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FISHERIES RESEARCH & DEVELOPMENT CORPORATION

Low-cost management regimes for small low-value fisheries based on coastal inshore species

Appendix Two: Guidelines for developing low-cost management regimes for small-scale, low-value fisheries

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GUIDELINES FOR DEVELOPING LOW-COST MANAGEMENT REGIMES FOR SMALL-SCALE, LOW-VALUE FISHERIES

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FRDC 2015-215 Low-cost management regimes for small-scale, low-value fisheries

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Context and intent

This guidelines document is intended to guide managers and stakeholders through the process of developing low-cost management regimes for small-scale, low-value fisheries.

Such fisheries face unique issues: they may be unfamiliar with formal management, they may contain multiple sectors/user groups, and they may be data- and/or capacity-limited, such that formal model-based stock assessments may be unable to be undertaken, and/or the resources to implement a harvest strategy (including gather data against monitoring protocols, enforcing control rules, and formally reviewing and updating the strategy) may be limited.

The level of data and/or resource poverty for these low-value/ small-scale fisheries is often such that they lack formal data collection protocols. Associated challenges in providing guidance, even at the level of basic data collection regimes, can include limited literacy and numeracy, and profound cultural issues associated with indigenous sectors.

These guidelines attempt to explicitly acknowledge such issues and provide practical advice in this context.

The guidelines are underpinned by:

- the National Harvest Strategy Guidelines (Sloan et al. 2014)
- the recommendations of the Joll et al. (2015) Australian Fisheries Management Forum (AFMF) Fisheries Management Workshop Report
- an accompanying literature review.

INTRODUCTION

The role of fisheries management is to manage fisheries resources, and the ecosystems that support them, in the face of uncertainty, to meet multiple and often competing objectives for a diversity of stakeholder groups (Sloan et al. 2014). This is a challenging task, particularly when factoring in the complexities and high costs associated with observing changes in the marine environment and the uncertainties in assessing the productivity of populations and the natural environment inherent to the ecosystems that support them (Sloan et al. 2014). Complicating this task further is the common property nature of fisheries resources and the variety of other competing uses in the aquatic environment surrounding and influencing fisheries management such as mineral resource development, coastal development, shipping, and biodiversity conservation.

High-value fisheries are often prioritised by management agencies and typically attract the majority of funds and resourcing. For management agencies where management fees are linked to the gross value of production (GVP) of fisheries (as in Western Australia), there can also be an economic incentive to ensure the high value fisheries are performing well. High value fisheries are typically information-rich, with a range of data and analyses available to inform management decisions.

Attributes of such fisheries may include the following, which, generally, result in high value fisheries being well managed:

- fishery independent data
- economic data
- monitoring plans with real time catch and effort data
- regular stock assessments
- advisory committees and technologically savvy licence holders willing to engage
- high-end monitoring and reporting approaches (e.g. vessel monitoring systems, electronic logbooks)
- compliance and enforcement
- pre-determined monitoring, assessment and decision rules incorporated in formal harvest strategies.

The above are typically lacking for low-value, data-limited fisheries, and their management is consequently challenging.

Definition of "low-cost"/ "low value" fisheries

A "low cost"/ "low value" fishery definition is not absolute. If a fishery is in a position where there exists concern around its budget and/or management from a standpoint of

- capacity,
- funding,
- priority, and/or
- willingness (stakeholder or agency),

then the fishery may be considered "low value", and these Guidelines are intended to provide help.

Alternatively, a fishery may be considered to be "low cost"/ "low value" if a government

- assigns it as such
- is unsure what species to manage
- has low capability in the context of that fishery.

A fishery may fit into the above definitions, but they are not intended to be exclusive. Importantly, "low cost"/ "low value" is not a closed definition that is going to impact on the use or applicability of these Guidelines.

It may be preferable to consider cost characterisation as opposed to definition in absolute terms. Care must also be taken around the definition of "value" – the emphasis is currently on economic value (e.g. relative to GVP), but environmental and social value are also important, especially to non-commercial sectors.

Definition of "data-limited" (= "data-poor") fisheries

The term "data-limited" (= "data-poor") is a relative term and can cover a range of conditions. For the purposes of the National HS Guidelines (Sloan et al. 2014), data-limited fisheries are typically characterised by the following (Dichmont et al. 2011):

1. Classic (quantitative) stock assessment models are unable to be used, for reasons either of
    - data availability,
    - data quality, and/ or
    - analytical capacity;

2. A large uncertainty in the status and dynamics of the stock due to poor data;

3. Uncertainty in the nature of fishing (e.g. in terms of fleet dynamics and targeting practices); or

4. Have a low GVP.

More generally, these are fisheries which, for any the above reasons, have struggled to resolve stock status and establish the associated fishery risk.

Dowling et al. (2015b) state that data-limited fisheries can include, but are not necessarily limited to:

a. new fisheries with limited observations and no time series of information;

b. those where fisheries research and management have lagged exploitation;

c. low-value fisheries or species for which comprehensive data col-lection is considered uneconomic or unjustified;

d. multi-gear, multi-species fisheries with many small operators and landing sites for which comprehensive monitoring is complex and resource demanding;

e. fisheries where data quality is poor or variable and difficult to verify (e.g. high levels of misreporting or non-reporting);

f. spatially-structured fisheries where data collected may not be representative of the whole stock;

g. fisheries that retain or discard by-catch species but do not adequately monitor by-catch; and

h. threatened or protected (TEP) fish species with which a fishery's gear interacts, but which are not monitored.

A key question in the context of data-limited fisheries is identifying the drivers for the need for more or better data, and the need for improved fishery management.

Challenges for low value, data-limited fisheries

The role of fisheries management is more challenging for low value fisheries, where there may be increased uncertainty due to a lack of information to inform decisions. Some of the issues affecting low-value fisheries include:

- Data limitation-

    - Even if reported, the spatial and temporal extent of the catch and effort data may provide a poor representation of the stock, as fishing is often restricted in time and space.
    - What data are collected can be poor in quality with fishers often having poor numeracy and literacy, compounded by isolation and cultural issues.
    - Vessels are often small, making it harder to implement equipment or technology (such as Vessel Monitoring Systems, or real-time catch log data) that can help collect better data.
    - There is often a lack of funds to implement the collection of costly fishery-independent data.
- Limited, or no formal, stock assessment (often only catch data may be available, which may not be a good indicator of abundance).
- Lack of funds to implement more costly and efficient management measures. Rather, managers are restricted to coarse management measures, such as limited licences, to prevent overexploitation.
- No formal harvest strategy. Management decisions are made *ad hoc* and lack transparency.
- Limited or no ability for management strategy evaluation.
- Poor engagement with stakeholders, with many fishers wanting to be left alone due to low levels of literacy, isolation and cultural issues. This often results in conflicts

As such, both practically and logistically, establishing a formal management regime for small-scale, low-value fisheries is challenging.

In particular, the lack of information to inform decisions in low value fisheries can result in high uncertainty and create risks for overfishing. Yet, with no real ability to assess how a low value fishery is performing, combined with these types of fisheries typically being assigned as lower priority, management is often static unless change or review is forced through legislative requirement. As a result, management stasis can prevail, with minimal understanding as to whether these fisheries are being optimally utilised, which is an object in many Fisheries Acts (e.g. Object 2a(c) of the NT Fisheries Act (https://legislation.nt.gov.au/Legislation/FISHERIES-ACT) and Section 3 of the 1991 Commonwealth Fisheries Act (https://www.legislation.gov.au/Details/C2004A04237)).

What is a management regime?

For the purposes of these guidelines, a management regime is defined as the process of developing and implementing a formal harvest or management strategy for a fishery, from the point of initial stakeholder engagement, to the point of implementation (Figure 1, Figure 2). The management regime equates to both the inner two layers of Figure 1 (from Sloan et al. 2014).

A management regime embeds the harvest strategy in the context of both the stakeholder engagement and elicitation that must precede it, and the implementation considerations that follow it (Figure 2). Alternatively, a management regime equates to the first two (yellow and green) layers of the diagram presented by Sloan et al. (2014) (Figure 1).

Management regimes therefore bookend the process of developing and implementing harvest strategies, to embrace

i) Pre-requisite issues that set the context for harvest strategies
ii) Issues that precede harvest strategy development
iii) Issues that pertain to the implementation of harvest strategies

A management regime may be developed in response to legislative or policy requirements, or it may be in response to a stakeholder-led desire (i.e. from management agency, fishers, or both) for improved or more formal management. Any management regime must be consistent with the Australian Fisheries Management Act and other legislation.

Central to a management regime is a harvest strategy, or management strategy (the terms are interchangeable).

Design Principles

As per Sloan et al. (2014), and Dowling et al. (2008) the same design principles that apply to the development of harvest strategies also apply to the development of management regimes.

Management regimes should, therefore, be

- Pragmatic (given the economic and data limitations)
- Unambiguous
- Cost effective
- Transparent and inclusive
- Easy to understand for all stakeholders
- Precautionary
- Consistent with the intent of any legislative or policy requirements
- Adaptive (e.g. assessments and decision rules can be changed as more information becomes available)
- Where appropriate, not constrain development for stakeholders
- Have a formal mechanism for review

What is a harvest strategy?

A harvest strategy (or management strategy) is the central component of, and underpins, a management regime (yellow layer in Figure 1).

In The National Guidelines to Develop Fishery Harvest Strategies, Sloan et al. (2014) defined a harvest strategy as a framework that specifies the pre-determined management actions in a fishery for defined species (at the stock or management unit level) necessary to achieve the agreed ecological, economic and/or social management objectives.

In its simplest form, a harvest strategy is a formal, pre-specified set of rules designed to achieve the management objectives for the fishery. It provides a framework to ensure that fishery managers, fishers and key stakeholders think about, and document, how they will respond to various fishery conditions (desirable or undesirable), before they occur (Sloan et al. 2014). Harvest strategies are usually applied to the target species (e.g. Sainsbury et al. 2000, Butterworth and Punt 2003, and Fisheries Research Special Issue 94 (3) 2008). They comprise a fully-specified set of rules for making tactical management decisions including specifications for

i) a monitoring program,
ii) the indicators to be calculated from monitoring data (usually via a stock assessment) and
iii) the use of those indicators and their associated reference points in management decisions, through application of decision (or control) rules (Butterworth 2007,

Butterworth and Punt 2003, DAFF 2007, Punt *et al.* 2002, Rayns 2007, Sainsbury *et al.*, 2000).

A harvest strategy does NOT equate to micro-managing an individual's operations, nor, within the bounds of legal management, their approach to fishing.

It is important to note that, while the terminology and structure associated with a harvest strategy may suggest a data-rich fishery, there exists a large range of options for monitoring, assessment, and decision rules. As such, harvest strategies can vary strongly among fisheries and the term is therefore very broad. Rather than being construed as an intimidating, over-restrictive, and prohibitive barrier, harvest strategy development should rather be viewed as an opportunity for stakeholder empowerment. In many cases, harvest strategies merely involved the formalisation of existing arrangements.

Many data-limited fisheries will not have harvest strategies that manage against biomass-or fishing-mortality based estimates of maximum sustainable yield (MSY) or maximum economic yield (MEY).

This is a basic data constraint and is regardless of legislative requirements. This in itself is a strong argument for embedding data-limited assessments within a harvest strategy with control rules that can be used to sustainably manage a fishery. Control rules within such harvest strategies can compensate (to some extent) for bias or imprecision in the assessment.

That is, assessments linked to precautionary harvest control rules can perform well in avoiding overfishing (although less well in terms of maximizing yield), even though the assessment method may poorly measure stock status. Fundamentally, context and consequence must be considered: the same reasons that resulted in the fishery being data-limited may also cause restrictions on assessment and management options.

Why are harvest strategies so important?

Harvest strategies are pro-active, rather than reactive, with pre-determined, formalised rules, and, as such, provide transparent, objective and defensible process to fishery management. Through this, they foster a climate of trust (thus increasing compliance), minimise risk by aiming for target and avoiding limit reference points, and provide increased stakeholder certainty regarding the management decision process. They improve stock sustainability and environmental health, as well as manager, fishery and public confidence, permit greater business planning, and optimise the chance of qualifying for certification, and obtaining export approvals. Conversely, a lack of harvest strategy, or using the wrong assessment, or inappropriate control rules or monitoring, create risks for fishery collapse

At the same time, managers lack expertise and confidence in developing data-limited harvest strategies and can expend considerable resources in ineffectual processes to develop harvest strategies. For example, for Australian Commonwealth fisheries, even with expert panels, it took 2-3 workshops to draft a harvest strategy for any one fishery - and many of the state-based fisheries are more complicated, with multi-sector and multi-species fisheries being common.

This inefficiency is costly, as is the lost opportunity due to management paralysis.

So too is the cost around not having a harvest strategy. Assuming data-limited fisheries comprise 10% of the gross value of capture fisheries globally, and conservatively assuming the *short-term* benefit of harvest strategies against achieving maximum economic yield to be ~5% across data-

limited fisheries, this represents an annual value of ~$450 million globally. Conversely, collapse of these fisheries could represent annual losses of up to ~$9 billion.[1]

These values do not account for longer term outcomes and gains, nor the additional benefits and value of increased stakeholder buy-in to formal management outlined above. There is considerable scope for improving economic, ecological and social outcomes for data-limited fisheries, via appropriate harvest strategies.

Figure 1: A schematic representation of how a harvest strategy fits within the overall fishery management framework (as a central component of the fisheries management process) (from Sloan et al. 2014). The management regime embraces both the harvest strategy and its embedding within the middle "Fishery" layer.

[1] Global total capture fishery production in 2014 was 93.4 million tonnes (81.5 million tonnes from marine fisheries) (FAO 2016). The U.N. estimated first sale value of 92 million tonnes of capture fisheries production in 2006 at US$91.2 billion. Assuming data-limited fisheries comprise 10% of these values (balancing their high volume with their low value, this equates to $9 billion.

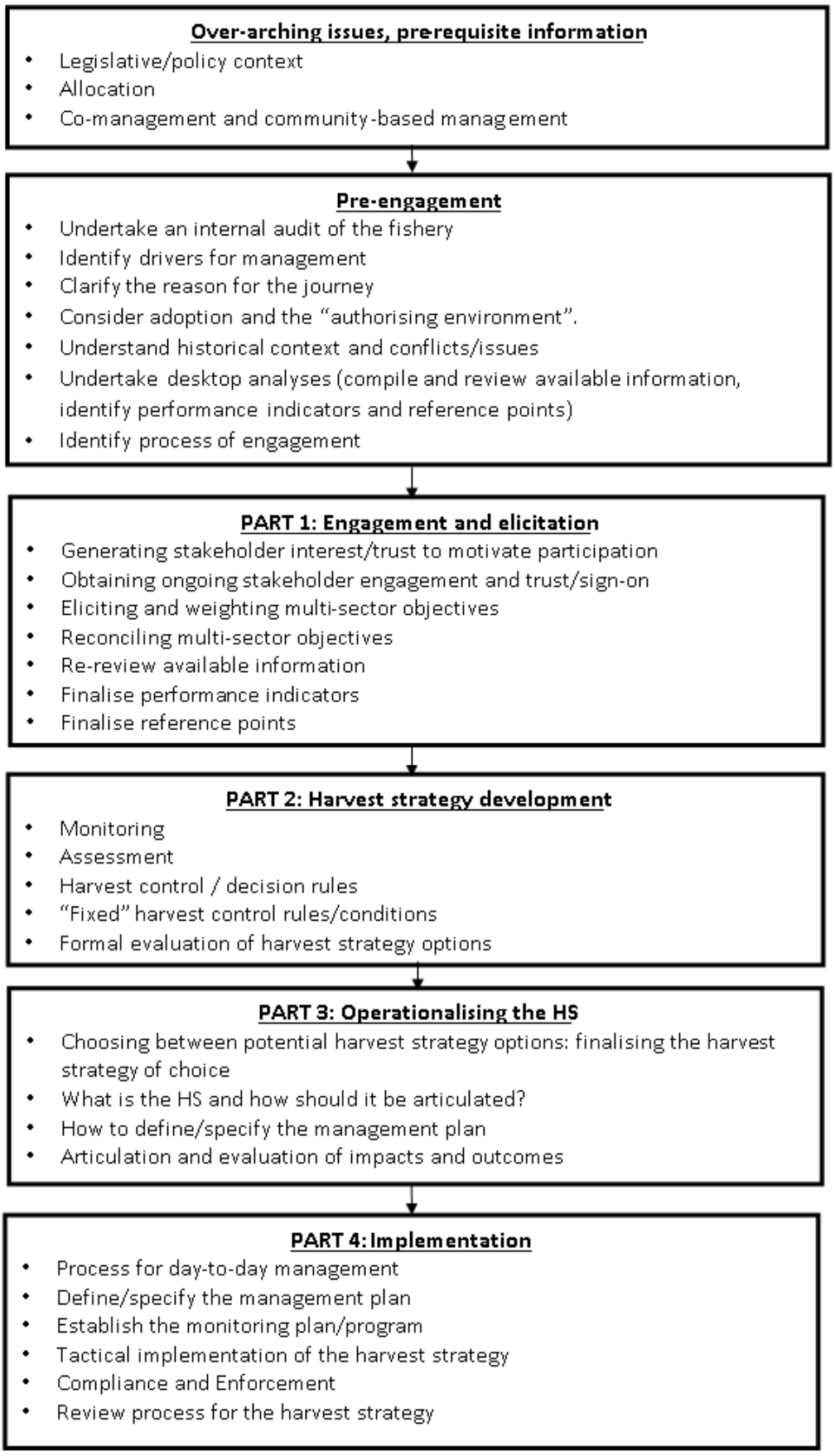


Figure 2: Flowchart describing the process of establishing a formal fishery management regime

The FishPath harvest strategy selection tool

Harvest strategy development is the core of any management regime. However, without a process-based guidance tool to identify viable data-limited harvest strategy options, this process can be ad-hoc: there is no means to do this in an efficient, transparent, defensible and standardised way. Often this can result in management paralysis, misapplication of stock assessments, or inappropriate control rules or monitoring, all resulting in high uncertainty and creating risks for overfishing. In contrast with approaches that provide top-down prescriptions and pre-suppose successful implementation, a process-oriented approach allows practitioners to work with local constituents to develop tailored options leading to equitable outcomes.

In order to bridge these critical gaps, Dowling et al. (2016) developed FishPath (www.fishpath.org): a generalised, process-based decision support system to guide the assessment and management of data-limited fisheries. FishPath automates the process of filtering harvest strategy options, given user responses to a set of caveat-driven questions. It navigates all available possibilities to reveal those most appropriate for the fishery, with relevant caveats.

FishPath is designed for fisheries that lack the data, resources, and/or institutional capacity to perform more formal (model-based) quantitative stock assessment and management. Information about the fishery is elicited through a diagnostic interface (questionnaire).

FishPath is a fisheries management software application that guides a stakeholder engagement process to select a context-appropriate fisheries harvest strategy. FishPath integrates user-specified inputs regarding available data, social, economic, operational, biological, ecological and governance characteristics of a fishery into a decision framework that provides the users with a subset of amenable monitoring, assessment and decision rule options for their fishery (Figure 3). FishPath highlights the relevant caveats, assumptions and challenges of implementing each approach so that the users can determine the approach that is best for their fishery. FishPath identifies the most significant and limiting gaps in knowledge and capacity that preclude certain approaches from being implemented, such that investments can be prioritised and key challenges can be addressed to improve management and conservation outcomes (Dowling et al. 2016). The decision logic behind FishPath was developed through a Science for Nature and People Partnership Working Group (SNAPP; http://snappartnership.net/groups/data-limited-fisheries/), which brought together 25 top fisheries scientists and practitioners from eight different countries. The Nature Conservancy (The Conservancy) has further developed FishPath into a user-friendly software application through a collaboration with CSIRO. The FishPath software contains 52 monitoring options, over 46 assessment options, and 51 types of management actions

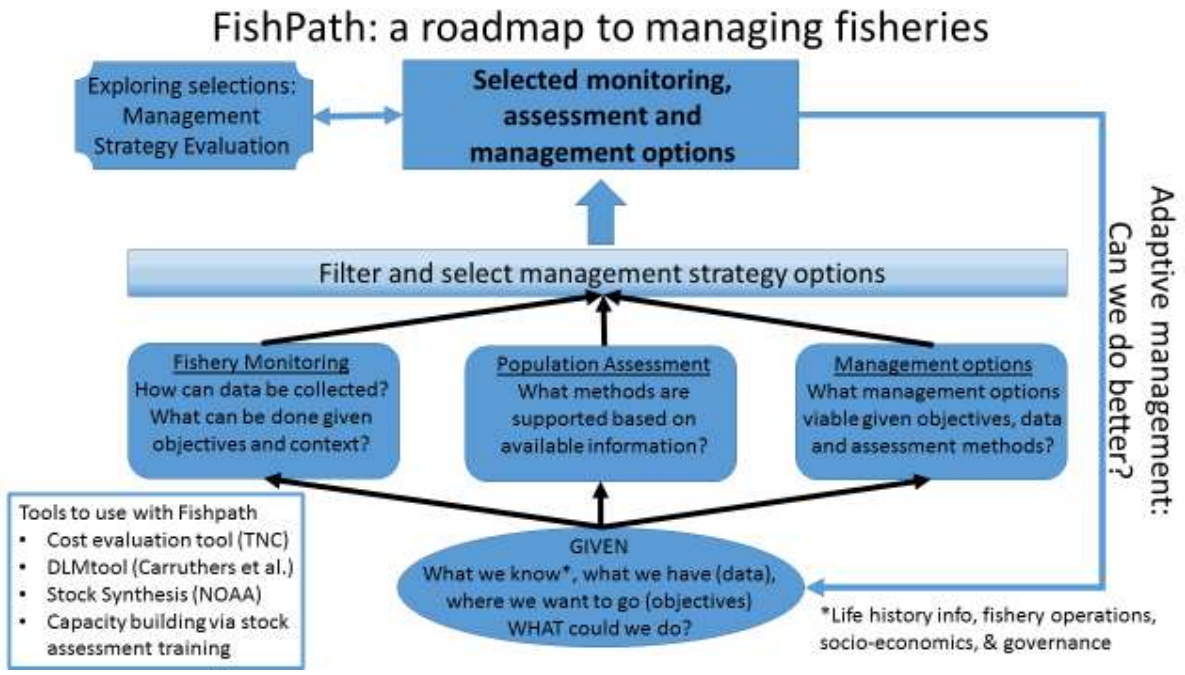


Figure 3: Visual overview of FishPath harvest strategy selection tool

FishPath explicitly considers five key categories of information (Table 1):

i) available fishery dependent and independent data (quantitative or qualitative);
ii) biological/life history attributes of relevant species;
iii) fishery operational characteristics;
iv) socio-economic indicators and characteristics; and,
v) governance context

(noting that the latter two have traditionally received less attention in a management strategy selection context).

FishPath does not provide a top-down recommendation of methods or approaches without considering specifics of the fishery. Rather, FishPath provides a subset of harvest strategy options given a set of fishery circumstances. This is as opposed to users being provided with a set of options and asked to select for themselves which is best for their circumstances.

FishPath is an efficient, transparent and objective (standardized) process to formalize engagement and empower decision making. It is comprehensive with a full inventory of options and is able to identify what can be done if specific caveats or limitations can be overcome. That is, FishPath identifies not only what options are possible, but why others are not.

For each of its three components (monitoring, assessment, decision rules), the FishPath software tool leads users through a series of questions against the 5 main information categories outlined above (Table 1). Some questions are repeated as they apply to more than one component. The questions within the FishPath software can readily be answered by a small team of key experts within a few hours.

Table 1: The five key information categories defining a fishery. Column headers represent the five main information categories, while the rows describe the general scope of questions under each category. From Dowling et al 2016.

Available data from monitoring programs	**Population/life history data**	**Fishery operational characteristics**	**Socio-economics**	**Governance**
Currently collected? (e.g species composition, length composition, age composition, mean length, mean weight, fishing location, catch, effort, CPUE, sex composition, fishery dependent density, fishery independent abundance, inside/outside MPA length and density)	Current state of knowledge?	(e.g.) type of gear, number of operators, fishing location/season, species targeted, possible latent effort, discarding practices…	Social structure within the fishery or the community or the region of interest?	Current institutional structure?
Possible to collect?	How obtained?	How do the fishermen and markets respond to environmental, management, economic and social changes at play in the fishery?	How are peer to peer interactions structured?	Strong top down or bottom up processes?
What types of information could be used as performance indicators and reference points?	Is information specific to the local fishery, specific to the species in general, or borrowed from related species?		Current relationship between different user-groups (fishermen, processors, managers, NGOs, etc.).	How is enforcement carried out?
Spatial/temporal consistency?			What is the current economic status of the fishery (prices, costs, volume, etc.)?	Concerns related to IUU fishing?
Data quality			Fishery subsistence or commercial?	Types of access rights?
Data quantity			Level of cooperation with managers? Extent of familiarity with formal management?	Strong legal or customary policies?
What is realistic given the current research capacity ?			Level of resource dependency?	

FishPath is not an assessment toolkit or software tool that identifies a single assessment options and undertakes the associated analysis. Additionally, FishPath does not

- Recommend any single option
- Provide reference points or assessments
- Tell you how to overcome sticking points and constraints
- Tell how hard to pull harvest control rule levers
- Evaluate options in context of objectives (e.g., by Management Strategy Evaluation)

The emphasis within the FishPath software tool is that information and details are not "hidden". Caveats against each option are readily visible and the influence of a question response on the available options is transparent. As such, having undergone the process, users can revisit their responses and reverse-engineer, or "game" the software.

There is often a lot of detail against each caveat invoked within FishPath. The notion is that each of these details would need to be discussed in weighing up options (and stakeholders may even recolour the associated "traffic light" judgements – described later). As such, the tool is about *empowering* judgement rather than replacing it. In this context, the FishPath tool

- Hones discussion around the appropriate foci (the caveats invoked)
- Improves efficiency (by immediately providing viable options in response to the range of questions)
- Provides a defensible basis for decision-making

Throughout FishPath, traffic light colours are often assigned to caveats invoked in response to specific questions, against specific (monitoring, assessment, decision rule) options. These colours represent a general judgement around whether the caveat

i) is a positive attribute that supports the option (green)
ii) invokes some cautionary warning that it should be carefully considered in the context of that option (yellow)
iii) invokes a strong cautionary warning that it should be carefully considered in the context of – and may not be able to be overcome to enable – that option (orange)
iv) suggests that the option is not feasible (red)
v) is neutral – the question is either not relevant to that option, or the advice does not carry a recommendation or cautionary judgement (grey).

The benefit of FishPath to managers

The availability of FishPath gives management their first real opportunity to formally confront their low value fisheries with options for formal harvest strategies. At a minimum, undertaking the FishPath process highlights the key issues and limiters within a fishery to managers, and hones discussion around these. FishPath provides a user-friendly, efficient, unbiased, transparent and standardised platform for management agencies to undertake an internal audit of their low value fisheries to identify harvest strategy options and explore these to see if they can improve the performance of low-value fisheries.

That stated, in the (more desirable) context of full stakeholder engagement within, for example, a workshop, it is strongly advocated that the FishPath questionnaire be approached as a two-phase process. The first phase should be one of encouraging stakeholders to speak generally against the 5 main information categories, with guidance from the full set of FishPath questions (Appendix 1).

Stakeholders should be encouraged to describe their fishery, so that a general sense of its context and characteristics may be obtained. Questions asked at this point should guide the user as appropriate, and stakeholders should be encouraged to speak freely.

Subsequently, any unresolved FishPath questions can be asked directly in the second phase of working through the software questions directly. These may also be honed so that they are relevant to the fishery context. A bottom-up "listen first, ask detailed questions later" approach is likely to be most effective in terms of empowering stakeholders, and avoids asking potentially redundant or irrelevant questions.

The full list of FishPath criteria and caveat questions, against these five information categories, is provided in Appendix 1.

The concept underpinning FishPath, whereby options are confronted with caveats, is applied within these Guidelines both directly, under the harvest strategy component, and more broadly, to embrace certain components of the management regime.

Format of the Guidelines

These Guidelines detail a process-based pathway, some or all components of which will inevitably need to be confronted regardless as part of a manager's core business. The stepwise process of developing and implementing a formal harvest strategy for a fishery, from the point of initial stakeholder engagement, to the point of implementation, are outlined in Table 2.

The Guidelines are intended to be user-friendly, process-based, and practical. They are presented in chronological order with stepwise advice and a series of "stop sign" check-points, as per:

User is being provided with a "stop sign" checkpoint

Certain components of the Guidelines are structured by presenting a comprehensive series of options, confronted by a suite of key caveats or considerations. These may be conceptualised as matrices of choices versus limitations, with specific advice against relevant elements of the matrix (Figure 4). This is the same approach as used in the FishPath decision support tool, to which the harvest strategy component of the Guidelines defers. The Guidelines also touch on issues outside the scope of management regimes (e.g. dealing with sectoral allocation issues).

These Guidelines **do not** extend to issues of policy and legislation, social licence and/or sectoral allocation issues, although they are briefly considered in the "over-arching issues/pre-requisites" section. However, these issues have the potential to strongly influence and/or derail the process of management regime development. Consistent with the recommendations of the National Harvest Strategy Guidelines (Sloan et al. 2014), these must be acknowledged and, ideally, addressed, upfront.

Management regime component	Option 1	Option 2	Option 3	Option 4
Caveat question 1	Recommend option on basis of this caveat (detail) (“green”)	N/A		N/A
Caveat question 2	N/A	Avoid option on basis of this caveat (detail) (“red”)	Caution against option on basis of this caveat (detail) (“yellow”)	Additional considerations on basis of this caveat (detail) (“yellow”)
……..				
Caveat question *n*	Caution against option on basis of this caveat (detail) (“yellow”)	Strongly caution against option on basis of this caveat (detail) (“orange”)	N/A	Recommend option on basis of this caveat (detail) (“green”)

Figure 4: Schematic of matrix conceptualisation for identification of viable options for certain components of a management regime. Options are confronted with caveat questions, the responses to which invoke recommendations, cautions, additional considerations or elimination of the option. Traffic light colours may be assigned according to the nature of the invoked caveat.

Table 2: Stepwise process of developing a management regime, which defines the structure of the Guidelines

1. Over-arching issues, pre-requisite information
    a. Legislative/policy context
    b. Allocation
    c. Co-management and community-based management
2. Pre-engagement:
    a. Internal audit of low-value fisheries
    b. ID drivers for management
    c. Clarify the reason for the journey
    d. Identify process of engagement
    e. Understand historical context and conflicts/issues
    f. Undertake desktop analyses: compile and review available information, identify performance indicators and reference points
3. Engagement and elicitation
    a. Generating stakeholder interest/trust to motivate participation
    b. Obtaining ongoing stakeholder engagement and trust/sign-on
    c. Eliciting and weighting multi-sector objectives; develop operational management objectives
    d. Reconciling objectives
    e. Re-review available information
    f. Finalising performance indicators
    g. Finalising reference points
4. Harvest strategy development
    a. Monitoring
    b. Assessment
    c. Harvest control / decision rules
    d. “Fixed” harvest control rules/conditions
5. Selecting and articulating the harvest strategy
    a. Choosing between FishPath options
    b. Challenges in articulating the harvest strategy
    c. Examples of how to being to articulate empirical assessments and decision rules
    d. Formal evaluation of harvest strategy options
    e. Finalise the harvest strategy of choice
6. Implementation
    a. Process for ongoing harvest strategy implementation (day-to-day management)
    b. Define/specify the management plan
    c. Establish the monitoring plan/program
    d. Tactical implementation of the harvest strategy
    e. Compliance and Enforcement
    f. Review process for the harvest strategy

Aim of the Guidelines

These Guidelines should:

- Provide an efficient, transparent, and objective process to formalize engagement and empower decision making.
- Provide a platform for engagement and informed discussion.
- Provide a broader perspective into management regime development (as opposed to recommending and undertaking an assessment).
- Allow for more thoughtful consideration of management regime selection process.
- Be comprehensive with a full inventory of options
- Help to identify what could be done if specific caveats or limitations can be overcome
- Translate the process of developing a management regime into a grass-roots currency and process that is relatable in terms of how fisheries management agencies operate

To achieve the above, it is important to understand that Guidelines typically fail because they are relatively abstract in nature: managers may read something once, but later meet and make a decision that is based on opinion, having forgotten the Guidelines.

In contrast, we aim to provide solutions-focused, direct, go-to advice. These Guidelines detail a process-based pathway, some or all components of which will inevitably need to be confronted regardless as part of a manager's core business.

Australian context

These Guidelines for low-cost management regimes for small-scale, low-value fisheries are cast in the following contexts.

i. Policy and legislation

Australian fisheries, whether Commonwealth- or State-based, are subject to policy or legislative requirements. See Part 1 of the Body of the Guidelines below.

ii. FRDC 2010/061 The National Harvest Strategy Guidelines (Sloan et al. 2014)

This outlines considerations for specific fishery scenarios, including customary/cultural/traditional fisheries.

iii. Joll et al.'s (2015) Australian Fisheries Management Forum (AFMF) report

From a Commonwealth perspective, the following fisheries are considered low-value or data-limited:

- Coral Sea Fishery Aquarium, Beche de Mer, Lobster and Trochus, and Line, Trawl and Trap sectors
- Western Deepwater Trawl Fishery

- North West Slope Trawl Fishery
- Arrow Squid Fishery
- Skipjack Tuna Fishery
- Bass Strait Central Zone Scallop Fishery

These all had harvest strategies established in 2008, in response to the 2007 Commonwealth Harvest Strategy Policy (DAFF, 2007). However, these will all be up for review in response to the upcoming revised Policy and Guidelines.

More generally, many of the more high value Commonwealth fisheries have low-value or data-limited components. The Status of Australian Fish Stocks aims to resolve the status of over 200 species currently designated as “unknown”.

From a state perspective, all jurisdictions are confronted with low-value, data-limited fisheries or fishery components. These fisheries are often multi-sector, multi-gear, or multi-species, which adds additional challenges to management.

International context

More than 90% of global fisheries, representing more than half the global catch, lack adequate data to be managed with statistical estimates of stock status (Costello et al. 2012). Such data-limited fisheries are generally further hindered by limited institutional capacity, infrastructure, personnel, expertise, and resources (Orensanz et al. 2005) to perform quantitative stock assessments and implement robust management actions (Dowling et al. 2015a,b); that is, they are also “capacity-limited”. Furthermore, management paralysis in response to data poverty is a problem that contributes to overfishing risk.

BODY OF THE GUIDELINES

OVERARCHING ISSUES, AND PREFERRED PRE-REQUISITES

In a practical and logistical sense, establishing a formal management regime for low-value, small-scale fisheries is challenging. The following section outlines overarching contextual issues, and preferred pre-requisites, that, consistent with the recommendations of the National Harvest Strategy Guidelines (Sloan et al. 2014), should be at least considered and acknowledged **prior** to developing a management regime.

These Guidelines **do not extend to solving the issues identified in this section** (e.g., social licence and/or sectoral allocation issues). However, these issues have the potential to strongly influence and/or derail the process of management regime development.

Policy and legislation

Australian fisheries, whether Commonwealth- or State-based, are subject to policy or legislative requirements (the outermost ring in Figure 1).

Therefore, in applying these Guidelines, managers

- must comply with The Australian Fisheries Management Act
- need to be aware of precedence and existing Policy
- set harvest strategies in the context of the Harvest Strategy Policy (or equivalent) for the jurisdiction (if one exists).

The Commonwealth Harvest Strategy Policy (DAFF 2007) requires that Commonwealth fisheries have formal harvest strategies and are managed according to a B_{MEY}-based target reference point (where B_{MEY} is the biomass at maximum economic yield), or suitable proxy, and avoidance of a $0.2B_0$-based limit reference point (where B_0 equates to unfished biomass).

State and Territory managed fisheries are subject to their own policies and legislation, but typically these are underpinned by similar requirements for transparent and proactive management, the striving to manage to a target reference point, and the avoidance of a limit.

Another key piece of legislation is the Inter-governmental Agreement of the Environment. This applies regardless of jurisdiction, and

- requires a minimal definition of Ecologically Sustainable Development, advocating a precautionary approach
- provides an underpinning set of objectives.

Sloan et al. (2014) summarised the extent of fishery harvest strategies nationally (their section 5.1.3). They undertook a qualitative snapshot audit of the extent to which the key elements of formal harvest strategies are currently applied in Australia, by Commonwealth, State and Territory

fisheries agencies, including whether pre-determined decision rules have (or have not) been adopted. Box 1 below contains an extract:

Box 1: Extract from the National Harvest Strategy Guidelines (Sloan et al. 2014), summarising the extent of fishery harvest strategies nationally.

> "Based on the data collected, most jurisdictions have management plans in more than three quarters of their fisheries, with Victoria (30%) and the Northern Territory (23%) the exceptions. Because management plans take various forms across fisheries jurisdictions in Australia, the following guidance was provided to fisheries jurisdictions when responding to this issue. "*A management plan may take the form of a statutory instrument or a policy document. A Management Plan should, in its simplest form, describe the fishery geographically, the species being managed, outline the relevant management arrangements/strategies for the fishery including the access arrangements in place, the specific objectives for the species being managed and any measures of management performance that are used.*"
>
> "For some jurisdictions (Queensland, New South Wales and Tasmania), management plans generally do not use target references points and decision rules. Similarly, social and economic indicators are rarely used in Queensland, Victoria and Tasmania, but are frequently considered in Northern Territory, Western Australia, South Australia and New South Wales. Note that all Commonwealth fisheries use the economic reference point of Maximum Economic Yield (MEY) under the Commonwealth harvest strategy policy."

In the context of small-scale, low-value fisheries, the demands of policy and legislation are challenging given the associated data- and/or capacity-limitations.

We reiterate that **many data-limited fisheries will not have harvest strategies that manage against biomass-or fishing-mortality based estimates of maximum sustainable yield (MSY) or maximum economic yield (MEY).** The emphasis must be on providing pragmatic, cost-effective options that are consistent with the intent of the policy and/or legislative requirements.

Have all legislative and/or policy requirements been identified?

Cost

Small scale fisheries can be complex and relatively expensive to manage, particularly when they occur in the coastal environment where stakeholder interactions and tensions tend to be greatest. Increased responsibilities fall on fisheries managers and stakeholders, including certification, environmental requirements, incorporation of explicit social and economic objectives and an increased recognition of the need to accommodate indigenous interests (Joll et al. 2015).

Management and associated costs must match the scale and capacity of a fishery to pay for the attributed costs associated with management.

Consideration may be given to concessions (subsidies) to these fisheries in recognition of public good and community social benefits, but how and on what basis needs to be carefully thought through.

The capacity of stakeholders to engage in formal management processes must also be considered, and all means should be taken to minimise or offset the costs of such engagement.

Risk analysis and risk-cost-catch trade-off approaches should be adopted to determine appropriate levels of science, management and compliance services. (e.g., Dichmont et al. 2016).

The bottom line is that if formal management is to be undertaken, this has associated costs. If "best practice" management is desired, and drivers from this are from the government, environmental pressure, and/or the public, then agencies need to put hard dollars against this. Conversely, if a fishery is deemed worthy of management, then the costs should be accepted as ultimately being offset by long-term benefits.

Managers will need to

- Determine the extent to which an early investment in a solid foundation for formal management (i.e., data collection, assessment, management measures, enforcement) will reduce costs in the longer term.
- Accept that investment in formal management, regardless of the current level of available data and capacity, is preferable to deferring management to a time when "better" data exist.
- Acknowledge that the cost of recovering from overfishing, or fishery collapse (both of which are risks in the absence of formal management), will far outweigh the cost of proactively investing in a pragmatic management regime.
- Ensure that any initial investment in developing a management regime is against a harvest strategy that is affordable into the future (i.e. do not over-capitalise on an overly sophisticated regime that is unable to be practicably maintained).
- These considerations need to be explicitly considered in the pre-engagement strategy.

The potential ramifications of not having a harvest strategy (and noting that these are not just limited to low-value fisheries) include

- overfishing risk
- risk of fishery collapse
- lack of public support
- difficulty in obtaining certification/ export approval
- legal risk
- social risk
- management paralysis, and
- opportunity cost.

Is there agreement on committing to costs of management, both in terms of hard dollars and resources? Does this commitment extend to both management agencies and stakeholders?

Obtaining an a priori estimate of stock status

The priorities or objectives for a fishery are often linked to stock status. For example, an economic objective such as maximising profit is likely to be a higher priority for an under-fished fishery than for one that is over-fished (where the highest priority is to ensure the fishery is sustainably fished).

Prior to a more formal, or comprehensive empirical, assessment of stock status, and particularly in the absence of any past assessments, it is recommended that a risk assessment, such as a Productivity-Susceptibility Analysis (PSA) (Patrick et al. 2010) be undertaken as a prior requirement.

A risk assessment will result in a “harm” or “no harm” classification of the stock status. This, together with other considerations, such as value, relative level of catch, spatial issues, reputational risk (onus to respond), and/or public perception, can be used to prioritise fisheries, stocks and species when committing to develop harvest strategies.

Has a risk assessment been undertaken on the species of interest?

Logistical and philosophical issues

The following is a list of logistical and philosophical issues whose consideration should be pre-requisite to embarking on the development of a management regime for a low-value fishery:

- The extent of infrastructure/agency support for a formal, open and comprehensive process.
- The extent of sectors – if there are many, identifying and obtaining adequate representation is more difficult.
    - A harvest strategy (monitoring, assessment, harvest control rules) should apply to the fishery as a whole. However, monitoring and harvest control rules may be sector-specific.
    - Lack of a clear leader or representative from a sector(s) may be problematic. There may be no “posterchild” candidate within a certain sector.
- Intra- and inter-sectorial conflict has the strong potential to derail the process.
- The need for the process to be bounded by expertise, and the associated costs of engaging with expert(s)
- The possible remoteness of participants, with also possible lack of access to/familiarity with internet and modern communication options.
    - all sectors should be included from the outset in mainstream management regimes, from the point of inception, regardless of geographic or cultural limitations.
- A "one size fits all" mentality, or the notion of simple and generic solutions for data-limited fishery assessments, should be strongly discouraged (Joll et al. 2015 pages 36-37; Dowling et al. 2018). Small-scale fisheries are typically unique in the balance of issues faced, and require a customised, bottom-up approach. While their application may be simple, data-limited assessment methods are context specific and each has its own assumptions and caveats, requiring expert guidance and/or local knowledge. As such, automated or generic packages may often be inappropriate or misapplied.

- Care also needs to be exercised to ensure that the methods used and the estimates produced are robust (to some level), and much more thought is required to adequately represent the (range of) uncertainties in all status determinations. Therefore, regardless of pressure for top-down approaches, due to associated low costs and perceived ease of application, it is strongly recommended that a bottom up approach should be taken to the development of management regimes for small-scale, low-value fisheries.

Where applicable, have logistical issues been discussed, acknowledged, and, to the extent possible, resolved?

Social licence

Managers need to be acknowledge the relative strength of social licence within the fishery, and the influence it may have on, for example, the selection of monitoring and harvest control rule options within a harvest strategy. Indicators of social licence may be used identify its relative strength and to determine whether action needs to be taken in response.

In recent times, social licence has been given an overtly strong platform, particularly with the advent of social media.

The social licence dilemma carries serious risk, and managers must acknowledge this. Given this, there need to be Terms of Reference for developing harvest strategies: that is, the process needs to be bounded by expertise. Users may provide rational input to formal discussions or decision support tools, but have a different opinion outside of a workshop forum.

Has social licence been considered in the context of the fishery?
Have Terms of Reference for harvest strategy development been established?

Allocation

An internal understanding on what allocation will look like by management is needed before engagement is undertaken with stakeholders. It must be stressed **that allocation is not needed to develop a harvest strategy**. A harvest strategy boils down to making decision that determine how much of a stock is to be exploited ("the size of the pie"), while allocation is about how this is distributed among stakeholders ("how the pie is sliced"). That stated, issues around allocation may strongly influence the choice of management options, and be an underlying point of contention throughout the process. Allocation is important, not least because the process of developing subsequent management arrangements is far easier if it has been explicitly addressed.

As such, allocation should ideally be addressed, at least in a blunt manner, prior to developing harvest strategies. Unresolved allocation has the potential to hijack and derail the process. At the very least, an attempt should be made to resolve internal commercial allocation. The discussion around, and development of, a harvest strategy, should be within the bounds of, and acknowledging the issue of allocation, but allocation issues should be otherwise shelved during this process.

If allocation issues are unresolved, this increases the risk of developing a successful management regime.

How should users approach these Guidelines if the issue of allocation has not been addressed?

An inability to resolve allocation should not be used as an excuse to not progress other management reforms. Even if the process of developing a management regime is starting from nothing, there at least needs to be an understood basis for allocation. At the same time, arrangements should be flexible, at least in the first instance, so that allocation does not become a stopping point that halts the process.

The process of allocation resolution should not equate to a large time or financial investment relative to addressing the other management reforms.

In the absence of established allocations, and to avoid impasses, initially blunt measures are probably best (e.g. allocation based on historical precedence, or, an assumed allocation based on the recent catch history). If available, current arrangements may be assumed, while explicitly stating any assumptions (e.g. based on current history but with an awareness that latent shares may be activated).

Beyond an initial, blunt "line in the sand" allocation, it is recommended that changes into the future be via a stakeholder-led process. The intention would be to put the onus of responsibility onto the stakeholders. Any required changes to allocation would have to be proposed via a formal case addressing pre-defined criteria to provide a costing and a justification for the proposed change.

The issue of allocation may not be able to be resolved, and this, together with its associated risk, should be explicitly acknowledged. The same difficulties may apply if re-allocation is occurring, or if new, additional quota is introduced. These would both affect the implementation of a harvest strategy.

For purposes of these Guidelines, we focus on principles structure only. Table 3 identifies broad allocation options, and confronts these with questions invoking caveats and issues that should be considered. Colour-coding against each caveat indicates whether a particular option is recommended or cautioned against, given the caveat.

Have allocation issues been acknowledged?

In the absence of established allocations, have blunt measures been established in the interim?

Work through the matrix of principles structure for allocation.

Table 3: A matrix of principles structure for allocation, confronting universal methods/principles with caveats.

	Universal methods/principles (applicable to inter- and intra-sectoral allocation)			
Caveats	**Equal distribution**	**Proportional distribution (history-based from an agreed point (or points) in time)**	**Mixed model (some proportional, some equal)**	**Primacy (social priority)**
Do legal or policy precedents and determinations exist (e.g. Court decisions that affect allocation)?	Legal precedents, prescriptive legislation/regulation or policy must be taken into consideration and procedural fairness applied.			
Duration - is the intention to provide for short (annual) allocation to address a critical issue (e.g. environmental risk)?		If short term (e.g. to address immediate sustainability or environmental issue) may be preferable to do this to allow active business to persist		Consider social, cultural and economic inflexibility to adapt to change and minimise impact
Duration - is the intention to provide for medium (multiyear) term allocation outcomes (e.g. to address sustainability risk)?			May be preferable to do this to provide some protection to viability for active operators whilst allowing markets to facilitate adjustment	
Duration - is the intention to provide for long (permanent) term allocation outcomes	If medium to long term, and transferability exists may be preferable to do this and allow markets to adjust			based on socio-economic objectives (equity and fairness)
Does exclusivity of right exist in any form?	May erode legal entitlement	May be necessary to ensure maintenance of exclusive right	May be necessary to ensure maintenance of exclusive right	Must take into account exclusivity
Do high levels of certainty (security) exist to facilitate forward planning?	May be preferable where security exists to allow normal market adjustment	May erode security by creating competitive advantage/disadvantage	May erode security by creating competitive advantage/disadvantage	May be relevant to consider this
Does transferability exist, or is it desirable?	May be preferable to allow normal market adjustment	Likely to create competitive advantage/disadvantage	May erode normal market value or create competitive advantage/disadvantage	May provide an opportunity to address social priorities and facilitate inter-sectoral trade
Is divisibility of allocation feasible to allow partial transfer or lease?	May be preferable to allow normal market adjustment	Likely to create competitive advantage/disadvantage	May erode normal market value or create competitive advantage/disadvantage	May provide an opportunity to address social priorities and facilitate inter-sectoral trade

General advice around allocation:

Per Joll et al. (2015) allocation can be

- Explicit – e.g. allocating catch or effort shares between commercial, recreational, charter and indigenous sectors
- Implicit – e.g. creating marine parks or recreational-only fishing areas or seasons (who fishes where and when?)

As with all management regime aspects, successful allocation equates to

- identifying and engaging all stakeholders
- understanding their various values
- seeking agreement and building support for resource sharing options.

For fisheries with indigenous sectors, the National Harvest Strategy Guidelines (Sloan et al. 2014) state “A customary/cultural/traditional fishing allocation should be dealt with before establishing a harvest strategy, so that the harvest strategy can work to meet the allocation. Note that this is not likely to be necessary in jurisdictions where the customary catch is given primacy in legislation over the catch of other fishing sectors.”

Several jurisdictions have developed resource-sharing allocation policies (e.g. South Australia; http://www.pir.sa.gov.au/__data/assets/pdf_file/0003/254523/Allocation_Policy.pdf) and principles (e.g. Western Australia; http://www.fish.wa.gov.au/Sustainability-and-Environment/Sustainable-Fisheries/Sharing%20our%20fisheries/Pages/Allocation-process.aspx). An example of catch allocation process within a multi-zonal, multi-sector, multispecies fishery is provided in the West Coast Demersal Scalefish Allocation Report (see Box 2 below). The process was undertaken by an Allocation Committee.

Box 2: The catch allocation process undertaken for a multi-zonal, multi-sector, multispecies fishery in Western Australia (WA Fisheries 2013)

As an example, WA Fisheries 2013 West Coast Demersal Scalefish Allocation Report details a catch allocation process within a multi-zonal, multi-sector, multispecies fishery. The process was undertaken by an Allocation Committee. The following guiding principles applied:

i) Fish resources are a common property resource managed by the Government for the benefit of present and future generations.
ii) Sustainability is paramount and ecological requirements must be considered in the determination of appropriate harvest levels.
iii) Decisions must be made on best available information and where this information is uncertain, unreliable, inadequate or not available, a precautionary approach adopted to manage risk to fish stocks, marine communities and the environment. The absence of, or any uncertainty in, information should not be used as a reason for delaying or failing to make a decision.
iv) A harvest level, that as far as possible includes the total mortality consequent upon the fishing activity of each sector, should be set for each fishery and the allocation designated for use by the commercial sector, the recreational sector, the Customary sector, and the aquaculture sector should be made explicit.
v) The total harvest across all user groups should not exceed the allowable harvest level. If this occurs, steps consistent with the impacts of each sector should be taken to reduce the take to a level that does not compromise future sustainability.
vi) Appropriate management structures and processes should be introduced to manage each sector within their prescribed allocation. These should incorporate pre-determined actions that are invoked if that group's catch increases above its allocation.
vii) Allocation decisions should aim to achieve the optimal benefit to the Western Australian community from the use of fish stocks and take account of economic, social, cultural and environmental factors. Realistically, this will take time to achieve and the implementation of these objectives is likely to be incremental over time.
viii) It should remain open to government policy to determine the priority use of fish resources where there is a clear case to do so.
ix) Management arrangements must provide sectors with the opportunity to access their allocation. There should be a limited capacity for transferring allocations unutilised by a sector for that sector's use in future years, provided the outcome does not affect resource sustainability.

The Allocation Committee adopted five additional guiding principles:

x) The approach should be pragmatic and incremental;
xi) There was a need to make explicit allocations (as distinct from making a general statement of principle about how allocations should be made);
xii) Allocations should not have the effect of merely deferring a decision indefinitely;
xiii) That until there are re-allocation mechanisms, the Allocation Committee should be cautious in making recommendations that would have the effect of immediately and significantly impacting on a sector; and
xiv) Re-allocation mechanisms should be developed within a specified timeframe, which should be set at not more than five years for west coast demersal scalefish.

As a general summery, options for allocation approaches and considerations include:

- By auction
- By tender
- By ballot
- By existing entitlements
- Based on past precedent (e.g. relative % of historical take – but need to consider over what past time period)
- Equal
- According to historical gear units held – i.e. number of pots, lines hooks
- By closed expert or executive decision
- Discretional allocation or application
- Competitive staking of claims
- Market based
- Informal spatial allocations (per Territorial User Rights Fisheries "TURF")
- Open access
- Number of boats, permits (open or closed fishery)
- Demonstration of intention (e.g. Keel laid by a certain date, gear purchased)
- Within and between sector
- Catch or effort, implicit or explicit

These options and considerations need to be confronted with the following potential caveat-inducing points (noting that this list is not exhaustive):

- Number of participants: low or high
- Number of sectors: few or many
- Amount of latent effort
- Displacement of effort
- Perception of/ faith in equitable process
- History of between- or within-sector conflict
- History of cooperation
- Past precedent: successful or unsuccessful
- Likelihood of fishers to adhere to arrangements
- Whether fishing is opportunistic/has no fixed target species
- Pressure to adhere to legality
- Political drivers - extent (e.g. food security, indigenous livelihood)
- If there is a strong extent of lobbying
- Recreational lobby power
- Potential for derailment by other agencies or non-government organisations
- Sense of fidelity/ right to fish and/or lifestyle and/or for licence
- Whether the current stock status is threatened
- Whether consultative forums currently exist
- Data availability - indicating historical relative catch proportions, and stock status
- Value of species: low or high
- Value of licence or permit
- Whether the target species is/are highly migratory
- The jurisdictional spatial extent versus the spatial extent of the target species

- Management units
- Existing management - input- versus output-based
- The capacity for change and potential for compensation
- The opportunity costs of staying in the fishery versus embracing alternative opportunities
- The extent of economic tension (considering the GVP, and recent trend in profit)

Co-management and community-based management

The extent and nature of co-management is an issue that needs to be resolved (or at least, acknowledged) upfront, and, ideally, prior to the development of a harvest strategy, as per Figure 2.

The need for audit mechanisms must be noted: because of Australian legal structure, regulators have to sign off on the transfer of responsibility. Thus there must be some kind of formal agreement underpinning any shared responsibility for fisheries management. Furthermore, monitoring or auditing would be needed to demonstrate that the co- or community management meets the requirements of the Australian Fisheries Management Act. Establishing management agency support for collaborative approaches to management is also a pre-requisite.

Stakeholders need to undertake their own self-assessment with regard to their potential ability to co-manage. An internal discussion is required to resolve whether they have the capability to accept the associated responsibility and costs.

For co- or community management to be effective, good relationships within and between sectors, and with management agencies is non-negotiable. Per Neville et al. (2008), co-management should be seen as a social process through which the partners gradually and voluntarily establish a close relationship of long-term duration through increased responsibility, commitment and trust.

This stated, it must be acknowledged and cautioned that fishers are typically not a homogeneous group, even within a single community or fishery. Assuming that fishers who drive the uptake of community-based management are representative of the community as a whole, rather than existing elites, can be problematic from a stakeholder buy-in perspective. Successful community-based management is predicated on the following assumptions (Allison and Ellis 2001):

- that the ‘‘community’’ as a group of individuals with fishing-based livelihoods can be effectively defined
- that the community’s administration is pre-occupied with the welfare of fishers and the conservation of fish stocks
- that territorial use rights are compatible with the behaviour of both the fishers and the targeted stocks.

Allison and Ellis (2001) point out that the concept of ‘community’ is rarely defined or carefully examined. It is assumed that if communities are involved in conservation, the benefits they receive will create incentives for them to become good stewards of the resource. “Community” is often seen in one of three ways: a spatial unit, a social structure, and a shared set of norms, and all these definitions can be problematic.

There is a current National Guidelines for co-management of fisheries (Neville et al. 2008). Within the Guidelines, fisheries co-management is defined as “an arrangement in which responsibilities and obligations for sustainable fisheries management are negotiated, shared and delegated between government, fishers, and other interest groups and stakeholders” (Neville et al 2008).

This definition reflects the increasing recognition among fishers and fisheries managers alike of the need for a cultural change — away from a confrontational "them versus us" approach to one of partnership in seeking to achieve a common objective of shared responsibility for the sustainable use of the resource. The definition also encompasses the key factor of delegation of functions to fishers, which many other co-management models do not envisage (Neville et al. 2008).

At least some degree of co-management, if not community management, is strongly recommended as a pragmatic way forward for low-value, small-scale fisheries, both from the perspectives of empowering and engaging fishers and stakeholders, and potentially saving costs. Case study literature resoundingly emphasises that management stands the greatest chance of success when there is a sense of ownership and buy-in from participants. Moreover, case study fisheries where top-down management has forcibly replaced community-based management have shown poor outcomes from both economic and sustainability perspectives (e.g. Hind et al. 2010).

An additional obvious perceived advantage of a lesser emphasis on institutional management is reduced financial costs – albeit, the issues of what constitutes "cost", and who wears these costs under co-management, are ones that will need to be resolved: co-management may be more cost-effective from an agency perspective, but not necessarily to stakeholders.

However, per Neville et al. (2008) "although there may be functions for some fisheries that could be delivered more cost-effectively, the more substantial and long-lasting gains in management will be made through enabling more direct involvement of fishers in, and fishers' responsibility for, making management decisions. Additionally, co-management could institute a more responsive and flexible process to fine-tune management decisions in a more timely fashion in the face of a fast-changing environment — particularly the changing economic environment. This conclusion arises from the reality that Management Advisory Committees (MACs) always include close scrutiny of costs of management and often approve budgets for fisheries. Further, for most fisheries, research and development, and compliance items account for between 75 and 80 per cent of the total costs. Given the overheads and infrastructure needed to operate these functions across a number of fisheries, it is impossible for stakeholders to achieve economies of scale to deliver such functions, particularly in a single fishery or circumstance.

"No doubt opportunities for greater cooperation exist in these areas and should be pursued if they can result in some cost savings. However, the ….most important issue is how decisions are made about the priorities to be focused on — not simply the delivery of functions related to those priorities. Therefore, greater involvement of fishers in making these decisions would have the effect of delivering better management, more cost-effectively." (Neville et al. 2008).

"Having said this……..fisheries agencies should continue to work towards greater transparency and a common language and definitions in identifying and recording the costs of fisheries management. This alone would enable direct comparisons and more informed debate about the costs of delivering fisheries management functions and the possible benefit that could arise from co-management." (Neville et al. 2008).

The National Guidelines state that "fisheries management arrangements vary in the degree of delegation for day-to-day management decision-making across a continuum. It is convenient to characterise them into four models", as per Box 3 below:

Box 3: Extract from the National Harvest Strategy Guidelines (Sloan et al. 2014), summarising the four models of management decision-making.

1. "Most fisheries commence under a centralised "command and control" framework in which government takes full responsibility for almost all management decisions, with little or no consultation with fishers and other stakeholders.
2. The progression towards co-management starts with the establishment of a consultative model in which management decisions are discussed and debated. However, the majority of management decisions are still made by the government or management agency.
3. The consultative arrangement may mature into a collaborative model, in which decision making is negotiated and shared between government and fishers, fisher organisations and other stakeholders with some decisions, such as fishing times or area closures, assigned to fishers or fisher organisations.
4. Under a delegated model, agreed, negotiated management decisions are made by governments, fishers, fisher organisations and other stakeholders within a broad framework and agreed functions are undertaken, or services delivered, by a fisher organisation under a formal agreement. Operating in this way within a broad regulatory framework is achievable when all pre-conditions for delegation to a fisher organisation have been met to the satisfaction of all parties."

Neville et al.'s (2008) Table 2 shows the change in performance of functions through management types, and postulates the activities that might be delivered by industry or fishers under a co-management model, under ideal circumstances.

Table 4 outlines options and associated caveats for co-management and for community management. These co-management categories roughly align with the four models described above, but we concentrate on the extremes. Specific options around community-based management are also considered. Again, colour-coding indicates whether a particular option is recommended or cautioned according to each caveat.

For the Australian context, only the "co-management" options, and the "traditional/cultural" option under "community management" are applicable (with the exception of Torres Strait where there is the potential for community management generally (but noting that this is not driven from a developing nation context).

Neville et al. (2008) provide an outline of steps to guide implementation of co-management (Box 4).

Box 4: Neville et al.'s (2008) steps for implementing co-management

Step 1: Birth of an idea
Start talking
Fishers or government decide to start a dialogue on co-management.
Action by: fishers, government, fisheries agency.
Form group
Core group of like-minded people formed and mutually acceptable spokesperson or "champion" selected.
Action by: fishers, government, fisheries agency.
Identify resources
Resources identified to enable preparation of a detailed proposal.
Action by: fishers, government, fisheries agency.

Step 2: Business case
Plan
Draft a business case showing desired outcomes, funding responsibilities and advantages of a co-management model and its form.
Action by: fishers, government, fisheries agency; with expert assistance.
Gain support

Negotiate acceptable level of support among fishers to proceed.
Action by: fishers (with expert assistance), fisheries agency.
Cover everything
Refine the business case to ensure coverage of all issues.
Action by: fishers (with expert assistance), fisheries agency.

Step 3: Acceptance and commitment
Seek government acceptance
Approach government formally for in-principle acceptance of the business case.
Action by: government; fishers (with expert assistance).
Refine
Refine business case through due-diligence study of proposed content and requirements.
Action by: fishers (with expert assistance), fisheries agency.
Achieve wider acceptance
Negotiate wider acceptance and commitment by fishers, other stakeholders and community.
Action by: fishers (with expert assistance), fisheries agency.

Step 4: Legal structure
Set up the structure
Develop an accountable legal structure for a fishers' organisation or company.
Action by: fishers (with expert assistance).
Amend legislation
Amend fisheries legislation, if necessary.
Action by: government.
Develop governance
Develop memorandum of understanding and contractual arrangements incorporating functions to be delegated, performance standards, accountability processes (auditing, reporting etc.) and funding responsibilities.
Action by: fishers (with expert assistance), government, fisheries agency.

Step 5: Implementation
Delegate functions
Government delegates functions to fishers' organisation with a legally binding instrument containing agreed conditions.
Action by: government, fishers' organisation, fisheries agency.
Deliver
Fishers' organisation ensures delivery of functions among members.
Action by: fishers.
Report
Reporting against standards commences, auditing protocols commence; on-going reviews occur as necessary.
Action by: fishers, fisheries agency.

Has a self-audit been undertaken on the ability and scope for co-management, considering the current capability to accept the associated responsibility and costs, and acknowledging any legislative restrictions?

Has the extent of homogeneity within a community group been considered?

Work through the matrix of co-management and community management options and caveats. This should be used to help stakeholders determine where they want to be in terms of actively contributing to the formal management of their fishery.

Table 4: Co-management and community management options and caveats

Caveats		Co-management			
		100% agency-based: no stakeholder involvement	Centralised: minimal stakeholder/strong agency (old/traditional model)	Collaborative (e.g. equal stakeholder/agency)	Fully delegated: strong stakeholder / low agency
Social/cultural basis/precedent/tradition	If strong and activities/arrangements not causing conflict or adversely affecting stock	N/A	N/A		May work well to defer to this
	If strong and activities/arrangements are causing conflict or adversely affecting stock	May be preferable, but may be higher propensity to not adhere/misreport	May be preferable, but may be higher propensity to not adhere/misreport		May need to work hard to change long-held beliefs and still have participants retain a sense of ownership
What do stakeholders/managers wish to wear in terms of cost? Here are the perceived relative costs to agencies (NB incentive for co-management)		Higher	Higher	Intermediate	Lower
Trust of industry of management process - belief/buy in	If low	May be higher propensity to not adhere/misreport	May be higher propensity to not adhere/misreport		May be difficult if proposed arrangements are causing conflict and/or adversely affecting stock
	If high	N/A	N/A		More likely to succeed
business acumen/bigger picture capability of industry	If high	N/A	N/A		More likely to succeed
	If commercial, or a high-take sector, AND this is low	May be preferable	May be preferable		Exercise caution (less relevant for subsistance or indigenous fishers)
sense of responsibility - who is accountable?	If low among sectors	May be preferable	May be preferable		Less likely to succeed
strength of agency (to do co-mgt at all)	If low	Less likely to succeed	Less likely to succeed		May be preferable
Extent of multiple sectors	If high, but level of conflict is low, level of engagement is high, and/or objectives are compatible or easily reconciled.	May be preferable	May be preferable		May work
	If high,and conflict exists, level of engagement is low, and/or competing objectives	May be preferable	May be preferable		Less likely to succeed
mixed gear fishery = complexity	If so	May be preferable, yet same challenges apply	May be preferable, yet same challenges apply		May be harder to obtain representative body, and more difficult to reconcile decisions amongst gears
multispecies/opportunistic - objectives differ by individual = complexity	If so	May be preferable, yet same challenges apply	May be preferable, yet same challenges apply		May be more difficult to reconcile decisions amongst species
Climate of cooperation and trust	If low from industry (i.e low maturity/readiness)	May be preferable	May be preferable		Less likely to succeed
	If low from government	Less likely to succeed	Less likely to succeed		May be preferable

Table 4 cont'd.: Co-management and community management options and caveats

Caveats		Co-management			
		100% agency-based: no stakeholder involvement	Centralised: minimal stakeholder/strong agency (old/traditional model)	Collaborative (e.g. equal stakeholder/agency)	Fully delegated: strong stakeholder / low agency
What does consensus look like for stakeholder endorsement?	If low	May be preferable	May be preferable		Less likely to succeed
Integrity of auditing/reporting	If high	N/A	N/A		More likely to succeed
	If low	May be preferable	May be preferable		Less likely to succeed
Institutional capacity to administer (as a priority)	If low	Less likely to succeed	Less likely to succeed		May be preferable
Efficiency and flexibility as benefits to industry (is this an industry priority?)	If so	May be delays due to bureacratic process	May be delays due to bureacratic process		May be preferable providing appropriate infrastructure exists to optimise efficiency and flexibility.
Can you delegate powers under relevant legislation?	If not	Most realistic	Most realistic	May work if final decisions rest with agency	Required
Existing fishery associations/cooperatives/networks - is there onground organisation in place?	If yes	Not recommended as stakeholders likely to wish to be at least consulted	N/A	More likely to succeed	More likely to succeed
	If no	May be only option	May be preferable	More difficult to establish mangament	More difficult to establish mangament
Is there an existing consultation forum/formal communication process to engage stakeholders?	If yes	Not recommended as stakeholders likely to wish to be at least	N/A		More likely to succeed
	If no	May be only option	May be preferable	May be a good compromise	May be more difficult
Extent of environmental stewardship/responsibility among fishers	If not strong, and relevant fisher group(s) account for a significant component of the total effort	May be preferable	May be preferable	May be a good compromise	Caution against meeting environmental objectives
Is there a clear allocation of resources in the fishery (if yes, much easier to co-manage, because everyone knows what they need to manage against).	If no	May be preferable	May be preferable	Required	Required
	If yes			Required	Required
Is there strong viscosity and/or lack of political will in responding to the need for management change? (speaks to the need to have the ability to lead through lack of consensus, and on basis of firm principles as opposed to "this was a push from industry"/ Clear long term direction (certainty) provided by governance structure	If yes	May be preferable	May be preferable	Required	Required
	If no			Required	Required
Is the area of the fishery small/tiny?	If yes			May be preferable	May be preferable
Is the number of participants low (<50)?	If yes			May be preferable	May be preferable
Is the community in a defined, fixed geographic area? (hence increased sense of ownership, social licence issues)	If yes			More likely to succeed	More likely to succeed

Table 4 cont'd.: Co-management and community management options and caveats

Caveats		Community management						
		Traditional/ cultural	Engaging stakeholders and partners in how to manage	Capacity development needed?	Access rights only?	TURFS/ ranching	self- enforcement	Informal (as opposed to formal)
Social/cultural basis/precedent/tradition	If strong and activities/arrangements not causing conflict or adversely affecting stock	May work well to defer to this	May be challenging if seen to be "interfering" with existing arrangements	N/A	May work well	May work well	May work well	May work well
	If strong and activities/arrangements are causing conflict or adversely affecting stock	May need to work hard to change long-held beliefs and still have participants retain a sense of ownership	May need to work hard to change long-held beliefs and still have participants retain a sense of ownership	May need to work hard to change long-held beliefs and still have participants retain a sense of ownership	May need to work hard to change long-held beliefs and still have participants retain a sense of ownership	May need to work hard to change long-held beliefs and still have participants retain a sense of ownership	May need to work hard to change long-held beliefs and still have participants retain a sense of ownership	Caution against lack of formal arrangements in this context
What do stakeholders/managers wish to wear in terms of cost? Here are the perceived relative costs to agencies (NB incentive for co-management)		Lower	N/A	Moderate-high if required	Lower	Low-moderate	Lower	Lower
Trust of industry of management process - belief/buy in	If low	May be difficult if proposed arrangements are causing conflict and/or adversely affecting stock	More difficult	Requires improved communication and education of benefits of management	Less likely to succeed but may be more appropriate than more detailed management arrangements.	Less likely to succeed	Less likely to succeed	Caution against lack of formal arrangements in this context
	If high	More likely to succeed	More likely to succeed	N/A	May work well	May work well	May work well	May work well
business acumen/bigger picture capability of industry	If high	More likely to succeed	Easier to engage	N/A	May work well	May work well	May work well	May work well
	If commercial, or a high-take sector, AND this is low	N/A	May be challenging	May require capacity building	Less likely to succeed but may be more appropriate than more detailed management arrangements.	Less likely to succeed	Less likely to succeed	Caution against lack of formal arrangements in this context
sense of responsibility - who is accountable?	If low among sectors	Less likely to succeed	May be challenging	N/A	Less likely to succeed	Less likely to succeed	Less likely to succeed	Unlikely to succeed
strength of agency (to do co-mgt at all)	If low	May be preferable	Who engages?	Who is responsible?	May work well	May work well	May be a more viable alternative to agency-based enforcement	May be only pragmatic option
Extent of multiple sectors	If high, but level of conflict is low, level of engagement is high, and/or objectives are compatible or easily reconciled.	May work	N/A	N/A	May work	May work	May work	N/A
	If high,and conflict exists, level of engagement is low, and/or competing objectives	Less likely to succeed	May be challenging	N/A	Less likely to succeed	Less likely to succeed	Less likely to succeed	Less likely to succeed
mixed gear fishery = complexity	If so	May be harder to obtain representative body, and more difficult to reconcile decisions amongst gears	May be harder to obtain representative body	N/A	Easier than more detailed management arrangements	May be difficult to define appropriate spatial delineations	May be more difficult than for single-gear fisheries	May be more difficult than for single-gear fisheries
multispecies/opportunistic - objectives differ by individual = complexity	If so	May be more difficult to reconcile decisions amongst species	N/A	N/A	Easier than more detailed management arrangements	May be difficult to define appropriate spatial delineations	May be more difficult than for single-species fisheries	May be more difficult than for single-species fisheries
Climate of cooperation and trust	If low from industry (i.e low maturity/readiness)	Less likely to succeed	More difficult	Requires improved communication and education of benefits of management	Less likely to succeed but may be more appropriate than more detailed management arrangements.	Less likely to succeed	Less likely to succeed	Unlikely to succeed
	If low from government	May be preferable	Who leads process of engagement?	N/A	May work well	May work well	May be a more viable alternative to agency-based enforcement	May be a more viable alternative to agency-based enforcement

Table 4 cont'd.: Co-management and community management options and caveats

Caveats		Community management						
		Traditional/ cultural	Engaging stakeholders and partners in how to manage	Capacity development needed?	Access rights only?	TURFS/ ranching	self- enforcement	Informal (as opposed to formal)
What does consensus look like for stakeholder endorsement?	If low	Less likely to succeed	More difficult	N/A	Less likely to succeed	Less likely to succeed	Less likely to succeed	Less likely to succeed
Integrity of auditing/reporting	If high	More likely to succeed	N/A	N/A	N/A	N/A	N/A	N/A
	If low	Less likely to succeed	N/A	Capacity building required	N/A	N/A	N/A	Less likely to succeed
Institutional capacity to administer (as a priority)	If low	May be preferable	Who leads process of engagement?	N/A	May work well	May work well	May be a more viable alternative to agency-based enforcement	May be a more viable alternative to agency-based enforcement
Efficiency and flexibility as benefits to industry (is this an industry priority?)	If so	May be preferable providing appropriate infrastructure exists to optimise efficiency and flexibility.	N/A	N/A	Affords more flexibility than detailed management arrangements	N/A	N/A	May afford more flexibility, but may also be more risky
Can you delegate powers under relevant legislation?	If not	Required	N/A	N/A	Required	Required	Required	N/A
Existing fishery associations/cooperatives/networks - is there onground organisation in place?	If yes	More likely to succeed	Easier to engage	N/A	More likely to succeed	More likely to succeed	More likely to succeed	More likely to succeed
	If no	More difficult to establish managment	More difficult to establish engagement	May wish to work to build this	More difficult to administer	More difficult to administer	More difficult to administer	More difficult to administer
Is there an existing consultation forum/formal communication process to engage stakeholders?	If yes	More likely to succeed	Easier to engage	N/A	More likely to succeed	More likely to succeed	More likely to succeed	More likely to succeed
	If no	May be more difficult	More difficult to establish engagement	May wish to work to build this	May be more challenging to help establish	May be more challenging to help establish	May be more challenging to help establish	May be more challenging to help establish
Extent of environmental stewardship/responsibility among fishers	If not strong, and relevant fisher group(s) account for a significant component of the total effort	Caution against meeting environmental objectives	Need to be aware of this when engaging	Requires improved communication and education of benefits of environmental stewardship	Caution given lack of environmental stewardship and flexibility afforded by this form of management	Caution re: area designations, given lack of environmental stewardship	Unlikely to work well against environmentally-driven management controls	Unlikely to work well against environmentally-driven management controls
Is there a clear allocation of resources in the fishery (if yes, much easier to co-manage, because everyone knows what they need to manage against).	If no	Required	More difficult	N/A	Required	Required	Less likely to succeed	Less likely to succeed
	If yes							
Is there strong viscosity and/or lack of political will in responding to the need for management change? (speaks to the need to have the ability to lead through lack of consensus, and on basis of firm principles as opposed to "this was a push from industry"/ Clear long term direction (certainty) provided by governance structure	If yes	Required	Need to be aware of this when engaging	N/A	Required	Required	May be more challenging to help establish	
	If no							
Is the area of the fishery small/tiny?	If yes		May be preferable		May be preferable		May be preferable	May be preferable
Is the number of participants low (<50)?	If yes		More likely to succeed	More likely to succeed	More likely to succeed		More likely to succeed	More likely to succeed
Is the community in a defined, fixed geographic area? (hence increased sense of ownership, social licence issues)	If yes	More likely to succeed	More likely to succeed		More likely to succeed	More likely to succeed	More likely to succeed	More likely to succeed

Ecosystem-based risk assessment

Ecosystem-based fishery management (EBFM)-style risk assessment (resulting in “harm”/”no harm” classifications for each ecosystem component) is an important upfront undertaking. These risk assessments also consider the economic and social elements of the fishery.

Outcomes of such an assessment are critical in informing and tailoring harvest strategy development: any identified threats have the potential to limit the fishery’s activities (e.g. due to conservation, environmental, and/or ecosystem-based-management legislation and/or concerns). These need to be explicitly acknowledged and addressed within the harvest strategy. For example, a gear may have the potential to damage habitat, or to incidentally catch a highly vulnerable species. In such cases, measures such as (for example) spatial and/or gear controls (against the former), and catch limits and/or move-on provisions (against the latter), can be included as proactive mitigation measures against the perceived threats.

There are several ways to undertake and EBFM-style risk assessment and there are clear Guidelines to this process elsewhere (e.g. Hobday et al. 2007). The most inexpensive is to undertake a preliminary risk assessment, and then finalise risk ratings in consultation with stakeholders (this was the process used in South Australia). Alternately, risk ratings can be elicited directly from stakeholders. This requires that stakeholders understand the risk assessment process (which can be problematic for stakeholders from low-value fisheries, particularly if there are cultural, language or literacy constraints), and typically takes at least a day to complete.

It should be noted that, for some very data-limited fisheries, risk assessments may be the only form of stock assessment available.

Has an ecosystem-based risk assessment been considered or undertaken?

Moving forward

Managers need to ensure that the fishery’s historical context and conflicts/issues are well understood. This may be challenging given past issues and poor past precedents. Moreover, in some instances there may be issues or conflicts that are insurmountable. This does not provide an excuse to avoid the development of a management regime, but the process will be strengthened by open acknowledgement and a realistic appraisal of such issues and conflicts.

Managers need to acknowledge past problems upfront, and work to build trust. This will require time and resources. Examples of problems can include (Joll et al. 2015 p61):

- latent effort
- effective controls on catch
- economic efficiency constrained as excess effort erodes benefits
- lack of certainty in future management measures
- poorly defined property rights = little incentive for stewardship
- assumed rights.

Resolution may be sought via (for example)

- "carrot and stick" approaches, whereby the incentive to collectively overcome issues and disputes outweighs penalties (Stanley et al. 2015)
- bringing in external leaders and/or independent chairs
- empowering stakeholders
- (should be an underlying principle, but, as a last resort) mediation via fair and equitable treatment.

Should these fail, then there must be acceptance either of a management regime that will not be optimal for all parties, and/or heightened risk in the absence of appropriate management. If there exists one or more impasses, there should be an agreed, reasonable timeframe within which to try to fix these issues or conflicts, before giving up and making decisions without stakeholder consultation. This may be a separate and dedicated process, with extra cost.

Regardless:

- Decisions will still have to be made against legislative requirements
- A management regime can still be developed in the absence of stakeholder, or bottom-up, engagement.
- There cannot be a simple "get-out" clause as an excuse to give up. There must be evidence that the maximum efforts have been dedicated to attempting to reconcile problematic issues.

Prior to entering into the management regime development process, stakeholders should explicitly identify key pre-requisites and potential "sticking points" upfront.

- **Identify any problems/"roadblocks"/"deal-breakers" that may prevent the process going forward**

- **Determine whether any identified issues can be realistically overcome (in some instances, resolution may not be possible), and agree upon a timeframe within which to attempt to resolve these.**

PRE-ENGAGEMENT

"Pre-engagement" process

Prior to commencing a formal process of engagement with stakeholders, it is critical to dedicate time and effort to considering the following issues. Failure to do so will compromise the effectiveness of the engagement process.

- Identify drivers for management (e.g. industry-driven, legal, certification needs, public perception, top-down pressure [if don't do it yourself, someone else will do it for you]). These sets the tone for the direction of management and assists with the engagement process.
- Who is driving the change? Is it forced by government (i.e. due to legislative change or an environmental need), or desired by industry (e.g. from a desire to expand the fishery, or because an opportunity to improve has been identified)?

Joll et al. (2015) suggest that the process of developing formal management works best is there are strong external driver(s) for change, or a firm legislative mandate to develop the fishery under a revised approach.

There are three main drivers for management change.

i) The first is in response to high level overarching legislative or policy requirements for Australian fisheries, whether Commonwealth- or State-based. These will be different for each jurisdiction, but there are some that will be consistent across jurisdictions such as the Commonwealth environment legislation (the Environment Protection and Biodiversity Conservation Act 1999; http://www.environment.gov.au/epbc); the United Nations (UN) Convention on the Law of the Sea (1982; http://www.un.org/depts/los/convention_agreements/texts/unclos/unclos_e.pdf); the FAO Code of Conduct for Responsible Fisheries (FAO 1995); or the National Strategy for Ecologically Sustainable Development (ESD) (Fletcher et al. 2002) and National Fisheries By-catch Policy (1999; http://www.agriculture.gov.au/SiteCollectionDocuments/fisheries/environment/bycatch/national-bycatch-policy-1999.pdf). Compliance to these legislative or policy requirements is typically driven by the government.

   For instance, the implementation of the South Australian Fisheries Management Act 2007 (https://www.legislation.sa.gov.au/LZ/C/A/FISHERIES%20MANAGEMENT%20ACT%202007/CURRENT/2007.4.UN.PDF) required under section 44 that all South Australian fisheries have a formal management plan. This legislative requirement was a major driver in introducing harvest strategies for all major fisheries in this state. Similarly, the Commonwealth Harvest Strategy Policy (DAFF 2007) required that all Commonwealth fisheries have formal harvest strategies and are managed according to a B_{MEY} based

target reference point, or suitable proxy, and avoidance of a 0.2B0 based limit reference point.

Changing the management regime in response to an overfished stock (and thereby abiding by the legislative requirement that all fisheries are fished sustainably) is also the responsibility of the government. For example, the WA government dedicated $14.5 million to assessing all of its fisheries for Marine Stewardship Council (MSC) certification. Those fisheries that wished to progress to the next level of MSC certification developed an improved harvest strategy.

ii) The second type of driver of change is when relevant stakeholders initiate the development of a management regime to improve and expand their fishery. A good example of this initiative by industry to develop and implement a formal harvest strategy is in the Northern Territory Offshore Snapper Fisheries. This was motivated by the desire to optimise their chances of MSC certification, which would allow product to be exported to Europe.

iii) The third driver is the potential for improved fishery performance (over the long term) resulting from an internal audit.

It is important to establish who is driving the process for management regime change because this will impact on engagement process and associated costs, and strongly influence the probability of management success.

Is the impetus for management change being driven by stakeholders, by the government in response to a legislative/policy change, or by an internal audit demanding improved performance?

The process is simpler when it is driven by stakeholders. This is because they are already motivated, engaged in the process, and likely understand that to expand and improve fishery performance typically requires additional resources (such as the implementation of a more detailed monitoring program to improve catch and effort data, or through the use of VMS to ensure compliance to new management measures).

Resistance to change in a management regime is likely to hinder when the process is driven by the government, especially if the stakeholders are currently happy with the status quo. Under these circumstances, it is common for the stakeholders to challenge the need for the proposed changes, particularly when dealing with a low value fishery. This resistance is often attributable to a fear that such changes could result in more restrictive licence conditions, or in increased management fees.

If the drivers of this change are from the government, environmental pressure, and/or the public, then management agencies need to put hard dollars against this. When the push for change is from industry wanting to expand the fishery, there is likely to be more support in terms of participation in the process and providing funds. If the driver is a fisheries manager who has found feasible options that could improve the management of this fishery in their internal audit, then industry will need to be convinced of the benefits. The extent of agency support for a formal, open and comprehensive process will then need to be decided.

Any change management has associated costs. Management and associated costs must match the scale and capacity of the fishery. Consideration may be given to concessions (subsidies) to fisheries in recognition of public good and community social benefits, but how and on what basis needs to be carefully thought through. However, the bottom line is that if a fishery is deemed worthy of management, then the costs should be accepted as ultimately being offset by long-term benefits.

The following steps should be undertaken:

1. Clarify the reason for the journey (provide clarity under different circumstances). Otherwise, any engagement process is likely to be met with apathy ("why are you doing something for no reason?"). Be aware of any history of over-consultation, with too much paper, most of which may have left stakeholders feeling worse off. There needs to be a perceived value against any investment.

   The drivers for formal management have to at least be acknowledged by, and, at best, come from, stakeholder groups. This may be challenging given past issues, and poor past precedents. The parties driving the change should be transparent. Managers need to acknowledge past problems upfront, and work to build trust. This will require time and resources.

2. Management agencies need to consider the adoption of harvest strategies in the context of co-management versus a top-down approach. This affects the manner in and method by which stakeholders are engaged, where to begin, and how engagement is funded. That is, managers need to clearly understand the "authorising environment".

3. Ensure that the fishery's historical context and conflicts/issues are well understood.

4. The process of stakeholder engagement (per Part 1), if done properly, is time consuming and costly to achieve. This should be tempered by cost.

   If engagement is likely to be hostile ([perceived to be] forced by government), then funds will need to support a subsequent formal process, that may be more protracted. If engagement is more likely to be "lukewarm" (with acknowledgement of the potential to change for the better), or supported (industry want to expand) then there must be the support of the agency to drive the change.

The above points can be achieved and/or informed by:

- Having conversations with stakeholders (without any other required investment), to ask: "What's going on? What do you want?"
- Identifying a "posterchild" via similar case studies elsewhere to demonstrate the efficacy of formal management and harvest strategies.
- Emphasising to stakeholders that formal management is currently in a development phase (and that have a unique opportunity to help shape this).
- Following a "Pre-engagement engagement" obtain the agreement to adopt a management regime in writing (e.g. against change in government) (and especially if no legislative requirements exist).

Have pre-engagement communications gauged the current "state of play" of the fishery, and people's willingness to engage in formal management process?

Compile and review available information

Punt (2017) suggested it is prudent to conduct a data inventory before initiating, or at the start of, the stakeholder consultation process, to ensure that there are sufficient data, so that there is some chance of reliably predicting the consequence of management strategies.

- Define the fishery to which the harvest strategy applies

Defining the fishery to which the harvest strategy and broader management regime will apply is a critical initial step in determining the scope of the harvest strategy to be developed (per National Harvest Strategy Guidelines, Sloan et al. 2014). This step involves compiling and reviewing all available information on the fishery. It is designed to set the scene and provide the information necessary for the more specific steps that follow to develop a harvest strategy (Dowling et al. 2015b). It provides a basic description of the fishery and its current management arrangements, including any management objectives and the measures that are in place (or might be available) to control catch or effort in the fishery. It also reviews the data that are available for key target species, and in particular tries to identify data that might be informative about the current status of the resources. Wherever possible, data should be sought that are informative about stock status or trends in abundance and/or exploitation rate (Dichmont et al. 2011).

Defining the fishery is often challenging for data-limited fisheries. Not all this information will be used in developing and implementing the harvest strategy, but it will form the basis for the harvest strategies options. Data gathering is more challenging for artisanal fisheries (such as the Torres Strait Beche-De-Mer Fishery; Plaganyi et al., 2013).

For multispecies fisheries, defining the fishery also involves identifying which species will be directly considered by the harvest strategy. Indicator or "key" species may be selected, typically according to their volume by catch, value, or level of identified risk. The remainder of the species would be assumed to be managed vicariously through monitoring and assessing only the indicator or "key" species. Alternatively, similar species may be grouped as "basket" species, with an awareness that species composition changes within the basket will not be detected within the harvest strategy.

In compiling information, stakeholder workshops can be useful in identifying and evaluating data (Dowling et al. 2015a).

Listed below is a summary of the five key information categories that should be considered (Dowling et al. 2016, with sub-points from the National Harvest Strategy Guidelines (Sloan et al. 2014)) (Table 1):

i) Available fishery dependent and independent data (quantitative or qualitative)

ii) Biological/life history attributes of relevant species:

   a. Identify the life history characteristics for each species;
   b. Identify any ecological impacts caused by fishing, including any threatened, endangered, or protected species (TEPS) interactions;
   c. Identify any environmental effects on the fishery.

iii) Fishery operational characteristics:

a. Identify the target species, geographical (management unit) and biological stock boundaries;
b. Identify all stakeholders and sectors;
c. Identify the method(s) of fishing such as gear type, vessel numbers and vessel type;
d. Identify the location of fishing, taking note whether there have been spatial changes over time;
e. Determine all sources of mortality.

iv) Socio-economic indicators and characteristics:

a. Identify user groups, including any information on catch shares;
b. Identify whether multiple jurisdictions need to be involved.

v) Governance context:

a. Identify the (formal or informal) existing management arrangements in terms of the management framework currently in use (whether input or outputs controls are used, including any spatial management), the jurisdictions involved, any regulations, compliance arrangements, and what management levers can be used to constrain fishing mortality.

At the same time as mining for data, it is important to identify the strengths and weaknesses of the data (Dichmont et al. 2011). For example, catch rate data is often used as an index of abundance, so it is worth considering whether this is indeed proportional to abundance. However, where substantial changes to the nature or spatial extent of the fishery may have occurred, it is important to ask questions such as:

- Are there changes in the species that are targeted over time?
- Has the gear type changed substantially over time or space?
- Has the species composition of the catch (if known) changed?
- Have fishers moved further from port or the initial fishing grounds over time?

Similar changes may also affect interpretation of other fishery dependent data such as the size composition of the catch, which is sometimes used to make inferences about exploitation rate.

By definition, information availability and/or technical capacity are typically low for data-limited fisheries (with technical capacity issues being typically more pronounced in developing fisheries or nations), increasing the importance of eliciting data, knowledge, and information from stakeholders and local experts.

Information may not be formally recorded, and as such appropriate and thorough communication is paramount. Data gathering is more challenging for artisanal fisheries. Logbook systems are atypical; information is usually obtained from fisher interviews, market-based records, and/or surveys (Dichmont et al. 2011). For indigenous sectors, specific and unique data needs should be considered, and tailored data collection methods established. Directly involving fishers in the process of information gathering is strongly advisable in these contexts.

It is important to use as many relevant sources of data and information as possible and, in the data-limited context, innovative approaches can be useful. This means that disparate sources of

information from management agencies, ports, landings, enumerators at markets, processors, fishers, local communities and import/export dockets can all be useful when combined (Dichmont et al. 2011). A good example of using many of these sources can be found in Blaber et al.'s (2005) research outcomes and management scenarios for shared stocks of snappers in Australia and Indonesia..

Information from similar fisheries elsewhere or from published meta-analyses such as FishBase (http://www.fishbase.org/) may be useful (noting that FishBase was recently evaluated in Thorson et al. (2014), who found that data entered was high quality, but imputed values were questionable) (Dowling et al. 2015a).

Internal audit of low value fisheries (e.g., using FishPath)

Managers should now proceed to undertake an internal audit of all their low-value fisheries, for example, by using the FishPath decision support tool (see Part 2 for a detailed description of the FishPath tool). The information collated for the fishery will inform the FishPath questionnaire. While the FishPath process will be repeated when developing formal harvest strategies in conjunction with stakeholders (per Part 2 below), the aim of the internal audit is to enable managers to:

- Broadly identify the types and extent of monitoring, assessment and decision rule options that may be available for their fisheries. This also enables managers to develop "straw men" harvest strategies prior to entering a full stakeholder engagement process. Managers should not use these "straw men" as overrides, or to dictate the harvest strategy development process, but rather as guidance and foresight in leading the process.
- To ascertain the extent of overlap in identified options between species and fisheries (this may provide some practical common ground from which to move forward).
- To obtain an understanding of the limitations of their available information or their fisheries, whereby the main limiting caveats are explicitly identified. As such, to focus and hone discussion on the appropriate issues within the fishery.
- To ensure that managers within a jurisdiction are proceeding from a common, standardised platform.

Identify possible performance indicators

Having identified and compiled the available data, the next step is usually to analyse the data in various ways to produce "indicators" that are informative about changes in the resource or the fishery (Dichmont et al. 2011). Performance indicators are (usually quantitative) measures that conveytrends in the status of a resource (e.g. its abundance or how heavily it is being exploited) (Dichmont et al. 2011; Sloan et al. 2014, Box 5). They are a key component of any harvest strategy as they are at the heart of the adaptive management cycle that defines the "detect and correct" management process. More specifically, they are indicators of risk that are the measures used to "detect" that things may be straying off course, while the harvest control rules are used to "correct" and get things back on track. Obtaining good indicators for data-limited fisheries can, ironically, be extremely difficult (Dichmont et al. 2011).

Critical analysis of possible indicators should be undertaken, including identifying those that have been used successfully in other fisheries and harvest strategies. Several FAO technical reports provide guidance on development and use of indicators for fisheries management (see FAO 1999). It will generally be helpful to have statistical expertise available at this stage, combined with

experience in analysing and interpreting the various sorts of data typically available in data-limited fisheries (Dichmont et al. 2011). If such expertise is not readily available, there are some good basic texts on analysis and interpretation of fishery data (e.g. Haddon 2011a).

Box 5: Extract from the National Harvest Strategy Guidelines (Sloan et al. 2014), describing performance indicators.

A performance indicator is a quantity that can be measured and used to track changes with respect to achieving an operational objective (Fletcher et al. 2002). Performance is measured by comparing where a performance indicator sits in relation to a reference point.

An example of a surrogate performance indicator is yearly commercial catch per unit of effort (CPUE; kilograms per pot lift) of Southern Rock Lobster, which is used by all Southern Rock Lobster fisheries in southeast Australia as an index of lobster abundance. The operational objective, indicator, and reference point form a package (Fletcher et al. 2002). Each of the three components of the package is essential to properly define and interpret an indicator and one or more reference points may form part of the system of measuring performance.

It is important that when choosing performance indicators, the data used to estimate them is also defined, to ensure clarity and certainty and avoid any changes in relation to the application of a harvest strategy. A guide to the development, use, evaluation and reporting of indicators for fisheries management is provided by FAO Fishery Resources Division (1999) and the National ESD Reporting Framework (Fletcher et al. 2002).

For many fisheries, much can be learnt from the results of analyses for similar fisheries elsewhere or from published meta-analyses, particularly about the biological characteristics or productivity of particular species (Dichmont et al. 2011). Meta-analysis joins the results of several studies on a particular topic into a systematic review. Similarly, research undertaken across a suite of species in a relevant region can be useful (e.g. sharks in Indonesia where most biological dynamic parameters are described – Blaber et al. 2009). This process can add enormously to the information base for a data-limited fishery. However, it is important to take into account the uncertainty that using data from other sources can bring to the process. For example, species in the same genus can sometimes have very different life history characteristics. In such cases, a more precautionary approach should be applied in developing a harvest strategy that relies on such information (Dichmont et al. 2011).

If a critical analysis does not result in identification of any suitable indicators (which may arise in extremely data-limited situations), then it may not be possible at that point in time to develop a formal harvest strategy for that fishery (Dichmont et al. 2011). The approach in this case should be to try to identify ways in which monitoring and data collection can be improved, with a view to providing the data that will allow development of suitable indicators. In the meantime, it would be prudent to prevent further expansion of catch or effort levels in the fishery until suitable data become available. One approach is to identify a set of trigger levels for catch or effort, where each time a trigger is reached, further collection or analysis of data is required. Such an approach can be built into a formal harvest strategy framework for a developing fishery.

Examples of indicators

Performance indicators can be direct measurements of performance, or surrogates (Fletcher et al. 2002). Examples include:

(direct)

- Fishery-dependent or fishery-independent estimates of abundance or density

(indirect)

- Fishery-dependent estimates of abundance or density
- Catch – by species, gear, area, sector
- Effort – by time, space, gear, sector
- Catch-per-unit effort – by species, across all species, by time, space, gear, sector, size-specific component of the catch
- Spawner-per-recruit
- Mean, median, upper or lower percentile size (length or weight) – by time, space, gear, sector, species
- Catch composition – by time, space, gear, sector
- Proportion of large, "optimal sized", mature, small fish in the catch – by time, space, gear, sector, species

Other advice

Multiple indicators are preferable for data-limited fisheries: one indicator may detect what another may not (e.g. estimates of overall density may not detect recruitment overfishing, whereas size estimates may). There is more information from indicators in combination (e.g. given the same density, if the size of large animals is increasing, things are in a better place than if the proportion of large animals is decreasing). Multiple indicators can also counter-check each other (some indicators may lag while others show immediate responses to change; CPUE and independent surveys may corroborate or contradict one another in estimating abundance)

Performance indicators for the recreational sector, where applicable, should be explicitly considered. The National Harvest Strategy Guidelines (Sloan et al. 2014) state: "An important step in designing a recreational fishery harvest strategy is translating measures of utility or satisfaction into catch-related operational objectives and measurements. One simple approach is use strike rates as targets, which is conceptually similar to using catch rate targets. In general, maximum sustainable yield is appropriate for subsistence fishing while maximum recreational utility (e.g. measures of aggregate satisfaction with the fishing experience) is appropriate for others.

"Where possible, broad objectives should be translated into simple operational objectives in terms of measures such as strike rate or catch rate. The objectives of different sub-sets of stakeholders in recreational fisheries can also differ and these differences need to be reconciled in the process. Fishery managers need to consider how to incorporate the range of stakeholder views into the design process. Recreational surveys consistently show that the majority of the catch is taken by a small percentage of 'avid' anglers who may have quite different objectives to the majority of anglers. For example, recreational fishers who fish mainly for pleasure, have diminishing marginal utility with catch, which is to say they receive less benefit from the last fish caught than from the first fish. This affects the development of performance indicators and reference points for this group and means for them that strike rate would be weighted higher than total catch. One way of bringing the diversity of objectives together into something measurable is to use recreational utility as a performance indicator – recreational utility is maximised by a large number of recreational fishers having an enjoyable fishing experience. The measurement of a recreational fisher's enjoyment is related to whether the fishing trip was successful, the strike rate and the size of the fish, etc. As with commercial fisheries, performance indicators that relate directly to fishing, and the decisions that flow from measuring those indicators, are more likely to be supported by fishers than indirect and technically complex indicators."(Sloan et al. 2014).

Identify possible reference points

If useful indicators have been identified, the next step is to identify reference points associated with these indicators (Dichmont et al. 2011). Reference points are particular values of indicators. In general, there are two types of indicators: 1) those that provide guidance on whether management objectives are being met (target and limit reference points); and 2) those that are used to guide a change in the harvest strategy (trigger points) (Dichmont et al. 2011). Some reference points can serve both purposes, but it is useful to keep the two separate purposes in mind in selecting reference points for indicators. A useful list of reference points can be found in (FAO 1999).

Reference points are essentially 'benchmarks' of performance and are linked to defining acceptable levels of biological impact on a stock or the desired social and/or economic outcomes. In this context, the operational objectives and reference points need to be explicitly linked (Sloan et al. 2014).

Limit reference points

Limit reference points (LRPs) are values of indicators that represent conditions that do not meet management objectives, and are values to be avoided. They are, therefore, thresholds of risk (Dichmont et al. 2011).

The National Harvest Strategy Guidelines (Sloan et al. 2014) provide the following definition (Box 6); noting that the described target metrics are often unattainable for data-limited fisheries. If a data-limited fishery has been known to have been in a poor state in the past, then the LRP can be set at the value of a proxy indicator corresponding to that period of time (Dichmont et al. 2011).

Box 6: Extract from the National Harvest Strategy Guidelines (Sloan et al. 2014), defining limit reference points.

Limit reference points (LRPs) define the values of an indicator for a fish stock or fisheries management unit that are no longer considered acceptable. Limit reference points have been typically associated with operational objectives that are tailored towards biological sustainability rather than economic or social objectives and therefore mostly relate to whether the stock is recruitment overfished and therefore likely to put the stocks upon which the fishery is based at unacceptable risk (FAO Fisheries Resources Division 1999; Fletcher et al. 2002; Davies et al. 2007; Flood et. al 2012).

In assessing fish stock status nationally, the Status of Key Australian Fish Stocks Report (Flood et al. 2012) adopted 'recruitment overfished' as the biological limit reference point for determining whether or not a fish stock is overfished. Recruitment overfished was defined as *"the point at which a stock is considered to be recruitment overfished is the point where the spawning stock biomass has been reduced through catch, so that average recruitment levels are significantly reduced"* (Flood et al. 2012). …… There are cases where limit reference points can be set above biological sustainability values to meet economic or social standards.

The *Commonwealth Fisheries Harvest Strategy Policy* stipulates that the limit reference point for biomass is equal to or greater than half of the biomass estimated for maximum sustainable yield (MSY), which defaults to 20% of the unfished biomass where BMSY cannot be calculated (Australian Government 2007). In practice, the default value is widely used as it can be difficult to measure BMSY accurately, and notional values can place limit reference points at very low levels.

Target reference points

Target reference points (TRP) are values of indicators that correspond to a desirable state of the fishery and are important in providing a goal towards which the decision rules need to move the fishery (Dichmont et al. 2011).

The National Harvest Strategy Guidelines (Sloan et al. 2014) provide the following definition (Box 7); however, note that the described target metrics are often unattainable for data-limited fisheries:

Box 7: Extract from the National Harvest Strategy Guidelines (Sloan et al. 2014), defining limit reference points.

> Target reference points (TRP's) define the values of an indicator for a fish stock or fisheries management unit that are desirable or ideal and at which management should aim (e.g. high catch rates, high long-term average yields). They typically relate to desired economic and/or social outcomes. A common economic objective is MEY. Target reference points for MEY are generally based on harvest rates, biomass targets or biomass proxies such as CPUE. The economic data required for establishing MEY targets are not always available, in which case proxies such as 1.2*BMSY, where BMSY is the biomass that delivers MSY, can be used. This is applied to Commonwealth fisheries, as determined in the *Commonwealth Fisheries Harvest Strategy Policy* (Australian Government 2007). Historical levels of CPUE that occurred during periods of high economic yield have also been used as target reference points.

If indicators that are proxies for biomass or exploitation rate have been identified and are being used, then the target levels might correspond to levels that support maximum sustainable yields (MSY) or other agreed objectives for the fishery (economic or social objectives). If a time series for the indicator is available, a common approach in data-limited fisheries is to select a time in the past when the fishery was thought to be in a good state and close to meeting its objectives, and set the TRP to the value of the indicator at that time (Dichmont et al. 2011).

Trigger reference points

Trigger reference points (TRPs) are levels of an indicator, usually a stock status indicator, at which a change in management is considered or adopted. Trigger reference points play a particularly important role in harvest decision rules, where they identify a point (such as a biomass level) at which a substantial change in the exploitation rate occurs (Sloan et al. 2014).

Trigger points can be used in two ways in harvest strategies. Where useful indicators have been identified, they are values of those indicators that correspond to some important change in how the fishery is managed (a change in the decision rule). For example, if an indicator of stock status is being used, and a TRP and LRP for that indicator have been identified, a trigger point might be a value of the indicator half way between the TRP and LRP that signals a need to take precautionary action to stop the fishery getting too close to the undesirable LRP (Dichmont et al. 2011). One example of trigger points is in the Great Australian Bight Trawl Fishery, where trigger catch levels have been set for several by-product species (Harrap et al. 2010). Trigger levels are precautionary to alert on possible increased pressure or targeting on by-product species: the catch exceeding the trigger initiates an increased research program to pre-emptively collect more data so that quantitative stock assessments could be undertaken in the future (e.g. if catch exceeds a further, higher trigger) (Sloan et al. 2014).

The second use of trigger points is in fisheries where it has not been possible to identify useful indicators (Dichmont et al. 2011). These triggers would be levels of catch or effort that signal the need to collect more information on the fishery to allow the development of useful indicators. This use of triggers is particularly helpful in new or developing fisheries, to help control the rate of

expansion of the fishery to make sure that the information and data available can assist in a safe development process (Dichmont et al 2011). A trigger system typically involves setting multiple levels for each trigger, with each level invoking an increasing strength of response in terms of data collection and analysis, with further expansion halted until such information becomes available (Dichmont et al. 2011). Braccini et al. (2006) describe an analogous multi-level hierarchical risk assessment that allows for a management response at any level.

In some circumstances a graded management response is appropriate as stock sizes reduce. This may involve a series of progressively more stringent management actions as a sequence of trigger reference points are exceeded (Sloan et al. 2014). However, if the stock falls below the limit reference point, drastic action (such as closure of the fishery) would be appropriate, until such time as the stock recovers. The intent of the graded response is to prevent the need for such drastic action. This graded approach, including reference triggers and reference limits, assists in reducing management shocks to a fishery. They lead to more orderly adjustments to fishing intensity and associated business activity when minor changes to the fishery are needed to respond to changes in stock size, while also providing for a substantial management response when required to recover stocks (Sloan et al. 2014).

Response to reference points

When monitoring and assessment indicate that the indicator reaches a trigger point or falls above the target reference point or below the limit reference point, pre-determined management actions should occur, consistent with established harvest strategy decision rules (Dichmont et al. 2011).

Note that that not all reference levels are a specified amount, for example in the case of data-limited or multi-species fisheries, reference levels may instead refer to trends (e.g. if catch exceeds the historical catch for 3 consecutive years, then a management action is triggered).

Performance measures

Performance measures are indicator values relative to some reference point. Punt (2017) provides the following guidance (Box 8):

Box 8: Punt's (2017) guidance on performance measures

Measures used to evaluate the performance of alternative candidate management strategies should be chosen so that they are easy for decision-makers and stakeholders to interpret. Standard deviations or coefficients of variation of catch limits are difficult for many stakeholders to understand. Experience suggests that stakeholders find it much easier to relate to performance measures, such as the fraction of years during which catch is less than some desirable level, than more complex metrics, such as standard deviation of catch over time. There should not be a large number of performance measures.

It may help the decision process if decision-makers can agree on acceptable performance for each performance measure (or at least a subset of those). Acceptable values for performance measures may reflect goals established by policy. For example, the Australian harvest strategy policy (DAFF, 2007) specifies that there be 10% chance of a stock being below the limit reference point (which is generally set at 20% of the unfished spawning biomass, i.e. 0.2B0).

It is easy to select too many performance measures, many of which will be highly correlated. The decision-making process is made considerably simpler if performance measures can be reduced to the smallest number possible. Care should, however, be taken to explain why a proposed performance measure is not presented even if it is scientifically obvious, because a decision maker may feel "deceived" if "their" performance measure is discarded.

Regarding non-commercial sectors, the National Harvest Strategy Guidelines (Sloan et al. 2014) advise that:

- for indigenous sectors - if the level of take by this sector is very low, it is questionable whether limit reference points and performance indicators need to apply.
- for recreational sectors - if the fishery is multi-sector, biological limit reference points for the recreational fishery can be established based on data collected in the commercial fishery.

Examples of performance measures

The following is a summary of performance measures used for Pacific Sardine, per Punt (2017):

- *Average catch (all years)*
- *Standard deviation of catch (all years)*
- *Average catch (all years for which the catch is non-zero)*
- *Standard deviation of catch (all years for which the catch is non-zero)*
- *Mean biomass (spawning and 1+ biomass)*
- *Standard deviation (spawning and 1+ biomass)*
- *Percentage (1+) biomass > 400 000 t*
- *Percentage of years with no catch (or catch below 50 000 t)*
- *Median catch (all years)*
- *Median biomass (spawning and 1+ biomass)*
- *Average number of consecutive years with zero catch*
- *How often the exploitation rate is set to its minimum/maximum value*
- *Average number of consecutive years the exploitation rate equals its minimum/maximum value*
- *Mean age of the population*
- *Mean age of the catch*
- *Mean and maximum number of consecutive years in which catch <50 000 ta*
- *Mean and maximum number of consecutive years in which 1+ biomass <400 000 t*

Other performance measures summarised by Punt (2017) include:

Target species (catch and profit):

- *Catch*
- *Catch variability*
- *Catch relative to need*
- *Probability catch < threshold value*
- *Lowest catch*
- *Probability of catching big fish*
- *Number of consecutive years catch <threshold value*
- *Average size of catch*
- *Catch rate*
- *Catch rate relative to the reference catch rate*
- *Discounted catch/revenue*
- *Costs (research, enforcement)*
- *Profit*
- *Profit variability*

- *Profit per tonne/per unit effort*
- *Catch composition (maximum*
- *proportion of one species)*

Target species (population size):

- *Biomass*
- *Biomass relative to unfished biomass*
- *Biomass relative to reference biomass*
- *Biomass relative to initial biomass*
- *Lowest biomass relative to unfished biomass*
- *Lowest biomass*
- *Probability of local depletion*
- *Probability biomass < (or >) threshold value*
- *Number of consecutive years biomass < (or >) threshold value*

Bycatch species/threatened species:

- *Biomass of non-target species*
- *Number of at-risk species*
- *Biomass of at-risk species*
- *Probability of species at risk*
- *Interactions with threatened species*

Other ecosystem components and fishing community impacts:

- *Public image*
- *Proportion of total habitat fished*
- *Biomass relative to unfished*
- *Predator numbers/biomass*
- *Employment*
- *Access and distribution equity among sectors and ports*
- *Conflict among sectors*
- *Effort*
- *Displaced effort*
- *Amount of quota trading*

Additional:

- *Changes in species composition ratios*
- *Changes in key target species*
- *Changes in mean, upper, or lower percentile weight or length relative to some reference value*
- *Catch, CPUE, or effort relative to some historical high level*
- *Size-specific CPUE or proportion of fish of certain size in catch relative to those at spawner potential ratio (SPR) target level (e.g. 40% of the SPR corresponding to that at unfished levels)*

<u>Prior to commencing the below engagement process:</u>

Have available data been compiled and reviewed?

Has an internal audit been undertaken, to broadly identify potential harvest strategy options, and to establish a common platform for proceeding?

Have performance indicators, and corresponding target, trigger (where appropriate) and limit reference points, been identified?

Having completed these desktop tasks and analyses will help identify an appropriate stakeholder engagement strategy, and will bring greater focus to the task of developing a harvest strategy.

PART 1: ENGAGEMENT

Engagement and elicitation

The following process is a step-by-step guide to optimise the chance for successful engagement with stakeholders.

a. Identify stakeholders and establish appropriate points of contact

First, the composition of the stakeholder group that the management regime directly applies should be identified.

Managers should establish appropriate points of contact, guided by the following:

- Identify who best to approach first. Options could include
    - Scientists
    - Executive Officers of Fishing Associations (particularly, those who are well versed with fishery complexities and who have the respect of the fishers)
    - Community, local, or indigenous leaders
    - Wives of small fishery business owners
- Identify fishery or community "leaders"/ advocates for management
- Identify appropriate locations (from perspectives of practicality, fisher cooperation, existing programs, safety [in terms of work place and sampling])
- Establish working group of earmarked participants (could be the "leaders")
- Acknowledge any existing or perceived local or cultural sensitivities (e.g. participants may not be internet-savvy, English may be second language, there may be an entrenched distrust of government)

The stakeholder set and any related working group should include members from the following groups, where applicable:

- Commercial sector
- Recreational sector
- Charter sector
- Indigenous sector
- Decision makers / management agencies
- Conservation agencies

Relevant parties from the following stakeholder groups should be identified, may also be considered and consulted, and should certainly be informed, but may not necessarily be directly involved in the development of a management regime:

- Non-government organisations
- Associated businesses
- Consumers
- Members of the public

Engagement will depend on who is driving the change in management, and the political will. If change is being forcibly driven, then all relevant stakeholders (including environment, NGOs, recreational, indigenous) need to be involved, and the consultation process needs to be formal. If the push for change is from industry to expand the fishery, or around the potential improvement in the management of the fishery, the engagement process is likely to be less formal, and more focussed on the commercial, recreational, and indigenous users, at least in the first instance. Regardless, but particularly for the latter circumstances, management should focus on identifying industry "champions". These "champions" are often motivated and can get the rest of industry (if they are indifferent or resistant) on-board.

Ideally, the group with whom to engage should comprise engaged, willing and transparent stakeholders, including active fishers who have evolved to cooperate in a proactive environment for the greater good. Additionally, there should be sufficient maturity and respect within stakeholders to enable self-regulation of any voluntarily imposed conditions (Joll et al. 2015).

Has an Engagement Strategy been developed?

b. Generating stakeholder interest/trust to motivate participation

Once a set of stakeholders has been identified, there are two challenges to overcome:

- First, interest must be generated among stakeholders so that they see the value of management and are motivated to be involved. **This will largely depend on having an appropriate pre-engagement process, as outlined above.**

- Beyond this initial engagement, ongoing active input and commitment must be sought and obtained.

In the first instance, this equates to "getting the right people in the room" and having them see the value of management – that is, having them acknowledge a need for change. The identified stakeholder set must be incentivised via a belief in the need to act. Ideally, this needs to occur **prior** to entering in to any discussions or plans against a management regime (per "Clarifying the reason for the journey" in the above (Pre-Engagement) section).

History has repeatedly shown that obtaining stakeholder buy in and trust from the outset is critical to the long-term success of management regimes. Generally, this works best in a face-to-face, workshop-style context. The cost of overcoming logistical constraints of attendance is usually far outweighed by the benefit of achieving adequate representation.

- Face-to-face engagement is important, but especially with culturally sensitive or indigenous sectors
- If internal conflict exists, an external facilitator may help (this is more costly, but beneficial in this context)
- Generally, the communication/facilitation role is expensive, but crucial. The associated short-term costs may be high and time consuming, but these confer long-term savings via improved engagement.

The following issues should be considered to optimise the chances of success:

Provide adequate motivation for management

As stated in the "Pre-engagement" section, the "need for change", and as such, the reason for the journey and the value against any investment must be clarified. The drivers for formal management have to at least be acknowledged by, and, at best, come from, stakeholder groups:

- Efforts to improve management need to be perceived not as a threat, but as an opportunity.
- Emphasize the provision of a process towards improvement, rather than any perception of a complete change.
- Consider market incentives/benefits to help make the overall management strategy appealing.

Provide adequate background to explain formal management and its benefits, as well as defining key terms and concepts.

This can be undertaken prior to a group workshop, but is typically more effective when done as a workshop opening. The dissemination of background material may occur within one meeting, or it may require two or more workshops. Adequate and understandable information on the issues should be provided, and meaningful discussion and participation encouraged:

- The process needs to be direct and iterative with stakeholders
- Managers need to articulate the environment of HOW the dissemination of this information occurs. This should be formalised in an engagement strategy.

Where possible, content should intentionally be kept general: the intent is to gain an in-principle understanding of the advantages of formal management.

All terminology should be defined and explained in lay terms. Such terminology includes (but is not limited to):

- "harvest strategy" (with emphasis that this is NOT about the micro-management of fishers' day-to-day activities and decisions)
- "management regime"
- "stock assessment"
- "monitoring"
- "harvest control rules", "decision rules"
- "performance indicators"
- "reference points", "target reference points", "limit reference points"
- "overfished", "overfishing"

See the glossary of the National Harvest Strategy Guidelines (Sloan et al. 2014) for further terms.

The style of presentation is paramount. Concepts should be presented succinctly, and, where possibly, pictorially.

Emphasis should be placed on

- What does it mean to the fishery/sector?

- What does it mean to me?
- Why does it matter?

A more comprehensive approach should be taken to defining a harvest strategy. In addition to the above questions, the following should also be addressed:

- What is required from me (as a stakeholder)?
- How can I (as a stakeholder) get involved?
- What flexibility is there?
- What might a harvest strategy look like for our data-limited fishery?
- How can a harvest strategy still be developed in the absence of a formal, model-based stock assessment?

Communication tools and packages should be considered to help deliver the above.

Box 9 below summarises advice from Joll et al. (2015; p63) regarding the engagement process.

Box 9: Extract from Joll et al. (2015) providing guidance on the process of stakeholder engagement.

Ensure messages

- are consistent in content; avoid "divide and conquer".
- are adaptive.
- do not rely solely on presenting facts with expectation that target audience will support management based on those facts.
- are delivered at level digestible by all audience members.
- targeted to the values of audience and their concerns.

Gain community confidence (e.g. independent peer reviews, engagement of community champions).

Employ strategies to gain a better understanding of community values and concerns.

Invest in establishing productive relationships with all relevant sectors of the community.

Consider mutually beneficial linkages with community programs.

Use examples of good news stories from similar contexts to encourage confidence.

Know the fishery and have an on-the-ground presence to build relationships/legitimacy.

Defend the process.

Addressing expectations (from all sides)

Stakeholder expectations should be addressed and managed from the start. In particular:

- Discuss and clarify amongst all parties what collaboration among stakeholders is expected to achieve. Avoid problems of false expectations.
- Be transparent about the process, and ability and extent to which stakeholders will be able to engage
- Discuss and clarify the anticipated or expected level of stakeholder contribution to outcome, while being open about the importance and ramifications of involvement. Emphasise the benefits of a higher level of contribution (information input, objective

elicitation, ownership, sense of trust and belief) as well as the costs (time commitment, possible lost time fishing)
- Be transparent regarding the perceived and desired benefits and outcomes
- If pertinent, emphasise to managers and stakeholders the absence of a “magic bullet”/single factor solution.
- Emphasise time scale as a key axis; be realistic about the timeframe within which to effect changes.

Allow adequate time and opportunity to take questions, defuse tangential issues, and obtain consensus.

- The time required for this is valuable, yet is commonly underestimated.
- While such sessions should be tightly chaired, stakeholders should be given full opportunity to air concerns and issues, so that this may be appropriately addressed or re-directed from the outset. Complication of issues can undermine or derail the process.
- While tangential issues should be acknowledged, they should ultimately be shelved.

Mutual respect and understanding should prevail

From a logistical perspective:

- There should be respect for stakeholder business constraints and obligations (time is money).
- Identify whether stakeholders have the capacity and capability (time, knowledge, skill, resources) to engage effectively.
- Recognise existing skills/experiences and build on these.
- Recognise existing peak bodies and their present and future capacities.
- Cover costs to attend meetings.
- Be flexible when deciding on locations and timings for consultative forums.

During engagements:

- Acknowledge that many stakeholders may wish to improve their well-being and/or avoid penalty in the short-term, without considering longer-term implications, and/or without willingness to engage to achieve long-term goals.
- Be aware that stakeholders “may not know that they don't know”.
- Respect the known unknowns, the known knowns and the unknown unknowns.
- Have awareness that stakeholders may be weary of repeated attempts from outsiders to manage their fishery.
- Be cognisant of differences of language and attitude and adapt processes to suit
- Acknowledge all sectors
- Recognise indigenous interests. Specifically (per P64 Joll et al. 2015)
    - The need for increased engagement.
    - Understand the needs/aspirations/structure of local indigenous communities.
    - Maintain cultural awareness.
    - Distinguish between customary and commercial fishing.
    - Acknowledge that increased resourcing may be required.

Work on the basis of a bottom-up approach

- Seek to understand the general nature of the fishery from a fisher, management and scientific perspective, via identifying
    - available data, life history/biology of key species
    - fishery operational characteristics
    - the socio-economic/governance "mood"
- It may help to begin with a more casual, open-ended exchange, before honing in on more focused questions to inform possible management options. The emphasis should be more on listening and reading between the lines, rather than forcing stakeholders through questionnaire-style hoops (e.g. per those in automated decision support software).

Consider information outreach

This needs to be culturally appropriate and socio-economic demographics need to be considered:

- The internet and mobile communication means may not be appropriate options for all stakeholders. For certain stakeholder groups, they may be the preferred means of communication.
- English may be a second language.

Social media may be highly effective but also needs to be carefully administered.

Seek past examples of process and success.

It is important to consider and include all stakeholders, not just workshop participants.

Have stakeholders been engaged via a bottom-up approach? Are stakeholders motivated to be involved in the process of formal management, and do they have realistic expectations?

c. Obtaining ongoing stakeholder engagement and trust/sign-on

The emphasis here is on maintaining ongoing active input and commitment from stakeholders: that, beyond motivating their involvement, they are signed on to the process of developing and implementing a management regime.

Obtaining ongoing stakeholder engagement and trust underpins all of the management regime process steps that follow.

The following are recommended actions:

Be upfront about the nature of outcomes

- Explain that outcomes are typically a trade-off of short term "quick" gains versus long term benefits
- Emphasise the absence of a "magic bullet"/single factor solution.
- Be explicit about uncertainty, particularly in the data-limited context, and about the corresponding need to be precautionary.

- Be accountable for decisions made.

Empower stakeholders by incorporating local knowledge

Where appropriate, empower fishers and, where the process is being led by an external facilitator, or a senior manager, managers by incorporating their local knowledge and capacities in some way.

  - Involve stakeholders from the start, as per the previous section.
  - Where appropriate, identify a core working group of key stakeholders
  - Provide periodic feedback throughout the process (including in-progress or partial outcomes) so that stakeholders, particularly fishers, can actively participate and see how their input is incorporated.

Incorporation of local knowledge helps to impart a sense of ownership. Transparent uptake of feedback is advantageous: for example, live (i.e. in front of stakeholders and in response to their feedback) updating/changes to decisions or processes engenders trust. However, managers should not promise incorporation of local knowledge. In many instances, local knowledge may only serve as a source of validation and/or provide context.

Identify a case study species (if applicable) to which to apply the management regime in the first instance

- Seek to develop a "posterchild" case study of assessment or management implementation.
- The choice of initial case study should ideally be one that is minimally contentious, whilst still a relevant priority.

Reiterate the incentives/benefits to remaining engaged

- Emphasise a process for improvement as opposed to complete change
- Ensure that the emphasis is on providing direct and pragmatic, bottom-up advice via a transparent process, using non-subjective criteria
  - The process is not "at arm's length" or top-down
  - The process is solutions-focussed
- Consider "artificial" interim incentives or rewards (i.e. external to increased profitability, or direct fishery benefits) (such as reduced licence costs, provision of ice, or other such benefits).
- Where appropriate, apply lessons from case studies of similar fishery "archetypes", and/or use past examples from similar situations as a means of demonstrating the efficacy of a formal management approach.
- Explain that there can be social and economic disincentives to disengaging from the process (e.g. ostracision)

Maintain ongoing communication and foster the relationship with the same local colleagues: the process should be iterative over repeated visits. Building trust and respect is paramount.

Establish formal communication channels, ideally through existing means.

- Ensure that these are culturally appropriate
- Provide a comfortable platform for all to remain engaged
- Identify ways to reach out to a broader participant base (NGOs can provide bridges in this context)

- Exercise cultural awareness using appropriate expertise and reputable people.

Ongoing two-way communication should be maintained into the future, with the manner of ongoing communication formalised. Questions to consider include:

- How often to touch base with stakeholders?
- What does this contact look like? (Meetings, phone/Skype, social-media-based, website-based?)

What will NOT work/things to avoid:

- A one-off visit, short course, or a "short-term fix" mentality
- Top-down approaches - e.g.
    - non-locals dictating to locals (collaborative relationships with mutual respect must be fostered), and/or presupposing that they can "fix" the fishery
    - attempting to impose a data-rich perspective
    - viewing data-rich assessments as a "gold standard" to which the fishery must aspire
    - blanket application of a "toolbox" " (whether this equates to a process for management strategy selection, or a suite of automated assessment models) rather than a process
- An approach presumptively advocating a particular form of assessment
- Recommendations without taking account of socio-economics/governance issues
- Failing to acknowledge the unique, and potentially challenging, aspects of the fishery and country context concerned
- If stakeholders cannot experience or be convinced of the benefits of the approach
- A lack of ongoing discussion of progress with stakeholders

Has stakeholder buy-in/sign-on been achieved?

d. Eliciting and weighting multi-sector objectives

Setting clear and measureable objectives for management is critical for all fisheries management processes. Objectives may include the "triple bottom line" of economic, environmental/ecological/sustainability, and social objectives, as well as governance/institutional objectives.

For a management regime to perform optimally, all possible objectives need to be elicited from stakeholders. The importance, and potentially, the complexity of eliciting objectives should not be trivialised or underestimated. Given the multi-user aspects that characterise inshore small-scale fisheries, there is heightened importance to define and prioritise management objectives, ensuring there are adequate indicators and monitoring processes to assess whether or not the objectives are being met (Joll et al. 2015).

Developing clear and measurable objectives for small-scale fisheries can be a complex task. Any one rule or a "one size fits all" approach is unlikely to be successful and there may be competing or conflicting objectives between fisheries or between sectors (Joll et al. 2015).

That said, managers should not be daunted at the prospect of setting objectives. In addition to the below guidance, the following tools are helpful:

- Ogier et al.'s (in prep) inventory of objectives for Australian fisheries.
- Triantafillos et al.'s (2014) list of social objectives ranked by all jurisdictions on their importance. (In the absence of clear social objectives, managers could select one or two that were ranked highly by all jurisdictions).

Objectives have the following tiers:

- Relevant legislation and overarching policy objectives

The first tier is defining all higher-level objectives for the fishery. All subsequent objectives should be formulated with acknowledgement of existing legislative or policy requirements and, hence, existing objectives. This is done by identifying relevant legislation and overarching policy objectives. In Australia, this includes: Commonwealth environment legislation (the Environment Protection and Biodiversity Conservation Act 1999), the United Nations (UN) Convention on the Law of the Sea (1982), the FAO Code of Conduct for Responsible Fisheries (FAO 1995), the National Strategy for ESD, and the National Fisheries By-catch Policy.

For Australian Commonwealth fisheries, objectives are defined by the Commonwealth Harvest Strategy Policy (Rayns, 2007). However, the difficulty for data-limited Australian fisheries lies in reconciling these objectives, which are based on biomass-based limit and target reference points (the limit biomass B_{lim}—proxies 0.5 BMSY or 0.2B0; and the target biomass B_{MEY}, the biomass at which economic yield is maximized—proxy $1.2B_{MSY}$), with the available information (Dowling et al. 2015a). Where information is limited, a pragmatic approach to developing defensible proxies must be taken.

- Medium-term management objectives

These are the short- to medium-term management goals for the fishery. They are determined in the first instance by managers, against the legislative and overarching policy objectives.

- Conceptual fisheries management objectives

Higher level objectives may be translated into guiding 'conceptual' fishery management objectives, usually contained within fishery-specific management plans, which are designed to be relevant at the fishery-specific level and to 'guide' management of individual fisheries, consistent with the overarching legislation (Sainsbury and Sumalia 2003). Alternatively, in some jurisdictions, such conceptual objectives may be contained in overarching policies.

Conceptual, or strategic, objectives should be defined and agreed upon by the various stakeholders early on in the development of a harvest strategy, because they directly influence the management options suitable for the fishery (Dowling et al. 2011). This should be done as a formal process that is clear, comprehensive and unambiguous. These conceptual management objectives take into consideration the scope of the fishery, ESD status, and results of any ecosystem-based risk assessment.

- Strict operational objectives

To be included in a management strategy evaluation, conceptual objectives need to be converted into operational objectives (expressed in terms of the values for performance

measures). This usually involves translating each conceptual objective into one or more operational objective(s) and performance measure(s) (Punt 2017).

The process of articulating the objectives needs to be undertaken for each sector at the same time as there is potential for conflict between ecological, social and economic objectives. Ensuring all three are considered together enables identification of any trade-offs or conflicts, and agreement on how to prioritise issues across the three types of objectives.

Whether the objectives are expressed in conceptual or operational currencies is irrelevant in the first instance. The emphasis must be on obtaining an open and honest set of objectives that are adequately representative of the views of all stakeholders.

Has a formal process for objective elicitation, that embraces all stakeholders, been identified?

The following 6 points provide an overview of the process of objective setting. They detail potential problems before providing direct guidance on the process of eliciting objectives, and, finally, on assimilating and weighting objectives.

1. Logistical and financial constraints. As with the engagement process generally, issues may include

- Cost – Joll et al. (2015) suggests identifying areas where the government can assist through existing programmes (such as state government Small to Medium Enterprise business incentive awards, and capacity building programs), and covering costs of attendance for fishers and other stakeholders where this is not covered by salary.
- The extent of sectors – if there are many, identifying and obtaining adequate representation is more difficult.
- The extent of infrastructure/agency support for a formal, open and comprehensive process.
- The possible remoteness of participants, with also possible lack of access to/familiarity with internet and modern communication options.

It must be recognised that once the Government commits to formally manage a minor fishery, it has legislative requirements to manage that fishery in just as an efficient and sustainable manner as any major fishery (Joll et al. 2015).

More generally, the value of obtaining a representative set of objectives cannot be measured in dollar terms. High initial dollar costs should be considered against the long-term benefits. All sectors should be included from the outset in mainstream management regimes, from the point of inception, regardless of geographic or cultural limitations.

Is the objective elicitation process logistically and financially practical?

2. Resolving conflicts

Problems may arise due to

- Misconceptions
- Cultural drivers and expectations

- Timeframes of interest
- Precedents for the process of objective elicitation and setting
- Existing levels of knowledge

These should be able to be resolved by effective and proactive communication. Effective grass-roots level communication with all stakeholders is vital, particularly in dealing with social values in an increasingly political and conflicted environment. There is an increasing need for professional assistance and capacity building of fishery managers, and for well-designed communication strategies (Joll et al. 2015). Material needs to be understandable and digestible. The description of processes and their potential impacts are as important as their factual underpinnings.

Has communication been effective and proactive around the setting of objectives for the fishery?

Other issues may skew responses or make stakeholders reluctant to articulate objectives. These include:

- A history of conflict or disparity between sectors
- Socio-political agendas
- Ambit claims and skewed expectations
- A lack of willingness to cooperate (this needs to be resolved via steps a “Identify stakeholders and establish appropriate points of contact” and b “Generating stakeholder interest/trust to motivate participation” above)
- A lack of cohesion or a cohesive voice within any sector (there may need to be multiple representatives from that sector).

To overcome such issues:

- Existing tensions first need to be defused. They must be acknowledged upfront and openly, with stakeholders being given a controlled opportunity to air their concerns. Concerns should not be trivialised, and it should be clarified that management may not immediately resolve these.
- However, it should also be pointed out that, with skewed or no forthcoming objectives, stakeholders are denying themselves the opportunity to benefit optimally from management.
- If stakeholders are still not willing to be forthcoming regarding their objectives, then the benefits of management need to be reiterated. Management must be perceived as preferable to the status quo. At worst, managers will have to lead the process by selecting objectives from the national inventory (Ogier et al. in prep.) and the social objectives list (Triantafillos et al. 2014) that embrace the triple bottom line, and that seem consistent with legislation, policy and their fishery.

Often the above issues are confounded by a lack of understanding of the context in which information is used. A clear and impartial explanation of how the objectives are to be used within the management regime should be provided. That is, the performance of the harvest strategy will be (ideally, formally) evaluated against the specified operational objectives, and the best possible compromise between achieving these will be sought.

It should be made explicit that management objectives are likely to be conflicting. Almost by definition, objectives stated by decision makers cannot be “wrong” and should be given serious

consideration even if there is no consensus among decision-makers regarding the appropriateness of some of the objectives. Nevertheless, the process of elucidating objectives should emphasize that they be quantifiable (Punt 2017).

Have conflicting circumstances been acknowledged and tensions defused?

3. The actual process of eliciting objectives

As mentioned, objective elicitation should be a formal process. Mapstone et al. (2008) provided a "gold standard" for iteratively elucidating objectives and quantifying them using performance measures in their evaluation of closure regimes for Australia's Great Barrier Reef. Representatives of the research team met separately with each stakeholder group several times over 2 years, then held workshops that brought all the stakeholders together to ensure that all objectives were collectively understood (though perhaps not agreed). These workshops also reviewed how objectives were to be expressed as performance measures that could be output by the MSE.

The approach taken by Mapstone et al. (2008) was very resource intensive, which may explain why their approach has seldom been adopted. A more common approach to identifying objectives and performance measures is to separate the process of identifying management objectives (which tend to be broad, vague, and likely inconsistent) from the process of translating those objectives into performance measures. This is the approach taken by the Scientific Committee of the International Whaling Commission (IWC SC). In this case, the Commission identified and ranked objectives, and the IWC SC developed quantitative performance measures to represent the objectives.

A third approach, adopted for the MSE for Pacific Sardine (*Sardinops sagax*) off the US west coast, recognized that management objectives are largely "pre-specified" through National Standards that are part of the US Magnuson-Stevens Act, along with guidelines adopted by the National Marine Fisheries Service. The choice of performance measures for this case involved an iterative process whereby an initial set of performance measures was selected by analysts conducting the management strategy evaluation (MSE) (PFMC, 2013), and those performance measures were modified based on input from decision-makers (the Pacific Fishery Management Council (PFMC)), their scientific and policy advisors, as well as members of stakeholder groups (fisher and environmental non-governmental organizations).

For low-value, small-scale fisheries, we suggest the following:

- Firstly, an advisory group may prepare a background presentation that includes the provision of a list of example objectives.
    - There is a fine line to walk here between providing meaningful guidance and biasing the process by providing objectives *a priori*. The aim is to present an overview of the management regime development process in order to align and focus stakeholders, and to present broad categories of objectives, including economic, environmental, social, and form-of-management objectives, paving the way for stakeholders to expand the list.
    - Wherever possible it is best to use a "blank slate" approach when designing objectives, working closely with stakeholders. This gives ownership to stakeholders and improves buy-on to resulting management measures/harvest strategies. For example, the South Australian Pipi Fishery (Ferguson and Ward 2014; Joll et al. 2015), the objective setting process showed that it was important to determine

what stakeholders wanted, which was maximum productivity, rather than maximum production.
    - Leaders of this process will need to walk the line between biasing the process with too many examples, and providing scope for input.

- Next, whether directly in a workshop setting, or via (e)mail, stakeholders may be canvassed to provide lists of objectives for the fishery, from the perspective of their role within the fishery. The following should be heeded:
    - Clarify that certain (legislative) objectives are non-negotiable.
    - Explain the above hierarchy of objectives with respect to helping stakeholders to articulate their own.
    - Explain the various categories under which objectives may sit (environmental, ecological, economic, social, form of management).
    - Clarify that this part of the process is about elucidating conceptual objectives – it is not necessary to articulate operational objectives at this stage.

- Alternatively, the approach of Pascoe et al. (2013) could be applied. Here, a review of natural resource management objectives employed internationally was used to develop a candidate list, and the objectives most relevant to the fishery were short-listed by a scientific advisory group. Additional objectives specific to the fishery, but not identified in the international review, were also identified and incorporated into the objective set.

  The list of objectives developed by Pascoe et al. (2013) for the Queensland East Coast Trawl Fishery is presented below (Box 10) as an example, while noting that this has a strong commercial focus. It provides one overarching objective under each of the four categories underlined above, with more detailed sub-objectives.

Box 10 : List of objectives developed by Pascoe et al. (2013) for the Queensland East Coast Trawl Fishery.

1. Maximise economic performance
Maximise value of tradable units
Minimise annual fixed and variable fishing costs
Improve product quality to improve product price
Maintain and improve market access to improve price
Maximise catch rates

2. Simplify and improve management structures
Foster resource stewardship
Strengthen partnerships between and within industry and government
Ensure management strategies have low compliance risk
Minimise other management costs
Minimise legislation volume and complexity
Maximise operational and administrative flexibility

3. Maximise social outcomes
Maximise employment in the fishing sector
Maximise associated onshore employment)
Ensure equitable access to the resource
Minimise conflicts with competing users
Respect customary fishing
Enhance community resilience
Improve quality of life in coastal communities

4. Ensure sustainability
Ensure harvested resource sustainability
Minimise bycatch
Maximise productive area of habitat
Minimise impacts of fishing on biodiversity and ecosystem function
Minimise pollution and carbon footprint of the industry

Ogier et al.'s (2017) inventory, as well as Triantafillos et al.'s (2014) social objectives study, provide detailed lists of objectives.

- When eliciting and defining objectives for low-value, small-scale fisheries, the following issues may be relevant to consider:
    - Social:
        - The operators in many small fisheries are not pursuing financial returns, but primarily a lifestyle. Valuing fisheries more broadly than in terms of economic contributions and economic viability has merit with regard to small-scale fisheries (Joll et al. 2015).
        - Level and emphasis placed on social outcomes of management – in small-scale fisheries, the process of setting objectives is likely to be heavily influenced by this.
        - Measurement and monitoring of social aspects will help to identify and address issues before they have unacceptable impacts (in Canada, a lack of monitoring of vessel size and ownership in the Herring Fishery failed to identify the aggregation of quota to small numbers of people and corporates, which subsequently led to the closure of processing plants in regional areas).
        - Public perception
        - Consumer drivers
    - Governance:
        - Strength of national policy filtering to/influencing states

        - Regional Fisheries Management Organisations/highly migratory species
    - Operational
        - Scale of fishery - local vs. regional
        - Size of boats
        - Range of sectors
    - Economic
        - Relative level of investment between sectors
        - Scale of opportunity (market scoping)
        - Scale of constraints (infrastructure limitations; costs; objectives must be scaled to what's achievable)
        - Markets (local to international)
    - Sustainability
        - Biology and life history of the species
        - Extent of interaction with habitat
    - Environmental
        - Vulnerable/threatened species and habitats
        - Extent of bycatch
        - Extent of pollution/carbon footprint

Has a formal process of objective elicitation, that embraces all stakeholders, been undertaken?

4. Assimilating and translating conceptual objectives into operational objectives

Having obtained objectives across a representative range of stakeholders, the next step is to assimilate all objectives into a harmonised list, with objectives categorised as environmental/ecological/sustainability, economic, social, or institutional/"form of management" (ultimately, management should confront a triple or quadruple bottom line of objectives).

Because conceptual fishery management objectives are frequently expressed in broad terms and are typically too vague to be particularly useful as actual reference points (targets, triggers or limits) for a harvest strategy, they need to be translated into 'operational' management objectives that are relevant for defined species within a fishery. Operational management objectives are very precise and are formulated in such a way that the extent to which they have been achieved during a specified period should be easily measured (Fletcher 2002; Cochrane 2002). Operational objectives should be easily measurable and linked to the performance indicators, reference points and decision rules of a harvest strategy. The operational objectives should clearly identify the fish stock or fisheries management unit to which they apply.

For the purposes of applying the National Harvest Strategy Guidelines (Sloan et al. 2014), an operational objective is defined as "*An objective that has a direct and practical interpretation in the context of a fishery and against which performance can be evaluated*" (Fletcher et al. 2002).

In developing operational objectives then, measurability, or measurable proxies (i.e. with quantifiable units) must be used. Where relevant, objectives should be phrased acknowledging legal or policy contexts.

Have objectives been assimilated into a harmonised list, and translated into operational objectives?

5. Weighting (prioritising) objectives by stakeholder group

Objectives of a management regime and whether a framework is viewed as a success depends largely on the values of the community, and how that community is defined (i.e. local, regional, global). For example, a fishery targeting sharks may be a major employer in an isolated community, and as such, the continuation of the fishery would be viewed locally as a success. Conversely, the same fishery when viewed from a broader perspective, and with consideration of pressures facing shark stocks globally, may be viewed as placing additional pressures on an already heavily fished resource (Joll et al. 2015). As such, weightings (priorities) by stakeholder group are important.

For as broad a range of stakeholders as possible, efforts should be dedicated to obtaining weighting profiles, that is, the relative emphasis or preference placed by an individual against each objective. Per Pascoe et al. (2013), stakeholders should be associated with specific categories (e.g. "fishing industry", "onshore industry", "fisheries managers", "conservation", "recreational", "charter/tour", "indigenous", "local community"). Objective preferences can be time-dependent within stakeholder groups (e.g. some may be financially challenged and want immediate returns; others are comfortable with the longer-term bigger picture). Groups should be split accordingly. The goal is to obtain aggregated relative weightings (priorities) profiles for each group.

<u>However, managers should not be concerned if a weighting exercise cannot be undertaken at this point.</u>

Often, stakeholders wish to see what they are trading off before they are able to weight (prioritise) the objectives. Objective preference weighting (prioritisation) may, therefore, instead be undertaken in a post-hoc manner, after stakeholders can see the output of MSE analysis, and adjust their weightings in response to these. The below-described Analytic Hierarchy Process to identify objective importance may still be undertaken at this point, but generally weightings (priorities) emerge as people can see trade-offs and output

At this stage of the process, the focus is more on obtaining a sense of where each stakeholder group is coming from. While it is worthwhile to start thinking about priorities/weightings early on, this may resolve itself more organically when looking at trade-offs. It will be situation-specific as to how far down the weighting (prioritising) path it is worth going at this stage. At a minimum, managers may consider some scaling of the objectives to constrain the scope of ultimately evaluating prospective objectives.

The Analytic Hierarchy Process, described in Box 11 below (Pascoe et al. 2013), is one method of identifying objective importance.

Box 11: Extract from Pascoe et al. (20143), describing the Analytic Hierarchy Process.

> The Analytic Hierarchy Process (AHP) has been used in a number of fisheries applications to determine management objective importance and assist in decision making. AHP is based upon the construction of a series of pairwise comparison matrices which compare sub-objectives to one another.
>
> One of the advantages of the pairwise comparison method is it makes the process of assigning weights much easier for participants because only two elements or objectives are being compared at any one time rather than all objectives having to be compared with each other simultaneously. The most common (and generally recommended) means of eliciting preference structures for AHP studies is to use a nine- point ''Intensity of Importance'' scale. The scale is based on psychological experiments and is designed to allow for, as closely as possible, a reflection of a person's true feelings in making comparisons between two items whilst minimising any confusions or difficulties involved.

Have stakeholders been categorised into groups?
Has consideration been given to weighting (prioritising) objectives by stakeholder group?

e. Reconciling multi-sector objectives

Formal reconciliation of objectives is dependent on having objective weighting profiles determined in the previous stage. This may not be possible prior to stakeholders seeing trade-offs between objectives. If this is the case, then this step will have to be undertaken in a qualitative (descriptive) manner.

For different fishery sectors, and different interest groups, objective preference weightings (priorities) will naturally vary. A management regime must attempt to reconcile not only the trade-offs between the objectives, but the relative weightings (priorities) placed on each by the different groups.

That is, trade-offs between the ecological, economic and social outcomes being sought must be identified and agreed upon (preferably in consultation with all key stakeholders).

Where there are multiple user groups, the impacts these objectives will have on the outcomes that each user group aspires to achieve should be considered at the beginning of the harvest strategy design process (Sloan et al. 2014).

Reconciling objectives is not about resource sharing, or allocation, or inter-sectoral conflict per se. Rather, it is about acknowledging that, even given good relations between sectors and an equitable division of fisher rights, objective weightings (priorities) will naturally differ between groups.

Reconciliation should aim to achieve the optimal compromise among user groups given their objective preferences, and therefore, ultimately, an equitable distribution of fisher rights.

Consideration of the following points should optimise the chances for success:

- Overarching fishery issues should be identified.
- Any conflicts regarding different value systems should be declared outright. It is important to proactively recognise differences and the basis/rationale for these.
- An understanding of each sector's needs and past history should be obtained.
- The largest differences in weighting profiles (priorities) should be identified (e.g. conservation groups versus industry).
- Policy mandate should be secured from decision makers. This is essential to maintain support for management change, as controversy and naysayers exert political influence to change processes and decisions.
- A common currency should be obtained: based on the combined list of objectives, agreed principles and commonalities should be determined and explored, before focusing on any difficulties. The aim is to achieve some kind of "axis of acceptability".

The process of objective reconciliation must be formal, open, transparent, and constructive, i.e. replicable and defensible.

The following are also highly desirable:

- Demonstrable past precedence of how objective reconciliation has worked in other fisheries

- Availability of experts who are deemed credible through experience and/or familiarity with the fishery.
- Stakeholders who see the worth in engaging and believe that this will ultimately benefit them, and be willing to recognise common ground
    - There must be stakeholder motivation and will to reconcile objectives: that is, there must be incentive to reconcile objectives as opposed to maintaining the status quo.

The following is a list of issues that have the potential to undermine objective reconciliation.

- Number of sector groups: there is potential for greater disparity in objective preference weightings (priorities) with a higher number of sectors. Small-scale, inshore fisheries often have a diverse range of sectors.

- Number of participants: selecting a representative core working group is important, but the propensity for within-group cohesion reduces with increasing numbers per sector.

- Political pull associated with biased representation from one or more sector groups: this harks to seeking a balanced stakeholder group in the first instance.

- Incentives for reconciling objectives must be equal across sectors: greater resistance from one sector will be problematic.

- Formal/governance motivation: objective reconciliation should ideally be a bottom-up process.

- Willingness of stakeholders to weight and prioritise objectives: both for their own sector in the first instance, and between sectors when attempting to reconcile objectives given alternative sets of weightings (priorities).

- Willingness of stakeholders to negotiate constructively: this is hopefully encouraged by having provided the opportunity to raise issues or conflicts upfront.

- Negotiation skill: cultural style, leadership strength, and representation. Particularly for indigenous sectors, negotiations must occur acknowledging that the process may be unfamiliar, and that communication styles may vary considerably.

- Controversial/agenda-stealing participants (railroaders): this harks back to taking care when selecting a core group of representative stakeholders.

- It is harder to achieve common ground if objective weighting (priority) profiles strongly align with sectors, as they can naturally tend to do (e.g. one sector is primarily about conservation while other is about profit).

- The realistic extent to which trade-offs can be rationalised/reconciled: there may not be readily acceptable compromise across objectives.

- While the range of objectives and their weighting (prioritisation) may lead to the consideration of radically different management structures (per Pascoe et al. 2013) the cost of change may be a barrier.

How to reconcile different objective weighting profiles when selecting harvest strategies

There are two basic approaches to selecting among harvest strategies (Punt 2017): (i) "trading-off" and (ii) "satisficing" (Miller and Shelton, 2010). Satisficing involves specifying minimum performance standards for all (or a subset) of the performance measures and only considering harvest strategies that satisfy those standards. In contrast, trading-off acknowledges that any minimum performance standards will always be somewhat arbitrary, and that decision-makers should attempt to find management strategies that achieve the best balance among performance measures (and hence objectives).

Various tools exist to reconcile among objectives when considering harvest strategies, bracketing approaches based in reality, and those considering optimal states. We structure the following section as per the qualitative to quantitative categories outlined by Pascoe et al. (2017). Punt (2017) notes that the selection among the harvest strategies, or those strategies that have acceptable performance when "satisficing" is implemented, is generally qualitative (decision-makers implicitly weighting the various performance measures). However, formal processes for making decisions given multiple performance measures exist, and are summarised briefly follows:

1) Qualitative approaches

- **Multi-criteria decision analysis techniques**

These techniques include:

  - "Traffic light" approaches (Caddy, 2004, 2009; Caddy et al., 2005; Halliday et al., 2001)
  - Cumulative sum (CUSUM) multiple indicator systems (Scandol 2003, 2005)
  - Multidimensional scaling analysis (RAPFISH) (Pitcher et al. 2013; Pitcher and Preikshot 2001)

- **Qualitative models (e.g. Bayesian Belief Networks)**

  - van Putten et al. (2013) used a Bayesian Belief(?) Network model for the Torres Strait Rock Lobster Fishery, to assess how the islander sector might respond to different management strategies and allocations.

2) "Data-limited" assessment approaches embedded within a simulation-based management strategy evaluation (MSE), that is tuned to achieve optimal performance against triple bottom line objectives

- These acknowledge, particularly against social and economic objectives, that there is likely to be data limitation.
- They also acknowledge the need for pragmatism in terms of (for example) the available capacity, and the nature of the fishery.
- These include intuitive forecasting methods, including a Delphic approach, which is a polling technique employed for the systematic solicitation of expert opinion (Bernstein and Cetron, 1969).

3) Commensurable units (that can be combined in single unit – e.g. biomass terms, dollar terms) e.g. socio-bio-economic optimisation models

These include:

- Simulations quantifying trade-offs between objectives (reality-based) (e.g. revenue vs biomass vs strike rate etc.)
- Modelling approaches calculating various reference points (e.g. maximum sustainable yield (MSY), maximum economic yield (MEY), maximum social yield (MSocY)), and trying to optimise over each (REFs required).
- Using the risk-cost-catch approach (Sainsbury 2005) to quantitatively evaluate trade-offs.

4) Non-commensurable units with explicit objective weights e.g. goal programming bio-economic models

- Multi-objective modelling (places explicit weightings on objectives, where objectives are in different units [e.g. profit in dollars, social in terms of numbers of jobs, environmental in terms of biomass] but these are all standardised to common scale (e.g. from 0 and 1), so that trade-offs can be evaluated). This yields an optimal solution.
- Viability analysis gives a "minimum acceptable space", per Pope's (1983) "minimum sustainable whinge" principle – that is, everyone is unhappy, but nobody is extremely unhappy.
    - Includes "Pretty Good Yield", "Pretty Good Sustainable Yield" (Hilborn 2010)
    - This results in the identification of target reference points but does not tell you how to get there. However, neither does Frontier analysis (below).
- Value functions: The ideal way to select among management strategies is to (i) define a utility function that balances the various factors and (ii) find the management strategy that achieves maximum utility. However, efforts to base MSEs on utility functions have generally been unsuccessful because decision-makers (and stakeholder groups) wish to see how well each candidate management strategy achieves each objective and how they trade-off (Punt 2017. A primary reason for the lack of interest in the use of utility functions is that relative weights among the objectives are often not well specified and usually differ among decision-makers. Dowling et al. (submitted) propose the following approach:
    - Define a value(s) for each objective (economic, environmental, social), each of which is some function (directly or indirectly) of catch, with value normalised to range from 0 to 1.
    - For any given set of objective weightings (priorities), apply the corresponding weight to each value, and sum to obtain an overall value function
    - Maximise this value function over the range of possible catches (or alternative strategies).
    - To formally reconcile/trade off the values across the stakeholder groups, in terms of their various sets of weightings (i.e. a rational approach to "mutually disagreeing"), the overall optimal set of stakeholder group weightings (the "value profile") is that which minimises the trade-off in optimal performance given the optimal strategy (level of catch) for any given stakeholder group.

5) Non-commensurable unit without explicit objective weights which provides separate outcomes under each objective (e.g. hybrid models, simulation approaches) and viability analysis approaches

These include:

- Viability Analysis: this involves identifying objectives and goals, and seeking solutions within feasible bounds, but avoids explicit trade-offs between objectives. Given (soft) constraints, it informs as to the likelihood of staying within these. It is analogous to MSE in that the analysis tests a harvest strategy, but gives the probability of achieving above a minimum level, rather than achieving a target.
- Frontier analysis: this identifies outcomes where behaviour is optimal relative to different objectives/targets. Again, this results in the identification of target reference points, but doesn't tell you how to get there.
- Constraints mapping: This is actual spatial mapping, overlaying different uses and users spatially. It is a very resource intensive process.

Has consideration been given to conceptually or quantitatively reconciling objectives?

f. Re- review available information

Having undergone a process of stakeholder engagement, managers should now revisit the review of available information that was undertaken at the pre-engagement stage, with the following questions in mind:

- **Has anything new emerged during the engagement process?**
- **Are there any contradictory sets of data?**
- **If so, these should be resolved, and agreement sought as to which data sources are deemed the most valid.**

- **Resolve instances where the same type of data is collected across different sectors**
  - For example, is recreational catch data going to contribute to stock assessments as well as commercial catch data?
  - How are similar data going to be assimilated and reconciled across different sources?

g. Finalise performance indicators

Revisit and finalise the performance indicators that were identified at the pre-engagement stage:

- **Has anything new emerged during the engagement process?**
- **Will the identified indicators be able to be calculated in an ongoing manner, given the current data collection protocols?**

- **Will the identified indicators be able to be calculated in an ongoing manner, given the research capacity, extent of funding, and agency support?**
- **Is the suite of agreed performance indicators able to "detect" all relevant changes in that fishery, which may indicate whether things may be straying off course?**
- **Do the agreed performance indicators reflect the identified set of stakeholder objectives? That is, are the appropriate things being monitored, given the objectives?**

h. Finalise reference points

Revisit the reference points that were identified at the pre-engagement stage:

- **Has anything new emerged during the engagement process?**
- **Have target and limit reference points been identified against each indicator?**
- **Do the reference points reflect (to the extent possible) the identified set of stakeholder objectives?**
- **Are the target and limit reference points consistent with the intention of any existing legislation and/or policy?**
- **Where relevant, have appropriate trigger points been identified (recalling that these are used to guide a change in the harvest strategy)?**

General advice against Section 1

- This section should not be rushed or taken superficially, as it underpins all that follows.
- Resolving the components of this section often needs to occur as an iterative process, often over multiple engagement sessions. The components may also be revised when evaluating harvest strategy performance (prior to implementation).
- Resolving these components in a careful, considered manner can be both time consuming and costly to achieve. As such the process needs to be rationalised against the level of available resources, and tempered by cost.
- As stated in the "Costs" section above, managers will need to
    - Determine the extent to which an early investment in a solid foundation will reduce costs in the longer term.
    - Accept that investment in formal management, regardless of the current level of available data and capacity, is preferable to deferring management to a time when "better" data exist.
    - Ensure that any initial investment in developing a management regime is against a harvest strategy that is affordable into the future (i.e. do not over-capitalise on an overly sophisticated regime that is unable to be practicably maintained).

Ways in which costs may be minimised (low-cost options for undertaking components) include:

- Appending stakeholder workshops to other existing meetings.
- Engaging with stakeholders online (providing this is culturally appropriate).
- Undertaking objective setting as a desktop review exercise (Pascoe et al. 2013).
- Identifying indicators and reference points as desktop exercise without iterative engagement.

PART 2: Harvest Strategy development: monitoring, assessment, decision rules

The fishery should now be in a position to develop possible harvest strategies (monitoring, assessment, and decision rules) to help guide the fishery in meeting its management objectives.

There will often be a range of available data collection, monitoring and stock assessment methods to consider when developing the harvest strategy. The right option will require judgement on a case by case basis to suit the individual fishery needs and will be influenced by the available data, future needs and the relative costs associated with the different methods (Sloan et al. 2014).

At the very least, monitoring arrangements need to be in place to continue to collect the data on which key indicators are based. If deficiencies have been identified in the data, this step is a good point at which to identify how these can be corrected for the future. If indicators are missing and a trigger system is being used, this will need to specify clearly what kinds of data and monitoring system will be put in place as each trigger point is reached.

Customary/cultural/traditional issues are often covered in a management plan but may not need to be considered in the harvest strategy for the fishery itself, particularly if the level of take is negligible. Highly technical harvest strategies are unlikely to be necessary for customary fisheries, where harvest levels do not threaten sustainability and the primary objective is to manage to a total catch allocation. Cultural, educational and community awareness are the core strategies for customary/cultural/traditional fisheries (Sloan et al. 2014).

Given the diversity of interests in the recreational sector, harvest strategies may need to avoid technical complexity to encourage community ownership. As with commercial fisheries, performance indicators that relate directly to fishing, and the decisions that flow from measuring those indicators, are more likely to be supported by fishers than indirect and technically complex indicators (Sloan et al. 2014).

In Part 2, the Guidelines defer to the FishPath decision support software tool when providing advice for harvest strategy development for low-value, small-scale fisheries. The reason for doing so is that FishPath was developed specifically to guide this process for data-limited fisheries, and comprises a comprehensive and growing suite of options.

Note that the final project report provides examples of FishPath output (for each of its three components) for the NT Spanish Mackerel Fishery as a worked example.

FishPath overview reiteration

The term “FishPath” embraces a process-oriented, feedback-based, practical approach, which empowers local expertise and provides a vehicle for operationalising their knowledge, via three components:

1. A philosophy/vision: that fisheries require a bottom-up, individually tailored approach to fisheries management that is identified through an engaged process.

2. The FishPath software: this is the first tool developed to provide a comprehensive, transparent, defensible, highly efficient process of obtaining harvest strategy options that are tailored to the fishery's context (Dowling et al. 2016). It serves as a standardised entry point for fisheries management improvement and to formalise engagement. It selects among a comprehensive list of data-limited harvest strategy options (monitoring, assessment, decision rules). It also describes each in detail and makes them accessible to all users.

The FishPath software identifies monitoring, assessment and decision rule options based on user responses to questions that consider i) available data, ii) biology/life history attributes of the target species, iii) the fishery operational characteristics, iv) socio-economics, and v) the governance context. Collectively, these 5 axes characterise the fishery. Against this context, the software automates the process of filtering harvest strategy options: given the user responses, the software navigates among the possible options to reveal those most appropriate for the fishery, together with relevant caveats. The software will also eliminate, or caution against, inappropriate options.

The FishPath software is a conduit that mitigates against decision paralysis, and/or using the wrong assessment, or inappropriate control rules or monitoring, all of which create risks for fishery collapse. The software provides a standardised platform for engagement and informed discussion, allowing for a more thoughtful consideration of the harvest strategy selection process. It also identifies what can be done if specific caveats or limitations can be overcome

The FishPath software does not:

- (Typically) recommend any single option.
- Provide reference points or assessments.
- Advise as to how to overcome sticking points and constraints.
- Advise as to the magnitude of decision rule levers.
- Undertake management strategy evaluation of options in context of objectives: this is the focus of other tools; most notably Carruthers et al.'s (2014) Data Limited Methods toolkit.

3. An engagement/on the ground strategy: this is the practical application of the philosophy and software, undertaken in such a way to educate and empower stakeholders. The software and philosophy is the means by which external experts can engage with fisheries, and enable an efficient, comprehensive process to fast-track and guide on the path of major engagement. This typically includes workshops, using the FishPath software to obtain a short-list of harvest strategy option, refining the shortlist, tailoring/designing assessments, assessment testing, developing an action plan to develop monitoring, and general capacity building.

<u>Multispecies, multi-gear, multiple-sector and/or straddling stocks</u>

Many data-limited fisheries:

- are multispecies (either with one or more target species plus associated by-product and bycatch species, or by virtue of being opportunistic).
- are multi-fleet or multi-gear.
- comprise multiple sectors (e.g. recreational, commercial, indigenous).
- have species or stocks that straddle more than one fishery (either within or between jurisdictions).

When developing harvest strategies for such fisheries, the following considerations apply. These are cached in the context of using the FishPath software, but are applicable generally:

- Within each harvest strategy component (monitoring, assessment, decision rule), the user can either i) apply FishPath separately to single (key or target) species within multispecies fisheries, or ii) to the species group collectively.

    - The former is typically applicable when considering assessments, and, to a lesser extent, decision rules, while the latter is often more appropriate when considering monitoring, although in non-targeted and/or opportunistic multispecies fisheries, it may be more appropriate to assess "baskets" of species, or the species group collectively (e.g. via indicators such as relative species catch compositions).
    - All three FishPath components explicitly acknowledge multispecies fisheries within their question sets.

    - Within each harvest strategy component (monitoring, assessment, decision rules), user cans either i) apply FishPath separately to each sector, gear, or fleet, or ii) to the fishery collectively.

        - The former is typically applicable when considering monitoring and decision rules, while it is more sensible to consider the fishery (stock) collectively when determining an appropriate assessment type (although this may equate to determining that the data from one sector, fleet or gear type is representative of the fishery as a whole).
        - Users should consider if and whether data from multiple sources can be merged. While it is desirable to have the maximum amount of information possible, this must be credible, and consistent across sources.
            - Where the same type of data (e.g. catch) shows different trends across gears, sectors, or fleets, careful consideration should be given as to why this is the case, and how the data can/should be incorporated in any assessment.
            - Alternatively, data of different types may be combined/merged across sectors, gears or fleets, but with an awareness of consistency. For example, if good size data exists in the recreational sector, but not from the commercial sector, this could be incorporated into an assessment, BUT with the caveat that each of the data sources (the recreational and commercial gears) should have the same selectivity.
        - If separate assessments are undertaken (based on separate sets of responses) for each sector, gear, or fleet, managers would need to consider whether and why outcomes may be contradictory. Strictly, assessments should be undertaken on data that is representative of the stock as a whole.

Generally, users will have to make an upfront decision about how they are going to assimilate their data, and how they should confront their fishery when developing a harvest strategy (whether applying FishPath or not). Where components of the FishPath software (or decision logic) are going to be applied repeatedly within a fishery, it should be acknowledged that there will likely be significant overlap in the questionnaire responses (or issues considered). For efficiency, those that differ can be flagged within the FishPath software for easy reference.

Monitoring

The first phase of the harvest strategy selection process is to identify possible options for future monitoring and data collection protocols. It is useful to list not only those options that are in current use, but also those that might be used, and to confront these with the outcomes of an impartial process to identify possibilities (e.g. FishPath). As explicitly considered within FishPath, it is essential to consider options that are both implementable and representative of the fishery. Options identified (e.g. from the FishPath tool) can either corroborate or point out deficiencies with existing monitoring programs. They can also highlight approaches that could augment or supplant existing protocols.

It should be emphasised that logbook systems for small-scale, low-value fisheries are often atypical; information is usually obtained from fisher interviews, market-based records, port or processor sampling, and/or surveys (Dowling et al. 2015a). Where logbooks exist, the impetus for these is often compliance, as opposed to data gathering, and in this context, fishers often have to be reassured of the value of sharing their logbook data to inform assessments within a harvest strategy. In general, involving fishers in the process of information gathering, or using local enumerators known to these fishers, can optimise the chances of ensuring ongoing data collection.

In a developed nation context, it is important to note that legislation may automatically require that a certain form of monitoring (e.g. logbooks) is in place, but that this form of monitoring may not equate to the most cost-effective means of data collection for the purposes of a harvest strategy (as stated, the main impetus for the monitoring may be compliance and enforcement, rather than data-gathering to inform an assessment, or the legislative requirement may not be sensitive to the constraints and context of each fishery to which it applies).

Joll et al. (2015) identified that the challenge for small-scale fisheries is to keep evidence-based decision making front and centre. Obtaining and analysing data from small-scale fisheries can be expensive relative to the value of the fishery, especially data on recreational catch and relative economic and other values of commercial, recreational and traditional Aboriginal fishing. Innovative ways are needed to ensure the necessary scientific information is available for decision making, which will undoubtedly require strengthened partnerships between fishing groups, government agencies, and, in some cases, community groups.

The National Harvest Strategy Guidelines (Sloan et al. 2014) state that, given that recreational fishery data tends to be less available than for commercial fisheries, the development of recreational harvest strategies may also involve initiating data collection programs. Novel approaches to data collection may be developed for this sector.

It should also be noted that multiple monitoring options may be a pragmatic way forward. For example, in the longline sector of the British Columbia Groundfish Fishery, logbooks are the primary monitoring method, but these are validated by random audits of 10% of the footage obtained from video camera footage (Stanley et al. 2015). Additionally, different monitoring options may be more applicable for different gear types, fleets, or sectors within a fishery.

The FishPath Monitoring Component (or, decision logic for determining Monitoring options)

The monitoring component of FishPath identifies options for the manner in which data may be collected. These range from market surveys, through to onboard observer programs (Table 5). Within each form of monitoring, there are (up to) 4 sub-categories pertaining to the general type of information that is able to be collected and the type of analysis able to be undertaken:

- Fishery (basic understanding of how fishery operates)
- Sustainability (trend analysis) - e.g. time series data that provides temporal trends, but is not rigorous enough to inform a more comprehensive analysis leading to (for example) F- or MSY-estimates
- Biological information - leads to analysis such as length analysis, spawner potential ratio, (SPR), etc.
- Reference points/stock status – a more rigorous time series that can inform a more sophisticated analysis.

Within FishPath, the fishery of interest is confronted with a range of i) minimum criteria and ii) caveats, based on responses to a suite of questions. Monitoring options are identified by eliminating those failing to meet the criteria, and with specific warnings or recommendations being invoked around caveats.

The five criteria questions used in the monitoring section of FishPath are an initial filter to eliminate certain forms of monitoring, if the fishery is below the minimum requirement associated with any criterion (Figure 5). The criteria equate to minimum required levels against the following socio-economic and governance-related ranking questions:

- Categorise the nature of the fishery, in terms of its main market. (If mixed, assign the highest market level (e.g. "commercial" over "intermediate"))
- How culturally ingrained in fishers is cooperation with fisheries management regulations, in terms of their willingness to share and record information?
- How much is data collection valued and prioritized by the governance agency that oversees, or other trusted organisations that support, the fishery of interest?
- Rank the current or potential monetary investment for a monitoring program for this species/species group.
- Rank the current or potential research and/or institutional capacity to implement and maintain a formal management strategy (i.e. monitoring, assessment, decision rules).

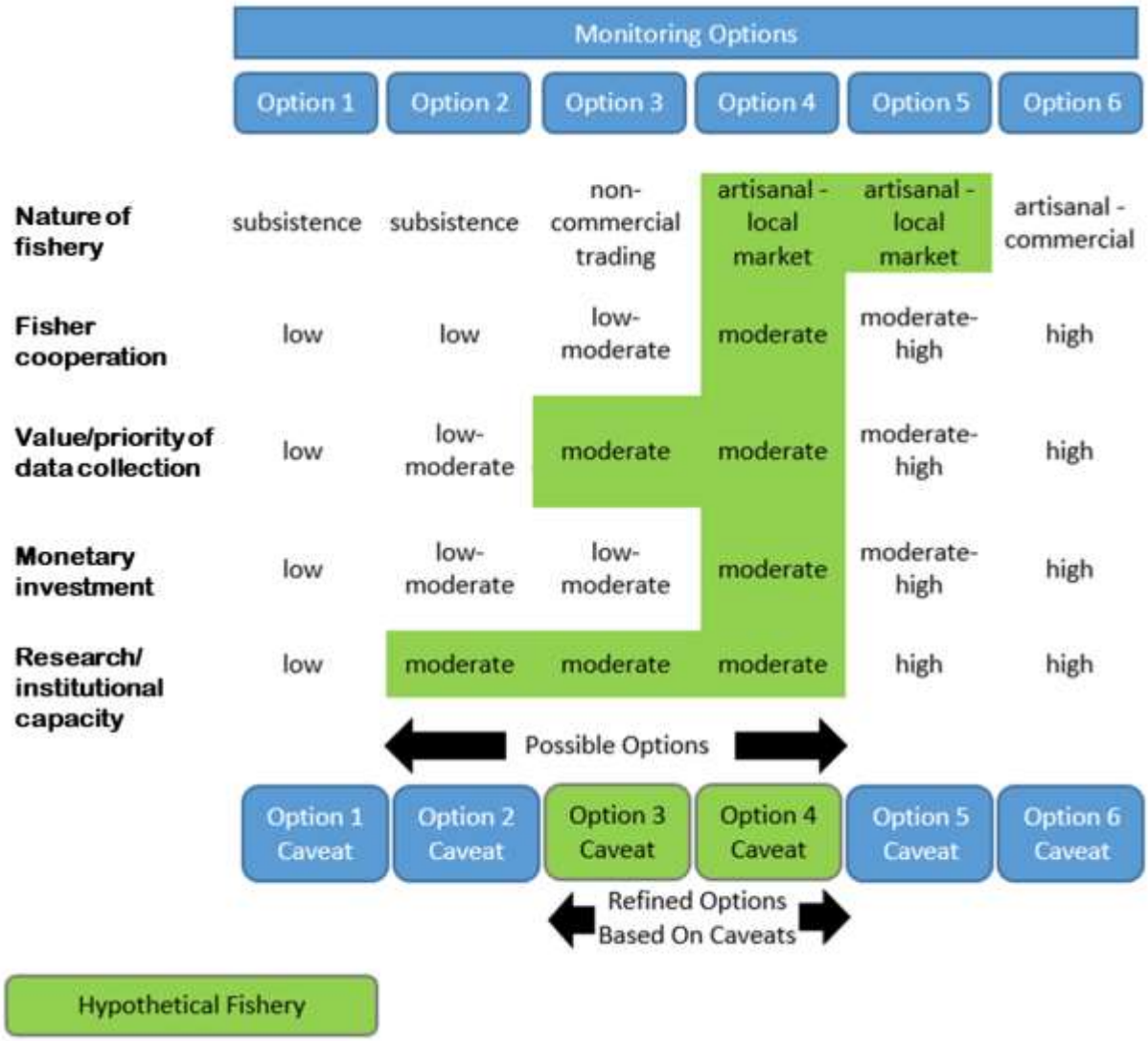


Figure 5: Schematic of the monitoring component of FishPath. Options are identified via responses to five criteria questions for the fishery, and further refined via the advice invoked in response to a series of caveat questions.

Of all the questions asked in FishPath, these are the most subjective. However, by acting as "first pass" eliminators, they cause stakeholders to carefully consider and reach consensus on how they perceive their fishery, and whether perceived sticking points are surmountable.

The subsequent (>30) caveat questions (Figure 5) have conditional "if" statements leading to (potentially) different caveats with (potentially) different associated "traffic light" colours. These "traffic light" caveats carry warnings, or recommendations, with a description that the option is less, or more, desirable given the fishery's circumstances.

Caveat questions also distinguish whether the issue is one of representation (ability to collect representative data) or implementation (ability to undertake the monitoring).

Has the monitoring component of the FishPath tool been undertaken, either for the fishery collectively, or by species/gear/fleet/sector?

Alternatively, have managers considered all relevant issues affecting their ability to undertake monitoring to inform an assessment?

Has a shortlist of monitoring options been identified as a result?

Table 5: List of the monitoring options considered within FishPath. These comprise 13 main monitoring approaches, most of which can be used to collect 4 main different types (categories) of data. Grey shading indicates that the monitoring type lends itself more to this type of information collection or analysis. The separate box includes options that were added into FishPath after its application within the project.

TYPE OF MONITORING		BROAD CATEGORIES OF INFORMATION COLLECTION/ANALYSIS	TYPES OF DATA that may be obtained via each type of monitoring for each category
		GREY indicates that the monitoring type lends itself more to this type of information collection/analysis	
Market surveys		Fishery (basic understanding of how fishery operates)	species ID, species composition
		Sustainability (trend analysis) - e.g. more temporal	broad temporal changes in catch characteristics
		Biological information - leads to analysis such as length analysis, SPR-type etc.	size data, maturity/reproductive state, sex ratios
		Reference points/stock status	unlikely to provide meaningful information
Port/landing site monitoring by trained enumerators		Fishery (basic understanding of how fishery operates)	species ID, species composition, location
		Sustainability (trend analysis) - e.g. more temporal	broad temporal changes in catch characteristics, landed catch, effort (trip duration)
		Biological information - leads to analysis such as length analysis, SPR-type etc.	size data, maturity/reproductive state, sex ratios
		Reference points/stock status	possibly estimates of CPUE but likely unreliable
Processor monitoring by trained enumerators		Fishery (basic understanding of how fishery operates)	species ID, species composition
		Sustainability (trend analysis) - e.g. more temporal	broad temporal changes in catch characteristics
		Biological information - leads to analysis such as length analysis, SPR-type etc.	size data, maturity/reproductive state, sex ratios
		Reference points/stock status	unlikely to provide meaningful information
Interviews - not specific to a trip/fishing event		Fishery (basic understanding of how fishery operates)	nature of operations; identifying target/key species; identifying key habitat/fishing grounds; understanding drivers behind historical changes; understanding recent (rapid) changes - local knowledge; broad understanding of size composition/prime or market size; nature of fisher interactions wrt information sharing, competition; understanding of behavioural drivers; market supply chain
		Sustainability (trend analysis) - e.g. more temporal	(if fishers have own records) - catch, effort; location; with appropriate questioning approach, may also elicit selective harvesting/biases; categories of fisher efficiency (useful ito evaluating value of information from specific individuals more than as information in and of itself)
		Biological information - leads to analysis such as length analysis, SPR-type etc.	unlikely to provide more than anecdotal information unless fishers have maintained private records of (for e.g.) size data
		Reference points/stock status	unlikely to provide meaningful information
Snapshot data gathering - fishery dependent info (e.g. student sampling; (creel) port-sampling)		Fishery (basic understanding of how fishery operates)	species ID, species composition, size data, landed catch, ? Effort, ? Fishing location
		Sustainability (trend analysis) - e.g. more temporal	information may not be gathered regularly
		Reference points/stock status	unlikely to provide meaningful information
Snapshot data gathering - biology/life history geared		Biological information - leads to analysis such as length analysis, SPR-type etc.	size data; maturity/reproductive state; sex ratios
Independent surveys (could include one-offs, pre-seasons, annual, monitoring on reserves) (i.e. visual surveys, charters, independent RVs)	irregular, undertaken by fishers	Biological information - leads to analysis such as length analysis, SPR-type etc.	size data; maturity/ reproductive state; sex ratios
	irregular, undertaken by fishers	Reference points/stock status	biomass estimates by time and space; density ratio (within and outside of reserves)
	regular, undertaken by fishers	Biological information - leads to analysis such as length analysis, SPR-type etc.	size data; maturity/ reproductive state; sex ratios
	regular, undertaken by fishers	Reference points/stock status	biomass estimates by time and space; density ratio (within and outside of reserves)
Independent surveys (could include one-offs, pre-seasons, annual, monitoring on reserves) (i.e. visual surveys, charters, independent RVs)	snapshot or regular but not annual, undertaken by independent practitioners	Biological information - leads to analysis such as length analysis, SPR-type etc.	size data; maturity/ reproductive state; sex ratios
	snapshot or regular but not annual, undertaken by	Reference points/stock status	biomass estimates by time and space; density ratio (within and outside of reserves)
	regular (annually), undertaken by independent practitioners	Biological information - leads to analysis such as length analysis, SPR-type etc.	size data; maturity/ reproductive state; sex ratios
	regular (annually), undertaken by independent practitioners	Reference points/stock status	biomass estimates by time and space; density ratio (within and outside of reserves)
Automated information gathering (e.g. VMS; cameras)		Fishery (basic understanding of how fishery operates)	catch location; distance between points - travel/steamer time; processing time, handling time; discarding vs what is offloaded; validation/verification; selective harvesting wrt size; ? species identification; ? species composition
Logbooks: informal (voluntary)		Fishery (basic understanding of how fishery operates)	across-fleet catch by species, (possibly) discarding
		Sustainability (trend analysis) - e.g. more temporal	across-fleet catch by species, time and space; across-fleet effort by time and space
		Biological information - leads to analysis such as length analysis, SPR-type etc.	(possibly) size data;
		Reference points/stock status	CPUE (NB will likely be more robust for FORMAL logbooks as per below)

Logbooks: formal government (licensing) requirement		Fishery (basic understanding of how fishery operates)	across-fleet catch by species, (possibly) discarding
		Sustainability (trend analysis) - e.g. more temporal	across-fleet catch by species, time and space; across-fleet effort by time and space
		Biological information - leads to analysis such as length analysis, SPR-type etc.	(possibly) size data
		Reference points/stock status	CPUE (likely more robust than informal logbooks)
Catch disposal records/sales docket/traceability		Fishery (basic understanding of how fishery operates)	across-fleet aggregated catch by species, (possibly) across-fleet aggregated effort
		Sustainability (trend analysis) - e.g. more temporal	across-fleet aggregated catch by species, (possibly) across-fleet aggregated effort
		Biological information - leads to analysis such as length analysis, SPR-type etc.	(possibly) size data;
		Reference points/stock status	broad-scale CPUE
Observers - industrial or high-artisinal on-board	Less so for fishery characterisation	Fishery (basic understanding of how fishery operates)	spatial information; discarding; species identification; species composition; distance between points - travel/steamer time; processing time, handling time; can draw attention to specifics (e.g. behaviour such as discarding) that might otherwise be oblivious to; validation/verification; selective harvesting wrt size
		Sustainability (trend analysis) - e.g. more temporal	catch (limited by coverage); effort (limited by coverage)
		Biological information - leads to analysis such as length analysis, SPR-type etc.	size data; maturity/ reproductive state; sex ratios
		Reference points/stock status	well collected, fine-scale information on all aspects, but to undertake reference-point based analysis requires large observer coverage
Local expert knowledge		Fishery (basic understanding of how fishery operates)	nature of operations; identifying target/key species; identifying key habitat/fishing grounds; understanding drivers behind historical changes; understanding recent (rapid) changes - local knowledge; broad understanding of size composition/prime or market size; nature of fisher interactions wrt information sharing, competition; understanding of behavioural drivers; market supply chain
		Sustainability (trend analysis) - e.g. more temporal	(if fishers have own records)catch, effort; location; with appropriate questioning approach, may also elicit selective harvesting/biases; categories of fisher efficiency (useful ito evaluating value of information from specific individuals more than as information in and of itself)
Electronic monitoring: mobile technologies		Fishery (basic understanding of how fishery operates)	nature of operations; identifying target/key species; identifying key habitat/fishing grounds; understanding drivers behind historical changes; broad understanding of size composition/prime or market size
		Sustainability (trend analysis) - e.g. more temporal	catch, effort, location, fisher efficiency by individual respondent
Electronic monitoring: shore-based cameras		Fishery (basic understanding of how fishery operates)	numbers and types of vessels; time of launch and retrieval
		Sustainability (trend analysis) - e.g. more temporal	effort in terms of numbers of vessels/fishers and time spent fishing
Electronic monitoring: vessel cameras		Fishery (basic understanding of how fishery operates)	nature of operations; identifying target/key species; identifying key habitat/fishing grounds; understanding drivers behind historical changes; understanding recent (rapid) changes - local knowledge; broad understanding of size composition/prime or market size; nature of fisher interactions wrt information sharing, competition; understanding of behavioural drivers; market supply chain
		Sustainability (trend analysis) - e.g. more temporal	catch; possibly effort
		Biological information - leads to analysis such as length analysis, SPR-type etc.	size data (if cameras capture measurement)
		Reference points/stock status	well collected, fine-scale information on all aspects, but to undertake reference-point based analysis requires good coverage and footage to be transcribed
Electronic monitoring: vessel monitoring systems		Fishery (basic understanding of how fishery operates)	fishing location, time spent fishing in each area
		Sustainability (trend analysis) - e.g. more temporal	effort in terms of location and time spent fishing

Assessment

The assessment component of the FishPath tool includes a large range of empirical assessments, consistent with the following advice from Sloan et al (2014):

"Empirical assessments of stock status are more often used to assess status of stock or fisheries management units rather than quantitative stock assessment models. Empirical assessments involve direct use of data that can be used to infer exploitation or stock status, such as catch per unit effort (CPUE), measures of age or size structure, or estimates derived from fishery independent surveys. This type of assessment is consistent with the 'weight–of-evidence approach' described in the Status of key Australian Fish Stocks Report by Flood et al. (2012). Empirical approaches are most often used due to the higher costs associated with producing and refining quantitative stock assessment models and the scale of the fisheries they are generally applied to. No formal stock assessment is undertaken in approximately one in four stocks or fisheries management units. It is important to note here, that the use of empirical assessments can be a valid and reliable assessment approach. In many cases an empirical assessment may be as reliable as the output from a more sophisticated model-based assessment and may be the most suitable approach given the scale and intensity of a fishery, the data and the resources available to conduct the assessment. Importantly, empirical approaches offer a cost-effective and pragmatic way of addressing the fisheries management needs in many fisheries."

It is useful to list not only those assessment options that are in current use, but also those that might be used, and to confront these with the outcomes of an impartial process to identify possibilities (e.g. FishPath).

In determining appropriate assessment approaches for the fishery, data quality is paramount. For example, a time series of catch data may not be informative if it:

- does not represent the fishery as a whole
- comprises temporal "snapshots", or intermittent or inconsistent reporting
- contains discontinuities due to (e.g.) gear, targeting or regulatory changes
- lacks "contrast" (i.e. does not span periods of high and low catches)
- is unidirectional in trend ("a one-way trip")
- omits significant bycatch or discards
- is erroneous in terms of species identification
- is unreliably reported.

These issues are often prevalent in data-limited fisheries, together with a desire to make best use of whatever information is available. However, careful consideration should be given to data before deeming it appropriate to inform an assessment. Simpler, empirical approaches or indicators are preferable to an ill-informed model estimate of maximum sustainable yield.

Consideration also should be given to what is logistically feasible given the available resourcing. While a model-based assessment may be undertaken with expert support during a one-off engagement, managers either need to commit resources to enable this approach be progressed, or directly acknowledge that simpler approaches will need to be taken in years where expert assistance may not be available.

Particularly in the data-limited context, combinations of assessments are encouraged, as collectively these may provide more insight by corroborating or contradicting one another.

The FishPath Assessment Component (or, decision logic for determining Assessment options)

The term "assessment" is applied within the data-limited context (and as such, in the FishPath tool) in its loosest form, to equate to any undertaking or analysis that speaks to an increased, if indirect, understanding of stock status. This can embrace analysis with outcomes providing:

- a conceptual grasp of "is there any sense of where things are at?"
- judgements of harm/no harm (per risk assessment outcomes)
- changes worthy of management response
- proxy indices of abundance
- an indirect notion of stock status across multiple indicators
- loose assumptions that trigger levels correspond to some status estimates of (for e.g.) fishing mortality (F), maximum sustainable yield (MSY), spawning potential ratio (SPR).

As per this definition, 46 possible assessment options have been identified from the published literature that are appropriate for data-limited fisheries lacking the data and/or capacity for formal model-based stock assessment to inform a model-based assessment (Dowling et al. 2015a) (Table 6).

Among these, production models and depletion-based stock reduction analysis (DB-SRA) are the most "data-rich" assessments considered. Exploratory analysis and expert judgement are the most "data-poor" assessments considered. Many of the included assessment methods are evolving. As newer methods emerge, fewer of these approaches may be adopted. The FishPath tool may ultimately make note of this as a static caveat against relevant methods.

FishPath includes an explanation of each assessment (what it does, what is estimated within each), as well as references, contacts, and, where applicable links to code. Assumptions and caveats are considered explicitly in the recommendations made given the fishery context.

The families of assessments include (see Table 6):

a) those where reference points equate to a harm/no harm judgement, such as expert judgement-based approaches and risk assessments (e.g. Productivity Susceptibility Analyses, Ecological Risk Assessment for the Effects of Fishing, and changes to species composition, gear deployment, and spatial distributions of effort and landings),

b) those with reference points that are indirect proxies for biomass, such as length-based indicators, regression analyses, marine reserve-based density ratios, or those based on standardised catch per unit effort (CPUE),

c) those with stock status-based reference points, such as estimators of fishing mortality (*F*), and spawning potential ratio (SPR) approaches, and

d) "frameworks" such as decision trees, traffic light systems, cumulative sum control charts (CUSUM), RAPFISH, or sequential trigger systems. These use a range of indicator values and/or indicator types, and may also incorporate some of the "stand-alone" assessment approaches. For example, combinations of indicator values can lead to specific branches of a decision tree, which in turn lead to specific types of assessments.

Assessments may alternatively be grouped according to the following categories (noting that such groupings have no bearing on which are recommended) (Table 7):

- Expert judgement
- Risk analysis/vulnerability
- Empirical reference points
- Multiple indicators
- Life-history-based reference points
- Size-/age-based
- Catch-only
- Abundance indicators
- Population dynamics model

Table 6. List of the 60 forms of data-limited assessments, with citations, as used in FishPath (blue shading indicates options that were added into FishPath after its application within the project). Assessments are categorised according to the type of input.

EXPERT JUDGEMENT	
Move directly to harvest control measures	Dowling et al. 2015a
Discourse/expert judgement	Dowling et al. 2008
Data exploration via plotting and descriptive statistics	Dowling et al. 2008
Analysis of changes in the spatial distribution of fishing effort	Dowling et al. 2008
Analysis of changes in the spatial distribution of catch	Dowling et al. 2008
Analysis of changes in gear type or manner of deployment	Dowling et al. 2008
EMPIRICAL REFERENCE POINTS	
Size-based sequential trigger system	Dowling et al. 2008
Sequential effort triggers	Dowling et al. 2008
Sequential catch triggers	Dowling et al. 2008
ABUNDANCE INDICATORS	
Analysis of changes in species-composition	Dowling et al. 2008
Single-indicator analysis using standardized CPUE	Hinton and Maunder 2004
Linear regression to recent time series of CPUE	Haddon 2011a
Use of biomass surveys to inform spatial management	Dowling et al. 2008
Ecosystem Based Biomass Targets	McClanahan 2018
RISK ASSESSMENT/VULNERABILITY	
Ecological Risk Assessment for the Effects of Fishing (ERAEF)	Hobday et al. 2007
Comprehensive assessment of risk to ecosystems (CARE)	Battista et al. 2017
Ecosystem threshold analysis	McClanahan et al. 2011
Productivity and Susceptibility Analysis (PSA) to estimate risk of overfishing	Patrick et al. 2010
RAPFISH (Multi-dimensional scaling)	Pitcher et al. 2001
Sustainability Assessment for Fishing Effects (SAFE)	Zhou et al. 2019
USE OF MARINE PROTECTED AREAS	
Analysis of ratio of density inside and outside marine protected areas (MPAs)	Babcock and MacCall 2011
Analysis of length/size-specific catch-rate indicators for fish sampled inside and outside of marine protected areas (MPAs), and per-recruit	Wilson et al. 2010
SIZE/AGE-BASED	
Analysis of sustainability indicators based on length-based reference points (LBRP)	Cope and Punt 2009
Analysis of changes in mean length/weight or length/weight percentiles	Dowling et al. 2015a
Analysis of size relative to size at maturity	Basson and Dowling 2008
Catch curve analysis	Chapman and Robson 1960
Length-based Spawning Potential Ratio (LB-SPR)	Hordyk et al. 2015b
Mean length mortality estimators	Gedamke and Hoenig 2006
Length-based Integrated Mixed Effects (LIME)	Rudd and Thorson 2017
Length-based Bayesian Biomass Estimation (LBB)	Froese et al. 2018
Catch Curve Stock-Reduction Analysis (CC-SRA)	Thorson and Cope 2015
CATCH ONLY	
Depletion analysis	Hilborn and Walters 1992
Boosted Regression Tree (BRT) model for stock depletion using catch data	Zhou et al. 2017
Only Reliable Catch Stocks (ORCS)	Berkson et al. 2011
Depletion-Corrected Average Catch (DCAC)	MacCall 2009
Depletion-Based Stock Reduction Analysis (DB-SRA)	Dick and MacCall 2011
Simple Stock Synthesis (SSS)	Cope 2013
Stochastic Stock Reduction Analysis (SRA)	Dombardi and Walters 2011
Catch-MSY/CMSY	Froese et al. 2017
Feasible stock trajectories	Bentley and Langley 2012
Optimized catch-only method (OCOM)	Zhou et al. 2017
Catch Only Model - Sampling Importance Resampling Model (COM-SIR)	Vasconcellos and Cochrane 2005
State-space Catch Only Model (SSCOM)	Thorson et al. 2013
Modified Panel Regression Model (mPRM)	Costello et al. 2012
POPULATION DYNAMICS MODEL	
Production model	Fox 1970
Statistical catch-at-age (SCAA)	Hilborn and Walters 1992
qR Method	McGarvey and Matthews 2001
Extended Simple Stock Synthesis (XSSS)	Cope et al. 2015
Extended Depletion-Based Stock Reduction Analysis (XDB-SRA)	Cope et al. 2015
LIFE-HISTORY-BASED REFERENCE POINTS	
Assessing escapement through samples of catch	California Department of Fish and Game 2005
Yield-Per-Recruit	Haddon 2011a
B-K Life History Model	Beddington and Kirkwood 2005
Matrix Models	Caswell 2001
Intrinsic Rebound Potential	Au and Smith 1997
Demographic FMSY	McAllister et al. 2001.
SPRMER	Brooks et al. 2009
MULTIPLE INDICATOR FRAMEWORKS	
CUSUM Control Charts	Mesnil and Petitgas 2009
Traffic lights	Caddy 2004
Hierarchical decision trees	Dowling et al. 2015a
Sequential trigger framework involving catch and/or effort, CPUE, size, sex ratio etc.	Dowling et al. 2008

Table 7: Alternate grouping of FishPath assessments.

"Family"	Assessment
Expert judgment	Move directly to decision rules
Expert judgment	Discourse/expert judgement
Expert judgment	Changes in spatial distribution of effort
Expert judgment	Changes in spatial distribution of catch
Expert judgment	Changes in gear type or manner of deployment
Expert judgment	Corral/explore data via descriptive statistics
Risk analysis/Vulnerability	PSA to estimate risk of overfishing
Risk analysis/Vulnerability	Ecosystem risk assessment for the effects of fishing
Risk analysis/Vulnerability	Comprehensive assessment of risk to ecosystems (CARE)
Risk analysis/Vulnerability	Ecosystem threshold analysis (coral reefs only)
Risk analysis/Vulnerability	RAPFISH (Multi-dimensional scaling)
Risk analysis/Vulnerability	SAFE (Zhou)
Empirical reference points	Sequential effort triggers
Empirical reference points	Sequential catch triggers
Empirical reference points	Size-based sequential trigger system
"Family"	**Assessment**
Multiple Indicators	CUSUM Control Charts
Multiple Indicators	Traffic lights
Multiple Indicators	Sequential trigger framework involving catch and/or effort, CPUE, size, sex ratio etc.
Multiple Indicators	Hierachical decision trees
"Family"	**Assessment**
Life history-based RPs	Modal analysis to estimate growth rates
Life history-based RPs	YPR
Life history-based RPs	Samples of catch; ensure 30% have spawned (per squid fishery in California)
Size/age-based	Catch curves
Size/age-based	Sustainability indicators (per Cope and Punt (2009) based on Froese's size-based indicators)
Size/age-based	Catch, CPUE by size indicators (per Froese)
Size/age-based	Changes in mean length/weight or length/weight percentiles
Size/age-based	Size relative to size at maturity
Size/age-based	Mortality estimates from length data in nonequilibrium situations (Gedamke and Hoenig 2006)
Size/age-based	Size-specific catch rate indicators for fish sampled inside and outside of MPAs, and per-recuit (per Wilson)
Size/age-based	Length-based SPR assessment (Prince and Hordyk)
Size/age-based	Estimate lifetime egg production per O'Farrell & Botsford
"Family"	**Assessment**
Catch only	Feasible stock trajectories (Bentley and Langley 2012)
Catch only	Zhou's catch-only method (estimates MSY)
Catch only	ORCS (Only Reliable Catch Series)
Catch only	DCAC (MacCall)
Catch only	DB-SRA
Catch only	Simple Stock Synthesis (SSS) using only a time series of catch (Cope 2013)
Catch only	Stochastic SRA (User Guide Lombardi and Walters)
Catch only	Catch-MSY (Martel and Froese 2013)
Abundance indicators	Standardised CPUE
Abundance indicators	Use of biomass surveys to inform spatial management
Abundance indicators	Ratio of density inside:outside MPAs (per Babcack and MacCall; McGilliard et al.)
Abundance indicators	Change of dominant species
Abundance indicators	Change in species composition ratios
Abundance indicators	Linear regression to recent time series of CPUE
Population dynamics model	Depletion analysis
Population dynamics model	Production model
Population dynamics model	SCA

The assessment component of FishPath comprises two phases. The first phase eliminates assessment options by screening the available information for the fishery against the minimum required information to undertake each of the assessments. The second phase invokes traffic light warnings or restrictions against approximately 30 secondary caveats and additional requirements or assumptions.

Note that users should consider the FishPath assessment questions based on their best available data.

For first phase of the assessment component, each assessment option is associated with a vector of non-subjective scores (Table 8) corresponding to the minimum required information to undertake the assessment. This information equates to:

- Life history/biological attributes:
    - General population biology
    - Life-history ratios M/K (can be borrowed from other species with similar life-histories, or, for finfish, estimated using life-history correlations (Thorson's FishLife tool, https://github.com/James-Thorson/FishLife)
    - Natural Mortality
    - Maturity ogive/ size at maturity
    - Relationship between length and fecundity
    - Stock-recruitment steepness
    - Recruitment deviations
    - Length-weight relationship
    - Length-at-first-capture
    - Von Bertalanffy parameters

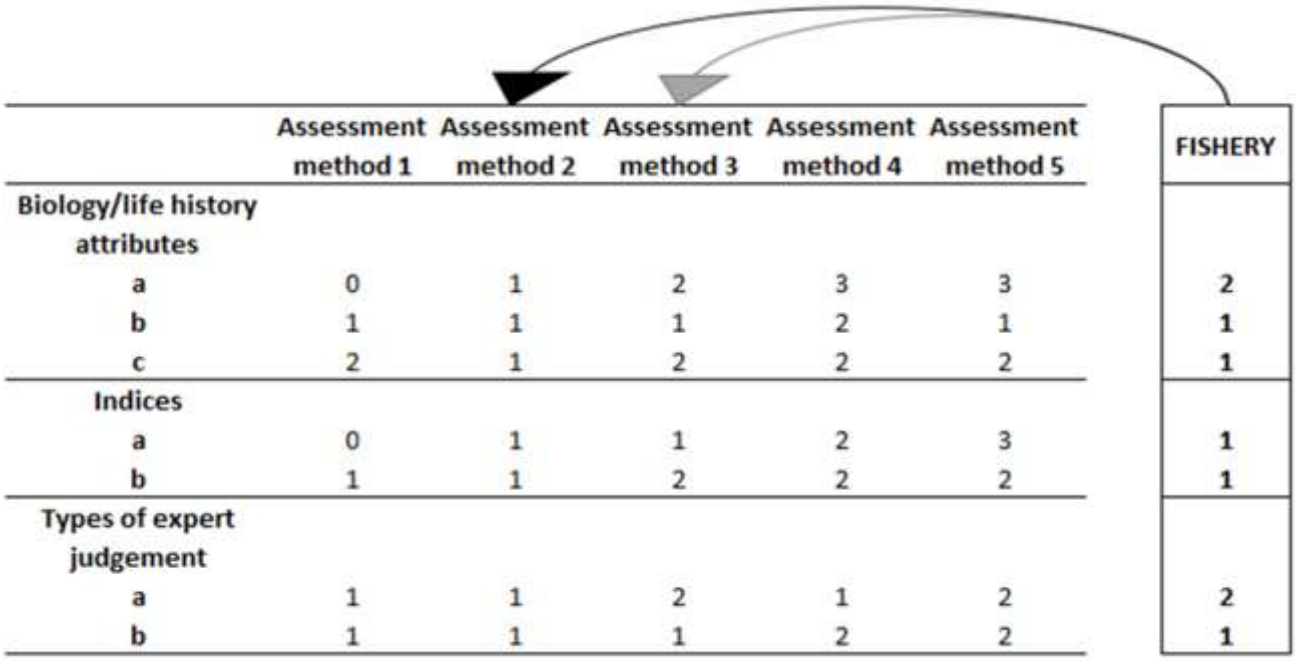
- Quality of available indices: time series of:
    - Catch
    - Effort
    - Catch-Per-Unit-Effort
    - Fishery independent abundance
    - Fishery independent sampling inside and outside of no-take zones (e.g. density, sizes)
    - Fishery dependent density
    - Length composition
    - Mean length or length percentiles
    - Mean weight or weight percentiles
    - Species composition
    - Sex composition

- Extent of available expert judgement:
    - Expert judgement/common knowledge of stock status or level of depletion
    - Expert judgement re: fishery operations and interaction with broader environment
    - Expert judgement re: non-fishing threats, ecosystem services, and/or threat interactions
    - Expert judgement re: MPAs (Marine Protected Areas) and/or habitat status

Table 8: Scoring definitions for data; FishPath assessment component

SCORING: TIME SERIES FOR INDICES - score according to minimum required			
blank		Absent	
1		Snapshots/intermittent/<5years	
2		5-10 regular years (i.e. not necessarily every year)	
3		10+ regular years (i.e. not necessarily every year)	
4		regularly since inception	
SCORING FOR BIOLOGY - score according to minimum required			
blank		Absent	
1		borrowed	
2		in situ but poor	
3		in situ but reliable	
SCORING FOR EXPERT JUDGEMENT - score according to minimum required			
blank		absent	
1		borrowed - outside expert	
2		in situ - local expert	

A corresponding vector of scores for the fishery of interest is determined directly from responses against the availability of the above information, within the FishPath questionnaire. The extent of matching between the minimum information requirements for each assessment option, and the vector of scores for the fishery of interest is used to identify possible assessment options (Figure 6). This approach can also identify areas where, if the quality of information was improved, an alternative, (presumably) more robust assessment could be undertaken.



	Assessment method 1	Assessment method 2	Assessment method 3	Assessment method 4	Assessment method 5	FISHERY
Biology/life history attributes						
a	0	1	2	3	3	2
b	1	1	1	2	1	1
c	2	1	2	2	2	1
Indices						
a	0	1	1	2	3	1
b	1	1	2	2	2	1
Types of expert judgement						
a	1	1	2	1	2	2
b	1	1	1	2	2	1

Figure 6: Schematic diagram illustrating the extent of matching between scoring vectors (equating to the presence and quality of indices, biology/life history information, and available expert judgement) for each assessment approach, and the vector for the fishery of interest. The scores in the body of the table correspond to the minimum levels of availability and/or quality of information required to undertake the assessment (1=high, 3=low??). In the right hand box are the scores that correspond to the information available for the

hypothetical fishery. For this example, the vector corresponding to the available information for the hypothetical fishery most closely approximates the vector equating to the minimum information requirements to undertake Assessment method 2. It can also be seen that, with some improvement in the quality of information under "Biology/life history attribute (c)", and "Indices (b)", the fishery stock status would alternatively be able to be assessed using Assessment method 3.

In the second phase of the assessment component, the assessment options are further refined via a set of caveat and criteria questions (per Table 9). These largely pertain to assumptions associated with the assessments (e.g. that the fleet is engaging in active targeting; that data are assumed to be spatially/temporally/fleet representative; that selectivity is constant; that the population is in equilibrium). They also consider the relative cost of the assessment and capacity required to undertake it.

Responses to secondary criteria questions may eliminate further assessment options, while responses to caveat questions, together with a set of static attributes that apply to the assessment regardless of fishery context, invoke recommendations or cautions that should be considered by the user.

Table 9: Secondary criteria and caveat questions within the FishPath assessment component

Is there a time series of data (as opposed to snapshot(s))?
What time series exists of catch data?
What time series exists of effort data?
What time series exists of catch-per-unit-effort data?
What time series exists of fishery independent abundance data?
What time series exists of fishery independent sampling inside and outside of no-take zones (e.g. density, sizes)?
What time series exists of fishery dependent density data?
What time series exists of length composition data?
What time series exists of mean length or length percentiles data?
What time series exists of mean weight or weight percentiles data?
What time series exists of species composition data?
What time series exists of sex composition data?
What is the extent of understanding of the general population biology of the species?
What is the extent of understanding of the length-at-first-capture of the species?
What is the extent of understanding of the length-weight relationship of the species?
What is the extent of understanding of the life-history ratio M/K of the species?
What is the extent of understanding of the maturity ogive/size at maturity of the species?

What is the extent of understanding of the natural mortality of the species?
What is the extent of understanding of the recruitment deviations of the species?
What is the extent of understanding of the relationships between length and fecundity of the species?
What is the extent of understanding of the stock recruitment steepness of the species?
What is the extent of understanding of the Von Bertalanffy parameters of the species?
What expert judgement is available on the stock status or level of depletion?
What expert judgement is available regarding fishery operations and interaction with the broader environment?
What expert judgement is available regarding MPAs (Marine Protected Areas) and/or habitat status?
What expert judgement is available regarding non-fishing threats, ecosystem services, and/or threat interactions?
Is catch data available by location, so that any spatial differences are discernible?
Is effort data available by location, so that any spatial differences are discernible?
If catch-per-unit-effort (CPUE) data are available, are there additional variables that may be used to standardize CPUE (e.g. oceanographic conditions, vessel type, gear type, location, area, time of year, and/or moon phase)?
Is the data collected for use within an assessment representative of the fleet as a whole?
Is the data collected for use within the assessment representative of the fishery across its entire spatial range?
Is the species being actively targeted?
Are gears and deployment manners known?
Does the stock move beyond the boundaries of where fishing takes place?
Have historical or recent changes occurred in how the fishery is operating (e.g. gear, distribution of effort, species composition, regulations)?
Prior estimates are a requirement for certain types of assessments: are there prior estimates or ranges for r (population intrinsic growth rate) and K (carrying capacity)?
Is there a starting estimate of MSY?
Is there a starting estimate of Z (total mortality)?
Is there an estimate of the annual exploitation rate that produces MSY at equilibrium (Umsy)? (noting that this is required as an input for certain types of assessments)

What is known about the selectivity of the fishery?
Where size data exists, is selectivity at least able to be inferred?
Are there gear selectivity considerations that would preclude the use of the assessment?
Has the selectivity pattern changed over time?
Have there been changes in the fishery that compromise how historical data is treated?
If there are multiple fleets, do the different fleets target/select different size ranges of the same species?
Is the number of participants (or vessels) low (<50)?
Is/are there no-take marine reserves, and if so, are these well enforced and can they represent unfished size and density?
Is there expert knowledge of suitable targets for indicators that could be used (directly or indirectly) to understand the status of the stock (or fishing pressure)?
Is there some starting estimate or notion of abundance?
Is there an estimate of depletion from recent years that can inform a general understanding of current depletion?
Are species within a multispecies fishery being assessed collectively (whether because of lack of data on each species, or because of a lack of species identification)?
Is there a desire to understand the fishery status from an ecosystem perspective (or multispecies perspective) rather than from a single species perspective?

Has the assessment component of the FishPath tool been undertaken, either for the fishery collectively, or by species/gear/fleet/sector?

Alternatively, have managers considered all relevant issues affecting their ability to undertake alternate forms of assessment?

Has a shortlist of assessment options been identified as a result?

Harvest control / decision rules

An important aspect in selecting harvest strategies is to know which management levers or options can be used to manage the fishery. Management levers are the basic “tools” by which catch and effort are regulated, according to decision rules. Such levers can include direct controls on catch or landings, as well as restrictions on gear, on the number and type of vessels, and on where and when fishing can take place (Dichmont et al. 2011). It is useful to list not only those options that are in current use, but also those that might be used, and to confront these with the outcomes of an impartial process to identify possibilities (e.g. FishPath). As explicitly considered within FishPath, it is essential to consider options that are both implementable and enforceable.

In many data-limited fisheries, total allowable catches (TACs), or catch controls generally, are unlikely to be practical from monitoring and compliance perspectives, as are total effort limits, although of the two, the latter may be preferable as they lessen the incentive to misreport catches (Pilling et al. 2008). Multi-sector fisheries will be confronted with allocation issues if using TACs or catch controls.

More appropriate management levers for data-limited fisheries are likely to be input controls, such as spatial rules (closures, rotational exploitation), gear restrictions, size limits or daily trip limits/move-on provisions. Additionally, "participation-style" assessment and self-regulation, that is, management that directly involves the participants, is likely to be more effective (see, for example, Medley, 2008).

The National Harvest Strategy Guidelines (Sloan et al. 2014) state that harvest strategies for recreational fisheries may be process-based – that is, they trigger a process of review to decide on the best response to the reference level being breached, rather than prescribing specific actions. The decision rules are likely to link to a range of management tools that may be used to adjust effort and/or catch including bag limits, size limits, spatial and temporal closures and the process will determine the most appropriate mix of tools in the circumstances to achieve the specified adjustment. Hopefully, the FishPath tool should take the place of such a discussion, by identifying which subset/mix of tools would be most appropriate given the fishery context.

The National Harvest Strategy Guidelines (Sloan et al. 2014) state that the ability to quantitatively analyse the extent of the take of most species for customary, cultural or traditional purposes is limited because indigenous people may partake in both recreational and fishing for customary, cultural or traditional purposes and the extent of fishing for each of these purposes is generally not well reported. It is important to recognise that customary rules for fishery management are common, such as thresholds at which fishing is initiated or stopped in an area or for a species.

The FishPath Decision Rules (Management Measures) Component (or, decision logic for determining Decision Rule options)

The decision rules (management measures) component of FishPath does NOT prescribe levers (e.g. an equation for a catch adjustment), nor the strength with which they should be pulled. Rather, it identifies the TYPE of decision rule that might be appropriate for the fishery, given its context (Table 10).

For some fisheries, legislative or higher level requirements may compel a particular form of decision rule – for example, the fishery may be mandated to be managed via a Total Allowable Catch (TAC). In such instances, the decision rules component of FishPath is still valid in that users can consider the various options under the decision rule "family" applicable to them. More generally, by explicitly identifying the caveats associated with each form of decision rule, users can consider whether what is mandated is actually the best fit for their fishery relative to other options – and where the pitfalls may be if they are obliged to remain with a certain form of decision rule.

FishPath does not have any minimum criteria listed for Decision Rules, but instead uses cautionary caveats, as many of these may be able to be overcome. There are no limitations on what type of decision rule or management measure can be put in place, but the caveats within the FishPath tool help to identify the possible limitations to the effectiveness of implementing one over another. The caveats, invoked by questionnaire responses, carry a "traffic light" colour-coded warning, or recommendation, that the option is less, or more, desirable given the fishery's circumstances. Red "traffic light" caveats indicate that it is highly unlikely that the decision rule would be appropriate.

Thirteen broad “families” of decision rules (including input and output controls) are included in FishPath, with various options within these (Table 10), which are evaluated against approximately 40 caveat questions (Appendix 1) pertaining to available data, biological/life history attributes, fishery operational characteristics, socio-economics, and governance attributes (Dowling et al. 2016).

Any form of decision rule can be applied to the outcome of any assessment. Often these are conceptually bolted together, for example as a “management procedure” that provides a TAC adjustment directly from an assessment outcome.

Additionally, in many instances, multiple decision rules can (and often, should) be applied in combination. For example, decision rules pertaining to gear or effort may be the main management lever, but these may be augmented by spatial closures to protect an incidentally caught, highly vulnerable or threatened species (e.g. Dowling et al. 2008).

Management measures and harvest control rules will still need to be considered in the context of the management objectives for the fishery. This may be achieved by undertaking a management strategy evaluation to examine the trade-offs between alternative forms of monitoring, assessment and management measures/decision rules.

When invoking any decision rule, managers need to consider the duration of the measure and determine a timeframe for its review. The level of research capacity and willingness of community to tolerate flexible management will be important in this context.

Has the decision rule component of the FishPath tool been undertaken, either for the fishery collectively, or by species/gear/fleet/sector?

Alternatively, have managers considered all relevant issues affecting their ability to implement alternative decision rules?

Has a shortlist of decision rule options been identified as a result?

Table 10: List of FishPath decision rule "families", and descriptions of the nature of each. Blue shaded options are those that may be applied as fixed measures (not adjusted dynamically in response to updated information)

	Harvest control rule "families"
1	**Catch limits (daily, seasonal, annual)**
a.	adjust by fixed proportions up or down (no feedback control rule)
b.	according to assessment outcomes (feedback control rule): i) target- or trend based, no F- or biomass-based reference point - empirical target only
c.	according to assessment outcomes (feedback): ii) target based with F- or biomass-based reference point
d.	from monitoring closed areas or marine protected areas (e.g. Babcock and MacCall (2011); McGilliard et al. (2011) ; Wilson et al. (2010))
e.	Catch restrictions by area (whether informed by formal assessment or not)
f.	Catch restrictions by time (e.g. seasons) (whether informed by formal assessment or not)
g.	Daily trip limit; with or without TAC
h.	Limit per gear unit (e.g. maximum catch per trap); with or without TAC
2	**Effort limits (daily, seasonal, annual)**
	Effort limits includes # days fishing/# hooks/# fishing hours/# lines set/net setting time/trip limits/
a.	adjust by fixed proportions up or down (no feedback control rule)
b.	according to assessment outcomes (feedback control rule): i) target- or trend based, no F- or biomass-based reference point - empirical target only
c.	according to assessment outcomes (feedback): ii) target based with F- or biomass-based reference point
d.	from monitoring closed areas or marine protected areas (e.g. Babcock and MacCall (2011); McGilliard et al. (2011) ; Wilson et al. (2010))
e.	Effort restrictions by area (whether informed by formal assessment or not)
f.	Effort restrictions by time (e.g. seasons) (whether informed by formal assessment or not)
g.	Daily effort limit; with or without TAE
h.	Fixed gear unit limits not adjusted in response to performance measures
i.	Maximum soak time for hooks/traps/other gear
j.	Limited entry
3	**Gear restrictions: managing by selectivity (gear DESIGN restrictions) (i.e. can manage towards targets, and can avoid effort creep issues)**
	NB subject to effort creep - need to define "effort", but don't necessarily manipulate effort directly as part of rule
	e.g. mesh/hook sizes; trap escape rings; use of light sticks, cod ends, escape hatches, size limits etc.
4	**Other gear controls not related to selectivity (gear TYPE restrictions)**
	These are focussed on avoiding limits rather than on achieving targets
	May be related to avoiding capture of vulnerable/at risk bycatch species, or related to selectivity (e.g. avoid catching juveniles)
	e.g. removal of seines, dredges, destrcutive gears (remove non-selective techniques)
5	**Spatial restrictions**
	Can be invoked or modified by harvest control rules
a.	Closures: permanent/Marine Protected Area
b.	Fixed seasonal closure on (for e.g.) spawning grounds
c.	Closures invoked in response to some perceived stock status (feedback-driven): rotational/in response to trigger being reached/stock status indicating overfished
d.	"move-on" provisions
e.	Territorial User Rights Fisheries
6	**Temporal restrictions**
	Can be invoked or modified by harvest control rules
a.	Adjust time of day allowed to fish (e.g. no day setting of longlines to avoid capturing seabirds)
b.	Adjust season duration (e.g. for highly productive, short-lived species subject to management by a fishing season of fixed duration, real-time within-season management may be applied to adjust season duration)
c.	Seasonal closure
d.	Closure in response to trigger being reached/stock status indicating overfished
e.	Fixed season length or number of fishing days, independent of performance measures
7	**Size limits**
	pertaining to controlling selectivity (e.g. protecting juveniles, or oldest (largest) fish that have highest reproductive contribution)
	May be indirectly achieved via gear/spatial/temporal restrictions
a.	Minimum legal size
b.	Size slot
c.	Maximum legal size
8	**Sex regulations**
a.	Take of one gender (usualy females) prohibited
b.	Gender-specific size limits
c.	Restrictions or prohibitions on taking gravid females
9	**Invoke data collection**
	This does not confer the necessity to immediately analyse the collected data. Data may be archived against a time when required and/or the GVP/capability exists to analyse it.
10	**Apply additional (precautionary) buffers/adjustments to catch or effort (e.g. catch, effort, size limits, closures)**
	These measures can be applied to the existing control rules (e.g. ramp catch down even further over that suggested by assessment outcomes), AND/OR applied as a separate measure (e.g. impose some spatial closures in additon to having size limits)
	e.g. if high discarding or illegal/unregulated/unreported activity known or suspected
	May be useful if uncertainty is high, or an assessment (such as a decision tree) suggests that overfishing is more probable.
	May be useful if latent effort may be activated
	May be used to avoid volatility in interannual changes in allowable catch or effort
11	**Overrides in case of exceptional circumstances**
	(could argue that these should be included in all harvest strategies, on the proviso they are scientifically defensible)
	May be useful if latent effort may be activated
12	**Retain status quo**
	"watch and wait", particularly if minimal current funds and capacity and no immediate concerns re: stock status
	Often goes together with commitment to invoke data collection
13	**Levies, taxes (e.g. as incentives to avoid areas)**
	Other incentives as proxy enforcement - i.e. rewarded for doing right thing (e.g. some kind of accreditation)

“Fixed” decision rules (management measures)

When trying to minimise costs, while simultaneously dealing with multiple sectors, and, commonly, data- and/or capacity-limitations, having fixed decision rules or management measures may be useful. Fixed measures are those that are not adjusted dynamically in response to updated information (e.g. from an assessment).

Moreover, in the absence of a high degree of certainty, it may be more precautionary to have multiple fixed rules, such as, for example, permanent area closures and gear restrictions, that limit fishing activity in a directed manner to address a range of objectives.

These rules or conditions can apply across all sectors (e.g. as in the case of spatial closures), or to the sector(s) of relevance (e.g. gear restrictions).

While all these rules and conditions can be invoked or adjusted in response to assessment outcomes, and, ideally, should be at least periodically reviewed, the idea is that they operate either:

- in a “set and forget” manner (e.g. some precautionary size limit is chosen as the major input control to manage the fishery).
    - Note that “set and forget” quotas (either catch or effort), or input controls (such as size limits), due to their lack of responsiveness to stock status, must be set in a highly conservative manner. “Set and forget” measures allow the fishery to continue but do not resolve stock status, nor allow the fishery to expand. As such, this may cost the fishery more in the long-term than would investing in some form of assessment against whose outcomes quotas or other restrictions can be adjusted.

- as fixed, augmenting measures to controls that are adjusted in response to assessment outcomes. Of these, measures are either intended to
    - Address alternate objectives to those addressed by dynamic control rules (e.g. seasonal closures to protect spawning aggregations).
    - Complement the achievement of objectives addressed by dynamic control rules (e.g. gear mesh sizes to ensure optimal sustainability via appropriate selectivity, in addition to a dynamically adjusted catch quota).
    - Proactively address areas of (for example, conservation or sustainability) concern that may otherwise have the potential to adversely impact the fishery due to stakeholder pressure (e.g. permanent spatial closures to protect vulnerable (non-target) species’ habitats).

The latter (augmenting) measures may be incorporated as permit or license conditions. Alternatively, they may be informal “handshake” measures agreed by the stakeholders (e.g. “move-on” provisions). That stated, the preference is for any agreed measures to be formalised within the fishery’s harvest strategy.

Options for fixed decision rules are included in FishPath subsets of the types of decision rules considered (as highlighted Table 10).

Has the decision rule component of the FishPath tool, or an appropriate alternative process, identified “fixed” decision rules that may be of relevance to the fishery?

Has consideration been given to how these might sit alongside more dynamic input/output controls?

PART 3: Selecting and articulating the Harvest Strategy

FishPath, or a considered alternative process, typically provides a range of workable harvest strategy options, usually with various caveats attached to each.

The intent of the FishPath tool is NOT to provide a "silver bullet" single recommendation for each component of the harvest strategy, but rather to empower stakeholder judgement via a focused discussion, and to encourage a considered decision by weighing up the identified caveats, among a range of feasible options.

That stated, the number of possible options can, at times, comprise a "longer shortlist", which can still be difficult to select between (note, however, that a longer shortlist is still preferable to "flying blind" when selecting options: FishPath's comprehensive list of options and caveats provides assurance that all possible options have been considered, and that those on the shortlist are feasible, with possible cautions or "trip points" explicitly identified).

This section is intended to provide guidance as to how to move forward given the recommendations from FishPath: that is, to help the user work through the possibly "longer shortlist" of options provided by FishPath, to achieve a "short shortlist". Regardless of whether managers choose to use the FishPath software, the decision logic applies.

Choosing between harvest strategy options

It is recommended that users undertake the following steps, in order, when trying to decide between alternative harvest strategy options. The aim here is to narrow the options to approximately 3 to 5 for each of the monitoring, assessment, and decision rule components, that can subsequently be more fully articulated and formally evaluated (using MSE or similar).

1. Be conscious of existing legal frameworks or requirements, and discard any options that are not consistent with legislative requirements (e.g. managers may be obliged to implement Individual Transferable Quotas (ITQs), so there is little point in working through alternative management measures, apart from considering augmenting measures, or possibly illustrating why those that are legislated may be setting the fishery up for failure).
2. Discard any options that are clearly not a good fit to the fishery (whether determined by "red" caveats, the large number of "orange" caveats, and/or by expert knowledge against these).
3. For the remaining options, consider the caveats, with particular attention to the yellow and orange "traffic lights". Can these limiters be overcome? If not, eliminate the option. If they can be overcome, the caveat can be removed.
4. Reinstate any options for which users feel the criteria or caveats were inappropriate, or where flaws in the original considerations were found. There will always be exceptions to the advice given by FishPath.
    - One worked example from Peru: partly as a result of the lack of enforcement capacity, temporal restrictions were not recommended by FishPath. However, in Lima, there is only one arterial road leading to the local market. As such, any

vehicles transporting fish out of season would be spotted and self-regulation would naturally occur. FishPath (at that point) had not included a question about "choke points" with regard to access to markets. As such, temporal restrictions, at least for the Lima-based fishery, were in fact an appropriate control rule option.

5. For the remaining options, broadly consider the balance of positive attributes ("green" caveats) versus cautionary ("orange" or "yellow") caveats. Are there "standout" options that appeal, because the balance of (a high number of) "green" vs. (a low number of) "yellow/orange" is favourable?
6. For the assessment component, where multiple options have been identified as feasible, those that are typically deemed more rigorous (in that they generate performance indicators more directly related to stock biomass), that are most workable in terms of ease of articulation (empirical assessments can be more difficult to articulate; see below), and that utilise most or all of the available data, should be favoured. For example, providing the required input data are of sufficient quality, an assessment option that estimate MSY should generally be favoured over those such as "undertake exploratory analysis" or "seek expert judgement" (for a "deemed at/not at risk" outcome). The exception is if research or financial capacity are low, and a less statistically rigorous option is deemed less demanding to undertake. Note also that undertaking greater than one assessment is encouraged, particularly in the data-limited context, as, collectively, these may provide more insight via corroborating or contradicting one another.
7. Similarly, for the monitoring component, where multiple options have been identified as feasible, those that are associated with the collection of more comprehensive data should generally be given priority (e.g. collecting biological data should be favoured over obtaining a basic understanding of how the fishery operates).
8. Identify whether there are other "standout" options that appeal, either because they are consistent with current practices, or because they were options that had already been identified as desirable or feasible.
9. Consider each of the remaining caveats for each option in detail. Do a broad weighting of options (short of a formal analysis) by using an empty-cell template that lists each of the remaining caveats, and explicitly identifying (i.e. writing in) how each caveat would be overcome.
10. Alternatively, each caveat can ranked or scored (e.g. from 1-3) in terms of its severity to overcome. These ranks can be summed across all caveats to give an overall score for each option, where the lowest score would equate to a more desirable option.
11. Among the remaining options, consider other key limiters such as:
    - Capacity (is there local capacity to undertake the option?)
    - Time
    - Long-term ability to implement
    - Cost (while noting that empirical work undertaken by Rude et al. (pers. comm.) has found that cost ranges show a heavy degree of overlap between harvest strategy options, depending on the available technical capacity. Also, most options can be implemented on a shoestring budget (e.g. for monitoring via port sampling: a fisher, trader, or aggregator spending two days every week at major ports/docks) as well as more comprehensively (e.g. trained government enumerators cover all ports at all times).
12. When considering options across the three components of the harvest strategy, consider the cost-benefit of, for example, investing in monitoring that may ultimately facilitate a

greater range of assessment options being available. A marginally greater investment in monitoring may pay large dividends in terms of an ultimate reduction in assessment uncertainty.

13. If the remaining options number greater than 5 in each component, perhaps consider a subset that embraces the range from low-cost/capacity through to a more sophisticated/robust option. The exception is for assessments: a quantitative analysis will almost always be preferable to a risk assessment or an expert judgement evaluation.
14. Try to finalise a "shorter shortlist" by assimilating the above, in order to identify the top 3-5 options for each harvest strategy component. It should be ensured that the options for each component are compatible with the other components. This typically occurs organically as a result of the questionnaire responses and invoked caveats for each of the three FishPath components. However, if a new monitoring program is being planned on the basis of FishPath recommendations, and the questions in the Assessment component of FishPath have been answered on the basis of information anticipated to be received out of this new monitoring program (as opposed to on the basis of existing data), users will have to ensure that the monitoring options they select from the "long shortlist" will yield the required data for the identified assessment(s).

Once the "longer shortlist" has been refined to a "shorter shortlist" of 3-5 options, these can begin to be articulated for the purpose of formal evaluation within (for example) an MSE. Such an evaluation should enable a single optimal (with respect to the trade-offs achieved among the fishery management objectives) harvest strategy to emerge.

Challenges in articulating the harvest strategy

Empirical assessments (risk analyses, empirical reference point-based analyses, and multiple indicator frameworks, per Table 7), and decision rules where the management measure is not directly quantitative (e.g. gear or spatial controls, as opposed to catch limits), pose a particular challenge for implementing and evaluating data-limited harvest strategy options. While conceptually simple, to explicitly articulate, and, in the case of assessments, interpret the outcomes of these, requires significant judgement in the face of ambiguity. Issues include, but are not limited to, issues of precedent, definition of reference points, quantifying management measures, implementation, interpretation of outcomes, and legislative (Dowling et al. 2016), as follows:

General:

- There is little precedent for these types of assessments and decision rules in the international fishery science community (e.g. FAO) (an exception is Pauly and David's (1981) length-based model-free assessment method)
- Defining proxy reference points for "assessments" for which these are lacking is challenging (e.g. for an assessment based on changes in mean length, what are the mean lengths corresponding to the target and limit reference points?)
- Quantifying decision rule types where these are not immediately explicit is challenging. For example, for the decision rule of achieving "improved data collection" – How much more data? Of what type of data? Over what time frame? Or, "overrides under exceptional circumstances" – What circumstances? How large an override? Of what nature? How to determine when the override conditions expire?

Implementation:

- It can be difficult to determine how to implement assessments and decision rules across the fishery – e.g., for an empirical assessment of catch triggers, should these be applied by spatial zone, or across the fishery as a whole? How should the magnitude of the adjustments be determined? (For multispecies fisheries) by which species? How many trigger levels (proxy reference points) should there be?
- Consideration should be given as to whether to include an "uncertainty buffer" around harvest control rules. This equates to applying a discount factor (Punt et al. 2012) or uncertainty buffer to be additionally precautionary, when assessment outcomes are considered to be less robust or defensible. If buffers or discounts are applied, managers need to determine how large these should be. Some guidance is provided in Dichmont et al. (2016).

Interpretation of outcomes:

- Empirical assessments tend to confer ambiguity in the interpretation of their outcomes (e.g., what do "unusually high catch levels", or increasing or declining trends in CPUE mean? What if the outcomes of several assessments appear to conflict with each other? What is the most plausible interpretation of the outcomes, accounting for all relevant factors (e.g., price and weather fluctuations, changes in stock abundance, etc.)?
- There can be unforeseen consequences of supposedly simple strategies. These may be i) operational – e.g. trophic interactions, vessel relocations; or ii) implementation-based – e.g. a system of catch triggers may cause the fishery to undesirably oscillate biennially between a trigger level at which the fishery is closed, and one where the fishery is open (e.g. Dowling 2011).

Legislative:

- It can be challenging justifying or ensuring that a harvest strategy based on an empirical assessment or non-catch-control rules is defensible in the context of legislative requirements. Where the existing data are limited, assessments, and the form of decision rules, may not be directly consistent with legislative frameworks or policy requirements (e.g. a requirement for maximum sustainable yield as a target reference point).

Examples of how to begin to articulate empirical assessments and decision rules

Once harvest strategy options have been refined to a "shortened shortlist", the next step is to decide how to articulate and operationalise empirical assessments, and decision rules. As discussed above, this is non-trivial and often requires expertise and experience.

Moreover, advice around achieving this articulation and operationalisation is difficult to generalise. There is no prescriptive process. Due to resource constraints, this was unable to be achieved in a consultative manner for NT Spanish Mackerel during the project. However, the following examples based on a FishPath process undertaken for Peruvian Chita (*Anisotremus scapularis*), a finfish species that is caught by multiple gears as part of a multispecies fishery of which Chita is a key target (TNC 2017), may be helpful. For other examples see Dowling et al. (2008), Dowling 2011, and Dichmont and Brown (2010).

Note that the Peruvian Chita example assessments and decision rules are yet to be formally evaluated using MSE. They are included here to provide insight into how users might proceed when beginning to articulate harvest strategies based on 3-4 assessments and types of decision rules that have been narrowed down from a longer shortlist. Evaluating these articulations, including variations in, and assumed quantities thereof, within an MSE framework, would be the next step.

The assessment options narrowed from an application of FishPath to Peruvian Chita were: size-based sequential trigger system; spawner-potential ratio; multi-indicator decision tree.

The decision rule options narrowed from FishPath for Peruvian Chita were: minimum legal size; closed areas; temporal closures (noting that the fishery is open access, and as such, catch or effort controls are infeasible).

1. Size-based sequential trigger system:

The size-based sequential trigger system applied here compared the mean size (length) of fish in the catch to corresponding multiple (hence "sequential") reference points. The reference points included mean length of fish in the catch in the first year of data collection as a target, and the length at reproductive maturity as a limit reference point (TNC 2017).

If the mean length is greater than the target mean length, this either

- Represents a true improvement in the fishery, whereby the decision rule would equate to retaining the status quo.
- Suggests that there could be recruitment failure, if the mean size of fish in the catch is being influenced by a lack of smaller fish in the catch.

Length distributions or anecdotal evidence would have to be used to determine what is causing the mean length to be above the target. If recruitment failure is suspected, a temporal closure may have to be invoked.

If the mean length is less than the size at maturity, this either suggests

- That the size limit is not complied with and/or enforced, and/or
- There are no larger fish available.

Decision rules would be to increase the size limit by a certain value (and let the fishery go for a while, as the decision rule is size-based and therefore affects the mean length indicator), and/or invoke a temporal closure (of duration to be determined), with the fishery to be reopened at the new higher size limit.

Alternatively, there may be a strong recruitment pulse biasing the mean size downwards. Length distributions or anecdotal evidence would have to be used to determine what is causing the mean length to be below the target. If a strong recruitment pulse is suspected, the status quo may be retained, possibly with a size limit invoked to protect the emergent cohort.

The period and spatial extent over which the "mean length" indicator (and how often the "assessment" is to be undertaken) would still need to be considered. Should this occur annually? Bi-annually? For the entire fishery? By region?

2. Spawner potential ratio (SPR)

The length-based SPR (LBSPR) method was used to estimate the spawner potential ratio (SPR) for Chita and the ratio of fishing to natural mortalities (F/M) (TNC 2017). The LBSPR method used is described in Hordyk et al. (2016). The method uses a length-structured model and assumes selectivity is length-based. The model estimates the selectivity-at-length and the ratio F/M, which in turn are used to calculate the SPR.

The current SPR can then be compared to target and limit reference points of 40% SPR_0 and 20% SPR_0, respectively. Possible decision rules could be

- If SPR is above the target, retain the status quo
- If SPR is below the target but above the limit, invoke a size limit that remains in place subsequently
- If SPR is below the limit, invoke a temporal closure for an agreed duration, and impose a size limit upon reopening.

3. Decision tree

The draft decision tree presented in Table 11 represents one type of empirical assessment that may be undertaken for the Chita fishery (TNC 2017). It considers three indicators, pertaining to underlying biomass (spawner potential ratio, SPR, and catch-per-unit-effort of targeted fish, CPUEtarg), fish availability (CPUEtarg), and oceanographic conditions (El Nino, neutral or La Nina; as indicated by ocean temperature and fish availability). The performance of each indicator is evaluated relative to some reference point, whether this be a target reference point of 40% of the virgin spawner potential ratio (SPR40), the temporal trend in CPUEtarg (increasing or decreasing), or the oceanographic condition relative to neutral. Collectively, these yield a suite of performance measures.

The intention is that each combination of performance measures equates to some unique interpretation regarding the state of the stock ("Explanation"). Each interpretation is assigned a cautionary level, which should dictate the strength of the management response, to be specified via the harvest control rule. The proxy target reference points would be those combination of indicators invoking a "status quo" response, while the limit reference points would be that combination invoking a (Level 4) response (with Levels 2 and 3 being increasingly undesirable, and Level 1 corresponding to a change in indicators deserving of management attention and response). The decision tree may be made hierarchical if the strength of cautionary level, and therefore the strength of the management response dictated by the harvest control rule, is determined by affording different (conceptual) weightings to the performance measures.

Table 11: Draft decision tree assessment for Peruvian Chita, with hypothetical corresponding decision (harvest control) rules.

Indicators			Cautionary Level	Explanation	Harvest Control Rule
SPR	CPUEtarg	OCEANOGRAPHY			
ABOVE SPR40	CPUEtarg ↓	El Nino (warmer, fish aggregated)	Level 2	OK SPR, but bad that CPUEs declining during period when fish should be abundant/aggregated	Invoke SPR-based size limit OR 6-month closure
ABOVE SPR40	CPUEtarg ↓	neutral	Level 1	OK SPR, but bad that CPUEs declining - oceanography not relevant	Invoke size-at-maturity-based size limit (per option 2 above) OR 3-month closure
ABOVE SPR40	CPUEtarg ↓	La Nina (fish less available)	Status quo	OK SPR, CPUEs declining probably due to lack of availability	Discussion around interpretation of indicators; keep track of how often the various branches arise
ABOVE SPR40	CPUEtarg ↑	El Nino (warmer, fish aggregated)	Status quo		Discussion around interpretation of indicators; keep track of how often the various branches arise
ABOVE SPR40	CPUEtarg ↑	neutral	Status quo		Discussion around interpretation of indicators; keep track of how often the various branches arise
ABOVE SPR40	CPUEtarg ↑	La Nina (fish less available)	? Means to restrict q?	Why CPUEs increasing when fish less available (beware increase in q)	
STABLE ABOUT SPR40	CPUEtarg ↓	El Nino (warmer, fish aggregated)	Level 3	SPR stable, but bad that CPUEs declining during period when fish should be abundant/aggregated	1-year closure; reopen with SPR-based size limit
STABLE ABOUT SPR40	CPUEtarg ↓	neutral	Level 2	SPR stable, but bad that CPUEs declining - oceanography not relevant	Invoke SPR-based size limit OR 6-month closure
STABLE ABOUT SPR40	CPUEtarg ↓	La Nina (fish less available)	Level 1	SPR stable, CPUEs declining probably due to lack of availability	Invoke size-at-maturity-based size limit (per option 2 above) OR 3-month closure
STABLE ABOUT SPR40	CPUEtarg ↑	El Nino (warmer, fish aggregated)	Invoke discussion	SPR stable, but increasing CPUEtarg could be due to increased catchability.	
STABLE ABOUT SPR40	CPUEtarg ↑	neutral	Status quo		Discussion around interpretation of indicators; keep track of how often the various branches arise
STABLE ABOUT SPR40	CPUEtarg ↑	La Nina (fish less available)	? Means to restrict q?	Why CPUEs increasing when fish less available (beware increase in q)	
BELOW SPR40	CPUEtarg ↓	El Nino (warmer, fish aggregated)	Level 4	SPR low,and bad that CPUEs declining during period when fish should be abundant/aggregated	2-year closure; reopen with SPR-based size limit
BELOW SPR40	CPUEtarg ↓	neutral	Level 3	SPR low, and bad that CPUEs declining - oceanography not relevant	1-year closure; reopen with SPR-based size limit
BELOW SPR40	CPUEtarg ↓	La Nina (fish less available)	Level 2	SPR low, but CPUEs declining probably due to lack of availability	Invoke SPR-based size limit OR 6-month closure
BELOW SPR40	CPUEtarg ↑	El Nino (warmer, fish aggregated)	Level 3	SPR low, CPUEs high because of increased availability	1-year closure; reopen with SPR-based size limit
BELOW SPR40	CPUEtarg ↑	neutral	Level 2	SPR low, CPUE high possibly because of increasing abundance	Invoke SPR-based size limit OR 6-month closure
BELOW SPR40	CPUEtarg ↑	La Nina (fish less available)	Level 2	SPR low, but why are CPUEs increasing when less fish available? (beware increase in q)	Invoke SPR-based size limit OR 6-month closure

Have the possible harvest strategy options been reduced to a "short shortlist" of ~3-5 options for each component?

Evaluation of harvest strategy options

Prior to implementation, an evaluation of the likely ability of any proposed harvest strategy to achieve operational objectives should be undertaken (Sloan et al. 2014). Such an evaluation is particularly important when information is incomplete and imprecise, and when the relationship between the decision rule and management actions is complex (Davies et al. 2007).

The focus of the evaluation is to identify whether the proposed harvest strategy is likely to be suitably 'robust' based on known and plausible sources of uncertainty in the status and dynamics of the fishery (Sloan et al. 2014). It provides a basis to identify the strategies that are most likely to meet objectives in spite of the uncertainty in the status and dynamics of the fishery and its response to different levels of harvest and management (Davies et al. 2007; Prince et al. 2011).

If objectives, or weightings (priorities) against objectives, have not been resolved earlier in the process, the formal evaluation of trade-offs may provide greater clarity to stakeholders, such that these may now be identified.

Several prospective harvest strategies (involving various combinations of indicators and forms of decision rules) should have been identified and their ability to achieve management objectives compared (Dowling et al. 2015b). However, there is still value in identifying strengths and weaknesses even if only one harvest strategy is identified. What might cause a harvest strategy to fail should be identified, so that there is a realistic view of likely performance, and fishery participants can be aware of circumstances likely to cause failure (Dowling et al. 2015b).

Evaluations of harvest strategy options may range from qualitative methods (e.g. expert judgement) to quantitative methods such as a formal management strategy evaluation (MSE) (Smith et al., 1999).

The data-limited methods (DLM) toolkit of Carruthers et al. (2014) is one possible starting point for evaluating the trade-offs of alternative harvest strategies, using an MSE simulation. This tool includes many of the assessment and decision rules considered within FishPath, considering them together as "management procedures".

An alternative approach to a formal quantitative MSE that still allows prospective evaluation of harvest strategies is to apply a harvest strategy under consideration "retrospectively" (Smith et al. 2004). This involves considering empirically what decisions would have been made in the past by applying a harvest strategy given the data and assessments available at the time. Although the longer term outcomes of such decisions are uncertain, this approach at least allows consideration of whether the decisions arising from the retrospective application make sense with regard to the subsequent history of the fishery. This approach has been used in revising harvest strategies for several fisheries in South Australia.

For example, proposed revisions to trigger reference levels in the harvest strategy for the Spencer Gulf Prawn (*Penaeus latisulcatus*) Fishery were "tested" by determining retrospectively what changes to management settings (days and areas fished) would have occurred had these triggers been applied (Annabel Jones, Primary Industries and Regions South Australia, pers. com.). Testing in this way provided reassurance to industry stakeholders that the new harvest strategy would result in "sensible" decisions.

The efficacy of many Australian data-limited fishery harvest strategies has been formally examined using MSE (e.g., Dichmont and Brown, 2010; Dowling, 2011; Haddon, 2011b; Klaer and Wayte, 2011; Plaganyi et al., 2013). A MSE undertaken on the catch trigger-based harvest strategy for Scampi (*Metanephrops australiensis, M.boschmai, M. velutinus*) in the North-West Slope Trawl Fishery (Dowling, 2011), the only species in the fishery with a time series of CPUE data adequate for production model assessment, predictably showed that harvest strategy performance depended on trigger values being set appropriately. This confirmed that even simple empirical harvest strategies can-not circumvent the need for appropriate data collection protocols. Plaganyi et al.'s (2013) spatial MSE applied to the multispecies (~16) data-limited Torres Strait Beche-de-mer fishery showed that spatial management approaches based on adaptive feedback performed best.

Regardless, for many data-limited fisheries, there remains a gap between what is ideal in terms of harvest strategy testing, and what is practical. For example, it may simply not be possible to test how well any proposed monitoring will track the stock. In the absence of a time series of data of adequate quality to inform a formal evaluation, it is important to commit to ongoing monitoring, either by linking the requirement for data collection to (for example), trigger based decision rules, or regardless of the perceived stock status.

In summary:

- An evaluation of harvest strategy options, be this fully quantitative or qualitative, should be undertaken prior to implementation of any harvest strategy.
- This evaluation should enable the trade-offs in performance against the management objectives to be identified.
- In situations where the articulation of objectives has been difficult, often stakeholder responses to trade-offs identified as part of this formal evaluation will quickly hone and resolve their objective preferences.

Has a formal evaluation of harvest strategy options been undertaken?

Where objectives and/or stakeholder objective preferences/weighting/priorities were previously undetermined, have these now been resolved in light of the trade-offs evident?

Finalise the harvest strategy of choice

It is important to manage expectations, to keep these realistic, and not to advocate, or prescribe, via a process-based tool, a single "magic bullet" harvest strategy. The process of active thinking and discussion around trade-offs of harvest strategy options, given their performance against management objectives, and the caveats associated with each, is valuable. Moreover, a sense of ownership of the harvest strategy, via engagement with a formal process of identifying and narrowing options, should be encouraged among stakeholders.

A formal evaluation of shortlisted harvest strategy options should have revealed a single, preferred strategy that gives the best overall performance against the management objectives for the fishery. Optimisation of every objective will be highly unlikely to be achieved via any one strategy. There will almost always be trade-offs between objectives.

In finalising the choice of harvest strategy, it should be kept in mind that harvest strategies are intended to be adaptive: they should be subject to regular review, and new information should be incorporated as it becomes available.

Has a single harvest strategy emerged from the above selection and evaluation process?

Is the fishery confident that it is well-placed to implement this single harvest strategy?

PART 4: Implementation

This section outlines in detail the process of, and considerations around, implementing a harvest strategy. Certain aspects of implementation, may, however, be a challenge for small scale/low-value fisheries with low-cost management. Many managers do not have the time or resources to be able to implement harvest strategies to the extent outlined below. It is emphasised that, while the below details require attention as time or resources permit, implementing a more basic harvest strategy in a cruder manner, is better than not having a harvest strategy at all.

The two most common reasons for harvest strategy failure at the implementation stage are the inability of the institutional framework to apply a harvest strategy (due to cost or capacity constraints), and/or lack of support from fishers (Dowling et al. 2015a). While these aspects are considered explicitly within the FishPath tool, it is reiterated that the risk of implementation failure can be reduced by adopting a participatory approach throughout. Effective engagement, particularly with industry, largely underpins the successful development and implementation of harvest strategies.

An institutional framework does not necessarily mean that the process be led and implemented by a government agency, although this is often the case. Other options, though these would have to be consistent with policy and legislation, include self-management, co-management or community management processes, which all have the potential to improve communication and compliance (Harris et al. 2002).

Process for ongoing harvest strategy implementation (i.e. day-to-day management)

Once the harvest strategy has been articulated, a process for the day-to-day implementation must be specified.

This needs to consider:

- Governance, administrative infrastructure and support:
    - Formalising the monitoring plan (considered in a separate section below). This could include arrangements with stakeholders, external consultants, research agencies, universities or students, and should consider
        - Formalising the storage of information and any database administration.
        - Identifying how the data will be communicated/sent to the relevant agency.
        - Identifying how the data will be accessed and ensuring that the data is in an appropriate format for ready access for input into a harvest strategy.
        - Identifying staff to undertake the assessments, and formalising a timeframe for these to occur (acknowledging that more regular assessments are more costly from a resourcing perspective, but may be

more economically beneficial to the fishery in the medium to long term).
        - Any rules around data confidentiality.
        - Whether and what processes exist for accounting for reporting/operating error.
- How will the harvest strategy be applied in an ongoing manner?
    - How often are decision rule adjustments to be made? (e.g., annually, or within-season). This will be resource-dependent, but also related to life history of the species of interest, and the form of the decision rule.
    - See below sections pertaining to the Monitoring Plan and Tactical Implementation.
- Development of advice:
    - Identifying at which point, and by what group, decision rule recommendations will be made, and how these will be passed up the bureaucratic chain.
    - Identifying set dates for harvest strategy implementation: preparation, consideration of outcomes of assessment, management recommendations.
    - How regularly will stakeholders be advised/consulted, outside of formal consultation or advice-development processes? Again, cost is a key issue here.
    - How will communication with stakeholders occur? Cultural considerations are important. For example, while online-based consultation may be a low-cost means to reach out to stakeholders, this is unlikely to be helpful in indigenous sectors with low levels of computer and general literacy.
- Operationalising decision rules
    - How will stakeholders be advised of assessment and decision rule outcomes?
    - How will decision rule outcomes be translated into (where applicable) quotas, or licence conditions?

Has a process for the day-to-day implementation of the harvest strategy been specified?
Who is responsible for implementation of the harvest strategy?

Define/specify the Management Plan

Managers now need to articulate all of the above stages in the form of a Management Plan. This is about making the management regime work in the area of jurisdiction, given harvest strategy to be implemented.

A management plan may be conceptualised as per Figure 7 below.

To operationalise management regimes in governance parlance, managers need to determine which parts belong to what governing documents. The advice here is not prescriptive regarding how management translates to hard or soft policy, but rather emphasises the need to consider how management fits within a jurisdictional context (legislative and policy framework). For example, if aspects of the management are dedicated to “hard” policy and regulation, these will have power, but lack flexibility. Managers need to determine which aspects require this power, and those for which it is worthwhile sacrificing power for flexibility.

Legislation documents are obviously “hard” policy. Embedding aspects within “softer” but more flexible Harvest Strategy Policies or Management Plans requires managers to weight the material appropriately such that it is taken up and operationalised, as opposed to buried obscurely.

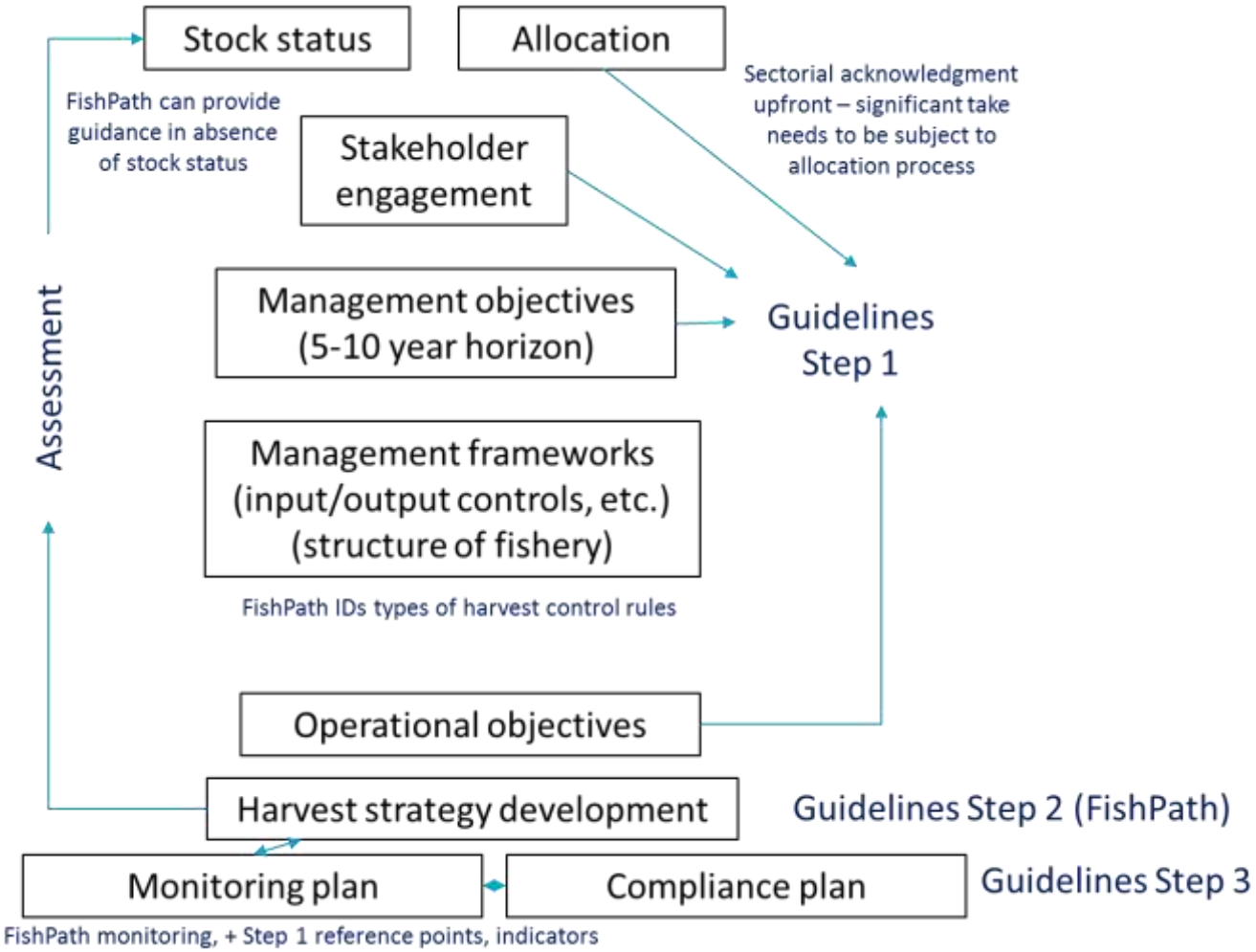


Figure 7: Conceptual diagram of a Management Plan, including pointers to the relevant parts of the Guidelines.

Has the management plan been drafted?

With a harvest strategy and management plan drafted, managers should attempt to articulate the anticipated

- changes to the status quo that will occur as a result of the harvest strategy, in terms of
  - Costs and resources
  - Monitoring programs
  - “Fixed” and dynamic decision rules.
- benefits to the fishery (in the short- and long-term)
  - These can be drawn directly from the formal evaluation of harvest strategies.

Documenting these will assist with accountability and outreach. Extension needs to be more than an afterthought: a harvest strategy is dynamic and ensuring ongoing stakeholder support is paramount.

Managers should also undertake an "audit" against the agreed objectives for the fishery, and the original engagement strategy, to ensure that the management plan (including the harvest strategy) is consistent with these, and that the management is responding to the drivers identified during the initial engagement (e.g. legislative, public, export certification, etc.).

There should also be a review to check that the relationships that were established at the beginning of the process are being maintained (i.e. the need for engagement and stakeholder participation needs to be acknowledged in an ongoing manner).

This is all costly and time-consuming. However, if engaged properly and sold ownership well, so that they have a sense of belief in the harvest strategy, there will be less of a need to appease stakeholders. At the same time, this needs to be approached in a pragmatic and cost-effective manner.

Have changes and anticipated benefits resulting from the harvest strategy been explicitly articulated?

Has there been an audit of the management plan against the agreed objectives and the original engagement strategy?

Are relationships being maintained with all relevant parties?

The Management Plan (per Figure 7) looks at the structure of the fishery and the general nature of the types of controls that may be legislated (e.g. input vs. output controls). The following should be considered:

- Is the Management Plan consistent with broad legislative principles and objectives?
- Is there a clear justification for the management decisions? (This should be directly specified within the harvest strategy)
- Is the management consistent across, and complementary to multiple sectors and other jurisdictions?
- Are the operational objectives clearly defined?

More broadly:

1. **Can the management be articulated?** (against the following check boxes of definition points)
    - Stakeholder engagement plan
    - Allocation
    - Operational objectives
    - Monitoring
    - Assessment
    - Decision rules
    - Compliance plan

2. **Ensure that all parts of the Management Plan are reconciled against each other.** For example:
    - objectives vs. form of control rule

- are input controls the best way to manage?

3. **Is there internal consistency in terms of how the key pieces of the Management Plan are connected?**
    - Users should beware of "ripple effects" within harvest strategies. That is, care should be given around eliminating harvest strategy options that could result in lost opportunity. For example, if the use of logbooks as a means of data collection is disregarded, because of high associated costs, this may preclude the use of cost-effective catch-only assessment methods.

Establish the Monitoring Plan/Program

The Management Plan includes a Monitoring Plan/Program (per Figure 7). This provides details against implementing data-gathering in an ongoing manner.

The following should be considered:

- Who is responsible?
    - This could include arrangements with stakeholders, external consultants, research agencies, universities or students.
- How is the monitoring to be funded?
- How is the monitoring going to be implemented?
    - Who is going to undertake the data collection?
    - Is training or capacity building required?
    - Is special equipment required?
    - Are there appropriate templates for data recording?
- What is the monitoring strategy?
    - What information is being collected? With what level of rigour? What is the level of spatial/temporal/fleet coverage?
    - What are the sample units?
    - How frequently will monitoring be undertaken?
    - What are the minimum requirements for representative sampling? Are there formal analyses that could be undertaken to determine this?
- Where will information be stored?
- Who owns the information?
- Who is responsible for database management and maintenance?
- How will data be communicated/sent to the relevant agency?
    - Have methods such as Smart Phone apps been considered for this purpose?
- How, and by whom, will the data will be accessed?
- Will the data be in an appropriate format for ready access for input into the assessment?
- How will rules around data confidentiality be acknowledged?
- What processes exist for accounting for reporting/operating error?
- Have delineations been made between monitoring for purposes of data-gathering to inform an assessment, and for compliance purposes?

The Monitoring Plan should also include

- A review process
- A stakeholder performance evaluation plan.

Has a Monitoring Plan been developed as part of the Management Plan?

Is there adequate resourcing for the Monitoring Plan to be executed?

Tactical implementation of the harvest strategy

The Management Plan should explicitly consider the tactical implementation of the harvest strategy. Considerations should include the following:

- Who is responsible for harvest strategy implementation?
    - How will multi-sector and cross-jurisdictional fisheries work together to operationalise the harvest strategy? How will there arrangements be formalised?
- How often will an assessment be undertaken? For fisheries with trigger-based "assessments", how often will the indicator values be checked against the trigger levels?
- How are assessments to be resourced?
- Have assessment staff been identified?
- Is there to be an assessment peer review panel? Who signs off on the outcomes of assessments?
- How often will decision rule adjustments (e.g., to catch, effort, gear) be made in response to assessments?
- How often will "fixed" decision rules, or "set and forget" management measures be reviewed?
- Is there a maximum threshold of acceptable magnitude of change from one decision rule application to the next? (If so, this should be explicitly written in to the harvest strategy. It also needs to be balanced against the frequency with which as assessment is to be undertaken).
- What is the likely delay between the outcome of an assessment and recommended decision rules, and the implementation of said rules?
- Who is responsible for compliance and enforcement?
- How frequently will there be engagement, and meetings, with stakeholders?
- Will there be compensation for any operators who "lose" as a result of the harvest strategy?
- How will the harvest strategy be shown to be defensible in the context of legislative and/or policy requirements?
- Have external requirements been considered (e.g. export fisheries have reviews built in to requirements)?
- Has a harvest strategy review process been developed (see below section)?

Has the tactical implementation of the harvest strategy been considered?

Is there adequate resourcing to enable tactical implementation?

Compliance and Enforcement

A successful harvest strategy needs to be supported by compliance and enforcement of decision rules/management measures.

This section provides guidance to managers as to what forms of enforcement may be best suited to the fishery of interest.

The Decision Rules component of the FishPath tool explicitly considers the climate of trust and cooperation, enforcement capability and governance strength, when providing caveats against types of decision rules. That stated, the first consideration around compliance should be the effectiveness of the control rules, in an implementation sense. If a particular form of rule lacks the appropriate management tools, or the support and endorsement of stakeholders, then its effectiveness is likely to be compromised. As such, compliance may be minimal and enforcement particularly challenging.

Table 12 below summarises options for enforcement against associated caveats and minimum required criteria, with the emphasis on low-cost fishery management. The issue of compliance is considered implicitly in both the caveat questions and advice.

Fishery operational, socio-economic and governance characteristics, and available management tools (per decision rules) are all considered. Fishery sector (commercial, recreational, charter or indigenous) is also explicitly considered. Multiple gears are considered, but users may need to further tease out appropriate enforcement options when considering individuals deploying multiple gears, as opposed to different gears within the fishery with individual operators only utilising one each.

Options may be excluded if they do not meet the minimum criteria. Cost is incorporated by indicating a minimum required relative level of GVP against each enforcement option, but this may be an over-simplification. The source and extent of funding for compliance and enforcement needs to be explicitly resolved.

Typically Table 12 would need to be considered separately for each sector within the fishery. For Australia, tight regulations and understanding exist against commercial compliance and enforcement, so the applicability of the table is likely to be limited to the indigenous, recreational and charter sectors.

More generally, questions that should be considered include:

- Are there potential concerns, or is there resistance from stakeholders regarding data privacy and protection?
- Is there adequate regulation in place to prevent information being abused (e.g. information is not stored on local servers)?

Particularly in a compliance and enforcement context, stakeholders need to have faith that management of data and actions taken are in their best interests.

It goes without saying that, in general, the propensity for compliance is highest when stakeholders have a sense of

- Belief in management

- Trust in decision-makers
- Ownership of the management approach
- Within- and between-sector cooperation and trust
- Equitable allocation and access to the resource.

The probability of achieving these is maximised when undertaking the above-outlined process to achieve stakeholder engagement and buy-in.

Self-regulation and/or automated approaches are strongly recommended for low-value, small-scale fisheries, per Greg Ryan page 36 Joll et al. (2015): "Compliance officers are generally concentrating efforts on the more high profile activities. It would be most unlikely for officers to be side-tracked from an abalone operation to look at some suspected illegal activity associated with periwinkles". Self-reporting is typically voluntary and has degrees of formality, ranging from validated to un-validated. However, from a statutory/legal perspective, within Australia, self-reporting is unlikely to be a viable option for compliance purposes.

The use of cooperatives or industry association in an enforcement sense equates to giving these groups power in a co-management context. A key advantage of doing so that these groups may be well placed to establish behavioural norms that align with management. The quality of enforcement would be reliant on what information is brought through these coops or associations by its members. Again, there may be legal issues for Australian fisheries in using such information for compliance purposes.

What minimum levels of enforcement are specified by agency/government/NGO obligations/legalities? Eliminate from consideration any options that fall below this minimum level.

Third party contracts may be a cost-efficient data collection (for compliance) option that is attractive to stakeholders. The appeal to stakeholders is that because this is a third party contract, and as such, the government does not have access to the entirety of the data, there is confidence and trust.

Who is responsible for compliance monitoring, and how is this to be funded?

With whom lies the responsibility of enforcement, and how is this to be funded?

Managers need to ensure that the compliance is appropriate to support the harvest strategy. There should be measures in places that are less about stakeholder compliance, but that verify/engender confidence that the decision rules or controls are working. Such measures should support/underpin the management and harvest strategy by tracking and informing of the effectiveness of the decision rules.

Work through the matrix of enforcement options.

Have compliance and enforcement measures been determined, that are consistent with the management tools, that support the harvest strategy, and that acknowledge the characteristics of the fishery?

Table 12: Enforcement options (rows) with associated criteria, and caveats invoked against questions (columns)

Enforcement options	Criteria			Caveats								
				Operational								
	Minimum required relative GVP of fishery	Minimum level of funding required	Minimum extent of agency/ governance support	Is fishing beach-based, as opposed to boat-based and ports? IF YES	Is there a high number of ports, and/or geographic isolation? IF YES	Is likelihood of discarding high? IF YES	Is number of participants low? IF YES	Is number of participants low? IF NO	Is the sector commercial? IF YES	Is the sector commercial? IF NO	Are there multiple gears? IF YES	Is the fishery quota-driven with a competitive season? IF YES
Self regulation	low	low	if low, may be pragmatic option	N/A	less costly, but obtaining a uniform approach may be difficult	N/A		can be more difficult if large numbers with mixed levels of support for management		less likely for commerical; more likely for indigenous or more informal subsistence/local market, possible exception for commerical fisheries with low numbers - move to column?	more difficult if so	May be less effective
Self reporting	low	low	if low, may be pragmatic option	N/A	less costly but need to ensure consistency	Higher propensity for mis-reporting if high		can be more difficult if large numbers with mixed levels of support for management		less likely for commerical; more likely for indigenous or more informal subsistence/local market, possible exception for commerical fisheries with low numbers - move to column?	more difficult if so	Propensity for mis-reporting may be higher
Incentives	low	moderate-high	Should be at least moderate	may be more difficult to implement for beach-based	may be more difficult to implement	Can be useful provided these are strong enough to overcome motivation for discarding	May work more effectively with lower number of participants if sense of ownership is high		more for commercial		may be more difficult/need to be gear specific	Incentives most effective if opportunities to achieve quota not compromised
Penalties	low-moderate	moderate	Should be at least moderate	may be more difficult to enforce for beach-based	may be more difficult to implement	Can be useful provided these are strong enough to overcome motivation for discarding	May not be needed with lower number of participants if sense of ownership, trust in each other and trust of process is high			Can be more difficult to control for indig/rec/charter	can be tailored to different gear types	May work well as fishers may be more willing to report others
Licensing	low-moderate	moderate-high	Should be at least moderate	Needs to be adequately centralised	Needs to be adequately centralised	N/A	Easier and less costly if low		more for commercial/charter	more for commercial/charter	gears would need to be acknowledged and conditions for each explicitly stated	N/A
Agency based - compliance officers at ports	moderate-high	high	Should be at least moderate	easier if boat and port-based	more difficult if high number of ports or geographic isolation	Difficult to control if discarding occurring at sea. Presence of officers may discourage practice.		May be preferable if high, provided sense of trust in process/governance is high	For commercial or indigenous: useful if sense of ownership or buy in to process or local leadership not strong. For charter, recreational, indigenous: useful but may be expensive relative to level of impact on fishery	For commercial or indigenous: useful if sense of ownership or buy in to process or local leadership not strong. For charter, recreational, indigenous: useful but may be expensive relative to level of impact on fishery	More complicated to control	Useful as independent
Cooperatives/associations	low	low	Can work even when the extent of agency support is low.	N/A	Can be useful but ideally needs to be universal sense of value of management	Can be useful providing level of buy-in to process is high	Easier if low		Useful in all contexts but can increase lobbying power within sector if these are strong (e.g. recreational vs commercial)	Useful in all contexts but can increase lobbying power within sector if these are strong (e.g. recreational vs commercial)	N/A	Requires strong leadership and buy-in to process in this context

Table 12 cont'd.: Enforcement options (rows) with associated criteria, and caveats invoked against questions (columns) (cont'd.)

	Criteria			Caveats											
				Socio-economic											
Enforcement options	Minimum required relative GVP of fishery	Minimum level of funding required	Minimum extent of agency/ governance support	Is there cultural precedent for responsible stewardship? IF NO	Is extent of buy-in to process low? IF YES	Is sense of accountability/ownership low? IF YES	Is sense of trust among one another low? IF YES	Is sense of trust of process/ goverance low? IF YES	Is the sense of the value of management low? IF YES	Is the level of respect for incentives/ penalties low? IF YES	Strength of incentive/penalty	Are rewards around breaking the rules worth the risk? (this is around risk perception vs strength of consequence) IF YES	Is there stigma around TEP interactions? IF YES	Are there measures that would received greater or less support?
Self regulation	low	low	if low, may be pragmatic option	Caution if not	if yes	if yes	if yes, but strength of governance high, can still work (e.g. sea cucumber). Both cannot be low (would invoke a red)	if yes, sense of trust among one another can be low. Both cannot be low.	if low, caution	inbuilt given mutual agreements	relates to how profitibility will be affected if agreement breached, and/or community ostracism	needs to be clear benefit in communmity cooperation that outweighs rule breaking	N/A	more likely to achieve compliance against "secondary" HCRs that augment the primary HCR AND the measures confer additional flexibility/freedom to participants- e.g. move-on provisions to augment sustainability and confer flexibility, but in context of overall catch limits
Self reporting	low	low	if low, may be pragmatic option	Caution if not	if yes	if yes	if yes, but strength of governance high, can still work (e.g. sea cucumber). Both cannot be low (would invoke a red)	if yes, sense of trust among one another can be low. Both cannot be low.	if low, caution	should be at least moderate	propensity for misreporting will be higher if these are not strong enough	propensity for misreporting will be higher if these are not strong enough	Propensity for misreporting if high	N/A
Incentives	low	moderate-high	Should be at least moderate	Would need to be strong to overcome, if low	may be less effective	less likely to be effective	Could work if effectively implemented via agency	Would have to be high to be effective	Would have to be high to be effective	Would have to be high to be effective	More likely to be effective if high	Need to be strong to overcome reward associated with rule-breaking	If high, need to be strong, but may be effective way of avoiding TEPs if incentives can be aligned with TEP interactions	More likely to be useful if measure is not limiting flexibility or ability to achieve (for example) quotas
Penalties	low-moderate	moderate	Should be at least moderate	Would need to be strong to overcome, if low	Would have to be strong to be effective	less likely to be effective unless high	May be higher propensity to report offenders if so	May have to be high to be effective	May have to be high to be effective	Would have to be high to be effective	More likely to be effective if high	Need to be strong to overcome reward associated with rule-breaking	If high, need to be strong , but may be effective if geared to TEP interactions	More likely to be effective if applied against measures that are perceived as important
Licensing	low-moderate	moderate-high	Should be at least moderate	N/A	Recommended	Recommended	N/A	May not be effective means of ensuring compliance	Recommended	N/A	N/A	Likely to make little difference if rewards high	Recommended	N/A
Agency based - compliance officers at ports	moderate-high	high	Should be at least moderate	Recommended if low, unless there is the sense that this has been due to a lack of a sense of ownership.	Recommended	Recommended	Recommended	May not be effective - would have to be tightly policed	Recommended	N/A	N/A	If yes, this needs to be strong	If high, should be strong	N/A
Cooperatives/associations	low	low	Can work even when the extent of agency support is low.	Better if precedent exists.	May be ineffective	Unlikely to be effective	Less likely to be effective	May be effective providing extent of buy-in to process is high	May be ineffective	N/A	N/A	If yes, these are likely to be less effective	If high, may be less effective	more likely to achieve compliance against "secondary" HCRs that augment the primary HCR AND the measures confer additional flexibility/freedom to participants- e.g. move-on provisions to augment sustainability and confer flexibility, but in context of overall catch limits

Table 12 cont'd.: Enforcement options (rows) with associated criteria, and caveats invoked against questions (columns) (cont'd)

	Criteria			Caveats							NEW QUESTIONS					
				Governance												
Enforcement options	Minimum required relative GVP of fishery	Minimum level of funding required	Minimum extent of agency/ governance support	Is local leadership strong? IF YES	Is local leadership strong? IF NO	Is the fishery open access? IF YES	Types of harvest control rule	Ability to validate (reporting)	Are there a high number of management restrictions (e.g. spatial, temporal)? IF YES	Other	Ability to access information	State of inter-sectorial relationships (including with management as well as people on the water)	In developed fisheries, most compliance and enforcement options are already in place (i.e. logbooks, port monitoring). Include static attribute "Is this already in place?"	Would the use of this measure compromise its ability/fisher willingness for it to be used for data gathering or validation? IF YES	Are there particular fisheries to which this is suited? (per above example of prior reporting systems suiting ITQ fisheries)	Confront enforcement options with types of control rules from FishPath (e.g. spatial closures), as a static attribute.
Self regulation	low	low	if low, may be pragmatic option		needs to be strong	caution	easier for gear/spatial/temporal /size, less so for catch/effort limits UNLESS a cooperative exists	Difficult if attempting to do so externally: relies on high level of sense of value of management, and high level of trust among fishers	May be less effective due to having to self-regulate across many control rules.		May be more difficult				Suited to small-scale fisheries with good history of cooperation and compliance, and where the stakeholders have the capability to undertake self-management	
Self reporting	low	low	if low, may be pragmatic option		needs to be strong	Caution - difficult to trace	N/A	low	Propensity for mis-reporting may be higher		May be more difficult				Suited to small-scale fisheries with good history of cooperation and compliance, and where the stakeholders have the capability to undertake self-management	
Incentives	low	moderate-high	Should be at least moderate	May be more effective if strong	May be more effective if strong	Difficult to control	Usually geared around catch/effort/spatial/t emporal	Depends on reliability of reporting	Value needs to be clearly articulated in this context, and focused on single management issue							Indiect at determining compliance of spatial/temporal/gear rules
Penalties	low-moderate	moderate	Should be at least moderate	May be less necessary if local leadership strong		Difficult to control	Can be applied to any	Depends on reliability of information	Value needs to be clearly articulated in this context, and focused on individual management issue							
Licensing	low-moderate	moderate-high	Should be at least moderate		N/A	Recommended	N/A	N/A	All restrictions need to be clearly articulated.							
Agency based - compliance officers at ports	moderate-high	high	Should be at least moderate		Preferable if this is not strong	Difficult to control	Difficult to enforce spatial/gear/size based rules	high	Preferable					May compromise effectiveness of port-based data gathering		Indiect at determining compliance of on-the-water (e.g. spatial) rules
Cooperatives/associations	low	low	Can work even when the extent of agency support is low.	More effective if this is strong		May be useful, except if undermined by participants who do not value good management	N/A	moderate; depends on strength of leadship and extent of buy-in to process	May be less effective due to having to self-regulate across many control rules.		May be more difficult					

Table 12 cont'd: Enforcement options continued, (rows) with associated criteria, and caveats invoked against questions (columns)

	Criteria			Caveats								
				Operational								
Enforcement options	Minimum required relative GVP of fishery	Minimum level of funding required	Minimum extent of agency/ governance support	Is fishing beach-based, as opposed to boat-based and ports? IF YES	Is there a high number of ports, and/or geographic isolation? IF YES	Is likelihood of discarding high? IF YES	Is number of participants low? IF YES	Is number of participants low? IF NO	Is the sector commercial? IF YES	Is the sector commercial? IF NO	Are there multiple gears? IF YES	Is the fishery quota-driven with a competitive season? IF YES
CDRs (caution - think about how/whether this actually differs from logbooks in context of compliance)	low-moderate	low-moderate	moderate	N/A	Quality may be variable	Will not be of assistance	N/A		Commercial only	Commercial only	Catch typically not associated with gear type	N/A
logbooks - formal	moderate-high	high	strong	N/A	higher propensity to misreport if not adequately centralised and/or buy-in to process not strong	If sense of trust or buy-in to process not high,and/or if penalties high may not report discarding.	N/A		more for commercial	more for commercial	Gear types need to be explicitly state	Higher propensity for misreporting
Logbooks - informal	low-moderate	moderate	can be low if strong cultural precedence for responsible stewardship	N/A	Quality may be variable; extent of buy-in to process should be high	If sense of trust or buy-in to process not high,and/or if penalties high may not report discarding.	Easier to reach handshake agreements to share information if low			May be useful way of encouraging non-commerical sectors to contribute to information gathering. Sense of buy-in to process needs to be high	May be difficult to obtain gear-specific catch breakdowns	Higher propensity for misreporting
VMS/automated	high for VMS; low for real time compliance e.g. via smart phone app	high for VMS; low-moderate for real time compliance e.g. via smart phone app	Strong for VMS; low for real time compliance e.g. via smart phone app	easier if boat and port-based	More difficult with higher number of ports and/or geographic isolation	Useful if can capture relevant activity	Less costly if low		commercial only, though may be useful for high value charter sector and recreational	commercial only, though may be useful for high value charter sector and recreational	Useful if can capture relevant activity - but multiple gears often consistent with non-commercial sectors.	Useful as independent
Cameras to record catch, effort, gear	high	high	high	easier if boat and port-based	More difficult with higher number of ports and/or geographic isolation	Useful if can capture relevant activity	Less costly if low		commercial only, though may be useful for high value charter sector and recreational	commercial only, though may be useful for high value charter sector and recreational	Useful if can capture relevant activity - but multiple gears often consistent with non-commercial sectors.	Useful as independent
Observers	moderate-high	moderate-high	moderate	easier if boat and port-based	More difficult with higher number of ports and/or geographic isolation	Discards would be directly monitored, though fisher behaviour may be artificial with observeres	Easier if low		commerical	commerical	May be difficult to obtain representative observer coverage across all gears	

Table 12 cont'd.: Enforcement options continued (rows) with associated criteria, and caveats invoked against questions (columns) (cont'd)

	Criteria			Caveats											
				Socio-economic											
Enforcement options	Minimum required relative GVP of fishery	Minimum level of funding required	Minimum extent of agency/ governance support	Is there cultural precedent for responsible stewardship? IF NO	Is extent of buy-in to process low? IF YES	Is sense of accountability/ownership low? IF YES	Is sense of trust among one another low? IF YES	Is sense of trust of process/ goverance low? IF YES	Is the sense of the value of management low? IF YES	Is the level of respect for incentives/ penalties low? IF YES	Strength of incentive/penalty	Are rewards around breaking the rules worth the risk? (this is around risk perception vs strength of consequence) IF YES	Is there stigma around TEP interactions? IF YES	Are there measures that would received greater or less support?
CDRs (caution - think about how/whether this actually differs from logbooks in context of compliance)	low-moderate	low-moderate	moderate	N/A	May be more reliable source of data than logbooks	May be more reliable source of data than logbooks	N/A	May be more reliable source of data than logbooks	May be more reliable source of data than logbooks	More likely to be accurate if penalties for misreporting respected	More likely to be accurate if penalties for misreporting high	Less likely to be accurate if yes	N/A	N/A
logbooks - formal	moderate-high	high	strong	stronger propensity to misreport if no	stronger propensity to misreport if yes	stronger propensity to misreport if yes	If low, may not report or misreport catch - but could work if trust in agency/strength of governance is high	stronger propensity to misreport if yes	If low, may not report or misreport catch	More likely to be accurate if penalties for misreporting respected	More likely to be accurate if penalties for misreporting high	Less likely to be accurate if yes	if high, likely to misreport	More incentive to misreport against catch/effort limits that will limit profitability, or spatial/temporal that limit access
Logbooks - informal	low-moderate	moderate	can be low if strong cultural precedence for responsible stewardship	stronger propensity to misreport if no	stronger propensity to misreport if yes	stronger propensity to misreport if yes	If low, may not report or misreport catch - but could work if trust in agency/strength of governance is high	stronger propensity to misreport if yes		N/A	N/A	Less likely to be accurate if yes	if high, likely to misreport	More incentive to misreport against catch/effort limits that will limit profitability, or spatial/temporal that limit access
VMS/automated	high for VMS; low for real time compliance e.g. via smart phone app	high for VMS; low-moderate for real time compliance e.g. via smart phone app	Strong for VMS; low for real time compliance e.g. via smart phone app	Useful if not	Useful if low	Useful if low	N/A	Useful if low	Useful if low	N/A	N/A	Useful if can capture relevant activity	Useful if can capture relevant activity	N/A
Cameras to record catch, effort, gear	high	high	high	Useful if not	Useful if low	Useful if low	N/A	Useful if low	Useful if low	N/A	N/A	Useful if can capture relevant activity	Useful if can capture relevant activity	N/A
Observers	moderate-high	moderate-high	moderate	Useful if not	May be difficult to implement	Useful if yes		Useful if yes, but may be difficult to implement	Useful if low, but may be difficult to implement				Useful if can capture relevant activity	

Table 12 cont'd.: Enforcement options continued (rows) with associated criteria, and caveats invoked against questions (columns) (cont'd)

	Criteria			Caveats							NEW QUESTIONS					
				Governance												
Enforcement options	Minimum required relative GVP of fishery	Minimum level of funding required	Minimum extent of agency/ governance support	Is local leadership strong? IF YES	Is local leadership strong? IF NO	Is the fishery open access? IF YES	Types of harvest control rule	Ability to validate (reporting)	Are there a high number of management restrictions (e.g. spatial, temporal)? IF YES	Other	Ability to access information	State of inter-sectorial relationships (including with management as well as people on the water)	In developed fisheries, most compliance and enforcement options are already in place (i.e. logbooks, port monitoring). Include static attribute "Is this already in place?"	Would the use of this measure compromise its ability/fisher willingness for it to be used for data gathering or validation? IF YES	Are there particular fisheries to which this is suited? (per above example of prior reporting systems suiting ITQ fisheries)	Confront enforcement options with types of control rules from FishPath (e.g. spatial closures), as a static attribute.
CDRs (caution - think about how/whether this actually differs from logbooks in context of compliance)	low-moderate	low-moderate	moderate			Difficult to control/audit	Mostly useful in context of catch-based rules.	moderate-high	N/A	Logbooks more useful for monitoring than compliance; CDRs more useful for compliance				May compromise effectiveness of CDR use for data gathering		Indiect at determining compliance of on-the-water (e.g. spatial) rules
logbooks - formal	moderate-high	high	strong		N/A	wont' work	Most common for catch/effort rules, but can be useful for gear/spatial/temporal /size rules if reported accurately	moderate	Probability to misreport increases with more regulations					May compromise effectiveness of logbook use for data gathering		Indiect at determining compliance of on-the-water (e.g. spatial) rules
Logbooks - informal	low-moderate	moderate	can be low if strong cultural precedence for responsible stewardship	Likely to be more accurate if strong	Likely to be more accurate if strong	Unlikely to be possible to implement	Most common for catch/effort rules, but can be useful for gear/spatial/temporal /size rules if reported accurately	low-moderate	Probability to misreport increases with more regulations		May be more difficult			May compromise effectiveness of logbook use for data gathering		Indiect at determining compliance of on-the-water (e.g. spatial) rules
VMS/automated	high for VMS; low for real time compliance e.g. via smart phone app	high for VMS; low-moderate for real time compliance e.g. via smart phone app	Strong for VMS; low for real time compliance e.g. via smart phone app		N/A	Difficult to control	Useful if spatial/temporal/gear /size controls	high	Useful if can capture relevant activity	Being considered for NSW charter fishing industry and Port Phillip Bay Scallop Dive Fishery (Joll et al. 2015)				May compromise effectiveness of VMS/automated use for data gathering		VMS can only account for spatial-temporal patterns.
Cameras to record catch, effort, gear	high	high	high	N/A		Difficult to control	Useful if catch/effort/gear/ size controls	high	Useful if can capture relevant activity					May compromise effectiveness of camera use for data gathering		Cameras may account for catch/effort/gear compliance
Observers	moderate-high	moderate-high	moderate			Unlikely to be possible to implement	Can be applied to any	high	Useful as onus not on operator					May compromise effectiveness of use of observers for data gathering		Can cover all forms of control rules

Table 12 cont'd: Enforcement options continued, (rows) with associated criteria, and caveats invoked against questions (columns)

	Criteria			Caveats								
Enforcement options	Minimum required relative GVP of fishery	Minimum level of funding required	Minimum extent of agency/ governance support	Operational								
				Is fishing beach-based, as opposed to boat-based and ports? IF YES	Is there a high number of ports, and/or geographic isolation? IF YES	Is likelihood of discarding high? IF YES	Is number of participants low? IF YES	Is number of participants low? IF NO	Is the sector commercial? IF YES	Is the sector commercial? IF NO	Are there multiple gears? IF YES	Is the fishery quota-driven with a competitive season? IF YES
Post-harvest checks for age-structured monitoring	moderate	moderate	moderate	easier if boat and port-based	More difficult with higher number of ports and/or geographic isolation	Unreported discards may have resulted in different age structure	Easier if low		commerical	commercial		
Processor supply chain rationalisation (grading information; total catches)	moderate	moderate	moderate		May be easier than targeting ports	Unreported discards may have resulted in different age structure			commercial	commercial	May be difficult to obtain gear-specific catch breakdowns	
Landing measures – regulating to whom and where you land (options are limited)	moderate	moderate	moderate-high	easier if boat and port-based	More difficult with higher number of ports and/or geographic isolation				more for commercial	more for commercial		
Prior reporting systems (prior to landing and/or pre-departure. Suits ITQ fisheries without VMS	moderate	moderate	moderate			Higher propensity for misreporting			commercial	commercial	May be difficult to obtain gear-specific catch breakdowns	Suits ITQ fisheries without VMS
Third-party contracts for secure management of information	moderate	moderate	moderate		More difficult with higher number of ports and/or geographic isolation	If sense of trust or buy-in to process not high,and/or if penalties high may not report discarding.	May not be cost-effective		more for commercial/charter	commercial	May be difficult to obtain gear-specific catch breakdowns	

Table 12 cont'd.: Enforcement options continued (rows) with associated criteria, and caveats invoked against questions (columns) (cont'd)

	Criteria			Caveats										
				Socio-economic										
Enforcement options	Minimum required relative GVP of fishery	Minimum level of funding required	Minimum extent of agency/ governance support	Is there cultural precedent for responsible stewardship? IF NO	Is extent of buy-in to process low? IF YES	Is sense of accountability/ownership low? IF YES	Is sense of trust among one another low? IF YES	Is sense of trust of process/ goverance low? IF YES	Is the sense of the value of management low? IF YES	Is the level of respect for incentives/ penalties low? IF YES	Strength of incentive/penalty	Are rewards around breaking the rules worth the risk? (this is around risk perception vs strength of consequence) IF YES	Is there stigma around TEP interactions? IF YES	Are there measures that would received greater or less support?
Post-harvest checks for age-structured monitoring	moderate	moderate	moderate	Useful if not	Useful if yes	Useful if yes	N/A	Useful if yes	Useful if low					
Processor supply chain rationalisation (grading information; total catches)	moderate	moderate	moderate				N/A							
Landing measures – regulating to whom and where you land (options are limited)	moderate	moderate	moderate-high				N/A							
Prior reporting systems (prior to landing and/or pre-departure. Suits ITQ fisheries without VMS	moderate	moderate	moderate	stronger propensity to misreport if no	stronger propensity to misreport if so	stronger propensity to misreport if so	N/A	stronger propensity to misreport if so	stronger propensity to misreport if low	More likely to be accurate if penalties for misreporting respected	More likely to be accurate if penalties for misreporting high	Less likely to be accurate if yes		More incentive to misreport against catch/effort limits that will limit profitability, or spatial/temporal that limit access
Third-party contracts for secure management of information	moderate	moderate	moderate	Helpful if so	If so, use of third party may help overcome this	If so, use of third party may help overcome this	May be more difficult to come to agreement on how data is to be shared	If so, use of third party may help overcome this	Useful if low				Buffer of third party may be helpful	Easier to apply against catch/effort limits

Table 12 cont'd.: Enforcement options continued (rows) with associated criteria, and caveats invoked against questions (columns) (cont'd)

	Criteria			Caveats							NEW QUESTIONS					
				Governance												
Enforcement options	Minimum required relative GVP of fishery	Minimum level of funding required	Minimum extent of agency/ governance support	Is local leadership strong? IF YES	Is local leadership strong? IF NO	Is the fishery open access? IF YES	Types of harvest control rule	Ability to validate (reporting)	Are there a high number of management restrictions (e.g. spatial, temporal)? IF YES	Other	Ability to access information	State of inter-sectorial relationships (including with management as well as people on the water)	In developed fisheries, most compliance and enforcement options are already in place (i.e. logbooks, port monitoring). Include static attribute "Is this already in place?"	Would the use of this measure compromise its ability/fisher willingness for it to be used for data gathering or validation? IF YES	Are there particular fisheries to which this is suited? (per above example of prior reporting systems suiting ITQ fisheries)	Confront enforcement options with types of control rules from FishPath (e.g. spatial closures), as a static attribute.
Post-harvest checks for age-structured monitoring	moderate	moderate	moderate			Difficult to control	Can be applied to any	high								Indiect at determining compliance of on-the-water (e.g. spatial) rules
Processor supply chain rationalisation (grading information; total catches)	moderate	moderate	moderate				Can be applied to any	high								Indiect at determining compliance of on-the-water (e.g. spatial) rules
Landing measures – regulating to whom and where you land (options are limited)	moderate	moderate	moderate-high			Difficult to control	Can be applied to any	moderate								Indiect at determining compliance of on-the-water (e.g. spatial) rules
Prior reporting systems (prior to landing and/or pre-departure. Suits ITQ fisheries without VMS	moderate	moderate	moderate			Difficult to control	Usually geared around catch/effort/spatial/temporal	moderate	Probability to misreport increases with more regulations						Suits ITQ fisheries	Indiect at determining compliance of on-the-water (e.g. spatial) rules
Third-party contracts for secure management of information	moderate	moderate	moderate			Unlikely to be possible to implement	Usually geared around catch/effort/spatial/temporal	moderate			May be more difficult			May be helpful in this context: stakeholders involved in determining how data will be used		

Review process for the harvest strategy

A timeframe should be set for formal review of the harvest strategy. Experience world-wide has demonstrated that irrespective of the amount of prior testing of a harvest strategy, periodic amendments to ensure optimal decisions are necessary (Smith et al. 2008). This may occur when there is new information that substantially changes understanding of the status of a fishery, when problems are identified in application of the harvest strategy, or when uncertainties that were not previously understood arise (Australian Government 2007).

To ensure the harvest strategy is up to date and takes into account the best available information, knowledge and understanding of a fish stock or fishery management unit, a regular periodic review should be undertaken and a timeframe for such review should be established in the harvest strategy (e.g. every 3-5 years (Sloan et al. 2014)). This should be a constructive and objective process as opposed to one that is agenda-driven.

For low-value fisheries, the costs, and resource requirements of review should be considered when determining a timeframe for review. Also, reviews should be undertaken in such a way to minimise costs. For example, desktop reviews could occur, and web conferencing could be employed among a core team, with larger stakeholder workshops not occurring with every review.

A formal review of a harvest strategy should be planned and undertaken on an agreed time frame (for example, every 3-5 years). In Australia, review timeframes typically range from 2-5 years, with a more minimal annual review to check if things have changed. The process should be iterative in building on existing arrangements. The timeframe for review needs to account for life-history and generation time of the species of relevance. The harvest strategy should be reviewed more often when new information becomes available. More generally, harvest strategies should be inherently adaptive, whereby the process of review enables revision and refinement as information improves, or circumstances change. This is of particular relevance to data-limited fisheries, where highly uncertain assessments should ultimately be improved through commitments to obtain more or improved data.

One way to build in flexibility to a harvest strategy is to identify the 'exceptional circumstances' that may trigger departure from, or even suspension of, the harvest strategy. This is one way to allow flexibility in a structured way, but not so much flexibility that it undermines the intent of having a harvest strategy. In this sense, understanding the boundaries of flexibility in a harvest strategy is a part of the iterative process to develop mutual understanding among managers, fishers and stakeholders about expectations from adopting a formal harvest strategy. Specifically, this would include defining the exceptional circumstances that may trigger such a change. Having flexibility to change the framework to deal with unforeseen circumstances should not be confused with flexibility in interpreting the results of assessments and applying the harvest decision rules within years, which will tend to undermine the process itself (Smith et al. 2008).

Managers and stakeholders must be cautious of utilising a harvest strategy review as an excuse to shift goalposts, in self-interest of change. This makes a farce of the review process and undermines the validity of the harvest strategy. The key point is that harvest strategies need to be adaptive enough to address deficiencies, unforeseen circumstances and to allow for improvements (Walters and Hilborn 1978), but should not be changed to relax or vary the harvest strategy when the decisions are not suitable to some, or all, stakeholders.

Has a timeframe been established for formal review of the harvest strategy?

Have cost-effective review processes been identified?

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Guidelines Appendix 1: List of FishPath criteria/caveat questions

These questions directly map to the criteria and caveats within FishPath for each of the three harvest strategy components (i.e. monitoring, assessment, decision rules).

Information Category	Criteria/ Caveat	Harvest strategy component	Questions (criteria, or caveat-invoking)
Operational Characteristics	Criteria	Monitoring	Categorise the nature of the fishery, in terms of its main market. If it is a mixed fishery, assign the highest market level (e.g. commercial" over "local market")."
Socio-economic	Criteria	Monitoring	How culturally ingrained in fishers is cooperation to management, in terms of their willingness to share and record information?
Socio-economic	Criteria	Monitoring	How is data collection valued and prioritized by the governance agency for the fishery of interest?
Socio-economic	Caveat	Monitoring	Rank the current or potential monetary investment for a monitoring program for this species/species group.
Governance (Fishery of Interest)	Criteria	Monitoring	Rank the current or potential research and/or institutional capacity to implement and maintain a formal management strategy (i.e. monitoring, assessment, decision rules).
Operational Characteristics	Caveat	Monitoring	Are the main fishing locations and/or ports variable, such that implementation of a monitoring program or obtaining a representative sample will be difficult?
Operational Characteristics	Caveat	Monitoring	Are home ports/landing sites and markets numerous/spatially disaggregated, such that representative sampling would be difficult to obtain given the available capacity?
Operational Characteristics	Caveat	Monitoring	Do fishing activities (regardless of current management) correspond with the spatial extent of the fishable stock?
Operational Characteristics	Caveat	Monitoring	Is the spatial range of the fishing activity geographically vast such that direct sampling (e.g. from landing sites or fishing activity) is challenging?
Operational Characteristics	Caveat	Monitoring	Is fishing highly spatially or temporally aggregated, such that this has the potential to bias sampling? (e.g. sampling by students may only be able to occur at the end of the year, and the peak fishing activity is mid-year; due to management plan)
Operational Characteristics	Caveat	Monitoring	Do known landing sites account for all fishing activity?
Operational Characteristics	Caveat	Monitoring	Do multiple gears harvest the species/species group?
Operational Characteristics	Caveat	Monitoring	Does the relative species composition of the fishery change over time or space (e.g. opportunistic, multiple species targeted, and/or exhibit shifting between target species)?
Operational Characteristics	Caveat	Monitoring	If the fishery is multispecies, is the species composition of the catch divided disproportionately across the supply chain? (e.g. only some species are marketed, while others are consumed for subsistence?)
Operational Characteristics	Caveat	Monitoring	Is the nature of fishing operations (e.g. target species, gear types, fishing locations, markets) changing?
Operational Characteristics	Caveat	Monitoring	Is there substantive illegal, unregulated, or unreported fishing such that the stock or species are affected to an extent that a monitoring program will not capture the extent of fishing mortality?
Management	Caveat	Monitoring	Are ports and/or markets matched to the managed area?
Management	Caveat	Monitoring	If <100% spatial coverage is able to be obtained for a monitoring program, would the existing coverage be representative of the entire fleet/geographic range of the fishery?
Management	Caveat	Monitoring	Is any monitoring program able to be conducted at the same time and in the same manner interannually and spatially?
Management	Caveat	Monitoring	Is any monitoring program able to be undertaken with temporal regularity and reasonable frequency (e.g. more than every 5 years)?
Socio-economic	Caveat	Monitoring	Does the ability to collect data show a significant spatial bias?
Socio-economic	Caveat	Monitoring	Are fishers, or can fishers be, incentivised/motivated/willing to be involved in a data collection program?
Socio-economic	Caveat	Monitoring	Are there existing cooperatives or associations that could provide a starting point to fisher cooperation?
Socio-economic	Caveat	Monitoring	Rank the number of levels of buying/distribution (as per points in the supply chain).
Governance (Fishery of Interest)	Caveat	Monitoring	Where is the capacity and mandate to facilitate or allow for monitoring?
Governance (Fishery of Interest)	Caveat	Monitoring	Is there strong governance leadership (i.e. agency and/or government-based, as distinguished from community leadership) in place to support/facilitate management measures?
Governance (Fishery of Interest)	Caveat	Monitoring	Are regulations enforced, and, if they are enforced, are the regulations/governance respected/complied with?
Governance (Fishery of Interest)	Caveat	Monitoring	Do government officials have the capacity for local enforcement of regulations?
Governance (Fishery of Interest)	Caveat	Monitoring	Do the jurisdictional boundaries and spatial extent of the fishable population match?
Governance (Fishery of Interest)	Caveat	Monitoring	Is the fishery open access, as opposed to limited entry?
Governance (Fishery of Interest)	Caveat	Monitoring	Are fishing permits community-based? "Community-based" could include individual permits issued, managed, or distributed by a community organisation, as well as permits issued to a co-op.
Biology / Life History	Caveat	Monitoring	Is the fished population transboundary (e.g. does the adult range cross management boundaries)?
Biology / Life History	Caveat	Monitoring	Does the species aggregate (i.e. schooling or other aggregations)?
Biology / Life History	Caveat	Monitoring	Does the species follow a boom-and-bust cycle (e.g. the species displays high volatility in its population dynamics, whereby availability is sudden, extreme, and unpredictable)? Examples include anchovies, scallops, and squid.
Biology / Life History	Caveat	Monitoring	Is the species cryptic, so that the representativeness of sampling may be compromised?
Biology / Life History	Caveat	Monitoring	If handled or captured and released, is survivorship compromised?

Information Category	Criteria/ Caveat	Harvest strategy component	Questions (criteria, or caveat-invoking)
Data Availability	Criteria	Assessment	Is there a time series of data (as opposed to snapshot(s))?
Data Availability	Criteria	Assessment	What time series exists of catch data?
Data Availability	Criteria	Assessment	What time series exists of effort data?
Data Availability	Criteria	Assessment	What time series exists of catch-per-unit-effort data?
Data Availability	Criteria	Assessment	What time series exists of fishery independent abundance data?
Data Availability	Criteria	Assessment	What time series exists of fishery independent sampling inside and outside of no-take zones (e.g. density, sizes)?
Data Availability	Criteria	Assessment	What time series exists of fishery dependent density or abundance data?
Data Availability	Criteria	Assessment	What time series exists of length composition data?
Data Availability	Criteria	Assessment	What time series exists of mean length or length percentiles data?
Data Availability	Criteria	Assessment	What time series exists of mean weight or weight percentiles data?
Data Availability	Criteria	Assessment	What time series exists of species composition data?
Data Availability	Caveat	Assessment	What time series exists of sex composition data?
Data Availability	Criteria	Assessment	What is the extent of understanding of the general population biology of the species?
Data Availability	Criteria	Assessment	What is the extent of understanding of the length-at-first-capture of the species?
Data Availability	Criteria	Assessment	What is the extent of understanding of the length-weight relationship of the species?
Data Availability	Criteria	Assessment	What is the extent of understanding of the life-history ratio M/K of the species?
Data Availability	Criteria	Assessment	What is the extent of understanding of the maturity ogive/size at maturity of the species?
Data Availability	Criteria	Assessment	What is the extent of understanding of the natural mortality of the species?
Data Availability	Criteria	Assessment	What is the extent of understanding of the recruitment deviations of the species?
Data Availability	Criteria	Assessment	What is the extent of understanding of the relationships between length and fecundity of the species?
Data Availability	Criteria	Assessment	What is the extent of understanding of the stock recruitment steepness of the species?
Data Availability	Criteria	Assessment	What is the extent of understanding of the Von Bertalanffy growth parameters of the species?
Data Availability	Criteria	Assessment	What expert judgement is available on the stock status or level of depletion?
Data Availability	Criteria	Assessment	What expert judgement is available regarding fishery operations and interaction with the broader environment?
Data Availability	Criteria	Assessment	What expert judgement is available regarding MPAs (Marine Protected Areas) and/or habitat status?
Data Availability	Criteria	Assessment	What expert judgement is available regarding non-fishing threats, ecosystem services, and/or threat interactions?
Data Availability	Criteria	Assessment	Is catch data available by location, so that any spatial differences are discernible?
Data Availability	Criteria	Assessment	Is effort data available by location, so that any spatial differences are discernible?
Data Availability	Criteria	Assessment	If catch-per-unit-effort (CPUE) data are available, are there additional variables that may be used to standardize CPUE (e.g. oceanographic conditions, vessel type, gear type, location, area, time of year, and/or moon phase)?
Data Availability	Criteria	Assessment	Is the data collected for use within an assessment representative of the fleet as a whole?
Data Availability	Criteria	Assessment	Are the data collected for use within the assessment representative of the fishery across its entire spatial range?
Operational Characteristics	Criteria	Assessment	Is the species being actively and consistently targeted?
Operational Characteristics	Criteria	Assessment	Are gears and deployment manners known?
Operational Characteristics	Criteria	Assessment	Does the stock move beyond the boundaries of where fishing takes place?
Operational Characteristics	Criteria	Assessment	Have historical or recent changes occurred in how the fishery is operating (e.g. gear, distribution of effort, species composition, regulations)?
Data Availability	Criteria	Assessment	Prior estimates are a requirement for certain types of assessments: are there prior estimates or ranges for r (population intrinsic growth rate) and K (carrying capacity)?
Data Availability	Criteria	Assessment	Is there a starting estimate of MSY?
Data Availability	Criteria	Assessment	Is there a starting estimate of Z (total mortality)?
Data Availability	Criteria	Assessment	Is there an estimate of the annual exploitation rate that produces MSY at equilibrium (Umsy)? (noting that this is required as an input for certain types of assessments)
Data Availability	Criteria	Assessment	What is known about the selectivity of the fishery?
Data Availability	Caveat	Assessment	Where size data exists, is selectivity at least able to be inferred?
Operational Characteristics	Caveat	Assessment	Have data used in the assessment been collected using a different gear than that used by the fishers?
Operational Characteristics	Caveat	Assessment	Has the selectivity pattern changed over time?
Operational Characteristics	Caveat	Assessment	Have there been changes in the fishery that compromise how historical data are treated?
Operational Characteristics	Caveat	Assessment	If there are multiple fleets or gear types, do the different fleets or gear types target/select different size ranges of the same species?
Operational Characteristics	Caveat	Assessment	Is the number of participants (or vessels) low (<50)?
Management	Caveat	Assessment	Is/are there no-take marine protected areas (MPAs) and if so, are these well enforced and can they represent unfished size and density?
Data Availability	Caveat	Assessment	Is there expert knowledge of suitable targets for indicators that could be used (directly or indirectly) to understand the status of the stock (or fishing pressure)?
Data Availability	Caveat	Assessment	Is there some starting estimate or notion of abundance?
Data Availability	Caveat	Assessment	What is the general understanding of the current depletion over recent years?
Management	Caveat	Assessment	Are species within a multispecies fishery being assessed collectively as a group or "basket" of species (whether because of lack of data on each species, or because of a lack of species identification, or because the species are commonly and consistently captured together)?
Management	Caveat	Assessment	Is there a desire, or legislative/policy mandate, to understand the fishery status from an ecosystem perspective (or multispecies perspective) within the harvest strategy, rather than from a single species perspective?

Information Category	Criteria/ Caveat	Harvest strategy component	Questions (criteria, or caveat-invoking)
Biology / Life History	Caveat	Decision rules	Does the species have a known spawning season?
Biology / Life History	Caveat	Decision rules	Does the species have known spawning grounds, and/or form spawning aggregations?
Biology / Life History	Caveat	Decision rules	Are there known locations that are nursery grounds for the species?
Biology / Life History	Caveat	Decision rules	Does the gear have the potential to damage nursery grounds?
Biology / Life History	Caveat	Decision rules	Does growth rate differ between sexes, or is there a gender differential in the age-at-maturity?
Biology / Life History	Caveat	Decision rules	Is the species sedentary or sessile enough that spatial management is effective?
Biology / Life History	Caveat	Decision rules	Is the species a "periodic strategist" (slow-growing, long-lived, steady state population but with variable recruitment)?
Biology / Life History	Caveat	Decision rules	Do any of the species of interest stop gaining length at a particular size (i.e. has determinant growth)?
Biology / Life History	Caveat	Decision rules	If biomass-based reference points could be calculated, would these be meaningful? (e.g. for a boom-and-bust species, equilibrium dynamics may not be appropriate and so biomass-based reference points are not meaningful)
Data Availability	Caveat	Decision rules	Are only effort data available?
Data Availability	Caveat	Decision rules	Is size composition or species composition the only type of data available?
Data Availability	Caveat	Decision rules	Is it possible to calculate, or define a proxy, for a target reference point?
Data Availability	Caveat	Decision rules	Is there a high degree of uncertainty in the indicator(s), whether direct (empirical) or determined by assessment, on which a decision rule may be based?
Data Availability	Caveat	Decision rules	Is there a total lack of knowledge about, and/or data for, the fishery?
Management	Caveat	Decision rules	Is monitoring difficult?
Data Availability	Caveat	Decision rules	Is there immediate concern, among any stakeholder group, regarding stock status?
Operational Characteristics	Caveat	Decision rules	Is the fishery multispecies, either in terms of target or bycatch species?
Operational Characteristics	Caveat	Decision rules	Are other species or habitat impacted by the gear?
Operational Characteristics	Caveat	Decision rules	Does the gear intersect with threatened or vulnerable species (regardless of whether these are targeted), and/or habitat locations?
Operational Characteristics	Caveat	Decision rules	Are there multiple fleets (if considering a single gear, are there other gears or fleets) impacting the species or species group?
Operational Characteristics	Caveat	Decision rules	Are there seasonal concentrations of effort, regardless of whether these are by mandate or not?
Operational Characteristics	Caveat	Decision rules	Are there spatial concentrations of effort?
Operational Characteristics	Caveat	Decision rules	Are there conditions (e.g. oceanographic, environmental, weather, temperature) that strongly affect either fish availability or ability to fish?
Operational Characteristics	Caveat	Decision rules	Is there latent effort in the fishery?
Operational Characteristics	Caveat	Decision rules	Is effort creep occurring, suspected, or likely?
Operational Characteristics	Caveat	Decision rules	Is high discarding or illegal/unregulated/unreported activity known or suspected?
Operational Characteristics	Caveat	Decision rules	Does an assessment suggest that overfishing is probable, for any species harvested using the gear?
Socio-economic	Caveat	Decision rules	Is there a general societal sense that formal management is a good thing, in terms of complying with and supporting management measures?
Socio-economic	Caveat	Decision rules	What is the level of fishery cooperation, in terms of complying with and supporting management measures?
Socio-economic	Caveat	Decision rules	What level of financial dependency and/or cultural importance is associated with the fishery?
Governance (Fishery of Interest)	Caveat	Decision rules	Is there strong leadership in place to design and support management measures?
Governance (Fishery of Interest)	Caveat	Decision rules	What is the extent of enforcement capability for this fishery?
Management	Caveat	Decision rules	Does an assessment (either current, or suggested by FishPath) suggest a certain form of decision rule?
Management	Caveat	Decision rules	Is length-based spawning potential ratio (length-based SPR) currently being used for, or has been identified by FishPath as a viable option for, assessment?
Management	Caveat	Decision rules	Is Depletion Corrected Average Catch (DCAC) currently being used for, or has been identified by FishPath as a viable option for, assessment?
Management	Caveat	Decision rules	Is Only Reliable Catch Stocks (ORCS) currently being used for, or has been identified by FishPath as a viable option for, assessment?
Management	Caveat	Decision rules	Is depletion-based stock reduction analysis (depletion-based SRA) currently being used for, or has been identified by FishPath as a viable option for, assessment?
Management	Caveat	Decision rules	Is a production model currently being used for, or has been identified by FishPath as a viable option for, assessment?
Management	Caveat	Decision rules	Is Zhou's catch-only approach currently being used for, or has been identified by FishPath as a viable option for, assessment?
Management	Caveat	Decision rules	Is depletion analysis currently being used for, or has been identified by FishPath as a viable option for, assessment?
Management	Caveat	Decision rules	Is linear regression on catch-per-unit-effort (CPUE) time series currently being used for, or has been identified by FishPath as a viable option for, assessment?
Management	Caveat	Decision rules	Are biomass surveys to inform spatial management" currently being used or have these been identified by FishPath in the Assessment section as a viable option?

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Our innovations contribute billions of dollars to the Australian economy every year. As the largest patent holder in the nation, our vast wealth of intellectual property has led to more than 150 spin-off companies.

With more than 5,000 experts and a burning desire to get things done, we are Australia's catalyst for innovation.

CSIRO. WE IMAGINE. WE COLLABORATE. WE INNOVATE.

FOR FURTHER INFORMATION

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