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

Appendix One: a review of the literature

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May 2020

FRDC Project No **2015-215**

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

a review of the literature

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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. The FishPath decision support tool

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

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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

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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

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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

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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

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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. Stakeholder engagement

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)

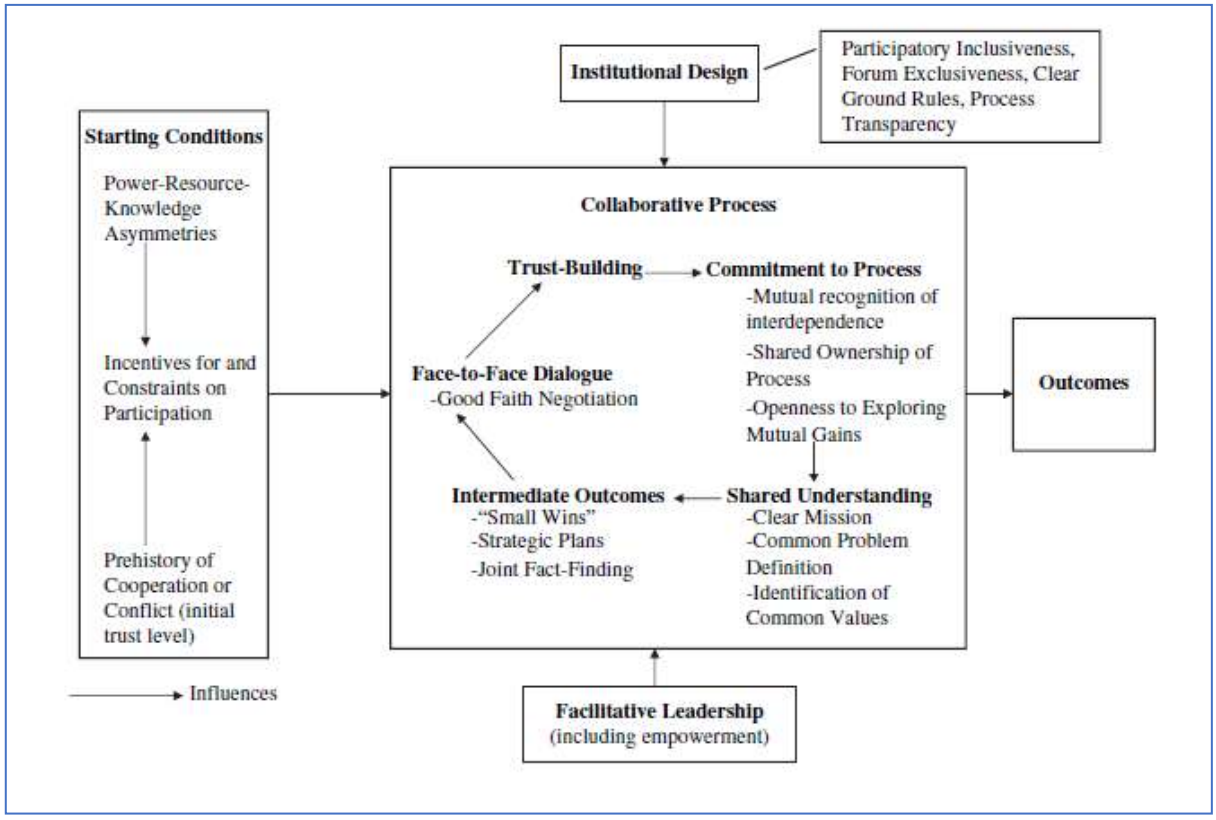


Figure 3: Ansell and Gash (2008)'s Figure 1: A model of collaborative governance

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.

Cautions

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.

<u>Drivers for co-management</u>

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 Hawai‘i 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				Collaborative Outcomes	
Dimension and Components	System Context	Drivers	Principled Engagement	Shared Motivation	Capacity for Joint Action	Outputs 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. Multi-sector: allocation issues – resource AND access

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.

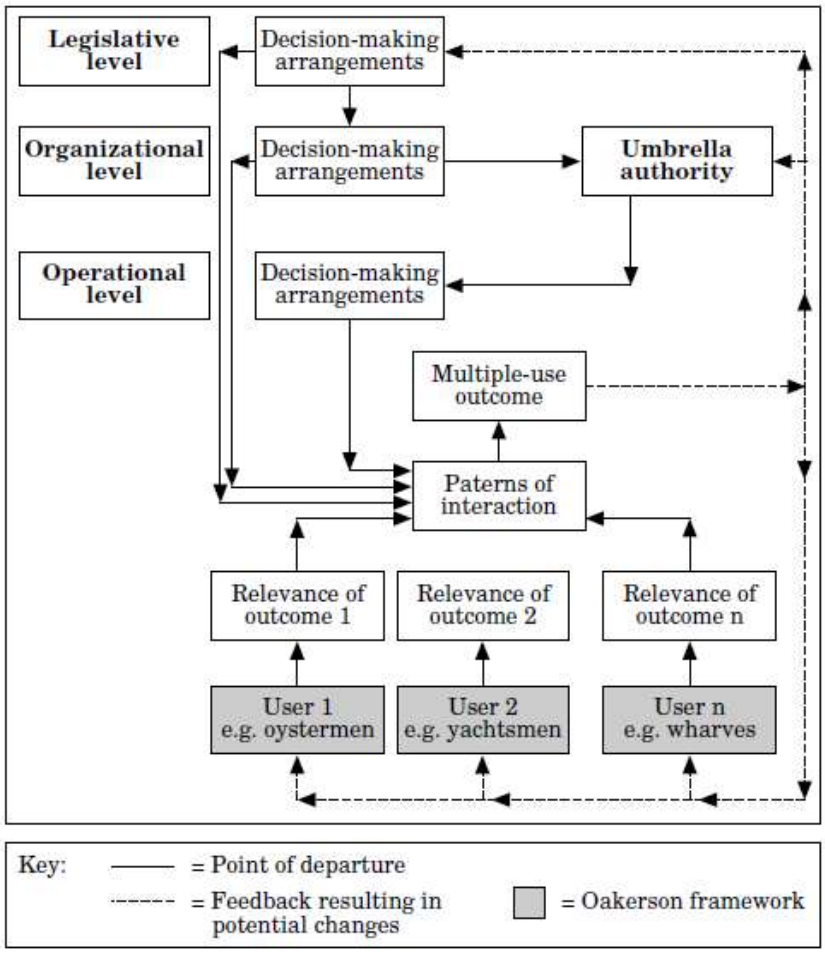
Wiber et al. (2004) state that a key research priority identified by fishers was the politics of access and allocation, overlap and conflicts between different regulation regimes, and how best to organize lobby efforts. Fishermen were particularly sensitive to allocation decisions that, under conditions 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. multiple resource user groups – e.g. other fisheries (bycatch, by-product), tourism

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. education, cultural issues, stakeholder endorsement and compliance, particularly with respect to indigenous and recreational sectors

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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