Technical reviews for the Commonwealth Fisheries Harvest Strategy Policy: economic issues

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Research by the Australian Bureau of Agricultural and Resource Economics and Sciences and CSIRO

May 2013

FRDC project no. 2012/225
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Cataloguing data


Internet

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Acknowledgements
This project was funded by the Fisheries Research and Development Corporation. This report has benefitted from review and constructive criticism of previous drafts by K. Cochrane (Department of Ichthyology and Fisheries Science, Rhodes University), R. Curtotti, M. Harris, P. Morris, I. Stobutzki and P. Ward (ABARES) and members of the Harvest Strategy Policy Review Steering and Advisory Committees.
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<th>FRDC project number:</th>
<th>2012/225</th>
</tr>
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<tr>
<td>Project title:</td>
<td>A technical review of formal fisheries harvest strategies</td>
</tr>
<tr>
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<td>Subproject title:</td>
<td>Technical reviews of the Commonwealth Harvest Strategy Policy: economic issues</td>
</tr>
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**Objective**

Alternative indicators and approaches to better setting economic target reference points and meeting the economic objective of the *Commonwealth Fisheries Harvest Strategy: policy and guidelines*.

**Outcomes achieved to date**

The project reviewed the operationalisation of the harvest strategy policy’s maximum economic yield objective across Commonwealth fisheries. To do this, a review of the relevant literature was undertaken to provide a detailed description of the challenges that have occurred. The report provides an outline of key economic definitions and concepts, the general experiences and challenges of operationalising maximum economic yield in Commonwealth fisheries. It then draws on the literature to list the potential options that are available to improve the way in which Commonwealth fishery management meets the intent of the policy.
Non-technical summary

The key objective of Australian Commonwealth fisheries management for key commercial species as defined in the *Commonwealth Fisheries Harvest Strategy: policy and guidelines* (referred to as ‘the policy’ throughout) is that Commonwealth fisheries be managed sustainably and the net economic returns to the Australian community are maximised (DAFF 2007). This is interpreted in the policy as maximum economic yield (MEY), which is the level of catch and fishing effort that maximises sustainable economic profits in the industry over time. To this end, the biomass associated with maximum economic yield ($B_{\text{MEY}}$) is recommended as the target reference point to be used for key commercial species in all Commonwealth fishery harvest strategies.

MEY ensures that all inputs used in fishing are used at their optimal level, including the fishery resource itself. A key component of the economic surplus generated is resource rent, which represents the return generated by the fish stock—a key input into the production process. How much (if any) resource rent is realised by the community directly is a separate issue: the concept of MEY is concerned with maximising its generation.

A key challenge in achieving MEY is determining the actual harvest target itself. MEY is more than just a catch target—it also relates to a stock size and level of fishing effort that enables the catch to be taken. Estimating MEY requires some form of a bioeconomic model, which in turn requires detailed information on the biology of the species, technical interactions between fishing gears and catches (especially in mixed fisheries), cost structures of the fishing fleet and market conditions. In many cases, information on one or more of the required model components is not available, such that bioeconomic modelling is unable to be undertaken.

Recently, there has also been some confusion over what sectors need to be considered when estimating MEY using a bioeconomic model. In particular, a small number of researchers have proposed that downstream businesses such as wholesalers, processors and retailers should be included in the definition, and that the impacts of upstream businesses supplying the fishing industry should also be considered. The effect of their inclusion is higher catch and effort levels in the fishery, but lower industry profits compared to the definition of MEY above. However, the use of greater levels of inputs in fishing beyond what is optimal not only reduces rent generation but also diverts resources from other sectors of the economy where they could be used to greater benefit. Further, empirical analysis has demonstrated that in most cases, improved profitability in fisheries leads to improved economic activity in regional communities (counter to the previous arguments).

While the estimation of MEY has its own set of challenges, implementation of the policy in Commonwealth fisheries has also demonstrated further challenges associated with operationalising MEY as a management target. Some issues have arisen for certain fishery types while other issues have been more general, occurring across fishery types. These issues are summarised here, together with potential options that may assist in resolving them.

General challenges

Detailed biological and economic information is often not readily available to construct bioeconomic models. Proxy measures of the target reference point as recommended in the policy are available for fisheries that possess indicators of stock biomass but do not have access to a bioeconomic model. However, there has been evidence of a general misunderstanding of the circumstances under which a bioeconomic model should be developed instead of using proxy
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reference points. Further uncertainty has also existed around the circumstances under which alternative proxies (those that differ to the policy’s recommendations) should be developed. A broader lack of stakeholder understanding regarding MEY, the information required to target it and the most cost effective approaches to obtaining that information have also been key issues that have affected the operationalisation and stakeholder support of MEY.

These challenges highlight the potential benefits that might eventuate from providing greater practical guidance on best practice approaches to operationalising MEY. Further, a multifaceted approach to improving stakeholder knowledge could also be pursued to improve MEY operationalisation. Potential options include the formation of an economic technical working group to deal with issues around MEY, ensuring the availability of economic advice to fishery managers and resource assessment groups, as well as improving definitions and guidelines in the policy and allowing these to be updated with new information when it becomes available. More generally, research into issues around the estimation and implementation of MEY is ongoing and will provide further guidance on how to operationalise MEY.

Data-poor fisheries

As the policy was developed with a focus on biomass reference points, application of the policy to data-poor stocks has been difficult. As a consequence, economic considerations have received far less attention relative to biological objectives for these stocks. Given that many data-poor fisheries are of low value, the application of any approach in a data-poor environment requires careful consideration of the tradeoffs between the costs, benefits and risks associated with reducing management uncertainty. Greater practical guidance in this regard may be useful.

Application of approaches developed by Zhou et al. (2012) to estimate MEY proxies represents one relevant option to improve MEY management for data-poor fisheries that could be associated with a relatively low cost. This approach provides rules of thumb for determining MEY proxies for single stock fisheries using information that is readily available for low information fisheries.

Further building on current biologically focused data-poor approaches to better incorporate economic information may also be an option. Furthermore, a range of other indicators exist that provide information about the potential excess level of fishing capacity in data-poor fisheries. These do not necessarily equate to either biological or economic reference points, but contribute to an estimation of fishery level performance (rather than individual species reference points). Data envelopment analysis may be a particularly relevant approach here given that it only requires catch and effort data.

Multispecies fisheries

The policy recognises that in multispecies fisheries MEY should be applied to the fishery as a whole and not necessarily to individual species (that is, optimised across all species). Deriving models to identify conditions for MEY in multispecies fisheries in such a way is difficult. While it has been done well in the Northern Prawn Fishery, this required significant time and resources. Furthermore, the fishery’s model includes only three species. For other multispecies fisheries such as the Southern and Eastern Scalefish and Shark Fishery, the large number of species and limited biological information are significant constraints.

Research is currently underway that is focused on developing rules of thumb to guide the setting of MEY proxies in the multispecies context and extends the approaches developed in Zhou et al. (2012). Alternative options include the use of aggregated yield functions (where total catch is
combined across all species) to determine target fishery effort levels. Approaches focused on fishing capacity measures may also provide similar guidance.

**Highly variable stocks**

For short-lived, essentially annual species, the optimal harvesting strategy requires that the stock available in a given year be fished down until it is unprofitable, provided that subsequent recruitment and sustainability is not affected. While economic theory assumes that operators in such a fishery will stop harvesting when it is optimal to do so, this is generally not the case. In Australian fisheries, this is partly due to crew and skippers being paid a share of revenue, creating revenue maximising incentives (rather than profit maximising incentives). Furthermore, high levels of profit generated at the start of a fishing season in a highly variable fishery are likely to attract excess capacity and promote a subsequent race to fish, lowering overall net economic returns within a given year.

To improve MEY management in highly variable fisheries, assessment of the levels of excess capacity is an option, although is complicated in such fisheries. Some excess capacity is optimal in ‘average’ years to allow sufficient capital to take advantage of the high years, although determining this optimal level of excess capacity is problematic. Other approaches focused on ensuring management arrangements provide fishers with efficient incentives may also be useful.

**Fisheries with market power**

Where fisheries have some degree of market power such that price varies with the quantity landed, the definition of MEY may need to be modified. In such fisheries, maximising industry profit results in lower quantities of fish being made available to consumers at a higher average price, in turn resulting in a net loss of benefits to society. Therefore, maximising net economic returns requires maximising the sum of both producer and consumer surplus. This results in a higher level of catch (and effort) than that which maximises industry profits alone. However, the number of fisheries where a significant degree of market power exists is small. Therefore, the default position that management should take to target MEY for most Commonwealth fisheries is to assume prices are fixed in the short term with respect to catch, as has usually been done.

**Internationally shared stocks**

The policy does not prescribe arrangements for stocks targeted by domestic fisheries that are managed by international management bodies or arrangements or for stocks managed under a joint authority. Therefore, there has been some uncertainty around what approaches should be taken where the policy has been applied to such fisheries with the intent to achieve MEY. Given that domestic catches are typically influenced by external negotiations, a focus on arrangements that promote cost minimisation is warranted. Also, domestic target reference points may be better expressed in terms of capacity utilisation.
1 Introduction

The *Fisheries Management Act 1991* requires that the management of Commonwealth fisheries pursue five legislated objectives. Summarised, these include ensuring efficient and cost-effective management arrangements, management consistent with ecologically sustainable development principles, accountability, achieving management cost recovery targets and 'maximising net economic returns to the Australian community from the management of Australian fisheries'.

The *Commonwealth Fisheries Harvest Strategy: policy and guidelines* (referred to here as ‘the policy’) intends to ensure that Commonwealth fishery harvest decisions are made in a fashion that is consistent with these objectives (DAFF 2007). The policy’s overarching objective requires ‘the sustainable and profitable utilisation of Australia’s Commonwealth fisheries in perpetuity through the implementation of harvest strategies that maintain key commercial stocks at ecologically sustainable levels and within this context, maximise the economic returns to the Australian community’ (DAFF 2007, p. 4). To achieve this, the policy requires that harvest strategies seek to ‘maintain fish stocks, on average, at a target biomass point ($B_{TARG}$) equal to the stock size required to produce maximum economic yield ($B_{MEY}$)’ with a proxy of 1.2 $B_{MSY}$ (biomass at maximum sustainable yield) recommended as the target if $B_{MEY}$ is unknown (DAFF 2007, p. 4). Furthermore, the policy’s guidelines identify some key operational issues relating to the targeting of $B_{MEY}$ and provide advice on how these issues should be dealt with.

Despite this, the targeting of maximum economic yield (MEY) in Commonwealth fisheries has faced challenges on multiple fronts. A lack of relevant biological and economic data has been a key issue. There have also been practical implementation challenges stemming from limited knowledge and understandings amongst relevant stakeholders. More specific issues have also arisen on a fishery-by-fishery basis for fisheries that are data-poor, catch multiple species, target highly variable stocks, exhibit a degree of market power (through an ability to influence price) and catch internationally shared stocks. Many Commonwealth fisheries exhibit more than one of these characteristics.

This report reviews relevant literature to provide a detailed description of the challenges to operationalising MEY and, where possible, identify potential approaches to resolving these issues. To do this, key economic definitions and concepts are first outlined. General experiences operationalising MEY in Commonwealth fisheries are then discussed. Finally, issues relevant to particular types of fisheries (e.g. international, mixed species fisheries, highly variable stocks and fisheries with market power) are addressed.
2 Economic definitions and understandings

A key constraint to operationalising MEY has been a lack of stakeholder understanding regarding the concept and its implications for fishery management (AFMA 2011). This partly reflects the novelty of MEY as an objective, a lack of economic training amongst stakeholders and a low level of stakeholder access to relevant technical expertise. While it is beyond the scope of the current review to fill this information gap, its focus warrants some explanation of the concept.

The net economic return objective

A commercial fishery’s net economic return is its revenue earned from fishing, less the costs of fishing. This revenue reflects the quantity of fish caught across the fishery multiplied by the average market price received for that catch. Similarly, the costs of fishing reflect the quantities of inputs (e.g. labour, fuel and capital) used in the fishery multiplied by the market prices paid to use or employ those inputs. Costs of fishing also include the costs of management, which are largely recovered from commercial fishers in Commonwealth fisheries. While the definition of a fishery’s costs is not always straightforward, the concept of net economic return itself is fairly uncomplicated as it ultimately reflects fishery-wide profitability.

The assumed link between a fishery’s net economic return and the benefit it generates for a community occurs through the market. Market prices received by the fishery for its output (if supplied to the domestic market) and paid by the fishery for its inputs reflect their value to the community. For example, the market price for fish is determined by the willingness of consumers to pay, in conjunction with the market supply of fish. A consumer’s willingness to pay for a good reflects the benefit they expect to derive from consuming it, and they will consume it if their willingness to pay is equal to or higher than the market price. Community benefit that accrues to consumers, known as consumer surplus, is represented by the difference between their willingness to pay and the market price. Similarly, the market price paid for an input is determined by the current supply of that input and its current demand, the latter being a function of the productive benefits that can be generated from that input for the community.

In measuring community benefit, net economic return provides an indication of the level of inputs that should be devoted to fishing. For example, if fishing becomes unprofitable, it indicates that fewer inputs should be devoted to producing catch in the fishery. Furthermore, it suggests that those inputs have a more beneficial (or productive) use for the community if employed in another sector of the economy.

The link between net economic return and community benefit is not always clear-cut. For example, net economic returns in export-focused fisheries partially reflect benefits that accrue to non-domestic consumers. Additionally, net economic returns typically do not capture costs

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1 For example, capital costs include ‘capital opportunity cost’ and ‘capital depreciation costs’, costs which are not readily measured on a market. The opportunity cost is the foregone earnings that could have been realised if an input such as capital was put to its next best alternative use. For example, unpaid owner- or family-labour also requires the estimation of a ‘labour opportunity cost’. It will reflect the income that could have been earned by the relevant person engaged in that unpaid labour.
associated with the environmental impacts of fishing. Such impacts, therefore, require the use of other indicators to measure overall fishery management performance. While such issues exist, net economic return still provides an accessible and easily understood indicator of community benefit.

Resource rent is a key component of a fishery’s net economic return. It reflects the return to the owner of the fishery resource, and represents the value generated by the fish stock as an input into the production process (Coglan & Pascoe 1999). A key reason for pursuing MEY is to maximise the resource rents generated from a fishery. A separate issue relates to what share of the total resource rent generated in a fishery is captured by the community (as opposed to those catching the fish). Resource rent capture in other resource based industries (e.g. mining) is a contentious and highly politicised issue (Ashiabor & Saccasan 2011). The policy and the concept of MEY is instead concerned with the generation rather than allocation of resource rent.

Although net economic return has been defined here in terms of a commercial fishery, the concept also applies to non-commercial use values (e.g. recreational fishing, charter fishing, diving) and non-use values (e.g. the value attached to knowing a fish species exists). The difference is that these values are not revealed in the market. Non-market valuation techniques are available to estimate a net economic return equivalent but are often associated with limitations (Vieira et al. 2009). The use of these measures in allocating fisheries resources between commercial, recreational and conservation sectors has had little practical application, as the measures themselves are generally poorly understood by non-economists and in many cases are mistrusted (Bateman et al. 2000). However, examples exist that demonstrate how these techniques could be applied for fishery resource allocation purposes (Berman et al. 1997)

**Maximum economic yield**

For a commercial fishery, net economic returns are maximised at MEY, a point associated with a conjointly occurring level of sustainable catch, fishing effort and stock biomass (Box 1). The concept was introduced by Gordon (1954) and Scott (1955). Clark (1973) and Clark and Munro (1975) made significant contributions to developing the concept further.

Achieving MEY involves a trade-off between higher revenues (through higher catches) and lower harvesting costs (through lower effort and more abundant stocks, which allows fish to be caught more easily, reducing the unit cost of capture). The latter ‘stock effect’ is the fundamental reason that MEY is associated with a more conservative (higher) level of biomass relative to maximum sustainable yield (MSY) (Grafton et al. 2007). In being more conservative, MEY is also advantageous in that it ensures that stocks will be more resilient to negative environmental shocks. Similarly, higher profitability at MEY means that industry will be more resilient to negative changes in economic conditions. The MEY concept is presented in Box 1.

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2 These costs can be directly incorporated into an economic analysis through the use of non-market values. However, these are generally costly to estimate. A range of multicriteria approaches also exists that allows economic performance to be combined with ecological and social performance (see Dichmont et al. [2013] for a recent example for Queensland fisheries).
Box 1 Demonstrating maximum economic yield using a simple static, single period, single species model

The horizontal axis measures fishing effort (e.g. trawl hours) while the vertical axis measures the dollar value shown on both the revenue and cost curves. Increases in effort are shown as movements along the horizontal axis and are associated with declines in fishery stock biomass.

The revenue curve shows the relationship between biomass, effort and revenue for a fishery. Every point along the revenue curve represents a revenue amount that is associated with a biologically sustainable catch. It is a function of the stock’s stock–recruitment relationship, the fishery’s harvest function (how catches vary with effort) and the price received for catch (which is assumed here to be constant). As effort increases, the level of sustainable revenue that is earned increases up until a point where lower stock levels start to constrain catches and, therefore, revenue. This turning point occurs at the maximum sustainable yield (MSY). Here the largest total revenue is generated but not the largest possible net economic return.

The total cost curve shows the relationship between costs and different levels of effort and biomass. Costs increase with increasing effort (as more inputs are employed in the fishery) and with lower biomass levels (as fish become more difficult to catch). Maximum economic yield (MEY) occurs at the level of effort (E_{MEY}) and biomass (B_{MEY}) where net economic returns—the difference between total revenue and total cost—are maximised. This occurs with revenue R_{MEY} and total cost C_{MEY}.

The reader is referred to Kompas and Gooday (2005) and Kompas et al. (2011) for a more detailed non-technical description.

The setting of a fishery’s harvest levels is equivalent to an investment decision about how many fish should be conserved to contribute to future stocks and catches (Clark & Munro 1975). The expected values of future revenues and costs from fishing need to be considered in this context by accounting for the fact that a dollar earned today will typically be valued more than a dollar earned in the future (this is not considered in Box 1). This is because a dollar earned today is immediately available to generate further economic returns.

The discounting of revenues and costs addresses these issues and involves multiplying the expected value of future revenues and costs by a discount rate that converts all future values into present dollar terms. This dynamic treatment of MEY has implications for the optimal MEY as well as the path that should be taken to this optimal point and is synonymous with maximising the flow of the present value of economic profits over time. It generally results in a higher level of catch and effort and a lower level of biomass than the static MEY levels. The
divergence between the static and dynamic MEY levels depends on the discount rate used—the lower the discount rate, the closer the two MEY points. Kompas et al. (2011) provide more detail on these topics.

The concept of economic efficiency measures a fishery’s net economic value compared to its potential (Gooday 2004). While managing a fishery at MEY means that ‘fishery-level efficiency’ is being achieved (the appropriate level of inputs are employed, such that there is not excess capacity), achieving full economic efficiency also requires ‘vessel-level efficiency’ (vessels harvest in a profit maximising manner) and ‘management efficiency’ (required management services are provided at least cost) (Kompas et al. 2011). It is often assumed that vessel-level efficiency will be achieved through vessel operators making profit maximising decisions, however, this may not always be the case. For example, revenue based share payments to skippers and crew can provide revenue maximising incentives (McConnell & Price 2006). The fishery management instrument used in a fishery can also distort the incentives of vessel operators (Gooday 2004). However, it should be noted that having a MEY management target will have economic benefits no matter what management instrument is applied.

A related concept is optimal fishing capacity. For a fishery, capacity utilisation (CU) measures the ratio of a fishery’s actual catch to its potential catch given the set of fixed assets (e.g. vessels and the given stock size). CU scores range from zero to one, with CU < 1 indicating the existence of excess capacity. That is, the same catch could have been taken with a smaller fleet. Capacity underutilisation is an indicator of less than optimal economic performance—a fleet that is fully utilised will be more economically efficient than one with substantial underutilisation. The exception to this is in the case of highly variable stocks where some level of excess capacity is economically efficient to ensure that good years are captured. Target levels of CU can provide a short term measure of economic performance, but do not necessarily infer sustainability or a long run optimal catch level.\(^3\)

Recently, there has been some debate about the concept of MEY. One area of debate has focused on whether \(B_{\text{MEY}}\) will always be greater than \(B_{\text{MSY}}\) for a single stock fishery (Clark et al. 2010a, 2010b; Grafton et al. 2012; Grafton et al. 2010). The two key influencing factors are the growth rate of the fish stock and the discount rate that is applied to future revenues and costs—a slow growth rate and a high discount rate will move \(B_{\text{MEY}}\) closer to \(B_{\text{MSY}}\), and, in the view of Clark et al. (2010a), potentially beyond \(B_{\text{MSY}}\). While this debate has interesting theoretical implications, the practical implications are that fishery managers should apply recommended MEY catch and effort settings cautiously for slow growing species to ensure stock sustainability.

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\(^3\) Excess capacity is essentially a short-run indicator and needs to be assessed in the context of current management or environmental conditions. For example, reduced quotas to allow stock recovery may result in excess capacity in the short term, but as stocks increase, capacity utilisation is likely to also increase. In contrast, overcapacity represents a longer term measure, and reflects fleet capacity relative to the management objective(s). Assessing overcapacity, however, requires the use of bioeconomic models.
There has also been confusion over what sectors need to be included in MEY calculations, with Christensen (2009) and Wang and Wang (2012) arguing that downstream businesses such as wholesalers, processors and retailers should be included. Doing so results in fishery catch and effort levels that are higher than traditional MEY levels. Not only would such an approach reduce rent generation, as noted by Kompas et al. (2011 pg 11) it would imply the use of

...more vessels, days at sea, gear, crew, bait and all of the other inputs used in fishing – resources that could be used instead in alternative employment. This is what economists mean by efficiency for the economy as a whole. If too many resources are being expended in fishing, too little are being used elsewhere.

Norman-Lopez and Pascoe's (2011) contribution to this debate involved an analysis of the net economic effects of achieving MEY for several Australian fisheries. They showed that although losses occur across sectors in the short term with a move to MEY, a net economic benefit to society results in the long term.
3 General challenges to operationalising maximum economic yield

What the literature tells us

The estimation of MEY requires the use of a bioeconomic model that summarises the biological characteristics of a fish stock together with the economic characteristics of the fishery that harvests it. These models are typically designed to derive the optimal biomass, catch and effort levels that achieve MEY. Many bioeconomic models presented in the literature focus on the economic optimal in a theoretical context, but empirical applications to existing fisheries also exist. Applications have covered a wide range of issues and scenarios including mixed target species fisheries (Bertignac et al. 2000; Bjørndal et al. 2012; Placenti et al. 1992; Punt et al. 2011), achieving ecosystem-based objectives (Fulton et al. 2007; Kasperski & Wieland 2010; Ryan et al. 2010) and low-information fisheries (Chae & Pascoe 2005; Resosudarmo 1995).

Most Commonwealth fisheries have no bioeconomic models, while those that do exist are old and unlikely to reflect the current biological understanding, consider current technologies or reflect current economic conditions (Table 1). The Northern Prawn Fishery (NPF) is the only case where a bioeconomic model has become a formal part of the management process (Dichmont et al. 2010; Punt et al. 2011). Experiences there suggest that developing bioeconomic models to feed into management decision processes has its own set of challenges. For example, the acceptance of a model by industry and managers will be greatly influenced by data quality (and quantity) (Dichmont et al. 2010).

Table 1 Most recent bioeconomic models for Commonwealth fisheries

<table>
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<tr>
<th>Commonwealth fishery</th>
<th>2009–10 GVP ($’000)</th>
<th>Most recent bioeconomic model</th>
<th>Reference</th>
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<tbody>
<tr>
<td>Northern Prawn</td>
<td>88 828</td>
<td>2011</td>
<td>(Punt et al. 2011)</td>
</tr>
<tr>
<td>Torres Strait</td>
<td>11 617</td>
<td>2012 (lobster) 1993 (prawns)</td>
<td>(Plagányi et al. 2012) (Reid et al. 1993)</td>
</tr>
<tr>
<td>SESS Commonwealth Trawl Sector</td>
<td>56 720</td>
<td>2006 (5 species only)</td>
<td>(Kompas &amp; Che 2006)</td>
</tr>
<tr>
<td>SESS Commonwealth Gillnet and Hook sectors</td>
<td>24 550</td>
<td>2006 (shark and ling)</td>
<td>(Kompas &amp; Che 2006)</td>
</tr>
<tr>
<td>SESS Commonwealth GAB Trawl Sector</td>
<td>8 977a</td>
<td>2012 (deepwater)</td>
<td>(Kompas et al. 2012)</td>
</tr>
<tr>
<td>Eastern Tuna and Billfish—longline and minor line</td>
<td>30 140</td>
<td>None</td>
<td></td>
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<tr>
<td>Southern Bluefin Tuna</td>
<td>38 095</td>
<td>1991</td>
<td>(Kennedy &amp; Pasternak 1991)</td>
</tr>
<tr>
<td>Western Tuna and Billfish</td>
<td>1 656b</td>
<td>None</td>
<td></td>
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<tr>
<td>Bass Strait Scallop</td>
<td>6 400</td>
<td>None</td>
<td></td>
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<tr>
<td>Southern Squid Jig</td>
<td>93</td>
<td>None</td>
<td></td>
</tr>
<tr>
<td>Other fisheries</td>
<td>60 295</td>
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Source: (ABARES 2011)
More recently, management strategy evaluation (MSE) approaches have also been used to inform management strategies against a MEY objective. The MSE approach is a framework that models a fishery’s various characteristics (biological, management, monitoring, economic) taking into account various sources of uncertainty. This enables potential approaches to management to be tested against pre-specified objectives (Holland 2010). In doing so, management strategies can be developed that are robust to uncertainty but also allows informed and desired trade-offs between management objectives (Rademeyer et al. 2007).

Examples of MSEs that incorporate economic factors exist for fisheries in Australia (Dichmont et al. 2008; Plagányi et al. 2012), the European Union (Bjørndal et al. 2004; Christensen 1997); New Zealand (Holland et al. 2005) and Antarctica (Hoshino et al. 2010). These have looked at the influence of management strategies on fishery profitability, fleet structure, fisher behaviour, employment and activity in other support sectors (such as the processing sector). More generally, MSEs provide the opportunity to assess performance against economic management objectives together with other relevant management objectives.

For Commonwealth fisheries, bioeconomic models and MSEs incorporating bioeconomics are currently the only two approaches that have been applied to determine harvest levels consistent with targeting MEY. The majority of recent economic research on Commonwealth fisheries to date has provided a retrospective view of fishery performance including economic surveys (George et al. 2012), analysis of historical drivers of profit (Skirtun & Vieira 2012), historical productivity (Perks et al. 2011) and efficiency (Kompas et al. 2004; New 2012; Pascoe et al. 2012). However, such approaches don’t provide advice on management settings to achieve MEY.

DeLeo and Seijo (1999) demonstrate a potential approach to estimating fishing mortality at MEY ($F_{\text{MEY}}$). It uses yield-mortality models to generate a biological production curve that incorporates both natural and fishing related mortality for the entire fish stock. Incorporation of average revenue and cost parameters allows the generation of an estimate of $F_{\text{MEY}}$. The authors note advantages of using such an approach over catch-effort surplus production model approaches typically used in bioeconomic models, including improved certainty given that each component can be measured with some certainty relative to effort, which can be difficult to standardise. Although the method still requires estimates of virgin biomass, natural and total mortality by age class and revenue and cost parameters, it represents an alternative approach that is relatively less data intensive that could be explored.

The alternative to estimating MEY reference points is to use proxies as recommended in the harvest strategy policy. Recent analysis presented by Zhou et al. (2012) attempts to provide rules of thumb for low-information fisheries regarding the selection of MEY proxies based on a fishery’s characteristics. This work represents a significant step towards improving the reliability of proxies for MEY for all fisheries more generally. Indeed, the work suggests that the proxies currently recommended in the policy could be improved (for more details, refer to Section 5 on ‘Data-poor stocks’).

**Current guidelines and assumptions**

While the policy recommends MEY as a harvest strategy target, there is little advice in the policy’s guidelines on how the target should be estimated and implemented. It points out that bioeconomic optimisation models are used to estimate MEY and provides a very general discussion of how MEY has been targeted in the NPF. It also provides the estimated $B_{\text{MEY}}$ for a small number of Commonwealth stocks. The only other advice offered is that targeting MEY should occur over the medium term (3–5 years) based on expectations around the variability of factors that influence MEY. It is also noted that the cost of using a bioeconomic model may
What the issues have been

A review of Australian Fisheries Management Authority's (AFMA's) arrangements for obtaining scientific and economic information highlights some of the key issues regarding the operationalisation of MEY (AFMA 2011). An overall finding was that research processes had not evolved with the fisheries management environment and, in particular, the novel focus on MEY. The key issues were a general lack of stakeholder understanding regarding MEY, the information required to target it and the most cost-effective approaches to obtaining that information. There was also evidence of a general misunderstanding of the circumstances under which a bioeconomic model should be developed instead of using proxy reference points. Further uncertainty also existed around the circumstances under which alternative proxies (those that differ to policy recommendations) should be developed.

A more focused synopsis of the challenges that arise when targeting MEY is provided by Dichmont et al. (2010) who drew on experiences in the NPF. Their discussion focuses on six key challenges:

- **Specifying the model**—Dichmont et al. (2010) note that modelling MEY is complicated by the many factors that affect it. They point out that a key factor that is often not well captured is fleet dynamics, particularly in terms of fleet responses to regulatory change and, for multispecies fisheries, targeting behaviour changes.

- **Defining the boundaries**—MEY optimises economic returns to the fishery and excludes sectors linked to the fishery such as the processing sector. If MEY is achieved over time with reductions in a fishery’s catch, it also reduces economic activity in these downstream sectors. Although the result of such action is that ‘resources previously consumed in fishing are freed up to be used more productively in other sectors’ (Dichmont et al. 2010), doing so can be politically difficult.

- **The best model outcome may not always be practical**—bioeconomic models can produce a result that ‘although potentially optimal in the “model world” is generally unacceptable in real life’ (Dichmont et al. 2010 pg. 17) as they may not capture factors relevant to the interests of industry or the community. This implies that careful design of the model is required, to include relevant constraints to account for these factors and/or careful interpretation of its outputs.

- **The need for accurate economic data**—economic parameters (such as output and input prices) will be a key determinant of MEY results but are highly variable and can create high levels of uncertainty regarding optimal harvest paths. Additionally, once economic cost data are obtained costs need to be appropriately incorporated into the model. Decisions such as how to separate fixed and variable costs are not necessarily straightforward. These data issues mean that regular revision of MEY results and management advice may be required.

- **A good target is not enough**—changes in things such as fisher behaviour, cost structure, stock biology and the regulatory environment will mean that the MEY path and target will need to be re-estimated regularly to allow optimal performance to be approximated.

- **Implementation in a co-management arena**—targeting of MEY in the NPF has been challenging, given the poor understanding of the concept possessed by most stakeholders. The relative variability of economic parameters and, therefore, MEY has also had negative implications for industry support of MEY. The authors note that ‘Education of stakeholders
about the reason for using MEY as a management target is critical, as is sharing of knowledge and experiences in modelling MEY’ (Dichmont et al. 2010, p. 20).

Overall, the authors state that approaches to developing bioeconomic models and to targeting MEY have been ad hoc given the lack of information that exists on applying MEY in practice. They point out the importance of using an adaptive management framework and ‘that operationalising MEY is not simply a matter of estimating the numbers but requires strong industry commitment and involvement’ (Dichmont et al. 2010 pg. 1), which requires a balanced combination of education and consultation.

The experiences in the NPF outlined by Dichmont et al. (2010) have presented many challenges. As a result, it has taken many years to develop the current NPF bioeconomic model and approach. Similarly, the development of relationships and trust with key stakeholders to garner their cooperation and support has also taken substantial time. This trust has benefited not only the implementation of MEY, but also access to the economic data required to pursue it. The NPF is also the most valuable single-method Commonwealth fishery (ABARES 2011). So while it provides a good example of how MEY can be targeted, the approach used by this fishery may be beyond the financial capability of most Commonwealth fisheries. For most other Commonwealth fisheries, MEY will need to be pursued at lower cost and, therefore, with greater uncertainty.

In the Southern and Eastern Scalefish and Shark Fishery (SESSF), MEY has been estimated for selected stocks targeted in the Commonwealth Trawl Sector and Gillnet, Hook and Trap Sector (Kompas et al. 2011). However, as the bioeconomic model used stock models that were developed in isolation of the fishery’s accepted stock assessment models, the MEY targets were not applied. This demonstrates a point noted by Larkin et al. (2011): MEY is more likely to be achieved when economic information is incorporated into stock assessment models for fish stocks during their initial development.

Since the introduction of the harvest strategy policy, the Great Australian Bight Trawl Sector (GABTS) of the SESSF is the only Commonwealth sector that has developed a bioeconomic model to determine total allowable catches (TACs) for its key target species—deepwater flathead and bight redfish (Kompas et al. 2012). The bioeconomic model was integrated with the accepted stock assessment models for both species. Estimation of the model involved close collaboration with scientists and industry to obtain relevant data. The authors noted that the model would benefit from further work to capture supply dependent market price sensitivities, a major influence on the expected revenue and, therefore, profit associated with different catch levels. This obviously has implications for the final MEY estimates of the model.

For the remaining SESSF species, proxy target reference points for MEY have been applied as recommended by the policy. While this should be considered an appropriate approach for stocks where bioeconomic models are not available (given the approach’s low cost), the policy’s recommended proxy of 0.48 $B_0$ (i.e. 48 per cent of unfished biomass) or $1.2 B_{MSY}$ has generally been applied across the board, irrespective of a stock’s biological and economic characteristics (with the exception of tiger flathead as explained below). There are likely to be some cases where informed adjustment of the target proxy according to a stock’s characteristics may lead to improved performance against the MEY objective.
**Alternative options and approaches**

**Setting targets**

It is expected that knowledge and experience in operationalising MEY will grow with the estimation of MEY for more Commonwealth stocks and ongoing research on alternative approaches to targeting MEY. As knowledge increases, it is likely that better informed decisions around the selection of appropriate MEY proxies will be possible. Communicating research results to RAGs, management advisory committees (MACs) and AFMA will be a priority. The updating of the policy’s guidelines with new research findings may also assist with targeting MEY. If proxies can be set more reliably, the relative benefits of using a bioeconomic model to accurately estimate MEY are likely to be reduced.

Where the development of a bioeconomic model is being considered, there has to be acknowledgement that the model (like any stock assessment model) is going to be updated and improved as techniques and data availability improves. Communication of this to stakeholders is essential to manage expectations around what can be delivered in the first instance.

For low-value fisheries, the application of proxies will continue to be the only feasible option for targeting MEY. While the policy allows for the recommended \( B_{MEY} \) proxy of 0.48\( B_0 \) to be altered to better achieve a stock’s MEY given its characteristics, this has rarely been done. One example where it has been done is for tiger flathead in the SESSF. Shelf Resource Assessment Group (RAG) members incorporated some assumed economic parameters (e.g. prices received for catch and per unit effort costs based on ABARES survey results) into the stock assessment to provide an estimate of likely profitability under different biomass ratios relative to \( B_{MSY} \) (Galeano D. 2011, pers comm.). The RAG was then able to select the biomass ratio that was expected to be associated with the highest fishery profitability, an outcome that is consistent with the economic intent of the policy. Guidance on the appropriate setting of proxies provided by recent work on data-poor fisheries (Zhou et al. 2013) and current work on mixed-species fisheries may also better allow such adjustment of proxies in the future (refer to Sections 4 and 5 for more information).

While biologically focused MSEs have been applied in Commonwealth fisheries such as the Bass Strait Central Zone Scallop Fishery (Haddon 2011) and the Small Pelagic Fishery (Giannini et al. 2010), the addition of economic parameters to the MSEs could have provided information about the relative profitability of different management strategies. The advantages of undertaking bioeconomic assessments in tandem with MSEs and stock assessments in terms of reduced research costs and accessing data can be significant (Larkin et al. 2011).

**Data**

Options also exist to more easily obtain relevant economic data to support targeting of MEY. Aggregated annual price information for fishery species is often readily available from ABARES. More detailed monthly export price data can also be used to augment information on catch prices for export focused fisheries. The greater challenge is obtaining boat cost information, which is generally confidential. ABARES surveys key Commonwealth fisheries (Table 2) and provides estimates of boat-level costs. Given that the ABARES surveys rely on finalised profit and loss statements, there is a delay in getting this information. However, these surveys can still provide detailed information on fishery revenues and costs at relatively low cost.

The NPF industry undertakes its own economic survey to update its bioeconomic model due to lags between ABARES’ surveys and the timing of the annual stock assessment process, illustrating the advantages of obtaining industry buy-in for targeting MEY. This requires a high
amount of industry support and trust; the strong engagement of the NPF industry in the
management process has assisted in the implementation of MEY in that fishery.

Where survey information is not available, approaches outlined in Zhou et al. (2012) to estimate
fishery level costs based on easily observed fishery characteristics (such as fishing method,
vessel size and days fished) may also provide an option (refer to section on data-poor stocks for
more detail).

Table 2 Commonwealth fisheries recently surveyed by the Australian Bureau of
Agricultural and Resource Economics and Sciences

<table>
<thead>
<tr>
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</tr>
</thead>
<tbody>
<tr>
<td>Bass Strait Central Zone Scallop Fishery</td>
<td></td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
</tr>
<tr>
<td>Northern Prawn Fishery</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
</tr>
<tr>
<td>Commonwealth Trawl Sector of SESSF</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
</tr>
<tr>
<td>Gillnet Hook and Trap Sector of SESSF</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
</tr>
<tr>
<td>Torres Strait Prawn Fishery</td>
<td>✔</td>
<td>✔</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Eastern Tuna and Billfish Fishery</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
</tr>
</tbody>
</table>

SESSF = Southern and Eastern Scalefish and Shark Fishery

Processes

Dichmont et al. (2010) suggest that the approach taken to implementing MEY in Commonwealth
fisheries to date has been ad hoc. This suggests that there may be benefits to providing greater
practical guidance on best practice; in particular, around the circumstances under which an MEY
target should be estimated and how it should be developed. This could be in the form of a
checklist or set of principles that, if used appropriately, could assist in addressing issues created
by the low input of economic expertise into RAG processes and allow for a more cost-effective
approach to implementing MEY.

AFMA’s framework for delivering cost-effective research (AFMA 2008) also provides a broader
overarching framework that can be drawn upon to make decisions on what research activities
should be pursued at the fishery level to meet the MEY objective. A key element of the
framework is the recognition that management decisions need to be made in the face of some
level of uncertainty and there needs to be some consideration of risk. This framework is
structured around four key questions, three of which are most relevant here, and include:

1) What decisions will AFMA need to make about a fishery?
2) What options are available to AFMA to ensure that the risks of not achieving objectives are
   within ‘acceptable’ levels?
3) Is purchasing research the most cost effective option to make a management decision?

Regarding the MEY objective, the answer to the first question is that AFMA needs to make
harvest-level decisions that meet the MEY objective. For the second question, the options
currently are, in order of decreasing certainty and decreasing research cost:

- develop a bioeconomic model of the stock or fishery to estimate an MEY target
- use additional information to adjust the policy’s recommended proxies for MEY
- adopt the policy’s recommended proxies.
Each option involves trade-offs between the risks of not achieving the MEY objective (associated with lost economic returns) and research costs. The process of selecting an option should also be undertaken on the basis of substantial industry consultation. As has already been suggested, the last two low-cost options will potentially become more reliable and beneficial with time as more research is undertaken to estimate MEY for a wider variety of fishery types and scenarios.

The third question provides the impetus to compare the costs and benefits of the options to pursue MEY with the intention of ensuring that the option likely to deliver the greatest net benefit is selected. The costs of pursuing alternative options will involve both up-front costs and ongoing costs. The up-front costs for the investment in a bioeconomic model to estimate MEY are likely to be relatively high. Ongoing costs include two components. The first component relates to the cost of monitoring performance and updating the target, which would once again be higher with a bioeconomic model. However, the second ongoing cost is the cost associated with not achieving MEY and the losses in net economic returns that result. The latter costs would be expected to be higher where options that exhibit higher uncertainty (such as proxies) are implemented to target MEY.

It should be noted that RAGs and MACs have found the framework outlined in AFMA (2008) difficult to apply in practice at the fishery level and investment decisions on acquiring economic and scientific information have remained inconsistent (AFMA 2011).

**Stakeholder knowledge**

Improving stakeholder understanding of MEY should be a focus that occurs on two fronts. First, in terms of providing a better understanding of the MEY concept and what it is trying to achieve. A greater understanding amongst stakeholders will provide for a more engaged debate and discussion around how to achieve MEY. The second front is in terms of understanding what managing to MEY means in a practical sense for fishery management decision making.

Achieving this increased understanding is a key issue and a multifaceted approach is likely needed. Some potential options include:

- **The formation of an economic technical working group**—as recommended by the Review of AFMA’s arrangements for obtaining and using scientific and economic information and advice (AFMA 2011) this group would focus on identifying where bioeconomic models would be cost-effective; establishing processes to ensure cost-effective collection of relevant economic data; considering the use of proxies for \( B_{\text{MEY}} \) and determining the required information to do this; and considering which RAGs require economic expertise. While this recommendation from the review had broad support, it has not yet been implemented.

- **Ensuring availability of economic expertise and advice**—in the absence of a technical working group, efforts to ensure economists are available to provide input to the RAG processes may improve decision making with reference to the MEY target. Economists with an adequate understanding of MEY as a concept and an ability to communicate effectively with all stakeholders (particularly those with a non-economist background) offer the greatest opportunity for providing input to RAG processes. For the actual estimation of MEY, this additionally requires a more technical level of expertise. Similarly, there may be benefits associated with providing fishery managers with relevant economic training. These requirements, together with the small pool of fishery economists within Australia, mean that this is not necessarily a straightforward outcome to achieve.

- **Improving definitions, explanations and guidelines in the policy**—while definitions are already provided in the policy’s guidelines, the lack of understanding amongst stakeholders suggests that there may be merit in revisiting these. More broadly, there may be benefits to
having the guidelines updated more regularly as new research is completed to inform the policy, such as work on datapoorn fisheries and mixed species fisheries.

Given the short amount of time in which MEY has been an explicit management target, understandings regarding some of the specific issues that occur on a fishery by fishery basis are also relatively poor. The remaining sections of this paper consider some of these issues and what the potential options may be for dealing with them.
4 Data-poor species

What the literature tells us

There is recognition that improved decision support methods and tools are needed for the general management of data-poor fisheries (Defeo & Seijo 1999; Dowling et al. 2008; Johannes 1998; Kelly & Codling 2006). While the literature provides some examples of such approaches for data-poor fisheries, the majority have a biological focus, with few covering economic factors and, more specifically, MEY management.

Zhou et al. (2012) provide one of the few examples of research with a focus on MEY reference points for data-poor fisheries. Their research developed a rule-of-thumb-based approach to determining MEY proxy reference points based on easily observed fishery characteristics. The MEY reference points are presented in terms of a ratio to a known equivalent (effort- or biomass-based) MSY reference point (e.g. $B_{\text{MEY}} = 1.2B_{\text{MSY}}$). This work builds on additional work presented by the authors focused on determining biological reference points (including $B_0$, MSY, $B_{\text{MSY}}$ and $F_{\text{MSY}}$) for data-poor stocks.

The approach developed to derive MEY proxy ratios involved two stages. For the first stage, a relationship between MSY and MEY reference points was estimated using a simulation method. Key fishery bioeconomic parameters were allowed to vary randomly across simulations within some assumed acceptable ranges. The relevant parameters were:

- intrinsic growth rate
- catchability
- carrying capacity
- costs
- output price
- discount rate.

Out of a total of 10,000 simulations, 5897 had parameter value combinations that were deemed to be realistic and acceptable. The optimal MEY-MSY ratio (in terms of both effort and biomass) was then estimated for the combination of parameter values that occurred in each accepted simulation. Regression analysis was then used to quantify the relationship between the estimated MEY-MSY ratios and the parameter values that occurred across all simulations.

The estimated relationship demonstrated that the cost share of revenue (defined as the cost per unit catch divided by the price) served as the most important and influential parameter on the optimal MEY proxy ratio. This result is presented by the authors in terms of a decision tree that guides how the MEY proxy ratio should be set using information about a fishery's cost share. The derived decision trees for the optimal MEY proxy ratio in terms of biomass and effort are summarised in Table 3.

Given the importance of fishery cost share, the second stage of the analysis focused on approaches to estimating a fishery's cost share given that such information is typically not readily available for data-poor fisheries. Vessel level cost data from 16 Australian fisheries were used to quantify relationships between key costs (variable costs, repairs and maintenance, fixed costs, capital costs) and easily observed fishery characteristics (e.g. approximate vessel size,
fishing method, days fished and management instrument). The estimated relationships then provided a means to estimating a fishery’s cost share based on these easily observed characteristics also using a decision tree. Vessel length, fishery type and the price received for landed fish were shown to be the major influences on cost shares. In summary, with knowledge of key variables for a particular fishery, a fleet’s likely cost share can be estimated, followed by its likely optimal biomass \( \left( \frac{B_{MEY}}{B_{MSY}} \right) \) or effort \( \left( \frac{E_{MEY}}{E_{MSY}} \right) \) ratio as is shown in Table 4.

Table 3 Summary of regression tree results showing the likely optimal maximum economic yield ratios in terms of biomass \( \left( \frac{B_{MEY}}{B_{MSY}} \right) \) and effort \( \left( \frac{E_{MEY}}{E_{MSY}} \right) \) for different fishery cost shares. For example, if a fishery’s cost share of revenue is greater than 45 per cent and less than 55 per cent, the ratio of \( \frac{B_{MEY}}{B_{MSY}} \) would be 1.23 and the ratio of \( \frac{E_{MEY}}{E_{MSY}} \) would be 0.77.

<table>
<thead>
<tr>
<th>Cost share</th>
<th>Optimal ( \frac{B_{MEY}}{B_{MSY}} ) ratio</th>
<th>Optimal ( \frac{E_{MEY}}{E_{MSY}} ) ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 0.25</td>
<td>1.05</td>
<td>0.95</td>
</tr>
<tr>
<td>&gt; 0.25, &lt; 0.35</td>
<td>1.12</td>
<td>0.88</td>
</tr>
<tr>
<td>&gt; 0.35, &lt; 0.45</td>
<td>1.17</td>
<td>0.83</td>
</tr>
<tr>
<td>&gt; 0.45, &lt; 0.55</td>
<td>1.23</td>
<td>0.77</td>
</tr>
<tr>
<td>&gt; 0.55, &lt; 0.65</td>
<td>1.28</td>
<td>0.72</td>
</tr>
<tr>
<td>&gt; 0.65, &lt; 0.75</td>
<td>1.33</td>
<td>0.67</td>
</tr>
<tr>
<td>&gt; 0.75, &lt; 0.85</td>
<td>1.38</td>
<td>0.62</td>
</tr>
<tr>
<td>&gt; 0.85</td>
<td>1.45</td>
<td>0.55</td>
</tr>
</tbody>
</table>

Note: the above decision tree results were derived using a 5 per cent discount rate. However, various discount rates were tested by Zhou et al. (2012).

Source: (Zhou et al. 2012)

Table 4 Summary of regression tree results for cost share and the determination of \( \frac{E_{MEY}}{E_{MSY}} \) ratio

<table>
<thead>
<tr>
<th>Main fishing gear</th>
<th>Vessel length class</th>
<th>Average first sale price of fish landed ($)</th>
<th>Estimated cost share of revenue at MSY</th>
<th>Cost share class</th>
<th>( \frac{E_{MEY}}{E_{MSY}} ) at 5% discount rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Longline</td>
<td>&lt; 13.5 m</td>
<td>Any</td>
<td>0.85</td>
<td>&gt; 0.85</td>
<td>0.55</td>
</tr>
<tr>
<td>Active gear</td>
<td>&gt; 13.5 m</td>
<td>&lt; 15.5</td>
<td>0.86</td>
<td>&gt; 0.85</td>
<td>0.55</td>
</tr>
<tr>
<td>Active gear</td>
<td>&gt; 13.5 m</td>
<td>&gt; 15.5</td>
<td>0.77</td>
<td>&gt; 0.75, &lt; 0.85</td>
<td>0.62</td>
</tr>
<tr>
<td>Active gear</td>
<td>&lt; 13.5 m</td>
<td>&gt; 10.5</td>
<td>0.66</td>
<td>&gt; 0.65, &lt; 0.75</td>
<td>0.67</td>
</tr>
<tr>
<td>Active gear</td>
<td>&lt; 13.5 m</td>
<td>&lt; 10.5</td>
<td>0.72</td>
<td>&gt; 0.65, &lt; 0.75</td>
<td>0.67</td>
</tr>
<tr>
<td>Other static gear</td>
<td>&gt; 20.5 m</td>
<td>Any</td>
<td>0.73</td>
<td>&gt; 0.65, &lt; 0.75</td>
<td>0.67</td>
</tr>
<tr>
<td>Other static gear</td>
<td>[13.5–20.5 m]</td>
<td>Any</td>
<td>0.56</td>
<td>&gt; 0.55, &lt; 0.65</td>
<td>0.72</td>
</tr>
<tr>
<td>Dive</td>
<td>&lt; 13.5 m</td>
<td>Any</td>
<td>0.48</td>
<td>&gt; 0.45, &lt; 0.55</td>
<td>0.77</td>
</tr>
</tbody>
</table>

Source: (Zhou et al. 2012)

The approach was tested on two fisheries for which MEY had previously been estimated. Application to the NPF gave a proxy \( \frac{B_{MEY}}{B_{MSY}} \) ratio of 1.38 (across all species). This compared to bioeconomic model based estimates for the fishery’s three key species of 1.15, 1.255 and 1.38 (Punt et al. 2011), which the authors concluded was consistent for one species and not substantially greater for the other two. Application to the Commonwealth Trawl Sector (CTS) also derived a ratio of 1.38 that compared to previously estimated ratios ranging from 1.06 (flathead) to 1.53 (orange roughy) and an average ratio of 1.26 across species (Kompas & Che
Commonwealth Fisheries Harvest Strategy Policy reviews: economic issues

ABARES

2006), representing an overestimate for some stocks and an underestimate for others. However, given that the approach was developed for single-stock fisheries, such divergences are expected as both fisheries catch multiple species (and for the CTS, using multiple gears). The overfished status of some of these stocks may have also contributed.

More generally, the distribution of optimal ratios for the likely range of fishery parameter values suggests that the harvest strategy policy’s recommended proxy values for $B_{\text{MEY}}$ may more appropriately be $1.3–1.4 B_{\text{MSY}}$ as opposed to the currently recommended $1.2 B_{\text{MSY}}$. This higher $1.3–1.4 B_{\text{MSY}}$ ratio is expected to be more relevant to the ‘average’ stock type. The authors also suggest that optimal effort levels are most likely to fall between 55 per cent and 65 per cent of MSY effort (Zhou et al. 2012).

Where reliable proxies cannot be derived, harvest control rule evaluation using MSE can be useful in testing the likely effectiveness of data-poor harvest strategies (Smith et al. 2009). Most MSE applications to Australian fisheries have not explicitly included economic factors. However, Plagányi et al.’s (2012) application of MSE to the Torres Strait Rock Lobster Fishery provides an example where economic objectives were incorporated. This evaluation tested a range of management scenarios against biological, economic, cultural and social objectives. In terms of economic factors, the MSE evaluated the likely impact of different quota management arrangements on processing sector activity, employment, fleet structure, efficiency and profitability. While some data collection was undertaken, significant assumptions about key economic parameters were still required and tested. The analysis provides a good example of how the trade-offs between economic profitability objectives (such as MEY) and other biological, social and cultural objectives can be quantified and presented in an economic data-poor setting.

While data-poor fishery management against economic objectives is not well covered in the literature, experiences meeting biological objectives are; these can provide guidance on how to better meet economic objectives. Dowling et al. (2008) worked with Commonwealth fishery managers and stakeholders to develop harvest strategies that would apply in data-poor contexts. The authors identified four broad principles that should be followed for the pragmatic development and implementation of harvest strategies in data-poor fisheries. These include:

- developing sets of triggers with conservative response levels, with progressively higher data and analysis requirements at higher response levels
- identifying data gathering protocols and subsequent simple analyses to better assess the fishery
- archiving biological data for possible future analysis
- using spatial management, either as the main aspect of the harvest strategy or to augment other measures.

The authors provide no discussion of the link between these principles and economic objectives. While examples of trigger-based approaches that implicitly consider economic factors do exist, these don’t explicitly include economic analysis. Examples include the data-poor Spanner Crab

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4 More recent preliminary analyses focusing on multispecies measures have found that both economic and biological information is an important determinant of $B_{\text{MEY}}/B_{\text{MSY}}$ ratios. Optimal ratios within multispecies fisheries ranged from 0.5 for species with a small revenue share (of total revenue), slow growth and high catchability; to 1.7 for species with higher revenue shares, moderate growth rates and low catchability.
Fishery in Queensland, Australia (Dichmont & Brown 2010; O’Neill et al. 2010), and the banana prawn component of the NPF.

Kelly and Codling (2006) propose the use of simple empirical indicators as an approach for informing harvest strategy rules in North Atlantic fisheries that have unreliable data. Drawing on the field of process management and work by Scandol (2003, 2004) who used a similar approach for fisheries in New South Wales, Australia, the suggested approach uses direct empirical measures of stocks status to simply track whether ‘things are getting worse’, or are ‘out of control’. They note that the approach would not replace traditional stock assessments, but ‘would allow a rationalisation of the cost of the current system while fulfilling the requirement for stock monitoring and advice provision’, particularly for data-poor fisheries. Similar principles might potentially be applicable to economic objectives for low value data-poor stocks.

Bentley and Stokes (2009a, 2009b) call for a shift of focus for data-poor fisheries from assessment to procedural based approaches, drawing on experiences in New Zealand. Furthermore, they recommend generic management procedures that depend on easily observed characteristics of a fishery, including biological, economic and social attributes. The authors demonstrate the potential benefits of monitoring even in low-value fisheries and show, in principle, the gains that can be made through the use of management procedures that include adaptive monitoring.

Current guidelines and assumptions

The harvest strategy policy’s guidelines state that ‘[i]n cases where B_{MSY} is unknown, a proxy of 1.2B_{MSY} (or a level 20 per cent higher than a given proxy for B_{MSY}) is to be used’ (DAFF 2007), p. 22). Furthermore, in cases where B_{MSY} is unknown, the policy’s guidelines suggest a proxy for B_{MSY} be 40 per cent of adult virgin biomass (B_{0}). Applying the B_{MEY} proxy to the latter B_{MSY} proxy results in a target of 48 per cent of B_{0}. The guidelines also state that ‘AFMA may approve the use of an alternative proxy for B_{MEY}’ and, further, that ‘alternative approaches to setting proxies for reference levels will need to be formulated and applied using the available information’ (DAFF 2007), p. 36). Despite this, there have been few cases where alternative proxies have been developed.

More generally, a tiered approach to control rules that caters for different levels of stock uncertainty is recommended. Furthermore, where economic data are minimal, it is recommended that decision rules may need to be empirical and involve monitoring of fishery profitability, productivity indices, or profit decompositions or through analysis of other indicators such as latent effort and analysis of sale and lease prices of fishing rights (DAFF 2007).

What the issues have been

As noted by Dowling et al. (2008), the policy was developed with a focus on biomass, which has made applying the policy to data-poor stocks difficult. Where harvest strategies have been developed for data-poor stocks, their design has focused on biological requirements (i.e. to prevent overfishing) (Smith et al. 2009). The low gross value of production (GVP) of many data-poor stocks means that such an approach is likely to be consistent with the intent of the policy, but is dependent on the degree to which including an economic objective and measures to meet it impose additional research and management costs on the fishery.
The SESSF harvest strategy uses tiers for different levels of uncertainty. It is one of the few fisheries that attempts to target MEY for relatively data-poor species, currently assessed under Tiers 3 and 4 (AFMA 2009). Tier 3 applies to stocks for which catch, age composition and basic biological parameters are available to generate catch-curves. These allow current fishing mortality ($F_{\text{CUR}}$) to be compared to limit ($F_{20}$) and target ($F_{48}$) reference levels. Tier 4 applies where only catch and effort data are available. Statistically standardised catch rates are compared to target and limit catch rates, which are assumed to correspond to $B_{\text{MEY}}$ and $B_{\text{LIM}}$, respectively. However, the setting of the target catch rate is quite subjective, being the average catch rate that occurred in a reference period when the species was considered to be fully fished, catch rates were relatively stable and the fishery was considered profitable and sustainable.

For both Tier 3 and Tier 4, the link between their respective target reference points and fishery profitability has not been explored. For the majority of Tier 3 and 4 species that exhibit a low value, a high uncertainty, low cost approach is justified. However, some lower tier species are associated with high GVP such as blue-eye trevalla, which has accounted for up to $5.0$ million or $5$ per cent of SESSF GVP (2006–07). If such species cannot be assessed at a higher tier, improving the reliability of the reference points used in these lower tiers may be beneficial.

Overall, while the approaches taken to managing data-poor Commonwealth fisheries since the implementation of the policy have been arguably pragmatic in meeting sustainability requirements in some cases (Dowling et al. 2008), the development of data-poor harvest strategies have typically been unsuccessful in addressing the MEY objective. This partly reflects a lack of understanding on how this objective can be met under these settings.

**Alternative options and approaches**

Given that many data-poor fisheries are low value, the application of any approach in a data-poor environment requires careful consideration of the trade-offs between the costs, benefits and risks associated with reducing management uncertainty. Practical guidance on the appropriate level of research investment for data-poor stocks and what constitutes meeting the MEY objective for such stocks may also be warranted.

Application of the approaches used in Zhou et al. (2012) to develop MEY proxies represents one relevant option that could be associated with a relatively low cost. Further development of the approach may improve its reliability and usability. A second related project that is currently underway aims to develop the approach to estimate MEY proxies for stocks in multispecies fisheries, making the approach more relevant to Commonwealth fisheries, which are typically multispecies.

Building on current data-poor approaches such as the SESSF Tier 3 and Tier 4 assessment approaches to better incorporate economic factors may also be an option. In the case of Tier 3 species, the approach used by Defeo and Seijo (1999) (discussed here on page 10) has similar data requirements and may offer an alternative approach to developing harvest controls for these species that moves beyond simply using the recommended policy proxies.

A range of other indicators exist that provide information about the potential excess level of capacity in fisheries when bioeconomic models are not available. These do not necessarily equate to either biological or economic reference points, but contribute to an estimation of fishery level performance (rather than individual species reference points). The use of data envelopment analysis (DEA) to estimate capacity utilisation and the level of excess capacity has been used to assess fishery performance in a wide range of fisheries (Dupont et al. 2002; Färe et al. 2000; Hoff & Frost 2007; Lindebo et al. 2007; Pascoe et al. 2003; Pascoe & Tingley 2006;
Tingley & Pascoe 2005; Tingley et al. 2003; Tsitsika et al. 2008; Vestergaard et al. 2003). An advantage of DEA approaches is that they can be used when only catch and effort data are available (e.g. Tingley et al. 2003), but ‘better’ estimates can be derived including prices (e.g. Lindebo et al. 2007) and costs (e.g. Pascoe & Tingley 2006).
5 Mixed species

What the literature tells us

The additional complexity in determining MEY in fisheries characterised by technical interactions (i.e. the same gear catches several species simultaneously) has been long established in the fisheries economic literature (e.g. Anderson 1975; Clark 1976; Silvert & Smith 1977). This is further complicated when different fisheries (in terms of gear types) are spatially overlayed, catching different combinations of the same sets of species. In such a case, deriving estimates of MEY requires taking into account the impacts of one fishery on the other, as well as the effects of a given level of effort on the sustainable yields of all species caught (Anderson 1975). A result of this is that each species' biomass at fishery MEY will be less than or equal to its individual $B_{MEY}$ level if each was caught independent of the others (Duarte 1992).

This is illustrated for a four-species fishery in Figure 1. The upper panel shows a fishery's revenue earned from four individual species and its total costs for different effort levels. The lower panel depicts total revenue (summed across the four species), total costs and total profit. For each effort level, each species will be associated with a given biomass level (with effort and biomass being inversely related). The level of fishing effort that maximises total sustainable fishery profits is around six units (shown by the dark green vertical line). At this level of effort, each species is associated with a given biomass that achieves fishery-wide MEY (denoted $B_{FMEY}$). For example, species 1 is fished beyond its MSY such that its $B_{FMEY} < B_{MSY}$ on a ‘single species’ basis, species 2 is close to its $B_{MSY}$ (such that $B_{FMEY} \approx B_{MSY}$), and $B_{FMEY}$ for species 3 and 4 are below $B_{MSY}$ and close to what may be considered their single species $B_{MEY}$. In this example, profits are also maximised at a level close to maximum sustainable revenue, although this is not always the case.

Deriving general analytical models to identify conditions for MEY in multispecies fisheries has been described as a formidable, if not impossible task (Chaudhuri 1986; Silvert & Smith 1977). Most attempts to estimate MEY in multispecies fisheries have been empirically based, using bioeconomic models to estimate MEY across the set of species in the catch (e.g. Holland & Maguire 2003; Placenti et al. 1992; Sandberg et al. 1998; Ward 1994). In Australia, multispecies bioeconomic models have been developed for several fisheries and used to provide management advice and estimates of fishery-level MEY (e.g. Kompas & Che 2006; Kompas et al. 2009; Punt et al. 2011; Punt et al. 2002).

The development of bioeconomic models requires considerable biological information on each individual species, which is often unavailable. In some data poor fisheries where only catch and effort data are available (plus some indicative economic variables), aggregated yield functions have been used. That is, total catch of all species is modelled as a function of total effort. These have been deployed largely in developing countries (e.g. Lorenzen et al. 2006) but have also been used in more developed countries where fisheries are based on a large number of species.

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5 This section will focus on species that have technical interactions rather than biological interactions. That is, the species are caught together as either ‘target’ and ‘byproduct’ species, or as a mixed-bag of species with no specific target. Numerous other studies exist looking at fisheries with biological interactions e.g. predator–prey interactions. These contain similar challenges in determining MEY, although most models assume that the species can be separately targeted (e.g. Anderson 1975; May et al. 1979; Silvert & Smith 1977).
each contributing a relatively small proportion to revenue (e.g. Chae & Pascoe 2005; Jin et al. 2012).

Figure 1 Example of multispecies definition of MEY based on four individual species caught together based on concepts presented in Anderson (1975) and Clark (1976). The upper figure illustrates the individual sustainable revenue curves (i.e. sustainable yield times price) for a given level of fishing effort. In the lower figure, the fishery total revenue curve is derived by the vertical summation of the individual species revenue curves shown in the upper figure. Total profits are derived from total revenue less total costs at each level of effort.

True joint production in fisheries—where species are caught in fixed proportions—is relatively rare. The relatively small numbers of studies that have empirically tested for joint production in fisheries have found that the ability to target some individual species may be limited, but not impossible. Most fisheries are characterised by a mix of both substitution relationships (where fishers can target and substitute between species) and complementarity relationships (where catches are taken in combination under joint production) (Pascoe et al. 2007; Pascoe et al. 2010; Squires 1987). Studies of fisher behaviour also suggest that apparent targeting behaviour (or lack of) may be an artefact of the management schemes, and changing management may change
this relationship as fishers respond to the new incentives created (Christensen & Raakaer 2006). In such cases, changes in catch composition can be achieved through either gear change or spatial fishing pattern changes.

Several empirical models have addressed the spatial component of mixed fisheries through modelling the fishery at the ‘metier’ level (Pascoe & Mardle 2001; Pelletier et al. 2009; Ulrich et al. 2002). Metiers are defined as a fishing activity that is defined spatially (i.e. a given location), using a given gear and catching a given combination of species. The models estimate catches, costs and profits based on effort allocation across these different metiers, capturing both multigear interactions as well as mixed species (technical interactions).

Current guidelines and assumptions

The harvest strategy policy’s guidelines (DAFF 2007) recognise that MEY applies to the fishery as a whole (i.e. optimised across all species) and not necessarily to individual species, and that secondary (lower valued) species may be fished at levels that result in biomass levels lower than their own individual $B_{MEY}$.

The guidelines stress, however, that all species should be maintained above their limit reference point (generally taken as 20 per cent of the unfished biomass). The guidelines also stress that consideration should also be given to:

- demonstrating that economic modelling and other advice supports such actions
- confirming that no cost-effective alternative management option is available (i.e. gear modifications or spatial management) that can more effectively separate the species
- ensuring the associated ecosystem risks have been considered in full.

What the issues have been

Estimating MEY in multispecies fisheries in Australia has been complex. The work in the NPF is the culmination of over 30 years of bioeconomic analysis involving mostly Commonwealth Scientific Industrial Research Organisation (CSIRO) and ABARES.6 The most recent versions of the model (Punt et al. 2011) represent a substantial investment by scientists, managers and industry (Dichmont et al. 2010), but is based on only three species.

In contrast, modelling work in the SESSF has been less successful due to the large number of species in the fishery, and the number of different gears that catch these species in differing combinations. An analysis of catch combinations in the fishery (Klaer & Smith 2012) suggests that a substantial proportion of most quota species in the SESSF are caught as byproduct when targeting other species. Further, nearly all species are caught to varying degrees with all other species (Klaer & Smith 2012). This in itself is not an issue, as other bioeconomic models with similar levels of technical interaction have been developed and successfully deployed (Pascoe & Mardle 2001; Pelletier et al. 2009; Ulrich et al. 2002). In these models, however, key biological parameters were available for almost all of the species, with the residual species included as fixed proportions in order to determine the full fishery revenue.

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6 The first bioeconomic modelling analysis in the fishery was undertaken by Clark and Kirkwood (1979).
In the case of the SESSF (e.g. Kompa & Che 2006), the reverse is the situation—with only a relatively small proportion of the key species having appropriate biological parameters available for bioeconomic analysis. This limits the usefulness of the model as a management tool, especially in relation to estimating target reference points. However, the cost of determining appropriate biological parameters for all species in the fishery is likely to be prohibitive.

Developing appropriate bioeconomic models to allow multispecies estimates of MEY is complex, but a more fundamental problem is the general lack of bioeconomic models for most Commonwealth fisheries (multispecies or otherwise). With the exception of the NPF, activity in developing bioeconomic models has been sporadic and usually linked to particular research projects than undertaken as ongoing investments in fisheries management.

**Alternative options and approaches**

A Fisheries Research and Development Corporation (FRDC) project (FRDC 2011/200) is underway, with a focus on MEY proxies for species (particularly secondary, non-target species) in multispecies fisheries. As reported by Zhou et al. (2012) (a previous FRDC project, 2010/044), which had a single species focus, the aim of the project is to develop rules of thumb to guide the modification of the currently applied ‘$B_{MEY} = 1.2 B_{MSY}$’ proxy, but in the multispecies context. The general results from the multispecies project are likely to be available in mid-2013, but preliminary results suggest that the additional complexity of multispecies fisheries makes deriving robust rules of thumb substantially more complicated than for single species fisheries.

An alternative option is to consider the use of aggregated yield functions (where catch across species is aggregated) in cases where only total catch and effort information is available. While these are less than ideal at identifying target reference points at the species level, they may be beneficial in identifying target effort levels for the fishery as a whole. Applications elsewhere have found that the estimate of effort at fishery level MEY is less sensitive to assumptions about the combined yield function than catch-based target reference points (Chae & Pascoe 2005).

Abandoning the use of MEY as a target reference point would not resolve these issues. Biological reference points such as MSY result in similar problems. While MSY may be easier to determine, it would still result in a set of incompatible reference points, resulting in discarding biological overexploitation of some species as well as levels of fishing effort that result in lower net economic returns. Further, if individual species MSY were considered acceptable in the absence of credible multispecies bioeconomic models, then individual species MEY estimates could be readily derived using data-poor methods. These would have the same consequences as the individual species MSY in terms of being incompatible, although the loss in economic returns may not be as great. In any case, achieving MSY or single species–based MEY reference points at an individual level in a multispecies fishery will not be possible for all species, so management would be destined to fail.

A range of other indicators exist that provide information about the potential excess level of capacity in multispecies fisheries (Pascoe 2007). The use of DEA to measure capacity utilisation has already been discussed for data-poor fisheries. These approaches do not necessarily equate to either biological or economic reference points, but contribute to an estimation of fishery level performance (rather than individual species reference points). Target levels of CU could be introduced as a proxy measure of short term economic performance for multispecies fisheries, but do not necessarily infer sustainability or a long run optimal level of output (see footnote 3).
6 Highly variable stocks

What the literature tells us

Highly variable stocks are referred to here as those stocks that exhibit substantial variation in biomass between years and for which the relationship between biomass in the current period and biomass in the next period is relatively weak. Most of the fisheries economic literature regarding such stocks is concerned more with the choice of management instrument rather than the appropriate level of harvest. Several authors have compared the use of taxes versus catch quotas (Androkovich & Stollery 1991; Hannesson & Kennedy 2005; Weitzman 2002), input controls versus catch quotas (Kompas et al. 2008; Yamazaki et al. 2009), or constant versus variable escapement targets (Clark & Kirkwood 1986; Reed 1979).

Relatively few studies have addressed the issue directly regarding optimal catch levels given variable stocks. Clark and Kirkwood (1986) found that a constant low catch may result in loss of benefits when recruitment was high without necessarily preventing stock collapse when recruitment was low. As a result, higher catch rates were optimal even though these also involved a higher risk of stock collapse. In this regard, information on recruitment was important, such as stock surveys. Without such information, a risk averse strategy would result in lower catch rates and lower benefits to the industry (Clark & Kirkwood 1986). Other studies have included stochastic variation in stock levels to estimate optimal catch and effort levels given stock uncertainty (e.g. Kugarajh et al. 2006; Pascoe & Mardle 2001).

An alternative to setting target reference points with highly variable stocks was to determine viable sets of catch or effort levels that were considered acceptable given this uncertainty. Models using the viability analysis approach are relatively limited in fisheries (Béné et al. 2001; Doyen et al. 2012; Eisenack et al. 2006), and are based on achieving a given level of economic performance and not necessarily maximising economic performance.

Of more importance in the Australian fisheries context are not just variable stocks, but highly variable stocks of short-lived species such as prawns, squid, scallops and small pelagics. Recruitment in these fisheries is often environmentally driven, and the ability to forecast recruitment is limited. Studies elsewhere have focused on estimating fixed capacity/effort levels that maximise the net present value over time given highly variable stocks from year to year (e.g. Maravelias et al. 2010). Other studies suggest an adaptive management approach is more appropriate, with in-season updating and pre-season surveys being critical components (Hoshino et al. 2012). Simulations within a management strategy evaluation framework suggest that in-season updating of a catch target provides greater benefits than a fixed effort target with a trigger mechanism to stop fishing if necessary, with both having the same potential downside risks (i.e. in terms of percentage of years that a loss would be made and the magnitude of any losses) (Hoshino et al. 2012).

For short-lived, essentially annual species, fishery production is essentially a ‘fish down’ operation. That is, provided that subsequent recruitment is not affected (i.e. spawning has taken place or a minimum level of escapement has been allowed for), the optimal strategy is to fish down the available stock until it is no longer economically viable to continue fishing. The criterion for maximising economic profits in such a case is to harvest until marginal revenue (the revenue earned from an additional unit of effort) is equal to marginal cost (the cost of the additional unit of effort). This is illustrated in Figure 2 for an annual fishery in both a good and poor year. Marginal revenue declines with effort as the available stock is fished down and the
criterion is met at around 12 units of effort (blue vertical line) in the good year and 5 units (red vertical line) in the poor year. This equates to the levels that maximise economic profits in each year.

In such a case, MEY should be achieved without the need for additional intervention. In theory, fishers should have no incentive to continue fishing beyond the point where marginal revenue equals marginal cost, as to do so would result in the additional cost exceeding the value of their additional catch. In such a case, management needs only to focus on ensuring that subsequent years’ recruitment is not jeopardised by ensuring sufficient escapement of spawners.

In practice, however, high levels of economic profit generated in the start of the year are likely to attract additional resources into the fishery, with a subsequent race to fish. This is likely to result in considerable excess capacity. The effect of these additional fixed costs in the fishery is to lower the level of profits, although the point at which these profits are optimised is the same (Figure 3). A mechanism to rationalise excess capacity in the fishery is consequently still required if economic returns are to be maximised.

\[7\] In practice this is not always the case as will be discussed later.
Figure 2 Maximum economic yield (MEY) for a short-lived species. Total fishery profits are optimised with marginal revenue per unit of effort equal to cost per unit of effort. As catch rates decline over the year, there is a natural 'stopping' point that is essentially equivalent to MEY. This point adjusts with stock abundance automatically correcting for good or bad years.
Figure 3 The impact of excess capacity on fishery profit. Excess capacity results in higher total costs and lower profits due to the fixed cost component. However, as marginal costs per unit of effort are the same, the optimal effort level is the same in both cases.

**Current guidelines and assumptions**

The harvest strategy policy’s guidelines (DAFF 2007) recommend an adaptive management strategy through:

- conducting pre-season surveys to provide estimates of abundance that then determines the harvest control rule response
- undertaking within-season monitoring and the use of catch triggers (e.g. as used in the banana prawn component of the NPF)
- allowing a set number of spawning events prior to harvest (e.g. as used in the Bass Strait Central Zone Scallop Fishery).

The aim of the pre-season survey is to provide an estimate of the initial stock size, from which catch or effort targets can be set.

**What the issues have been**

To date, MEY has only been applied as a functional target reference point to tiger prawn stocks and the blue endeavour prawn stock in the NPF. So experiences with applying MEY to highly variable stocks have been limited. However, recent work in the same fishery to investigate the appropriate setting of a TAC for the fishery’s highly variable banana prawn stocks has provided some insights. Over recent years (while still an input-controlled fishery), trigger reference points have been imposed on this component of the fishery.

In theory, as illustrated above, trigger points should not be necessary as fishers should stop fishing once it becomes unprofitable. The trigger point applied in the NPF was a proxy for this condition, but did not vary from year to year with changes in fuel costs and prices. Analysis of
logbook information suggests that many fishers stopped fishing before the trigger point was reached, consistent with profit maximising behaviour and reflecting individual variations in costs. Some fishers, however, continued to fish until the forced closure, and individuals have expressed a desire to continue to fish beyond this point. While lower cost producers could potentially fish longer than higher cost producers, much of the push to extend fishing time relates to the incentives created by the crew share system and the need to retain good crew. Crew (including hired skippers) are generally paid a percentage of catch revenue, and hence have an incentive to fish even if marginal revenue is less than marginal costs. Changing the crew payment system to one based on a percentage of profits rather than revenue would better align the crew incentives with those of the vessel owners and fishery managers. Profit-based crew payment systems are common worldwide (McConnell & Price 2006), and Australia is in the minority using revenue-based crew share payments.

The trigger-based method also encourages the race to fish, in that expectations of early closure encourage all fishers to operate. While individually they may operate as profit maximisers, the greater involvement of capital in the fishery may reduce the overall level of economic profits achieved (as per Figure 3). This is less of an issue for the NPF as the fleet has been reduced to a level at which excess capacity is likely to be minimal. A recent MSE of management options for the banana prawn fishery concluded that a trigger reference point may be developed that is consistent with MEY and may perform better than current trigger mechanisms in terms of maximising industry profits (Buckworth et al. 2013).

The proposed move to individual transfer quotas in the NPF has caused further difficulty in that a TAC is required for banana prawns. Pre-season surveys in the fishery have been undertaken by CSIRO for several years. These have mostly been designed to provide information for the tiger prawn component of the fishery, but also provide an index of banana prawn availability. Attempts at estimating a banana prawn TAC using these data, however, have proven difficult, and would have potentially resulted in a substantial loss of economic profits if actually implemented. More recently, attention has focused on improving the ability to forecast using rainfall information (current CSIRO project), although the relationship between catch and estimates of availability has appeared unreliable in recent years (although this could also be due to changes in economic conditions in the fishery).

It is important to separate the use of a management target from the management instrument used to achieve the target. In the case of the NPF, estimating a TAC for MSY is just as difficult as estimating a TAC for MEY.

**Alternative options and approaches**

Assessment of levels of excess capacity remains an option, although this is also complicated in highly variable fisheries. Some excess capacity is optimal in ‘average’ years to allow sufficient capital to take advantage of the high years, although determining this optimal level of excess capacity is problematic (Squires et al. 2003).

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8 The impact of this on overall fisheries performance is uncertain. Boats that operate in the banana prawn fishery also operate in the tiger prawn fishery, so fixed costs are still incurred irrespective of whether they operate in the banana prawn fishery or not. However, excess capacity could still exist in the banana prawn component of the fishery if fewer boats could still take the same the level of catch over a longer period of time.
For many highly variable, short-lived species, it is likely that MEY can be achieved by ensuring appropriate incentives are in place (rather than attempting to impose a particular catch or effort limit), provided that escapement is sufficient to reduce the impact of the catch on subsequent recruitment (e.g. through ensuring that spawning as already taken place). This includes removing incentives created under the race to fish to harvest the animals at too small a size (e.g. by imposing pre-season closures). While beyond the control of managers, but within the control of industry, changing the way in which crew are paid from a revenue share model to a profit share model would also help align incentives in the fishery.

Without some form of property right, however, incentives still exist to race to fish. An option may be to introduce some form of individual quota share, and encourage fishers to pool quota and profit share. This will create incentives to reduce fishing capacity while ensuring that all fishers retain benefits from their allocation. Again, this is an industry solution rather than a solution that can be imposed by management. Potentially, the fishery would be self regulating in terms of fishing effort and arbitrarily high TACs could be set to establish quota shares.
7 Market power

What the literature tells us

Most bioeconomic modelling analyses assume that prices are independent of the quantity landed, such that a constant price can be imposed in the model (e.g. Kompas et al. 2010; Punt et al. 2011). This assumption is largely supported by demand studies of fish species that conclude that prices are relatively inflexible with regard to quantity supplied at the fishery level (e.g. Bose 2004; Burton 1992; Fousekis & Revell 2005; Jaffry et al. 1999; Smith et al. 1998), although more recent analyses suggest that prices for some species are more responsive to quantity landed in the longer term, even if relatively unresponsive in the short term (e.g. Andersen et al. 2008; Pascoe & Revill 2004).

The ability to affect the price through varying the catch has implications for the definition of MEY. In Figure 4(a), the traditional supply and demand model is presented for the case of a price setting fishery with a downward sloping demand curve. That is, the unit price it receives (which represents average revenue, defined as total revenue divided by catch) decreases as the quantity supplied by the fishery increases. The marginal revenue curve (which shows the extra revenue earned with each additional unit of output) lies below the average revenue curve. The industry supply curve is given by the marginal cost of sustainable catch (defined as the extra cost associated with an additional unit of catch) which is shown to increase. This differs from the marginal cost per unit effort in the traditional model (which is generally assumed to be constant), as the sustainable catch per unit of effort decreases as effort increases, with fish becoming more difficult to catch with decreasing biomass. Hence the marginal cost per unit of sustainable catch increases as catch increases, and as it cannot increase beyond maximum sustainable yield (by definition), the marginal cost curve asymptotes at this point.

The fishing industry would maximise its profit at the point where its marginal cost is equal to marginal revenue, depicted by MEY₁ in Figure 4(a). This is equivalent to the point Emey₁ in Figure 4(b). At this level of output, prices are P₁. However, while producer profits are maximised here, society’s total benefits (the sum of consumer and producer surplus) are not. Rather, these total benefits are maximised where average revenue equals marginal cost, with a higher production quantity (MEY₂) and a lower price (P_*). The benefits to society at this optimal production point are depicted by the shaded areas in Figure 4(a). The yellow area represents consumer surplus, which is the difference between what consumers are willing to pay and what they are required to pay. The green area is producer surplus—the difference between the price received and the marginal cost of production.

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9 Price flexibility is measured as the percentage change in price given a 1 per cent change in quantity supplied. The own-price flexibility is the inverse of the price elasticity, which is the percentage change in quantity demanded due to a 1 per cent change in price. The measure of price flexibility is more appropriate when dealing with highly perishable products with (to some extent) exogenously determined output, as the price adjusts to clear the market. Fisheries falls into this category as output is a function of stock and fleet size, and the price adjusts depending on the resultant catch (although there is feedback in that effort is likely to decline at lower price levels). A product’s price is inflexible if it does not change with quantity supplied (which is equivalent to a perfectly elastic demand).

10 A review of studies of price elasticities (c.f. price flexibilities) has also concluded that fish prices, in general, are elastic (i.e. inflexible) (Asche et al. 2007).
Figure 4 Effects of variable prices on optimal output. Figure 4(a) represents the traditional market model (i.e. supply and demand) and illustrates the degree to which consumer benefits are affected by fisheries production decisions. Figure 4(b) represents the fishery-centric bioeconomic model with variable prices. In such a model maximum economic yield (MEY) may result in a lower revenue than lower catch levels.

Note: **MSY** Maximum sustainable yield. **MEY** Maximum economic yield where producers maximise profit. **Emey** The effort level associated with MEY. **P** The price that occurs with MEY catch. **MEY** Catch where benefits to both consumers and producers are maximised. **P** The price associated with MEY. **Emey** the effort level associated with MEY.

Ignoring consumer surplus and producing at MEY maximises benefits to the industry and represents a net transfer of benefits from consumers to producers. That is, producers capture additional producer surplus benefits associated with areas C and D in Figure 4 (a) at the lower MEY quantity (given that the higher price P prevails). These are benefits that would be captured by consumers if the efficient MEY catch was produced. In addition, by not producing at MEY, areas A and B are not captured by anyone and represent an actual loss of benefits to society, traditionally referred to as a net ‘deadweight’ loss. Therefore, in order to maximise the benefits to society as a whole, the more appropriate target is the natural ‘market’ equilibrium given by MEY (Anderson 1973, 1980), with the equivalent level of effort Emey in Figure 4 (b). At this point, the sum of consumer and producer surplus is maximised (Turvey 1964). However, industry profits are less than they might be at lower effort and catch levels.

In contrast, when producers are price takers and prices are relatively inflexible (i.e. invariant to the quantity supplied), the demand curve is effectively flat, and consumer surplus does not exist. Hence, maximising producer benefits in such a case is an appropriate strategy for achieving MEY.
With globalisation of world fisheries markets, the ability of fishers (or even a fishery at an aggregate level) to influence their price is limited for most species. Too high a price would attract imports, while higher prices overseas would attract exports. Conditions under which the scenario depicted in Figure 4 could occur are limited, and rely on the case where the fishery was the main (or ideally sole) supplier to a domestic market with little competition from imports.

As noted previously, relatively few bioeconomic models include price variability as a component. Many of these ignored consumer surplus implications (e.g. Danielsson et al. 1997; Gillig et al. 2001; Önal et al. 1991; Shalliker 1987), although others considered consumer surplus as a key component of economic benefits from fisheries management when estimating optimal yields (e.g. Blomo et al. 1982; Cook 1990; Edwards & Murawski 1993; Grafton et al. 2012).

**Current guidelines and assumptions**

The policy (DAFF 2007) does not refer to issues of market power. Implicit in the guidelines is that MEY is defined in terms of industry profitability only. Descriptions in the policy refer to variations in prices only in the context of inter-annual variability, and assume that price is exogenously determined (external to the fishery).

**What the issues have been**

For most Commonwealth fisheries, the assumption of exogenous prices (and associated with this the assumption of perfectly elastic demand, or inflexible prices) is reasonable. Most fisheries produce products that compete either on the domestic market with other domestically produced and/or imported substitutes, or on the export market with other countries; in both cases, market share is generally small.

There are, however, a small number of fisheries in which price–quantity relationships may be an important consideration when determining MEY targets. In particular, the recent shift in the supply of banana prawns from the NPF to the domestic market is believed to have had an adverse impact on its own price (Buckworth et al. 2013).

Anecdotal evidence suggests that the recent reopening of the Bass Strait Central Zone Scallop Fishery and the subsequent increase in fresh scallops on the domestic market has also potentially had an influence on market prices—both for this fishery as well as the adjacent Victorian and Tasmanian State fisheries (AFMA 2010). However, this effect has not been formally quantified.

**Alternative options and approaches**

Incorporating the effects of changes in quantity on price and subsequently the appropriate definition of MEY first requires an understanding of the demand relationship for the species (including cross-species price interactions); second, it requires a bioeconomic model with an integrated demand component in order to determine the appropriate target reference point. From the diagrammatic model in Figure 4, the optimal yield will generally lie somewhere between the catch that maximises industry profits, and MSY. The more inflexible the price, the closer the optimal yield will equate to that which maximises industry profits.

Given that most empirical studies (in Australia and elsewhere) have found that fish prices are generally inflexible, a default position may be to estimate MEY as the yield that maximises industry profits at the prevailing price—as is current practice. However, where there is evidence of flexibility, research needs to be undertaken to derive more appropriate catch–price
relationships to further refine the model and ensure that the target reference point reflects the yield that maximises total benefits to the broader society (industry and consumers).
8 Internationally shared fisheries

What the literature tells us

Most studies of international fisheries have focused on approaches to estimate non-cooperative (or cooperative) outcomes between fishing nations under different conditions (Abbott et al. 2010; Bailey et al. 2010; e.g. Klieve & MacAulay 1993; Lindroos 2004; McWhinnie 2009; Munro 2009). These have included theoretical studies to identify the necessary conditions for ‘international MEY-like’ catch levels to evolve across nations (Chiarella et al. 1984), assuming all nations share the same objective of maximising economic returns. These conditions are relatively restrictive, requiring homogeneity in technology (the fishing fleets of all nations use similar technology) and also the absence of market externalities (i.e. each nation’s catch is sold on its respective domestic market with no import competition from other harvesting nations) (Chiarella et al. 1984). Subsequent studies have focused on asymmetry in production as a more realistic assumption (i.e. differences in harvesting costs), and concluded that the ‘natural’ state of international fisheries is effectively the open-access situation (Munro 2009) and shared stocks are more prone to overexploitation (McWhinnie 2009).

For high-valued, highly migratory species such as tuna, cooperation between coastal states has been improving since the early 1990s (Munro 1990). However, where formal allocations are made between member states, these are often based on historical catch levels rather than a specific target reference point (Grafton et al. 2011). The Commission for the Conservation of Southern Bluefin Tuna (CCSBT) has, in some instances, failed to provide an agreed total quota and allocation due to differences in objectives of the member countries (Kurota et al. 2010). In international waters, new individuals can enter the fishery and potentially undermine any allocations agreed between co-operating parties. For example, in the case of Southern Bluefin Tuna, non-members of the CCSBT have previously taken as much as one third the total harvest (Polacheck et al. 1999).

A substantial complication in the management of international fisheries is the problem of disparate social-value systems, which in turn may be driven by local needs and dependencies on the marine environment (Crutchfield 1973). In the case of Australian fisheries, the stated objective is the maximisation of the net economic returns from the resource. However, for other adjacent jurisdictions, the management objective may be substantially different. The objectives of international fishery management must be modified to accommodate different national objectives (Crutchfield 1973).

The fisheries economic literature has not addressed the issue of how to best use any allocation once determined. From an economic perspective, when output is given exogenously, economic returns can only be maximised through minimising the cost of production. These maximum returns to the state may (but most likely will not) equate to what could be achieved if a global maximum economic yield is imposed in the fishery as a whole. While considerable work has been undertaken on cost minimisation by individual fishers (e.g. Jensen 2002; Nostbakken 2006), most of the relevant literature relates to capacity and capacity utilisation described in previous sections (e.g. for data-poor species fisheries).

Current guidelines and assumptions

The policy does not prescribe management arrangements in the case of species managed by international management bodies and/or arrangements or for fisheries managed under a joint
authority. However, the policy states that the Australian Government will negotiate with the relevant bodies to ensure sustainable fisheries (DAFF 2007). In this sense, the policy recognises implicitly that an MEY target is an unrealistic expectation for such fisheries at the international level. However, as noted above, maximising economic returns from the Australian allocation is still achievable, but is not identified as a target for these Australian fisheries in the policy. This notwithstanding, the Australian share of the fishery is subject to the *Fisheries Management Act 1991* that still specifies maximising the net economic returns as an overall management objective.

**What the issues have been**

For all intents and purposes, the Australian components of international fisheries have been managed as any other fishery. The exception is that catch and/or effort limits are exogenously determined or, at the very least, influenced by negotiations with international agencies or joint authorities.

The fact that international stocks are being shared with other countries implies that the returns to targeting a biomass level will be dependent on the relative share of catch. If the Australian share dominates, then management actions may have some power to influence stock size (and future economic returns). But if Australia only takes a small share of the international catch, then its influence over future stock levels (and the fishery’s profitability) is reduced. In the latter case, a biomass target for the domestic fishery is not going to be appropriate. In such cases, it has then been unclear how harvest strategies can best meet the MEY intent of the policy.

For example, the Eastern Tuna and Billfish Fishery targets some stocks for which the Australian catch makes up a relatively small proportion of the total international catch. The fishery’s harvest strategy control rules utilise a target catch rate that is equivalent to the rate that prevailed during a historically profitable period (1997 to 2001). However, this period was also associated with a relatively favourable terms of trade (high fish prices, low fuel prices). This means that achieving the same catch rate now may not necessarily result in positive profits and, therefore, may not be consistent with targeting MEY (Ward et al. 2013).

**Alternative options and approaches**

In cases where catch is determined under a separate international negotiation process, target reference points for management of the Australian component may be better expressed in terms of capacity utilisation (instead of biomass). As noted previously, underutilised capacity represents an opportunity for a more efficient fleet configuration, although some underutilisation is desirable given fluctuations in stock and price conditions from year to year. Identifying an optimal level of underutilisation in such fisheries is an area for future research.

Related to the use of capacity utilisation measures is the use of profit functions (e.g. Pascoe et al. 2011) and cost functions (e.g. Asche et al. 2009) to identify optimal levels of individual catch, and from this the possible extent of excess capacity.

While not a reference point per se, the harvest strategy policy could also advocate the use of management instruments that encourage cost minimisation, such as individual transferable quotas.
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