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

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Executive Summary

Overview

We here provide the first comprehensive, process-based guidance to developing low-cost management regimes for small-scale, low-value fisheries. Our approach is strongly “bottom-up” in that it seeks to identify pragmatic options and provide practical advice that specifically acknowledge(s) the context and (resource, managerial and research capacity, data, socio-economic) constraints within the fishery. That is, it attempts to provide advice that is tailored to each fishery’s unique circumstances. This includes incorporating and formalising, where appropriate, existing management arrangements into a harvest strategy, and recommending assessment approaches based only on currently available information.

Underpinned by a review of the literature, we have developed an accompanying ‘Low-cost Management Regime Guidelines’ document. Our Guidelines provide to users an efficient, transparent, defensible and standardised process to identify management options that are best suited to the fishery’s context. Such a process mitigates against decision paralysis and inefficiency in having to develop a harvest strategy in the absence of a pro-forma, and against using the wrong assessment, or inappropriate control rules or monitoring programs.

Where relevant, the Guidelines present users with options with associated caveats, according to the specific context of the fishery as informed by the user. The FishPath harvest strategy decision support tool follows this format and underpins the harvest strategy section of the Guidelines. We present a worked example of harvest strategy development (using FishPath) for the Northern Territory Spanish Mackerel (*Scomberomorus commerson*) Fishery.

The Guidelines document is intended to be a “go-to” guide for managers and practitioners to develop formal low-cost management regimes for data-limited fisheries, from point of inception to point of implementation. This embraces pre-requisites and pre-engagement, engagement with stakeholders, objective elicitation and reconciliation, and the determination of performance indicators and reference points that precede harvest strategy development. The Guidelines, while standalone, reference the FishPath harvest strategy selection software as a tool to identify viable harvest strategy options given the fishery’s context.

Finally, the Guidelines provides advice on how to choose between harvest strategy options, and how to articulate and implement the harvest strategy, including embedding it within a management plan, and considering the issues around compliance and enforcement. The Guidelines are unique in that they provide stepwise, context-specific guidance. Where relevant, they are interactive in providing recommendations customised to the fishery’s context. We intend the Guidelines to be the global reference for development of management regimes in data-limited contexts.

Background

Northern Territory Fisheries had long flagged the need for the development of low cost, practical management approaches for low-value, small-scale fisheries. These fisheries are typically information- and resource-poor, and thus require inexpensive, pragmatic tools that yield relatively robust outcomes. The demographics of such fisheries is secondary but can include recreational and indigenous sectors in addition to commercial. Moreover, prior lack of engagement with management, levels of literacy, isolation and cultural issues are inherent traits of many low-value, small-scale fisheries, and these must be explicitly acknowledged and considered.

Harvest strategies, comprising the pre-agreed monitoring, assessment and decision rules that collectively are used to formally manage a fishery, lie at the heart of any management regime. 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. Within Australia, many State fisheries are seeking to implement (and Commonwealth fisheries are seeking to review) formal fishery harvest strategies, embracing many data-limited species, while FRDC's Status of Australian Fish Stocks aims to resolve the status of over 200 species whose status is currently designated as "unknown".

Without a process-based guidance tool to identify viable data-limited harvest strategy options, this process is ad-hoc: there is no means to do this in an efficient, transparent, defensible and standardised way. Often this can result in management paralysis, inefficiency and confusion, misapplication of stock assessments, or inappropriate control rules or monitoring, all resulting in high uncertainty and creating risks for overfishing.

Aims/objectives

1	To review and inventory existing approaches for management regimes for small-scale fisheries, with emphasis on low-cost approaches.
2	To provide a guidelines document of advice and recommendations for the development of management regimes for small-scale, low-value fisheries, according to fishery family/archetype.
3	To use the NT Spanish Mackerel Fishery as a case study to inform and refine the guidelines document for one fishery family/archetype.
4	Via the case study fishery, to consider how to incorporate multiple sector objectives and how best to engage relevant stakeholders, in the context of pragmatic management regimes.
5	In association with relevant management agencies, develop a new proposal to apply the guidelines to additional case study fisheries, and to continue the engagement with the Spanish Mackerel fishery.

Methodology

The Guidelines were formulated based on the collective experience of the project team in engaging with small-scale, data-limited fisheries, and developing and implementing pragmatic, low-cost harvest strategies, and were informed by a literature review that included an informal gap analysis. They were refined based on feedback from an international stakeholder workshop, and from case-study worked examples applications, not only to NT Spanish Mackerel, but also in New South Wales, California, Canada, Jamaica, Peru and Kenya.

The Spanish Mackerel worked example was undertaken with a core group of experts from NT Fisheries.

Results/key findings

Our review of the literature confirmed that a key gap was process-based advice on *how* to develop and implement low-cost management regimes. The emphasis of much of the literature around data-limited/low-cost management regimes was on developing nations and was heavily weighted around community and co-management. This suggests that management regimes, as a whole, have received little consideration in the context of low-value fisheries

This demands an end-to-end tool to provide explicit and direct, transparent and objective guidance to practitioners. This includes not only the aspects that surround harvest strategy development (stakeholder engagement, objective elicitation and weighting, performance indicator and reference point identification, compliance and enforcement), but also on how to articulate the details of harvest strategies, how to embed harvest strategies in management plans, and how to implement them.

The Guidelines are presented in chronological order with stepwise advice and check-points. Where relevant, the Guidelines are structured by presenting, for each relevant component of the management regime process, a comprehensive series of options, confronted by a suite of key caveats or considerations. This is the same approach as used in the FishPath harvest strategy selection software tool, to which the harvest strategy component of the Guidelines defers.

Five main information categories are collectively considered when evaluating options for each of the above components.

i. available data;
ii. biological/life history attributes of relevant species;
iii. fishery operational characteristics;
iv. socio-economic indicators/characteristics; and,
v. governance context.

The latter two categories have traditionally received less attention in a harvest strategy selection context. In the context of low-value, small-scale fisheries, however, they often are a main limiting factor. This applies not just to the harvest strategy but to the management regime as a whole.

The Guidelines

- Provide a platform for engagement and informed discussion
- Provide a broader perspective into harvest strategy development (as opposed to recommending and undertaking an assessment).
- Allow for more thoughtful consideration of management regime process
- Provide bottom-up, practical advice that directly considers the specifics of the fishery of interest.
- Provide an efficient, transparent, objective process to formalise engagement and empower decision making.

A worked example of the FishPath harvest strategy selection tool, and of the newly drafted compliance/enforcement, and community-based/co-management decision matrices within the Guidelines, is presented in this report for the NT Spanish Mackerel Fishery. This provided a shortlist of potential monitoring, assessment, decision rule, compliance/enforcement, and co-management options, with associated caveats. These were presented at the stakeholder workshop and the decision matrices and Guidelines further refined based on the comprehensive feedback received.

Implications for relevant stakeholders

In engaging with the Northern Territory Department of Primary Industry and Resources: Fisheries (“NT Fisheries”), New South Wales Fisheries Research Institute and the Queensland Department of Agriculture, Forestry and Fisheries, it is evident that there is need not only for advice and guidance on harvest strategy development, but more broadly in terms of end-to-end advice. Many of the problems in harvest strategy development occur at the point of engagement with stakeholders, and managers can also flounder without advice as to how to interpret, refine, and apply harvest strategy options, and embed these in management plans. By providing stepwise comprehensive, practical guidance against all steps of management regime development, the Guidelines provide clarity to managers and provide a standardised and comprehensive pathway forward.

Assuming data-limited fisheries comprise 10% of the gross value of capture fisheries in Australia and 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 ~$800K to Australia and ~$450 million globally. Conversely, collapse of these fisheries could represent annual losses of up to ~$16 million to Australia, and ~$9 billion globally.

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, increased compliance, increased business certainty, public confidence and export approvals associated with harvest strategies.

Recommendations

- The Guidelines provide a transparent and standard pathway to developing low-cost management regimes for low-value, small-scale fisheries, and inherent within them are the recommendations to arise from the project.

- Central to a management regime is the harvest strategy. The Guidelines empower stakeholders to simultaneously evaluate a large amount of harvest strategy options in an objective manner that is sensitive to the particulars of any given fishery.

- Beyond the development of a harvest strategy, the workshopping and case study application of the Guidelines revealed that the most critical aspects to a successful management regime were i) obtaining stakeholder engagement and buy-in (and that the probability of this was optimised by having an explicit pre-engagement strategy), and ii) that, having drafted the harvest strategy, ensuring that there was adequate detailed, practical advice on how to fully articulate its detail, and on how to operationalise it.

- The over-arching recommendation from the project is that the Guidelines are viewed as the "go-to" national standard for providing process-based advice to practitioners charged with managing low-value, small-scale fisheries. To achieve this requires that the Guidelines are applied to develop fully articulated case studies across a wide range of fishery types, both to showcase their value, and to enable their further critique and refinement. In the first instance, this should involve working with NT Fisheries, Northern Territory Seafood Council and the Spanish Mackerel Fishery to convert the current worked example into a more fully articulated case study.

- In the longer term, the uptake and acceptance of the Guidelines may be optimised by:

    - training facilitators who can apply the Guidelines in different contexts, from workshops to more grass-roots outreach styles of engagement.
    - maintaining a centralised database of case studies/applications.
    - bringing in more governance and social scientists, and managers across a broad range of fisheries, to critique those aspects of the Guidelines that are less scientifically oriented.
    - identifying a process for continuing to raise awareness of the existence and application of the Guidelines, while noting that this is best achieved by their successful application.
    - considering whether aspects of the Guidelines could be best operationalised as a user friendly software interface.

Keywords

Data-limited fishery, low-cost management, management regime, harvest strategy, Spanish Mackerel (*Scomberomorus commerson*)

Introduction

Northern Territory Fisheries have long flagged the need for the development of low cost, practical management approaches for low-value, small-scale fisheries. These fisheries are typically information- and resource-poor, and hence, require inexpensive, pragmatic tools that still yield relatively robust outcomes. The demographics of such fisheries are secondary, but they can include recreational and indigenous sectors in addition to commercial.

The majority of the world's fisheries are data-limited and lack effective management plans (Costello et al. 2012). Developing and implementing a complete, science-based management plan in these fisheries is difficult, given the unique circumstances that may make them 'data-limited', including limited resources or low capacity for research or enforcement. Management planning requires a bottom-up, customised approach, yet often little resources are dedicated to data-limited fisheries.

Low cost, practical management regimes for small-scale, low-value fisheries are desperately needed, to ensure long term sustainability for these fisheries without the need for resource hungry management frameworks. While management should focus on output regimes to provide business cases to support investment, input regimes should also be considered. 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 management providing guidance to such fisheries, even at the level of basic data collection regimes, can include limited literacy and numeracy, prior lack of engagement with management, isolation, and cultural issues. These are inherent traits of many low-value, small-scale fisheries, and must be explicitly acknowledged and considered by managers.

Most of the world's large, high-value fisheries are considered to be well-managed, not least due to the implementation of harvest strategies. However, the 90% of fisheries that are data-limited, and that lack harvest strategies, are thought to be in worse shape and at risk of overfishing (Costello et al. 2012). Collapse, or growth-overfishing (because of low-cost/ineffective management compromising productivity) of these fisheries represents significant economic, social and ecological losses. There is considerable scope for improving economic, ecological and social outcomes for data-limited fisheries, via appropriate harvest strategies.

A harvest strategy is the central component of a developing a plan for fisheries management reform and sustainability. A harvest strategy is a framework that specifies 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 (Sloan et al. 2014). It comprises a fully specified set of rules including specifications for i) a monitoring program, ii) the calculation of performance indicators (usually via a stock assessment), iii) the use of those indicators and their associated reference points in management decisions, through decision (or control) rules.

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, 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, 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.

The value of harvest strategies extends beyond the hard dollar value against more closely achieving maximum economic yield, to increased stakeholder buy-in to formal management, increased compliance, increased business certainty, public confidence and export approvals associated with harvest strategies.

A sensible and cost-effective starting point for the provision of general advice is a desktop study that reviews and inventories existing approaches for low-cost management regimes for small-scale fisheries, in order to develop a practical, stepwise guidelines document. Where appropriate, the project applied the general advice from Sloan et al.'s (2014) National Harvest Strategy Guidelines. It was also enhanced by i) the experience of the project team within the Commonwealth context, and in providing general guidance to the Food and Agriculture Organisation (FAO), for data-poor fisheries; and ii) the experience, local knowledge and trusted reputation of the NT members of the project team.

Objectives

Number	Details
1	To review and inventory existing approaches for management regimes for small-scale fisheries, with emphasis on low-cost approaches.
2	To provide a guidelines document of advice and recommendations for the development of management regimes for small-scale, low-value fisheries, according to fishery family/archetype.
3	To use the NT Spanish Mackerel Fishery as a case study to inform and refine the guidelines document for one fishery family/archetype.
4	Via the case study fishery, to consider how to incorporate multiple sector objectives and how best to engage relevant stakeholders, in the context of pragmatic management regimes.
5	In association with relevant management agencies, develop a new proposal to apply the guidelines to additional case study fisheries, and to continue the engagement with the Spanish Mackerel Fishery.

Method

<u>Objective 1: Review and inventory existing approaches for management regimes for small-scale fisheries, with emphasis on low-cost approaches</u>

The first objective of the project was to scope the components of developing management regimes for small-scale, low-value fisheries by undertaking a review of the literature. This review was partially an inventory of existing approaches for low cost, small scale fishery management regimes, but also focused on key issues around such approaches, as identified by the project team, and from the literature. The review covered both primary and grey literature for Australia, and primary literature internationally. It outlined the Australian and global small-scale fishery contexts and identified the need for the review: while the National Harvest Strategy Guidelines (Sloan et al. 2014) acknowledged issues unique to multi-sector and data-limited fisheries, they did not consider the management regime as a whole, nor, explicitly, small-scale, low-value fishery-specific issues. The review aimed to consider how management regimes, underpinned by harvest strategies, can be developed for small scale, low-value fisheries.

The literature review, which is appended to this report as Appendix 1, first concentrated on the definitions of "low cost/low-value, small fisheries", "management regime" and "harvest strategy", the latter because this is central to a management regime. The project team identified, and, as an organic part of the review process, refined, the components that collectively comprise a management regime (Figure 1).

We then summarised published case studies and attempted to seek insight against many of the management regime components. Few of the case studies identified in the review addressed more than one of the components of a management regime nor outlined the general process of developing a low-cost management regime. As such, this part of the review was case study- and component-specific. However, we attempted to draw general conclusions considering the developing versus developed nation contexts, what has typically worked well in other fisheries, and examples of pitfalls.

The next section focused on the identified "key issues", specifically:

- evaluation of harvest strategy performance
- the need for low cost management regime development and implementation
- reconciling objectives and having management in "currencies" that are relevant and translatable between multiple sectors
- multi-sector allocation issues
- multiple resource user groups
- Cultural issues, stakeholder endorsement and compliance, particularly with respect to indigenous and recreational sectors
- overcapacity
- sustainability accreditation

The review concluded with a brief gap analysis to surmise what is lacking from existing options and advice for developing management regimes, and the extent to which the literature can be collectively interpreted to draw process-based advice. It was confirmed that key gaps for low-value, data-limited fisheries were i) case studies considering multiple aspects of the management regime, and ii) over-arching (i.e. independent of any one fishery), process-based advice on how to develop and implement low-cost management regimes. This provided a solid justification for the second project objective: to provide a guidelines document of advice and recommendations for the development of management regimes for small-scale, low-value fisheries.

Objective 2: Provide a guidelines document of advice and recommendations for the development of management regimes for small-scale, low-value fisheries, according to fishery family/archetype

The guidelines document "Guidelines for developing low-cost management regimes for small-scale, low-value fisheries" (hereafter, "the Guidelines"), forms Appendix 2 to this report.

As well as being informed by the literature review, the Guidelines were formulated based on the collective international experience of the project team in engaging with small-scale, data-limited fisheries, and developing and implementing pragmatic, low-cost harvest strategies. Relevant aspects of the application of the National Guidelines to Develop Fishery Harvest Strategies (Sloan et al. 2014) to small scale, low value fisheries were also considered, as were the recommendations of the Joll et al. (2015) Australian Fisheries Management Forum (AFMF) Fisheries Management Workshop Report.

The Guidelines attempt to provide pragmatic, practical, and stepwise guidance explicitly to confront and address the data and capacity limitations associated with small-scale, low-value fisheries. The Guidelines are intended to be broadly applicable to fisheries globally, while being solutions-focused, that is, their application should provide practical advice and recommendations for the requirements of, and best way forward in, management regime development and implementation.

The Guidelines are also intended to:

- Provide an efficient, transparent, and objective process to formalize engagement and empower decision making.
- Provide a platform for engagement and informed discussion.
- Allow for more thoughtful consideration of the management regime selection process.
- Comprise comprehensive suites 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" documents 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. The 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 advice is intended to be commensurate with the scale of the fisheries and their low value. The data poverty, lack of management to date, and, sometimes, profound cultural issues faced by small, low-value community fisheries must be explicitly acknowledged: management regimes must be pragmatic and confront the issues unique to these fisheries.

It follows that providing general guidance for such fisheries, each of which face their own individual combinations of challenges, requires careful treatment. Attempting to tailor advice by grouping fisheries into typologies ("families", or "archetypes") by, for example, species or gear type, does not acknowledge that fisheries are defined by multiple dimensions. That is, a fishery is characterised not only by the life history/biology of its main target species, or by its operational characteristics (of which gear types are one), but also by its available data, and by its socio-economic and governance contexts.

Therefore, as opposed to a prescriptive approach, the Guidelines instead took a “bottom-up” approach, by:

i) providing advice as a sequential set of “stop sign” gateways that the user had to confront and overcome for their fishery, and
ii) when considering harvest strategies, enforcement, or the extent of co-management, confronting the user with a series of questions to characterise their fishery, so as to provide customised options for each of these.

This results in practical advice that directly considers the specifics of the fishery of interest.

The “stop sign” gateways are presented in chronological order, against the main management regime components (described in Figure 1), as follows:

STOP **User is being provided with a “stop sign” checkpoint**

The intention is that users will need to address or overcome each of these checkpoints to develop a defensible low-cost fishery management regime. To assist with this, the checkpoints are preceded by a detailed consideration of, and advice against, the point, or process in question.

Collectively, the stepwise advice provided by these “stop sign” checkpoints, against each of the components of the management regime, forms an abridged or succinct version of the Guidelines. This is presented in the Results section as “Concise Guidelines” and can be used as a “go-to” or “front-end” reference, to accompany the more comprehensive version of the Guidelines.

Over-arching issues, pre-requisite information

- Legislative/policy context
- Allocation of resource among stakeholders/sectors
- Co-management and community-based management

↓

Pre-engagement

- Undertake an internal audit of the fishery
- Identify drivers for management
- Clarify the reason for the journey
- Consider adoption and the “authorising environment”.
- Understand historical context and conflicts/issues
- Undertake desktop analyses (compile and review available information, identify performance indicators and reference points)
- Identify process of engagement

↓

PART 1: Engagement and elicitation

- Generating stakeholder interest/trust to motivate participation
- Obtaining ongoing stakeholder engagement and trust/sign-on
- Eliciting and weighting multi-sector objectives
- Reconciling multi-sector objectives
- Re-review available information
- Finalise performance indicators
- Finalise reference points

↓

PART 2: Identifying harvest strategy options

- Monitoring (data collection)
- Stock assessment
- Harvest control / decision rules
- “Fixed” harvest control rules/conditions
- Formal evaluation of harvest strategy options

↓

PART 3: Operationalising the Harvest Strategy

- Choosing between potential harvest strategy options: finalising the harvest strategy of choice
- What is the harvest strategy and how should it be articulated?”
- Defining/specifying the management plan
- Articulation and evaluation of impacts and outcomes

↓

PART 4: Implementation

- Process for day-to-day management
- Define/specify the management plan
- Establish the monitoring plan/program
- Tactical implementation of the harvest strategy
- Compliance and enforcement
- Review process for the harvest strategy

Figure 1: The stepwise process of developing a management strategy, which defines the structure of the Guidelines.

Central to any management regime is the fishery's harvest strategy; the pre-agreed specifications for i) a monitoring program, ii) the calculation of performance indicators (usually via a stock assessment), iii) the use of those indicators and their associated reference points in management decisions, through decision (or control) rules), and its enforcement. Another key aspect is the extent to which management is centralised versus community-based. One of the greatest challenges in developing a fishery management regime is navigating amount the "universe" of possible options to select those that are best suited to the fishery's specific characteristics. These options include

- the three harvest strategy components (monitoring (data collection), assessment, decision rules)
- enforcement, and
- co-management

The components of the Guidelines pertaining to the harvest strategy and to enforcement are structured by presenting a comprehensive series of options, confronted by a suite of key caveats or considerations that are invoked based on user responses to a set of questions. These may be conceptualised as matrices of choices versus limitations, with specific advice against relevant elements of the matrix. The harvest strategy matrices have been formalised as a decision support tool, called FishPath (Dowling et al. 2016), to which the harvest strategy section (Part 2) of the Guidelines refers. However, the Guidelines can be used in a standalone manner, as both the options, and the questions that should be considered against these, are explicitly presented.

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

A concise version of the Guidelines was also prepared, comprising a brief overview, the section headings and the "traffic light" checkpoints. This summary can be used as a "front end" to the main document, as a user manual for quick reference, and as a reporting pro-forma. (Note: a prose-style concise version of the Guidelines was prepared against its first draft and presented at the September 2016 stakeholder workshop. This prose-style summary was unanimously rejected as being redundant given the detailed version. Subsequently, it was decided that a terser, prose-free version would have greater utility).

Objective 3: To use the NT Spanish Mackerel Fishery as a case study to inform and refine the guidelines document for one fishery family/archetype.

The initial draft Guidelines were refined based on feedback from a stakeholder workshop which shared a case-study worked example for the NT Spanish Mackerel (*Scomberomorus commerson*) fishery that is presented in the Results and Discussion sections below. Held in Hobart in September 2016, the three-day workshop attendees included representatives from multiple State and Territory fisheries agencies, New Zealand, the South Pacific Commission, indigenous liaison teams, and relevant industry participants. The workshop report is included as Appendix 3.

Some project funding was allocated to offset costs of attendance, which encouraged broader involvement beyond parties related to the case study fishery. However, where fishery-specific issues arose, these were considered in the context of the case study fishery in the first instance.

Spanish Mackerel are important to fisheries globally, with notable cases of over-fishing across their distribution. Spanish Mackerel grow rapidly, up to around 200+ cm fork length (McPherson 1993), maturing at a young age, achieving 50% reproductive maturity within 2 years (McPherson 1993; Buckworth and Clarke 2001). Spanish Mackerel are batch spawners (McPherson 1993), having a high production potential (McPherson 1993; Buckworth 2004, Newman et al. 2012). The species shows restricted movements and meta-population structuring, at least in the adult phase.

The distribution of Australian commercial catches of Spanish Mackerel is north of about 30°S, in northern NSW, Queensland, NT and northern WA; with management tools and fishing methods differing among States. Australian commercial catches for Spanish Mackerel peaked at over 2000t in 2003, and have generally remained above 1200t, with NT commercial catches ranging from about 200t to 400t annually. Recreational catch (including fishing tour operators and charters) is of the order of 400t, and there is a small indigenous catch component (Langstreth et al. 2016). In Australia, current issues are mostly about sustainable limits, allocation, and the development of appropriate harvest strategies to ensure recovery or continued sustainable fishing.

The NT Spanish Mackerel Fishery was chosen as the case study fishery for the project, due to its being relatively non-politically contentious, while still having a need for management. The fishery has small-scale commercial, recreational and tourism sectors, and faces issues of allocation between these, as well as between the target and shark fishery commercial operators. Previous assessments, have been undertaken (Walters and Buckworth 1997; Buckworth 2004; Buckworth et al. 2007; Grubert et al. 2013; Macbeth et al. 2013), but uncertainties exist around the following:

- The degree of inaccuracy in the information on the Taiwanese-Australia joint venture fishery of the 1970s and 1980s.
- The quality of CPUE data as indicator of abundance/ any fishing power change over time
- Variations in age and size structure
- Meta-population properties and how these might affect assessment and management measures
- Other spatial effects (fishery targeting and operational drivers), that might additionally change in time
- Boundary effects (movement of fish and fishing across borders etc.)
- Selectivity with age or size changes (these might arise from sampling or be market- or operationally driven)
- Accuracy of sector catches
- Environmental drivers in recruitment and catchability
- That important population biology parameters are poorly known, including the natural mortality rate, and the stock-recruitment relationship.

The specific aims of the workshop were to:

- Share the draft Guidelines
- Familiarise attendees with the process outlined within the Guidelines
- Seek critical feedback regarding the structure and content of the Guidelines, against both
    - Technical detail
    - "Bigger picture" issues – i.e. is this approach outline considered useful?
- Discuss and finalise the project Extension Plan

- Identify ambassadors for future fully articulated case study applications.

The Overarching Issues/Pre-requisites, Pre-engagement, and Part 1 sections of the Guidelines were walked through and revised in detail in the workshop. Feedback was not specific to the NT Spanish Mackerel Fishery, but, advantageously, represented collective experience across a broad range of fisheries. The advice in Part 1 is predominantly around stepwise processes that apply regardless of fishery context, and as such, an a priori worked example for Spanish Mackerel was not especially relevant.

The greatest interest from managers and industry representatives at the stakeholder workshop, and generally, was in the harvest strategy component (Part 2) of the Guidelines, that is, the FishPath decision support tool. The preparation of the possible harvest strategy options for the NT Spanish Mackerel Fishery worked example (refer to Results, Discussion section) was undertaken, using FishPath, prior to the workshop, with a core group of experts from NT Fisheries. This enabled the workshop time to be most effectively utilised to share the process and outcomes, in order to seek feedback.

The initial draft of Parts 3 and 4 of the Guidelines (Operationalising and Implementing the Harvest Strategy) was significantly expanded in response to feedback from the stakeholder workshop around the Spanish Mackerel worked example.

<u>Objective 4: Via the case study fishery, to consider how to incorporate multiple sector objectives and how best to engage relevant stakeholders, in the context of pragmatic management regimes.</u>

A substantive portion of the September 2016 workshop was spent considering, in a pragmatic and practical manner, how to reconcile multiple sector objectives and how best to engage relevant stakeholders in the process of management regime development. As a result, the draft Guidelines were considerably re-organised, both to make these more relevant to stakeholders, and to improve the logical flow of the process.

A key outcome was the introduction of an explicit “Pre-Engagement” section in the Guidelines. Among other considerations, this requires practitioners to identify the drivers for management, clarify the reason for the “journey” of management change, understand the fishery’s historical context and any conflicts, and to identify a process of stakeholder engagement.

A second outcome was the detailed consideration given within the “Part 1: Engagement and elicitation” section of the Guidelines to i) generating stakeholder interest/trust to motivate their participation, ii) obtaining ongoing stakeholder engagement and trust/sign-on to the management regime process, iii) eliciting and weighting multi-sector objectives, and iv) reconciling multi-sector objectives. Each of these has their own sub-heading within this section, and, in addition to the case study fishery, the advice was partially informed by the literature review, which identified and explicitly considered the following key issues:

- stakeholder engagement
- ensuring ongoing stakeholder involvement
- reconciling objectives and having management in “currencies” that is relevant and translatable between multiple sectors
- multi-sector allocation
- multiple resource user groups
- education, cultural issues, stakeholder endorsement and compliance, particularly with respect to indigenous and recreational sectors

As a result of feedback from the September 2016 workshop, close attention was paid in the Guidelines to the style of narrative, definitions, and language. The focus was on ensuring the Guidelines were accessible to a grass-roots-level audience, and that all technical terms were explicitly defined throughout.

The concise version of the Guidelines, which provides a brief overview, summarises the headings and presents the “traffic light” checkpoints, enhances the accessibility of the Guidelines and can be used to help facilitate stakeholder engagement: it can be used as a front end user manual, a quick reference, and as a reporting pro-forma.

Objective 5: In association with relevant management agencies, develop a new proposal to apply the guidelines to additional case study fisheries, and to continue the engagement with the Spanish Mackerel fishery.

The final part of the project involved developing the outline of a new proposal for the development of management regimes for one or more fully articulated case studies, and to further apply, refine and extend the Guidelines and the FishPath tool. The additional case studies would ideally embrace fisheries with a varied range of characteristics and issues.

The key message from the September 2016 workshop participants was that the Guidelines and proposed process to develop low-cost fishery management regimes were felt to be of value, but that they strongly required extension. Beyond the scope of the current project, the need for further engagement and fully blown case studies was identified, particularly given that the NT Spanish Mackerel worked example did not embrace issues of key interest for other fisheries (e.g. multispecies issues).

An FRDC Expression of Interest, “Cost Effective Management Strategies for Small Scale/Capacity Limited Fisheries” was developed in late 2017. The project proposes to focus on one or two fisheries in each of at least three state jurisdictions: NT, Western Australia, New South Wales, and/or Queensland. Fisheries selected would embrace a range of issues such as cultural fishing, multiple sectors, and capacity constraints. Jurisdictions would be integrally involved in choosing and developing the harvest strategy for the case studies, while the project team will synthesise the findings and enhance the Guidelines and the FishPath tool for further Australian application. For each case study, we would work to develop draft harvest strategies from point of engagement to point of evaluation and implementation.

Results, Discussion, Conclusion

The main outputs from the project are the Literature Review and Guidelines. These form Appendices 1 and 2 (respectively) of this report, with overviews and key points provided here.

Literature review: Low-cost management regimes for small-scale, low-value fisheries

Overview

This review sought to identify how management regimes have typically been developed in low-cost, small-scale fisheries globally. In an Australian context, low cost, practical management regimes for small-scale, low-value fisheries are needed, to ensure long term sustainability for these fisheries without the need for resource hungry management frameworks. A logical first step is to develop guidance and a recommended approach to developing low-cost fishery management regimes. This has been long been flagged as a priority by the Northern Territory for its small-scale, low-value fisheries, including those with an indigenous and/or community emphasis. A sensible and cost-effective starting point for the provision of general advice is a review and inventory of existing approaches for low-cost management regimes for small-scale fisheries.

While the National Harvest Strategy Guidelines (Sloan et al. 2014) acknowledge issues unique to multi-sector (including recreational and indigenous) and data-limited fisheries, they do not consider the management regime as a whole, nor, explicitly, small-scale, low-value fishery-specific issues. We here tried to consider how management regimes, underpinned by harvest strategies, can be developed for small scale, low value fisheries, in the context of strong collaborative approach with, as appropriate, state agencies and indigenous and community liaison teams.

Harvest strategies are central to any management regime, and there has been much attention given to data-limited harvest strategies in the literature, specifically, to data-limited assessment methods and "management procedures" (assessment methods with associated harvest control rules). This review briefly revisits harvest strategies from the low-cost, low-value perspective. In the main, however, it defers to the recent literature review undertaken by Dowling et al. (2015a), and, in terms of process-based guidance, to the Dowling et al. (2016) FishPath harvest strategy decision support tool (www.fishpath.org). FishPath itself is underpinned by continually updated literature reviews, with references included explicitly in the software. That stated, a range of additional relevant papers pertaining to the application of low-cost harvest strategy principles and options were reviewed and included.

The complete literature review is provided in Appendix 1.

Glossary of key terms

As part of the literature review, we developed a glossary of key terms. This is presented here as a reference for readers.

a. Definition of "low cost/low-value, small fisheries"

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

- capacity (management, scientific, or enforcement),
- funding,
- its management priority relative to other fisheries within the jurisdiction, and/or
- stakeholder or agency willingness to formally manage the fishery,

then the fishery could be considered to be “low cost”/”low value”.

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 these are not intended to be exclusive. Importantly, “low cost”/”low value” is not a closed definition.

Generally, such fisheries lack, whether for reasons of data poverty and/or capacity limitations, formal, quantitative stock assessments (or at best, these have been undertaken sporadically), that are used to inform management.

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 the gross value of production (GVP)), but environmental and social values are also important, especially to non-commercial sectors.

b. Definition of “management regime”

A management regime is defined as the process of developing and implementing a formal harvest or management strategy for a fishery (with its associated data collection/monitoring, assessment, harvest control rules and compliance/enforcement) from the point of initial stakeholder engagement, to the point of implementation (Figure 1, Figure 2).

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 and/or more formal management. Within Australia, any management regime must be consistent with the Australian Fisheries Management Act and other legislation.

Central to a management regime is a harvest or management strategy (the terms are interchangeable), hereafter, “harvest strategy”. 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 1). Alternatively, a management regime equates to the inner two (yellow and green) layers of the diagram presented by Sloan et al. (2014) (Figure 2).

Figure 2: 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 green "fishery" layer.

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:
    a. Legislative and policy requirements
    b. Allocation
    c. Co-management and community-based management

ii) Issues that precede harvest strategy development:
    a. Generating stakeholder interest/trust to motivate participation
    b. Obtaining ongoing stakeholder engagement and trust/sign-on
    c. Eliciting and weighting multi-sector objectives
    d. Identifying performance indicators and reference points

iii) Issues that pertain to the implementation of harvest strategies:
    a. Operationalising a harvest strategy
    b. Defining/specifying the management plan
    c. Articulation and evaluation of impacts and outcomes
    d. Compliance
    e. Enforcement

They therefore expand on the guidelines for harvest strategy development provided in Dowling et al. (2015b):

(1) compile and review available information,

(2) identify possibly indicators,
(3) identify reference points for key indicators,
(4) select an appropriate harvest strategy,
(5) if possible, formally evaluate whether the harvest strategy options are likely to achieve the management objectives, and
(6) implementation.

c. Definition of "harvest strategy"

A harvest or management strategy is a formal, pre-specified set of rules designed to achieve the management objectives for the fishery. Harvest strategies (HSs, "management strategies", "management procedures") are formal frameworks for managing exploitation of fisheries, 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 (data collection) 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).

It is critical to note that the harvest strategy is the central component of, and underpins, a management regime.

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, which embrace data-limited contexts. As such, harvest strategies can vary strongly across 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 strategy development may merely involve the formalisation of existing arrangements.

The majority of 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 (Dowling et al. 2018).

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. The bottoms line is that 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.

The advantages of harvest strategies include:

- Proactive rather than reactive management: reference points are established and management responses are pre-agreed

- Transparency
- Objectivity
- No lost opportunity due to management paralysis
- Improved public perception
- Defensible management
- Increased stakeholder certainty re: management decision processes
- Fostering a climate of trust
- Improved manager, fishery, public confidence
- Permitting greater business planning through transparent and formal management
- Improved stock sustainability and supporting for environment health
- Maximising potential for export approvals

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

Per Fletcher et al. (2016)'s implementation of harvest strategies in Western Australia: "Where there is now an agreed and explicit harvest strategy this is providing more certainty and a better understanding by each sector for what happens when indicators change plus how sectoral allocation decisions will be delivered. This has already generated dividends from increased management efficiency because many of the negotiations within and among sectors that previously were not clearly defined have now been made explicit…….This holistic approach is already generating efficiency dividends through the adoption of tolerance levels that are minimising unnecessary management interventions. Similarly, fewer management elements now require pre-season negotiation which is also reducing administrative costs."

d. The FishPath decision support tool

Using the principle of confronting harvest strategy options with minimum criteria and caveats, Dowling et al. (2016) developed a data-limited harvest strategy decision support tool, called "FishPath" (www.fishpath.org). FishPath automates the process of filtering harvest strategy options, given user responses to a set of caveat-driven questions, against five information categories:

a. available data
b. biology/life history
c. fishery operational characteristics
d. socio-economics, and
e. governance context.

For each of the monitoring, assessment, and decision rule components of the harvest strategy, FishPath navigates among a comprehensive suite of possibilities to reveal those most appropriate for the fishery, with relevant caveats explicitly articulated. As such, FishPath is a participatory process for identifying appropriate and feasible harvest strategy options given any fishery's context. It is an organisational tool to empower a formal guided process.

<u>What has typically worked well in other fisheries?</u>

Strength of governance, strong leadership, perceived legitimacy, successful institutional interplay, a bottom-up paradigm of developing context-appropriate management mechanism, positive stakeholder engagement, empowerment and participation, incorporation of local ecological knowledge, management that maintains access to the resource, and working at appropriate spatial scales, all emerged as consistent factors that predicate successful management regimes in small-scale, low value fisheries. Appropriate motivation to ensure stakeholder engagement and support is also critical: viz-a-viz “stick or carrot” approaches to incentives for involvement in formal management.

<u>Gap analysis</u>

Our review of the literature confirmed that a key gap was process-based advice on *how* to develop and implement low-cost management regimes. There are many case-study-specific descriptions, and there is advice about *what* needs to occur, in terms of favourable circumstances for management, but there is little about the *how*, that is, the process of operationalising general advice. Process-based, end-to-end guidance to provide explicit and direct, transparent and objective advice to practitioners is a major gap in data-limited fisheries advice and the associated literature. Specifically, such guidance needs to embrace

- How to IDENTIFY viable harvest strategy (monitoring, assessment, decision rule) options for a fishery, given its unique context and circumstances (the FishPath tool (Dowling et al. 2016) directly addresses this need)
- For each stage of the management regime process, a guide to what WILL and WILL NOT work
- How to ARTICULATE the details of harvest strategies.
- How to EMBED harvest strategies into management plans.
- How to IMPLEMENT harvest strategies

The following points are also required to be included in end-to-end guidance. The literature does cover off on the below themes, but in case-specific contexts, as opposed to extending this to providing general advice:

- How to ENGAGE with stakeholders, obtain their buy-in to formal management, and involve them in the process in a bottom-up manner
- How to ELICIT and RECONCILE stakeholder objectives
- How to DETERMINE the appropriate level of co-management
- How to MAXIMISE compliance and the best options for ENFORCEMENT of decision rules.

The issue of reconciling the management of small-scale, low-value fisheries with legislative mandate is global. At best, there is acknowledgement of the issues around the management of such fisheries, and accompanying guidance regarding proxy reference points and data-limited assessment methods. The lack of guidance is even more pronounced in developing nations, where there is often little legislative mandate, and limiting factors typically pertain at least as much to socio-economics and governance and enforcement issues as they do to data limitation.

The emphasis of much of the literature around data-limited/low-cost management regimes was on developing nations, and was heavily weighted around stakeholder engagement, community and co-management, and harvest strategies (Table 1). There were relatively fewer examples of low-cost management regimes for low-value, small-scale fisheries in a developed nation context (Table 1). With some exceptions, much of the advice for managing low-value, small-scale fisheries was case-study-specific. There is little evidence in the literature of attempts to develop broad-scale, process-based advice across the whole of the management regime. Additionally, the literature was focused on specific aspects of the management regime, as opposed to a comprehensive, over-arching consideration. There was a general lack of advice or case studies that embraced the entire process.

This suggests that management regimes as a whole have received little consideration in the context of low-value fisheries.

The above-identified deficiencies demand end-to-end approach to provide explicit and direct, transparent and objective guidance to practitioners. This includes not only the aspects that surround harvest strategy development (stakeholder engagement, objective elicitation and weighting, performance indicator and reference point identification, compliance and enforcement), but also on how to articulate the details of harvest strategies, how to embed harvest strategies in management plans, and how to implement them. Practical advice as to what will and will not work, according to the circumstances, should also be provided.

Table 1: A summary of the reviewed case-study-specific literature, by region, and by broad management regime theme considered.

	Stakeholder engagement		Community-based monitoring/management		Co-Management		Harvest strategy components: low-cost monitoring/assessments/ performance indicators		
	Country/region	Reference	Country/region	Reference	Country/region	Reference	Country/region	Type	Reference
South-east Asia	Vietnam	Van Trung Ho et al. 2014	Philippines	Chaigneau and Daw 2015	Philippines	Hind et al. 2010			
	Indonesia	Siry 2011	Philippines	Maliao et al. 2009	American Samoa	Levine and Richmond 2014			
	Indonesia	Syakur et al. 2012	Sri Lanka	Deepanada et al. 2015	Taiwan	Chen 2012			
			Malaysia	Nauschon and Charles 2010					
			Cambodia	Nauschon and Charles 2012					
			Thailand	Nauschon and Charles 2013					
South Asia	Bangladesh	Pemsl and Seidel-Lass 2010	Bangladesh	Islam et al. 2011	India	Thomson and Gray 2009			
			Bangladesh	Islam et al. 2014					
			Bangladesh	Pemsl and Seidel-Lass 2010					
			Bangladesh	Rab 2009					
			India	Lobe and Berkes 2004					
			India	Thomson and Gray 2009					
Pacific Islands			Fiji	Breckwoldt and Seidel 2012	Hawai'i	Ayers and Kittinger 2014	Fiji	Local ecological knowledge	Golden et al. 2014
			Fiji	Clarke and Jupiter 2010	Hawai'i	Levine and Richmond 2015	Solomon Islands	Local ecological knowledge	Brewer 2013
			Fiji	Clements et al. 2012			Vanuatu	Marine reserves	Dumas et al. 2010
			Fiji	Mills et al. 2011					
			Solomon Islands	Abernathy et al. 2014					
			Vanuatu	Leopold et al 2013					
			Vanuatu	Nauschon and Charles 2011					
Australia, New Zealand					Australia	DoF 2000	New Zealand	Quota prices	Batstone and Sharp 2003
					Australia	Neville 2008			
North America	Canada	Stanley et al. 2014	California, USA	Schoeter et al. 2009	California, USA	Wendt and Starr 2009	NE Atlantic, USA	Less frequent data collection	Zimmermann and Enberg 2017
							USA	Marine protected areas as a reference	Wilson et al. 2010
							Washington, USA	Local ecological knowledge	Beaudreau and Levin 2014
							Hawai'i, USA	Local ecological knowledge	Friedlander et al. 2013
							Eastern Bering Sea	Abundance estimation	Honkalehto et al. 2011
Central and South America			Brazil	Calvalcanti et al. 2010	Mexico	McCay et al. 2014	Mexico	Community-based no-take zones	Velez et al. 2014
			Mexico	Basuto and Coleman 2010	Mexico	Perez-Ramirez et al. 2012			
			Amazon region	Pinho et al. 2012					
Middle East							Yemen	Local ecological knowledge	Tesfamichael et al. 2016
Africa	Namibia	Kahlet et al 2013	Mozambique	Nkhata et al. 2009	Kenya	Cinner et al. 2009	Eritrea	Local ecological knowledge	Tesfamichael et al. 2014
			South Africa	Carvalho et al. 2009	Kenya	Cinner et al. 2012	South Africa	Effort estimation	Ellender et al. 2010
			Tanzania	Nkhata et al. 2010	Nicaragua	Crawford et al. 2011	Sudan	Local ecological knowledge	Tesfamichael et al. 2015
			Uganda	Barratt et al. 2015	South Africa	Cinner et al. 2009			
			Zanzibar	Gustavsoon et al. 2014	South Africa	Cinner et al. 2012			
					Tanzania	Crawford et al. 2010			
Western Indian Ocean	Mozambique	McClanahan et al. 2013	Comoros	Hauzer et al. 2013	Madagascar	Cinner et al. 2009	Madagascar	Community-based assessments	Humber et al. 2011
					Madagascar	Cinner et al. 2012			
Europe			Netherlands	Kraan et al. 2013	Spain	Freire and Garcia-Allut 2000	Ireland	Local ecological knowledge	Shepperson et al. 2014
					Spain	Rivera et al. 2014			

Table 1 continued

	Allocation		Objectives		Harvest strategies		Enforcement and compliance		Indigenous and recreational sectors	
	Country/region	Reference	Country/region	Reference	Country/region	Reference	Country/region	Reference	Country/region	Reference
South-east Asia										
South Asia										
Pacific Islands										
Australia, New Zealand	Australia	Crowe et al. 2013	Australia	Waycot et al. 2016	Australia	Dichmont and Brown 2010			Australia	Plaganyi et al. 2013b
	Australia	Mitchell and Baba 2006	Australia	Pascoe et al. 2014	Australia	Dichmont et al. 2011				
			Australia	Pascoe et al. 2014	Australia	Dichmont et al. 2013				
					Australia	Dowling et al. 2008				
					Australia	Dowling 2011				
					Australia	Fletcher et al. 2016				
					Australia	Haddon 2011				
					Australia	Klaer and Wayte 2011				
					Australia	Mapstone et al. 2008				
					Australia	Plaganyi et al. 2015a				
					Australia	Punt et al. 2002				
North America							Hawai'i, USA	Kittinger 2013	Canada	Klain et al. 2014
									Alaska, Hawai'i, USA	Richmond 2013
Central and South America							Brazil	Mcgarth et al. 2015		
Middle East										
Africa					South Africa	Geromont et al. 1999	Kenya	McClanahan et al. 2005		
					South Africa	Pollack et al. 2008	Kenya	McClanahan and Abunge 2016		
							Mozambique	McClanahan and Abunge 2016		
							Tanzania	McClanahan and Abunge 2016		
Western Indian Ocean							Madagascar	McClanahan and Abunge 2016		
Europe										

A solutions-focused, adoption-ready Guidelines for developing cost-effective management regimes for small scale fisheries.

The Guidelines document, appended as Appendix 2, is intended to guide managers and stakeholders through the process of developing low-cost management regimes for small-scale, low-value fisheries. 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 Guidelines are presented in chronological order, addressing the components identified in Figure 1, and provide stepwise advice and check-points.

The management regime components described in Figure 1 form a stepwise process of

- addressing over-arching issues and obtaining requisite information,
- undertaking a pre-engagement process,
- stakeholder engagement and elicitation,
- developing the harvest strategy (data collection, assessment, and management measures/decision rules),
- operationalising the harvest strategy, and
- implementation.

After confronting their fishery against the Guidelines, practitioners should emerge with an explicit low-cost draft management plan for their fishery, which includes shortlists of options for a harvest strategy.

Where relevant, the Guidelines are structured by presenting, for a specific component of the management regime process (Fig. 1), 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. The components of the management regime to which this approach applies are:

- Principles structure for allocation (Table 2)
- Co-management and community-based management (Table 3)
- Harvest strategies: monitoring (via the FishPath tool) (a list of the monitoring options is provided in Table 4)
- Harvest strategies: assessment (via the FishPath tool) (a list of the assessment options is provided in Table 5)
- Harvest strategies: harvest control/decision rules (via the FishPath tool) (a list of the monitoring options is provided in Table 6)
- Compliance and enforcement (Table 7)

Tables 4 to 7 are updated versions of those presented in Dowling et al. (2016).

The logic of confronting options with caveats removes the biases of opinion, and provides a highly efficient, transparent, defensible means of identifying the most viable options, from among a comprehensive suite. Moreover, this approach provides customised advice based on the user responses tailored to the fishery's circumstances and characteristics.

In weighing options for each of these components, the entire context of the fishery must be considered. Defining fisheries by, for example, life history or gear type alone will not embrace all aspects that are relevant in considering whether any option will be viable. Varying combinations of the following five main information categories must be collectively considered when evaluating options for each of the above components:

i. available data;
ii. biological/life history attributes of relevant species;
iii. fishery operational characteristics;
iv. socio-economic indicators/characteristics; and,
v. governance context.

The latter two categories have traditionally received less attention in a harvest strategy selection context. In the context of low-value, small-scale fisheries, however, they often are a main limiting factor. This applies not just to the harvest strategy but to the management regime as a whole.

Working definition of harvest strategy components in the context of the Guidelines

The harvest strategy is central to the management regime, and is comprised of three components: monitoring, assessment and management measures. We here define how each of the three harvest strategy components are considered within the Guidelines (and in the FishPath decision support tool, to which the harvest strategy section of the Guidelines defers).

A *monitoring* program defines the method and the type of data that will be collected on the fishery and the species that it impacts. The collection of this data is critical for developing an understanding of how the fishery is operating and the health of the species that is/are being caught; that is, in informing a stock assessment.

There are a wide range of monitoring options available to fisheries, ranging from market surveys, through to logbooks and observer programs. Thirteen broad monitoring options are included in the Guidelines. These are subdivided according to the broad types of data that may be collected, as these also influence the caveats and recommendations against each monitoring option. The four categories of data types are: 1) biology and life history information; 2) fishery operational characteristics; 3) data that yield broad sustainability trends; and 4) comprehensive time series of data that could inform stock status.

We define an *assessment* as any analysis that gives useful information for management, whether via direct or indirect measures of stock status or sustainable levels of fishing mortality. We include 46 forms of “assessment”, that result in outcomes ranging from a “cause for concern” arising from expert judgement, to a harm/no harm judgement from a risk assessment, to values of empirical indicators relative to pre-defined trigger levels, to multiple indicator frameworks, to analyses such as (for example) a stock reduction analysis, that provide estimates of fishing mortality (F), or maximum sustainable yield (MSY).

Management measures result in decision, or harvest control rules. These are pre-agreed management actions that are taken given the status of the fishery, as determined by an assessment. Management measures can take many forms including spatial, temporal, effort, catch and gear related restrictions (Table 6).

When considering management measure options, often there is no one “solution”. Some measures are more or less appropriate under certain circumstances, and multiple management measures (decision rules) could (often, should) be applied. The guidance we provide is concerned with what decision rules should be avoided, particularly recommended, or applied with caution, given the context of the fishery.

We identify 13 “families” of decision rules, with 40 “sub-family” options (including 8 catch, 10 effort, 4 spatial, 5 temporal), and considers these against approximately 45 caveat questions. These options do not include advice on the formulation or strength of the management measure or its adjustments (i.e. hard to pull harvest control rule levers), but rather identify its nature.

Table 2: A matrix of inter- and intra-sectoral allocation methods/principles, confronted with relevant caveats. The traffic light colours indicate the relative strength of the caveat, where red implies a limiting caveat, yellow a warning, and green a positive attribute.

	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

Table 3: 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 3 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 3 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 3 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

Table 4: List of the monitoring options considered within FishPath. These comprise 13 main monitoring approaches, most of which can be used to collect 4 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

Table 5: 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 2011
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. 2015
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)	Lombardi 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 2011
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 6: List of FishPath decision rule “families”, and descriptions of the nature of each.

	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.	Maxmimum 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)

Table 7: Enforcement options (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
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 commercial; 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 commercial; 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 7 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 commmunity 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 7 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 7 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 7 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 7 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 7 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
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 7 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 7 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		

Concise Guidelines for developing low-cost management regimes for small-scale, low-value fisheries: overview of Harvest Strategies and Reporting Pro-forma

This document is intended to be a “go-to” or “front-end” reference to accompany the more comprehensive Guidelines. It is a brief summary of the various steps to developing a low-cost management regimes for small-scale, low-value fisheries. This concise version of the Guidelines enhances the accessibility of the main Guidelines, and can be used to help facilitate stakeholder engagement: it can be used a “look up” front end user manual, or a quick reference.

The full Guidelines are intended to guide managers and stakeholders through the process of developing low-cost management regimes for small-scale, low-value fisheries. They 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 Guidelines are presented in chronological order, addressing the components of the management regime identified in Figure 1, and provide stepwise advice and check-points.

As opposed to a top-down imposition of a “sophisticated” management regime that is impractical and infeasible, the Guidelines directly acknowledge the resource and capacity limitations of low value/data-limited fisheries and their managers, and aim to provide a process and options that are pragmatic and tailored to a fishery’s specific context.

The approach is strongly “bottom up” in that it seeks to identify pragmatic options and provide practical advice that specifically acknowledge(s) the context and (resource, managerial and research capacity, data, socio-economic) constraints within the fishery. That is, it provides advice that is tailored to each fishery’s unique circumstances. This includes incorporating and formalising, where appropriate, existing management arrangements into a harvest strategy, and recommending assessment approaches based only on currently available information.

The Guidelines provide to users an efficient, transparent, defensible and standardised process that identifies management options that are best suited to the fishery’s context. Such a process mitigates against decision paralysis and inefficiency in having to develop a harvest strategy in the absence of a proforma, and against using the wrong assessment, or inappropriate control rules or monitoring.

The Guidelines document details a user-friendly, process-based practical pathway to developing a low-cost fishery management regime. The guidance is presented in chronological order with stepwise advice and a series of “stop sign” checkpoints, as per:

User is being provided with a “stop sign” checkpoint

These checkpoints can also be used as the basis for a reporting pro-forma.

As harvest strategies are central to the management regime, this document firstly provides an overview of harvest strategies in the data-limited fishery context. It then collates all of the main process headings and the “stop sign” check points from the more comprehensive Guidelines document, as a reference for managers.

Harvest strategies and the problems for data-limited fisheries

A harvest strategy is the central component of a developing a plan for fisheries management reform and sustainability. A harvest strategy is a framework that specifies 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 (Sloan et al. 2014). It comprises a fully specified set of rules including specifications for i) a monitoring program, ii) the calculation of performance indicators (usually via a stock assessment), iii) the use of those indicators and their associated reference points in management decisions, through decision (or control) rules.

Often, 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 may take two to three 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. So too is the cost around not having a harvest strategy.

However, without a process-based guidance tool to identify of viable data-limited harvest strategy options, this process is 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.

Guiding Principles for Harvest Strategies

1. Pre-agreed, scientifically informed harvest strategies are critical to maintaining trust, ensuring stakeholder support for management and ultimately leading to sustainable outcomes.
2. Assessments linked to precautionary harvest control rules can perform well in avoiding overfishing even though the assessment method may poorly measure stock status.
3. There is no one size fits all approach to managing or assessing a fishery: each fishery is unique and requires a unique management strategy and management plan.
4. Effective management design requires a bottom-up approach, with active participation from all stakeholders. This is achieved by developing an explicit engagement process or strategy.

Concise Guidelines

The below comprises the process headings and “stop-sign” checkpoints from the full Guidelines (Appendix 2), and is intended to serves as a “look up” front end user manual, or a quick reference. The headings and “stop sign” checkpoints can also be adopted as the basis for a reporting pro-forma. Regardless, these concise Guidelines are intended to be a used in conjunction with the full Guidelines (Appendix 2), in which comprehensive full details against each of the below points are provided.

OVERARCHING ISSUES, AND PREFERRED PRE-REQUISITES

Policy and legislation

STOP Have all legislative and/or policy requirements been identified?

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

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

Logistical and philosophical issues:

Where applicable, have logistical and philosophical issues, including -

- the extent of agency support;
- the extent of sectors;
- the level of intra- and inter-sectorial conflict;
- the need for the process to be bounded by expertise;
- the possible remoteness of participants;
- the need to caution against a “one size fits all mentality”;
- robustness of assessment methods

- been discussed, acknowledged, and, to the extent possible, resolved?

Social licence

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

Allocation

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.

Co-management and community-based management

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

Ecosystem-based risk assessment

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

Moving forward

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 identifying drivers for management. Failure to do so will compromise the effectiveness of the engagement process.

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?

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

It is important to undertake 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. At the same time as mining for data, it is important to identify the strengths and weaknesses of the data.

The five key information categories that should be considered are:

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:

v) Governance context:

Undertake an internal audit of the low-value fishery

This aims to broadly identify possibly harvest strategy options, ascertain common options between species and fisheries, identify information gaps, and to proceed from a common platform. The audit can be undertaken

- Using the FishPath software tool
- By managers reviewing the fisheries in terms of available information, and viable assessment and management options, and reaching a mutual consensus

Identify possible performance indicators

This involves analysing the available data in various ways to produce “indicators” that are informative about changes in the resource or the fishery. Performance indicators are (usually quantitative) measures that inform trends in the status of a resource (e.g. its abundance or how heavily it is being exploited).

Identify possible reference points

If useful indicators have been identified, the next step is to identify reference points associated with these indicators. 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).

STOP 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?

PART 1: ENGAGEMENT

Engagement and elicitation

STOP Has an Engagement Strategy been developed?

STOP 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?

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

STOP Has a formal process for objective elicitation, that embraces all stakeholders, been identified? Is the objective elicitation process logistically and financially practical?

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

STOP

Have conflicting circumstances been acknowledged and tensions defused?

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

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

Have stakeholders been categorised into groups?

Has consideration been given to weighting (prioritising) objectives by stakeholder group?

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 the trade-offs between objectives. If this is the case, then this step will have to be undertaken in a qualitative (descriptive) manner.

Has consideration been given to conceptually/qualitatively or quantitatively reconciling objectives?

Re-reviewing available information:

- 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
    - e.g. 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?

Finalising performance indicators:

- 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, that 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?
-

Finalising reference points

- Has anything new emerged during the engagement process?
- Have target and limit reference points been identified against each indicator?
- Do the target 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)?

PART 2: HARVEST STRATEGY DEVELOPMENT: MONITORING, ASSESSMENT, DECISION RULES

Monitoring

Work through the monitoring component of the FishPath support tool, either for the fishery collectively, or by species/gear/fleet/sector.

Alternatively, managers should consider all relevant issues (pertaining to fishery operational characteristics, life history of the target species, socio-economics and governance) affecting their ability to undertake monitoring to inform an assessment.

A shortlist of monitoring options should be identified as a result.

Assessment

Work through the assessment component of the FishPath decision support tool, either for the fishery collectively, or by species/gear/fleet/sector.

Alternatively, managers should consider all relevant issues (pertaining to data availability and quality, fishery operational characteristics, life history of the target species, and research/funding capacity) affecting their ability to undertake alternate forms of assessment.

A shortlist of assessment options should be identified as a result.

Harvest control / decision rules

Work through the decision rule component of the FishPath decision support tool, either for the fishery collectively, or by species/gear/fleet/sector.

Alternatively, managers should consider all relevant issues (pertaining to fishery operational characteristics, life history of the target species, socio-economics (including compliance) and governance (including enforcement capacity) affecting their ability to implement alternative decision rules.

A shortlist of decision rule options should be identified as a result.

"Fixed" decision rules (management measures)

Has the decision rule component of the FishPath decision support 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

Choosing between harvest strategy options

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

Evaluation of harvest strategy options

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

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

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

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

Define/specify the management plan

Has the management plan been drafted?

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?

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

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

Has the tactical implementation of the harvest strategy been considered?

Is there adequate resourcing to enable tactical implementation?

Compliance and Enforcement

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

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?

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?

Review process for the harvest strategy

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

Have cost-effective review processes been identified?

The NT Spanish Mackerel Fishery as a worked example to inform and refine the Guidelines

Overview of approach taken for worked example

The Guidelines (and, for harvest strategies, the FishPath decision support tool), were applied to the NT Spanish Mackerel Fishery as a worked example The NT Spanish Mackerel Fishery was chosen as the case study fishery for the project, due to its being relatively non-politically contentious, while still having a need for management. The fishery has small-scale commercial, recreational and tourism sectors. Previous assessments have been undertaken (Walters and Buckworth 1997; Buckworth 2004; Buckworth et al. 2007; Grubert et al. 2013; Macbeth et al. 2013), but with associated uncertainties in data quality and availability, biology and life history, selectivity, meta-population dynamics, and boundary effects.

This worked example had two-way benefit: it showcased the capability of the Guidelines and, in more detail, the FishPath harvest strategy selection tool, but it was also a valuable process to highlight limitations, and areas where clarification or alternative structure was required.

An initial attempt at confronting the Guidelines and completing the FishPath questionnaire with the NT Spanish Mackerel Fishery was undertaken prior to the 2016 workshop with a core group of experts from NT Fisheries, and using data provided. The Overarching Issues/Pre-requisites, Pre-engagement, and Part 1 sections of the Guidelines were walked through and revised in detail in the 2016 stakeholder workshop. Feedback was not specific to the NT Spanish Mackerel Fishery, but, advantageously, represented collective experience across a broad range of fisheries. The advice in Part 1 is predominantly around stepwise processes that apply regardless of fishery context, and as such, an a priori worked example for Spanish Mackerel was not especially relevant. Therefore, there are no results presented here against Part 1 of the Guidelines

That stated, there remains a strong need to road-test and evaluate this component of the Guidelines in a fully articulated case study context, that is, involving all relevant stakeholders and interest groups for a fishery and applying the Guidelines in earnest. Due to resource constraints, this was beyond the scope of the current project.

Moreover, the greatest interest from managers and industry representatives at the stakeholder workshop, and generally, was in the harvest strategy component (Part 2) of the Guidelines, that is, the FishPath decision support tool. This is understandable, as harvest strategies are central to, and underpin, the management regime.

The initial draft of Parts 3 and 4 of the Guidelines (Operationalising and Implementing the Harvest Strategy) was significantly expanded in response to feedback from the stakeholder workshop around the Spanish Mackerel worked example. In particular, there was dissatisfaction around the following identified deficiencies:

- A lack of detailed guidance as to how to interpret and further narrow the harvest strategy options presented by the FishPath process.
- A lack of advice as to how to more fully articulate the details of the harvest strategy (e.g. what is the exact form of the decision rules? What should the strength of adjustments be in response to assessment outcomes? How are the more empirical assessments (e.g. a hierarchal decision tree) to be formulated, and what do these look like?

- A lack of advice as to how to translate the harvest strategy into a management plan – that is, how to operationalise the harvest strategy.

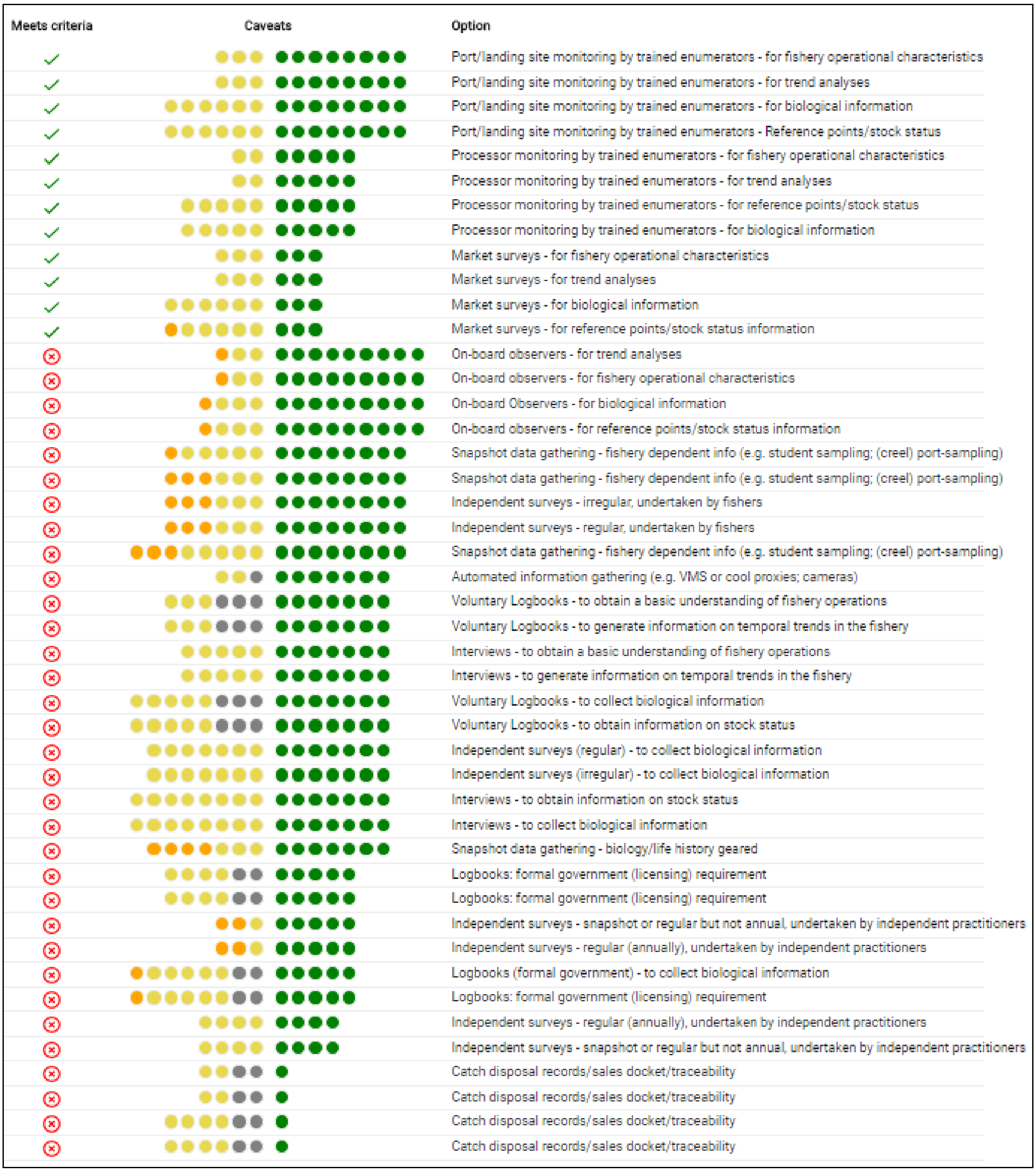
Again, the revised version of these components of the Guidelines will have to be confronted with a fully articulated case study in order to evaluate their efficacy, but in the meantime, the Spanish Mackerel example was highly valuable in spotlighting these earlier deficiencies, and we have hopefully moved to address these within the Guidelines. Again, there are no results reported per se for Spanish mackerel for much of Parts 3 and 4, as the value of the case study fishery was in refining and expanding these sections of the Guidelines.

The “Community-based management/co-management” (under “Over-arching issues, pre-requisite information” and “Compliance and enforcement” [“Part 4: Implementation]) sub-components of the Guidelines are constructed similarly to the FishPath tool, in that they confront options with caveats based on question responses to identify key issues specific to the fishery. Worked examples of these draft options vs. caveat matrices were undertaken for the NT Spanish Mackerel Fishery, and presented at the stakeholder workshop.

As such, the results subsequently presented pertain to Parts 2 and 4 of the Guidelines. The reader is referred to the appended Guidelines document (Appendix 2), and to Dowling et al. (2016) for full details of the approaches that underpin them. First, we present the harvest strategy options for monitoring, assessment, and management measures, identified from the FishPath process (Part 2 of the Guidelines). We then present the results from decision matrices to identify options for compliance/enforcement, and for co-management/community-based management (from Part 4 of the Guidelines), for the NT Spanish Mackerel Fishery.

Harvest strategy: Monitoring

Figure 3 displays all monitoring options available in FishPath, with information on whether, based on the questionnaire responses, the NT Spanish Mackerel Fishery meets the minimum criteria for each option, and the number of caveats associated with each option. The results table displays via green check mark or red crosses, whether the fishery met the minimum criteria required for the option, and the number of positive attributes (greens) and increasingly cautionary caveats (yellow, orange and red) for each option, as they relate to the NT Spanish Mackerel fishery. The key questions that invoked the eliminations and caveats are summarised in Table 8.



Meets criteria	Caveats	Option
✓		Port/landing site monitoring by trained enumerators - for fishery operational characteristics
✓		Port/landing site monitoring by trained enumerators - for trend analyses
✓		Port/landing site monitoring by trained enumerators - for biological information
✓		Port/landing site monitoring by trained enumerators - Reference points/stock status
✓		Processor monitoring by trained enumerators - for fishery operational characteristics
✓		Processor monitoring by trained enumerators - for trend analyses
✓		Processor monitoring by trained enumerators - for reference points/stock status
✓		Processor monitoring by trained enumerators - for biological information
✓		Market surveys - for fishery operational characteristics
✓		Market surveys - for trend analyses
✓		Market surveys - for biological information
✓		Market surveys - for reference points/stock status information
⊗		On-board observers - for trend analyses
⊗		On-board observers - for fishery operational characteristics
⊗		On-board Observers - for biological information
⊗		On-board observers - for reference points/stock status information
⊗		Snapshot data gathering - fishery dependent info (e.g. student sampling; (creel) port-sampling)
⊗		Snapshot data gathering - fishery dependent info (e.g. student sampling; (creel) port-sampling)
⊗		Independent surveys - irregular, undertaken by fishers
⊗		Independent surveys - regular, undertaken by fishers
⊗		Snapshot data gathering - fishery dependent info (e.g. student sampling; (creel) port-sampling)
⊗		Automated information gathering (e.g. VMS or cool proxies; cameras)
⊗		Voluntary Logbooks - to obtain a basic understanding of fishery operations
⊗		Voluntary Logbooks - to generate information on temporal trends in the fishery
⊗		Interviews - to obtain a basic understanding of fishery operations
⊗		Interviews - to generate information on temporal trends in the fishery
⊗		Voluntary Logbooks - to collect biological information
⊗		Voluntary Logbooks - to obtain information on stock status
⊗		Independent surveys (regular) - to collect biological information
⊗		Independent surveys (irregular) - to collect biological information
⊗		Interviews - to obtain information on stock status
⊗		Interviews - to collect biological information
⊗		Snapshot data gathering - biology/life history geared
⊗		Logbooks: formal government (licensing) requirement
⊗		Logbooks: formal government (licensing) requirement
⊗		Independent surveys - snapshot or regular but not annual, undertaken by independent practitioners
⊗		Independent surveys - regular (annually), undertaken by independent practitioners
⊗		Logbooks (formal government) - to collect biological information
⊗		Logbooks: formal government (licensing) requirement
⊗		Independent surveys - regular (annually), undertaken by independent practitioners
⊗		Independent surveys - snapshot or regular but not annual, undertaken by independent practitioners
⊗		Catch disposal records/sales docket/traceability
⊗		Catch disposal records/sales docket/traceability
⊗		Catch disposal records/sales docket/traceability
⊗		Catch disposal records/sales docket/traceability

Figure 3: Monitoring results output from FishPath. This image displays all available monitoring options in FishPath, with crosses indicating that the minimum criteria to undertake the option were not met. The coloured circles represent each individual positive attribute (green) caveats, moderate (yellow) or strong (orange cautionary caveats invoked according to the questionnaire responses, and static (grey) caveats (invoked regardless of user responses associated with the NT Spanish Mackerel fishery.

In terms of cautionary caveats, per Table 8, the responses that invoked the most cautionary caveats were that:

- jurisdictional boundaries **do not** match the spatial extent of the fishable population
- fishing is highly spatially or temporally aggregated, such that this has the potential to bias sampling
- the spatial range of the fishing activity is such that direct sampling is challenging

- fishing activities **do not** correspond with the spatial extent of the fishable stock
- multiple gears harvest the species
- survivorship is compromised if handled or captured and released
- regulations **are not** well enforced

These are the key (but not the only) points that would have to be acknowledged when comparing possible monitoring options.

Table 8: Relevant questionnaire responses pertaining to minimum criteria, and invoking caveats, against monitoring options for the NT Spanish Mackerel Fishery.

	CRITERIA	
Socio-economic	Rank the current or potential monetary investment for a monitoring program for this species/species group.	low
Operational	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")	Artisinal - commerical (large range of boats - may sell locally and/or for export)
Socio-economic	How culturally ingrained in fishers is cooperation to management, in terms of their willingness to share and record information?	3 - willing to share and record but may not do so reliably
Governance	Rank the current or potential research and/or institutional capacity to implement and maintain a formal management strategy (i.e. monitoring, assessment, decision rules)	moderate
Socio-economic	How is data collection valued and prioritized by the governance agency for the fishery of interest?	moderate-high
	CAVEATS	
Governance	Do the jurisdictional boundaries and spatial extent of the fishable population match?	NO
Governance	Where is the capacity and mandate to faciliate or allow for monitoring?	STATE
Governance	Is there strong governance leadership (i.e. agency-based, as distinguished from community leadership) in place to support/facilitate management measures?	YES
Socio-economic	Are there existing cooperatives or associations that could provide a starting point to fisher cooperation?	YES
Socio-economic	Are fishers, or can fishers be, incentivised/motivated/willing to be involved in a data collection program?	YES
Governance	Do local government officials hold power over fishing regulations (is there the capacity for local enforcement)?	YES
Operational	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)	YES
Operational	Is the spatial range of the fishing activity such that direct sampling is challenging?	YES
Operational	Do fishing activities (regardless of current management) correspond with the spatial extent of the fishable stock?	NO
Operational	Do multiple gears harvest the species/species group?	YES
Biology/life history	If handled or captured and released, is survivorship compromised?	YES
Governance	Are regulations enforced, and, if they are enforced, are the regulations/governance respected/complied with?	NO
Governance	Is any monitoring program able to be undertaken with temporal regularity and reasonable frequency (e.g. more than every 5 years)?	YES
Governance	Can monitoring be conducted at the same time and in the same manner interannually and spatially?	YES
Operational	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?	YES

The majority of options were eliminated on the basis of a single criterion not being met: the current or potential monetary investment for a monitoring program was ranked as “low”. This left only market surveys, port/landing site monitoring by trained enumerators, and processor monitoring as possible options.

Re-casting the current or potential monetary investment for a monitoring program as “medium” opened up a range of additional options (per Figure 4), specifically, snapshot data gathering, interview, voluntary logbooks, and catch disposal records/sales dockets. However, independent surveys, automated information gathering, formal government logbooks and observer programs remained excluded, on the basis of criteria summarised in Table 9 below.

Table 9: Criteria eliminating monitoring responses (once the current or potential monetary investment for a monitoring program was recast as “medium”). The red cells detail the minimum required response deemed necessary to make the option viable.

Criteria question	How culturally ingrained in fishers is cooperation to management, in terms of their willingness to share and record information?	Rank the current or potential research and/or institutional capacity to implement and maintain a formal management strategy	Rank the current or potential monetary investment for a monitoring program for this species/species group.	How is data collection valued and prioritized by the governance agency for the fishery of interest?
Response -> Options:	Willing to share and record but may not do so reliably	moderate	moderate	moderate-high
Independent surveys by fishers	Willing to share and record and do so reliably			
Independent surveys by independent practitioners		Snapshot/less than annual= comprehensive time series to inform stock status = moderate-high Regular (annual) =high	Snapshot/less than annual; biological data = moderate Snapshot/less than annual; biological data = comprehensive time series to inform stock status = moderate-high Regular (annual) =high	Snapshot/less than annual= comprehensive time series to inform stock status = moderate-high Regular (annual) =high
Automated information gathering		high		high
Formal government logbooks		high	Moderate-high	
Observer programs		high	comprehensive time series to inform stock status = high Otherwise, moderate-high	high

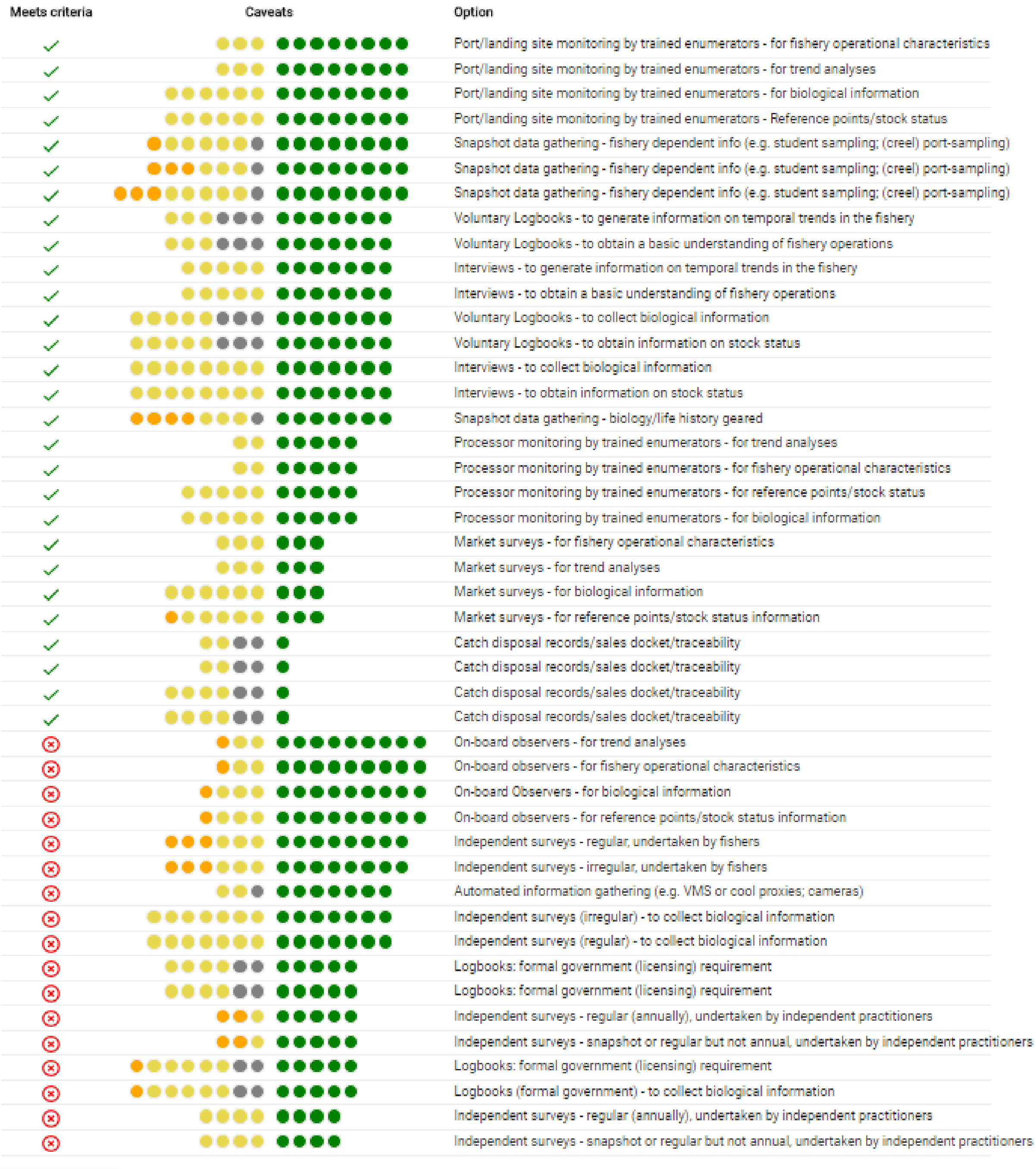


Figure 4: Monitoring results output from FishPath, changing the response to the criteria question, "what is the current or potential monetary investment for a monitoring program?" to "medium" from "low". This image displays all available monitoring options in FishPath, with crosses indicating that the minimum criteria to undertake the option were not met. The coloured circles represent each individual positive attribute (green) caveats, moderate (yellow) or strong (orange cautionary caveats invoked according to the questionnaire responses, and static (grey) caveats (invoked regardless of user responses) associated with the NT Spanish Mackerel fishery. Options for which the criteria were met are ordered according to the highest number of positive (green) attributes invoked, and then according to the least number of cautionary (orange and yellow) caveats.

Herein lies a key issue in the current structure of the monitoring component of FishPath (and the Spanish Mackerel example is certainly not the first time this has arisen): three of the five criteria questions are subjective, yet the responses have the power to eliminate options. In many ways, this is a constructive aspect of the process: users are confronted with the consequence of their (possibly differing) perceptions. This immediately focuses discussion and elicits where their level of commitment truly lies, or where they should seek to overcome obstacles, given what options they feel they wish to see operationalised within the fishery. It is extremely simple within the software to amend the response to any question and to instantly view how this changes the available options. While this confers the ability to "game" the system by adjusting responses to, for example, justify the management status quo, the software holds users accountable by transparently reveals the questionnaire responses.

On the other hand, users who are more uncertain about interacting with the FishPath tool may take the outcomes at face value and thus run the risk of being provided with an overly restrictive shortlist. Given the relatively few criteria, however, this rarely occurs. Moreover, the "most influential" responses (in terms of invoking the most caveats) are clearly high

Specific details of the caveats invoked against each monitoring option are readily able to be viewed, and are expanded below for two example options (processor monitoring by trained enumerators, to obtain a basic understanding of how the fishery operates, and formal logbooks to obtain a comprehensive time series of data that could inform stock status) in Table 10 below. Here it can be seen that the above-summarised responses are those that invoked orange and yellow coloured caveats.

Where multiple monitoring options have been identified by FishPath as feasible, we state in the Guidelines that those that are associated with the collection of more comprehensive data should perhaps be given priority (e.g. collecting a comprehensive time series of data that could inform stock status should be favoured over obtaining a basic understanding of how the fishery operates). However, due to their greater rigour, these options typically invoke more caveats (per second row of Table 10), each of which would need to be addressed or overcome.

One other key issue was that the monitoring component of FishPath does not explicitly consider existing monitoring arrangements. This was by design, because there are often cases where the status quo management arrangements are sub-optimal: simply because an option is currently employed does not necessarily mean it is the most appropriate for the fishery. That stated, it has been an encouraging validation of the FishPath tool that, generally, existing monitoring options have typically been amongst those that it independently recommends. However, the Spanish Mackerel worked example highlighted the fact that monitoring measures may be in place that are not directly aimed at gathering information to inform stock assessments in a harvest strategy context but are nonetheless valid sources of information.

In the case of NT Spanish Mackerel, government logbooks are an existing legislative condition of the fishing permit. While FishPath correctly identifies that formal logbooks have a high monetary and institutional capacity cost, that they are already present in the fishery would have been identified earlier in the process, when considering available data. However, it should be acknowledged that existing monitoring programs, such as logbooks, may not (necessarily) have been aimed at gathering information on target species, but may have been motivated more around environmental issues (e.g. observer programs given the propensity of the fishery to interact with threatened/endangered/protected species), or, as in the case of NT Spanish Mackerel, legislative requirements as a condition of permitting, but being largely driven by, and used for, compliance purposes.

Table 10: Two monitoring options for the NT Spanish Mackerel Fishery (processor monitoring by trained enumerators, to obtain a basic understanding of how the fishery operates, and formal logbooks to obtain a comprehensive time series of data that could inform stock status), expanded to show all relevant caveat details.

TYPE OF MONITORING	BROAD CATEGORIES OF INFORMATION COLLECTION/ANALYSIS	TYPES OF DATA that may be obtained via each type of monitoring for each category	Do the jurisdictional boundaries and spatial extent of the fishable population match?	Where is the capacity and mandate to faciliate or allow for monitoring?	Is there strong governance leadership (i.e. agency-based, as distinguished from community leadership) in place to support/facilitate management measures?	Are there existing cooperatives or associations that could provide a starting point to fisher cooperation?	Do local government officials hold power over fishing regulations (is there the capacity for local enforcement)?	Is fishing highly spatially or temporally aggregated, such that this has the potential to bias sampling?	Is the spatial range of the fishing activity such that direct sampling is challenging?	Do fishing activities (regardless of current management) correspond with the spatial extent of the fishable stock?
			IF NO	IF REGIONAL, STATE OR NATIONAL	IF YES	IF YES	IF YES	IF YES	IF YES	IF NO
		SPANISH MACKEREL	NO	STATE	YES	YES	YES	YES	YES	NO
Processor monitoring by trained enumerators	Fishery (basic understanding of how fishery operates)	Species ID, species composition,			Helpful if so	Helpful if so				
Formal logbooks	Reference points/stock status	CPUE (likely more robust than informal logbooks)	could be difficult if jurisdictional boundaries do not embrace spatial extent of fishing	Easier if at least at regional level	Helpful if so		Helpful if so	May not be representative	Useful if fisher willingness/trust, and strong community leadership and/or governance	Status estimates not based on entire stock; biomass-based reference points may not be meaningful

Table 10 cont'd.: Two monitoring options for the NT Spanish Mackerel Fishery (processor monitoring by trained enumerators, to obtain a basic understanding of how the fishery operates, and formal logbooks to obtain a comprehensive time series of data that could inform stock status), expanded to show all relevant caveat details.

TYPE OF MONITORING	BROAD CATEGORIES OF INFORMATION COLLECTION/ANALYSIS	TYPES OF DATA that may be obtained via each type of monitoring for each category	ADDITIONAL CAVEATS	If handled or captured and released, is survivorship compromised?	Are regulations enforced, and, if they are enforced, are the regulations/governance respected/complied with?	Is any monitoring program able to be undertaken with temporal regularity and reasonable frequency (e.g. more than every 5 years)?	Can monitoring be conducted at the same time and in the same manner interannually and spatially?	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?
				IF YES	IF NOT ENFORCED	IF YES	IF YES	IF YES
		SPANISH MACKEREL		YES	NO	YES	YES	YES
Processor monitoring by trained enumerators	Fishery (basic understanding of how fishery operates)	Species ID, species composition,	Motivation from buyers (and e.g. for export approval, chain of custody, RFMO affiliation)	If discarding rate (re: barotrauma), or handling without capturing (for disease-susceptible), is suspected to be significant, need to acknowledge fishing-induced mortality of non-retained individuals		Helpful if so	Helpful if so	May be more representative than having good coverage but only across part of the fleet/fishery range
Formal logbooks	Reference points/stock status	CPUE (likely more robust than informal logbooks)	Requires database infrastructure and capability; potential for misreporting (especially for fisheries with low cooperation/subsistence/low GVP/low research capacity); ? Potential to work well if done in a capacity building context with external capacity (also technological developments - e.g. tablets); Accuracy of logbooks can be improved by tying data reporting requirement to secure catch right as a responsibility in return for the right (e.g., area license to fish in a TURF, or catch share)	If discarding rate (re: barotrauma), or handling without capturing (for disease-susceptible), is suspected to be significant, need to acknowledge fishing-induced mortality of non-retained individuals	May get more honest representation if no accountability/fear of consequence of reporting illegal activity BUT no incentive or motivation to report accurately	Assumption is that logbooks are continuous	Assumption is that logbooks are continuous	May be more representative than having good coverage but only across part of the fleet/fishery range

Harvest strategies: Assessment

Table 11 displays all assessment options identified by FishPath for the NT Spanish Mackerel worked example, with information on whether minimum criteria – which pertain to the minimum data requirement to undertake the analysis – have been met, and detailing the cautionary caveats invoked. The following should be considered when reading the Table:

i) Caveats stating that the assessment "may not be suited to/work with fisheries with a low number of participants" are speaking to the level of fishing intensity rather than the actual number of fishers. If effort is low, then almost all formal (model-based) stock assessments are compromised. Major revisions of the questionnaire have occurred since 2016, many of which have addressed ambiguity in questions, and the underlying issues they intend to address. This question since been replaced by the following questions: "When data are collected (for intended use within an assessment), are they representative of the entire spatial extent of the fishery's fleet(s) or fishers? If no data have been collected, could future data collection efforts for use within an assessment be representative of the fleet's or fishers' entire spatial extent?", and "When data are collected (for intended use within an assessment), are they representative of the operational characteristics of the fleet(s) or fishers? If no data have been collected, could future data collection efforts for use within an assessment be representative of the fleet or fishers as a whole?" These speaks more directly to the issue of concern around a lack of representative data.

ii) Most of the data-limited assessment methods in FishPath, with the exception of those that are explicitly stochastic, do not explicitly address uncertainty. However, the problem is more around any assumptions regarding uncertainty that are inherent in the methods.

iii) The Table presents only the criteria or caveats associated with assessment methods that are <u>NOT</u> met for the NT Spanish Mackerel Fishery. It does not include assumptions that can be met or informed for the fishery. For example, the Depletion-Corrected Average Catch assessment method assumes a prior level of stock depletion. As it was indicated that a rough estimate of depletion existed for the NT Spanish Mackerel Fishery, this assumption does not appear in the below table as a potentially limiting factor that would preclude the use of the method.

iv) Many of the listed methods are evolving. As newer methods emerge, some of the current list may become obsolete.

The results clearly underscore that, as indicated in the summary of the fishery above, data is not a majorly limiting factor for assessing the fishery. Only seven assessment options were eliminated outright, due to a lack of data. Five were risk assessments or analyses that each required fishery-independent abundance estimates, and time series of abundance both inside and outside no-take zones or marine protected areas. The other two assessment options were eliminated due to an insufficient time series of length data – something that could be readily overcome with a few years of additional data.

Otherwise, cautionary caveats were invoked only around the only moderate research capacity, the fact that there have been historical or recent operational changes, and the low number of participants (and hence, representative data) associated with the fishery. The first is an issue that can be addressed by re-prioritisation of resourcing and funding. The other two issues are inherent attributes of the fishery that will have to be directly acknowledged, and that may lead to the associated assessment options being eliminated in favour of other analyses for which these are not limiting factors. Conversely, FishPath highlighted that for many of the assessment options, it is helpful that there exists in the fishery expert knowledge of suitable targets for indicators that could be used (directly or indirectly) to understand the status of the stock (or the fishing pressure).

Where multiple assessment options have been identified by FishPath as feasible, we state in the Guidelines that those that are typically deemed more “rigorous” (in that they generate performance indicators more directly related to stock biomass), and that utilise most or all of the available data, should be favoured. For example, an assessment option that estimates maximum sustainable yield (MSY) should generally be favoured over “undertak(ing) exploratory analysis” or “seek(ing) expert judgement” (for a “deemed at risk /not at risk” outcome). The assumption is if research or financial capacity are low, a statistically lesser rigorous option might better fit the capacity available.

More generally, combinations of assessments are encouraged, particularly in the data-limited context, as collectively these optimise the use of the available information, and may provide more insight via their corroboration or contradiction.

It should be noted that the assessment options identified by FishPath as being viable for the NT Spanish Mackerel fishery included those that have been previously undertaken, namely production models, depletion-based stock reduction analysis (DB-SRA) and length-based spawner potential ratio (SPR) analysis (Walters and Buckworth 1997; Buckworth 2004; Buckworth et al. 2012; Grubert et al. 2013; Macbeth et al. 2013). It is noted, however, that these require moderate-high research capacity and/or (in the case of DB-SRA) may not work with a lower number of participants (that is, data that are not representative of the stock). The fishery’s assessment history, summarised above, corroborates that these assessments were indeed undertaken sporadically, and, on three occasions (1997, 2001, 2011) with the assistance of outside expertise (i.e. renowned fishery stock assessment expert Professor Carl Walters).

Shijie Zhou’s optimised catch-only assessment method (Zhou et al. 2018) was resounding endorsed as a viable option by FishPath for the NT Spanish Mackerel fishery. FishPath cautioned against the low number of participants in the fishery, and the method carries static caveats that it does not explicitly address uncertainty, and that it assumes that unfished biomass is stationary (i.e. meaningful regardless of time).The first caveat was disregarded given the data were felt to be representative, the second was accepted as a limitation of the method, and the third was an assumption that was met for this species. This assessment method was subsequently undertaken using the most updated available data for the NT Spanish Mackerel Fishery. The results are described in the subsequent section.

Table 11: Assessment options against minimum data criteria and caveats for the NT Spanish Mackerel Fishery.

			Spanish Mackerel		
		ASSESSMENT OPTIONS	**Meets minimum data requirement**	**Caveats**	**Static Caveats**
NO REFERENCE POINTS	is there any sense of where things are at?	Move directly to decision rules	Y		Does not explicitly consider uncertainty
		Discourse/expert judgement	Y		Does not explicitly consider uncertainty
		Corral/explore data via descriptive statistics	Y		Does not explicitly consider uncertainty
	Harm/no harm	Ecosystem risk assessment for the effects of fishing	Needs time series of fishery independent abundance; time series of inside/outside no-take zones/MPAs		Does not explicitly consider uncertainty; additional information regarding application of assessment: info needs vary depending on whether a PSA is included
		Comprehensive assessment of risk to ecosystems (CARE)	Y		Does not explicitly consider uncertainty; additional information regarding application of assessment: info needs vary depending on whether a PSA is included
		Ecosystem threshold analysis (coral reefs only)	Needs time series of fishery independent abundance; time series of inside/outside no-take zones/MPAs		Does not explicitly consider uncertainty
		PSA to estimate risk of overfishing	Y		Does not explicitly consider uncertainty
		Sustainability indicators (per Cope and Punt (2009) based on Froese's size-based indicators)	Length composition (score 2; needs 3)		Does not explicitly consider uncertainty
	Changes worthy of some management response	Change of dominant species	N/A	Historical or recent operational changes	Does not explicitly consider uncertainty
		Change in species composition ratios	N/A	Historical or recent operational changes	Does not explicitly consider uncertainty
		Changes in spatial distribution of effort	Y	Historical or recent operational changes	Does not explicitly consider uncertainty
		Changes in spatial distribution of catch	Y	Historical or recent operational changes	Does not explicitly consider uncertainty
		Changes in gear type or manner of deployment	Y	Historical or recent operational changes	Does not explicitly consider uncertainty
PROXY REFERENCE POINTS	Time series-based, ideally with reference point (e.g. slope-to-target)	Standardised CPUE	Y	Historical or recent operational changes; may not be suited to fisheries with a low number of participants.	Does not explicitly consider uncertainty
		Catch, CPUE by size indicators (per Froese)	Y	Historical or recent operational changes	Does not explicitly consider uncertainty
		Changes in mean length/weight or length/weight percentiles	Y		Does not explicitly consider uncertainty
		Linear regression to recent time series of CPUE	Y	Historical or recent operational changes; may not be suited to fisheries with a low number of participants.	Does not explicitly consider uncertainty
		Depletion analysis	Y	Requires high research capacity (due to within-season updating)	Does not explicitly consider uncertainty; additional information regarding application of assessment: suits short-lived, highly productive life history
		Size relative to size at maturity	Y		Does not explicitly consider uncertainty
		Ratio of density inside:outside MPAs (per Babcack and MacCall; McGilliard et al.)	Needs time series of abundance; time series of inside/outside no-take zones/MPAs	Requires high research capacity; requires mature MPA (well enforced, similar habitat to fished area)	Does not explicitly consider uncertainty
		Use of biomass surveys to inform spatial management	Needs time series of fishery independent abundance; time series of inside/outside no-take zones/MPAs		Does not explicitly consider uncertainty
		Size-specific catch rate indicators for fish sampled inside and outside of MPAs, and per-recuit (per Wilson)	Needs time series of fishery independent abundance; time series of inside/outside no-take zones/MPAs	Requires high research capacity; requires mature MPA (well enforced, similar habitat to fished area)	Does not explicitly consider uncertainty
	Estimating proportion spawned	Escapement: Samples of catch; ensure 30% have spawned (per squid fishery in California)	Y		Does not explicitly consider uncertainty

EMPIRICAL INDICATOR-BASED FRAMEWORKS	Useful where multiple reliable, independent indicators are available, but these may be fragmented or disparate. Also, "quasi assessments", as per those to the left of these, may be incorporated in frameworks. For hierarchical appraoches, there is a primary and then a secondary control rule(s)	CUSUM Control Charts	Y	May not work with a low number of participants.	Does not explicitly consider uncertainty
		Traffic lights	Y		Does not explicitly consider uncertainty
		RAPFISH (Multi-dimensional scaling)	Y		Does not explicitly consider uncertainty
		Hierachical decision trees	Y		Does not explicitly consider uncertainty
		Size-based sequential trigger system	Y		Does not explicitly consider uncertainty
		Sequential effort triggers	Y		Does not explicitly consider uncertainty
		Sequential catch triggers	Y		Does not explicitly consider uncertainty
		Sequential trigger framework involving catch and/or effort, CPUE, size, sex ratio etc.	Y		Does not explicitly consider uncertainty
STOCK-STATUS-BASED REFERENCE POINTS	estimating F	Catch curves	Y		Approach assumes that the population is currently in equilibrium; approach requires that B0 is stationary (i.e. meaningful regardless of time). Does not explicitly consider uncertainty
		Estimate lifetime egg production per O'Farrell & Botsford	Y		Approach assumes that the population is currently in equilibrium; approach requires that B0 is stationary (i.e. meaningful regardless of time). Requires 2 samples of size structure (temporal snapshots). Does not explicitly consider uncertainty
		SAFE (Zhou)	Y		Need at least some notion of species distribution, even if indirect e.g. by habitat map. Does not explicitly consider uncertainty.
	estimate sustainable yield	Zhou's catch-only method (estimates MSY)	Y	May not work with a low number of participants	Approach requires that B0 is stationary (i.e. meaningful regardless of time). Does not explicitly consider uncertainty
		ORCS (Only Reliable Catch Series)	Y	May not work with a low number of participants; requires moderate-high research capacity	Requires mean or median catches. Does not explicitly consider uncertainty.
		DCAC (MacCall)	Y	May not work with a low number of participants; requires moderate-high research capacity	Approach requires that B0 is stationary (i.e. meaningful regardless of time). Does not explicitly consider uncertainty
		DB-SRA	Y	May not work with a low number of participants; requires moderate-high research capacity	Approach requires that B0 is stationary (i.e. meaningful regardless of time). Does not explicitly consider uncertainty
		Length-based SPR assessment (Prince and Hordyk)	Y		Assumes age- and time-independent mortality. Approach requires that B0 is stationary (i.e. meaningful regardless of time). Does not explicitly consider uncertainty
		Production model	Y	requires moderate-high research capacity	Requires adequate "contrast" reflecting higher and lower relative abundance. Approach requires that B0 is stationary (i.e. meaningful regardless of time).
		Stock synthesis using only a time series of catch SS-CO (Cope 2013)	Y	May not work with a low number of participants; requires moderate-high research capacity	Approach requires that B0 is stationary (i.e. meaningful regardless of time).
		Stochastic SRA (User Guide Lombardi and Walters)	Y	May not work with a low number of participants; requires moderate-high research capacity	Approach requires that B0 is stationary (i.e. meaningful regardless of time). Does not explicitly consider uncertainty
		Catch-MSY (Martel and Froese 2013)	Y	requires moderate-high research capacity	Approach requires that B0 is stationary (i.e. meaningful regardless of time).
		Feasible stock trajectories (Bentley and Langley 2012; Can J.)	Y	requires high research capacity	Approach requires that B0 is stationary (i.e. meaningful regardless of time).
	estimating F	Mortality estimates from length data in nonequilibrium situations (Gedamke and Hoenig 2006) -see https://cran.r-project.org/web/packages/fishmethods/fishmethods.pdf	Mean length or length percentiles (score 2; needs 3)	requires moderate-high research capacity	

Harvest strategies: Management Measures

Figure 5 displays all management measure options available in FishPath, with the number and type of caveats for each option, for the NT Spanish Mackerel Fishery. Relevant responses invoking caveats for the fishery are summarised in Table 12. The strongest cautions were against effort controls and size-based rules. The key issues limiting the decision rule options for the fishery included:

- Determinate growth – this strongly cautions against (red caveat) size-based rules, as length-based information is unlikely to reflect mortality (noting also that the gear does not intersect with smaller fish)
- Susceptibility to handling mortality
- Spatial and seasonal effort concentrations
- Latent effort and effort creep (while noting these are common for many [most] fisheries): these currently eliminates most (though not all) effort-based controls. It is suggested that this question should be revised to better consider the fishery context (e.g. hook days may be acceptable for a limited entry, fully developed fishery, such as NT Spanish Mackerel)
- Low GVP
- Moderate research capacity
- Moderate enforcement capability

Table 13 presents a more detailed summary for two decision rule options, expanded to show all relevant caveat details. These options were

- catch adjustments according to assessment outcomes (feedback): ii) target based with F- or biomass-based reference point;
- effort restrictions by area (whether informed by formal assessment or not)

These were chosen as having, respectively, low and high ratios of green (positive attribute) caveats to orange and yellow (cautionary) caveats.

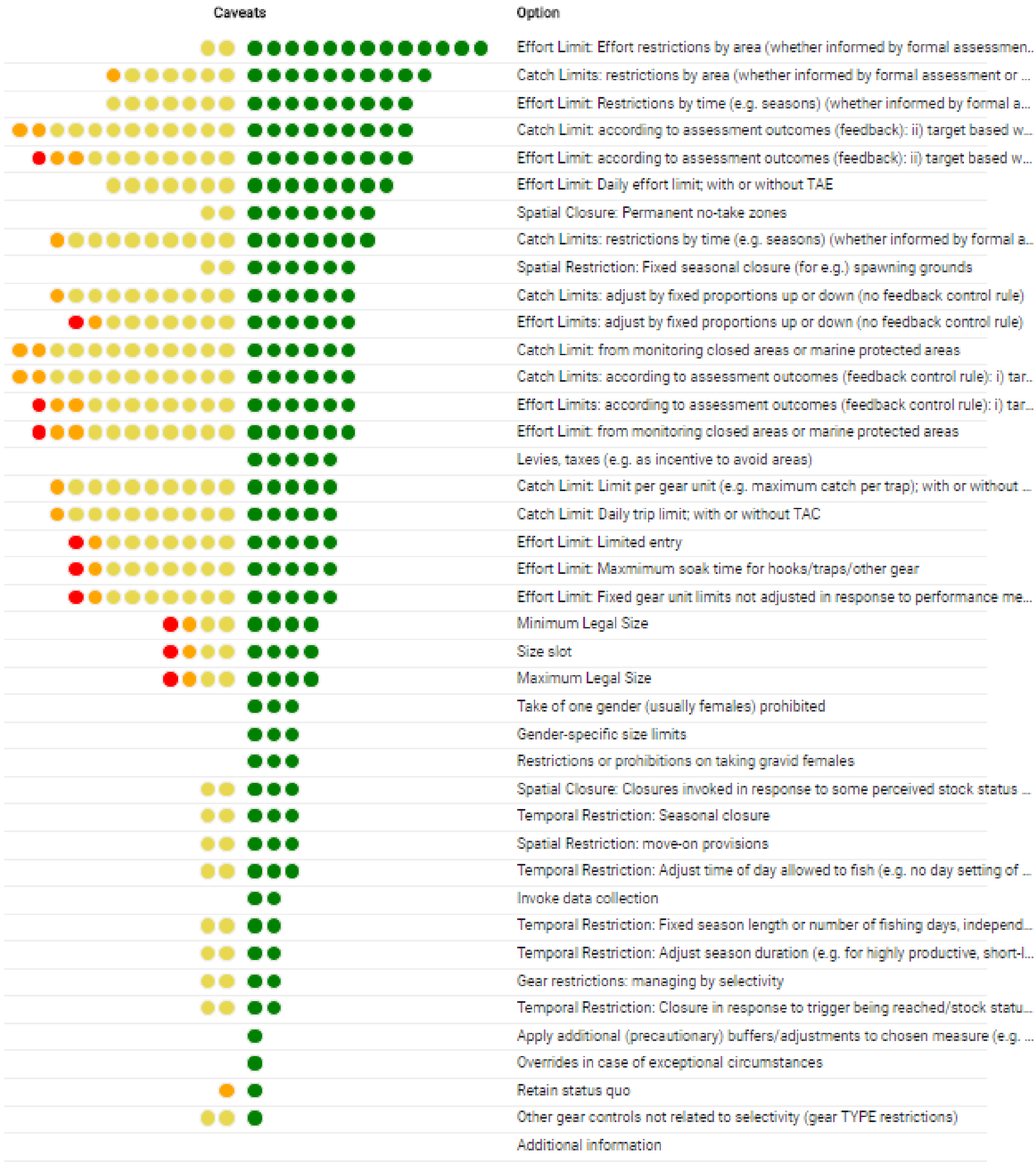


Figure 5: Decision rule option results from FishPath for NT Spanish Mackerel. This image displays all available decision rule options in FishPath with circles representing caveats associated with the fishery. The red circles indicate that the decision rule is strongly cautioned against, orange and yellow indicate more moderate cautionary caveats (with orange implying a stronger caution than yellow), and green indicates that the type of decision rule is recommended in the context of that caveat.

As with many of the FishPath outcomes, there is a considerable amount of detail to be considered across the range of potential options, but the process of identifying the key issues and honing discussion around these is highly efficient, while at the same time a comprehensive range of options is transparently presented with the trade-offs between these clearly able to be identified.

The Guidelines attempt to provide stepwise advice as to how users may confront the outputs from FishPath to home in on a shorter list (of ~3) options for each harvest strategy component.

Feedback from the 2016 stakeholder workshop raised the following key points, which have been added to a broader list for revising the current version of FishPath:

- Consider
    - Meta-population structure
        - The option "overall catch adjustments according to assessment outcomes" may invoke a caution to consider potential for localised depletion
        - The option "effort restrictions by area" may be assigned a positive (green) attribute in this context
        - Spatial controls may be desirable, but there would need to be an awareness of meta-population structure for these be effective
    - Management objectives
        - If inter-annual economic stability is an important objective, then invoke cautions against spatial, temporal, size etc. restrictions in the absence of direct quota-style controls
        - Decision rule recommendations currently do not allow for allocations, or efficiency gains.

Table 12: Relevant questionnaire responses pertaining to minimum criteria, and invoking caveats, against decision rule options for the NT Spanish Mackerel Fishery.

Biology/life history	Determinate growth?	Yes
	Do any of the species of interest stop gaining length at a particular size (i.e. has determinant growth)?	Yes
	Are there known locations that are nursery grounds for the species?	Yes
	Does the species have known spawning grounds, and/or form spawning aggregations?	Yes
	Does the gear intersect with threatened or vulnerable species (regardless of whether these are targeted), and/or habitat locations?	Yes
	If handled or captured and released, is survivorship compromised?	Yes
	Is there immediate concern, among any stakeholder group, regarding stock status?	No
Does assessment suggest a certain form of decision rule?	Is depletion-based stock reduction analysis (depletion-based SRA) currently being used for, or has been	Yes
	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?	Yes
	Is a production model currently being used for, or has been identified by FishPath as a viable option for, assessment?	Yes
Operational	Are there multiple fleets (if considering a single gear, are there other gears or fleets) impacting the species or species group?	Yes
	Is there latent effort in the fishery?	Yes
	Is effort creep occurring, suspected, or likely?	Yes
	Are there spatial concentrations of effort?	Yes
	Are there seasonal concentrations of effort?	Yes
	Are there conditions (e.g. environmental, oceanographic, weather temperature) that strongly affect either fish availability or ability to fish?	Yes
Socio-economic	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").	Commercial
	Rank the current or potential monetary investment for management measures for this species/species group.	Low
	What is the level of fishery cooperation, in terms of complying with and supporting management measures?	High
	Is there a general societal sense that formal management is a good thing, in terms of complying with and supporting management measures?	High
	What level of financial dependency and/or cultural importance is associated with the fishery?	Moderate
Governance	Is the fishery open access, as opposed to limited entry?	Limited
	What is the extent of enforcement capability for this fishery?	Moderate
	Is there strong leadership in place to design and support management measures?	High
	Rank the current or potential research and/or institutional capacity to implement and maintain a formal management strategy (i.e. monitoring, assessment, decision rules).	Moderate

Table 13: Two decision rule options for the NT Spanish Mackerel Fishery (catch adjustments according to assessment outcomes (feedback): i) target based with F- or biomass-based reference point; ii) effort restrictions by area (whether informed by formal assessment or not)), expanded to show all relevant caveat details.

		Catch adjustments according to assessment outcomes (feedback): ii) target based with F- or biomass-based reference point	Effort restrictions by area (whether informed by formal assessment or not)
Are there known locations that are nursery grounds for the species?	YES	Consider augmenting with spatial measures	YES
Does the species have known spawning grounds, and/or form spawning aggregations?	YES	Consider augmenting with spatial measures	YES
Does the gear intersect with threatened or vulnerable species (regardless of whether these are targeted), and/or habitat locations?	YES	Consider augmenting with spatial measures	YES
If handled or captured and released, is survivorship compromised?	YES	Caution re: discarding when limit exceeded	
Does an assessment (either current, or suggested by FishPath) suggest a certain form of decision rule?	YES	YES	
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?	YES	YES	
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?	YES	YES	
Is a production model currently being used for, or has been identified by FishPath as a viable option for, assessment?	YES	YES	
Are there multiple fleets (if considering a single gear, are there other gears or fleets) impacting the species or species group?	YES	Difficult to reconcile catch quotas across the fleets without allocation disputes, while aiming for sustainable management. BUT often more difficult to manage WITHOUT quotas	YES
Is there latent effort in the fishery?	YES	Effectiveness may be compromised by activation of latent effort IF allocations are not explicitly resolved.	YES
Is effort creep occurring, suspected, or likely?	YES		YES
Are there spatial concentrations of effort?	YES	Consider impact of fishing in concentrated area	YES
Are there seasonal concentrations of effort?	YES	Consider impact of fishing in concentrated area	
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").	COMMERCIAL	YES	YES
Rank the current or potential monetary investment for management measures for this species/species group.	Low	May not be able to afford	YES - if sense of ownership is high and measure is able to be enforced
What is the level of fishery cooperation, in terms of complying with and supporting management measures?	High	YES	YES
Is there a general societal sense that formal management is a good thing, in terms of complying with and supporting management measures?	High	YES	YES
What level of financial dependency and/or cultural importance is associated with the fishery?	Moderate	Difficult to enforce	Difficult to enforce
Is the fishery open access, as opposed to limited entry?	Limited entry	YES	YES
What is the extent of enforcement capability for this fishery?	Moderate	CAUTION	CAUTION
Is there strong leadership in place to design and support management measures?	High	YES	YES
Rank the current or potential research and/or institutional capacity to implement and maintain a formal management strategy (i.e. monitoring, assessment, decision rules).	Moderate	May not be able to undertake	

Broader management regime issues

The types of decision matrices developed for the harvest strategy components in FishPath were also drafted for the broader management regime components of i) compliance and enforcement, and ii) community-based/co-management considerations, to help interactively guide practitioners towards options that may be most appropriate given their fishery circumstances.

Whereas FishPath had already been refined following several international case study applications, prior to its application to the NT Spanish Mackerel Fishery. These two new decision matrices were newly formulated and applied first to the NT Spanish Mackerel Fishery as a pilot worked example, to test proof of concept. As such, there was considerable constructive feedback received, and revising that was undertaken following the worked example. The revised versions of these new decision matrices are presented in the Guidelines (Appendix 2). Nonetheless, this interactive approach, whereby options are challenged by caveats invoked according to the specific circumstances of the fishery, goes beyond the original project scope of providing practical, yet generic, guidance.

The results from the NT Spanish Mackerel worked example, using revised drafts of the matrices, are presented below.

Compliance and enforcement decision matrix

As per the monitoring component of the FishPath tool, a set of minimum criteria applied, together with a range of questions that invoked secondary caveat-questions invoked positive attributes (green), or cautionary (yellow, or, if more strongly cautionary, orange) caveats. Minimum required relative GVP of fishery, level of funding required, and extent of agency/governance support, were considered as inclusion/exclusion criteria.

Outcomes for the NT Spanish Mackerel Fishery are summarised by comparing the combined number of yellow and orange (cautionary) caveats induced, with the number of green (recommendation) caveats, for each option (Figure 6). The summary suggests that self-reporting, formal logbooks and third party contracts for secure management of information are less desirable options, with numerous cautionary caveats invoked and with minimal supporting caveats. Incentives and informal logbooks conferred the most supporting caveats (3), while noting that a lack of green caveats *per se* should not be interpreted as the option being less desirable.

Those measures currently in use in the fishery incurred up to four cautionary caveats (formal logbooks 4, licensing 1, penalties 2, and compliance officers at ports 4). The cautions around licensing and penalties pertained to the difficulties of these for the non-commercial sectors, and, for penalties, it was pointed out that these may not need to be severe given there exists strong local leadership. Cautions against the effectiveness of compliance officers at ports pertained to the multi-sector and multi-gear complexities, as well as the potential of this measure to compromise any port-based monitoring program for data collection purposes, and the lack of ability to ensure on-the-water compliance. The cautions around formal logbooks pertained to the non-commercial sectors, potential misreporting given the perceived low levels of trust among fishers, the potential of this compliance measure to compromise the use of logbook data for data collection purposes, and their lack of ability to ensure on-the-water compliance.

In terms of the criteria questions in the matrix (those questions that eliminate options), the perceived low value of the fishery and low-moderate levels of funding suggested precluding most of the options already in place for the fishery. As such, the nature of the criteria questions and/or the structure of the decision matrix may need to be revised, with the criteria perhaps being replaced by caveats that (for example) invoke a stronger orange caution, as opposed to eliminating the option outright.

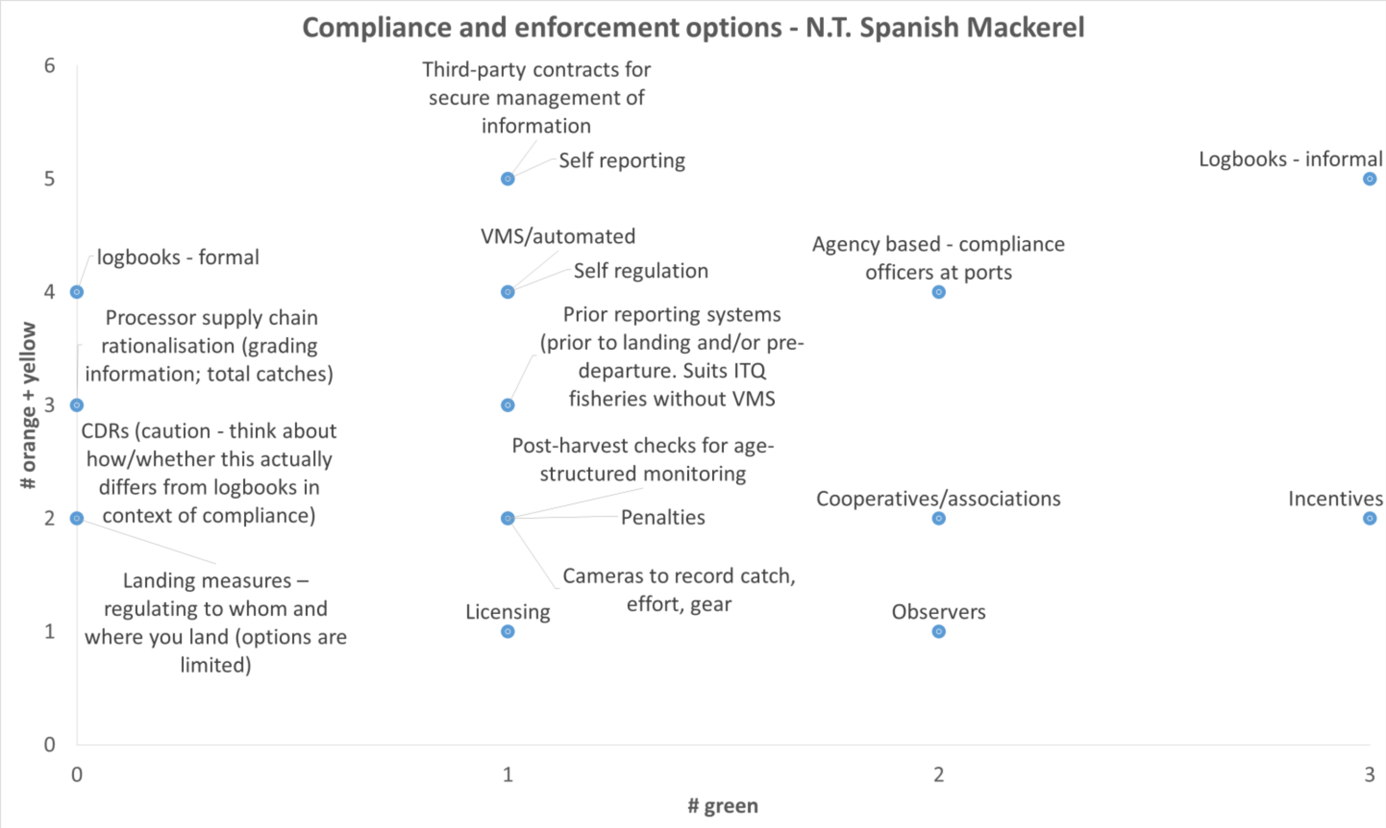


Figure 6: Compliance and enforcement options presented according to the number of cautionary (yellow + orange) caveats invoked, versus the number of green caveats invoked.

Figure 7 provides details for two “best” and “worst” identified options (per the number of cautionary caveats versus the number of supportive caveats): i) incentives, and ii) self-reporting. The latter invokes a supporting caveat for the non-commercial sectors of the fishery, but raises cautionary caveats around multiple gears, low sense of trust among fishers, the strength of penalties, and the ability to access information, with a strong cautionary caveat around the ability to validate reporting. Incentives are supported given that the commercial sector was the one of interest, the low number of commercial participants and the strength of leadership (while noting feedback that this should be split to two questions: “Are there formal local leadership groups/associations/councils?” vs. “Are there actual industry members who are respected leaders/is the industry actively engaged?”), with cautions around the multiple gears, and the fact that incentives are an indirect instrument.

	Criteria													NEW QUESTIONS		
Enforcement options	Minimum required relative GVP of fishery	Minimum level of funding required	Minimum extent of agency/ governance support	Is number of participants low? IF YES	Is the sector commercial? IF YES	Is the sector commercial? IF NO	Are there multiple gears? IF YES	Is sense of trust among one another low? IF YES	Strength of incentive/penalty	Are there measures that would received greater or less support?	Is local leadership strong? IF YES	Types of harvest control rule	Ability to validate (reporting)	Ability to access information	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 reporting	low	low	if low, may be pragmatic option			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	if yes, but strength of governance high, can still work (e.g. sea cucumber). Both cannot be low (would invoke a red)	propensity for misreporting will be higher if these are not strong enough	N/A		N/A	low	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 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	Could work if effectively implemented via agency	More likely to be effective if high	More likely to be useful if measure is not limiting flexibility or ability to achieve (for example) quotas	May be more effective if strong	Usually geared around catch/effort/spatial/temporal	Depends on reliability of reporting			Indiect at determining compliance of spatial/temporal/gear rules

Figure 7: Two compliance/enforcement ("best" and "worst") options for the NT Spanish Mackerel Fishery (incentives, and self-reporting), expanded to show all relevant caveat details.

Co-management and community-based management decision matrix

According to the decision matrix, the following precluded collaborative or fully delegated co-management approaches, and on the same basis, most of the community-based management options were also eliminated (Figure 8):

- Inability to delegate powers under relevant legislation
- Lack of allocation
- Perceived strong viscosity and/or lack of political will in responding to the need for management change

Centralised or 100% agency-based management was recommended, albeit with cautions around higher costs, and existing co-operations/associations. A strong caveat invoked around centralised agency-based management was that, given the existing associations and consultative forums, stakeholder consultation should be sought (Figure 9).

Under the community-based management options, the matrix indicates potential scope for capacity building, engaging stakeholders on how to manage, and informal community management arrangements. Again, each has its own range of cautionary caveats that would require consideration (Figure 9), with the multi-sector nature of the fishery, the perceived general lack of bigger picture business acumen, lack of consensus for stakeholder endorsement, and lack of allocation being the most critical issues identified.

Caveats		Co-management			Community management			
		Collaborative (e.g. equal stakeholder/agency)	Fully delegated: strong stakeholder / low agency		Traditional/ cultural	Access rights only?	TURFS/ ranching	self- enforcement
Can you delegate powers under relevant legislation?	If not	May work if final decisions rest with agency	Required		Required	Required	Required	Required
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	Required		Required	Required	Required	Less likely to succeed
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	Required		Required	Required	Required	May be more challenging to help establish

Figure 8: Caveat question responses invoking red preclusions of co-management and community-based management options for the NT Spanish Mackerel Fishery

Caveats		Co-management		Community management		
		100% agency-based: no stakeholder involvement	Centralised: minimal stakeholder/strong agency (old/traditional model)	Engaging stakeholders and partners in how to manage	Capacity development needed?	Informal (as opposed to formal)
Social/cultural basis/precedent/tradition	If strong and activities/arrangements not causing conflict or adversely affecting stock	N/A	N/A	May be challenging if seen to be "interfering" with existing arrangements	N/A	May work well
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	N/A	Moderate-high if required	Lower
Trust of industry of management process - belief/buy in	If high	N/A	N/A	More likely to succeed	N/A	May work well
business acumen/bigger picture capability of industry	If commercial, or a high-take sector, AND this is low	May be preferable	May be preferable	May be challenging	May require capacity building	Caution against lack of formal arrangements in this context
Extent of multiple sectors	If high,and conflict exists, level of engagement is low, and/or competing objectives	May be preferable	May be preferable	May be challenging	N/A	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	N/A	May be more difficult than for single-gear fisheries
What does consensus look like for stakeholder endorsement?	If low	May be preferable	May be preferable	More difficult	N/A	Less likely to succeed
Integrity of auditing/reporting	If high	N/A	N/A	N/A	N/A	N/A
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	N/A	N/A	May afford more flexibility, but may also be more risky
Can you delegate powers under relevant legislation?	If not	Most realistic	Most realistic	N/A	N/A	N/A
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	Easier to engage	N/A	More likely to succeed
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 consulted	N/A	Easier to engage	N/A	More likely to succeed
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	More difficult	N/A	Less likely to succeed
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	Need to be aware of this when engaging	N/A	
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			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

Figure 9: Caveat question responses for non-excluded co-management and community-based management options for the NT Spanish Mackerel Fishery

Bullet points on a proposed way forward for NT Spanish Mackerel, based on the worked example

Based on the above results, the following points form a brief outline of potential harvest strategy options, and around community-based/co-management, and compliance/enforcement. These are yet to be fully articulated, but may rather form a starting point for a fully blown case study:

- Monitoring (data gathering):
  - Logbook program to continue with increased emphasis on data to inform assessment as much as being used for compliance
  - Augment with (for example) port sampling to obtain biological data.
- Assessment:
  - Shijie Zhou’s catch-only assessment – can be undertaken annually with little required research capacity and at low cost
  - Supplemented every few years, for example by additional assessments such as SPR and/or DB-SRA (underpinned by a production model) – while noting that these require somewhat more research capacity/resourcing
- Management measures (Decision rules):
  - Will have to account for the meta-population structure of the stock – effort restrictions by area may be an option
  - Alternatively, catch limits might be established augmented by minimum sizes.
- Centralised management with stakeholder consultation through appropriate forums is recommended, and with ongoing capacity building so that fishers could be encouraged to participate more in data gathering.
- The current compliance/enforcement measures, though expensive relative to the value of the fishery, should be revisited in the context of the caveats raised, and could potentially be augmented using, for example, incentives, or cameras.

Note against Objective 4

Project objective 4 stated, “Via the case study fishery, to consider how to incorporate multiple sector objectives and how best to engage relevant stakeholders, in the context of pragmatic management regimes”.

As illustrated for the NT Spanish Mackerel Fishery worked example, The Guidelines and the FishPath tool provide an interactive means for stakeholders to engage with the development of a management regime, in that recommendations are tailored to the specific context of the fishery of interest.

Beyond the above worked example illustrating the interactive components of the Guidelines, the broader Guidelines document provides explicit, stepwise guidance on how best to undertake the stakeholder engagement process.

Multiple sector objectives are dealt with explicitly, via some of the caveat questions within FishPath and the compliance/enforcement and co-management/community-based management decision matrices. It is also implicit (and the Guidelines provide this advice) that the monitoring and decision rule components of the FishPath tool can be run separately for each sector of interest (ideally, a combined assessment approach should be used). Overlaps and differences in the recommended outputs can then be compared.

Implications

Assuming data-limited fisheries comprise 10% of the gross value of capture fisheries in Australia and 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 ~$800K to Australia and ~$450 million globally. Conversely, collapse of these fisheries could represent annual losses of up to ~$16 million to Australia, and ~$9 billion globally[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 fishery management, increased compliance, increased business certainty, public confidence and export approvals associated with harvest strategies, nor for the increased efficiency of the harvest strategy development process afforded by the Guidelines and the FishPath tool.

Regardless of the dollar value estimates around these fisheries, there is considerable scope for improving economic, ecological and social outcomes for data-limited fisheries, via appropriate management regimes, underpinned by harvest strategies. Having pre-defined, agreed-upon data collection, assessment and harvest control measures, leads to improved fishery sustainability, economic return, business certainty, and public approval. These harvest strategy components are possible to achieve even with limited resources.

Yet many fisheries lack formal management (in terms of an assessment and pre-defined decision rules) not only because of the perceived issues around data limitation, cost, and capacity, but also the unique circumstances and issues associated with any data-limited fishery, and a pervasive "top-down" engagement mentality, which fails to empower local practitioners. These often result in a sense of isolation, hopelessness or management paralysis.

The Guidelines empower local practitioners to take a "bottom-up" approach to developing low-cost management regimes, which are tailored to, and acknowledge, a fishery's specific circumstances. The process-based Guidelines, and the FishPath decision support tool, provide a readily-accessible map of the "universe" of options laid out to practitioners, in the context of their specific fishery. They support the critical process of diagnosing the needs of a fishery, and allow practitioners to understand and utilize their available information in the identification of appropriate harvest control rules and management measures.

The Guidelines:

- Provide step-by-step advice and checkpoints against every aspect of the development of a low-cost fishery management regime, from inception to implementation.

- Provide a standardised and replicable process that is transparent and comprehensive.

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[1] In 2014–15, the Australian wild-caught sector had a gross value of $1.6 billion (Savage 2015). 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, and noting that i) the top 4 capture species for Australia had a combined value of $1.35 billion (Savage 2015's Table 2), and ii) NSW, Qld and NT fisheries, most of which lack harvest strategies, comprised 18% of the gross value of Australian production (Savage 2015's Figure 17)), this equates to an Australian $16 million, and global $9 billion.

- Provide a basis for engagement and informed discussion. By bringing stakeholders "along for the journey", they confer a greater sense of ownership, comprehension, and trust.

- Present information and options as a platform. Having a "larger universe" or "map" of options that is conveniently accessible, avoids the "tunnel vision" associated with "silver bullet", generic, or prescribed "top-down" approaches, and confers assurance that the approach selected is the most appropriate among all those available.

- Focus stakeholder discussion on the correct issues, and as such, a reduce the probability of derailment of the process due to overt focus on tangential side issues

- Provide practical advice that directly considers the specifics of the fishery of interest.

The FishPath tool:

- Is an efficient, transparent, objective (standardised) process to formalize engagement and empower decision making.

- Is comprehensive with a considered list of harvest strategy options.

- Provides an understanding of assumptions, limitations, and requirements that enables users to critically evaluate options. This information is transparently presented in a user-friendly way that allows users to consider details – as opposed to undertaking prescriptive assessment "handle cranking".

- Identifies what can be done if specific caveats or limitations can be overcome.

- Confers a reduced likelihood of misapplication of "off the shelf" or expert-prescribed assessments or approaches.

- By providing honed options, gives guidance as to how funds may be effectively targeted for focused training or outreach.

In engaging with Northern Territory, New South Wales, and Queensland Fisheries, it has been evident that there is demand and need for guidance and a process-based approach, both for harvest strategies (per FishPath), and broadly in terms of end-to-end advice, as provided in the Guidelines. Many of the problems in harvest strategy development occur at the point of engagement with stakeholders, and managers can also flounder without advice as to how to interpret, refine, apply and embed in management plans, potential harvest strategy options. By providing stepwise comprehensive, practical guidance against all steps of management regime development, the Guidelines provide clarity to managers and provide a standardised and comprehensive pathway forward.

Recommendations

- The Guidelines provide a transparent and standard pathway to developing low-cost management regimes for low-value, small-scale fisheries, and inherent within them are the recommendations to arise from the project. The Guidelines seek to overcome the challenges of developing low-cost fishery management regimes in a pragmatic and stepwise manner, and provide a customised, “bottom up” approach, which is key to confronting the specific issues associated with each individual fishery.

- The application of the Guidelines results in the efficient identification of an explicit pathway to formal management. Many low-value, small-scale fisheries have experienced management paralysis due to a lack of a prescribed process that is still specific and customised to their unique needs and circumstances, combined with a lack of data, funding and capacity.

- Central to a management regime is the harvest strategy. The Guidelines empower stakeholders to simultaneously evaluate a large amount of harvest strategy options in an objective manner that is sensitive to the particulars of any given fishery. FishPath is a decision support tool that is nimble, replicable, and accessible, and contains a broad suite of options for data collection, assessment methods, and management measures. By confronting the sweeping set of harvest strategy options with a fishery’s and stock’s specific characteristics, the approach supports a stakeholder-driven, objective, automated, transparent, bottom-up evaluation of possibilities. This enables stakeholders to concurrently study options and defensibly identify harvest strategies preferences appropriate to the unique context of their fishery. It is important to note that this process must occur regardless in developing any harvest strategy. The FishPath tool, and the other (compliance and enforcement; community and co-management) decision matrices within the Guidelines merely provide a means to more formally, efficiently, and defensibly guide this process, across a broader range of available options than those that may be have been identified ad-hoc.

- Beyond the development of a harvest strategy, the workshopping and case study application of the Guidelines revealed that the most critical aspects to a successful management regime were i) obtaining stakeholder engagement and buy-in (and that the probability of this was optimised by having a pre-engagement strategy), and ii) that, having drafted the harvest strategy, ensuring that there was adequate detailed advice on how to fully articulate its detail, and on how to operationalise it (that is, “how to put the petrol in the car and drive it away”).

- The over-arching recommendation from the project is that the Guidelines are viewed as the “go-to” national standard for providing process-based advice to practitioners charged with managing low-value, small-scale fisheries. To achieve this requires that the Guidelines are applied to develop fully articulated case studies across a wide range of fishery types, both to showcase their value, and to enable their further critique and refinement. In the first instance, this should involve working with NT Fisheries, NTSC and the NT Spanish Mackerel Fishery to convert the current worked example into a more fully articulated case study.

- In the longer term, the uptake and acceptance of the Guidelines may be optimised by:
    - training facilitators who can apply the Guidelines in different contexts, from workshops to more grass-roots outreach styles of engagement.
    - maintaining a centralised database of worked case studies.
    - bringing in more governance and social scientists, and managers across a broad range of fisheries, to critique those aspects of the Guidelines that are less scientifically oriented.
    - identifying a process for continuing to raise awareness of the existence and application of the Guidelines, while noting that this is best achieved by their successful application.
    - considering whether aspects of the Guidelines could be best operationalised as a user-friendly software interface.

Further development

- Based on this work we recommend that there is a need to further run case studies across a range of species. Appendix 4, an Expression of Interest submitted to FRDC in February 2018, provides full details of proposed further development.

- The key message from the 2016 stakeholder workshop participants was that the Guidelines and proposed process were felt to be of value, but strongly require extension. Beyond the scope of the current project, the need for further engagement and fully articulated case studies was identified. Spanish Mackerel as a “tool-testing” worked example with a vignetted group largely resulted in dissatisfaction around a desire to see more complete articulation, and because this example did not embrace issues of key interest for other fisheries (such as multispecies issues).

- There was also the suggestion of a need to establish a network of FishPath and (data-limited) stock assessment core groups of experts as “go-to” points. The importance of continual engagement with the same people was emphasised. Equally important is to build greater “in house” capacity in data-limited stock assessment and harvest strategy development within state-based agencies, so that the range of tools and guidelines at hand may be effectively utilised.

Extension and Adoption

<u>2016 Stakeholder Workshop</u>

The main proactive form of outreach during the project was the September 2016 stakeholder workshop. The workshop was held from September 6-8 and was attended by 16 experts from state agencies and industry bodies. FRDC, FRDC’s Social Science and Economics Research Coordination Program (SSERCP) (now the Human Dimensions Research Subprogram), AFMA, New Zealand and the South Pacific Commission were also represented. The workshop represented a major opportunity to engage with stakeholders. The workshop unfortunately suffered from the late withdrawal of several participants due to major and unforeseen circumstances, but the group of 16 in attendance were active in their engagement and it was a valuable forum for the exchange of information and for receiving invaluable feedback and critiquing of the draft Guidelines.

Feedback from the workshop was positive, with participants endorsing in principle the process outlined in the Guidelines, and the FishPath harvest strategy selection tool, while wishing to see their application in more fully articulated case studies. The quality of the feedback received, both technical and against the structure, content and style of the Guidelines, was invaluable in revising and finalising the Guidelines and in continuing to develop the FishPath tool. There was a strong message from workshop participants that, while the Guidelines and proposed process were felt to be of value, there was need for further engagement and fully developed case studies that collectively embrace a broader range of issues.

<u>Other communication with beneficiaries</u>

NT Fisheries, NTSIC, and the AFMF Fisheries Management Sub-Committee were kept regularly updated throughout the project, with reports provided by project team members Bryan McDonald, Rob Fish, and Lindsay Joll, respectively. Each group also received a written summary of the September 2016 project team meeting outcomes. The PI gave an overview of the project and the Guidelines to the AFMF Fisheries Management Sub-Committee meeting in November 2016.

An overview presentation of the project was provided to the NT RAC in March 2017.

Natalie Dowling attended the Seafood Directions Conference in Sydney, September 2017. She gave a presentation on the FishPath harvest strategy selection tool and was a panellist in the same session.

Due to their interest in the project and the extent of feedback provided in the 2016 workshop, a copy of the revised draft Guidelines, with invitation to comment, was sent to industry representatives Tricia Beatty (NSW) and Katherine Winchester (NT) in early 2017.No feedback was received.

<u>Demand for, and adoption of, the Guidelines and the FishPath tool</u>

The Guidelines developed in this project, and the FishPath harvest strategy selection tool, are demand-driven. Australian and international small-scale, low-value fisheries (both from developed and developing nations) are commonly starting with no or minimal precedent with respect to formal management using harvest strategies. They often have limited or no expertise as regards harvest strategy development and require guidance from point of inception. They are actively seeking process-based guidance such as that provided herein.

The demand and success of the Guidelines and the FishPath tool has been evident not only from their endorsement within this project from NT Fisheries, NTSIC and the AFMF Fisheries Management Subcommittee, achieved via continuous communication and the illustrative worked example, but also through:

- The unsolicited request to engage with NSW Fisheries, following the presentation of the FishPath tool at the workshop for FRDC 2016–063 “Assessment Methods for Undefined Species”, at which Natalie Dowling was an invited attendee. Natalie subsequently presented FishPath and the Guidelines at a NSW senior manager’s meeting in Port Stephens in February 2017, and then led a 3-day workshop for NSW Fisheries in Sydney in May 2017. The Guidelines and FishPath were unanimously supported and requested to underpin the process of harvest strategy development for NSW data-limited fisheries.

    - An excerpt from the NSW FishPath workshop report: "*FishPath* was widely viewed as a positive process providing a transparent, flexible and repeatable framework to structure discussions essential for the development of harvest strategies for data-poor fisheries. It provides an explicit and comprehensive suite of options, with caveats for Monitoring, Assessment and Decision Rules, based on characterisation of the fishery/species by stakeholders………*FishPath* was unanimously supported as a positive framework to support structured, explicit discussions and limit 'decision paralysis' among stakeholders around essential issues for harvest strategy development. It provides some corroboration of existing fishery assessments, and outputs support proposals for ongoing improvements to Monitoring, Assessment and Decision Rules."

- The unsolicited request to engage with Queensland DAF, given their exposure to the FishPath tool via FRDC 2015-013, and their desire and need for a process-based tool to guide their recently-released harvest strategy development process for Queensland State Fisheries. Natalie Dowling ran a 3-day workshop for Queensland DAF in July 2017.

<u>Other forms of engagement and extension</u>

- Natalie Dowling hosted a 3-week visit from University of Washington Evans School of Public Policy and Governance PhD student Kate Crosman, who has a strong background in policy and social science. Together with the project team, Kate and Natalie ran a FishPath workshop in Darwin on November 17, 2017 (FRDC 2017-125). As part of this, they undertook a formal experiment investigating the level of efficacy support required for the successful application of the FishPath tool.

- The project team, together with Kate Crosman (UW) developed a simple, hypothetical case study fishery example ("FishPath Straw Man") that includes key fishery "sticking points" (e.g. multispecies, multi-gear, intra-/inter-sectorial conflicts, low trust and willingness to be involved; different questions). The intention is that this can be used as a generic communication tool that provides a central selling point.

- In September 2016, Natalie Dowling was an invited expert panellist at the British Columbia, Canada, Groundfish Fishery's Commercial Industry Caucus (CIC) Multi-species Management Systems (MSMS) 1 Phase 3 Workshop: Stock Assessment and Harvest Control Rules. Natalie ran a day-long FishPath mini workshop and provided a worked example for one rockfish species.

Project coverage

An article on FishPath, "Cutting Edge Tool a Must Have", was featured in the October 2017 issue of the Northern Territory Seafood Council News.

Appendices

Researchers and project staff

Natalie Dowling (Principal Investigator) (CSIRO), Bryan McDonald (NT Fisheries), Lindsay Joll (WA Fisheries), Rik Buckworth (CSIRO), Shijie Zhou (CSIRO), Rob Fish (NTSC), Lianos Triantafillos (NT Fisheries)

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Appendix 1: Low-cost management regimes for small-scale, low-value fisheries: a review of the literature

Low-cost management regimes for small-scale, low-value fisheries:

a review of the literature

Natalie Dowling

Contents

1. Glossary of key terms

a. Definition of “low cost/low-value, small fisheries”

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

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

then the fishery could be considered to be “low cost”/”low value”.

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 these are not intended to be exclusive. Importantly, “low cost”/”low value” is not a closed definition.

Generally, such fisheries lack, whether for reasons of data poverty and/or capacity limitations, formal, quantitative stock assessments (or at best, these have been undertaken sporadically), that are used to inform management.

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 the gross value of production (GVP)), but environmental and social values are also important, especially to non-commercial sectors.

b. Definition of “management regime”

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).

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 and/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 or management strategy (the terms are interchangeable), hereafter, “harvest strategy”. 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 1). Alternatively, a management regime equates to the inner t two (yellow and green) layers of the diagram presented by Sloan et al. (2014) (Figure 2).

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:
   a. Legislative and policy requirements
   b. Allocation
   c. Co-management and community-based management

ii) Issues that precede harvest strategy development:
   a. Generating stakeholder interest/trust to motivate participation
   b. Obtaining ongoing stakeholder engagement and trust/sign-on
   c. Eliciting and weighting multi-sector objectives
   d. Identifying performance indicators and reference points

iii) Issues that pertain to the implementation of harvest strategies:
   a. Operationalising a harvest strategy
   b. Defining/specifying the management plan
   c. Articulation and evaluation of impacts and outcomes
   d. Compliance
   e. Enforcement

They therefore expand on the guidelines for harvest strategy development provided in Dowling et al. (2014b):

(1) compile and review available information,
(2) identify possibly indicators,
(3) identify reference points for key indicators,
(4) select an appropriate harvest strategy,
(5) if possible, formally evaluate whether the harvest strategy options are likely to achieve the management objectives, and
(6) implementation.

c. Definition of "harvest strategy"

A harvest or management strategy is a formal, pre-specified set of rules designed to achieve the management objectives for the fishery. Harvest strategies (HSs, "management strategies", "management procedures") are formal frameworks for managing exploitation of fisheries, 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 (data collection) 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).

It is critical to note that the harvest strategy is the central component of, and underpins, a management regime.

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, which embrace data-limited contexts. As such, harvest strategies can vary strongly across 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 strategy development may merely involve the formalisation of existing arrangements.

The majority of 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 (Dowling et al. 2018).

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. The bottoms line is that 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.

The advantages of harvest strategies include:

- Proactive rather than reactive management: management responses are pre-agreed
- Transparency
- Objectivity
- No lost opportunity due to management paralysis
- Improved public perception
- Defensible management
- Increased stakeholder certainty re: management decision processes
- Fostering a climate of trust
- Improved manager, fishery, public confidence
- Permitting greater business planning through transparent and formal management
- Improved stock sustainability and supporting for environment health
- Maximising potential for export approvals

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

Per Fletcher et al. (2016)'s implementation of harvest strategies in Western Australia: "Where there is now an agreed and explicit harvest strategy this is providing more certainty and a better understanding by each sector for what happens when indicators change plus how sectoral allocation decisions will be delivered. This has already generated dividends from increased management efficiency because many of the negotiations within and among sectors that previously were not clearly defined have now been made explicit…….This holistic approach is already generating efficiency dividends through the adoption of tolerance levels that are minimising unnecessary management interventions. Similarly, fewer management elements now require pre-season negotiation which is also reducing administrative costs."

d. <u>The FishPath decision support tool</u>

Using the principle of confronting harvest strategy options with minimum criteria and caveats, Dowling et al. (2016) have developed a data-limited harvest strategy decision support tool, called "FishPath"(www.fishpath.org). FishPath automates the process of filtering harvest strategy options, given user responses to a set of caveat-driven questions, against five information categories:

i) available data
ii) biology/life history
iii) fishery operational characteristics
iv) socio-economics, and
v) governance context.

For each of the monitoring, assessment, and decision rule components of the harvest strategy, FishPath navigates among a comprehensive suite of possibilities to reveal those most appropriate for the fishery, with relevant caveats explicitly articulated. As such, FishPath is a participatory process for identifying appropriate and feasible harvest strategy options given any fishery's context. It is an organisational tool to empower a formal guided process.

Over-arching issues, pre-requisite information

- Legislative/policy context
- Allocation of resource among stakeholders/sectors
- Co-management and community-based management

Pre-engagement

- Undertake an internal audit of the fishery
- Identify drivers for management
- Clarify the reason for the journey
- Consider adoption and the “authorising environment”.
- Understand historical context and conflicts/issues
- Undertake desktop analyses (compile and review available information, identify performance indicators and reference points)
- Identify process of engagement

PART 1: Engagement and elicitation

- Generating stakeholder interest/trust to motivate participation
- Obtaining ongoing stakeholder engagement and trust/sign-on
- Eliciting and weighting multi-sector objectives
- Reconciling multi-sector objectives
- Re-review available information
- Finalise performance indicators
- Finalise reference points

PART 2: Identifying harvest strategy options

- Monitoring (data collection)
- Stock assessment
- Harvest control / decision rules
- “Fixed” harvest control rules/conditions
- Formal evaluation of harvest strategy options

PART 3: Operationalising the Harvest Strategy

- Choosing between potential harvest strategy options: finalising the harvest strategy of choice
- What is the harvest strategy and how should it be articulated?”
- Defining/specifying the management plan
- Articulation and evaluation of impacts and outcomes

PART 4: Implementation

- Process for day-to-day management
- Define/specify the management plan
- Establish the monitoring plan/program
- Tactical implementation of the harvest strategy
- Compliance and enforcement
- Review process for the harvest strategy

Figure 1: Flowchart describing the process of establishing a formal fishery management regime

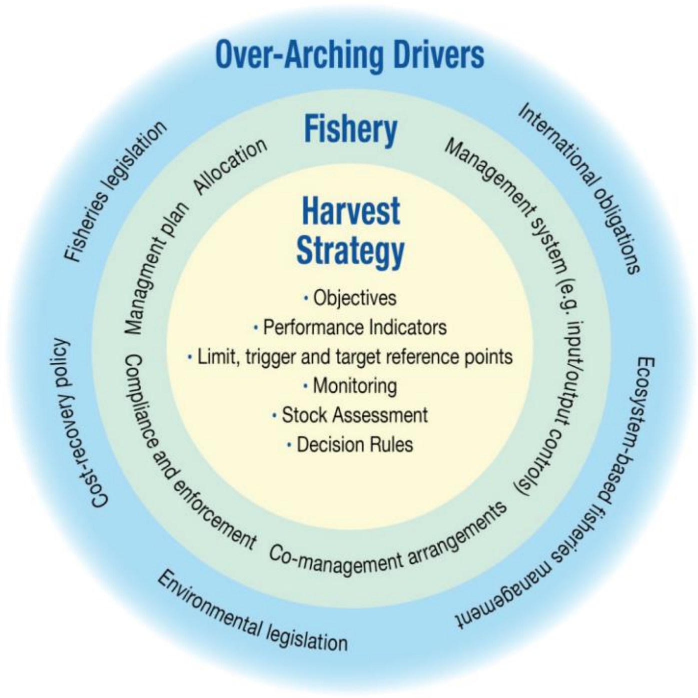


Figure 2: A schematic representation of how a harvest strategy fits within the overall fishery management framework (as a central component of the fisheries management process) (from Sloan et al. 2014). The management regime embraces both the harvest strategy and its embedding within the green "Fishery" layer.

2. The Australian context

a. Need for this review

Low cost, practical management regimes for small-scale, low-value fisheries are desperately needed, to ensure long term sustainability for these fisheries without the need for resource hungry management frameworks. While output-based management regimes, for example, centred about a total allowable catch, provide business cases to support investment, it is also valuable to consider input controls (e.g. gear, spatial, temporal or effort controls). The level of data and/or resource poverty for 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 cultural issues (such as style of communication, and the sense of traditional stewardship of fishery resources) associated with indigenous sectors.

A logical first step is to develop guidance and a recommended approach to developing low-cost fishery management regimes. This has been long been flagged as a priority by the Northern Territory for its small-scale, low-value fisheries, including those with an indigenous and/or community emphasis. A sensible and cost-effective starting point for the provision of general advice is a review and inventory of existing approaches for low-cost management regimes for small-scale fisheries.

While the National Harvest Strategy Guidelines (Sloan et al. 2014) acknowledge issues unique to multi-sector (including recreational and indigenous) and data-limited fisheries, they do not consider the management regime as a whole, nor, explicitly, small-scale, low-value fishery-specific issues. We here try to consider how management regimes, underpinned by harvest strategies, can be developed for small scale, low value fisheries, in the context of strong collaborative approach with, as appropriate, state agencies and indigenous liaison teams.

b. Why the Northern Territory in the first instance?

Northern Territory (NT) Fisheries have long recognised the need for the development of low cost, practical management approaches for low-value, small-scale fisheries. NT fisheries are typically information- and resource-poor. Hence, they require inexpensive, pragmatic tools that still yield relatively robust outcomes. The demographic of such fisheries is secondary, but can include recreational and indigenous sectors in addition to commercial sectors. Moreover, prior lack of engagement with management, levels of literacy, isolation and cultural issues are inherent traits of many low-value, small-scale fisheries, and these must be explicitly acknowledged and considered.

That stated, the issues faced by the NT are equally applicable to other small-scale, low-value, state and Commonwealth fisheries, per the AFMF “Fisheries at a Glance” documents, and Joll et al (2015). These review Australian fisheries and their existing management, and highlight the ubiquitousness of the challenges faced by small-scale, low-value fisheries.

3. Acknowledging legislative and policy frameworks as basis/underpinning any management regimes in area of jurisdiction. Is there a legislative basis for proceeding?

Australian fisheries, whether Commonwealth- or State-based, are subject to policy or legislative requirements.

Therefore, in developing any management regime, 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} corresponds to the biomass at maximum economic yield), or suitable proxy, and avoidance of a $0.2B_0$-based limit reference point (where $0.2B_0$ equates to 20% of the unfished biomass level).

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 ESD, advocating a precautionary approach

- provides an underpinning set of objectives

Sloan et al. (2014) summarised the extent of fishery harvest strategies nationally in 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.

In the context of small-scale, low-value fisheries, the demands of policy and legislation are challenging given the (typically) associated data- and/or capacity-limitations. It is emphasised emphatically the majority of 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 policy and/or legislative requirements.

That stated, care must be taken in developing any process-based guidance tools, lest they create regulatory conflict, or confer a lack of adaptive capacity. Advice should be cognisant of sustainability, equity and optimisation, as per the legislative Acts and Policies, and consistent with their intent.

4. Broader context

The issue of reconciling the management of small-scale, low-value fisheries with legislative mandate is global. At best, there is acknowledgement of the issues around the management of such fisheries, and accompanying guidance regarding proxy reference points and data-limited assessment methods. For example,

- In the United States, the National Standards Guidelines accompanying the Magnusson-Stevens Act have been recently revised to better accommodate data-limited fisheries, but there is no accompanying practical guidance, nor acknowledgement of the range of issues that may be faced in the data-limited context.
- The British Columbian Groundfish Fishery in Canada is struggling to reconcile strict catch quota requirements and an exceptional monitoring regime against life history and fishery operational characteristics that make catch quotas problematic (with regard to “choke” species), and the identification of meaningful performance indicators and reference points challenging.
- Queensland and New South Wales are both in the process of recommending or embedding harvest strategies as part of management reforms. Both states are seeking process-based advice on how harvest strategies may be developed and implemented, particularly in the data-limited context.
- New Zealand representatives attending both a workshop held under this project, and a SAFS data-limited stock assessment workshop (January 2017) have shown strong interest in process-based tools that can assist with identifying harvest strategy options for their data-limited fisheries.

The lack of guidance is even more pronounced in developing nations, where there is often little legislative mandate, and limiting factors typically pertain at least as much to socio-economics and governance and enforcement issues as they do to data limitation. The Nature Conservancy, CSIRO, The Marine Stewardship Council and NOAA have been involved in engaging with fisheries management agencies in Peru, Kenya, Spain, Mexico, the USA (Hawai’i, Rhode Island, California), Bahamas, Jamaica, and Indonesia, using the FishPath tool to efficiently identify feasible harvest strategy options and to empower and encourage stakeholders to move towards fully articulated harvest strategies that are pragmatic in acknowledging their unique circumstances.

That is, while there may exist some specification on *what* managers need to do in low-value/small-scale/data-limited contexts, there is little process-based advice on *how* to achieve this, given the challenges. There is strong demand and scope for process-based approaches that embrace the whole of the management regime development process.

5. Review and inventory of low-cost / small-scale management regimes, emphasising low-cost approaches.

This review seeks to identify how management regimes have typically been developed in low-cost, small-scale fisheries globally.

Harvest strategies are central to any management regime, and there has been much attention given to data-limited harvest strategies in the literature, specifically, to data-limited assessment methods and "management procedures" (assessment methods with associated harvest control rules). We state upfront that this review briefly revisits harvest strategies from the low-cost, low-value perspective, but, in the main, it defers to the recent literature review undertaken by Dowling et al. (2015a), and in terms of process-based guidance, to the Dowling et al. (2016) FishPath harvest strategy decision support tool (www.fishpath.org), which is itself underpinned by an up-to-date review of the literature, with references included explicitly in the software.

The closest related available tool to FishPath is the U.S. Environmental Defence Fund's "FISHE" (Framework for Integrated Stock and Habitat Evaluation) package (http://fishe.edf.org/). Similar to FishPath, this tool is intended to guide practitioners through a structured step-by-step framework that combines multiple assessment methods. However, FishPath provides i) a more comprehensive suite of data-limited assessment options, ii) explicit advice against viable monitoring (data collection) and decision rule (management measure)options, iii) a less "arm's length" approach via the provision of specific options given fishery circumstances, as opposed to more general guidance.

The Carruthers et al. (2014) data-limited methods toolkit ("the DLM toolkit") is the emerging leading management strategy evaluation (MSE) simulation tool within which a range of management procedures can be rapidly evaluated. The FishPath tool (Dowling et al. 2016) identifies harvest strategy options for data-limited fisheries given their context, and can therefore be used to inform the types of management procedures that users may evaluate using conditioned MSEs, or the DLM toolkit.

Regarding management regimes as a whole, this review identified a general lack of advice or case studies embracing the entire process:

- Management regimes were highly case-specific. There is little evidence in the literature of attempts to develop broad-scale, process-based advice across the whole of the management regime
- Case studies typically focused on specific aspects of the management regime, as opposed to its entirety.
- Most case studies around low-cost, low-value fisheries were from a developing nation perspective. There were very few examples of low-cost management regimes for low-value, small-scale fisheries in a developed nation context.
- When searching for low-value, small-scale fisheries management literature, there was heavy emphasis on

- Harvest strategies, as aforementioned
- Stakeholder engagement
- Community management
- Co-management

This section of the review roughly follows the processes identified in Figure 1, in that it reviews the specific components that, collectively, comprise the management regime.

a. <u>Stakeholder engagement</u>

Successful fisheries management is highly dependent on the level of stakeholder engagement, and on engaging from the outset (Dowling et al. 2008). Per Barsuto and Coleman (2010), the sooner communities adopt institutions, and the stronger the institutions they adopt, the more likely they are to sustain the resource stock.

The benefits of stakeholder engagement are two-way. Early engagement engenders a sense of ownership of formal management, and increases the probability of buy-in and, ultimately, compliance. Communities should feel that they own the process and even that they can use data for their day-to-day decision-making (Breckwoldt and Seidel 2012).

At the same time, local knowledge, monitoring and expertise can usefully inform harvest strategies: Breckwoldt and Seidel (2012) advocate engaging communities in data analysis to improve the understanding of the relationship between resource pressure and stock condition. Moreover, understanding resource stakeholders' perceptions of resource condition and management is vital, as agreement among stakeholders is likely to result in more effective outcomes (Brewer 2013 – Solomon Islands).

This two-way benefit is illustrated well by Syakur et al. (2012), who present the conservation planning results from a locally-managed marine area programme in Indonesia. This aimed to empower coastal communities to sustainably and equitably manage marine resources with local government. The stakeholder participation phase, involving intensive local consultations, generated a strong sense of local ownership. For communities it initiated a process for recognizing their customary claimed areas and resolved overlapping boundaries between neighbouring communities, thereby reducing the likelihood of future conflicts over natural resource use. For government, it provided the basis of a robust governance system.

Trust, via an understanding of fisher perceptions and acknowledgement of stakeholder beliefs, is paramount. Velez et al. (2014) analysed fishers' perceptions as indicators of social acceptance of no-take zones (NTZs) in the Mexican Caribbean, and identified facilitating factors and challenges of the community-based process. Most fishers found the decision-making process inclusive, were willing to take responsibility for enforcing NTZs and believed people leading the process were trustworthy. Differences in endorsement of no-take zones among cooperatives emphasised the importance of understanding fishers' incentives to collaborate, and the leadership and organizational dynamics which shape participatory processes. This analysis underscored the need for community-based processes that transcend understanding of conservation measures but also invests in sustainable, operative and trustful working relationships.

Cavalcanti et al (2010) showed that stakeholder beliefs and the willingness to contribute are highly correlated. Many fishermen reported they would contribute more if they believed others would contribute as well, which is consistent with the interpretation that many fishermen are conditionally cooperative. In principle at least, participatory processes should thus offer an opportunity to favourably influence beliefs. The enhanced communication initiated by participatory research could help develop reputation and trust among the participants, and this may in turn change the beliefs in a direction that is favourable for successful collective action.

Engagement is more readily facilitated where existing institutional/agency support, and/or fisher cooperatives or groups exist. In Pemba, Mozambique, fishers associated with community or conservation groups generally had more positive views of spatial closures and other less-preferred management restriction (McClanahan et al. 2013). Additionally, existing structure such as operational rules in use, clearly defined boundaries, clearly defined membership, rights to organise, graduated sanctions, and conflict resolution mechanisms, all assisted with obtaining stakeholder engagement (McClanahan et al. 2013). Pemsl and Seidel-Lass (2010), using the case of community-based fisheries management in Bangladesh, described the emergence of an informal network that directly links local non-governmental organisations and grass-root organisations to development and administrative government organs. On the other hand, in Indonesia, the legacy of years of centralist New Order regime and high controlling administration have made the community wary of participation and involvement (Siry 2011). This legacy needs to be improved it to prevent similar generic problems of mismanagement, nepotism and corruption and to recover the community's resilience and adaptive learning capacities (Thorburn, 2002 cited Siry 2011).

Beyond the fisheries context, both time and thoughtful inclusion of participants were explored by Johnston et al. (2011) as favourably affecting early stages of stakeholder collaboration, and ultimate outcomes. Informed by field observations from uniquely successful community health programs, they identified i) the use of time instrumentally to build trust and commitment in the collaboration, and ii) the inclusion of new participants thoughtfully, to limit their risk exposure, as associated with favourable group outcomes, as key design processes. Based on experimental economics, strategic behaviours of stakeholders were formalized as a minimum effort coordination game in a multi-agent model. This showed how the two design processes uniquely engendered and reinforce commitment among stakeholders, minimize uncertainty, and increase the likelihood of positive process outcomes.

Emerson et al. (2012)'s Community Governance Regime Propositions (Box 1) summarise the key drivers for stakeholder engagement, and factors that should maximise chances of success. Foremost among these is shared motivation, and repeated quality interactions. Emerson et al. (2012) agree that "principled engagement" occurs over time and may include different stakeholders at different points and take place in face-to-face or virtual formats, cross-organizational networks, or private and public meetings, among other settings. Through principled engagement, people with differing content, relational, and identity goals work across their respective institutional, sectoral, or jurisdictional boundaries to solve problems, resolve conflicts, or create value (Cahn 1994, Cupach and Canary 1997, Lulofs and Cahn 2000). Although face-to-face dialogue is advantageous at the outset, it is not always essential, particularly when conflict may be low and shared values and objectives quickly surface.

Box 1: Emerson et al. (2012)'s Community Governance Regime (CGR) Propositions

Proposition One: One or more of the drivers of leadership, consequential incentives, interdependence, or uncertainty are necessary for a CGR to begin. The more drivers are present and recognized by participants, the more likely a CGR will be initiated.

Proposition Two: Principled engagement is generated and sustained by the interactive processes of discovery, definition, deliberation, and determination. The effectiveness of principled engagement is determined, in part, by the quality of these interactive processes.

Proposition Three: Repeated, quality interactions through principled engagement will help foster trust, mutual understanding, internal legitimacy, and shared commitment, thereby generating and sustaining shared motivation.

Proposition Four: Once generated, shared motivation will enhance and help sustain principled engagement and vice versa in a ''virtuous cycle.''

Proposition Five: Principled engagement and shared motivation will stimulate the development of institutional arrangements, leadership, knowledge, and resources, thereby generating and sustaining capacity for joint action.

Proposition Six: The necessary levels for the four elements of capacity for joint action are determined by the CGR's purpose, shared theory of action, and targeted outcomes.

Proposition Seven: The quality and extent of collaborative dynamics depends on the productive and self-reinforcing interactions among principled engagement, shared motivation, and the capacity for joint action.

Proposition Eight: Collaborative actions are more likely to be implemented if 1) a shared theory of action is identified explicitly among the collaboration partners and 2) the collaborative dynamics function to generate the needed capacity for joint action.

Proposition Nine: The impacts resulting from collaborative action are likely to be closer to the targeted outcomes with fewer unintended negative consequences when they are specified and derived from a shared theory of action during collaborative dynamics.

Proposition Ten: CGRs will be more sustainable over time when they adapt to the nature and level of impacts resulting from their joint actions.

Ansell and Gash (2008) emphasise other key points for optimising the chances of successful stakeholder engagement: active seeking of participation, an inclusive approach, honest brokers and strong leadership, and the need to remedy any antagonistic history.

From Ansell and Gash's (2008) review: "Broad participation is not simply tolerated but must be actively sought. Reilly (2001), for example, found that successful collaboratives pay considerable attention to getting stakeholders to participate and that exclusion of critical stakeholders is a key reason for failure. Broad-based inclusion is not simply a reflection of the open and cooperative spirit of collaborative governance. It is at the heart of a legitimation process based on (1) the opportunity for stakeholders to deliberate with others about policy outcomes and (2) the claim that the policy outcome represents a broad-based consensus. Weak or non-inclusive representation, therefore, threatens to undermine the legitimacy of collaborative outcomes. Proactive strategies of mobilizing less well-represented stakeholders are thus often seen as important. Yet stakeholders may not have an incentive to participate, particularly if they see alternative venues for realizing their agenda. The literature suggests that inclusiveness is therefore closely linked to the exclusiveness of the collaborative forum. When the collaborative forum is ''the only game in town,'' it is easier to motivate stakeholders to participate, conversely, when they are excluded, they may be impelled to seek out alternative venues."

Ansell and Gash's (2008) points are summarised in their Figure 1 (Figure 3 below), and a Contingency Model (Box 2)

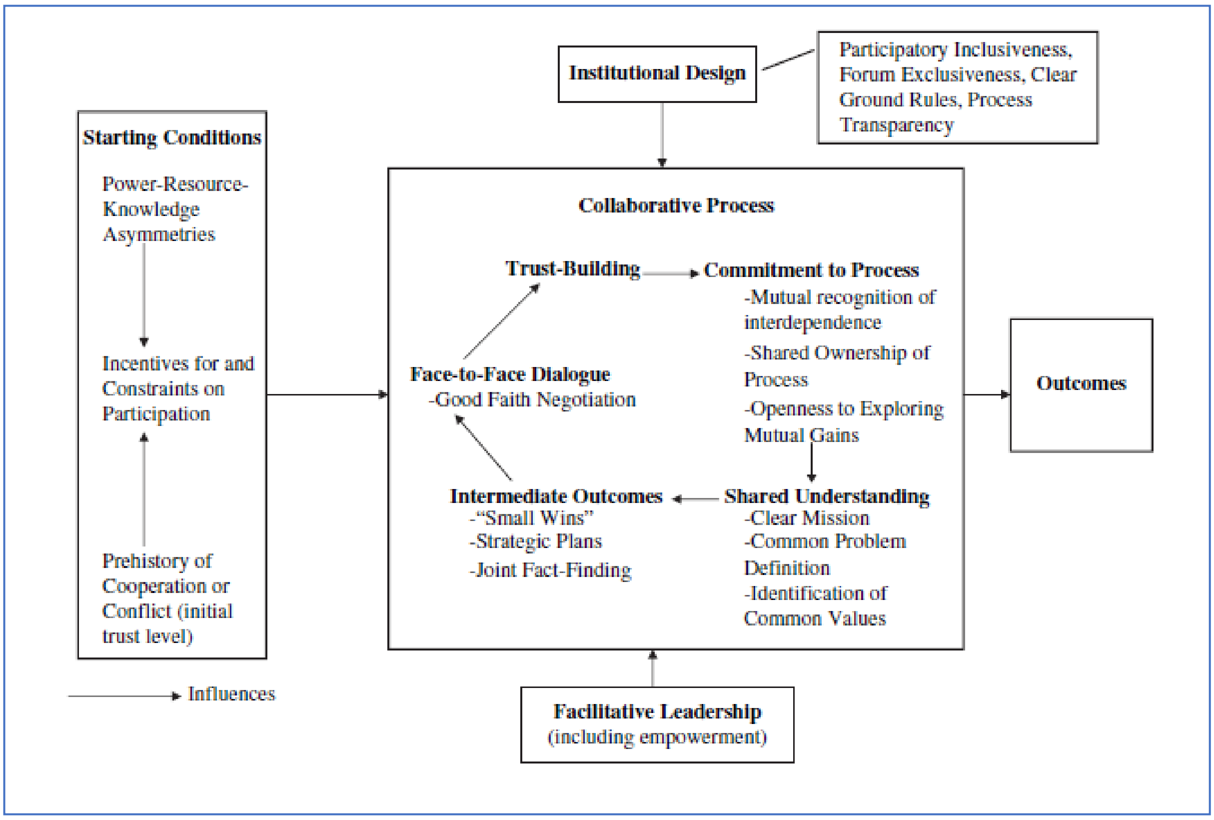


Figure 3: Ansell and Gash (2008)'s Figure 1: A model of collaborative governance

Box 2: Ansell and Gash (2008)'s Contingency Model:

(1) If there are significant power/resource imbalances between stakeholders, such that important stakeholders cannot participate in a meaningful way, then effective collaborative governance requires a commitment to a positive strategy of empowerment and representation of weaker or disadvantaged stakeholders.
(2) If alternative venues exist where stakeholders can pursue their goals unilaterally, then collaborative governance will only work if stakeholders perceive themselves to be highly interdependent.
(3) If interdependence is conditional upon the collaborative forum being an exclusive venue, then sponsors must be willing to do the advance work of getting alternative forums (courts, legislators, and executives) to respect and honour the outcomes of collaborative processes.
(4) If there is a prehistory of antagonism among stakeholders, then collaborative governance is unlikely to succeed unless (a) there is a high degree of interdependence among the stakeholders or (b) positive steps are taken to remediate the low levels of trust and social capital among the stakeholders.
(5) Where conflict is high and trust is low, but power distribution is relatively equal and stakeholders have an incentive to participate, then collaborative governance can successfully proceed by relying on the services of an honest broker that the respective stakeholders accept and trust. This honest broker might be a professional mediator.
(6) Where power distribution is more asymmetric or incentives to participate are weak or asymmetric, then collaborative governance is more likely to succeed if there is a strong ''organic'' leader who commands the respect and trust of the various stakeholders at the outset of the process. ''Organic'' leaders are leaders who emerge from within the community of stakeholders. The availability of such leaders is likely to be highly contingent upon local circumstances.
(7) If the prehistory is highly antagonistic, then policy makers or stakeholders should budget time for effective remedial trust building. If they cannot justify the necessary time and cost, then they should not embark on a collaborative strategy.
(8) Even when collaborative governance is mandated, achieving ''buy in'' is still an essential aspect of the collaborative process.
(9) Collaborative governance strategies are particularly suited for situations that require ongoing cooperation.
(10) If prior antagonism is high and a long-term commitment to trust building is necessary, then intermediate outcomes that produce small wins are particularly crucial. If, under these circumstances, stakeholders or policy makers cannot anticipate these small wins, then they probably should not embark on a collaborative path.

b. Ensuring ongoing stakeholder involvement

Engaging stakeholders at the outset of formal management processes is crucial, yet equally important is maintaining their involvement in an ongoing manner. Similar principles apply as with obtaining initial engagement.

The integrated management approach used in Western Australia incorporates all stakeholders in the decision making process (DoF 2000). A forum in which members from various sectors have an opportunity to discuss problems, present ideas and attempt to resolve issues is provided via a Recreational Fishery Advisory Committee, and Management Advisory Committee, where decision-making power is horizontal: participants contribute to the management of their fishery, their opinions are assessed objectively, and final decisions relating to fisheries policy do not come from a detached and subjective source (vertical or top-down).

Van Trung Ho (2014) grouped inter-relations and mutual influences of institutions and governance into three components (i) formal institutions, (ii) political behaviour and organizational structure, and (iii) local communities' engagement, social capital and socio-economic conditions. These components interact with each other and influence the interplays of actors, both state and non-state. It was suggested that institutions should be adaptive and regularly amended based on their performance in real-world governance processes. There should be accountable and transparent dialogues and mechanisms for all the stakeholders and actors to be actively involved in the development of institutions, and evaluating and monitoring governance processes. Bridging actors or organisations also need to be available as active facilitators of these dialogues and mechanisms.

Differences between locations and the importance of local context must be acknowledged in maintaining stakeholder support. In the Solomon Islands, Brewer (2013) found that fishers perceived that fish declines were caused by fishing for survival-related reasons or fishing for reasons of affluence and aspiration, pointing to perceived inequality. Differences between some fisher and middlemen discourses were explained by the location in which interviews were conducted. This suggested that harvest strategies must embrace the entire fishery, because resource user perceptions differ between locations, and because many threats to the fishery and preferred management strategies are likely to be context specific. However, stakeholder involvement tends to advantage groups that have a lower cost of attendance (Brzenzinski et al. 2010).

Differences in stakeholder opinion must also be acknowledged, which harks to the principle of inclusiveness discussed earlier. Practitioners must beware the tendency for stakeholder representation to be dominated, and hence skewed, not only by participants geographically local to the process, but also by financially resourceful and extreme-opinion stakeholders. The opposites of these traits tend to characterize the disadvantaged, such as the middle-ground opinions, the less wealthy or organized, and the more remote stakeholders (Brzezinski et al 2010).

A key advantage of harvest strategies is their proactive transparency, which enhances credibility between scientists and fishers. This is highlighted in Geremont et al (1999), for the case of developing management procedures (stock assessments linked to harvest control rules) in southern Africa, where it was noted that the management procedure approach rendered the process of providing scientific total allowable catch recommendations more transparent.

Assessing and acknowledging social, economic, and cultural values provided by small-scale food systems is important in ensuring ongoing stakeholder involvement. For example, Kittinger et al (2015) undertook spatial analysis to assess the geographic distribution of community beneficiaries from coral reef fisheries, and found that 20% of seafood is used for socio-cultural events that are important for social cohesion.

More generally, it must be acknowledged that fisheries do not always operate in a rational manner. Stakeholder involvement is key to understanding the nature of fishing operations, and acknowledging this goes a long way to maintaining stakeholder buy-in. Jentoft and Chuenpagdee (2009) argue that fisheries and coastal governance is confronted with problems that are inherently ''wicked.'' Problems are wicked (as opposed to ''tame'') when they are difficult to define and delineate from other and bigger problems and when they are not solved once and for all but tend to reappear. Wicked problems have no technical solution, it is not clear when they are solved, and they have no right or wrong solution that can be determined scientifically. Instead, for wicked problems governance must rely on the collective judgment of stakeholders involved in a process that is experiential, interactive and deliberative. The wicked problem was here identified as a governability issue, recognizing that there are limitations to how rational and effective fisheries and coastal governance can possibly be.

Ongoing stakeholder involvement is important when addressing social science questions, particularly in the context of community-based management. Wiber et al. (2004, 2008) engaged researchers and fishers in adapting social science approaches to the purposes and the constraints of community-based fisher organisations. Their results demonstrated the effectiveness of extending participatory methods to challenge traditional scientific notions of the research process, acknowledging that (1) effective community-based management requires that managers are able to pose and address social science questions, (2) participatory research, involving true cooperation in all stages, can support this process, and (3) there is a need to overcome practical and methodological barriers faced in developing participatory research protocols, to serve the needs of community-based management while not demanding excessive transaction costs. Several research themes proved crucial, including those of power sharing, defining boundaries of a community-based group, access and equity, designing effective management plans, enforcement, and scaling up for effective regional and ecosystem-wide management.

Ongoing stakeholder involvement affects fisher attitudes to formal management. Chaigneau and Daw (2014) undertook multiple regression analysis/factor analysis around fisher attitudes to MPAs in the Philippines, and found that knowledge of MPA objectives, perceived participation in decision making, trust towards other fishers and differences between villages all significantly predicted attitudes towards MPAs.

Ongoing involvement may occur by directly involving fishers in management. However, stakeholder buy-in and involvement is an obvious pre-requisite to conducting participatory fishery research. True participatory fishery research, as utilised in support of community-based management, can a powerful, low-cost tool. However, it has few effective shortcuts, it must deal early in the research process with power imbalances, and it should involve significant political engagement and empowerment through co-learning (Wiber et al. 2008): see Wiber et al. (2008)'s Table 2 below (Table 1). It should also be made clear a priori that there is no guarantee that local expert knowledge will be directly incorporated into management, but rather that all input will be subject to critical scrutiny and evaluation.

Table 1: Wiber et al.'s (2008) Summary of challenges and advantages associated with ongoing stakeholder engagement in fisheries management

Summary of project lessons

	Negative	Positive
Institutional frameworks	• Partners often viewed community-based management as illusory, since they had little real control • Complexity of research setting consumed time and resources • Financial accountability constraints limited community role in top-level decision making within the project • Academic need to publish not a priority for community partners and community capacity building not valued in academic institutions	• "Community" as conceptual framework continually expanding as original partners pulled in others • Complexity of maritime fisheries created great diversity in options for research across the five case studies • Flexibility of the funding source, and its mandate for innovation enabled power sharing in research design • The interface between science and community within this experiment expanded the world view of both
Barriers	• Working in an alternative paradigm within the initiative made communicating with bureaucrats difficult • Capacity building was required both for communities and for academic institutions—recognition of this slower on academic side • Lack of awareness of coastal issues among wider society • A discrepancy in expectations (i.e. communities expected academics to have great policy influence) • Average age of fishermen and problems of burn-out in fisher organizations	• Need to establish common values amongst participants was time consuming but a positive force in collaboration • Communities recognized both their need for and their lack of capacity for social science research • The need to get our message out forced us to explore new ways of communicating • Recognizing serious political and economic limitations in effecting real change and finding innovative ways to address them • Capability to find resources to support fisher organizations and First Nations—i.e. inviting in community and students
Politics	• Politics were both internal and external to the project (e.g. individual goals and narrow interests could be disruptive to group objectives) • Some communities had experiences with research in their communities that had created negative prior impressions of social science • Physical distance created difficulties for all partners in remaining engaged with and truly understanding the context of others	• The long record of applied work in the area by two of the academics enhanced support for the project within communities and recognition among bureaucrats • Expectations underwent transformation on both sides, with personal and organizational growth (as through *Turning the Tide*) • Finding alternative ways to communicate enhanced self-organization (learning communities) within and among partner groups

That stated, there are clear advantages to involving stakeholders in an ongoing manner via their active participation in implementing harvest strategies. Kahler et al (2013) used local-stakeholder knowledge and poaching records to rank and map the risk of poaching incidents in two areas where natural resources are managed by community members in Caprivi, Namibia. Involving stakeholders in the assessment of poaching risks promoted their participation in local conservation efforts. Golden et al. (2014) describe the use of fisher local ecological knowledge to inform management in Fiji. Fiji possesses a unique system of customary marine tenure, in which local clans or villages control individual units of a reef, and make independent management decisions based on traditional beliefs and conservation concerns. Fisheries targets were identified through fisher interviews, which identified heavily targeted species, assessed villagers' understanding of reef dynamics over 30 or 40 years of fisheries expansion, and evaluated village support and expectations for a proposed conservation program. Carvalho et al. (2009) found that a key advantage (beyond reliable data gathering) of a South African fishery community-monitoring program, was providing fishing communities with an opportunity to make input into, and become part of, the management and decision-making processes that affect their fishery. This represents an empowerment of the community with respect to their rights as fishers, citizens and partners. Deepananda et al. (2015), examining indigenous knowledge as a factor in community-based fisheries in Sri Lanka, found that traditional fishers' expectations on composition and quantity of fish arriving at their fishing territory were accurate and reliable at the realisation. As such, there exist opportunities for fisheries co-management for coastal fisheries in Sri Lanka, that incorporate fishers' indigenous knowledge in resource exploitation.

Pollack et al. (2008) examined local fishers' perspectives in complement to a context analysis that found that external management models were not suited to make Cape Horn fisheries sustainable. They instead recommended that efforts should be dedicated to a continuous process of stakeholder collaboration for developing site-specific management concepts and structures. Their key recommendations for a stakeholder process included i) influencing the public discourse, ii) instituting the right leader, iii) differentiating inside the actor groups (It is not enough to distinguish between local and non-local fishers, owners of fishing fleets, middlemen, and processing plants: the adherence to one actor group is not determinant of an actor's position. Local fishermen have divergent opinions, resources, horizons and knowledge, dependent on whether they have been born in the area or whether they belong to the significant group of those who arrived more recently in the area), and iv) balancing public attention with confidentiality.

Schroeter et al. (2009) outline the following keys for success in a cooperative-based data collection program for Californian nearshore fishery: (1) a relatively small group of fishermen harvesting a relatively small area for a long period of time, (2) the formation of the San Diego Watermen's Association, giving strong community cohesion, good communication, and effectiveness in bringing funds for research activities, educational programs, and development of markets, (3) strong leadership among several members of the community and a sense of trust in external consultants, (4) a mutual understanding and cooperation among the management agency, scientists, and fishermen in designing, implementing, and executing the sampling protocols, and (5) the recognition of this program by the community as a first step towards community-based fishery management, where fishermen have a prime responsibility for stewardship and management, including taking part in decision making for every aspect of management, such as access, harvesting, compliance and enforcement, research, and final product marketing.

c. Performance indicators and reference point setting

Performance indicators are (usually quantitative) measures that provide information about trends in the status of a resource (e.g. its abundance, or how heavily it is being exploited). 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, the indicators of risk 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. Ironically, obtaining good indicators for data poor fisheries can be the hardest part of the harvest strategy development process (Dichmont et al. 2011).

If useful indicators have been identified, the next step is to identify reference points associated with these indicators. Reference points are just 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).

Alternative reference points to those directly pertaining to biomass or fishing mortality are generally specified ("trigger") values of some empirical indicator (that is, one in which performance indicators are based on directly-measured properties),or combination of indicators. For example, if both catch-per-unit-effort and mean size indicators are at a certain undesirable levels, this may be considered to equate to a limit reference point. Alternatively, a trigger reference point may indicate changes in the fishery that might not correspond to a target or limit reference point, but that warrant attention and possible management action. Indicators in combination are generally considered to be more informative and defensible. Such indicators are often based on levels of catch, effort, or catch-per-unit-effort (e.g., relative to historical highs), but could also include (for example) changes in the spatial distribution of effort, changes in catch composition, changes in size or weight (mean or percentiles), or, for multispecies fisheries, changes in catch composition, or total catch or catch-per-unit-effort (Dowling et al. 2008).

Empirical indicators and assessment approaches should be associated with target and limit reference points that are consistent with the intent of the fishery objectives. Approaches can be defended by simulation testing using MSE, by retrospective examination (i.e. how often would the empirical limit reference point have been triggered in the past?) (Smith et al. 2004), by pragmatic consideration of the relative impact of the fishing effort (e.g. % of habitat fished, total tonnage of catch), and by having intermediate “check and balance” triggers that detect changes and trigger some response, independent of target and limit reference points

Limit reference points typically pertain to values of empirical indicators (e.g. catch, effort, CPUE, size-based, catch composition ratios, spatial effort patterns used in a quasi-assessment framework or trigger system), that, if exceeded, would be deemed to be placing the fishery at high risk of overfishing. Typically these values are set on a basis of historical precedence (e.g. some multiple of the historical high catch), local ecological knowledge, expert advice, or a combination thereof (Dowling et al. 2008). Multiple indicator frameworks may have reference points corresponding to certain combinations of indicator values, or to certain numbers of “traffic lights” being reached, or to certain values of some diagnostic statistic. Assessments estimating life-history attributes, or sustainable yield, typically set reference points that correspond to these values at the target and limit biomass levels.

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.

Performance measures are values of indicators relative to reference points. Punt (2017) illustrates the basis for identifying management objectives and representing them mathematically using performance measures, as well as how trade-offs among management objectives have been displayed to various audiences who provide input into decision-making. Punt (2017) also provides a comprehensive list of example performance measures. The desirability and consequences of having minimum acceptable standards of performance for management strategies, as well as difficulties assigning plausibility ranks to alternative states of nature, are among the major challenges to effective provision of strategic advice on trade-offs among harvest strategies.

Mapstone et al. (2008) worked with stakeholders to identify: (i) specific objectives, (ii) alternative harvest strategies, and (iii) performance indicators to compare likelihoods of meeting economic, recreational and stock objectives for the fishery and conservation objectives for the effects of line fishing on the Great Barrier Reef. Stakeholders identified objectives and associated performance indicators in four categories, for: (1) conservation of unfished populations, (2) the harvestable stock, (3) economic performance of the fishery, (4) satisfaction of recreational fishers. The research provided a case study of productive engagement with stakeholders to address fisheries and conservation management needs in a multi-sectoral spatial management context. The prospect of meeting quantified objectives provided a common currency for impartial evaluation of performance of alternative management options against diverse and often competing stakeholder agendas.

Pilling et al. (2016) examined candidate target reference points that might achieve wider management objectives for south Pacific albacore tuna, using a deterministic bio-economic model, and stochastic stock projections. Both biological and economic target reference points were considered. Results suggested that economic, rather than biological, requirements would provide the standards for an albacore target reference point. However, achieving maximum economic yield (MEY) implied severe reductions in effort, likely incompatible with objectives for employment within the local fishery sector or the level of vessel licensing revenue. Sub-optimal but improved economic performance could be obtained with less severe reductions in effort.

d. Harvest strategies (monitoring, assessment, harvest control rules)

As stated at the outset, comprehensive reviews of low-cost, data-limited harvest strategies have already been undertaken. As such, in terms of laying out a list of options for data-limited harvest strategies this section defers largely to

- The FishPath decision support tool, per Dowling et al. (2016) (www.fishpath.org), which provides a comprehensive suite of monitoring, assessment, and harvest control rule options, based on the review of data-limited harvest strategies by Dowling et al. (2015a) (but frequently updated since). These options are presented explicitly in the accompanying Guidelines document.
- The Carruthers et al. (2014) data-limited methods toolkit, which enables MSE testing of a range of data-limited assessment and harvest control rule options (collectively, "management procedures").

That stated, below are reviewed a range of additional relevant papers pertaining to the application of low-cost harvest strategy principles and options.

General principles

The majority of fish stocks worldwide are not managed quantitatively as they lack sufficient data, particularly a direct index of abundance, on which to base an assessment (Costello et al. 2012, Geromont and Butterworth 2015a). In considering and articulating harvest strategies, acknowledgement needs to be made of the data-limitations typically associated with small-scale, low-value fisheries. In particular, there are data-limited target and by-product species, and/or fisheries for which biomass-based target or limit reference points will be unable to be determined 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 quality or quantity of data,

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

4. A low gross value of production (GVP).

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

However, much of the literature defaults to biomass-based reference points, and the assumption that harvest control rules pertain to direct catch or effort limits. An example is Froese et al (2011) in describing generic reference points and harvest control rules for EU fisheries: reference points are specified relative to B_{MSY}, the biomass producing the maximum sustainable yield, and harvest control rules are specified in terms of a total allowable catch the is adjusted with respect to the status of the stock relative to the reference points.

Specific caveats and issues that confront data-limited fisheries must be explicitly acknowledged when considering possible harvest strategy approaches. We caution against a “knee-jerk” mentality of attempting to apply assessment methods and management decision rules (such as a total allowable catch) without a broader consideration of whether, for example, data quality is adequate (e.g. reliable, temporally and spatially consistent, of an adequate duration, and showing adequate “contrast” (i.e. periods of highs and lows throughout a time series)), assessment assumptions are met, or the social, economic, or governance contexts are such that a certain form of management measure (decision rule) would be effective.

In some cases, a risk assessment (PSA, ERA or similar) may be the most formal assessment options available. In these instances, a “harm”/”high risk” outcome should invoke a rule to expand no further until a more defensible assessment is undertaken on the species of relevance (e.g. Dowling et al. 2008). Decision rules should incorporate a commitment to improved data collection (. As such, the harvest strategy is inherently adaptive, triggering decision rules that will ultimately lead to its overriding by the introduction of a new form of assessment, and, presumably, more informed target and limit reference point proxies (Dowling et al. 2008).

Fletcher et al. (2016) emphasise that, even for small-scale, low-value fisheries, it is possible to develop harvest strategies that cover ecological, social and economic objectives, by taking a holistic, resource-level approach to coordinate ecosystem-based fishery management of all fishing sectors. Key refinements included the use of indicator species for multi-species resources and establishing appropriate tolerance levels to determine the acceptable range of annual deviations in catch/effort that meet the levels specified by the harvest control rules or sectoral allocation decisions. Their Western Australian case studies demonstrate that a single, comprehensive harvest strategy can collectively address all target species objectives and intra and inter-sectoral allocations at the resource-level, plus any other relevant economic, social or ecological objectives (e.g. habitat and protected species interactions) at the appropriate level (resource or activity/sector). Using four case study harvest strategies, they illustrate that assessments can embrace a suite of approaches to generate performance indicators across multiple objectives. These ranged from the more traditional analyses to estimate stock status or relevant proxies thereof, to, for example, (for threatened species bycatch) the number of entanglements in gear, or the recreational catch comparted to the total allowable. The four case studies demonstrated how the selection of the indicators, reference and tolerance levels for the sustainability objective must be seen as a package and matched to the level of precaution used in the management settings.

Many of the low-cost approaches described below (and particularly those relating to monitoring), hark to direct stakeholder involvement. Freire and Garcia-Allut (2000) advocated integrating fishers in the assessment and management process, collaborating with government agencies. Wendt and Starr (2009) discuss the advantages of collaborative fisheries research in the context of fishery co-management. They helpfully delineate between collaborative fisheries research and cooperative research. The former is based on the intellectual partnership between scientists and fishermen and is an effective way to collect data for stock assessments and to evaluate marine protected areas. In contrast, ‘‘cooperate’’ is defined as a situation where parties ‘‘work together or act toward a common end or purpose.’’ While both terms can describe a situation in which fishermen and scientists are working together, a major difference is that collaborative research involves the incorporation of fishers’ knowledge into the scientific and management process. Collaborative research explicitly suggests a ‘‘joint intellectual effort.’’ Many benefits result from collaborative fisheries research, including the incorporation of fishers’ knowledge and expertise into the management process and the development of shared perspectives derived through science-based investigations on the status of marine resources.

Low-cost monitoring approaches

The obvious approach to achieving low-cost monitoring is by empowering fishers to coordinate and/or undertake community-based monitoring programs. Fishers are uniquely positioned to enforce and monitor (for example) no-take zones, and evaluate their effectiveness (Velez et al. 2014). Kraan et al. (2013) agree that top-down monitoring approaches such as observer programs are relatively expensive, moreover, observer data often equates to clustered samples and effectively small sample sizes. From these perspectives, sampling by fishermen themselves (self-sampling) is an attractive alternative, because a larger number of trips can be sampled at lower cost. However, despite the potential of local knowledge and fisher-based sampling to provide reliable, quick, and low cost data, its use has been limited due to the lack of understanding of the accuracy and biases (Shepperson et al. 2014).

Shepperson et al. (2014) compared fishers' spatial local knowledge data and fishery independent data from vessel monitoring systems to analyse the concurrence between fisher derived and independently derived information. Examining the effect of sample size and scale on the match, they found that local knowledge can provide data of a similar accuracy to conventional scientific data, which is of particular use in data poor situations. However, the proportion of the community sampled should be maximised to minimise inaccuracy between individual fishers. Kraan et al (2013) also caution against the issues of data-acceptance related to self-sampling, and showed that are not easily dealt with in a statistical manner. They suggest that improvements might be made if self-sampling is understood as a form of cooperative research, and, if the guidelines for cooperative research are taken into account, the benefits are more likely to materialise. Also, the acknowledgement of the dilemmas, and consciously dealing with them might increase trust-building, which is an essential element in the acceptance of data derived from self-sampling programmes.

Tesfamichael et al. (2014) note that the data requirements for most quantitative fishery assessment models are extensive, and most of the fisheries in the world lack time series of the required biological and socioeconomic data. They assessed changes in fisheries using fishers' knowledge to generate long time series of catch rates, using data from fishers' interviews to estimate time series of approximate "best" catch rates. It was suggested that analysis of approximate data, quickly acquired at low cost from fishers through interviews, could be used to supplement other data-recording systems or used independently to document the changes that have occurred in the resource base over a lifetime of fishing.

Participatory approaches that incorporate local communities and customary knowledge were also encouraged by Schemmel et al. (2016), in the context of obtaining biological information. They developed a low-cost, low-tech method to assess the seasonal spawning peaks, lunar spawning cycles, and size at maturity for key targeted reef fish, combining traditional knowledge and practice with modern scientific approaches, including gonadosomatic index (GSI) and histology. Comparisons between community-collected GSI data and scientifically (histologically) assessed spawning cycles and size at reproductive maturity produced similar results suggesting that these approaches can be applied in data-poor fisheries to assess spawning seasons and size at maturity.

Carvalho et al. (2009) describe a community-based monitoring system developed for the Olifants River harder fishery as providing reliable information that can be used to inform management decisions. Cavalcanti et al (2010) found some evidence that participatory processes made fishermen think about the role of self-monitoring in resource management. They suggested that a participatory approach in developing management proposals may promote cooperation in situations where resources are difficult to monitor.

Moore et al. (2010) used an interview-based approach to assess marine mammals and sea turtles in artisanal fisheries, in a pilot study to evaluate whether interview surveys can be effective in assessing fishing effort and threatened species bycatch. Fisheries and bycatch data from interviews with >6100 fishermen in seven developing countries were collected in <1 year for approximately USD $47,000, indicating that this approach may rapidly yield coarse-level information over large areas at low cost. This effort provided the first fisheries characterizations for many areas and revealed the widespread nature of high bycatch in artisanal fisheries. The below Box 3 describes their interview process and provides insight as to effective survey design.

Box 3: Description of interview process undertaken by Moore et al. (2010) in seven developing countries.

Surveys consisted of three components: long questionnaire, short questionnaire and a port description form. The long and short questionnaires included mostly closed questions and were completed in-person with fishermen at landing sites, they included questions about fishers' practices, gear use, and bycatch of marine mammals and sea turtles. Relatively short (<30 min) closed-question surveys have generally been recommended for collecting quantifiable or factual information. The short questionnaire was a subset of the long questionnaire and was intended for fishermen with only 5–10 min to spare for an interview, so as to maximize the amount of bycatch information collected. It contained questions on type of gear used, how many marine mammals and sea turtles were caught per month or year, and what the fishermen did with captured animals. The long questionnaire also included more detailed questions about fishing gear usage, target species catch, boat specifications, and seasonality and location of fishing effort. It was designed to be used with fishing community leaders and to be completed in approximately 20–30 min. The port description forms did not involve interviews, field workers used them to record boat-count estimates and a general characterisation of each visited fishing port or village (e.g., gear types used, boat descriptions, general physical description of the landing site).

Breckwoldt and Seidel (2012) also utilised face-to-face interviews, questionnaires and observations (including photographic documentation) from fishers on their return from fishing trips. They also applied the following monitoring approaches to decentralised, community-based marine resource management in Fiji: voluntary fishing logbooks, and accompanying the fishers and logging catch data during fishing trips. They emphasised that problems in data collection often stem from the sample design used, rather than the skill and/or competency of data collectors'. This underlines the importance of keeping monitoring simple, both to minimize opportunities for mistakes and motivation loss, and to maximize community involvement.

Local knowledge and community monitoring programs are just as valuable in the low-cost management of developed nations' fisheries (Schroeter et al. 2009). Responding to the need for management of California's nearshore fisheries mandated in state law by the Marine Life Management and Marine Life Protection acts, the San Diego Watermen's Association (SDWA) initiated a community-based data collection program in 2001. They collaboratively developed an ongoing program to gather, organize, and analyse both fishery-dependent and fishery-independent data on the local red sea urchin fishery, to inform stock assessments.

Ellender et al. (2010) estimated angling effort and participation in a multi-user, inland fishery in South Africa. They tested a low cost method of assessing participation by applying a mark-recapture model to the proportion of anglers whom had been previously interviewed during bimonthly sampling events. The method revealed similar numbers of anglers to the estimate of regular anglers from a household survey and was considered an appropriate estimator for the number of subsistence anglers. Such an approach may have applicability to monitoring within recreational sectors.

Honkalehto et al. (2011) investigated the use of commercial vessel acoustic data to estimate a new annual abundance index, whose performance can be evaluated by a biennial research vessel bottom-trawl survey. The new index will benefit managers by providing more accurate information on near-term abundance trends when dedicated research ship time is not available, and may reduce costs associated with implementing independent surveys.

Low-cost assessment approaches

The task of assessing marine resources should begin with defining management units (Cope and Punt 2009). Often this step is overlooked or defined at temporal scales irrelevant to management needs. Additionally, traditional methods to define stock structure can be data intensive and (or) cost prohibitive and thus not available for emerging or data-limited fisheries. Cope and Punt (2009) used commonly available catch and effort data to delineate management units for dynamically independent populations. Spatially explicit standardized indices of abundance were grouped using a two-step partitioning cluster analysis that includes abundance index uncertainty. This "management unit estimator'' was simulation tested and was generally able to recover the true number of management units across data of different temporal length, sample size, and quality.

The integration of multiple knowledge sources for assessing species abundance and distribution has gained traction over the past decade as a growing number of case studies show concordance between local ecological knowledge (LEK) and scientific data (Beaudreau and Levin 2014). Beaudreau and Levin (2014) developed an historical record of abundance for 22 marine species in Puget Sound, Washington (USA), using LEK, and quantified variation in perceptions of abundance trends among fishers, divers, and researchers, using bootstrapping and statistical modelling. They concluded that, when aggregated at appropriate spatial–temporal scales and in a culturally appropriate manner, observations of resource users are a valuable source of ecological information.

Kittinger (2013) described participatory fishing community assessments to support co-management of data-poor, small-scale coral reef fisheries. A community-led survey effort described current single species catch levels relative to those when fishers commenced fishing, and reported qualitative observations from fishers (their Table 3). These revealed temporal changes in habitat use patterns and declines in key fisheries species and habitats. Participatory resource assessments are not only a low-cost assessment options, but hold promise for building local social adaptive capacity, bringing together disparate stakeholder groups, and building place-based natural resource management plans reflective of local contexts and community priorities.

Low-cost performance indicators were calculated in empirical assessments undertaken by Islam et al. (2010), who aimed to measure productivity in Peninsular Malaysian fisheries. Based on the data for landings and effort, weighted catch per unit of effort (CPUE) was computed for trawl, purse seine and traditional fleets. The weighted CPUE differentiates the quality or composition of catch through weighting of the species mix in the catch by the share of total revenue of each species. The various inputs that constitute fishing effort were also weighted by their respective cost shares.

An alternative low-cost assessment approach is to use catch data (provided that this is statistically appropriate for the approach) to undertake retrospective stock assessments (Freire and Garcia-Allut 2000). These have been used for species such as squid, in order to estimate total catch, or spider crab, to estimate the biomass harvested and fishing mortality (using methods based on stock depletion, due to the high exploitation rate).

Leopold et al. (2013) used a habitat map derived from high-resolution satellite imagery to stratify survey sampling and assess the harvestable stock biomass of assess small-scale, data-limited sea cucumber fisheries in Pacific Island countries. The biomass estimates were used to set adaptive local total allowable catches and regulations of fishing effort. Results showed the excellent performance of this fishery between 2008 and 2012, both biologically (167% increase in total stock biomass) and economically.

Encouragingly, Geromont and Butterworth (2015b), using retrospective analysis of management performance over the last 20 years for four North Atlantic fish stocks, showed that simple catch control rules (constant catch, slope-to-target) based upon age-aggregated survey indices achieved virtually equivalent catch and risk performance, with much less inter-annual variability in total allowable catch, compared with complex assessment methods using age data.

Low-cost decision (harvest control) rules

Decision, or harvest control rules fall within three main categories. Input controls limit access to fish stocks through measures like boat or operator licenses, restrictions on vessel capacity, closed seasons, or closed fishing zones. Technical measures restrict the efficiency or selectivity of fishing gears through devices such as minimum mesh size for nets and prohibition of certain types of gear. A third set of top-down instruments, prevalent in industrialised countries, set out to regulate the catch directly (output controls), through such devices as total allowable catches (TACs) and limits on permissible by-catch proportions in single species fisheries. These latter instruments are rarely, if ever, found in low-income developing countries due to the high cost and administrative unfeasibility of implementing them effectively, but they do impinge upon the activities of small-scale fishers exploiting high-value inshore fisheries in some developed countries (Allison and Ellis, 2001).

For small-scale, low value fisheries, there is often great appeal in the use of one or more inexpensive, passive input controls, such as spatial or temporal closures, size limits, or gear restrictions. These do not limit participation in the fishery, and are often appealing within community or co-management contexts due to their relative ease of implementation and self-enforcement.

There is heavy emphasis in the small-scale, low-cost fishery management literature on the use of spatial/temporal closures, size limits, and marine protected areas as a means to maintain fishery sustainability. Freire and Garcia-Allut (2000) stated that marine protected areas and minimum landing sizes are preferred harvest control mechanisms for Galician fisheries, as the control of the compliance of the fishers with no-take zones is considerably easier than with other regulations of fishing effort. Both regulations are easily implemented, and understood and accepted by fishers. Ferse et al (2010) discuss increasing the role of local communities in marine protected area implementation, stating that participatory processes need to be improved towards effective rights, meaningful regulations and reliable procedures and protocols for local resource users, per (1) The establishment of MPAs both territorially and institutionally. (2) The development of monitoring criteria and the evaluation of monitoring outcomes. (3) The adaptive management of MPAs especially when faced with uncertainty, surprise, sudden shocks and unforeseen conflicts. (4) The inclusion of emergent rules and their associated rationales, especially in areas where there is little or no tradition in marine management. (5) A distribution of costs and benefits of MPAs which is locally perceived as just and equitable. Plaganyi et al. (2015) modelled the rotational zone strategy applied to the multispecies sea cucumber fishery in Australia’s Great Barrier Reef Marine Park and showed a substantial reduction in the risk of localised depletion, higher long-term yields, and improved economic performance.

However, ultimately the only means to directly confront overcapacity and overfishing are via hard input or output controls that directly limit the catch and cap the level of effort. Such measures are often met with strong resistance from stakeholders, and are difficult to implement because of relative poverty, cultural importance of, or a sense of entitlement to the resource, historical precedence (e.g. of open access), a lack of enforcement capability, and/or lack of strength of, and/or respect for, governance or institutional capacity. Cohen and Foale (2013) underline that the root causes of overfishing will continue to challenge community-based and co- management approaches, and fisheries management tools such as periodic closures. Indeed, permanent reductions of fishing grounds may be something that some fishing communities are unable or unwilling to bear. In interviews to identify management preferences and institutional organisational rules in Pemba, Mozambique, McClanahan et al. (2013) found that stakeholder preferences strongly favoured gear and minimum size restrictions over effort reductions. Yet Islam et al. (2010) advocated restricting fishing effort through vessel limitation programs as a possible way of raising the productivities of Peninsular Malaysian fisheries (while also suggesting enhancement of the resource through, for example, the construction of artificial reefs).

Throughout the Indo-Pacific, Cohen and Foale (2013) found that permanent no-take marine reserves tended to fit poorly with social, economic and consumptive needs of communities and tend to receive lower levels of compliance and acceptance than closures that will at some point be harvested. Conversely, periodic closures appeared to be met with relative enthusiasm, provide regular access to resources and have potential, under the right conditions, to contribute to fisheries management objectives. Areas are periodically-harvested but predominantly closed, reflecting attempts to reduce fishing effort and enhance ecological sustainability. When areas are opened, harvests are relatively short and largely triggered by the social and economic needs of particular individuals or whole communities (Cohen and Steenbergen 2015).

Yet, underlining the point that closed areas do not directly confront over-exploitation, fisheries management benefits were only observed for short-lived, fast-growing taxa or for a range of taxa in low fishing pressure situations. Stocks declines were observed for long-lived taxa or for a range of taxa if harvesting was intense (Cohen and Foale, 2013). Dumas et al (2010), investigating the effectiveness of village-based marine reserves in Vanuatu, found that, under certain conditions, very small-scale reserves, such as those implemented by village-based conservation initiatives, could rapidly and efficiently enhance local reef invertebrate resource. Yet it was unclear whether the changes would be sufficient to restore critical levels of spawning biomass at larger scale and reverse the severe depletion of invertebrate resources occurring in Vanuatu.

That stated, a clear benefit of more indirect input controls such as periodic closures or small-scale village-based reserves, is they get stakeholders on the ladder of formal management. In the case of the periodic closures described in Cohen and Steenbergen (2015), engagement with environmental management interventions led to more formalised access and use arrangements. The “zero to hero” mentality of moving from no formal harvest control rules to a fully-blown output system of catch limits and quotas is unrealistic, and likely to prove unsuccessful due to lack of resourcing and stakeholder resistance. It is ultimately better to do something than nothing, and in doing so, to gradually groom stakeholders for formal management and its benefits.

Moreover, the issue of input versus output controls is not as clear-cut as the former being more appealing, while the latter being the only direct mean to cap fishing mortality. There is also the issues of the effectiveness of top-down (typically, output) controls, versus bottom-up controls. Allison and Ellis (2001) warn that attempts to match catching capacity with resource productivity through a combination of state-imposed input, output and technical control measures have a high failure rate (which can partly be attributed to the high degree of short-term, unpredictable variability in fish stocks). Top-down management instruments tend to be insufficiently responsive to trends and shocks, as they lack adaptability and resilience. Together with Wilson et al (2010), they argue that, instead of controlling ‘how many’ fish are caught (via total allowable catches), the best alternative was to develop fishing restraints that affect ‘how, when and where, fish are caught’, to ensure that core ecosystem functions that support fisheries productivity are preserved. In (Galician) artisanal fisheries where a centralized management scheme was unable to develop useful compliance systems, Freire and Garcia-Allut (2000) favoured the implementation of territorial users' rights for fishers, and a system of co-management that establishes regulations around marine protected areas and size limits within each territory.

More generally, multiple decision rules could (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). Cohen and Foale (2013) state that combining periodic harvesting with other strategies or other resource use controls can reduce the effect of concentrating effort into pulse-fishing events or re-distributing effort to other fishing grounds. Fishing or management activities (such as size limits or effort restrictions) outside of reserves can significantly influence the fisheries benefits of the reserve itself. Others include limited access, size limits, species bans, catch limits and gear restrictions.

Care needs to be taken around the applicability of harvest control rules, and it is here that decision support tools (such as FishPath) can provide useful guidance, by explicitly identifying caveats around the suitability of alternative management measures. Pollack et al. (2008) examined the development and trajectory of King and Snow Crab fisheries in the Cape Horn Biosphere Reserve (BR), assessing the feasibility of Marine Management Areas (MMA) as a tool for mitigating impacts of overfishing in the area. Examining the local fishers' perspectives in complement to a context analysis, it was found that external management models such as the MMA were not suited to make Cape Horn fisheries sustainable (biophysical – mobile species, finding suitable location, costs, institutional aspects, user-group aspects). Also, Allison and Ellis (2001) found that, if predicated on an incomplete understanding of livelihoods, both state-led management and certain community or territorial use-rights approaches, could result in management directives incompatible with both resource conservation and the social and economic goals of management.

More generic harvest strategy testing is one way to reduce costs: Bentley and Stokes (2009) suggest that that data-poor management procedures (MPs) might require more "strategic" (generic, applicable to multiple species) testing to justify their expense than more system-specific testing for data-rich (high cost) species. Geromont and Butterworth (2015a) considered generic, and hence low-cost, MPs for low-value, data-poor fisheries, by simulation testing simple "off-the-shelf" assessments and catch control rules that could be applied to groups of data-poor stocks which share similar key characteristics in terms of status and demographic parameters. While data-moderate MPs (based on an index of abundance) predictably performed better than the data-limited ones, the latter nevertheless performed well across wide ranges of uncertainty. Total allowable catch-based harvest control rules tested ranged from constant catch, to slope-to-target rules. The data-limited methods toolkit of Carruthers et al. (2014) provides a useful platform for generic MSE testing of a large range of alternative MPs.

e. Harvest Strategy Implementation

The success of implementation will largely depend on the extent of stakeholder buy-in, and the appropriateness of the harvest strategy to the fishery context. Dowling et al. (2015b) state that the two most common reasons for failure at the implementation stage are the inability of the institutional framework to apply a harvest strategy, and/or lack of support from fishers. The risk of implementation failure can be reduced by adopting a participatory approach throughout. The ability to implement and enforce the harvest strategy should be explicitly considered during harvest strategy development (Dowling et al. 2016). 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 include self-management, co-management or community management processes, discussed below.

In the developing nation context of river fisheries management in Bangladesh, Rab (2009) underlines that the implementation process may be painful and requires time. It is not an easy task to change peoples' age-old behaviour. It requires continuous motivation, skill development and awareness building. Where fisheries are culturally ingrained, Rab (2009) suggests that even folk songs and folk theatre may be important tools to motivate and raise mass level awareness among the resource users, along with training and workshops. Although the institutionalisation process may involve costs and effort, its benefits are enormous.

f. Adaptive responses

Within the available levels of resources for small-scale, low-value, and pending the implementation of effective monitoring, a pragmatic commitment should be made to work realistically with the available information, taking a more precautionary approach where necessary. Particularly for data-limited, small scale or low value fisheries, is it important to embrace adaptive management (Dowling et al. 2015a). This includes identifying how improvements may be made in data collection so that more rigourous assessments may be able to be undertaken, as and when the nature of the fishery changes such that risk is perceived to be increasing and stock status needs to be determined with greater certainty.

Harvest strategies should be reviewed periodically, as has been done for the Australian Commonwealth Fisheries (Dowling et al. 2015b), and open to being updated given new understanding: a simple initial framework may be expanded and improved with more information and experience. For example, decision rules within Tier 3 harvest strategies of the Australian Southern and Eastern Scalefish and Shark Fishery have been modified post-review (Wayte and Klaer,2010). Additionally, many harvest strategies define what constitutes exceptional circumstances that would result in the strategy being overridden (Dowling et al., 2008).

Not only do harvest strategies have to be adaptive in their capacity to be updated as information improves, but they need to be flexible enough to embrace the adaptive behaviour of fishers to changing circumstances. Small-scale fisheries’ management is complex given its often multi-gear, multispecies nature, despite this, fishing effort has usually been controlled by nominal units, ignoring changes in effective fishing effort. Saldana et al. (2017) aimed to understand the adaptive strategies of small-scale fishers in San Felipe, Yucatan, Mexico through an analysis of their fishing operations. Minor changes in trip numbers among three seasons were observed, but increases in fishing time, depth and travel costs from one season to another at the operational level were found. It was also evident that high-value species at the beginning of the season were gradually replaced by low-value finfish as the season progresses. That is, fishers adapt their operations over time according to different conditions, which include, in this case, resource availability, species price and management regulations (for access). To develop viable management policies, it is crucial to understand the driving factors and conditions that lead to fishers’ decisions and adaptive strategies when facing constraints or different incentives (Saldana et al. 2017).

g. Enforcement and compliance

As with harvest strategy implementation, compliance is more assured, and enforcement costs are lower when stakeholders have been engaged from the outset, have participated in the development of the harvest strategy, and feel some sense of ownership towards the resource, and when the harvest strategy is appropriate to the fishery’s operational and socio-economic contexts. Transparent negotiations with stakeholders about the scales of costs and benefits should increase compliance with regulations (McClanahan and Abunge 2015).

On Ngazidja Island, Comoros, village fishing associations play an active role in fisheries management by collectively designing, monitoring, and enforcing local regulations (Hauzer et al. 2013). Compliance with local regulations is high, primarily due to participatory decision-making, community-monitoring, and strong feelings of solidarity among fishers. Perceptions of the benefits of these regulations are also high. Examination of trends in community-based fishery management systems in Vanuatu showed that community and national fishing rules that were highly acceptable by local societies were more likely to be enforced in the long run Leopold et al. (2013). In particular, the establishment of marine reserves was the most widespread and best enforced community rule for the purposes of conservation, ecotourism, and/or fisheries.

Kittinger (2013) provide a summary of the perception of fisheries enforcement and existing regulations within Maunalua Bay, Hawai'i (their Table 6, below as Table 2).

Table 2: Kittinger's (2013) Table 6, showing perceptions of fisheries enforcement and existing regulations in Maunalua Bary, Hawai'i.

Perceptions of Fisheries Enforcement and Existing Regulations in Maunalua Bay (MB) ($n = 58$)

Questions Answered by Fishers	Agree/ Strongly Agree	Disagree/ Strongly Disagree	Neutral	Don't Know
A. I know/understand the rules and regulations of fishing in MB	91%	7%	2%	0%
B. The current rules and regulations are easy to understand	56%	32%	9%	3%
C. The current rules and regulations are sufficiently enforced in MB	12%	77%	4%	7%
D. I hardly ever see enforcement personnel in MB	81%	14%	5%	0%
E. I know guys who have been cited for illegal fishing recently	11%	68%	3%	18%
F. I've heard of guys who've been cited for illegal fishing recently	39%	47%	3%	11%
G. If the current rules/regulations were enforced, they would be sufficient to protect marine resources in MB	42%	47%	9%	2%
H. If management of the bay were to continue as it is now, my grandchildren will enjoy an abundant and diverse environment	16%	77%	3%	4%

Abernathy et al. (2014) found that electing and adapting harvest control rules appropriate to the situation, respecting ownership of resources, and involving the whole community in rule enforcement improved compliance and the acceptance of rules in the community in a Solomon Islands study. In a manipulated experiment, Calvacanti et al. (2010) agreed that, under the participation treatment, fishermen tended to be more willing to denounce fishing misbehaviour. This finding was in agreement with results of laboratory experiments showing that altruistic punishment of uncooperative acts is a key element in promoting cooperation.

The level of respect for authority, and perceptions around the benefits, limitations and legitimacy imposed by different types of harvest control rules also affect the willingness to comply (e.g. McClanahan and Abunge 2016). For example, Cohen and Foale (2013) found that achieving compliance with a closure or limits placed on harvesting was an ongoing challenge, even where traditional governance is intact and social capital is high, and that the Indo-Pacific region potentially faces declining respect for traditional or local authority.

While stakeholder participation in, and endorsement of formal management increase the chances of compliance, communities still require support from a strong government. For inshore resources in the Western Indian Ocean, locally managed areas (independently by local communities, or through collaborative management arrangements with governments or non-state actors) were hampered by underdeveloped local and national legal structures and enforcement mechanisms (Rocliffe et al. 2014). Establishing a network of locally managed area practitioners in the Western Indian Ocean region was recommended, in order to share experiences and best practice. McClanahan et al (2005) found that shared perceptions alone were insufficient to achieve high compliance for Kenyan coral reef fisheries, and that active enabling and enforcement by managers is required: despite good agreement among most groups and traditional leaders about the gears discouraged by government, compliance was poor since nearly two-thirds of fishers used these recently prohibited gears. The gears persist because of the lack of shared evidence about the yields and sustainability of the various gears, and social and economic aspects, such as increased competitiveness and decreased costs of the gears.

McClanahan and Abunge (2016) interviewed and evaluated the perceptions of fishing restrictions among stakeholders in 102 fishing villages in Kenya, Madagascar, Mozambique and Tanzania. They hypothesized that perceived benefits would decline, and social inequity increase along a gradient of increasing access restriction, ranging from size limits to fisheries closures. Managers did not recognize the hypothesised access restriction gradient, seeing most restrictions as beneficial. Results suggested that countries with stronger central governments contained villages with more between-community variability and perceived social disparity than weaker governments.

Burton (2003) modelled the use of community sanctions to restrict effort. The withdrawal of cooperation in other areas of life was used to both restrict effort and to sanction those who continue to cooperate with those who have not restricted effort. Relatively low-cost fishers are more likely to support entry restrictions and ignore community attempts to restrict individual effort while high-cost fishers are more likely to support quotas.

External incentives to achieve compliance may be met with mixed success: McGrath et al 2015, considering community fisheries in the Brazilian Amazon, argued that market-oriented solutions, such as third-party certification, were insufficient to ensure compliance. Government support for, and collaboration with, producers and industry are essential to creating conditions that enable fishing communities to sustainably manage their fisheries.

h. Community-based management/self-regulation

Burton (2003) provides the following definition of community-based management: “Community-based management may consist of endogenously developed systems of customs and taboos which control behaviour within the fishery. Alternatively, it may adopt the form of a standard producer cooperative which, in turn, develops formal rules of behaviour. Management may consist of methods of avoiding ‘‘technological’’ externalities such as physical interference between individual fishers or gear types. It may consist of means of avoiding allocation conflict such as competition for choice fishing spots. Or, it may consist of restrictions on effort through area closures, gear restrictions, or restrictions on harvesting juveniles/spawners”. Colin-Castillo and Woodward (2015) state that self-governance can be a suitable instrument for the community-based management of a common pool resource, to deal with problems of overexploitation and low profits that arise due to open access. Fishery cooperatives as solutions for sustainable fisheries management form in a variety of development and governance contexts, and in diverse kinds of fisheries, and take actions directed toward coordinating harvest activities, adopting and enforcing restrictions on fishing methods and effort, and taking direct conservation actions such as establishment of private marine protected areas (Ovando et al. 2013).

Recognition of the problems of fisheries development in small-scale fisheries and limitations of centralised, state-led fisheries management has led to widespread policy support for the principle of decentralised management in fisheries (Allison and Ellis 2001). For small-scale, low-value fisheries, the consideration of community-based management prevails strongly in the literature, for obvious reasons of minimising top-down costs, and empowering a sense of ownership that encourages responsible stewardship and compliance. A community-based approach to fisheries management would appear to satisfy several different desirable goals: it places decision-making at a level that should ensure that local knowledge of the resource is brought into play, it ensures participation by fishing families themselves in decision-making processes and it lifts from overstretched governments the burden and cost of administrative functions that they are unable to discharge effectively (Allison and Ellis 2001).

Community-based management has also been successful when conventional top-down, exogenous approaches to fisheries management have been ineffective in traditional and small-scale fisheries (Hauzer et al. 2013). Within Australia, community-based harvest strategies and adaptive co-management are in progress for the Torres Strait beche-de-mer fishery (Plaganyi et al., 2013b). Basuto and Coleman (2010) compared two Mexican benthic fisheries, for one of which community members successfully engaged in collective action to limit harvesting efforts. This fishery maintained a sustainable harvest for more than two decades, whilst the other fishery was overexploited. In studying social capital, community-based management, and fishers' livelihood in Bangladesh, Islam et al. (2011) found that fishers in community-based fisheries management project areas have improved their access to different assets including social, human, physical, financial and natural capitals.

A return to local-scale management has occurred in Hawai'i (Friedlander et al. 2013). This renaissance of traditional community-based management and rediscovery of traditional technique represents a form of contemporary adaptation of traditional management practices to modern governance contexts (their Table 1, below as Table 3). Scientific surveys showed that locations under community-based management with customary stewardship harboured fish biomass that is equal to or greater than that in no-take marine protected areas.

The Mexican lobster was the first community-based fishery to be certified by the Marine Stewardship Council (MSC) in recognition of sustainable fishing practices. MSC certification has had a positive impact on fishermen's cooperatives and gained international recognition for the Mexican fishery policy, with the possibility of increased renewal of fishermen's access rights. The benefits of MSC certification could not be repeated in other fisheries in Mexico, where fishermen do not share strong management and community identity (Pérez-Ramírez et al. 2012).

Table 3: Friedlander et al.'s (2013) Table 1, comparing customary and conventional resource management in Hawai'i and its application in integrated management approaches.

Customary Management	Description	Conventional Management	Integrated Approaches
Spatial	Areas closed to fishing (kapu zones) can be temporary or permanent (e.g., during Makahiki; rotating aku/ʻōpelu kapu)	Marine Protected Areas, temporary fisheries closures	Community-managed marine areas, with established kapu zones to replenish resources if needed
Temporal	Restricting fishing/harvesting activities during specific times. Often short duration, specific to certain species, and for specific events (e.g., religious ceremonies, protect spawning aggregations)	Closed seasons	Community-based moon calendars showing which species are spawning and should be kapu
Gear	Restrictions on certain harvesting methods or techniques; chiefly control of materials for fishing gears and boats, which limited access to some fisheries resources	Gear prohibitions	Restrictions on certain gears (e.g., for lay nets, or no spearfishing with scuba)
Effort	Limits on access to certain areas (e.g., only residents of an ahupuaʻa could access adjacent reef); limiting who can harvest certain species, use certain gears, or fish certain areas	Permitting; territorial user rights systems for fisheries (TURFS); limited entry fisheries	Community-based subsistence fishing areas with rules developed in an inclusive, place-based manner; permitted access for local families or residents in a district (moku)
Species	Prohibitions on consumption of certain species, often related to class, gender, or lineage	Protection of vulnerable or endangered species	Bans on certain species until populations regenerate; limits on harvest for culturally significant species or resources that contribute significantly to local food security
Catch	Restricting the quantity of harvest; social norms discourage wasting and other harmful practices	Total allowable catch; individually transferable quotas (ITQs)	Communal harvest events to sustain connections to local resources; educational and outreach programs to connect community members and build social capital
Aquaculture	Creation of fishponds, stocked with wild-caught juveniles, which sequestered nutrients from uplands and served as insurance against famines	Modern aquaculture	Rebuild and revitalize fishponds to provide fisheries resources to communities; explore creation of Community Supported Fisheries (CSF) models to connect communities to local fishponds
Enforcement	Violations of customary restrictions resulted in sanctions or punishments that could be severe	Fines, penalties, license revocation	Develop and implement a penalty schedule of graduated sanctions that includes community service by violators in restoration activities

Source: Adapted from Cinner and Aswani (2007), McClenachan and Kittinger (2012), and Jokiel et al. (2011).

What factors contribute to effective community-based management?

In 1990, Elinor Ostrom proposed eight design principles, positing them to characterize robust institutions for managing common-pool resources such as forests or fisheries (Cox et al. 2010). Cox et al. (2010) reviewed these design principles, to provide a reformulation, drawing from commonalities found across 91 review studies (Box 4).

Box 4: Ostrom's eight design principles for effective community-based management

Principle Description

1A User boundaries: Clear boundaries between legitimate users and nonusers must be clearly defined.

1B Resource boundaries: Clear boundaries are present that define a resource system and separate it from the larger biophysical environment.

2A Congruence with local conditions: Appropriation and provision rules are congruent with local social and environmental conditions.

2B Appropriation and provision: The benefits obtained by users from a common-pool resource (CPR), as determined by appropriation rules, are proportional to the amount of inputs required in the form of labour, material, or money, as determined by provision rules.

3 Collective-choice arrangements: Most individuals affected by the operational rules can participate in modifying the operational rules.

4A Monitoring users: Monitors who are accountable to the users monitor the appropriation and provision levels of the users.

4B Monitoring the resource: Monitors who are accountable to the users monitor the condition of the resource.

5 Graduated sanctions: Appropriators who violate operational rules are likely to be assessed graduated sanctions (depending on the seriousness and the context of the offense) by other appropriators, by officials accountable to the appropriators, or by both.

6 Conflict-resolution mechanisms: Appropriators and their officials have rapid access to low-cost local arenas to resolve conflicts among appropriators or between appropriators and officials.

7 Minimal recognition of rights to organize: The rights of appropriators to devise their own institutions are not challenged by external governmental authorities.

8 Nested enterprises: Appropriation, provision, monitoring, enforcement, conflict resolution, and governance activities are organized in multiple layers of nested enterprises.

Pinho et al. (2012) proposed an expansion to Ostrom's principles, arguing that cultural and political factors, which are given less emphasis in Ostrom's model, may help explain how Amazon communities overcome barriers to collective action. This community-based common-pool resource system emerged despite several features that were, in Ostrom's view, barriers to local institutional development: fish populations are migratory rather than stationary, spatial boundaries are ambiguous rather than fixed, and state support of local management is weak or non-existent rather than strong.

Abernathy et al. (2014) emphasised that, from five case study sites in the Solomon Islands, there was no blueprint to the community-based resource management (CBRM) institutionalisation processes. Rather, this depended on the community context. The processes are not linear journeys and there are periods of rapid change and stability or stagnation. Sustained institutionalisation and active support of CBRM depended on the types of events that happened at the beginning of the process. Taking a social-ecological inventory, rather than purely an ecological inventory, appeared to be effective for matching CBRM to the community need.

The need for context-specific approaches to community involvement is typified in the study of Nasuchon and Charles (2010), who explored initiatives to decentralize management to local governing bodies, to utilize traditional management methods and to engage in community agreements to protect local resources in Malaysia, Vietnam, Cambodia and Thailand. In Vietnam and Cambodia, there was a need for significant legislation to control fisheries operations and greater clarity of the role of communities in management, in Malaysia, there was an overall need for more support to local fisheries management, and in Thailand, the need was for greater support of local-level enforcement and monitoring activities. More generally, it was concluded that community-based fisheries management needs to be flexible so that it can adapt to the needs of the individual community in each habitat or locale. So too must the informational and institutional support systems: the success of community-based fisheries management depends heavily on the level of cooperation between government and the relevant communities (as well as between government departments). The government is not always aware of the real problems in the community, and the community often lacks technical knowledge.

Cavalcanti et al. (2010) undertook a field experience to test whether participation in developing specific measures for community-based sustainable common-pool resource (CPR) management increased the willingness to contribute to the implementation of these measures. Each community was also exposed to information about their community leaders' advice about the proposed measures. While participation and leader advice affected the willingness of participants to contribute in one of three proposed measures, the strongest influence was the individual beliefs about the cooperation of others in CPR management.

Hauzer et al. (2013) examined the effectiveness of community-based governance (through local fishing associations) of small-scale CPR fisheries, to provide some understanding of the underlying characteristics of effectiveness. Successful pre- established informal management systems were in place on Ngazidja Island, Comoros, enabling collective governance of common pool resources to be readily achieved within communities. The sense of empowerment and shared responsibility among resource users led to effective management practices. Customary regulations included gear, spatial and species restrictions, and social taboos approximating temporal restrictions and catch restrictions.

Conditions for effective and sustainable institutions detailed by Hauzer et al. (2013) included

- management effectiveness
- use of traditional methods
- incorporating local input
- capacity-building
- institutional viability
- simple key rules
- dual enforcement
- adaptability
- ownership
- nested institutions
- change imposed being moderate.

Key characteristics of the local institutions outlined by Hauzer et al. (2013) were

- high compliance rates
- direct involvement of fishers
- fishers’ contributions fund local projects
- association leaders are respected, and electoral procedures abide by local customs
- resource conflicts are infrequent and resolved by culturally appropriate mechanisms
- cross-scale linkages exist between governance institutions
- National Fishing Syndicate acts on behalf of fisher needs and interests
- use of traditional knowledge and methods
- government and enforcement authorities respect fishers’ right to organise and create local regulations
- Comorian society remains isolated from outside influences.

McCay et al. (2014) studied ten fishery cooperatives of the Pacific coast of Mexico to examine reasons for successful community-based management of the fishery commons. Key factors included smallness of scale, the productivity, visibility and legibility of the resources and fisheries involved, clarity of social and territorial boundaries, adjacency and linkages among territorial units, and a strong sense of community. The cooperatives also made considerable investments in attaining high levels of knowledge, leadership, transparent and democratic decision-making, and “vigilance,” or enforcement of the rules and the running of the organization.

In establishing community-based fisheries management of degraded river fisheries in Bangladesh, the management and institution building process was found to be complex, and required participation of all concerned stakeholders including local government institutions and administration (Rab 2009). The introduction of community-based fisheries management aimed to provide access rights to the fishers through organizing poor fishers and the community to introduce sustainable fisheries management A broad-based institutional framework was developed that include community and local government along with the direct beneficiaries and resource users. A positive feature of such institutions is its ability to facilitate flow of information among agents, which is a key to maintain solidarity within and across groups.

Leaders are increasingly regarded as essential for viable community-based fisheries management (Sutton and Rudd 2014). Sutton and Rudd (2014) found that ecological and social context influence leaders' ability to help deliver successful community-based fisheries management, and that personal and professional attributes of leaders may be beneficial or inhibitory depending on that context. Examining fifty case studies from Southeast Asia were using Qualitative Comparative Analysis, Sutton and Rudd (2015) found local leadership to be an important determinant of ecological and social success for many case studies. However, the absence of a local leadership did not necessarily indicate that community-based fisheries management would fail: strong local leadership could even play an important role in achieving negative outcomes in some circumstances. Effective local leadership can be supported via high level institutions and communities, through access to resources, and simply through community-oriented motivations or intentions among leaders.

<u>Cautions</u>

Care must be taken when establishing community-based management programs that ecological/sustainability considerations are not ignored. The performance of 16 community-based coastal resource management (CBCRM) programs in the Philippines was evaluated by Maliao et al. (2009) using a meta-analysis of eight indicators (participation in, influence over, control over coastal resources, fair allocation of access rights, household income, conflict management, resource abundance, community compliance with fishery control rule) that represented the perceptions of local resource users. While the CBCRM programs were perceived to be effective in empowering the local fishing communities, their impact on improving the state of the local fisheries resources remained limited. This highlights the importance of incorporating ecological and socio-economic considerations in setting fisheries management regimes. However, creating a culture of local concern for the marine environment and for the health of the fish stocks will always be a challenge (Nasuchon and Charles, 2010). Approaches outside the fishery per se can be useful in this regard, for example, communities may be able to raise coastal awareness by involving and positively influencing school children in marine activities as possible.

Community-based management should ideally align with broader (e.g. national) level goals. In Fiji, several community-based, marine management actions differed in their contribution to national-level conservation goals (Mills et al. 2011). In a gap analysis, Mills et al. (2011) translated conservation goals, developed by the national government, into ecosystem-specific quantitative objectives, and evaluated the relative effectiveness of Fiji's community-based management actions (in order of effectiveness, permanent closures, conditional closures, conditional closures harvested without predetermined frequency or duration, and other management actions, such as regulations on gear and species harvested in achieving these objectives).

Based on a study of a community-based fishery on the Rovuma River (that forms the border between Mozambique and Tanzania), Nkhata et al. (2009) postulated a relationship between social capital and community-based governance over access to and the use of the fish resource. In historical times, social capital was high and community-based governance regulated access to and use of the fishery as a common property resource. Transforming forces, particularly colonial administration, advocating Christianity, war and an emerging market economy undermined social capital, which in turn affected community-based governance. The deconstruction of social capital resulted in attitudes and behaviours that challenge governance processes with dire consequences for sustainable resource utilisation. Harvesting of fish stocks occurs at levels that are no longer sustainable and inappropriate practices are being adopted. While the Mozambique government policy promotes community-based fisheries management in artisanal fisheries, Nkata et al. (2009) argued that a strong focus on reconstruction of social capital will be required before a community-based resource management process can be effectively implemented.

While acknowledging the reasons behind the widespread support for the concept of community-based management, Allison and Ellis (2001) caution that the approach is predicated on some important assumptions that may not hold in practical cases. Specifically, it assumes

- that the ‘‘community’’ as a group of individuals or families with fishing-based livelihoods can be effectively defined
- that village administrations in ‘‘fishing villages’’ are pre-occupied with the welfare of fisherfolk and the conservation of fish stocks
- that territorial use rights, based on village location, are compatible with the behaviour of both the fisherfolk and the fish they endeavour to catch.

In particular, 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.

Within Australia, 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. Co-management is therefore likely to be a more realistic option for Australian fisheries, rather than community-based management.

i. Co-management

Definition

From Neville et al.’s (2008) Report of the FRDC’s national working group for the Fisheries Co-management Initiative — project no. 2006/068:

“Co-management is 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.

“Co-management is not about government delegating all responsibility for core functions. Service responsibilities mandated by government (or management agency) include:

- powers to make regulations
- powers to grant the initial authorisation to fish
- compliance, investigation and prosecution powers
- participation in international and national fisheries management planning exercises.

“Governments are concerned that current (centralised) management regimes are becoming increasingly costly to administer and that many of these costs cannot be passed on to fishers.

“What can co-management offer?

“The working group considered that the following improvements could be achieved with a co-management model:

- a fundamental change towards a partnership approach based on shared responsibilities for implementing sustainable management, a more transparent and effective cost structure, and more efficient delivery of services and functions
- potentially, but not necessarily, lower costs of fisheries management
- improved trust and working relationships among parties
- more flexible and adaptive management processes costly to administer and that many of these costs cannot be passed on to fishers.
- reduced necessity for political decision-making
- greater scrutiny of legislative frameworks and regulatory controls
- opportunity to enhance the public perception of fishers
- opportunity for building capacity and skills of people involved in managing the fishery
- greater ability to innovate and respond to industry development needs."

For small-scale, low-value fisheries, co-management, involving both authorities and users in joint management, has an advantage over top-down approaches, because of its potential to improve communication and compliance (Harris et al. 2002 cited Dowling et al. 2015a).

Rivera et al. (2014) describe how fisheries worldwide are experiencing a paradigm shift from top-down toward a more bottom-up, community-based approach. They state that co-management has the potential to strengthen community integration, enhance fishing stocks, empower resource users, adapt to changing condition, and incorporate fisher’s knowledge and scientific information in management strategies. Co-management systems vary according to the extent of authority delegated to each party, ranging from instructive, where the decision-making process is centralised and the resource users are instructed on the decisions, to informative, where decisions are made locally, and the government agencies are informed.

Drivers for co-management

In Hawai’i, co-management was engaged as a viable, alternative pathway over increased state enforcement or other strategies because of reasons including pervasive budget cuts due to stagnant Hawai’i economy, a renewal of traditional and customary stewardship practices across Hawaiʻi and the perception by some that these customary forms of government were more effective than existing top-down management, resource dependence in many rural areas, and a government open to testing out a new management arrangement (Ayers and Kittinger 2014). Drivers included resource depletion and conflict, and social responses comprise self-organization, consensus building, and collective action.

Cinner et al (2012) explored the transition to decentralisation in marine resource management systems in three East African countries, and particularly, five key governance transition concepts: (1) drivers of change, (2) institutional arrangements, (3) institutional fit, (4) actor interactions, and (5) adaptive management. Decentralized management in the region was largely donor-driven and only partly transferred power to local stakeholders. However, increased accountability created a degree of democracy in regards to natural resource governance that was not previously present. Additionally, increased local-level adaptive management had emerged in most systems and the experimental management helped to change resource user’s views from metaphysical to more scientific cause-and-effect attribution of changes to resource conditions.

In response to decentralisation laws, Siry (2011) examined community-based and co-management approaches in coastal zone management in Indonesia. Co-management was argued to be an appropriate approach to managing Indonesian coastal zone as it allows a balance of power and partnership arrangements between the various levels of government, communities as whole and a wide range of individual stakeholders. Co-management was felt to have more chance of success than a more radically decentralised approach, such as total community-based management, which would only place additional pressure on local communities during a period of considerable change. In the Cochin Estuary, India, a shift from a community-based fishery management system to a co-management system was concluded to be potentially effective, providing that the co-management system incorporates community principles (Thomson and Gray 2008).

Emerson et al. (2011) synthesized and extended a suite of conceptual frameworks, research findings, and practice-based knowledge into an integrative framework for collaborative governance (their Table 1, below as Table 4). The framework integrates knowledge about individual incentives and barriers to collection action, collaborative social learning and conflict resolution processes, and institutional arrangements for cross-boundary collaboration.

Table 4: Emerson et al.'s (2011) Table 1, showing a diagnostic or logic model approach to collaborative governance.

			The Collaborative Governance Regime					
			Collaborative Dynamics			Outputs	Collaborative Outcomes	
Dimension and Components	System Context	Drivers	Principled Engagement	Shared Motivation	Capacity for Joint Action	Collaborative Actions	Impacts	Adaptation
Elements within Component	- Resource Conditions - Policy Legal Frameworks - Prior Failure to Address Issues - Political Dynamics/ Power Relations - Network Connectedness - Levels of Conflict/Trust - Socio-economic/ Cultural Health & Diversity	- Leadership - Consequential Incentives - Interdependence - Uncertainty	- Discovery - Definition - Deliberation - Determinaton	- Mutual Trust - Mutual Understanding - Internal Legitimacy - Shared Commitment	- Procedural/ Institutional Arrangements - Leadership - Knowledge - Resources	Will depend on context and charge, but might include: - Securing Endorsements - Enacting Policy, Law, or Rule - Marshalling Resources - Deploying Staff - Siting/ Permitting - Building/ Cleaning Up - Enacting New Management Practice - Monitoring Implementation - Enforcing Compliance	Will depend on context and charge, but aim is to alter pre-existing or projected conditions in System Context	- Change in System Context - Change in the CGR - Change in Collaboration Dynamics

Moving from community-based to centralised national management was felt to be detrimental to the governance of the marine protected area in Apo Island, Philippines (Hind et al. 2010). Prior to the mid-1990s, Apo Island, Philippines, was often described as one of the world's best examples of community-based marine management. Interviews of islanders revealed a lack of support for the subsequent centralised regime, due to its exclusion of stakeholders from management and its poor institutional performance. The limitations of top-down management highlighted the need for a system of co- management between community and national state actors, in order to restore local stakeholder participation and ensure the long-term sustainability of Apo's marine resources.

In analysing community-based management of near-shore fisheries in Vanuatu, Leopold et al. (2013) stated that community initiatives (developed to compensate for chronically low capacity of governments) must be strengthened by new specific national regulations governing subsistence and commercial reef fisheries as part of a multi-scale co-management approach. They found increasing and excessive reliance of community-based fishery management systems on external agencies that promoted overly complex management plans.

Factors contributing to successful co-management

Theorists and applied researchers have suggested a series of preconditions or factors thought to improve the chances of successful co-management. Wamukota et al. (2011) examined four measures of ecological conditions and five measures of contextual condition improvement using the data presented in 38 papers, which examined 49 co-management projects. Fewer than half of the 49 studies met the inclusion criteria of the analyses for documenting key design principles or contextual conditions. Additionally, most projects did not systematically report on contextual conditions, common property design principles and measures of success (Wamukota et al.'s (2011) Table 7, as Table 5 below).

Table 5: Wamukota et al.'s (2011) Table 7, showing measures of improvement or success based on analysis of various community or co-management projects.

Measures of improvement or success relating to each of the community or co-management projects analyzed. The number of projects with information about each success measure is denoted by *n* while % positive indicates the percentage of those cases that reported improvements in each measure of success.

Measure of improvement or success	*n*	% Positive
Ecological		
Proof of resource improvement (E1)	48	66.67
Proof of ecosystem success (E2)	30	96.67
Ecological impacts on target species (E3 a)	48	14.58
Ecological impacts on field observation (E3 b)	48	29.17
Ecological impacts on wider ecosystem (E3 c)	48	29.17
Proof of resource improvement with management (E4)	42	64.29
Socioeconomic		
Project showed proof of economic success (S1)	14	85.71
Proof of behavioral success (S2)	43	46.51
Proof of social success (S3)	23	91.30
Project viewed as sustainable (S4)	16	81.25
Project was meeting goals (S5)	48	68.75
Project was economically improved (S6)	48	33.33
Project showed improved behavior (S7)	48	29.17
Project successful in reducing conflicts (S8)	7	100.00

Leopold et al. (2013) developed methodological guidelines for implementing a spatial co-management framework for small-scale sea cucumber fisheries, focusing on biological, technical, financial and social factors (their Table 2, below as Table 6).

Table 6: Leopold et al.'s (2013) Table 2, showing methodological guidance for implementing a spatial co-management framework for small-scale sea cucumber fisheries (GIS = geographical information system).

	Main objectives	Operational tasks of the Fisheries Department
Biological factors	Estimating stock reference biomass per species in each fishery	• Estimate reference biomass before opening fishing • Define spatially-explicit total allowable catch (TAC) • Ensure real-time catch monitoring to prevent overexploitation
Technical factors	Strengthening Fisheries Department capacities to reduce external assistance	• Collect biological data using simple survey techniques • Map marine habitats using simple GIS techniques • Use habitat-based stratified sampling and high sampling effort to estimate reference biomass • Use simple database and GIS softwares (e.g. QuantumGIS) • Process the biological data in real time using pre- and user-defined routines created in the database
Financial factors	Careful planning to reduce and recover management costs	• Identify priority sea cucumber fisheries • Set appropriate time duration of fishery comanagement cycles (e.g. maximum of one per year or for five years) to limit the costs associated with reference biomass updates • Set appropriate/rotating open fishing periods at provincial or national scale to be able to monitor each fishery without time conflicts • Define adequate fishing ground size to enhance cost-effectiveness of monitoring programmes (monitoring costs versus returns from catches) • Ensure that all beneficiaries financially support management costs (e.g. licence fees)
Social factors	Promoting participation to enhance local stewardship and compliance with fishing regulations in the long term	• Strengthen comanagement by encouraging local fishers' organizations • Ensure that fishers' organizations contribute to the decision-making process (e.g. by participating in data collection, having access to survey results, setting local fishing restrictions, and enforcing TAC) • Ensure that fishers' organizations are the main beneficiaries of management • Involve scientists when initiating the management procedure (e.g. to optimize the biological sampling efforts) • Ensure that buyers and processors respect spatial fishing bans and open fishing periods

Ansell and Gash (2007) conducted a meta-analytical study, reviewing 137 cases with the goal of elaborating a contingency model of collaborative governance. Critical variables influencing successful collaboration included the prior history of conflict or cooperation, incentives for stakeholders to participate, power and resources imbalances, leadership, and institutional design. Within the collaborative process itself, face-to-face dialogue, trust building, and the development of commitment and shared understanding were crucial. A virtuous cycle of collaboration tended to develop when collaborative forums focus on ''small wins'' that deepen trust, commitment, and shared understanding.

Gutierrez et al. (2011) identified strong leadership as the most important attribute contributing to co-management success, followed by individual or community quotas, social cohesion and protected areas. They examined 130 co-managed fisheries with different degrees of development, ecosystems, fishing sectors and type of resources, and extracted 19 variables relating co-management attributes under five categories (their Table 1, below as Table 7). These were used to predict eight binary measures of success grouped into ecological, social, and economic indicators, which were summed to obtain a single holistic success score that captures natural and human dimensions of fisheries.

Table 7: Guitierrez et al.'s (2011) Table 1, summarising fisheries co-management attributes and outcomes.

Group	Variable name	Frequency (%)
Co-management	Type (consultative, cooperative, delegated)	-
	Phase (pre-, implementation, post-)	-
	Time frame	-
Resource system	HDI (low, medium, high, very high)	-
	Governance Index	-
	Corruption Perceptions Index	-
	Resource type (single*, multi-species)	-
	Ecosystem (inland, coastal, offshore)	-
	Fishing sector (artisanal, industrial, sequential)	-
	Defined geographic boundaries	52
Resource unit	Sedentary/low mobility resources	38
Governance system	Central government support (local)	93
	Scientific advice	92
	Minimum size restrictions	76
	Long-term management policy	71
	Global catch quotas	52
	Monitoring, control and surveillance	47
	Protected areas	39
	Spatially explicit management	37
	Individual or community quotas	33
	Co-management in law (national)	32
	Seeding or restocking programs	19
	TURF	18
Users system	Social cohesion	78
	Self-enforcement mechanisms	71
	Leadership	62
	Tradition in self-organization	55
	Influence in local market	28
Outcomes	Community empowerment	85
	Fishery status (under or fully, over-exploited)	67
	Sustainable catches	62
	Increase in social welfare	61
	Increase in catch per unit of effort	54
	Add-on conservation benefits	45
	Increase in abundance	38
	Increase in unit prices	30

All attributes were grouped according to the classification of Ostrom[16]. Values in the frequency column denote percentage of co-management attributes reported as present within the co-management systems. For complete variable descriptions see Supplementary Table 2.
* Benthic, demersal, pelagic, mammal.

Kosamu (2015) found that the prime role for governments in small-scale fisheries in developing countries was apparently to be as intelligently absent as possible, by way of respecting, protecting, and supporting local institutions. They undertook qualitative comparative analysis to examine 17 cases of small-scale fisheries in developing countries, in order to assess the degree of state involvement which may be most effective in realizing sustainable small-scale fisheries. These degrees vary between: (a) strong top-down regulation irrespective of fishing community wishes, (b) a co-management mode of negotiation with fishing communities, (c) a merely supportive role of the state, or absence from the fishing scene. Contrary to expectations, the sustainability of small-scale fisheries depended solely on the strength of collective social capital of the local communities at the resource scale. With weak local social capital, degrees of government involvement did not make any difference, the fisheries were unsustainable in all cases.

Co-management programs meet a variety of political, social, economic, ecological, and logistical challenges upon implementation. Levine and Richmond (2014) examined enabling conditions for community-based fisheries co- management by comparing efforts in Hawai‘i and American Samoa. Hawai’i’s initiative struggled, with only two Community-Based Subsistence Fishing Area designated, neither of which had an approved management plan. However, American Samoa’s program successfully established a functioning network of 12 villages. Factors contributing to the divergent outcomes of these initiatives included cultural and ethnic diversity, the intactness of traditional tenure systems and community organizing structures, local leadership, and government support.

Differences in program design, including processes for program implementation and community involvement, supportive government institutions, adequate enforcement, and adaptive capacity, also played important roles in the implementation of co-management regimes on the two island groups.

In terms of specific case studies, Frangoudes et al. (2008) considered the transformation of on-foot shellfish gathering in Galicia, an activity that has traditionally been developed mainly by women in a regime similar to an open access regime, to a situation of active co-governance, with a type of license system. Through co-governance, fishers have avoided overexploitation and have shown highly improved marketing management. The role of the administration in this process has been decisive, by investing in training and improving the organizations and the social dimension of the activity. The empowerment of women has also been an essential element. The reduction in the risk of localised depletion, higher long-term yields, and improved economic performance around rotational zone harvest strategies modelled for Australian sea cucumber (Plaganyi et al. 2015) provided motivation for increased use of relatively low-information, low-cost, co-management rotational harvest approaches in coastal and reef systems globally.

Rivera et al. (2014) describe how the gooseneck barnacle fishery in the coast of Asturias has been co-managed by assigning Territorial User Rights to fishers′ associations, allowing fishers to participate actively in the management and data gathering processes. The incorporation of fishers′ knowledge successfully led to within-area fragmentation of the management units down to single rocks as small as 3m long. The system has empowered resource users and provided an opportunity for the use of both scientific information and fishers′ knowledge to be integrated in management guidelines. Results suggest the adaptive capacity provided by the co-management framework has been essential to manage this heterogeneous fishery (their Table 2, below as Table 8).

Table 8: Rivera et al.'s (2014) Table 2, describing the adaptive capacity characteristics of the Asturain gooseneck barnacle co-management system.

Characteristic	Examples
Versatile effort management	Fishing season length varies among plans. Fishing season length may vary yearly. Daily TAC adjusted between plans. Daily TAC adjusted in the 2004–2005 fishing season. Compatible fisheries vary among plans. Conditions for license bestowal depend on the *cofradía*. Conditions for license renewal.
Flexible management of bans	Yearly determination of bans for each zone. Regular meetings to determine condition of zones. Emergency closures to prevent overexploitation.
Incorporation of life history traits	Fishing season adapted to species' reproductive cycle. Daily TAC adapted to species' settlement strategy.
Matching biological, social and management scales	Fine-scale distribution of the resource based on fishers' knowledge. Management scale adapted to resource dispersal range. Management adapted to the social context of each plan.

Obstacles to co-management.

There are various obstacles to the successful implementation of co-management. For gillnet fisheries in South Africa, these included lack of human and financial resources to support community-monitoring programmes in the long term and participate in ongoing co-management meetings, governments' firm stance on the eventual closure of all gillnet fisheries in South Africa regardless of local context, and differing views on what constitutes a co-management arrangement (Cavalho et al. 2009). Co-management frameworks in Kenya and Madagascar faced challenges as they systematically lacked monitoring of resources and surveillance, while several other design principles were only partially implemented, including clearly defined geographic boundaries, collective choice arrangements, monitoring of monitors, graduated sanctions and in Kenya, nested enterprises (Cinner et al. 2009).

In the 2000s, Taiwan's government initiated a remodelling of a rights-based approach to fisheries management, as an attempt to address conflicts between fishers and developers regarding the use of coastal space and to put community-based co-management into practice. Despite this being a positive step, concerns emerged, mostly involving fishers' low participation, fishermen's association's lack of technical skills and financial resources, competition for access, and the division of management responsibility (Chen 2012). The government was advised to play a more active role in dealing with these concerns, and integrated coastal management or marine spatial planning practices, to ameliorate concerns around competition, were recommended. Crawford et al. (2010) described two initiatives for co-management of women dominated cockle (Anadara spp.) fisheries implemented in Zanzibar Island of Tanzania and in Nicaragua that were based on a Fiji model. In each case, significant progress was made at the pilot scale but required adaptation to the community and national context.

j. Developing vs. developed nation contexts

The majority of case studies cited herein pertain to small-scale, low-value fisheries in developing nations. However, many of the principles and findings are applicable generally.

Key differences for developed nations include the general strength of governance and committed financial support, the presence of legislative and/or policy underpinning and requirements, a greater probability of local capacity (and hence less reliance on outside experts), and typically, limited entry conditions. As aforementioned, within Australia, 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.

Such differences are highlighted by (for example) the issues raised by Breckwoldt and Seidel (2012) when considering the drawbacks of the Fijian customary fishing rights system (including traditional authority and resource ownership) as a basis for management actions. The importance of chiefly leadership is decreasing, causing difficulties in decision-making, responsibility distribution and compliance. Additionally, both the customary fishing rights regulating the main access rights of indigenous Fijians, as well as the outdated Fisheries Act, do not include inshore monitoring of catches.

From a developed nation perspective, community-supported fisheries have emerged and expanded rapidly in the United States and Canada and have been proposed as a way to reduce the environmental impacts associated with seafood production, distribution, and consumption. McClenachan et al (2014) found that consuming seafood distributed by local community-supported fisheries reduces the average seafood carbon footprint by more than two orders of magnitude relative to industrial fisheries.

Large differences may also exist around socio-economic context, (possibly) levels of education, and motivations for involvement, all of which speak to the need for any small-scale, low-value management regime to be developed from a bottom-up perspective and customised to the fishery context.

k. What has typically worked well in other fisheries?

Strength of governance, strong leadership, perceived legitimacy, successful institutional interplay, a bottom-up paradigm of developing context-appropriate management mechanism, positive stakeholder engagement, empowerment and participation, incorporation of local ecological knowledge, management that maintains access to the resource, and working at appropriate spatial scales, have all emerged as consistent factors that predicate successful management regimes in small-scale, low value fisheries.

Klain et al. (2014) provide a summary of enablers of and barriers to devolving fisheries management to Coastal First Nations (Table 9).

Table 9: Klein et al.'s (2014) table of enablers of and barriers to devolving fisheries management to Coastal First Nations

	Current Problems & Barriers	**Enablers & Solutions**
Legal environment	• Historical exclusion from decision-making • Conflicts over monitoring & enforcement authority • Cost of legal action/conflict resolution	• Aboriginal rights & title recognized • Documenting historical use & occupancy • Affirming pertinent traditional laws and rules (e.g. Gvi'ilas -- the Heiltsuk Nation's laws of their ancestors -- are their guiding principles for resource management) • New relationships with province, industry • Just redistribution of commercial harvesting rights to First Nations

Policy environment	• Dominant top-down paradigm
	• Industry interests dominate
	• Government silos; disconnect between political & operational at DFO
	• Limited local participation in decision-making
		• Harmonized Marine Use Plans for CCFN
		• New relationships and understandings
		  • Reconciliation protocols
		  • Government-to-government letters of intent and agreements
		• Increasing participation in industry and commercial activities

Governance and decision-making processes	• Insufficient/excessively expensive conflict resolution mechanisms
	• Inappropriate inclusion rules for "stakeholder" negotiations
	• Poor communication across scales
	• Decreasing DFO capacity due to staff and funding cuts
		• Increasing local organization & capacity
		• Harmonized Marine Use Plans for CCFN
		• New cross-scale, bridging organizations and processes
		  • eg. CCIRA, MaPP, CGWN, FNFC
		• De facto authority
		  • E.g. coastal guardian watchmen, Kitasoo prevented sea cucumber harvest in an area adjacent to their community

Knowledge, science, and information	• Insufficient science baseline • DFO often lacks fine-scale information to inform local plans • Local ecological knowledge (LEK) undervalued by current regime • Local science capacity not adequately recognized	• Increasing capacity for science and monitoring • Increseased integration of LEK into scientific studies to improve monitoring • E.g. CCIRA, Coastal Guardian Watchmen Network collecting baseline data and developing capacity

Relationships	• Poor communication between actors
	• Insufficient collaborative capacity in government
	• Tense relations between First Nations and federal government
		• Improving relationships between
		  • First Nations and industry
		  • First Nations and BC government
		  • First Nations

Local organizing & community capacity	• Colonial legacy of disenfranchisement • Out-migration • Few trained locals • Continuity of leadership/programming • Cost of travel, distance between communities	• Strong vision & harmonized marine plans • Strengthening ties between nations • Local/FN resource management offices • Increasing capacity in science and monitoring (e.g. CGWN and CCIRA)

Capital, funding, & incentives	• Limited access to local resources & associated revenue
	  • Expensive licenses
	  • Perception of inequitable allocation
		• Revenue sharing agreements
		• Initiatives to increase access to licenses
		  • Pacific Integrated Commercial Fisheries Initiative)
		  • Aboriginal Fisheries Strateg (AFS)
		• Support from non-profit funders (e.g. Moore foundation)
		• Diversified economic development opportunities
		  • Aquaculture
		  • Processing
		  • Value-added products

Appropriate motivation to ensure stakeholder engagement and support is also critical: viz-a-viz the "stick or carrot" approaches to incentives for involvement in formal management. This is epitomised by the example of the groundfish hook and line fishery in British Columbia, Canada: Stanley et al. (2014) describe how industry support was facilitated by the "carrot" of coincident full introduction of individual vessel quotas (ITQs). The "stick" was that Government support was conditional on improving catch monitoring with the proviso that ITQs would not be considered and the fishery would be closed until the monitoring was improved.

Some additional case study examples citing factors that have led to success in small-scale management include:

For the Solomon Islands, Abernathy et al. (2014) found that using governance structures and decision-making processes that were perceived to be legitimate through the eyes of the community were both particularly significant. Without legitimacy it was difficult to gain or hold on to support for community-based resource management within the community. Garnering support through community-facilitated participatory and inclusive awareness raising and dialogue was important for initiating support. Then, observing promised improvements to community life was a powerful mechanism for maintaining active support.

The importance of government support for small-scale fisheries management was highlighted by Crawford et al (2010), for the case of cockle harvesters in Africa. In Zanzibar, local and national government played highly supporting roles whereas in Nicaragua, local government was supportive but national government continues to exhibit top-down decision-making, while still evaluating the alternative co-management approach. In both cases, university extension initiatives were influential in building community capacity for management and playing an advocacy role with national government.

Grilo (2011) illustrated how institutional interplay, or the ability of one institution to affect another, is a key feature of multi-level environmental governance that can influence the performance of institutions, such as marine protected areas (MPAs). Institutional interplay is generally concerned with information exchanges and issues of control and authority and seemed to have positive effects on the success of marine protected area networks. In the Western Indian Ocean, MPA networks are being created to meet top-down, internationally defined MPA targets, while simultaneously there is a strong regional focus on bottom-up, community-based marine management. These apparently contradictory trends can be bridged through networks of community-based MPAs.

I. Examples of pitfalls

In case studies presented by Abernathy et al. (2014) for the Solomon Islands, most innovations took place in governance rather than management, possibly because the underlying tipping point for transforming to community-based resource management was to address social problems rather than ecological ones. Addressing the ecological need of fisheries has been under-emphasised in community-based resource management in certain cases (Cohen and Foale, 2013, Cohen et al., 2013). Communities may need to invest in innovations in management approaches, especially to be resilient in the long run.

Ferse et al. (2010) cited overall poor performance of marine protected areas, and suggested this can be traced to a failure to effectively include local communities in the design and implementation of relevant measures. They advocate increasing the role of local communities in marine protected area implementation, for example by incorporating aspects of community-based management into a hybrid form of management, which ideally builds upon existing local management practices. Marine protected areas and community-based marine resource management could also be complemented by increased management flexibility, accounting for local views and priorities, providing support platforms for knowledge exchange, generating meaningful incentives, and building on local norms and rules. A key challenge lies in the development of appropriate frameworks that allow for the successful participation of local communities in management.

Alternatively, Cudney-Bueno and Basuto (2009) found that spatial closures within community-based fisheries management were compromised by lack of cross-scale linkages. While locally created and enforced harvest control rules led to a rapid increase abundance, across a regional scale, there was poaching from outsiders and a subsequent rapid cascading effect on fishing resources and locally-designed rule compliance. The same study showed that cooperation for management of common-pool fisheries, in which marine reserves form a core component of the system, can emerge, evolve rapidly, and be effective at a local scale. Stakeholder participation in monitoring can play a key role in reinforcing cooperation. However, without cross-scale linkages with higher levels of governance, increase of local fishery stocks may attract outsiders who, if not restricted, will overharvest and threaten local governance. Fishers and fishing communities require incentives to maintain their management efforts. Rewarding local effective management with formal cross-scale governance recognition and support can generate these incentives.

Gustavsson et al. (2014) describe an example where institutional interplay, per Grilo (2011) has not been successful. Local participation in governance and management is assumed to lead to something good. But it is rarely explicitly stated who are participating and in what. The study investigated how participation in a marine conservation area in Zanzibar facilitated procedural and distributive justice. Participation was mainly in the form of manipulative and passive participation, and other local actors did not participate at all. Instead, the government assumed that justice was achieved by distributing equipment, alternative income generating projects, and relying on tourism for local development. However, the distributed equipment and tourism development created conflict and injustice within and between villages, because of the insufficient resources which did not target those in need. It is suggested that interactive participation by all local actors is needed to create just trade-offs.

6. Key issues – how have the following been handled in the literature?

This section identifies several key issues pertaining to low-value or data-limited fishery management regimes and considers how these have been addressed in the literature.

a. Evaluation of Harvest Strategy performance

Several prospective harvest strategies (involving various combinations of indicators and forms of decision rules) should be developed 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 the “gold standard” for quantitative determination of harvest strategy performance: management strategy evaluation (MSE) (Smith et al. 2007, 1999). Within an MSE, an operating model is used to represent the underlying reality, and pseudo data are generated for use within a stock assessment that uses data to estimate parameters of interest and a management decision rule to recommendations for the subsequent time step.

Ideally, evaluation of the harvest strategy should be undertaken prior to implementation, to ensure it is robust, and to assess its performance in meeting management objectives (Dowling et al. 2015b).

Even for data-poor cases, Australian examples (e.g., Dichmont and Brown, 2010,Dowling, 2011, Haddon, 2011, Klaer and Wayte, 2011, Plaganyi et al., 2013a) indicate that a formal MSE or other such approaches still provide the best basis for fishery management, in terms of objective performance evaluation, robustness testing, and in detecting responses that cannot be intuitively anticipated. However, these approaches will not be possible or plausible in some circumstances, due to data and/or capacity limitations (even where consistent time series of catch data exist, this needs to contain adequate contrast over the time series to show how the stock responds to varying levels of fishing mortality). These approaches generally demand an analytically-rich capability that may exceed the ability of any other than first-rate fishery analysts (Dowling et al. 2015b).

Ironically, the demands of a data-poor MSE may require greater insight from practitioners than would be the case for a data-rich MSE where the elements are already recognized and quantified from observations (Dowling et al. 2015b). In lieu of a formal quantitative approaches, qualitative expert judgement can be used to evaluate alternative harvest strategies, particularly if the process is properly structured. Dichmont et al. (2013) provide examples of such a structured but qualitative application.

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” (Dowling et al. 2015b). 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.

Punt (2017) emphasises that, while the use of management strategy evaluation (MSE) techniques to inform strategic decision-making is now standard in fisheries management, MSE evaluations seldom identify strategies that will satisfy all the objectives of decision-makers simultaneously, i.e. each strategy will achieve a different trade-off among the objectives. For example, Mapstone et al. (2008) used a meta-population and fishing simulation model (ELFSim) to assess the effects of three effort regimes in combination with three area closure regimes. Controlling fishing effort most improved prospects of meeting economic, stock and recreational satisfaction objectives for the fishery.

Few MSE studies have considered the full spectrum from data-rich to data-limited strategies, in the context of evaluating whether the cost of implementing a harvest strategy, the risk to the resource and catch taken from the resource have been appropriately balanced, given the value of the resource. Dichmont et al. (2017) evaluated the performance of Australian Commonwealth data-rich to data-limited harvest strategies evaluated using an MSE based on a full end-to-end ecosystem model. Generally, the risk to the resource increased as fewer data were available, due to biases in the assessments and slow response times to unexpected declines in resource status. On average, more data led to improved management in terms of risk of being overfished and not reaching a target, but this required lower initial catches to recover the resources and lower short-term discounted profits.

b. Low costs

Low-value fisheries have corresponding low levels of resources, and management options must therefore be cost-effective. This section reviews some of the novel techniques proposed or applied to minimise the costs of management.

In terms of the form of management, Coglan and Pascoe (2015) discuss corporate management, which involves total devolution of management responsibilities to a corporation that effectively operates the fishery as a sole owner. Hence, many of the economic benefits of sole ownership might be realised – benefits that individual transferable quota (ITQ) and other imperfect rights-based system aim to achieve but often fall short due to imperfect property rights and other impediments to the market based instruments that prevent their full functioning. The key benefits of such a system include: integration of harvest strategies with marketing strategies, co-ordination of both catch and sales to ensure best prices and lowest fishing costs, greater industry involvement in determining the future of their fishery and how it is to be managed, and, ability to share in the profits of the company even if not fully active in harvesting.

New Zealand's government agency has relied almost exclusively on the results of stock assessment research when setting the allowable harvest, but the reliance on biological data has attracted criticism. Batstone and Sharp (2003) suggested that quota prices can be used as a minimum information system to guide the setting of harvest limits. They conducted an empirical test of Arnason's proposition that ITQ prices are functionally related to profit and that quota prices can be used to inform the fisheries management process. Econometric analysis of the time-series data confirmed Arnason's proposition.

Self-surveillance, sharing the costs of co-management, and using community members to undertake assessment was considered by Frangoudes et al. (2008), in the context of on-foot shellfish gathering in Galicia, an activity that has traditionally been developed mainly by women in a regime similar to an open access regime. The cost of surveillance, an important condition for the success of management of common resources, seems to be well organized by the women. By providing themselves part of this service, they seem to have an efficient and cheap surveillance action. Another area, part of the costs of a co-management scheme, is the cost of support networking as a source of information flow and also a means to preserve the minimum social cohesion needed for adaptive capacity. Until now, this cost has been shared between local "mariscadoras" groups and the regional authorities or local institutions. This includes not only local and regional networking, but also participation in international networks. Generally, the system has been very cost-efficient but may be threatened by a reduction of public support.

Humber et al. (2011) also considered the use of community members to assess artisanal fisheries, for the marine turtle fishery in Madagascar. Using community members to collect data can provide access to a greater wealth of information than that obtained by local or foreign researchers, often at a reduced financial cost. Community members were trained to collect biological and fisheries data on turtles landed and to use digital cameras to provide a visual record of each turtle catch recorded

In more data-moderate fishery contexts, costs can be saved by reducing the frequency of surveys and stock assessments. Annual scientific surveys and assessment group meetings require frequent use of research vessels and skilled research staff and are, therefore, particularly costly. This data- and work-intensive approach is often considered paramount for reliable stock estimates and risk management. However, it remains an open question whether the benefits of increasing assessment effort outweigh its marginal costs, or whether the potential impacts of investing less in assessments could generate net benefits. Zimmermann and Enberg (2017) explored how different scenarios of reduced survey and assessment frequencies affect estimated stock biomass, predicted catch, and uncertainty. Data of two Northeast Atlantic stocks, blue whiting (*Micromesistius poutassou*) and Norwegian spring-spawning herring (*Clupea harengus*), and a widely applied stock assessment model were used to compare the impacts of removing surveys and/or annual assessments. Lower survey and/or assessment frequencies tended to result in deviating estimates of spawning stock biomass and catch and larger confidence intervals, however, the observed differences were mostly small. Biannual surveys in general did not affect assessment performance substantially. This indicates that a reduced frequency of surveys and assessments could be an acceptable measure to reduce assessment costs and increase the efficiency of fisheries management, particularly when accompanied by thorough management strategy evaluations and risk assessments.

Cost-effective monitoring (data collection) approaches for recreational sectors include the combined use of cameras and interviews. Hartill et al. (2016) describe a cost-effective method of continuously monitoring relative trends in recreational effort and harvest, based on web camera imagery and interview data provided by a concurrent low intensity creel survey. The relative difference in harvest estimates provided by aerial-access surveys closely matched the difference in the harvest landed at the high traffic ramp that was monitored in the same time period. This independent confirmation of relative trends inferred from combined web camera and creel survey monitoring at a small number of sites not only validated the approach, but further highlighted the need to continuously monitor recreational fisheries, which are potentially far more dynamic than previously thought.

Keller et al. (2016) also used (shore-based) cameras to quantify recreational fishing effort on an artificial reef off coastal Sydney. Stratified random sampling was used to select days for analysis of fishing effort from digital images. Fishing effort estimates derived from the digital images were adjusted to account for visibility bias using information from a validation study. Camera-based technologies were validated as a cost-effective monitoring methods for small areas of concentrated effort, providing the accuracy of fishing effort information derived from camera images is validated.

c. Multi-sector fisheries: reconciling objectives and having management in "currencies" that is relevant and translatable between sectors

Small-scale, low value fisheries are commonly comprised of multiple sectors. It is important not only to reconcile objectives between sectors (e.g. Pascoe et al. 2013), but for objectives to be in "currencies" that are relevant and translatable between sectors: e.g., a total allowable catch is going to be of less relevance to the recreational sector (Sloan et al. 2014)).

More generally, Klain et al. (2014) cite Cox et al. (2010)'s overview of common-pool resource design principles (per their Table 1, below as Table 10):

Table 10: Klain et al.'s (2014) Table 1, providing an overview of common-pool resource (CPR) design principles

Design principle	Description
1A. Clearly defined user boundaries	Individuals or households who have rights to withdraw resource units from the CPR are clearly defined
1B. Clearly defined resource boundaries	The physical boundaries of the CPR are well defined
2A. Congruence between appropriation and provision rules and local conditions	Appropriation rules restricting time, place, technology, and/or quantity of resource units are related to local social and ecological conditions
2B. Inputs proportional to benefits	The benefits obtained by users from a CPR are proportional to the amount of inputs required in the form of labor, material, or money, as determined by provision rules
3. Collective-choice arrangements	Most individuals affected by the operational rules can participate in modifying the operational rules
4A. Monitoring users	Monitors are present and actively audit CPR conditions and appropriator behavior
4B. Monitoring resource	Condition of the resource is monitored by people who are accountable to the users
5. Graduated sanctions	Appropriators who violate operational rules are likely to be assessed graduated sanctions by other appropriators, officials accountable to these appropriators, or both
6. Conflict-resolution mechanisms	Appropriators and their officials have rapid access to low-cost local arenas to resolve conflicts among appropriators or between appropriators and officials
7. Minimal recognition of rights to organize	The rights of appropriators to devise their own institutions are not challenged by external governmental authorities
8. Nested enterprises	Appropriation, provision, monitoring, enforcement, conflict resolution, and governance activities are organized in multiple layers of nested enterprises that are connected and coordinated vertically and horizontally

Sloan et al. (2014) state: "….the biological objectives and limit reference points for a recreational fishery should essentially be the same as would be used for a commercial fishery, particularly in the multi-sector fisheries context. Importantly, many species targeted by recreational fishers are also caught commercially and, more generally, multi-sector fisheries need special consideration in developing harvest strategies as the management tools used often differ between sectors. Recreational fisheries may, however, have other management objectives and the focus of any targets in the harvest strategy may need to differ depending on whether the fishery is for purely recreational, trophy or subsistence purposes.

"Measuring economic benefits (for recreational fisheries) requires different methods because the goal is to increase utility or enjoyment rather than financial profit. There are standard methods for surveying recreational fishers to measure utility that are comparable to measuring profit in commercial fisheries. A proxy is the use of satisfaction surveys, which include catch rates, time spent fishing recreationally and catch levels. It should be noted that a common mistake in the discussion of recreational benefit is to equate total benefit with total expenditure – the services and goods purchased by this sector (Hundloe, 2004). 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."

Sloan et al. (2014) also provide a summary of useful considerations in developing harvest strategies for recreational fisheries (including as part of multi sectors) (Box 5).

Box 5: Extract from the National Harvest Strategy Guidelines (Sloan et al. 2014), summarising key points for consideration for the inclusion of recreational fisheries in multi-sector fishery harvest strategies.

1. Establish clearly articulated and measurable objectives that are tailored to the recreational sector and that do not clash with objectives for other sectors. 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, translate the broad objectives into simple operational objectives in terms of measures such as strike rate or catch rate.

2. If the recreational sector is one part of a multi-sector fishery, the process of articulating the objectives needs to be undertaken for each sector at the same time so that the objectives determined are compatible and not in conflict.

3. 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.

4. 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.

5. The harvest strategy will vary depending on whether the recreational sector is the only sector accessing the stock/species or if the stock/species is accessed by multiple sectors.

Recreational-only fisheries will require a more tailored harvest strategy development process, in part, because performance indicators from other sectors can't be used (e.g. commercial catch rate as an index of abundance).

6. Allocation between fishing sectors assists the development of harvest strategies for recreational fisheries.

7. 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.

8. 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.

9. 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.

10. Decision rules for recreational fisheries may be process-based – 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.

Fletcher et al. (2016) describe the suite of reforms underpinning the Ecosystem Based Fisheries Management (EBFM) approach adopted in Western Australia to address increasing community expectations and deliver the 'social licence to operate'. EBFM extends beyond the fishery-level 'ecosystem approach' of considering ecological, social and economic objectives by taking a resource-level approach to coordinate management of all fishing sectors that capture a 'resource' (which can be defined as one or more species) to better deliver overall community outcomes. This initiative required refinements to harvest strategies to cover the broader EBFM scope and also to deal with the challenges associated with their application to the multi-sector, multi-species fisheries common in W.A.

Mitchell and Baba (2006) described an example of the success of the Western Australian integrated management using the case of abalone stocks: managers accomplished a set of goals with regards to sustainability issues, social objectives and allocation of catch shares among all users. Integration of the recreational sector in fisheries management does not occur when the regulation of this sector is feeble and fishing mortality is not adequately constrained. Competition between the recreational and commercial sectors and resource sharing had been identified as important issues that needed urgent attention. Conflict often arises through disputes over inconsistent management policies between sectors, with criticism often focusing on unrestricted catches from the commercial sector and unconstrained access from the recreational sector. By integrating the recreational sector in the overall management process, the primary objective of the new agenda was to decrease conflict between competing users and develop a management system without partisanship. By introducing complementary management regime for each sector, security of access, and an enduring and equitable system by which aquatic resources can be allocated to all user groups, may be achieved.

In attempting to reconcile objectives between stakeholder groups, the approach of Pascoe et al. (2013) may be applied. This uses the Analytic Hierarchy Process (AHP) to assess the relative importance of different objectives to different stakeholder groups, and to derive the individual objective weights. AHP has been used in a number of fisheries applications to determine management objective importance and assist in decision making, and is based upon the construction of a series of pairwise comparison matrices which compare sub-objectives to one another. One advantage 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.

The AHP process was applied by Dutra et al. (2016) in Queensland. This study aimed: (i) to apply and test a collaborative method to elicit goals and objectives for inshore fisheries and biodiversity in the coastal zone of a regional city in Australia, (ii) to understand the relative importance of management objectives for different community members and stakeholders, and (iii) to understand how diverse perceptions about the importance of management objectives can be used to support multiple-use management in Australia’s iconic Great Barrier Reef. Management goals and objectives were elicited and weighted via the following steps: (i) literature review of management objectives, (ii) development of a hierarchy tree of objectives, and (iii) ranking of management objectives using survey methods.

d. <u>Multi-sector: allocation issues – resource AND access</u>

Many low-value or data-limited fisheries are exploited by multiple sectors, or gears. Addressing the access and allocation among these to the resource is challenging. While not within the scope of developing a management regime, resolving the issue of allocation is critical to its success.

Mitchell and Baba (2006) described the success of the Western Australian multisector resource allocation approach, achieved via Integrated Fisheries Management (IFM). This is based on a systematic approach involving the inclusion of all sectors in the management process. An increased burden on fisheries stocks, caused by higher recreational user participation, forced policy makers to make large changes relating to the allocation process. The relative contributions of each sector to the fisheries management process were evaluated, by analysing the license payments from recreational and commercial fishers, quantifying each sector's catch, and estimating relative cost-recovery values for each sector. Recreational angler surveys were used to assess the needs of the recreational sector and to identify which marine resources are important to them. From the survey results, the relative value of the abalone resource in Western Australia was identified, and opinions regarding license costs and recreational fisher's attitudes about the allocation of the resource were assessed. This information was used to evaluate priority species within each sector, and based on the importance of those species to each user group, policy makers allocated resources accordingly.

Crowe et al. (2013) further described the process of recreational and commercial allocation in Western Australia. Western Australia's Integrated Fisheries Management (IFM) Policy involves setting an allowable harvest level for each resource, using an independent allocation committee process to allocate explicit catch shares for commercial, recreational and customary sectors, and monitoring sectoral catch. IFM provides guidance for managing each sector within its catch share, providing access to that share, and developing reallocation mechanisms to transfer sectoral catch shares. Allocation outcomes demonstrate the need to account for each sector's catch, with credible scientific data to underpin decision making, independent transparent allocation processes, robust sectoral representation, workable reallocation mechanisms and management arrangements to ensure that all sectors can access their allocated share. A broad conceptual framework, which includes the basis for allocation and reallocation, was developed. This includes the parameters summarise in Box 6 below.

Box 6: Crowe et al.'s (2013) summary of the process of recreational and commercial allocation in Western Australia

• Definition of what is being allocated, that is, the biological resource or suite of resources.

• Definition of the nature of allocation, that is, how the allocation should be described and in what terms, under IFM, this is described as a proportional allocation of the allowable harvest between sectors.

• Definition of the tradeable unit or units (currency) to be allocated or reallocated, and the duration of the units. For example, are the tradeable units tonnes (catch), tonnes per year/season, spatial units (area) or time/gear units (effort), or another surrogate for the proportional use of the resource? A key consideration is whether this should be consistent across all resources, or adapted to specific circumstances, or a mixture of both.

• Definition of who owns and may trade in the allocation, and what limitations on trade may apply.

• Valuation of the units or entitlements using markets, modified by social and other considerations.

• Creation of suitable legislative tools, including penalties, to give effect to the allowable harvest level, the allocation, its units and the processes associated with it.

• Description of the accounting mechanisms for tracking and trading in allocations.

• Establishment/determination of the bodies (legal entities) to administer reallocation and ensuing transfers (e.g. purchase, trading, recording and holding).

• Allocation of rights through market or administrative processes, or a combination of both.

• Agreement on a timeline and process for review.

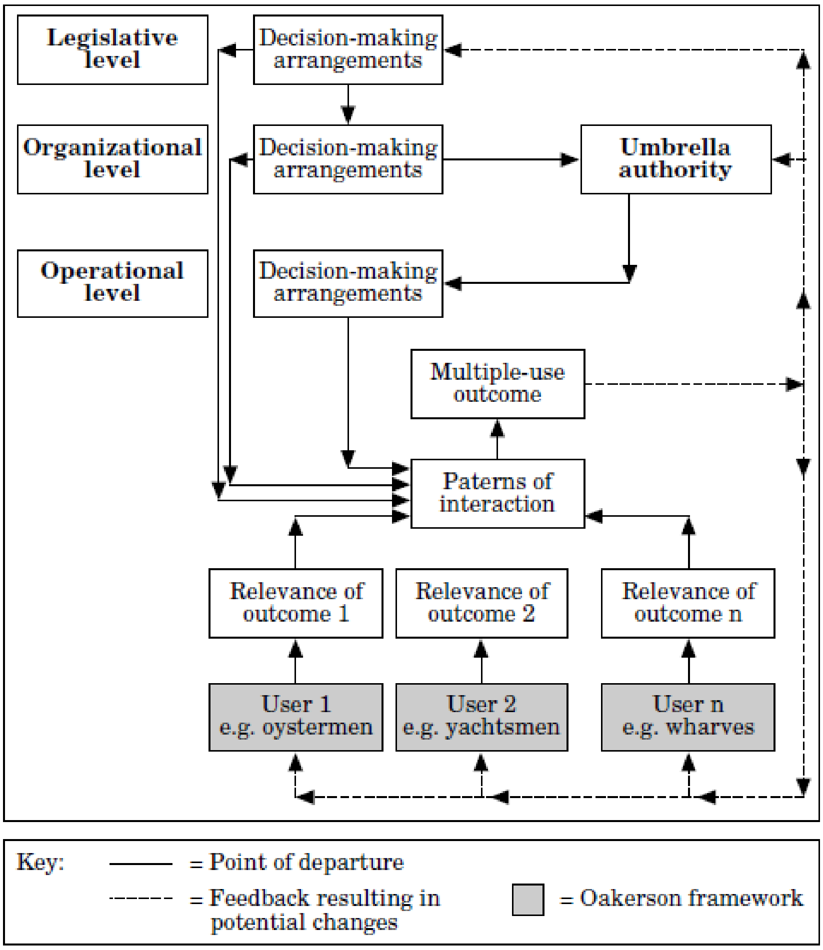
Wiber et al. (2004) state that a key research priority identified by fishers was the politics of access and allocation, overlap and conflicts between different regulation regimes, and how best to organize lobby efforts. Fishermen were particularly sensitive to allocation decisions that, under conditions of increasing stock scarcity, award fish to one community or sector while at the same time remove fish from another. Where fishermen organisations have taken on management roles, these concerns have become vital, not only in terms of their relations with the state, but also in terms of their relations with each other, with other gear sectors in the industry, and with respect to internal allocations within the organisations themselves. Fishers are sensitive to the political implications of any research that touches on these political and potentially volatile relationships. Nevertheless, some fisher groups struggled to design appropriate research into the criterion used when allocation decisions were made, and into the decision-making process itself. Their objective was to have bureaucrats better understand the opportunity costs and consequences of decisions that are taken in favour of one gear sector over another.

d. <u>multiple resource user groups – e.g. other fisheries (bycatch, by-product), tourism</u>

Small-scale, low-value fisheries commonly intersect with multiple user groups. These can include other fisheries that capture similar species, either as target, by-product or bycatch species, or tourism operators.

Steins and Edwards (1998) presented a multiple use perspective on the governance of common-pool resources (CPRs), developing a heuristic framework for the analysis of decision-making processes in multiple-use CPRs (their Figure 8 below, as Box 4). CPRs develop over time to include new extractive and non-extractive users. In 'multiple-use CPRs' co-ordination and monitoring of the various activities is an integral part of resource management, decision-making processes play a key role in this collective management. Institutional analysis, although important, is arguably more challenging in a multiple-use scenario, where there is: (1) a long history of use, (2) multiple types of use (extractive and non-extractive) of the resource system, and (3) multiple user groups. In such cases, the decision-making arrangements that have evolved to govern use of the resource system are likely to be highly complex, both vertically and horizontally.

Box 4: Steins and Edwards' (1998) Framework for institutional analysis of multiple-use common-pool resources.



e. <u>education, cultural issues, stakeholder endorsement and compliance, particularly with respect to indigenous and recreational sectors</u>

Sloan et al. (2014) provide useful considerations in developing harvest strategies for customary/cultural/traditional fisheries (Box 7). Such fisheries often comprise a sector of small-scale, low value fisheries.

Box 7: Extract from the National Harvest Strategy Guidelines (Sloan et al. 2014), summarising considerations in developing harvest strategies for customary/cultural/traditional fisheries.

1. 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.

2. 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.

3. Need to establish if the traditional Indigenous sector is the only sector accessing the stock/species or if the stock/species is accessed by multiple sectors. If it is the latter, considerations in relation to multi-sector fisheries also apply. Customary/cultural/traditional-only fisheries will require a more tailored harvest strategy development process.

4. Need to work closely with the Indigenous community on how they want to manage the share and what objectives should be established.

5. Need to specifically consider cultural, educational, community awareness elements.

6. Need to consider the specific and unique data needs and establish tailored data collection methods.

7. 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.

8. Retro-fitting management arrangements to fit cultural fishing is inappropriate, rather

recognition should be given to the fact that cultural fishing took place before any other type of fishing.

9. Cultural, educational and community awareness are the core elements in developing harvest strategies for customary/cultural/traditional fisheries.

10. If the level of take by this sector is very low, it is questionable whether limit reference points and performance indicators need to apply.

Richmond (2013) emphasised that, in order to introduce meaningful change, environmental policies that incorporate indigenous rights and environmental justice require a commitment of financial and institutional support from natural resource agencies, a commitment from indigenous groups and communities to organize and develop capacity, and careful consideration of contextual and cultural factors in the design of the policy framework. In analysing Alaskan and Hawai'ian fisheries policies that intended to confront colonial legacy by better accommodating indigenous perspectives and rights in fishery management practices, striking similarities between the trajectories of these two policies: while both offered significant potential for incorporating indigenous rights and environmental justice into state or federal fishery management, they have so far largely failed to do so.

Agency support was also important in community-based resource management (CBRM) in the Solomon Islands: building support for the idea required intensive engagement with the whole community and facilitation by an enthusiastic and determined group from within the community (Abernathy et al. 2014). While communities generated effective and active support for CBRM ideas without direct non-government organisation (NGO) input, and a supportive leadership with an active youth appeared to be a successful combination, NGOs still were important in the co-production of CBRM. NGOs supported and provided access to information on resource problem recognition, marine ecosystem function, management options, and long-term monitoring of CBRM and fisheries. However, delivery of this information, the type of information, and potential power asymmetries need to be considered carefully.

From a cultural perspective, globally, the success of pioneering formal management has been mixed. In a further Solomon Islands example, Brewer (2013) showed that similarity between scientific understanding and local perceptions suggests that local resource users are aware of, and might support, fishery management strategies based on scientific evidence. Such strategies must consider factors such as location because resource user perceptions differ between locations and because many threats to the fishery and preferred management strategies are likely to be context specific.

Greater cultural resistance was experienced in Fiji (Breckwoldt and Seidel 2012), per community survey responses such as ‘Conservation is important but making money is more important.’ (Community member from Dravuni) ‘Recording is not part of their life, they simply want to catch as much as possible.’ (Head of the National Fisheries Extension Office). This anecdotal evidence suggests potential lack of willingness to cooperate with management or continuously complete logbooks, due to different priorities or because the rationale for, or benefits of, formal management are unclear. Furthermore, cultural attitudes may not be consistent with a conservation ethic, or a need for conservation is not perceived: ‘God made man to dominate nature. He will provide us with unlimited fish.’ (Community member from Nakaugasele). Incentives to implement management and monitoring may only occur in pro-active villages that have witnessed a steep decline in catches and thus seek outside assistance, or where training or awareness raising efforts exist.

Evaluating indigenous peoples’ involvement in commercial sea cucumber and geoduck fisheries on the central coast of British Columbia, Canada, Klain et al. (2014) found that, while the current social-ecological system configuration was relatively ecologically sustainable, the it also resulted in perceived inequities in decision making processes, harvesting allocations, and socio-economic benefits. It was suggested that greater local involvement in these invertebrate fisheries and their management could provide more benefits to local communities than the status quo while maintaining an ecologically sustainable resource.

As a commons institution, the Padu system in India and Sri Lanka defines the group of rights holders and resource boundaries and fishing sites. It is caste-specific, gear-specific, and species specific. Padu is characterized by the use of lottery for rotational access, and provides equitable access, collective social responsibility, and rule-making and conflict resolution. The system may partly be seen a response of fishing communities to be flexible and resilient (Lobe and Berkes 2004). While the Padu system has long been acknowledged as an example of customary marine tenure that has survived despite rapid development and change throughout South Asia’s fisheries, more recently the system has become unstable, driven by pressures of an expanding fishing population, reduced access to fishing grounds and a growing ‘shared poverty’ (Coulthard 2011). Regardless, fisher loyalty to the Padu system remains strong. Couthard (2011) highlights a trade-off between the benefits received through Padu membership at a societal level through collective action, and the individual costs of partaking in ‘shared poverty’, which is inherently distributed unequally amongst fishing families. It is suggested that the high social values attributed to the Padu system, alongside complex power structures, may hinder institutional adaptation.

More broadly, Burton (2003) point out that generating interest in community-based management is challenging in part due to difficulties encountered with external regulation. Management by a central authority is often seen as insensitive to the interests of fishers and fishing communities and susceptible to political interest to maintain short-term employment, even if this endangers stocks. There is also concern that central authorities do not have the intimate knowledge of the resource that maybe held by local residents, particularly those active in the fishery. Furthermore, they may not have the psychological/physical investment in the local community. By placing management and enforcement decisions with someone else it has also been argued that fishers are ‘‘alienated’’ from their resource (i.e., the resource is seen as ‘‘belonging’’ to the central authority rather than the fishers) and as a result existing cultural controls on use are abandoned. In particular, many local residents may participate in, or at least not report, illegal activities. As such, the expense of central decision making and maintaining an enforcement body may outweigh the net benefits of the fishery to society.

f. Overcapacity

Overcapacity can be a problem in small-scale, low-value fisheries, particularly when fisheries are open access, subsistence fisheries (common in developing nations, such as, for example, Peru and Indonesia). It can also occur when markets for dormant fisheries suddenly open or expand, resulting in the activation of latent effort, or when fishery licences are held as adjuncts to other activities, but become suddenly utilised in a dedicated manner. Policy concerns pertain either to the risk of high inward mobility leading to over-exploitation of an open access resource, as classically laid out by Gordon, or about the lack of outward mobility in the event of diminishing returns to labour and other assets, or a collapse in the fishery for a particular species (Allison and Ellis, 2001).

However, Allison and Ellis (2001) point out that what may appear from a simple count of fishing boats or number of fishers to be excess fishing capacity may actually be an adaptation to maximise catches in periods of abundance, with the apparent 'overcapacity' not actually being utilised in periods of scarcity. Reciprocal access agreements, rather than exclusive territoriality, are common features of indigenous 'community-based' management systems. Flexible financial mechanisms at local level recognise the inherent variability of fishing. Permeable barriers to entry allow those in need of a 'safety net' access to the fishery, while there is recognition of the importance of ease of exit from the fishery in times of resource scarcity.

g. Sustainability accreditation

Accreditation of a fishery's sustainability by an external agency, such as the Marine Stewardship Council (MSC), is generally considered very positive in terms of enhancing the fishery's value, public perception, and export opportunities. Achieving such accreditation is challenging for low-value or data-limited fisheries, although there is scope provided under, for example the MSC's Fishery Improvement Projects.

However, Foley and McKay (2014) caution against MSC certification and other forms of eco-labelling, in that these create new institutions of private property rights and collective action, which can result in exclusionary practices, inclusionary collective action, or both. Much will depend on the specific common pool context and history of the fishery.

7. Gap analysis: what is missing/lacking from the literature?

Our review of the literature confirms that a key gap for low-value, data-limited fisheries is over-arching (i.e. independent of any one fishery), process-based advice on *how* to develop and implement low-cost management regimes. There are many case-study-specific descriptions, and there is advice about *what* needs to occur, in terms of favourable circumstances for management, but there is little about the *how*, that is, the process of operationalising general advice. A process-based, end-to-end tool to provide explicit and direct, transparent and objective guidance to practitioners is a major gap in data-limited fisheries advice and the associated literature.

Specifically, such guidance needs to embrace

- How to IDENTIFY viable harvest strategy (monitoring, assessment, decision rule) options for a fishery, given its unique context and circumstances (the FishPath tool (Dowling et al. 2016) directly addresses this need)
- For each stage of the management regime process, a guide to what WILL and WILL NOT work
- How to ARTICULATE the details of harvest strategies.
- How to EMBED harvest strategies into management plans.
- How to IMPLEMENT harvest strategies

The following points are also required to be included in end-to-end guidance. The literature, as reviewed above, does cover off on the below themes, but in case-specific contexts, as opposed to extending this to providing general advice:

- How to ENGAGE with stakeholders, obtain their buy-in to formal management, and involve them in the process in a bottom-up manner
- How to ELICIT and RECONCILE stakeholder objectives
- How to DETERMINE the appropriate level of co-management
- How to MAXIMISE compliance and the best options for ENFORCEMENT of decision rules

The emphasis of much of the literature around data-limited/low-cost management regimes was on developing nations, and was heavily weighted around stakeholder engagement, community and co-management, and harvest strategies (Table 11). There were relatively fewer examples of low-cost management regimes for low-value, small-scale fisheries in a developed nation context (Table 11). With some exceptions, much of the advice for managing low-value, small-scale fisheries was case-study-specific. There is little evidence in the literature of attempts to develop broad-scale, process-based advice across the whole of the management regime. Additionally, the literature was focused on specific aspects of the management regime, as opposed to a comprehensive, over-arching consideration. There was a general lack of advice or case studies that embraced the entire process. This suggests that management regimes as a whole have received little consideration in the context of low-value fisheries.

The above-identified deficiencies demand end-to-end guidance, or decision support system, to provide explicit and direct, transparent and objective guidance to practitioners, that is customisable to their specific fishery. This includes not only the aspects that surround harvest strategy development (stakeholder engagement, objective elicitation and weighting, performance indicator and reference point identification, compliance and enforcement), but also on how to articulate the details of harvest strategies, how to embed harvest strategies in management plans, and how to implement them. Practical advice as to what will and will not work should also be provided.

Table 11: A summary of the reviewed case-study-specific literature, by region, and by broad management regime theme considered.

	Stakeholder engagement		Community-based monitoring/management		Co-Management		Harvest strategy components: low-cost monitoring/assessments/ performance indicators		
	Country/region	Reference	Country/region	Reference	Country/region	Reference	Country/region	Type	Reference
South-east Asia	Vietnam	Van Trung Ho et al. 2014	Philippines	Chaigneau and Daw 2015	Philippines	Hind et al. 2010			
	Indonesia	Siry 2011	Philippines	Maliao et al. 2009	American Samoa	Levine and Richmond 2014			
	Indonesia	Syakur et al. 2012	Sri Lanka	Deepanada et al. 2015	Taiwan	Chen 2012			
			Malaysia	Nauschon and Charles 2010					
			Cambodia	Nauschon and Charles 2012					
			Thailand	Nauschon and Charles 2013					
South Asia	Bangladesh	Pemsl and Seidel-Lass 2010	Bangladesh	Islam et al. 2011	India	Thomson and Gray 2009			
			Bangladesh	Islam et al. 2014					
			Bangladesh	Pemsl and Seidel-Lass 2010					
			Bangladesh	Rab 2009					
			India	Lobe and Berkes 2004					
			India	Thomson and Gray 2009					
Pacific Islands			Fiji	Breckwoldt and Seidel 2012	Hawai'i	Ayers and Kittinger 2014	Fiji	Local ecological knowledge	Golden et al. 2014
			Fiji	Clarke and Jupiter 2010	Hawai'i	Levine and Richmond 2015	Solomon Islands	Local ecological knowledge	Brewer 2013
			Fiji	Clements et al. 2012			Vanuatu	Marine reserves	Dumas et al. 2010
			Fiji	Mills et al. 2011					
			Solomon Islands	Abernathy et al. 2014					
			Vanuatu	Leopold et al 2013					
			Vanuatu	Nauschon and Charles 2011					
Australia, New Zealand					Australia	DoF 2000	New Zealand	Quota prices	Batstone and Sharp 2003
					Australia	Neville 2008			
North America	Canada	Stanley et al. 2014	California, USA	Schoeter et al. 2009	California, USA	Wendt and Starr 2009	NE Atlantic, USA	Less frequent data collection	Zimmermann and Enberg 2017
							USA	Marine protected areas as a reference	Wilson et al. 2010
							Washington, USA	Local ecological knowledge	Beaudreau and Levin 2014
							Hawai'i, USA	Local ecological knowledge	Friedlander et al. 2013
							Eastern Bering Sea	Abundance estimation	Honkalehto et al. 2011
Central and South America			Brazil	Calvalcanti et al. 2010	Mexico	McCay et al. 2014	Mexico	Community-based no-take zones	Velez et al. 2014
			Mexico	Basuto and Coleman 2010	Mexico	Perez-Ramirez et al. 2012			
			Amazon region	Pinho et al. 2012					
Middle East							Yemen	Local ecological knowledge	Tesfamichael et al. 2016
Africa	Namibia	Kahlet et al 2013	Mozambique	Nkhata et al. 2009	Kenya	Cinner et al. 2009	Eritrea	Local ecological knowledge	Tesfamichael et al. 2014
			South Africa	Carvalho et al. 2009	Kenya	Cinner et al. 2012	South Africa	Effort estimation	Ellender et al. 2010
			Tanzania	Nkhata et al. 2010	Nicaragua	Crawford et al. 2011	Sudan	Local ecological knowledge	Tesfamichael et al. 2015
			Uganda	Barratt et al. 2015	South Africa	Cinner et al. 2009			
			Zanzibar	Gustavsoon et al. 2014	South Africa	Cinner et al. 2012			
					Tanzania	Crawford et al. 2010			
Western Indian Ocean	Mozambique	McClanahan et al. 2013	Comoros	Hauzer et al. 2013	Madagascar	Cinner et al. 2009	Madagascar	Community-based assessments	Humber et al. 2011
					Madagascar	Cinner et al. 2012			
Europe			Netherlands	Kraan et al. 2013	Spain	Freire and Garcia-Allut 2000	Ireland	Local ecological knowledge	Shepperson et al. 2014
					Spain	Rivera et al. 2014			

Table 11 continued

	Allocation		Objectives		Harvest strategies		Enforcement and compliance		Indigenous and recreational sectors	
	Country/region	Reference	Country/region	Reference	Country/region	Reference	Country/region	Reference	Country/region	Reference
South-east Asia										
South Asia										
Pacific Islands										
Australia, New Zealand	Australia	Crowe et al. 2013	Australia	Waycot et al. 2016	Australia	Dichmont and Brown 2010			Australia	Plaganyi et al. 2013b
	Australia	Mitchell and Baba 2006	Australia	Pascoe et al. 2014	Australia	Dichmont et al. 2011				
			Australia	Pascoe et al. 2014	Australia	Dichmont et al. 2013				
					Australia	Dowling et al. 2008				
					Australia	Dowling 2011				
					Australia	Fletcher et al. 2016				
					Australia	Haddon 2011				
					Australia	Klaer and Wayte 2011				
					Australia	Mapstone et al. 2008				
					Australia	Plaganyi et al. 2015a				
					Australia	Punt et al. 2002				
North America							Hawai'i, USA	Kittinger 2013	Canada	Klain et al. 2014
									Alaska, Hawai'i, USA	Richmond 2013
Central and South America							Brazil	Mcgarth et al. 2015		
Middle East										
Africa					South Africa	Geromont et al. 1999	Kenya	McClanahan et al. 2005		
					South Africa	Pollack et al. 2008	Kenya	McClanahan and Abunge 2016		
							Mozambique	McClanahan and Abunge 2016		
							Tanzania	McClanahan and Abunge 2016		
Western Indian Ocean							Madagascar	McClanahan and Abunge 2016		
Europe										

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Appendix 2: Guidelines for developing low-cost management regimes for small-scale, low-value fisheries

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

November 2018

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.

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

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

iv) a monitoring program,

v) the indicators to be calculated from monitoring data (usually via a stock assessment) and

vi) 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.[2]

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.

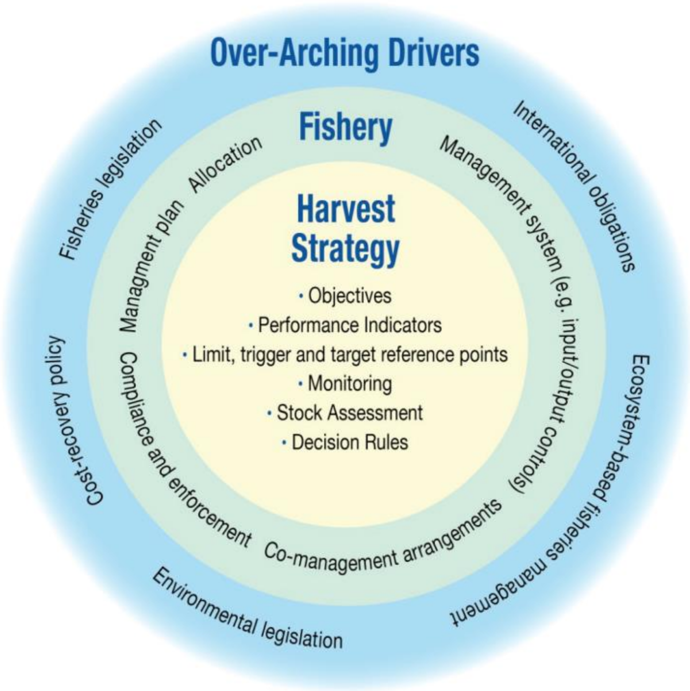

Figure 1: A schematic representation of how a harvest strategy fits within the overall fishery management framework (as a central component of the fisheries management process) (from Sloan et al. 2014). The management regime embraces both the harvest strategy and its embedding within the middle "Fishery"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

[2] 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.

Over-arching issues, pre-requisite information

- Legislative/policy context
- Allocation
- Co-management and community-based management

↓

Pre-engagement

- Undertake an internal audit of the fishery
- Identify drivers for management
- Clarify the reason for the journey
- Consider adoption and the "authorising environment".
- Understand historical context and conflicts/issues
- Undertake desktop analyses (compile and review available information, identify performance indicators and reference points)
- Identify process of engagement

↓

PART 1: Engagement and elicitation

- Generating stakeholder interest/trust to motivate participation
- Obtaining ongoing stakeholder engagement and trust/sign-on
- Eliciting and weighting multi-sector objectives
- Reconciling multi-sector objectives
- Re-review available information
- Finalise performance indicators
- Finalise reference points

↓

PART 2: Harvest strategy development

- Monitoring
- Assessment
- Harvest control / decision rules
- "Fixed" harvest control rules/conditions
- Formal evaluation of harvest strategy options

↓

PART 3: Operationalising the HS

- Choosing between potential harvest strategy options: finalising the harvest strategy of choice
- What is the HS and how should it be articulated?
- How to define/specify the management plan
- Articulation and evaluation of impacts and outcomes

↓

PART 4: Implementation

- Process for day-to-day management
- Define/specify the management plan
- Establish the monitoring plan/program
- Tactical implementation of the harvest strategy
- Compliance and Enforcement
- Review process for the harvest strategy

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

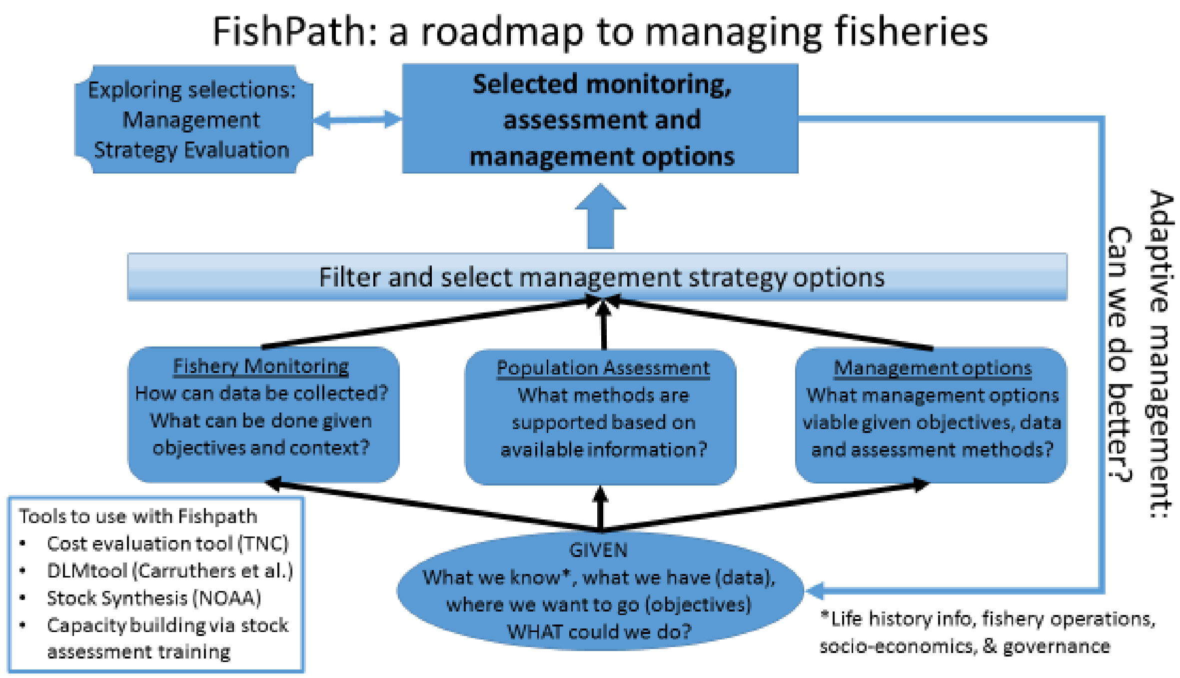

Figure 3: Visual overview of FishPath harvest strategy selection tool

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:

STOP **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.

STOP **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.

STOP

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.

Caveats	Universal methods/principles (applicable to inter- and intra-sectoral allocation) 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 <u>centralised</u> "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.

STOP **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):

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

vii) 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.

viii) 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.

ix) Socio-economic indicators and characteristics:

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

x) 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)*

Prior to commencing the below engagement process:

STOP

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.

<u>Managers should establish appropriate points of contact, guided by the following:</u>

- 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

STOP **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

STOP **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.

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

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.

<u>How to reconcile different objective weighting profiles when selecting harvest strategies</u>

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

- **<u>Multi-criteria decision analysis techniques</u>**

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)

- **<u>Qualitative models (e.g. Bayesian Belief Networks)</u>**

    - 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.

STOP **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:

STOP

- **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.

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

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).

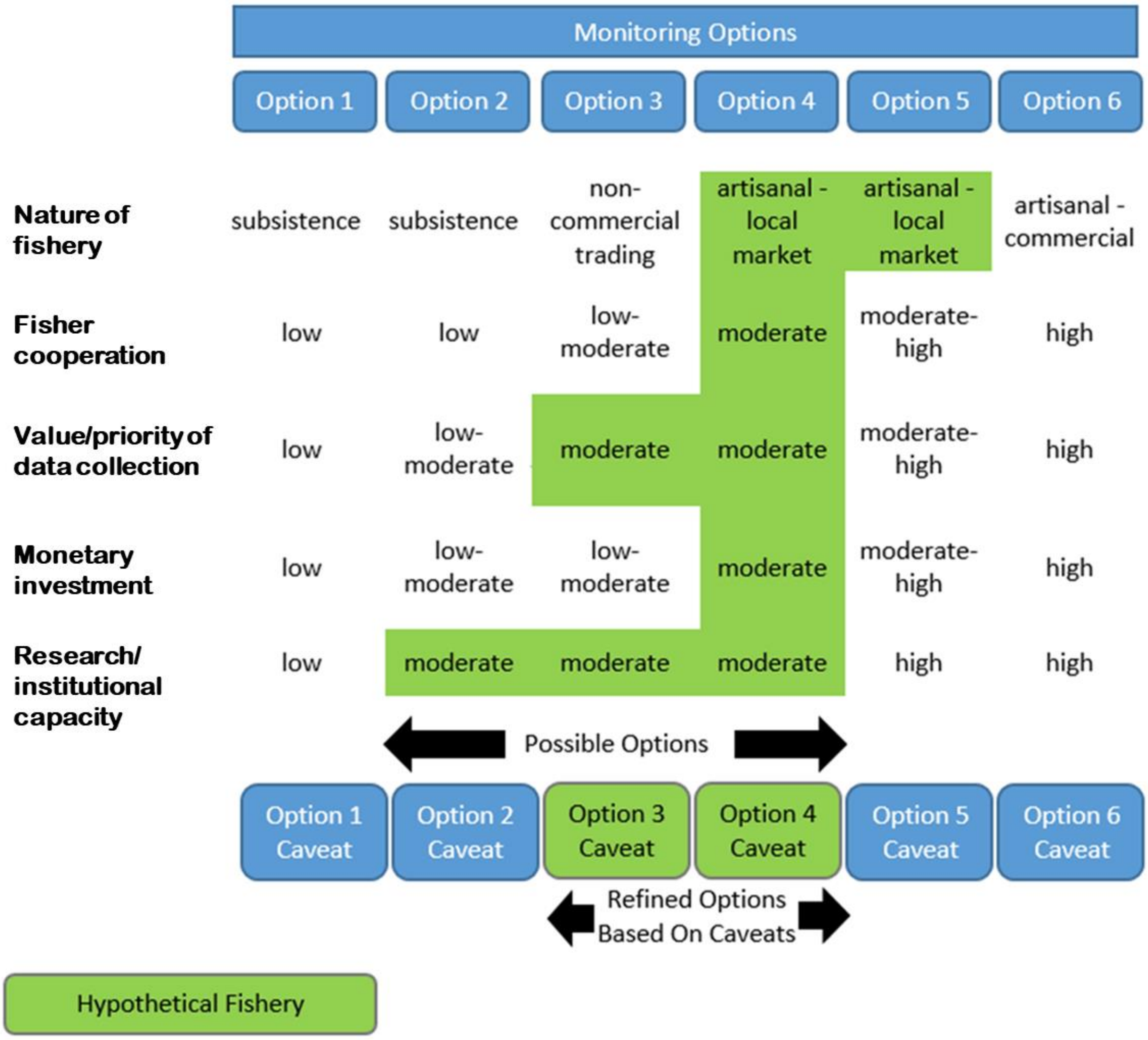

Figure 5: Schematic of the monitoring component of FishPath. Options are identified via responses to five criteria questions for the fishery, and further refined via the advice invoked in response to a series of caveat questions.

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)	Lombardi 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?

STOP **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.

STOP

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.

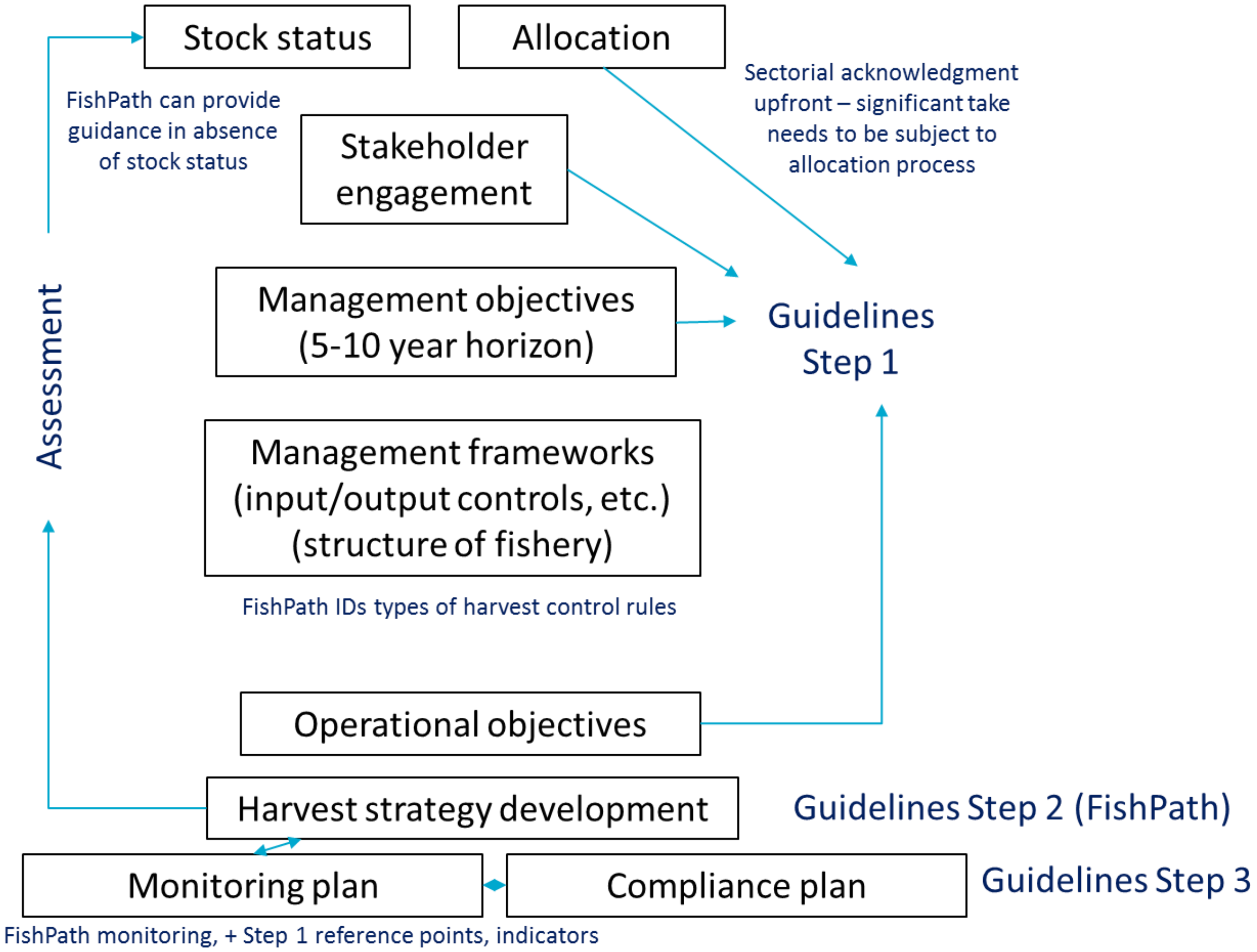

Figure 7: Conceptual diagram of a Management Plan, including pointers to the relevant parts of the Guidelines.

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:

4. **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

5. **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?

6. **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)

	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
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 commercial; 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 commercial; 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						Other						
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		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						Other						
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		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								
				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
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?

Appendix 3: Stakeholder Workshop report, September 2016

<u>LOW-COST MANAGEMENT REGIMES FOR SMALL-SCALE, LOW-VALUE FISHERIES WORKSHOP</u>

September 6-8, 2016

Freycinet Room, CSIRO Marine Laboratories, Castray Esplanade, Hobart

Convenor: Natalie Dowling, CSIRO

FRDC 2015/215 Project Team: Natalie Dowling (PI), Rik Buckworth, Bryan McDonald, Lindsay Joll, Shijie Zhou, Rob Fish

WORKSHOP REPORT

OVERVIEW

A three-day workshop was held with attendance from 11 key management and industry leaders from the Australian state and territory agencies and industry groups, as well as from New Zealand and the South Pacific Commission.

In attendance were:

Tricia Beatty	EO NSW Professional Fishermen's Industry Association
Katherine Winchester	CEO NT Seafood Council, Chief Executive Officer
John Kung	Qld Department of Agriculture and Fisheries
Steve Newman	WA Department of Primary Industries and Regional Development
Emily Ogier	SSERCP
Selina Stout	AFMA
Brad Moore	South Pacific Commission
Keith Sainsbury	University of Tasmania
Renzo Tascheri	University of Tasmania, Institute of Marine and Antarctic Studies
Crispian Ashby	FRDC
John Taunton-Clark	Principal Advisor - Fisheries at Ministry for Primary Industries, NZ

<u>The objectives from the workshop</u> were to:

- Share the draft Guidelines
- Familiarise attendees with the process outlined within the Guidelines, and with FishPath, a tool that assists with the harvest strategy selection process
- Seek critical feedback regarding the structure and content of Guidelines, and FishPath in the context of the Spanish Mackerel example application, against both
    - Technical detail
    - "Bigger picture" issues – is this approach deemed useful?
- Discuss and finalise the Extension Plan
- Identify ambassadors for future fully articulated case study applications.

uggestions for revisions were made against many points; comprehensive notes were taken on all feedback.

There was a high level of engagement and interest from all attendees. Specifically:

- There was acknowledgement of the benefits of a process-based tool to guide the development of a management regime, tempered by a strong desire to see more specific and direct applications to case studies of interest.
- Heaviest interest was focused on the harvest strategy components of the guidelines (as harvest strategy development is the main area of the management regime process that is in need of expertise) and, as such, on the existing FishPath tool.
- Shijie Zhou's optimised catch-only method as applied to NT Spanish Mackerel Fishery was presented and generated substantial interest as a low-cost, simple stock assessment approach.
- The entire group actively engaged throughout the three days and provided a wealth of constructive and valuable feedback against all aspects of the proposed Guidelines.

SUMMARY OF FEEDBACK

Feedback was highly constructive and valuable (to the extent that 20 pages of written notes resulted).

In brief, the feedback on the presented version of the Guidelines fell under the following categories:

- Considerable re-organisation of structure of the guidelines was proposed, both to make these more relevant to managers and to improve logical flow of process (SEE REVISED GUIDELINES OUTLINE BELOW)

- Additional sections were proposed and are indicated in italics in the revised Guidelines outline below.

- Style of narrative; definitions; language – generally this has to appeal to a grass-roots-level audience, and all technical terms (such as "harvest strategy") must be explicitly defined throughout.

- Technical feedback against the FishPath harvest strategy selection tool
    - new overarching aspects, and
    - additional options and caveat questions within existing components.

- Technical suggestion of addition of flags corresponding to processional "health-checks" (user is made aware of aspects that must be acknowledged or resolved prior to being able to move forward), thus making Part 1 in particular more process-based

- Improved processes for objective elicitation

REVISED GUIDELINES OUTLINE

(*newly suggested sections in italics*)

Overarching / pre-requisites

General
Allocation (*moved from part 4*)
Co-management and community-based management
Compile and review available information
Identify possible performance indicators

Identify possible reference points
Identify a pre-engagement strategy
Other pre-requirements

Part 1: Engagement and elicitation

Generating stakeholder interest/trust to motivate participation
Obtaining ongoing stakeholder engagement and trust/sign-on
Eliciting and weighting multi-sector objectives
Reconciling objectives
Compile and review available information
Identifying performance indicators
Identifying reference points

Part 2: Harvest Strategy development (FishPath tool):

Monitoring
Assessment
Harvest Control / Decision Rules
"Fixed" Harvest Control Rules/conditions
Formal evaluation of harvest strategy options
Choice of harvest strategy

New: Part 3: Harvest Strategy articulation and progression

How to choose between FishPath options
What is the harvest strategy and how should it be articulated?
Process for ongoing harvest strategy implementation
How to define/specify the management plan
Articulation and evaluation of impacts and outcomes

Part 4: Implementation

Missing components:
1) *Defining the "Management Framework"*
2) *Monitoring plan/program*
3) *Tactical implementation of harvest strategy*

Compliance and enforcement
Control rule effectiveness or management tools
Review process

KEY MESSAGES

The key message from workshop participants was that the guidelines and proposed process were felt to be of value, but strongly require extension. Beyond the scope of the current project, the need for further engagement and fully blown case studies was identified. Spanish Mackerel as a "tool-testing" example with a vignetted group largely resulted in dissatisfaction around desire to see more complete articulation, and because this example did not embrace issues of key interest for other fisheries (such as multispecies issues).

The FishPath harvest strategy selection tool was acknowledged as filling a void and as a useful means to contribute to better management.

There was also the suggestion of a need to establish FishPath and (Data-limited) Assessment core groups of experts as “go-to” points. The importance of continual engagement with the same people was emphasised.

THOUGHTS FROM GROUP RE: EXTENSION

Proposed steps forward: re engagement and extension for current project:

1. Polish the Guidelines as per the above revisions, and present these only as a fully detailed document, as opposed to also presenting a concise “front end”.
2. Complete the Spanish Mackerel example properly – NB re-word this to emphasise that this was not a full-blown case study involving the recommended process of full stakeholder engagement, but was rather an example for testing the tool with a vignetted group.
3. Provide interim reports to AFMF, AFMA. Emphasise that
    - This project is a tool that fills a void and contributes to bigger issues via improved management help
    - What this project ISN’T doing: tackling overcapacity, social licence, allocation (we only go as far as recognising the allocation environment)
4. Via AFMF, distribute and disseminate to engage other industry/fisheries/key stakeholders (mitigate against “will it break if we take it elsewhere?”)
    - Getting message out and showing how it works
    - Need to flag importance of implementation, and of direct engagement with the FishPath expert team, who can cement the process, so that it is not misread, mis-interpreted, or falls below the line.

Future phase (new project): Seek future funds for the rollout of and extensions to project (SEE ALSO BELOW SECTION):

5. Run additional case study(ies) with full stakeholder engagement
6. Refine the tool in response
    - Modifications to existing FishPath harvest strategy selection tool components
    - Ongoing development of new extensions of FishPath to embrace the full management regime
7. Further determination of end users
8. Work with TNC (NOAA?) to include extensions and modifications to existing FishPath tool into software.

Additional:

9. Possibly a small, separate project to develop a communication tool/package for managers (e.g. a set of template slides defining a harvest strategy)
10. Funding for an ongoing FishPath go-to core team of experts
    - Need mentoring with the same people, over several meetings
11. Funding for an ongoing (?data-limited) stock assessment capacity/resource/expertise core group, that could also provide technical support around MSE

Meanwhile:

- Develop a simple, hypothetical case study fishery example (“FishPath Straw Man”) that includes key “sticking points” (e.g. multispecies, multi-gear, conflicting sectors (intra- and inter-sectorial conflicts, low trust and willingness to be involved; different questions) and use this as a communication and selling tool. Central selling point – simplified “fishery-like” hypothetical example.
- Develop “Press Pack” as part of Extension Plan

- "Glossy" one-pager plus key FishPath summary slides

We must be sure to clarify what this project isn't doing (i.e. it does not address issues pertaining to overcapacity, social licence, or allocation – we only go so far as recognising the allocation environment).

DETAIL OF PROPOSED FUTURE WORK

So what does the proposed next phase look like?

1. Resounding feedback from the workshop is that people need to get their hands dirty with FishPath through full blown case study engagements, so that they can evaluate and be convinced of the efficacy of the process
    a. This is a resource-intensive exercise, but one that is worth pursuing for key "champions", because if successful, this will go a long way towards selling the process nationally
    b. This would involve identifying ~2-3 key case studies that embrace a breadth of fishery characteristics, and applying the FishPath process in a direct engagement, ideally stakeholder workshop, context.
    c. It will be important that the same core group of FishPath experts engages with the fishery throughout.
    d. NB we should have at least a beta version of FishPath software by this point.

2. At the same time, FishPath and its proposed extensions will be improved and refined through case study applications. (Two-way process – FishPath learns through the case studies with which it assists).
    a. Required additions, holes, trip points and refinements can only be identified via case study testing.
    b. Improvements/refinements would be against two main areas:
        i. The existing FishPath harvest strategy selection tool (development of which commenced in 2014) – refinements and extensions are ongoing as the tool is intended to evolve with continued exposure to case studies. Software has an administrative front end for this purpose.
        ii. The early draft articulations of the other components of the management regime.
            1. These will need to be completed to a point where they can be translated to software.
            2. These are in an earlier phase of development that the original FishPath tool and will require considerably more attention.

3. Consider establishment of a core "FishPath advisory group" that can provide hands-on support on demand.
    a. This is over and above the direct engagement for the case studies
    b. The group should include the capacity to advise on assessment options and, were appropriate, to guide users to appropriate technical experts.

Appendix 4: A new proposal to apply the Guidelines to additional case study fisheries, and to continue the engagement with the Spanish mackerel fishery.

The following Expression of Interest was submitted to FRDC in February 2018, in response to a Research Priority, “Cost Effective Management Strategies for Small Scale/Capacity Limited Fisheries”, identified in FRDC’s November 2017 Call for Expressions of Interest. This had been nominated as a priority by the NT, N.S.W., Queensland and W.A. Research Advisory Committees.

FRDC EXPRESSION OF INTEREST:

Submitted: 15^{th} February 2018

PROJECT TITLE: Cost Effective Management Strategies for Small Scale/Capacity Limited Fisheries

Proposed start date: 1/07/2018

Proposed end date: 30/6/2021

Current estimated total project cost: $526,984 (FRDC $370,064; CSIRO $156,920; In Kind $53,685)

Proposed staff: Natalie Dowling (CSIRO; PI), Bryan McDonald (NT Fisheries), Nathan Harrison (WA Fisheries), Katherine Winchester (industry), Rowan Chick (NSW), Rik Buckworth, Cathy Dichmont, Ruth Sharples (CSIRO)

Partners: Chris Gilles (The Nature Conservancy, Australia), Jono Wilson, Dawn Dougherty, Carmen Revenga, Jeremy Rude (The Nature Conservancy, USA), Jason Cope (NOAA, USA)

NEED (300 words)

Managing small scale and socially complex, but capacity limited fisheries can be time-intensive and financially expensive. There is a need to develop tools to streamline and improve decision-making processes to make them efficient and well-informed, and more transparent and approachable to stakeholders. Such tool(s) need to:

• Aid and inform objective setting processes

• Identify management options that match the fishery’s characteristics and circumstances

• Provide guidance on stock status and monitoring options that should be associated with each management option, to inform decisions and allow for cost-appropriate choices to be made

Australian state fishery management agencies are seeking to implement formal harvest strategies, including for small-scale, capacity-limited fisheries. Such fisheries often have additional complexities in being multi-sector, multi-species or multi-gear fisheries, and typically have limited resources dedicated to management. These issues can make it challenging to develop pragmatic and appropriate harvest strategies. Moreover, harvest strategies require thoughtful consideration and planning. There is no “one size fits all approach”: each fishery requires a unique harvest strategy and management plan.

Without a tool to identify viable monitoring, assessment and decision rule options, managers can struggle to develop and implement harvest strategies for small-scale fisheries. Harvest strategies are currently not developed in a standardised manner that is efficient, transparent, and defensible. Instead, management paralysis, circular discussions, and lack of progression of harvest strategy development, are common. In the absence of harvest strategies, fisheries risk overfishing, wasting capacity, or management failure. With FRDC emphasis on reducing the number of ‘undefined’ Australian fish stock classifications, embedding assessments in harvest strategies with appropriate monitoring, will confer greater medium-term certainty in stock status.

The FishPath decision support system is achieving significant national and international attention. Applying FishPath to Australian small-scale fisheries, will be useful to each jurisdiction and in a broader Australian management context.

METHODS (1000 words)

Progress to date

Project 2015-215, “Low-cost management regimes for small low-value fisheries based on coastal inshore species undertook a literature review and developed Guidelines on establishing low-cost fishery management regimes.

The proposed project seeks to operationalise these Guidelines, and apply the FishPath decision support tool, to develop harvest strategies in an efficient, comprehensive, transparent and standardised manner. Case studies would embrace small-scale fisheries from several state jurisdictions, provisionally the N.T., W.A., N.S.W, and/or Queensland, and would provide an opportunity to further apply, refine, and develop new tools based around the Guidelines document, and the FishPath decision support system that underpins its harvest strategy component.

FishPath description

The Research Priority states ‘Developing tools to streamline, improve the accuracy throughout decision making processes, and making them more transparent and approachable to stakeholders is important”. FishPath, an engagement process and software tool conceived, designed and developed by The Nature Conservancy and partners, including the proposed PI, provides a comprehensive, transparent, defensible, efficient process of identifying harvest strategy options tailored to each fishery’s context . A key advantage of the FishPath tool is in its transparency and ease of use: it not only identifies feasible options, but “brings people along for the journey” via a standardised process of “bottom-up” engagement. It is also available freely to fisheries engaged with the process, so does not require on-going access costs – a major issue for capacity limited fisheries. Like all tools where each case study enhances the tool, FishPath’s evolution will continue to improve and become more relevant to similar contexts and fisheries. This is the benefit of applying the tool to case studies across several jurisdictions and fishery types.

Proposed project

FRDC project 2015-215 provided a clear and repeatable process for management planning and harvest strategy development via the FishPath tool. The need now (and intent here) is to operationalise the FishPath tool as the centrepiece of that process.

We will implement the project through three workshops, and ongoing engagement with state agencies and other fisheries stakeholders, in each fishery. The project proposes to focus on one or two fisheries in each of at least three state jurisdictions: N.T., Western Australia, N.S.W., and/or Queensland. Fisheries selected would be nominated by stakeholders prior to workshops, and would embrace a range of issues such as cultural fishing, multiple sectors, and capacity constraints. Jurisdictions will be integrally involved in choosing and developing the harvest strategy for the case studies, while the project team will synthesise the findings and enhance the tool for further Australian application using internal resources.

For each case study, we would work to develop draft harvest strategies from point of engagement to point of evaluation and implementation. The identification and finalisation of options, and the outlining of draft harvest strategies would largely occur within workshops, with “straw men” options and detailed articulations being prepared inter-sessionally. It is preferable to undertake the process of harvest strategy development for a few fisheries comprehensively, to establish a firm precedent, rather than for multiple fisheries superficially.

Workshop 1: One introductory workshop in each jurisdiction where we would introduce FishPath in detail, and focus on targeted engagement and capacity building.

Post-Workshop 1: Led by state agencies, we would work with the relevant stakeholder (industry, recreational, indigenous, environmental) bodies to identify a core working group with whom we will work to develop the harvest strategies.

Workshop 2: A second workshop would run FishPath for the case study fishery and identify harvest strategy options, including a detailed documentation of the fishery and all decisions made. As described above, the project will assimilate feedback and learnings from the user experience, to develop a standardised process that would be applied to reduce these options to a workable shortlist for each harvest strategy component.

Workshop 3: This would focus on finer articulation of possible harvest strategies. This workshop will produce evaluation-ready, fully articulated draft harvest strategies.

We would not formally evaluate the harvest strategies (e.g. using management strategy evaluation (MSE)) as part of this project. This requires significant additional capacity and is beyond the scope of the current project.

We will address previous criticisms of FishPath. Specifically, workshops conducted as part of project 2015-015 showed that users find FishPath's output confronting: it can be difficult to assimilate and select between the options provided. There is a need to help users work through the options to achieve a workable "short shortlist" or, ideally, one preferred option. We would develop a more detailed advice module, which will ideally be provided as an adjunct piece of software. This would enable users to undertake a formal process of sorting and honing their options as an automated and integrated part of the tool.

We will also develop an advice module on how to develop a fully articulated draft harvest strategy, given the options presented by FishPath. This will further develop and expand on the 2015-215 Guidelines, in providing process-based advice for users on how to flesh out the details and specifics of a harvest strategy, beyond identifying the type of monitoring, assessment and decision rules to be used.

DELIVERABLES:

<u>1/07/2018</u>:

- Commence organisation of Workshop 1 for each jurisdiction
- Formalise agreement and sign.

<u>15/2/2019</u>:

Progress report

- Workshop 1 finalised and reports completed
- Commence organisation of Workshop 2 for each jurisdiction
- Draft approach for developing advice modules on i) reducing FishPath output to a workable shortlist of options; ii) process-based advice for users on how to flesh out the details and specifics of ("articulate") a harvest strategy

Communications

- Workshop 1 reports
- Sharing of reports with core FishPath team internationally

<u>15/08/2019</u>

Progress report

- Workshop 2 planned or held for each jurisdiction

Communications

- Workshop 2 reports
- Sharing of reports with core FishPath team internationally

<u>15/2/2020</u>

Progress report

- Workshop 2 finalised and reports completed
- Commence organisation of Workshop 3 for each jurisdiction
- Progress against developing advice modules on i) reducing FishPath output to a workable shortlist of options; ii) process-based advice for users on how to flesh out the details and specifics of ("articulate") a harvest strategy

15/8/2020

Progress report

- Workshop 3 planned or held for each jurisdiction
- Draft harvest strategies completed
- Commence organisation of Workshop 3 for each jurisdiction
- Sharing of reports with core FishPath team internationally

Communications

- Workshop 3 reports
- Sharing of reports with core FishPath team internationally

15/2/2021

Progress Report

- Workshop 3 finalised and reports completed
- Finalise advice modules on i) reducing FishPath output to a workable shortlist of options; ii) process-based advice for users on how to flesh out the details and specifics of ("articulate") a harvest strategy
- Finalise draft harvest strategies with all jurisdictions

Communications

- Draft harvest strategies disseminated to all jurisdictions

30/4/2021

- Draft Final Report

30/6/2021

- Final Report

OUTPUTS AND OUTCOMES (300 words)

By objective:

OBJECTIVE 1

OUTPUT: Improved, more consistent approaches to managing small scale/capacity limited fisheries; a standardised approach to harvest strategy development regardless of context/species/sector/jurisdiction (via FishPath tool and associated Guidelines)

OUTCOMES:

- Improved management of the small scale/capacity limited fisheries to which FishPath has been applied.
- Acknowledgement of Australia as a leader in broader international efforts to develop and apply a standardised approach for customised harvest strategy development.

OBJECTIVES 2 and 3

OUTPUT: Evaluation-ready, fully articulated draft harvest strategies for three case study fisheries across three state jurisdictions (via workshops, reports and commitment from agencies)

OUTCOMES:

- Workshops enable
    - managers to apply FishPath to their own fisheries, leading to improved understanding of FishPath's benefits FishPath and furthering support of its utilisation.
    - stakeholders to experience the process of using FishPath, helping to reduce potential conflict or negative commentary that may arise during larger-scale implementation

- Practitioners and stakeholders experienced in the concept and application of the FishPath tool, and who, through engagement, develop understanding and ownership of the outputs.
- An improved FishPath tool via learnings and feedback from case study applications.

<u>OBJECTIVE 4.</u>

OUTPUT: In the form of Guidelines or a software application, formal guidance/process to i) reducing the number of options output by FishPath to a workable shortlist, and ii) how to flesh out/articulate a fully-developed harvest strategy.

OUTCOME: A more user-friendly, accessible tool, with improvements removing or reducing previous barriers related to functionality.

<u>OBJECTIVE 5.</u>

OUTPUT: A workplan for FishPath's expansion, given the advice modules developed

OUTCOMES:

- An improved FishPath tool based on learnings/feedback from case study applications.
- (5-year vision) to expand FishPath beyond a harvest strategy tool, to a decision support tool embracing the entire management regime, partially informed by the outcomes of the proposed project.

EXTENSION (500 words)

This is an extension project that focuses on applying a tool with significant potential to a range of fisheries, and building capacity to use this tool as a routine part of fisheries management in Australia. The project will result in evaluation-ready draft harvest strategies for at least 3 fisheries in 3 state jurisdictions. This will showcase the efficacy of the tool and the case studies will assist with finalising the software ready for widespread management adoption. This is analogous to the final stages of 'market validation', which in business is required before 'commercialisation'. By "going deep", in undertaking the process this for a few fisheries comprehensively, we are likely to encourage greater use/uptake by managers.

Using its existing connections, the proposed project continue to build on the existing strong support and extension achieved as part of project 2015-015, and through answering the demand from state agencies for a decision support tool. The project team has very strong and trusted relationships with the relevant state agencies, and with the AFMF.

Dissemination of outcomes would occur

- Directly through engagement with state management agencies and industry bodies
- Through the formation of harvest strategy working groups for the selected fisheries
- Via formal written reports and draft harvest strategy documents
- Via regular reports and presentations to the AFMF
- Through publication in the primary literature
- Via the provision of a Guidelines or software tool enabling the user to work through the output of the FishPath tool.

The proposed project also forms part of a broader global effort to develop and apply a standardised decision support tool for data-limited fisheries. The FishPath tool and philosophy has been applied to data-limited fisheries in countries including Peru, Kenya, Indonesia, Jamaica, Bahamas, Mexico, Spain, and the USA.

The proposed PI has been a member of the core FishPath development team since the inception of the tool. FishPath continues to develop and evolve in an international context, and the proposed project provides a direct conduit to uptake feedback from the Australian perspective. We acknowledge The Nature Conservancy and the National Oceanographic and Atmospheric Administration, USA as partners in this global work.

RELEVANT EXPERTISE AND ACTIVITY (300 words)

Dr Natalie Dowling has extensive experience in harvest strategy development for data-poor/low-value fisheries. She was a leading partner in developing the FishPath decision support system. She has a successful history of engaging with stakeholders unfamiliar with formal management, nationally and internationally, and led the development of, and obtained sustained industry confidence and endorsement on, low value, data-poor Commonwealth fishery harvest strategies.

Dr Bryan McDonald (N.T. Fisheries) has significant science, fisheries management and policy development experience and has long recognised the need for guidance and policy for small-scale fisheries management nationally. He Chairs the Australian Fisheries Management Forum sub-committee tasked with considering future improvements for managing small scale fisheries nationally.

Dr Rik Buckworth's experience in fisheries assessment, developing harvest strategies, and in research/management ranges from the N.T. Coastal Line and Offshore Net and Line fisheries, to the Northern Prawn Fishery. A scientific member/chair of various advisory groups, he has led many research projects, all demonstrating strong stakeholder collaboration.

Dr Cathy Dichmont has a national and international reputation in stock assessment, modelling natural systems, natural resource management, shared fisheries stocks, and management strategy evaluation (MSE) and has been Principal Investigator in numerous collaborative and multi-disciplinary projects over her career.

As CEO of the N.T. Seafood Council, Katherine Winchester has insight into industry needs and aspirations coupled with an understanding of government policy process and constraints.

Dr Rowan Chick (NSW Fisheries) has over 20 years' experience in fisheries research, with a primary interest in the role of research in supporting sustainable utilisation of living marine resources.

Nathan Harrison (Director, Aquatic Resource Management, WA Fisheries) has over 20 years' experience in fisheries management in Western Australia, of which a significant component has been managing data poor nearshore and estuarine fisheries – many with significant resource sharing issues. Nathan is a member of the AFMF sub-committee.

OBJECTIVES

1. To apply and promote the FishPath decision support tool within Australia, and to enhance it for further application to small-scale/capacity limited fisheries.
2. To apply FishPath to develop fully articulated draft harvest strategies for four case study fisheries.
3. To develop, within the practitioner and stakeholder groups, capacity for understanding and applying the process of harvest strategy development, as assisted by the FishPath and associated tools.
4. To develop process-based, standardised, user-friendly guidance on how to interpret the output of FishPath and reduce the options to a workable shortlist.
5. To consider what aspects of the management regime guidelines should be operationalised as user friendly software, as such expanding the FishPath tool.

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