Fisheries New Zealand
Tini a Tangaroa

Review of Red Rock Lobster Stock Assessment Modelling and the Determination of Management Reference Points

New Zealand Fisheries Science Review 2024/01

S. de Lestang,

M. Haddon,

S. Hoyle

ISSN 2382-2406 (online)

ISBN 978-1-991308-56-6 (online)

August 2024

Te Kāwanatanga o Aotearoa
New Zealand Government

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Fisheries New Zealand

Ministry for Primary Industries

PO Box 2526

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NEW ZEALAND

Email: Fisheries-Science.Editor@mpi.govt.nz

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Please cite this report as:

de Lestang, S.; Haddon, M.; Hoyle, S. (2024). Review of Red Rock Lobster Stock Assessment Modelling and the Determination of Management Reference Points. New Zealand Fisheries Science Review 2024/01. 28 p.

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PLAIN LANGUAGE SUMMARY

An international panel met in July 2024 to review the Rock Lobster stock assessment model, the associated biological reference points, Management Procedures, and the Rapid Assessment Updates that have been used in recent years. This report is their summary of their deliberations, with 25 recommendations for future work. The panel endorsed the Lobster Stock Dynamics (LSD) modelling framework as a sophisticated state-of-the-art modelling approach, utilising the latest statistical methods with excellent performance. Its continued use was strongly supported with further development and recommendations outlined in this report. The highest priority recommendation was to improve the consistency of data collected through the Electronic Recording System (ERS) and to ensure that all data streams required for stock assessment are being collected.

EXECUTIVE SUMMARY

de Lestang, S.; Haddon, M.; Hoyle, S. (2024). Review of Red Rock Lobster Stock Assessment Modelling and the Determination of Management Reference Points.

***New Zealand Fisheries Science Review 2024/01.* 28 p.**

An international, fully independent Panel of three scientists met in July 2024 to receive and evaluate information on the Rock Lobster Stock Assessment Model, the associated biological reference points, the Management Procedures, and the Rapid Assessment Updates that have been used in recent years, with 25 recommendations for future development and improvement. The panel endorsed the Lobster Stock Dynamics (LSD) modelling framework as a sophisticated state-of-the-art modelling approach, utilising the latest statistical methods with excellent performance. Its continued use was strongly supported with further development and recommendations outlined here. This report is an independent summary of our deliberations and recommendations for future work.

Recommendations

High Priority

1. The highest and most immediate priority is to ensure that all data streams required for stock assessment are being collected, and to improve the consistency of the data collected through the Electronic Recording System (ERS). Delays in modifying the ERS collection will result in further data being lost unnecessarily.

Medium Priority

2. Prior to future assessments it would be warranted to conduct a meta-analysis on all data sets to ascertain a contemporary understanding of key biological traits and whether these vary spatially or temporally.
3. In future assessments it would be warranted to examine vessel within the standardisation process for length composition and sex ratio data sets.
4. In future assessments it would be warranted to re-formulate growth based on tag-recapture data to incorporate tag-release date and the annual moulting synchronicity.
5. Discussions should occur with the commercial fishing industry to gauge their interest in developing co-managed annual independent surveys across the quota management areas.
6. The assessment team should consider using a weight of evidence approach in future full assessments.
7. Consider using an ensemble approach to develop management advice, particularly in cases with large unresolved structural uncertainties.
8. There would be benefit in generating additional model diagnostics, including likelihood profiles on R_0 and natural mortality, to help understanding of which data sources are driving model outcomes.
9. It may be useful to transition to TMB in the short term rather than spend time developing new features in Stan that would then need to be redeveloped in TMB.
10. The proposed change to reduce the number of sexes from three to two should be prioritised among model structural changes.
11. The proposed changes to modelling selectivity may considerably improve model fits and the range of hypotheses that can be modelled. The highest priority is to implement changes that allow multiple fleets in the same region.
12. Of the proposed changes to recruitment estimation, priority is recommended for estimation of the recruitment size distribution.
13. There appear to be no good reasons to change the currently defined soft and hard limits in the red rock lobster fishery, and there are reasonable defences for their retention, so no changes need to be considered.
14. The defence presented for using the estimated vulnerable biomass as the target reference point needs to be developed further to clarify the reasons for and advantages of its adoption over the better-known default proxy of 40% B_0.

15. As well as considering how well the novel VB_R performs, in terms of avoiding the soft limit, once its associated U_R has been identified, its performance relative to a similarly identified $U_{40\%B0}$ should be compared so that direct comparisons can be made between using VB_R or 40% B_0 as the target reference point.
16. The uncertainty captured by utilising the MCMC replicates and sampling projection recruitment deviates from the (lognormal) recruitment deviates estimated by the assessment model should be characterised in more detail, to demonstrate that the VB_R estimate is not compromised by the variation around the soft limit reference point estimate and that there is realistic fluctuation of vulnerable biomass around the target through time.
17. Compare the use of VB_R as an absolute estimate, as it currently is, with a ratio relative to the unfished AW adjusted vulnerable biomass, or some other measure, to determine whether the ratio estimator is more stable than the absolute.
18. Produce a review or discussion to provide a convincing defence for using the arithmetic average between the estimates from the two strategies of a constant catch and a constant harvest rate: $VB_R = (VB_{RC} + VB_{RU})/2$.
19. Produce a review or discussion to provide a defence for accounting for the objectives that target reference points are intended to meet, making the case that the estimated vulnerable biomass target reference point is not as arbitrary as selecting 40% B_0.
20. The objectives behind developing the management procedures should be made explicit, in particular, whether their intent is likely to increase risk to the stock.
21. The use of the management procedures appears to be inherently risky. Either find a way to demonstrate that increased risk is not occurring or only use the management procedures to keep the TACC stable or to decrease it.
22. The objectives behind developing the Rapid Update Assessments should be made explicit especially if they lead to an increased risk to the stock. If they are used to modify the TACC then the implied control rule used should also be made explicit.
23. As with the management procedures, either find a way to demonstrate that increased risk is not a problem if the Rapid Update Assessments are used to increase TACC, or, only use them to either keep the TACC stable or decrease it.
24. Amend the process of utilising the Rapid Update Assessments so that if the assessment indicates that catches remain stable then a very simple report and a single agenda item at an Assessment Working Group meeting is required (attendance by the assessment scientist need not even be required). Only if a decrease in TACC is implied should a more detailed report be presented.
25. If the Rapid Update Assessments are amended to only allow for stability or reductions in TACC then, because they use more than just CPUE, these are to be preferred over the Management Procedures as a way of managing the resources in between full assessments.

1. TIMELINE OF REVIEW

Over the week of 22–26 July 2024, Fisheries New Zealand gathered an independent panel of experts to review the stock assessment modelling of rock lobster (*Jasus edwardsii*) around New Zealand along with the estimation and application of the associated management reference points used in the harvest control rule. The panel consisted of Drs de Lestang, Haddon, and Hoyle. The first two days were spent in sessions in which an array of presentations were made about the structure and application of the recent assessment model and associated reference points. The presentations on the first day were made by Dr Darcy Webber, who both developed and has applied the stock assessment models. On the second day presentations were made by Dr Darcy Webber and Dr Merrill Rudd.

These two open sessions were attended by representatives of scientific, management and industry organisations, with a list of attendees provided in the Appendices, along with the Formal Terms of Reference for the review, and the agenda.

The third and fourth days constituted private workshop sessions among the review panel during which they developed a draft version of the present report. The panel continued to interact with and seek advice and clarifications from the assessment team and others. On the final day of the review, Friday 26 July 2024, the panel presented the draft report and invited discussion and further elaboration in an open session. This report was finalised following that discussion.

2. PRIMARY OBJECTIVES

2.1 TOR 1: Lobster Stock Dynamics (LSD) modelling framework

2.1.1 Data

The assessment incorporates all available forms of data (all derived from fisheries-dependent sources). Data is collected and stored by both the industry (voluntary logbooks) and Fisheries New Zealand. Data is sourced by the assessment team through data requests, with some minor delays occurring with some data sets. High quality metadata descriptions are available for all data sets (Mackay & George 2002, Walker & Mackay 2002, Mackay & Wood 2010, EDW Fisheries Data Dictionary External Users_v3).

Electronic data collection (ERS) was implemented in 2019 to replace paper-based CELR forms (both systems collect fishers' catch and effort data including catches that are discarded (high-graded, non-legal) and stored in holding pots). As such these two data collection tools are vital for determining commercial fishing CPUE. For the ERS at least three different software platforms are currently available to rock lobster fishers. Unfortunately, there appear to be discrepancies in how the data requirements have been interpreted across platforms, and there may also be a problem with the specifications provided to the software developers. As such, analysing and developing indices useful for input into the model from the ERS data stream has proved both challenging and ultimately inadequate due to omissions in the data collected. The assessment team surmised that, for the ERS data, one of the three platforms being used by industry produced data more applicable for stock assessment, and that data from none of the three platforms produced information that was on a scale relative to that derived from the CELR paper submission system. A result of this has been a break in the CPUE time series, and due to the recency of the ERS implementation (and variation between platforms), no new CPUE series has been able to be developed from the ERS. Additionally, there is some indication that, due to the way the data is being captured by different fishers using the same platform, it may not be possible to build a consistent time series from the current ERS dataset.

Recommendation 1 The highest and most immediate priority is to ensure that all data streams required for stock assessment are being collected, and to improve the consistency of the data collected through the Electronic Recording System (ERS). Delays in modifying the ERS collection will result in further data being lost unnecessarily.

2.1.2 Meta analysis

The biology of the red rock lobster has been shown to vary markedly throughout New Zealand, with size at maturity, timing of reproduction and moulting as well as the rates of natural mortality and growth all varying spatially (MacDiarmid 1989, Fisheries New Zealand 2023). It is vital that the assessment team have a thorough understanding of this variation and whether there exist consistent spatial patterns. Global examination of the available data streams searching for spatial and temporal trends in the various indices (such as size at maturity) can be extremely useful to inform (1) model design, (2) appropriate model priors, and (3) model diagnostics (reality checking).

In its current form, the model is structured to run annually with two timesteps (autumn/winter (AW) (Apr-Sep) and spring/summer (SS) (Oct-Mar)) per year. This temporal structure is completely appropriate so long as it aligns with the biology being replicated in that area. The fact that biological processes exhibited by the red rock lobster do vary north to south suggests that the seasonal split within the model could be aligned with this variation and changed between quota management areas as required. For example, the model's current process within each timestep is to remove animals (natural mortality and fishing), apply growth, maturation, movement, and add new recruits (Webber et al. 2023). Under the seasonal model (AW, SS) this implies that growth is applied to both female and male cohorts at the start of the AW and SS timesteps. However, previous records of moulting frequency showed that males moulted mainly in October/November and females (in the north of New Zealand) mainly in April/June (MacDiarmid, 1989). As such, a better model structure could be to limit growth to only females during the AW season and males only in the SS season.

The model contains priors for all estimated parameters, with many of these being "relatively uninformative" and not substantially influencing parameter estimation. This is appropriate when little knowledge exists for a parameter. However, it can also allow parameters to become unrealistic. In the assessment of CRA 3, the model's estimate for natural mortality in region 1 is high (0.35) when compared to reported levels of M for other long-lived lobster stocks or to general longevity-M equations (Hoenig, 1983). As such, the assessment team have tightened up the associated prior to drive the estimation of M towards a more realistic level. If a meta-analysis examining M around New Zealand showed a spatial trend, an estimated value for M could be used for this prior applied in QMA 3.

Potential meta-analyses that may prove valuable to the assessment team include:

- Examination of the voluntary logbook data. Do the spatial locations of logbooks change over time and does this data match the spatial complexities apportioned within the models (e.g. does the differentiation of Statistical Areas 909/910 from 911 fit with the data collection)? Are fishers who complete logbooks "an average fisher" or are they more unique and therefore their data provides a filtered view – how should this be recognised within the model? Can fishers with long temporal coverage of logbook records be used to compare progressive changes in CPUE between fishers, thus providing insight into fishing efficiency changes? Can logbook data be used to examine temporal and spatial changes in key biological variables such as size at maturity, timing of egg bearing and moulting (presence of soft shells)? It should be noted that changes in size at maturity can inform changes in growth.
- Examination of catch sampling data. Similar analysis to above with voluntary logbooks.
- Examination of tag-recapture data. This is an extensive data set that appears to contain the potential to inform a range of processes including M, selectivity and fishing efficiency. Large numbers of tagged lobster have consistently been released in many of the QMAs (e.g., CRA1, table 31, Webber et al. 2024), with relatively good recapture rates also occurring in many QMAs (e.g., CRA 1, table 28, Webber et al. 2024). In fact, this table (table 28, Webber et al. 2024) shows that (in CRA 1) recaptures of tagged lobster continued for almost ten years after release and that in many years lobsters were recaptured from up to eight different release years. Multiple recaptures from multiple release years can be examined using models such as a Brownie tag-recapture model (Brownie et al. 1986) which derives much of its precision from contrast between multiple release events. If the various assumptions associated with tagging models can be satisfied/determined (e.g., level of tag mixing, measure of effort, tag reporting and tag loss rate), these models can determine the key population parameter of M as well as estimating sample-specific catchability. A progressive change

in sample-specific catchability is analogous to changes in fishing efficiency. It should be noted that to inform the model regarding tag loss, double tagging should be implemented in the tagging protocol (Hearn et al. 2003).

Recommendation 2 Prior to future assessments it would be warranted to conduct a meta-analysis on all data sets to ascertain a contemporary understanding of key biological traits and whether these vary spatially or temporally.

2.1.3 Data standardisation

Unbalanced sampling of a population is a common problem in fisheries data, caused when only a sub-set of the fishing fleet's data is collected and/or when the fleet is not spread homogeneously throughout the fished population. The assessment team has conducted substantial exploration of potential biases in CPUE, size composition and sex ratio data. This is especially true for the voluntary logbook CPUE where a larger range of covariates (such as water depth, soak time, moon phase, octopus, packhorse presence, GPS position and skipper) were examined and found not to have a significant contribution to the variation in CPUE.

Following this exploration appropriate standardising procedures have been applied to these data to reduce any impacts of unbalanced sampling. The final standardised models employed were:

CPUE ~ period + area + re.month + re.vessel + re.period:area

Length Frequency ~ year + month + area + re.year:area.

Sex ratios ~ year + month + area + re.year:area

(where "re." defines random effects and area is statistical area).

For the CPUE, the most influential term was generally vessel "usually the most important term (sometimes ahead of year)!". This is expected and has been reported from similar data standardisations for red rock lobster in South Australian waters (Feenstra 2018). It was not reported within the documentation or presentations whether this factor was examined as part of the standardisation process for either length-composition or sex ratio data sets, but as it was found to be the most significant factor for CPUE, its investigation for these other indices is warranted.

Recommendation 3 In future assessments it would be warranted to examine vessel within the standardisation process for length composition and sex ratio data sets.

2.1.4 Tag data

Tag recapture data is used within the stock assessment model to inform the estimation of growth. This is a significant positive for this modelling framework and is rather unique within length-based stock assessment models due to the (normally) high demands it places on processing time (Punt 2024). Under the process implemented in this stock assessment, growth rates can be informed by both tag recaptures and length composition.

In the assessment, growth is modelled using a very flexible relationship (Schnute-Francis growth model) which is appropriate for a spiny rock lobster species that displays non-linear changes in growth rate throughout life, including no terminal moult and a maintenance of growth in very large individuals due to a moulting requirement to replace damaged shells and pleopods (de Lestang 2018). In juvenile red rock lobsters, growth is rapid with multiple moults occurring annually (generally synchronous), whereas in the adult population moulting becomes far less frequent (generally only annually) and remains synchronous (MacDiarmid 1989, Ziegler et al. 2004, Feenstra 2018). Mature males and females have been reported to moult in October/November and April/June, respectively, in in northeast New Zealand during the 1980s (MacDiarmid 1989).

The tag-recapture data used in the model is assumed to have the same probability of growth depending on time at liberty. This assumption fails to incorporate the timing of tag release within a year (see table 43 Webber et al. 2024 for example of monthly spread), which also has a significant impact on moulting probability. For example, for male lobsters released in northeast New Zealand in September, one recaptured in December and one the following September, would have markedly different liberties (3 vs 12 months), yet based on moulting schedules, the same probability of having moulted (and thus the same growth). This impact is observed within the tag-recapture summary by the statement "Annualised growth was greater for individuals that spend less than one year at liberty compared with greater than one year at liberty" (Webber et al. 2024).

Recommendation 4 In future assessments it would be warranted to re-formulate growth based on tag-recapture data to incorporate tag-release date and the annual moulting synchronicity.

2.1.5 Fishing efficiency

CPUE is the primary index of relative abundance used to drive the dynamics of the LSD model. As stated above, substantial work has been done to standardise this data set for heterogeneity prior to it being incorporated into the model. However, another form of bias often occurs with commercial CPUE data, namely that of progressive changes in fishers' behaviour, which results in increases in their fishing efficiency. Within the model, compounding temporal changes in fishing efficiency are incorporated through the parameter q_{drift}, which assumes that over the temporal scale of the model, a consistent and progressive change occurs. Model sensitivity analysis conducted by the assessment team highlighted the ability of this parameter to influence key model outputs such as relative spawning stock biomass (SSB_{curr}/SSB_0). This 'effort creep' parameter can be very hard to estimate unless it is informed either within the model through the inclusion of multiple concurrent indices with differential efficiencies (i.e., contain commercial and fisheries-independent standardised surveys devoid of fishing efficiency) or from priors based on external data analysis.

Fisheries-independent surveys are those conducted within a fishery under a repeatable and consistent framework aimed at reducing fisher-induced changes in the catchability of the target species(s) (e.g., fishing efficiency creep). For invertebrate fisheries, factors that can be regimented include moon phase, time of year, fishing method, fishing gear, bait, soak time and location. The influence of environmental factors such as water temperature, swell and turbidity remains beyond the control of such surveys. Such surveys have become common practise in lobster fisheries, now operating annually in many industrial fisheries worldwide (Harley et al. 2001, Caputi et al. 2021). The inclusion of fisheries-independent data into an assessment has been shown to have positive stock and financial outcomes for fisheries through more robust stock assessments, resulting in less conservative quotas being set (Dennis et al. 2015, Prellezo 2017). Most significantly, independent surveys have proved very useful for informing changes in fishing efficiency, because they act as a baseline against which to compare fisheries-dependent indices (de Lestang et al. 2018).

There remains a common perception that fisheries-independent surveys are prohibitively expensive. However, under the scenario of co-management, where fishers are actively engaged in the collection of data and have committed substantial investments to a fishery, these surveys can occur at minimal cost. For example, in a deepwater crustacean fishery in Western Australia, commercial fishers change their fishing pattern to fish in a standardised and consistent manner in the same locations each year, a design constructed in consultation with regulators. They do this as part of their fishing operation at zero cost. This produces catch rates and catch composition information of crustaceans that are directly comparable between years, being devoid of the influences of a range of factors including fishing efficiency (How et al. 2022).

Recommendation 5 Discussions should occur with the commercial fishing industry to gauge their interest in developing co-managed annual independent surveys across the quota management areas.

2.1.6 Stock Assessment Model

2.1.6.1 Analysis strategy

It is becoming more common within fisheries to use a weight-of-evidence approach for stock assessments (e.g., Braccini et al. 2021) by applying multiple analyses of varying complexity to components of the available data. For example, outputs from the LSD model could be compared to similar measures derived from simpler models such as surplus production, length-based catch curve and tag-recapture models, to provide greater certainty around model conclusions. Such comparison can clarify the information contained within each such data stream.

It may also be helpful to build the assessment strategy more explicitly around a set of biological hypotheses (linking the modelling and its presentation more closely to these hypotheses).

Recommendation 6 The assessment team should consider using a weight of evidence approach in future full assessments.

2.1.6.2 Dealing with uncertainty

When multiple hypotheses may explain outcomes, it is helpful to outline the hypotheses and provide analyses that address the plausible options. When these approaches lead to different outcomes, an ensemble approach may be warranted (Gronnevik & Evensen, 2001, Rudd et al. 2019). This approach would be useful in scenarios where there are alternative explanations for observed patterns, such as in the CRA 3 assessment.

For example, in the draft CRA 3 assessment the transition to smaller observed sizes in 2000 is very influential but has multiple plausible explanations. For example, it may be associated with change in the spatial distribution of the fishing. However, a change in the distribution or abundance of the stock associated with changing environmental conditions (e.g., SST) may also be plausible. There is also uncertainty associated with the low proportion of females in sex ratio, and the contributions of large environmental changes in recent years.

Recommendation 7 Consider using an ensemble approach to develop management advice, particularly in cases with large unresolved structural uncertainties.

2.1.6.3 LSD model structure

The LSD is a sophisticated state-of-the-art modelling approach, utilising the latest statistical methods such that it has very efficient MCMC, with excellent performance. Its continued use and further development are strongly supported. One negative aspect is that it is a bespoke model developed by one individual, which has risks associated with continuity. These risks could be mitigated by increasing the transparency of modelling methods and developing a community of practice as is happening across the southern part of Australia.

The model implicitly assumes a spatially uniform population structure, but, in fact, there is potential for spatial variation (Roberts et al. 2023). There is likely to be spatial heterogeneity in lobster sizes by habitat and with depth, with evidence for differences in size composition with depth in the far north (CRA 1) and south (CRA 7&8). In both these QMAs, fishing has historically been deeper to catch smaller lobsters which seem to avoid the shallower waters (Jim Roberts personal communication). There are also strong fishing effects on size, due to depletion. Limited movement of lobsters within QMAs and spatially varying fishing pressure thus has the potential to affect population size distributions. There is variation among individual fishers in the sizes they catch, though this is confounded with location since fishers tend to keep fishing the same patch, often close to where they live. These patterns are also variable among QMAs, with diverse patterns in CRA 3 and CRA 7&8.

Recommendation 8: There would be benefit in generating additional model diagnostics, including likelihood profiles on R_0 and natural mortality, to help understanding of which data sources are driving model outcomes.

The current approach to recruitment does not allow for any relationship between recruitment and the spawning stock size, whereas it is common practice in stock assessment to implement a stock recruitment relationship. It is suggested that such relationships should be considered, particularly for projections.

The current definitions of QMAs and statistical areas were not defined to be representative of lobster biology, and they constrain the process of model fitting and estimation. Individual assessments estimate significantly different growth rates between areas, but these represent average growth rates across each QMA. Analyses at a finer scale would help to improve understanding of where the transitions are, what factors may be associated with them, and which potential biases may be associated with pooling data across areas with different biological parameters. Given the spatial differences in growth and natural mortality, there is also likely to be temporal variation, particularly with recent trends in sea surface temperature including marine heat waves. Natural mortality estimates are confounded with growth and selectivity. However, it is not feasible to adapt the model to allow for all potential sources of variation. Sensitivity analyses are needed to identify the most important issues.

Standardised residuals at length by sex from the tagging data show trends, with more negative residuals for lobsters released at larger sizes. In CRA 3 this is observed mainly in Statistical Area 910 where there is the most data, and there is also significant bias in most statistical areas within CRA 2. There is a need to identify what is causing this lack of fit.

Recoding the lobster assessment model using Template Model Builder (TMB) (Kristensen et al. 2016) would result in efficiencies for developing new methods, since the analyst is already developing similar approaches for other species using TMB. TMB has better capability for applying random effects, sparse matrices, and can be run through R. It is not tied to Linux as is command line Stan. It supports the development of new modelling methodologies including methods for speeding up MCMCs.

Working in TMB would also make the model more transparent and easier for others to use and collaborate, since in fisheries modelling, TMB is more widely used than Stan. For example, the *Crustmod* size-based assessment model in Australia is being developed in TMB. This change could support the development of a community of practice around length-based modelling methods using TMB.

Recommendation 9: It may be useful to transition to TMB in the short term rather than spend time developing new features in Stan that would then need to be redeveloped in TMB.

2.1.6.4 New model features to consider

Including proposals by Punt (2024) the assessment team should consider:

- The analysts have proposed changing the model structure to remove the immature female class and switch to a two-sex model with a maturity ogive, rather than modelling maturation as a transition probability. This would be a worthwhile simplification of the model which would speed up the analysis. It would also improve the feasibility of developing spatio-temporal models to prepare data, particularly for sex ratio data. Proportion mature at size could be estimated outside the model using meta-analysis.

Recommendation 10: The proposed change to reduce the number of sexes from three to two should be prioritised among model structural changes.

- Currently selectivity can be modelled by size, sex, region, season, and year. However, the model is sensitive to variation in selectivity. The model currently assumes selectivity to be time-invariant, which means that size variation associated with selectivity changes can bias recruitment estimates. This is illustrated by the impact on recruitment of the large changes in size structure observed since 2000 in CRA 3. The recruitment history affects estimates of current biomass and also projections, so the model needs to be able to accommodate alternative hypotheses about the causes of size variation.

- There is a proposal to add the ability to model multiple fleets per region and include random effects / correlation (e.g., Gaussian-Markov Random Fields, GMRF) structure in selectivities, which would allow selectivity to vary through time.
- Applying an "areas as fleets" (AAF) approach can help the model address spatial variation in size structure without the requirement for separate regions with movement between them. When developing a multi-region model it is recommended that a single-region AAF model should be developed in parallel (Goethel et al. 2024).
- Adding flexibility to fleet definitions would also permit the use of an index fishery approach (Maunder et al. 2020). Using an index fishery approach would increase the range of hypotheses that could be considered to explain observed changes in size frequency data. This is likely to be useful because the fishery size frequency distribution is likely to differ from the population size frequency distribution, particularly when there are changes in the fishery such as have occurred recently in CRA 3. Spatial and seasonal variations in fish sizes can indicate that changes in spatial and seasonal effort distribution may be what is changing the fishery LFs, independently of the population LFs.
- We agree that it would be useful to explore estimation of time-variation / process error in selectivity, since selectivity will inevitably vary through time (Sampson & Scott 2012) and it is confounded with other parameters including recruitment.

Recommendation 11: The proposed changes to modelling selectivity may considerably improve model fits and the range of hypotheses that can be modelled. The highest priority is to implement changes that allow multiple fleets in the same region.

Age/size-based integrated models may be best assessment practice (Punt 2024), but are difficult to develop and fit, and their utility is constrained by the lack of age data for lobsters. They will potentially be more useful in future, after development of reliable *Jasus edwardsii* ageing methods, and with software that allows for faster assessment model fits.

We support the proposal to estimate initial conditions.

CRA 8 CPUE is steadily increasing. At high CPUE there is potential for pot saturation, especially with q_{drift} implying that the same biomass is associated with higher catch per pot. Pot saturation is one mechanism that could result in hyperstability in the CPUE index.

It would be useful to generate the estimated growth ogives as a diagnostic, to check that they are realistic.

Tag recapture data should be used to inform selectivity. This does not have to entail the complexity of growing and tracking of animals over time (although this would increase sample size). In its simplest form, from a platoon of tags released, the relative recapture rate of all tags returned prior to the synchronous moult in that area will be indicative of the relative selectivity of that suite of lobsters across length bins.

The panel supports the parameterisation of M as a length-based process. Parameterisation as $M(\mathrm{L}) = a/\mathrm{L}$ is well supported by the literature (e.g., Lorenzen 2022), in contrast with constant M which is a modelling convenience. Mean M at L may be fixed or estimated with a prior, and the relationship between M and L should be fixed. In general, we would not recommend estimating the relationship between M and L, given lack of information in the data and likely confounding with other parameters such as selectivity and growth.

Dirichlet-multinomial - we generally support the application of automated data weighting that is internally estimated, but with some caveats. Dirichlet-multinomial weighting tends to result in weights that are similar to McAllister-Ianelli weighting and higher than Francis weighting, whereas Francis weighting is generally seen as a better approach that allows for overdispersion due to correlations among classes. It may be better to wait to apply automatic weighting until these issues are resolved, and better methods are developed for automatic weighting.

Three proposals were made to change recruitment estimation.

- Treating recruitment deviates as random-effects and estimating the standard deviation and autocorrelation of recruitment (AR1) may currently be a low priority. Autocorrelation is difficult to estimate in penalised likelihood models (Brooks, 2024, Johnson et al. 2016), although this may not be the case in Bayesian models. However, we support applying autocorrelation in the projections (Brooks 2024) as is currently the case.

- Similarly, adding features to relate recruitment to environmental covariates (see p 6 of Punt 2024) is seen as a lower priority. Relationships between environment and recruitment may be identified and then break down.
- Estimating the recruitment size distribution would be worthwhile. It is unclear how sensitive the model is to this, but it is likely to vary spatially, so estimating it may improve the fit of the growth estimation and the size data.

Recommendation 12: Of the proposed changes to recruitment estimation, priority is recommended for estimation of the recruitment size distribution.

2.2 TOR 2: Vulnerable biomass reference points

2.2.1 Defining Management Reference points

2.2.1.1 Context of the issue

In a scientific review this section is somewhat unusual because the management reference points are where the science and the policy sides of fisheries management meet. The objectives of fisheries management are not defined solely from scientific considerations so final decisions regarding policy settings are usually made by elected officials or their delegates. However, at least some of the implications of such policy decisions can be clarified by fisheries scientists and that is where this review will attempt to remain. In this section there is more exposition than might normally be present but there are recommendations at the end. As this is all about management and policy, such exposition was considered necessary to defend making those recommendations.

It should be noted that in the following section, we are using the international standard that *B* refers to spawning stock biomass (*SSB*). We have referred to reference vulnerable biomass as VB_R.

Changes are being considered concerning the definition of the reference points used in formal harvest strategy for the red rock lobsters (*Jasus edwardsii*). It is these suggested changes that are under review.

As described in the Harvest Strategy Standard (Ministry of Fisheries, 2008), formal harvest strategies require that the stock status of managed fisheries be determined by comparing some explicit measures of each stock's performance against defined reference points. There are limit reference points that are supposed to reflect what are deemed undesirable stock status levels and there are target references points that are supposed to reflect what are deemed desirable stock states. Defining such limit and target reference points is obviously a vital step and invariably constitutes a compromise between potentially conflicting objectives relating to meeting ecological, economic, and societal goals.

2.2.1.2 Limit Reference Points

Of the two types of reference point, limit reference points are more easily discussed because they relate mostly to ensuring that fished stocks avoid serious depletion leading to such consequential outcomes as fisheries closures and stock collapse. This now seems like such an obvious state of affairs to avoid and yet prior to the introduction of formal harvest strategies such collapses were disappointingly common. Given the assumption that fishers are very good at what they do, and that, given technological advances, they get better at what they do as soon as they can, it should not be surprising that without strong, interventionist management, catastrophic collapses will occur (Hardin, 1968). The disparity of outcomes in those fisheries with management versus those without effective management, with more positive outcomes in the former, continues to make this clear.

The Harvest Strategy Standard for New Zealand's fisheries (Ministry of Fisheries 2008, p 7) has expanded the notion of the limit reference point to include a:

soft limit: that triggers a requirement for a formal, time-constrained rebuilding plan; and a

hard limit below which fisheries should be considered for closure.

The Harvest Strategy Standard also defines default values for these limits such that the "default soft limit is ½ B_{MSY} or 20% B_0, whichever is higher.", where B_{MSY} refers to the spawning stock biomass that, at equilibrium, will give rise to the maximum sustainable yield, and B_0 refers to either the long-term average or equilibrium unfished spawning stock biomass (often female only spawning biomass). These values are very commonly used across a wide range of fisheries world-wide and despite these being model based concepts their origin is largely empirical.

The earliest reference to this Limit Reference Point depletion level of 20% B_0 appears in Beddington & Cooke (1983). Their analyses, looking at potential yields from different stocks, were given a constraint such that:

> "… an escapement level of 20% of the expected unexploited spawning stock biomass is used. This is not a conservative figure, but it represents a lower limit where recruitment declines might be expected to be observable. … We have chosen a twenty year period in which to investigate the probability that the escapement will fall below the 20% level.
>
> "… In presenting the results of this analysis, we have calculated the appropriate level of catch, that will ensure that the probability that the SSB falls below 20% of its unexploited *level is less than 0.1"* (Beddington & Cooke, 1983, p 9-10)."

The most influential document giving rise to the notion that $B_{20\%}$ is a reasonable depletion level to use as a threshold beyond which the potential for recruitment overfishing increased was a document prepared for the National Marine Fisheries Service in the USA (Restrepo et al. 1998). In fact, they recommend ½B_{MSY} but consider $B_{20\%}$ to be an acceptable replacement for that figure. However, it is important to note that this is only a 'rule of thumb' and there is no empirical basis that links the proxy $B_{20\%}$ and 0.5 B_{MSY}. Indeed, selecting 0.5 B_{MSY} for some species could result in limit reference points much lower than 20% B_0, which is why most modern harvest strategies use wording such as $B_{20\%}$ and 0.5B_{MSY}, *whichever is higher*.

The Harvest Strategy Standard also provides a default for the hard limit: "The default hard limit is ¼B_{MSY} or 10% B_0, whichever is higher" and adds the additional caveats that "The hard limit will be considered to have been breached when the probability that stock biomass is below the hard limit is greater than 50%.", and "The default level at which the hard limit is set represents a minimum standard; higher hard limits may be appropriate for some stocks, particularly those with low productivity." (Ministry of Fisheries 2008, p 9).

The objective behind using limit reference points relative to the spawning stock biomass (mature biomass) is an attempt to ensure sustainability by ensuring that there is at least a minimum degree of protection afforded to the mature biomass, and hence to potential future recruitment. The intention of the soft limit is to increase the probability that the hard limit will not be breached through requiring a rebuilding plan. The principal aim of the limit reference points is to ensure that each stock remains sustainable in the face of fishing pressure. By its very nature this should also ensure that a viable fishery also remains.

Despite an inability to demonstrate a stock recruitment relationship for red rock lobster (Pons et al. 2022), it seems reasonable that the more spawning biomass available, the greater the chance of recruitment at levels that will sustain a stock. Assuming that all quota management areas act as sources of recruitment for the whole is the safest assumption in the absence of information concerning whether any areas are primary sources of rock lobster recruits and any other areas are primarily sinks for recruits. This would imply that it is in the whole fishery's best interest is to maintain the spawning biomass above some minimum in all areas. Given the success of the current stock assessment modelling framework (Rudd et al. 2023, Webber et al. 2023), which estimates the Autumn/Winter spawning stock biomass before fishing when applied to each lobster quota management area, then the continued use of the spawning stock biomass derived limit reference points is defensible. Even though there do not appear to be any plans to alter these it is often best to be explicit about deciding to retain the status quo.

Recommendation 13: There appear to be no good reasons to change the currently defined soft and hard limits in the red rock lobster fishery, and there are reasonable defences for their retention, so no changes need to be considered.

2.2.2 Target Reference Points

The third core element of the Harvest Strategy Standard is setting a "specified target about which a fishery or stock should fluctuate" (Ministry of Fisheries, 2008, p 6). The Standard goes on to state: "The Harvest Strategy Standard does not explicitly specify a %B_0 target, and alternative %B_0 targets will be acceptable, provided they can be adequately justified by, for example, considerations of stock productivity. However, it is becoming increasingly difficult to justify stock targets less than 30–40% B_0 (or, equivalently, removing more than 60–70% of the unfished biomass)." (Ministry of Fisheries, 2008, p 6, footnote 6).

2.2.2.1 Target Reference Point Objectives

Selecting a target reference point is difficult because such things are attempting to meet multiple potentially conflicting objectives (ecological, economic, and societal) (Caputi et al. 2018). Unfortunately, how to successfully articulate or define those three objectives more precisely is unclear. Ecologically, rock lobsters are undoubtedly important as both predators and scavengers within the systems they inhabit, but exactly how many animals are required to fulfil what are known as 'ecosystem services' is unknown. Similarly, it is an over-simplification to consider that economic objectives will always be met by maximising catches. That might be an optimum strategy when stocks are depleted and one might maximise catches while maintaining rebuilding, but if a stock is large and healthy then continually increasing its Total Allowable Commercial Catch may risk saturating its market, lowering port prices and reducing profitability. At the same time, in a marine environment undergoing significant directional changes, there are ecological advantages to building increased resilience by not 'maximising' catches, even in what can be perceived as healthy stocks. The societal objectives are perhaps the hardest of all to quantify. For example, some recreational fishers prefer trophy sized captures while others prefer to have high catches, so even within sectors conflicting objectives can arise. There are numerous other conflicting objectives both within and between different stakeholders in any one fishery. The vagueness associated with such varied 'objectives' is at least one good reason why selecting a particular target reference point is so difficult.

Reference points based upon spawning stock size are fundamentally model based. As noted in the Harvest Strategy Standard a target reference point commonly used internationally, is to treat 40% B_0 as a proxy for B_{MSY} and hence can be used as a valid target reference point. It is a level of spawning biomass that is commonly used internationally as a proxy for B_{MSY} – and is the default recommended proxy made by the Marine Stewardship Council. However, most studies that have examined the use of such targets as $F_{40\%}$ and related proxy values, have involved finfish (e.g., Clark, 1993) and these do not translate well to invertebrates. As implied by Rudd et al. (2021), selecting some level such as 40% B_{0-} as a target for rock lobsters would be an arbitrary decision they consider difficult to defend. While it is certainly better than not selecting a target reference point at all, the authors make the case that if a formal and valid method for selecting a target could be estimated then that might be more defensible.

2.2.2.2 Progress in Harvest Strategy Development

It is simple to defend the argument that there has been considerable progress in stock assessment methods. The contrast between the first age-structured integrated stock assessment method (Fournier & Archibald, 1982) and the likes of modern age-structured integrated assessment models (Methot & Wetzel 2013, Methot et al. 2024) is enormous. Similarly, the contrast between the first integrated size-based stock assessment models (Sullivan et al. 1990) and the current New Zealand rock lobster model (Webber et al. 2023) is difficult to summarise. The increase in sophistication, attention paid to uncertainty, routine availability of different probability density functions, and many other innovations demonstrates the tremendous improvements since the 1980s and 1990s within stock assessment models.

The obvious developments and improvements in stock assessment methods are in great contrast with progress in the developments that have occurred following the introduction of formal harvest strategies in and around the 1990s. Three documents from FAO, and many similar ones, were particularly influential (FAO, 1995, 1996, 1997) for introducing and encouraging the adoption of formal harvest strategies. Since then, there has been a great deal of discussion, but the main advances might be summarised as a recognition that harvest strategies should invariably have an 'exceptional circumstances' clause and should include meta-rules to mitigate against undesirable unintended consequences of control rules after they have been introduced. This lack of innovation appears to reflect the difficulties in providing precise specifications of the objectives which the reference points selected are intended to achieve. An exception to this lack of innovation is found in various attempts that have been made to explore the effectiveness of different limit and target reference levels using simulation and other efforts to estimate target levels of catch or fishing mortality rate that are confidently known to avoid breaching a given limit reference point to a selected level of probability. Such estimated target reference points would at least have such demonstrations to act as a support or defence for their effectiveness at avoiding a selected limit reference point.

2.2.2.3 Estimated Reference Points

Various workers have examined different ideas for estimating defensible target reference points (Mace 1994, Caddy & Mahon 1995, Caddy & McGarvey 1996, and Prager et al. 2003). Rudd et al. (2021) pursued the idea of simulating the application of constant fishing mortality rates or constant catch levels within projections of the size-structured model developed for rock lobster stock assessments in New Zealand. They did this to determine the levels (of constant catch or constant fishing mortality rate) at which limit reference points are consistently avoided while at the same time catches are maximised. This would be a form of maximum sustainable yield and hence should constitute a suitable proxy. They state explicitly: "These reference levels can be interpreted as proxies for B_{MSY} and represent a lower bound for a management target."

Rudd et al. (2021) differ from most earlier simulation work in that they work with vulnerable biomass rather than spawning biomass. In this case, vulnerable biomass is defined as the biomass above the Minimum Legal Size (MLS), not egg-bearing if female, and as modified by selectivity and vulnerability. In particular, they work with the vulnerable biomass available in the autumn-winter season. They use vulnerable biomass as the basis of the estimated reference point, instead of spawning biomass, because it is directly related to commercial catches (especially in a species with a minimum legal size). Their simulations use the standard stock assessment model for each available lobster quota management area and project the final 1000 MCMC replicates forward under the different control rules (constant catches or constant fishing mortality rates) explored. They conclude by describing the estimation of a target reference vulnerable biomass. This is the arithmetic mean of the equilibrium average vulnerable biomass obtained after applying fixed catch or fixed fishing mortality rate harvest control rules such that catch is maximised while risk constraints are met. The risk constraints derive from excluding fixed catch or fixed fishing mortality rates that breach the 20% B_0 soft limit reference point in the model in more than 5% of replicates (which is considered a soft-limit level suitable for avoiding the hard limit with a probability of 2%).

This approach to estimating the target reference point has since been modified in the latest assessment for CRA 2 (Rudd et al. 2023) to account for the shift in the assessment model from using the instantaneous fishing mortality rate to using annual harvest rates.

2.2.2.4 Issues with Estimated Target Reference Points

The defence presented (Rudd et al. 2021, Rudd et al. 2023) for using this novel estimated target reference point rather than, for example, the internationally accepted target reference point of 40% B_0, may appear overly complex to many stakeholders.

Recommendation 14: The defence presented for using the estimated vulnerable biomass as the target reference point needs to be developed further to clarify the reasons for and advantages of its adoption over the better-known default proxy of 40% B_0.

For example, currently the novel target reference level, VB_R, is estimated for the autumn-winter (AW) season when the vulnerable biomass excludes a high proportion of female biomass on the assumption that they will be ovigerous. While this would not detract from such a reference point as long as it was always compared with the AW vulnerable biomass, why this seemingly low level of vulnerable biomass was selected could be clarified (see Rudd et al. 2021, p 11 Fig 7).

Currently, the advantages of moving to the novel vulnerable biomass target are not clear. It is clear, however, that the new VB_R can be considered as a lower bound for the management target. As such it constitutes an acceptable candidate for a place to start in terms of the Harvest Strategy Standard's: "MSY-compatible reference points or better". By "or better", the Standard implies "…means being above B_{MSY} or its proxies, and/or below F_{MSY} or its proxies, and/or below MSY or its proxies." (Ministry of Fisheries 2008, p 5).

When used in an assessment (Rudd et al. 2021), once the VB_R has been estimated then the target U_R was identified by searching for the fixed U associated with the estimated VB_R over the final 20 years of the 30-year projection period (where U is an annual harvest rate, and U_R is the harvest rate that should give rise to the VB_R at equilibrium).

Recommendation 15: As well as considering how well the novel VB_R performs, in terms of avoiding the soft limit, once its associated U_R has been identified, its performance relative to a similarly identified $U_{40\%B0}$ should be compared so that direct comparisons can be made between using VB_R or 40% B_0 as the target reference point.

The Operational Guidelines for the Harvest Strategy Standard (Ministry of Fisheries 2011) provide guideline values for default %B and $F_{\%SPR}$ in terms of the predicted productivity of the stocks concerned. Unfortunately, red rock lobster appears to express properties that do not fit neatly into any of the categories listed. For example, the assessment model does not use a stock recruitment relationship but instead uses recruitment deviations away from an average unfished recruitment level. This is equivalent to assuming a Beverton-Holt stock recruitment relationship with a steepness = 1.0. At the same time, its natural mortality value of about 0.12 – 0.2 suggests a relatively low productivity. The guidelines are thus not helpful for rock lobsters except that it is noted in two footnotes on page 8 that: "The most commonly recommended and used single species %B_0 target reference point is 40% B_0." and "The most commonly recommended and used single species $F_{\%SPR}$ target reference point is $F_{40\%}$." (Ministry of Fisheries, 2011, p 8 footnotes 7 and 8). Just being commonly used does not constitute evidence that they are best but reinforces that the defence needed to move to an alternative target needs to be strong.

2.2.2.5 Other Potential Issues with VB_R

Other issues that might be raised with respect to the transition to using the estimated AW vulnerable biomass target reference point will require the preparation of adequate defences.

The VB_R is estimated by projecting the 1000 MCMC replicates forward to equilibrium. In this way it captures a large degree of the variation inherent in the assessment. Part of the estimation determines whether each replicate projection adheres to the risk criterion adopted, which is that less than 5% of replicates fall below the soft limit in any of the replicates in any of the years of projection. Unfortunately, this neglects to account for the uncertainty in the estimation of the soft-limit reference point (see Rudd et al. 2023, p 86, figure 61), and relates to equilibrium conditions. Given that the risk criterion is relatively severe at only 5% of replicates being allowed to fail this may not be a severe criticism, but it does require a response. Most management decisions are based upon using median or other stated quantile estimates from a range of model outputs. This, by itself, may be a sufficient defence for using the median estimate of the soft limit reference point. Nevertheless, such a defence needs to be made explicitly.

A related issue is that the current estimated VB_R appears to neglect the intent for a target reference point stated in the Harvest Strategy Standard (Ministry of Fisheries, 2008, p 7): "A specified target about which a fishery or stock should fluctuate" (it is assumed this implies "…about which a fishery or stock is expected to fluctuate"). The degree to which this might be an issue for achieving the risk requirement of the novel target reference point will depend on just how variable the stock size is under the "lower bound for a management target". This appears to have already been answered through using the 1000 MCMC replicates, and sampling from estimated recruitment residuals to propagate into the projections. Such analyses should lead to the projected catches fluctuating around the estimated value of VB_R. Such projected trajectories appeared more variable in the fixed catch scenarios than the fixed harvest rate scenarios (as seen in the presentation by M. Rudd during the review). For VB_R to reliably represent the 'minimum target' requires that the model should sufficiently represent all sources of uncertainty, which is arguably not feasible - many sources of uncertainty are necessarily omitted from assessment models.

Recommendation 16: The uncertainty captured by utilising the MCMC replicates and sampling projection recruitment deviates from the (lognormal) recruitment deviates estimated by the assessment model should be characterised in more detail, to demonstrate that the VB_R estimate is not compromised by the variation around the soft limit reference point estimate and that there is realistic fluctuation of vulnerable biomass around the target through time.

As occurred in the latest CRA 2 assessment, using an estimated target reference point will be expected to lead to the reference point potentially changing from assessment to assessment. Absolute estimates tend to be much more variable than ratio or proportional reference points (Punt et al. 2018).

Recommendation 17: Compare the use of VB_R as an absolute estimate, as it currently is, with a ratio relative to the unfished AW adjusted vulnerable biomass, or some other measure, to determine whether the ratio estimator is more stable than the absolute.

Averaging the outcome from the constant catch and the constant harvest rate control rules appears to be a reasonable compromise but it could also appear to constitute an arbitrary choice between two contrasting strategies.

Recommendation 18: Produce a review or discussion to provide a convincing defence for using the arithmetic average between the estimates from the two strategies of a constant catch and a constant harvest rate: $VB_R = (VB_{RC} + VB_{RU})/2$.

Similarly, while the estimated VB_R meets a more than acceptable risk criterion, there are other ecological, economic, and societal objectives that it is not seen to explicitly meet. Simply multiplying the estimate by some constant to account for these imprecise and only implied objectives would make this as arbitrary as the use of 40% B_0.

Recommendation 19: Produce a review or discussion to provide a defence for accounting for the objectives that target reference points are intended to meet, making the case that the estimated vulnerable biomass target reference point is not as arbitrary as selecting 40% B_0.

2.3 TOR 3: Management Procedure approach

The use of the management procedures to set TACCs in New Zealand rock lobsters requires the use of standardised Catch Per Unit of Effort (CPUE). They are harvest control rules that have been simulation tested (Webber & Starr, 2020). With the advent of the Electronic Reporting System (ERS) its failure to capture all the required information needed to conduct a valid standardisation means that a workable CPUE time-series is no longer available. This has been preventing the continued use of the management procedures since 2019 (which led to the development of the Rapid Update Assessments).

The objectives behind the use of the management procedure (when it was used) appears to be to enable rapid changes to the TACC, either up or down, without conducting a full assessment.

Recommendation 20: The objectives behind developing the management procedures should be made explicit, in particular, whether their intent is likely to increase risk to the stock.

Given the time-lag between full stock assessments occurring in each lobster quota management area, the TACC set at the time of the assessment is effectively a multi-year TACC unless an action is taken to modify it during the interval. As the years extend away from when a full assessment was conducted the risk to the stock of continuing to take the initial TACC increases simply due to the increasing uncertainty about the state of the stock. Generally, with multi-year TACCs, it is good practice to allow for the TACC to decrease between full assessments but not to increase. Increasing a TACC between full assessments can only increase potential risks to the stock.

A potential problem with the current Management Procedure is that it is reliant on the assumption that increases in the CPUE are in fact directly related to increases in the stock's vulnerable biomass rather than, for example, a change in fishing behaviour or gear. This is particularly the case if in the projections the q_{drift} is not included and the starting CPUE is close to a transition to a higher catch (see Webber et al. 2023, p 20). If CPUE, at least for the next few years, is to be dependent on the voluntary logbook CPUE this reliance on CPUE becomes more critical as it represents only a small sub-set of pots from a sub-set of the fleet.

Currently, the management procedures are tested using projections from the stock assessment. This implies that the conditions experienced within the stock assessment's time frame are assumed to remain the same.

Recommendation 21: The use of the management procedures appears to be inherently risky. Either find a way to demonstrate that increased risk is not occurring, or only use the management procedures to keep the TACC stable or to decrease it.

2.4 TOR 4: Rapid Update Assessments

The use of rapid update assessments, where only new data are included into a base case model and that model is then refit without re-weighting or conducting sensitivities is commonly done in jurisdictions where multiple years can pass between full assessments. The intent of such (rapid) update assessments is to monitor whether the stock is indeed following the predicted or expected track within the predicted errors bounds.

The objective(s) behind the rapid update assessments in New Zealand, once again, appears unclear.

Recommendation 22: The objectives behind developing the Rapid Update Assessments should be made explicit especially if they lead to an increased risk to the stock. If they are used to modify the TACC then the implied control rule used should also be made explicit.

As with the Management Procedures there will be increased risk to the stock if the Rapid Update Assessments are used to increase the TACC in between full assessments, although their use to decrease the TACC is less of a problem.

Recommendation 23: As with the management procedures, either find a way to demonstrate that increased risk is not a problem if the Rapid Update Assessments are used to increase TACC, or, only use them to either keep the TACC stable or decrease it.

The Rapid Update Assessments are not, apparently, very rapid, because while the analysis does not take a great deal of time, attending all the consequent meetings does take time and resources. If the Rapid Update Assessments are only used to keep the TACC stable or decrease them then, in cases where the update follows the predicted dynamics, that would imply that the TACC should stay the same. Such an outcome could be communicated to the Assessment group with only a figure or two and a statement that the current catches can continue. If they suggest catches should decline, then that might trigger a more detailed response.

Recommendation 24: Amend the process of utilising the Rapid Update Assessments so that if the assessment indicates that catches remain stable then a very simple report and a single agenda item at an Assessment Working Group meeting is required (attendance by the assessment scientist need not even be required). Only if a decrease in TACC is implied should a more detailed report be presented.

Recommendation 25: If the Rapid Update Assessments are amended to only allow for stability of, or reductions in TACC then, because they use more than just CPUE, these are to be preferred over the Management Procedures as a way of managing the resources in between full assessments.

3. ACKNOWLEDGEMENTS

The panel would like to thank the presenters for the effort they put into producing and sharing their presentations. The openness of everyone attending to questions and interruptions was particularly appreciated. The rapidity with which later queries were responded to by multiple attendees to the meeting was of immediate assistance in writing the review.

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5. APPENDIX 1 TERMS OF REFERENCE

Fisheries New Zealand
Tini a Tangaroa

Fisheries New Zealand Terms of Reference for an independent review of red rock lobster stock assessment modelling and the determination of management reference points

1. Background

There are two species of rock lobster in New Zealand that support substantial commercial fisheries; for red rock lobster (*Jasus edwardsii*) that is caught all around the North Island, South Island, Stewart Island and the Chatham Islands, and for packhorse rock lobster (*Sagmariasus verreauxi*) which is caught in northern waters. Export receipts for these fisheries exceed $300 M p.a., which exceeds the value of any other wild caught fishery. These species are also highly valued by Māori, recreational stakeholders, and environmental groups. Lobster also play a significant role as inshore reef predators of invertebrate species such as kina (sea urchins), that can have a profound impact on the health of inshore reef ecosystems if their abundance is not suppressed by predation.

New Zealand's rock lobster stocks are all managed as part of a Quota Management System (QMS), for which annual sector catch limits are set based on the results of stock assessments that are undertaken on a regular basis. There are nine Quota Management Areas (QMAs) for red rock lobster, with packhorse lobster being managed as a single QMA.

Length-based stock assessment models have been used to assess the status of red rock lobster stocks since the early 1990s, leading to the development of a Lobster Stock Dynamic (LSD) modelling framework in 2016, which has been used for all subsequent lobster assessments. Projections of these models have also been used to calculate empirical target vulnerable biomass reference levels, at which catch is maximised while meeting risk constraints. The use of these proxy B_{MSY} reference levels, based on vulnerable biomass rather than spawning stock biomass, is unique to fisheries management in New Zealand. Recent stock assessment models have also been used to explore the potential consequences of managing lobster stocks to higher then B_{MSY} management target levels, and as operating models that have been used to evaluate proposed management procedure harvest control rules.

The modelling approach used to assess these stocks and underpin their management is therefore bespoke to rock lobster, and an independent review of the suitability and application of these methods is warranted given the high value of these fisheries. The purpose of this independent review is to critically examine these methods and draw conclusions about their suitability for future use, and to recommend any further avenues of investigation or changes that are considered to be potentially useful.

2. Terms of Reference

- An independent panel comprising Simon Hoyle (Independent consultant), Malcolm Haddon (Independent consultant), and Simon de Lestang (Department of Fisheries – Western Australia). Collectively, this panel has extensive scientific expertise and experience with length-based modelling of exploited crustacean fish stocks.

- In order to be fully independent, panel members must have no current or previous connection with the research, monitoring, assessment or management of New Zealand rock lobster stocks and must declare any actual or potential conflicts of interest that might affect their ability to come to an objective view on the suitability of the methods currently used to assess and classify the status of New Zealand's rock lobster stocks.

Primary Objectives

- The primary objective for the expert panel is to provide Fisheries New Zealand with a review of the methods used to assess the status of New Zealand's rock lobster stocks and the reference points against which stock status is assessed. Specifically:
  - To review the suitability of the Lobster Stock Dynamics (LSD) modelling framework to assess the status of New Zealand's rock lobster stocks.
  - To review the calculation and use of model based vulnerable biomass reference points that are used to determine target reference points for New Zealand's rock lobster stocks, as well as the spawning stock biomass target and limit reference points.
  - To review the suitability of the Management Procedure approach that has been used to guide the setting of Total Allowable Annual Catches (TACC) limits for rock lobster stocks.
  - To review the suitability of rapid update assessments to indicate changes in stock status for the intervening years between five yearly full assessments.

- Based on the information presented, the Panel shall report back on their assessment of the suitability of the methods currently used to assess the status of New Zealand rock lobster stocks and the choice of and estimation of the management reference points that stock status is assessed against. This review should indicate any aspects of particular concern and recommend approaches that could be used to investigate or address these concerns. The Panel will have the latitude to recommend alternative assessment methods and reference points that are not currently in use.

Secondary Objectives

  - To provide recommendations on other potential considerations in circumstances where the performance of current management measures may undermine the performance of specific rock lobster stocks, e.g., where lower minimum legal size limits are currently specified, or sex ratios may become increasingly skewed.

Out of scope

  - the efficacy of past FNZ rock lobster fisheries management measures themselves, or the Quota Management System in general
  - recommended future management actions
  - the effects of rock lobster fishing on the formation of kina (sea urchin) barrens and other EBFM issues

Outcomes

- The expert panel will summarise their findings and any recommendations in a report to the Principal Advisor Fisheries Science, Fisheries New Zealand. Where consensus cannot be reached by the external reviewers, any differences of opinion should be recorded.

3. Background documents

The following documents will be provided:

Primary (•) and secondary (○) documents

- 2023 Plenary Reports regarding rock lobster stocks – pages 205 to 482. (here)
- Webber, D.N.; Rudd, M.B.; Starr, P.J.; Roberts, J.; Pons, M. (2023). The lobster stock dynamics (LSD) model. *New Zealand Fisheries Assessment Report 2023/11*. 28 p. (here)
- ○ Pons, M.; Rudd, M.B.; Webber, D.N. (2022). Exploratory analysis of stock-recruitment relationships for New Zealand red rock lobster (*Jasus edwardsii*). *New Zealand Fisheries Assessment Report 2022/50*. 30 p. (here)
- ○ Webber, D.N. (2022). Modelling the length frequency of red rock lobsters (*Jasus edwardsii*) in New Zealand. *New Zealand Fisheries Assessment Report 2022/30*. 261 p. (here)
- ○ Webber, D.N.; Starr, P.J. (2022). Catch per unit effort of red rock lobsters (*Jasus edwardsii*) in CRA 2 (1990–2021). *New Zealand Fisheries Assessment Report 2022/47*. 118 p. (here)
- Rudd, M.B.; Webber, D.N.; Starr, P.J. (2021). Model-based reference levels for New Zealand red rock lobster (*Jasus edwardsii*). *New Zealand Fisheries Assessment Report 2021/81*. 46 p. (here)
- Roberts, J.; Webber, D.N.; Starr, P.J.; Rudd, M.B.; Pons, M.; Goeden, Z. (2023). Data for the 2022 stock assessment of red rock lobsters (*Jasus edwardsii*) in CRA 2. *New Zealand Fisheries Assessment Report 2023/42*. 91 p. (here)
- Rudd, M.B.; Pons, M.; Webber, D.N.; Starr, P.J.; Roberts, J.; Goeden Z.D. (2023). The 2022 stock assessment of red rock lobsters (*Jasus edwardsii*) in CRA 2. *New Zealand Fisheries Assessment Report 2023/43*. 108 p. (here)
- Webber, D.N.; Starr, P.J.; Haist, V.; Rudd, M.B.; Edwards, C.T.T. (2018). The 2017 stock assessment and management procedure review for rock lobsters (*Jasus edwardsii*) in CRA 2. *New Zealand Fisheries Assessment Report 2018/17*. 87 p. (here)
- ○ Pons, M.; Rudd, M.B.; Webber, D. N. (2022). Retrospective-Analysis-Of-Red-Rock-Lobster-Stocks. *New Zealand Fisheries Assessment Report 2022/17*. 66 p. (here)
- ○ Ministry of Fisheries (2008). Harvest Strategy Standard for New Zealand's fisheries. (here)

(Note: Additional documents may be added to this list).

4. Rules of participation

Relevant aspects of the "Membership and Protocols for all Science Working Groups in 2024" will be followed for this review. Participants must commit to:

- participating appropriately in discussions;
- maintaining confidentiality of presentations, discussions and deliberations;
- adopting a constructive approach;
- avoiding repetition of earlier deliberations;

- facilitating an atmosphere of honesty, openness and trust;
- respecting the role of the Chair and the Panel; and
- listening to the views of others, and treating them with respect

It is extremely important to the proper conduct of these reviews that all contact with the Panel reviewers is through the Chair of the Rock Lobster Working Group or the Principal Advisor Fisheries Science. Under no circumstances should participants approach the Panel reviewers directly until after the final report of the review has been published.

5. Format for review

The format for the review will be a workshop involving the independent external expert reviewers ("the Panel"), key players and other interested parties in Wellington, New Zealand to discuss rock lobster stocks assessment methods and the suitability of current management reference points in detail over a period of 5 days. The review will start with a number of presentations to ensure a common understanding of the work (about 1.5) and will be followed by a period of contemplation by the Panel, focused discussions with lead researchers or other parties (at the Panel's discretion) and drafting of a report containing the Panel's conclusions and recommendations (2–3 days). The Panel will present a draft version of their findings to interested parties on the last day to receive feedback and suggested corrections on matters of fact. The Panel may, at their discretion, reflect such feedback in their report. The aim is to have a near-final version of the Panel's report by the end of the week.

6. Timetable

The workshop is set down for 22–26 July 2023 and will be held in the Allen Boardroom, National Institute for Water and Atmospheric Research (NIWA), Greta Point, Wellington, New Zealand. Pamela Mace, Principal Advisor Fisheries Science, MPI, will chair the open sessions.

Monday 22 July	Presentations on the LSD model and reference point calculations	Open session
Tuesday 23 July a.m.	Presentation on management procedures (MPs) and management procedure evaluation (MPE)	Open session
Tuesday p.m. and Wednesday 23 July	Panel confers with individuals or works alone on review	Panel's discretion
Thursday 25 July	Panel works on review	Closed session
Friday 26 July a.m.	Panel presents draft findings	Open session
Friday 26 July p.m.	Panel concludes review	Closed session

It is anticipated that the review will be concluded by 5 pm on Friday 26 July, although final drafting of the report may take place over subsequent days.

Fisheries New Zealand Terms of Reference for an independent review of rock lobster stock assessment modelling and the determination of management reference points

Allen Boardroom, NIWA, Greta Point, Evans Bay Parade, Wellington

Chair (of open sessions): Pamela Mace, DDI (027) 240 8262, email Pamela.Mace@mpi.govt.nz

PRELIMINARY AGENDA (Note that times are approximate)

Monday 22 July

1. 9:30 am – Welcome and introductions
2. 9:45 am – Terms of reference (including out of scope) & management context: Chair
3. 10:00 am – Rock lobster LSD model: Darcy Webber

11:00 Morning tea

4. 11:30 am – Rock lobster LSD model - continued: Darcy Webber

1:00 pm Lunch

5. 1:45 pm – Rationale and calculation of reference points: Darcy Webber and Merrill Rudd

3:15 pm – Afternoon tea

6. 3:45 pm – Discussion, if needed: led by Expert Panel

5:00 pm Adjourn

Tuesday 23 July am

7. 9:30 am – Management procedure evaluation: Darcy Webber
8. 10:30 am – Rapid update methodology: Darcy Webber

11:00 am – Morning tea

9. 11:30 am – Further discussion, if needed: led by Expert Panel

1:00 pm Lunch

Tuesday 23 July pm, Wednesday 24 July, Thursday 25 July

Panel sequestered – no open sessions, but the panel may request further information upon request

Friday 26 July

9:30 am – Panel presents draft conclusions and recommendations to open session; participants offer comment

12:30 onwards – Panel finalises report: no open sessions

6. APPENDIX 2: List of attendees

Fisheries New Zealand, Chair
Pamela Mace

Independent Review Panel Members
Malcolm Haddon
Simon de Lestang
Simon Hoyle

Rock Lobster Working Group Chair, Fisheries New Zealand
Bruce Hartill

Fisheries New Zealand
Charli Mortimer
Duncan Petrie
Howard Reid
Ian Tuck
Nathan Walker

Rock lobster stock assessment team
Darcy Webber
Merrill Rudd
Maite Pons
Jim Roberts
Paul Starr

Rock Lobster Industry Council – RLIC
Mark Edwards
Julie Hills
Angela Russell
Daryl Sykes

New Zealand Sports Fishing Council
John Holdsworth
Sydney Curtis

Auckland University
Benn Hanns

6.1 Independent Review Panel Members Biographies

6.1.1 Dr Simon de Lestang

Dr Simon de Lestang has over 20 years of postdoctoral experience as a team leader and researcher at a range of institutions including Murdoch University, Challenger TAFE and the Department of Primary Industries and Regional Development (DPIRD - Fisheries).

Currently he is the Principal Research Scientist for rock lobster and crab fisheries, with his primary duties being the stock assessments of these target species.

Dr de Lestang has also conducted many consultancy jobs on a range of marine species including finfish and sharks. He has also had extensive experience in marine ecology, examining the biodiversity of a range of ecosystems in response to anthropogenic impacts including dredging, marina development and seismic surveys.

6.1.2 Dr Malcolm Haddon

Dr Malcolm Haddon has 37 years of postdoctoral experience in fisheries science and is currently both retired and a part-time consultant focussing on stock assessment methods, harvest strategies, and management strategy evaluation. He has worked on various Crustacean, Molluscan, and Scalefish species, including biological studies, stock assessments, and management strategy evaluation. Most of his current focus is on abalone population dynamics, assessment, and harvest strategy.

Dr Haddon has worked as a fisheries scientist in MAF Fisheries New Zealand, a lecturer in marine ecology at the Victoria University of Wellington, has been the editor of the New Zealand Journal of Marine and Freshwater Research, a Senior Research Fellow at Sydney University, Head of Fisheries at the Australian Maritime College, Associate Professor at the Tasmanian Institute of Fisheries and Aquaculture at the University of Tasmania, and a Principal Research Scientist at CSIRO, Hobart. Currently, he is an Adjunct Professor at the Institute of Marine and Antarctic Sciences at the University of Tasmania.

6.1.3 Dr Simon Hoyle

Dr Simon Hoyle is an independent fisheries scientist and consultant based in Nelson, New Zealand, and an honorary academic in the Department of Statistics at the University of Auckland. He has over 30 years' experience in stock assessment, statistical modelling, and software development.

He has worked as a Senior Scientist at the Inter-American Tropical Tuna Commission, Senior Stock Assessment Scientist at the Pacific Community, and Principal Scientist at NIWA, and as a consultant to all five tuna RFMOs.

He has worked on a variety of taxonomic groups, including tunas, eels, sharks, birds, and marine and terrestrial mammals. His research interests include spatial modelling and the development of biological parameters and data inputs for stock assessment, including the analysis of CPUE, tag recapture, size composition, and biological data.