Reducing Uncertainty in Stock Status:

Harvest Strategy Testing, Evaluation, and Development. General Discussion and Summary

Malcolm Haddon
Wealth from Oceans Flagship,
CSIRO,
GPO Box 1538, Hobart,
TAS 7001, Australia

December 2012

Report prepared for the Department of Agriculture, Fisheries and Forestry (DAFF) as part of the Reducing Uncertainty in Stock Status Project.

www.csiro.au

Enquiries should be addressed to:

Malcolm Haddon
CSIRO Marine and Atmospheric Research
GPO Box 1538, Hobart
Tas 7001, Australia
Tel: 61-3-6232-5097
Fax: 61-3-6232-5053
Email: malcolm.haddon@csiro.au

Preferred citation:
Haddon, M. (*ed.)* (2012) *Reducing Uncertainty in Stock Status: Harvest Strategy Testing, Evaluation, and Development. General Discussion and Summary.* CSIRO Marine and Atmospheric Research. 42 p.

Contents

1 ACKNOWLEDGEMENTS

This work was funded by the Reducing Uncertainty in Stock Status (RUSS) Project through the Australian Government's Department of Fisheries, Forestry and Agriculture (DAFF) and the CSIRO, Wealth from Oceans Flagship.

The RUSS Stream 2 project team is thanked for contributions and discussions during this project.

CSIRO team members

Cathy Dichmont
Natalie Dowling
Malcolm Haddon
Neil Klaer
Eva Plagányi
Tim Skewes
Sally Wayte
Shijie Zhou

ABARES team members

Fiona Giannini
Belinda Barnes
Veronica Rodriguez
Peter Ward

2 SUMMARY

The Reducing Uncertainty in Stock Status (RUSS) research project was begun in 2009 and was a collaboration between the CSIRO and the Bureau of Rural Sciences (which became the Australian Bureau of Agricultural and Resource Economics and Sciences; ABARES). This research had the objective of reducing the number of fisheries classified as uncertain in the annual ABARES Fishery Status reports. The strategy adopted for achieving this objective involved two streams of activity. The first stream related to examining an array of relatively data-poor assessment methods to determine whether some uncertain species could be assessed such that their uncertain status could be altered. The second stream related to using management strategy evaluation (MSE) to test the particular harvest strategies implemented in an array of different fisheries. This document summarizes the outcomes of the second stream, in particular the results of the MSE analyses carried out by CSIRO staff within the RUSS project. The document comprises the executive summaries of each of the five MSE analyses conducted, the reporting framework for each fishery agreed at the start of the project, and a short discussion of the findings.

The five fisheries considered here were the Bass Strait scallop fishery, the Coral Sea bêche de mer fishery, spatial aspects of the demersal trawl fishery in the southern and eastern scalefish and shark fishery, the North West slope trawl fishery, and the Torres Strait bêche de mer fishery. In all cases the harvest strategies were found to be effective at achieving the intent of the harvest strategy policy, although assumptions and limitations were also discovered. While final reports have been produced for each of these MSE analyses some of the work has already been formally published and other parts are in the process of being published (Klaer *et al*., 2012; Plagányi *et al*., 2012).

3 INTRODUCTION AND BACKGROUND

3.1 Management Strategy Evaluation

Management Strategy Evaluation (MSE) is regarded as the best available approach for contrasting and comparing the performance of alternative fisheries management strategies. For a given fishery, each different combination of data collection or monitoring, stock assessment/estimation of performance measures, and decision/control rules leading to management actions, is termed a Management Strategy. There can be numerous alternative management strategies developed for any single fishery. For example, 1) the data collected could be the daily catch rates across all vessels in an area for the whole season; 2) The assessment or estimate of the performance measure could be the estimation of the geometric mean catch rates and variation about these values, and 3) a decision rule could be that a 30% decline in the geometric mean across a two year period would lead to a 10% drop in the TAC. All three steps would constitute a management strategy. If the decision rule happened to be a 20% drop in TAC then the three combined would constitute a separate and different management strategy. A very significant question to be answered is which of these management strategies are most effective at achieving the management objectives selected for a fishery (especially in the context of uncertain data and possible delays in management responses)? Clearly this approach to management also requires an explicit statement concerning the objectives towards which each fishery is intended to be managed.

An advantage of using MSE rather than experimentally manipulating real fisheries is the obvious one of being able to explore options that would have unacceptable risks with a real fishery. Truly experimenting with the management of a real fishery would not only be risky in practice it would also be extremely slow, especially if management proceeded cautiously. Instead, it is more efficient to use MSE to search for those management strategies which are robust to uncertainties in available data and in our knowledge of the stock dynamics or at least to reject those strategies that are not robust.

In fact there are many sources of uncertainty in resource management. When generating management advice one is aware of uncertain data, uncertain knowledge about the dynamics of the stock involved, which is the same as assessment uncertainty, uncertainty about the future distribution of effort, uncertainty about the biology of the species concerned, and finally, there is uncertainty about how management decisions are implemented. MSE involves a simulation framework that considers the whole management system. It consists of an Operating Model (which is a Simulation of a Virtual Fishery) that is regarded as representing the accepted as “true” underlying dynamics of the resource and the fishery. It is best practice, where possible, to use multiple or different Operating Models so as to capture uncertainty about the true underlying dynamics of the stock. The Operating Model also includes methods for generating the types of data usually collected from each fishery. The MSE framework includes the different assessment procedures and performance measures that are used to analyse the various fishery or monitoring data generated by the Operating Model. The assessment procedures that estimate the performance measures are only "aware" of the generated data, which can contain error, and are not aware of the underlying dynamics of the assumed true Operating Model. Finally, there are sets of decision rules that interpret the results from the performance measure estimates and generate management advice that can be acted upon. This modelled management advice is fed back into the Operating Model where it can obviously influence the dynamics of the virtual stocks being managed. This feedback loop is key to the process of examining how the implications of different management strategies might differ. In this way different management strategies can be simulated and the predicted outcomes from the assessments can be compared with the "true" situation from inside the Operating Model. By including a wide range of uncertainties into the simulated data the MSE process can identify those management strategies and performance measures that are most robust to uncertainty and that enable management to best achieve its objectives. Developing and conducting a full MSE may take significant time (years) but would still provide for many more comparisons than could be contemplated with a real fishery.

Management strategy evaluation constitutes the simulation testing of all aspects of the assessment and management of a fishery (**Figure 1**). Generally MSEs are used to test an

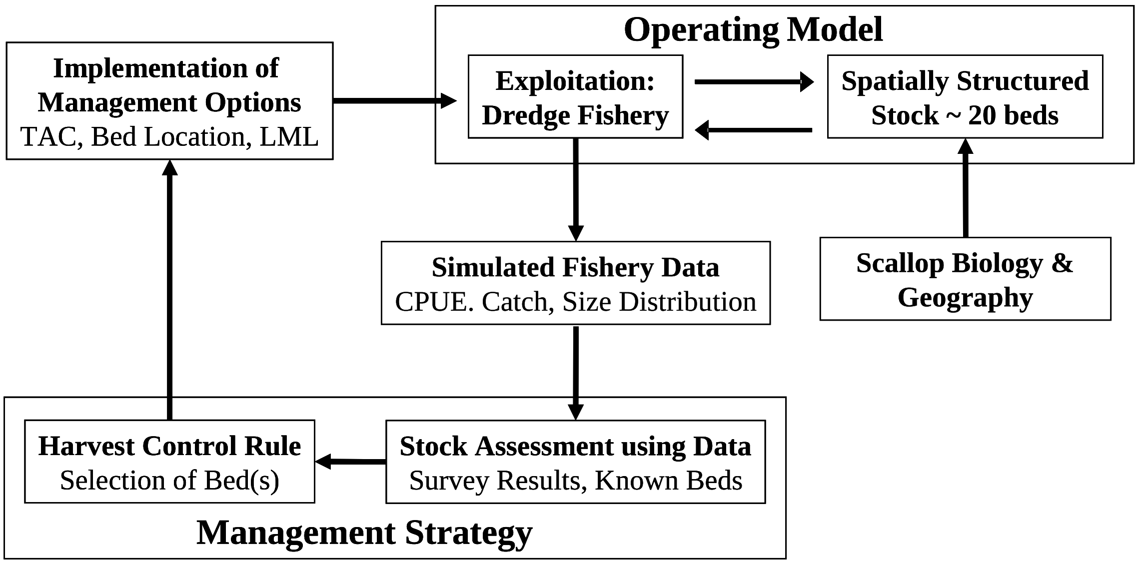

Figure 1. The procedural structure of the Management Strategy Evaluation simulations for the scallop fisheries in the south-east of Australia. Similar diagrams could be specified for other fisheries with the details within each box varying by fishery but each fishery having every component.

array of alternative management strategies but in this instance, the question being considered is focused on whether the sources of uncertainty that influence the management of a fishery compromise the effectiveness of the management strategy in place within the different Commonwealth fisheries examined. Despite being focussed on particular fisheries there are some aspects of the results that can be generalized to fisheries that are managed in similar ways.

This present document provides a brief overview of five different MSE simulation tests conducted on the harvest strategies implemented in five different Commonwealth fisheries. Four of these relate to relatively difficult and relatively data-poor fisheries (Bass Strait scallops (Haddon, 2001), the North West Shelf trawl fishery (Dowling, 2011), the Coral Sea Beche de Mer and the Torres Straits Beche de Mer fisheries (Plagányi *et al*., 2011, 2011b)). In addition, some more involved analyses were conducted on the Demersal trawl fishery (Klaer and Wayte, 2011). This work extends and develops earlier work in Australia conducting MSE analyses on various Commonwealth fisheries (Smith *et al*., 1999; Punt *et al*., 2001a; Punt *et al., 2001b;* Punt *et al*., 2002; Punt *et al*., 2005; Smith *et al*, 2008; Wayte, 2009; Fay *et al*, 2009; Little *et al*., 2011). An additional MSE analysis was carried out on the Commonwealth Small Pelagic Fishery based on some extensions to a Fisheries Research Development Corporation project 2008/064 (Giannini *et al*., 2010), the results of this extension are not covered here.

Each of the MSE documents was the product of separate sub-projects within the umbrella Reducing Uncertainty in Stock Status project that was instigated within ABARES. One of the objectives was to attempt to reduce the number of fisheries in the uncertain status classification within the annual ABARES Fishery Status Reports.
The present document presents the executive summaries of each of the MSE projects and then a brief discussion, finally the separate standard reporting framework that details the particular fishery concerned are presented.

3.2 The Commonwealth Scallop Fishery (Haddon, 2011)

- The current Harvest Strategy performs remarkably well with regard the limit reference points considering the extremely variable nature of scallop populations. With a B_{LIM} of 500 t the HS as it stands keeps the proportion of times the stock falls below B_{LIM} to less than 6%. At the same time it reduces fishing mortality as the stock size declines. The requirement to retain 40% of beds or at least one bed at all times is very effective but also has the effect of there being a real probability of there not being a fishery every year, even with a token TAC of 25 t.
- Large areas of uncertainty remain in the management of the scallop fishery. The probability and scale of successful recruitment are two areas of immediate concern but it will be extremely difficult to improve our understanding. Nevertheless, continued observations of time to establish and scale of recruitment will permit an empirical understanding to develop over time.
- Before the biology and fishery for commercial scallops (*Pecten fumatus*) could be successfully simulated to test the effectiveness of the current harvest strategy, biological details, such as the variation in growth rates and the variation in the weight at length, had to be characterized from data collected in previous research projects.
- The current HS has a good proxy for the intent of the limit reference point (LRP) but only an approximate proxy for the intent of the target reference point (TRP).
- The proxy for the LRP is the requirement to retain at least one viable scallop area or bed, and that bed must be of at least 500 t. Combined with the requirement to achieve better than a limit discard rate of 20%, this acts to maintain more than a minimum amount of exploitable and spawning biomass more than 90% of the time.
- The proxy for the TRP is less well defined but constitutes the objectives of having a fishery every year. Just in the Commonwealth fishery the probability of there being a fishery every year varied from 0.25 to 0.66. Even with an insignificant fishery the natural variation in scallop stocks indicates there would be years when no fishery could occur given the harvest strategy.
- Given the ability of the HS to maintain the stock biomass above a minimum amount for better than 90% of the time, and that the HS is successful in limiting fishing mortality when the stock is in a low state, the HS can be claimed to be successful at achieving the intent of the HSP; at least in terms of preventing over-fishing and preventing the stock from being overfished, which is what matters with respect to determining status.
- When analyses are limited to a consideration of only the Central Bass Strait scallop fishery this ignores the fact that there are significant fisheries for scallops in both Tasmania and Victoria. Preliminary explorations indicate that the performance of the scallop fishery is greatly enhanced if all jurisdictions are treated as a single cooperative fishery (meaning there is a much greater probability of a fishery each year and a higher probability of there always being a residual stock of scallops present). It is recognized that there remain difficulties in achieving such a co-ordinated fishery but the advantages mean that this is a valuable direction in which to move.

3.3 The North West Slope Trawl Fishery (Dowling, 2011)

- A management strategy evaluation approach was used to test the catch trigger harvest strategy regime for the North-West Slope Trawl Fishery, and the Western Deepwater Trawl Fishery, using scampi as a case study.
- The harvest strategy is not based on estimates of stock status but on catch triggers that invoke a decision rule that progressively increase data and analysis requirements on the fisheries (Levels 1 and 2) and establish a limit reference point (Level 3). The harvest strategy aims to strike a balance between precautionary management arrangements and allowing industry to capitalise on fishing opportunities, while emphasising the need to collect biological data. In the absence of other information or assessments, the triggers for target species are based around the highest historical catch.
- Explicit decision rules at Levels 1 and 2, not previously defined in the current version of the harvest strategy, were imposed. At Level 1, an empirical CPUE "Tier 4" style rule was used, and at Level 2, a production model assessment was undertaken.
- Both a hypothetical and conditioned MSE were developed and results using each compared. Eight alternative harvest strategy implementations were considered using each MSE framework. A range of sensitivity analyses examining the assumed values for natural mortality and selectivity-at-age were tested using the conditioned version of the model. For each scenario and model, the simulated fishery was subjected to an interim period of constant fishing mortality between the historical years and the commencement of the harvest strategy, so that three different fishery conditions (heavily, fished to target, and lightly fished) were considered.
- The majority of the scenarios examined successfully maintained or recovered the spawner biomass above the limit reference point (as determined using the production model assessment), well over 90% of the time as required by the Policy, except when the population had been heavily fished historically AND either triggers were specified inappropriately relative to the population biology (i.e. such that only Level 1 was ever triggered), or there was a mismatch in the assumed population biology between the historical and projection years.
- Generally, the Level 2 trigger response in the harvest strategies also worked to move the spawning biomass towards the target reference point, allowing more effort if the stock was above the reference point, and reducing effort if the stock was below the target.
- Zone-specific triggers, or a system where zones are closed in response to any triggers being reached, resulted in high inter-annual variability in effort and hence in catch. This high volatility is an undesirable feature of a harvest strategy that was intended to allow gradual expansion of the fishery by assigning progressively higher data and analysis requirements with higher trigger values. However, a zone-independent trigger system resulted in less volatility.

3.4 The Demersal Trawl Fishery in the SESSF (Klaer & Wayte, 2011)

- Uncertainty in stock status for Southern and Eastern Scalefish and Shark Fishery (SESSF) demersal trawl species can be described as falling into four categories: uncertainty within the assessment applied, uncertainty over whether the most appropriate assessment has been applied, data uncertainty, and uncertainty in the determination of stock status as determined by an authority. This RUSS sub-project addresses these questions using examples from the SESSF.
- Objectives were developed to examine these sources of uncertainty. The first was to test and evaluate all current SESSF harvest strategies against the HSP (and stock status) objectives and reference points, the second was to develop and test alternative harvest strategies, and the third was to test the data requirements of existing and proposed harvest strategies to determine what sampling is sufficient to meet policy objectives.

Test and evaluate all current SESSF harvest strategies against the HSP (and stock status) objectives and reference points

- Chapter 4 details the procedure and results that achieve this objective. All current SESSF harvest strategies achieve the primary stock objective of not allowing the stock to fall below the limit reference point more than 10% of the time.

Develop and test alternative harvest strategies.

- An alternative length-based harvest strategy that may be used in data poor situations was developed and tested in Chapter 5. Average length of fish in the catch has long been used as a simple indicator of stock condition. Studies have been carried out to determine under what fishery conditions and species biological characteristics such an indicator performs best. The current study used a management strategy evaluation framework to test the combination of an average-length-based assessment with a target and limit-based harvest control rule in terms of specific long-term management objectives. Results showed that for typical SESSF demersal temperate trawl species with relatively high productivity that the average-length-based harvest strategy performs acceptably well. It is essential to take into account the variability in length-at-age in order for this harvest strategy to work effectively. The length-based harvest strategy showed promise as an alternative to the current SESSF Tier 3.
- An alternative harvest strategy that used a production model assessment method was developed and tested in Chapter 6. The production model harvest strategy can work well if the data are informative, with wide variations in effort and CPUE, but otherwise it performs poorly. Thus the data for a particular species should be carefully considered before applying this harvest strategy.

Test the data requirements of existing and proposed harvest strategies to determine what sampling is sufficient to meet policy objectives.

- General data requirements of the existing and proposed strategies tested in previous Chapters were characterized in Chapter 7. A major source of variability that makes random fishery sampling difficult is sub-stock structuring. Most SESSF stocks occur across large areas where we know there has been a non-random distribution of historical fishing patterns that may lead to spatially different population depletion and age structure changes. A simulation study to examine the consequences of spatial sub-structure on the performance of existing and proposed harvest strategies was developed and carried out in Chapter 8. It was shown that the harvest strategies examined all performed well at the overall stock level, even though in some cases the stock condition of sub-stocks were greatly different. These results indicate that the harvest strategies examined were robust to spatial sub-structure and the form of sampling bias that may derive from it.

3.5 Coral Sea Bêche de Mer Fishery (Plagányi *et al*. 2011b)

- Large areas of uncertainty remain in assessing the status and trends of the Coral Sea sea cucumber fishery. The analysis was aided substantially by estimates of abundance that were provided by extrapolation of survey data in the National Nature Reserves to other areas of the Coral Sea, but there were suggestions that some of these might be too conservative due to a number of factors. One of the key uncertainties is the nature and dynamics of recruitment. However, despite incorporating a broad range of uncertainty as to the underlying stock-recruitment relationship and annual probability of recruitment in the Reference Set of Operating Models, it was still possible to discriminate between the performance of different harvest strategies.
- There is a substantial decrease in risk to the resource (in terms of local and overall depletion) if a spatial rotational harvest strategy is implemented. The risk is reduced even further if this is coupled with move-on provisions, although the combination may be too constraining to viably catch the TAC.
- The species predicted to be most at risk under the current harvest strategy was the surf redfish. This is because the TAC of 10t is too large to be taken from the primary source reef for this species, Cato Reef, and hence the catch needs to be spread amongst the other zones which have low surf redfish density, particularly in those years when Cato Reef is closed due to the rotational closures. Historically some 71% of surf redfish catches derive from Cato Reef with a maximum annual catch of 4t, and hence it is not surprising that the TAC is predicted to be too large. Model results suggest there is little risk to the resource if the catches are lower, particularly in years when Cato reef is closed, as seems to be the case in practice.
- The prickly redfish TAC of 20t appears sustainable under most spatial rotation harvest strategies, but is too high if the location choice drivers become such that fishing effort is not sufficiently distributed spatially.
- The black teatfish and white teatfish TACs are low enough to pose minimal risk to the resource.
- This study focused on the major fished species and hence it was not possible to assess the risks to the remaining species that are fished.
- Implementing location choice model variants based on profitability resulted in much heavier depletion of reefs close to the major ports because of the large travel distances to some reefs in the Coral Sea. It is thus not possible to maximise profitability without a large associated risk of depletion to the resource. If implemented fully (ie 3-yr spatial rotation, move-on provisions), it may not be possible to achieve the full TAC for all species in all years.
- The risks to the resource are substantially reduced because of the relatively large area of reef protected by the Lihou and Coringa-Herald National Nature Reserves. The biomass in these closed areas was explicitly included in the model.

3.6 Torres Straits Bêche de Mer Fishery (Plagányi *et al*. 2011)

- Large areas of uncertainty remain in the assessment of the status and trends of the Torres Strait bêche-de-mer fishery. The largest uncertainty is the nature and dynamics of recruitment, and although it is difficult to improve our understanding of this process, the historical survey data was useful in narrowing the hypotheses that were consistent with the data. Moreover, despite incorporating a broad range of uncertainty as to the underlying stock-recruitment relationship and annual probability of recruitment in the Reference Set of Operating Models, it was possible to discriminate between the performances of different harvest strategies.
- The current harvest strategy for the Torres Strait is very simple - limited TACs (Total Allowable Catch) and size limits, however, a move to a more responsive and potentially robust co-management strategy, where communities will have more say in management, is currently under way. The MSE model developed for testing the current harvest strategy would also be suitable for testing new co-management harvest strategies, especially those that have spatial components.
- There is currently insufficient information on trochus to reliably test the harvest strategy for this species.
- The TAC for black teatfish, surf redfish and sandfish is currently zero. MSE analyses suggest that sandfish may not recover in the short term even in the absence of fishing, supporting the current zero TAC for this species. Moreover, results suggested that a larger size limit might be more appropriate for this species. Simulations suggested that black teatfish and surf redfish could sustain small experimental quotas without unduly increasing risk. However, there is a relatively greater risk of localised depletion occurring at Warraber and Warrior.
- The MSE simulations suggested that the current TACs for white teatfish and prickly redfish perform well with regard to controlling the risk of overfishing.
- The remaining three species (deepwater redfish, hairy blackfish and leopardfish) are regulated as part of a joint 80t TAC. Across all model simulations there was a relatively greater risk to deepwater redfish than to the other species, and model results suggested this may reflect a need to increase the size limit for this species. The current TACs were conservative enough if fishing continues in roughly the same way as in the past, but if spatial and species-selection fishing patterns change (for example if they are driven predominantly by profit considerations), then there is a greater risk posed by a joint rather than species-specific TAC, for deepwater redfish and hairy blackfish in particular.

4 DISCUSSION

The current Harvest Strategy Policy discusses limit and target reference points in terms of spawning biomass or fishing mortality related performance measures or their proxies. The basic intent of the policy is to ensure sustainability and to aim to maximize the profitability of each fishery. However, the sustainability aspect of each Harvest Strategy, especially for those fisheries with only simple or relatively data-poor situations or assessments, is very often implemented or supported using other regulations (such as minimum sizes as in the scallop and Torres Straits Beche de Mer fisheries, or rotational harvesting also in the scallop and Beche de Mer fisheries) and a range of other input controls. In the absence of reasonable estimates of either fishing mortality or stock size such input controls are vital for the success of the harvest strategies adopted for these fisheries. Despite the contributions that they make to sustainable management such controls do not receive a great deal of emphasis within the current HSP so care is needed that they are not overlooked.

The HSP currently has detailed allowances for internationally shared stocks but fails to emphasize that some fisheries overlap greatly with different Australian States. The present mechanism for interactions with the States is to develop off-shore constitutional settlements, although these are not mentioned in the HSP. The HSP states: “It takes into account mortality resulting from all types of fishing, including recreational and state managed-catches. It does not necessarily require that all types of fishing be regulated, …” (DAFF, 2007, p 6). The influence of the HSP extends only the proportion of each stock that falls within the Commonwealth jurisdiction, which complicates the management of some fisheries such as Bass Strait scallops and various species within the SESSF (e.g. school whiting).

The simulation testing of the North West Trawl Fishery (Dowling, 2011) was the first MSE analysis conducted on harvest strategies consisting of trigger points and a scaled response depending on catch levels. This required the definition of explicit decision rules for the higher catches levels that consisted of increased information and assessment requirements. Generally, such data-poor fisheries also have the lowest catches which by their nature are unlikely to have a major impact; although this assumes the stock is not very small. The nature of the triggers is such that as long as the minimal monitoring requirements are maintained, so that catches do not expand without managers knowing it, then the intent of the HSP can be met. Exceptions can occur but this seems to only occur when there is a strong mis-match between the assumed biology and the reality. Nevertheless, the option for learning and adapting to such data sparse fisheries remains.

For the fisheries considered each of the MSE’s demonstrated that, under most conditions, the Harvest Strategies put in place will achieve the intent of the HSP with respect to the sustainability objective even where there cannot be direct estimates of fishing mortality or stock biomass. The specific target objective of managing a data-poor fishery towards the biomass that should generate the maximum economic yield (B_{MEY}) or its proxy ($B_{48\%}$) is difficult or impossible to achieve without significant increased data collection. It appears to be possible to determine the direction of management to improve profitability by observing conditions in each current fishery but, when data (including biological, fishery, and economic) is scarce or non-existent, fishing mortality or biomass estimates cannot easily be achieved. It is clear that more work is required to develop B_{MEY} proxies for use with such data-poor fisheries.

In many of the data-poor fisheries the catches remain relatively minor and so it might be assumed that their implied potential impact could not be great. However, the potential risks of accepting that implication is that without adequate monitoring of such species and fisheries they could potentially expand and do damage to a resource before management was implemented. This emphasizes the need at least to maintain adequate monitoring of commercial catches of key species and ensure that the management agencies have the resources to appropriately collect, store, and produce preliminary summaries in a timely fashion. Each harvest strategy, even the data poor ones has particular resource requirements in terms of monitoring, data storage, and assessment of performance measures to determine whether management action is required.

While it is always possible to produce a simulation of some species for which information can be gained from either similar species or taxa there is insufficient information available to conduct a MSE analysis on a particular species such Trochus and, for example in the Beche de Mer studies (Plagányi *et al.*, 2011, 2011b), only the major commercial species were considered, again because there was insufficient information to conduct a MSE conditioned on the many other occasional species that might be taken. The present HSP states that the policy is a framework for developing “harvest strategies for key commercial species taken in Australia’s Commonwealth fisheries.” (DAFF, 2007, p2). Key commercial species are defined as those species which are specifically targeted or have been a significant component of a fishery. However, defining the notion of a key commercial species in this way does not clarify which species within each fishery can be recognized as commercially important and key to each fishery. For example, trochus could be considered a significant component of a fishery but this ignores the fact that the fishery itself is only of marginal value. There is no theoretical reason not to apply the Harvest Strategy Policy to any number of fisheries but there is a risk of failure if the resource implications of its application are not recognized.

5 REFERENCES

DAFF (2007) Commonwealth Fisheries Harvest Strategy. Policy and Guidelines. Department of Agriculture, Fisheries and Forestry. 55p.

Dowling, N. (2011) Management Strategy Evaluation testing of the Management Strategies used with North West Slope Trawl Fisheries. CSIRO, Marine and Atmospheric Research, Hobart. 86p.

Fay G., Punt, A.E. and A.D.M. Smith (2009b) Operating model specifications, in: Wayte, S.E. (Ed.), Evaluation of new harvest strategies for SESSF species. CSIRO Marine and Atmospheric Research, Hobart and Australian Fisheries Management Authority, Canberra, pp. 125–133.

Giannini, F., Hobsbawn, P.I., Begg, G.A. and M. Chambers (2010) *Management Strategy Evaluation of the Small Pelagic Fishery Harvest Strategy*. Bureau of Rural Sciences. FRDC Project 2008/064 157p.

Haddon, M. (2011) Management Strategy Evaluation testing of the Management Strategies used with South-Eastern Scallop Fisheries. CSIRO, Marine and Atmospheric Research, Hobart. 98 p.

Klaer, N. and S. Wayte (2011) Demersal MSE for trawl fish in the Southern and Eastern Scalefish and Shark Fishery and other like-species. CSIRO, Marine and Atmospheric Research, Hobart. 67 p.

Klaer, N.L., Wayte, S.E. and Fay, G. (2012) An evaluation of the performance of a harvest strategy that uses an average-length-based assessment method. *Fisheries Research*, **134-136,** 42-51.

Little, L.R., Wayte, S.E., Tuck, G.N. Smith, A.D.M., Klaer, N.L., Haddon, M., Punt, A.E. Thomson, R., Day, J. and M. Fuller (2011) Development and evaluation of a cpue-based Harvest Control Rule for the Southern and Eastern Scalefish and Shark Fishery of Australia. *ICES Journal of Marine Science*: **68**: 1699-1705.

Plagányi, É., Skewes, T., Dowling, N. and M. Haddon (2011) Evaluating management strategies for data-poor sea cucumber species in the Torres Strait. CSIRO, Marine and Atmospheric Research, Hobart. 81p.

Plagányi, É., Skewes, T., Dowling, N., Haddon, M., Woodham, J., Larcombe, J. and M. Chambers (2011b) Evaluating management strategies for data-poor sea cucumber species in the Coral Sea Fishery. CSIRO, Marine and Atmospheric Research, Hobart. 73 p.

Plagányi, É.E., Skewes, T.D., Dowling, N.A. and M. Haddon (2012) Risk management tools for sustainable fisheries management under changing climate: a sea cucumber example. *Climate Change* DOI 10.1007/s10584-012-0596-0.

Punt, A.E., Campbell, R.A., and A.D.M. Smith (2001) Evaluating empirical indicators and reference points for fisheries management: application to the broadbill swordfish fishery off eastern Australia. *Marine and Freshwater Research* 52, 819–832.

Punt, A.E., Smith A.D.M. and G.R. Cui (2001) Review of progress in the introduction of management strategy evaluation (MSE) approaches in Australia’s South East Fishery. *Marine and Freshwater Research* 52, 719–726.

Punt, A.E., Smith, A.D.M. and G.R. Cui (2002) Evaluation of management tools for Australia’s South East Fishery 2. How well can management quantities be estimated? *Marine and Freshwater Research* 53 (3), 631–644.

Punt, A.E., Pribac, F., Taylor, B.L. and T.I. Walker (2005) Harvest Strategy Evaluation for School and Gummy Shark. *J. Northw. Atl. Fish. Sci*. 35, 387–406.
Smith, A.D.M., K.J. Sainsbury, and R.A. Stevens. (1999) Implementing effective fisheries-management systems – management strategy evaluation and the Australian partnership approach. *ICES Journal of Marine Science* 56: 967-979.
Smith, A.D.M., Smith, D.C., Tuck, G.N., Klaer, N., Punt, A.E., Knuckey, I., Prince, J., Morison, A., Kloser, R., Haddon, M., Wayte, S., Day, J., Fay, G., Pribac, F., Fuller, M., Taylor, B. and L.R. Little (2008) Experience in implementing harvest strategies in Australia's south-eastern fisheries. *Fisheries Research* 94: 373-379
Wayte, S.E. (ed.) (2009) Evaluation of new harvest strategies for SESSF species. CSIRO Marine and Atmospheric Research, Hobart and Australian Fisheries Management Authority, Canberra. 137p.

6 GLOSSARY

Biomass: Numbers at length times weight at length.
Catch Rate: Kilogram per hour, but estimated as the geometric mean catch rate of individual catch records and cited relative to the catch rate in 1985. Standardized statistically taking into account the Year of fishing, the Diver, the block in which fishing occurred, the month of fishing, and any interactions between Month and block.
Exploitable Biomass: emergent abalone available above the Legal Minimum Length. Selectivity applied to the emergent abalone. Estimated as the numbers emergent at length times selectivity times weight at length.
Harvest Rate: The proportion of the exploitable biomass taken by the fishery. Literally the catch divided by the exploitable biomass.
Selectivity: The proportional selection of different sized animals. Knife-edged selection could be occurring at the Legal Minimum Length.
Total Biomass: All abalone combined, including all cryptic and emergent animals. Estimated as all numbers at length times weight at length.
Unfished Biomass: Biomass predicted

7 APPENDICES

7.1 Reporting Framework: Bass Strait Scallops

Does the Harvest Strategy Achieve the intention of the Harvest Strategy Policy?

The current harvest strategy generally succeeds in achieving the intent of the HSP. In the long term there tends to be a positive exploitable biomass more than 90% of the time (for most combinations of simulation definitions, and for all combinations with a B_{LIM} of 500 t). The proxy for the limit reference point works to avoid unsustainable practices. In addition, fishing mortality is restricted in times of low stock levels. The harvest strategy is less successful in achieving the target reference point of having a fishery each year. Given the inherent uncertainty in the stock dynamics and biology the probability of having a fishery each year varied between about 0.25 and 0.66. Even with only a trivial fishery of 25 t there is 18 – 49% chance of there not being a fishery in any one year (driven largely by the requirement to retain at least one viable bed at all times).

There remains significant uncertainty in the management of scallops. A key uncertainty, the probability of establishment (or successful recruitment) of beds remains unknown, and it is also unknown whether there are density dependent effects at work both in increasing the chances of establishment in nearby beds and in reducing the establishment of second cohorts in established beds.

1 Complete coverage

a Which species or stocks that are classified by the Status Reports does the harvest strategy cover?

Central Bass Strait scallop fishery.

b Does the harvest strategy apply throughout the stock's entire range?

No, the Commonwealth harvest strategy only applies to the central Bass Strait zone. There is a similar harvest strategy applied in the Tasmanian fishery, but a spatially explicit HS for the Victorian fishery is still developing. Victoria is examining the utility of spatial closures for improving management, and is also implementing Industry based surveys.

c Is the RBC adjusted for fishing mortality that occurs outside the fishery's control?

No, the control rules used to control which beds get fished in the Commonwealth, so far, only take into account details of which beds are available within the Central Bass Strait jurisdiction.

There have so far not been any attempts to decide which beds to open across the whole fishery. This will become an issue in 2011 when there are likely to *be suitable scallop beds available in at least Tasmania and the Commonwealth (and possibly Victoria). If beds are opened in each jurisdiction irrespective of what is happening in the other jurisdictions, there are likely to be far more scallops available than the current market can absorb. It seems likely that without rationalization, the profitability of the fishery may drop badly. In addition, the probability of there being a fishery each year is likely to decline. There will still be improvements over the old boom and bust management but there will still be wide variation in the availability of scallops to be fished.*

2 Appropriate Proxies for reference points

a Are the adopted proxies consistent with the Commonwealth Fisheries Harvest Strategy Policy and Guidelines (HSP)?

Yes, the central Bass Strait harvest strategy operates in terms of scallop beds (made up of "viable areas"). The limit reference point requires that at least one scallop bed, of at least 500 t exploitable biomass, be retained in all years. The proxy for the target reference point can be characterized as attempting to have a fishery in each year as often as possible without falling below the limit.

b Is there evidence that the harvest strategy's proxies reliably index stock biomass and fishing mortality rates?

The proxies succeed in conserving a minimum amount of exploitable biomass for most of the time but the estimates of biomass are only approximate and it cannot be claimed that the proxies reliably index the stock biomass. Fishing mortality rates within a scallop bed being fished are extreme and the whole bed is effectively removed. But in the context of the whole stock the harvest strategy controls fishing mortality effectively; nevertheless, the proxies cannot be claimed to reliably index fishing mortality rates. These ideas are not appropriate for the spatially structured scallop stock.

3 Effective control rules

a Will targeted fishing cease when $B \le B_{LIM}$?

Yes, both the performance measure based on the number of viable beds as well as the minimum available biomass being greater than 500 t work to stop fishing when stocks are low. There should be no bycatch in other fisheries.

b What is the probability of the harvest strategy maintaining $B > B_{LIM}$?

This was uncertain as it is a function of the average level of recruitment that occurs combined with the probability of a recruitment event happening. Even in the absence of fishing there are some years where the level of exploitable biomass is expected to fall below 500 t. However if the B_{LIM} remains at 500 t then the probability of maintaining $B > B_{LIM}$ is expected to range between 0.93 – 0.99. If B_{LIM} is increased to 1000 t, then this probability ranges from 0.85 – 0.99. Nevertheless, even in the face of the very great variation and uncertainty about the biology of scallops, the harvest strategy succeeds in maintaining a long term average level of exploitable biomass.

c Will the harvest strategy achieve the target?

With commercial scallops, clearly defining a proxy for the HSP target is extremely difficult because of the natural variability of the species. The control rule may allow the fleet to be profitable in those years where there is a fish-

ery, and the likelihood of having a fishery each year can be considered a target. However, with the on-going likelihood that there will be a significant number of years without a fishery (even when only token fishing occurs) then, with a strict interpretation of the HSP, the scallop control rule could be said to fail. If the expected TAC was small enough then there may be a fishery every year, however, that TAC may require to be so small that in itself it would not be economically viable. One solution to this would be to manage the whole fishery (all three jurisdictions) as a whole.

d What is the probability of the harvest strategy maintaining stock biomass at or around the target for the species?

The probability of a fishery happening each year varied between about 0.26 to 0.66. The selection of a target TAC will involve a trade-off between the average size of landed scallops being smaller for higher TACs and the probability of a fishery happening each year being smaller with higher TACs balanced against a lower cumulative catch through time with lower TACs. The notion of a target biomass is not sensible with scallops but this has been replaced with the requirement of a minimum of 1 bed and > 500 t more than 90% of the time, and most of the time this is achieved.

e Will F be reduced when $F>F_{MSY}$?

No sensible estimate of F_{MSY} can be made, and the fact that fishing a scallop bed leaves only a small remnant means that the fishing mortality within a bed is expected to be extremely high. However, the requirement to retain at least one scallop bed at all times implies that fishing mortality cannot become excessive when considered across all beds. F_{MSY} is an equilibrium concept that is usually applied to species considered as a unit stock. It is not appropriate in a spatially disaggregated species.

f Will targeted fishing cease when $F>F_{LIM}$?

The proxy for F_{LIM} is the requirement to retain at least one scallop bed greater than some minimum biomass and in this way fishing ceases before fishing mortality becomes too high.

g What is the probability of the harvest strategy maintaining $F \leq F_{LIM}$?

In terms of scallops this is equivalent to the probability that there will always be a scallop bed greater than 500 t. The current HS achieves this with a better than 93% success rate; which meets the standards within the HSP.

h Is the harvest strategy robust to the initial state of the stock i.e. will it achieve the target and avoid the limit from all initial conditions?

Starting from totally collapsed the stock should recover and achieve the limit reference point. The stock naturally varies from very small biomass levels to relatively high but it achieves the limit reference point sufficiently often to meet the HSP criteria.

i To what extent does uncertainty over mixing rates affect the risk of breaching limit reference points?

Mixing rates are irrelevant in the scallop fishery. Rather, uncertainty in the biomass estimates might influence breaching the limit reference point. But there is a substantial risk that the LRP would be breached occasionally even in the effective absence of fishing. But the harvest strategy requirement to retain at least one bed is generally conservative as there are also likely to be *beds that remain undiscovered or which are in water too deep to allow the scallops ever to reach the LML.*

4 Correct implementation

a Has the harvest strategy been cranked?
Yes, in 2009 and 2010.

b Have control rules and RBCs been implemented?
Yes, though the RBCs are not expected to be precise.

c Is the implementation timely, e.g., are the results relevant to the Status Reports' assessment year?
The scallop fishery operates from about April – May through to about December, although this depends to some extent on the scallop condition. Pre-season surveys are expected to happen in March or April.

d Are any data, which are required for setting the RBC, missing or uncertain?
The biomass estimates from the surveys are uncertain, but they remain sufficient for the purposes of the HSP. The minimum biomass remaining is being reviewed. Even if mistakes are made in the biomass estimates this will mainly affect the success at achieving the allocated TAC rather than breaching the B_{LIM}. *The biomass estimates are deliberately made in a conservative fashion and so far do not appear to have over-estimated available biomass.*

e Are adjustments to RBCs consistent with the HSP?
Yes, when the stock increases the TAC can increase and when the stock declines the recommended TAC declines, which interacts with the minimum number of beds requirement for added stock security. A problem is likely to occur in the future when operations in different jurisdictions may interfere with the markets for scallops.

f Do adjustments to RBCs reflect increasing uncertainty at higher tiers?
Not applicable. There is only one form of assessment applied to the central Bass Strait scallop fishery so there is only one tier used. There are uncertainties but the strategy of only opening a single area at a time with ongoing monitoring during the fishing season means that sufficient precaution is built in to the harvest strategy to control total harvest.

g Is there a need for a meta-rule to be invoked?
There are currently no meta-rules suitable for scallops. However, there is a need to coordinate the fishing in all three jurisdictions to avoid inefficiencies and the harvesting of excess product. Such cooperation may take the form of meta-rules. There are currently none in place and this seems likely to constitute a major challenge to the profitability of the fishery in the future.

5 Harvest strategy evaluation

a What range of uncertainties has been tested?
There are three major uncertainties affecting the number of available scallops, these are a) the probability of the scallop beds establishing themselves through a successful settlement, b) there is considerable uncertainty in the scale of any successful settlement, and c) there is considerable uncertainty with respect to the survivorship schedule. In addition to these three sources there are two others which affect the conversion of numbers of scallops at

length into the biomass units in which the management of this resource is couched. These two additional uncertainties relate to d) the growth rate of each population and e) the length to weight relationship. The outcome of including variation in each of these five uncertainties is included in the analyses,

b How do those uncertainties relate to the full range of uncertainties for the stocks or species group concerned?

There are always further uncertainties that could be included but the five considered appear to constitute the major sources of uncertainty.

c Have a broad range of stakeholders and independent experts been consulted?

Yes, two visits to the Commonwealth scallop RAG have been made and those opportunities were used to discuss the project, its design and expected outcomes.

d Do fisheries on the same or similar species in other parts of the world provide any insights into uncertainties?

All scallop fisheries canvassed, especially those based on Pecten *species, exhibit similar dynamics. The properties of scallop beds re-occurring in about the same locations, the natural variation in stock size, and the variation in survivorship appear to be shared world-wide. The boom and bust nature of those stocks that are not managed using an explicit form of spatial management is also common.*

e What further work could be done?

A great deal more could be done. It would be useful to compare the outcome within the Commonwealth when it is considered in isolation from the other jurisdictions with outcomes from treating all stocks under the same harvest strategy. Preliminary considerations indicate that when managing the whole stock, the stability of the fishery would be greatly improved in terms of a minimum exploitable biomass remaining at all times, the probability of there being a fishery each year would also increase markedly. However, it is recognized that not all fishers have licenses in all jurisdictions so it is expected that it would be very difficult to implement such inter-jurisdictional cooperation.

It would also be useful to establish the minimum catch levels required from each jurisdiction for an economic fishery. At present, while it is understood that fishing in the Commonwealth is more expensive because of the distance from port, economic details are missing. These would be helpful in establishing rules for deciding which beds to open to fishing.

In addition, it would be useful to re-examine the issue of the LML applied. Greater catches are possible with the smaller LML but the meat recovery is lower. A study of the processing of populations fished at different LMLs could establish the most valuable LML to the scallop fishery. Given sufficient Industry based surveys it should be possible to retain the notion of at least two years of major spawning (which doesn't always happen with an LML of 80 mm – see Appendix 2).

Finally, the details of any new changes to the current harvest strategy could be investigated using the simulation framework developed in this subproject.

f What changes are required to the harvest strategy?

The harvest strategy appears to work quite effectively as it is. Increasing the minimum available biomass to 1000 t (as has been mooted at the RAG) would reduce the probability of there being a fishery every year but it would mostly remain within the bounds of expectation from the HSP. It would be helpful to do research to determine the value of the catch and the ease of processing, if the LML was changed to 80 or 85 mm. Certainly the catches could be larger but it is not certain if the meat weight would increase equally. The processors prefer ratios of 70-80 meats per kilogram, but the smaller shell can reach 120 meats per kilogram, which are far less attractive as a product

6 Other issues relevant to using the harvest strategy for status determination

If the harvest strategy is used and the fishery meets the minimum requirements of bed size and presence, then there should be confidence that the harvest strategy will achieve the intent of the HSP. However, it will require an assessment every year and the large scale mortality events that can happen with scallops will also need to be accounted for.

7.2 Reporting Framework: North West Slope Trawl

---

1 Complete coverage

a Which species or stocks that are classified by the Status Reports does the harvest strategy cover?

North West Slope Trawl Fishery, using scampi as a case study.

b Does the harvest strategy apply throughout the stock's entire range?

No; however the Western Deepwater Trawl Fishery is managed using a similar harvest strategy The MSE assumes a single stock.

c Is the RBC adjusted for fishing mortality that occurs outside the fishery's control?

The annual effort is adjusted for fishing mortality that occurs entirely within the NWSTF. The adjacent Western Deepwater Trawl Fishery is managed via the same form of harvest strategy. Outside of these fisheries, there is not believed to be any extraneous fishing mortality.

---

2 Appropriate Proxies for reference points

a Are the adopted proxies consistent with the Commonwealth Fisheries Harvest Strategy Policy and Guidelines (HSP)?

Clearly it is not possible to set meaningful triggers for each species captured by the fisheries, particularly for Western Deepwater Trawl where catch is opportunistic and species composition is highly variable.

However, by identifying a suite of key species based on industry consultation and historical catch patterns, it is argued that the entire fishery will be represented and hence managed. Additionally, the inclusion of separate triggers for highly vulnerable species, and the setting of permanent spatial closures, defensibly renders the strategy as precautionary. Applying the triggers independently to separate functional management regions acknowledges the distinct sub-regions within the extensive areas over which the fishery is conducted (although a non-spatial trigger system was found to perform rather better than the spatially disaggregated trigger system).

Given that the fisheries are largely opportunistic, and that species composition has been temporally variable (WDWTF), or has shown a shift in target species (NWSTF), there is as yet no qualitative or quantitative estimates of maximum economic yield. For these low GVP fisheries there is a need to strike a balance between allowing for industry to capitalize on sporadic economic opportunities while still managing the fishery in a precautionary and proactive manner, consistent with the intent of the Harvest Strategy Policy.

The inclusion of three levels of values for each trigger facilitates the expansion of the fishery by assigning progressively higher data and analysis requirements with higher trigger values. As such, the risk associated with further expansion is minimized; at the risk of volatility in effort and catches.

The two levels of trigger aim to do this by setting the lower triggers level at a value that will detect early changes and result in low-cost analysis to identify the reasons behind these without immediately placing limitations on the fishery. The third trigger level acts a limit reference point in the absence of further information. Should the fishery wish to further expand, it will need to invest in more detailed/robust assessments that will provide stronger justification for continued *expansion and upward revision of the trigger point.*

b Is there evidence that the harvest strategy's proxies reliably index stock biomass and fishing mortality rates?

The proxies succeed in either maintaining the stock at current levels (Level 1), and, where adequate information exists to undertake a production model stock assessment, the trigger levels move the stock towards the appropriate target reference points.

Moreover, there is the option to revise trigger values in light of information gained from stock assessments, and to revise the Level 1 simple empirical CPUE decision rule in light of information on biomass-based reference points, so that the fishing mortality moves the stock towards the target biomass as opposed to maintaining it at a status quo level. Thus the harvest strategy is one of adaptive management given improved information.

---

3 Effective control rules

a Will targeted fishing cease when $B \leq B_{LIM}$?

There is no absolute guarantee that targeted fishing will cease when $B \leq B_{LIM}$, *particularly if trigger values have been set inappropriately relative to the stock status and population dynamics. Should the current stock level be below the limit reference point, the decision rule associated with the Level 1 trigger will not recover the stock. However, the trigger levels have aimed to have been set as conservatively as possible given the history of the fishery and inferred expert knowledge, such that it is unlikely that the current stock levels are below the limit reference point.*

Once the Level 2 trigger is reached, a stock assessment, providing this is based on adequate information, should act to recover the fishery, and/or revise the Level 3 (cease fishing) trigger if the assessment shows the stock to be below the limit reference point.

Thus, provided the trigger levels have been appropriately set, the harvest strategy should act to cease targeted fishing when $B \leq B_{LIM..}$ *Again, there is scope for the triggers to be revised in light of improved information on stock status.*

Even if the stock really is in a depleted state, if the triggers are set appropriately for the stock dynamics, the trigger systems were shown to be capable of recovering from the depleted state, especially with either the zone independent system of triggers or the annual production modelling.

b What is the probability of the harvest strategy maintaining $B > B_{LIM}$?

Providing the triggers are appropriately set, the harvest strategy acts conservatively. For the vast majority of scenarios examined, spawning biomass dropped below B_{LIM} *on average much less than the 10% of the time permitted within the Policy. Given that the fishery is believed to have been only lightly exploited to date, the conservative nature of the Level 1 response's empirical CPUE rule (maintaining the effort at status quo) gives a high probability that the stock will be maintained above* B_{LIM}. *However, if the stock is heavily depleted, and the triggers are not set appropriately, the risk is that the status quo is maintained at a level below* B_{LIM} *but this will remain unknown.*

c Will the harvest strategy achieve the target?

Providing the trigger levels have been set appropriately set with respect to the stock status and the population biology, the assessment invoked as the Level 2 trigger response moves the stock towards the target, where this itself is determined by the assessment.

d What is the probability of the harvest strategy maintaining stock biomass at or around the target for the species?

This depends on whether the triggers are set appropriately, and whether or not they are zone specific. If the triggers are invoked too early, or are zone-specific, the trigger responses are overly conservative and the stock is maintained above the target species, although this may take over 10 years to achieve if the stock has been heavily exploited prior to the implementation of the trigger harvest strategy.

e Will F be reduced when $F>F_{MSY}$?

The trigger system acts to reduce effort and hence fishing mortality if the stock is below its target biomass level, once the Level 2 trigger has been reached. Provided the trigger values have been set appropriately relative to the stock status and population biology, fishing mortality will be reduced when it exceeds its target level.

f Will targeted fishing cease when $F>F_{LIM}$?

There is no direct correspondence between the Level 3 (cease fishing) catch trigger and the HSP limit reference point, and as such there is no guarantee that targeted fishing will cease when fishing mortality exceeds F_{LIM}. However, provided the triggers are set appropriate to the stock status and population biology, the harvest strategy successfully recovers stocks fishing to below B_{LIM}, both via effort reduction and fishery closure.

g What is the probability of the harvest strategy maintaining $F \leq F_{LIM}$?

There is no estimate of F_{LIM}; see response to 3b above.

h Is the harvest strategy robust to the initial state of the stock i.e. will it achieve the target and avoid the limit from all initial conditions?

Generally the harvest strategy is capable of recovering even a heavily exploited to above $B_{LIM.}$ The main exception is when there is a mismatch between the historical population biology and that assumed during harvest strategy implementation.

i To what extent does uncertainty over mixing rates affect the risk of breaching limit reference points?

Mixing rates are assumed to be low in the scampi fishery. For other species, the lack of external fishing pressure on NWSTF/WDWTF stocks, and the application of the trigger harvest strategy across the entire domestic fishery, means that, when mixing occurs, this is likely to result in more conservative harvest strategy performance due to the reserve effect of "source" populations. If the triggers are zone-specific, mixing rates could result in trigger levels being overly sensitive, but this would result in a more volatile fishery as opposed to limit reference points being breached.

---

4 Correct implementation

a Has the harvest strategy been cranked?

No, due to the current low level of effort and lack of resources applied to the Harvest Strategy.

b Have control rules and RBCs been implemented?

No, due to the current low level of effort and lack of resources applied to the Harvest Strategy

c Is the implementation timely, e.g., are the results relevant to the Status Reports' assessment year?

The harvest strategy is intended to be implemented on an annual basis. However, it has yet to be implemented so the annual schedule is unknown.

d Are any data, which are required for setting the RBC, missing or uncertain?

The exact population biology is uncertain and the simulations have shown sensitivity and reduced harvest strategy performance if the natural mortality and/or selectivity-at-age vector is *incorrectly assumed. Additionally, if the triggers are set inappropriately relative to the status of the stock, such that they are reached either too often or too infrequently, the success of the harvest strategy will be compromised. However, this is an inherent problem with any data-poor fishery: if the stock status and population biology was known, a more sophisticated assessment-based harvest strategy would be able to be applied, negating the need for a trigger system.*

e Are adjustments to RBCs consistent with the HSP?

Once the Level 2 trigger has been reached, the adjustments to the allowable effort allow increased fishing when the stock is above the target reference point and the assessment reduces effort when the stock is below its target reference point. Effort is also reduced or ceased when the stock is below the limit reference point.

f Do adjustments to RBCs reflect increasing uncertainty at higher tiers?

The same harvest strategy framework is applied across all species, so this is not directly applicable. However, the harvest strategy is intended to be adaptive, with a quantitative assessment being undertaken as the Level 2 trigger response. The aim is to reduce risk and uncertainty via more sophisticated assessments as the fishery expands.

g Is there a need for a meta-rule to be invoked?

There are currently no meta-rules in the fishery and the current value of the fishery means that this would be an economically disproportionate management measure.

---

5 Harvest strategy evaluation

a What range of uncertainties has been tested?

Uncertainty in the natural mortality and the selectivity at age vector were investigated, and alternative trigger level values and forms of implementation of the harvest strategy (i.e. the responses invoked by the trigger levels) were tested. The harvest strategy performance was sensitive to whether the natural mortality or selectivity at age were incorrectly assumed during the projection period relative to the historical period, and if the trigger values were set inappropriately relative to the population biology. The performance of the harvest strategy also varied according to the manner in which it was implemented.

b How do those uncertainties relate to the full range of uncertainties for the stocks or species group concerned?

These constitute the major uncertainties, but there is also uncertainty in the steepness, the frequency of recruitment (assumed annual, but may not occur every year), the spatial distribution of recruitment, and the growth rate. The uncertainties tested have provided a good insight into the performance and robustness of the harvest strategy, but further testing could always be undertaken.

c Have a broad range of stakeholders and independent experts been consulted?

The harvest strategy was developed across two meetings of WestMAC. However, this project has not been discussed with stakeholders or independent consultants as there have been no subsequent WestMAC meetings.

d Do fisheries on the same or similar species in other parts of the world provide any insights into uncertainties?

The data-poor nature of the fisheries considered mean that the approaches used elsewhere with larger more valuable scampi fisheries (for example, off Europe) would not be achievable with Australian fisheries. No similar testing of trigger management systems has been undertaken elsewhere.

e What further work could be done?

It would be highly relevant to consider harvest strategy performance for the other main species in the fishery, particularly those for which a production model stock assessment is not able to be *applied, and/or for which population parameters are not clearly understood. It would also be worthwhile investigating more comprehensively the effect of the supplementary permanent spatial closures that form part of the harvest strategy. However, the current study provides useful insights into the performance of a trigger-based harvest strategy. Further explorations should be made of the operation of the Harvest Strategy in the face of reduced fishing effort resulting from fisher decisions rather than management decisions. This appears intuitively to be inherently conservative but the interaction of such opportunistic behaviour and the stock dynamics needs to be explored.*

f What changes are required to the harvest strategy?

It appears that a zone-independent system of triggers outperforms the proposed regime of spatially explicit triggers. While it may also appear that Level 1and 3 triggers are not necessary, eliminating these triggers would incur the risk of the remaining Level 2 trigger not being appropriately set and the stock collapsing before it is reached. Explicit decision rules in response to the trigger levels need to be specified formally within the harvest strategy. The MSE undertaken here assumes an effort quota fishery, but this could be amended to a catch quota system.

6 Other issues relevant to using the harvest strategy for status determination

For the case study of scampi, providing the trigger levels are set appropriate to the population biology, and a zone-independent trigger system is applied, the harvests strategy appears to perform well against the policy objectives. However, it provides no insight as to stock status until an assessment is undertaken once the Level 2 trigger has been reached. The key issue will be how the harvest strategy can be practically implemented in a multispecies context with low capacity for stock assessment. Additionally, the effect of permanent closures is likely to result in a more conservative protection of biomass than suggested by the scenarios intended to approximate the effect of such closures. As such the application of the Harvest Strategy should achieve the objectives of the Harvest Strategy Policy, but the specific trigger levels will need to be reviewed regularly to ensure they are precautionary.

7.3 Reporting Framework: Coral Sea Bêche de Mer

Does the Harvest Strategy Achieve the intention of the Harvest Strategy Policy?

The MSE simulations suggested that the current TACs for black teatfish and white teatfish perform well with respect to controlling the risk of overfishing. There is relatively greater risk to surf redfish and prickly redfish.
The spatial rotation policy substantially reduces risk to all species.
The natural variation in the dynamics of the species studied mean that it is sometimes difficult to distinguish between scenarios with no fishing and those with fishing. Given this very great variation coupled with very great uncertainty about biology and fisheries ecology it remains difficult to devise a harvest strategy that achieves the intent of the Policy. However, the large closed areas in the Coral Sea prevent a significant proportion of the resource from being fished. Achieving an economically optimal outcome may not always be possible under the spatial rotation and move-on provision arrangements. However, this small fishery is a valuable resource, especially when considered in combination with licenses to fish other species. Overall, the current harvest strategy could be said to achieve the intent of the HSP

1 Complete coverage

a Which species or stocks that are classified by the Status Reports does the harvest strategy cover?

The Coral Sea bêche-de-mer fishery, and specifically the 4 species listed below:

Holothuria whitmaei	Black teatfish
Actinopyga mauritiana	Surf redfish
Holothuria fuscogilva	White teatfish
Thelenota ananus	Prickly redfish

.

b Does the harvest strategy apply throughout the stock's entire range?

No, the harvest strategy only applies to the Coral Sea region. There are separate harvest strategies that apply to the Torres Strait bêche-de-mer fishery, and the Queensland sea cucumber fishery on the GBR. Some stocks also straddle the International border with PNG.

c Is the RBC adjusted for fishing mortality that occurs outside the fishery's control?

No, the RBC is currently fixed at a constant level. But this has been set in an attempt to match the productivity of the local region. However, some of the TACs could be revised after the current study.

2 Appropriate Proxies for reference points

a Are the adopted proxies consistent with the Commonwealth Fisheries Harvest Strategy Policy and Guidelines (HSP)?

No, there are no currently adopted proxies. However, the current TACs are mostly set conservatively and in that respect reflect an intention to meet the HSP. Moreover, some of the proxies suggested as part of this study are rela-

tively conservative and consistent with the HSP.

b Is there evidence that the harvest strategy's proxies reliably index stock biomass and fishing mortality rates?

No, there are no such clear proxies and nor are these ideas necessarily appropriate for the hand collectable fisheries, given the large temporal and spatial variability of the stocks. Our results showed that species appear to be performing satisfactorily overall.

3 Effective control rules

a Will targeted fishing cease when $B \leq B_{LIM}$?

Yes, because the TACs are set fairly conservatively and a spatial rotation policy is implemented. Moreover, there are fairly large closed areas (such as the large areas of reef protected by the Lihou and Coringa-Herald marine reserves) and hence these areas alone might contain a substantial proportion of the overall populations, ensuring that harvest levels should avoid overall overharvesting.

b What is the probability of the harvest strategy maintaining $B>B_{LIM}$?

Given the high recruitment variability there was a high risk of both the overall population, as well as local spatial regions, becoming depleted below B_{LIM} even in the absence of fishing. For this reason, we compared the depletion and risk relative to comparable no-fishing trials. This suggested that the current TACs had a very low probability of depleting stocks over and above levels of natural fluctuations, apart from a relatively greater risk for surf redfish if fished consistently at the TAC level.

c Will the harvest strategy achieve the target?

As above, clearly defining a proxy for the HSP target is extremely difficult because of the natural variability of the species. We attempted to derive some proxy reference points, and these suggested that all four species modelled may be roughly achieving the target. There were some indications that the TAC for surf redfish and prickly redfish should be decreased slightly unless the estimates of biomass are demonstrated to be too low. The low TAC for black teatfish appears to be necessary to ensure that the target is achieved for this valuable species.

d What is the probability of the harvest strategy maintaining stock biomass at or around the target for the species?

As above, this is not straightforwardly answered for this group of species. However, given suggested proxies and the limitations and uncertainties associated with this study, it does seem that there is a reasonable probability of the harvest strategy maintaining stock biomass at or around the target for all species. There remains the problem that species such as the black teatfish may take a considerable time to recover, even in the absence of fishing.

e Will F be reduced when $F>F_{MSY}$?

It is not possible to easily and sensibly estimate F_{MSY} for these highly variable species. Under the current catches and fishing patterns, it seems the catches are small enough to maintain $F<F_{MSY}$. However simulation results suggest

that under some location and species-choice models, there is a risk that $F>F_{MSY}$ for some species.

f Will targeted fishing cease when $F>F_{LIM}$?

If using the rough suggested proxy for F_{LIM} derived in this study, the answer is yes, but not if fishing patterns change as noted above.

g What is the probability of the harvest strategy maintaining $F \leq F_{LIM}$?

See above

h Is the harvest strategy robust to the initial state of the stock i.e. will it achieve the target and avoid the limit from all initial conditions?

No, see above.

i To what extent does uncertainty over mixing rates affect the risk of breaching limit reference points?

It is unlikely that bêche-de-mer are able to mix throughout their range as adults, but recruitment is likely shared between adjacent reefs, provided they are close enough. We have tested the management strategy erring on the conservative side by assuming that recruitment is not shared across the widely spaced reefs such as Holmes, Flinders, Osprey and Wreck reefs in the Coral Sea region, and hence locally depleted zones cannot be easily reseeded.

4 Correct implementation

a Has the harvest strategy been cranked?

Yes, but there are currently low catches only.

b Have control rules and RBCs been implemented?

No, currently there are fixed TACs.

c Is the implementation timely, e.g., are the results relevant to the Status Reports' assessment year?

d Are any data, which are required for setting the RBC, missing or uncertain?

The biomass estimates are uncertain but they are critical for setting RBCs. Additional biological and survey data would be advantageous. There are good spatial catch data available. It is doubted whether an analysis of associated CPUE data would prove particularly helpful.

e Are adjustments to RBCs consistent with the HSP?

Yes, if a catch trigger or the combined TAC is reached, fishing ceases in that fishing year on that species (if a species-specific trigger is reached), or completely (if the combined TAC is reached) until an assessment is completed. An assessment in the form of data analysis is conducted with the aim of establishing conservative TACs on a species-by-species basis and/or a revised combined TAC. If the data is considered insufficient to deliver a TAC, cost-effective abundance surveys may be considered.

f Do adjustments to RBCs reflect increasing uncertainty at higher tiers?

Not applicable.

g Is there a need for a meta-rule to be invoked?

There are currently no meta-rules suitable for the Coral Sea hand collectable fisheries.

5 Harvest strategy evaluation

a What range of uncertainties has been tested?

A large range of uncertainties have been tested. These pertain to data (e.g. biomass estimates) available for each species as well as the population dynamics and meta-population structure. All model simulations were run using a reference set (RS) of operating models rather than a single operating model, thereby incorporating uncertainty in growth and mortality rates, the carrying capacity per species and recruitment. The key uncertainty is the recruitment, and hence the RS included uncertainty in the steepness of the underlying stock-recruit relationship as well as the frequency of successful recruitment events. Future projections also tested strategies across a range of different future location- and species-choice models to capture the uncertainty as to future fishing patterns.

b How do those uncertainties relate to the full range of uncertainties for the stocks or species group concerned?

There are always further uncertainties that could be included but our analyses appear to have included the major sources of uncertainty.

c Have a broad range of stakeholders and independent experts been consulted?

No, there hasn't been an opportunity as yet to consult with a broad range of stakeholders. However some helpful consultations with stakeholders occurred during a Coral Sea workshop help in May 2011.

d Do fisheries on the same or similar species in other parts of the world provide any insights into uncertainties?

There is even less known about similar species in most other regions of the world, but some commonalities too, such as the slow observed recovery times for some species. There are more data collected for the Torres Strait bêche-de-mer stocks than the Coral Sea fisheries, and hence the Torres Strait study was used to inform the related Coral Sea study.

e What further work could be done?

A lot more work could be done to test and compare practical and effective spatial rotation harvest strategies and the trade-offs in terms of profit and risk to the resource. The location choice models could be refined.

f What changes are required to the harvest strategy?

There are no obvious immediate changes needed, apart from possible reductions in the surf redfish and prickly redfish TACs.

6 Other issues relevant to using the harvest strategy for status determination

As above, further development of the harvest strategy is required to refine the use of surveys as the sole basis for assessing the status of individual species.

7.4 Reporting Framework: Torres Straits Bêche de Mer

Does the Harvest Strategy Achieve the intention of the Harvest Strategy Policy?

The current harvest strategy for the Torres Strait is very simple (limited TACs (Total Allowable Catch), size limits), however, they are moving to a co-management strategy where communities will have a greater say in management. The fishery is based on a large number of species and although the analyses reported here focused on the eight most important species, the results likely pertain in general to the remaining species too, given we modelled a range of species with different growth rates and spatial habitat characteristics. There is currently insufficient information on trochus to reliably test the harvest strategy for this species, hence we do not discuss our preliminary results for trochus further.

The TAC for black teatfish, surf redfish and sandfish is currently zero. MSE analyses suggest that sandfish may not recover in the short term even in the absence of fishing, supporting the current zero TAC for this species. Moreover, our results suggested that a larger size limit might be more appropriate for this slow growing species. Simulations suggested that the other two species could sustain small experimental quotas without unduly increasing risk. However, there is a relatively greater risk of localised depletion occurring at Warraber and Warrior subzones.

The MSE simulations suggested that the current TACs for white teatfish and prickly redfish perform well with respect to controlling the risk of overfishing. The remaining three species (deepwater redfish, hairy blackfish and leopardfish) are regulated as part of a joint 80t TAC. Across all model simulations there was a relatively greater risk to deepwater redfish than to the other species, and model results suggested this may reflect a need to increase the size limit of this species. The current TACs were conservative enough if fishing continues in roughly the same way as in the past, but if spatial and species-selection fishing patterns change (for example if they are driven predominantly by profit considerations), then there is a greater risk posed by a joint rather than species-specific TAC, for deepwater redfish and hairy blackfish in particular.

There remains significant uncertainty in the management of the Torres Strait hand collectable fishery due to uncertainty in the recruitment dynamics of beche-de-mer species, and the lack of suitable trigger limits and monitoring of the fishery.

The natural variation in the dynamics of the species studied mean that it is sometimes difficult to distinguish between scenarios with no fishing and those with fishing. Given this very great variation coupled with very great uncertainty about biology and fisheries ecology it remains difficult to devise a harvest strategy that achieves the intent of the Policy. There are no large closed *areas in the Torres Straits to prevent a significant proportion of the resource from being fished, but fishing on some species is not permitted based on survey assessments of stock status. Achieving an economic target is even less straightforward. However, this fishery remains potentially a valuable resource to the Torres Straits islanders who operate in the fishery. As such it contributes to their economic and social well-being, which reflects the intent of the HSP. Therefore, even though it is difficult to fit the hand collectible fishery into the HSP, the current harvest strategy could be said to achieve the intent of the HSP.*

1 Complete coverage

a Which species or stocks that are classified by the Status Reports does the harvest strategy cover?

The Torres Strait bêche-de-mer fishery, and specifically the 8 species listed below:

Holothuria scabra	Sandfish
Holothuria whitmaei	Black teatfish
Actinopyga mauritiana	Surf redfish
Holothuria fuscogilva	White teatfish
Thelenota ananus	Prickly redfish
Actinopyga echinites	Deepwater redfish
Actinopyga miliaris	Hairy blackfish
Bohadschia argus	Leopardfish

.

b Does the harvest strategy apply throughout the stock's entire range?

No, the Commonwealth harvest strategy only applies to the Torres Strait region. There is a spatial rotation harvest strategy that applies to the Coral Sea bêche-de-mer fishery, and the Queensland sea cucumber fishery on the GBR. Some stocks, sandfish and deepwater redfish in particular, also straddle the International border with PNG.

c Is the RBC adjusted for fishing mortality that occurs outside the fishery's control?

No, the RBC is currently fixed at a constant level. But this has been set in an attempt to match the productivity of the local region. However, some of the TACs could be revised after the current study.

.

2 Appropriate Proxies for reference points

a Are the adopted proxies consistent with the Commonwealth Fisheries Harvest Strategy Policy and Guidelines (HSP)?

No, as there are no currently adopted proxies. However, the current TACs are set conservatively and in that respect reflect an intention to meet the HSP. Moreover, some of the proxies suggested as part of this study are fairly conservative and consistent with the HSP.

b Is there evidence that the harvest strategy's proxies reliably index stock biomass and fishing mortality rates?

No, as there are no such clear proxies and nor are these ideas necessarily appropriate for the hand collectable fisheries, given the large temporal and spa-

tial variability of the stocks. Our results showed that species appear to be performing satisfactorily overall.

.

3 Effective control rules

a Will targeted fishing cease when $B \leq B_{LIM}$?

No, there are no adequate harvest rules to curtail fishing a species below B_{LIM}. However the TACs are set fairly conservatively and hence, if effort is spread across the area of the fishery and a variety of species are harvested, harvest levels should avoid the stocks becoming overfished, although localised depletion may still occur.

b What is the probability of the harvest strategy maintaining $B > B_{LIM}$?

Given the high recruitment variability there was a high risk of both the overall population, as well as local spatial regions, becoming depleted below B_{LIM} even in the absence of fishing. For this reason, we compared the depletion and risk relative to comparable no-fishing trials. This suggested that the current TACs had a very low probability of depleting stocks over and above levels of natural fluctuations, apart from a relatively greater risk for deepwater redfish.

c Will the harvest strategy achieve the target?

As above, clearly defining a proxy for the HSP target is extremely difficult because of the natural variability of the species. We attempted to derive some proxy reference points, and these suggested that for those species with a current TAC > 0, they may be roughly achieving the target. There were some indications that the TAC for prickly redfish could be increased slightly.

d What is the probability of the harvest strategy maintaining stock biomass at or around the target for the species?

As above, this is not straightforwardly answered for this group of species. However, given suggested proxies and the limitations and uncertainties associated with this study, it does seem that there is a reasonable probability of the harvest strategy maintaining stock biomass at or around the target for all species with the possible exception of deepwater redfish. There remains the problem that species such as the sandfish may take a considerable time to recover, even in the absence of fishing.

e Will F be reduced when $F > F_{MSY}$?

It is not possible to easily and sensibly estimate F_{MSY} for these highly variable species. Under the current catches and fishing patterns, it seems the catches are small enough to maintain $F < F_{MSY}$. However simulation results suggest that under some location and species-choice models, there is a risk that $F > F_{MSY}$ for some species for some of the time.

f Will targeted fishing cease when $F > F_{LIM}$?

If using the rough suggested proxy for F_{LIM} derived in this study, the answer is yes, but not if fishing patterns change as noted above.

g What is the probability of the harvest strategy maintaining $F \leq F_{LIM}$?

See above

h Is the harvest strategy robust to the initial state of the stock i.e. will it achieve the target and avoid the limit from all initial conditions?

No, see above.

i To what extent does uncertainty over mixing rates affect the risk of breaching limit reference points?

It is unlikely that bêche-de-mer are able to mix throughout their range as adults, but recruitment is likely shared between adjacent reefs. We have tested the management strategy erring slightly on the conservative side by assuming that recruitment is not shared across the entire Torres Strait region and hence locally depleted zones cannot be easily reseeded.

---

4 Correct implementation

a Has the harvest strategy been cranked?

No, there are currently very low or zero catches, as has been the case since about 2006.

b Have control rules and RBCs been implemented?

No

c Is the implementation timely, e.g., are the results relevant to the Status Reports' assessment year?

d Are any data, which are required for setting the RBC, missing or uncertain?

The biomass estimates from the surveys are uncertain and these are conducted every few years only, but they are critical for setting RBCs. Additional data would be advantageous and there are plans to involve communities in data collection. Catch data is also scant and difficult to collect at remote island processing facilities. AFMA has implemented a docket book program that should address this in the future.

e Are adjustments to RBCs consistent with the HSP?

Yes, based on periodic surveys, catches are either controlled or species are closed to fishing.

f Do adjustments to RBCs reflect increasing uncertainty at higher tiers?

Not applicable.

g Is there a need for a meta-rule to be invoked?

There are currently no meta-rules suitable for the Torres Strait hand collectable fisheries.

---

5 Harvest strategy evaluation

a What range of uncertainties has been tested?

A large range of uncertainties have been tested. These pertain to data (e.g. catches, surveys) available for each species as well as the population dynamics and meta-population structure. All model simulations were run using a reference set (RS) of operating models rather than a single operating model, thereby incorporating uncertainty in growth and mortality rates, the carrying capacity per species and recruitment. The key uncertainty is the recruitment, and hence the RS included uncertainty in the steepness of the underlying stock-recruit relationship as well as the frequency of successful recruitment events. Future projections also tested strategies across a range of different future location- and species-choice models to capture the uncertainty as to *future fishing patterns.*

b How do those uncertainties relate to the full range of uncertainties for the stocks or species group concerned?

There are always further uncertainties that could be included but our analyses appear to have included the major sources of uncertainty.

c Have a broad range of stakeholders and independent experts been consulted?

No, there hasn't been an opportunity as yet to consult with the Islanders and managers. Although not specifically as part of this project, a project member (T.S.) is closely involved with all aspects of the fishery and has disseminated and gathered some information.

d Do fisheries on the same or similar species in other parts of the world provide any insights into uncertainties?

There is even less known about similar species in most other regions of the world, but some commonalities too such as the slow observed recovery times for some species. There is more data collected for the Torres Strait bêche-de-mer stocks than the Coral Sea fisheries, and hence the current study will be used to inform the related Coral Sea study.

e What further work could be done?

A lot more work could be done. There is currently the expressed desire by stakeholders to move towards a co-management system that incorporates both classical modern harvest strategies and traditional fisheries practices and local decision making. The methodology developed as part of this subproject is ideal for testing a broader range of harvest strategies proposed as part of a move to community based management.

Preliminary results suggest that spatial harvest rotation strategies outperform non-spatial strategies, particularly with regard to preventing localised depletion. There is a lot more work that could be done to test practical and effective spatial rotation harvest strategies if the concept is supported by stakeholders.

f What changes are required to the harvest strategy?

The harvest strategy currently consists of fixed TACs, some of which are zero, and hence both resource and economic performance could be improved through the use of carefully tested control rules. The minimum size limit may need to be revised for two species in particular – the deepwater redfish and sandfish. In particular, there is a need to develop control rules to mitigate against localised depletion. It is worth investigating the feasibility and cost-benefits of spatial rotation harvest strategies. Harvest strategies that are closely aligned with the vision of moving towards co-management are the most likely to succeed – it would thus be advantageous to develop control rules that depend on information collected by communities themselves. The transparency of such a system would increase understanding of sustainable fisheries management, as well as engender a sense of ownership.

6 Other issues relevant to using the harvest strategy for status determination

As above, further development of the harvest strategy is required to refine the use of surveys as the sole basis for assessing the status of individual species.

7.5 Reporting Framework: Demersal Trawl in the SESSF

Does the Harvest Strategy Achieve the intention of the Harvest Strategy Policy?

Chapter 4 examines this question for all of the harvest strategies examined here (Tier 1, 3a, 3b and 4). All the harvest strategies for both example species (with the exception of flathead Tier 4) lead to the median of the relative SSB values stabilising close to the target level, and in all cases the median minimum depletion is above the limit reference level. Thus, the first two objectives of the CHSP are achieved by all harvest strategies, with the exception of the Tier 4 strategy when the choice of reference period is inappropriate (although in practice this would never be known). All of the harvest strategies for both the species tested have a zero median probability for the stock being below the limit reference point at any time in the projection period. Thus the third objective of the CHSP, that the stock stays above the limit biomass level at least 90% of the time, is achieved by all harvest strategies.

1 Complete coverage

a Which species or stocks that are classified by the Status Reports does the harvest strategy cover?

Testing here was carried out using tiger flathead and school whiting in the SESSF as examples. Tiers 1, 3a and 4 are actively applied in the SESSF (Tier 1: tiger flathead, jackass morwong, school whiting, blue grenadier, pink ling, gemfish east, orange roughy, school shark, gummy shark; Tier 3a: Alfonsino, John dory, redfish, mirror dory; Tier 4: silver trevally, blue-eye trevalla, blue warehou, gemfish west, ocean perch, silver warehou, ribaldo, elephant fish, sawshark). Tier 3b is a new development and has not been applied to any SESSF species.

b Does the harvest strategy apply throughout the stock's entire range?

Yes.

c Is the RBC adjusted for fishing mortality that occurs outside the fishery's control?

Yes, in the SESSF, state catches are included in stock assessments, and are subsequently subtracted from RBC values to calculate a Commonwealth TAC.

2 Appropriate Proxies for reference points

a Are the adopted proxies consistent with the Commonwealth Fisheries Harvest Strategy Policy and Guidelines (HSP)?

Yes. Tiers 1, 3a and 3b have default target F values of F_{48}, and a limit SSB level of 20%. Tier 4 has a target reference catch and catch rate that is assumed to be a proxy for the target B_{48}.

b Is there evidence that the harvest strategy's proxies reliably index stock biomass and fishing mortality rates?

Tiers 1, 3a and 3b show good evidence of ability to estimate current F values (with reduced precision at Tier 3), and a corresponding ability to estimate biomass depletion. Tier 4 does not require estimation of current F or depletion levels, and relies on the selection of an appropriate time period in the fishery *that can be used to indicate target F and biomass levels.*

3 Effective control rules

a Will targeted fishing cease when $B \leq B_{LIM}$?

Yes, for all Tiers tested.

b What is the probability of the harvest strategy maintaining $B>B_{LIM}$?

This question is specifically addressed in Chapter 4. All of the harvest strategies for both the species tested have a zero median probability for the stock being below the limit reference point at any time in the projection period..

c Will the harvest strategy achieve the target?

All the harvest strategies for both example species (with the exception of flathead Tier 4) lead to the median of the relative SSB values stabilising close to the target level.

d What is the probability of the harvest strategy maintaining stock biomass at or around the target for the species?

This probability was not explicitly calculated as a performance measure, but as all Tiers except Tier 4 in some circumstances achieved equilibrium at the target, they had long-term high probabilities of the stock remaining in the target region.

e Will F be reduced when $F>F_{MSY}$?

The default proxy for F_{MSY} for the Tier 1, 3a and 3b harvest strategies was F_{48}, and the shape of the harvest control rule determines that F does decline between the target biomass and the limit biomass to zero. Tier 4 has a reducing F dependent on current catch rates compared to the target catch rate.

f Will targeted fishing cease when $F>F_{LIM}$?

There is no specific account taken for $F>F_{LIM}$ in the Tier 1 harvest control rule in the SESSF, but F_{RBC} reduces to zero when $F_{cur}>F_{LIM}$ for Tiers 3a, and tested for Tier 3b. In all of these cases the harvest control rule specifies that fishery F should not exceed F_{TARG} (usually F_{48}) at any time, and RBC values are calculated accordingly. There is an implied F_{LIM} in Tier 4 where the current catch rate is less than a portion of the target catch rate.

g What is the probability of the harvest strategy maintaining $F \leq F_{LIM}$?

With proper implementation (and no error in assessment procedures), the SESSF Tier 1, 3a and 3b strategies have a low probability of exceeding F_{TARG}, and a very low probability of exceeding F_{LIM} if that was defined as F_{20}. The performance of Tier 4 depends on appropriate choice of reference period.

h Is the harvest strategy robust to the initial state of the stock i.e. will it achieve the target and avoid the limit from all initial conditions?

This was explicitly tested in Chapter 4 for flathead- and whiting-like species starting at both high and low levels of initial depletion. All harvest strategies tested performed well at achieving target biomass levels regardless of initial depletion (except Tier 4 depending on the appropriateness of the chosen reference period.

i To what extent does uncertainty over mixing rates affect the risk of breaching limit reference points?

Harvest strategies in the SESSF are assumed to be applied to single biological stocks that are well mixed. Chapter 8 examines the situation where this assumption was not met to various degrees, with the stock partitioned into two non-mixing regions. All tested harvest strategies performed well at the level of the overall combined stock, and adverse outcomes were only apparent for individual component stocks. The risk of breaching limit reference points for the combined stock with unmixed components was found to be low for all tested harvest strategies (Tier 1, 3a, 3b, 4).

4 Correct implementation

a Has the harvest strategy been cranked?

Tier1 has been applied since 2005, 3a and 4 in the current configurations since 2009. Tier 3b has not been implemented in the SESSF.

b Have control rules and RBCs been implemented?

Yes, since 2005.

c Is the implementation timely, e.g., are the results relevant to the Status Reports' assessment year?

There is an unavoidable delay between comprehensive data becoming available, and then stock assessments. In the SESSF, calendar year assessments are completed in the year following the data becoming available, and RBC values are used to calculate TAC values to apply at the start of the following fishing year (June 1). This means that overall there is a 17 month delay between data completion and TAC application.

d Are any data, which are required for setting the RBC, missing or uncertain?

Various degrees of uncertainty apply to all data sets used for stock assessment in the SESSF. Which are the most uncertain, or even missing is very stock specific. For example, age-length data from otoliths are not available for some species, forcing the Tier 4 harvest strategy to be used in those circumstances. The major uncertainties that apply to a number of species are stock definition (e.g. east-west mixing), total catch (state catch uncertainty), and natural mortality information. Natural mortality is a major uncertainty in most assessments, and could be called a data deficiency, because population age structure samples from when the fishery was unexploited is the best source of data that could be used to determine the most appropriate value.

e Are adjustments to RBCs consistent with the HSP?

Yes, the harvest strategies implemented in the SESSF comply with the HSP.

f Do adjustments to RBCs reflect increasing uncertainty at higher tiers?

Yes. A discount factor has been applied to RBC values from Tiers greater than 1 that was designed to account for uncertainty at higher Tier levels. In practice, other mitigating measures (such as closed areas) have been used in some cases to offset the perceived risk so that the discount was not applied.

g Is there a need for a meta-rule to be invoked?

There are meta rules relating to the rates of change of TAC (changes cannot be greater than 50%), but these should be required less often if stocks and catches stabilize.

5 Harvest strategy evaluation

a What range of uncertainties has been tested?

Uncertainty tested in the analyses presented here were to different life history characteristics (whiting, flathead, sometimes morwong), current depletion level and spatial sub-structuring of the stock. Robustness testing to model mis-specification was not examined.

b How do those uncertainties relate to the full range of uncertainties for the stocks or species group concerned?

There are always further uncertainties that could be included but those considered constitute the major sources of uncertainty.

c Have a broad range of stakeholders and independent experts been consulted?

Yes, within project planning meetings for the RUSS project the project design was presented and discussed several times.

d Do fisheries on the same or similar species in other parts of the world provide any insights into uncertainties?

Yes. Consideration of the results of simulation work in other fisheries has been accounted for in the discussion of relevant chapters.

e What further work could be done?

Robustness testing of the harvest strategies to mis-specification of natural mortality and steepness was examined for Tier 3a in Wayte (2009). Such robustness testing for Tiers 1 and 3b should also be carried out (and is planned for the near future for Tier 3b).

There is still further opportunity to develop additional assessment methods and harvest control rules for use in the SESSF - particularly for data poor species. A harvest strategy that incorporates spatial overlap of fishing effort and species distribution, such as examined in the ecological risk assessment of the effects of fishing approach (Hobday et al. 2011) warrants examination.

f What changes are required to the harvest strategy?

The harvest strategies implemented in the SESSF have been updated to improve their performance and now appear to work effectively. Improvement will be gained through the implementation of new harvest strategies that better account for the circumstances of individual species in terms of the most appropriate assessment and applicable harvest control rule. One arising from this project is the average length method.

6 Other issues relevant to using the harvest strategy for status determination

Specific issues have been discussed in the text relating to specific harvest strategies.

Contact Us

Phone: 1300 363 400
+61 3 9545 2176

Email: enquiries@csiro.au

Web: www.csiro.au

Your CSIRO

Australia is founding its future on science and innovation. Its national science agency, CSIRO, is a powerhouse of ideas, technologies and skills for building prosperity, growth, health and sustainability. It serves governments, industries, business and communities across the nation.