Independent review of the 2021 stock assessment of Australian pearl perch.

Prepared by

Neil Klaer

Prepared for

Queensland Department of Agriculture and Fisheries

Desk-top review
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Contents

Executive Summary

This is a desktop review of the 2021 Australian pearl perch stock assessment by the Department of Agriculture and Fisheries (DAF) Queensland carried out during the period 20 August to 13 September 2021. Major uncertainties for the stock assessment (also acknowledged by the authors) are estimates of fishery catches particularly historically, model starting conditions, spatial sub-units of the stock subject to different fishing pressures and depletion, change in fishing efficiency by fishing fleets, and uncertainty in natural mortality and stock-recruitment compensation that affect overall stock productivity. I believe that more consideration could be given to some of these uncertainties that should be included in advice to management. I was unable to agree that the base-case represented a central scenario for determination of the status of this stock due to the selection of a low fixed steepness value. I have also recommended that uncertainty in initial biomass be accounted for by allowing for error in historical catch or setting the start year for the model to a period informed by the available data.

1 Review Activities

This is a desktop review of the 2021 Australian pearl perch (*Glaucosoma scapulare*) fishery stock assessment by the Department of Agriculture and Fisheries (DAF) Queensland (Lovett and Northrop 2021). The review process was sent out by DAF for competitive tender, and I was contracted to do the review. Formal terms of reference for the review were included in the contract. I received the pearl perch stock assessment report and associated model input files on 29 July with those for east coast snapper. I commenced work on snapper first and started this review on 20 August. Having access to the model files greatly assisted the review as I could examine more detailed diagnostics not provided by the assessment report. I provided specific comments on R4SS diagnostic output of base-case models to the authors on 3 September, and only describe those in general terms here. I completed the review on 10 September and sent my draft report to Robyn Lovett and Sue Helmke. Confirmation was received on 10 September that the report met the terms of reference for the review and the report was finalised on 13 September. I thank all who I have had contact with for this review which progressed efficiently and professionally.

2 Review of stock assessment of Australian pearl perch

2.1 Objectives of the stock assessment

The stock assessment had the following objectives:

1. Collate the relevant fisheries data.
2. Develop harvest estimates, standardised catch rates and biological data to input to the population model.
3. Estimate stock status with respect to reference points described in the Queensland Sustainable Fisheries Strategy 2017–2027
4. Propose Recommended Biological Catches (RBCs).
5. Provide recommendations for management and monitoring.

2.2 Terms of reference for the review

The Department of Agriculture and Fisheries (DAF) is seeking an independent review of the "Stock assessment of pearl perch (*Glaucosoma scapulare*) in Queensland and NSW, Australia". The review is not limited to, but should address the following points:

1. Review the model inputs and outputs and adequacy of these data to achieve the objectives of the assessment, including:

   (a) Providing biomass ratio estimates in relation to the fishery reference points

   (b) Assumptions used in the analysis of catch rates

   (c) Assumptions used in the estimation of harvest sizes

   (d) Confidence in model inputs and outputs

   (e) Assumptions used in the stock synthesis models

   (f) The adequacy of the population dynamic model used in the assessment

   (g) Appropriate recommended biological catch / Total Allowable Catch.

2. Provide comment on the accuracy of key statements in the report summary and conclusion. How well are they supported by available data, analysis and literature?
3. Provide comment on recommendations for management, monitoring and inclusion of additional data in future assessments.
4. Any other outputs or graphical figures that the report could have provided.

A formal written report of the findings of the review is to be provided to the stock assessment author and a nominated person from Fisheries Queensland. The written review and review author identification may be released and made publicly available.

2.3 Findings by term of reference

2.3.1 Review the report inputs and outputs and adequacy of these data in order to achieve the objectives of the assessment

(a) Providing biomass ratio estimates in relation to the fishery reference points

A time series of total spawning biomass (spawning output) is estimated for the stock as input to QDAF (2020) harvest control rules to reach future catch recommendations. The ratio of $B_{current}/B_0$ can be determined with more accuracy than absolute spawning biomass, and current management is based on a target for that ratio of 0.6 and a limit of 0.2 (QDAF 2020). This is a common procedure used by many assessments, with target and limit levels that may vary by fisheries jurisdiction. The method is acceptable for status determination within any accepted stock assessment model run that may be used by fisheries management. Management currently relies on central values of these estimates from a selected base-case, and do not specifically take account of stock assessment uncertainty, except indirectly through selection of the target and limit ratios and potentially an uncertainty buffer, and across alternative base-cases if those are provided. Uncertainty in individual stock assessment results is provided as asymptotic distributional ranges, and via results from several sensitivity model scenarios. The current pearl perch assessment primarily provides a single base-case and associated sensitivity test results to management, which is acceptable, but does not fully highlight or integrate stock assessment uncertainty. However, I have recommended changes to the base-case that would alter the recommendations as presented in this assessment report.

(b) Assumptions used in the analysis of catch rates

The pearl perch fishery does not currently have fishery-independent surveys and therefore must rely on fishery-dependent sources. Many fishery assessments that rely on fishery-dependent sources largely ignore fishing power change because addressing the problem is a considerable task, and historical records of such changes are inadequate for that purpose. Efforts have been made to account for and include fishing power changes to abundance indices used in the pearl perch assessment.

Fishing power estimates from Sumpton et al. (2013) and Thurstan et al. (2016) have been variously applied to commercial fishery catch rates as categorised by “no”, “reduced”, “approximate” or “high” scenarios. I agree with the selection of scenarios used for the assessment and continue to recognise the importance of including fishing power change through time as a general and often overlooked procedure.

Methods used to standardise QLD commercial line, NSW line and NSW trap data were essentially the same as used by comparable assessments. I have commented in a previous review on the methods used for the Wortmann et al. (2018) assessment which appeared to be acceptable, so I will not repeat those comments here.

I believe that index standardisation falls into the category of data preparation for stock assessment and is a separate and specialised task. It may be an improvement to present the standardisations in a separate document to the assessment where the details could be more closely examined – for example to see the model selection process, plausibility of estimates of terms included in the models etc. Examination of those aspects would probably benefit from review by professional statisticians most familiar with such analyses. Data filtering is an important consideration for standardisation and requires description in such a document – for example, how non-pearl perch records may have been identified and excluded from analysis in a multi-species fishery.

(c) Assumptions used in the estimation of harvest sizes

A major driver of estimated population trends for a fish stock that has been subjected to considerable fishing pressure is the time series of total fishery catches. For pearl perch, reasonable estimates are available of total catch of QLD and NSW commercial and charter fisheries since about 1988. Hindcasted catches from 1938 to 1987 were apportioned according to more recent ratios among fishing sectors with an overall assumed pattern of total fishery catch increase. Catches 1880 to 1937 were hindcasted using human population statistics. Sporadic survey estimates of total recreational catch are only available since the 1990s and were variously interpolated and hindcasted to provide total estimated recreational catches. Estimation of historical catches for pearl perch is more difficult when compared to the associated major target species snapper as pearl perch were often not specifically identified in historical records. It has been noted that pearl perch are found further offshore than snapper, so the development of target fishing for each species is not directly comparable.

The method chosen for this assessment was to attempt a full catch history reconstruction, so from that viewpoint estimates of harvest prior to 1988 must be made. While I don’t disagree with the scenario presented, alternative scenarios could have been created for the interpolated/extrapolated periods as estimates from those times are highly uncertain. Alternative catch scenarios were not investigated as part of the assessment, and a single fixed historical catch scenario has been used which was assumed to be almost exactly known (se 0.01 for all values). For future assessments, construction of alternative catch series or the use of error estimates for historical catch values (allowed by SS) should be considered at least for sensitivity testing. An improvement would be the incorporation of this assessment uncertainty into advice to fisheries management regarding current stock status. A means to circumvent most of these investigations is to build an assessment that does not start at unexploited biomass. That is discussed in more detail later.

Discards are not explicitly modelled within the assessment via discard mortality and the use of retention curves as part of selectivity. A simpler approach has been used where dead discards have been estimated outside of the model and added to the retained historical catch. This approach assumes that selectivity applying to discards matches that of the retained catch for which length and age composition data are available. It may be possible to improve the assessment by including any available data on the size/age of discarded fish by fishing sector, but the authors note that information regarding discards is poor. For example, can the apparent lack of average fit to peak asymptotic selectivity for length compositions be explained using knife-edge retention? Collection of future information regarding discards by fishing sector should be given some priority.

The methods used to construct the central estimate of total harvest by sector through time is acceptable.

(d) Confidence in model inputs and outputs

Confidence in model outputs derives from the correct use of an appropriate assessment model, while making full use of input data and estimating properties specific to the stock to allow total population estimation for management.

The current assessment has been developed using Stock Synthesis (SS) (Methot and Wetzel 2013) that has many advantages including use of input data of most types even if incomplete, verification via simulation of the basic dynamics and many assessment options, fitting of growth within the assessment, appropriate procedures for estimation of parameter uncertainty, wide use throughout the world with many previous applications, and automated methods for production and display of model diagnostics. There are also disadvantages of SS including a steep learning curve and potential risk of inappropriately using it and its many options, but I believe that the stock assessment team have undertaken appropriate formal SS training. I agree with the choice and appropriateness of the stock assessment framework and acknowledge that there are perhaps equally capable alternatives available such as CASAL.

For assessment purposes the Australian pearl perch population is assumed to be a single reproductively isolated stock from about Port Jackson on the NSW coast to Rockhampton in QLD. A small tagging study suggests that pearl perch movement is predominantly localised with only a few small fish moving substantial distances between release and recapture areas. This characteristic is likely to result in regional sub-populations with sufficient cross-mixing to make them genetically indistinguishable, but important within stock assessment timeframes where localised depletion is possible.

This assessment attempts to use data from the full extent of the assumed single stock, so therefore included catches, catch at length, catch at age, and available abundance indices from QLD and NSW. The creation of a coast-wide assessment was an objective of the earlier 2017 stock assessment (Sumpton et al. 2017), which has been carried forward to the current one. This does, however, somewhat hide a major assessment uncertainty – the influence of spatial stock structure and particularly potential localised depletion differences in sub-areas. The QLD region accounts for the greatest portion of historical catches, so is most influential on assessment results, at least from an exploitation viewpoint. The stock assessment is heavily influenced by trends in abundance indices, and those currently available are from different fishery sectors in different areas that show conflicting trends. It is perhaps an advantage that the current coast-wide assessment is most influenced by QLD CPUE trends.

One approach to examine potential bias caused by ignoring spatial structure could be separate assessments that use QLD and NSW data, with results then added together as a sensitivity analysis for comparison with the combined model. A combined model with spatial sub-structuring could be investigated and has been recommended by the authors as potential future research. There has been general research into appropriate scales for stock assessment where different regions have been subjected to different catch histories (e.g., Cope and Punt, 2011). Those conclude that the assessment scale is best matched with the scale used to manage the stock.

The assessment has a start year of 1880. There are almost no data available (catch, CPUE or composition) for pearl perch prior to about 1988. The current assessment uses simple assumptions to hindcast historical catch to 1880 which appears to follow the procedure of Sumpton et al. (2017) who say, "although there are no reliable harvest data recorded before 1988, it was unrealistic to start the modelling in 1988 from an unexploited state (virgin population)". The authors also say that the 1880 start date was used for alignment with the snapper stock assessment. SS allows a model to start at a time supported by available data using an equilibrium starting *F* (not virgin), which seems to be a more appropriate procedure for this species.

It has long been recognised that steepness is a highly influential but uncertain parameter for fisheries stock assessments. It has been generalised in the past that estimation of steepness within a stock assessment requires input data to support estimation of individual stock and recruitment points (informed by abundance or size/age composition data) that cover a wide range of stock size and potentially multiple fish-down and recovery periods (e.g. see Lee et al. 2012). Appropriate fixed values or prior distributions for steepness for most fish taxonomic groups have not been studied in detail, perhaps except for US Pacific coast rockfish. Until recently, many stock assessments have assumed that steepness is unknown and have used a default generic value, such as 0.75 for marine demersal fish stocks from Shertzer and Conn (2012). It has been common past practice to assume that schooling pelagic bony fish species have relatively high reproductive resilience, with many assessments of those assuming steepness of 0.7 or more, and not a small number at or near steepness 1.0 (e.g. Zhu 2012 for bigeye tuna). Low steepness values have commonly been accepted for stock assessments of species that produce relatively small numbers of live young or large eggs (e.g., sharks, skate, dogfish, rockfish) where a more direct relationship of adults and recruited offspring may be expected, and exceptionally large recruitment events due to favourable environmental conditions seem less biologically possible.

Pearl perch do not fit the profile of a species likely to allow robust steepness estimation. It does not provide long contrasting periods at different stock sizes that are informed by sufficient data to estimate recruitment deviations during those periods. This is highlighted by the likelihood profile for steepness provided in the assessment document (Fig D.13) that shows no significant difference across steepness values from 0.25 to 0.6 that were examined (a change in likelihood of two units is the commonly accepted level for statistical significance). On this basis, a prior fixed value for steepness is therefore required to be selected from sources external to the current or previous pearl perch assessments that were based on similar input data. My recommendation is to select an uninformed generic value as outlined above of 0.7 or 0.75 using those justifications. I also note that a new meta-analysis by Thorson (2020) provides similar values near 0.7 for comparable species in the family Glaucosomatidae, although additional work is required to justify which values might be selected from that source. The current assessment uses a fixed low value of 0.4 for steepness for the base-case which I do not consider is justified. Sensitivity analyses shown in the report suggest that results are not especially sensitive to the steepness value (Table 3.5) but a value near 0.7 was not tested and would be expected to vary from the base-case more than the 0.5 value examined.

(e) Assumptions used in the stock synthesis models

SS input files for all models (base-case plus sensitivities) were provided for review. These enabled a detailed examination of those models for initial settings and detailed diagnostics.

The pearl perch SS model is simply structured. It is annual, 1 season, 7 fleet (1=Charter_qld, 2=Commercial_qld, 3=Rec_qld, 4=Charter_nsw, 5=Comm_trap_nsw, 6=Comm_line_nsw, 7=Rec_nsw), 0 surveys, 1 area, 1 gender, start 1880 (no prior fishing), CPUE 1 (fleet 2), 2 (base - fleets 5,6) or 3 (fleets 2,5,6), no discards, length composition observations (fleets 1,2,3,6) very recent, composition observations (fleets 1,2,3) very recent, no age error, no age-length compositions, composition sample sizes tuned, *M* fixed or estimated, growth fixed, age-maturity matrix by growth pattern, fecundity f=a*l^b, selectivity all asymptotic and fitted, steepness fixed 0.4 or sensitivity fixed alternatives, recruitment deviations 1988-2018 tuned, floating q with estimated sd. I examined detailed model settings for all models and did not find any that were unusual in comparison to other SS assessments, although noted that recruitment deviations should have been to 2019 which was corrected by the authors.

R4SS output for the base-case revealed some notable aspects. The R_0 and therefore B_0 estimate has little uncertainty most likely due to high determination by certain catches, known steepness, and no composition or abundance index data prior to 1985. Uncertainty in this is not captured by assessment results. I recommend that a likelihood profile for R_0 be produced as a standard stock assessment procedure to investigate data influences more comprehensively on that important estimate. Catches are based on simple assumptions from 1880 to about 1988. I advise consideration of an assessment that starts in about 1985 (when CPUE commences) or 1988 (good catch data commences) with an estimated equilibrium *F* to account for previous fishing, as there is little available data prior to those years. There will be uncertainty in the estimated starting equilibrium *F* value that is likely to better capture uncertainty about R_0 for this assessment. A good CPUE fit was obtained for the Commercial_qld index but fits to NSW indices were poor. Very different results were achieved when the model was fitted to NSW abundance indices (NSW only sensitivity test).

There are systematic residuals in length composition fits and missed average age of catches. These differences potentially arise from regional differences in growth, maturity, and exploitation. Potential resolution of these issues would require a model or models that deal with apparent regional differences in the available data.

Average fits of selectivity to length data suggest that a change is required to the functional form of selectivity. It appears that a knife-edge truncation of the left-hand side of the asymptotic selectivity curves would result in an improved fit to the data. This could be achieved by using the current length-based selectivity in combination with knife-edged age-based selectivity. However, it may be a far better solution to include discards in the assessment with a knife-edged retention curve and the current length-based asymptotic selectivity. This may be achievable without additional data supporting discards, but additional information on the length composition or at least proportion of discarded catch would be most valuable. Current assumed proportion of discards that have been added to the retained catch could be used for this immediately.

I agree that the current base-case model as configured for a coast-wide assessment is acceptable except for reservation about the steepness value and the starting year chosen for the base-case. There is considerable scope to improve the assessment model, but I also acknowledge that historical data availability is a substantial problem for this assessment.

(f) The adequacy of the population dynamic model used in the assessment

The next key question is whether major uncertainties have been sufficiently considered and conveyed by results. Uncertainties are examined in the pearl perch assessment through the construction of nine sensitivity tests that examine the influence of fishing power change, emphasis on available CPUE series and alternative fixed values for steepness and natural mortality. The range of results from sensitivity tests do provide an improved indication of the uncertainty for this assessment. At present, the sensitivity tests are offset from a base-case that I recommend requires at least modification to the fixed value for steepness. If uncertainty is introduced to also account for lack of knowledge of historical catch, then an expansion of the extent of assessment uncertainty would be expected. Management advice from the assessment mostly centres on results from the base-case, and should incorporate more of the true uncertainly via model averaging or selection of a range of representative base-case results as has been done for other QDAF assessments (e.g. 2021 east coast snapper).

There are considerable uncertainties in the pearl perch assessment, and comprehensive accounting for all of them is a large undertaking at a level not normally done for most accepted stock assessments. Judgement on the category and importance of the uncertainties as described in this report in Table 1 is my own and is open to differing opinions. I believe that more consideration could be given to some of these uncertainties to improve the current base-case.

Table 1 Dimensions of uncertainty and level addressed via alternative model scenarios

Major uncertainty	**Degree addressed**	**Method**
Total catch	No	Alternative scenarios for hindcasted/interpolated catch and discards by fishing sector are not examined. Near zero error is assumed for highly uncertain values. An alternative procedure for handling discards via retention curves could be examined.
Starting year	No	Model starts in 1880. Consider an alternative model that starts in a more data-rich period that estimates an equilibrium starting *F*. For this assessment this procedure seems most appropriate given absence of data for most historical years.
Spatial structuring	Partial	Use of combinations of available abundance indices result in different emphasis on abundance trends from QLD and NSW fisheries. Regional differences in stock depletion may be an issue. Growth and maturity are fixed for the entire stock, but regional differences in these may cause problems in fitting composition data.
Fishing efficiency	Yes	Different levels of fishing power change have been devised and applied to line fishery catch rates.
Major productivity parameters (M/h)	Yes	Different fixed natural mortality and steepness values were tested via sensitivity analysis. However, I have recommended a different base-case value for steepness.

Model developments to address major uncertainties include alternative model starting conditions and examination of alternative methods for dealing with discards. Age-at-length data were not used for this assessment and could be considered depending on availability. This would greatly assist if at least some growth parameters were to be estimated. A more ambitious future research program might commence the development of an operating model for pearl perch (potentially as part of a complex that includes species such as snapper) that includes plausible population complexities and use Management Strategy Evaluation to determine robust assessment methods and management procedures to achieve management objectives.

(g) Appropriate recommended biological catch / Total Allowable Catch

Policy for the estimation of catch levels to achieve a target spawning biomass is outlined by QDAF (2020). Model results were projected forward to 2029 following the 20:60:60 harvest control rule. This harvest control rule is consistent with the DAF Sustainable Fisheries Strategy. A discount factor to account for uncertainty in recommended target estimates is mentioned in DAF policy but is not referred to in the assessment. I agree that the form of the harvest control rule and therefore projections follow from the policy. Methods used are therefore acceptable. However, I have recommended changes to the base-case that would alter the recommendations as presented in this assessment report.

2.3.2 Comment on the accuracy of key statements in the report summary and conclusion

Common stock assessment practice is to choose a “most likely” model from a range of plausible alternatives, and to base management advice mostly on that single base-case. However, it is increasingly recognised that the uncertainty as estimated from a single base-case normally underestimates what is probably closer to true uncertainty as captured by a range of alternative models based on plausible scenarios. In other words, model structural uncertainty is normally greater than that estimated within any selected model scenario. Model averaging and ensemble models are gaining favour to more correctly account for stock assessment uncertainty (e.g., see Millar et al. 2015). Base-case results have primarily been used in the report for provision of management advice which I believe does not convey the true uncertainty of the stock assessment. However, I have recommended changes to the base-case that would alter the recommendations as presented in this assessment report.

2.3.3 Comment on recommendations for management, monitoring and inclusion of additional data in future assessments

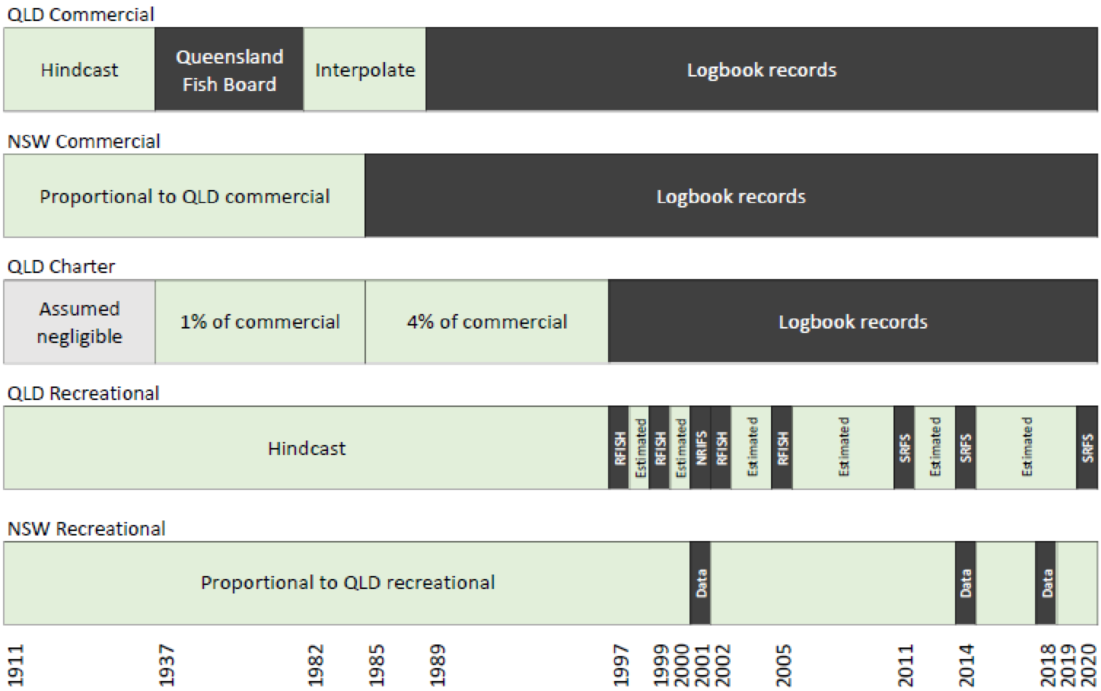
The assessment report included a section on recommendations separated as they apply to research and monitoring, management and stock assessment. I agree with those recommendations. I have included recommendations for additional exploration of model uncertainty in this report. It is a standard research recommendation to develop fishery-independent abundance indices for fisheries that do not have them. Whether this is possible is normally determined by the value and importance of the fishery. How this might be cost-effectively achieved for pearl perch should be considered – e.g., close-kin genetic analysis. Sumpton et al. (2017) state that “fish numbers from Baited Remote Underwater Videos (BRUVs) at this time was of little value to the current stock assessment, although we acknowledge that a properly designed and implemented BRUV program may provide a fishery-independent index of relative abundance suitable to include in stock assessments.”

These recommendations should be closely examined and prioritised according to their effect on reducing uncertainty of the assessment for making management decisions. It is also useful to decide the timeframe that potentially applies to each recommended item (e.g., short-, medium-, and long-term). Each item should be reviewed within a stock assessment to determine what progress has been made since the last assessment.

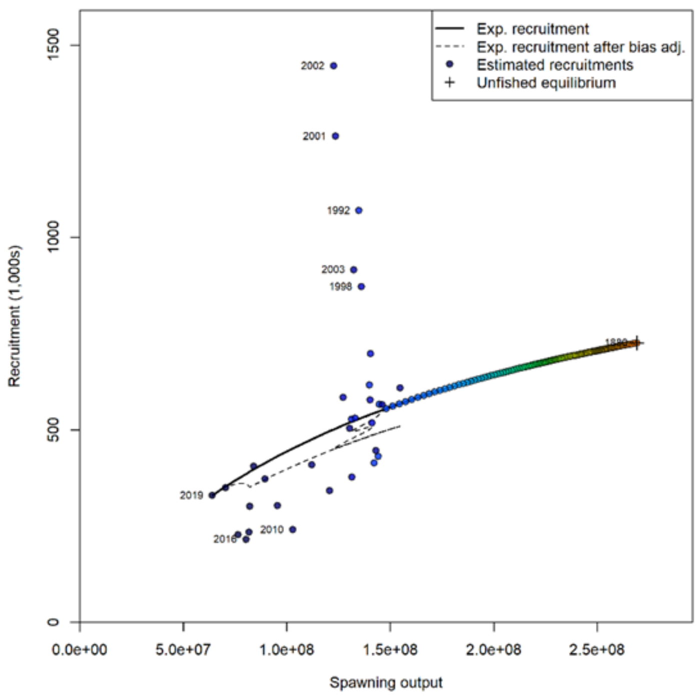
2.3.4 Any other outputs or graphical figures that the report could have provided

Outputs and graphical figures provided in the report were sufficient for fishery management purposes. However, they were not sufficient to allow scientific review of the stock assessment. As I was provided with model input files, I was able to run my own diagnostics to support this review. I believe that it has become necessary to provide such files to scientific reviewers to allow a thorough examination of the assessment implementation.

A plot that summarises the assumptions made for historical harvest reconstruction would be a beneficial inclusion. The following is an example from the recent QDAF east coast Spanish mackerel assessment.



A standard inclusion for most stock assessments that provides key information is the stock-recruitment plot as shown below for the base-case.



Where assessments are regularly made for the same species using the same modelling framework, an opportunity arises to provide an audit trail that comprehensively and transparently shows model changes since the last assessment – commonly called a bridging analysis. Such a bridging analysis involves examination of absolute spawning biomass and recruitment trends over time after the application of sequential changes to model source code version revision, structural assumptions, changes to fixed parameter values or priors, and the inclusion of recent data (source by source where possible – catch, index, age and length composition by fleet). This provides a continuum from the previous assessment to the current base-case. Such a process (or an improvement on it) could be considered in the future for any regular SS assessments by DAF. It is understood that a detailed bridging analysis may not be required if the absolute biomass and recruitment series have changed little from one assessment to the next, but experience says that this is rarely the case.

Although the previous stock assessment for pearl perch by Sumpton et al. (2017) did not use SS, there may still have been an opportunity to construct a bridging analysis by commencing with a model that attempted to replicate those results – at least for a selected representative case. Provision of such a bridging analysis gives confidence to interested groups (e.g., managers or industry) that there is consistency among stock assessments for the same species. It also highlights where differences have arisen from – either via changes in modelling approach, or new data.

A likelihood profile for R_0 could be produced as a standard stock assessment procedure to investigate data influences more comprehensively on that important estimate.

Inclusion of the overall likelihood values in the summary table of sensitivity analysis results (Table 3.5) is useful, although differences in model structure and tuning sometimes make those statistically incomparable. A separate table with likelihood components further broken down into sub-components such as CPUE or composition fit often still allows much insight into model behaviour that is unobtainable otherwise.

Evidence for model convergence should be considered and can be based on jittering starting values for estimated parameters. An improvement on this is via MCMC or bootstrap runs, although the additional time required for such procedures is recognised.

Model mis-specification and bias can also be examined via retrospective analyses - e.g. see Hurtado-Ferro et al. (2014).

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Annex 1: Bibliography of materials provided for review

Lovett R and Northrop A. 2021. Stock assessment of Australian pearl perch (*Glaucosoma scapulare*). Draft DAF Report.

Supplementary data files

SS .dat, .ctl and starter files for the base-case and sensitivity analyses presented in the draft assessment report.