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PILBARA RED EMPEROR SCIENCE REVIEW

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Pilbara red emperor science review

Prepared by Smarter Fisheries Consulting for Pilbara Demersal Scalefish Resource Stakeholders, July 2026

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About Smarter Fisheries Consulting

Smarter Fisheries Consulting provides independent scientific advice and analysis to support sustainable fisheries management and marine conservation.

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Funding and independence

Dr Jonathan Smart is an independent stock assessment scientist. He has worked for multiple state based Australian fisheries jurisdictions as a Principal Research Scientist and now operates independently. He provides scientific assessments and management advice to multiple Australian state, territory and commonwealth agencies, and collaborates with fishery stakeholders and academic institutions. Since 2024, he has worked with stakeholders from the Pilbara Demersal Scalefish Resource (PDSR) to provide independent scientific advice on the implementation of the PDSR recovery plan.

This review was commissioned by PDSR stakeholders. It is an independent report with no caveats except to provide an objective and unbiased scientific review. It was funded by industry as part of Dr Smart's advisory role with PDSR stakeholders that commenced in 2024.

Glossary

B₀ (Virgin Biomass) – The estimated unexploited spawning biomass of a fish stock prior to any fishing mortality occurring. (see spawning biomass)

B_{rel} (Relative Spawning Biomass) – The ratio of current spawning stock biomass relative to its unexploited initial level (B₀), used as a reference point for stock status. (see spawning biomass)

CPUE (Catch-Per-Unit-Effort) – A quantitative metric used as an index of relative fish abundance, calculated by dividing total catch by the amount of fishing effort exerted.

Demographic Reservoir – A protected area or sub-population featuring older, larger, and more fecund individuals that helps sustain the wider stock's reproductive potential.

Demersal – Living on or near the seabed or ocean bottom, referring to fish species or fisheries that target benthic habitats.

Fleet Selectivity – The probability of fish of different ages or sizes being encountered, caught, and retained by a specific fishing gear or sector.

Harvest Strategy – A formalised management framework outlining predefined decision rules and target reference points to ensure a fishery remains sustainable.

Limit Reference Point – A biological benchmark defining a minimum acceptable stock level, below which the stock is considered at severe risk and urgent management intervention is required. In WA the limit reference point is defined as a relative spawning biomass of 20% (B₂₀).

Minimum Legal Size (MLS / MLL) – The legally mandated minimum body length a captured fish must possess to be lawfully retained by commercial or recreational fishers.

MSY (Maximum Sustainable Yield) — The largest theoretical catch or yield that can be continuously harvested from a stock over an indefinite period under constant environmental conditions without overfishing a stock.

Over-Exploitation – A condition where harvesting rates exceed sustainable biological limits, leading to stock depletion and reduced future productivity.

Size Truncation – A change in a fish population's demographic structure characterised by a reduced proportion of larger, older individuals due to excessive fishing mortality.

Spatial Assessment Model – A stock assessment model that divides a fishery into distinct geographic zones to account for localised differences in fishing or population dynamics. (see stock assessment)

Spawning biomass – The component of the fish stock that is mature and contributes reproductively to the population. In two-sex models, spawning biomass is defined as the biomass of females. In single sex models (males and females combined) spawning biomass is the combination of both sexes.

Spillover Effect – The net emigration of juvenile, adult, or larval fish from protected non-fishing areas into surrounding fished grounds.

Stock Assessment – The statistical process of collecting and analysing biological and fisheries data to determine stock size, status and exploitation history.

Stock Synthesis (SS) – An integrated, age-and-length-structured statistical modeling framework widely used globally for complex fisheries stock assessments.

Target Reference Point – A desirable management benchmark representing the ideal stock biomass or harvesting level that maximises sustainable yield. In WA the limit reference point is defined as a relative spawning biomass of 40% (B_{40}).

Targeted Fishery Closure (TFC) – A spatially defined marine area closed to specific commercial fishing activities to conserve habitat or recover protected fish stocks. Area three of the PDSR is a TFC implemented since 1998.

Threshold Reference Point – An intermediate stock biomass level that serves as an early trigger for management adjustments before a limit reference point is reached. In WA the threshold reference point is defined as a relative spawning biomass of 30% (B_{30}).

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1. Key Findings and Advice

Based on the information documented in this review, the current state of the red emperor stock assessment shows that much of the science is uncertain due to missing or conflicting information. As a result, the true stock status (relative spawning biomass) of red emperor cannot be confidently estimated and remains unresolved.

The 2024 stock assessment demonstrated the need for cautious management and a recovery plan was developed using suitable model projections to meet management objectives. Accordingly, there was opportunity in the recovery plan to: 1) address uncertainties and recommendations from an external independent review, and 2) consider new scientific information as stock status is better resolved through future assessments.

The current science is insufficient to justify the permanent closure of the trawl fishery and to disregard the current recovery plan which was co-developed with industry. Contrary to statements provided by DPIRD, the limit reference point was not breached for red emperor when the last stock assessment was undertaken in 2024. Available evidence highlighted in this review shows a strong probability that red emperor remains above the limit reference point due to levels of biomass available in Area 3 of the fishery, which has been closed to fishing since 1998. This closed area was not considered in the published assessment. However, the exact level of relative spawning biomass cannot be determined due to remaining scientific uncertainty. There has also been no scientific research undertaken to demonstrate the necessity nor effectiveness of closing the trawl fishery, and no evidence exists to substantiate the 77% reduction in catch used to justify its closure. Therefore, the magnitude of the management implemented on 1 January 2026 through recent fishery reforms was not justifiable and is unsubstantiated based on available scientific evidence.

It is recommended that:

1. Sufficient resources be directed towards the science program to more confidently determine the stock status of species in the the Pilbara Demersal Scalefish Resource (PDSR).
2. The PDSR recovery plan developed and an implemented in 2024 be reinstated and used to manage the Pilbara trawl, trap and line fisheries. Updates to the recovery plan should also be considered which could include:
 - a. Improved industry engagement through a dedicated working group.
 - b. Consideration of expanded routine sampling of the targeted fishery closure in Area 3 to better inform stock status.
 - c. A commissioned external review of the next scheduled stock assessment to ensure uncertainties highlighted in all existing science reviews have been addressed or acknowledged.

2. General Summary

2.1. Key Considerations

Substantial Unaccounted Biomass in Area 3 (TFC): The Targeted Fishery Closure (TFC) in Area 3 encompasses 2,450 km² and has been closed to commercial fishing since 1998. Independent empirical surveys demonstrated that red emperor abundance and biomass inside the TFC were approximately three times higher than in open areas. Evidence also confirms a positive adult "spillover" to adjacent fishing grounds. Excluding the significant population contribution of this demographic reservoir from the stock assessment heavily biases estimated biomass downward.

Sensitivity of Spatial Model Designs: Preliminary spatial modelling that includes the TFC demonstrated that management advice changed drastically based on conceptual design. Models excluding spatial structure estimated the stock near the limit reference point (20% relative biomass) while models incorporating the TFC and fleet spatial structures place the relative spawning biomass closer to, or above, the target reference point (40% relative biomass).

Flawed Biological and Survey Inputs: Early age-composition data (1983 and 1987) included in the model were collected by historical CSIRO Soela research surveys rather than domestic commercial operations. These surveys used highly selective nets lined with a 10–20 mm mesh to target small fish, resulting in catches where most of the fish were below the modern legal minimum length of 410 mm. Treating these survey catches identically to modern commercial trawl gear (that uses 100 mm mesh) distorts early selectivity trends and artificially skews historical mortality benchmarks.

Misrepresentation of International Review Findings: While DPIRD publicised that its assessments were independently reviewed and endorsed by international expert Professor André Punt, his review was strictly a high-level technical evaluation of the transition to the Stock Synthesis framework. It did not critically evaluate the 2024 red emperor assessment or comment on its appropriate use in management. Several issues with this assessment were highlighted in this review; some of which have been addressed by DPIRD. However, several outstanding issues remain, particularly regarding spatial model structure.

Inability to Estimate Stock Status Undermines Management Decisions: The 2024 assessment relied on a non-spatial model design that is technically incapable of providing a reliable estimate of true stock status, due to uncertainties in historical catch reconstructions, and the contribution of the TFC to stock biomass. By DPIRD's own management framework, severe interventions, such as an outright trawl ban and an immediate 50% catch reduction, are meant to be data-driven responses triggered when a stock breaches explicit biological limits. Implementing management measures of this magnitude based on a model that cannot accurately benchmark the stock against

biological reference points is not appropriate. Major policy decisions are therefore unsubstantiated by scientific evidence.

2.2. Conclusions

Stock assessment updates: This review has raised issues in the stock assessments regarding fleet structure, incorrect use of biological data and uncertainty in historical catch reconstructions. These issues prevent stock status from being reliably estimated and need to be addressed as part of the stock assessment work scheduled in the 2024 recovery plan.

Spatial Integration: The development of a spatial model that explicitly includes Area 3 must be prioritised. This includes a sampling program that can provide the necessary data to support this level of complexity.

Reinstate the Pilbara Trawl Fishery: There has been no scientific evidence presented to justify the closure of the trawl fishery. This management measure is not needed to facilitate stock recovery of red emperor.

Reversion to 38% Plan: The 2024 recovery plan should be reinstated as it was scientifically substantiated to allow optimum stock recovery.

3. Technical Review

3.1. Stock Assessment and Science Updates

3.1.1. 2024 Stock Assessment and Recovery Plan

The red emperor stock in the Pilbara was last formally assessed up and including the 2022 fishing season by Wakefield et al. (2024). The relative spawning biomass of females (B_{rel}) in 2022 was estimated at 21% and the stock was assessed as “Severe risk”. Model projections from that assessment determined that a 38% reduction in catch would allow the stock to recover according to the conditions prescribed by the harvest strategy (DPIRD, 2017). This was implemented through the fishery’s recovery plan, which was co-designed with industry. Part of this recovery plan included a scheduled 2026 stock assessment, and the opportunity to revisit these catch reductions if that assessment provided a different risk rating. Substantial scientific uncertainty was recognised in the recent red emperor assessment (Wakefield et al., 2024) and it is worth noting that the previous 2021 assessment which considered data up to and including 2020 estimated B_{rel} to be at or above 40% depending on how CPUE was treated in the stock assessment (Newman, Wise, Santaro, et al., 2023). Changes in stock status and risk rating of this magnitude in adjacent assessments are concerning and demonstrate that these models require further development and investigation. Hence, the opportunity for the Pilbara recovery plan to be updated accordingly by future assessments should they yield different outcomes.

3.1.2. External reviews

3.1.2.1. Smart (2024) review

In November of 2024, commercial industry stakeholders from the Pilbara trawl and trap sectors commissioned an independent review (Smart, 2024) of the most recent stock assessment (Wakefield et al., 2024). This review supported the stock status determined (B_{rel} = 21% in 2022) by Wakefield et al. (2024) and the resulting management. However, since this review several additional points of uncertainty have become apparent in the 2024 assessment which are highlighted in the current review.

Ten recommendations were made for improving future assessments. Most of these recommendations related to the transition from a bespoke model to the Stock Synthesis framework. However, the incorporation of the targeted fishery closure (TFC) in Area 3, better differentiation of commercial fishing fleets and CPUE standardisation were highlighted as points of concern

3.1.2.2. Punt (2024) review

In August 2024, Professor André Punt was commissioned by DPIRD to provide a technical review of the transition of several stock assessments to Stock Synthesis (Punt, 2024), including the red emperor model presented in Wakefield et al. (2024). This was a technical

review conducted through in person workshops with DPIRD scientists which had four objectives:

- (1) To provide scientific comment on the assumptions and outputs compared for the integrated SS bridging models and bespoke models.
- (2) To provide scientific comment on the preliminary SS extended models and suggestions regarding how to further develop these models to ensure they are optimal for use in future assessments.
- (3) To provide scientific comment on the data inputs currently available for use in stock assessments and suggestions for refining future data for improving future assessments, considering constraints on departmental resourcing and changing fishery dynamics.
- (4) To provide any additional scientific comment or advice that may be useful to assist with the future monitoring, assessment and management of these species.

Importantly, the Punt (2024) review did not critically review nor endorse the findings of Wakefield et al. (2024). Instead, the purpose of the Punt (2024) was to support the transition to the Stock Synthesis for multiple WA demersal fish stock assessments. Objective 3 provided an opportunity to comment on the quality of the inputs to the assessment, which is presented in this review (Punt 2024). However, a technical review of the work presented in Wakefield et al. (2024) was not undertaken as part of the Punt (2024) review. This distinction appears to be misrepresented in press releases provided by DPIRD and Minister Jarvis that stated, “The stock assessments have been independently reviewed by international expert and CSIRO scientist Professor André E. Punt.” In fact, the stock status results of the stock assessments were not commented on or endorsed by Punt (2024).

3.1.2.3. Summary of Key Recommendations

Both the Smart (2024) and Punt (2024) reviews provided a series of recommendations for future research.

The recommendations from Punt (2024) were:

- **Spatial Modelling for Area 3:** Continue developing spatial assessment models to account for the area closed to fishing (Area 3), as there is "good reason" to expect higher relative abundance, considering its relatively large size and long-term closure to fishing since 1998.
- **Stability in Multi-Area Models:** To increase the stability of complex spatial models, represent CPUE as densities and mirror catchability among regions so fished areas can inform the abundance "scale" of closed areas.

- Estimation of Early Catches: Direct research to better reconstruct catches taken by foreign fishing fleets prior to the 1970s, as these significantly influence model outcomes.
- Initial Conditions and Fishing Mortality (F): Modify the model to drop the "initial equilibrium catch" assumption and instead estimate the initial F rate using an informative prior.
- Data Weighting and Conflicts: Fit abundance trends more closely by removing or reducing "extra SD" parameters for CPUE indices, ensuring the model prioritises observed trends over other data signals.
- Biological Parameter Variation: Develop methods to distinguish actual changes over time in growth and maturity from estimation imprecision, potentially using state-space approaches.
- Sex-Specific Data: Attempt to obtain sex information for aged animals to enable the estimation of sex-specific growth for this dimorphic species.
- Age-Reading Error: Analyse multiple reads of otoliths to estimate and account for age-reading error and bias within the model.
- Policy on Spawning Biomass: Establish a clear policy on how stock status is defined when using multi-area models—specifically whether biomass in closed areas like Area 3 "counts" toward management limits.

The recommendations from Smart (2024) were:

- CPUE Standardisation: Transition from nominal CPUE to a formally standardised index to improve reliability and account for spatial/temporal biases.
- Fleet Separation: Maintain separate fleets (Trawl, Trap, Line, and Recreational) throughout the assessment to better account for differing selectivity and harvest impacts.
- Retention Function Adjustments: Adjust the retention function for the period prior to 1991 to account for the lack of a minimum legal size (MLS), preventing the overestimation of historical discards.
- Improved Documentation: Ensure critical model results, such as the unexplained 45% starting biomass anomaly in 1973, are fully documented and justified in the report.

- **Recreational Catch Transparency:** Provide a clearer overview of how recreational catches were calculated and how their post-release mortality is accounted for.
- **Sensitivity Testing:** Use the flexibility of Stock Synthesis to perform more thorough sensitivity testing.

3.1.3. Response to Punt (2024) review

In March 2026, a response to the Punt (2024) review was published by DPIRD (Evans-Powell et al., 2026) which addressed some, but not all, of the comments and recommendations of that review. Additional stock assessment modelling was undertaken to address some of these comments where necessary. As a result of these updated stock assessment models that were further developed during the Punt (2024) review, there are effectively four major versions of the red emperor assessment model. These are (in chronological order):

1. The “bespoke model” originally presented in Wakefield et al. (2024).
2. “SS bridging models” conducted as part of the Punt (2024) review where the bespoke model was converted to Stock Synthesis and other updates were applied as part of this process.
3. “Extended SS models” which were presented in the Punt (2024) response (Evans-Powell et al., 2026). No further work on these models was undertaken following the Punt (2024) review.
4. “Revised SS model” which was presented in the Punt (2024) response (Evans-Powell et al., 2026) following implementation of some of the reviews advice.

Each of these models are referred to where necessary throughout this report using this terminology.

The Punt (2024) response (Evans-Powell et al., 2026) addressed the following recommendations:

- **Implementation of Likelihood Profiles:** Punt (2024) recommended using likelihood profiles for key parameters (R_0 , steepness (h), natural mortality (M), and B_{2023}) to identify which data sources drive model conclusions.
 - Adopted by DPIRD.
- **Initial Fishing Mortality (F):** Punt (2024) recommended estimating initial F with a prior rather than assuming an initial equilibrium catch, which can cause model conflicts.
 - DPIRD modified the model to estimate an initial F (applying a weak prior) and removed constraints on the equilibrium catch estimate.
- **CPUE Trend Fitting:** Punt (2024) suggested removing "extra SD" parameters for CPUE indices to ensure the model follows abundance trends more closely.
 - Adopted by DPIRD.

- **Data Weighting Methods:** Punt (2024) recommended modern weighting techniques to resolve conflicts between data types.
 - Adopted by DPIRD.
- **Historical Catch Reconstructions:** Punt (2024) recommended a better understanding of foreign catches taken before 1970.
 - DPIRD contacted CSIRO and AFMA to obtain more robust datasets and publications, confirming that much higher levels of catch were taken in early years than previously understood. However, these catches still remain uncertain and need better justification.
- **Reporting and Transparency:** Punt (2024) suggested developing a Terms of Reference (ToR) for stock assessment documents and documenting available but unused data sources.
 - Adopted by DPIRD.

Several critical recommendations were explicitly excluded from the 2026 review response or marked for future consideration:

- **Inclusion of Area 3 (fishery closure):** Punt (2024) recommended developing spatial models to account for the higher relative abundance likely found in the closed area.
 - DPIRD explicitly omitted responses to Objective 2 (Extended SS models/Spatial structure) in this publication. They stated that multi-area models are still in development and responses will only be provided when those models are published.
- **Policy Decision on spawning biomass:** Punt noted that using spatial models requires a policy decision on whether biomass in closed areas like Area 3 "counts" toward management limits.
 - DPIRD categorised this as a "policy issue" to be considered separately by departmental staff rather than a technical model adjustment.
- **Sex-specific growth for red emperor:** Punt recommended obtaining sex information for aged animals to account for dimorphic growth.
 - DPIRD stated that obtaining this information is "difficult" because the fishery is remote and dissecting fish to determine sex reduces their commercial value. They are "investigating" alternatives like otolith morphometrics.
- **Age-reading error:** Punt (2024) recommended accounting for age-reading error and bias within the model.
 - DPIRD has not implemented this but currently follows a validation process to minimise error rather than accounting for it directly in the model. They have begun exploring this for WA Dhufish but have not yet implemented it for the Pilbara stocks.

- CPUE standardisation: Punt recommended formal statistical standardisation to improve the reliability of the abundance index.
 - DPIRD stated that while standardisation was done for other species, it has not yet been done for Pilbara Red Emperor; it is slated for the next assessment.
- Rebuilding analysis ensembles: Punt (2024) suggested using SS to conduct rebuilding analyses based on an ensemble of model runs to account for steepness uncertainty.
 - DPIRD researchers noted the suggestion and will "explore these options in future work".

3.1.4. WA State of the fisheries status report updates

Each year DPIRD publishes a state of the fisheries status report. These contain information on key species and reference the most recent science undertaken by the department. A stock status and risk level is also assigned for each stock and/or fishery accordingly. While Wakefield et al. (2024) (presented in the Newman et al. (2024) status report) assessed red emperor as “unsustainable” and “severe risk”, this was a marked departure from the three previous annual reports (Table 1). These assigned a “sustainable” status and a “medium risk” level. They also recommended sustainable catch levels whose upper bound exceeded the combined catches of the trawl, trap and line sectors (Table 1).

Table 1: A summary of stock status and risk levels assigned to red emperor by DPIRD State of the Fisheries Status Reports from 2020/21 to 2023/24.

REPORTING PERIOD	STOCK STATUS SUMMARY	RISK LEVEL	ACCEPTABLE COMMERCIAL CATCH RANGE	ACTUAL COMMERCIAL CATCH	REFERENCE
2020/21	Sustainable	Medium Risk	136–244 t	216 t	(Newman et al., 2021)
2021/22	Sustainable	Medium Risk	136–244 t	192 t	(Newman, Wise, Santoro, et al., 2023)
2022/23	Sustainable	Medium Risk	136–244 t	158 t	(Newman, Santoro, et al., 2023)
2023/24	Unsustainable	Severe Risk	Recovery plan initiated	137 t	(Newman et al., 2024)

3.2. Remaining Scientific Issues and Uncertainties

3.2.1. Targeted Fishery Closure (TFC) – Area 3

3.2.1.1. Description of Fishery Closure

Since 1998, a targeted fishing closure (TFC) has been implemented in Area 3 which constitutes approximately 2,450 km². This closure was established primarily to address the over-exploitation of long-lived indicator species (including red emperor) and the degradation of benthic habitats (Langlois et al., 2021; Sainsbury et al., 1997). This TFC is a separate policy instrument to the recently announced trawl fishery closure in January 2026, and is a key component of fishery management that has been in place for the past 28 years.

Scientific monitoring and mortality experiments conducted in the early 1990s revealed that slower-growing, long-lived species such as red emperor and rankin cod (*Epinephelus rankini*) were being over-exploited at then-current effort levels (Langlois et al., 2021; Sainsbury, 1991). Furthermore, decades of foreign pair-trawling between 1959 and 1990 had significantly modified the seafloor, replacing complex epibenthic structures like sponges and soft corals with sparser habitats, a change linked to a decline in high-value snappers and emperors in favour of lower-value species (Langlois et al., 2021; Sainsbury, 1987). The primary goals for establishing the TFC were to facilitate biomass recovery, allow for the restoration of epibenthic habitats, and provide a scientific reference point to distinguish between fishing impacts and natural environmental variability (Langlois et al., 2021; Sainsbury, 1991). Managers also expected that the cessation of fishing in this area would enhance neighbouring fisheries through the spillover of adult fish and the export of larvae into adjacent management zones (Langlois et al., 2021).

Area 3 was specifically chosen for the TFC as it was situated in the middle of the fishery (Figure 1), a central placement intended to maximise the potential for spillover to both eastern and western management areas (Langlois et al., 2021). This location was also designed to ensure an equitable impact on the commercial fleet by distributing the loss of access across different effort zones (Langlois et al., 2021). Additionally, its offshore position, located approximately 75 to 100 kilometres from the coast (Figure 1), effectively limited access by recreational fishers, ensuring the area functioned as a genuine refuge for the demersal resource (Langlois et al., 2021). The decision-making process was part of a rigorous adaptive management experiment that involved extensive stakeholder consultation between the department, the Western Australian Fishing Industry Council (WAFIC), and commercial industry members (Langlois et al., 2021; Sainsbury et al., 1997).

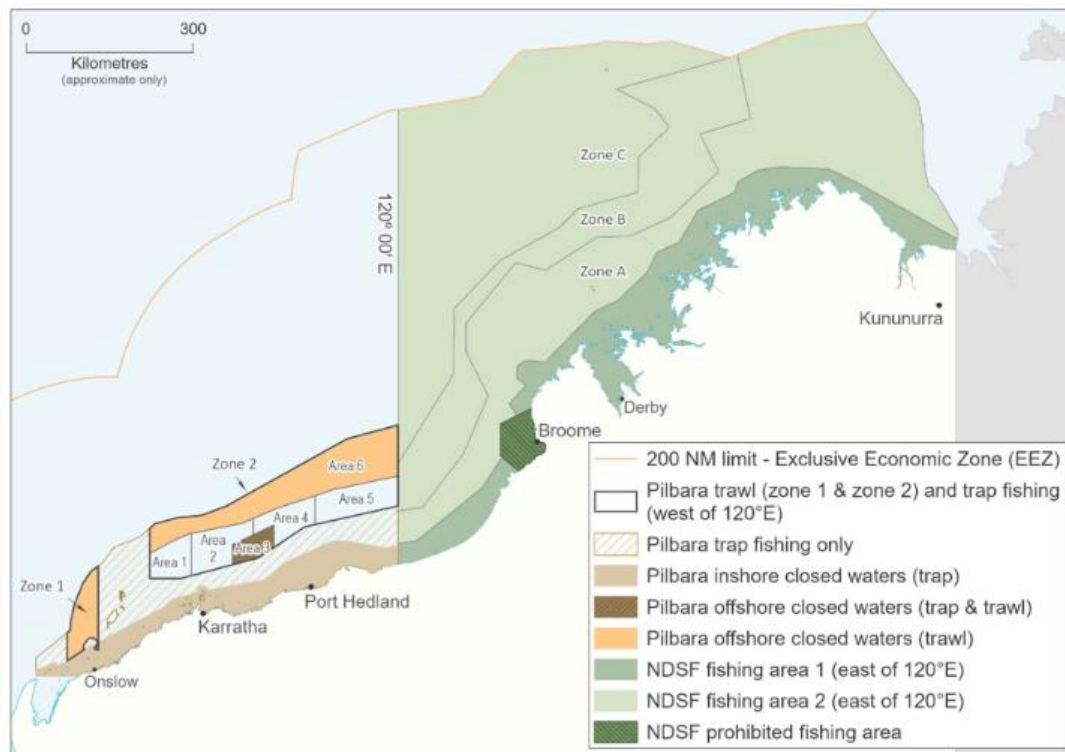


Figure 1: Demersal scalefish fisheries of the North Coast Bioregion of WA. Taken from Wakefield et al. (2024).

While the implementation of the TFC in Area 3 was thoroughly considered and justifiably implemented, it has received insufficient monitoring to determine its effectiveness. This has prevented it from being considered in stock assessment modelling to date. Consequently, its impact on the population was not considered as part of the recent management reforms. This is problematic for several reasons, and the Punt (2024) review recognised that substantial biomass could be in this area and should be accounted for in the population assessments.

The lack of attention on the TFC has likely occurred due to the fishery's 'sustainable' status and 'low to medium' risk assigned up until 2023/24 (Table 1). If these status and risk levels were already achieved without accounting for the TFC, then its consideration in assessments was not strictly needed to inform management. Hence why it may not have been fully considered in assessments previously. However, the updated stock status and risk ratings assigned by Wakefield et al. (2024) now justify the consideration and inclusion of this area in assessments, as the biomass available inside the TFC is likely to be consequential for these assignments and the recent management implemented as a response to them.

3.2.1.2. Effectiveness of the Fishery Closure for Red Emperor

The benthic biota and fish assemblages of the northwest shelf were surveyed across the Pilbara, including the TFC in 2010 (Langlois et al., 2021). This provided an opportunity to examine the impact of the closure after twelve years on the densities of fish species, including red emperor. This survey found that slow-growing, long-lived target species like red emperor and goldband snapper (*Pristimoides multidens*) were significantly more abundant and exhibited much higher biomass within the TFC (Langlois et al., 2021). For red emperor, the abundance and biomass were approximately three times higher within the TFC than surveyed areas that remained open to fishing (Figure 2).

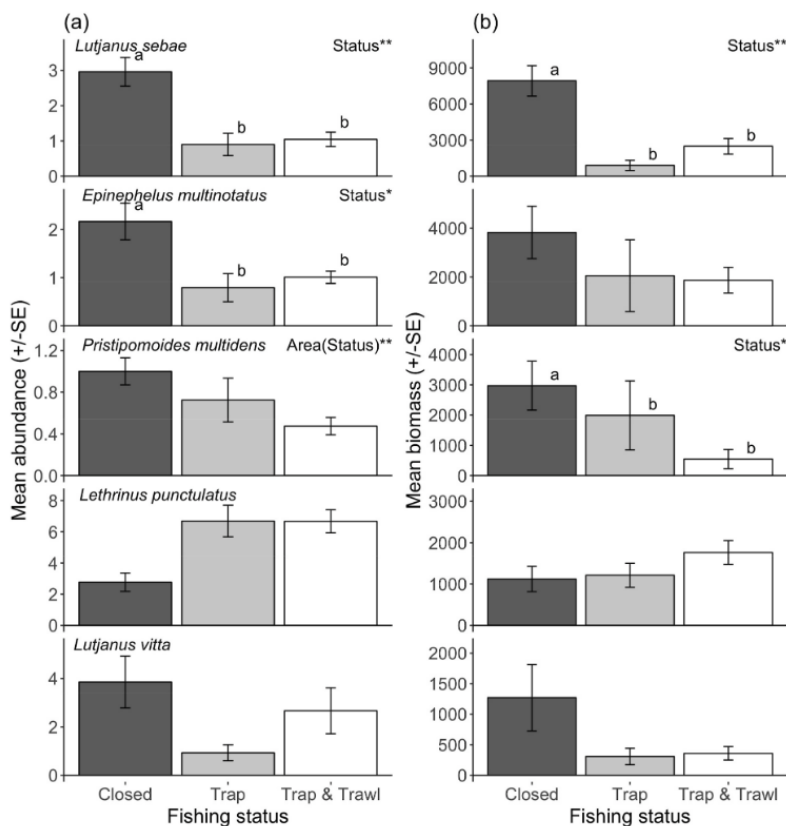


Figure 2: Relative (a) abundance; and (b) biomass (grams) for the two shorter lived and three longer lived target species by fishing status; TFC (Closed), Trap-only (Trap) and Trap & Trawl. Factors of interest in the PERMANOVA model that approached significance (● $p < 0.1$) or were significant (* $p < 0.05$, ** $p < 0.01$) are shown and the results of pair-wise comparisons are indicated by an alphabetic character. Reproduced from Figure 5 of Langlois et al. (2021).

The higher abundances of red emperor inside the TFC have also led to a degree of ‘spillover’ to the surrounding fishing grounds. The spillover effect is the net movement of juvenile and adult fish, and the larvae they produce, to adjacent fishing grounds (McClanahan & Mangi, 2000). This is driven by higher densities achieved within a fishery closure that results in the density dependent emigration of fish, and potentially the increased abundance of spawning individuals that leads to greater reproductive potential and larval supply. Red emperor is an archetypal species for the spillover effect as their broad larval dispersal (van Herwerden et al., 2009) means that these individuals are able to readily supply more distant fished areas. While the provision of larvae to distant areas can be difficult to empirically demonstrate, this is not the case for the spillover of adult fish to adjacent areas. An analysis of trawl CPUE has shown higher catch rates in proximity to both the east and west boundaries of the TFC between 2004 – 2008 (Wakefield et al 2024). Given that CPUE is a strong measure of density (Hoyle et al., 2024) and the evidence of high abundance of red emperor within the TFC (Langlois et al., 2021), this demonstrates that the spillover of fish from the TFC to the surrounding trawl grounds is likely occurring.

Given that red emperor was estimated to have a relative spawning biomass of 21% in 2022 (Wakefield et al. 2024), the consideration of the biomass within the TFC may place the red emperor stock status closer to or above the 30% threshold, rather than below the 20% limit. This was demonstrated by the extended SS models presented by Evans-Powell et al. (2026), which remain the most thorough attempts at including the TFC in the stock assessment model. Extended SS model 2 included the TFC as a distinct area with its biomass estimated separately from the rest of the stock (Figure 3). This version of the SS model estimated a relative biomass for the whole stock to be safely above 20% and increasing through the model projections (Figure 3). Notably, the biomass in the TFC (denoted as area 2 in Figure 3) was almost at 80% of relative spawning biomass. Extended SS model 3 had an even greater degree of spatial structure, incorporating the TFC as well as East and West areas (Figure 3). The west area represents a trap only region, while the east area is a trap, trawl and line fishery (Evans-Powell et al. 2026). The areas presented in Figure 3 were not clearly labelled in Evans-Powell et al. (2026) but from context areas 1, 2 and 3 correspond to west, east and the TFC, respectively.

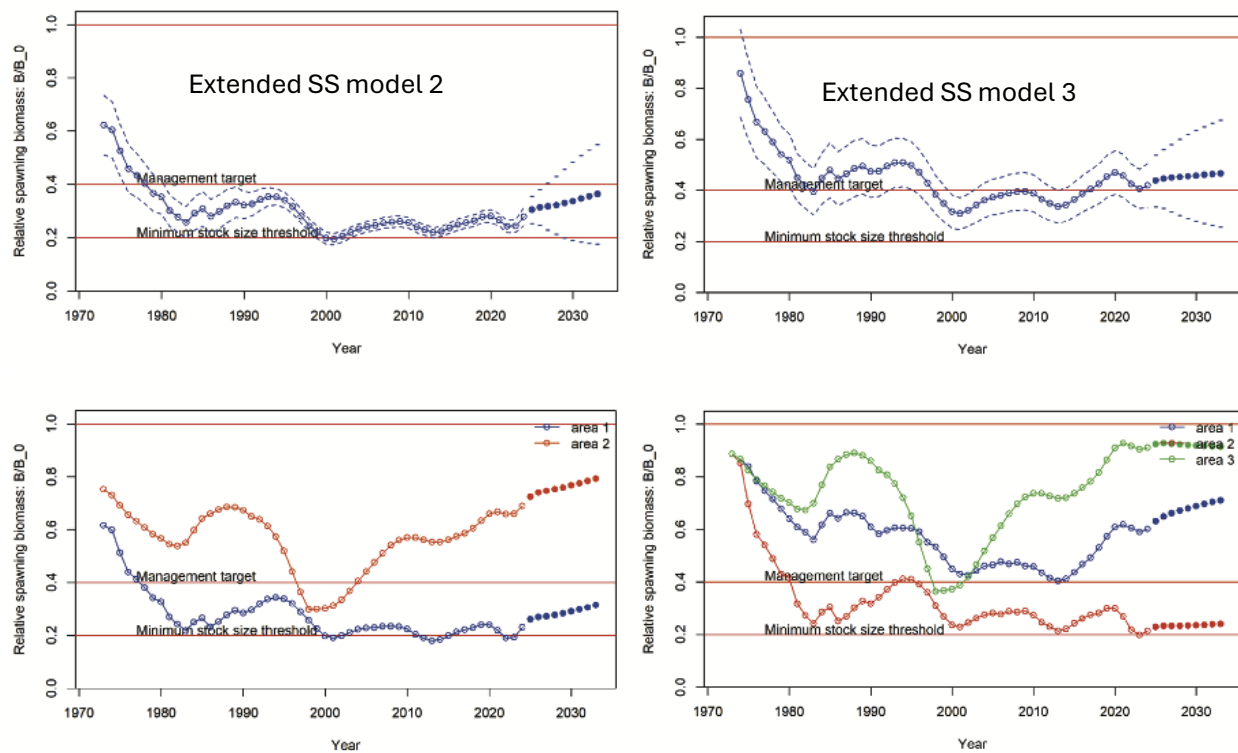


Figure 3: The relative spawning biomass results for the whole stock (top panels) and by area (bottom panels) from Extended SS models 2 and 3 (left and right panels respectively) from Evans-Powell et al. (2026).

The diagnostics of extended SS models 2 and 3 showed that they still require development, particularly with some of the fits to length composition data (Evans-Powell et al. 2026). As a result, the authors seem to have defaulted back to the ‘bridging model’ when developing the ‘revised bridging model’ due to its increased stability. This was a trade-off with model complexity, as simpler models (i.e. ones with less fleet and spatial structure) require less data and tend to be more stable. However, improved stability does not address nor capture whether or not the models conceptual design is appropriate. The extended models presented in Evans-Powell et al. (2026) are an attempt at correct conceptual design and demonstrated the importance of this. If the TFC is included in the model structure (even in a reductive manner) the resulting management advice is substantially different to that of Wakefield et al. (2024). If no spatial structure is considered then the model estimates the stock to be close to the limit reference point ($B_{rel} = 21\%$), adding the TFC estimates the stock to be nearer to the threshold reference point ($B_{rel} > 25\%$) and considering the TFC and fleet spatial structure estimates the stock to be above the target ($B_{rel} > 40\%$).

In summary, it is highly likely that the stock status of red emperor is more positive than the stock status presented in Wakefield et al. (2024) based on the available information on the TFC and its likely effect on population dynamics. Surveys demonstrated that red emperor abundance in the TFC was substantially larger than fished areas (Langlois et al., 2021). Also, preliminary modelling of spatial structure demonstrated a substantial increase in relative

spawning biomass for the whole stock (Evans-Powell et al., 2026). From this evidence, it is highly likely that the stock status presented in Wakefield et al. (2024) is biased low due to the exclusion of the TFC from the assessment. Comments from the Punt (2024) review align with this and the major comment for the red emperor assessment from that review was: “There is good reason to expect that the relative abundance in the closed area is higher than in the areas open to fishing, supporting the use of a spatial assessment model.” From the additional information presented here, this comment is further substantiated.

Consideration of the TFC in the red emperor assessment and science program has been requested numerous times by industry in recent years, largely due to a recognition that this would provide a different stock status if effectively accounted for. The information presented in this section demonstrates why these industry requests were warranted and that the uncertainty in the assessments has been recognised well before this review was undertaken.

3.2.2. CPUE

Catch-per-unit-effort is the primary abundance indicator for the red emperor stock assessment which suffers from limitations due to an exclusive reliance on the trawl fleet (Smart 2024). This fails to capture approximately half of the commercial fishing dynamics for red emperor, whose harvest is roughly equal between the trawl and trap sectors (Wakefield et al. 2024). The omission of CPUE for the trap is compounded by the fishery's spatial structure, as the trawl CPUE index provides a narrow signal from a constrained footprint representing less than 2% of the continental shelf out of a possible 11% that is available to trawling (Amoroso et al., 2018; Harry et al., 2024; Newman, Wise, Santoro, et al., 2023). The trap fishery operates across a much larger area (Figure 1), and this justification was used to switch from trawl to trap sampling for age compositions (Wakefield et al. 2024). However, this same logic hasn't been applied to the fishery's main index of abundance which remains reliant on trawl catch and effort.

To improve the reliability of abundance indices, it is necessary to transition to formal statistical standardisation that accounts for variables such as specific areas fished and skipper experience (Smart 2024, Punt 2024). This is now a standard part of the stock assessment process and is widely used across Australian assessments. DPIRD scientists have recognised this and stated that this work is underway (Evans-Powell et al. 2026). However, this still represents another area of uncertainty and opportunity for improvement in the assessment.

While CPUE standardisation has not been undertaken, efficiency gains of 2-4% have been applied to the CPUE time series. However, there is a lack of documentation justifying the specific values chosen for these efficiency gains, which are used to scale CPUE to biomass in the models (Punt 2024). Furthermore, a conflict exists between departmental assumptions and industry evidence regarding technological drivers; specifically, CPUE increases between 2014 and 2019 were attributed to the adoption of multi-beam sonar, yet industry reports indicate this technology was applied inconsistently across the trap and

trawl fisheries during this period (Smart 2024). Efficiency adjustments should therefore be fleet-specific and subjected to rigorous sensitivity testing to ensure they do not produce overly pessimistic outcomes (Smart 2024).

3.2.3. Early age structures (1982 - 1988) collected by CSIRO surveys

Wakefield et al. (2024) present age structures from 1983 – 2007 from the “trawl fishery” which are key data input to the stock assessment model. However, the first two samples (1983 and 1987) were not collected from the domestic trawl fishery, but rather surveys conducted by CSIRO onboard the Soela survey vessel. Information on these CSIRO surveys showed large differences in the gear used in comparison to modern day trawl fishing, leading to very different length and likely age selectivity’s. For example, the CSIRO survey used trawl nets that had the cod-end lined with 10-20mm mesh to retain small fish as they were assessing community compositions (Liu et al., 1985). The modern trawl fishery is very different to this as the minimum mesh size is 100mm (Government of Western Australia, 1997).

There is some recognition of this issue in the extended modelling section of the Punt review response (Evans-Powell et al., 2026), where the authors included length-based selectivity as well as age-based selectivity in the extended models. When applying this they noted:

“For these comparisons, composition data for fish below this length are not included in the model, i.e. below the legal limit. For a few years, some fish in samples were considerably smaller than the size limit, likely associated with opportunistic sampling for biological studies. A refinement to the model would be to include 2 periods for retention, to account for the MLL being introduced in 1991 (i.e. prior to this period, it appears reasonable to assume that, for early years, all fish were retained. This would also mean any of the smaller fish in the two earliest composition samples could be included in the model.”

This information indicates that small fish are currently included in early composition data of the 2024 stock assessment (Wakefield et al. 2024) when they should not be. The authors have recognised this issue and the bias that it causes and have begun considering how to address this. However, this issue likely goes beyond the need for a different retention and instead requires a separate selectivity for these surveys as well as the foreign fishing fleets that were operating up to and including the 1990’s. Stock assessment models are strongly influenced by the removals and fishing mortality at the beginning of their time series (Stacy, 2023). Therefore, these necessary updates may change the estimated biomass in the early years of the time series and will therefore impact the stock status estimated in recent years. Accounting for these differences in selectivity should be a priority for future work.

3.2.4. Fleet selectivity

Currently, all versions of the red emperor models, with the exception of the revised bridging model and extended SS model 1, had a combined commercial fishing fleet regardless of gear type. Extended SS model 1 separated the commercial fleets into trawl, trap and line

sectors which is a better reflection of real-world dynamics (Evans-Powell et al., 2026). However, in this model the trawl fleet still remained a combination of 1) the modern trawl fleet, 2) CSIRO benthic surveys and 3) multiple foreign fleets, predominantly Taiwan and Japan (but also Korean, Russian and Chinese). The revised bridging model has a separate fleet for the foreign trawlers and a combined commercial fleet for the three sectors.

The bespoke stock assessment model (Wakefield et al., 2024) handled selectivity very reductively, by combining all fleets together into a single catch series. Likewise, all of the age composition information has been amalgamated into a single commercial fleet, which did not consider separate fleet selectivity's. There are three phases of age composition collection in the assessment: 1) early age structures (1983 and 1987), 2) Pilbara trawl sampling (1997 – 2007), and 3) Pilbara trap sampling (2015 onwards) (Figure 4). A single year of overlapping age structures was collected from both the Pilbara trawl and trap sectors in 2010 which was used to determine the differences between these sectors. This showed near identical age compositions from each of these sectors in that year, which demonstrated limited impact by their combination (Smart, 2024). However, this analysis only considered retained fish above legal size, and thus differences in the selectivity for sublegal fish have not been compared. This remains an area of uncertainty.

A key difference between the trawl and trap sectors is that the trap fishery can operate over a much larger area (Figure 1). This was a reason for the switch from trawl to trap for biological sampling (Wakefield et al., 2024), but also demonstrates the need to consider a different selectivity for the trap fleet given that spatial structuring of red emperor can occur, and may bias the age compositions if not accounted for. Additionally, no dimensions or specifications for fish trap slots are listed in the Pilbara Trap Fishery Management Plan (Government of Western Australia, 1992), and operators have been experimenting with new designs in recent years (D. Gibson, pers comm.). This will affect length and age compositions for this sector going forward and likely requires time-varying selectivity to be considered in future assessments.

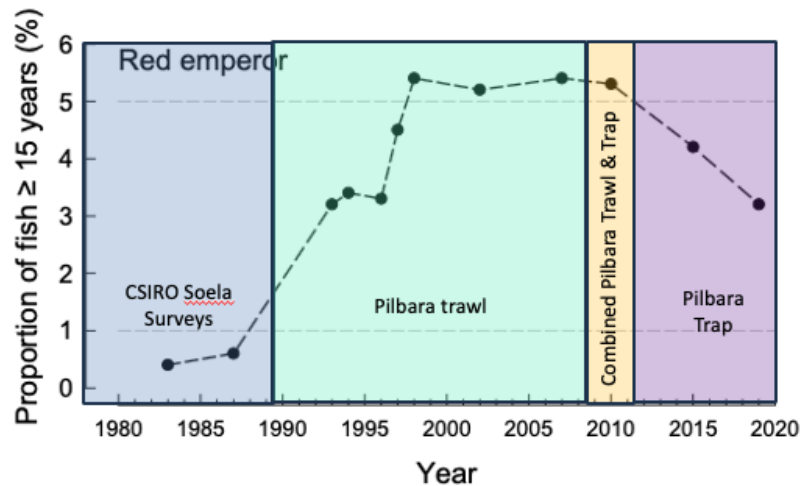


Figure 4: The proportion of red emperor that were 15 years or older in each year's age samples. Adapted from Wakefield et al. (2024) to show the source of age compositions through time with coloured shading.

The fleet selectivity for red emperor not only differs between the domestic fleets, but also for surveys and foreign fleets from the 1950's to the 1990's. There is substantial information on the fishing dynamics of these fleets documented by CSIRO research during the 1980's and 1990's. From this research, we know that Taiwanese trawlers had a mesh size of 45 mm that increased to 60 mm in 1981 (Sainsbury, 1984). This fleet constituted the majority of the early foreign fishing effort, and these gear specifications could be used to better characterise the difference in selectivity between the foreign and domestic fleets. Selectivity trials conducted with these fleets demonstrated that red emperor were fully selected by mesh sizes less than 70 mm (Liu et al., 1985). However, the regulated mesh size of the domestic trawl fishery is 100 mm and a legal size limit for red emperor has been set at 410 mm TL since 1991 (Government of Western Australia, 1997). Therefore, the selectivity of both the foreign trawl fleet and the CSIRO surveys would have been different to the domestic trawl fishery, retaining considerably smaller fish. This is important to capture in the population dynamics as heavy fishing of juveniles is often detrimental to fish population growth (Vasilakopoulos et al., 2016). However, it also highlights issues with the age structures collected by the CSIRO Soela cruises (discussed in Section 3.2.3) which contained far fewer older fish by proportion than the domestic trawl fishery (Figure 4).

The proportion of old red emperor in age compositions has changed through time (Figure 4) and the largest differences have occurred when the source of the samples has changed. There is substantial evidence to demonstrate that compositions from the 1980's would have a different selectivity to the rest of the time period, which is not currently recognised in any of the stock assessments presented to date. While the dual fleet sampling during 2010 suggests that the domestic trawl and trap sectors have similar age selectivity's, under-sized fish that were discarded are not included in analyses and this requires further investigation. Therefore, while the change from trawl to trap sampling could be coincidental, an

examination of this is still required. The simplest way to account for this would be the separation of the domestic trawl and trap fleets in all future stock assessment models.

Accurate specification of selectivity is critical in fisheries stock assessment models, as it determines how different age or length classes are represented in the catch and thus influences key management quantities. Mis-specification of selectivity, particularly when combining multiple fleets with distinct selectivity patterns into a single fleet, can introduce significant biases in estimates of stock status, fishing mortality, and sustainable yield. Simulation studies and empirical analyses have consistently showed that such mis-specification leads to estimation bias, data conflicts, and can result in unreliable management advice (Cheng et al., 2024; Punt et al., 2014). Multi-fleet models generally perform better at capturing true dynamics when sufficient data are available, while single-fleet models risk masking important differences if fleet-specific selectivity is ignored (Cheng et al., 2024). Consideration of different fleet dynamics can be difficult in bespoke models, such as the one presented in Wakefield et al. (2024), as the addition or removal of fleets requires a large amount of programming, costing valuable time and potentially introducing human error. However, the recent transition to Stock Synthesis removes this barrier, hence why it has been pursued and strongly recommended for WA fisheries assessments (Punt, 2024; Smart, 2024). Subsequently, different fleet structures have been investigated since Wakefield et al. (2024), although none of these have sufficiently differentiated the different commercial sectors and gears (Evans-Powell et al., 2026). Extended SS model 1 (which separates trawl, trap and line sectors) is the best approximation of the true fleet structure, but differences in selectivity for the foreign trawl fleet and the CSIRO Soela surveys have not been included (Evans-Powell et al., 2026). These selectivity's are likely to be the most substantial of the commercial gears and needs to be considered in future stock assessment model development.

3.2.5. Uncertainty in foreign catches

While the total catch, effort and CPUE of foreign fleets that fished until the 1990's has been reasonably well documented (Liu et al., 1985; Sainsbury, 1984, 1987), most catch summaries only provided information to family level, or grouped species based on size or similarity (e.g. 'large snappers'). The true catch of red emperor by these foreign fleets is unknown due to a lack of species-specific reporting. Therefore, catch reconstructions of red emperor are needed in order to incorporate these harvests in the stock assessment. An inherent issue with this is that these catch reconstructions are provided to the model as data, rather than estimates and any error or uncertainty of these values are not propagated through the model. This is a common issue with stock assessments and is not a specific short coming of the red emperor modelling undertaken to date (Evans-Powell et al., 2026; Wakefield et al., 2024). However, the uncertainty that is created through this short coming must be considered via sensitivity analyses and acknowledged in resulting management. The former has occurred as Evans-Powell et al. (2026) have conducted sensitivity testing on historical catch series (Figure 5).

Results presented in the Punt (2024) review response by Evans-Powell et al. (2026) provide predictable outcomes when levels of historical foreign fishing is adjusted. Depending on the direction of bias, the following occurs:

Underestimated historical catch will produce lower estimates of virgin biomass (B_0) and consequently absolute biomass. However, the relative biomass throughout the time series will be higher and more optimistic. Essentially, underestimating historical catches can mask overfishing.

Overestimated historical catch will produce a larger B_0 and maximum sustainable yield (MSY), as the model needs to estimate a larger population size to accommodate higher harvests. As the virgin population size is bigger, relative biomass is lowered across the timeseries even if the absolute biomass would be larger than that caused by underestimating historical catch.

These results have been consistently demonstrated by simulation studies (Feltrim & Dias, 2025; Hordyk et al., 2019; Rudd & Branch, 2017) and real world examples exist where overfishing has been masked by catch underreporting (Van Beveren et al., 2017). Results from one of the sensitivity analyses for red emperor demonstrates this effect (Figure 5). Here, the higher the levels of historical catch included in the stock assessment model, the more pessimistic the relative biomass was (Evans-Powell et al. 2026; Figure 5). Unfortunately, B_0 nor estimates of absolute biomass were presented for these models. However, it is likely that these would have matched the descriptions above with larger B_0 and absolute biomass estimates occurring with increased levels of historical catch.

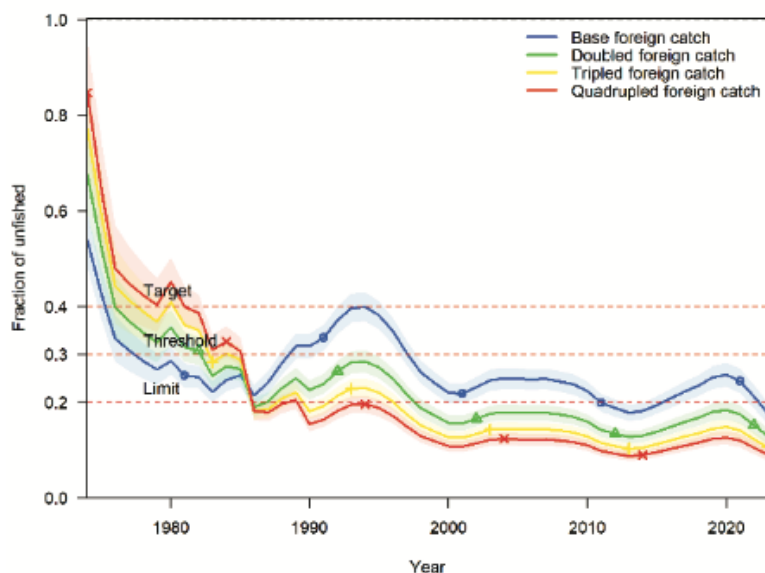


Figure 5: Sensitivity scenarios that arbitrarily change historical foreign catch reconstructions. Presented as Figure 1.4 in Evans-Powell et al. (2026)

Currently, management reforms have relied on the accuracy of relative biomass in 2022 being estimated at 21%. However, our mechanistic understanding of how stock assessments respond to imprecise estimates of historical catch, coupled with a demonstration that the red emperor model behaves in this way (Figure 5), demonstrates that relative biomass in 2022 is too uncertain to base the recent permanent and irreversible management decisions over. Evans-Powell et al. (2026) state that it is likely that historical catches are higher than those originally included in the stock assessment by Wakefield et al. (2024). However, this observation was based on improved fits by higher historical catches to the early age compositions. These are themselves uncertain, and as discussed in Section 3.2.3, should not be included in the stock assessment model in the manner they are currently. Evans-Powell et al. (2026) also state that further review of historical catches is ongoing in order to determine the most likely harvest levels of red emperor by foreign trawl fleets. Given the importance of this information to the stock assessment demonstrated here, this review of historical catches should be completed before any stock assessment results can be used in management. Consideration of the appropriate use of early age compositions should be a part of this process.

3.3. Conclusions

3.3.1. Assessment uncertainties

A number of assessment uncertainties were highlighted by previous reviews for the red emperor stock assessment (Punt, 2024; Smart, 2024). While some of these uncertainties have been investigated by Evans-Powell et al. (2026) in their response to the Punt (2024) review, a number of key uncertainties still remain. This current review has provided an in-depth exploration of some of these key areas which are outlined in Section 3.2. The current model uncertainties and their impacts include:

Lack of model spatial structure: This ignores the positive benefit of a targeted fishery closure (TFC) in Area 3 which protects fish stocks and benthic structure across a large area. Available evidence demonstrates that the TFC implemented in 1998 has a positive impact on red emperor populations which is not included in the main scientific assessments. In particular, both absolute and relative biomass are underestimated without considering this area in a spatial model. This is supported by initial spatial models developed by DPIRD (Evans-Powell et al., 2026), advice from André Punt (Punt, 2024), and scientific literature published by WA fishery scientists (Langlois et al., 2021).

Incorrect source for early age structures: A consistent oversight across all the models is the inclusion of age compositions from 1983 and 1987 as domestic trawl samples. In fact, these samples came from CSIRO research cruises exploring benthic community compositions on the northwest shelf. While these samples were collected from trawls during the survey, the gear used was markedly different from the domestic trawl fishery. This would over sample smaller fish and present age structures that appear truncated. This explains some of the issues that the bespoke and SS models had to fitting these early age structures at the beginning of the time series.

Uncertainty in foreign catches: The largest harvests of red emperor have occurred from foreign fishing fleets from the 1950's to 1990's but these were not well documented and require catch reconstructions. These fleets did not record species specific information and had different fishing gears to the modern-day trawl fishery which has a different selectivity. Uncertainty in these catches is a significant barrier to estimating stock status. Stock assessment models are sensitive to harvests at the beginning of the time series as these influence estimates of B_0 . This introduces uncertainty into stock status as estimated as B_0 divided by current biomass.

Fleet selectivity: Fleet structures have not been correctly specified across any models conducted by DPIRD so far (five models in total, not including sensitivity analyses). There should be four commercial fleets in total: foreign, trawl, trap and line, as well as a survey fleet that collected age structures in the 1980's. A further survey fleet is required for trap sampling conducted in Area 3 when spatial models are considered. While selectivity between the domestic trawl and trap fleets may be similar, the selectivity between the foreign and domestic trawl fleets is likely different due to distinct mesh sizes, as well as a minimum legal size implemented in 1991. The combination of fleets with different selectivity's within the stock assessment model will likely lead to errors and should be addressed as quickly as possible.

3.3.2. Ability to estimate stock status

It is clear that the stock assessment models conducted to date have not accurately estimated stock status based on the information presented in this review, as well as comments provided by the Punt (2024) review. This is not due to lack of effort or scientific expertise on the part of DPIRD scientists, but the information (or lack thereof) that is necessary to accurately estimate virgin biomass (B_0).

The science available for red emperor in the Pilbara has several sources of uncertainty that creates uncertain estimates of B_0 . However, uncertainty in foreign catch reconstructions is the most significant issue preventing an accurate B_0 from being confidently estimated. One issue with reconstructing catches of large and uncertain volumes is that they require corresponding magnitudes of B_0 in order to explain their existence. This has a direct effect on stock status as current biomass levels may be well estimated, but dividing these by a large B_0 estimate will negatively bias virgin biomass. This is demonstrated in Figure 6, where two simulated and hypothetical stocks with similar absolute biomasses in recent years have different B_0 estimates. As a result, the stock with higher B_0 has a worse stock status, despite the current biomass estimate being a similar tonnage (Figure 6). This same effect is likely occurring in the Pilbara red emperor models as a result of uncertain historical catch (Section 3.2.5), incorrect inclusion of early composition data (Section 3.2.3) and oversimplified fleet selectivity's (Section 3.2.4).

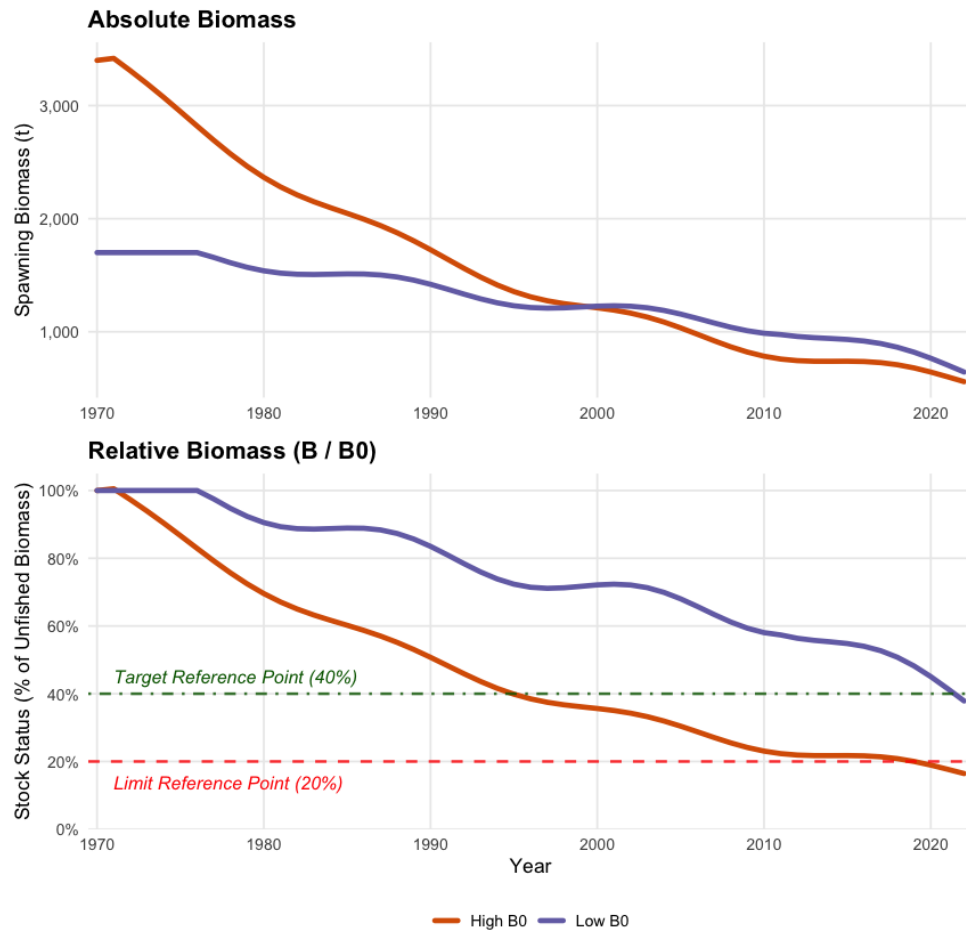


Figure 6: Theoretical diagram of two hypothetical stocks that have similar levels of recent absolute biomass but different virgin biomass (B_0) estimates. Note the impact this has on stock status (bottom plot)

A further issue preventing stock status from being estimated is the uncertainty surrounding the TFC in Area 3. The biomass in this closed area has had substantial protection and is likely at much higher levels than the fished areas (Punt 2024). However, this needs to be included in the stock assessment models to account for these effects. This, coupled with the uncertainties just highlighted on catch reconstructions, creates further complications for the assessment as not only is B_0 difficult to estimate, but so is current biomass if the recovery of red emperor in the TFC is not accounted for.

As a result of these issues, a stock status cannot be reliably estimated. This was highlighted by Punt (2024) who observed:

“The ability to estimate stock biomass relative to unfished stock biomass is less certain than initially anticipated, with the analyses, for example, reliably estimating spawning biomass but not spawning biomass relative to unfished spawning biomass, owing to incomplete time-series of historical catches coupled with a the-then necessary assumption about initial

fishing mortality. This was the case for all three stocks, but particularly the case for Pilbara red emperor.”

And;

”All of the models exhibited considerable sensitivity of the “scale” of the time-trajectory of spawning biomass relative to the unfished level even though spawning biomass in absolute terms was estimated well. For example, the initial status of the Pilbara red emperor stock changed substantially when first two age-compositions (1983 and 1987) were dropped from the model. This feature of the results relates to how status in the first year is determined.”

3.3.3. Appropriate management response

Given the uncertainty in stock status estimated from the existing stock assessment models, it was inappropriate to base long-term and irreversible management decisions on these model outputs. Instead, the recovery plan implemented following the publication of Wakefield et al. (2024) should have been maintained. This was justified as:

- The stock status of 21% estimated by Wakefield et al. (2024), while uncertain, was concerning and the cautious management outlined in the recovery plan can be justified.
- Model projections conducted by Wakefield et al. (2024) were used to inform the long term catch reduction of 38% which would recover the stock in line with guidelines in the harvest strategy (DPIRD, 2017).

The recovery plan included a scheduled re-assessment in 2026 which would inform any updates to the recovery plan and the continued appropriateness of the 38% catch reduction of red emperor. Given the volatility of stock status changes through time (Table 1), this would reaffirm or update the need for this 38% catch reduction, which is already a conservative reduction given that the lower confidence intervals (i.e., the worst case scenario) of the model projections achieved the 20 year recovery target.

The current fishery reforms enacted on 1 January 2026 have gone beyond what was necessary and are damaging to the industry and WA communities that rely on access to seafood from the Pilbara Demersal Scalefish Resource (PDSR). A 50% reduction in catch was larger than the science recommended (Wakefield et al. 2024). Meanwhile, the permanent closure of the trawl fishery had no scientific basis and the 77% reduction in catch needed to justify this decision has not been factored into any stock recovery projections. The permanency of this management reform does not provide the opportunity for the scientific uncertainties highlighted in this review, as well as Smart (2024) and Punt (2024), to be addressed. The magnitude of management response is therefore not justifiable and was unsubstantiated by scientific evidence.

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