indices decreased from 2008 to 2012 (the first three surveys) relative to FIS2 and then increased in 2014 and 2016 (the last two surveys), as occurred for Blue Grenadier (Figure 84 and Figure 85). The apparent trend between FIS2 and FIS3 were similar in the east (both declining) and different in the west (increasing for FIS3 and declining/flat for FIS2).

For Silver Warehou, the overall shapes were similar for FIS2 and FIS3 but with dampened amplitude for all three fleet configurations (Figure 86 to Figure 88). The apparent trends between FIS2 and FIS3 were similar for two configurations, all zones and east, but differed in the west.

In all years, FIS3 CVs reduced compared with FIS2 CVs for Tiger Flathead – zone 10, 20, Blue Grenadier non-spawning, Pink Ling east and Pink Ling west. In most years, FIS3 CVs reduced compared with FIS2 CVs for Tiger Flathead – zone 30, Blue Grenadier spawning, Silver Warehou east and Silver Warehou west. In the two cases with large (>100%, Silver Warehou west, two different survey years) increases in CV between FIS2 and FIS3, the FIS2 CV was low (0.11, 0.09) and the FIS3 CV was moderate (0.34, 0.22). Changes to CVs and CV ranges are summarised by species below (see also Table 10):

1. <u>Tiger Flathead – Zone 10, 20</u>: low CVs on the FIS abundance series (FIS2: 0.12 – 0.13; FIS3: 0.09 – 0.13). CVs decreased in all surveys, with decreases between 3% - 30%.
2. <u>Tiger Flathead – Zone 30</u>: low CVs on the FIS abundance series (FIS2: 0.13 – 0.19; FIS3: 0.11 – 0.17). CVs decreased in four surveys, with reductions between 4% - 12%. For the 2012 survey, the CV increased by 1%.
3. <u>Blue Grenadier – Non-spawning</u>: low to moderate CVs on the FIS2 abundance series (FIS2: 0.11 – 0.28; FIS3: 0.08 - 0.21). CVs decreased in all surveys, with decreases between 2% - 71%.

4. Blue Grenadier – Spawning: low CVs on the FIS abundance series (FIS2: 0.16 – 0.21; FIS3: 0.12 – 0.21). CVs decreased in three out of five surveys, with reduction between 5% - 25%. For the two remaining surveys, CV's increased minimally between 3% - 4%.
5. Silver Warehou – East: low CVs on the FIS abundance series (FIS2: 0.09 – 0.18; FIS3: 0.07 - 0.11) but high inter-survey variability due to infrequent very large catches of this schooling species. CVs decreased in three out of five surveys, with reduction between 17% - 41%. For the two remaining surveys, CV's increased between 0.2% - 7%.
6. Silver Warehou – West: low-very high CVs on the FIS2 abundance series and low-moderate CVs on the FIS3 abundance series (FIS2: 0.11 – 1.25; FIS3: 0.07 - 0.34) but high inter-survey variability due to infrequent very large catches of this schooling species. CVs decreased in three surveys, with reductions between 83% - 87%. For the remaining surveys, CV's increased between 148% - 197%.
7. Pink Ling – West: low CVs on the FIS abundance series (FIS2: 0.18 – 0.21; FIS3: 0.14 - 0.17). CVs decreased in all five surveys, with reductions between 17% - 25%.
8. Pink Ling – East: low CVs on the FIS abundance series (FIS2: 0.16 – 0.18; FIS3: 0.11 - 0.17). CVs decreased in all five surveys, with reductions between 2% - 32%.

Table 8. Estimated biennial winter abundance indices based on the 2018 reconditioned model including within-year variation (FIS3) for selected species. ZONE: see Figure 3 for the SESSF statistical reporting zones.

COMMON NAME	ZONE	2008	2010	2012	2014	2016
Tiger Flathead	All Zones	8823.7	8164.372	13047.23	8697.166	8772.711
	10, 20	11496.27	8585.835	16344.18	9574.546	8500.622
	30	6019.180	7868.283	7808.308	9102.491	12961.75
Pink Ling	10, 20, 30	1450.035	1044.443	1434.837	1080.305	1050.165
	40, 50	88.959	119.528	129.454	128.807	218.736
Blue Grenadier	All Zones	2221.990	534.367	342.908	26213.576	95435.337
	Spawning: 40	8097.150	3285.207	842.635	29974.132	118080.521
	Non-spawning (10, 20, 30, 50)	2234.807	129.329	291.403	23889.989	49680.525
Silver Warehou	All Zones	2803.654	1620.729	2057.389	1510.584	4168.350
	10, 20, 30	3725.423	1572.977	1813.483	628.9051	7742.304
	40, 50	3342.809	744.5673	2044.294	2242.734	1597.513

Table 9. Estimated biennial winter coefficient of variation (CVs) based on the 2018 reconditioned model including within-year variation (FIS3) for selected species. ZONE: see Figure 3 for the SESSF statistical reporting zones.

COMMON NAME	ZONE	2008	2010	2012	2014	2016
Tiger Flathead	All Zones	0.0770	0.0947	0.0819	0.0709	0.0861
	10, 20	0.0926	0.1253	0.0974	0.0883	0.1015
	30	0.1422	0.1737	0.1612	0.1121	0.1744
Pink Ling	10, 20, 30	0.1115	0.1737	0.1402	0.1243	0.1206
	40, 50	0.1694	0.1586	0.1579	0.1391	0.1400
Blue Grenadier	All Zones	0.1060	0.1124	0.1073	0.0823	0.0774
	Spawning: 40	0.2013	0.2136	0.1743	0.1531	0.1206
	Non-spawning (10, 20, 30, 50)	0.1060	0.2105	0.1073	0.0823	0.0774
Silver Warehou	All Zones	0.0534	0.0641	0.0678	0.0560	0.0778
	10, 20, 30	0.0667	0.0903	0.1071	0.0861	0.0979
	40, 50	0.3352	0.0747	0.2050	0.2249	0.1602

Table 10. Comparison of FIS2 and FIS3 relative abundance indices. Relative percent change of FIS3 compared to FIS2. CV: coefficient of variation; Min: minimum; Max: maximum.

COMMON NAME-FLEET CONFIGURATION	RELATIVE ABUNDANCE % CHANGE					CV % CHANGE					RELATIVE ABUNDANCE		CV	
	2008	2010	2012	2014	2016	2008	2010	2012	2014	2016	Min	Max	Min	Max
Blue Grenadier- all Zones	-90.5	-85.3	-95.8	42.2	34.1	12.8	-11.6	3.2	-17.8	4.5	-95.8	42.2	-17.8	12.8
Blue Grenadier-non-spawning	-92.9	-93.7	-97.7	19.6	396.7	-1.8	-26.0	-25.3	-46.0	-70.6	-97.7	396.7	-70.6	-1.8
Blue Grenadier-spawning	-40.6	-24.8	-82.4	70.4	-1.5	3.9	3.2	-5.2	-14.8	-25.2	-82.4	70.4	-25.2	3.9
Tiger Flathead – all Zones	11.7	9.1	9.9	10.4	-29.1	-22.9	-12.0	-19.6	-16.9	-10.6	-29.1	11.7	-22.9	-10.6
Tiger Flathead – Zone 10, 20	2.0	17.6	20.0	6.7	-36.3	-29.9	-2.6	-26.0	-26.3	-18.7	-36.3	20.0	-29.9	-2.6
Tiger Flathead – Zone 30	16.2	16.0	-5.7	10.3	-15.1	-6.0	-3.8	0.9	-11.9	-6.3	-15.1	16.2	-11.9	0.9
Silver Warehou – all Zones	3.3	114.4	5.3	39.9	-26.3	-1.1	-4.3	-49.3	-11.5	8.5	-26.3	114.4	-49.3	8.5
Silver Warehou - East	68.0	104.0	-37.5	24.0	-14.8	-26.1	0.2	-41.2	-17.4	7.0	-37.5	104.0	-41.2	7.0
Silver Warehou - West	-2.7	22.6	123.1	34.5	-52.2	197.2	-84.1	-83.1	148.2	-87.2	-52.2	123.1	-87.2	197.2
Pink Ling – East	-15.3	-17.6	-1.7	23.0	41.3	-31.7	-2.1	-19.1	-21.3	-23.8	-17.6	41.3	-31.7	-2.1
Pink Ling – West	-42.3	-20.2	-2.6	51.1	33.9	-17.2	-18.9	-24.0	-24.2	-25.3	-42.3	51.1	-25.3	-17.2

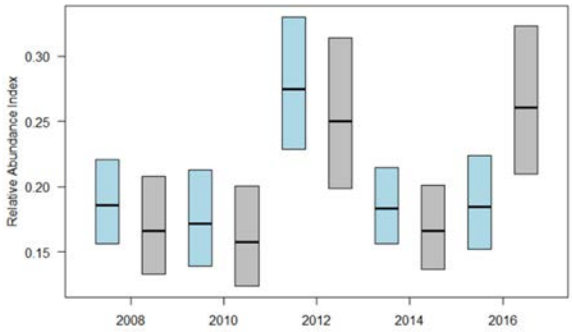

Figure 78. Flathead – All Zones: Relative biennial abundance indices for the 2018 including within-year variation model (light blue; FIS3) and 2018 reconditioned model (grey; FIS2).

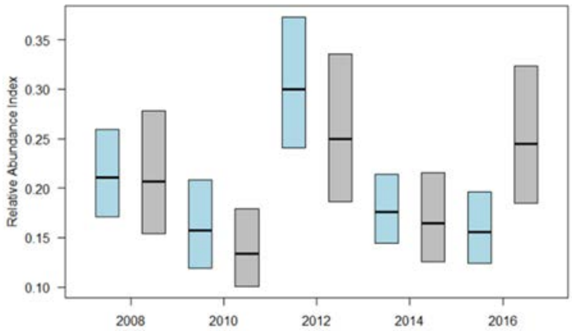

Figure 79. Flathead – Zones 10, 20: Relative biennial abundance indices for the 2018 including within-year variation model (light blue; FIS3) and 2018 reconditioned model (grey; FIS2).

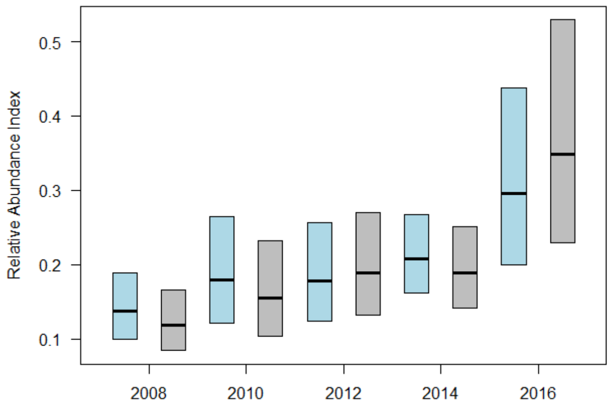

Figure 80. Flathead – Tas (Zone 30): Relative biennial abundance indices for the 2018 including within-year variation model (light blue; FIS3) and 2018 reconditioned model (grey; FIS2).

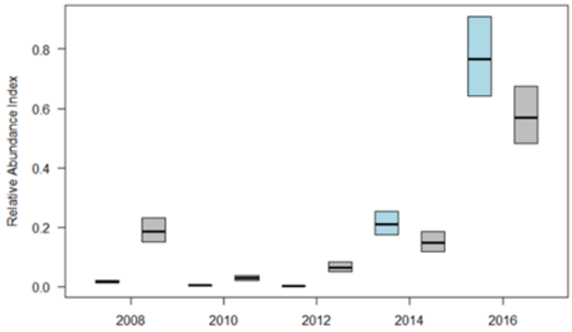

Figure 81. Blue Grenadier – All Zones: Relative biennial abundance indices for the 2018 including within-year variation model (light blue; FIS3) and 2018 reconditioned model (grey; FIS2).

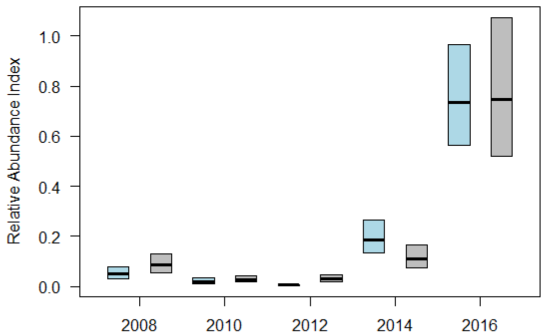

Figure 82. Blue Grenadier – Spawning (Zone 40): Relative biennial abundance indices for the 2018 including within-year variation model (light blue; FIS3) and 2018 reconditioned model (grey; FIS2).

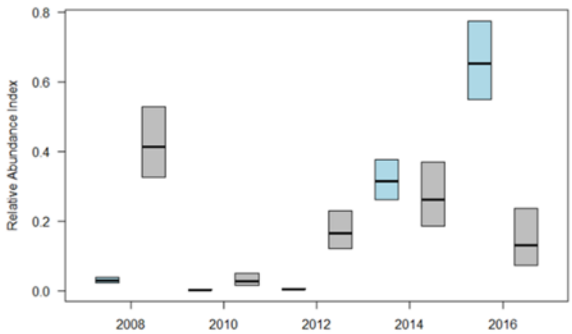

Figure 83. Blue Grenadier – Non-spawning: Relative biennial abundance indices for the 2018 including within-year variation model (light blue; FIS3) and 2018 reconditioned model (grey; FIS2).

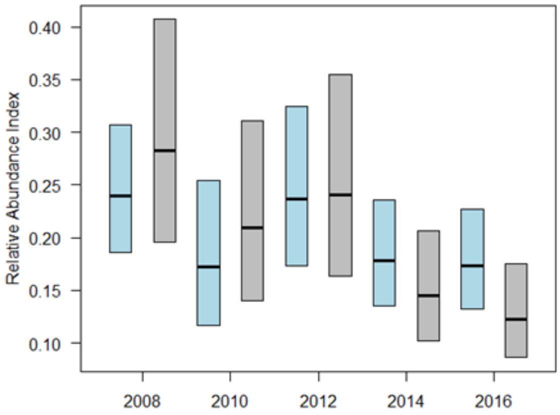

Figure 84. Pink Ling – East: Relative biennial abundance indices for the 2018 including within-year variation model (light blue; FIS3) and 2018 reconditioned model (grey; FIS2).

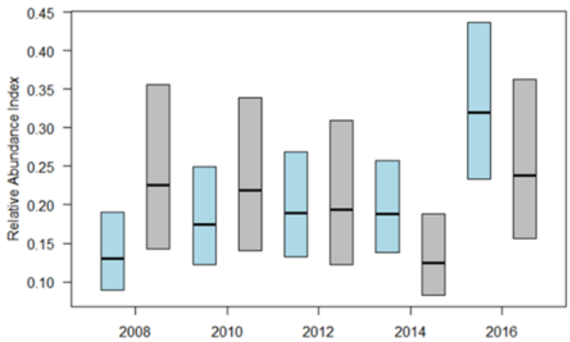

Figure 85. Pink Ling – West: Relative biennial abundance indices for the 2018 including within-year variation model (light blue; FIS3) and 2018 reconditioned model (grey; FIS2).

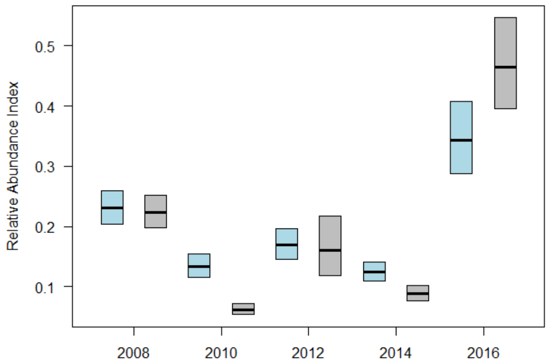

Figure 86. Silver Warehou – All Zones: Relative biennial abundance indices for the 2018 including within-year variation model (light blue; FIS3) and 2018 reconditioned model (grey; FIS2).

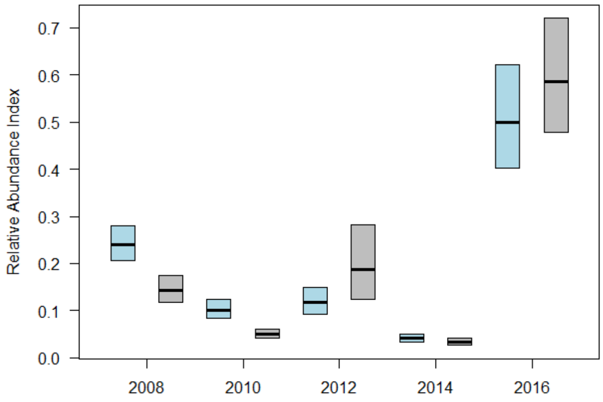

Figure 87. Silver Warehou – East: Relative biennial abundance indices for the 2018 including within-year variation model (light blue; FIS3) and 2018 reconditioned model (grey; FIS2).

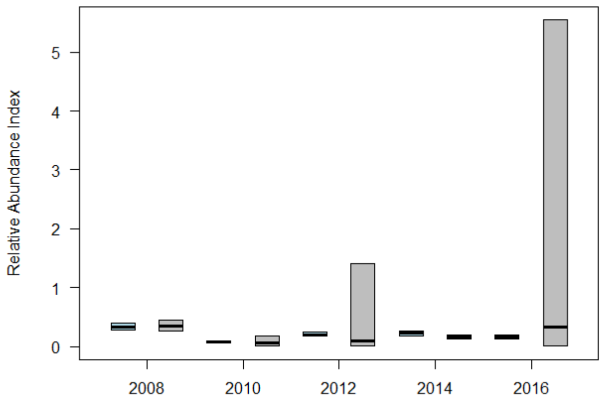

Figure 88. Silver Warehou – West: Relative biennial abundance indices for the 2018 including within-year variation model (light blue; FIS3) and 2018 reconditioned model (grey; FIS2).

4.5 Additional Objective 5 Results: Stock assessment scenario exploration

4.5.1 Western Jackass Morwong

The inclusion of FIS abundance indices and length frequency data made very little difference to any of the key assessment outcomes (Figure 97 to Figure 103), including the model scenario with no FIS. Likewise there was very little difference in the assessment results when using the FIS2 abundance series compared to the FIS1 abundance series under any of the different scenarios.

This result was not surprising as the relative FIS1 and FIS2 abundance series were very similar for western Jackass Morwong, with the only notable difference being an increase in 2016 for the FIS2 series (Figure 102 and Figure 103). The FIS1 data was plotted in the green shaded (lower) circles in Figure 102 and Figure 103 with the FIS2 series data plotted in red shaded circles. The CVs for each series were also similar, (FIS1: 0.25 - 0.34; FIS2: 0.23 - 0.48), although generally larger for FIS2 than for FIS1, with the largest increase in CVs in 2008 and 2016 in the FIS2 series.

The fits to CPUE were generally poor (Figure 100 and Figure 101). When CPUE was excluded after 2006 there were differences in the abundance series, with higher absolute abundance estimated throughout the series (Figure 97) and higher relative abundance from around 2005 onwards (Figure 98). When CPUE was excluded after 2006 the estimate of average recruitment increased and the actual recruitments were all higher from 2000 onwards (Figure 99). The FIS abundance series fits were slightly worse when CPUE was excluded after 2006 (Figure 102 and Figure 103).

4.5.2 Eastern Jackass Morwong

The inclusion of FIS abundance and length frequency data made very little difference to any of the key assessment outcomes (Figure 104 to Figure 114). Likewise there was very little difference in the assessment results when using the two abundance series (FIS1 and FIS2) under any of the different scenarios.

Even though the assessments outcomes had little change between FIS1 and FIS2, the abundance series did change. Unlike western Jackass Morwong, the eastern FIS abundance series had substantial changes from FIS1 to FIS2, both series showing a decline from 2008 to 2016, but with a less substantial decline shown in FIS2 with the largest relative differences in 2014 and 2016. The FIS2 eastern series (zones 10 and 20) had higher relative values in 2014 and 2016 than FIS1, and increased from 2014 to 2016 (Figure 111). The CVs for the eastern FIS show a general increase for FIS2, (FIS1: 0.28 - 0.68; FIS2: 0.31 - 0.93), although generally larger for FIS2 than for FIS1, with the largest increases in CV in 2014 and 2016. The Tasmanian FIS abundance series (zone 30) had minor changes from FIS1 to FIS2 with a very similar pattern but perhaps a marginally steeper decline for FIS2 (Figure 113). The CV for each year is larger for FIS2 compared to FIS1 (FIS2: 0.41 - 1.03; FIS1: 0.30 - 0.77). The changes between the FIS1 and FIS2 series in the Tasmanian and eastern FIS indices were in opposite directions, so it is possible that any effects were cancelled out with changes to both series.

The fits to the CPUE (Figure 107 to Figure 110) were better than those for western morwong, but featured periods with poor fits. When CPUE was excluded after 2006, there were minor differences in the abundance series, with marginally higher absolute spawning biomass estimated throughout the series and notably so after 2010 (Figure 104). The relative abundance series was confounded by the productivity shift implemented in this model from 1988 onwards, but notably the relative biomass was higher from 2012 when the CPUE was excluded after 2006 (Figure 105). Recruitments were very similar until about 2008 for all scenarios but after 2008, when CPUE was excluded after 2006, the recruitments were estimated to be higher than the scenarios with all CPUE included (Figure 106). The fits to the FIS abundance series are slightly worse when the CPUE was excluded after 2006 (Figure 111 to Figure 114).

4.5.3 Blue Grenadier – non-spawning FIS

The inclusion of FIS abundance data made very little difference to any of the key assessment outcomes (Figure 115 to Figure 121) when the full CPUE series was included to 2017. However, when CPUE was excluded after 2006, there were substantial differences to the key assessment outcomes, both in terms of differences to the scenario with no FIS data and then further differences between the FIS1 and FIS2 scenarios.

The relative abundance values for individual surveys changed substantially from FIS1 to FIS2. However, this did not change the overall shape of each series. This is partly due to a very low abundance estimate in 2012 for FIS2 and a high value in 2014 for FIS1. However there was no change to the apparent trends because (i) the relative changes were in opposite direction in each survey, and (ii) the outliers in 2010 and 2014 did not significantly influence the trend in either FIS series.

At the same time, the values of the CV decreased substantially for FIS2 (FIS1: 0.34 - 2.31; FIS2: 0.11 - 0.28). In both cases there also appeared to be considerable inter-survey variability in the FIS abundance index (Figure 120).

When CPUE was excluded after 2006, there were changes to the abundance series, with lower absolute values at the start and the end of the time series for FIS1, but with very similar estimates of 2018 stock status (Figure 115 and Figure 116). The pattern in recruitment looked very similar for FIS1 (Figure 117) with small variations in the relative size of the larger recruitment events. By contrast, using the FIS2 abundance series with no CPUE data after 2006, the spawning biomass patterns followed similar trends to the other scenarios until 2012. This was explained by a change in the estimated recruitment series, which again followed similar trends to other scenarios until 2010, at which stage recruitment was estimated to remain very low for FIS2, compared to five years of above average recruitment in all other scenarios. This “recruitment failure” in the FIS2 scenario produced dramatically lower stock status estimates in 2018 (stock collapse).

As observed in the base case assessment for Blue Grenadier, the fits to the CPUE series (Figure 118 and Figure 119) were relatively poor in all scenarios. There were minor improvements to these fits when CPUE was excluded from 2006 onwards, but these fits were still poor. The variability in FIS abundance estimates between surveys mean that fits to the FIS were always likely to be poor (Figure 120 and Figure 121). When CPUE was excluded beyond 2006, fits appeared to improve marginally for the FIS1 series and considerably for the FIS2 series, particularly in the years 2008, 2012 and 2016 in both scenarios (Figure 120 and Figure 121).

4.5.4 Blue Grenadier – spawning FIS

The inclusion of FIS abundance data made very little difference to any of the key assessment outcomes (Figure 122 to Figure 128) when the full CPUE series was included to 2017. However, when CPUE was excluded after 2006, there were substantial differences to the key assessment outcomes, both in terms of difference to the scenarios with no FIS data and some smaller differences between the FIS1 and FIS2 scenarios.

The FIS abundance series had substantial changes from FIS1 to FIS2 with a relative decrease to the first four points and an increase in 2016. However, there was less change to the overall shape of the series as was seen with the non-spawning series. The abundance estimates from 2008 to 2014 were relatively lower in FIS2 than in FIS1. At the same time, the values of the CV decrease substantially in FIS2, (FIS1: 0.26 - 0.59; FIS2: 0.16 - 0.21). In both FIS1 and FIS2, the CVs were considerably lower for the spawning FIS than the non-spawning FIS abundance indices, and in both cases the CVs were reduced substantially with the FIS2 analysis.

When CPUE was excluded after 2006, there were some changes to the abundance series with lower absolute values throughout for both FIS1 and FIS2 (Figure 122), but with higher relative values at the start of the time series and lower relative values at the end of the time series (Figure 123) and lower estimates of 2018 stock status as a result. There were small differences between the FIS1 and FIS2 series, especially at the end, resulting in slightly different estimates of stock status in 2018, but with both being substantially lower than the stock status estimates for the other three scenarios. As in the Blue Grenadier non-spawning FIS case, the differences (with CPUE excluded after 2006) were largely due to substantially lower recruitment estimates in the period from 2010-2014, with relatively minor differences between the FIS1 and FIS2 scenarios.

The fits to the CPUE series (Figure 125 and Figure 126) were relatively poor in all scenarios. There were some improvements to these fits when CPUE was excluded from 2006 onwards, but little difference in the fits between the FIS1 and FIS2 scenarios. By contrast to the non-spawning FIS, the fits to the spawning FIS abundance indices (Figure 127 and Figure 128) appear to deteriorate when the CPUE was excluded beyond 2006, which suggests that there must be improvements to fits of other components of the data.

4.5.5 Silver Warehou

The inclusion of FIS abundance data made very little difference to any of the key assessment outcomes (Figure 129 to Figure 131) when the full CPUE series was included to 2017. However, when CPUE was excluded after 2006, there are substantial differences to the key assessment outcomes, largely in terms of difference to the scenario with no FIS data, and also minor differences between the FIS1 and FIS2 scenarios.

This result was not surprising as the inter-survey variability was large for Silver Warehou and it was difficult to get good fits to the FIS abundance indices for either FIS1 or FIS2 abundance series. There were separate eastern and western FIS abundance series for Silver Warehou and the FIS2 series generally showed a relative decrease in the first three abundance indices, followed by a relative increase in the last two, in comparison with the FIS1 series. For the eastern abundance series, the estimated CVs all decreased, (FIS1: 0. 18 - 0. 28; FIS2: 0. 09 - 0.18). By contrast, for the western FIS abundance series, the estimated CVs decreased in some years but increased markedly in others, (FIS1: 0.15 - 0.35; FIS2: 0.09 - 1.25). Regardless of the values of the estimated CVs, the inter-survey variability for Silver Warehou was still large, compared to other species.

With the CPUE data excluded after 2006, there were considerable changes to the abundance series, with higher absolute values throughout for both FIS1 and FIS2 (Figure 129), and with lower relative values at the start of the time series and higher relative values at the end of the time series (Figure 130) and considerably higher estimates of 2018 stock status as a result. There were small differences between the FIS1 and FIS2 series, resulting in slightly different estimates of stock status in 2018, but with both being substantially higher than the stock status estimates for the other three scenarios. The differences (with CPUE excluded after 2006) were largely due to substantially higher recruitment estimates in the period from 2010-2014, and a higher estimate for R_0, with relatively minor differences between the FIS1 and FIS2 scenarios.

The fits to the CPUE series were relatively poor for the eastern trawl CPUE (Figure 132 and Figure 133), and the differences in fits to the CPUE were minor between all scenarios, both in the east and the west (Figure 134 and Figure 135). The fits to the two FIS abundance series improved slightly, more so in the east (Figure 136 and Figure 137) than the west (Figure 138 and Figure 139) when the recent CPUE was excluded, with slightly greater improvements for FIS2.

4.5.6 Western Pink Ling

The inclusion of FIS1 abundance data made very little difference to any of the key assessment outcomes (Figure 140 to Figure 142) when the full CPUE series was included to 2017 for western Pink Ling. However the inclusion of the FIS2 abundance index made a substantial difference to the key assessment outcomes. When CPUE was excluded after 2006, there were substantial differences to the key assessment outcomes with differences from the scenarios including CPUE data to 2017 and also between the outcomes from FIS1 and FIS2 with recent CPUE excluded.

This was a result of substantial changes in values and trends between the abundance series from FIS1 to FIS2 (Figure 145) and a different trend between FIS2 and CPUE. The inter-survey variability was low for western Pink Ling, the estimated FIS CVs were low and the CPUE fits were good, so this large change to the trend and shape of the FIS abundance series was unexpected. The CPUE and the FIS1 series both had a generally increasing trend between 2008 and 2016, whereas the FIS2 series had a trend that was declining from 2008 to 2014, followed by a sharp increase in 2016 to just above the 2008 level. By contrast to the changes in the abundance between FIS1 and FIS2, the CVs were similar for each series, (FIS1: 0.18 - 0.22; FIS2: 0.18 - 0.21), and were amongst the lowest values of FIS CVs for stocks considered here.

The fits to CPUE are good and appear similar for all scenarios (Figure 143 and Figure 144). When CPUE was excluded after 2006 there were reductions in the estimates of both B_0 and R_0 for both FIS series, and also reductions in the estimate of R_0 for the FIS2 series with all recent CPUE included. Consequently the abundance estimates are reduced for all scenarios other than no-FIS and FIS1, with changes to recruitment for all these scenarios as well, with reductions in absolute magnitude generally and relative reductions for the more recent recruitment events as well. The timing of peaks and troughs in recruitment was similar for all scenarios, but with differences in relative magnitude. The fits to the FIS abundance series improve (Figure 145 and Figure 146) when the recent CPUE was excluded.

4.5.7 Eastern Pink Ling

For eastern Pink Ling, the inclusion of FIS abundance data made very little difference to any of the key assessment outcomes (Figure 147 to Figure 149) when the full CPUE series was included to 2017. However, when CPUE was excluded after 2006, there are differences to the key assessment outcomes, largely in terms of difference to the scenario with no FIS data but also some minor differences between the FIS1 and FIS2 scenarios.

The FIS abundance series had substantial changes from FIS1 to FIS2 with a relative increase to the first point and a decrease in 2014 and 2016, resulting in a declining series (FIS2) compared to a dome shaped series (FIS1). The values of the CV decrease in FIS2, (FIS1: 0.18 - 0.22; FIS2: 0.16 - 0.18). When the recent CPUE is excluded, the fits to each of these series give a markedly different trend, especially for the FIS2 series. The recent CPUE series was somewhat variable, but generally has a flat trend since 2007, in contrast to the FIS2 series.

The differences between the FIS1 and FIS2 series resulted in slightly different estimates of stock status after 2010, but with both being substantially lower than the stock status estimates for the other three scenarios. As in the Blue Grenadier non-spawning FIS case, the differences (with CPUE excluded after 2006) were largely due to substantially lower recruitment estimates in the period from 2008-2014, with relatively minor differences between the FIS1 and FIS2 scenarios.

The fits to CPUE are good and appear similar for all scenarios (Figure 143 and Figure 144). When CPUE was excluded after 2006 there were reductions in the estimates of both B_0 and R_0 for both FIS series, and also reductions in the estimate of R_0 for the FIS2 series with all recent CPUE included. Consequently the abundance estimates are reduced for all scenarios other than no FIS and FIS1, with changes to recruitment for all these scenarios as well, with reductions in absolute magnitude generally and relative reductions for the more recent recruitment events as well. The timing of peaks and troughs in recruitment was similar for all scenarios, but with differences in relative magnitude. The fits to the FIS abundance series improve (Figure 145 and Figure 146) when the recent CPUE was excluded.

The fits to the CPUE series (Figure 150 and Figure 151) were good in all scenarios. There were some improvements to these fits when CPUE was excluded from 2006 onwards, notably between 1986 and 1998. Fits improved for FIS2 but deteriorated for FIS1, with recent CPUE excluded (Figure 152 and Figure 153).

4.6 Summary results: FIS1, FIS2, FIS3 and stock assessment scenarios

Changes between FIS1, FIS2 and FIS3 abundance series, changes in CVs and effects on stock assessment results are summarised in Table 11.

Table 11. Summary of FIS and stock assessment scenarios. Assessment change: Change in estimated 2018 stock status, relative to B_0, for each scenario analysed when the recent CPUE was excluded for either FIS1 or FIS2. Note: negligible, small, moderate, large differences are qualitative. Arrows indicate direction of change (↑ up; ↓ down; ~↔ similar, ↓↓ large decrease.)

	no FIS *vs* FIS1	no FIS *vs* FIS2	FIS1 *vs* FIS2						FIS2 *vs* FIS3	
Common name	Assessment change (no FIS *vs* FIS1)	Assessment change (no FIS *vs* FIS2)	FIS1 *vs* FIS2 abundance	FIS1 CV *vs* FIS2 CV	Assessment change (direction)	Assessment change (magnitude)	Assessment: FIS1 fits with CPUE excluded	Assessment: FIS2 fits with CPUE excluded	FIS2 *vs* FIS3 abundance	FIS2 CV *vs* FIS3 CV
Jackass Morwong - West	negligible	negligible	negligible	↑	↑	moderate	↓	↓	-	-
Jackass Morwong - East	negligible	negligible	moderate	↑	↑	small	↓	↓	-	-
Blue Grenadier – non-spawning[a]	negligible	negligible	large	↓↓	↓	large	↑	↑	large	↓
Blue Grenadier – spawning[b]	negligible	negligible	large	↓↓	↓	large	↓	↓	small	↓
Silver Warehou[c]	negligible	negligible	small	↓(E) ↑(W)	↑	large	↑	↑	large	↓(E) ~↔ (W)
Pink Ling - West	negligible	moderate (↓)	large	~↔	↓	large	↑	↑	large	↓
Pink Ling - East	negligible	negligible	large	↓	↓	moderate	↓	↑	small	↓

[a]: non-spawning refers to the FIS index (i.e. excluding Zone 40)
[b]: spawning refers to the FIS index (i.e. Zone 40 only)
[c]: East and West FIS included as separate indices in this model (i.e. not using the all Zones FIS index)

5. Discussion and Conclusions

5.1 Objective 1: Station re-examination

A framework has been developed to identify potential stations for redesign, which could include moving location/depth or station removal. Given a list of species, the approach provides an ordered list of stations that could be selected for redesign. An important aspect of the resulting list of potential redesign stations is that this list is ordered and cannot be subdivided, as each station in the list requires the earlier stations in the list to be also included in the redesign. The list is only valid by starting at the first station and removing stations in the order without skipping stations.

Future work could consider iteratively merging the selection and redesign process. This was not considered here due to the additional complexities involved with redesigning the survey. If a redesign was to be carried out, it may be worth considering a process of selecting and moving one station, before the next station is selected. The approach adopted here simply identified how to select a list of stations for redesign. The stations selected were based on a change to CV of abundance lower than a threshold (precision) and then selecting stations with the nearest neighbours, to reduce duplication. The nearest neighbour criteria ensures a robust design, by selecting a station for redesign from densely sampled areas, in preference to more isolated stations. These isolated stations may still be important for the analysis, even with little catch, due to the potential for future range expansion. These points may also help inform the GAM in uncertain areas.

To demonstrate the approach, a list of stations was produced for the four agreed key species (Tiger Flathead, Pink Ling, Blue Grenadier, Silver Warehou). All of the top 12 redesign stations were in shallower water (<200 m) and most in the eastern half of the fishery. The redesign stations being related to depth is a reflection of the current FIS survey having a distinct shallow water bias, as the original survey design (Peel et al., 2012) over-sampled shallower waters in winter and over-sampled deeper waters in the summer. The summer survey was discontinued from 2014, resulting in the deeper water being under-sampled.

A theoretical set of 12 candidate stations for redesign was produced, based on the four key species chosen as representative of the species in the fishery. These 12 stations are dependent on the particular set of species selected. The selection of species should be carefully reviewed if a redesign is recommended in the future. The number of stations chosen could be reviewed.

This analysis focused on four key species highlighted a potential sampling bias towards shallow water (<200m) in the current FIS which is now conducted only in summer. By contrast, the winter component of the initial implementation of the FIS had greater emphasis on deep water (>200 m) sampling, to balance the summer component, which had greater emphasis on shallow sampling (<200 m). While the existing survey results are still valid, it may be desirable to carefully review the depth balance in future.

The five stations identified as outside the species range for all four key species, may have been important for other species and were retained in any case to account for future range expansion and also in case they were really important for other species.

5.2 Objective 2: 2018 reconditioned model (FIS2)

Revisions to spatial and depth bounds used to recondition the model resulted in minor changes to these bounds. The model was revised (FIS2) using Commonwealth logbook data from 2008-2016. For the majority of stocks examined, the model converged. For some stocks, usually those with limited data, there were minor issues with convergence, due to over-parameterisation. This was rectified by reducing the number of parameters (knots) used in the spatial smooth. Diagnostics suggested no clear departures from model assumptions, indicating that the reconditioned statistical model (GAM) was valid (Appendix A).

In the reconditioned model, while the model predicted abundance index changed for individual survey years, there were relatively small differences in the overall series (FIS1 vs FIS2) for most stocks. Pink Ling was an exception with considerable changes in the shape and apparent trend in the series in both the east and west. This was surprising given the CVs for Pink Ling were low compared to the CVs from FIS1, which could be explained by changes in fishing practices and how adequately CPUE indexes the stock from 2008-2016, compared to 2001-2005.

Model estimated FIS2 CVs were lower than FIS1 CVs for many fleet configurations (stocks). For Blue Grenadier, the FIS2 CVs were substantially reduced to below 0.3, the upper bound for a reasonable CV (Knuckey et al., 2012, Knuckey et al., 2013, SMARP, 2015). The exception to this general reduction in FIS2 CVs were stocks with high inter-survey variability (e.g. Silver Warehou) or moderate to high CVs and relatively low catches (e.g. Jackass Morwong).

Given the changes to the fishing fleet and practices after the 2007 structural adjustment, continuing to apply a model conditioned on data from 2001-2005 could invalidate the model, as these data are unlikely to reflect current fishing practices. When the FIS was originally designed, data were only available prior to the structural adjustment for model conditioning, so the option to use more appropriate logbook data was not available until these data were collected.

For any species with high levels of seasonal (within-year) variability, the FIS1 and FIS2 indices are likely to be snapshots of species availability rather than to be representative of abundance. Seasonal variability could be partly accounted for with summer and winter surveys, but once the summer FIS was discontinued (from 2014), this source of variation was no longer available for consideration. To partially address this, a day-of-year model term could be added to the GAM model (see Additional Objective 4), using additional data from the logbook data.

The utility of the FIS abundance series is difficult to assess with only five survey data points, especially for stocks that have other long-term abundance indices (i.e. commercial CPUE). For species with Tier 1 integrated assessments which use a number of different data sources, longer data sets can dominate shorter data sets (e.g. the Tiger Flathead assessment uses data back to 1915). As a result, the FIS abundance series may have little impact on assessment results, simply due to the relative length of different data sets (see Additional Objective 5). The utility of five FIS survey points is even lower when there is high inter-survey variability beyond biological feasibility (process error) for particular species (e.g. Silver Warehou).

As part of this objective, essential updates to software versions (R) and packages (mgcv), were incorporated in the code, allowing this code to be more easily maintained and used for analyses of future surveys. Efficiencies were also gained through the use of BAMs (GAMs for large data sets) which were unavailable when the initial analysis was done (FIS1).

5.3 Objective 3: Data simulation using 2018 reconditioned model estimates

Simulations showed considerable trend variability using sampling error only, with the CVs calculated in FIS2. There were quite different trajectories from the same simulated distribution, indicating the potential for markedly different apparent trends. This problem is exacerbated by the short time series, corresponding to only five FIS surveys. This variability increased considerably when process error was added.

Currently, a subjective CV threshold of less than 0.3 is used to provide a guide as to the utility of abundance indices for each species. While previous FIS reports (Knuckey et al., 2012, Knuckey et al., 2013) and the SMARP (2015) review states that this level of CV is “acceptable” (as agreed by the SESSF Resource Assessment Group and used in the initial FIS1 design), a better understanding of this level of variation provides a more formal characterization of what such variation implies. Lower CVs and longer time series would both improve the utility and stability of the FIS as an abundance series. Greater consistency and precision in the FIS abundance time-series could be achieved by (i) continuing the FIS and (ii) increased sampling intensity, both spatially and temporally.

However, as there is a desire to use the series in current assessments (such as Jackass Morwong, Silver Warehou, Tiger Flathead, Pink Ling, Blue Grenadier), simulated process error can provide insights into the utility of the series, given the low number of data points and the large inter- and intra-annual variability.

5.4 Additional Objective 4: Reconditioned model accounting for within-year variation (FIS3)

Unlike the transition from FIS1 to FIS2, where the changes were minor for most stocks, the transition from FIS2 to FIS3 resulted in generally greater changes to the shape and apparent trend of the abundance series for all species/stocks examined. The changes for Tiger Flathead were mostly in one year (reduction in 2016 index), for all years for Blue Grenadier (down in the early years, up in the later years in FIS3) and a dampening of amplitude for Silver Warehou over the whole series.

For FIS1 and FIS2, the shape and trend of the Blue Grenadier non-spawning series contrasted strongly with the spawning series and the all zones series. By contrast, for FIS3 all three series had a similar shape. The non-spawning series changed distinctly and is now similar to the other two series, with all three series having a J-curve shape with a large increase in 2016. This J-curve shape is consistent with indications of a series of good recent recruitments, observed in length and age data, and reductions to recent fishing catches (Castillo-Jordán and Tuck 2018).

The FIS3 abundance series increased for Pink Ling west, with similar a shape to the FIS1 series, and in contrast to the flat/declining FIS2 series. By contrast, for Pink Ling east, there was a change in shape from FIS1 to FIS2, but no further change in shape in FIS3.

Generally, FIS3 CVs were lower than FIS2 CVs for the four key species examined. All CVs were less than 0.3 (the upper bound for a reasonable CV; Knuckey et al., 2012, Knuckey et al., 2013, SMARP, 2015), except for Silver Warehou west (CV = 0.34).

It is important that the model assumptions are appropriate and the model structure reflects the fishery being sampled. This can be a complex process, with iterative improvements. There may be a trade-off between true fishery independence and using some aspects of the data from logbooks, which is clearly fishery dependent. The data used from the logbook (depth, time of day, day-of-year) is less dependent on changes to fishery operations.

Problems such as effort creep and long-term fishery change issues, will not affect day-of-year, as this term is calculated separately for each year. The advantage of the model-based design is it can fill gaps in the logbook data by sampling locations that have low commercial effort, to give a more representative spatial coverage. The use of logbook data in the spatial smooth provides a base that is then modified by the FIS, so should not be influenced by fishery operations.

These issues may be accentuated by only having five surveys to date, with limited within-year sampling. In some cases, the shape of the resulting series changed with a different model structure, which may be related to the number of survey years or just the change in model structure. With additional surveys, these issues are likely to resolve, with the signal less dominated by noise. A longer abundance time series is likely to be more informative as emergent trends become clearer and less influenced by short term variation (sampling error).

5.5 Additional Objective 5: Stock assessment scenario exploration

Integrated stock assessments attempt to balance potentially conflicting data sources, with this balance achieved through a combination of tuning and maximising a composite likelihood function. Likelihood profiles can often reveal the tensions from competing data sources, namely when one data source suggested a high estimated (or derived) parameter value and another data source suggested a lower value. (Day and Castillo-Jordán 2018a, 2018b, Castillo-Jordán and Tuck 2018, Burch et al., 2019).

Changing the input data in a stock assessment can produce unexpected results. Tension released by deleting one component data source, which may constrain other data sources, can allow other components to produce improved fits to the data. However, in integrated assessment, this may also allow for some components to produce improved fits while others show worse fits, as long as the overall likelihood is improved. Picking the components *a priori* which give improved fits and those with poorer fits is unlikely to be obvious in advance. Excluding CPUE data after 2006 sometimes resulted in improvements to the fits to the FIS abundance indices (as the spawning biomass was no longer constrained to try to fit as many different abundance indices in the period 2008-2016, so could fit the FIS better in this period) and sometimes showed some deterioration in these fits (as greater improvement to fits in discard, length and age data counter balanced deterioration in fits to the FIS abundance indices). All data sources contribute to the likelihood and the interactions between different components can be complex, especially if there are conflicts between data.

The addition of five FIS abundance points to a well-established stock assessment with a long time series of data can sometimes have very little effect on the assessment outcomes. This could be because the FIS series supports the results suggested by the other data sources (so little conflict between the FIS -and other data sources), or it could be that the quantity of other data overwhelms any influence from the FIS (so conflict between the FIS and other data sources exists, but where the signal from the FIS is "drowned out" by the quantity of alternative data). On occasions, removing some CPUE data allows the five FIS data points to have quite significant influence on assessment outcomes. In this case it could be due to a relatively unstable assessment, where the balance of the various tensions between data sources can be upset relatively easily.

Inclusion of different FIS scenarios have produced a wide range of results. Inclusion of length frequency data (for Jackass Morwong only) appeared to have little effect, indicating that these data had little additional information to inform the assessments. Inclusion of FIS abundance data often had little effect on the assessment outcomes, unless the recent CPUE data was also excluded. The exception to this case was western Pink Ling, where the inclusion of FIS2 abundance data had a large effect on the assessment outcomes, even with only five abundance points.

When recent CPUE was excluded, there were widely variable changes to assessment outcomes in terms of changes to estimated 2018 spawning stock biomass, with these changes varying both in size and direction for different stocks. In some cases, fits to the FIS indices improved and in others they deteriorated. Likewise, the changes between the FIS1 and FIS2 abundance series varied between species, with some showing very little difference and others producing substantial changes. In some stocks the estimated FIS CVs improved and in others they deteriorated.

While this may indicate that results of including the FIS are unpredictable, it also highlights that this is not a simple system. Whether the FIS abundance series should be included in an assessment or not should depend both on the estimated CVs of the series, giving some measure of quality of the data series, and also on the inter-survey variability. Silver Warehou has FIS indices with low CVs, but this is a poor index to use in the assessment because of the large inter-survey variability, likely due to the schooling nature of the species and occasional very large shots featuring in the FIS for a particular year (Day and Peel, 2015). By contrast Pink Ling has low CVs and low inter-survey variability and so in theory, the FIS abundance index should be informative for this species. However, there were large changes between the FIS1 and FIS2 abundance indices for this stock, which may reflect substantial changes to the nature of the fishery after the structural adjustment in 2007. In any case, having an informative FIS abundance index with low CVs may require careful consideration if it is sensitive to assumptions used in producing this series. Note that only FIS1 and FIS2 abundance series were examined in this section. Similar analyses could be performed using the FIS3 series in the future.

The 2018 Blue Grenadier assessment only used the non-spawning FIS abundance index (as a sensitivity), as SERAG decided that the spawning stock was not well indexed by a demersal trawl survey, given that the spawning fishery is largely a mid-water fishery. The non-spawning FIS abundance series used in the 2018 assessment had very large calculated CVs for the point estimates, ranging from 0.57 to 2.31. By contrast the CVs for the point estimates of the spawning FIS abundance index were much smaller, ranging from 0.26 to

0.59. The alternative scenarios were explored to examine the effect of including FIS abundance indices with different characteristics. This included abundance indices with either moderate CVs or high CVs. The FIS abundance series with high CV (Blue Grenadier non-spawning FIS) showed quite different patterns between FIS1 and FIS2. This highlighted the potential for different effects from the two FIS series, as this increased the likelihood of a different patterns in the abundance index between the FIS1 and FIS2 abundance series. In most cases, the general form of the abundance time series was quite similar between FIS1 and FIS2.

The Blue Grenadier assessment featured some poor fits to the CPUE series, which suggest either considerable conflict between data sources, namely between the CPUE series and the length and age composition data, or changes in the CPUE data that were more rapid than can be reflected in the dynamics of this species. This perhaps raises some question around the reliability of this CPUE series as an abundance index. It also allows for differences from the various scenarios to become much more obvious.

The FIS3 abundance series increased with time for Pink Ling west, with similar shape to the FIS1 series, and in contrast to the flat/declining FIS2 series. By contrast, for Pink Ling east, there was a change in shape from FIS1 to FIS2, but no further change in shape in FIS3. The change in shape from the FIS1 to FIS2 abundance series for Pink Ling west resulted in quite different assessment outcomes, so examining the assessment results for this stock with the FIS3 series included to those with the FIS1 and FIS2 series would be worthwhile.

5.6 General discussion

A longer FIS time series will clearly have greater utility, as also recognised in the initial design process and by both the SMARP and NIWA reviews (SMARP, 2015; O'Driscoll and Doonan, 2015). Continued reliance on standardised-CPUE as an abundance index is a potential vulnerability of the current assessment framework, which assumes that CPUE is a reliable index of abundance. Incorporating alternative abundance indices such as a FIS can mitigate this risk, especially if external factors (e.g. effort creep, fisher behaviour, management changes, spatial closures) other than abundance begin to influence CPUE.

An independent abundance index could either validate standardised-CPUE as in index, or if it was in conflict with CPUE, indicate potential biases. In the latter case, an independent index has increased value if it is more accurately indexing the abundance than CPUE. Combining a fishery independent index appropriately with historical CPUE will clearly be important for many species as fishery independent indices are often unavailable in the early years of a fishery. This applies equally for data rich and data poor assessments which use CPUE.

6. Implications

A framework was developed to identify 12 potential stations for redesign or refinement of the SESSF FIS, should this be required in the future to refocus the survey on a different selection of species (Objective 1). This framework could assist with any future refinements to the FIS design. As a byproduct of reconditioning the FIS (Objective 2), essential updates to software versions (R) and packages (mgcv), were incorporated in the code, allowing this code to be more easily maintained and used for analyses of future surveys. The reconditioning analyses led to a reduction in the CVs associated with the abundance estimates, hence increasing the both the utility and confidence in the FIS2 results. The simulation analyses (Objective 3) demonstrated that once sampling and process error were considered, the potential range of results for an individual year abundance and the consequent trends observed over all survey years is quite variable for the CVs observed. This suggests that process error should be considered as sampling error alone could not produce such variable results, which implies there may be other underlying processes in the fishery. As within-year variability could be an important factor which could influence the observed inter-survey variability, further analyses were conducted that accounted for differences in seasonal patterns between years (additional Objective 4). This led to a further reduction in both abundance CVs and inter-survey variability, hence increasing the utility of the FIS3 results. The inclusion of the various FIS series in the integrated assessment generally did not lead to markedly different results with regard to key stock indicators (e.g. biomass trajectories), unless recent CPUE is excluded (additional Objective 5). However it is likely that the FIS time series is too short to adequately assess the impact on stock assessment results in most scenarios explored. The number of surveys required for the potential of the FIS to be realised is an open question but longer time series will certainly be more useful than short series.

One of the main issues with the SESSF FIS has been the perception that the abundance CVs (sampling error) for many stocks are too large for either the series, or an individual year index, to be considered reliable (whether included in an assessment or not). This project has clearly demonstrated that refinements through reconditioning the FIS and accounting for differences in seasonal patterns between years has led to a reduction in CVs. This should provide greater confidence for managers in the series produced. This project shows that statistical refinements can and have led to substantial improvements in the series.

7. Recommendations

7.1 Objective 1: Station re-examination

The list of species for which the design is sufficiently robust into the future should be reviewed to ensure an appropriate ecologically and economically diverse range of species is chosen, to cater for existing and potential future commercial species. If required, the framework developed could be used to advise on the potential refinement of the existing design of the FIS, further optimising the survey to estimate more reliable indices for the species selected. This in turn may reduce the reliability of indices for other species. For example, greater emphasis on deeper water may be desirable to improve the statistical balance of the survey design. While this model-based design allows for flexibility in station sampling location from survey to survey, care should be taken before undertaking a full redesign. For compatibility with the existing survey data/structure, it would be prudent to retain some consistency with previous surveys, by minimising the changes to station locations. When stations are sampled, for various practical reasons, there is flexibility in choosing the actual shot location from survey to survey. It is recommended that if minor changes are made to the selected sample location, that attempts are made to repeat sampling in the same location in future surveys to avoid unnecessary scatter in sampling locations.

7.2 Objective 2: 2018 reconditioned model (FIS2)

As the reconditioned FIS series (FIS2), used data after the structural adjustment to condition the model, which coincides with the collection of FIS data, it is recommended that the FIS2 abundance series be used in preference to the FIS1 series in the future (however, see additional Objective 4 and Section 7.4 below). Clearly, the use of more recent data to condition the model is an improvement over the initial conditioning that used data from year 2001 to 2005. This was not possible when the FIS was initially implemented as these data were not available then.

7.3 Objective 3: Data simulation using 2018 reconditioned model estimates

If an objective is to reduce the apparent variation in the series and provide greater confidence in the indices and consequent trend, it is recommended that additional FIS surveys are conducted, as a longer time series will reduce the impact of variation (sampling and process error). Accounting for the process error (e.g. see additional Objective 4 and Section 7.4 below) would improve the utility of the FIS.

7.4 Additional Objective 4: Reconditioned model accounting for within-year variation (FIS3)

It is recommended that the FIS3 abundance series be used in preference to the FIS2 or FIS1 series in the future. Changes in fishing practice (e.g. targeting, duration, gear type, market pressures and management changes) could influence the FIS3 abundance series via logbook data, either through conditioning or examining within-year variation. Further work is required to apply this to more stocks, consultation with industry, management and other key stakeholders would be beneficial to ensure that within season variations is not a result of changes in commercial fishing practice. This will require further work to calculate FIS3 abundance indices for additional species, with careful examination of model fits and diagnostics for all species.

7.5 Additional Objective 5: Stock assessment scenario exploration

It is recommended that the effects of including the FIS3 abundance series are examined in stock assessments as additional scenario explorations. Given the varying results when FIS2 was included for different stocks, investigating the effects of including FIS3 on assessment outcomes could be informative. Alternative scenarios could be explored by down-weighting the most recent CPUE rather than excluding CPUE after 2006 or including the full series.

7.6 Further development

The model could be updated after a few more surveys to revise model assumptions and changes to species depth and spatial range. This would ensure any potential range shifts are incorporated in the model design.

It may be possible to reduce inter-survey CVs by investigating plausible links between environmental influences on availability and observed inter-survey changes in FIS abundance series.

The length of FIS abundance series required to influence assessment results could be examined in more detail (against different sampling and process errors) and this could involve statistical analysis and/or Management Strategy Evaluation testing. In addition, the effects of varying the frequency of surveys could be investigated.

8. Extension and Adoption

Results and recommendations of this report have been presented to key stakeholders, who include AFMA managers, Industry representatives and researchers at the February 2019 AFMA meetings associated with the SESSF Resource Assessment Group (RAG) Chair's Meeting and may be discussed further at future relevant RAG meetings (i.e., SERAG). An outcome of this meeting was an in-principle decision to conduct another FIS survey as soon as practicable, i.e., to end the temporary suspension of this multi-species survey since 2016.

Subject to RAG approval, resulting FIS3 abundance indices from existing surveys, and potentially future surveys, could be incorporated in Tier 1 stock assessments for the four species analysed here (Tiger Flathead, Blue Grenadier, Silver Warehou and Pink Ling). FIS3 abundance indices could also be used Tier 1 stock assessments for additional species subject to funding availability.

Whilst outside the scope of the original project, the additional objectives added significant value. This report contributes highly valuable information to industry and management which will help inform decisions about on-going investment in the SESSF FIS. Existing relationships will be strengthened both between CSIRO and Fishwell, and SESSF researchers, management and industry. This work will enhance the sustainability of Australia's SESSF fishing industry, and the primary beneficiaries will be management and industry. A summary of this project may also be made available through Industry, AFMA and FRDC newsletters, where applicable.

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Appendix A. Diagnostic Plots (FIS2) for selected species

Tiger Flathead – Zone 10, 20

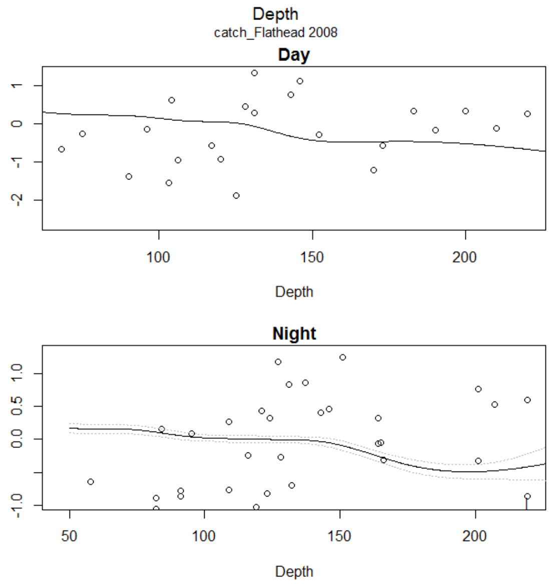

Figure 89. Tiger Flathead – Zone 10, 20: Estimated smooth of depth (m) by time of day: day (upper) and night (lower) in 2008.

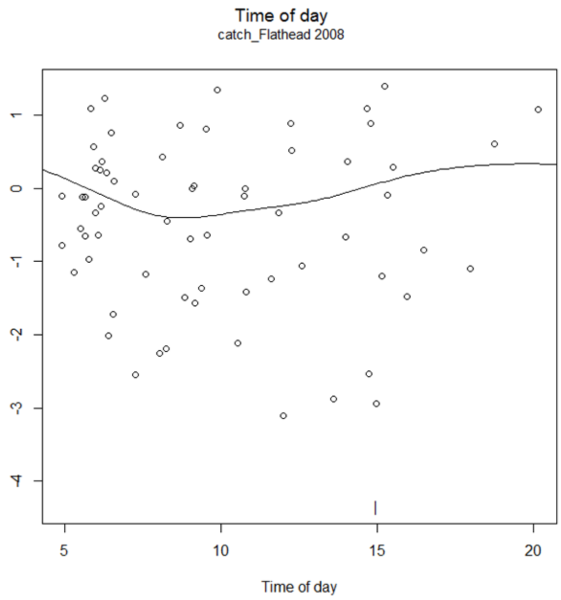

Figure 90. Tiger Flathead – Zone 10, 20: Time of day effect for 2008 survey.

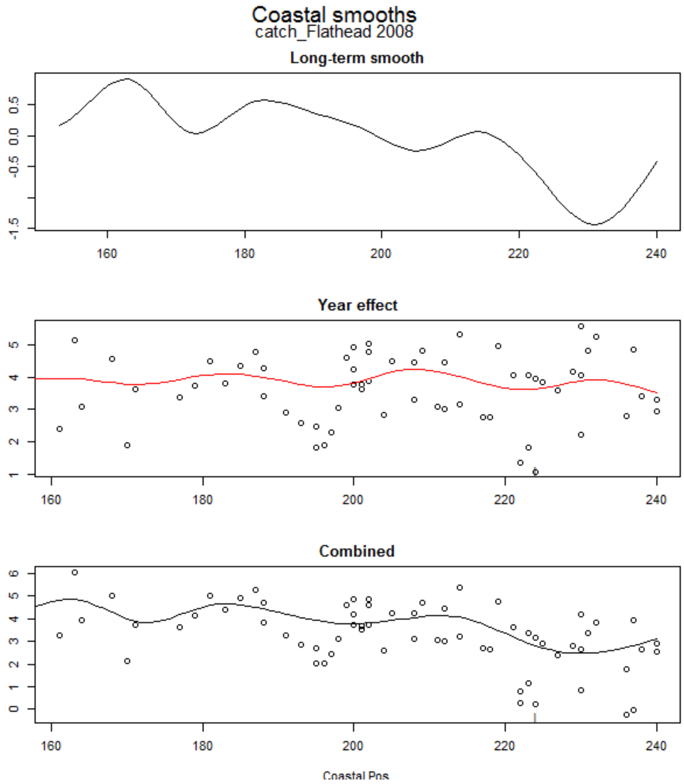

Figure 91. Tiger Flathead – Zone 10, 20: Coastal position for 2008 survey.

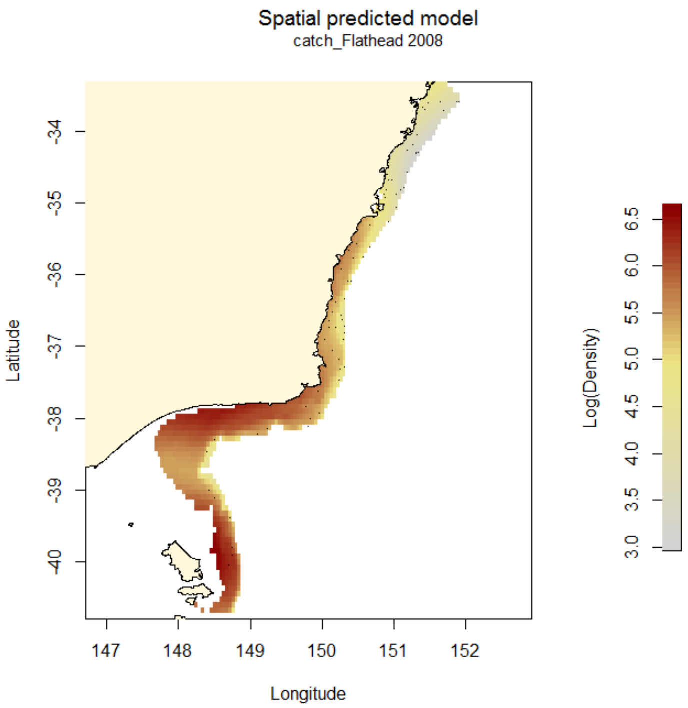

Figure 92. Tiger Flathead – Zone 10, 20: predicted abundance index for 2008 survey.

Blue Grenadier spawning - Zone 40

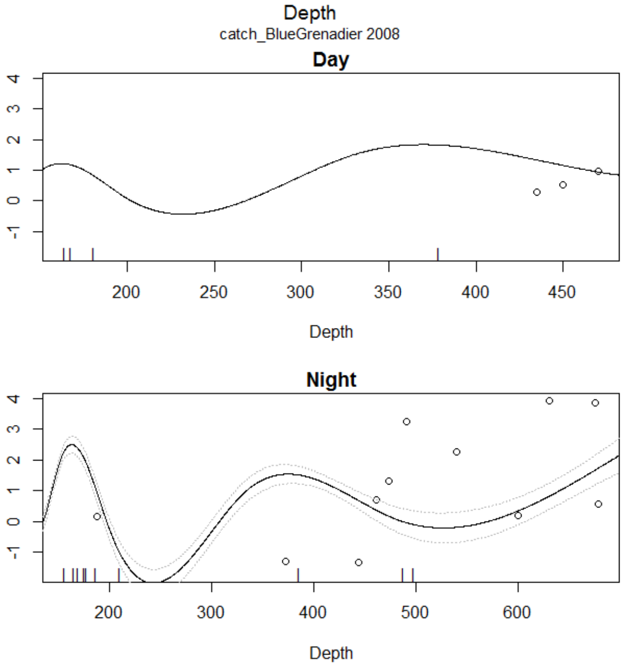

Figure 93. Blue Grenadier – Zone 40: Estimated smooth of depth (m) by time of day: day (upper) and night (lower) in 2008.

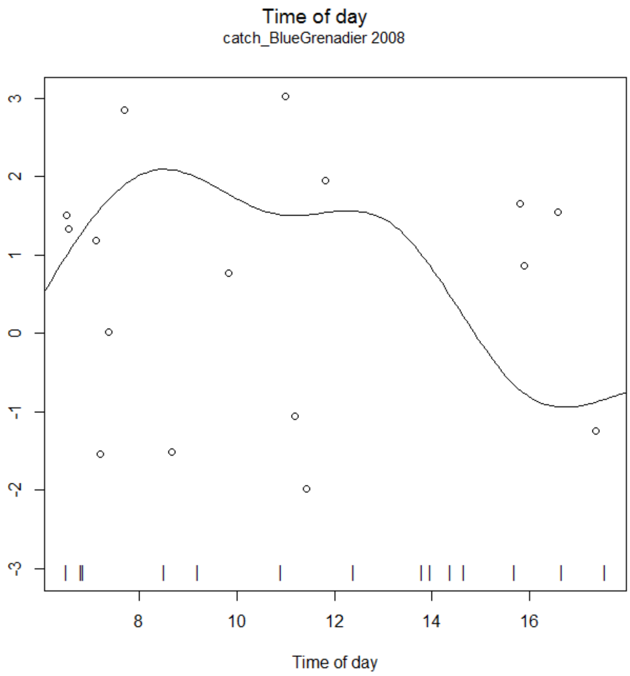

Figure 94. Blue Grenadier – Zone 40: Time of day effect for 2008 survey.

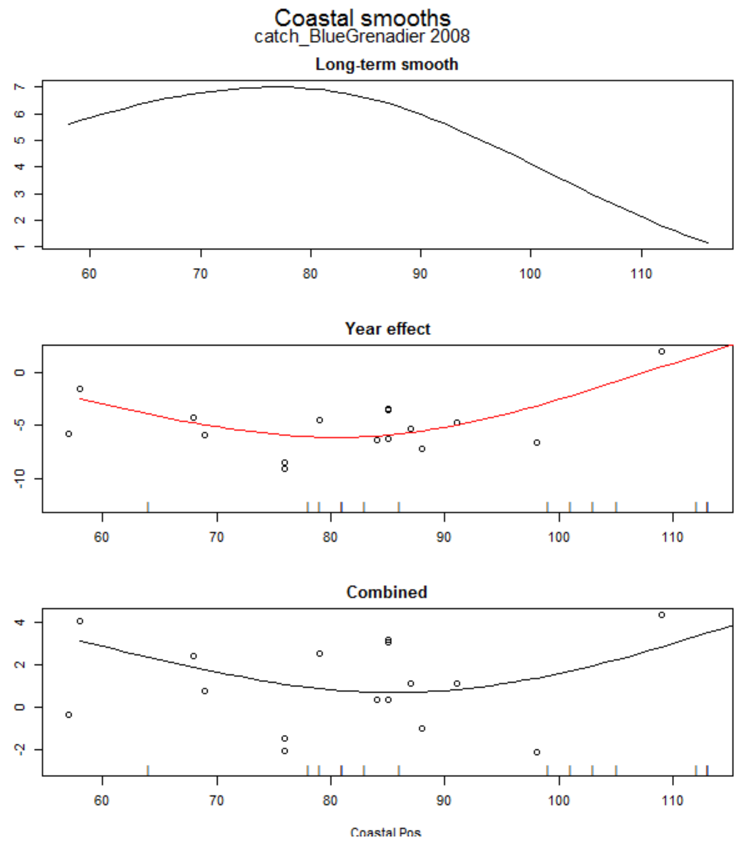

Figure 95. Blue Grenadier – Zone 40: Coastal position for 2008 survey.

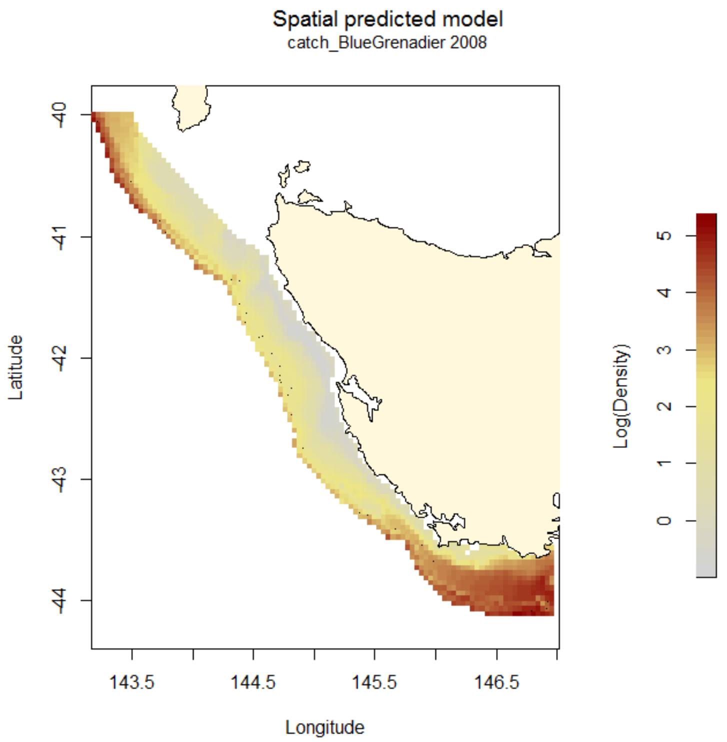

Figure 96. Blue Grenadier – Zone 40: Predicted abundance index for 2008 survey.

Appendix B. Jackass Morwong – west

Scientific name: *Nemadactylus macropterus*; CAAB code: 37377003

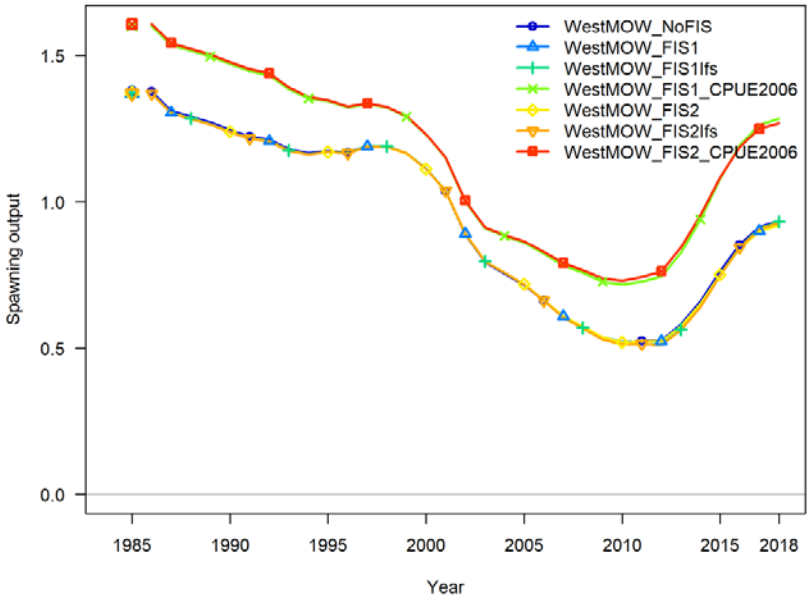

Figure 97. Western Jackass Morwong: Absolute spawning biomass time-trajectory. Scenarios consist of: (i) no FIS data (NoFIS); three scenarios each containing FIS abundance indices from the original series (FIS1); i.e., (ii) using only FIS1 abundance indices, (iii) adding FIS length frequencies (lfs) and (iv) excluding CPUE after 2006 (CPUE_2006). Scenarios (ii)-(iv) were repeated using 2018 reconditioned FIS abundance series (FIS2).

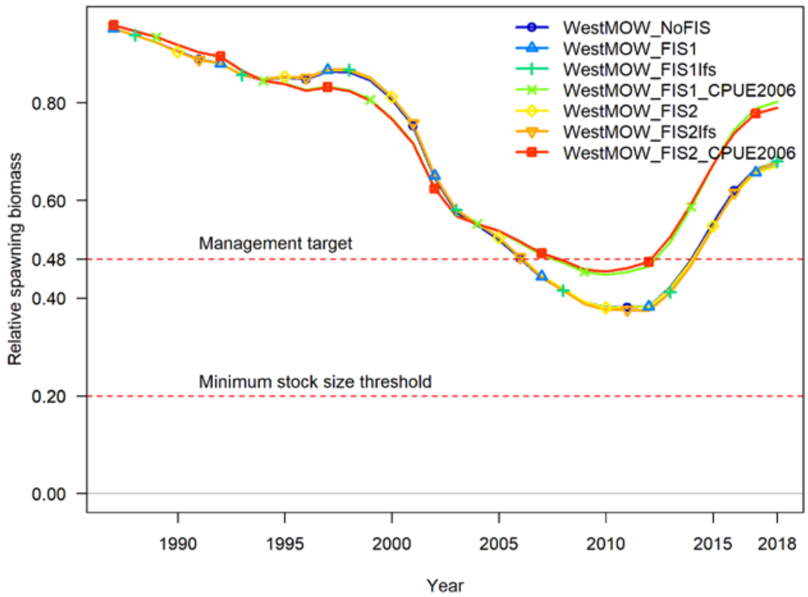

Figure 98. Western Jackass Morwong: Relative spawning biomass time-trajectory. Scenarios consist of: (i) no FIS data (NoFIS); three scenarios each containing FIS abundance indices from the original series (FIS1); i.e., (ii) using only FIS1 abundance indices, (iii) adding FIS length frequencies (lfs) and (iv) excluding CPUE after 2006 (CPUE_2006). Scenarios (ii)-(iv) were repeated using 2018 reconditioned FIS abundance series (FIS2).

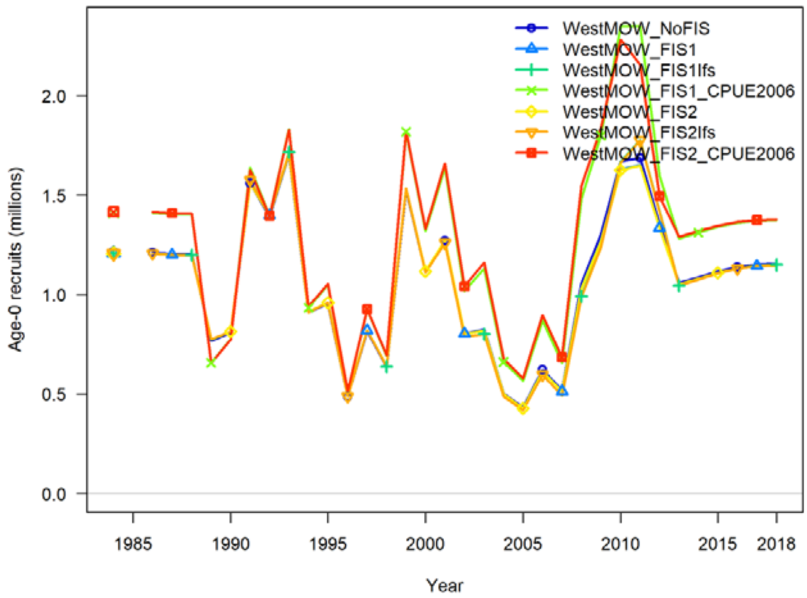

Figure 99. Western Jackass Morwong: Estimated recruitment time-trajectory. Scenarios consist of: (i) no FIS data (NoFIS); three scenarios each containing FIS abundance indices from the original series (FIS1); i.e., (ii) using only FIS1 abundance indices, (iii) adding FIS length frequencies (lfs) and (iv) excluding CPUE after 2006 (CPUE_2006). Scenarios (ii)-(iv) were repeated using 2018 reconditioned FIS abundance series (FIS2).

B.1 Jackass Morwong – west differences

Minimal differences

1. Differences when including either FIS abundance series are minimal (limited difference between models with: no FIS; FIS1; and FIS2).
2. Differences between scenarios including FIS length composition data and scenarios excluding this data are minimal (limited difference between FIS1 and FIS1lfs, or between FIS2 and FIS2lfs).
3. Fits to the FIS abundance data are largely unchanged by excluding CPUE after 2006 (seen in red and green lines (WestMOW_FIS1_CPUE2006 and WestMOW_FIS2_CPUE2006) in Figure 102 and Figure 103).

Clear differences

4. Excluding CPUE after 2006 makes a substantial difference (seen in red and green lines (WestMOW_FIS1_CPUE2006 and WestMOW_FIS2_CPUE2006) in the absolute biomass time series (Figure 97), the relative biomass time series (Figure 98) and the recruitment time series (Figure 99)).

Moderate differences

5. Fits to the CPUE are improved slightly by excluding CPUE after 2006 (seen in red and green lines (WestMOW_FIS1_CPUE2006 and WestMOW_FIS2_CPUE2006) in Figure 100 and Figure 101).

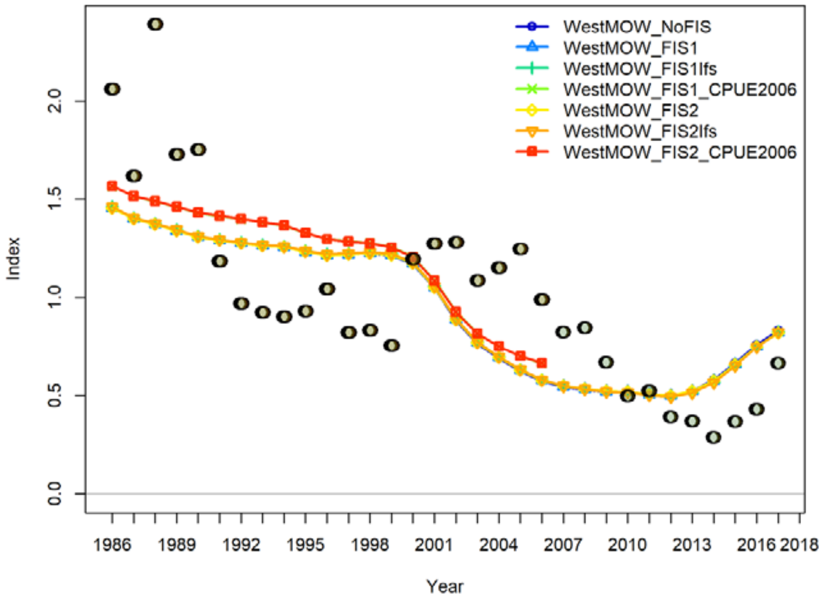

Figure 100. Western Jackass Morwong: Fits to CPUE series for trawl fleet. Scenarios consist of: (i) no FIS data (NoFIS); three scenarios each containing FIS abundance indices from the original series (FIS1); i.e., (ii) using only FIS1 abundance indices, (iii) adding FIS length frequencies (lfs) and (iv) excluding CPUE after 2006 (CPUE_2006). Scenarios (ii)-(iv) were repeated using 2018 reconditioned FIS abundance series (FIS2).

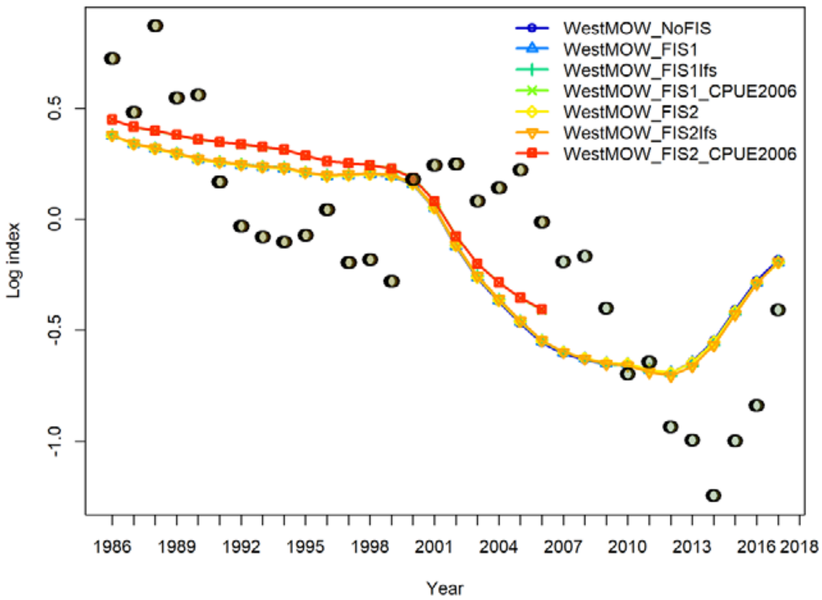

Figure 101. Western Jackass Morwong: Fits to CPUE series (log scale) for trawl fleet. Scenarios consist of: (i) no FIS data (NoFIS); three scenarios each containing FIS abundance indices from the original series (FIS1); i.e., (ii) using only FIS1 abundance indices, (iii) adding FIS length frequencies (lfs) and (iv) excluding CPUE after 2006 (CPUE_2006). Scenarios (ii)-(iv) were repeated using 2018 reconditioned FIS abundance series (FIS2).

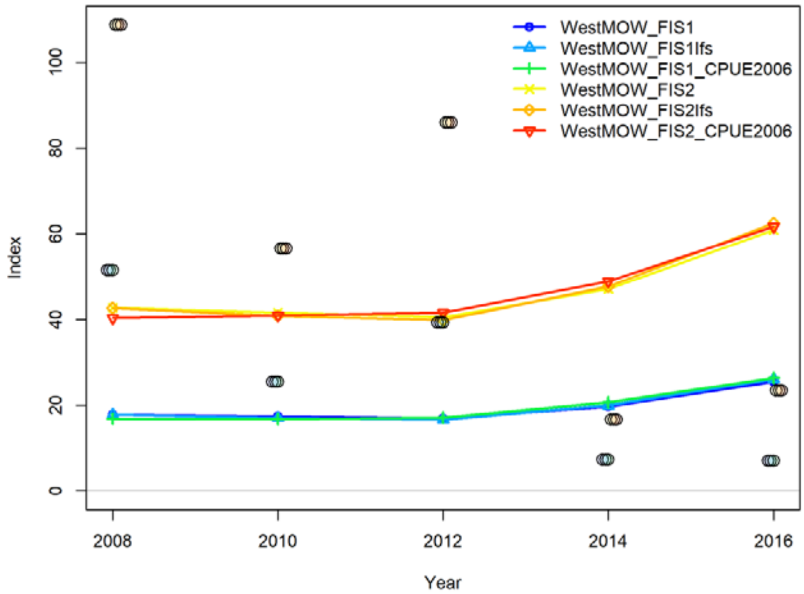

Figure 102. Western Jackass Morwong: Fits to FIS abundance series. Scenarios consist of: (i) no FIS data (NoFIS); three scenarios each containing FIS abundance indices from the original series (FIS1); i.e., (ii) using only FIS1 abundance indices, (iii) adding FIS length frequencies (lfs) and (iv) excluding CPUE after 2006 (CPUE_2006). Scenarios (ii)-(iv) were repeated using 2018 reconditioned FIS abundance series (FIS2).

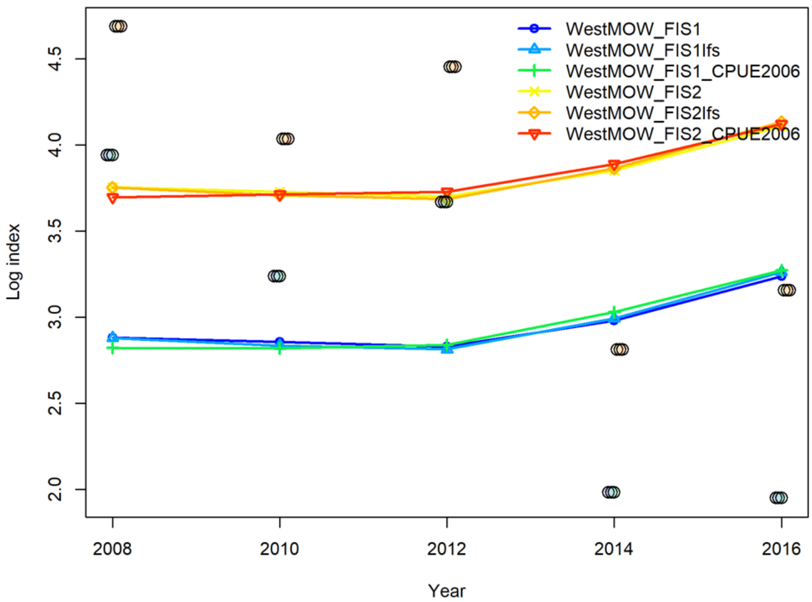

Figure 103. Western Jackass Morwong: Fits to FIS abundance series (log scale). Scenarios consist of: (i) no FIS data (NoFIS); three scenarios each containing FIS abundance indices from the original series (FIS1); i.e., (ii) using only FIS1 abundance indices, (iii) adding FIS length frequencies (lfs) and (iv) excluding CPUE after 2006 (CPUE_2006). Scenarios (ii)-(iv) were repeated using 2018 reconditioned FIS abundance series (FIS2).

Analysis of differences due to excluding CPUE after 2006

Instead of allowing a better fit to the FIS abundance indices from 2008-2016, excluding CPUE after 2006 appears to enable the model to maximise the likelihood by allowing the fit to the FIS abundance series to deteriorate to some extent, with this decrease in likelihood counterbalanced by a larger increase in likelihood due to improved fits to other components (such as length and age data). This suggests that there may be a stronger conflict between the abundance (CPUE and FIS) data and the composition data than there is between the FIS abundance data and the recent CPUE data in this model.

This attempt to improve the fit to the FIS data by removing recent CPUE data, assuming there may be some conflict between these two abundance indices, only reveals greater conflict between other sources of data. The resulting model produces poorer fits to the FIS abundance data, although the differences in fit are very small (see the red and green lines in Figure 102 and Figure 103).

Either the FIS abundance data has less signal than other sources of data, or there are insufficient data points in the FIS for the signal in this data to have an effect. Clearly the data is complex and an integrated model does not perform as may be expected as data inputs are removed. While it may be expected that removing the CPUE data after 2006 will allow or force better fits to the FIS data from 2008 onwards, the improvements in likelihood due to the combination of fits to length, age and discard data during this period clearly have more influence than the FIS time series.

Removing the CPUE series after 2006 results in changes to the recruitment estimates. The absolute number of recruits estimated from 1989-1999 is very similar for all scenarios (Figure 99). However, both the initial recruitment (R_0) and the recruitment estimates from 2000 onwards are higher in the two scenarios where the CPUE is excluded after 2006. These changes to the recruitment series are driving the differences seen in the biomass time series (Figure 97 and Figure 98).

Appendix C. Jackass Morwong – east

Scientific name: *Nemadactylus macropterus*; CAAB code: 37377003

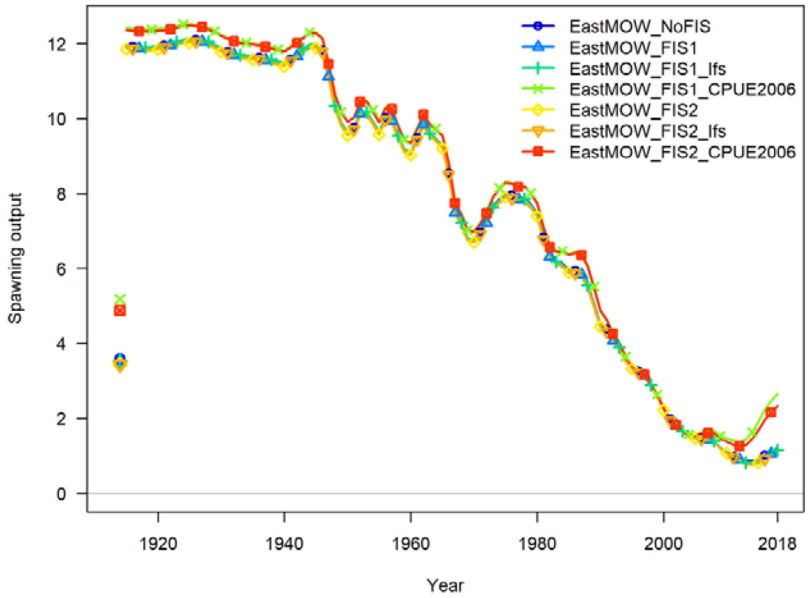

Figure 104. Eastern Jackass Morwong: Absolute spawning biomass time-trajectory. Scenarios consist of: (i) no FIS data (NoFIS); three scenarios each containing FIS abundance indices from the original series (FIS1); i.e., (ii) using only FIS1 abundance indices, (iii) adding FIS length frequencies (lfs) and (iv) excluding CPUE after 2006 (CPUE_2006). Scenarios (ii)-(iv) were repeated using 2018 reconditioned FIS abundance series (FIS2).

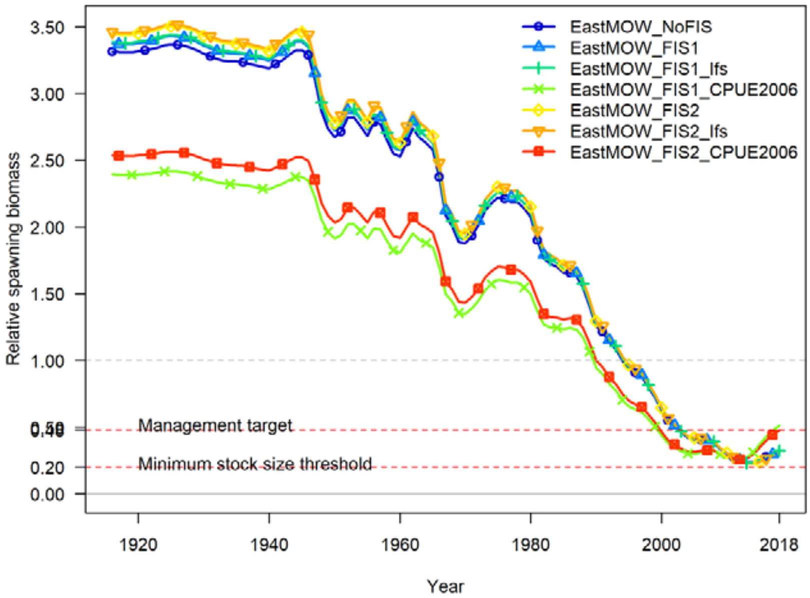

Figure 105. Eastern Jackass Morwong: Relative spawning biomass time-trajectory (relative to the 1998 productivity shift initial biomass). Scenarios consist of: (i) no FIS data (NoFIS); three scenarios each containing FIS abundance indices from the original series (FIS1); i.e., (ii) using only FIS1 abundance indices, (iii) adding FIS length frequencies (lfs) and (iv) excluding CPUE after 2006 (CPUE_2006). Scenarios (ii)-(iv) were repeated using 2018 reconditioned FIS abundance series (FIS2).

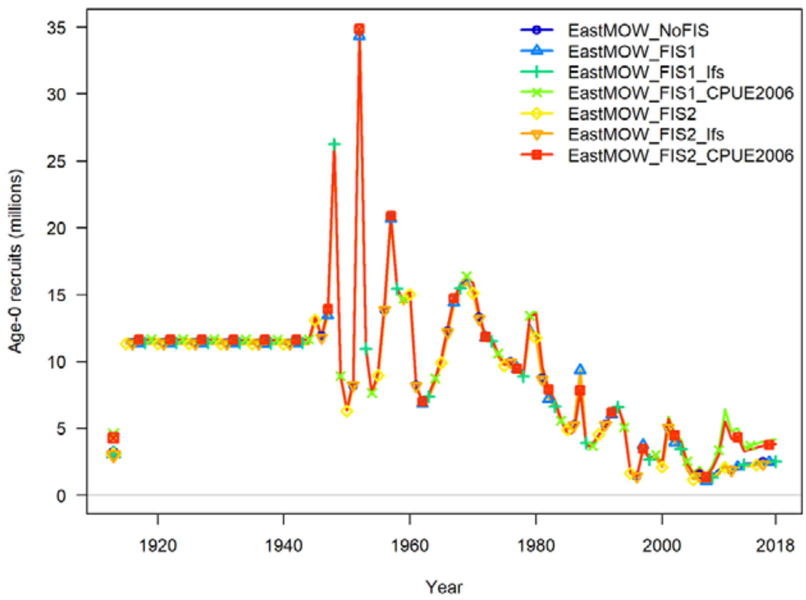

Figure 106. Eastern Jackass Morwong: Estimated recruitment time-trajectory. Scenarios consist of: (i) no FIS data (NoFIS); three scenarios each containing FIS abundance indices from the original series (FIS1); i.e., (ii) using only FIS1 abundance indices, (iii) adding FIS length frequencies (lfs) and (iv) excluding CPUE after 2006 (CPUE_2006). Scenarios (ii)-(iv) were repeated using 2018 reconditioned FIS abundance series (FIS2).

C.1 Jackass Morwong – east differences

Minimal differences

1. Differences when including either FIS abundance series are minimal (limited difference between models with: no FIS; FIS1; and FIS2). Differences appear larger with the relative abundance plot (Figure 105) – but this is confounded by the productivity shift.
2. Differences between scenarios including FIS length composition data and scenarios excluding this data are minimal (limited difference between FIS1 and FIS1lfs, or between FIS2 and FIS2lfs).

Clear differences

3. Excluding CPUE after 2006 makes a notable difference (seen in red and green lines (EastMOW_FIS1_CPUE2006 and EastMOW_FIS2_CPUE2006) in the absolute biomass time series (Figure 104), the relative biomass time series ((Figure 105) and the recruitment time series (Figure 106)).
4. Fits to the FIS abundance data deteriorate by excluding CPUE after 2006 (seen in red and green lines (EastMOW_FIS1_CPUE2006 and EastMOW_FIS2_CPUE2006) in Figure 111, Figure 112, Figure 113 and Figure 114).

Moderate differences

5. Fits to the CPUE are improved slightly by excluding CPUE after 2006 (seen in red and green lines (EastMOW_FIS1_CPUE2006 and EastMOW_FIS2_CPUE2006) in Figure 107, Figure 108, Figure 109 and Figure 110).

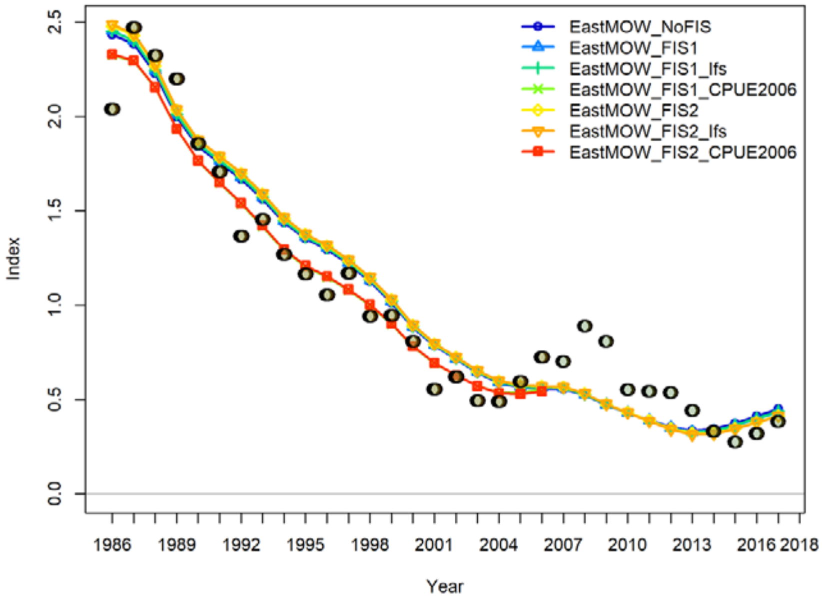

Figure 107. Eastern Jackass Morwong: Fits to CPUE series for eastern trawl fleet. Scenarios consist of: (i) no FIS data (NoFIS); three scenarios each containing FIS abundance indices from the original series (FIS1); i.e., (ii) using only FIS1 abundance indices, (iii) adding FIS length frequencies (lfs) and (iv) excluding CPUE after 2006 (CPUE_2006). Scenarios (ii)-(iv) were repeated using 2018 reconditioned FIS abundance series (FIS2).

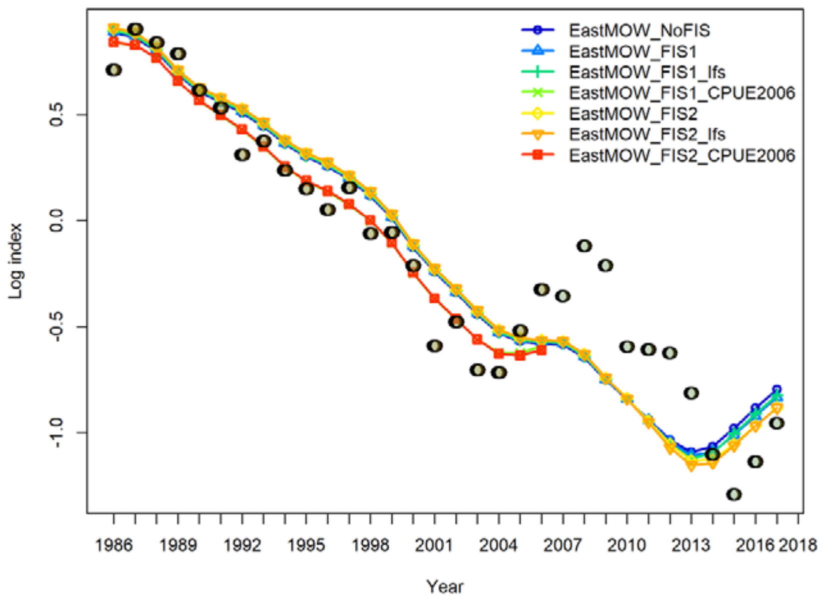

Figure 108. Eastern Jackass Morwong: Fits to CPUE series (log scale) for eastern trawl fleet. Scenarios consist of: (i) no FIS data (NoFIS); three scenarios each containing FIS abundance indices from the original series (FIS1); i.e., (ii) using only FIS1 abundance indices, (iii) adding FIS length frequencies (lfs) and (iv) excluding CPUE after 2006 (CPUE_2006). Scenarios (ii)-(iv) were repeated using 2018 reconditioned FIS abundance series (FIS2).

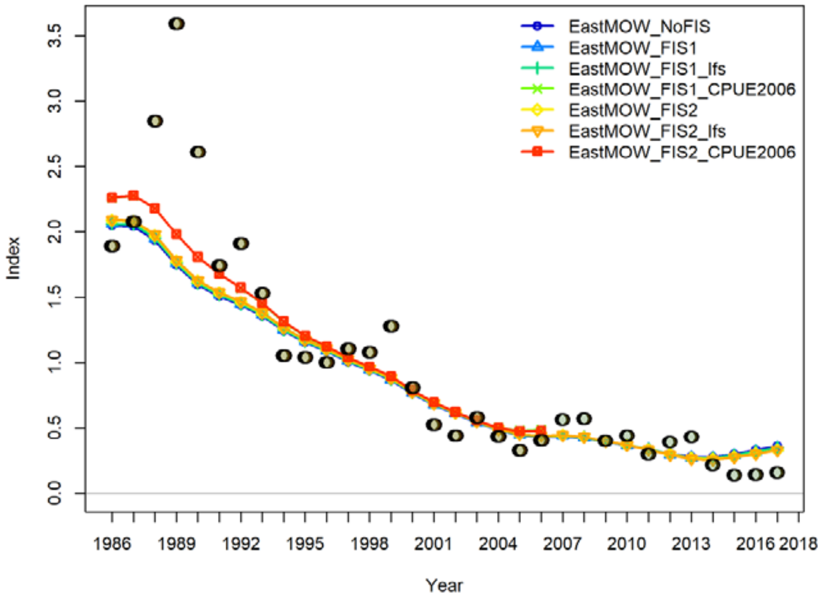

Figure 109. Eastern Jackass Morwong: Fits to CPUE series for Tasmanian trawl fleet. Scenarios consist of: (i) no FIS data (NoFIS); three scenarios each containing FIS abundance indices from the original series (FIS1); i.e., (ii) using only FIS1 abundance indices, (iii) adding FIS length frequencies (lfs) and (iv) excluding CPUE after 2006 (CPUE_2006). Scenarios (ii)-(iv) were repeated using 2018 reconditioned FIS abundance series (FIS2).

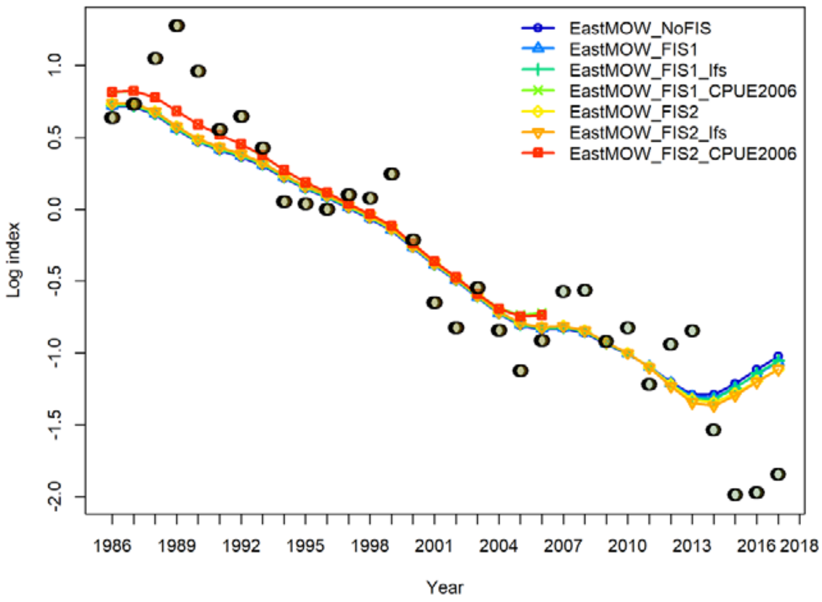

Figure 110. Eastern Jackass Morwong: Fits to to CPUE series (log scale) for Tasmanian trawl fleet. Scenarios consist of: (i) no FIS data (NoFIS); three scenarios each containing FIS abundance indices from the original series (FIS1); i.e., (ii) using only FIS1 abundance indices, (iii) adding FIS length frequencies (lfs) and (iv) excluding CPUE after 2006 (CPUE_2006). Scenarios (ii)-(iv) were repeated using 2018 reconditioned FIS abundance series (FIS2).

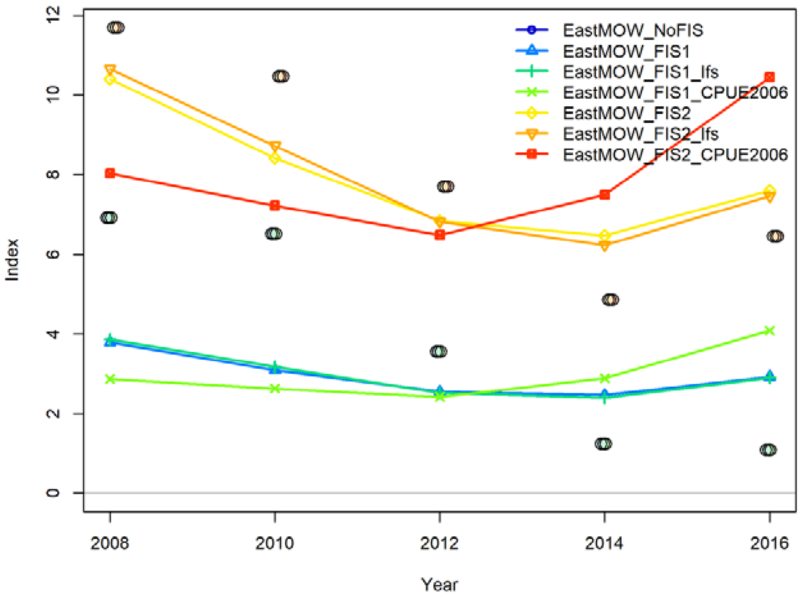

Figure 111. Eastern Jackass Morwong: Fits to the eastern FIS abundance series. Scenarios consist of: (i) no FIS data (NoFIS); three scenarios each containing FIS abundance indices from the original series (FIS1); i.e., (ii) using only FIS1 abundance indices, (iii) adding FIS length frequencies (lfs) and (iv) excluding CPUE after 2006 (CPUE_2006). Scenarios (ii)-(iv) were repeated using 2018 reconditioned FIS abundance series (FIS2).

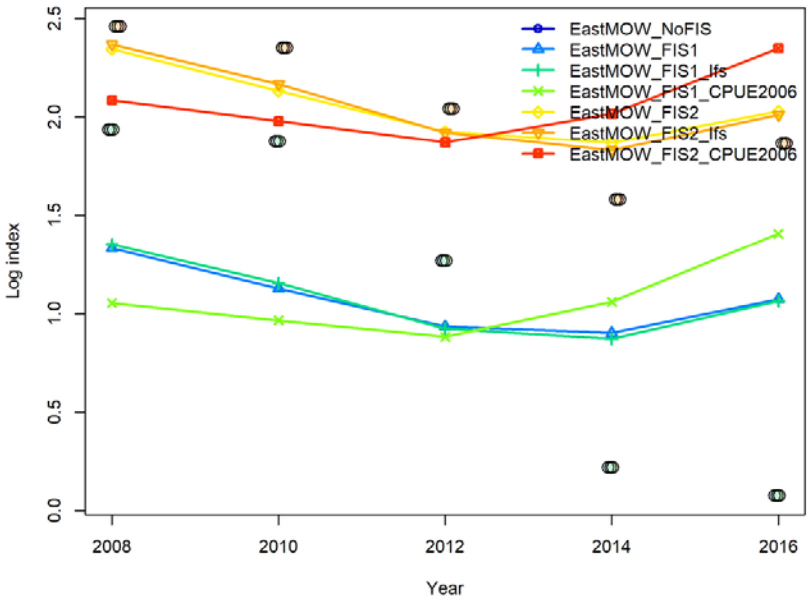

Figure 112. Eastern Jackass Morwong: Fits to the eastern FIS abundance series (log scale). Scenarios consist of: (i) no FIS data (NoFIS); three scenarios each containing FIS abundance indices from the original series (FIS1); i.e., (ii) using only FIS1 abundance indices, (iii) adding FIS length frequencies (lfs) and (iv) excluding CPUE after 2006 (CPUE_2006). Scenarios (ii)-(iv) were repeated using 2018 reconditioned FIS abundance series (FIS2).

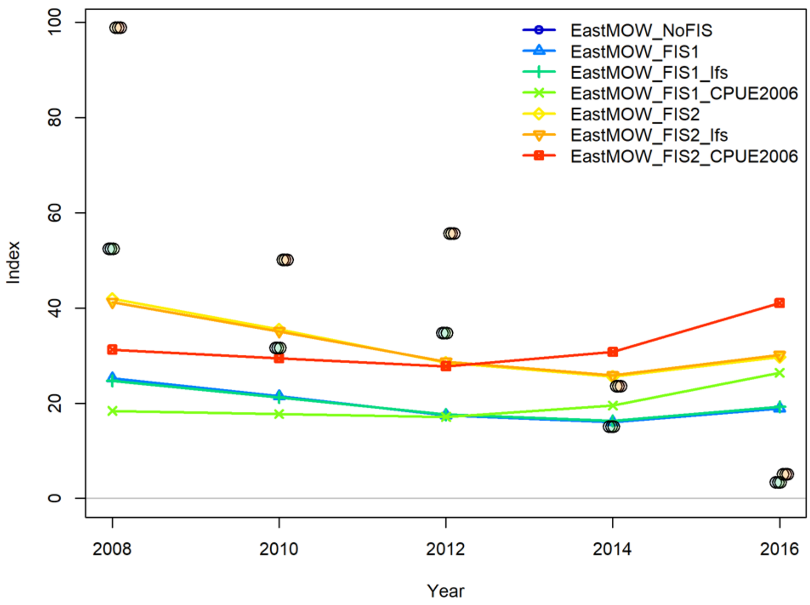

Figure 113. Eastern Jackass Morwong: Fits to the Tasmanian FIS abundance series. Scenarios consist of: (i) no FIS data (NoFIS); three scenarios each containing FIS abundance indices from the original series (FIS1); i.e., (ii) using only FIS1 abundance indices, (iii) adding FIS length frequencies (lfs) and (iv) excluding CPUE after 2006 (CPUE_2006). Scenarios (ii)-(iv) were repeated using 2018 reconditioned FIS abundance series (FIS2).

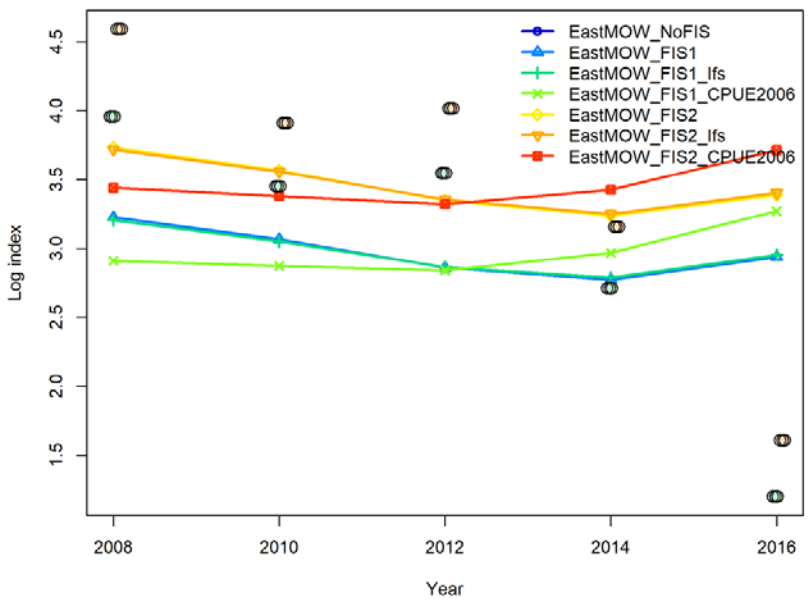

Figure 114. Eastern Jackass Morwong: Fits to Tasmanian FIS abundance series (log scale). Scenarios consist of: (i) no FIS data (NoFIS); three scenarios each containing FIS abundance indices from the original series (FIS1); i.e., (ii) using only FIS1 abundance indices, (iii) adding FIS length frequencies (lfs) and (iv) excluding CPUE after 2006 (CPUE_2006). Scenarios (ii)-(iv) were repeated using 2018 reconditioned FIS abundance series (FIS2).

Analysis of differences due to excluding CPUE after 2006

Instead of allowing a better fit to the FIS abundance indices from 2008-2016, excluding CPUE after 2006 appears to enable the model to maximise the likelihood by allowing the fit to the FIS abundance series to deteriorate, with this decrease in likelihood counterbalanced by a larger increase in likelihood due to improved fits to other components (such as length and age data). For eastern morwong, the deterioration in fit to the FIS abundance indices is much larger than for western morwong. This suggests there may be an even stronger conflict between the abundance (CPUE and FIS) data and the composition data than there is between the FIS abundance data and the recent CPUE data for eastern morwong than for western morwong.

This attempt to improve the fit to the FIS data by removing recent CPUE data, assuming there may be some conflict between these two abundance indices, only reveals greater conflict between other sources of data. The resulting model produces notably poorer fits to the FIS abundance data, (see the red and green lines in Figure 111, Figure 112, Figure 113 and Figure 114) and the removal of constraints on the length and age data imposed by the CPUE series post 2006, allow the fits to the composition data to have greater influence than the FIS data. The deterioration in fit to the FIS abundance indices is much greater for eastern morwong than for western morwong.

As with western morwong, either the FIS abundance data has less signal than other sources of data, or there are insufficient data points in the FIS for the signal in this data to have an effect. Clearly the data is complex and an integrated model does not perform as may be expected as data inputs are removed. While it may be expected that removing the CPUE data after 2006 will allow or force better fits to the FIS data from 2008 onwards, the improvements in likelihood due to the combination of fits to length, age and discard data during this period clearly have more influence than the FIS time series.

Removing the CPUE series after 2006 results in changes to the recruitment estimates. The absolute number of recruits estimated from 1989-1999 is very similar for all scenarios (Figure 106). However, both the initial recruitment (R_0) and the recruitment estimates from 2007 onwards are higher in the two scenarios where the CPUE is excluded after 2006, with a noticeable spike in recruitment around 2010 and a small difference around 1980. These changes to the recruitment series are driving the differences seen in the biomass time series (Figure 104 and Figure 105). Note that there is a productivity shift for eastern morwong from 1988, which explains some of the apparent differences in relative biomass in (Figure 105), where the equilibrium biomass is set relative to 1988 rather than 1915.

The patterns observed in eastern morwong are similar to those seen in western morwong, despite the large difference in number of years of data used in these two assessments. For eastern morwong, removing CPUE after 2006 results in improved fits to CPUE from 1985-2006 (see the red and green lines in Figure 107, Figure 108, Figure 109 and Figure 110). This is not surprising as this model is not constrained to also fit additional CPUE data from 2007-2017, a period where there is conflict between the two CPUE series (eastern trawl and Tasmanian trawl) and where the CPUE series appears to show different behaviour to the earlier part of each series. This same improvement in CPUE fit with a shortened time series is not seen in western morwong (Figure 100 and Figure 101), but this CPUE series, is much more variable and has known issues relating to limited data quantity and quality and possible changes in the fishery behaviour over time which suggest that the CPUE may not be a reliable index of abundance (Sporcic and Haddon 2018).

Appendix D. Blue Grenadier – non-spawning FIS

Scientific name: *Macruronus novaezelandiae*; CAAB code: 37227001

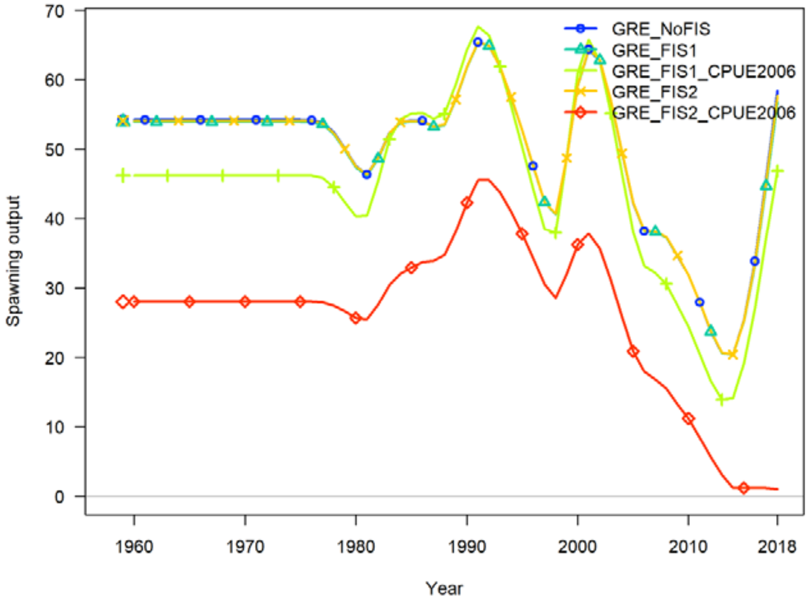

Figure 115. Blue Grenadier – non-spawning FIS: Absolute spawning biomass time-trajectory. Scenarios consist of: (i) no FIS data (NoFIS); two scenarios each containing non-spawning FIS abundance indices from the original series (FIS1); i.e., (ii) using only FIS1 abundance indices and (iii) excluding CPUE after 2006 (CPUE_2006). Scenarios (ii)-(iii) were repeated using 2018 reconditioned FIS abundance series (FIS2).

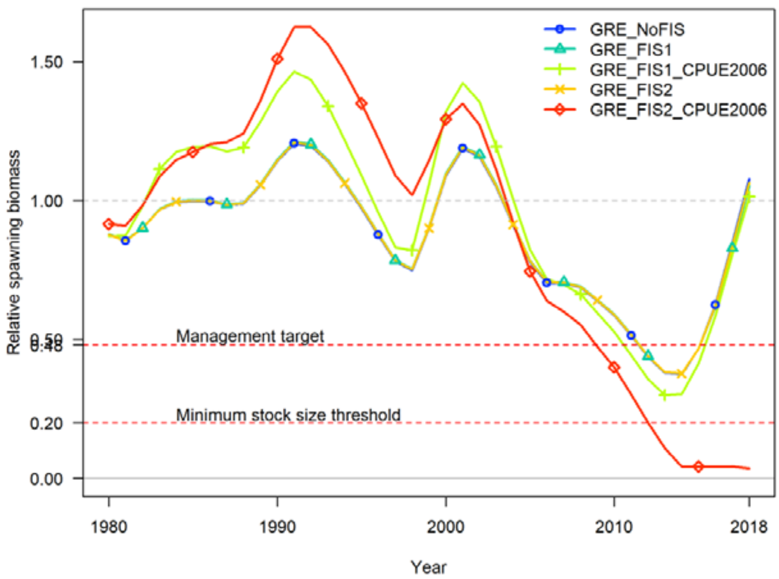

Figure 116. Blue Grenadier – non-spawning FIS: Relative spawning biomass time-trajectory. Scenarios consist of: (i) no FIS data (NoFIS); two scenarios each containing non-spawning FIS abundance indices from the original series (FIS1); i.e., (ii) using only FIS1 abundance indices and (iii) excluding CPUE after 2006 (CPUE_2006). Scenarios (ii)-(iii) were repeated using 2018 reconditioned FIS abundance series (FIS2).

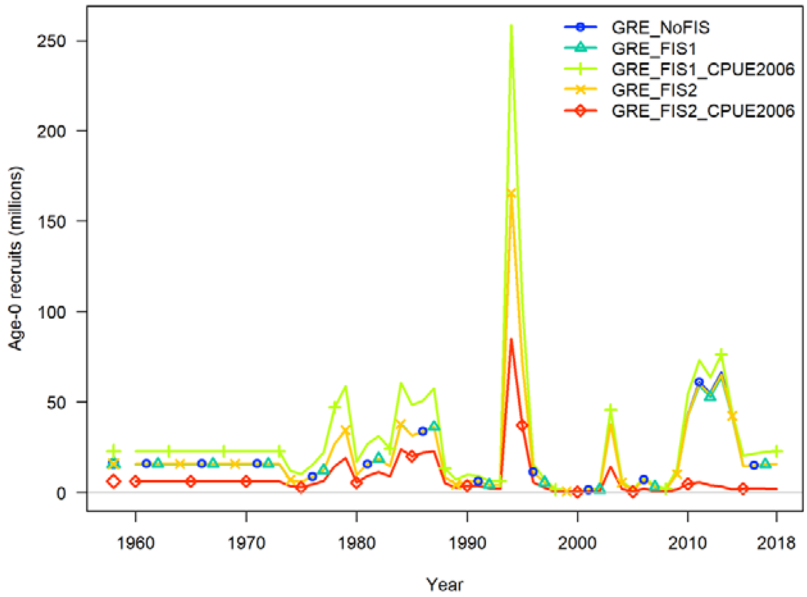

Figure 117. Blue Grenadier – non-spawning FIS: Estimated recruitment time-trajectory. Scenarios consist of: (i) no FIS data (NoFIS); two scenarios each containing non-spawning FIS abundance indices from the original series (FIS1); i.e., (ii) using only FIS1 abundance indices and (iii) excluding CPUE after 2006 (CPUE_2006). Scenarios (ii)-(iii) were repeated using 2018 reconditioned FIS abundance series (FIS2).

D.1 Blue Grenadier – non-spawning FIS differences

Minimal differences

1. Differences when including either FIS abundance series are minimal (limited difference between models with: no FIS; FIS1; and FIS2).

Clear differences

2. Excluding CPUE after 2006 makes a substantial difference (seen in red and green lines (GRE_FIS1_CPUE2006 and GRE_FIS2_CPUE2006) in the absolute biomass time series (Figure 115), the relative biomass time series (Figure 116) and the recruitment time series (Figure 117)), especially for the FIS2 series.
3. Fits to the FIS abundance data improve by excluding CPUE after 2006 (seen in red and green lines (GRE_FIS1_CPUE2006 and GRE_FIS2_CPUE2006) in Figure 120 and Figure 121), especially for the FIS2 series.

Moderate differences

4. Fits to the CPUE are improved slightly by excluding CPUE after 2006 (seen in red and green lines (GRE_FIS1_CPUE2006 and GRE_FIS2_CPUE2006) in Figure 118 and Figure 119). Note that these fits to the CPUE are generally poor in all cases.

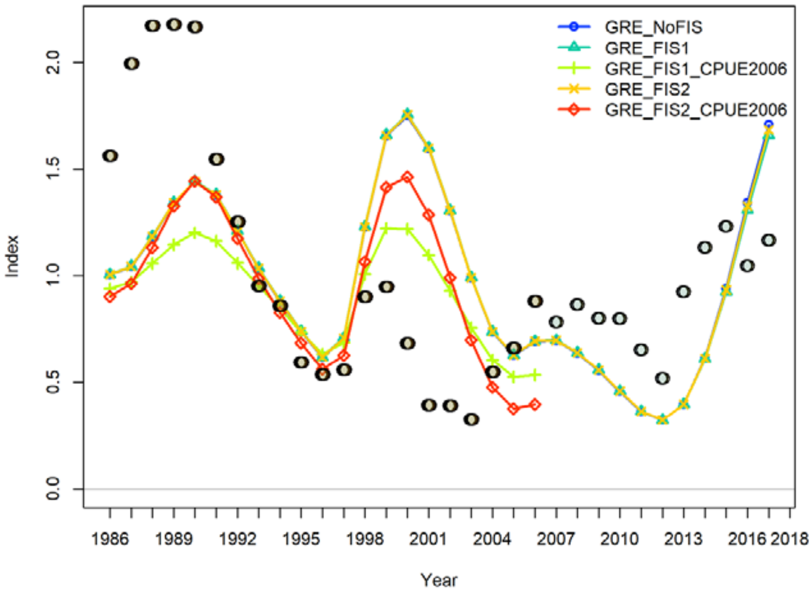

Figure 118. Blue Grenadier – non-spawning FIS: Fits to CPUE series for the non-spawning trawl fleet. Scenarios consist of: (i) no FIS data (NoFIS); two scenarios each containing non-spawning FIS abundance indices from the original series (FIS1); i.e., (ii) using only FIS1 abundance indices and (iii) excluding CPUE after 2006 (CPUE_2006). Scenarios (ii)-(iii) were repeated using 2018 reconditioned FIS abundance series (FIS2).

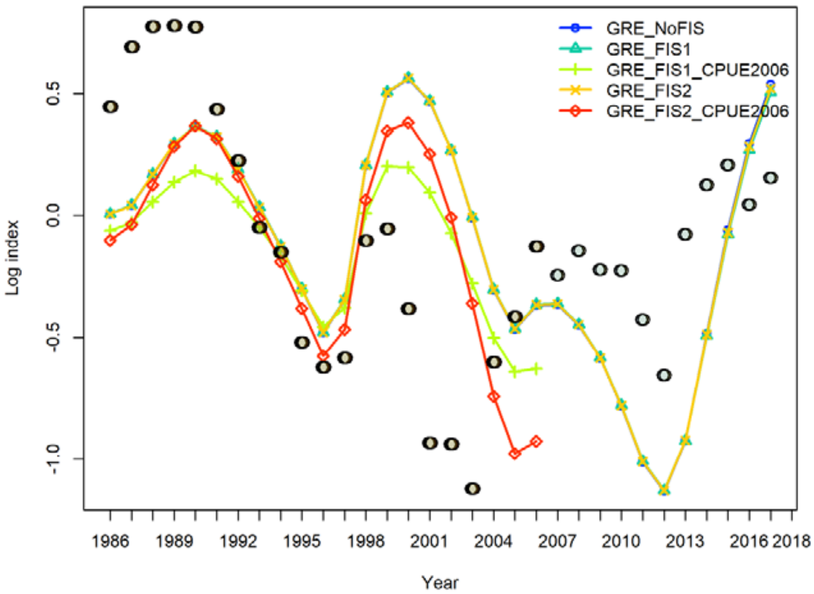

Figure 119. Blue Grenadier – non-spawning FIS: Fits to CPUE series (log_e scale) for the non-spawning trawl fleet. Scenarios consist of: (i) no FIS data (NoFIS); two scenarios each containing non-spawning FIS abundance indices from the original series (FIS1); i.e., (ii) using only FIS1 abundance indices and (iii) excluding CPUE after 2006 (CPUE_2006). Scenarios (ii)-(iii) were repeated using 2018 reconditioned FIS abundance series (FIS2).

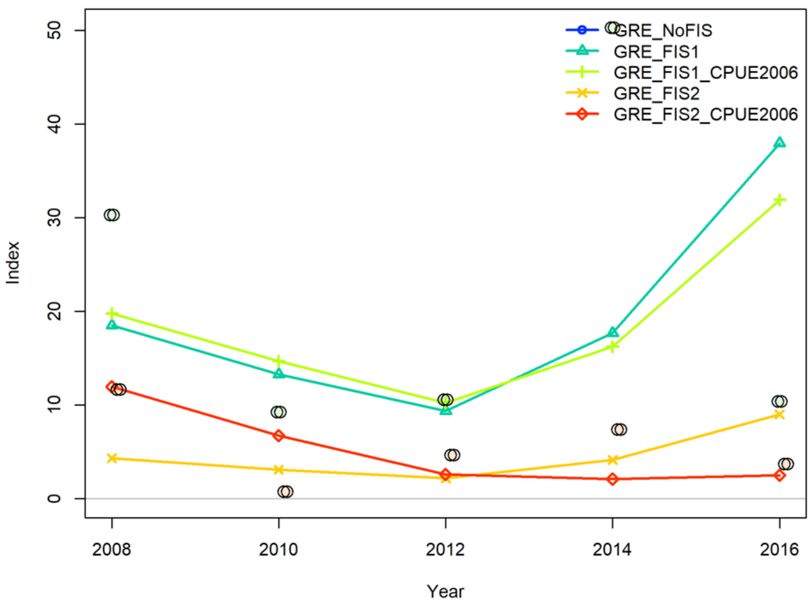

Figure 120. Blue Grenadier – non-spawning FIS: Fits to FIS abundance series. Scenarios consist of: (i) no FIS data (NoFIS); two scenarios each containing non-spawning FIS abundance indices from the original series (FIS1); i.e., (ii) using only FIS1 abundance indices and (iii) excluding CPUE after 2006 (CPUE_2006). Scenarios (ii)-(iii) were repeated using 2018 reconditioned FIS abundance series (FIS2).

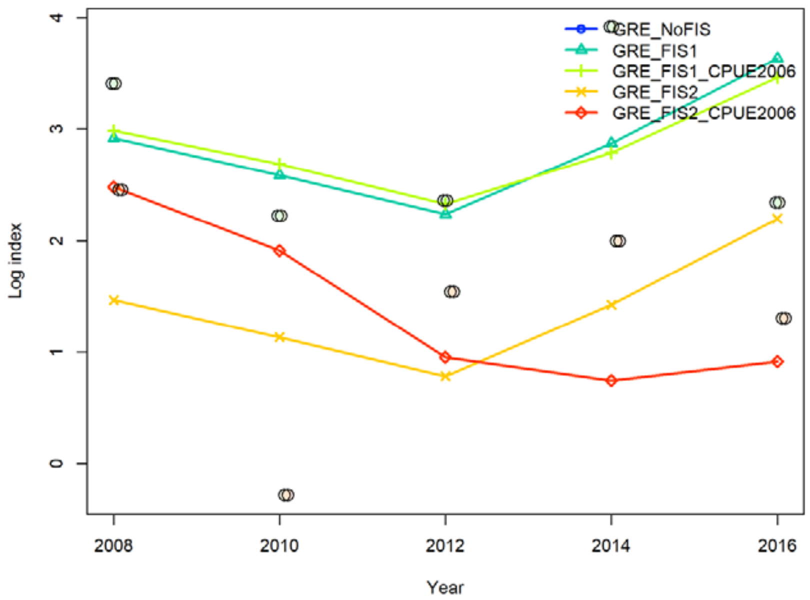

Figure 121. Blue Grenadier – non-spawning FIS: Fits to FIS abundance series (log scale). Scenarios consist of: (i) no FIS data (NoFIS); two scenarios each containing non-spawning FIS abundance indices from the original series (FIS1); i.e., (ii) using only FIS1 abundance indices and (iii) excluding CPUE after 2006 (CPUE_2006). Scenarios (ii)-(iii) were repeated using 2018 reconditioned FIS abundance series (FIS2).

Choice of FIS abundance index – spawning or non-spawning FIS

The FIS1 abundance series was used in the 2018 Blue Grenadier assessment (Castillo-Jordán and Tuck, 2018), and this index corresponds to the non-spawning fishery (SESSF zones 10, 20 30 and 50). Blue Grenadier are known to spawn in the winter months in zone 40. An argument could be made that the non-spawning index may not be that informative as an index of abundance, given it is calculated during the winter months, when most of the Blue Grenadier are at the spawning grounds in zone 40. When Blue Grenadier was assessed in 2018, the FIS abundance index from zone 40 was not used, as it was argued that the spawning fishery is a mid-water fishery and, as the FIS operates as a demersal fishery, it was suggested that the zone 40 FIS abundance may not be representative. However, it is possible that the zone 40 FIS abundance is more representative, given that it is from the zone where most Blue Grenadier are aggregated in the winter. Further, the coefficient of variation for the non-spawning FIS1 abundance indices (cv ranging from 0.34 to 2.31) is much larger than for the spawning FIS1 abundance index (cv ranging from 0.26 to 0.59), so on these grounds alone it may be argued that the spawning FIS1 abundance index is more suitable than the non-spawning FIS1 abundance index.

The analysis in this section is from using the non-spawning FIS index. The impacts of switching to the spawning FIS index (zone 40 only) are explored in the next section.

Analysis of differences due to excluding CPUE after 2006

For Blue Grenadier, there are considerable changes to the FIS abundance series between FIS1 and FIS2 for the non-spawning areas, as highlighted in Figure 120 and Figure 121. The FIS1 data is plotted in the green shaded (upper) circles in Figure 120 and Figure 121 with the FIS2 series data plotted in red shaded circles, with the FIS1 series showing generally higher absolute values. Figure 121 plots the abundance indices on a log scale, which is the scale at which this data is actually fitted. However, the trend in these two series is quite different, due to the changes in point estimates for 2010 and 2014. The FIS1 series has a very high point estimate for abundance in 2014, the highest of the series, partly obscured by the legend, and this single value has considerable leverage. Attempts to fit this point pull the estimated spawning biomass up at the end of the series. By contrast, the FIS2 series has a very low value in 2010, and this time series does not support an increase in biomass towards the end of the series.

In contrast to western and eastern Jackass Morwong, excluding recent CPUE data for Blue Grenadier results in improvements to fits in the FIS data, in addition to changes in the biomass (Figure 115 and Figure 116) and recruitment (Figure 117) time series. While the fits to composition data may not improve, the overall likelihood is maximised through improved fits to the FIS data and both the FIS data itself and the fits to this data are considerably different for the FIS1 and FIS2 time series when CPUE is excluded beyond 2006.

The recruitment series from the FIS1 abundance index with CPUE data removed after 2006 shows a similar relative pattern to the series with no FIS data, (Figure 117), with peaks and troughs in the same years, albeit with different absolute values. There is a similar pattern until 2009 using the FIS2 abundance index with CPUE data removed after 2006. However, the period of good recruitment seen from 2010-2014, observed for all other series, is absent using the FIS2 abundance index with CPUE data removed after 2006, instead showing recruitment failure in this period. This period of recruitment failure also flows through to the spawning biomass (red line in Figure 115 and Figure 116) resulting in a very different spawning biomass time series and very low spawning biomass by 2018. The information on recent recruitment contained within the length and conditional age-at-length data is essentially suppressed by the information in the FIS2 series, producing a very different result compared to the same data with CPUE included through until 2018. Improvements in fits to the FIS data outweigh the deterioration in fits to age and length data, and 5 years of FIS data has a considerable impact on model results.

In the case of Blue Grenadier, removing CPUE data after 2006 appears to enable the model to maximise the likelihood by allowing improvements in fit to the FIS data, while allowing fits to age and length data to deteriorate slightly. This suggests that while there may be some conflict between the FIS data and the age and length, the conflict is much stronger between the FIS data and the CPUE data in this model.

This shows that in some circumstances, only five data points in a FIS abundance index can have substantial influence on model outcomes. It also highlights that there can be considerable conflict within data sources. The fit to the CPUE series (Figure 118 and Figure 119) is relatively poor regardless of whether the CPUE is continued past 2006 or not and perhaps this allows more room for the FIS abundance index to have an influence in some cases. However, it is notable that the last five points in this CPUE series (2013-2017) are all higher than the previous 20 points, and despite the generally poor fits to the CPUE series, these last five points have considerable influence. As a result, excluding the CPUE series after 2006 has a large effect. It is not suggested here that this latter part of the CPUE series should be excluded, nor that the non-spawning FIS series is more representative then the CPUE as an abundance index. This analysis should be considered as hypothetical scenario exploration, rather than a comment on quality of data sources, which series should be used in a stock assessment, or any comment on the quality of the stock assessment as such.

Appendix E. Blue Grenadier – spawning FIS

Scientific name: *Macruronus novaezelandiae*; CAAB code: 37227001

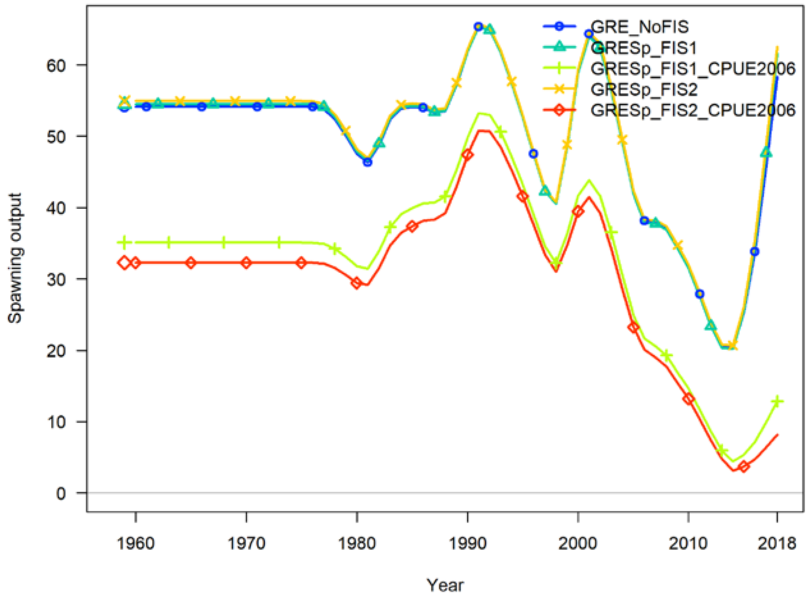

Figure 122. Blue Grenadier – spawning FIS: Absolute spawning biomass time-trajectory. Scenarios consist of: (i) no FIS data (NoFIS); two scenarios each containing spawning FIS abundance indices from the original series (FIS1); i.e., (ii) using only FIS1 abundance indices and (iii) excluding CPUE after 2006 (CPUE_2006). Scenarios (ii)-(iii) were repeated using 2018 reconditioned FIS abundance series (FIS2).

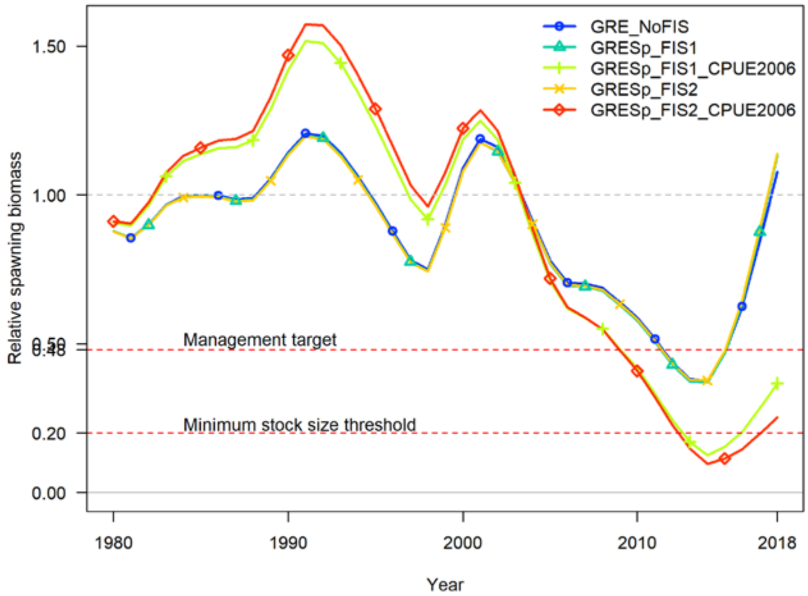

Figure 123. Blue Grenadier – spawning FIS: Relative spawning biomass time-trajectory. Scenarios consist of: (i) no FIS data (NoFIS); two scenarios each containing spawning FIS abundance indices from the original series (FIS1); i.e., (ii) using only FIS1 abundance indices and (iii) excluding CPUE after 2006 (CPUE_2006). Scenarios (ii)-(iii) were repeated using 2018 reconditioned FIS abundance series (FIS2).

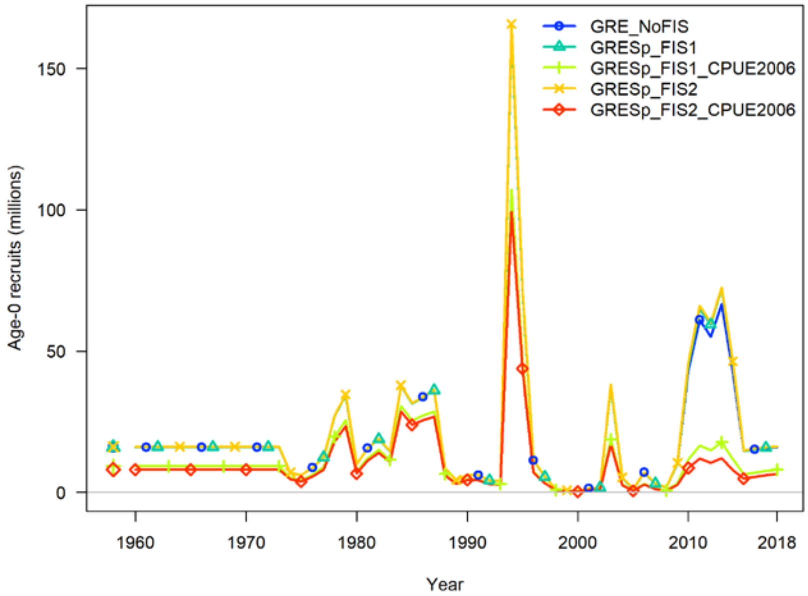

Figure 124. Blue Grenadier – spawning FIS: Estimated recruitment time-trajectory. Scenarios consist of: (i) no FIS data (NoFIS); two scenarios each containing spawning FIS abundance indices from the original series (FIS1); i.e., (ii) using only FIS1 abundance indices and (iii) excluding CPUE after 2006 (CPUE_2006). Scenarios (ii)-(iii) were repeated using 2018 reconditioned FIS abundance series (FIS2).

E.1 Blue Grenadier – spawning FIS differences

Minimal differences

1. Differences when including either FIS abundance series are minimal (limited difference between models with: no FIS; FIS1; and FIS2).

Clear differences

2. Excluding CPUE after 2006 makes a substantial difference (seen in red and green lines (GRESp_FIS1_CPUE2006 and GRESp_FIS2_CPUE2006) in the absolute biomass time series (Figure 122), the relative biomass time series (Figure 123) and the recruitment time series (Figure 124).

Moderate differences

3. Fits to the CPUE are improved slightly by excluding CPUE after 2006 (seen in red and green lines (GRESp_FIS1_CPUE2006 and GRE_FIS2SP_CPUE2006) in Figure 125 and Figure 126). Note that, as with the non-spawning FIS scenario, the fits to the CPUE are generally poor in all cases.
4. Fits to the FIS abundance data deteriorate by excluding CPUE after 2006 (seen in red and green lines (GRESp_FIS1_CPUE2006 and GRESp_FIS2_CPUE2006) in Figure 127 and Figure 128), especially for the FIS2 series.

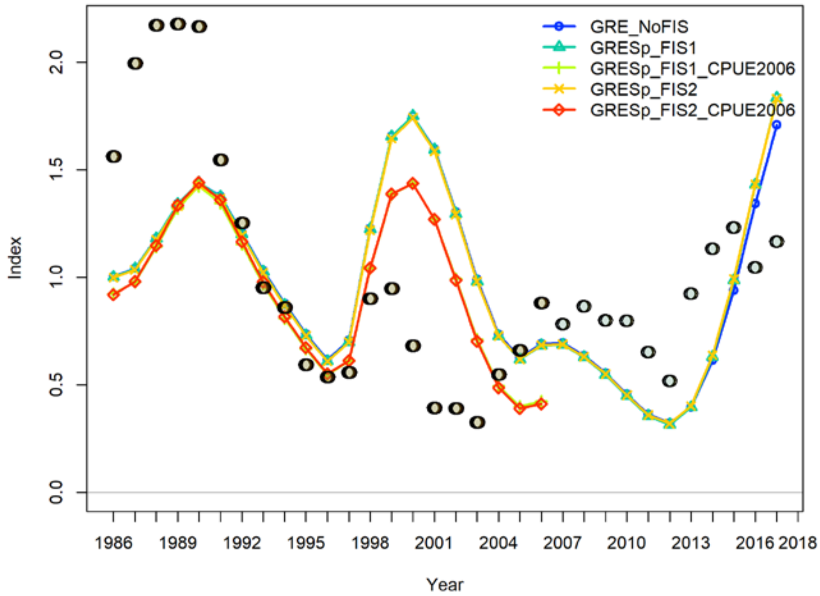

Figure 125. Blue Grenadier – spawning FIS: Fits to CPUE series for trawl fleet. Scenarios consist of: (i) no FIS data (NoFIS); two scenarios each containing spawning FIS abundance indices from the original series (FIS1); i.e., (ii) using only FIS1 abundance indices and (iii) excluding CPUE after 2006 (CPUE_2006). Scenarios (ii)-(iii) were repeated using 2018 reconditioned FIS abundance series (FIS2).

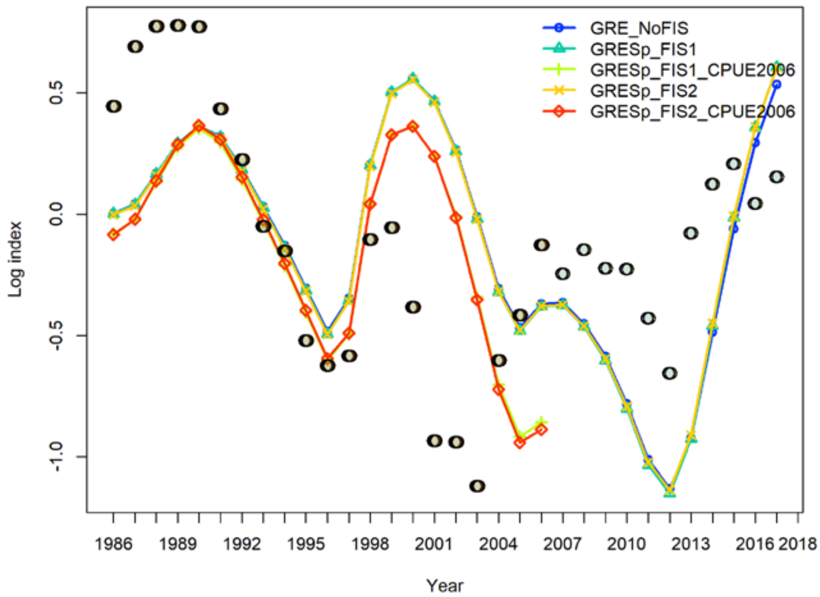

Figure 126. Blue Grenadier – spawning FIS: Fits to CPUE series (log scale) for trawl fleet. Scenarios consist of: (i) no FIS data (NoFIS); two scenarios each containing spawning FIS abundance indices from the original series (FIS1); i.e., (ii) using only FIS1 abundance indices and (iii) excluding CPUE after 2006 (CPUE_2006). Scenarios (ii)-(iii) were repeated using 2018 reconditioned FIS abundance series (FIS2).

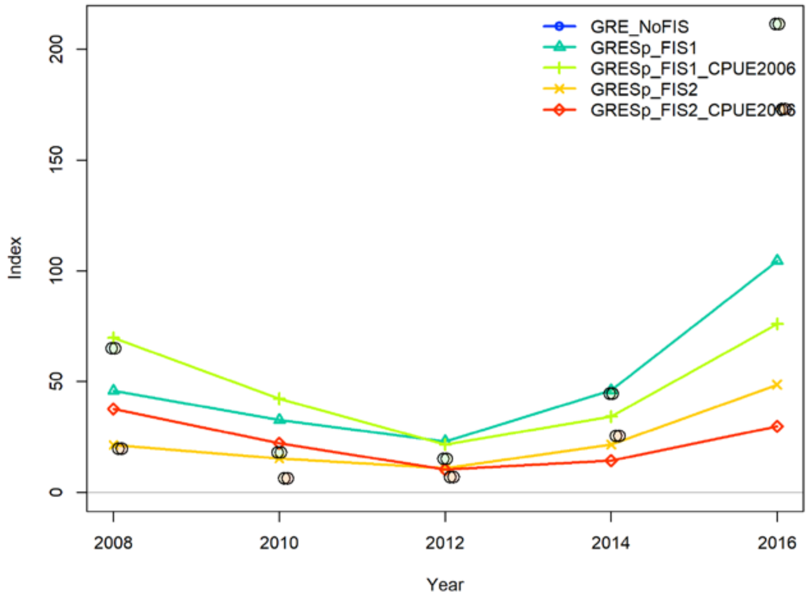

Figure 127. Blue Grenadier – spawning FIS: Fits to FIS abundance series. Scenarios consist of: (i) no FIS data (NoFIS); two scenarios each containing spawning FIS abundance indices from the original series (FIS1); i.e., (ii) using only FIS1 abundance indices and (iii) excluding CPUE after 2006 (CPUE_2006). Scenarios (ii)-(iii) were repeated using 2018 reconditioned FIS abundance series (FIS2).

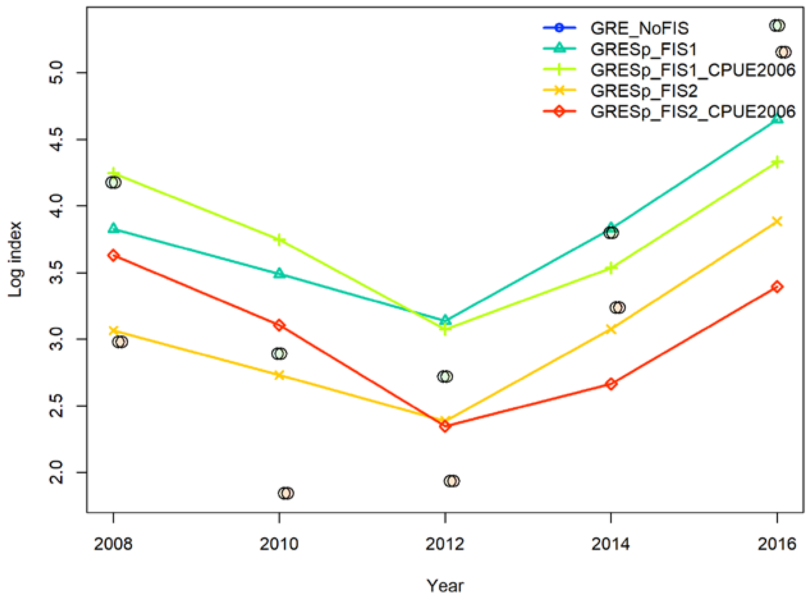

Figure 128. Blue Grenadier – spawning FIS: Fits to FIS abundance series (log scale). Scenarios consist of: (i) no FIS data (NoFIS); two scenarios each containing spawning FIS abundance indices from the original series (FIS1); i.e., (ii) using only FIS1 abundance indices and (iii) excluding CPUE after 2006 (CPUE_2006). Scenarios (ii)-(iii) were repeated using 2018 reconditioned FIS abundance series (FIS2).

Analysis of differences due to excluding CPUE after 2006

For Blue Grenadier, there are some changes to the spawning FIS abundance series between FIS1 and FIS2, (Figure 127 and Figure 128) although the changes in both the individual values and the overall shape of the time series is smaller than seen with the non-spawning FIS. The FIS1 data is plotted in the green shaded (upper) circles in Figure 127 and Figure 128 with the FIS2 series data plotted in red shaded circles, with the FIS1 series showing generally higher absolute values. Figure 128 plots the abundance indices on a log scale, which is the scale within which this data is actually fitted. By contrast to the non-spawning FIS series, the trend in these two series is similar, both showing increases in the last two points in the series with a large jump in 2016. The most notable difference is a relative drop in the FIS2 abundance index for 2010 seen in the FIS2 series.

By contrast to the non-spawning FIS abundance index, excluding recent CPUE data for Blue Grenadier results in poorer to fits in the FIS data. There are also changes in the biomass (Figure 122 and Figure 123) and recruitment (Figure 124) time series from excluding recent CPUE. This highlights that changes in assessment outcomes can be a complex and unpredictable function of the data included or excluded. While the fits to the FIS abundance index may not improve, the overall likelihood is maximised through improved fits to the composition data. For the spawning FIS index, the FIS data and the fits both change slightly between the FIS1 and FIS2 time series when CPUE is excluded beyond 2006.

The recruitment series from the FIS1 abundance index with CPUE data removed after 2006 shows a similar relative pattern to the series with no FIS data, (Figure 124), with peaks and troughs in the same years, albeit with different absolute and relative values. Notably the relative size of the period of good recent recruitment from 2010-2014 is reduced when the CPUE data after 2006 is removed, and reduced even further with the FIS2 abundance series, compared to the FIS1 series. This is in contrast to the non-spawning abundance index, with CPUE data removed after 2006, where the FIS1 index estimated increased recruitment in this period, and the FIS2 index estimated close to recruitment failure in the same period (Figure 117).

Improvements in fits to the composition data outweigh the deterioration in fits to FIS data, and with recent CPUE data excluded, 5 years of FIS data has a considerable effect on model results. In the case of Blue Grenadier with spawning FIS, removing CPUE data after 2006 appears to enable the model to maximise the likelihood by allowing improvements in fit to the age and length data, while allowing fits to the FIS data to deteriorate slightly. This suggests that while there may be some conflict between the FIS data and the age and length, the conflict is much stronger between the composition data and the CPUE data in this model.

This reinforce that in some circumstances, only five data points in a FIS abundance index can have an influence on model outcomes. It also highlights that there can be conflict within data sources. This fit to the CPUE series (Figure 125 and Figure 126) is relatively poor regardless of whether the CPUE is continued past 2006 or not. However, it is notable that the last five points in this CPUE series (2013-2017) are all higher than the previous 20 points, and despite the generally poor fits to the CPUE series, these last five points have considerable influence. As a result excluding the CPUE series after 2006 has an impact. It is not implied that this CPUE series should be excluded, nor that the spawning FIS series is more representative then the CPUE as an abundance index. Instead, this analysis should be considered as hypothetical scenario exploration, rather than a comment on which series should be used in a stock assessment, or any comment on the quality of the stock assessment.

Appendix F. Silver Warehou

Scientific name: *Seriolella punctata*; CAAB code: 37445006

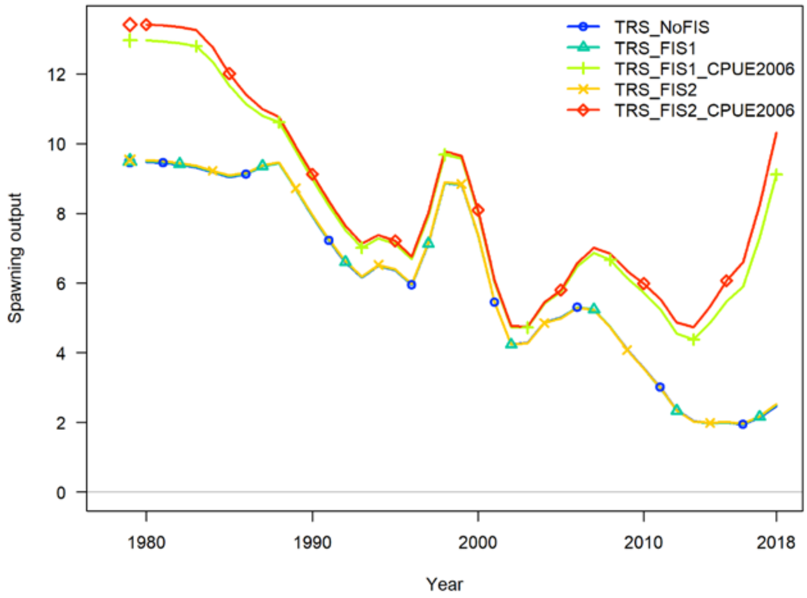

Figure 129. Silver Warehou: Absolute spawning biomass time-trajectory. Scenarios consist of: (i) no FIS data (NoFIS); two scenarios each containing FIS abundance indices from the original series (FIS1); i.e., (ii) using only FIS1 abundance indices and (iii) excluding CPUE after 2006 (CPUE_2006). Scenarios (ii)-(iii) were repeated using 2018 reconditioned FIS abundance series (FIS2).

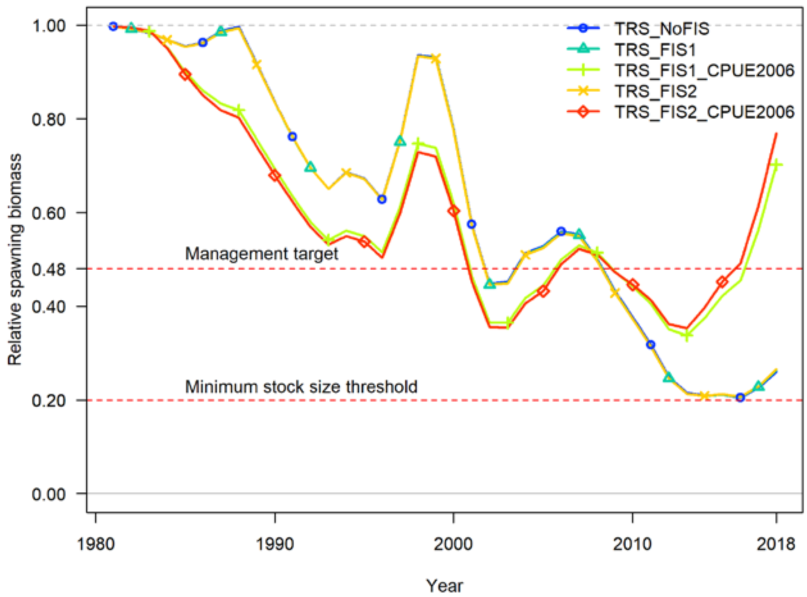

Figure 130. Silver Warehou: Relative spawning biomass time-trajectory. Scenarios consist of: (i) no FIS data (NoFIS); two scenarios each containing FIS abundance indices from the original series (FIS1); i.e., (ii) using only FIS1 abundance indices and (iii) excluding CPUE after 2006 (CPUE_2006). Scenarios (ii)-(iii) were repeated using 2018 reconditioned FIS abundance series (FIS2).

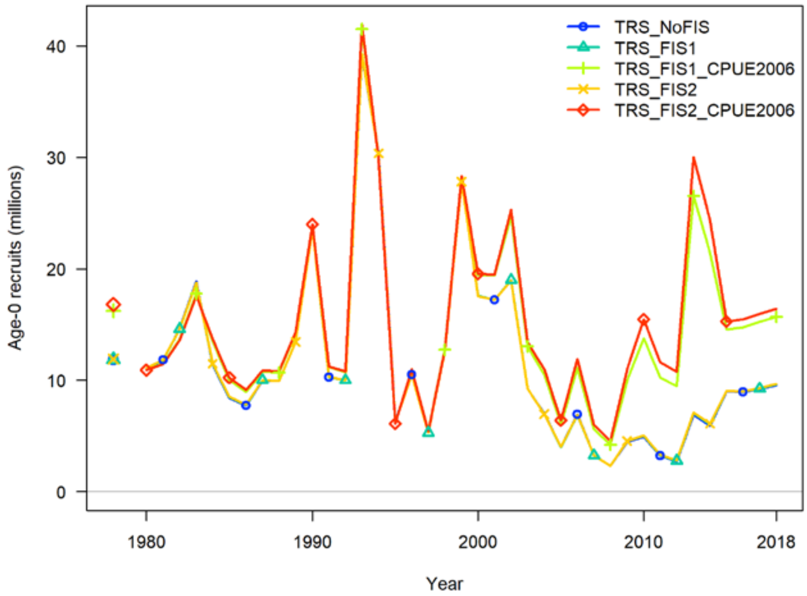

Figure 131. Silver Warehou: Estimated recruitment time-trajectory. Scenarios consist of: (i) no FIS data (NoFIS); two scenarios each containing FIS abundance indices from the original series (FIS1); i.e., (ii) using only FIS1 abundance indices and (iii) excluding CPUE after 2006 (CPUE_2006). Scenarios (ii)-(iii) were repeated using 2018 reconditioned FIS abundance series (FIS2).

F.1 Silver Warehou– non-spawning FIS differences

Minimal differences

1. Differences when including either FIS abundance series are minimal (limited difference between models with: no FIS; FIS1; and FIS2).

Clear differences

2. Excluding CPUE after 2006 makes a substantial difference (seen in red and green lines (TRS_FIS1_CPUE2006 and TRS_FIS2_CPUE2006) in the absolute biomass time series (Figure 129), the relative biomass time series (Figure 130) and the recruitment time series (Figure 131)).
3. Fits to the FIS abundance data generally improve by excluding CPUE after 2006 (seen in red and green lines (TRS_FIS1_CPUE2006 and TRS_FIS2_CPUE2006) in Figure 136, Figure 137, Figure 138 and Figure 139), especially for the eastern trawl FIS series, and generally better improvements using the FIS2 series compared to the FIS1 series.

Moderate differences

4. Fits to the CPUE are modified slightly by excluding CPUE after 2006 (seen in red and green lines (TRS_FIS1_CPUE2006 and TRS_FIS2_CPUE2006) in Figure 132, Figure 133, Figure 134 and Figure 135). Note that these fits to the eastern trawl CPUE are generally poor, with better fits for the western trawl CPUE.

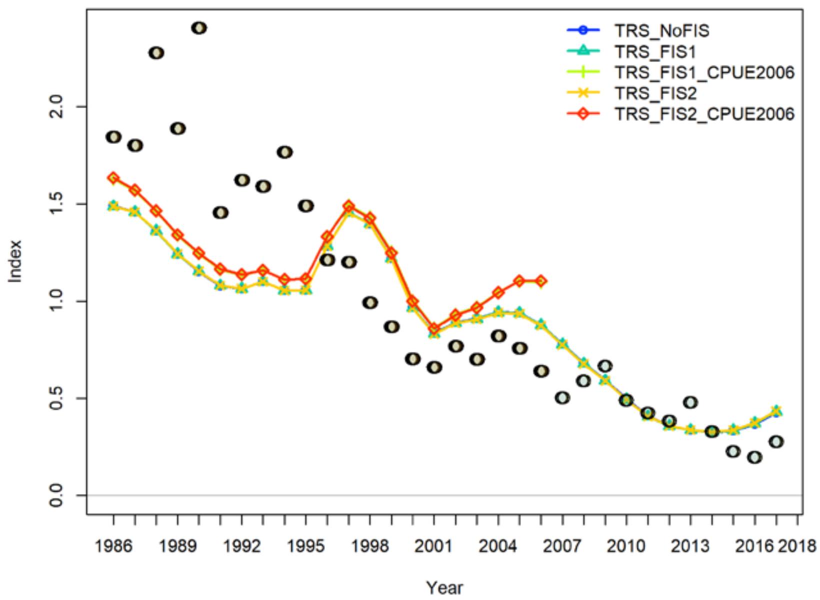

Figure 132. Silver Warehou: Fits to CPUE series for eastern trawl fleet. Scenarios consist of: (i) no FIS data (NoFIS); two scenarios each containing FIS abundance indices from the original series (FIS1); i.e., (ii) using only FIS1 abundance indices and (iii) excluding CPUE after 2006 (CPUE_2006). Scenarios (ii)-(iii) were repeated using 2018 reconditioned FIS abundance series (FIS2).

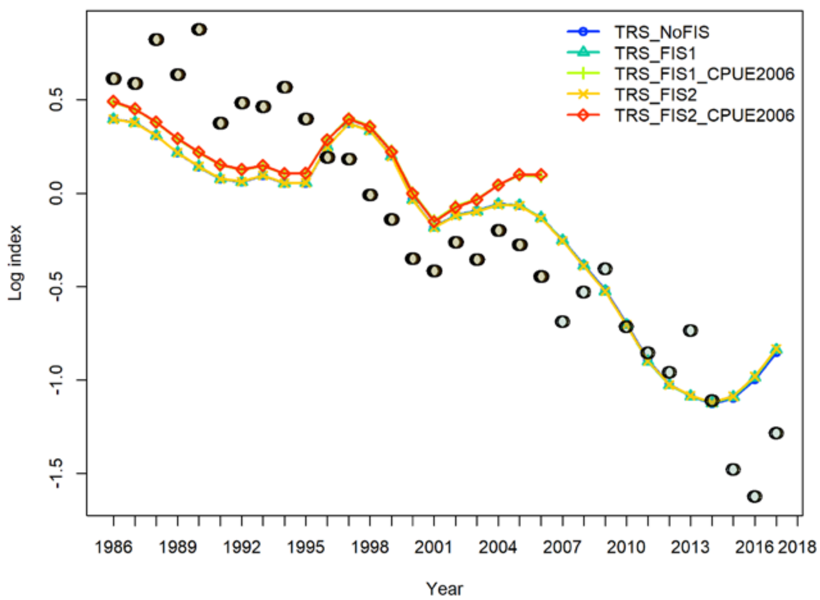

Figure 133. Silver Warehou: Fits to CPUE series (log scale) for eastern trawl fleet. Scenarios consist of: (i) no FIS data (NoFIS); two scenarios each containing FIS abundance indices from the original series (FIS1); i.e., (ii) using only FIS1 abundance indices and (iii) excluding CPUE after 2006 (CPUE_2006). Scenarios (ii)-(iii) were repeated using 2018 reconditioned FIS abundance series (FIS2).

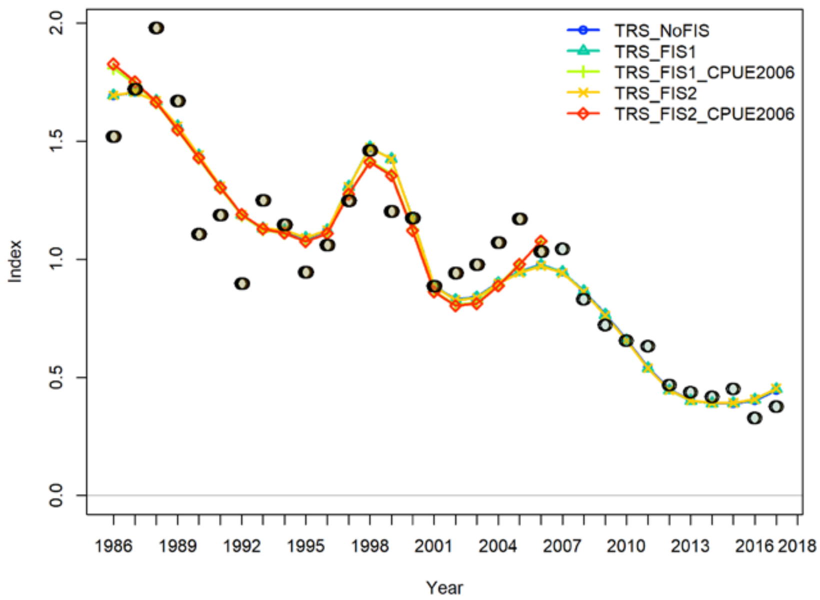

Figure 134. Silver Warehou: Fits to CPUE series for western trawl fleet. Scenarios consist of: (i) no FIS data (NoFIS); two scenarios each containing FIS abundance indices from the original series (FIS1); i.e., (ii) using only FIS1 abundance indices and (iii) excluding CPUE after 2006 (CPUE_2006). Scenarios (ii)-(iii) were repeated using 2018 reconditioned FIS abundance series (FIS2).

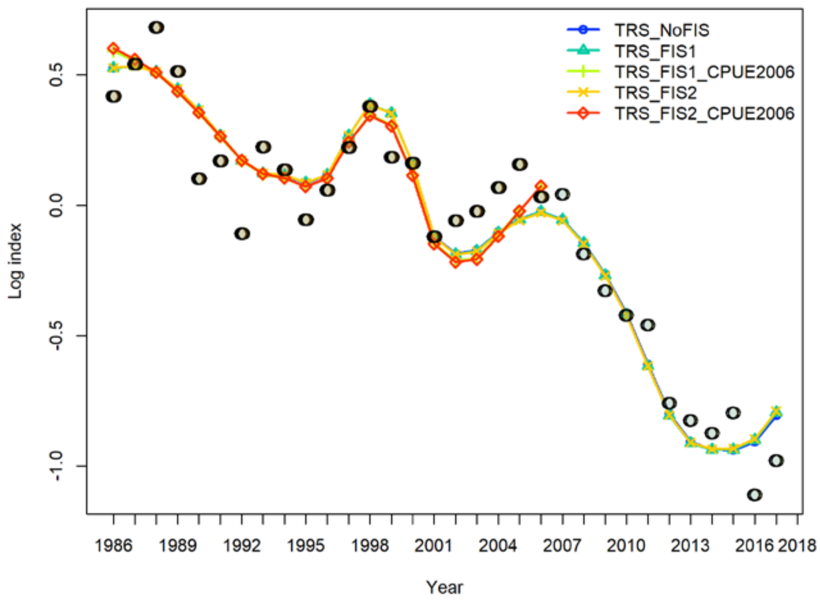

Figure 135. Silver Warehou: Fits to CPUE series (log scale) for western trawl fleet. Scenarios consist of: (i) no FIS data (NoFIS); two scenarios each containing FIS abundance indices from the original series (FIS1); i.e., (ii) using only FIS1 abundance indices and (iii) excluding CPUE after 2006 (CPUE_2006). Scenarios (ii)-(iii) were repeated using 2018 reconditioned FIS abundance series (FIS2).

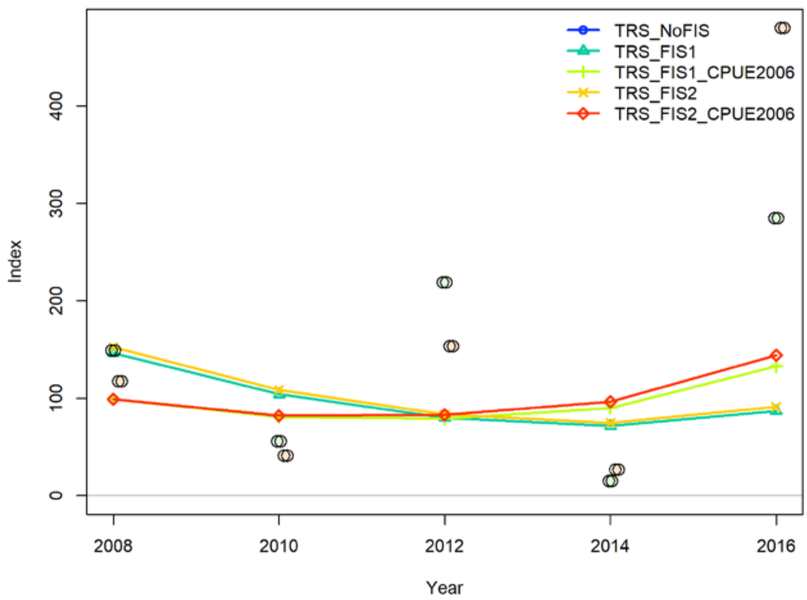

Figure 136. Silver Warehou: Fits to eastern FIS abundance series. Scenarios consist of: (i) no FIS data (NoFIS); two scenarios each containing FIS abundance indices from the original series (FIS1); i.e., (ii) using only FIS1 abundance indices and (iii) excluding CPUE after 2006 (CPUE_2006). Scenarios (ii)-(iii) were repeated using 2018 reconditioned FIS abundance series (FIS2).

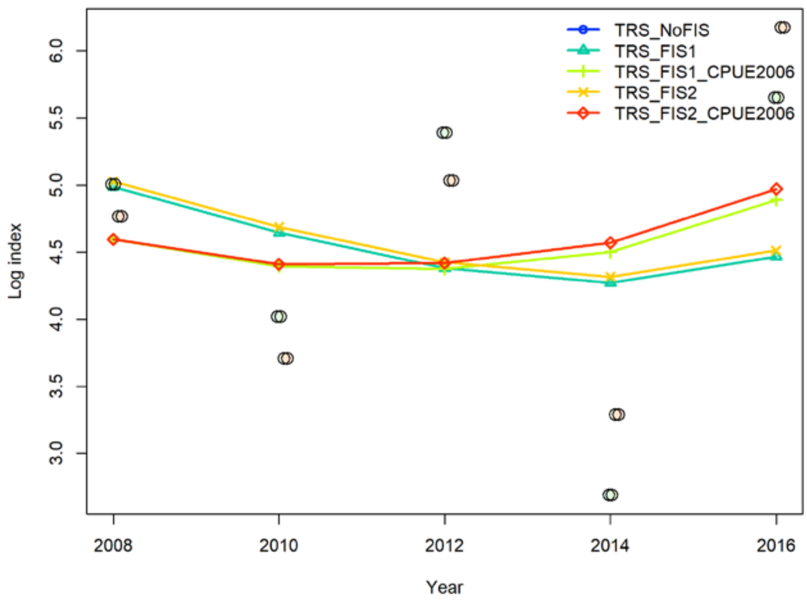

Figure 137. Silver Warehou: Fits to eastern FIS abundance series (log scale). Scenarios consist of: (i) no FIS data (NoFIS); two scenarios each containing FIS abundance indices from the original series (FIS1); i.e., (ii) using only FIS1 abundance indices and (iii) excluding CPUE after 2006 (CPUE_2006). Scenarios (ii)-(iii) were repeated using 2018 reconditioned FIS abundance series (FIS2).

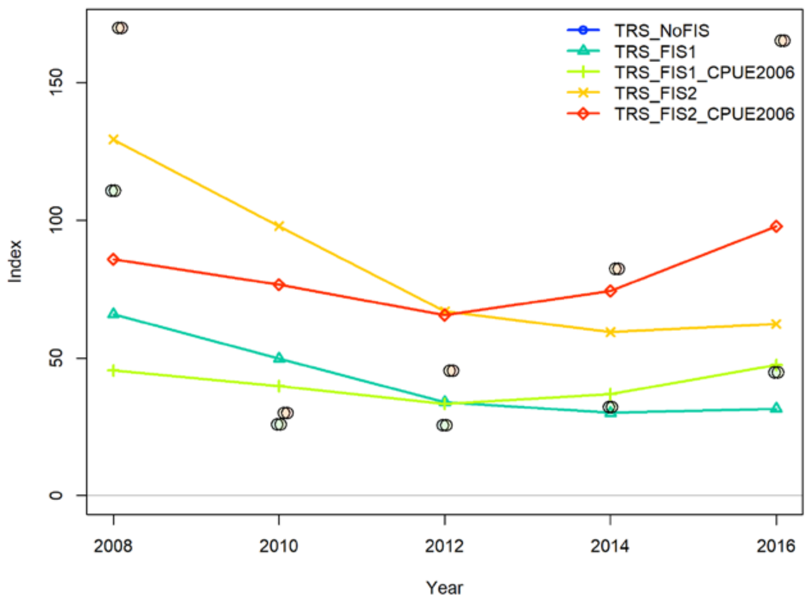

Figure 138. Silver Warehou: Fits to western FIS abundance series. Scenarios consist of: (i) no FIS data (NoFIS); two scenarios each containing FIS abundance indices from the original series (FIS1); i.e., (ii) using only FIS1 abundance indices and (iii) excluding CPUE after 2006 (CPUE_2006). Scenarios (ii)-(iii) were repeated using 2018 reconditioned FIS abundance series (FIS2).

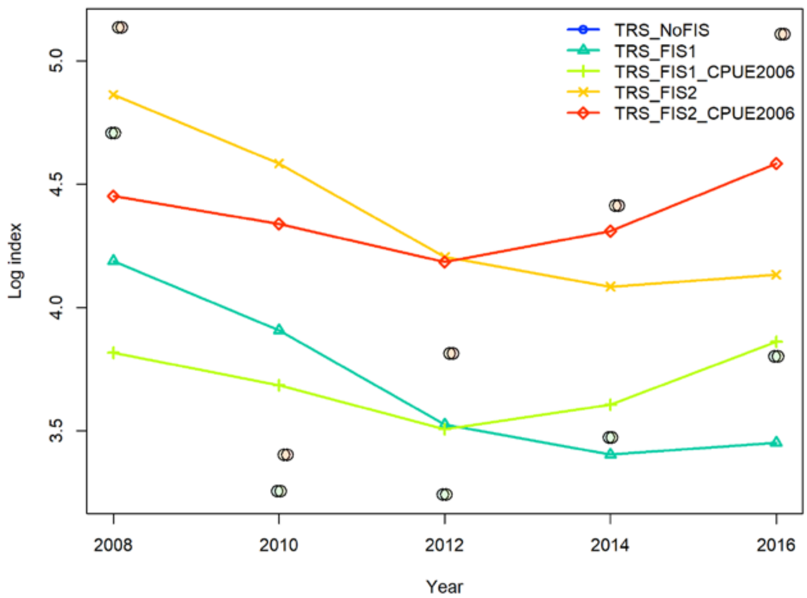

Figure 139. Silver Warehou: Fits to western FIS abundance series (log scale). Scenarios consist of: (i) no FIS data (NoFIS); two scenarios each containing FIS abundance indices from the original series (FIS1); i.e., (ii) using only FIS1 abundance indices and (iii) excluding CPUE after 2006 (CPUE_2006). Scenarios (ii)-(iii) were repeated using 2018 reconditioned FIS abundance series (FIS2).

Analysis of differences due to excluding CPUE after 2006

For Silver Warehou, there are moderate changes to the FIS abundance series between FIS1 and FIS2 for the eastern and western trawl fleets, as highlighted in Figure 136, Figure 137, Figure 138 and Figure 139. The FIS1 data is plotted in the green shaded (upper) circles in Figure 136, Figure 137, Figure 138 and Figure 139 with the FIS2 series data plotted in red shaded circles, with the FIS1 series showing generally higher absolute values for the western FIS but mixed changes for the eastern FIS. Figure 137 and Figure 139 plot the abundance indices on a log scale, which is the scale at which this data is actually fitted. While the pattern in the eastern and western series is quite different, the changes between the values in the FIS1 and FIS2 series result in similar patterns in temporal changes to the index, but with some changes to the relative values between the FIS1 and FIS2 series. The eastern series has a generally increasing series with strong oscillations between surveys and a stronger overall increase for the FIS2 series. The western series has a sharp decline initially, followed by a gradual increase, with only the FIS2 series recovering to the 2008 value by 2016.

Excluding recent CPUE data results in considerably higher estimates of 2019 spawning biomass, a similar pattern seen in both eastern and western morwong, although with a much bigger relative difference, and the opposite pattern to that generally seen in Blue Grenadier. In contrast to western and eastern Jackass Morwong and Blue Grenadier non-spawning FIS, excluding recent CPUE data for Silver Warehou generally results in improvements to fits in the FIS data, in addition to changes in the biomass (Figure 129 and Figure 130) and recruitment (Figure 131) time series. While fits to the FIS abundance series generally improve when CPUE is excluded beyond 2006, these abundance series show different patterns between the east and the west in addition to large inter-survey variability, so it difficult to achieve good fits to both abundance series.

While there are relatively minor changes to the abundance series between FIS1 and FIS2, and the resulting model fits, the largest difference for Silver Warehou come from excluding the recent CPUE data, which results in improvements to the fits in the FIS abundance data. It appears that the FIS abundance data is more influential than the composition data for Silver Warehou. Due the variability between FIS surveys and between east and west suggest, the FIS abundance index may not be that useful for Silver Warehou. This is likely to be influenced by small numbers of very large shots of Silver Warehou that are seen in some years in the FIS but not in others, which suggests that for this schooling species, the FIS may not have sufficient samples to produce a very reliable abundance index.

The recruitment series from the FIS1 abundance index with CPUE data removed after 2006 is very similar to the series with no FIS data before the year 2000, with some small differences in the late 1980s. Moderate differences in the estimated recruitment series occur between 2000 and 2010 and then increase from 2010 onwards, (Figure 131), with a larger average recruitment for the series without recent CPUE data. These patterns are very similar for both the FIS1 and FIS2 series. These differences in estimated recruitment series flow through to the estimated abundance (Figure 129 and Figure 130), with a lower relative abundance up until 2008 and then a large increase in spawning biomass towards the end of the series, as the model is no longer restricted to try to fit the low recent CPUE series. Unlike Jackass Morwong and Blue Grenadier, there appears to be little tension between the composition data and the abundance indices for Silver Warehou, with improvements in fits to the FIS abundance index when recent CPUE data is excluded.

As with analyses on other species here, it is not suggested that this latter part of the CPUE series should be excluded. This analysis should be considered as hypothetical scenario exploration, rather than a comment on quality of data sources, which series should be used in a stock assessment, or any comment on the quality of the stock assessment.

Appendix G. Pink Ling – west

Scientific name: *Genypterus blacodes*; CAAB code: 37228002

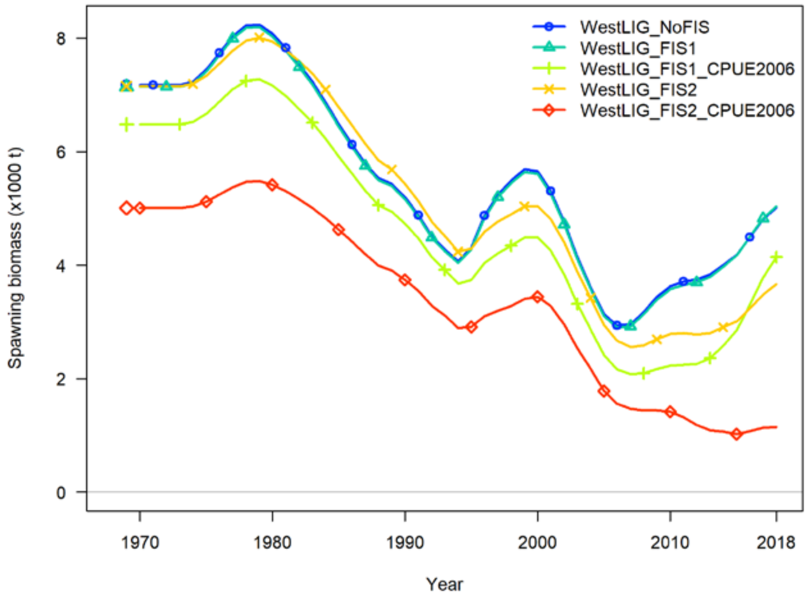

Figure 140. Western Pink Ling: Absolute spawning biomass time-trajectory. Scenarios consist of: (i) no FIS data (NoFIS); two scenarios each containing FIS abundance indices from the original series (FIS1); i.e., (ii) using only FIS1 abundance indices and (iii) excluding CPUE after 2006 (CPUE_2006). Scenarios (ii)-(iii) were repeated using 2018 reconditioned FIS abundance series (FIS2).

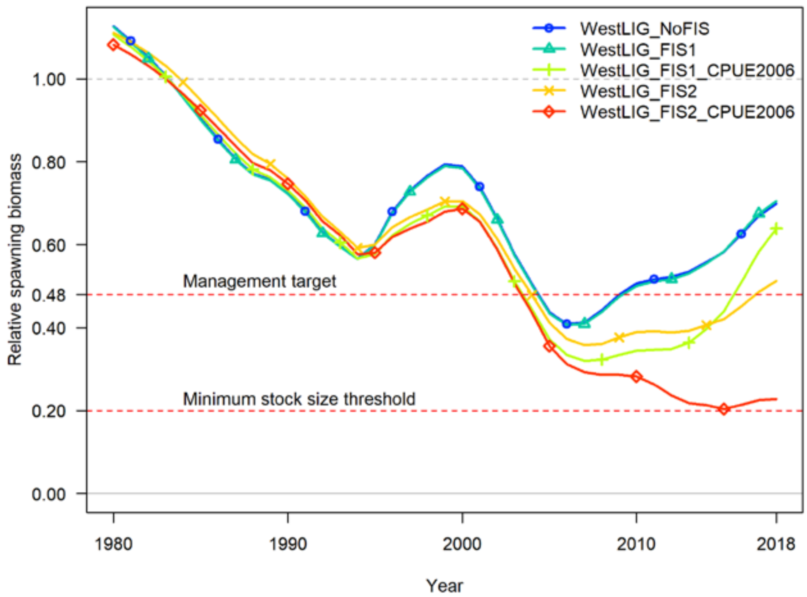

Figure 141. Western Pink Ling: Relative spawning biomass time-trajectory (relative to the 1998 productivity shift initial biomass). Scenarios consist of: (i) no FIS data (NoFIS); two scenarios each containing FIS abundance indices from the original series (FIS1); i.e., (ii) using only FIS1 abundance indices and (iii) excluding CPUE after 2006 (CPUE_2006). Scenarios (ii)-(iii) were repeated using 2018 reconditioned FIS abundance series (FIS2).

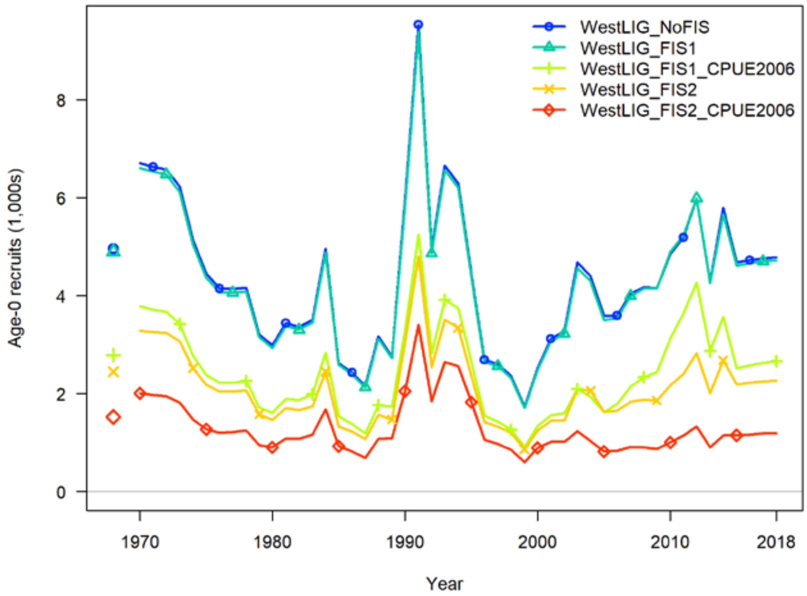

Figure 142. Western Pink Ling: Estimated recruitment time-trajectory. Scenarios consist of: (i) no FIS data (NoFIS); two scenarios each containing FIS abundance indices from the original series (FIS1); i.e., (ii) using only FIS1 abundance indices and (iii) excluding CPUE after 2006 (CPUE_2006). Scenarios (ii)-(iii) were repeated using 2018 reconditioned FIS abundance series (FIS2).

G.1 Pink Ling west differences

Minimal differences

1. Differences when including the FIS1 abundance series are minimal (limited difference between models with: no FIS; and FIS1).
2. Fits to the CPUE are largely unchanged for all scenarios (Figure 143 and Figure 144). Note that these fits to the CPUE are generally good in all cases.

Clear differences

3. Differences when including the FIS2 abundance series are substantial (seen between the blue and orange lines (WestLIG_NoFIS and WestLIG_FIS2) in the absolute biomass time series (Figure 140), the relative biomass time series (Figure 141) and the recruitment time series (Figure 142)), compared to both the NoFIS and FIS1 series.
4. Excluding CPUE after 2006 also makes a substantial difference (seen in red and green lines (WestLIG_NoFIS and WestLIG_FIS2) in the absolute biomass time series (Figure 140), the relative biomass time series (Figure 141) and the recruitment time series (Figure 142)), compared to all other series with CPUE to 2017.
5. Fits to the FIS abundance data improve by excluding CPUE after 2006 (seen in red and green lines (WestLIG _FIS1_CPUE2006 and WestLIG _FIS2_CPUE2006) in Figure 145 and Figure 146).

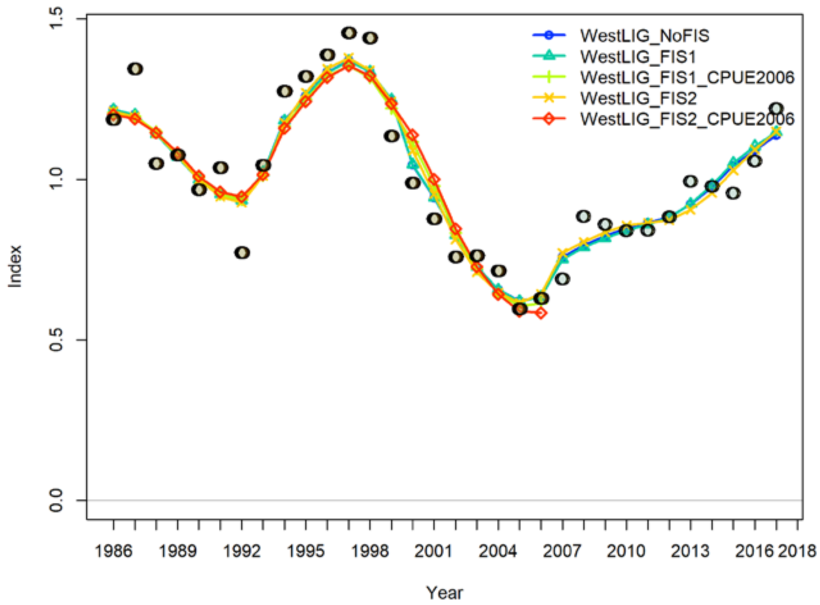

Figure 143. Western Pink Ling: Fits to CPUE series for western trawl fleet. Scenarios consist of: (i) no FIS data (NoFIS); two scenarios each containing FIS abundance indices from the original series (FIS1); i.e., (ii) using only FIS1 abundance indices and (iii) excluding CPUE after 2006 (CPUE_2006). Scenarios (ii)-(iii) were repeated using 2018 reconditioned FIS abundance series (FIS2).

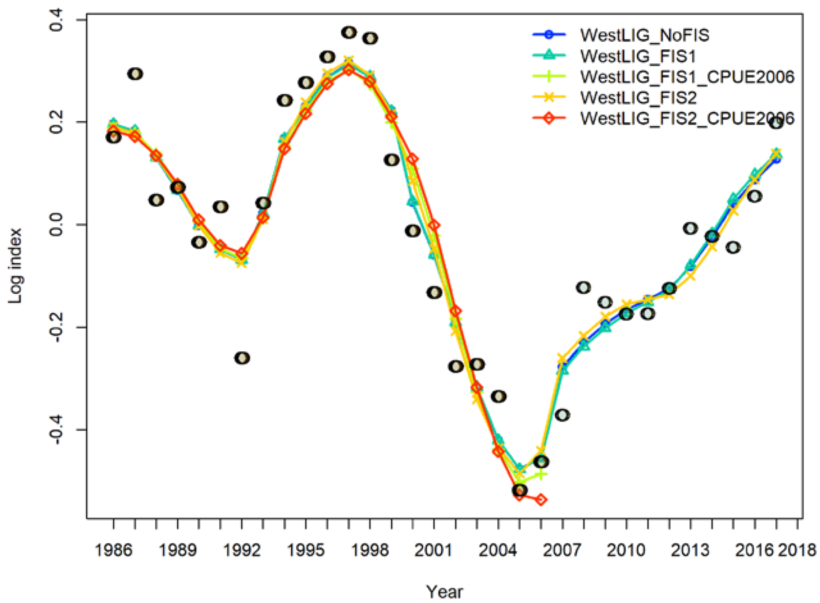

Figure 144. Western Pink Ling: Fits to CPUE series (log scale) for western trawl fleet. Scenarios consist of: (i) no FIS data (NoFIS); two scenarios each containing FIS abundance indices from the original series (FIS1); i.e., (ii) using only FIS1 abundance indices and (iii) excluding CPUE after 2006 (CPUE_2006). Scenarios (ii)-(iii) were repeated using 2018 reconditioned FIS abundance series (FIS2).

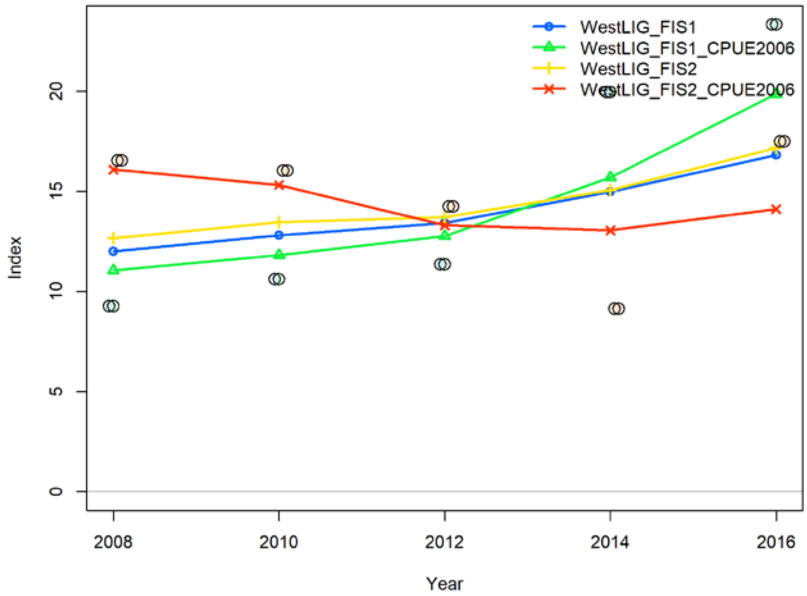

Figure 145. Western Pink Ling: Fits to the western FIS abundance series. Scenarios consist of: (i) no FIS data (NoFIS); two scenarios each containing FIS abundance indices from the original series (FIS1); i.e., (ii) using only FIS1 abundance indices and (iii) excluding CPUE after 2006 (CPUE_2006). Scenarios (ii)-(iii) were repeated using 2018 reconditioned FIS abundance series (FIS2).

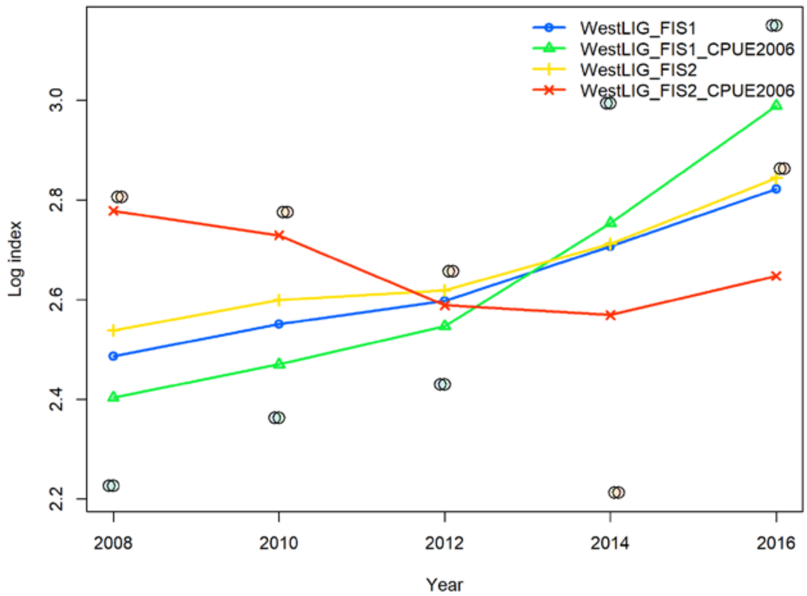

Figure 146. Western Pink Ling: Fits to the western FIS abundance series (log scale). Scenarios consist of: (i) no FIS data (NoFIS); two scenarios each containing FIS abundance indices from the original series (FIS1); i.e., (ii) using only FIS1 abundance indices and (iii) excluding CPUE after 2006 (CPUE_2006). Scenarios (ii)-(iii) were repeated using 2018 reconditioned FIS abundance series (FIS2).

Analysis of differences due to using FIS2 or excluding CPUE after 2006

For Pink Ling west, there are substantial changes to the FIS abundance series between FIS1 and FIS2, as highlighted in Figure 145 and Figure 146. The FIS1 data is plotted in the green shaded circles in Figure 145 and Figure 146 with the FIS2 series data plotted in red shaded circles. Figure 146 plots the abundance indices on a log scale, which is the scale at which this data is actually fitted. The trend in these two series is clearly different. The FIS1 series features a steady increase with each survey point, with the largest increase from 2012 to 2014. By contrast, the FIS2 series features a steady decline for the first 4 points, with the largest decline from 2012 to 2014 and then a large increase in 2016 to just above the initial value, from 2008. The fits to each of these series give a markedly different trend, especially when the recent CPUE is excluded, but also when FIS2 replaces FIS1, even with all the CPUE data included. The results produce a lower 2019 spawning biomass estimate if either the FIS2 series is used or if the recent CPUE is excluded (Figure 142), with the lowest values produced by removing the recent CPUE. This is not surprising given the CPUE shows a steady increase from 2006 onwards.

As with Blue Grenadier spawning and Silver Warehou, excluding recent CPUE data for western Pink Ling results in improvements to fits in the FIS data, in addition to changes in the biomass (Figure 140 and Figure 141) and recruitment (Figure 142) time series.

The recruitment series from the FIS1 abundance index with CPUE data removed after 2006 is very similar to the series with no FIS data, (Figure 142). When the FIS2 series is used, or the recent CPUE is excluded, the peaks and trough remain in the same positions, but the absolute and relative values of recruitment estimates both change, with absolute recruitment estimate to be lower than the model without FIS data. While there may also be changes to the fits to length and age composition data, it appears the change in fits to the abundance indices are much more influential with this species, than Jackass Morwong, Blue Grenadier and Silver Warehou.

In the case of western Pink Ling, the CPUE data and the FIS1 abundance index show similar trends, but with a slightly stronger increase seen in the FIS1 abundance index. By contrast, the FIS2 series appears to be in some conflict with the CPUE data. These two factors combine to give a range of model outcomes, depending on which data is included in the model.

This shows that even with a model with low estimated CV on the five FIS abundance index points, reconditioning the FIS abundance data (FIS1 to FIS2) can produce substantial changes to the FIS abundance series, which in turn can flow through to substantial changes in assessment outcomes. It also highlights that there can be some conflict between data sources, and even when different indices have a similar shape to the trend, the magnitude of the changes can be important.

Compared to Jackass Morwong, Blue Grenadier and Silver Warehou, the fits to CPUE for Pink Ling are remarkably good. Likewise, the CVs on the FIS abundance indices are much lower for Pink Ling, which suggests that the FIS abundance index may be more useful for this species. Despite these low CV values, the change in the FIS abundance series from FIS1 to FIS2 is substantial, perhaps more than would be expected given the low CVs. This suggests that there may have been considerable changes to this fishery after the structural adjustment, so conditioning the FIS abundance index on data after 2006 may be more important for Pink Ling than for the other species considered here. Western Pink Ling demonstrates that there can be large changes in the FIS abundance series through reconditioning, even when the CVs are low. Further, these changes can be influential on stock assessment results, even with only five points in the FIS abundance series, and these changes can be seen even when the full CPUE series is included (using data up to 2017).

Appendix H. Pink Ling – east

Scientific name: *Genypterus blacodes; CAAB code: 37228002*

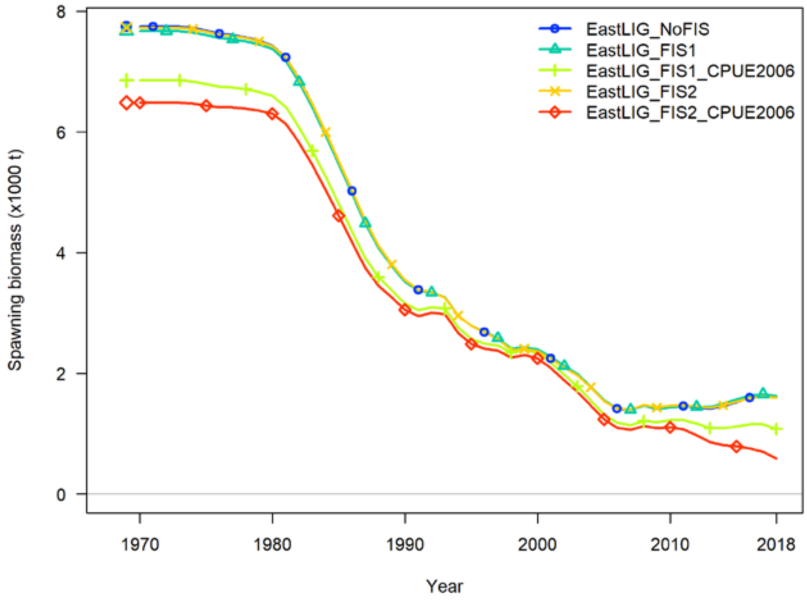

Figure 147. Eastern Pink Ling: Absolute spawning biomass time-trajectory. Scenarios consist of: (i) no FIS data (NoFIS); two scenarios each containing FIS abundance indices from the original series (FIS1); i.e., (ii) using only FIS1 abundance indices and (iii) excluding CPUE after 2006 (CPUE_2006). Scenarios (ii)-(iii) were repeated using 2018 reconditioned FIS abundance series (FIS2).

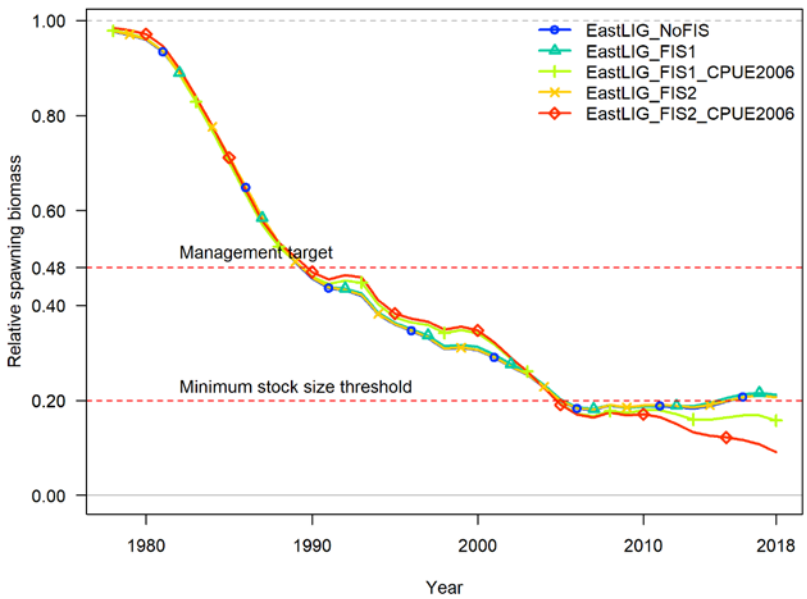

Figure 148. Eastern Pink Ling: Relative spawning biomass time-trajectory. Scenarios consist of: (i) no FIS data (NoFIS); two scenarios each containing FIS abundance indices from the original series (FIS1); i.e., (ii) using only FIS1 abundance indices and (iii) excluding CPUE after 2006 (CPUE_2006). Scenarios (ii)-(iii) were repeated using 2018 reconditioned FIS abundance series (FIS2).

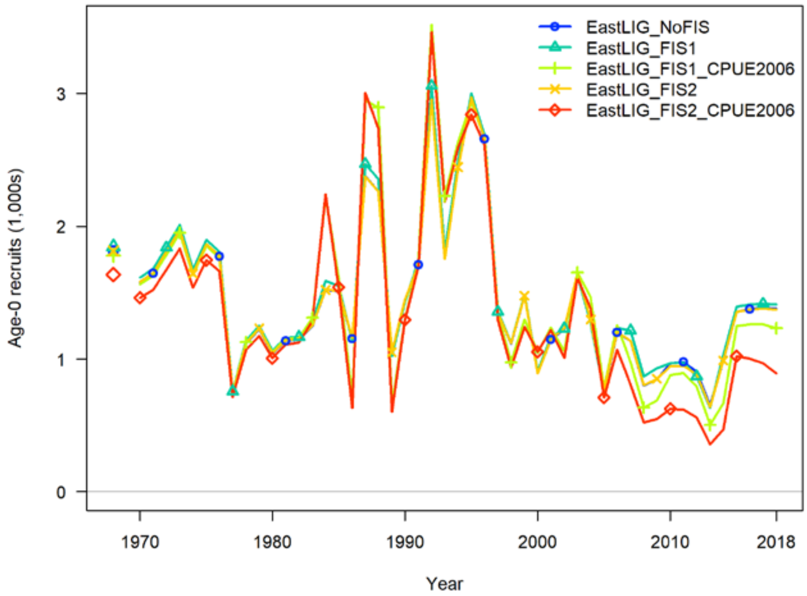

Figure 149. Eastern Pink Ling: Estimated recruitment time-trajectory. Scenarios consist of: (i) no FIS data (NoFIS); two scenarios each containing FIS abundance indices from the original series (FIS1); i.e., (ii) using only FIS1 abundance indices and (iii) excluding CPUE after 2006 (CPUE_2006). Scenarios (ii)-(iii) were repeated using 2018 reconditioned FIS abundance series (FIS2).

H.1 Pink Ling – east differences

Minimal differences

1. Differences when including either FIS abundance series are minimal (limited difference between models with: no FIS; FIS1; and FIS2).

Clear differences

2. Excluding CPUE after 2006 makes a difference (seen in red and green lines (EastLIG_FIS1_CPUE2006 and EastLIG_FIS2_CPUE2006) in the absolute biomass time series (Figure 147), the relative biomass time series (Figure 148) and the recruitment time series (Figure 149)).
3. Fits to the CPUE are improved for all scenarios (Figure 150 and Figure 151), especially in the period 1986-1998. Note that these fits to the CPUE are generally good in all cases.
4. Fits to the FIS2 abundance data improve by excluding CPUE after 2006 (seen in comparing the red and yellow lines (EastLIG_FIS2_CPUE2006 and EastLIG_FIS2) in Figure 152 and Figure 153). By contrast, fits to the FIS1 abundance series deteriorate by excluding CPUE after 2006 (seen in comparing the green and blue lines (EastLIG_FIS1_CPUE2006 and EastLIG_FIS1) in Figure 152 and Figure 153).

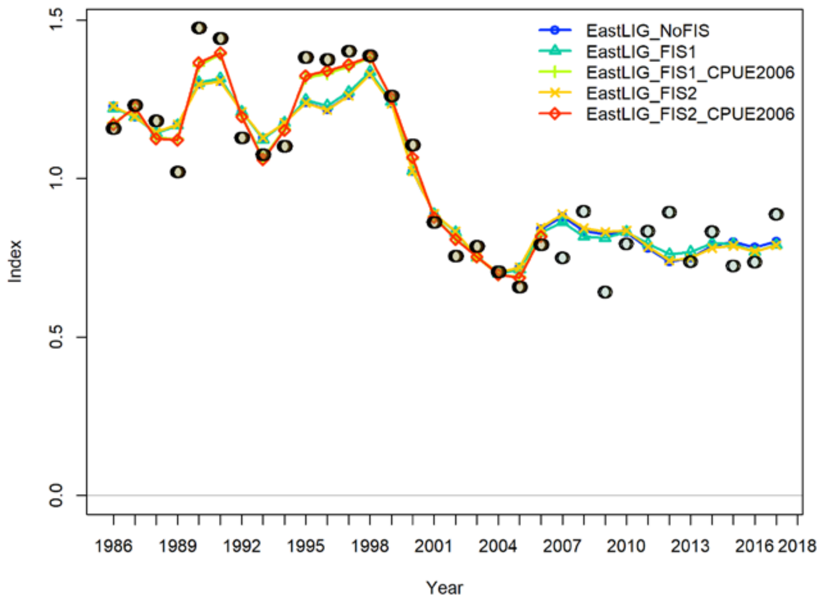

Figure 150. Eastern Pink Ling: Fits to CPUE series for eastern trawl fleet. Scenarios consist of: (i) no FIS data (NoFIS); two scenarios each containing FIS abundance indices from the original series (FIS1); i.e., (ii) using only FIS1 abundance indices and (iii) excluding CPUE after 2006 (CPUE_2006). Scenarios (ii)-(iii) were repeated using 2018 reconditioned FIS abundance series (FIS2).

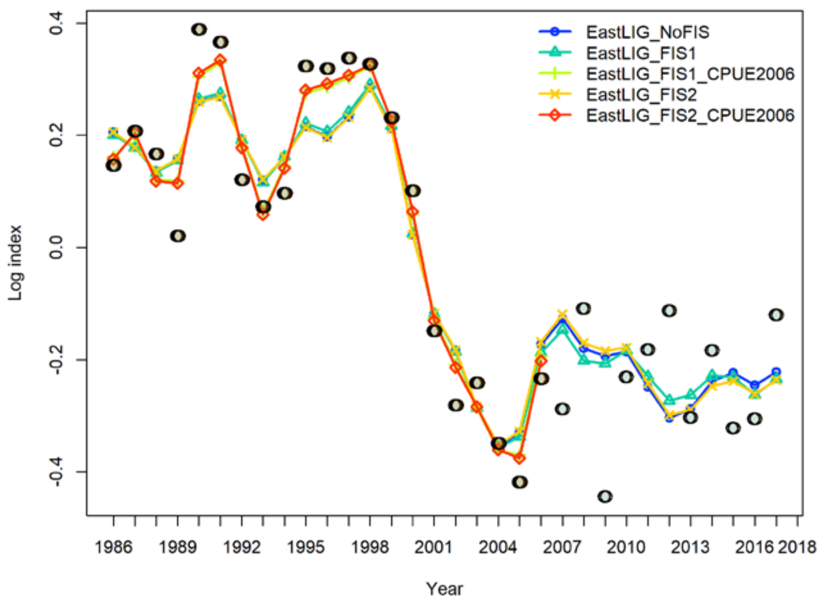

Figure 151. Eastern Pink Ling: Fits to CPUE series (log scale) for eastern trawl fleet. Scenarios consist of: (i) no FIS data (NoFIS); two scenarios each containing FIS abundance indices from the original series (FIS1); i.e., (ii) using only FIS1 abundance indices and (iii) excluding CPUE after 2006 (CPUE_2006). Scenarios (ii)-(iii) were repeated using 2018 reconditioned FIS abundance series (FIS2).

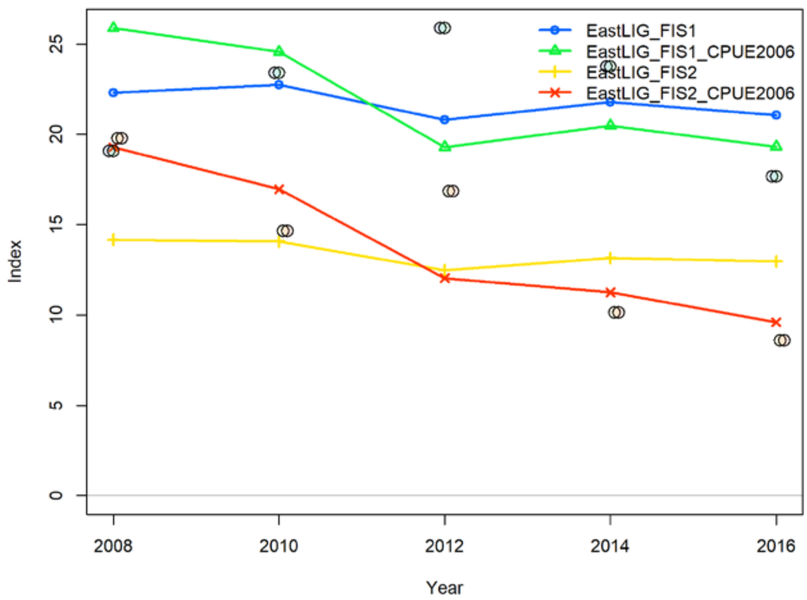

Figure 152. Eastern Pink Ling: Fits to the eastern FIS abundance series. Scenarios consist of: two scenarios each containing FIS abundance indices from the original series (FIS1); i.e., (i) using only FIS1 abundance indices and (ii) excluding CPUE after 2006 (CPUE_2006). Scenarios (i)-(ii) were repeated using 2018 reconditioned FIS abundance series (FIS2).

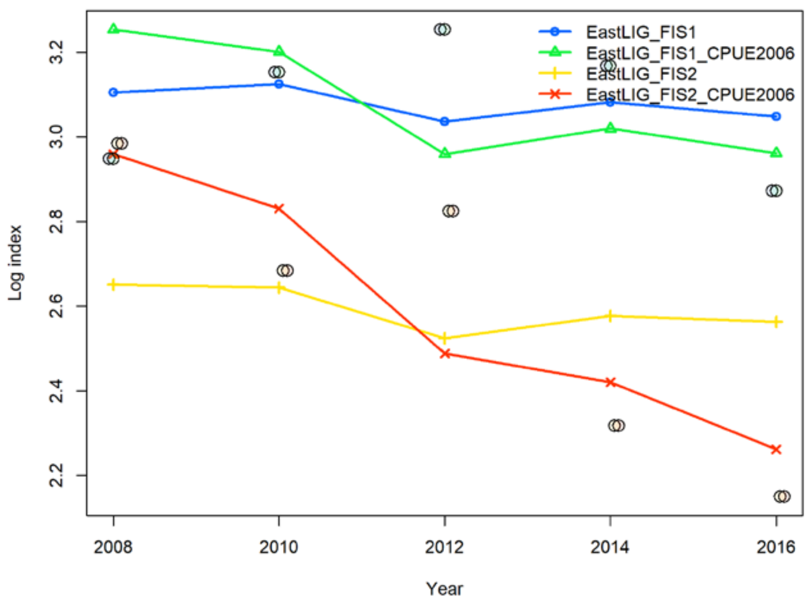

Figure 153. Eastern Pink Ling: Fits to the eastern FIS abundance series (log scale). Scenarios consist of: two scenarios each containing FIS abundance indices from the original series (FIS1); i.e., (i) using only FIS1 abundance indices and (ii) excluding CPUE after 2006 (CPUE_2006). Scenarios (i)-(ii) were repeated using 2018 reconditioned FIS abundance series (FIS2).

Analysis of differences due to excluding CPUE after 2006

As was the case for Pink Ling west, there are substantial changes to the FIS abundance series between FIS1 and FIS2 for Pink Ling east, as highlighted in Figure 152 and Figure 153. The FIS1 data is plotted in the green shaded circles in Figure 152 and Figure 153 with the FIS2 series data plotted in red shaded circles. Figure 153 plots the abundance indices on a log scale, which is the scale at which this data is actually fitted. The trend in these two series is clearly different. The FIS1 series features a dome shaped series, with an initial increase for two survey, followed by a decrease, with similar values in 2008 and 2016. By contrast, the FIS2 series features a general decline for the whole, with the largest declines in the last two data points. When the recent CPUE is excluded, the fits to each of these series give a markedly different trend, especially for the FIS2 series. The recent CPUE series is somewhat variable, but generally has a flat trend since 2007, which is in contrast to the FIS2 series.

As with Blue Grenadier spawning, Silver Warehou and western Pink Ling, excluding recent CPUE data for eastern Pink Ling results in improvements to fits in the FIS2 data, in addition to changes in the biomass time series (red line in Figure 147 and Figure 148) and the recruitment time series (Figure 149). By contrast, excluding recent CPUE results in a deterioration in fits to the FIS1 time series, with more moderate changes to the biomass and recruitment time series (green line in the same figures). This suggest that there is a fine balance between changes to the overall likelihood through improvements to fits to the FIS abundance index and changes to fits in the length and age data, with different results for each FIS series used.

With recent CPUE data excluded, there are reductions to the recruitment series from around 2008 onwards (Figure 149). The CPUE data and the FIS1 abundance index show roughly similar trends. By contrast, the FIS2 series appears to be in some conflict with the CPUE data. However, in both the FIS1 and FIS2 series, excluding recent CPUE data results in lower estimates of recent spawning biomass.

As with western Pink Ling, the fits to CPUE for eastern Pink Ling are remarkably good. Likewise, the CVs on the FIS abundance indices are lower for Pink Ling than for other species, which suggests that the FIS abundance index may be more useful for this species. Despite these low CV values, there is a clear change in the FIS abundance series from FIS1 to FIS2 for eastern Pink Ling. This suggests that there may have been considerable changes to this fishery after the structural adjustment, so conditioning the FIS abundance index on data after 2006 may be more important for Pink Ling than for the other species considered here. As with western Pink Ling, there can be large changes in the FIS abundance series through reconditioning with eastern Pink Ling, even when the CVs are low. In contrast to western Pink Ling, these changes only flow through to the assessment outcomes when the recent CPUE data is excluded.

Appendix I. List of researchers

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