Development of a tier Harvest Strategy approach for Torres Strait tropical rock lobster (TRL)

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Summary

The amount and quality of data and surveys available to inform assessments of the Torres Strait tropical rock lobster (TRL) stock has varied over time, and stakeholders have requested flexibility to increase or decrease the frequency and intensity of fishery-independent surveys in future. To accommodate potential changes in the amount of monitoring information available and number and timing of surveys, and hence changes in the associated level of confidence in the scientific advice for decision-making, a hierarchical tier system is proposed. Tier systems broadly aim to reduce the risk when data are poorer, and ideally aim for risk equivalency such that different tiers have the same risk of the stock falling below the limit reference point. This is achieved by adjusting catch limits upwards or downwards based on the available data and assessment type, with the adjustment factors referred to as buffers or discount rates. A four Tier system is proposed for TRL, where Tier 1 represents the highest quality of information (as was collected during 2005-2008, 2014) and Tier 4 the lowest. The top three tiers all include applying a stock assessment every three years, and each tier has its own empirical Harvest Control Rule (eHCR) based on available inputs, but discount factors are applied to the Recommended Biological Catch (RBC) from Tiers 1, 3 and 4. This is because these tiers are assessed relative to the current/base Tier 2, with any upward move to the data-rich Tier 1 involving a bonus in the form of a positive discount, and a move down the tiers incurring a penalty in the form of a negative discount. A preliminary suggested framework is as shown in Table 1 below.

Table 1. Summary of proposed tier system for TRL (penalty or bonus relative to Tier 2 – current approach).

Tier level	Information requirements	eHCR	Penalty or bonus discount factor applied to RBC
1	Catch, Midyear survey, Preseason survey, CPUE_TIB, CPUE_TVH	Based on all indices with weightings and rule as specified in App. 2.	5%
2	Catch, Preseason survey, CPUE_TIB, CPUE_TVH	Based on all indices with weightings and rule as specified in App. 1.	-
3	Catch, CPUE_TIB, CPUE_TVH	Based on CPUE indices and average catch as specified in App. 3.	-20%
4	Only for assessment	Fixed catch = 360t	-

Introduction

The amount and quality of data and surveys available to inform assessments of the Torres Strait tropical rock lobster (TRL) stock has varied over time, and stakeholders have requested flexibility to increase or decrease the frequency and intensity of fishery-independent surveys in future. It is generally accepted that as monitoring, management and costs increase for a fishery, the risk associated with being overfished declines (Sainsbury 2005). Risk is often defined as the probability of a resource falling below the limit reference point, and is related to the stock's productivity and amount of catch taken from it (Dichmont et al. 2015). The Australian Commonwealth Harvest Policy (HSP) defines risk equivalency based on the criterion that the stock stays above the limit biomass level at least 90% of the time (DAFF 2007; Rayns 2007). Traditional owners in Torres Strait are generally highly risk averse also because of the local cultural and socio-economic importance of TRL. Here we additionally consider the risk of a fishery closure based on the harvest strategy rules currently under development. The trade-offs between managing a fishery in a biologically and economically optimal way whilst minimising management costs is referred to as the risk-cost-catch frontier (Dowling et al. 2013; Little et al. 2014).

To accommodate potential changes in the amount of monitoring information available, and hence changes in the associated level of confidence in the scientific advice for decision-making, a hierarchical tier system is proposed. Tier systems broadly aim to reduce the risk when data are poorer, and ideally aim for risk equivalency such that different tiers have the same risk of the stock falling below the limit reference point. This is achieved by adjusting catch limits upwards or downwards based on the available data and assessment type, with the adjustment factors referred to as buffers or discount rates. Examples of tier systems that have been formally implemented include Australia's Southern and Eastern Scalefish and Shark Fishery (SESSF), the USA Federal system and ICES (Dichmont et al. 2015; Fulton et al. 2016; Punt et al. 2012). However these systems are designed to accommodate a suite of different species with different data and assessment methods that are applied to individual species which are then assigned to a tier. Existing tier systems involve an element of expert judgement as to choice of discount rates applied to different tiers, although it is recognised that Management Strategy Evaluation (MSE) testing (Rademeyer et al. 2007; Smith et al. 1999) can be used to quantify discount rates that would meet the aim of achieving risk equivalency. For the SESSF, each individual tier has been tested using Management Strategy Evaluation (MSE), and recently MSE was used to evaluate the tier system in an ecosystem context using Atlantis (Fulton et al. 2016). The analyses suggested that neither the SESSF or USA systems achieved complete risk equivalency and highlighted that achieving risk equivalency depends partly on the definition of risk as performance metrics may differ (Fulton et al. 2016). In another Australian example, Plaganyi et al. (2015) applied an MSE approach to simulation test alternative rotational zone strategies for the multispecies Queensland East Coast Sea Cucumber (bêche de mer) fishery. They demonstrated that for the same risk level (based on risk of depletion below a limit reference point), the average annual catch could be greater with increasing length of the rotation cycle.

The TRL case differs from the SESSF because it is intended for application to a single stock to account for potential monitoring data changes over time, and hence support stakeholders in making decisions regarding the level of monitoring (and amount and timing of surveys). The TRL case also differs from other fisheries such as SESSF as TRL harvests a short-lived species largely dependent on an ever-changing environment which means that data from recruitment surveys (and mid-year surveys) are actually very informative. These concepts have been discussed at several previous TRLRAG meetings using the example as shown in Fig. 1.

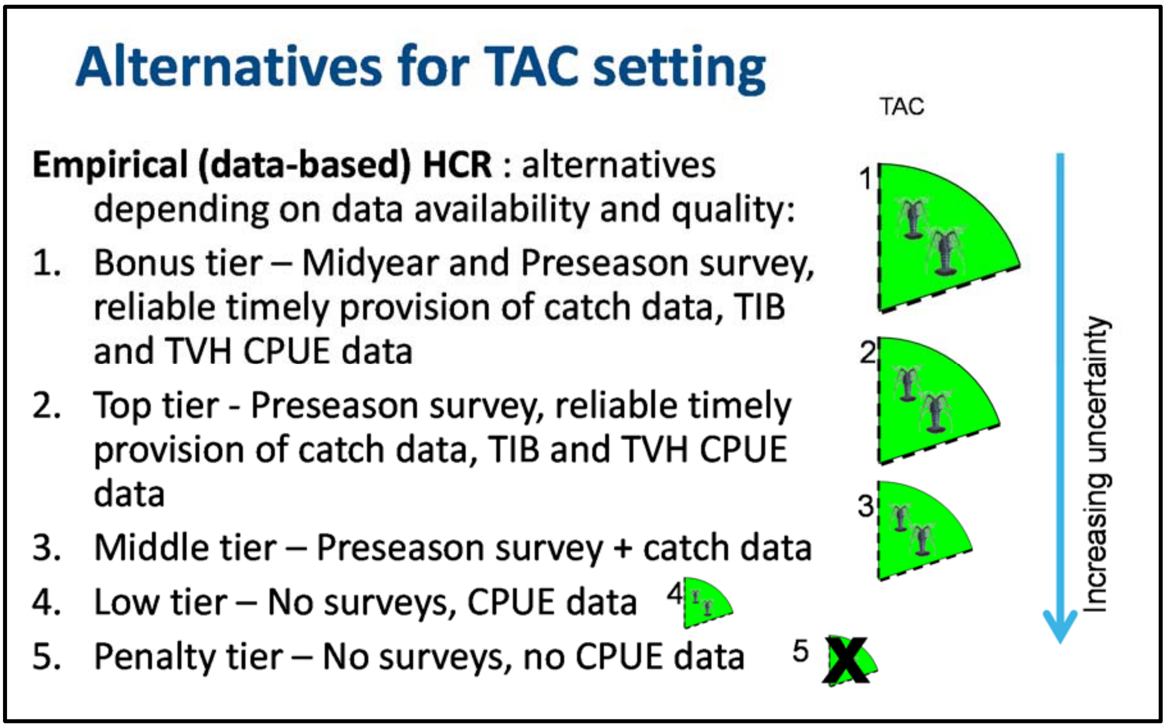

Fig. 1. Preliminary tier-based framework for TRL presented at previous meetings. The framework presented in this document has dropped number 3, with number 4 in the above relabelled Tier 3 and the "penalty tier" as Tier 4.

This paper summarises a preliminary approach for developing a tier system for TRL that uses MSE testing to inform choice of discount rates consistent with the aim of achieving risk equivalency across tiers. Applying a more precautionary approach to harvest control rules for which data and/or assessments are more uncertain is consistent with the Commonwealth Fisheries Harvest Strategy Policy 2007 (HSP) (DAFF 2007). This acknowledges higher risk associated with having less data to inform an assessment, as well as encouraging data collection that would move the fishery to a higher tier. Maintenance of long-term data sets are also important as each survey's yearly data points true value is greater than its fractional individual value, as even though this is a short lived species dependent on environmental fluctuations a trend in any time series is valuable in terms of additional information. Moreover, Dennis et al. (2015) showed that including one or more fishery-independent surveys returned a positive net present value over a 20 year timeframe even when randomly varying biomass using the historical range estimated from stock assessments, and accounting for increasing survey costs, lower gross margins, and lower lobster prices.

A four Tier system is proposed as follows, where Tier 1 represents the highest quality of information (as was collected during 2005-2008, 2014) and Tier 4 the lowest. The top three tiers all include applying a stock assessment every three years, and each tier has its own empirical Harvest Control Rule (eHCR) based on available inputs, but discount factors are applied to the Recommended Biological Catch (RBC) from Tiers 1, 3 and 4. This is because these tiers are assessed relative to the current/base Tier 2, with any upward move to the data-rich Tier 1 involving a bonus in the form of a positive discount, and a move down the tiers incurring a penalty in the form of a negative discount.

Tier 1 (Bonus Tier): Monitoring information: Total catch (TIB, TVH,PNG), Midyear survey (1+ and 2+ relative abundance), Preseason survey (0+, 1+ relative abundance), CPUE standardised indices of abundance from TIB and TVH sectors (2+ index).

Tier 2 (Current Tier): Monitoring information: Total catch (TIB, TVH,PNG), Preseason survey (0+, 1+ relative abundance), CPUE standardised indices of abundance from TIB and TVH sectors (2+ index).

Tier 3 (Penalty Tier): Monitoring information: Total catch (TIB, TVH,PNG), CPUE standardised indices of abundance from TIB and TVH sectors (2+ index).

Tier 4 (Lowest Tier): No monitoring information

Empirical Harvest Control Rules for different tiers

Here we commence with a review of Tier 2 because this is the current situation and is used as the base level for comparison with the other tiers. Next we review Tier 4 because this is based on work presented previously, followed by Tier 1 and finally Tier 3.

Tier 2 eHCR

The current Tier 2 eHCR being considered for adoption by the TRLRAG outputs a RBC based on the slopes of the regression lines fitted to the Preseason survey and CPUE indices, with different weightings applied to the different data sources (70% Preseason 1+; 10% Preseason 0+; 10% CPUE_TIB; 10% CPUE_TVH) (Fig. 2), and the overall resultant trend multiplied by the average of the last 5 years' catch (Appendix 1). This eHCR implies that if the performance of the fishery is improving then the RBC will increase while if the performance of the fishery is decreasing then the RBC will also decrease. Over the long-term this eHCR should maintain the stock around the target biomass level.

Different weightings are applied to the four abundance indices included in the relative performance statistic used in the eHCR, based on extensive testing to compare performance of alternative weightings and also on considerations of the information content and reliability of each series, as well as a preference expressed by the stakeholders to use a portfolio approach in determining the RBC. The Preseason 1+ index is the most reliable and direct in terms of indexing the biomass of lobsters that will be available to be caught in the next fishing season, and hence this index is assigned the highest weighting of 70%. The Preseason 0+ index provides an early indication of the following year's recruitment, whereas the CPUE indices reflect the abundance of the large 2+ lobsters, the survivors of which will migrate out of the Torres Strait to spawning grounds to the East, and hence they index spawning biomass which is an important consideration in terms of ensuring the future sustainability of the stock. Each of these three secondary indices (Survey 0+ and CPUE (TIB and TVH)) are assigned a weighting of 10% in the eHCR formula.

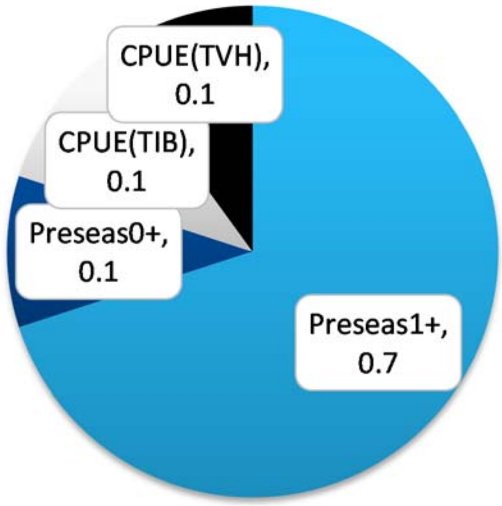

Fig. 2. Tier 2 eHCR weightings selected by TRLRAG.

Tier 4 rule:

MSE testing was also used to highlight the comparison with a constant catch strategy (with catch set at 680t or alternatively, the average of the past 10 years' catch). Results highlighted that such a constant catch strategy poses an unacceptably high risk to the resource and importantly a substantially higher risk of invoking a closure of the fishery in the future, compared to the adaptive Tier 2 eHCR, which adjusts catches in line with stock fluctuations. It is worth noting that previous TAC estimates were as low as 470 t; hence a constant catch may result in overfishing by 200 t in low stock years. Simulations suggest that to achieve the same level of risk as the adaptive Tier 2 eHCR, the constant catch would need to be set at a low total of 360t, which is approximately half the average catch that could be achieved using an adaptive eHCR. Hence the Tier 4 rule would simply be to set the RBC = 360t.

Tier 1 eHCR

For Tier 1, it is possible to expand the eHCR to include data inputs from a Midyear survey. MSE testing has been done to compare the performance of a range of alternative candidate Tier 1 eHCRs. The alternative weightings for consideration by the TRLRAG are as shown in Fig. 3, and summarised in Appendix 2. All of the options correspond to a similar level of risk to the resource, and the overall risk to the resource is similar to the Tier 2 level except for option Mid1 which had slightly higher risk. The average catch expected when applying this rule is up to 50t greater per year than when using the Tier 2 eHCR.

In addition, a discount factor or bonus *b* can be applied as follows:

Tier 1: $RBC_{DISC} = RBC(1+b/100)$

This was tested by substituting the average catch from Tier 2 in the rule in place of the average for the last 5 years' catch. Results from the application of a discount factor of 10% or 5% (*b*=5 or 10) will be presented at the RAG.

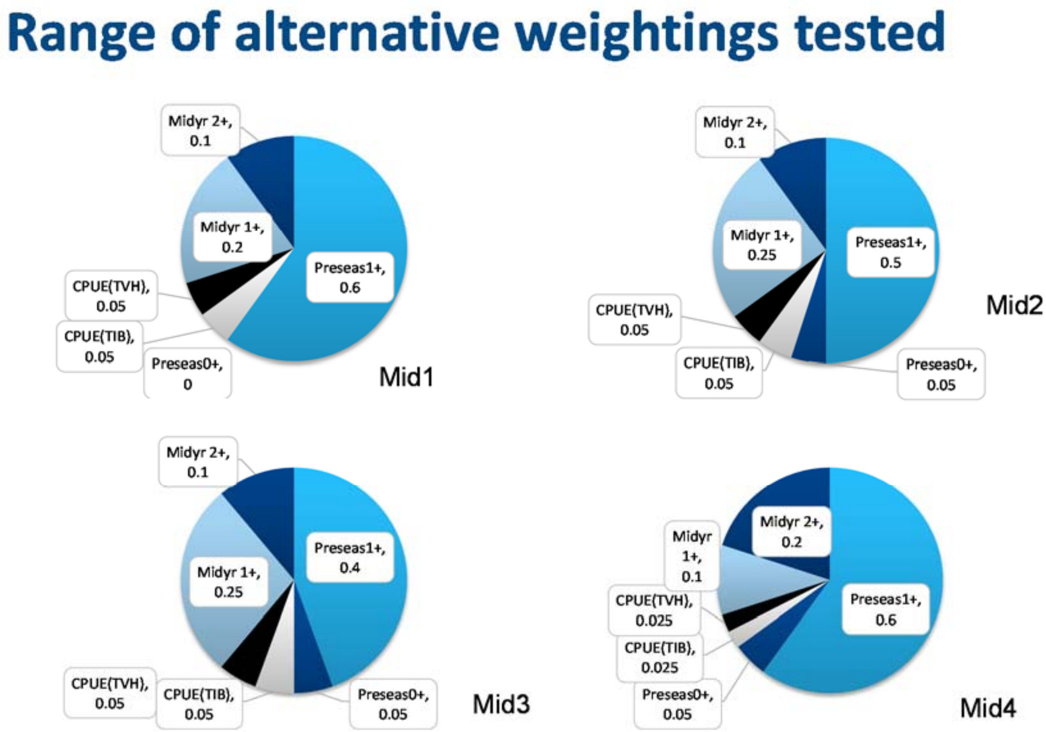

Fig. 3. Alternative Tier 1 eHCR weightings when including information from a midyear survey

Tier 3 eHCR

For Tier 3, the eHCR needs to be based on only the two CPUE input series, with equal weight assigned to each input, as shown in Fig. 4 and summarised in Appendix 3. If a discount factor is applied consistently to a eHCR that uses the average of the last five years' catch, this results in the catch ramping down substantially over time (full results available in electronic Appendix). Hence an alternative eHCR was tested which uses instead the average catch from the Tier 2 testing, and adjusts this upwards or downwards based on the CPUE trends (see Appendix 3) before applying a penalty *p* of a 10% or 20% reduction in the RBC as follows:

Tier 3: $RBC_{DISC} = RBC(1-p/100)$

Results from application of a discount factor of -10% or - 20% (*p*=10 or 20) will be presented at the RAG. In addition, given the considerable uncertainty in the reliability of CPUE as an index of abundance (because of e.g. changes in catchability or fishing efficiency) an additional sensitivity test was run (assuming a 10% future increase in catchability and 20% increase in sigma) to evaluate the additional risk and inform choice of an appropriate penalty to achieve risk equivalency.

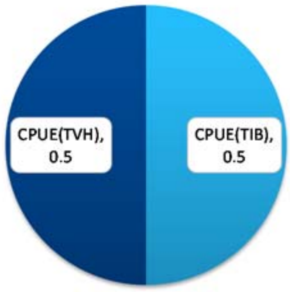

Fig. 4. Tier 3 eHCR weightings

CONCLUSIONS

A preliminary summary of the findings is shown in Fig. 5 and the full set of MSE results is available on request in an electronic Appendix, and a more detailed description of the methods is being prepared in a report that will be finalised once feedback from the TRL RAG is obtained. Broadly preliminary results are as summarise in Table 1.

This summary paper outlines the motivation for adopting a tier approach and some suggestions for a framework that could be used, but any further work will depend on detailed discussion and feedback from the TRLRAG.

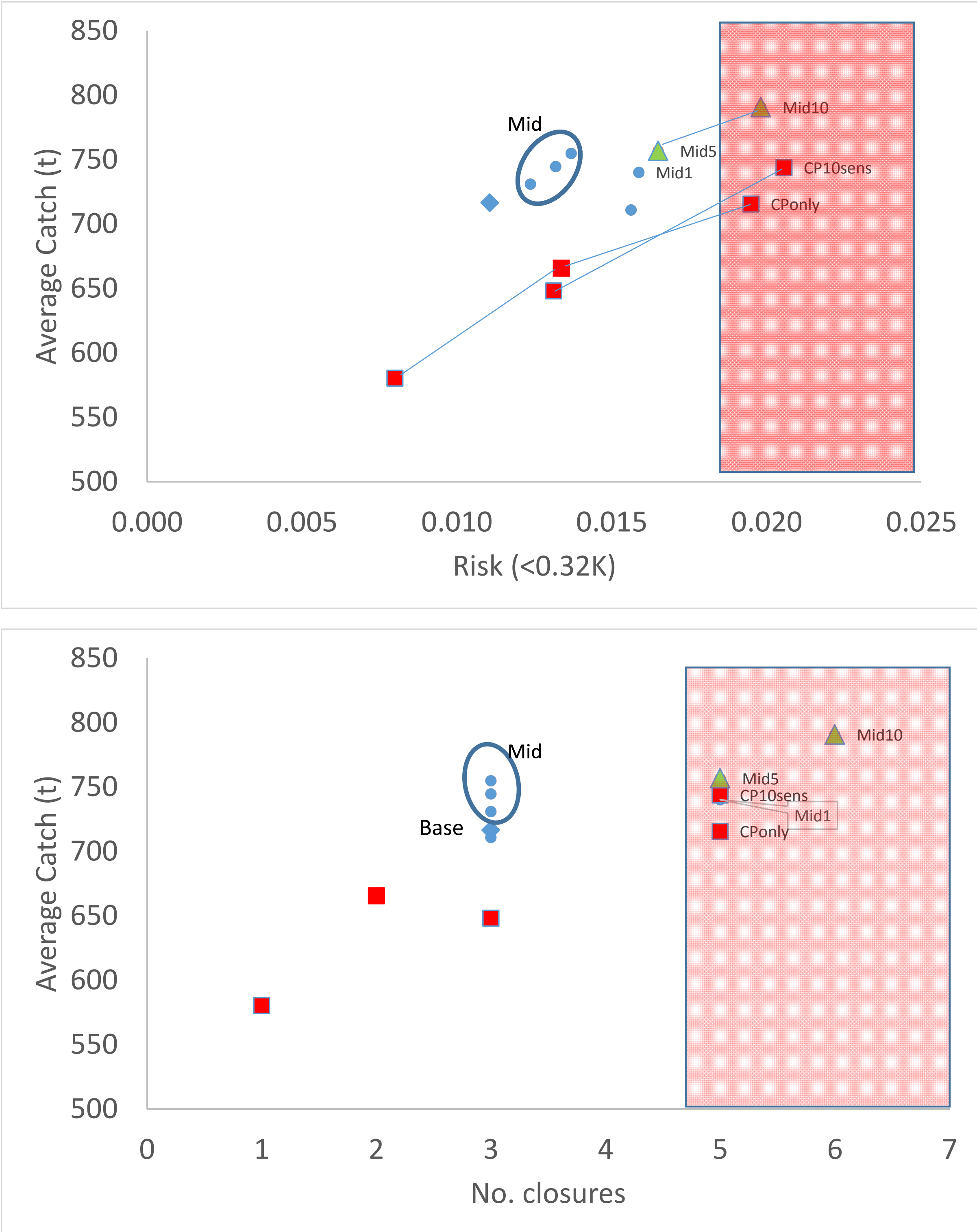

Fig. 5. Trade-off plot showing average catch (t) versus risk for a number of alternative harvest control rule variants across tiers 1-3, to illustrate the higher risks associated with some variants, and adjusted versions that aim to achieve risk equivalency across the tiers. The top figure uses as risk criterion the probability of falling below the limit reference point whereas the bottom figure risk definition is based on risk of a fishery closure when evaluated over a 20-year projection period (Blue dots and green triangles are Tier 1 evaluations with green triangles higher discount rates; Red squares are evaluations of Tier 3 sensitivity tests).

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APPENDIX 1 – Tier 2 Harvest Control Rule

The eHCR selected by the TRLRAG (August 2016), from a number of alternative candidates that were evaluated, is a formula that outputs a RBC in December for the following year. This formula is the multiple of the average catch over the last 5 years and a statistic which measures the relative performance of the fishery based on the following 5 data inputs: (1) Preseason recruiting lobster (1+) standardised relative numbers; (2) Preseason recently-settled lobster (0+) standardised relative numbers; (3) CPUE (TIB sector) and (4) standardised CPUE (TVH sector) (using data available up until end of October); and (5) total catch (TIB,TVH,PNG) (using data available up until end of October.

The selected HCR rule is as follows, and uses the preseason survey 1+ and 0+ indices, both CPUE indices, taking natural logarithms of the slopes, an upper catch limit, and using weightings as follows:

$$TAC_{y+1} = \left[0.7 \cdot \left(1+s_y^{presurv,1}\right) + 0.1 \cdot \left[\left(1+s_y^{presurv,0}\right) + \left(1+s_y^{CPUE,TVH}\right) + \left(1+s_y^{CPUE,TIB}\right)\right]\right] \cdot \bar{C}_{y-4,y}$$

or if TAC_{y+1} > 1000t, TAC_{y+1} = 1000.

where

$\bar{C}_{y-4,y}$ is the average achieved catch during the past 5 years, including the current year i.e. from year *y*-4 to year *y*,

$s_y^{presurv,1}$ is the slope of the logarithms of the preseason survey 1+ abundance index, based on the 5 most recent values;

$s_y^{presurv,0}$ is the slope of the logarithms of the preseason survey 0+ abundance index, based on the 5 most recent values;

$s_y^{CPUE,TVH}, s_y^{CPUE,TIB}$ is the slope of the logarithms of the TVH and TIB CPUE abundance index, based on the 5 most recent values;

0.7, 0.1 are tuning parameters

APPENDIX 2 – Tier 1 Harvest Control Rule

The eHCR formula is the multiple of the average catch over the last 5 years and a statistic which measures the relative performance of the fishery based on the following 7 data inputs: (1) Preseason recruiting lobster (1+) standardised relative numbers; (2) Preseason recently-settled lobster (0+) standardised relative numbers; (3) CPUE (TIB sector) and (4) standardised CPUE (TVH sector) (using data available up until end of October); (5) Midyear survey 1+ index; (6) Midyear survey 0+ index, and (7) total catch (TIB,TVH,PNG) (using data available up until end of October.

The general form of the rule is as follows:

$$TAC_{y+1} = \begin{bmatrix} w_1 \cdot \left(1+s_y^{presurv,1}\right) + w_2\left(1+s_y^{presurv,0}\right) + w_3\left(1+s_y^{CPUE,TVH}\right) + w_4\left(1+s_y^{CPUE,TIB}\right) \\ +w_5\left(1+s_y^{Midsurv,1}\right) + w_6\left(1+s_y^{Midsurv,2}\right) \end{bmatrix} \cdot \bar{C}_{y-4,y}$$

or if TAC_{y+1} > 1000t, TAC_{y+1} = 1000.

where

$\bar{C}_{y-4,y}$ is the average achieved catch during the past 5 years, including the current year i.e. from year *y*-4 to year *y*,

$s_y^{presurv,1}$ is the slope of the logarithms of the preseason survey 1+ abundance index, based on the 5 most recent values;

$s_y^{Midsurv,1}$ is the slope of the logarithms of the Midyear survey 1+ abundance index, based on the 5 most recent values;

$s_y^{Midsurv,2}$ is the slope of the logarithms of the Midyear survey 2+ abundance index, based on the 5 most recent values;

$s_y^{presurv,0}$ is the slope of the logarithms of the preseason survey 0+ abundance index, based on the 5 most recent values;

$s_y^{CPUE,TVH}, s_y^{CPUE,TIB}$ is the slope of the logarithms of the TVH and TIB CPUE abundance index, based on the 5 most recent values;

w1,w2,w3,w4,w5,w6 are tuning parameters that assign relative weight respectively to the preseason 1+, preseason 0+ survey trends, CPUE TVH, CPUE TIB trends and the midyear survey 1+ and 2+ trends.

Alternative weights tested:

	Pre1	Pre0	TIB_CPUE	TVH_CPUE	Mid1	Mid2	sum
Base	0.7	0.1	0.1	0.1	0	0	1
Mid1	0.6	0	0.05	0.05	0.2	0.1	1
Mid2	0.5	0.05	0.05	0.05	0.25	0.1	1
Mid3	0.4	0.05	0.05	0.05	0.35	0.1	1
Mid4	0.6	0.05	0.025	0.025	0.1	0.2	1
NoSurv	0	0	0.5	0.5	0	0	1

APPENDIX 3 – Tier 3 Harvest Control Rule

The eHCR suggested doesn't use the average catch over the last 5 years but rather a fixed average catch with the RBC scaled down by a penalty. Hence only the following 2 data inputs are used: (1) CPUE (TIB sector) and (2) standardised CPUE (TVH sector) (using data available up until end of October).

$$TAC_{y+1} = 0.5 \cdot \left[\left(1 + s_y^{CPUE,TVH}\right) + \left(1 + s_y^{CPUE,TIB}\right) \right] \cdot \overline{C}$$

or if TAC_{y+1} > 1000t, TAC_{y+1} = 1000.

where

$\overline{C}$ is a fixed average catch,

$s_y^{CPUE,TVH}, s_y^{CPUE,TIB}$ is the slope of the logarithms of the TVH and TIB CPUE abundance index, based on the 5 most recent values.

APPENDIX 4 – MSE testing results (available on request in electronic pdf)