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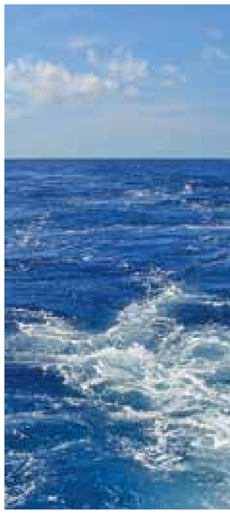
PART 2



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Cover photographs

Front cover, blue grenadier, ocean perch, flathead and orange roughy.

Report structure

Part 1 of this report describes the Tier 1 assessments of 2012. Part 2 describes the Tier 3 and Tier 4 assessments, catch rate standardisations and other general work contributing to the assessment and management of SESSF stocks in 2012.

Stock Assessment for the Southern and Eastern Scalefish and Shark Fishery: 2012

Part 2: Tier 3 and Tier 4, catch rate standardisations and other work contributing to the assessment and management of SESSF stocks in 2012

G.N. Tuck
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Australian Fisheries Management Authority

Stock Assessment for the Southern and Eastern Scalefish and Shark Fishery: 2012 Part 2

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12. Maintaining risk equivalency among fishery harvest control rules in the SESSF

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12.1 Summary

This chapter presents results from using management strategy evaluation (MSE) to test alternative ways of implementing precaution among the tier system of harvest control rules (HCRs) in the Southern and Eastern Scalefish and Shark fishery (SESSF). The work considers the relative performance of two data-poor harvest control rules (Tier 3, Tier 4) when compared to that obtained under Tier 1 (the most data-rich case).

We tested a range of discount factors and compared the risk of failing to achieve the fishery objectives under different management strategies, with that from the Tier 1 HCR. The *perceived risk* to the stock was defined as:

- the probability of estimating the stock to be below the limit reference point more than 10% of the time during the MSE simulations.

The discount factors were compared to three other approaches to achieving risk equivalency that relied on catch rate stability, reference point adjustment, and observation error. Three species were considered, tiger flathead, school whiting, and jackass morwong. Simulations made use of available information from recent stock assessments for these data-rich species.

Scenarios that only applied discount factors when catch rates were deemed to be stable (at least in the manner defined in these analyses) were found to be inadequate for implementing precaution. In these scenarios, larger discount factors were required to obtain risk equivalency.
As the outcomes were variable across the species, the harvest strategies, and the methods used to implement precaution, it is not possible to provide a simple conclusion that a single optimum method exists for balancing risk against uncertainty for each Tier level of assessment. Further work could include analyses utilizing different initial stock status, and alternative levels of observation error, to help explain the impact of these factors.

A critical assumption underlying the Tier 4 HCR is a linear relationship between CPUE and biomass. The analyses did not account for the effect of possible nonlinearity in this relationship. It can be expected that, if the true relationship is non-linear, then further precaution would be required in order to maintain the same perceived risk to the stock.

The analyses considered risk equivalency in terms of the perceived risk to the stock (as determined by the applied stock assessment method), as opposed to the actual risk to the stock (as determined by the underlying MSE operating model). In practice the perceived risk is what would be observed and used to judge the ability to meet management objectives. Risk could also be defined in terms of the probability and magnitude of the methods giving very low (and/or variable) catch quota advice.

While the analyses focused on risk equivalency with Tier 1, it may be more relevant to judge performance against a metric that quantifies an acceptable level of not meeting the harvest strategy objectives; such as staying above the limit reference point more than 10% of the time with a probability of 0.9. Exactly how to implement such metrics, along with the time periods over which to calculate them, still needs to be prescribed.

12.2 Introduction

Marine fisheries are increasingly being managed using formal harvest strategies that include specification of harvest control rules (HCRs). Management agencies are also recognizing the need to incorporate estimates of uncertainty into the decision-making process, with the precautionary approach to management calling for more conservative action as the uncertainty regarding estimates of resource state increases (e.g. Caddy and McGarvey 1996). Specification of management action through the use of HCRs in data-poor situations can respond to this uncertainty by explicitly adjusting the output (e.g. recommended catch) as a function of uncertainty. Many fisheries management agencies have chosen to adopt precautionary targets within harvest control rule specifications (e.g. Deroba and Bence 2008, Froese et al. 2011). These methods assume that the selection and estimation of the appropriate reference points are sufficiently robust to uncertainty, and advice is not based on the amount of information available. In many cases these reference points will not all be equally estimable. Uncertainty associated with estimation and implementation error can impact the performance of such harvest control rules (Deroba and Bence 2008).

Methods for incorporating uncertainty into the management advice arising from HCRs have varied. The Revised Management Procedure of the International Whaling Commission directly penalizes catch limits based on data availability and also sets catch limits based on a percentile of a posterior distribution less than the mean estimate (e.g. Punt and Donovan 2007). Similarly the Potential Biological Removals (PBR) method, applied to set catch limits for U.S. marine mammal populations, uses an abundance estimate based on a percentile of the current estimate of abundance (Wade 1998). Control rules for toothfish stocks in the Antarctic adopted by the Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR) are based on model projections that include both process and observation error (Constable et al. 2000). In South Africa, the management procedure for anchovy includes a scale-down factor whereby the Total Allowable Catch (TAC) is reduced prior to information on recruitment strength becoming available (de Moor et al. 2011). In the U.S., buffers to account for scientific uncertainty are applied to overfishing level estimates to calculate allowable catch limits for managed fished species (e.g. Punt et al 2012). A similar approach has been adopted in the Southern and Eastern Scalefish and Shark fishery (SESSF) in Australia, where a discount factor is applied to the TAC for quota species that are assessed and managed under data-poor HCRs (Smith et al. 2008, Smith et al. 2009).

The SESSF has operated in some form off Southeast Australia since the early 1900s, and is the leading source of fresh fish for Sydney and Melbourne. The fishery employs a diverse range of gears exploiting over one hundred species. The primary management tool within the SESSF for the major commercial species is an annual TAC implemented under an Individual Transferable Quota (ITQ) system. Additional management measures include gear restrictions and area closures, the latter of which are used mainly for conserving protected or at risk species (Smith and Wayte 2002, Smith et al. 2008). The TAC for each species is based on the calculation of a Recommended Biological Catch (RBC). RBCs are determined using a tier framework of HCRs, with the choice of tier rule for each species determined by the information available (Table 12.1). The Tier 1 HCR is used with the most information rich species, and the HCR relies on current estimates of biomass and fishing mortality rate. The data-poor Tier 3 and Tier 4 analyses rely on either equilibrium-based estimates of fishing mortality (Tier 3), or an empirical rule based on the current catch-per-unit-effort (cpue) relative to a selected reference level (Tier 4).

As the results of data-poor (Tier 3 and Tier 4) analyses are expected to be more uncertain than those from the data-rich Tier 1 (because the estimates of stock status are based on less information), this uncertainty is factored into the TAC calculation by application of a discount factor (currently 5% for Tier 3 and 15% for Tier 4 species), which reduces the RBC from the Tier 3 and 4 analyses (Smith et al. 2008, Smith et al 2009). Such a measure is important as the target and limit reference points used in the Tier 3 and Tier 4 HCRs are equivalent (at least in intent) to those used for Tier 1 stocks, and do not in themselves prescribe additional precaution.

In theory, if uncertainty associated with the data-poor HCRs is to be buffered, then management action should operate such that the risk (to the stock or fishery) of managing under the data-poor control rules should be at least the same as the data-rich case. That is, discount factors should operate so that they maintain risk equivalency among HCRs (Figure 12.1). Currently, perceived risk is defined as the estimated probability of failing to meet the objective that the stock should not fall below 20% of unfished spawning biomass more than 10% of the time (DAFF 2007).

While the method of discounting catch recommendations from less certain assessments in the SESSF is both transparent and consistent with a precautionary approach, there has been considerable discussion over the conditions under which these discount factors should be applied. Arguments for not applying the discount factors have included alternative management actions (e.g. the presence of closed areas), or the stability of indicators such as time series of catches and catch rates. The use of a discount factor is not the only possible method of implementing precaution among Tier levels, and it is not clear whether the current method actually achieves its intent of equalizing relative risk among Tier levels. Alternative methods could include the use of different reference points (e.g. alternative targets and limits), incorporating estimation uncertainty into the estimate of stock status used to calculate the RBC (as per the PBR method of Wade (1998)), and stability (or otherwise) in other stock indicators (the more unstable the indicator, the greater the reduction in the recommended catch). While the application of discount factors is designed to result in similar behaviour to these other approaches, it is not clear whether a) their application is appropriate, b) whether the current values applied are the 4‘best’ ones, and c) whether uniform application across species is desirable.

This paper uses Management Strategy Evaluation (MSE, c.f. Bunnefeld et al. 2011) to investigate the performance of both the discount factors and alternative methods of implementing precaution when applying the SESSF data-poor harvest strategies. The MSE approach enables incorporation of many of the uncertainties associated with management of fish stocks, including process error in the stock dynamics (annual recruitments), observation error (sampling variability), estimation error (from stock assessment models and HCR application), and implementation error (actual catches may differ from the recommended management action).

We first use MSE to compare the performance of the data-poor harvest strategies both with and without the currently applied discount factors. These comparisons are made for three quota species in the SESSF for which data rich (Tier 1) assessments are available. We then determine the discount factors required for the data-poor harvest strategies so that these strategies are perceived to be risk equivalent with the Tier 1 HCR. Finally, we identify and explore tradeoffs among risk, catch, and stock size for alternative approaches of including precaution when implementing the harvest strategies. The analyses focus on using the perceived performance of the Tier 1 HCR as a baseline for judging the relative performance of the data-poor control rules, with respect to HCR performance against the risk-based objective of Australia’s harvest strategy policy.

12.3 Methods

12.3.1 Simulation framework

The general MSE framework is similar to that previously conducted for SESSF species (e.g. Fay et al. 2011, Little et al. 2011, Wayte and Klaer 2010). An operating model, representing the true state of the system, is conditioned using the most recent stock assessment for each species, with uncertainty in true stock status characterised by the uncertainty in parameter estimates obtained using Bayesian methods (e.g. Fay and Tuck 2011). A set of scenarios are run for three species, with each scenario being characterised by the combination of a particular HCR (Tiers 1, 3, or 4), and for Tiers 3 and 4, a method for implementing precaution in the harvest strategy. The operating model is projected forward under the application of a specified harvest strategy for thirty years, with data generated annually from the operating model representing the quantity and quality of data currently available, estimation using the appropriate stock assessment method for the HCR, application of the HCR, and updating of the TAC. This TAC is then converted to an actual catch that is used to update the dynamics of the operating model. A set of summary statistics are calculated after the thirty year projection period.
Table 12.1 describes the specifications for the three harvest strategies.

12.3.2 Species

The analyses were applied to three SESSF target species, using information from recent stock assessments: tiger flathead (Klaer 2010), school whiting (Day 2009), and jackass morwong (Wayte 2010). These species have biological characteristics representative of species typically caught in the SESSF on the continental shelf. Maximum age varies among the species (school whiting: 9, tiger flathead: 20, jackass morwong: 25). The fishable school whiting population size is mostly determined by annual recruitment strength. The current assessment for jackass morwong indicates that the spawning stock biomass is close to the limit reference point and that the stock is depleted. Tiger flathead is currently assessed to be near the biomass target that is a proxy for the level needed to achieve maximum economic yield.

12.3.3 Harvest strategies

12.3.3.1 Tier 1

Tier 1 (T1) stock assessments are conducted annually using Stock Synthesis (SS; e.g. Methot 2007), according to the specifications for the base-case model of the most recent stock assessment (Table 12.2 and Table 12.3). Data available for the Tier 1 stock assessments within the MSE are: the historical data on catches, generated catch rates, and for some years the age structure and length structure of the catch. In addition, data are generated by the operating model according to the effective sample sizes of the contemporary data, as calculated in the published stock assessment reports (Table 12.2).

RBC calculation under T1 is obtained from the SS output using a F-based harvest control rule (
Table 12.1) with a target fishing mortality rate equivalent to that which on average would achieve a spawning biomass of 0.48 B_0 using the current year's fishing pattern by fleet.

12.3.3.2 Tier 3

The Tier 3 (T3) harvest strategy uses recent age composition data to obtain an estimate of the current rate of fishing mortality (Wayte and Klaer 2010). Target and limit reference points are the values for the fishing mortality rate that result in the equilibrium stock depletion (ESD) values given in Table 12.1 (Cordue 2012). ESD is akin to the spawning potential ratio (SPR) except that the stock-recruitment relationship is taken into account.

12.3.3.3 Tier 4

The Tier 4 (T4) harvest strategy compares an estimate of current catch per unit effort (cpue) to that during a pre-specified reference period and adjusts a target catch from this reference period accordingly (Little et al. 2011). To account for uncertainty in the calculation of reference points when implementing T4, the reference catch (C*) and reference cpue ($CPUE_{ref}$) for each simulation are randomly determined from the historical data during the default reference period (1986-1995, Table 12.3). T4 can then be biased with respect to the T1 target biomass of 0.48 B_0, and it is possible that C* and $CPUE_{ref}$ may not be in equilibrium with each other, as is assumed to be the case when applying T4 (Smith et al. 2008; Little et al. 2011). Data available to T4 are the historical cpue data, and data generated from the operating model according to the observation error ascribed to the cpue data in the most recent Tier 1 stock assessment (Table 12.2). RBC calculation is achieved by comparing the recent average cpue in the simulation to the selected value for the reference period, as described in Haddon (2011).

12.3.4 TAC calculation

The TAC is calculated by subtracting estimates of the discards (Table 12.2) from the RBC, and applying the discount factor (depending on the scenario). The TAC is also constrained so as not to change by more than 50% from one year to the next. Implementation error, such that the catch taken in the next year from the operating model may not be equal to the TAC, is applied using estimates of the relationship between TAC and catch obtained from data on SESSF species (L. Richard Little, unpublished data).

12.3.5 Application of discount factor

Discount factors were applied to the TAC by reducing the prescribed TAC by a fixed percentage in each year that the harvest strategies were applied. Values currently applied in the SESSF are 5% for T3, and 15% for T4. In addition, simulations also considered discount factor values ranging from 0 (i.e. no discount factor) to 50%.

The resulting estimates of catch were then input into the operating model based on the current proportional allocation by fishing fleet (averaged over the final 5 years of the stock assessment; Table 12.4).

12.3.6 Scenarios for implementing precaution

Four scenarios for implementing precaution were tested:

1. **Discount factor**. TACs were reduced by a fixed percentage (Section 3.5).
2. **CPUE stability**. This scenario included a discount factor, but also includes a rule where the discount factor was not applied if catch rates have historically been stable. The discount factor (risk premium) is not applied in a given year if the CV of the cpue data over a time period is less than 20%. The time period examined was set at the estimated mean generation time for the species (Table 12.3), the values for which were obtained using the base-case life history parameters in the most recent stock assessment.
3. **Conservative target**. The target reference point was adjusted. No discount factor applied. For T3, the target fishing mortality was adjusted to different values of ESD (e.g. F_{60} rather than F_{48}). For T4, the target cpue was increased by a fixed percentage (ranges from 101% to 150%).
4. **Estimation error.** A more conservative value for the stock indicator was used in the HCR when calculating the RBC, based on the estimation error of the stock indicator. No discount factor was applied. A fixed percentage of the cumulative error distribution of the stock indicator was used, with this ordinarily being 50% such that values less than 50% are more conservative (e.g. Figure 12.2). For T3, the error associated with the estimate of the current rate of fishing mortality is calculated using asymptotic methods by the estimation procedure (e.g. Wayte and Klaer 2010, Fay et al. 2011). For T4, the error distribution is obtained by calculating the standard error of the mean current cpue (Figure 12.2).

12.3.7 Performance measures

Performance was primarily assessed by using the simulation results to calculate the perceived risk to the stock. Risk was defined according to the harvest strategy policy as:

- the probability of the stock declining below the estimated limit biomass reference point more than 10% of the time (in this case estimated over the thirty year projection period).

Note that the performance metric is the perceived probability of going below the limit based on the results of stock assessments, not the true probability according to the dynamics of the operating model.

A set of additional performance measures were calculated, which included the mean and variability of estimated and true final stock biomass, the magnitudes of TAC and catch obtained under the harvest strategy, and the true value for the risk to the stock. The true risk was calculated in the same way as the perceived risk, except that the actual stock status from the operating model was used rather than the estimated stock status.

12.4 Results

12.4.1 Tier 3 and Tier 4 performance with current discount factors

Differences in the MSE performance when the current discount factors (5% T3 and 15% T4) were applied compared to when these factors were not applied were primarily associated with the risk to the stock. There was no apparent difference in summaries of the distribution of relative spawning biomass (perceived or true) under T3 when the 5% discount factor was applied (Figure 12.3). TAC variability was however constrained with the 5% discount factor compared to no discount factor, particularly with tiger flathead (Figure 12.3, 3f, 3i). Under T4, both perceived and true relative spawning biomasses were higher with the 15% discount factor than when no discount factor was applied (Figure 12.4, Figure 12.5). For tiger flathead under T4, the average TAC in the first seven years of harvest strategy application was lower with the 15% discount, but this difference in the average TAC was minimal towards the end of the projected period (Figure 12.4c). True risk for tiger flathead was slightly higher than perceived risk under T4, but lower than that estimated under T3 (Table 12.5).

12.4.2 Tiger flathead

The perceived risk that the management objective would not be met (i.e. the probability that the stock would go below the limit reference point more than 10% of the time) under T1 was very low (<1%, Table 12.5). Perceived risks under T3 and T4 were high and did not approach the T1 value even with very high discount factors (Figure 12.5).

For the conservative target scenario, the T4 CPUE target needed to be just 2% larger to meet the same risk as implementing a 15% discount factor (Table 12.6). When accounting for uncertainty in the estimate of the T4 multiplier on catch, the value associated with the 42nd percentile of the error distribution around the multiplier gave the same level of risk as a 15% discount factor (Figure 12.5; Table 12.6)

When stability in catch rates was used to determine whether or not to apply a discount factor to T4 results, a discount factor of only 6% was needed to match the perceived risk obtained when using a 15% discount factor every year (Table 12.6). However, the perceived risk using just a discount factor of 6% was the same as that for a 15% discount factor (Figure 12.6), meaning that the catch rate stability scenario was not actually precautionary. Average TACs were 2,798t in the stable catch rate scenario, compared to 2,768t when the 15% discount factor was applied every year.

T3 had higher perceived (and true) risks to the stock than T4 for flathead (Table 12.6, Figure 12.5). In general, similar performance (in terms of perceived risk) could be achieved either by use of the current 5% discount factor, or using a slightly more conservative target (F_{51} vs F_{48}, Table 12.6). Under the assessment uncertainty scenario, the average TAC was lower for the percentile of estimate consistent with the same perceived risk than when applying the 5% discount factor (Table 12.6).

Figure 12.5 shows that the perceived risk under T3 was much more sensitive to the different scenarios than that under T4. The catch rate stability scenario was not conservative, as the same (or higher) discount factors were required in this scenario to achieve the same perceived risk as when just using a discount factor every year (Figure 12.5a), the catch rate stability line has the same or increased risk for a given % discount factor. If CPUE stability was more conservative than using the discount factor alone, then the risk should be lower for this scenario for the same % discount factor).

12.4.3 School whiting

Under T1, the perceived risk was zero (Figure 12.6). This was also the case for T3 and T4 without any need for a discount factor (results not shown). Implementation error on average tends to set catches lower than the prescribed TAC, except when the stock is at low levels relative to the target (L. Richard Little, unpublished data). The current (2009) stock status for school whiting is estimated to be above the biomass target, and so the final biomass tends to be above the target. This is exacerbated under T4 by the default reference period (Table 12.3) in fact representing a stock above the 0.48 B_0 target (Little et al. 2011).

The simulations were also conducted with no implementation error (i.e. the annual retained catch was equal to the TAC). With no implementation error, the perceived risk to the stock under T1 was still very low (although non-zero, Table 12.5). However, perceived risks under T3 and T4 were below the T1 risk level without need for a discount factor (Table 12.5, Figure 12.6). Average TACs under T3 and T4 were substantially lower than those under T1 (Table 12.5).

The T3 HCR appears to under-estimate stock status, with the estimated final depletion being around the target (Figure 12.3, Table 12.4), but with the true value for depletion being close to 70% unfished biomass (Table 12.5). Consequently, the mean average TACs associated with the T3 scenarios were low (Table 12.5). This is unsurprising, as the T3 HCR is not thought to be appropriate to school whiting because of its potential to have a rapidly changing age structure and with few age classes being fully selected by the fishery (Smith et al. 2008, Wayte and Klaer 2010).

12.4.4 Jackass morwong

In contrast to tiger flathead, T4 had higher perceived risk than T3 for jackass morwong (Table 12.5, Figure 12.7). The current T1 assessment for jackass morwong estimates relative spawning biomass to be close to the limit biomass reference point (e.g. Figure

12.3). However, the recent fishing mortality rate for morwong has been low (Wayte 2010). Consequently, T3 over-estimates stock status (in terms of ESD, Figure 12.3). The SESSF 50% change rule (whereby the TAC cannot change by more than 50% from year to year) constrains increases in the TAC, and so the perceived risk does not increase as to increase risk (results of simulations that did not include this constraint showed higher levels of risk, results not shown).

It was not possible to obtain risk equivalency of T4 with T1 over the entire projection period, even with very large discounts (Figure 12.7). This is because there is a high probability that T4 estimates CPUE to be below the limit (given the reference period CPUE in Table 12.3) at the start of the projection period, particularly given the uncertainty in the target catch rate during the default reference period. This can be partially attributed to the high CV of CPUE during the default reference period (used to determine possible values for the target CPUE), which can result in high (possibly unattainable given the reference period catches) target CPUE values. Despite this, the true risk to the stock associated with a 15% discount factor under T4 is less than that under T1 (Table 12.5), even though the perceived risk under T4 with the 15% discount is 0.18 (Table 12.5). The Catch rate stability scenario required a 25% discount factor to obtain risk equivalency with the Discount factor scenario with the discount factor of 15% applied every year (Table 12.7, Figure 12.7). The T4 reference catch rate only needed to be increased by 5% to match the risk with a 15% discount under the conservative target scenario (Table 12.7), whereas the assessment uncertainty scenario needed to be very conservative for risk equivalency, with the 16th percentile of the T4 result needed (Table 12.7).

12.5 Discussion

Implementing precaution in fisheries management advice based on uncertain estimates of resource status is clearly warranted. This is perhaps even more important when stocks are assessed using data-poor methods, because these methods frequently make assumptions that can result in biased estimates of stock status, in addition to providing uncertain estimates. Additional uncertainties associated with both the management process, and the methods used to determine the scientific advice, will tend to increase the need for further precautionary advice (Ralston et al. 2011).

The analyses detailed in this paper clearly demonstrate that application of a discount factor can work to buffer additional perceived risk associated with managing under data-poor harvest strategies (T3 and T4) in the SESSF relative to the data-rich harvest strategy (T1). However, for some of the data-rich cases presented here, these discounts were not necessary as perceived risks were already low. The analyses also demonstrated that the values for the discount factor that resulted (where possible) in the same risk equivalency as estimated under T1 varied by species. Furthermore, these values were different from those currently applied in the SESSF. That these values are not identical among stocks is unsurprising as the uncertainty associated with the stock status estimates differs among particular assessments, and the degree of observation error differs among species (Table 12.2). This suggests that not all stocks should be managed with the same level of discount factor to achieve the same outcome. However, choosing appropriate unique values for each stock is problematic. In principle, these values could be based on knowledge of the level of observation error and life history, given that the role of these factors in determining risk can be more formally assessed.

The T3 harvest strategy was shown to have higher perceived risk than T4 for tiger flathead, but the reverse was true for jackass morwong. The precision of T3 estimates of stock status through the MSE projections for jackass morwong compared to flathead (Figure 12.3) was due to the fact that the annual sample sizes for the age data were 200 for morwong compared to 100 for flathead (Table 12.2), and that more years are included in the reference catch calculations for morwong than for flathead, resulting in TACs that respond more slowly to changes in current fishing mortality rate. Conversely, the CPUE data used in T4 were more precise for flathead than for morwong (Table 12.2). Conducting the simulations with different levels of observation error (sample size) would enable exploration of the effects of such factors. Data-limited species would likely have lower sample sizes.

Critical assumptions for T4 include that the reference catch and target CPUE be chosen appropriately, and that a linear relationship exists between CPUE and biomass. We attempted to capture uncertainty in the choice of reference values for T4 by sampling from the distribution of the historical data during the ‘default’ reference period (Table 12.3). This increased uncertainty did not however translate into higher risk, either because the historical data were not variable (tiger flathead) or the combination of reference catch and CPUE were associated with spawning biomass above target levels (school whiting). No accounting was made in the analyses for possible failure in the assumption of linearity in the relationship between CPUE and biomass. It can be expected that, if the true relationship is non-linear and T4 is applied assuming linearity, then additional precaution would be required to maintain the same perceived risk to the stock. Including a non-linear relationship between CPUE and biomass is recommended as an important next step for this work. This will require incorporating estimates of non-linearity into the operating model, and recalculating the T1 scenario, as this will also be sensitive to this assumption. In theory, T1 should be more robust to this assumption as the associated stock assessments also include additional data streams (e.g. length and age composition, Table 12.1) that T4 does not.

Alternative methods of implementing precaution were capable of producing similar results as applying the discount factor, with performance measures for biomass and catch approximating those for the discount factor scenario following risk equalization. Using stability in catch rates (at least in the manner defined in these analyses) as rationale for not applying a discount factor does not seem to be an adequate approach for implementing precaution. Either larger or the same level of discount factors were required in concert with this approach to obtain the same perceived risk as when applying discount factors every year (e.g. Figure 12.5a). The conservative target and assessment uncertainty scenarios both were able to match risks with the discount factor scenario. However, as with the values for the discount factor, the values for the adjustments needed for these scenarios varied by species.

The time period used to evaluate the performance of the harvest strategy can be important; stocks that are initially at lower stock levels will tend to have higher probabilities of going below the limit biomass purely due to variability in stock dynamics. Indeed, the perceived risk obtained under T4 for jackass morwong was largely due to the stock initially being at low levels relative to the (variable) target. Perceived risk would be reduced if the initial years were not included in the risk calculation.

The analyses considered risk equivalency in terms of the perceived risk to the stock, as this is based on what is observed from the resource, and is closest to that used to determine if management objectives are met. Alternatively, the scenarios could be tuned to the true risk to the stock from the operating model. The results in Table 12.5-Table 12.7 suggest that the true risk in the operating model was generally lower than the perceived risk, across species and harvest strategies, although this was not the case for T3 for jackass morwong and T4 for tiger flathead. Risk was defined in terms of the probability of the estimate of the stock not meeting the limit biomass-related objective of Australia's harvest strategy policy. It is important to note that this is not the only risk associated with managing a fishery. Risk may also need to be managed with respect to catch (e.g. Sethi 2010), such as the probability that TACs will be low, and/or undesirableexcessive variability in the prescribed catch levels. For example, Figure 12.3c and Figure 12.4c show that low TACs were prescribed frequently during the projections for tiger flathead. Managing for risk associated with a quantity other than the limit biomass objective will result in different values for the discount factors (or chosen precautionary method). Figure 8 shows the values of the discount factor for tiger flathead required for the different scenarios to obtain the same (or lower) mean average TAC as under T1. T4 would require either a discount factor of 12% (23% under the catch rate stability scenario), an increase in the target of 7%, or using the 20th percentile of the assessment uncertainty distribution (Figure 12.8) lower panels). The results can also be viewed in terms of the estimates for relative spawning biomass at the end of the projection period, namely, what discount factor is required to result in the same average stock status (Figure 12.9). In both cases (for tiger flathead), the discount factor required in the catch rate stability scenario results in greater risks to achieving the particular management objective than solely applying a discount factor.

Management agencies may augment HCRs with additional 'meta-rules' that serve to constrain catches to reduce the variability of advice (e.g. catch quota), or otherwise incorporate additional information. One such rule in the SESSF specifies that the TAC for a species cannot change by more than 50% from one year to the next. Including this '50% change rule' in the analyses led to changes in the performance of the harvest strategies (particularly for T3). This rule (included in the analyses presented in this paper) resulted in reduced perceived risk for T3, a result that is compatible with findings of Wayte and Klaer (2010) with regard to the performance of this harvest strategy. Other meta-rules in place in the SESSF such as a CPUE multiplier rule and a minimum required TAC change of greater than 10% were not included.

Implementation of discount factors for SESSF species/stocks managed under T3 and T4 has been controversial. Arguments for not using discount factors have included stability in catch rates and the presence of closed areas. The analyses in this paper demonstrate that catch rate stability cannot be expected to increase precaution, even when there is a linear relationship between CPUE and abundance. The presence of closed areas being used as an uncertainty buffer was not addressed in this paper. Arguments for using the presence of areas closed to fishing rely on the closed area being 'on the table' as part of the fishable stock, and when assessment methods do not account for these closures when calculating indicators of stock status (for example, when using solely fishery dependent data that by necessity, is from areas open to fishing). The presence of closed areas has the potential to complicate stock assessment and the reliability of stock status indicators, and the effect on management outcomes is not necessarily straightforward (e.g. Field et al. 2006).

This chapter shows that it is possible to achieve the same end (i.e. same perceived risk to the stock) with multiple methods for accounting for uncertainty when determining TACs. However, using a conservative target, or specifying a percentile of the estimation error may be more attractive to stakeholders as accounting for uncertainty is then part of the RBC calculation, removing the potential for obtaining a high (or low) result from the HCR, only to then further take something away (via the discount factor). Using the uncertainty of the estimate is intuitive as it implies that the impact of the uncertainty on management advice can be lessened through more intensive monitoring. However this method only considers the error associated with the estimation of the stock indicator given the method used, and does not easily accommodate the uncertainty associated with assumptions related to the chosen assessment method or harvest strategy. Ralston et al. (2011) show that often only a fraction of the uncertainty can be attributed to the error quantified within stock assessments. This was clearly shown for T4, in which the harvest strategy is fairly precise, although with potential for large bias and subsequent deviation from desired target stock state if the values chosen for the reference period are incorrect / poorly chosen. However the need to accommodate for ‘known unknowns’ also applies to the scope of our analyses, which limited the quantification of operating model uncertainty to the parametric uncertainty associated with the current base-case stock assessment for each species. In this respect, simple methods (such as the discount factor or conservative target) that are able to account for additional uncertainty, may in fact be more easily implemented.

We focused on obtaining risk equivalency with T1, the data-rich harvest strategy. However, a perhaps more relevant assessment would be to determine the values in the different scenarios needed that meet the harvest strategy objectives. Unfortunately, the harvest policy does not prescribe the acceptable tolerance level for the risk objective. That is, there is no definition for an acceptable level of failing to meet the limit-based objective. Explicit management for risk must be based with respect to some level that is deemed appropriate. In the US, policy dictates that the risk of exceeding the overfishing level (catch that results in a rate of fishing mortality greater than prescribed under a HCR) must not exceed 0.5. However, individual regional management councils have had to determine how best to implement this when setting catch limits (e.g. Punt et al. 2012). Indeed, although T1 is the most information-rich case, it must also carry some risk. Our analyses provide a means for comparing risk among harvest strategies, and can be used to identify tradeoffs related to biomass and catch-based fishery objectives given a specific level of risk. When determining an acceptable level of risk, both the magnitude of risk, and (for the current limit reference point objective) the time period over which to calculate the risk (i.e. over how many years, and which years) need to be defined in order to properly apply the results of analyses such as those described here.

12.6 Acknowledgements

The authors thank Sandy Morison and SESSFRAG members and observers for discussions and advice regarding the analyses.

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12.8 Tables

Table 12.1. Specifications for the harvest strategies, and data used in them.

Harvest strategy	Assessment method	Stock Indicator	Response Indicator	Target reference point	Limit reference point	Data input
Tier 1	Stock Synthesis (Methot 2007)	Spawning biomass relative to unfished.	Fishing mortality rate	48% unfished spawning biomass	20% unfished spawning biomass	CPUE time series Fishery dependent size and age composition Discard rates Biological parameters Stock-recruit relationship
Tier 3	Catch curve (Wayte and Klaer 2010)	Equilibrium fishing mortality rate	Fishing mortality rate	Fishing mortality rate resulting in 48% Equilibrium stock depletion	Fishing mortality rate resulting in 20% Equilibrium stock depletion	Fishery dependent size and age composition Discard rates Biological parameters Stock-recruit relationship
Tier 4	CPUE (Little et al. 2011)	Catch per unit effort	Total Catch	Mean cpue during reference period	40% reference cpue	CPUE time series Discard rates

Table 12.2. Observation error for the data generated from the operating model, and key parameters used in the harvest strategies.

Species	Assessment used to condition operating model	Harvest strategy	Assumed natural mortality rate	Assumed steepness	CPUE CV	Discard rate CV	Length composition sample size	Age composition sample size (for T1 this is age-at-length)
Tiger flathead	Klaer 2010	T1	0.27	0.62	0.21	0.27	100 (retained)	100
					0.17	0.75		
					0.37	0.75	50 (discard)	
		T3	0.27	0.62	0.17	0.27	NA	100
						0.75		
						0.75		
		T4	NA	NA	0.17	0.27	NA	NA
						0.75		
						0.75		
School whiting	Day 2009	T1	Estimated	0.75	0.26	0.25	100 (retained)	200
							100 (discard)	
		T3	0.6	0.75	0.26	0.25		200
		T4	NA	NA	0.26	0.25	NA	NA
Jackass morwong	Wayte 2010	T1	0.15	0.7	0.20	0.25	500 (retained)	200
					0.34			
							100 (discard)	
		T3	0.15	0.7	0.20	0.25	NA	200
		T4	NA	NA	0.20	0.25	NA	NA

Table 12.3. Specifications for the target reference period catches and CPUE for the Tier 4 HCR (T4). In each simulation, a reference catch and target CPUE are randomly drawn from normal distributions with the given mean and standard deviation (sd).

Species	Reference period		Reference catch		Reference CPUE		Mean generation time (yrs)
	Yr 1	Yr 2	Mean	sd	mean	sd	
Tiger flathead	1986	1995	2871	458	1.06	0.217	9
School whiting	1986	1995	1896	382	1.24	0.270	5
Jackass morwong	1986	1995	1377	365	1.52	0.406	12

Table 12.4 : Proportional allocation of catches to fleets during implementation of the harvest strategies.

Species	Fleet	Proportion annual catch
Tiger flathead	Danish seine	0.466
	Eastern trawl	0.478
	Tasmanian trawl	0.056
School whiting	Danish seine	0.324
	Trawl	0.676
Jackass morwong	Eastern trawl	0.761
	Danish seine	0.057
	Tasmanian trawl	0.182

Table 12.5. Performance measures for the three harvest strategies, and performance of T3 and T4 with the currently applied values for the discount factors.

Species	Harvest strategy	Discount factor	Perceived risk	True risk in operating model	Median estimated final depletion	CV estimated final depletion	Median true final depletion	CV true final depletion	Mean ave TAC	Mean CV of annual TACs
Tiger flathead	T1	0	0.005	0.01	0.55	0.15	0.54	0.21	2,825	0.13
	T3	0	0.504	0.34	0.50	0.74	0.45	0.63	2,207	1.01
	T3	5%	0.473	0.32	0.50	0.70	0.47	0.60	2,151	0.99
	T4	0	0.127	0.18	0.49	0.44	0.43	0.46	2,960	0.66
	T4	15%	0.124	0.15	0.53	0.44	0.46	0.45	2,774	0.64
School whiting	T1	0	0.003	0.00	0.47	0.29	0.44	0.29	1,940	0.37
	T3	0	0.001	0.00	0.47	0.28	0.67	0.26	1,145	0.41
	T3	5%	0.000	0.00	0.49	0.28	0.68	0.25	1,069	0.40
	T4	0	0.000	0.00	0.44	0.28	0.51	0.29	1,691	0.38
	T4	15%	0.000	0.00	0.46	0.27	0.54	0.28	1,552	0.37
Jackass morwong	T1	0	0.006	0.07	0.46	0.10	0.45	0.32	780	0.30
	T3	0	0.005	0.05	0.63	0.21	0.66	0.28	564	0.35
	T3	5%	0.002	0.05	0.65	0.20	0.67	0.28	532	0.34
	T4	0	0.191	0.09	0.42	0.28	0.42	0.33	964	0.55
	T4	15%	0.179	0.05	0.45	0.27	0.45	0.31	900	0.54

Table 12.6. Performance measures for optimized results for tiger flathead with implementation error. It was not possible to achieve risk equivalency with T1 (

Figure 12.5). Entries in 'Value needed for risk equivalency' are the values for the adjusting factors (e.g. discount factor, conservative target) needed to obtain the same risk as for T3 and T4 with current SESSF discount factors. Remaining columns show performance statistics associated with the optimized HCR parameters.

Harvest strategy / Scenario	Value needed for risk equivalency	Perceived risk	True risk in operating model	Median estimated final depletion	CV of estimated final depletion	Median true final depletion	CV of true final depletion	Mean Average TAC	Mean CV of TACs
T1	NA	0.005	0.013	0.55	0.15	0.54	0.21	2,825	0.13
T3									
Discount factor	5%	0.473	0.32	0.50	0.70	0.47	0.60	2,151	0.99
Catch rate stability	5%	0.464	0.33	0.49	0.77	0.45	0.64	2,192	1.00
Conservative target	F_{51}	0.471	0.32	0.50	0.73	0.45	0.62	2,176	1.00
Assessment uncertainty	0.54	0.448	0.31	0.51	0.72	0.48	0.61	2,095	0.97
T4									
Discount factor	15%	0.124	0.15	0.53	0.44	0.46	0.45	2,774	0.64
Catch rate stability	6%	0.124	0.17	0.50	0.44	0.43	0.46	2,927	0.66
Conservative target	+2%	0.124	0.17	0.50	0.44	0.43	0.46	2,917	0.64
Assessment uncertainty	0.42	0.124	0.17	0.50	0.44	0.43	0.46	2,929	0.68

Table 12.7. Performance measures for optimized results for jackass morwong.

Scenario	Value needed for risk equivalency	Perceived risk	True risk in operating model	Median estimated final depletion	CV of estimated final depletion	Median True final depletion	CV of True final depletion	Mean Average TAC	Mean CV of TACs
T1	NA	0.007	0.075	0.46	0.10	0.45	0.32	766	0.30
T3									
Discount factor	5%	0.002	0.05	0.65	0.20	0.67	0.28	532	0.34
Catch rate stability	7%	0.002	0.04	0.66	0.20	0.68	0.28	523	0.35
Conservative target	F_{52}	0.001	0.04	0.66	0.19	0.68	0.27	514	0.34
Assessment uncertainty	0.52	0.002	0.05	0.64	0.20	0.66	0.28	559	0.34
T4									
Discount factor	15%	0.179	0.05	0.45	0.27	0.45	0.31	900	0.54
Catch rate stability	25%	0.179	0.04	0.46	0.27	0.45	0.31	880	0.55
Conservative target	+5%	0.177	0.06	0.42	0.27	0.43	0.32	930	0.54
Assessment uncertainty	0.16	0.179	0.03	0.46	0.26	0.45	0.32	914	0.60

12.9 Figures

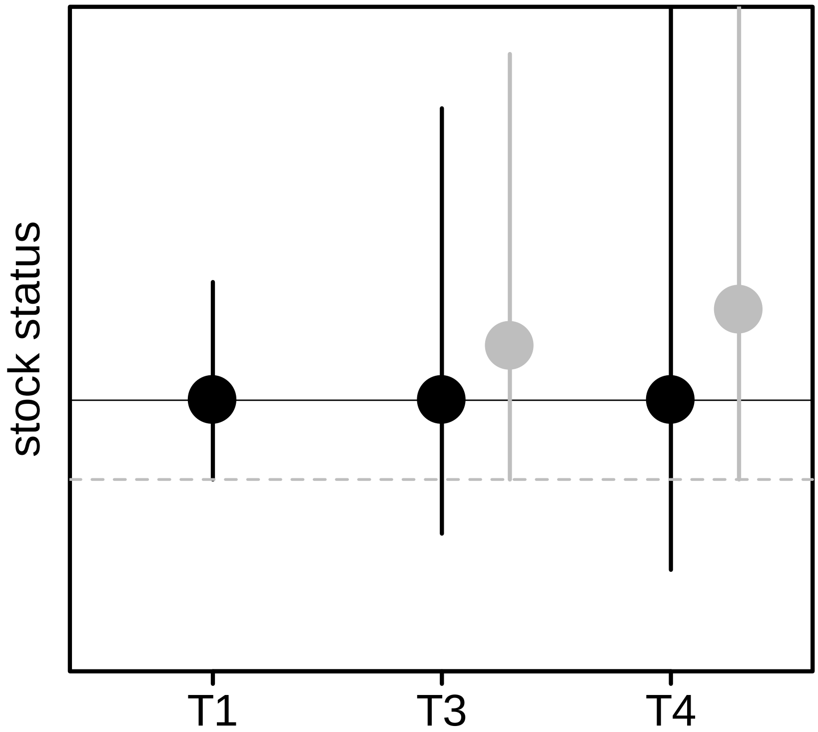

Figure 12.1. Example of risk equivalency among harvest control rules. All three control rules provide the same point estimate of stock status (black points), but with increasing level of uncertainty (vertical error bars). To obtain risk equivalency with T1, T3 and T4 must be conservative (gray points/bars) so that the probability of being below some level is the same as that for T1 (grey dashed horizontal line).

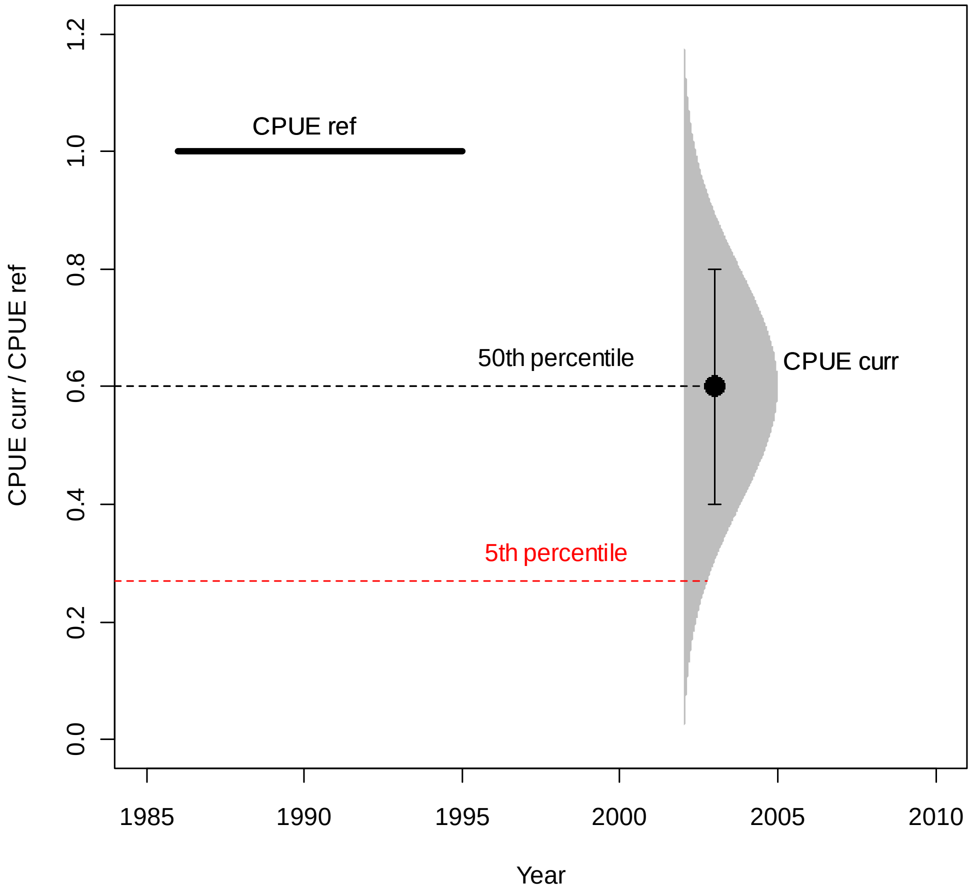

Figure 12.2. Assessment uncertainty scenario: example for Tier 4 HCR. Rather than use point estimate of current CPUE to determine status relative to reference CPUE, some percentile (here the 5^{th}) of the error distribution (based on CV of current mean CPUE) is used.

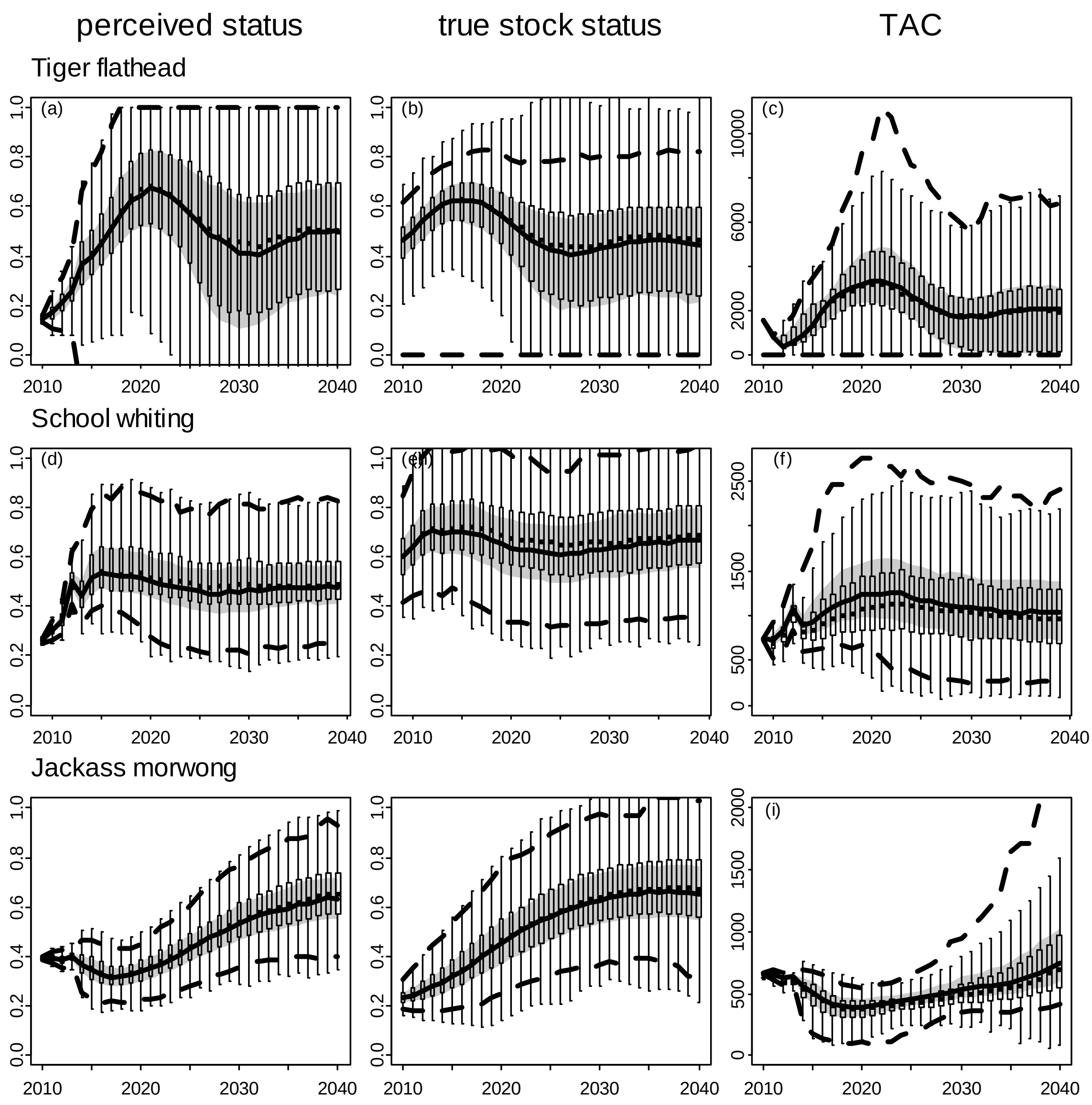

Figure 12.3. T3 summaries of perceived status (equilibrium stock depletion), true stock status (relative spawning biomass), and Total Allowable Catch (TAC, t) when no discount factor is applied (solid line [median], shading [inter-quartile range], dotted lines [central 95% interval]), and when a 5% discount factor is applied (boxplots).

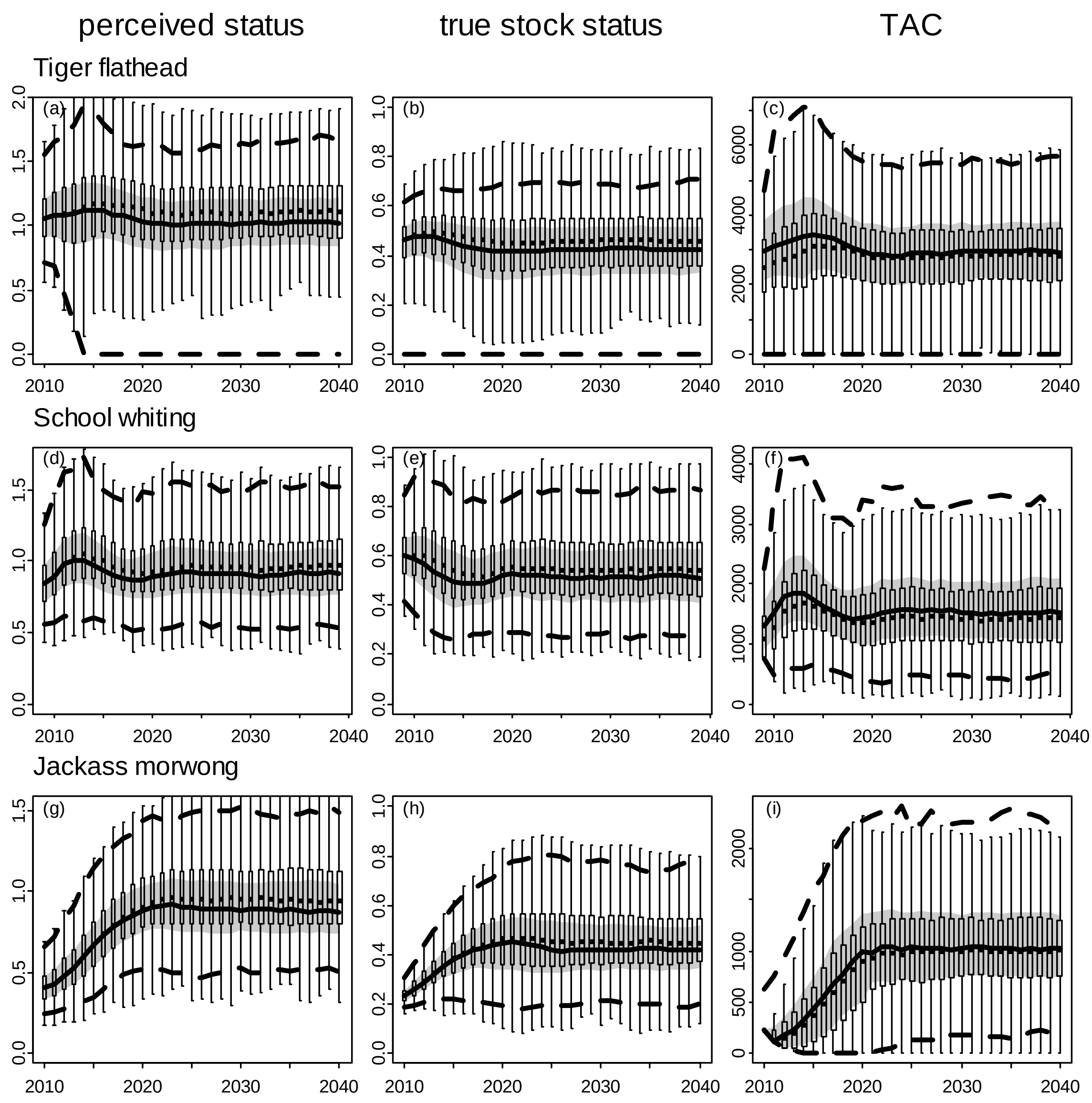

Figure 12.4. T4 summaries of perceived status (relative to cpue target), true stock status (relative spawning biomass), and Total Allowable Catch (TAC, t) when no discount factor is applied (solid line [median], shading [inter-quartile range], dotted lines [central 95% interval]), and when a 15% discount factor is applied (boxplots).

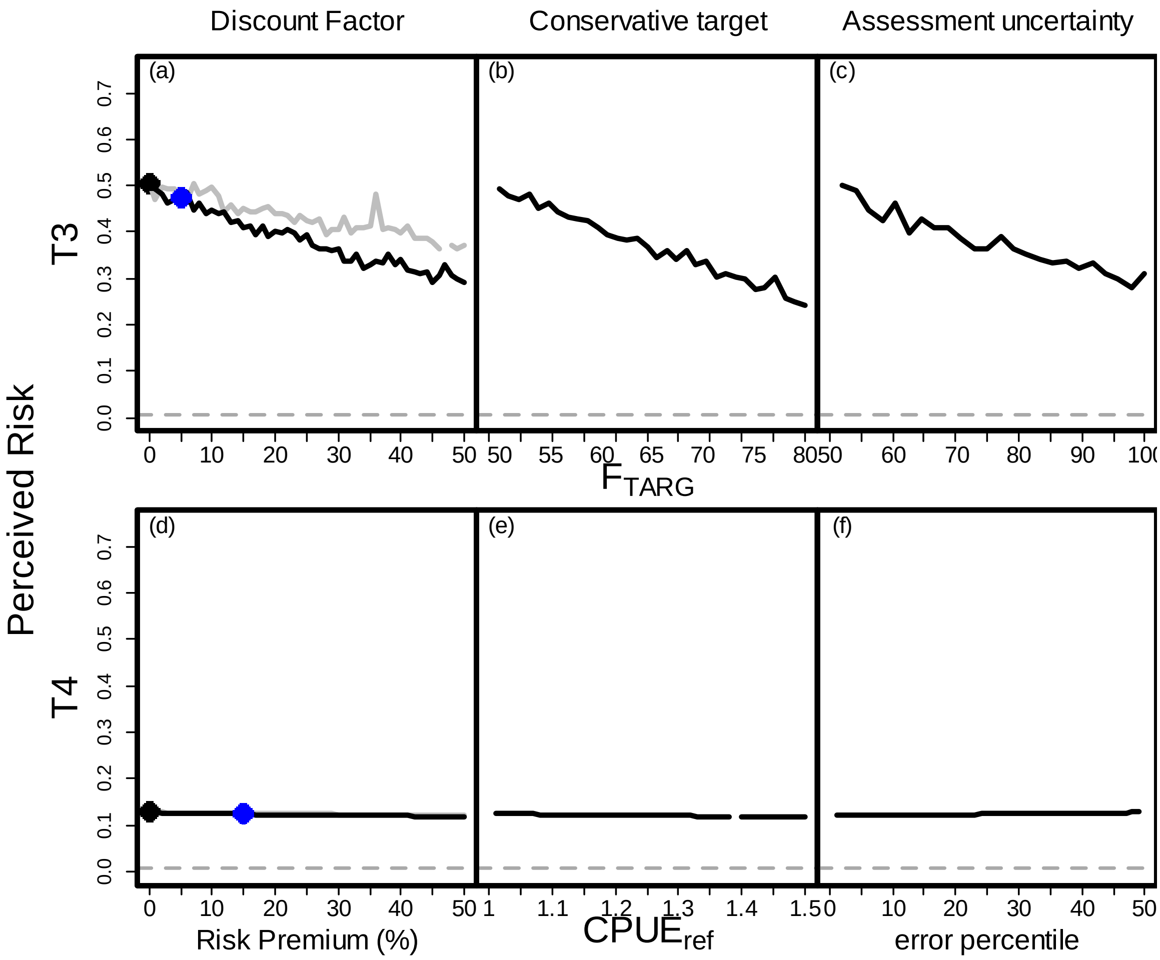

Figure 12.5. Perceived risk for tiger flathead for the four scenarios. Results of CPUE stability are shown in grey in panels (a) and (d). Dashed grey horizontal line represents perceived risk under T1. Black points indicate values for perceived risk given no discount factor. Blue points indicate perceived risk given currently applied values for the discount factor.

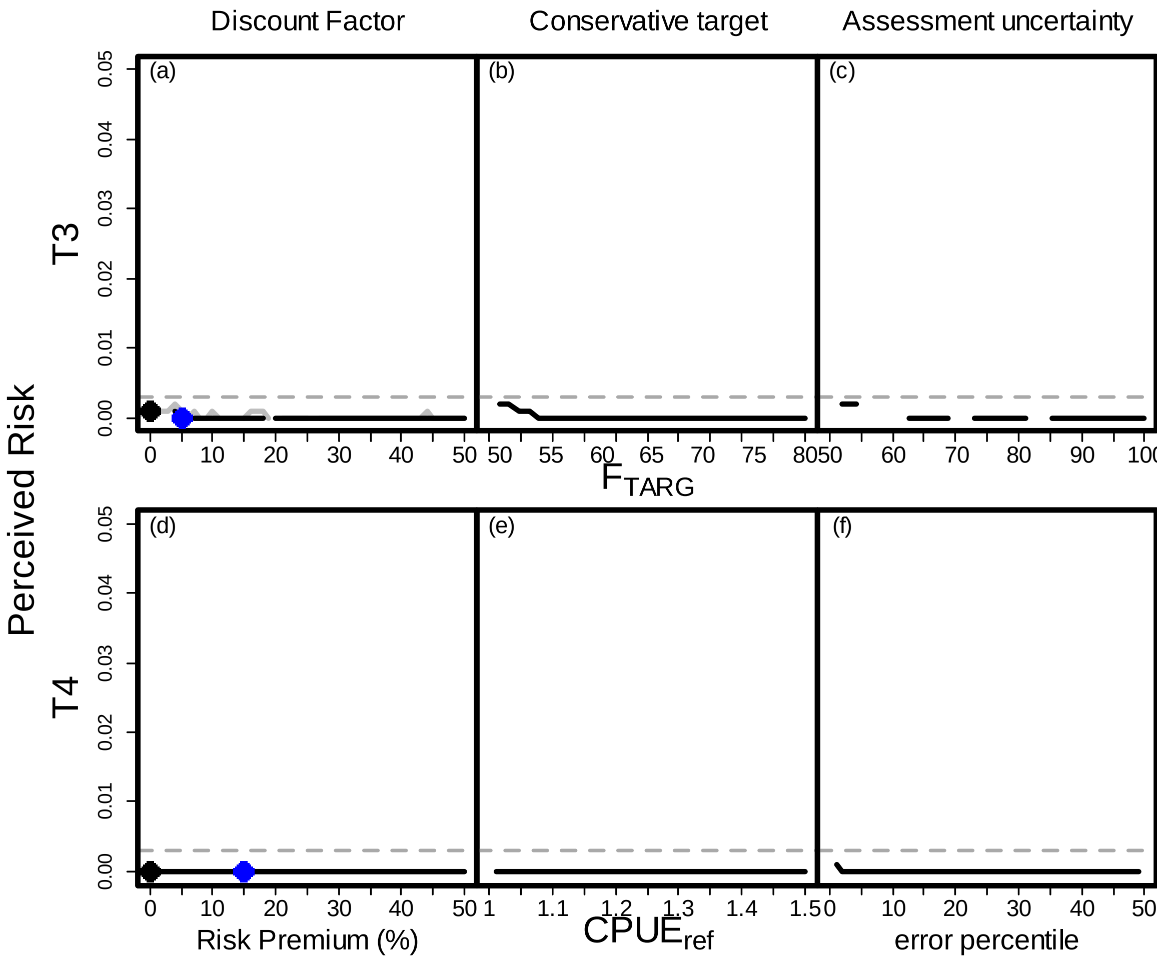

Figure 12.6. Perceived risk for school whiting for the four scenarios. Results of CPUE stability are shown in grey in panels (a) and (d). Dashed horizontal line represents perceived risk under T1. Black points indicate values for perceived risk given no discount factor. Blue points indicate perceived risk given currently applied values for the discount factor.

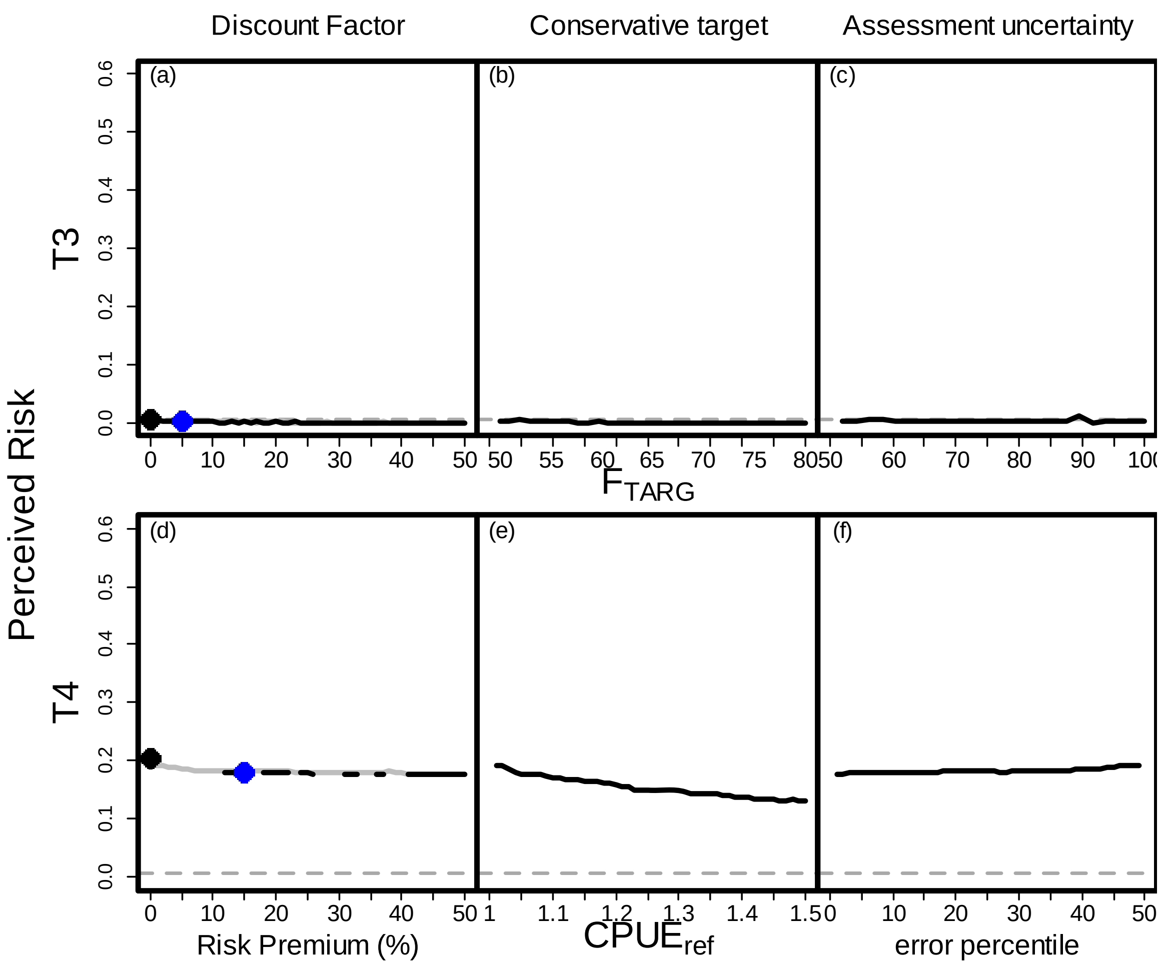

Figure 12.7. Perceived risk for jackass morwong for the four scenarios. Results of CPUE stability are shown in grey in panels (a) and (d). Dashed horizontal line represents perceived risk under T1. Black points indicate values for perceived risk given no discount factor. Blue points indicate perceived risk given currently applied values for the discount factor.

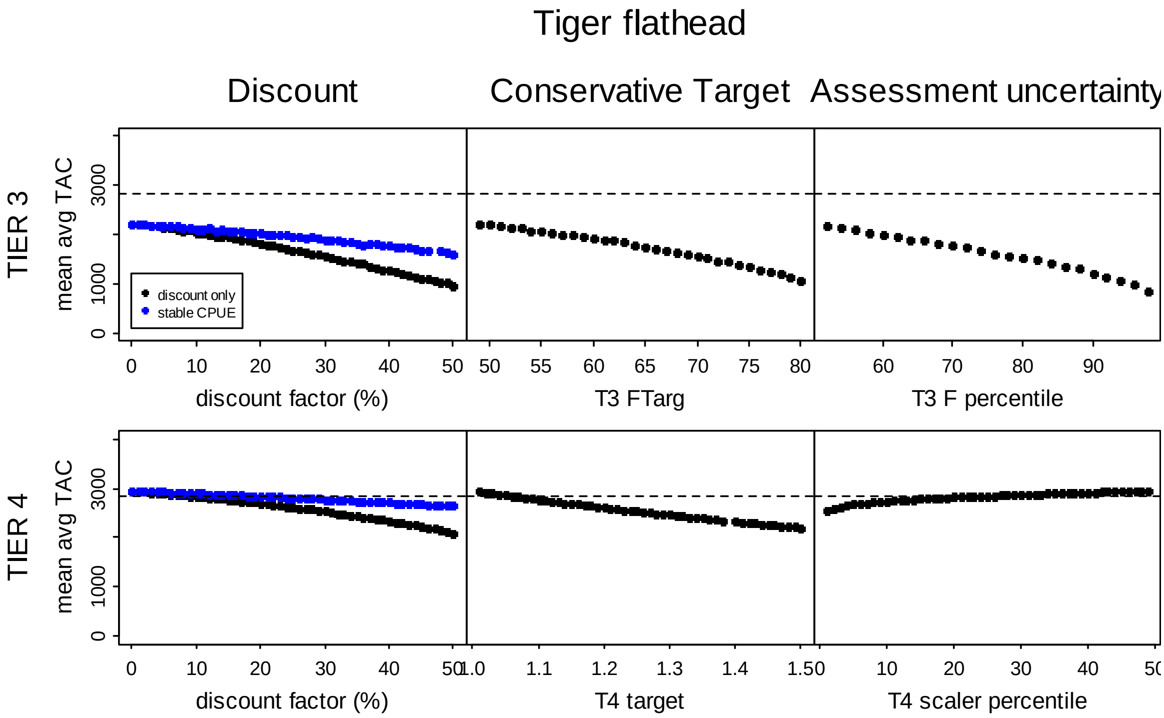

Figure 12.8. Mean average TACs for tiger flathead. Results for T3 and T4 are compared to mean avg TAC obtained under T1 (dashed line). 'discount only' corresponds to discount factor scenario,' stable CPUE' corresponds to CPUE stability scenario.

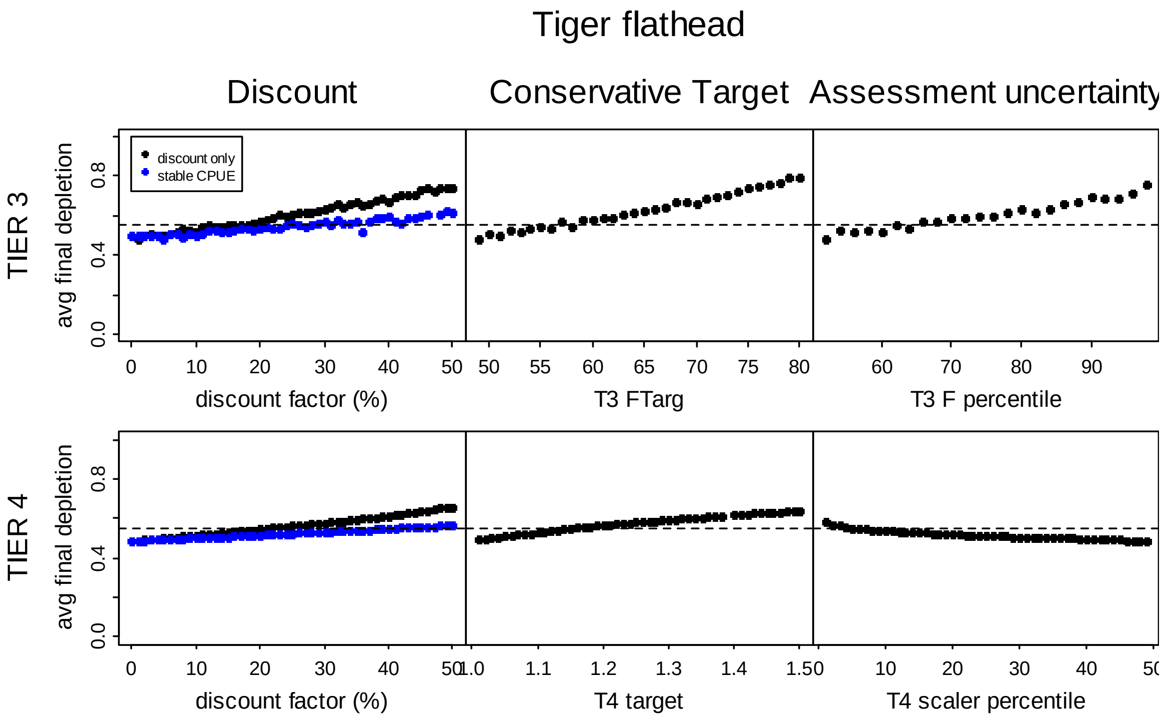

Figure 12.9. Median estimated final depletion for tiger flathead. Results for T3 and T4 are compared to the median estimated final depletion under T1 (dashed line). Scenarios in left-hand panels as for Figure 12.8.

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13. Catch Rate Standardizations for Selected Species from the SESSF (data 1986 – 2011)

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13.1 Summary

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

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

This document reports the statistical standardization of the commercial catch and effort data for 19 species, distributed across 44 different combinations of stocks and fisheries ready for inclusion in the annual round of stock assessments. These included School Whiting, Eastern Gemfish, Jackass Morwong, Flathead, Redfish, Silver Trevally, Royal Red Prawn, Blue Eye, Blue Grenadier, Spotted/Silver Warehou, Blue Warehou, Pink Ling, Western Gemfish, Ocean Perch, John Dory, Mirror Dory, Ribaldo, and Ocean Jackets. The statistical package R was used, with especial use being made of the biglm library, which was necessary because of the large amount of data available for some

species. Despite the large numbers of observations available in most analyses, the use of the AIC was able to discriminate between the more complex models. In fact, the visual difference between the CPUE trends exhibited by the top few models tends to be only minor.

Summary graphs are provided across all species (Figure 13.2 and Figure 13.3), as well as more detailed information for each stock. Out of 36 stocks there were 10 whose catch rates have increased over the last 10 years, there were 13 stocks where catch rates were stable (two of which were stable and low; Blue Warehou 102030 and Jackass Morwong 30), and there were 7 stocks whose catch rates have declined over the last 10 years. Many of the species are also examined for trends in catches and geometric catch rates between zones; this was to provide a check that there were only minor year x zone interactions (differences in catch rate trends between zones).

13.2 Introduction

Commercial catch and effort data are used in in very many fishery stock assessments in Australia as an index of relative abundance through time. The assumption is made that there is a direct relationship between catch rates and the amount of exploitable biomass. However, many factors can influence catch rates, including who was fishing with what gear in what depth, in what season, in what area, and whether it was day or night (plus other factors). The use of catch rates as an index of relative abundance means that it would be best to remove the effects of variation due to changes in these other factors on the assumption that what remains will provide a better estimate of the dynamics of the underlying stock biomass. This process of adjusting the time series for the effects of other influential factors is known as standardization and the accepted way of doing this is to use some statistical modelling procedure that focuses attention onto the annual average catch rates adjusted for the variation in the averages brought about by all the other factors identified.

The diversity of species and methods in the SESSF fishery means that each fishery/stock for which standardized catch rates are required entails its own set of conditions and selection of data. The Resource Assessment Groups (RAGs) have direct input on what combinations of depths and area need to be used in the standardization of each species/stock.

13.2.1 The Limits of Standardization

The assumption behind using commercial catch rates in stock assessments is that they reflect the relative abundance of the exploitable biomass through time. The legitimacy behind using commercial catch rates can be questioned when there are factors significantly influencing catch rates which cannot be included in any standardization. Over the last two decades there have been a number of major management interventions in the South East Scalefish and Shark Fishery (SESSF) including the introduction of the quota management system in 1992 and that of the Harvest Strategy Policy (HSP) and associated structural adjustment in 2005 – 2007. The combination of limited quotas and the HSP is now controlling catches in such a way that many fishers have been altering their fishing behaviour to take into account the availability of quota and their own access to quota needed to land the species taken in the mixed species SESSF.

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

Another example of catch rates not necessarily reflecting the stock dynamics can be found with BlueEye Autoline catch rates. Some of the closures (e.g. the gulper closures north east of Flinders Island) cover areas where auto-line catch rates were previously relatively high. Fishing continues mostly along the western edge of the St Helens Hill closure (even though this closure is open to Autoline vessels but the catch rates on the periphery are only about 2/3 the catch rates on the St Helens Hill itself. The geographical scale of these changes is much finer than that already included in the analyses and so the impression gained is that catch rates in general have declined whereas this may be much more about exactly where the fishing is occurring than what the stock is doing. A FRDC funded research project has only recently begun to examine the influence of closures on stock assessments and this exploration is on-going. The preliminary findings findings, however, indicate that again, great care needs to be taken when trying to interpret the outcomes of the catch rate standardization.

13.3 Methods

13.3.1 Catch Rate Standardization

13.3.1.1 Preliminary Data Selection

The precise methods used when standardizing commercial catch and effort data in the SESSF continue to be discussed in the Commonwealth stock assessment RAGs. This discussion continues because the catch rate time series are very influential in many of the assessments. Previously, various filters were placed on the data available in a preliminary attempt to focus on those vessels that actively target a species. These data filters involved only using vessels that had taken the species for more than two years and those that had taken some minimum annual catch level. The objective of these selections was to remove noise from whatever signal was present in the available data. After examining the effects of these data selections they appear to have only very minor influences on the catch rate trends because the number of records involved was only minor (often differences were not apparent in the graphs, i.e. less effect than the thickness of the lines) and so such selections are again not used this year. Far more influential were restrictions based upon depth of operation. In recognition that there are records which report activity in unlikely depths, there are usually restrictions placed on the depth range from which records could be validly reported. This is necessary as depth tends to be one of the most influential factors used in the statistical standardizations and rare outlying depths only served to confuse the analysis by introducing many combinations of factors that contained no data. In addition the choice of which particular reporting zones or areas are to be examined also leads to a prior selection of data.

Briefly, initial data selection for a particular species consists of using those data relating to a specific fishery (e.g. SET, GHT, GAB, etc), those data within a specified depth range and taken with a specified method in specified statistical zones within the years specified for the analysis.

The graphical representation of results includes the depiction of the unstandardized geometric mean catch rate along with the optimum statistical model representing the standardized time series. This provides a visual indication of whether the standardization changes any trend away from the nominal catch rate. To avoid visual distortions introduced by scaling the standardization relative to a particular year, the time series have all been scaled relative to the average of each time series of yearly indices, which means that the overall average in each case equates to one; this centres the vertical location of each series but does not change the relative trends through time. In all cases the differences between this year's analysis and last years' were minimal; both are illustrated in the individual stock graphs. In addition, for most analyses there is a graph of the relative contribution made by the different factors considered to the changes in the trend between the geometric mean and the optimum model. The scale of the changes introduced by a factor is not always in the same order as the relative proportion of the variation accounted for by a particular factor.

13.3.1.2 General Linear Modelling

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

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

where Ln($CPUE_i$) is the natural logarithm of the catch rate (usually kg/h, but sometimes kg/shot) for the *i*-th shot, x_{ij} are the values of the explanatory variables *j* for the *i*-th shot and the α_j are the coefficients for the *N* factors *j* to be estimated (α_0 is the intercept, α_1 is the coefficient for the first factor, *etc*.).

13.3.1.3 The Overall Year Effect

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

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

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

$$CE_t = \frac{CPUE_t}{\left(\sum CPUE_t\right)/n} \quad (3)$$

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

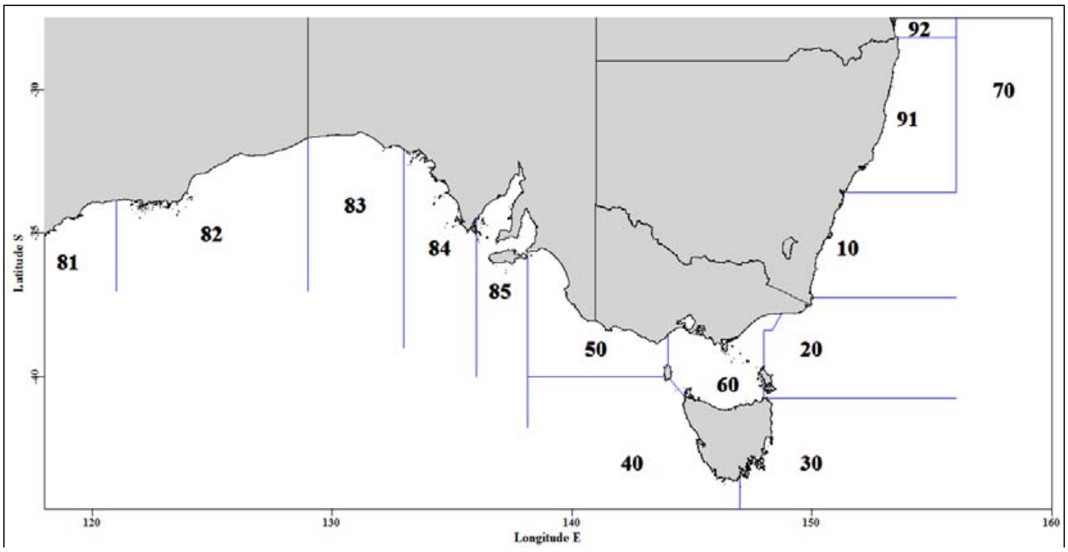

Figure 13.1. A schematic diagram depicting the statistical reporting zones in the SESSF, as used in this document. The GAB fishery is to the west of Zone 50. The main SESSF trawl zones are zones 10 – 50. Each zone extends out to the boundary of the EEZ, except for zones 50 and 60, and for zones 92 and 91, which are bounded by zone 70.

13.3.1.4 Data Manipulations

A standard set of database extracts were designed to identify positive shots containing the species of interest in each case. For each species the analyses were restricted to particular zones and depth ranges within a particular fishery and using a particular method (Table 13.1).

The statistical software *R* was used in all analyses (R Development Core Team, 2009), which, because of the large size of the datasets, required the use of the library "biglm".

13.4 Results

Table 13.1. Data characteristics for each analysis. Records show the number of records, the depths, the zones, and other details used in the data selection for the analyses.

	Species	Zone	Depths	Comment	Records
1	School Whiting	60	0-100	Danish Seine, catch per shot.	78728
2	Eastern Gemfish	10-30,40/2	200-500	June-Sept 93 onwards, Spawning	14402
3	Eastern Gemfish	10-30,40/2	0-600	Oct-May 86-09 0-600m, Jun-Sep	38323
4	Jackass Morwong	10-50	70-360		143899
5	Jackass Morwong	10,20	70-300		110061
6	Jackass Morwong	30	70-300		18557
7	Jackass Morwong	40,50	70-360		12525
8	Flathead	10,20	0-400	Trawl	245841
9	Flathead	30	0-400		19485
10	Flathead DS	20,60	0-200	Danish Seine, catch per shot	174461
11	RedFish	10	0-400		69927
12	RedFish	20	0-400		26195
13	Silver Trevally	10,20	0-200	Remove State waters and MPAs	32456
14	Royal Red Prawn	10	200-700		23586
15	Blue Eye	20,30	0-1000		12048
16	Blue Eye	40,50	0-1000		12317
17	Blue Eye	10-50,83-	200-600	Autolining and Droplining 1997	13855
18	Blue Grenadier	40	100-	Spawning Jun-Aug, Combined big	12238
19	Blue Grenadier	10-60	0-1000	Except Zone 40 Jun-Aug	126964
20	Silver Warehou	10-50	0-600		122577
21	Blue Warehou	10-30	0-400		36668
22	Blue Warehou	40,50	0-600		12576
23	Blue Warehou	10-50	0-600		49703
24	Pink Ling	10-30	0-600		148537
25	Pink Ling	40,50	200-800		71064
26	Pink Ling	10	250-600	For use in disaggregated analyses	43615
27	Pink Ling	20	250-600	“	42339
28	Pink Ling	30	250-600	“	7800
29	Pink Ling	40	350-800	“	29435
30	Pink Ling	50	200-800	“	41427
31	Western Gemfish	40,50,GAB	100-600		41220
32	Western Gemfish	40,50	200-600		30604
33	Western Gemfish	GAB	100-600	Only 1995 onwards	9045
34	Off-Ocean Perch	10,20	200-700		75911
35	In-Ocean Perch	10,20	0-200		16044
36	Total Ocean	10,20	0-700		91409
37	John Dory	10,20	0-200		130809
38	Mirror Dory	10-50	0-600		117422
39	Mirror Dory East	10-30	0-600		88365
40	Mirror Dory West	40,50	0-600		29025
41	Ribaldo (RBD)	10-50	0-1000		19029
42	Ribaldo	20-50,81-	0-1000		4249
43	Ocean Jackets	10-50	0-300		75344
44	Ocean Jackets	82-83	0-300		43965

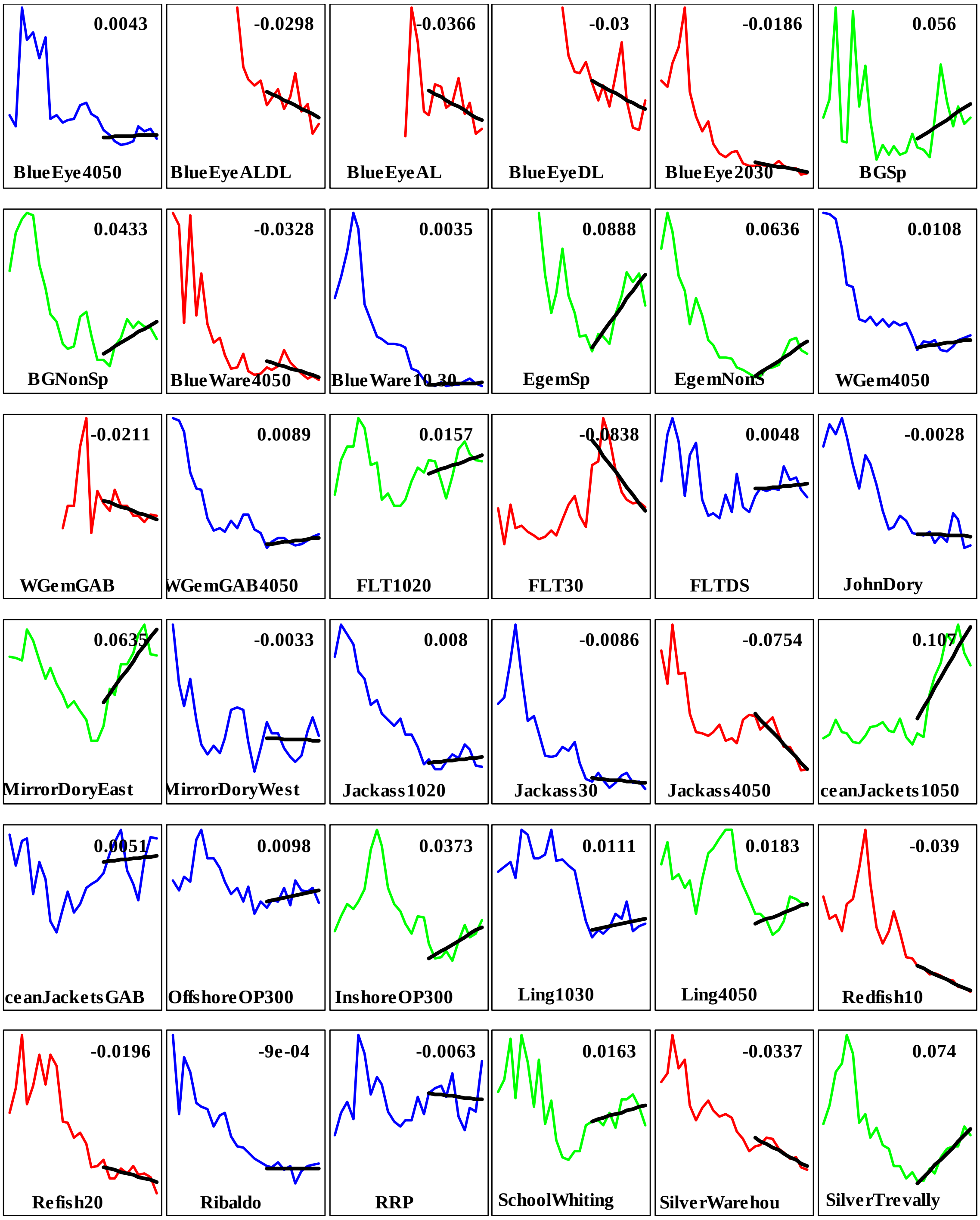

Figure 13.2**.** Summary graph of the optimum standardizations for 19 species and 36 different stocks, each with a linear regression across the last ten years (2002-2011). The gradient is given in the top right corner of each graph and the colour of the standardized CPUE line relates to the gradient: Green indicates a positive gradient > 0.015, blue a flat line with a gradient between 0.0149 and – 0.0149, while red indicates a negative gradient < -0.015. There were 11 stocks with a positive gradient, 14 stocks with a flat gradient, and 11 stocks with a negative gradient. Composite stocks, such as MirrorDory10-50 and TotalOceanPerch are omitted.

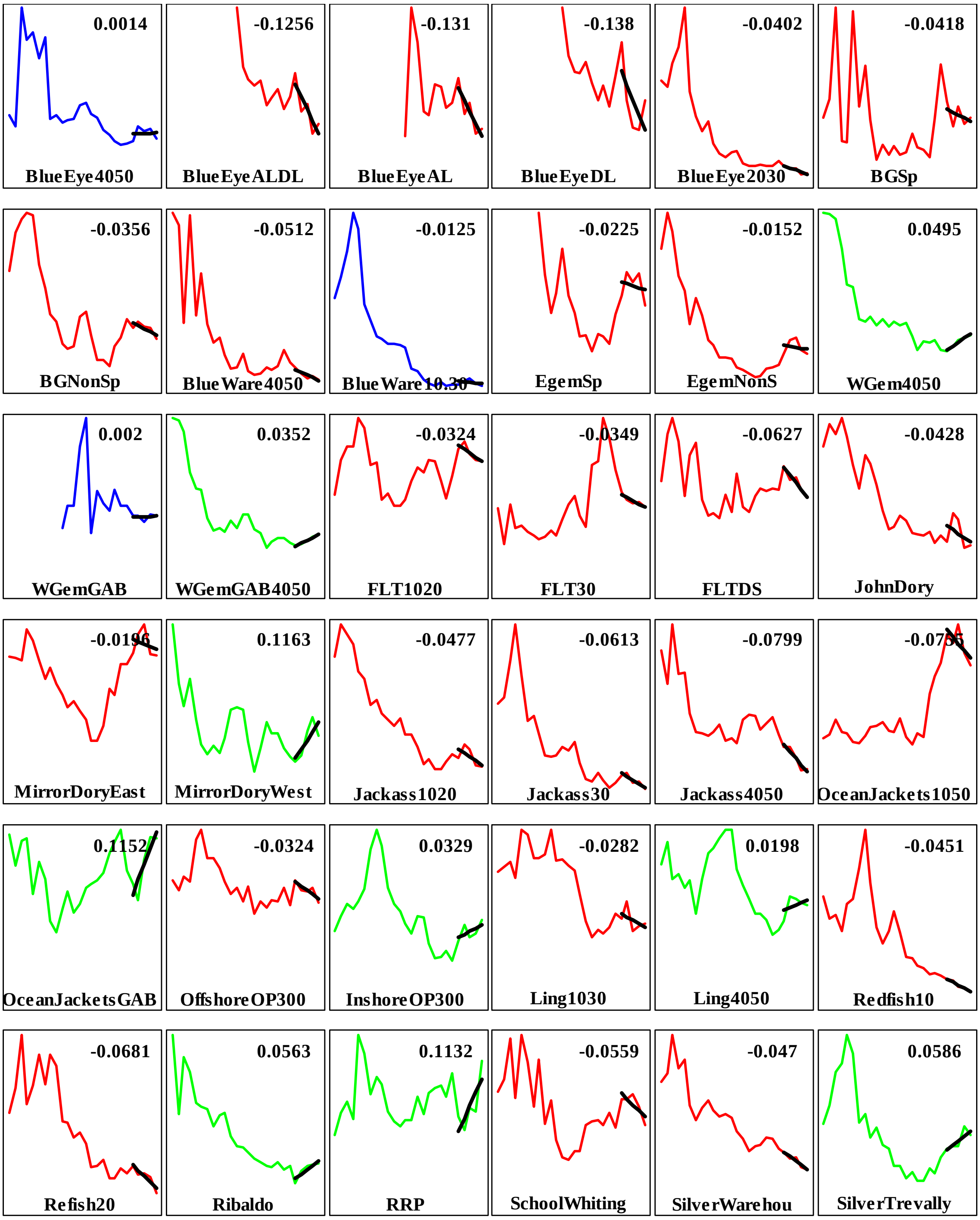

Figure 13.3**.** Summary graph of the optimum standardizations for 19 species and 36 different stocks, each with a linear regression across the last five years (2007-2011). The gradient is given in the top right corner of each graph and the colour of the standardized CPUE line relates to the gradient: Green indicates a positive gradient > 0.015, blue a flat line with a gradient between 0.0149 and – 0.0149, while red indicates a negative gradient < -0.015. There were 9 stocks with a positive gradient, 3 stocks with a flat gradient, and 24 stocks with a negative gradient. In many instances five years provides a false impression, for example, Pink Ling 10-30 appears negative here but positive across ten years. While declines can be serious, responding to noise would just make management variable over short time periods.

13.5 School Whiting (WHS – 37330014) *Sillago flindersi*

School Whiting are taken primarily by Danish Seine (and within State waters). In Commonwealth waters the catches are primarily within Zone 60, and in depths less than or equal to 100 m. All vessels and all records were included in the analysis. Catch rates were expressed as the natural log of catch per shot. There were a total of 78,728 records used.

Table 13.2. School Whiting from Zone 60 in depths 0 to 100 m by Danish Seine. Total Catch is the total reported in the database, Records are the number used in the analysis, CatchT is the reported catch in the area and depth used in the analysis, Vessels relates to all vessels used in the analysis. Geomean is the geometric mean of catch rates (kg/hr). Mth:DepC is the optimum model and StDev is the standard deviation relating to the data in the optimum model.

Year	TotCatch	Records	CatchT	Vessels	GeoMean	Mth:DepC	StDev
1986	1302.410	5667	1181.583	26	112.3054	1.1573	0.0000
1987	995.965	4119	920.495	23	131.1624	1.2735	0.0292
1988	1255.688	3815	1177.456	25	168.5490	1.6496	0.0298
1989	1061.513	4440	994.408	27	127.0438	1.0919	0.0288
1990	1930.368	6263	1859.923	24	165.2959	1.6853	0.0269
1991	1630.255	4871	1517.794	26	164.1905	1.4283	0.0285
1992	854.106	2980	777.524	23	124.7066	1.0180	0.0327
1993	1694.896	4696	1471.559	23	152.4819	1.4500	0.0288
1994	946.201	4503	879.162	24	93.9314	0.8477	0.0290
1995	1212.561	4270	1065.934	21	122.4731	1.0666	0.0294
1996	898.213	4297	718.814	22	81.4339	0.6978	0.0296
1997	697.380	3314	481.660	20	64.5619	0.5411	0.0318
1998	594.153	2988	464.154	20	66.0158	0.5219	0.0327
1999	681.252	2044	452.215	21	84.3634	0.5966	0.0375
2000	700.880	1913	335.075	17	65.1233	0.6006	0.0380
2001	890.925	1980	425.095	18	93.2089	0.8457	0.0391
2002	788.331	2192	429.218	20	90.8874	0.8697	0.0374
2003	866.808	2352	463.528	20	87.1013	0.8898	0.0368
2004	604.886	1771	334.631	20	79.7648	0.8435	0.0395
2005	662.684	1750	311.428	20	77.2502	0.9513	0.0412
2006	667.505	1428	270.272	18	76.2250	0.8220	0.0430
2007	535.358	1488	347.049	14	89.2381	1.0799	0.0420
2008	502.245	1260	317.058	15	92.3448	1.0860	0.0451
2009	461.891	1569	350.723	15	93.6200	1.1350	0.0418
2010	409.501	1179	273.470	15	88.7190	1.0156	0.0461
2011	373.911	1579	260.300	14	72.0269	0.8354	0.0415

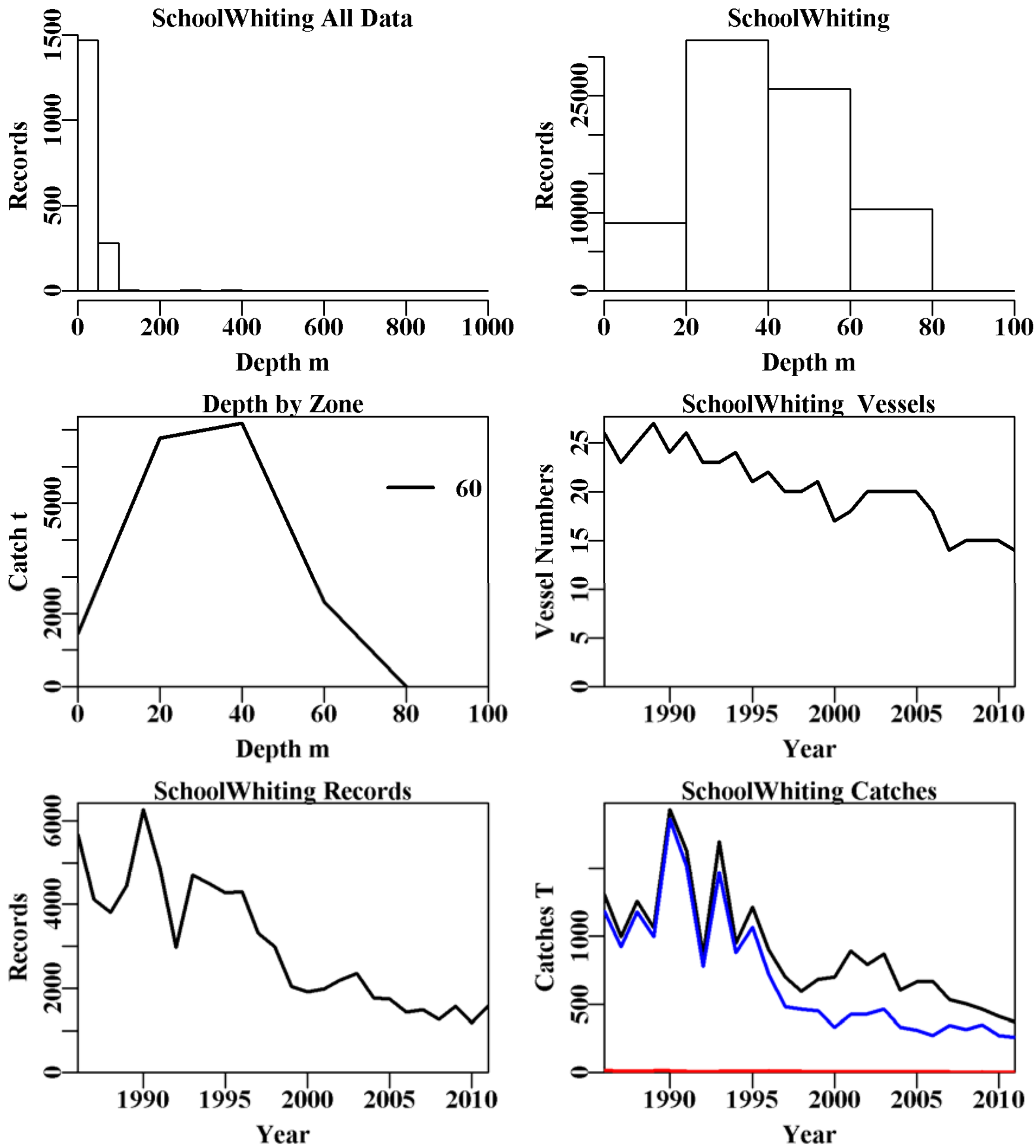

Figure 13.4. School Whiting in zone 60 in depths 0 to 100 m taken by Danish Seine. The top left is the depth distribution of all records reporting School Whiting, the top right graph depicts the depth distribution of shots containing School Whiting in Zone 60 and depths 0-100 m. The middle left diagram depicts the distribution of catch by depth within zone 60 across all years, the middle right hand graph depicts the number of vessels through time. The bottom left reflects the number of records used in analysis, and bottom right is the School Whiting catches (top line, black is total catches, middle line, blue, are those used in the analysis, and bottom, red, are catches < 30Kg).

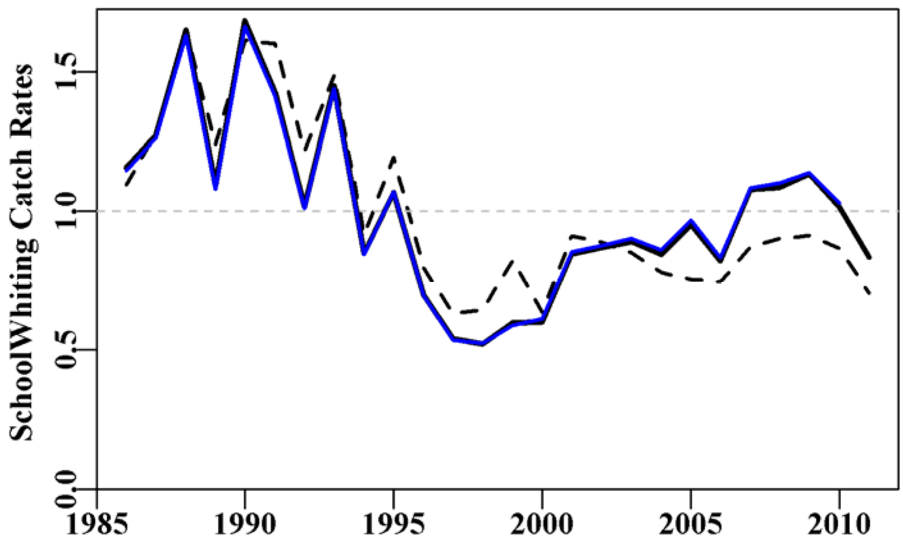

Figure 13.5. School Whiting in zone 60 in depths 0 to 100 m by Danish Seine. The dashed black line represents the geometric mean catch rate, the solid black line the standardized catch rates, and the blue line is last year's analysis. The graph standardizes catch rates relative to the mean of the standardized catch rates.

Table 13.3**.** School Whiting from Zone 60 in depths 0 to 100 m by Danish Seine. Statistical model structures used in this analysis. DepCat is a series of 20 metre depth categories. DN is DayNight

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

Table 13.4. School Whiting from Zone 60 in depths 0 to 100 m by Danish Seine. Model selection criteria, including the AIC, the adjusted r^2 and the change in adjusted r^2. The optimum was model 7. DN is DayNight, DepC is depth category and Mth is Month.

	Year	Vessel	DayNight	Month	DepCat	DN:DepC	DepC:Mth	DN:Mth
AIC	55414	53351	51068	49087	47636	47460	47127	47488
RSS	159048	154753	150319	146543	142760	142392	141662	142365
MSS	7531	11826	16261	20036	23819	24187	24917	24214
Nobs	78728	78728	78728	78728	77211	77211	77211	77211
Npars	26	72	75	86	90	102	134	123
adj_r2	4.491	7.015	9.677	11.933	14.200	14.408	14.811	14.401
%Change	0.000	2.525	2.661	2.256	2.267	0.208	0.404	-0.410

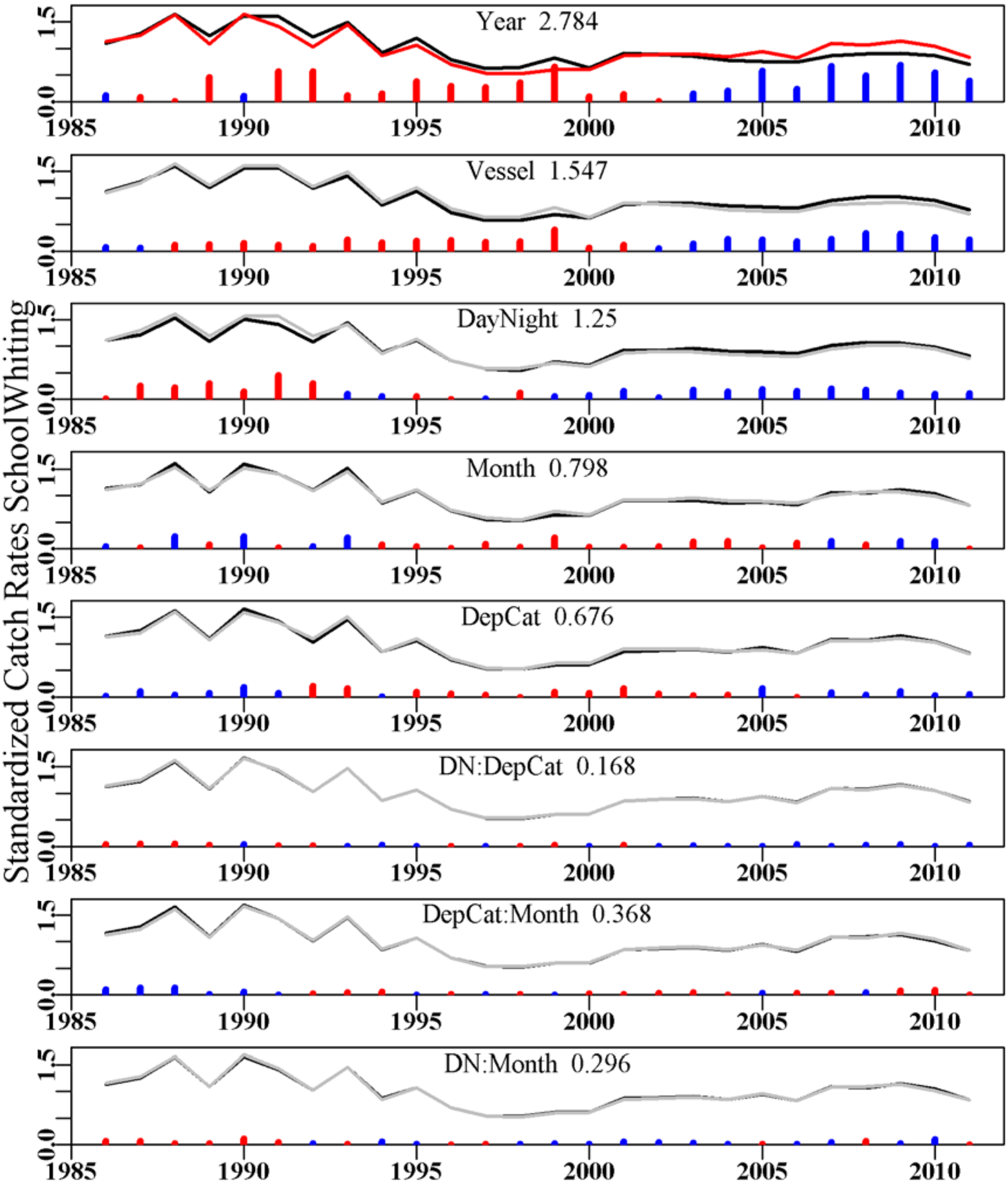

Figure 13.6**.** The relative influence of each factor used on the final trend in the optimal standardization for School Whiting in Zone 60. The top graph depicts the geometric mean (the black line) and the optimum model (the red line). The difference between them is illustrated by the vertical bars with blue bars indicating the optimum model is higher than the geometric mean and red bars indicating it is lower. The top graph bars are the sum of all the bars in the graphs below. The graphs for individual factors are cumulative. Thus the second graph has the geometric mean (grey line) and the effect of adding Year + factor2 (model 2). In the third graph, the grey line represents model 2 and the black line the effect of adding factor3 to the model. The remaining graphs continue in the same cumulative manner except for the interaction terms which are added singularly to the final single factor model.

13.6 Eastern Gemfish (GEM – 37439002 – *Rexea solandri*) Spawning Fishery

Only use June through September from 1993 – 2010, 300-500m depth, Catch effort > 0.0, Zones 10 – 30 plus below 42 degrees on the west coast of Tasmania (zone 40).

Eastern Gemfish are taken by trawl in the spawning season from June to September in Zones 10, 20, 30, in the bottom half of 40 and between depths of 300 to 500 m. There were 13,270 records used. The spawning run of Eastern Gemfish is considered to be a bycatch fishery. Particular records related to the Eastern Gemfish surveys in 2007 and 2008 are removed from the data set prior to the analysis.

Table 13.5**.** Eastern Gemfish, spawning fishery in depths between 300 – 500m, taken by trawl. Total Catch is the total reported in the database, Records is the number of records used in the analysis, CatchT is the reported catch in the area and depth used in the analysis, and Vessels relates to all vessels used in the analysis. Geomean is the geometric mean of catch rates (kg/hr). Zone:Month is the optimum model and StDev is the standard deviation relating to the data in the optimum model.

Year	TotCatch	Records	CatchT	Vessels	GeoMean	Zone:Mth	StDev
1993	353.410	825	143.241	50	17.7557	1.9638	0.0000
1994	232.179	825	49.142	48	11.8113	1.2980	0.0616
1995	181.746	661	21.946	50	7.3422	0.8735	0.0650
1996	382.196	773	135.175	50	10.8392	1.0971	0.0626
1997	571.976	1239	268.914	50	18.7012	1.5816	0.0580
1998	404.817	887	144.689	47	11.4499	1.0604	0.0621
1999	448.677	1092	88.365	48	8.0762	0.8808	0.0600
2000	336.464	1235	37.978	48	4.6672	0.6138	0.0604
2001	331.486	902	34.567	50	4.4410	0.6324	0.0638
2002	196.526	977	22.949	47	3.3317	0.4550	0.0632
2003	269.227	976	31.653	49	4.4807	0.6497	0.0624
2004	525.201	694	20.563	50	3.9729	0.6155	0.0688
2005	498.511	666	20.076	40	4.4130	0.5452	0.0684
2006	509.019	580	35.198	36	7.5671	0.8669	0.0709
2007	542.778	313	25.424	21	8.7558	1.0657	0.0858
2008	252.302	450	35.264	25	10.2842	1.3209	0.0782
2009	194.843	426	37.246	26	9.0364	1.2096	0.0789
2010	220.639	422	42.549	26	9.6316	1.3126	0.0791
2011	147.321	459	28.479	26	6.8540	0.9574	0.0771

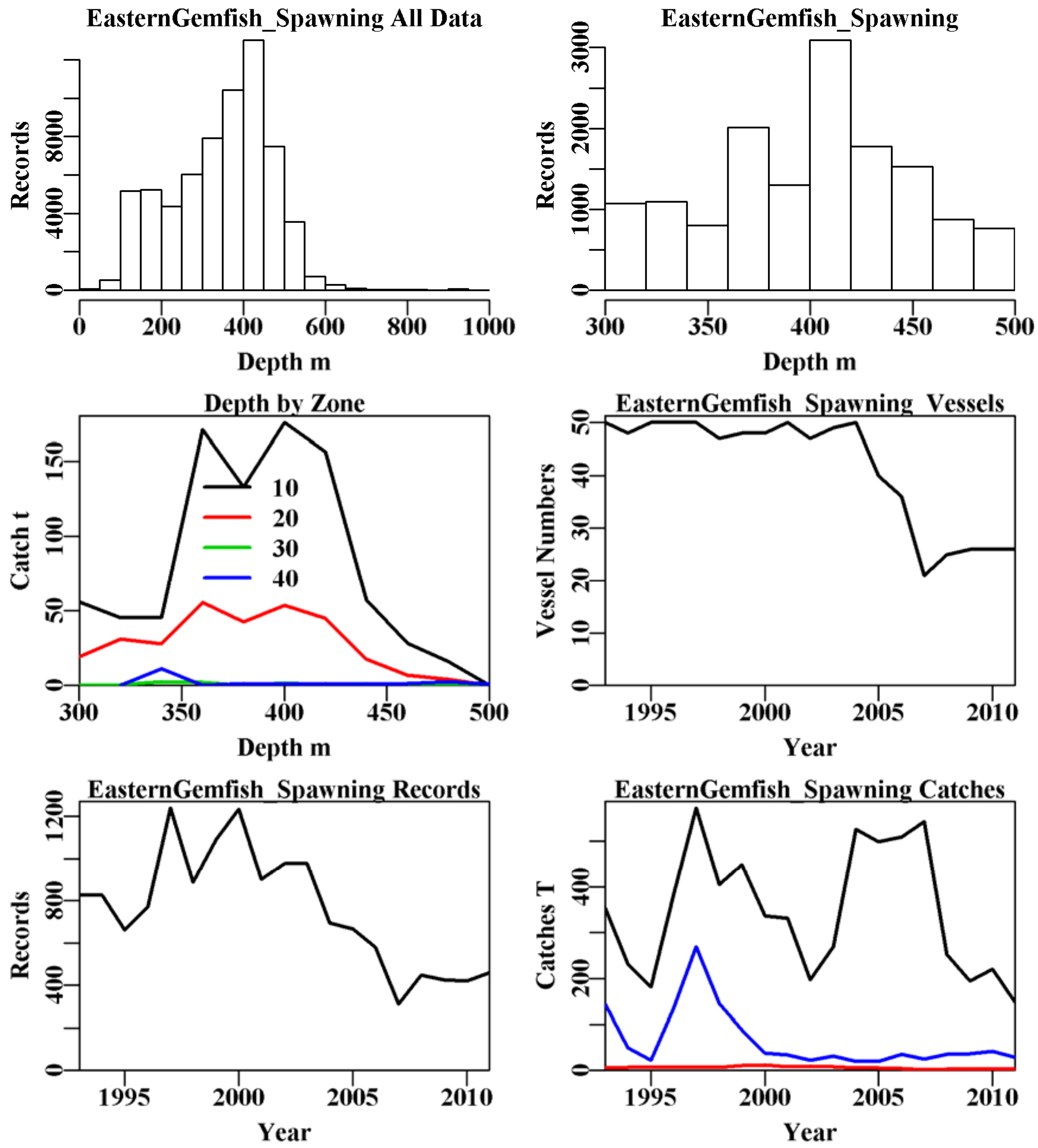

Figure 13.7. Eastern Gemfish, spawning fishery in depths between 300 – 500m, taken by trawl. The top left is the depth distribution of all records reporting Eastern Gemfish, the top right graph depicts the depth distribution of shots containing Eastern Gemfish, spawning fishery in depths between 300 – 500m, taken by trawl. The middle left diagram depicts the distribution of catch by depth by SESSF zone, the middle right hand graph depicts the number of vessels through time. The bottom left reflects the number of records used in analysis, and bottom right is the Eastern Gemfish catches (top line, black is total catches, middle line, blue, are those used in the analysis, and bottom, red, are catches < 30Kg).

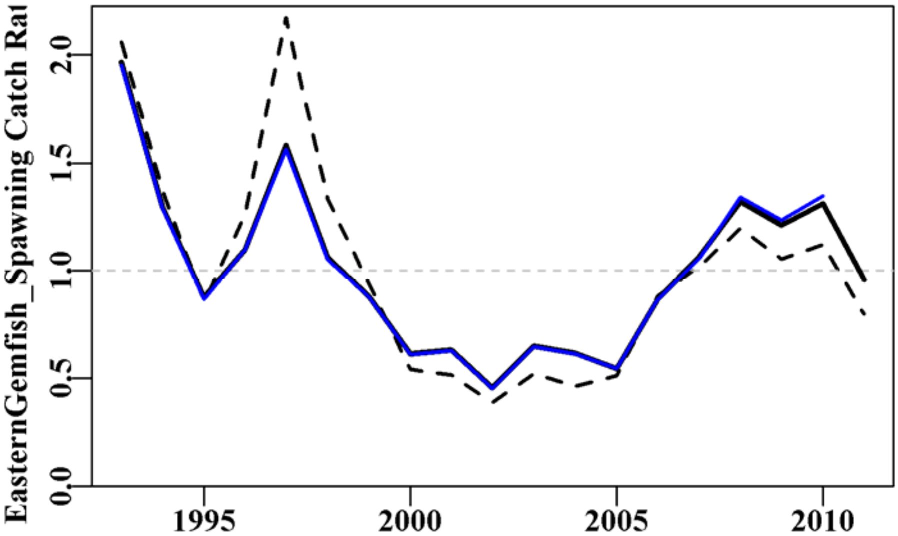

Figure 13.8. Eastern Gemfish, spawning fishery in depths between 300 – 500m, taken by trawl. The dashed black line represents the geometric mean catch rate and the solid black line the standardized catch rates. The graph standardizes catch rates relative to the mean of the standardized catch rates.

Table 13.6. Eastern Gemfish, spawning fishery in depths between 300 – 500m, taken by trawl. Statistical model structures used in this analysis. DepCat is a series of 20 metre depth categories.

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

Table 13.7. Eastern Gemfish, spawning fishery in depths between 300 – 500m, taken by trawl. Model selection criteria, including the AIC, the deviance and the change in deviance. The optimum is model Zone:Month.

	Year	Vessel	DepCat	Month	DayNight	Zone	Zone:Mth	Zone:DepC
AIC	8690	6694	5940	5436	5396	5284	5026	5265
RSS	26261	22532	21374	20518	20452	20283	19896	20172
MSS	4079	7807	8965	9822	9888	10056	10443	10168
Nobs	14402	14402	14402	14301	14301	14301	14301	14301
Npars	19	124	127	137	140	143	152	173
adj_r2	13.335	25.093	28.928	31.724	31.929	32.476	33.722	32.704
%Change	0.000	11.759	3.835	2.796	0.206	0.546	1.246	-1.018

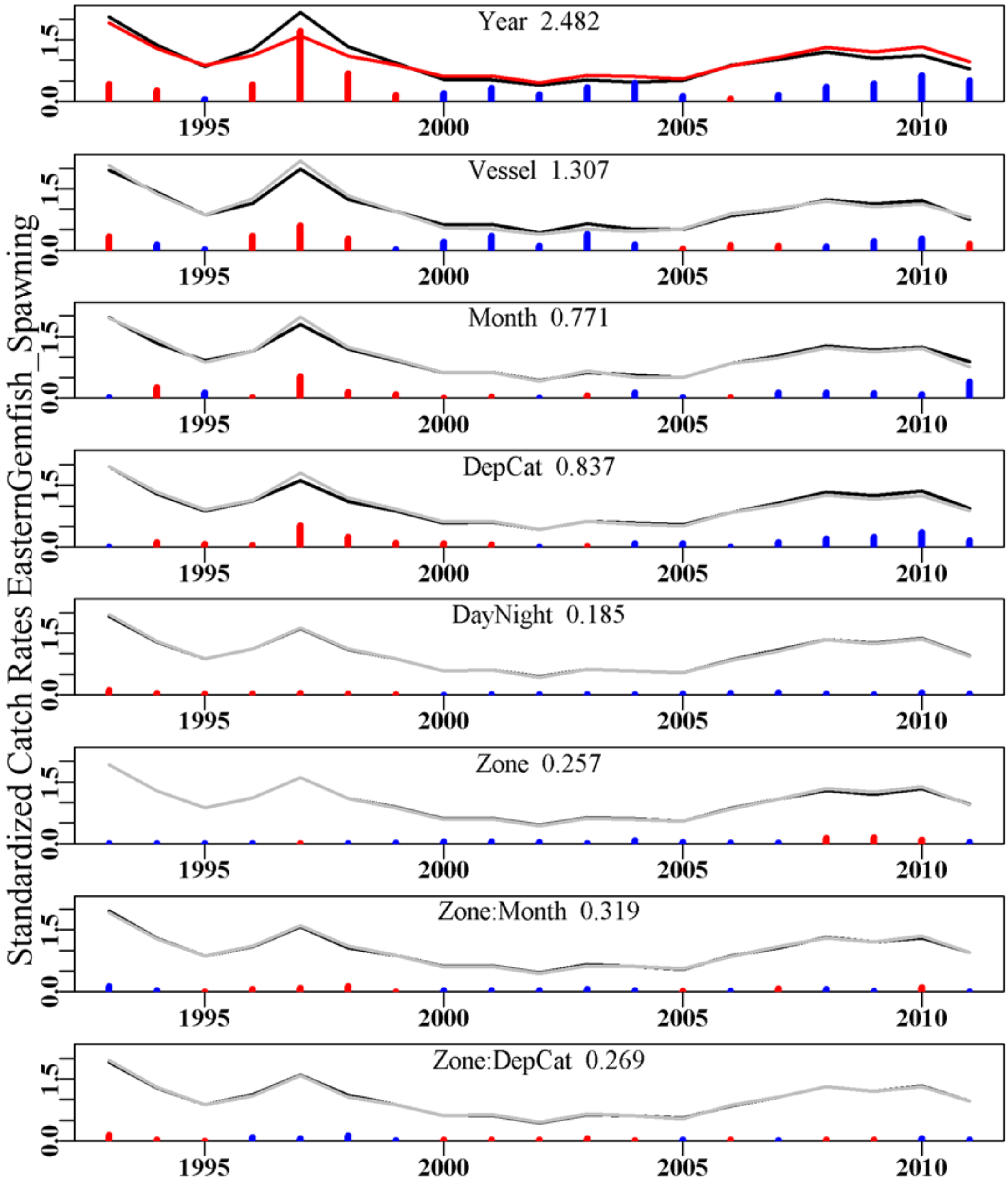

Figure 13.9**.** The relative influence of each factor used on the final trend in the optimal standardization for the eastern gemfish spawning fishery. The top graph depicts the geometric mean (the black line) and the optimum model (the red line). The difference between them is illustrated by the vertical bars with blue bars indicating the optimum model is higher than the geometric mean and red bars indicating it is lower. The top graph bars are the sum of all the bars in the graphs below. The graphs for individual factors are cumulative. Thus the second graph has the geometric mean (grey line) and the effect of adding Year + factor2 (model 2). In the third graph, the grey line represents model 2 and the black line the effect of adding factor3 to the model. The remaining graphs continue in the same cumulative manner except for the interaction terms which are added singularly to the final single factor model.

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

Use October to May 1986-2010, all depths to 600m, June to September, < 300m depth, Zones 10 – 30 plus below 42 on the west coast of Tasmania (zone 40).

Table 13.8. Non-spawning Eastern Gemfish from the SET in depths between 0 – 600m, taken by trawl. Total Catch is the total reported in the database, Records is the number of records used in the analysis, CatchT is the reported catch in the area and depth used in the analysis, and Vessels relates to all vessels used in the analysis. Geomean is the geometric mean of catch rates (kg/hr). Zone:DepCat is the optimum model and StDev is the standard deviation relating to the data in the optimum model.

Year	TotCatch	Records	CatchT	Vessels	GeoMean	**Zone:DepC**	StDev
1986	3639.955	2203	414.317	89	15.3241	2.3896	0.0000
1987	4660.447	2019	784.860	80	25.2674	2.9835	0.0413
1988	3515.819	2372	532.525	84	20.3738	2.6781	0.0411
1989	1778.325	1742	189.588	78	12.8697	1.9458	0.0444
1990	1206.897	858	107.120	73	12.0080	1.7081	0.0547
1991	580.322	863	70.785	73	8.4919	1.1499	0.0543
1992	494.441	717	135.384	52	10.6133	1.5743	0.0576
1993	353.410	1543	94.850	62	8.9852	1.2954	0.0467
1994	232.179	1845	69.080	56	6.2854	0.8826	0.0448
1995	181.746	1714	50.937	54	5.4906	0.8009	0.0454
1996	382.196	1930	55.795	61	3.9966	0.5858	0.0447
1997	571.976	1829	67.152	57	4.1253	0.5934	0.0464
1998	404.817	1304	45.991	52	4.0091	0.5742	0.0491
1999	448.677	1432	30.842	54	2.7336	0.4234	0.0483
2000	336.464	1856	33.128	60	2.5299	0.3905	0.0462
2001	331.486	1680	31.424	53	1.9996	0.3369	0.0476
2002	196.526	1727	20.203	53	1.5421	0.2622	0.0475
2003	269.227	1627	20.423	51	1.6954	0.2954	0.0479
2004	525.201	1825	39.127	56	2.5873	0.4142	0.0473
2005	498.511	1772	44.504	51	2.7875	0.4370	0.0471
2006	509.019	1364	34.001	43	2.8952	0.4652	0.0501
2007	542.778	812	24.887	27	4.0265	0.6460	0.0570
2008	252.302	843	34.918	27	5.5997	0.8828	0.0567
2009	194.843	646	29.796	31	5.4510	0.9137	0.0620
2010	220.639	909	28.997	27	3.8269	0.7197	0.0559
2011	147.321	891	24.935	26	3.5366	0.6515	0.0566

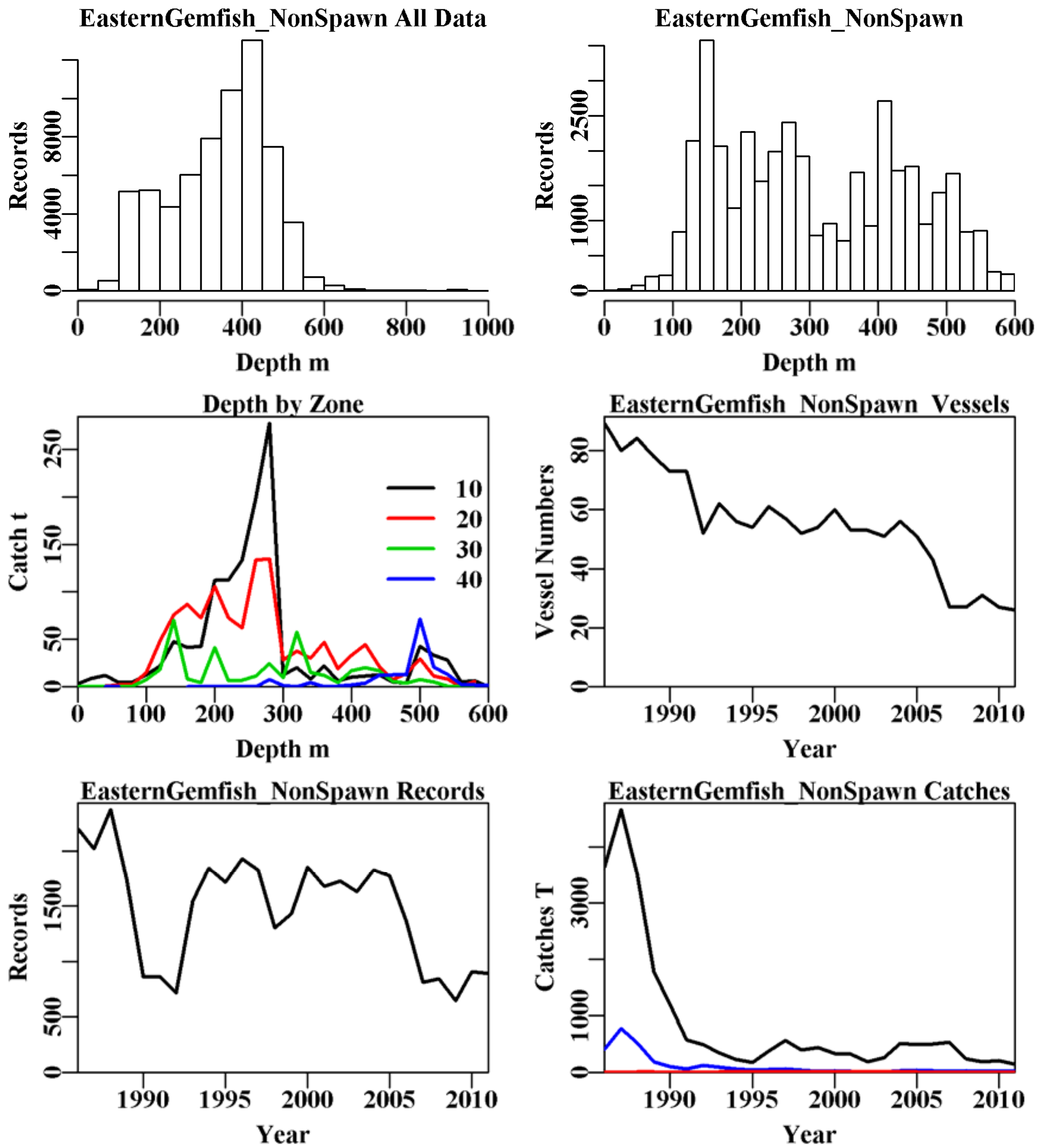

Figure 13.10. Non-spawning Eastern Gemfish from the SET in depths between 0 – 600m, taken by trawl. The top left is the depth distribution of all records reporting Eastern Gemfish, the top right graph depicts the depth distribution of shots containing Non-spawning Eastern Gemfish from the SET in depths between 0 – 600m, taken by trawl. The middle left diagram depicts the distribution of catch by depth by SESSF zone, the middle right hand graph depicts the number of vessels through time. The bottom left reflects the number of records used in analysis, and bottom right is the Eastern Gemfish catches (top line, black is total catches, middle line, blue, are those used in the analysis, and bottom, red, are catches < 30Kg).

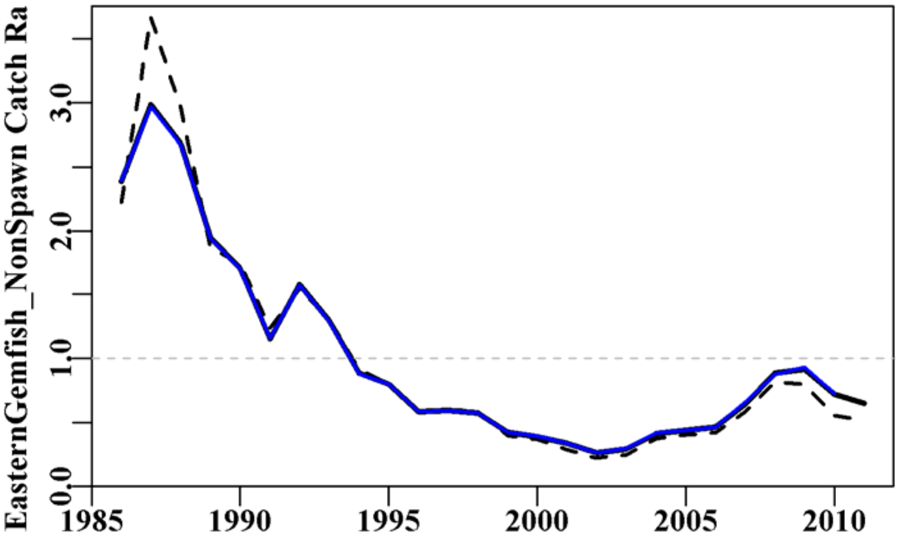

Figure 13.11. Non-spawning Eastern Gemfish from the SET in depths between 0 – 600m, taken by trawl. The dashed black line represents the geometric mean catch rate and the solid black line the standardized catch rates. The blue line is last year's optimum standardization. The graph standardizes catch rates relative to the mean of the standardized catch rates.

Table 13.9. Non-spawning Eastern Gemfish from the SET in depths between 0 – 600m, taken by trawl. Statistical model structures used in this analysis. DepCat is a series of 20 metre depth categories.

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

Table 13.10. Nonspawning Eastern Gemfish from the SET in depths between 0 – 600m, taken by trawl. Model selection criteria, including the AIC, the deviance and the change in deviance. The optimum is model Zone:DepCat.

	Year	Vessel	DepCat	Month	Zone	DayNight	Zone:Mth	Zone:DepC
AIC	24000	18632	16127	15730	15317	15028	14658	14561
RSS	71589	61609	57341	56712	56091	55656	55023	54717
MSS	25504	35485	39753	40381	41002	41437	42071	42377
Nobs	38323	38323	38009	38009	38009	38009	38009	38009
Npars	26	219	249	260	263	266	299	356
adj_r2	26.220	36.184	40.555	41.189	41.829	42.275	42.883	43.114
%Change	0.000	9.964	4.371	0.634	0.639	0.447	0.607	0.231

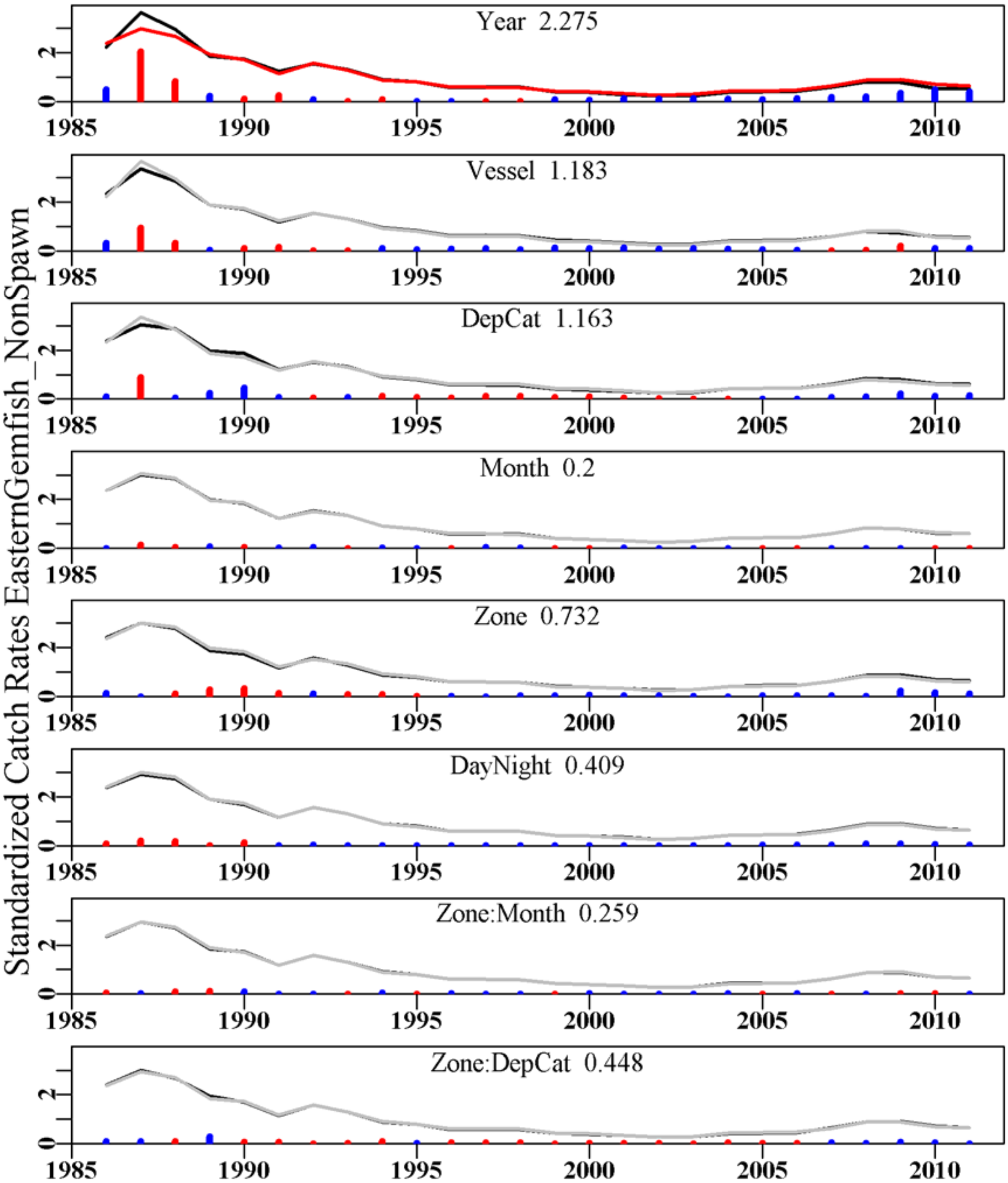

Figure 13.12. The relative influence of each factor used on the final trend in the optimal standardization for Non-spawning Eastern Gemfish. The top graph depicts the geometric mean (the black line) and the optimum model (the red line). The difference between them is illustrated by the vertical bars with blue bars indicating the optimum model is higher than the geometric mean and red bars indicating it is lower. The top graph bars are the sum of all the bars in the graphs below. The graphs for individual factors are cumulative. Thus the second graph has the geometric mean (grey line) and the effect of adding Year + factor2 (model 2). In the third graph, the grey line represents model 2 and the black line the effect of adding factor3 to the model. The remaining graphs continue in the same cumulative manner except for the interaction terms which are added singularly to the final single factor model.

13.8 Jackass Morwong Z10–50 (MOR – 37377003 Nemadactylus macropterus)

Only data from Zones 10 to 50 in depths 70 – 360m taken by trawl.

Table 13.11. Jackass Morwong from zones 10 to 50 in depths 70 – 360m by trawl. Total Catch is the total reported in the database, Records is the number of records used in the analysis, CatchT is the reported catch in the area and depth used in the analysis, and Vessels relates to all vessels used in the analysis. Geomean is the geometric mean of catch rates (kg/hr). Zone:Mth is the optimum model and StDev is the standard deviation relating to the data in the optimum model.

Year	TotCatch	Records	CatchT	Vessels	GeoMean	Zone:Mth	StDev
1986	982.811	5772	873.211	106	22.5592	1.8326	0.0000
1987	1087.690	4948	1000.054	104	26.1917	2.0862	0.0265
1988	1483.512	5984	1314.397	102	29.1554	2.0565	0.0258
1989	1667.373	5434	1500.604	89	33.9001	1.9994	0.0266
1990	1001.414	5022	837.357	86	24.2137	1.6572	0.0276
1991	1138.070	5233	899.685	85	21.1181	1.4684	0.0274
1992	758.254	3483	523.779	63	19.1937	1.2157	0.0306
1993	1014.985	4732	821.881	73	21.3530	1.2320	0.0287
1994	818.418	5660	684.800	71	18.0744	1.0502	0.0274
1995	789.528	5852	705.409	63	16.3623	0.9875	0.0271
1996	827.191	7535	749.574	70	13.8607	0.9246	0.0260
1997	1063.363	7561	934.001	70	16.1581	0.9910	0.0264
1998	876.404	5941	688.705	65	13.4363	0.8476	0.0274
1999	961.262	5801	779.703	66	14.1587	0.8793	0.0276
2000	945.098	6902	732.188	77	10.1983	0.7263	0.0269
2001	790.188	6786	644.178	71	8.3295	0.5431	0.0271
2002	811.136	7761	691.282	65	8.3275	0.5693	0.0267
2003	775.123	6538	601.484	64	7.9077	0.4899	0.0273
2004	765.506	6483	604.476	70	8.6153	0.4905	0.0276
2005	784.128	6376	597.416	58	8.9785	0.5259	0.0276
2006	811.298	5446	616.102	49	11.5427	0.6003	0.0285
2007	607.870	3812	443.366	30	12.2504	0.5987	0.0309
2008	700.439	4491	546.640	33	13.7889	0.7042	0.0299
2009	454.352	3383	344.429	27	11.4713	0.6212	0.0318
2010	380.248	3438	292.104	30	8.5497	0.4635	0.0319
2011	422.130	3525	303.284	28	8.5254	0.4389	0.0318

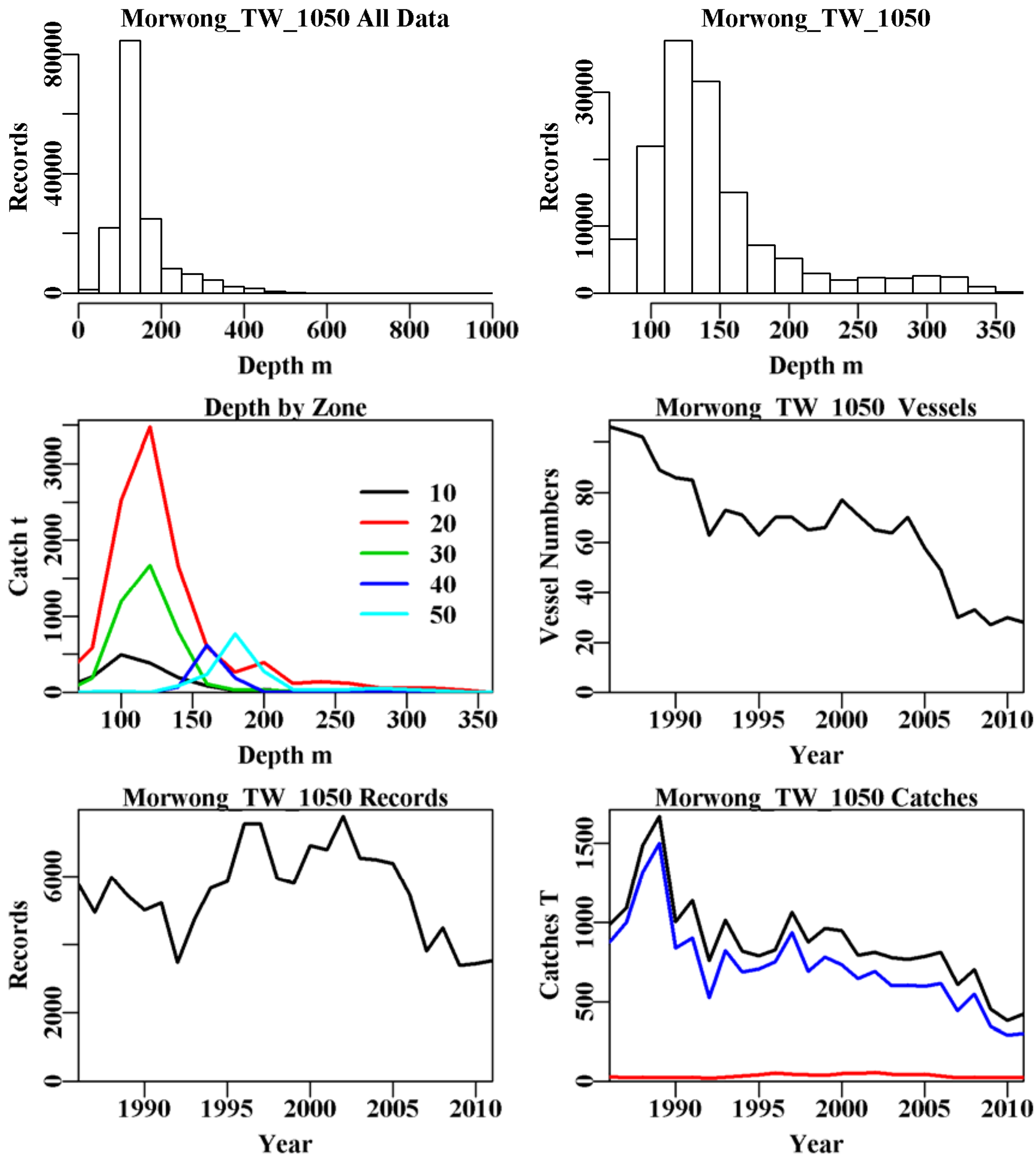

Figure 13.13. Jackass Morwong from zones 10 to 50 in depths 70 – 360m by trawl. The top left is the depth distribution of all records reporting Jackass Morwong, the top right graph depicts the depth distribution of shots containing Jackass Morwong from zones 10 to 50 in depths 70 – 360m by trawl. The middle left diagram depicts the distribution of catch by depth within zones 10 to 50, the middle right hand graph depicts the number of vessels through time. The bottom left reflects the number of records used in analysis, and bottom right is the Jackass Morwong catches (top line, black is total catches, middle line, blue, are those used in the analysis, and bottom, red, are catches < 30Kg).

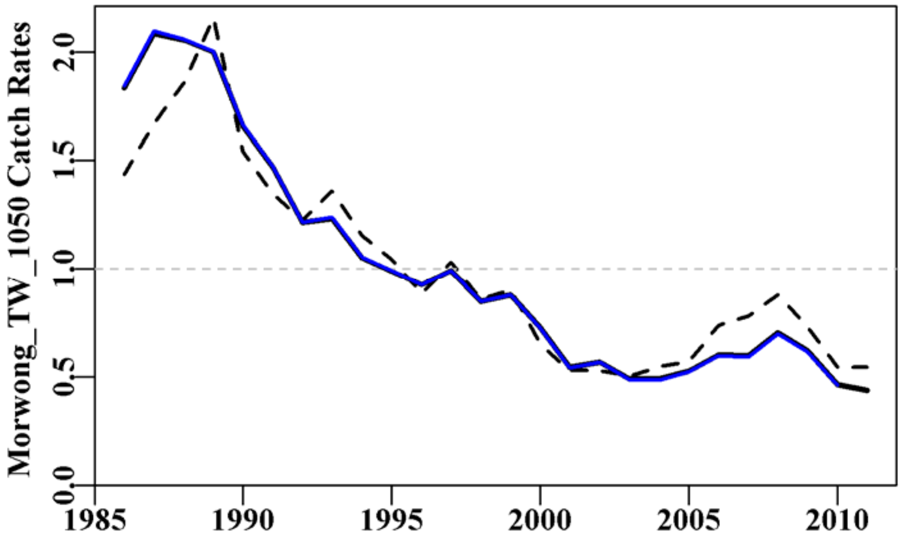

Figure 13.14. Jackass Morwong from zones 10 to 50 in depths 70 – 360m by trawl. The dashed black line represents the geometric mean catch rate and the solid black line the standardized catch rates. The graph standardizes catch rates relative to the mean of the standardized catch rates.

Table 13.12. Jackass Morwong from zones 10 to 50 in depths 70 – 360m by trawl. Statistical model structures used in this analysis. DepCat is a series of 20 metre depth categories.

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

Table 13.13. Jackass Morwong from zones 10 to 50 in depths 70 – 360m by trawl. Model selection criteria, including the AIC, the adjusted r2 and the change in adjusted r2. The optimum was model Zone:Month.

	Year	Vessel	Month	DepCat	Zone	DayNight	Zone:Month	Zone:DepCat
AIC	109820	87780	81545	77470	72787	71485	69341	70000
RSS	308563	263954	252722	244625	236711	234551	230909	231926
MSS	26624	71234	82465	90563	98476	100637	104279	103262
Nobs	143899	143899	143899	142649	142649	142649	142649	142649
Npars	26	241	252	267	271	274	318	334
adj_r2	7.927	21.120	24.471	26.882	29.246	29.890	30.957	30.645
%Change	0.000	13.193	3.351	2.411	2.363	0.644	1.067	-0.312

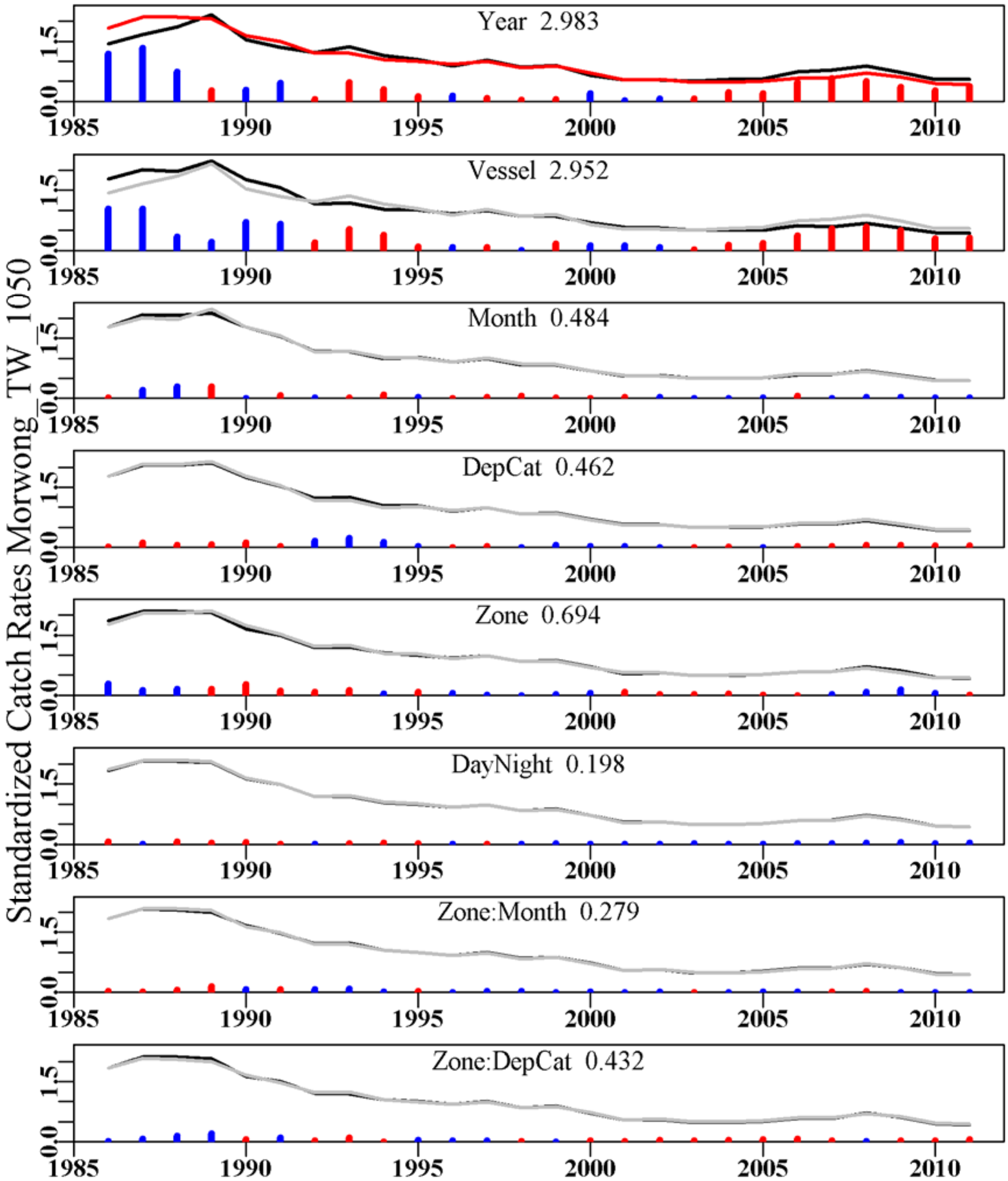

Figure 13.15. The relative influence of each factor used on the final trend in the optimal standardization for Jackass Morwong in Zones 10 – 50. The top graph depicts the geometric mean (the black line) and the optimum model (the red line). The difference between them is illustrated by the vertical bars with blue bars indicating the optimum model is higher than the geometric mean and red bars indicating it is lower. The top graph bars are the sum of all the bars in the graphs below. The graphs for individual factors are cumulative. Thus the second graph has the geometric mean (grey line) and the effect of adding Year + factor2 (model 2). In the third graph, the grey line represents model 2 and the black line the effect of adding factor3 to the model. The remaining graphs continue in the same cumulative manner except for the interaction terms which are added singularly to the final single factor model.

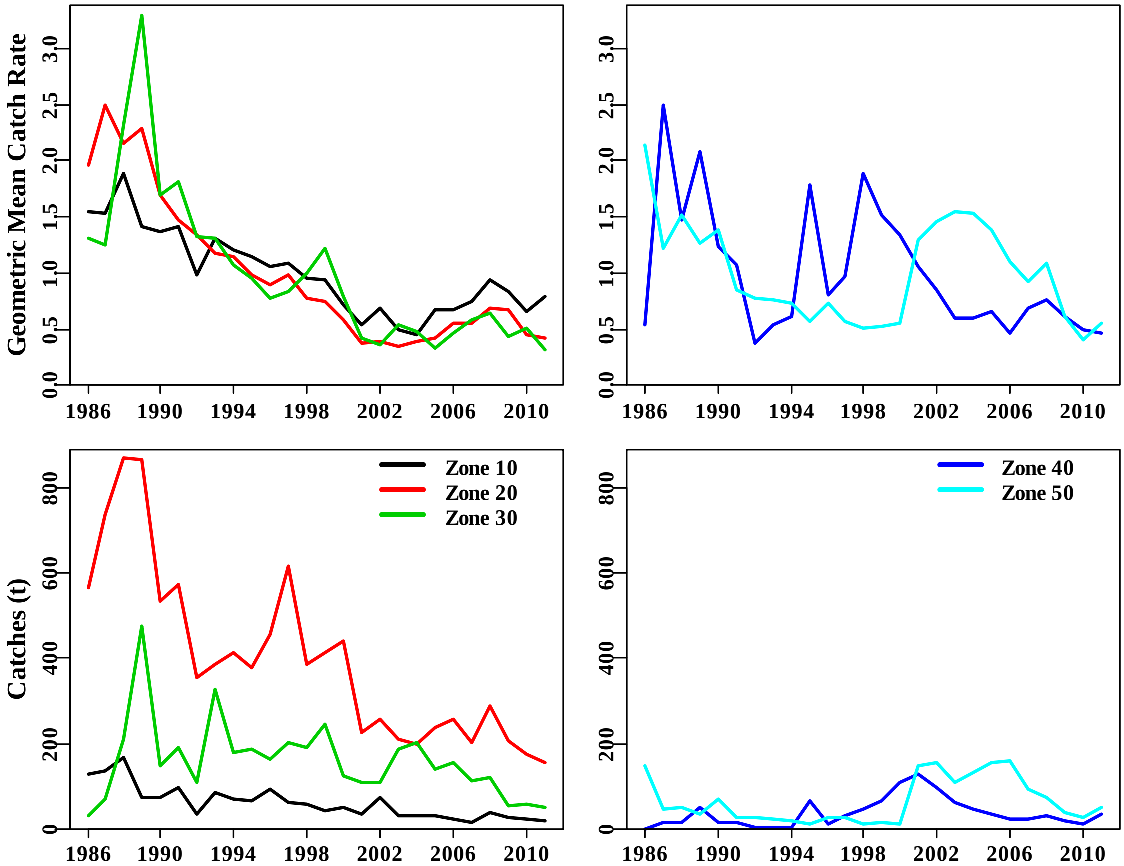

Figure 13.16. The trends in catch and geometric mean catch rates for Jackass Morwong taken by trawl across SESSF zones 10 – 50. The catch rate trends across zones 10 – 30 are very similar, whilst those for zones 40 to 50 are noisy due to low catches until after 1996.

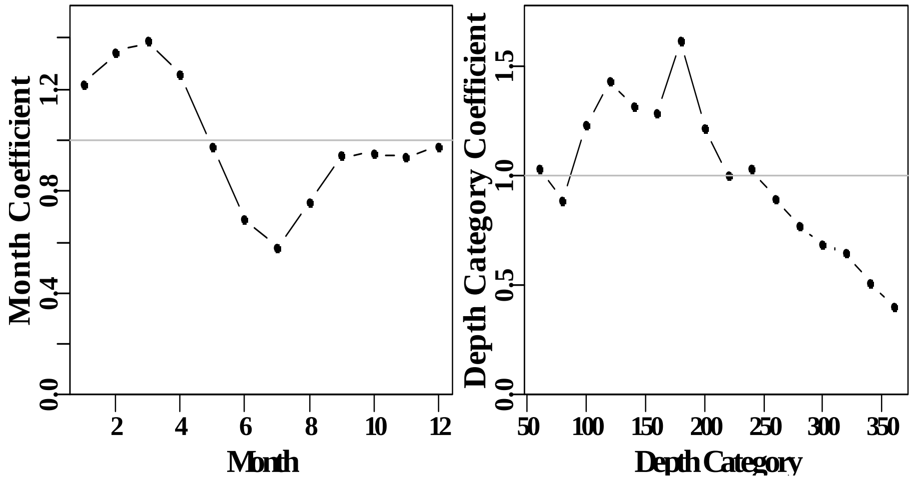

Figure 13.17. The standardized trends for the Month and DepCat factors for Jackass Morwong taken by trawl across SESSF zones 10 – 50.

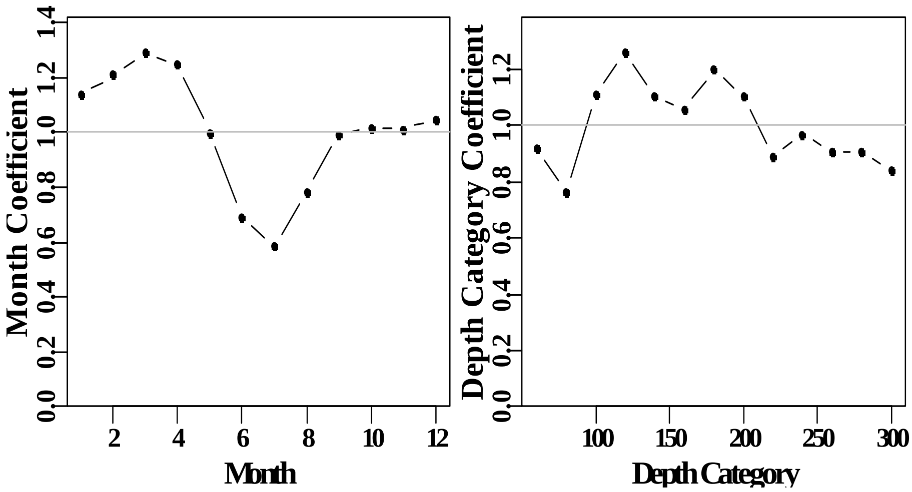

Figure 13.18. The standardized trends for the Month and DepCat factors for Jackass Morwong taken by trawl across SESSF zones 10 – 20.

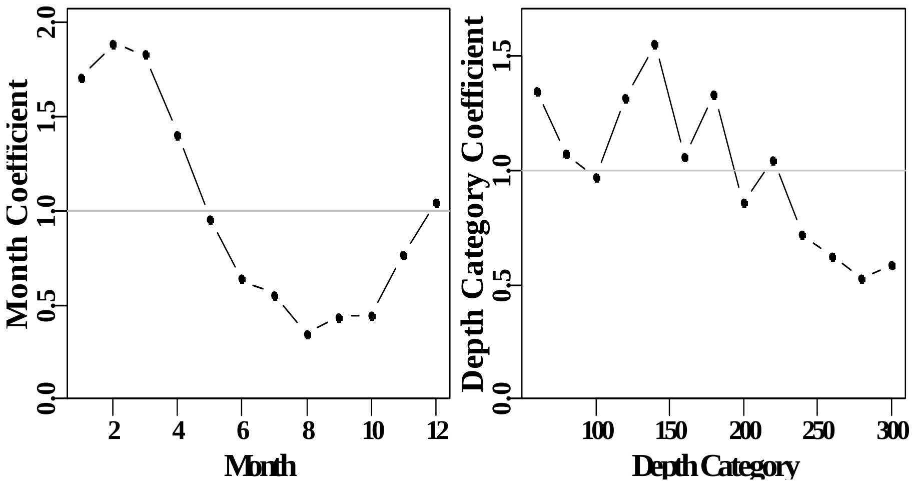

Figure 13.19. The standardized trends for the Month and DepCat factors for Jackass Morwong taken by trawl across SESSF zone 30.

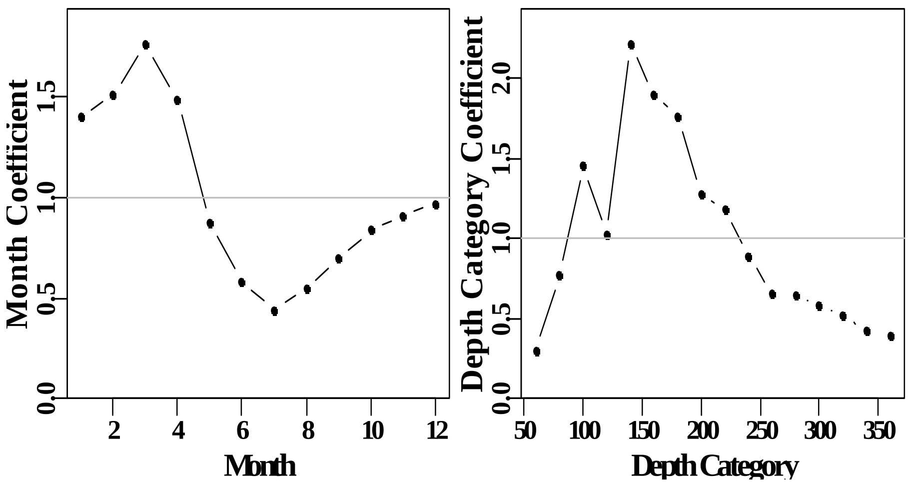

Figure 13.20. The standardized trends for the Month and DepCat factors for Jackass Morwong taken by trawl across SESSF zones 40– 50.

Table 13.14. The split of reported catches in tonnes by zone as taken by trawl in the identified depths. GAB includes zones 82, 83, 84, and 85.

Year	**10**	**20**	**30**	**40**	**50**	**60**	**GAB**
1986	153.290	597.906	32.287	0.400	152.246	27.077	16.565
1987	142.674	770.594	80.446	13.775	46.426	19.748	12.960
1988	177.971	922.634	213.955	16.700	51.072	56.980	41.625
1989	80.174	896.639	505.097	50.770	34.226	39.482	51.348
1990	82.706	606.652	158.494	14.701	68.417	22.015	45.800
1991	107.642	690.990	225.715	14.382	33.105	22.191	32.935
1992	56.005	444.369	132.726	27.490	34.501	7.577	45.160
1993	104.483	431.220	344.380	4.474	21.107	20.498	46.599
1994	105.480	436.446	185.204	4.641	18.665	18.064	46.813
1995	77.205	388.259	187.464	67.835	10.855	3.854	52.929
1996	97.641	475.605	162.715	10.917	27.350	6.793	45.263
1997	62.813	652.029	205.295	29.995	27.213	13.946	66.733
1998	58.295	441.898	193.305	45.258	12.960	13.458	72.596
1999	44.685	445.380	249.027	64.502	16.404	8.962	102.751
2000	49.760	475.166	126.249	107.740	13.703	20.428	73.115
2001	37.154	273.619	112.989	137.773	149.603	17.559	52.075
2002	76.130	291.396	110.840	98.844	156.460	15.729	48.200
2003	32.855	240.440	196.687	62.151	114.646	12.053	98.563
2004	31.203	223.494	205.915	48.383	141.841	7.189	104.330
2005	37.108	288.939	151.947	36.915	162.915	8.309	96.830
2006	30.714	289.117	166.045	24.665	167.622	6.735	121.021
2007	14.548	230.969	118.917	25.839	96.708	5.620	109.069
2008	38.791	327.492	122.652	29.875	74.678	6.366	91.719
2009	27.405	230.783	55.928	20.819	45.113	3.843	64.330
2010	21.984	190.938	59.890	13.603	27.382	3.445	39.384
2011	17.680	184.592	51.259	35.147	51.226	11.685	24.997

13.9 Jackass Morwong Z1020 (MOR–37377003 N. macropterus)

Only data from zone 10 and 20 were used for trawl vessels only (i.e. exclude Danish Seine vessels), and depths between 70 and 300 m.

Table 13.15. Jackass Morwong from zones 10 and 20 in depths 70 – 300m by trawl. Total Catch is the total reported in the database, Records is the number of reported records used in the analysis, CatchT is the reported catch in the area and depth used in the analysis, and Vessels relates to all vessels used in the analysis. Geomean is the geometric mean of catch rates (kg/hr). Zone:Mth is the optimum model and StDev is the standard deviation relating to the data in the optimum model.

Year	TotCatch	Records	CatchT	Vessels	GeoMean	Zone:Mth	StDev
1986	982.811	5045	686.225	87	21.2677	1.8013	0.0000
1987	1087.690	4266	858.475	79	26.2295	2.1904	0.0291
1988	1483.512	5147	1025.256	79	27.6740	2.0603	0.0283
1989	1667.373	4325	929.409	65	27.9306	1.9409	0.0293
1990	1001.414	4127	600.553	59	21.9897	1.6146	0.0303
1991	1138.070	4436	661.796	55	19.4037	1.5285	0.0301
1992	758.254	2842	378.592	46	17.3690	1.2047	0.0339
1993	1014.985	3363	464.955	49	17.0123	1.2640	0.0325
1994	818.418	4470	473.423	49	16.1919	1.1081	0.0304
1995	789.528	4600	435.209	47	14.0323	1.0326	0.0301
1996	827.191	6218	544.828	51	12.3880	0.9524	0.0286
1997	1063.363	6031	672.142	53	14.8970	1.0413	0.0294
1998	876.404	4790	435.779	46	11.3605	0.8423	0.0304
1999	961.262	4429	447.847	50	11.3334	0.8527	0.0309
2000	945.098	5719	479.565	54	8.7637	0.6997	0.0296
2001	790.188	4930	258.551	48	5.8826	0.4890	0.0306
2002	811.136	5702	328.002	44	6.3660	0.5411	0.0300
2003	775.123	4585	237.585	47	5.3371	0.4243	0.0310
2004	765.506	4196	220.279	52	5.4124	0.4215	0.0319
2005	784.128	4378	262.616	39	6.8948	0.5102	0.0315
2006	811.298	3417	275.501	36	8.8173	0.6092	0.0332
2007	607.870	2437	212.373	20	9.2385	0.5636	0.0366
2008	700.439	3167	321.578	25	11.2739	0.7233	0.0345
2009	454.352	2447	228.460	19	10.4057	0.6625	0.0367
2010	380.248	2593	193.811	19	7.6433	0.4697	0.0364
2011	422.130	2401	170.945	18	7.3903	0.4519	0.0374

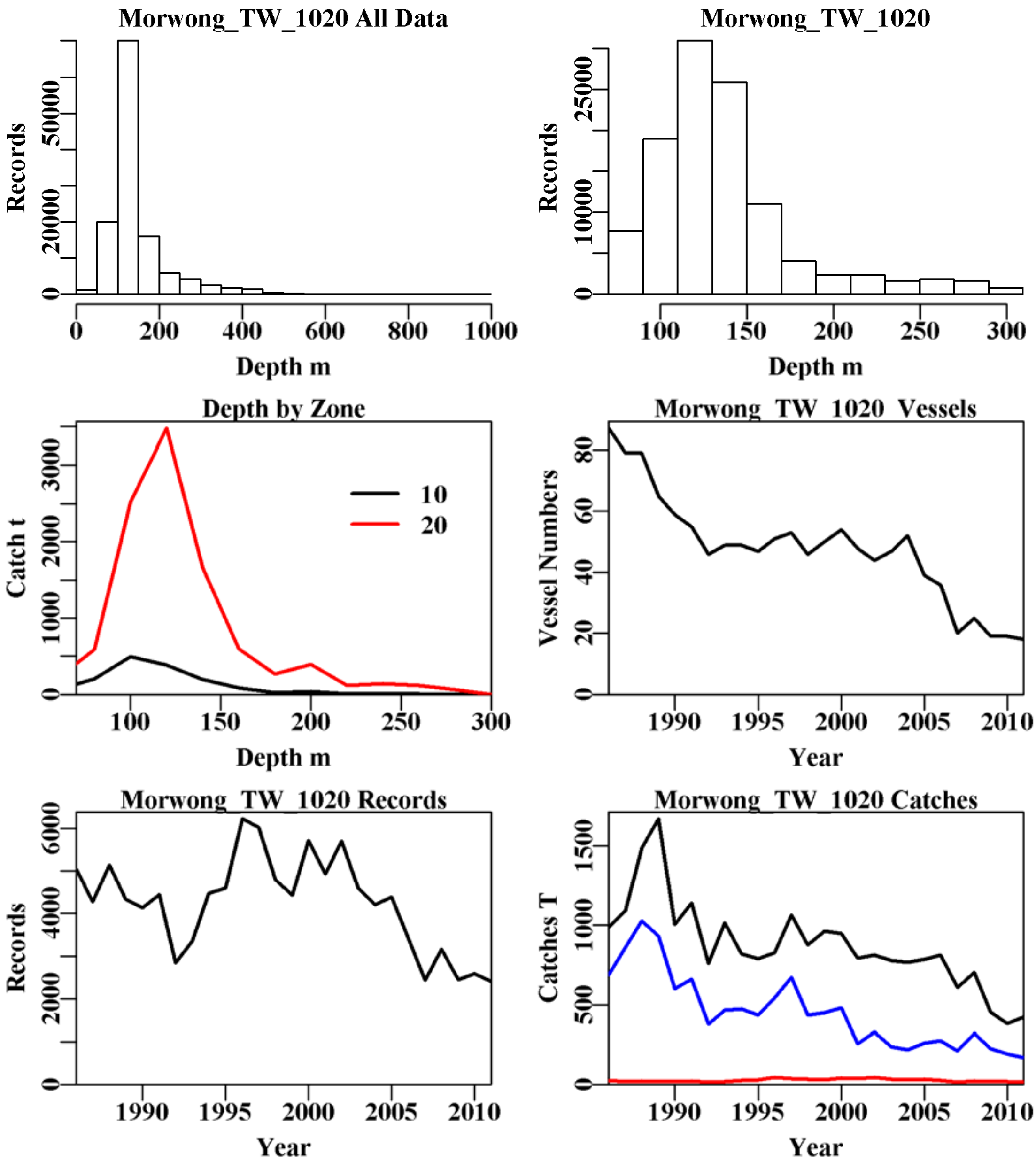

Figure 13.21. Jackass Morwong from zones 10 and 20 in depths 70 – 300m by trawl. The top left is the depth distribution of all records reporting Jackass Morwong, the top right graph depicts the depth distribution of shots containing Jackass Morwong from zones 10 and 20 in depths 70 – 300m by trawl. The middle left diagram depicts the distribution of catch by depth within zones 10 and 20 (20 is top red line), the middle right hand graph depicts the number of vessels through time. The bottom left reflects the number of records used in analysis, and bottom right is the Jackass Morwong catches (top line, black is total catches, middle line, blue, are those used in the analysis, and bottom, red, are catches < 30Kg).

Table 13.16. Jackass Morwong from zones 10 and 20 in depths 70 – 300m by trawl. Statistical model structures used in this analysis. DepCat is a series of 20 metre depth categories.

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

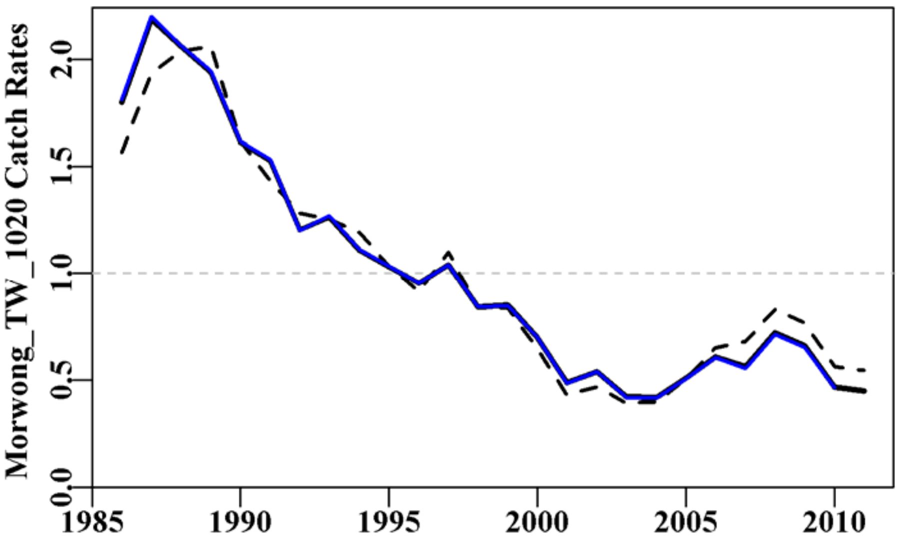

Figure 13.22. Jackass Morwong from zones 10 and 20 in depths 70 – 300m by trawl. The dashed black line represents the geometric mean catch rate and the solid black line the standardized catch rates. The graph standardizes catch rates relative to the mean of the standardized catch rates.

Table 13.17. Jackass Morwong from zones 10 and 20 in depths 70 – 300m by trawl. Model selection criteria, including the AIC, the adjusted r^2 and the change in adjusted r^2. The optimum was model Zone:Month.

	Year	Vessel	Month	DepCat	Zone	DayNight	Zone:Mth	Zone:DepC
AIC	78210	63936	61270	59207	57411	56112	55278	55810
RSS	223893	196049	191319	186963	183908	181721	180301	181179
MSS	29119	56963	61693	66049	69105	71292	72712	71833
Nobs	110061	110061	110061	109099	109099	109099	109099	109099
Npars	26	197	208	220	221	224	235	236
adj_r2	11.489	22.376	24.241	25.957	27.166	28.030	28.585	28.237
%Change	0.000	10.887	1.865	1.715	1.209	0.864	0.555	-0.349

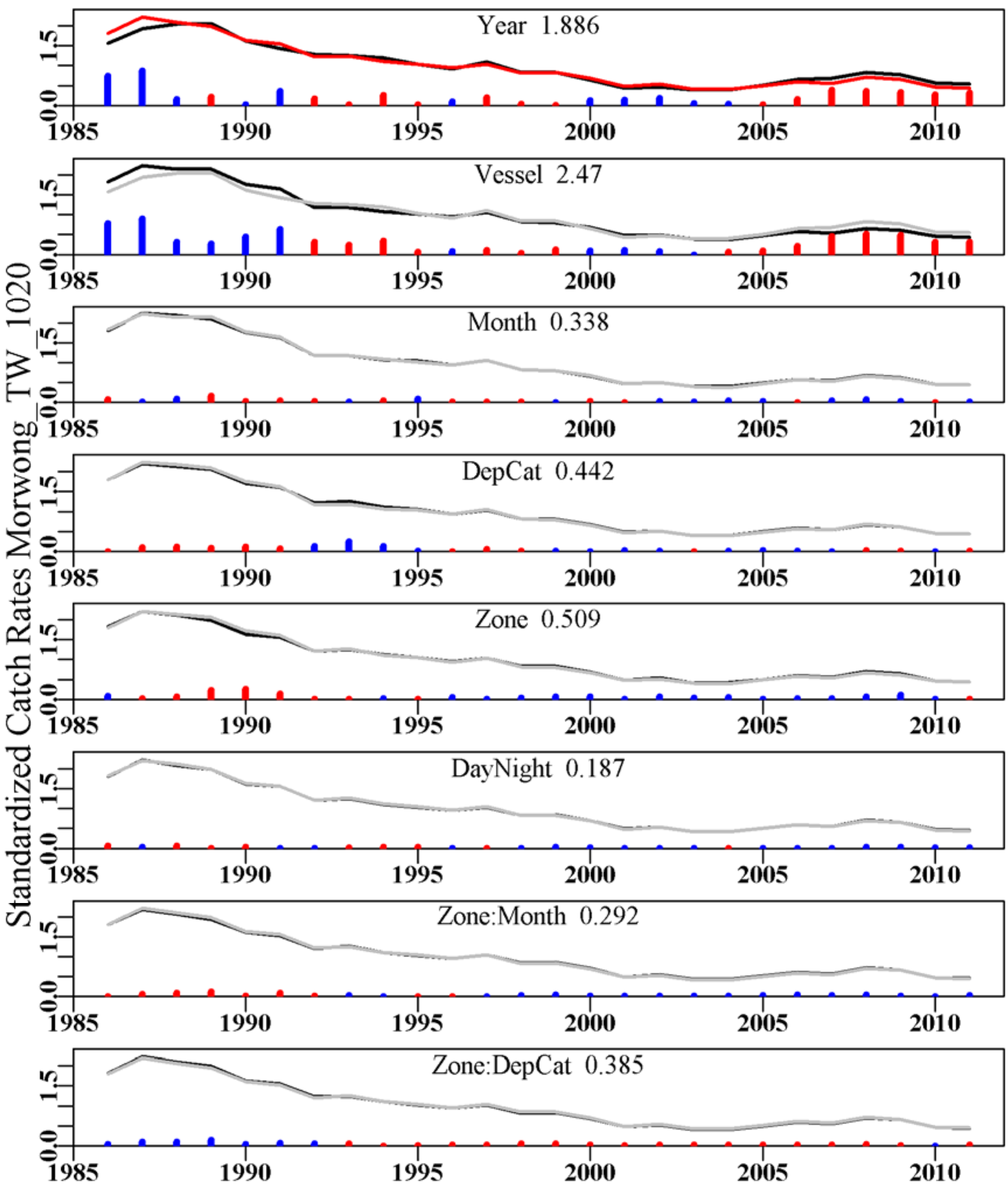

Figure 13.23. The relative influence of each factor used on the final trend in the optimal standardization for Jackass Morwong in Zones 10 – 20. The top graph depicts the geometric mean (the black line) and the optimum model (the red line). The difference between them is illustrated by the vertical bars with blue bars indicating the optimum model is higher than the geometric mean and red bars indicating it is lower. The top graph bars are the sum of all the bars in the graphs below. The graphs for individual factors are cumulative. Thus the second graph has the geometric mean (grey line) and the effect of adding Year + factor2 (model 2). In the third graph, the grey line represents model 2 and the black line the effect of adding factor3 to the model. The remaining graphs continue in the same cumulative manner except for the interaction terms which are added singularly to the final single factor model.

13.10 Jackass Morwong Z30 (MOR – 37377003 N. macropterus)

Only data from zone 30 were used, depths between 70 and 300 m taken by trawl.

Table 13.18. Jackass Morwong from zone 30 in depths 70 – 300m by trawl. Total Catch is the total reported in the database, Records is the number of records used in the analysis, CatchT is the reported catch in the area and depth used in the analysis, and Vessels relates to all vessels used in the analysis. Geomean is the geometric mean of catch rates (kg/hr). Month:DepCat is the optimum model and StDev is the standard deviation relating to the data in the optimum model.

Year	TotCatch	Records	CatchT	Vessels	GeoMean	Month:DepC	StDev
1986	982.811	69	29.887	6	52.3193	1.7155	0.0000
1987	1087.690	210	57.476	13	45.8807	1.8206	0.1762
1988	1483.512	283	207.935	13	90.9064	2.4624	0.1710
1989	1667.373	687	475.039	19	125.0173	3.0771	0.1642
1990	1001.414	386	148.857	26	64.6762	2.2018	0.1649
1991	1138.070	427	189.534	29	68.3860	1.4168	0.1633
1992	758.254	335	106.819	18	50.3448	1.5066	0.1680
1993	1014.985	1042	325.873	27	49.6567	1.2045	0.1580
1994	818.418	762	180.185	22	40.3412	0.8326	0.1590
1995	789.528	826	185.282	19	36.4017	0.8047	0.1599
1996	827.191	890	161.402	19	29.4500	0.8239	0.1588
1997	1063.363	940	202.389	15	32.4284	0.9798	0.1573
1998	876.404	772	191.733	15	38.4649	0.9081	0.1587
1999	961.262	855	246.913	17	46.7614	1.0608	0.1592
2000	945.098	552	123.785	22	30.7755	0.7116	0.1611
2001	790.188	796	108.097	19	16.1559	0.4402	0.1583
2002	811.136	1044	108.944	15	13.9509	0.3855	0.1579
2003	775.123	1126	187.053	19	20.4814	0.5377	0.1569
2004	765.506	1500	201.278	15	18.1516	0.4021	0.1561
2005	784.128	1159	137.710	17	12.3142	0.2886	0.1574
2006	811.298	1127	154.482	14	17.6164	0.3623	0.1579
2007	607.870	714	111.625	8	22.5650	0.5004	0.1600
2008	700.439	768	119.020	9	24.1797	0.5271	0.1599
2009	454.352	463	54.343	10	16.5669	0.3751	0.1634
2010	380.248	372	58.189	9	19.1085	0.3938	0.1664
2011	422.130	452	48.260	8	11.9546	0.2606	0.1640

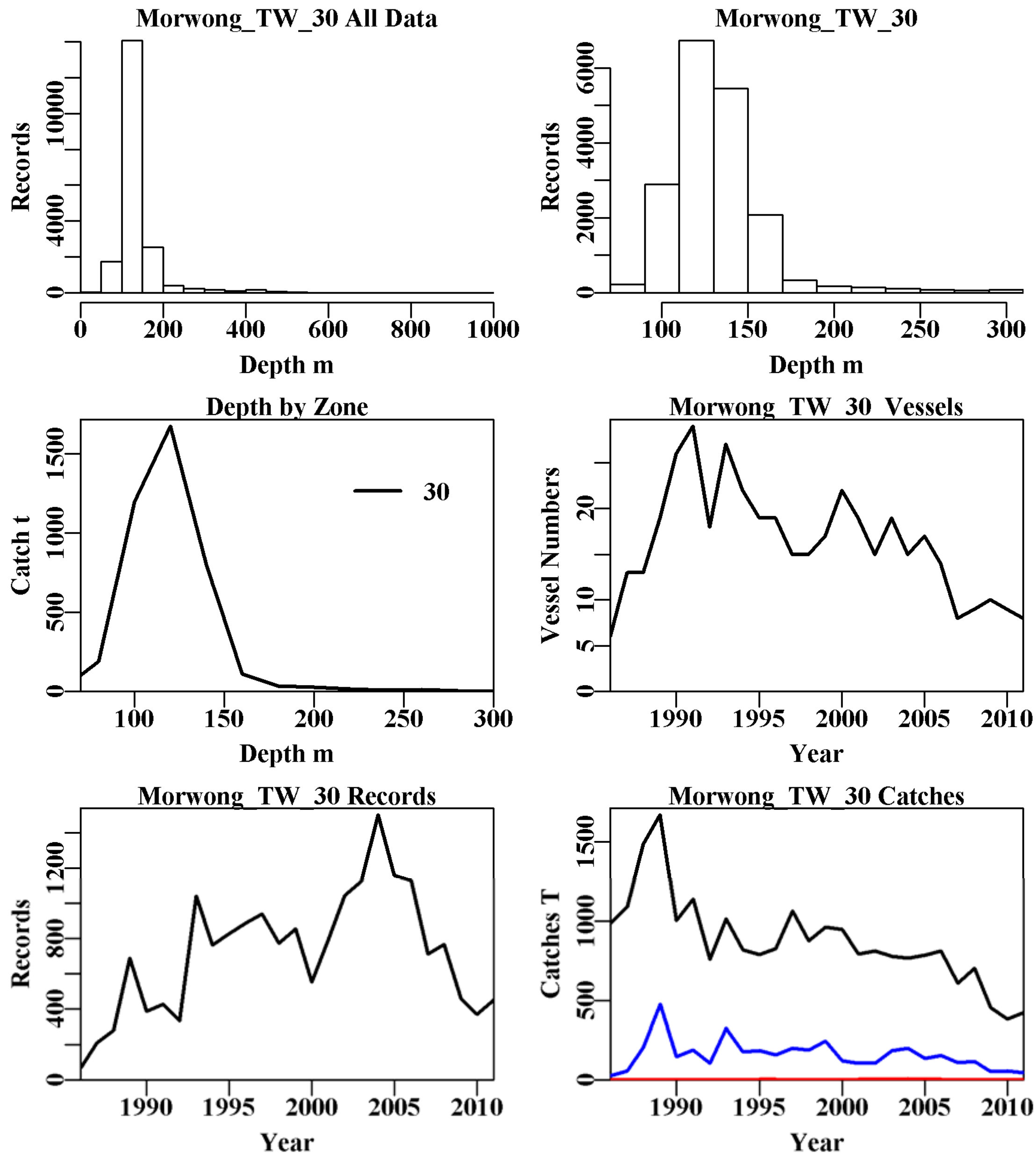

Figure 13.24. Jackass Morwong from zone 30 in depths 70 – 300m by trawl. The top left is the depth distribution of all records reporting Jackass Morwong, the top right graph depicts the depth distribution of shots containing Jackass Morwong from zone 30 in depths 70 – 300m by trawl. The middle left diagram depicts the distribution of catch by depth within zone 30, the middle right hand graph depicts the number of vessels through time. The bottom left reflects the number of records used in analysis, and bottom right is the Jackass Morwong catches (top line, black is total catches, middle line, blue, are those used in the analysis, and bottom, red, are catches < 30Kg).

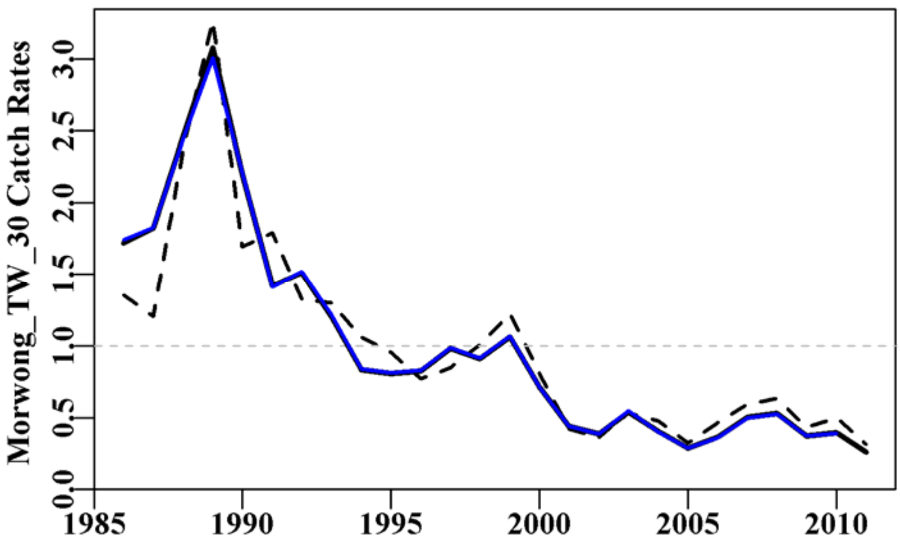

Figure 13.25. Jackass Morwong from zone 30 in depths 70 – 300m by trawl. The dashed black line represents the geometric mean catch rate and the solid black line the standardized catch rates. The graph standardizes catch rates relative to the mean of the standardized catch rates.

Table 13.19. Jackass Morwong from zone 30 in depths 70 – 300m by trawl. Statistical model structures used in this analysis. DepCat is a series of 20 metre depth categories.

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

Table 13.20. Jackass Morwong from zone 30 in depths 70 – 300m by trawl. Model selection criteria, including the AIC, the adjusted r2 and the change in adjusted r2. The optimum was model Month:DepCat.

	Year	Month	Vessel	DepC	DN	DN:Mth	Mth:DepC	DN:DepC
AIC	9058	7165	6093	5614	5492	5449	5398	5533
RSS	30150	27193	25418	24554	24383	24239	23912	24342
MSS	6284	9241	11016	11880	12051	12196	12522	12092
Nobs	18557	18557	18557	18361	18361	18361	18361	18361
Npars	26	37	127	139	142	175	274	178
adj_r2	17.137	25.219	29.758	32.098	32.558	32.837	33.379	32.539
%Change	0.000	8.081	4.539	2.340	0.461	0.278	0.542	-0.840

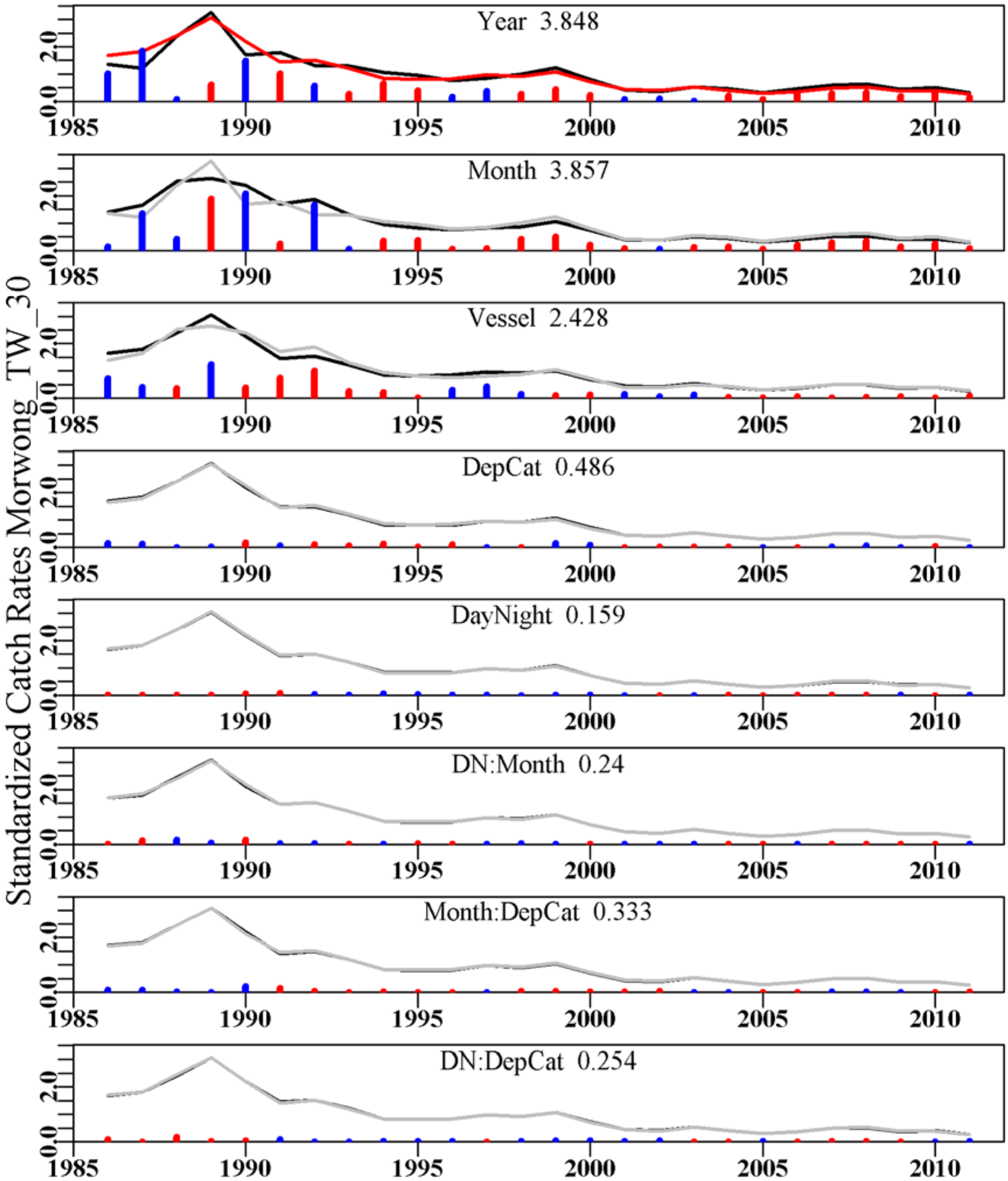

Figure 13.26. The relative influence of each factor used on the final trend in the optimal standardization for Jackass Morwong in Zone 30. The top graph depicts the geometric mean (the black line) and the optimum model (the red line). The difference between them is illustrated by the vertical bars with blue bars indicating the optimum model is higher than the geometric mean and red bars indicating it is lower. The top graph bars are the sum of all the bars in the graphs below. The graphs for individual factors are cumulative. Thus the second graph has the geometric mean (grey line) and the effect of adding Year + factor2 (model 2). In the third graph, the grey line represents model 2 and the black line the effect of adding factor3 to the model. The remaining graphs continue in the same cumulative manner except for the interaction terms which are added singularly to the final single factor model.

13.11 Jackass Morwong Z4050 OT (MOR – 37377003 N. macropterus)

The data restrictions used in selecting the data for analysis were, depths between 70 and 360 m.

Table 13.21. Jackass Morwong from zones 40 and 50 in depths 70 – 360m by trawl. Total Catch is the total reported in the database, Records is the number of records used in the analysis, CatchT is the reported catch in the area and depth used in the analysis, and Vessels relates to all vessels used in the analysis. Geomean is the geometric mean of catch rates (kg/hr). Zone:Mth is the optimum model and StDev is the standard deviation relating to the data in the optimum model.

Year	TotCatch	Records	CatchT	Vessels	GeoMean	Zone:Mth	StDev
1986	982.811	551	149.261	19	40.7569	1.8476	0.0000
1987	1087.690	350	58.464	21	24.4475	1.4499	0.0873
1988	1483.512	402	65.444	19	32.2567	2.1629	0.0876
1989	1667.373	346	83.203	21	32.2213	1.5649	0.0924
1990	1001.414	412	80.657	22	28.9610	1.5788	0.0938
1991	1138.070	281	40.380	26	18.6097	1.0830	0.0980
1992	758.254	252	28.878	14	15.3915	0.8735	0.1009
1993	1014.985	248	24.971	17	15.5454	0.8514	0.1021
1994	818.418	312	22.679	16	14.6606	0.8207	0.0954
1995	789.528	295	77.615	17	21.5262	0.8724	0.0964
1996	827.191	346	37.071	17	15.3414	0.9493	0.0937
1997	1063.363	489	53.851	20	12.8372	0.7580	0.0870
1998	876.404	267	54.630	19	14.8359	0.7991	0.0990
1999	961.262	383	77.235	17	15.5951	0.7257	0.0917
2000	945.098	429	118.868	25	22.5254	1.0187	0.0919
2001	790.188	914	273.953	25	34.2135	1.0783	0.0810
2002	811.136	860	251.749	22	33.1596	1.0560	0.0814
2003	775.123	655	171.726	24	30.9832	0.9012	0.0847
2004	765.506	681	176.677	25	30.6678	0.9677	0.0837
2005	784.128	722	190.703	21	28.0502	1.0456	0.0832
2006	811.298	818	183.204	19	21.6176	0.8384	0.0823
2007	607.870	594	115.405	15	19.7196	0.6831	0.0851
2008	700.439	473	101.945	16	24.9534	0.6936	0.0883
2009	454.352	413	59.154	13	14.8023	0.5479	0.0913
2010	380.248	411	38.336	13	10.0135	0.4047	0.0908
2011	422.130	621	82.817	14	12.6335	0.4278	0.0864

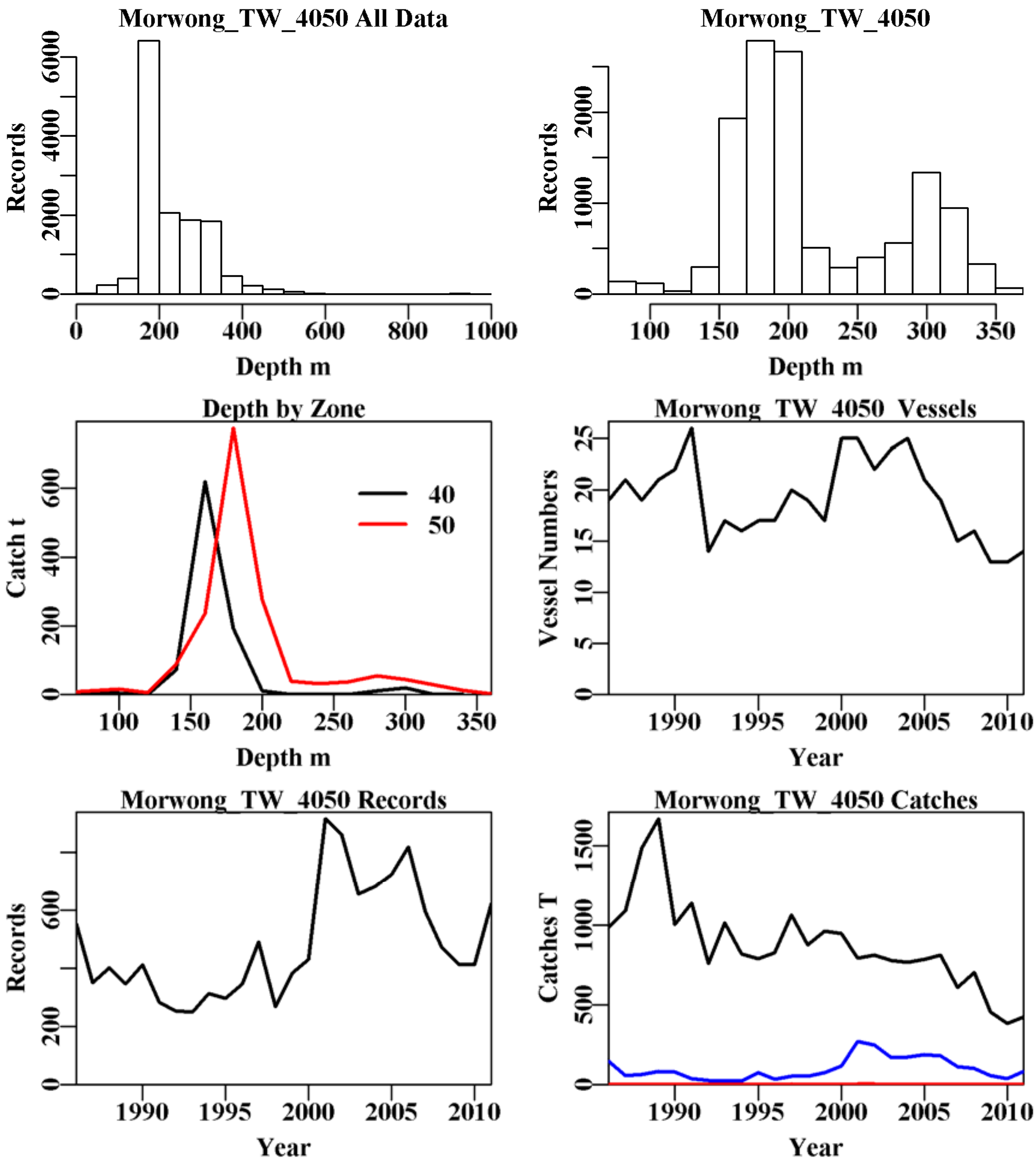

Figure 13.27. Jackass Morwong from zones 40 and 50 in depths 70 – 360m by trawl. The top left is the depth distribution of all records reporting Jackass Morwong, the top right graph depicts the depth distribution of shots containing Jackass Morwong from zone 40 and 50 in depths 70 – 360m by trawl. The middle left diagram depicts the distribution of catch by depth within zone40 and 50 (50 is top red line), the middle right hand graph depicts the number of vessels through time. The bottom left reflects the number of records used in analysis, and bottom right is the Jackass Morwong catches (top line, black is total catches, middle line, blue, are those used in the analysis, and bottom, red, are catches < 30Kg).

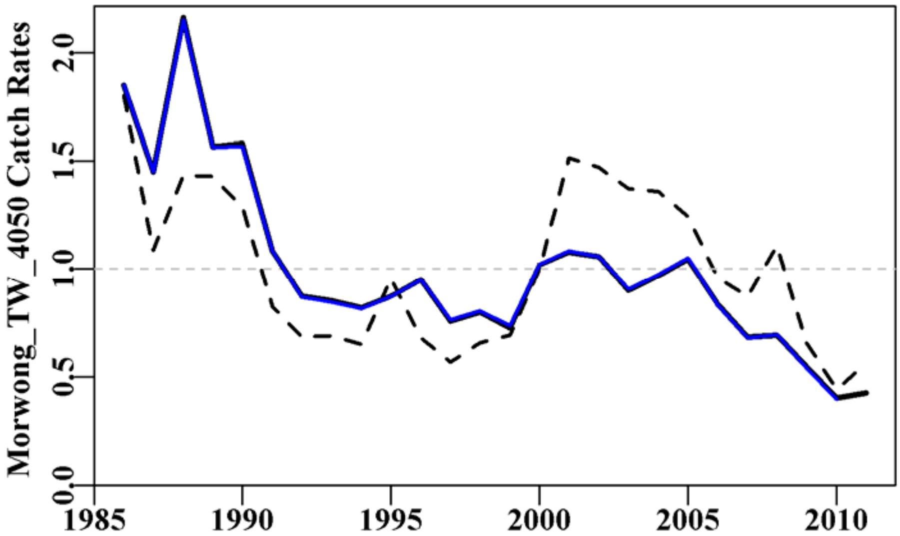

Figure 13.28. Jackass Morwong from zones 40 and 50 in depths 70 – 360m by trawl. The dashed black line represents the geometric mean catch rate and the solid black line the standardized catch rates. The graph standardizes catch rates relative to the mean of the standardized catch rates.

Table 13.22. Jackass Morwong from zones 40 and 50 in depths 70 – 360m by trawl. Statistical model structures used in this analysis. DepCat is a series of 20 metre depth categories.

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

Table 13.23. Jackass Morwong from zones 40 and 50 in depths 70 – 360m by trawl. Model selection criteria, including the AIC, the adjusted r2 and the change in adjusted r2.The optimum was model 7.

	Year	DepCat	Month	Vessel	DayNight	Zone	Zone:Mth	Zone:DepC
AIC	7635	5345	4160	3556	3478	3389	3246	3285
RSS	22946	18985	17229	16194	16086	15968	15758	15797
MSS	1783	5744	7500	8535	8643	8761	8971	8932
Nobs	12525	12433	12433	12433	12433	12433	12433	12433
Npars	26	41	52	135	138	139	150	154
adj_r2	7.025	22.979	30.041	33.800	34.228	34.702	35.505	35.323
%Change	0.000	15.954	7.062	3.759	0.428	0.474	0.803	-0.182

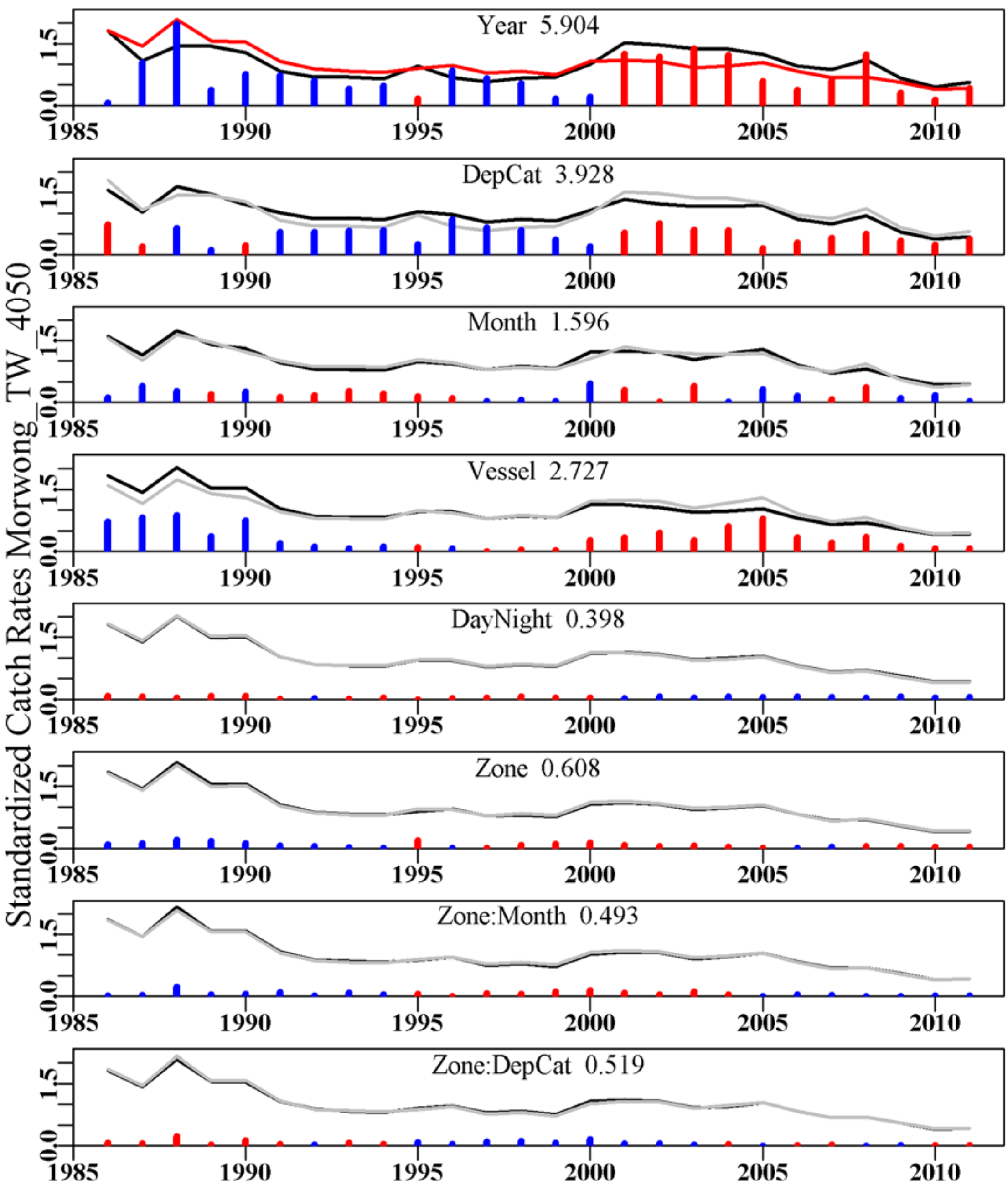

Figure 13.29. The relative influence of each factor used on the final trend in the optimal standardization for Jackass Morwong in Zones 40 – 50. The top graph depicts the geometric mean (the black line) and the optimum model (the red line). The difference between them is illustrated by the vertical bars with blue bars indicating the optimum model is higher than the geometric mean and red bars indicating it is lower. The top graph bars are the sum of all the bars in the graphs below. The graphs for individual factors are cumulative. Thus the second graph has the geometric mean (grey line) and the effect of adding Year + factor2 (model 2). In the third graph, the grey line represents model 2 and the black line the effect of adding factor3 to the model. The remaining graphs continue in the same cumulative manner except for the interaction terms which are added singularly to the final single factor model.

13.12 Flathead Trawl (FLT – 37296001 – Neoplatycephalus richardsoni)

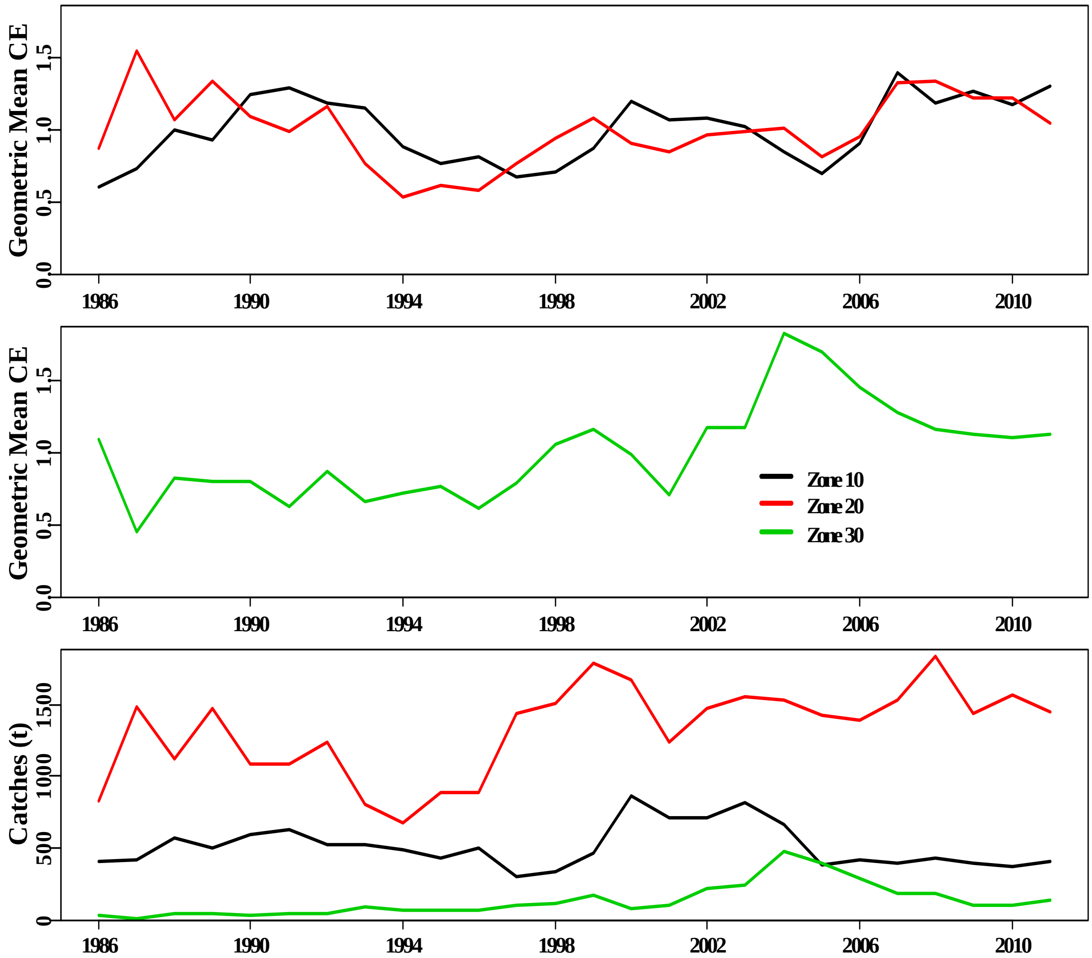

Figure 13.30. The trends in catches and geometric mean catch rates for flathead as taken by trawl in Zones 10 to 30. The catch rate trends in 10 and 20 are similar to each other but are different from that expressed in zone 30. For this reason, zones 10 and 20 are standardized separately from Zone 30.

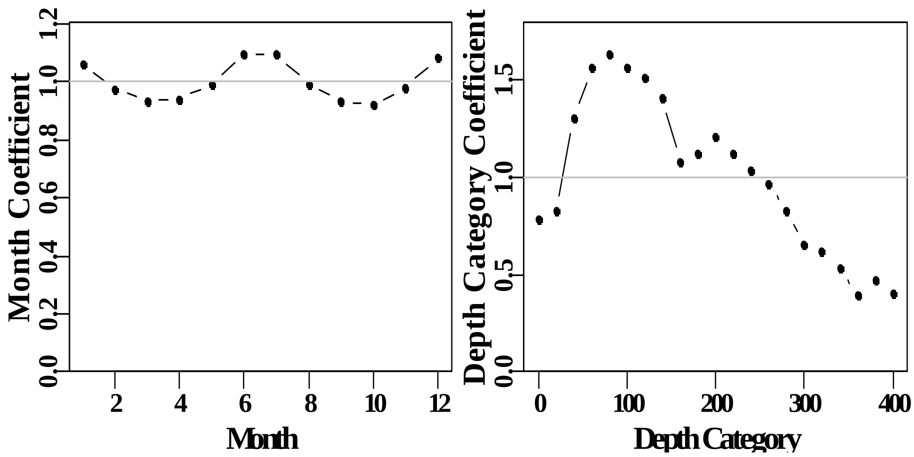

Figure 13.31. The standardized trends for the Month and DepCat factors for Flathead taken by trawl across SESSF zones 10 - 20.

13.13 Flathead Trawl Z1020(FLT – 37296001 – N. richardsoni)

Only data from zones 10 and 20 were used, depths less than 400 m.

Table 13.24. Flathead from zones 10 and 20 in depths 0 – 400m by trawl. Total Catch is the total reported in the database, Records was the number of records used in the analysis, CatchT is the reported catch in the area and depth used in the analysis, and Vessels relates to all vessels used in the analysis. Geomean is the geometric mean of catch rates (kg/hr). Zone:DepCat is the optimum model and StDev is the standard deviation relating to the data in the optimum model.

Year	TotCatch	Records	CatchT	Vessels	GeoMean	Zone:DepC	StDev
1986	1892.183	10196	963.031	95	16.7357	0.8010	0.0000
1987	2461.337	8104	1008.332	86	20.4621	1.0713	0.0160
1988	2469.526	9175	1171.699	86	23.7988	1.1721	0.0158
1989	2599.063	8841	1210.472	74	23.9908	1.1672	0.0159
1990	2032.323	7765	1221.459	64	30.1854	1.3861	0.0168
1991	2230.185	7797	1145.652	57	28.7154	1.3155	0.0168
1992	2375.366	6810	871.934	53	23.8898	1.0282	0.0175
1993	1879.140	8782	998.146	58	23.8001	1.0500	0.0167
1994	1710.404	10280	902.906	56	17.9798	0.7610	0.0160
1995	1800.616	10305	994.134	54	18.0790	0.8067	0.0159
1996	1879.872	11089	958.779	59	16.4549	0.7138	0.0158
1997	2355.987	10395	997.137	60	16.8264	0.7166	0.0162
1998	2306.407	9986	999.535	52	17.7430	0.7588	0.0162
1999	3117.465	10377	1129.356	57	20.4344	0.9100	0.0160
2000	2945.581	13110	1696.814	59	24.4338	1.0130	0.0155
2001	2599.512	11957	1375.379	53	22.3118	0.9759	0.0158
2002	2876.253	12357	1444.049	49	22.8273	1.0657	0.0157
2003	3230.066	12879	1593.850	52	22.5536	1.0530	0.0156
2004	3222.611	12220	1343.072	52	19.7879	0.9091	0.0158
2005	2844.045	10703	1154.986	49	17.7159	0.7770	0.0162
2006	2585.823	9137	1148.779	46	22.2550	0.9429	0.0167
2007	2648.311	6337	1076.563	25	31.3544	1.1537	0.0184
2008	2910.286	7292	1330.559	27	31.6602	1.2088	0.0178
2009	2460.393	6311	1060.713	26	30.0219	1.1115	0.0185
2010	2501.518	6872	1124.212	25	29.4565	1.0698	0.0181
2011	2465.166	6764	1095.324	24	28.3798	1.0611	0.0182

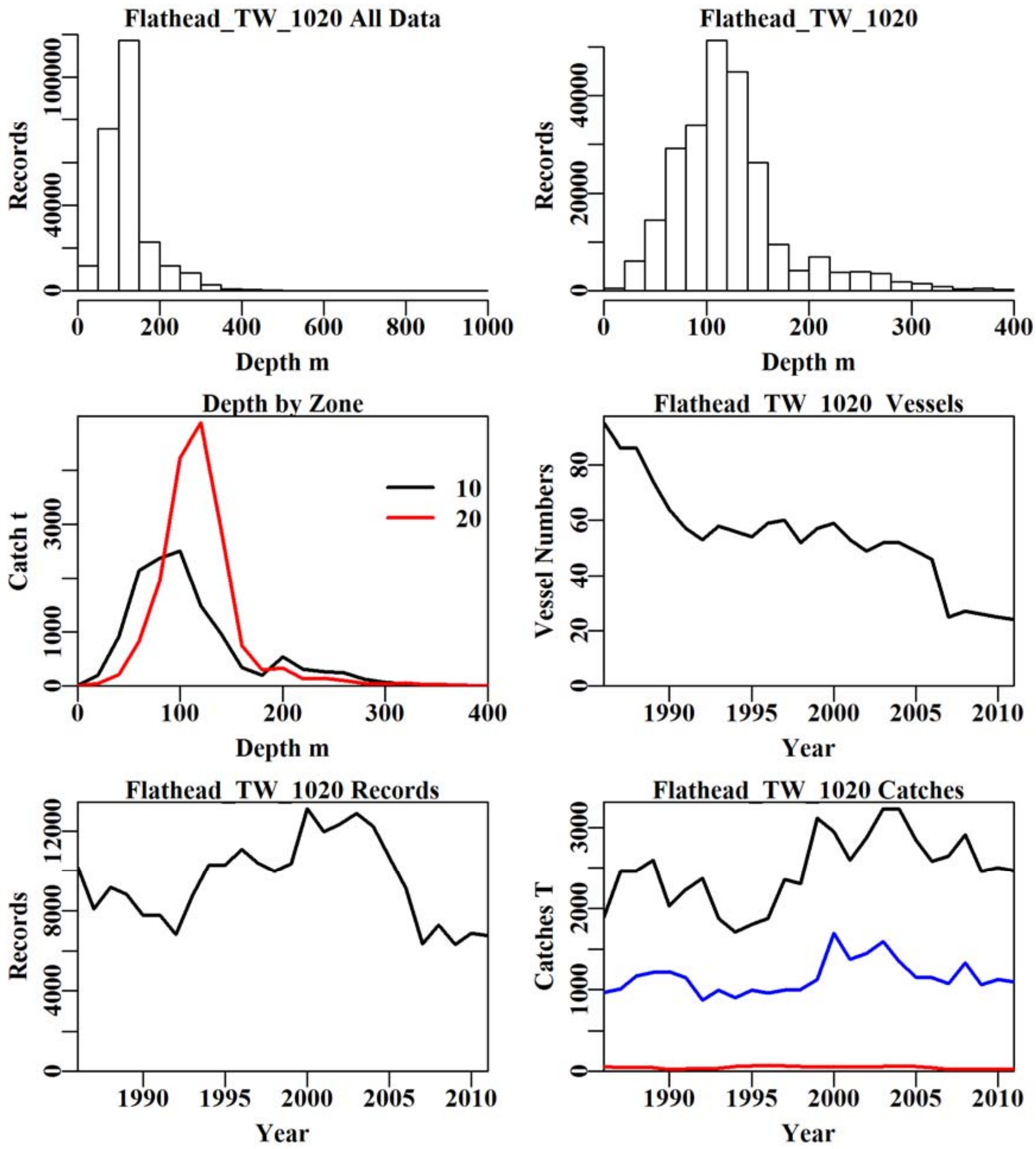

Figure 13.32. Flathead from zones 10 and 20 in depths 0 – 400m by trawl. The top left is the depth distribution of all records reporting Jackass Morwong, the top right graph depicts the depth distribution of shots containing Flathead from zones 10 and 20 in depths 0 – 400m by trawl. The middle left diagram depicts the distribution of catch by depth within zones 10 and 20 (20 is top red line), the middle right hand graph depicts the number of vessels through time. The bottom left reflects the number of records used in analysis, and bottom right is the Flathead catches (top line, black is total catches, middle line, blue, are those used in the analysis, and bottom, red, are catches < 30Kg).

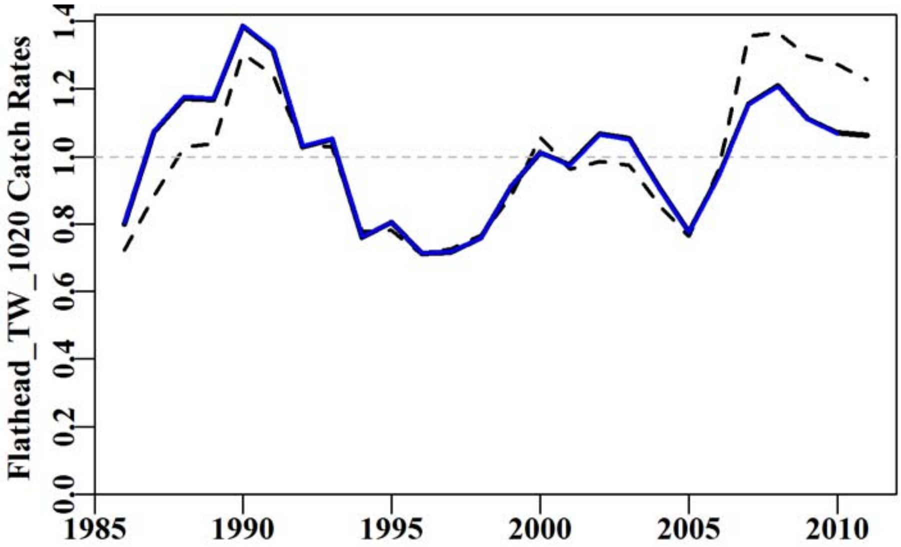

Figure 13.33. Flathead from zones 10 and 20 in depths 0 – 400m by trawl. The dashed black line represents the geometric mean catch rate and the solid black line the standardized catch rates. The graph standardizes catch rates relative to the mean of the standardized catch rates.

Table 13.25. Flathead from zones 10 and 20 in depths 0 – 400m by trawl. Statistical model structures used in this analysis. DepCat is a series of 20 metre depth categories.

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

Table 13.26. Flathead from zones 10 and 20 in depths 0 – 400m by trawl. Model selection criteria, including the AIC, the adjusted r2 and the change in adjusted r2. The optimum was model Zone:DepCat.

	Year	Vessel	DepCat	Month	DayNight	Zone	Zone:Month	Zone:DepCat
AIC	44640	17349	9494	8636	8503	8456	6606	5504
RSS	294728	263379	253108	252197	252053	252002	250075	248929
MSS	9583	40932	51203	52114	52258	52309	54236	55382
Nobs	245841	245841	243892	243892	243892	243892	243892	243892
Npars	26	204	224	235	238	239	250	259
adj_r2	3.139	13.379	16.750	17.046	17.092	17.108	17.738	18.112
%Change	0.000	10.240	3.371	0.296	0.046	0.016	0.630	0.374

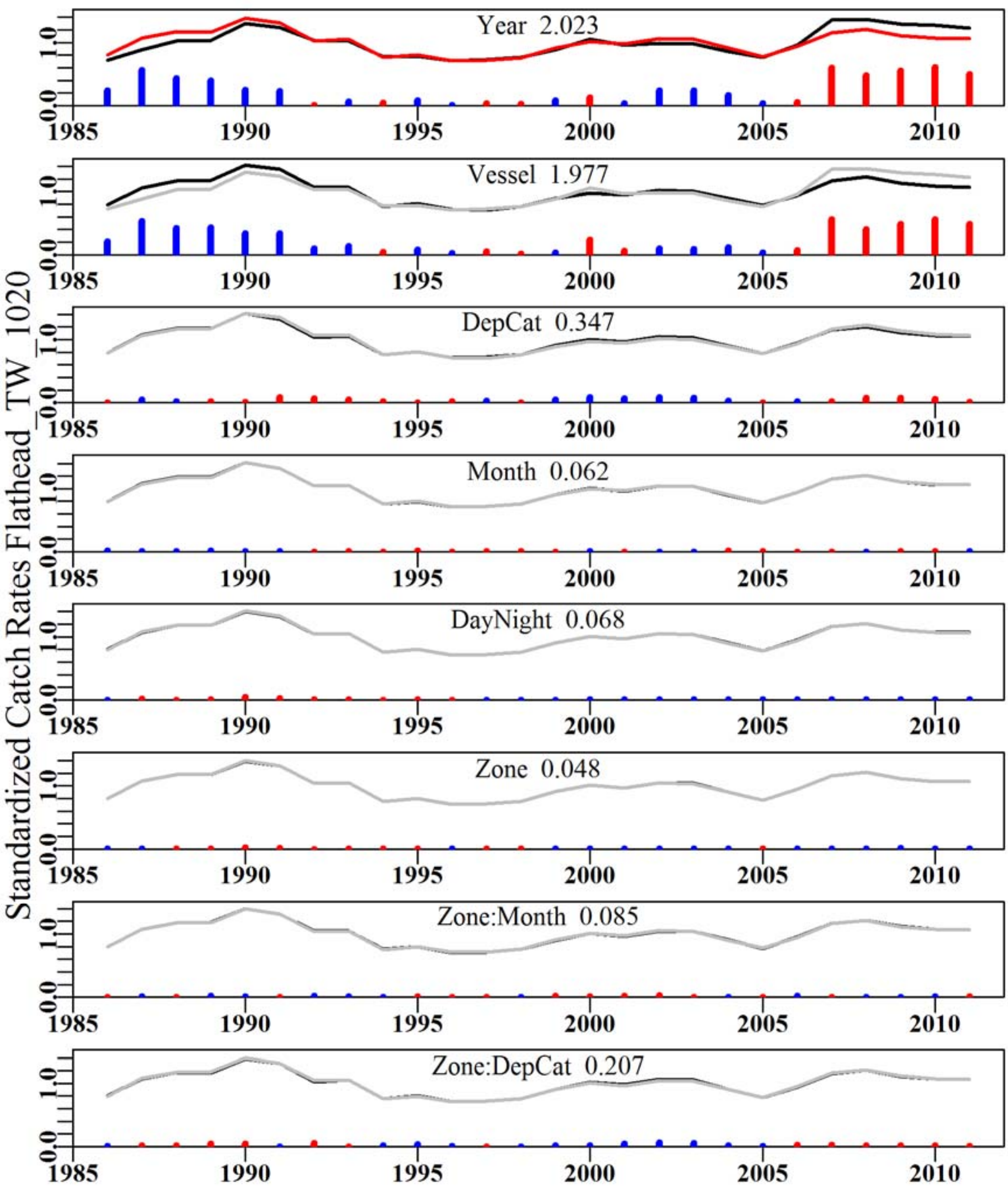

Figure 13.34. The relative influence of each factor used on the final trend in the optimal standardization for Flathead in Zones 10 – 20. The top graph depicts the geometric mean (the black line) and the optimum model (the red line). The difference between them is illustrated by the vertical bars with blue bars indicating the optimum model is higher than the geometric mean and red bars indicating it is lower. The top graph bars are the sum of all the bars in the graphs below. The graphs for individual factors are cumulative. Thus the second graph has the geometric mean (grey line) and the effect of adding Year + factor2 (model 2). In the third graph, the grey line represents model 2 and the black line the effect of adding factor3 to the model. The remaining graphs continue in the same cumulative manner except for the interaction terms which are added singularly to the final single factor model.

13.14 Flathead Trawl Z30 (FLT – 37296001 – N. richardsoni)

Only data from zone 30 were used, depths less than 400 m.

Table 13.27. Flathead from zone 30 in depths 0 – 400m by trawl. Total Catch is the total reported in the database, Records was the number of records used in the analysis, CatchT is the reported catch in the area and depth used in the analysis, and Vessels relates to all vessels used in the analysis. Geomean is the geometric mean of catch rates (kg/hr). Month:DepCat is the optimum model and StDev is the standard deviation relating to the data in the optimum model.

Year	TotCatch	Records	CatchT	Vessels	GeoMean	Mth:DepC	StDev
1986	1892.183	71	16.754	6	23.1157	0.9649	0.0000
1987	2461.337	90	5.155	9	11.1912	0.5830	0.1898
1988	2469.526	193	39.976	9	21.2587	1.0107	0.1701
1989	2599.063	516	48.443	19	20.5177	0.7583	0.1625
1990	2032.323	253	24.619	27	20.3187	0.7837	0.1647
1991	2230.185	314	33.353	29	15.9189	0.7143	0.1608
1992	2375.366	272	33.897	15	22.4408	0.6725	0.1649
1993	1879.140	902	92.079	24	17.1065	0.6436	0.1563
1994	1710.404	612	64.487	17	18.5289	0.6696	0.1573
1995	1800.616	694	71.349	17	19.8905	0.7323	0.1576
1996	1879.872	714	61.425	17	15.7596	0.6761	0.1571
1997	2355.987	885	104.875	14	20.7052	0.8488	0.1554
1998	2306.407	707	118.552	14	28.8666	1.0027	0.1563
1999	3117.465	770	175.052	17	31.0992	1.1046	0.1567
2000	2945.581	520	83.664	20	25.4446	0.8942	0.1580
2001	2599.512	916	101.308	17	18.0579	0.7669	0.1553
2002	2876.253	1367	212.158	15	30.1174	1.4329	0.1544
2003	3230.066	1454	240.110	21	30.0485	1.4655	0.1538
2004	3222.611	1923	477.416	15	47.0053	1.9274	0.1534
2005	2844.045	1540	388.325	18	43.4956	1.7224	0.1539
2006	2585.823	1315	287.968	13	37.5195	1.3838	0.1547
2007	2648.311	823	173.155	8	33.0381	1.1403	0.1562
2008	2910.286	874	173.739	11	29.3148	1.0596	0.1560
2009	2460.393	600	100.225	10	29.0939	1.0262	0.1576
2010	2501.518	537	104.186	10	28.3260	1.0402	0.1586
2011	2465.166	623	131.274	9	29.1229	0.9756	0.1577

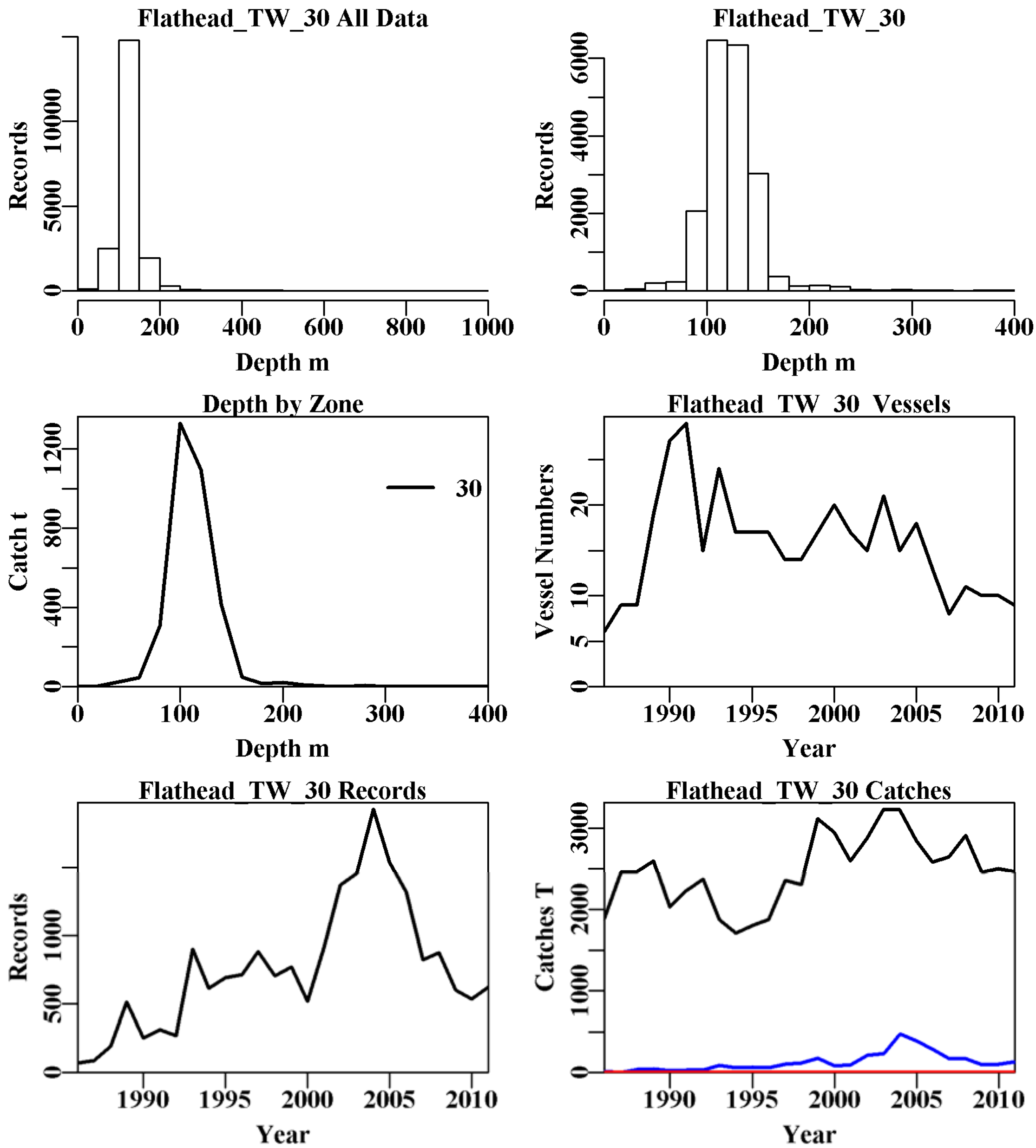

Figure 13.35. Flathead from zone 30 in depths 0 – 400m by trawl. The top left is the depth distribution of all records reporting Flathead, the top right graph depicts the depth distribution of shots containing Flathead from zone 30 in depths 0 – 400m by trawl. The middle left diagram depicts the distribution of catch by depth within zone 30, the middle right hand graph depicts the number of vessels through time. The bottom left reflects the number of records used in analysis, and bottom right is the Flathead catches (top line, black is total catches, middle line, blue, are those used in the analysis, and bottom, red, are catches < 30Kg).

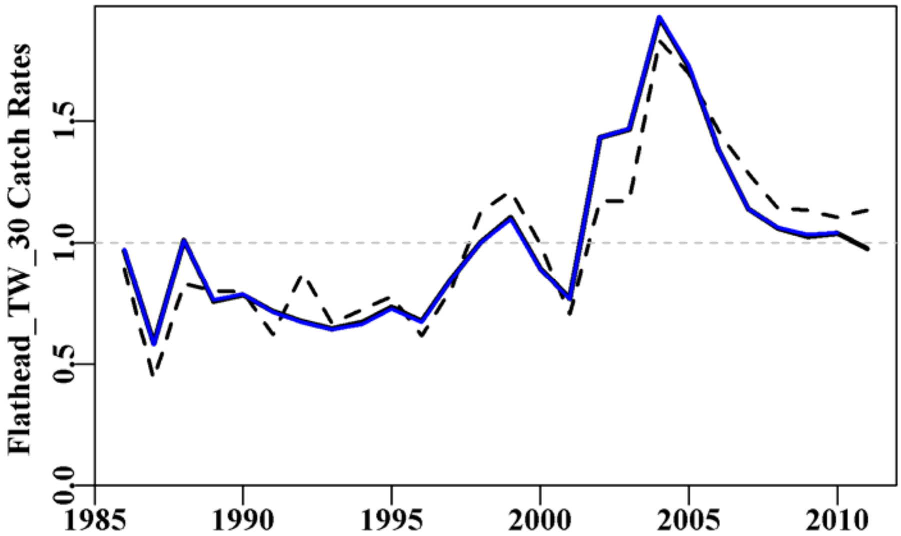

Figure 13.36. Flathead from zone 30 in depths 0 – 400m by trawl. The dashed black line represents the geometric mean catch rate and the solid black line the standardized catch rates. The graph standardizes catch rates relative to the mean of the standardized catch rates.

Table 13.28. Flathead from zone 30 in depths 0 – 400m by trawl. Statistical model structures used in this analysis. DepCat is a series of 20 metre depth categories.

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

Table 13.29. Flathead from zone 30 in depths 0 – 400m by trawl. Model selection criteria, including the AIC, the adjusted r2 and the change in adjusted r2. The optimum was model 7.

	Year	Vessel	DepCat	DN	Mth	DN:Mth	Mth:DepC	DN:DepC
AIC	2767	1076	41	-304	-613	-664	-987	-695
RSS	22398	20352	19052	18708	18390	18279	17629	18198
MSS	2161	4208	5508	5851	6169	6280	6930	6362
Nobs	19485	19485	19278	19278	19278	19278	19278	19278
Npars	26	114	134	137	148	181	368	208
adj_r2	8.683	16.651	21.887	23.283	24.544	24.871	26.825	25.098
%Change	0.000	7.968	5.236	1.396	1.260	0.327	1.954	-1.727

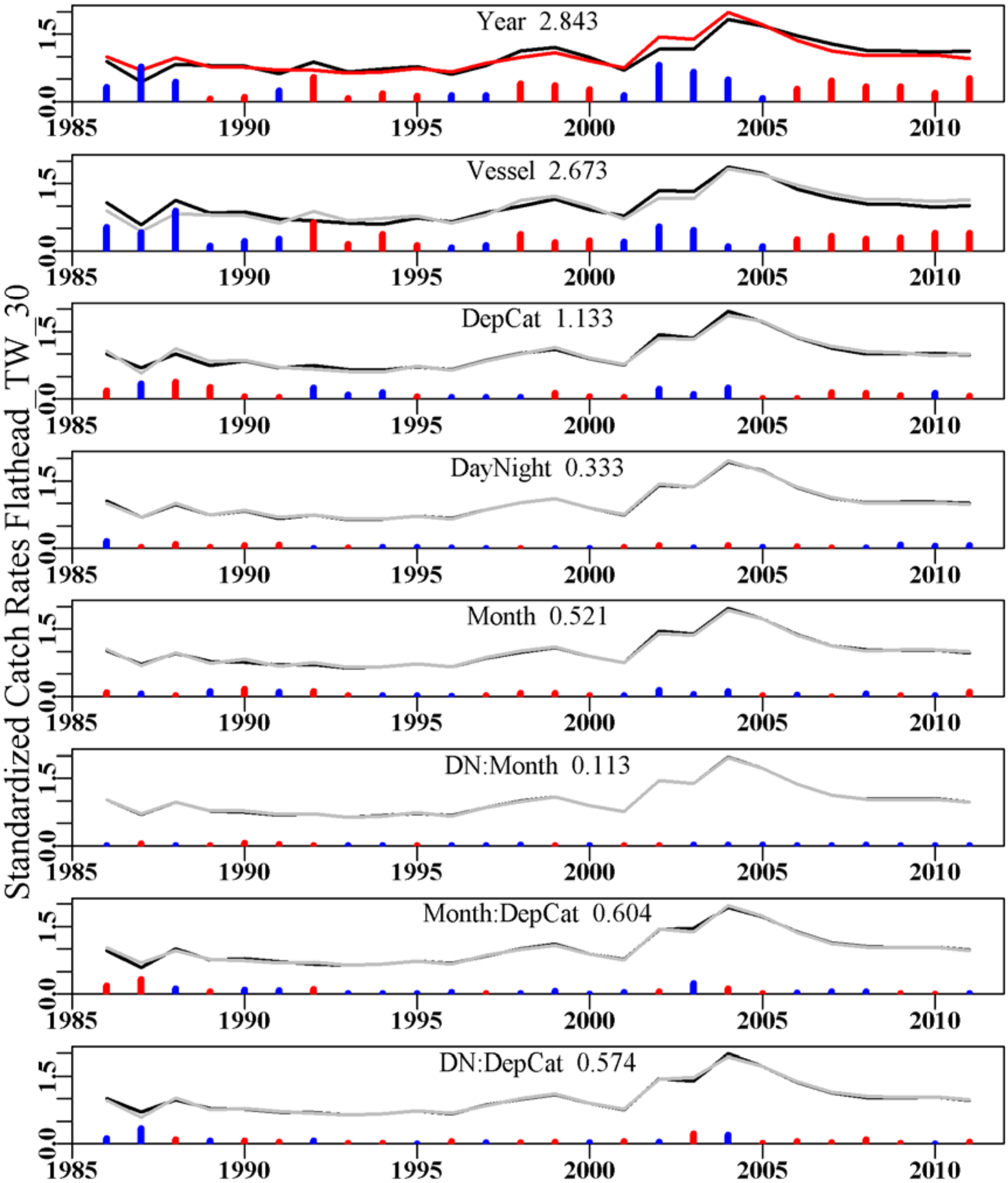

Figure 13.37. The relative influence of each factor used on the final trend in the optimal standardization for Flathead from zone 30. The top graph depicts the geometric mean (the black line) and the optimum model (the red line). The difference between them is illustrated by the vertical bars with blue bars indicating the optimum model is higher than the geometric mean and red bars indicating it is lower. The top graph bars are the sum of all the bars in the graphs below. The graphs for individual factors are cumulative. Thus the second graph has the geometric mean (grey line) and the effect of adding Year + factor2 (model 2). In the third graph, the grey line represents model 2 and the black line the effect of adding factor3 to the model. The remaining graphs continue in the same cumulative manner except for the interaction terms which are added singularly to the final single factor model.

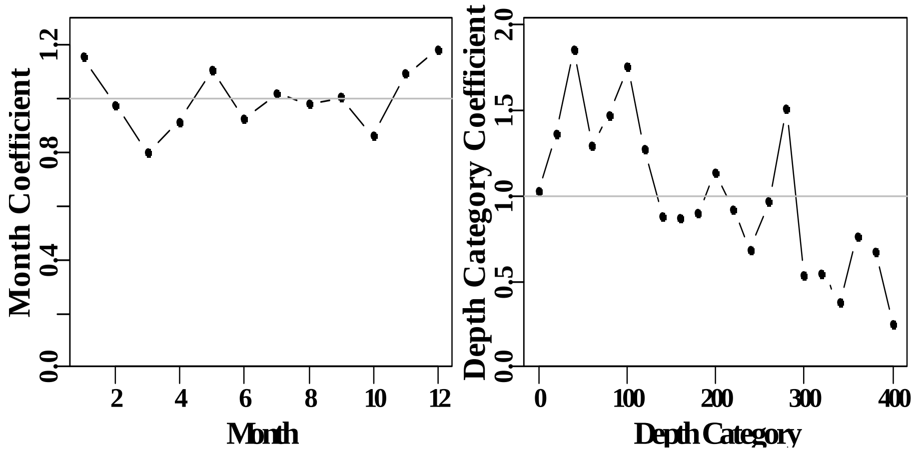

Figure 13.38. The standardized trends for the Month and DepCat factors for Flathead taken by trawl across SESSF zone 30.

13.15 Flathead Danish Seine (FLT – 37296001 – N. richardsoni)

Only data from zones 20, and 60 were used, for Danish Seine vessels only (i.e. exclude Otter Trawl vessels), and depths less than 200 m.

Table 13.30. Flathead from zones 20 and 60 in depths 0 – 200m by Danish Seine. Total Catch is the total reported in the database, Records is the number of records used in the analysis, CatchT is the reported catch in the area and depth used in the analysis, and Vessels relates to all vessels used in the analysis. Geomean is the geometric mean of catch rates (kg/hr). Zone:Month is the optimum model and StDev is the standard deviation relating to the data in the optimum model.

Year	TotCatch	Records	CatchT	Vessels	GeoMean	Zone:Mth	StDev
1986	1892.183	5501	763.945	26	45.0535	1.0196	0.0000
1987	2461.337	5651	1366.944	23	88.6187	1.4382	0.0227
1988	2469.526	5823	1097.541	25	88.9194	1.5679	0.0225
1989	2599.063	5412	1142.708	27	78.4955	1.3677	0.0229
1990	2032.323	4653	586.018	25	48.3882	0.8956	0.0241
1991	2230.185	4670	775.768	28	69.8580	1.2546	0.0242
1992	2375.366	6643	1218.041	24	85.5977	1.3526	0.0223
1993	1879.140	5859	539.588	24	39.0251	0.8576	0.0230
1994	1710.404	7332	649.481	25	37.6721	0.7210	0.0218
1995	1800.616	5505	656.665	21	36.2337	0.7409	0.0232
1996	1879.872	7679	755.670	22	33.6052	0.6993	0.0218
1997	2355.987	8480	1150.436	21	60.3446	0.9063	0.0215
1998	2306.407	9904	1134.732	21	60.5323	0.7587	0.0210
1999	3117.465	8818	1702.605	23	98.4160	1.0917	0.0214
2000	2945.581	7092	1037.689	19	64.0436	0.8036	0.0225
2001	2599.512	7457	1004.507	18	62.0182	0.7550	0.0226
2002	2876.253	8218	1144.075	22	75.2709	0.8971	0.0222
2003	3230.066	9006	1210.597	23	80.7627	0.9580	0.0219
2004	3222.611	7784	1253.026	22	83.7818	0.9388	0.0224
2005	2844.045	7212	1125.753	22	87.7421	0.9572	0.0228
2006	2585.823	5563	968.051	21	89.1577	0.9501	0.0239
2007	2648.311	5551	1182.067	15	104.4620	1.1512	0.0238
2008	2910.286	6214	1283.489	15	103.2936	1.0314	0.0234
2009	2460.393	5499	1168.928	15	91.4234	1.0605	0.0239
2010	2501.518	6048	1166.861	15	101.4483	0.9437	0.0235
2011	2465.166	6887	1121.755	14	85.7656	0.8817	0.0230

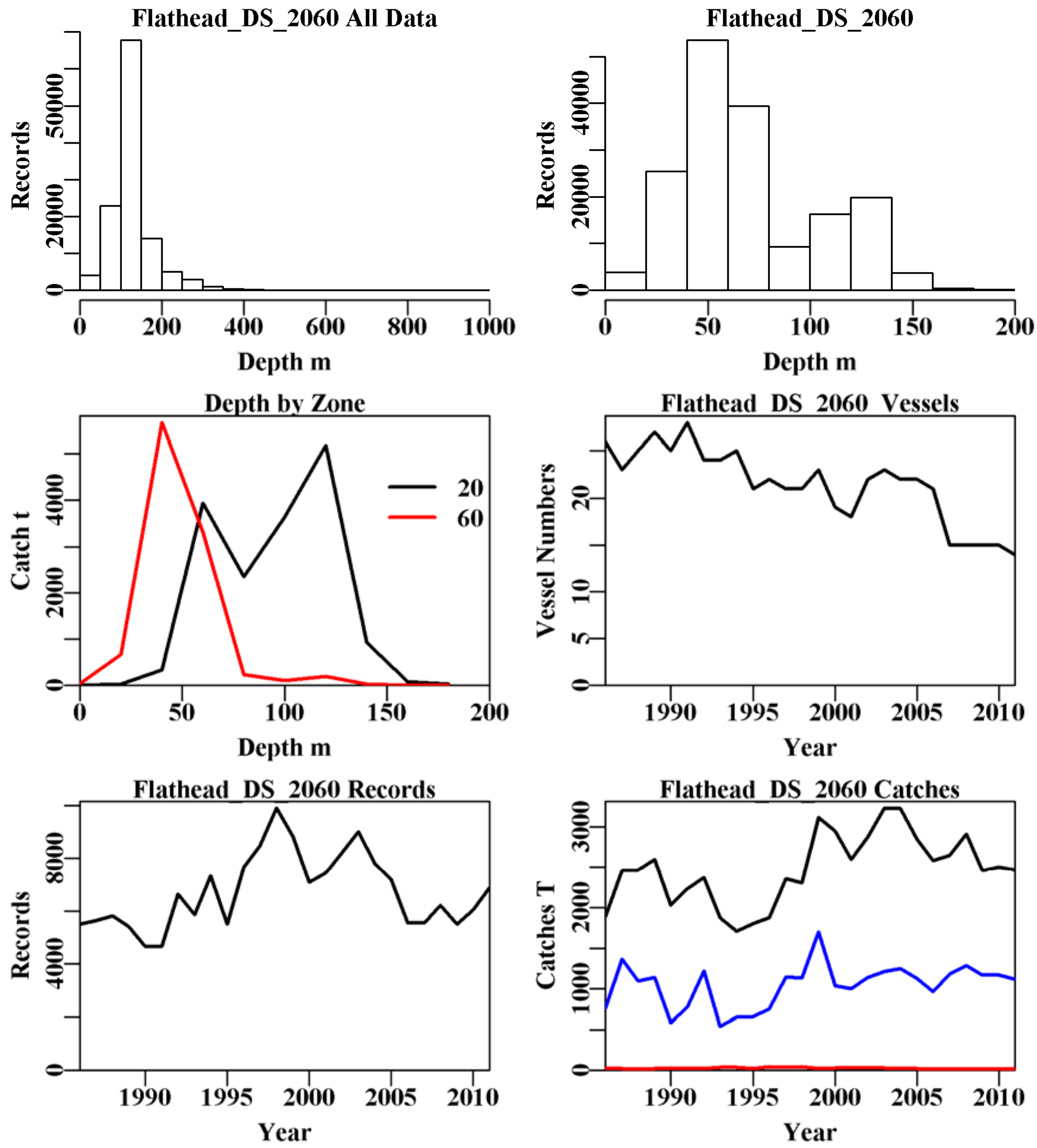

Figure 13.39. Flathead from zones 20 and 60 in depths 0 – 200m by Danish Seine. The top left is the depth distribution of all records reporting Flathead, the top right graph depicts the depth distribution of shots containing Flathead from zones 20 and 60 in depths 0 – 200m by Danish Seine. The middle left diagram depicts the distribution of catch by depth within zones 20 and 60, the middle right hand graph depicts the number of vessels through time. The bottom left reflects the number of records used in analysis, and bottom right is the Flathead catches (top line, black is total catches, middle line, blue, are those used in the analysis, and bottom, red, are catches < 30Kg).

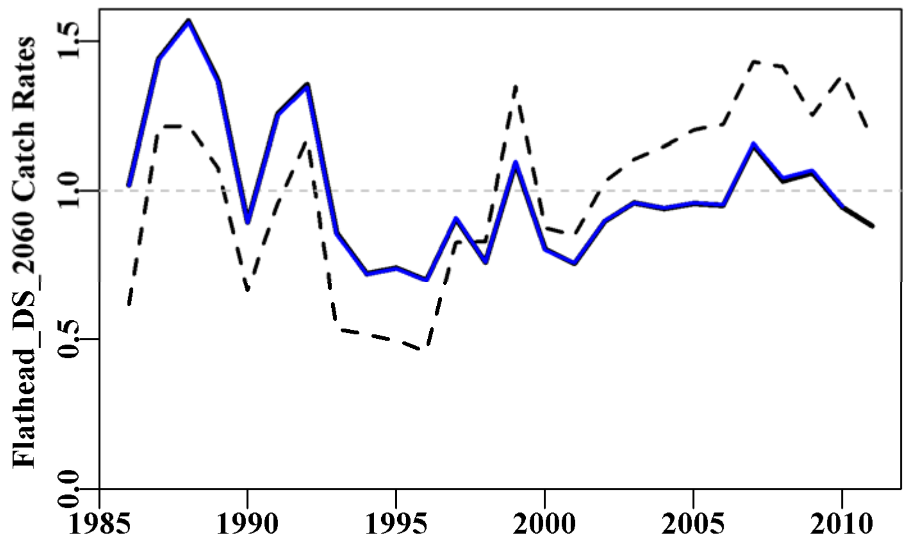

Figure 13.40**.** Flathead from zones 20 and 60 in depths 0 – 200m by Danish Seine. The dashed black line represents the geometric mean catch rate and the solid black line the standardized catch rates. The graph standardizes catch rates relative to the mean of the standardized catch rates.

Table 13.31**.** Flathead from zones 20 and 60 in depths 0 – 200m by Danish Seine. Statistical model structures used in this analysis. DepCat is a series of 20 metre depth categories.

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

Table 13.32**.** Flathead from zones 20 and 60 in depths 0 – 200m by Danish Seine. Model selection criteria, including the AIC, the adjusted r^2 and the change in adjusted r^2. The optimum was model Zone:Month.

	Year	Zone	DepCat	Vessel	Month	DayNight	Zone:Mth	Zone:DepC
AIC	134857	101886	70810	63465	52577	49609	45236	49256
RSS	377811	312748	259136	248127	232841	228840	223054	228346
MSS	20103	85165	138777	149786	165072	169073	174860	169567
Nobs	174461	174461	171588	171588	171588	171588	171588	171588
Npars	26	27	36	88	99	102	113	111
adj_r2	5.038	21.391	34.863	37.611	41.451	42.456	43.908	42.577
%Change	0.000	16.353	13.472	2.748	3.840	1.005	1.451	-1.330

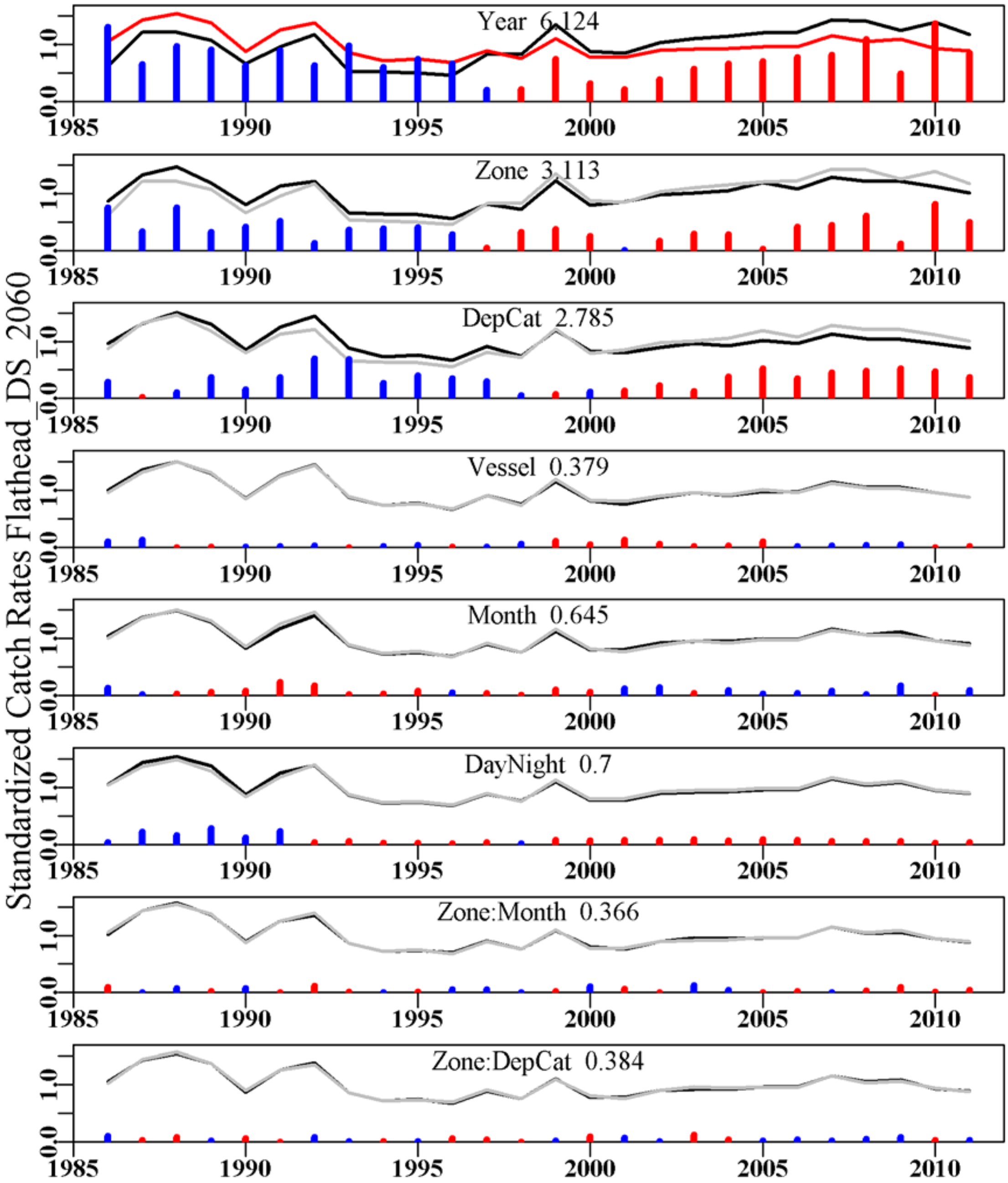

Figure 13.41. The relative influence of each factor used on the final trend in the optimal standardization for Flathead by Danish Seine in Zones 20 & 60. The top graph depicts the geometric mean (the black line) and the optimum model (the red line). The difference between them is illustrated by the vertical bars with blue bars indicating the optimum model is higher than the geometric mean and red bars indicating it is lower. The top graph bars are the sum of all the bars in the graphs below. The graphs for individual factors are cumulative. Thus the second graph has the geometric mean (grey line) and the effect of adding Year + factor2 (model 2). In the third graph, the grey line represents model 2 and the black line the effect of adding factor3 to the model. The remaining graphs continue in the same cumulative manner except for the interaction terms which are added singularly to the final single factor model.

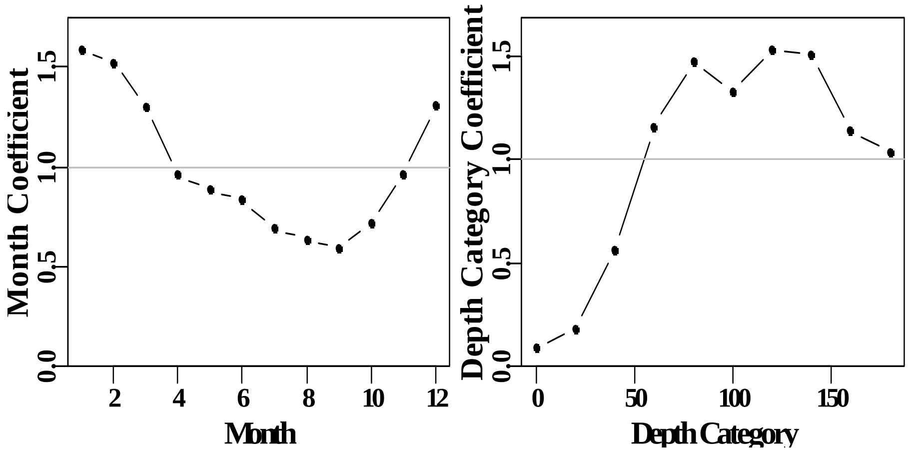

Figure 13.42. Standardized trends for Month and DepCat factors for Flathead taken by trawl Danish Seine.

13.16 RedFish Zone 10 (RED – 37258003 – *Centroberyx affinis*)

Only data from zone 10 were used, depths less than 400 m.

Table 13.33. Redfish from zone 10 in depths 0 – 400m by trawl. Total Catch is the total reported in the database, Records is the number of records used in the analysis, CatchT is the reported catch in the area and depth used in the analysis, and Vessels relates to all vessels used in the analysis. Geomean is the geometric mean of catch rates (kg/hr). Month:DepCat is the optimum model and StDev is the standard deviation relating to the data in the optimum model.

Year	TotCatch	Records	CatchT	Vessels	GeoMean	Mth:DepC	StDev
1986	1687.471	4503	1528.926	81	38.3044	1.5835	0.0000
1987	1252.658	3383	1114.805	73	35.9993	1.2675	0.0371
1988	1125.492	2966	904.361	70	37.3114	1.3164	0.0390
1989	714.316	2156	586.942	64	29.4122	1.0928	0.0431
1990	931.370	1894	699.754	49	37.2522	1.4854	0.0453
1991	1570.607	2467	1056.996	44	39.9367	1.5398	0.0421
1992	1636.687	2428	1393.725	41	50.0990	1.9882	0.0430
1993	1921.347	2960	1611.795	47	56.0385	2.5202	0.0407
1994	1487.717	4208	1140.891	49	35.8972	1.7668	0.0378
1995	1240.617	4397	1027.576	46	27.8589	1.1458	0.0368
1996	1344.049	4063	1094.993	50	26.2588	0.9344	0.0375
1997	1397.328	2952	1157.743	50	33.5183	1.0959	0.0406
1998	1553.718	3072	1363.404	43	43.1196	1.3762	0.0402
1999	1116.403	2998	969.424	44	32.7876	1.0812	0.0402
2000	758.275	3300	642.137	48	22.7760	0.7288	0.0398
2001	742.268	3209	607.215	41	17.8301	0.7123	0.0398
2002	807.133	3481	601.823	44	16.4201	0.6089	0.0396
2003	615.183	2690	478.879	43	17.0122	0.5826	0.0417
2004	476.009	2717	390.967	44	15.2541	0.4941	0.0416
2005	483.516	2443	360.961	41	16.1484	0.5057	0.0429
2006	325.092	1768	256.212	34	15.6812	0.4745	0.0472
2007	216.279	1207	149.288	18	15.4678	0.4237	0.0547
2008	183.757	1396	155.290	22	13.9780	0.3993	0.0524
2009	160.525	1171	123.810	20	11.3207	0.3253	0.0558
2010	152.816	1228	112.793	19	10.4815	0.3059	0.0547
2011	87.305	870	63.806	17	8.5118	0.2447	0.0615

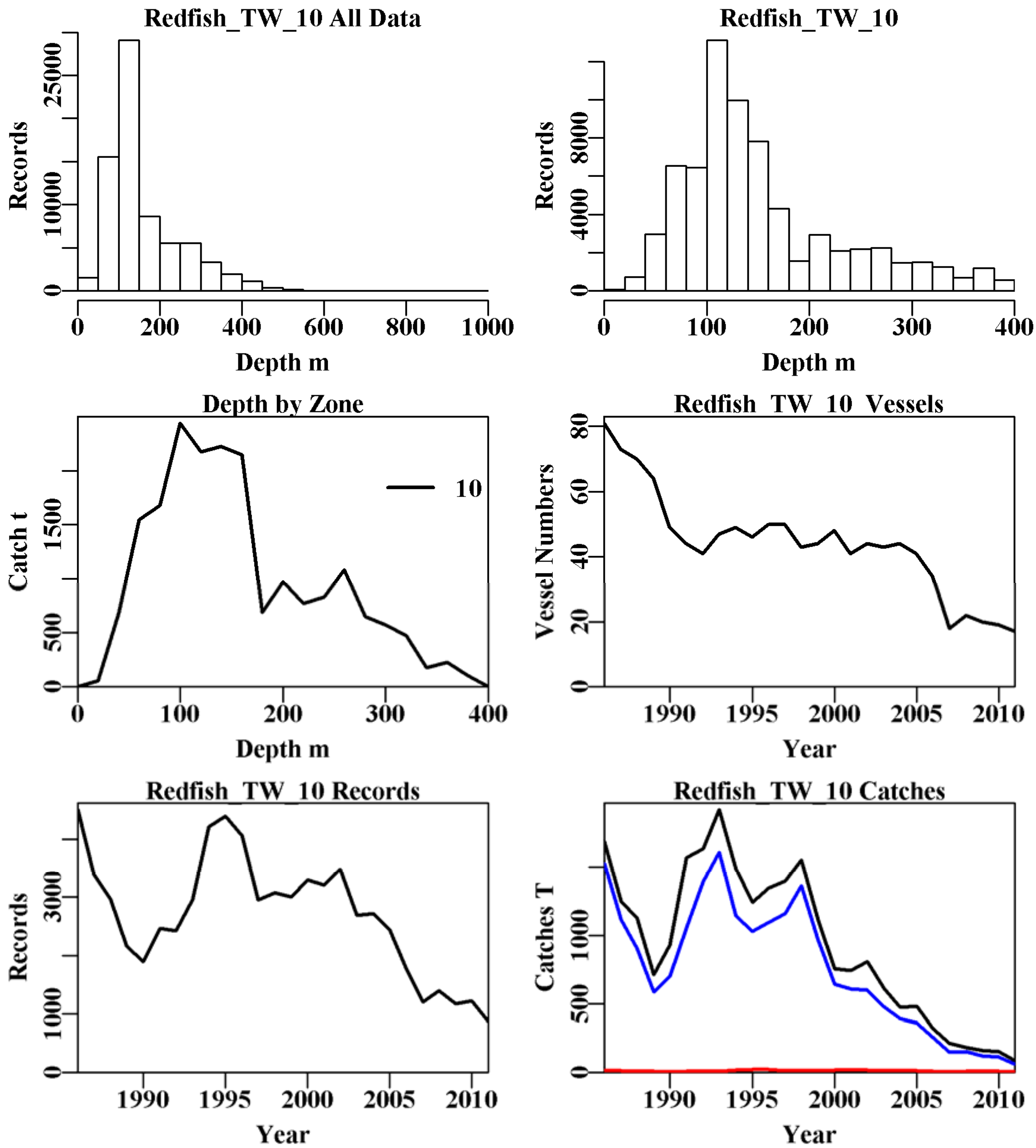

Figure 13.43. Redfish from zone 10 in depths 0 – 400m by trawl. The top left is the depth distribution of all records reporting Redfish, the top right graph depicts the depth distribution of shots containing Redfish from zone 10 in depths 0 – 400m by trawl. The middle left diagram depicts the distribution of catch by depth within zone 10, the middle right hand graph depicts the number of vessels through time. The bottom left reflects the number of records used in analysis, and bottom right is the Redfish catches (top line, black is total catches, middle line, blue, are those used in the analysis, and bottom, red, are catches < 30Kg).

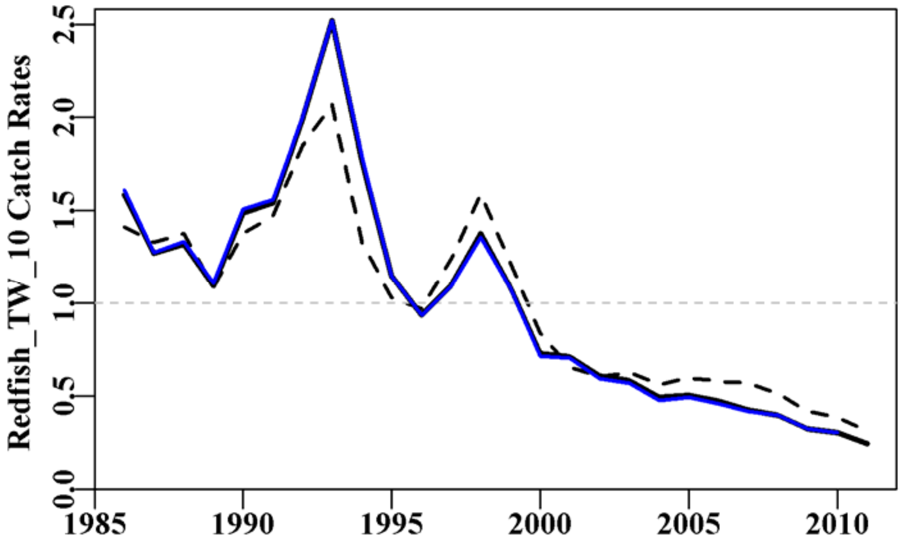

Figure 13.44. Redfish from zone 10 in depths 0 – 400m by trawl. The dashed black line represents the geometric mean catch rate and the solid black line the standardized catch rates. The graph standardizes catch rates relative to the mean of the standardized catch rates.

Table 13.34. Redfish from zone 10 in depths 0 – 400m by trawl. Statistical model structures used in this analysis. DepCat is a series of 20 metre depth categories.

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

Table 13.35. Redfish from zone 10 in depths 0 – 400m by trawl. Model selection criteria, including the AIC, the adjusted r^2 and the change in adjusted r^2. The optimum was model Month:DepCat.

	Year	Vessel	DepC	DN	Mth	DN:Mth	Mth:DepC	DN:DepC
AIC	74101	66157	61252	60659	60164	60033	58865	59387
RSS	201623	179231	166879	165448	164223	163758	160168	162119
MSS	13765	36156	48508	49939	51165	51630	55220	53268
Nobs	69927	69927	69550	69550	69550	69550	69550	69550
Npars	26	170	190	193	204	237	424	264
adj_r2	6.357	16.585	22.310	22.973	23.532	23.712	25.182	24.446
%Change	0.000	10.228	5.725	0.663	0.558	0.180	1.471	-0.737

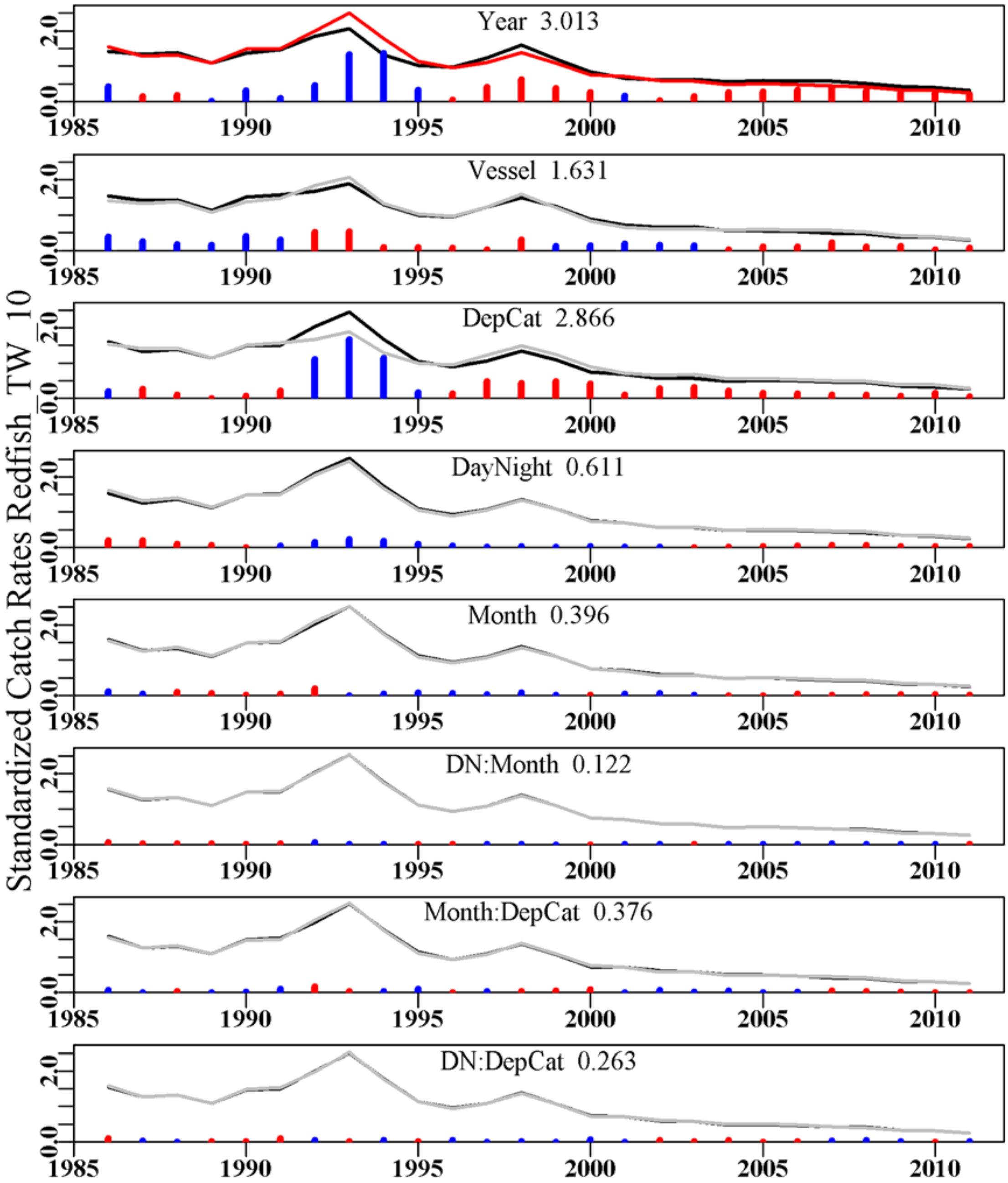

Figure 13.45. The relative influence of each factor used on the final trend in the optimal standardization for Redfish in Zone 10. The top graph depicts the geometric mean (the black line) and the optimum model (the red line). The difference between them is illustrated by the vertical bars with blue bars indicating the optimum model is higher than the geometric mean and red bars indicating it is lower. The top graph bars are the sum of all the bars in the graphs below. The graphs for individual factors are cumulative. Thus the second graph has the geometric mean (grey line) and the effect of adding Year + factor2 (model 2). In the third graph, the grey line represents model 2 and the black line the effect of adding factor3 to the model. The remaining graphs continue in the same cumulative manner except for the interaction terms which are added singularly to the final single factor model.

13.17 RedFish Zone 20 (RED – 37258003 – *Centroberyx affinis*)

Only data from zone 20 were used, depths less than 400 m.

Table 13.36. Redfish from zone 20 in depths 0 – 400m by trawl. Total Catch is the total reported in the database, Records is the number of records used in the analysis, CatchT is the reported catch in the area and depth used in the analysis, and Vessels relates to all vessels used in the analysis. Geomean is the geometric mean of catch rates (kg/hr). Month:DepCat is the optimum model and StDev is the standard deviation relating to the data in the optimum model.

Year	TotCatch	Records	CatchT	Vessels	GeoMean	Mth:DepC	StDev
1986	1687.471	838	69.648	34	12.7888	1.2276	0.0000
1987	1252.658	548	70.567	28	16.3056	1.5256	0.0867
1988	1125.492	1008	174.671	35	22.5742	2.1550	0.0784
1989	714.316	567	57.490	32	13.8221	1.3220	0.0880
1990	931.370	699	95.090	34	16.4273	1.5491	0.0864
1991	1570.607	886	181.397	27	20.9240	1.9209	0.0851
1992	1636.687	691	100.149	25	18.2135	1.5608	0.0902
1993	1921.347	836	175.486	25	23.8774	1.9120	0.0871
1994	1487.717	1291	212.848	26	22.1556	1.7884	0.0820
1995	1240.617	1316	169.079	24	14.7891	1.1242	0.0805
1996	1344.049	1751	210.919	26	11.8255	1.1110	0.0787
1997	1397.328	1456	196.332	28	10.9003	0.9231	0.0811
1998	1553.718	1237	164.642	24	11.9357	0.9827	0.0822
1999	1116.403	947	122.433	25	9.4628	0.8459	0.0853
2000	758.275	1364	92.988	27	5.0564	0.5684	0.0825
2001	742.268	1345	113.456	24	5.9658	0.5810	0.0831
2002	807.133	1725	172.165	24	6.7628	0.6660	0.0818
2003	615.183	1428	77.081	26	4.5183	0.4330	0.0831
2004	476.009	1248	59.212	22	4.2622	0.4417	0.0855
2005	483.516	1353	92.209	20	5.5759	0.5611	0.0840
2006	325.092	821	46.469	21	4.7612	0.4929	0.0895
2007	216.279	673	59.701	11	5.6299	0.5908	0.0934
2008	183.757	536	24.505	17	4.1887	0.4893	0.0978
2009	160.525	448	30.527	12	4.9795	0.5023	0.1016
2010	152.816	644	34.686	15	4.4782	0.4597	0.0971
2011	87.305	539	20.314	12	2.6852	0.2652	0.0996

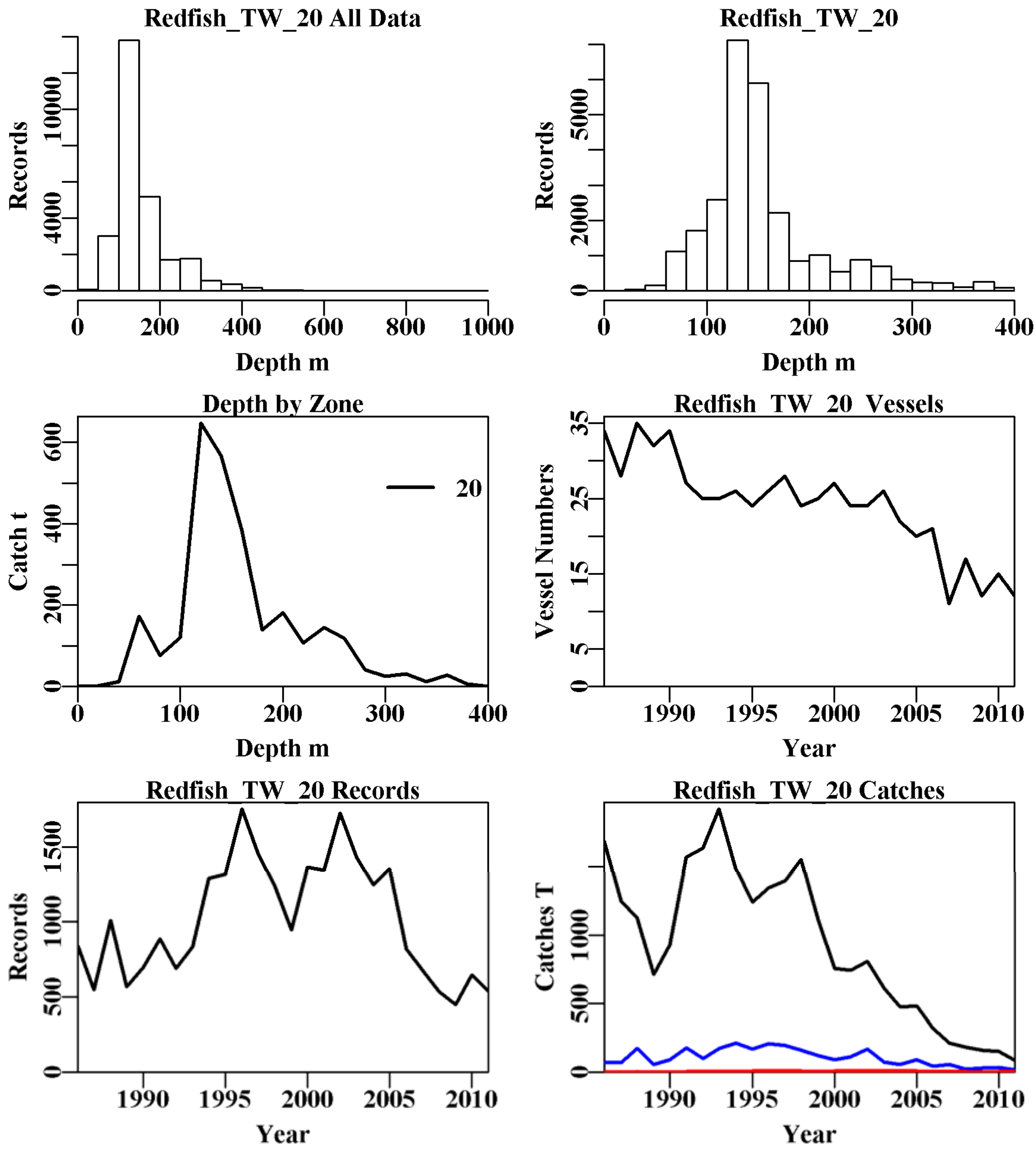

Figure 13.46**.** Redfish from zone 20 in depths 0 – 400m by trawl. The top left is the depth distribution of all records reporting Redfish, the top right graph depicts the depth distribution of shots containing Redfish from zone 20 in depths 0 – 400m by trawl. The middle left diagram depicts the distribution of catch by depth within zone 20, the middle right hand graph depicts the number of vessels through time. The bottom left reflects the number of records used in analysis, and bottom right is the Redfish catches (top line, black is total catches, middle line, blue, are those used in the analysis, and bottom, red, are catches < 30Kg).

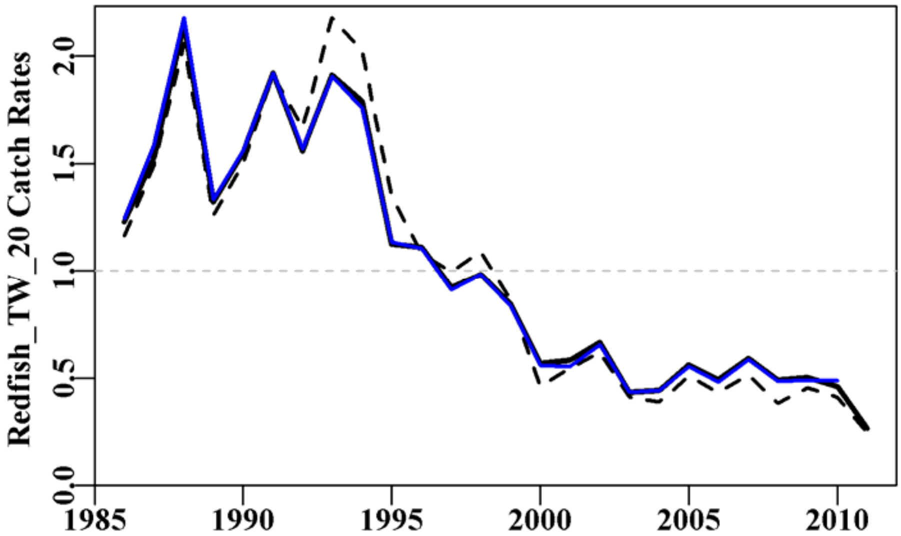

Figure 13.47**.** Redfish from zone 20 in depths 0 – 400m by trawl. The dashed black line represents the geometric mean catch rate and the solid black line the standardized catch rates. The graph standardizes catch rates relative to the mean of the standardized catch rates.

Table 13.37. Redfish from zone 20 in depths 0 – 400m by trawl. Statistical model structures used in this analysis. DepCat is a series of 20 metre depth categories.

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

Table 13.38. Redfish from zone 20 in depths 0 – 400m by trawl. Model selection criteria, including the AIC, the adjusted r^2 and the change in adjusted r^2. The optimum was model Month:DepCat.

	Year	Vessel	DepCat	Mth	DayNight	DN:Mth	Mth:DepCat	DN:DepCat
AIC	24240	20932	19183	18735	18700	18668	18404	18616
RSS	65955	57674	53783	52822	52737	52540	51269	52326
MSS	9493	17773	21665	22626	22710	22908	24179	23122
Nobs	26195	26195	26049	26049	26049	26049	26049	26049
Npars	26	129	149	160	163	196	383	223
adj_r2	12.499	23.182	28.308	29.558	29.663	29.837	31.036	30.050
%Change	0.000	10.683	5.126	1.251	0.105	0.174	1.198	-0.986

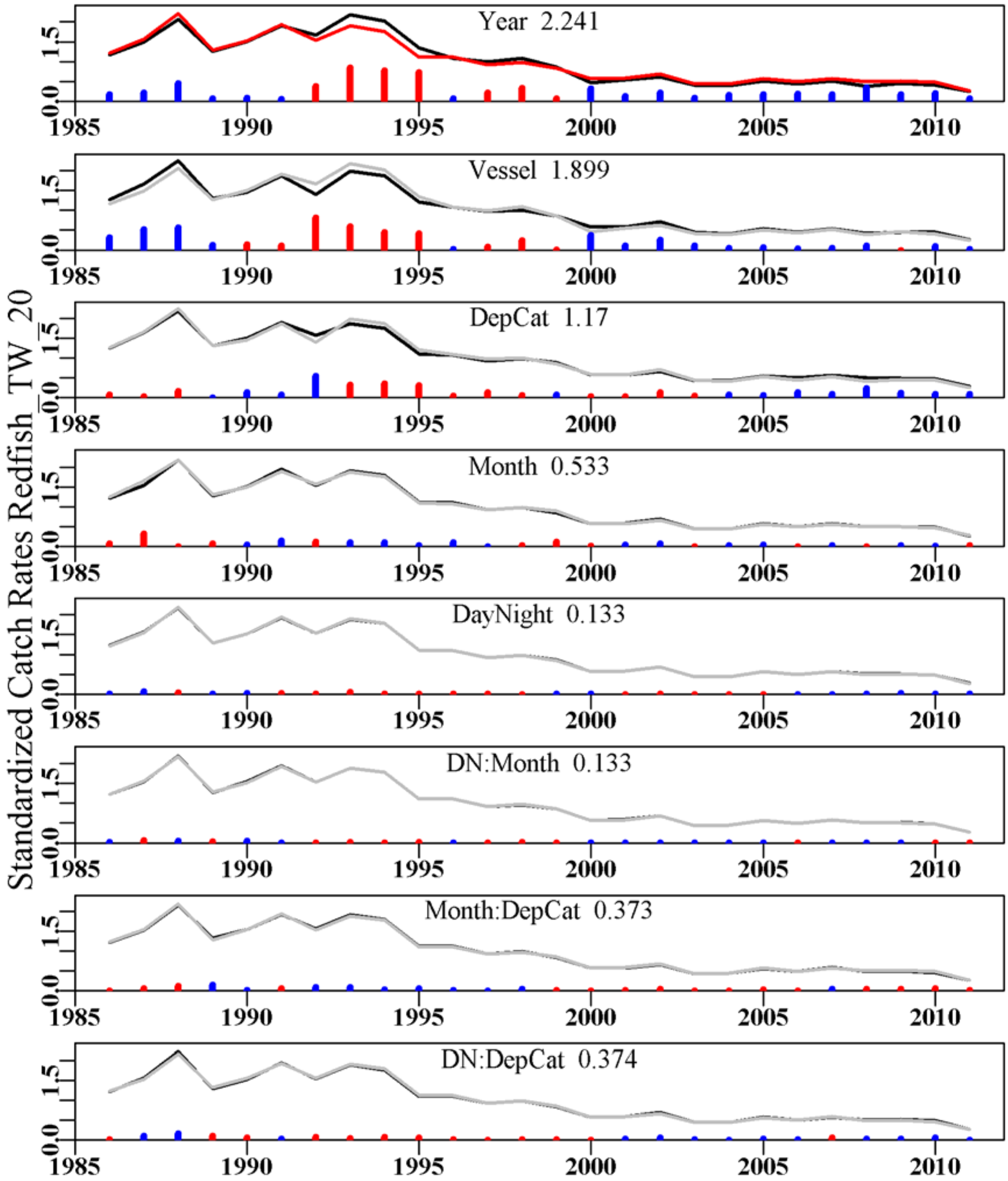

Figure 13.48**.** The relative influence of each factor used on the final trend in the optimal standardization for Redfish in Zone 20. The top graph depicts the geometric mean (the black line) and the optimum model (the red line). The difference between them is illustrated by the vertical bars with blue bars indicating the optimum model is higher than the geometric mean and red bars indicating it is lower. The top graph bars are the sum of all the bars in the graphs below. The graphs for individual factors are cumulative. Thus the second graph has the geometric mean (grey line) and the effect of adding Year + factor2 (model 2). In the third graph, the grey line represents model 2 and the black line the effect of adding factor3 to the model. The remaining graphs continue in the same cumulative manner except for the interaction terms which are added singularly to the final single factor model.

13.18 Silver Trevally (TRE – 37337062 – Pseudocaranx dentex)

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

Table 13.39**.** Silver Trevally from Zones 10 and 20 in depths 0 to 200 m, excluding data taken in State waters (Bateman's Bay MPA). Total Catch is the total reported in the database, Records is the number of records used in the analysis, CatchT is the reported catch in the area and depth used in the analysis, and Vessels relates to all vessels used in the analysis. Geomean is the geometric mean of catch rates (kg/hr). Zone:Month is the optimum model and StDev is the standard deviation relating to the data in the optimum model.

Year	TotCatch	Records	CatchT	Vessels	GeoMean	Zone:Mth	StDev
1986	469.508	1765	278.628	74	17.0086	1.1373	0.0000
1987	198.490	1090	116.317	63	17.5072	1.3565	0.0593
1988	278.541	1299	226.620	52	23.7642	1.7779	0.0546
1989	376.196	1838	278.037	62	23.0657	1.8873	0.0501
1990	450.391	1841	288.809	52	23.2975	2.2336	0.0518
1991	340.683	1909	213.903	49	18.1137	2.0038	0.0522
1992	296.493	1194	108.366	44	12.0774	1.1420	0.0586
1993	377.673	1262	132.861	47	13.4863	1.2467	0.0575
1994	392.828	1839	139.154	46	9.4912	0.9557	0.0531
1995	413.439	1570	136.637	43	10.2789	1.0853	0.0551
1996	340.616	1883	129.536	47	7.5806	0.8718	0.0534
1997	328.839	1450	88.499	48	6.2012	0.8265	0.0572
1998	210.136	1023	48.972	40	5.2414	0.6064	0.0610
1999	166.018	882	41.568	39	4.9696	0.6057	0.0642
2000	154.753	1020	43.620	42	3.6777	0.4529	0.0615
2001	270.175	1536	82.085	43	4.1345	0.5290	0.0554
2002	232.787	1474	67.852	40	3.0864	0.4299	0.0572
2003	337.667	1124	57.733	45	3.3755	0.4218	0.0595
2004	458.075	1345	84.499	42	4.5401	0.5836	0.0579
2005	290.940	673	59.560	40	4.7971	0.5154	0.0691
2006	247.284	493	48.824	32	5.7178	0.7212	0.0764
2007	172.720	463	47.115	20	7.4274	0.8211	0.0791
2008	128.386	818	69.665	23	8.0833	0.8476	0.0658
2009	164.752	838	94.881	23	9.2632	0.8553	0.0651
2010	240.308	967	135.510	24	11.7000	1.0954	0.0634
2011	192.047	860	139.299	20	11.0945	0.9902	0.0654

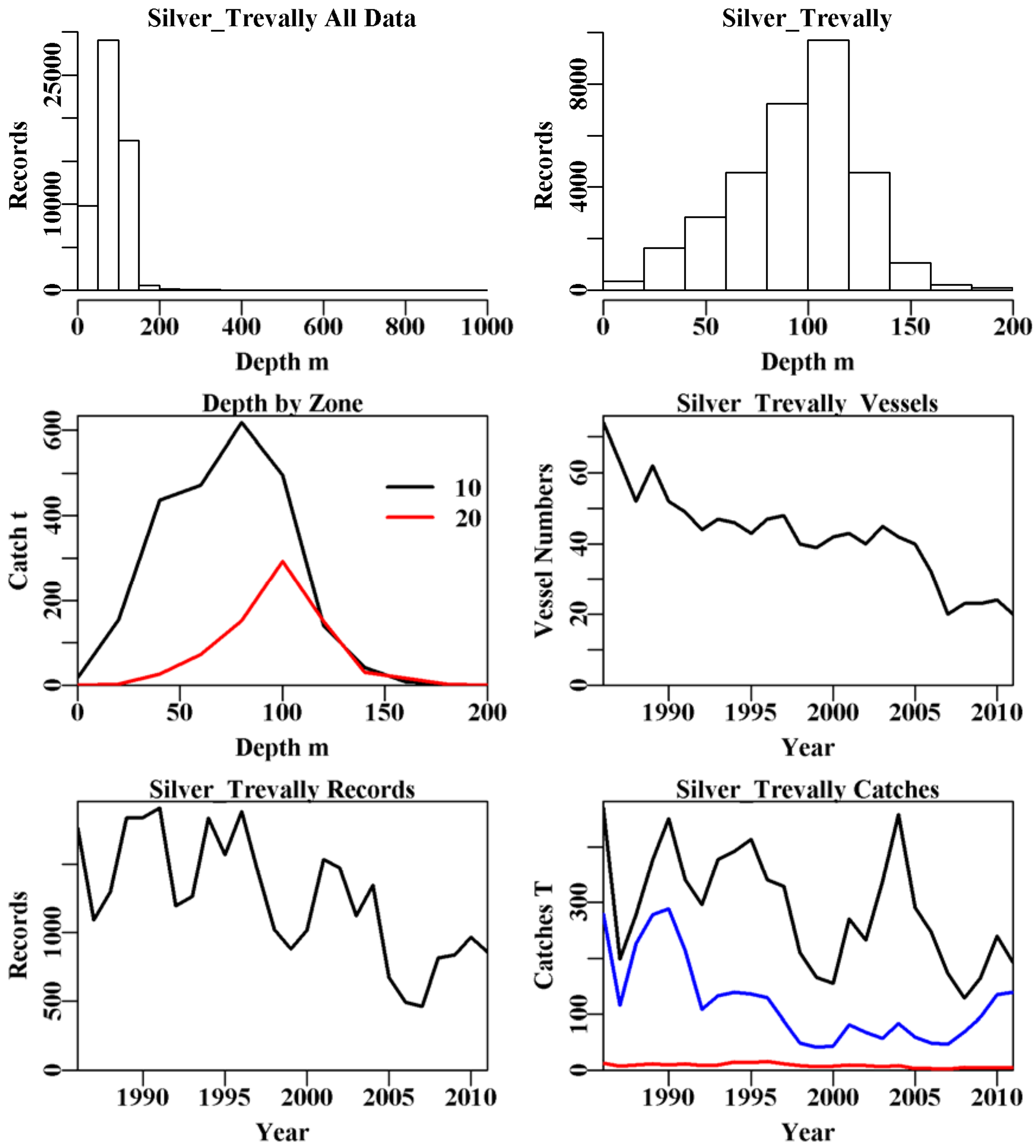

Figure 13.49**.** Silver Trevally from Zones 10 and 20 in depths 0 to 200 m, excluding data taken in State waters (Bateman's Bay MPA). The top left is the depth distribution of all records reporting Silver Trevally, the top right graph depicts the depth distribution of shots containing Silver Trevally from Zones 10 and 20 in depths 0 to 200 m by trawl, excluding data taken in State waters (Bateman's Bay MPA). The middle left diagram depicts the distribution of catch by depth within zones 10 and 20 (20 is top red line), the middle right hand graph depicts the number of vessels through time. The bottom left reflects the number of records used in analysis, and bottom right is the Silver Trevally catches (top line, black is total catches, middle line, blue, are those used in the analysis, and bottom, red, are catches < 30Kg).

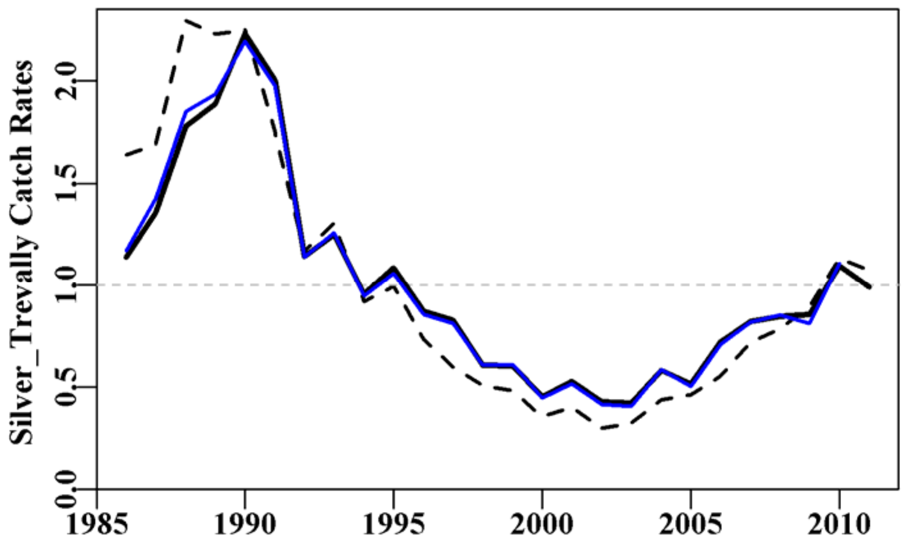

Figure 13.50**.** Silver Trevally from Zones 10 and 20 in depths 0 to 200 m, excluding data taken in State waters (Bateman's Bay MPA). The dashed black line represents the geometric mean catch rate and the solid black line the standardized catch rates. The graph standardizes catch rates relative to the mean of the standardized catch rates.

Table 13.40**.** Silver Trevally from Zones 10 and 20 in depths 0 to 200 m, excluding data taken in State waters (Bateman's Bay MPA). Statistical model structures used in this analysis. DepCat is a series of 20 metre depth categories.

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

Table 13.41. Silver Trevally from Zones 10 and 20 in depths 0 to 200 m, excluding data taken in State waters (Bateman's Bay MPA). Model selection criteria, including the AIC, the adjusted r^2 and the change in adjusted r^2. The optimum is model Zone:Month.

	Year	Vessel	DepCat	Month	DayNight	Zone	Zone:Mth	Zone:DepC
AIC	29656	23222	22216	21553	21206	21163	21091	21138
RSS	80804	65675	63488	62154	61477	61391	61212	61306
MSS	13468	28596	30784	32117	32795	32881	33060	32966
Nobs	32456	32456	32232	32232	32232	32232	32232	32232
Npars	26	173	183	194	197	198	209	208
adj_r2	14.220	29.963	32.272	33.672	34.388	34.478	34.647	34.549
%Change	0.000	15.743	2.309	1.400	0.717	0.090	0.169	-0.098

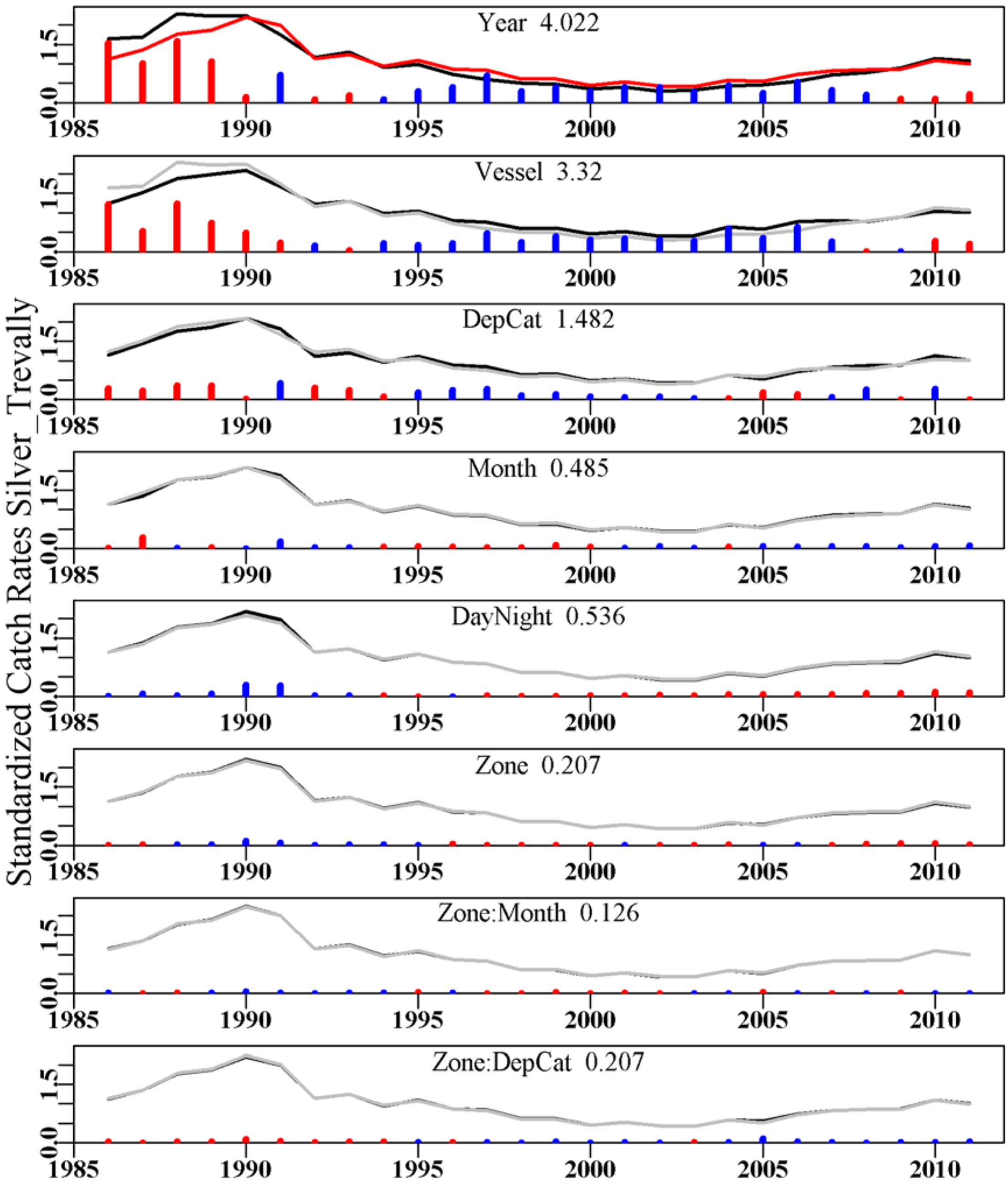

Figure 13.51**.** The relative influence of each factor used on the final trend in the optimal standardization for Silver Trevally in Zones 10 and 20. The top graph depicts the geometric mean (the black line) and the optimum model (the red line). The difference between them is illustrated by the vertical bars with blue bars indicating the optimum model is higher than the geometric mean and red bars indicating it is lower. The top graph bars are the sum of all the bars in the graphs below. The graphs for individual factors are cumulative. Thus the second graph has the geometric mean (grey line) and the effect of adding Year + factor2 (model 2). In the third graph, the grey line represents model 2 and the black line the effect of adding factor3 to the model. The remaining graphs continue in the same cumulative manner except for the interaction terms which are added singularly to the final single factor model.

13.19 Royal Red Prawn (PRR – 28714005 - Haliporoides sibogae)

Only data from Zone 10 were used, depths between 200 – 700 m.

Table 13.42**.** Royal Red Prawn from zone 10 in depths 200 – 700m by trawl. Total Catch is the total reported in the database, Records is the number of records used in the analysis, CatchT is the reported catch in the area and depth used in the analysis, and Vessels relates to all vessels used in the analysis. Geomean is the geometric mean of catch rates (kg/hr). Month:DepCat is the optimum model and StDev is the standard deviation relating to the data in the optimum model.

Year	TotCatch	Records	CatchT	Vessels	GeoMean	Mth:DepC	StDev
1986	277.717	1592	231.844	47	27.7627	0.6928	0.0000
1987	351.294	1764	324.716	47	41.9857	0.8818	0.0380
1988	362.505	1395	344.457	41	49.1496	0.9761	0.0409
1989	329.254	1143	310.760	39	45.8268	0.8322	0.0428
1990	337.134	727	311.118	25	95.1525	1.5596	0.0491
1991	334.134	734	299.370	29	79.4866	1.3942	0.0495
1992	166.860	434	146.081	19	70.3817	1.0429	0.0579
1993	298.797	673	232.774	21	68.5216	1.1944	0.0493
1994	359.830	661	240.363	26	77.7193	1.1363	0.0496
1995	335.592	1070	252.905	25	58.4998	0.9009	0.0435
1996	360.776	1216	272.675	25	60.5827	0.8126	0.0420
1997	252.693	855	166.703	21	51.9861	0.7661	0.0463
1998	233.298	1234	190.732	23	39.1713	0.8258	0.0427
1999	367.042	1607	348.804	25	49.7799	0.8163	0.0404
2000	434.931	1538	398.474	27	49.6136	1.0256	0.0408
2001	276.786	1307	228.699	22	35.9685	0.8744	0.0431
2002	484.209	1740	417.370	23	47.9208	1.0510	0.0402
2003	230.805	801	163.184	26	39.7063	1.0958	0.0491
2004	193.801	579	170.681	22	50.4687	1.1216	0.0535
2005	173.896	601	159.805	21	47.1225	1.0226	0.0536
2006	192.262	455	178.579	17	55.0038	1.2309	0.0580
2007	121.545	324	116.430	9	48.8072	0.8506	0.0663
2008	75.799	252	70.605	8	39.0864	0.7329	0.0751
2009	68.785	250	67.607	9	59.2670	0.9328	0.0788
2010	96.765	343	82.821	9	40.3732	0.8928	0.0662
2011	110.923	291	108.960	8	82.0762	1.3368	0.0706

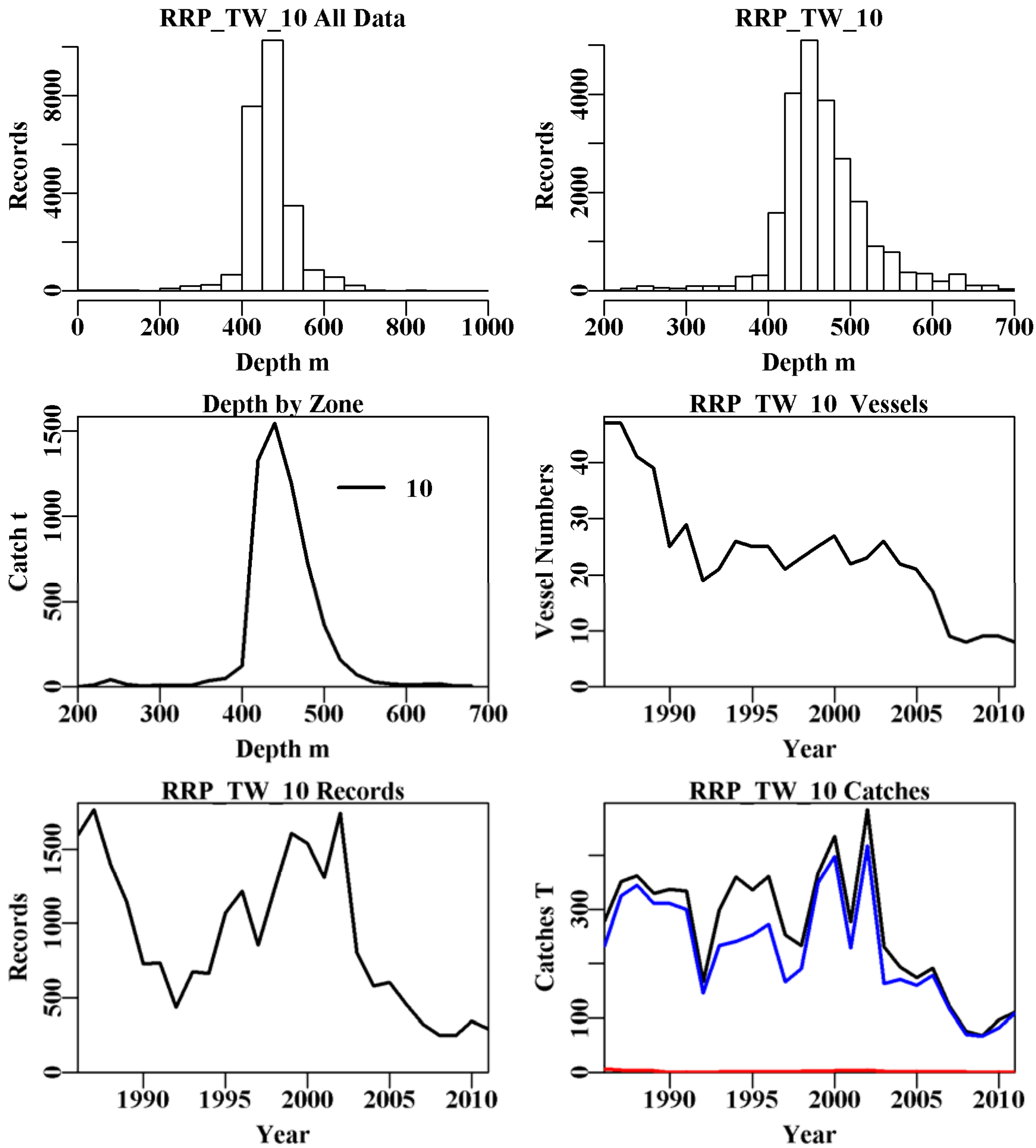

Figure 13.52**.** Royal Red Prawn from zone 10 in depths 200 – 700m by trawl. The top left is the depth distribution of all records reporting Royal Red Prawn, the top right graph depicts the depth distribution of shots containing Royal Red Prawn from zone 10 in depths 200 – 700m by trawl. The middle left diagram depicts the distribution of catch by depth within zone 10, the middle right hand graph depicts the number of vessels through time. The bottom left reflects the number of records used in analysis, and bottom right is the Royal Red Prawn catches (top line, black is total catches, middle line, blue, are those used in the analysis, and bottom, red, are catches < 30Kg).

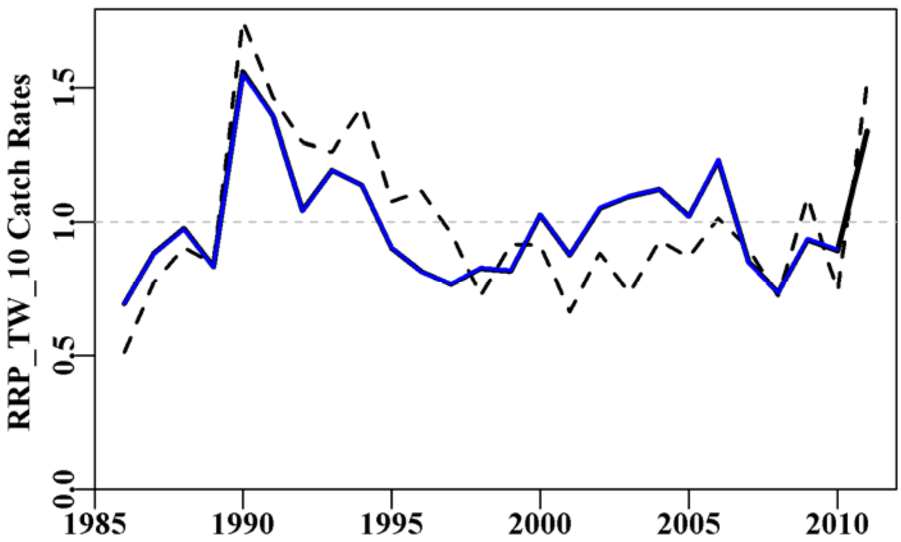

Figure 13.53. Royal Red Prawn from zone 10 in depths 200 – 700m by trawl. The dashed black line represents the geometric mean catch rate and the solid black line the standardized catch rates. The graph standardizes catch rates relative to the mean of the standardized catch rates.

Table 13.43. Royal Red Prawn from zone 10 in depths 200 – 700m by trawl. Statistical model structures used in this analysis. DepCat is a series of 20 metre depth categories.

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

Table 13.44. Royal Red Prawn from zone 10 in depths 200 – 700m by trawl. Model selection criteria, including the AIC, the adjusted r^2 and the change in adjusted r^2. The optimum was model Month:DepCat.

	Year	DepCat	Vessel	Mth	DayNight	DN:Mth	Mth:DepCat	DN:DepCat
AIC	12994	8188	2947	1341	1250	1218	762	1205
RSS	40828	33110	26293	24530	24429	24327	23393	24232
MSS	1761	9479	16295	18059	18160	18262	19196	18356
Nobs	23586	23453	23453	23453	23453	23453	23453	23453
Npars	26	50	133	144	147	180	411	219
adj_r2	4.033	22.094	37.913	42.050	42.281	42.440	44.096	42.568
%Change	0.000	18.061	15.819	4.137	0.231	0.159	1.656	-1.528

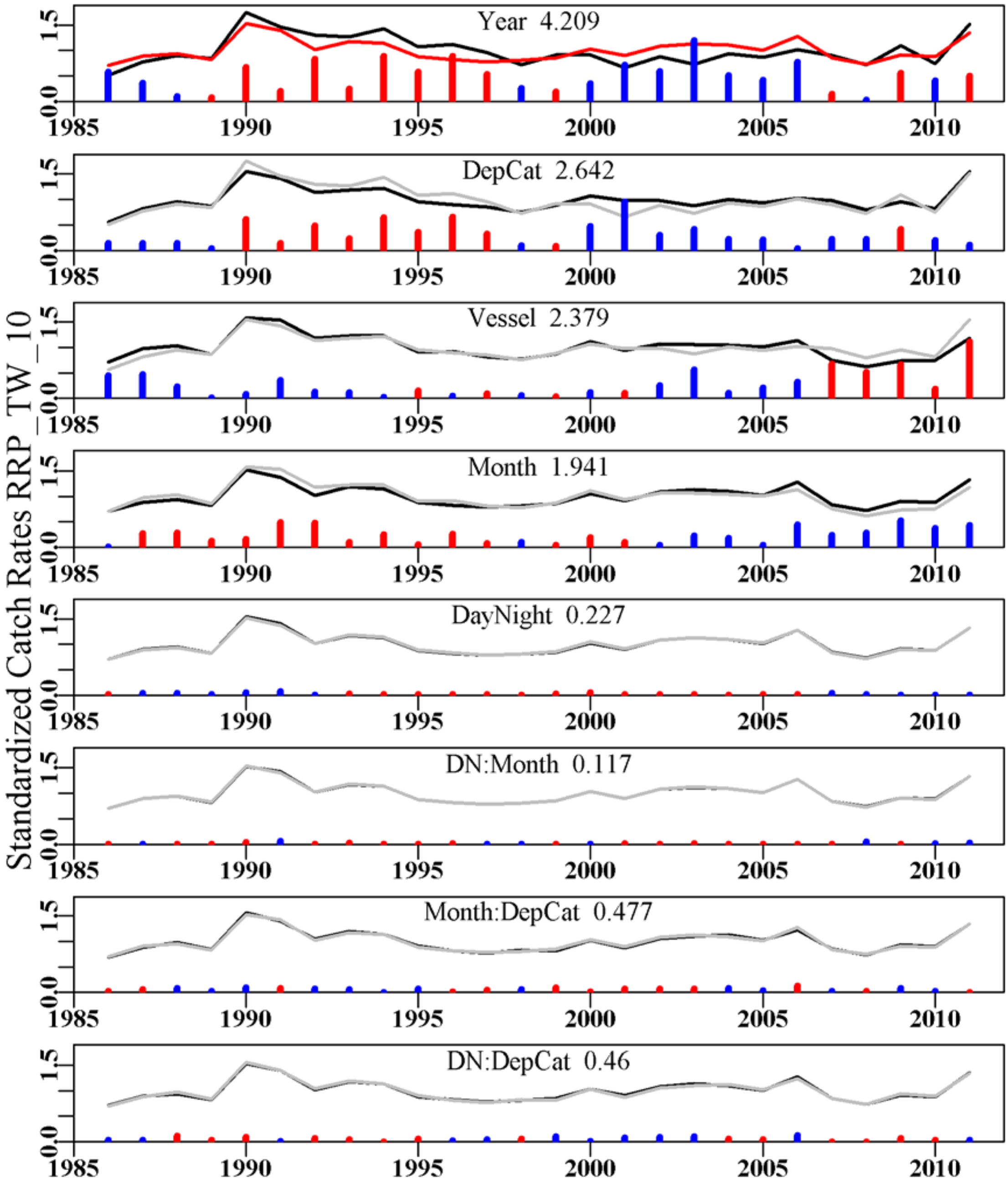

Figure 13.54**.** The relative influence of each factor used on the final trend in the optimal standardization for Royal Red Prawn in Zone 10. The top graph depicts the geometric mean (the black line) and the optimum model (the red line). The difference between them is illustrated by the vertical bars with blue bars indicating the optimum model is higher than the geometric mean and red bars indicating it is lower. The top graph bars are the sum of all the bars in the graphs below. The graphs for individual factors are cumulative. Thus the second graph has the geometric mean (grey line) and the effect of adding Year + factor2 (model 2). In the third graph, the grey line represents model 2 and the black line the effect of adding factor3 to the model. The remaining graphs continue in the same cumulative manner except for the interaction terms which are added singularly to the final single factor model.

13.19.1 Comparison between Different Mesh Sizes

Royal Red Prawns are targeted with so-called prawn nets that are significantly smaller meshed than usual trawl nets (Figure 13.55). The smaller mesh nets, < 60mm, have significantly higher catch rates than larger mesh nets with rates between 4 and 6 times higher than meshes > 80mm (Figure 13.56).

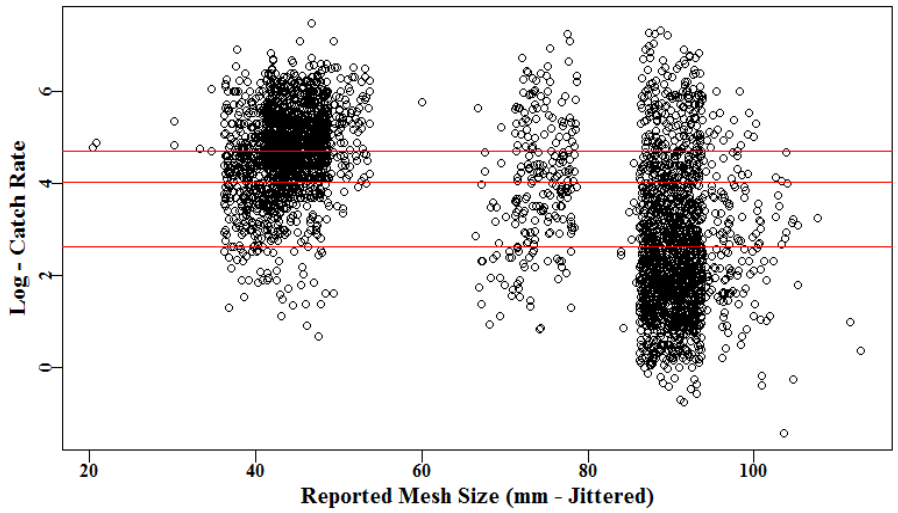

Figure 13.55**.** A scatter plot depicting the size distribution of reported mesh sizes used when Royal Red Prawn were landed. Each individual operation has been varied slightly (jittered) so as to illustrate the concentrations of mesh size and related catch rates. Thus, there are concentrations around 40 – 45mm, another at around 60 – 65mm, and another around 90mm. The three red lines depict the average log catch rates for the three clusters of data points, with the larger values relating to the clusters left to right.

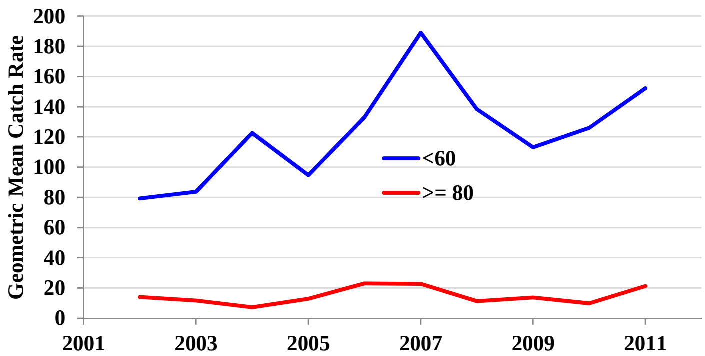

Figure 13.56**.** The geometric mean catch rates (kg/hr) of shots using nets with meshes less than 60mm and those with meshes greater than 80 mm.

While it is undoubtedly true that the absolute catch rates of Royal Red Prawn are much higher than when fishing with a normal trawl net the important aspect for the assessment of the relative abundance through time is any trend in the catch rates through time. By re-scaling all catch rates to a mean of 1.0 the trends in the catch rates from the different data sets can be directly compared Figure 13.57.

The trends exhibited by the different data selections are noisy but essentially track a similar path. The optimum model, that uses all available data but doesn't distinguish between mesh sizes, is less variable than the smaller and larger mesh categories. Nevertheless, all series exhibit a rise between 2006 and 2007, and a further rise from average in 2011. These trend lines are clearly noisy about the average in each case, with the variation being greater from >=80mm, <60mm, and the Optimum series, which reflects the number of records in each data set. The conclusion remains that the use of the total dataset provides a good representation of the changes in the catch rates and can continue to be used in the Tier 4 assessment.

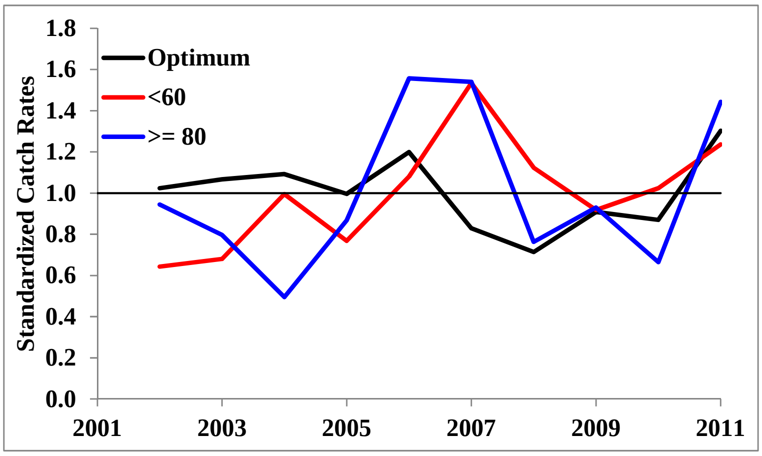

Figure 13.57. A comparison of the standardized catch rates, scaled to a mean of 1.0, for the optimum model using all data, and the separate statistical models for those data from meshes < 60mm and those > 80mm. The CV for the optimum series is 17.8%, for <60mm it is 26.9% and for the >=80mm it is 37.8%. The CVs in each case also reflect the relative amount of data available in each analysis.

Table 13.45. The scaled standardized catch rate data for different data selections. The Geomean and Optimum relate to all available data, < 60 relates to data from net meshes < 60mm, >=80 relate to data from meshes >=80mm, and BothMeshes relates to a standardization that includes data from both < 60 and >= 80 mm, using mesh size as a factor in the standardization, where it is, not surprisingly, highly influential. Columns 3 – 5 contain the data plotted in Figure 13.57.

Year	GeoMean	Optimum	<60	>= 80	BothMeshes
2002	0.93993	1.02359	0.64274	0.94438	1.03085
2003	0.77881	1.06722	0.67969	0.79677	0.98518
2004	0.98991	1.09235	0.99474	0.49541	1.03903
2005	0.92427	0.99593	0.76834	0.86704	0.94001
2006	1.07886	1.19880	1.08025	1.55634	1.15983
2007	0.95732	0.82842	1.53417	1.54000	1.02956
2008	0.76665	0.71378	1.12281	0.76311	0.82392
2009	1.16248	0.90847	0.91818	0.93033	0.80293
2010	0.79189	0.86951	1.02308	0.66411	0.88371
2011	1.60987	1.30193	1.23600	1.44252	1.30499

13.20 Blue Eye, Z2030 (TBE – 37445001 – *Hyperoglyphe antarctica*)

Trawling data from zones 20 and 30, depths less than 1000 m.

Table 13.46**.** BlueEye from zones 20 and 30 in depths 0 – 1000m by trawl. Total Catch is the total reported in the database, Records is the number of records used in the analysis, CatchT is the reported catch in the area and depth used in the analysis, and Vessels relates to all vessels used in the analysis. Geomean is the geometric mean of catch rates (kg/hr). Zone:DepCat is the optimum model and StDev is the standard deviation relating to the data in the optimum model.

Year	TotCatch	Records	CatchT	Vessels	GeoMean	Zone:DepC	StDev
1986	37.962	166	9.117	17	10.0553	2.0191	0.0000
1987	15.495	190	10.026	14	9.8390	1.8963	0.1371
1988	105.177	307	19.433	21	14.4132	2.3535	0.1297
1989	88.066	315	33.371	32	14.6333	2.6517	0.1321
1990	79.298	264	39.845	36	24.1892	3.3877	0.1347
1991	76.024	474	29.189	37	9.3594	1.8116	0.1268
1992	49.305	313	14.232	23	8.3976	1.3516	0.1339
1993	59.654	736	37.789	31	7.9893	1.0762	0.1239
1994	109.975	855	89.033	33	10.7324	1.2447	0.1232
1995	58.572	489	28.335	29	5.8281	0.8326	0.1279
1996	71.684	648	35.518	29	5.7645	0.6522	0.1254
1997	470.716	604	19.921	31	4.6731	0.5711	0.1269
1998	475.965	475	18.704	24	4.1103	0.6687	0.1295
1999	574.484	633	41.733	27	3.5948	0.6835	0.1260
2000	667.056	657	37.661	33	2.7104	0.4728	0.1245
2001	612.354	692	25.038	24	2.2460	0.4228	0.1248
2002	758.103	700	33.732	28	3.0245	0.4238	0.1266
2003	592.295	723	14.094	25	2.2565	0.4333	0.1258
2004	598.119	623	15.172	28	2.7233	0.4238	0.1275
2005	455.408	502	17.920	26	2.6096	0.4175	0.1307
2006	573.719	327	36.782	17	3.9462	0.5129	0.1349
2007	631.172	248	10.641	11	3.1268	0.4084	0.1404
2008	337.335	434	13.654	15	5.6341	0.3804	0.1344
2009	443.095	246	22.849	14	5.4891	0.3759	0.1420
2010	385.706	199	11.939	13	3.5048	0.2615	0.1473
2011	517.919	228	7.870	12	2.2147	0.2667	0.1442

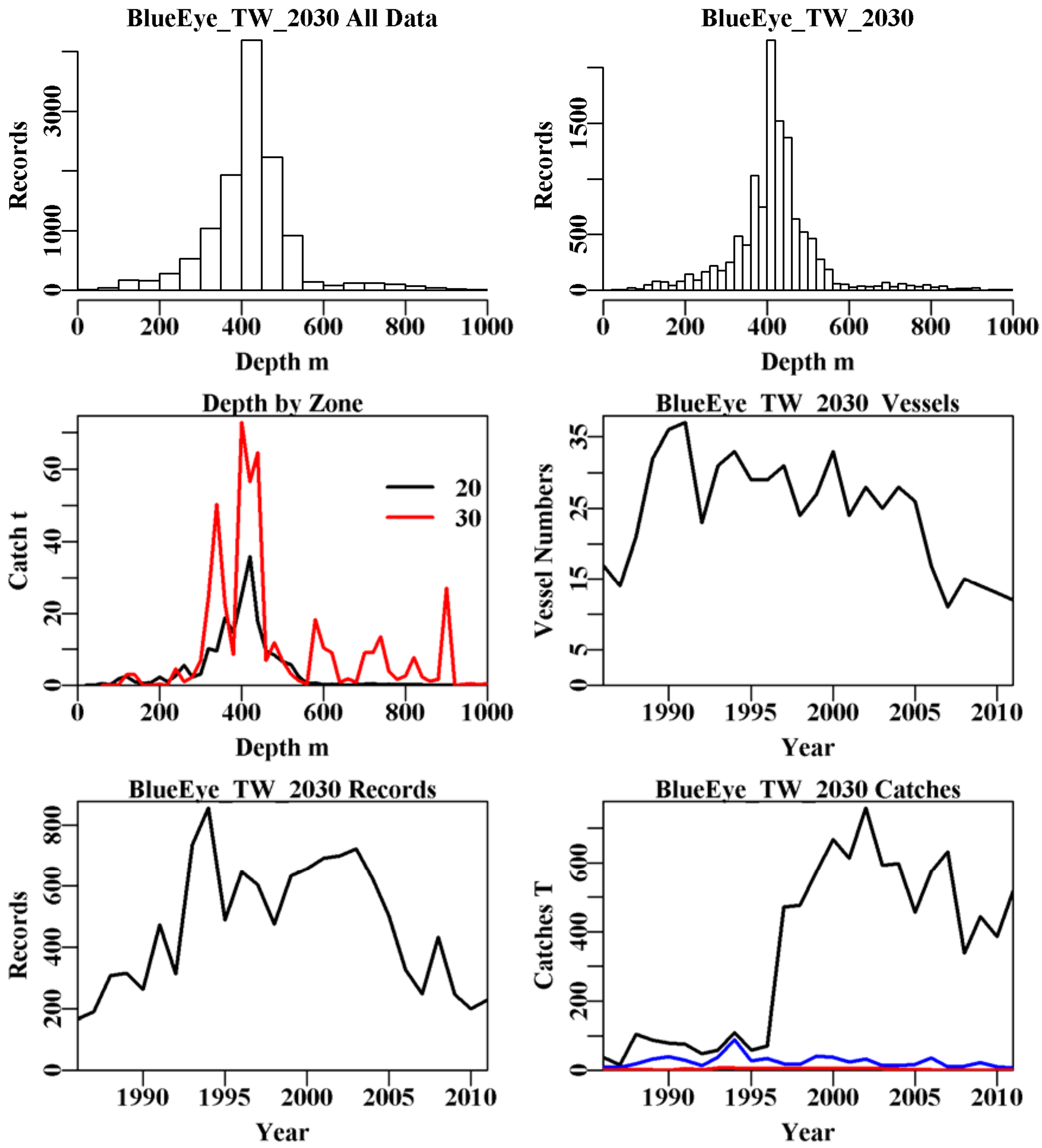

Figure 13.58. BlueEye from zones 20 and 30 in depths 0 – 1000m by trawl. The top left is the depth distribution of all records reporting BlueEye, the top right graph depicts the depth distribution of shots containing BlueEye from zones 20 and 30 in depths 0 – 1000m by trawl. The middle left diagram depicts the distribution of catch by depth within zones 20 and 30 (30 is top red line), the middle right hand graph depicts the number of vessels through time. The bottom left reflects the number of records used in analysis, and bottom right is the BlueEye catches (top line, black is total catches, middle line, blue, are those used in the analysis, and bottom, red, are catches < 30Kg).

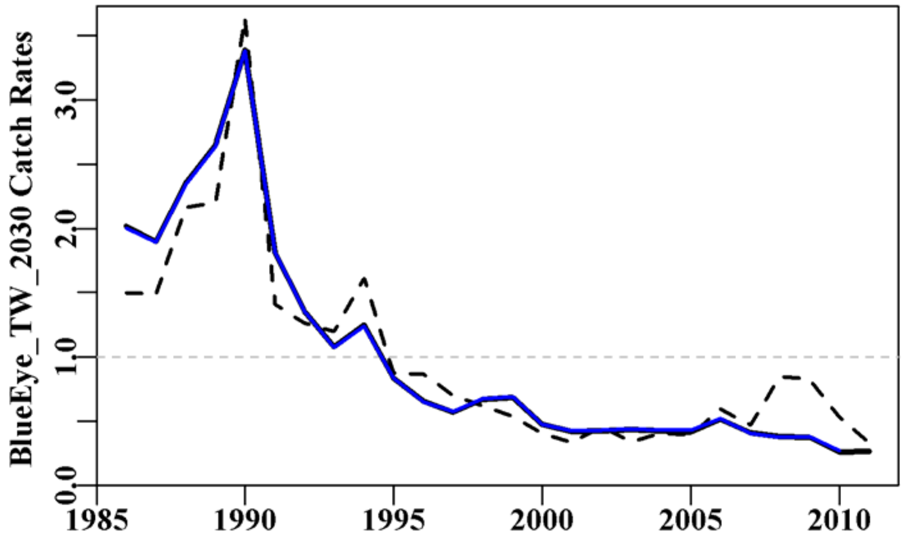

Figure 13.59**.** BlueEye from zones 20 and 30 in depths 0 – 1000m by trawl. The dashed black line represents the geometric mean catch rate and the solid black line the standardized catch rates. The graph standardizes catch rates relative to the mean of the standardized catch rates.

Table 13.47. BlueEye from zones 20 and 30 in depths 0 – 1000m by trawl. Statistical model structures used in this analysis. DepCat is a series of 20 metre depth categories.

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

Table 13.48**.** BlueEye from zones 20 and 30 in depths 0 – 1000m by trawl. Model selection criteria, including the AIC, the deviance and the change in deviance. The optimum was model Zone:DepCat.

	Year	Vessel	Zone	DepCat	DayNight	Month	Zone:Mth	Zone:DepC
AIC	10592	4594	4201	4083	3971	3956	3938	3765
RSS	28898	17227	16671	16308	16149	16099	16045	15718
MSS	4590	16261	16817	17180	17339	17389	17443	17770
Nobs	12048	12048	12048	11975	11975	11975	11975	11975
Npars	26	143	144	192	195	206	217	254
adj_r2	13.528	47.944	49.619	50.512	50.982	51.089	51.207	52.050
%Change	0.000	34.416	1.675	0.893	0.470	0.107	0.118	0.843

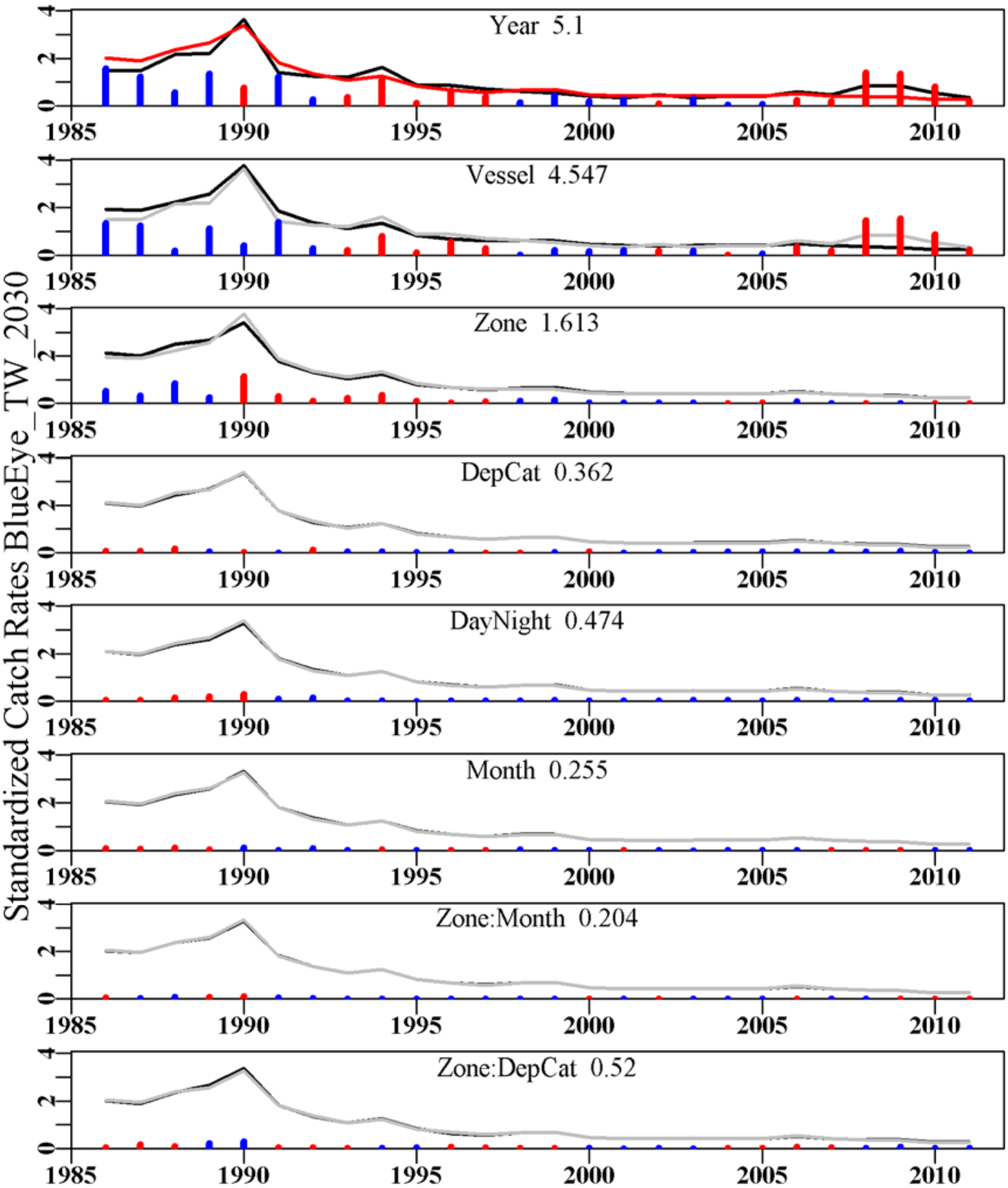

Figure 13.60**.** The relative influence of each factor used on the final trend in the optimal standardization for BlueEye in Zones 20 – 30. The top graph depicts the geometric mean (the black line) and the optimum model (the red line). The difference between them is illustrated by the vertical bars with blue bars indicating the optimum model is higher than the geometric mean and red bars indicating it is lower. The top graph bars are the sum of all the bars in the graphs below. The graphs for individual factors are cumulative. Thus the second graph has the geometric mean (grey line) and the effect of adding Year + factor2 (model 2). In the third graph, the grey line represents model 2 and the black line the effect of adding factor3 to the model. The remaining graphs continue in the same cumulative manner except for the interaction terms which are added singularly to the final single factor model.

13.21 Blue Eye, Z4050 (TBE – 37445001 – H. antarctica)

Data from zones 40 and 50, depths less than 1000 m.

Table 13.49**.** BlueEye from Zones 40 and 50 in depths 0 to 1000 m by Trawl. Total Catch is the total reported in the database, Records is the number of records used in the analysis, CatchT is the reported catch in the area and depth used in the analysis, and Vessels relates to all vessels used in the analysis. Geomean is the geometric mean of catch rates (kg/hr). Zone:Month is the optimum model and StDev is the standard deviation relating to the data in the optimum model.

Year	TotCatch	Records	CatchT	Vessels	GeoMean	Zone:Mth	StDev
1986	37.962	194	15.955	18	13.1296	0.9050	0.0000
1987	15.495	56	3.145	14	11.6895	0.7678	0.1748
1988	105.177	142	76.410	15	41.5696	2.2576	0.1554
1989	88.066	238	43.985	24	25.5841	1.8566	0.1371
1990	79.298	157	30.910	16	13.0702	1.9495	0.1575
1991	76.024	129	18.954	18	17.4424	1.6212	0.1558
1992	49.305	129	28.643	15	21.8842	1.8823	0.1556
1993	59.654	289	18.109	19	8.5334	0.8648	0.1394
1994	109.975	348	16.282	19	8.8991	0.9188	0.1360
1995	58.572	500	26.381	21	6.4723	0.8197	0.1323
1996	71.684	523	30.184	24	8.0361	0.8539	0.1328
1997	470.716	788	82.371	18	6.5139	0.8725	0.1295
1998	475.965	780	58.946	19	5.3540	1.0375	0.1307
1999	574.484	877	46.303	19	6.4046	1.0684	0.1298
2000	667.056	1109	44.729	22	5.2927	0.9274	0.1290
2001	612.354	955	42.188	26	5.7866	0.8756	0.1306
2002	758.103	802	32.268	26	5.0532	0.7333	0.1307
2003	592.295	392	11.023	25	3.1895	0.6717	0.1372
2004	598.119	852	31.296	24	4.2166	0.5914	0.1309
2005	455.408	508	12.750	22	3.6280	0.5420	0.1340
2006	573.719	533	16.279	17	3.6218	0.5591	0.1337
2007	631.172	538	26.188	16	4.4303	0.5942	0.1337
2008	337.335	324	16.371	14	4.9605	0.7664	0.1388
2009	443.095	343	15.751	13	4.0530	0.7055	0.1385
2010	385.706	430	31.436	14	5.5190	0.7466	0.1358
2011	517.919	381	14.696	14	2.8213	0.6110	0.1370

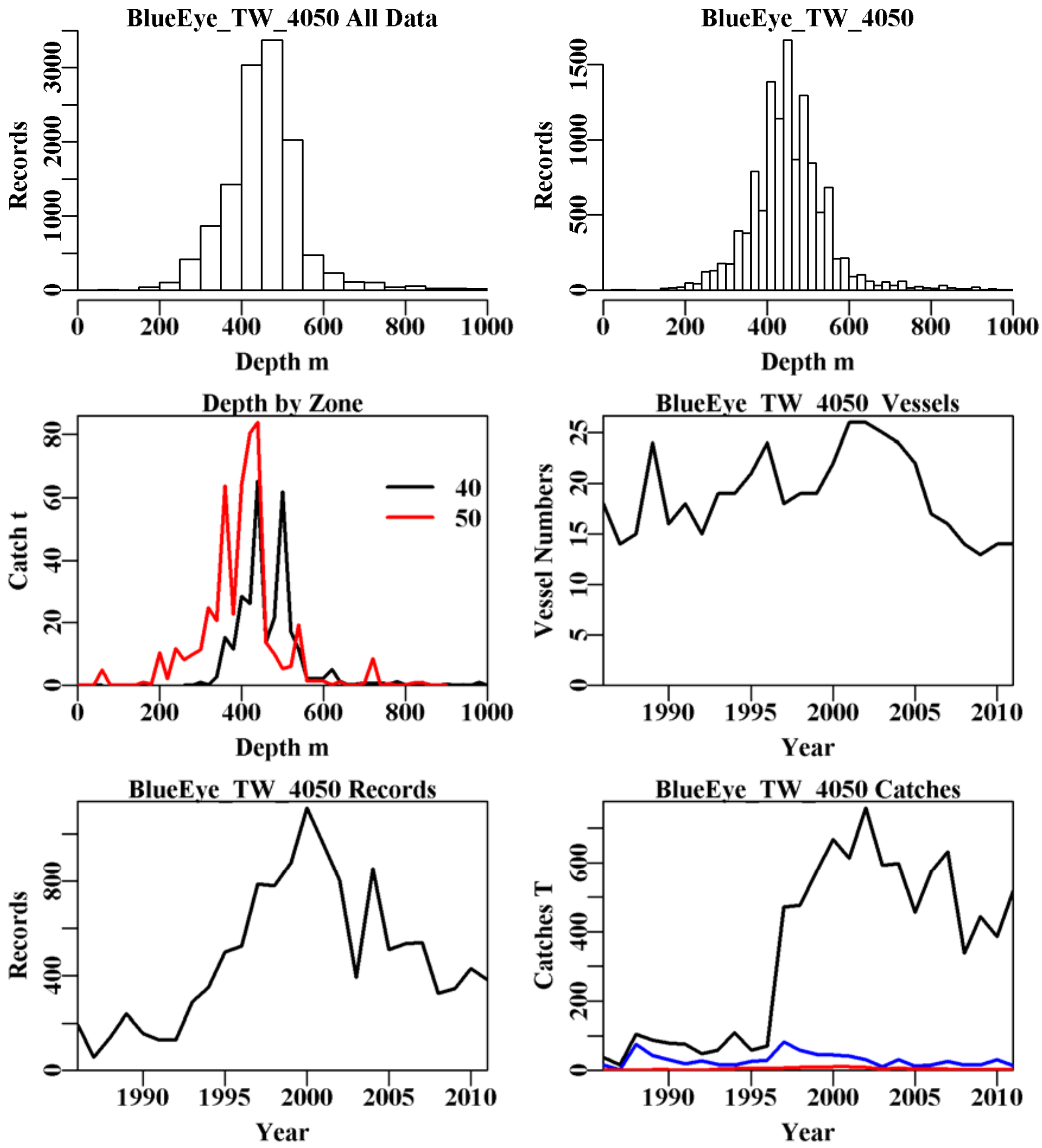

Figure 13.61. BlueEye from Zones 40 and 50 in depths 0 to 1000 m by Trawl. The top left is the depth distribution of all records reporting BlueEye, the top right graph depicts the depth distribution of shots containing BlueEye from Zones 40 and 50 in depths 0 to 1000 m by Trawl. The middle left diagram depicts the distribution of catch by depth within zones 40 and 50 (50 is top red line), the middle right hand graph depicts the number of vessels through time. The bottom left reflects the number of records used in analysis, and bottom right is the BlueEye catches (top line, black is total catches, middle line, blue, are those used in the analysis, and bottom, red, are catches < 30Kg).

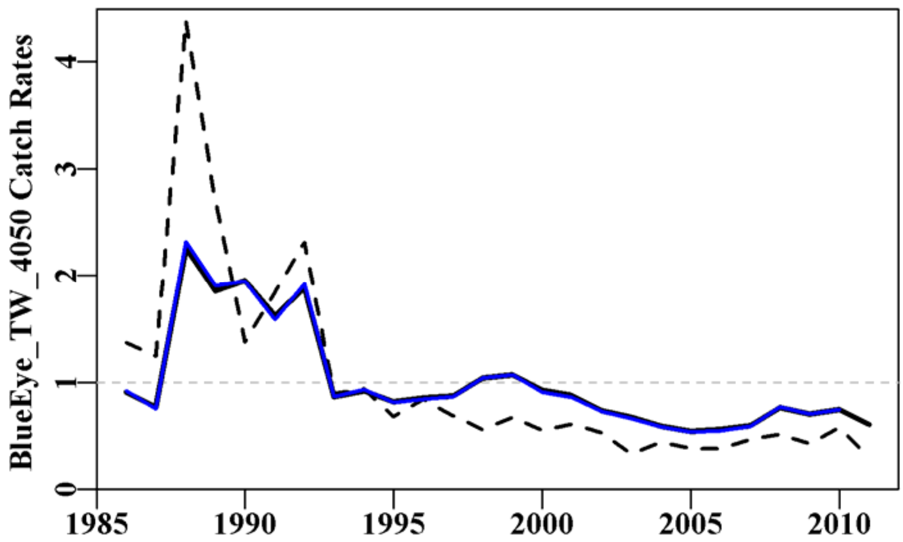

Figure 13.62**.** BlueEye from Zones 40 and 50 in depths 0 to 1000 m by Trawl. The dashed black line represents the geometric mean catch rate and the solid black line the standardized catch rates. The graph standardizes catch rates relative to the mean of the standardized catch rates.

Table 13.50. BlueEye from Zones 40 and 50 in depths 0 to 1000 m by Trawl. Statistical model structures used in this analysis. DepCat is a series of 20 metre depth categories.

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

Table 13.51. BlueEye from Zones 40 and 50 in depths 0 to 1000 m by Trawl . Model selection criteria, including the AIC, the adjusted r^2 and the change in adjusted r^2. The optimum was model Zone:DepCat.

	Year	Vessel	DepCat	DayNight	Month	Zone	Zone:Mth	Zone:DepC
AIC	8034	2689	2278	2017	1974	1927	1911	1903
RSS	23547	15061	14399	14090	14015	13959	13917	13821
MSS	2683	11169	11831	12141	12216	12272	12314	12409
Nobs	12317	12317	12265	12265	12265	12265	12265	12265
Npars	26	106	155	158	169	170	181	219
adj_r2	10.047	42.088	44.406	45.587	45.829	46.040	46.155	46.354
%Change	0.000	32.040	2.319	1.181	0.242	0.211	0.115	0.199

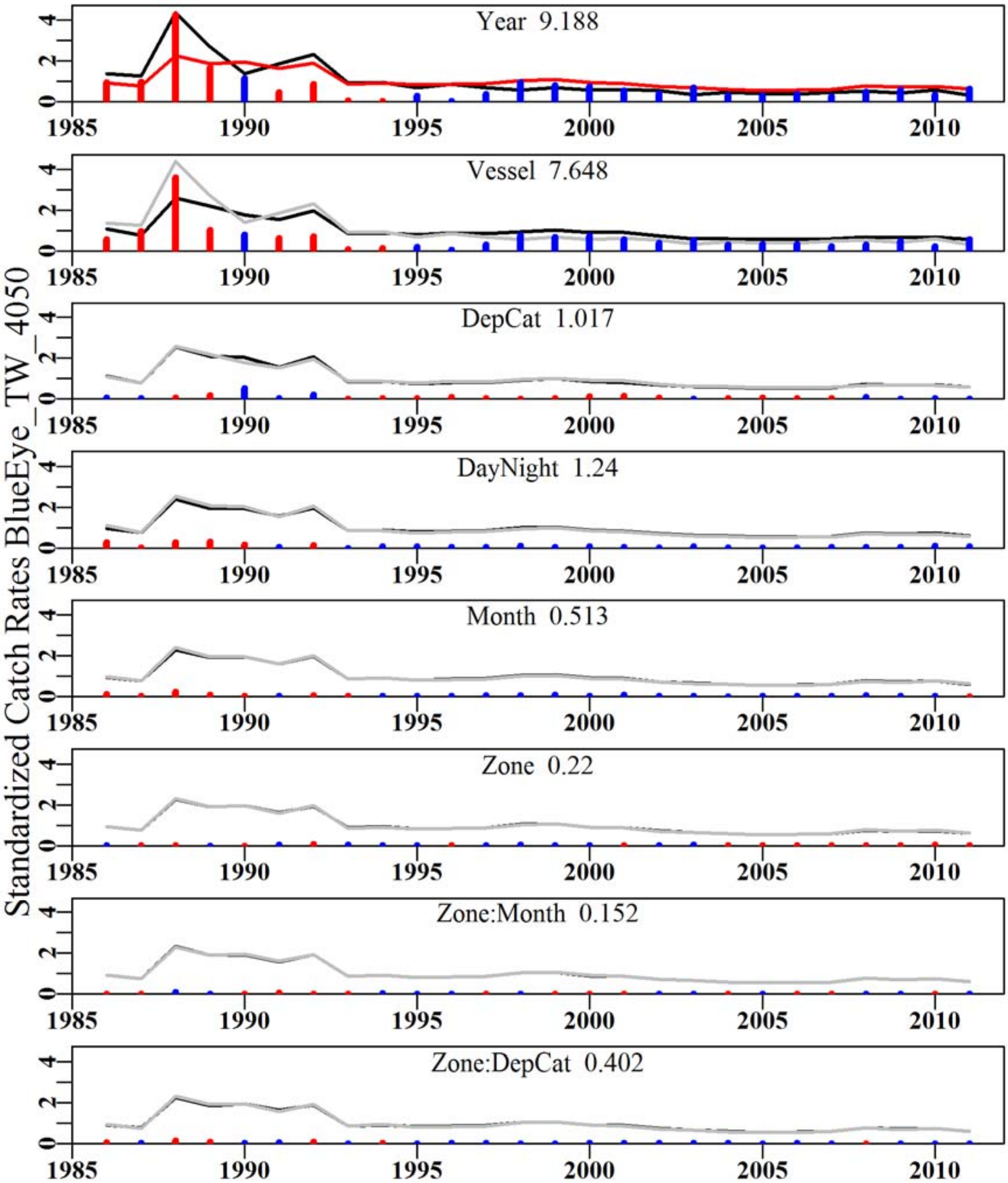

Figure 13.63**.** The relative influence of each factor used on the final trend in the optimal standardization for BlueEye in Zones 40 – 50. The top graph depicts the geometric mean (the black line) and the optimum model (the red line). The difference between them is illustrated by the vertical bars with blue bars indicating the optimum model is higher than the geometric mean and red bars indicating it is lower. The top graph bars are the sum of all the bars in the graphs below. The graphs for individual factors are cumulative. Thus the second graph has the geometric mean (grey line) and the effect of adding Year + factor2 (model 2). In the third graph, the grey line represents model 2 and the black line the effect of adding factor3 to the model. The remaining graphs continue in the same cumulative manner except for the interaction terms which are added singularly to the final single factor model.

13.22 Blue Eye, AL (TBE – 37445001 – H. antarctica)

Depths between 200-600m. All data from auto-longlining. 1997 was omitted as being unrepresentative due to very lower numbers of records.

Table 13.52. BlueEye from the SESSF in depths 200 – 600m by AutoLongLine. Total Catch is the total reported in the database, Records is the number of records used in the analysis, CatchT is the reported catch in the area and depth used in the analysis, and Vessels relates to all vessels used in the analysis. Geomean is the geometric mean of catch rates (kg/hr). Zone:DepCat is the optimum model and StDev is the standard deviation relating to the data in the optimum model.

Year	TotCatch	Records	CatchT	Vessels	GeoMean	Zone:DepC	StDev
1998	475.965	28	14.989	2	249.6862	0.5615	0.0000
1999	574.484	50	47.670	2	536.1933	1.9718	0.3284
2000	667.056	29	28.299	2	608.0267	1.5945	0.3624
2001	612.354	65	40.232	2	246.5002	0.8418	0.3151
2002	758.103	228	131.686	4	162.2961	0.7989	0.2880
2003	592.295	434	157.016	7	133.4303	1.1368	0.2818
2004	598.119	1147	269.120	11	72.0019	1.1079	0.2776
2005	455.408	1137	300.462	7	77.8010	0.8835	0.2778
2006	573.719	1067	345.481	9	102.2372	0.9318	0.2767
2007	631.172	658	453.819	6	364.8943	1.1963	0.2787
2008	337.335	604	277.917	6	232.1695	0.8064	0.2789
2009	443.095	550	313.987	6	289.6046	0.9263	0.2784
2010	385.706	483	230.042	5	184.8051	0.5961	0.2795
2011	517.919	526	225.716	5	209.8939	0.6464	0.2792

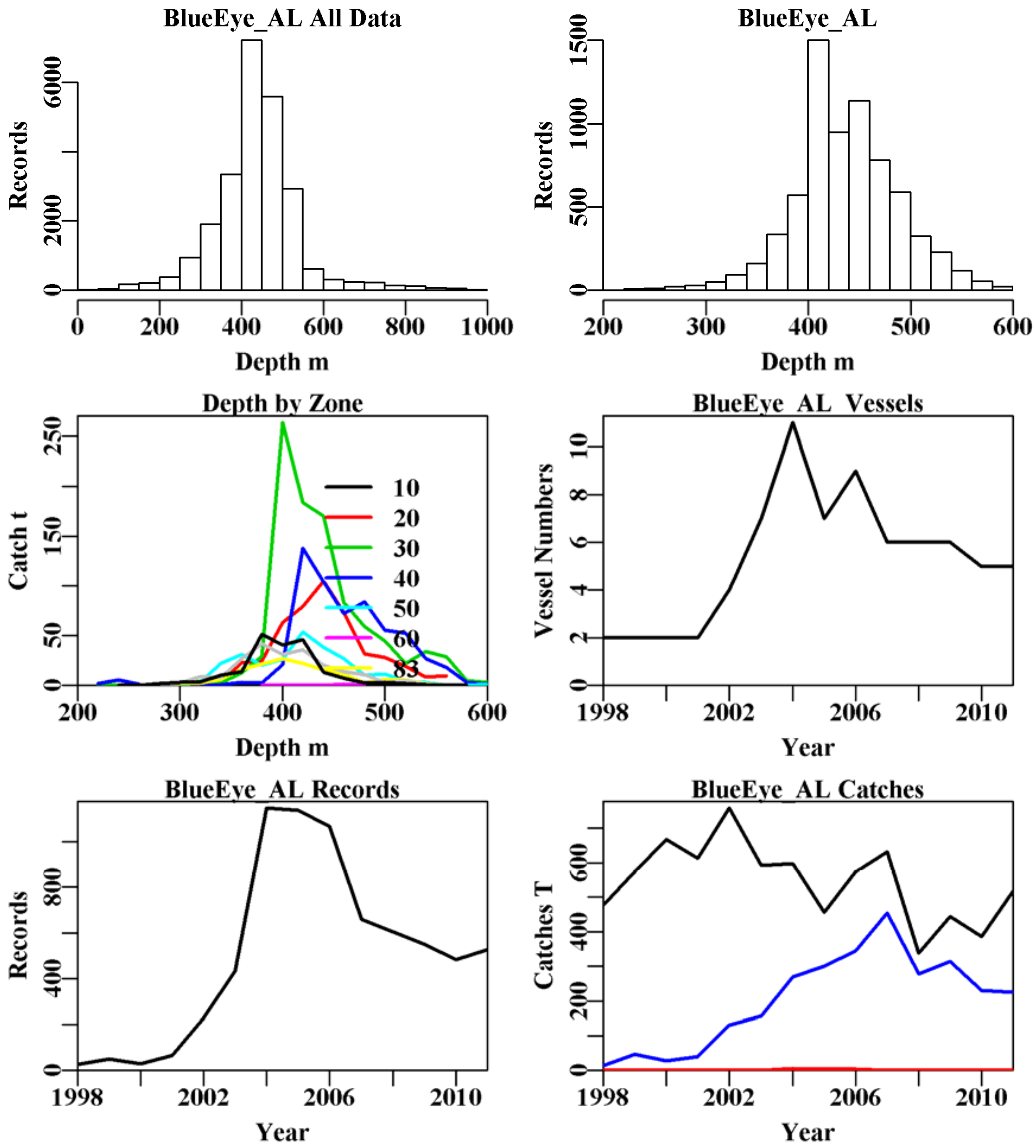

Figure 13.64. BlueEye from the SESSF in depths 200 – 600m by Auto-LongLine. The top left is the depth distribution of all records reporting BlueEye, the top right graph depicts the depth distribution of shots containing BlueEye from the SESSF in depths 200 – 600m by Auto-LongLine. The middle left diagram depicts the distribution of catch by depth across the zones of the SESSF, the middle right hand graph depicts the number of vessels through time. The bottom left reflects the number of records used in analysis, and bottom right is the BlueEye catches (top line, black is total catches, middle line, blue, are those used in the analysis, and bottom, red, are catches < 30Kg).

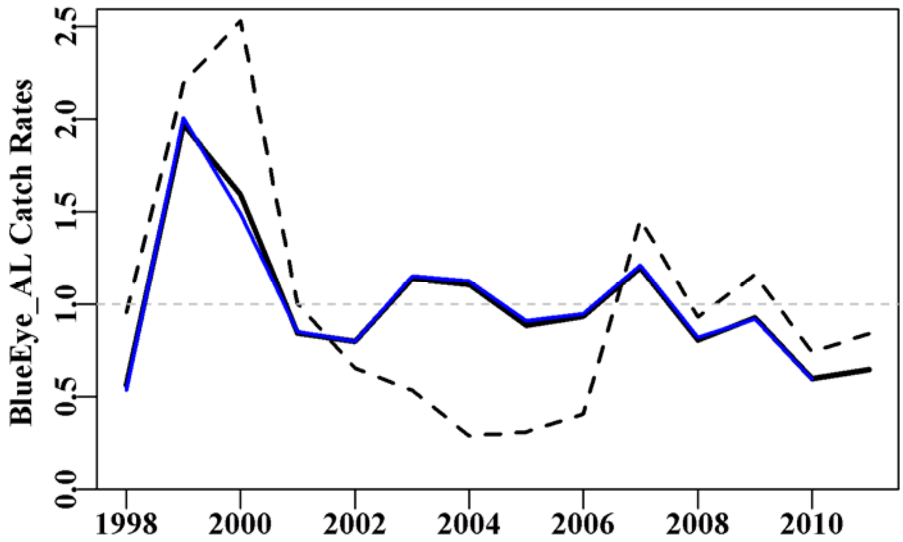

Figure 13.65. BlueEye from the SESSF in depths 200 – 600m by Auto-LongLine. The dashed black line represents the geometric mean catch rate and the solid black line the standardized catch rates. The graph standardizes catch rates relative to the mean of the standardized catch rates.

Table 13.53. BlueEye from the SESSF in depths 200 – 600m by Auto-LongLine. Statistical model structures used in this analysis. DepCat is a series of 20 metre depth categories.

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

Table 13.54. BlueEye from the SESSF in depths 200 – 600m by Auto-LongLine. Model selection criteria, including the AIC, the adjusted r^2 and the change in adjusted r^2. The optimum was model Zone:Month.

	Year	Vessel	Month	Zone	DayNight	DepCat	Zone:Mth	Zone:DepC
AIC	6449	4429	3824	3682	3630	3589	3574	3589
RSS	17519	13086	11965	11717	11621	11470	11408	11403
MSS	2365	6798	7919	8167	8263	8414	8476	8481
Nobs	7006	7006	7006	7001	7001	6979	6979	6979
Npars	14	26	37	38	41	61	72	80
adj_r2	11.731	33.954	39.517	40.760	41.222	41.816	42.038	41.994
%Change	0.000	22.223	5.563	1.243	0.462	0.594	0.222	-0.045

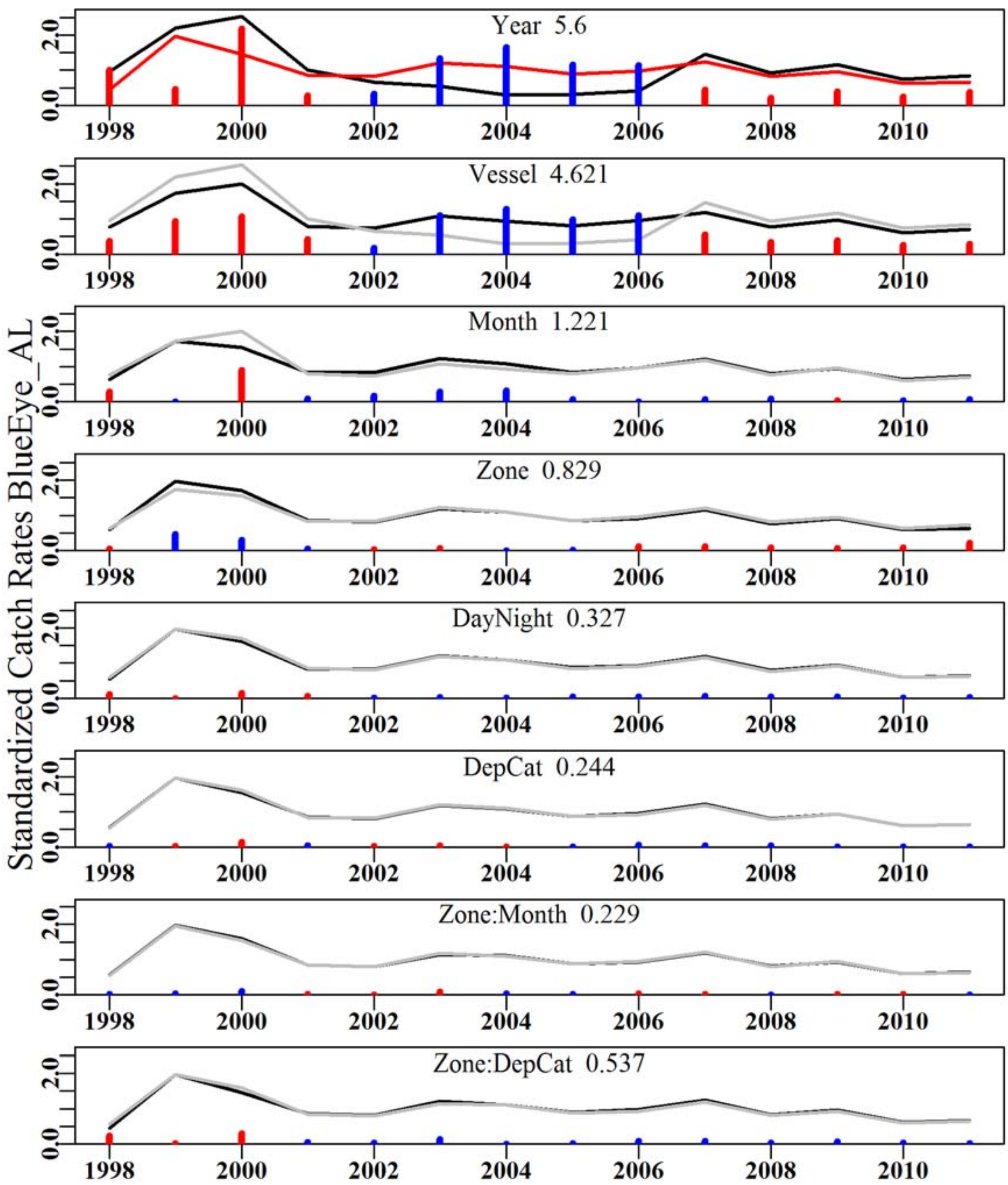

Figure 13.66**.** The relative influence of each factor used on the final trend in the optimal standardization for BlueEye in by Auto-Longline. The top graph depicts the geometric mean (the black line) and the optimum model (the red line). The difference between them is illustrated by the vertical bars with blue bars indicating the optimum model is higher than the geometric mean and red bars indicating it is lower. The top graph bars are the sum of all the bars in the graphs below. The graphs for individual factors are cumulative. Thus the second graph has the geometric mean (grey line) and the effect of adding Year + factor2 (model 2). In the third graph, the grey line represents model 2 and the black line the effect of adding factor3 to the model. The remaining graphs continue in the same cumulative manner except for the interaction terms which are added singularly to the final single factor model.

13.23 Blue Eye, DL (TBE – 37445001 – H. antarctica)

Depths between 200-600m. All data from Drop-lining. All vessels reporting blue eye by drop line are included. There are records following 2005 but there does not appear to be any depth data associated with Drop Line records.

Table 13.55. BlueEye from the SET and GHT fishery in depths between 200 – 600m, taken by Drop Line. Total Catch is the total reported in the database, Records is the number of records used in the analysis, CatchT is the reported catch in the area and depth used in the analysis, and Vessels relates to all vessels used in the analysis. Geomean is the geometric mean of catch rates (kg/hr). Zone:Month is the optimum model and StDev is the standard deviation relating to the data in the optimum model.

Year	TotCatch	Records	CatchT	Vessels	GeoMean	Zone:Mth	StDev
1997	470.091	515	248.463	38	269.5548	1.6934	0.0000
1998	475.965	700	320.649	30	234.7678	1.2383	0.0769
1999	574.484	868	338.923	29	182.2847	1.0864	0.0794
2000	667.056	1056	377.828	33	172.0296	1.0734	0.0817
2001	612.354	739	318.120	26	200.3223	1.1806	0.0856
2002	758.103	570	180.454	22	164.7123	0.9831	0.0908
2003	592.295	533	167.639	22	162.1210	0.8273	0.0945
2004	598.119	484	148.266	23	161.8513	0.9684	0.0972
2005	455.408	338	79.885	16	133.7709	0.7652	0.1064
2006	573.719	303	104.599	13	224.9012	1.0556	0.1143
2007	631.172	125	45.301	10	213.7543	1.3748	0.1411
2008	337.335	77	15.679	7	137.5913	0.8192	0.1612
2009	443.095	81	17.818	9	124.4663	0.5704	0.1729
2010	385.706	191	28.218	9	77.7373	0.5393	0.1405
2011	517.919	166	32.368	9	104.9216	0.8247	0.1513

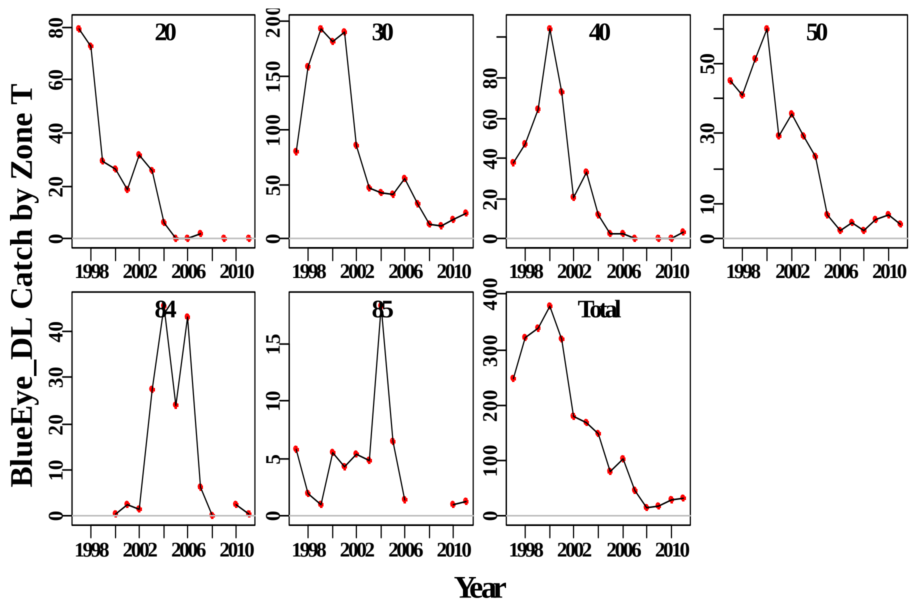

Figure 13.67**.** BlueEye catches by zone from the SESSF in depths 200 – 600m by DropLine.

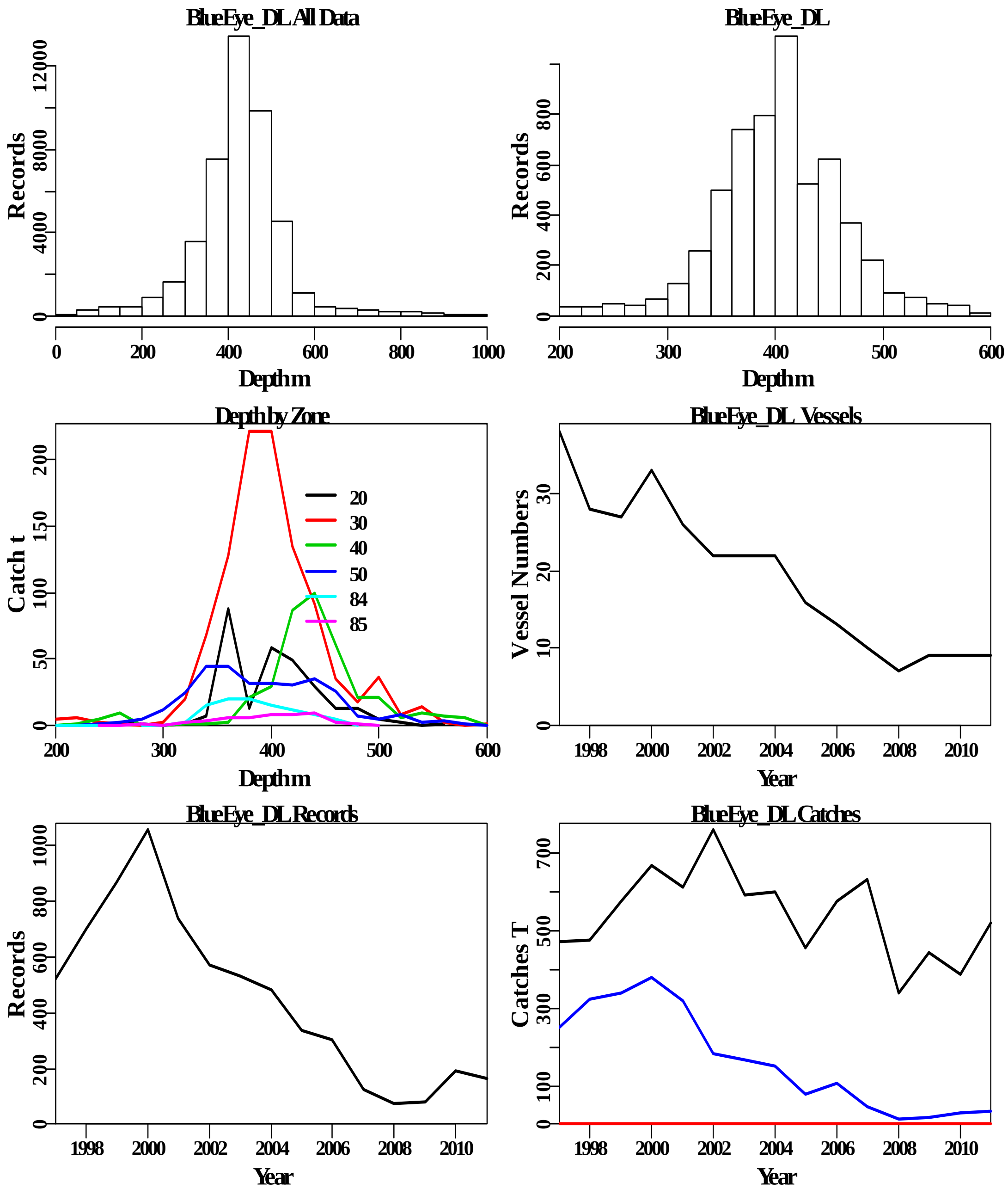

Figure 13.68**.** BlueEye from the SET and GHT fishery in depths between 200 – 600m, taken by Drop Line. The top left is the depth distribution of all records reporting BlueEye, the top right graph depicts the depth distribution of shots containing BlueEye from the SET and GHT fishery in depths between 200 – 600m, taken by Drop Line. The middle left diagram depicts the distribution of catch by depth by SESSF zone, the middle right hand graph depicts the number of vessels through time. The bottom left reflects the number of records used in analysis, and bottom right is the BlueEye catches (top line, black is total catches, middle line, blue, are those used in the analysis, and bottom, red, are catches < 30Kg).

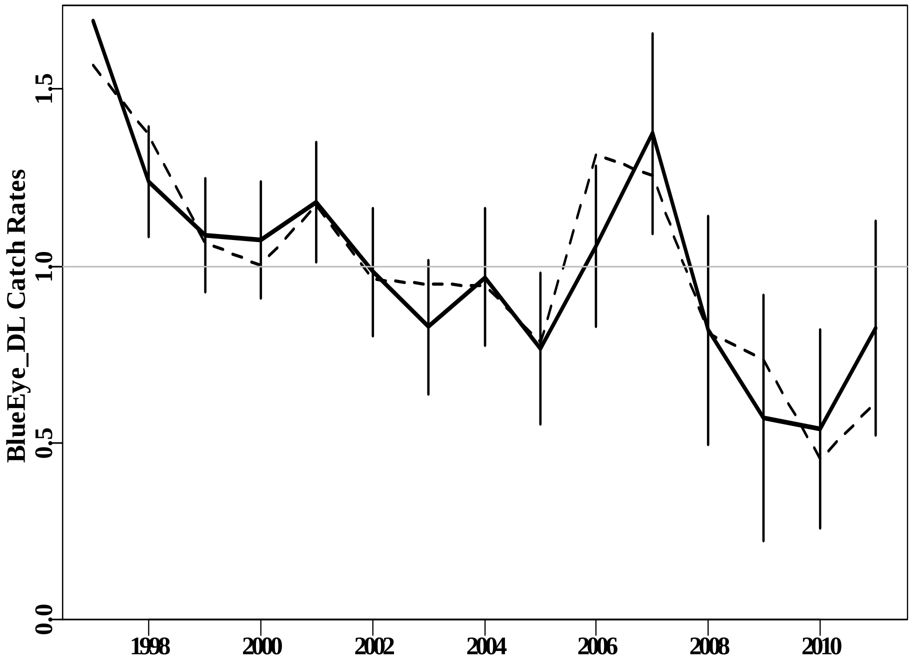

Figure 13.69**.** BlueEye from the SEN and GHT fishery in depths between 200 – 600m, taken by Drop Line. The dashed black line represents the geometric mean catch rate and the solid black line the standardized catch rates. The graph standardizes catch rates relative to the mean of the standardized catch rates.

Table 13.56**.** BlueEye from the SET and GHT fishery in depths between 200 – 600m, taken by Drop Line. Statistical model structures used in this analysis. DepCat is a series of 20 metre depth categories.

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

Table 13.57**.** BlueEye from the SET and GHT fishery in depths between 200 – 600m, taken by Drop Line. Model selection criteria, including the AIC, the adjusted r^2 and the change in adjusted r^2. The optimum is model 7.

	Year	Vessel	Month	Zone	DayNight	Zone:Mth
AIC	3949	2904	2533	2513	2502	2482
RSS	12060	10063	9494	9457	9438	9381
MSS	408	2405	2973	3010	3029	3087
Nobs	6746	6746	6746	6746	6746	6746
Npars	15	103	114	117	118	129
adj_r2	3.070	18.047	22.550	22.816	22.959	23.302
%Change	0.000	14.977	4.502	0.266	0.143	0.344

13.24 Blue Eye, AL & DL (TBE – 37445001 – H. antarctica)

Depths between 200-600m m. All data from auto-longlining and droplining combined. Zones 20 – 50, and 83 – 85 included (83 – 85 are in the GAB).

Table 13.58**.** BlueEye from the SEN and GHT in depths 200 – 600m by Auto Long Line and Drop Line. Total Catch is the total reported in the database, Records is the number of records used in the analysis, CatchT is the reported catch in the area and depth used in the analysis, and Vessels relates to all vessels used in the analysis. Geomean is the geometric mean of catch rates (kg/hr). Zone:Month is the optimum model and StDev is the standard deviation relating to the data in the optimum model.

Year	TotCatch	Records	CatchT	Vessels	GeoMean	Zone:Mth	StDev
1997	470.716	547	254.786	39	258.2795	1.8553	0.0000
1998	475.965	758	340.896	30	226.1524	1.2439	0.0795
1999	574.484	927	387.055	30	189.1263	1.1126	0.0815
2000	667.056	1086	406.152	34	177.6127	1.0566	0.0843
2001	612.354	807	358.910	27	202.9873	1.1035	0.0873
2002	758.103	799	312.210	24	163.8436	0.8559	0.0889
2003	592.295	969	324.984	25	148.5823	0.9295	0.0883
2004	598.119	1638	418.296	29	91.4807	1.0215	0.0874
2005	455.408	1479	381.087	23	88.2645	0.8194	0.0899
2006	573.719	1368	447.130	19	121.2856	0.9396	0.0900
2007	631.172	783	498.943	15	333.7817	1.1791	0.0959
2008	337.335	684	293.497	13	214.3734	0.7867	0.0975
2009	443.095	631	331.806	15	259.8521	0.8701	0.0977
2010	385.706	680	259.006	14	142.9654	0.5634	0.0978
2011	517.919	692	258.084	14	177.7306	0.6629	0.0976

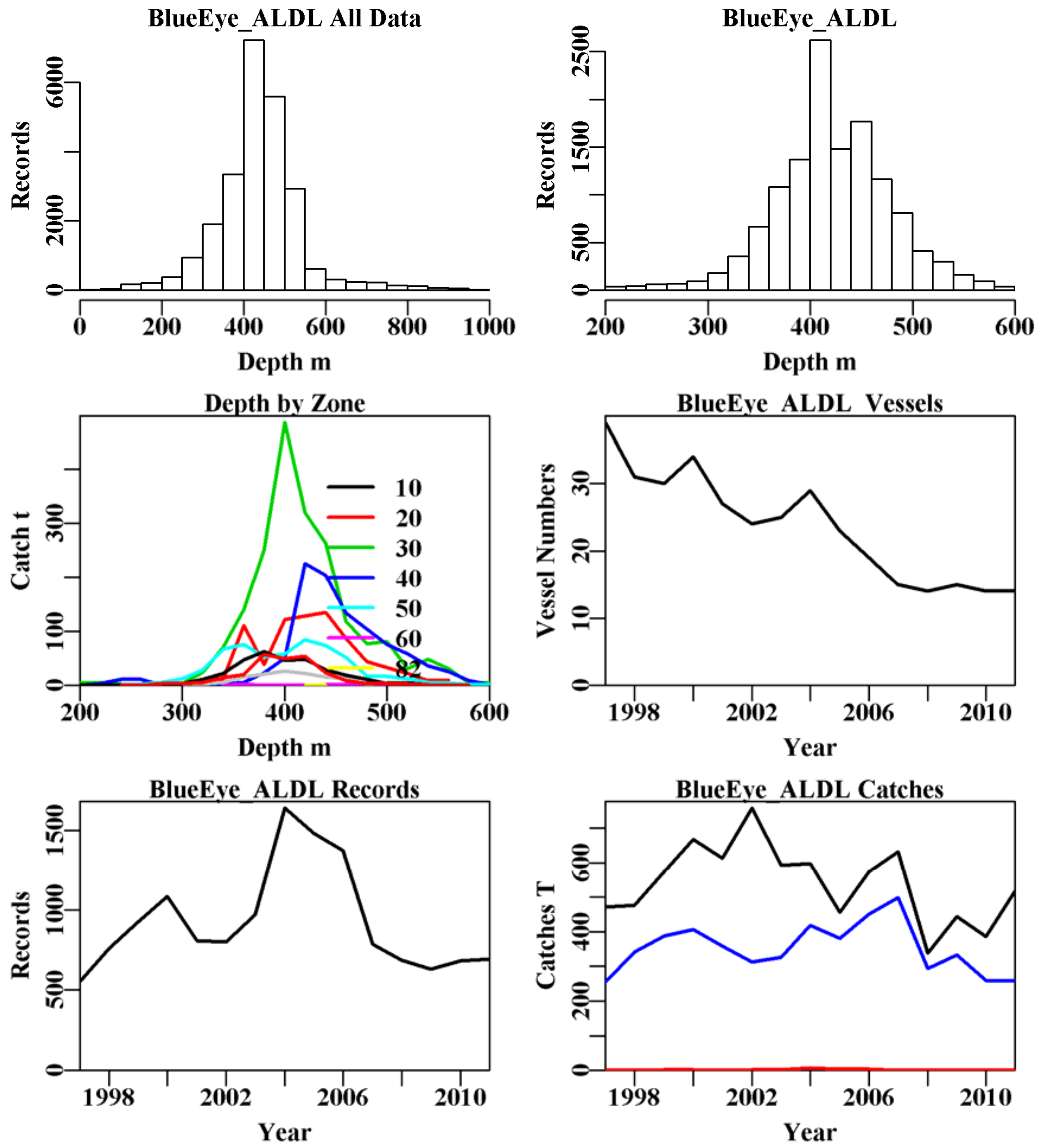

Figure 13.70**.** BlueEye from the SEN and GHT in depths 200 – 600m by Auto Long Line and Drop Line. The top left is the depth distribution of all records reporting BlueEye, the top right graph depicts the depth distribution of shots containing BlueEye from the SEN and GHT in depths 200 – 600m by Auto Long Line and Drop Line. The middle left diagram depicts the distribution of catch by depth, the middle right hand graph depicts the number of vessels through time. The bottom left reflects the number of records used in analysis, and bottom right is the BlueEye catches (top line, black is total catches, middle line, blue, are those used in the analysis, and bottom, red, are catches < 30Kg).

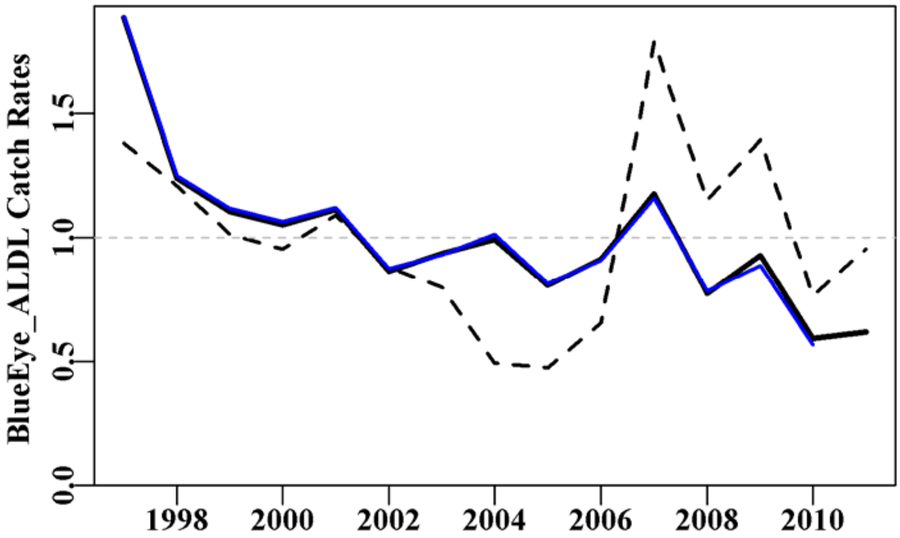

Figure 13.71. BlueEye from the SEN and GHT in depths 200 – 600m by Auto Long Line and Drop Line. The dashed black line represents the geometric mean catch rate and the solid black line the standardized catch rates. The graph standardizes catch rates relative to the mean of the standardized catch rates

Table 13.59. BlueEye from the SEN and GHT in depths 200 – 600m by Auto Long Line and Drop Line. Statistical model structures used in this analysis. DepCat is a series of 20 metre depth categories.

Model 1	LnCE~Year
Model 2	LnCE~Year+Vessel
Model 3	LnCE~Year+Vessel+DepCat
Model 4	LnCE~Year+Vessel+DepCat+Month
Model 5	LnCE~Year+Vessel+DepCat+Month+DayNight
Model 6	LnCE~Year+Vessel+DepCat+Month+DayNight+Zone
Model 7	LnCE~Year+Vessel+DepCat+Month+DayNight+Zone+Method
Model 8	LnCE~Year+Vessel+DepCat+Month+DayNight+Zone+Method+Zone:Month
Model 9	LnCE~Year+Vessel+DepCat+Month+DayNight+Zone+Method+Zone:DepCat
Model 10	LnCE~Year+Vessel+DepCat+Month+DayNight+Zone+Method+Zone:Method
Model 11	LnCE~Year+Vessel+DepCat+Month+DayNight+Zone+Method+Month:Method

Table 13.60. BlueEye from the SEN and GHT in depths 200 – 600m by Auto Long Line and Drop Line. Model selection criteria, including the AIC, the adjusted r^2 and the change in adjusted r^2. The optimum is model Zone, though Zone:Month is very close. DepC is Depth Category, Mth is Month, DN is DayNight, Meth is Method and Zon is Zone.

	Year	Vessel	DepC	Mth	DN	Zone	Meth	Zon:Mth	Zon:DepC	Zon:Meth	Mth:Meth
AIC	11057	7575	7133	6388	6372	6191	6221	6192	6207	6246	6285
RSS	30709	23556	21896	20624	20587	20281	20280	20200	20194	20272	19863
MSS	2086	9239	10898	12171	12207	12514	12515	12595	12600	12522	12932
Nobs	13855	13855	12802	12802	12802	12784	12784	12784	12784	12784	12784
Npars	15	111	131	142	145	146	147	172	181	162	326
adj_r2	6.265	27.597	32.547	36.412	36.509	37.449	37.446	37.570	37.542	37.396	37.852
%Change	0	21.332	4.950	3.865	0.096	0.940	-0.003	0.124	-0.028	-0.146	0.456

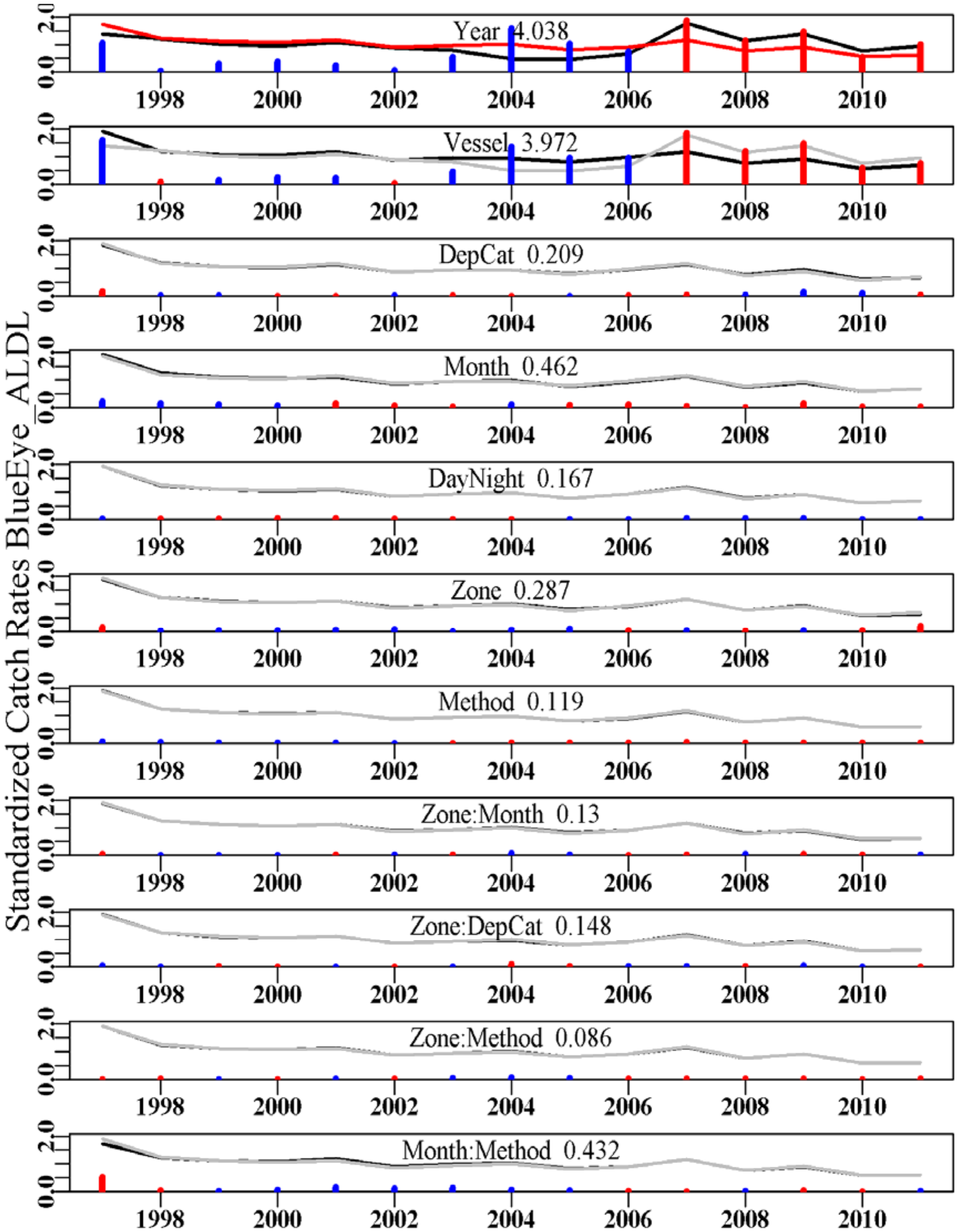

Figure 13.72. The relative influence of each factor used on the final trend in the optimal standardization for BlueEye by AL and DL. The top graph depicts the geometric mean (the black line) and the optimum model (the red line). The difference between them is illustrated by the vertical bars with blue bars indicating the optimum model is higher than the geometric mean and red bars indicating it is lower. The top graph bars are the sum of all the bars in the graphs below. The graphs for individual factors are cumulative. Thus the second graph has the geometric mean (grey line) and the effect of adding Year + factor2 (model 2). In the third graph, the grey line represents model 2 and the black line the effect of adding factor3 to the model. The remaining graphs continue in the same cumulative manner except for the interaction terms which are added singularly to the final single factor model.

13.24.1 Preliminary Consideration of Closure Effects on CPUE

One issue relating to the impacts of closures, for which a working solution has still to be found, is the effect of Industry members fishing close along the edges of closures. While there is nothing wrong with fishing in this manner the resolution of the GPS data entered in to the catch effort database is sometimes such that an array of reported shots appear to have been conducted inside the closures. Given the use of VMS in all cases these locations are assumed to be a result of small rounding errors when reporting locations.

In order to validly compare the older catch rates within a closure and the catch rates outside it is currently necessary to consider the data shot-by-shot and decide whether those on the edges and just inside the boundary of closures are to be treated as if they were made inside or outside. Owing to the scale of this only the St Helens Hill closure has been examined in the first instance (Figure 13.73).

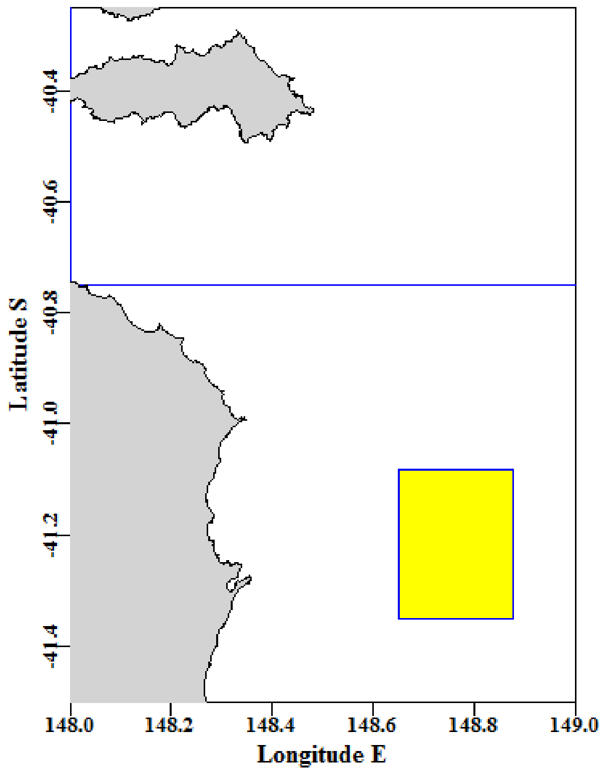

Figure 13.73. A schematic map illustrating the location and extent of the St Helens Hill closure on the east coast of Tasmania. Since the introduction of the closure in 2007 catches have been very much reduced inside the closure although there has been some confusion brought about by what is assumed to be rounding errors on the reporting of GPS locations (Table 13.61).

While there was a surge of catches in 2007, since then catches have been reduced relative to those taken in the general area in earlier years.

Table 13.61. Catches of BlueEye in the vicinity of the St Helens Closure. Actually Outside relates to the catches reported that came from the edge or seemingly just inside the closure (these are the sum of the Apparently Outside and the Inside Edge of Closure). Actually Inside relates to the catches that are inferred to have in fact been taken inside the closure.

Year	Actually Outside	Apparently Outside	Actually Inside	Inside Edge of Closure	Apparently Inside
1997	3.155	3.155	12.735		12.735
1998	17.179	16.179	21.428	1.000	22.428
1999	18.109	17.739	46.907	0.370	47.277
2000	4.898	4.573	61.971	0.325	62.296
2001	10.627	6.187	62.234	4.440	66.674
2002	18.415	5.990	38.205	12.425	50.630
2003	8.011	5.897	40.758	2.114	42.872
2004	5.597	3.329	37.070	2.268	39.338
2005	2.518	2.218	18.827	0.300	19.127
2006	6.948	6.728	10.120	0.220	10.340
2007	52.284	40.600	0.823	11.684	12.507
2008	15.156	13.764	1.100	1.392	2.492
2009	14.001	10.217	0.308	3.784	4.092
2010	14.036	9.619	1.793	4.417	6.210
2011	17.358	16.947		0.411	0.411

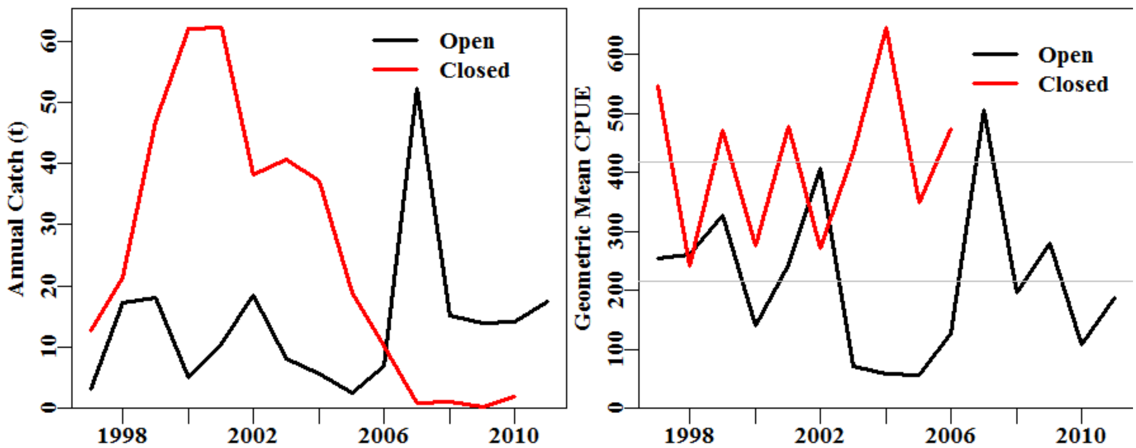

Figure 13.74. The catches and geometric mean catch-rates for both inside and outside the St Helens Closure. The average catch rate inside and outside (the grey lines) were 418kg/hr relative to 215 kg/hr. There were only 6 records for the years 2007 – 2011 inside the closure so those catch rates are omitted as being accidentally high.

The catch rates on the edge of the closure relative to those inside were almost 50% lower, albeit rather more variable. At least in and around the St Helens closure the closure does appear to have led to the appearance that catch rates have declined. Of course this analysis cannot be certain that catch rates will be better on the St Helens hill, as in the past, and the only solid way to determine this would be to sample within the closure.

13.25 Blue Grenadier Spawning (GRE – 37227001 – Macruronus novaezelandiae)

Data from Zone 40 in months June to August, depths between 100 and 1000m.

Table 13.62**.** Blue Grenadier from Zone 40 between June and August in depths between 100 – 1000m, taken by Trawl. Total Catch is the total reported in the database, Records is the number of records used in the analysis, CatchT is the reported catch in the area and depth used in the analysis, and Vessels relates to all vessels used in the analysis. Geomean is the geometric mean of catch rates (kg/hr). Model 5 is the optimum model and StDev is the standard deviation relating to the data in the optimum model.

Year	TotCatch	Records	CatchT	Vessels	GeoMean	DayNight	StDev
1986	1451.778	89	237.730	8	252.1522	1.0104	0.0000
1987	2244.828	205	780.225	12	444.9725	1.2815	0.3107
1988	1849.147	92	319.022	8	387.7497	2.5819	0.3208
1989	1890.855	31	36.120	4	125.3994	0.6686	0.4459
1990	2280.471	158	565.635	10	268.6781	0.6558	0.3078
1991	3669.036	112	618.606	14	745.6978	2.5251	0.3500
1992	2474.546	152	500.586	10	484.1498	1.1723	0.3312
1993	2482.270	181	789.508	14	527.5902	1.7533	0.3289
1994	2315.490	323	974.288	17	311.1013	0.9693	0.3155
1995	1931.046	478	908.891	15	65.6455	0.4066	0.3138
1996	2304.234	497	1198.174	14	71.7968	0.6127	0.3209
1997	3654.679	555	2622.788	11	114.6872	0.4675	0.3204
1998	4226.177	581	2704.903	18	127.2732	0.5976	0.3154
1999	7572.998	1058	5441.838	14	359.1395	0.4746	0.3132
2000	7503.140	945	5627.807	15	299.1618	0.5129	0.3133
2001	8370.799	1089	7281.264	15	482.7733	0.7799	0.3130
2002	7978.310	1038	6825.011	14	333.3040	0.5865	0.3129
2003	7948.324	1054	7201.361	17	620.3759	0.5402	0.3141
2004	6093.498	825	4614.533	15	225.8117	0.4352	0.3154
2005	4506.740	417	2845.032	11	488.4239	0.9876	0.3226
2006	3544.354	470	2034.825	13	475.8843	1.7716	0.3240
2007	3128.212	306	1738.986	8	270.5783	1.2380	0.3332
2008	4152.329	293	2808.682	10	737.4291	0.8791	0.3279
2009	3874.668	349	2704.191	9	620.2829	1.1669	0.3248
2010	4552.385	456	3362.757	6	681.3735	0.9120	0.3218
2011	4476.805	484	3527.195	10	387.0848	1.0127	0.3191

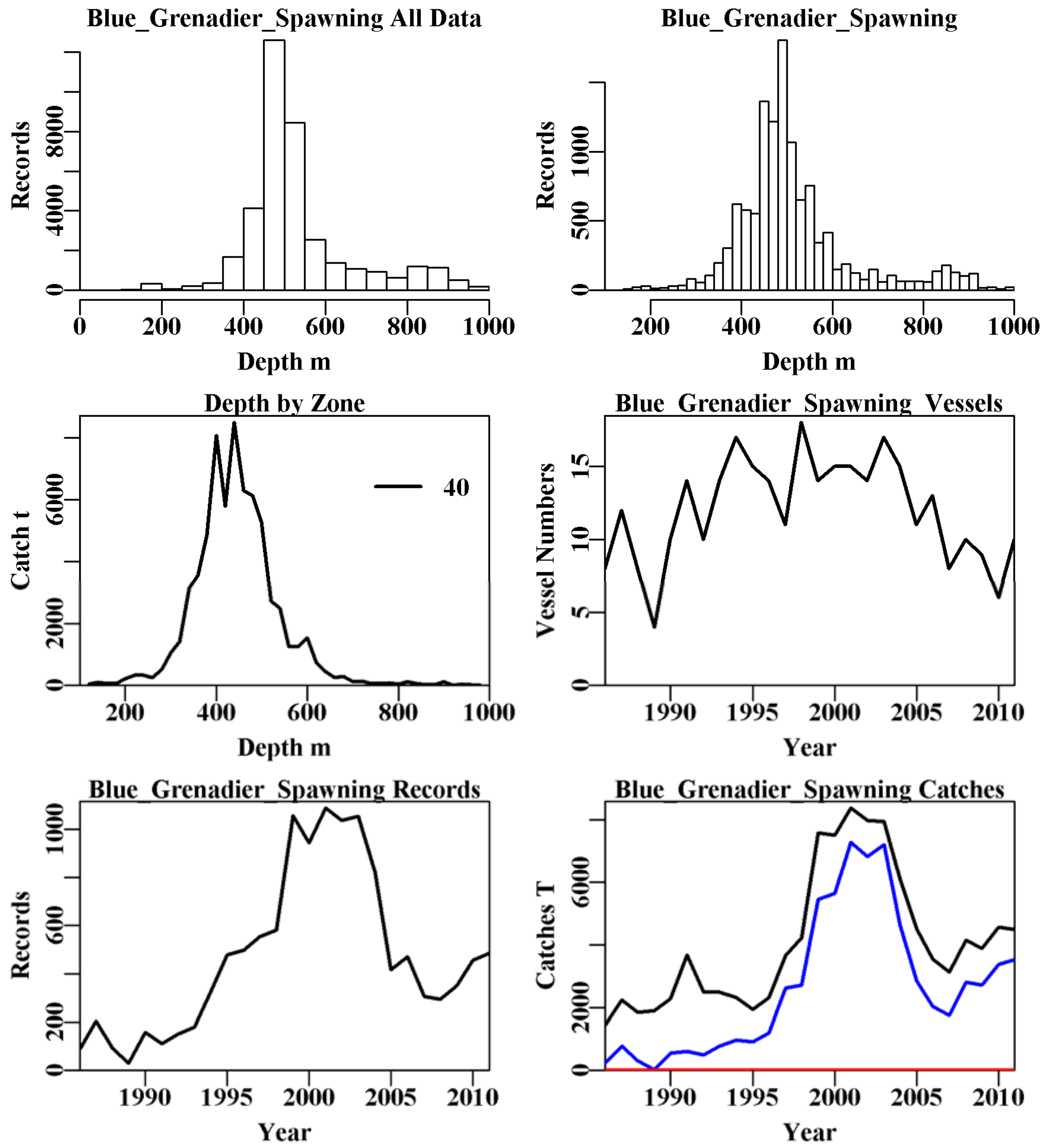

Figure 13.75. Blue Grenadier from Zone 40 between June and August in depths between 100 – 1000m, taken by Trawl. The top left is the depth distribution of all records reporting Blue Grenadier, the top right graph depicts the depth distribution of shots containing Blue Grenadier from Zone 40 between June and August in depths between 100 – 1000m, taken by Trawl. The middle left diagram depicts the distribution of catch by depth by SESSF zone, the middle right hand graph depicts the number of vessels through time. The bottom left reflects the number of records used in analysis, and bottom right is the Blue Grenadier catches (top line, black is total catches, middle line, blue, are those used in the analysis, and bottom, red, are catches < 30Kg).

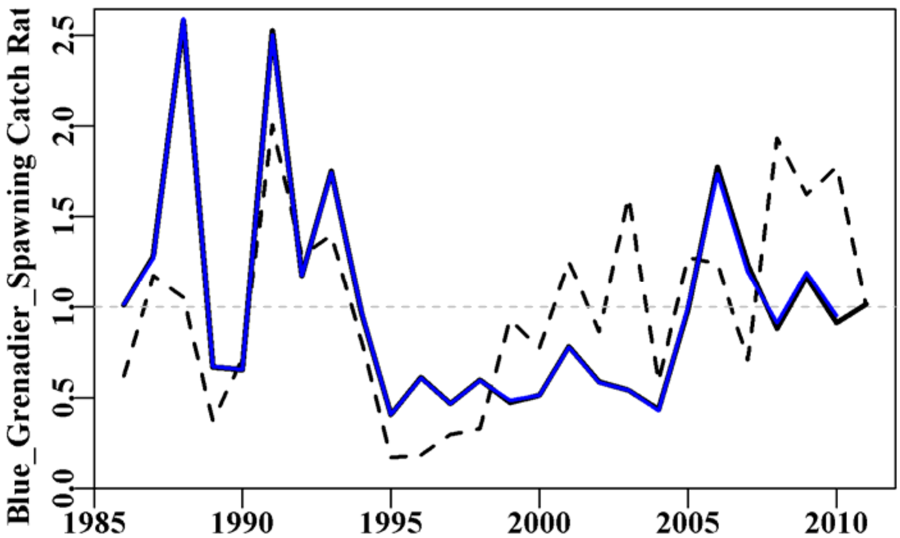

Figure 13.76. Blue Grenadier from Zone 40 between June and August in depths between 100 – 1000m, taken by Trawl. The dashed black line represents the geometric mean catch rate and the solid black line the standardized catch rates. The graph standardizes catch rates relative to the mean of the standardized catch rates.

Table 13.63. Blue Grenadier from Zone 40 between June and August in depths between 100 – 1000m, taken by Trawl. Statistical model structures used in this analysis. DepCat is a series of 20 metre depth categories.

Model 1	LnCE~Year
Model 2	LnCE~Year+Vessel
Model 3	LnCE~Year+Vessel+DepCat
Model 4	LnCE~Year+Vessel+DepCat+Weeknum
Model 5	LnCE~Year+Vessel+DepCat+Weeknum+DayNight
Model 6	LnCE~Year+Vessel+DepCat+Weeknum+DayNight+Weeknum:DepCat

Table 13.64. Blue Grenadier from Zone 40 between June and August in depths between 100 – 1000m, taken by Trawl. Model selection criteria, including the AIC, the deviance and the change in deviance. The optimum is model DayNight (model 5).

	Year	Vessel	DepCat	Weeknum	DayNight	Weeknum:DepCat
AIC	27246	18472	16740	16026	15508	15733
RSS	112915	54485	47096	44312	42438	39430
MSS	5158	63588	70977	73761	75635	78643
Nobs	12238	12238	12141	12141	12141	12141
Npars	26	98	141	154	157	716
adj_r2	4.173	53.486	59.647	61.992	63.590	64.515
%Change	0.000	49.313	6.161	2.345	1.598	0.925

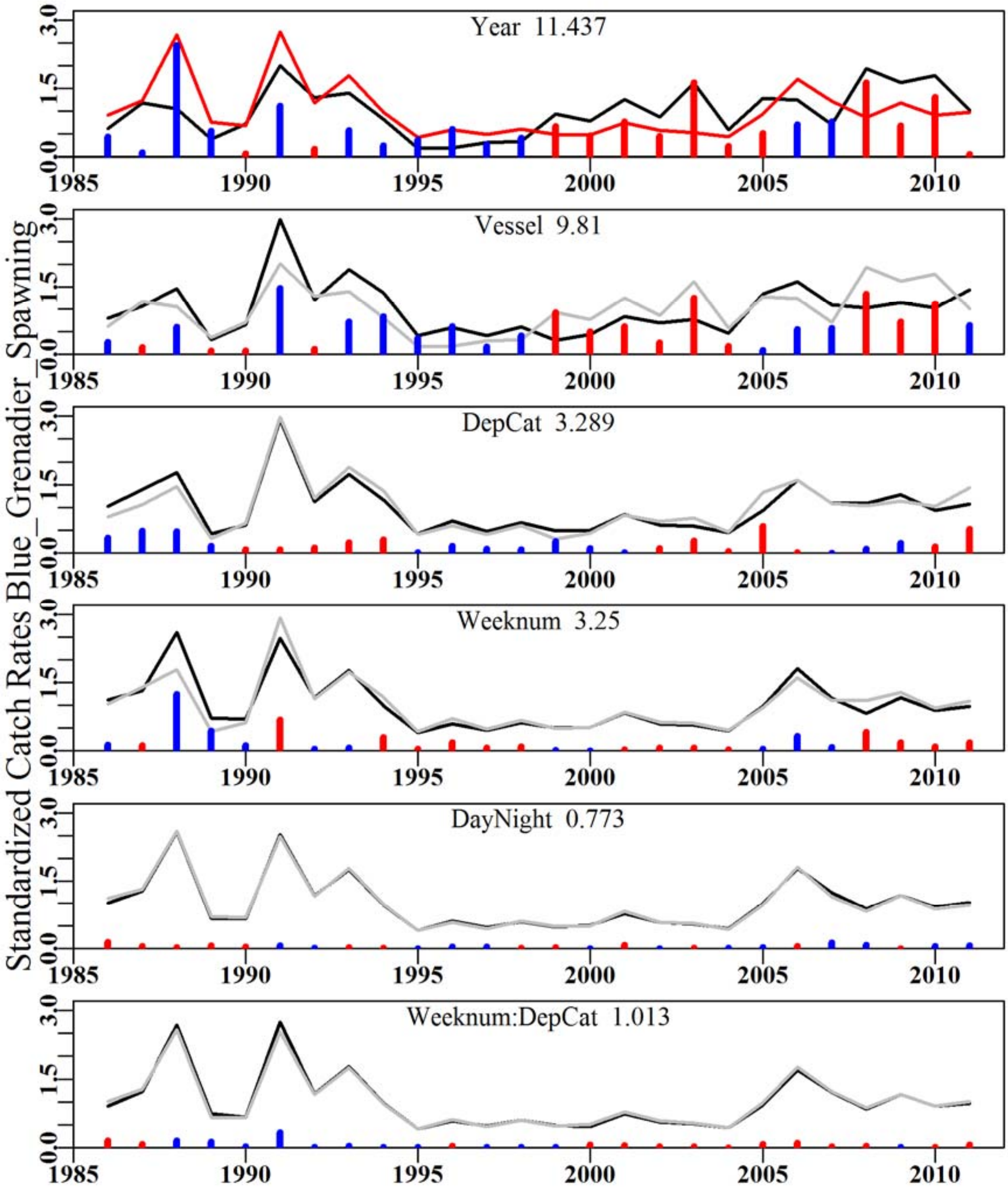

Figure 13.77**.** The relative influence of each factor used on the final trend in the optimal standardization for Blue Grenadier spawning fishery. The top graph depicts the geometric mean (the black line) and the optimum model (the red line). The difference between them is illustrated by the vertical bars with blue bars indicating the optimum model is higher than the geometric mean and red bars indicating it is lower. The top graph bars are the sum of all the bars in the graphs below. The graphs for individual factors are cumulative. Thus the second graph has the geometric mean (grey line) and the effect of adding Year + factor2 (model 2). In the third graph, the grey line represents model 2 and the black line the effect of adding factor3 to the model. The remaining graphs continue in the same cumulative manner except for the interaction terms which are added singularly to the final single factor model.

13.26 Blue Grenadier Non-Spawning (GRE – 37227001 – M. novaezelandiae)

Data from zones 10 to 60 except Zone 40 in months June to August, depths less than 1000 m and greater than 0 m.

Table 13.65**.** Blue Grenadier from the SET in depths between 200 – 600m, taken by Trawl, omitting the Spawning fishery (zone 40 between June and August). Total Catch is the total reported in the database, Records is the number of records used in the analysis, CatchT is the reported catch in the area and depth used in the analysis, and Vessels relates to all vessels used in the analysis. Geomean is the geometric mean of catch rates (kg/hr). Zone:Month is the optimum model and StDev is the standard deviation relating to the data in the optimum model.

Year	TotCatch	Records	CatchT	Vessels	GeoMean	Zone:Mth	StDev
1986	1451.778	3189	1183.307	92	36.7375	1.4764	0.0000
1987	2244.828	3569	1437.434	91	37.3307	1.9414	0.0338
1988	1849.147	3961	1470.196	102	36.6778	2.1038	0.0339
1989	1890.855	4309	1813.501	99	45.3866	2.1808	0.0339
1990	2280.471	3577	1625.146	92	47.9497	2.1567	0.0358
1991	3669.036	4308	2392.687	86	48.2874	1.5519	0.0345
1992	2474.546	3228	1505.799	61	40.5408	1.2755	0.0367
1993	2482.270	4203	1619.049	63	33.2638	0.9613	0.0352
1994	2315.490	4491	1309.563	66	29.5414	0.8636	0.0347
1995	1931.046	5076	1015.261	61	19.4025	0.5978	0.0339
1996	2304.234	5370	1055.340	73	15.8910	0.5459	0.0338
1997	3654.679	6194	994.604	73	13.3293	0.5664	0.0333
1998	4226.177	6599	1452.552	65	18.8682	0.9286	0.0331
1999	7572.998	8045	2051.946	65	22.7820	0.9810	0.0324
2000	7503.140	7679	1751.230	69	16.8751	0.6986	0.0328
2001	8370.799	7279	1013.774	60	11.4735	0.3992	0.0332
2002	7978.310	6344	1125.943	57	13.3454	0.4006	0.0337
2003	7948.324	5675	670.745	56	10.1345	0.3344	0.0340
2004	6093.498	6393	1206.698	56	16.9690	0.5633	0.0338
2005	4506.740	5346	1174.711	54	19.8341	0.6724	0.0345
2006	3544.354	4362	1308.840	42	26.9839	0.8930	0.0356
2007	3128.212	3659	1204.518	27	25.1832	0.7950	0.0366
2008	4152.329	3407	1276.536	26	28.8353	0.8654	0.0372
2009	3874.668	3443	1128.896	23	25.9256	0.8035	0.0371
2010	4552.385	3308	1136.546	25	25.9279	0.7879	0.0375
2011	4476.805	3950	894.117	26	19.3008	0.6557	0.0367

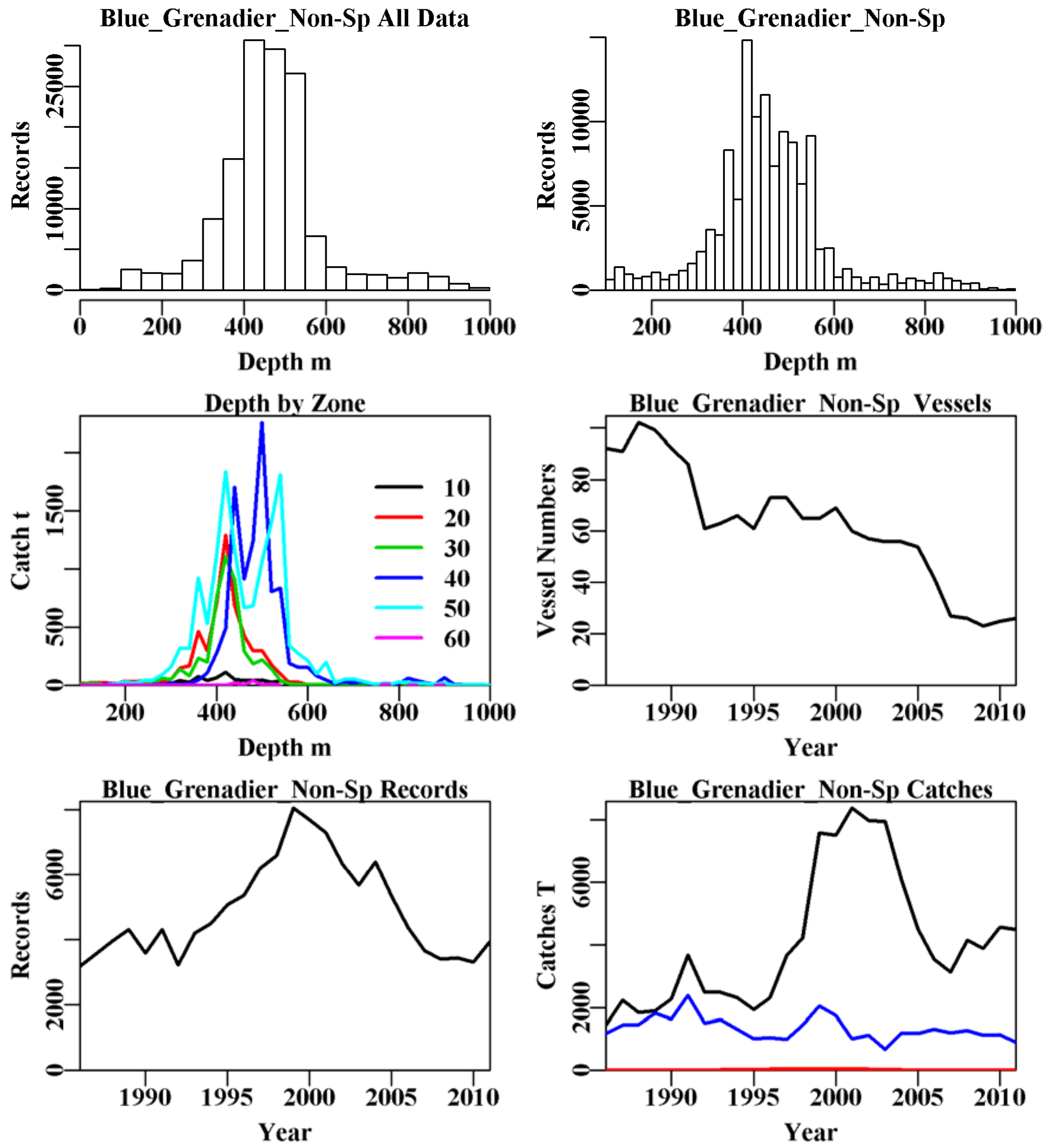

Figure 13.78**.** Blue Grenadier from the SET in depths between 200 – 600m, taken by Trawl, omitting the Spawning fishery (zone 40 between June and August). The top left is the depth distribution of all records reporting Blue Grenadier, the top right graph depicts the depth distribution of shots containing Blue Grenadier from the SET in depths between 200 – 600m, taken by Trawl, omitting the Spawning fishery (zone 40 between June and August). The middle left diagram depicts the distribution of catch by depth by SESSF zone, the middle right hand graph depicts the number of vessels through time. The bottom left reflects the number of records used in analysis, and bottom right is the Blue Grenadier catches (top line, black is total catches, middle line, blue, are those used in the analysis, and bottom, red, are catches < 30Kg).

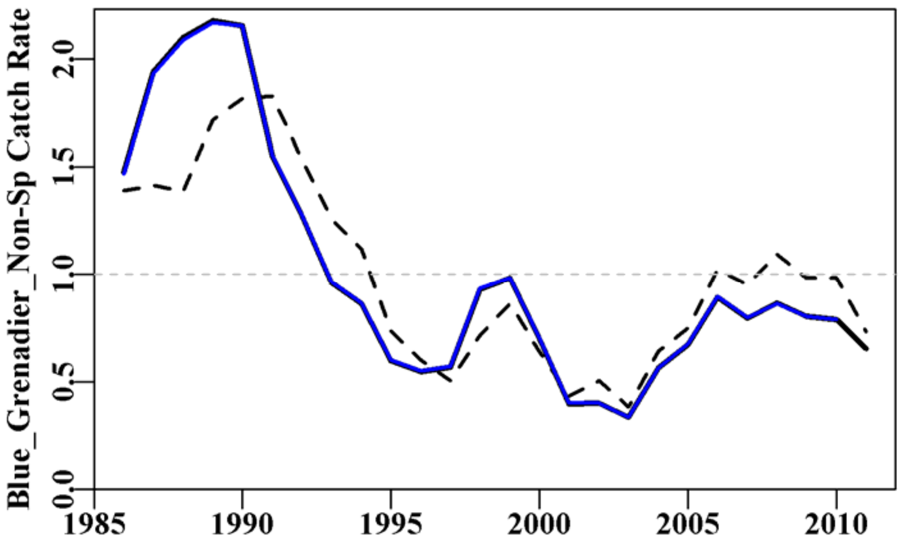

Figure 13.79. Blue Grenadier from the SET in depths between 200 – 600m, taken by Trawl, omitting the Spawning fishery (zone 40 between June and August). The dashed black line represents the geometric mean catch rate and the solid black line the standardized catch rates. The graph standardizes catch rates relative to the mean of the standardized catch rates.

Table 13.66**.** Blue Grenadier from the SET in depths between 200 – 600m, taken by Trawl, omitting the Spawning fishery (zone 40 between June and August). Statistical model structures used in this analysis. DepCat is a series of 20 metre depth categories.

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

Table 13.67**.** Blue Grenadier from the SET in depths between 200 – 600m, taken by Trawl, omitting the Spawning fishery (zone 40 between June and August). Model selection criteria, including the AIC, the deviance and the change in deviance. The optimum is model 7.

	Year	Vessel	DepCat	Month	Zone	DayNight	Zone:Mth	Zone:DepC
AIC	118368	94176	80603	75723	73177	70855	67740	69526
RSS	322399	265666	238061	228994	224403	220304	214747	217220
MSS	24504	81237	108842	117909	122500	126599	132156	129682
Nobs	126964	126964	126240	126240	126240	126240	126240	126240
Npars	26	217	262	273	278	281	336	506
adj_r2	7.045	23.287	31.233	33.847	35.170	36.353	37.931	37.131
%Change	0.000	16.242	7.946	2.613	1.324	1.183	1.578	-0.800

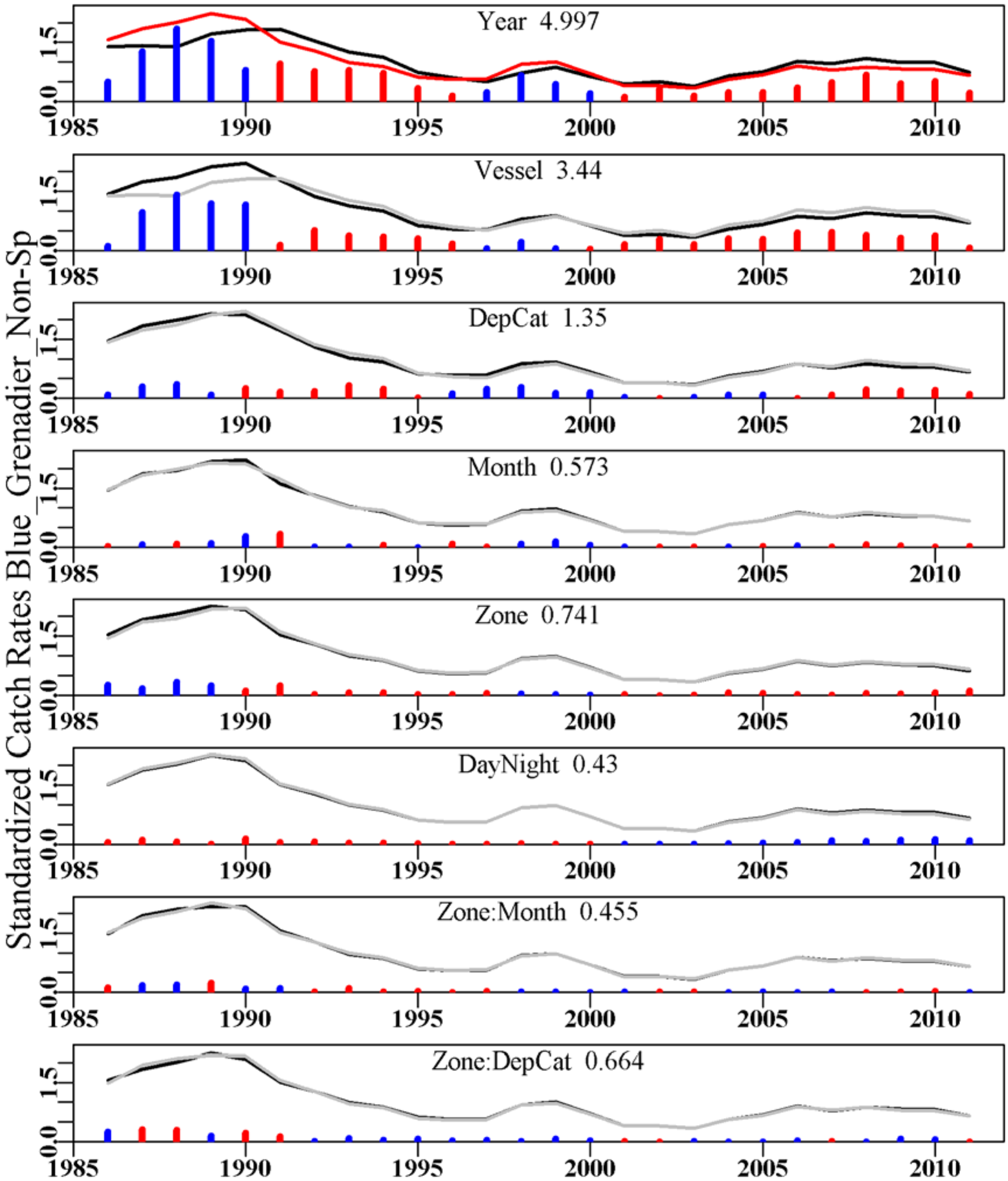

Figure 13.80**.** The relative influence of each factor used on the final trend in the optimal standardization for Blue Grenadier non-spawning fishery. The top graph depicts the geometric mean (the black line) and the optimum model (the red line). The difference between them is illustrated by the vertical bars with blue bars indicating the optimum model is higher than the geometric mean and red bars indicating it is lower. The top graph bars are the sum of all the bars in the graphs below. The graphs for individual factors are cumulative. Thus the second graph has the geometric mean (grey line) and the effect of adding Year + factor2 (model 2). In the third graph, the grey line represents model 2 and the black line the effect of adding factor3 to the model. The remaining graphs continue in the same cumulative manner except for the interaction terms which are added singularly to the final single factor model.

13.27 Silver Warehou (TRS – 37445006 – Seriolella punctata)

Data from zones 10 to 50, depths between 0 – 600 m.

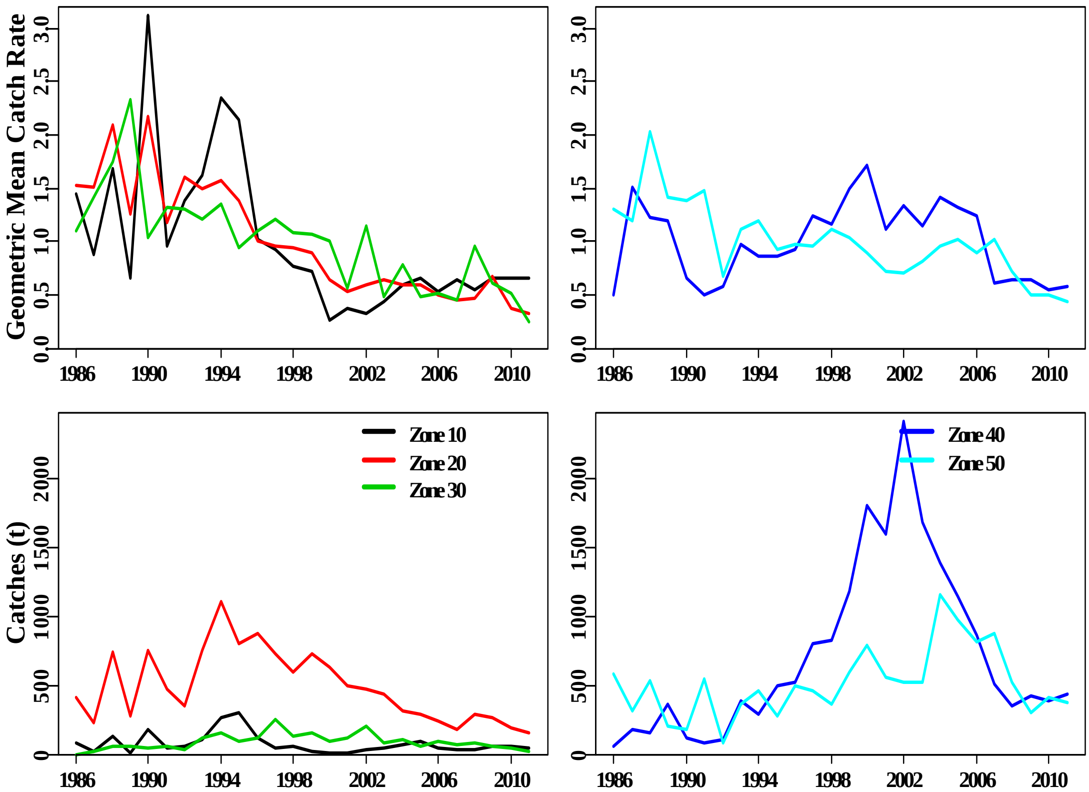

Figure 13.81**.** The trends in catches and catch rates for zones 10 – 50, split east and west.

The catch rates in the east show approximately the same trends, though there are some differences between 2000 and 2003. In the west the same pattern of noisy but flat from 1992 to 2006 followed by a decline are exhibited. But the trends are different between the east and west.

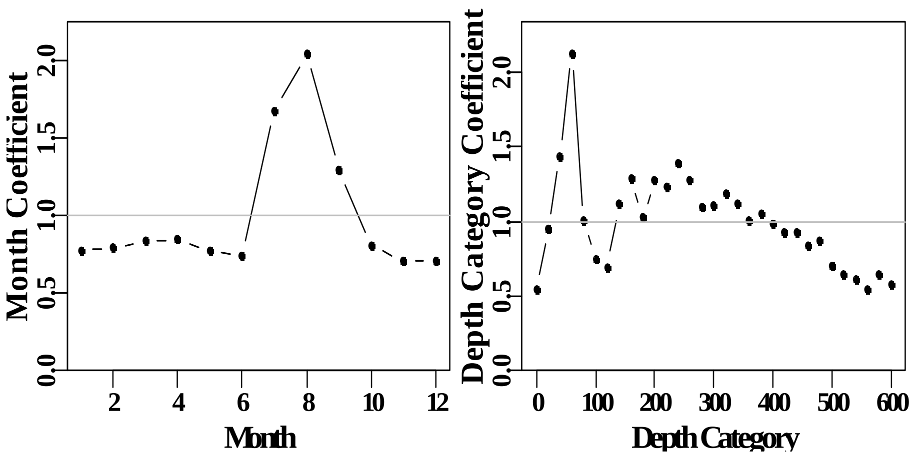

Figure 13.82. The standardized trends for the Month and DepCat factors for Silver Warehou taken by trawl across SESSF zones 10 - 50.

Table 13.68. Silver Warehou from Zones 10 to 50 and depths 0 – 600m by trawl. Total Catch is the total reported in the database, Records is the number of records use din the analysis, CatchT is the reported catch in the area and depth used in the analysis, and Vessels relates to all vessels used in the analysis. Geomean is the geometric mean of catch rates (kg/hr). Zone:Month is the optimum model and StDev is the standard deviation relating to the data in the optimum model.

Year	TotCatch	Records	CatchT	Vessels	GeoMean	Zone:Mth	StDev
1986	1156.533	2438	1135.296	86	32.2897	1.4228	0.0000
1987	782.151	1509	757.298	76	35.5040	1.5121	0.0563
1988	1646.187	2249	1617.240	87	42.9346	1.9169	0.0510
1989	926.257	2049	907.420	80	30.7291	1.5678	0.0539
1990	1346.585	1983	1290.959	81	40.6488	1.6590	0.0544
1991	1453.169	2289	1207.361	78	25.6848	1.1675	0.0532
1992	733.767	1857	625.074	55	27.9469	1.0123	0.0558
1993	1815.801	3866	1735.163	61	33.2988	1.1448	0.0487
1994	2309.510	4519	2300.083	57	34.7142	1.2249	0.0477
1995	2002.881	5016	1969.857	58	29.7825	1.1080	0.0470
1996	2188.244	6080	2137.373	67	22.7319	1.0502	0.0462
1997	2562.016	5765	2305.785	61	25.3481	1.0783	0.0469
1998	2166.021	4702	1976.667	57	26.6416	1.0390	0.0478
1999	2834.052	5148	2685.678	58	31.2330	0.8951	0.0474
2000	3401.563	6738	3324.009	63	26.0708	0.8113	0.0464
2001	2970.407	7293	2789.412	59	21.7853	0.6811	0.0462
2002	3841.439	8418	3656.597	57	22.9919	0.7357	0.0456
2003	2910.130	7402	2782.813	64	20.4815	0.7411	0.0461
2004	3198.195	7860	3032.860	58	23.3323	0.8231	0.0459
2005	2647.967	6920	2558.281	56	20.0277	0.8088	0.0464
2006	2191.402	5663	2076.280	47	18.2160	0.7116	0.0473
2007	1816.516	4657	1665.236	33	20.1239	0.6722	0.0484
2008	1381.159	4400	1279.929	32	16.1202	0.6018	0.0487
2009	1285.306	4387	1109.646	28	15.8837	0.6203	0.0488
2010	1189.353	4481	1082.522	28	13.2653	0.5126	0.0488
2011	1108.751	4888	1025.651	30	12.5782	0.4816	0.0484

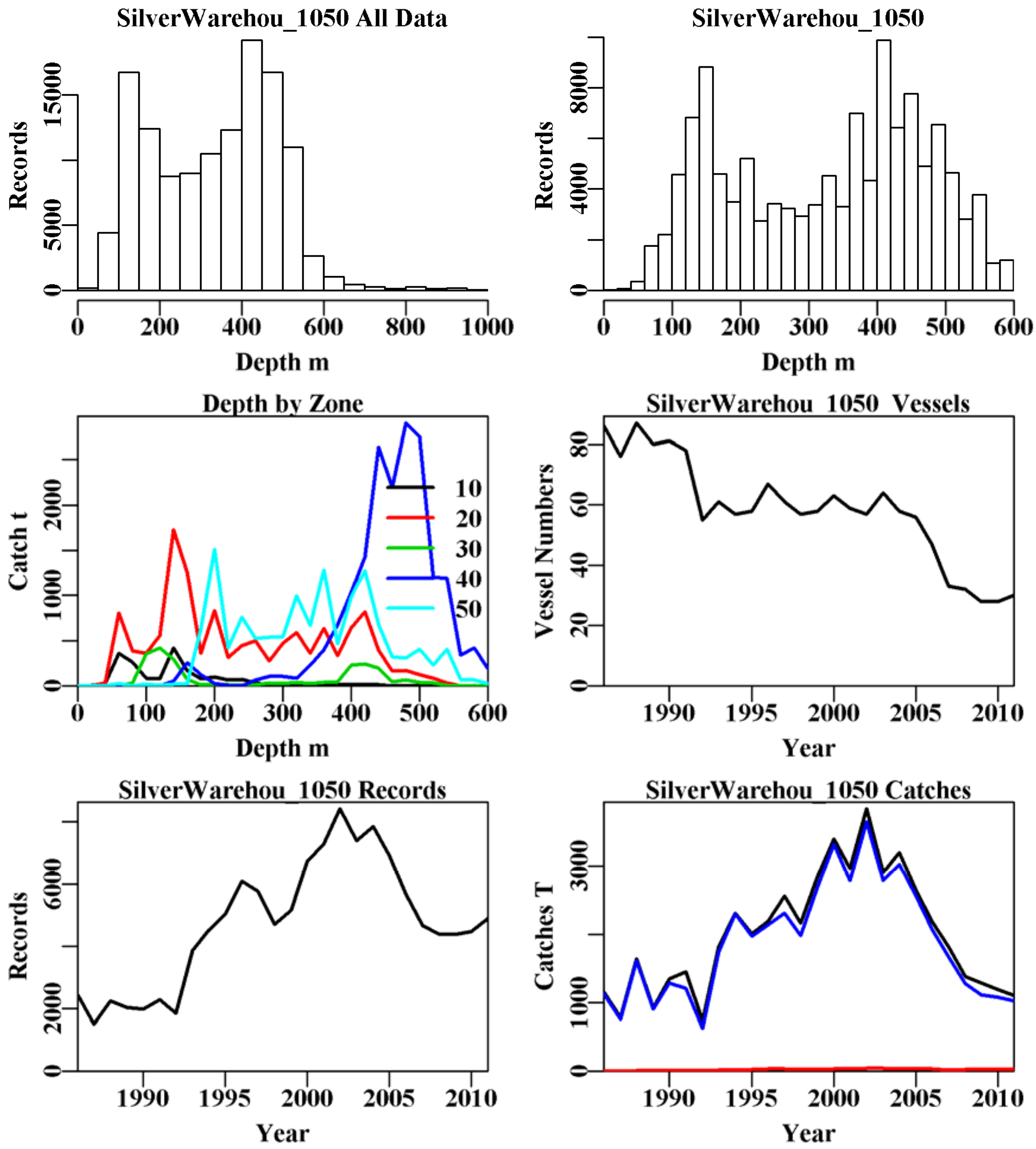

Figure 13.83**.** Silver Warehou from Zones 10 to 50 and depths 0 – 600m by trawl. The top left is the depth distribution of all records reporting Silver Warehou, the top right graph depicts the depth distribution of shots containing Silver Warehou from Zones 10 to 50 and depths 0 – 600m by trawl.. The middle left diagram depicts the distribution of catch by depth within zones 10 to 50, the middle right hand graph depicts the number of vessels through time. The bottom left reflects the number of records used in analysis, and bottom right is the Silver Warehou catches (top line, black is total catches, middle line, blue, are those used in the analysis, and bottom, red, are catches < 30Kg).

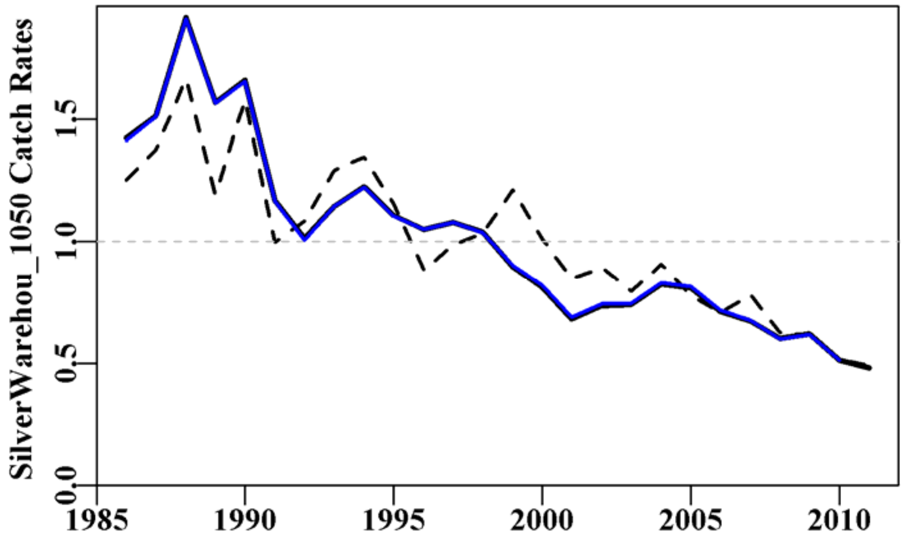

Figure 13.84. Silver Warehou from Zones 10 to 50 and depths 0 – 600m by trawl. The dashed black line represents the geometric mean catch rate and the solid black line the standardized catch rates. The graph standardizes catch rates relative to the mean of the standardized catch rates.

Table 13.69. Silver Warehou from Zones 10 to 50 and depths 0 – 600m by trawl. Statistical model structures used in this analysis. DepCat is a series of 20 metre depth categories.

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

Table 13.70. Silver Warehou from Zones 10 to 50 and depths 0 – 600m by trawl. Model selection criteria, including the AIC, the adjusted r^2 and the change in adjusted r^2. The optimum is Zone:Month (model 7).

	Year	Vessel	Month	Zone	DepCat	DayNight	Zone:Month	Zone:DepCat
AIC	147644	125985	119751	117595	115256	115050	113290	113744
RSS	408633	341361	324374	318478	312402	311858	307164	307925
MSS	9666	76938	93925	99820	105897	106440	111135	110374
Nobs	122577	122577	122577	121809	121809	121809	121809	121809
Npars	26	221	232	262	266	269	313	389
adj_r2	2.291	18.246	22.308	23.700	25.153	25.282	26.380	26.151
%Change	0.000	15.956	4.061	1.392	1.453	0.128	1.098	-0.229

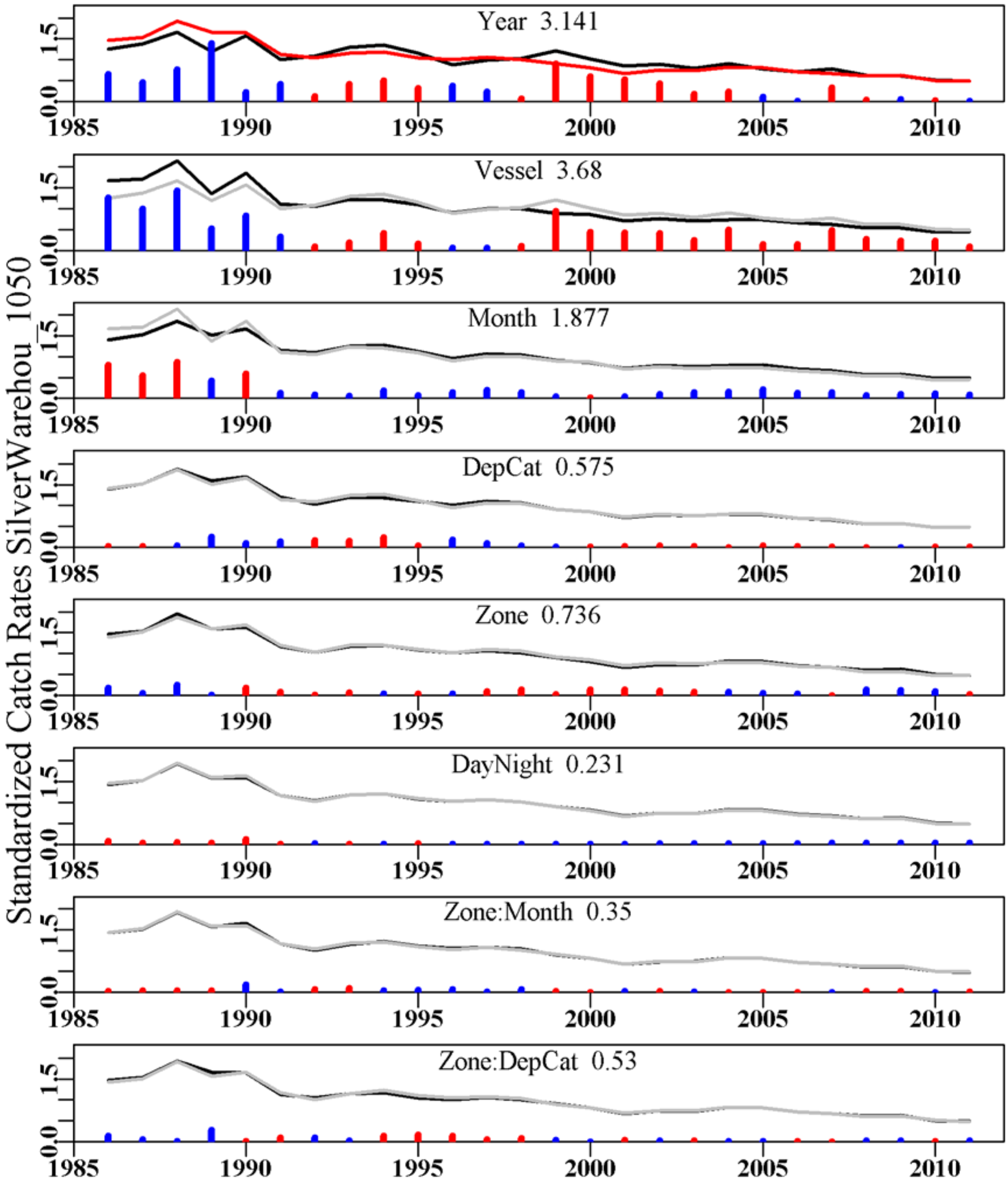

Figure 13.85**.** The relative influence of each factor used on the final trend in the optimal standardization for Silver Warehou in Zones 10 – 50. The top graph depicts the geometric mean (the black line) and the optimum model (the red line). The difference between them is illustrated by the vertical bars with blue bars indicating the optimum model is higher than the geometric mean and red bars indicating it is lower. The top graph bars are the sum of all the bars in the graphs below. The graphs for individual factors are cumulative. Thus the second graph has the geometric mean (grey line) and the effect of adding Year + factor2 (model 2). In the third graph, the grey line represents model 2 and the black line the effect of adding factor3 to the model. The remaining graphs continue in the same cumulative manner except for the interaction terms which are added singularly to the final single factor model.

13.28 Blue Warehou Zones 10, 20, 30 (TRT – 37445005 – *Seriolella brama*)

Data from zones 10, 20, and 30, depths less than or equal to 400 m.

Table 13.71**.** Blue Warehou from zones 10 to 30 in depths 0 – 400m by trawl. Total Catch is the total reported in the database, Records is the number of records used in the analysis, CatchT is the reported catch in the area and depth used in the analysis, and Vessels relates to all vessels used in the analysis. Geomean is the geometric mean of catch rates (kg/hr). Zone:DepCat is the optimum model and StDev is the standard deviation relating to the data in the optimum model.

Year	TotCatch	Records	CatchT	Vessels	GeoMean	Zone:DepC	StDev
1986	211.877	702	138.822	40	22.9216	1.8787	0.0000
1987	405.851	457	168.152	40	23.2716	2.2848	0.1048
1988	543.976	775	334.047	33	34.8726	2.8020	0.0953
1989	776.041	1178	664.709	41	52.6588	3.5366	0.0926
1990	881.353	826	508.270	42	46.5510	3.2341	0.0977
1991	1284.194	1567	465.158	54	23.0208	1.7420	0.0920
1992	934.405	1343	406.749	39	24.3304	1.4238	0.0926
1993	829.573	2195	431.735	45	20.7054	1.1069	0.0892
1994	944.805	2449	473.899	44	17.5997	1.0674	0.0882
1995	815.384	2646	467.825	44	15.3567	0.9784	0.0880
1996	724.408	3551	531.223	49	14.6415	0.9835	0.0872
1997	935.159	2481	404.281	42	11.8760	0.9519	0.0894
1998	903.242	2556	457.247	39	13.8592	0.8996	0.0890
1999	590.975	1643	131.641	39	5.7097	0.4842	0.0918
2000	470.248	2217	185.083	40	5.0072	0.4275	0.0902
2001	285.464	1470	57.242	33	2.7867	0.2561	0.0937
2002	290.477	1856	62.867	36	2.2036	0.1966	0.0921
2003	233.998	1324	42.078	38	1.8331	0.1558	0.0950
2004	232.446	1249	52.051	38	2.7248	0.2122	0.0967
2005	289.063	830	21.286	33	1.8011	0.1409	0.1011
2006	379.527	776	25.720	28	2.2327	0.1689	0.1022
2007	177.774	583	16.757	14	1.8677	0.1826	0.1068
2008	163.260	738	27.441	18	2.6539	0.2522	0.1026
2009	135.224	447	36.884	15	3.5956	0.2922	0.1118
2010	130.098	374	12.266	15	2.1227	0.1894	0.1172
2011	103.243	435	9.812	13	1.7081	0.1516	0.1134

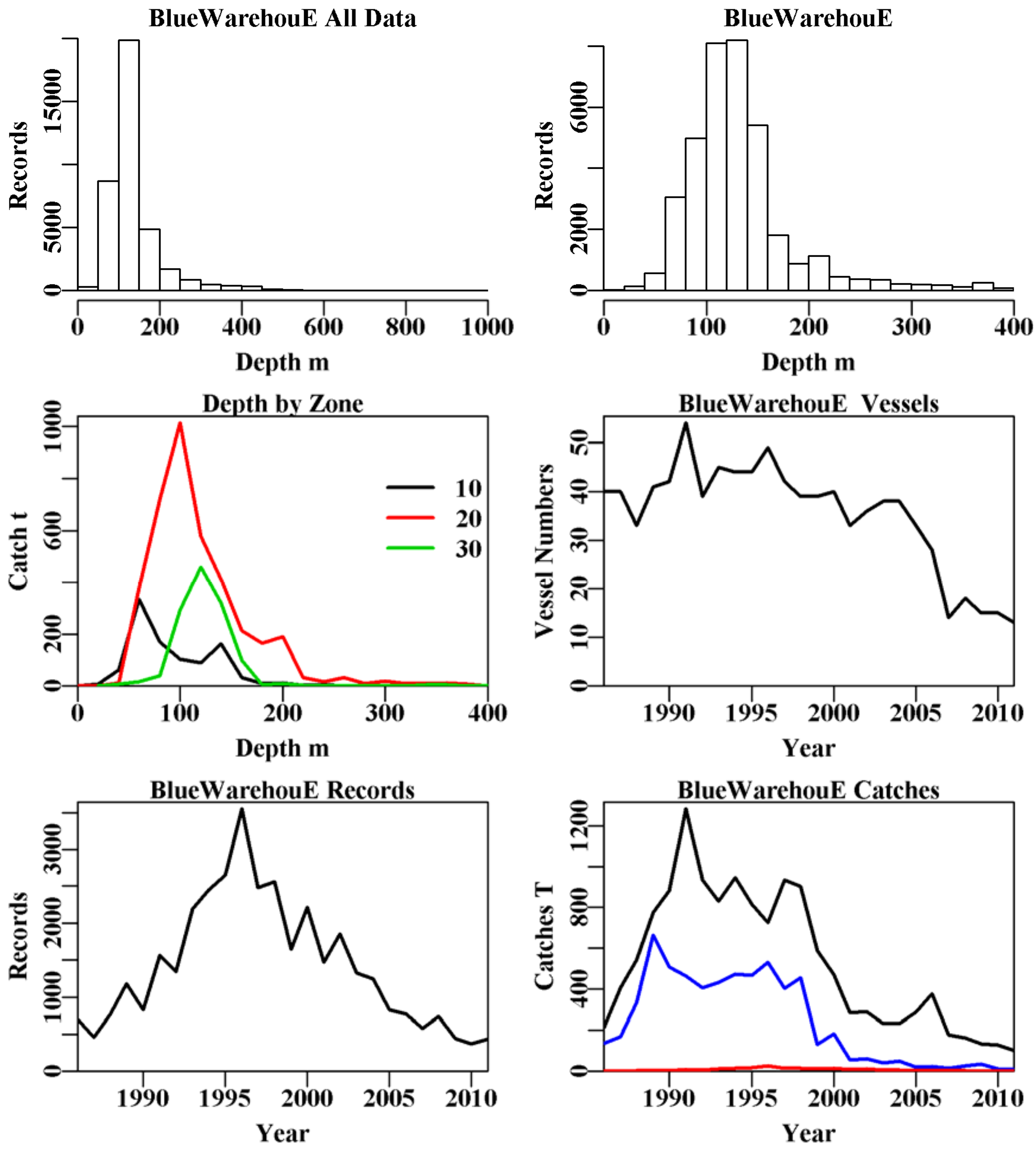

Figure 13.86. Blue Warehou from zones 10 to 30 in depths 0 – 400m by trawl. The top left is the depth distribution of all records reporting Blue Warehou, the top right graph depicts the depth distribution of shots containing Blue Warehou from zones 10 to 30 in depths 0 – 400m by trawl. The middle left diagram depicts the distribution of catch by depth within zones 10 to 30, the middle right hand graph depicts the number of vessels through time. The bottom left reflects the number of records used in analysis, and bottom right is the Blue Warehou catches (top line, black is total catches, middle line, blue, are those used in the analysis, and bottom, red, are catches < 30Kg).

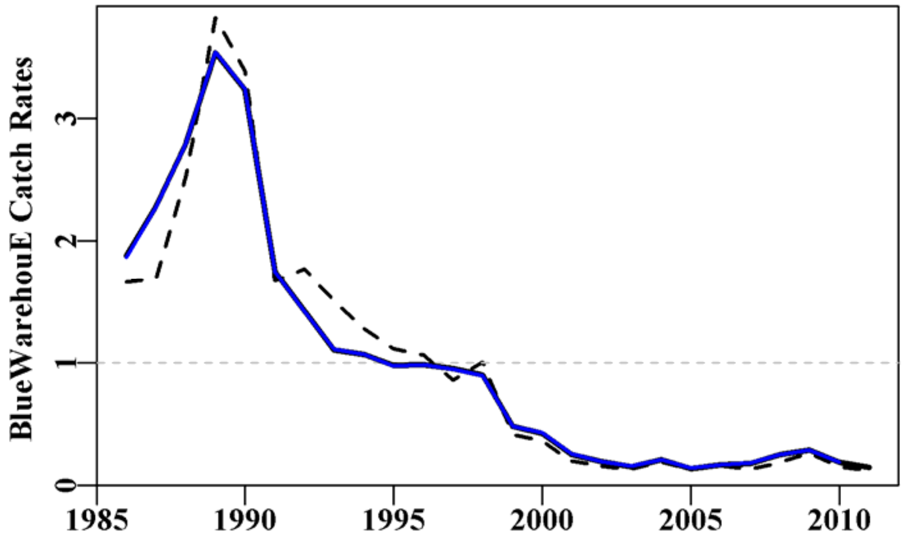

Figure 13.87. Blue Warehou from zones 10 to 30 in depths 0 – 400m by trawl. The dashed black line represents the geometric mean catch rate and the solid black line the standardized catch rates. The graph standardizes catch rates relative to the mean of the standardized catch rates.

Table 13.72. Blue Warehou from zones 10 to 30 in depths 0 – 400m by trawl. Statistical model structures used in this analysis. DepCat is a series of 20 metre depth categories.

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

Table 13.73. Blue Warehou from zones 10 to 30 in depths 0 – 400m by trawl. Model selection criteria, including the AIC, the adjusted r^2 and the change in adjusted r^2. The optimum is Zone:DSepCat (model 8).

	Year	Vessel	DepCat	Month	Zone	DayNight	Zone:Mth	Zone:DepC
AIC	36763	32110	31473	31276	30791	30789	30539	30508
RSS	99792	87133	85466	84955	83823	83805	83132	82980
MSS	36422	49081	50748	51259	52391	52410	53082	53234
Nobs	36668	36668	36458	36458	36458	36458	36458	36458
Npars	26	186	206	217	219	222	244	262
adj_r2	26.689	35.708	36.901	37.260	38.092	38.101	38.560	38.642
%Change	0.000	9.019	1.194	0.358	0.833	0.008	0.460	0.082

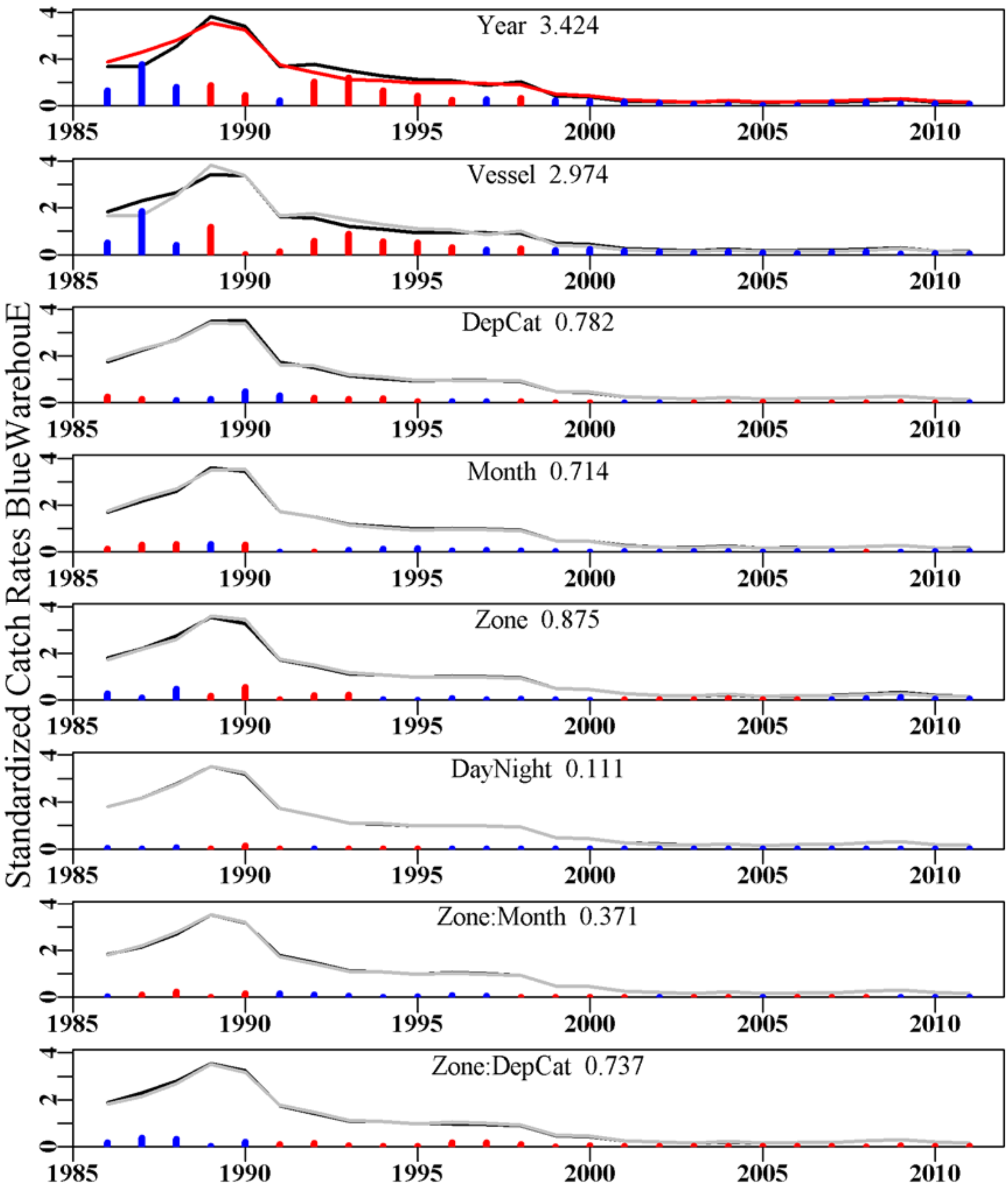

Figure 13.88. The relative influence of each factor used on the final trend in the optimal standardization for Blue Warehou in Zone 10 – 30. The top graph depicts the geometric mean (the black line) and the optimum model (the red line). The difference between them is illustrated by the vertical bars with blue bars indicating the optimum model is higher than the geometric mean and red bars indicating it is lower. The top graph bars are the sum of all the bars in the graphs below. The graphs for individual factors are cumulative. Thus the second graph has the geometric mean (grey line) and the effect of adding Year + factor2 (model 2). In the third graph, the grey line represents model 2 and the black line the effect of adding factor3 to the model. The remaining graphs continue in the same cumulative manner except for the interaction terms which are added singularly to the final single factor model.

13.29 Blue Warehou Z4050 (TRT – 37445005 – S. brama)

Data from zones 40 – 50 depths less than or equal to 600 m.

Table 13.74**.** Blue Warehou from zones 40 and 50 in depths 0 – 600m by trawl. Total Catch is the total reported in the database, Records is the number of records used in the analysis, CatchT is the reported catch in the area and depth used in the analysis, and Vessels relates to all vessels used in the analysis. Geomean is the geometric mean of catch rates (kg/hr). Zone:Month is the optimum model and StDev is the standard deviation relating to the data in the optimum model.

Year	TotCatch	Records	CatchT	Vessels	GeoMean	Zone:Mth	StDev
1986	211.877	159	71.389	14	34.3927	3.3403	0.0000
1987	405.851	183	215.645	10	153.6342	3.1136	0.2443
1988	543.976	180	197.989	12	104.5294	1.2972	0.2537
1989	776.041	56	81.343	13	91.5270	3.3111	0.3142
1990	881.353	444	298.296	14	55.8069	1.4434	0.2394
1991	1284.194	597	647.537	18	159.6429	2.2301	0.2374
1992	934.405	538	430.133	17	88.9759	1.2798	0.2395
1993	829.573	495	362.854	21	92.3447	0.9374	0.2409
1994	944.805	824	449.901	21	67.3117	1.0262	0.2365
1995	815.384	825	325.150	22	45.1964	0.7000	0.2342
1996	724.408	700	183.550	24	26.4215	0.4568	0.2353
1997	935.159	431	243.547	23	35.6095	0.4907	0.2410
1998	903.242	582	354.483	19	58.9967	0.7327	0.2393
1999	590.975	688	174.376	19	32.5226	0.4211	0.2388
2000	470.248	650	203.390	24	28.0473	0.3439	0.2391
2001	285.464	685	194.156	23	27.5825	0.3634	0.2379
2002	290.477	530	218.017	23	35.4216	0.4896	0.2405
2003	233.998	363	175.478	19	28.1023	0.4422	0.2463
2004	232.446	437	159.255	21	28.4995	0.5050	0.2430
2005	289.063	461	257.801	18	53.5991	0.7955	0.2434
2006	379.527	695	337.473	16	31.8482	0.5634	0.2399
2007	177.774	466	148.640	16	22.9820	0.4887	0.2437
2008	163.260	353	117.774	12	20.3955	0.3739	0.2459
2009	135.224	308	89.003	11	18.4388	0.2769	0.2482
2010	130.098	407	105.291	12	17.5511	0.3152	0.2435
2011	103.243	519	77.907	14	14.3658	0.2618	0.2432

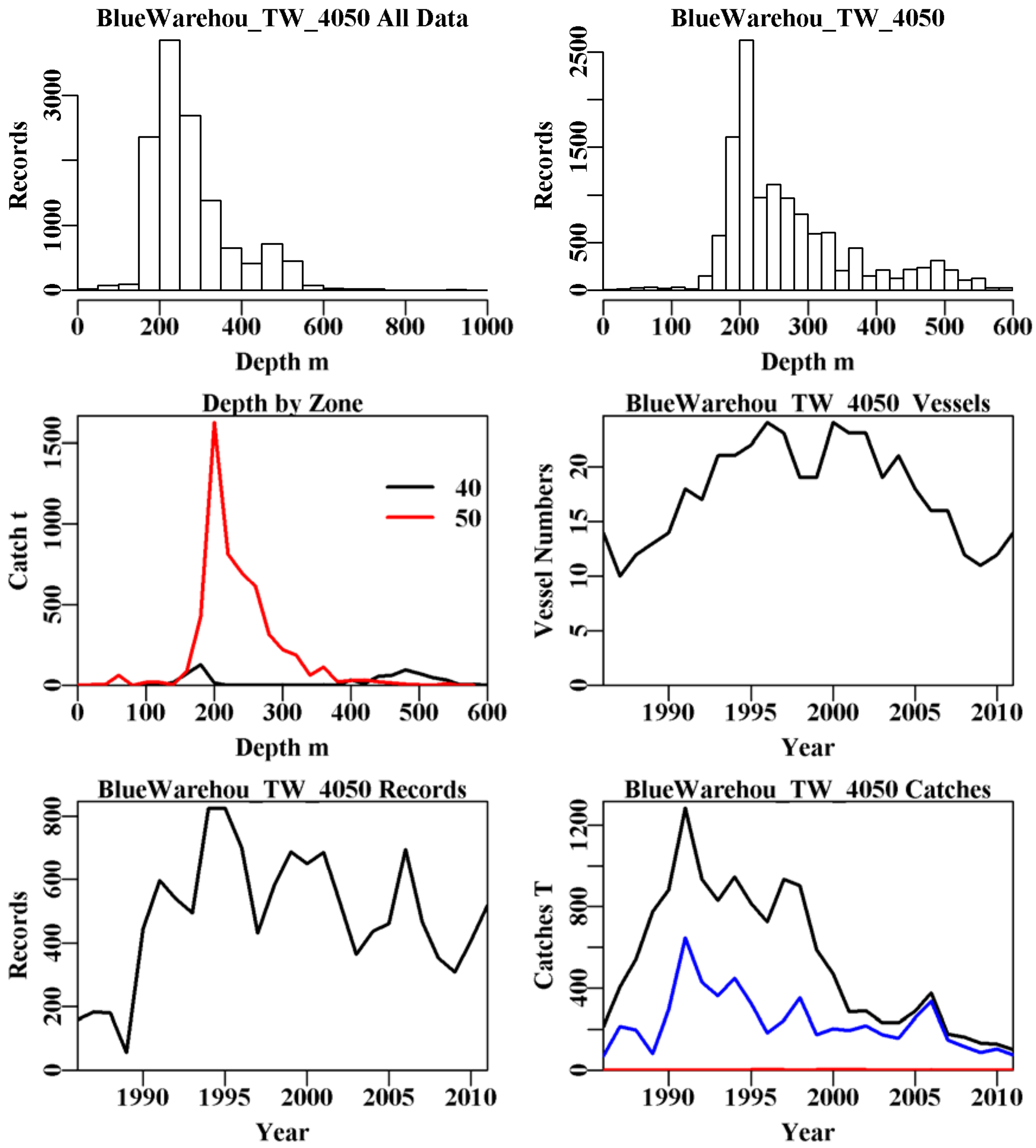

Figure 13.89**.** Blue Warehou from zones 40 and 50 in depths 0 – 600m by trawl. The top left is the depth distribution of all records reporting Blue Warehou, the top right graph depicts the depth distribution of shots containing Blue Warehou from zones 40 and 50 in depths 0 – 600m by trawl. The middle left diagram depicts the distribution of catch by depth within zones 40 and 50 (50 is top red line), the middle right hand graph depicts the number of vessels through time. The bottom left reflects the number of records used in analysis, and bottom right is the Blue Warehou catches (top line, black is total catches, middle line, blue, are those used in the analysis, and bottom, red, are catches < 30Kg).

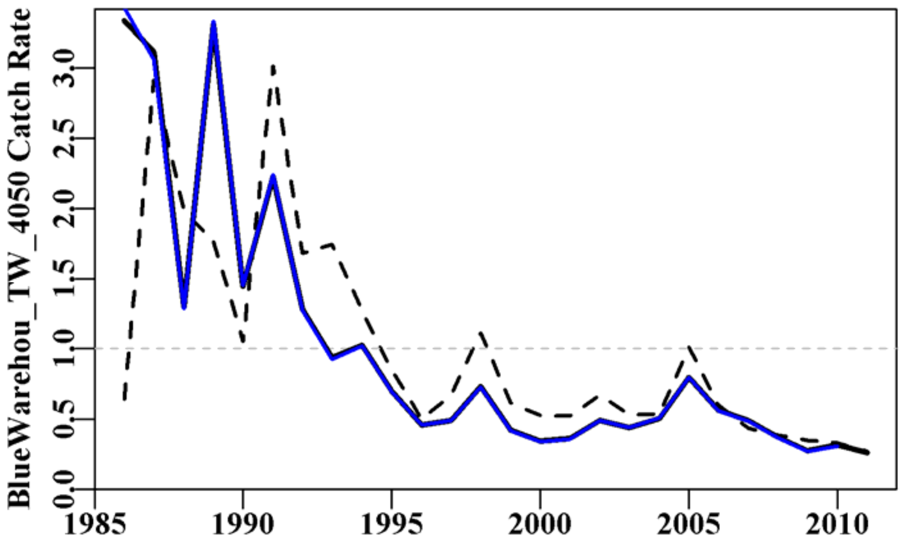

Figure 13.90. Blue Warehou from zones 40 and 50 in depths 0 – 600m by trawl. The dashed black line represents the geometric mean catch rate and the solid black line the standardized catch rates. The graph standardizes catch rates relative to the mean of the standardized catch rates.

Table 13.75. Blue Warehou from zones 40 and 50 in depths 0 – 600m by trawl. Statistical model structures used in this analysis. DepCat is a series of 20 metre depth categories.

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

Table 13.76. Blue Warehou from zones 40 and 50 in depths 0 – 600m by trawl. Model selection criteria, including the AIC, the adjusted r^2 and the change in adjusted r^2. The optimum is Zone:Month (model 7).

	Year	Vessel	Month	DepCat	DayNight	Zone	Zone:Mth	Zone:DepC
AIC	14134	13013	12032	11232	11066	11060	11011	11032
RSS	38533	34807	32139	29999	29588	29570	29403	29364
MSS	4565	8291	10959	13099	13510	13528	13695	13734
Nobs	12576	12576	12576	12522	12522	12522	12522	12522
Npars	26	105	116	146	149	150	161	180
adj_r2	10.414	18.564	24.739	29.578	30.525	30.563	30.893	30.879
%Change	0.000	8.150	6.175	4.839	0.947	0.038	0.330	-0.014

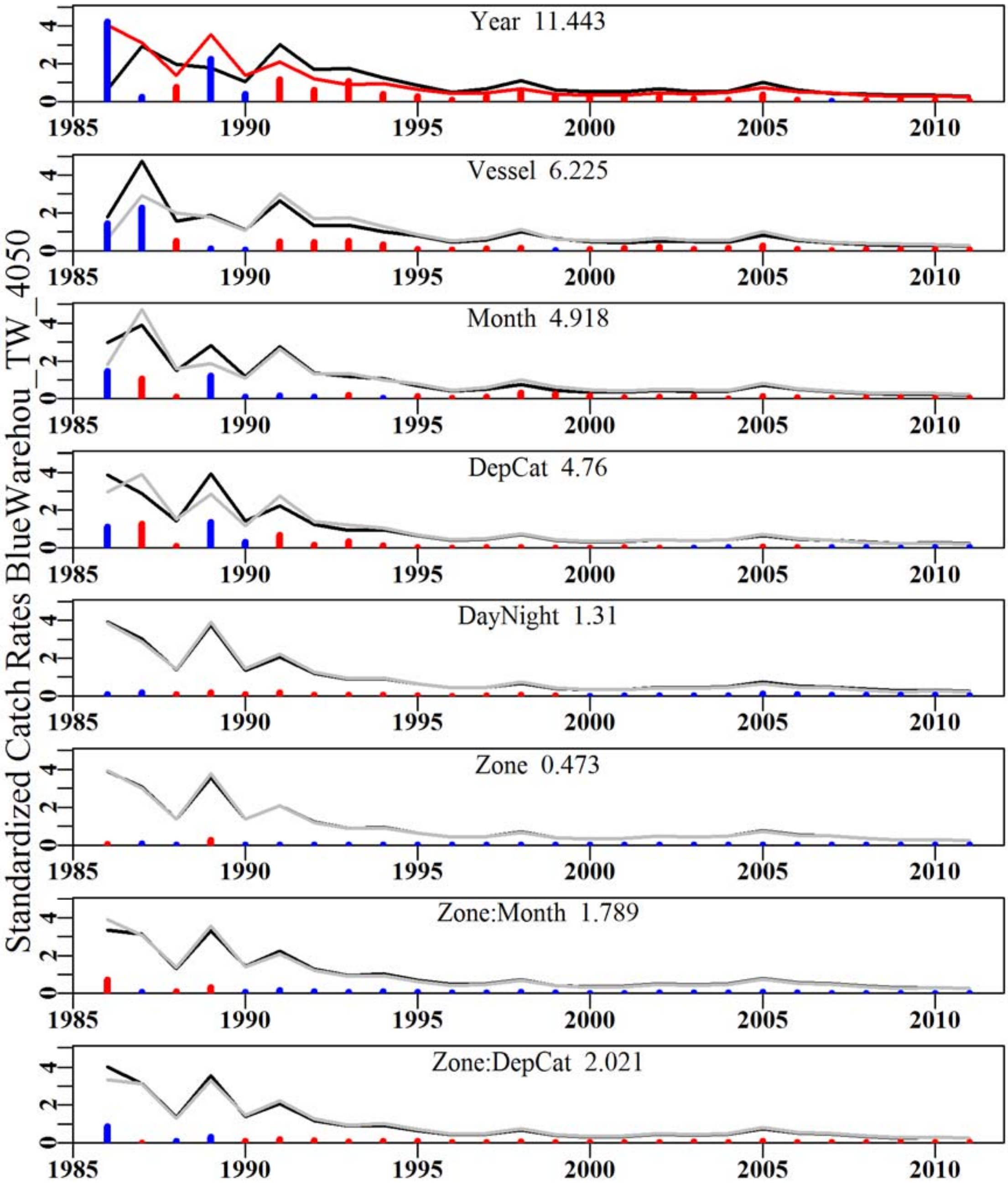

Figure 13.91**.** The relative influence of each factor used on the final trend in the optimal standardization for Blue Warehou in Zone 40 – 50. The top graph depicts the geometric mean (the black line) and the optimum model (the red line). The difference between them is illustrated by the vertical bars with blue bars indicating the optimum model is higher than the geometric mean and red bars indicating it is lower. The top graph bars are the sum of all the bars in the graphs below. The graphs for individual factors are cumulative. Thus the second graph has the geometric mean (grey line) and the effect of adding Year + factor2 (model 2). In the third graph, the grey line represents model 2 and the black line the effect of adding factor3 to the model. The remaining graphs continue in the same cumulative manner except for the interaction terms which are added singularly to the final single factor model.

13.30 Blue Warehou Z10-50 (TRT – 37445005 – S. brama)

Only data from Zones 10 to 50 in depths 0 – 600m. Only vessels present in the fishery for more than 2 years were included.

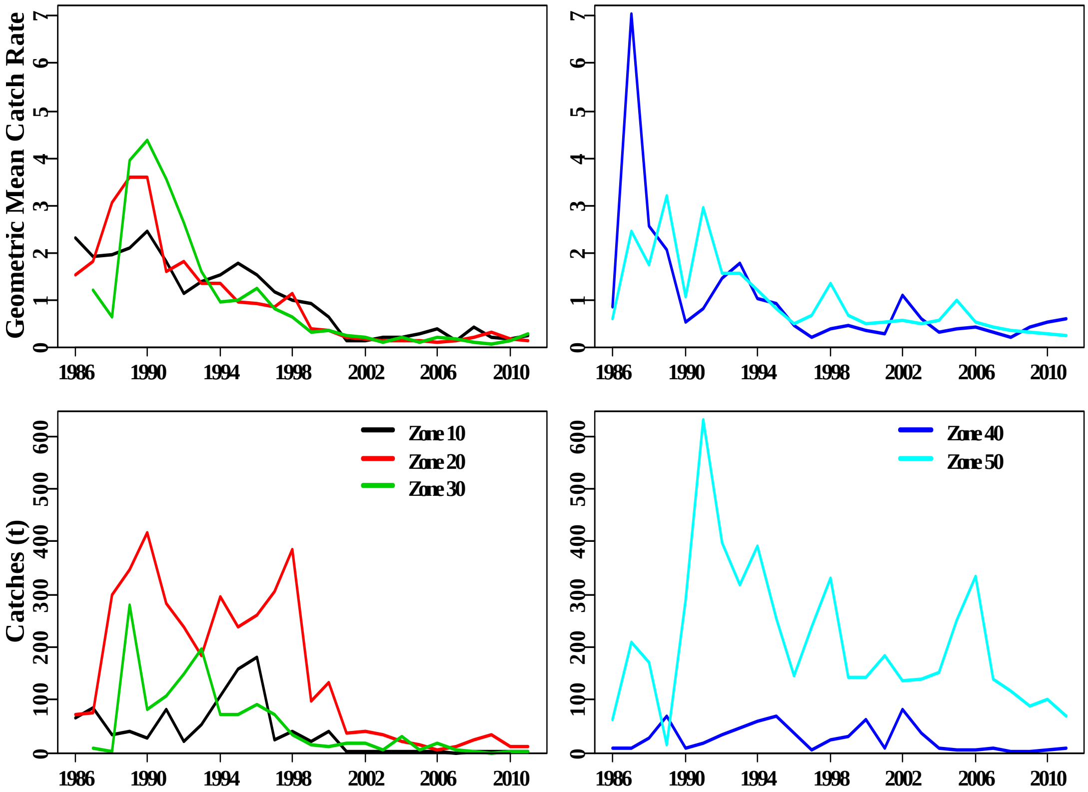

Figure 13.92**.** Trends in the catches and geometric mean catch rates for Blue Warehou across each of the zones 10 – 50, split east and west. The extreme catch rates in zone 40 reflect very small catches

The severe depletion in the east is evident but in the west the catch rates are noisy then flat. They are depressed primarily because of early high values that reflect very low catches or relatively high catches. Zone 50 is the main part of the western Blue Warehou fishery.

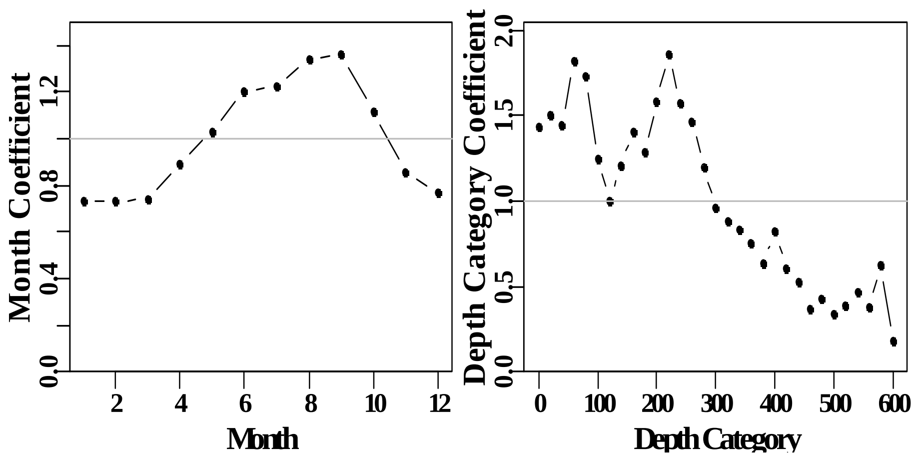

Figure 13.93**.** The standardized trends for the Month and DepCat factors for Blue Warehou taken by trawl across SESSF zones 10 - 50.

Table 13.77**.** Blue Warehou from zones 10 to 50 in depths 0 – 600m by trawl. Total Catch is the total reported in the database, Records is the number of records used in the analysis, CatchT is the reported catch in the area and depth used in the analysis, and Vessels relates to all vessels used in the analysis. Geomean is the geometric mean of catch rates (kg/hr). Zone:Mth is the optimum model and StDev is the standard deviation relating to the data in the optimum model.

Year	TotCatch	Records	CatchT	Vessels	GeoMean	Zone:Mth	StDev
1986	211.877	863	210.321	54	24.6419	2.0083	0.0000
1987	405.851	655	384.556	51	38.9818	2.3004	0.0921
1988	543.976	963	532.358	45	42.2791	2.5658	0.0892
1989	776.041	1239	746.152	50	53.5132	3.5440	0.0876
1990	881.353	1284	822.419	56	49.3618	2.5233	0.0889
1991	1284.194	2193	1119.788	66	38.9026	1.9961	0.0845
1992	934.405	1902	840.304	56	34.9011	1.4626	0.0854
1993	829.573	2717	797.308	58	27.0143	1.1328	0.0832
1994	944.805	3300	927.228	58	24.5388	1.0921	0.0820
1995	815.384	3497	794.697	58	19.7435	0.9299	0.0817
1996	724.408	4278	715.754	66	16.0446	0.9250	0.0812
1997	935.159	2925	648.139	57	13.9027	0.9172	0.0834
1998	903.242	3152	813.727	50	18.0335	0.9174	0.0829
1999	590.975	2372	309.696	57	9.5323	0.4883	0.0847
2000	470.248	2899	389.591	58	7.2891	0.4352	0.0837
2001	285.464	2208	253.279	53	5.6327	0.2942	0.0857
2002	290.477	2408	281.036	53	4.0433	0.2499	0.0854
2003	233.998	1709	218.370	51	3.2843	0.2056	0.0879
2004	232.446	1700	211.509	51	4.9660	0.2815	0.0885
2005	289.063	1297	279.429	45	6.0446	0.2614	0.0909
2006	379.527	1474	363.242	36	7.8259	0.2625	0.0899
2007	177.774	1051	165.406	25	5.6784	0.2449	0.0933
2008	163.260	1100	145.318	27	5.0903	0.2749	0.0925
2009	135.224	766	126.232	24	6.9116	0.2721	0.0975
2010	130.098	785	117.741	22	6.3388	0.2177	0.0974
2011	103.243	966	91.479	23	5.5194	0.1969	0.0953

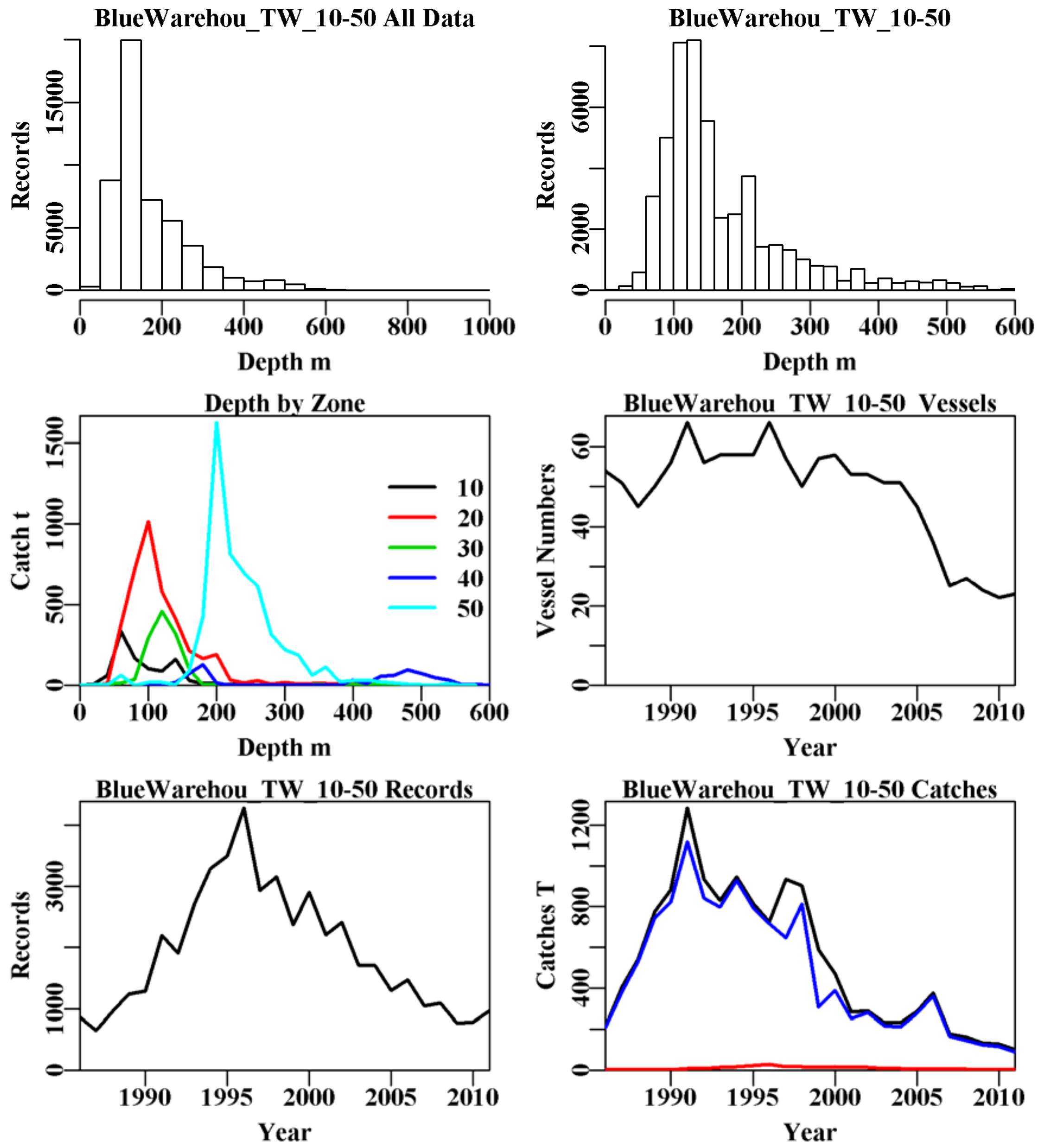

Figure 13.94**.** Blue Warehou from zones 10 to 50 in depths 0 – 400m by trawl. The top left is the depth distribution of all records reporting Blue Warehou, the top right graph depicts the depth distribution of shots containing Blue Warehou from zones 10 to 50 in depths 0 – 400m by trawl. The middle left diagram depicts the distribution of catch by depth within zones 10 50, the middle right hand graph depicts the number of vessels through time. The bottom left reflects the number of records used in analysis, and bottom right is the Blue Warehou catches (top line, black is total catches, middle line, blue, are those used in the analysis, and bottom, red, are catches < 30Kg)

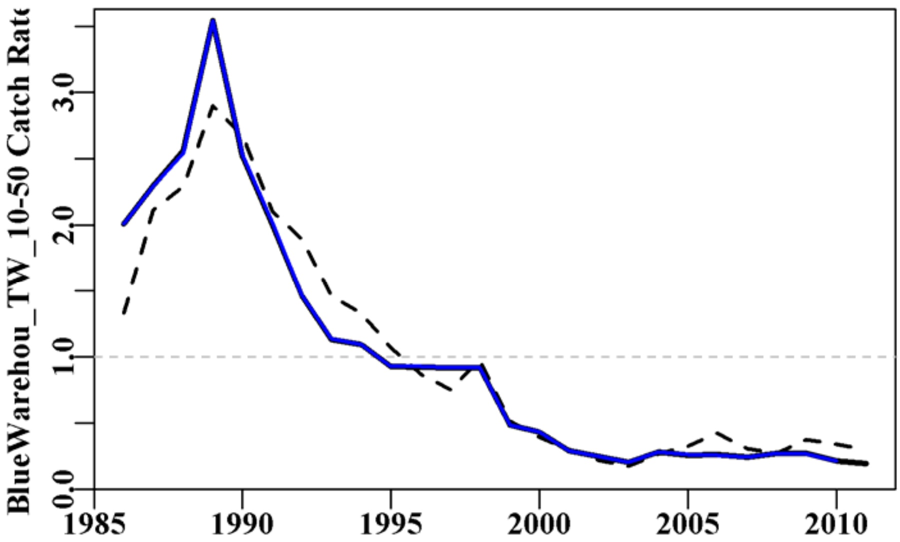

Figure 13.95**.** Blue Warehou from zones 10 to 50 in depths 0 – 400m by trawl. The dashed black line represents the geometric mean catch rate and the solid black line the standardized catch rates. The graph standardizes catch rates relative to the mean of the standardized catch rates.

Table 13.78**.** Blue Warehou from zones 10 to 50 in depths 0 – 400m by trawl. Statistical model structures used in this analysis. DepCat is a series of 20 metre depth categories.

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

Table 13.79. Blue Warehou from zones 10 to 50 in depths 0 – 400m by trawl. Model selection criteria, including the AIC, the adjusted r^2 and the change in adjusted r^2. The optimum is Zone:Month (model 7).

	Year	Vessel	DepCat	Zone	Month	DayNight	Zone:Mth	Zone:DepC
AIC	61386	47536	46286	45197	44475	44410	43419	43729
RSS	170727	128225	124838	122097	120274	120101	117509	117886
MSS	30728	73231	76618	79358	81181	81354	83947	83569
Nobs	49703	49703	49439	49439	49439	49439	49439	49439
Npars	26	216	246	250	261	264	308	384
adj_r2	15.210	36.074	37.723	39.086	39.982	40.064	41.306	41.026
%Change	0.000	20.864	1.649	1.362	0.896	0.083	1.241	-0.280

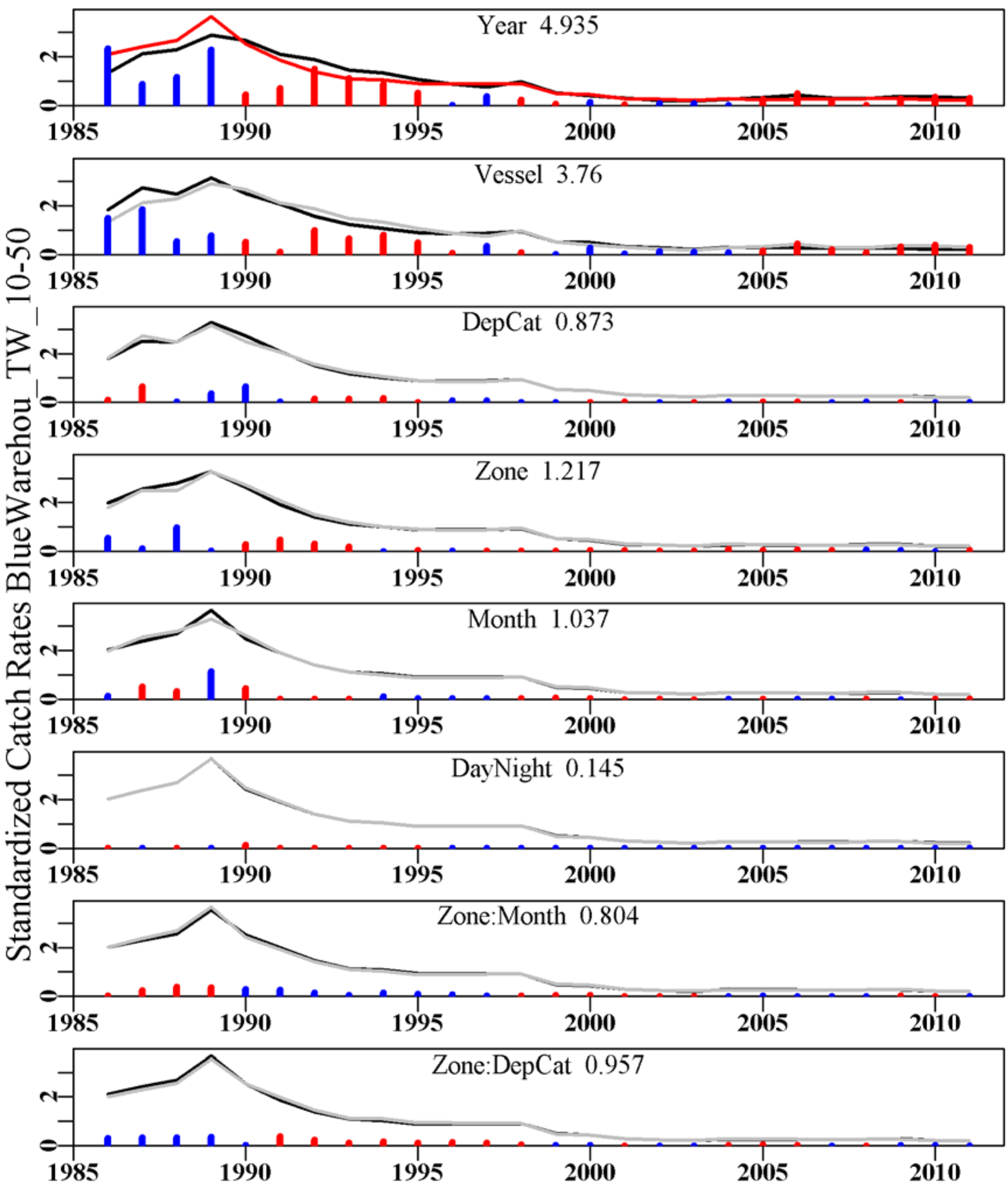

Figure 13.96**.** The relative influence of each factor used on the final trend in the optimal standardization for Blue Warehou in Zone 10 – 50. The top graph depicts the geometric mean (the black line) and the optimum model (the red line). The difference between them is illustrated by the vertical bars with blue bars indicating the optimum model is higher than the geometric mean and red bars indicating it is lower. The top graph bars are the sum of all the bars in the graphs below. The graphs for individual factors are cumulative. Thus the second graph has the geometric mean (grey line) and the effect of adding Year + factor2 (model 2). In the third graph, the grey line represents model 2 and the black line the effect of adding factor3 to the model. The remaining graphs continue in the same cumulative manner except for the interaction terms which are added singularly to the final single factor model.

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

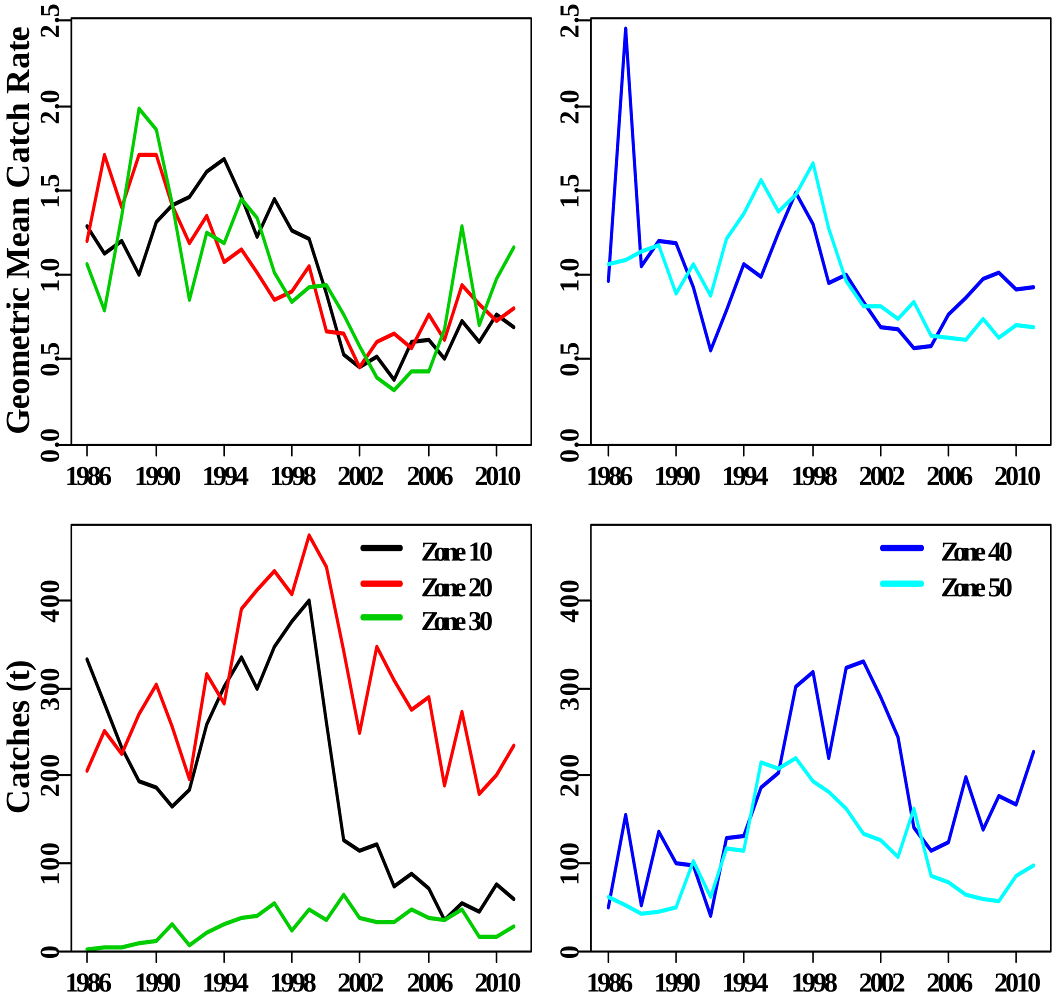

Figure 13.97**.** Trends in the catches and geometric mean catch rates for Pink Ling taken by trawler across zones 10 – 50 split between east and west.

The trends in the geometric mean catch rates in the east all follow approximately the same trajectory, albeit with some noise. In the west, however, zones 40 and 50 appear to follow rather different trajectories with rates increasing since 2005 in zone 40 whilst staying flat in zone 50. However, this may simply reflect that catches were increasing in zone 40 and were decreasing in zone 50.

13.32 Pink Ling, Z102030 (LIG – 37228002 – G. blacodes)

Data from zones 10, 20 and 30, depths greater than 250 m and less than 600 m.

Table 13.80. Pink Ling from zones 10 to 30 in depths between 250 – 600m by trawl. Total Catch is the total reported in the database, Records is the number of records used in the analysis, CatchT is the reported catch in the area and depth used in the analysis, and Vessels relates to all vessels used in the analysis. Geomean is the geometric mean of catch rates (kg/hr). Zone:Month is the optimum model and StDev is the standard deviation relating to the data in the optimum model.

Year	TotCatch	Records	CatchT	Vessels	GeoMean	Zone:Mth	StDev
1986	678.977	4512	498.298	80	20.665	1.102	0.0000
1987	765.066	4260	492.314	77	19.424	1.168	0.0224
1988	583.077	3613	400.077	77	20.259	1.114	0.0235
1989	678.896	3879	422.077	77	19.157	0.959	0.0233
1990	674.479	2794	413.082	68	26.820	1.411	0.0256
1991	736.803	2938	370.297	72	26.305	1.412	0.0256
1992	568.308	2417	324.371	57	24.850	1.089	0.0269
1993	892.796	3525	504.474	59	25.307	1.023	0.0245
1994	895.431	4066	470.265	63	23.516	1.037	0.0236
1995	1208.893	4361	586.686	57	25.811	1.307	0.0231
1996	1233.265	4268	667.583	63	27.657	1.300	0.0233
1997	1696.855	4808	732.654	62	27.937	1.323	0.0229
1998	1591.988	4909	730.458	57	26.016	1.323	0.0227
1999	1651.572	5964	832.655	59	25.229	1.209	0.0222
2000	1507.379	5113	660.280	62	22.405	1.077	0.0231
2001	1392.822	4544	484.022	52	19.062	0.839	0.0239
2002	1330.296	3898	360.465	52	15.866	0.733	0.0248
2003	1353.243	4309	445.759	57	18.293	0.752	0.0243
2004	1495.581	3359	347.369	54	16.798	0.672	0.0258
2005	1203.256	3454	329.969	51	16.334	0.628	0.0255
2006	1069.222	2593	323.101	38	21.319	0.750	0.0274
2007	875.926	1652	204.307	23	20.501	0.736	0.0315
2008	980.268	2382	329.036	24	25.151	0.852	0.0286
2009	775.047	1947	212.362	27	18.295	0.622	0.0303
2010	906.088	1990	271.121	23	20.721	0.761	0.0299
2011	1081.674	2199	294.797	22	23.444	0.803	0.0292

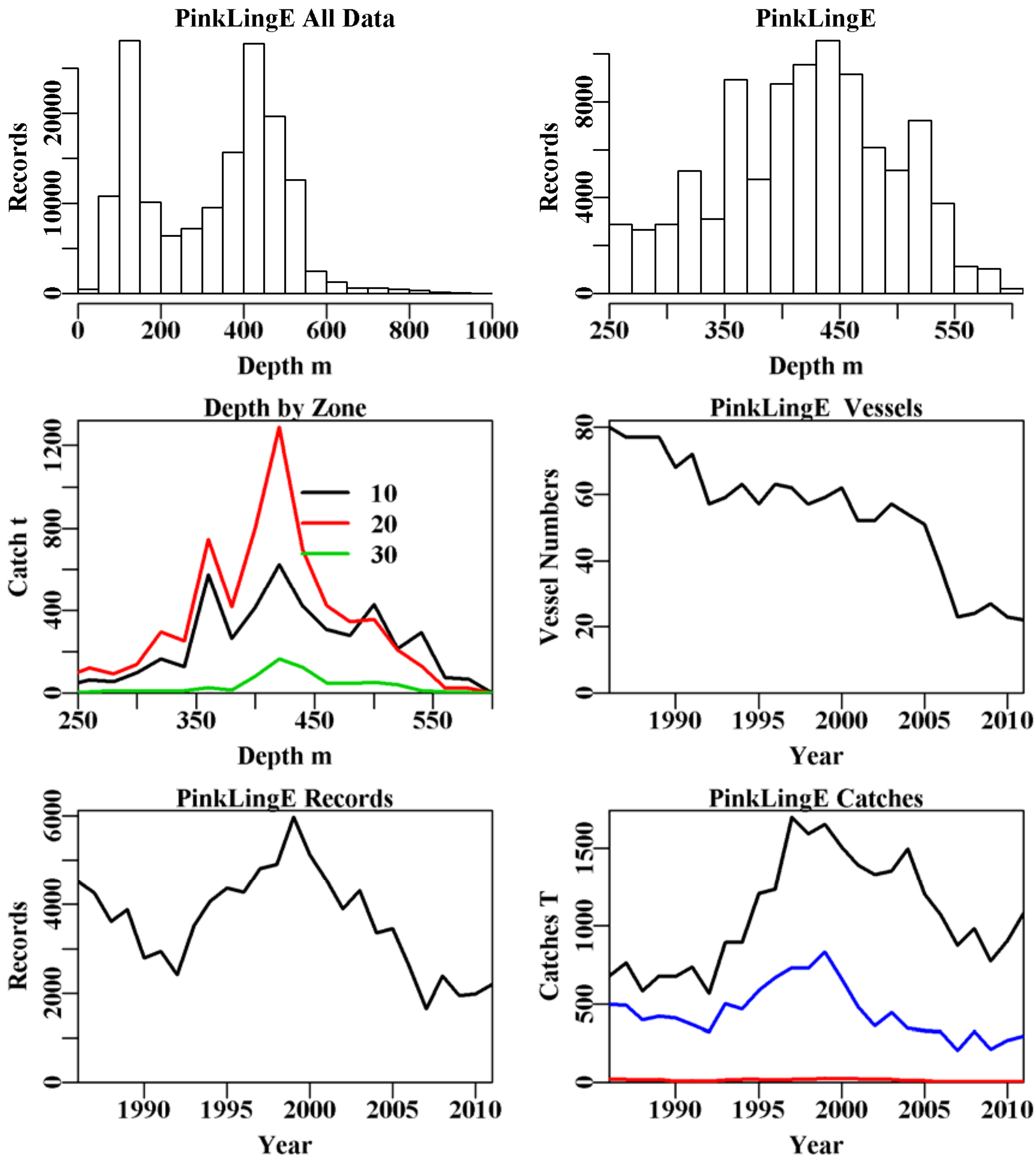

Figure 13.98. Pink Ling from zones 10 to 30 in depths between 250 – 600m by trawl. The top left is the depth distribution of all records reporting Pink Ling, the top right graph depicts the depth distribution of shots containing Pink Ling from zones 10 to 30 in depths between 250 – 600m by trawl. The middle left diagram depicts the distribution of catch by depth within zones 10 to 30, the middle right hand graph depicts the number of vessels through time. The bottom left reflects the number of records used in analysis, and bottom right is the Pink Ling catches (top line, black is total catches, middle line, blue, are those used in the analysis, and bottom, red, are catches < 30Kg).

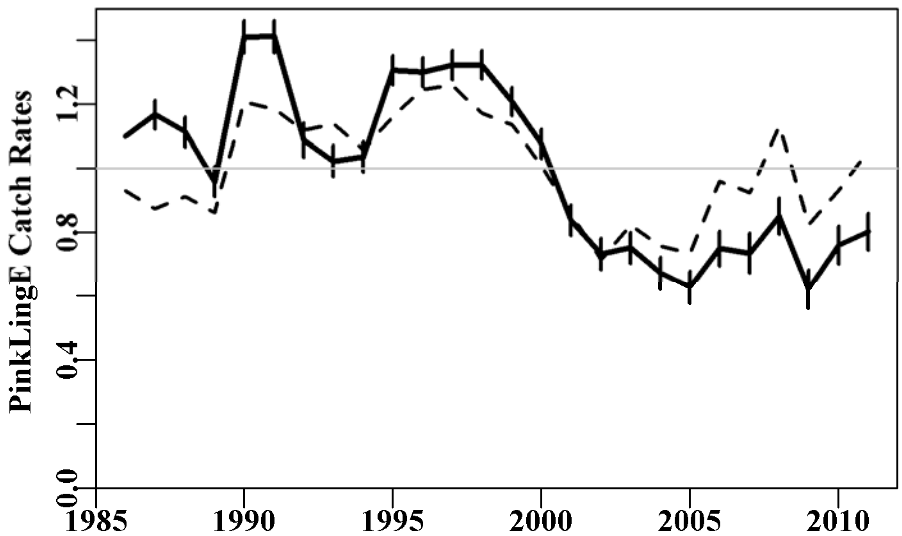

Figure 13.99**.** Pink Ling from zones 10 to 30 in depths between 250 – 600m by trawl. The dashed black line represents the geometric mean catch rate and the solid black line the standardized catch rates. The graph standardizes catch rates relative to the mean of the standardized catch rates.

Table 13.81**.** Pink Ling from zones 10 to 30 in depths between 250 – 600m by trawl. Statistical model structures used in this analysis. DepCat is a series of 20 metre depth categories.

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

Table 13.82**.** Pink Ling from zones 10 to 30 in depths between 250 – 600m by trawl. Model selection criteria, including the AIC, the adjusted r^2 and the change in adjusted r^2. The optimum is Zone:Month (model 7).

	Year	DepCat	Vessel	Month	Zone	DayNight	Zone:Mth	Zone:DepC
AIC	31726	24789	4336	605	-1	-44	-1143	-1015
RSS	131436	121237	96914	93079	92470	92420	91291	91390
MSS	2713	12911	37234	41070	41679	41728	42857	42759
Nobs	93754	92943	92943	92943	92943	92943	92943	92943
Npars	26	44	223	235	237	240	262	276
adj_r2	1.996	9.583	27.583	30.440	30.894	30.928	31.756	31.672
%Change	0.000	7.587	18.001	2.857	0.454	0.035	0.828	0.744

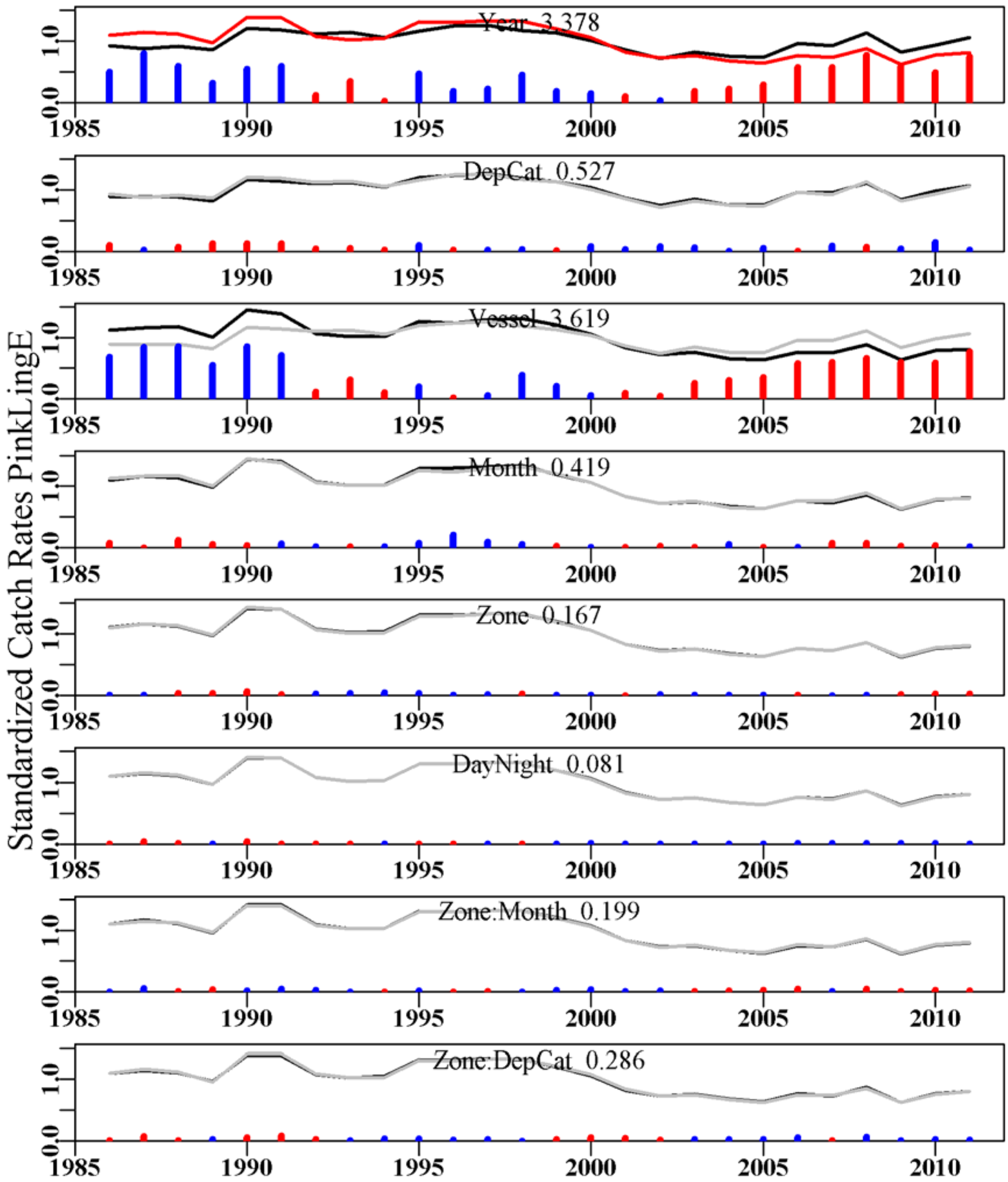

Figure 13.100**.** The relative influence of each factor used on the final trend in the optimal standardization for Pink Ling from zones 10 to 30. The top graph depicts the geometric mean (the black line) and the optimum model (the red line). The difference between them is illustrated by the vertical bars with blue bars indicating the optimum model is higher than the geometric mean and red bars indicating it is lower. The top graph bars are the sum of all the bars in the graphs below. The graphs for individual factors are cumulative. Thus the second graph has the geometric mean (grey line) and the effect of adding Year + factor2 (model 2). In the third graph, the grey line represents model 2 and the black line the effect of adding factor3 to the model. The remaining graphs continue in the same cumulative manner except for the interaction terms which are added singularly to the final single factor model.

13.33 Pink Ling, Z4050 (LIG – 37228002 – G. blacodes)

Data from zones 40 and 50, depths greater than 200 m and less or equal to 800 m.

Table 13.83. Pink Ling from zones 40 and 50 in depths between 200 – 800m by trawl. Total Catch is the total reported in the database, Records is the number of records used in the analysis, CatchT is the reported catch in the area and depth used in the analysis, and Vessels relates to all vessels used in the analysis. Geomean is the geometric mean of catch rates (kg/hr). Zone:Mth is the optimum model and StDev is the standard deviation relating to the data in the optimum model.

Year	TotCatch	Records	CatchT	Vessels	GeoMean	Zone:Mth	StDev
1986	678.977	1265	112.944	23	17.1417	1.1680	0.0000
1987	765.066	1310	206.341	28	24.0155	1.3435	0.0376
1988	583.077	1026	95.703	32	17.6676	1.0475	0.0407
1989	678.896	1469	183.121	34	21.9840	1.0835	0.0389
1990	674.479	1524	147.412	32	16.9021	0.9750	0.0393
1991	736.803	1897	198.945	37	16.3936	1.0334	0.0375
1992	568.308	1633	102.164	24	11.9963	0.7724	0.0386
1993	892.796	2253	235.485	24	17.1332	1.0467	0.0373
1994	895.431	2110	247.793	24	20.5621	1.2583	0.0372
1995	1208.893	3516	426.907	25	20.0613	1.2904	0.0350
1996	1233.265	3403	448.044	26	19.9984	1.3731	0.0354
1997	1696.855	3732	577.434	24	21.1891	1.4460	0.0350
1998	1591.988	3710	558.641	21	22.4111	1.4405	0.0352
1999	1651.572	3794	427.920	24	18.0495	1.1255	0.0351
2000	1507.379	4655	509.304	27	16.3679	0.9974	0.0348
2001	1392.822	5061	500.022	28	14.7513	0.8910	0.0346
2002	1330.296	4631	429.572	27	13.4100	0.7697	0.0347
2003	1353.243	3821	360.388	27	12.6444	0.7741	0.0352
2004	1495.581	3901	306.551	25	11.7195	0.7207	0.0353
2005	1203.256	2663	195.741	23	9.9467	0.5988	0.0366
2006	1069.222	2322	209.985	21	10.6509	0.6418	0.0373
2007	875.926	2532	287.345	16	12.6778	0.7114	0.0369
2008	980.268	1795	214.232	17	14.6108	0.9077	0.0383
2009	775.047	1976	260.609	13	14.0039	0.8909	0.0378
2010	906.088	2337	272.103	14	13.1465	0.8572	0.0371
2011	1081.674	2728	346.774	16	13.1057	0.8357	0.0370

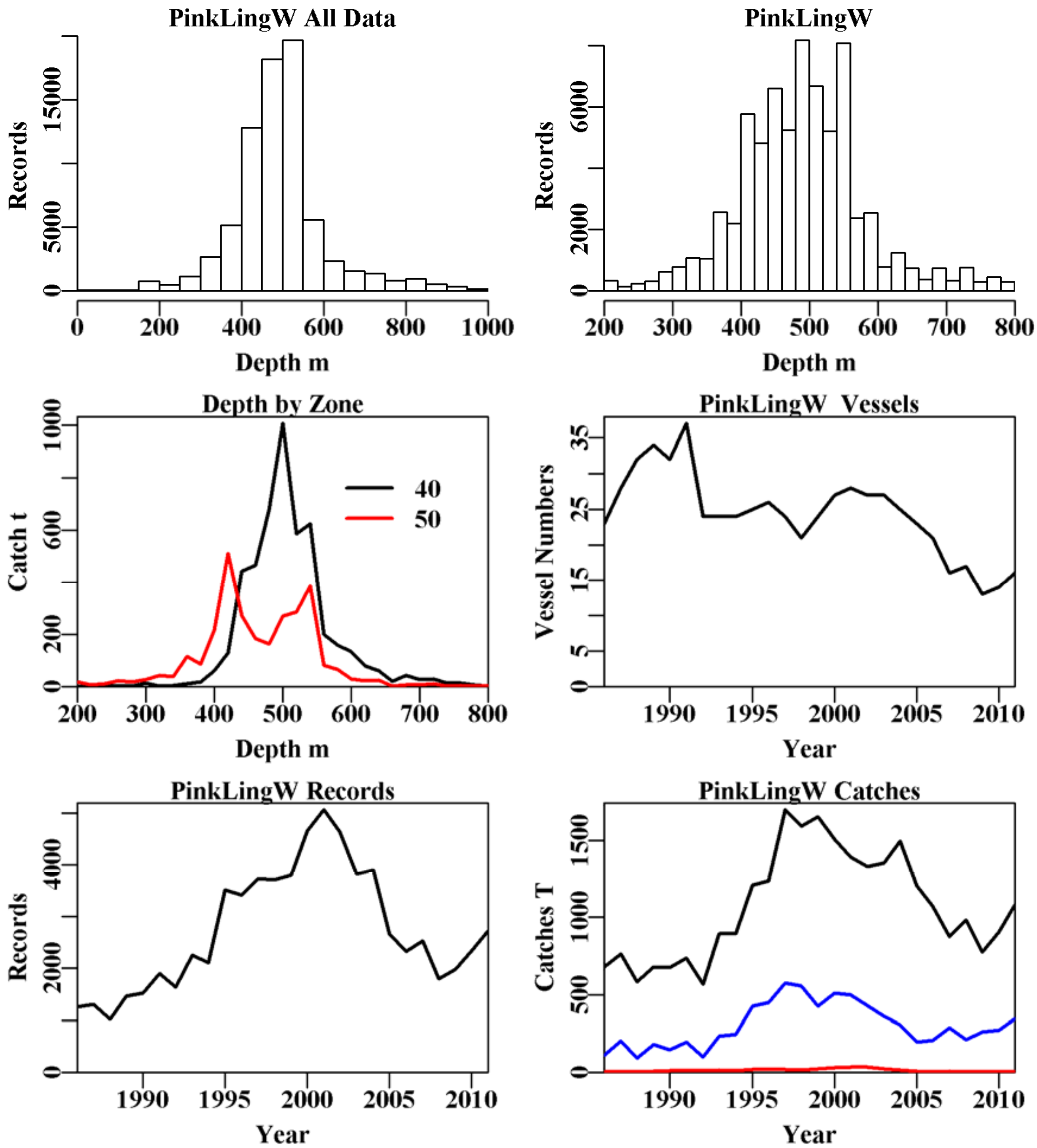

Figure 13.101**.** Pink Ling from zones 40 and 50 in depths between 200 – 800m by trawl. The top left is the depth distribution of all records reporting Pink Ling, the top right graph depicts the depth distribution of shots containing Pink Ling from zones 40 and 50 in depths between 200 – 800m by trawl. The middle left diagram depicts the distribution of catch by depth within zones 40 and 50 (50 is top red line), the middle right hand graph depicts the number of vessels through time. The bottom left reflects the number of records used in analysis, and bottom right is the Pink Ling catches (top line, black is total catches, middle line, blue, are those used in the analysis, and bottom, red, are catches < 30Kg).

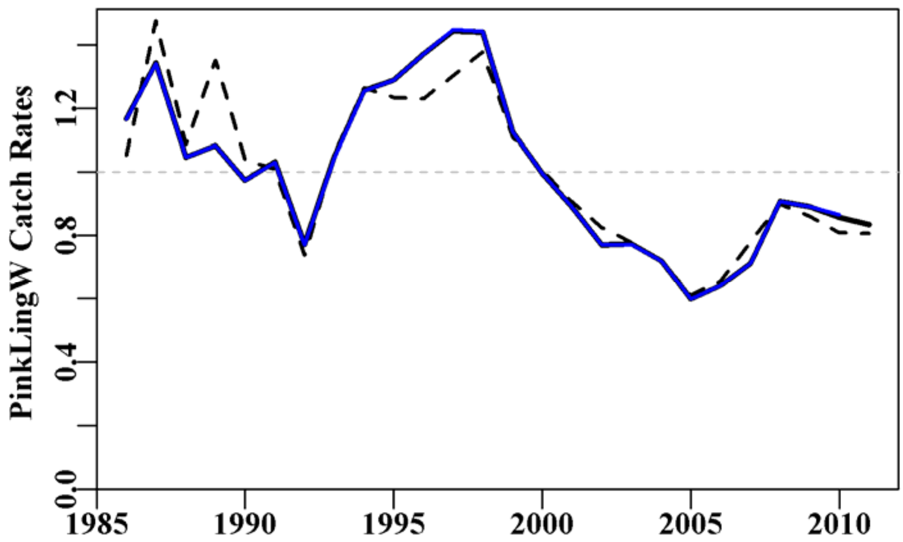

Figure 13.102. Pink Ling from zones 40 and 50 in depths between 200 – 800m by trawl. The dashed black line represents the geometric mean catch rate and the solid black line the standardized catch rates. The graph standardizes catch rates relative to the mean of the standardized catch rates.

Table 13.84. Pink Ling from zones 40 and 50 in depths between 200 – 800m by trawl. Statistical model structures used in this analysis. DepCat is a series of 20 metre depth categories.

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

Table 13.85. Pink Ling from zones 40 and 50 in depths between 200 – 800m by trawl. Model selection criteria, including the AIC, the adjusted r^2 and the change in adjusted r^2. The optimum is Zone:Month (model 7).

	Year	DepCat	Vessel	Month	Zone	DayNight	Zone:Mth	Zone:DepC
AIC	-232	-9783	-15835	-18000	-18677	-18698	-19964	-19316
RSS	70780	61450	56260	54546	54025	54004	53029	53488
MSS	3890	13220	18410	20124	20645	20666	21641	21182
Nobs	71064	70683	70683	70683	70683	70683	70683	70683
Npars	26	56	148	159	160	163	174	193
adj_r2	5.176	17.641	24.498	26.787	27.486	27.510	28.808	28.172
%Change	0.000	12.465	6.857	2.289	0.699	0.025	1.298	0.662

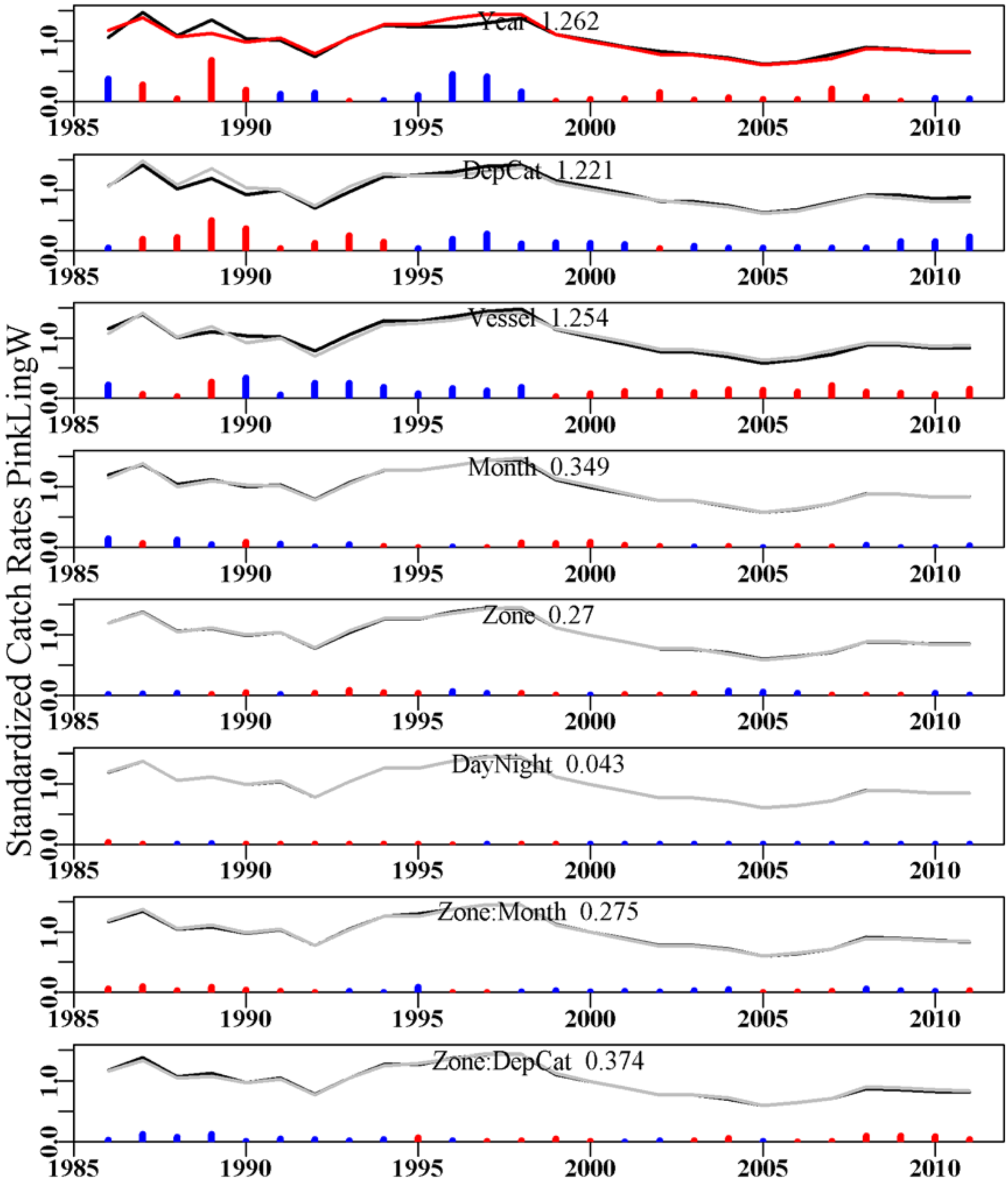

Figure 13.103**.** The relative influence of each factor used on the final trend in the optimal standardization for Pink Ling from zones 40 and 50. The top graph depicts the geometric mean (the black line) and the optimum model (the red line). The difference between them is illustrated by the vertical bars with blue bars indicating the optimum model is higher than the geometric mean and red bars indicating it is lower. The top graph bars are the sum of all the bars in the graphs below. The graphs for individual factors are cumulative. Thus the second graph has the geometric mean (grey line) and the effect of adding Year + factor2 (model 2). In the third graph, the grey line represents model 2 and the black line the effect of adding factor3 to the model. The remaining graphs continue in the same cumulative manner except for the interaction terms which are added singularly to the final single factor model.

13.34 Pink Ling, Z10 (LIG – 37228002 – G. blacodes)

Data from zone 10, depths greater than 250 m and less or equal to 600 m.

Table 13.86. Pink Ling from zone 10 in depths between 250 – 600m by trawl. Total Catch is the total Pink Ling catch from all zones reported in the database, Records is the number of records used in the analysis, CatchT is the reported catch in the area and depth used in this analysis, and Vessels relates to all vessels used in the analysis. Geomean is the unstandardized geometric mean of catch rates (kg/hr). Vessel:Mth is the optimum model and StDev is the standard deviation relating to the data in the optimum model.

Year	TotCatch	Records	CatchT	Vessels	GeoMean	Vessel:Mth	StDev
1986	678.977	3324	314.213	69	18.2806	1.1717	0.0000
1987	765.066	3017	270.907	65	15.1828	1.1250	0.0271
1988	583.077	2154	207.947	62	16.5795	1.1510	0.0295
1989	678.896	2356	177.865	61	13.2037	0.8811	0.0292
1990	674.479	1436	157.171	50	18.6577	1.2797	0.0332
1991	736.803	1319	145.022	39	23.1009	1.5669	0.0345
1992	568.308	1171	167.548	42	26.4272	1.3995	0.0357
1993	892.796	1613	224.873	43	24.5764	1.1595	0.0323
1994	895.431	1865	231.643	44	26.4614	1.4164	0.0308
1995	1208.893	2366	246.588	42	22.3982	1.5260	0.0289
1996	1233.265	2343	278.016	45	21.7797	1.3515	0.0291
1997	1696.855	2505	328.403	46	24.4094	1.4477	0.0287
1998	1591.988	2873	356.785	42	21.4118	1.4226	0.0280
1999	1651.572	3066	382.112	39	20.6881	1.3606	0.0279
2000	1507.379	2235	250.746	40	18.7962	1.1667	0.0305
2001	1392.822	1376	118.901	34	14.0899	0.8609	0.0351
2002	1330.296	1464	106.843	37	11.8033	0.7056	0.0343
2003	1353.243	1428	114.389	39	13.7771	0.6848	0.0350
2004	1495.581	1028	67.395	41	10.9097	0.4993	0.0382
2005	1203.256	1292	75.762	35	11.1472	0.4582	0.0353
2006	1069.222	795	63.499	27	12.5966	0.4686	0.0420
2007	875.926	397	31.023	16	11.4186	0.4864	0.0555
2008	980.268	559	48.896	17	15.1211	0.5929	0.0496
2009	775.047	421	39.817	15	15.9787	0.5246	0.0559
2010	906.088	636	72.524	15	17.9099	0.6973	0.0478
2011	1081.674	576	54.275	14	17.1346	0.5955	0.0489

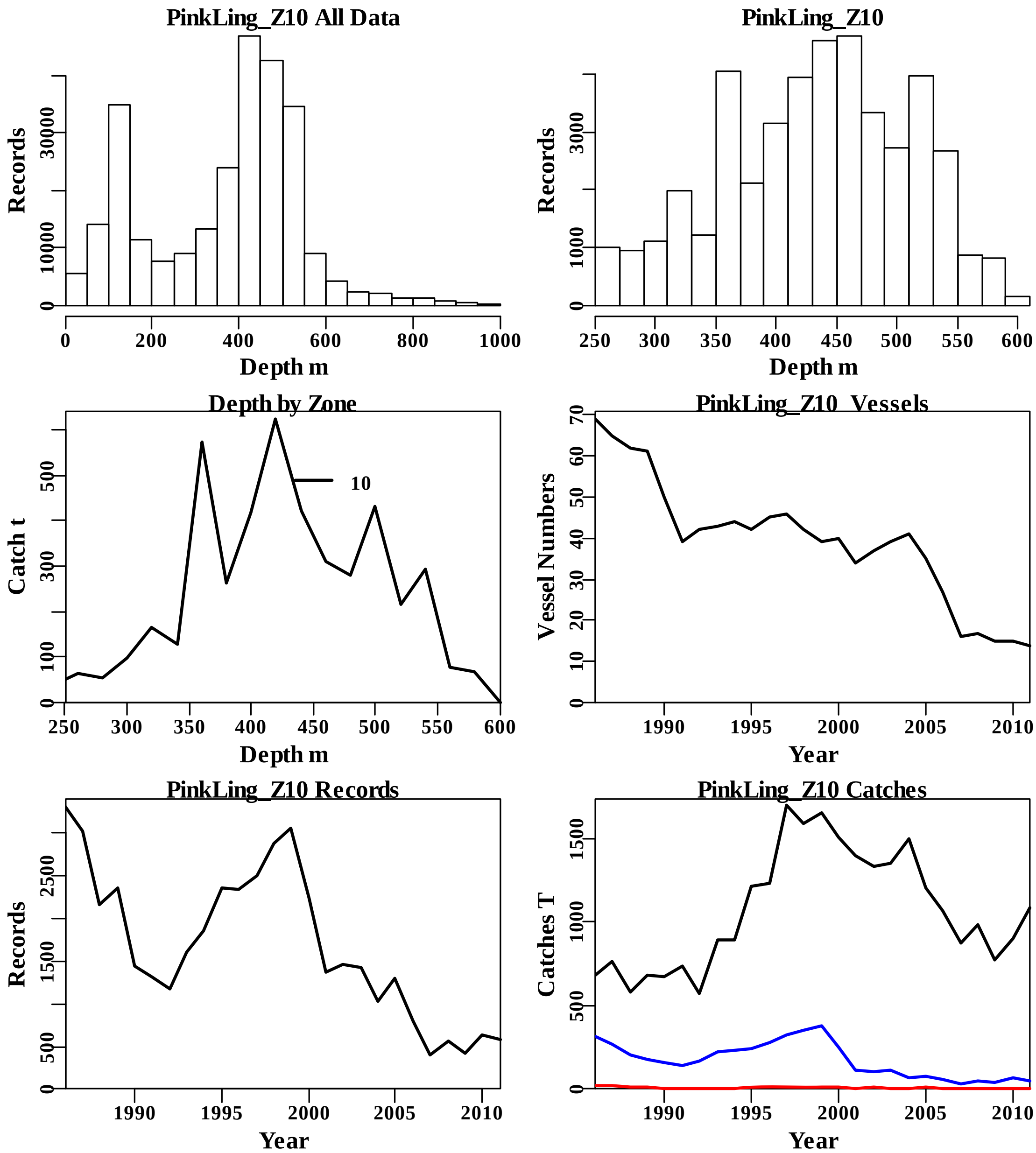

Figure 13.104**.** Pink Ling from zone 10 in depths between 250 – 600m by trawl. The top left is the depth distribution of all records reporting Pink Ling from zone 10 taken in the SET down to 1000m, the top right graph depicts the depth distribution of shots containing Pink Ling from zone 10 in depths between 250 – 600m by trawl. The middle left diagram depicts the distribution of catch by depth within zone 10, the middle right hand graph depicts the number of vessels reporting Pink Ling catches through time. The bottom left reflects the number of records used in analysis, and bottom right is the Pink Ling catches (top line, black is total catches, all zones, all methods, the middle line, blue, are those used in the analysis, and bottom, red, are catches < 30Kg).

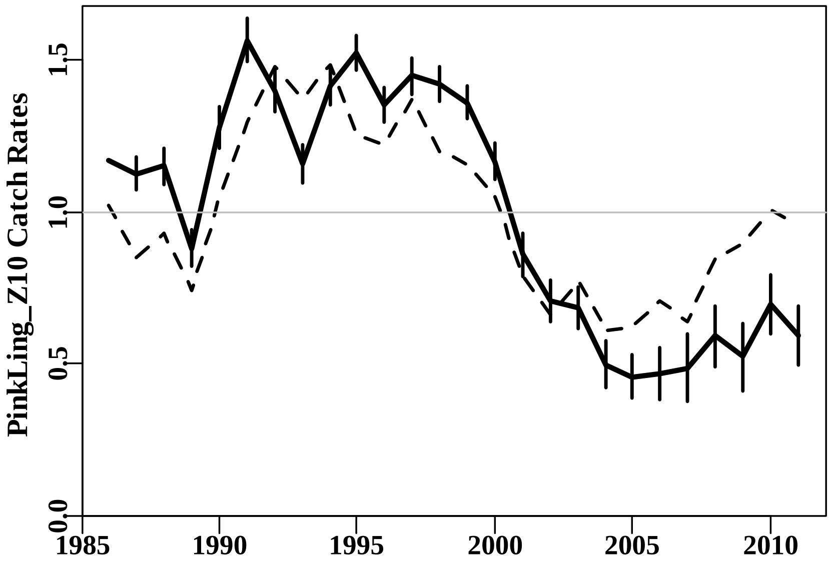

Figure 13.105. Pink Ling from zone 10 in depths between 250 – 600m by trawl. The dashed black line represents the geometric mean catch rate and the solid black line the standardized catch rates. The graph standardizes catch rates relative to the mean of the standardized catch rates; giving a mean for the series of 1.0.

Table 13.87. Pink Ling from zone 10 in depths between 250 – 600m by trawl. Statistical model structures used in this analysis. DepCat is a series of 20 metre depth categories.

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

Table 13.88. Pink Ling from zone 10 in depths between 250 – 600m by trawl. Model selection criteria, including the AIC, the adjusted r^2 and the change in adjusted r^2. The optimum is Vessel:Month (model 6).

	Year	Vessel	DepCat	Month	DayNight	Vessel:Month	Month:DepCat
AIC	19195	6531	2613	-592	-625	-1429	-1300
RSS	67647	50302	45720	42443	42406	38992	41372
MSS	2805	20150	24732	28009	28047	31460	29080
Nobs	43615	43615	43393	43393	43393	43393	43393
Npars	26	155	173	184	187	1606	385
adj_r2	3.926	28.349	34.846	39.501	39.550	42.529	40.752
%Change	0.000	24.422	6.498	4.654	0.050	2.979	1.202

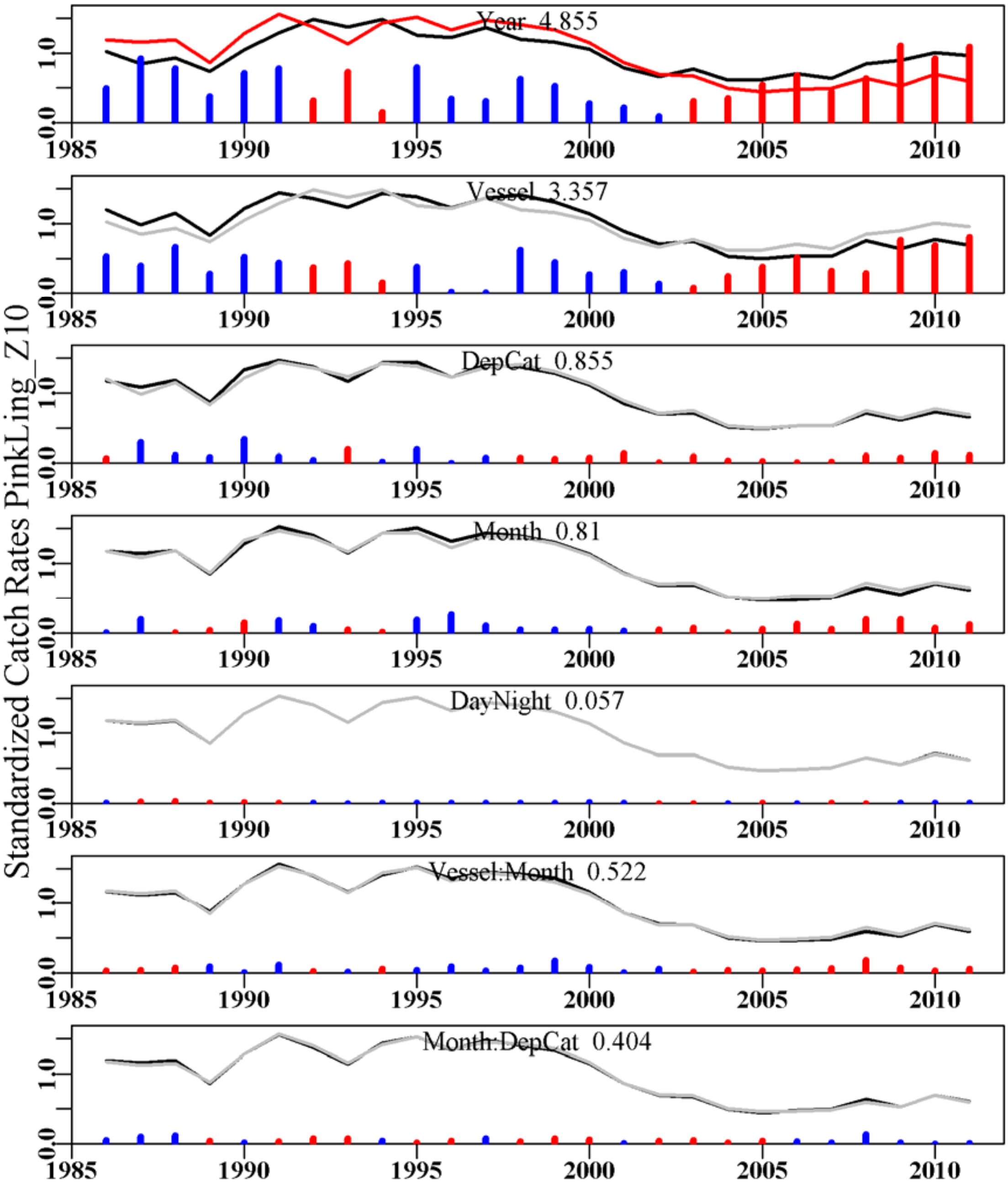

Figure 13.106**.** The relative influence of each factor used on the final trend in the optimal standardization for Pink Ling in Zone 10. The top graph depicts the geometric mean (the black line) and the optimum model (the red line). The difference between them is illustrated by the vertical bars with blue bars indicating the optimum model is higher than the geometric mean and red bars indicating it is lower. The top graph bars are the sum of all the bars in the graphs below. The graphs for individual factors are cumulative. Thus the second graph for Vessel has the geometric mean (grey line) and the effect of adding Year + Vessel (model 2). In the third graph, for DepCat, the grey line represents model 2 and the black line the effect of adding DepCat to the model. The remaining graphs continue in the same cumulative manner except for the interaction terms which are added singularly to the final single factor model.

13.35 Pink Ling, Z20 (LIG – 37228002 – G. blacodes)

Data from zone 20, depths greater than 250 m and less or equal to 600 m.

Table 13.89. Pink Ling from zone 20 in depths between 250 – 600m by trawl. Total Catch is the total Pink Ling catch from all zones reported in the database, Records is the number of records used in the analysis, CatchT is the reported catch in the area and depth used in this analysis, and Vessels relates to all vessels used in the analysis. Geomean is the unstandardized geometric mean of catch rates (kg/hr).Mth:DepCat is the optimum model and StDev is the standard deviation relating to the data in the optimum model.

Year	TotCatch	Records	CatchT	Vessels	GeoMean	Mth:DepCat	StDev
1986	678.977	1173	182.189	38	29.2240	1.0087	0.0000
1987	765.066	1207	219.162	37	36.1063	1.4565	0.0430
1988	583.077	1409	187.752	39	27.1962	0.9857	0.0422
1989	678.896	1462	236.224	34	34.1990	1.0624	0.0420
1990	674.479	1253	247.526	33	40.5063	1.2737	0.0453
1991	736.803	1243	196.325	31	32.4251	1.0324	0.0460
1992	568.308	1112	151.017	25	25.4253	0.8487	0.0471
1993	892.796	1585	258.998	25	27.3764	0.8842	0.0444
1994	895.431	1713	210.108	24	22.5143	0.7841	0.0437
1995	1208.893	1584	303.948	24	33.0905	1.2571	0.0440
1996	1233.265	1544	353.759	26	41.1747	1.3787	0.0445
1997	1696.855	1860	358.577	28	36.3858	1.2880	0.0441
1998	1591.988	1870	355.885	23	35.8703	1.3284	0.0439
1999	1651.572	2421	409.166	26	34.3684	1.1772	0.0426
2000	1507.379	2493	375.436	31	27.0471	1.0360	0.0426
2001	1392.822	2427	304.034	24	23.7631	0.8142	0.0430
2002	1330.296	1934	218.025	24	20.1429	0.7770	0.0444
2003	1353.243	2473	301.477	30	22.0973	0.8344	0.0430
2004	1495.581	1954	253.007	25	22.4000	0.8566	0.0449
2005	1203.256	1768	212.464	24	20.8376	0.7881	0.0454
2006	1069.222	1542	228.071	20	27.6927	0.9720	0.0459
2007	875.926	1025	141.086	12	24.5067	0.8174	0.0492
2008	980.268	1458	235.294	13	30.6898	0.9655	0.0464
2009	775.047	1291	156.773	16	20.0214	0.6769	0.0474
2010	906.088	1175	182.205	13	22.6841	0.7855	0.0489
2011	1081.674	1363	212.576	13	27.4133	0.9104	0.0478

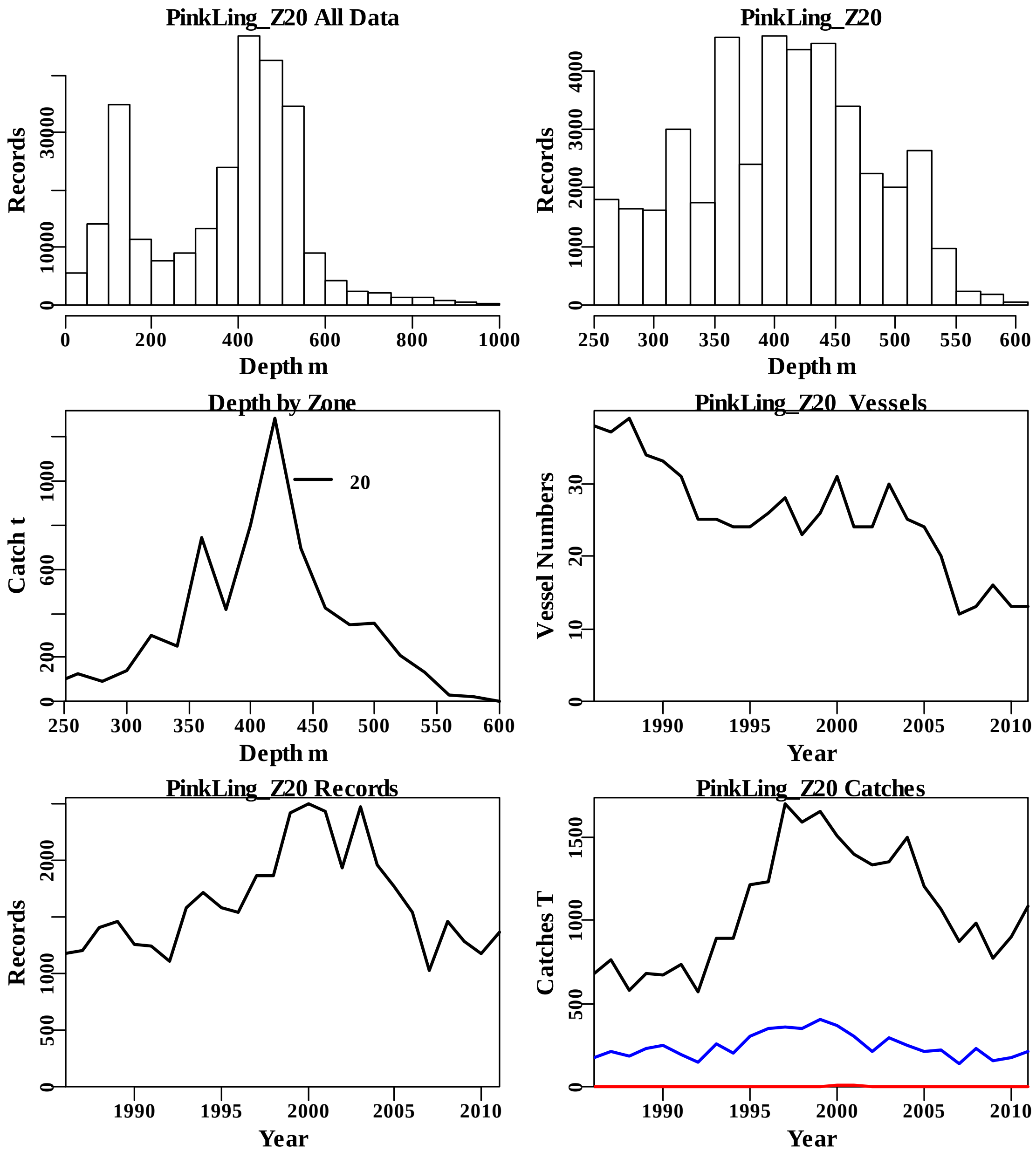

Figure 13.107**.** Pink Ling from zone 20 in depths between 250 – 600m by trawl. The top left is the depth distribution of all records reporting Pink Ling from zone 20 taken in the SET down to 1000m, the top right graph depicts the depth distribution of shots containing Pink Ling from zone 20 in depths between 250 – 600m by trawl. The middle left diagram depicts the distribution of catch by depth within zone 20, the middle right hand graph depicts the number of vessels reporting Pink Ling catches through time. The bottom left reflects the number of records used in analysis, and bottom right is the Pink Ling catches (top line, black is total catches, all zones, all methods, the middle line, blue, are those used in the analysis, and bottom, red, are catches < 30Kg).

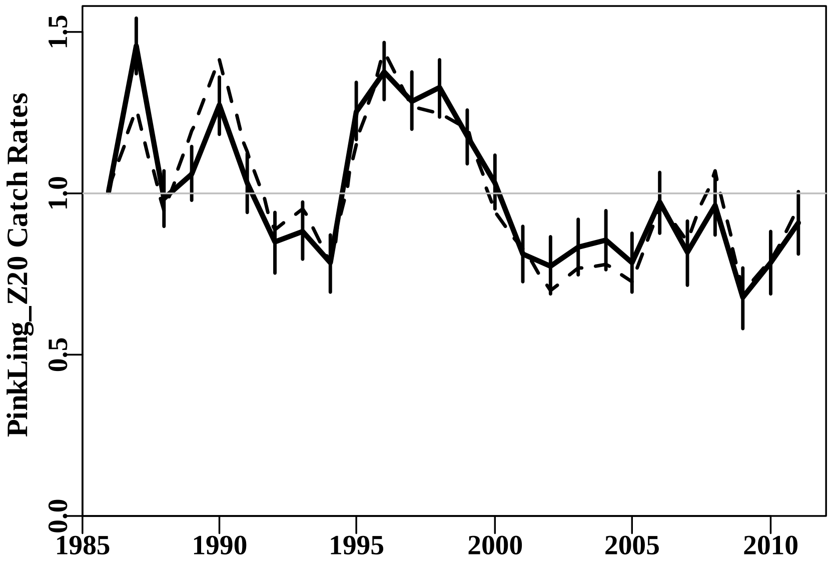

Figure 13.108**.** Pink Ling from zone 20 in depths between 250 – 600m by trawl. The dashed black line represents the geometric mean catch rate and the solid black line the standardized catch rates. The graph standardizes catch rates relative to the mean of the standardized catch rates; giving a mean for the series of 1.0.

Table 13.90. Pink Ling from zone 20 in depths between 250 – 600m by trawl. Statistical model structures used in this analysis. DepCat is a series of 20 metre depth categories.

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

Table 13.91**.** Pink Ling from zone 20 in depths between 250 – 600m by trawl. Model selection criteria, including the AIC, the adjusted r^2 and the change in adjusted r^2. The optimum is Month:DepCat (model 7).

	Year	Vessel	DepCat	Month	DayNight	Vessel:Month	Month:DepCat
AIC	7614	-937	-2216	-3350	-3445	-3523	-3725
RSS	50619	40822	39364	38291	38199	35777	37587
MSS	1942	11739	13196	14270	14362	16783	14974
Nobs	42339	41834	41834	41834	41834	41834	41834
Npars	26	44	164	176	179	1510	377
adj_r2	3.638	22.254	24.814	26.843	27.014	29.384	27.840
%Change	0.000	18.616	2.560	2.029	0.171	2.370	0.827

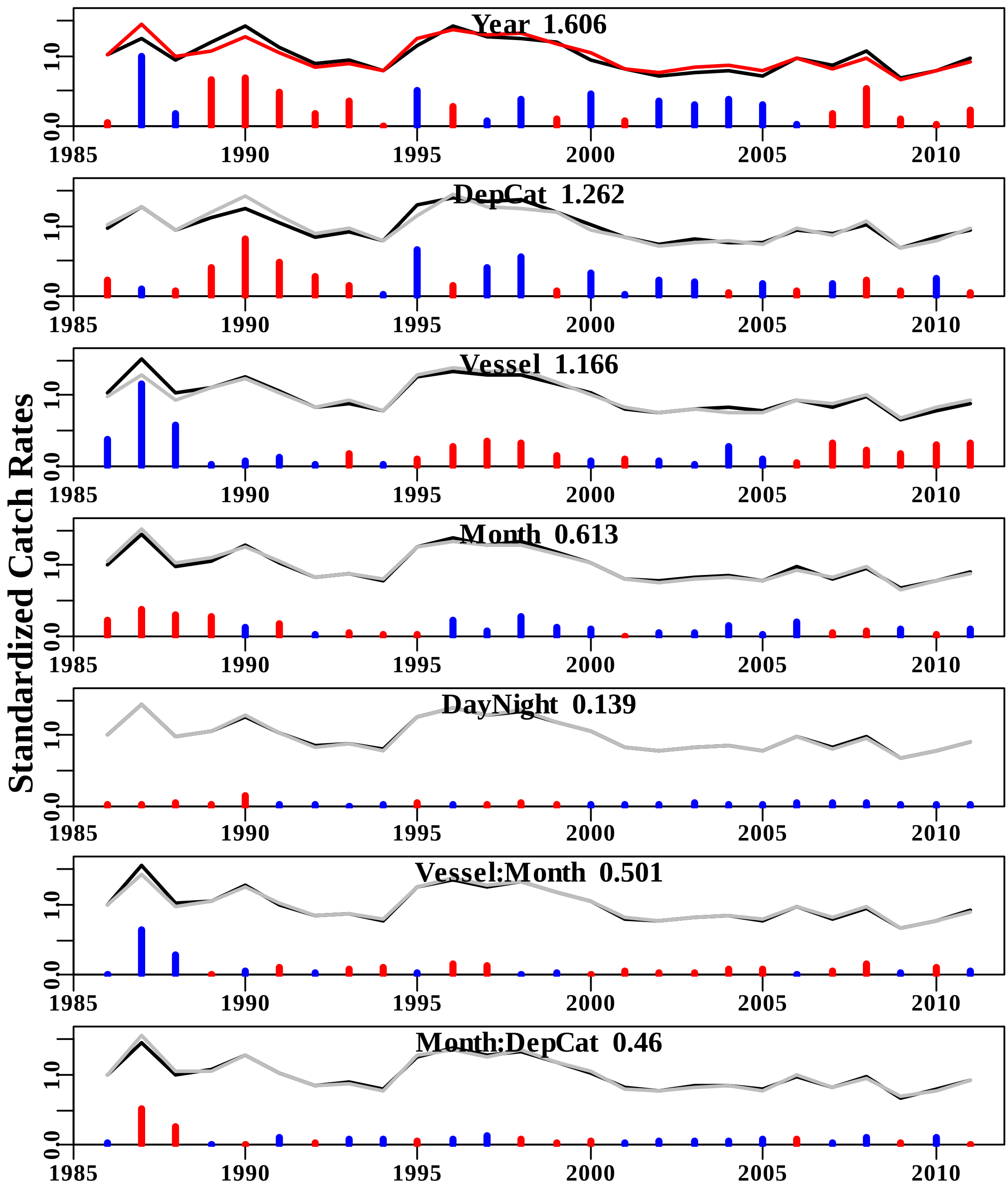

Figure 13.109. The relative influence of each factor used on the final trend in the optimal standardization for Pink Ling in Zone 20. The top graph depicts the geometric mean (the black line) and the optimum model (the red line). The difference between them is illustrated by the vertical bars with blue bars indicating the optimum model is higher than the geometric mean and red bars indicating it is lower. The top graph bars are the sum of all the bars in the graphs below. The graphs for individual factors are cumulative. Thus the second graph for Vessel has the geometric mean (grey line) and the effect of adding Year + Vessel (model 2). In the third graph, for DepCat, the grey line represents model 2 and the black line the effect of adding DepCat to the model. The remaining graphs continue in the same cumulative manner except for the interaction terms which are added singularly to the final single factor model.

13.36 Pink Ling, Z30 (LIG – 37228002 – G. blacodes)

Data from zone 30, depths greater than 250 m and less or equal to 600 m.

Table 13.92. Pink Ling from zone 30 in depths between 250 – 600m by trawl. Total Catch is the total Pink Ling catch from all zones reported in the database, Records is the number of records used in the analysis, CatchT is the reported catch in the area and depth used in this analysis, and Vessels relates to all vessels used in the analysis. Geomean is the unstandardized geometric mean of catch rates (kg/hr). DayNight is the optimum model and StDev is the standard deviation relating to the data in the optimum model.

Year	TotCatch	Records	CatchT	Vessels	GeoMean	DayNight	StDev
1986	678.977	15	1.896	3	22.1580	2.0010	0.0000
1987	765.066	36	2.245	5	16.8408	1.0199	0.2887
1988	583.077	50	4.378	4	28.4036	2.1634	0.2767
1989	678.896	61	7.988	11	31.1539	1.3596	0.2729
1990	674.479	105	8.385	17	27.9919	1.4765	0.2517
1991	736.803	376	28.950	27	20.7784	0.9609	0.2408
1992	568.308	134	5.806	14	12.0005	0.5687	0.2462
1993	892.796	327	20.603	17	19.9815	0.9560	0.2380
1994	895.431	488	28.514	22	17.4518	0.7898	0.2359
1995	1208.893	411	36.150	17	22.4107	1.0315	0.2366
1996	1233.265	381	35.808	18	23.9592	1.1644	0.2369
1997	1696.855	443	45.674	17	19.7673	1.0964	0.2359
1998	1591.988	166	17.788	16	20.3063	1.0470	0.2416
1999	1651.572	477	41.377	15	18.8073	1.0044	0.2366
2000	1507.379	385	34.098	18	18.3481	0.8927	0.2363
2001	1392.822	741	61.087	19	16.2336	0.7676	0.2328
2002	1330.296	500	35.598	17	14.9854	0.7536	0.2345
2003	1353.243	408	29.893	19	15.6988	0.7112	0.2362
2004	1495.581	377	26.968	14	12.2641	0.5961	0.2361
2005	1203.256	394	41.743	14	19.1660	0.8352	0.2371
2006	1069.222	256	31.531	11	22.6012	0.8236	0.2400
2007	875.926	230	32.198	8	25.4173	1.0015	0.2405
2008	980.268	365	44.846	8	24.7573	0.9377	0.2386
2009	775.047	235	15.772	10	14.2097	0.5549	0.2408
2010	906.088	179	16.392	8	19.2029	0.6997	0.2425
2011	1081.674	260	27.946	7	20.6797	0.7868	0.2395

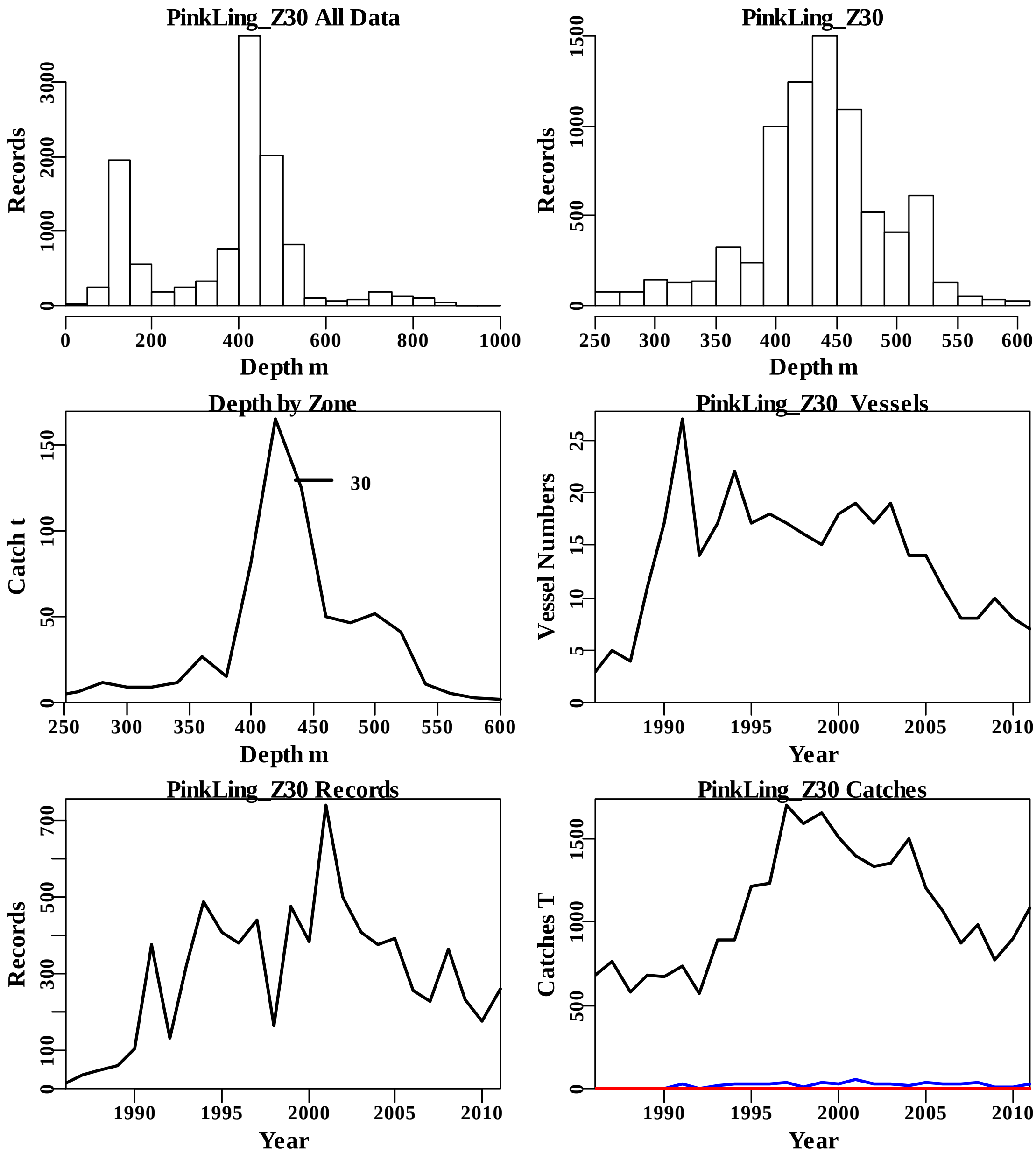

Figure 13.110. Pink Ling from zone 30 in depths between 250 – 600m by trawl. The top left is the depth distribution of all records reporting Pink Ling from zone 30 taken in the SET down to 1000m, the top right graph depicts the depth distribution of shots containing Pink Ling from zone 30 in depths between 250 – 600m by trawl. The middle left diagram depicts the distribution of catch by depth within zone 30, the middle right hand graph depicts the number of vessels reporting Pink Ling catches through time. The bottom left reflects the number of records used in analysis, and bottom right is the Pink Ling catches (top line, black is total catches, all zones, all methods, the middle line, blue, are those used in the analysis, and bottom, red, are catches < 30Kg).

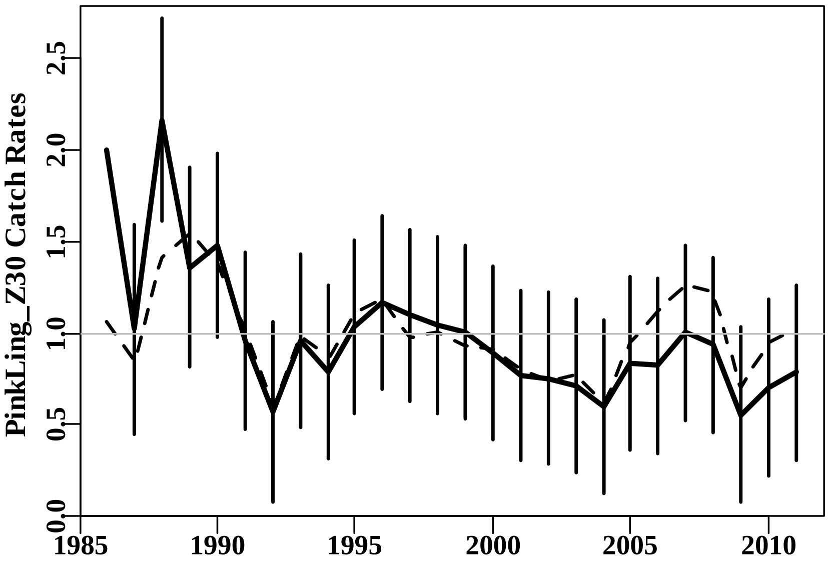

Figure 13.111**.** Pink Ling from zone 30 in depths between 250 – 600m by trawl. The dashed black line represents the geometric mean catch rate and the solid black line the standardized catch rates. The graph standardizes catch rates relative to the mean of the standardized catch rates; giving a mean for the series of 1.0. The confidence intervals are wider due to the relatively low number of records.

Table 13.93. Pink Ling from zone 30 in depths between 250 – 600m by trawl. Statistical model structures used in this analysis. DepCat is a series of 20 metre depth categories.

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

Table 13.94**.** Pink Ling from zone 30 in depths between 250 – 600m by trawl. Model selection criteria, including the AIC, the adjusted r^2 and the change in adjusted r^2. The optimum is DayNight (model 5).

	Year	Vessel	DepCat	Month	DayNight	Vessel:Month	Month:DepCat
AIC	-1143	-1767	-2163	-2224	-2282	-1407	-2184
RSS	6692	6063	5655	5595	5549	5047	5338
MSS	316	945	1352	1412	1458	1960	1669
Nobs	7800	7800	7716	7716	7716	7716	7716
Npars	26	99	117	128	131	934	329
adj_r2	4.196	12.378	18.062	18.818	19.457	18.064	20.433
%Change	0.000	8.182	5.684	0.756	0.639	-1.393	2.368

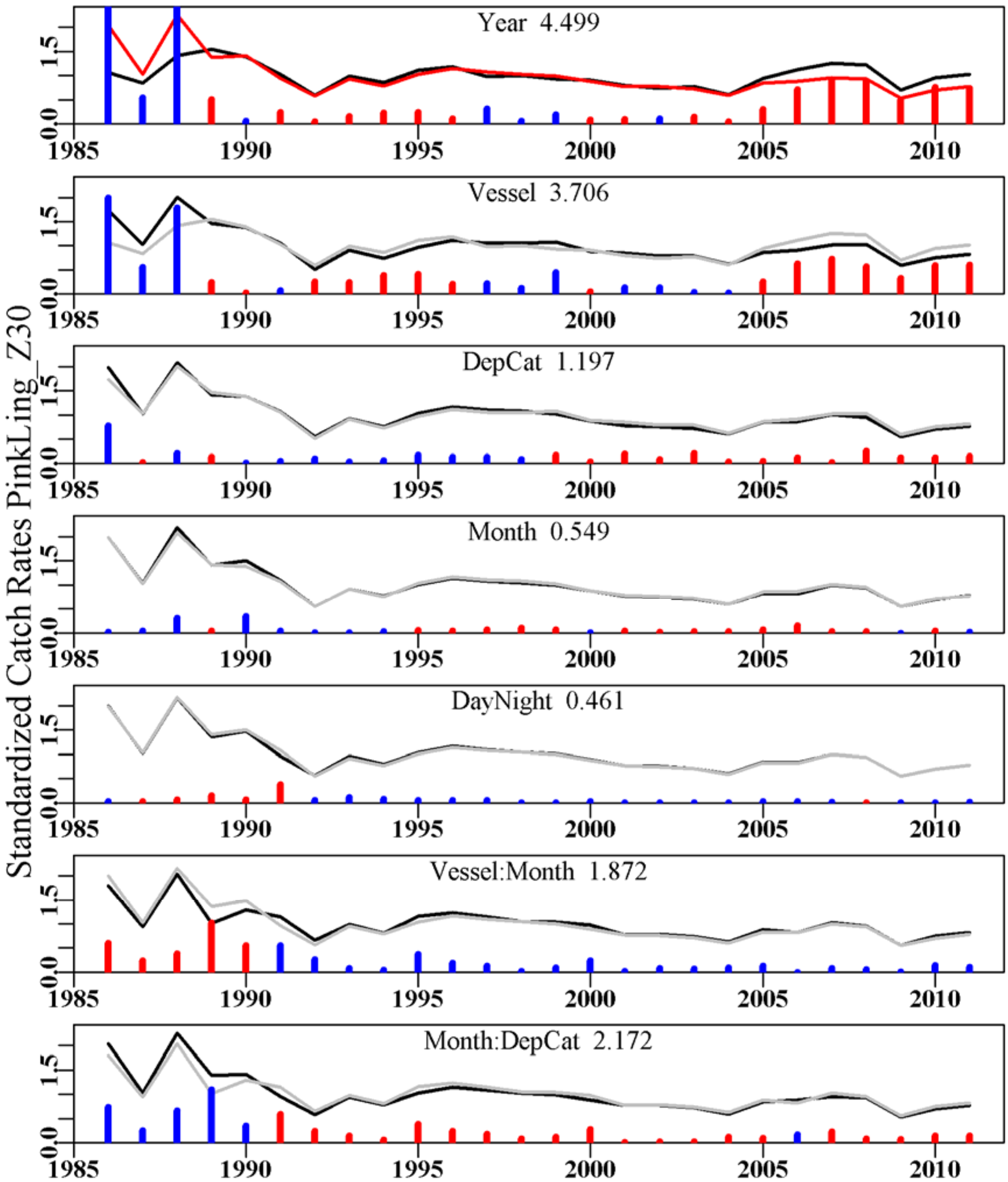

Figure 13.112**.** The relative influence of each factor used on the final trend in the optimal standardization for Pink Ling in Zone 30. The top graph depicts the geometric mean (the black line) and the optimum model (the red line). The difference between them is illustrated by the vertical bars with blue bars indicating the optimum model is higher than the geometric mean and red bars indicating it is lower. The top graph bars are the sum of all the bars in the graphs below. The graphs for individual factors are cumulative. Thus the second graph for Vessel has the geometric mean (grey line) and the effect of adding Year + Vessel (model 2). In the third graph, for DepCat, the grey line represents model 2 and the black line the effect of adding DepCat to the model. The remaining graphs continue in the same cumulative manner except for the interaction terms which are added singularly to the final single factor model.

13.37 Pink Ling, Z40 (LIG – 37228002 – G. blacodes)

Data from zone 40, depths greater than 350 m and less or equal to 800 m.

Table 13.95**.** Pink Ling from zone 40 in depths between 350 – 800m by trawl. Total Catch is the total Pink Ling catch from all zones reported in the database, Records is the number of records used in the analysis, CatchT is the reported catch in the area and depth used in this analysis, and Vessels relates to all vessels used in the analysis. Geomean is the unstandardized geometric mean of catch rates (kg/hr). Mth:DepCat is the optimum model and StDev is the standard deviation relating to the data in the optimum model.

Year	TotCatch	Records	CatchT	Vessels	GeoMean	Mth:DepCat	StDev
1986	678.977	340	50.622	12	24.8664	1.1577	0.0000
1987	765.066	464	149.303	17	61.5525	1.7336	0.0815
1988	583.077	323	52.147	20	26.7665	0.9423	0.0856
1989	678.896	727	134.342	20	31.2668	0.9999	0.0787
1990	674.479	543	92.429	22	29.7271	0.9472	0.0789
1991	736.803	597	97.883	29	23.7829	0.8809	0.0774
1992	568.308	483	39.702	17	14.1316	0.6003	0.0805
1993	892.796	841	118.853	19	20.2159	0.9014	0.0760
1994	895.431	775	133.541	21	27.0651	1.1136	0.0761
1995	1208.893	1564	211.632	18	20.1818	1.1006	0.0723
1996	1233.265	1205	235.651	17	26.7059	1.2508	0.0751
1997	1696.855	1419	340.323	16	27.8818	1.3665	0.0739
1998	1591.988	1671	349.366	16	26.2074	1.3275	0.0736
1999	1651.572	1628	241.419	18	21.1431	0.9963	0.0734
2000	1507.379	2060	338.192	23	23.8936	1.0500	0.0730
2001	1392.822	2531	359.654	24	20.5368	0.9436	0.0726
2002	1330.296	2290	298.182	21	17.3590	0.7497	0.0726
2003	1353.243	1814	251.303	22	17.1223	0.7740	0.0735
2004	1495.581	1292	143.083	20	14.1120	0.5990	0.0749
2005	1203.256	966	114.114	18	14.2226	0.5955	0.0762
2006	1069.222	826	129.898	16	17.2693	0.7420	0.0772
2007	875.926	1254	221.488	15	20.4467	0.8823	0.0750
2008	980.268	806	151.663	14	24.2630	1.2079	0.0768
2009	775.047	965	200.785	13	24.1352	1.1482	0.0755
2010	906.088	947	182.003	10	22.1986	1.0373	0.0757
2011	1081.674	1104	241.948	12	22.2744	0.9520	0.0746

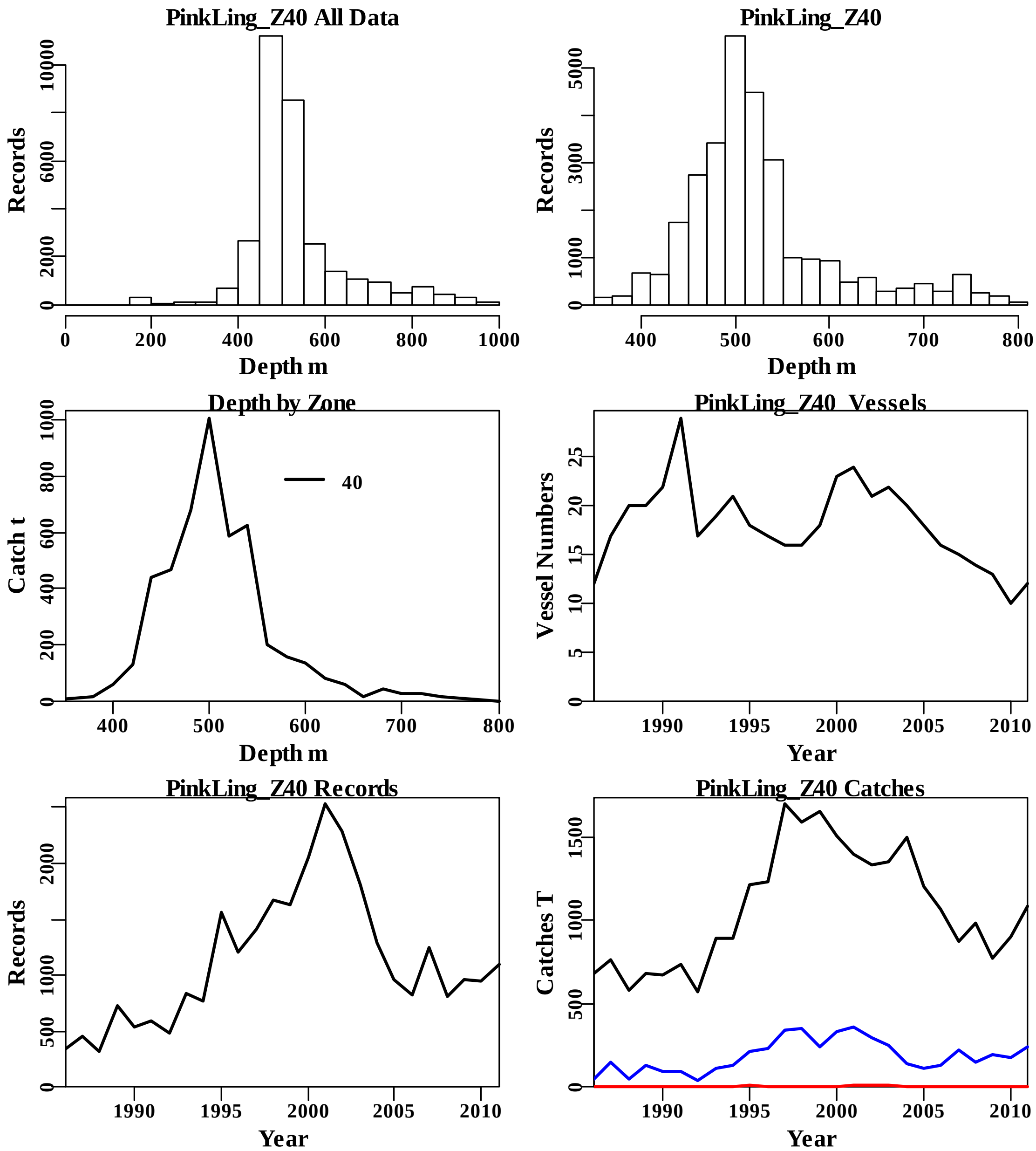

Figure 13.113**.** Pink Ling from zone 40 in depths between 350 – 800m by trawl. The top left is the depth distribution of all records reporting Pink Ling from zone 40 taken in the SET down to 1000m, the top right graph depicts the depth distribution of shots containing Pink Ling from zone 40 in depths between 350 – 800m by trawl. The middle left diagram depicts the distribution of catch by depth within zone 40, the middle right hand graph depicts the number of vessels reporting Pink Ling catches through time. The bottom left reflects the number of records used in analysis, and bottom right is the Pink Ling catches (top line, black is total catches, all zones, all methods, the middle line, blue, are those used in the analysis, and bottom, red, are catches < 30Kg).

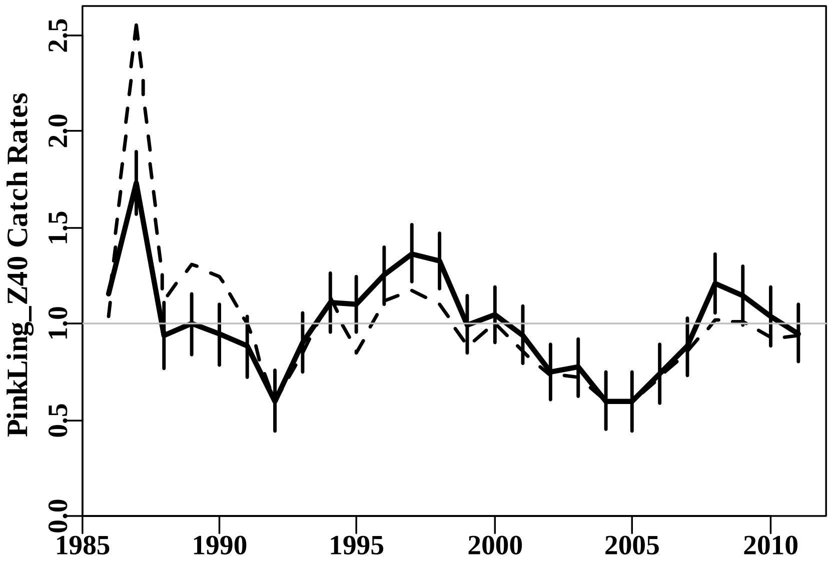

Figure 13.114**.** Pink Ling from zone 40 in depths between 350 – 800m by trawl. The dashed black line represents the geometric mean catch rate and the solid black line the standardized catch rates. The graph standardizes catch rates relative to the mean of the standardized catch rates; giving a mean for the series of 1.0. The confidence intervals are wider due to the relatively low number of records.

Table 13.96**.** Pink Ling from zone 40 in depths between 350 – 800m by trawl. Statistical model structures used in this analysis. DepCat is a series of 20 metre depth categories.

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

Table 13.97**.** Pink Ling from zone 40 in depths between 350 – 800m by trawl. Model selection criteria, including the AIC, the adjusted r^2 and the change in adjusted r^2. The optimum is Month:DepCat (model 7).

	Year	Vessel	DepCat	Month	DayNight	Vessel:Month	Month:DepCat
AIC	3976	559	-1884	-3064	-3107	-2790	-4314
RSS	33633	29652	27250	26022	25978	24669	24498
MSS	1745	5726	8128	9356	9400	10709	10880
Nobs	29435	29187	29187	29187	29187	29187	29187
Npars	26	49	60	143	146	1059	399
adj_r2	4.852	16.047	22.819	26.085	26.202	27.646	29.797
%Change	0.000	11.195	6.771	3.267	0.117	1.444	3.594

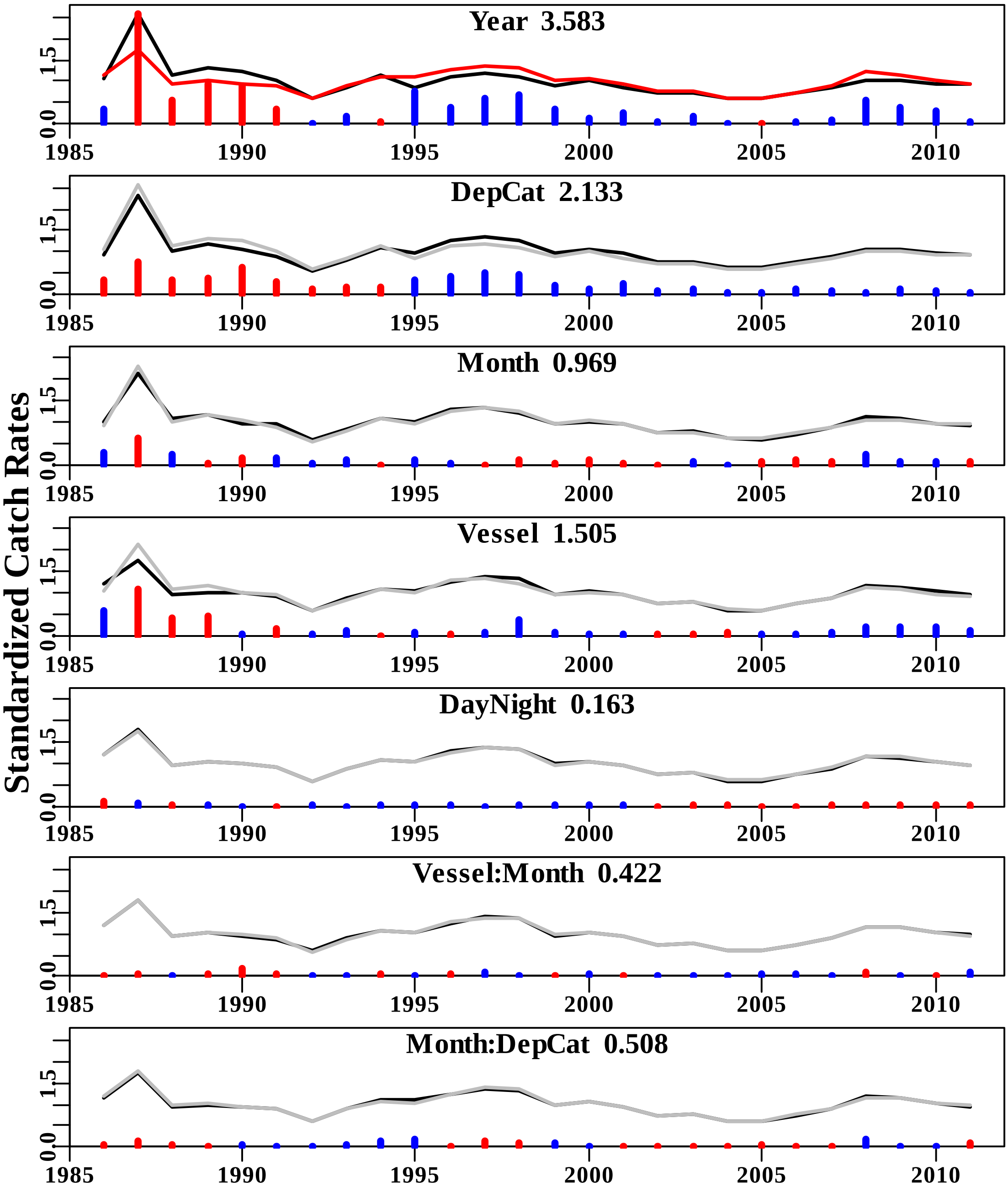

Figure 13.115**.** The relative influence of each factor used on the final trend in the optimal standardization for Pink Ling in Zone 40. The top graph depicts the geometric mean (the black line) and the optimum model (the red line). The difference between them is illustrated by the vertical bars with blue bars indicating the optimum model is higher than the geometric mean and red bars indicating it is lower. The top graph bars are the sum of all the bars in the graphs below. The graphs for individual factors are cumulative. Thus the second graph for Vessel has the geometric mean (grey line) and the effect of adding Year + Vessel (model 2). In the third graph, for DepCat, the grey line represents model 2 and the black line the effect of adding DepCat to the model. The remaining graphs continue in the same cumulative manner except for the interaction terms which are added singularly to the final single factor model. Note that the influence, which is simply the deviations between the two lines squared, are not always reflective of the adj-r^2 for each factor.

13.38 Pink Ling, Z50 (LIG – 37228002 – G. blacodes)

Data from zone 50, depths greater than 200 m and less or equal to 800 m.

Table 13.98**.** Pink Ling from zone 50 in depths between 200 – 800m by trawl. Total Catch is the total Pink Ling catch from all zones reported in the database, Records is the number of records used in the analysis, CatchT is the reported catch in the area and depth used in this analysis, and Vessels relates to all vessels used in the analysis. Geomean is the unstandardized geometric mean of catch rates (kg/hr). Vessel:Mth is the optimum model and StDev is the standard deviation relating to the data in the optimum model.

Year	TotCatch	Records	CatchT	Vessels	GeoMean	Vessel:Mth	StDev
1986	678.977	923	62.212	17	14.9346	1.0579	0.0000
1987	765.066	841	54.428	23	14.1775	1.0217	0.0456
1988	583.077	701	42.836	25	14.5280	1.1529	0.0476
1989	678.896	729	45.389	25	15.3818	1.1792	0.0469
1990	674.479	957	47.873	18	11.9104	0.9867	0.0469
1991	736.803	1294	100.787	20	13.8309	1.1260	0.0434
1992	568.308	1150	62.462	17	11.1987	0.8732	0.0439
1993	892.796	1410	116.532	12	15.5287	1.1594	0.0429
1994	895.431	1335	114.252	14	17.5302	1.3934	0.0428
1995	1208.893	1950	214.425	18	19.9408	1.5556	0.0407
1996	1233.265	2197	211.853	23	17.0478	1.4577	0.0403
1997	1696.855	2311	236.711	21	17.8914	1.5065	0.0399
1998	1591.988	2039	209.275	18	19.7137	1.5719	0.0406
1999	1651.572	2159	186.384	17	16.0778	1.2620	0.0402
2000	1507.379	2587	170.657	19	12.1381	0.9971	0.0400
2001	1392.822	2504	138.777	21	10.5409	0.8417	0.0402
2002	1330.296	2318	129.610	20	10.4073	0.8121	0.0403
2003	1353.243	1991	108.241	20	9.6163	0.7802	0.0406
2004	1495.581	2589	162.033	20	10.7076	0.7658	0.0401
2005	1203.256	1689	80.704	19	8.0776	0.5846	0.0417
2006	1069.222	1494	79.938	17	8.1572	0.5741	0.0427
2007	875.926	1270	64.909	13	7.8759	0.5849	0.0434
2008	980.268	987	62.435	14	9.6601	0.7181	0.0447
2009	775.047	1009	58.834	9	8.3008	0.6471	0.0446
2010	906.088	1382	89.591	12	9.1906	0.7152	0.0430
2011	1081.674	1611	103.784	13	9.1207	0.6748	0.0434

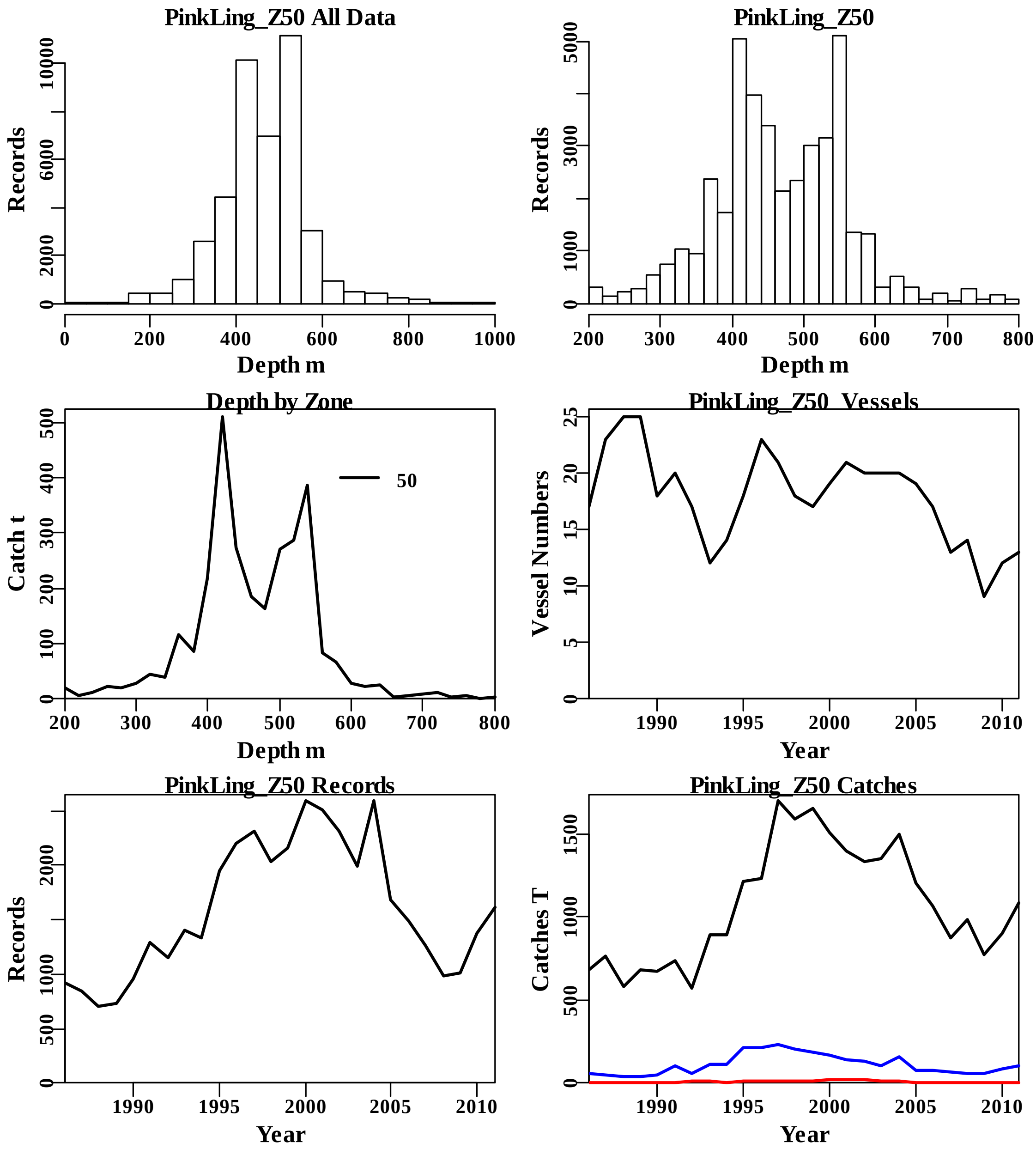

Figure 13.116. Pink Ling from zone 50 in depths between 200 – 800m by trawl. The top left is the depth distribution of all records reporting Pink Ling from zone 50 taken in the SET down to 1000m, the top right graph depicts the depth distribution of shots containing Pink Ling from zone 50 in depths between 200 – 800m by trawl. The middle left diagram depicts the distribution of catch by depth within zone 50, the middle right hand graph depicts the number of vessels reporting Pink Ling catches through time. The bottom left reflects the number of records used in analysis, and bottom right is the Pink Ling catches (top line, black is total catches, all zones, all methods, the middle line, blue, are those used in the analysis, and bottom, red, are catches < 30Kg).

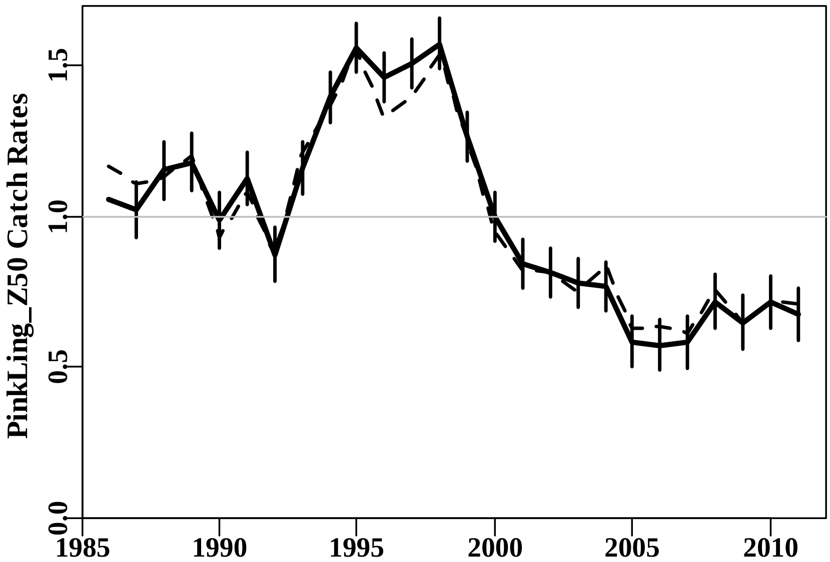

Figure 13.117**.** Pink Ling from zone 50 in depths between 200 – 800m by trawl. The dashed black line represents the geometric mean catch rate and the solid black line the standardized catch rates. The graph standardizes catch rates relative to the mean of the standardized catch rates; giving a mean for the series of 1.0. The confidence intervals are wider due to the relatively low number of records.

Table 13.99**.** Pink Ling from zone 50 in depths between 200 – 800m by trawl. Statistical model structures used in this analysis. DepCat is a series of 20 metre depth categories.

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

Table 13.100. Pink Ling from zone 50 in depths between 200 – 800m by trawl. Model selection criteria, including the AIC, the adjusted r^2 and the change in adjusted r^2. The optimum is Vessel:Month (model 6).

	Year	Vessel	DepCat	Month	DayNight	Vessel:Month	Month:DepCat
AIC	-13213	-18069	-20247	-20460	-20582	-20806	-20804
RSS	30076	26587	25132	24990	24912	23832	24386
MSS	3573	7062	8517	8659	8737	9817	9263
Nobs	41427	41294	41294	41294	41294	41294	41294
Npars	26	56	129	140	143	946	473
adj_r2	10.564	20.881	25.079	25.483	25.710	27.515	26.690
%Change	0.000	10.317	4.198	0.404	0.226	1.805	-0.825

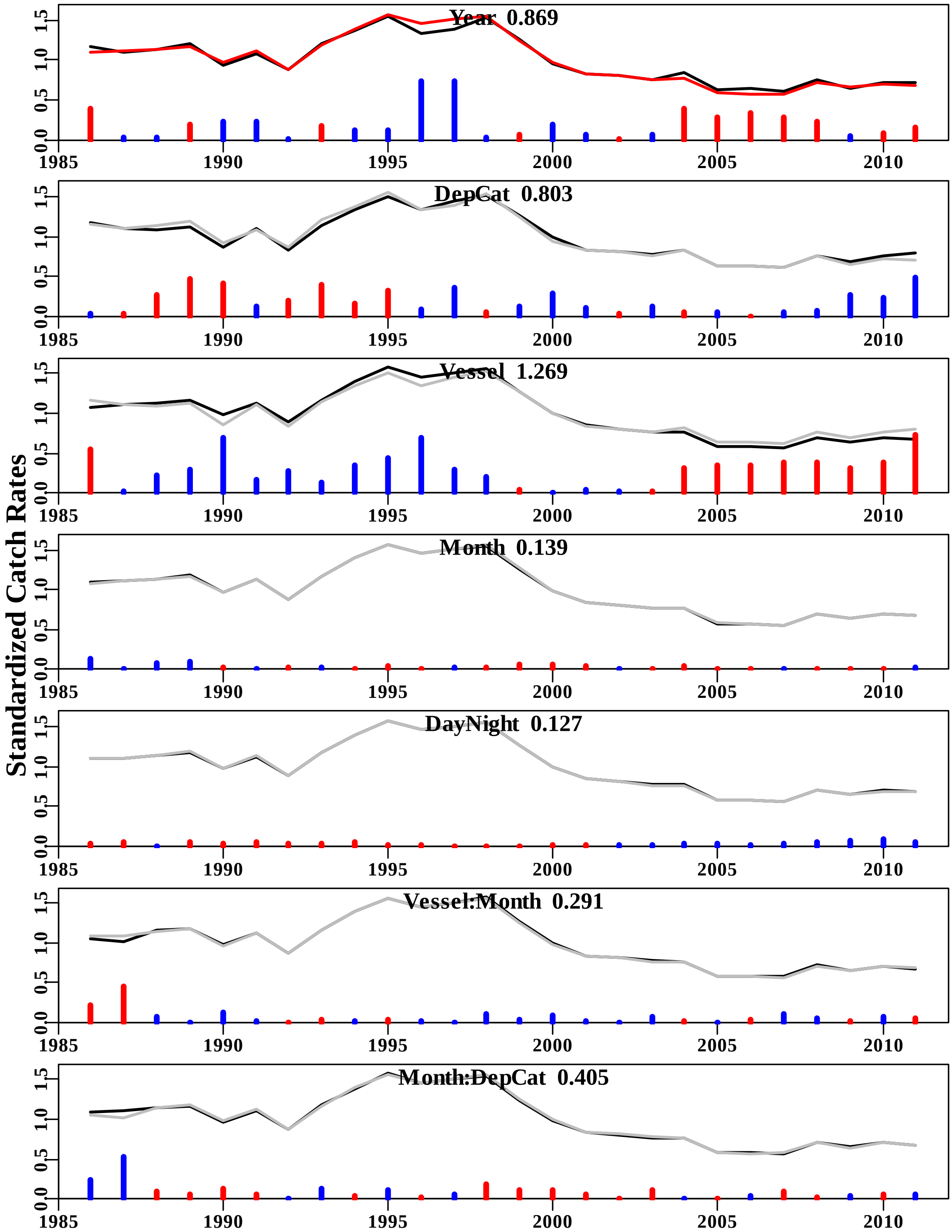

Figure 13.118**.** The relative influence of each factor used on the final trend in the optimal standardization for Pink Ling in Zone 50. The top graph depicts the geometric mean (the black line) and the optimum model (the red line). The difference between them is illustrated by the vertical bars with blue bars indicating the optimum model is higher than the geometric mean and red bars indicating it is lower. The top graph bars are the sum of all the bars in the graphs below. The graphs for individual factors are cumulative. Thus the second graph for Vessel has the geometric mean (grey line) and the effect of adding Year + Vessel (model 2). In the third graph, for DepCat, the grey line represents model 2 and the black line the effect of adding DepCat to the model. The remaining graphs continue in the same cumulative manner except for the interaction terms which are added singularly to the final single factor model. Note that the influence, which is simply the deviations between the two lines squared, are not always reflective of the adj-r^2 for each factor.

13.39 Western Gemfish and GAB (GEM – 37439002 – Rexea solandri)

Data from zones 40 and 50 with 82, 83, 84, and 85 (the GAB), depths greater than 100 and less than or equal to 600 m.

Table 13.101**.** Western Gemfish from zones 40 and 50, and the GAB (zones 82, 83, 84, and 85) in depths between 200 – 600m by trawl. Total Catch is the total reported in the database, Records is the number of records used in the analysis, CatchT is the reported catch in the area and depth used in the analysis., and Vessels relates to all vessels used in the analysis. Geomean is the geometric mean of catch rates (kg/hr). Zone:Mth is the optimum model and StDev is the standard deviation relating to the data in the optimum model.

Year	TotCatch	Records	CatchT	Vessels	GeoMean	Zone:Mth	StDev
1986	3639.955	1721	308.061	25	28.8362	2.1398	0.0000
1987	4660.447	1284	262.356	29	30.7827	2.1151	0.0460
1988	3515.819	1427	261.309	36	25.6522	1.9795	0.0478
1989	1778.325	1405	184.753	38	19.0566	1.5062	0.0489
1990	1206.897	1261	146.900	38	14.3866	1.3103	0.0527
1991	580.322	1592	280.530	35	19.1105	1.2962	0.0493
1992	494.441	801	96.906	21	15.0886	0.9534	0.0567
1993	353.410	902	109.371	21	11.5160	0.8132	0.0556
1994	232.179	1053	110.188	26	11.3093	0.8341	0.0531
1995	181.746	1316	107.533	26	9.0719	0.7977	0.0506
1996	382.196	1631	164.827	32	9.5592	0.9324	0.0488
1997	571.976	2106	215.362	28	8.9766	0.8369	0.0470
1998	404.817	1967	206.881	26	10.1690	1.0076	0.0479
1999	448.677	2347	323.256	25	11.9957	1.0051	0.0467
2000	336.464	2357	260.267	31	9.5636	0.8284	0.0472
2001	331.486	2335	255.222	31	9.9454	0.7806	0.0473
2002	196.526	1770	129.588	29	6.4625	0.6004	0.0490
2003	269.227	1642	203.076	34	8.8216	0.6743	0.0497
2004	525.201	1952	434.958	32	10.3074	0.7246	0.0497
2005	498.511	1816	359.400	27	12.3888	0.7247	0.0503
2006	509.019	1599	399.243	26	11.5504	0.6696	0.0514
2007	561.238	1412	382.551	22	10.3604	0.6329	0.0523
2008	289.477	1265	152.175	21	6.6254	0.6486	0.0527
2009	194.843	1275	105.771	16	5.8778	0.6888	0.0525
2010	220.639	1703	129.526	18	6.0572	0.7331	0.0500
2011	147.321	1348	75.776	17	5.4642	0.7665	0.0528

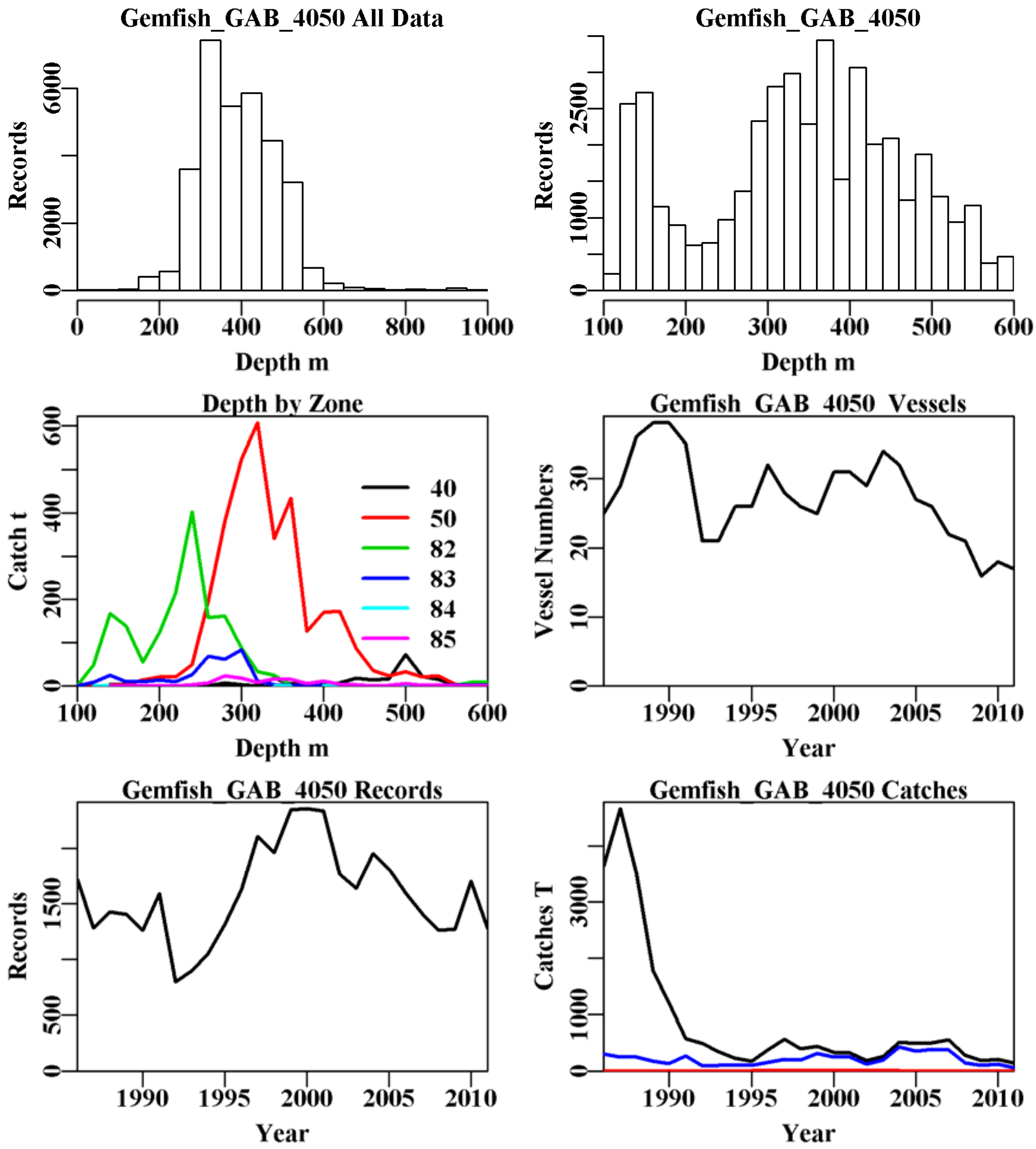

Figure 13.119**.** Western Gemfish from zones 40 and 50, and the GAB (zones 82, 83, 84, and 85) in depths between 200 – 600m by trawl. The top left is the depth distribution of all records reporting Gemfish, the top right graph depicts the depth distribution of shots containing Western Gemfish from zones 40 and 50, and the GAB (zones 82, 83, 84, and 85) in depths between 200 – 600m by trawl. The middle left diagram depicts the distribution of catch by depth within zones, the middle right hand graph depicts the number of vessels through time. The bottom left reflects the number of records used in analysis, and bottom right is the Gemfish catches (top line, black is total catches, middle line, blue, are those used in the analysis, and bottom, red, are catches < 30Kg).

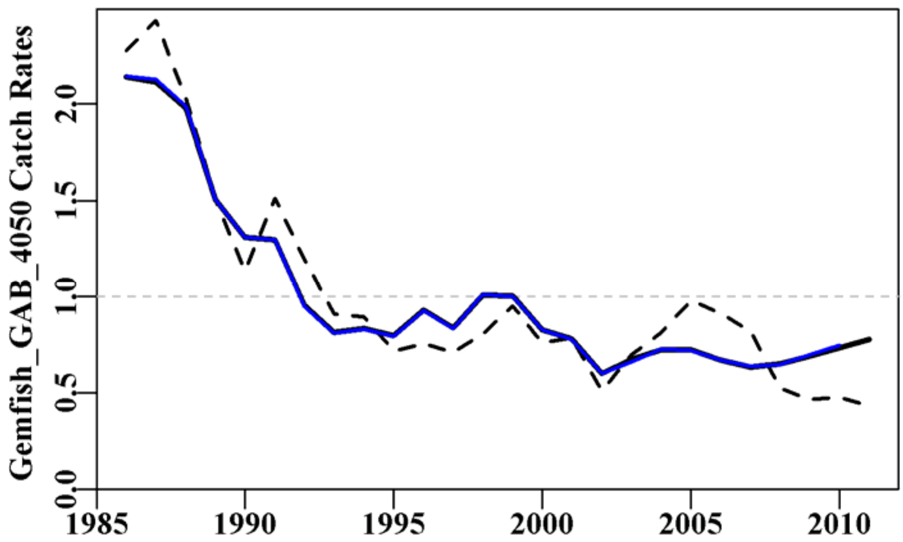

Figure 13.120**.** Western Gemfish from zones 40 and 50, and the GAB (zones 82, 83, 84, and 85) in depths between 200 – 600m by trawl. The dashed black line represents the geometric mean catch rate and the solid black line the standardized catch rates. The graph standardizes catch rates relative to the mean of the standardized catch rates.

Table 13.102. Western Gemfish from zones 40 and 50, and the GAB (zones 82, 83, 84, and 85) in depths between 200 – 600m by trawl. Statistical model structures used in this analysis. DepCat is a series of 20 metre depth categories.

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

Table 13.103. Western Gemfish from zones 40 and 50, and the GAB (zones 82, 83, 84, and 85) in depths between 200 – 600m by trawl. Model selection criteria, including the AIC, the deviance and the change in deviance. The optimum is Zone:Month (model 7).

	Year	DepCat	Vessel	Zone	DayNight	Month	Zone:Mth	Zone:DepC
AIC	35504	21879	14758	13979	13312	12939	12009	12326
RSS	97439	69841	58432	57321	56391	55853	54459	54693
MSS	8043	35641	47050	48160	49091	49629	51023	50789
Nobs	41287	41130	41130	41130	41130	41130	41130	41130
Npars	26	51	158	163	166	177	232	302
adj_r2	7.569	33.708	44.392	45.443	46.324	46.822	48.080	47.767
%Change	0.000	26.139	10.684	1.051	0.881	0.498	1.257	-0.313

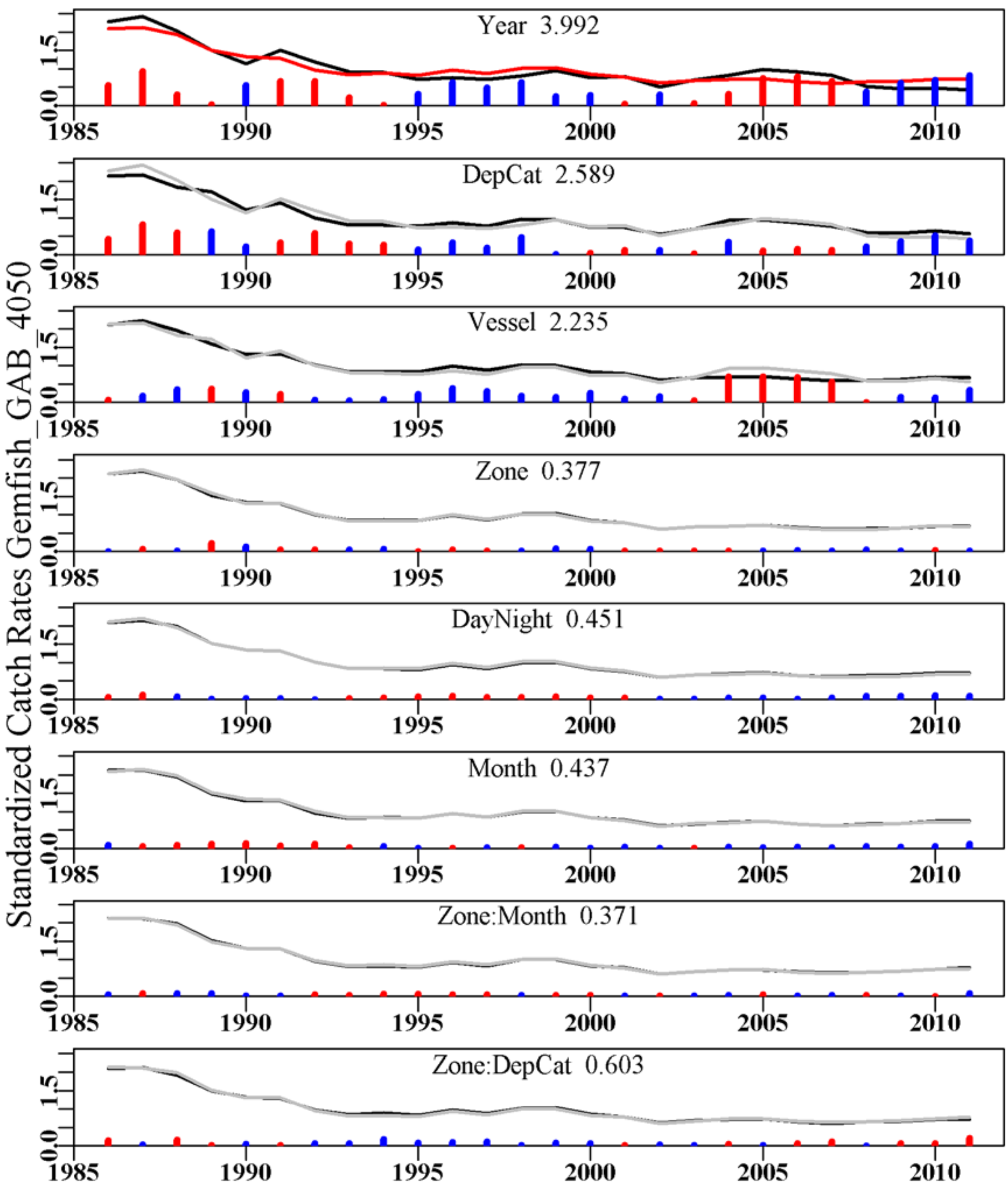

Figure 13.121**.** The relative influence of each factor used on the final trend in the optimal standardization for Western Gemfish from zones 40 and 50 and the GAB. The top graph depicts the geometric mean (the black line) and the optimum model (the red line). The difference between them is illustrated by the vertical bars with blue bars indicating the optimum model is higher than the geometric mean and red bars indicating it is lower. The top graph bars are the sum of all the bars in the graphs below. The graphs for individual factors are cumulative. Thus the second graph has the geometric mean (grey line) and the effect of adding Year + factor2 (model 2). In the third graph, the grey line represents model 2 and the black line the effect of adding factor3 to the model. The remaining graphs continue in the same cumulative manner except for the interaction terms which are added singularly to the final single factor model.

13.40 Western Gemfish Z4050 (GEM – 37439002 – R. solandri)

Data from zones 40 and 50, depths greater than 200 and less than or equal to 600 m.

Table 13.104**.** Western Gemfish from zones 40 and 50 in depths between 200 – 600m by trawl. Total Catch is the total reported in the database, Records is the number of records used in the analysis, CatchT is the reported catch in the area and depth used in the analysis., and Vessels relates to all vessels used in the analysis. Geomean is the geometric mean of catch rates (kg/hr). Zone:Mth is the optimum model and StDev is the standard deviation relating to the data in the optimum model.

Year	TotCatch	Records	CatchT	Vessels	GeoMean	Zone:Mth	StDev
1986	3639.955	1687	306.861	24	29.5835	2.2392	0.0000
1987	4660.447	1209	248.879	26	31.5896	2.2272	0.0451
1988	3515.819	1235	226.956	27	26.9924	2.1712	0.0472
1989	1778.325	1082	156.578	29	23.3363	1.8043	0.0495
1990	1206.897	1057	136.085	29	15.9031	1.3602	0.0528
1991	580.322	1384	249.415	28	22.0062	1.3188	0.0493
1992	494.441	665	80.930	15	16.7792	0.9226	0.0575
1993	353.410	718	102.489	17	16.5820	0.8868	0.0570
1994	232.179	839	95.378	20	16.2263	0.9566	0.0543
1995	181.746	990	84.688	21	12.0017	0.8385	0.0520
1996	382.196	1182	145.588	26	13.4563	0.9255	0.0499
1997	571.976	1389	153.589	21	13.2702	0.8307	0.0484
1998	404.817	1259	121.661	20	13.2167	0.8937	0.0498
1999	448.677	1694	176.323	19	12.8407	0.8486	0.0474
2000	336.464	1932	228.165	27	12.4996	0.8705	0.0475
2001	331.486	1694	169.890	27	12.1589	0.7042	0.0484
2002	196.526	1418	86.261	24	7.1243	0.5364	0.0496
2003	269.227	1077	123.722	24	11.3050	0.6520	0.0521
2004	525.201	1232	105.674	24	7.9049	0.6352	0.0522
2005	498.511	1073	117.678	18	10.6004	0.6620	0.0532
2006	509.019	889	101.417	18	8.9869	0.5380	0.0560
2007	561.238	715	61.053	16	7.4717	0.5238	0.0583
2008	289.477	770	53.096	16	7.5220	0.5815	0.0572
2009	194.843	925	56.810	12	6.4871	0.6658	0.0546
2010	220.639	1364	86.888	14	6.3681	0.6892	0.0508
2011	147.321	1125	54.897	13	5.5076	0.7175	0.0536

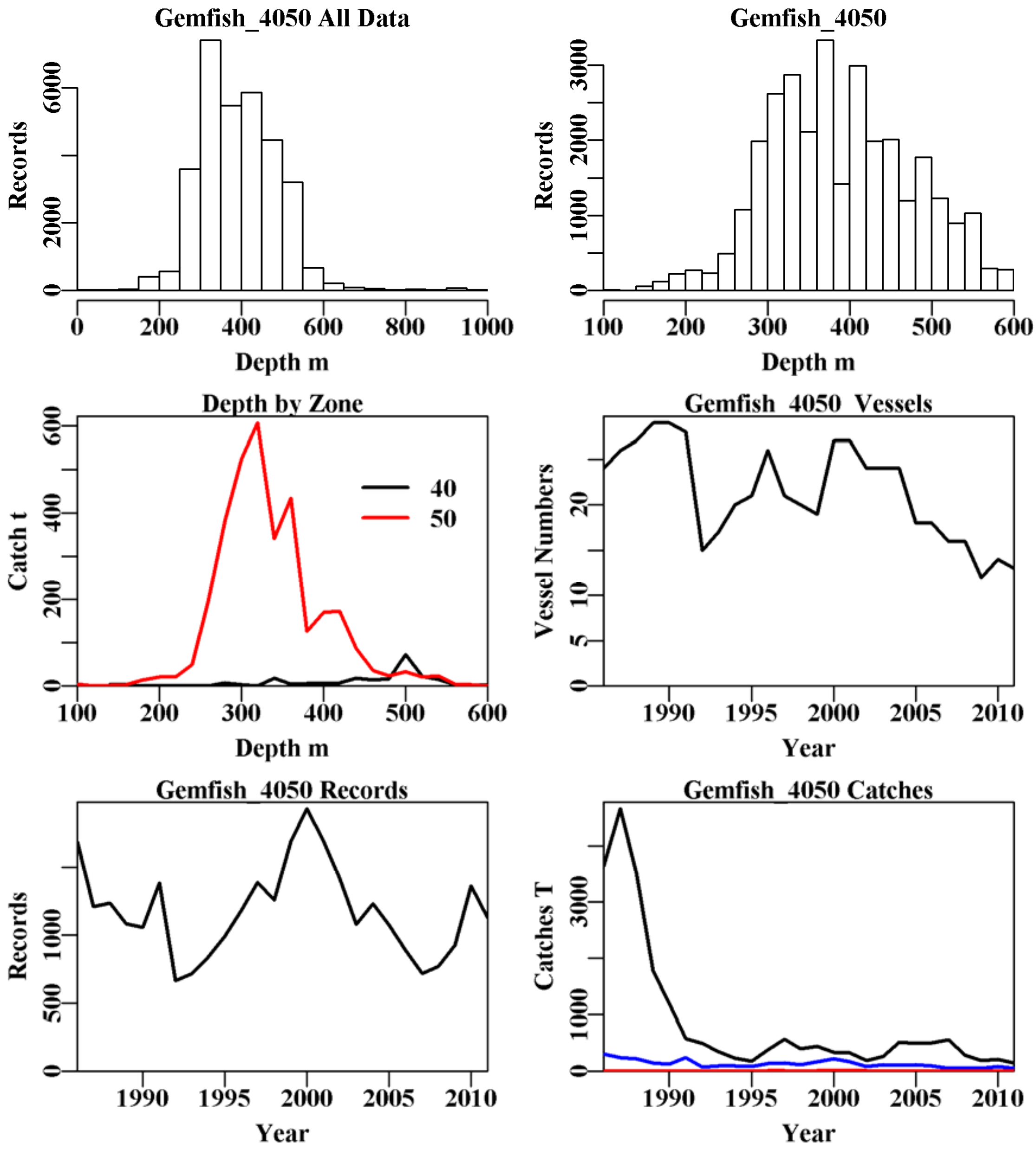

Figure 13.122**.** Western Gemfish from zones 40 and 50 in depths between 200 – 600m by trawl. The top left is the depth distribution of all records reporting Gemfish, the top right graph depicts the depth distribution of shots containing Western Gemfish from zones 40 and 50 in depths between 200 – 600m by trawl.. The middle left diagram depicts the distribution of catch by depth within zones 40 and 50 (50 is top red line), the middle right hand graph depicts the number of vessels through time. The bottom left reflects the number of records used in analysis, and bottom right is the Gemfish catches (top line, black is total catches, middle line, blue, are those used in the analysis, and bottom, red, are catches < 30Kg).

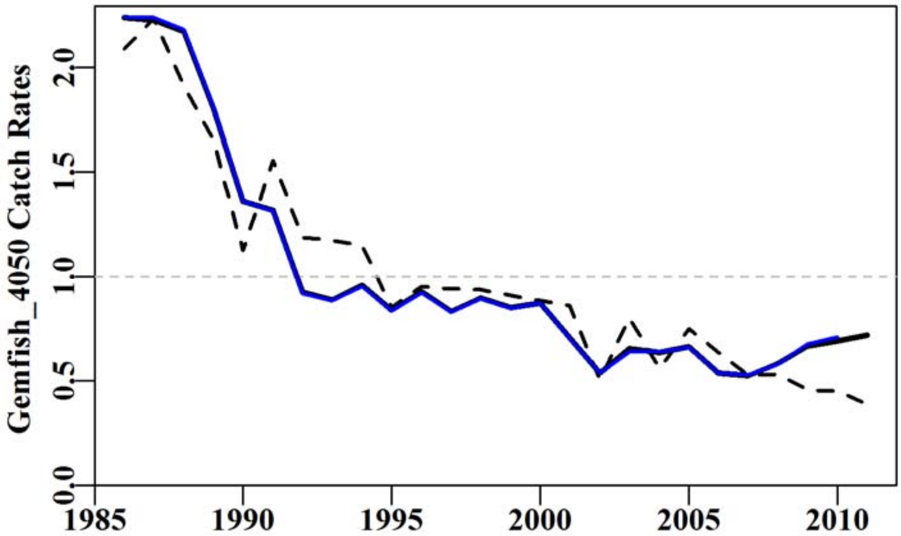

Figure 13.123**.** Western Gemfish from zones 40 and 50 in depths between 200 – 600m by trawl. The dashed black line represents the geometric mean catch rate and the solid black line the standardized catch rates. The graph standardizes catch rates relative to the mean of the standardized catch rates.

Table 13.105. Western Gemfish from zones 40 and 50 in depths between 200 – 600m by trawl. Statistical model structures used in this analysis. DepCat is a series of 20 metre depth categories.

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

Table 13.106. Western Gemfish from zones 40 and 50 in depths between 200 – 600m by trawl. Model selection criteria, including the AIC, the adjusted r^2 and the change in adjusted r^2. The optimum is Zone:Month (model 7).

	Year	Vessel	DepCat	DayNight	Month	Zone	Zone:Mth	Zone:DepC
AIC	20863	13653	7176	6695	6416	6418	6246	6274
RSS	60408	47453	38240	37634	37264	37264	37028	37028
MSS	7119	20075	29287	29893	30263	30264	30500	30500
Nobs	30604	30604	30502	30502	30502	30502	30502	30502
Npars	26	115	140	143	154	155	166	180
adj_r2	10.470	29.466	43.112	44.008	44.538	44.537	44.868	44.842
%Change	0.000	18.996	13.646	0.896	0.531	-0.002	0.332	-0.026

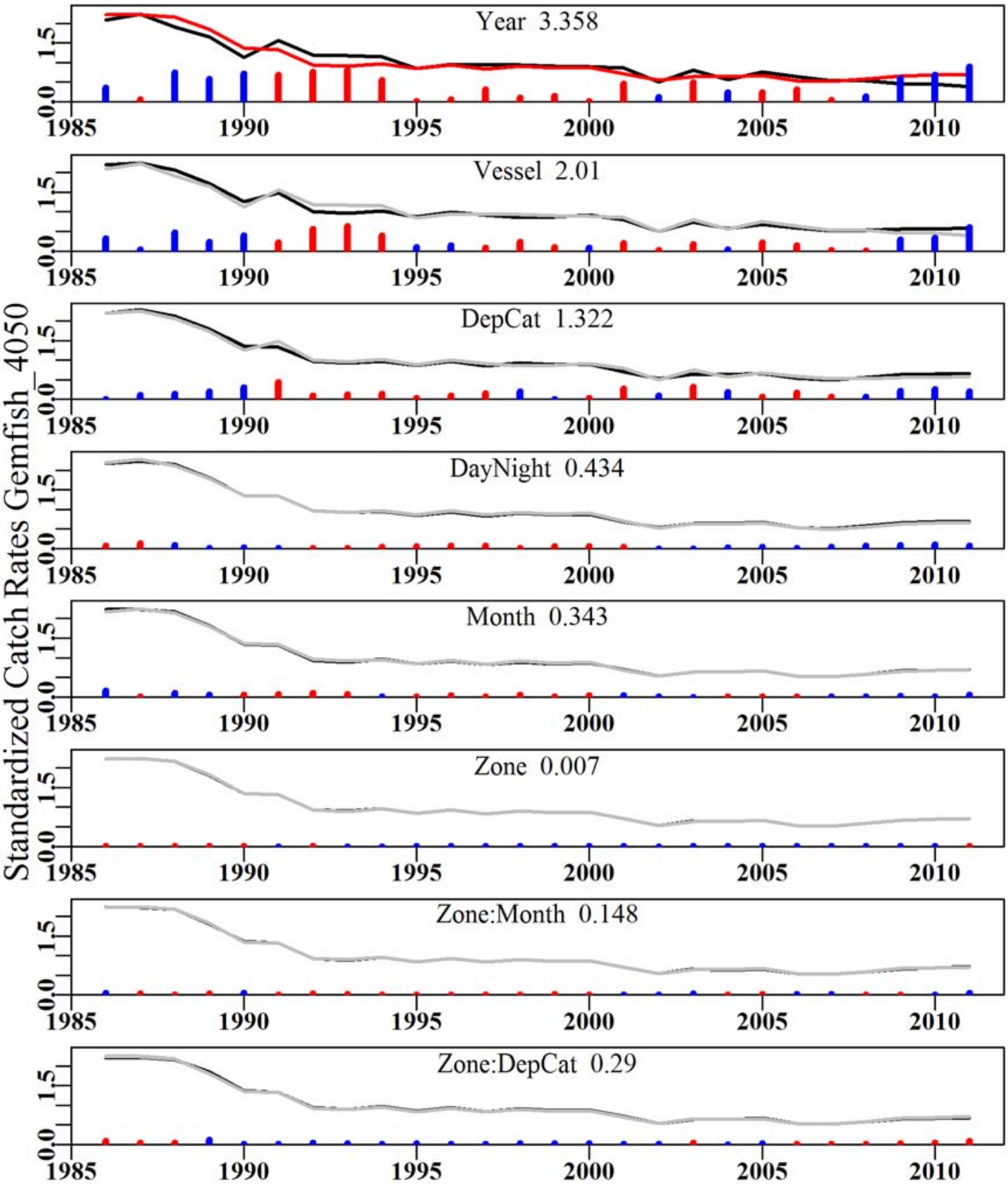

Figure 13.124**.** The relative influence of each factor used on the final trend in the optimal standardization for Western Gemfish from zones 40 and 50. The top graph depicts the geometric mean (the black line) and the optimum model (the red line). The difference between them is illustrated by the vertical bars with blue bars indicating the optimum model is higher than the geometric mean and red bars indicating it is lower. The top graph bars are the sum of all the bars in the graphs below. The graphs for individual factors are cumulative. Thus the second graph has the geometric mean (grey line) and the effect of adding Year + factor2 (model 2). In the third graph, the grey line represents model 2 and the black line the effect of adding factor3 to the model. The remaining graphs continue in the same cumulative manner except for the interaction terms which are added singularly to the final single factor model.

13.41 Western Gemfish GAB (GEM – 37439002 – R. solandri)

Data from zones 82, 83, 84, and 85 (the GAB), depths greater than 100 and less than or equal to 600 m. All vessels included

Table 13.107. Western Gemfish in the GAB (zones 82, 83, 84, and 85) in depths between 100 and 600 m by trawl. Total Catch is the total reported in the database, Records is the number of records used in the analysis, CatchT is the reported catch in the area and depth used in the analysis, and Vessels relates to all vessels used in the analysis. Geomean is the geometric mean of catch rates (kg/hr). Zone:Month is the optimum model and StDev is the standard deviation relating to the data in the optimum model.

Year	TotCatch	Records	CatchT	Vessels	GeoMean	Zone:Mth	StDev
1995	181.746	326	22.845	6	3.8779	0.7240	0.0000
1996	382.196	449	19.239	7	3.8858	0.9574	0.0937
1997	571.976	717	61.773	9	4.2096	0.9576	0.0890
1998	404.817	708	85.220	8	6.3801	1.5654	0.0910
1999	448.677	653	146.933	7	10.0539	1.8525	0.0937
2000	336.464	425	32.102	6	2.8318	0.6743	0.0996
2001	331.486	641	85.332	8	5.8477	1.1128	0.0942
2002	196.526	352	43.326	8	4.3633	0.9821	0.1025
2003	269.227	565	79.354	11	5.4980	0.9045	0.0981
2004	525.201	720	329.284	10	16.2315	1.1274	0.0987
2005	498.511	743	241.723	10	15.5168	0.9565	0.0999
2006	509.019	709	297.706	11	15.7716	0.9620	0.0986
2007	561.238	697	321.498	10	14.4877	0.8490	0.0970
2008	289.477	495	99.079	7	5.4384	0.8573	0.0989
2009	194.843	350	48.961	4	4.5291	0.7948	0.1054
2010	220.639	339	42.638	4	4.9524	0.8698	0.1060
2011	147.321	223	20.879	4	5.2504	0.8526	0.1181

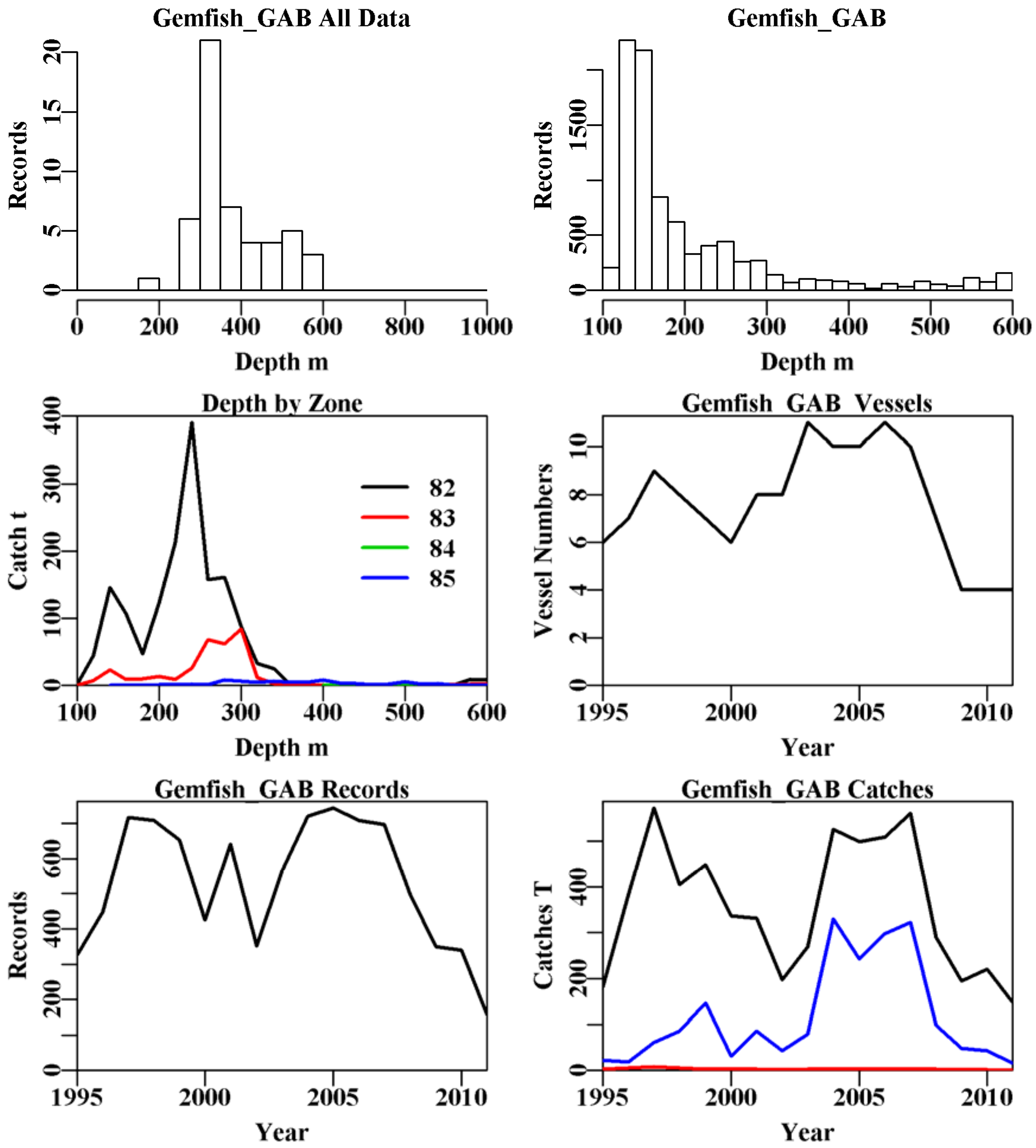

Figure 13.125**.** Western Gemfish in the GAB (zones 82, 83, 84, and 85) in depths between 100 and 600 m by trawl. The top left is the depth distribution of all records reporting western gemfish, the top right graph depicts the depth distribution of shots containing Western Gemfish in the GAB (zones 82, 83, 84, and 85) in depths between 100 and 600 m by trawl. The middle left diagram depicts the distribution of catch by depth within zones 82 and 85, the middle right hand graph depicts the number of vessels through time. The bottom left reflects the number of records used in analysis, and bottom right is the western Gemfish catches (top line, black is total catches, middle line, blue, are those used in the analysis, and bottom, red, are catches < 30Kg).

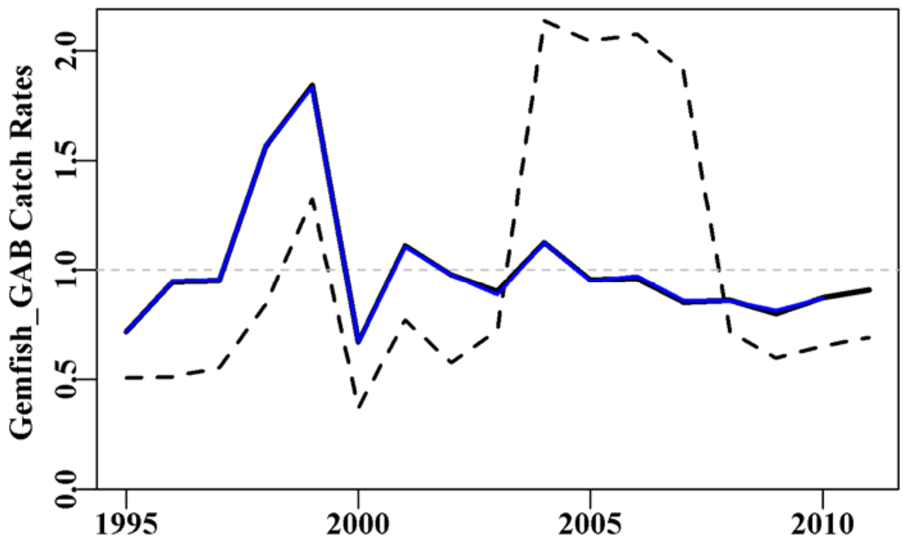

Figure 13.126**.** Western Gemfish in the GAB (zones 82, 83, 84, and 85) in depths between 100 and 600 m by trawl. The dashed black line represents the geometric mean catch rate and the solid black line the standardized catch rates. The graph standardizes catch rates relative to the mean of the standardized catch rates.

Table 13.108. Western Gemfish in the GAB (zones 82, 83, 84, and 85) in depths between 100 and 600 m by trawl. Statistical model structures used in this analysis. DepCat is a series of 20 metre depth categories.

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

Table 13.109**.** Western Gemfish in the GAB (zones 82, 83, 84, and 85) in depths between 100 and 600 m by trawl. Model selection criteria, including the AIC, the adjusted r^2 and the change in adjusted r^2. The optimum is Zone:Month (model 7).

	Year	DepCat	Vessel	Month	DayNight	Zone	Zone:Mth	Zone:DepC
AIC	10454	6747	5422	4823	4572	4338	4054	4268
RSS	28592	18909	16253	15178	14753	14368	13824	14024
MSS	2986	12668	15324	16399	16824	17210	17753	17553
Nobs	9112	9071	9071	9071	9071	9071	9071	9071
Npars	17	42	66	77	80	83	116	158
adj_r2	9.296	39.847	48.156	51.528	52.869	54.085	55.660	54.806
%Change	0.000	30.551	8.310	3.372	1.341	1.216	1.575	-0.854

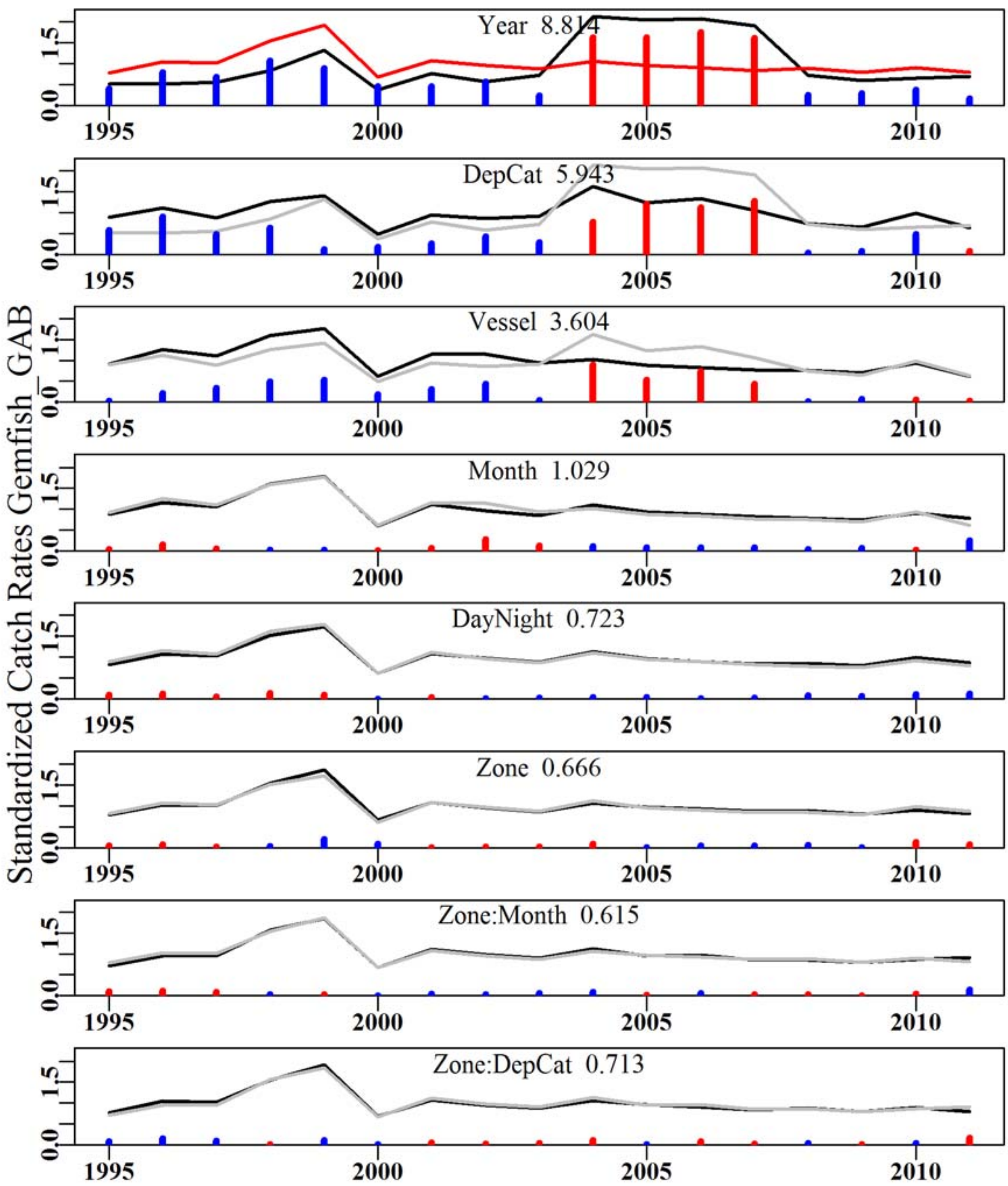

Figure 13.127**.** The relative influence of each factor used on the final trend in the optimal standardization for Western Gemfish in the GAB (zones 82, 83, 84, and 85). The top graph depicts the geometric mean (the black line) and the optimum model (the red line). The difference between them is illustrated by the vertical bars with blue bars indicating the optimum model is higher than the geometric mean and red bars indicating it is lower. The top graph bars are the sum of all the bars in the graphs below. The graphs for individual factors are cumulative. Thus the second graph has the geometric mean (grey line) and the effect of adding Year + factor2 (model 2). In the third graph, the grey line represents model 2 and the black line the effect of adding factor3 to the model. The remaining graphs continue in the same cumulative manner except for the interaction terms which are added singularly to the final single factor model.

13.42 Offshore Ocean Perch, Z1020 (REG – 37287001 – H. percoides) 200m

In the November 2009 Slope RAG meeting the depth distribution of offshore Ocean Perch was revised to 300-700m to avoid overlap with inshore Ocean Perch; however, this decision was reversed in 2010 and so the analysis was repeated using 200-700 m.

Table 13.110. Offshore Ocean Perch from zones 10 and 20 in depths 200 – 700m by trawl. Total Catch is the total reported in the database, Records is the number of records used in the analysis, CatchT is the reported catch in the area and depth used in the analysis, and Vessels relates to all vessels used in the analysis. Geomean is the geometric mean of catch rates (kg/hr). Zone:Month is the optimum model and StDev is the standard deviation relating to the data in the optimum model.

Year	TotCatch	Records	CatchT	Vessels	GeoMean	Zone:Mth	StDev
1986	262.446	3479	207.363	77	12.1440	1.0298	0.0000
1987	198.347	3140	132.797	70	8.9237	0.9538	0.0254
1988	186.712	2808	150.765	73	10.5074	1.0669	0.0264
1989	206.258	3036	160.004	67	10.6494	1.0257	0.0263
1990	180.560	1970	115.943	57	12.0207	1.3644	0.0295
1991	223.188	2093	138.991	53	13.4339	1.4423	0.0292
1992	169.669	1845	114.079	47	11.9264	1.2143	0.0301
1993	259.310	2924	199.186	53	12.9555	1.2142	0.0268
1994	257.241	3014	180.955	49	11.8001	1.1325	0.0265
1995	239.951	3146	150.341	50	10.4874	1.0249	0.0262
1996	263.235	3411	176.808	53	9.8364	0.9240	0.0258
1997	296.334	3725	193.773	54	9.7119	0.9739	0.0256
1998	292.098	3850	194.629	49	9.4285	0.8662	0.0253
1999	290.643	4406	219.065	52	9.7566	0.9802	0.0250
2000	269.827	4178	180.750	52	7.5464	0.7702	0.0255
2001	281.541	4038	183.911	43	8.3956	0.8632	0.0257
2002	255.307	3646	150.622	45	7.3709	0.8206	0.0264
2003	322.581	3960	185.006	53	7.6242	0.8719	0.0261
2004	315.869	3129	150.459	46	8.0648	0.8707	0.0275
2005	316.769	3089	170.080	46	9.3641	0.9783	0.0273
2006	237.601	2326	113.168	39	7.8433	0.8351	0.0292
2007	180.579	1528	94.900	22	9.9183	1.0332	0.0329
2008	184.267	1843	101.836	23	9.1917	0.9554	0.0315
2009	173.879	1694	99.608	23	9.0355	0.9499	0.0324
2010	195.594	1759	118.107	21	9.8647	0.9792	0.0319
2011	186.639	1874	116.696	22	9.0998	0.8592	0.0314

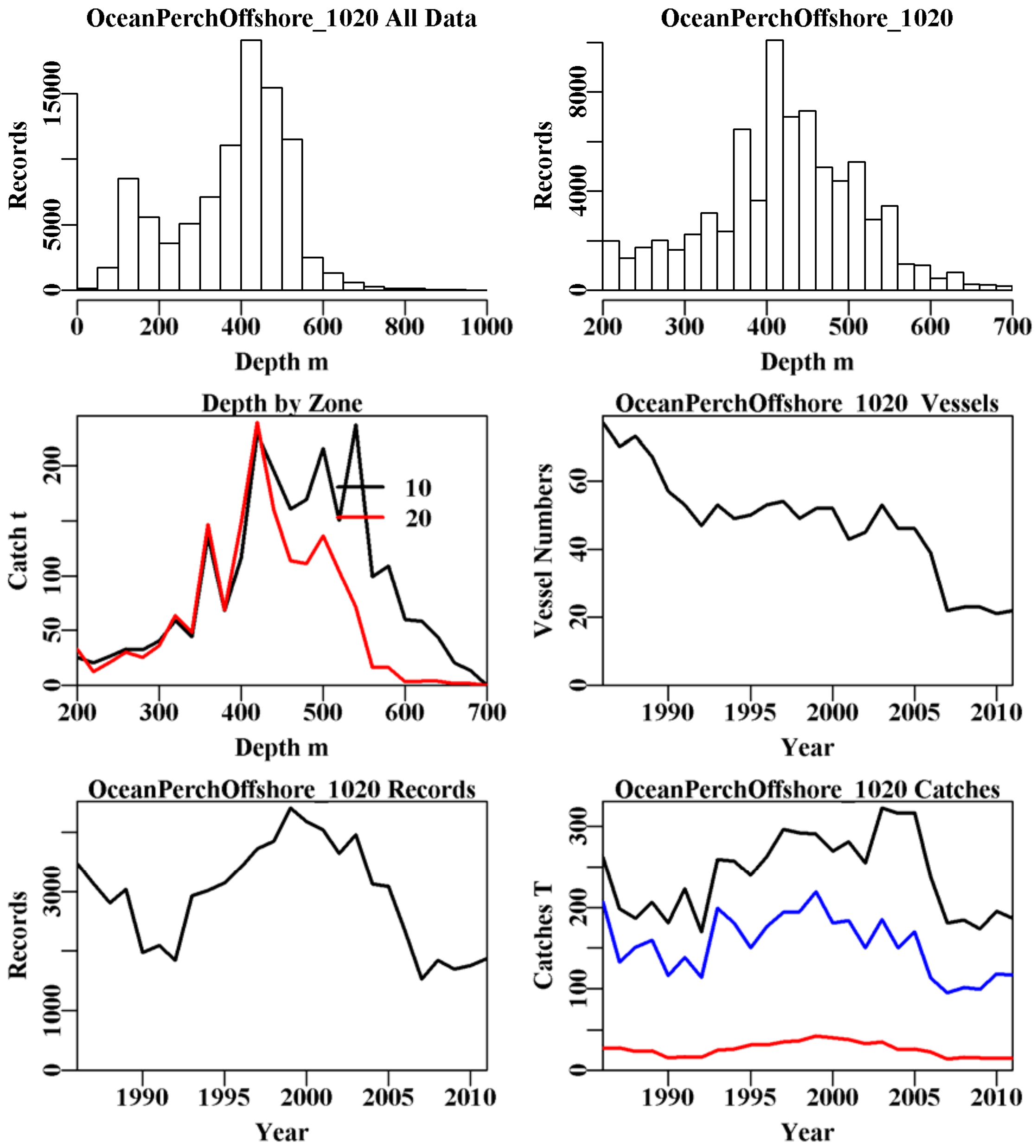

Figure 13.128**.** Offshore Ocean Perch from zones 10 and 20 in depths 200 – 700m by trawl. The top left is the depth distribution of all records reporting Ocean perch, the top right graph depicts the depth distribution of shots containing Offshore Ocean Perch from zones 10 and 20 in depths 200 – 700m by trawl. . The middle left diagram depicts the distribution of catch by depth within zones 10 and 20 (20 is top red line), the middle right hand graph depicts the number of vessels through time. The bottom left reflects the number of records used in analysis, and bottom right is the Ocean Perch catches (top line, black is total catches, middle line, red, are those used in the analysis).

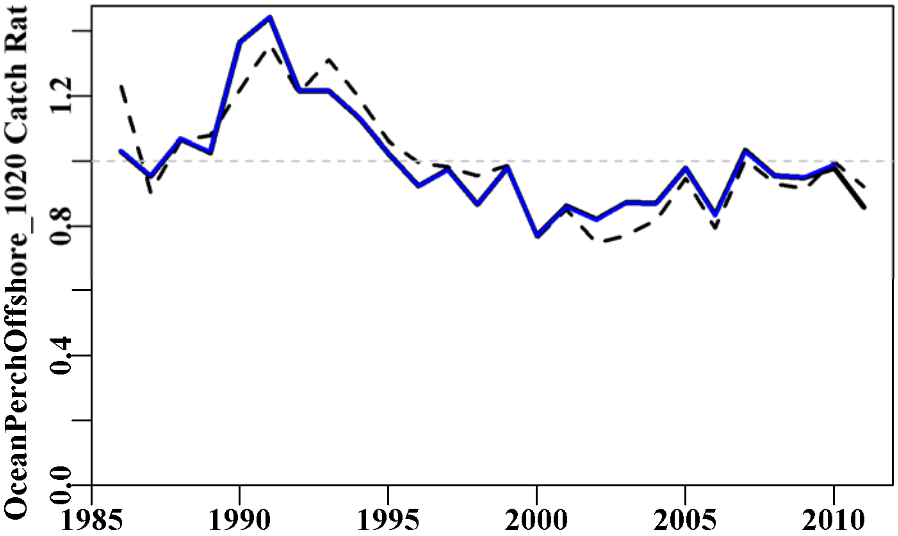

Figure 13.129. Offshore Ocean Perch from zones 10 and 20 in depths 200 – 700m by trawl. The dashed black line represents the geometric mean catch rate and the solid black line the standardized catch rates. The graph standardizes catch rates relative to the mean of the standardized catch rates.

Table 13.111. Offshore Ocean Perch from zones 10 and 20 in depths 200 – 700m by trawl. Statistical model structures used in this analysis. DepCat is a series of 20 metre depth categories.

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

Table 13.112. Offshore Ocean Perch from zones 10 and 20 in depths 200 – 700m by trawl. Model selection criteria, including the AIC, the adjusted r^2 and the change in adjusted r^2. The optimum is Zone:Month (model 7).

	Year	DepCat	Vessel	Month	DayNight	Zone	Zone:Mth	Zone:DepC
AIC	20116	8803	571	-1484	-1722	-1751	-3645	-2100
RSS	98877	84734	75671	73618	73381	73351	71513	72964
MSS	2097	16240	25303	27356	27594	27623	29462	28011
Nobs	75911	75512	75512	75512	75512	75512	75512	75512
Npars	26	51	206	217	220	221	232	246
adj_r2	2.045	16.028	24.855	26.883	27.116	27.144	28.960	27.505
%Change	0.000	13.983	8.827	2.028	0.233	0.028	1.816	-1.455

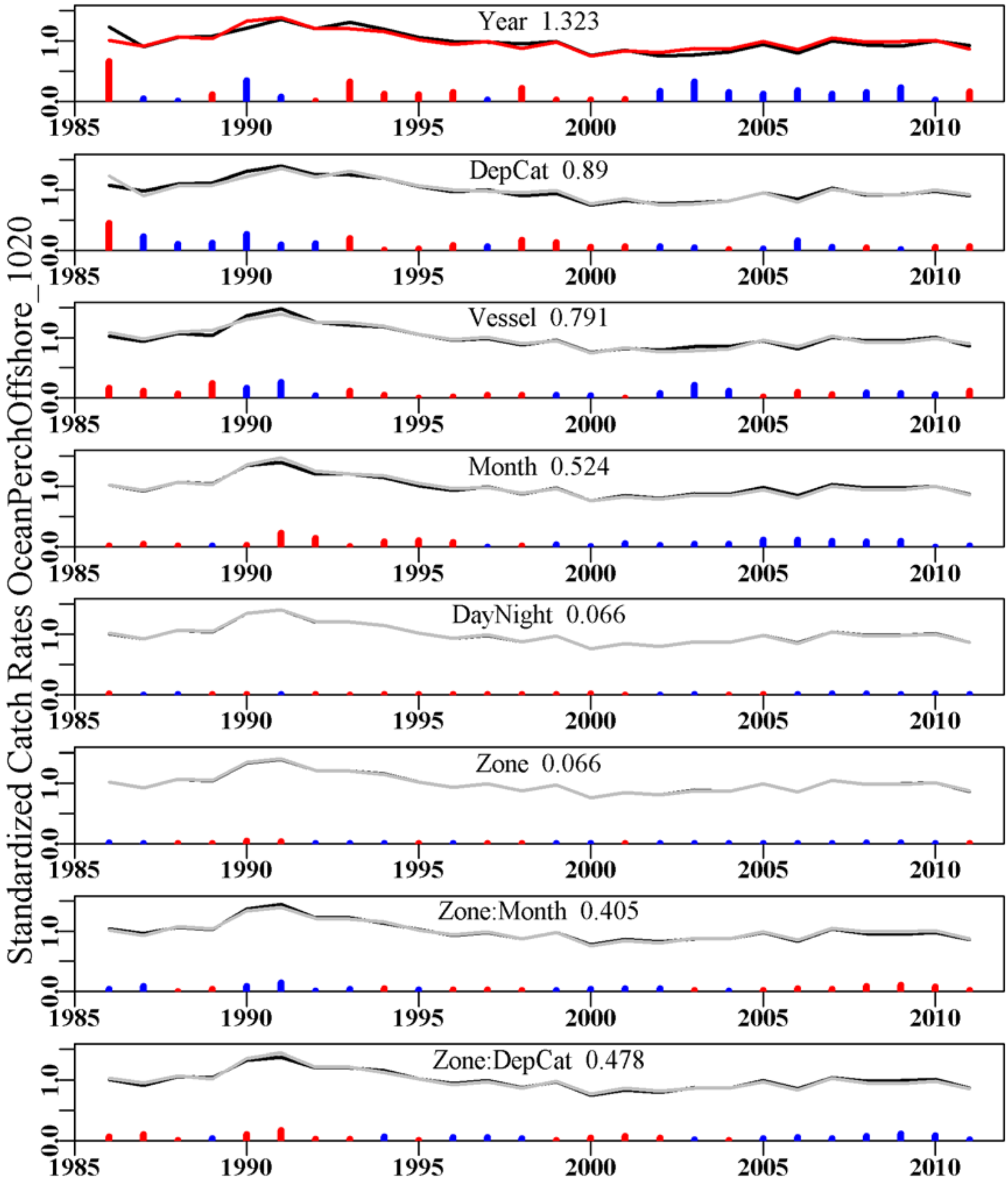

Figure 13.130**.** The relative influence of each factor used on the final trend in the optimal standardization for Offshore Ocean Perch from zones 10 and 20. The top graph depicts the geometric mean (the black line) and the optimum model (the red line). The difference between them is illustrated by the vertical bars with blue bars indicating the optimum model is higher than the geometric mean and red bars indicating it is lower. The top graph bars are the sum of all the bars in the graphs below. The graphs for individual factors are cumulative. Thus the second graph has the geometric mean (grey line) and the effect of adding Year + factor2 (model 2). In the third graph, the grey line represents model 2 and the black line the effect of adding factor3 to the model. The remaining graphs continue in the same cumulative manner except for the interaction terms which are added singularly to the final single factor model.

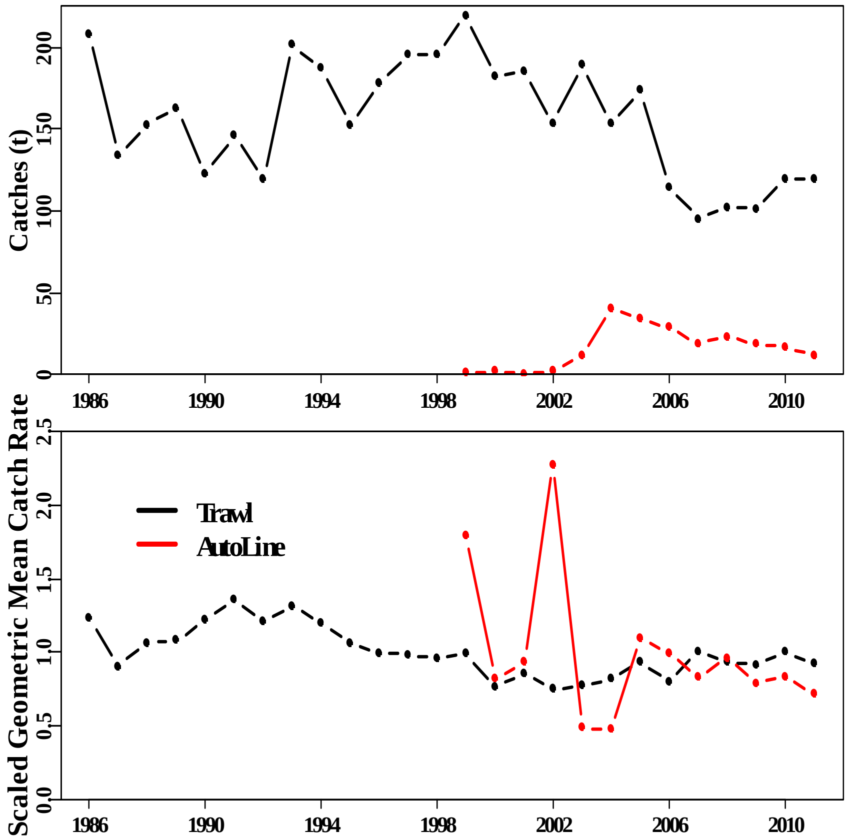

Figure 13.131. Offshore Ocean Perch, depths > 200 for trawl and AutoLongLine, in zones 10 and 20. Catches through time taken by trawl and by AutoLongLine. Some of the decline in trawl catches in recent years have been made up by the AutoLong Lining. Geometric mean catch rates for Offshore Ocean Perch in depth 200 – 700 metres for both trawl and autolongline; scaled to the mean of each series for comparison.

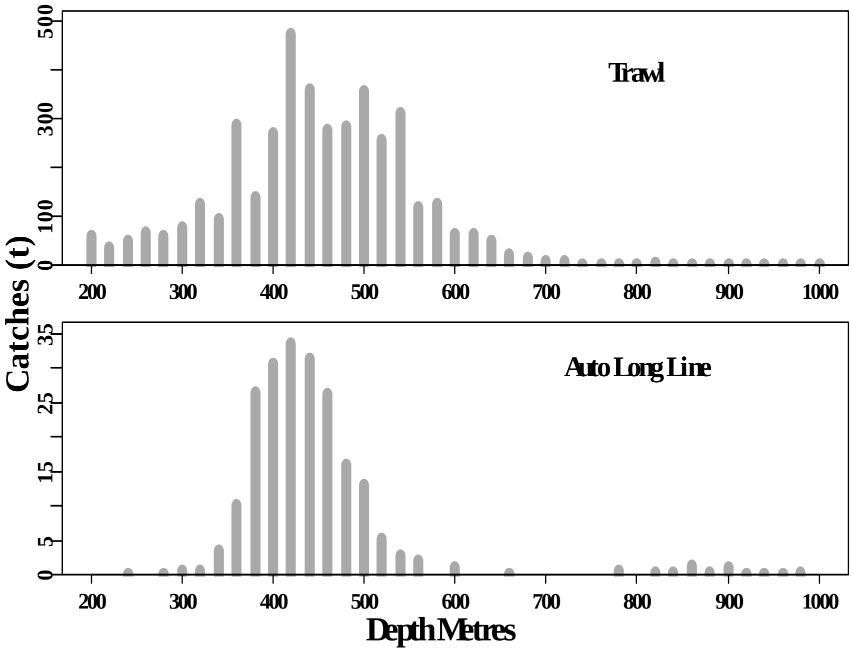

Figure 13.132. Depth distribution of catches of Offshore Ocean Perch, depths 200-700 for trawl, 0-1000m for AutoLongLine. Most catches by AutoLongLine are taken in the same depths as trawl catches.

13.43 Inshore Ocean Perch, Z1020 (REG – 37287001 – H. percoides) 0-200m

In the November 2009 Slope RAG meeting a separate analysis was required for the Inshore Ocean Perch. These were defined as all those Ocean Perch reported as caught between 0-299m to avoid overlap with Offshore Ocean Perch. However, in 2010 this decision was reversed and so the analysis was repeated for depths 0-200 m.

Table 13.113**.** Inshore Ocean Perch from zones 10 and 20 in depths 0 – 200m by trawl. Total Catch is the total reported in the database, Records is the number of records used in the analysis, CatchT is the reported catch in the area and depth used in the analysis, and Vessels relates to all vessels used in the analysis. Geomean is the geometric mean of catch rates (kg/hr). Zone:DepCat is the optimum model and StDev is the standard deviation relating to the data in the optimum model.

Year	TotCatch	Records	CatchT	Vessels	GeoMean	Zone:DepC	StDev
1986	262.446	339	15.239	50	6.8543	0.8363	0.0000
1987	198.347	406	11.971	58	5.9511	0.9828	0.0919
1988	186.712	518	16.548	59	7.2891	1.1184	0.0884
1989	206.258	443	15.392	52	8.0367	1.0713	0.0924
1990	180.560	450	15.614	45	7.7738	1.1429	0.0936
1991	223.188	498	20.364	43	8.1374	1.2818	0.0927
1992	169.669	258	13.830	28	9.5229	1.6960	0.1042
1993	259.310	467	25.080	38	10.1873	1.9063	0.0956
1994	257.241	558	23.340	35	9.4326	1.7357	0.0925
1995	239.951	600	21.200	35	8.7548	1.2840	0.0902
1996	263.235	688	21.307	39	7.0539	1.1194	0.0895
1997	296.334	572	16.365	40	5.9056	1.0464	0.0923
1998	292.098	646	15.628	41	5.7524	0.9151	0.0910
1999	290.643	675	15.978	40	4.9974	0.8112	0.0901
2000	269.827	1326	30.551	39	4.5708	0.9859	0.0861
2001	281.541	1035	23.397	34	4.2075	0.9800	0.0878
2002	255.307	1422	25.185	36	2.6164	0.6996	0.0866
2003	322.581	1085	17.438	40	2.3132	0.5408	0.0875
2004	315.869	962	15.461	41	2.2440	0.5522	0.0891
2005	316.769	898	19.849	41	2.9880	0.6250	0.0898
2006	237.601	602	9.339	35	2.2501	0.5206	0.0929
2007	180.579	395	8.745	21	3.5455	0.7329	0.0991
2008	184.267	330	7.969	21	4.2486	0.9001	0.1025
2009	173.879	289	6.671	21	4.1335	0.7656	0.1065
2010	195.594	307	7.136	21	3.8363	0.8049	0.1052
2011	186.639	275	6.431	19	3.6642	0.9448	0.1074

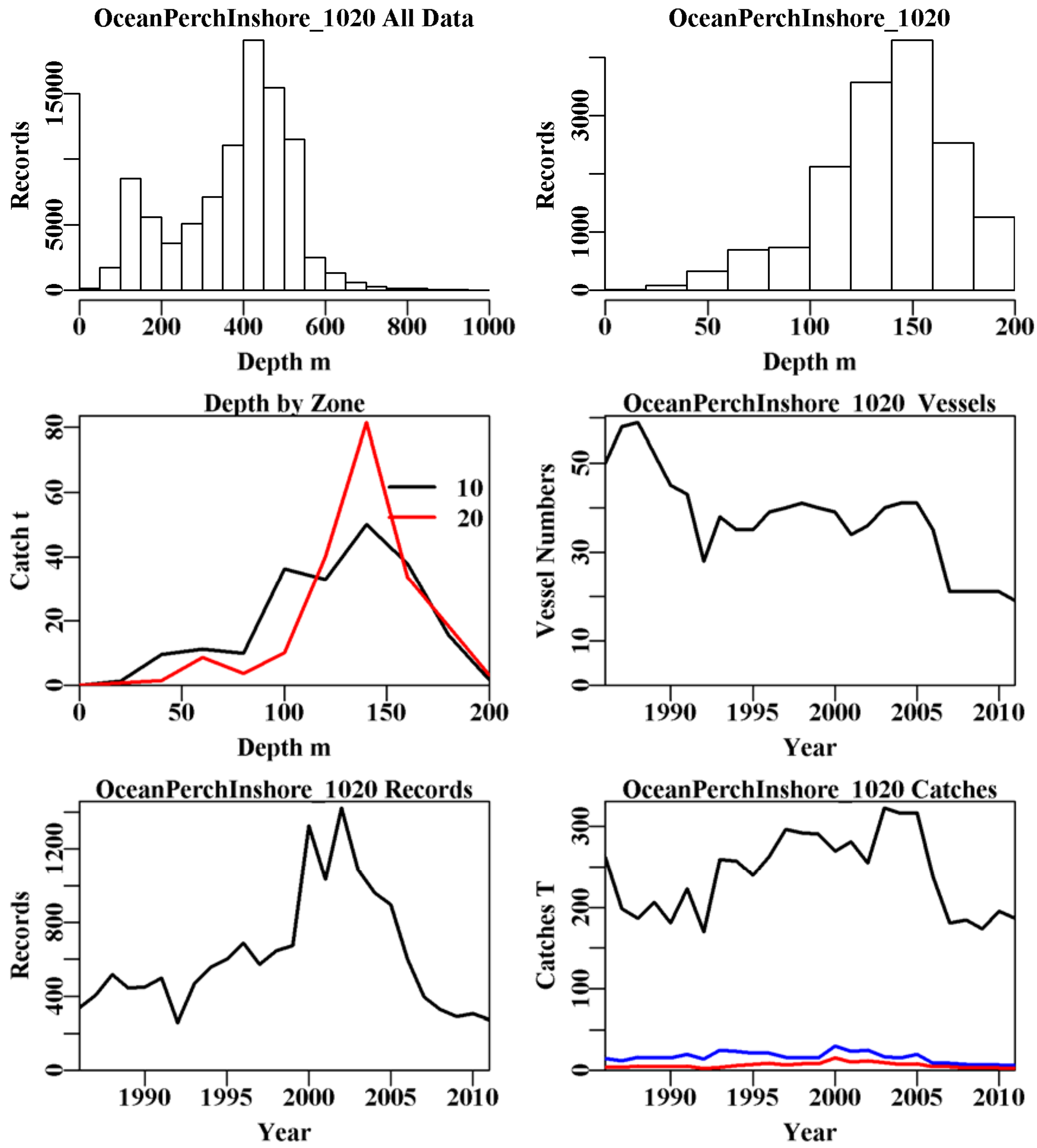

Figure 13.133. Inshore Ocean Perch from zones 10 and 20 in depths 0 – 200m by trawl. The top left is the depth distribution of all records reporting Ocean Perch, the top right graph depicts the depth distribution of shots containing Inshore Ocean Perch from zones 10 and 20 in depths 0 – 200m by trawl. The middle left diagram depicts the distribution of catch by depth within zones 10 and 20 (20 is top red line), the middle right hand graph depicts the number of vessels through time. The bottom left reflects the number of records used in analysis, and bottom right is the Ocean Perch catches (top line, black is total catches, middle line, red, are those used in the analysis.

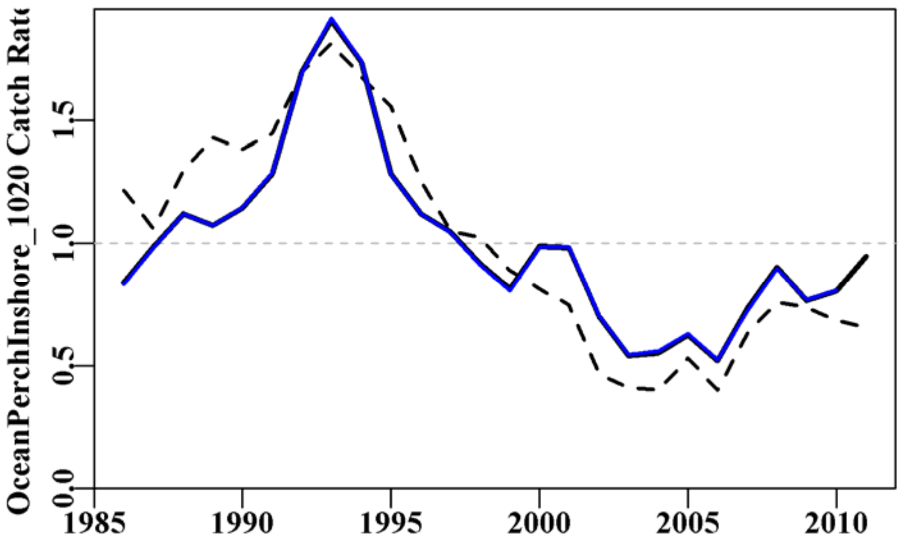

Figure 13.134**.** Inshore Ocean Perch from zones 10 and 20 in depths 0 – 200m by trawl. The dashed black line represents the geometric mean catch rate and the solid black line the standardized catch rates. The graph standardizes catch rates relative to the mean of the standardized catch rates.

Table 13.114. Inshore Ocean Perch from zones 10 and 20 in depths 0 – 200m by trawl. Statistical model structures used in this analysis. DepCat is a series of 20 metre depth categories.

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

Table 13.115. Inshore Ocean Perch from zones 10 and 20 in depths 0 – 200m by trawl. Model selection criteria, including the AIC, the adjusted r^2 and the change in adjusted r^2. The optimum is Zone:DepCat (model 8).

	Year	Vessel	DepCat	Month	DayNight	Zone	Zone:Mth	Zone:DepC
AIC	5669	2214	1345	1274	1227	1155	1157	1065
RSS	22769	18036	16666	16567	16511	16433	16412	16318
MSS	3779	8512	9883	9981	10037	10116	10137	10230
Nobs	16044	16044	15645	15645	15645	15645	15645	15645
Npars	26	168	178	189	192	193	204	203
adj_r2	14.101	31.347	36.507	36.836	37.039	37.333	37.369	37.731
%Change	0.000	17.246	5.160	0.329	0.203	0.295	0.035	0.362

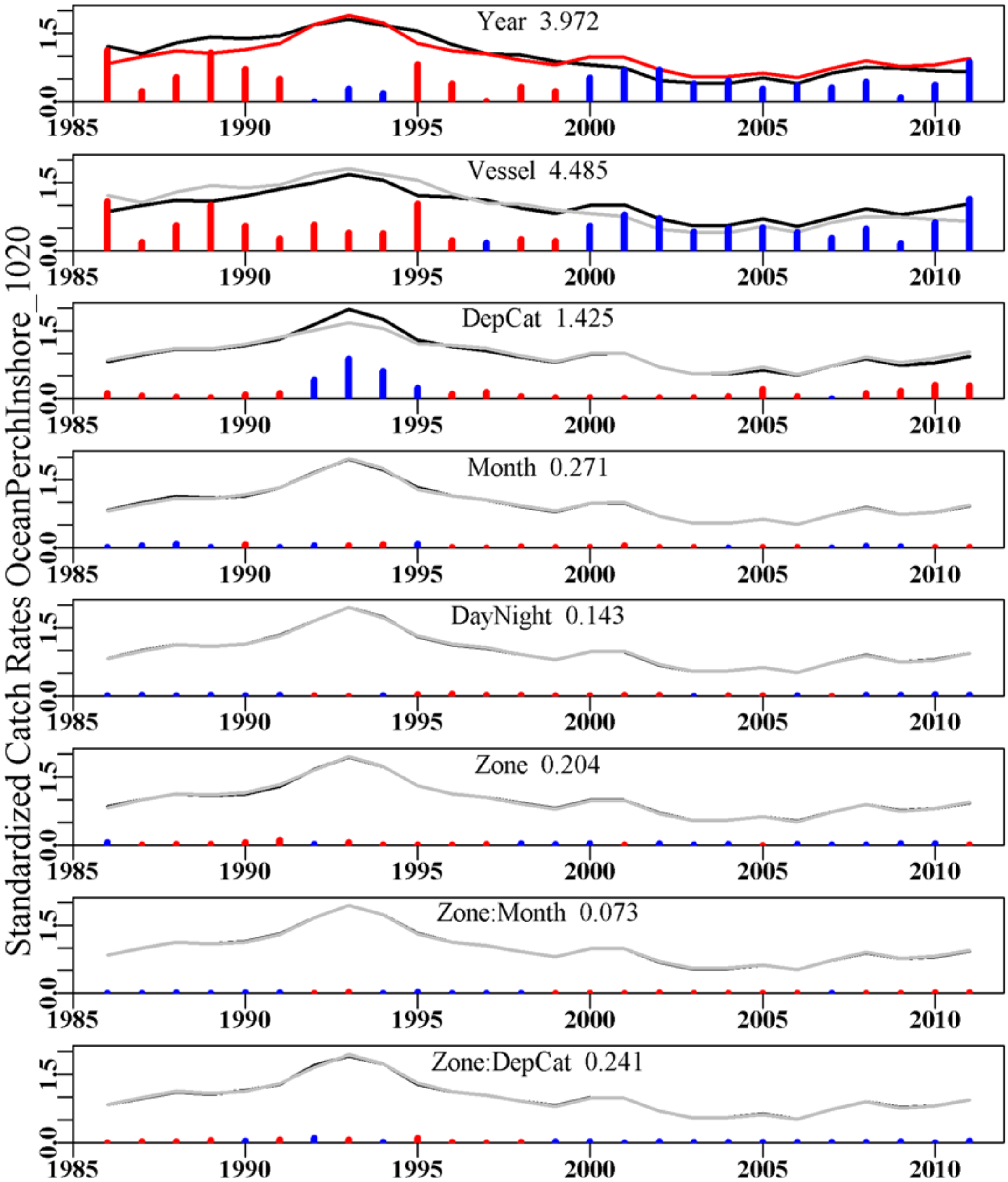

Figure 13.135**.** The relative influence of each factor used on the final trend in the optimal standardization for Inshore Ocean Perch from zones 10 and 20. The top graph depicts the geometric mean (the black line) and the optimum model (the red line). The difference between them is illustrated by the vertical bars with blue bars indicating the optimum model is higher than the geometric mean and red bars indicating it is lower. The top graph bars are the sum of all the bars in the graphs below. The graphs for individual factors are cumulative. Thus the second graph has the geometric mean (grey line) and the effect of adding Year + factor2 (model 2). In the third graph, the grey line represents model 2 and the black line the effect of adding factor3 to the model. The remaining graphs continue in the same cumulative manner except for the interaction terms which are added singularly to the final single factor model.

13.44 John Dory (DOJ – 37264004) *Zeus faber*

Zones 10 and 20 in depths 0 – 200m

Table 13.116**.** John Dory from Zones 10 and 20 in depths 0 to 200 m by trawl. Total Catch is the total reported in the database, Records is the number of records used in the analysis, CatchT is the reported catch in the area and depth used in the analysis, and Vessels relates to all vessels used in the analysis. Geomean is the geometric mean of catch rates (kg/hr). Zone:DepCat is the optimum model and StDev is the standard deviation relating to the data in the optimum model.

Year	TotCatch	Records	CatchT	Vessels	GeoMean	Zone:DepC	StDev
1986	231.715	6418	202.235	90	7.6948	1.5483	0.0000
1987	206.090	4663	181.591	78	8.5155	1.7713	0.0208
1988	181.984	4538	161.563	73	8.3856	1.6647	0.0211
1989	217.924	4813	188.443	70	9.5319	1.8250	0.0210
1990	167.853	3700	136.764	60	8.7451	1.6491	0.0230
1991	172.291	4041	126.696	53	7.1954	1.3564	0.0226
1992	130.849	3809	100.026	48	5.6282	1.1209	0.0231
1993	240.438	5446	181.622	56	7.0963	1.4522	0.0214
1994	267.868	6573	209.897	55	6.7516	1.3690	0.0204
1995	185.672	6070	168.531	52	5.9610	1.1594	0.0205
1996	160.753	6411	146.769	59	4.5279	0.8950	0.0204
1997	87.766	4473	79.224	60	3.3776	0.7008	0.0224
1998	109.029	5091	98.479	53	3.6350	0.7274	0.0215
1999	132.842	5553	121.021	56	3.9411	0.8410	0.0212
2000	164.053	7094	147.876	58	3.5716	0.7920	0.0203
2001	129.300	6789	116.224	51	2.9450	0.6650	0.0205
2002	150.974	6670	136.130	49	3.1506	0.6556	0.0208
2003	156.740	6559	137.336	51	3.1538	0.6388	0.0207
2004	165.858	7093	147.526	51	3.4191	0.6745	0.0204
2005	107.390	4934	88.640	48	2.6772	0.5638	0.0222
2006	85.401	3727	71.625	43	2.8463	0.6354	0.0237
2007	62.479	2844	51.685	23	2.8023	0.5790	0.0259
2008	116.789	3852	102.992	26	4.3014	0.8620	0.0239
2009	91.707	3148	79.746	23	4.1921	0.7984	0.0252
2010	61.785	3074	52.258	24	2.6414	0.5177	0.0256
2011	72.253	3426	57.450	22	2.7474	0.5373	0.0248

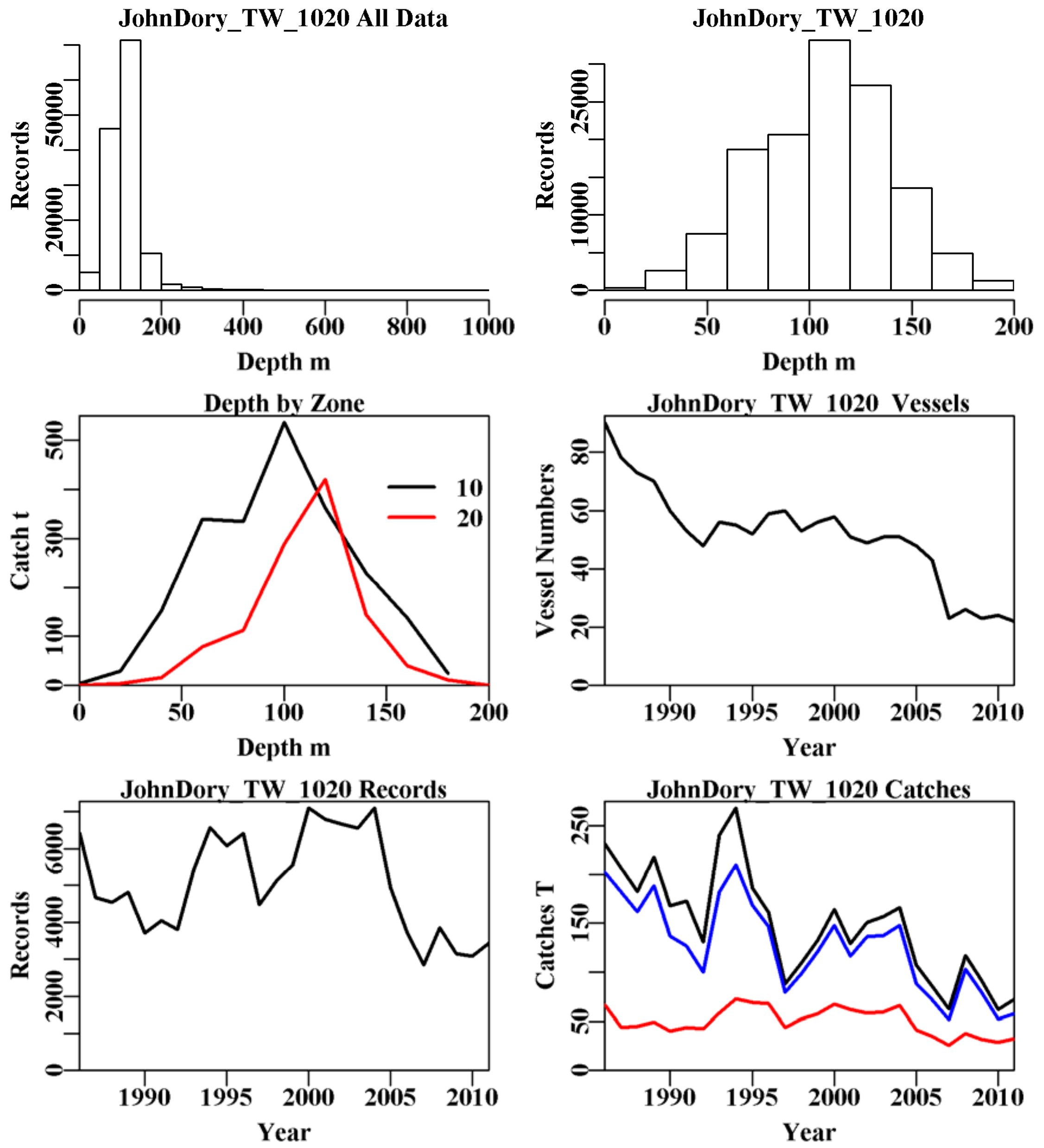

Figure 13.136**.** John Dory from Zones 10 and 20 in depths 0 to 200 m by trawl. The top left is the depth distribution of all records reporting John Dory, the top right graph depicts the depth distribution of shots containing John Dory from Zones 10 and 20 in depths 0 to 200 m by trawl. The middle left diagram depicts the distribution of catch by depth within zones 10 and 20 (20 is top red line), the middle right hand graph depicts the number of vessels through time. The bottom left reflects the number of records used in analysis, and bottom right is the John Dory catches (top line, black is total catches, middle line, blue, are those used in the analysis, and bottom, red, are catches < 30Kg).

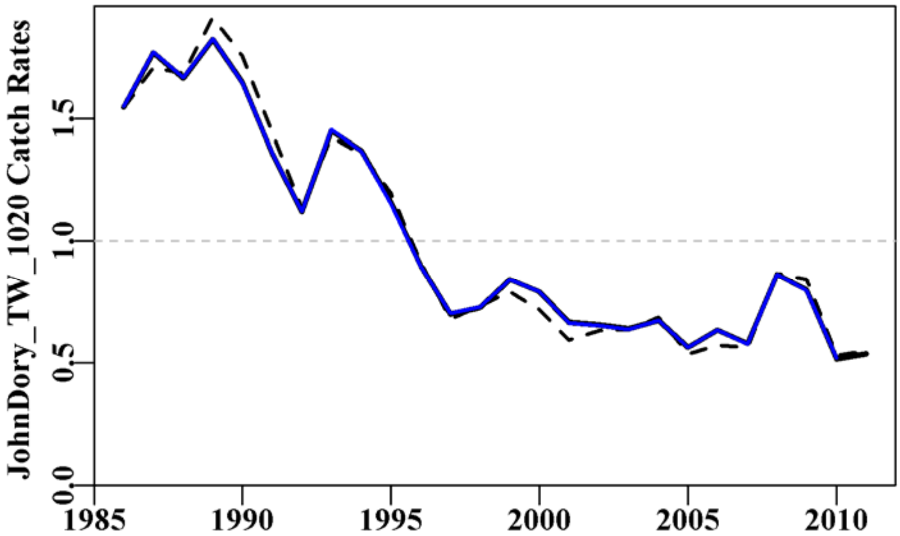

Figure 13.137**.** John Dory from Zones 10 and 20 in depths 0 to 200 m by trawl. The dashed black line represents the geometric mean catch rate and the solid black line the standardized catch rates. The graph standardizes catch rates relative to the mean of the standardized catch rates.

Table 13.117**.** John Dory from Zones 10 and 20 in depths 0 to 200 m by trawl. Statistical model structures used in this analysis. DepCat is a series of 20 metre depth categories.

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

Table 13.118**.** John Dory from Zones 10 and 20 in depths 0 to 200 m by trawl. Model selection criteria, including the AIC, the adjusted r^2 and the change in adjusted r^2. The optimum is Zone:DepCat (model 8).

	Year	Vessel	DepCat	DayNight	Month	Zone	Zone:Mth	Zone:DepC
AIC	26049	10945	9295	7667	6995	6953	6164	5772
RSS	159570	141821	138945	137206	136475	136428	135578	135171
MSS	22595	40344	43220	44959	45690	45737	46588	46995
Nobs	130809	130809	129730	129730	129730	129730	129730	129730
Npars	26	186	196	199	210	211	222	221
adj_r2	12.387	22.037	23.611	24.565	24.961	24.986	25.447	25.672
%Change	0.000	9.650	1.574	0.954	0.396	0.025	0.461	0.224

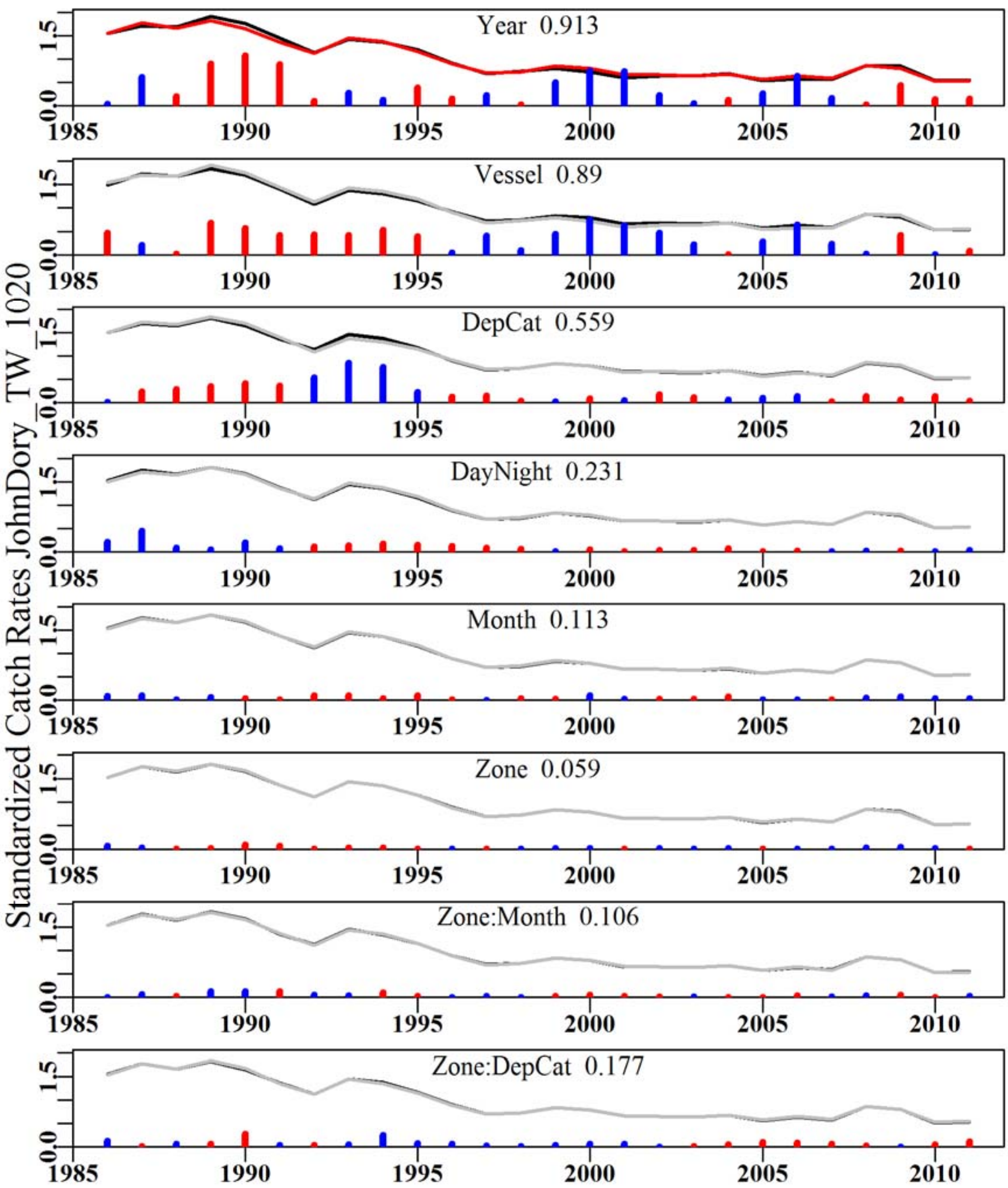

Figure 13.138**.** The relative influence of each factor used on the final trend in the optimal standardization for John Dory from Zones 10 and 20. The top graph depicts the geometric mean (the black line) and the optimum model (the red line). The difference between them is illustrated by the vertical bars with blue bars indicating the optimum model is higher than the geometric mean and red bars indicating it is lower. The top graph bars are the sum of all the bars in the graphs below. The graphs for individual factors are cumulative. Thus the second graph has the geometric mean (grey line) and the effect of adding Year + factor2 (model 2). In the third graph, the grey line represents model 2 and the black line the effect of adding factor3 to the model. The remaining graphs continue in the same cumulative manner except for the interaction terms which are added singularly to the final single factor model.

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

Only data from Zones 10 to 50 in depths 0 – 600m. All vessels reporting Mirror Dory were included.

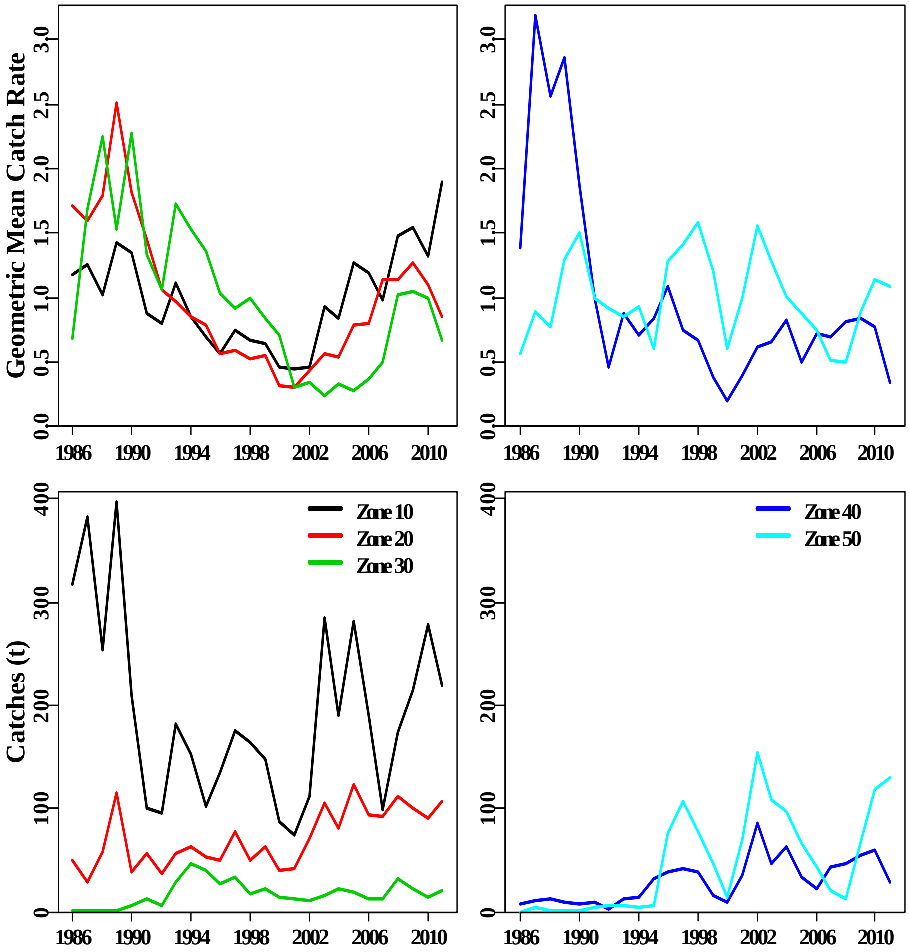

Figure 13.139**.** The catches and geometric mean catch rates from 1986 – 2010 for Mirror Dory split between east (Zones 10 -3 0) and west (zones 40 and 50. The general trends in catch rates, in periods of significant catches, are similar across zones within the east and west. This implies that the assumption that there are no year x zone interactions is valid.

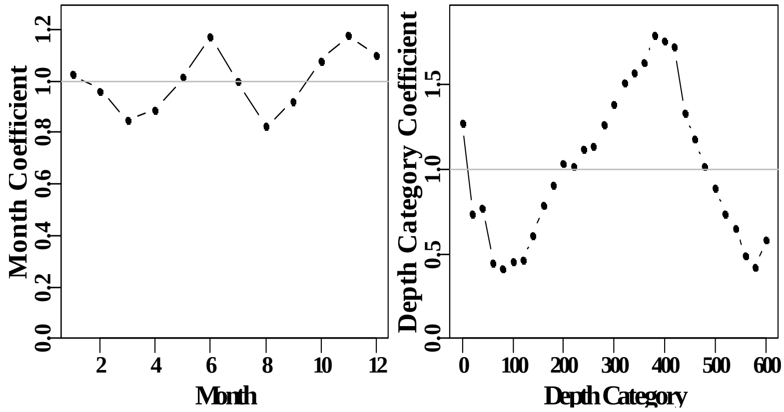

Figure 13.140**.** Standardized trends for Month and DepCat factors for Mirror Dory taken by trawl.

Table 13.119**.** Mirror Dory from Zones 10 to 50 in depths 0 to 600 m by trawl. Total Catch is the total reported in the database, Records is the number of records used in the analysis, CatchT is the reported catch in the area and depth used in the analysis, and Vessels relates to all vessels used in the analysis. Geomean is the geometric mean of catch rates (kg/hr). Zone:Month is the optimum model and StDev is the standard deviation relating to the data in the optimum model.

Year	TotCatch	Records	CatchT	Vessels	GeoMean	Zone:Mth	StDev
1986	402.048	3199	375.385	91	18.6423	1.2117	0.0000
1987	450.766	3103	429.090	92	19.7476	1.2147	0.0308
1988	346.014	3189	328.220	88	16.9455	1.1875	0.0306
1989	591.631	3068	524.863	84	23.1957	1.4715	0.0311
1990	295.764	1906	264.346	73	20.6077	1.3530	0.0357
1991	240.313	2230	183.737	77	13.9567	1.1550	0.0343
1992	166.980	2228	147.170	71	11.3487	0.9990	0.0345
1993	306.220	3290	285.221	72	13.7999	1.0955	0.0314
1994	297.268	3828	280.195	70	11.4667	0.9802	0.0306
1995	244.924	4209	234.433	70	10.0782	0.9047	0.0300
1996	352.722	5835	327.514	84	8.9039	0.8782	0.0287
1997	459.626	6681	436.446	80	9.6820	0.9362	0.0284
1998	355.794	5572	346.706	68	9.0983	0.8485	0.0290
1999	309.481	5543	298.167	74	8.0995	0.7039	0.0292
2000	171.066	5613	165.229	79	4.6519	0.4847	0.0294
2001	243.362	7016	233.924	75	5.1157	0.5653	0.0288
2002	449.555	8199	435.035	69	7.1647	0.7542	0.0283
2003	613.832	7796	560.887	71	8.6661	0.9179	0.0283
2004	507.392	6485	452.616	69	8.2044	0.8819	0.0291
2005	579.886	6190	523.814	66	9.3924	0.9762	0.0292
2006	419.556	4293	363.075	54	9.7517	0.9631	0.0308
2007	289.603	3400	268.103	33	9.5152	0.9292	0.0324
2008	396.242	3377	376.364	34	12.2034	1.1150	0.0325
2009	476.515	3567	461.781	32	13.1797	1.2256	0.0322
2010	579.973	3702	561.230	32	12.8612	1.1642	0.0321
2011	516.330	3903	505.245	33	10.8311	1.0831	0.0318

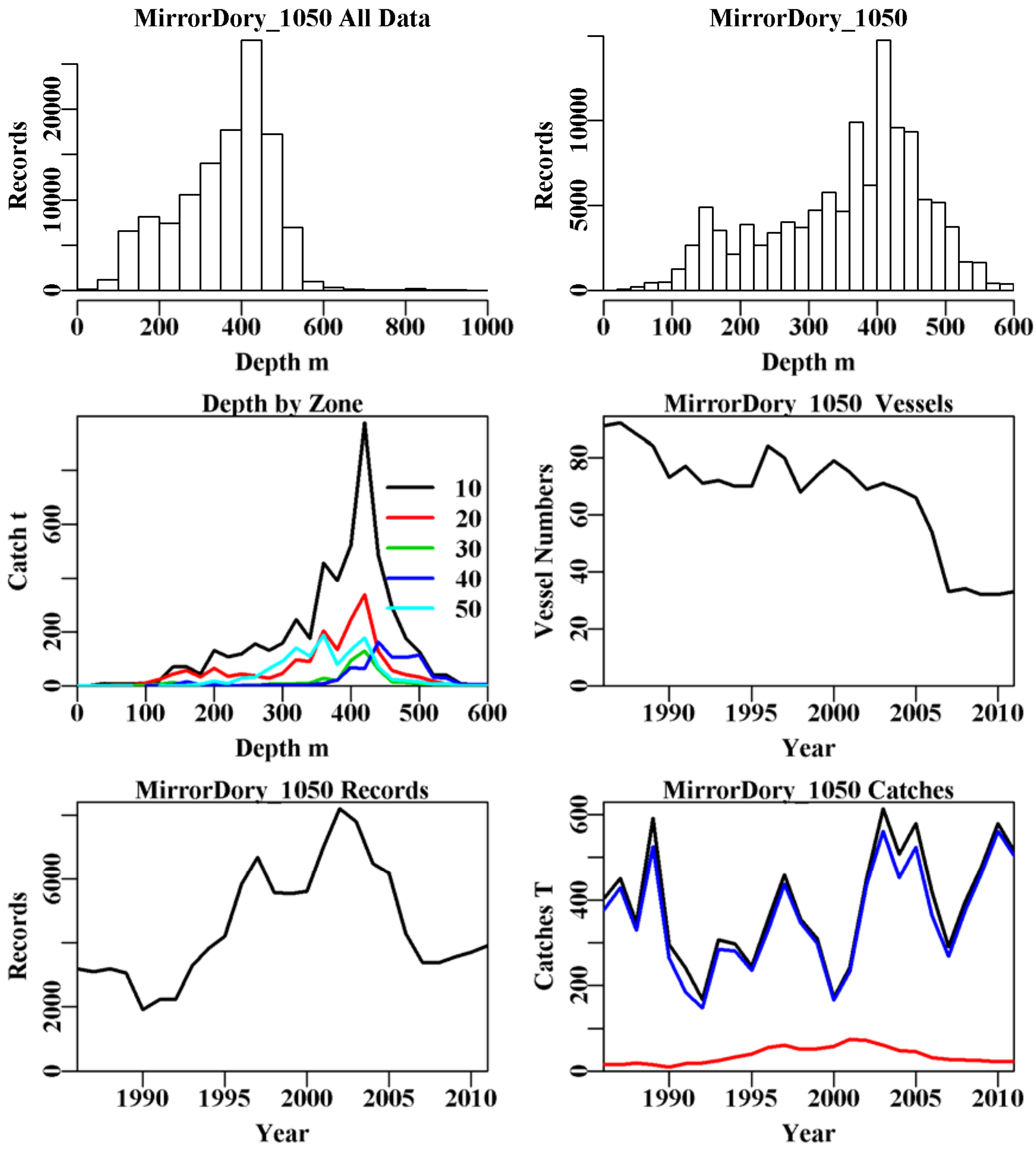

Figure 13.141**.** Mirror Dory from Zones 10 to 50 in depths 0 to 600 m by trawl. The top left is the depth distribution of all records reporting Mirror Dory, the top right graph depicts the depth distribution of shots containing Mirror Dory from Zones 10 to 50 in depths 0 to 600 m by trawl. The middle left diagram depicts the distribution of catch by depth within zones 10 to 50, the middle right hand graph depicts the number of vessels through time. The bottom left reflects the number of records used in analysis, and bottom right is the Mirror Dory catches (top line, black is total catches, middle line, blue, are those used in the analysis, and bottom, red, are catches < 30Kg).

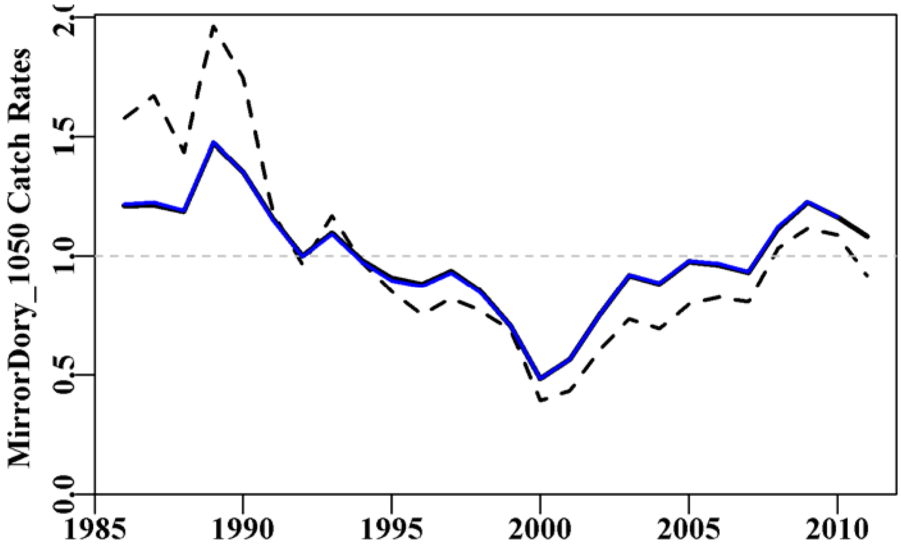

Figure 13.142. Mirror Dory from Zones 10 to 50 in depths 0 to 600 m by trawl. The dashed black line represents the geometric mean catch rate and the solid black line the standardized catch rates. The graph standardizes catch rates relative to the mean of the standardized catch rates.

Table 13.120. Mirror Dory from Zones 10 to 50 in depths 0 to 600 m by trawl. Statistical model structures used in this analysis. DepCat is a series of 20 metre depth categories.

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

Table 13.121. Mirror Dory from Zones 10 to 50 in depths 0 to 600 m by trawl. Model selection criteria, including the AIC, the adjusted r^2 and the change in adjusted r^2. The optimum is Zone:Month (model 7).

	Year	Vessel	DepCat	Month	DayNight	Zone	Zone:Mth	Zone:DepC
AIC	71566	50600	49043	38502	37257	36610	32447	35740
RSS	215899	179983	177579	161686	159964	159070	153386	157566
MSS	16240	52155	54560	70453	72175	73069	78753	74573
Nobs	117422	117422	117422	116819	116819	116819	116819	116819
Npars	26	225	236	266	269	273	317	393
adj_r2	6.976	22.319	23.350	30.191	30.933	31.317	33.746	31.896
%Change	0.000	15.343	1.030	6.841	0.742	0.384	2.429	-1.850

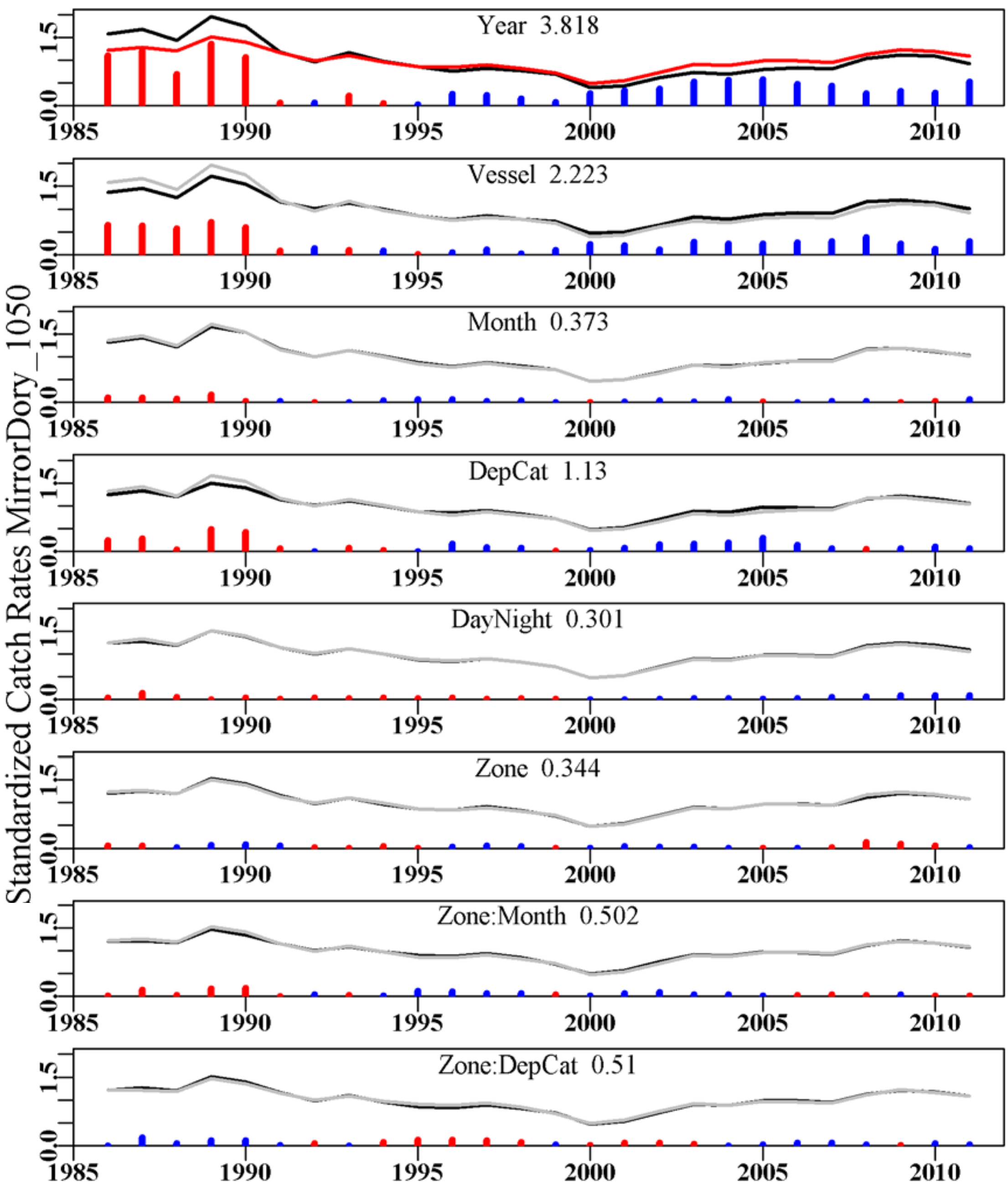

Figure 13.143. The relative influence of each factor used on the final trend in the optimal standardization for Mirror Dory from Zones 10 to 50. The top graph depicts the geometric mean (the black line) and the optimum model (the red line). The difference between them is illustrated by the vertical bars with blue bars indicating the optimum model is higher than the geometric mean and red bars indicating it is lower. The top graph bars are the sum of all the bars in the graphs below. The graphs for individual factors are cumulative. Thus the second graph has the geometric mean (grey line) and the effect of adding Year + factor2 (model 2). In the third graph, the grey line represents model 2 and the black line the effect of adding factor3 to the model. The remaining graphs continue in the same cumulative manner except for the interaction terms which are added singularly to the final single factor model.

13.46 Mirror Dory East (DOM – 37264003 *Zenopsis nebulosus*)

Only data from Zones 10 to 30 in depths 0 – 600m. All vessels reporting Mirror Dory were included.

Table 13.122**.** Mirror Dory from Zones 10 to 30 in depths 0 to 600 m by trawl. Total Catch is the total reported in the database, Records is the number of records used in the analysis, CatchT is the reported catch in the area and depth used in the analysis, and Vessels relates to all vessels used in the analysis. Geomean is the geometric mean of catch rates (kg/hr). Zone:Month is the optimum model and StDev is the standard deviation relating to the data in the optimum model.

Year	TotCatch	Records	CatchT	Vessels	GeoMean	Zone:Mth	StDev
1986	402.048	3141	367.985	80	18.7487	1.1585	0.0000
1987	450.766	2961	413.571	70	19.9429	1.1556	0.0322
1988	346.014	3067	313.237	77	16.8882	1.1336	0.0318
1989	591.631	2997	513.736	70	23.1617	1.3791	0.0323
1990	295.764	1811	254.380	61	20.5538	1.2896	0.0373
1991	240.313	2021	170.954	68	14.2052	1.1339	0.0366
1992	166.980	2022	138.871	56	11.7312	0.9845	0.0366
1993	306.220	3013	267.091	62	14.1976	1.0792	0.0332
1994	297.268	3498	262.033	62	11.6924	0.9448	0.0323
1995	244.924	3500	196.290	59	10.2913	0.8577	0.0322
1996	352.722	4397	212.369	69	7.7998	0.7617	0.0309
1997	459.626	4775	288.136	65	8.6425	0.8100	0.0308
1998	355.794	4103	230.495	55	8.0944	0.7297	0.0314
1999	309.481	4225	234.873	59	7.8713	0.6626	0.0315
2000	171.066	4633	142.768	63	4.7885	0.4995	0.0315
2001	243.362	4570	128.644	55	4.0443	0.4995	0.0318
2002	449.555	5038	194.433	53	5.2594	0.6208	0.0313
2003	613.832	5362	405.679	58	7.7688	0.9105	0.0308
2004	507.392	4275	292.676	57	7.2635	0.8636	0.0320
2005	579.886	4417	423.631	55	9.9946	1.1053	0.0319
2006	419.556	3230	297.559	44	10.3893	1.1074	0.0337
2007	289.603	2223	203.162	22	11.4463	1.1963	0.0369
2008	396.242	2495	317.705	26	14.4563	1.3389	0.0363
2009	476.515	2232	338.488	27	15.8458	1.4196	0.0373
2010	579.973	2105	383.480	25	14.3976	1.1806	0.0376
2011	516.330	2254	347.067	26	12.7502	1.1774	0.0372

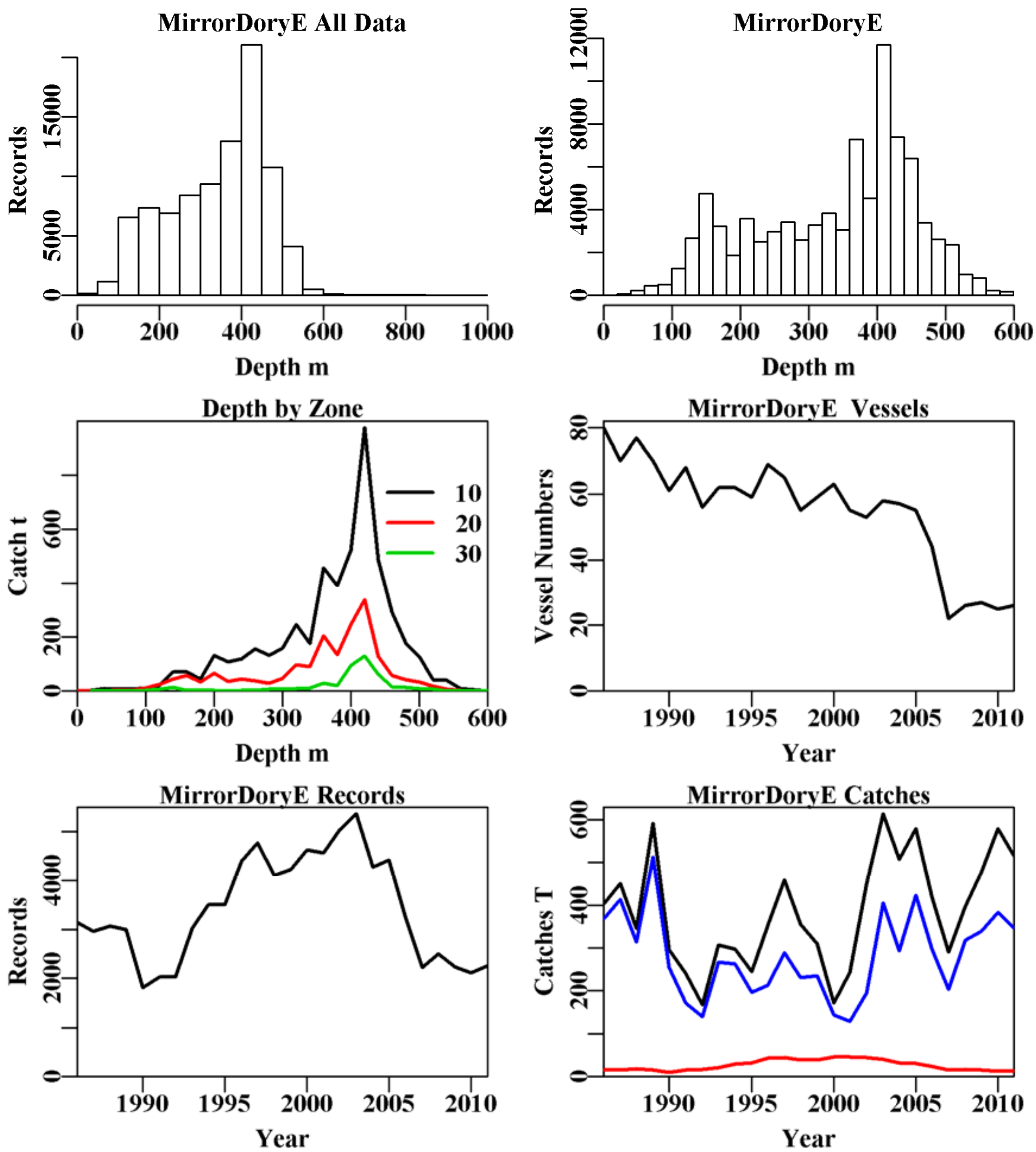

Figure 13.144**.** Mirror Dory from Zones 10 to 30 in depths 0 to 600 m by trawl. The top left is the depth distribution of all records reporting Mirror Dory, the top right graph depicts the depth distribution of shots containing Mirror Dory from Zones 10 to 30 in depths 0 to 600 m by trawl. The middle left diagram depicts the distribution of catch by depth within zones 10 to 30, the middle right hand graph depicts the number of vessels through time. The bottom left reflects the number of records used in analysis, and bottom right is the Mirror Dory catches (top line, black is total catches, middle line, blue, are those used in the analysis, and bottom, red, are catches < 30Kg).

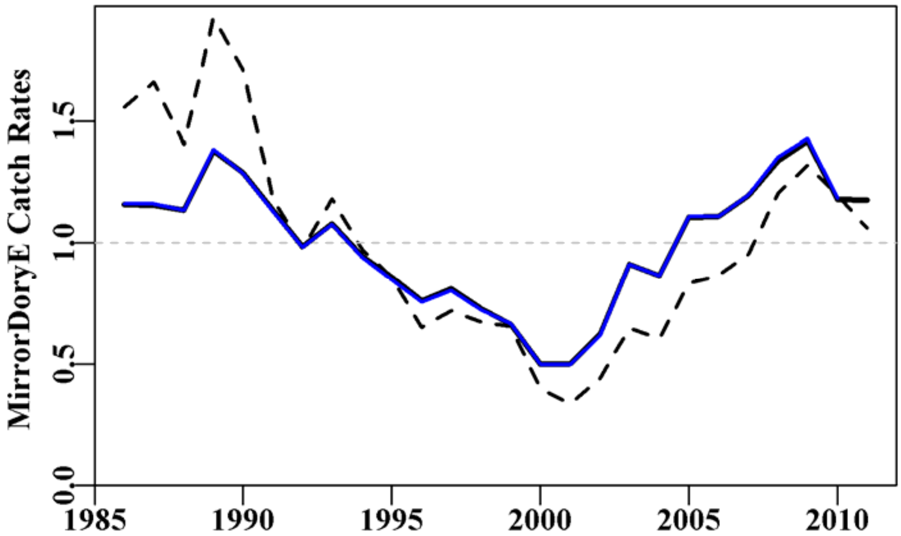

Figure 13.145**.** Mirror Dory from Zones 10 to 30 in depths 0 to 600 m by trawl. The dashed black line represents the geometric mean catch rate and the solid black line the standardized catch rates. The graph standardizes catch rates relative to the mean of the standardized catch rates.

Table 13.123**.** Mirror Dory from Zones 10 to 30 in depths 0 to 600 m by trawl. Statistical model structures used in this analysis. DepCat is a series of 20 metre depth categories.

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

Table 13.124**.** Mirror Dory from Zones 10 to 30 in depths 0 to 600 m by trawl. Model selection criteria, including the AIC, the adjusted r^2 and the change in adjusted r^2. The optimum is Zone:Month (model 7).

	Year	Vessel	DepCat	Month	DayNight	Zone	Zone:Mth	Zone:DepC
AIC	58701	43347	33534	31899	31243	30638	29161	30360
RSS	171604	143670	128072	125680	124738	123877	121751	123317
MSS	18473	46407	62005	64397	65339	66200	68326	66760
Nobs	88365	88365	87914	87914	87914	87914	87914	87914
Npars	26	199	229	240	243	245	267	305
adj_r2	9.693	24.245	32.446	33.699	34.194	34.647	35.752	34.898
%Change	0.000	14.552	8.201	1.253	0.495	0.453	1.105	-0.855

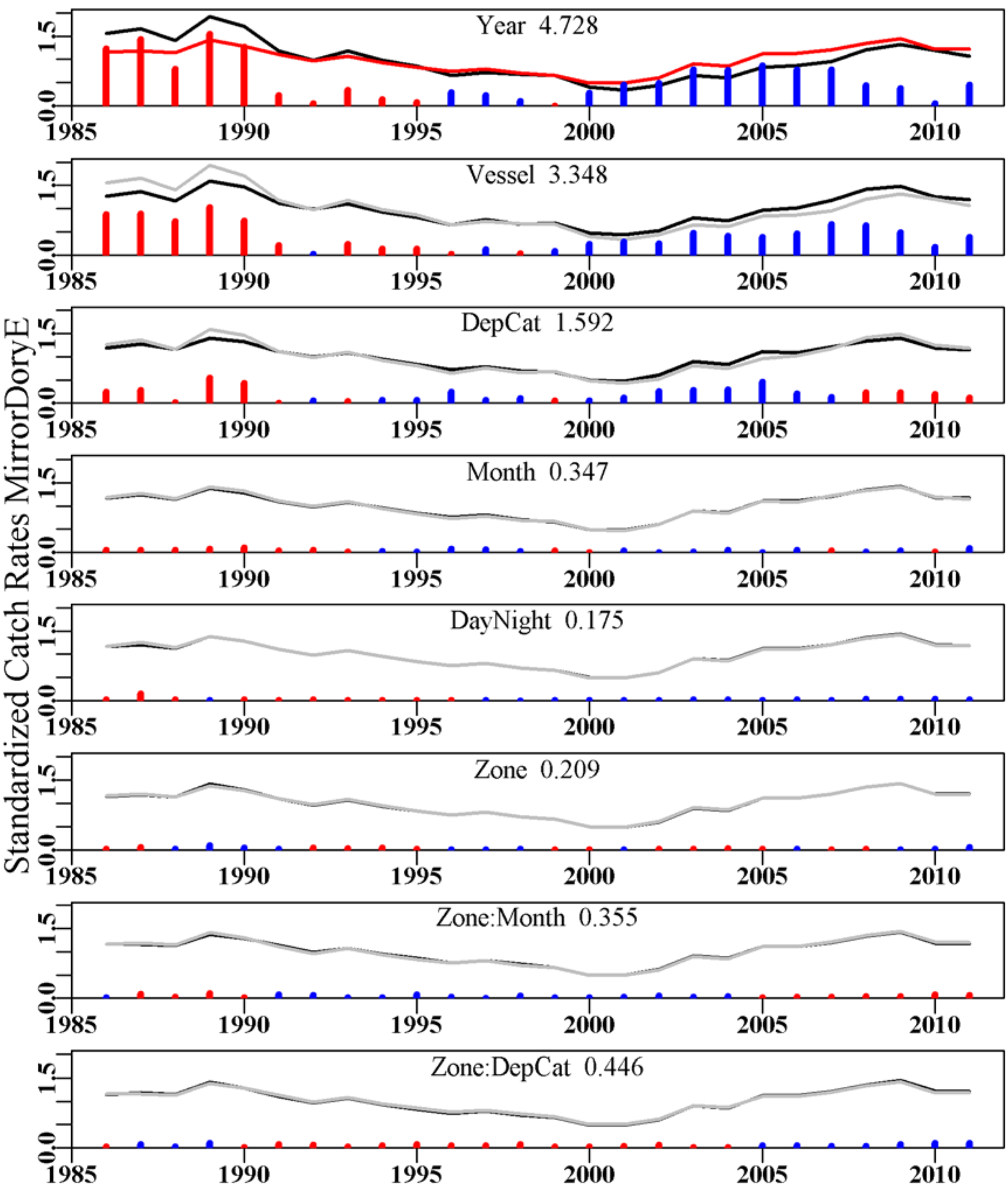

Figure 13.146**.** The relative influence of each factor used on the final trend in the optimal standardization for Mirror Dory from Zones 10 to 30. The top graph depicts the geometric mean (the black line) and the optimum model (the red line). The difference between them is illustrated by the vertical bars with blue bars indicating the optimum model is higher than the geometric mean and red bars indicating it is lower. The top graph bars are the sum of all the bars in the graphs below. The graphs for individual factors are cumulative. Thus the second graph has the geometric mean (grey line) and the effect of adding Year + factor2 (model 2). In the third graph, the grey line represents model 2 and the black line the effect of adding factor3 to the model. The remaining graphs continue in the same cumulative manner except for the interaction terms which are added singularly to the final single factor model.

13.47 Mirror Dory West (DOM – 37264003 *Zenopsis nebulosus*)

Only data from Zones 40 to 50 in depths 0 – 600m. All vessels reporting Mirror Dory were included.

Table 13.125**.** Mirror Dory from Zones 40 to 50 in depths 0 to 600 m by trawl. Total Catch is the total reported in the database, Records is the number of records used in the analysis, CatchT is the reported catch in the area and depth used in the analysis, and Vessels relates to all vessels used in the analysis. Geomean is the geometric mean of catch rates (kg/hr). Zone:Month is the optimum model and StDev is the standard deviation relating to the data in the optimum model.

Year	TotCatch	Records	CatchT	Vessels	GeoMean	Zone:Mth	StDev
1986	402.048	57	7.374	10	13.7130	2.3666	0.0000
1987	450.766	142	15.519	23	16.0832	1.5740	0.1989
1988	346.014	122	14.983	17	18.4525	1.2966	0.2076
1989	591.631	71	11.127	15	24.6757	1.6475	0.2191
1990	295.764	95	9.966	14	21.6631	1.1110	0.2226
1991	240.313	209	12.783	17	11.7670	0.7909	0.1963
1992	166.980	205	8.289	20	8.1608	0.6541	0.1979
1993	306.220	276	18.010	18	10.1017	0.7732	0.1931
1994	297.268	330	18.162	20	9.3264	0.6758	0.1915
1995	244.924	709	38.143	23	9.0896	0.8594	0.1886
1996	352.722	1438	115.145	26	13.3473	1.2433	0.1885
1997	459.626	1906	148.310	24	12.8686	1.2670	0.1880
1998	355.794	1469	116.211	20	12.6121	1.2404	0.1884
1999	309.481	1318	63.294	23	8.8763	0.8103	0.1886
2000	171.066	980	22.461	27	4.0569	0.4281	0.1896
2001	243.362	2446	105.280	29	7.9361	0.7384	0.1879
2002	449.555	3156	240.252	28	11.7181	1.0837	0.1876
2003	613.832	2429	154.899	27	11.0165	0.9361	0.1879
2004	507.392	2208	159.809	25	10.3786	0.9388	0.1881
2005	579.886	1769	100.006	23	8.0456	0.7379	0.1883
2006	419.556	1061	65.351	19	8.0395	0.6304	0.1894
2007	289.603	1177	64.941	16	6.7120	0.5653	0.1892
2008	396.242	879	58.533	17	7.5767	0.6335	0.1898
2009	476.515	1333	123.246	14	9.7010	0.9617	0.1886
2010	579.973	1596	177.550	14	11.0745	1.1448	0.1885
2011	516.330	1644	156.846	16	8.6540	0.8911	0.1886

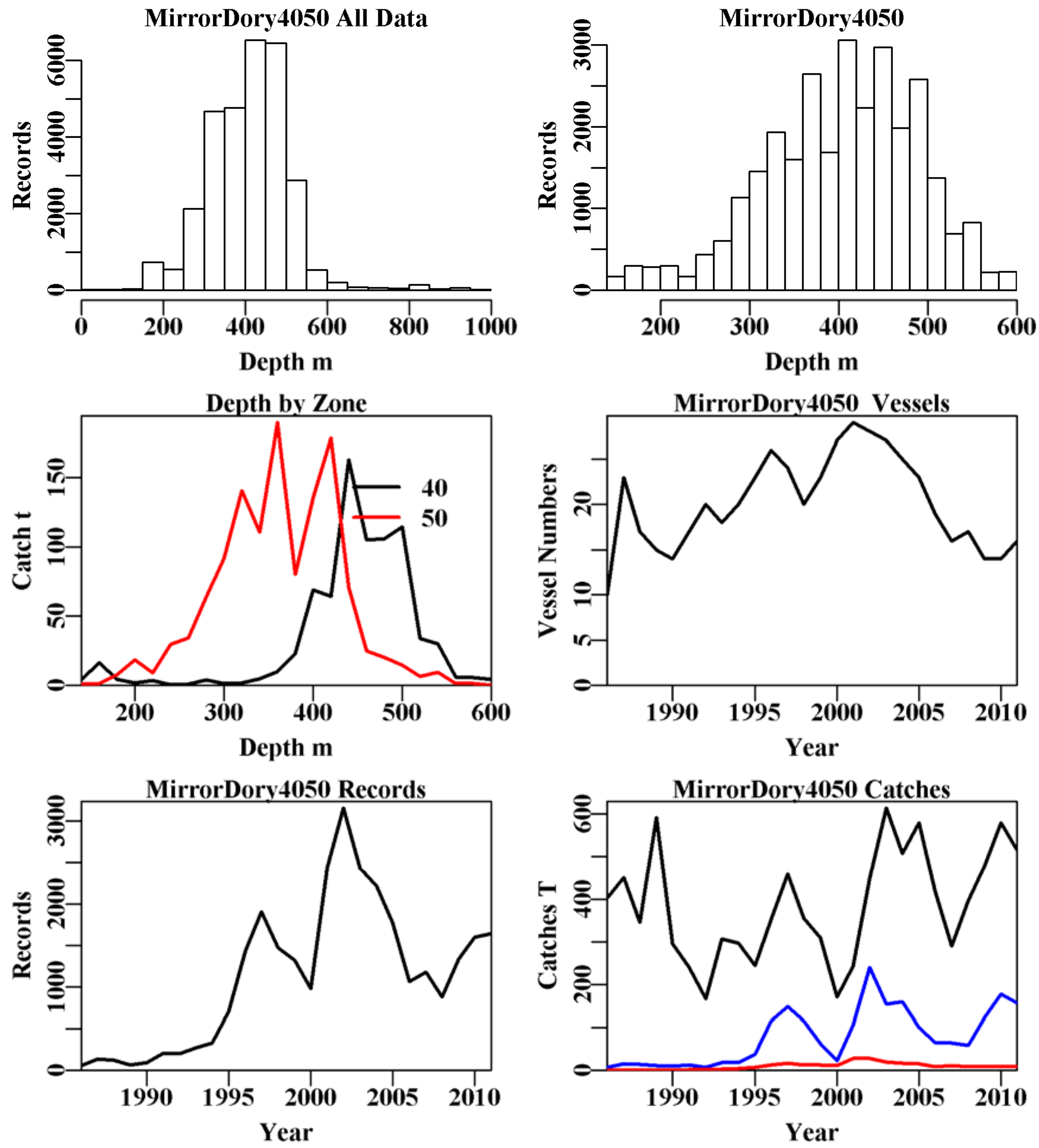

Figure 13.147**.** Mirror Dory from Zones 40 to 50 in depths 0 to 600 m by trawl. The top left is the depth distribution of all records reporting Mirror Dory, the top right graph depicts the depth distribution of shots containing Mirror Dory from Zones 40 to 50 in depths 0 to 600 m by trawl. The middle left diagram depicts the distribution of catch by depth within zones 40 to 50, the middle right hand graph depicts the number of vessels through time. The bottom left reflects the number of records used in analysis, and bottom right is the Mirror Dory catches (top line, black is total catches, middle line, blue, are those used in the analysis, and bottom, red, are catches < 30Kg).

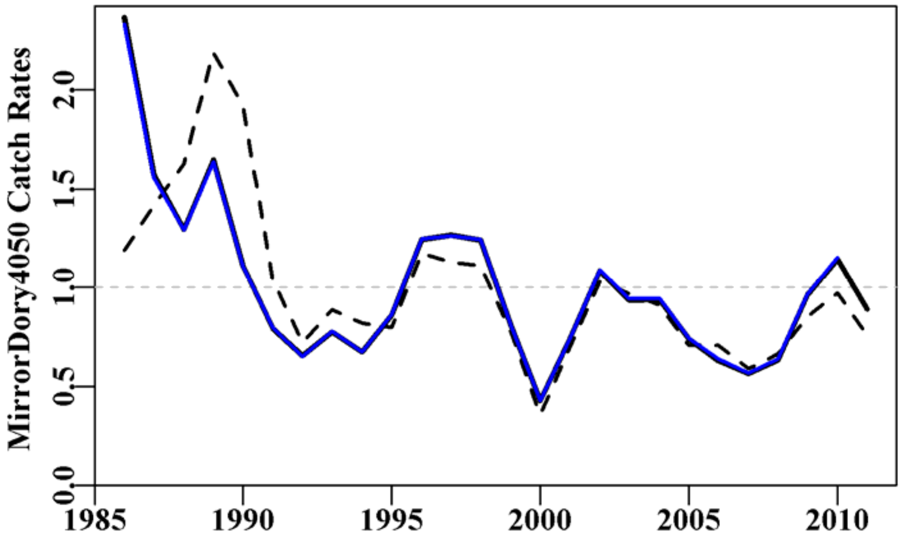

Figure 13.148. Mirror Dory from Zones 40 to 50 in depths 0 to 600 m by trawl. The dashed black line represents the geometric mean catch rate and the solid black line the standardized catch rates. The graph standardizes catch rates relative to the mean of the standardized catch rates.

Table 13.126**.** Mirror Dory from Zones 40 to 50 in depths 0 to 600 m by trawl. Statistical model structures used in this analysis. DepCat is a series of 20 metre depth categories.

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

Table 13.127**.** Mirror Dory from Zones 40 to 50 in depths 0 to 600 m by trawl. Model selection criteria, including the AIC, the adjusted r^2 and the change in adjusted r^2. The optimum is Zone:Month (model 7).

	Year	Vessel	Month	DepCat	DayNight	Zone	Zone:Mth	Zone:DepC
AIC	9354	2688	1318	115	-514	-849	-1190	-881
RSS	39990	31597	30117	28697	28073	27747	27400	27672
MSS	2012	10406	11885	13306	13930	14255	14602	14330
Nobs	29025	29025	29025	28873	28873	28873	28873	28873
Npars	26	112	123	146	149	150	161	173
adj_r2	4.709	24.485	27.993	31.334	32.820	33.597	34.402	33.723
%Change	0.000	19.777	3.508	3.340	1.486	0.777	0.805	-0.679

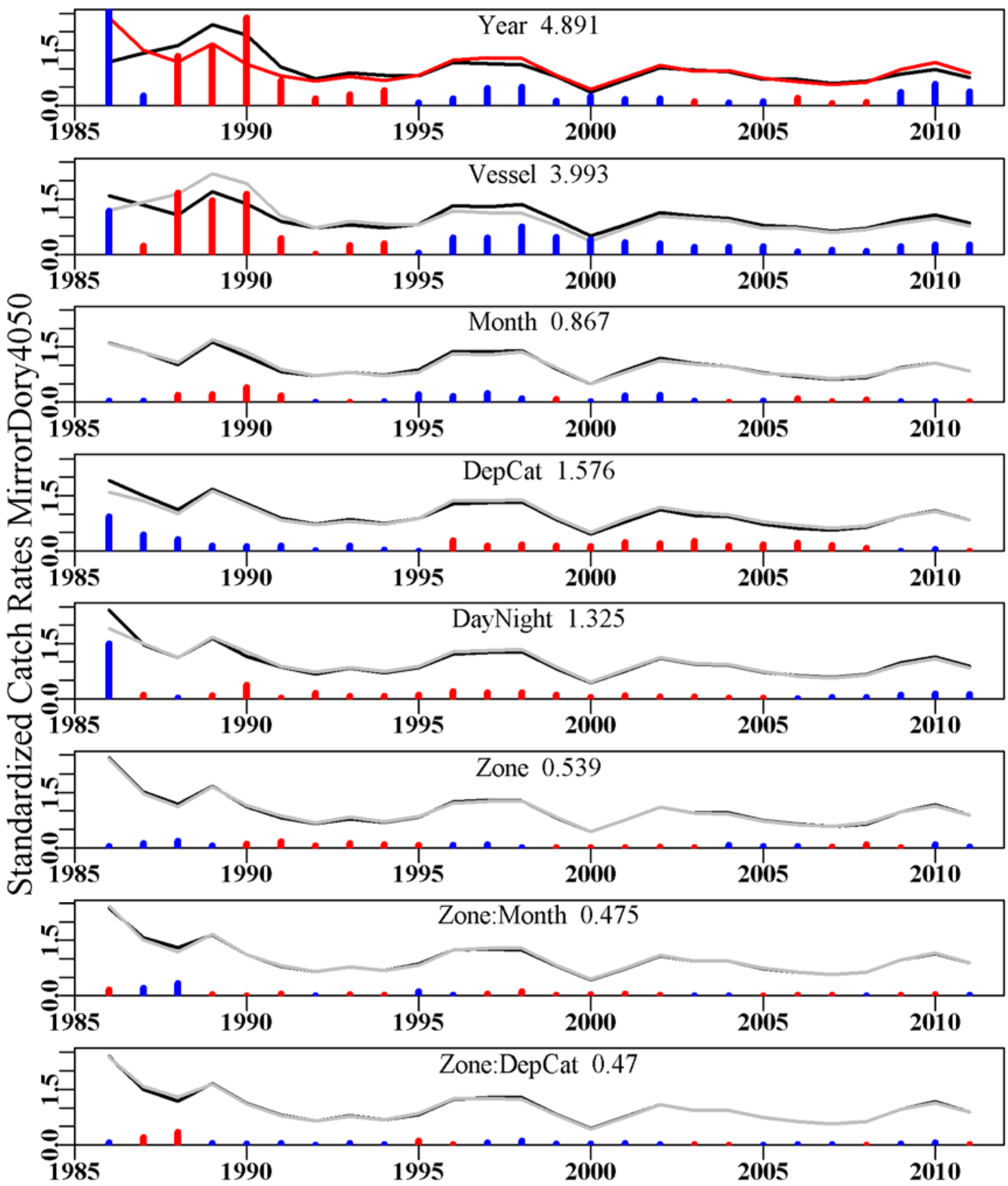

Figure 13.149**.** The relative influence of each factor used on the final trend in the optimal standardization for Mirror Dory from Zones 40 – 50. The top graph depicts the geometric mean (the black line) and the optimum model (the red line). The difference between them is illustrated by the vertical bars with blue bars indicating the optimum model is higher than the geometric mean and red bars indicating it is lower. The top graph bars are the sum of all the bars in the graphs below. The graphs for individual factors are cumulative. Thus the second graph has the geometric mean (grey line) and the effect of adding Year + factor2 (model 2). In the third graph, the grey line represents model 2 and the black line the effect of adding factor3 to the model. The remaining graphs continue in the same cumulative manner except for the interaction terms which are added singularly to the final single factor model.

13.48 Ribaldo (RBD – 37224002 – Mora moro)

Only data from Zones 10 to 50 in depths 0 – 1000m.

Table 13.128. Ribaldo from Zones 10 to 50 in depths 0 to 1000 m by trawl. Total Catch is the total reported in the database, Records is the number of records used in the analysis, CatchT is the reported catch in the area and depth used in the analysis, and Vessels relates to all vessels used in the analysis. Geomean is the geometric mean of catch rates (kg/hr). Zone:Mth is the optimum model and StDev is the standard deviation relating to the data in the optimum model.

Year	TotCatch	Records	CatchT	Vessels	GeoMean	Zone:Mth	StDev
1986	4.104	72	3.524	11	14.6630	2.2797	0.0000
1987	7.941	158	7.292	14	10.2593	1.2772	0.1379
1988	10.898	123	8.049	22	16.5570	2.0037	0.1542
1989	11.342	136	7.711	14	18.2556	1.8029	0.1526
1990	3.668	58	2.259	11	8.9113	1.4196	0.1728
1991	7.808	145	5.162	22	7.9930	1.3647	0.1522
1992	13.333	226	11.689	26	9.7616	1.3480	0.1441
1993	22.777	330	19.762	37	11.2449	1.1172	0.1439
1994	41.938	423	23.622	30	11.8156	1.2565	0.1416
1995	90.323	1147	86.299	26	12.3128	1.3011	0.1382
1996	82.278	1492	77.012	32	10.1757	1.0009	0.1379
1997	103.111	1714	96.567	30	9.8023	0.8776	0.1376
1998	99.924	1667	92.015	33	9.6696	0.8530	0.1377
1999	72.157	1133	59.668	32	8.7093	0.7871	0.1386
2000	66.791	1174	53.845	37	7.4217	0.7152	0.1385
2001	82.479	1122	52.390	37	6.7639	0.6655	0.1384
2002	157.878	1142	57.271	30	6.7944	0.6229	0.1387
2003	181.036	1310	66.180	35	6.7153	0.6103	0.1384
2004	180.961	1257	66.417	33	7.2233	0.6613	0.1386
2005	90.375	671	30.046	32	6.3488	0.5715	0.1404
2006	122.615	637	32.083	34	6.3304	0.6153	0.1405
2007	78.314	404	15.571	24	3.2493	0.4015	0.1433
2008	78.475	367	17.618	24	4.7326	0.5556	0.1438
2009	104.960	572	33.410	20	5.6978	0.6149	0.1409
2010	92.104	685	37.305	22	5.5851	0.6321	0.1401
2011	94.029	864	44.555	20	5.8331	0.6447	0.1392

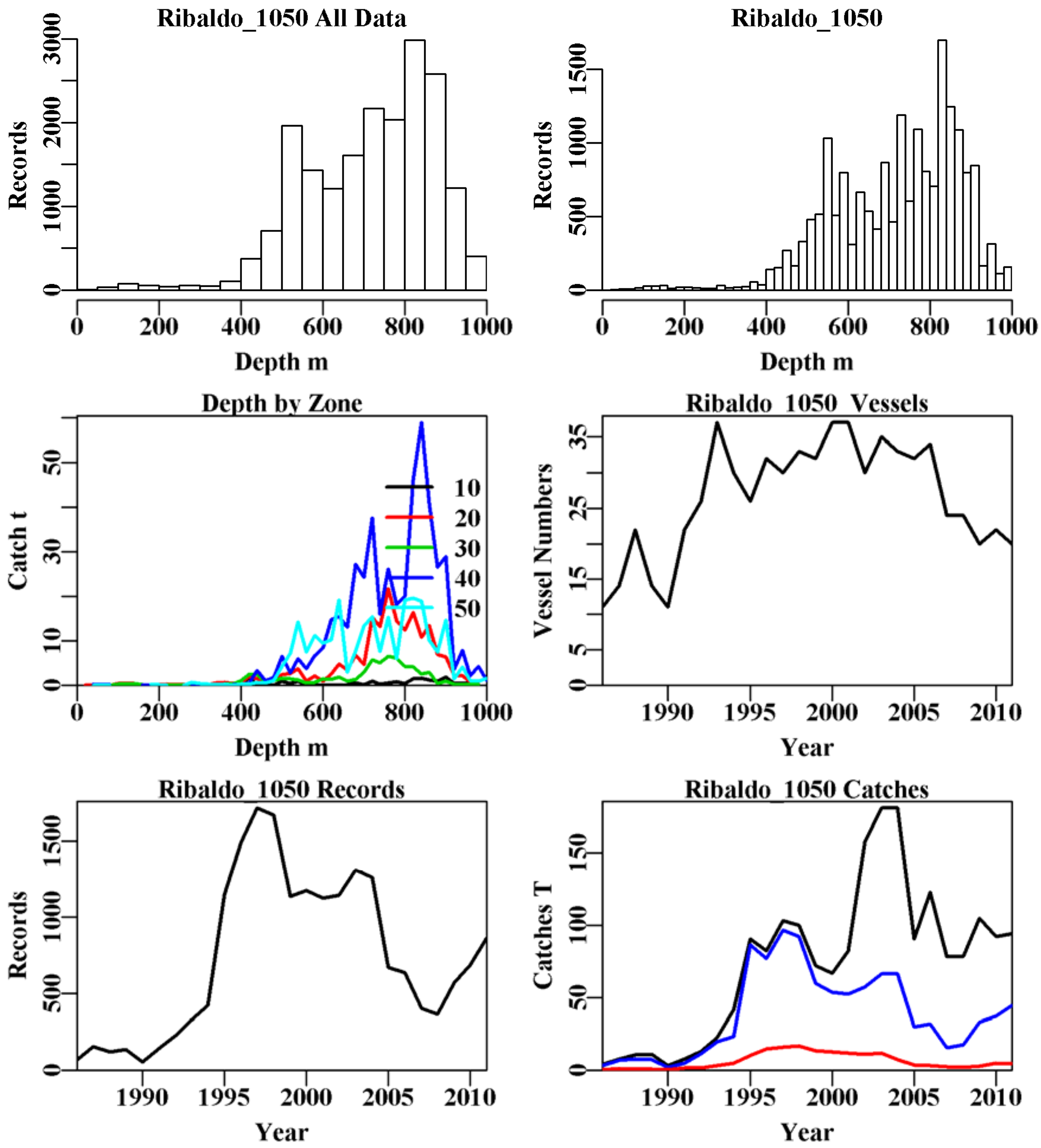

Figure 13.150**.** Ribaldo from Zones 10 to 50 in depths 0 to 1000 m by trawl. The top left is the depth distribution of all records reporting Ribaldo, the top right graph depicts the depth distribution of shots containing Ribaldo from Zones 10 to 50 in depths 0 to 1000 m by trawl. The middle left diagram depicts the distribution of catch by depth within zones 10 to 50, the middle right hand graph depicts the number of vessels through time. The bottom left reflects the number of records used in analysis, and bottom right is the Ribaldo catches (top line, black is total catches, middle line, blue, are those used in the analysis, and bottom, red, are catches < 30Kg).

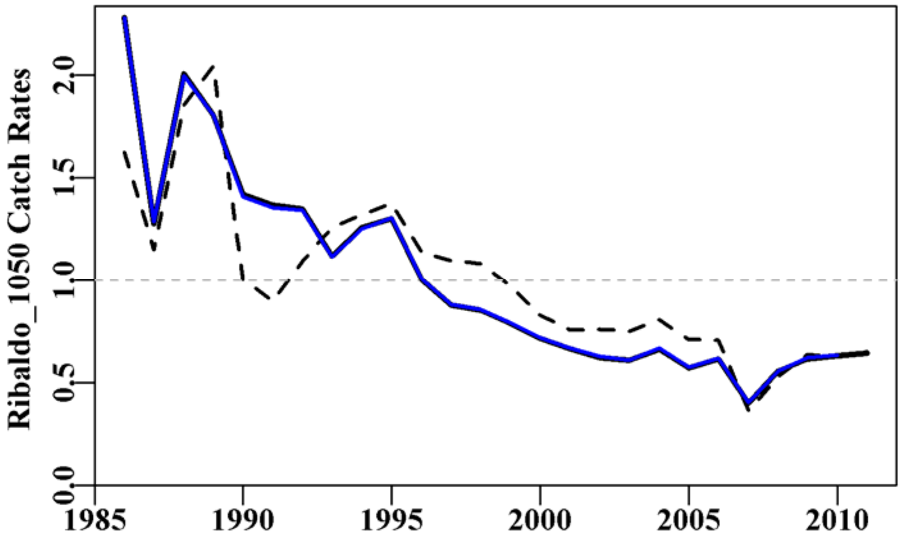

Figure 13.151**.** Ribaldo from Zones 10 to 50 in depths 0 to 1000 m by trawl. The dashed black line represents the geometric mean catch rate and the solid black line the standardized catch rates. The graph standardizes catch rates relative to the mean of the standardized catch rates.

Table 13.129**.** Ribaldo from Zones 10 to 50 in depths 0 to 1000 m by trawl. Statistical model structures used in this analysis. DepCat is a series of 50 metre depth categories.

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

Table 13.130. Ribaldo from Zones 10 to 50 in depths 0 to 1000 m by trawl. Model selection criteria, including the AIC, the adjusted r^2 and the change in adjusted r^2. The optimum is Zone:Month (model 7).

	Year	Vessel	DepCat	Zone	DayNight	Month	Zone:Mth	Zone:DepC
AIC	-2112	-4223	-6347	-6990	-7097	-7127	-7595	-7373
RSS	16983	15011	13226	12779	12702	12667	12300	12241
MSS	1605	3577	5363	5810	5887	5921	6289	6347
Nobs	19029	19029	18893	18893	18893	18893	18893	18893
Npars	26	145	195	199	202	213	257	413
adj_r2	8.516	18.629	28.111	30.528	30.933	31.081	32.923	32.678
%Change	0.000	10.113	9.482	2.417	0.405	0.149	1.841	-0.244

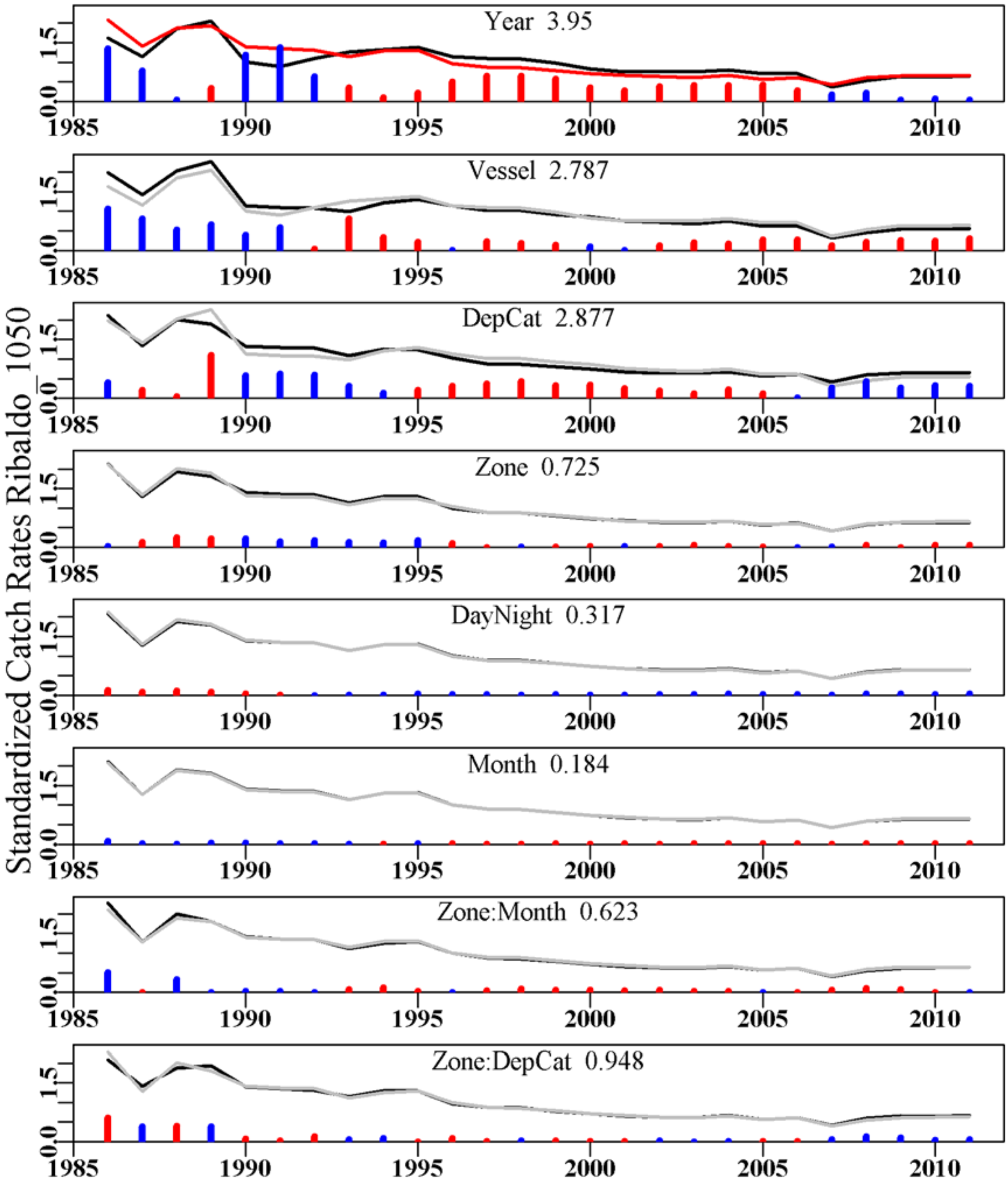

Figure 13.152**.** The relative influence of each factor used on the final trend in the optimal standardization for Ribaldo from Zones 10 to 50. The top graph depicts the geometric mean (the black line) and the optimum model (the red line). The difference between them is illustrated by the vertical bars with blue bars indicating the optimum model is higher than the geometric mean and red bars indicating it is lower. The top graph bars are the sum of all the bars in the graphs below. The graphs for individual factors are cumulative. Thus the second graph has the geometric mean (grey line) and the effect of adding Year + factor2 (model 2). In the third graph, the grey line represents model 2 and the black line the effect of adding factor3 to the model. The remaining graphs continue in the same cumulative manner except for the interaction terms which are added singularly to the final single factor model.

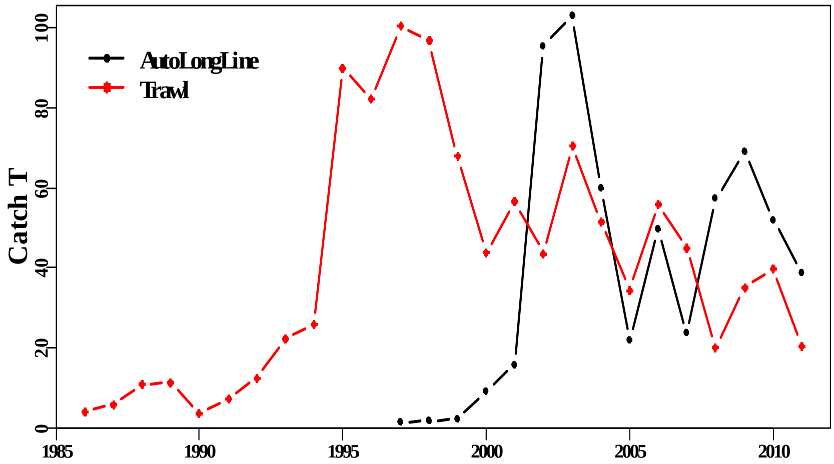

Figure 13.153**.** Ribaldo, all zones 10-50, plus the GAB and north of Barrenjoey. Catches by the two main methods, trawl and AutoLongLine. As with trawling, most catches by AutoLongLine are taken in zones 20-50.

13.48.1 The Effect of Closures

An alternative analysis was conducted (Haddon (2010) that included a factor for inside and outside of the current deepwater closures. After the other single factors had been included in the standardization there was no significant effect of being inside or outside of a closure.

By considering the current deepwater closures and identifying each shot with respect to its starting position the catches within and outside the closures can be characterized (Figure 13.154, Figure 13.155, Table 13.131).

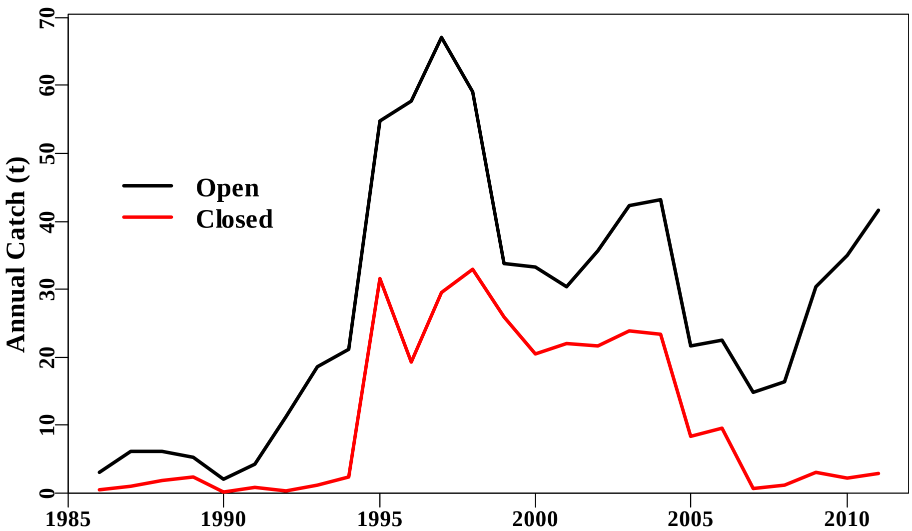

Figure 13.154. The annual catches of Ribaldo taken by trawl inside and outside of declared deepwater closures. The low catches taken from 2008 onwards derive from the precision of the available location data to discern all shots that are taken along the outer edge of a closure.

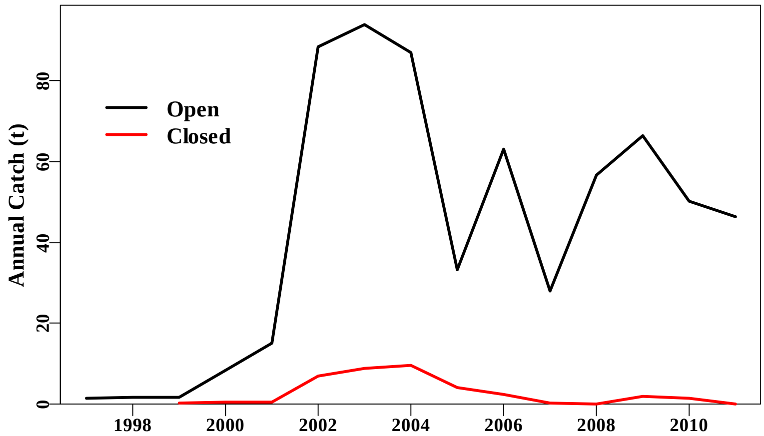

Figure 13.155. The annual catches of Ribaldo taken by AutoLine inside and outside of declared deepwater closures. The low catches taken from 2008 onwards derive from the precision of the available location data to discern all shots that are taken along the outer edge of a closure.

Table 13.131. Catches of Ribaldo by Trawl and AutoLine in open and closed areas.

	Trawl		AutoLine	
Year	Open	Closed	Open	Closed
1986	3.054	0.470		
1987	6.173	1.119		
1988	6.082	1.967		
1989	5.266	2.445		
1990	2.144	0.115		
1991	4.278	0.884		
1992	11.354	0.335		
1993	18.539	1.223		
1994	21.175	2.447		
1995	54.787	31.512		
1996	57.647	19.365		
1997	67.066	29.501	1.375	0.030
1998	59.008	33.007	1.753	
1999	33.724	25.944	1.687	0.260
2000	33.332	20.513	8.486	0.553
2001	30.350	22.040	15.110	0.610
2002	35.577	21.695	88.474	7.023
2003	42.289	23.891	93.960	8.922
2004	43.108	23.309	87.052	9.537
2005	21.626	8.421	33.177	4.013
2006	22.564	9.520	63.046	2.329
2007	14.802	0.769	27.887	0.239
2008	16.348	1.271	56.655	0.118
2009	30.393	3.017	66.447	1.827
2010	35.040	2.265	50.216	1.472
2011	41.630	2.925	46.364	0.113

13.49 Ribaldo (RBD – 37224002 – Mora moro) AutoLine

Table 13.132. Ribaldo taken by Autoline in Zones 20,30 40,50,81,82,83,84,85 in depths 0 to 1000 m. Total Catch is the total reported in the database, Records is the number of records used in the analysis, CatchT is the reported catch in the area and depth used in the analysis, and Vessels relates to all vessels used in the analysis. Geomean is the geometric mean of catch rates (kg/hr). Zone:Month is the optimum model and StDev is the standard deviation relating to the data in the optimum model.

Year	TotCatch	Records	CatchT	Vessels	GeoMean	Zone:Month	StDev
2001	82.479	63	15.720	2	157.4316	1.0602	0.0000
2002	157.878	259	95.497	4	135.9460	2.3811	0.1817
2003	181.036	337	102.882	7	75.0323	1.6703	0.1786
2004	180.961	714	96.589	11	51.6307	1.3981	0.1736
2005	90.375	308	37.189	7	44.5029	0.7914	0.1801
2006	122.615	605	65.374	8	39.5786	0.8238	0.1739
2007	78.314	393	28.125	6	25.0254	0.4843	0.1771
2008	78.475	401	56.772	6	39.2440	0.5789	0.1750
2009	104.960	432	68.270	6	49.8911	0.5870	0.1727
2010	92.104	381	51.687	5	47.4986	0.5594	0.1751
2011	94.029	356	46.476	5	45.6603	0.6656	0.1754

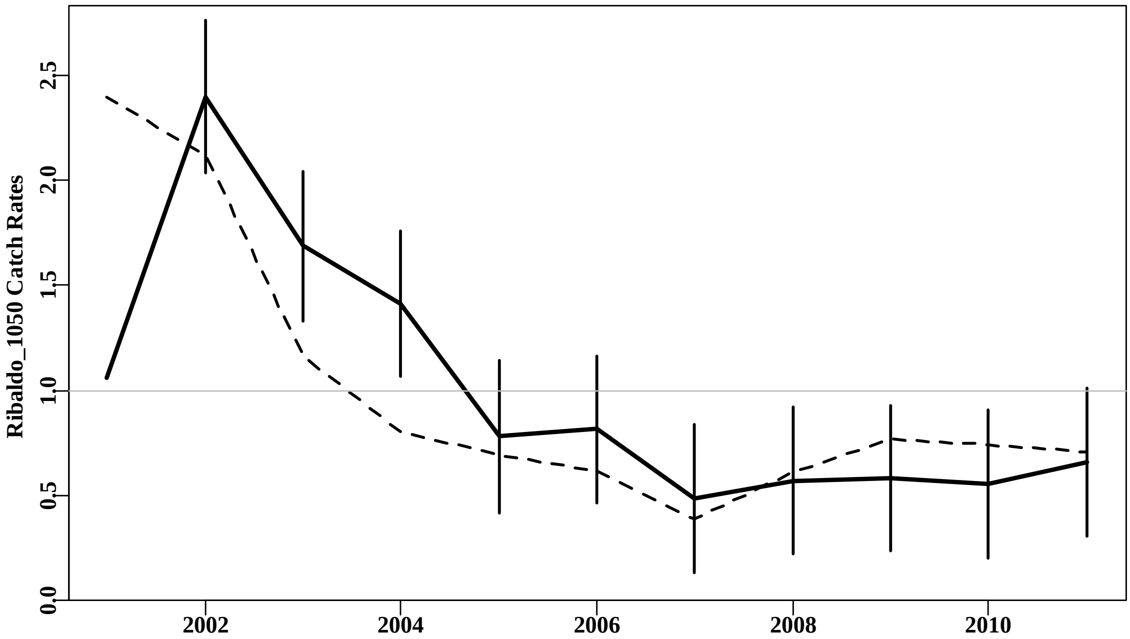

Figure 13.156. Standardized catch rates for Ribaldo by Autoline. The dashed black line represents the geometric mean catch rate and the solid black line the standardized catch rates. The graph standardizes catch rates relative to the mean of the standardized catch rates. The vertical black lines represent 1.96 times the standard errors. The same statistical models that were used for the trawl analysis were also used here (Table 13.129).

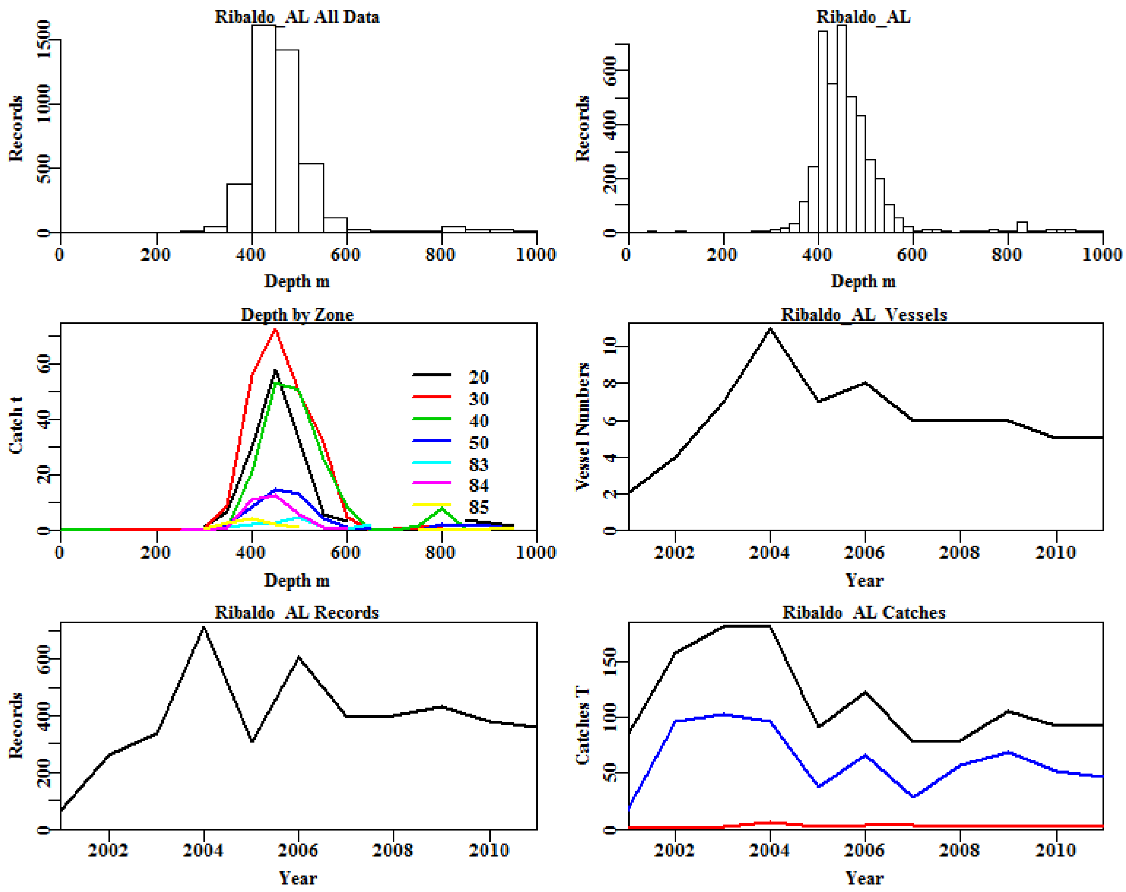

Figure 13.157. Ribaldo by Autoline. The top left is the depth distribution of all records reporting Ribaldo taken by autoline, the top right graph depicts the depth distribution of shots containing Ribaldo taken by Autoline as used in the standardization. The middle left diagram depicts the distribution of catch by depth within each zone, the middle right hand graph depicts the number of vessels through time. The bottom left reflects the number of records used in analysis, and bottom right is the Ribaldo catches (top line, black is total catches, middle line, blue, are those used in the analysis, and bottom, red, are catches < 30Kg).

Table 13.133**.** Ribaldo taken by Autoline. Model selection criteria, including the AIC, the adjusted r^2 and the change in adjusted r^2. The optimum is Zone:Month (model 7).

	Year	Vessel	DepCat	Zone	DayNight	Month	Zone:Mth	Zone:DepC
AIC	3784	2277	1991	1925	1903	1841	1707	2113
RSS	10300	7185	6580	6455	6413	6287	5874	5875
MSS	648	3764	4369	4493	4536	4661	5074	5074
Nobs	4250	4250	4236	4236	4236	4236	4236	4236
Npars	11	23	63	70	73	84	161	364
adj_r2	5.700	34.036	39.011	40.063	40.413	41.428	44.240	41.314
%Change	0.000	28.337	4.974	1.053	0.350	1.014	2.812	-0.114

13.50 Ocean Jackets (LTC – 37465006 – *Nelusetta ayraudi*)

Alternate: LeatherJackets (LTH – 37465000)

Only data from Zones 10 to 50 in depths 0 – 300m. All vessels and records reporting leatherjackets are included. This is the first year this data has been considered.

Table 13.134**.** Ocean Jackets from Zones 10 to 50 in depths 0 to 300 m by trawl. Total Catch is the total reported in the database, Records is the number of records used in the analysis, CatchT is the reported catch in the area and depth used in the analysis, and Vessels relates to all vessels used in the analysis. Geomean is the geometric mean of catch rates (kg/hr). Zone:DepCat is the optimum model and StDev is the standard deviation relating to the data in the optimum model.

Year	TotCatch	Records	CatchT	Vessels	GeoMean	Zone:DepCat	StDev
1986	56.429	2473	44.715	75	5.0337	0.6900	0.0000
1987	53.354	1445	28.151	61	5.1085	0.7302	0.0357
1988	66.304	1911	45.725	66	6.2067	0.8855	0.0332
1989	71.666	1808	32.778	65	4.8860	0.7620	0.0338
1990	90.969	1548	33.157	46	4.9715	0.7474	0.0357
1991	170.481	1329	24.788	46	4.4265	0.6489	0.0375
1992	88.884	1127	22.074	40	4.7352	0.6445	0.0392
1993	71.897	1342	29.245	42	5.0852	0.7226	0.0380
1994	74.438	1455	35.044	45	5.9717	0.8095	0.0366
1995	140.179	2237	59.316	42	5.9904	0.8226	0.0331
1996	199.571	2576	72.307	54	6.3230	0.8599	0.0323
1997	177.419	2009	52.492	51	5.4540	0.7762	0.0341
1998	189.899	2488	68.017	44	5.2603	0.7632	0.0327
1999	202.805	2691	88.415	52	7.0029	0.9046	0.0321
2000	198.811	2983	73.176	51	5.1836	0.7116	0.0318
2001	222.570	3160	63.794	55	4.2040	0.6267	0.0317
2002	378.516	4863	199.088	61	5.4894	0.7472	0.0298
2003	482.582	5503	187.624	58	5.0890	0.7125	0.0293
2004	692.874	6214	313.391	60	8.3226	1.1598	0.0289
2005	890.644	5162	342.889	54	9.8920	1.3488	0.0297
2006	741.530	4636	301.737	50	10.2758	1.4852	0.0303
2007	564.833	3092	285.396	27	14.0314	1.7918	0.0326
2008	490.402	3554	318.317	29	13.7150	1.6963	0.0320
2009	609.980	3260	376.112	28	16.0145	1.8956	0.0325
2010	484.039	3258	300.273	29	13.2712	1.5906	0.0325
2011	487.141	3220	277.118	29	12.3501	1.4670	0.0325

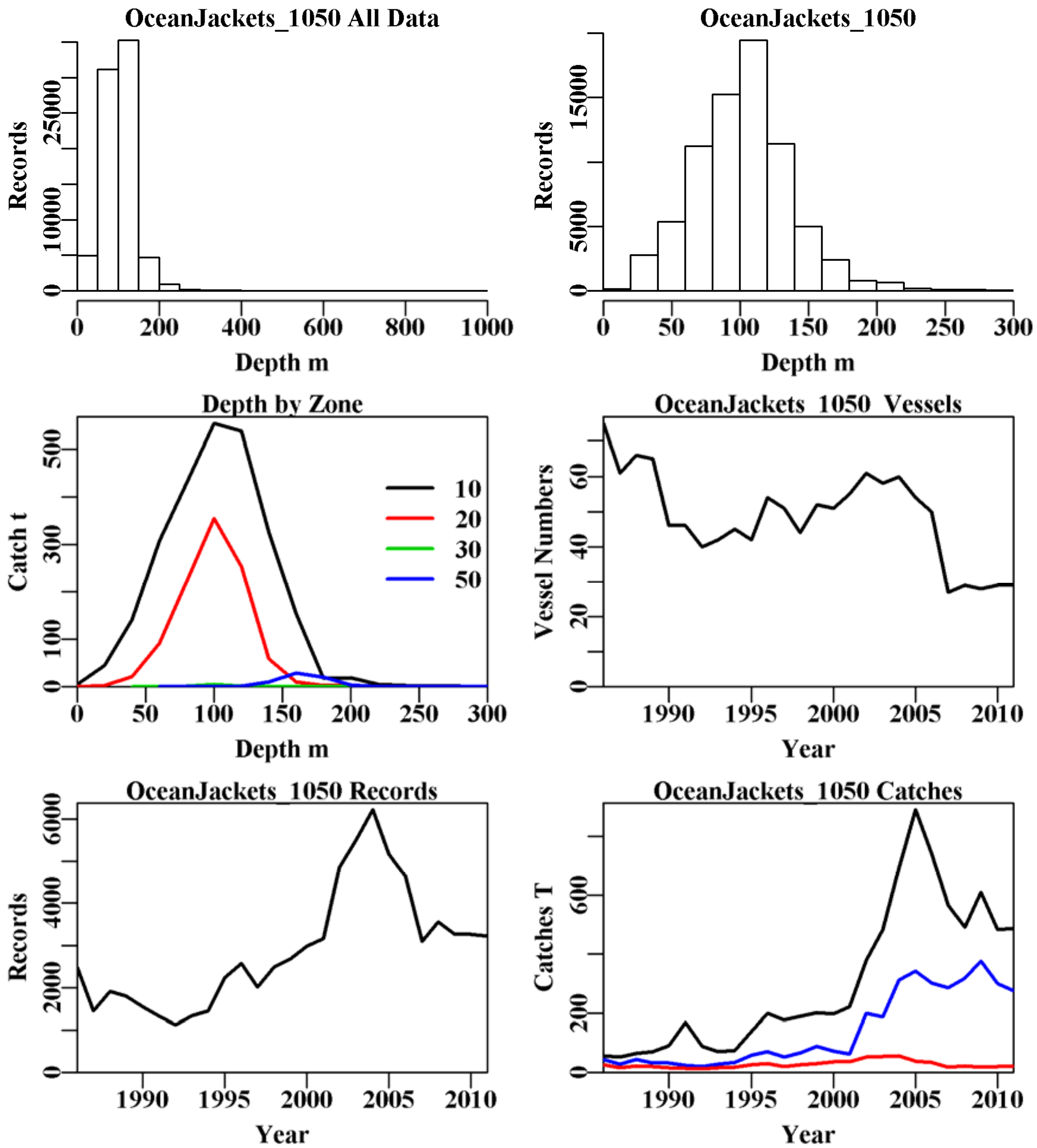

Figure 13.158**.** Ocean Jackets from Zones 10 to 50 in depths 0 to 300 m by trawl. The top left is the depth distribution of all records reporting Leatherjackets, the top right graph depicts the depth distribution of shots containing Ocean Jackets from Zones 10 to 50 in depths 0 to 300 m by trawl. The middle left diagram depicts the distribution of catch by depth within zones 10 to 50, the middle right hand graph depicts the number of vessels through time. The bottom left reflects the number of records used in analysis, and bottom right is the Leatherjacket catches (top line, black is total catches, middle line, blue, are those used in the analysis, and bottom, red, are catches < 30Kg).

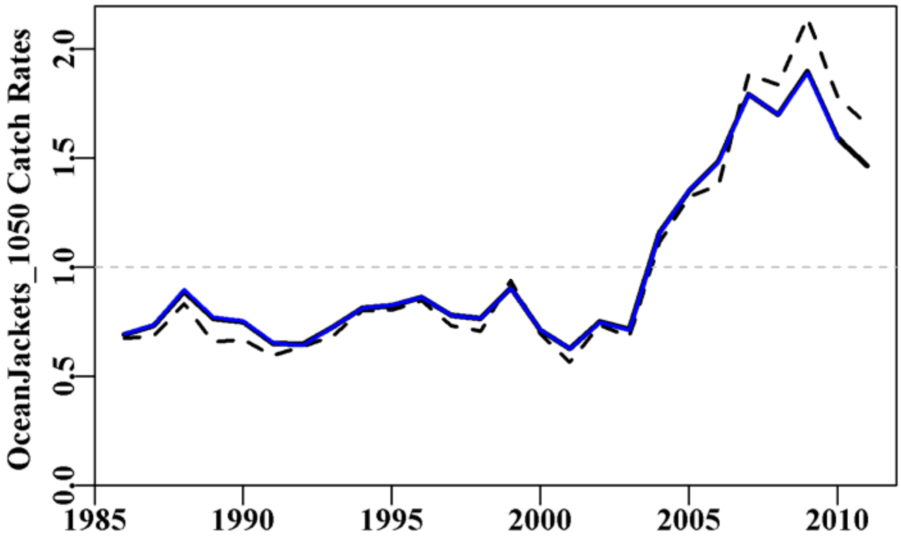

Figure 13.159. Ocean Jackets from Zones 10 to 50 in depths 0 to 300 m by trawl. The dashed black line represents the geometric mean catch rate and the solid black line the standardized catch rates. The graph standardizes catch rates relative to the mean of the standardized catch rates. The fine vertical lines are the 95% confidence intervals. The horizontal blue line is at one, which is the average of the time series. If the standardization is only applied to data from Zones 10 and 20 differences occur only at the third decimal place in the standardization.

Table 13.135. Ocean Jackets from Zones 10 to 50 in depths 0 to 300 m by trawl. Statistical model structures used in this analysis. DepCat is a series of 20 metre depth categories.

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

Table 13.136. Ocean Jackets from Zones 10 to 50 in depths 0 to 300 m by trawl. Model selection criteria, including the AIC, the adjusted r^2 and the change in adjusted r^2. The optimum is Zone:DepCat (model 8).

	Year	Vessel	DepCat	Month	Zone	DayNight	Zone:Mth	Zone:DepC
AIC	13804	534	216	-301	-763	-827	-987	-1620
RSS	90431	75496	74654	74118	73656	73586	73365	72724
MSS	12793	27728	28570	29106	29568	29637	29859	30500
Nobs	75344	75344	74849	74849	74849	74849	74849	74849
Npars	26	191	206	217	220	223	256	268
adj_r2	12.364	26.677	27.479	27.989	28.435	28.500	28.684	29.295
%Change	0.000	14.312	0.802	0.510	0.446	0.065	0.184	0.611

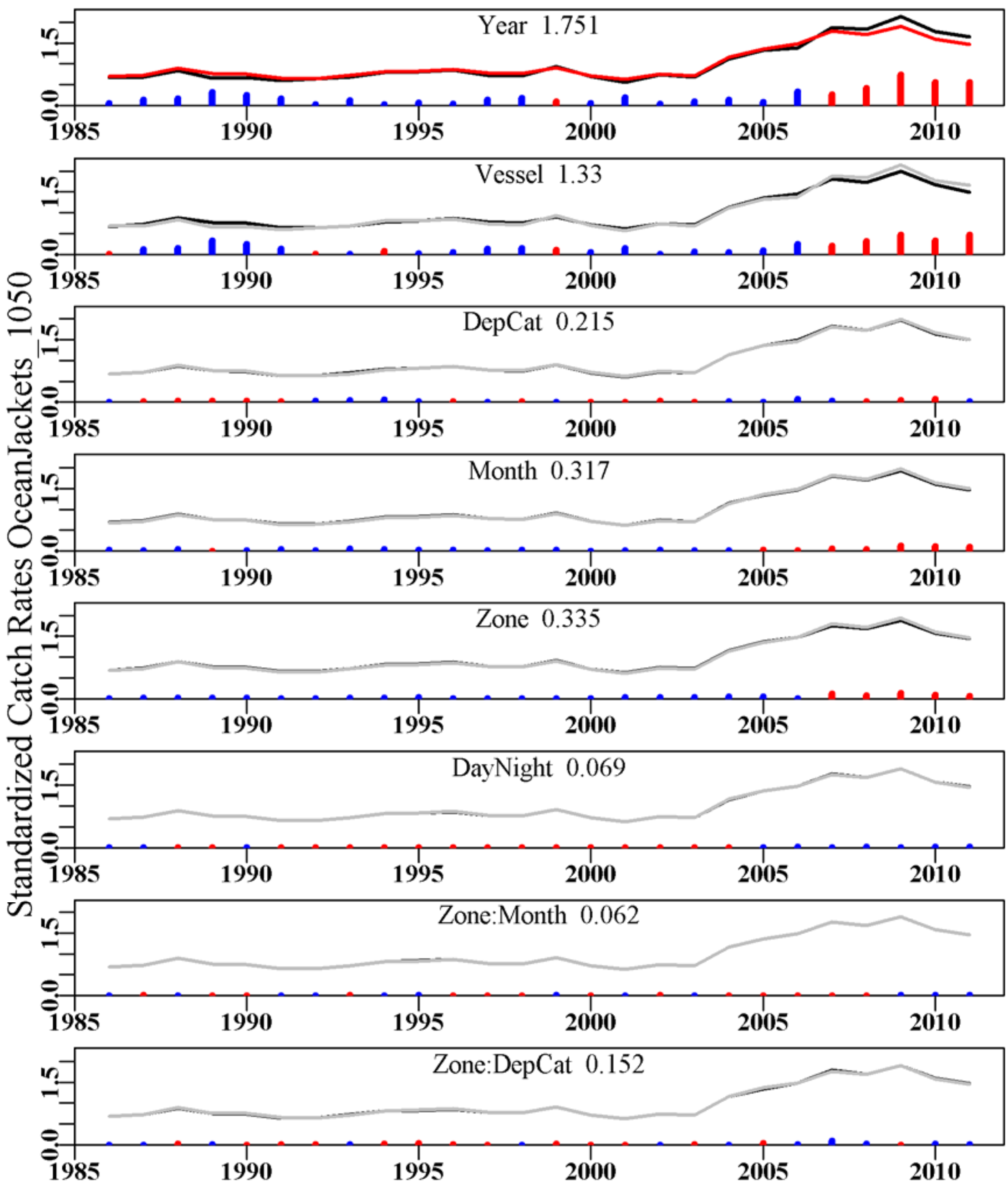

Figure 13.160**.** The relative influence of each factor used on the final trend in the optimal standardization for Ocean Jackets from Zones 10 to 50. The top graph depicts the geometric mean (the black line) and the optimum model (the red line). The difference between them is illustrated by the vertical bars with blue bars indicating the optimum model is higher than the geometric mean and red bars indicating it is lower. The top graph bars are the sum of all the bars in the graphs below. The graphs for individual factors are cumulative. Thus the second graph has the geometric mean (grey line) and the effect of adding Year + factor2 (model 2). In the third graph, the grey line represents model 2 and the black line the effect of adding factor3 to the model. The remaining graphs continue in the same cumulative manner except for the interaction terms which are added singularly to the final single factor model.

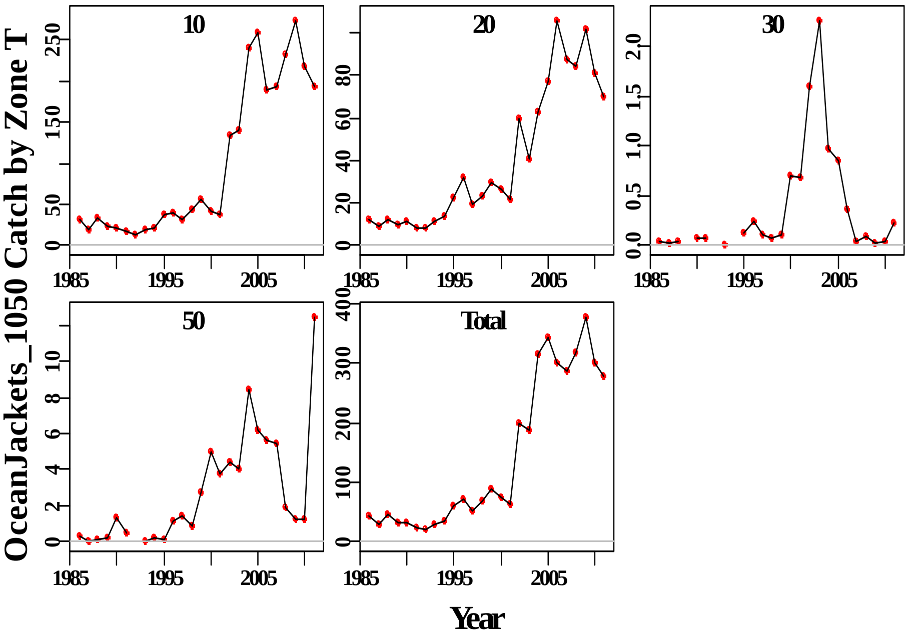

Figure 13.161. Ocean Jackets from Zones 10 to 50 in depths 0 to 300 m by trawl. The catches taken in each of the four main SESSF zones is depicted with the total catch across these zones. The scales on the y-axis changes between graphs.

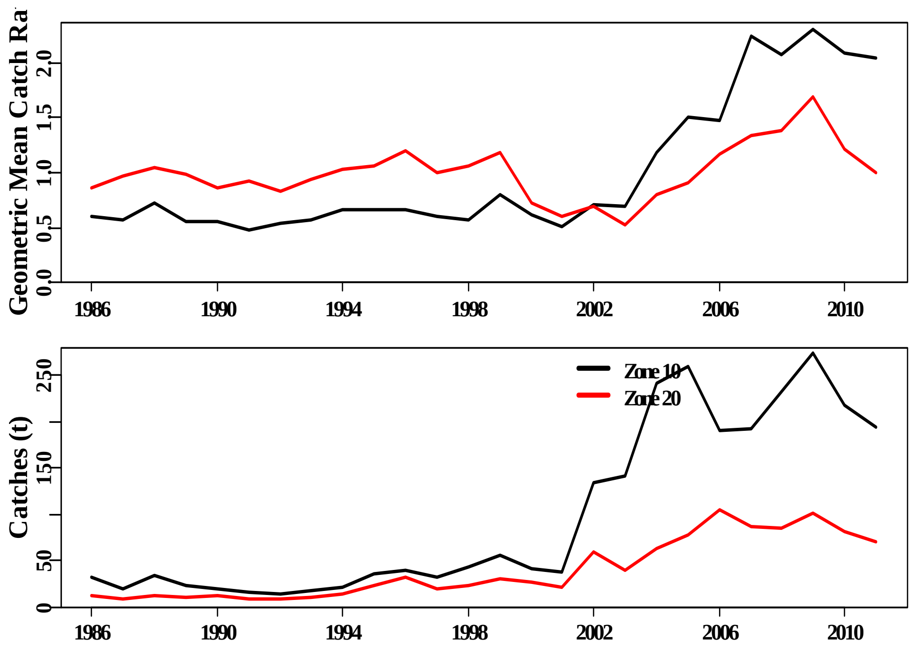

Figure 13.162. Trends in catches and geometric mean catch rates for zones 10 and 20. The catches in the other zones remains too low to be informative about catch rates.

Table 13.137. Ocean Jackets, catch by zone. Only those zones reporting more than 5 tonnes over the years are included (Zone 40 is included for completeness). Zones 82 and 83 are in the GAB and are not included in the CPUE standardization above. See Figure 13.161

Zone	10	20	30	40	50	60	82	83
1977							4.465	2.487
1978							373.114	25.268
1979							40.664	0.517
1985	15.299	6.450	0.205		0.551	2.097		
1986	32.330	12.456	0.040		0.366	1.505	6.900	1.620
1987	19.467	9.655	0.025		0.075	0.329	22.794	0.168
1988	33.812	12.793	0.042		0.175	1.186	15.259	0.361
1989	23.302	10.381			0.265	0.603	24.463	11.057
1990	22.457	12.412	0.075		1.335	2.109	4.336	47.775
1991	18.174	8.984	0.065		0.560	0.834	49.655	91.172
1992	17.790	8.742			0.030	0.406	19.869	41.280
1993	19.052	11.435	0.010		0.050	0.398	19.048	20.096
1994	21.729	13.920	0.060		0.229	0.363	21.415	15.757
1995	36.659	22.843	0.130		0.160	0.434	34.935	44.667
1996	39.696	31.988	0.270	0.035	1.280	0.592	60.575	64.399
1997	32.263	19.767	0.101	0.005	1.393	0.735	57.039	64.664
1998	43.919	23.707	0.070		0.901	0.577	51.033	66.430
1999	56.431	30.112	0.106		2.784	1.528	43.265	66.750
2000	41.329	26.344	0.705	0.001	5.116	0.152	42.115	82.373
2001	38.970	23.082	0.722		3.830	0.545	68.411	79.797
2002	134.630	61.212	1.611	0.021	4.488	0.193	79.197	69.986
2003	145.927	43.126	2.257	0.005	4.174	0.650	99.595	183.790
2004	242.908	64.483	0.973	0.321	8.713	0.885	146.522	220.003
2005	262.599	80.953	0.860	0.015	6.454	2.130	222.886	304.358
2006	192.177	108.936	0.358		5.870	2.600	143.171	270.716
2007	194.781	99.582	0.045	0.065	5.530	1.410	116.410	140.539
2008	235.622	96.248	0.137		1.947	1.439	42.070	105.828
2009	277.180	106.624	0.015		1.355	1.647	83.024	137.576
2010	220.167	86.237	0.045		1.400	1.637	82.178	86.630
2011	197.143	78.452	0.225		12.764	2.262	65.644	129.319
Total	2615.811	1110.923	9.149	0.467	71.793	29.245	2040.050	2375.382

13.51 Ocean Jackets – GAB (LTC – 37465006 – N. ayraudi)

Alternate: LeatherJackets (LTH – 37465000)

Only data from Zones 82 and 83 in the GAB in depths 0 – 300m. All vessels and records reporting leatherjackets are included. This is the first year this data has been considered.

Table 13.138**.** Ocean Jackets from Zones 82 and 83 in depths 80 to 220 m by trawl. Total Catch is the total reported in the database, Records is the number of records used in the analysis, CatchT is the reported catch in the area and depth used in the analysis, and Vessels relates to all vessels used in the analysis. Geomean is the geometric mean of catch rates (kg/hr). Zone:Month is the optimum model and StDev is the standard deviation relating to the data in the optimum model.

Year	TotCatch	Records	CatchT	Vessels	GeoMean	Zone:Month	StDev
1986	56.429	141	8.490	1	11.5206	1.2913	0.0000
1987	53.354	212	22.632	3	13.7002	1.0634	0.1115
1988	66.304	245	15.590	7	14.0350	1.2440	0.1950
1989	71.666	576	34.714	7	11.9652	1.2598	0.1932
1990	90.969	920	51.380	11	11.1086	0.8543	0.1907
1991	170.481	1252	139.797	8	15.0694	1.0924	0.1901
1992	88.884	954	59.534	7	9.0287	0.9602	0.1900
1993	71.897	819	38.764	4	6.3105	0.6543	0.1899
1994	74.438	745	36.660	5	5.7741	0.5675	0.1907
1995	140.179	1316	78.832	5	6.2242	0.7460	0.1893
1996	199.571	1725	123.469	6	7.8262	0.8679	0.1889
1997	177.419	2135	121.064	9	6.4622	0.7189	0.1889
1998	189.899	1799	116.437	9	7.1373	0.7804	0.1890
1999	202.805	1585	108.970	7	7.8084	0.9009	0.1893
2000	198.811	1540	121.614	5	7.8119	0.9264	0.1895
2001	222.570	1877	138.429	6	8.7175	0.9556	0.1894
2002	378.516	1788	147.551	6	9.0818	1.0093	0.1894
2003	482.582	2837	279.605	9	10.8621	1.1495	0.1891
2004	692.874	3433	364.440	9	12.7575	1.2370	0.1890
2005	890.644	4317	522.910	10	13.9012	1.3275	0.1889
2006	741.530	3609	408.448	11	12.0564	1.0231	0.1890
2007	564.833	2647	254.851	8	10.2989	0.9211	0.1893
2008	490.402	2351	146.362	6	7.4758	0.8048	0.1894
2009	609.980	2160	219.965	4	10.4196	1.1106	0.1894
2010	484.039	1792	168.203	4	12.6091	1.2685	0.1898
2011	487.141	1877	192.596	4	13.0498	1.2653	0.1897

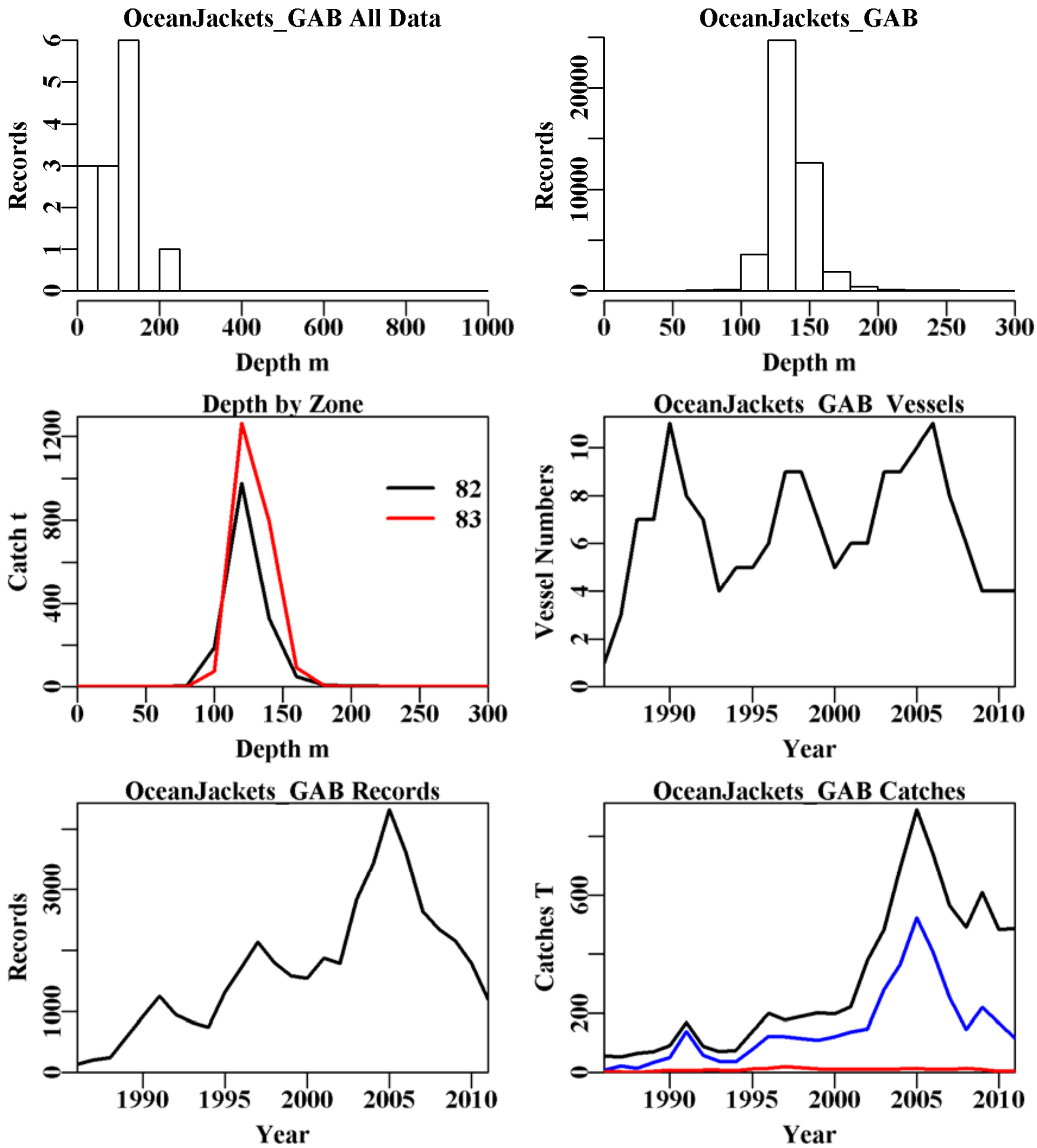

Figure 13.163**.** Ocean Jackets from Zones 82 and 83 in depths 80 to 220 m by trawl. The top left is the depth distribution of all records reporting Leatherjackets, the top right graph depicts the depth distribution of shots containing Ocean Jackets from Zones 82 and 83 in depths 80 to 220 m by trawl. The middle left diagram depicts the distribution of catch by depth within zones 82 and 83, the middle right hand graph depicts the number of vessels through time. The bottom left reflects the number of records used in analysis, and bottom right is the Leatherjacket catches (top line, black is total catches, middle line, blue, are those used in the analysis, and bottom, red, are catches < 30Kg).

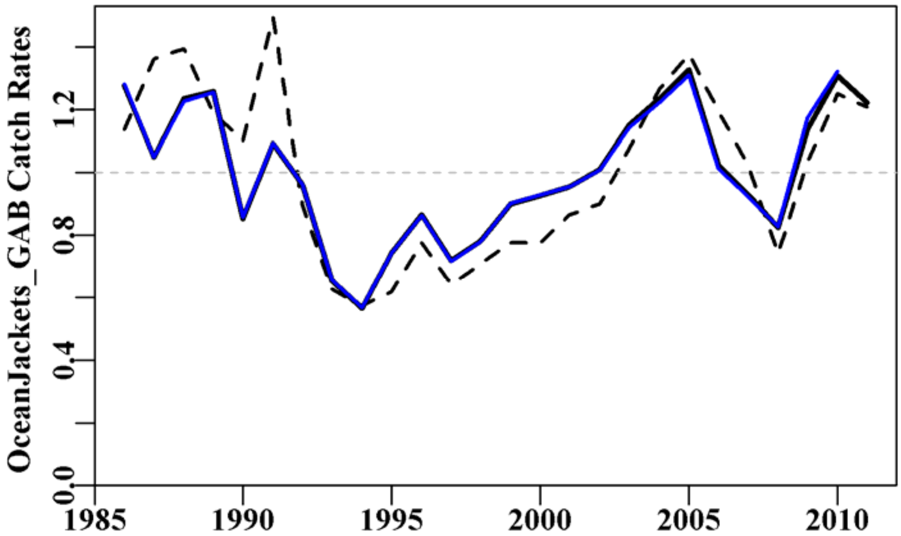

Figure 13.164**.** Ocean Jackets from Zones 82 and 83 in depths 80 to 220 m by trawl. The dashed black line represents the geometric mean catch rate and the solid black line the standardized catch rates. The graph standardizes catch rates relative to the mean of the standardized catch rates. The fine vertical lines are the 95% confidence intervals. The horizontal blue line is at one, which is the average of the time series. This is the first time this analysis has been conducted.

Table 13.139. Ocean Jackets from Zones 82 and 83 in depths 80 to 220 m by trawl. Statistical model structures used in this analysis. DepCat is a series of 20 metre depth categories.

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

Table 13.140**.** Ocean Jackets from Zones 82 and 83 in depths 80 to 220 m by trawl. Model selection criteria, including the AIC, the adjusted r^2 and the change in adjusted r^2. The optimum is Zone:Month (model 8).

	Year	Vessel	DepCat	Zone	DayNight	Month	Zone:Mth	Zone:DepC
AIC	5879	1182	-1071	-3298	-4471	-4498	-4744	-4516
RSS	50877	45790	43094	40913	39823	39797	39557	39754
MSS	3204	8291	10987	13167	14257	14284	14524	14327
Nobs	44652	44652	44238	44238	44238	44238	44238	44238
Npars	26	29	44	79	90	91	102	106
adj_r2	5.872	15.277	20.238	24.214	26.214	26.262	26.688	26.316
%Change	0.000	9.405	4.960	3.977	2.000	0.048	0.426	-0.372

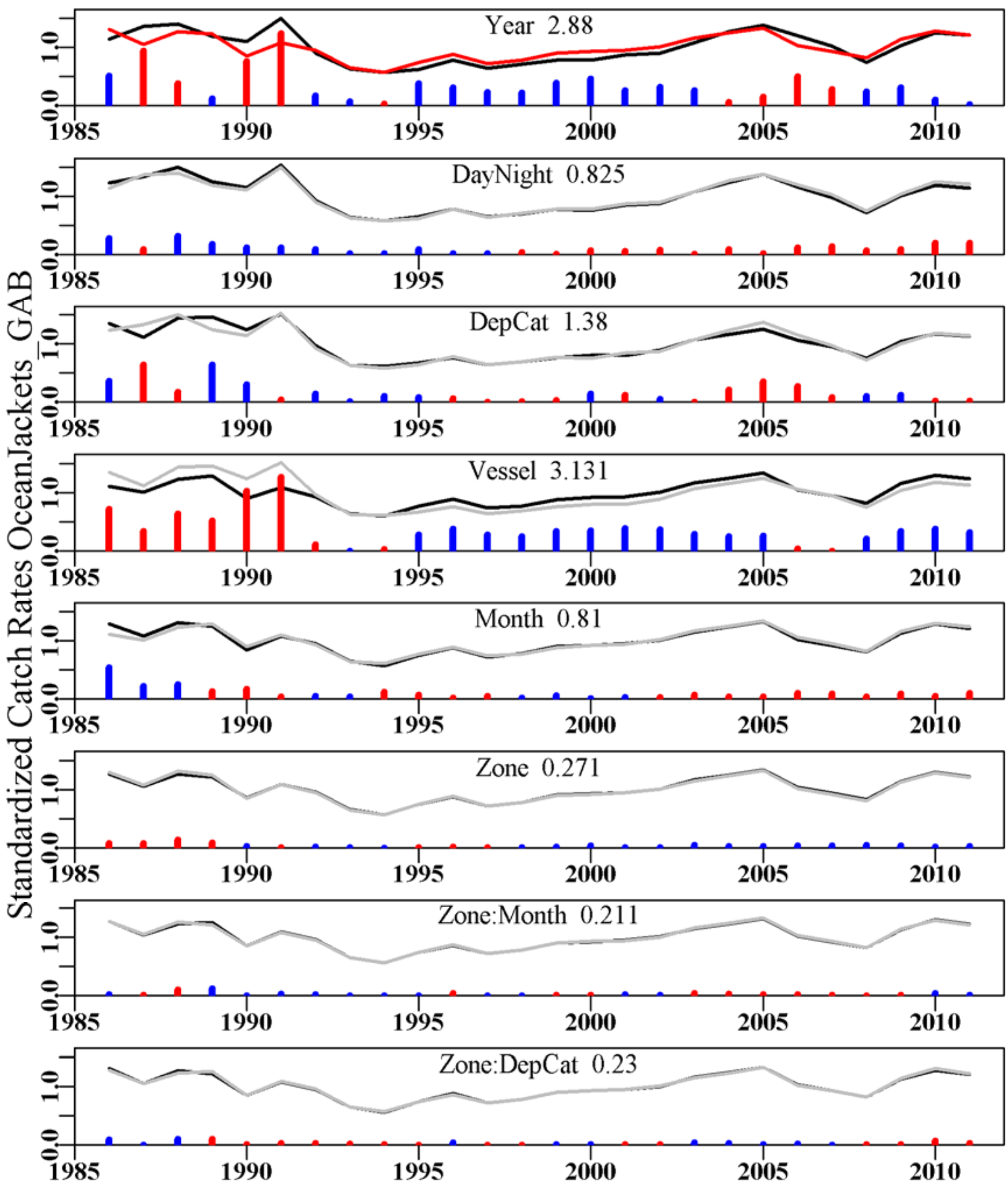

Figure 13.165**.** The relative influence of each factor used on the final trend in the optimal standardization for Ocean Jackets from Zones 82 and 83. The top graph depicts the geometric mean (the black line) and the optimum model (the red line). The difference between them is illustrated by the vertical bars with blue bars indicating the optimum model is higher than the geometric mean and red bars indicating it is lower. The top graph bars are the sum of all the bars in the graphs below. The graphs for individual factors are cumulative. Thus the second graph has the geometric mean (grey line) and the effect of adding Year + factor2 (model 2). In the third graph, the grey line represents model 2 and the black line the effect of adding factor3 to the model. The remaining graphs continue in the same cumulative manner except for the interaction terms which are added singularly to the final single factor model.

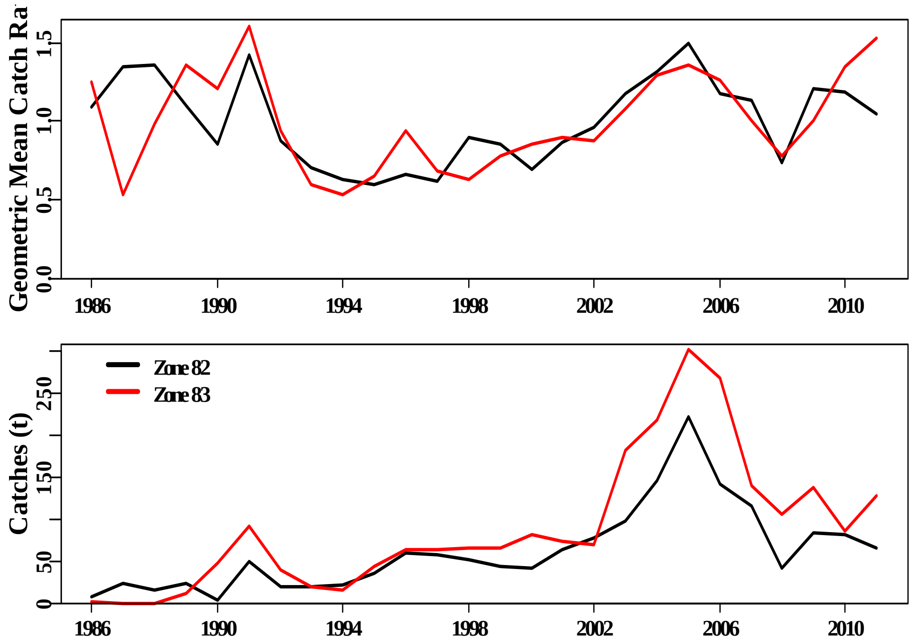

Figure 13.166. Trends in catches and geometric mean catch rates for zones 82 and 83 in the GAB. The catches in the other zones remains too low to be informative about catch rates.

13.52 Bibliography

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

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14. Catch Rate Standardization Updates with Data to Oct 2012

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14.1 Summary

In order that the most recent catch rate data might influence the TAC setting procedures the most up-to-data catch and effort data were sent for analysis from AFMA. Using standard extracts and analyses the commercial catch and effort data, to October 2012, were standardized and the ratio of the 2012 and 2011 indices were compared and used as the basis for calculating the TAC Multiplier in each fishery.

A total of 24 standardizations were conducted which related to a total of 16 TACs considered. In 14 of the 16 fisheries the TAC Multiplier was between 0.9 – 1.1 meaning they implied less than a 10% increase or decrease to the allocated TAC. However, there were two fisheries, Royal Red Prawn and Blue grenadier where the final TAC multiplier was only 0.86 and 0.84 respectively. However, an inspection of the standardization with its error bars indicates that the catch rates have simply returned to the long run average. Blue grenadier certainly exhibits a strong decline in its catch rates for the non-spawning fishery.

This year Inshore and Offshore Ocean Perch were treated separately. Inshore Ocean Perch were only just above the 10% threshold for a reduction.

The fishery for Silver Trevally was a special case because of the influence of the Batemans Bay marine protected area. Previously, catch rate standardizations have removed records taken within State waters within the MPA. However, now that there is sufficient data available to determine empirically where the fishers are no longer reporting catches it becomes apparent that removing all State waters is too stringent and removes too many records. An improved analysis is given here but it has no effect on the update calculations which only relate to the last two years.

The TAC Multiplier is based upon a comparison of two years of catch rate data. The Tier 4 method usually uses an average of the four most recent years while the tier 3 is a fishing mortality based method that ignores catch rates. It should be remembered that the CPUE multiplier places exceptional emphasis on catch rates, which is a potential problem for those species where catch rates are becoming less informative.

The RAG has not considered that applying this catch rate meta-rule to those species where Industry members report avoidance is occurring or which are not directly targeted may produce anomalous results leading to reductions in TAC that are not strictly warranted. Further discussion is required to confirm whether this TAC Multiplier approach should be approved for all fisheries or only selected ones.

14.2 Introduction

14.2.1 The Catch Rate Multiplier Rule

In recent years, industry members have voiced concerns that the SESSF stock assessments, and therefore the resultant TACs, are conducted using data that are at least 12 months old. For example, to calculate the RBCs and set the TACs for 2013, data from the fisheries up to the end of 2011 are analysed but usually data from 2012 are unavailable. The SESSF industry were therefore concerned that the most recent information regarding stock availability and/or relative abundance was not being used to inform the most recent assessments of stock status and thus influence the TAC setting procedures. To mitigate this perceived problem it was proposed that management needed to include the most recent year's CPUE data when deriving the proposed TACs.

CSIRO, in dialogue with RAG Chairs, developed a rule by which TACs can be adjusted based on recent CPUE trends (described in the Methods). MSE testing of the procedure was applied to TIERs 1, 3, and 4 so it was assumed that this rule could be applied to the outcomes of assessments from all Tiers. The rule requires generating the natural log of the ratio of catch rates between the most recent year and the previous year (e.g. 2012 with 2011). If there is more than one significant fishing method within a particular fishery, or different regions in the fishery are considered separately in the assessment, then the RAGs decided that a catch weighted ratio of the analysis on both approaches or multiple regions (or both) was to be used. The use of log-transformed catch rates focuses on proportional changes and ensures that increases and decreases in catch rates give rise to the same adjustment to the RBC, up or down (Thomson *et al.,* 2008). The effects of this rule have been explored using management strategy evaluation (Wayte *et al.,* 2009). This rule has not been applied by the Shark RAG or Deep RAG. The GAB RAG has an alternative meta-rule (Haddon, 2012b).

The simulation tests (Wayte *et al*, 2009) indicate that the use of the catch rate adjustment rule does not significantly alter the performance of the harvest strategy being applied to a particular fishery. This means there is no increased risk to the stock and overall catch levels are not affected in the long term, although, not surprisingly, applying the rule does significantly increase year-to-year catch variability.

Nevertheless, there are some other issues with the use of this rule. It constitutes an increase in the weight given to the most recent CPUE trends above other factors in stock assessments (although this is only a temporary increase in influence). It is questionable whether it should be applied to those fisheries assessed using a TIER 4 approach. The TIER 4 method estimates the RBC using the average of the catch rates from the last four year's. By focussing attention on the catch rates from the very last year this is changing the intent of the assessment method.

After discussions with RAG chairs, stock assessment scientists and industry, the preference is to apply the rule to all species for the purposes of calculating final TACs for each fishing season. However, while the MSE did not find any negative effects of using catch rates from just the last year (the outcome was effectively adding noise to the time series) this still appears to circumvent the intention of the assessment method and this should be discussed. Similarly with the TIER 3 assessments, the TIER 3 approach is based around estimating fishing mortality based performance measures and it should also be discussed whether the intent of the method is being subverted by using the one year catch rate rule.

14.3 Methods

14.3.1 The Balanced Multiplier Rule

The TAC modifying rule is simply the original TAC from the given stock assessment multiplied by a proportional increase or decrease depending on the ratio of the most recent catch rate to the previous catch rate:

$$TAC_{new} = TAC_{ass}\left(1 + \alpha\hat{R}\right) \tag{4}$$

In order for the proportional change to the TAC ($\alpha\hat{R}$) to be equivalent whether it be increasing or decreasing, the method needs to natural log transform (*i.e.* using base *e*) the catch rate ratio:

$$\hat{R} = Ln\left(CE_{y+1} / CE_y\right) \tag{5}$$

where CE_y is the standardized catch rate in year *y*. Last year this log-ratio was divided by e^1 but the same effect can be induced by setting the scaling factor to a value of α = 0.367879 (instead of α = 1.0), which was found to provide outcomes acceptable to the RAG; this value was used in the forthcoming analyses. This rule provides a symmetrical relationship between changes in the catch rates and in the TAC. Thus, for any catch rate ratio the percentage change in TAC is the same whether the ratio steps up from a smaller to a larger catch rate, or down from a larger to a smaller catch rate. What this means is that if the catch rate trajectory starts at *X*, then increases to *Y* but then decreases back to *X* again, the TAC imposed at *X* is the same. Without this symmetrical relationship the TAC at *X* would end up larger after these changes, which would be an undesirable side effect of such a rule.

The same species/fisheries as analysed in Haddon (2012) are presented here except for those species which have only been allocated a bycatch TAC. Only those catch rate standardizations are produced which were used in an assessment.

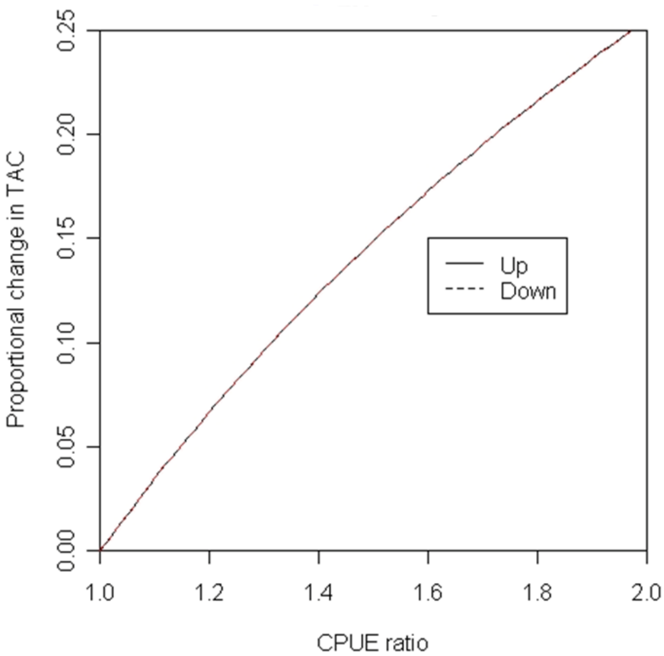

Figure 14.1. The proportional change in TAC when the proportional change in catch rate is either up (solid line) or down (dotted line). The lines overlap and are therefore hard to distinguish (Copied from Wayte et al, 2009).

1.1.1 Catch Weighting

The assessment for five species, Jackass Morwong, Flathead, Pink Ling, Ocean Perch, and now Mirror Dory are based on multiple time series of catch rates (from different zones) and, in some cases, multiple methods. Only one TAC Multiplier is used to modify the allocated TAC and so, in these species the separate TAC Multipliers from the different time series need to be combined in some way. They are combined by weighting each contribution by the proportion of the total catch taken in each region of the fishery or by each method. The areas are combined first (within methods), and then the methods are combined. The relative catches are determined using the same catch and effort data used in the catch rate standardizations.

1.1.2 Data Manipulations

Data from 2011 to at least the end of the third week in October for each fishery were sent from AFMA and processed in the usual way (Danish Seine vessels are identified, Zones are added, DayNight is added, depths are standardized across different ways of estimating it through the years, and the vessel IDs are made consistent through time).

The same standard set of database extracts were used as those used to generate the standardized catch rates (Haddon, 2012). These were designed to identify positive shots containing the species of interest in each case. For each species the standardization analyses were restricted to data from particular methods, zones and depth ranges as listed in Haddon (2012). A repeat standardization for Pink Ling Autoline was also conducted to add this method to the weighted ratio analysis for Pink Ling.

The statistical software *R* was used in all analyses (R Development Core Team, 2009), which, because of the large size of the datasets, required the use of the library “biglm”. The extra analyses needed for the application of the rule and the calculation of the TAC Multiplier, Eq. 4, were also programmed into the R scripts.

14.4 Results

A summary of the TAC Multiplier for each fishery demonstrates that there were only two fisheries (Royal Red Prawn and Blue Grenadier) for which the CPUE ratio change was greater than 10%, which is the cut-off level in the meta-rule for action to be taken.

Table 14.1. Summary results for each analysis. Only using the final TAC multiplier values for those species where a weighted TAC multiplier was generated, there were only two reducing multipliers (those which were either greater than 1.1 or less than 0.9. The Final TAC multipliers relate to whole fisheries, while the sub-group multipliers relate to individual component fisheries.

	Species	Zone	Final TAC Multiplier	Sub-Group
1	School Whiting	60	1.0272	
2	Jackass Morwong Summary		1.0052	
	Jackass Morwong	10,20		1.0276
	Jackass Morwong	30		1.1016
	Jackass Morwong	40,50		0.8761
3	Flathead Summary		1.0083	
	Flathead	10,20		1.0364
	Flathead	30		1.1058
	Flathead DS	20,60		0.9596
4	RedFish	10	0.9352	
5	Silver Trevally	10,20	0.9617	
6	Royal Red Prawn	10	0.8604	
7	Blue Eye	10-50	0.9373	
8	Blue Grenadier Summary		0.8358	
	Blue Grenadier Spawning	40		0.8549
	Blue Grenadier Non-Sp	10-60		0.7768
9	Spotted/Silver Warehou	10-50	0.9157	
10	Pink Ling Summary		0.9854	
	Pink Ling,	10,20,30		0.9755
	Pink Ling,	40,50		0.9874
	Pink Ling AutoLine	20-50,83-		1.0322
11	Western Gemfish	40,50	0.9973	
12	Offshore Ocean Perch	10,20	1.0317	
13	Inshore Ocean Perch	10,20	0.9004	
14	John Dory	10,20	0.9931	
15	Mirror Dory Summary	10-50	0.9187	
	Mirror Dory East	10,20,30		0.9384
	Mirror Dory West	40,50		0.8691
16	Ribaldo	10-50	0.9295	

14.5 School Whiting (WHS – 37330014) Sillago flindersi

School Whiting are taken primarily by Danish Seine (and within State waters). In Commonwealth waters the catches are primarily within Zone 60, and in depths less than or equal to 100 m. Catch rates were expressed as the natural log of catch per shot.

Only data from Zone 60 in depths 0 – 100m taken by Danish Seine were used. All vessels reporting School Whiting were included.

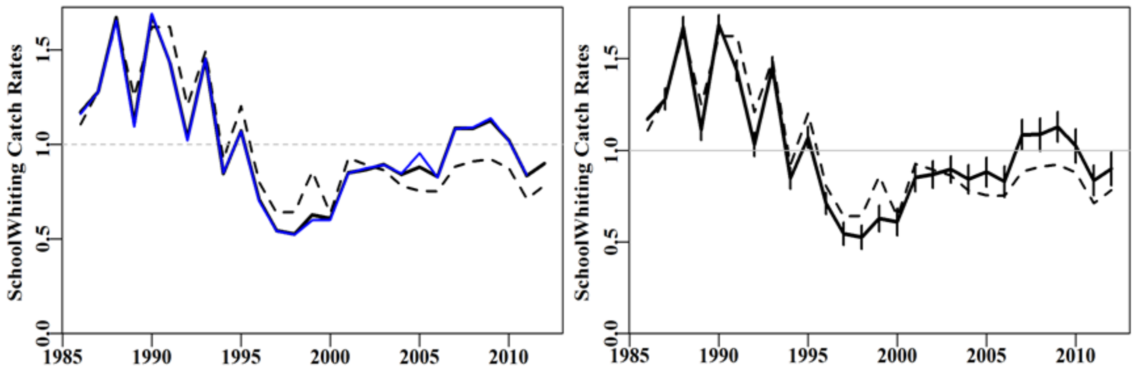

Figure 14.2**.** School Whiting reported from Danish Seine in Zone 60, in depths 0 to 100 m. The solid black line represents the optimal standardized catch rates (the model including the Month:DepCat interaction term) to October 2012, while the blue overlapping line represents the same optimal standardized catch rates from the 2011 analysis. The graph standardizes catch rates relative to the mean of the standardized catch rates. The dashed line is the geometric mean catch rate, used to illustrate the effect of the standardization. The right hand graph illustrates 2 x Standard Errors around the curve.

The catch rates in 2012 are slightly higher than in 2011, overall leading to a TAC multiplier of 1.0272.

Table 14.2. The standardized catch rates for the alternative statistical models for School Whiting are reported from Zone 60 in depths 0 to 100 m. The optimal model was Model 7.

Statistic	Value
2011_CE	0.8351
2012_CE	0.8992
Ln(CE_Ratio)	0.0739
Rprime	0.0272
TAC_Multiplier	1.0272

14.6 Jackass Morwong Summary (MOR–37377003 Nemadactylus macropterus)

Three regions are assessed in the formal assessment and so a weighted TAC Multiplier is required that combines all three regions.

Table 14.3. Catch in tonnes by Zone (Zones 10 – 20, 30, and 40 – 50) of Jackass Morwong across all depths for the years 2000 – 2011. The relative percent between assessment regions are labelled with a %.

Year	10-20	30	40-50	%1020	%30	%4050
2000	605.099	126.264	121.507	70.95	14.80	14.25
2001	312.265	113.019	287.745	43.79	15.85	40.36
2002	379.784	110.840	255.919	50.87	14.85	34.28
2003	290.756	196.717	177.131	43.75	29.60	26.65
2004	255.636	205.965	190.392	39.21	31.59	29.20
2005	326.526	151.993	199.892	48.13	22.40	29.46
2006	324.883	166.055	192.288	47.55	24.30	28.14
2007	251.842	118.953	122.517	51.05	24.11	24.84
2008	375.240	122.652	105.954	62.14	20.31	17.55
2009	264.633	55.928	65.965	68.46	14.47	17.07
2010	231.117	59.890	40.983	69.62	18.04	12.34
2011	247.835	51.259	86.373	64.29	13.30	22.41
2012	199.503	77.302	27.702	65.52	25.39	9.10
Average percent between 2000 and 2011				54.99	20.30	24.71

Table 14.4**.** Calculation of the weighted TAC Multiplier using the regional multipliers from Zones 10 – 20, 30, and 40 – 50. The Proportion is the proportion of the total catch from the specified zones. The TACm are the regional multipliers, and the Contribution is the first two rows multiplied together, The Weighted TAC Multiplier is then obtained by summing the contributions.

Region	1020	30	4050
Proportion	0.5499	0.2030	0.2471
TACm	1.0276	1.1016	0.8761
Contribution	0.5650	0.2237	0.2165
Weighted TAC Multiplier for Jackass Morwong			1.0052

14.7 Jackass Morwong Z1020 (MOR–37377003 N. macropterus)

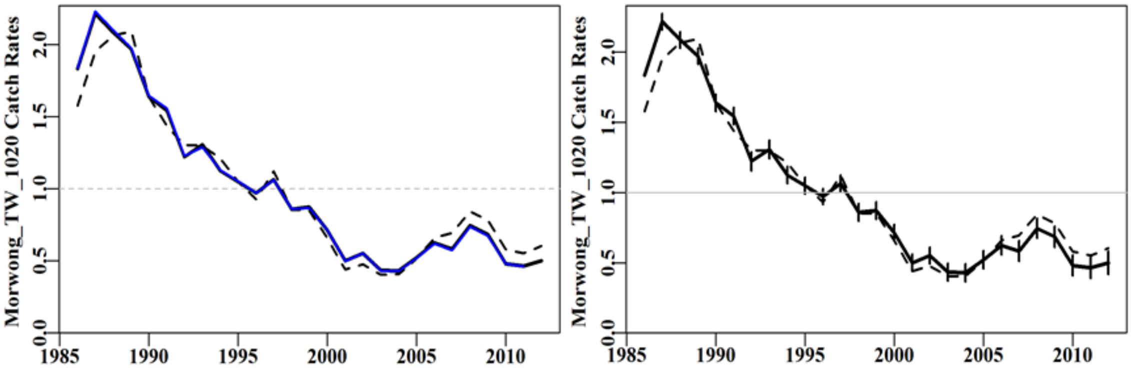

Figure 14.3**.** Jackass Morwong reported from trawl in Zones 10 – 20, in depths 70 to 300 m. The solid black line represents the optimal standardized catch rates (the model including the Zone:Month interaction term) to October 2012, while the blue overlapping line represents the same optimal standardized catch rates from the 2011 analysis. The graph standardizes catch rates relative to the mean of the standardized catch rates. The dashed line is the geometric mean catch rate, used to illustrate the effect of the standardization. The right hand graph illustrates 2 x Standard Errors around the curve.

The catch rates in 2012 are somewhat higher than in 2011, overall leading to a TAC multiplier of 1.0276. However, to obtain an appropriately weighted single TAC multiplier it is necessary to weight the analyses for each of the three assessment regions with respect to their relative catches.

Table 14.5. The standardized catch rates for the alternative statistical models for Jackass Morwong reported from trawl in Zones 10 – 20, in depths 70 to 300 m. The optimal model was Model 8. The weighted TAC Multiplier is shown in Table 14.4.

Statistic	Value
2011_CE	0.4641
2012_CE	0.5002
Ln(CE_Ratio)	0.0750
Rprime	0.0276
TAC_Multiplier	1.0276

14.8 Jackass Morwong Z30 (MOR – 37377003 N. macropterus)

Only data from zone 30 were used with depths between 70 and 300 m.

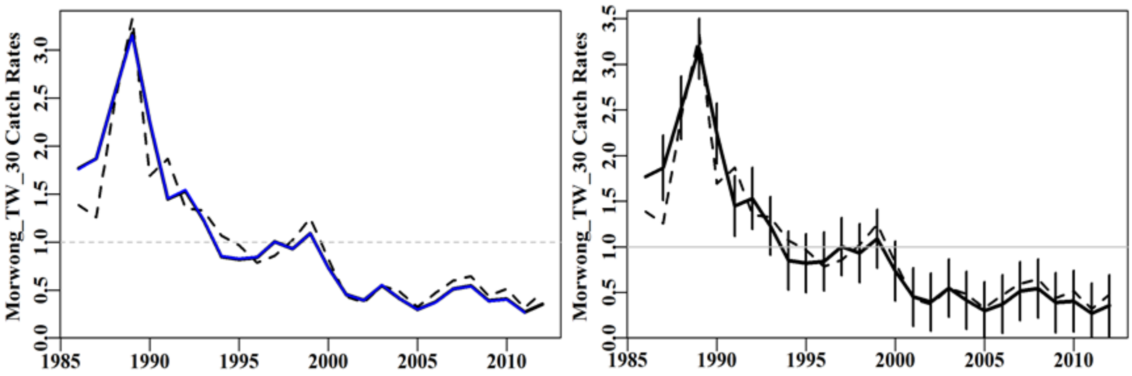

Figure 14.4**.** Jackass Morwong reported from trawl in Zone 30, in depths 70 to 300 m. The solid black line represents the optimal standardized catch rates (the model including the Month:DepCat interaction term) to Oct 2012, while the blue overlapping line represents the same optimal standardized catch rates from the 2011 analysis. The graph standardizes catch rates relative to the mean of the standardized catch rates. The dashed line is the geometric mean catch rate, used to illustrate the effect of the standardization. The right hand graph illustrates 2 x Standard Errors around the curve.

The catch rates in 2012 are rather higher than in 2011, overall leading to a TAC multiplier of 1.1016. However, to obtain an appropriately weighted single TAC multiplier it is necessary to weight the analyses for each of the three assessment regions with respect to their relative catches.

Table 14.6. The standardized catch rates for the alternative statistical models for Jackass Morwong reported from trawl in Zone 30, in depths 70 to 300 m. The optimal model was Model 6. The weighted TAC Multiplier is shown in Table 14.4.

Statistic	Value
2011_CE	0.2689
2012_CE	0.3545
Ln(CE_Ratio)	0.2763
Rprime	0.1016
TAC_Multiplier	1.1016

14.9 Jackass Morwong Z4050 (MOR – 37377003 N. macropterus)

The data restrictions used in selecting the data for analysis were trawl caught Jackass Morwong from Zones 40 and 50, and depths between 70 and 360 m.

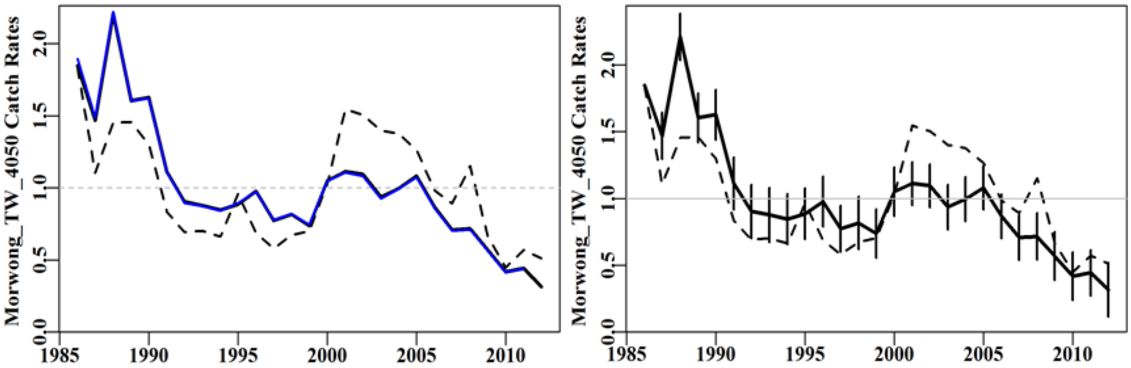

Figure 14.5. Jackass Morwong reported from trawl in Zones 40 – 50, in depths 70 to 360 m. The solid black line represents the optimal standardized catch rates (the model including the Zone:Month interaction term) to October 2012, while the blue overlapping line represents the same optimal standardized catch rates from the 2011 analysis. The graph standardizes catch rates relative to the mean of the standardized catch rates. The dashed line is the geometric mean catch rate, used to illustrate the effect of the standardization. The right hand graph illustrates 2 x Standard Errors around the curve.

The catch rates in 2012 are rather lower than in 2011, overall leading to a TAC multiplier of 0.8761. However, to obtain an appropriately weighted single TAC multiplier it is necessary to weight the analyses for each of the three assessment regions with respect to their relative catches.

Table 14.7. The standardized catch rates for the alternative statistical models for Jackass Morwong reported from trawl in Zones 40 – 50, in depths 70 to 360 m. The optimal model was Model 8. The weighted TAC Multiplier is shown in Table 14.4.

Statistic	Value
2011_CE	0.4439
2012_CE	0.3169
Ln(CE_Ratio)	-0.3369
Rprime	-0.1239
TAC_Multiplier	0.8761

14.10 Flathead Summary (FLT – 37296001 – Neoplatycephalus richardsoni)

The flathead stock assessment uses trawl caught catches from Zones 10 – 20 and from Zone 30 separately, it also uses Danish Seine catches (from Zones 20 and 60).

Table 14.8. Annual catches of Flathead by Zone and method. The average percent over the years 2000 – 2008 are given at the bottom.

Year	1020	30	TW	DS	%1020	%30	%TW	%DS
2000	1699.619	83.664	1783.283	1038.428	95.31	4.69	63.20	36.80
2001	1388.282	101.308	1489.590	1005.508	93.20	6.80	59.70	40.30
2002	1447.242	212.158	1659.400	1147.232	87.21	12.79	59.12	40.88
2003	1599.972	240.860	1840.832	1214.571	86.92	13.08	60.25	39.75
2004	1349.783	477.426	1827.209	1254.558	73.87	26.13	59.29	40.71
2005	1159.545	388.383	1547.928	1126.864	74.91	25.09	57.87	42.13
2006	1154.279	288.378	1442.657	970.529	80.01	19.99	59.78	40.22
2007	1077.223	173.180	1250.404	1182.317	86.15	13.85	51.40	48.60
2008	1332.344	173.739	1506.083	1283.714	88.46	11.54	53.99	46.01
2009	1063.573	100.225	1163.798	1169.299	91.39	8.61	49.88	50.12
2010	1127.232	104.186	1231.418	1173.237	91.54	8.46	51.21	48.79
2011	1096.784	131.274	1228.059	1125.254	89.31	10.69	52.18	47.82
2012	884.820	139.493	1024.313	1104.554	86.38	13.62	48.12	51.88
Average percent across the years 2000 – 2010					86.52	13.48	56.49	43.51

Table 14.9. Calculation of the weighted TAC Multiplier using the regional multipliers from Zones 10 – 20 and 30, and from Trawl and Danish Seine. The Proportions are from Table 14.8. The TACm are the regional multipliers, and the Contribution is the first two rows multiplied together. The Trawl TACm is the left hand two contributions added together. The Weighted TAC Multiplier is then obtained by summing the contributions from the Trawl and the Danish Seine.

Region/Method	TW10202	TW30	Trawl	DS
Proportion	0.8652	0.1348	0.5649	0.4351
TACm	1.0364	1.1058	1.0458	0.9596
Contribution	0.8967	0.1490	0.5907	0.4175
Weighted TAC Multiplier				1.0083

14.10.1 Flathead Trawl Z1020(FLT – 37296001 – N. Richardsoni)

Only trawl data from zones 10 and 20 were used from depths less than 400 m.

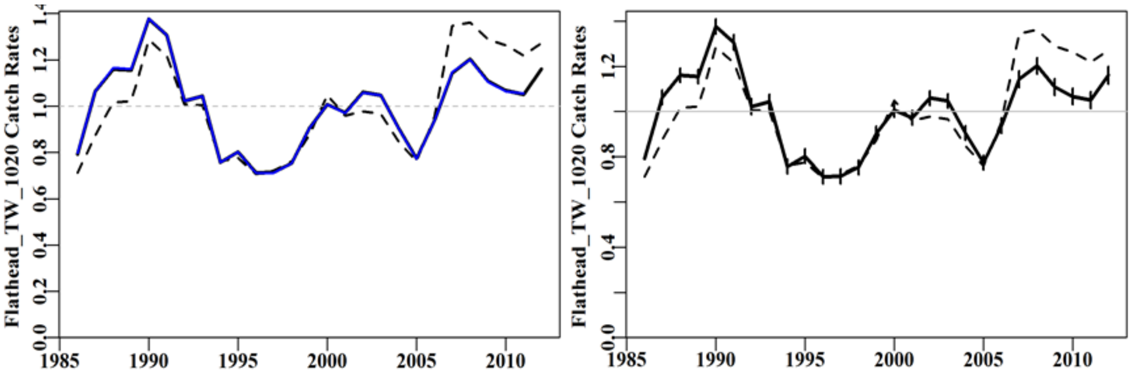

Figure 14.6. Flathead reported from trawl in Zones 10 – 20, in depths 0 to 400 m. The solid black line represents the optimal standardized catch rates (the model including the DepCat:Zone interaction term) to October 2012, while the blue overlapping line represents the same optimal standardized catch rates from the 2011 analysis. The graph standardizes catch rates relative to the mean of the standardized catch rates. The dashed line is the geometric mean catch rate, used to illustrate the effect of the standardization. The right hand graph illustrates 2 x Standard Errors around the curve.

The catch rates in 2012 are somewhat higher than in 2011, overall leading to a TAC multiplier of 1.0364. However, to obtain an appropriately weighted single TAC multiplier it is necessary to weight the analyses for each of the three assessment regions and two methods with respect to their relative catches.

Table 14.10. The standardized catch rates for the alternative statistical models for Flathead reported from trawl in Zones 10 – 20, in depths 0 to 400 m. The optimal model was Model 8. The weighted TAC Multiplier is shown in Table 14.9.

Statistic	Value
2011_CE	1.0511
2012_CE	1.1604
Ln(CE_Ratio)	0.0990
Rprime	0.0364
TAC_Multiplier	1.0364

14.10.2 Flathead Trawl Z30 (FLT – 37296001 – N. Richardsoni)

Only trawl data from zone 30 were used from depths between 0 – 400 m.

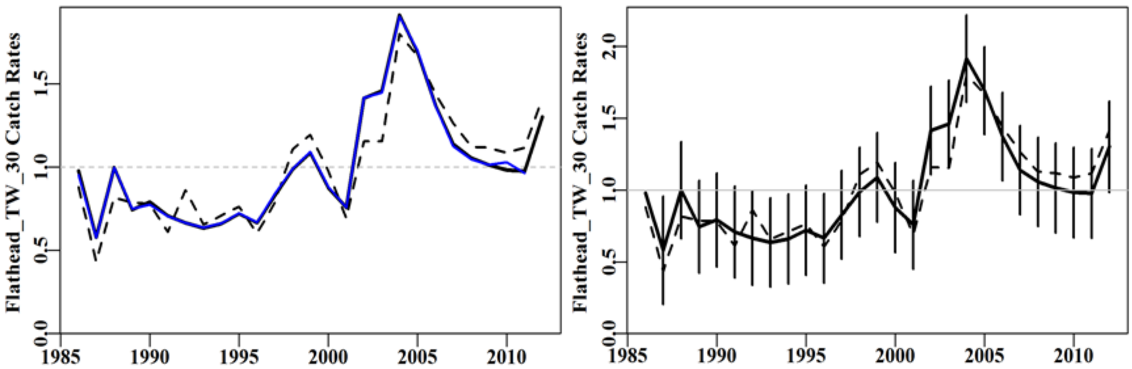

Figure 14.7**.** Flathead reported from trawl in Zone 30, in depths 0 to 400 m. The solid black line represents the optimal standardized catch rates (the model including the DepCat:Month interaction term) to October 2012, while the blue overlapping line represents the same optimal standardized catch rates from the 2011 analysis. The graph standardizes catch rates relative to the mean of the standardized catch rates. The dashed line is the geometric mean catch rate, used to illustrate the effect of the standardization. The right hand graph illustrates 2 x Standard Errors around the curve. Table 14.9).

Table 14.11.The standardized catch rates for the alternative statistical models for Flathead reported from trawl in Zone 30, in depths 0 to 400 m. The optimal model was Model 6. The weighted TAC Multiplier is shown in Table 14.9.

Statistic	Value
2011_CE	0.9760
2011_CE	1.3010
Ln(CE_Ratio)	0.2875
Rprime	0.1058
TAC_Multiplier	1.1058

14.10.3 Flathead Danish Seine (FLT – 37296001 – N. Richardsoni)

Only Danish Seine data from zones 20, and 60 were used (i.e. Otter Trawl vessels were excluded), and from depths less than 200 m.

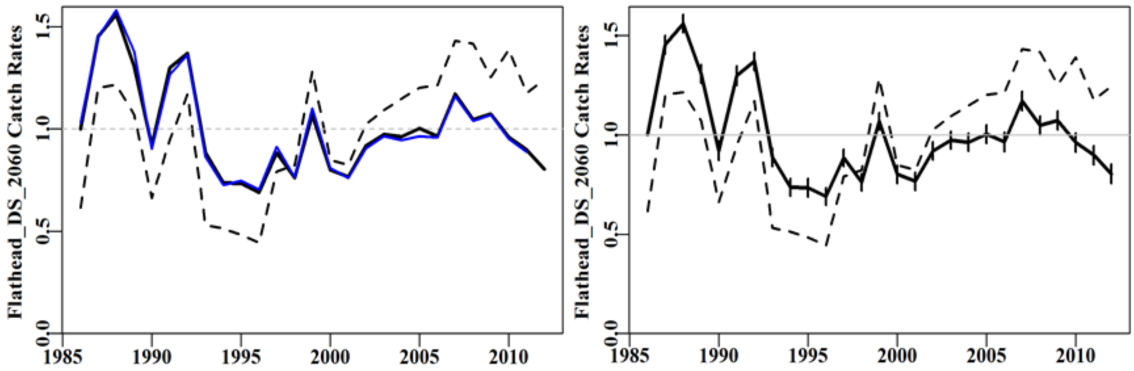

Figure 14.8**.** Flathead reported from Danish Seine in Zones 20 and 60 in depths 0 to 200 m. The solid black line represents the optimal standardized catch rates (the model including the DepCat:Month interaction term) to October 2012, while the blue overlapping line represents the same optimal standardized catch rates from the 2011 analysis. The graph standardizes catch rates relative to the mean of the standardized catch rates. The dashed line is the geometric mean catch rate, used to illustrate the effect of the standardization. The right hand graph illustrates 2 x Standard Errors around the curve.

The catch rates in 2012 are again lower than in 2011, overall leading to a TAC multiplier of 0.9596. However, to obtain an appropriately weighted single TAC multiplier it is necessary to weight the analyses for each of the three assessment regions and two methods with respect to their relative catches (see Table 14.9).

Table 14.12.The standardized catch rates for the alternative statistical models for Flathead reported from Danish Seine in Zones 20 and 60 in depths 0 to 200 m. The optimal model was Model 6. The weighted TAC Multiplier is shown in Table 14.9

Statistic	Value
2011_CE	0.8972
2012_CE	0.8038
Ln(CE_Ratio)	-0.1099
Rprime	-0.0404
TAC_Multiplier	0.9596

14.11 RedFish Zone 10 (RED – 37258003 – *Centroberyx affinis*)

Only data taken by trawl from Zone 10 were used from depths less than 400 m.

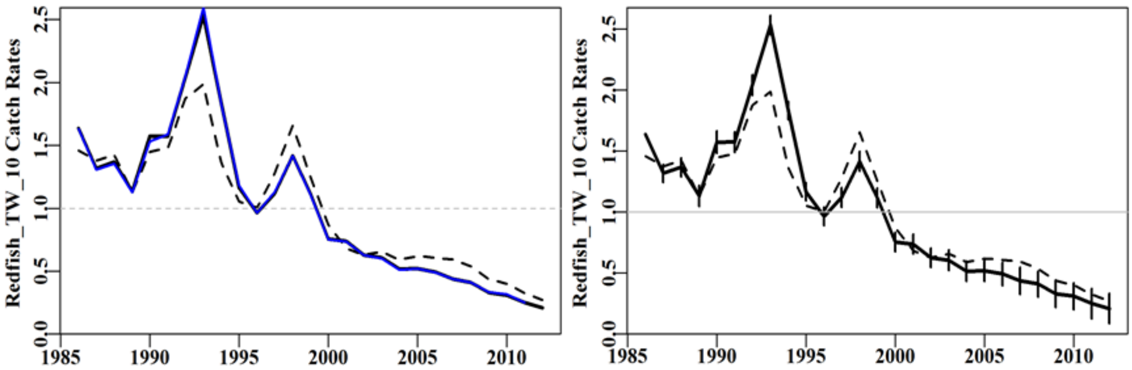

Figure 14.9**.** Redfish reported from trawl in Zone 10, in depths 0 to 400 m. The solid black line represents the optimal standardized catch rates (the model including the Month:DepCat interaction term) to October 2012, while the blue overlapping line represents the same optimal standardized catch rates from the 2011 analysis. The graph standardizes catch rates relative to the mean of the standardized catch rates. The dashed line is the geometric mean catch rate, used to illustrate the effect of the standardization. The right hand graph illustrates 2 x Standard Errors around the curve.

The catch rate in 2012 was again somewhat lower than in 2011, overall leading to a TAC multiplier of 0.9352.

Table 14.11. The standardized catch rates for the alternative statistical models for Redfish reported from trawl in Zone 10, in depths 0 to 400 m. The optimal model was Model 6.

Statistic	Value
2011_CE	0.2506
2012_CE	0.2101
Ln(CE_Ratio)	-0.1760
Rprime	-0.0648
TAC_Multiplier	0.9352

14.12 Silver Trevally (TRE – 37337062 – *Pseudocaranx dentex*)

Only data from zones 10 and 20 combined were used, depths less than 200 m. Previously, to discount the influence of catches taken within the Batemans Bay MPA, all data in State waters within the MPA have been excluded from the analysis. This usage removed more records than required in practice. There are now sufficient data to permit an empirical determination of what areas to exclude from the analysis (Figure 14.10).

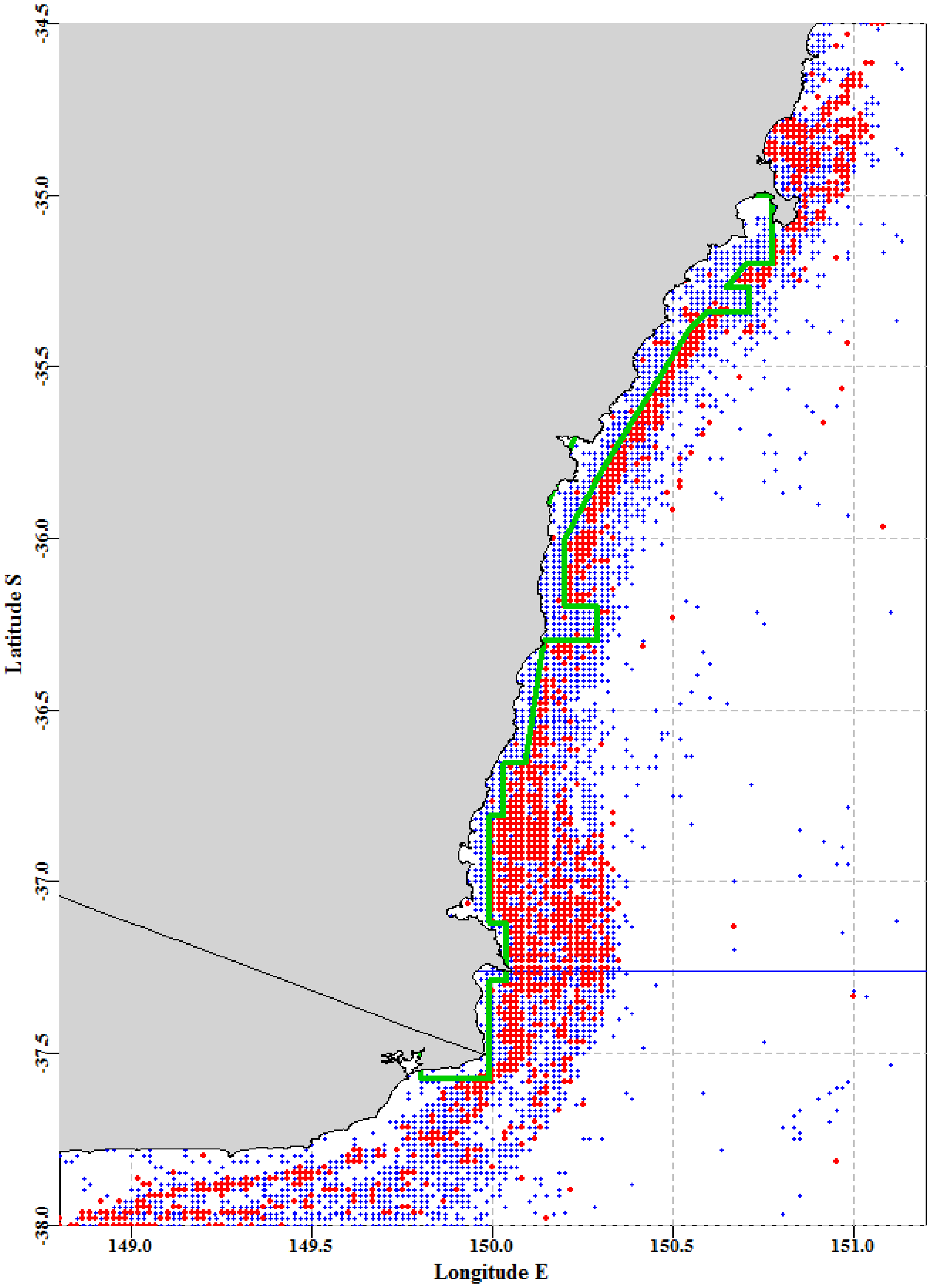

Figure 14.10**.** Schematic map of individual sites where fishing for Silver Trevally has been reported. The blue dots are all records from 1986 – 2012, whereas the red dots are all data from 2009 – 2012; the few red dots inside the green exclusion area are assumed to be erroneous reporting from inside the MPA. The green line indicates the region whose previous catches were excluded from the analysis.

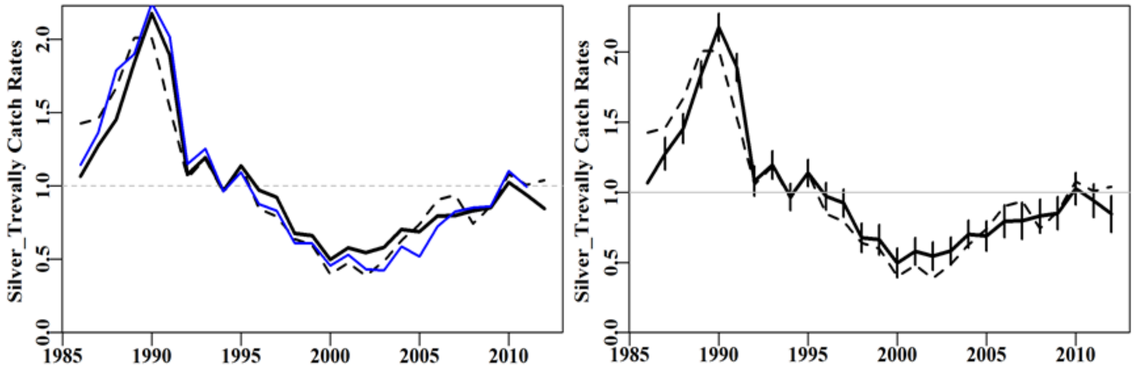

Figure 14.11**.** Silver Trevally from Zones 10 and 20, in depths 0 to 200 m, minus the records from those areas within the Bateman's Bay MPA, from which recent catches have been excluded (Figure 14.10). The solid black line represents the optimal standardized catch rates (the model including the Zone:Month interaction term) to October 20122, while the blue overlapping line represents the same optimal standardized catch rates from the 2011 analysis. The graph standardizes catch rates relative to the mean of the standardized catch rates. The dashed line is the geometric mean catch rate, used to illustrate the effect of the standardization and the vertical lines are 2 x Standard Error.

This analysis of catch rates is slightly different from the analysis given in the original standardization document. This can be seen from the differences between this analysis and that used in the standardization document (Haddon, 2012). However, it would appear to be more valid to remove only those catches from areas where catches are no longer taken than from all apparently closed areas (Figure 14.10). The new analysis more closely follows the geometric mean catch rate except in the latest year where the standardized rates go down while the geometric rates go up. The total catches in this analysis are greater than that in Haddon (2012). This use of an alternative analysis has had no effect on the difference between the last two years and so has not influenced the outcome of the update analysis.

The catch rates in 2012 are somewhat lower than in 2011, overall leading to a TAC multiplier of 0.9617.

Table 14.12. The standardized catch rates for the alternative statistical models for Silver Trevally from Zones 10 and 20, in depths 0 to 200 m, minus the records from State Waters within the Bateman's Bay MPA. The optimal model was Model 7.

Statistic	Value
2011_CE	0.9399
2011_CE	0.8469
Ln(CE_Ratio)	-0.1041
Rprime	-0.0383
TAC_Multiplier	0.9617

14.13 Royal Red Prawn (PRR – 28714005 - Haliporoides sibogae)

Only data taken by trawl from Zone 10 were used between depths of 200 – 700 m.

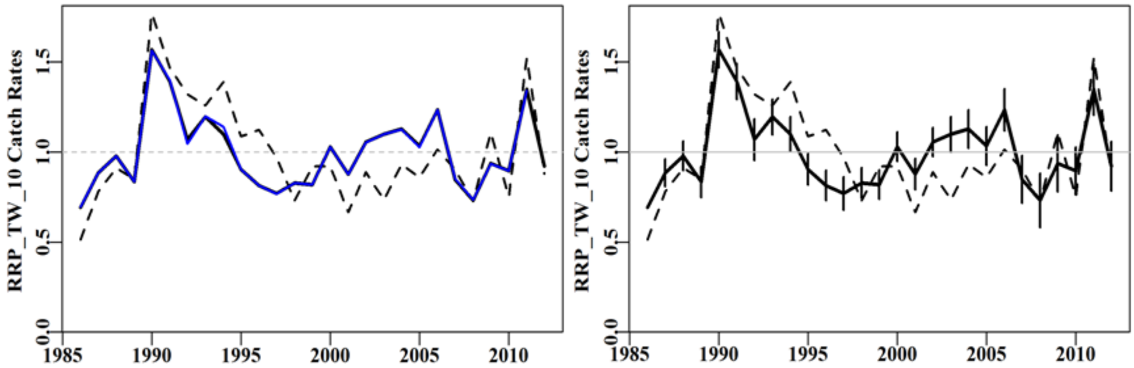

Figure 14.12**.** Royal Red Prawn reported from trawl in Zone 10, in depths 200 to 700 m. The solid black line represents the optimal standardized catch rates (the model including the Month:DepCat interaction term) to October 2012, while the blue overlapping line represents the same optimal standardized catch rates from the 2011 analysis. The graph standardizes catch rates relative to the mean of the standardized catch rates. The dashed line is the geometric mean catch rate, used to illustrate the effect of the standardization. The right hand graph illustrates 2 x Standard Errors around the curve.

The catch rates in 2012 are rather higher than in 2011, overall leading to a TAC multiplier of 0.8604. This analysis fails to take into account the use of specialized prawn nets so the TAC setting committee should consider whether to use this result.

Table 14.13. The standardized catch rates for the alternative statistical models for Royal Red Prawn reported from trawl in Zone 10, in depths 200 to 700 m. The optimal model was Model 6.

Statistic	Value
2011_CE	1.3482
2012_CE	0.9223
Ln(CE_Ratio)	-0.3796
Rprime	-0.1396
TAC_Multiplier	0.8604

14.14 Blue Eye, AL & DL (TBE – 37445001 – H. antarctica)

Depths between 200-600m m. All data from auto-longlining and droplining combined. Zones 20, 30, 40, 50, 83, 84, and 85 included (83 – 85 are in the GAB).

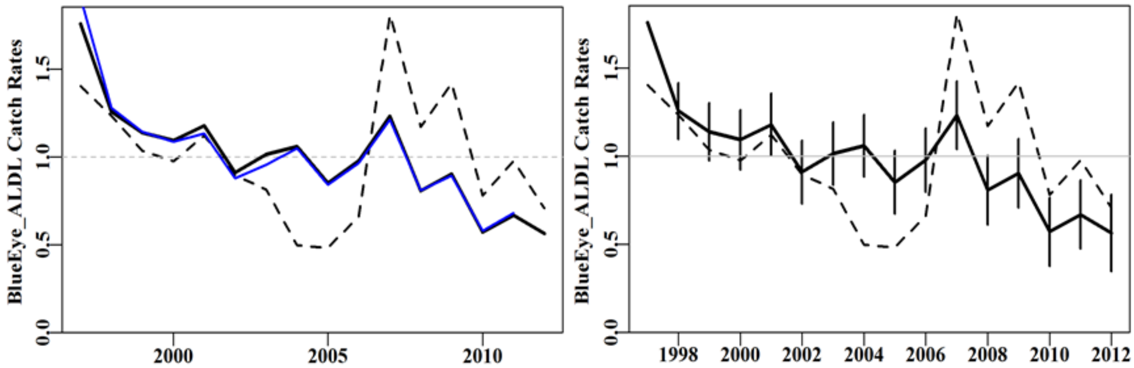

Figure 14.13**.** Blue Eye reported from Autolong line and Drop line in Zones 20 – 50 and 83 -85, from depths 200 to 600 m. The solid black line represents the optimal standardized catch rates (the model including the Month:Zone interaction term) to October 2012, while the blue overlapping line represents the same optimal standardized catch rates from the 2011 analysis. The graph standardizes catch rates relative to the mean of the standardized catch rates. The dashed line is the geometric mean catch rate, used to illustrate the effect of the standardization. The right hand graph illustrates 2 x Standard Errors around the curve.

The catch rates in 2012 are somewhat higher than in 2011, overall leading to a TAC multiplier of 0.9373.

Table 14.14. The standardized catch rates for the alternative statistical models for Blue Eye reported from Auto-long-line and Drop line in Zones 20 – 50 and 83 -85, from depths 200 to 600 m. The optimal model was Model 7.

Statistic	Value
2011_CE	0.6704
2012_CE	0.5653
Ln(CE_Ratio)	-0.1704
Rprime	-0.0627
TAC_Multiplier	0.9373

14.15 Blue Grenadier Summary (GRE – 37227001 – *Macruronus novaezelandiae*)

There is a spawning fishery and a non-spawning fishery, each of which is currently used in the stock assessment. In future the spawning time series is no longer going to be used in the assessment but for the setting of the multi-year TAC the pair was used. There is therefore a need to weight their respective TAC Multipliers by their relative contribution to the total catches. Because of the Multi-year TAC this analysis would appear to be redundant.

Table 14.15. Annual catches of Blue Grenadier by fishery with their relative contribution to the total catch.

Year	Non-Spawning	Spawning	%NonSp	%Sp
2000	1715.640	5616.097	23.40	76.60
2001	1013.169	7281.279	12.22	87.78
2002	1126.150	6782.001	14.24	85.76
2003	670.094	7132.933	8.59	91.41
2004	1204.672	4603.280	20.74	79.26
2005	1166.433	2829.270	29.19	70.81
2006	1293.355	2034.510	38.86	61.14
2007	1196.315	1728.897	40.90	59.10
2008	1256.788	2805.832	30.94	69.06
2009	1112.922	2700.396	29.19	70.81
2010	1131.383	3280.615	25.64	74.36
2011	878.786	3525.454	19.95	80.05
2012	339.396	3746.786	8.31	91.69
Average percent contribution from 2000 - 2010			24.96	75.04

Table 14.16. Calculation of the weighted TAC Multiplier using the fishery multipliers from the Non-Spawning and Spawning fisheries. The Proportions are from . The TACm are the fishery multipliers, and the Contribution is the first two rows multiplied together, The Weighted TAC Multiplier is then obtained by summing the contributions from the Non-Spawning and Spawning fisheries

	Non-Spawning	Spawning
Proportion	0.2449	0.7551
TACm	0.7768	0.8549
Contribution	0.1902	0.6456
Weighted TAC Multiplier		0.8358

14.15.1 Blue Grenadier Spawning (GRE – 37227001 – M. novaezelandiae)

Data from Zone 40 in months June to August, depths between 100 and 1000m, all vessels that reporting fishing in the spawning fishery were included in the analysis.

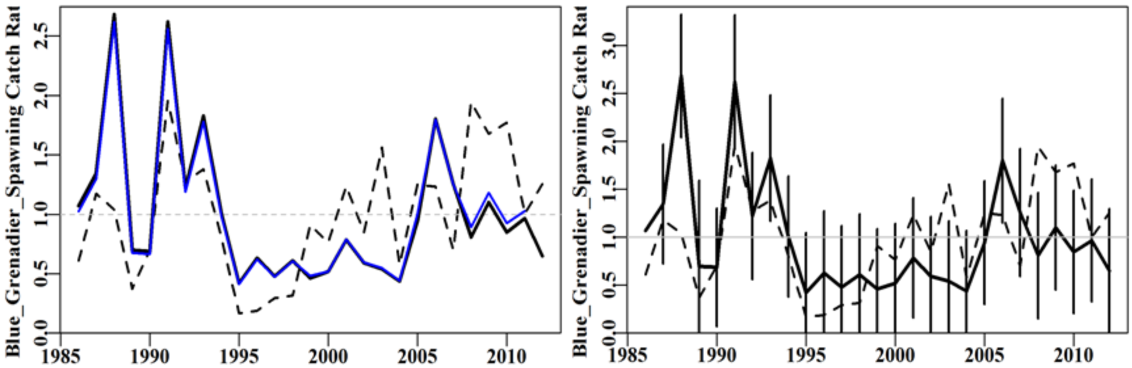

Figure 14.14. Blue Grenadier from the Spawning fishery reported from Trawl in Zone 40 during June to August from depths 200 to 1000 m. The solid black line represents the optimal standardized catch rates (the model included no significant interaction terms) to October 2012, while the blue overlapping line represents the same optimal standardized catch rates from the 2011 analysis. The graph standardizes catch rates relative to the mean of the standardized catch rates. The dashed line is the geometric mean catch rate, used to illustrate the effect of the standardization. The right hand graph illustrates 2 x Standard Errors around the curve.

The catch rates in 2012 are slighter lower than in 2011, overall leading to a TAC multiplier of 0.8549. However, this multiplier needs to be weighted with that from the non-spawning fishery.

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Table 14.17. The standardized catch rates for the alternative statistical models for Blue Eye reported from Auto-long-line and Drop line in Zones 20 – 50 and 83 -85, from depths 200 to 600 m. The optimal model was Model 7.

Statistic	Value
2011_CE	0.9651
2012_CE	0.6505
Ln(CE_Ratio)	-0.3945
Rprime	-0.1451
TAC_Multiplier	0.8549

14.15.2 Blue Grenadier Non-Spawning (GRE – 37227001 – M. novaezelandiae)

Data from zones 10 to 60, except Zone 40 in months June to August, depths less than 1000 m and greater than 0 m.

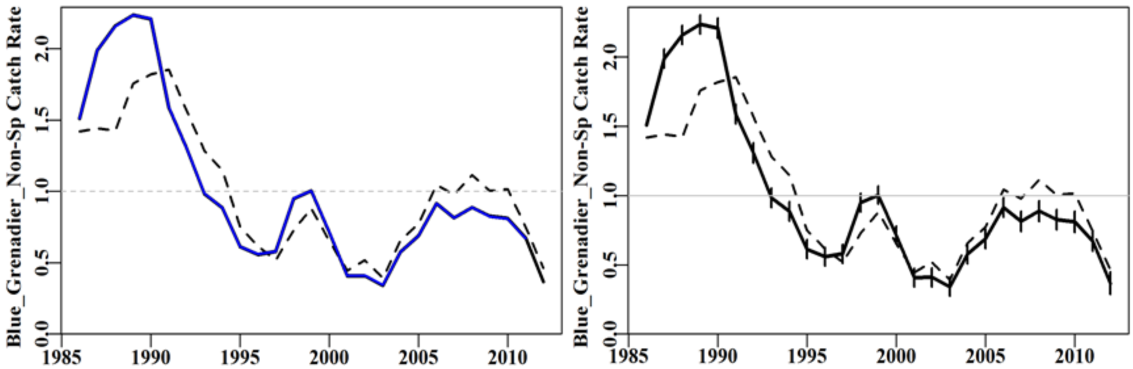

Figure 14.15. Blue Grenadier from the Non-Spawning fishery reported from Trawl in Zones 10 – 60 (except Zone 40 in June to August) from depths 0 to 1000 m. The solid black line represents the optimal standardized catch rates (the model including the Zone:Month interaction term) to October 2012, while the blue overlapping line represents the same optimal standardized catch rates from the 2011 analysis. The graph standardizes catch rates relative to the mean of the standardized catch rates. The dashed line is the geometric mean catch rate, used to illustrate the effect of the standardization. The right hand graph illustrates 2 x Standard Errors around the curve.

The catch rates in 2012 are rather lower than in 2011, overall leading to a TAC multiplier of 0.7768. However, this multiplier needs to be weighted with that from the spawning fishery.

Table 14.18. The standardized catch rates for the alternative statistical models for Blue Eye reported from Auto-long-line and Drop line in Zones 20 – 50 and 83 -85, from depths 200 to 600 m. The optimal model was Model 7.

Statistic	Value
2011_CE	0.6735
2012_CE	0.3671
Ln(CE_Ratio)	-0.6068
Rprime	-0.2232
TAC_Multiplier	0.7768

14.16 Silver Warehou (TRS – 37445006 – Seriolella punctata)

Trawl data for Silver/Spotted Warehou from zones 10 to 50, depths greater than 0 m.

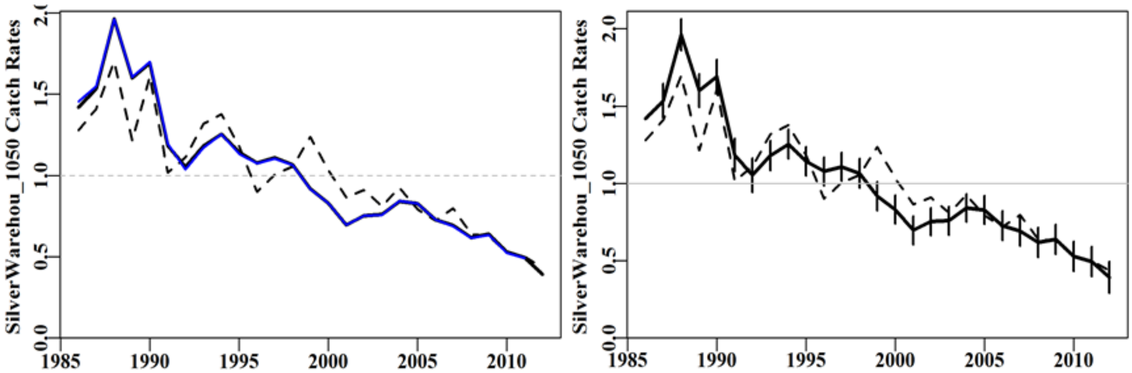

Figure 14.16. Silver Warehou data from Zones 10 – 50 and depths greater than 0 m The solid black line represents the optimal standardized catch rates (the model including the Zone:Month interaction term) to October 2012, while the blue overlapping line represents the same optimal standardized catch rates from the 2011 analysis. The graph standardizes catch rates relative to the mean of the standardized catch rates. The dashed line is the geometric mean catch rate, used to illustrate the effect of the standardization. The right hand graph illustrates 2 x Standard Errors around the curve.

The catch rates in 2012 are rather lower than in 2011, overall leading to a TAC multiplier of 0.9157.

Table 14.19. The standardized catch rates for the alternative statistical models for Silver Warehou data from Zones 10 – 50 and depths greater than 0 m The optimal model was Model 7.

Statistic	Value
2011_CE	0.4954
2012_CE	0.3939
Ln(CE_Ratio)	-0.2292
Rprime	-0.0843
TAC_Multiplier	0.9157

14.17 Pink Ling Summary (LIG – 37228002 – Genypterus blacodes)

Table 14.20. Trawl Catch of Pink Ling by Zonal region, including Zones 10 – 30 and Zones 40 – 50. The percent contribution by each region is shown in the %102030 and %4050 columns. The relative weightings given the two areas are 0.5534 and 0.4466.

Year	10-30	40-50	%102030	%4050
2000	658.895	508.949	56.42	43.58
2001	483.313	498.442	49.23	50.77
2002	360.184	429.004	45.64	54.36
2003	444.627	358.987	55.33	44.67
2004	346.188	304.417	53.21	46.79
2005	324.814	195.212	62.46	37.54
2006	321.107	207.895	60.70	39.30
2007	202.762	284.511	41.61	58.39
2008	325.428	211.797	60.58	39.42
2009	208.330	258.294	44.65	55.35
2010	265.716	268.810	49.71	50.29
2011	287.423	345.186	45.43	54.57
2012	180.264	193.406	48.24	51.76
Average Annual Percentage from 2000 to 2010			52.08	47.92

Table 14.21. Catch of Pink Ling by Method. The percent contribution by each region is shown in the %AutoLine and %Trawl columns. The relative weightings given to the two methods are 0.3805 and 0.6195. 2002 was selected as the start year because the Auto Line method had become established by then.

Year	AutoLine	Trawl	%AutoLine	%Trawl
2000	54.720	1167.844	4.48	95.52
2001	176.418	981.755	15.23	84.77
2002	379.354	789.188	32.46	67.54
2003	382.861	803.614	32.27	67.73
2004	704.479	650.605	51.99	48.01
2005	524.440	520.026	50.21	49.79
2006	419.985	529.002	44.26	55.74
2007	294.705	487.273	37.69	62.31
2008	365.753	537.225	40.51	59.49
2009	253.504	466.624	35.20	64.80
2010	318.338	534.526	37.33	62.67
2011	373.726	632.609	37.14	62.86
2012	198.487	373.670	34.69	65.31
Average Annual Percentage from 2002 to 2010			34.90	65.10

Table 14.22. Calculation of the weighted TAC Multiplier using the regional multipliers from Zones 10 – 30 and 40 – 50, and from Trawl and Danish Seine. The Proportions are from Table 14.20 and Table 14.21. The TACm are the regional multipliers, and the Contribution is the first two rows multiplied together. The Trawl TACm is the left hand two contributions added together. The Weighted TAC Multiplier is then obtained by summing the contributions from the Trawl and the Danish Seine.

Region/Method	TW102030	TW4050	Trawl	AutoL
Proportion	0.5208	0.4792	0.3490	0.6510
TACm	0.9755	0.9874	0.9812	0.9876
Contribution	0.5080	0.4732	0.3424	0.6429
Weighted TAC Multiplier				0.9854

14.17.1 Pink Ling, Z102030 (LIG – 37228002 – G. blacodes)

Data from zones 10, 20 and 30, depths greater than 0 m and less than 600 m.

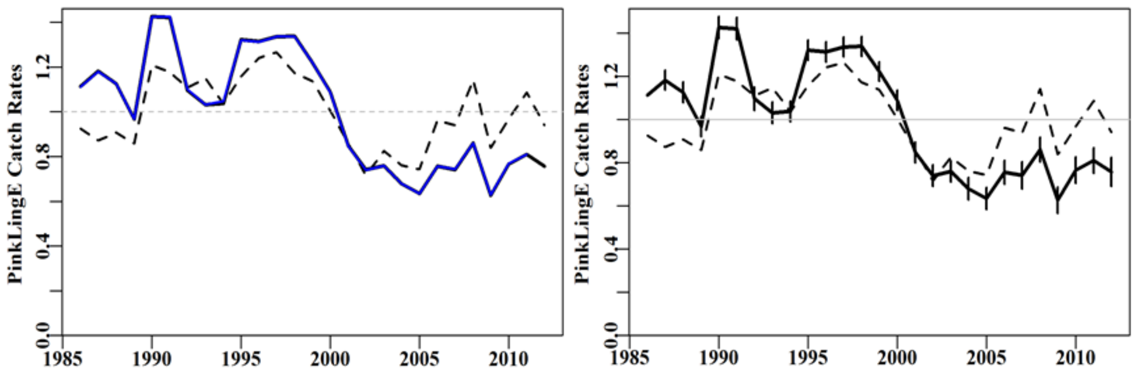

Figure 14.17**.** Pink Ling trawl data from Zones 10 – 30 and depths between 0 m and 600m. The solid black line represents the optimal standardized catch rates (the model including the Zone:DepCat interaction term) to October 2012, while the blue overlapping line represents the same optimal standardized catch rates from the 2011 analysis. The graph standardizes catch rates relative to the mean of the standardized catch rates. The dashed line is the geometric mean catch rate, used to illustrate the effect of the standardization.

The catch rates in 2012 are lower than those in 2011, overall leading to a TAC multiplier of 0.9755.

Table 14.23. The standardized catch rates for the alternative statistical models for Pink Ling trawl data from Zones 10 – 30 and depths between 0 m and 600m. The optimal model was Model 8.

Statistic	Value
2011_CE	0.8095
2012_CE	0.7573
Ln(CE_Ratio)	-0.0667
Rprime	-0.0245
TAC_Multiplier	0.9755

14.17.2 Pink Ling, Z4050 (LIG – 37228002 – G. blacodes)

Data from zones 40 and 50, depths greater than 200 m and less or equal to 800 m.

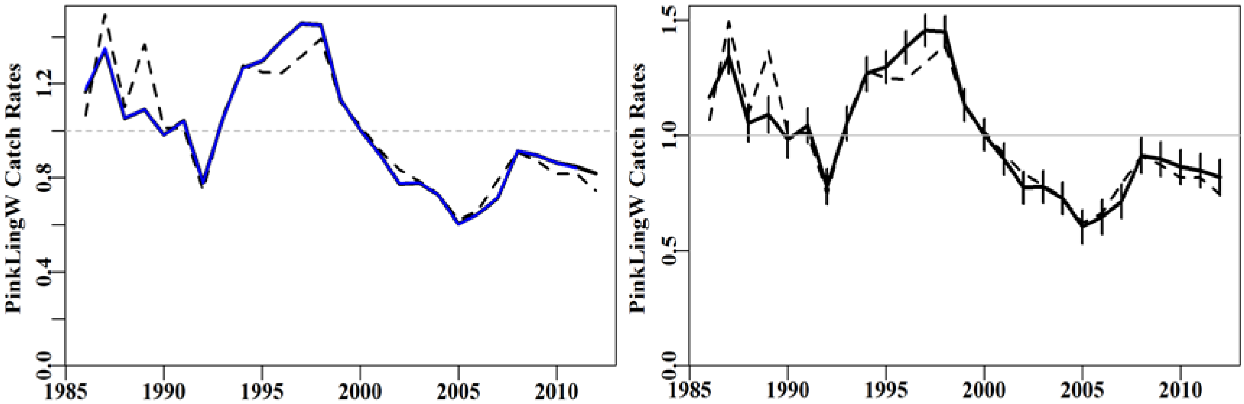

Figure 14.18**.** Pink Ling trawl data from Zones 40 – 50 and depths between 200 m and 800m. The solid black line represents the optimal standardized catch rates (the model including the Zone:Month interaction term) to October 2012, while the blue overlapping line represents the same optimal standardized catch rates from the 2011 analysis. The graph standardizes catch rates relative to the mean of the standardized catch rates. The dashed line is the geometric mean catch rate, used to illustrate the effect of the standardization.

The catch rates in 2012 are slightly lower than in 2011, overall leading to a TAC multiplier of 0.9874.

Table 14.24. The standardized catch rates for the alternative statistical models for Pink Ling trawl data from Zones 40 – 50 and depths between 200 m and 800m. The optimal model was Model 7.

Statistic	Value
2011_CE	0.8478
2012_CE	0.8193
Ln(CE_Ratio)	-0.0343
Rprime	-0.0126
TAC_Multiplier	0.9874

14.17.3 Pink Ling, AutoLine (LIG – 37228002 – G. blacodes)

For the TAC Multiplier to be appropriately calculated a standardized catch rate series for Auto-Long-Line caught Pink Ling was required. This was produced before the multiplier calculations. Methods were the same as in Haddon (2012).

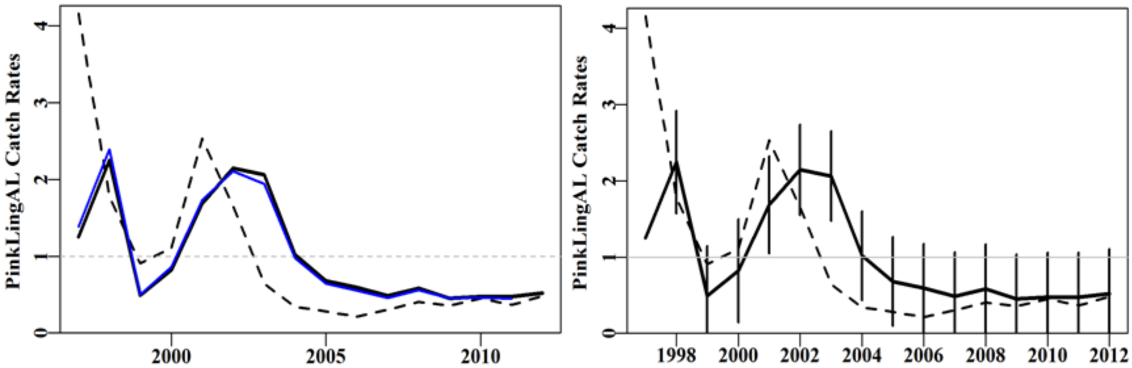

Figure 14.19. Pink Ling as reported from Auto-Long-Line in Zones 20 – 50 and 83 – 85 in depths 200 to 800 m. The dashed black line represents the geometric mean catch rate and the solid black line the standardized catch rates (the model including the Zone:Month interaction term) to October 2012. The blue line on top of the black is last year's analysis. The graph standardizes catch rates relative to the mean of the standardized catch rates.

The catch rates in 2012 are slightly higher than in 2011, overall leading to a TAC multiplier of 1.0322.

Table 14.25. The standardized catch rates for the alternative statistical models for Pink Ling Auto-Long-Line data from Zones 20 – 50 and 83 – 85 in depths between 200 m and 800m. The optimal model was Model 7.

Statistic	Value
2011_CE	0.4748
2012_CE	0.5181
Ln(CE_Ratio)	0.0874
Rprime	0.0322
TAC_Multiplier	1.0322

14.18 Western Gemfish Z4050 (GEM – 37439002 – R. solandri)

Data from zones 40 and 50, depths greater than 200 and less than or equal to 600 m.

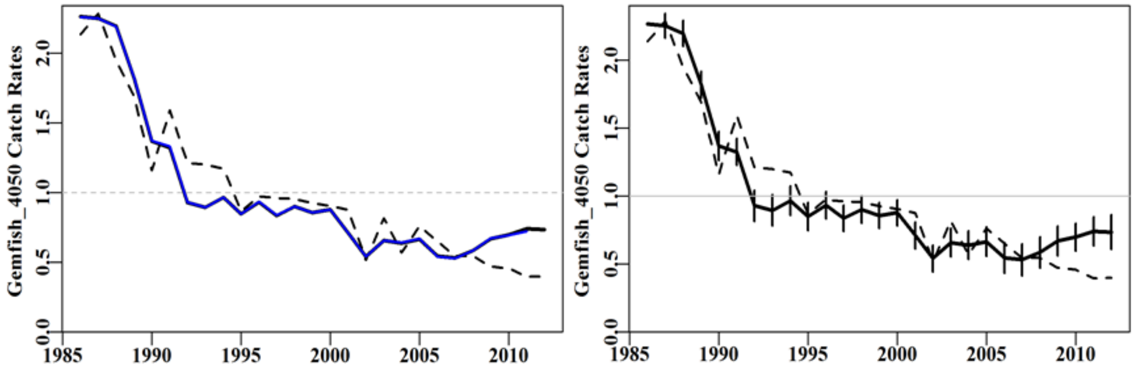

Figure 14.20. Western Gemfish from Zones 40 – 50 and depths 200 to 600 m. The solid black line represents the optimal standardized catch rates (the model including the Zone:Month interaction term) to October 2012, while the blue overlapping line represents the same optimal standardized catch rates from the 2011 analysis. The graph standardizes catch rates relative to the mean of the standardized catch rates. The dashed line is the geometric mean catch rate, used to illustrate the effect of the standardization.

The catch rates in 2012 are effectively the same as in 2011, overall leading to a TAC multiplier of 0.9973.

Table 14.26. The standardized catch rates for the alternative statistical models for Western Gemfish from Zones 40 – 50 and depths 200 to 600 m. The optimal model included Zone:Month.

Statistic	Value
2011_CE	0.7417
2012_CE	0.7362
Ln(CE_Ratio)	-0.0074
Rprime	-0.0027
TAC_Multiplier	0.9973

14.19 Offshore Ocean Perch, Z1020 (REG – 37287001 – H. percoides) 200m

Previous analyses identified Offshore Ocean Perch by selecting records of Ocean Perch from depths between 300-700m. In the July 2010 Slope RAG again revised this figure down to 200-700m to avoid overlap with inshore Ocean Perch. The following analyses are therefore restricted to data from 200-700m by trawl from Zones 10 – 20. The TAC this year is being set using both the Inshore and the Offshore Ocean Perch catch rate series, so a weighted TAC Multiplier combining Offshore and Inshore Ocean Perch is required.

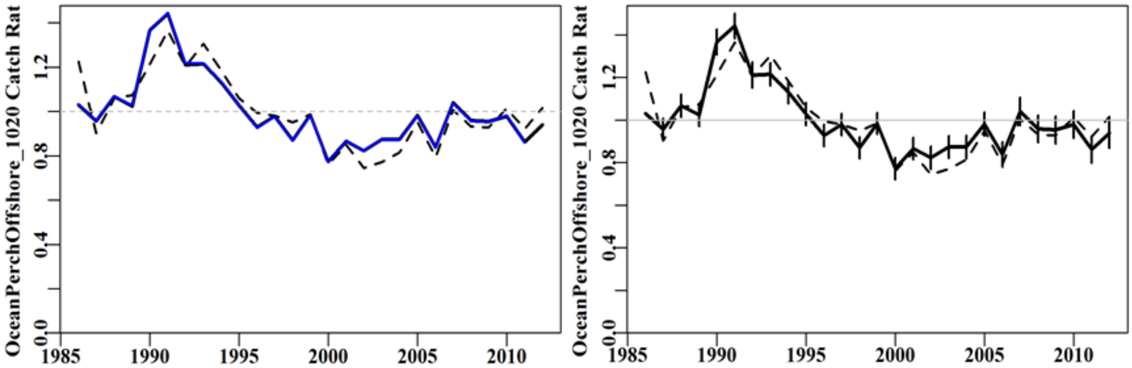

Figure 14.21**.** Offshore Ocean Perch by trawl from Zones 10 – 20 and depths 300 to 700 m. The solid black line represents the optimal standardized catch rates (the model including the Zone:Month interaction term) to October 2012, while the blue overlapping line represents the same optimal standardized catch rates from the 2011 analysis. The graph standardizes catch rates relative to the mean of the standardized catch rates. The dashed line is the geometric mean catch rate, used to illustrate the effect of the standardization.

The catch rates in 2012 are somewhat higher than in 2011, overall leading to a TAC multiplier of 1.0317.

Table 14.27. The standardized catch rates for the alternative statistical models for Offshore Ocean Perch by trawl from Zones 10 – 20 and depths 300 to 700 m. The optimal model was Model 7.

Statistic	Value
2011_CE	0.8616
2012_CE	0.9391
Ln(CE_Ratio)	0.0862
Rprime	0.0317
TAC_Multiplier	1.0317

14.20 Inshore Ocean Perch, Z1020 (REG – 37287001 – H. percoides) 0-200m

The catch rate series for inshore Ocean Perch complements the Offshore Ocean Perch in that only data taken by trawl in Zones 10 and 20 between 0 and 200 m depth are used.

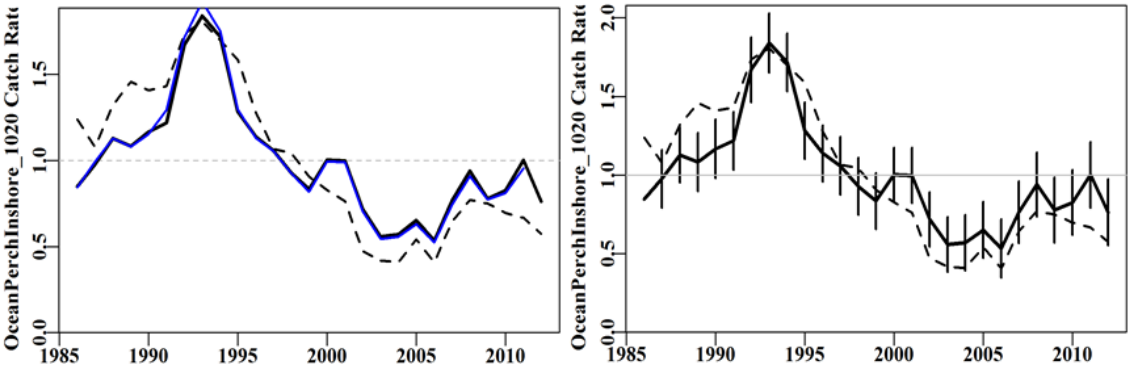

Figure 14.22. Inshore Ocean Perch by trawl from Zones 10 – 20 and depths 0 to 299 m. The solid black line represents the optimal standardized catch rates (the model including the Zone:DepCat interaction term) to October 2012, while the blue overlapping line represents the same optimal standardized catch rates from the 2011 analysis. The graph standardizes catch rates relative to the mean of the standardized catch rates. The dashed line is the geometric mean catch rate, used to illustrate the effect of the standardization.

The catch rates in 2012 are slightly lower than in 2011, overall leading to a TAC multiplier of 0.9004.

Table 14.28. The standardized catch rates for the alternative statistical models for Inshore Ocean Perch by trawl from Zones 10 – 20 and depths 0 to 200 m. The optimal model was Model 8.

Statistic	Value
2011_CE	1.0016
2012_CE	0.7640
Ln(CE_Ratio)	-0.2708
Rprime	-0.0996
TAC_Multiplier	0.9004

14.21 John Dory (DOJ - 37264004) Zeus faber

Only included are trawl catches from Zones 10 and 20 in depths 0 – 200m

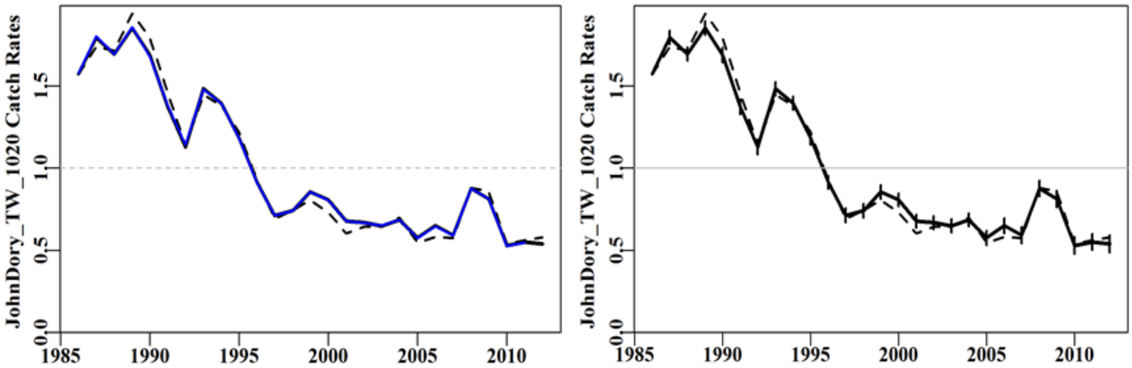

Figure 14.23**.** John Dory from Zones 10 – 20 in depths 0 to 200 m. The solid black line represents the optimal standardized catch rates (the model including the Zone:DepCat interaction term) to October 2012, while the blue overlapping line represents the same optimal standardized catch rates from the 2011 analysis. The graph standardizes catch rates relative to the mean of the standardized catch rates. The dashed line is the geometric mean catch rate, used to illustrate the effect of the standardization.

The catch rates in 2012 are very slightly lower than in 2011, overall leading to a TAC multiplier of 0.9931.

Table 14.29. The standardized catch rates for the alternative statistical models for John Dory from Zones 10 – 20 in depths 0 to 200 m. The optimal model was Model 8.

Statistic	Value
2011_CE	0.5509
2012_CE	0.5407
Ln(CE_Ratio)	-0.0187
Rprime	-0.0069
TAC_Multiplier	0.9931

14.22 Mirror Dory Summary (DOM – 37264003 Zenopsis nebulosus)

To generate an overall TAC multiplier for Mirror Dory the multipliers from east and west need to be combined.

Table 14.30. Trawl Catch of Mirror Dory by Zonal region, including Zones 10 – 30 and Zones 40 – 50. The percent contribution by each region is shown in the %102030 and %4050 columns. The relative weightings given the two areas are 0.7194 and 0.2806.

Year	10-30	40-50	%102030	%4050
2000	142.938	22.361	86.47	13.53
2001	128.790	104.890	55.11	44.89
2002	194.460	240.337	44.72	55.28
2003	406.214	153.916	72.52	27.48
2004	293.861	159.782	64.78	35.22
2005	424.496	99.625	80.99	19.01
2006	298.028	64.647	82.17	17.83
2007	203.162	63.157	76.29	23.71
2008	317.705	57.233	84.74	15.26
2009	338.488	122.938	73.36	26.64
2010	385.470	176.825	68.55	31.45
2011	347.527	155.046	69.15	30.85
2012	241.126	62.666	79.37	20.63
Average Annual Percentage from 2000 to 2010			71.27	28.73

Table 14.31. Calculation of the weighted TAC Multiplier using the fishery multipliers from the east and west Mirror Dory fisheries. The Proportions are from Table 14.30. The TACm are the fishery multipliers, and the Contribution is the first two rows multiplied together, The Weighted TAC Multiplier is then obtained by summing the contributions from each fisheries

	%10-30	%40-50
Proportion	0.7157	0.2843
TACm	0.9384	0.8691
Contribution	0.6716	0.2471
Weighted TAC Multiplier		0.9187

14.23 Mirror Dory East (DOM – 37264003 Z. nebulosus)

Catches of Mirror Dory are primarily taken by trawl. Other methods are ignored in this analysis. Only data from Zones 10 to 30 in depths 0 – 600m. All vessels reporting Mirror Dory were included.

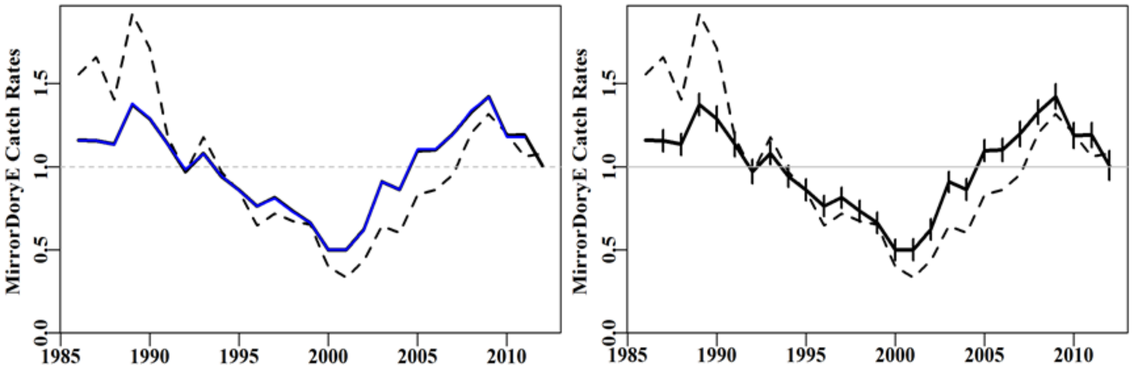

Figure 14.24. Mirror Dory reported from trawling in Zones 10 to 30, in depths 0 to 600 m. The solid black line represents the optimal standardized catch rates (the model including the Zone:Month interaction term) to October 2012, while the blue overlapping line represents the same optimal standardized catch rates from the 2011 analysis. The graph standardizes catch rates relative to the mean of the standardized catch rates. The dashed line is the geometric mean catch rate, used to illustrate the effect of the standardization.

The catch rates in 2012 are lower than in 2011, overall leading to a TAC multiplier of 0.9384.

Table 14.32. The standardized catch rates for the alternative statistical models for Mirror Dory are reported from Zones 10 to 50 in depths 0 to 600 m. The optimal model was Model 7.

Statistic	Value
2011_CE	1.1908
2012_CE	1.0072
Ln(CE_Ratio)	-0.1674
Rprime	-0.0616
TAC_Multiplier	0.9384

14.24 Mirror Dory West (DOM – 37264003 *Z. nebulosus*)

As with Eastern Mirror Dory, the majority of catches are taken by trawl and all other methods are ignored.

Only data from Zones 40 to 50 in depths 0 – 600m. All vessels reporting Mirror Dory were included.

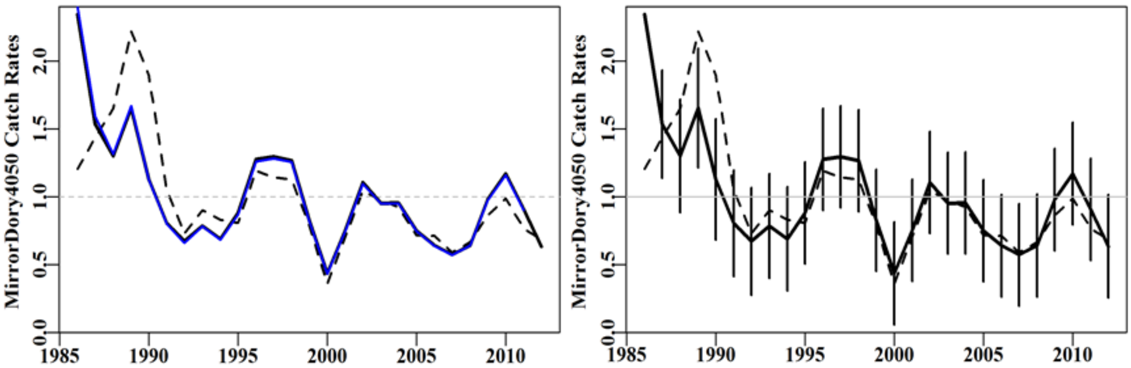

Figure 14.25**.** Mirror Dory reported from trawling in Zones 40 to 50, in depths 0 to 600 m. The solid black line represents the optimal standardized catch rates (the model including the Zone:Month interaction term) to October 2012, while the blue overlapping line represents the same optimal standardized catch rates from the 2011 analysis. The graph standardizes catch rates relative to the mean of the standardized catch rates. The dashed line is the geometric mean catch rate, used to illustrate the effect of the standardization.

The catch rates in 2012 are somewhat lower than in 2011, overall leading to a TAC multiplier of 0.8691. The fact that the catch rate trends in the east and west are different indicate that the decision to analyse the east and west separately is well founded.

Table 14.33. The standardized catch rates for the alternative statistical models for Mirror Dory are reported from Zones 40 to 50 in depths 0 to 600 m. The optimal model was Model 7.

Statistic	Value
2011_CE	0.9097
2012_CE	0.6373
Ln(CE_Ratio)	-0.3558
Rprime	-0.1309
TAC_Multiplier	0.8691

14.25 Ribaldo (RBD – 37224002 – Mora moro)

Catches of Ribaldo are taken by trawl, and more recently also by autoline. Other methods are ignored in this analysis.

Table 14.34. Catch in tonnes by Method of Ribaldo across all zones and depths. Unk is unknown method, AL is autoline, TW is trawl, and Other is all other methods (with minor amounts being reported from 10 other methods).

Year	Unk	AL	TW	Other
1986			4.104	
1987			7.941	
1988			10.898	
1989			11.342	
1990			3.668	
1991	0.295		7.513	
1992	0.495		12.838	
1993			22.761	0.016
1994			41.938	
1995	0.060		90.263	
1996	0.070		82.208	
1997	0.341	1.480	100.436	0.854
1998	0.190	1.853	96.686	1.195
1999	0.225	2.197	67.976	1.759
2000	0.080	9.159	55.140	2.412
2001	0.229	15.720	59.724	6.806
2002		95.497	60.770	1.611
2003		103.017	77.575	0.443
2004		103.062	77.155	0.744
2005		37.209	53.071	0.095
2006		66.167	56.164	0.284
2007		28.725	49.080	0.510
2008		57.415	20.136	0.923
2009		68.921	35.121	0.918
2010		51.940	39.764	0.400
2011		46.521	46.915	0.593
2012		36.757	24.150	3.802

Only data from Zones 10 to 50 in depths 0 – 1000m. A significant amount of Ribaldo is now taken by Autoline and if future assessments include this aspect of the fishery this will need to be included in future assessments and updates of catch rates.

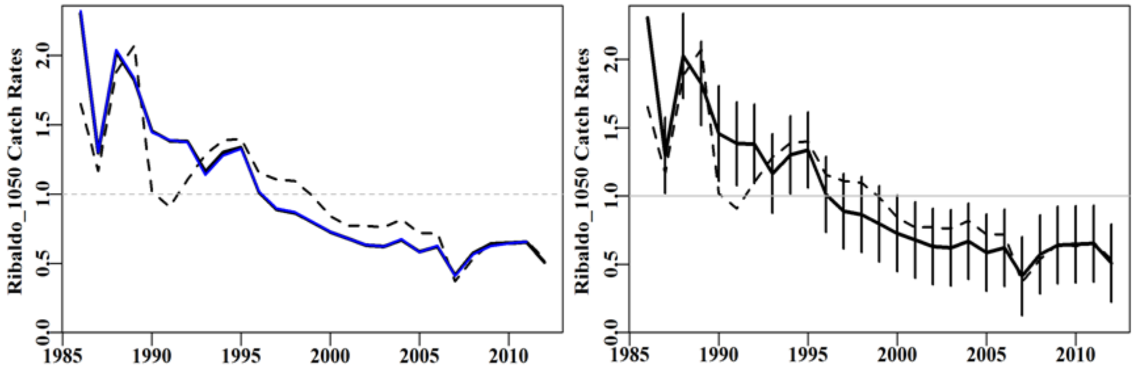

Figure 14.26**.** Ribaldo reported from trawling in Zones 10 to 50, in depths 0 to 1000 m. The solid black line represents the optimal standardized catch rates (the model including the Zone:Month interaction term) to October 2012, while the blue overlapping line represents the same optimal standardized catch rates from the 2011 analysis. The graph standardizes catch rates relative to the mean of the standardized catch rates. The dashed line is the geometric mean catch rate, used to illustrate the effect of the standardization.

The catch rates in 2012 are lower than in 2011, leading to a TAC multiplier of 0.9095. The catch by Autoline is now equal to or greater than the trawl catch and should be included in future assessments (Table Table 14.34).

Table 14.35. The standardized catch rates for the alternative statistical models for Ribaldo are reported from Zones 10 to 50 in depths 0 to 1000 m, taken by trawl. The optimal model was Model 7.

Statistic	Value
2011_CE	0.6519
2012_CE	0.5097
Ln(CE_Ratio)	-0.2460
Rprime	-0.0905
TAC_Multiplier	0.9095

14.26 Bibliography

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Wayte, S.E., Thomson, R.B., Knuckey, I.A., Tuck, G.N., Fay, G., Little, L.R., Klaer, N.L., Day, J.R., Haddon, M. and A.D.M. Smith (2009) Simulation testing of an adjustment to the TAC in response to the most recent year's CPUE. Pp113-124 in Wayte, S.E. (ed) Evaluation of new harvest strategies for SESSF species. CSIRO Marine and Atmospheric Research, Hobart, and the Australian Fisheries Management Authority, Canberra. 137 p.

15. Standardization of Bight Redfish in the GAB 2000/2001 – Feb 2011/2012. Catch Rate Update

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15.1 Summary

The change in catch rates between 2009/2010 and July-Feb 2010/2011 is less than 20% (+7.71) (Figure 15.3; Table 15.7), therefore the control rule suggests no change should be made to the default TAC.

15.2 Methods

Data was provided from July 2000 to February 2012 for catches of bight redfish from the GAB (Table 15.1). Records were only included in the analysis that adhered to the following selection criteria:

Depths were between 50 – 500 metres (Table 15.2; Figure 15.1),
Non-zero catches of bight redfish,
Shot length > 1.0 and < 10 hours,
Only from Zone 80 (GAB),
The DayNight factor only used Day, Night, and Mixed (Unknown was omitted).

The analysis conducted included all vessels which had reported catches of bight redfish as well as adhering to the conditions listed above (Table 15.3).

Seven statistical models (Table 15.4) were examined using six different factors:

Fishing Year (July – June),
Vessel,
Depth Category (50 metre categories),
Month,
SubZone (5 degree of longitude subdivisions),
DayNight (Day, Night, Mixed – a small number of Unknown were omitted).

All statistical models were plotted after dividing each series by the average of each series. This means that the average of each series becomes one, and this ensures they are all on the same scale and hence directly comparable.

The percent difference of the catch rates between years is calculated as:

$$\%D = 100 \times (CE_{10/11} - CE_{09/10})/CE_{09/10}$$

15.3 Results

Catch rates exhibited a highly skewed distribution which was approximately log-normally distribution but a log transformation approximately normalizes the data prior to analysis; Figure 15.2). There are numerous records grouped around catch rates of 1, 2, 5, 10, 15, and 30 kg/hr, which appear as spikes in the observed log of catch rates; this seems likely to be due to rounding to nearest convenient weight of catch.

The optimum statistical model was the most complex having the most parameters (Table 15.5; Table 15.6; Figure 15.2). Catch rates for bight redfish from the GAB initially increased to a peak in 2003/2004 and then after which catch rates have remained relatively stable varying slightly up and down until 2009/2010 when they started to decline. However, in the latest year, 20111/2012, catch rates increased by 7.71% (Figure 15.2; Table 15.7).

The standardization analysis with this year's data follows essentially the same trajectory as that produced by last year's analysis Figure 15.3 which indicates that data to the end of February are sufficient to describe each year's trends.

The GABTF Harvest Strategy decision rules, applied to both deepwater flathead and bight redfish are:

The FIS and the collection of age and length frequency data as well as the monitoring of catch and effort information will be ongoing regardless of whether an assessment is to take place in that year. The information obtained from these sources will be analysed and presented to the RAG each year well prior to the date at which a decision on the TAC for the next year is made.

- Any adjustment to the TAC limit through the application of the decision rules would apply to the default TAC

- When the Fishery Independent Survey (FIS) has been conducted in two consecutive years, the catch rates from the first leg of the survey will be the indicator of abundance used to make any adjustment to the default TAC.

- In a year when the Fishery Independent Survey (FIS) is not conducted, the standardised commercial catch rate for the period July-February inclusive is the indicator of abundance used to make any adjustment to the default TAC, comparing the current year to the immediately preceding year.

- If there is a change of ≥20% to the indicator of abundance, a 10% (increase or decrease) to the default TAC will occur.

- If the RAG is concerned with any indicators over the period between stock assessments (length frequency distributions, standardised commercial catch rates, age distributions etc), then it can decide to undertake a full assessment in that year

15.4 Conclusion

The change in catch rates between 2010/2011 and July-Feb 2011/2012 is less than 20% (+7.71) Figure 15.3; Table 15.7), therefore the control rule suggests no change should be made to the default TAC.

15.5 Acknowledgements

John Garvey of AFMA is thanked for providing the original data extract. Dr Neil Klaer of CSIRO is especially thanked for pre-processing the catch and effort data so rapidly.

Table 15.1. The frequency of catch rate observations in each month and fishing year (financial year – July/June) for Bight Redfish from the GAB following data selection.

Mth	00/01	01/02	02/03	03/04	04/05	05/06	06/07	07/08	08/09	09/10	10/11	11/12
7	41	33	77	188	152	178	187	142	159	145	68	121
8	39	89	63	211	185	222	231	204	108	152	67	213
9	143	160	147	181	305	253	335	280	196	196	186	208
10	181	219	136	337	317	294	316	281	268	211	177	182
11	161	216	201	338	346	287	321	307	229	200	180	200
12	99	89	103	192	241	224	198	244	164	163	155	182
1	124	114	235	304	485	437	219	334	206	184	181	228
2	159	159	259	276	492	371	235	229	192	207	144	211
3	176	180	225	289	521	363	332	223	197	248	202	0
4	211	134	218	272	290	313	325	230	189	261	157	0
5	210	133	204	242	234	248	169	208	227	153	195	0
6	71	93	169	118	230	343	215	171	181	125	133	0
Total	1615	1619	2037	2948	3798	3533	3083	2853	2316	2245	1845	1545

Table 15.2. The relative frequency of depths records for Bight Redfish from the GAB see (Figure 15.1).

Depth M	Count
0	0
50	8
100	6232
150	21359
200	1638
250	181
300	10
350	0
400	2
450	4
500	3

Table 15.3. Summary statistics characterizing the data included in the standardization.

	Records	Catches	Effort	GeomCE	Vessels
2000/2001	1615	261.868	8422	13.448	5
2001/2002	1619	200.566	8466	10.410	7
2002/2003	2037	294.920	11034	12.630	9
2003/2004	2948	541.632	16041	17.453	11
2004/2005	3798	712.731	20591	18.617	10
2005/2006	3533	586.826	18928	16.236	11
2006/2007	3083	599.814	16194	19.014	9
2007/2008	2853	532.261	14876	17.290	7
2008/2009	2316	470.236	11975	19.573	4
2009/2010	2245	396.187	11644	16.682	4
2010/2011	1845	277.004	9463	14.269	4
2011/2012	1545	214.974	8253	14.026	4

Table 15.4. The seven statistical models examined for Bight Redfish from the GAB.

Model 1	Fyear
Model 2	Fyear + Vessel
Model 3	Fyear + Vessel + DepCat
Model 4	Fyear + Vessel + DepCat + Month
Model 5	Fyear + Vessel + DepCat + Month + SubZone
Model 6	Fyear + Vessel + DepCat + Month + SubZone + DN
Model 7	Fyear + Vessel + DepCat + Month + SubZone + DN + DepCat:Month

Table 15.5. The standardized catch rates for the alternative statistical models for Bight Redfish from the GAB in depths 50 to 500 m. Values are relative to the mean of the standardized catch rates so that the average of the series remains 1.0. Fishing Years were from July/June, DepCat were 50 m categories, Subzones were 5° of Longitude, and DN relates to DayNight categories.

	FYear	DN	Month	Vessel	Subzone	DepCat	DepCat:Mth	StErr
00/01	0.8502	0.8547	0.8355	0.8062	0.8983	0.8978	**0.8880**	0.0000
01/02	0.6589	0.6467	0.6481	0.6605	0.7390	0.7447	**0.7465**	0.0404
02/03	0.7992	0.7943	0.7593	0.7689	0.8233	0.8220	**0.8215**	0.0392
03/04	1.1044	1.1231	1.1252	1.0975	1.1432	1.1466	**1.1438**	0.0382
04/05	1.1779	1.2040	1.1202	1.1830	1.1656	1.1671	**1.1641**	0.0374
05/06	1.0273	1.0154	1.0014	1.0680	1.0737	1.0678	**1.0647**	0.0376
06/07	1.2031	1.2364	1.2582	1.1930	1.0865	1.0820	**1.0841**	0.0380
07/08	1.0940	1.1294	1.1598	1.1432	1.0914	1.0980	**1.1283**	0.0394
08/09	1.2386	1.2784	1.3393	1.2119	1.1782	1.1894	**1.1831**	0.0404
09/10	1.0557	1.0202	1.0045	1.0362	1.0151	1.0223	**1.0186**	0.0408
10/11	0.9030	0.8510	0.8527	0.8918	0.8725	0.8592	**0.8461**	0.0433
11/12	0.8877	0.8464	0.8958	0.9398	0.9133	0.9031	**0.9113**	0.0458

Table 15.6. Model selection criteria, including the AIC, the adjusted r^2, and the proportional change in adj $R^{2.}$. Optimal model was model 7: FYear + Vessel + DepCat + Month + SubZone + DayNight + DepCat:Month. The Daynight factor is clearly the most influential with Bight Redfish.

	Year	DN	Month	Vessel	Subzone	DepCat	DepCat:Month
AIC	17921	13286	10246	8800	7875	7802	**7629**
RSS	54066	46185	41622	39623	38357	38240	**37898**
MSS	826	8708	13271	15269	16536	16653	**16994**
Nobs	29437	29437	29437	29437	29437	29437	**29437**
Npars	12	14	25	26	42	50	**96**
Adj_r2	1.469	15.827	24.115	27.755	30.027	30.220	**30.736**
%Change		14.358	8.288	3.641	2.271	0.194	**0.515**

Table 15.7. The optimum standardized catch rate model relative to the unstandardized geometric mean catch rates (Fyear) with the percent difference between years for each. The value of interest is at the bottom right showing the difference between 10/11 and 11/12.

	Fyear	Diff	Optimum	Diff
00/01	0.8502		0.8880	
01/02	0.6589	-22.51	0.7465	-15.93
02/03	0.7992	21.31	0.8215	10.05
03/04	1.1044	38.18	1.1438	39.23
04/05	1.1779	6.66	1.1641	1.77
05/06	1.0273	-12.79	1.0647	-8.54
06/07	1.2031	17.11	1.0841	1.82
07/08	1.0940	-9.06	1.1283	4.08
08/09	1.2386	13.21	1.1831	4.86
09/10	1.0557	-14.77	1.0186	-13.91
10/11	0.9030	-14.46	0.8461	-16.94
11/12	0.8877	-1.69	0.9113	**7.71**

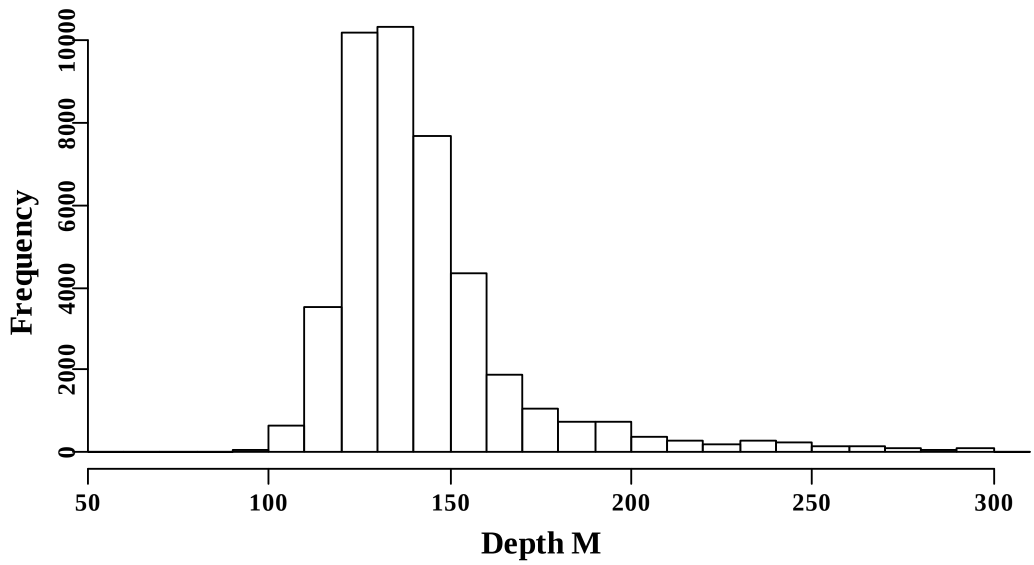

Figure 15.1. The relative frequency of depth records from Bight Redfish from the GAB. The lower graph is a repeat of the upper graph except with more detail. Data is from 2000/2001 – Feb 2011/2012.

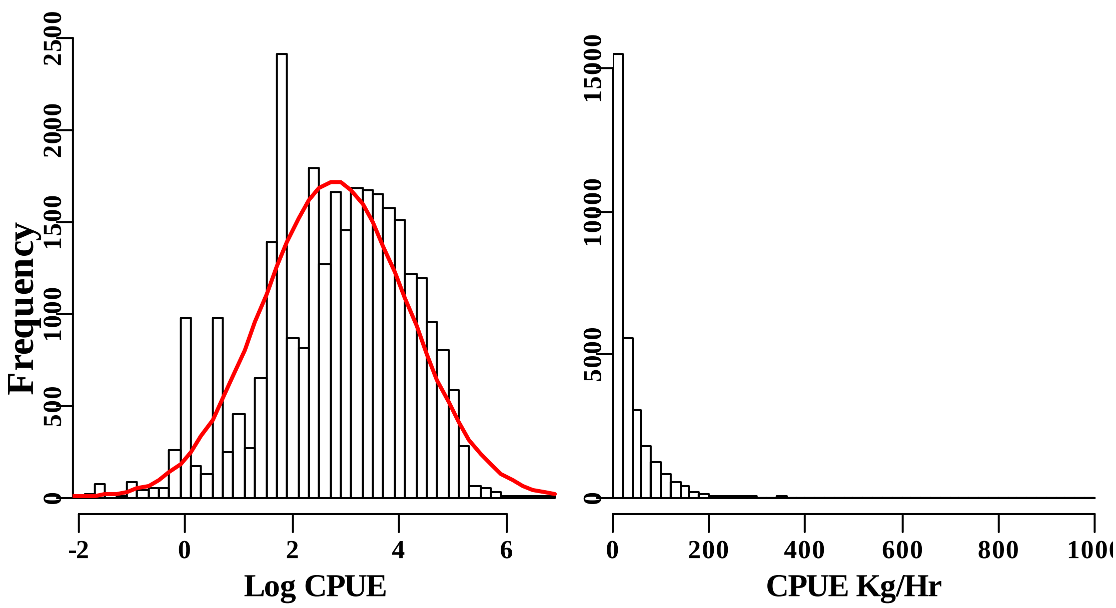

Figure 15.2. The catch rates for Bight Redfish are normalized by a natural log transformation. Data is from 2000/2001 – Feb 2011/2012. The spikes in the distribution, which distort the distribution away from a strict log-normal, relate to catch rates of 1, 2, 5, 10, 15, and 30 kg/hr. There are a very few very large catch rates, but they are so few they do not influence the standardized catch rate trend.

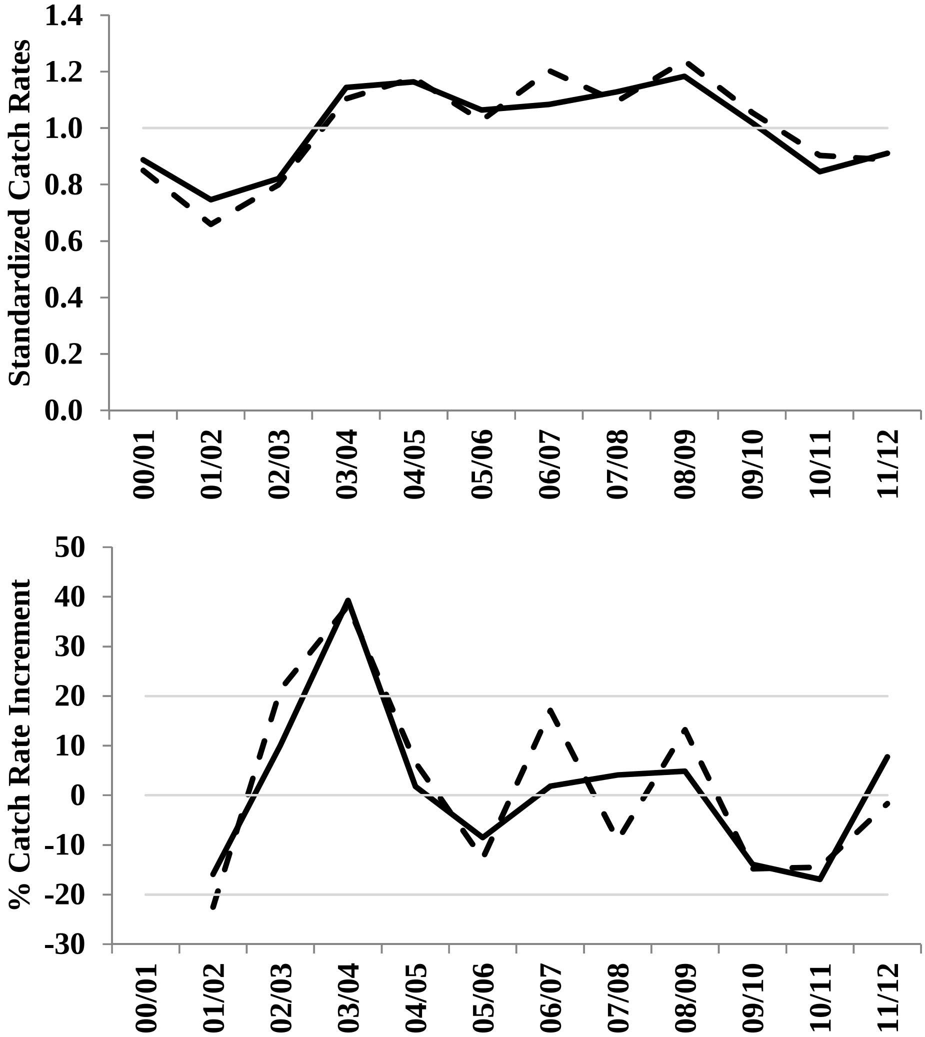

Figure 15.3. The standardized catch rates for Bight Redfish from the GAB. The dashed line is the unstandardized geometric mean catch rates see Table 15.7. The lower graph depicts the percent difference between consecutive fishing years (see Table 15.7).

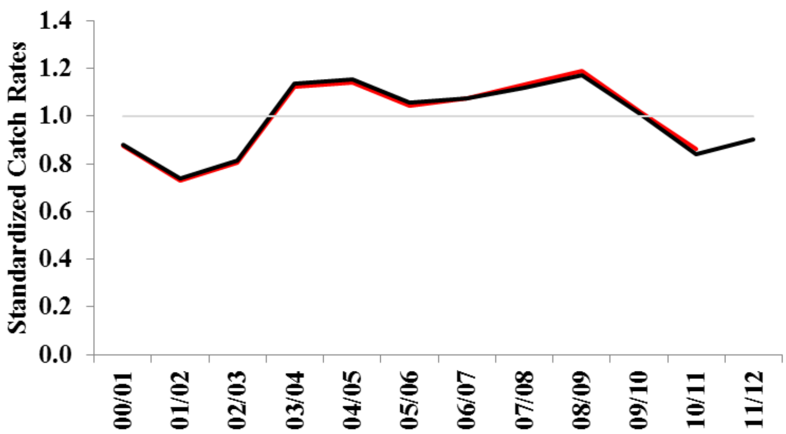

Figure 15.4. Comparison of this year's analysis (black line) with last year's (red line - scaling this year's analysis to the mean of 00/01 – 10/11 to make it comparable with last year's analysis).

16. Standardization of Deepwater Flathead in the GAB 2000/2001 – Feb 2011/2012. Catch rate Update.

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16.1 Summary

As the change in catch rates between 2010/2011 and July-Feb 2011/2012 is greater than -20% (Figure 16.3; Table 16.7) the control rule suggests a 10% decrease should be made to the default TAC.

16.2 Methods

Data was provided from July 2000 to February 2012 for catches of deepwater flathead from the GAB (Table 16.1). Records were only included in the analysis that adhered to the following selection criteria (Table 16.3):

Depths were between 50 – 500 metres (Table 16.2; Figure 16.1),

Non-zero catches of deepwater flathead,
Shot length > 0.5 and < 10 hours,
Only from Zone 80 (GAB),
The DayNight factor only used Day, Night, and Mixed (Unknown was omitted).
Only Vessels in the fishery for more than 2 years were included.

Seven statistical models (Table 16.4) were examined using six different factors:

Fishing Year (July – June),
Vessel,
Depth Category (50 metre categories),
Month,
SubZone (5 degree of longitude subdivisions),
DayNight (Day, Night, Mixed – a small number of Unknown were omitted).

Catch rates are log-normally distributed but a log transformation successfully normalizes the data prior to analysis (Figure 16.2).

The percent difference between years is calculated as:

$$\%D = 100 \text{ x } (CE_{11/12} - CE_{10/11})/CE_{10/11}$$

16.3 Results

The optimum statistical model was the most complex having the most parameters (Table 16.6; Figure 16.3).

Catch rates for Deepwater Flathead from the GAB initially increased to a peak in 2002/2003 and 2003/2004 and then declined to half the maximum levels in 2005/2006 after which catch rates have exhibited a slow increase although almost all the gains over the last four years appear to have been lost in this most recent year. In the latest year catch rates decreased by 25.59% (Figure 16.3; Table 16.7).

The standardization analysis with this year's data follows essentially the same trajectory as that produced by last year's analysis (Figure 16.4) with only a very slight deviation in the 10/11 points, which again indicates that data to the end of February are sufficient to describe each year's trends.

The GABTF Harvest Strategy decision rules, applied to both deepwater flathead and bight redfish are:

The FIS and the collection of age and length frequency data as well as the monitoring of catch and effort information will be ongoing regardless of whether an assessment is to take place in that year. The information obtained from these sources will be analysed and presented to the RAG each year well prior to the date at which a decision on the TAC for the next year is made.

- Any adjustment to the TAC limit through the application of the decision rules would apply to the default TAC
- When the Fishery Independent Survey (FIS) has been conducted in two consecutive years, the catch rates from the first leg of the survey will be the indicator of abundance used to make any adjustment to the default TAC.
- In a year when the Fishery Independent Survey (FIS) is not conducted, the standardised commercial catch rate for the period July-February inclusive is the indicator of abundance used to make any adjustment to the default TAC, comparing the current year to the immediately preceding year.
- If there is a change of ≥20% to the indicator of abundance, a 10% (increase or decrease) to the default TAC will occur.
- If the RAG is concerned with any indicators over the period between stock assessments (length frequency distributions, standardised commercial catch rates, age distributions etc), then it can decide to undertake a full assessment in that year

16.4 Conclusion

As the change in catch rates between 2010/2011 and July-Feb 2011/2012 is greater than -20% (Figure 16.3; Table 16.7) the control rule suggests a 10% decrease should be made to the default TAC.

16.5 Acknowledgements

John Garvey of AFMA is thanked for providing the original data extract. Dr Neil Klaer of CSIRO is especially thanked for pre-processing the catch and effort data so rapidly.

Table 16.1. The frequency of catch rate observations in each month and fishing year (financial year – July/June) for deepwater flathead from the GAB following data selection.

Mth	00/01	01/02	02/03	03/04	04/05	05/06	06/07	07/08	08/09	09/10	10/11	11/12
1	215	184	320	430	648	624	304	455	287	278	236	329
2	189	246	380	412	595	550	317	294	263	304	177	278
3	255	259	354	491	627	480	401	301	280	315	267	55
4	270	184	353	492	414	463	432	368	285	332	310	0
5	308	195	323	394	467	436	311	345	312	221	287	0
6	121	147	250	242	418	497	317	222	234	207	221	0
7	60	58	111	237	287	282	273	187	186	205	131	189
8	69	139	106	288	303	337	318	274	129	198	106	316
9	206	211	208	295	425	380	421	339	226	248	293	288
10	250	306	241	450	473	402	403	376	337	298	269	291
11	268	331	316	470	488	472	419	447	315	320	275	327
12	187	167	154	276	367	358	275	326	224	249	251	281
Total	2398	2427	3116	4477	5512	5281	4191	3934	3078	3175	2823	2354

Table 16.2. The relative frequency of depths records for Deepwater Flathead from the GAB see Figure 15.1). Data from 2000/2001 to Feb 2011/2012

Depth M	Count
0	531
50	19
100	8705
150	30314
200	2916
250	884
300	353
350	37
400	39
450	10
500	6
550	3
600	9
650	1
750	1
800	3
850	2
900	1
950	3
1000	1
1100	1
1250	1
1350	1
1500	1

Table 16.3. Summary statistics characterizing the data included in the standardization

	Records	Catches	Effort	GeomCE	Vessels
2000/2001	2398	771.247	12248	44.134	6
2001/2002	2427	906.838	12486	52.982	6
2002/2003	3116	1613.140	16763	73.451	9
2003/2004	4477	2157.200	24119	68.429	11
2004/2005	5512	2087.262	29731	55.122	10
2005/2006	5281	1341.148	28037	37.579	11
2006/2007	4191	952.492	21895	32.912	10
2007/2008	3934	957.801	20243	36.186	7
2008/2009	3078	775.565	15766	41.015	5
2009/2010	3175	805.629	16333	38.679	4
2010/2011	2823	932.788	14351	50.702	4
2011/2012	2299	570.140	12197	40.247	4

Table 16.4. The seven statistical models examined for Deepwater Flathead from the GAB.

Model 1	Fyear
Model 2	Fyear + Vessel
Model 3	Fyear + Vessel + DepCat
Model 4	Fyear + Vessel + DepCat + Month
Model 5	Fyear + Vessel + DepCat + Month + SubZone
Model 6	Fyear + Vessel + DepCat + Month + SubZone + DN
Model 7	Fyear + Vessel + DepCat + Month + SubZone + DN + DepCat:Month

Table 16.5. The standardized catch rates for the alternative statistical models for Deepwater Flathead from the GAB in depths 50 to 500 m. Values are relative to the mean of the standardized catch rates so that the average of the series remains 1.0. Fishing Years were from July/June, DepCat were 50 m categories, Subzones were 5° of Longitude, and DN relates to DayNight categories.

	FYear	Vessel	DepCat	Month	Subzone	DN	DepCat:Mth	StErr
00/01	0.9244	0.9253	0.9400	0.9267	0.9353	0.9350	0.9655	0.0000
01/02	1.1100	1.1289	1.1348	1.1296	1.1031	1.1046	1.1306	0.0196
02/03	1.5388	1.5810	1.6039	1.5818	1.5497	1.5486	1.5588	0.0190
03/04	1.4336	1.5073	1.5307	1.5196	1.5325	1.5333	1.5226	0.0187
04/05	1.1548	1.2029	1.2257	1.2340	1.2102	1.2117	1.1756	0.0183
05/06	0.7873	0.7946	0.7900	0.7936	0.7770	0.7779	0.7677	0.0184
06/07	0.6895	0.6571	0.6578	0.6687	0.6968	0.6967	0.6867	0.0190
07/08	0.7867	0.7161	0.7273	0.7274	0.7519	0.7521	0.7506	0.0195
08/09	0.8593	0.8293	0.8491	0.8519	0.9028	0.9029	0.9060	0.0202
09/10	0.8103	0.7999	0.8102	0.8217	0.8050	0.8035	0.8109	0.0202
10/11	1.0622	1.0303	0.9635	0.9703	0.9635	0.9652	0.9891	0.0211
00/01	0.8432	0.8271	0.7670	0.7748	0.7723	0.7684	0.7360	0.0225

Table 16.6. Model selection criteria, including the AIC, the adjusted r^2, and the proportional change in adj R^{2}. Optimal model was model 7: FYear + Vessel + DepCat + Month + SubZone + DayNight + DepCat:Month.

	FYear	Vessel	DepCat	Month	subzone	DN	DepCat:Month
AIC	-21129	-25011	-26709	-28313	-29770	-30215	-33478
RSS	25781	23512	22580	21732	20995	20774	19172
MSS	2659	4928	5860	6708	7445	7666	9268
Nobs	42439	42439	42439	42439	42439	42439	42439
Npars	12	26	35	46	49	51	123
Adj_r2	9.327	17.279	20.541	23.507	26.095	26.869	32.395
%Change		7.952	3.262	2.966	2.588	0.774	5.526

Table 16.7. The optimum standardized catch rate model relative to the unstandardized geometric mean catch rates (Fyear) with the percent difference between years for each. The value of interest is at the bottom right showing the difference between 10/11 and 11/12.

	Fyear	Diff	Optimum	Diff
00/01	0.9244		0.9655	
01/02	1.1100	20.08	1.1306	17.09
02/03	1.5388	38.63	1.5588	37.88
03/04	1.4336	-6.84	1.5226	-2.32
04/05	1.1548	-19.45	1.1756	-22.79
05/06	0.7873	-31.83	0.7677	-34.70
06/07	0.6895	-12.42	0.6867	-10.55
07/08	0.7867	14.10	0.7506	9.31
08/09	0.8593	9.22	0.9060	20.70
09/10	0.8103	-5.70	0.8109	-10.49
10/11	1.0622	31.09	0.9891	21.96
11/12	0.8432	-20.62	0.7360	**-25.59**

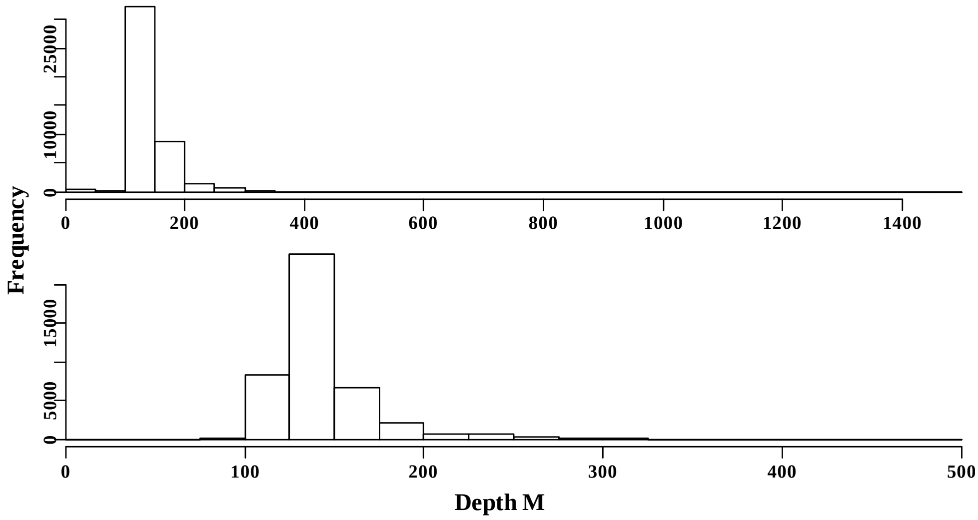


Figure 16.1. The relative frequency of depth records from Deepwater Flathead from the GAB. The lower graph is a repeat of the upper graph except with more detail. Data is from 2000/2001 – Feb 2011/2012.

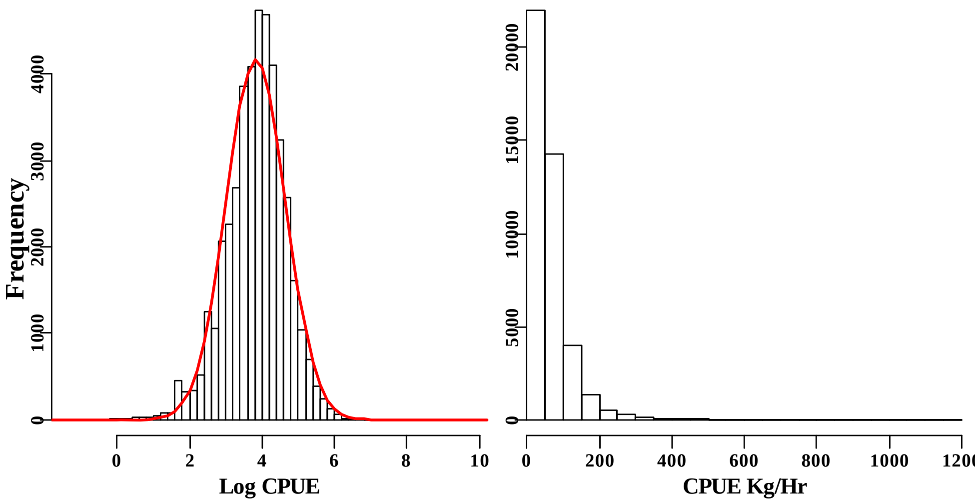
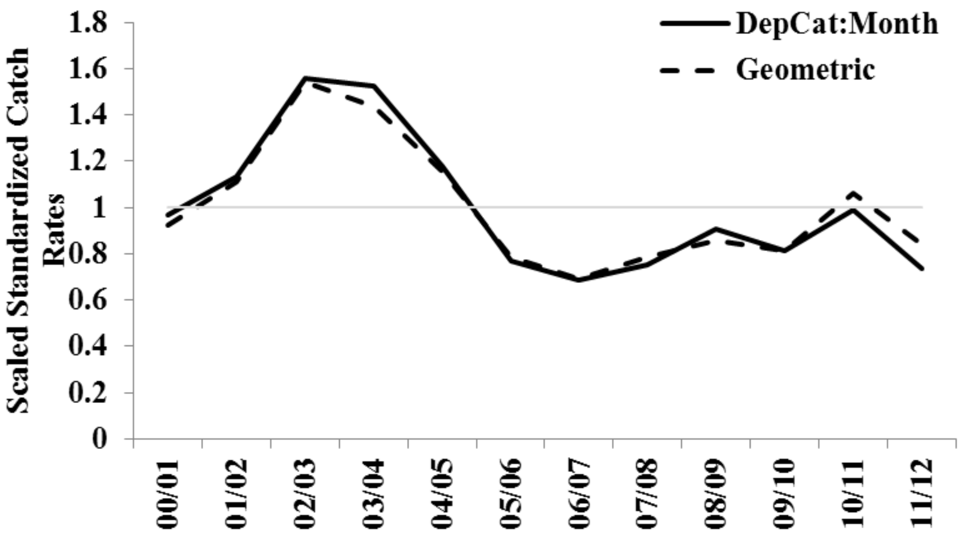


Figure 16.2. The catch rates for Deepwater Flathead are normalized by a natural log transformation. Data is from 2000/2001 – Feb 2011/2012.



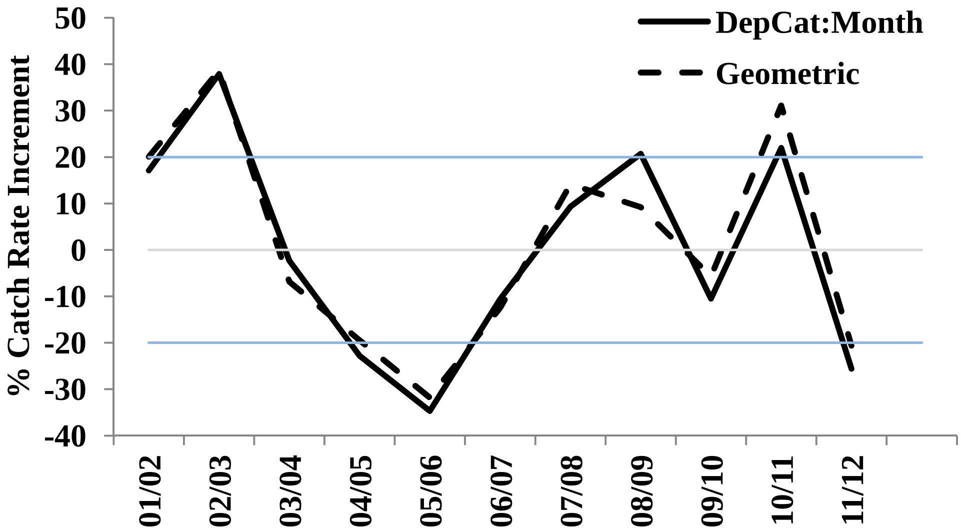


Figure 16.3. The standardized catch rates for Deepwater Flathead from the GAB. The dashed line is the unstandardized geometric mean catch rates see Table 15.7. The lower graph depicts the percent difference between consecutive fishing years (see Table 15.7).

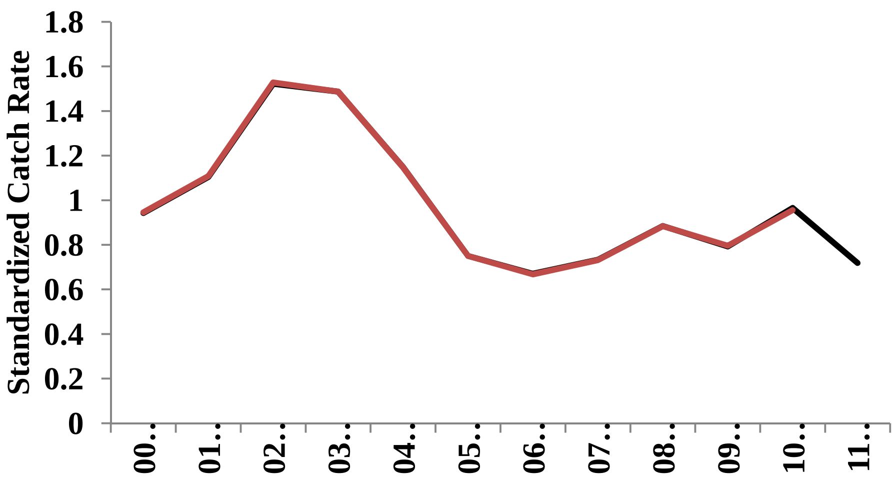


Figure 16.4. Comparison of this year's analysis (black line) with last year's (red line - scaling this year's analysis to the mean of 00/01 – 10/11 to make it comparable with last year's analysis).

17. Standardized Catch Rates for the SESSF Gummy Shark Fishery: Data from 1976 - 2011

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17.1 Summary

Reported catches of gummy sharks has declined from a high in 2008, although interpreting this is made more complex because of the 16 month TAC put in place for the 2007/2008 season. Nevertheless, the recent decline is real and is related to parallel declines in catches from South Australia and Bass Strait. Catches from South Australia decreased further in 2011 but recovered slightly in Bass Strait. These changes appear related to the introduction of gillnet fishery closures to protect Australian Sea Lions and dolphins in South Australian waters. At the same time the proportion of catches taken by gillnets declined over the period 2001 – 2011.

Standardized catch rates in South Australia have also exhibited a decline since 2008, however, the general trend since 1984 remains flat but noisy. The most recent mean estimate is slightly below the long term average, which again is thought to be related to the influence of the marine closures in South Australia.

In Bass Strait, standardized catch rates have also declined since 2008 but they are now still above or at the long term average depending on how the standardization for positive shots is combined with the standardization of the probability of obtaining a positive shot. Catches in the gummy shark fishery continue to be greatest in Bass Strait.

Standardized catch rates in Tasmania also remain noisy but flat. There is some indication of a very slow decline since about 2000 but given the variation surrounding the mean estimates the apparent decline is not yet statistically significant.

17.2 Introduction

The shark fishery off southern Australia has a long history starting with a long-line fishery which began in the 1920s which switched to gillnets in the 1960s and 1970s when the primary target also switched to gummy sharks (*Mustelus antarcticus*; Punt *et al.,* 2000; Punt & Gason, 2006; Thomson & Punt, 2010). This gillnet fishery now mainly targets gummy sharks although used to target relatively large quantities of School sharks (*Galeorhinus galeus*) but this is now a bycatch only species. In this shark fishery there are significant amounts of the common saw shark (*Pristiophorus cirratus*) and southern saw shark (*P. nudipinnis*; not distinguished from each other in the catch effort records) as well as elephant fish (*Callorhinchus milii*) taken as bycatch.

In 1990 – 1995 some major management changes were introduced. These included the amalgamation of endorsements and a reduction in the net unit from 6000m to 4,200m (by 1993 in Bass Strait and by 1995 in South Australia and Tasmania). With respect to gummy sharks the next big change came in 2001 when Individual Transferable Quotas (based on catch histories from 1994 – 1997) were introduced for both gummy and school sharks. The structural adjustment package across 2006/2007 led to 26 gillnet vessel SFRs and 17 shark hook vessel SFRs leaving the fishery.

Previous attempts to standardize commercial catch rates for sharks in Australia began with Punt *et al.* (2000) who used the Delta method, which analyses any trend in the probability of obtaining a positive shot and separately any trends in catch rates in the positive shots and then combining these two trends to obtain a single standardized catch rate for the fishery. Punt *et al.* (2000) focused on school sharks but their method was revised and extended when it was later applied to Gummy sharks (Punt & Gason, 2006; Thomson & Punt, 2010).

As Kimura (1981, p211) says: "Since the 1950s it has been recognized that fishing power generally differs among vessels, and if c.p.u.e. is to be proportional to abundance, effort measurements must be standardized." The most commonly used method of standardization is to include the various factors thought to effect catch rates into a generalized linear model and to include Year as a factor, in this way the parameters derived for each year become the indices of relative abundance (Venables & Dichmont, 2004).

After standardization we are left with a set of yearly coefficients that represent the catch rate relative to some reference year (usually with reference to the mean of the time series, which simplifies visual comparisons with other times series). Unfortunately, even if the standardization accounts for a large proportion of the variability in the data there are no guarantees that catch effort, even standardized catch effort, can act as a good proxy for stock size. Instead of the statistical success of the standardization, one should be able to argue from the nature of the fishery and the species concerned whether or not there is likely to be even an approximate relationship between catch rates and the exploitable biomass.

In this present work we focus on the catch rates for gummy shark, treating South Australia, Bass Strait, and Tasmania separately, because this reflects the assumed stock structure.

17.3 Methods

17.3.1 Catch Rate Standardization

The original data was provided in a text file named CANDE10.txt. This contained 421,977 records each with 23 fields (described in Haddon, 2012). The data provided received some pre-treatment in order to add the catch rate variables of interest and identify those records for inclusion in the analyses. Catch rates were calculated where there were positive catches of gummy sharks associated with positive effort levels. Where catch rates could be calculated they were also log transformed in preparation for the log-linear modelling of positive catches. Depth information, where present, was sub-divided into 10 metre depth categories for inclusion in the standardization. Finally, a field was added that identified which records contained positive catches of gummy sharks. This latter was necessary as a separate analysis is conducted to characterize the occurrence of zero shots (the complement of positive shots) and whether their incidence has altered through time (see below).

In previous standardizations (Punt & Gason, 2006; Thomson & Punt, 2010) a wide array of criteria were used to select records for analysis. An important aspect of any standardization where the trend in the probability of zero shots is included is how to identify zero shots, which relate to targeted effort that fails to catch the species of interest. In the SESSF trawl fishery identifying those shots that might have captured a species but didn't is extremely difficult because targeting is so difficult to establish. Fortunately, in the shark gillnet fishery this is less of a problem because gillnet shark fishers are targeting sharks, especially gummy sharks. The problem thus becomes one of focusing attention on those vessels and areas where the fishery is a main focus of effort. The primary data selection criteria are to select the years where the fishery was operating normally (as defined by the SharkRAG), to use records only where gillnets with mesh sizes of 6", 6.5" and 7" were used, to select only those vessels catching a defined minimum total catch per year and a defined number of years in the fishery, to include only those areas which were the main focus of the fishery, and to exclude those records with effort less than 1000m. In addition, records used were limited to particular gears and finally, those vessels that only caught small amounts of gummy shark across the years of the study were also excluded. The sensitivity of the analyses to the specific values selected as being a minimum reported catch for each area and vessel was tested by comparing an array of different combinations. In addition, the minimum number of years for a vessel to be active in the fishery was also considered.

17.3.2 The Delta Distribution

Including zero shots has two parts: 1) First, determine the relative probability of obtaining a positive catch. 2) Secondly, conduct a log-linear standardization on those records containing positive catches. These two analyses are then combined to provide the overall estimate of the yearly changes in catch rates required for inclusion in stock assessments.

17.3.3 Zero Catches

To estimate the probability of a positive observation (i.e. the species of interest is present in a shot) a binomial GLM (using a logit link function) is used to determine the effect of an array of factors on the probability p_i, which is the probability that the species of interest is present in the i^{th} shot:

$$\ln\left(\frac{p_i}{1-p_i}\right) = \beta_0 + \beta_1 x_{i,1} + \beta_2 x_{i,2} + \sum_{j=3}^{N} \beta_j x_{ij} \tag{1}$$

where p_i is the probability that the species of interest was present in the i^{th} shot, and x_{ij} are the values of the explanatory variables, j, for the i^{th} shot and the β_j are the coefficients for the N factors j, to be estimated (β_0 is the intercept, β_1 the coefficient for the first factor, *etc*.).

The catch rate standardizations all used individual records from the database, which in a number of cases appeared to be aggregated data, potentially aggregated within months, although there were also many individual shots recorded. This is apparent because the reported effort as net length is sometimes in the 100's of thousands of metres for a single record. The catch rate data for positive catches were normalized by using a natural-log transformation. General Linear Models were used with this transformed data rather than using Generalized Linear Models on the untransformed data with a log-link;

the approach used has advantages in terms of normalizing the data while stabilizing the variance, which the Generalized Linear Model approach does not always achieve appropriately (Venables & Dichmont, 2004).

Up to eight different log-linear models were fitted and compared in an effort to account for the effects of year, area, month of fishing, vessel, which depth category was used, which gear was used, and any interactions between area and month, and area and gear (see Haddon, 2011). All variables were treated as categorical variables (alternatively termed factors). The optimum statistical model was selected on the basis of the Akaike's Information Criterion (Burnham & Anderson, 1998), and the adjusted r^2 (Neter *et al.,*1996). The resulting optimal model was plotted in comparison with the geometric mean catch rate, both being scaled to the mean of each series for ease of visual comparison. The standardized catch rates for the year factor can be used in assessment models as the index of relative abundance through time.

Standard analyses were conducted in each case and all were coded in the statistical software R (R development Core Team, 2009). In each case, catch rates, as kilograms per metre of gillnet fished, were natural log-transformed to normalize the data and stabilize the variance. The General Linear Models all had the same form:

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

where Ln($CPUE_i$) is the natural logarithm of the catch rate (kg/m) for the i-th record, x_{ij} are the values of the explanatory variables j for the i-th shot (i.e. Year, Disting, Month, etc), and the α_j are the coefficients for the N factors j to be estimated (α_0 is the intercept, α_1 is the coefficient for the first factor, *etc*.), and ε_{ij} are the normal random residual errors.

17.3.4 The Year Effect

The standardised overall year effect for the fishery is calculated as the product of the Year coefficients from the binomial and log-linear GLMs (Eqs (1) and (2)) transformed back onto their original scales. For back-transformation all other predictor variables were set to zero, indicating the reference level of each categorical factor. The expected probability (back-transformed from logit) of a non-zero catch in year t is therefore

$$\hat{p}_t = \frac{\exp\left(\beta_0 + \lambda_t\right)}{1 + \exp\left(\beta_0 + \lambda_t\right)} \tag{3}$$

where p_t is the probability of a non-zero catch in year t, β_0 is the intercept and the λ_t is the Year coefficient for year t. As a test of the procedure the back transformation of the simple PA = Year model should deliver the annual proportion of positive shots.

For the log-normal model the expected back-transformed year effect involves a bias-correction for log-normality; the back transformation without the correction estimates the median of the distribution rather than the mean, adding $\sigma^2/2$ before back-transformation improves the approximation to the mean of the distribution:

$$CPUE_t = e^{\left(\gamma_t + \sigma_t^2/2\right)} \tag{4}$$

where γ_t is the Year coefficient for year *t* and σ_t is its standard error.

Total standardised catch rates for year *t* are calculated as the product of Eqs (3) and (4), stated relative to the average of all values:

$$\bar{Y} = \frac{\sum_{t=1}^{n} p_t CPUE_t}{n} \tag{5}$$

where *n* is the number of years of data. So the standardized catch rates are given relative to the mean of the series. This implies that the average of the time series of standardized catch rates will always be one, and hence each series is directly comparable with all the others:

$$Y_t = \frac{p_t CPUE_t}{\bar{Y}} \tag{6}$$

The factors considered in the analyses were all taken as categorical variables and were:

Year	the standard calendar year,
Disting	each vessel is uniquely and confidentially identified,
Month	standard calendar months,
Area	Standard shark statistical reporting blocks (Figure 17.1).
Gear	6.0”, 6.5”, or 7.0” mesh nets.
DepCat	10m categories (novel this year)
Area:Month	An interaction term used to include any seasonal changes across areas.

17.3.5 Data Selection Gummy Sharks

Data selection occurred with the years of data used by zone, the gear used, the depths, used, and with areas only included if total catches exceeded a given limit, vessels only included if their average annual catches exceeded a given limit, and they were reporting catches for more than a given number of years in the fishery (Table 17.7).

There were also some records where no effort data were included (effort = -1) and these could not be included in the standardization. In addition, if the reported effort was < 1000m these records were also excluded.

Depth data was not provided from South Australia until after 1997 so depth cannot be included in the South Australia standardization.

There are a large number of vessels contributing to the final analysis, even with the restricted number of years and areas used. To remove noise generated by those vessels reporting very small amounts of gummy sharks those vessels reporting less than an average of 2 tonne per year (for the years in which they reported saw sharks) were removed from the analysis. In addition, if they reported for less than 3 years they were excluded.

17.3.6 Disjunction in the 1990s

Major changes appear to have occurred in the data from the fishery during the early 1990s. To illustrate this disjunction the catch per vessel per year (as identified by their distinguishing marks) can be tabulated. From this table it is possible to sum the catches per vessel from 1976 – 1993 and, separately, the catches by vessel from 1994 – 2010. These data can then be used to estimate the proportional representation of the catches by vessel across these two periods.

17.4 Results

17.4.1 The Shark Fishery

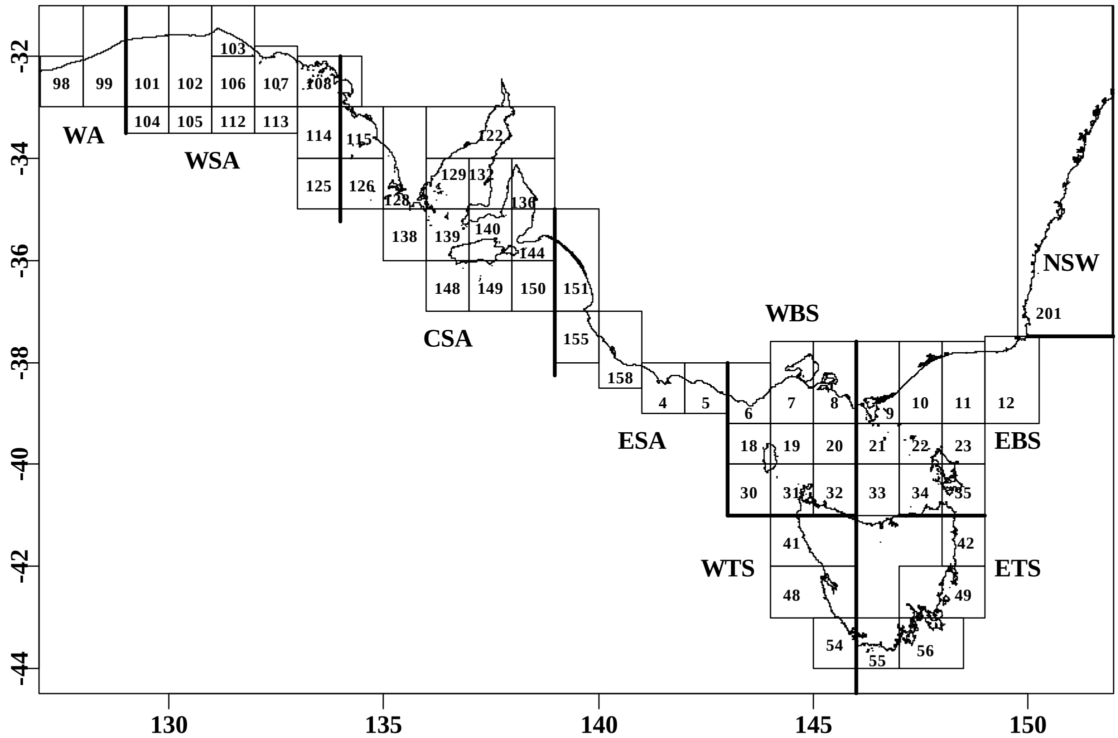

Figure 17.1. Map of shark statistical reporting areas along with the statistical regions. WA is Western Australia, WSA is Western South Australia, CSA is Central South Australia, ESA is Eastern South Australia (sometimes known as SAV – South Australia Victoria), WBS is Western Bass Strait, EBS is Eastern Bass Strait, NSW is New South Wales, ETS is Eastern Tasmania and WTS is Western Tasmania.

17.4.2 The Gummy Shark Fishery

Following the decline in the school shark fishery, the non-trawl shark fishery is now dominated by the gummy shark fishery (Figure 17.2, Figure 17.3,Table 17.4).

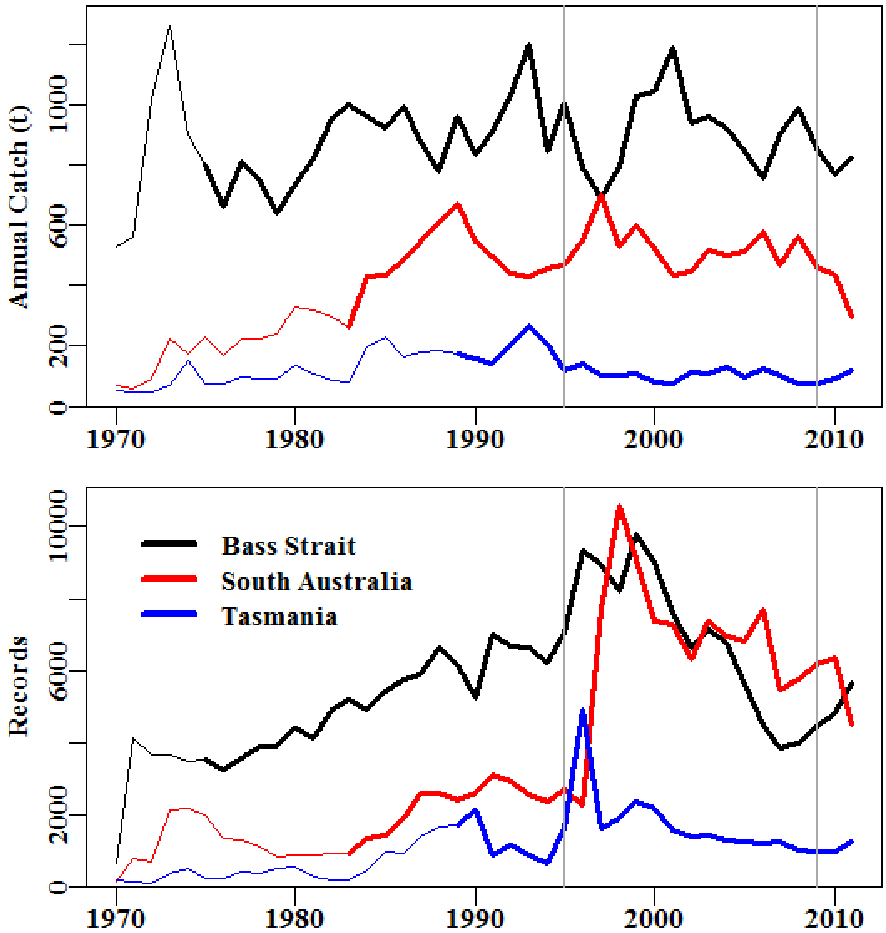

Figure 17.2. The total annual catch and number of records for the three main regions in the Gummy shark fishery for all gears. The thick lines represent the range of years chosen by the SharkRAG to represent the fishery, while the fine lines represent the available data in the log book data base. The grey vertical lines relate to 1995 and 2009.

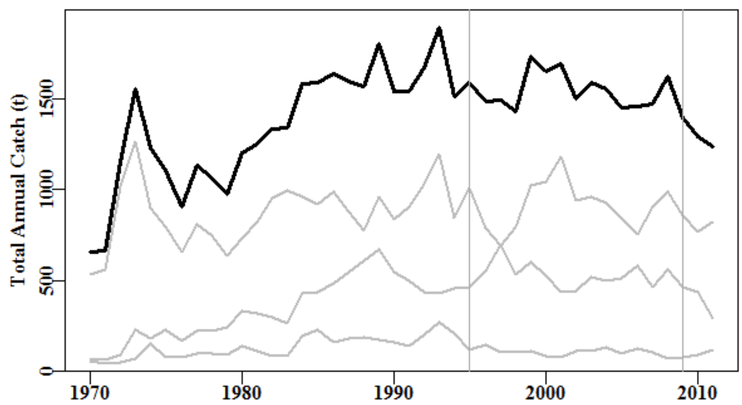

Figure 17.3. Total reported catches of gummy sharks, 1976 – 2011 from the log-books. The grey lines relate to the individual regions. These data relate to all gillnet catches by all mesh sizes. The vertical grey lines relate to 1995 and 2009

There is a clear disjunction between the available data prior to 1995 and that after, and this is especially apparent in South Australia and Tasmania (Figure 17.2, Figure 17.3 and Figure 17.4). This also becomes apparent in the standardized catch rates. Total catches have been relatively stable since 1995 although have been declining since 2009, primarily in South Australia, where the Australian Sea Lion closures began to impact the gummy shark fishery.

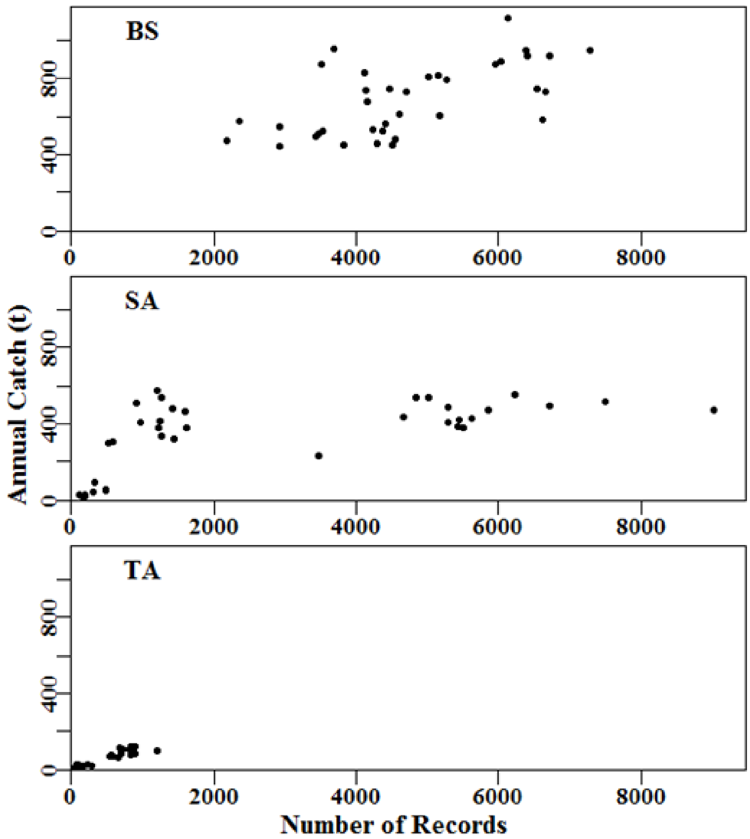

Figure 17.4 The relationship between the number of records and the resulting catch each year in each of the three regions. This data relate only to catches taken with 6", 6.5" and 7" nets are include data from all years 1970 to 2011.

Reported catches of gummy sharks has declined from a high in 2008, although interpreting this is made more complex because of the 16 month TAC put in place for the 2007/2008 season (Table 17.8; Figure 17.13). Nevertheless, the recent decline is real and is related to parallel declines of catches in South Australia and Bass Strait. Catches from South Australia decreased further in 2011 but recovered slightly in Bass Strait. These changes appear to be related to the introduction of closures to protect Australian Sea Lions and dolphins in South Australian waters.

At the same time the proportion of catches taken by gillnets declined over the period 2001 – 2011 (Table 17.8).

17.5 South Australia

The standardization of the South Australian gummy shark catch-rates reduces the variation exhibited by the trend through time, with the geometric mean catch rates having a CV of 22.8% while the optimum model has a CV of 16.8% (Figure 17.5; Table 17.1). Nevertheless, each mean estimate is relatively uncertain, as indicated by the 95% confidence intervals on the graphs) and only a few years could be considered statistically significant. It should be noted that the width of these confidence intervals are likely to be under-estimates owing to the various influential factors that have not been able to be included in the analysis.

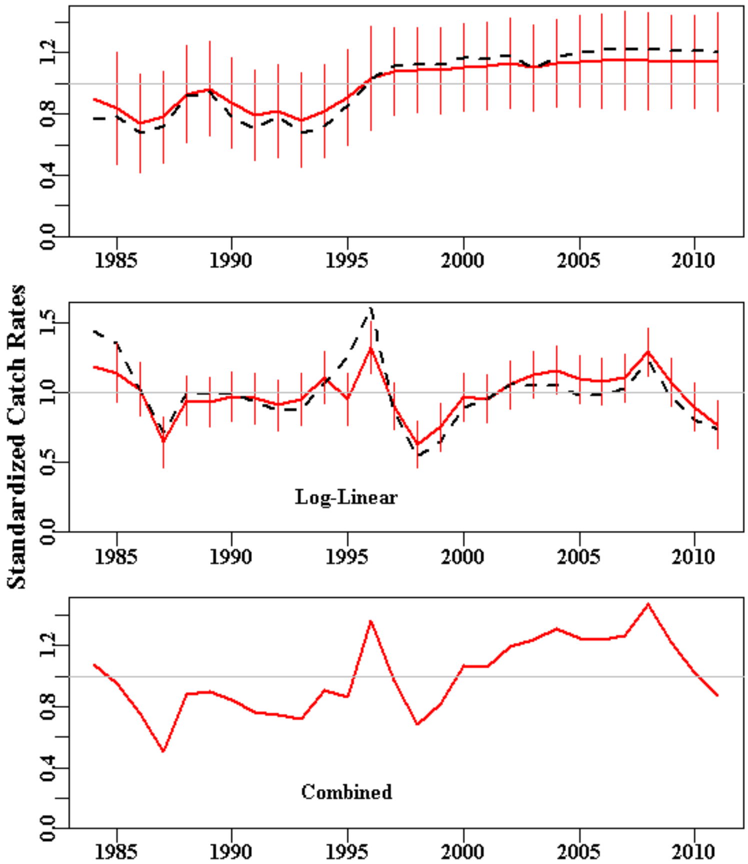

Figure 17.5. Standardized catch rates for South Australia gummy sharks using data relating to 6.0”, 6.5”, and 7.0” mesh gear, from areas that reported more than 10 tonnes across the 28 years considered (1984 – 2011), and from vessels with average catches greater than 2 tonnes per annum which had been present in the fishery for at least 3 years. The top panel represents the probability of obtaining a positive catch, the dashed line being the proportion of positive catches in the raw data and the solid line being the statistical optimum model (with the 95% error bars surrounding the trend). The central panel represents the log-linear modelling of positive catches. The dashed line is the geometric mean while the solid line is the optimal model, and again the bars are the 95% confidence limits on the mean estimates. The bottom panel represents the final standardized catch rates, combining the results from the log-linear modelling and the binomial modelling of the probability of a positive catch. All trends have been scaled to the mean of each series to ease visual comparison.

When the analysis of positive catches is combined with the analysis of the relative incidence of positive shots then there does not appear to have been the overall trend through time. Perhaps catch rates were lower pre-1995 and generally higher after 1995. The decline from the high in 2008 is associated with a reduction in the catch landed in South Australia and with a reduction of greater than 40% in the number of records in

2011 brought about by the Australian sea lion closures. These closures appear likely to lead to a decline in observed catch rates.

The overall conclusion is that the catch rates for gummy shark in South Australia remain flat but noisy about the long term average.

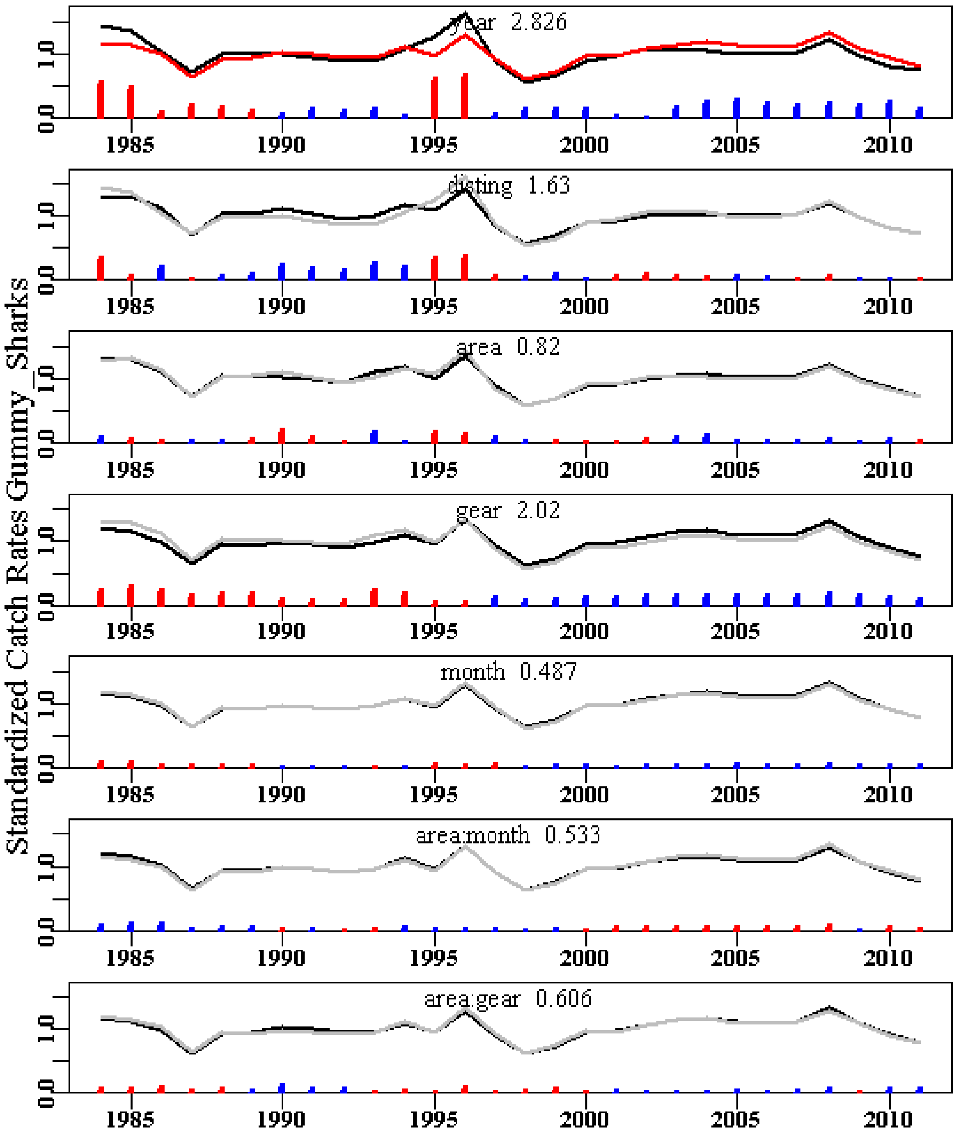

Figure 17.6. South Australian Gummy shark: The relative influence of each factor used on the final trend in the optimal standardization. The top graph depicts the geometric mean (the black line) and the optimum model (the red line). The difference between them is illustrated by the vertical bars with blue bars indicating the optimum model is higher than the geometric mean and red bars indicating it is lower. The top graph bars are the sum of all the bars in the graphs below. The graphs for individual factors are cumulative. Thus the second graph has the geometric mean (grey line) and the effect of adding Year + factor2 (model 2). In the third graph, the grey line represents model 2 and the black line the effect of adding factor3 to the model. The remaining graphs continue in the same cumulative manner except for the interaction terms which are added singularly to the final single factor model.

Table 17.1. The different standardization models fitted to the South Australian gummy shark data. The models are cumulative across the table with the optimum being the Area:Month model.

Year	GeoMean	Vessel	Area	Month	Gear	Area:Month	Area:Gear
1984	1.4462	1.2708	1.3151	1.2845	1.1569	1.1954	1.1687
1985	1.3532	1.3147	1.2931	1.2586	1.0986	1.1439	1.1168
1986	1.0231	1.1240	1.1092	1.1093	0.9751	1.0258	0.9794
1987	0.7198	0.7100	0.7179	0.7164	0.6328	0.6471	0.6242
1988	0.9903	1.0242	1.0434	1.0316	0.9262	0.9465	0.9081
1989	0.9935	1.0399	1.0136	1.0058	0.9069	0.9332	0.9465
1990	1.0002	1.1116	1.0201	1.0335	0.9832	0.9749	1.0305
1991	0.9340	1.0252	0.9866	0.9967	0.9551	0.9613	0.9997
1992	0.8779	0.9482	0.9450	0.9580	0.9128	0.9117	0.9372
1993	0.8826	1.0155	1.0942	1.1027	0.9711	0.9543	0.9478
1994	1.0748	1.1738	1.1809	1.2001	1.0888	1.1133	1.0933
1995	1.2560	1.0781	0.9922	0.9678	0.9414	0.9582	0.9528
1996	1.6133	1.4242	1.3536	1.3343	1.3151	1.3253	1.2860
1997	0.8717	0.8339	0.8751	0.8433	0.9042	0.9082	0.8990
1998	0.5469	0.5709	0.5832	0.5827	0.6275	0.6297	0.6101
1999	0.6535	0.6953	0.6877	0.6943	0.7485	0.7554	0.7262
2000	0.8939	0.8998	0.8969	0.9036	0.9737	0.9704	0.9625
2001	0.9554	0.9147	0.9102	0.9082	0.9822	0.9588	0.9716
2002	1.0623	1.0151	0.9914	0.9942	1.0770	1.0589	1.0626
2003	1.0556	1.0176	1.0604	1.0637	1.1516	1.1316	1.1392
2004	1.0550	1.0352	1.0850	1.0923	1.1821	1.1633	1.1726
2005	0.9800	1.0080	1.0272	1.0402	1.1271	1.1006	1.1224
2006	0.9856	1.0010	1.0112	1.0211	1.1035	1.0818	1.0932
2007	1.0328	1.0234	1.0427	1.0501	1.1347	1.1103	1.1248
2008	1.2250	1.1964	1.2200	1.2342	1.3351	1.2936	1.3302
2009	0.9737	0.9785	0.9850	0.9943	1.0768	1.0774	1.0732
2010	0.8082	0.8177	0.8454	0.8543	0.9259	0.8990	0.9251
2011	0.7354	0.7322	0.7137	0.7242	0.7863	0.7702	0.7967
CV	22.84	19.00	18.49	18.12	17.15	16.81	17.09

Table 17.2. The statistical diagnostics for the South Australian gummy shark standardization. The smallest AIC and largest adjusted r^2 indicates the optimum statistical model.

	GeoMean	Vessel	Area	Month	Gear	Area:Month	Area:Gear
AIC	28566	23815	20658	19942	19883	17901	19474
RSS	117772	111032	106857	105920	105840	102609	105184
MSS	4160	10899	15075	16012	16092	19322	16748
Nobs	83813	83813	83813	83813	83813	83813	83813
Npars	28	122	150	161	163	471	219
adj_r2	3.380	8.807	12.207	12.966	13.029	15.372	13.510
%Change	0.000	5.427	3.400	0.758	0.064	2.343	0.481

17.6 Bass Strait

The transition in the character of the gillnet commercial catch and effort data before and after 1995 is clearly apparent in the catch rate standardization, although in the case of Bass Strait this is only apparent in the standardization of the probability of obtaining a positive shot. Zero shots for gummy sharks became far less likely following 1995 (Figure 17.7) which corresponds to changes in allowable net length and other related management changes. This transition is very apparent in the plot of the influence of each factor on the trend in the standardized catch rates (Figure 17.8).

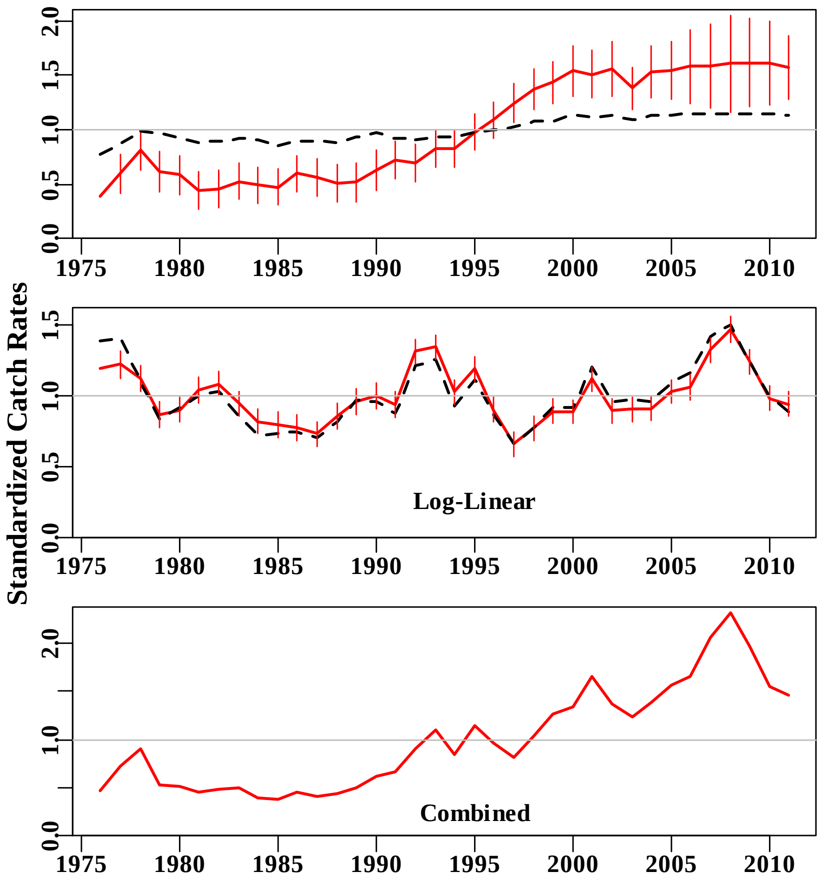

Figure 17.7. Standardized catch rates for Bass Strait gummy sharks using data relating to 6.0", 6.5", and 7.0" mesh gear, from areas that reported more than 10 tonnes across the 36 years considered (1976 – 2011), and from vessels with average catches greater than 2 tonnes per annum which had been present in the fishery for at least 3 years. The top panel represents the probability of obtaining a positive catch, the dashed line being the proportion of positive catches in the raw data and the solid line being the statistical optimum model (with the 95% error bars surrounding the trend). The central panel represents the log-linear modelling of positive catches. The dashed line is the geometric mean while the solid line is the optimal model, and again the bars are the 95% confidence limits on the mean estimates. The bottom panel represents the final standardized catch rates, combining the results from the log-linear modelling and the binomial modelling of the probability of a positive catch. All trends have been scaled to the mean of each series to ease visual comparison.

As with the positive catches in South Australia, the gummy shark catch rates in Bass Strait are noisy and flat relative to the long term catch rate. The probability of a positive catch, however, undergoes a significant change between 1993 – 1997 so when these two series are combined the net result is stable catch rates from 1976 – about 1990 followed by a gradual increase up until 2008, followed by a decline to the present day. Despite the decline the catch rates since 2008 the catch rates are still above the long term average. The catch rates (for the positive catches only) for both South Australia and

Bass Strait (Figure 17.7) follow approximately the same trajectory through time (Figure 17.9).

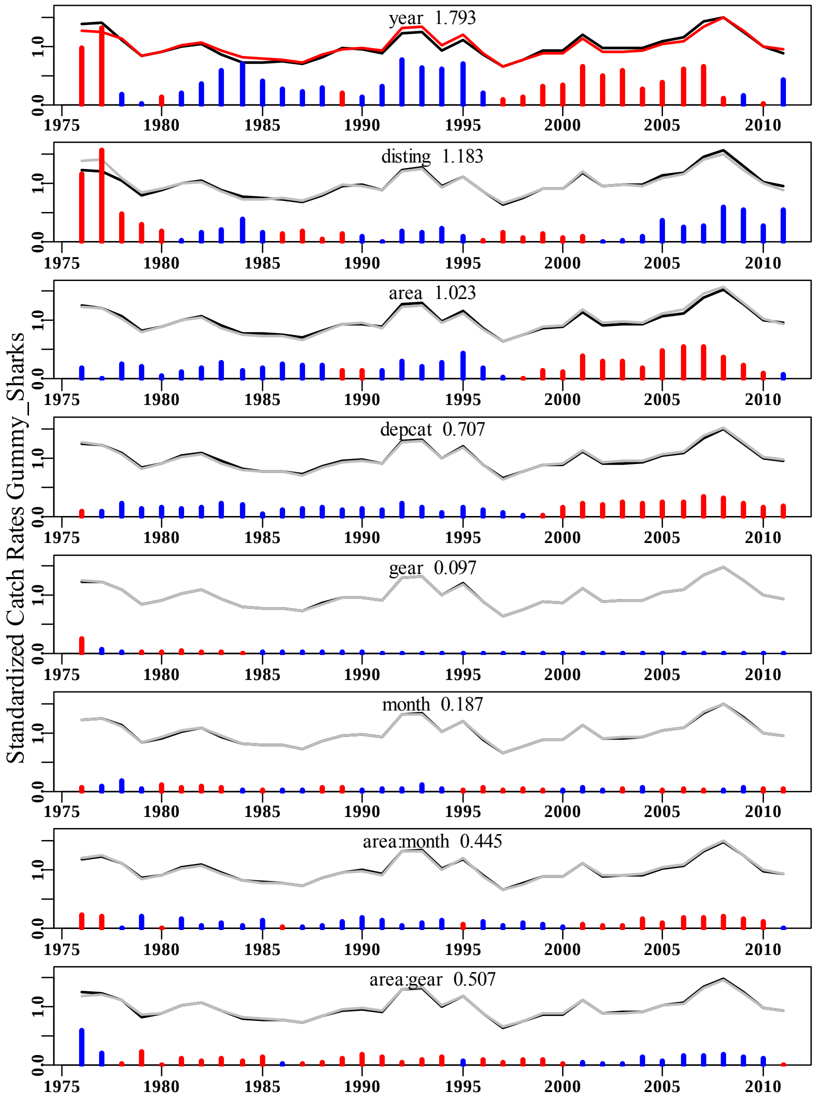

Figure 17.8.The relative influence of each factor used on the final trend in the optimal standardization for Bass Strait Gummy shark. The top graph depicts the geometric mean (the black line) and the optimum model (the red line). The difference between them is illustrated by the vertical bars with blue bars indicating the optimum model is higher than the geometric mean and red bars indicating it is lower. The top graph bars are the sum of all the bars in the graphs below. The graphs for individual factors are cumulative. Thus the second graph has the geometric mean (grey line) and the effect of adding Year + factor2 (model 2). In the third graph, the grey line represents model 2 and the black line the effect of adding factor3 to the model. The remaining graphs continue in the same cumulative manner except for the interaction terms which are added singularly to the final single factor model.

In case the large transition in the probability of a positive shot in the 1990s had a large influence on the outcome the trend was re-plotted using the same trend for the positive catches, but the probability of a positive shot was rescaled to the mean of the estimates between 1996 – 2011. When this is done there is still an increase in catch rates from 1987 through to 2008 but the current catch rates are now at the long term average rather than being above (Figure 17.10).

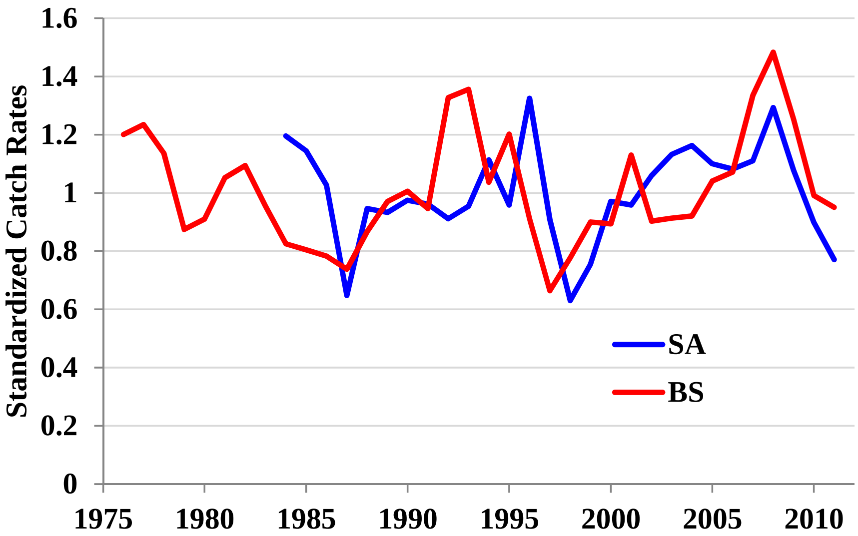

Figure 17.9. A comparison of the optimum standardized catch rates for positive catches for South Australia (SA) and Bass Strait (BS), both scaled to a mean of 1.0 over the years 1984 – 2011.

Table 17.3. The statistical diagnostics for the South Australian gummy shark standardization. The smallest AIC and largest adjusted r^2 indicates the optimum statistical model.

	GeoMean	Vessel	Area	Month	Gear	Depth	Area:Month
AIC	42045	36699	31733	30962	30951	29680	27166
RSS	188934	181559	175186	174198	174179	172545	168995
MSS	5351	12727	19099	20088	20107	21740	25291
Nobs	139990	139990	139990	139990	139990	139990	139990
Npars	36	150	168	179	181	205	403
adj_r2	2.730	6.451	9.723	10.225	10.234	11.060	12.767
%Change		3.721	3.272	0.502	0.009	0.826	1.706

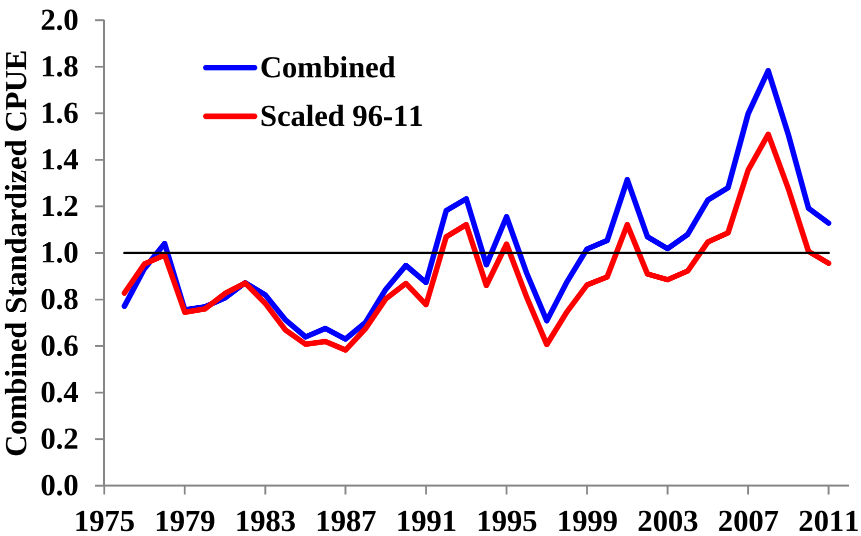

Figure 17.10. A comparison of the overall combined standardized catch rates for Bass Strait (Combined) with the same time series for the positive catches, but the probability of a positive shot being scaled to the mean of the time series over the years 1984 – 2011. This was to illustrate the influence of the large change in the probability of a positive shot during the 1990s.

Table 17.4**.** The different standardization models fitted to the Bass Strait gummy shark data. The models are cumulative across the table with the optimum being the Area:Month model. The CVs reflect the relative variability of each time series.

Year	GeoMean	Vessel	Area	Month	Gear	Depth	Area:Month
1976	1.3817	1.2373	1.2609	1.2555	1.2249	1.2134	1.1860
1977	1.4091	1.2128	1.2138	1.2264	1.2347	1.2437	1.2189
1978	1.0946	1.0350	1.0671	1.0894	1.0931	1.1210	1.1217
1979	0.8321	0.7942	0.8212	0.8256	0.8230	0.8389	0.8631
1980	0.9121	0.8892	0.8956	0.8841	0.8819	0.8993	0.8985
1981	0.9972	0.9996	1.0161	1.0108	1.0058	1.0201	1.0393
1982	1.0260	1.0459	1.0697	1.0613	1.0570	1.0740	1.0806
1983	0.8532	0.8788	0.9132	0.9076	0.9051	0.9319	0.9422
1984	0.7172	0.7666	0.7856	0.7864	0.7854	0.8089	0.8150
1985	0.7268	0.7474	0.7727	0.7692	0.7727	0.7787	0.7949
1986	0.7430	0.7263	0.7580	0.7580	0.7613	0.7760	0.7728
1987	0.6979	0.6761	0.7069	0.7081	0.7111	0.7259	0.7285
1988	0.8135	0.8072	0.8364	0.8295	0.8325	0.8509	0.8561
1989	0.9686	0.9520	0.9334	0.9268	0.9302	0.9447	0.9588
1990	0.9548	0.9669	0.9497	0.9533	0.9553	0.9711	0.9935
1991	0.8763	0.8772	0.8954	0.8998	0.9016	0.9168	0.9347
1992	1.2095	1.2311	1.2705	1.2764	1.2767	1.3047	1.3101
1993	1.2479	1.2693	1.2951	1.3077	1.3090	1.3269	1.3393
1994	0.9295	0.9592	0.9935	0.9983	0.9993	1.0076	1.0234
1995	1.1091	1.1215	1.1769	1.1760	1.1771	1.1959	1.1871
1996	0.8604	0.8565	0.8799	0.8729	0.8737	0.8867	0.8997
1997	0.6595	0.6392	0.6431	0.6414	0.6420	0.6497	0.6556
1998	0.7687	0.7612	0.7586	0.7535	0.7541	0.7567	0.7674
1999	0.9177	0.9005	0.8823	0.8805	0.8812	0.8792	0.8889
2000	0.9195	0.9117	0.8965	0.8968	0.8975	0.8790	0.8827
2001	1.2038	1.1918	1.1415	1.1479	1.1488	1.1225	1.1153
2002	0.9579	0.9588	0.9212	0.9212	0.9220	0.8967	0.8919
2003	0.9779	0.9818	0.9432	0.9370	0.9377	0.9077	0.9014
2004	0.9581	0.9708	0.9478	0.9554	0.9558	0.9288	0.9089
2005	1.0871	1.1325	1.0708	1.0693	1.0700	1.0402	1.0277
2006	1.1554	1.1881	1.1174	1.1120	1.1128	1.0820	1.0584
2007	1.4187	1.4534	1.3847	1.3812	1.3822	1.3407	1.3187
2008	1.5009	1.5749	1.5268	1.5278	1.5289	1.4902	1.4646
2009	1.2362	1.3051	1.2755	1.2831	1.2841	1.2582	1.2376
2010	0.9949	1.0279	1.0164	1.0126	1.0134	0.9937	0.9785
2011	0.8833	0.9522	0.9626	0.9573	0.9582	0.9376	0.9383
CV	21.66	21.52	20.22	20.42	20.34	19.62	18.88

17.7 Tasmania

Even though the RAG decided to use the years 1990 onwards there are major changes prior to 1995. The catches are all < 20t from 1979 – 2004, and the number of records jumps from <200 to >800 between 1994 and 1995 (Figure 17.7). Nevertheless, the trend in the probability of a positive catch is effectively flat throughout the time series and so is the standardized catch rates for positive shots, at least since 1996 (Figure 17.11)

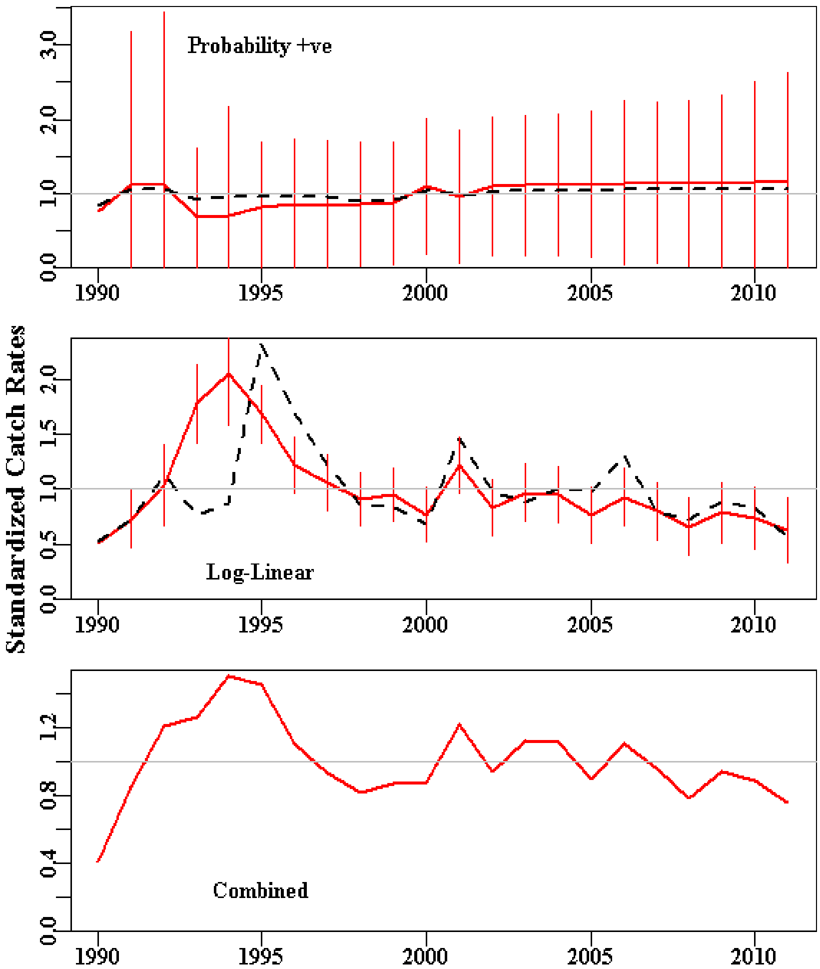

Figure 17.11**.** Standardized catch rates for Tasmanian gummy sharks using data relating to 6.0”, 6.5”, and 7.0” mesh gear, from areas that reported more than 10 tonnes across the 36 years considered (1976 – 2011), and from vessels with average catches greater than 2 tonnes per annum which had been present in the fishery for at least 3 years. The top panel represents the probability of obtaining a positive catch, the dashed line being the proportion of positive catches in the raw data and the solid line being the statistical optimum model (with the 95% error bars surrounding the trend). The central panel represents the log-linear modelling of positive catches. The dashed line is the geometric mean while the solid line is the optimal model, and again the bars are the 95% confidence limits on the mean estimates. The bottom panel represents the final standardized catch rates, combining the results from the log-linear modelling and the binomial modelling of the probability of a positive catch. All trends have been scaled to the mean of each series to ease visual comparison.

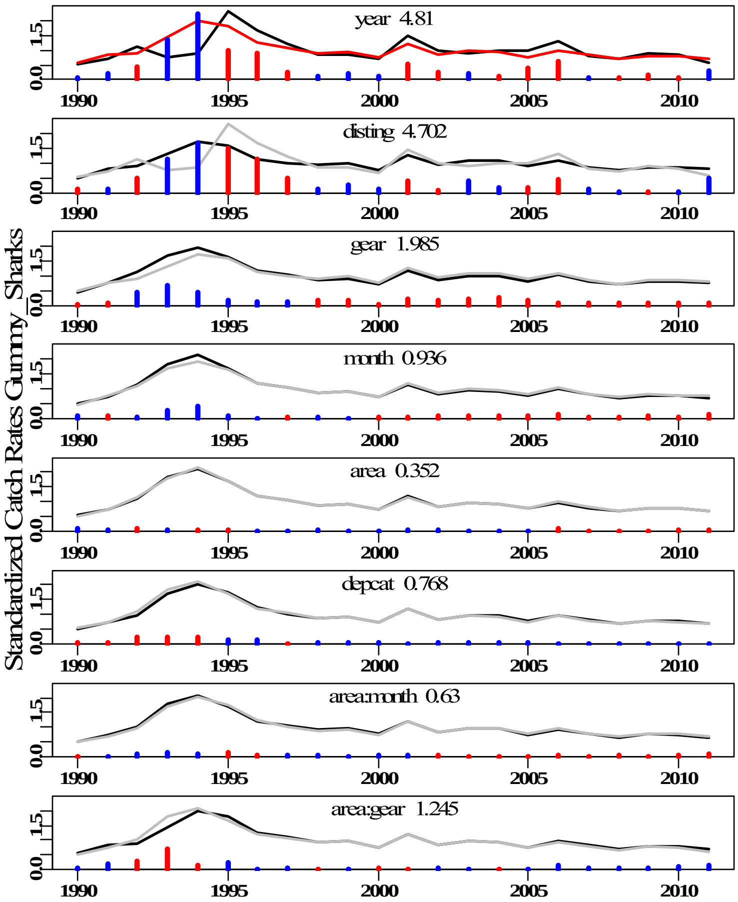

Figure 17.12. The relative influence of each factor used on the final trend in the optimal standardization for Tasmanian Gummy shark. The top graph depicts the geometric mean (the black line) and the optimum model (the red line). The difference between them is illustrated by the vertical bars with blue bars indicating the optimum model is higher than the geometric mean and red bars indicating it is lower. The top graph bars are the sum of all the bars in the graphs below. The graphs for individual factors are cumulative. Thus the second graph has the geometric mean (grey line) and the effect of adding Year + factor2 (model 2). In the third graph, the grey line represents model 2 and the black line the effect of adding factor3 to the model. The remaining graphs continue in the same cumulative manner except for the interaction terms which are added singularly to the final single factor model.

Some large changes occurred in the Tasmanian fishery prior to 1997 with respect to both the vessels doing the fishing and the gear that was used (6”, 6.5”, or 7”). Otherwise there were few differences between the geometric mean catch rates and the optimum model, so other factors only contributed very little to changes in the observed trend.

Table 17.5. The different standardization models fitted to the Tasmanian gummy shark data. The models are cumulative across the table with the optimum being the Area:Month model. The CVs reflect the relative variability of each time series.

Year	GeoMean	Vessel	Area	Month	Gear	Depth	Area:Month
1990	0.5216	0.4727	0.4540	0.4933	0.5386	0.5214	0.5102
1991	0.7267	0.7851	0.7480	0.7156	0.7380	0.7182	0.7268
1992	1.1218	0.8897	1.1116	1.1414	1.0937	0.9816	1.0389
1993	0.7605	1.3214	1.6681	1.8050	1.8253	1.7128	1.7786
1994	0.8685	1.7159	1.9366	2.1388	2.1129	2.0013	2.0572
1995	2.3132	1.5672	1.6532	1.6929	1.6759	1.7498	1.6829
1996	1.6851	1.1283	1.1798	1.1847	1.1859	1.2516	1.2222
1997	1.2163	0.9804	1.0461	1.0337	1.0412	1.0303	1.0617
1998	0.8585	0.9230	0.8434	0.8551	0.8661	0.8915	0.9149
1999	0.8518	0.9883	0.9039	0.9076	0.9162	0.9418	0.9568
2000	0.6864	0.7419	0.7197	0.7085	0.7170	0.7456	0.7703
2001	1.4667	1.2770	1.1798	1.1534	1.1760	1.1858	1.2189
2002	0.9812	0.9400	0.8490	0.8118	0.8264	0.8448	0.8279
2003	0.8824	1.0858	0.9873	0.9439	0.9473	0.9739	0.9715
2004	1.0043	1.0923	0.9720	0.9236	0.9308	0.9523	0.9516
2005	0.9734	0.8934	0.7988	0.7546	0.7582	0.7750	0.7630
2006	1.2969	1.0886	1.0522	0.9897	0.9545	0.9667	0.9282
2007	0.7882	0.8542	0.8203	0.8047	0.7970	0.8096	0.8001
2008	0.7282	0.7414	0.7071	0.6841	0.6736	0.6855	0.6589
2009	0.8839	0.8717	0.8223	0.7905	0.7860	0.7991	0.7885
2010	0.8267	0.8408	0.7930	0.7700	0.7584	0.7710	0.7404
2011	0.5577	0.8008	0.7538	0.6971	0.6811	0.6902	0.6304
CV	40.55	28.02	35.34	40.16	39.59	37.56	38.84

Table 17.6. The statistical diagnostics for the Tasmanian gummy shark standardization. The smallest AIC and largest adjusted r^2 indicates the optimum statistical model.

	GeoMean	Vessel	Area	Month	Gear	Depth	Area:Month
AIC	3470	588	550	380	328	302	117
RSS	13718	10101	10058	9859	9793	9720	9449
MSS	864	4480	4523	4722	4788	4861	5132
Nobs	9601	9601	9601	9601	9601	9601	9601
Npars	22	50	52	63	69	92	135
adj_r2	5.716	30.370	30.652	31.947	32.361	32.700	34.278
%Change	0.000	24.654	0.282	1.295	0.414	0.339	1.578

17.8 Extra Tables

Table 17.7**.** The annual catches and reported number of records for each of the three main regions. The greyed cells illustrate the years used in the analyses for each region.

	Bass Strait		South Australia		Tasmania		Unknown	
Year	Catch	Records	Catch	Records	Catch	Records	Catch	Records
1976	471.093	2185	52.926	490	27.485	71		
1977	578.470	2351	47.503	479	28.538	93		
1978	544.502	2921	44.285	304	27.808	63		
1979	444.641	2925	23.885	187	2.354	23		
1980	508.746	3463	22.351	178	10.666	71		
1981	492.028	3433	23.761	118	7.573	47		
1982	678.532	4152	9.916	176	6.171	17		
1983	609.786	4600	91.031	324	2.053	17		
1984	532.883	4242	299.894	513	1.829	11		
1985	458.243	4287	306.673	575	4.718	67		
1986	526.546	4379	409.420	972	2.582	25		
1987	449.632	4515	482.599	1416	2.978	12		
1988	480.744	4550	540.592	1255	9.171	150		
1989	450.105	3829	575.254	1204	8.363	153		
1990	525.466	3539	465.773	1597	18.741	278		
1991	562.129	4408	375.650	1621	11.637	131		
1992	732.125	4706	317.716	1435	23.068	218		
1993	809.244	5019	331.363	1253	17.376	162		
1994	605.967	5163	375.433	1219	7.655	126		
1995	950.690	6387	415.897	1248	105.810	818		
1996	744.193	6545	507.163	919	122.991	836		
1997	586.505	6614	537.713	4846	89.276	825		
1998	730.726	6656	473.153	9020	84.490	883		
1999	948.874	7285	520.038	7494	98.170	1203		
2000	922.686	6714	431.015	5631	73.967	839		
2001	1118.283	6133	381.404	5507	67.015	574		
2002	887.361	6035	420.466	5439	104.135	716		
2003	916.533	6412	498.628	6725	99.713	838		
2004	873.027	5963	475.288	5855	120.701	898	0.303	10
2005	815.843	5145	484.716	5293	87.476	690	2.011	7
2006	735.996	4139	554.176	6227	115.736	682		
2007	875.038	3511	438.039	4665	93.865	839	1.837	4
2008	954.048	3691	540.465	5011	62.183	648	0.21	5
2009	833.293	4125	410.399	5283	68.633	546	0.33	2
2010	744.537	4468	382.473	5430	76.467	553		
2011	797.564	5270	229.194	3467	102.800	699		

Table 17.8. A comparison of reported weights with landed weights from the CDR database. Quotas were only introduced in 2001, which was when this data began to be reported in the CDRs. LogBook relate to all methods, GillNets relates to GillNet catches reported in the logbooks.

Year	Commonwealth	Log-Books	GillNets	%LogBook	%GillNet	TAC
2001	1702.654	1660.869	1566.702	97.55	92.02	
2002	1605.165	1494.666	1411.962	93.12	87.96	
2003	1678.243	1618.277	1514.874	96.43	90.27	
2004	1735.455	1656.367	1469.319	95.44	84.66	1717
2005	1644.881	1570.52	1390.046	95.48	84.51	1717
2006	1645.733	1577.138	1405.908	95.83	85.43	1717
2007	1665.106	1574.951	1408.779	94.59	84.61	2467
2008	1865.681	1727.945	1556.906	92.62	83.45	1717
2009	1646.200	1500.789	1312.655	91.17	79.74	1717
2010	1540.178	1404.716	1203.477	91.20	78.14	1717
2011	1516.728	1348.002	1129.558	88.88	74.47	1717

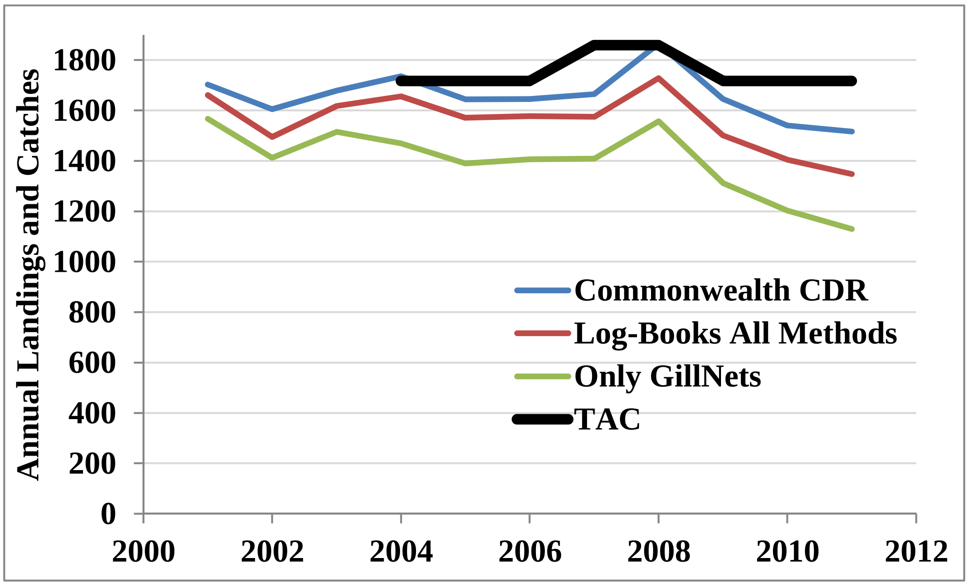

Figure 17.13. A comparison of the landings reported against quota in the CDRs and catches reported in the log-books, both across all methods and for Gill Nets only.

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18. Standardized Catch Rates for the SESSF Saw Shark and Elephant Fish Fisheries. Data from 1980 – 2011

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18.1 Summary

As recommended by the RAG, catch rates for sawshark were standardized for the years 1980 – 1991 and 1998 – 2011, while those for elephant fish were standardized for the years 1980 – 2011. Both were treated as fisheries across their full geographical ranges but, in addition, in an attempt to focus on the approximate details of the geographical range of the two species of sawsharks, these were also briefly considered as two populations split across eastern and western Bass Strait but because this made only very minor differences to the analyses it was not pursued further. To account for the occurrence of zero catches, the standardizations used a Delta method whereby the probability of obtaining a positive catch is estimated using a Generalized Linear Model with a binomial error structure (to describe the presence or absence of catches). This probability is combined with the yearly indices from a log-linear statistical model that standardizes those catch rates coming from positive catches. Data selection for saw sharks was restricted to the years used (1980 – 1991 and 1998 – 2011), those statistical areas from which, cumulatively across the 25 years, more than 10 tonne of sawshark were reported, those vessels that had an average annual catch greater than 0.25 tonnes, and from depths < 160 m. For elephant fish (*Callorhinchus milii*), data selection was a minimum cumulative catch by statistical area of 4 tonnes, a minimum annual catch per vessel of 0.25 tonnes, and depths < 200 m. For both species only the records pertaining to 6” mesh gear were used. The depth threshold for elephant fish (family *Callorhinchidae*) is designed to exclude catches of ghost sharks (family *Chimaeridae*), which are included in the quota allocation for elephant fish; when trunked these can be difficult to separate.

For sawsharks, taking into account the approximate 95% confidence intervals around the mean estimates for each year, the combined standardized catch rates were noisy but approximately flat from 1981 – 2011, although 1980 differed significantly from this and 1988 – 1990 appeared to be below the average while 1998 – 2000 appear to be above the long term average. The 2010 and 2011 values appear to be below the scaled average of 1.0. A declining trend to 2010 appears to have begun in 2008 but catch rates in 2011 were the same as in 2010. The combined standardization was robust to different data selection criteria and to splitting the data into eastern and western fisheries. The relatively flat combined catch rate arose because a declining catch rate for positive catches was counter-acted by an increase in the probability of obtaining a positive catch. The drop in 2010 resulted from a recent decline in the relative probability of a positive catch combined with a continuation of the decline in the catch rate of positive catches. Vessels accounted for most variation in the catch rates followed by year, area, and depth category. The Area x Month interaction term accounted for more than twice the variation accounted by Month indicating that seasonal patterns are expressed more by where fishing occurs than by when fishing occurs.

Trawl caught sawsharks exhibited a similar pattern of standardized catch rates to those seen in the GHT for the positive catches. The seasonality of sawshark availability is clearly apparent in the monthly catch rates.

For elephant fish, the standardized catch rates were more variable than those for saw sharks and there was a significant decline between 1984 and 1991. However, catch rates could not be distinguished from the average across the time series from 1992 – 2006. A significant rise from 2007 – 2009 has been reversed and the values for 2010 and 2011 have declined and are not significantly different from the mean of the complete time series. This recent decline is a result of a small decrease in the standardized catch rates for positive catches combined with a decrease in the relative probability of a positive shot. Most of the variation accounted for in the log-linear modelling was driven by Vessel followed by year. Area, month, and depth category were all minor contributors, although, like saw-sharks, the Area x Month interaction was important, suggesting that location of fishing changes with the season which emphasizes that spatial details in this fishery are as important as in the other shark fisheries.

18.2 Introduction

The shark fishery off southern Australia has a long history starting with a long-line fishery which began in the 1920s which switched to gillnets in the 1960s and 1970s when the primary target also switched from school sharks (*Galeorhinus galeus*) to gummy sharks (*Mustelus antarcticus*; Punt et al., 2000; Punt & Gason, 2006; Thomson & Punt, 2010). This gillnet fishery now mainly targets gummy sharks but also used to target relatively large quantities of School sharks although since this became depleted to low levels of the unfished spawning biomass this is now a bycatch only species.

An attempt was made at age-structured stock assessment modelling for both Saw Sharks and Elephant Fish (Punt, et al., 2004). This suggested that pup production in 2003 for both Saw Sharks and Elephant Fish was below 40% of the 1950 pup production (the assumed virgin stock). However, the catch rate series used was that from the Gummy shark fishery, the analysis was restricted to Bass Strait only, owing to a lack of data, and the effect of combining both species of Saw Sharks was unknown. As the authors stated "The analyses of this paper are clearly preliminary".

Attempts at stock assessment of Saw Sharks and Elephant Fish since Punt et al. (2004) have so far been limited to the application of the SESSF Tier 4 empirical assessment rule in 2009 (Rodriguez & McLoughlin, 2009a, b) and in 2010 and 2011 (Haddon, 2010a, 2012). These Tier 4 assessments are based upon time series of catches and of standardized catch rates (Little et al., 2011; Haddon, 2012). The intent of the present document is to conduct a standardization of the catch per unit effort data available for both saw sharks and elephant fish in preparation for conducting a third Tier 4 analysis for each group.

As Kimura (1981, p211) says: "Since the 1950s it has been recognized that fishing power generally differs among vessels, and if c.p.u.e. is to be proportional to abundance, effort measurements must be standardized." The most commonly used method of standardization is to include the various factors thought to effect catch rates into a generalized linear model and to include Year as a factor, in this way the parameters derived for each year become the indices of relative abundance (Venables & Dichmont, 2004).

After standardization we are left with a set of yearly coefficients that represent the catch rate relative to some reference year (usually scaled to the mean of the time series; thus the average of the series equals one). Unfortunately, even if the standardization accounts for a large proportion of the variability in the data there are no guarantees that catch effort, even standardized catch effort, can act as a good proxy for stock size. Instead of the statistical success of the standardization, one should be able to argue from the nature of the fishery and the species concerned whether or not there is likely to be even an approximate relationship between catch rates and the exploitable biomass.

18.3 Methods

18.3.1 Catch Rate Standardization

The original data was provided in a text file named CANDE11.txt. This contained 421,977 records each with 23 fields (Table 18.1). There are numerous fields that contain codes in this data set with the codes used for the different regions (Table 18.2) and gears (Table 18.3) being necessary for appropriate record selection (Table 18.6). The data provided received some pre-treatment in order to add the catch rate variables of interest and identify those records for inclusion in the analyses. Catch rates were calculated where there were positive catches of saw sharks or, separately, elephant fish associated with positive effort levels. Where catch rates could be calculated they were also log transformed in preparation for the log-linear modelling. Finally, two fields were added that identified which records contained positive catches of saw sharks and of elephant fish. This latter was necessary as a separate analysis is conducted to characterize the occurrence of zero shots and whether their incidence has altered through time (see below).

In previous standardizations (Rodriguez & McLoughlin, 2009a, b; Haddon, 2010b) various criteria were used to select records for analysis. An important aspect of any standardization is the number of zero shots, which relate to targeted effort that fails to catch the species of interest. In the SESSF trawl fishery identifying those shots that might have captured a species but didn't is extremely difficult because targeting is so difficult to establish. Fortunately, in the shark gillnet fishery this is less of a problem; gillnet shark fishers are targeting sharks. However, for bycatch species, such as saw sharks and elephant fish, especially those not captured in all areas, there is still an issue in deciding what records to include in the analysis. Both saw sharks and elephant fish are bycatch species and so record selection in each case focused on excluding those areas where few saw sharks or elephant fish are taken (see below; Table 18.9, Table 18.10, Table 18.11, Table 18.12). In addition, records used were limited to particular gears and finally, those vessels that caught very few of either of the two species groups were omitted from consideration.

18.3.2 The Delta Distribution

Catch rates are known, generally, to be highly variable, ranging from very high catch rates to shots that contain none of the species of interest. The inclusion of these zero shots is important if there is a trend in the likelihood of failing to catch a species (Stefánsson, 1996). Including zero shots has two parts: 1) First, determine the relative probability of obtaining a positive catch. 2) Secondly, conduct a log-linear standardization on those records containing positive catches. These two analyses are then combined to provide the overall estimate of the yearly changes in catch rates required for inclusion in stock assessments.

18.3.3 Zero Catches

To estimate the probability of a positive observation (i.e. the species of interest is present in a shot) a binomial GLM (using a logit link function) is used to determine the effect of an array of factors on the probability p_i, which is the probability that the species of interest is present in the i^{th} shot:

$$\ln\left(\frac{p_i}{1-p_i}\right)=\beta_0+\beta_1 x_{i,1}+\beta_2 x_{i,2}+\sum_{j=3}^{N}\beta_j x_{ij} \quad (1)$$

where p_i is the probability that the species of interest was present in the i^{th} shot, and x_{ij} are the values of the explanatory variables, j, for the i^{th} shot and the β_j are the coefficients for the N factors j, to be estimated (β_0 is the intercept, β_1 the coefficient for the first factor, *etc*.).

The catch rate standardizations all used individual records from the database, which in a number of cases appeared to be aggregated data, potentially aggregated within months, although there were also many individual shots recorded. The catch rate data for positive catches were normalized by using a natural-log transformation. General Linear Models were used with this transformed data rather than using Generalized Linear Models on the untransformed data with a log-link; the approach used has advantages in terms of normalizing the data while stabilizing the variance, which the Generalized Linear Model approach does not always achieve appropriately (Venables & Dichmont, 2004).

Up to six different log-linear models were fitted and compared in an effort to account for the effects of year, area, month of fishing, vessel, which depth category was used, and any interactions between area and month (Table 18.4). All variables were treated as categorical variables (alternatively termed factors). The optimum statistical model was selected on the basis of the Akaike's Information Criterion (Burnham & Anderson, 1998), and the adjusted r^2 (Neter *et al.,*1996). The resulting optimal model was plotted in comparison with the geometric mean catch rate, both being scaled to the mean of each series for ease of visual comparison. The standardized catch rates for the year factor are used in the Tier 4 assessment as the index of relative abundance through time.

Standard analyses were conducted in each case and all were coded in the statistical software R (R development Core Team, 2009). In each case, catch rates, as kilograms per metre of gillnet fished, were natural log-transformed to normalize the data and stabilize the variance. The General Linear Models all had the same form:

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

where Ln($CPUE_i$) is the natural logarithm of the catch rate (kg/m) for the i-th record, x_{ij} are the values of the explanatory variables j for the i-th shot (i.e. Year, Disting, Month, etc), and the α_j are the coefficients for the N factors j to be estimated (α_0 is the intercept, α_1 is the coefficient for the first factor, *etc*.), and ε_{ij} are the normal random residual errors.

18.3.4 The Year Effect

The standardised overall year effect for the fishery is calculated as the product of the Year coefficients from the binomial and log-linear GLMs (Eqs (1) and (2)) transformed back onto their original scales. For back-transformation all other predictor variables were set to zero, indicating the reference level of each categorical factor. The expected probability (back-transformed from logit) of a non-zero catch in year *t* is therefore

$$\hat{p}_t = \frac{\exp(\beta_0 + \lambda_t)}{1 + \exp(\beta_0 + \lambda_t)} \tag{3}$$

where p_t is the probability of a non-zero catch in year *t*, β_0 is the intercept and the λ_t is the Year coefficient for year *t*. As a test of the procedure the back transformation of the simple PA = Year model should deliver the annual proportion of positive shots.

For the log-normal model the expected back-transformed year effect involves a bias-correction for log-normality; the back transformation without the correction estimates the median of the distribution rather than the mean, adding $\sigma^2/2$ before back-transformation improves the approximation to the mean of the distribution:

$$CPUE_t = e^{\left(\gamma_t + \sigma_t^2/2\right)} \tag{4}$$

where γ_t is the Year coefficient for year *t* and σ_t is its standard error.

Total standardised catch rates for year *t* are calculated as the product of Eqs (3) and (4), stated relative to the average of all values:

$$\bar{Y} = \frac{\sum_{t=1}^{n} p_t CPUE_t}{n} \tag{5}$$

where *n* is the number of years of data. So the standardized catch rates are given relative to the mean of the series. This implies that the average of the time series of standardized catch rates will always be one, and hence each series is directly comparable with all the others:

$$Y_t = \frac{p_t CPUE_t}{\bar{Y}} \tag{6}$$

The factors considered in the analyses were all taken as categorical variables and were:

Year	the standard calendar year,
Disting	each vessel is uniquely and confidentially identified,
Month	standard calendar months,
Area	Standard shark statistical reporting blocks.
DepCat	20m categories (novel this year)
Area:Month	An interaction term used to include any seasonal changes across areas.

18.3.5 Saw Sharks

Shark RAG decided (May 2009) that operator behaviour before 1980 was sufficiently different that pre-1980 data should be excluded. It was also decided that conditions (targeting increased so that catches and catch rates increased markedly) changed between 1992 and 1996 before quotas were introduced for saw sharks (Rodriguez & McLoughlin, 2009a). Therefore Shark RAG's recommendation of standardizing the CPUE for the years 1980 – 1991 and 1997 – 2009 was adopted in the base case against which all other standardizations were compared.

The fishing gear used has an important influence of catches. Predominantly saw sharks have been taken by 6 inch mesh gill nets (with some taken by unknown mesh sizes; (Figure 18.4; Table 18.7). Thus, only those records where 6 inch gill mesh was reported were used in the base case standardization.

There were also some records where no effort data were included (effort = -1) and these could not be included in the standardization.

The zero shots considered in the binomial standardization are very influential on the final combined standardization so the selection of which areas to include is very important. There are nine shark regions and multiple shark areas identified within the SESSF (Figure 18.1) and catches are distributed very heterogeneously across these regions and areas in a manner that reflects the geographical distribution of sawsharks. If the total catches taken in each area using 6 inch gear in the years 1980 – 1991 and 1997 – 2010 are considered there are 25 areas catching more than 10 t, 36 areas with less than 10 tonnes reported, within which 27 reported less than two tonnes Table 18.10). Thus, inspection of available data suggested omitting those areas that reported less than 10 tonnes over the years 1980 – 1991 and 1997 - 2009; Table 18.10). This area selection excluded 34 areas and two categories of unknown areas but this only removed about 1.18% of the reported catch taken by 6" mesh gear in the years under consideration. The main regions reporting saw shark catches are Eastern Bass Strait and Western Bass Strait, with smaller amounts coming from Eastern South Australia and Eastern Tasmania (Table 18.9, Table 18.12; Figure 18.11). The amount of effort expended in Central South Australia is quite high relative to the saw shark catches (Table 18.5; Table 18.7). If the bulk of the Central South Australian catches were to be included the number of zero shots seems likely to be increased in an inappropriate manner. The main geographical area where saw sharks are found is in Bass Strait with peripheral areas surrounding (Figure 18.11, Table 18.10, Table 18.9).

There are a large number of vessels contributing to the final analysis, even with the restricted number of years and areas used. To remove noise generated by those vessels reporting very small amounts of saw sharks those vessels reporting less than an average of 0.25 tonne per year (for the years in which they reported saw sharks) were removed from the analysis. This removed a further 25 t of catches (0.6% of the catches) from consideration and left a total of 134021 records (Table 18.11).

Finally, to provide depth information the reported minimum and maximum depths were averaged for each record. Previously these were then categorized into depth categories of 0 – 19 m, 20 – 80m, and > 80 m (for comparability with Rodriguez & McLoughlin, 2009a). However, by plotting the average depths) it was clear that most catches were taken between 0 and 160m. Removing those records that had no depth information excluded a further 101 t of catch so that the exclusions left out about 1.2% of the catches that could have been analysed. Removing catches reported in depths greater than 160 m eliminated about 2% of catches leaving 129,263 records for the analysis of the probability of a positive catch and 92,323 records for the standardization of positive catch rates (Table 18.11).

Despite these data selection criteria appearing to be a reasonable choice, sensitivity tests were made by conducting the analyses with somewhat different choices. Thus, the results from the 10 t by area, 0.25 t by vessel and gear as 6 inch mesh were contrasted with a limit of 5 t per area, 1.0 t per vessel, and 6 inch, 6.5inch and 7 inch gear considered together.

In addition, the base case trends across the fishery were compared to analyses conducted separately split across Bass Strait in an effort to isolate at least the southern sawshark. Gomon, Bray, and Kuiter (2008) provide approximate distribution maps which indicate significant overlap although the southern saw shark is not indicated in north east Bass Strait, which is a significant catching area for saw sharks.

18.3.6 Elephant Fish

As with the saw sharks, Shark RAG decided (May 2009) that operator behaviour before 1980 was sufficiently different that pre-1980 data should be excluded. No other years were considered necessary for exclusion, therefore Shark RAG's recommendation of standardizing the CPUE for the years including and following 1980 was adopted.

Rodrigues & McLoughlin (2009b) excluded areas 99 to 108, 112 to 115, 126 to 140, 148, 149, and 201. These were also eliminated here but in addition areas 122, 144, 155, and 158 were excluded on the grounds of minimal catches. Excluding those areas that had reports of less than 4 tonnes of elephant fish over the period 1980 – 2010 led to 30 areas being excluded along with two categories of unknown areas. Out of 1,177 tonnes in total this selection excluded about 27 tonnes. Finally, there were hundreds of vessels in the database but a large proportion never reported catching elephant fish. With the much lower catches of elephant fish, those vessels reporting less than an annual average catch of 250 kg were omitted from consideration. Increasing this value to 500 kg made very little difference to the overall standardized trend so the lower value was used to maintain a larger number of observations. Finally, by excluding shots with depths > 200m, 60.5% of all catches taken between 1980 – 2010 were included in the analysis; the biggest reduction in catches used was from excluding gear other than 6" mesh nets (Table 18.21).

18.4 Results

18.4.1 The General Southern Shark Fishery

The southern shark fishery extends across from New South Wales, around Tasmania, and across to Western Australia (Figure 18.1).

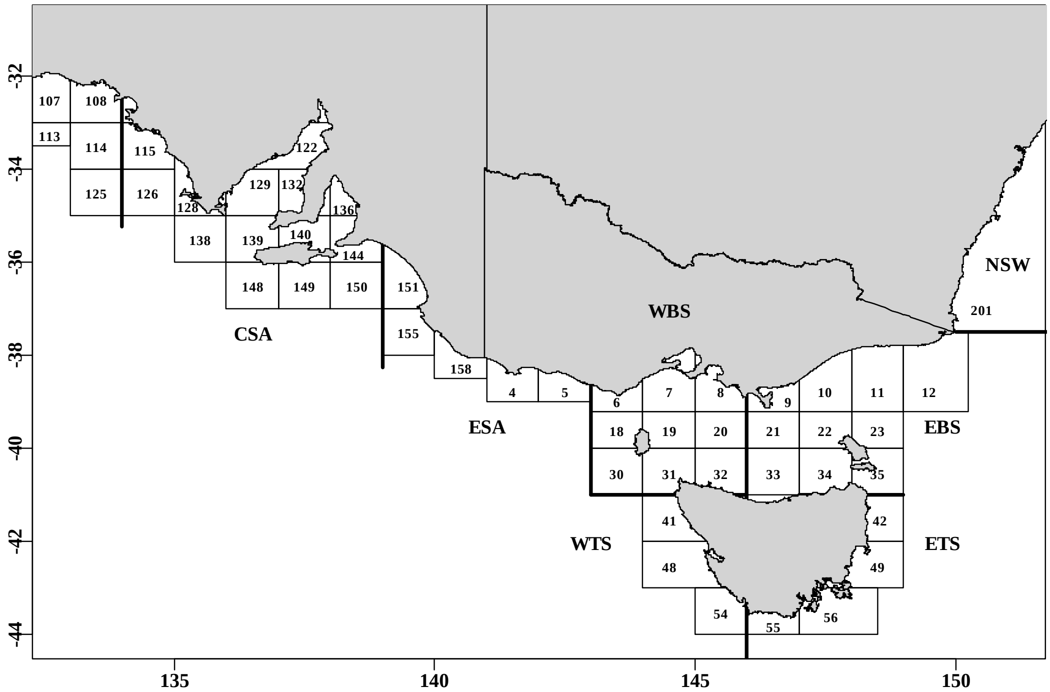

Figure 18.1. Map of shark statistical reporting areas along with the statistical regions. WA is Western Australia, WSA is Western South Australia, CSA is Central South Australia, ESA is Eastern South Australia (sometimes known as SAV – South Australia Victoria), WBS is Western Bass Strait, EBS is Eastern Bass Strait, NSW is New South Wales, ETS is Eastern Tasmania and WTS is Western Tasmania.

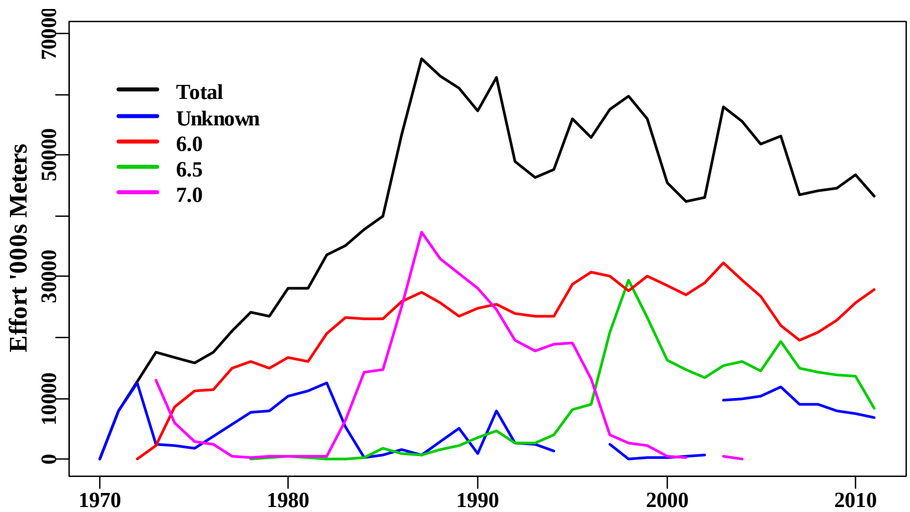

Figure 18.2. The amount of mesh effort across the whole shark fishery applied over the period 1970 to 2011. 8.0' mesh net effort is not shown but only achieved an average of ~850 across the years it was used. Unknown increased dramatically from 2003 onwards.

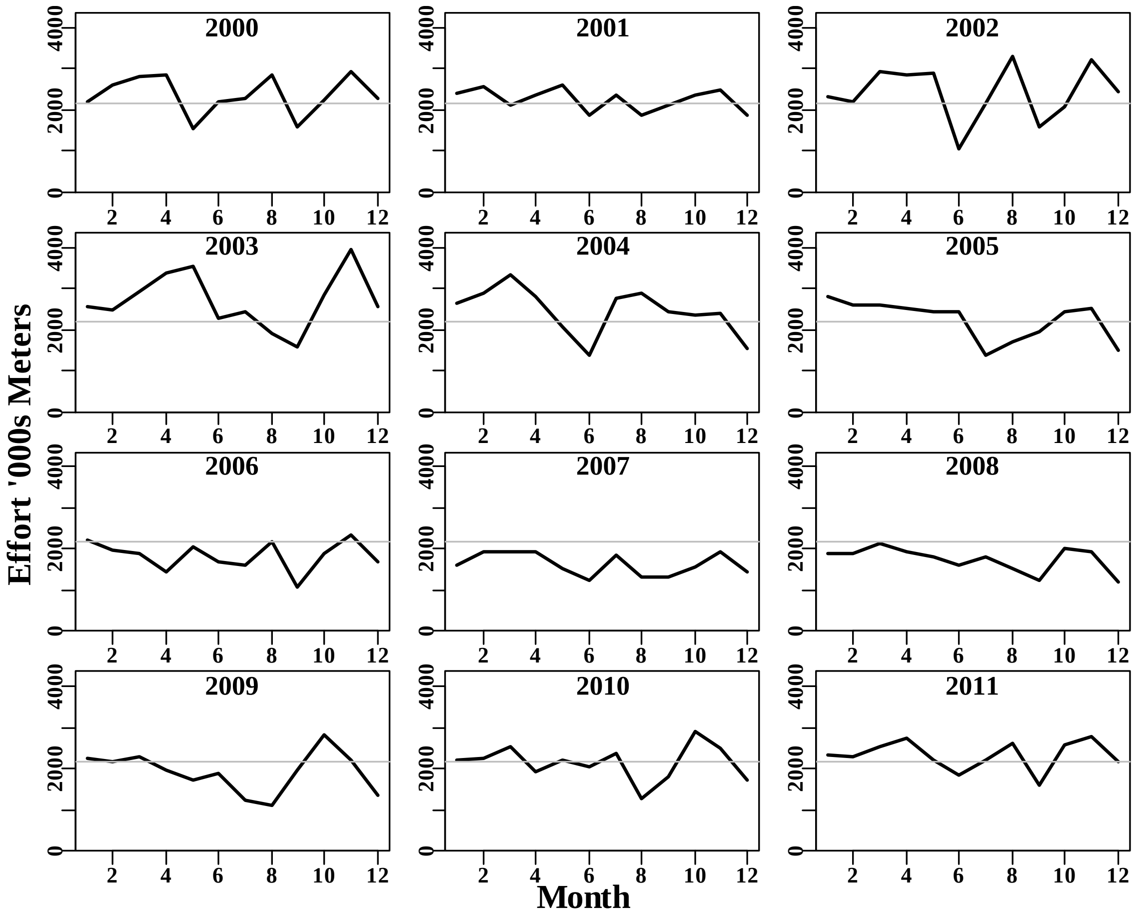

Figure 18.3. The seasonality of effort across the whole shark fishery applied over the period 2000 to 2011. The horizontal grey line is the overall average monthly effort across the 12 years.

18.4.2 Saw Sharks

18.4.2.1 Saw Shark Catches

Saw shark have always been taken mostly by 6.0" mesh nets and only minor amounts by other gears (Table 18.7). Total catches were approximately 250 tonnes ± 100 t from 1980 – 2000 but since then have slowly declined to about 100 tonnes (Figure 18.4).

Saw shark are caught predominantly in depths of 30 – 80 m (Figure 18.5) with slightly over 99% of all catches taken in depths of 130 m and less (Table 18.8).

There is some evidence of a seasonal trend in the catches with more being taken in the November – January and in May – July periods than other months (Figure 18.7). The pattern of seasonality is rather different to that exhibited by the effort through the year (Figure 18.3**)** so the seasonal fluctuations in catch may reflect changes in availability.

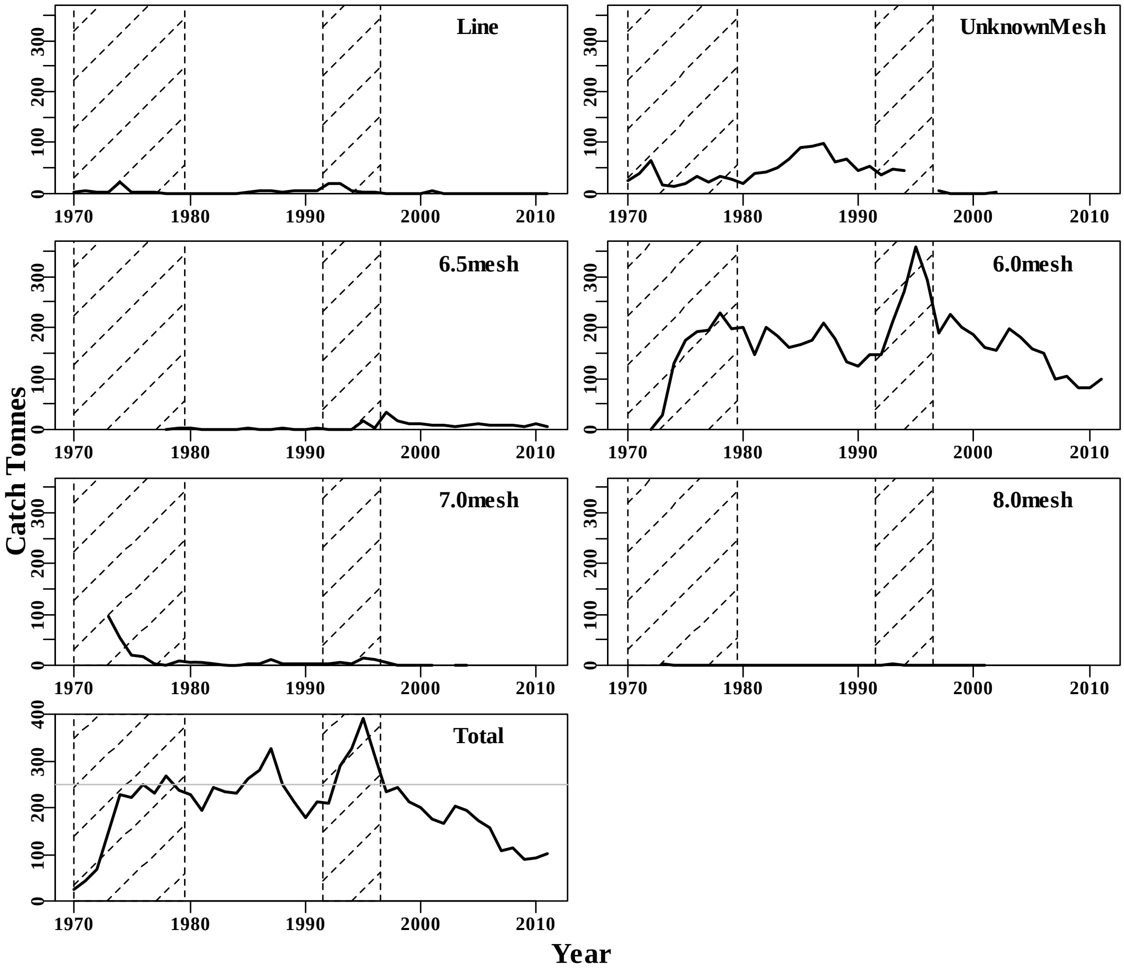

Figure 18.4. Catches of saw sharks by fishing gear method. The hatched areas relate to the periods of exclusion decided upon by SharkRAG (1970-1980, 1992-1996).

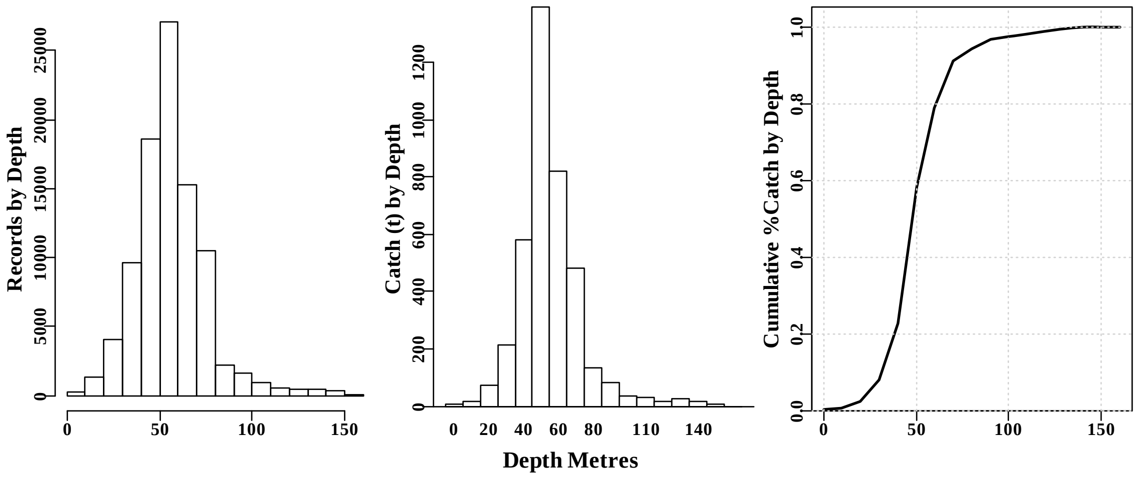

Figure 18.5. Number of records and catches of saw sharks by 10 m depth category using data from 1980 – 1991 and 1997 - 2011.

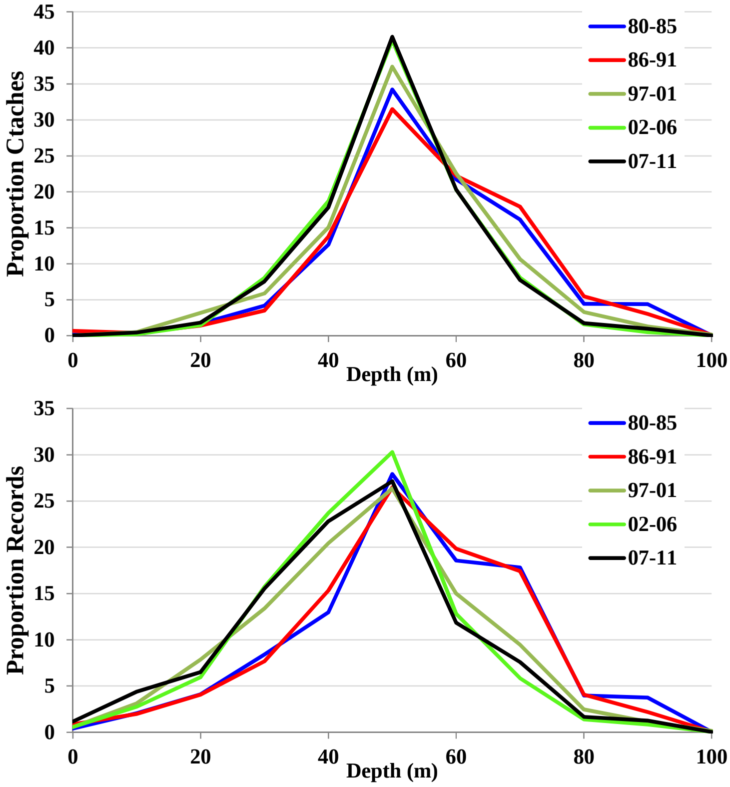

Figure 18.6. The percentage of catches and of records taken between 0 and 100 metres depth by five year group. The first ten years data were taken from deeper water on average than in the last 15 years.

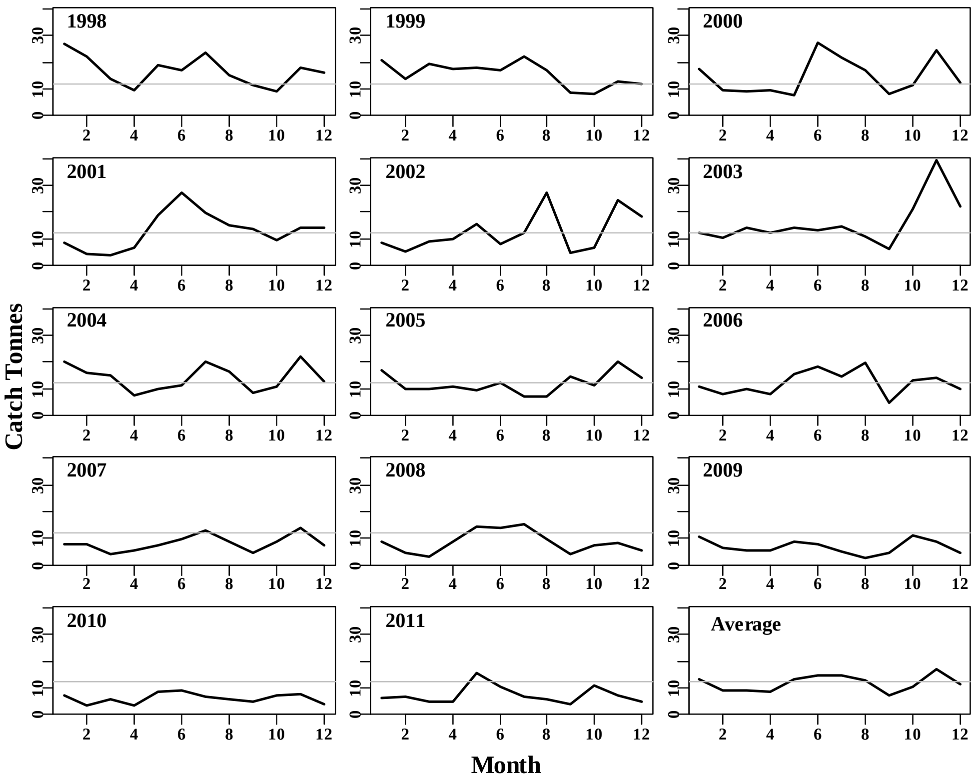

Figure 18.7. Catch by Month for saw sharks since 1998 along with an average across years to illustrate the approximate seasonality of the fishery and its variation through time. In each graph the average catch per month across years is illustrated by the grey line.

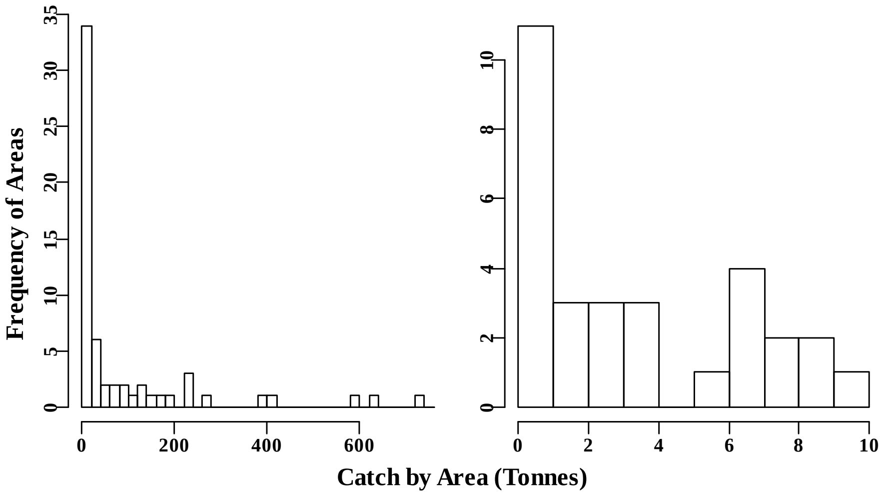

Figure 18.8. Relative frequency of statistical reporting areas reporting different levels of total catch of saw shark. There are 30 reporting less than 10 tonnes (left panel) with most of those areas reporting less than 4 tonnes (right panel). The data considered related to gear = 6” mesh. Effort > 0, years 1980-91, 1997-2011.

Only a few statistical areas have relatively high catches while 30 areas out of a total of 61 had catches < 10 t (Figure 18.8). Saw shark are mostly taken in Eastern and Western Bass Strait with the next most abundant catches being in Eastern South Australia (Figure 18.9, Figure 18.10, Figure 18.11; Table 18.9, Table 18.12); these three regions dominate the fishery. Relatively minor catches are also taken in eastern and western Tasmania and Central South Australia.

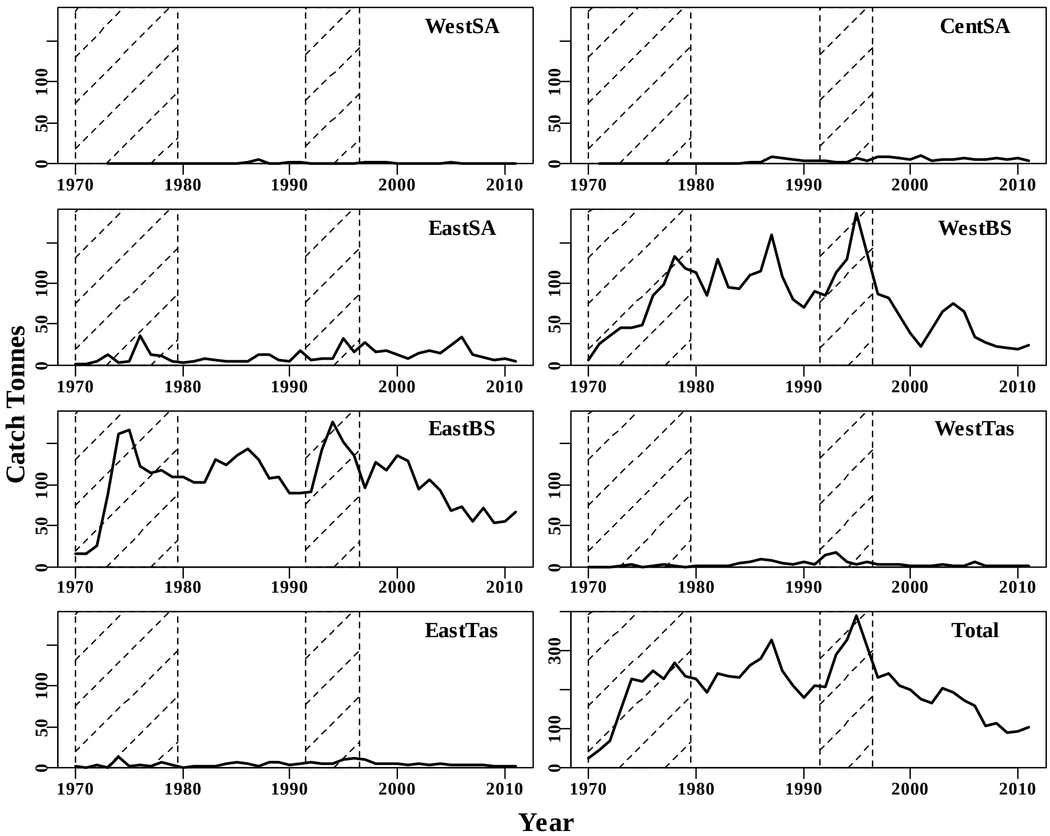

Figure 18.9. Catches by region through time for saw sharks. The hatched areas relate to periods of exclusion decided upon by SharkRAG (1970-1980, 1992-1996).

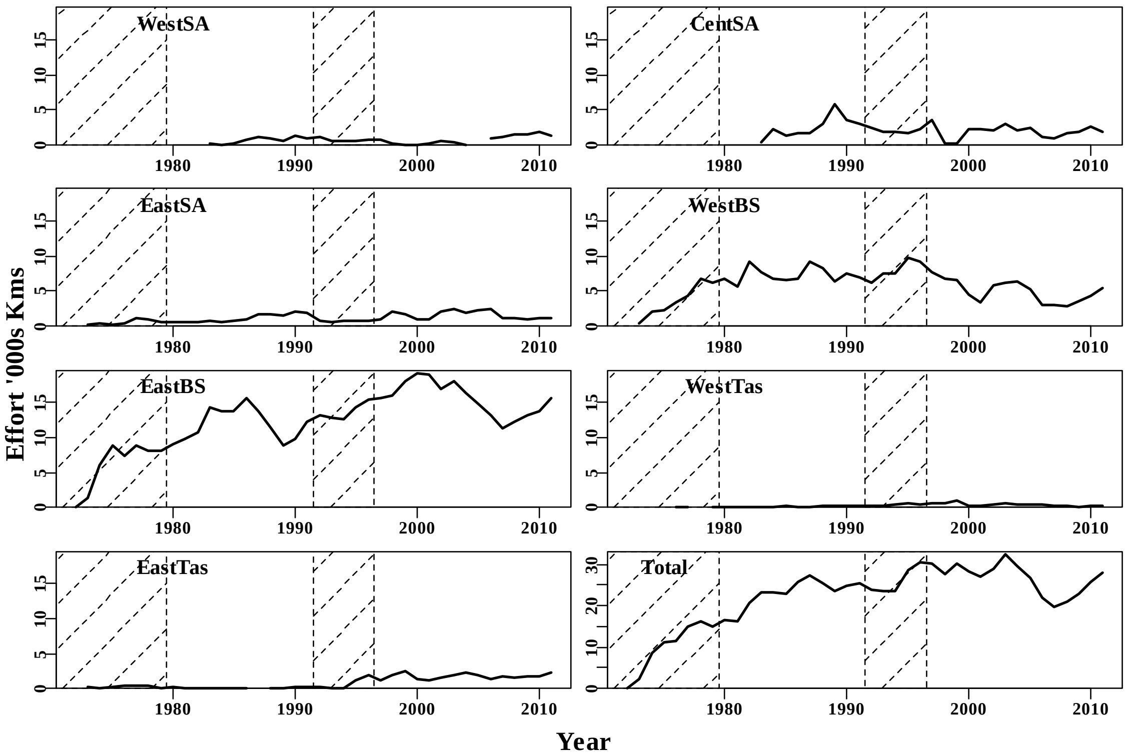

Figure 18.10. Total 6 inch mesh effort in thousands of kilometres across the years. The amount of effort in Central South Australia is far greater than the catches and would contribute, inappropriately, to zero catches if included.

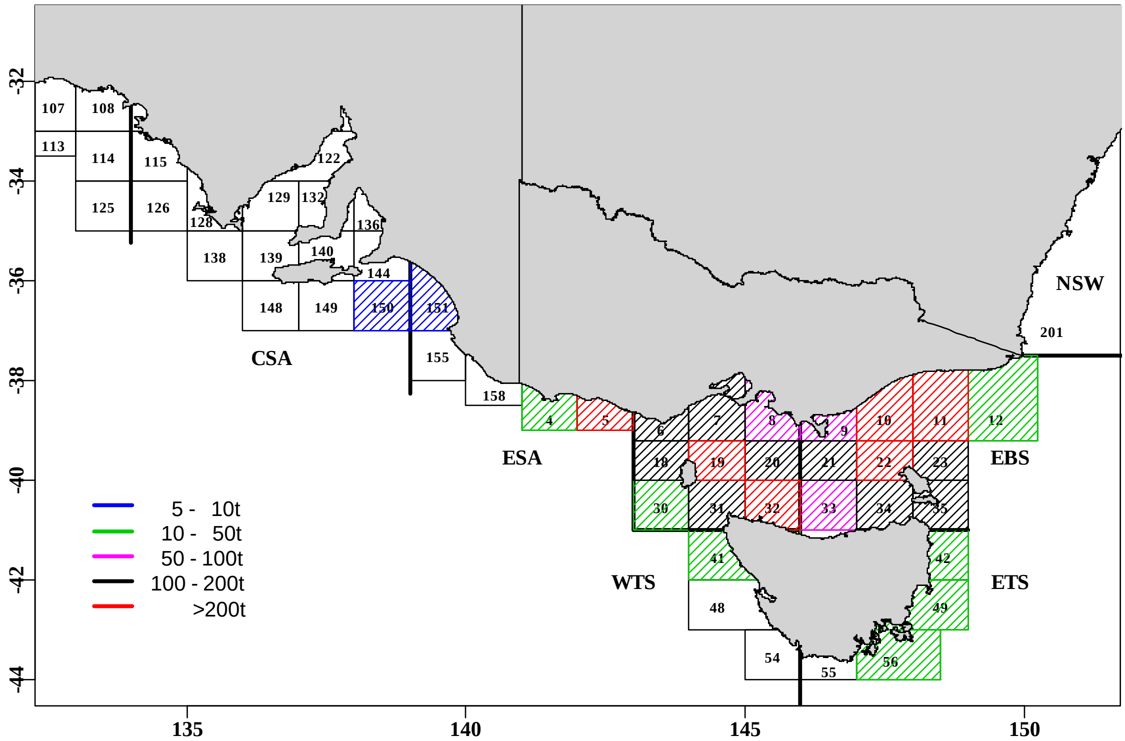

Figure 18.11. Sawshark catches by area for years 1980-1991 and 1997-2011. Only areas with catches > 10 t are used in the CPUE standardizations. Data used included areas with catches > 10t, and Effort > 0.

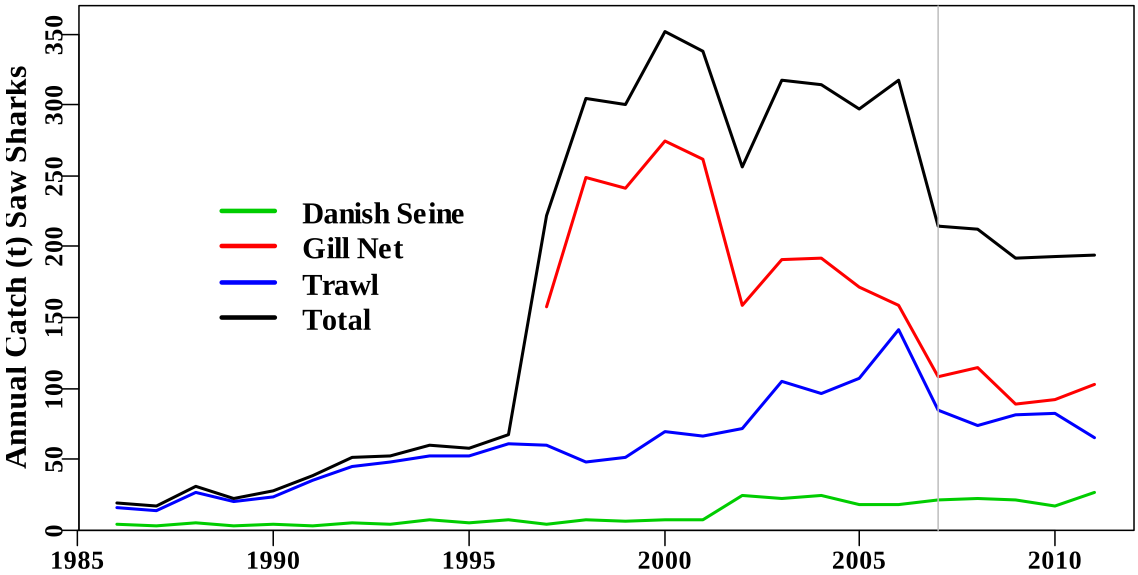

Figure 18.12. The annual catch in tonnes by different methods recorded in the log book data from the SESSF. The grey vertical line indicates post-structural adjustment.

18.4.2.2 Saw Shark Catch Rate Standardization

The base case standardization removed those areas that reported less than 10 tonnes over the total period examined, in addition, vessels with an average annual catch less than 0.25 tonnes were also removed (this left 176 vessels). The log-linear modelling of the positive catches tends to reduce the variation exhibited by the geometric mean catch rates, although they generally followed the same trends as the unstandardized CPUE. Catch rates appear relatively flat in the early period (1980 – 1991) and exhibit an almost 40% decline in the second period from 1997 to 2011 (Figure 18.13; Table 18.13). Overall, from 1980 to 2011 catch rates of positive catches decline by about 60%, but there are many reasons to consider ignoring the earlier time series as there appear to be many changes in fishing practices between the two periods modelled. The binomial modelling of the probability of obtaining a positive catch exhibits a slight decline in the early period with a higher probability of a positive catch in the second period with an almost 35% increase from 1997 to 2009, followed by a drop of about 25% in 2011.

When the two analyses are combined, Equ (6), the optimum model exhibits a downward trend during the early period followed by a relatively flat series in the second period (Figure 18.13; Table 18.13), with a final downturn in 2010 that continued in to 2011. All factors in the log-linear standardization had important impacts on the trends in catch rates, although the interaction term between area and month only had a relatively minor influence (Figure 18.14; Table 18.14). In the binomial modelling the same order of factors were influential except that the depth category factor was more important than the month factor. When the contribution to changes in the trends are graphed (Figure 18.14) then it becomes very clear that there are major differences between the two periods in the data with respect to the vessels operating, the areas operated in, the depths in which operations occur, and to a lesser extent the seasonality of fishing. This is a strong indication that the two data time series are not strictly comparable.

The log-linear modelling is relatively robust to different assumptions about which data to include. Reducing the total catch per area to 5.0 tonnes across the years and increasing the average catch per annum to 1 tonne had very little effect on the outcome. Even when the reported catch per area was 1.0 tonnes, average catch per vessel was

0.25 tonne, and gears used included 6", 6.5", and 7" mesh, only a slight difference was observed in 2006 but otherwise the curves were effectively coincident.

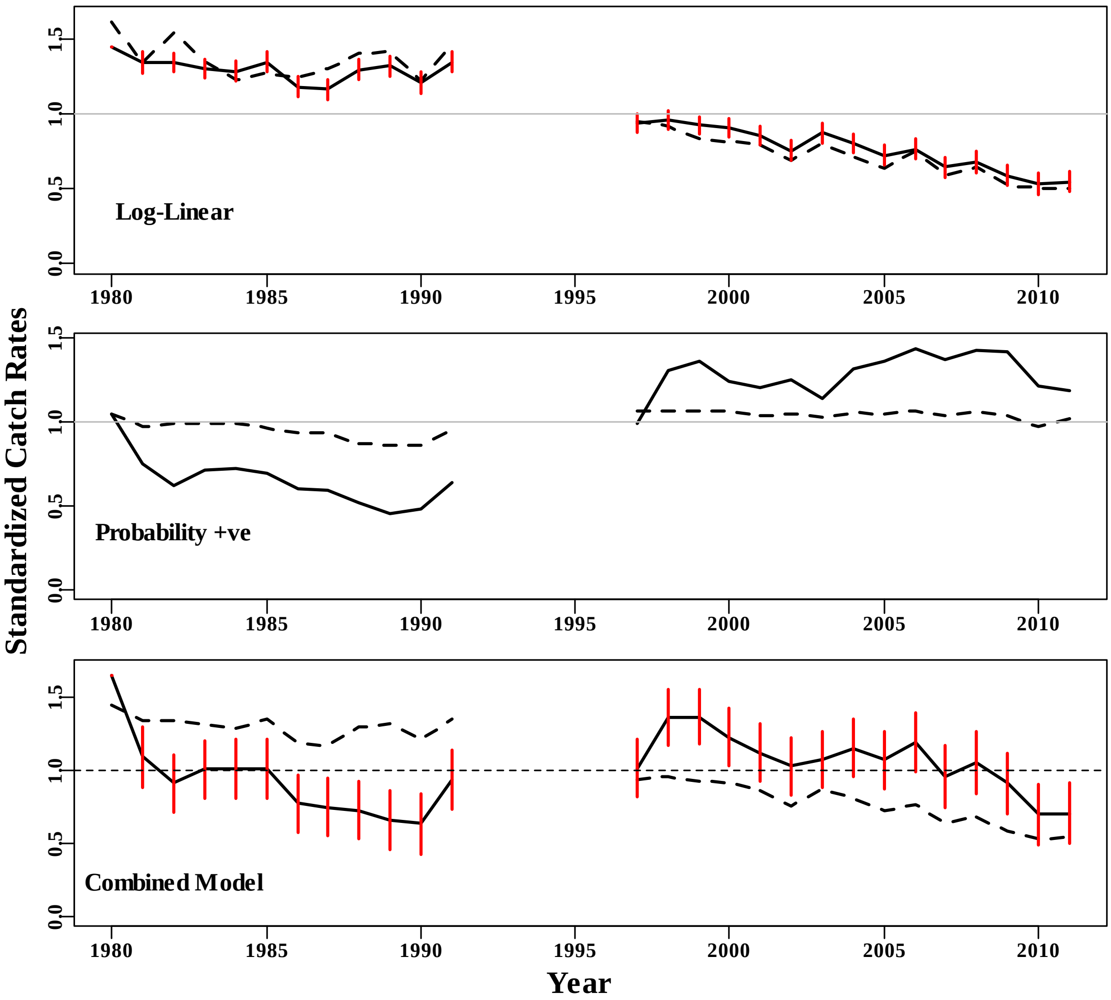

Figure 18.13. Standardized catch rates for saw sharks using data relating to 6" mesh gear, from areas that reported more than 10 tonnes across the 24 years considered, and from vessels with average catches greater than 0.25 tonnes per annum. The top panel represents the log-linear modelling of positive catches. The dashed line is the geometric mean while the solid line is the optimal model. The central panel represents the probability of obtaining a positive catch, the dashed line being the proportion of positive catches in the raw data and the solid line being the statistical optimum model. The bottom panel represents the final standardized catch rates, combining the results from the log-linear modelling and the binomial modelling of the probability of a positive catch (the dashed line represents the optimum log-linear model while the solid line is the optimum combined model, the dotted line is the mean of the optimum combined model and the short vertical red lines are the approximate 95% confidence intervals).

When the sawshark fishery is divided through the middle of Bass Strait, most of the records and catches are in the east (Table 18.9; Figure 18.23).

In conclusion, for saw sharks, when conducted without attention being paid to the probability of catching saw sharks the log-linear modelling exhibits no real trend from 1980 to 1991 being noisy but flat. However, between 1997 to 2011 there was a significant decline in both nominal and standardized catch rates. With the binomial modelling of the probability of a positive catch, the 1980 to 1991 period was noisy but was lower than the overall average, however, the 1997 to 2010 period had a higher than average probability of a positive catch, which mostly, had the effect of cancelling out the declining nominal catch rates. Thus, with the two time series combined, the inclusion of 1980 leads to the appearance of a large initial decline by 1981, followed by a relatively flat period during which a reduction occurs but only between 1988 to 1990. The periods from 1981 to 2010 only differs significantly from a flat line between 1988 – 1990 (with inter-annual noise) and most importantly in 2010 and 2011 where the standardized catch rates are below the average, possibly continuing a trend that has occurred since 2008.

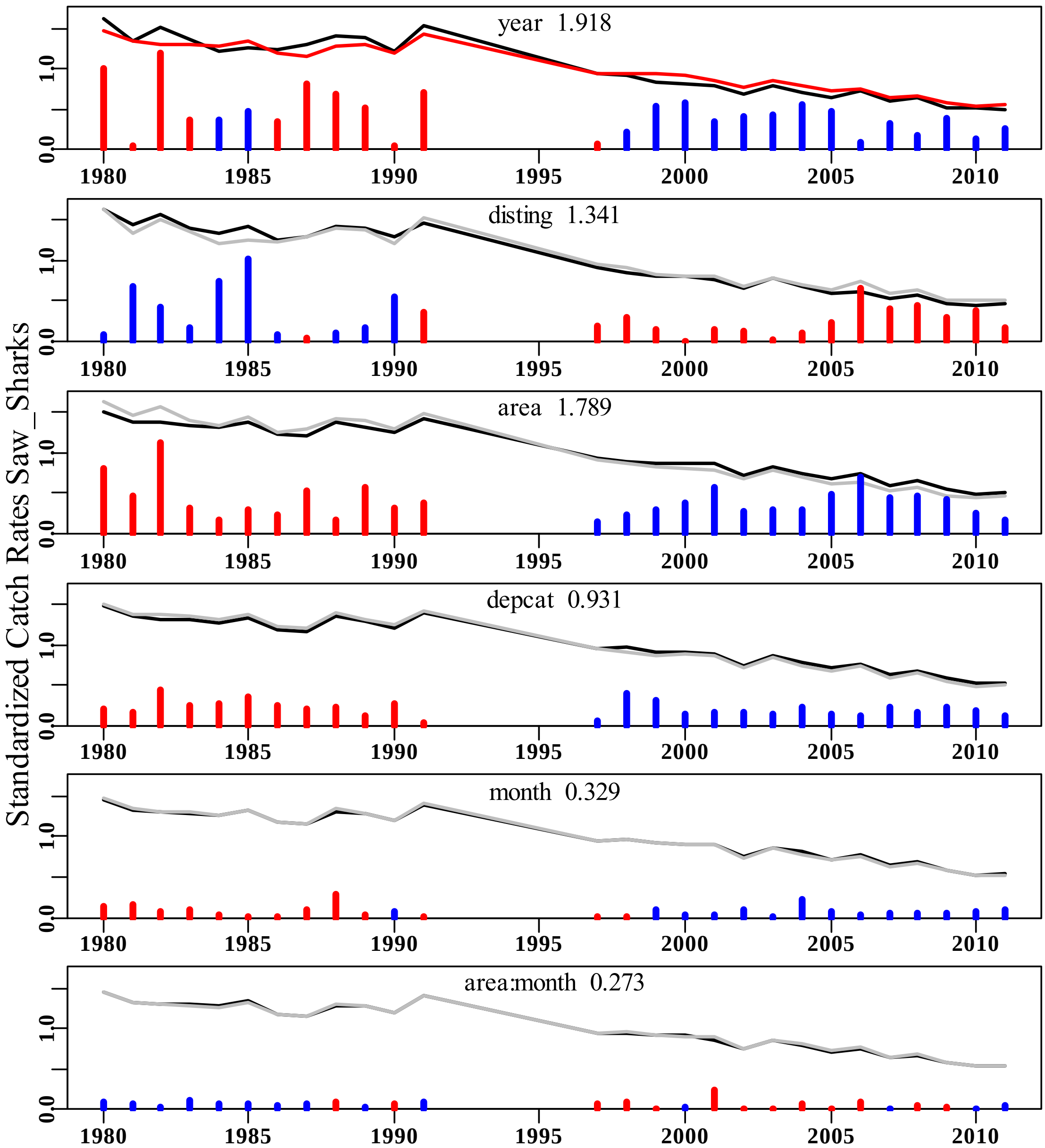

Figure 18.14. The relative contribution of each factor to changes in the trends in the log-linear modelling. Blue bars indicate the line moves above the previous combination of factors while a red line indicates the opposite. The number in each graph is the sum of squared differences between the trends on each graph. The grey line is the black line from the previous graph (top to bottom). The black line in the top graph is the geometric mean and the red line the final trend.

Significant catches of saw sharks are taken as a bycatch in the trawl fishery (Table 18.15). When the catch rates for positive shots in this fishery are standardized (Table 18.16 and Table 18.17) the trends observed are remarkably similar to those seen in the positive shots within the gillnet fishery (Figure 18.25; Figure 18.26). In addition, the relative catch rates in each month also follow a strong cycle (Figure 18.24), which is also seen in the gill net fishery.

There conditions and operation of the fishery were clearly different in the first time series relative to the second. Because the two time series do not appear to be comparable it is not valid to compare the two separate time series.

18.4.3 Elephant fish

18.4.3.1 Elephant Fish Catches

The majority of elephant fish catches are taken in Eastern Bass Strait, with smaller amounts in Eastern Tasmania and Western Bass Strait (Table 18.18). Only minor catches are taken in other regions.

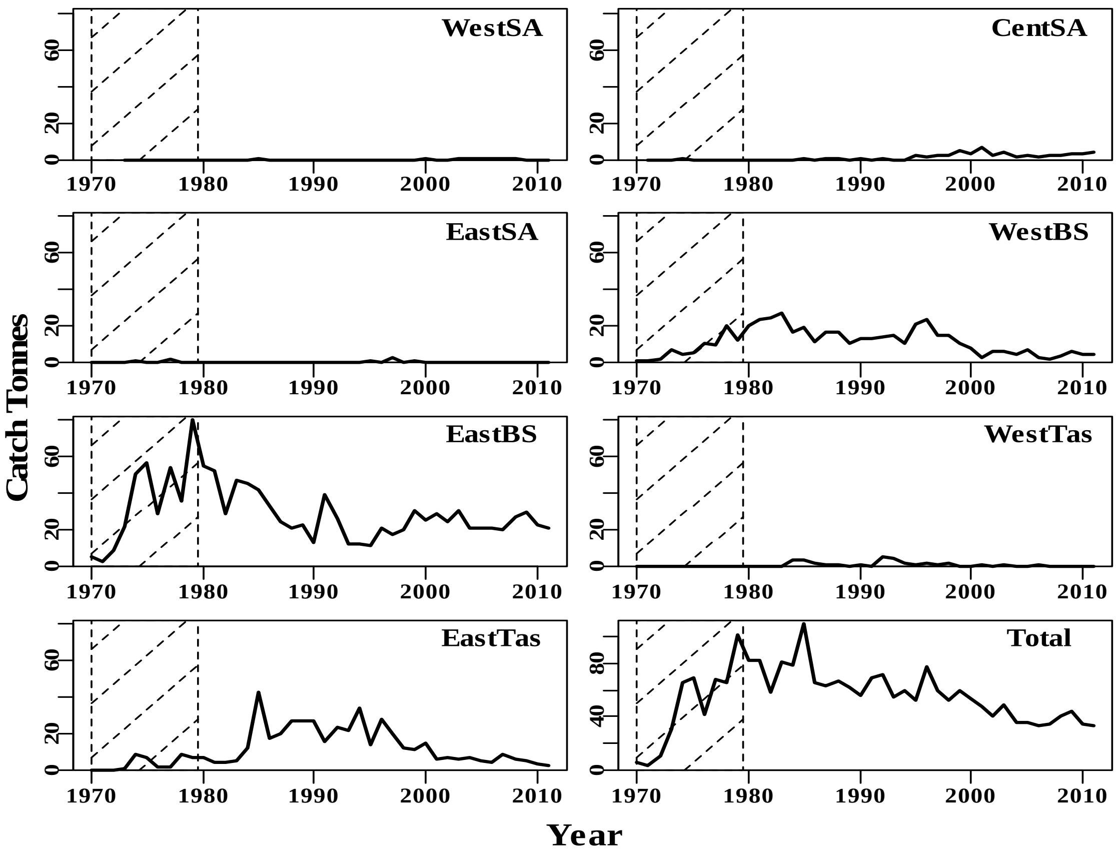

Figure 18.15. Catches in the shark fishery by region from 1970 – 2011 for elephant fish; these data include all methods, all vessels, and all areas. The hatched area relates to the periods of exclusion decided upon by SharkRAG (the years prior to 1980).

Like the saw sharks, catches of elephant fish are primarily taken now by 6.0 inch mesh gillnets although similar quantities were taken in the 1980s by unknown mesh nets (Figure 18.16; Table 18.19). Approximately the same seasonal pattern of catches are seen in elephant fish as is seen in saw sharks with more being taken in the November – January and in May – July periods than other months. As with saw sharks, the pattern of seasonality is rather different to that exhibited by the effort through the year (Figure 18.17) so the seasonal fluctuations in catch may reflect changes in availability. Total catches have declined from about 80 t in 1980 to about 60 t in 2000, with present catches at about 50 t (Figure 18.16).

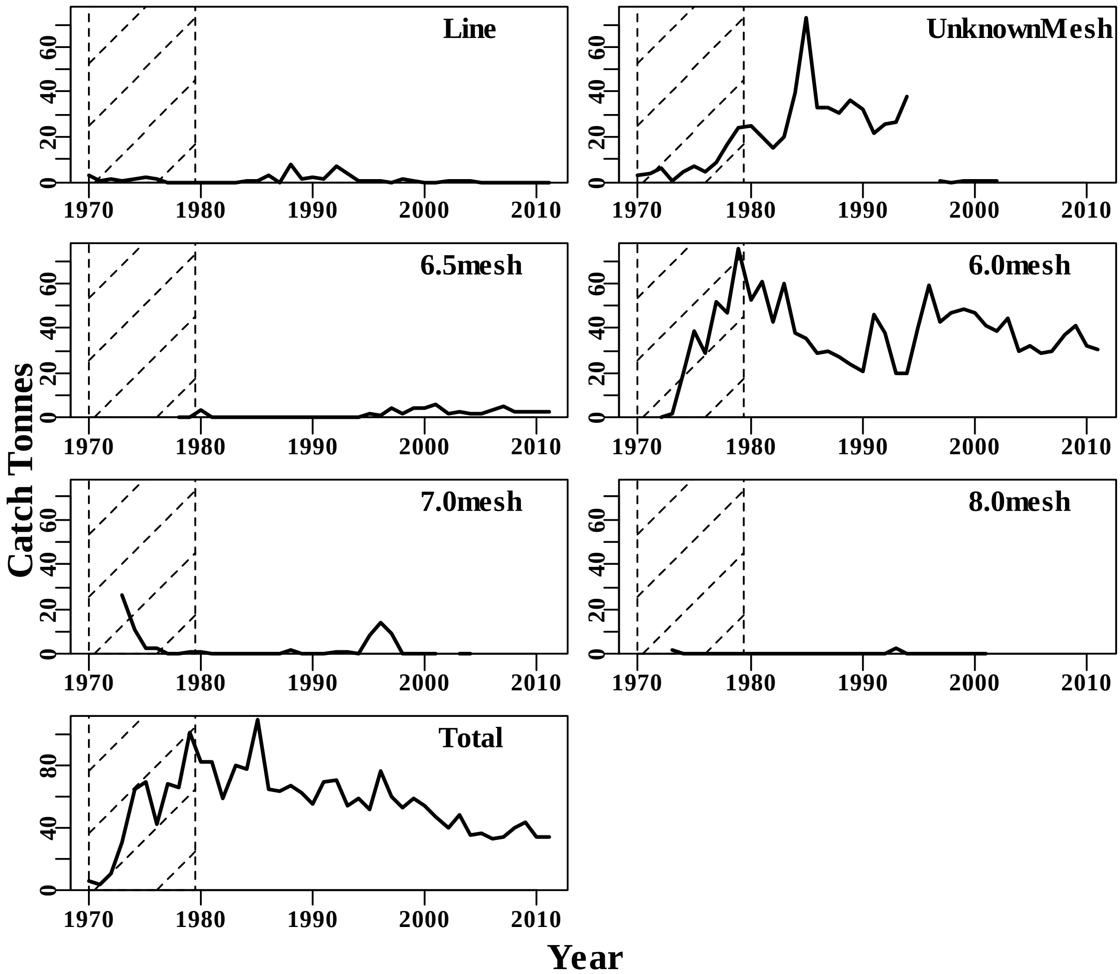

Figure 18.16 Catches of elephant fish by fishing gear method 1970 – 2011; these data include all vessels and areas. The hatched area relates to the period of exclusion decided upon by SharkRAG (1980).

As with sawsharks, elephant fish are mostly taken in small amounts with most statistical areas only reporting less than seven tonnes over the 30 year period from 1980 – 2011 (Figure 18.20). The distribution of catches is mostly focussed across Bass Strait with the largest amounts from eastern Bass Strait (areas 9, 10, and 11). Eastern Tasmania has reported catches whereas western Tasmania only reports minor catches (Figure 18.20; Table 18.18).

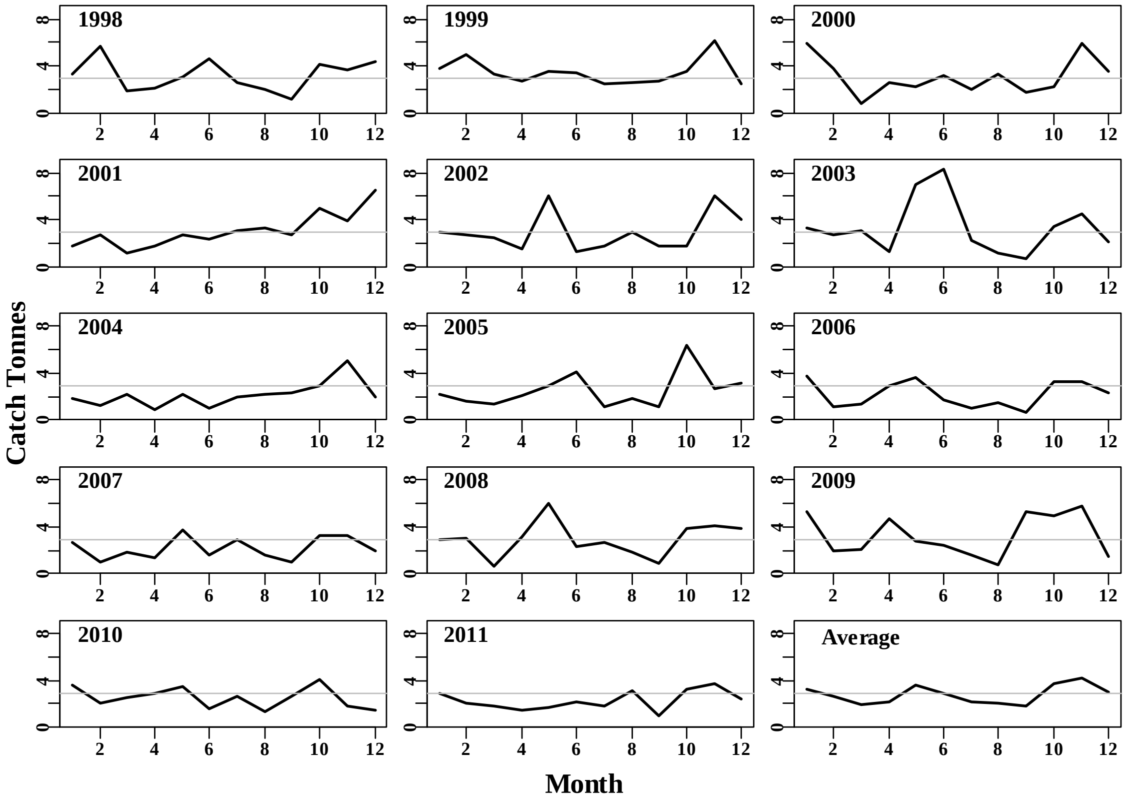

Figure 18.17**.** Catch by Month for elephant fish since 1998 along with a total across years to illustrate the approximate seasonality of the fishery and its variation through time.

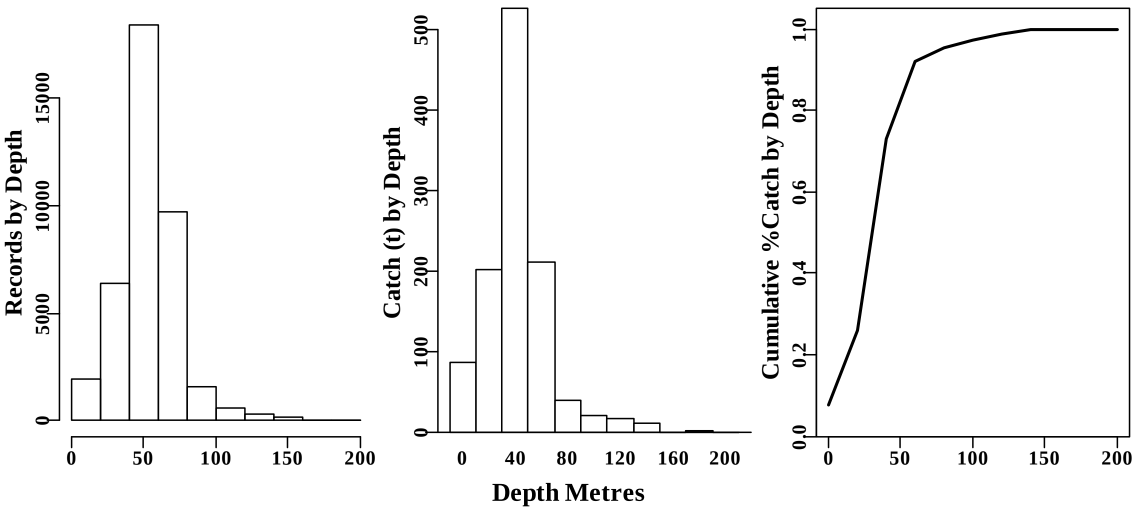

Figure 18.18**.** Catch by depth. Left panel is the relative frequency of records of elephant fish catches at different depths and the right panel is the catch in tonnes across the years 1980 – 2011as taken by 6" mesh nets.

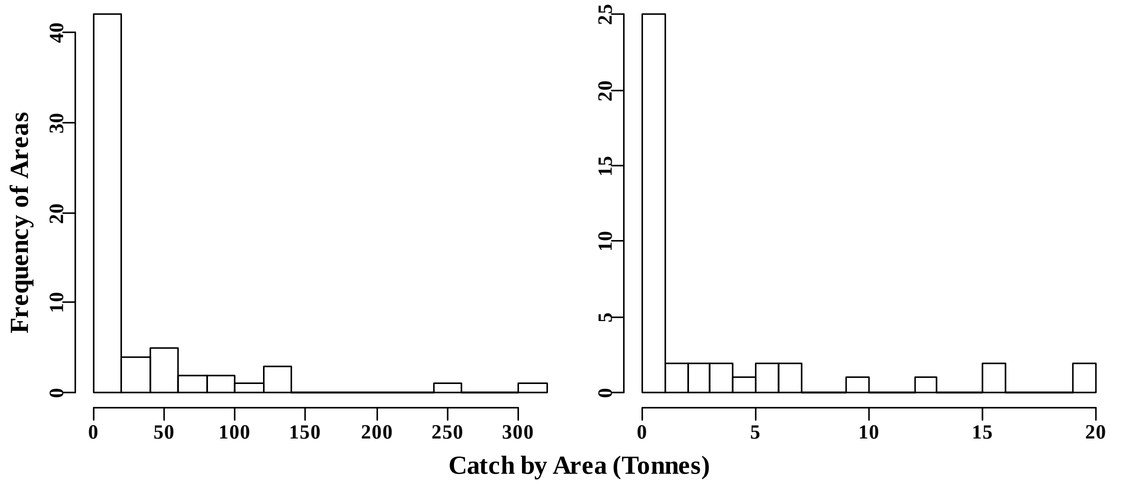

Figure 18.19**.** Catch by depth. Left panel is the relative frequency of records of elephant fish catches at different depths and the right panel is the catch in tonnes across the years 1980 – 2011 as taken by 6" mesh nets.

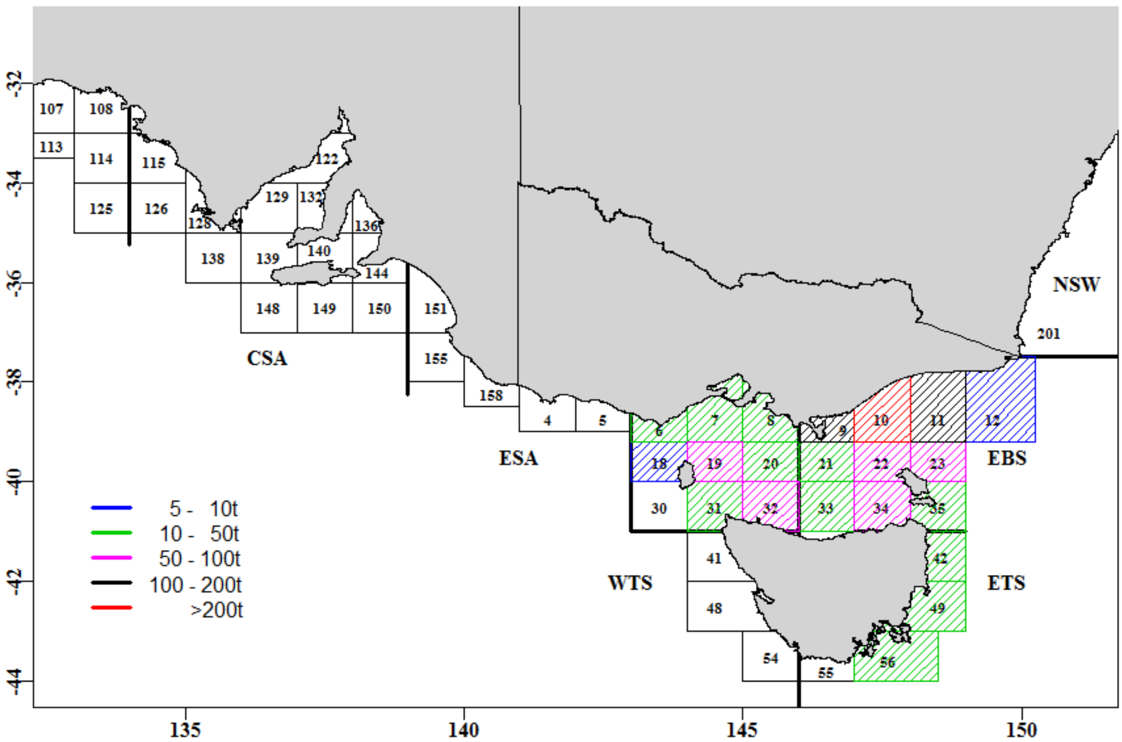

Figure 18.20**.** Elephant fish catches by area taken by 6" gear. The relative catch levels across the years 1980 – 2011. Only those areas with catches greater than 4 t (not the empty areas) were used. If 6.5" gear is included then areas 150 and 151 show green and areas 5 and 54 shows blue. All areas remain as they were in the analysis using data up until the end of 2010.

18.4.3.2 Elephant Fish Standardized Catch Rates

The base case standardization removed those areas reporting less than 4 tonnes across the 30 years from 1980 – 2009. In addition, vessels with an annual average catch less than 0.25 tonnes were also removed, which reduces the number of vessels from 296 down to 86 but only reduces the catch accounted for by about 4.5% (Table 18.21). The selection by gear had a much greater impact on the available records and the catch accounted for in the analysis, which stemmed for the large amount of catch taken with unknown mesh size in the early years of the fishery.

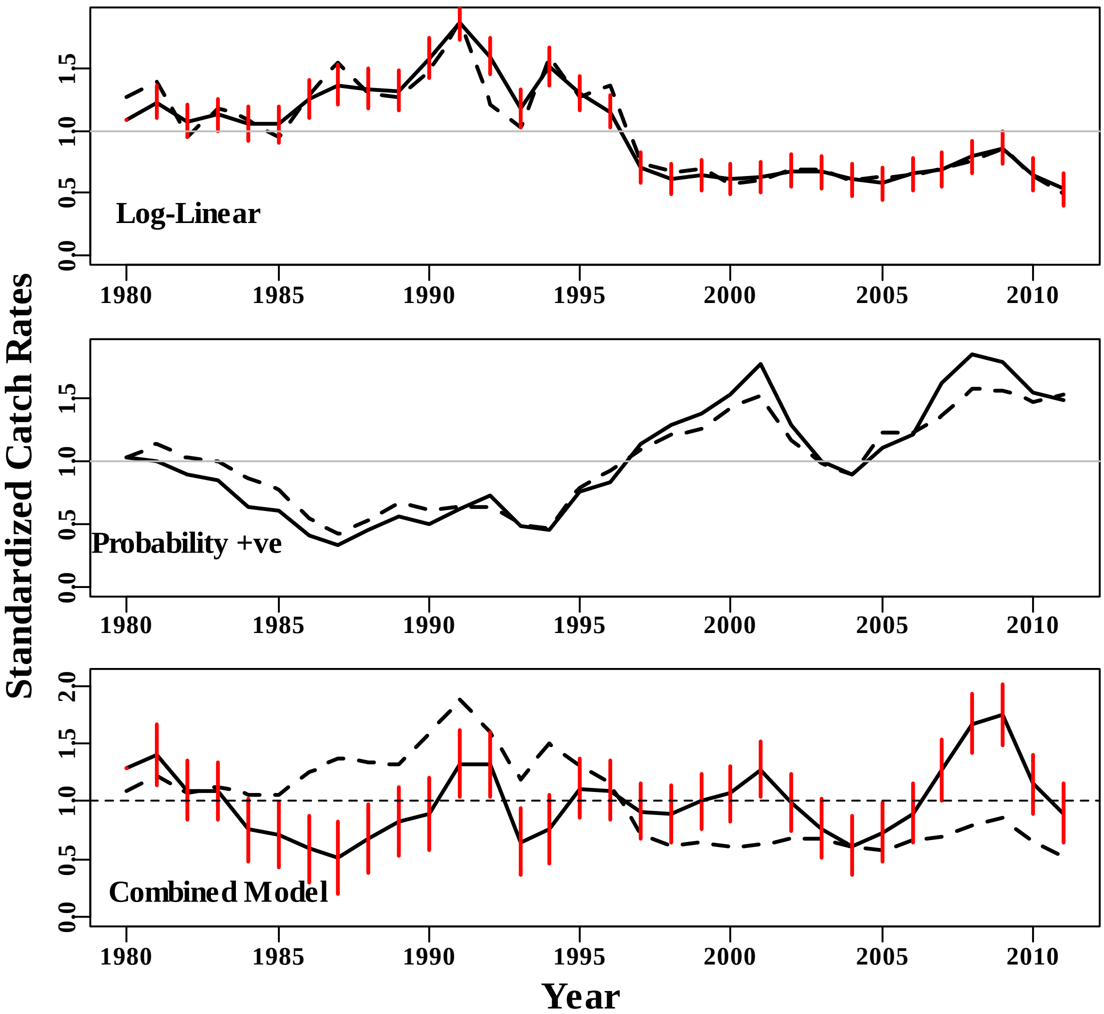

Figure 18.21. Standardized catch rates for elephant fish using data relating to 6" mesh gear, from areas that reported more than 4 tonnes across the 32 years considered, and from vessels with average catches greater than 0.25 tonnes per annum. The top panel represents the log-linear modelling of positive catches. The dashed line is the geometric mean while the solid line is the optimal model. The central panel represents the probability of obtaining a positive catch, the dashed line being the proportion of positive catches in the raw data and the solid line being the statistical optimum model. The bottom panel represents the final standardized catch rates, combining the results from the log-linear modelling and the binomial modelling of the probability of a positive catch (the dashed line represents the optimum log-linear model while the solid line is the optimum combined model, the dotted line is the mean of the optimum combined model and the short vertical red lines are the approximate 95% confidence intervals).

The log-linear modelling of positive catch rates was relatively flat with some oscillations up and down from 1985 to 1995. The standardization is somewhat less variable than the geometric mean catch rates. Over the last 12 years there has been a slight upward trend but essentially these catch rates were flat (Table 18.23; Figure 18.22).

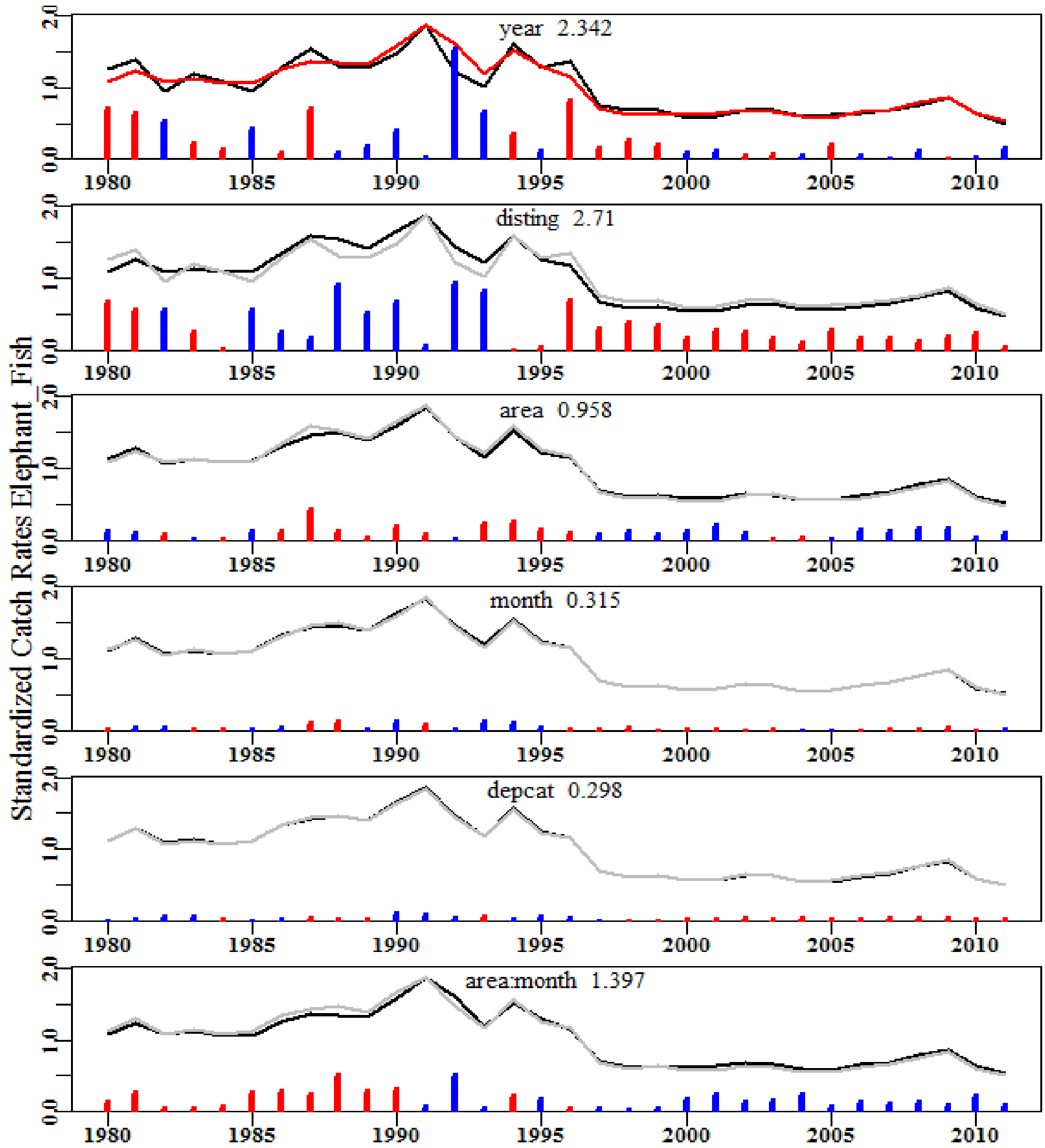

Figure 18.22**.** The relative contribution of each factor to changes in the trends in the log-linear modelling. Blue bars indicate the line moves above the previous combination of factors while a red line indicates the opposite. The number in each graph is the sum of squared differences between the trends on each graph. The grey line is the black line from the previous graph (top to bottom). The black line in the top graph is the geometric mean and the red line the final trend.

The probability of obtaining elephant fish in a set is much more variable than the log-linear modelling. The probability of catching elephant fish has more than doubled since 1980. There was a decline in the probability of catching elephant fish from 1980 to about 1987, following which there was a slow increase to a peak in 2008 and 2009. The binomial modelling follows the same general trend as the simple probability of a positive catch but is somewhat less variable. The combination of the increasing trend in the probability of a positive catch with the slow increase in catch rates from the log-linear modelling has led to the combined model being very different from the log-linear model (which ignores the effects of zero shots). By considering the 95% confidence intervals about the yearly mean estimates, for long periods of time the catch rate trend does not differ from the overall average. However, there appears to have been a significant decline from 1984 – 1990 and the last three years (2007 – 2009) have exhibited above average catch rates followed by three years of decline back to the long term average (Figure 18.21). As with sawsharks the most influential factors were Vessel followed by Area, though the Area x Month interaction term contributed ~5.7%; the year factor only accounted for 4.2% of variability (Table 18.22).

The standardization was insensitive or robust to altering the data filtering so that with a minimum catch per area of 10 t and a minimum annual catch of 0.5 t, there were only minor and insignificant differences between both the log-linear modelling of positive catch rates and the probability of obtaining a positive set.

18.5 Discussion

18.5.1 Saw Sharks

The sawshark standardization is relatively robust to an array of alternative data selection criteria and to the data being split between east and west Bass Strait. The amount of catch in the early period taken with unknown mesh size adds a degree of uncertainty to the analysis. The reporting in the later period appears to be more complete.

The inclusion of the zero shots had a significant effect on the overall catch rate trend. Because the probability of obtaining a positive shot increased in recent years this had the effect of converting a slightly decreasing catch rate trend into an essentially flat pattern. For 1981 to 2010 (ignoring events in 1992-1997) the catch rates for sawsharks appears to show no overall trends. There is a significant drop in 1980 to 1981 (and this is also an exceptional year in the elephant fish standardization). It is possible that starting the time series in 1980 instead of 1981 is affecting the outcome. Fishing behaviour was clearly very different in the 1970s with catch rates of sawsharks very much higher than later (mainly due to a higher probability of capturing a saw shark. The reason for the Shark RAG choosing the years that were selected need to be made clear, although the influence of 1980 on the TIER 4 analysis will be minor.

18.5.2 Elephant Fish

The elephant fish standardization is also robust to alternative data selection scenarios. Increasing the total catch per area for inclusion to 10 tonnes, and increasing the average annual catch per vessel to 0.5 tonnes had almost no effect on either the log-linear modelling of the positive catches or the binomial modelling of the probability of catching elephant fish. The elephant fish standardization is based on records of much smaller catches (usually less than half the catches of sawsharks) and the geographical distribution of elephant fish is more restricted than that of saws sharks. Again there was a significant amount of elephant fish taken with unknown mesh sizes in the 1980s and this may have influenced the results.

The standardization of positive shots exhibited some variation from 1985 to 1995 but otherwise was relatively flat. However, the probability of catching elephant fish has increased markedly over the study period with a recent decline in 2010. Since about 1990 the probability of capturing elephant fish appears to have trebled. When the two time series are combined the trend is approximately flat for many years, although it declined significantly between 1984 and 1991 but has increased significantly above average between 2007 – 2009 followed by a large decrease in 2010. The increase in

2007 – 2009 is due to a small rise in the log-linear modelling of positive catches but is especially due to a recent increase in the probability of catching elephant fish. The 2010 decrease was a combination of both a decline in the log-linear modelling and the probability of a positive catch decreasing.

18.6 References

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18.7 Additional Graphs

18.7.1 Saw Shark

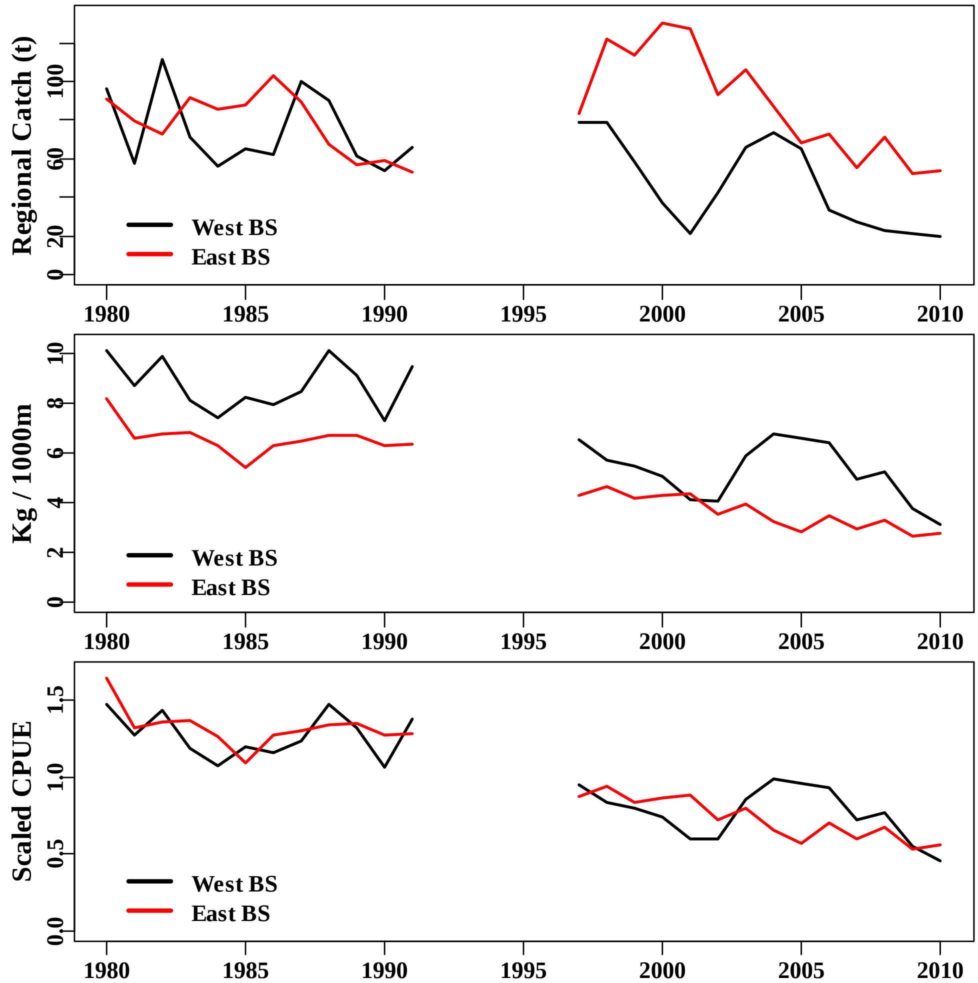


Figure 18.23**.** Top panel**:** The relative catches of sawshark when the fishery is split across Bass Strait. Eastern Bass Strait dominates in the second part of the time series. Middle panel: the observed geometric mean catch rates for the east and western Bass Strait regions, and the bottom panel depicts the geometric mean catch rates scaled to a mean of one to simplify the visual comparison of the trends. Data only until 2010.

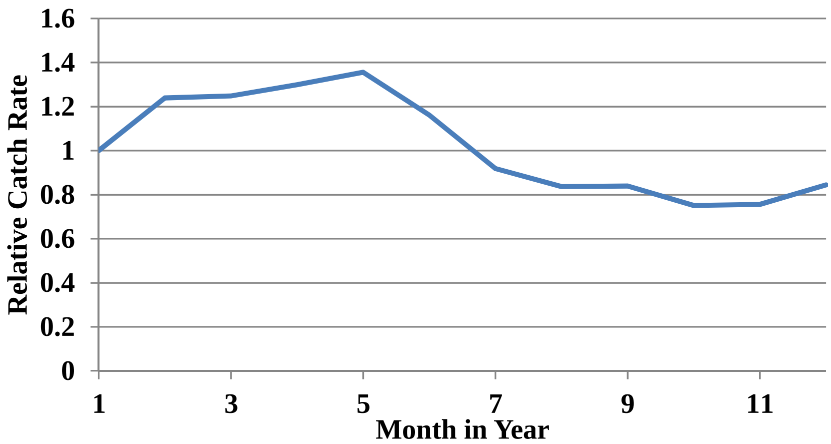


Figure 18.24. The relative catch rates of saw sharks taken by trawl in the SET as a function of season (by month), illustrating a clear seasonal trend in catch rates.

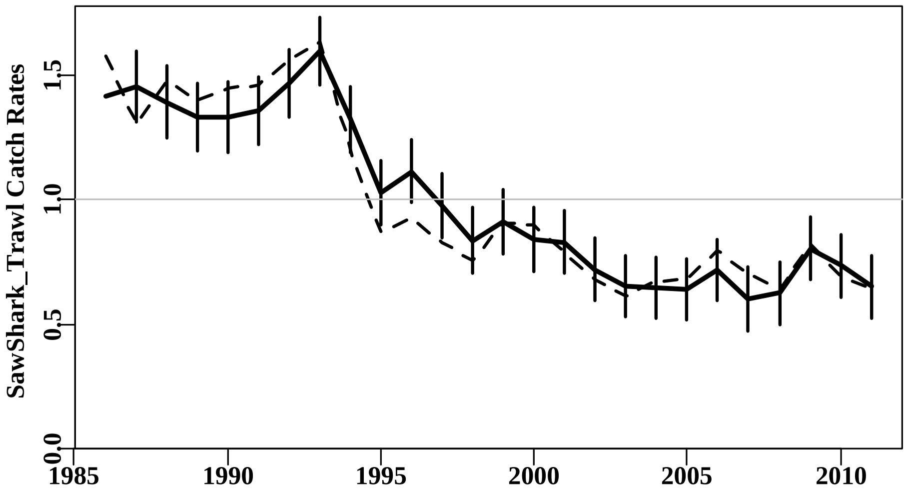


Figure 18.25**.** The standardized catch rates for trawl caught saw sharks. The dotted line is the unstandardized geometric mean catch rate. The solid line is the optimum model with approximate 95% confidence bounds. Following the introduction of quotas to the trawl fishery a clear change occurred. When the gillnet fishery analysis includes the 1992-1996 period it exhibits a huge increase in catch rates, completely inconsistent with the trawl fishery. As with the gill net fishery, the early time series of trawl data for saw sharks, prior to 1995, does not appear comparable to the later series.

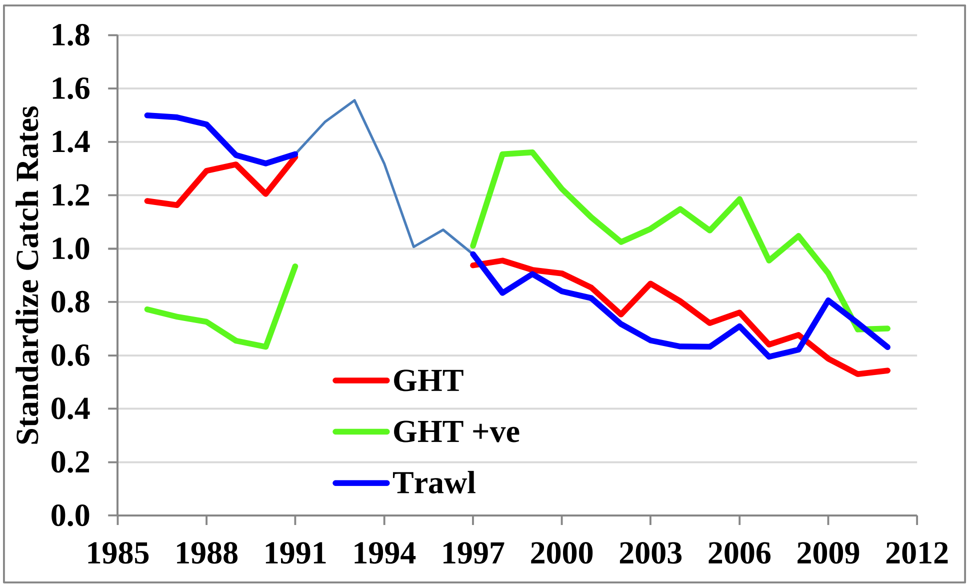


Figure 18.26**.** A comparison between the trawl caught catch rates and the standardization of positive shots in the GHT, and the GHT standardization where the probability of a positive shot is included. The trends in the positive shots are surprisingly similar.

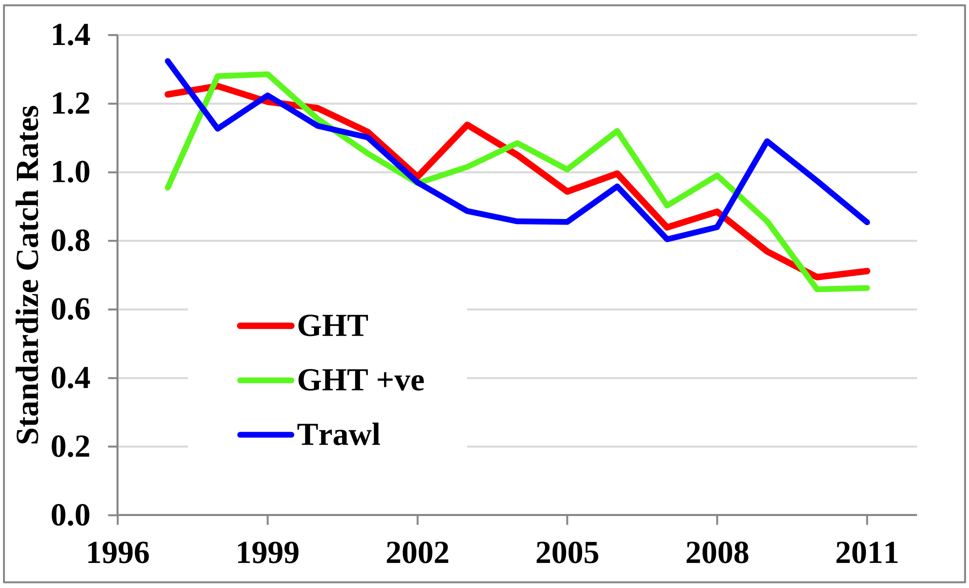
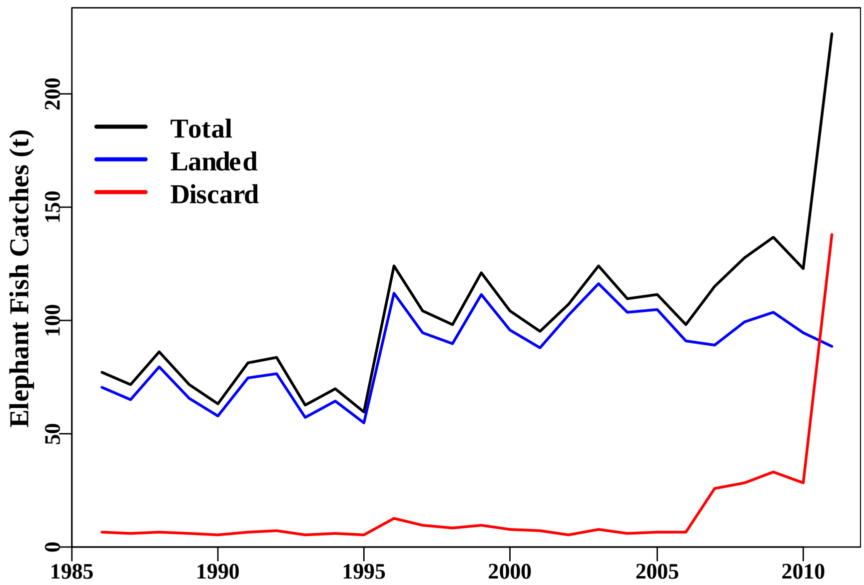


Figure 18.27. A comparison between the trawl caught catch rates and the standardization of positive shots in the GHT, and the GHT standardization where the probability of a positive shot is included for the years 1997 – 2011 only.

18.7.2 Elephant Fish



18.8 Tables

18.8.1 General Methods

Table 18.1. Data fields contained in the original file, CANDE11.csv, used in the analyses. The fields from CE down (24 – 28) were added prior to analysis.

FieldNo	Column	Contents
1	Year	Calendar Year
2	Month	Calendar Month
3	Vessel	Vessel Name – only available consistently in two years
4	Disting	Vessel Distinguishing mark – across all years
5	orig	Presumably region of original port
6	op	Operation within the month
7	Gear	Type of fishing gear mesh size, hooks, or unknown
8	Region	Fishery Region
9	Zone	Fishery zone name : BS, SA, TS, or UN
10	Gummy	Gummy shark catches
11	School	School shark catches
12	Comb	Combined School and Gummy shark catches
13	Saw	Saw shark catches
14	Eleph	Elephant fish/shark catches
15	other	Other sharks - seven gill, etc.
16	Scale	Scalefish catches
17	Effort	Fishing effort: -1 = no data
18	sh	
19	Area	Statistical reporting area
20	dmin	minimum depth
21	dmax	maximum depth
22	gear2	Second type of gear when used
23	effort2	Effort in second type of gear where used.
24	CE	Catch rate where catches>0 and effort>0
25	LnCE	Log of CE, where CE is valid
26	Dav	Average of dmin and dmax.
27	DepCat	Four depth categories: >90, <=90 & >75, <=75 & >30, <=30
28	PA	Positive School shark catches vs zero School shark catch

Table 18.2. The regions codes (column originally headed r in CANDE11.csv).

Code	**Region**
-1	Unknown
1	Western South Australia
2	Central South Australia
3	Eastern Southern Australia
4	Western Bass Strait
5	Eastern Bass Strait
6	Western Tasmania
7	Eastern Tasmania
8	New South Wales
10	Western Australia

Table 18.3. The gear codes (column headed g in CANDE11.csv).

Code	Meaning
-1	Unknown?
0	Unknown?
1	Unknown
2	Line
3	Unknown Mesh Gillnet
5	6.5" Gillnet
6	6.0" Gillnet
7	7.0" Gillnet
8	8.0" Gillnet

Table 18.4. The statistical models used in the log-linear modelling of positive catches. The same models were used in the binomial modelling except the LnCE term was replaced by PA (present/absent). DepCat relates to three classes (0-19m, 20-80m, and >80m).

Year	LnCE ~ Year
Area	LnCE ~ Year + Disting
Disting	LnCE ~ Year + Disting + Area
Month	LnCE ~ Year + Disting + Area + Month
DepCat	LnCE ~ Year + Disting + Area + Month + DepCat
Month:Gear	LnCE ~ Year + Disting + Area + Month + DepCat + Month:Area

Table 18.5**.** Effort in the southern shark fishery; in all cases divided by 1000.

Year	Unknown	Line	UnknownMesh	6.5mesh	6.0mesh	7.0mesh	8.0mesh
1970		204.060	21.948				
1971		2690.294	7888.331				
1972		936.330	12623.219		21.945		
1973		930.871	2411.539	24.690	2220.639	12915.206	2717.387
1974		1084.127	2186.466		8483.933	5997.578	2217.489
1975		956.823	1747.700		11236.080	2836.997	2343.468
1976		631.105	3648.162		11522.868	2490.020	1114.297
1977		659.227	5701.002		14882.550	432.528	843.523
1978		855.017	7748.690	79.527	16119.190	221.336	155.920
1979		401.625	7915.678	158.060	14988.435	492.960	35.700
1980		473.647	10342.961	463.562	16682.365	535.434	3.000
1981		1074.182	11119.481	327.838	16141.491	553.200	33.000
1982		608.045	12542.753	23.200	20592.177	423.493	110.250
1983		874.825	5388.237	27.000	23286.048	6467.716	137.102
1984		1614.408	198.780	153.130	23163.088	14329.863	4128.200
1985		2224.698	569.083	1761.740	23000.926	14624.391	1481.500
1986		3525.794	1663.080	826.300	25866.748	25082.980	1707.000
1987	16.000	3477.219	669.831	570.360	27407.196	37276.910	2285.851
1988		3471.042	2874.292	1656.346	25597.776	32898.900	1964.710
1989		4654.487	4982.911	2140.300	23429.352	30523.901	753.045
1990		2765.441	996.928	3567.600	24783.737	28014.864	326.700
1991	2.000	4219.227	7881.462	4586.325	25594.586	24664.335	138.200
1992		4600.058	2736.286	2675.800	23987.503	19639.390	87.350
1993		3944.153	2506.150	2578.600	23528.226	17727.660	1004.400
1994		2713.568	1242.540	3986.100	23534.358	18854.380	542.100
1995		2850.390		8138.380	28739.786	19098.260	161.400
1996		2427.501		9117.120	30656.291	13262.300	297.600
1997		3692.668	2472.850	20970.240	30205.536	3948.900	442.300
1998		2939.503	102.600	29436.280	27698.295	2594.100	76.300
1999		1475.458	292.600	23289.672	30104.841	2263.200	19.000
2000		570.050	304.300	16245.780	28452.620	501.600	
2001		1454.511	413.150	14702.870	27051.340	128.600	79.400
2002		283.900	602.900	13339.380	29097.982		
2003	9702.759	440.605		15438.285	32353.550	430.400	
2004	9953.572	252.808		16057.994	29540.560	34.000	
2005	10412.111	230.600		14571.380	26884.860		
2006	11841.305	1.979		19351.326	21998.770		
2007	9056.540	2.686		14895.725	19624.580		
2008	9035.687	2.247		14250.907	20941.455	4.200	28.800
2009	7926.485	2.584		13827.510	22881.940		
2010	7575.732	2.493		13626.920	25668.159		
2011	6920.496	3.715		8443.700	27852.090		

18.8.2 Saw Sharks

Table 18.6. Selection criteria for which records to include in the standardization of saw shark.

Criteria	Values
Years Included	1980 – 1991 & 1997 – 2009
Gear Types	6 inch mesh gillnet
Depth	10 m depth classes 0 – 160 m
Areas	Reporting > 10 t over years.
Vessels	Average annual catch > 0.25 t
No minimum effort	Remove effort = -1 records

Table 18.7. Catch by gear for sawsharks across the years of interest.

Year	Unknown	Line	UnkMesh	6.0"	6.5"	7.0"	8.0"
1980		0.114	20.040	199.781	2.302	5.732	
1981		0.104	39.775	146.912	0.984	5.817	
1982		0.119	42.140	199.480	0.238	2.070	
1983	0.888	0.348	50.154	182.923	0.220	0.140	
1984		0.259	67.008	162.274	0.400	0.524	
1985	0.012	2.658	89.538	166.407	2.302	1.996	
1986	0.970	4.583	94.038	176.238	0.828	3.841	0.031
1987	1.895	3.839	99.034	209.040	0.790	11.556	1.211
1988	0.125	2.942	61.455	177.952	1.761	4.401	0.072
1989	2.561	4.660	67.549	132.396	1.231	4.088	0.105
1990	0.935	6.351	44.211	123.735	1.279	3.612	
1991	0.301	6.313	52.778	147.796	1.942	2.476	
1997	1.819	0.613	3.849	187.891	33.976	5.084	0.097
1998	1.131	0.358	0.002	226.693	15.731	0.232	
1999	1.760	0.399	0.000	199.836	10.179	0.599	
2000	0.717	0.371	0.386	186.984	12.415	0.137	
2001	0.161	4.307	0.136	162.149	9.059		
2002	0.124	0.066	1.458	156.478	8.665		
2003	0.162	0.174		197.944	6.134	0.119	
2004	3.886	0.146		179.798	9.483		
2005	1.023	0.209		159.531	11.885		
2006	0.212	0.061		148.534	9.857		
2007	1.092	0.062		99.325	7.398		
2008	0.407	0.097		105.845	8.856	0.015	0.090
2009	0.542	0.129		83.271	5.497		
2010	0.492	0.368		81.260	10.597		
2011	0.223	0.187		97.747	4.807		
Total	21.438	39.836	733.551	4298.219	178.815	52.439	1.606

Table 18.8. Catches of Saw Shark by depth category from 1980 – 1991 & 1997 – 2011.

Depth	Catch t	Cumulative %	Cumulative C
0	7.337	0.00186	7.337
10	15.494	0.00580	22.831
20	73.622	0.02451	96.453
30	212.803	0.07860	309.256
40	580.605	0.22616	889.862
50	1390.688	0.57960	2280.550
60	819.352	0.78783	3099.902
70	481.329	0.91016	3581.230
80	133.327	0.94405	3714.557
90	83.634	0.96530	3798.191
100	37.720	0.97489	3835.910
110	29.456	0.98238	3865.366
120	17.748	0.98689	3883.114
130	25.843	0.99345	3908.957
140	18.125	0.99806	3927.082
150	7.541	0.99998	3934.623
160	0.088	1.00000	3934.711

Table 18.9. Catch of saw sharks included in the analysis and those excluded, sub-divided by region. Totals relate to years 1980 – 1991 & 1997 – 2011. The included data also constituted those areas reporting more than 10 t over the years and those vessels reporting an average catch greater than 0.25 t per annum, Effort > -1, and depths < 160m. The total data was only restricted to the same years.

Region	**Included**	**Total**	**Excluded t**	**% Excluded**
Unknown		0.369	0.369	100
Western SA		31.624	31.328	100
Central SA		129.219	126.402	100
Eastern SA	233.067	325.627	92.560	58.28
Western BS	1559.598	1941.783	382.186	55.46
Eastern BS	2237.704	2717.051	479.347	54.84
Western Tas	17.183	66.121	48.938	79.37
Eastern Tas	44.956	113.387	68.432	71.61
NSW	0.106	0.702	0.596	86.88
West Australia		0.023	0.023	100
Total	4092.613	5325.905	1246.944	56.55

Table 18.10**.** Catches of saw shark in the shark fishery in tonnes by statistical reporting area. 80-10 refers to all catches taken between 1980-1991 plus 1997 and 2011 by 6" mesh. 70-11 relates to all catches in Cande11.csv from 1970 to 2011 using all gears. Those areas reporting less than 10 tonnes during the analysis period (the right hand three columns) were omitted from the analysis. Areas 0 and -1 are unknown. Percent is the proportion of the total catch in the year group included in the catch rate analysis.

Area	80-11	70-11	Area	80-11	70-11
10	708.244	1081.944	151	8.984	37.428
19	548.839	1071.368	150	6.783	40.213
22	466.817	943.440	158	4.567	22.859
11	386.200	814.643	155	3.733	16.767
32	290.191	558.667	54	3.407	13.063
5	219.384	391.833	144	2.872	8.251
21	196.351	350.929	55	2.524	27.703
31	172.273	329.012	114	2.273	9.918
23	165.803	379.417	48	2.237	22.726
20	146.466	274.280	149	2.031	15.442
34	138.323	256.891	105	1.225	3.238
6	122.955	266.578	112	1.215	2.624
7	106.643	242.960	115	1.087	7.232
18	106.121	273.715	148	0.889	10.819
35	102.855	216.939	104	0.869	2.555
9	92.495	143.869	113	0.826	4.587
8	62.686	123.739	126	0.741	9.268
33	59.609	114.893	107	0.709	2.480
30	40.488	98.770	108	0.660	6.408
4	23.971	60.872	138	0.567	7.436
42	23.481	57.643	0	0.551	0.601
12	19.876	48.154	139	0.541	3.530
41	17.768	80.609	-1	0.441	3.673
49	15.092	47.334	106	0.331	1.057
56	14.568	56.589	102	0.279	0.604
Total	4247.494	8285.084	140	0.100	5.188
			128	0.079	1.671
			132	0.074	0.339
Percent	98.82	96.61	101	0.071	1.166
			129	0.036	1.096
			99	0.020	0.020
			103	0.008	0.498
			122		0.007
			136		0.050
			13		0.010
			201		0.003
			Total	50.726	290.525

Table 18.11. Reduction in records and associated catch of saw sharks made by the data selection decisions. Years used refers to 1980 – 1991 & 1997 – 2011 (with data available from 1970 – 2012), Gear Used refers to 6 inch gill nets, Effort < 0 refers to those records for which no effort data was available, areas used refers to those remaining after the removal of areas reporting < 10 t over the time period, Vessels Used refers to those vessels whose average annual catch was >0.25 t. The estimation of the probability of a positive catch had 135740 records and the standardized catch rates for positive catches had 96932 records. The % loss is relative to each line, whereas the %records and %catch relates to the totals following selection by YearsUsed.

	Records	Catch	CatchReduct	%Catch	%Records	%Loss
Records	431156	8575.609	0		0	0
YearsUsed	323687	5325.905	3249.704	100.00	100.00	37.89
GearUsed	165323	4298.219	1027.686	80.70	51.07	11.98
Effort<0	163575	4274.312	23.907	80.26	50.53	0.28
Areasused	148563	4223.667	50.646	79.30	45.90	0.59
VesselsUsed	140370	4202.008	21.659	78.90	43.37	0.25
Depths	135740	4092.613	109.396	76.84	41.94	1.28
'+veCatch	96932	4092.613	0.000	76.84	29.95	0.00

Table 18.12. Total catches t, of saw shark, by assessment region, in CANDE11.csv

Year	WestSA	CentSA	EastSA	WestBS	EastBS	WestTas	EastTas	NSW	WA
1970	0	0	1.728	7.247	15.839	0	1.503	0	0
1971	0	0	1.197	26.772	16.309	0	0.034	0	0
1972	0	0	4.591	35.638	25.717	0	3.976	0	0
1973	0	0.224	13.384	46.323	87.869	0.209	0.377	0	0
1974	0.028	0.197	3.701	45.441	162.459	2.393	13.059	0	0
1975	0	0.020	4.570	49.025	166.018	0.008	1.198	0	0
1976	0	0.431	35.518	85.531	122.478	0.452	4.240	0	0
1977	0	0.320	13.665	98.608	114.037	2.028	1.719	0	0
1978	0	0	11.417	133.508	116.783	0.171	7.321	0	0
1979	0	0	5.391	118.550	108.596	0	4.223	0	0
1980	0	0.120	4.023	113.508	108.781	0.370	1.167	0	0
1981	0.018	0	4.462	84.540	102.892	0.441	1.239	0	0
1982	0	0	8.292	130.106	101.910	0.960	2.779	0	0
1983	0	0	6.425	95.327	130.641	0.575	1.705	0	0
1984	0	0.194	4.206	92.811	124.495	3.621	5.138	0	0
1985	0.025	1.452	5.239	109.432	134.874	5.219	6.672	0	0
1986	1.603	2.538	4.595	114.500	143.532	8.793	4.968	0	0
1987	5.190	8.396	13.374	159.258	131.112	7.230	2.805	0	0
1988	1.167	7.483	13.210	108.335	107.515	4.399	6.599	0	0
1989	0.751	5.810	7.314	80.008	109.515	1.969	7.223	0	0
1990	2.669	3.753	4.472	70.764	90.263	5.200	3.002	0	0
1991	2.824	4.383	17.320	89.838	89.511	2.709	5.021	0	0
1992	1.179	3.356	6.951	85.717	90.742	14.755	6.542	0	0
1993	0.211	2.137	8.629	113.184	142.494	17.241	5.309	0	0
1994	0.996	2.538	7.480	129.354	176.588	5.348	5.102	0	0
1995	0.473	6.951	31.963	185.733	152.381	2.518	10.964	0	0
1996	0.623	3.431	16.519	136.674	136.033	5.591	11.956	0	0
1997	2.528	7.980	28.404	86.981	95.393	2.536	9.507	0	0

1998	2.866	8.600	16.997	81.192	126.555	2.019	5.918	0	0
1999	1.969	7.007	18.561	60.195	117.536	1.924	5.581	0	0
2000	0.826	5.802	12.247	39.917	134.874	1.424	5.920	0	0
2001	1.059	10.114	8.187	22.578	129.058	1.406	3.410	0	0
2002	0.722	4.247	15.288	44.423	95.083	1.511	5.517	0	0
2003	1.170	5.079	18.542	66.343	106.741	2.510	4.149	0	0
2004	0.492	5.050	15.069	74.666	92.126	0.808	5.061	0.041	0
2005	1.948	6.989	23.809	65.962	68.609	0.845	3.928	0.558	0
2006	0.917	5.895	33.697	34.519	73.476	6.505	3.631	0	0
2007	0.556	5.770	12.760	28.365	55.522	1.156	3.745	0.004	0
2008	0.679	7.105	9.805	22.834	71.450	0.189	3.202	0.028	0.020
2009	0.592	5.027	6.873	21.464	52.866	0.367	1.903	0	0.003
2010	0.706	6.477	8.206	19.951	55.383	0.278	1.645	0.071	0
2011	0.348	3.949	4.251	23.967	67.339	1.157	1.953	0	0
Total	35.134	148.824	492.331	3239.088	4351.394	116.835	190.910	0.702	0.023

Table 18.13. The optimum models and geometric mean catch rates and the proportion of positive catches through time for saw sharks. YearS is the geometric mean catch rate relative to the mean of the series, AreaMonth is the optimum statistical model for the log-linear modelling, YearP is the proportion of positive shots and GearP is the proportion of positive shots after standaridzation. Finally, Combined is the combination of both optimum series. This is the base case (>10t /area, >0.25t/vessel, 6" mesh).

Year	YearS	AreaMonth	YearP	Area:MthP	Combined	StErr
1980	1.6280	1.4620	1.0488	1.0433	1.6610	0.0000
1981	1.3428	1.3343	0.9666	0.7461	1.0841	0.1080
1982	1.5023	1.3047	0.9904	0.6220	0.8837	0.1037
1983	1.3690	1.3075	0.9871	0.7083	1.0085	0.1034
1984	1.2182	1.2778	0.9924	0.7237	1.0070	0.1058
1985	1.2617	1.3389	0.9649	0.6928	1.0101	0.1051
1986	1.2418	1.1863	0.9297	0.6023	0.7781	0.1025
1987	1.2948	1.1603	0.9321	0.5881	0.7430	0.1036
1988	1.3964	1.2824	0.8732	0.5156	0.7200	0.1031
1989	1.3763	1.2902	0.8606	0.4573	0.6425	0.1070
1990	1.2052	1.1968	0.8594	0.4819	0.6281	0.1085
1991	1.5343	1.4175	0.9524	0.6384	0.9854	0.1057
1997	0.9482	0.9382	1.0657	0.9902	1.0117	0.1007
1998	0.9100	0.9468	1.0628	1.3012	1.3416	0.0995
1999	0.8388	0.9284	1.0669	1.3577	1.3726	0.0980
2000	0.8139	0.9104	1.0623	1.2391	1.2284	0.0994
2001	0.7969	0.8559	1.0328	1.2011	1.1195	0.1001
2002	0.6897	0.7582	1.0410	1.2484	1.0308	0.0998
2003	0.7907	0.8621	1.0234	1.1354	1.0659	0.0989
2004	0.7044	0.7981	1.0541	1.3145	1.1425	0.1005
2005	0.6420	0.7187	1.0488	1.3597	1.0642	0.1025
2006	0.7348	0.7508	1.0639	1.4312	1.1701	0.1057
2007	0.5889	0.6419	1.0319	1.3690	0.9570	0.1081
2008	0.6433	0.6725	1.0614	1.4235	1.0424	0.1082

2009	0.5201	0.5848	1.0372	1.4172	0.9026	0.1070
2010	0.5063	0.5290	0.9739	1.2080	0.6958	0.1068
2011	0.5011	0.5455	1.0164	1.1840	0.7034	0.1067

Table 18.14**.** Statistical model diagnostics for the log-linear modelling for saw-sharks. The optimum model (smallest AIC plus greatest adjusted r^2) included all factors.

	Year	Vessel	Area	DepCat	Montht	**Area:Month**
AIC	45873	37788	30522	25652	23275	18307
RSS	150122	136923	126289	119643	116512	109645
MSS	10538	23738	34372	41018	44149	51016
Nobs	90465	90465	90465	90465	90465	90465
Npars	27	147	171	181	192	456
adj_r2	6.533	14.637	21.246	25.382	27.326	31.409
%Change	0.000	8.105	6.609	4.136	1.944	4.083

Table 18.15. SawShark catches in the Table 18.17. Statistical model diagnostics for the log-linear modelling of trawl caught saw-sharks. The optimum model (smallest AIC plus greatest adjusted r2) included all factors up to Zone:Month. Commonwealth Logbooks. 37023000 and 37023900 are both generic sawshark codes, while 37023001 is the Southern sawshark and 37023002 is the Common sawshark. DS is Danish Seine, GN is gill net, and TW is trawl.

Year	37023000	37023001	37023002	37023900	DS	GN	TW
1986	19.478				3.578		15.900
1987	16.431			0.015	2.402		14.044
1988	30.514			0.505	4.832		26.187
1989	18.608			3.983	2.479		20.112
1990	17.598			9.601	3.441		23.578
1991	23.931			14.442	2.541		34.649
1992	25.541			25.265	4.597		45.031
1993	31.782			20.506	3.962		48.316
1994	43.078			17.149	7.446		52.781
1995	32.762			24.375	4.822		52.196
1996	37.963			29.537	6.964		60.536
1997	194.616			27.611	4.018	157.406	59.769
1998	278.915			25.726	6.750	249.079	48.323
1999	177.741	33.985	65.618	23.123	6.464	241.592	51.660
2000	69.471	138.485	136.310	8.108	7.165	274.250	69.851
2001	75.549	107.596	155.001		7.029	262.152	65.856
2002	97.507	52.710	105.540		24.454	158.055	72.094
2003	126.951	59.937	131.019		22.429	190.646	104.482
2004	121.206	68.145	125.265		24.336	192.374	96.756
2005	124.542	66.292	105.837		17.418	171.412	106.638
2006	159.035	51.031	107.632		18.028	158.508	140.957
2007	106.644	38.155	69.736		21.624	107.724	85.020
2008	96.580	41.003	74.307		22.596	114.904	73.873
2009	102.026	29.769	59.670		21.127	88.997	80.897
2010	99.820	29.005	63.712		17.043	92.256	82.762

2011	91.004	28.817	74.147		25.997	102.554	64.997

Table 18.16**.** Standardization of trawl catch rates for Saw Sharks in the Commonwealth SET fishery. The optimum model included all factors up to Zone:Month. Zone: DepCat is excluded as being less optimal.

	Year	Vessel	DepCat	Month	DayNight	Zone	Zone:Month
1986	1.5798	1.4120	1.4517	1.4240	1.4173	1.4742	**1.4989**
1987	1.3047	1.4302	1.4359	1.4631	1.4535	1.5010	**1.4919**
1988	1.4740	1.4419	1.3992	1.3951	1.3921	1.4235	**1.4655**
1989	1.4040	1.2808	1.2897	1.3359	1.3328	1.3265	**1.3498**
1990	1.4467	1.2639	1.3049	1.3369	1.3329	1.3133	**1.3190**
1991	1.4639	1.3249	1.3568	1.3615	1.3582	1.3373	**1.3542**
1992	1.5595	1.4458	1.4541	1.4672	1.4679	1.4655	**1.4757**
1993	1.6356	1.6490	1.5862	1.5945	1.5978	1.5923	**1.5561**
1994	1.2002	1.3569	1.3192	1.3196	1.3228	1.3076	**1.3184**
1995	0.8748	0.9927	1.0114	1.0240	1.0260	1.0024	**1.0072**
1996	0.9264	1.0956	1.1248	1.1145	1.1144	1.0731	**1.0707**
1997	0.8274	0.9511	0.9835	0.9747	0.9751	0.9582	**0.9793**
1998	0.7548	0.8432	0.8639	0.8358	0.8363	0.8446	**0.8334**
1999	0.9081	0.9220	0.9225	0.9109	0.9110	0.9219	**0.9049**
2000	0.8978	0.8649	0.8479	0.8418	0.8412	0.8376	**0.8394**
2001	0.7915	0.8351	0.8277	0.8283	0.8296	0.8265	**0.8147**
2002	0.6808	0.7015	0.7052	0.7182	0.7196	0.7282	**0.7171**
2003	0.6159	0.6508	0.6423	0.6487	0.6504	0.6568	**0.6558**
2004	0.6745	0.6585	0.6500	0.6464	0.6483	0.6484	**0.6336**
2005	0.6807	0.6610	0.6408	0.6357	0.6382	0.6387	**0.6319**
2006	0.7984	0.7585	0.7315	0.7165	0.7181	0.7094	**0.7087**
2007	0.7028	0.6231	0.6058	0.6008	0.6021	0.6032	**0.5948**
2008	0.6393	0.6356	0.6316	0.6231	0.6246	0.6341	**0.6209**
2009	0.8225	0.8119	0.8138	0.8002	0.8036	0.8102	**0.8065**
2010	0.6900	0.7176	0.7324	0.7324	0.7347	0.7225	**0.7206**
2011	0.6460	0.6716	0.6670	0.6503	0.6515	0.6431	**0.6313**

Table 18.17. Statistical model diagnostics for the log-linear modelling of trawl caught saw-sharks. The optimum model (smallest AIC plus greatest adjusted r^2) included all factors up to Zone:Month.

	Year	Vessel	DepCat	Month	DayNight	Zone	**Zone:Month**	Zone:DepCat
AIC	21681	8606	7332	5948	5910	5028	3376	4411
RSS	79526	61662	59653	58071	58022	57044	55177	56160
MSS	3698	21562	23571	25152	25202	26180	28047	27064
Nobs	52793	52793	52307	52307	52307	52307	52307	52307
Npars	26	204	229	240	243	247	291	347
adj_r2	4.398	25.622	28.008	29.902	29.958	31.133	33.331	32.070
%Change	0.000	21.224	2.386	1.894	0.056	1.176	2.197	0.937

18.8.3 Elephant Fish

Table 18.18. Total catches of elephant fish, in tonnes, by assessment region, in the data table provided, these data are from all methods.

Year	WestSA	CentSA	EastSA	WestBS	EastBS	WestTas	EastTas	NSW
1970			0	0.884	5.166	0.476	0.007	
1971		0	0	1.155	2.852	0	0.034	
1972		0	0	2.333	8.686	0	0.041	
1973	0	0	0	7.715	22.253	0.024	1.324	
1974	0.029	0.170	0.931	4.651	50.927	0.135	8.551	
1975	0	0	0	5.870	56.790	0	6.894	
1976	0	0	0.030	10.903	28.981	0.452	1.822	
1977	0	0	2.087	10.219	54.200	0	1.828	
1978	0	0	0.029	20.587	36.249	0	8.710	
1979	0	0	0.339	12.968	80.013	0	7.261	
1980	0	0	0.215	20.337	54.688	0.217	6.826	
1981	0	0.003	0.357	24.093	52.571	0.155	4.886	
1982	0	0	0.254	24.494	28.959	0.615	4.341	
1983	0	0	0.356	27.246	47.466	0.244	5.166	
1984	0	0.003	0.073	16.601	45.888	3.627	12.003	
1985	0.148	0.182	0.053	19.479	42.485	3.642	42.998	
1986	0	0	0.052	11.962	33.639	2.365	17.350	
1987	0	0.325	0.263	17.128	24.393	0.742	20.512	
1988	0	0.442	0.623	16.882	21.230	1.046	26.877	
1989	0	0.065	0.080	11.178	22.757	0.478	27.551	
1990	0	0.300	0.058	13.618	13.599	1.194	27.023	
1991	0.022	0.025	0.027	13.689	39.226	0.093	16.118	
1992	0	0.116	0.371	14.543	26.426	5.894	23.721	
1993	0	0.007	0.025	15.537	12.642	4.370	21.754	
1994	0	0.057	0.031	10.551	12.739	1.859	34.265	
1995	0	1.867	0.906	21.388	12.001	1.589	14.085	
1996	0	1.267	0.718	24.274	21.291	1.794	27.767	
1997	0	2.306	3.072	15.511	17.999	0.797	20.172	
1998	0.012	2.264	0.409	15.443	20.580	1.761	12.363	
1999	0.008	4.501	1.267	10.825	30.737	0.480	11.381	
2000	0.148	3.133	0.509	8.417	25.942	0.655	15.084	
2001	0.047	6.597	0.833	3.289	29.320	1.242	6.002	
2002	0	2.086	0.519	6.654	24.328	0.084	6.899	
2003	0.115	3.905	0.627	6.168	30.463	1.465	6.090	
2004	0.152	1.689	0.830	4.588	20.913	0.661	6.732	0.020
2005	0.173	2.041	0.149	6.998	20.896	0.463	5.568	0.013
2006	0.858	1.498	0.086	3.227	21.524	1.275	4.827	0
2007	0.332	2.492	0.121	2.559	20.270	0.368	8.587	0.040
2008	0.184	2.604	0.399	3.493	27.290	0.210	6.272	0.020
2009	0.035	2.932	0.234	6.088	29.718	0.105	4.992	0
2010	0.058	3.170	0.248	5.103	22.501	0.055	3.582	0.038
2011	0.014	4.329	0.506	4.688	20.805	0.334	3.230	0
Total	2.334	50.376	17.687	483.335	1221.400	40.966	491.495	0.131

Table 18.19. Catch of elephant fish across gear types from 1970 - 2011.

Year	Unknown	Line	Unknown Mesh	6.5"	6"	7"	8"
1970	0.483	2.942	3.108				
1971	0.132	0.148	3.761				
1972	3.324	1.143	6.593		0		
1973	0.486	0.425	0.399	0	2.160	26.108	1.738
1974	29.045	0.932	4.368		20.045	10.834	0.170
1975	18.786	2.361	7.206		38.340	2.861	0
1976	4.752	1.163	4.623		28.692	2.928	0.030
1977	7.753	0	8.599		51.979	0.003	0
1978	1.762	0	16.712	0.130	46.966	0.005	0
1979	0	0	23.797	0.285	75.706	0.793	0
1980	0	0.002	24.897	3.998	52.320	1.066	0
1981	0	0	20.179	0.341	60.991	0.554	0
1982	0	0.064	15.461	0.100	43.014	0.024	0
1983	0.408	0.020	19.950	0.020	60.016	0.064	0
1984	0	0.236	39.972	0.486	37.498	0.003	0
1985	0	0.565	72.741	0.026	35.440	0.215	0
1986	0.530	2.589	33.395	0.059	28.795	0	0
1987	0	0.069	33.299	0	29.449	0.277	0.269
1988	0.015	7.735	30.750	0	26.890	1.710	0
1989	0.784	1.022	36.314	0	23.857	0.107	0.025
1990	0.245	2.295	31.905	0.181	20.856	0.310	0
1991	0.184	1.380	21.913	0	45.698	0.025	0
1992	0.022	6.899	25.674	0.070	37.512	0.893	0.001
1993	0.943	3.762	26.413	0	19.896	0.911	2.410
1994	0.798	0.504	38.013	0.021	19.550	0.156	0.460
1995	0.092	0.291		2.395	40.482	8.576	0
1996	2.209	0.437		1.046	58.894	14.525	0
1997	2.908	0.069	0.500	4.437	42.999	8.944	0
1998	2.373	1.347	0	2.303	46.809	0	0
1999	5.390	0.435	0.498	4.557	48.278	0.041	0
2000	3.058	0.033	0.120	4.204	46.473	0	0
2001	0.231	0.053	0.122	5.917	41.007	0	0
2002	0.010	0.122	0.089	2.069	38.280		
2003	0.863	0.096		2.932	44.740	0.202	
2004	3.220	0.525		2.265	29.575	0	
2005	2.065	0		1.674	32.562		
2006	1.081	0.003		3.347	28.863		
2007	0.273	0.037		4.893	29.565		
2008	0.003	0.007		3.057	37.389	0.005	0.010
2009	0.019	0.002		2.703	41.412		
2010	0.014	0.004		2.929	31.808		
2011	0.004	0.025		3.032	30.845		

Table 18.20**.** Catch of elephant fish by 20m depth category from 1980 - 2011. All catches below 200m were ignored which removed 4.761 t from 1116.357 t.

Year	**0**	**20**	**40**	**60**	**80**	**100**	**120**	**140**	**160**	**180**	**200**
1980	5.748	9.424	23.601	8.140	0.739	1.062	3.009	0.110	0	0	
1981	7.880	18.109	20.086	8.914	0.757	0.221	0.212	0.330			
1982	4.067	2.581	17.990	10.967	6.033	0.200	0	0.060	0	0.145	
1983	13.094	7.133	23.48	10.797	2.249	0.574	0.248	0.070	0	0	
1984	5.906	7.164	16.942	4.080	2.028	0.386	0.302	0.262	0.070	0	
1985	0.914	6.482	19.662	4.279	1.591	0.623	0.462	0.210	0	0	
1986	0.216	5.424	15.129	5.415	1.166	0.434	0.122	0.100	0	0	
1987	1.063	2.871	17.202	3.830	0.825	1.641	0.388	0.103			
1988	3.550	3.448	10.218	5.401	1.180	1.012	0.090	0.475	0	0	
1989	1.947	5.022	10.290	4.244	0.288	0.215	0.666	0.072	0	0	
1990	0.886	2.633	10.646	5.108	0.658	0.181	0.055	0.015	0	0	
1991	10.12	4.204	10.020	5.410	1.679	5.454	3.312	3.122	0.121	0.899	
1992	5.597	2.306	6.821	11.393	0.662	1.499	3.821	3.932	0.025	0	
1993	0.919	2.232	8.716	4.955	0.629	0.048	0.606	1.146	0.015	0	
1994	1.291	1.639	10.758	4.538	0.231	0.006	0.104	0.030	0.018	0	
1995	2.865	6.301	13.696	10.162	1.046	0.666	0.936	0.244	0.016	0.325	
1996	2.685	12.035	19.940	11.959	3.136	0.911	0.320	0.181	0.043	0.088	
1997	2.005	6.182	13.023	9.775	1.161	0.108	0.025	0.038	0	0.020	0
1998	1.100	8.747	13.52	11.445	2.160	1.328	0.302	0.003	0.005	0.043	0.002
1999	1.576	7.726	22.027	9.365	0.760	0.332	0.025	0	0	0	0
2000	2.119	6.441	20.671	5.791	1.662	0.304	0.070	0.016	0	0	
2001	1.638	4.607	19.975	7.756	0.814	0.805	0.936	0	0	0	
2002	0.932	8.112	18.451	5.568	1.758	0.248	0.020	0		0	
2003	0.737	11.775	21.407	4.966	0.523	0.008	0.001	0.004	0		
2004	0.557	6.902	14.648	3.377	0.188	0.006	0.012				
2005	1.377	6.202	17.187	4.807	0.759	0.170	0	0	0.002	0.001	
2006	0.498	8.240	13.858	3.588	0.435	0.110	0	0	0	0	
2007	1.120	5.991	16.146	1.976	0.776	0.215	0	0			
2008	1.0305	6.402	22.144	4.500	0.878	0.117	0	0.080	0		
2009	1.1725	5.476	25.697	4.899	1.374	0.581	0	0.002			
2010	1.260	4.843	16.186	6.937	0.636	0.243	0.045	0.110	0.006		0.004
2011	0.667	4.143	14.768	5.963	0.940	0.596	0.219	0.156	0	0.004	

Table 18.21**.** Reduction in records and associated catch of elephant fish made by the data selection decisions. Years used refers to 1980 – 2011 (with data available from 1970 – 2011), Gear Used refers to 6 inch gill nets, Effort < 0 refers to those records for which no effort data was available, areas used refers to the removal of those areas reporting < 4 t over the time period, Vessels Used refers to eliminating those vessels whose average annual catch was less than 0.25 tonnes. The estimation of the probability of a positive catch had 157551 records and the standardized catch rates for positive catches had 39,085records. The % loss and used are relative to the original totals, whereas the %records and %catch relates to the totals following selection by year.

	Records	Catch	CatchReduct	%Loss	%Catch	%Records
Records	431156	2307.756	0	0		
YearsUsed 80 - 11	381721	1843.180	464.576	20.13	100.00	100
GearUsed = 6”	196812	1211.762	631.419	34.26	65.74	51.56
Effort<0	194929	1208.228	3.534	0.29	65.55	51.07
Areasused > 4 t	168115	1179.399	28.829	2.39	63.99	44.04
vesselsUsed > 250kg	159589	1116.357	63.042	5.35	60.57	41.81
Depths 0 -200m	157551	1111.596	4.761	0.43	60.31	41.27
'+veCatch	39085	1111.596	0	0.00	60.31	10.24

Table 18.22. The statistical outcome of the log-linear modelling for elephant fish.

	Year	**Vessel**	**Area**	**Month**	**DepCat**	**Area:Month**
AIC	27121	22553	21383	21155	21081	**18517**
RSS	78101	68905	66802	66376	66216	**61283**
MSS	4464	13661	15764	16190	16350	**21283**
Nobs	39085	39085	39085	39085	39085	**39085**
Npars	32	196	217	228	238	**469**
adj_r2	5.332	16.127	18.643	19.139	19.313	**24.877**
%Change	0.000	10.795	2.516	0.496	0.174	**5.564**

Table 18.23. The optimum models and geometric mean catch rates and the proportion of positive catches through time for elephant fish. YearS is the geometric mean catch rate relative to the mean of the series, AreaMonth is the optimum statistical model for the log-linear modelling, YearP is the proportion of positive shots and Opt_P is the proportion of positive shots after standardization (which was also included the Area:Month interaction term). Finally, Combined is the combination of both optimum series. This is the base case (>4t /area, >0.25t/vessel, 6” mesh). The combined have been scaled to the mean of the time series; making the mean 1.0.

Year	YearS	AreaMonth	YearP	Opt_P	Combined	95%CI
1980	1.2626	1.0871	1.0225	1.0335	1.2954	0.0000
1981	1.3885	1.2275	1.1302	1.0011	1.4169	0.2599
1982	0.9419	1.0753	1.0318	0.8914	1.1052	0.2550
1983	1.1861	1.1276	1.0020	0.8482	1.1028	0.2526
1984	1.0884	1.0503	0.8595	0.6341	0.7679	0.2692
1985	0.9441	1.0494	0.7704	0.6016	0.7279	0.2793
1986	1.2830	1.2561	0.5386	0.4116	0.5961	0.2900
1987	1.5381	1.3630	0.4231	0.3295	0.5178	0.3085
1988	1.3081	1.3348	0.5333	0.4489	0.6909	0.2995
1989	1.2762	1.3218	0.6614	0.5520	0.8412	0.2965
1990	1.4753	1.5785	0.6042	0.4971	0.9046	0.3067
1991	1.8630	1.8712	0.6258	0.6211	1.3399	0.2856
1992	1.2081	1.5936	0.6352	0.7252	1.3325	0.2816
1993	1.0183	1.1842	0.4968	0.4825	0.6588	0.2903
1994	1.5961	1.5081	0.4657	0.4444	0.7727	0.2906
1995	1.2695	1.2987	0.7906	0.7498	1.1228	0.2558
1996	1.3551	1.1502	0.9171	0.8363	1.1090	0.2512
1997	0.7479	0.7088	1.0926	1.1338	0.9266	0.2439
1998	0.6788	0.6122	1.2089	1.2792	0.9030	0.2428
1999	0.6965	0.6422	1.2604	1.3767	1.0194	0.2384
2000	0.5863	0.6109	1.4198	1.5370	1.0827	0.2407
2001	0.6019	0.6343	1.5081	1.7678	1.2929	0.2419
2002	0.6900	0.6787	1.1640	1.2838	1.0046	0.2487
2003	0.6869	0.6700	0.9887	1.0050	0.7764	0.2515
2004	0.5929	0.6070	0.8907	0.8970	0.6278	0.2570
2005	0.6318	0.5787	1.2255	1.1056	0.7377	0.2544
2006	0.6399	0.6556	1.2288	1.2060	0.9117	0.2617
2007	0.6864	0.6888	1.3665	1.6278	1.2929	0.2643
2008	0.7591	0.7917	1.5743	1.8535	1.6919	0.2597
2009	0.8618	0.8596	1.5625	1.7884	1.7726	0.2582
2010	0.6445	0.6509	1.4737	1.5496	1.1630	0.2610
2011	0.4931	0.5332	1.5272	1.4807	0.9103	0.2615

19. Yield, total mortality values and Tier 3 estimates for selected shelf and slope species in the SESSF 2012

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19.1 Summary

This chapter updates yield analyses presented in Klaer (2011a) for major commercial species caught in the Southern and Eastern Scalefish and Shark Fishery (SESSF) on the shelf and slope. Much of the data processing and analysis has been automated, following procedures documented particularly in Thomson (2002a) and Klaer *et al*. (2008).

Yield and total mortality estimates are provided for major commercial fish species from the shelf and slope in the South East Fishery. Yield estimates were made using a yield-per-recruit model with the following input: selectivity-at-age, length-at-age, weight-at-age, age-at-maturity, and natural mortality. Total mortality values corresponding to various reference equilibrium biomass depletions were calculated for each species.

Recent average total mortality was estimated from catch curves constructed from length frequency information. Length frequency data were from ISMP port and/or onboard measurements. The method used to estimate total mortality also estimates average fishery selectivity.

Tier 3 calculations use the estimates of total mortality, natural mortality and average recent catches to decide the Recommended Biological Catch (RBC) for next year. The method used to calculate the Tier 3 RBC is described in Klaer *et al*. 2008 and Wayte and Klaer (2010). An average length procedure was developed and tested (Klaer *et al*., 2012) for species with only length data and no age samples are available. The average length method has been applied here for discussion and evaluation, as in Klaer (2011a).

Tier 3 calculations were applied to all SESSF quota species with sufficient available information, regardless of the actual Tier that applies to the species because (a) the Tier that will apply to each species in the current year is decided by the Research Assessment Groups and (b) it is useful to compare Tier 3 results with those from other Tiers to check performance of the methods.
There were no current Tier 3 species without age samples to 2011. While average length results are comparable to age-based catch curves, the performance of Tier 3 using age based catch curves was shown to result in less catch variability (Klaer *et al*., 2012). As age data are available, there is currently no need to use the average length procedure for Tier 3 species in the SESSF. Consequently, RBC calculations are only shown here that used the age-based catch curve procedure.

At the SESSFRAG meeting in early 2012 it was agreed to allow the investigation of an *M*-based threshold to limit the size of the RBC multiplier produced by Tier 3 analyses. In the results here, F_{cur} has been limited to a lowest possible value of $M/10$. Alfonsino, John dory and mirror dory all reached this threshold, so have had the RBC limited by

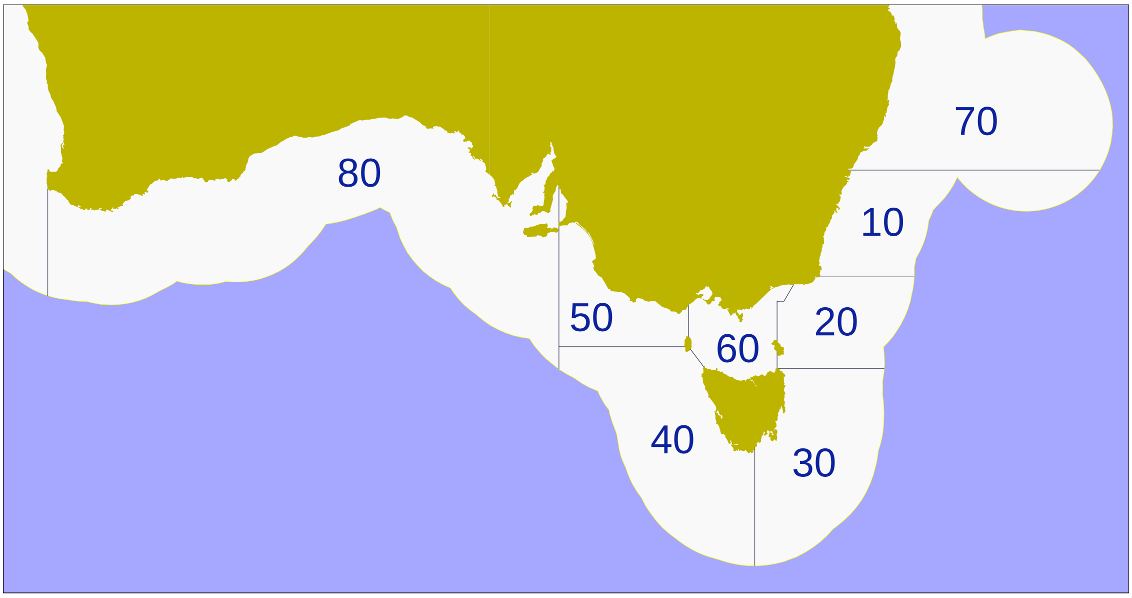
this rule. RBC values for alfonsino, John dory mirror dory and redfish were all greater than reference average catches.

19.2 Methods

19.2.1 Zoning

The fishery region and zones referred to here are as shown in Figure 19.1.

Figure 19.1. Map of the SESSF showing 8 statistical zones used in analyses here.



19.2.2 Yield analysis

The information required for this calculation was: selectivity-at-age, length-at-age, weight-at-age; age-at-maturity; and natural mortality. The parameters used are shown in Table 19.1. A mix of shelf and slope quota species has been considered and results are presented where the automated process appears to have produced sensible results, and where sufficient data were available.

Table 19.1. Population parameters used for yield analysis.

Species	M	h	L_∞	k	t_0	a	b	l_{25}	l_{50}	l_{mat}	a_{max}	cc_{amax}	S_{25}
Alfonsino	0.22	0.75	54.3	0.099	-3.83	0.019	3.061	20	25	19	20	10	0.8102
John Dory	0.36	0.45	53.2	0.15	-1	0.0458	2.9	15.54	30	31.5	20	19	1.303
Mirror Dory	0.3	0.75	57.44	0.2345	0	0.0164	3	15.54	40	35	20	19	1.345
Tiger Flathead	0.22	0.62	50.87	0.168	-3.053	0.0059	3.31	27.93	31.02	30	20	19	1.688
Gemfish E	0.47	0.75	109.4	0.18	-0.61	0.0014	3.39	26.95	31.7	70	20	19	0.9612
Gemfish W	0.47	0.75	109.4	0.18	-0.61	0.0014	3.39	26.95	31.7	70	20	12	0.9612
Blue Grenadier	0.189	0.9	101	0.18	0.58	0.0038	3.013	37.8	50.73	70	20	19	3.185
Pink Ling	0.268	0.8	103.4	0.166	3.139	0.0029	3.139	39.9	43	67	20	19	6.078
Jackass Morwong E	0.15	0.7	36.39	0.34	-0.45	0.0429	3	21.94	21.95	22	25	20	2.266
Jackass Morwong W	0.15	0.7	36.39	0.34	-0.45	0.0429	3	21.94	21.95	22	25	20	2.266
Ribaldo													
Redfish	0.1	0.75	25.28	0.224	-0.719	0.0577	2.77	15.94	17.25	19	40	20	3.727
Ocean Perch	0.1	0.75	43.72	0.114	0	0.0118	2.997	15.93	18.23	31	40	20	3.975
Blue-eye Trevalla	0.1	0.75	96	0.08	-5.25	0.018	3.016	48	50	62	20	19	3.414
Silver Trevally	0.1	0.8	63.16	0.051	-6.47	0.0443	2.786	22.31	22.32	28	20	19	2.074
Silver Warehou	0.3	0.75	51.25	0.464	-0.65	0.0153	3	31.05	40	37	23	20	1.357
Blue Warehou	0.45	0.75	54.65	0.37	-0.67	0.03	2.9	17.61	35	33.4	25	20	0.3812
School Whiting	0.6	0.75	26	0.25	-1.15	0.0132	2.93	14	15	16	6	5	1.943

For species for which a recent stock assessment has been performed, the population parameters used in the assessment were used here. Otherwise, the primary source of information on population parameters was Smith and Wayte (2002) or, failing that, the Fishbase website (http://www.fishbase.com). A meta-analysis performed by Koopman *et al.* (2001) was used to provide values for steepness.

19.2.2.1 Length- and weight-at-age

Length-at-age was calculated using the von Bertalanffy growth equation (parameters are l_∞, k and t_0) and the weight-at-age using the allometric length-weight relationship (parameters are a and b). The von Bertalanffy was calculated using length and age data supplied by the Fish Ageing Services (FAS, Kyne Krusic-Golub pers com). The type of length measurement (e.g. standard length or total length) used was specified in the data. It is assumed the parameters of the length-weight relationship (Smith and Wayte, 2002) use the same measures. The units for these parameters are not specified and do not all appear to use the same units. These were manipulated until the results appeared to be in kg per cm. Parameters that were not available from Smith and Wayte (2002) were obtained from the Fishbase website (http://www.fishbase.org), using values that had been calculated from Australian fish or, if necessary, New Zealand fish.

19.2.2.2 Female length-at-maturity

Length-at-maturity for females (l_{mat}) (which is converted into a knife-edged function of age using the calculated lengths-at-age) was obtained, where possible, from Wayte and Smith (2002). If separate figures were not available for males and females, that for both sexes combined was used. In some cases several different figures were available and an arbitrary selection was made - when there were three of more figures the median figure was chosen.

19.2.2.3 Natural mortality

Natural mortality (*M*) figures were obtained from Smith and Wayte (2002) or by calculating the median of the figures presented by Bax and Knuckey (2001). The value of *M* for John dory was updated by the Shelf Research Assessment Group in 2005 based on an additional meta-analysis performed by Matt Koopman. The value of *M* for tiger flathead was updated for the 2010 stock assessment (Klaer, 2011b).

19.2.2.4 Selectivity

A logistic selectivity curve is assumed for all species. Selectivity parameters (l_{25}, l_{50}) were drawn from Bax and Knuckey's calculated selectivity factors. All parameters used in the present investigation apply to a 90mm trawl mesh (except for school whiting where 42mm has been assumed) and non-trawl gear types are not considered. Figures were not available, from Bax and Knuckey, for John dory or silver trevally. Those for mirror dory were applied to John dory because, of all the quota species, mirror dory are most like John dory in shape.

The selectivity parameters used in this study have been estimated from an empirical relationship between fish size and mesh size derived from covered cod end (or trouser haul) experiments on a subset of the species. These pertain purely to gear selectivity, which is not the function often referred to in stock assessments as "selectivity". Fishers are able to target fish of a particular size by fishing in particular areas and in particular different depths -- all SEF quota shelf-associated species show a pattern of larger fish being caught at greater depths. No account is taken in this study of how trawl selectivity changes as a function of gear design or gear deployment (e.g. changing door separation with depth) that have been shown to exert large influences on overall selectivity in other studies.

It has been suggested that practices such as double bagging might reduce the selectivity of commercial trawls below that expected for a 90 mm mesh cod end, however there was no evidence for this, with the possible exception of school whiting and redfish off Eastern Victoria.

The "selectivity" estimated in stock assessment models is a function of both gear selectivity, targeting by the fishery and availability of fish to being caught.

19.2.2.5 Maximum age

Maximum observed age ($a_{\max}$) values were selected after examining available aged otolith samples. As the maximum age is treated as a plus group, a maximum age for catch curve analysis ($cca_{\max}$) is also required that is normally at least one age less than the maximum. This was chosen after examination of age samples from the last 5 years.

19.2.2.6 Stock-recruit relationship

A Beverton-Holt stock-recruit relationship is assumed using the single-parameter formulation suggested by Francis (1992a). The value of this parameter (steepness - *h*) was investigated by Koopman *et al*. (2001) using meta-population analysis. The histograms presented by Koopman *et al*. were examined and likely figures for steepness chosen. The default figure of 0.75 suggested by Francis (1992b) is used when the results of Koopman *et al*. do not suggest a clear pattern.

19.2.2.7 Management reference points

Using virgin biomass estimates provided by stock reduction analysis in combination with yield-per-recruit analysis, a number of common *F*-based management reference point values were calculated. While $F_{0.1}$ (Gulland and Boerema 1973) and F_{spr30} (or $F_{30\%SPR}$, Gabriel *et al.* 1989) are reasonably widely known, the method used to calculate F_{msy} is given below (from Klaer 2006).

Fisheries management decisions are often based on abundance relative to target and limit reference points. The most common reference point is the population size where maximum sustainable yield (MSY) is achieved. The fully-selected fishing mortality corresponding to MSY, F_{msy}, is defined as the instantaneous rate of fishing mortality at which yield is maximized, i.e.:

$$\left.\frac{dY(F)}{dF}\right|_{F_{MSY}} = 0$$

where $Y(F)$ is yield as a function of fully-selected fishing mortality, i.e.:

$Y(F) = \tilde{Y}(F)\, R(F)$

$\tilde{Y}(F)$ is yield-per-recruit as a function of *F*, and

$R(F)$ is recruitment as a function of *F*.

Yield-per-recruit is defined according to the formula:

$$\tilde{Y}(F) = \sum_s \sum_{a=0}^{x} w_a^s \frac{S_a^s F}{Z_a^s(F)} N_a^s(F)(1 - e^{-Z_a^s(F)})$$

where w_a^s is the weight of an animal of sex *s* and age *a*,

S_a^s is the selectivity for animals of sex *s* and age *a*,

$Z_a^s(F)$ is the total mortality on fish of sex *s* and age *a*,

$Z_a^s(F) = M + S_a^s F$

$N_a^s(F)$ is the number of fish of sex *s* and age *a* relative to the number of animals of age 0 (both sexes combined):

$$N_a^s(F) = \begin{cases} 0.5 & \text{if } a = 0 \\ N_{a-1}^s(F)\, e^{-Z_{a-1}^s(F)} & \text{if } 0 < a < x \\ N_{x-1}^s(F)\, e^{-Z_{x-1}^s(F)} / (1 - e^{-Z_x^s(F)}) & \text{if } a = x \end{cases}$$

x is the maximum age-class.

The recruitment as a function of *F* depends on the assumed form of the stock-recruitment relationship, e.g.:

$$R(F) = \frac{S(F)}{\alpha + \beta\, S(F)}$$

where $S(F)$ is spawner biomass as a function of *F*:

$S(F) = \tilde{S}(F)\, R(F)$

$\tilde{S}(F)$ is spawner biomass-per-recruit as a function of *F*:

$$\tilde{S}(F) = \sum_{a=1}^{x} f_a \, N_a^{\text{fem}}(F)$$

f_a is fecundity as a function of age.

19.2.3 Catch curves

19.2.3.1 Data

This investigation used length frequency data from ISMP port measurements (eg Knuckey *et al*, 2001). For a given year, fleet and population (see below for further detail) length frequencies are catch-weighted and summed to give annual length frequencies.

Age and length data were obtained from the Central Ageing Facility. Age-length keys (ALKs) were constructed from these data.

Two methods were used to convert length frequencies data into age frequencies: ALKs and chopping. The ALK method was used, where possible, to generate age frequencies data by multiplying the length frequency for a given year by the ALK for that same year. No allowances were made for inadequate sampling of an ALK so that, if no age samples were taken from a particular length class then all samples from this length class in the length frequency were ignored. This occurs because the ALK has a zero for all ages for that length class so that the length frequency is always multiplied by zero. 'Chopping' involves using the von Bertalanffy to chop the length frequency into age classes. Catch curve analysis was applied to all resulting age frequencies. In the future it may be desirable to use a chopping method that allows variance in length-at-age about the von Bertalanffy curve.

Age samples from the 2010 and 2011 calendar years became available for both mirror dory and John dory during October 2011, and were used to provide age-based Tier 3 results here for both species. In both cases, all samples from 2010 and 2011 were used to provide an average age-length key that was applied to length data from the most recent 5 years.

19.2.3.2 Fleets and Populations

The difference between a fleet and a population is that although the length frequency data are separated for both, the ALK data are separated into populations but are combined across fleets.

For species except tiger flathead, redfish, spotted warehou and blue grenadier, the length frequency data were separated into trawl and non-trawl (including Danish seine) fleets. Tiger flathead was separated into trawl and Danish seine. Non-trawl data for redfish was ignored so that there was only one fleet - a trawl fleet. Spotted warehou was divided into trawl and non-trawl fleets but any Danish seine records were ignored. For blue grenadier the fleets were separated into the summer non-spawning trawl fishery and the winter spawning trawl fishery.

Redfish was divided into two populations – north and south of 36^{o}S. Population 1 is north and Population 2 south of this latitude.

As there was no recent age data for redfish, all available age data was combined into a single average ALK for that species.

19.2.3.3 Automated catch curve analysis

An improved catch curve method for estimating F_{cur} has been developed. This method uses all selected ages, rather than just the fully-selected ages. F_{cur} and two selectivity parameters are estimated by fitting an age-structured production model to the observed catches at age over the last five years.

19.2.4 Average length method

Catch curve analysis relies on measurement of the decline in numbers at age of a population in equilibrium under constant levels of fishing pressure. If equilibrium conditions apply, the slope of the right hand limb of an age frequency distribution can be used to estimate fishing mortality. For some SESSF fish populations, otoliths have not been collected or aged, sometimes because of the physical difficulty in doing so. Some species, for example, have very tiny otoliths that are both difficult to collect and age. Normally, however, all quota species are measured by onboard observers, or in the port data collection program, so we have reasonably large length frequency samples for most quota species in most years.

The current Tier 3 method for dealing with species with length samples but no age samples is to slice the length-frequency distribution into assumed ages based on the age transitions calculated from the von Bertalanffy parameters, and then apply the standard catch curve analysis to the derived age distribution. This method is not optimal compared to an analysis based on age samples at least because it does not account for the distribution of lengths at age – that the lengths of fish at any age follow a distribution that overlaps with lengths at age for adjacent aged fish.

A procedure has been developed as part of the Reducing Uncertainty in Stock Status (RUSS) project that uses length frequency samples alone to estimate fishing mortality, and is described in detail in Klaer *et al*. (2012). Management Strategy Evaluation (MSE) testing of the procedure indicated that it works in theory, and provides comparable results to the age-based catch curve method. The greatest disadvantage of the procedure determined by testing was that it produced more variable RBC values than standard catch curve analysis.

The key assumption of the average length method is that the relative number of large fish in the population will reduce as fishing pressure increases. This is intuitively true, and the determination of stock status indicators from average length measurements has a long history (e.g. see Pauly 1984).

The procedure implemented here first requires the selection of a reference length (L_{ref}) where the stock can be assumed to be fully selected. By default, L_{ref} is assumed to be 2cm greater than the length at 50% selection (S_{50}), as most species are assumed to have relatively knife-edged selection for Tier 3 analyses. The intention was to select a reference length greater than where selectivity effects occur, but as low as possible to allow the largest sample sizes from existing fishery length-frequencies.

Using yield-per-recruit calculations, it is possible to calculate what the average length of the catch above L_{ref} would be for any level of F (Figure 19.2). To determine current F (F_{cur}) that corresponds to F_{cur} using catch curves, calculate the average length of the catch above L_{ref}, then use the relationship in Figure 19.2 to determine F_{cur}. The average length of the catch at the limit F_{20} and target F_{48} are shown as dotted lines in Figure 19.2.

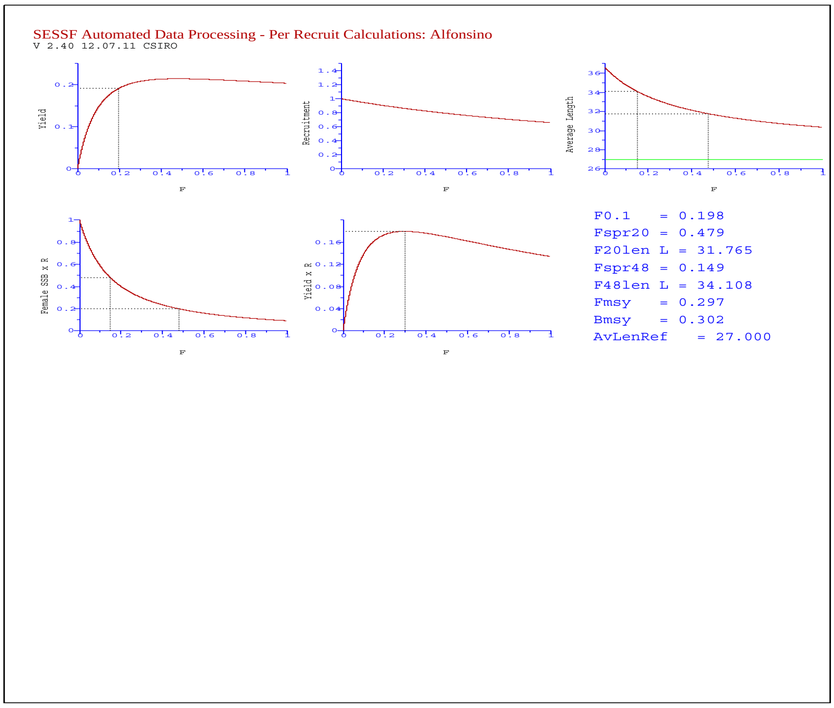


Figure 19.2. Average length reference point calculations.

19.2.5 Harvest control rule

The method used to calculate the Tier 3 RBC has been improved and is described in Klaer *et al*. 2008 and Wayte and Klaer (2010). The new Tier 3 control rule that has limit and target fishing levels was implemented and applied for the first time for the 2008 stock assessments.

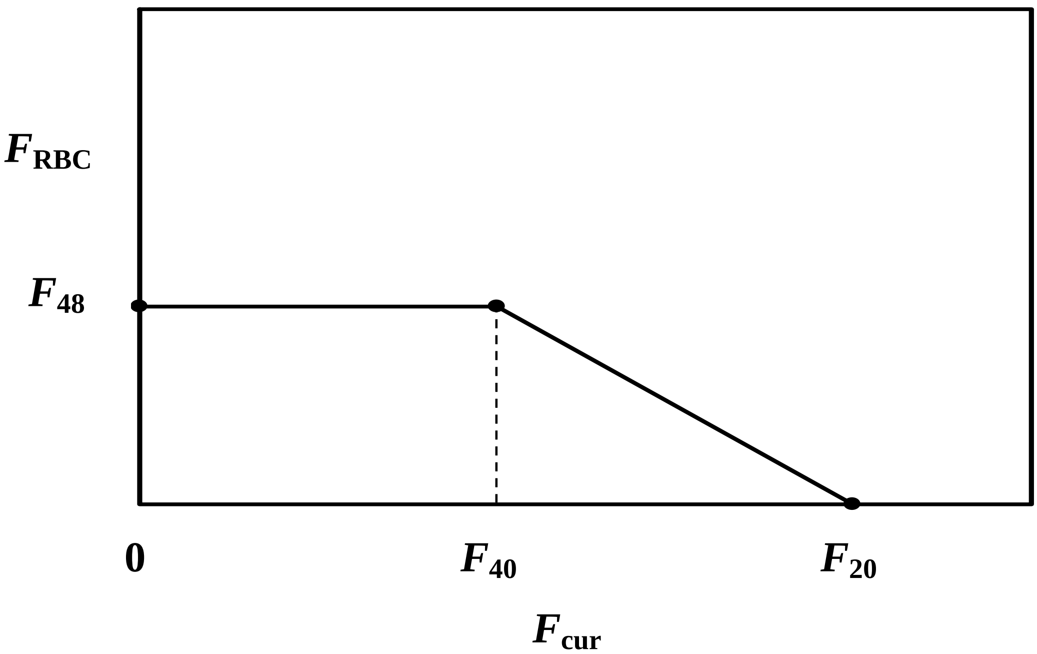


Figure 19.3. Method for selecting F_{RBC} based on estimated F_{cur}.

Yield per recruit calculations were used to calculate F values that will reduce the spawning biomass to 20% (F_{20}), 40% (F_{40}) and 48% (F_{48}) of the unexploited level. The relationship given in Fig. 1 is then used to assign the value of F_{RBC} using F_{cur}. This relationship has properties similar to the Tier 1 harvest control rule, with F_{20} as the limit and F_{48} as the target fishing mortality rate.

The following formula that adjusts current catch according to the ratio of the intended and current exploitation rates is then used to calculate C_{RBC}:

$$C_{RBC} = \frac{(1-e^{-F_{RBC}})}{(1-e^{-F_{cur}})} C_{cur}$$

where F_{cur} is the estimated current fishing mortality, C_{cur} is current catch, F_{RBC} is the selected F for the recommended biological catch from the control rule, and C_{RBC} is the recommended biological catch from the control rule.

It can be seen from the above formula that as the F_{cur} estimate approaches zero, that the multiplier on C_{cur} exponentially increases to infinity at M. Clearly, it is possible for the control rule to generate very large RBC values that are not realistic, and would not result in good behaviour of the HCR. One method for avoiding such behaviour would be to apply direct limits on possible values for the C_{cur} multiplier. The upper limit of the multiplier on recent average catch was 1.2 in the previous and first implementation of Tier 3 in the SESSF (Klaer and Thomson 2007). To date there has been no agreement via the RAG process on what direct limits may be applied to the new implementation.

The current SESSF application of harvest control rules includes a TAC change limitation rule that was designed to dampen RBC changes from year to year. This applies to all TACs generated from RBCs. In testing the Tier 3 HCR (Wayte and Klaer 2010), the current SESSF catch change limitation rule was also included, which effectively limits the extreme values that may be generated by the Tier 3 HCR. Testing of the Tier 3 rule showed that it was effective in meeting expected management performance measures in the case where the TAC change limitation rule was applied. If such a change limitation rules was not applied, then it is likely that the Tier 3 behaviour would be considerably degraded.

Good performance of the Tier 3 HCR depends on the application of the catch change limitation rule to avoid extreme behaviour. In practice, when the Tier 3 HCR produces unrealistically high or low RBC values due to (1) noise in population age structure data (2) incorrect fixed value for M (3) incorrect biological assumptions in yield-per-recruit calculations (4) incorrect assumptions about fishery selectivity, the behaviour is limited by the TAC change control rule.

In the past, the actual RBC value generated by the Tier 3 HCR has been criticised if it was well above any of the known historical catch levels. The reason why such values are possible using the current HCR have been described here, and how they are correctly dealt with in the overall TAC setting framework. Unexpectedly large RBC values can be generated using the current HCR simply due to the imprecision in the method used to estimate F_{cur}, and it is probably not possible in a short time-frame to determine whether this is the main cause. To avoid misinterpretation of Tier 3 RBCs, both the RBC as generated by the harvest control rule and also the effectively limited values based on the most recent TAC are reported in this document.

A Tier 3 analysis that consistently produces inflated RBC values suggests either that the fishery is having a low impact on the stock, or that some assumptions of the method (e.g. M value) need to be re-examined.

19.3 Results

19.3.1 Yield per recruit analyses

Figure 19.4. Alfonsino yield per recruit reference point calculations.

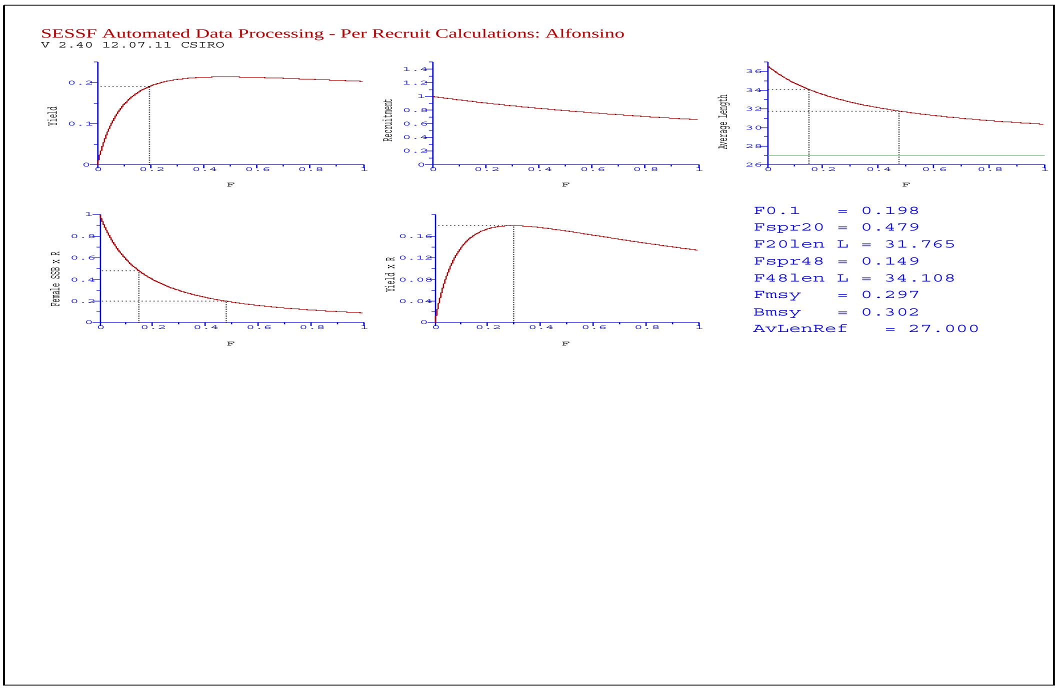


Figure 19.5. John dory yield per recruit reference point calculations.

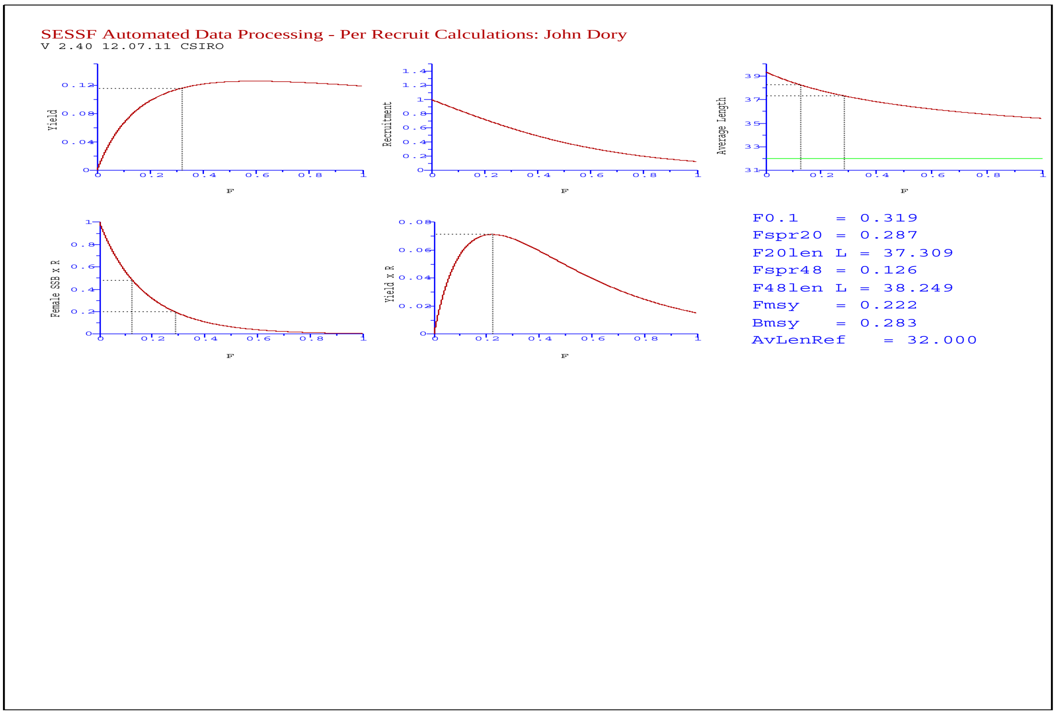


Figure 19.6. Mirror dory yield per recruit reference point calculations.

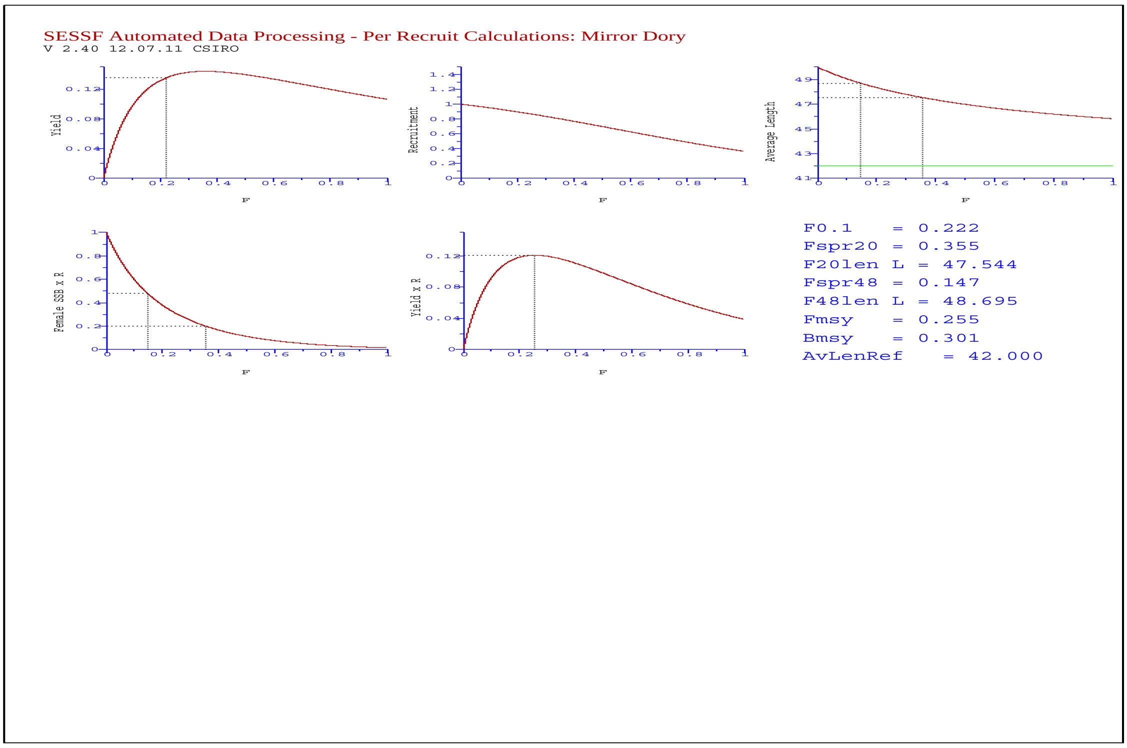


Figure 19.7. Tiger flathead yield per recruit reference point calculations.

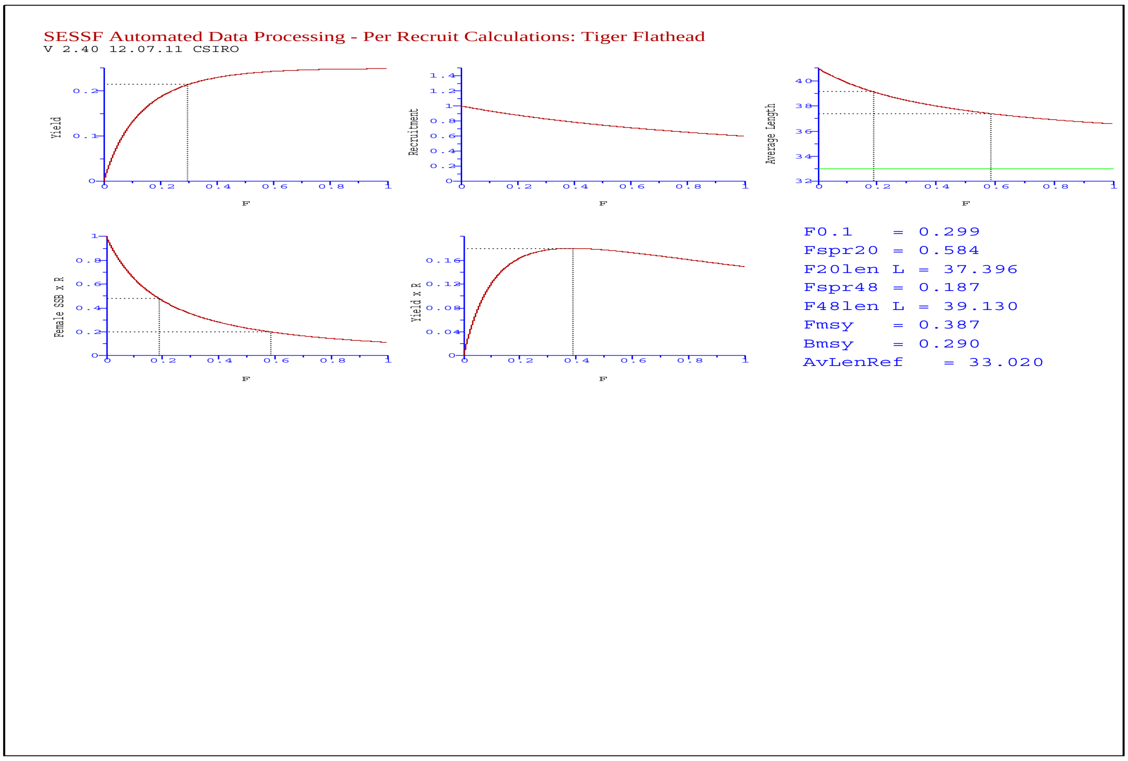


Figure 19.8. Gemfish east yield per recruit reference point calculations.

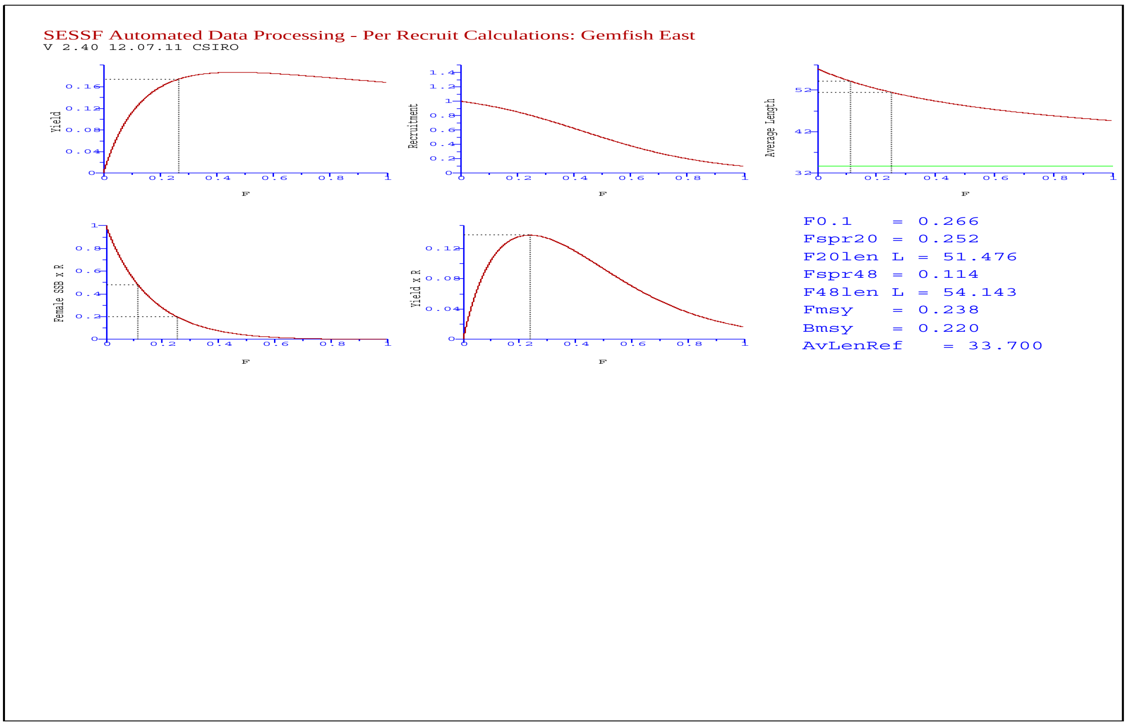


Figure 19.9. Gemfish west yield per recruit reference point calculations.

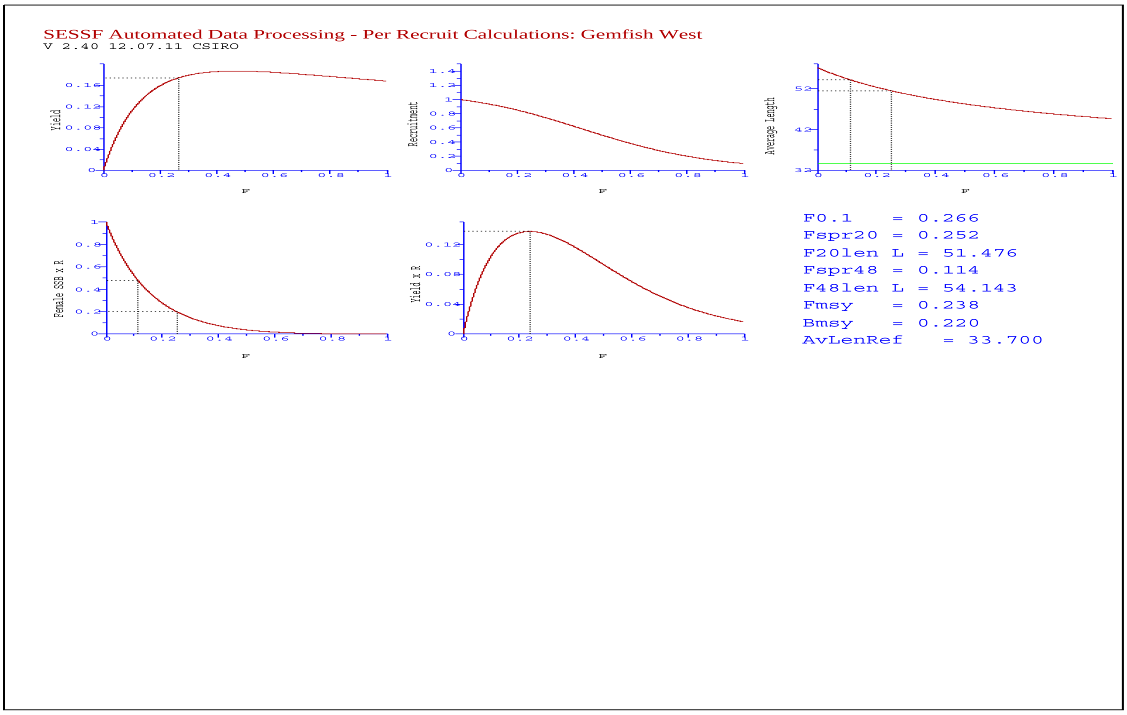


Figure 19.10. Blue grenadier yield per recruit reference point calculations.

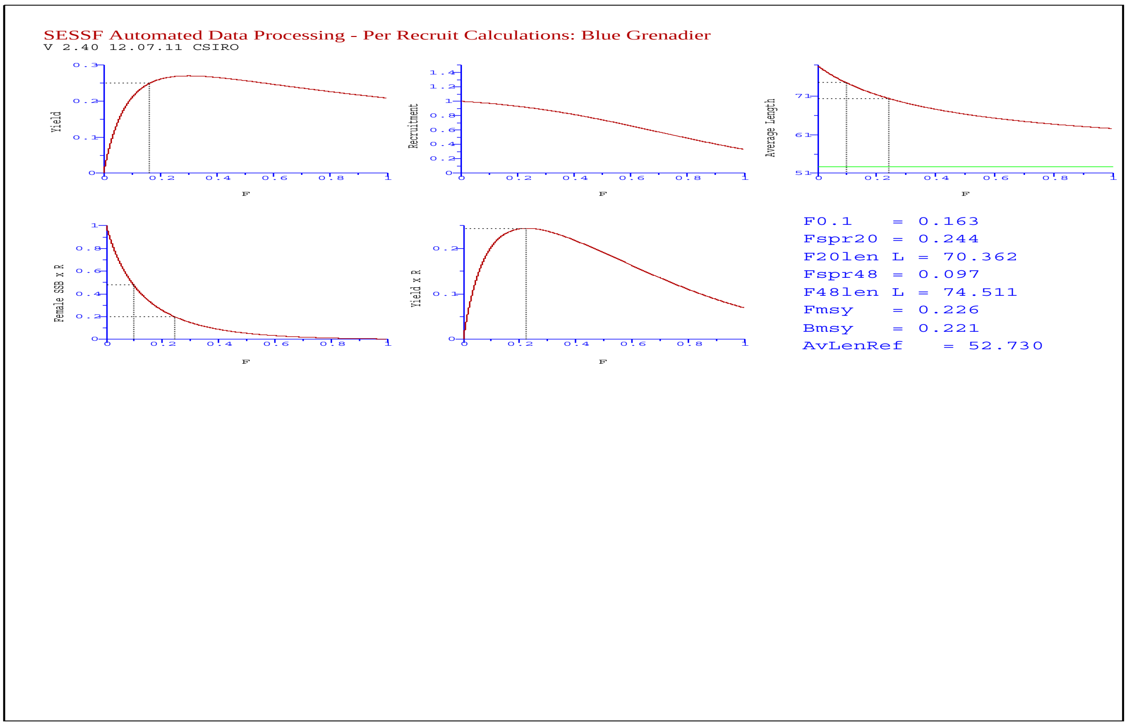


Figure 19.11. Pink ling yield per recruit reference point calculations.

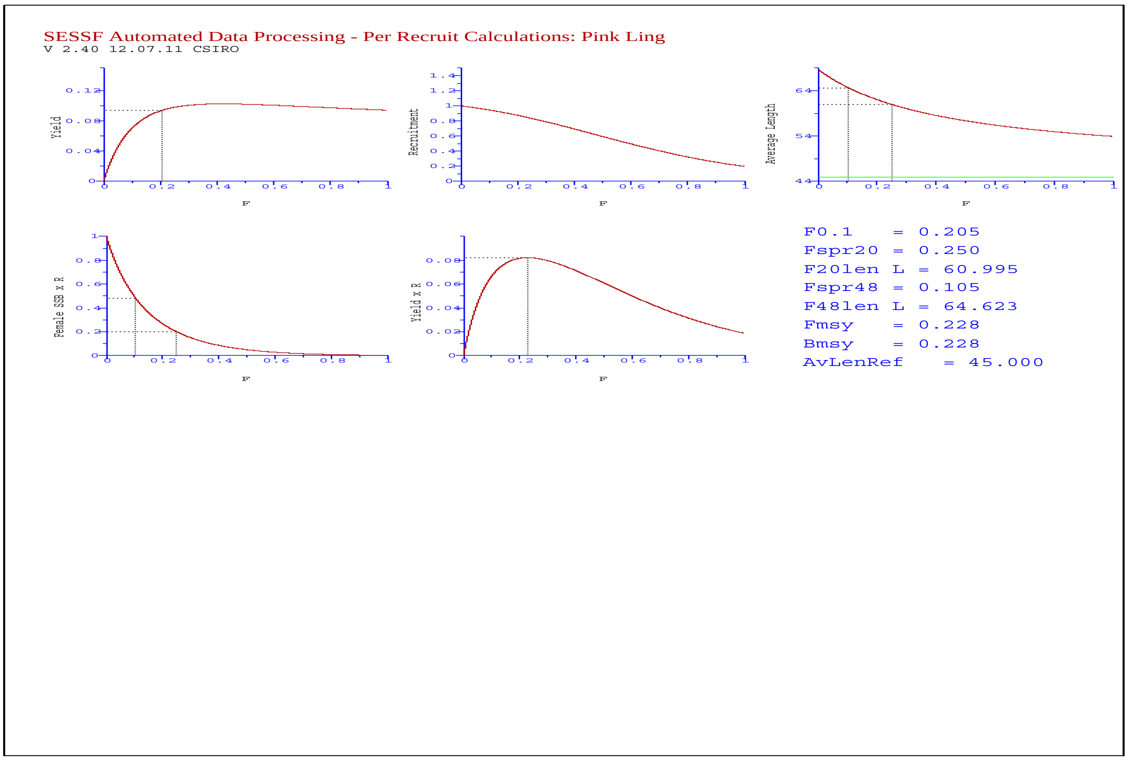


Figure 19.12. Jackass morwong yield per recruit reference point calculations.

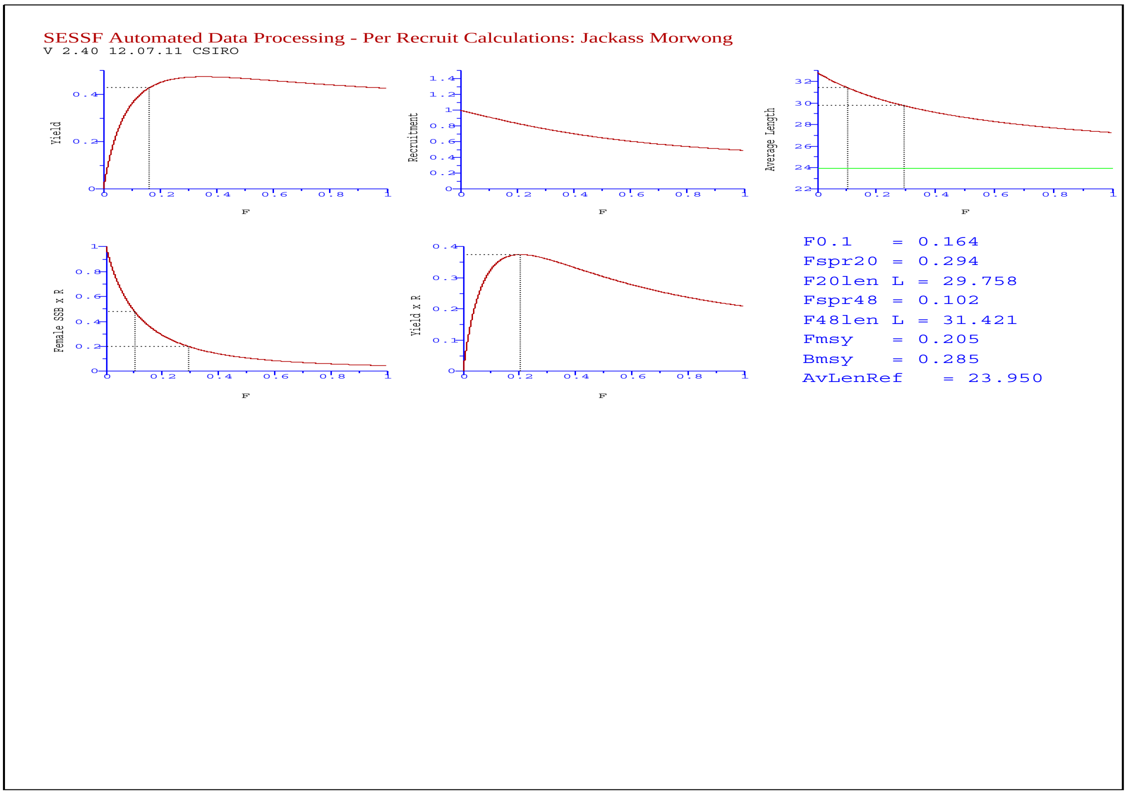


Figure 19.13. Ribaldo yield per recruit reference point calculations.

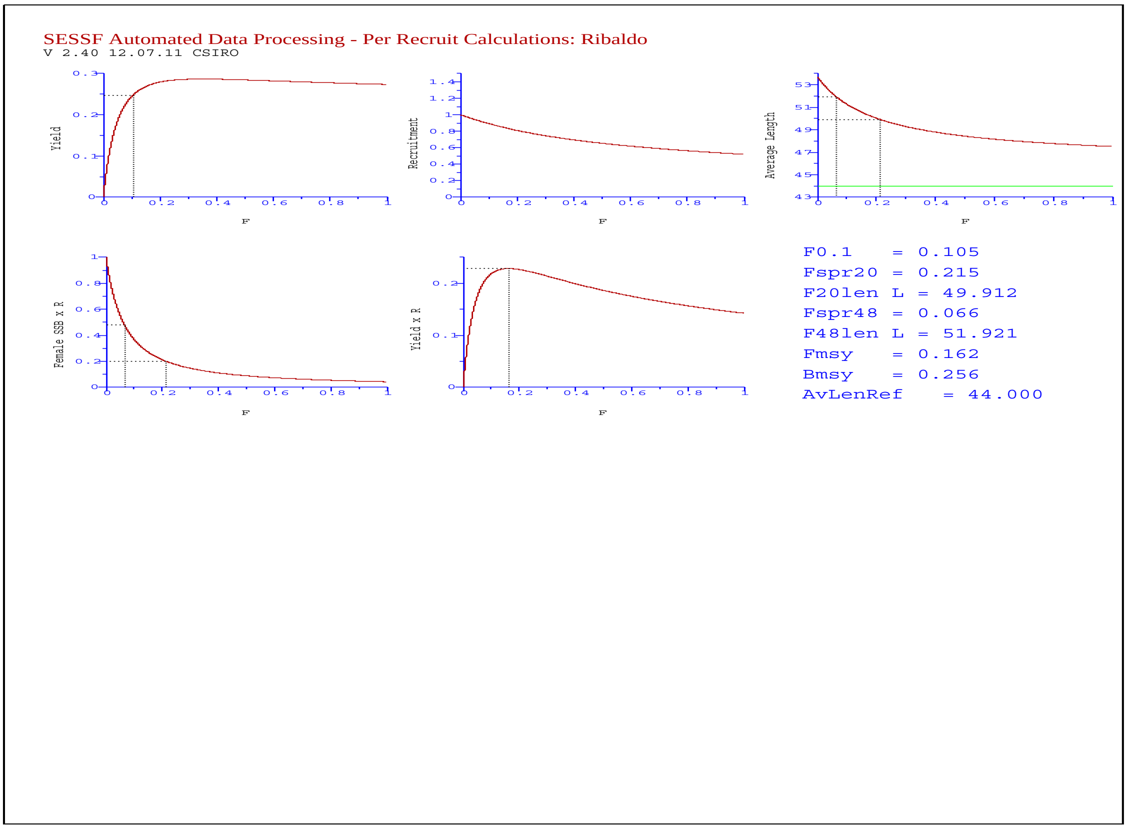


Figure 19.14. Redfish yield per recruit reference point calculations.

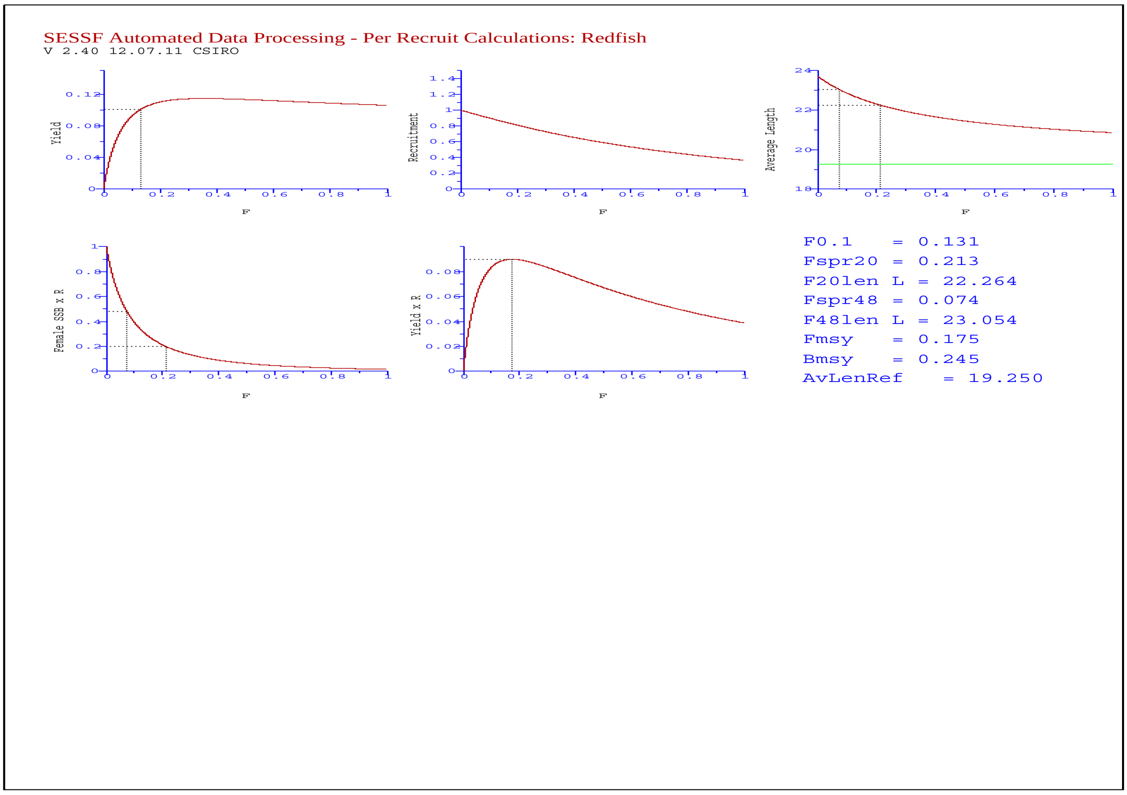


Figure 19.15. Ocean perch yield per recruit reference point calculations.

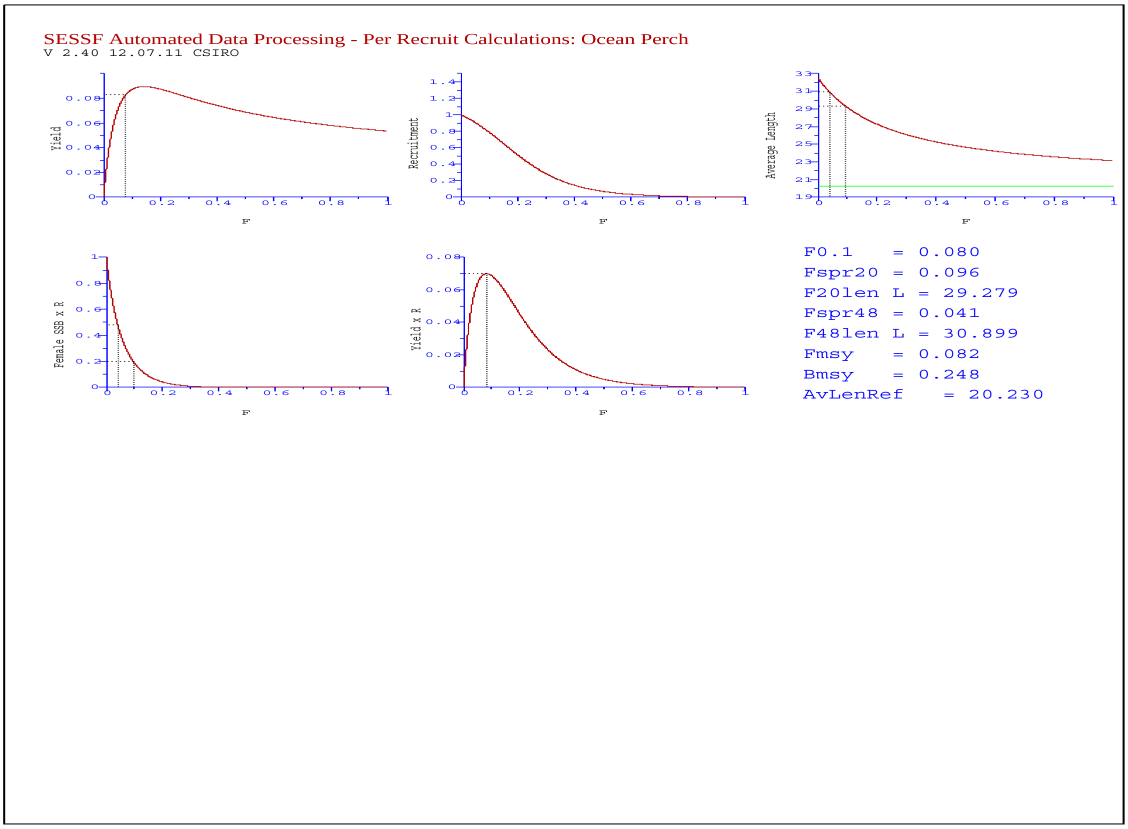


Figure 19.16. Blue-eye trevalla yield per recruit reference point calculations.

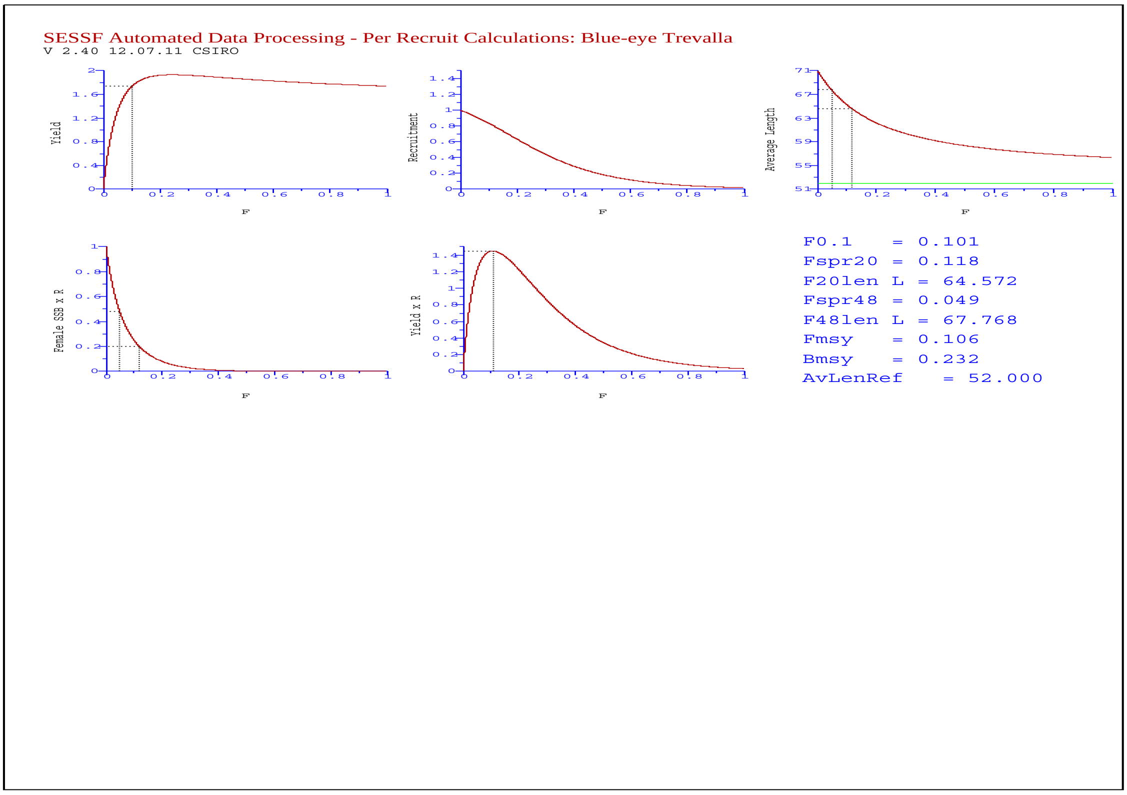


Figure 19.17. Silver trevally yield per recruit reference point calculations.

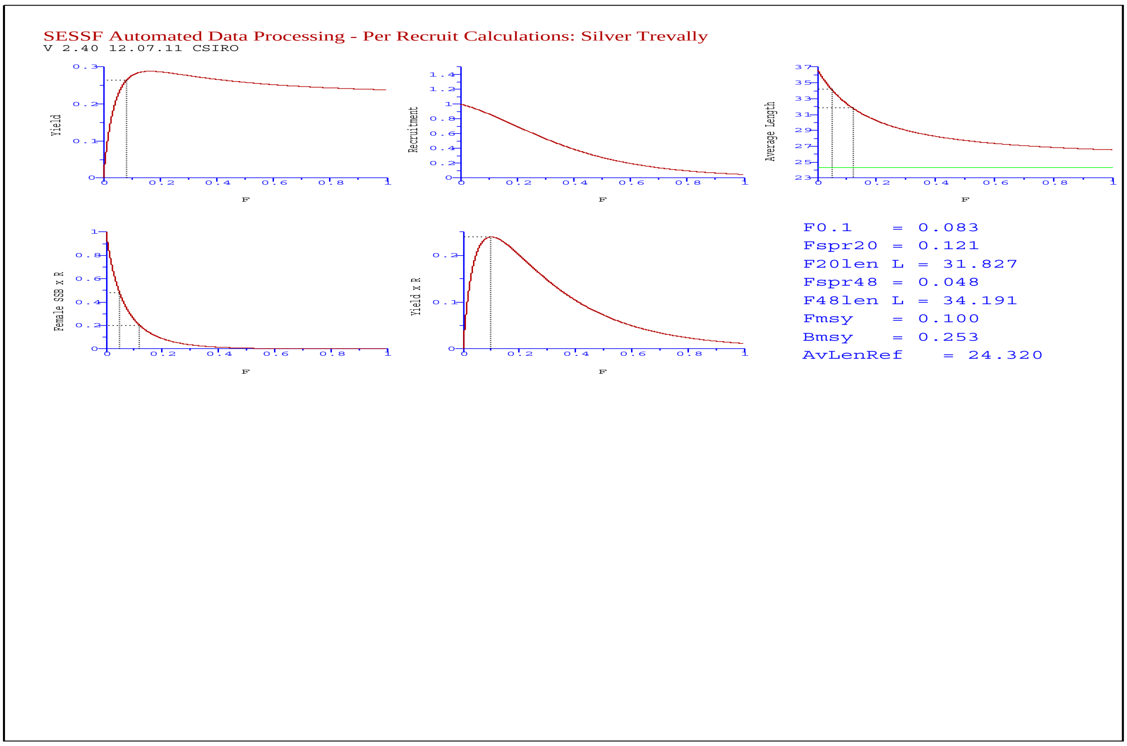


Figure 19.18. Silver warehou yield per recruit reference point calculations.

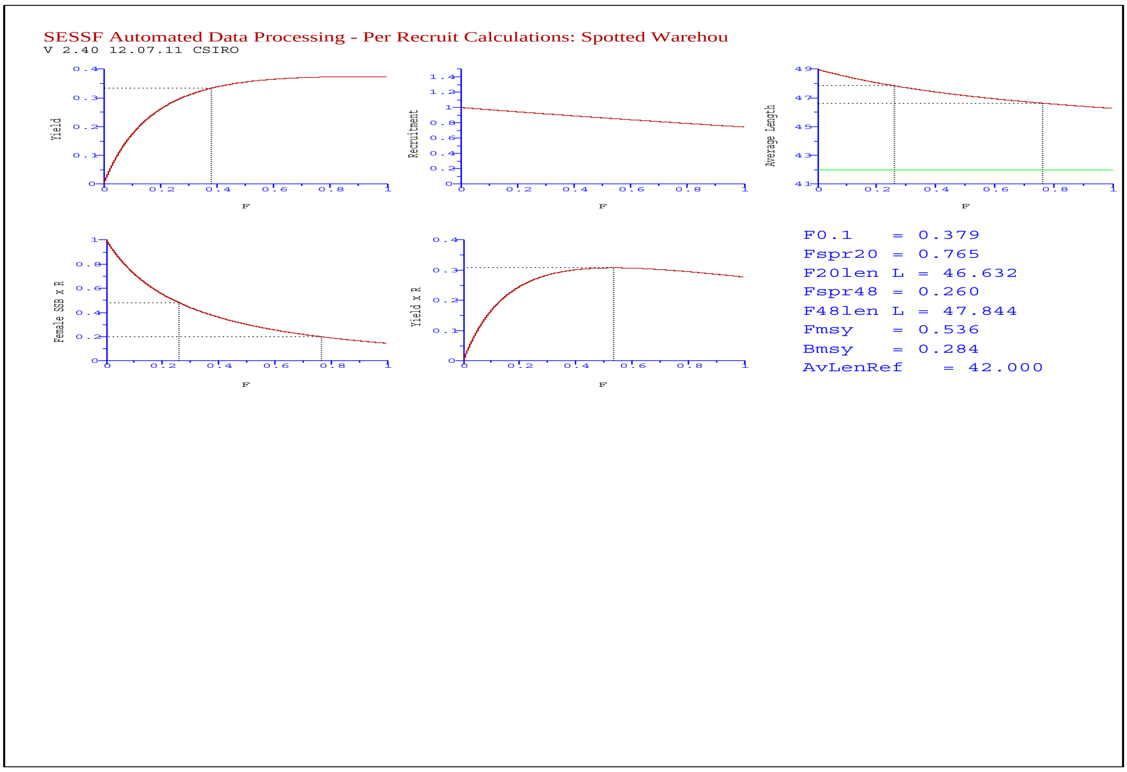


Figure 19.19. Blue warehou yield per recruit reference point calculations.

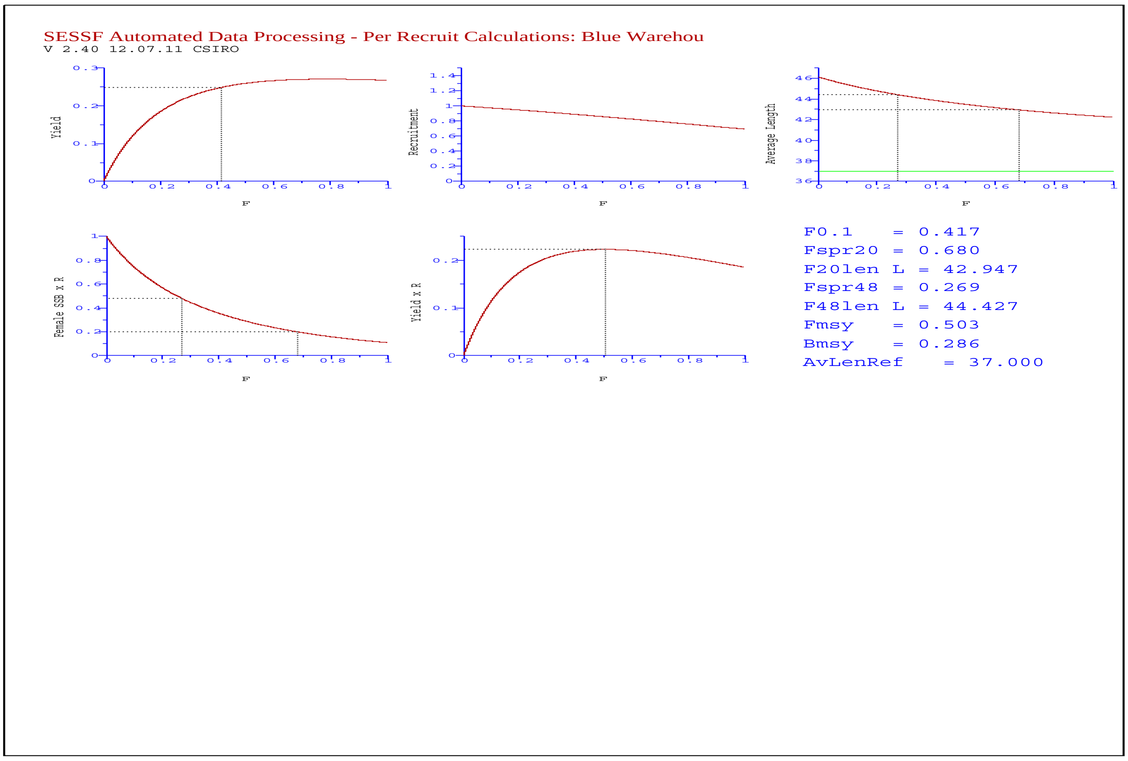
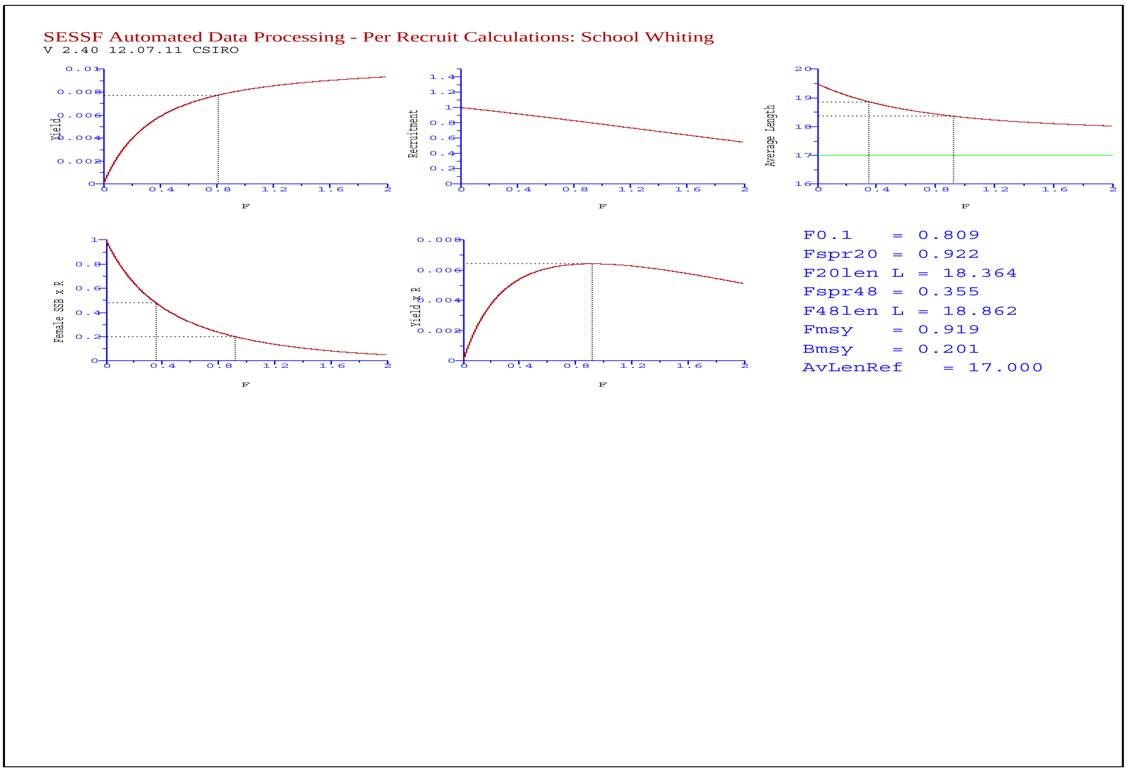


Figure 19.20. School whiting yield per recruit reference point calculations.



19.3.2 Catch curves

The resulting estimates of Z are shown in Figure 19.21 to Figure 19.37. Average catch curve fits to annual age compositions are shown, as well as plots of the estimated Z value versus year per population and fleet.

The results of catch curve analysis are shown together with the total mortality figures (Z) that resulted in spawning biomasses of 20% and 48% of pristine (dotted horizontal lines).

19.3.3 Average length

The resulting estimates of Z using the average length method are shown in Figure 19.38 to Figure 19.54. These results are only presented for information and discussion. Of the current Tier 3 species, only John dory has F_{cur} estimation based on length data alone in 2010 (and now age-based in 2011).

MSE testing has shown that the average length performs reasonably well with unbiased sampling, but if age data are available, it would be preferable to use age-based catch curves.

Figure 19.21. Alfonsino catch curve results.

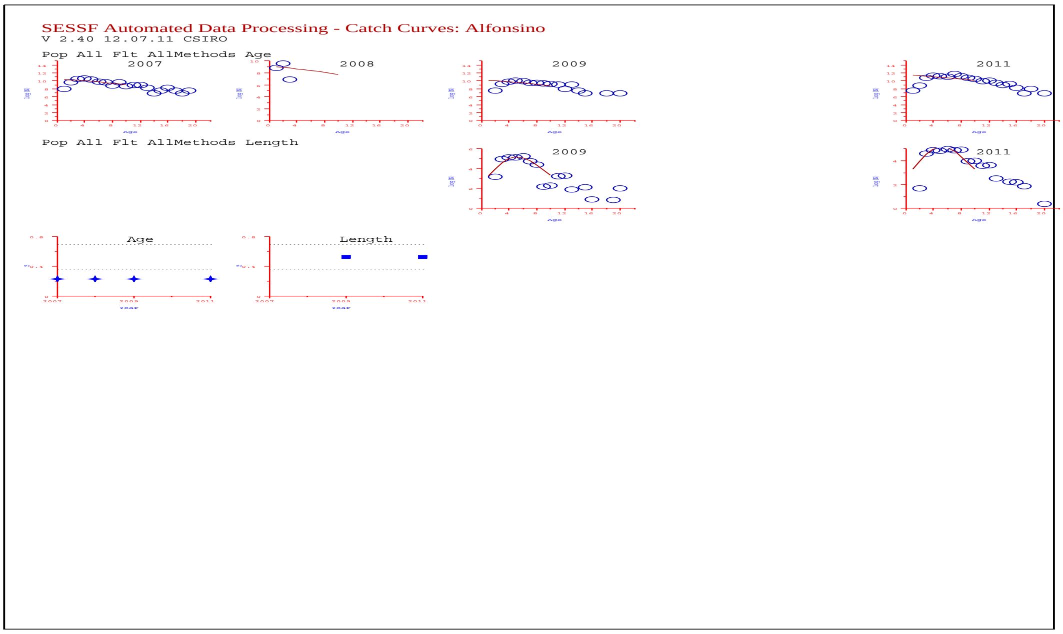


Figure 19.22. John dory catch curve results.

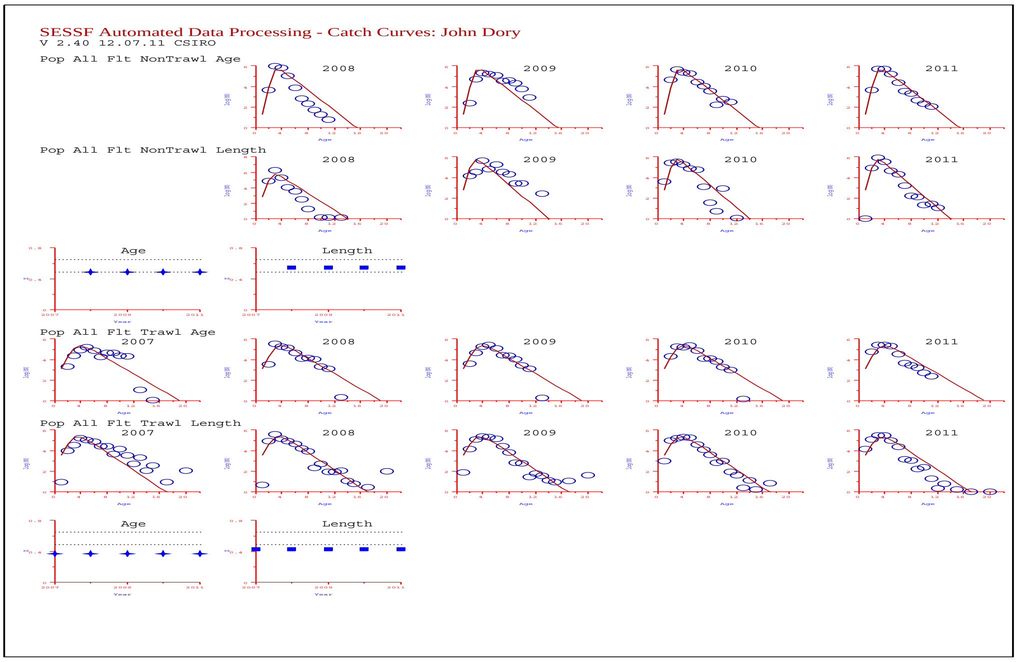


Figure 19.23. Mirror dory catch curve results.

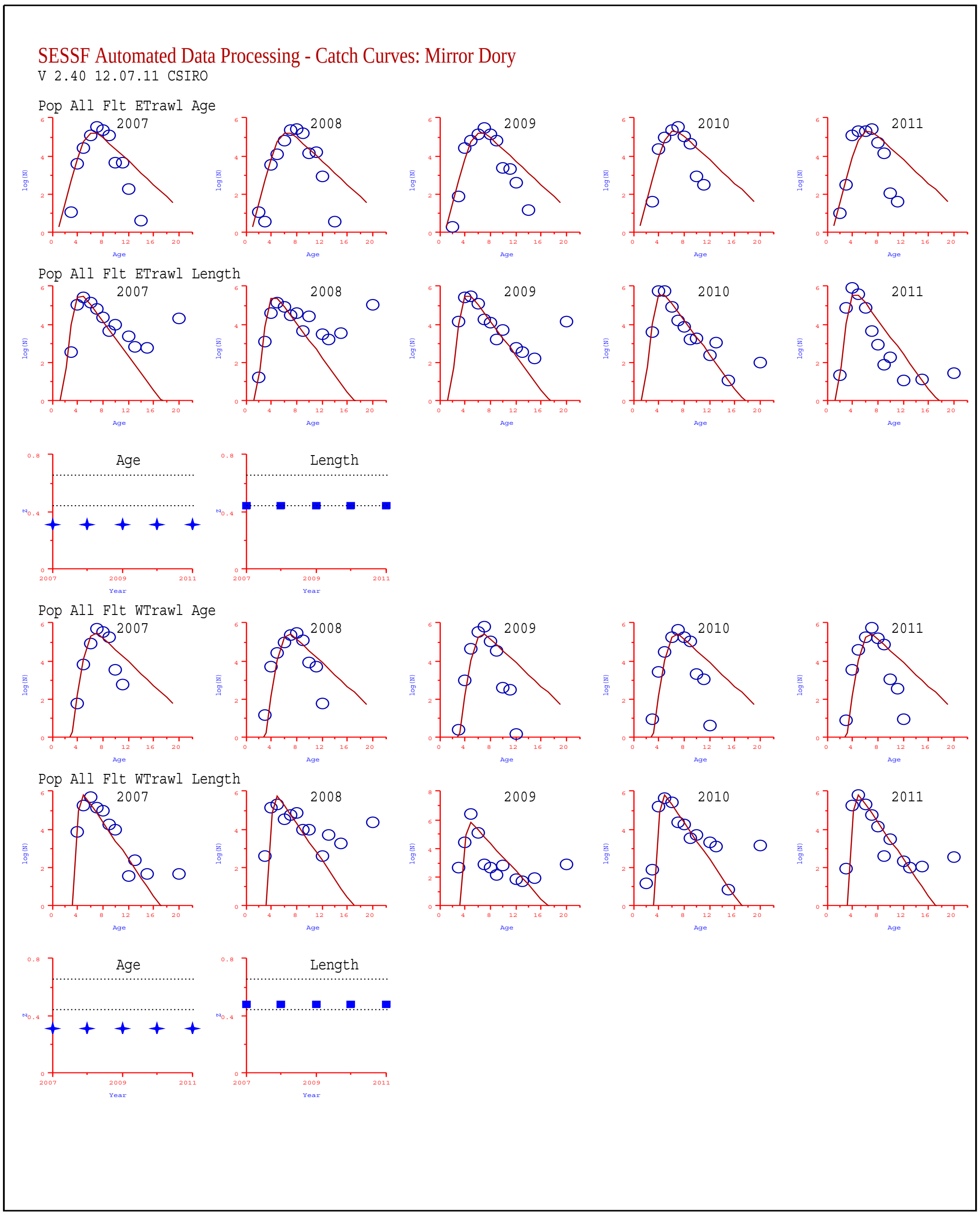


Figure 19.24. Flathead catch curve results.

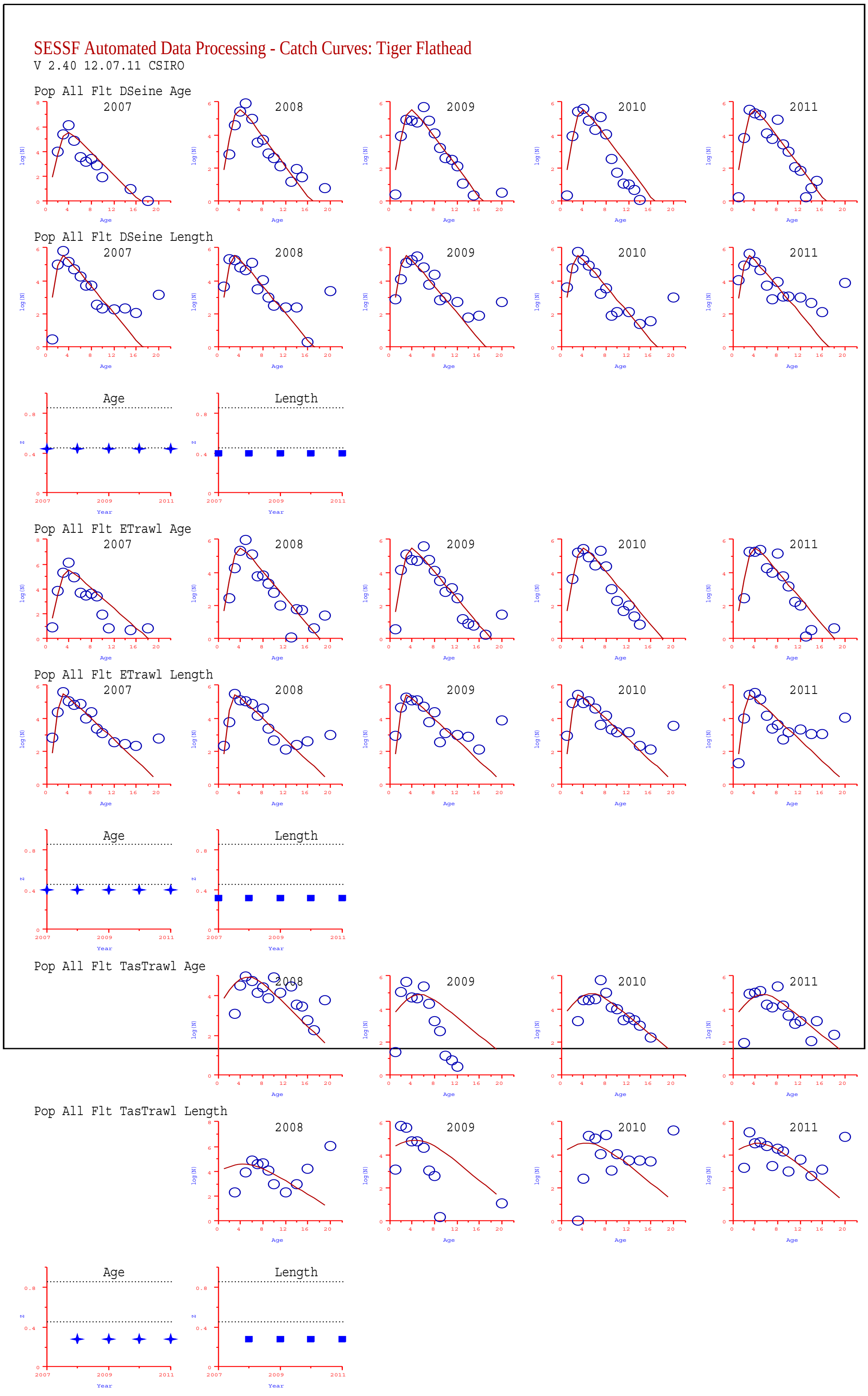


Figure 19.25. Gemfish east catch curve results.

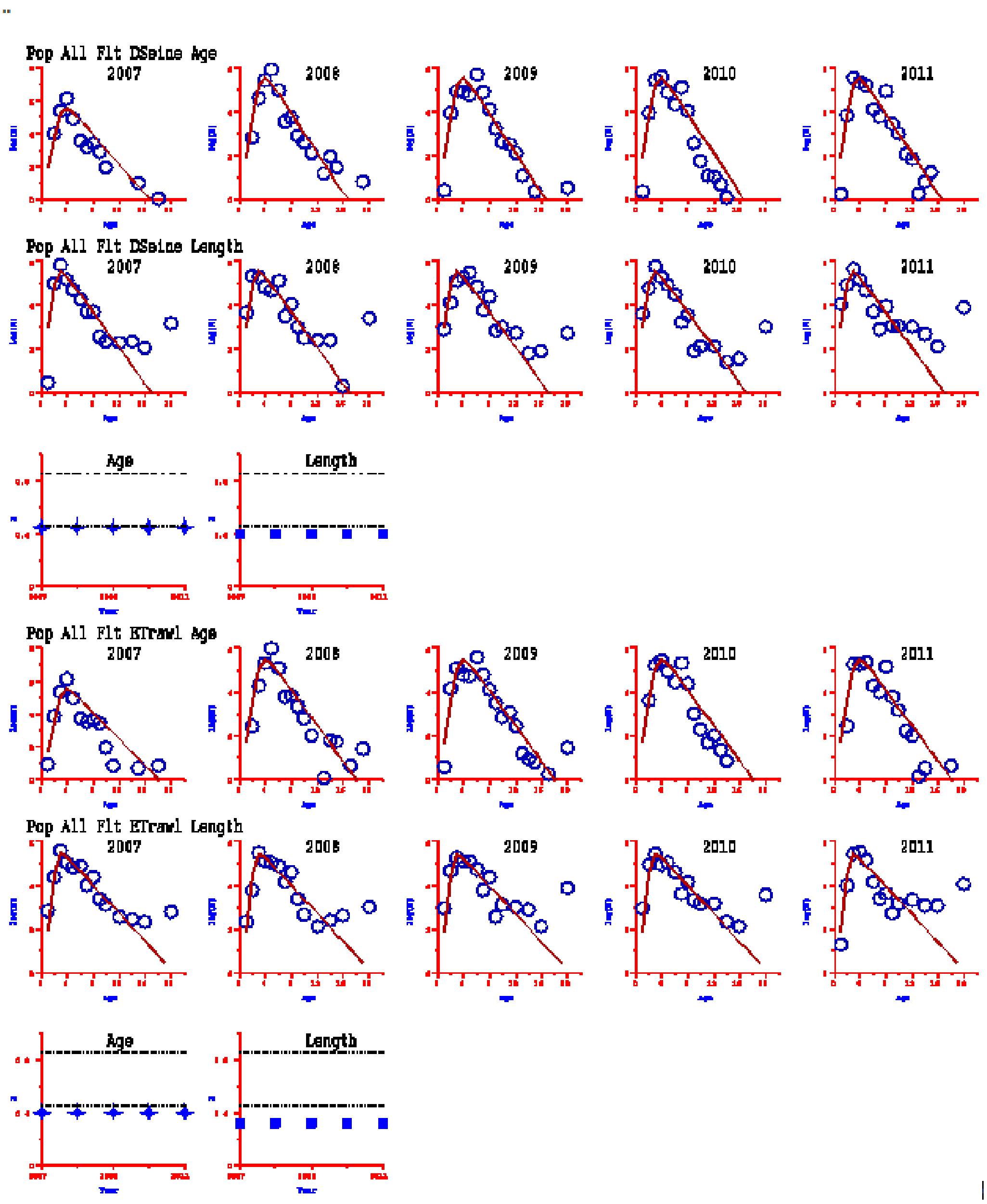


Figure 19.26. Gemfish west catch curve results.

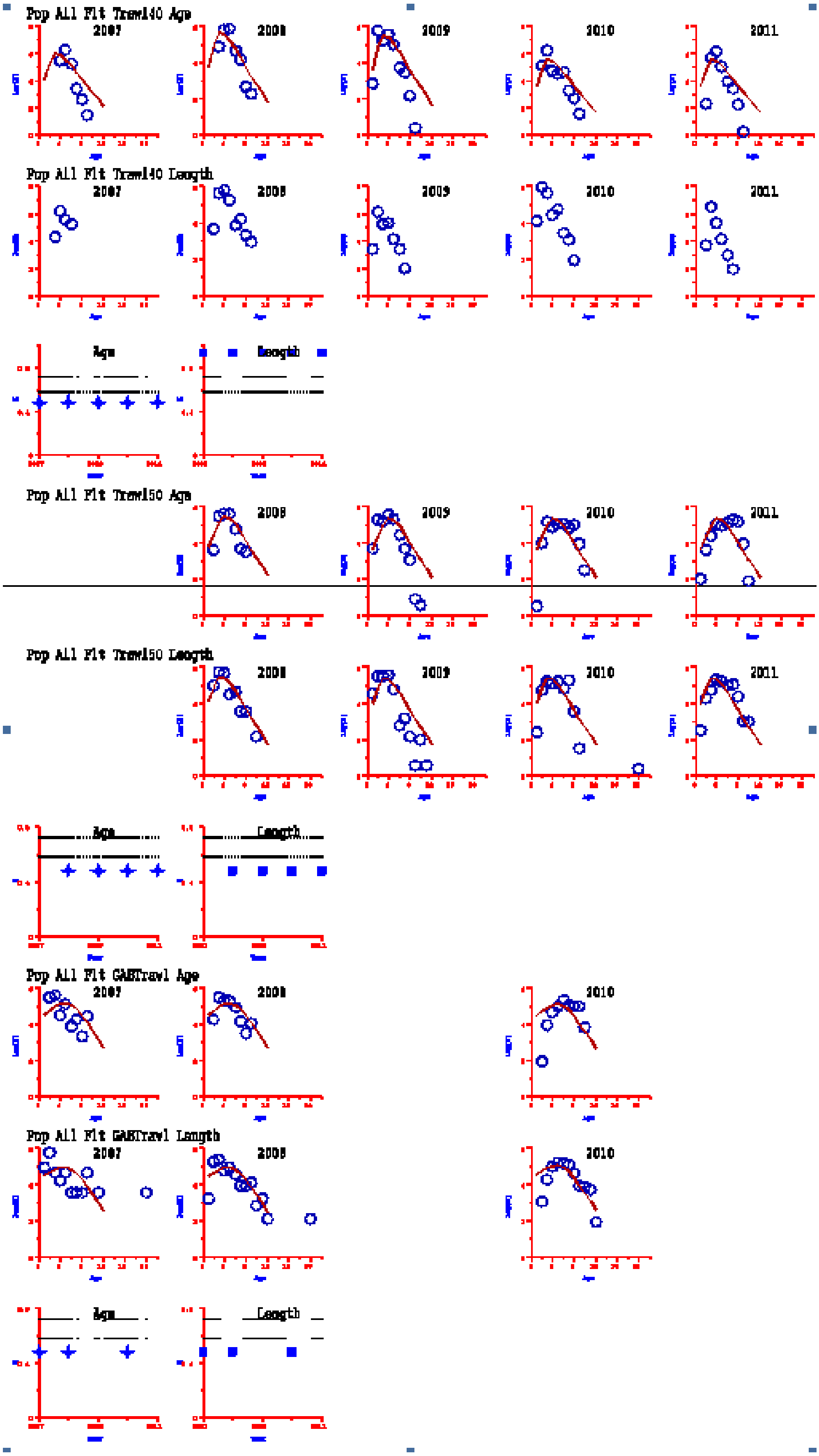


Figure 19.27. Blue grenadier catch curve results – need to add in port spawn lf.

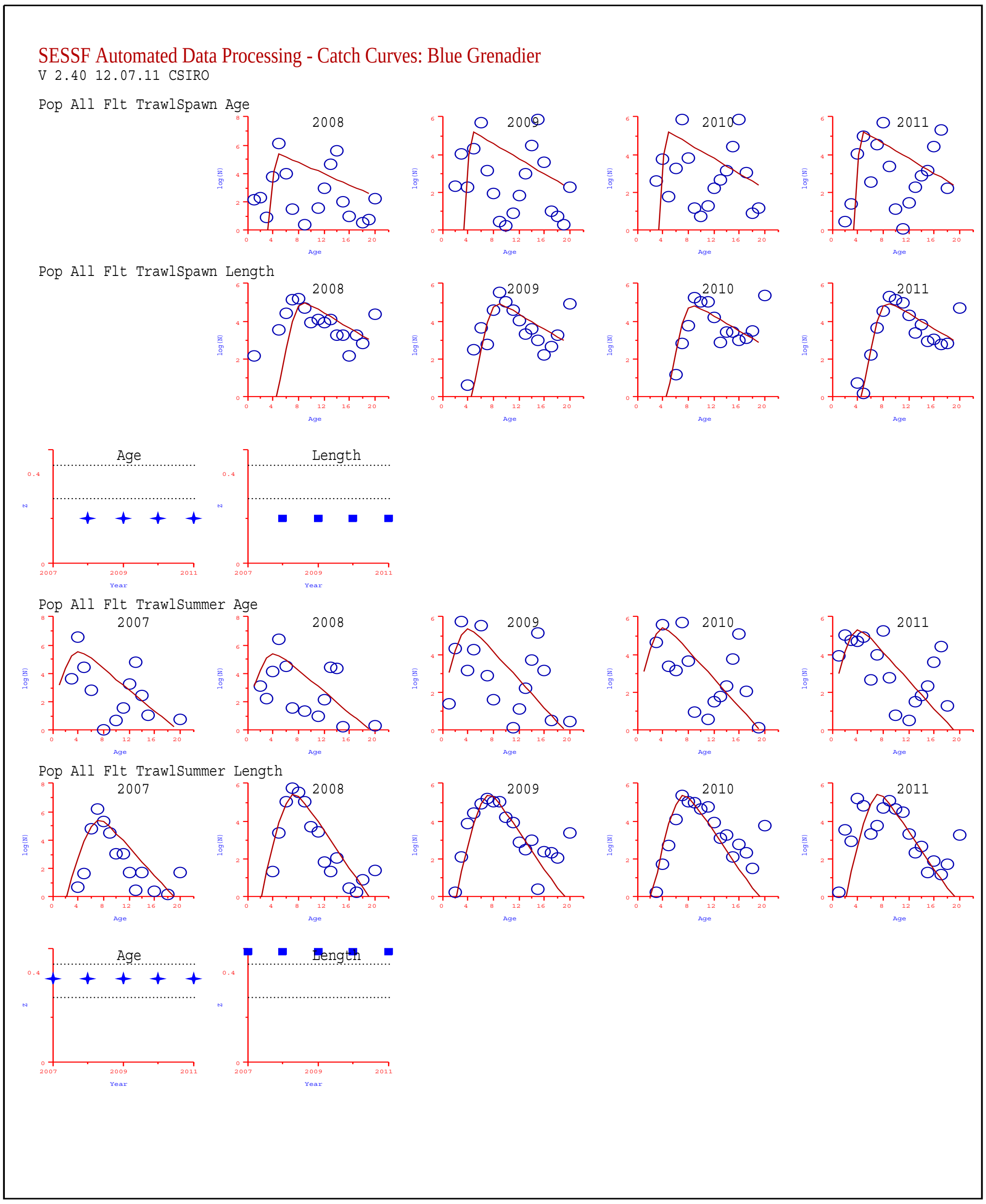


Figure 19.28. Pink ling catch curve results.

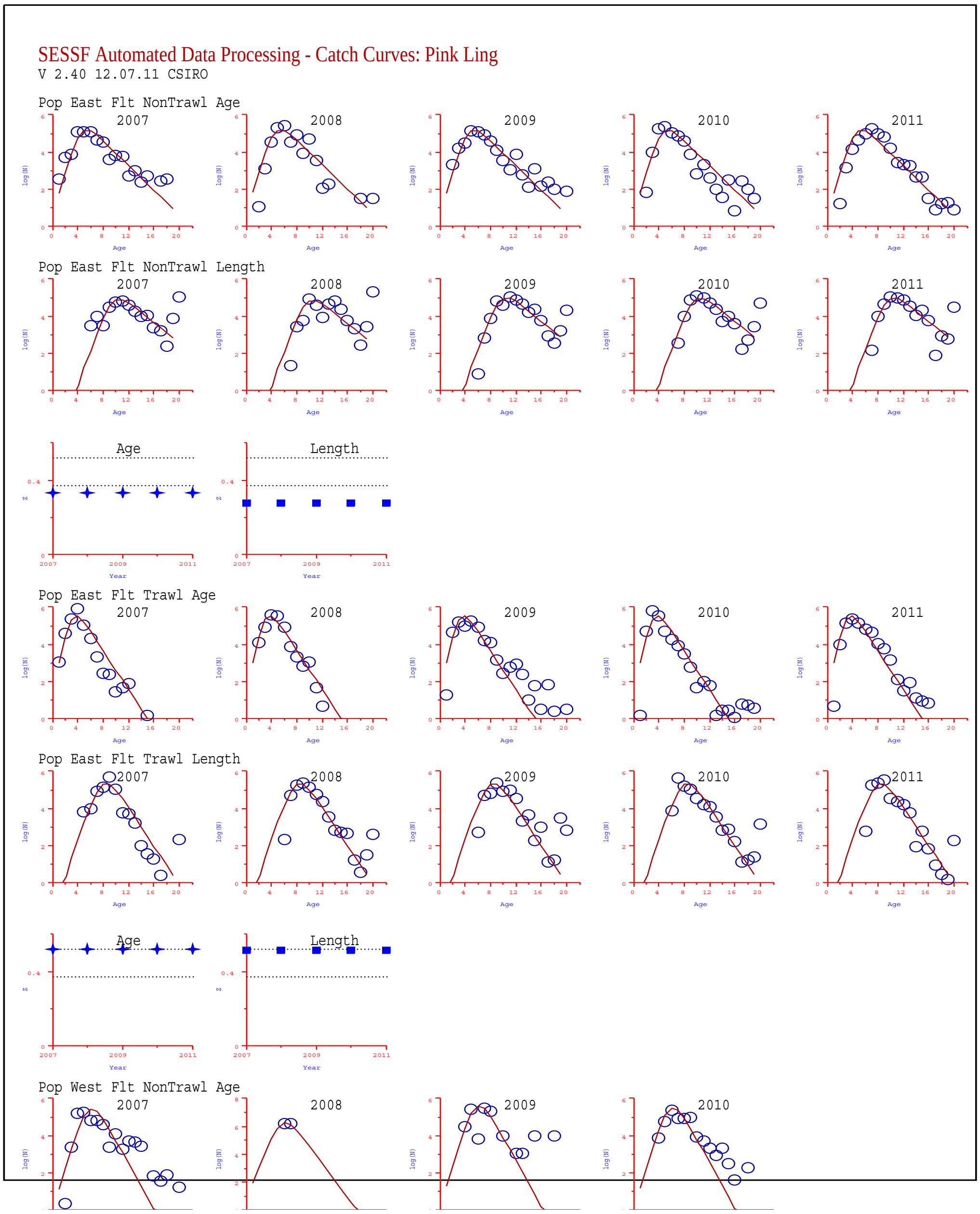


Figure 19.29. Jackass morwong catch curve results.

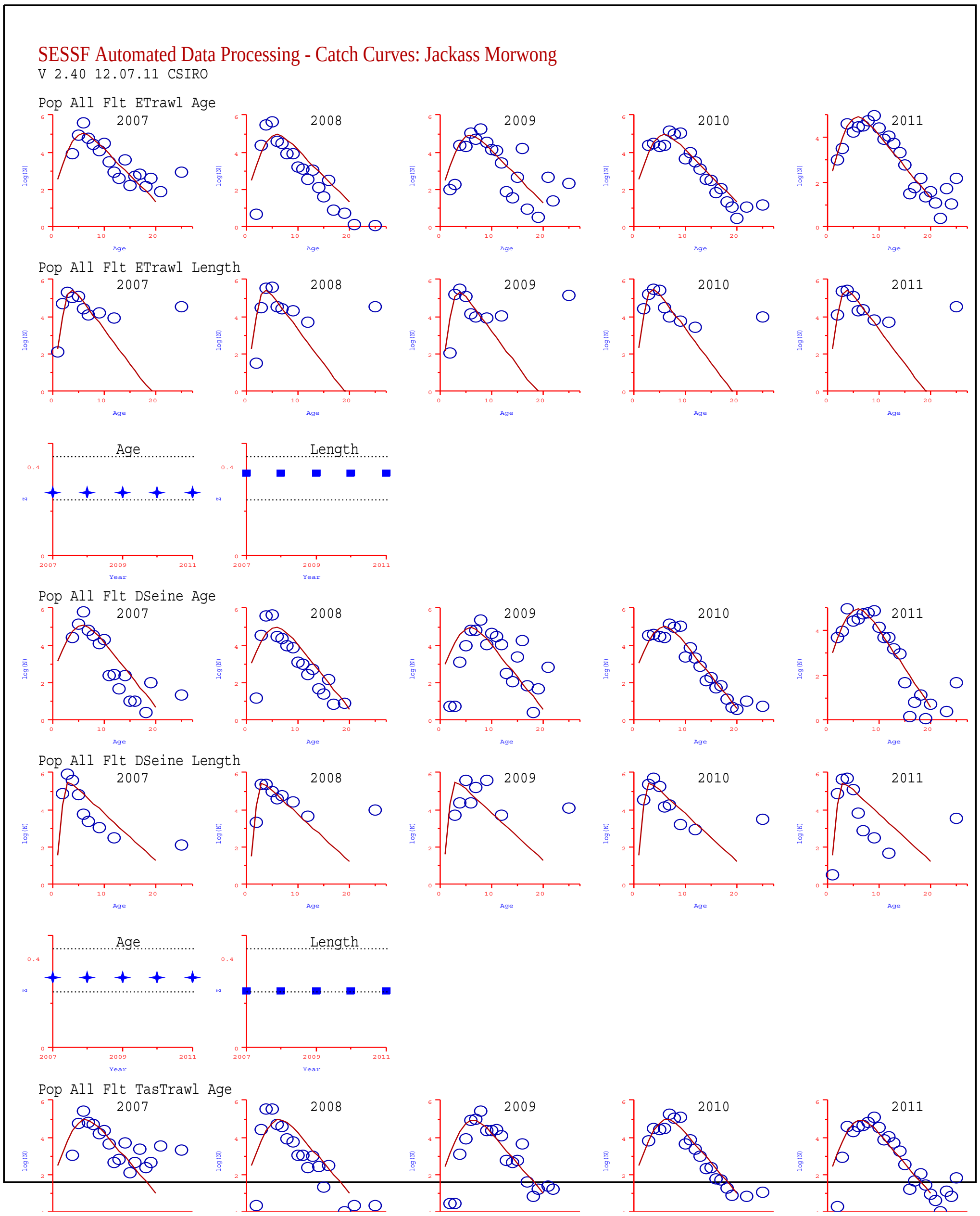


Figure 19.30. Ribaldo catch curve results place holder - analysis not completed in 2012

Figure 19.31. Redfish catch curve results

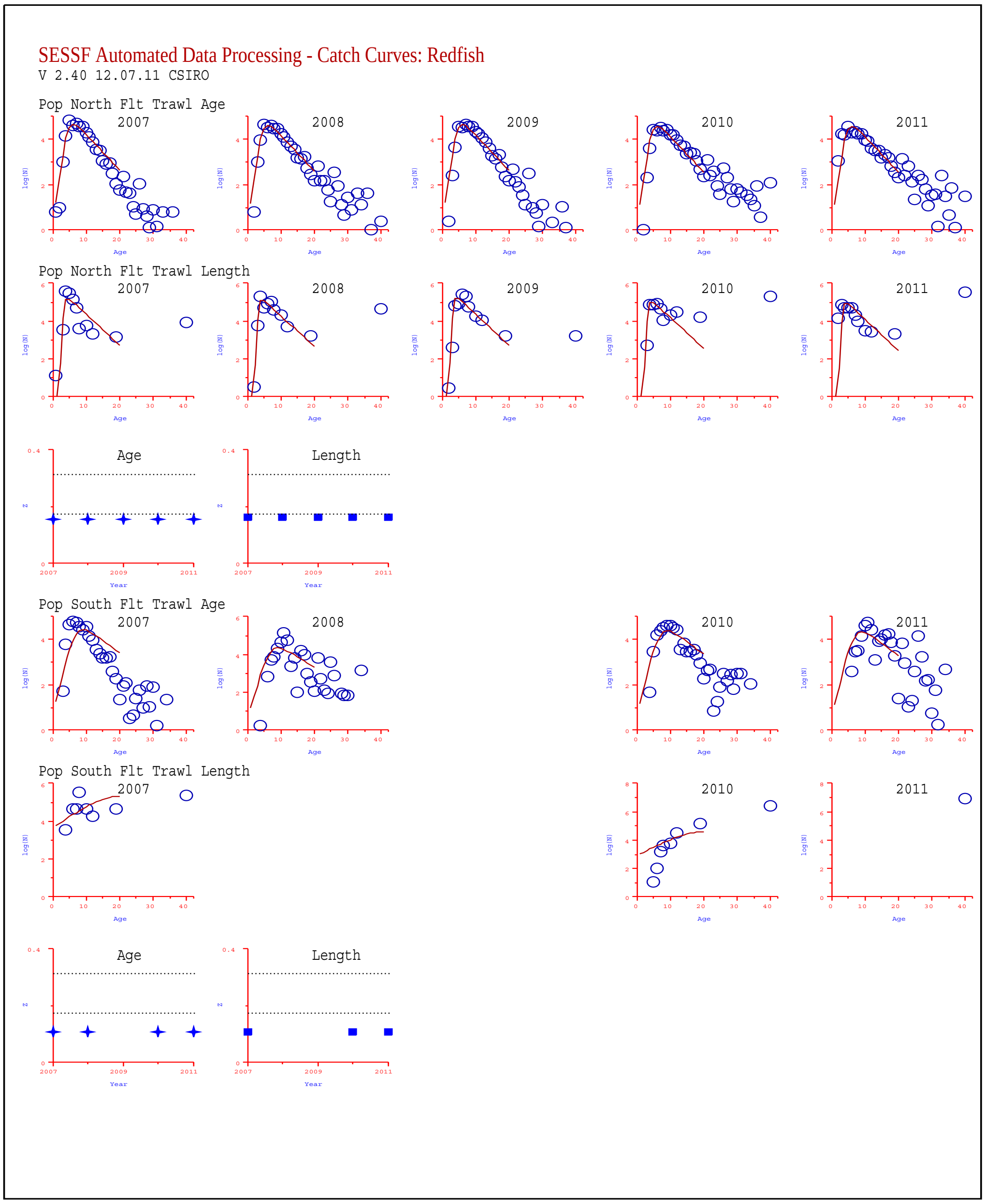


Figure 19.32. Ocean perch catch curve results – where are the SEF1 records?

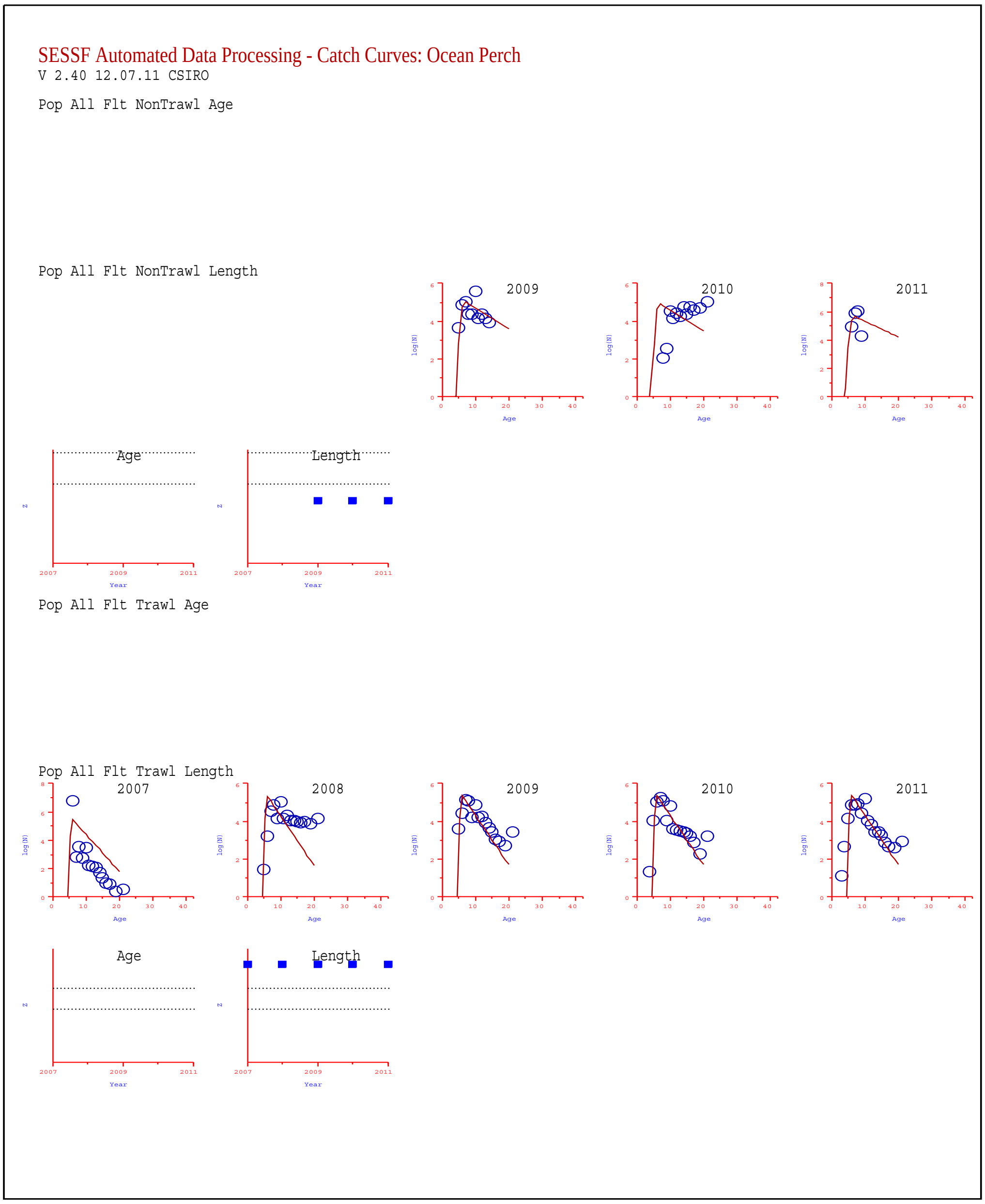


Figure 19.33. Blue-eye trevalla catch curve results.

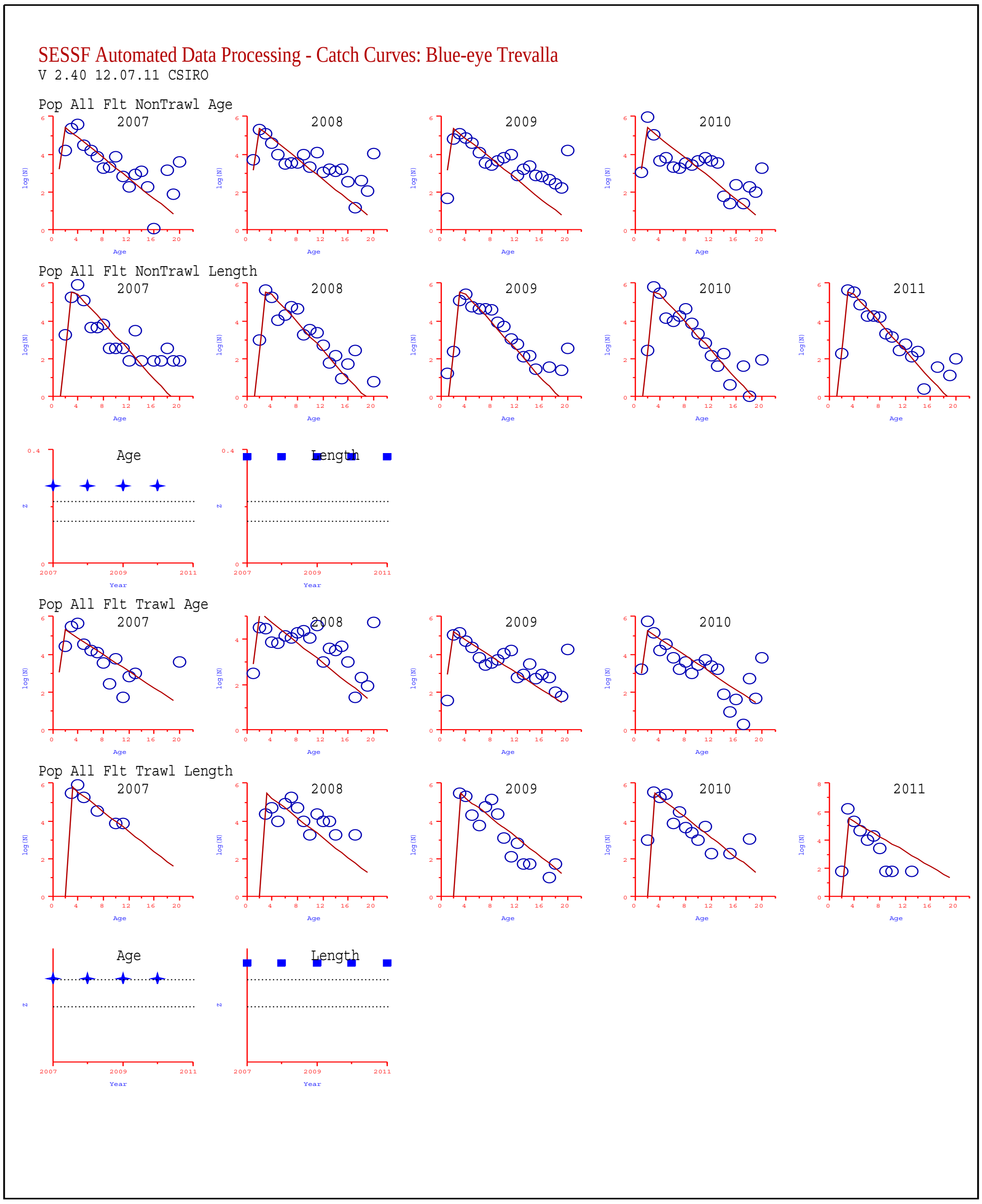


Figure 19.34. Silver trevally catch curve results.

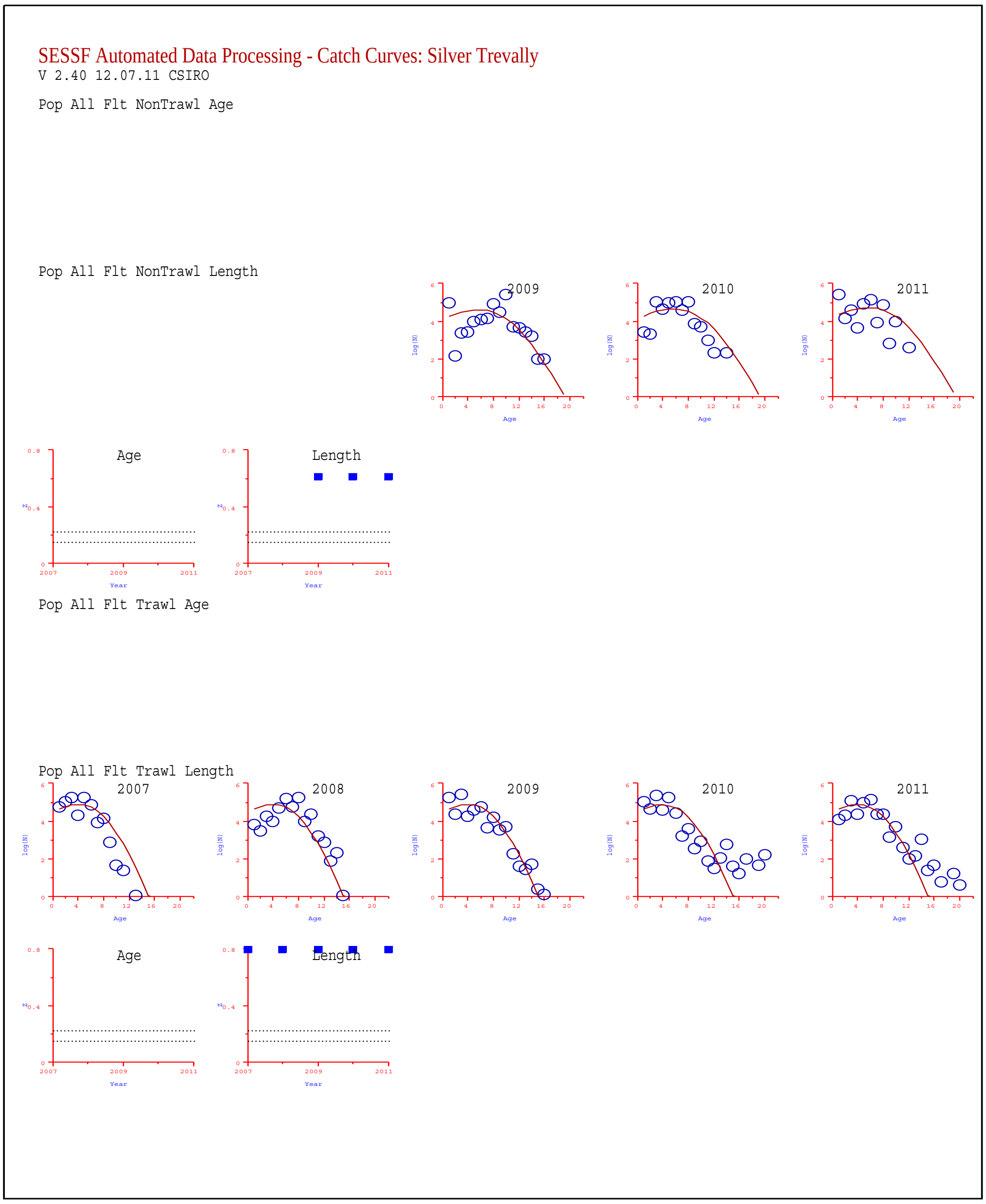


Figure 19.35. Silver warehou catch curve results.

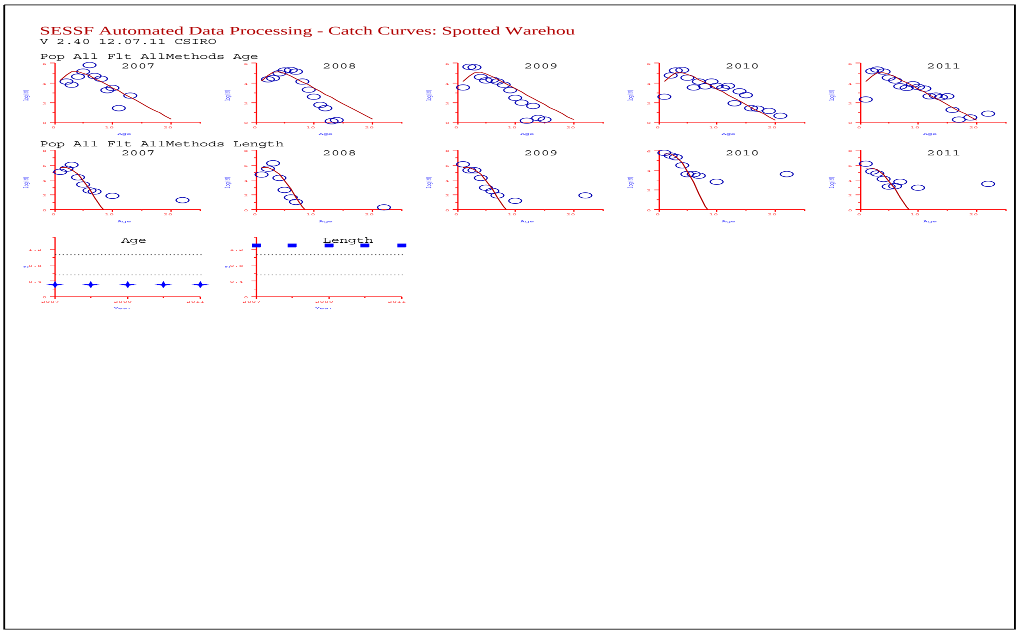


Figure 19.36 Blue warehou catch curve results.

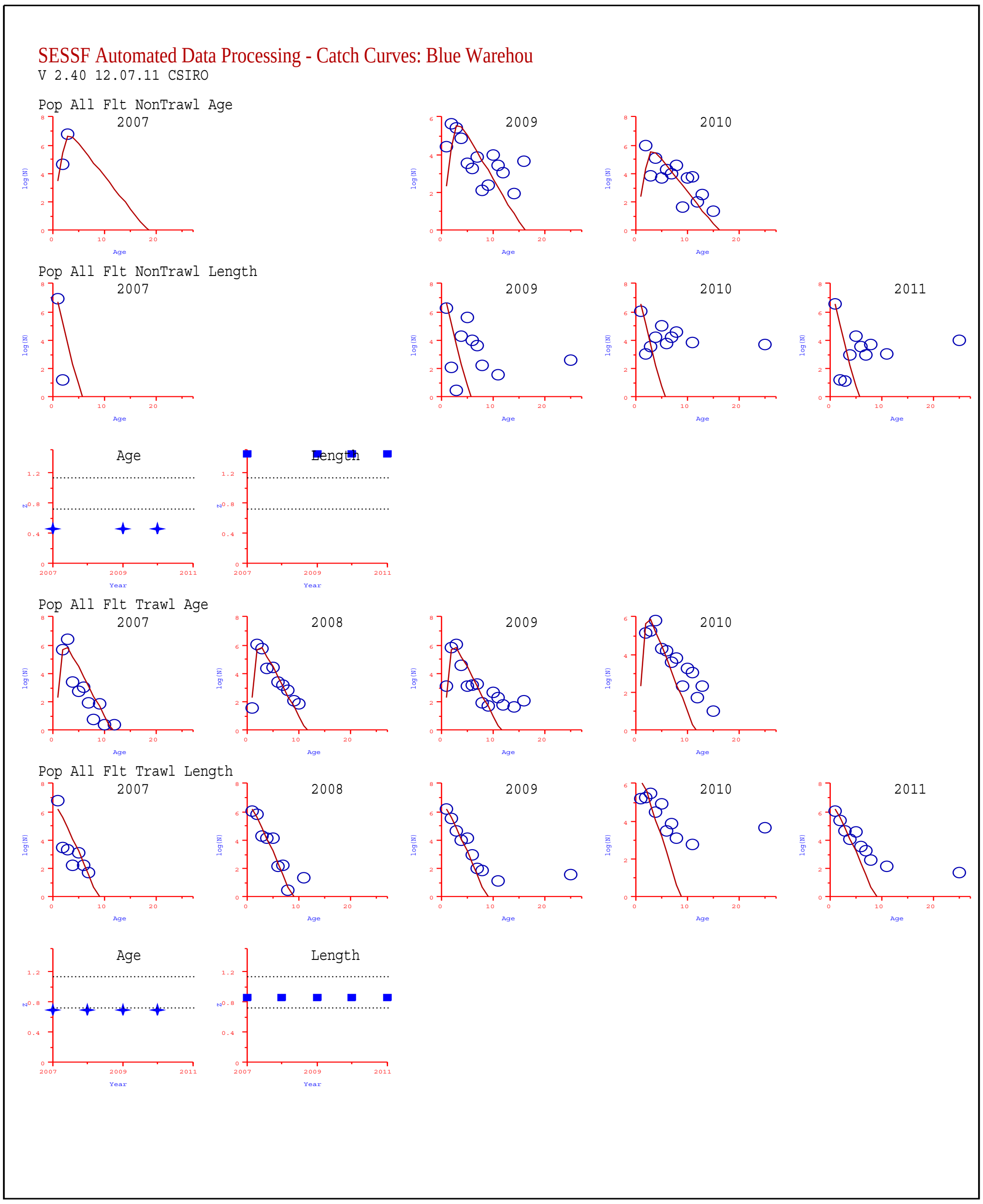


Figure 19.37. School whiting catch curve results.

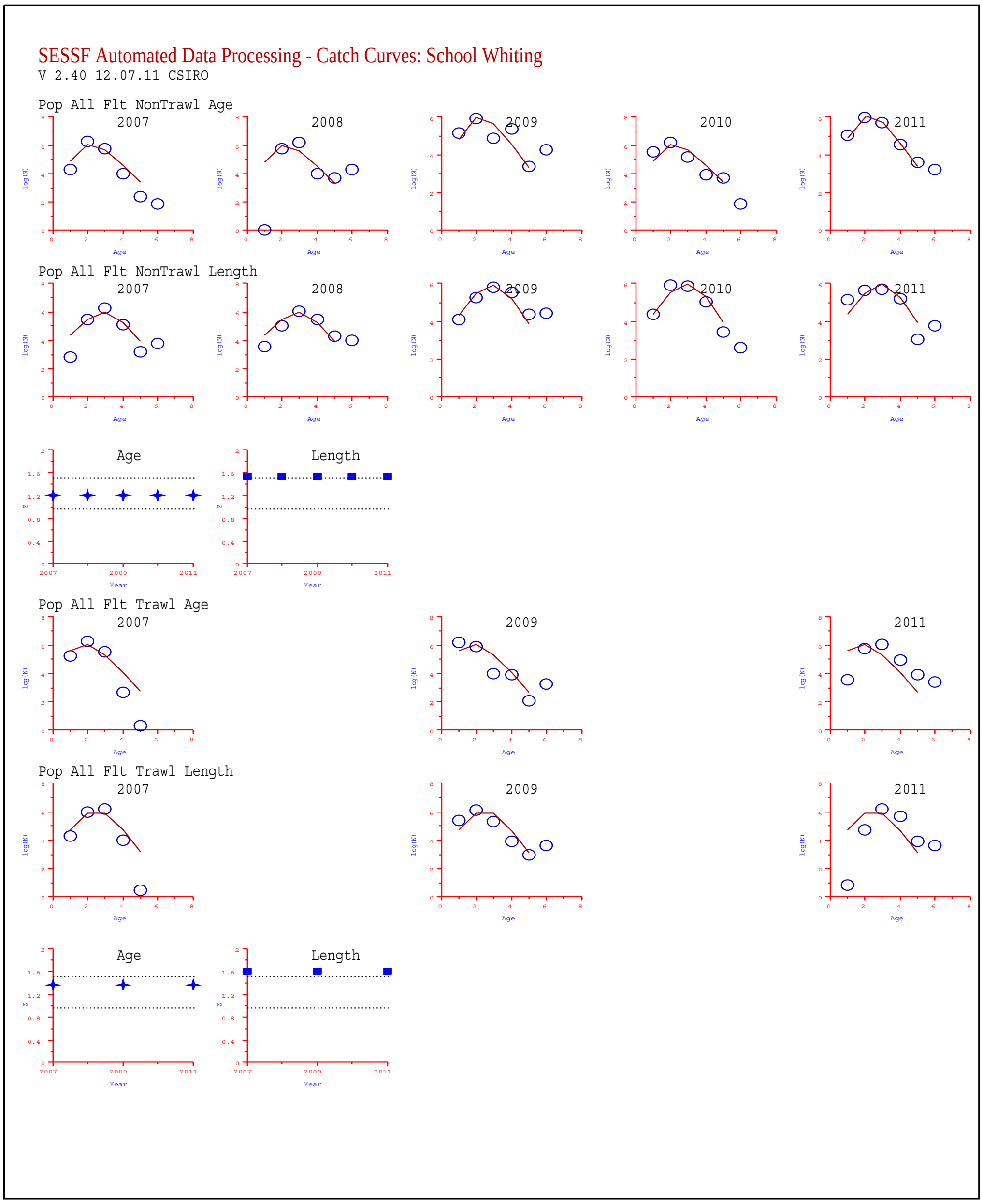


Figure 19.38. Alfonsino average length results.

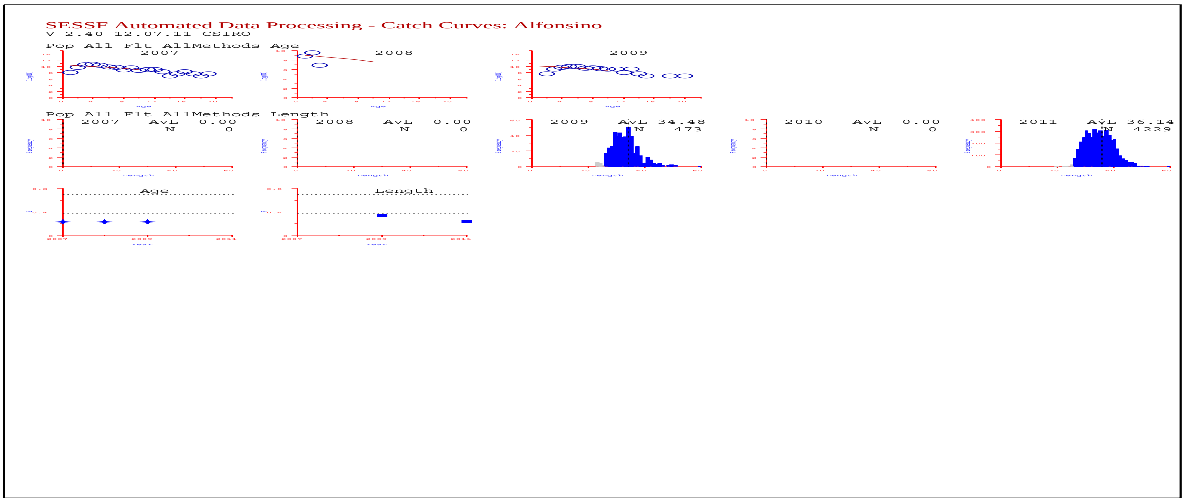


Figure 19.39. John dory average length results.

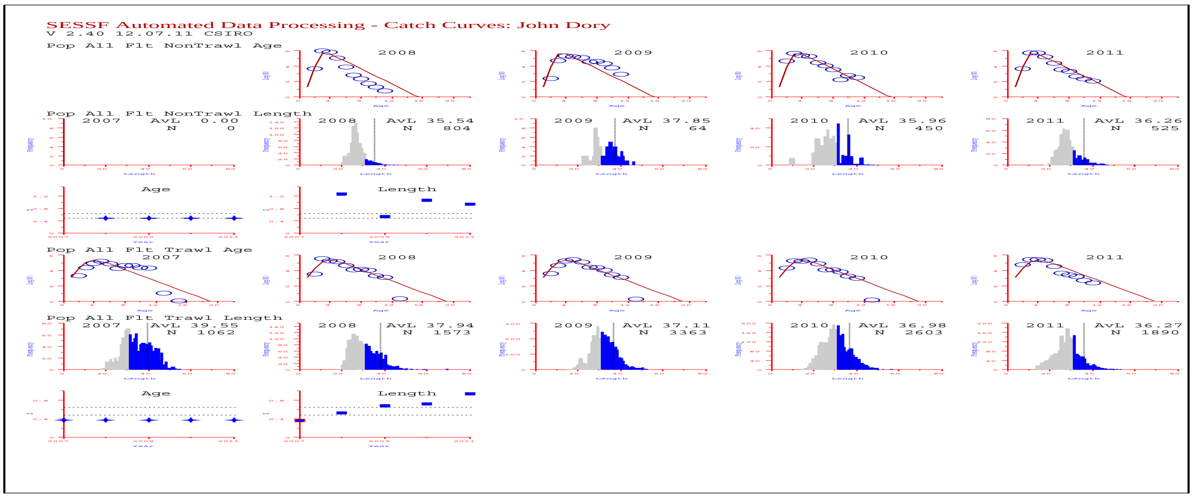
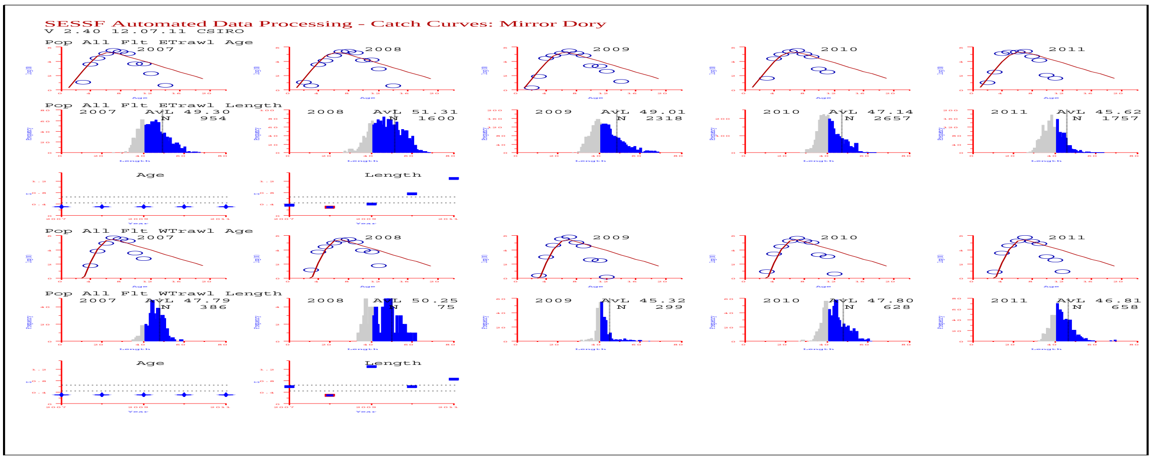


Figure 19.40. Mirror dory average length results.



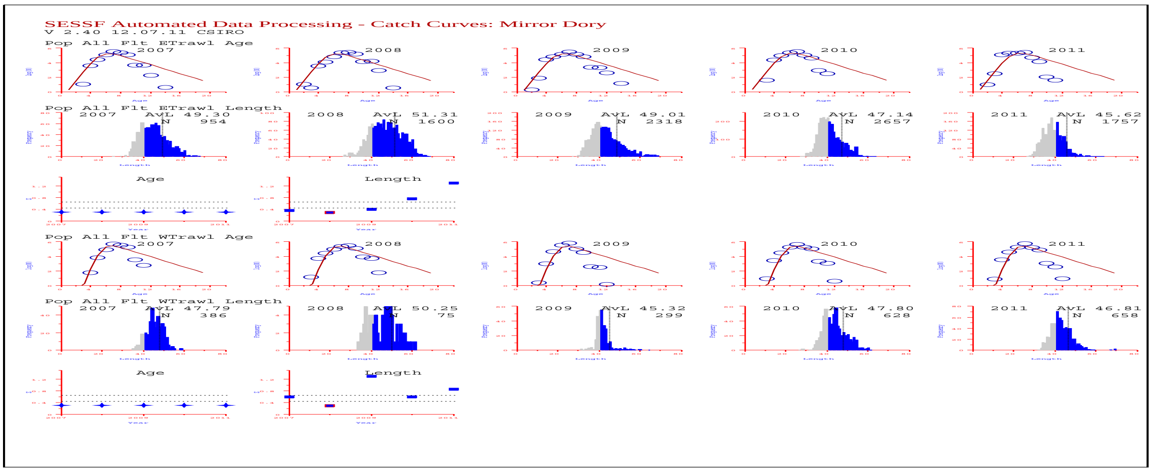
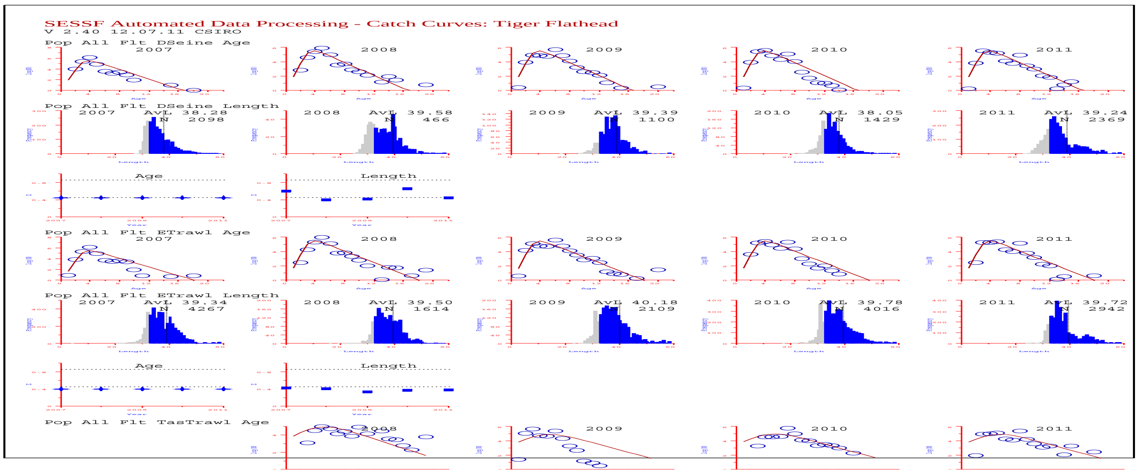


Figure 19.41. Tiger flathead average length results.



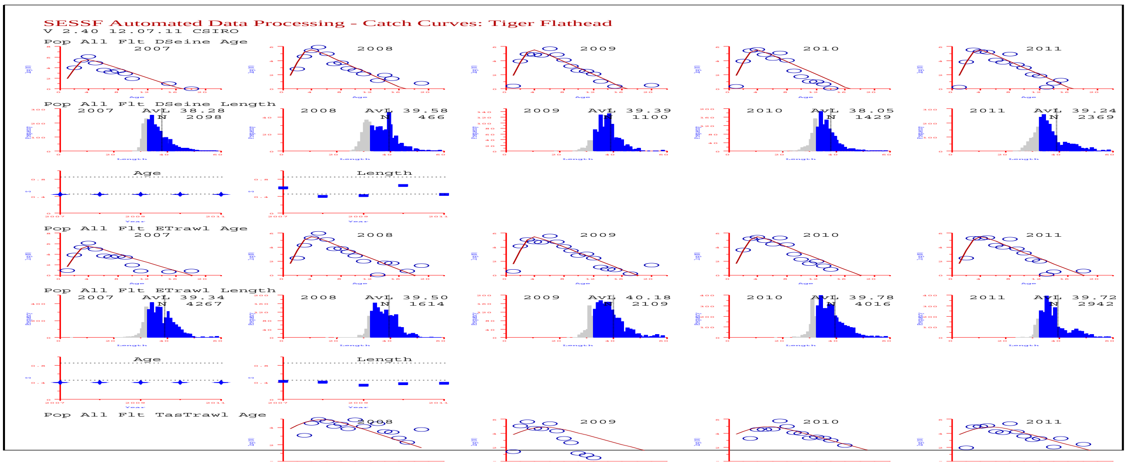


Figure 19.42. Gemfish east average length results.

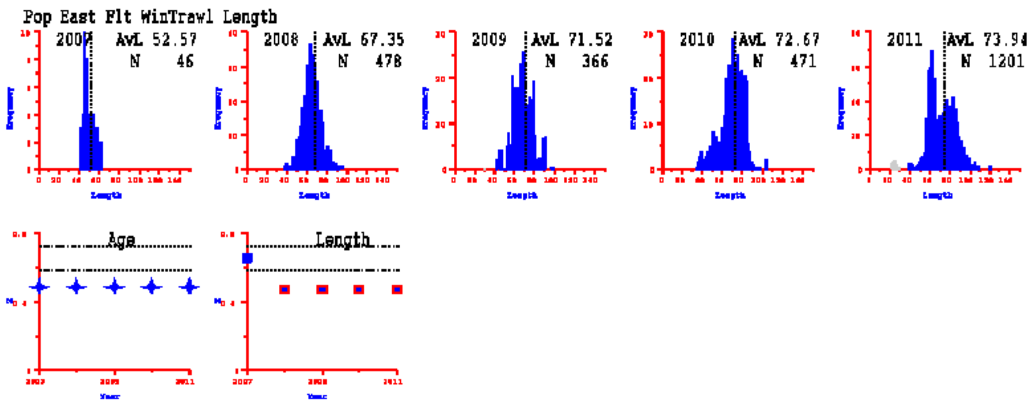


Figure 19.43. Gemfish west average length results.

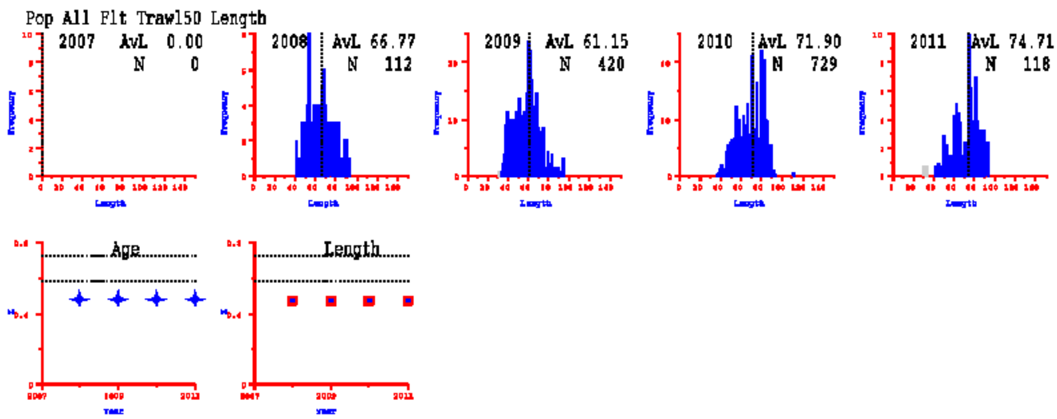


Figure 19.44. Blue grenadier average length results.

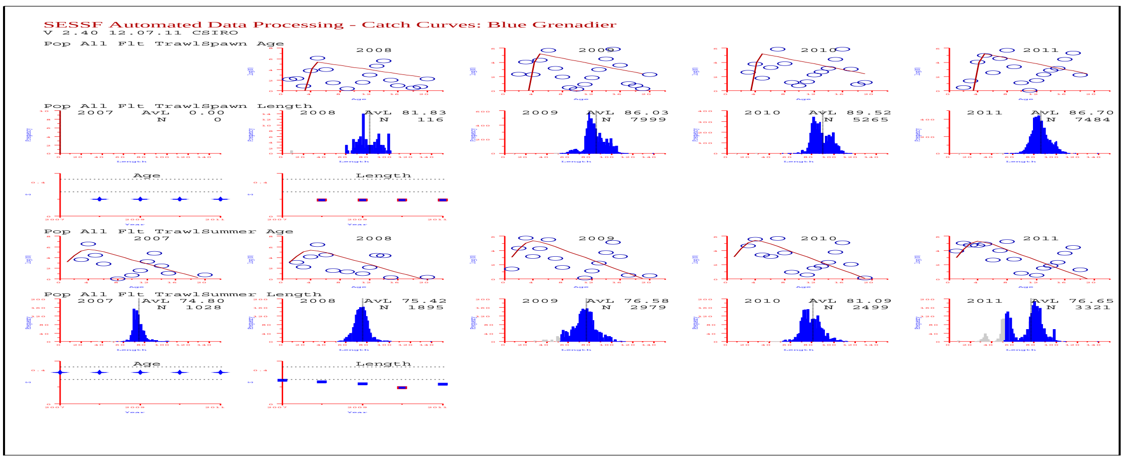


Figure 19.45. Pink ling average length results.

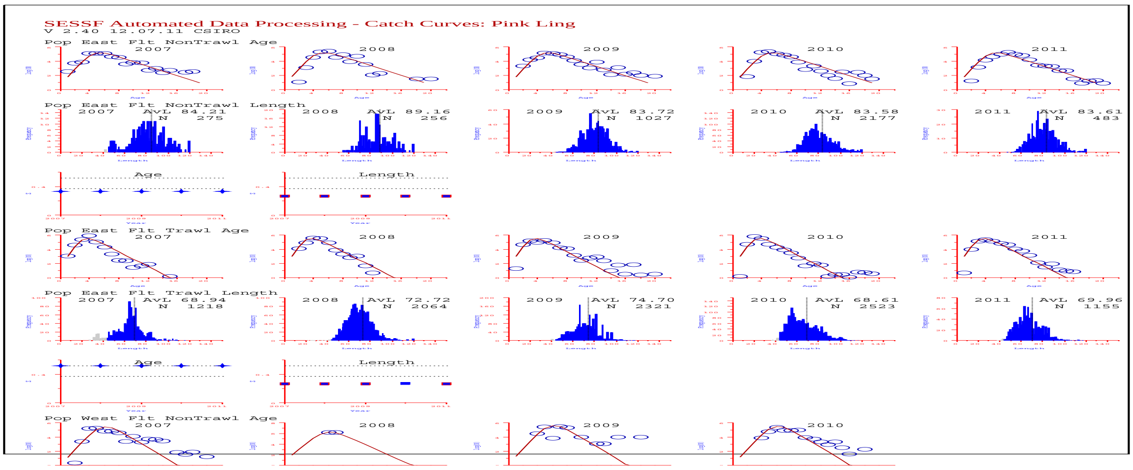


Figure 19.46. Jackass morwong average length results.

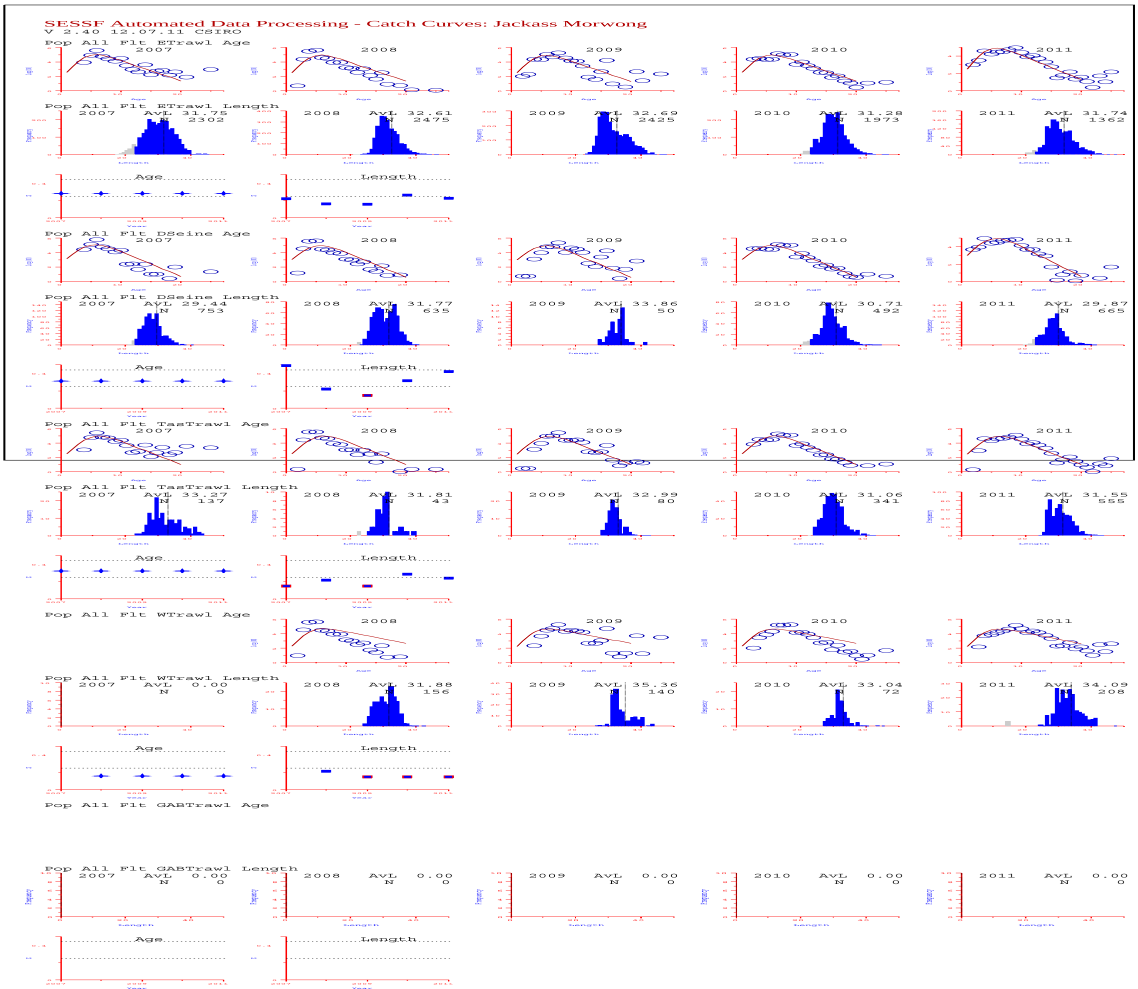


Figure 19.47. Ribaldo average length results.

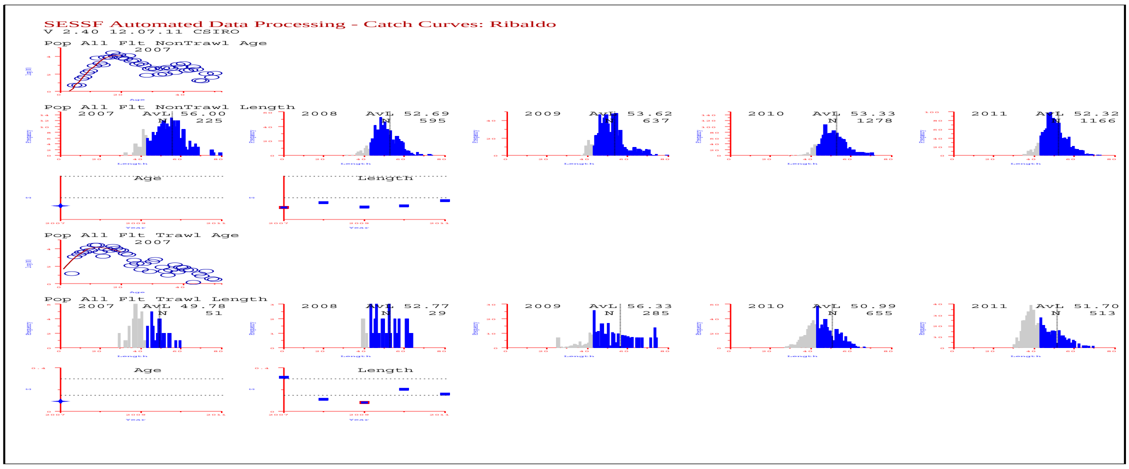
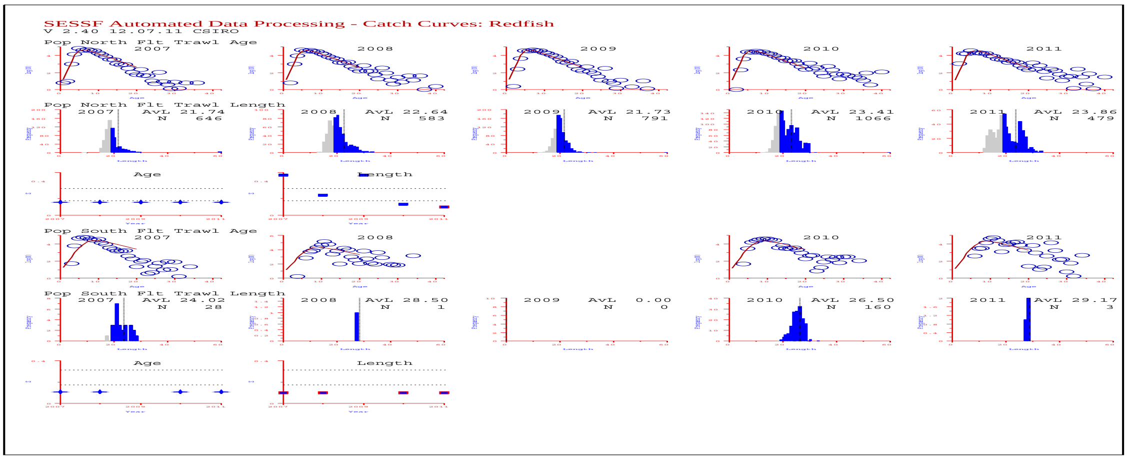


Figure 19.48. Redfish average length results.



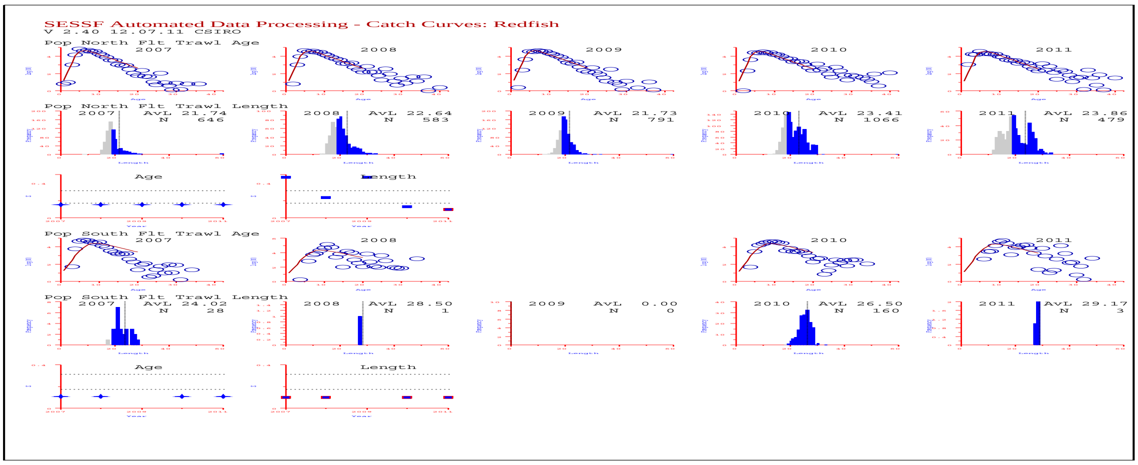


Figure 19.49. Ocean perch average length results. (Port lengths 2007 require revision)

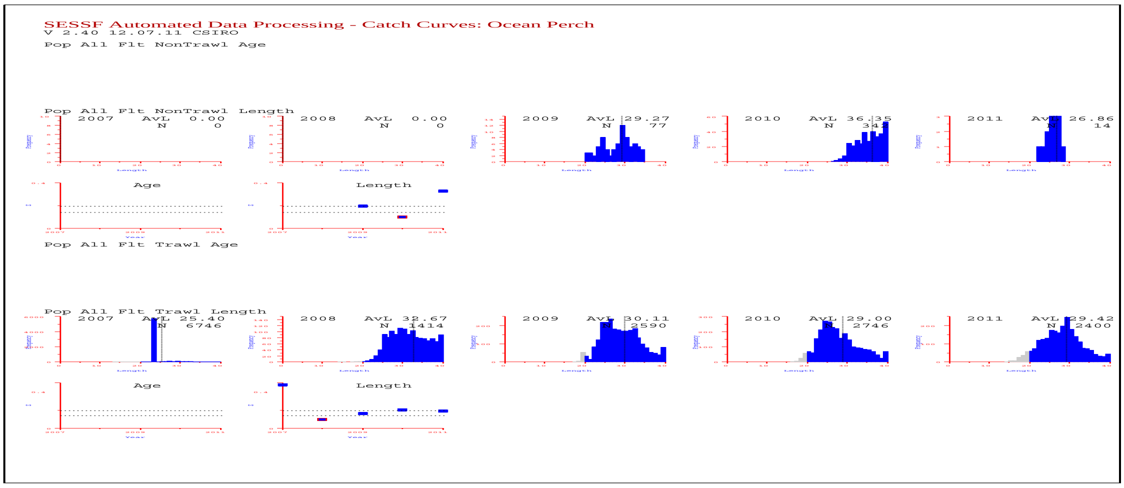
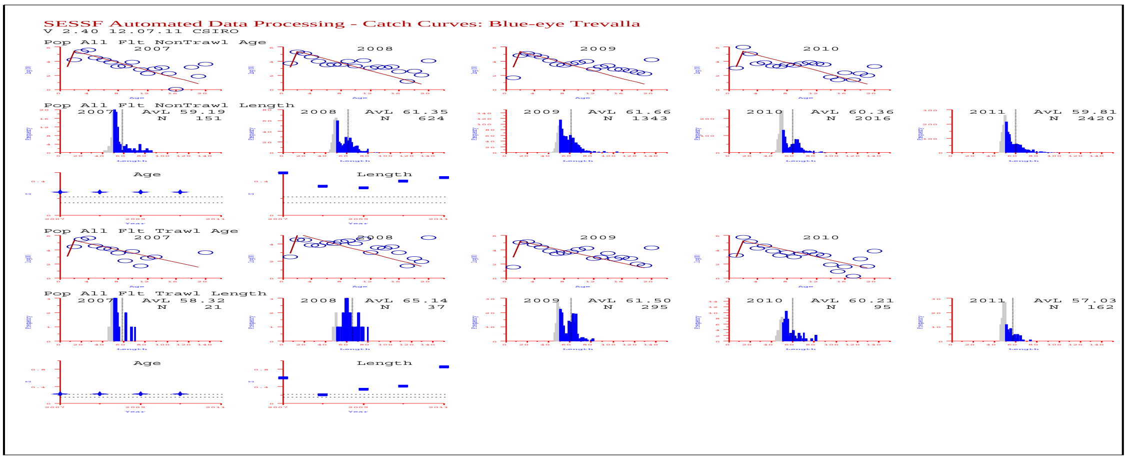


Figure 19.50. Blue eye trevalla average length results.



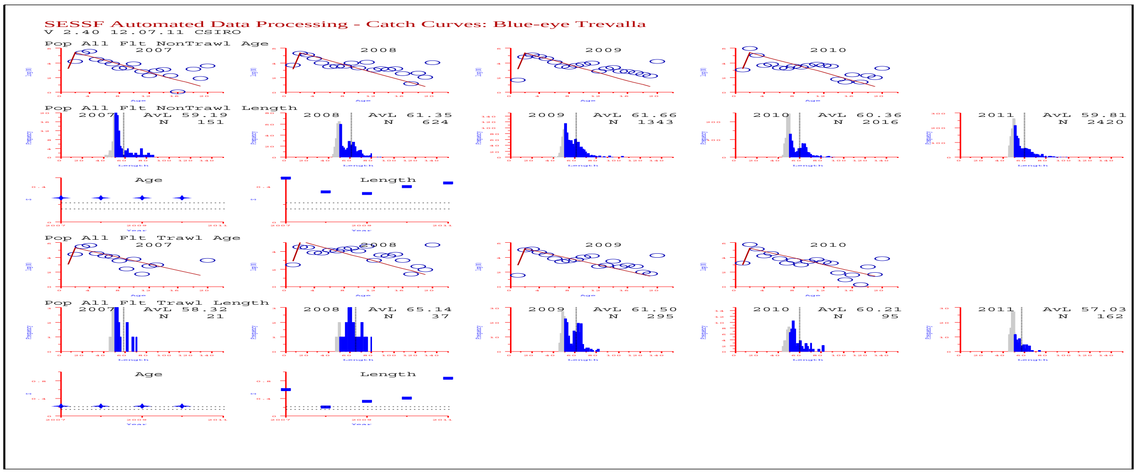


Figure 19.51. Silver trevally average length results.

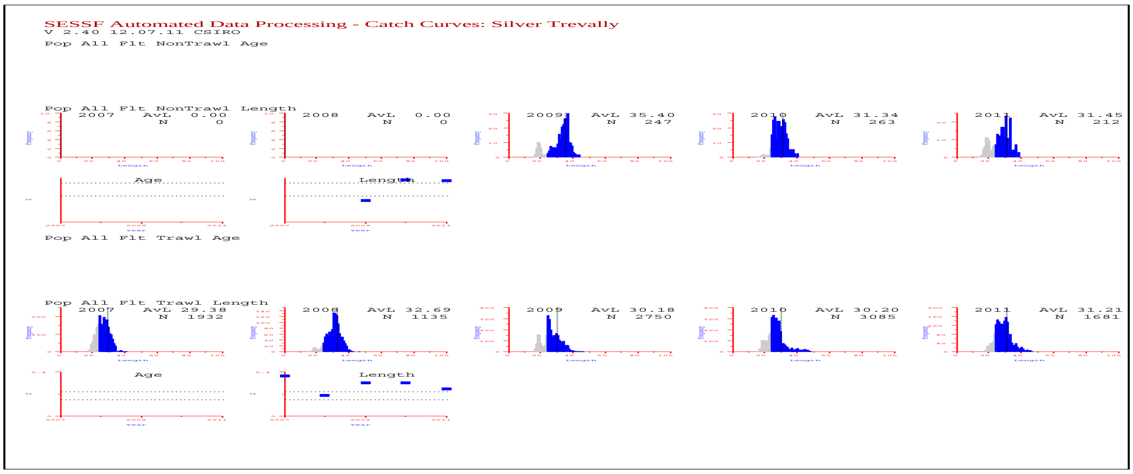


Figure 19.52. Silver warehou average length results.

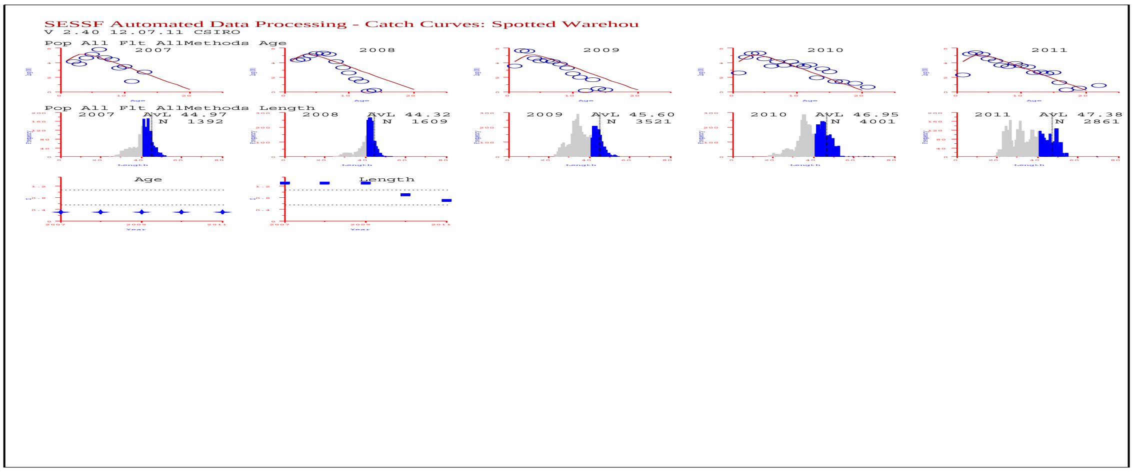


Figure 19.53. Blue warehou average length results.

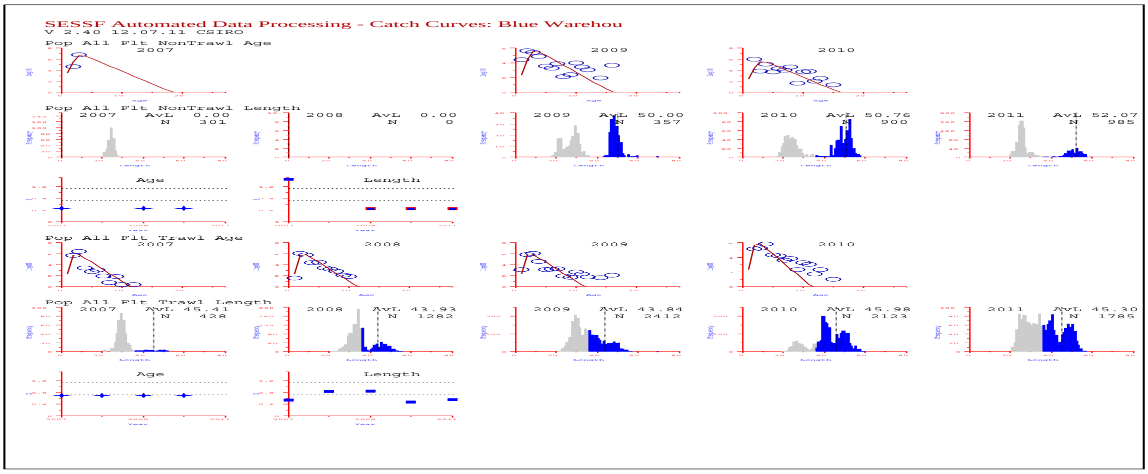
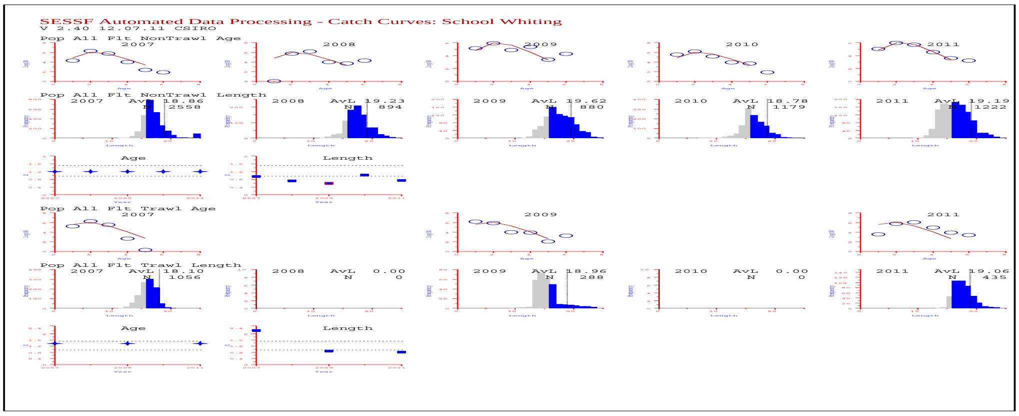


Figure 19.54. School whiting average length results.



19.4 RBC Calculations

A summary of *Z* and current *F* estimates from catch curve analysis is given in Table 2, and the *F* values resulting in 20% and 48% depletion from the previous yield analysis are also shown. Recent *Z* estimates are taken from the values in Figures 19 to 35 from age-based estimates from fleets that take the majority of catches. The actual values chosen for averaging are highlighted in Appendix 1.

At the SESSFRAG meeting in early 2012 it was agreed to allow the investigation of an *M*-based threshold to limit the size of the RBC multiplier produced by Tier 3 analyses. In the results here, F_{cur} has been limited to a lowest possible value of *M*/10. Alfonsino, John dory and mirror dory all reached this threshold, so have had the RBC limited by this rule. Without the limitation, the RBC values were 2,616t, 2,131t and 8,104t respectively.

At Shelf and Slope RAG October 2012 it was agreed to follow the advice from SESSFRAG in 2011 that non-target species MEY target values may be set to F_{spr40} rather than F_{spr48}. In Table 19.2 the F_{spr} target used for RBC calculations is highlighted in bold, and the targets for John dory, redfish, silver trevally and blue warehou are now F_{spr40}. Other species also agreed, but not included in the Tier 3 calculations below were ribaldo and elephant fish.

Table 19.2. *F* reference points, Z_{cur}, C_{cur} and RBC estimates (ribaldo to be included, blue grenadier to be updated).

Species	Fspr20	Fspr40	Fspr48	Zcur	Fcur	p	ymin	ymax	Ccur	Frbc	Limit?	RBC
Alfonsino	**0.479**	0.201	**0.149**	**0.230**	**0.022**	**6.362**	**2002**	**2011**	**188**	**0.149**	**Yes**	**1,196**
John Dory	**0.287**	**0.159**	0.126	**0.370**	**0.036**	**4.145**	**1993**	**2010**	**184**	**0.159**	**Yes**	**763**
Mirror Dory	**0.355**	0.188	**0.147**	**0.310**	**0.030**	**4.626**	**1993**	**2010**	**604**	**0.147**	**Yes**	**2,794**
Tiger Flathead	0.585	0.251	**0.187**	0.425	0.155	1.189	1993	2010				
Gemfish E	0.252	0.143	**0.114**	0.483	0.047	2.337	1993	2011				
Gemfish W	0.252	0.143	**0.114**	0.480	0.047	2.337	2000	2011				
Blue Grenadier	0.244	0.125	**0.097**	0.444	0.255	0.000	1993	2008				
Pink Ling	0.250	0.134	**0.105**	0.282	0.027	3.769	1993	2005				
Morwong East	0.294	0.135	**0.102**	0.487	0.337	0.000	1992	2009				
Morwong West	0.294	0.135	**0.102**	0.160	0.015	6.513	1992	2009				
Ribaldo												
Redfish	**0.213**	**0.098**	0.074	**0.334**	**0.055**	**1.740**	**1992**	**2008**	**2,209**	**0.098**	**No**	**3,843**
Ocean Perch	0.096	0.052	**0.041**	0.261	0.161	0.000	1992	2008				
Blue-eye Trevalla	0.118	0.062	**0.049**	0.272	0.172	0.000	1993	2008				
Silver Trevally	0.121	**0.062**	0.048	0.798	0.698	0.000	1993	2009				
Silver Warehou	0.766	0.347	**0.260**	0.316	0.030	7.747	1992	2010				
Blue Warehou	0.680	**0.348**	0.269	0.697	0.247	1.341	1992	2011				
School Whiting	0.922	0.461	**0.355**	1.198	0.598	0.491	2007	2010				

Notes: Species that were Tier 3 in 2011 are highlighted in bold.
RBC values for alfonsino, John dory, mirror dory and redfish were greater than reference average catches (p>1). Western gemfish, blue grenadier, pink ling, blue-eye trevalla and silver trevally were unable to be assessed using catch curves due to probable dome-shaped selectivity or high recruitment variability.

19.5 References

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Appendix 1 – details of values that were used as estimates of total Z (shown highlighted)

Species	Pop	Flt	Year	Catch	CCType	Iage	Ilen	Zage	Zlen	SSa	SSl
ALFCCRes	All	AllMethods	2007	175.43	1	-99	-99	0.23	-99	224	0
ALFCCRes	All	AllMethods	2008	0	1	-99	-99	0.23	-99	23	0
ALFCCRes	All	AllMethods	2009	14.197	1	-99	-99	0.23	0.53264	148	473
ALFCCRes	All	AllMethods	2010	0.0135	1	-99	-99	-99	-99	0	0
ALFCCRes	All	AllMethods	2011	210.98	1	-99	-99	0.23	0.53264	640	4229
DOJCCRes	All	NonTrawl	2007	5.8498	1	-99	-99	-99	-99	0	0
DOJCCRes	All	NonTrawl	2008	6.9068	1	-99	-99	0.49004	0.54451	611	804
DOJCCRes	All	NonTrawl	2009	6.0869	1	-99	-99	0.49004	0.54451	611	64
DOJCCRes	All	NonTrawl	2010	4.819	1	-99	-99	0.49004	0.54451	611	450
DOJCCRes	All	NonTrawl	2011	11.045	1	-99	-99	0.49004	0.54451	611	525
DOJCCRes	All	Trawl	2007	53.742	1	-99	-99	0.37024	0.42608	611	1062
DOJCCRes	All	Trawl	2008	106.21	1	-99	-99	0.37024	0.42608	611	1573
DOJCCRes	All	Trawl	2009	84.209	1	-99	-99	0.37024	0.42608	611	3363
DOJCCRes	All	Trawl	2010	55.143	1	-99	-99	0.37024	0.42608	611	2603
DOJCCRes	All	Trawl	2011	60.308	1	-99	-99	0.37024	0.42608	611	1890
DOMCCRes	All	ETrawl	2007	204.78	1	-99	-99	0.31024	0.44692	1634	954
DOMCCRes	All	ETrawl	2008	326.32	1	-99	-99	0.31024	0.44692	1634	1600
DOMCCRes	All	ETrawl	2009	343.91	1	-99	-99	0.31024	0.44692	1634	2318
DOMCCRes	All	ETrawl	2010	389.14	1	-99	-99	0.31024	0.44692	1634	2657
DOMCCRes	All	ETrawl	2011	354.12	1	-99	-99	0.31024	0.44692	1634	1757
DOMCCRes	All	WTrawl	2007	66.706	1	-99	-99	0.31024	0.47958	1634	386
DOMCCRes	All	WTrawl	2008	66.053	1	-99	-99	0.31024	0.47958	1634	75
DOMCCRes	All	WTrawl	2009	131.07	1	-99	-99	0.31024	0.47958	1634	299
DOMCCRes	All	WTrawl	2010	187.75	1	-99	-99	0.31024	0.47958	1634	628
DOMCCRes	All	WTrawl	2011	161.89	1	-99	-99	0.31024	0.47958	1634	658
FLDCCRes	All	Trawl	2007	980.85	1	-99	-99	0.54902	0.53618	650	299
FLDCCRes	All	Trawl	2008	783.44	1	-99	-99	0.54902	0.53618	554	467
FLDCCRes	All	Trawl	2009	834.01	1	-99	-99	0.54902	0.53618	465	13911
FLDCCRes	All	Trawl	2010	916.38	1	-99	-99	0.54902	0.53618	290	2502
FLDCCRes	All	Trawl	2011	248.71	1	-99	-99	-99	0.53618	0	1006
FLTCCRes	All	DSeine	2007	1310.7	1	-99	-99	0.44778	0.40306	474	2098
FLTCCRes	All	DSeine	2008	1321.4	1	-99	-99	0.44778	0.40306	714	466
FLTCCRes	All	DSeine	2009	1221.4	1	-99	-99	0.44778	0.40306	1093	1100
FLTCCRes	All	DSeine	2010	1231.4	1	-99	-99	0.44778	0.40306	1134	1429
FLTCCRes	All	DSeine	2011	1170	1	-99	-99	0.44778	0.40306	1130	2369
FLTCCRes	All	ETrawl	2007	1149.6	1	-99	-99	0.40197	0.3163	474	4267
FLTCCRes	All	ETrawl	2008	1390.3	1	-99	-99	0.40197	0.3163	714	1614
FLTCCRes	All	ETrawl	2009	1126.4	1	-99	-99	0.40197	0.3163	1093	2109
FLTCCRes	All	ETrawl	2010	1157.1	1	-99	-99	0.40197	0.3163	1134	4016
FLTCCRes	All	ETrawl	2011	1157.9	1	-99	-99	0.40197	0.3163	1130	2942
FLTCCRes	All	TasTrawl	2007	177.23	1	-99	-99	-99	-99	0	0

FLTCCRes	All	TasTrawl	2008	175.73	1	-99	-99	0.28	0.28	714	101
FLTCCRes	All	TasTrawl	2009	102.03	1	-99	-99	0.28	0.28	1093	176
FLTCCRes	All	TasTrawl	2010	105.25	1	-99	-99	0.28	0.28	1134	303
FLTCCRes	All	TasTrawl	2011	132.18	1	-99	-99	0.28	0.28	1130	538
GEECCRes	East	NonTrawl	2007	7.5442	1	-99	-99	-99	-99	0	0
GEECCRes	East	NonTrawl	2008	15.908	1	-99	-99	0.48	0.64845	625	37
GEECCRes	East	NonTrawl	2009	11.966	1	-99	-99	0.48	-99	396	0
GEECCRes	East	NonTrawl	2010	12.26	1	-99	-99	0.48	0.64845	580	122
GEECCRes	East	NonTrawl	2011	7.258	1	-99	-99	0.48	0.64845	626	551
GEECCRes	East	SumTrawl	2007	18.601	1	-99	-99	0.48296	0.48405	636	299
GEECCRes	East	SumTrawl	2008	27.524	1	-99	-99	0.48296	0.48405	625	1109
GEECCRes	East	SumTrawl	2009	18.679	1	-99	-99	0.48296	0.48405	396	218
GEECCRes	East	SumTrawl	2010	15.054	1	-99	-99	0.48296	0.48405	580	835
GEECCRes	East	SumTrawl	2011	13.643	1	-99	-99	0.48296	0.48405	626	1281
GEECCRes	East	WinTrawl	2007	49.447	1	-99	-99	0.48688	0.48006	636	46
GEECCRes	East	WinTrawl	2008	79.051	1	-99	-99	0.48688	0.48006	625	478
GEECCRes	East	WinTrawl	2009	43.522	1	-99	-99	0.48688	0.48006	396	366
GEECCRes	East	WinTrawl	2010	48.673	1	-99	-99	0.48688	0.48006	580	471
GEECCRes	East	WinTrawl	2011	31.131	1	-99	-99	0.48688	0.48006	626	1201
GEWCCRes	All	NonTrawl	2007	7.0588	1	-99	-99	0.63032	0.48031	722	17
GEWCCRes	All	NonTrawl	2008	9.5857	1	-99	-99	0.63032	0.48031	625	76
GEWCCRes	All	NonTrawl	2009	7.2278	1	-99	-99	-99	-99	0	0
GEWCCRes	All	NonTrawl	2010	9.7676	1	-99	-99	0.63032	0.48031	1167	34
GEWCCRes	All	NonTrawl	2011	12.738	1	-99	-99	0.63032	0.48031	925	321
GEWCCRes	All	Trawl40	2007	4.9823	1	-99	-99	0.48297	0.94	722	27
GEWCCRes	All	Trawl40	2008	4.105	1	-99	-99	0.48297	0.94	625	105
GEWCCRes	All	Trawl40	2009	5.2583	1	-99	-99	0.48297	0.94	1002	129
GEWCCRes	All	Trawl40	2010	11.585	1	-99	-99	0.48297	0.94	1167	137
GEWCCRes	All	Trawl40	2011	14.856	1	-99	-99	0.48297	0.94	925	334
GEWCCRes	All	Trawl50	2007	58.041	1	-99	-99	-99	-99	0	0
GEWCCRes	All	Trawl50	2008	53	1	-99	-99	0.48008	0.48154	625	112
GEWCCRes	All	Trawl50	2009	54.167	1	-99	-99	0.48008	0.48154	1002	420
GEWCCRes	All	Trawl50	2010	78.374	1	-99	-99	0.48008	0.48154	1167	729
GEWCCRes	All	Trawl50	2011	44.479	1	-99	-99	0.48008	0.48154	925	118
GEWCCRes	All	GABTrawl	2007	324.63	1	-99	-99	0.48	0.48	722	29
GEWCCRes	All	GABTrawl	2008	99.371	1	-99	-99	0.48	0.48	625	117
GEWCCRes	All	GABTrawl	2009	48.961	1	-99	-99	-99	-99	0	0
GEWCCRes	All	GABTrawl	2010	42.731	1	-99	-99	0.48	0.48	1167	140
GEWCCRes	All	GABTrawl	2011	17.589	1	-99	-99	-99	-99	0	0
GRECCRes	All	TrawlSpawn	2007	1815.4	1	-99	-99	-99	-99	0	0
GRECCRes	All	TrawlSpawn	2008	2837.6	1	-99	-99	0.19912	0.19905	1848	116
GRECCRes	All	TrawlSpawn	2009	2712.2	1	-99	-99	0.19912	0.19905	2086	7999
GRECCRes	All	TrawlSpawn	2010	3384.3	1	-99	-99	0.19912	0.19905	1642	5265
GRECCRes	All	TrawlSpawn	2011	3553.8	1	-99	-99	0.19912	0.19905	2007	7484
GRECCRes	All	TrawlSummer	2007	1229.3	1	-99	-99	0.36706	0.48737	1574	1028

GRECCRes	All	TrawlSummer	2008	1305.8	1	-99	-99	0.36706	0.48737	1848	1895
GRECCRes	All	TrawlSummer	2009	1144.7	1	-99	-99	0.36706	0.48737	2086	2979
GRECCRes	All	TrawlSummer	2010	1158.1	1	-99	-99	0.36706	0.48737	1642	2499
GRECCRes	All	TrawlSummer	2011	913.14	1	-99	-99	0.36706	0.48737	2007	3321
GRWCCRes	All	TrawlSummer	2007	58.266	1	-99	-99	-99	-99	0	0
GRWCCRes	All	TrawlSummer	2008	3.321	1	-99	-99	-99	-99	0	0
GRWCCRes	All	TrawlSummer	2009	0.5625	1	-99	-99	-99	-99	0	0
GRWCCRes	All	TrawlSummer	2010	5.145	1	-99	-99	-99	-99	0	0
GRWCCRes	All	TrawlSummer	2011	4.8425	1	-99	-99	-99	-99	0	0
GRWCCRes	All	TrawlSpawn	2007	19.055	1	-99	-99	-99	-99	0	0
GRWCCRes	All	TrawlSpawn	2008	0.27	1	-99	-99	0.53872	0.26326	1848	48
GRWCCRes	All	TrawlSpawn	2009	0	1	-99	-99	-99	-99	0	0
GRWCCRes	All	TrawlSpawn	2010	0.5925	1	-99	-99	-99	-99	0	0
GRWCCRes	All	TrawlSpawn	2011	0.5025	1	-99	-99	-99	-99	0	0
LIGCCRes	East	NonTrawl	2007	163.13	1	-99	-99	0.33366	0.278	558	275
LIGCCRes	East	NonTrawl	2008	231.94	1	-99	-99	0.33366	0.278	910	256
LIGCCRes	East	NonTrawl	2009	159.38	1	-99	-99	0.33366	0.278	1122	1027
LIGCCRes	East	NonTrawl	2010	140.36	1	-99	-99	0.33366	0.278	1036	2177
LIGCCRes	East	NonTrawl	2011	159.38	1	-99	-99	0.33366	0.278	1296	483
LIGCCRes	East	Trawl	2007	262.31	1	-99	-99	0.52156	0.51698	558	1218
LIGCCRes	East	Trawl	2008	379.83	1	-99	-99	0.52156	0.51698	910	2064
LIGCCRes	East	Trawl	2009	245.24	1	-99	-99	0.52156	0.51698	1122	2321
LIGCCRes	East	Trawl	2010	298.67	1	-99	-99	0.52156	0.51698	1036	2523
LIGCCRes	East	Trawl	2011	331.68	1	-99	-99	0.52156	0.51698	1296	1155
LIGCCRes	West	NonTrawl	2007	63.409	1	-99	-99	0.61971	0.27802	225	727
LIGCCRes	West	NonTrawl	2008	38.447	1	-99	-99	0.61971	-99	45	0
LIGCCRes	West	NonTrawl	2009	52.321	1	-99	-99	0.61971	0.27802	88	21
LIGCCRes	West	NonTrawl	2010	93.7	1	-99	-99	0.61971	0.27802	177	212
LIGCCRes	West	NonTrawl	2011	145.46	1	-99	-99	-99	-99	0	0
LIGCCRes	West	Trawl	2007	295.7	1	-99	-99	0.36683	0.38321	225	828
LIGCCRes	West	Trawl	2008	226.06	1	-99	-99	0.36683	0.38321	45	133
LIGCCRes	West	Trawl	2009	271.59	1	-99	-99	0.36683	0.38321	88	231
LIGCCRes	West	Trawl	2010	281.67	1	-99	-99	0.36683	0.38321	177	491
LIGCCRes	West	Trawl	2011	368.64	1	-99	-99	0.36683	0.38321	95	182
LIGCCRes	GAB	NonTrawl	2007	75.354	1	-99	-99	-99	0.278	0	107
LIGCCRes	GAB	NonTrawl	2008	102.21	1	-99	-99	0.278	0.278	69	100
LIGCCRes	GAB	NonTrawl	2009	45.784	1	-99	-99	0.278	0.278	93	98
LIGCCRes	GAB	NonTrawl	2010	86.363	1	-99	-99	0.278	0.278	99	1127
LIGCCRes	GAB	NonTrawl	2011	72.47	1	-99	-99	0.278	0.278	113	374
LIGCCRes	GAB	Trawl	2007	15.859	1	-99	-99	-99	-99	0	0
LIGCCRes	GAB	Trawl	2008	1.7864	1	-99	-99	-99	-99	0	0
LIGCCRes	GAB	Trawl	2009	0.132	1	-99	-99	-99	-99	0	0
LIGCCRes	GAB	Trawl	2010	4.699	1	-99	-99	-99	-99	0	0
LIGCCRes	GAB	Trawl	2011	3.137	1	-99	-99	-99	-99	0	0
MOWCCRes	All	ETrawl	2007	234.92	1	-99	-99	0.28158	0.37072	193	2302

MOWCCRes	All	ETrawl	2008	335.84	1	-99	-99	0.28158	0.37072	751	2475
MOWCCRes	All	ETrawl	2009	243.4	1	-99	-99	0.28158	0.37072	620	2425
MOWCCRes	All	ETrawl	2010	199.27	1	-99	-99	0.28158	0.37072	892	1973
MOWCCRes	All	ETrawl	2011	185	1	-99	-99	0.28158	0.37072	855	1362
MOWCCRes	All	DSeine	2007	17.436	1	-99	-99	0.31493	0.25666	193	753
MOWCCRes	All	DSeine	2008	36.779	1	-99	-99	0.31493	0.25666	751	635
MOWCCRes	All	DSeine	2009	18.538	1	-99	-99	0.31493	0.25666	620	50
MOWCCRes	All	DSeine	2010	17.324	1	-99	-99	0.31493	0.25666	892	492
MOWCCRes	All	DSeine	2011	29.4	1	-99	-99	0.31493	0.25666	855	665
MOWCCRes	All	TasTrawl	2007	116.85	1	-99	-99	0.32535	0.86766	193	137
MOWCCRes	All	TasTrawl	2008	121.07	1	-99	-99	0.32535	0.86766	751	43
MOWCCRes	All	TasTrawl	2009	55.817	1	-99	-99	0.32535	0.86766	620	80
MOWCCRes	All	TasTrawl	2010	59.871	1	-99	-99	0.32535	0.86766	892	341
MOWCCRes	All	TasTrawl	2011	50.633	1	-99	-99	0.32535	0.86766	855	555
MOWCCRes	All	WTrawl	2007	121.82	1	-99	-99	-99	-99	0	0
MOWCCRes	All	WTrawl	2008	104.28	1	-99	-99	0.16	0.29543	751	156
MOWCCRes	All	WTrawl	2009	64.952	1	-99	-99	0.16	0.29543	620	140
MOWCCRes	All	WTrawl	2010	40.549	1	-99	-99	0.16	0.29543	892	72
MOWCCRes	All	WTrawl	2011	85.874	1	-99	-99	0.16	0.29543	855	208
MOWCCRes	All	GABTrawl	2007	108.01	1	-99	-99	-99	-99	0	0
MOWCCRes	All	GABTrawl	2008	89.765	1	-99	-99	-99	-99	0	0
MOWCCRes	All	GABTrawl	2009	64.352	1	-99	-99	-99	-99	0	0
MOWCCRes	All	GABTrawl	2010	39.148	1	-99	-99	-99	-99	0	0
MOWCCRes	All	GABTrawl	2011	24.545	1	-99	-99	-99	-99	0	0
REBCCRes	All	Trawl	2007	758.28	1	-99	-99	0.11	0.11	443	141
REBCCRes	All	Trawl	2008	664.9	1	-99	-99	0.11	0.11	561	716
REBCCRes	All	Trawl	2009	463.44	1	-99	-99	0.11	0.11	668	9093
REBCCRes	All	Trawl	2010	275.41	1	-99	-99	0.11	0.11	148	861
REBCCRes	All	Trawl	2011	65.017	1	-99	-99	-99	0.11	0	714
REDCCRes	North	Trawl	2007	171.2	1	-99	-99	0.15487	0.16336	7310	646
REDCCRes	North	Trawl	2008	165.35	1	-99	-99	0.15487	0.16336	7310	583
REDCCRes	North	Trawl	2009	145.52	1	-99	-99	0.15487	0.16336	7310	791
REDCCRes	North	Trawl	2010	136.37	1	-99	-99	0.15487	0.16336	7310	1066
REDCCRes	North	Trawl	2011	76.48	1	-99	-99	0.15487	0.16336	7310	479
REDCCRes	South	Trawl	2007	40.809	1	-99	-99	0.11001	0.11	7677	28
REDCCRes	South	Trawl	2008	16.665	1	-99	-99	0.11001	-99	7677	0
REDCCRes	South	Trawl	2009	12.444	1	-99	-99	-99	-99	0	0
REDCCRes	South	Trawl	2010	13.213	1	-99	-99	0.11001	0.11	7677	160
REDCCRes	South	Trawl	2011	8.8647	1	-99	-99	0.11001	0.11	7677	3
REGCCRes	All	NonTrawl	2007	0.06	1	-99	-99	-99	-99	0	0
REGCCRes	All	NonTrawl	2008	0	1	-99	-99	-99	-99	0	0
REGCCRes	All	NonTrawl	2009	0.035	1	-99	-99	-99	0.1112	0	77
REGCCRes	All	NonTrawl	2010	0	1	-99	-99	-99	0.1112	0	342
REGCCRes	All	NonTrawl	2011	0.005	1	-99	-99	-99	0.1112	0	14
REGCCRes	All	Trawl	2007	0.761	1	-99	-99	-99	0.26111	0	6746
REGCCRes	All	Trawl	2008	0.844	1	-99	-99	-99	0.26111	0	1414

REGCCRes	All	Trawl	2009	1.272	1	-99	-99	-99	0.26111	0	2590
REGCCRes	All	Trawl	2010	1.32	1	-99	-99	-99	0.26111	0	2746
REGCCRes	All	Trawl	2011	1.39	1	-99	-99	-99	0.26111	0	2400
TBECCRes	All	NonTrawl	2007	362.52	1	-99	-99	0.27235	0.375	340	151
TBECCRes	All	NonTrawl	2008	226.22	1	-99	-99	0.27235	0.375	557	624
TBECCRes	All	NonTrawl	2009	311.52	1	-99	-99	0.27235	0.375	960	1343
TBECCRes	All	NonTrawl	2010	238.74	1	-99	-99	0.27235	0.375	743	2016
TBECCRes	All	NonTrawl	2011	187.12	1	-99	-99	-99	0.375	0	2420
TBECCRes	All	Trawl	2007	37.321	1	-99	-99	0.22274	0.26357	340	21
TBECCRes	All	Trawl	2008	35.899	1	-99	-99	0.22274	0.26357	557	37
TBECCRes	All	Trawl	2009	39.343	1	-99	-99	0.22274	0.26357	960	295
TBECCRes	All	Trawl	2010	44.302	1	-99	-99	0.22274	0.26357	743	95
TBECCRes	All	Trawl	2011	23.327	1	-99	-99	-99	0.26357	0	162
TRECCRes	All	NonTrawl	2007	2.5192	1	-99	-99	-99	-99	0	0
TRECCRes	All	NonTrawl	2008	1.9973	1	-99	-99	-99	-99	0	0
TRECCRes	All	NonTrawl	2009	1.0371	1	-99	-99	-99	0.61157	0	247
TRECCRes	All	NonTrawl	2010	25.114	1	-99	-99	-99	0.61157	0	263
TRECCRes	All	NonTrawl	2011	0.2565	1	-99	-99	-99	0.61157	0	212
TRECCRes	All	Trawl	2007	129.81	1	-99	-99	-99	0.7984	0	1932
TRECCRes	All	Trawl	2008	101.86	1	-99	-99	-99	0.7984	0	1135
TRECCRes	All	Trawl	2009	142.53	1	-99	-99	-99	0.7984	0	2750
TRECCRes	All	Trawl	2010	203.27	1	-99	-99	-99	0.7984	0	3085
TRECCRes	All	Trawl	2011	186.93	1	-99	-99	-99	0.7984	0	1681
TRSCCRes	All	AllMethods	2007	1797.6	1	-99	-99	0.3157	1.29926	316	1392
TRSCCRes	All	AllMethods	2008	1378.1	1	-99	-99	0.3157	1.29926	547	1609
TRSCCRes	All	AllMethods	2009	1285.1	1	-99	-99	0.3157	1.29926	821	3521
TRSCCRes	All	AllMethods	2010	1188.8	1	-99	-99	0.3157	1.29926	822	4001
TRSCCRes	All	AllMethods	2011	1106.5	1	-99	-99	0.3157	1.29926	852	2861
TRTCCRes	All	NonTrawl	2007	1.6461	1	-99	-99	0.46011	1.44933	123	301
TRTCCRes	All	NonTrawl	2008	6.6546	1	-99	-99	-99	-99	0	0
TRTCCRes	All	NonTrawl	2009	3.8073	1	-99	-99	0.46011	1.44933	274	357
TRTCCRes	All	NonTrawl	2010	11.384	1	-99	-99	0.46011	1.44933	428	900
TRTCCRes	All	NonTrawl	2011	4.2449	1	-99	-99	-99	1.44933	0	985
TRTCCRes	All	Trawl	2007	170.06	1	-99	-99	0.69743	0.86593	123	428
TRTCCRes	All	Trawl	2008	159.26	1	-99	-99	0.69743	0.86593	597	1282
TRTCCRes	All	Trawl	2009	117.14	1	-99	-99	0.69743	0.86593	274	2412
TRTCCRes	All	Trawl	2010	123.18	1	-99	-99	0.69743	0.86593	428	2123
TRTCCRes	All	Trawl	2011	83.546	1	-99	-99	-99	0.86593	0	1785
WHSCCRes	All	NonTrawl	2007	444	1	-99	-99	1.19757	1.5321	415	2558
WHSCCRes	All	NonTrawl	2008	393.34	1	-99	-99	1.19757	1.5321	479	894
WHSCCRes	All	NonTrawl	2009	425.43	1	-99	-99	1.19757	1.5321	421	880
WHSCCRes	All	NonTrawl	2010	360.1	1	-99	-99	1.19757	1.5321	620	1179
WHSCCRes	All	NonTrawl	2011	308.17	1	-99	-99	1.19757	1.5321	581	1222
WHSCCRes	All	Trawl	2007	85.053	1	-99	-99	1.36906	1.5969	415	1056
WHSCCRes	All	Trawl	2008	69.16	1	-99	-99	-99	-99	0	0

WHSCCRes	All	Trawl	2009	29.744	1	-99	-99	1.36906	1.5969	421	288
WHSCCRes	All	Trawl	2010	38.438	1	-99	-99	-99	-99	0	0
WHSCCRes	All	Trawl	2011	50.689	1	-99	-99	1.36906	1.5969	581	435

20. Tier 4 Analyses in the SESSF, including Deep Water Species. Data from 1986 – 2011

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20.1 Summary

Thirty four TIER 4 analyses are documented here which included a number of species where spatial information was available (Blue Warehou and Mirror Dory) leading to analyses for the east and west presumed stock regions. There are also Tier 4 analyses for some species where discard estimates were included in the analysis of catch rates. In addition, some non-key commercial species were assessed at the RAG's request, at a target assuming a proxy of 40%B_0 as well as a proxy target assuming 48%B_0.

Six fisheries are assessed using Tier 4 methodology: BlueEye Trevalla, Blue Warehou (split east and west), Inshore Ocean Perch and Offshore Ocean Perch, Redfish, Royal Red Prawns, and Silver Trevally. Three fisheries generated zero RBCs and these were Blue Warehou, Jackass Morwong and Redfish.

Alternative analyses were provided for Redfish and Inshore Ocean Perch in which discards were included in the estimation of the catch rate trends. The inclusion of discards in estimating catch rates adds a great deal of noise to the CPUE trends so the uncertainty in these analyses expands. At the same time it is not clear whether to remove the discards from the RBC to generate a TAC or not. The use of this approach for setting RBCs needs further discussion and examination.

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

TIER 4 analyses require, as a minimum, knowledge of the time series of total catches and of catch rates, either standardized or simple geometric mean catch rates. This year, only standardized catch rates were used except where discards were explicitly included in the analyses.

The TIER 4 analyses conducting this year used the analytical method developed and tested in 2008 and 2009. This has the capacity to provide advice that will manage a fishery in such a manner that it should achieve the target catch rate derived from the chosen reference period. However, the TIER 4 control rule can only succeed if catch

rates do in fact reflect stock size. Many factors could contribute to make this assumption fail so care needs to be taken when applying this control rule.

To ensure consistency and provide for efficient operation once data becomes available, standard analyses were set up in the statistical software, R, which provided the results as the tables and graphs required for the TIER4 analyses. Both the data and results for each analysis are presented for transparency. The TIER 4 harvest control rule formulation essentially uses a ratio of current catch rates with respect to selected limit and target reference points to calculate a scaling factor. This scaling factor is applied to the target catch to generate an RBC. In all cases where individual attention was required by a particular analysis it was more difficult to automate analyses and these therefore took a disproportionate amount of time.

20.2 Summary of RBCs and Discards

The Recommended Biological Catch from this year's analyses are compared (Table 20.1) with those from the previous three years (Haddon, 2010, 2011b). Blue Warehou and Mirror Dory are sub-divided spatially as east and west. Those species where the Tier 4 rule is not used to set a TAC have the RBC, given in the specific sections throughout the document, replaced with NA.

The upper group of species are those whose TAC is determined using the Tier 4 and the lower group the remainder.

In addition, this year, a number of species were assessed using a proxy target of 48% and of 40% B0. In all such cases the RBC, if it starts above zero, will increase simply because the ratio of the current average catch rate to the new proxy target of 40% will be greater than the ratio at a proxy target of 48% (Table 20.2).

Table 20.1. TIER 4 outcomes by species. The RBC in tonnes, while the weighted discards are a percentage. RBC09 are the 2009 estimates and RBC10 are this year's estimates. For those species where the total catches have been sub-divided (Blue Warehou, Silver Trevally, Ocean Perch, and Mirror Dory) the sub-division of catches and discards was done using the ratio of catches, by the respective areas, observed in the catch effort database. Discards t is the weighted estimate of the discards in 2013.

Species	RBC09	RBC10	RBC11	RBC12	Discard t
Blue Eye Trevalla AL	536	521	415	288	4.022
Blue Warehou	0	0	0	0	44.954
Blue Warehou East	0	0	0	0	6.763
Blue Warehou West	0	0	0	0	38.191
Ocean Perch Inshore	25	26	35	43	193.067
Ocean Perch Inshore D	NA	NA	95	126	193.067
Ocean Perch Offshore	219	193	215	196	36.906
Redfish	62	0	0	0	52.107
Redfish Discards	NA	NA	0	0	52.107
Royal Red Prawn	336	351	276	352	6.672
Silver Trevally	649	754	863	980	6.582
Deep Water Taxa					
Cascade Smooth Oreo				Catch < 10t	12.3
Non-Cascade Smooth Oreo				Catch < 10t	12.3
Mixed Oreos				132.213	16.2
Eastern Deepwater Sharks				Catch < 10t	2.8
Western Deepwater Sharks				Catch < 10t	2.8
Alfonsino				NA	0.0
Non-Tier4 Species					
Blue Grenadier	639	729	645	NA	381.989
Flathead	2684	3071	3129	NA	353.129
Gemfish Eastern	324	150	225	NA	141.554
Gemfish Western	102	93	109	NA	80.108
Jackass Morwong	0	0	0	NA	43.680
John Dory	19	35	25	NA	22.597
Mirror Dory	381	422	423	NA	0.350
Mirror Dory East	NA	569	544	NA	182.545
Mirror Dory West	NA	NA	161	NA	78.441
Pink Ling	347	337	320	NA	30.850
Ribaldo	160	202	197	NA	4.954
School Whiting	1213	1236	1212	NA	36.575
Silver Warehou	1690	1507	1348	NA	240.987

Table 20.2. Comparison of the calculated RBCs for those species/stock combinations that were assessed using catch rates that included the effects of discards and that used alternative proxy targets of 48% and 40% B_0.

Species/Stock	Proxy Target %	CPUE	RBC
Inshore Ocean Perch	48	Discard	125.661
Inshore Ocean Perch	40	Discard	173.993
Offshore Ocean Perch	48	Discard	204.026
Offshore Ocean Perch	40	Discard	282.500
Offshore Ocean Perch	48		196.498
Offshore Ocean Perch	40		272.077
John Dory	48		NA
John Dory	40		NA
Redfish	48		NA
Redfish	48	Discard	NA
Ribaldo	48		232.054
Ribaldo	40		321.309

20.3 Introduction

20.3.1 Tier 4 Harvest Control Rule

The TIER 4 harvest control rules are the default procedure applied to species for which only limited information is available; specifically no reliable information on either current biomass levels or current exploitation rates.

Ideally, in line with the notion of being more precautionary in the absence of information, the outcome from these analyses should be more conservative than those available from higher TIER analyses; this is now explicitly implemented by imposing a 15% discount factor on the RBC as a precautionary measure unless there are good reasons for not imposing such a discount on particular species. The application of the discount factor will occur unless RAGs generate explicit advice that alternative equivalent precautionary measures are in place (such as spatial or temporal closures) or that there is evidence of historical stability of the stock at current catch levels (AFMA, 2009).

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

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

20.4 Methods

20.4.1 TIER 4 Harvest Control Rule

The data required are time series of catches and catch rates. The analyses have been conducted on total catches across the entire SESSF (including State catches, SEF2 landing records, and any discards). For some species, where there is only a single stock and a single primary fishing method, analyses are presented using standardized CPUE data (Haddon, 2012). For other species, there may be multiple stocks or areas or multiple methods and selecting which time series of catch rates to use in the analyses is not always straightforward. In those cases, the standardized time series for the method now accounting for the majority of current catch was used.

All 2010 data relating to catches and discards, from both State waters and SEF2 data sets, were provided by AFMA, with initial processing by Dr Neil Klaer and Dr Judy Upston of CSIRO. All catch rate data were derived from the standard commercial catch and effort database processed from the AFMA data by Mike Fuller of CSIRO Hobart.

Standard analyses were set up in the statistical software, R (2009), which provided the tables and graphs required for the TIER4 analyses. The data and results for each analysis are presented for transparency. The TIER 4 harvest control rule formulation essentially uses a ratio of current catch rates with respect to the selected limit and target reference points to calculate a scaling factor for the current year (SF_t). This scaling factor is applied to the target catch to generate an RBC. To generate a TAC, known discards and State catches are first removed and then, if applicable, the 15% discount is applied. The TAC calculations are conducted by AFMA. This report focusses on providing the estimates of the Recommended Biological Catches.

$$\text{Scaling Factor } = SF_t = \max\left(0, \frac{\overline{CPUE} - CPUE_{\text{lim}}}{CPUE_{\text{targ}} - CPUE_{\text{lim}}}\right) \tag{1}$$

$$RBC = C_{\text{targ}} \times SF_t \tag{2}$$

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

$$\begin{array}{l|l} RBC_y = 1.5RBC_{y-1} & RBC_y > 1.5RBC_{y-1} \\ RBC_y = 0.5RBC_{y-1} & RBC_y < 0.5RBC_{y-1} \end{array} \tag{3}$$

where

RBC_y is the RBC in year y

$CPUE_{targ}$ is the target CPUE for the species; Eq. (5)

$CPUE_{lim}$ is the limit CPUE for the species = 0.4 * $\text{CPUE}_{\text{targ}}$

$\overline{CPUE}$ the average CPUE over the past *m* years; *m* tends to be the most recent four years.

C_{targ} is a catch target derived from a period of historical catch that has been identified as a desirable target in terms of CPUE, catches and status of the fishery, e.g. 1986 – 1995 (Table 20.3). This is an average of the total removals for the selected reference period, including any discards; Eq. (4).

$$C_{\text{targ}} = \frac{\sum_{y=yr1}^{yr2} L_y}{(yr2 - yr1 + 1)} \tag{4}$$

where L_y represents the landings in year y.

$$CPUE_{\text{targ}} = \frac{\sum_{y=yr1}^{yr2} CPUE_y}{(yr2 - yr1 + 1)} \tag{5}$$

where $CPUE_y$ is the catch rate in year y, *yr2* and *yr1* represent the last and the first years in the reference period respectively.

For each species a table of landings and of standardized catch rates was assembled. These included all catches (Commonwealth landings, Non-trawl catches, combined State catches, and discards). The State catches are available back to 1994 and non-trawl catches are from 1998. Catches prior to 1994 are either taken from an historical catch database or, if no data is available for the species, then they are taken from the AFMA

GenLog Catch and Effort database. The catch rates are standardized, usually from 1986, using methods described in Haddon (2012).

Percent discards are estimated from ISMP observations from 1998 to the current year. Discards for earlier years, prior to ISMP sampling, are estimated by taking the overall average percent discard from 1998 to the 2006 and applying that discard rate to the reported landings for the earlier years. The year 2006 was selected as the final year as discarding practices altered at about that time following the structural adjustment and the introduction of the Harvest Strategy Policy. For Eastern Gemfish the average discard rate was determined for 1998-2002 to allow for the non-target nature of the fishery following 2002. The calculation of the earlier discards is done so that the total catches can be estimated even though only the landed catches are available. To calculate the discards for a given year we used

$$D_y = \frac{C_y \bar{D}_{98-06}}{\left(1 - \bar{D}_{98-06}\right)} \tag{6}$$

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

$$D_{CUR} = (1.0D_{y-1} + 0.5D_{y-2} + 0.25D_{y-3} + 0.125D_{y-4})/1.875 \tag{7}$$

Where D_{CUR} is the estimated discard rate for the coming year *y*, D_{y-1} is the discards rate in year *y-1*. The discard rate in year *y* is the ratio of discards to the sum of landed catches plus those discards (this can vary between 0 – 100%):

$$D_y = \frac{Discard_y}{\left(Catches_y + Discard_y\right)} \tag{8}$$

For each species, reference years were selected by the RAGs to generate estimates of target catches and target catch rates. In addition, a decision was required as to whether the fishery could be considered as fully developed or otherwise (Table 20.3). Where a fishery was not considered to be fully developed the target catch rate, $CPUE_{targ}$, was divided by two as a proxy for expected changes to catch rates as the fishery develops and the resource stock size declines towards the target of 48% unfished biomass.

Plots are given of the total removals illustrating the target catch level. In addition, the standardized catch rates are illustrated with the target catch rate and the limit catch rate. Finally, where the data is available, plots are given of the Total removals contrasted with State removals, and of discards and non-trawl catches.

20.4.2 Data Manipulations

The default reference years were 1986-1995, but various species required different reference years to account for the specific development of each fishery; these are noted in each analysis. In addition, Silver Warehou and Ribaldo were two fisheries where the state of development was such that the exhibited catch rates were unlikely to be representative of a developed fishery and so the target catch rates were halved; these details are provided in Table 20.3.

20.4.3 The Inclusion of Discards

Some species, especially redfish (*Centroberyx affinis*) and inshore Ocean Perch (*Helicolenus percoides*), have experienced high levels of discarding but the reported catch rates relate only to the estimated landed weights. In those species where discarding makes up a significant proportion of the catch (in some years more redfish were discarded than landed and more inshore ocean perch tend to be discarded than landed) it is reasonable to ask how the discards would have affected catch rates. This is an important question because standardized commercial catch rates are used in Australian stock assessments as an index of relative abundance (Haddon, 2010a, b); if ignoring discards leads to a consistent bias this could affect the outcome of the assessments and thus, the assessments should become aware of the effects of discards.

Catch rates are used in assessments as an index of relative abundance through time and it is the trends exhibited by the catch rates that are important rather than their absolute values. If the discard levels are relatively constant through time and evenly distributed amongst the fleet, then their inclusion would not be expected to influence the trends in catch rates except to add noise. In all cases the discard rates are estimates based on sub-sampling the fleet of vessels. That the estimates are uncertain can be seen simply by considering the summary data tables in this document; where discards rates are not low they are very variable between years. Redfish provide an extreme where in 1998 the estimate was 2324 t, which was nearly 56 % of the total catch, while in 1999 discards estimated at only 69 t, making up on about 5 % of the total catch. So in those cases where discard levels are low, adding ion discards to the estimation of catch rates is not expected to alter outcomes.

For those species, such as redfish and ocean perch, where discard rates are much higher it was decided to include those estimated catches to determine their effect on the outcome of the Tier 4 analyses. In 2010 it was concluded that while the inclusion of discards contributed a great deal of noise to the analyses, for those species where discarding made up significant proportions of the overall catch the discard augmented catch rates should be examined each year as a sensitivity analysis to contrast with the outcome from the un-augmented catch rates (Haddon, 2010).

20.4.4 The Analyses Including Discards

Discard rates cannot simply be added to known catches on the way to calculating catch rates. The standardized catch rates are estimated from individual catch and effort records but the estimates of discards are summary estimates for each fishery. While a method for incrementing the standardized catch rates has been developed it should be noted that this ignores all complications relating to unknown aspects of discarding behaviour (is the discard rate constant across all catch sizes, across all vessels, across all areas? etc). This means that including discard catches into the annual catch rate estimates introduces an unknown amount of uncertainty into the analysis. It should also be noted that the discard estimates are highly variable from year to year and derive from relatively small samples of all trips contributing to catches.

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

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

$$\hat{I}_{R,t} = \frac{\sum C_t}{\sum E_t} \tag{9}$$

where $\hat{I}_{R,t}$ is the ratio mean catch rate for year t, ΣC_t is the sum of landed catches in year t, and ΣE_t is the sum of effort (as hours trawled) in year t. If ΣD_t is the sum of discards in year t then the discard incremented ratio mean catch rate would be

$$\hat{I}_{D,t} = \frac{\sum C_t + \sum D_t}{\sum E_t} \tag{10}$$

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

$$\hat{I}_{D,t} = \left[\left(\sum D_t / \sum C_t \right) + 1 \right] \times I_t \tag{11}$$

where I_t is the catch rate estimate to be modified by the inclusion of discards. If this is the ratio mean from Equ (9) then the augmented catch rates would be identical to those produced by Equ (10). In practice, the catch rates used with the multiplier are the standardized catch rates from Haddon (2010a).

In the case of redfish and inshore ocean perch the discard augmented standardized mean catch rates were calculated, and compared visually with the geometric mean and original standardized catch rates. After the re-analysis of the catch rates these can be introduced into the TIER 4 analysis for Inshore Ocean Perch using the standard methods as described in Haddon (2010b).

Table 20.3. Characteristics used in the TIER 4 method. If a species is not considered to be fully fished during the reference period then the target catch rate is to be divided by two.

Species	Reference Years	Fully Fished by Reference Period	First year with catches > 100t.
Blue Eye Trevalla ALDL	1997-2006	1	1997
Blue Warehou	1986-1995	1	1986
Blue Warehou East	1986-1996	1	1986
Blue Warehou West	1986-1997	1	1986
Ocean Perch Inshore	1986-1995	1	1986
Ocean Perch Inshore Discards	1986-1996	1	1986
Ocean Perch Offshore	1986-1997	1	1986
Royal Red Prawn	1986-1995	1	1986
Silver Trevally	1992-2001	1	1986
Blue Grenadier	1986-1995	1	1986
Flathead	1986-1995	1	1986
Eastern Gemfish	1993-2002	1	1986
Western Gemfish	1992-2001	1	1992
Jackass Morwong	1986-1995	1	1986
John Dory	1986-1995	1	1986
Mirror Dory	1986-1995	1	1986
Mirror Dory East	1986-1995	1	1986
Mirror Dory West	1996-2005	1	1996
Pink Ling	1986-1995	1	1986
Redfish	86-90;99-03	1	1986
Redfish Discards	86-90;99-04	1	1986
Ribaldo	1995-2004	0.5	1995
School Whiting	1986-1995	1	1986
Spotted/Silver Warehou	1986-1995	0.5	1986

20.4.5 Selection of Reference Periods

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

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

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

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

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

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

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

20.4.6 Treatment of Non-Target Species

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

20.4.7 The Assumption underlying the Tier 4

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

- There is a linear relationship between catch rates and exploitable biomass; if there is hyper-stability (catch rates remain stable while stock size changes) or hyper-depletion (catch rates decline much faster than stock size changes) then the standard Tier 4 analysis would provide biased results.

- The character of the estimated catch rates has not changed in significant ways through the period from the start of the reference period to the end of the most recent year; If there has been significant effort creep altering the catchability, or there have been changes to the fleet that have altered the relative efficiency of the vessels fishing then the comparability of the catch rates now relative to the target period may be compromised, which would obviously reduce the responsiveness of the Tier 4 method to change.
- The reference period provides a good estimate of the stock when at a depletion level of 48% unfished spawning biomass; the Tier 4 method is based on catch rates and thus relates to exploitable biomass and not spawning biomass. As a minimum the reference period will refer to a period when the stock was in an acceptable, productive and sustainable state. But there can be no guarantees that the target aimed for is really $B_{48\%}$.

20.5 Results

20.5.1 Blue Eye (TBE – 37445001 – Hyperoglyphe antarctica)

Table 20.4 Blue eye Trevalla data for the TIER 4 calculations. Total is the sum of Discards, State, Non Trawl, SEF2, and ECDW catches. All values in Tonnes. CE is the standardized catch rate for all Zones 10 to 50 in depths 0 – 1000m (Haddon, 2012). GeoMean is the geometric mean catch rates. Discards are estimates from 1998 to present. The ratio of discards to catch over the 1998 – 2006 period was used to estimate the discards between 1986 and 1997, the proportion of which is the PDiscard.

Year	Catch	Discards	Total	State	Non-T	PDiscard	CE	GeoMean
1997	732.786		732.786	620.157	0.000	1.21	1.8553	258.2795
1998	599.413	0.000	599.413	123.012	380.439	0.00	1.2439	226.1524
1999	706.643	0.000	706.643	132.608	464.658	0.00	1.1126	189.1263
2000	743.525	37.000	780.525	89.462	565.410	4.74	1.0566	177.6127
2001	665.345	33.000	698.345	77.613	478.397	4.73	1.1035	202.9873
2002	615.379	0.100	615.479	102.362	427.969	0.02	0.8559	163.8436
2003	650.952	0.160	651.112	51.623	556.565	0.02	0.9295	148.5823
2004	715.134	1.400	716.534	64.457	566.917	0.20	1.0215	91.4807
2005	549.140	0.000	549.140	55.557	450.678	0.00	0.8194	88.2645
2006	607.945	0.060	608.005	44.095	496.743	0.01	0.9396	121.2856
2007	638.412	2.808	641.220	53.102	536.267	0.45	1.1791	333.7817
2008	408.027	0.993	409.020	34.980	338.852	0.24	0.7867	214.3734
2009	478.452	0.000	478.452	35.090	404.049	0.00	0.8701	259.8521
2010	442.893	0.142	443.035	42.997	358.784	0.03	0.5634	142.9654
2011	492.825	7.347	500.172	33.744	430.038	1.48	0.6629	177.7306

Discards make up approximately 1.2 % of the catch over the 1998-2006 period.
The catch rate time series used came from the combined autolongline and drop line fishery.

Table 20.5 RBC calculations for Blue Eye. C_{targ} and $CPUE_{targ}$ relate to the period 1997-2006, $CPUE_{Lim}$ is 40% of the target, and $\overline{CPUE}$ is the average catch rate over the last four years. The RBC calculation does not account for predicted discards of predicted State catches. Wt_Discard is the weighted average discards from the last four years, as with Equ (7).

Ref_Year	1997-2006
CE_Targ	1.0938
CE_Lim	0.4375
CE_Recent	0.7208
Wt_Discard	4.022
Scaling	0.4316
Last Year's TAC	
C_{targ}	665.798
RBC	**287.376**

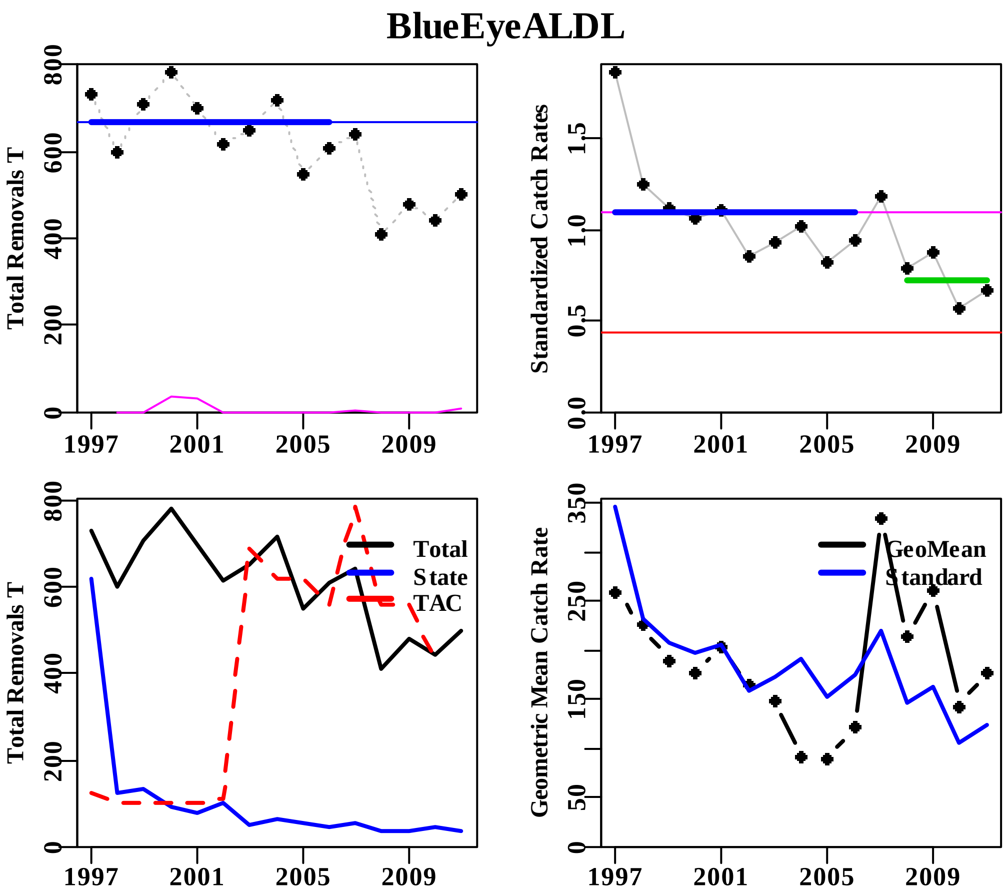

Figure 20.1 Blue Eye Trevalla. Top left is the total removals with the fine line illustrating the target catch. Top right represents the standardized catch rates with the upper fine line representing the target catch rate and the lower line the limit catch rate. Thickened lines represents the reference period for catches, catch rates, and the recent average catch rate.

20.5.2 Blue Warehou (TRT – 37445005 – Seriolella brama) Zones 10 - 50

Table 20.6 Blue Warehou data for the TIER 4 calculations. Total is the sum of Discards, State, Non Trawl and SEF2 catches. All values in Tonnes. CE is the standardized catch rate for Zones 10 to 50 in depths 0 – 400m (Haddon, 2012). GeoMean is the geometric mean catch rates. Discards are estimates from 1998 to present. The ratio of discards to catch over the 1998 – 2006 period was used to estimate the discards between 1986 and 1997, the proportion of which is the PDiscard.

Year	Catch	Discards	Total	State	Non-T	PDiscard	CE	GeoMean
1986	277.200	53.638	330.838			16.21	2.0083	24.6419
1987	1010.400	195.512	1205.912			16.21	2.3004	38.9818
1988	999.600	193.422	1193.022			16.21	2.5658	42.2791
1989	1598.400	309.290	1907.690			16.21	3.5440	53.5132
1990	2272.800	439.786	2712.586			16.21	2.5233	49.3618
1991	2478.000	479.492	2957.492			16.21	1.9961	38.9026
1992	1869.600	361.767	2231.367			16.21	1.4626	34.9011
1993	1440.000	278.639	1718.639			16.21	1.1328	27.0143
1994	1308.081	253.113	1561.194	458.856	0.000	16.21	1.0921	24.5388
1995	1086.315	210.201	1296.516	328.851	0.000	16.21	0.9299	19.7435
1996	1223.451	236.737	1460.189	376.605	0.000	16.21	0.9250	16.0446
1997	981.513	189.922	1171.436	193.002	0.000	16.21	0.9172	13.9027
1998	1271.881	86.000	1357.881	270.399	80.448	6.33	0.9174	18.0335
1999	925.892	16.000	941.892	283.422	287.791	1.70	0.4883	9.5323
2000	628.918	16.000	644.918	113.511	82.121	2.48	0.4352	7.2891
2001	354.866	39.000	393.866	26.249	30.742	9.90	0.2942	5.6327
2002	389.328	7.370	396.698	71.962	3.720	1.86	0.2499	4.0433
2003	296.069	19.490	315.559	42.301	2.077	6.18	0.2056	3.2843
2004	293.191	381.440	674.631	31.188	1.719	56.54	0.2815	4.9660
2005	329.935	273.920	603.855	17.249	1.318	45.36	0.2614	6.0446
2006	412.776	109.480	522.256	26.282	0.732	20.96	0.2625	7.8259
2007	224.990	24.929	249.919	29.306	0.780	9.97	0.2449	5.6784
2008	194.125	265.391	459.516	36.859	0.976	57.75	0.2749	5.0903
2009	171.807	16.561	188.368	33.663	1.704	8.79	0.2721	6.9116
2010	154.353	14.878	169.231	22.624	4.584	8.79	0.2177	6.3388
2011	117.773	39.535	157.308	7.316	11.805	25.13	0.1969	5.5194

Discards make up approximately 16.2 % of the catch over the 1998-2006 period.

Table 20.7 RBC calculations for Blue Warehou1050. C_{targ} and $CPUE_{targ}$ relate to the period 1986-1995, $CPUE_{Lim}$ is 40% of the target, and $\overline{CPUE}$ is the average catch rate over the last four years. The RBC calculation does not account for predicted discards of predicted State catches. Wt_Discard is the weighted average discards from the last four years, as with Equ (7).

Ref_Year	1986-1995
CE_Targ	1.9555
CE_Lim	0.7822
CE_Recent	0.2404
Wt_Discard	44.954
Scaling	0
Last Year's TAC	
C_{targ}	1711.526
RBC	**0**

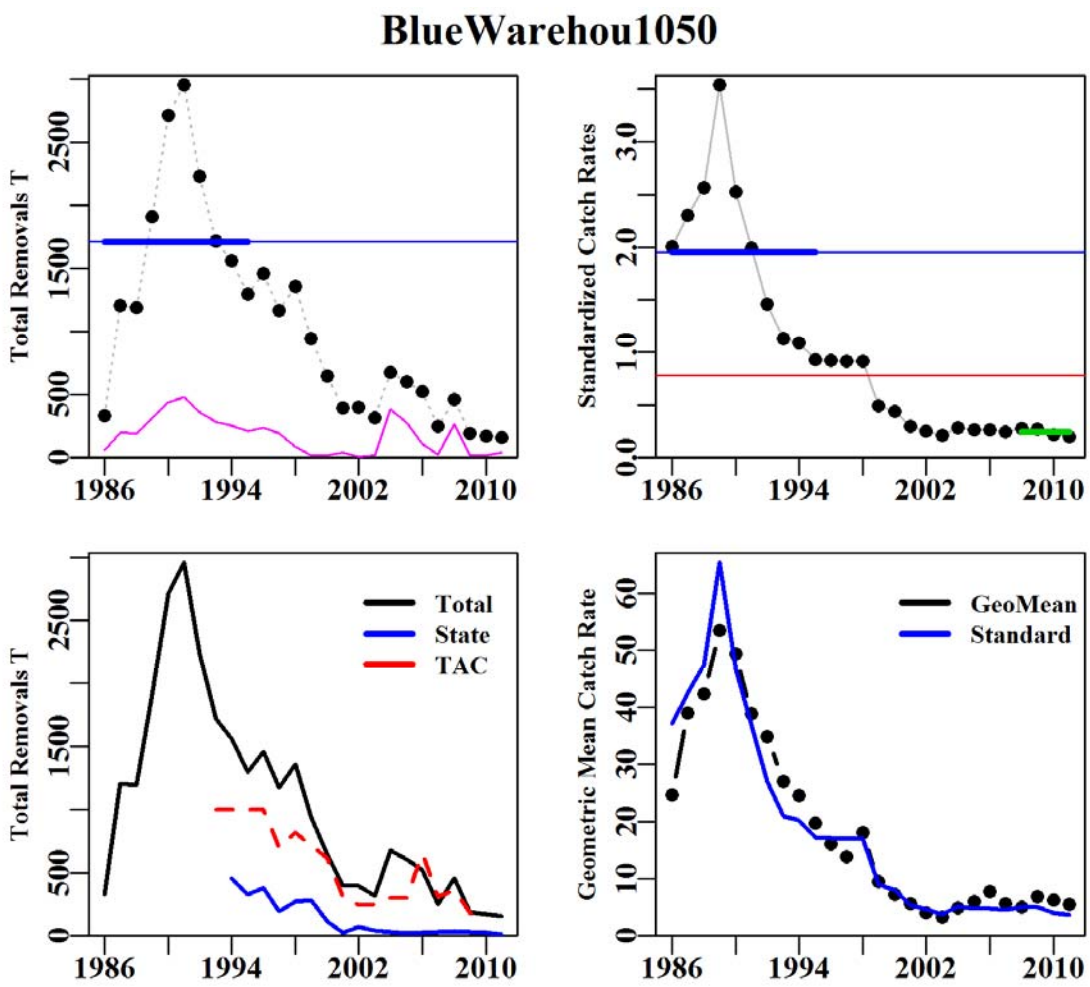

Figure 20.2 Blue Warehou. Top left is the total removals with the fine line illustrating the target catch. Top right represents the standardized catch rates with the upper fine line representing the target catch rate and the lower line the limit catch rate. Thickened lines represents the reference period for catches, catch rates, and the recent average catch rate.

20.5.3 Blue Warehou (TRT – 37445005 – Seriolella brama) Zones 10, 20 & 30

To provide an analysis more relevant to the two stocks of Blue Warehou (east and west) the landed catches, which are reported in total across zones 10 – 50, were subdivided in the same ratio as the reported catches from the catch effort log books, the discards were treated in the same fashion. Thus the catches and discards in Table 20.8 and Table 20.10 should sum in each year to the catches and discards in Table 20.6. The separate columns for the State and Non-Trawl catches were not adjusted and so, for these analyses are not meaningful.

Table 20.8 Blue Warehou data for the TIER 4 calculations. Total is the sum of Discards, State, Non Trawl and SEF2 catches. All values in Tonnes. CE is the standardized catch rate for Zones 10 to 30 in depths 0 – 400m (Haddon, 2012). GeoMean is the geometric mean catch rates. Discards are estimates from 1998 to present. The ratio of discards to catch over the 1998 – 2006 period was used to estimate the discards between 1986 and 1997. Prop is the proportion of the Commonwealth catch taken in zones 10 – 30.

Year	Catch	Discards	Total	State	Non-T	PDiscard	CE	GeoMean	Prop
1986	183.061	35.422	218.483			16.21	1.8787	22.9216	0.660
1987	442.684	85.659	528.343			16.21	2.2848	23.2716	0.438
1988	627.614	121.443	749.057			16.21	2.8020	34.8726	0.628
1989	1424.124	275.567	1699.692			16.21	3.5366	52.6588	0.891
1990	1432.240	277.138	1709.378			16.21	3.2341	46.5510	0.630
1991	1035.919	200.450	1236.368			16.21	1.7420	23.0208	0.418
1992	908.680	175.829	1084.509			16.21	1.4238	24.3304	0.486
1993	782.415	151.397	933.812			16.21	1.1069	20.7054	0.543
1994	671.031	129.844	800.875	235.388		16.21	1.0674	17.5997	0.513
1995	640.884	124.011	764.895	194.010		16.21	0.9784	15.3567	0.590
1996	909.275	175.944	1085.220	279.895		16.21	0.9835	14.6415	0.743
1997	612.519	118.522	731.041	120.444		16.21	0.9519	11.8760	0.624
1998	716.450	48.444	764.894	152.316	45.316	6.33	0.8996	13.8592	0.563
1999	398.296	6.883	405.179	121.921	123.801	1.70	0.4842	5.7097	0.430
2000	299.640	7.623	307.263	54.081	39.126	2.48	0.4275	5.0072	0.476
2001	80.801	8.880	89.681	5.977	7.000	9.90	0.2561	2.7867	0.228
2002	87.139	1.650	88.788	16.106	0.833	1.86	0.1966	2.2036	0.224
2003	57.263	3.770	61.033	8.182	0.402	6.18	0.1558	1.8331	0.193
2004	72.222	93.960	166.182	7.683	0.423	56.54	0.2122	2.7248	0.246
2005	25.164	20.892	46.056	1.316	0.101	45.36	0.1409	1.8011	0.076
2006	29.231	7.753	36.984	1.861	0.052	20.96	0.1689	2.2327	0.071
2007	22.795	2.526	25.320	2.969	0.079	9.97	0.1826	1.8677	0.101
2008	36.683	50.150	86.834	6.965	0.184	57.75	0.2522	2.6539	0.189
2009	50.338	4.852	55.190	9.863	0.499	8.79	0.2922	3.5956	0.293
2010	16.105	1.552	17.658	2.361	0.478	8.79	0.1894	2.1227	0.104
2011	13.174	4.422	17.596	0.818	1.320	25.13	0.1516	1.7081	0.112

Discards make up approximately 16.2% for the period 1998 – 2006.

Table 20.9 RBC calculations for Blue Warehou East. C_{targ} and $CPUE_{targ}$ relate to the period 1986-1995, $CPUE_{Lim}$ is 40% of the target, and $\overline{CPUE}$ is the average catch rate over the last four years. The RBC calculation does not account for predicted discards of predicted State catches. Wt_Discard is the weighted average discards from the last four years, as with Equ (7).

Ref_Year	1986-1995
CE_Targ	2.0055
CE_Lim	0.8022
CE_Recent	0.2214
Wt_Discard	6.763
Scaling	0
Last Year's TAC	
C_{targ}	972.541
RBC	**0**

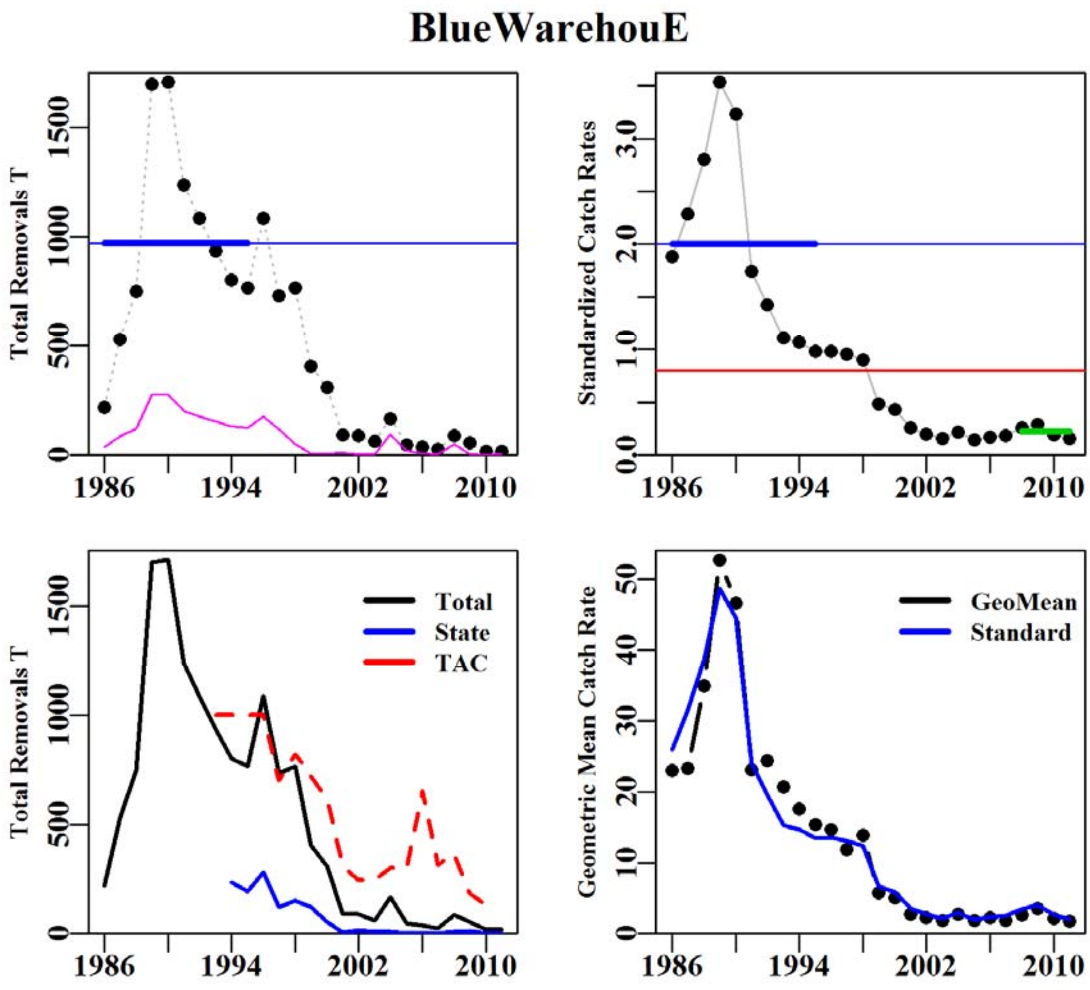

Figure 20.3 Blue Warehou zones 10 - 30. Top left is the total removals with the fine line illustrating the target catch. Top right represents the standardized catch rates with the upper fine line representing the target catch rate and the lower line the limit catch rate. Thickened lines represents the reference period for catches, catch rates, and the recent average catch rate.

20.5.4 Blue Warehou (TRT – 37445005 – Seriolella brama) Zones 40 & 50

To provide an analysis more relevant to the two stocks of Blue Warehou (east and west) the landed catches, which are reported in total across zones 10 – 50, were subdivided in the same ratio as the reported catches from the catch effort log books, the discards were treated in the same fashion. Thus the catches and discards in Table 20.8 and Table 20.10 should sum in each year to the catches and discards in Table 20.6. The separate columns for the State and Non-Trawl catches were not adjusted and so, for these analyses are not meaningful.

Table 20.10 Blue Warehou data for the TIER 4 calculations. Total is the sum of Discards, State, Non Trawl and SEF2 catches. All values in Tonnes. CE is the standardized catch rate for Zones 40 to 50 in depths 0 – 400m (Haddon, 2012). GeoMean is the geometric mean catch rates. Discards are estimates from 1998 to present. The ratio of discards to catch over the 1998 – 2006 period was used to estimate the discards between 1986 and 1997. Prop is the proportion of the Commonwealth catch taken in zones 40 – 50.

Year	Catch	Discards	Total	State	Non-T	PDiscard	CE	GeoMean	Prop
1986	94.139	18.216	112.355			16.21	3.3403	34.3927	0.340
1987	567.716	109.853	677.569			16.21	3.1136	153.6342	0.562
1988	371.986	71.979	443.965			16.21	1.2972	104.5294	0.372
1989	174.276	33.722	207.998			16.21	3.3111	91.5270	0.109
1990	840.560	162.648	1003.208			16.21	1.4434	55.8069	0.370
1991	1442.081	279.042	1721.123			16.21	2.2301	159.6429	0.582
1992	960.920	185.938	1146.858			16.21	1.2798	88.9759	0.514
1993	657.585	127.242	784.827			16.21	0.9374	92.3447	0.457
1994	637.050	123.269	760.319	223.468		16.21	1.0262	67.3117	0.487
1995	445.431	86.191	531.621	134.841		16.21	0.7000	45.1964	0.410
1996	314.176	60.793	374.969	96.710		16.21	0.4568	26.4215	0.257
1997	368.994	71.400	440.394	72.558		16.21	0.4907	35.6095	0.376
1998	555.431	37.556	592.987	118.083	35.132	6.33	0.7327	58.9967	0.437
1999	527.596	9.117	536.713	161.501	163.990	1.70	0.4211	32.5226	0.570
2000	329.278	8.377	337.655	59.430	42.995	2.48	0.3439	28.0473	0.524
2001	274.065	30.120	304.185	20.272	23.742	9.90	0.3634	27.5825	0.772
2002	302.189	5.720	307.910	55.855	2.887	1.86	0.4896	35.4216	0.776
2003	238.806	15.720	254.526	34.120	1.675	6.18	0.4422	28.1023	0.807
2004	220.969	287.480	508.449	23.506	1.296	56.54	0.5050	28.4995	0.754
2005	304.771	253.028	557.799	15.934	1.217	45.36	0.7955	53.5991	0.924
2006	383.544	101.727	485.271	24.420	0.680	20.96	0.5634	31.8482	0.929
2007	202.195	22.404	224.599	26.337	0.701	9.97	0.4887	22.9820	0.899
2008	157.441	215.241	372.682	29.894	0.791	57.75	0.3739	20.3955	0.811
2009	121.469	11.709	133.177	23.800	1.205	8.79	0.2769	18.4388	0.707
2010	138.248	13.326	151.574	20.263	4.106	8.79	0.3152	17.5511	0.896
2011	104.599	35.113	139.712	6.498	10.484	25.13	0.2618	14.3658	0.888

Discards make up approximately 16.2 % of the catch over the 1998-2006 period.

Table 20.11 RBC calculations for Blue Warehou West (Zones 40-50). C_{targ} and $CPUE_{targ}$ relate to the period 1986-1995, $CPUE_{Lim}$ is 40% of the target, and $\overline{CPUE}$ is the average catch rate over the last four years. The RBC calculation does not account for predicted discards of predicted State catches. Wt_Discard is the weighted average discards from the last four years, as with Equ (7).

Ref_Year	1986-1995
CE_Targ	1.8679
CE_Lim	0.7472
CE_Recent	0.307
Wt_Discard	38.191
Scaling	0
Last Year's TAC	
C_{targ}	738.984
RBC	**0**

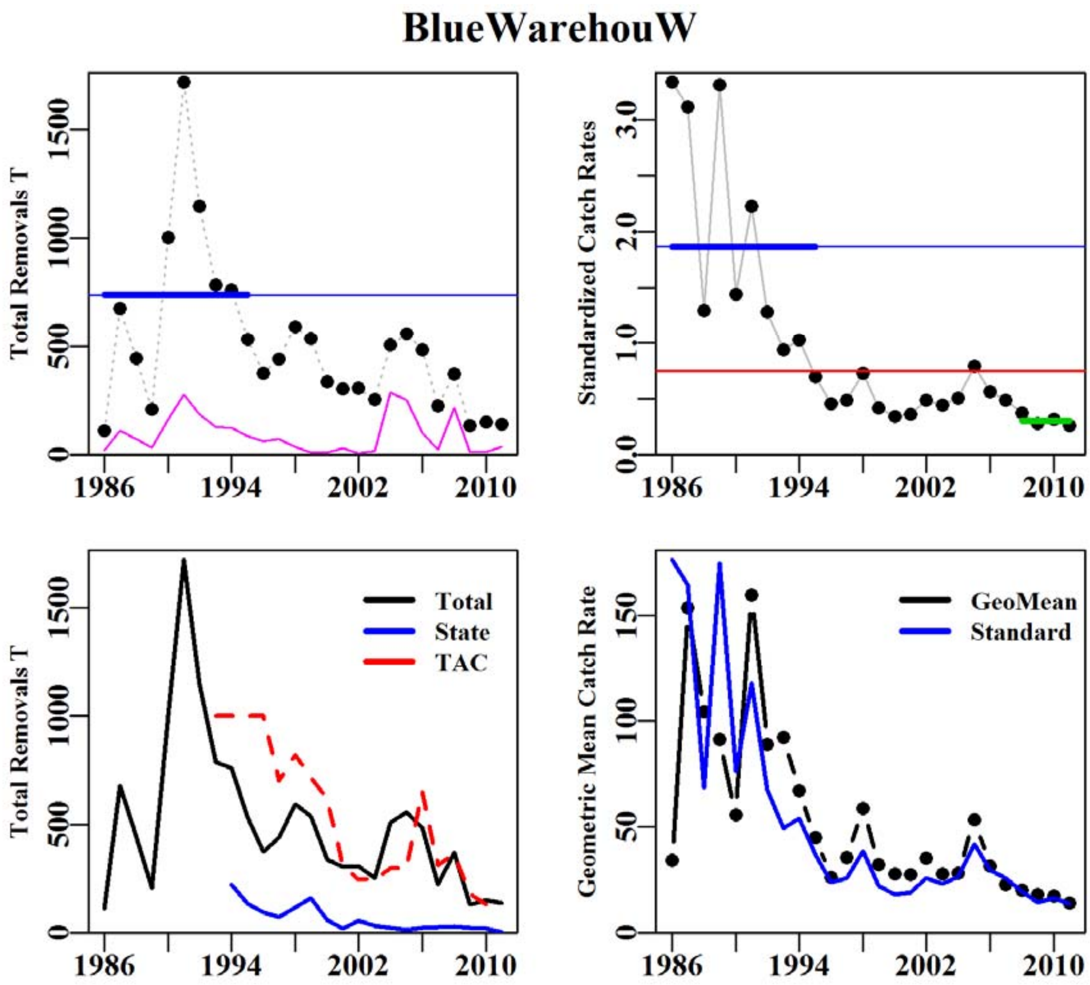

Figure 20.4 Blue Warehou zones 40 - 50. Top left is the total removals with the fine line illustrating the target catch. Top right represents the standardized catch rates with the upper fine line representing the target catch rate and the lower line the limit catch rate. Thickened lines represents the reference period for catches, catch rates, and the recent average catch rate.

20.5.5 Inshore Ocean Perch Including Discards (REG – 37287001 – Helicolenus percoides)

Inshore Ocean Perch are subject to relatively high levels of discarding, which was likely to have large effects on the perceived catch rates. By including the estimated discards in with the reported catches revised catch rates were possible. No standardization was possible using the simple ratio means but a method was devised that attempted to use the standardized catch rates with a multiplier devised from ratio means of total catches (reported catches + discards) divided by total effort.

Table 20.12 Inshore Ocean Perch data for the Alternative TIER 4 calculations using ratio mean catch rates that include discards in the catch rate calculations. Total is the sum of Discards, and other catches. All values in Tonnes. StandCE is the standardized catch rate for Inshore Ocean perch from Zones 10 and 20 in depths 0 – 200m (Haddon, 2012). GeoMean is the geometric mean catch rates (without discards). Discards are estimates from 1998 to present. DiscCE is the standardized catch rates multiplied by [(Discard/Catch)+1], see Haddon (2011c) for methods.

Year	Catch	Discards	Total	Effort	(D/C)+1	StandCE	DiscCE	GeoMean
1986	15.239	49.930	65.169	978.4	4.276462	0.8363	0.7531	1.2184
1987	12.441	34.842	47.283	1319.8	3.800579	0.9828	0.7865	1.0578
1988	16.643	49.027	65.670	1599.5	3.945803	1.1184	0.9292	1.2957
1989	16.758	50.257	67.015	1315.2	3.998986	1.0713	0.9021	1.4286
1990	17.076	88.665	105.741	1416.9	6.192375	1.1429	1.4903	1.3818
1991	26.084	106.551	132.635	1495.5	5.084918	1.2818	1.3725	1.4465
1992	16.106	106.112	122.218	742.8	7.588352	1.696	2.7100	1.6928
1993	29.267	100.307	129.574	1390.1	4.427307	1.9063	1.7772	1.8109
1994	38.765	99.192	137.957	1599.4	3.55882	1.7357	1.3007	1.6767
1995	40.881	104.606	145.487	1712.4	3.558816	1.284	0.9622	1.5562
1996	51.250	131.139	182.389	2127.5	3.558824	1.1194	0.8389	1.2539
1997	34.279	87.713	121.992	1750.3	3.558833	1.0464	0.7842	1.0498
1998	39.085	124.000	163.085	1858.4	4.17256	0.9151	0.8040	1.0225
1999	25.438	78.000	103.438	2073.3	4.066274	0.8112	0.6946	0.8883
2000	47.846	100.000	147.846	4148.9	3.090058	0.9859	0.6415	0.8125
2001	37.815	89.000	126.815	3191.9	3.353576	0.98	0.6920	0.7479
2002	48.363	145.110	193.473	4661.2	4.000439	0.6996	0.5893	0.4651
2003	30.865	61.320	92.185	3742.2	2.986715	0.5408	0.3401	0.4112
2004	25.887	194.450	220.337	3285.2	8.51161	0.5522	0.9897	0.3989
2005	23.829	41.680	65.509	3103.4	2.749095	0.625	0.3618	0.5311
2006	50.439	9.760	60.199	2153.8	1.193503	0.5206	0.1308	0.4000
2007	35.923	17.195	53.117	1369.8	1.478654	0.7329	0.2282	0.6302
2008	29.746	23.433	53.180	1094.1	1.787777	0.9001	0.3388	0.7552
2009	19.480	91.350	110.830	947.4	5.689398	0.7656	0.9172	0.7348
2010	21.952	132.847	154.798	1095.3	7.051795	0.8049	1.1952	0.6819
2011	16.411	269.811	286.222	1010.5	17.44092	0.9448	3.4698	0.6513

Discards are calculated now according to the latest ISMP design and this has led to a re-assessment of the levels of discards from 2008 onwards; hence the difference between this year's analysis and last year's.

Table 20.13 RBC calculations for Inshore Ocean Perch. C_{targ} and $\overline{CPUE_{targ}}$ relate to the period 1986-1995, $CPUE_{Lim}$ is 40% of the target, and $\overline{CPUE}$ is the average catch rate over the last four years. The RBC calculation does not account for predicted discards of predicted State catches. Wt_Discard is the weighted average discards from the last four years, as with Equ (7).

Ref_Year	1986-1995
CE_Targ	1.2984
CE_Lim	0.5194
CE_Recent	1.4803
Wt_Discard	193.067
Scaling	1.2335
Last Year's TAC	
C_{targ}	101.875
RBC	**125.661**

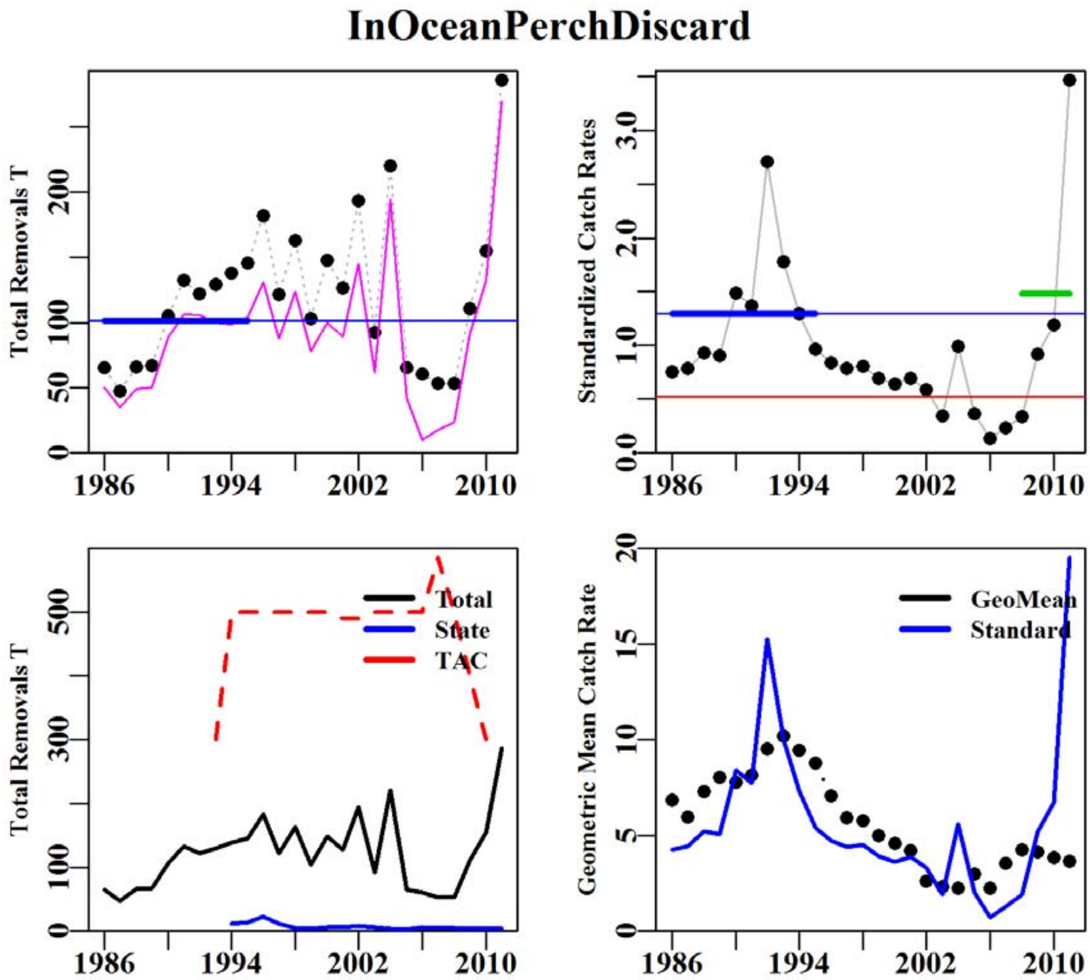

Figure 20.5 Alternative InShore Ocean Perch (where catch rates include discards). Top left is the total removals with the fine line illustrating the target catch. Top right represents the standardized catch rates with the upper fine line representing the target catch rate and the lower line the limit catch rate. Thickened lines represents the reference period for catches, catch rates, and the recent average catch rate.

Table 20.14 RBC calculations for Inshore Ocean Perch. C_{targ} and $CPUE_{targ}$ relate to the period 1986-1995, $CPUE_{Lim}$ is 40% of the target, and $\overline{CPUE}$ is the average catch rate over the last four years. The RBC calculation does not account for predicted discards of predicted State catches. Wt_Discard is the weighted average discards from the last four years, as with Equ (7). The proxy target is here B40%.

Ref_Year	1986-1995
CE_Targ	1.2984
CE_Lim	0.5194
CE_Recent	1.4803
Wt_Discard	193.067
Scaling	1.7079
Last Year's TAC	
C_{targ}	101.875
RBC	**173.993**

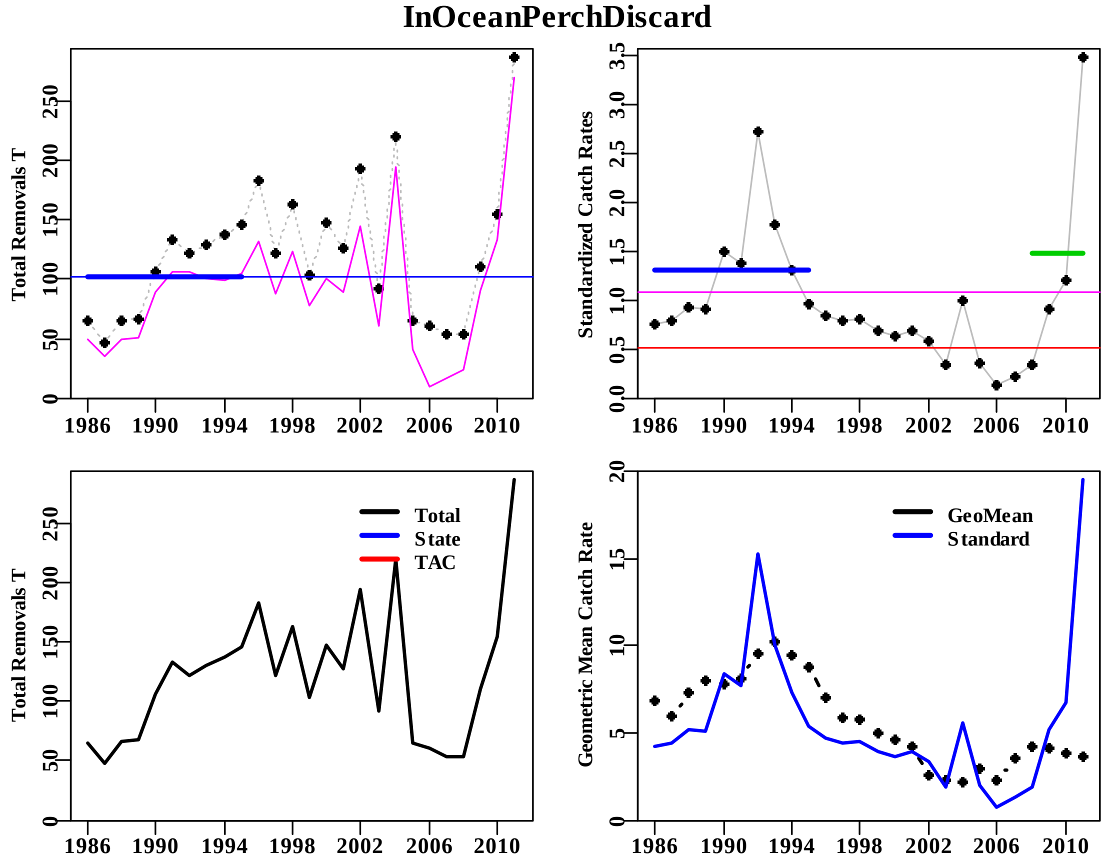

Figure 20.6 Alternative InShore Ocean Perch (where catch rates include discards). Top left is the total removals with the fine line illustrating the target catch. Top right represents the standardized catch rates with the upper fine line representing the target catch rate and the lower line the limit catch rate. Thickened lines represents the reference period for catches, catch rates, and the recent average catch rate.

20.5.6 Offshore Ocean Perch (REG – 37287001 – H percoides) 48% Target Proxy

The RAG agreed, this year, to attempt to estimate the RBC for Ocean Perch by separately estimating the RBCs for Offshore and Inshore Ocean Perch and combining the result. Offshore Ocean Perch were defined as those records that were reported as being from 200 – 700 metres depth; Inshore Ocean Perch were defined as those records from depths of 0 – 200 metres (A decision of the RAG in 2010, reversing a different decision made in 2009). In addition, the data series of reported catches differ from those previously used as they have been recently reviewed and revised, splitting the landings between Offshore and Inshore Ocean Perch relative to the Commonwealth log book catches for the two depth ranges. This increased the total catches reported, but these data are now the best available information on Ocean Perch catches.

Table 20.15 Offshore Ocean Perch data for the TIER 4 calculations. Total is the sum of Discards, State, Non Trawl and SEF2 catches. All values in Tonnes. CE is the standardized catch rate for Offshore Ocean perch from Zones 10 and 20 in depths 200 – 700m (Haddon, 2012). GeoMean is the geometric mean catch rates. Discards are estimates from 1998 to present. The ratio of discards to catch over the 1998 – 2006 period was used to estimate the discards between 1986 and 1997. Landings before 1994 were subdivided according to the ratio of inshore to offshore in the Commonwealth logbook data.

Year	Catch	Discards	Total	State	Non-T	Pdiscard	CE	GeoMean
1986	218.366	31.876	250.242			12.74	1.0298	12.1440
1987	179.087	26.142	205.230			12.74	0.9538	8.9237
1988	178.089	25.997	204.086			12.74	1.0669	10.5074
1989	207.462	30.284	237.746			12.74	1.0257	10.6494
1990	176.918	25.826	202.744			12.74	1.3644	12.0207
1991	234.031	34.163	268.193			12.74	1.4423	13.4339
1992	349.336	50.994	400.330			12.74	1.2143	11.9264
1993	314.476	45.906	360.382			12.74	1.2142	12.9555
1994	294.313	42.962	337.276	35.478	0.000	12.74	1.1325	11.8001
1995	320.654	46.807	367.461	35.712	0.000	12.74	1.0249	10.4874
1996	363.621	53.080	416.701	35.992	0.000	12.74	0.9240	9.8364
1997	440.479	64.299	504.777	37.041	5.312	12.74	0.9739	9.7119
1998	372.254	174.000	546.254	35.974	6.250	31.85	0.8662	9.4285
1999	395.062	64.000	459.062	39.250	7.018	13.94	0.9802	9.7566
2000	344.156	34.000	378.156	36.369	9.086	8.99	0.7702	7.5464
2001	356.183	46.000	402.183	29.725	8.597	11.44	0.8632	8.3956
2002	322.376	22.470	344.846	36.660	18.885	6.52	0.8206	7.3709
2003	373.003	27.800	400.803	28.965	30.940	6.94	0.8719	7.6242
2004	362.369	42.440	404.809	19.579	66.129	10.48	0.8707	8.0648
2005	322.617	17.100	339.717	15.404	34.518	5.03	0.9783	9.3641
2006	226.413	20.980	247.393	15.835	46.229	8.48	0.8351	7.8433
2007	186.607	100.727	287.334	13.362	28.638	35.06	1.0332	9.9183
2008	208.930	22.187	231.117	13.489	37.801	9.60	0.9554	9.1917
2009	218.732	28.233	246.965	18.551	32.967	11.43	0.9499	9.0355
2010	238.512	81.596	320.108	27.782	28.977	25.49	0.9792	9.8647
2011	223.984	18.569	242.553	10.842	24.104	7.66	0.8592	9.0998

Discards make up approximately 12.68% % of the catch over the 1998-2006 period. The catch rates used were for Offshore Ocean Perch from 200 to 700 metres depth. State catches from 1994 to 1997 were compromised through including some

Commonwealth catches. As an agreed upon better estimates, the State catches in these years were replaced with the average State catch from the years 1998 to 2003.

Table 20.16 RBC calculations for Offshore Ocean Perch. C_{targ} and $CPUE_{targ}$ relate to the period 1986-1995, $CPUE_{Lim}$ is 40% of the target, and $\overline{CPUE}$ is the average catch rate over the last four years. The RBC calculation does not account for predicted discards of predicted State catches. Wt_Discard is the weighted average discards from the last four years, as with Equ (7).

Ref_Year	1986-1995
CE_Targ	1.1469
CE_Lim	0.4588
CE_Recent	0.9359
Wt_Discard	36.906
Scaling	0.6934
Last Year's TAC	
C_{targ}	283.369
RBC	**196.498**

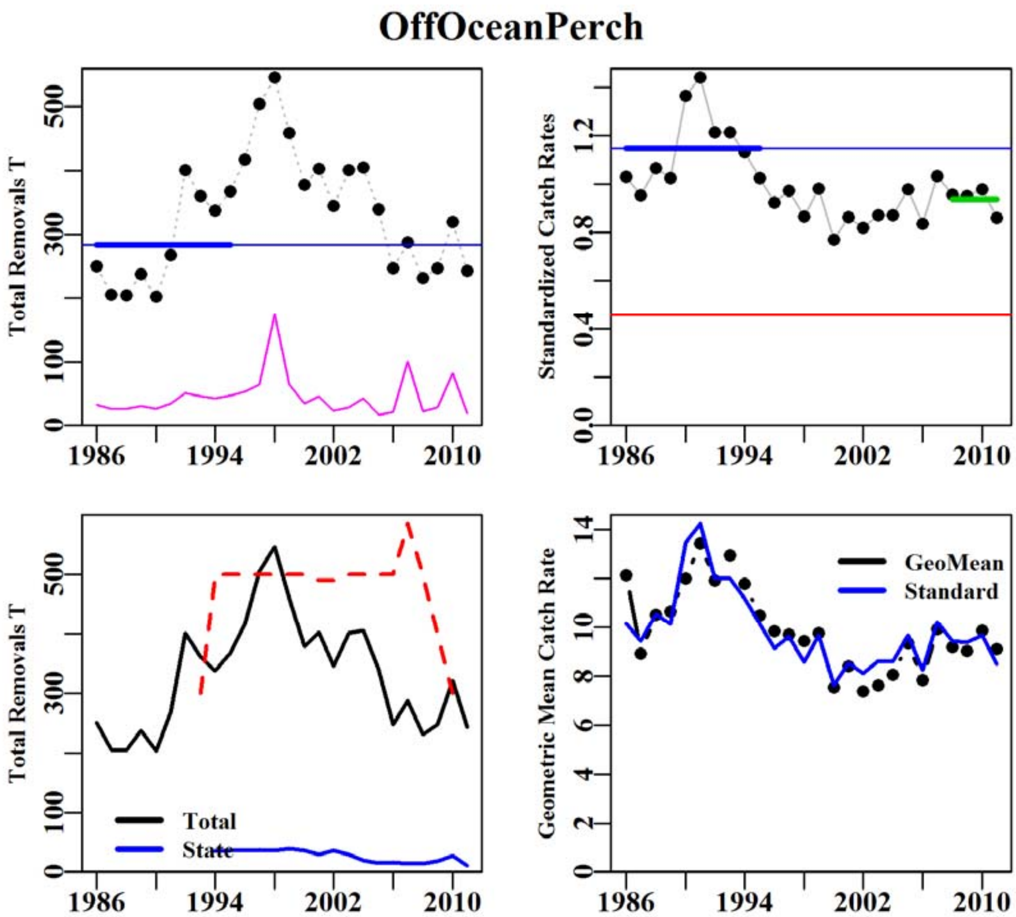

Figure 20.7 OffShore Ocean Perch. Top left is the total removals with the fine line illustrating the target catch. Top right represents the standardized catch rates with the upper fine line representing the target catch rate and the lower line the limit catch rate. Thickened lines represents the reference period for catches, catch rates, and the recent average catch rate.

Table 20.17 RBC calculations for Offshore Ocean Perch. C_{targ} and $CPUE_{targ}$ relate to the period 1986-1995, $CPUE_{Lim}$ is 40% of the target, and $\overline{CPUE}$ is the average catch rate over the last four years. The RBC calculation does not account for predicted discards of predicted State catches. Wt_Discard is the weighted average discards from the last four years, as with Equ (7). The proxy target is here B40%.

Ref_Year	1986-1995
CE_Targ	0.9557
CE_Lim	0.4588
CE_Recent	0.9359
Wt_Discard	36.906
Scaling	0.9602
Last Year's TAC	
C_{targ}	283.369
RBC	**272.077**

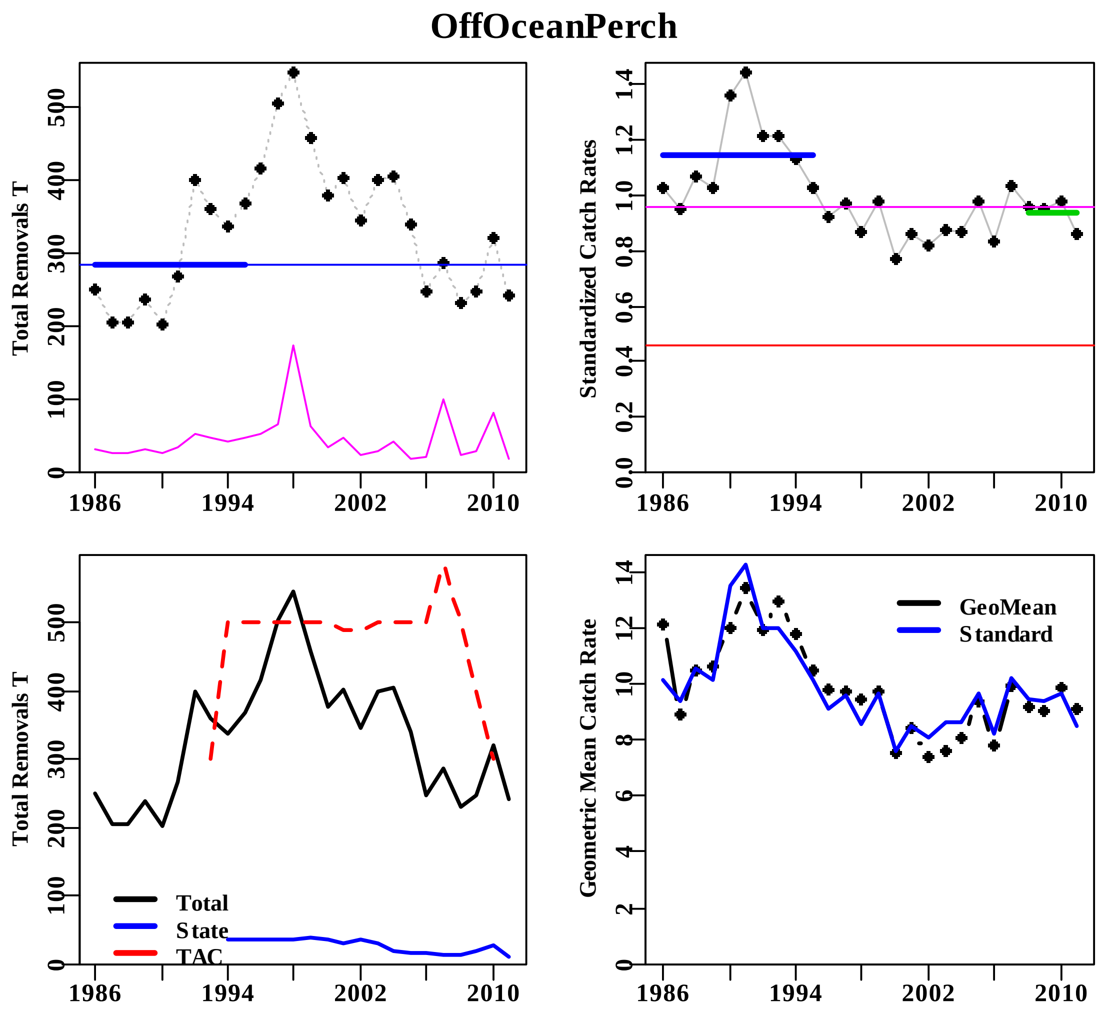

Figure 20.8 OffShore Ocean Perch. Top left is the total removals with the fine line illustrating the target catch. Top right represents the standardized catch rates with the upper fine line representing the target catch rate and the lower line the limit catch rate. Thickened lines represents the reference period for catches, catch rates, and the recent average catch rate.

Table 20.18 RBC calculations for Offshore Ocean Perch. C_{targ} and $CPUE_{targ}$ relate to the period 1986-1995, $CPUE_{Lim}$ is 40% of the target, and $\overline{CPUE}$ is the average catch rate over the last four years. The RBC calculation does not account for predicted discards of predicted State catches. Wt_Discard is the weighted average discards from the last four years, as with Equ (7). Includes Discards

Ref_Year	1986-1995
CE_Targ	1.1299
CE_Lim	0.4519
CE_Recent	0.9401
Wt_Discard	36.906
Scaling	0.72
Last Year's TAC	
C_{targ}	283.369
RBC	**204.026**

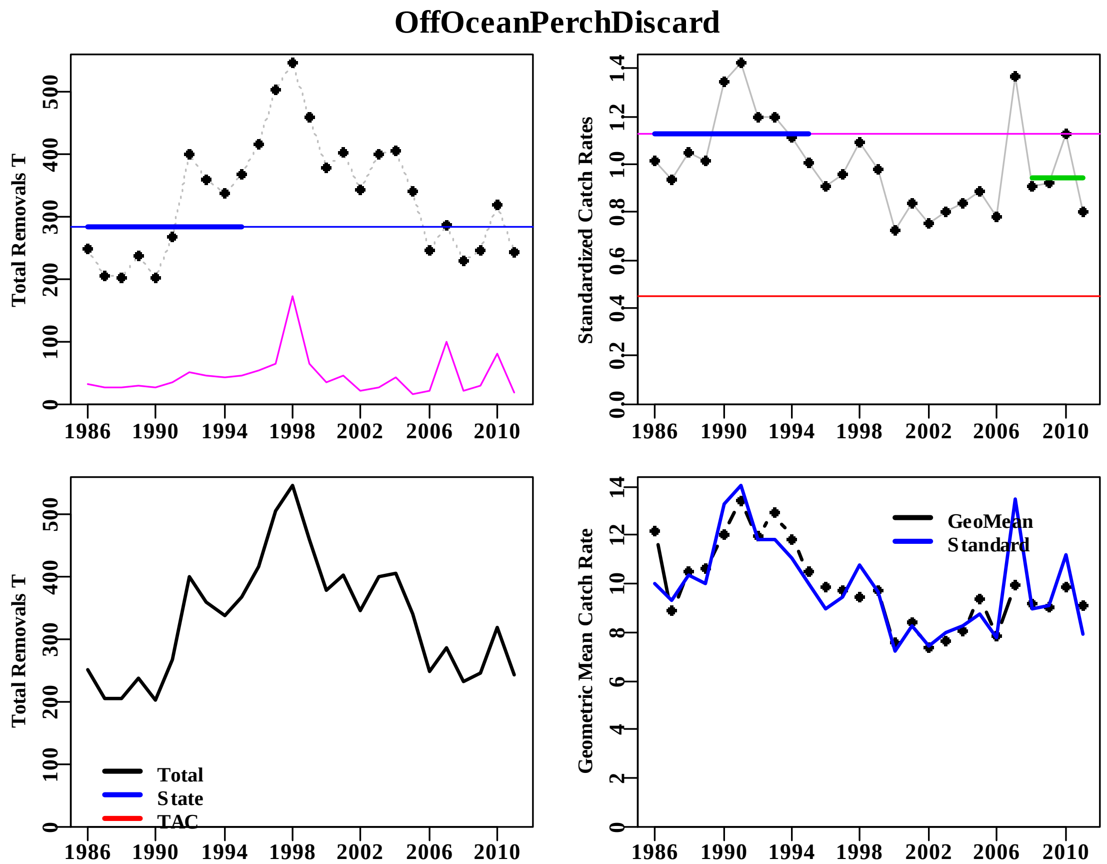

Figure 20.9 OffShore Ocean Perch. Top left is the total removals with the fine line illustrating the target catch. Top right represents the standardized catch rates with the upper fine line representing the target catch rate and the lower line the limit catch rate. Thickened lines represents the reference period for catches, catch rates, and the recent average catch rate.

Table 20.19 RBC calculations for Offshore Ocean Perch. C_{targ} and $CPUE_{targ}$ relate to the period 1986-1995, $CPUE_{Lim}$ is 40% of the target, and $\overline{CPUE}$ is the average catch rate over the last four years. The RBC calculation does not account for predicted discards of predicted State catches. Wt_Discard is the weighted average discards from the last four years, as with Equ (7). Discards Included. The proxy target is here B40%.

Ref_Year	1986-1995
CE_Targ	0.9416
CE_Lim	0.4519
CE_Recent	0.9401
Wt_Discard	36.906
Scaling	0.9969
Last Year's TAC	
C_{targ}	283.369
RBC	**282.500**

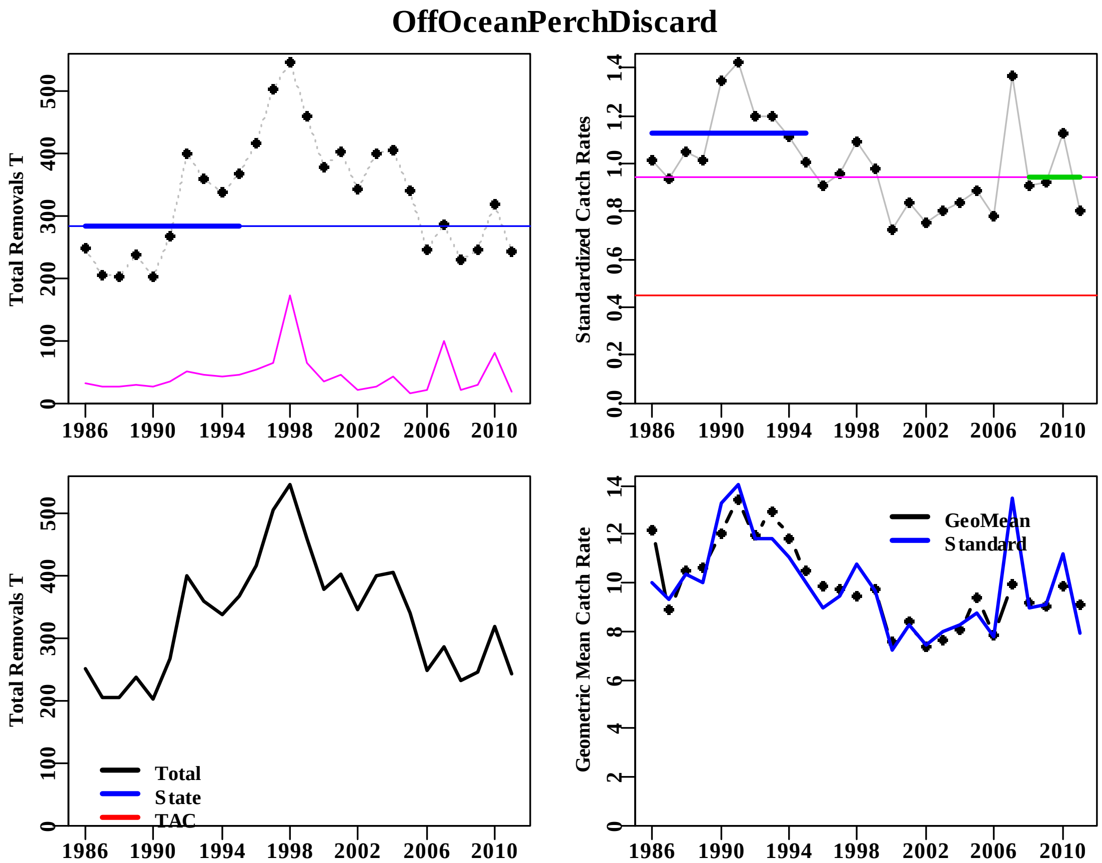

Figure 20.10 OffShore Ocean Perch. Top left is the total removals with the fine line illustrating the target catch. Top right represents the standardized catch rates with the upper fine line representing the target catch rate and the lower line the limit catch rate. Thickened lines represents the reference period for catches, catch rates, and the recent average catch rate.

20.5.7 Royal Red Prawn (PRR – 28714005 – Haliporoides sibogae)

Table 20.20 Royal Red Prawn data for the TIER 4 calculations. Total is the sum of Discards, State, Non Trawl and SEF2 catches. All values in Tonnes. CE is the standardized catch rate for Zone 10 in depths 0 – 400m (Haddon, 2012). GeoMean is the geometric mean catch rates. Discards are estimates from 1998 to present. The ratio of discards to catch over the 1998 – 2006 period was used to estimate the discards between 1986 and 1997, the proportion of which is the PDiscard.

Year	Catch	Discards	Total	State	Non-T	PDiscard	CE	GeoMean
1986	271.200	12.234	283.434			4.32	0.6928	27.7627
1987	177.600	8.012	185.612			4.32	0.8818	41.9857
1988	273.600	12.342	285.942			4.32	0.9761	49.1496
1989	224.400	10.123	234.523			4.32	0.8322	45.8268
1990	315.600	14.237	329.837			4.32	1.5596	95.1525
1991	441.600	19.921	461.521			4.32	1.3942	79.4866
1992	639.600	28.853	668.453			4.32	1.0429	70.3817
1993	549.600	24.793	574.393			4.32	1.1944	68.5216
1994	482.073	21.747	503.820	334.299	0	4.32	1.1363	77.7193
1995	529.336	23.879	553.215	335.820	0	4.32	0.9009	58.4998
1996	424.963	19.171	444.134	157.685	0	4.32	0.8126	60.5827
1997	473.406	21.356	494.762	285.669	0	4.32	0.7661	51.9861
1998	438.916	12.000	450.916	228.345	0	2.66	0.8258	39.1713
1999	581.324	2.000	583.324	205.320	0	0.34	0.8163	49.7799
2000	623.637	3.000	626.637	206.945	0	0.48	1.0256	49.6136
2001	470.039	11.000	481.039	227.810	0	2.29	0.8744	35.9685
2002	674.384	15.580	689.964	240.645	0	2.26	1.0510	47.9208
2003	323.442	17.370	340.812	135.277	0	5.10	1.0958	39.7063
2004	247.193	43.460	290.653	74.965	0	14.95	1.1216	50.4687
2005	212.742	40.290	253.032	46.255	0	15.92	1.0226	47.1225
2006	224.276	26.540	250.816	31.868	0	10.58	1.2309	55.0038
2007	154.746	18.312	173.058	20.207	0	10.58	0.8506	48.8072
2008	112.198	13.277	125.475	24.592	0	10.58	0.7329	39.0864
2009	91.320	10.806	102.126	12.646	0	10.58	0.9328	59.2670
2010	113.736	13.459	127.195	5.409	0	10.58	0.8928	40.3732
2011	132.613	1.419	134.032	5.409	0	1.06	1.3368	82.0762

Discards make up approximately 4.3 % of the catch over the 1998-2006 period.

Table 20.21 RBC calculations for Royal Red Prawn. C_{targ} and $CPUE_{targ}$ relate to the period 1986-1995, $CPUE_{Lim}$ is 40% of the target, and $\overline{CPUE}$ is the average catch rate over the last four years. The RBC calculation does not account for predicted discards of predicted State catches. Wt_Discard is the weighted average discards from the last four years, as with Equ (7).

Ref_Year	1986-1995
CE_Targ	1.0611
CE_Lim	0.4244
CE_Recent	0.9738
Wt_Discard	6.672
Scaling	0.8629
Last Year's TAC	
C_{targ}	408.075
RBC	**352.123**

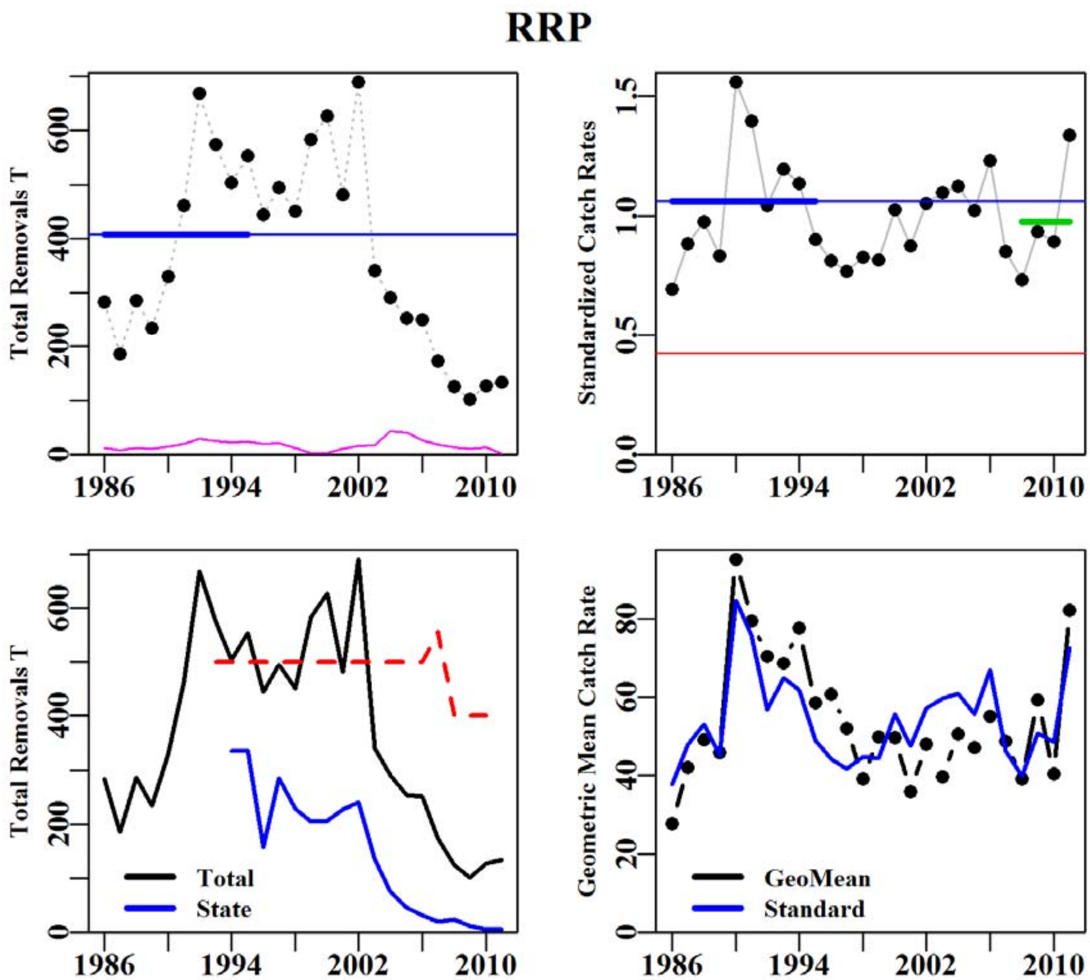

Figure 20.11 Royal Red Prawn. Top left is the total removals with the fine line illustrating the target catch. Top right represents the standardized catch rates with the upper fine line representing the target catch rate and the lower line the limit catch rate. Thickened lines represents the reference period for catches, catch rates, and the recent average catch rate.

20.5.7.1 Royal Red Prawn Taken with Different Mesh Sizes

Royal Red Prawns are principally taken in SESSF zone 10 and just north of the northern border of the SESSF along the NSW coastline (including relatively small amounts north of Barrenjoey). When they are specifically targeted it is standard practice to change the net to one with a much smaller mesh. However, in the standard analysis of catch rates, because the information on mesh size is only available for a limited number of years (2002 – 2011) no attention has been paid to which mesh is in use for each shot despite there being higher catch rates with the smaller meshed nets (Figure 20.12). It has been requested that the effect of mesh size on catch rates be examined for the limited years data was available.

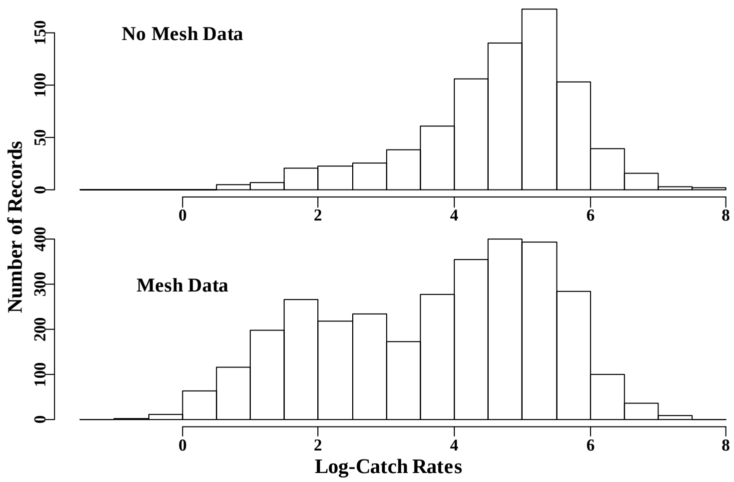

Figure 20.12. Log book data for Royal Red Prawn since 2003 (about 81% of data has mesh data provided each year; in 2002 only about 12% mesh data was provided). The two modes in the log transformed catch rate data illustrates, crudely, the difference between the smaller meshed nets (higher catch rates) and the larger meshed nets (lower catch rates).

In the log books there are 23 different mesh sizes recorded. When the log-transformed catch rates are plotted against the mesh size used to make each individual catch there are three clusters apparent (Figure 20.13), with the mean catch rate of each cluster increasing as the mesh size increases.

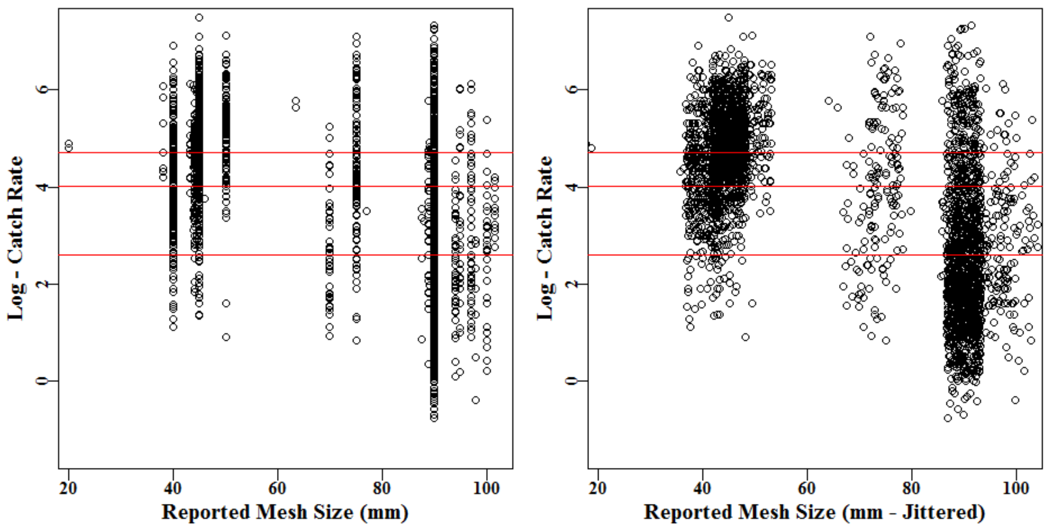

Figure 20.13. The catch rates of Royal Red Prawn obtained by different meshed nets. The mesh size has been jittered (a small random number added) so as to make clusters of observations apparent. The three red lines represent the mean catch rate of each of the three groups of observations.

Given that there is a clear difference between the smaller meshes and the larger meshes and there were only few records around 70 – 75 mm (Table 20.22), the data were grouped into those vessels with meshes < 60 mm, those with meshes > 80 mm, and those in between. Subsequent analyses were then conducted only on the smaller and larger meshed groups.

Table 20.22. The relative catches reported in the log books by mesh categories. In 2002 only 12% of catches had mesh size recorded.

Year	No Mesh	<60 mm	>=60 & < 80mm	>= 80 mm
2003	41.475	80.250	20.840	20.619
2004	48.150	84.858	29.951	7.722
2005	50.046	80.135	6.770	22.854
2006	69.820	50.185		58.574
2007	18.445	50.410		47.575
2008		51.215	0.700	18.690
2009	8.625	54.248		4.734
2010	28.158	45.550		9.113
2011	40.970	56.200		11.790

Table 20.23. The standardized catch rates for the eight different models fitted to the Royal Red Prawn data (including the smaller and larger mesh classes). The optimum model was LnCE = Year + Vessel + Mesh + DepCat + Month + DayNight.

Year	Year	Vessel	Mesh	DepCat	Month	**DayNight**	Month:DepCat	DN:Month
2002	0.9923	1.1450	0.9687	1.0375	1.0299	**1.0308**	1.0133	1.0275
2003	0.7535	1.2447	0.9751	1.0464	1.0022	**0.9852**	0.9970	0.9866
2004	0.8767	1.1113	1.0311	1.0725	1.0516	**1.0390**	1.0842	1.0524
2005	0.8780	1.0594	0.9697	0.9914	0.9527	**0.9400**	0.9376	0.9370
2006	0.8688	1.1939	1.3374	1.2319	1.1756	**1.1598**	1.1819	1.1558
2007	1.0624	0.7905	1.0345	1.0031	1.0074	**1.0296**	0.9995	1.0057
2008	0.9007	0.6595	0.7815	0.7959	0.8098	**0.8239**	0.8019	0.8191
2009	1.4024	0.8534	0.7784	0.7550	0.7978	**0.8029**	0.8080	0.8072
2010	0.7655	0.7555	0.8487	0.8340	0.8747	**0.8837**	0.8622	0.8829
2011	1.4998	1.1869	1.2749	1.2324	1.2982	**1.3050**	1.3145	1.3259

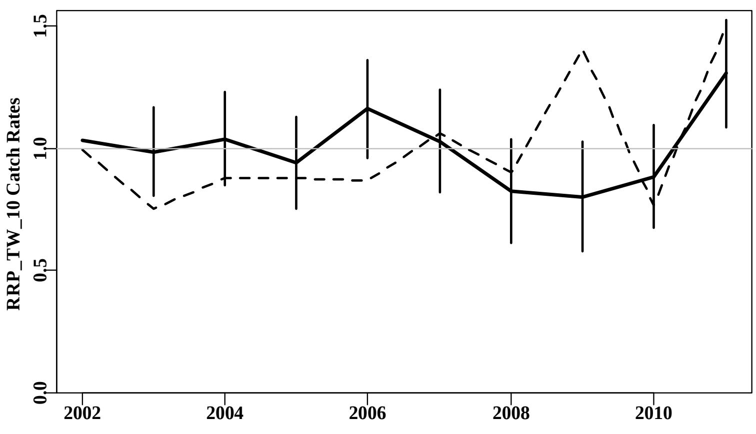

Figure 20.14. Standardized catch rates for Royal Red Prawn including Mesh size in the standardization. The geometric mean is represented by the dashed line and the vertical bars are two times the standard errors.

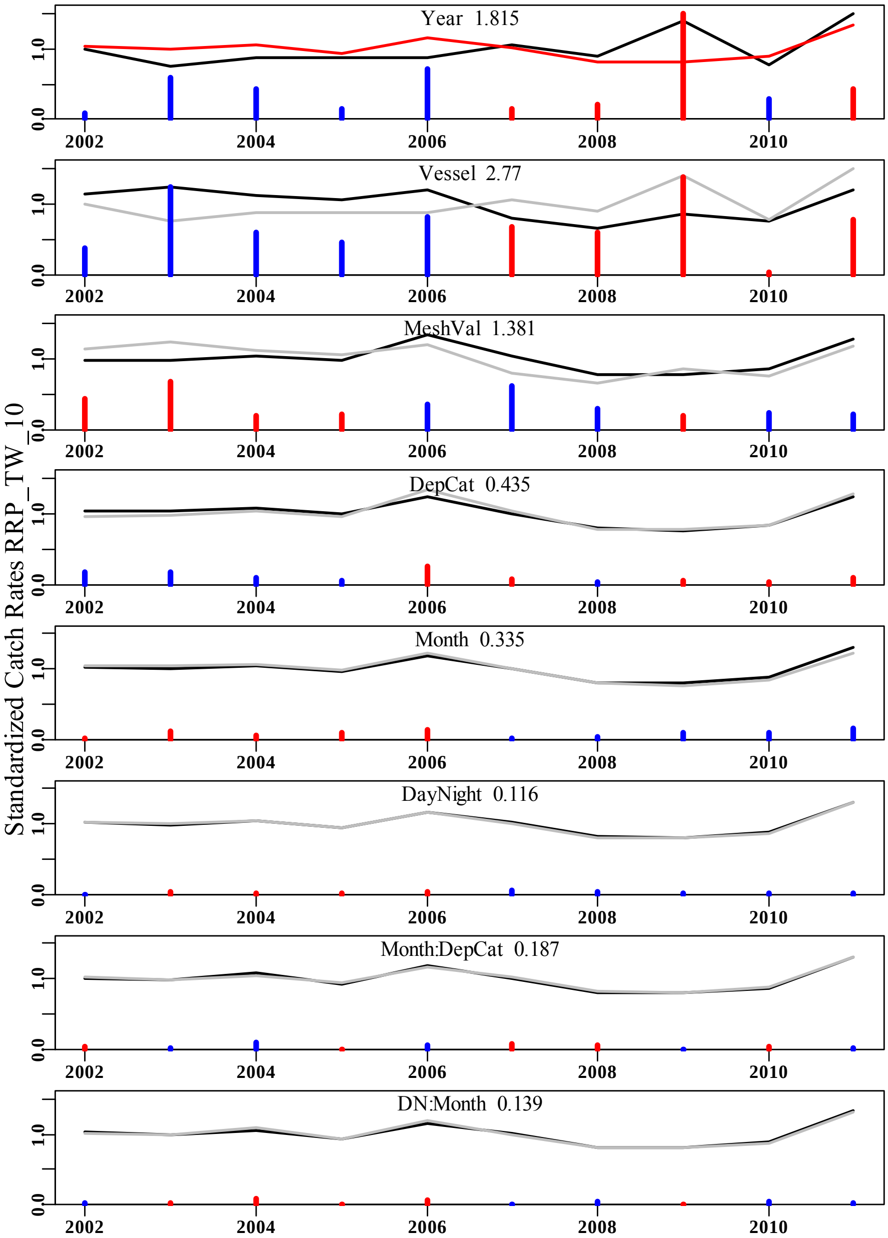

Figure 20.15. The relative impact of the different factors on the trend in catch rates. The blue bars indicate where the addition of a factor leads to the trend rising above the previous model while a red bar indiciats where the trend drops below the previous model's prediction. The effect of mesh appears to relate to the reduced catches taken by the bigger meshes and increased catches with no mesh. The impact of vessel reflects the completion of the structural adjustment.

While there are some differences when a comparison is made between standardizations using all available data, the larger and smaller mesh only data, and the smaller mesh data only (Figure 20.16) the general trends over the period 2002 – 2011 are basically the same. In all cases the catch rates in 2011 have all increased markedly.

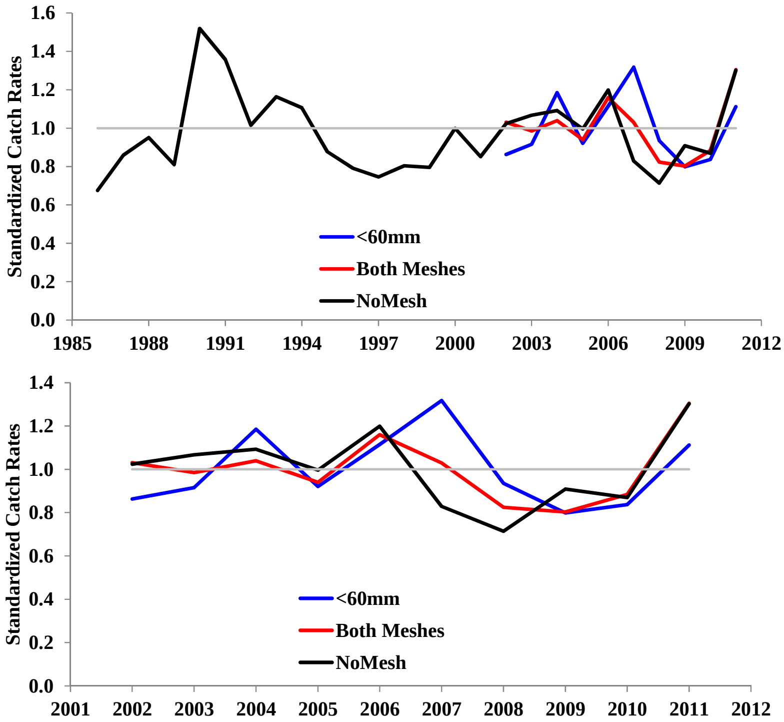

Figure 20.16. a comparison of the standardization based on all data with the standardizations that relate to the data where mesh size information was available for both large and small meshes, and also for a separate analysis where only the small mesh data were standardized.

20.5.7.2 *The Effect of the Endeavour Dogfish Closure*

Catches in the final version of the Endeavour Dogfish closure reached between 15 – 21% between 1998 – 2001 but have always been less than that in other years (Table 20.24).

Table 20.24. Catches of Royal Red Prawn in the Endeavour dogfish closure and elsewhere.

Year	Open	Endeavour	Year	Open	Endeavour
1986	228.150	3.694	1999	283.239	65.565
1987	320.209	4.507	2000	340.739	57.735
1988	340.567	3.890	2001	180.289	48.410
1989	303.417	7.343	2002	406.385	10.985
1990	311.118		2003	156.969	6.215
1991	299.370		2004	167.451	3.230
1992	145.291	0.790	2005	159.605	0.200
1993	232.774		2006	177.629	0.950
1994	240.363		2007	116.430	
1995	237.595	15.310	2008	70.605	
1996	258.345	14.330	2009	67.587	0.020
1997	152.173	14.530	2010	82.221	0.600
1998	152.960	37.772	2011	108.960	

Catches within what has become the Endeavour dogfish closure have been less than 4 tonnes since 2004. Once all data from this area are removed from the Royal Red Prawn data a standardization demonstrated no appreciable difference from the trend exhibited by using all data.

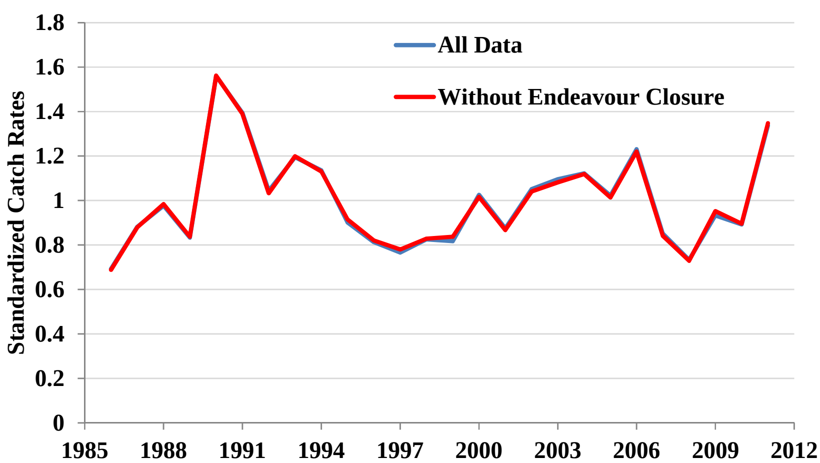

Figure 20.17. The standardization of all Royal Red Prawn

20.5.8 Silver Trevally (TRE – 37337062 – Pseudocaranx dentex)

Table 20.25 Silver Trevally data for the TIER 4 calculations. Total is the sum of Discards, State, Non Trawl and SEF2 catches. All values in Tonnes. CE is the standardized catch rate for Zones 10 and 20 from depths 0 to 200 m (Haddon, 2012) with records from the Bateman's Bay MPA removed. GeoMean is the geometric mean catch rates. Discards are estimates from the ISMP from 1998 to present. The ratio of discards to catch over the 1998 – 2006 period was used to estimate the discards between 1986 and 1997, the proportion of which is the PDiscard.

Year	Catch	Discards	Total	State	Non-T	PDiscard	CE	GeoM
1986	1166.400	5.413	1171.813			0.46	1.1373	17.0086
1987	1142.400	5.301	1147.701			0.46	1.3565	17.5072
1988	1226.400	5.691	1232.091			0.46	1.7779	23.7642
1989	1394.400	6.471	1400.871			0.46	1.8873	23.0657
1990	1587.600	7.367	1594.967			0.46	2.2336	23.2975
1991	990.000	4.594	994.594			0.46	2.0038	18.1137
1992	949.200	4.405	953.605			0.46	1.1420	12.0774
1993	1030.800	4.783	1035.583			0.46	1.2467	13.4863
1994	842.815	3.911	846.726	711.358	0.000	0.46	0.9557	9.4912
1995	1001.628	4.648	1006.276	799.748	0.000	0.46	1.0853	10.2789
1996	1025.880	4.761	1030.640	810.673	0.000	0.46	0.8718	7.5806
1997	794.220	3.686	797.905	626.612	0.526	0.46	0.8265	6.2012
1998	648.496	0.000	648.496	536.581	12.215	0.00	0.6064	5.2414
1999	492.585	2.000	494.585	412.781	7.275	0.40	0.6057	4.9696
2000	500.297	0.000	500.297	405.277	2.707	0.00	0.4529	3.6777
2001	646.433	9.000	655.433	490.555	2.170	1.37	0.5290	4.1345
2002	521.838	1.100	522.938	361.519	2.444	0.21	0.4299	3.0864
2003	528.815	1.510	530.325	402.604	2.452	0.28	0.4218	3.3755
2004	659.720	7.400	667.120	519.086	2.036	1.11	0.5836	4.5401
2005	513.373	0.100	513.473	416.717	0.640	0.02	0.5154	4.7971
2006	429.737	1.820	431.557	358.778	2.045	0.42	0.7212	5.7178
2007	369.851	3.065	372.916	303.373	2.070	0.82	0.8211	7.4274
2008	296.810	2.460	299.270	185.746	0.319	0.82	0.8476	8.0833
2009	324.382	0.000	324.382	167.808	0.740	0.00	0.8553	9.2632
2010	386.444	0.160	375.400	164.161	0.302	0.04	1.0954	11.7000
2011	331.176	11.955	375.400	125.817	0.122	3.18	0.9902	11.0945

Discards make up approximately 0.16% of the catch over the 1998-2006 period.

Silver Trevally exhibited a period of high catch rates during 1989-1991 which were the result of a set of highly efficient vessels entering the fishery. These catch rates were considered not to represent a sustainable fishery and are not expected to be repeated. Therefore 1992-2001 was selected by the RAG as being a more representative reference period. In addition, the coastal waters within the Bateman's Bay MPA were removed from consideration during the catch rate standardization; the catches were deemed possible as fish could move from the MPA, but catch rates are not expected to be so high outside the MPA.

Table 20.26 RBC calculations for Silver Trevally. C_{targ} and $CPUE_{targ}$ relate to the period 1992-2001, $CPUE_{Lim}$ is 40% of the target, and $\overline{CPUE}$ is the average catch rate over the last four years. The RBC calculation does not account for predicted discards of predicted State catches. Wt_Discard is the weighted average discards from the last four years, as with Equ (7).

Ref_Year	1992-2001
CE_Targ	0.8322
CE_Lim	0.3329
CE_Recent	0.9471
Wt_Discard (t)	6.582
Scaling	1.2302
Last Year's TAC	540.000
C_{targ}	796.955
RBC	**980.384**

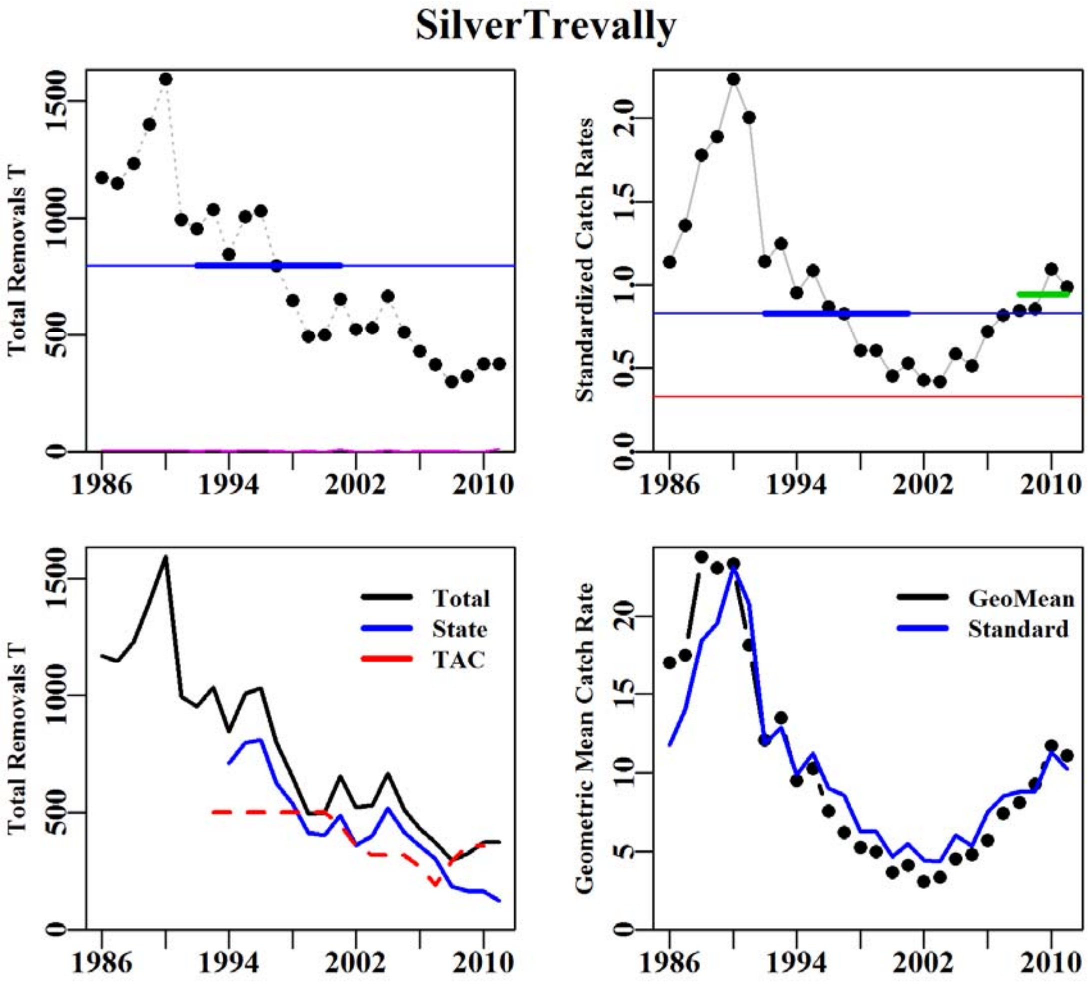

Figure 20.18 Silver Trevally. Top left is the total removals with the fine line illustrating the target catch. Top right represents the standardized catch rates (with records within the Bateman's Bay MPA removed; Haddon, 2012) with the upper fine line representing the target catch rate and the lower line the limit catch rate. Thickened lines represents the reference period for catches, catch rates, and the recent average catch rate.

20.5.9 Ribaldo (RBD – 37224002 – Mora moro)

It was decided that this year the option of treating Ribaldo as one of the primary target species would be examined. This entailed changing the implied target reference point from 48% of the unfished state to 40% of the unfished state. Because the target catch rate is taken as a proxy for 48% unfished biomass, to make it equivalent to 40% means the average catch rate over the reference period should be multiplied by 0.8333 (thus 0.83334 × 48 = 40).

Table 20.27 Ribaldo data for the TIER 4 calculations. Total is the sum of Discards, State, Non Trawl and SEF2 catches. All values in Tonnes. CE is the standardized catch rate for Zones 10 to 50 in depths 0 – 1000m (Haddon, 2012). GeoMean is the geometric mean catch rates. Discards are estimates from 1998 to present. The ratio of discards to catch over the 1998 – 2006 period was used to estimate the discards between 1986 and 1997, the proportion of which is the PDiscard.

Year	Catch	Discards	Total	State	Non-T	PDiscard	CE	GeoMean
1986	4.800	0.723	5.523			13.09	2.2797	14.6630
1987	8.400	1.265	9.665			13.09	1.2772	10.2593
1988	8.400	1.265	9.665			13.09	2.0037	16.5570
1989	8.400	1.265	9.665			13.09	1.8029	18.2556
1990	2.400	0.362	2.762			13.09	1.4196	8.9113
1991	7.200	1.085	8.285			13.09	1.3647	7.9930
1992	15.600	2.350	17.950			13.09	1.3480	9.7616
1993	36.000	5.423	41.423			13.09	1.1172	11.2449
1994	28.021	0.063	28.021	0.418	0.000	13.09	1.2565	11.8156
1995	95.719	0.814	95.719	5.401	0.000	13.09	1.3011	12.3128
1996	85.154	0.529	85.154	3.510	0.000	13.09	1.0009	10.1757
1997	103.704	0.907	103.704	4.057	1.962	13.09	0.8776	9.8023
1998	95.427	23.766	119.193	0.102	2.431	90.37	0.8530	9.6696
1999	64.076	6.555	70.631	0.031	3.335	66.07	0.7871	8.7093
2000	63.117	8.284	71.401	0.022	8.736	48.61	0.7152	7.4217
2001	75.565	4.468	80.033	0.303	21.161	17.23	0.6655	6.7639
2002	171.727	7.305	179.033	0.000	95.820	4.08	0.6229	6.7944
2003	205.908	26.457	232.365	0.037	103.460	11.39	0.6103	6.7153
2004	199.188	16.087	215.275	0.061	102.509	7.47	0.6613	7.2233
2005	105.471	21.800	127.271	0.118	52.297	29.37	0.5715	6.3488
2006	116.822	3.100	119.921	0.000	73.324	2.58	0.6153	6.3304
2007	61.126	0.451	61.577	0.000	36.371	0.73	0.4015	3.2493
2008	97.215	2.629	99.843	0.000	70.985	2.63	0.5556	4.7326
2009	134.086	3.626	137.712	0.000	86.624	2.63	0.6149	5.6978
2010	111.395	1.955	113.350	0.000	65.348	1.72	0.6321	5.5851
2011	116.712	7.076	123.789	0.030	56.931	5.72	0.6447	5.8331

Discards make up approximately 13.1 % of the catch over the 1998-2006 period.

There was no significant effect on the catch rate standardization of whether a shot was within or outside of one of the current closures (Haddon, 2011). As the standardized catch rate trend was indistinguishable from the series without the spatial factor it was not included.

Table 20.28 RBC calculations for Ribaldo. C_{targ} and $CPUE_{targ}$ relate to the period 1995-2004, $CPUE_{Lim}$ is 40% of the target, and $\overline{CPUE}$ is the average catch rate over the last four years. The RBC calculation does not account for predicted discards of predicted State catches. Wt_Discard is the weighted average discards from the last four years, as with Equ (7).

Ref_Year	1995-2004
CE_Targ	0.4047
CE_Lim	0.1619
CE_Recent	0.6118
Wt_Discard	4.954
Scaling	1.8527
Last Year's TAC	168
C_{targ}	125.251
RBC	**232.054**

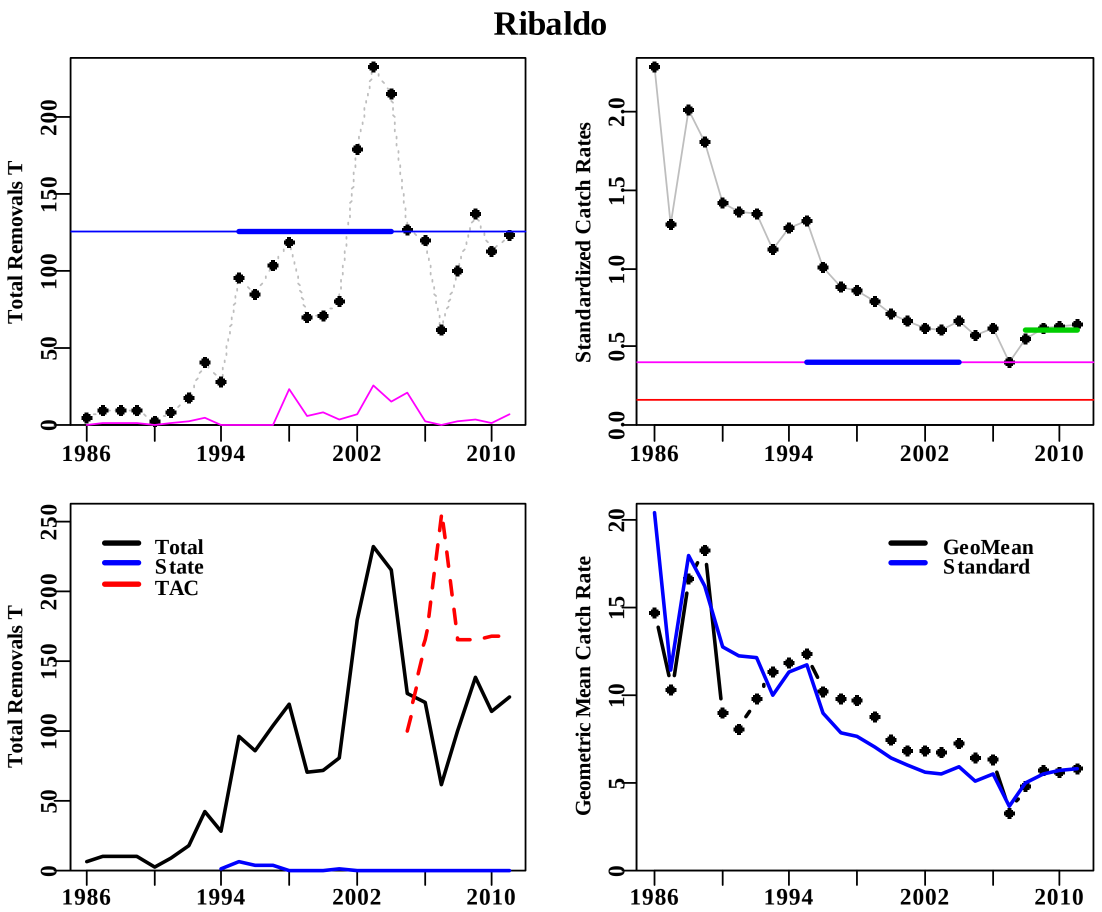

Figure 20.19 Ribaldo. Top left is the total removals with the fine line illustrating the target catch. Top right represents the standardized catch rates with the upper fine line representing the target catch rate and the lower line the limit catch rate. Thickened lines represents the reference period for catches, catch rates, and the recent average catch rate.

Table 20.29 RBC calculations for Ribaldo. C_{targ} and $CPUE_{targ}$ relate to 83.33% of the average over 1995-2004, $CPUE_{Lim}$ is 40% of the target, and $\overline{CPUE}$ is the average catch rate over the last four years. The RBC calculation does not account for predicted discards of predicted State catches. Wt_Discard is the weighted average discards from the last four years, as with Equ (7). The proxy target is here B40%. The 50% rule may be required if this RBC is used.

Ref_Year	1995-2004
CE_Targ	0.3373
CE_Lim	0.1619
CE_Recent	0.6118
Wt_Discard	4.954
Scaling	2.5653
Last Year's TAC	168
C_{targ}	125.251
RBC	**321.309**

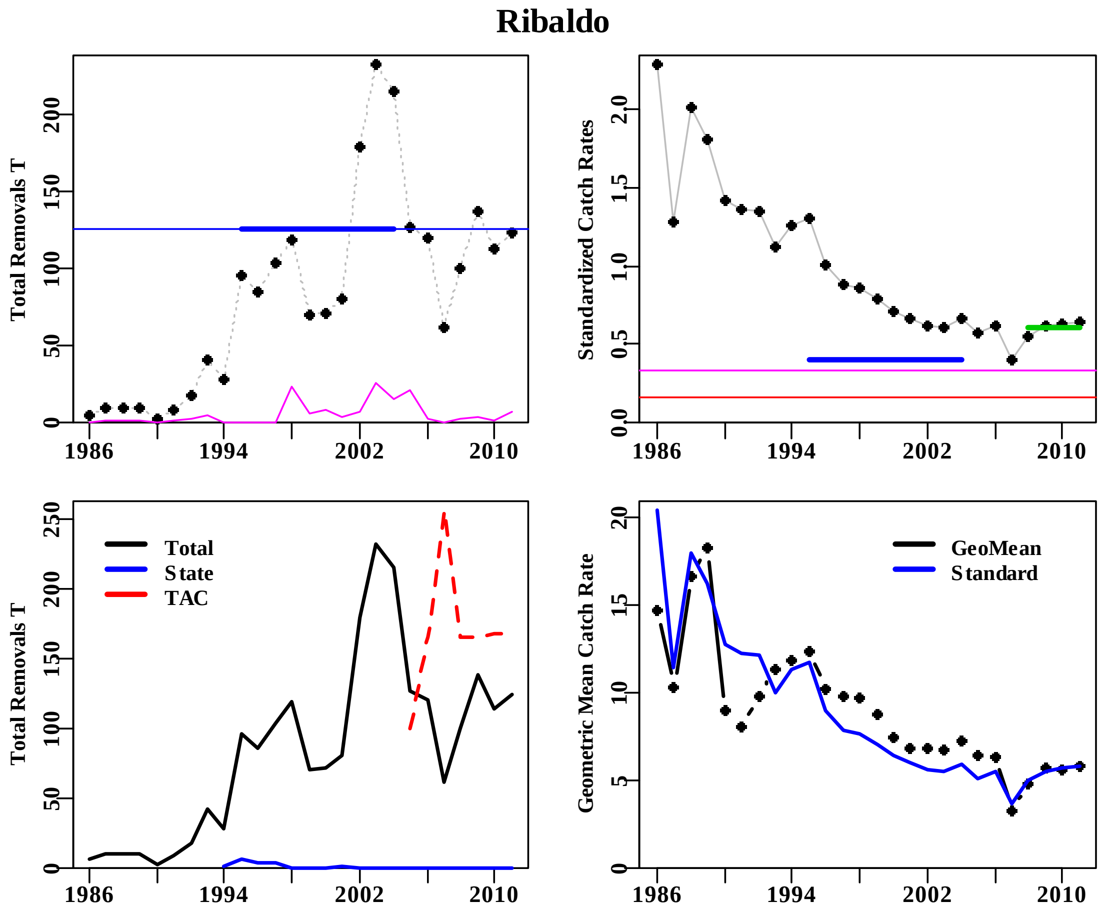

Figure 20.20 Ribaldo. Top left is the total removals with the fine line illustrating the target catch. Top right represents the standardized catch rates with the upper fine purple line representing the target catch rate (83.33% of the average over the reference period) and the lower line the limit catch rate. Thickened lines represents the reference period for catches, catch rates, and the recent average catch rate.

20.6 Deep-Water

20.6.1 Summary Results

Table 20.30. Summary statistics from the TIER 4 analyses for each fishery.

Fishery	Ref Years	Target Catch	RBC	50% Meta
Smooth Oreo Cascade	1996-2005	199.260	710.823	Yes
Smooth Oreo Non-Cascade	1989-1998 (-1992)	23.264	20.638	Yes
Mixed Oreo	1993-2001	151.822	120.412	Yes
Western Deepwater Shark	1995-2004	124.207	374.417	Yes
Eastern Deepwater Shark	1995-2004	105.307	89.511	
Alfonsino	2001-2005	127.620	189.548	Yes

20.6.2 Oreos General

Table 20.31**.** The catch of all species of Oreos in tonnes reported in each fishery. GAB is the Great Australian Bight, SET is the South East Fishery, and HST is High Seas Trawl STR is South Tasman Rise fishery and the WDW is the Western Deep Water Trawl fishery.

Year	GAB	GHT	HSN	HST	SEN	SET	SPF	SSF	STR	VIT	WDW
1986						56.636					
1987	0.581					89.630					
1988	67.935					89.242					
1989	215.481					533.720					
1990	10.178					1090.260					
1991	6.982					1129.201					
1992	94.219					3201.806					58.000
1993	2.780					1036.616					58.030
1994	48.184					1043.359					20.795
1995	0.730					1025.771					1.186
1996	5.264					771.783					8.268
1997	39.757					2050.730					0.635
1998	20.916				0.009	2021.332					
1999	20.437			2.896	0.019	882.455					
2000	49.187				0.001	1010.255		0.100			0.111
2001	12.647				0.007	1079.123			25.450		4.314
2002	0.580		0.007	24.389	0.137	828.422			2.500		
2003	5.678	0.527		129.630		750.909				0.070	
2004	8.782	0.702		168.647		432.483			32.683		0.633
2005	24.215	0.807		92.576		233.887			151.600		
2006	16.621	1.168		0.246		173.732	0.034		22.520		
2007	3.447	0.823		1.224		129.664					
2008	0.275	0.685				77.386					0.020
2009	1.796	1.958		101.491		85.975					
2010	1.180	1.047		146.562		89.314					
2011	0.080	0.400		4.579		101.976					

Table 20.32. The catch of each recognized species of Oreos in tonnes reported in the GenLog (SEF1) database. Smooth and Spiky Oreos are the most commonly reported.

	Oreo	Spiky	Oxeye	Smooth	Warty	Black	Oreo Dory
Year	37266000	37266001	37266002	37266003	37266004	37266005	37266902
1986		20.565	3.608		32.463		
1987		45.771	18.706	6.534	19.200		
1988	13.451	46.386	10.830	62.969	23.541		
1989	0.970	372.495	33.817	324.499	17.420		
1990	0.430	274.056	4.080	819.615	2.257		
1991		117.596	2.722	1015.337	0.528		
1992		743.462	12.285	2597.228	1.050		
1993	0.580	409.933	4.110	679.732	3.071		
1994		351.801	3.103	738.534	18.900		
1995		486.155	17.195	509.587	14.750		
1996		431.104	0.900	337.355	15.956		
1997		1080.351	4.927	984.844	21.000		
1998		1297.604	0.940	718.907	24.806		
1999	0.400	554.449	0.080	339.483	11.275	0.120	
2000		474.784	0.030	553.853	30.987		
2001		513.634	0.400	601.417	6.090		
2002		305.105	0.095	533.431	1.595	15.809	
2003		457.110		367.077	0.800	61.827	
2004		366.919	0.120	263.296	1.570	12.025	
2005		183.308	3.549	296.377		12.278	7.573
2006		67.263	10.490	87.811		0.261	48.496
2007		21.435	11.983	44.908			56.832
2008		8.558	1.182	13.745		0.007	54.874
2009		110.205	2.145	3.632			75.238
2010		54.371	1.282	108.244			74.206
2011		15.764	7.951	5.972			77.348
Total	15.831	8810.183	156.530	12014.388	247.259	102.327	394.567

20.6.3 Smooth Oreo (Cascade) (DOO – 37266003 – Smooth Oreo Pseudocyttus maculatus and DOE 37266902 – Oreo Dory)

After examination of the depth distribution of records, only data from OR Zone 40 in depths 650 – 1250m were used. All vessels recording smooth oreos in orange roughy zone 40 were included in the analysis. The discard rate estimated in 2007 was 12.3 %. Catch rates as Kg/Tow.

Table 20.33**.** Number of records where Smooth Oreos or Oreos (CAAB codes 37266003, and 37266902 = Smooth Oreo, and Oreo Dory) on the Cascade are reported by trawling in OR Zone 40, in depths 650 to 1250 m. Used are the number of records excluding those reported as being in the 700 m closure. Vessels represent the count of vessels reporting oreos. Effort H and CatchT are the reported effort and catch of Smooth Oreos from the used records. The geometric mean CE is the raw unstandardized catch rate in Kg/tow. StandCE is the standardized catch rates and StErrCE is the standard error of the standardized catch rates (Figure 20.24).

Year	Records	Vessels	Effort H	CatchT	Geo Mean CE	StandCE	StErrCE
1989	211	5	120.80	127.768	267.387		
1990	296	7	126.30	91.494	146.934		
1991	7	1	2.70	1.060	86.926		
1992	13	4	7.55	11.320	426.816		
1993	19	1	7.96	2.098	50.017		
1994	241	4	140.02	94.474	142.348	0.5044	0
1995	94	6	88.44	14.288	49.713	0.3827	0.3282
1996	457	8	311.20	142.244	64.177	0.4944	0.3574
1997	305	7	185.87	281.722	99.386	0.5764	0.3784
1998	166	8	126.66	103.366	128.204	0.6806	0.3833
1999	94	9	52.75	98.568	191.733	0.9863	0.4000
2000	358	10	240.07	295.843	195.144	0.9112	0.3678
2001	216	9	109.39	276.287	234.844	1.2054	0.3770
2002	354	9	118.38	284.595	110.842	0.5629	0.3635
2003	161	7	63.81	104.069	139.562	0.6631	0.3877
2004	116	5	27.73	100.785	375.609	2.2969	0.3912
2005	88	5	35.19	60.033	149.794	1.1473	0.4051
2006	46	3	10.94	61.300	288.216	1.3624	0.4395
2007	53	2	28.49	45.408	168.150	1.1275	0.4328
2008	85	3	50.72	16.245	44.721	0.8945	0.4395
2009	35	2	18.85	2.485	41.907	0.6613	0.4780
2010	29	2	27.13	7.315	144.194	2.1550	0.5002
2011	10	2	7.99	1.320	73.602	1.3877	0.6754

Table 20.34. Catches and numbers of records for Smooth Oreo (CAAB 37266003) and, from 2006, for both Smooth Oreo and the new category Oreo Dory (CAAB 37266902).

Year	Smooth	Smooth	Year	Smooth	Smooth	OreoDory	OreoDory
1989	127.768	211	2006	60.910	34	0.390	8
1990	91.494	296	2007	43.698	32	1.710	16
1991	1.060	7	2008	12.365	14	3.880	71
1992	11.320	13	2009	0.060	3	2.425	32
1993	2.098	19	2010	3.200	5	4.115	24
1994	94.474	241	2011			1.320	10
1995	14.288	94					
1996	142.244	457					
1997	281.722	305					
1998	103.366	166					
1999	98.568	94					
2000	295.843	358					
2001	276.287	216					
2002	284.595	354					
2003	104.069	161					
2004	100.785	116					
2005	60.033	88					

Table 20.35. Statistical model structures used in this analysis. DepCat is a series of 50 metre depth categories.

Model 1	Year
Model 2	Year + Vessel
Model 3	Year + Vessel + DepCat
Model 4	Year + Vessel + DepCat + Month
Model 5	Year + Vessel + DepCat + Month + DayNight
Model 6	Year + Vessel + DepCat + Month + DayNight + Vessel:Month
Model 7	Year + Vessel + DepCat + Month + DayNight + DepCat:Month

Table 20.36**.** Model selection criteria, including the AIC and other diagnostics. Smooth Oreos (Cascade). The model with the smallest AIC and largest Adjusted r^2 is accepted as best. RSS is residual sum of squares, MSS is Model sum of squares.

	Year	Vessel	DepCat	Month	**DayNight**	Vessel:Mth	DepCat:Mth
AIC	3298	3193	2809	2800	**2797**	2895	2914
RSS	8929	8529	7411	7331	**7310**	6797	6946
MSS	799	1198	2317	2397	**2418**	2931	2782
Nobs	2908	2908	2895	2895	**2895**	2895	2895
Npars	18	32	44	55	**58**	212	190
Adj_r2	7.672	11.375	22.666	23.208	**23.348**	24.635	23.606
Δr^2	0.000	3.703	11.291	0.541	**0.141**	1.287	-1.029

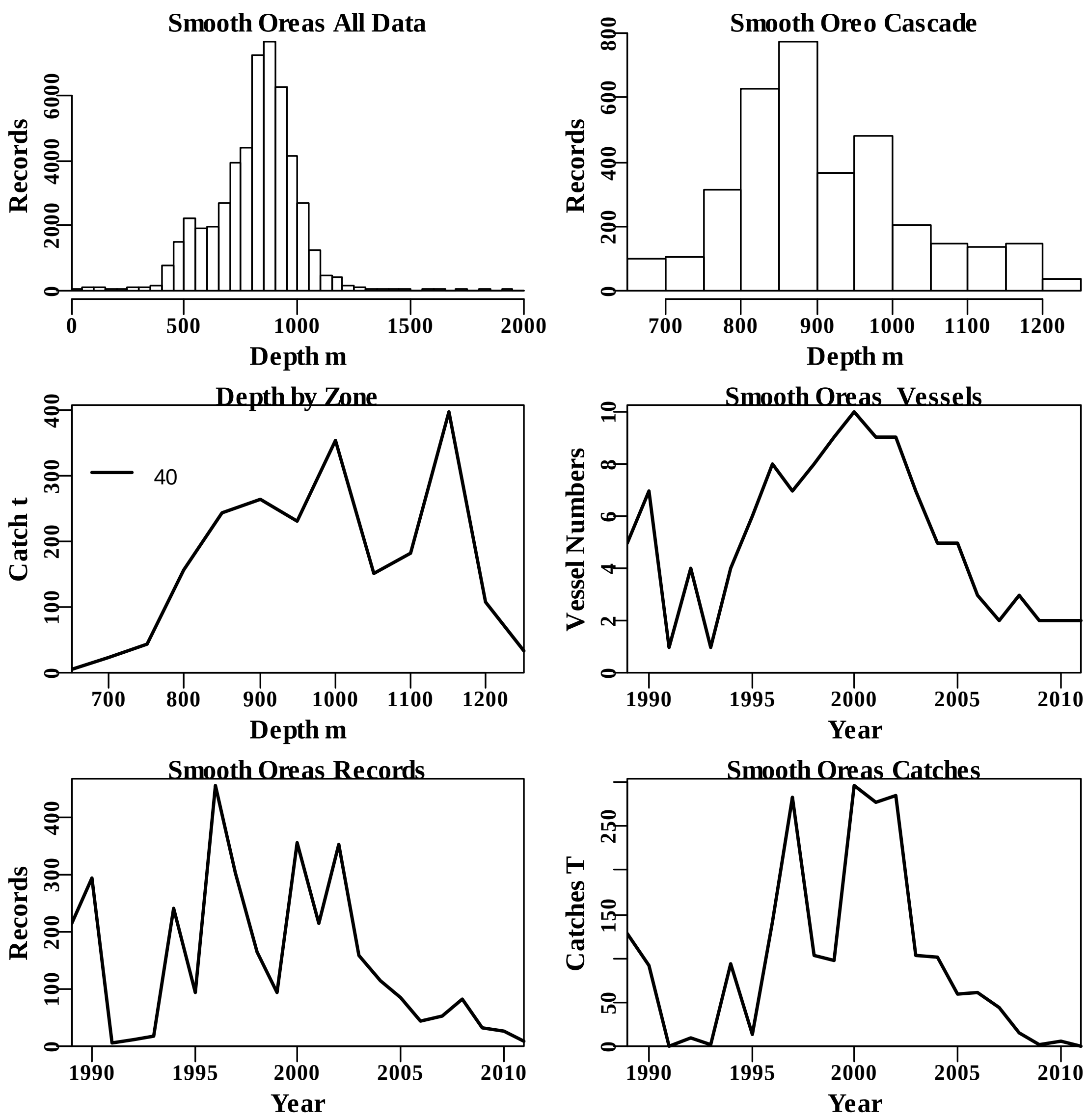

Figure 20.21. Smooth Oreo (Cascade) are reported from trawling in OR Zone 40, in depths 650 to 1250 m. The top left is the depth distribution of all records reporting Smooth Oreo (not just Cascade), the top right graph depicts the depth distribution of shots containing Smooth Oreo in OR Zone 40 and depths 650-1250 m. The middle left diagram depicts the distribution of catch across all years by depth within OR zone 40, the right hand middle graph depicts the number of vessels reporting smooth oreos through time. The bottom left reflects the number of records used in analysis, and bottom right are the Smooth Oreo catches used in the analysis.

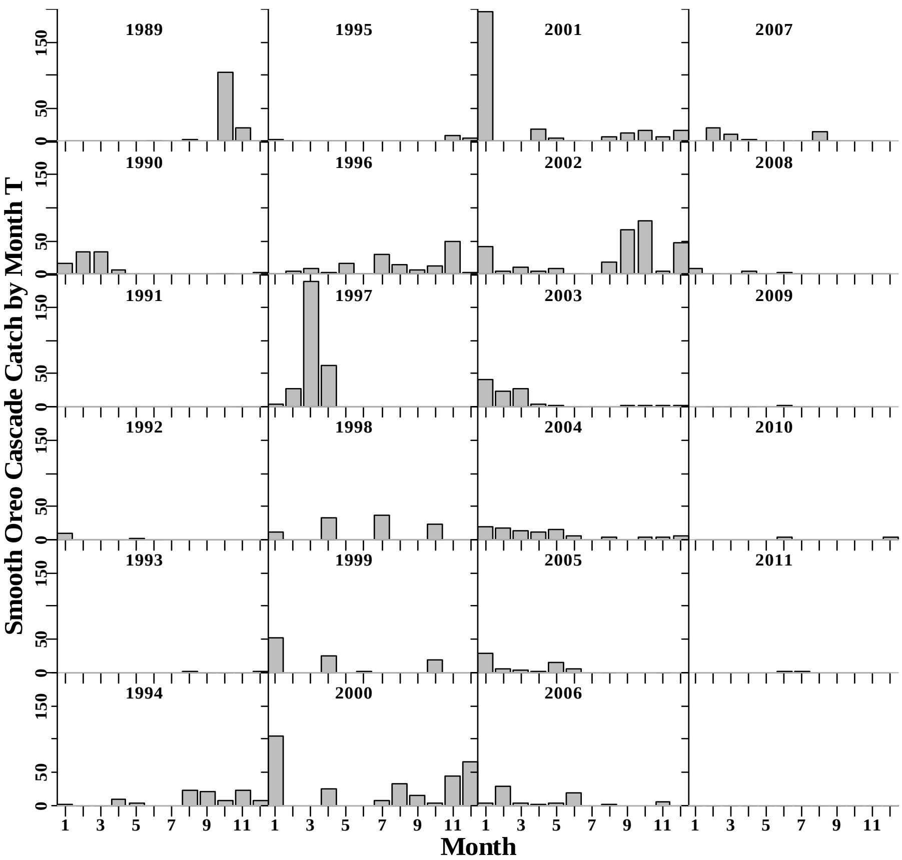

Figure 20.22. The catch by month for each year of smooth oreos on the Cascade from 1989 - 2011. Each axis is identical.

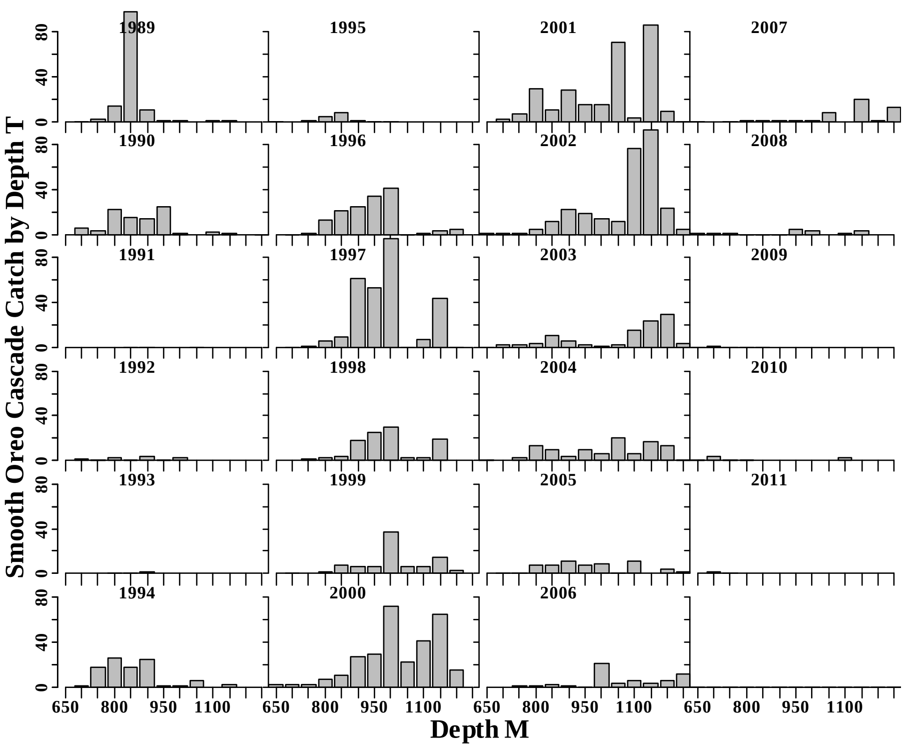

Figure 20.23**.** Catch in tonnes by depth category (in metres) for smooth oreos on the cascade from 1989 – 2011.

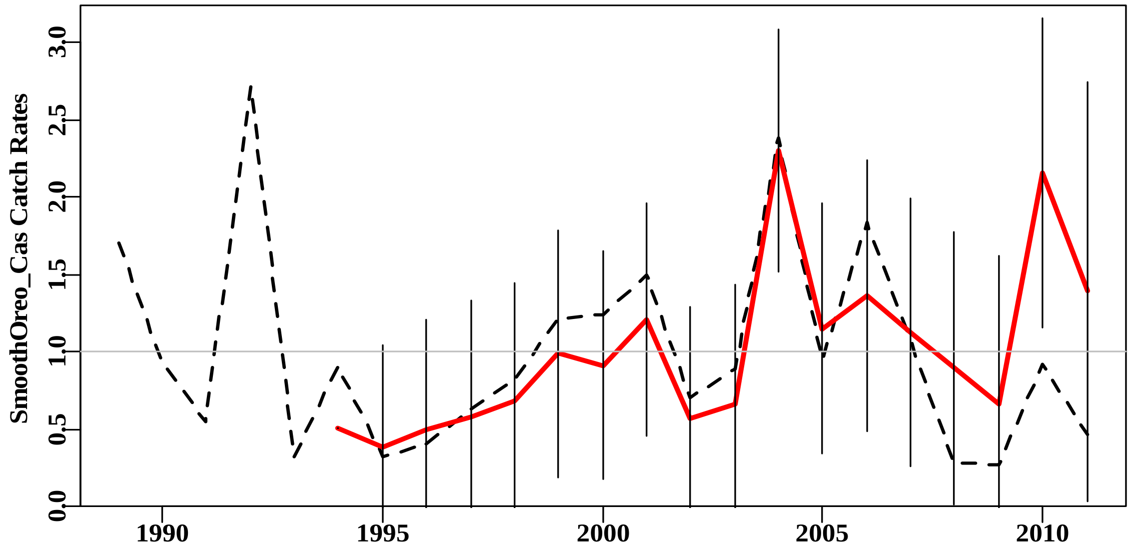

Figure 20.24**.** Standardized catch rates for the Smooth Oreo on the Cascade. The geometric mean catch rates are depicted as a dashed line, while the standardized catch rates are the solid line. Numbers of data points before 1994 were too few for standardization. The error bars are two times the Standard Errors.

20.6.3.1 TIER 4 Smooth Oreo (Cascade)

It is very doubtful whether the catch rate values for 2009 – 2011 are valid as there were so few data points, especially in 2011. In addition, the extremely rapid changes in apparent catch rates indicates that the observed catch rates are unlikely to be representative of the stock size, so the validity of applying even a TIER 4 needs to be questioned. The error bars illustrated in Figure 20.24 are expected to overestimate the certainty with which the mean catch rates are estimated, which suggests that the catch rates have not deviated significantly from each other since 1994 (despite the large changes in the apparent mean catch rate). Catches were so small because the deepwater fishery is barely being pursued anywhere. Because the catches were so small it would not have been valid to update the TIER 4 analysis, which is in-line with a RAG decision to only update the Tier 4 assessment if there were more than 10 t of catch taken. Despite the lack of assessment there were no signs of stress in these fishery data in terms of the distribution of catches or the catch rates of those catches that were reported.

20.6.4 Smooth Oreo (non-Cascade) (DOO – 37266003 – Pseudocyttus maculates)

After examination of the depth distribution of records, only data from OR Zones 10, 20, 21, 30, and 50, taken by trawl in the SET fishery in depths 400 – 1200m were used. All vessels recording smooth oreos were included in the analysis. The Cascade, GAB and zone 70 Smooth Oreos were excluded. The discard rate estimated in 2007 was 12.3 % and this was assumed for other years. The ratio of catches inside relative to outside the current closures is 84.9% versus 15.7 % out of a total of 7236 t considered in the analysis.

Table 20.37. Number of records where Smooth Oreos not on the Cascade are reported from trawling in OR Zones 10, 20, 21, 30, 50, in depths 400 to 1200 m. Vessels represents the count of vessels reporting smooth oreos. CatchT is the reported catch of Smooth Oreos. The geometric mean CE is the raw unstandardized catch rate in Kg/tow. The left hand five columns represent data, in both the closed and currently open areas the right hand five columns (post-fixed O) represent the areas left open following the 700m closure.

Year	Records	Vessels	Effort	Yield	Geom	RecordsO	VesselsO	EffortO	YieldO	GeomO
1987	33	3	74.3	6.250	118.343	27	2	61.8	4.660	112.932
1988	41	9	71.8	39.363	232.252	15	6	21.0	5.218	144.408
1989	247	22	151.9	177.234	209.771	25	8	33.2	8.855	136.437
1990	648	38	478.5	715.045	302.562	54	12	35.9	62.269	382.833
1991	667	34	689.3	904.830	242.766	134	20	236.2	119.733	129.486
1992	1327	30	1062.7	2216.456	396.338	231	21	289.5	384.811	206.685
1993	999	31	691.2	605.649	136.366	95	19	140.4	68.926	97.532
1994	1068	26	743.7	574.904	93.488	109	18	171.7	43.981	91.736
1995	667	21	1175.5	493.353	114.545	76	11	260.6	34.425	105.413
1996	498	18	810.0	171.377	72.869	77	15	178.3	13.503	54.227
1997	407	20	774.9	153.412	108.713	77	16	223.8	21.482	107.409
1998	342	19	900.8	134.877	114.236	59	16	200.4	28.092	116.670
1999	278	21	1043.9	61.895	101.167	51	13	253.1	5.444	60.900
2000	314	23	1133.2	91.490	94.029	80	16	375.5	19.153	71.681
2001	520	23	2017.3	282.152	175.312	194	22	844.2	86.807	159.792
2002	516	22	2538.8	222.806	132.965	163	19	876.1	56.186	109.442
2003	444	17	2008.6	166.908	114.728	141	14	788.4	40.513	90.968
2004	404	18	1987.7	110.666	95.065	126	16	655.9	32.213	101.907
2005	191	10	762.7	53.557	89.466	60	9	295.9	12.648	69.210
2006	26	7	49.7	15.019	113.430	11	4	44.2	0.589	13.588
2007	8	2	3.5	0.886	73.216	3	2	2.7	0.156	49.716
2008	3	2	19.3	0.910	125.992	3	2	19.3	0.910	125.992
2009	15	8	49.0	1.295	47.042	14	7	43.0	1.265	48.579
2010	11	4	48.9	0.579	32.832	11	4	48.9	0.579	32.832
2011	17	7	104.7	4.727	92.224	17	7	104.7	4.727	92.224

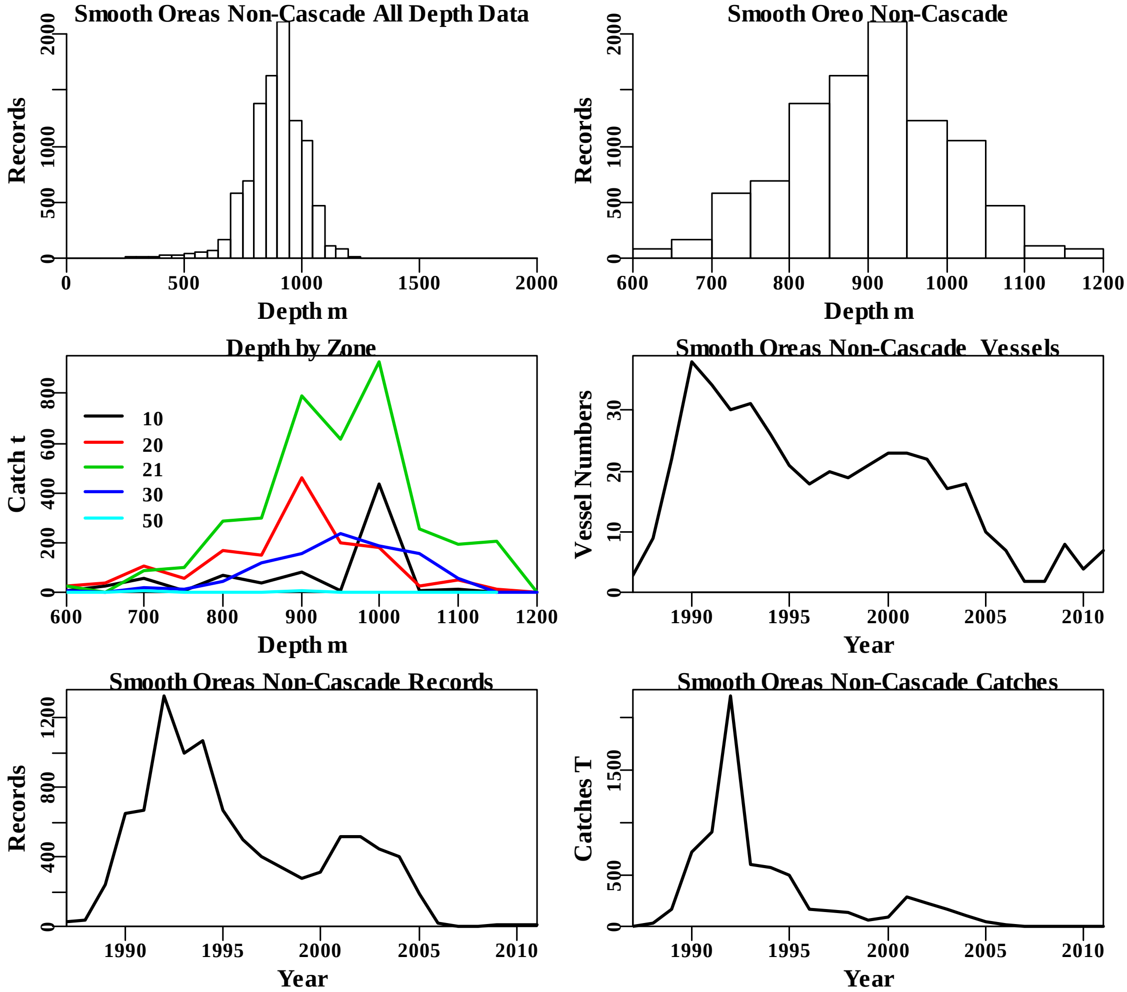

Figure 20.25. Smooth Oreo (Non-Cascade) are reported from trawling in OR Zones 10, 20, 21, 30, and 50, in depths 600 to 1200 m. The top left is the depth distribution of all records reporting Smooth Oreo (not just Cascade), the top right graph depicts the depth distribution of shots containing Smooth Oreo (non-Cascade) in OR Zones 10, 20, 21, 30, and 50, in depths 600 to 1200 m. The middle left diagram depicts the distribution of catch across all years by depth within OR zones, the right hand middle graph depicts the number of vessels reporting smooth oreos through time. The bottom left reflects the number of records for the non-Cascade, and bottom right are the Smooth Oreo catches used in the analysis.

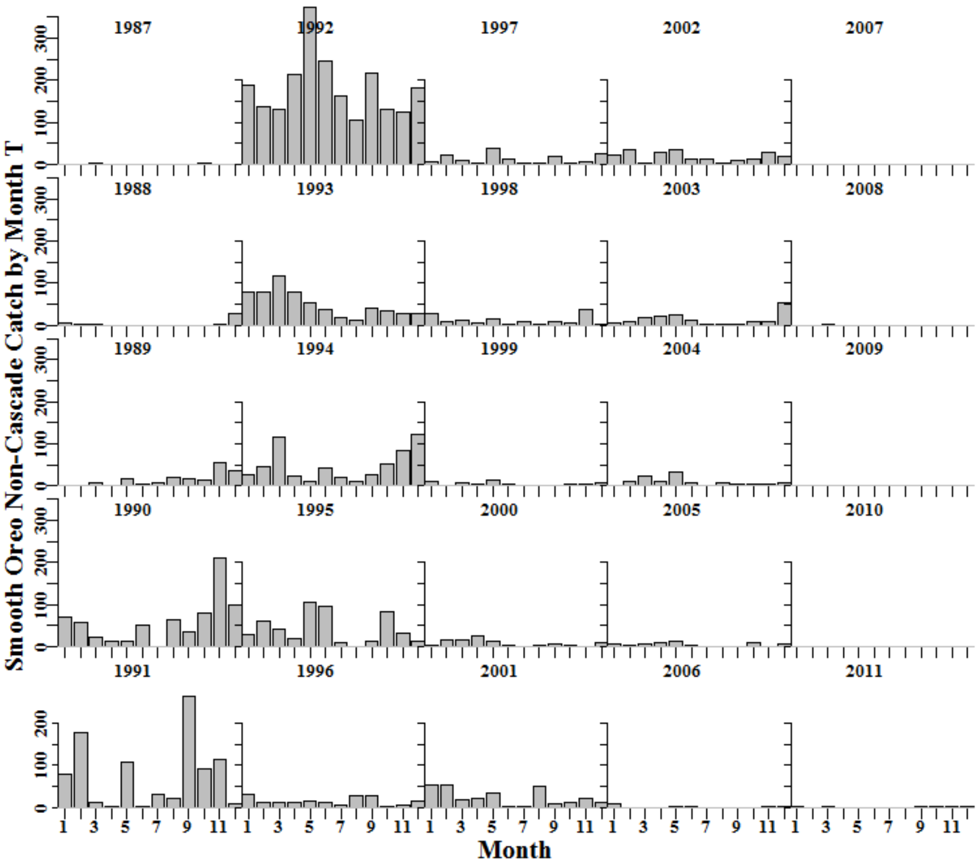

Figure 20.26. Catch by month for smooth oreo from non-Cascade areas (except GAB and Zone 70) from 1989 - 2011. Catches since 2006 have been very low.

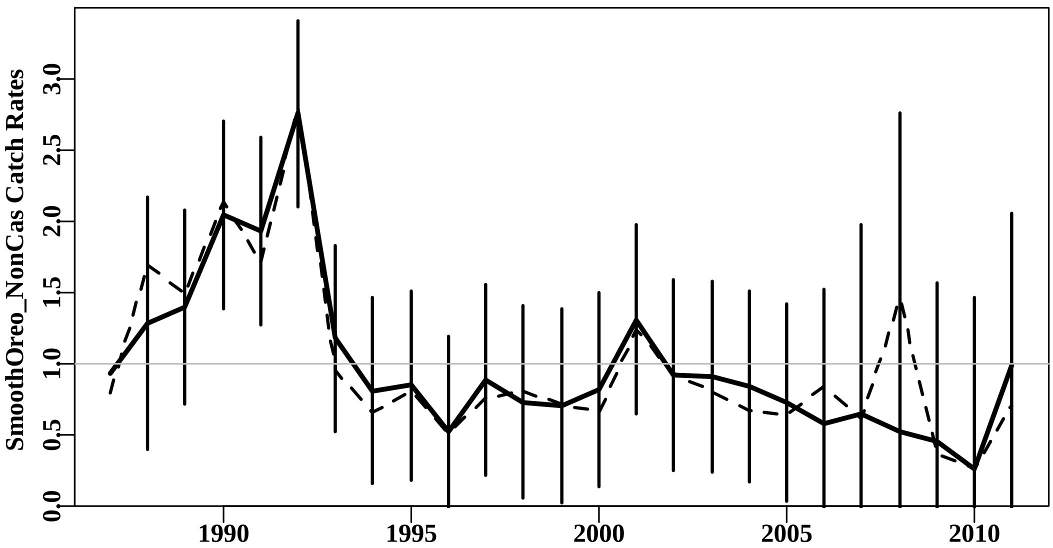

Figure 20.27**.** Standardized catch rates for the Smooth Oreo not on the Cascade. The geometric mean catch rates are depicted as a dashed line, while the standardized catch rates are the solid line. The error bars are two times the Standard Errors. The times series are scaled to the mean of each series for visual comparison. Data since 2007 has been minimal.

Table 20.38**.** Model selection criteria, including the AIC, the residual sum of squares, the Model sum of squares, the number of usable observations, the number of parameters, the adjusted r^2 and the increment in adjusted r^2. The complete model was optimal. The effect of being in the open or closed areas (Closure) was only minor.

	Year	Vessel	DepCat	Month	ORZone	Closure	DayNight	DepCat:Month
AIC	10568	9783	9381	9355	9340	9325	9316	**9313**
RSS	28689	25956	24828	24704	24645	24602	24563	**23890**
MSS	2741	5474	6601	6726	6784	6827	6866	**7540**
Nobs	9691	9691	9618	9618	9618	9618	9618	**9618**
Npars	25	118	130	141	145	146	149	**281**
adj_r^2	8.494	16.407	19.929	20.238	20.394	20.525	20.625	**21.710**
Δr^2	0.000	7.913	3.522	0.309	0.156	0.131	0.100	**1.086**

Table 20.39. The standardized catch rates for the alternative statistical models for Smooth Oreos in OR zones 10, 20, 21, 30, and 50, in depths 600 to 1200 m. The optimal model was included all factors to DayNight (not Closure). St Err is the estimate of standard error for the optimum model. Values are relative to the mean of the standardized catch rates. Month is omitted for brevity. Note the relatively large standard errors, which imply the trend does not differ from 1.0 since 1993.

Year	Year	Vessel	DepCat	ORZone	Closure	DayNight	DepCat:Month	StErr
1987	0.7942	0.9492	0.7319	0.7634	0.8381	0.8269	**0.9300**	0.0000
1988	1.6905	1.3412	1.2717	1.3302	1.3950	1.3535	**1.2803**	0.4417
1989	1.4815	1.3067	1.4426	1.4952	1.4619	1.4319	**1.3981**	0.3418
1990	2.1288	2.1056	2.0817	2.0305	1.9741	1.9463	**2.0452**	0.3275
1991	1.7080	2.0953	1.9875	1.8502	1.8148	1.7909	**1.9271**	0.3283
1992	2.7854	2.8512	2.9614	2.8050	2.7374	2.7579	**2.7546**	0.3254
1993	0.9587	1.1058	1.2181	1.1800	1.1479	1.1588	**1.1777**	0.3271
1994	0.6572	0.6891	0.7926	0.7952	0.7763	0.7850	**0.8096**	0.3274
1995	0.8059	0.7798	0.8533	0.8514	0.8297	0.8366	**0.8460**	0.3293
1996	0.5131	0.4681	0.5161	0.5246	0.5137	0.5171	**0.5253**	0.3324
1997	0.7659	0.8202	0.8835	0.8849	0.8687	0.8788	**0.8858**	0.3344
1998	0.8054	0.6994	0.7016	0.7282	0.7093	0.7157	**0.7281**	0.3372
1999	0.7140	0.6585	0.6555	0.6809	0.6641	0.6694	**0.7022**	0.3402
2000	0.6632	0.7823	0.8235	0.8130	0.8015	0.8053	**0.8179**	0.3383
2001	1.2342	1.3053	1.2592	1.2565	1.2691	1.2826	**1.3096**	0.3326
2002	0.9361	0.8766	0.8607	0.9083	0.8998	0.9115	**0.9178**	0.3338
2003	0.8081	0.8486	0.8383	0.8882	0.8823	0.8914	**0.9068**	0.3346
2004	0.6698	0.7806	0.7793	0.8285	0.8182	0.8237	**0.8414**	0.3365
2005	0.6329	0.7299	0.6706	0.6874	0.6834	0.6849	**0.7310**	0.3461
2006	0.8430	0.9402	0.7735	0.7804	0.7879	0.7893	**0.5806**	0.4724
2007	0.6187	0.7805	0.6681	0.5989	0.6113	0.6215	**0.6505**	0.6635
2008	1.4505	0.6834	0.6930	0.6918	0.7247	0.7249	**0.5191**	1.1207
2009	0.3646	0.4831	0.3459	0.3991	0.4276	0.4342	**0.4587**	0.5561
2010	0.2638	0.2557	0.2270	0.2466	0.2745	0.2715	**0.2654**	0.5968
2011	0.7065	0.6640	0.9635	0.9816	1.0889	1.0905	**0.9911**	0.5315

20.6.4.1 TIER 4 Smooth Oreo (Non-Cascade)

As with the Cascade smooth oreos assessment it is doubtful whether the catch rate value for 2011 is valid as there were less than 5 t of data that met the reporting requirements. It remains unknown whether catch rates reflect the stock status but there are so few records it appears highly unlikely. Certainly since 1993 the standard error estimates for the standardized catch rates are so large that the mean catch rates cannot be claimed to have differed significantly from 1.0 since 1993.

Again, as for Cascade smooth oreo, catches were so small because the deepwater fishery is barely being pursued anywhere. Because the catches were so small it would not have been valid to update the TIER 4 analysis, which is in-line with a RAG decision to only update the Tier 4 assessment if there were more than 10 t of catch taken. Despite the lack of assessment there were no signs of stress in this fishery in terms of the distribution of catches or the catch rates of those catches that were reported.

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

Allocyttus verrucosus (warty), *Neocyttus rhomboidalis* (spiky), *Neocyttus psilorhynchus* (rough), *Allocyttus niger* black). CAAB codes : 37266004, 37266001, 37266006, 37266005, 37266901, 37266902 (group code). Estimated discard rate in 2007 was 16.2 % and there is no update on that figure. 97.01% of the reported catch is given as spikey oreo (*Neocyttus rhomboidalis*), 2.98% as warty oreo (*Allocyttus verrucosus*), and 0.01% as black oreo (*Allocyttus niger*)(Table 20.32). In the last five years 80 – 91% has been reported as Oreo Dory and the remainder as Spiky oreos. Only data from OR Zones 10, 20, 21, 30, 50, in depths 500 – 1200m were used, in particular only the data from outside the closures are used. All vessels recording mixed oreos were included in the analysis. Orange Roughy zones 40, 60, 70 and unknown were removed.

Table 20.40**.** Number of records where Mixed Oreos are reported from trawling in OR Zones 10, 20, 21, 30, and 50, in depths 500 to 1200 m. Vessels represents the count of vessels reporting mixed oreos. Yield is the reported catch of mixed Oreos. The geometric mean CE is the raw unstandardized catch rate in Kg/tow. The left hand five columns represent all data, the right hand five columns represent the areas left open following the 700m closure.

Year	Records	Vessels	Effort	Yield	Geom	RecordsO	VesselsO	EffortO	YieldO	GeomO
1986	166	9	367	50.966	114.224	138	9	329	47.586	128.028
1987	145	16	353	59.909	133.794	84	12	217	17.390	108.044
1988	161	12	372	33.809	82.647	68	7	192	12.228	77.821
1989	352	18	497	189.239	137.647	114	10	263	25.771	103.141
1990	257	22	172	257.178	292.016	23	11	61	7.335	107.273
1991	215	22	532	86.887	85.155	113	16	389	18.421	72.479
1992	577	31	848	607.582	227.389	174	22	499	76.258	111.068
1993	832	38	1621	281.255	94.969	337	29	1144	80.648	111.752
1994	1077	34	2494	284.569	75.354	419	32	1543	97.882	86.332
1995	1766	30	6060	482.242	92.167	953	23	3835	311.961	128.068
1996	2107	33	6898	420.967	69.658	1237	32	4824	284.955	91.185
1997	2274	34	9607	572.827	103.523	1502	31	6813	387.711	115.469
1998	2348	33	9873	666.856	121.631	1455	30	6170	448.279	132.626
1999	1912	33	7905	441.017	105.804	1191	31	4968	313.340	120.753
2000	1726	38	7739	376.494	97.319	1033	36	4541	253.999	114.544
2001	1926	37	8622	399.034	98.900	1262	36	5714	247.178	101.183
2002	1457	36	7174	212.546	70.372	931	33	4597	145.658	75.006
2003	1462	30	7411	229.224	75.450	915	28	4685	145.208	77.220
2004	1445	30	7502	181.402	66.947	912	28	4802	121.256	72.045
2005	813	22	4271	101.266	64.123	553	20	2882	72.176	67.852
2006	643	23	3230	80.260	50.683	422	22	2168	53.096	53.582
2007	388	17	2026	58.754	55.456	340	17	1831	52.028	54.586
2008	305	16	1751	48.564	72.522	280	16	1602	42.937	70.213
2009	500	17	2743	73.639	65.057	455	17	2482	65.576	62.511
2010	508	15	2900	76.137	65.407	467	15	2683	62.542	60.014
2011	571	17	3514	78.262	76.354	529	17	3244	70.490	74.866

Table 20.41. The catch in tonnes of mixed oreos by Orange Roughy Zone, and, across ORzones in the current open and closed areas.

Year	Total	10	20	21	30	50	Open	Closed
1986	50.966	0.160	30.520		20.278	0.008	47.586	3.380
1987	59.909	0.130	6.470		53.309		17.390	42.519
1988	33.809	0.020	0.150		33.549	0.090	12.228	21.581
1989	189.239	0.030	98.650	37.090	53.409	0.060	25.771	163.468
1990	257.178	4.340	183.043	62.965	6.700	0.130	7.335	249.843
1991	86.887	3.191	47.720	17.251	18.340	0.385	18.421	68.466
1992	607.582	31.646	352.204	190.614	31.622	1.496	76.258	531.324
1993	281.255	1.392	106.148	36.651	107.769	29.295	80.648	200.607
1994	284.569	0.882	90.447	34.734	136.647	21.859	97.882	186.687
1995	482.242	1.388	64.172	8.076	402.359	6.247	311.961	170.281
1996	420.967	8.539	92.953	3.451	278.999	37.025	284.955	136.012
1997	572.827	43.955	129.864	1.390	377.317	20.301	387.711	185.116
1998	666.856	33.724	130.862	1.492	379.621	121.157	448.279	218.577
1999	441.017	13.860	126.159	1.295	241.554	58.149	313.340	127.677
2000	376.494	26.075	111.417	0.775	213.565	24.662	253.999	122.495
2001	399.034	17.880	134.639	7.785	218.687	20.043	247.178	151.856
2002	212.546	36.018	59.214	1.025	105.532	10.757	145.658	66.888
2003	229.224	33.272	57.005	7.550	118.164	13.233	145.208	84.016
2004	181.402	12.011	40.705	1.820	115.255	11.612	121.256	60.145
2005	101.266	5.967	22.182	1.500	62.499	9.118	72.176	29.090
2006	80.260	8.581	12.259	0.270	56.955	2.195	53.096	27.164
2007	58.754	2.340	18.565	1.194	35.345	1.310	52.028	6.726
2008	48.564	2.262	17.114		26.527	2.661	42.937	5.627
2009	73.639	4.105	17.271	0.058	48.027	4.178	65.576	8.063
2010	76.137	5.344	25.346	5.860	37.301	2.286	62.542	13.595
2011	78.262	3.643	20.661	1.990	48.064	3.904	70.490	7.772
Total	6350.885	300.755	1995.740	424.836	3227.394	402.161	3461.910	2888.975

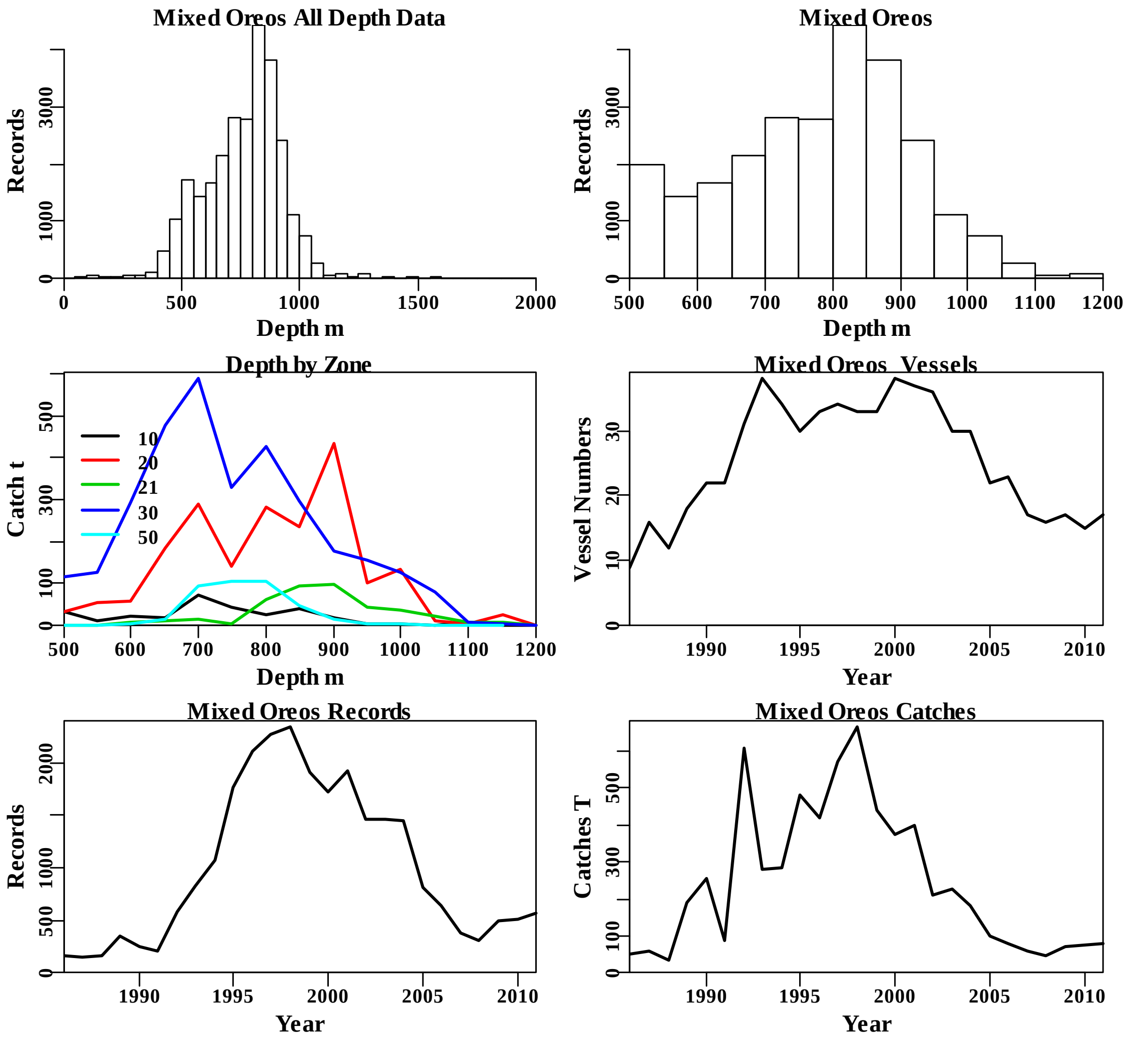

Figure 20.28. Mixed Oreo are reported from trawling in OR Zones 10, 20, 21, 30, and 50, in depths 500 to 1200 m. The top left is the depth distribution of all records reporting Mixed Oreo, the top right graph depicts the depth distribution of shots containing Mixed Oreo in OR Zones 10, 20, 21, 30, 50, in depths 500 to 1200 m. The middle left diagram depicts the distribution of catch across all years by depth within separate OR zones, the right hand middle graph depicts the number of vessels reporting mixed oreos through time. The bottom left reflects the number of records for mixed oreos, and bottom right are the Mixed Oreo catches used in the analysis.

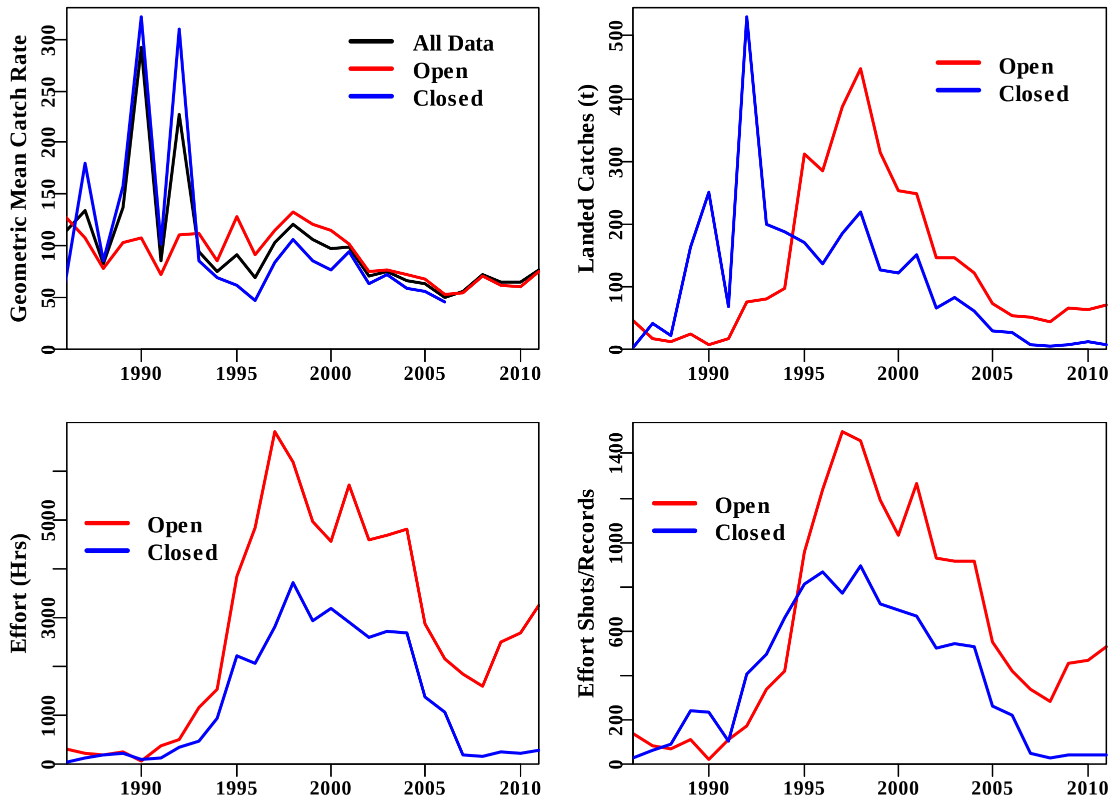

Figure 20.29. Mixed Oreo are reported from trawling in OR Zones 10, 20, 21, 30, and 50, in depths 500 to 1200 m. The top left show the geometric mean catch rate. The top right graph depicts the catch from the open and closed areas. The bottom left graph depicts the number of hours effort recorded for the open and closed areas. Finally, the bottom right hand graph depicts the number of records/shots of effort for the open and closed areas.

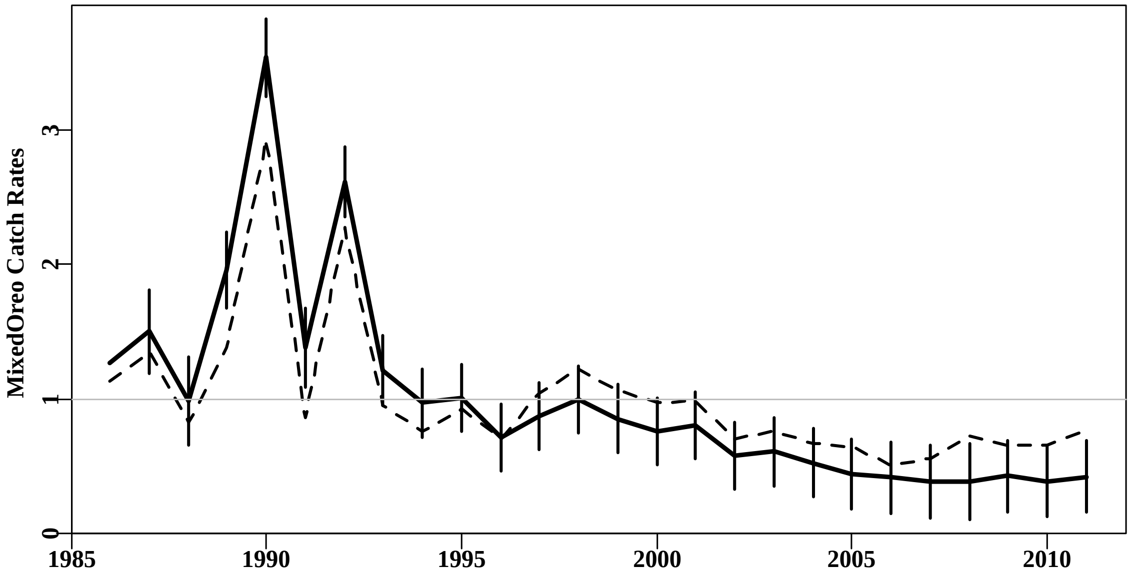

Figure 20.30. The standardized catch rates showing the optimum model (solid black line) and the geometric mean catch rate (dashed line) each scaled to the mean of each time series. The error bars are two times the standard errors.

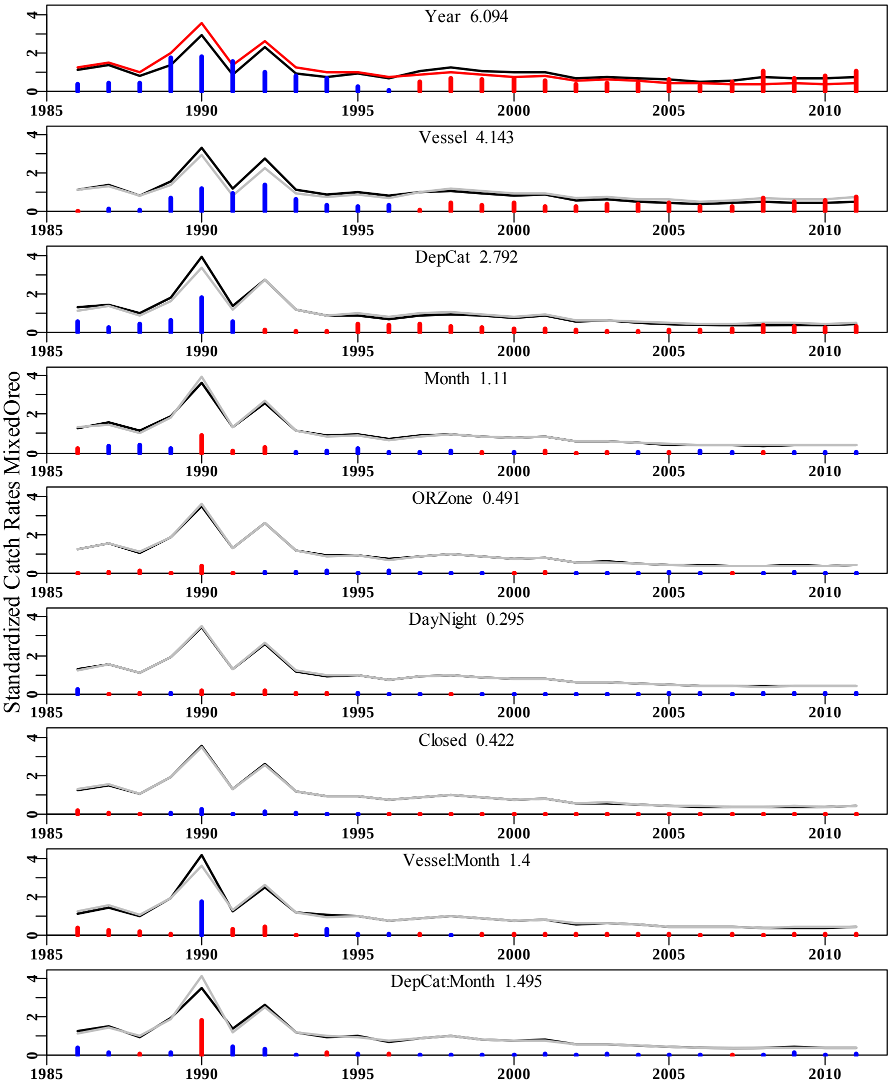

Figure 20.31**.** Relative impact of each factor on the final trend. Blue bars indicate the standardization is above the previous model, red bars indicate it is below. Closures appear to have only a very small effect.

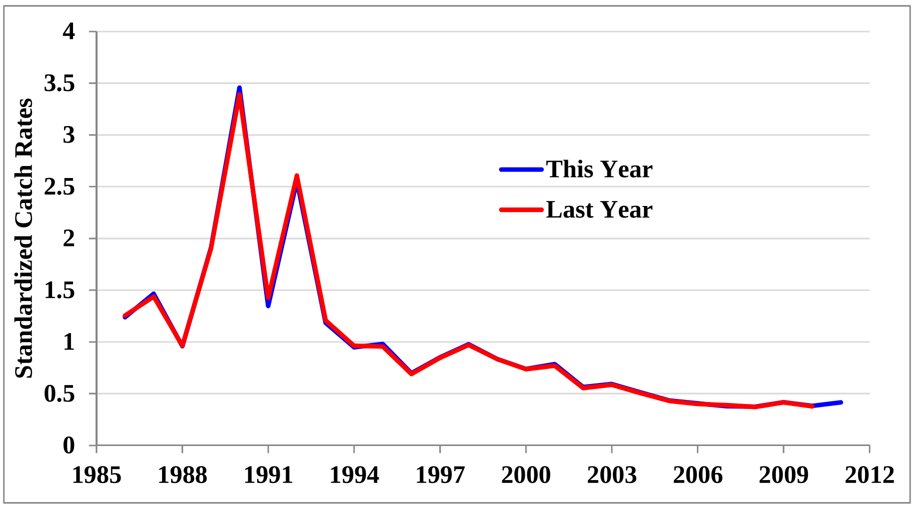

Figure 20.32**.** A comparison of last year's standardization with this year's.

Table 20.42. Statistical model structures used with Mixed Oreos. DepCat is a series of 50 metre depth categories. Closure relates to whether the area is open or closed.

Model 1	Year
Model 2	Year + Vessel
Model 3	Year + Vessel + DepCat
Model 4	Year + Vessel + DepCat + Month
Model 5	Year + Vessel + DepCat + Month + ORZone
Model 6	Year + Vessel + DepCat + Month + ORZone + DayNight
Model 7	Year + Vessel + DepCat + Month + ORZone + DayNight + Closure
Model 8	Year + Vessel + DepCat + Month + ORZone + DayNight + Closure + Vessel:Month
Model 9	Year + Vessel + DepCat + Month + ORZone + DayNight + Closure + DepCat:Month

Table 20.43. Model selection criteria, including the AIC, the residual sum of squares, the Model sum of squares, the number of usable observations, the number of parameters, the adjusted r^2 and the increment in adjusted r^2. The DepCat:Month model (model 9) was optimal. The effect of being in the open or closed areas (Closed) was minor (Figure 20.31).

	Year	Vessel	DepCat	Month	ORZone	DayNight	Closed	Vess:Mth	**Dep:Mth**
AIC	16486	11838	10083	9143	8532	8354	8317	8382	**8022**
RSS	48873	40521	37665	36284	35421	35169	35117	32158	**34304**
MSS	2248	10599	13456	14836	15699	15952	16004	18963	**16817**
Nobs	25933	25933	25752	25752	25752	25752	25752	25752	**25752**
Npars	26	132	146	157	161	164	165	1331	**319**
adj_r^2	4.304	20.332	25.904	28.590	30.277	30.766	30.866	33.669	**32.057**
Δr^2	0.000	16.027	5.573	2.686	1.687	0.489	0.100	2.803	**1.191**

Table 20.44**.** Reported catches by CAAB code for the data analysed. In 2010 the group code Oreo Dory, 37266902, was previously omitted from the analysis because of confusion with Black Oreo (37266901). The 37266902 reporting code (Oreo Dories) appears only to have been introduced in 2005 when quotas were first applied to Mixed Oreos.

	Spiky	Warty	OreoDory		Spiky	Warty	OreoDory
Year	37266001	37266004	37266902	Year	37266001	37266004	37266902
1986	19.269	31.697		1999	429.802	11.215	
1987	40.834	19.075		2000	345.507	30.987	
1988	13.860	19.949		2001	392.974	6.060	
1989	175.798	13.441		2002	210.951	1.595	
1990	254.921	2.257		2003	228.924	0.300	
1991	86.359	0.528		2004	179.862	1.540	
1992	606.532	1.050		2005	93.756		7.510
1993	278.224	3.031		2006	38.109		42.151
1994	265.949	18.620		2007	11.771		46.983
1995	468.212	14.030		2008	6.983		41.581
1996	405.361	15.606		2009	6.851		66.788
1997	552.637	20.190		2010	8.061		68.076
1998	642.05	24.806		2011	6.802		71.460

Table 20.45. The standardized catch rates for the alternative statistical models for Mixed Oreos in OR zones 10, 20, 21, 30, and 50, in depths 500 to 1200 m. The optimal model was DepCat:Month. St Err is the estimate of standard error for the optimum model. Values are relative to the mean of the standardized catch rates. The Month and closure factors column was omitted for clarity; their relative effect can be seen in Figure 20.31

Year	Year	Vessel	DepCat	ORZone	DayNight	Vess:Mth	**Dep:Mth**	StErr
1986	1.1362	1.1326	1.3198	1.2399	1.3170	1.1242	**1.2654**	0.0000
1987	1.3472	1.3873	1.4599	1.5452	1.5435	1.4421	**1.4997**	0.1560
1988	0.8317	0.8665	1.0074	1.0935	1.0860	1.0109	**0.9811**	0.1643
1989	1.3807	1.6139	1.8223	1.9028	1.9166	1.9174	**1.9580**	0.1408
1990	2.9320	3.3330	3.9427	3.5164	3.4706	4.1547	**3.5359**	0.1444
1991	0.8556	1.1797	1.3570	1.3128	1.3121	1.2199	**1.3793**	0.1469
1992	2.2785	2.7537	2.7093	2.6352	2.5811	2.4923	**2.6126**	0.1281
1993	0.9511	1.1773	1.1666	1.1977	1.1736	1.1961	**1.2128**	0.1283
1994	0.7545	0.8761	0.8639	0.9444	0.9315	1.0303	**0.9715**	0.1266
1995	0.9225	1.0227	0.8766	0.9586	0.9668	0.9782	**1.0030**	0.1242
1996	0.6972	0.8124	0.6864	0.7325	0.7340	0.7445	**0.7150**	0.1246
1997	1.0361	1.0099	0.8712	0.8903	0.8908	0.8686	**0.8714**	0.1245
1998	1.2173	1.0642	0.9611	0.9941	0.9931	0.9904	**0.9990**	0.1245
1999	1.0590	0.9422	0.8640	0.8627	0.8630	0.8493	**0.8543**	0.1249
2000	0.9741	0.8273	0.7697	0.7613	0.7628	0.7395	**0.7557**	0.1253
2001	0.9899	0.9074	0.8480	0.8031	0.8043	0.7830	**0.8048**	0.1251
2002	0.7044	0.6062	0.5737	0.5806	0.5836	0.5632	**0.5765**	0.1261
2003	0.7553	0.6236	0.5988	0.6056	0.6083	0.5804	**0.6068**	0.1262
2004	0.6702	0.5399	0.5213	0.5305	0.5328	0.5178	**0.5250**	0.1264
2005	0.6422	0.4846	0.4485	0.4484	0.4519	0.4368	**0.4451**	0.1291
2006	0.5078	0.4245	0.3847	0.4168	0.4211	0.4143	**0.4146**	0.1311
2007	0.5561	0.4602	0.3883	0.4055	0.4084	0.3977	**0.3873**	0.1368
2008	0.7278	0.5009	0.3826	0.3824	0.3864	0.3784	**0.3824**	0.1408
2009	0.6520	0.4862	0.3895	0.4192	0.4257	0.3899	**0.4284**	0.1335
2010	0.6555	0.4520	0.3765	0.3998	0.4049	0.3741	**0.3894**	0.1327
2011	0.7651	0.5158	0.4103	0.4208	0.4302	0.4061	**0.4250**	0.1316

20.6.5.1 TIER 4 Mixed Oreo Target Proxy 48%

Using the standardized catch rates and the updated catches for 2010, which now include the Oreo Dory (CAAB code 37266902) previously omitted, the TIER 4 analysis shows the recent catch rates to be not far from the target (~82% of the target) so the RBC calculation is restrained.

The RAG, in Oct 2011, recommended the reference period be moved from 1992-2001 to become 1993-2001. The reasoning behind this move was that 1992 was the last year of the Orange Roughy fishery in which mixed oreos were a significant discard component, while from 1993 onwards Oreos were landed much more often.

Table 20.46. CE are the standardized catch rates. GeoCE is the geometric mean catch rate from the raw data. Total is the total catch in the open areas, including discards (estimated at 16.2%). The target catch rate and target catch are both halved to allow for an assumed lack of exploitation prior to the reference period.

Year	Catch	Total	CE	GeoCE		
1986	47.586	56.785	1.2654	128.0280	Ref_Year	1993
1987	17.390	20.752	1.4997	108.0437	Ref_Year	2001
1988	12.228	14.592	0.9811	77.8207	Except Yr	
1989	25.771	30.753	1.9580	103.1413	CE_Targ	0.4549
1990	7.335	8.753	3.5359	107.2726	CE_Lim	0.1819
1991	18.421	21.982	1.3793	72.4795	CE_Recent	0.4063
1992	76.258	91.000	2.6126	111.0680	Wt_Discard	12.735
1993	80.648	96.239	1.2128	111.7519	Scaling	0.8221
1994	97.882	116.804	0.9715	86.3323		
1995	311.961	372.268	1.0030	128.0685	C*(target)	160.830
1996	284.955	340.042	0.7150	91.1849	**RBC**	**132.213**
1997	387.711	462.662	0.8714	115.4691		
1998	448.279	534.939	0.9990	132.6256		
1999	313.340	373.914	0.8543	120.7534		
2000	253.999	303.101	0.7557	114.5441		
2001	247.178	294.962	0.8048	101.1833		
2002	145.658	173.816	0.5765	75.0058	Years	TAC
2003	145.208	173.279	0.6068	77.2203	2005	200
2004	121.256	144.697	0.5250	72.0455	2006	200
2005	72.176	86.129	0.4451	67.8523	2007/08	190
2006	53.096	63.360	0.4146	53.5816	2008/09	150
2007	52.028	62.086	0.3873	54.5861	2009/10	188
2008	42.937	51.237	0.3824	70.2134	2010/11	188
2009	65.576	78.253	0.4284	62.5112	2011/12	113
2010	62.542	74.632	0.3894	60.0141	2012/13	
2011	70.490	84.117	0.4250	74.8662		

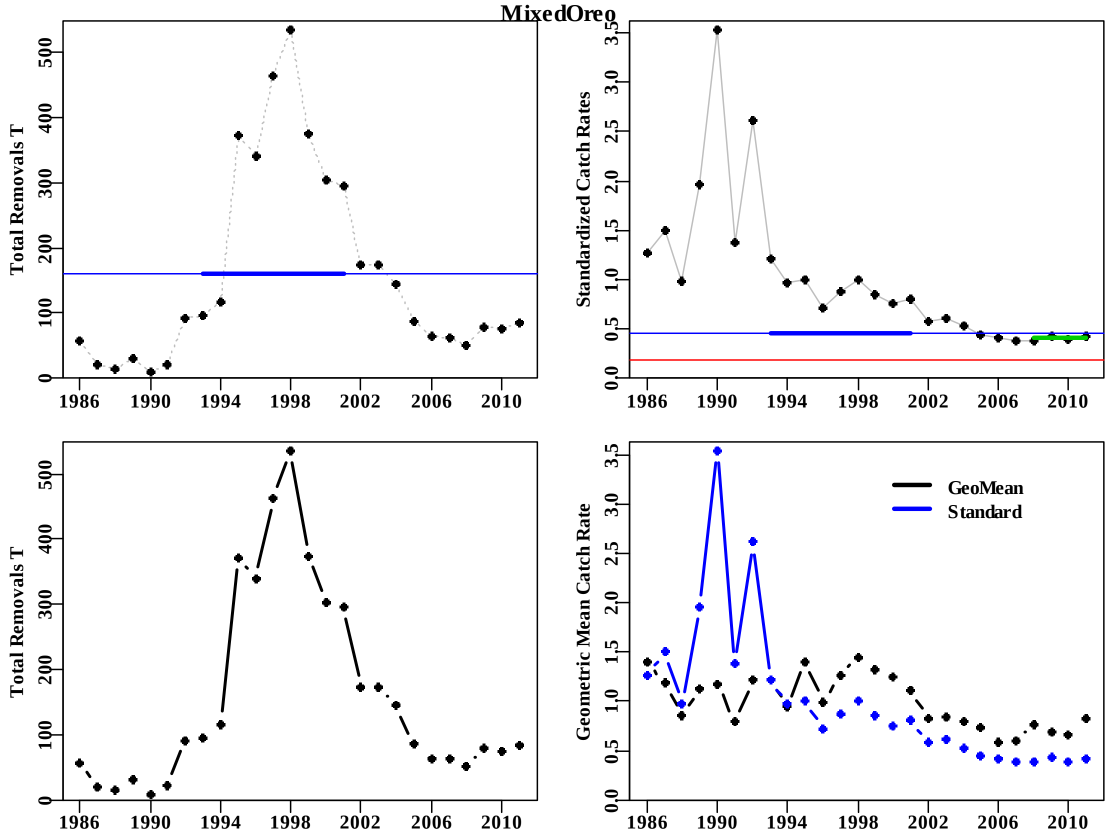

Figure 20.33. Tier 4 analysis for mixed oreos. Top left is the total catch in the open areas with the target catch indicated by the horizontal line. The target period is indicated by the thickened section of the line. Top right, illustrates the standardized catch rates plus both the target and limit catch rates, as well as the recent average catch rate, again with the target period identified with a thickened line. The distance of the mean of the last four points from the target indicates the potential scaling used to produce the RBC. Bottom left is total removals. Bottom left is the geometric mean catch rate compared to the standardized catch rates, scaled to the mean of the unstandardized rates.

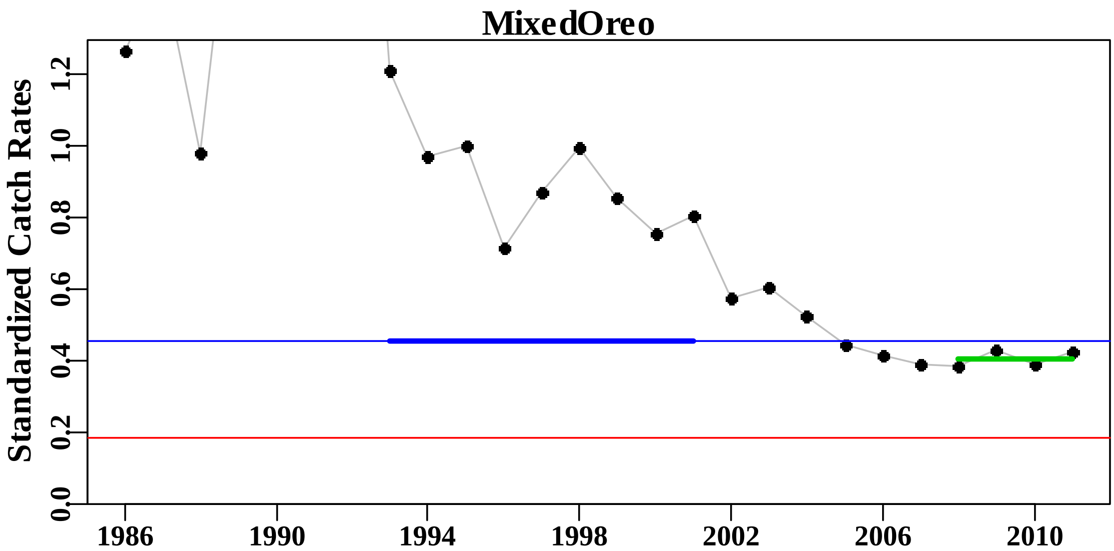

Figure 20.34**.** An expanded version of the Tier 4 analysis of catch rates to improve the illustration of the reference period and the recent mean catch rates.

20.6.6 Eastern Deepwater Sharks

Table 20.47. The names of the various species identified in the catch and effort database.

CAAB Code	Common Name	Scientific Name
37020000	Dogfish	Squalidae
37020002	Black	*Dalatias licha*
37020003	Brier	*Deania calcea*
37020004	Platypus	*Deania quadrispinosa*
37020013	Plunket's Dogfish	*Centroscymnus plunketi*
37020904	Roughskin	*Centroscymnus & Deania sps.*
37020905	Pearl	*Deania calcea & D. quadrispinosa*
37020906	Black (roughskin)	*Centroscymnus sps.*
37990003	Other Sharks	Other Sharks

The estimated discard rate is 2.8% (Wayte & Fuller (2009).

This basket quota group is made up of many recognized species but only ten have any records, and only eight of these have any significant catches. Dogfish and Other Sharks dominate catches until about 2000. The Black Shark is possibly confounded with two group categories, the Roughskin and the Black Shark – Roughskin. Plunket's Dogfish is possibly confounded with the Roughskin Shark group. Similarly, the Pearl Shark group is a combination of the Brier and Platypus Sharks. The reported distributions of the Brier shark, the Roughskin Shark, and especially the Plunket's Dogfish categories are much less widespread than the others.

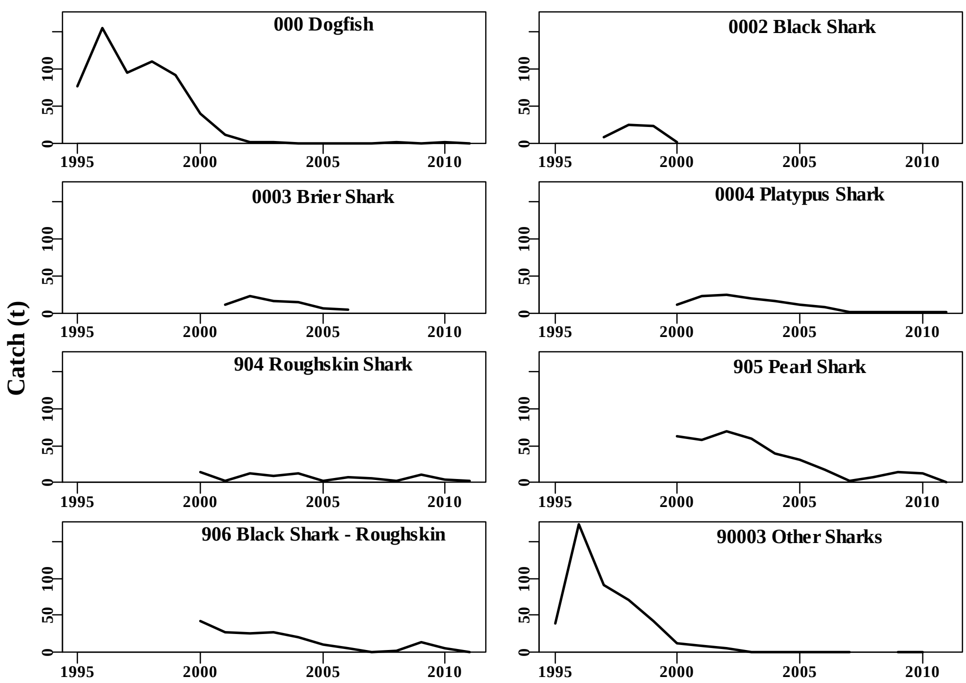

Figure 20.35. Eastern Deepwater Sharks catches broken down by species taken by trawling in OR Zones 10, 20, and 50 (catches in 21 and 40 were trivial), in depths 600 to 1250 m.

Table 20.48**.** Number of records where Eastern Deepwater Sharks are reported from trawling in OR Zones 10, 20, 21, and 50, in depths 600 to 1250 m. Recs is the number of records used. Vess represents the count of vessels reporting Deepwater Sharks. Yield is the total reported catch in tonnes. The geometric mean CE is the raw unstandardized catch rate in Kg/tow. The left hand five columns represent all data, the right hand five columns represent the areas left open following the 700m closure.

Year	Yield	Records	Effort	Vessels	Geom	YieldO	RecordsO	EffortO	VesselsO	GeomO
1986	28.926	254	1052	25	45.111	25.898	209	874	24	46.096
1987	6.061	105	327	28	26.456	4.821	89	272	24	26.085
1988	5.746	47	137	22	45.312	4.919	37	107	17	45.225
1989	5.561	85	220	21	37.910	5.080	76	191	19	37.505
1990	7.228	69	125	23	42.032	3.189	42	67	19	23.441
1991	20.213	129	316	24	62.171	10.119	87	208	21	54.265
1992	64.054	115	463	25	120.583	5.527	49	206	20	48.652
1993	95.237	295	968	26	132.886	17.922	118	322	22	48.635
1994	112.086	434	1605	30	130.137	38.050	215	780	27	96.916
1995	115.605	368	1453	22	179.615	61.899	220	804	22	163.944
1996	327.383	966	3712	30	191.197	260.404	777	2949	26	183.367
1997	194.243	907	4091	26	131.258	135.947	684	3062	24	122.844
1998	206.076	1105	4989	24	117.628	170.931	927	4093	23	114.465
1999	156.977	1013	4667	28	95.560	128.817	842	3829	26	91.905
2000	187.075	889	4252	28	124.127	150.371	707	3326	24	121.916
2001	140.954	893	4097	28	86.377	113.107	724	3224	26	90.318
2002	161.446	898	4230	29	102.917	130.026	752	3450	28	97.882
2003	130.839	974	4769	25	76.461	93.895	749	3534	22	73.496
2004	104.208	724	3459	29	79.814	78.429	587	2773	27	79.701
2005	61.426	480	2470	17	74.410	48.427	377	1949	15	75.336
2006	43.617	410	1960	21	51.361	33.066	279	1274	20	63.563
2007	8.418	106	494	17	43.938	8.378	104	484	17	44.636
2008	12.904	100	658	10	65.755	11.859	96	628	10	62.155
2009	39.137	232	1227	14	81.789	38.692	229	1208	14	81.183
2010	25.529	251	1264	13	48.906	24.302	241	1198	13	49.139
2011	4.154	36	151	8	51.408	4.154	36	151	8	51.408

Table 20.49. Statistical model structures used with Deepwater Sharks. DepCat is a series of 20 metre depth categories. Deep relates to whether the area is open or closed. DayNight reduced the quality of fit..

Model 1	Year
Model 2	Year + Vessel
Model 3	Year + Vessel + DepCat
Model 4	Year + Vessel + DepCat + Month
Model 5	Year + Vessel + DepCat + Month + ORZone
Model 6	Year + Vessel + DepCat + Month + ORZone + Deep
Model 7	Year + Vessel + DepCat + Month + ORZone + Deep + ORZone:Month
Model 8	Year + Vessel + DepCat + Month + ORZone + Deep + Vessel:Month

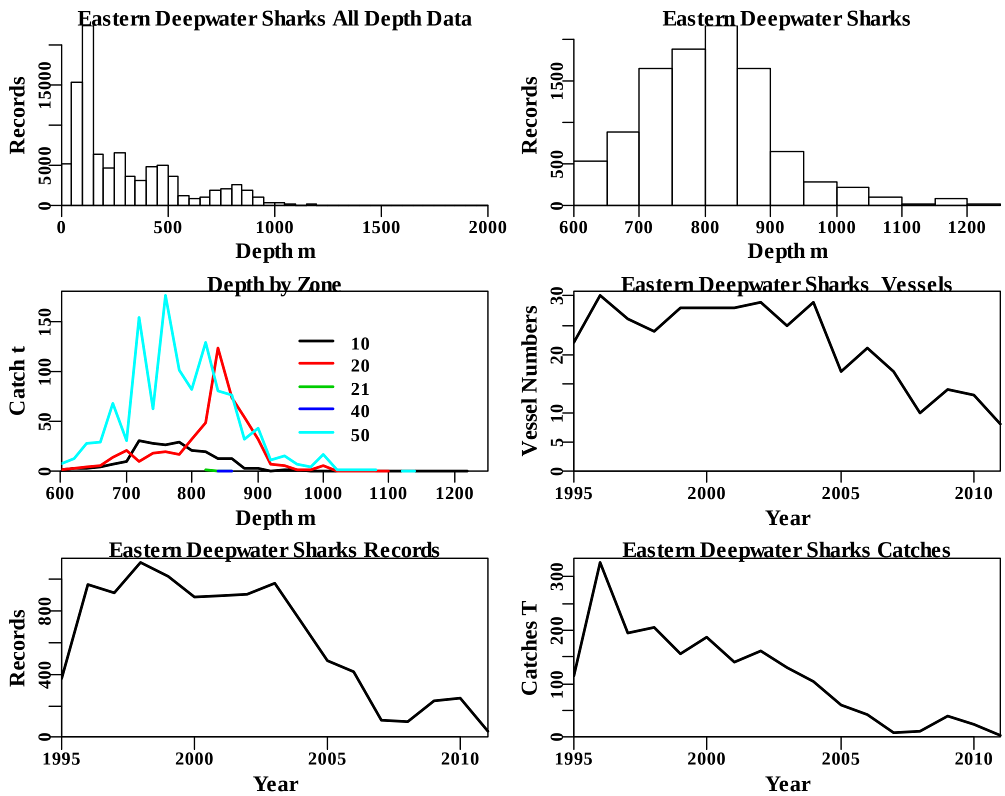

Figure 20.36. Eastern Deepwater Sharks reported from trawling in OR Zones 10, 20, 21, 50, in depths 600 to 1250 m. The top left is the depth distribution of all records reporting Deepwater Sharks, the top right graph depicts the depth distribution of shots containing Deepwater Sharks in OR Zones 10, 20, 21, 50, in depths 600 to 1250 m. The middle left diagram depicts the distribution of catch across all years by depth within separate OR zones (most catch is in zones 10, 20, and 50), the right hand middle graph depicts the number of vessels reporting Eastern Deepwater Sharks through time. The bottom left reflects the number of records for Deepwater Sharks, and bottom right are the Deepwater Shark catches used in the analysis.

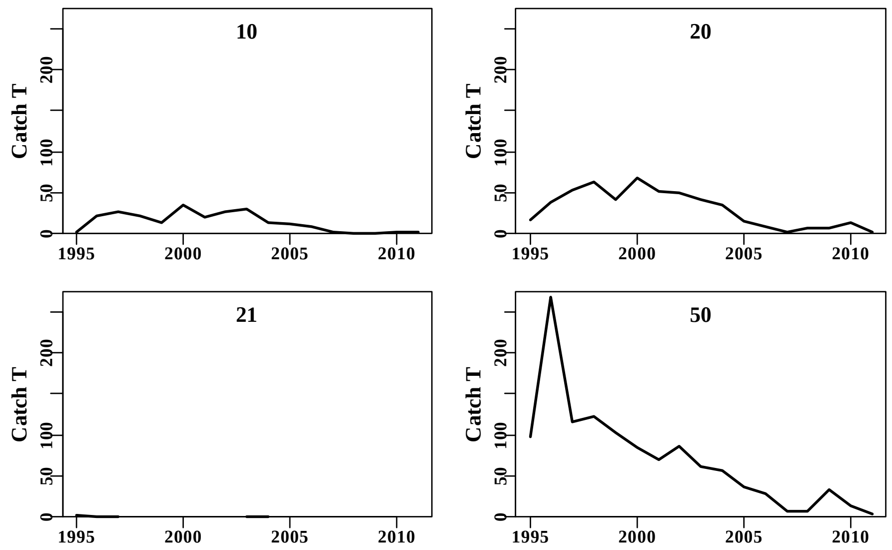

Figure 20.37**.** Eastern Deepwater Sharks catches taken by trawling in OR Zones 10, 20, 21, and 50, in depths 600 to 1250 m. Less than 7.0 t was reported in OR Zone 70 across all years.

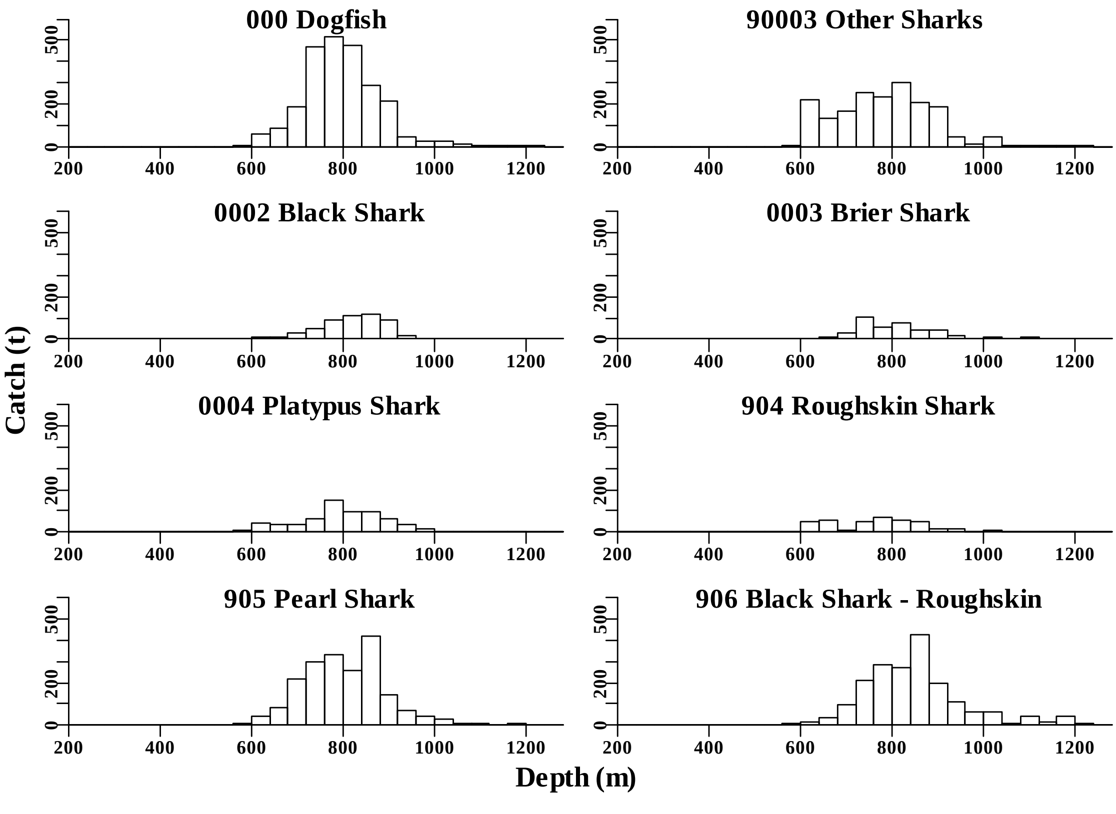

Figure 20.38**.** Depth distribution of the eight main species of Eastern Deepwater Sharks catches taken by trawling in OR Zones 10, 20, 21,and 50, in depths 600 to 1250 m. 37020000: Dogfish, 37020002: Black Shark, 37020003: Brier Shark, 37020004: Platypus Shark, 37020904:Roughskin Shark, 37020905: Pearl Shark, and 37020906: Black Shark – Roughskin category, 37990003: Other Shark. Data updated to 2010.

Table 20.50. Model selection criteria, including the AIC, the residual sum of squares, the Model sum of squares, the number of usable observations, the number of parameters, the adjusted r^2 and the increment in adjusted r^2. The model including the ORZone:Month interaction term (model 7) was optimal. There was a trivial effect of being in the open or closed areas (Deep) on the statistical model fit. Year, Vessel, and DepCat dominated the analysis. The DayNight factor was omitted because it detracted from the fit.

	Year	Vessel	DepCat	Month	ORzone	deep	**ORzone:Mth**	Vessel:Month
AIC	3077	1602	751	740	736	737	**704**	1743
RSS	13890	11870	10631	10596	10583	10582	**10457**	9908
MSS	1265	3286	4524	4559	4572	4573	**4698**	5247
Nobs	10352	10352	10115	10115	10115	10115	**10115**	10115
Npars	17	93	124	135	139	140	**184**	976
adj_r^2	8.204	20.977	28.990	29.145	29.200	29.201	**29.728**	27.648
Δr^2	0.000	12.773	8.013	0.155	0.055	0.001	**0.527**	-1.553

Table 20.51. The standardized catch rates for the alternative statistical models for Eastern Deepwater Sharks in OR zones10, 20, 21, and 50, in depths 600 to 1250 m. The optimal model was Model 7. St Err is the estimate of standard error for the optimum model. Values are relative to the mean of the standardized catch rates. The models for Deep and Vessel:Month were omitted for brevity.

Year	Year	Vessel	DepCat	Month	ORzone	Deep	**ORzone:Mth**	StErr
1995	1.8988	1.8206	1.6859	1.7180	1.7287	1.7191	**1.6863**	0.0000
1996	2.0263	2.0835	2.0721	2.0806	2.0162	2.0128	**2.0084**	0.0726
1997	1.3912	1.3797	1.2422	1.2467	1.2311	1.2284	**1.2445**	0.0704
1998	1.2465	1.1467	1.0327	1.0378	1.0393	1.0401	**1.0518**	0.0695
1999	1.0127	1.0171	0.8896	0.8929	0.8972	0.8978	**0.8868**	0.0697
2000	1.3156	1.3093	1.1287	1.1260	1.1280	1.1297	**1.1151**	0.0715
2001	0.9155	1.0355	0.9330	0.9330	0.9439	0.9457	**0.9473**	0.0721
2002	1.0908	1.1143	1.0451	1.0577	1.0666	1.0681	**1.0639**	0.0719
2003	0.8103	0.8230	0.7431	0.7431	0.7474	0.7469	**0.7518**	0.0718
2004	0.8461	0.8128	0.7616	0.7560	0.7652	0.7659	**0.7723**	0.0740
2005	0.7892	0.7595	0.7301	0.7293	0.7355	0.7353	**0.7357**	0.0797
2006	0.5448	0.5307	0.6440	0.6391	0.6405	0.6398	**0.6466**	0.0825
2007	0.4683	0.4716	0.7287	0.7289	0.7315	0.7336	**0.7310**	0.1299
2008	0.7011	0.6604	1.0293	1.0340	1.0424	1.0445	**1.0389**	0.1271
2009	0.8687	0.9349	1.1736	1.1806	1.1882	1.1905	**1.2082**	0.0963
2010	0.5193	0.5312	0.5793	0.5811	0.5849	0.5864	**0.5877**	0.0939
2011	0.5547	0.5692	0.5810	0.5150	0.5135	0.5154	**0.5235**	0.1962

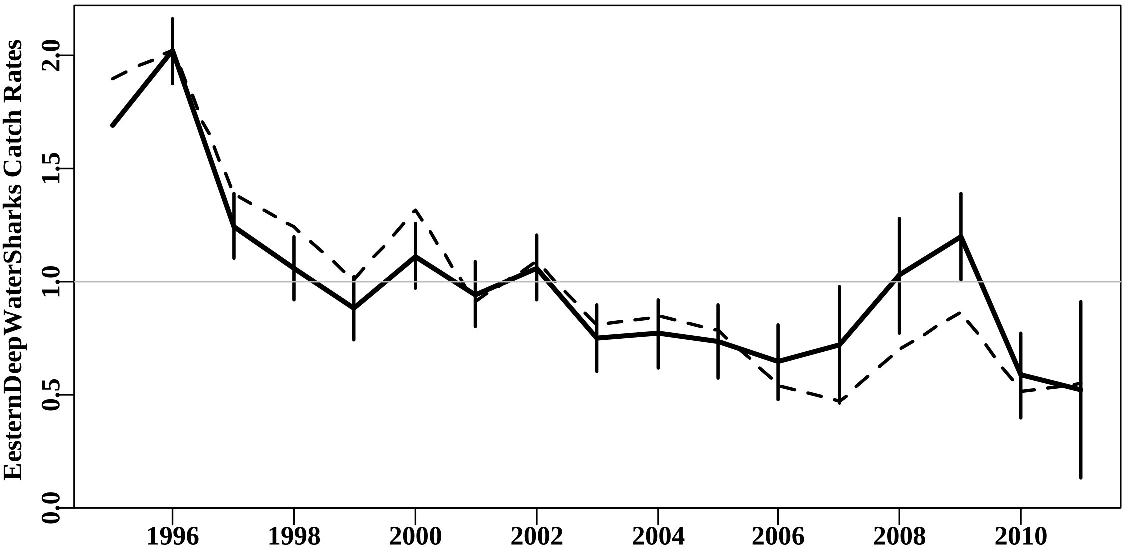

Figure 20.39. Eastern Deepwater Sharks reported from trawling in OR Zones 10, 20, 21, and 50, in depths 600 to 1250 m. The black dashed line from 86-11 represents the geometric mean catch rate and the solid black line the optimum standardized catch rates (Model 7). The graph scales the catch rates relative to the mean of the standardized catch rates (depicted by the horizontal grey line at 1.0).

20.6.6.1 TIER 4 Eastern Deepwater Sharks

As with the western deepwater sharks it is doubtful whether the catch rate value for 2011 is valid as there were less than 5 t of data that met the reporting requirements. It remains unknown whether catch rates reflect the stock status but there are so few records it appears highly unlikely. Certainly the standard error estimates in 2011 is relatively large. The RAG decided last year that when catches were less than 10 t no update of the Tier 4 would be made.

The low catches are in fact an artefact of trying to identify which shots are in closures and which are out. Many trawl shots are made immediately next to the closure boundary because the catch rates there are the best that are available. However, the precision with which a vessel's position is recorded is less than the precision with which we can define the closure boundaries. Western deep water sharks were used as an example in the RAG to demonstrate this but the same phenomenon occurs in the eastern fishery. Actual reported catches were approximately 33 t in the east but to conduct an analysis of catch rates it remains necessary to identify those shots that were definitely outside the reserves. It may be necessary to simply assume all shots are now outside the reserves and use all available data. Because the TAC was rolled over this year it was decided to analyse this in more detail in next year's assessment.

The closures have undoubtedly had a great impact.. A consideration of Figure 20.38 indicates that many earlier catches were taken in water deeper than 700 m. The closures introduced in the deepwater have thus removed large areas where catches of deepwater catches were taken.

20.6.7 Western Deepwater Sharks

There are numerous species grouped together into the Deepwater Sharks (Table 20.52) but only some have data and even fewer have significant catches reported.

Table 20.52. The names of the various species identified in the catch and effort database.

CAAB Code	Common Name	Scientific Name
37020000	Dogfish	Squalidae
37020002	Black	*Dalatias licha*
37020003	Brier	*Deania calcea*
37020004	Platypus	*Deania quadrispinosa*
37020904	Roughskin	*Centroscymnus & Deania sps.*
37020905	Pearl	*Deania calcea & D. quadrispinosa*
37020906	Black (roughskin)	*Centroscymnus sps.*
37990003	Other Sharks	Other Sharks

The estimated discard rate is 2.8% (Wayte & Fuller (2009).

This basket quota group is made up of many recognized species but only seven have any records, and only four have any significant catches reported recently. The Black Shark is possibly confounded with two group categories, the Roughskin and the Black Shark – Roughskin. Similarly, the Pearl Shark is a combination of the Brier and Platypus Sharks.

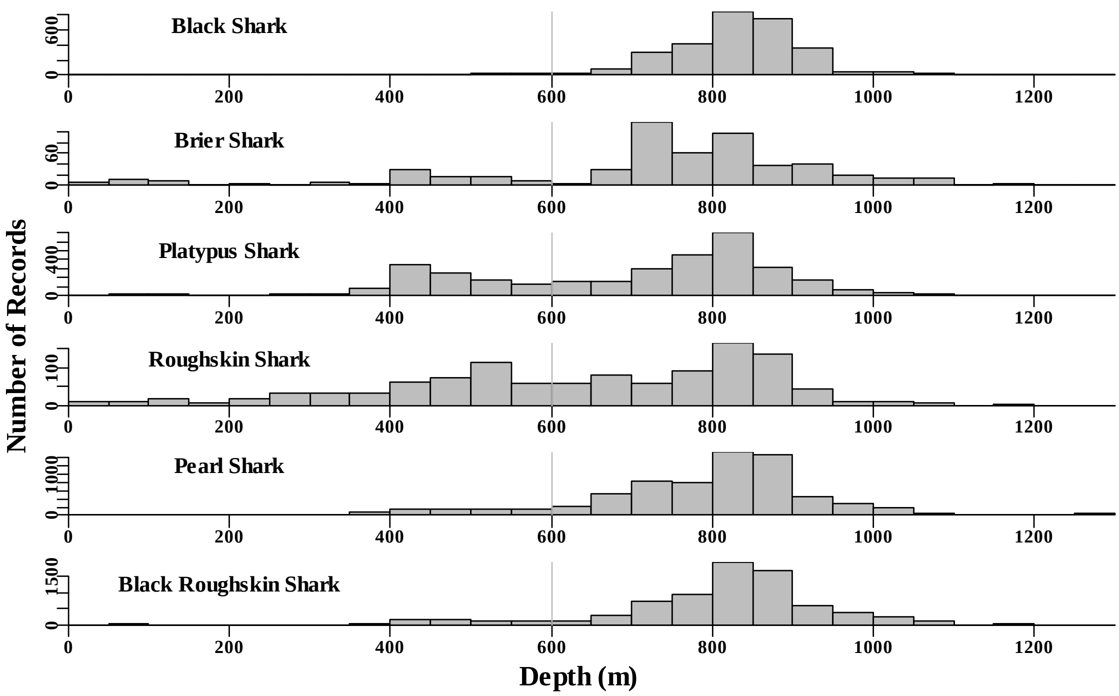

Figure 20.40. The depth distribution of the six main species with catches reported in the western deepwater shark fishery. The vertical line at 600 m illustrates the cut-off used in data selection.

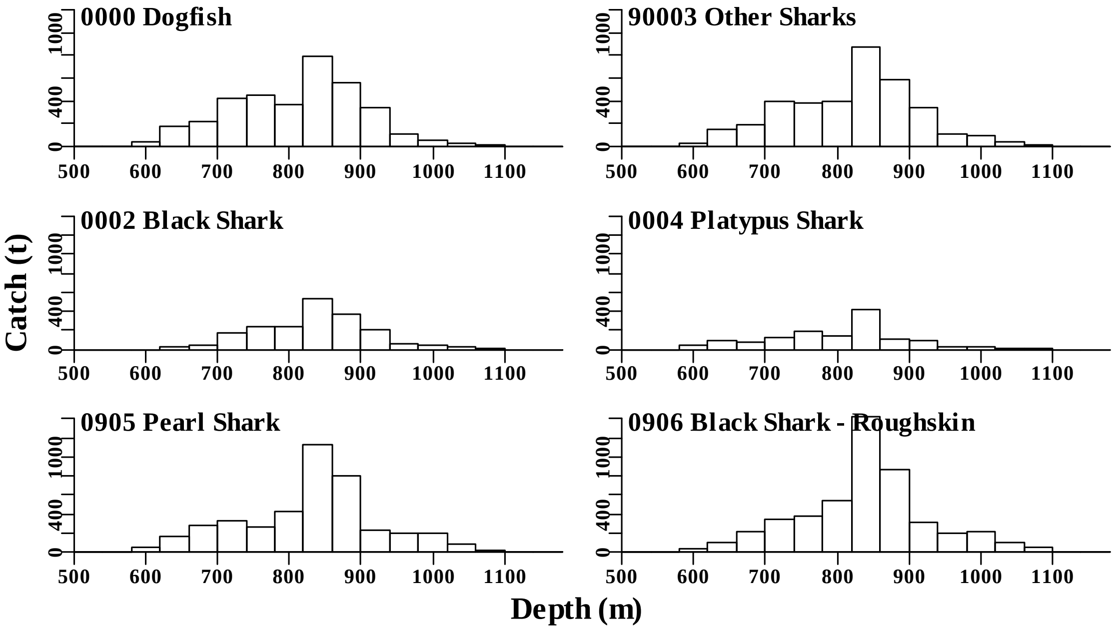

Figure 20.41. Catch by depth for the six main species and species groups. 37020000: Dogfish, 37020002: Black Shark, 37020003: Brier Shark, 37020004: Platypus Shark, 37020905: Pearl Shark, and 37020906: Black Shark – Roughskin category, 37990003: Other Shark.

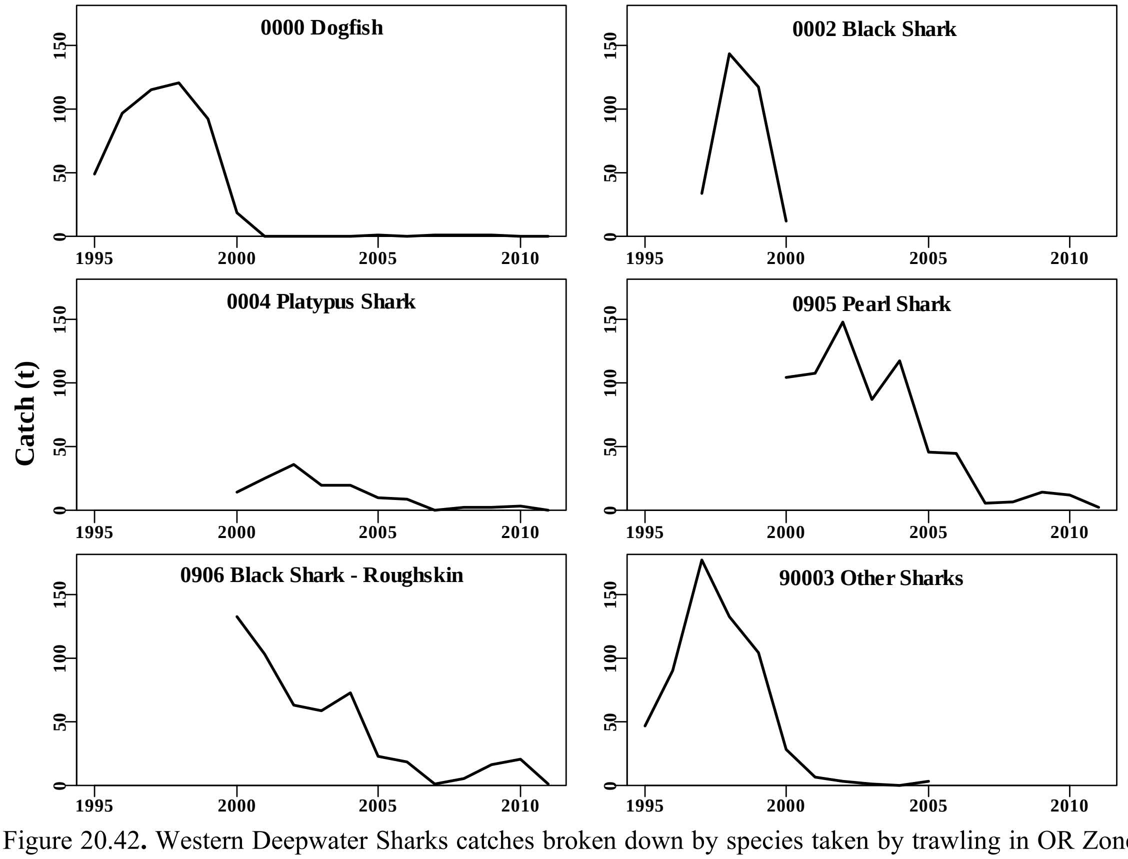

Figure 20.42. Western Deepwater Sharks catches broken down by species taken by trawling in OR Zone 30, in depths 600 to 1100 m for the years 1995 – 2010.

Table 20.53. Number of records where Western Deepwater Sharks are reported from trawling in OR Zone 30, in depths 600 to 1100 m. Vess represents the count of vessels reporting Deepwater Sharks. Yield is the total reported catch. The geometric mean CE is the raw unstandardized catch rate in Kg/tow. The left hand five columns represent all data, the right hand five columns represent the areas left open following the 700m closure. There appear to be captures in the closed areas because many vessels track the edge of the closures and the software is making category errors.

Year	Yield	Records	Effort	Vessels	Geom	YieldO	RecordsO	EffortO	VesselsO	GeomO
1986	1.030	14	56	3	54.016	0.290	5	19	3	45.731
1987	0.603	21	62	5	22.509	0.498	17	48	4	22.239
1988	0.525	4	11	2	122.474	0.100	1	2	1	100.000
1989	1.238	15	40	3	65.597	0.428	7	16	3	44.501
1990	0.314	5	13	4	34.822	0.010	1	2	1	10.000
1991	0.315	5	18	3	42.929	0.195	2	5	2	51.962
1992	3.600	21	94	4	128.049	3.460	19	86	4	137.919
1993	2.025	18	61	3	79.840	1.725	13	43	2	91.106
1994	1.612	23	128	4	55.626	0.572	9	43	3	57.241
1995	95.106	593	2929	10	93.596	43.007	256	1221	8	97.550
1996	186.252	956	4491	23	105.541	96.030	526	2365	17	108.016
1997	325.955	1975	10102	19	95.986	157.971	1054	5142	19	92.683
1998	396.667	2905	16202	18	88.170	147.941	1180	6124	18	82.990
1999	312.960	2212	12544	19	89.926	117.333	970	5227	18	81.342
2000	311.679	1872	10454	17	111.018	124.522	818	4155	17	103.720
2001	242.052	1832	10384	19	84.155	99.095	834	4490	19	79.789
2002	251.392	1625	10161	17	98.832	115.775	734	4399	17	100.324
2003	166.630	1431	9008	16	73.359	75.445	665	4024	16	74.507
2004	209.774	1733	10870	15	78.244	99.719	798	4778	14	80.257
2005	82.725	818	4816	13	61.230	40.390	396	2246	12	62.709
2006	72.064	617	3806	12	70.529	38.211	312	1832	12	75.480
2007	8.612	112	682	9	38.108	6.041	73	406	8	46.414
2008	15.625	121	784	8	76.979	10.211	83	538	8	71.433
2009	34.072	233	1487	10	79.505	25.736	168	1085	9	87.506
2010	35.775	268	1620	10	68.800	28.171	214	1271	10	69.635
2011	4.004	46	338	5	61.421	2.729	33	240	4	59.548

Table 20.54. Statistical model structures used with Deepwater Sharks. DepCat is a series of 20 metre depth categories. Deep relates to whether the area is open or closed.

Model 1	Year
Model 2	Year + Vessel
Model 3	Year + Vessel + DepCat
Model 4	Year + Vessel + DepCat + Month
Model 5	Year + Vessel + DepCat + Month + DayNight
Model 6	Year + Vessel + DepCat + Month + DayNight + Deep
Model 7	Year + Vessel + DepCat + Month + DayNight + Deep + Vessel:Month

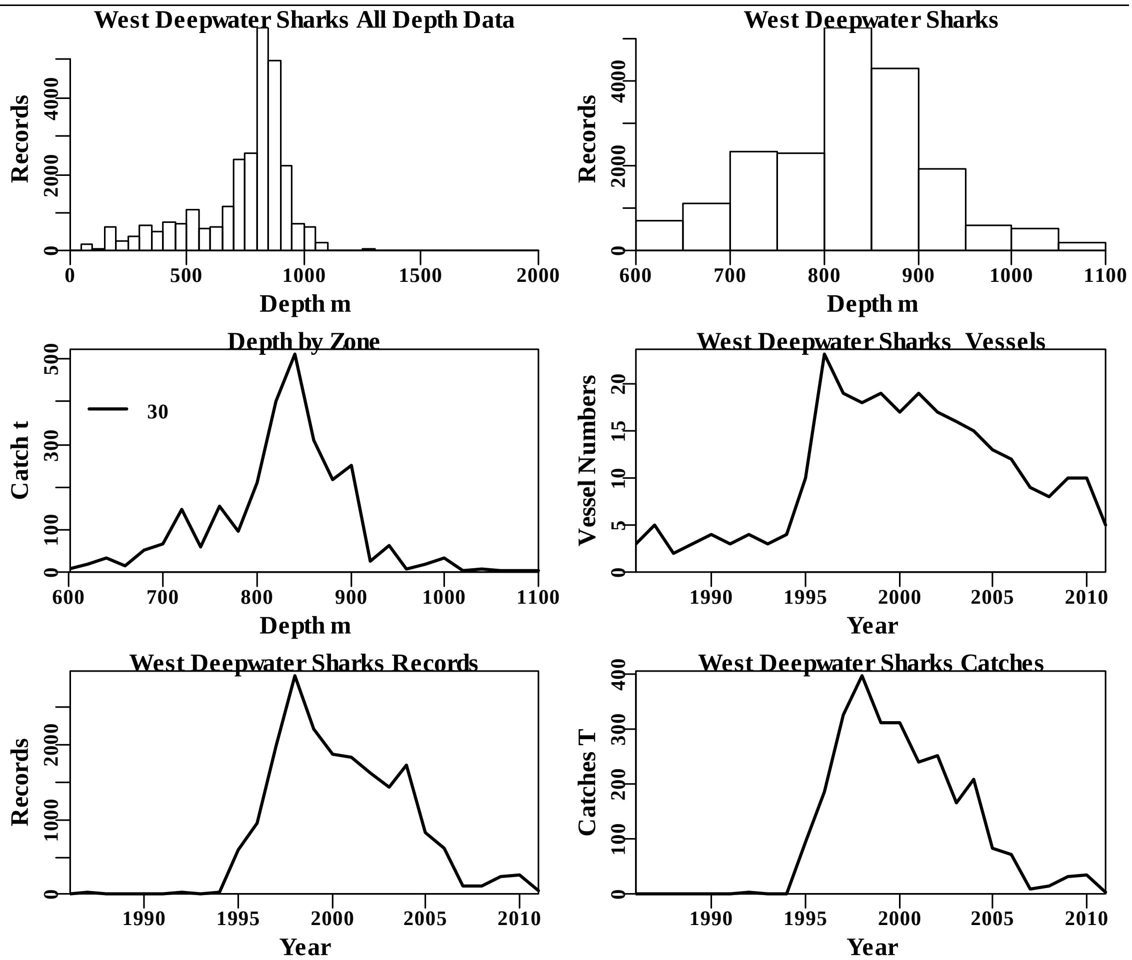

Figure 20.43. Western Deepwater Sharks reported from trawling in OR Zone 30, in depths 600 to 1100 m. The top left is the depth distribution of all records reporting Deepwater Sharks, the top right graph depicts the depth distribution of shots containing Deepwater Sharks in OR Zone 30, in depths 600 to 1100 m. The middle left diagram depicts the distribution of catch across all years by depth within separate OR zones (only catch from zone 30), the right hand middle graph depicts the number of vessels reporting Western Deepwater Sharks through time. The bottom left reflects the number of records for Deepwater Sharks, and bottom right are the Deepwater Shark catches used in the analysis.

Table 20.55. Model selection criteria, including the AIC, the residual sum of squares, the Model sum of squares, the number of usable observations, the number of parameters, the adjusted r^2 and the increment in adjusted r^2. Model 6 was optimal. The effect of being in the open or closed areas (Deep) was minor.

	Year	Vessel	DepCat	Month	DayNight	Deep	Vessel:Month
AIC	1364	71	-2507	-2680	-2694	-2699	-2399
RSS	20725	19304	16782	16613	16596	16590	16080
MSS	490	1911	4433	4602	4619	4625	5135
Nobs	19349	19349	19278	19278	19278	19278	19278
Npars	17	58	83	94	97	98	549
adj_r^2	2.228	8.740	20.558	21.312	21.381	21.406	21.988
Δr^2	0.000	6.512	11.817	0.755	0.069	0.025	0.582

Table 20.56. The standardized catch rates for the alternative statistical models for Western Deepwater Sharks in OR zone 30, in depths 600 to 1100 m. The optimal model was Model 6. St Err is the estimate of standard error for the optimum model. Values are relative to the mean of the standardized catch rates.

Year	Year	DepCat	Vessel	Month	DayNight	**Deep**	Vessel:Month	StErr
1995	1.1543	1.1188	1.1296	1.1737	1.1741	**1.1775**	1.1803	0.0000
1996	1.3035	1.2490	1.4409	1.4279	1.4276	**1.4325**	1.4876	0.0506
1997	1.1851	1.0799	1.1450	1.1491	1.1495	**1.1526**	1.1533	0.0459
1998	1.0885	0.9070	0.9236	0.9130	0.9151	**0.9197**	0.8969	0.0447
1999	1.1103	0.8825	0.9340	0.9365	0.9366	**0.9399**	0.9180	0.0458
2000	1.3707	1.0575	1.1456	1.1351	1.1350	**1.1386**	1.1226	0.0467
2001	1.0391	0.8405	0.9003	0.9076	0.9079	**0.9101**	0.9070	0.0469
2002	1.2203	1.0206	1.0327	1.0404	1.0412	**1.0428**	1.0341	0.0473
2003	0.9058	0.7703	0.7667	0.7749	0.7760	**0.7780**	0.7819	0.0478
2004	0.9661	0.7680	0.7879	0.7915	0.7900	**0.7914**	0.7882	0.0473
2005	0.7563	0.6725	0.6632	0.6499	0.6497	**0.6502**	0.6546	0.0526
2006	0.8713	0.8189	0.8855	0.8806	0.8816	**0.8824**	0.8690	0.0571
2007	0.4726	0.8408	0.8608	0.8664	0.8720	**0.8705**	0.9283	0.1005
2008	0.9544	1.6594	1.4032	1.4336	1.4357	**1.4329**	1.3978	0.0971
2009	0.9836	1.3910	1.2456	1.2507	1.2431	**1.2335**	1.2534	0.0752
2010	0.8509	1.0358	0.9479	0.9716	0.9702	**0.9595**	0.9637	0.0728
2011	0.7670	0.8875	0.7873	0.6974	0.6946	**0.6879**	0.6633	0.1459

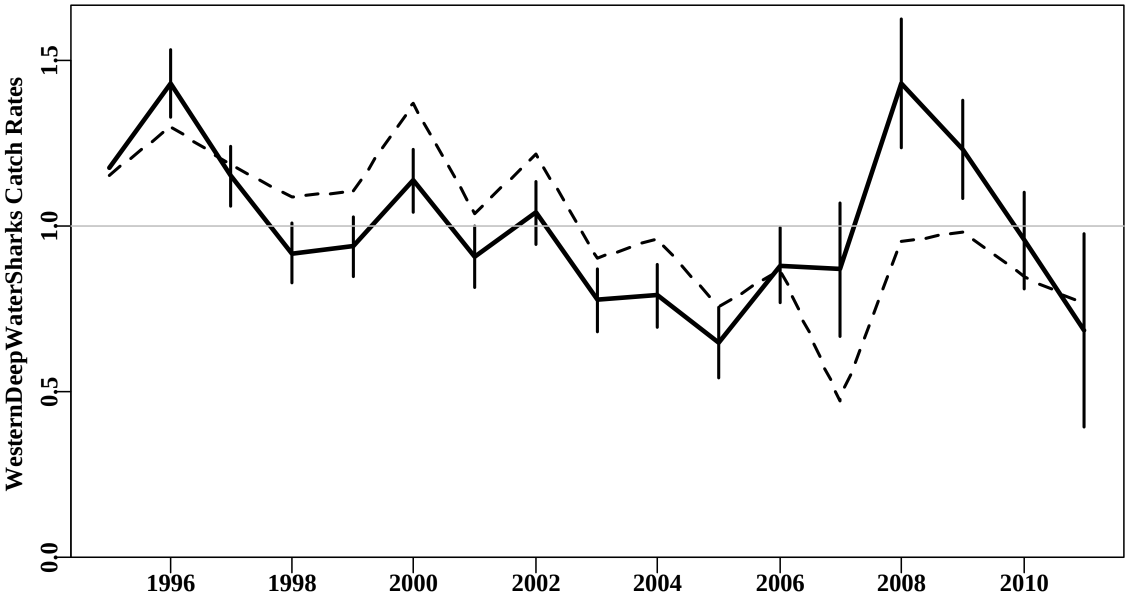

Figure 20.44. Western Deepwater Sharks reported from trawling in OR Zone 30, in depths 600 to 1100 m. The black dashed line from 95-10 represents the geometric mean catch rate and the solid black line the optimum standardized catch rates (Model 6). The graph standardizes catch rates relative to the mean of the standardized catch rates, represented by the horizontal fine grey line**.**

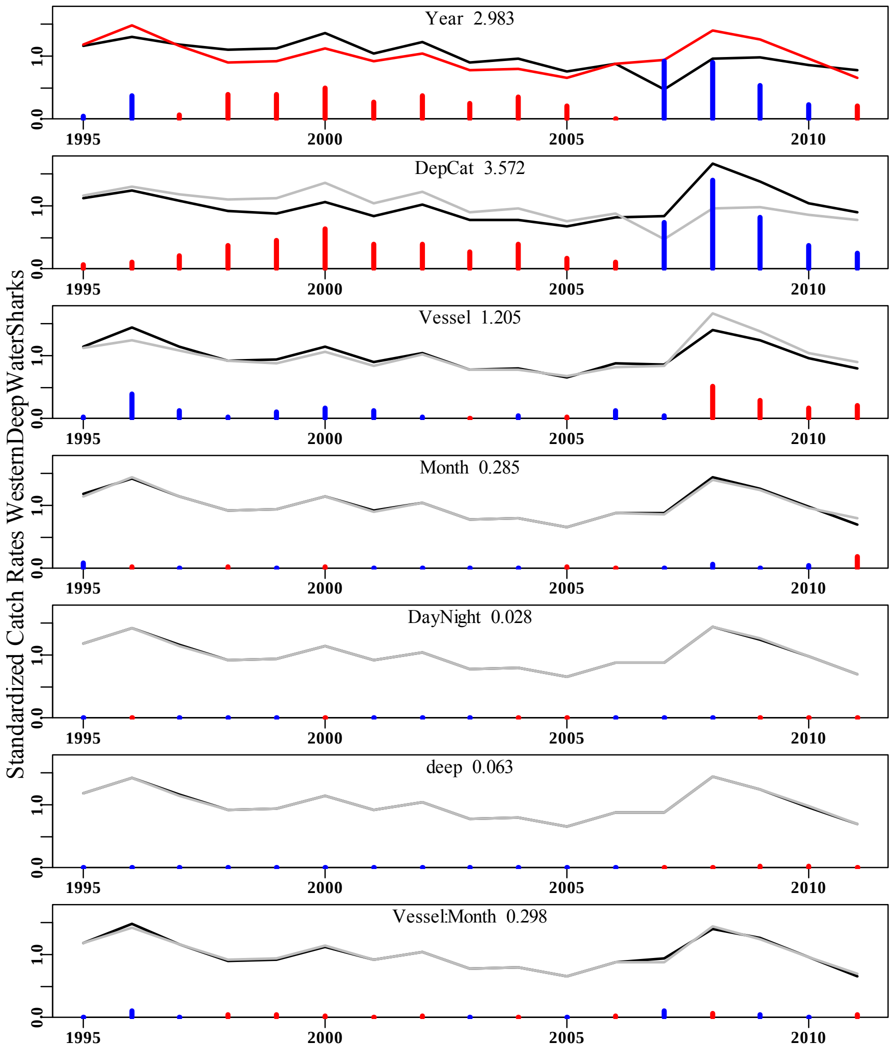

Figure 20.45**.** The relative impact of the different factors on the changes in the standardized trend. The major effects of both the structural adjustment, with its change of vessels, and the deepwater closures is clear.

20.6.7.1 TIER 4 Western Deepwater Sharks

It is doubtful whether the catch rate value for 2011 is valid as there were less than 5 t of data that met the reporting requirements. It remains unknown whether catch rates reflect the stock status but there are so few records it appears highly unlikely. Certainly the standard error estimates in 2011 is relatively large. The RAG decided last year that when catches were less than 10 t no update of the Tier 4 would be made.

The low catches are in fact an artefact of trying to identify which shots are in closures and which are out. Many trawl shots are made immediately next to the closure boundary because the catch rates there are the best that are available. However, the precision with which a vessel's position is recorded is less than the precision with which we can define the closure boundaries. Western deep water sharks were used as an example in the RAG to demonstrate this but the same phenomenon occurs in the eastern fishery. Actual reported catches were approximately 53 t in the west but to conduct an analysis of catch rates it remains necessary to identify those shots that were definitely outside the reserves. It may be necessary to simply assume all shots are now outside the reserves and use all available data. Because the TAC was rolled over this year it was decided to analyse this in more detail in next year's assessment.

20.6.8 Alfonsino (ALF – 37258002)

There were no reported catches of Alfonsino in the East Coast Deepwater fishery in 2010 so the analysis conducted in 2011 (Haddon, 2012b) still stands. This year some summary information is given instead of simply reiterating the same information.

The SESSF is made up of the Commonwealth trawl sector, the Great Australian Bight Sector, the East Coast Deepwater Trawl sector, and the Gillnet, Hook and Trap sector. Currently the Tier 4 analysis focuses on the East Coast Deepwater trawl fishery but it should include the South east Trawl fishery and the GAB. Currently there are only intermittent reported catches of Alfonsino in the ECD, so no analyses can proceed, but the TAC set (via a Tier 3 analysis) is applicable to the SET and the ECD. If a Tier 4 analysis were to be used, strictly it should include catches taken in each of these jurisdictions.

Table 20.57. Reported catches of Alfonsino by method. AL – autoline, BL – Bottom Line, DL – Drop Line, DS – Danish Seine, FP - , GN – Gill net, LL – Long Line, RR - , TL – Trot Line, and TW – trawl.

Year	Unknown	AL	BL	DL	DS	FP	GN	HL	RR	TL	TW
1988											0.538
1989											2.578
1990											3.644
1991	0.050										5.652
1992	0.497				0.450						17.787
1993											5.231
1994											15.602
1995											8.589
1996											12.427
1997			0.034	0.766		0.030	2.461			0.200	8.306
1998				1.106			0.955				4.762
1999	0.068			1.667		0.010	1.549				51.666
2000	5.880			1.291		0.006	2.792				494.612
2001	6.300	0.200		0.790			4.690				325.944
2002		0.984		0.954			0.941				2640.163
2003		1.603		0.522			0.276				1816.677
2004		2.961	0.290	0.358							1407.713
2005		3.315		0.266							441.579
2006		2.885		0.226							455.270
2007		3.914		0.042							526.289
2008		2.831		0.091			0.001				257.251
2009		4.400		0.104					0.001		94.343
2010		1.832		0.151					0.009		55.941
2011		2.119		0.386					0.044		612.824

While the obvious hotspots are in the ECD, there are catches taken in the SET. There are very low catches spread widely there appear to be relative hot spots, the same order of magnitude as in the ECD) one off Eddystone point on the East Coast of Tasmania, one south of the Tasman Peninsula. There is another, somewhat smaller spot, off Macquarie Harbour on the west coast of Tasmania and another spot off Robe or Cape Jaffa in western Victoria.

Table 20.58**.** Catch of Alfonsino taken by trawl in the different fisheries. CSF – Coral Sea Fishery, ECD – East Coast Deepwater, GAB – Great Australian Bight, HST – High Seas Trawl, NFO – Norfolk Island Offshore Demersal Finfish, SET – South East Trawl, and WDW – Western Deepwater. Currently no attention is paid to the catches in the SET

	CSF	ECD	GAB	HST	NFO	SET	WDW
1988						0.538	
1989			0.276			2.302	
1990			0.010			3.634	
1991						5.652	
1992						17.787	
1993						5.231	
1994						7.842	7.760
1995						8.423	0.166
1996						12.427	
1997						8.290	0.016
1998						4.762	
1999			4.094	8.836		38.736	
2000		66.950	384.332			40.620	2.710
2001		307.271	0.827	6.720	0.010	6.774	4.342
2002	63.560	42.036	0.270	2508.871	0.245	25.181	
2003	58.640	140.771	0.025	1611.061		6.180	
2004	14.163	509.466	0.042	867.980		16.062	
2005		136.050	0.039	296.964		8.525	
2006	14.091		0.320	429.620		11.239	
2007	55.582	85.397	0.124	372.904		12.283	
2008			0.052	206.851		50.348	
2009		14.156	0.042	62.275		17.870	
2010			0.028	46.999		8.914	
2011		147.500		460.950		4.374	

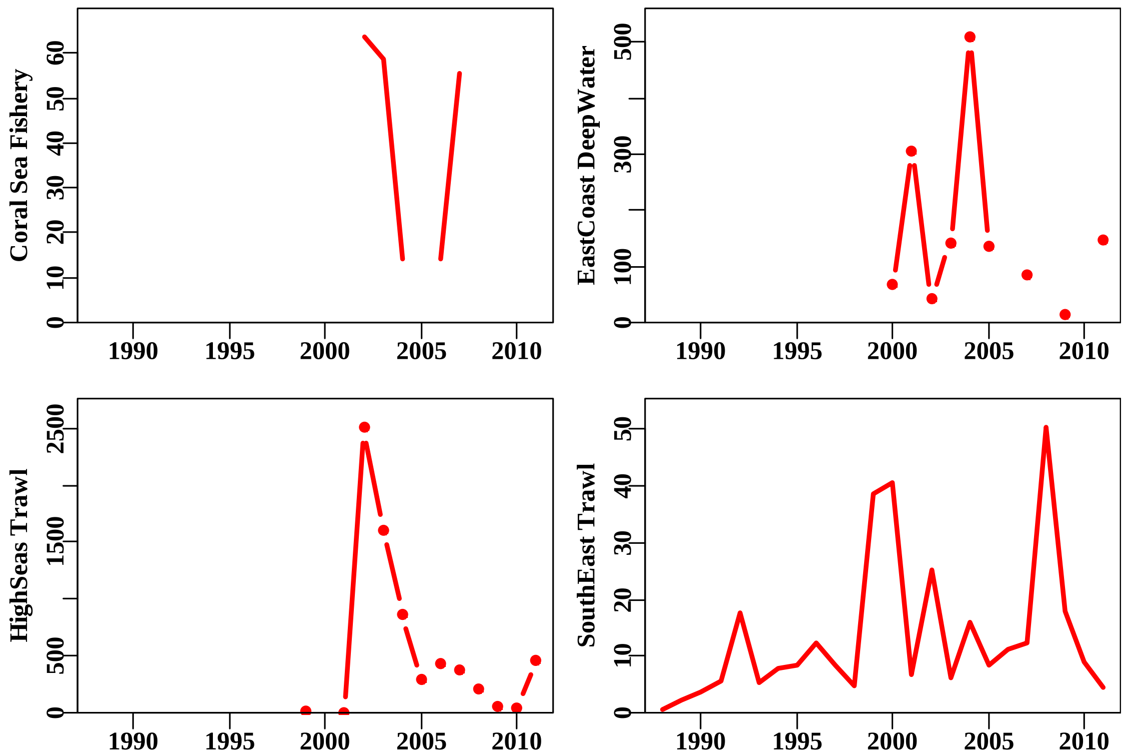

Figure 20.46. The relative catch in four of the fisheries listed in Table 20.58.Table 20.58 Note the different scales in the different fisheries. To indicate isolated years of reported catches points are added to the graphs.

20.7 Non-Tier 4 Species

20.7.1 Blue Grenadier (GRE – 37227001 – *Macruronus novaezelandiae*)

Table 20.59 Blue Grenadier data for the TIER 4 calculations. Total is the sum of Discards, State, Non Trawl and SEF2 catches. All values in Tonnes. CE is the standardized catch rate the non-spawning fishery (Haddon, 2012). GeoMean is the geometric mean catch rates. Discards are estimates from 1998 to present. The ratio of discards to catch over the 1998 – 2006 period was used to estimate the discards between 1986 and 1997, the proportion of which is the PDiscard.

Year	Catch	Discards	Total	State	Non-T	PDiscard	CE	GeoMean
1986	1408.800	87.889	1496.689			5.87	1.4764	36.7375
1987	2197.200	137.074	2334.274			5.87	1.9414	37.3307
1988	1760.400	109.824	1870.224			5.87	2.1038	36.6778
1989	1798.800	112.220	1911.020			5.87	2.1808	45.3866
1990	2433.600	151.822	2585.422			5.87	2.1567	47.9497
1991	3812.400	237.840	4050.240			5.87	1.5519	48.2874
1992	3338.400	208.269	3546.669			5.87	1.2755	40.5408
1993	3412.800	212.910	3625.710			5.87	0.9613	33.2638
1994	3282.175	204.761	3486.936	126.682	0.000	5.87	0.8636	29.5414
1995	2812.359	175.451	2987.811	51.541	0.000	5.87	0.5978	19.4025
1996	3078.789	192.073	3270.861	40.338	0.000	5.87	0.5459	15.8910
1997	4550.755	283.902	4834.658	17.700	0.000	5.87	0.5664	13.3293
1998	5745.683	2959.000	8704.683	12.824	0.000	33.99	0.9286	18.8682
1999	9333.962	140.000	9473.962	8.359	0.000	1.48	0.9810	22.7820
2000	8655.402	129.000	8784.402	0.599	0.000	1.47	0.6986	16.8751
2001	9128.199	1.000	9129.199	0.469	3.684	0.01	0.3992	11.4735
2002	9164.727	5.270	9169.997	0.011	3.808	0.06	0.4006	13.3454
2003	8482.833	9.810	8492.643	0.057	8.925	0.12	0.3344	10.1345
2004	6401.449	27.190	6428.639	0.042	9.878	0.42	0.5633	16.9690
2005	4293.080	526.640	4819.720	0.075	10.222	10.93	0.6724	19.8341
2006	3624.811	246.570	3871.381	0.076	11.436	6.37	0.8930	26.9839
2007	3183.767	63.140	3246.907	4.584	8.015	1.94	0.7950	25.1832
2008	3937.055	41.982	3979.037	0.033	6.285	1.06	0.8654	28.8353
2009	3269.003	66.605	3335.609	0.075	9.655	2.00	0.8035	25.9256
2010	4194.794	20.010	4214.803	0.147	9.545	0.47	0.7879	25.9279
2011	2820.365	684.326	3504.691	0.147	5.913	19.53	0.6557	19.3008

Discards make up approximately 5.9 % of the catch over the 1998-2006 period. NOTE: Actual landings in 2011 were in fact 4201.400 t rather than 2820 t, the source of this error is still being investigated. However, had this been used in a full Tier 4 it would not have influenced the result because the RBC depends on catch rates and the target catch not the current catch.

Table 20.60 RBC calculations for Blue Grenadier. C_{targ} and $CPUE_{targ}$ relate to the period 1986-1995, $CPUE_{Lim}$ is 40% of the target, and $\overline{CPUE}$ is the average catch rate over the last four years. The RBC calculation does not account for predicted discards of predicted State catches. Wt_Discard is the weighted average discards from the last four years, as with Equ (7).

Ref_Year	1986-1995
CE_Targ	1.5109
CE_Lim	0.6044
CE_Recent	0.7781
Wt_Discard	381.989
Scaling	0.1917
Last Year's TAC	
C_{targ}	2789.499

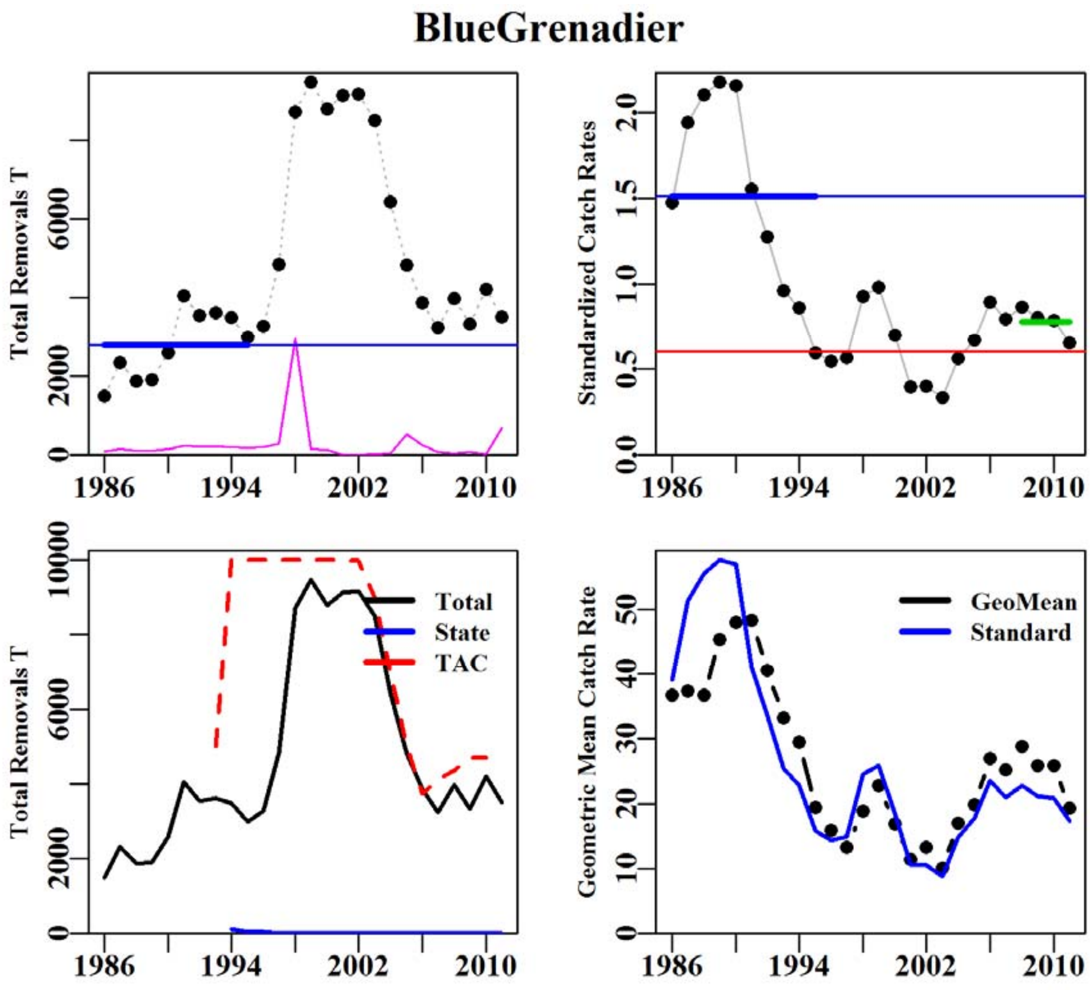

Figure 20.47 Blue Grenadier. Top left is the total removals with the fine line illustrating the target catch. Top right represents the standardized catch rates with the upper fine line representing the target catch rate and the lower line the limit catch rate. Thickened lines represents the reference period for catches, catch rates, and the recent average catch rate.

20.7.2 Flathead (FLT – 37296001 – Neoplatycephalus richardsoni)

Table 20.61 Tiger Flathead data for the TIER 4 calculations. Total is the sum of Discards, State, Non Trawl and SEF2 catches. All values in Tonnes. CE is the standardized catch rate for otter trawl for Zones 10 and 20 in depths 0 – 400m (Haddon, 2012).GeoMean is the geometric mean catch rates. Discards are estimates from 1998 to present. The ratio of discards to catch over the 1998 – 2006 period was used to estimate the discards between 1986 and 1997, the proportion of which is the PDiscard.

Year	Catch	Discards	Total	State	Non-T	PDiscard	CE	GeoMean
1986	2133.600	158.670	2292.270			6.92	0.8010	16.7357
1987	2496.000	185.620	2681.620			6.92	1.0713	20.4621
1988	2444.400	181.783	2626.183			6.92	1.1721	23.7988
1989	2623.200	195.080	2818.280			6.92	1.1672	23.9908
1990	2188.800	162.775	2351.575			6.92	1.3861	30.1854
1991	2620.800	194.901	2815.701			6.92	1.3155	28.7154
1992	3564.000	265.044	3829.044			6.92	1.0282	23.8898
1993	3132.000	232.918	3364.918			6.92	1.0500	23.8001
1994	2786.959	207.258	2994.217	1290.69	0.000	6.92	0.7610	17.9798
1995	2735.929	203.463	2939.392	1023.89	0.000	6.92	0.8067	18.0790
1996	2725.609	202.696	2928.305	832.370	0.000	6.92	0.7138	16.4549
1997	3093.299	230.040	3323.339	586.530	0.000	6.92	0.7166	16.8264
1998	2933.991	291.000	3224.991	391.360	0.000	9.02	0.7588	17.7430
1999	3729.333	267.000	3996.333	272.155	0.000	6.68	0.9100	20.4344
2000	3427.408	511.000	3938.408	205.714	0.000	12.97	1.0130	24.4338
2001	2992.436	160.000	3152.436	147.950	0.281	5.08	0.9759	22.3118
2002	3272.572	193.970	3466.542	128.764	0.337	5.60	1.0657	22.8273
2003	3670.170	178.030	3848.200	175.179	0.809	4.63	1.0530	22.5536
2004	3596.871	228.380	3825.251	214.094	0.858	5.97	0.9091	19.7879
2005	3295.823	195.140	3490.963	293.570	1.145	5.59	0.7770	17.7159
2006	3017.332	201.730	3219.062	318.879	0.607	6.27	0.9429	22.2550
2007	3052.284	278.562	3330.847	204.789	0.486	8.36	1.1537	31.3544
2008	3446.847	43.736	3490.582	249.130	0.362	1.25	1.2088	31.6602
2009	2925.235	155.881	3081.116	246.308	0.403	5.06	1.1115	30.0219
2010	2991.840	251.039	3242.878	265.559	0.297	7.74	1.0698	29.4565
2011	2876.701	492.160	3368.861	205.907	0.686	14.61	1.0611	28.3798

Discards make up approximately 6.9 % of the catch over the 1998-2006 period.

The catch rate trend used was from trawl caught flathead in zones 10 and 20. The fishery was well developed before 1986, the start of our data series.

Table 20.62 RBC for Flathead. C_{targ} and $CPUE_{targ}$ relate to the period 1986-1995, $CPUE_{Lim}$ is 40% of the target, and $\overline{CPUE}$ is the average catch rate over the last four years. The RBC calculation does not account for predicted discards of predicted State catches. Wt_Discard is the weighted average discards from the last four years, as with Equ (7).

Ref_Year	1986-1995
CE_Targ	1.0559
CE_Lim	0.4224
CE_Recent	1.1128
Wt_Discard	353.129
Scaling	1.0898
Last Year's TAC	
C_{targ}	2871.32

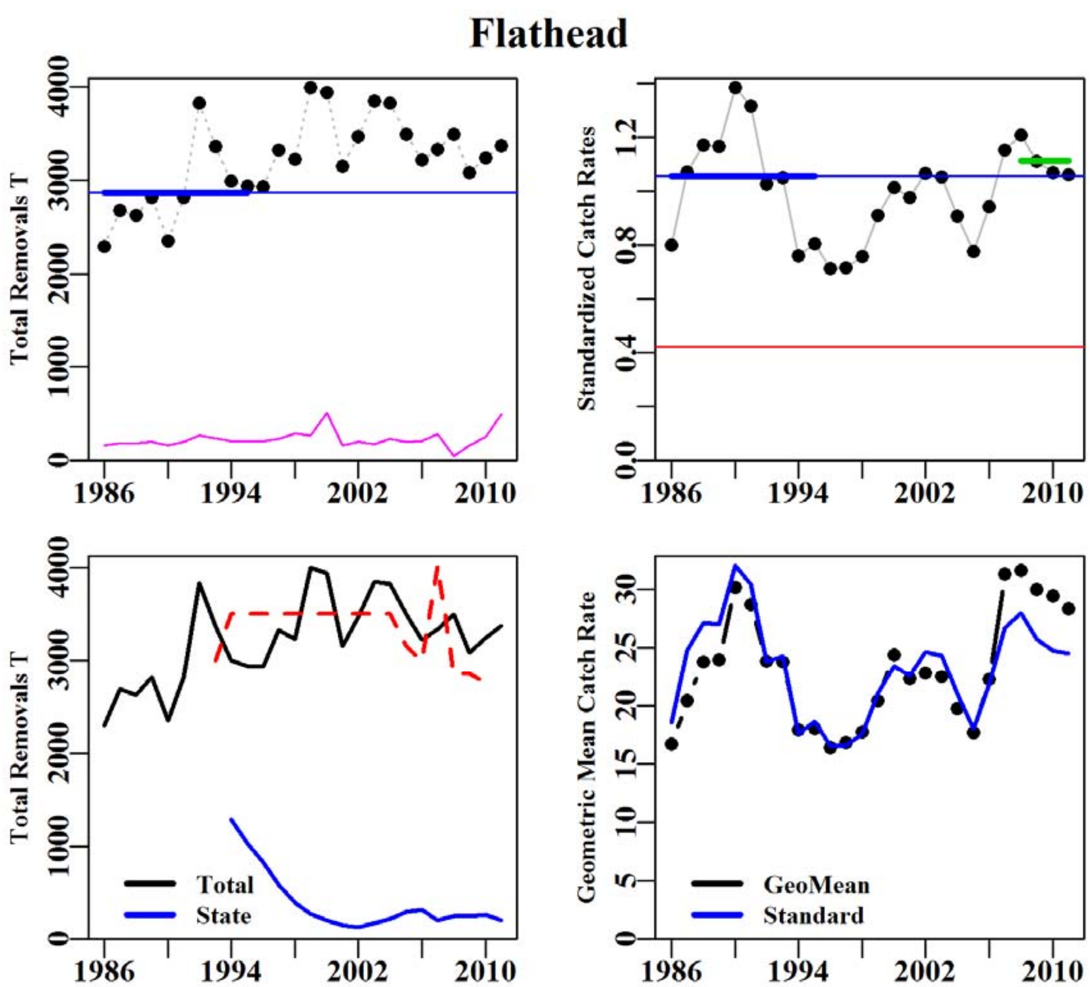

Figure 20.48 Tiger Flathead. Top left is the total removals with the fine line illustrating the target catch. Top right represents the standardized catch rates with the upper fine line representing the target catch rate and the lower line the limit catch rate. Thickened lines represents the reference period for catches, catch rates, and the recent average catch rate.

20.7.3 Eastern Gemfish (GEM – 37439002 – Rexea solandri)

Table 20.63 Eastern Gemfish data for the TIER 4 calculations. Total is the sum of Discards, State, Non Trawl and SEF2 catches. All values in Tonnes. CE is the standardized catch rate for Zones 10, 20, and 30 in depths 300 – 500m from June to September (Haddon, 2012). GeoMean is the geometric mean catch rate. Discards are estimates from 1998 to present. The ratio of discards to catch over the 1998 – 2006 period was used to estimate the discards between 1986 and 1997, the proportion of which is the PDiscard.

Year	Catch	Discards	Total	State	Non-T	PDiscard	CE	GeoMean
1986	1945.200	218.268	2163.468			10.09	2.3896	15.3241
1987	2208.000	247.757	2455.757			10.09	2.9835	25.2674
1988	1148.400	128.860	1277.260			10.09	2.6781	20.3738
1989	980.400	110.009	1090.409			10.09	1.9458	12.8697
1990	979.200	109.875	1089.075			10.09	1.7081	12.0080
1991	301.200	33.797	334.997			10.09	1.1499	8.4919
1992	1028.400	115.395	1143.795			10.09	1.5743	10.6133
1993	457.200	51.302	508.502			10.09	1.2954	8.9852
1994	266.110	29.860	295.970	131.931	0.000	10.09	0.8826	6.2854
1995	251.022	28.167	279.189	157.756	0.000	10.09	0.8009	5.4906
1996	315.471	35.399	350.869	204.700	0.000	10.09	0.5858	3.9966
1997	529.152	59.375	588.527	136.395	0.000	10.09	0.5934	4.1253
1998	373.133	23.000	396.133	127.144	0.000	5.81	0.5742	4.0091
1999	247.201	31.000	278.201	88.664	0.000	11.14	0.4234	2.7336
2000	123.746	29.000	152.746	30.747	0.000	18.99	0.3905	2.5299
2001	110.245	8.000	118.245	23.859	2.702	6.77	0.3369	1.9996
2002	77.867	13.600	91.467	16.174	3.564	14.87	0.2622	1.5421
2003	82.841	115.170	198.011	7.781	2.697	58.16	0.2954	1.6954
2004	97.542	83.210	180.752	17.731	2.683	46.04	0.4142	2.5873
2005	112.493	77.650	190.143	15.751	8.598	40.84	0.4370	2.7875
2006	101.951	46.350	148.301	15.153	6.564	31.25	0.4652	2.8952
2007	93.213	128.758	221.971	14.091	10.096	58.01	0.6460	4.0265
2008	118.957	164.319	283.276	11.607	20.277	58.01	0.8828	5.5997
2009	101.999	171.228	273.227	16.294	11.688	62.67	0.9137	5.4510
2010	112.643	190.964	303.607	20.128	16.264	62.90	0.7197	3.8269
2011	85.035	106.586	191.620	14.579	10.492	55.62	0.6515	3.5366

Discards make up approximately 10.08 % of the catch over the 1998-2002 period. The reduced period, relative to other species, reflects the bycatch nature of the fishery in recent years.

Table 20.64 RBC calculations for Eastern Gemfish. C_{targ} and $CPUE_{targ}$ relate to the period 1993-2002, $CPUE_{Lim}$ is 40% of the target, and $\overline{CPUE}$ is the average catch rate over the last four years. The RBC calculation does not account for predicted discards of predicted State catches. Wt_Discard is the weighted average discards from the last four years, as with Equ (7).

Ref_Year	1993-2002
CE_Targ	0.6145
CE_Lim	0.2458
CE_Recent	0.7919
Wt_Discard	141.554
Scaling	1.4811
Last Year's TAC	
C_{targ}	305.985

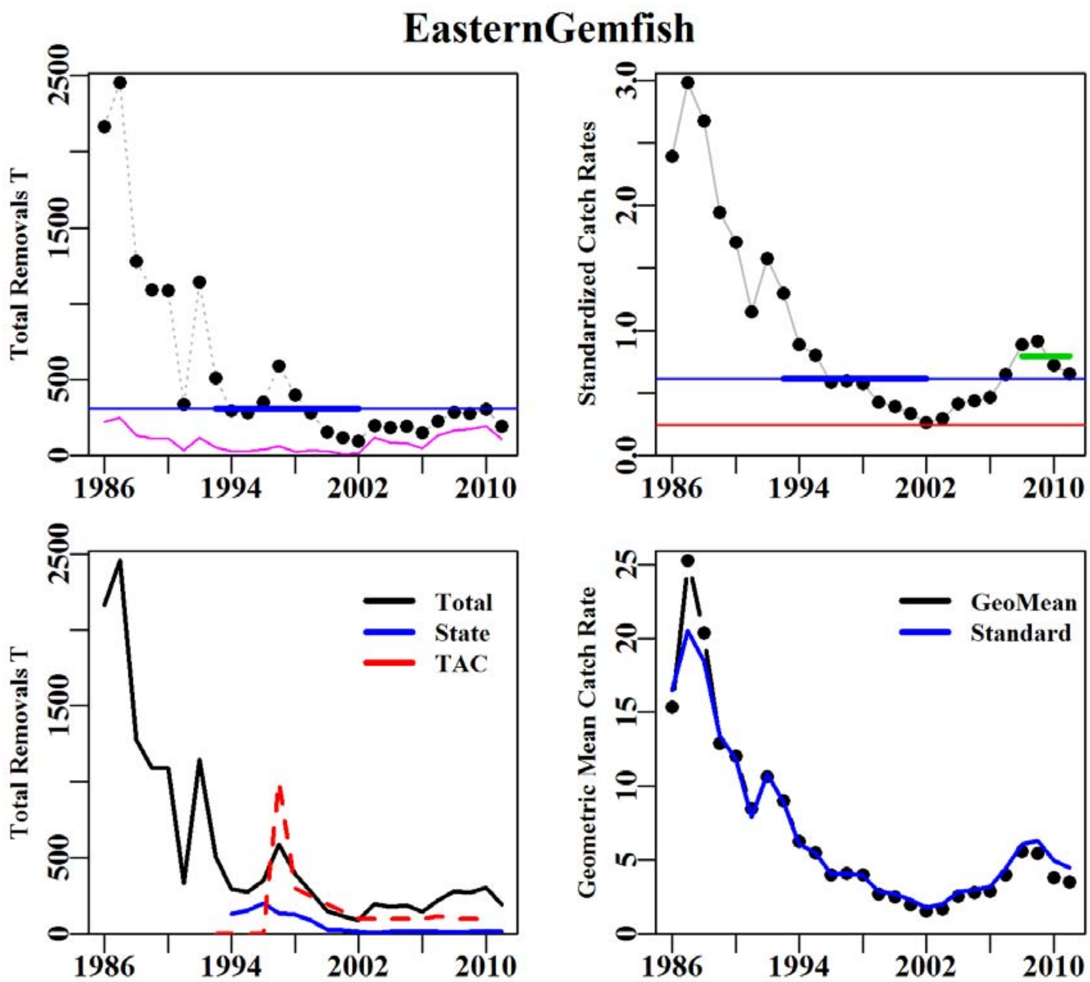

Figure 20.49 Eastern Gemfish. Top left is the total removals with the fine line illustrating the target catch. Top right represents the standardized catch rates with the upper fine line representing the target catch rate and the lower line the limit catch rate. Thickened lines represents the reference period for catches, catch rates, and the recent average catch rate.

20.7.4 Western Gemfish (GEM – 37439002 – Rexea solandri)

This relates solely to the SESSF zones 40 and 50; specifically it does not include the GAB, either in the catch rate standardization or the catches.

Table 20.65 Western Gemfish data for the TIER 4 calculations. Total is the sum of Discards, State, Non Trawl and SEF2 catches. All values in Tonnes. CE is the standardized catch rate for Zones 40 & 50 in depths 0 – 600m, GAB not included (Haddon, 2012). GeoMean is the geometric mean catch rates. Discards are estimates from 1998 to present. The ratio of discards to catch over the 1998 – 2006 period was used to estimate the discards between 1986 and 1997, the proportion of which is the PDiscard.

Year	Catch	Discards	Total	State	Non-T	PDiscard	CE	GeoMean
1986	256.262	12.318	268.580			4.59	2.2392	29.5835
1987	228.792	10.997	239.789			4.59	2.2272	31.5896
1988	226.320	10.879	237.199			4.59	2.1712	26.9924
1989	156.496	7.522	164.018			4.59	1.8043	23.3363
1990	132.675	6.377	139.052			4.59	1.3602	15.9031
1991	251.158	12.072	263.230			4.59	1.3188	22.0062
1992	84.384	4.056	88.440			4.59	0.9226	16.7792
1993	90.489	4.350	94.839			4.59	0.8868	16.5820
1994	138.266	6.646	144.912	0.000	0.000	4.59	0.9566	16.2263
1995	124.409	5.980	130.389	0.000	0.000	4.59	0.8385	12.0017
1996	208.329	10.014	218.343	0.000	0.000	4.59	0.9255	13.4563
1997	226.983	10.910	237.893	0.000	0.000	4.59	0.8307	13.2702
1998	185.371	12.000	197.371	0.000	0.000	6.08	0.8937	13.2167
1999	271.813	5.000	276.813	0.000	0.000	1.81	0.8486	12.8407
2000	349.236	30.000	379.236	0.000	0.000	7.91	0.8705	12.4996
2001	253.393	9.000	262.393	0.000	0.363	3.43	0.7042	12.1589
2002	138.915	9.140	148.055	0.000	0.441	6.17	0.5364	7.1243
2003	177.524	12.580	190.104	0.000	3.918	6.62	0.6520	11.3050
2004	149.840	8.920	158.760	0.000	3.655	5.62	0.6352	7.9049
2005	162.317	1.640	163.957	0.000	5.732	1.00	0.6620	10.6004
2006	159.639	0.550	160.189	0.000	23.656	0.34	0.5380	8.9869
2007	99.359	5.122	104.481	0.129	8.854	4.90	0.5238	7.4717
2008	86.396	9.008	95.404	0.000	10.682	9.44	0.5815	7.5220
2009	87.488	51.008	138.496	0.000	9.516	36.83	0.6658	6.4871
2010	121.226	31.771	152.998	0.000	14.468	20.77	0.6892	6.3681
2011	79.705	120.438	200.143	0.000	14.926	60.18	0.7175	5.5076

Discards make up approximately 4.6 % of the catch over the 1998-2006 period.

Table 20.66 RBC calculations for Western Gemfish. C_{targ} and $CPUE_{targ}$ relate to the period 1992-2001, $CPUE_{Lim}$ is 40% of the target, and $\overline{CPUE}$ is the average catch rate over the last four years. The RBC calculation does not account for predicted discards of predicted State catches. Only catches from zones 40 and 50 included. Wt_Discard is the weighted average discards from the last four years, as with Equ (7).

Ref_Year	1992-2001
CE_Targ	0.8678
CE_Lim	0.3471
CE_Recent	0.6635
Wt_Discard	80.108
Scaling	0.6077
Last Year's TAC	
C_{targ}	203.063

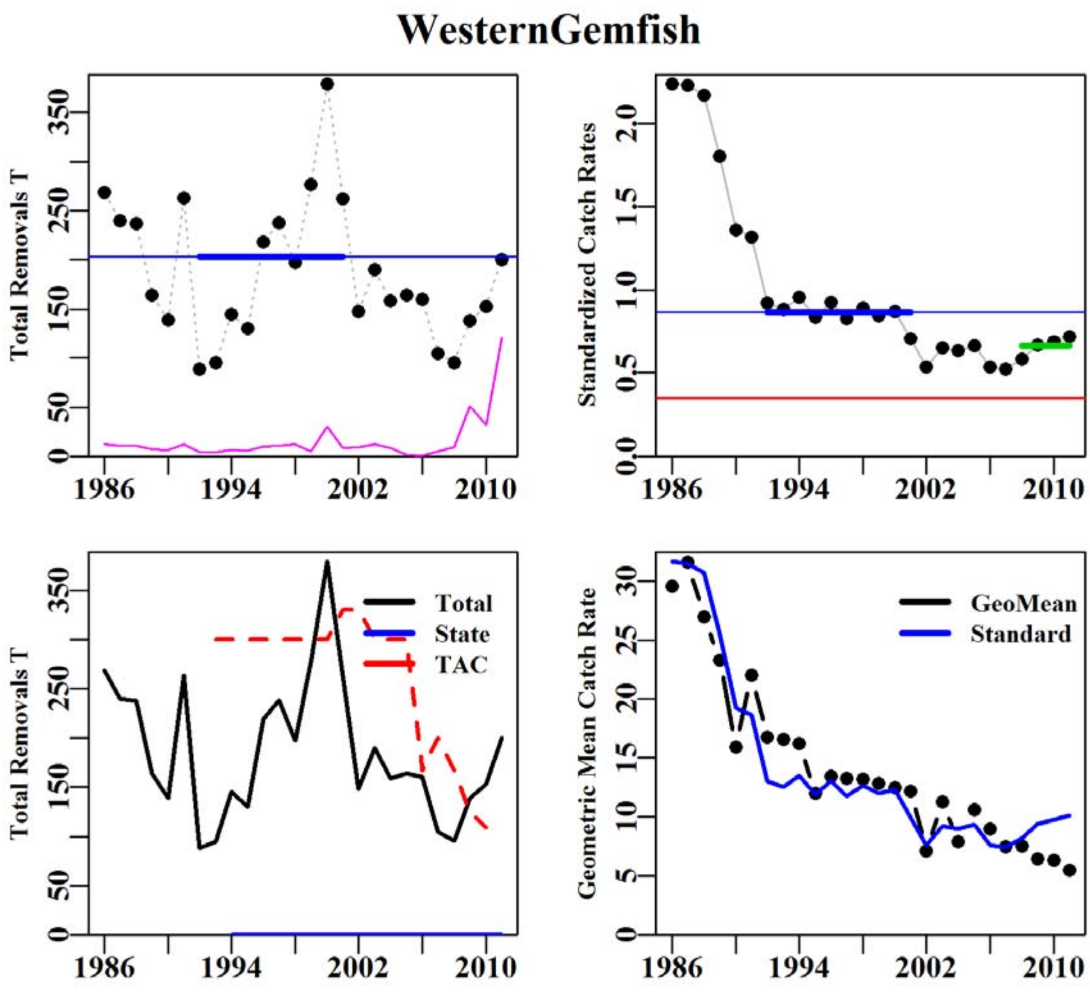

Figure 20.50 Western Gemfish. Top left is the total removals with the fine line illustrating the target catch. Top right represents the standardized catch rates with the upper fine line representing the target catch rate and the lower line the limit catch rate. Thickened lines represents the reference period for catches, catch rates, and the recent average catch rate.

20.7.5 Jackass Morwong (MOR – 37377003 –Nemadactylus macropterus)

Table 20.67 Jackass Morwong data for the TIER 4 calculations. Total is the sum of Discards, State, Non Trawl and SEF2 catches. All values in Tonnes. CE is the standardized catch rate for Zones 10 to 50 in depths 70 – 360m (Haddon, 2012). GeoMean is the geometric mean catch rates. Discards are estimates from 1998 to present. The ratio of discards to catch over the 1998 – 2006 period was used to estimate the discards between 1986 and 1997, the proportion of which is the PDiscard.

Year	Catch	Discards	Total	State	Non-T	PDiscard	CE	GeoMean
1986	1390.800	67.232	1458.032			4.61	1.8326	22.5592
1987	1459.200	70.538	1529.738			4.61	2.0862	26.1917
1988	1742.400	84.228	1826.628			4.61	2.0565	29.1554
1989	1971.600	95.308	2066.908			4.61	1.9994	33.9001
1990	1129.200	54.586	1183.786			4.61	1.6572	24.2137
1991	1406.400	67.986	1474.386			4.61	1.4684	21.1181
1992	888.000	42.926	930.926			4.61	1.2157	19.1937
1993	1132.800	54.760	1187.560			4.61	1.2320	21.3530
1994	1034.932	50.029	1084.961	243.396	0.000	4.61	1.0502	18.0744
1995	981.801	47.461	1029.261	160.992	0.000	4.61	0.9875	16.3623
1996	972.505	47.011	1019.517	89.072	0.211	4.61	0.9246	13.8607
1997	1213.726	58.672	1272.398	95.060	3.192	4.61	0.9910	16.1581
1998	942.082	34.000	976.082	59.783	4.519	3.48	0.8476	13.4363
1999	992.195	45.000	1037.195	41.481	17.667	4.34	0.8793	14.1587
2000	950.483	27.000	977.483	41.087	29.294	2.76	0.7263	10.1983
2001	866.752	12.000	878.752	50.298	2.263	1.37	0.5431	8.3295
2002	879.234	25.440	904.674	29.445	1.874	2.81	0.5693	8.3275
2003	776.411	71.850	848.261	28.583	3.311	8.47	0.4899	7.9077
2004	797.330	47.380	844.710	37.380	4.593	5.61	0.4905	8.6153
2005	840.172	38.610	878.782	42.118	5.979	4.39	0.5259	8.9785
2006	812.736	78.550	891.286	34.415	5.306	8.81	0.6003	11.5427
2007	586.065	70.704	656.769	18.299	4.507	10.77	0.5987	12.2504
2008	715.142	86.276	801.418	12.108	5.740	10.77	0.7042	13.7889
2009	465.638	56.176	521.814	11.506	2.812	10.77	0.6212	11.4713
2010	376.393	21.121	397.515	8.435	3.007	5.31	0.4635	8.5497
2011	411.007	46.510	457.517	5.001	2.399	10.17	0.4389	8.5254

Discards make up approximately 4.6 % of the catch over the 1998-2006 period.

Table 20.68**.** RBC calculations for Jackass Morwong. C_{targ} and $CPUE_{targ}$ relate to the period 1986-1995, $CPUE_{Lim}$ is 40% of the target, and $\overline{CPUE}$ is the average catch rate over the last four years. The RBC calculation does not account for predicted discards of predicted State catches. The Wt_Discard is the weighted discards from 2008 – 2011, as in Equ (7) .

Ref_Year	1986-1995
CE_Targ	1.5586
CE_Lim	0.6234
CE_Recent	0.557
Wt_Discard	43.680
Scaling	0
Last Year's TAC	
C_{targ}	1377.219

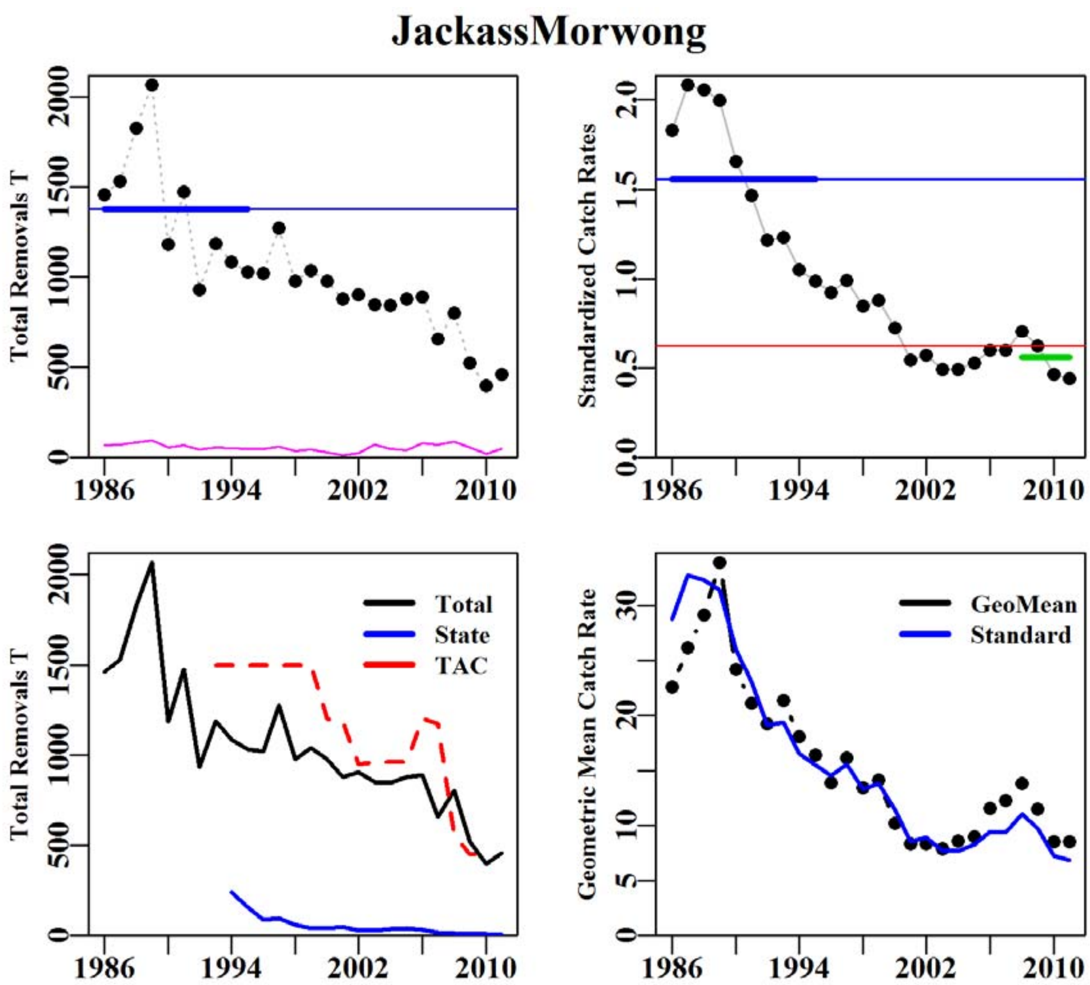

Figure 20.51 Jackass Morwong. Top left is the total removals with the line illustrating the target catch. Top right represents the standardized catch rates with the upper line representing the target catch rate and the lower line the limit catch rate. Thickened lines represents the reference period for catches, catch rates, and the recent average catch rate.

20.7.6 John Dory (DOJ – 37264004 – Zeus faber)

It was decided that this year the option of treating John Dory as a non-target species would be examined. This entailed changing the implied target reference point from 48% of the unfished state to 40% of the unfished state. Because the target catch rate is taken as a proxy for 48% unfished biomass, to make it equivalent to 40% means the average catch rate over the reference period should be multiplied by 0.8333 (thus 0.83334 × 48 = 40).

Table 20.69 John Dory data for the TIER 4 calculations. Total is the sum of Discards, State, Non Trawl and SEF2 catches. All values in Tonnes. CE is the standardized catch rate for Zones 10 and 20 in depths 0 – 200m (Haddon, 2012). GeoMean is the geometric mean catch rates. Discards are estimates from 1998 to present. The ratio of discards to catch over the 1998 – 2006 period was used to estimate the discards between 1986 and 1997, the proportion of which is the PDiscard.

Year	Catch	Discards	Total	State	Non-T	PDiscard	CE	GeoMean
1986	301.200	7.987	309.187			2.58	1.5483	7.6948
1987	240.000	6.364	246.364			2.58	1.7713	8.5155
1988	226.800	6.014	232.814			2.58	1.6647	8.3856
1989	252.000	6.683	258.683			2.58	1.8250	9.5319
1990	212.400	5.633	218.033			2.58	1.6491	8.7451
1991	236.400	6.269	242.669			2.58	1.3564	7.1954
1992	240.000	6.364	246.364			2.58	1.1209	5.6282
1993	400.800	10.629	411.429			2.58	1.4522	7.0963
1994	289.728	7.683	297.411	176.767	0.000	2.58	1.3690	6.7516
1995	243.673	6.462	250.135	129.268	0.000	2.58	1.1594	5.9610
1996	137.004	3.633	140.637	2.107	0.000	2.58	0.8950	4.5279
1997	178.118	4.723	182.841	88.373	0.000	2.58	0.7008	3.3776
1998	138.811	3.000	141.811	23.993	0.000	2.12	0.7274	3.6350
1999	178.334	3.000	181.334	40.806	0.000	1.65	0.8410	3.9411
2000	209.229	17.000	226.229	39.601	0.000	7.51	0.7920	3.5716
2001	164.643	6.000	170.643	29.821	0.051	3.52	0.6650	2.9450
2002	182.316	1.660	183.976	19.794	0.014	0.90	0.6556	3.1506
2003	193.130	3.190	196.320	28.348	0.084	1.62	0.6388	3.1538
2004	193.824	1.740	195.564	27.679	0.113	0.89	0.6745	3.4191
2005	132.030	3.530	135.560	29.319	0.060	2.60	0.5638	2.6772
2006	107.020	0.640	107.660	23.481	0.011	0.59	0.6354	2.8463
2007	82.383	1.355	83.738	13.849	0.016	1.62	0.5790	2.8023
2008	177.122	0.596	177.718	41.012	0.011	0.34	0.8620	4.3014
2009	127.476	4.252	131.728	19.671	0.012	3.23	0.7984	4.1921
2010	86.573	2.942	89.515	14.267	0.025	3.29	0.5177	2.6414
2011	119.316	39.760	159.076	27.282	0.013	24.99	0.5373	2.7474

Discards make up approximately 2.6% of the catch over the 1998-2006 period.

Table 20.70 RBC calculations for John Dory. C_{targ} and $CPUE_{targ}$ relate to the period 1986-1995, $CPUE_{Lim}$ is 40% of the target, and $\overline{CPUE}$ is the average catch rate over the last four years. The RBC calculation does not account for predicted discards of predicted State catches. Wt_Discard is the weighted average discards from the last four years, as with Equ (7).

Ref_Year	1986-1995
CE_Targ	1.4916
CE_Lim	0.5967
CE_Recent	0.6788
Wt_Discard	5.686
Scaling	0.0918
Last Year's TAC	221
C_{targ}	271.309

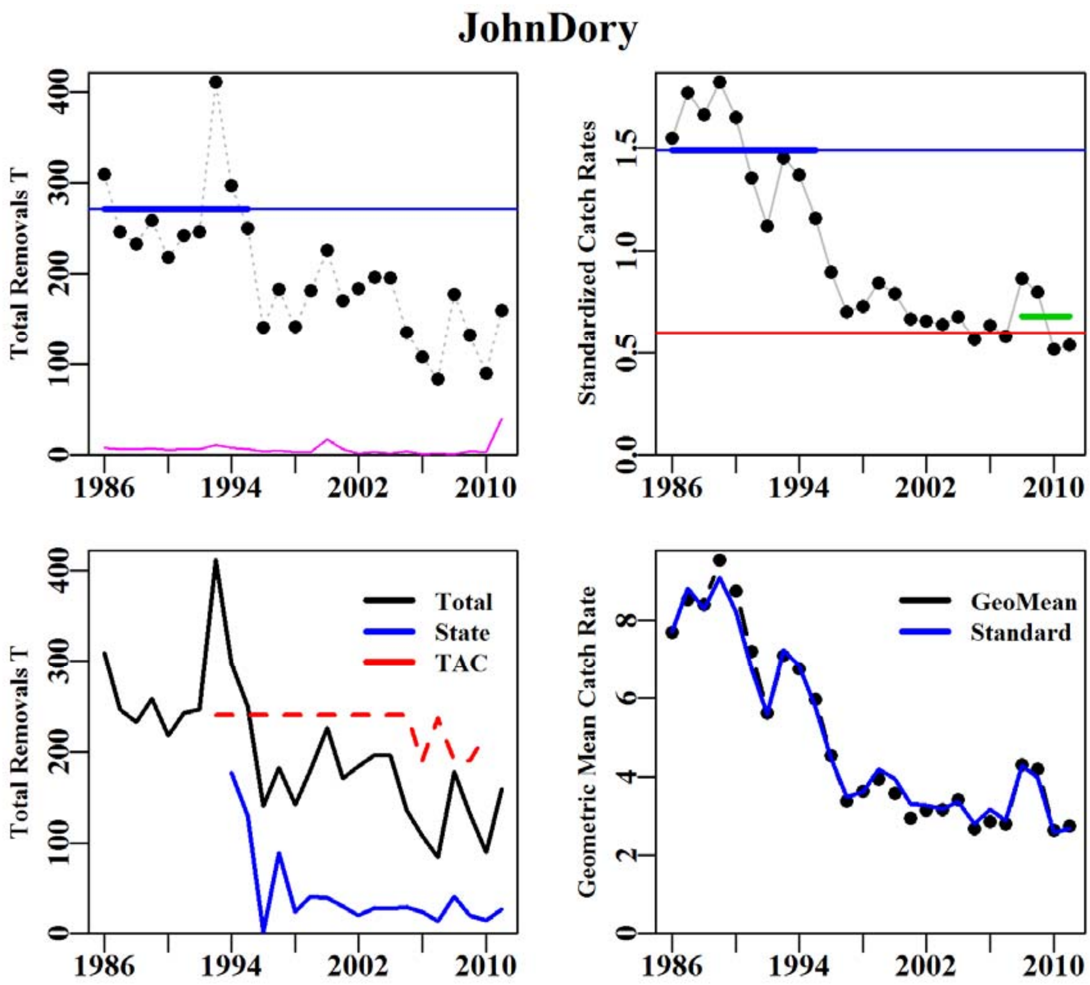

Figure 20.52. John Dory. Top left is the total removals with the fine line illustrating the target catch. Top right represents the standardized catch rates with the upper fine line representing the target catch rate and the lower line the limit catch rate. Thickened lines represents the reference period for catches, catch rates, and the recent average catch rate.

Table 20.71 RBC calculations for John Dory. C_{targ} and $CPUE_{targ}$ relate to 83.33% of the average over 1986-1995, $CPUE_{Lim}$ is 40% of the target, and $\overline{CPUE}$ is the average catch rate over the last four years. The RBC calculation does not account for predicted discards of predicted State catches. Wt_Discard is the weighted average discards from the last four years, as with Equ (7). The proxy target is here B40%.

Ref_Year	1986-1995
CE_Targ	1.2430
CE_Lim	0.5967
CE_Recent	0.6788
Wt_Discard	5.686
Scaling	0.1272
Last Year's TAC	221
C_{targ}	271.309

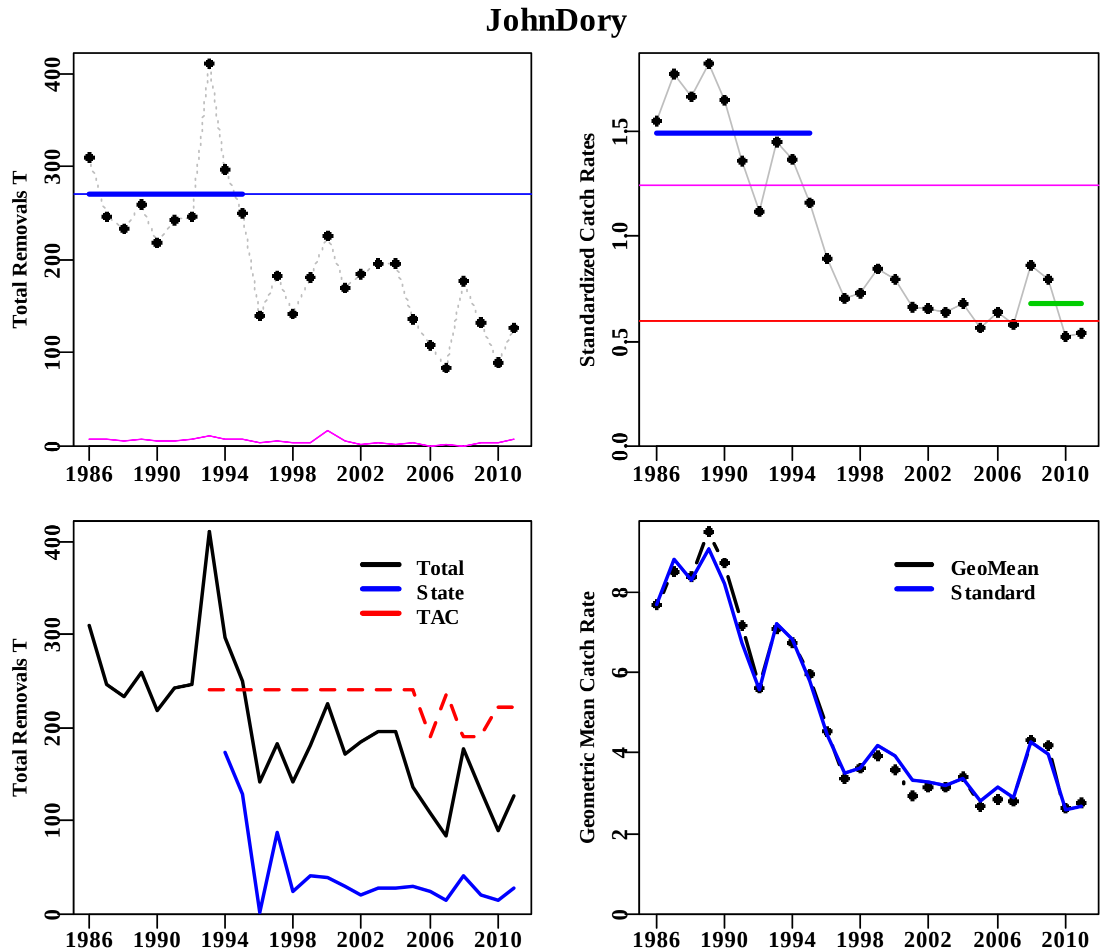

Figure 20.53. John Dory. Top left is the total removals with the fine line illustrating the target catch. Top right represents the standardized catch rates with the upper fine purple line representing the target catch rate (83.33% of the average over the reference period) and the lower line the limit catch rate. Thickened lines represents the reference period for catches, catch rates, and the recent average catch rate.

20.7.7 Mirror Dory (DOM – 37264003 – Zenopsis nebulosus)

Table 20.72 Mirror Dory data for the TIER 4 calculations. Total is the sum of Discards, State, Non Trawl and SEF2 catches. All values in Tonnes. CE is the standardized catch rate for Zones 10 to 50 in depths 0 – 600m (Haddon, 2012). GeoMean is the geometric mean catch rates. Discards are estimates from 1998 to present. The ratio of discards to catch over the 1998 – 2006 period was used to estimate the discards between 1986 and 1997, the proportion of which is the PDiscard.

Year	Catch	Discards	Total	State	Non-T	PDiscard	CE	GeoMean
1986	336.000	80.920	416.920			19.41	1.2117	18.6423
1987	340.800	82.076	422.876			19.41	1.2147	19.7476
1988	373.200	89.879	463.079			19.41	1.1875	16.9455
1989	542.400	130.628	673.028			19.41	1.4715	23.1957
1990	267.600	64.447	332.047			19.41	1.3530	20.6077
1991	277.200	66.759	343.959			19.41	1.1550	13.9567
1992	357.600	86.122	443.722			19.41	0.9990	11.3487
1993	537.600	129.472	667.072			19.41	1.0955	13.7999
1994	324.664	78.190	402.854	21.816	0.000	19.41	0.9802	11.4667
1995	289.953	69.830	359.783	22.320	0.000	19.41	0.9047	10.0782
1996	404.725	97.471	502.196	21.715	0.000	19.41	0.8782	8.9039
1997	547.416	131.836	679.252	22.021	0.000	19.41	0.9362	9.6820
1998	439.374	115.000	554.374	26.988	0.000	20.74	0.8485	9.0983
1999	382.139	52.000	434.139	36.911	0.000	11.98	0.7039	8.0995
2000	217.405	93.000	310.405	11.121	0.000	29.96	0.4847	4.6519
2001	306.752	292.000	598.752	10.600	0.096	48.77	0.5653	5.1157
2002	545.156	96.920	642.076	21.650	0.029	15.09	0.7542	7.1647
2003	737.989	163.710	901.699	68.468	0.000	18.16	0.9179	8.6661
2004	628.392	170.310	798.702	106.386	0.505	21.32	0.8819	8.2044
2005	663.887	52.720	716.607	73.442	0.008	7.36	0.9762	9.3924
2006	490.852	26.880	517.732	85.434	0.058	5.19	0.9631	9.7517
2007	335.763	64.522	400.284	29.067	0.060	16.12	0.9292	9.5152
2008	463.424	89.595	553.019	22.103	0.002	16.20	1.1150	12.2034
2009	561.250	369.419	930.669	35.112	0.000	39.69	1.2256	13.1797
2010	629.323	275.697	905.020	12.028	0.037	30.46	1.1642	12.8612
2011	571.704	247.571	819.275	6.077	3.492	30.22	1.0831	10.8311

Discards make up approximately 19.41 % of the catch over the 1998-2006 years.

Table 20.73 RBC calculations for Mirror Dory. C_{targ} and $CPUE_{targ}$ relate to the period 1986-1995, $CPUE_{Lim}$ is 40% of the target, and $\overline{CPUE}$ is the average catch rate over the last four years. The RBC calculation does not account for predicted discards of predicted State catches. Wt_Discard is the weighted average discards from the last four years, as with Equ (7).

Ref_Year	1992-1997&2003-2006
CE_Targ	0.9533
CE_Lim	0.3813
CE_Recent	1.147
Wt_Discard	260.786
Scaling	1.3386
Last Year's TAC	
C_{targ}	598.962

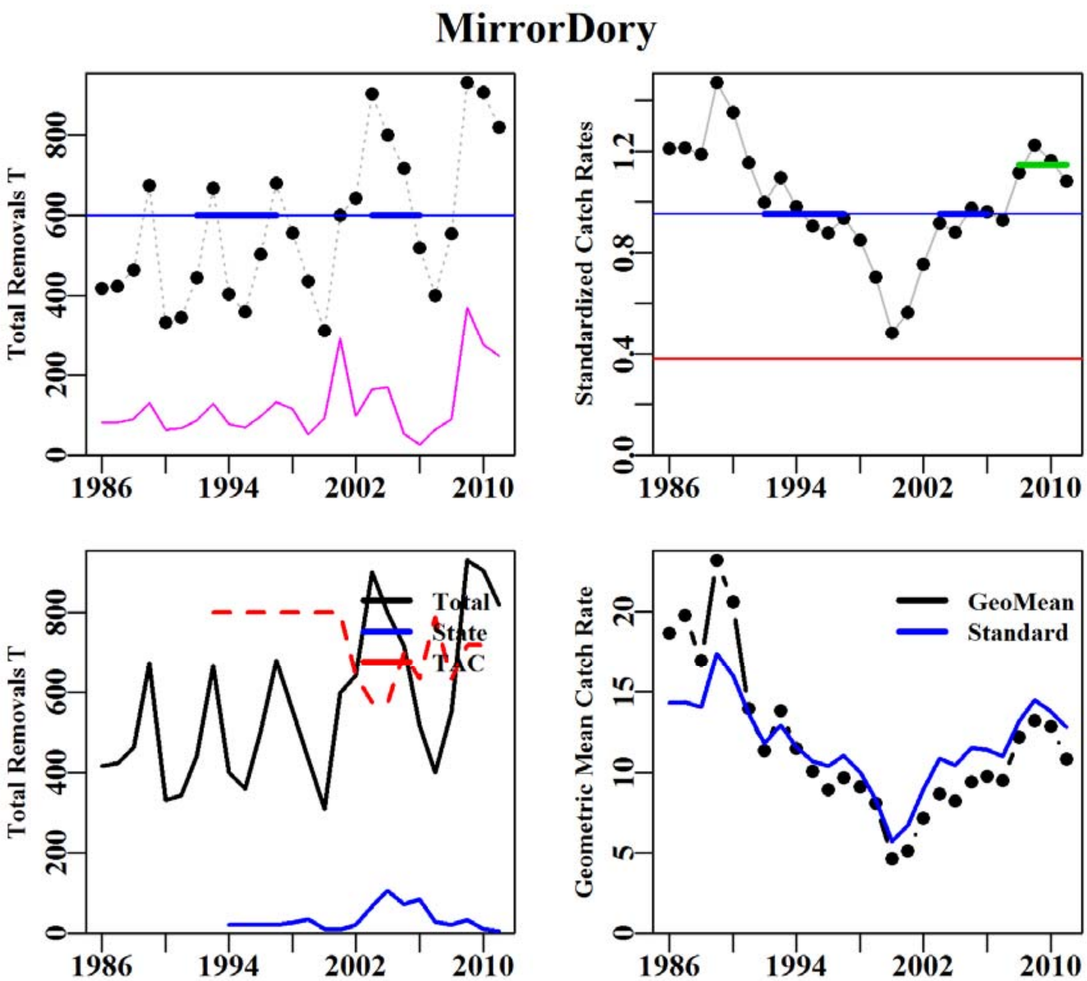

Figure 20.54 Mirror Dory. Top left is the total removals with the fine line illustrating the target catch. Top right represents the standardized catch rates with the upper fine line representing the target catch rate and the lower line the limit catch rate. Thickened lines represents the reference period for catches, catch rates, and the recent average catch rate.

20.7.8 Mirror Dory East (DOM – 37264003 – Z. nebulosus)

Table 20.74 Mirror Dory data for the TIER 4 calculations. Total is the sum of Discards, State, Non Trawl and SEF2 catches. All values in Tonnes. CE is the standardized catch rate for Zones 10 to 30 in depths 0 – 600m (Haddon, 2012). GeoMean is the geometric mean catch rates. Discards are estimates from 1998 to present. The ratio of discards to catch over the 1998 – 2006 period was used to estimate the discards between 1986 and 1997, the proportion of which is the PDiscard.

Year	Catch	Discards	Total	State	Non-T	PDiscard	CE	GeoMean
1986	329.399	79.330	408.729			19.41	1.1585	18.7487
1987	328.474	79.107	407.581			19.41	1.1556	19.9429
1988	356.164	85.776	441.939			19.41	1.1336	16.8882
1989	530.901	127.858	658.759			19.41	1.3791	23.1617
1990	257.511	62.017	319.528			19.41	1.2896	20.5538
1991	257.915	62.114	320.029			19.41	1.1339	14.2052
1992	337.458	81.271	418.728			19.41	0.9845	11.7312
1993	503.639	121.293	624.932			19.41	1.0792	14.1976
1994	303.620	73.121	376.741	20.402	0.000	19.41	0.9448	11.6924
1995	242.777	58.469	301.245	18.688	0.000	19.41	0.8577	10.2913
1996	262.435	63.203	325.638	14.081	0.000	19.41	0.7617	7.7998
1997	361.397	87.036	448.433	14.538	0.000	19.41	0.8100	8.6425
1998	292.102	76.454	368.556	17.942	0.000	20.74	0.7297	8.0944
1999	301.020	40.962	341.981	29.076	0.000	11.98	0.6626	7.8713
2000	187.852	80.358	268.209	9.610	0.000	29.96	0.4995	4.7885
2001	168.695	160.582	329.277	5.829	0.053	48.77	0.4995	4.0443
2002	243.846	43.352	287.198	9.684	0.013	15.09	0.6208	5.2594
2003	534.068	118.474	652.541	49.549	0.000	18.16	0.9105	7.7688
2004	406.456	110.160	516.616	68.813	0.327	21.32	0.8636	7.2635
2005	537.095	42.651	579.747	59.416	0.006	7.36	1.1053	9.9946
2006	402.462	22.040	424.502	70.049	0.048	5.19	1.1074	10.3893
2007	254.433	48.893	303.326	22.026	0.046	16.12	1.1963	11.4463
2008	391.327	75.656	466.983	18.664	0.002	16.20	1.3389	14.4563
2009	411.441	270.813	682.255	25.740	0.000	39.69	1.4196	15.8458
2010	430.160	188.446	618.607	8.221	0.025	30.46	1.1806	14.3976
2011	393.757	170.513	564.270	4.185	2.405	30.22	1.1774	12.7502

Discards make up approximately 19.41 % of the catch over the 1998-2006 period.

Table 20.75 RBC calculations for Mirror Dory East. C_{targ} and $CPUE_{targ}$ relate to the period 1986-1995, $CPUE_{Lim}$ is 40% of the target, and $\overline{CPUE}$ is the average catch rate over the last four years. The RBC calculation does not account for predicted discards of predicted State catches. Wt_Discard is the weighted average discards from the last four years, as with Equ (7).

Ref_Year	1986-1995
CE_Targ	1.1117
CE_Lim	0.4447
CE_Recent	1.2791
Wt_Discard	182.345
Scaling	1.2511
Last Year's TAC	
C_{targ}	427.821

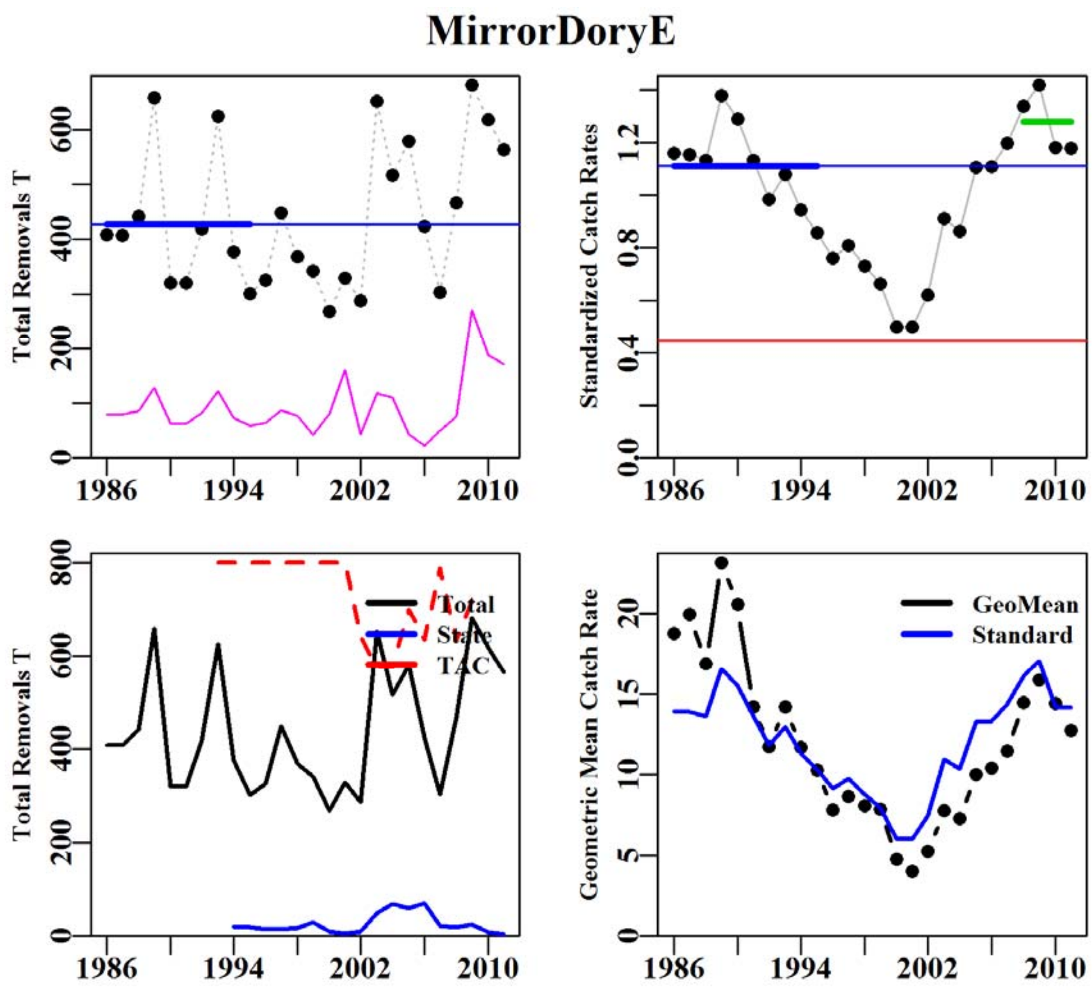

Figure 20.55 Mirror Dory. Top left is the total removals with the fine line illustrating the target catch. Top right represents the standardized catch rates with the upper fine line representing the target catch rate and the lower line the limit catch rate. Thickened lines represents the reference period for catches, catch rates, and the recent average catch rate.

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

Table 20.76 Mirror Dory data for the TIER 4 calculations. Total is the sum of Discards, State, Non Trawl and SEF2 catches. All values in Tonnes. CE is the standardized catch rate for Zones 40 to 50 in depths 0 – 600m (Haddon, 2012). GeoMean is the geometric mean catch rates. Discards are estimates from 1998 to present. The ratio of discards to catch over the 1998 – 2006 period was used to estimate the discards between 1986 and 1997, the proportion of which is the PDiscard.

Year	Catch	Discards	Total	State	Non-T	PDiscard	CE	GeoMean
1986	6.601	1.590	8.190			19.41	2.3666	13.7130
1987	12.326	2.968	15.294			19.41	1.5740	16.0832
1988	17.036	4.103	21.139			19.41	1.2966	18.4525
1989	11.499	2.769	14.268			19.41	1.6475	24.6757
1990	10.089	2.430	12.518			19.41	1.1110	21.6631
1991	19.285	4.645	23.930			19.41	0.7909	11.7670
1992	20.142	4.851	24.993			19.41	0.6541	8.1608
1993	33.961	8.179	42.139			19.41	0.7732	10.1017
1994	21.044	5.068	26.113	1.414	0.000	19.41	0.6758	9.3264
1995	47.176	11.362	58.538	3.632	0.000	19.41	0.8594	9.0896
1996	142.290	34.268	176.558	7.634	0.000	19.41	1.2433	13.3473
1997	186.019	44.799	230.818	7.483	0.000	19.41	1.2670	12.8686
1998	147.272	38.546	185.818	9.046	0.000	20.74	1.2404	12.6121
1999	81.119	11.038	92.158	7.835	0.000	11.98	0.8103	8.8763
2000	29.554	12.642	42.196	1.512	0.000	29.96	0.4281	4.0569
2001	138.057	131.418	269.475	4.771	0.043	48.77	0.7384	7.9361
2002	301.310	53.568	354.878	11.966	0.016	15.09	1.0837	11.7181
2003	203.921	45.236	249.158	18.919	0.000	18.16	0.9361	11.0165
2004	221.936	60.150	282.086	37.573	0.178	21.32	0.9388	10.3786
2005	126.791	10.069	136.860	14.026	0.002	7.36	0.7379	8.0456
2006	88.390	4.840	93.231	15.385	0.010	5.19	0.6304	8.0395
2007	81.330	15.629	96.959	7.041	0.015	16.12	0.5653	6.7120
2008	72.097	13.939	86.036	3.439	0.000	16.20	0.6335	7.5767
2009	149.809	98.605	248.414	9.372	0.000	39.69	0.9617	9.7010
2010	199.163	87.250	286.413	3.807	0.012	30.46	1.1448	11.0745
2011	177.946	77.058	255.004	1.891	1.087	30.22	0.8911	8.6540

Discards make up approximately 19.41 % of the catch over the 1998-2006 period.

Table 20.77 RBC calculations for Mirror Dory. C_{targ} and $CPUE_{targ}$ relate to the period 1996-2005, $CPUE_{Lim}$ is 40% of the target, and $\overline{CPUE}$ is the average catch rate over the last four years. The RBC calculation does not account for predicted discards of predicted State catches. Wt_Discard is the weighted average discards from the last four years, as with Equ (7).

Ref_Year	1996-2005
CE_Targ	0.9424
CE_Lim	0.377
CE_Recent	0.9078
Wt_Discard	78.441
Scaling	0.9388
Last Year's TAC	
C_{targ}	202.001

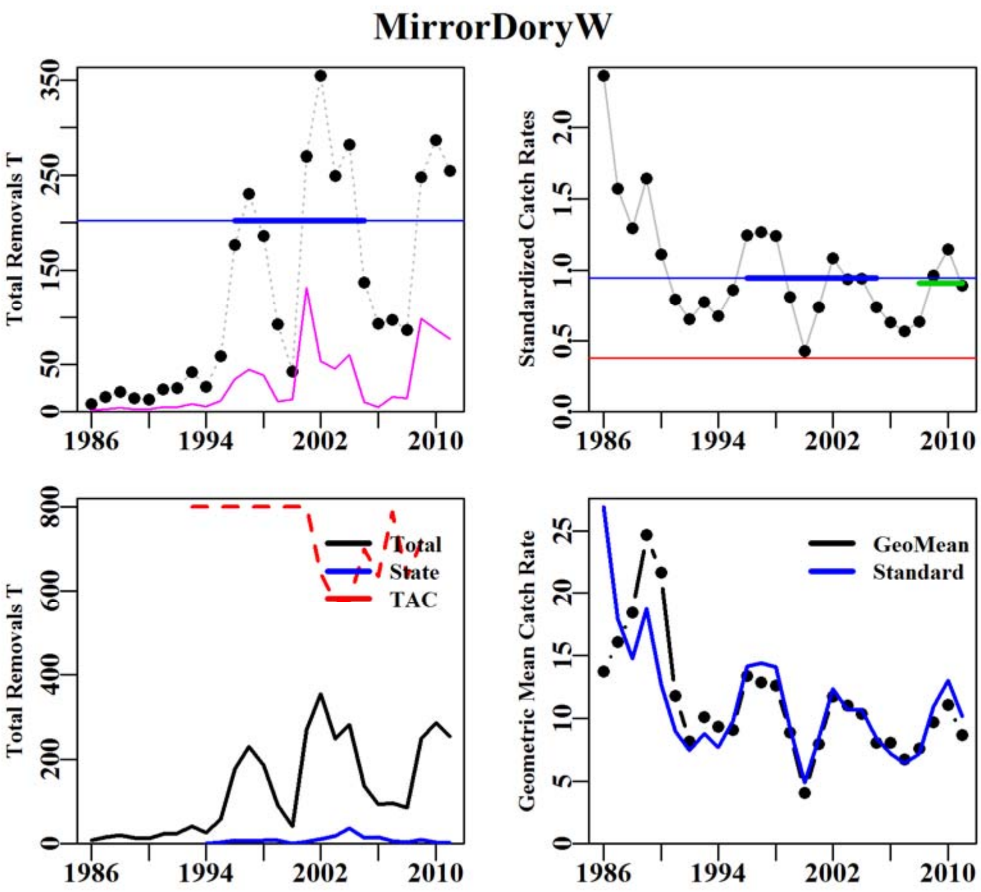

Figure 20.56 Mirror Dory. Top left is the total removals with the fine line illustrating the target catch. Top right represents the standardized catch rates with the upper fine line representing the target catch rate and the lower line the limit catch rate. Thickened lines represents the reference period for catches, catch rates, and the recent average catch rate.

20.7.10 Pink Ling (LIG – 37228002 – Genypterus blacodes)

Table 20.78 Pink Ling data for the TIER 4 calculations. Total is the sum of Discards, State, Non Trawl and SEF2 catches. All values in Tonnes. CE is the standardized catch rate for Zones 10, 20 and 30 in depths 0 – 1000m (Haddon, 2012). GeoMean is the geometric mean catch rates. Discards are estimates from 1998 to present. The ratio of discards to catch over the 1998 – 2006 period was used to estimate the discards between 1986 and 1997, the proportion of which is the PDiscard.

Year	Catch	Discards	Total	State	Non-T	PDiscard	CE	LnCE
1986	650.400	3.627	654.027			0.55	1.1020	20.6650
1987	802.800	4.477	807.277			0.55	1.1680	19.4240
1988	621.600	3.467	625.067			0.55	1.1140	20.2590
1989	744.000	4.149	748.149			0.55	0.9590	19.1570
1990	776.400	4.330	780.730			0.55	1.4110	26.8200
1991	910.800	5.080	915.880			0.55	1.4120	26.3050
1992	1081.200	6.030	1087.230			0.55	1.0890	24.8500
1993	1657.200	9.243	1666.443			0.55	1.0230	25.3070
1994	1463.324	8.161	1471.485	538.219	0.000	0.55	1.0370	23.5160
1995	1944.501	10.845	1955.346	672.495	0.000	0.55	1.3070	25.8110
1996	2244.320	12.517	2256.837	811.461	0.000	0.55	1.3000	27.6570
1997	2128.990	11.874	2140.864	393.906	0.000	0.55	1.3230	27.9370
1998	1933.870	41.000	1974.870	52.110	202.385	2.08	1.3230	26.0160
1999	2022.297	12.000	2034.297	50.847	270.504	0.59	1.2090	25.2290
2000	1860.795	11.000	1871.795	19.036	251.991	0.59	1.0770	22.4050
2001	1733.968	5.000	1738.968	9.879	376.583	0.29	0.8390	19.0620
2002	1610.520	6.640	1617.160	15.634	522.209	0.41	0.7330	15.8660
2003	1617.638	1.390	1619.028	8.277	477.475	0.09	0.7520	18.2930
2004	1766.179	1.390	1767.569	12.201	850.448	0.08	0.6720	16.7980
2005	1421.688	3.330	1425.018	20.897	644.493	0.23	0.6280	16.3340
2006	1200.188	2.840	1203.028	15.646	455.183	0.24	0.7500	21.3190
2007	1010.801	21.554	1032.355	23.812	339.055	2.09	0.7360	20.5010
2008	1182.085	16.542	1198.627	32.212	443.663	1.38	0.8520	25.1510
2009	900.949	50.088	951.036	16.474	298.114	5.27	0.6220	18.2950
2010	1098.359	57.616	1155.975	54.356	388.518	4.98	0.7610	20.7210
2011	1244.238	14.446	1258.684	25.420	429.517	1.15	0.8030	23.4440

Discards make up approximately 0.54 % of the catch over the 1998-2006 period. The standardized catch rate series used was from Zones 10, 20 and 30 as taken by trawl.

Table 20.79 RBC calculations for Pink Ling. C_{targ} and $CPUE_{targ}$ relate to the period 1986-1995, $CPUE_{Lim}$ is 40% of the target, and $\overline{CPUE}$ is the average catch rate over the last four years. The RBC calculation does not account for predicted discards of predicted State catches. Wt_Discard is the weighted average discards from the last four years, as with Equ (7).

Ref_Year	1986-1995
CE_Targ	1.1622
CE_Lim	0.4649
CE_Recent	0.7595
Wt_Discard	30.85
Scaling	0.4225
Last Year's TAC	
C_{targ}	1071.163

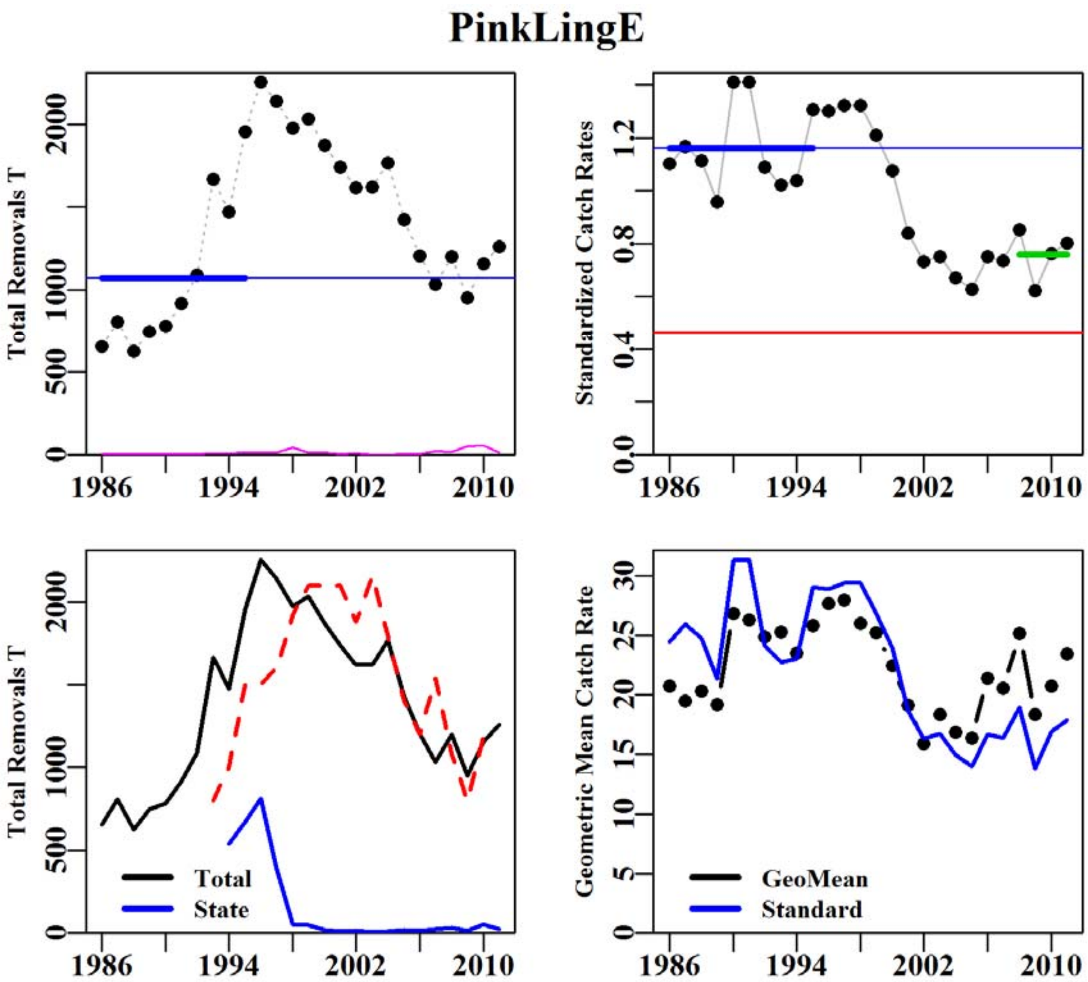

Figure 20.57 Top left is the total removals with the fine line illustrating the target catch. Top right represents the standardized catch rates with the upper fine line representing the target catch rate and the lower line the limit catch rate. Thickened lines represents the reference period for catches, catch rates, and the recent average catch rate.

20.7.11 RedFish (RED – 37258003 – *Centroberyx affinis*)

The period of the redfish fishery between 1991 to 1998 appears to have been during an era of heightened availability for redfish. This period is no longer considered to be representative of the fishery as it normally runs and has been running for the last few years.

Table 20.80 Redfish data for the TIER 4 calculations. Total is the sum of Discards, State, Non Trawl and SEF2 catches. All values in Tonnes. CE is the standardized catch rate for Zone 10 in depths 0 – 400m (Haddon, 2012) relative to the catch rate in 1986. GeoMean is the geometric mean catch rates. Discards are estimates from 1998 to present. The ratio of discards to catch over the 1998 – 2006 period was used to estimate the discards between 1986 and 1997, the proportion of which is the PDiscard.

Year	Catch	Discards	Total	State	Non-T	PDiscard	CE	GeoMean
1986	1426.800	904.992	2331.792			38.81	1.5835	38.3044
1987	986.400	625.655	1612.055			38.81	1.2675	35.9993
1988	961.200	609.671	1570.871			38.81	1.3164	37.3114
1989	649.200	411.775	1060.975			38.81	1.0928	29.4122
1990	792.000	502.350	1294.350			38.81	1.4854	37.2522
1991	1737.600	1102.126	2839.726			38.81	1.5398	39.9367
1992	2443.200	1549.675	3992.875			38.81	1.9882	50.0990
1993	2114.400	1341.123	3455.523			38.81	2.5202	56.0385
1994	1957.210	1241.421	3198.631	1345.606	0.000	38.81	1.7668	35.8972
1995	1999.572	1268.290	3267.862	789.249	0.000	38.81	1.1458	27.8589
1996	2219.833	1407.997	3627.831	784.092	0.000	38.81	0.9344	26.2588
1997	1840.798	1167.583	3008.380	304.137	0.000	38.81	1.0959	33.5183
1998	1835.469	2324.000	4159.469	83.849	0.000	55.87	1.3762	43.1196
1999	1346.976	69.000	1415.976	94.939	0.000	4.87	1.0812	32.7876
2000	859.909	233.000	1092.909	27.446	0.000	21.32	0.7288	22.7760
2001	846.662	738.000	1584.662	52.093	0.545	46.57	0.7123	17.8301
2002	926.928	894.850	1821.778	46.951	0.155	49.12	0.6089	16.4201
2003	726.661	347.500	1074.161	48.604	0.828	32.35	0.5826	17.0122
2004	557.603	377.440	935.043	58.124	1.005	40.37	0.4941	15.2541
2005	579.526	126.180	705.706	46.690	0.568	17.88	0.5057	16.1484
2006	397.194	13.070	410.264	75.690	0.541	3.19	0.4745	15.6812
2007	283.332	2.681	286.013	53.689	0.089	0.94	0.4237	15.4678
2008	230.566	2.182	232.748	29.369	0.163	0.94	0.3993	13.9780
2009	207.440	231.285	438.726	25.489	0.076	52.72	0.3253	11.3207
2010	187.992	27.086	215.079	22.340	0.019	12.59	0.3059	10.4815
2011	111.956	26.064	138.020	13.438	0.247	18.88	0.2447	8.5118

Discards make up approximately 38.8% of the catch over the 1998-2006 period. The standardized catch rate series is from Zone 10.

Table 20.81 RBC calculations for Redfish. C_{targ} and $CPUE_{targ}$ relate to the period 1986-1990 and 1999-2003 (omitting a period of enhanced availability during the 1990s). $CPUE_{Lim}$ is 40% of the target, and $\overline{CPUE}$ is the average catch rate over the last four years. The RBC calculation does not account for predicted discards of predicted State catches. Wt_Discard is the weighted average discards from the last four years, as with Equ (7).

Ref_Year	1986-1990&1999-2003
CE_Targ	1.0459
CE_Lim	0.4184
CE_Recent	0.3188
Wt_Discard	52.107
Scaling	0
Last Year's TAC	276
C_{targ}	1485.953

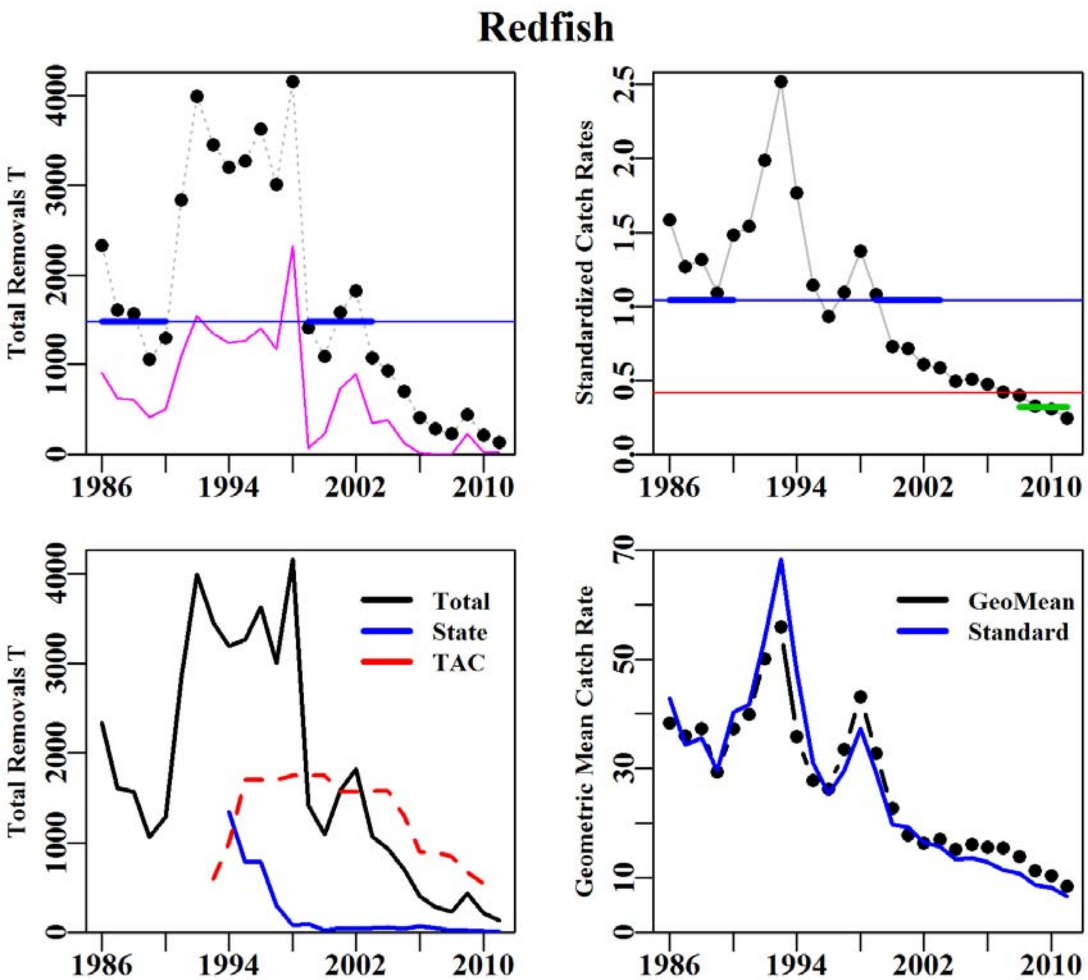

Figure 20.58 Redfish. Left is the total removals with the fine line illustrating the target catch. Right represents the standardized catch rates with the upper fine line representing the target catch rate and the lower line the limit catch rate. Thickened lines represents the reference period for catches, catch rates, and the recent average catch rate.

20.7.12 RedFish plus Discards (RED – 37258003 – C. affinis)

The period of the redfish fishery between 1991 to 1998 appears to have been during an era of heightened availability for redfish. This period is no longer considered to be representative of the fishery as it normally runs and has been running for the last few years.

Table 20.82 Redfish data for the Alternative TIER 4 calculations using ratio mean catch rates that include discards in the catch rate calculations. Total is the sum of Discards, and other catches. All values in Tonnes. StandCE is the standardized catch rate for redfish from Zone 10 in depths 0 – 400m (Haddon, 2012). GeoMean is the geometric mean catch rates (without discards). Discards are estimates from 1998 to present. DiscCE is the standardized catch rates multiplied by [(Discard/Catch)+1], see Haddon (2011c) for methods.

Year	Catch	Discards	Total	Effort	(D/C)+1	StandCE	DiscCE	GeoMean
1986	1426.800	904.992	2331.792	15230	1.6343	1.5835	1.6149	1.4133
1987	986.400	625.655	1612.055	11696	1.6343	1.2675	1.2927	1.3282
1988	961.200	609.671	1570.871	12009	1.6343	1.3164	1.3425	1.3767
1989	649.200	411.775	1060.975	8184	1.6343	1.0928	1.1145	1.0852
1990	792.000	502.350	1294.350	8217	1.6343	1.4854	1.5149	1.3745
1991	1737.600	1102.126	2839.726	10584	1.6343	1.5398	1.5704	1.4735
1992	2443.200	1549.675	3992.875	9440	1.6343	1.9882	2.0277	1.8485
1993	2114.400	1341.123	3455.523	11231	1.6343	2.5202	2.5702	2.0676
1994	1957.210	1241.421	3198.631	16182	1.6343	1.7668	1.8019	1.3245
1995	1999.572	1268.290	3267.862	16829	1.6343	1.1458	1.1685	1.0279
1996	2219.833	1407.997	3627.831	17763	1.6343	0.9344	0.9529	0.9689
1997	1840.798	1167.583	3008.380	13300	1.6343	1.0959	1.1177	1.2367
1998	1835.469	2324.000	4159.469	12958	2.2662	1.3762	1.9462	1.5910
1999	1346.976	69.000	1415.976	12048	1.0512	1.0812	0.7093	1.2097
2000	859.909	233.000	1092.909	14534	1.2710	0.7288	0.5780	0.8404
2001	846.662	738.000	1584.662	14186	1.8717	0.7123	0.8320	0.6579
2002	926.928	894.850	1821.778	16725	1.9654	0.6089	0.7468	0.6058
2003	726.661	347.500	1074.161	13389	1.4782	0.5826	0.5374	0.6277
2004	557.603	377.440	935.043	13137	1.6769	0.4941	0.5170	0.5628
2005	579.526	126.180	705.706	12939	1.2177	0.5057	0.3843	0.5958
2006	397.194	13.070	410.264	8826	1.0329	0.4745	0.3058	0.5786
2007	283.332	2.681	286.013	6104	1.0095	0.4237	0.2669	0.5707
2008	230.566	2.182	232.748	6407	1.0095	0.3993	0.2515	0.5157
2009	207.440	231.285	438.726	5457	2.1149	0.3253	0.4293	0.4177
2010	187.992	27.086	215.079	6456	1.1441	0.3059	0.2184	0.3867
2011	111.956	26.064	138.020	4760	1.2328	0.2447	0.1883	0.3141

Discards make up approximately 38.8% of the catch over the 1998-2006 period. The standardized catch rate series is from Zone 10.

Table 20.83 RBC calculations for Redfish. C_{targ} and $CPUE_{targ}$ relate to the period 1986-1990 and 1999-2003 (omitting a period of enhanced availability during the 1990s). $CPUE_{Lim}$ is 40% of the target, and $\overline{CPUE}$ is the average catch rate over the last four years. The RBC calculation does not account for predicted discards of predicted State catches. Wt_Discard is the weighted average discards from the last four years, as with Equ (7).

Ref_Year	1986-1990&1999-2003
CE_Targ	1.0283
CE_Lim	0.4113
CE_Recent	0.2719
Wt_Discard	52.107
Scaling	0
Last Year's TAC	
C_{targ}	1485.953

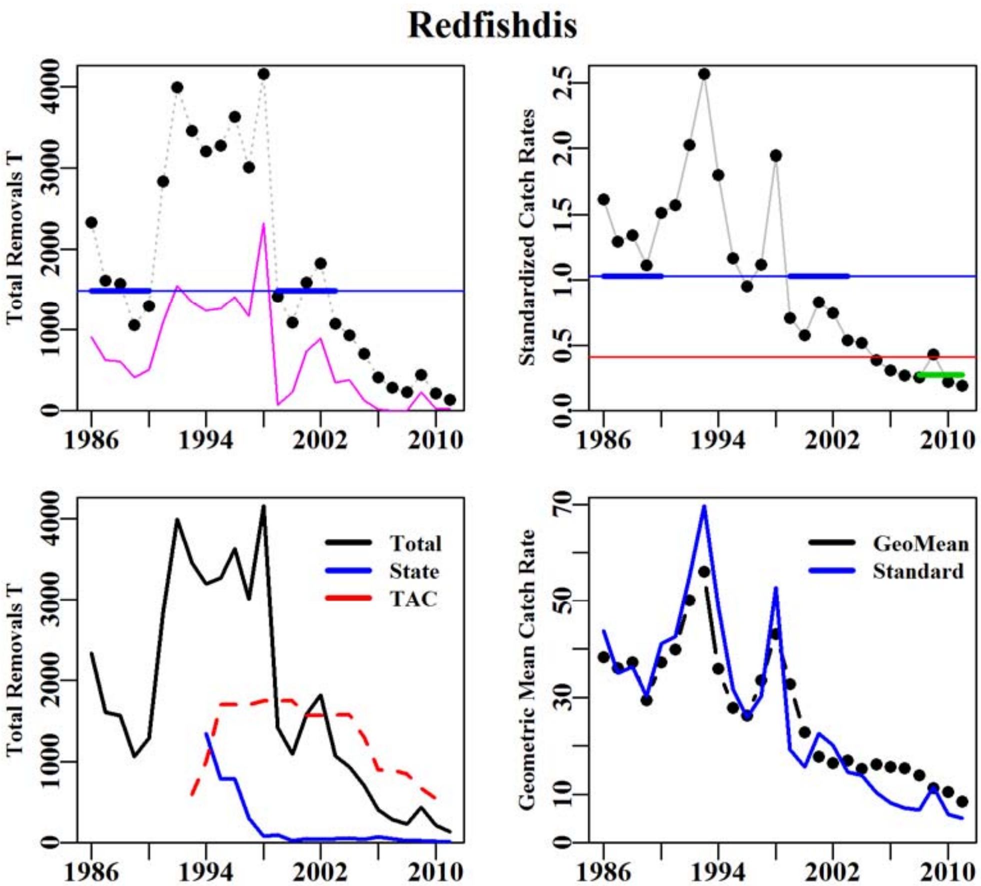

Figure 20.59 Redfish. Left is the total removals with the fine line illustrating the target catch. Right represents the standardized catch rates with the upper fine line representing the target catch rate and the lower line the limit catch rate. Thickened lines represents the reference period for catches, catch rates, and the recent average catch rate.

20.7.13 School Whiting (WHS – 37330014 – Sillago flindersi)

Table 20.84 School Whiting data for the TIER 4 calculations. Total is the sum of Discards, State, Non Trawl and SEF2 catches. All values in Tonnes. CE is the standardized catch rate for Zone 60 from depths 0 to 100 m (Haddon, 2012). GeoMean is the geometric mean catch rates. Discards are estimates from 1998 to present. The ratio of discards to catch over the 1998 – 2006 period was used to estimate the discards between 1986 and 1997, the proportion of which is the PDiscard.

Year	Catch	Discards	Total	State	Non -T	PDiscard	CE	GeoMean
1986	1903.200	29.333	1932.533			1.518	1.1573	112.3054
1987	1320.000	20.344	1340.344			1.518	1.2735	131.1624
1988	1549.200	23.877	1573.077			1.518	1.6496	168.5490
1989	1220.400	18.809	1239.209			1.518	1.0919	127.0438
1990	2007.600	30.942	2038.542			1.518	1.6853	165.2959
1991	1866.000	28.760	1894.760			1.518	1.4283	164.1905
1992	1219.200	18.791	1237.991			1.518	1.0180	124.7066
1993	2007.600	30.942	2038.542			1.518	1.4500	152.4819
1994	1647.018	25.385	1672.403	766.818	0	1.518	0.8477	93.9314
1995	1990.79	30.683	2021.473	910.4204	0	1.518	1.0666	122.4731
1996	1695.105	26.126	1721.231	1038.743	0	1.518	0.6978	81.4339
1997	1556.38	23.988	1580.367	1169.811	0	1.518	0.5411	64.5619
1998	1813.848	48.000	1861.848	1396.053	0	2.578	0.5219	66.0158
1999	1448.81	5.000	1453.810	1011.862	0	0.344	0.5966	84.3634
2000	1289.46	9.000	1298.460	797.749	0	0.693	0.6006	65.1233
2001	1719.332	28.000	1747.332	1217.815	0	1.602	0.8457	93.2089
2002	1577.598	9.760	1587.358	1052.245	0	0.615	0.8697	90.8874
2003	1490.494	46.340	1536.834	926.2246	0	3.015	0.8898	87.1013
2004	1463.803	26.360	1490.163	1040.482	0	1.769	0.8435	79.7648
2005	1468.64	37.500	1506.140	1013.53	0	2.490	0.9513	77.2502
2006	1551.224	3.090	1554.314	1095.517	0.0011	0.199	0.8220	76.2250
2007	1636.456	3.260	1639.716	1197.766	0	0.199	1.0799	89.2381
2008	1369.947	2.729	1372.676	959.3665	0	0.199	1.0860	92.3448
2009	1227.521	2.445	1229.966	814.915	0	0.199	1.1350	93.6200
2010	1226.626	18.316	1244.942	846.88	0	1.471	1.0156	88.7190
2011	1240.111	58.467	1298.578	880.657	0	4.502	0.8354	72.0269

Discards make up approximately 1.5% of the catch over the 1998-2006 period.

Table 20.85 RBC calculations for School Whiting. C_{targ} and $CPUE_{targ}$ relate to the period 1986-1995, $CPUE_{Lim}$ is 40% of the target, and $\overline{CPUE}$ is the average catch rate over the last four years. The RBC calculation does not account for predicted discards of predicted State catches. Wt_Discard is the weighted average discards from the last four years, as with Equ (7).

Ref_Year	1986-1995
CE_Targ	1.2668
CE_Lim	0.5067
CE_Recent	1.018
Wt_Discard	36.575
Scaling	0.6726
Last Year's TAC	
C_{targ}	1698.887

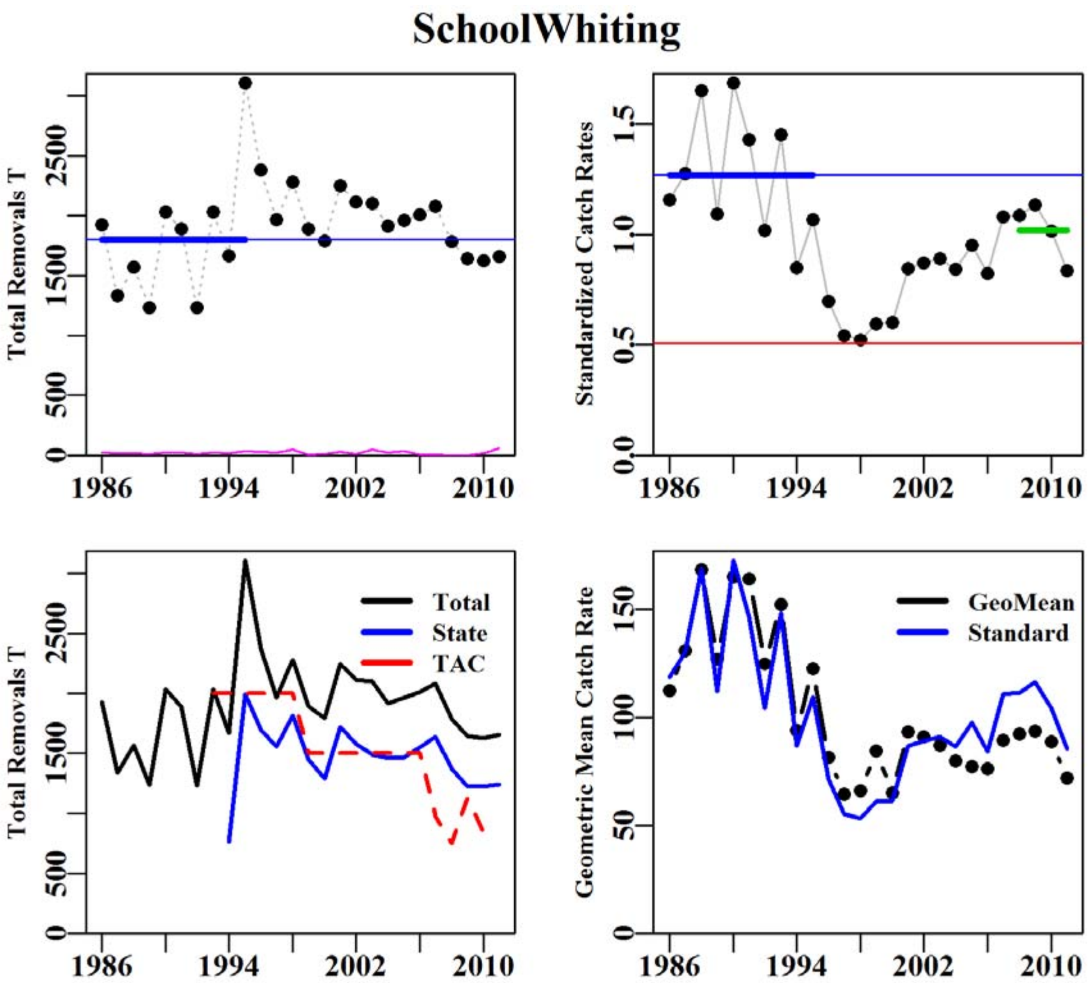

Figure 20.60 School Whiting. Top left is the total removals with the fine line illustrating the target catch. Top right represents the standardized catch rates with the upper fine line representing the target catch rate and the lower line the limit catch rate. Thickened lines represents the reference period for catches, catch rates, and the recent average catch rate.

20.7.14 Silver Warehou (TRS – 37445006 – *Seriolella punctata*)

Table 20.86 Spotted/Silver Warehou data for the TIER 4 calculations. Total is the sum of Discards, State, Non Trawl and SEF2 catches. All values in Tonnes. CE is the standardized catch rate for Zones 10 to 50 in depths 0 – 1000m (Haddon, 2012). GeoMean is the geometric mean catch rates. Discards are estimates from 1998 to present. The ratio of discards to catch over the 1998 – 2006 period was used to estimate the discards between 1986 and 1997, the proportion of which is the PDiscard.

Year	Catch	Discards	Total	State	Non-T	PDiscard	CE	GeoMean
1986	1142.927	242.793	1385.720			17.52	1.4228	32.2897
1987	779.270	165.541	944.811			17.52	1.5121	35.5040
1988	1637.312	347.815	1985.127			17.52	1.9169	42.9346
1989	916.714	194.738	1111.452			17.52	1.5678	30.7291
1990	1319.413	280.284	1599.697			17.52	1.6590	40.6488
1991	1421.943	302.064	1724.007			17.52	1.1675	25.6848
1992	709.181	150.652	859.833			17.52	1.0123	27.9469
1993	1775.414	377.152	2152.566			17.52	1.1448	33.2988
1994	2054.296	436.396	2490.692	188.226		17.52	1.2249	34.7142
1995	2213.896	470.299	2684.196	148.791		17.52	1.1080	29.7825
1996	2735.681	581.143	3316.824	181.480		17.52	1.0502	22.7319
1997	2807.462	596.391	3403.853	37.925		17.52	1.0783	25.3481
1998	2433.954	2150.000	4583.954	24.112		46.90	1.0390	26.6416
1999	3255.217	45.000	3300.217	1.746		1.36	0.8951	31.2330
2000	3726.592	123.000	3849.592	0.464		3.20	0.8113	26.0708
2001	3295.454	695.000	3990.454	0.324	0.923	17.42	0.6811	21.7853
2002	4101.870	552.470	4654.340	0.487	0.701	11.87	0.7357	22.9919
2003	3060.003	769.760	3829.763	1.007	12.642	20.10	0.7411	20.4815
2004	3315.032	1183.280	4498.312	3.774	0.251	26.30	0.8231	23.3323
2005	2912.725	434.830	3347.555	4.996	0.139	12.99	0.8088	20.0277
2006	2374.182	95.630	2469.812	2.494	0.086	3.87	0.7116	18.2160
2007	1987.060	82.453	2069.513	4.373	0.056	3.98	0.6722	20.1239
2008	1522.999	49.718	1572.717	0.541	0.063	3.16	0.6018	16.1202
2009	1379.268	33.280	1412.548	1.240	0.002	2.36	0.6203	15.8837
2010	1288.673	17.155	1305.827	0.561	1.285	1.31	0.5126	13.2653
2011	1229.278	428.738	1658.015	0.547	0.1116	25.858	0.4816	12.5782

Discards make up approximately 17.52 % of the catch over the 1998-2006 period. The standardization is an annual analysis conducted for the TIER 4 analysis.

Table 20.87 RBC calculations for Silver Warehou. C_{targ} and $CPUE_{targ}$ relate to the period 1986-1995, $CPUE_{Lim}$ is 40% of the target, and $\overline{CPUE}$ is the average catch rate over the last four years. The RBC calculation does not account for predicted discards of predicted State catches. Wt_Discard is the weighted average discards from the last four years, as with Equ (7).

Ref_Year	1986-1995
CE_Targ	0.6868
CE_Lim	0.2747
CE_Recent	0.5541
Wt_Discard	240.987
Scaling	0.6779
Last Year's TAC	
C_{targ}	1693.81

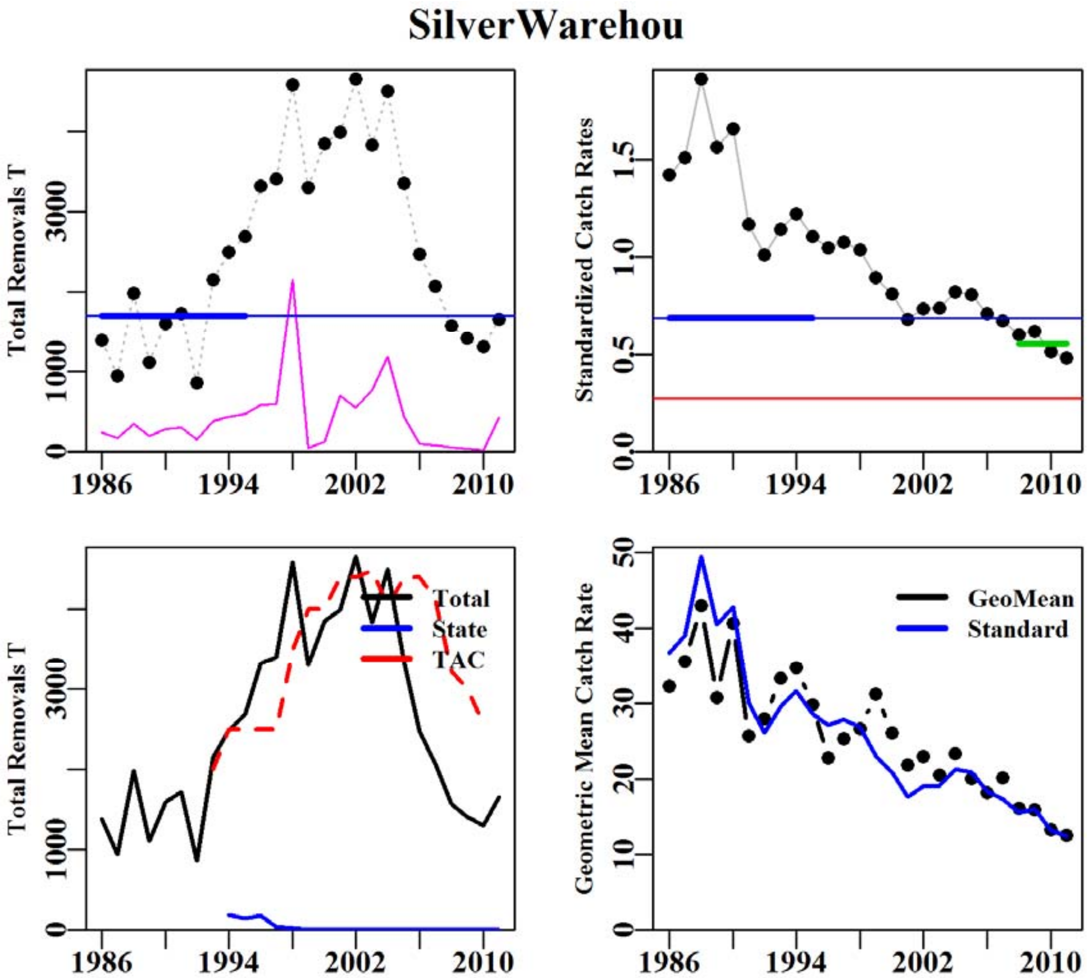

Figure 20.61 Spotted/Silver Warehou. Top left is the total removals with the fine line illustrating the target catch. Top right represents the standardized catch rates with the upper fine line representing the target catch rate and the lower line the limit catch rate. Thickened lines represents the reference period for catches, catch rates, and the recent average catch rate.

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21. Saw Shark and Elephant Fish TIER 4 Analyses (Data 1980 – 2011)

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21.1 Summary

The stock assessments that feed into the management control rules that reflect the harvest strategy adopted in the SESSF are arranged in a tiered system ranging from fully quantified modelled stock assessments (Tier 1) down to empirical rules based only on catch and catch rates (Tier 4). For those species where biological and fisheries data are limited an examination of trends in catch rates is used to modify allowable catches with the objective of managing the particular fishery towards a target that represents a desirable state for the fishery that also acts as a proxy for the general Harvest Strategy Policy target of 48% B_0.

The Tier 4 control rule is used to calculate Recommended Biological Catches (RBCs) for saw sharks and elephant fish from the southern shark fishery. Standardized catch rates for both species (Haddon, 2012) were used along with total catches of the respective species in a standard analysis. This year's analysis varied from previous analyses by comparing the outcome of treating the catch rate target as a proxy for 48% B_0 versus with a proxy for 40%B_0 as an alternative target for these non-target species. For saw sharks the reported catches by trawl are now approaching the level of gill net catches so an additional analysis was conducted where the standardized catch rate for trawl saw shark catches was used instead of the gillnet catch rates.

The gillnet catch rates for saw sharks in 2011 barely differed from that in 2010 but owing to the initial drop in catch rates in 2010 the tier 4 analysis, which considers the average catch rate over the last four years, generates a RBC for saw sharks at the 48% target that has now declined to about 64% of the target catch. Whether the decline in the gillnet catch rates constitute a reasonable reflection of the stock status remains questionable due to the level of avoidance that occurs in the fishery (due to low and reducing value of saw sharks in the market). Importantly, when the trawl catch rates for saw sharks are standardized a different trend is apparent; the catches by trawl are almost a the same level as that taken by gill net.

The decline in catch rates in elephant fish seen in 2010 continued in 2011 and this implies a decrease in the RBC (Table 20.1). However, these values relate to the target catch rate being a proxy for 48% of unfished biomass. Neither saw sharks or elephant fish are targeted in the fishery (when using any method) and so the analyses were repeated except using a proxy target of 40% B_0 which, given the control rule, will always increase the RBC if it is above zero.

Table 21.1. TIER 4 outcomes by species. The RBC in tonnes; this has not had discards, State catches, or recreational catches removed. The 2010 and 2011 values came from Haddon (2010; 2011) and the 2009 values came from Rodriguez and McLoughlin (2009a,b).

Species		RBC09	RBC10	RBC11	RBC12
SawSharks @ 48%		369.610	339.756	268.186	**234.010**
Saw Sharks Trawl @ 48%	Zones 20,60,50				**513.612**
Saw Sharks Trawl @ 48%	Zones 20,60,50,83,82				**477.009**
Elephant Fish @ 48%		122.81	135.499	208.263	**186.428**
SawSharks @ 40%					**324.016**
Saw Sharks Trawl @ 40%					**711.160**
Elephant Fish @ 40%					**258.132**

21.2 Introduction

The TIER 4 harvest control rule is the default procedure applied to species for which only limited information is available; specifically, if no reliable information is available relating to either current biomass levels or current exploitation rates. Ideally, in line with the notion of being more precautionary in the absence of information, the outcome from these analyses should be more conservative than those available from higher TIER analyses. In essence TIER 4 analyses require as a minimum, knowledge of the time series of total catches and of standardized catch rates.

Initially a control rule was implemented that was based around using any trend in recent catch rates to scale average recent catches. However, in 2008, an alternative was proposed that would not be prone to a declining ratchet effect on catches, and, in line with the Harvest Strategy Policy, could manage each fishery towards a target catch rate and away from a limit catch rate (Little, *et al*., 2008) The current TIER 4 analysis and control rule underwent Management Strategy Evaluation (Wayte, 2009; Little *et al,* 2011), which demonstrated its advantages over the original implementation.

The Tier 4 assessment requires the definition of a reference period for catches and catch rates which are to constitute the effective target for the fishery. This reference period is intended to act as a proxy for the fishery in a desirable state; ideally close to the stock size that leads to the maximum economic yield, and so in practice this target is also taken as a proxy for B_{MEY}. In practice, in TIER 4 analyses, all that is really known about the reference period is that the RAG considers this period to be when the fishery was in a desirable state both biologically and economically. The Harvest Strategy Policy does not require that all species in a multi-species fishery aim to achieve the maximum economic yield, and this is especially the case with bycatch species. Nevertheless, the objective of avoiding the limit reference point remains. Within the current Tier 4 methodology the limit reference point is defined as 40 % of the target catch rate. In addition, the Harvest Strategy Policy also states that:

> Consideration should also be given to:
> - Demonstrating that economic modelling and other advice clearly supports such action;
> - No cost effective, alternative management options (e.g. gear modifications or spatial management) are available; and
> - The associated ecosystem risks have been considered in full.
>
> (DAFF, 2007, p 25)

If the average catch rate over the last four years drops below this limit the RBC is automatically zero.

21.3 Methods

21.3.1 TIER 4 Methods

The data required are time series of catches and catch rates. The analyses have been conducted on total catches across the entire SESSF (including State catches, SEF2 landing records, any discards, and any recreational catches (for elephant fish). Despite the fishery now operating from May through to April each year, the fishery data was collated in calendar years for consistency with the earlier fishery.

The fishery for both saw sharks and elephant fish was established before the catch rate standardization period selected by the RAG (i.e. significant catches were taken in the 1970s). Thus, although the Shark RAG did not consider the stocks of saw sharks and elephant fish to be seriously depleted by 1980, the stock was not pristine. In previous TIER 4 analyses (Rodriguez & McLoughlin, 2009a, b) two reference periods were examined for saw sharks, 1986-2001 and 2002-2008, and two for elephant fish, 1980 – 1992 and 1998 – 2004. The earlier period had an extra source of uncertainty because the estimates of trawl bycatch and discards were likely under-estimated. To avoid these uncertainties and focus on a period when the total catches are known with most certainty the Shark RAG has selected 2002 – 2008 as the reference period for saw sharks and 1996 – 2007 for elephant fish.

All data to the end of 2010 relating to catches and discards, from both State waters and SEF2 data sets were provided by John Garvey of AFMA, with initial processing by Dr Neil Klaer and Mike Fuller of CSIRO. For saw sharks the species codes used in the landings database were SAW (*Pristiophorus cirratus or Common Saw Shark*), SHN (*Pristiophorus nudipinnis* or Southern Saw Shark), and SHW (*Pristiophoridae* or saw sharks). For elephant fish the species code in the landings database was SHE (*Callorhinchus milii* or Elephantfish). All catch rate data from the GHT fishery for both species were derived from the CANDE11.csv data files and analysed in Haddon (2012). All analyses of trawl caught fish used data straight from the AFMA Log Book database following pre-processing by Mike Fuller and Neil Klaer of CSIRO.

Standard analyses were set up in the statistical software, R, which provided the tables and graphs required for the TIER 4 analyses. The data and results for each analysis are presented for clarity. The TIER 4 harvest control rule formulation essentially uses a ratio of current catch rates with respect to the selected limit and target reference points to calculate a scaling factor. This scaling factor is applied to the target catch to generate an RBC:

$$\text{Scaling Factor } = SF = \max\left(0, \frac{\overline{CPUE} - CPUE_{\lim}}{CPUE_{targ} - CPUE_{\lim}}\right) \tag{1}$$

$$RBC = C^{*} \times SF \tag{2}$$

where

$CPUE_{targ}$ is the target CPUE for the species (half the average CPUE for the reference period).
$CPUE_{lim}$ is the limit CPUE for the species; which is 40% CPUE $_{targ}$
$\overline{CPUE}$ the average CPUE over the past *m* years

C^* is a catch target derived from a period of historical catch that has been identified as a desirable target in terms of CPUE, catches and status of the fishery (e.g. 1996 – 2007, as for Elephant fish). This is an average of the total removals for the selected reference period, including any discards.

$$CPUE_{\text{targ}} = \frac{\sum_{y=yr1}^{yr2} CPUE_y}{\left(yr2 - yr1 + 1\right)} \tag{3}$$

where $CPUE_y$ is the catch rate in year y, $yr2$ and $yr1$ represent the last and the first years in the reference period respectively. The catch target is the mean of the total catch across the reference years.

$$C^* = \frac{\sum_{y=yr1}^{yr2} L_y}{\left(yr2 - yr1 + 1\right)} \tag{4}$$

where L_y represents the total catch (landings plus discards) in year y.

Usually there are three rules used to select/estimate the CPUE/catch target:

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

With bycatch shark species these rules are not always applicable (for example, with elephant fish the total catch rarely reaches 100 tonnes. Instead periods were chosen during which the fishery was considered to be well developed but in a good and relatively stable condition. For elephant fish the reference period chosen was 1996 – 2007 and for saw sharks the reference period chosen was 2002 – 2008.

Once the average CPUE for the reference period has been selected as the target CPUE (assumed a proxy for $B_{48\%}$ which is assumed to be a proxy for B_{MEY}) then the limit CPUE is defined as 40% of the that target. The maximum of the terms in the brackets, that is either zero or the ratio of CPUE values, is a scaling factor which is multiplied by the catch target (C*) to determine the expected total catch. If the $\overline{CPUE}$ is less than the $CPUE_{\text{lim}}$ this will automatically set the scaling factor to be negative, which means that the scaling factor will be set to zero and the consequent RBC will be zero.

To estimate the expected discards in the coming year a weighted average is used:

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

where D_i is the discards rate in year i, the discard rate in year i is the ratio of discards to the sum of landed catches plus discards:

$$D_i = \frac{Discard_i}{\left(Catches_i + Discard_i\right)}$$

Plots are given of the total removals illustrating the target catch level. In addition, the standardized catch rates are illustrated with the target catch rate and the limit catch rate.

There are a number of meta-rules that are used when translating the RBCs into TACs. Two that relate to all species are:

- No TAC will change by more than 50% (either increase or decrease)
- Only changes greater than 10% (up or down) will be implemented.

21.3.2 Catches

The discard data for both saw sharks and elephant fish have been included in the most recent SESSF data summaries (Klaer and Upston, 2012) and this has led to some changes in the histories. Fortunately, the changes to the tier4 targets have barely changed as a result so this aspect of the change should have little effect. On the other hand the discard rate for elephant fish appears to have increased dramatically in 2011 from a base level of about 30 t up to about 132 t. This change calls into question the previous discard estimates. There have been no updates of information concerning State or recreational catches and these have been assumed to be equal to the last available estimates. This is unfortunate because there are anecdotal reports that recreational catches of elephant fish has been larger recently. Commonwealth landings were derived from the Quota landings database.

21.3.3 Treatment of Non-Target Species

In 2012, the SESSF RAG determined that the assessments of those species which do not constitute the economic drivers for a fishery might use the proxy for B_{MSY} as the target instead of B_{MEY}. In practice this means that the target is assumed to be a proxy for B_{40} rather than B_{48}. For the Tier 4, this means modifying the control rule used to estimate the RBC by multiplying the original target catch rate by 5/6. If the original target was a proxy for $B_{48\%}$ and B_{MEY}, then 5/6th or 0.83333 of this target would be a proxy for $B_{40\%}$. The graphs illustrate this by a line below the original target. The limit reference point is not altered so as to maintain the same level of low risk to the stock.

The key requirement for non-key commercial species is to avoid allowing the stock to fall below the proxy for B_{LIM} and there does not appear to be anything in the current Harvest Strategy Policy that recommends an alternative target. However, for the Tier 4 (and Tier 3) control rules to operate a specified target reference point is required. Clark (1993) used simulations to demonstrate that fishing at $F_{40\%}$ instead of $F_{35\%}$ didn't change the predicted yield by much but reduced the number of times the stock approached a limit of $B_{20\%}$ (which Clark used as a threshold to indicate overfishing). Setting a target of $B_{40\%}$ was thus considered to be a reasonable solution for setting a different target from $B_{48\%}$ for use in the Tier 4 control rule, see Equ. 1, whilst retaining some robustness to falling below $B_{20\%}$.

21.4 Results

21.4.1 Saw Sharks

Table 21.2. Saw Sharks. Data used in the Tier 4 analysis of saw sharks (full details of the available data are given in the Tables appendix (see Table 21.11). See the methods for a description of how the discards are calculated. The standardized catch rates (CE) are derived from Haddon (2012). The greyed cells reflect the reference period.

Year	Catch	Discards	Total	CE
1986	300.007	31.407	331.414	0.7981
1987	343.811	31.937	375.748	0.7692
1988	279.727	37.755	317.482	0.7489
1989	234.846	26.428	261.274	0.6761
1990	207.187	23.874	231.061	0.6530
1991	246.785	28.213	274.998	0.9637
1992	259.68	31.399	291.079	
1993	340.195	40.162	380.357	
1994	387.141	51.517	438.658	
1995	447.775	47.723	495.498	
1996	378.107	49.728	427.835	
1997	296.93	38.773	335.703	1.0433
1998	278.413	39.659	318.072	1.3982
1999	223.661	34.922	258.583	1.4052
2000	195.973	32.211	228.184	1.2633
2001	264.441	30.699	295.140	1.1532
2002	315.372	30.592	345.964	1.0579
2003	367.676	32.486	400.162	1.1094
2004	376.150	32.981	409.131	1.1856
2005	353.910	31.671	385.581	1.1021
2006	373.515	30.656	404.171	1.2245
2007	269.940	41.977	311.917	0.9862
2008	273.382	42.512	315.894	1.0821
2009	259.743	40.392	300.135	0.9363
2010	245.475	38.173	283.648	0.7200
2011	251.408	39.095	290.503	0.7238

21.4.1.1 Proxy Target 48% Gillnet

Table 21.3. Saw Sharks RBC calculations. C* and $CPUE_{targ}$ relate to the period 2002 – 2008, $CPUE_{Lim}$ is 40% of the target, and $\overline{CPUE}$ is the average catch rate over the last four years. The RBC calculation does not account for predicted discards of predicted State catches. The Wt_discards is the expected weight of discards. Implied proxy target = 48% B_0.

1st Reference Year	2002
2nd Reference Year	2008
C*	367.546
$CPUE_{targ}$	1.107
$CPUE_{Lim}$	0.4427
$\overline{CPUE}$	0.8656
Scaling Factor	0.6367
Wt_Discard	39.250
RBC	**234.010**

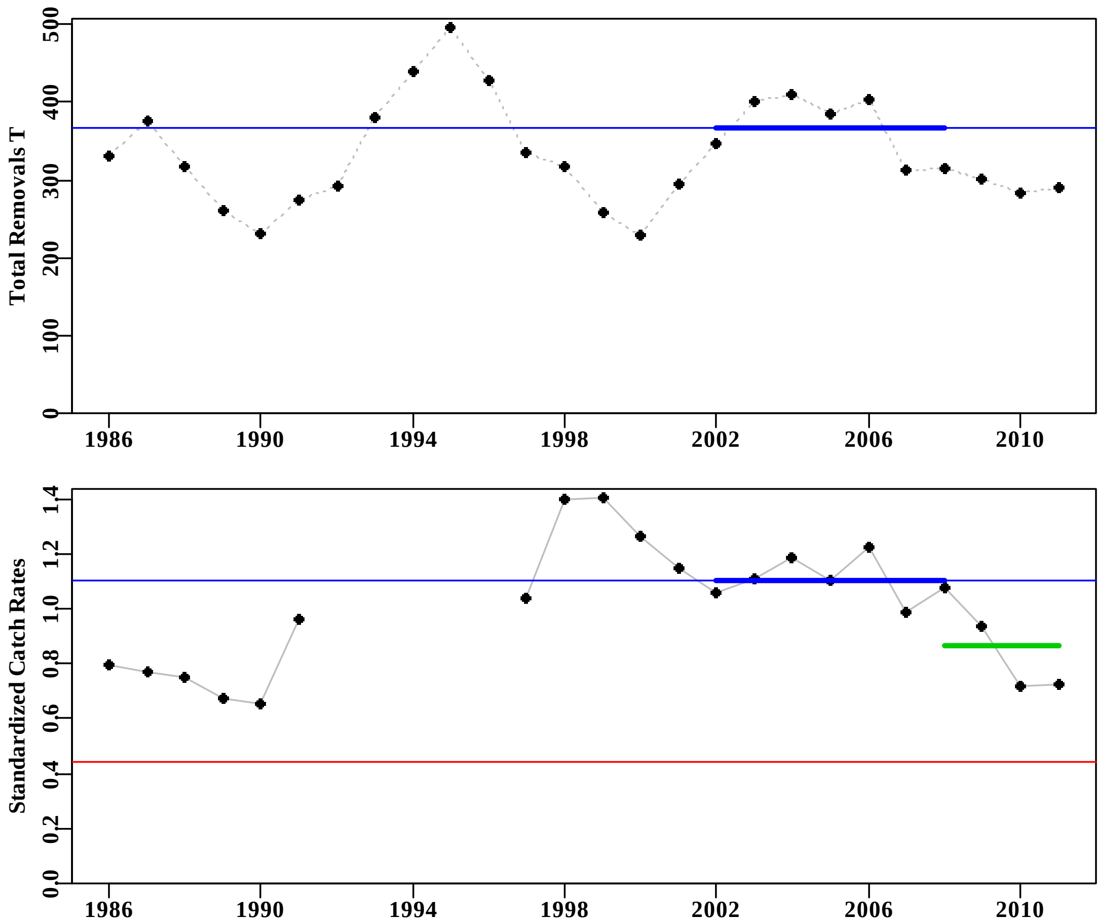

Figure 21.1 Saw Sharks. Top panel is the total removals with the fine line illustrating the target catch. Bottom panel represents the standardized catch rates with the upper fine line representing the target catch rate and the lower line the limit catch rate. Thickened lines represents the reference period for catches, catch rates, and the recent average catch rate.

21.4.1.2 Proxy Target 40% Gillnet

Table 21.4. Saw Sharks RBC calculations. C* and $CPUE_{targ}$ relate to the period 2002 – 2008, $CPUE_{Lim}$ is 40% of the target, and $\overline{CPUE}$ is the average catch rate over the last four years. The RBC calculation does not account for predicted discards of predicted State catches. The Wt_discards is the expected weight of discards. Implied proxy target = 40% B_0.

1st Reference Year	2002
2nd Reference Year	2008
C*	367.546
$CPUE_{targ}$	0.9220
$CPUE_{Lim}$	0.4427
$\overline{CPUE}$	0.8656
Scaling Factor	8816
Wt_Discard	39.250
RBC	**324.016**

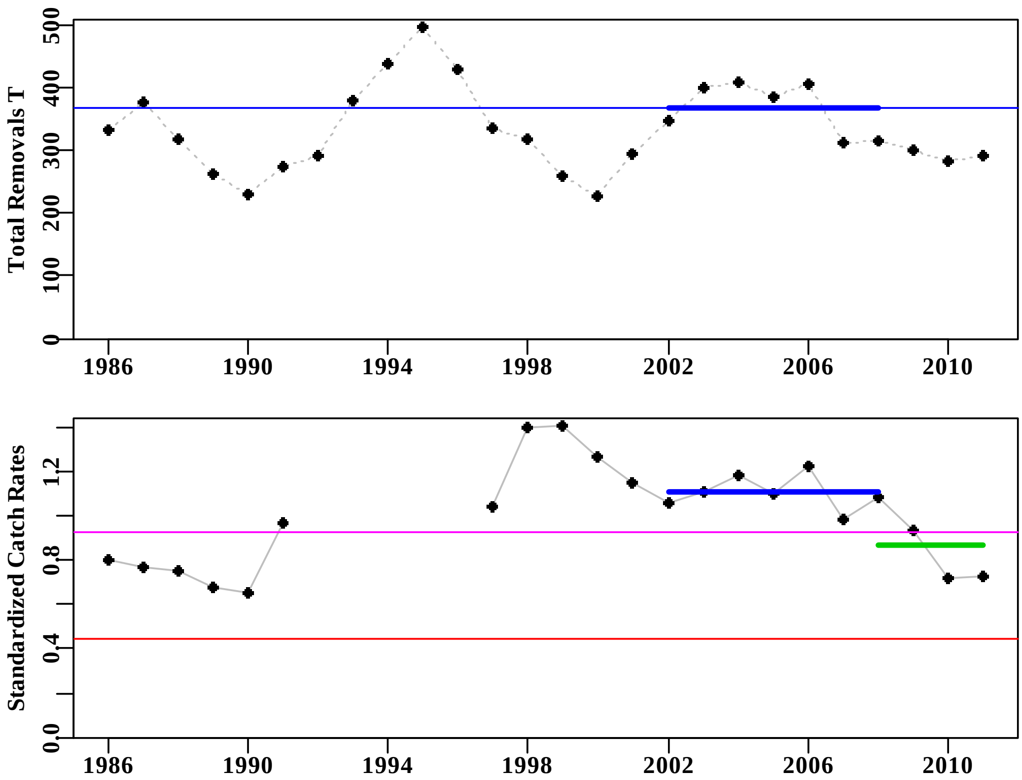

Figure 21.2 Saw Sharks. Top panel is the total removals with the fine line illustrating the target catch. Bottom panel represents the standardized catch rates with the upper fine line representing the target catch rate and the lower line the limit catch rate. Thickened lines represents the reference period for catches, catch rates, and the recent average catch rate. The fine purple line below the target CPUE target is the revised target based on a 40% B_0 proxy target for non-target species in a mixed fishery. The limit reference point (the red line) does not change.

21.4.1.3 Proxy Target 48% Trawl SESSF Zones 20,60,50

Table 21.5. TRAWL: Saw Sharks RBC calculations. C* and $CPUE_{targ}$ relate to the period 2002 – 2008, $CPUE_{Lim}$ is 48% of the target, and $\overline{CPUE}$ is the average catch rate over the last four years. The RBC calculation does not account for predicted discards of predicted State catches. The Wt_discards is the expected weight of discards. Implied proxy target = 48% B_0.

1st Reference Year	2002
2nd Reference Year	2008
C*	367.546
$CPUE_{targ}$	0.794
$CPUE_{Lim}$	0.3177
$\overline{CPUE}$	0.9838
Scaling Factor	1.3974
Wt_Discard	39.250
RBC	**513.612**

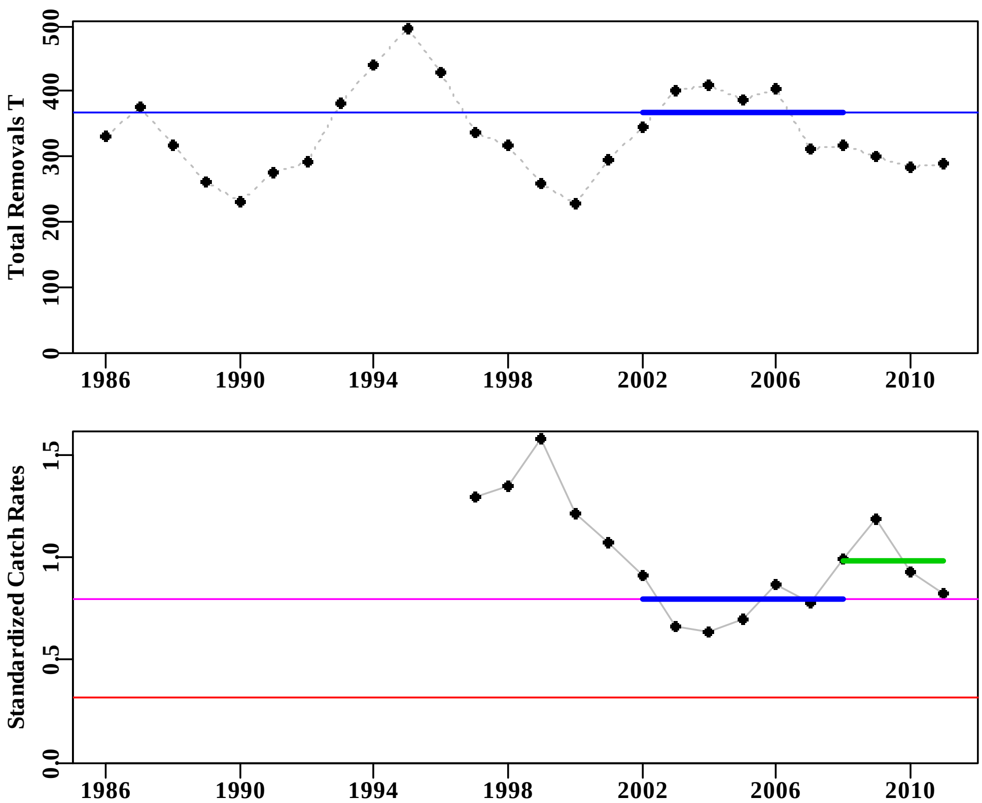

Figure 21.3 Saw Sharks taken by Trawl in Zones 20, 60, and 50. Top panel is the total removals with the fine line illustrating the target catch. Bottom panel represents the standardized catch rates with the upper fine line representing the target catch rate and the lower line the limit catch rate. Thickened lines represents the reference period for catches, catch rates, and the recent average catch rate. The fine purple line below the target CPUE target is the revised target based on a 48% B_0 proxy target for non-target species in a mixed fishery. The limit reference point is represented by the red line.

21.4.1.4 Proxy Target 40% Trawl SESSF Zones 20,60,50

Table 21.6. TRAWL: Saw Sharks RBC calculations. C* and $CPUE_{targ}$ relate to the period 2002 – 2008, $CPUE_{Lim}$ is 40% of the target, and $\overline{CPUE}$ is the average catch rate over the last four years. The RBC calculation does not account for predicted discards of predicted State catches. The Wt_discards is the expected weight of discards. Implied proxy target = 40% B_0.

1st Reference Year	2002
2nd Reference Year	2008
C*	367.546
$CPUE_{targ}$	0.662
$CPUE_{Lim}$	0.3177
$\overline{CPUE}$	0.9838
Scaling Factor	1.9349
Wt_Discard	39.250
RBC	**711.160**

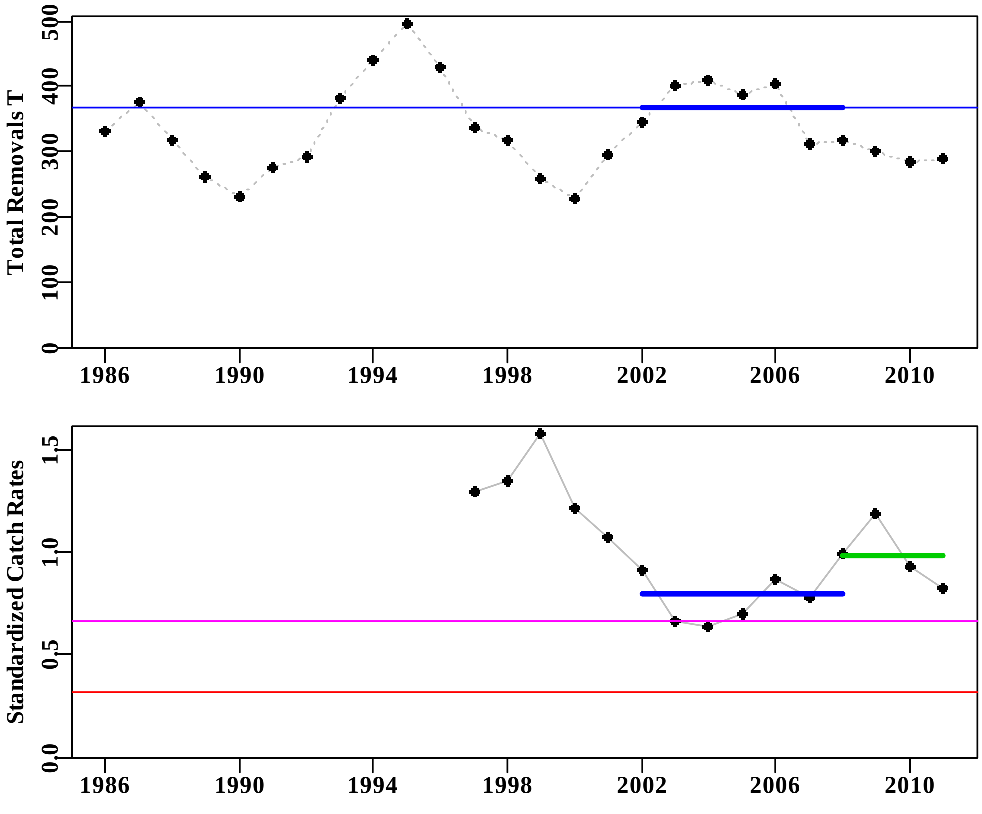

Figure 21.4 Saw Sharks taken by Trawl in Zones 20, 60, and 50. Top panel is the total removals with the fine line illustrating the target catch. Bottom panel represents the standardized catch rates with the upper fine line representing the target catch rate and the lower line the limit catch rate. Thickened lines represents the reference period for catches, catch rates, and the recent average catch rate. The fine purple line below the original target CPUE is the revised target based on a 40% B_0 proxy target for non-target species in a mixed fishery. The limit reference point does not change.

21.4.1.5 Proxy Target 48% Trawl SESSF Zones 20,60,50,83 & 82

Table 21.7**.** TRAWL (20,60,50,83,82): Saw Sharks RBC calculations. C* and $CPUE_{targ}$ relate to the period 2002 – 2008, $CPUE_{Lim}$ is 48% of the target, and $\overline{CPUE}$ is average catch rate over the last four years. The RBC calculation does not account for predicted discards of predicted State catches. The Wt_ discards is the expected weight of discards. Implied proxy target = 48% B_0.

1st Reference Year	2002
2nd Reference Year	2008
C*	367.546
$CPUE_{targ}$	0.852
$CPUE_{Lim}$	0.3408
$\overline{CPUE}$	1.0043
Scaling Factor	1.2978
Wt_Discard	39.250
RBC	**477.009**

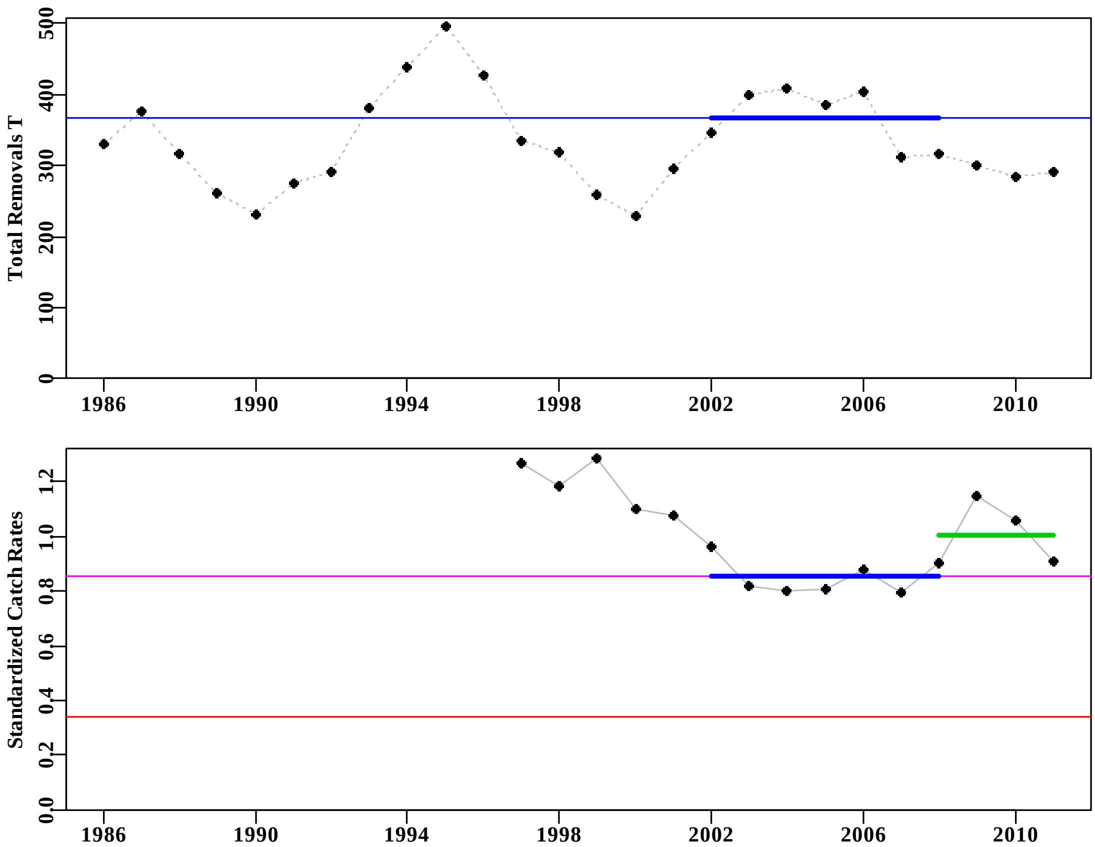

Figure 21.5 Saw Sharks taken by Trawl in Zones 20, 60, 50, 83 and 82. Top panel is the total removals with the fine line illustrating the target catch. Bottom panel represents the standardized catch rates with the upper fine line representing the target catch rate and the lower line the limit catch rate. Thickened lines represents the reference period for catches, catch rates, and the recent average catch rate.

21.4.2 Elephant Fish

Table 21.8. Elephant Fish. Data used in the Tier 4 analysis of saw sharks (full details of the available data are given in the Tables appendix (see Table 21.12). See the methods for a description of how the discards are calculated. The standardized catch rates (CE) are derived from Haddon (2012). The greyed cells relate to the reference period. Catch from 2002 onwards is the reported catches from the CDRs plus 29t of recreational fishing.

Year	Catch	Discards	Total	CE
1986	70.522	6.537	77.059	0.5961
1987	65.209	6.336	71.545	0.5178
1988	79.400	6.710	86.110	0.6909
1989	65.460	6.211	71.671	0.8412
1990	57.729	5.579	63.308	0.9046
1991	74.617	6.920	81.537	1.3399
1992	76.829	7.107	83.936	1.3325
1993	57.060	5.434	62.494	0.6588
1994	64.199	5.950	70.149	0.7727
1995	54.694	5.184	59.878	1.1228
1996	111.796	12.524	124.320	1.1090
1997	94.550	9.573	104.123	0.9266
1998	89.802	8.539	98.341	0.9030
1999	111.624	9.448	121.072	1.0194
2000	95.801	8.189	103.990	1.0827
2001	87.880	7.533	95.413	1.2929
2002	88.744	18.782	107.526	1.0046
2003	105.582	18.500	124.082	0.7764
2004	109.548	0.176	109.724	0.6278
2005	114.461	4.150	118.611	0.7377
2006	104.498	0.306	104.804	0.9117
2007	96.642	18.628	115.270	1.2929
2008	100.291	27.523	127.814	1.6919
2009	114.555	22.190	136.745	1.7726
2010	100.035	22.940	122.975	1.1630
2011	94.227	132.325	226.552	0.9103

21.4.2.1 Proxy Target 48% Gillnet

Table 21.9. Elephant Fish RBC calculations. C* and $CPUE_{targ}$ relate to the period 1996 – 2007, $CPUE_{Lim}$ is 48% of the original target, and $\overline{CPUE}$ is the average catch rate over the last four years. The RBC calculation does not account for predicted discards of predicted State catches. The Wt_discards is the expected weight of discards. Implied proxy target = 48% B_0.

1st Reference Year	1996
2nd Reference Year	2007
C*	109.467
$CPUE_{targ}$	0.974
$CPUE_{Lim}$	0.3895
$\overline{CPUE}$	1.3845
Scaling Factor	1.703
Wt_Discard	81.484
RBC	**186.428**

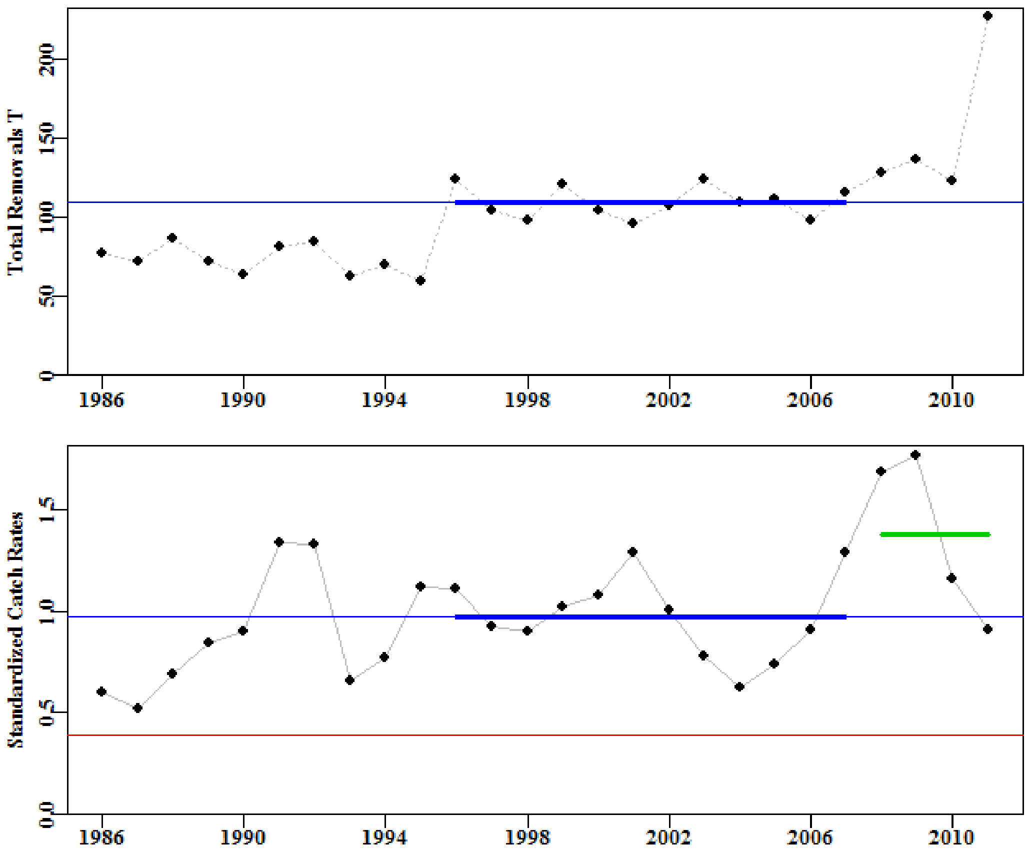

Figure 21.6 Elephant Fish. Top panel is the total removals with the fine line illustrating the target catch. Bottom panel represents the standardized catch rates with the upper fine line representing the target catch rate and the lower line the limit catch rate. Thickened lines represents the reference period for catches, catch rates (1996 – 2007), and the recent average catch rate (last four years).

21.4.2.2 Proxy Target 40% Gillnet

Table 21.10. Elephant Fish RBC calculations. C* and $CPUE_{targ}$ relate to the period 1996 – 2007, $CPUE_{Lim}$ is 40% of the target, and $\overline{CPUE}$ is the average catch rate over the last four years. The RBC calculation does not account for predicted discards of predicted State catches. The Wt_discards is the expected weight of discards. Implied proxy target = 40% B_0.

1st Reference Year	1996
2nd Reference Year	2007
C*	109.467
$CPUE_{targ}$	0.811
$CPUE_{Lim}$	0.3895
$\overline{CPUE}$	1.3845
Scaling Factor	2.3581
Wt_Discard	81.484
RBC	**258.132**

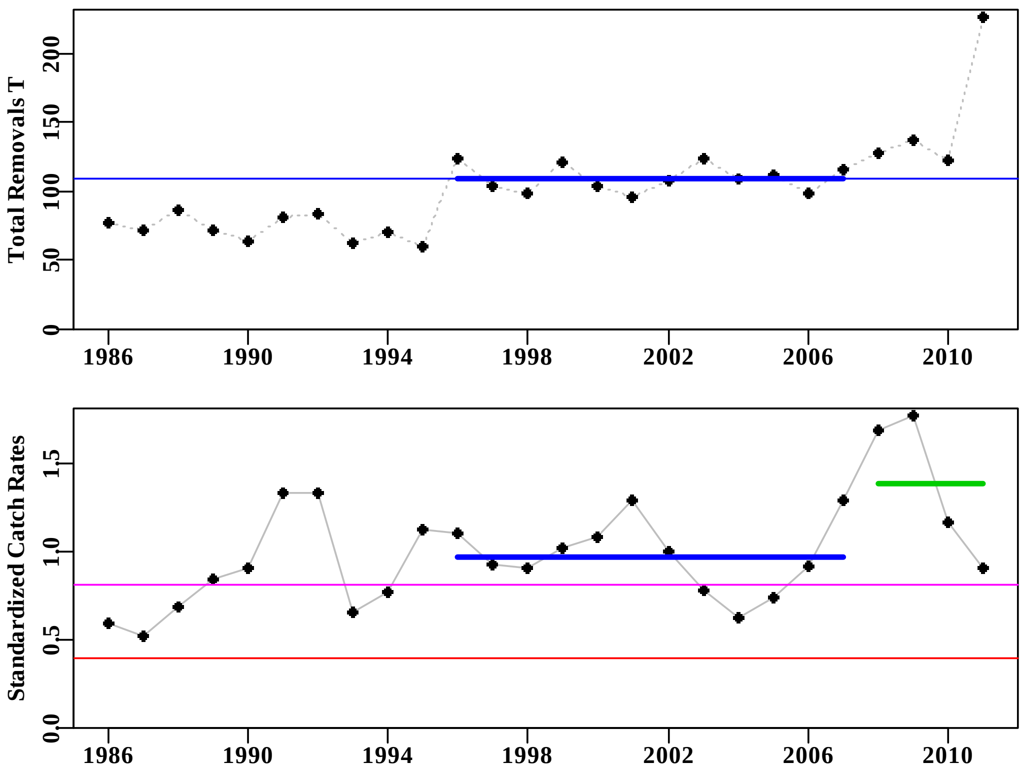

Figure 21.7 Elephant Fish. Top panel is the total removals with the fine line illustrating the target catch. Bottom panel represents the standardized catch rates with the upper fine line representing the target catch rate and the lower line the limit catch rate. Thickened lines represents the reference period for catches, catch rates, and the recent average catch rate (1996 – 2007). The fine purple line below the target CPUE target is the revised target based on a 40% B_0 proxy target for non-target species in a mixed fishery. The limit reference point does not change.

21.5 Discussion

The Recommended Biological Catches recommended by the original TIER 4 analyses recommend a slight drop for saw sharks and a slight increase for elephant fish. The RBCs usually have the State and recreational catches, and the discards removed as well as a 15% discount factor applied to estimate the Total Allowable Catch.

In the case of Saw sharks the reference years overlap the last four years used to generate an estimate of the recent catches, which will tend to keep the reference estimates and the current rate estimates similar. Fortunately, this now only includes 2008 in both series and any effects of this will decline as the years advance but it does mean there is an element of uncertainty about these estimates that doesn't normally enter into the calculations. This year, this problem no longer applies to elephant fish.

The capture of Elephant fish by recreational fishers is not insignificant but the estimates of catch are uncertain. In the analysis these have been held constant at 29 t since 1996. Braccini *et al* (2009) derive an estimated catch of Elephant fish of 13.931 t in 2008 inside Western Port (of which they estimated 70% were females). If this were included rather than the default 29t it would not influence the Tier 4 calculation of the RBC but it might influence the removals taken from the RBC to form the TAC, although that would depend on whether such an adjustment to the total catches were made across the reference period as well as more recently. However, this may not represent all recreational catches of Elephant fish around Victoria and so the analysis retained the default value for recreational catches. Clearly a new estimate of total recreational catch would have value. It does suggest that the catch rate dynamics are likely being influenced by larger catches than believed, which in terms of the commercial fishery implies that the resulting RBC will be relatively conservative, as long as recreational catches are now stable, which is unknown.

As expected the use of a proxy CPUE target for $B_{40\%}$ led to increases in the RBC in all cases. This is simply because the ratio of the target to the current average is bound to increase as long as the average is above the limit.

Not as expected, the standardized catch rates for trawl caught saw sharks behave differently to those from the gill net fishery, so much so that the analysis of trawl caught catch rates recommends an increase in the RBC (Table 20.1). Catches of saw sharks by trawl are now almost as high as those taken by gill net so this finding illustrates the uncertainty in this analysis, which provides some evidence that there may be an element of avoidance by gill net fishers. This avoidance would, in turn, lead to a reduction in gill net catch rates.

21.6 Tables

Table 21.11. Saw Sharks. Total catches and discards by fishery and Standardized catch rates, ready for the TIER 4 analysis (only the total catches and Standardized catch rates are used). Columns starting with Disc relate to discards. Only the Catch T and Std CE columns are used in the Tier 4 analysis, the first four columns derive from log-book data and under-estimate the landings and leave out the discards.

Year	GHAT	SET	GAB	State	Discard	Catch T	Std CE
1976	248.65					263.569	
1977	230.377					244.200	
1978	269.2					285.352	
1979	236.76					250.966	
1980	227.969					241.647	1.6438
1981	193.592					205.208	1.0880
1982	244.047					258.690	0.9073
1983	234.673					248.753	1.0027
1984	230.465					244.293	1.0074
1985	262.913	4.11			3.075	285.873	1.0121
1986	280.529	19.478			14.575	331.414	0.7729
1987	327.365	16.431	0.015		12.295	375.748	0.7450
1988	248.708	30.514	0.505		22.833	317.482	0.7253
1989	212.59	18.608	3.983		13.673	261.274	0.6548
1990	180.123	17.598	9.601		13.067	231.061	0.6325
1991	211.606	23.931	14.442		15.517	274.998	0.9334
1992	209.242	25.541	25.265		18.844	291.079	
1993	289.205	31.782	20.506		22.810	380.357	
1994	327.406	43.078	17.149		31.873	438.658	
1995	390.983	32.762	24.375		24.264	495.498	
1996	310.827	37.963	29.537		31.078	427.835	
1997	158.440	36.176	27.611	17.528	24.773	335.703	1.0105
1998	249.497	29.418	25.726	10.444	25.010	318.072	1.3542
1999	242.185	35.155	23.123	14.33	22.156	258.583	1.3609
2000	274.919	53.421	23.645	15.24	20.150	228.184	1.2236
2001	262.689	41.698	33.684	8.387	20.150	295.140	1.1168
2002	158.250	75.473	20.355	17.106	20.150	345.964	1.0245
2003	190.996	78.034	47.541	26.31	20.150	400.162	1.0745
2004	193.424	87.501	33.488	28.953	20.150	409.131	1.1482
2005	172.616	85.607	38.071	33.949	20.150	385.581	1.0674
2006	158.713	112.938	45.982	36.352	20.150	404.171	1.1859
2007	107.878	77.417	28.719	34.602	41.977	311.917	0.9551
2008	115.421	75.926	19.648	24.718	42.512	315.894	1.0480
2009	89.441	79.631	22.344	33.357	40.392	300.135	0.9068
2010	92.732	67.389	32.260	32.371	38.173	283.648	0.6973
2011	102.973	72.867	17.637	22.527	39.095	290.503	0.7010

Table 21.12. Elephant Fish. Total catches and discards by fishery and Standardized catch rates, ready for the TIER 4 analysis (only the total catches and Standardized catch rates are used). Columns starting with Disc relate to discards. Recr is the recreational catch.

Year	GHAT	SET	GAB	State	Recr	DiscSSF	DiscS_G	CatchT	Std CE
1976	42.188					4.219		46.407	
1977	68.334					6.833		75.167	
1978	65.575					6.558		72.133	
1979	100.581					10.058		110.639	
1980	82.283					8.228		90.511	1.2954
1981	82.065					8.207		90.272	1.4169
1982	58.663					5.866		64.529	1.1052
1983	80.478					8.048		88.526	1.1028
1984	78.195					7.82		86.015	0.7679
1985	108.987	0.911				10.899		120.797	0.7279
1986	65.368	5.154				6.537		77.059	0.5961
1987	63.363	1.846				6.336		71.545	0.5178
1988	67.1	12.2	0.1			6.71		86.11	0.6909
1989	62.109	3.207	0.144			6.211		71.671	0.8412
1990	55.792	1.892	0.045			5.579		63.308	0.9046
1991	69.2	5.385	0.032			6.92		81.537	1.3399
1992	71.071	5.698	0.06			7.107		83.936	1.3325
1993	54.335	2.725	0			5.434		62.494	0.6588
1994	59.502	3.987	0.71			5.95		70.149	0.7727
1995	51.836	2.819	0.039			5.184		59.878	1.1228
1996	77.111	5.41	0.275		29	7.711	4.813	124.32	1.1090
1997	59.857	5.598	0.095		29	5.986	3.587	104.123	0.9266
1998	52.832	7.9	0.07		29	5.283	3.256	98.341	0.9030
1999	59.199	7.46	0.965	0.384	29	5.92	3.528	121.072	1.0194
2000	53.888	8.913	0	0.699	29	5.389	2.8	103.99	1.0827
2001	47.33	8.444	0.106	0.420	29	4.733	2.8	95.413	1.2929
2002	24.659	17.888	0.191	0.472	29	2.466	2.8	107.526	1.0046
2003	42.763	20.4088	2.032	0.439	29	4.879	2.8	124.082	0.7764
2004	29.088	27.2915	1.619	0.731	29	3.523	2.8	109.724	0.6278
2005	34.853	27.2535	1.878	0.663	29	4.052	2.8	118.611	0.7377
2006	36.061	17.865	1.426	3.933	29	4.014	2.8	104.804	0.9117
2007	36.206	14.093	1.701	11.954	29	21.845	2.8	115.270	1.2929
2008	40.471	19.297	0.834	2.092	29	23.023	2.8	127.814	1.6919
2009	44.136	20.2703	0.520	3.848	29	27.630	2.8	136.745	1.7726
2010	34.754	20.7817	0.310	3.553	29	22.941	2.8	122.975	1.1630
2011	33.906	15.7776	0.285	7.150	29	132.395	2.8	226.552	0.9103

21.7 Acknowledgements

Thanks are due to Mike Fuller and Neil Klaer of CSIRO Hobart, for their preliminary processing of the landings data as received from the Australian Fisheries management Authority. Dr Robin Thomson provided the copy of CANDE10.txt used for the original catch rate analysis.

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22. Projecting the School Shark Model into the Future: Rebuilding Timeframes and Auto-Longlining in South Australia[1]

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22.1 Summary

The current version of the school shark model predicts that catches of up to 250t allow recovery of the stock, but 275t will not.

Rebuilding to the limit reference point (B_{20}) cannot be achieved in a generation time plus time 10 years (32 years) given current levels of catch (176t). Rebuilding in three generation times (66 years) can be achieved with future catches of up to 225t. If the limit reference point is moved from B_{20} to half B_{MSY} (i.e. B_{25}), then rebuilding within 32 years would require catches of close to zero; future catches would need to be of the order of 200t in order to achieve rebuilding in 66 years.

Recovery times are only slightly lengthened by higher levels of auto-line fishing in South Australia (SA), however, this lowers B_{MSY} so the impact of an auto-line fishery would be felt when the school shark stock has recovered to levels where the overall catch can be increased to levels closer to B_{MSY}. If the auto-line fishery in SA is allowed to take a substantial portion of the catches in that state, the overall maximum sustainable catch for school shark will be lower than it would be if the auto-line fishery remained small relative to the gillnet fishery.

The results shown here are valid for a fishery whose seasonality and regional distribution are similar to that of the 2011 school shark fishery. Substantial (or perhaps even subtle) deviations from this pattern could alter these findings by altering the size and sex composition of the commercial school shark catch.

22.2 Background

The School Shark Recovery Plan (DEWHA, 2008) states that school shark recovery to a limit and a target reference point should occur within a biologically reasonable timeframe, and suggests that one generation time plus 10 years is such a timeframe. The Commonwealth Fisheries Harvest Strategy Policy (HSP) (DAFF 2007) also gives 3 generation times as a possible time frame to use for recovery. This policy states that the target reference point should be B_{MSY} and the limit reference point should be half B_{MSY}. If B_{MSY} is unknown, B_{40} is used as a proxy, along with B_{20} for the limit. At the time of writing of the School Shark Recovery Plan, B_{MSY} for school shark had not been calculated so B_{40} was recommended. However, B_{MSY} has since been calculated to be

[1] Paper presented to Shark RAG November 2012

approximately 50% of pristine (Thomson and Punt, 2009), giving B_{50} as a target and B_{25} as a limit reference point.

The current rebuilding timeframe of one generation time plus 10 years is 32 years (Thomson and Punt, 2009). The ability of the stock to recover in this timeframe is explored here.

Management of the southern shark fishery has included restriction to fishing with smaller gillnet mesh sizes in order to protect large, more fecund, females. Figure 22.1 shows the impact on a pristine school shark stock of fishing heavily (taking 900t p.a. until 2011) with just one gear type. Line gear, and large mesh sizes, deplete the stock more rapidly and to lower levels than smaller mesh sizes. For this reason the planned introduction of an auto-line fishery for sharks in South Australia in response to exclusion of mesh gear from certain areas (to protect Australian sea lions and dolphins) needs to be carefully considered.

This paper explores recovery times for the school shark stock given a range of future fishing scenarios, both in terms of catch and gear composition.

22.3 Methods

The 2006 stock assessment update (Punt et al 2006) used an MSYR value of 3.5%, which is essentially a measure of the productivity of the stock. Unlike previous school shark stock assessments, this parameter was fixed at 3.5% instead of being estimated by the model. The reason for this may have been that the estimated value was 3.5% and that fixing the parameter at its estimated value would have greatly speeded subsequent calculations. The MSYR parameter has remained fixed at a value of 3.5% in all subsequent calculations with the school shark model, possibly leading to lower perceived productivity than might otherwise have been the case. The parameter has been freed in the calculations shown in this paper, resulting in an estimated value of 4.4%.

The most recent school shark assessment update used data to 2008 (Thomson and Punt, 2009). Catches taken between 2009 and 2011 were extracted from the GENLOG database (see a summary in Table 22.1). Catches were entered into the model by year, gear, month and shark region. The database contained only partial information for 2012 so the catches for 2011 were used again to represent those for 2012.

The *2009 base case* model was used, except that the small SAV region which spans the South Australian – Victorian border which has traditionally been used in school shark stock assessments, but was excluded from the 2009 Base Case, was include here. The 2009 base case model dissolved that region into the two adjacent regions, but as this is not possible to do for all data sources, and has created technical problems, that change has not been made here. The MSYR parameter was freely estimated. This model:

- uses ISMP data for West only (not WSA, not East) (see Thomson and Punt 2009 for explanation)
- uses commercial gillnet CPUE to 1996
- uses commercial gillnet CPUE for WBAS

- uses survey CPUE data
- uses recent CPUE series (1998-2008) separate to the CPUE up to 1996

22.3.1 Future auto longline fishery for South Australia

We assume that future catches are split among months, regions and gears in the same proportions seen in recent catches – with one exception: that a proportion of the catch currently taken by the gillnet fishery *in South Australia* (shark regions 1 WSA, 2 CSA and 3 SAV) is taken by a new auto-line fishery. This fishery has a knife-edged size at first selectivity of 536mm (the smallest school shark caught in a recent auto-line survey, Figure 22.2). In the past a size threshold of approximately 630mm for males and 640mm for females (calculated from an age-based threshold of 2 years) has been assumed for a combined line and trawl fishery/fleet.

We consider a recovery scenario in which all future catches are 150t, or 200t or 250t p.a., for a range of future gear configurations. Alternatively, to mimic the harvest strategy, we fixed catches at 200t or 250t p.a. for 50 years and after that allowed catches to increase by 2t p.a.

22.4 Results and conclusions

22.4.1 Rebuilding times for status quo fishing

Catches of up to 250t allow recovery of the school shark stock, but 275t is not sustainable (Figure 22.3, Table 22.2a).

Rebuilding to the limit reference point (B_{20}) cannot be achieved in a generation time plus time 10 years (32 years) given current levels of catch (150t). Rebuilding in three generation times (66 years) can be achieved with future catches of up to 225t. If the limit reference point is moved from B_{20} to half B_{MSY} (i.e. B_{25}), then rebuilding within 32 years would require catches of close to zero; future catches would need to be of the order of 200t in order to achieve rebuilding in 66 years.

22.4.2 Split of future catches

Note that the future projections used here assume that the split of the catch between months, and regions is the same as that observed during 2011. If the split observed during 2008 is maintained instead (as was done for projections previously show to the sharkRAG), somewhat more pessimistic results are obtained (Table 22.2). This is due to interannual differences in the seasonality and spatial distribution of catches, highlighting that the results shown here pertain only to a fishery similar to that operating in 2011. Any substantial shifts in the timing or location of the bulk of the catches would require another investigation into the sustainability, and rebuilding timeframe of the new catch regime.

22.4.3 Future auto longline fishery for South Australia

For interest sake, we present the model prediction of the status of the future school shark population if the whole fishery moved to auto-line gear, as compared with using only 6 inch or 6.5 inch mesh gillnets in future.

As the size of any future auto-line fishery is unknown, we consider 3 possible futures ranging from no future auto-line fishery (0%) to 100% auto-line fishing (in South Australia alone).

Compared with 6 inch gillnets, auto-line fishing takes both younger fish and the larger, more fecund females (Figure 22.2). It therefore impacts the stock more heavily than does fishing with 6 or 6.5 inch gillnets (Figure 22.1).

However, if catches remain at the present level (150t p.a.) the impact on the stock of an auto-line fishery in South Australia is forecast to be negligible (Figure 22.4, Table 22.3). However, more realistic scenarios in which larger catches are taken, particularly in the future, reveal that a large line fishery in South Australia would reduce the overall sustainable catch for the stock (Figure 22.5). This is because B_{MSY} is lower for a line only fishery than for a 6.5 inch mesh, only, fishery.

Recovery times are only slightly lengthened by higher levels of auto-line fishing in South Australia (SA) (Table 22.3), however, this lowers B_{MSY} so the impact of an auto-line fishery would be felt when the school shark stock has recovered to levels where the overall catch can be increased to levels closer to B_{MSY}. If the auto-line fishery in SA is allowed to take a substantial portion of the catches in that state, the overall maximum sustainable catch for the school shark fishery will be lower than it would be if the auto-line fishery remained small relative to the gillnet fishery.

22.5 References

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22.6 Figures

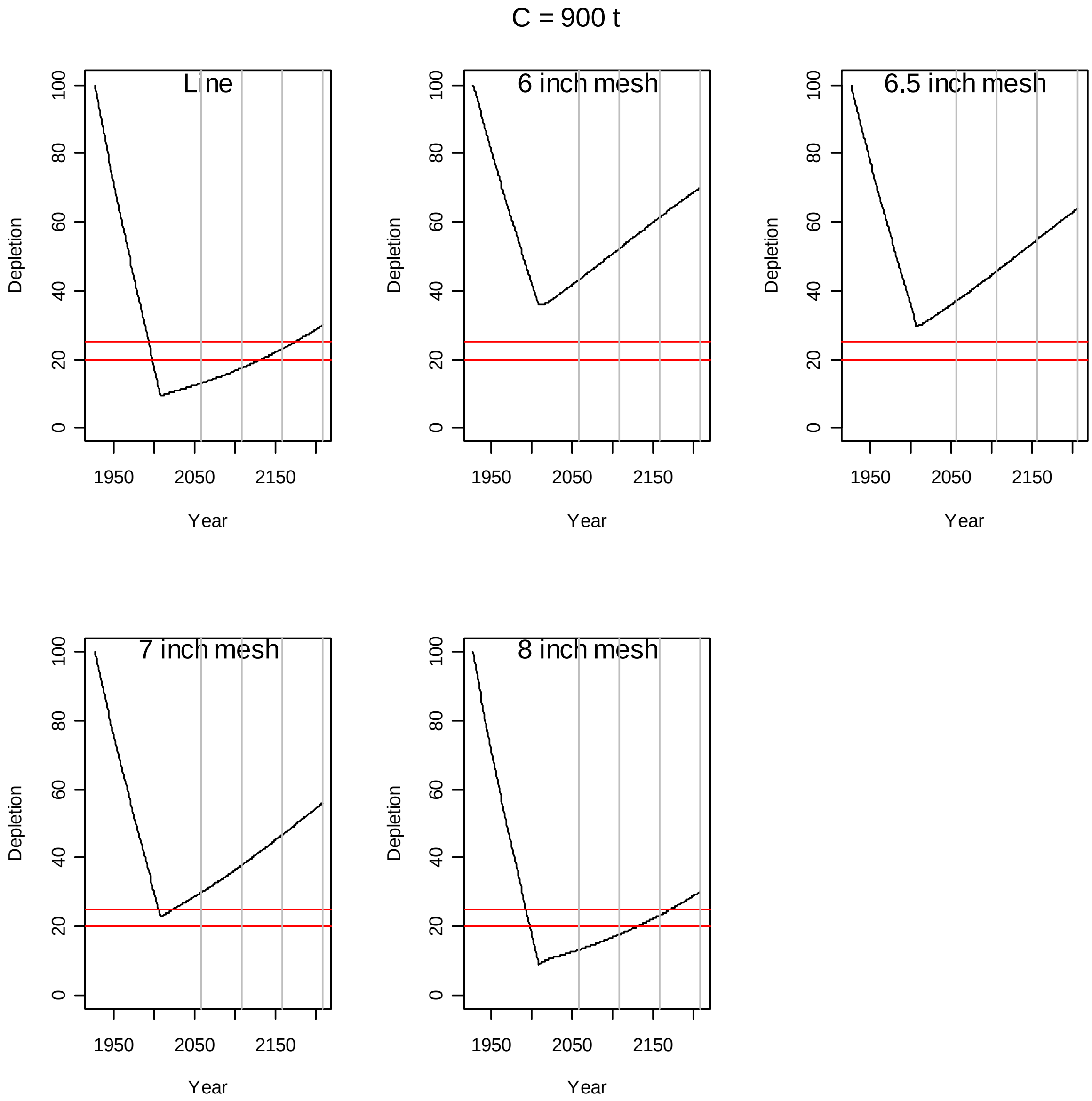

Figure 22.1. Using a greatly simplified version of the school shark Tier 1 model, catches of 900t p.a. were taken every year from 1927 to 2011 after which all fishing stopped. All of the catch was taking using a single gear type.

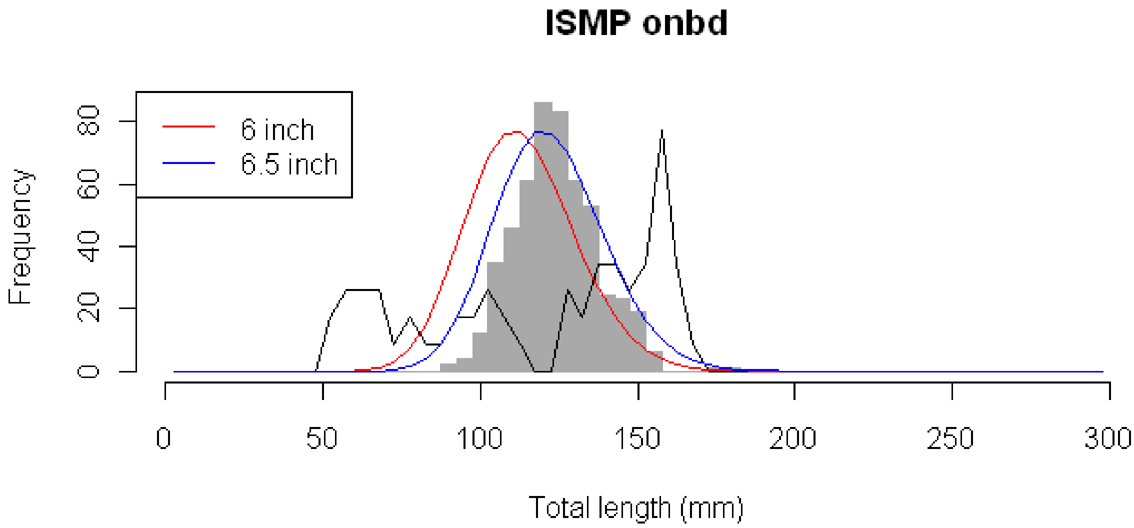

Figure 22.2. Length frequencies (grey bars) for commercially (gillnet) caught school shark in South Australia during summer, measured onboard by the ISMP Observer Program. The length frequency for the school shark caught during the summer auto-line survey in South Australia is shown (black line). The gear selectivity for 6 inch (red) and 6.5 inch (blue) mesh gillnets are shown.

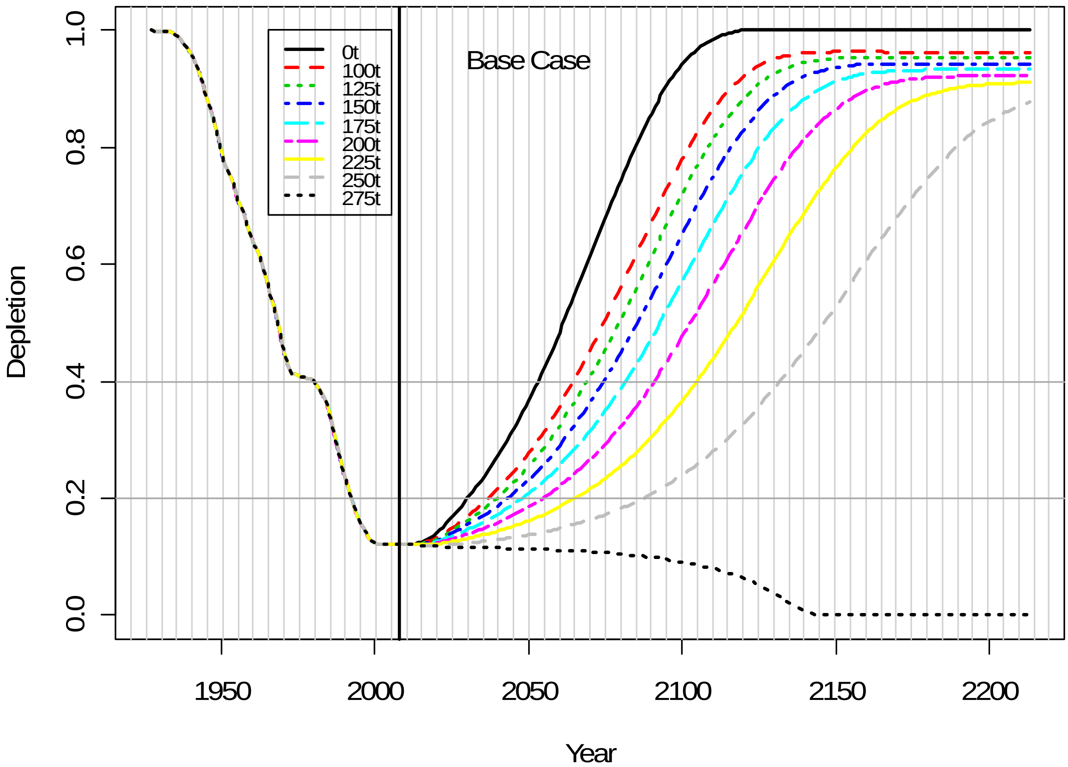

Figure 22.3. Projected future depletion (pup production divided by pristine pup production) for the school shark stock for the Tier 1 2009 base case assessment model. Projections are shown for 9 future catch scenarios. Catches between 2008 (marked by a vertical line) and 2011 are the actual catches taken by the fishery.

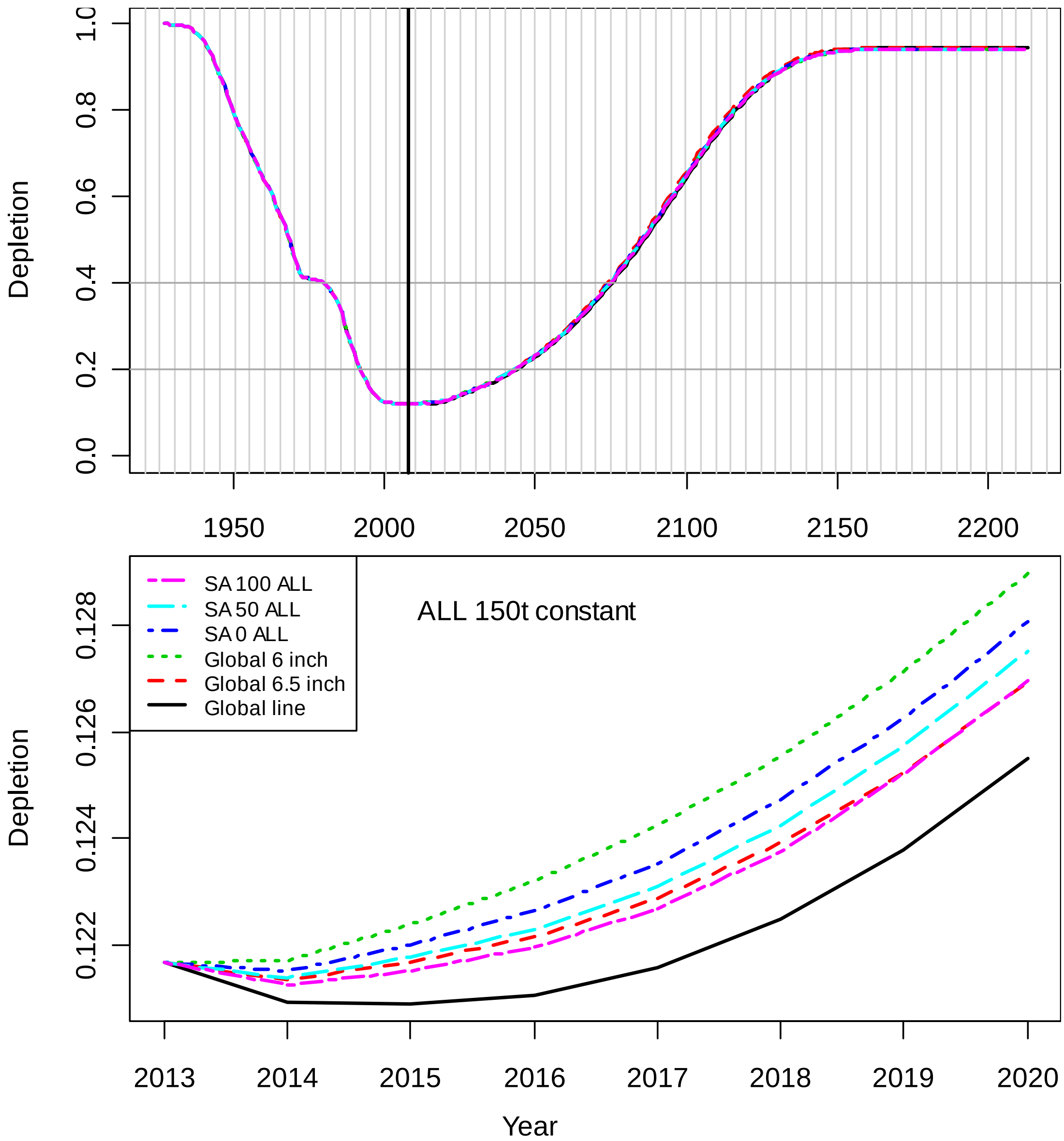

Figure 22.4. Projected future depletion (pup production divided by pristine pup production) for the school shark stock for the Tier 1 2009 base case assessment model. Projections are shown for various future catch combinations. The lower plot shows results for just the years 2013 to 2020, in more detail.

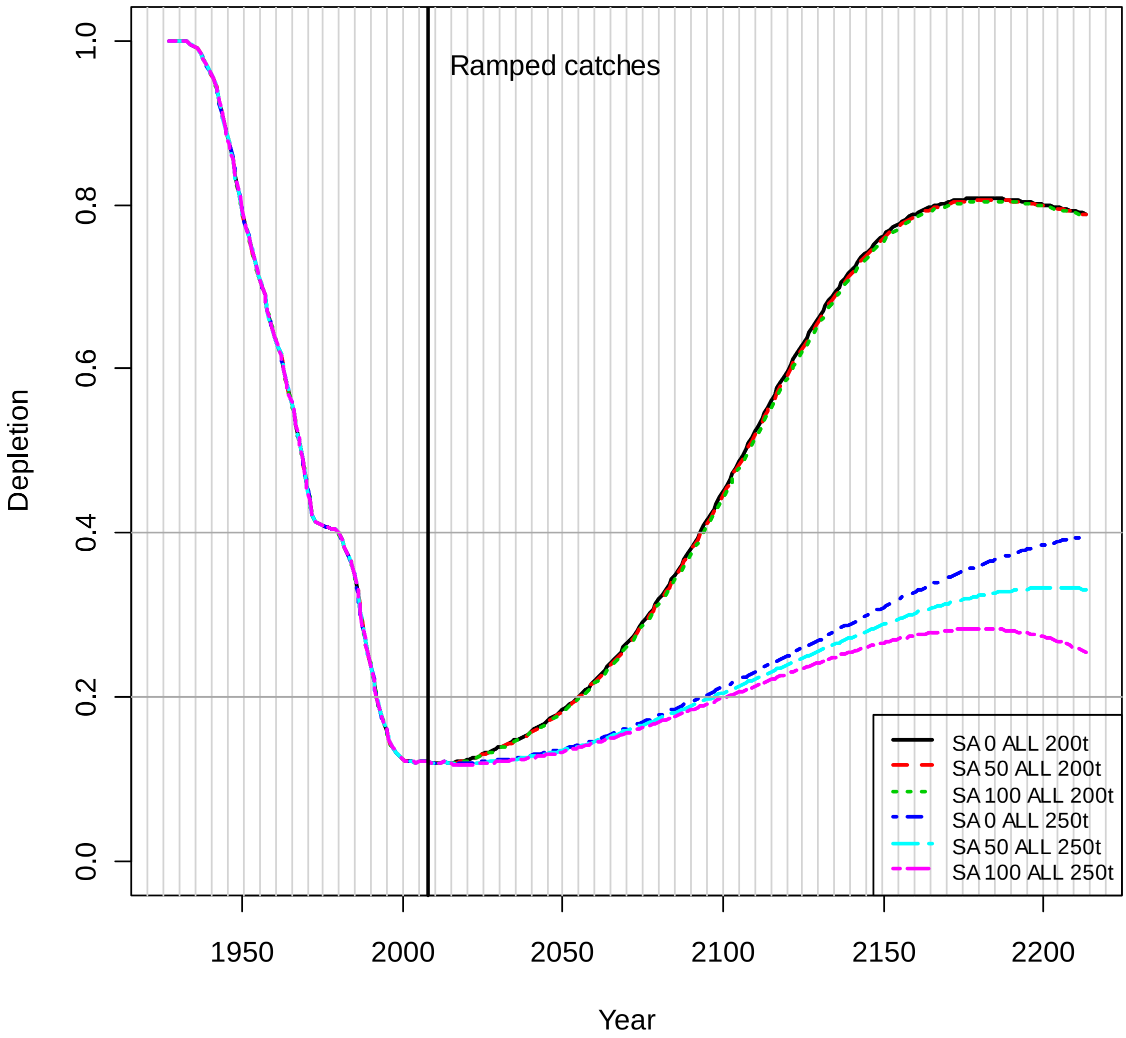

Figure 22.5. Projected future depletion (pup production divided by pristine pup production) for the school shark stock for the Tier 1 2009 base case assessment model. Projections are shown for future catch scenarios in which 200t p.a. (*ALL 200t*) or 250t (*ALL 250t*) are taken for 50 years from 2013 after which catches are increased by 2t p.a. results are shown for scenarios in which an auto-line fleet in South Australia takes 0%, 50% or 100% of the catches previously taken by gillnet in that state.

22.7 Tables

Table 22.1. Catches of school shark between 2009 and 2011 by gear (taken from GENLOG database). Catches for 2012 are assumed to be the same as those for 2011.

Year	Line and Trawl	6 inch	6.5 inch	Total
2009	19.1	140.6	85.6	245.4
2010	23.0	108.2	38.8	169.9
2011	7.8*	113.8	32.7	154.3

* this figure appears to be missing the trawl component of the catch, but this does not noticeably affect the conclusions of this paper.

Table 22.2. Number of years after 2008 when the school shark stock is predicted to achieve limit (B_{20}, B_{25}) or target reference points (B_{40}, B_{50}) under future catches ranging between 0 and 275t. Future projections assume either that catches are distributed according to 2011 proportions, or 2008 proportions. A generation time plus 10 years is 32 years.

	0t	100t	125t	150t	175t	200t	225t	250t	275t
2009 Base Case – 2011 proportions									
B_{20}	23	30	32	36	40	47	58	80	-
B_{25}	30	38	42	46	51	59	71	95	-
B_{40}	45	57	62	67	74	83	97	124	-
B_{50}	50	62	67	73	80	89	104	132	-
2009 Base Case – 2008 proportions									
B_{20}	23	30	33	37	42	50	64	99	-
B_{25}	30	39	42	47	53	63	78	117	-
B_{40}	45	58	63	69	76	87	105	150	-
B_{50}	50	63	68	74	82	93	111	159	-

Table 22.3. Number of years after 2008 when the school shark stock is predicted to achieve limit (B_{20}, B_{25}) or target reference points (B_{40}, B_{50}) under different future gear combinations, taking a constant catch over all future years. Three scenarios in which a single gear is used across all regions are included for interest sake only. Three projections in which a proportion (0, 50 or 100%) of the gillnet catch in South Australia is transferred to a new auto-line fishery are shown (note that the 0% column resembles the 175t and matches the 200t or 250t columns in Table 2). A generation time plus 10 years is 32 years.

	Global line	Global 6.5inch	Global 6 inch	0% ALL	50% ALL	100% ALL
150t p.a.						
B_{20}	42	40	41	41	41	41
B_{25}	53	51	52	52	52	52
B_{40}	75	73	75	74	75	75
B_{50}	81	79	81	80	80	81
200t p.a.						
B_{20}	49	46	47	47	47	48
B_{25}	61	58	60	59	60	60
B_{40}	85	82	84	83	84	84
B_{50}	91	88	90	89	90	90
250t p.a.						
B_{20}	87	75	83	80	82	83
B_{25}	103	90	99	95	97	99
B_{40}	130	117	129	124	126	128
B_{50}	137	124	137	132	134	136

23. Incidental bycatch ratios of school shark (*Galeorhinus galeus*) to gummy shark (*Mustelus antarcticus*) off South Australia when using automatic longlines compared with gillnets

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23.1 Summary

This chapter compares relative incidental bycatch ratios of school shark (*Galeorhinus galeus*) and gummy shark (*Mustelus antarcticus*) off South Australia using automatic longlines and gillnets. Data on catches of school and gummy sharks collected during scientific fishing trials using automatic longlines across South Australia were compared with reported catches using gillnets during the same period and broad area from the Commonwealth logbook database. We used a variety of methods for averaging and calculating the ratio of school shark to gummy shark, including or excluding zero catches and discards. Overall, these results provide strong evidence in favour of the conclusion that the bycatch of school shark is not greater when using automatic longlines as compared with gillnets. However, sample sizes from the automatic longline trials are relatively small, seasonal coverage is lacking (being confined to just summer months) and deliberate avoidance of school shark during the trial may have been greater than that practiced by gillnet fishers not participating in the trial. Consequently, we recommend proceeding with great caution should fishing using automatic longlines in South Australia commence. The ratio of unavoidable bycatch of school shark to gummy shark based on ordinary fishing operations (i.e. non-trials) should also be closely monitored.

23.2 Introduction

The gummy shark (*Mustelus antarcticus*) comprises the main species targeted using demersal gillnets in the Southern and Eastern Scalefish and Shark Fishery (SESSF). School shark (*Galeorhinus galeus*), common sawshark (*Pristiophorus cirratus*), southern sawshark (*Pristiophorus nudipinnis*) and elephant fish (*Callorhinchidae* and *Rhinochimaeridae*) are considered by-product species (Klaer *et al*. 2012; Woodhams and Vieira, 2012).

Concerns regarding incidental bycatch of TEP species (i.e. Australian sea lion) by gillnets, resulted in area closures in waters off South Australia (SA). This has prompted calls to allow the use of automatic longline gear in SA waters shallower than 183 m. There is, however, a concern that such a shift in gear type could result in high levels of unavoidable bycatch of school shark, which is classified as conservation-dependent under the EPBC Act, and is currently undergoing a rebuilding strategy (Woodhams *et al*. 2012). To address these concerns, trials using automatic longlines targeting gummy shark were conducted between November 2011 and January 2012 in SESSF waters off SA to determine the potential impact if fishers who currently employ demersal gillnets to target gummy shark shift to automatic longline gear (Knuckey *et al*. 2012).

This chapter compares incidental bycatch ratios of school shark to gummy shark when using automatic longlines compared to gillnets in three management zones in waters off SA.

23.3 Methods

Trials and Commonwealth logbook data

Catch data, including retained and/or discarded catches, arising from four automatic longline trials targeting gummy shark in SESSF waters off SA between November 2011 and January 2012 (Knuckey *et al*. 2012) were used to estimate incidental bycatch ratios of school shark to gummy shark (SS-GS). These SS-GS ratios were also estimated using gillnet catch data extracted from the Commonwealth logbook database (GENLOG) corresponding to the same period. Relative ratios were then calculated as the quotient of these two ratios.

Two estimation methods were examined. The “Ratio [mean]” method estimates the ratio of the average school shark catch across all sets to that of gummy shark. By contrast, the “Mean[ratio]” method calculates the ratio of school shark to gummy shark in each set and then estimates the average across all sets. The latter tends to over-estimate the true ratio (Ye, 2002).

Relative SS-GS ratios were estimated for three management zones in waters off SA: western (WSA), central (CSA) and eastern SA (ESA) (Figure 23.1). Separate ratios were estimated using (i) retained catches and (ii) retained and discarded catches as well as including or excluding zero catches (Table 23.1). Variance estimates were not calculated since (i) the trials data contained small sample sizes and (ii) estimation methods were available to us.

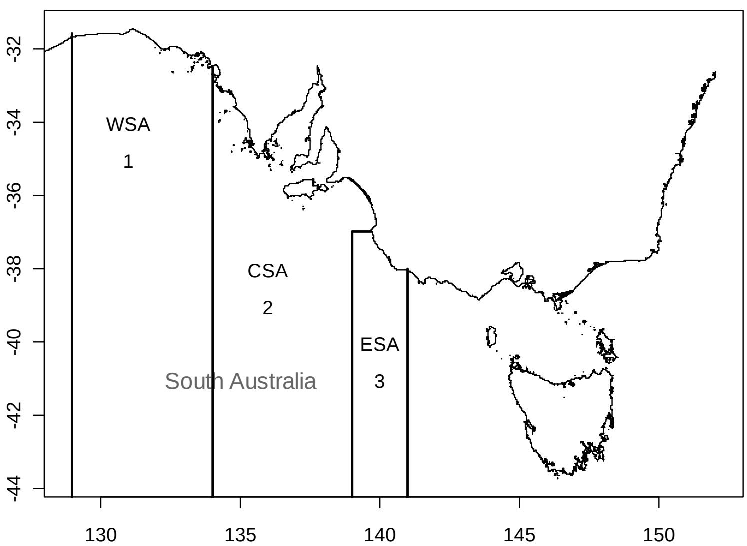

Figure 23.1. Gummy shark management zones in waters off SA used in SS-GS ratio analyses.

23.4 Results

Relative SS-GS ratios of <1 suggest that school shark are less likely to be caught incidentally compared to gummy shark using automatic longlines (Table 23.1).

Relative ratios using the Ratio[mean] method ranged between 0.24-0.41 based on retained and discarded catches (including zero catches) across the three zones (Table 23.1). These ratios ranged between 0.15-1.24 when zeros were excluded from the analyses.

Relative ratios using the Mean[ratio] method were >1 in four instances, two when excluding zero observations in the CSA and ESA, based on both retained and discarded catches (Table 23.1). The ratio of 11.355 was based on one automatic longline set where 13 kg of school shark were retained and only 0.2kg of gummy shark were discarded.

Relative incidental bycatch ratios were similar using the Ratio[mean] method when either retained or both retained and discarded catches were combined in analyses, and also similar when zero catches were either included or excluded from analyses (Table 23.1). However, care should be taken when interpreting these results as the automatic longline trials employed in the analyses were based on small sample sizes when aggregated by management zone.

Table 23.1. Incidental relative school shark to gummy shark ratio (SS-GS) using automatic longlines compared to gillnets × management zone (WSA, CSA and ESA) × Data type × Method × use of retained catch and/or discards. Data type: Include refers to the inclusion of zero catches; exclude: exclude zero catches. Retained: retained catches included only; Retained + discarded: retained and discarded catches included.

		Retained		**Retained + discarded**	
Data type	**Zone**	**Ratio [mean]**	**Mean [ratio]**	**Ratio [mean]**	**Mean [ratio]**
include	WSA	0.063	0.044	**0.244**	0.326
	CSA	0.383	0.192	**0.408**	9.449[b]
	ESA	0.291	0.501	**0.382**	0.479
exclude	WSA	0.070	0.060	0.146	0.195
	CSA	0.497	0.281	0.486	11.355[b]
	ESA	1.176[a]	1.663[a]	1.237[c]	1.549[c]

Note: Overall relative ratio exceeds 1 in a-c above.

[a]: Ratios for school and gummy sharks are low and similar for auto-longline and logbook-gillnets respectively. Overall ratio exceeds 1.
[b]: One set (auto-longline shots) dominates this ratio (school shark: retained (13 kg) and gummy shark: discarded (0.2 kg)).
[c]: Ratios for school and gummy sharks are low and similar for auto-longline and logbook-gillnets.
Zone: west South Australia (WSA), central South Australia (CSA) and east South Australia (ESA).

23.5 Conclusions

Overall, these results suggest that the incidental catch of school shark when targeting gummy shark is not higher using automatic longlines gear than gillnets. However, fishing trials were conducted during summer (November to January) only and it has been suggested that large female school shark are abundant off King Island in winter (SharkRAG 2012). Trials were conducted during winter 2011 but unfortunately these were confined to a small area off the Coorong region (Knuckey *et al.* 2012).

In addition, sample sizes were relatively small and gillnet fishing wasn't conducted alongside ALL operations. Great care was taken during this trial to avoid areas of known school shark abundance (Ian Knuckey pers. comm.) but these results had to be compared with general gillnet fishing recorded in the Commonwealth logbook database. This may be an unfair comparison, hence biasing these results towards lower apparent school shark bycatch using ALL.

Given the relative paucity of data on which these results are based, the lack of seasonal coverage, and the possibility of a (perhaps grossly) biased comparison, we recommend proceeding with great caution if longline fishing in South Australia is to be commenced. The ratio of school to gummy shark in non-trial catches should be closely monitored.

23.6 Acknowledgements

Matt Koopman (Fishwell Consulting) is thanked for providing data corresponding to the four automatic longline trials conducted between November 2011 and January 2012, and discussions during data error checks. Thanks also go to Russell Hudson (Fishwell consulting) for his useful insights into vessel operations during the trials and Ian Knuckey (Fishwell consulting) for useful discussions. Both Neil Klaer (CSIRO) and Mike Fuller (CSIRO) are thanked for providing the Commonwealth logbook data used in the analyses. Members of SharkRAG are also thanked for useful discussions.

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24. Predicted pup production of Gummy Shark (*Mustelus antartictcus*) assuming an automatic longline fishery off South Australia

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24.1 Summary

This chapter estimates relative changes in the pup production of gummy shark (*Mustelus antarcticus*) in South Australia under different levels of fishing effort using automatic longline (ALL) gear. Results indicate that to achieve the same equilibrium level of future pup production based on a 300 t future annual catch and using an existing combination of 6 and 6.5 inch gillnets and small line gears, catches would need to drop to (i) 280-285 t if half of the catch currently taken by gillnets shifts to ALL gear, and to (ii) 260-270 t if all of the catch is obtained by ALL gear. If behavioral factors which cause larger, older gummy shark to be unavailable to gillnet gear do not apply to ALL gear, to achieve the same equilibrium levels of pup production, a 300 t catch would need to be reduced to 250-280 t or 210-250 t based on a 50% or 100% transfer of catch from gillnet to ALL gear respectively. Higher future catches widen the gap between sustainable catch levels for gillnet versus mixed gillnet and ALL sectors. Although the gummy shark stock in SA would be able to sustain an introduction of a future ALL fishery, sustainable catch levels would be lower than they would be in the absence of a large line fishery. These calculations were based on an update of the gummy shark stock assessment in 2010 (which employed data to end of 2009), and assumed that all (available) fish greater than 76 cm were caught by ALL gear. These results are based on an introduction of an ALL sector in SA only, despite potential for related changes to the fishery in Victoria.

24.2 Introduction

Gummy shark (*Mustelus antarcticus*) are mostly caught using demersal gillnets and comprise the main species targeted in the Southern and Eastern Scalefish and Shark Fishery (SESSF). Gummy shark are also caught using otter trawls, Danish seines and hooks, although captures are significantly lower compared to gillnets (Klaer *et al.* 2012). However, due to existing area closures and potential incidental captures of TEP species by gillnets in waters off South Australia (SA), calls have been made to legalize the use of automatic longline (ALL) gear in waters shallower than 183 m. In addition, a relatively narrow size-range of sub-adult gummy shark are caught using gillnets, whereas a much wider size range (including adults), are likely to be vulnerable to capture using ALL gear.

Trials using ALLs to target gummy shark were conducted between November 2011 and January 2012 within the SESSF in South Australia to determine the potential impact on fishers who currently employ demersal gillnet gear (Knuckey *et al.* 2012).

Using information gained from the ALL trials, this chapter examines the likely impact of a change in selectivity on (i) future equilibrium pup production of gummy shark and (ii) sustainable yields in SA. The existing stock assessment methodology for gummy shark approved by sharkRAG is based on three reproductively separate populations: SA, Bass Strait (Victoria), and Tasmania. We used the existing gummy shark stock assessment developed for SA (Punt and Thomson 2011) and employed three model configurations to simulate future pup production assuming (i) different levels of harvesting based on ALL and gillnet gear and (ii) whether or not large sharks are available to ALL gear.

We also examine the future annual catch required to provide the same equilibrium pup production obtained under current harvesting, when half or all of the catch is obtained from ALL gear.

24.3 Methods

The most recent gummy shark stock assessment conducted in 2010 (using data to end of 2009) does not employ one base case model. Instead it employs six alternative model configurations assuming the same weight of belief (see Punt and Thomson 2011). Although, a stock assessment update was not performed, recorded Commonwealth logbook catches for 2010-11 inclusive, obtained from the AFMA logbook database were included in the analyses (Table 24.1). Each of the six model configurations are detailed in Table 24.2.

Table 24.1. Yearly Commonwealth logbook catches (t) for the period 2009-2011 and gear type for South Australia (shark regions WSA, CSA and ESA). Note that "Line" indicates gummy shark catches recorded as caught by lines, but precedes the start of ALL fishing.

Year	Gear				
	Line	6" mesh	6.5" mesh	7" mesh	8" mesh
2009	43.6	74.68	319.38	0.01	0
2010	39.57	97.03	286.17	0	0
2011	60.01	76.78	152.62	0	0

Initial analyses based on six different model configurations (B, D, F, G, I, J; Table 24.2) and reported as the final set of models assessed in 2010 (Punt and Thomson 2011) were projected to 2112. Model configurations F, G and J were excluded from further analyses since they produced unstable oscillations in projections (Table 24.2). Model configurations (B, D, I) were projected for 100 years (to 2112) to ensure that equilibrium conditions were achieved.

Table 24.2. Model configurations used in 2010 gummy shark stock assessment. Model configurations B, D and I (bold) were used to obtain projections due to the instability of the other configurations (F, G and J). M = natural mortality; DD = density dependence.

Model configuration	Description
B^ (reference case)	- DD is a function of total (1+) biomass - DD impacts rate of M for animals 0-30 years - gear competition modeled on Equation 1a (Punt and Thomson 2010)
D	Model B; DD on M for ages 0-15 (B1+)
F	Model B; DD on M for ages 0-30 (B_mat)
G	Model B; DD on M for ages 0-15 (B_mat)
I	Model B; DD on M for ages 0-2 (B1+)
J	Model B; DD on M for ages 0-2 (B_mat)

^ closest model configuration to that used in July 2010 preliminary gummy shark assessment from Thomson and Punt (2010).

The mean proportion of total annual catch from the most recent year (2011) was estimated for each gear type. Future proportions used in the scenarios through the transfer of catches from gillnet to ALL gear were based on these estimated proportions. Given that the TACs have been greatly reduced in recent years, it was assumed that the most recent catches (and their proportional catch by gear type) are more representative of the fishery than those in the past. Transfers of 0%, 50% or 100% of gummy shark catches from gillnet to ALL gear types off SA were considered. Note that a 0% transfer does not correspond to 0 t catch corresponding to line gear since line catches are non-zero. Instead, a 0% transfer corresponds to no additional transfer of catch resulting from gillnets to ALLs (Table 24.3). Also, a 50% transfer corresponds to 50% of the catch obtained from gillnets is transferred to ALLs in same relative proportions among the four mesh sizes (Table 24.3).

Table 24.3**.** Line and gillnet gear proportions employed in analyses.

	Gear				
Transfer to ALL (%)	Line	6" mesh	6.5" mesh	7" mesh	8" mesh
0	0.207	0.265	0.528	0	0
50	0.604	0.132	0.264	0	0

Two future catch levels were also considered i.e., based on the total catch across all gear types in 2011 (~300 t) and higher future catches (~450 t), which corresponds to the highest catch recorded over the 1927-2011 period. Higher future catches are plausible because the gummy shark fishery is currently constrained by the need to keep the bycatch of school shark (*Galeorhinus galeus*) at low levels. As school shark populations recover, higher gummy shark catches may be permitted.

24.4 Results and discussion

Examination of the size range of gummy sharks caught and retained using ALL gear (Figure 24.1, see also Knucky *et al.* 2012) supports the assumption made in previous gummy shark stock assessments (e.g. Punt and Thomson, 2011) i.e., that sharks greater than 76 cm are caught and that there is no upper size limit. However, some smaller sharks are caught and discarded using ALL gear (Figure 24.1). While, existing gummy shark stock assessment models do not include discarding, future calculations should consider the effects of discard mortality. Since Commonwealth logbook catches based on gillnets were used to calculate gummy shark to school shark catch ratios (Sporcic and Thomson 2013), the 76 cm minimum size limit was employed here.

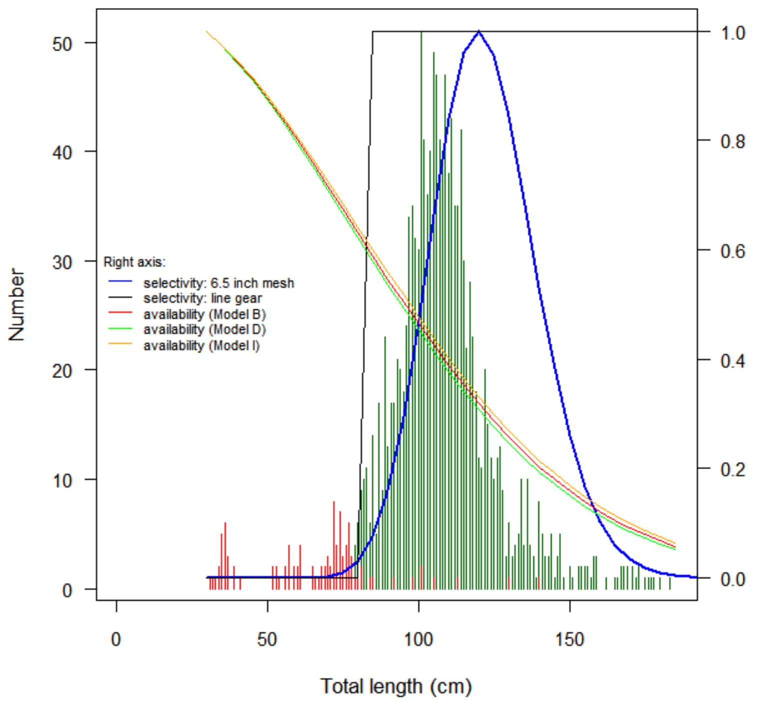

Figure 24.1. Length distribution of gummy sharks retained (dark green bars) and discarded (red bars) during ALL trials (left axis). Measurements are total length (cm) binned in 1 cm length intervals. Right axis: Selectivity of (i) 6.5 inch mesh (solid blue line) and (ii) line gear (solid black line). Model estimated availability from Models B, D and I (solid red, green and orange lines respectively).

In addition to gear selectivity, the stock assessment models of Punt and Thomson (2011) assume that larger sharks are unavailable to the fishery based on an estimated availability function. It is unknown whether or not this would apply to ALL gear. However, opinion was expressed during presentation of this work to sharkRAG members that it would not apply to ALL gear (sharkRAG, November 2012).

24.4.1 Gear selectivity; availability applied to line

Predicted equilibrium pup production (relative to pristine; 1927, hereafter referred to as "pup production") ranged from 42% to 80% (Model B, D, I;Table 24.4). This was based on the assumption that large gummy sharks are unavailable to the fishery. A predicted 42% pup production estimate was obtained when all catches in SA were taken using

ALLs and future annual landed catches of 450 t were maintained (Model I; Table 24.4). Minimal changes in pup production occurred if future annual catches of 300 t were maintained across the three percentage transfers to ALLs (0-100%) under three model configurations (Model B, D, I). If the total annual future catch increased to 450 t, pup production ranged from 42% to 67% (Model B, D, I;Table 24.4). A 62% pup production estimate resulted in SA if all catches were obtained from ALLs (Model B), 58% (Model D) and 42% (Model I), respectively. Estimated annual pup production is based on model runs to 2112, but equilibrium levels were obtained by approximately 2030.

If 50% of the catch transferred to ALLs in SA, and future annual catches were 300 t, i.e., similar to current levels, future equilibrium pup production ranged from 64% to 78% (Model B, D, I; Table 24.4). Minimal changes to these production estimates occurred if the entire SA fishery shifted to using ALLs under the same future catch scenario (Table 24.4).

Table 24.4. Large sharks unavailable to automatic longline (ALL) gear. Equilibrium pup production levels for model configurations B, D and I, under three transfer (%) to ALL gear scenarios and two annual future catch scenarios (300 t, 450 t). P = pup production.

Model	Transfer to ALL (%)	Pup production (P_{2112}/P_{1927}) (300 t)	Pup production (P_{2112}/P_{1927}) (450 t)
B	0	0.80	0.67
	50	0.78	0.64
	100	0.77	0.62
D	0	0.76	0.61
	50	0.75	0.60
	100	0.74	0.58
I	0	0.67	0.48
	50	0.64	0.45
	100	0.63	0.42

If 50% of the SA catch transferred to the ALLs, then future annual catches of 280-285 t would yield the same future equilibrium pup production that would be obtained if the fishery continued taking 300 t annually with no transfer from gillnets to ALLs (Table 24.5). If 100% of the catch transferred to ALLs, the equivalent future annual catches ranged between 260 t and 270 t. These results assumed that an availability function applied to ALL gear (Table 24.5).

Table 24.5**.** Large sharks unavailable to automatic longline (ALL) gear. Changes in future catch levels required to provide pup production at the same equilibrium levels obtained under current harvesting when transferring 50% and 100 % of the total annual catch to ALLs.

Model	Transfer to ALL (%)	Current catch (t)	Equivalent catch (t)
B	50	300	280
D			285
I			285
B	100	300	260
D			270
I			270

24.4.2 Gear selectivity; availability not applied to line

Future equilibrium pup production ranged from 34% to 78% (Table 24.6). The lowest value was based on the scenario where 100% of the SA gummy shark fishery converted its catch to ALLs, large gummy shark were available to the fishery and annual future catches were high (Model I; 450 t). The only other pup production estimate below 40% occurred when half of the SA fishery converted its catch to ALLs and future catches were high (Model I; 450 t). Pup production estimates below 40%, occurred when both future annual catches were high (450 t) and at least 50% of the total annual catch was obtained by ALL gear. If the total annual catch remained at approximately 300 t, pup production was estimated to be above 40% across the three percentage transfers to ALLs (Models B, D and I; Table 24.6).

Table 24.6. Large sharks available to automatic longline (ALL) gear. Equilibrium pup production levels for model configurations B, D and I, under three transfer (%) to ALL gear scenarios and two future annual catch scenarios (300 t, 450 t). P = pup production.

Model	Transfer to ALL (%)	Pup production (P_{2112}/P_{1927}) (300 t)	Pup production (P_{2112}/P_{1927}) (450 t)
B	0	0.78	0.60
	50	0.72	0.53
	100	0.68	0.47
D	0	0.74	0.50
	50	0.70	0.45
	100	0.66	0.41
I	0	0.63	0.45
	50	0.58	0.39
	100	0.54	0.34

If 50% of the SA catch was transferred to the ALL sector, then future annual catches of 250-280 t would give the same future equilibrium pup production that would be obtained if the fishery continued taking 300t annually with no transfer from gillnets to ALLs (Model B, D, I; Table 24.7). If 100% of the catch of gummy shark by the SA fishery transferred to ALLs, equivalent future annual catches ranged between 210 t and 250 t. These calculations assumed that an availability function did not apply to ALL gear (Table 24.7).

Table 24.7. Large sharks available to automatic longline (ALL) gear. Changes in future catch levels required to provide pup production at the same equilibrium levels obtained under current harvesting when transferring 50 and 100 % of the total annual catch to ALL gear.

Model	Transfer to ALL (%)	Current catch (t)	Equivalent catch (t)
B			250
D	50	300	270
I			280
B			210
D	100	300	220
I			250

24.5 Conclusions

As expected, information gained from the automatic longline trials indicate that larger (and older) gummy sharks are caught by ALLs than gillnets. Consequently, harvesting employing ALLs would require lower TACs compared to employing gillnets alone in order to achieve the same level of sustainability in terms of future pup production (Tables 24.4 to 24.7). If future annual catches remain at current levels (~ 300 t in SA), and if larger sharks are unavailable to the fishery (e.g. due to behavioral reasons), the impact of an ALL fishery can be predicted to be relatively low: future pup production drops from 67-80% (relative to pristine) to 63-78% depending on (i) catch levels using ALL gear and (ii) model configuration employed. To achieve the same level of pup production in the absence of an ALL sector, future catches are required to drop from 300 t to 280-285 t if 50% of former gillnet catch is obtained by ALLs, and 260-270 t if 100% of former gillnet catch is obtained by ALLs.

The presence of an ALL sector has a greater impact if future annual catches are higher. Catches of 450 t decrease pup production from 48-67% to 42-64% following the introduction of an ALL fishery in SA, depending on the percent transfer of catches from gillnets to ALLs and the model configuration used. This assumes that larger sharks are unavailable to the fishery.

If large sharks are available to ALL gear, as suggested by sharkRAG, the effect of an ALL sector is still greater. Future pup production drops from 63-78% to 54-72% under a 300 t future catch scenario, and from 45-60% to 34-53% under a 450 t catch scenario. Future catches would have to drop from 300 t to 250-280 t or 210-250 t given 50% or 100% transfer of catch from gillnet to ALL gear respectively.

This work considers the introduction of an ALL sector in SA alone. Sustainable catch levels in Victoria could also be affected if ALL quotas are issued across the SA-Vic border and between different gears.

The gummy shark population in SA waters can sustain the introduction of a future ALL fishery, though sustainable catch levels will be lower than they would be in the absence of a large ALL fishery. Future work should consider the effect of capture and possible mortality of gummy shark smaller than 76cm.

24.6 Acknowledgements

Members of SharkRAG are thanked for their useful discussions, in particular Colin Simpfendor (James Cook University) is thanked for his input. Both Mike Fuller (CSIRO) and Neil Klaer (CSIRO) are thanked for providing the Commonwealth logbook data employed for analyses. Andre Punt developed the gummy shark stock assessment models that were employed in this chapter.

24.7 References

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25. Benefits

The results of this project have had a direct bearing on the management of the Southern and Eastern Scalefish and Shark Fishery. Direct benefits to the commercial fishing industry in the SESSF have arisen from improvements to, or the development of, assessments under the various Tier Rules of the Commonwealth Harvest Strategy Policy for selected quota and non-quota species. Information from the stock assessments has fed directly into the TAC setting process for SESSF quota species. As specific and agreed harvest strategies are being developed for SESSF species (a process required by and agreed to under EPBC approval for the fishery), improvements in the assessments developed under this project have had direct and immediate impacts on quota levels or other fishery management measures (in the case of non-quota species).

Participation by the project's staff on the SESSF Resource Assessment Groups has enabled the production of critical assessment reports and clear communication of the reports' results to a wide audience (including managers, industry). Project staff's scientific advice on quantitative and qualitative matters is also clearly valued.

The stock assessments presented in this report have provided managers and industry greater confidence when making key commercial and sustainability decisions for species in the SESSF. These assessments have provided the most up-to-date information, in terms of data and methods, to facilitate the management of the Southern and Eastern Scalefish and Shark Fishery.

26. Conclusion

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

The 2012 assessment of the stock status of key Southern and Eastern Scalefish and Shark fishery species is based on the methods presented in this report. Documented are the latest quantitative assessments (Tier 1) for several of the key quota species (pink ling (east and west), silver warehou, and deepwater flathead), as well as catch curve analyses and cpue standardisations for shelf, slope, deepwater and shark species. Typical assessment outputs provided indications of current stock status and an application of the Commonwealth Harvest Strategy framework. This framework is based on a set of assessment methods and harvest control rules, with the decision to apply a particular combination dependent on the type and quality of information available to determine stock status (Tiers 1 to 4).

The assessment outputs from this project are a critical component of the management and TAC setting process for these fisheries. The results from these studies are being used by SESSFRAG, industry and management to help manage the fishery in accordance with agreed sustainability objectives.

Stock status and Recommended Biological Catch (RBC) conclusions:

The 2012 base-case (aggregated zones model) Tier 1 assessment of pink ling (*Genypterus blacodes*) concluded that the eastern stock is $0.26B_0$ at the start of 2013 and the western stock is $0.43B_0$ at this time (under the assumption that the TAC for 2012 of 1,000 t is taken). The Recommended Biological Catches (RBCs) arising from the base-case models are 223 t for the eastern stock and 490 t for the western stock; giving a total RBC of 713 t for the SESSF pink ling stocks. The long term RBC (for the year 2032) is 829 tonnes for the eastern stock and 548 tonnes for the western stock; giving a total long-term RBC of 1,377 t. An alternative model was considered in addition to the base-case as a next step towards the development of a model to account for lack of spatial homogeneity in population processes within the eastern and western stocks of pink ling. This alternative model treats the zone-based CPUE indices and the age- and length-compositions by zone as coming from different ‘fleets’. Further work on the zone-based model is expected over the coming years.

A quantitative Tier 1 assessment of silver warehou (*Seriolella punctata*) in the SESSF was conducted using data up to 31 December 2011. The last full quantitative assessment was presented in 2009. The base-case assessment estimates that the projected 2013 spawning stock biomass will be 46.6% ($0.466B_0$) of virgin stock biomass. The RBC from the base-case model for 2013 is 2,544t for the 20:35:48 harvest control rule, with a long-term yield of 2,618t. If recent recruitments (2008-2011), which are not currently estimated by the model, are assumed to be poor and at similar levels to recruitment during the period 2002-2005, then depletion in 2013 could fall below 40%. Under this scenario, setting a multi-year TAC could result in depletion levels falling below 30% by 2015.

While a full quantitative assessment of jackass morwong (*Nemadactylus macropterus*) was not conducted in 2012, to calculate the 2013 RBC, the 2011 assessments for both eastern and western morwong were projected for one more year, using actual catches from 2011, and estimated catches for 2012. No other data were added and no new parameter estimation was performed. The 'recruitment shift' assessment model accepted as the base-case for the eastern stock in 2011, and the base-case model for the western stock from 2011 were used for the projections. Current spawning biomass in the eastern stock is projected to be 37.7% of 1988 spawning stock biomass, and the 2013 RBC under the 20:35:48 harvest control rule is 380 t. For the western stock, current spawning biomass is projected to be 66% of unexploited stock biomass, and the 2013 RBC is 275t.

The current version of the school shark (*Galeorhinus galeus*) model predicts that catches of up to 250t allow recovery of the stock, but that 275t will not. Rebuilding to the limit reference point (B_{20}) cannot be achieved in a generation time plus time 10 years (32 years) given current levels of catch (176t). Rebuilding in three generation times (66 years) can be achieved with future catches of up to 225t. If the limit reference point is moved from B_{20} to half B_{MSY} (i.e. B_{25}), then rebuilding within 32 years would require catches of close to zero; future catches would need to be of the order of 200t in order to achieve rebuilding in 66 years.

An update of the 2010 assessment of deepwater flathead (*Neoplatycephalus conatus*) was conducted, providing estimates of stock status in the Great Australian Bight at the start of 2013/14. The base-case assessment estimates an unexploited spawning stock biomass (SSB_0) of 8,921t and a current depletion of 39% of SSB_0. The 2013/14 RBC under the 20:35:43 harvest control rule is 979t and the long-term yield (assuming average recruitment in the future) is 1,051 t.

Tier 3 calculations use the estimates of total mortality, natural mortality and average recent catches to determine the RBC for the following year. RBCs for alfonsino, John dory, redfish and mirror dory were greater than reference average catches using the Tier 3 rule. Western gemfish, blue grenadier, pink ling, blue-eye trevalla and silver trevally were unable to be assessed using catch curves due to probable dome-shaped selectivity or high recruitment variability.

The Tier 4 harvest control rules are the default procedure applied to species for which only limited information is available; specifically no reliable information on either current biomass levels or current exploitation rates. In 2012 Tier 4 RBCs were only calculated for species that are assessed using the Tier 4 analysis, that is: Blue Eye, Blue Warehou, Inshore Ocean Perch, Offshore Ocean Perch, Redfish, Royal Red Prawns, and Silver Trevally. Among the non-deep water scalefish a total of 18 species with 24 separate Tier 4 analyses were conducted, but these included a number of species for which spatial information was available (blue warehou and mirror dory) leading to analyses for east and west; with an alternative Royal Red Prawn analysis relating catch rates from different mesh sizes. Two fisheries had zero RBCs: blue warehou and redfish.

Among the deep water species the Tier 4 control rule was used to calculate RBCs for the six deepwater fisheries. The target catches were obtained using the total catches reported outside of the closed areas deeper than 700m. Reported catches were relatively low in four fisheries so no change could be recommended to the RBC. For mixed oreos the RBC increased slightly from 120 – 132 t. It should be noted that even the standardised catch rates may not reflect changes in stock sizes particularly well. Some of the apparent changes in catch rates exhibited by deep water species are so rapid and so large as to be implausible biologically.

27. Appendix: Intellectual Property

No intellectual property has arisen from the project that is likely to lead to significant commercial benefits, patents or licenses.

28. Appendix: Project Staff

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