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Technical reviews for the Commonwealth Fisheries Harvest Strategy Policy: technical overview

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Project details

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Objectives

The original objectives of FRDC project 2012/225, as agreed in June 2012, were as follows:

1) Provide a technical review of recent research on fisheries harvest strategies (both in Australia and overseas) so as to identify information, methods or strategies that may help to address key issues identified by the review of the Commonwealth Fisheries Harvest Strategy: policy and guidelines (Commonwealth Fisheries Harvest Strategy Policy, or the policy) (DAFF 2007).

2) Identify further research required to update the harvest strategies used for Australian fisheries.

3) Provide technical advice on how the policy (including the guidelines) might be revised in the light of the review conducted in this project and, where relevant, suggest associated technical refinements of the policy's wording.

4) Identify alternative indicators of economic performance.

Further components were added to this project on 30 October 2012, adding objectives that would:

5) Provide a detailed review of the implementation of the policy, including the identification of potential performance measures.

6) Draft a technical overview paper for consideration by stakeholders and Australian Government agencies as part of the review of the policy.

This overview report addresses objective six, and summarises key conclusions and advice on potential improvements to technical aspects of the Commonwealth Fisheries Harvest Strategy Policy from the reports prepared under the preceding objectives, to provide a summary and interface between the technical detail in those reports, and a discussion of potential improvements to the policy and implementation guidelines.

Outcomes achieved to date

An advisory committee was established to guide the Commonwealth Fisheries Harvest Strategy Policy review, consisting of Australian Government agencies (Department of Agriculture, Fisheries and Forestry [DAFF], Australian Fisheries Management Authority [AFMA], Department of Sustainability, Environment, Water, Population and Communities [SEWPaC], Fisheries Research and Development Corporation, Commonwealth Scientific and Industrial Research Organisation and Australian Bureau of Agricultural and Resource Economics and Sciences [ABARES]), the fishing industry (Commonwealth Fisheries Association [CFA], Great Australian Bight Industry Association and Australian Southern Bluefin Tuna Industry Association), recreational anglers (Amateur Fishermen's Association of the Northern Territory) and nongovernment organisations (Worldwide Fund for Nature, Australian Marine Conservation Society). ABARES and DAFF presented an issues paper at the advisory committee's first meeting (May 2012).

The proposal for this project was developed in consultation with DAFF and CFA after identification of technical issues with the Commonwealth Fisheries Harvest Strategy Policy in an issues paper drafted by ABARES and DAFF, and confirmed by the advisory committee. The steering committee (DAFF, AFMA, SEWPaC) received regular updates on project progress. Draft review papers were provided to the advisory committee before presenting key results of the technical reviews to an advisory committee meeting on 5 February 2013.

The commissioned contributory technical review reports to the Harvest Strategy Policy Review were completed by December 2012. Key issues arising from these reports were identified and discussed with DAFF staff responsible for the policy review itself, to identify issues for inclusion in this Technical Overview. Drafts of the various technical review reports, including this overview, were provided to the Harvest Strategy Review Steering Committee in January 2013, and discussed at a meeting of the Advisory Committee in February 2013.

All key issues identified in the technical review reports were summarised in this overview and communicated to the DAFF team responsible for preparing the Harvest Strategy Policy Review report, to ensure that the review process remained informed of all emerging technical issues and potential improvements. This Technical Overview was finalised in May 2013.

Non-technical summary

The main conclusions and issues of direct relevance to revision of the *Commonwealth Fisheries Harvest Strategy: policy and guidelines* (Commonwealth Fisheries Harvest Strategy Policy, or the policy) (DAFF 2007), as identified in the various technical review reports written to inform the review, group themselves into a number of key categories. The key issues raised under each of these categories are summarised below. Under each category, a statement on the current situation is followed by identification of aspects of the policy or guidelines that might benefit from improvement at the moment, as well as aspects that likely require further work before options for improvement can be identified (in *italics*).

As a direct result of the fact that these issues have been identified in technical reports, most of the potential improvements identified relate to the implementation guidelines, and not to the wording of the policy itself. However, some of the suggested improvement in the guidelines may require some supporting or enabling text in the policy.

Before identifying the potential improvements, it must first be emphasised that the various contributory technical reports reviewed all noted that the policy provides comprehensive and effective guidance on design and implementation of harvest strategies to ensure that optimal benefits are derived from harvesting of Commonwealth marine resources. Most aspects of the policy and guidelines are considered to meet or exceed world's best practice. Harvest strategies developed under this policy have been implemented for all of the important Commonwealth fish stocks, and management actions implemented under these harvest strategies have contributed to improvements in stock status and economic yields for most of these stocks. Many of the potential improvements identified result from experience accumulated in developing and implementing the existing harvest strategies, and from improvements in stock assessment and management strategy methodology.

The key issues and potential improvements identified in the reviewed technical review reports and papers group themselves logically into a number of categories. The key conclusions for each of these categories are summarised below. Under each category, the recommendations or options for improvement, which are embedded in the main text of this summary report, are individually bulleted out for emphasis. In addition, options for future work to support further improvement under each category are bulleted out *in italics*.

Harvest Strategy Technical Reviews

Reference points and proxies

Current typical target and limit reference points (such as B_{MEY}, B_{MSY}, B_{LIM}; see the glossary for definitions of these terms) and their proxies ($0.48B_0$, $0.40B_0$, $0.20B_0$) meet international best practice. Use of B_{MEY} ($0.48B_0$) as a target exceeds international best practice. The use of F_{MSY} as the default effort limit reference point, and to define overfishing, is also international best practice.

- More explicit account should be taken of recent work suggesting that best practice targets for different species groups vary, depending on biology and productivity:
  - Targets for important forage fish, such as small pelagic species, should be above B_{MSY} and B_{MEY} at around $0.75B_0$ to ensure that stocks remain large enough to fulfil their ecotrophic function (Smith et al. 2011; Pikitch et al. 2012).

- Actual maximum sustainable yield (MSY) estimates for a range of teleost species groups range from $0.26B_0$ to $0.46B_0$ (Thorston 2012). For chondrichthyans, Brooks et al. (2010) obtained similar values of $0.21B_0$ to $0.47B_0$, with most sharks lying towards the upper end of that range.
- Although estimated B_{MSY}/B_0 ratios are similar for bony fishes and sharks, Zhou et al. (2012) found that the ratio of F/M differs substantially between teleosts and chondrichthyans, with $F_{MSY} = 0.87M$ for teleosts and $F_{MSY} = 0.41M$ for chondrichthyans due to lower productivity of the latter.

- Proxy B_{MSY} in the range of $0.35B_0 - 0.40B_0$ minimises the potential loss in yield for teleost species compared to the yield that would arise if B_{MSY} was known exactly (Punt et al. in press). This is consistent with the current policy proxy of $0.40B_0$ for B_{MSY}.
- The proxy B_{MSY} for some shark species may need to be closer to $0.50B_0$.
- Given the differences in B_{MSY} ratios for different species groups, the principle of setting $B_{LIM} = 0.50B_{MSY}$ should be retained to cater for those species where $B_{MSY} > 0.40B_0$, to ensure that limits designed to prevent unacceptable biological risk also take into account factors that dictate a higher B_{MSY} proxies (and therefore higher limits based on ½ B_{MSY}).
- *Due to higher uncertainty in cost data, the proxy for B_{MEY} to minimise the potential loss in profit is estimated to lie in the range $0.50B_0 - 0.60B_0$ (Punt et al. in press). This is higher than the current proxy of $0.48B_0$ for B_{MEY} as a result of higher uncertainty around cost data. Proxy values for B_{MEY} may more appropriately be $1.3B_{MSY} - 1.4B_{MSY}$, rather than the current recommended $1.2B_{MSY}$. Economically optimal effort levels are most likely to fall between 55 per cent and 65 per cent of MSY effort levels (Zhou et al. 2013).*
- *Harvest strategies may need to be revised and MSE retested for some species or fisheries if higher B_{MEY} targets are indicated, to ensure a high probability that harvest strategies and control rules will manage fisheries towards these objectives.*

Alternative maximum economic yield targets

Maximum economic yield (MEY) targets have been estimated for the Northern Prawn and Great Australia Bight fisheries. For all others, the proxy (1.2BMSY or 0.48B0) is used. One of the main problems is estimating BMEY for other species has been the difficulty in getting the necessary representative cost data to enable bioeconomic modelling.

- Where alternative targets (B_{MSY} or lower) are established for secondary species in multispecies fisheries, these should be MSE tested to ensure that risks remain acceptable.
- *Better guidance is required on economic objectives (what MEY means) and how they can be best achieved for different fisheries, such as highly variable fisheries and those where market process can be controlled by adjusting catch volumes.*
- *Further practical guidance is required on the circumstances under which an MEY target should be quantitatively estimated, rather than using a proxy value, how this should be estimated for different fishery types and the key principles for successful implementation.*
- *A more practical approach is required to using existing economic data and incorporating economic parameters into current stock assessments to estimate B_{MEY}, as opposed to developing separate bioeconomic assessments.*
- *There should be further exploration of alternative indicators and reference points for MEY, including those based on optimal fishing capacity and catch rates, and more appropriate proxies for different fisheries and gear types.*

Target ranges and dynamic targets

With the exception of the Northern Prawn Fishery, targets and limits are generally set as single fixed (static) values, either estimated from assessments or using default proxy values, assuming that the stock will achieve some long-term equilibrium. However, even in a perfectly managed fishery, stocks will fluctuate naturally around the target due to inter-annual variability in environmental conditions, spawning success and recruitment.

- Target ranges can cater for this natural variability by defining the target as a range between two plausible values, or using the uncertainty around estimates of MSY or MEY as a target range. Target ranges can be implemented within harvest strategies by adopting decision rules that incorporate a total allowable catch (TAC) plateau over the target range (Haddon et al. 2013).

- Where target ranges are set, these should be tested to ensure that there is still a less than 10 per cent probability of stocks declining below the limit if managed at the lower end of the target range.

- Limits should remain as single specified values (whether static or dynamic), as the required probability of not breaching these (> 90 per cent) already constitutes a range.

- *In addition to natural interannual variability, highly variable stocks can show interdecadal cycles in recruitment and productivity in response to environmental cycles (e.g. El Niño), or long-term climatic trends or regime shifts. Fixed target levels or ranges are inappropriate for such species; targets for such species are more appropriately specified as a ratio of the stock status if no fishing had occurred, referred to as $B_{Unfished}$ (e.g. $0.40B_{Unfished}$), where this can be estimated.*

- *Where variability in species productivity indicates the need for a dynamic target as a result of trends in productivity, a similarly dynamic limit (e.g. set at half the target) would also be indicated.*

Tiered harvest strategies

There is a wide range in data availability for different fish stocks, from low information for discarded bycatch species to high information for main commercial target species. Tiered assessment approaches and harvest strategies have been developed to deal with this range in data availability and applied to stocks in the Southern and Eastern Scalefish and Shark Fishery (SESSF). These tiers have recently been expanded to cater for lower information stocks, such as where only catch data are available (Dichmont et al. 2013).

- Discount factors (5–15 per cent) applied to recommended biological catches derived from various assessment tiers, to compensate for increased uncertainty as a result of lower information, are not always consistently applied. These discounts should be MSE tested to ensure that they achieve comparable risk across the tiers.

- Below these analytical approaches, ecological risk assessments (ERAs) can be used for low information species to determine whether particular species are vulnerable to the effects of fishing. ERA approaches would be appropriate for minor byproduct species that do not contribute substantially to catches or revenue.

- The full range of potential assessment methods should be integrated into a comprehensive hierarchical guide to assessment methods, data requirements, potential indicators and feasible harvest strategies at each tier in the hierarchy, covering the full range from Level 1 ERA to Tier 1 stock assessment.

- *Additional byproduct species brought into a revised harvest strategy policy would need to be evaluated to determine whether they are at low biological risk (analogous to being above Blim) from current fishing levels, using existing or updated Level 1 or 2 ERAs.*
- *ERAs may need to be reviewed to ensure that determination of 'low risk' under an ERA is analogous to there being a low probability of these species declining below BLIM levels under current fishing.*
- *Additional work is required to develop and test harvest strategies that could be applied effectively to the additional lower information assessment tiers (Tiers 5–7) developed by Dichmont et al. (2013).*
- *Development and MSE testing of harvest strategies designed to manage stocks towards targets and away from limits at each tier level should mean that additional discount factors are not required. If harvest strategies have not been tested to ensure low risk of breaching limits, and if discount factors are to be applied, then these discount factors should be extended to the new Tiers 5–7, and should themselves be MSE tested.*

Data requirements and risk-catch-cost trade-off

Data requirements for the various ERA and analytical assessment tiers are well understood (Dichmont et al. 2013). However, managing data-poor fisheries towards maximum economic yield (B_{MEY}) or proxy ($0.48B_0$) is less well understood, and will be difficult without increased data collection.

- There are increasing costs associated with moving to more certain, lower risk assessments. Selection of assessment tiers and data collection requirements should be guided by the trade-off between risk, catch and cost.
- *More work is required to develop B_{MEY} proxies for use with such data-poor fisheries.*

Multiyear total allowable catches

Multiyear TACs have been established for a number of species in the SESSF to reduce the annual assessment cost. Multiyear TACs provide greater certainty regarding the levels of future TACs and can provide greater catch stability during the multiyear TAC. In general, multiyear TACs require a discount of some level of catch below optimised annual TACs to balance the greater risk associated with less frequent review and adjustment.

When multiyear TACs are established, 'breakout' rules are usually adopted to detect extraordinary conditions not tested for when the multiyear TACs were initially determined (such as an unexpectedly large increase or decrease in catch-per-unit effort [CPUE]), and therefore require stock status and the multiyear TAC to be reviewed. Collection of the data required to calculate the breakout rule has to continue to allow these breakout rules to be evaluated every year.

- Additional guidance is required on when and how best to set multiyear TACs.
- For stocks with quantitative stock assessments and for which projections can be generated, projections at various catch levels and during various periods of time should be used to determine the level of multiyear TAC appropriate during various time periods (i.e. what level of catch is 'safe' over 2, 3 or 5 years).
- *For lower information stocks for which projections cannot be run, MSE testing should be used to determine the appropriate discount rates to use when setting multiyear TACs during different periods.*

Rebuilding strategies

The Commonwealth Fisheries Harvest Strategy Policy requires that active rebuilding strategies be implemented for all stocks that decline below B_{LIM}, to rebuild these towards B_{TARG}. Targeted fishing must cease below B_{LIM}. Stocks managed under rebuilding strategies have not shown the expected rebuilding within the planned or assumed timeframe. Some depleted species (e.g. eastern gemfish) would not recover in the 10 years plus one generation time stipulated in the policy. Reductions in productivity have been proposed (jackass morwong, Wayte 2012) and suggested (eastern gemfish, Morison et al. 2013) as the reason why these stocks have not recovered as predicted.

- There is some uncertainty regarding whether recovery timeframes stipulated in the policy apply to recovery to above B_{LIM}, or recovery to B_{TARG}, and whether targeted fishing can occur on conservation-dependent species even if they are above B_{LIM}. This should be clarified.
- Recovery timeframes stipulated in the policy (minimum of 10 years plus one generation, or three generation times) may not account for differences in productivity, variability in recruitment, and the possible relationship between spawning biomass and recruitment. A biologically appropriate definition of recovery time is required that can account for differences in productivity.
- The United States (US) and New Zealand (NZ) require rebuilding in relation to T_{min}, the minimum time to recovery under zero fishing: USA = T_{min} plus one generation; NZ = 2 × T_{min}. This sort of approach is able to deal with a wide range in species productivity and recovery rates, and provides better estimates to what might be considered to be a 'biologically appropriate' recovery time.
- Persuasive evidence of a change in productivity resulting from some external environmental factor is required before an environmental change can be adopted as the justification for changing the productivity parameters, targets and limits for a species under a rebuilding plan.
- Reduced recruitment as a result of spawning depensation in a depleted stock does not necessarily alter the long-term productivity of the stock, and so should not justify a change in targets. However, recruitment depensation can result in low productivity in the short-term, requiring substantial reductions in fishing mortality.
- *McIlgorm (2012) notes that the formally legislated recovery plans used in the United States appear to have one of the best records of stock recovery.*

Reduction of discards

International best practice aims to achieve zero discards by either prohibiting discards, or by implementing a system whereby fishers are required to land all catches, to deduct these from quotas or to pay 'deemed values' for catches above their quota allocations. One of the factors that has reduced the ability to monitor rebuilding of depleted stocks is poor estimates of discards for stocks subject to rebuilding plans. Reduced information on discard rates can mask recovery that may be occurring.

- Rebuilding plans for depleted stocks should include requirements to ensure adequate monitoring and data collection, to be able to obtain accurate estimates of discards, and to track increases in abundance or availability.

Spatial management

The Commonwealth Fisheries Harvest Strategy Policy recognises that spatial management may be used in various ways, including rotational closures to protect spawning seasons or nursery areas, rotational harvesting, separate TACs by area or protection of key habitat areas. These are all valid and useful management options that are particularly applicable to protection of nonmobile (e.g. shellfish, sea cucumbers), highly resident or seasonally aggregating species.

- Additional guidance is required on evaluating the extent to which a stock is considered to have been protected—and fishing mortality rates decreased—by closures, or how management of the remaining stock in open areas should be revised to account for the effects of closures.
- *Work is under way (FRDC project 2011/032: Incorporating the effects of marine spatial closures in risk assessments and fisheries stock assessments) to evaluate the extent to which fishing mortality on a range of stocks has been decreased by the establishment of an increasing number of marine protected areas (MPAs) or large-scale, permanent closures for protection of other species.*
- *Assessment approaches and harvest strategies may need to be revised for some species to account for the protective effect of these spatial closures. This will require some understanding of the rate of movement between closed and open areas, as well as agreement on objectives for how the remaining stock in open areas is to be exploited.*

Review of International Best Practice

Ecosystem-based fisheries management

The harvest strategy policy was not intended to meet Australia's international undertakings to implement an ecosystem approach to fisheries under the United Nations Convention on Biodiversity (UN 1992) or the Food and Agriculture Organization Code of Conduct for Responsible Fisheries (FAO 1995) and associated guidelines.

Nonetheless, McIlgorm (2012) did make some observations on ecosystem based fisheries management in his review of international best practices, noting that there are several recent international ecosystem and environmental monitoring and management trends that have surpassed the Commonwealth Fisheries Harvest Strategy Policy. In this regard, McIlgorm (2012) concluded that:

- Australia has a multiagency approach to environmental management, probably requiring some additional broader or overarching policy to address requirements for ecosystem-based fisheries management.

Implementation review

In addition to the technical reviews of various aspects of the policy and guidelines conducted by Haddon et al (2013) and Vieira & Pascoe (2013), the separate *A technical review of the implementation of the Commonwealth Fisheries Harvest Strategy Policy* (Ward et al. 2013) summarises experiences, successes and difficulties with development and implementation of harvest strategies for Commonwealth fisheries since adoption of the Commonwealth Harvest Strategy Policy.

This review identifies many of the same technical issues relating to harvest strategies that are identified in the Haddon et al. (2013) technical review of the policy, as well as some additional issues relating specifically to implementation. The recommended improvements listed below, arising from the implementation review, therefore duplicate some of those arising from the other technical reviews.

Reference points and indicators

Most harvest strategies do not use estimated B_{MEY} targets; instead they use the Commonwealth Fisheries Harvest Strategy Policy's proxies for target reference points. For most stocks, reference points are fixed and do not reflect the non-equilibrium nature of variable fish populations. It has been difficult to identify meaningful reference points for spatially structured species.

Harvest strategies for several low-value and data-poor fisheries have catch or CPUE triggers instead of reference points because it has been difficult to identify meaningful biomass-related reference points. For many of these, the most appropriate levels of these triggers are unknown, and the assessments and management actions that are triggered may not be feasible within an appropriate timeframe.

Targets required to optimise fishery-wide MEY have not been estimated for most Commonwealth fisheries.

- The reliance on proxies for targets and limits for most stocks emphasises the importance of ensuring that these proxies reflect appropriately the different biology and productivity of various species groups.
- Where catch or CPUE triggers for low-information stocks are designed to trigger immediate additional assessment work (e.g. to support in-season adjustment or some other immediate management action), data collections programs need to be in place to ensure that the data required for such additional assessments are available.
- *The implementation review also noted the need for further work on appropriate MEY proxies for various species groups and fisheries.*

Spatial management

The use of marine reserves and other spatio-temporal closures as fishery management tools, and the evaluation of the effect of such closures, has differed across fisheries.

- Harvest strategy implementation could be improved with additional guidance on evaluating the effects of closures on protection of stocks in closed areas and effective management of remaining stocks in open areas.
- *Assessment approaches and harvest strategies may need to be revised for some species to account for the effects of spatial closures.*

Management strategy evaluation and testing

Most harvest strategies have been tested using management strategy evaluation (MSE) to ensure that there is low risk (i.e. < 10 per cent) of breaching limits. For low-information species, some of this MSE testing has been generic, rather than species specific, evaluating the performance of a particular harvest strategy approach across a group of species in a fishery.

Insufficient information has precluded testing of the harvest strategies of some small fisheries and data-poor fisheries. MSE testing has also not been conducted to evaluate the effectiveness of proposed discount factors applied when moving from Tier 1 to higher tier (Tier 3 and 4) assessments, to evaluate the increase in risk that might be associated with moving to alternative targets below B_{MEY} for secondary species, or to evaluate multiyear TACs where these have not been developed using projections from a Tier 1 assessment.

- *Additional MSE testing should be used to evaluate the effectiveness of discount factors and multiyear TAC catch levels for low-information stocks.*

Application of harvest strategies

Harvest strategies for small fisheries and data-poor fisheries are often rudimentary or are not run routinely. Several stocks or species are assessed and managed as 'multispecies stocks'. Harvest strategies have not been implemented for a few significant commercial species in some fisheries, such as ocean jacket in the SESSF.

For several species, reliable estimates have not been available for significant sources of mortality, such as recreational catches and discards. Delays in data acquisition, processing and assessment have contributed to uncertainty in stock status.

It is unclear whether harvest strategies are required for the domestic component of three Eastern Tuna and Billfish Fishery stocks because of uncertainty over stock connectivity between the 200-nautical mile exclusive economic zone and high seas, and uncertainty about the effects of high-seas fishing on stock abundance in the Australian zone.

- Inclusion of additional low-information species under a revised Commonwealth Fisheries Harvest Strategy Policy will require consideration of whether a harvest strategy is required and what form this should take—depending on information availability and the risk-catch-cost trade-off. Harvest strategies could be unnecessary and unfeasible for low-information, low-risk (as determined using ERA), minor byproduct species.
- Where harvest strategies are agreed to and adopted, guaranteed monitoring and data collection programs need to be implemented to ensure that the data required to apply those harvest strategies will be available.
- *Additional harvest strategies may be required for important secondary species not currently under harvest strategies (e.g. ocean jacket) or minor species evaluated by ERA to be at medium or high risk from current fishing activities.*

Rebuilding strategies

A number of stocks depleted to below limits before the introduction of the Commonwealth Fisheries Harvest Strategy Policy and placed under rebuilding plans have so far failed to rebuild to above limits reference levels. A number of factors may have contributed to the failure of these stocks to rebuild, including rebuilding timeframes may have been too optimistic, some level of targeted fishing may have continued and fishing mortality may have been high enough to prevent rebuilding, or changes in the stock's productivity or ecosystem changes may have inhibited rebuilding.

- Harvest strategies for stocks under rebuilding plans currently state that recommended biological catches are zero, but provide no guidance on setting of incidental catch levels. More guidance is required in the policy on harvest strategy requirements that will ensure rebuilding of stocks placed under rebuilding plans.
- *Alternative approaches should be explored, and consideration given, to how to best define biologically appropriate rebuilding timeframes that are able to deal with differing species productivity and recovery rates.*

- *Persuasive evidence of a change in productivity is required before an environmental productivity shift can be adopted as the justification for changing the productivity parameters, targets and limits for a species under a rebuilding plan.*

Background

The development and implementation of harvest strategies is a crucial step towards improving fishery management in Australia (Smith et al. 2008) and internationally (Cadrin et al. 2004; Cadrin & Pastoors 2008). The *Commonwealth Fisheries Harvest Strategy: policy and guidelines* (Commonwealth Fisheries Harvest Strategy Policy, or the policy) is widely acknowledged as a key driver of improvements in the performance of Commonwealth fisheries since its introduction in 2007 (DAFF 2007). The policy has cultivated a transparent, evidence and risk-based approach to developing harvest strategies that incorporate target and limit reference points and performance measures for assessing a wide range of species, along with decision rules for generating advice for managing key commercial species in Commonwealth fisheries. Many aspects of the policy are considered to be examples of world's best practice for managing fisheries (McIlgorm 2012).

A review of the policy was conducted between July 2012 and May 2013, with the review's report submitted to ministers in May 2013. As part of the review, the Australian Bureau of Agricultural and Resource Economics and Sciencs (ABARES) and the Australian Department of Agriculture, Fisheries and Forestry (DAFF) consulted various Commonwealth agencies, scientists, economists and stakeholders on their views on the policy and identified areas where it might be improved. The review's advisory committee (representing a wide range of stakeholders) provided input, and wider opinion was sought through public consultation. This project was designed to link past and current research with the review, and provide technical advice on areas of potential improvement in either the policy itself or in the implementation guidelines.

Need

Since the Commonwealth Fisheries Harvest Strategy Policy was introduced in 2007 (DAFF 2007) there has been a great deal published nationally and internationally concerning the development and application of harvest strategies. Therefore, this policy needed to be reviewed for new technical content, especially with respect to new and developing methodologies for stock assessments and risk evaluation, and how the new work relates to issues of concern identified with the current policy.

The Commonwealth Fisheries Harvest Strategy Policy is generally regarded as having been largely successful in achieving the stated objectives. However, initial stages of the policy review have identified aspects of the policy, guidelines and implementation that might be improved to better meet the policy's objectives. Areas of potential improvement identified include:

- consideration of appropriate limit reference points based on trophic role or the biological characteristics of different groups of species (e.g. teleosts v. chondrichthyans)
- incorporation of spatial management
- approaches to setting total allowable catches (TACs) in multispecies fisheries
- data-poor stocks (including byproduct)
- rebuilding strategies
- indicators of economic performance.

This project reviewed the latest publications relevant to those priority areas, along with research work in progress, to provide the policy's advisory committee with technical advice on potential improvements to these aspects of the existing policy. Evaluation of current research and developing technologies can provide a basis for a revised policy to incorporate greater flexibility in responding to shifts in stocks and ecosystems in response to environmental drivers, such as climate change. This work should ultimately contribute to continued improvements in the economic performance and sustainability of Commonwealth fisheries, and will have relevance to shared fisheries, fisheries in other jurisdictions and internationally.

Methods

This technical overview was conducted by reviewing all of the technical review reports commissioned under Fisheries Research and Development Corporation (FRDC) Project 2012/225 to inform the review of the Commonwealth Fisheries Harvest Strategy Policy, as well as additional technical review reports not commissioned for the review, but nonetheless relevant to particular aspects thereof. A number of directly relevant peer-reviewed scientific journal publications on key aspects of harvest strategy design and implementation were also reviewed.

Conclusions from these reports on technical challenges with interpretation or implementation of objectives and requirements of the policy were distilled from these reports. Common themes were identified and grouped into categories. Potential improvements were then identified under each category relating to improving some of the enabling wording of the policy itself, or providing clearer or additional guidance in the implementation guidelines.

Technical reports reviewed

The following technical reports were reviewed in preparation of this technical overview:

- ***Technical reviews for the Commonwealth Fisheries Harvest Strategy Policy*** (Haddon et al. 2013). This is the main product of FRDC project 2012/225, addressing the first three objectives. The report focuses on technical details of existing harvest strategies under separate chapters on reference points appropriate to life-history characteristics, buffered targets or meta-rules, data-poor fisheries and tiered harvest strategies, TAC setting and multiyear TACs, rebuilding strategies and bycatch-only TACs, and spatial management. Information is provided under each of these chapters on how the requirements of the Commonwealth Fisheries Harvest Strategy Policy have been interpreted technically in the harvest strategies developed for Commonwealth fisheries. Where difficulties have been experienced with harvest strategy development or implementation, technical reasons for this are analysed and advice is provided on how these may be addressed.

- ***Technical reviews for the Commonwealth Fisheries Harvest Strategy Policy: economic issues*** (Vieira & Pascoe 2013). This report addressed economic aspects relevant to the first three objectives of the project, as well as its fourth objective. The harvest strategy policy requires that Commonwealth fisheries be managed to maximise the net economic returns to the Australian community. Estimating maximum economic yield (MEY) requires a bioeconomic model that has high biological, fishery and economic data requirements. Data limitations have prevented bioeconomic models from being developed for most fisheries, so that proxy values for B_{MEY} have to be used. The report considers circumstances under which the current interpretation of MEY, and the actual targets used for different stocks, could be modified to better achieve the economic objective and intent of the Commonwealth Fisheries Harvest Strategy Policy.

- ***A technical review of the implementation of the Commonwealth Fisheries Harvest Strategy Policy*** (Ward et al. 2013). This report addresses the fifth objective to this project. An overview table of the implementation of policy-compliant harvest strategies across all Commonwealth fisheries is provided. A number of fisheries exhibiting particular characteristics that affect the implementation of harvest strategies for those fisheries are then used as case studies to identify circumstances under which harvest strategy policy implementation has worked well, and to explain why implementation has encountered difficulties under other circumstances.

- ***Literature study and review of international best practice in fisheries harvest strategy policy approaches*** (McIlgorm 2012). This report was commissioned by DAFF to inform the Commonwealth Fisheries Harvest Strategy Policy review regarding recent international developments and best practices relating to fisheries harvest strategies. The report identifies aspects of harvest strategy best practice in international agreements and guidelines, and in harvest strategy approaches developed by the United States, New Zealand, Iceland and Norway. Aspects of the policy are contrasted with these to evaluate the extent to which the Australian policy meets or exceeds international best practice.

- ***Risk-based approaches, reference points and decisions rules for managing fisheries bycatch and byproduct species*** (Kirby et al. 2013). This report was commissioned under FRDC project 2011/251 to inform the review of the *Commonwealth policy on fisheries bycatch* (DAFF 2000). An objective, to evaluate the application of risk-based approaches to byproduct (secondary commercial) species, was added to the project, which makes aspects of this report relevant to the Commonwealth Fisheries Harvest Strategy Policy review. This report recognises that a broad hierarchy of assessment approaches are potentially applicable to any species subject to fishing mortality, depending on data availability. These approaches range from qualitative ecological risk assessment (ERA) approaches, through quantitative ERAs, low to moderate analytical assessments, to high-information stock assessments. Each approach has specific data requirements and the preferred approach is driven by a risk-catch-cost trade-off.

A number of other reports or recent scientific publications considered to be directly relevant to an overview of issues raised in the above reports were also reviewed:

- ***Reducing uncertainty in stock status: harvest strategy testing, evaluation, and development. General discussion and summary*** (Haddon 2012). The Reducing Uncertainty in Stock Status (RUSS) project was a substantial research project initiated in 2009 in collaboration between Commonwealth Scientific and Industrial Research Organisation and the Bureau of Rural Sciences (now ABARES); the objective was to reduce the number of fisheries classified as 'uncertain' in the annual ABARES fishery status reports. The project consisted of two streams. Stream 1 examined a range of data-poor assessment methods to determine whether some low-information uncertain status stocks could be assessed using these methods. Stream 2 used management strategy evaluation (MSE) to test the harvest strategies implemented in an array of different fisheries. This document summarises the outcomes of the second stream; in particular, the results of the MSE analyses conducted.

- ***'Impacts of fishing low trophic level species'*** (Smith et al. 2011). This paper uses a range of ecosystem models to explore the effects of fishing low trophic–level species (such as small, pelagic, shoaling species) in five marine ecosystems. Results show that that fishing these species at maximum sustainable yield (MSY) levels can have large impacts on other parts of the ecosystem. Halving exploitation rates would result in lower impacts on marine ecosystems while achieving 80 per cent of MSY.

- ***'On the use of BMSY and BMEY as reference points: selecting proxy target biomass levels to achieve pretty good yield and pretty good profit'*** (Punt et al. in press). There are difficulties in estimating actual B_{MSY} and B_{MEY} target reference points. This paper explores proxies for each of these targets, expressed as depletion levels relative to carrying capacity, which are more easily estimated than actual levels. Integration across a range of uncertainties about stock dynamics and the costs of fishing suggests that a proxy for B_{MSY} in the range of 35–40 per cent of carrying capacity (B_0) minimises the potential loss in yield compared to what would arise if B_{MSY} was known exactly. A proxy for B_{MEY} of 50–60 per cent of carrying capacity minimises the corresponding potential loss in profit.

- ***Setting target reference points for secondary species in the SESSF*** (Vieira et al. in prep). This report to the Australian Fisheries Management Authority (AFMA) provides an overview of the theoretical justification for use of alternative target reference points below B_{MEY} for secondary species in the Southern and Eastern Scalefish and Shark Fishery (SESSF), to optimise multispecies MEY across this fishery. Criteria for identifying nontargeted, low–economic return species are identified and used to select candidate secondary species in the SESSF. Potential increases in economic returns from reducing targets for these secondary species to B_{MSY} are evaluated.

Technical overview

There have been many achievements in implementing harvest strategies under the Commonwealth Fisheries Harvest Strategy Policy (Ward et al. 2013), and many aspects of the technical guidelines and approaches taken have resulted in effective harvest strategies (Haddon et al. 2013). Many aspects of the policy and resulting harvest strategies also meet or exceed international best practice (McIlgorm 2012). This overview focuses on difficulties experienced with development and implementation of harvest strategies under the policy, and summarises advice from the reviewed technical reports on how these might be addressed through improvements to the policy or guidelines.

The issues of concern identified in the various technical reports group themselves into a number of clear themes. Key issues under each of these themes are summarised below, together with any advice provided in the technical reports on how technical difficulties might be addressed and improvements made, either by improving the enabling provisions of the policy or the guidance provided in the implementation guidelines.

Reference points and proxies

Target and limit reference points are essential components of any effective management strategy. Without them, there is no consistent and objective basis for evaluating stock status or trends in performance indicators against management targets. McIlgorm (2012) notes that international best practice adopted BMSY as the biomass objective following the adoption of the United Nations Convention on the Law of the Sea (UNCLOS) in 1982 (UN 1982). There is increasing evidence that targets should be set above B_{MSY} for various reasons (Sainsbury 2008), but Australia is unique in explicitly setting targets at B_{MEY} and in adopting a proxy of $1.2B_{MSY}$ (or $0.48B_0$) for this target.

Following the adoption of the United Nations (UN) Fish Stocks Implementation Agreement (UNFSIA) (UN 1995), limit reference points (B_{LIM}) have been adopted by most countries to prevent stocks from being fished down to levels below which reproductive capacity becomes impaired. The most common proxy for B_{LIM} is ½ B_{MSY}, or $0.2B_0$. Most jurisdictions, including Australia, have adopted B_{LIM} as the point below which stocks are considered to be overfished. The policy prescribes ½ B_{MSY} or $0.2B_0$ as proxies for this limit. The policy additionally requires a 90 per cent probability of not being below B_{LIM}, which is a higher standard than other nations examined, depending on how B_{LIM} is defined. For example, the New Zealand Harvest Strategy Standard (Ministry of Fisheries 2008) defines a 'soft limit' of $0.2B_0$, and considers this to have been breached when there is a 50 per cent probability that biomass is below this level.

F_{MSY} is widely accepted internationally as the limit above which overfishing is considered to be occurring, and fishing mortality should be reduced (Mace 2001). Australia applies this definition of overfishing, with F_{MSY} being used as the default proxy for the overfishing limit, F_{LIM}.

Alternative target reference points

The policy approach to, and recommended proxies for, target and limit reference points therefore meet and, in the case of biomass targets exceeds, international best practice. However, B_{MSY} and B_{MEY} are difficult to estimate accurately for most stocks (Punt et al. in press) and are often not estimable for low-information stocks. As a result, proxies for targets and limits are used for most stocks in Australian fisheries. While the harvest strategy policy default proxy values comply with historical best practice, there is an increasing amount of recent research questioning these default proxy values and, particularly, whether one fixed proxy value is appropriate for species with widely differing biological characteristics and productivity.

As a result of increased focus on ecosystem approaches to fisheries, there has been a recent focus on appropriate target and limit reference points for important low trophic–level forage species. Several recent studies (Smith et al. 2011; Pikitch et al. 2012) have used ecosystem models to examine the effects on predators and other parts of the marine ecosystem of fishing these forage species. There is an emerging consensus that exploitation rates for these important food species should be set more conservatively than conventional single species MSY. Smith et al. (2011) conclude that considerable reductions in ecosystem impact can be achieved by moving from exploitation at MSY levels (typically close to 60 per cent depletion levels) to a target of 75 per cent of unexploited biomass (25 per cent depletion) for these species.

Pikitch et al. (2012) go further to recommend a tiered approach relating to data availability for low trophic–level species: high data—no more than $0.75F_{MSY}$ and no less than $0.30B_0$ to be left in the ocean; intermediate data—no more than $0.50F_{MSY}$ and B_{LIM} at least $0.40B_0$; and data poor—B_{LIM} no less than $0.80B_0$. As a result, the Marine Stewardship Council now identifies criteria for identifying 'key' low trophic–level species and requires that default target biomass reference points be set at $0.75B_0$, corresponding to exploitation rates of about $0.5F_{MSY}$. The harvest strategy framework adopted for the Small Pelagic Fishery (SPF) is compatible with these guidelines, limiting harvest levels to a maximum of $0.20B_0$ if a recent stock assessment is available and reducing this harvest level down to a maximum of $0.075B_0$ as time elapses since the last assessment.

In recent studies, Thorston et al. (2012) found average B_{MSY}/B_0 values for Pleuronectiformes (flatfish) of 39.5 per cent, Gadiformes (grenadiers, cods, hakes) of 43.9 per cent, Perciformes (perch-like fish—morwong, whiting, tunas, swordfish) of 35.3 per cent, Clupeiformes (herring and anchovy) of 26.1 per cent, Scorpaeniformes (gurnards, flathead, rockfish, ocean perch) of 46.3 per cent and other species of 40.5 per cent. While $0.40B_0$ does still seem to be a useful compromise as a proxy for B_{MSY}, default targets for some species groups should be higher or lower than this. For fishing mortality targets or limits, Zhou et al. (2012), based on analysis of 245 fish species worldwide, found $F_{MSY} = 0.87M$ for teleosts and $F_{MSY} = 0.41M$ for chondrichthyans. As an example of adapting targets to this range in productivity, New Zealand has adopted an approach to setting alternative targets using productivity categories, defined by the Food and Agriculture Organization (FAO) (2001) and Musick (1999), to define biomass targets ranging from $0.25B_0$ for high-productivity species to $> 0.45B_0$ for low-productivity species (Haddon et al. 2012).

Particular difficulties arise in trying to estimate target reference points for low-information stocks, for which estimates of MSY are highly uncertain. Tested and robust proxies, appropriate for the species group concerned, are better than attempting to use highly uncertain estimates of MSY. Integrating a range of uncertainties about stock dynamics and costs of fishing, Punt et al. (in press) demonstrate that a proxy for B_{MSY} in the range of 35–40 per cent of carrying capacity minimises the potential loss in yield compared to the yield that would arise if B_{MSY} was known exactly. This corresponds well with the Commonwealth Fisheries Harvest Strategy Policy default B_{MSY} proxy value of $0.4B_0$. However, because cost information for these fisheries is particularly uncertain, the corresponding proxy for B_{MEY} to minimise the potential loss in profit lies in the range of 50–60 per cent of carrying capacity. For the two fisheries analysed, target biomass of $0.45–0.63B_0$ for blue grenadier and $0.43–0.58B_0$ for tiger flathead achieve at least 90 per cent of the potential profit, integrated over uncertainties in the input parameters.

Zhou et al. (2013) note that proxy values for B_{MEY} may more appropriately be $1.3–1.4B_{MSY}$, rather than the currently recommended $1.2B_{MSY}$, and that optimal effort levels are most likely to fall between 55 per cent and 65 per cent of MSY effort levels. They point out that both economic and biological information is an important determinant of optimal biomass ratios, and that optimal B_{MEY}/B_{MSY} ratios range from 0.5 for species with slow growth, high catchability and contributing a small share of total revenue, to 1.7 for species with higher revenue shares, moderate growth rates and low catchability. The Commonwealth Fisheries Harvest Strategy Policy may need to be more explicit about ensuring that targets and limits are appropriate for different species and fisheries, and be more flexible in allowing a range of proxy values to be used. The guidelines will need to provide more advice on how this is to be done, and harvest strategies for some stocks may need to be revised to reflect revised MSY and MEY proxy levels.

Alternative limit reference points

The selection of $0.20B_0$ as the default limit reference point in the Commonwealth Fisheries Harvest Strategy Policy reflects earlier literature (Haddon et al. 2012). As an indicator of potential recruitment overfishing, Restrepo et al. (1998) recommend $½B_{MSY}$ as an appropriate limit, but consider $0.20B_0$ to be an acceptable proxy for that figure. However, for productive species with estimates of $B_{MSY} < 0.20B_0$, $0.50B_{MSY}$ would be $< 0.20B_0$. Given the uncertainty inherent in estimation of stock productivity, a precautionary approach would require good evidence that $0.50B_{MSY}$ is indeed below $B_{20\%}$. Even then, it is appropriate to retain $0.20B_0$ as the lowest proxy value for $B_{LIM.}$

The policy requires that there be a < 10 per cent probability that stocks will decline below established limit reference points. However, for many stocks, particularly those with low information, it is not possible to determine the confidence intervals around current stock status estimates with the precision required to ascertain whether stocks have a < 10 per cent probability of being below B_{LIM}. In recognition of the uncertainty around estimating B_{LIM} reference points and stock status against these, the International Council for the Exploration of the Sea (ICES) proposed the use of 'precautionary approach' reference points, B_{pa} and F_{pa}, set at some level above conventional B_{LIM} reference levels (1997). This approach to dealing with uncertainty in evaluation of stock status against limit reference points has been taken up in the FAO Stock assessment manual (Cadima 2003), which provides a method for calculating B_{pa} and F_{pa} reference points based on the work by ICES (1997):

$$F_{pa} = F_{LIM.}e^{-1.645.\sigma} \quad \text{and} \quad B_{pa} = B_{LIM}.e^{+1.645.\sigma}$$

The constant σ is a measure of the uncertainty in the estimation of the fishing mortality level F. The values obtained in several fisheries indicate that values of σ are 0.2–0.3 (ICES 1997), so that estimates of F_{pa} lie in the range $0.47–0.61F_{LIM}$ and estimates of B_{pa} lie in the range $1.39–1.64B_{LIM}$. For a B_{MSY} proxy of $0.40B_0$, recommended B_{pa} reference points calculated using the above formula would lie in the range $0.29–0.33\ B_0$, about halfway between the current proxies for B_{MSY} and B_{LIM}. Where there is high uncertainty around determining stock status in relation to a $0.20B_0$ limit, or concerns that this may not be an appropriate proxy for low-productivity species, use of B_{pa} reference points can constitute an explicit precautionary approach to dealing with this uncertainty.

Alternative maximum economic yield targets

Due to limitations in available economic data, or difficulties in collecting adequate economic data to support bio-economic modelling, bio-economic models have only been used to develop fishery-specific estimates of maximum economic yield (MEY)-related reference points, expressed in terms of biomass or fishing effort, for the Northern Prawn and Great Australian

Bight fisheries. Vieira and Pascoe (2012) have identified a number of opportunities or options for estimating alternative MEY-related targets, or alternative proxies for MEY targets, for lower information fisheries for which bioeconomic modelling has proved difficult.

The relevance of using an optimal fishing capacity approach to achieving the objectives of the policy, and potential decision rules around fishing capacity, should be explored. This could allow for improved performance against the economic intent of the policy for variable fisheries, international fisheries (fisheries where biomass targets are less relevant) and multispecies fisheries. Application of the approaches used by Zhou et al. (2013) for data-poor fisheries may be an option for improving performance against economic targets. However, further development of the approach is required to improve its reliability.

Options for incorporating readily available economic information into stock assessments, rather than conducting separate economic analyses, to provide better information for management to MEY targets should be explored. These options include applying an assumed price to TAC outputs and assumed cost parameter to fishing effort. Vieira and Pascoe (2013) recommend that such options should be explored to build on current Tier 3 (catch-curve) and Tier 4 (catch-per-unit-effort [CPUE]) assessments for data-poor fisheries to incorporate economic factors, such done by Defeo and Seijo (1999). They also recommend incorporating economic aspects into management strategy evaluation (MSE) testing of MEY-related targets.

A FRDC project (FRDC 2011/200) is under way to look at proxy measures for MEY in multispecies fisheries, particularly for secondary species. Preliminary results from this project should be available in mid-2013 and should allow more appropriate proxies to be determined for multispecies fisheries. Ensuring communication of these results to resource assessment groups (RAGs) should assist with setting of multispecies targets. Vieira et al (in prep) note that, where alternative targets (such as B_{MSY} or lower) are adopted for secondary species, these should be MSE tested to ensure that they do not result in unacceptable risks of breaching BLIM reference points.

The implementation guidelines could benefit from additional guidance on the following aspects relating to alternative MEY targets for different fisheries:

- Provision of practical guidance on the circumstances under which an MEY target should be estimated, how it should be estimated for different fishery types and key principles of successful implementation, would help guide RAG recommendations on these aspects.
- Better guidance on what MEY means, and how economic objectives change, for different fishery types when trying to maximise net economic returns for variable fisheries or those with market power.
- Further guidance on what constitutes meeting the MEY objective for data-poor stocks and the appropriate level of research investment for such stocks.

While some recent work has been conducted on aspects of alternative MEY targets for low-information fisheries (Vieira & Pascoe 2012), additional work will be required to inform the drafting of guidance on the above aspects.

Target ranges and dynamic targets

Where explicit targets have been expressed in harvest strategies developed under the Commonwealth Fisheries Harvest Strategy Policy, they are expressed as single values, usually as proportions of a theoretical equilibrium 'unfished' biomass (e.g. $0.48B_0$), as B_{MSY} (the proxy for which is also a proportion of B_0), or some proportion of an average fishing mortality or CPUE over a chosen historical reference period during which the stock was considered to have been lightly fished and stable. In reality, fish stocks are not expected to achieve a stable equilibrium, and natural variation in stock productivity and biomass will result from changing environmental conditions and recruitment variability from year to year. Even in well-managed fisheries, stocks will therefore fluctuate naturally around the target and, for species with substantial interannual variability in recruitment, this fluctuation can be substantial.

In addition to (and, partially, as a result of) this variability in recruitment, there is uncertainty around the determination of target values such as B_{MSY}, as well as around estimates of the ratio of current status to B_0. All of these estimates are therefore not single, precise values, but are more correctly expressed as probability ranges around a median best estimate. This also represents international best practice on how to report stock status (McIlgorm 2012). The combination of natural stock fluctuations around targets and uncertainty in estimates of targets and current status mean that expressing targets as single numbers can result in unrealistic determinations that stocks are sequentially above and below targets, when they are actually within the uncertainty around the target or within natural stock variability ranges.

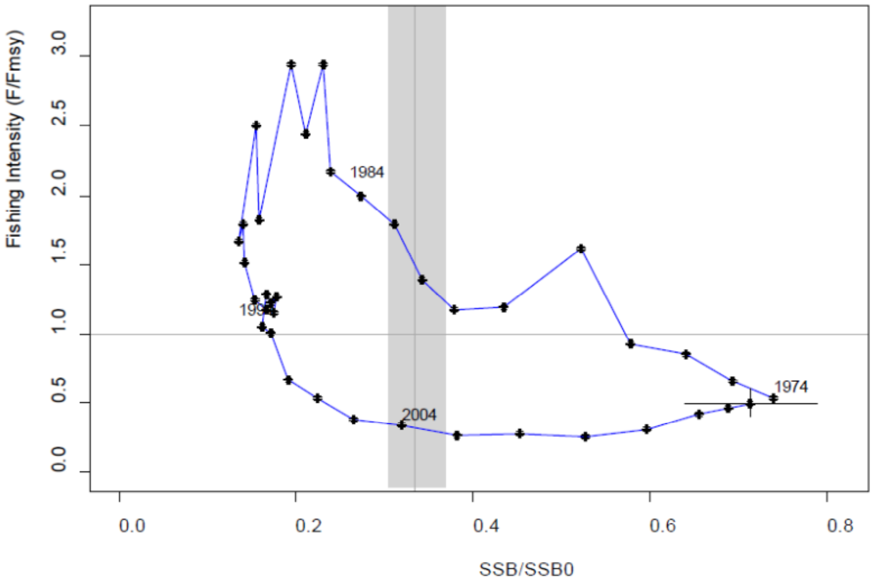
There are various ways of dealing with uncertainty around equilibrium estimates of targets, or with natural variability in these targets, in management strategies. Haddon et al. (2013) describe approaches whereby this can be dealt with by including a plateau in decision rules, providing a buffer region above which changes in stock status do not result in changes in TACs. For example, a decision rule designed around a target of $0.48B_0$ could include a plateau down to $0.40B_0$, with TACs being kept constant (and fishing mortality allowed to increase) until the stock reaches $0.40B_0$, after which TAC changes would be recommended. Plateau decision rules are used for a number of New Zealand rock lobster (*Jasus edwardsii*) fisheries (see decision rules for the CRA 4, CRA5, CRA7 and CRA8 stocks in Ministry for Primary Industries 2012b), and are generally designed to maintain stocks well above B_{MSY} levels.

A simpler approach to addressing natural variability, and uncertainty in stock status around targets, is to express targets as target ranges, rather than single numbers. There are various ways of doing this. One approach is to set the target range to include some proportion of the uncertainty around estimates of B_{MSY} or B_{MEY}. Estimates of these theoretical equilibrium values are typically uncertain and this uncertainty can be used to set a target range (e.g. the 90 per cent or 75 per cent confidence interval around the estimate), expressing this as the resulting target range in $\%B_0$. This uncertainty range would be expected to be narrower for stocks with reliable assessments and stable productivity (such as longer lived species with steady recruitment) and wider for highly variable species (with highly variable recruitment). Uncertainty-based target ranges can therefore potentially deal appropriately with species with different biological characteristics. Figure 1 shows an example uncertainty range (90 per cent confidence interval) around B_{MSY} for the New Zealand CRA 8 rock lobster stock (Ministry for Primary Industries 2012b).

Another approach is to set target ranges based on a range of estimates of B_{MSY} or B_{MEY} from stock assessments, or to choose a target range to achieve specific management objectives. A range of estimates for these targets could result, for example, from alternative assessment model runs using different values of the key input parameters (such as natural mortality or stock recruit steepness) or from different weighting of alternative biomass abundance indices (such as CPUE and fisheries independent surveys). Managers can choose to set target ranges to ensure the maintenance of a large stock size, such as the target range set by fishery managers for the New

Zealand eastern hoki (blue grenadier, *Macruronus novaezelandiae*) stock at 0.35–0.50B_0, well above the estimated B_{MSY} for this stock of 0.25B0 (Figure 2).

Figure 1 Historical trajectory of spawning biomass and fishing intensity for the New Zealand CRA 8 rock lobster stock from 1974 to 2011.

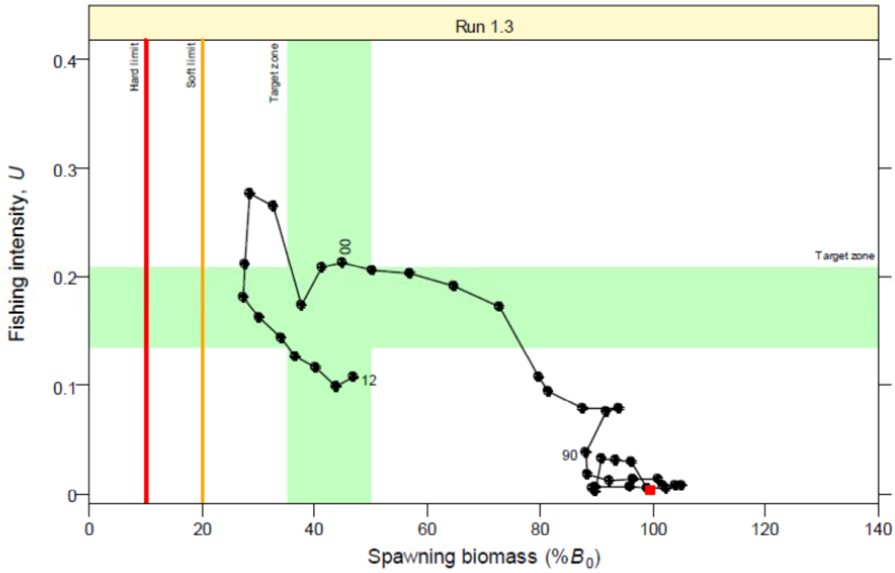


Note: This figure shows an example of a target range based on uncertainty around the estimate of B_{MSY}. The x-axis is spawning stock biomass (SSB) in each year as a proportion of the unfished spawning stock, SSB0. The y-axis is fishing intensity in each year as a proportion of the fishing intensity (F_{MSY}) that would have given maximum sustainable yield (MSY) under the fishing patterns in that year. The vertical shaded area shows the median (line) and 90% confidence interval around SSB_{MSY}.

Data source: Ministry for Primary Industries (2012b)

Targets specified as ranges can still be inadequate to deal with stocks that exhibit highly variable productivity (e.g. extended periods of alternating high and low recruitment), longer term trends in productivity over time (climate-related increases or decreases) or productivity shifts in response to environmental change. For such species, the unfished biomass itself can vary substantially over time, either cyclically in response to variable recruitment driven by environmental cycles, or following a trend in response to climatically or oceanographically driven regime shifts. Within the Southern and Eastern Scalefish and Shark Fishery (SESSF), there is already an example of a relatively depleted species that was near the limit reference point (jackass morwong, *Nemadactylus macropterus*) and exhibited a 20-year series of estimated below-average recruitment (as estimated by the stock assessment), preventing recovery to the original target. This was eventually characterised as a change in the species productivity, or an alteration in prevailing environmental conditions that affected productivity and has lasted for decades (Wayte 2012). The original target for this species is no longer attainable under these conditions and would need to be reduced to reflect the reduced B_0 capability of this stock.

Figure 2 Historical trajectory of fishing intensity (U) and spawning biomass (%B_0), for the New Zealand eastern hoki stock from 1972 to 2012.



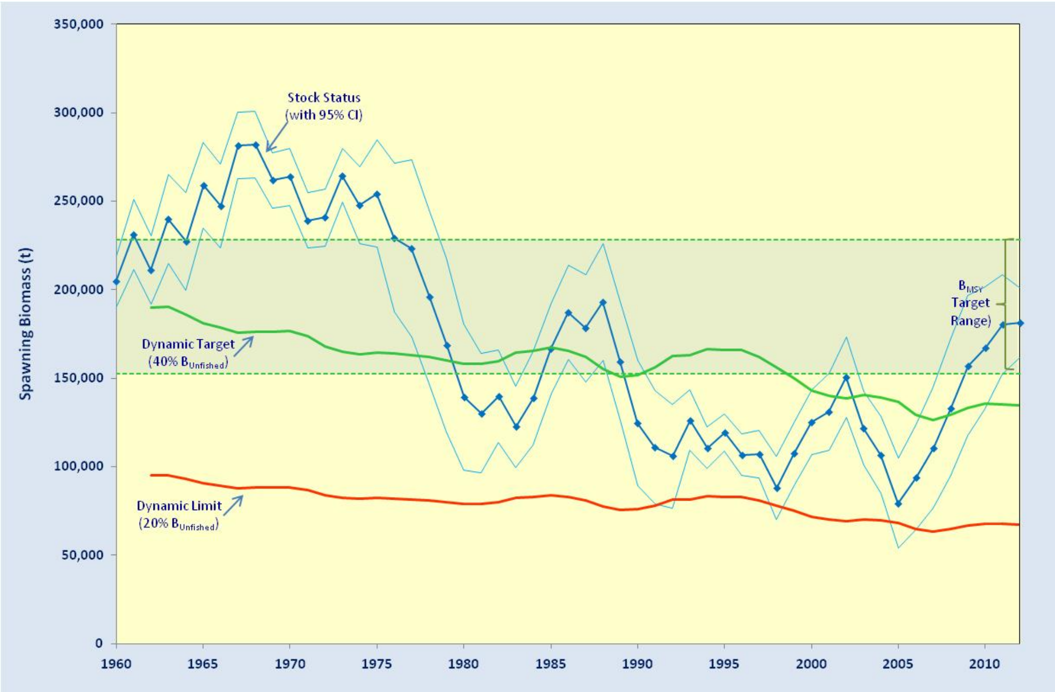
Note: This figure shows an example of explicitly set management target ranges around biomass and fishing mortality. The vertical line at $0.20B_0$ is the soft limit and the shaded areas represent the management target ranges in biomass (0.35–$0.50B_0$) and fishing intensity

Data source: Ministry for Primary Industries (2012b)

Under such circumstances, the concept of a stable, average, equilibrium MSY or limit reference point is inappropriate and it is better to express stock status in relation to dynamic reference points, such as $B_{Current}/B_{Unfished}$. Provided $B_{Unfished}$ can be estimated, this type of dynamic biomass reference point automatically compensates for recruitment variability, trends in productivity and environmentally induced recruitment regime shifts. Dynamic biomass target and limit reference points are used, for example, by international regional fisheries management organisations for variable pelagic species such as tunas and jack mackerel (SPRFMO 2012). The Northern Prawn Fishery currently uses a dynamic F-based reference point.

Figure 3 illustrates these alternative options around reporting stock status incorporating assessment uncertainty—in relation to a target range, or to dynamic targets and limits. This hypothetical example shows a stock that is interannually variable, but is also exhibiting a long-term decline in productivity (and therefore in attainable targets), which is contributing to a decline in biomass of the species.

Figure 3 Illustration of alternative approaches to setting target ranges or dynamic targets to account for natural variability and uncertainty in targets and current stock status



Note: Uncertainty around estimates of stock status (expressed as 95% confidence intervals); uncertainty or an explicit range around a B_{MSY} target; and a dynamic target and limit, expressed as $\%B_0$, changing over time as a result of changes in stock productivity.

In setting target ranges, management decision rules should be designed to manage towards the centre of the target range. Nonetheless, it would be necessary to ensure that the lower end of such ranges still represents an appropriate target, with a < 10 per cent probability of breaching limits. In terms of future research, if it was decided to pursue buffered decision rules, target ranges or dynamic targets, results would need to be MSE tested to determine whether such a harvest strategy increases or decreases the risk of breaching limit reference points.

Data-poor fisheries and tiered harvest strategies

Haddon et al. (2013) note that data-poor stocks lack sufficient biological and/or fisheries information to:

- estimate the exploitation status of the targeted stocks
- determine meaningful reference points
- produce a defensible stock assessment
- evaluate stock status against reference points.

Nonetheless, the Commonwealth Fisheries Harvest Strategy Policy requires approaches that ensure a consistent degree of risk across all fisheries. This creates particular challenges for data-poor fisheries. In this regard, the harvest strategy policy states that:

> *A tiered approach to control rules is encouraged in order to cater for different levels of certainty (or knowledge) about a stock … Such an approach provides for an increased level of precaution in association with increasing levels of uncertainty about stock status, such that the level of risk is approximately constant across the tiers*. (DAFF 2007)

This has resulted in the development of a tiered system of analytical assessment methods and associated control rules, pioneered in the SESSF (Smith et al. 2008; Little et al. 2011). An extended tiered approach (Dichmont et al. 2013) specifies a broad range of assessment approaches from integrated stock assessments (Tier 1), where substantial data are available, to approaches where data are limited to catch-at-size and catch rates (Tiers 3 and 4), to approaches where only catch data are available (Tiers 5–7) (Dichmont et al. 2013; Dowling et al. 2013). Catch triggers can also be used for data-poor species to trigger increased data collection, should catches increase above a certain level, to provide for higher information assessments in an adaptive management approach. Where such triggers are intended to trigger an immediate re-assessment (e.g. to support in-season adjustment or some other immediate management response), data collection programs need to be in place to ensure that the data required for such re-assessment are available.

Haddon et al. (2013) cite numerous international reviews that have been conducted on alternative indicators and assessment methods for data-poor species. Many of these have proposed hierarchical approaches to selection of assessment methods, depending on data availability. Scandol (2003, 2005) investigated a wide range of potential indicators including total catch, catch rate, length distribution, age distribution, catch, CPUE, mean age, mean length, recruitment fraction, total mortality and fishery-independent surveys. Biomass surveys were found to provide best results, followed by mean age and length, and recruitment fractions. Time series of CPUE and catch had the worst performance but were still acceptable.

In developing scientific guidance for evaluation of bycatch and discards in Canadian commercial fisheries, Fisheries and Oceans Canada developed a hierarchical guide to selection of the most appropriate of these many analytical assessment approaches, depending on data availability (DFO 2012). The Canadian approach is similar in concept to the extended tiered approach proposed by Dowling et al. (2013) and Dichmont et al. (2013).

Below this broad range of analytical assessment methods, ecological risk assessment for the effects of fishing (ERAEF; Hobday et al. 2011) can be used for species with very low levels of information, to determine whether particular species are highly vulnerable to fishing. If numerous data-poor species become included under the revised Commonwealth Fisheries Harvest Strategy Policy as a result of being identified as minor byproduct species, there will be a need to use ecological risk assessment (ERA) results to determine which of these minor species are at low risk of being overfished at current fishing levels. Species assessed as being at high risk, or species for which catches increase above predetermined catch trigger levels to become significant contributors to commercial catches, would either need to move to being assessed using an appropriate analytical method under one of the assessment tiers, or managed under a precautionary approach to reduce risk. There is, therefore, a need to integrate ERAEF and the various analytical assessment tiers into a comprehensive, hierarchical guide to assessment methods, data requirements, potential indicators and harvest strategies at each tier, covering the full range from Level 1 ERA to Tier 1 stock assessment.

To date, most developmental work in this regard has focused on comparing data-poor assessment methods, rather than comparing the effectiveness of data-poor harvest control rules. Further work is therefore required to develop appropriate harvest strategy approaches for application to species under the lower information tiers (Tiers 5–7) proposed by Dowling et al. (2013) and Dichmont et al. (2013). Haddon et al. (2013) emphasise that there remains a real need to provide guidance on formulating control rules that link empirical indicators with suitable management responses for low-information stocks.

MSE testing across a range of the current tiered assessment methods and fisheries (Haddon 2011; Little et al. 2011; Klaer et al. 2012) shows that most of these approaches can potentially meet the objectives of the Commonwealth Fisheries Harvest Strategy Policy, provided certain conditions are met under each method. Where MSE testing indicates that a given information strategy and control-rule combination will meet objectives, the approach can be used as is. Where MSE is inconclusive, increasing precaution should be applied to lower information tiers (Haddon et al. 2013). In particular, candidate harvest strategies developed for the newly proposed lower information tiers (Tiers 5–7) need to be MSE tested to ensure that the risks of breaching limits remain acceptable under these low-information harvest strategies.

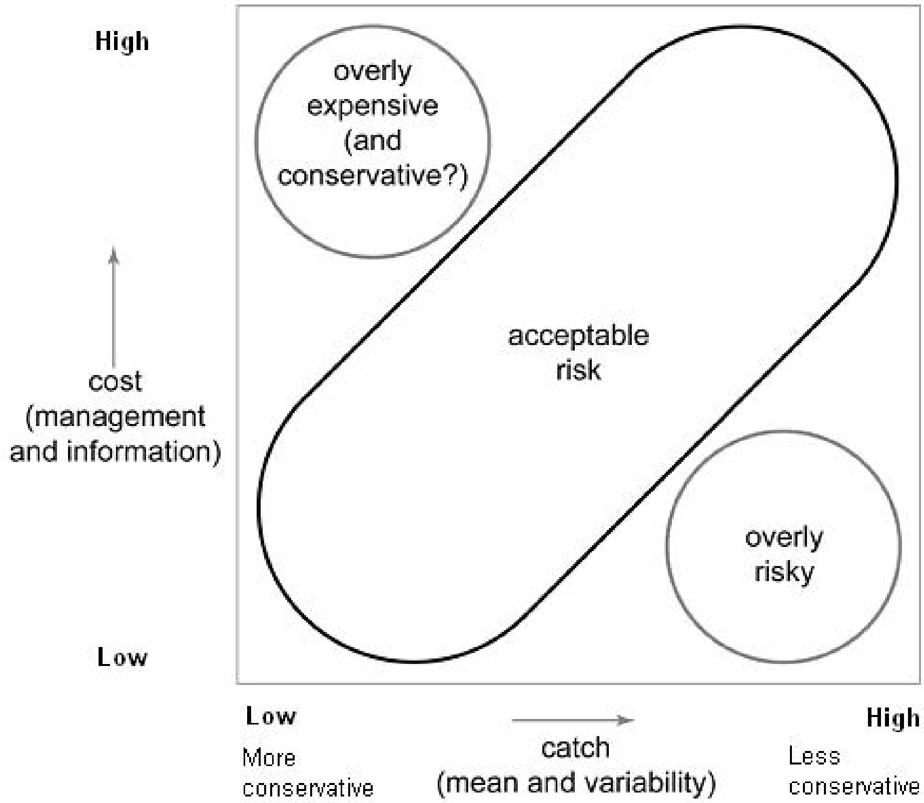
Data requirements and the risk-catch-cost trade-off

Each assessment method under the tiered assessment approach described above has certain minimum data requirements, described in Dichmont et al. (2013, tables 2 and 3). There are certain types of data that all fisheries should collect on a routine basis, such as fishing dates and positions, fishing effort and catch weight for all retained species. This would usually be supplemented with representative length and age data for the primary commercial species. Haddon et al. (2013) note that additional minimum data standards could then apply to some fisheries depending on their scale and likely level of ecological impact, to allow the impacts of fishing on secondary stocks, minor byproduct species and the ecosystem to be evaluated. Determination of which fisheries these additional requirements would apply to could be based on the value of the fishery, the volume of landings in the fishery and/or the overall ecological footprint of the fishery. This could be determined using risk assessments or on a case-by-case basis using the steps described in Dichmont et al. (2013). How this is dealt with should form part of the guidance provided on implementation of a broadened tiered approach to stock assessment and harvest strategy development.

The minimum data requirements for each assessment tier have direct costs for data collection, storage and analysis. Each assessment tier also has a particular level of uncertainty, with higher information assessments providing higher certainty and lower risk compared to low-information assessments. There is, therefore, a direct risk-cost-catch trade-off associated with a decision to assess and manage a particular stock at a particular assessment tier level. Higher information tiers are more expensive, but have lower risk and so permit higher fishing intensity and potentially higher catches (Figure 4). An FRDC-funded project (2012/202) on 'Operationalising the risk cost catch trade-off', which began in July 2012 at the Commonwealth Scientific and Industrial Research Organisation and is due to finish in June 2014, will provide advice on practical application of this risk-cost-catch trade-off when selecting assessment tiers for particular stocks.

Whether assessments are conducted using ERA or analytical assessment tiers, there are potentially two options for a management response to indications of high risk: 1) move to a more data rich and certain method, and test if this risk still remains; or 2) mitigate this risk through precautionary management action. Haddon et al. (2013) note that development work to date has tended to focus on data-rich approaches, with less guidance provided on appropriate risk mitigation under data-poor circumstances. However, the assumption that moving to a more data-rich approach is a better way of addressing risk assumes that the necessary resources will be provided for additional data collection and analysis. This is not affordable for all stocks and so a funding model is required that provides optimal balance between the option to demonstrate that low-information harvest strategies are effective (through MSE testing) and the option to collect additional data to support more complex assessments.

Figure 4 Schematic of unacceptable catch-cost combinations and the spectrum of acceptable risk combinations extending from high catch-high cost to low catch-low cost



Data source: Sainsbury (2005)

Application of discount factors

As a direct result of the increasing uncertainty associated with lower information assessment tiers, there is associated increased risk for these assessments. To meet the objectives of the Commonwealth Fisheries Harvest Strategy Policy across all of the tiers consistently, some process is required to ensure that risk remains comparable across the tiers. This has been addressed in the SESSF by applying discount factors to the total allowable catches (TACs) for stocks assessed using lower information assessments. A 5 per cent discount is applied to the TACs derived from catch curve (Tier 3) methods and a 15 per cent discount is applied to the TACs from CPUE trend (Tier 4) methods. However, these discount factors were essentially arbitrarily chosen and it is likely that the appropriate discount factors should differ for different species. These discounts are also not applied consistently, and may be waived if, in the opinion of the SESSF RAGs, other factors (such as spatial closures) are reducing risk to the extent that discounts are no longer necessary. More importantly, the effectiveness of these discounts in reducing risk to comparable levels has not been MSE tested.

The principle of not applying discounts where other factors have reduced the risk adequately is sound, but further guidance is required on what might constitute adequate grounds for waiving the agreed discounts. The more appropriate approach would be to develop appropriate harvest strategies for each assessment tier level that directly compensates for the increased uncertainty in lower information assessments. Additional discount factors should then not be necessary. If discounts are to be used, then the effect of these discount factors in reducing risk should be tested and demonstrated using MSE approaches, to show that management objectives will be achieved and that the risk of breaching limits remains comparable across the tiers.

Multiyear total allowable catches

The initial approach taken to setting TACs after adoption of the Commonwealth Fisheries Harvest Strategy Policy was to set TACs for each species on an annual basis. This created the requirement that each species under a TAC be re-assessed annually. Since then, budget and time constraints have increasingly resulted in the need to prioritise and stagger stock assessments, and not to conduct these annually for all species. This, in turn, means that revised advice on recommended biological catches will not be available every year. Under such circumstances, fishery managers need to decide whether to simply retain TACs at their existing levels, or to apply some level of TAC decrease to compensate for the increased uncertainty in stock status as time elapses since the last assessment.

The latter option is explicitly applied, for example, in the harvest strategy for the Small Pelagic Fishery (SPF), under which the SPF version of a Tier 1 approach requires a biomass estimate from daily egg production method (DEPM) surveys, plus age and length frequency data. Harvest strategy rules limit harvest to a maximum catch of 20 per cent of the best Tier 1 biomass estimate, with provision for a discount of 2.5 per cent in this maximum for each year after a DEPM assessment is not undertaken. After 5 years without a DEPM survey, the stock reverts to a Tier 2, with a maximum catch of 7.5 per cent of the best biomass estimate.

Provided that risk is not increased as a result, there are benefits to setting multiyear TACs. Doing away with the need to conduct annual assessments results in cost savings and allows available time and resources to be dedicated to assessments of fewer stocks on a rotational basis. Whether resulting TACs are fixed or determined for a number of years ahead, multiyear TACs result in greater certainty and stability for the industry. In general, multiyear TACs require a discount of some level of catch to balance the greater risk associated with less frequent review and adjustment.

The effect of setting of multiyear TACs has not been subject to formal MSE and no decisions have yet been made about how best to set multiyear TACs. Haddon et al. (2013) note that this is offset to some extent by the adoption of break-out rules to trigger a re-assessment if some indicator of stock status goes outside expected 'safe' ranges of some monitored performance indicator. However, the effectiveness of these breakout rules in triggering a response that prevents increased risk have also not been MSE tested, and rules are currently set rather arbitrarily on a case-by-case basis. The exploration of the risk-cost-catch trade-off currently under way in a FRDC project should evaluate the different options for setting multiyear TACs and should provide insights on whether multiyear TACs should always be reduced below single year TACs to reduce the risk of overfishing.

Rebuilding strategies

Stocks that have declined to below the B_{LIM} limit reference point (more correctly, that can be shown to have a > 10 per cent probability of having declined to below B_{LIM}), need to placed under a rebuilding strategy to rebuild the stock towards B_{TARG}. Targeted commercial fishing of such stocks should cease until they have recovered to above B_{LIM}. Although this is not explicitly stated, this should be interpreted as requiring that targeted fishing not be permitted until there is a 90 per cent probability that stocks have recovered to above B_{LIM}. Rebuilding strategies have been implemented for four species that were depleted before implementation of the harvest strategy policy: orange roughy, eastern gemfish, school shark and blue warehou. The latter three of these species have so far not shown clear evidence of rebuilding.

In terms of timeframes for rebuilding, the policy states that 'typically recovery times are defined as the minimum of 1) the mean generation time plus ten years, or 2) three times the mean generation time' (DAFF 2007). Haddon et al. (2013) note that there has been some debate about the scientific basis for these timeframes, and whether this statement pertains to the timeframe for moving the stock to above B_{LIM} or to B_{TARG}. Attempting to meet these recovery timeframes has been problematic for these three stocks.

Depleted species may be subject to general productivity declines. The failure of the northern cod fishery to recover is currently considered to have been exacerbated by a decline in the productivity of the stock, such that recovery, if it ever happens, is not presently predictable. Haddon et al. (2013) note that some low-productivity species, particularly if they are fished as a group of mixed species (such as gulper sharks), may be reduced to such low levels that the probability of them recovering is impacted by random environmental events that result in poor recruitment, even at low F levels. Recent work has shown that depleted stocks may suffer a substantial loss of resilience, with recovery being far slower than predicted from assessments of productivity of the nondepleted stock (Neubauer et al. 2013)

Feasible recovery timeframes to any particular recovery target are therefore dependent on species productivity. Different species will have different feasible recovery timeframes, establishing the need to base these on estimates of life span, and preferably on estimates of T_{min}—the minimum time to recovery under zero fishing mortality. If species productivity changes, then recovery potential will also change and so, provided these productivity changes can be detected, this approach would automatically compensate for productivity shifts, such as is considered to have happened for jackass morwong. If overfishing of a stock to below B_{LIM} does result in reduced productivity (as a result of spawning depensation), then estimates of T_{min} and recovery timeframes will change. This provides further support for the use of dynamic targets which, together with T_{min}-related recovery schedules, will result in recovery timeframes being able to be adjusted to compensate for detected changes in productivity.

Haddon et al. (2013) note that different countries have different rebuilding requirements and timeframes. The New Zealand approach is designed to adjust rebuilding timeframes in direct response to the biological productivity of different species, basing recovery on T_{min}, the minimum possible time to recovery under zero fishing mortality. The New Zealand Harvest Strategy Standard states:

> Where the probability that a stock is at or below the soft limit [$0.2B_0$] is greater than 50 per cent, the stock should be rebuilt to the target [$0.4B_0$] within a time period between T_{min} and $2 \times T_{min}$ (where T_{min} is the theoretical number of years required to rebuild a stock to the target with zero fishing mortality). (Ministry of Fisheries 2008)

The United States has a similar T_{MIN}-related approach:

> The maximum rebuilding period, T_{max}, should be 10 years, unless T_{min} (the expected time to rebuilding under zero fishing mortality) is greater than 10 years, when T_{max} should be equal to T_{min} plus one mean generation time. (Restrepo et al. 1998)

Australia's approach of ten years plus the mean generation does not account for variable recruitment and the possible relationship between spawning biomass and recruitment, whereby low biomass can result in reduced recruitment (Myers & Barrowman 1996). There are some depleted species in Australia (such as Eastern gemfish) that, given the previous variation inferred from the Tier 1 assessment, would not be expected to recover in a maximum of 10 years plus the mean generation time. The New Zealand approach therefore appears to be more appropriate, allowing for longer recovery timeframes that are biologically feasible, while allowing for some level of fishing mortality while the stock rebuilds.

The Commonwealth Fisheries Harvest Strategy Policy also does not explicitly require that harvest strategies impose a zero catch limit on stocks below B_{LIM}. Some of these species (notably school shark) are unavoidably caught as bycatch in multispecies fisheries. Incidental catch allowances are usually still provided for species under rebuilding strategies, set at the estimated level of 'unavoidable bycatch', in recent years including discards. These incidental bycatches would certainly be expected to delay recovery and may in fact exceed the annual sustainable yield levels of a depleted resource, potentially preventing recovery. Haddon et al. (2013) note that recent assessments and projections suggest that the total fishing mortality for eastern gemfish, school shark and blue warehou has not been reduced sufficiently to allow rebuilding within the specified timeframes.

Haddon et al. (2013) consider that there may be some lack of clarity in the policy about rebuilding targets, and whether an overfished stock must be rebuilt to B_{MSY} before targeted fishing can recommence. However, it appears to be clear in the policy that targeted fishing may restart once a stock has been rebuilt to above B_{LIM}, provided this is conducted under a harvest strategy that continues to rebuild the stock towards B_{TARG}. The policy is clear about the targets for rebuilding, stating that 'for a stock below B_{LIM}, a stock rebuilding strategy will be developed to rebuild the stock to B_{TARG}. Once such a stock is above B_{LIM} it may be appropriate for targeted fishing to re-commence in-line with the stock rebuilding strategy and harvest strategy' (DAFF 2007).

There may be a question as to whether targeted fishing can occur on conservation-dependent species when they have been rebuilt to above B_{LIM}. This may require clarification from those administering the *Environment Protection and Biodiversity Conservation Act 1999* (Cwlth). Haddon et al. (2013) also ask whether there is a requirement to rebuild secondary species to a B_{MEY} target. The policy would also seem to be clear on this aspect. B_{LIM} limits would still apply to secondary species and initial rebuilding would have to be to above B_{LIM}. After that, if a secondary species is being managed to an alternative target below B_{MEY}, then rebuilding should continue under a harvest strategy towards that alternative target.

In a review of internal best practices, McIlgorm (2012) notes that the United States, which has formal legislated species recovery plans, appears to have one of the best records of stock recovery (Wakeford et al. 2009).

Reduction of discards

International best practice aims to achieve zero fishery discards by either legislating for this, or by implementing a system whereby fishers are required to land all quota species and to deduct these catches off quota, or to pay a predetermined 'deemed value' (such as is applied in New Zealand) for catches in excess of the TAC (McIlgorm 2012). One of the complicating factors that has reduced the ability to monitor rebuilding of depleted stocks is poor estimates of discards for stocks subject to rebuilding plans, and for which targeted fishing has been prevented. Reduced information on discard rates can mask any recovery that may be occurring.

An unintended problem that arises from implementation of rebuilding strategies and preventing targeted fishing is that, under cost recovery, it becomes difficult to fund research on fisheries for which directed commercial activity has ceased. It is not clear how the necessary additional work to demonstrate that recovery is occurring should be funded. McIlgorm (2012) concludes that the Commonwealth Fisheries Harvest Strategy Policy could benefit from revisions to make stock rebuilding plans more effective, including consideration of active measures to reduce discards.

Spatial management

Haddon et al. (2013) note that spatial management can be incorporated into fisheries management approaches in various ways. Spatial management can form the main harvest strategy framework (such as in a system of rotational closures), be used to augment a harvest strategy framework or be invoked under a control rule. For some resident or slowly dispersing species, a system of spatial or temporal fishery closures can be more robust to uncertainty than control of catch, since only a component of the stock is exposed to the fishery. Spatial management may therefore be a cost-effective approach in the absence of other information required to inform other management measures.

Closed areas may be used to augment a harvest strategy in the face of uncertainty (Dowling et al. 2008a,b) or when a fishery interacts with highly vulnerable species that occur in limited identifiable areas. Closures can be permanent or implemented under a control rule in response to trigger levels being reached for vulnerable species interactions. Alternatively, similar protection under uncertainty could be achieved using 'move on' provisions, again triggered by predefined trigger catch levels. Rotational spatial management can form part of harvest strategies, using control rules to determine which areas to open or close to fishing during a given period, thereby maintaining a level of stock protection in each area and avoiding the breaching of biomass limit reference points.

Haddon et al. (2013) note that differences in fish density within and outside marine protected areas (MPAs) could be used to evaluate the relative status of stocks or portions of stocks outside MPAs. Such approaches are potentially applicable to fisheries targeting near-shore rocky reef species that exhibit spatial variation, limiting traditional stock assessment approaches. For example, McGilliard et al. (2011) used the ratio of the density of fish inside and outside an MPA in a control rule to recommend the fishing effort level for the next year. Such approaches should be MSE tested to evaluate the performance of the density ratio under different productivity and fish-movement scenarios, to optimise long-term cumulative catch.

Barnes and Sidhu (submitted), using a variety of modelling approaches, conclude that the main benefits of closures for fisheries are reliable (rather than increased) yields and an effective safeguard against uncertainty. While total yield is likely to be similar to the yield without closed areas, there are advantages in regular replenishment and faster recovery. Closed areas can generate improved longer term yield when stocks are severely depleted, providing benefits in terms of conservation and improved yield. These results support the earlier conclusions by Lauck et al. (1998), who stated that closed areas may be the simplest means of implementing the precautionary principle and achieving sustainability, particularly where there is uncertainty regarding stock status.

In all the above cases, further guidance is needed in the Commonwealth Fisheries Harvest Strategy Policy on evaluating the effects of closures in protecting resources inside the closed areas, and on how management of stocks outside the closed areas may need to be revised to take account of the effects of closures.

Ecosystem-based fisheries management

The current Harvest Strategy Policy was not intended to meet Australia's international undertakings to implement an ecosystem approach to fisheries under the Convention for Biodiversity (UN 1992) or the FAO Code of Conduct for Responsible Fisheries (FAO 1995) and associated guidelines, and so the scope of the policy does not extend to ecosystem-based fisheries management (EBFM). However, in his review of international best practices relating to harvest strategy policies, McIlgorm (2012) does make some observations and recommendations regarding ecosystem approaches to fisheries management, and so these are summarised here.

McIlgorm (2012) notes that there are several recent international ecosystem and environmental monitoring and management trends that have surpassed the Commonwealth Fisheries Harvest Strategy Policy. For example, the European Union (EU) has explicitly included biodiversity and trophic measures under a broader marine agency environmental approach of the Marine Strategy Framework Directive. It appears that the EU intends to address impacts on nontarget species, bycatch, discards, stock structure and environmental impacts on trophic relationships more fully during the next decade.

These international trends suggest there will be a greater emphasis on the marine ecosystem, biodiversity and trophic functioning in the future. (McIlgorm 2012) notes that, within Australian fisheries, there is a multiagency approach to environmental issues and this requires a wider whole-of-government policy incorporating broader ecosystem objectives to address EBFM. Further progress on wider environmental and ecosystem management will require clarification of the role of the policy in an Australian whole-of-government approach to the ecosystem attitude to fisheries.

Issues identified by the implementation review

The supporting technical review report, *A technical review of the implementation of the Commonwealth Fisheries Harvest Strategy Policy* (Ward et al. 2013), identifies key issues and problems that have arisen during efforts to develop and implement harvest strategies since the adoption of the policy. These are summarised in Table 1, extracted from that report.

Table 1 Key issues and problems since the adoption of the Commonwealth Fisheries Harvest Strategy Policy

Successes	**Issues**
Reference points and indicators	
Bioeconomic models have been used to estimate B_{MEY} for six stocks.	Most harvest strategies use the policy’s proxies for target reference points.
Fishery-wide MEY has been estimated for two fisheries.	Fishery-wide MEY has not been estimated for most Commonwealth fisheries.
Most harvest strategies use the Commonwealth Fisheries Harvest Strategy Policy’s proxies for reference points.	The default proxies may not be appropriate for all species, particularly not for low-productivity species and important forage fish. Several harvest strategies do not have target and/or limit reference points. Harvest strategies for several low-value and data-poor fisheries have triggers instead of reference points because it has been difficult to identify meaningful reference points. The correct levels of triggers are largely unknown and have not been MSE tested. The assessments and management actions that are triggered may not be feasible within an appropriate timeframe.
Apparent changes in productivity have resulted in revised reference points for one species (jackass morwong).	For most species, reference points are fixed; they do not reflect the non-equilibrium nature of fish populations or environmentally induced changes in productivity.
Data and assessment	

Successes	**Issues**
Many stocks are assessed with quantitative models, which integrate a variety of data.	Many assessments rely on CPUE reported by commercial vessels. They assume that CPUE is a reliable index of stock biomass They assume that the reference period represents BMEY. These assumptions may not be valid for some stocks.
Control rules and TACs	
Multiyear TACs have reduced assessment costs and provided industry with stability and certainty about short-term catch levels.	Some multiyear TACs do not take into account the increasing uncertainty in stock status with time since the last assessment, or have not been MSE tested.
Several harvest strategies have attempted to deal with the effects of spatial closures implemented for other reasons.	The policy provides little guidance on the treatment of the effects of marine reserves and other closures on existing harvest strategies. It has been difficult to identify meaningful reference points for spatially structured species.
Management strategy evaluation and testing	
MSE testing has demonstrated that harvest strategies are robust to uncertainty in valuable fisheries for which adequate data exist to allow stock assessments.	Insufficient information has precluded testing of the harvest strategies of several small fisheries and data-poor stocks. Most of the testing has been generic rather than species specific.
Application	
Harvest strategies have been implemented for all quota species and key commercial species in all active Commonwealth fisheries.	Harvest strategies for small fisheries and data-poor fisheries are often rudimentary or are not routinely run. Harvest strategies have not been implemented for a few significant commercial species that are currently considered to be byproduct species (e.g. ocean jacket). Several stocks and several species are assessed and managed as multistock 'baskets'.
Many fisheries have established routine processes for assessing stocks and running harvest strategies.	Delays or reductions in data acquisition, processing and assessment have contributed to uncertainty in stock status for some stocks.
Harvest strategies have attempted to take into account fishing mortality from all sources.	For several species, and in the absence of catch-sharing arrangements, increasing state catches have been deducted from recommended biological catches, and the TAC available to Commonwealth fisheries has been reduced.
	For several species, reliable estimates have not been available for significant sources of mortality, particularly recreational catches and discards.
Australia's domestic policy settings have been advocated at several RFMOs.	There may be politically driven delays within regional fisheries management organisations to adopt approaches to fishery management that are consistent with the Commonwealth Fisheries Harvest Strategy Policy.
Harvest strategies have been implemented for the domestic components of several international stocks.	Harvest strategies have not been used to set TACs for the domestic component of two Eastern Tuna and Billfish Fishery stocks (yellowfin tuna and bigeye tuna) because of uncertainty about stock connectivity. For these stocks, TACs have been set based on historical catch levels.
Fishery performance	

Successes	**Issues**
Harvest strategies have prevented many stocks from becoming overfished.	The contribution of harvest strategies to stock status is difficult to separate from other factors, such as effort reductions as a result of structural adjustment. Several stocks have failed to rebuild because: targeted fishing may have continued fishing mortality from incidental catches may have hampered rebuilding changes in the stock's productivity or ecosystem changes may have reduced productivity rebuilding timeframes may have been too optimistic.
The economic performance of many of the main Commonwealth fisheries has improved as a result of harvest strategies.	The economic performance of several fisheries is uncertain or cannot be evaluated due to a lack of the required economic data.
	The contribution of harvest strategies to improved economic performance is difficult to separate from other factors.

Note: CPUE = catch-per-unit effort; MEY = maximum economic yield; MSE = management strategy evaluation; MSY = maximum sustainable yield; TAC = total allowable catch

Source: Ward et al. (2013)

Future research

There are already a number of FRDC-funded research projects under way that are expected to provide results and conclusions that will be useful to the Commonwealth Fisheries Harvest Strategy Policy review. Several of these projects have started only recently, but they are likely to generate outputs of relevance to future improvement of the policy and guidelines:

- ***The risk-cost-catch trade-off***. FRDC project 2012/202, 'Operationalising the risk-cost-catch trade-off'.
- ***The influence of closures on the harvest strategy policy***. FRDC project 2011/032, 'Incorporating the effects of marine spatial closures in risk assessments and fisheries stock assessments'.
- ***The management of byproduct species***. FRDC project 2011/028, 'Development of robust methods to estimate acceptable levels of incidental catches of different commercial and byproduct species'.
- ***Proxy measures for MEY in multispecies fisheries***. FRDC project 2011/200, *'Setting economic target reference points for multiple species in mixed fisheries*'.

Additional useful work identified as a result of this review includes:

- ***Multiyear TACs***. While some criteria have been drafted for selecting those species deemed suitable for multiyear TACs, these have yet to be tested formally using MSE.
- ***Alternative data-poor harvest strategies***. For the major mixed fisheries, it would be valuable to conduct research to devise or recommend further data-poor stock assessment methods and harvest strategies to improve the management of such fisheries.

Acronyms and abbreviations

ABARES	**Australian Bureau of Agricultural and Resource Economics and Sciences**
B	stock biomass
B_0	unfished stock biomass
B_{LIM}	minimum stock biomass limit reference point, below which reproduction is likely to be impaired and the stock is considered to be overfished
B_{MEY}	stock biomass producing maximum economic yield
B_{MSY}	stock biomass producing maximum sustainable yield
CPUE	catch-per-unit effort
DAFF	Australian Government Department of Agriculture, Fisheries and Forestry
ERA	ecological risk assessment
F	fishing mortality rate
M	natural mortality rate
MEY	maximum economic yield
MSE	management strategy evaluation
MSY	maximum sustainable yield
RBC	recommended biological catch
SESSF	Southern and Eastern Scalefish and Shark Fishery
TAC	total allowable catch

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Appendix A. Intellectual Property

The information compiled by this project is published, widely disseminated and promoted. There is no need to protect intellectual property beyond the Australian Government's standard copyright that applies to the project's report and other outputs.

Appendix B. Staff

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