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Integrating recreational fishing information into harvest strategies for multi-sector fisheries

Fowler AM, Dowling NA, Doyle FA, Folpp H, Lowry M, Lyle JM, Lynch TP, Tracey SR and Chick RC

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Researcher Contact Details

Name: Dr Ashley Fowler
Address: 19 Chowder Bay Road, Mosman, 2088
Phone: +61 2 8251 2609
Fax: -
Email: ashley.fowler@dpi.nsw.gov.au

FRDC Contact Details

Address: 25 Geils Court
Deakin ACT 2600
Phone: 02 6122 2100
Email: frdc@frdc.com.au
Web: www.frdc.com.au

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Abbreviations

CSIRO – Commonwealth Scientific and Industrial Research Organisation

HCR – Harvest Control Rule

HS – Harvest Strategy

NSW DPI – New South Wales Department of Primary Industries

PI – Performance Indicator

RF - Recreational Fishing

RFRW - Recreational Fishing Research Workshops

TBL -Triple Bottom Line

SC – Steering Committee

WG – Working Group

Executive Summary

Background

Recreational fishing (RF) is an important component of fisheries globally, particularly in high-income nations. Despite its importance, recognition and governance of RF remains underdeveloped, particularly when compared to the commercial sector.

Harvest strategies (HSs) offer a means to integrate RF into the monitoring, assessment and management of fisheries that also include a commercial or small-scale sector (hereafter termed 'multi-sector fisheries'). HSs aim to achieve fishing objectives, yet RF objectives are diverse and poorly understood compared to the commercial sector. Given limited inclusion of the RF sector in HSs to date, it is also unclear: 1) what types of RF data and monitoring best service stock assessments, (2) which data also track indicators of recreational objectives (often related to the fishing experience), and (3) how to integrate HS components for multiple sectors into a single HS.

Integration of RF into HSs is necessary for many fisheries in Australia, to account for catches that can equal or exceed commercial catch for a number of key species and to address equally valid biological and experiential objectives of the RF sector. Fisheries management in NSW is transitioning to a harvest strategy (HS) approach that includes all relevant sectors within a fishery. The jurisdiction has a substantial RF sector with strong interests in numerous stocks that are also utilised by the commercial sector and Aboriginal cultural fishers, including Mulloway (*Argyrosomus japonicus*), Yellowtail Kingfish (*Seriola lalandi*), and Snapper (*Chrysophrys auratus*) which are scheduled for formal HS development.

Project aim, objectives and outcomes

The current project aims to guide the integration of RF into multi-sector HSs throughout the entire process of HS development, from identification of objectives for the sector, through selection of suitable HS components, to approaches for integrating these with components from other sectors in functional HSs. Specific objectives and outcomes of the project are:

1. *Obtain information on recreational fishing objectives and facilitate improved understanding among recreational fishers of the role of harvest strategies.*
   Outcomes
   - Engagement of recreational fishers in the development and management of their fisheries.
   - More experienced and educated primary stakeholders (recreational fishers), fisheries scientists and managers with regard to recreational fishery objectives.

2. *Identify types of recreational fishing data and monitoring that provide reliable measures of both the biological and experiential performance of fished populations.*
   Outcomes
   - Improved understanding of current capacity for measuring fishery performance relative to recreational specific and biological objectives.
   - Improved assessments and stock status determinations for multi-sector fisheries through the identification of monitoring types that will produce robust recreational fishing data (2018 FRDC Research Priority).

3. *Interrogate and extend the FishPath decision support software tool to better characterise and integrate recreational fishing information into harvest strategy development for multi-sector fisheries.*

<u>Outcomes</u>
- Better characterisation of the monitoring, assessment, and control rules for recreational fisheries.
- Streamlined and efficient development of HSs for multi-sector fisheries.

4. *Develop guidelines and recommendations for the integration of recreational fishing information into harvest strategies for multi-sector fisheries.*
   <u>Outcomes</u>
   - Increased ability to develop harvest strategies for multi-sector fisheries.
   - Greater likelihood of developing harvest strategies that can achieve the objectives of multiple sectors.

5. *Develop draft harvest strategies for key multi-sector fisheries using outcomes from Objectives 1-4.*
   <u>Outcomes</u>
   - More certainty regarding recreational fisheries resources for current and future generations of recreational fishers.
   - Greater likelihood of achieving fishery objectives for all sectors.

Methods

Workshops and offsite surveys were used to identify RF objectives in NSW and determine their relative importance, to prioritise them for consideration during future HS development. Objectives and their ranked preference were developed separately for each of three recreationally-important stocks in NSW - Mulloway (*Argyrosomus japonicus*), Yellowtail Kingfish (*Seriola lalandi*), and Snapper (*Chrysophrys auratus*). Objectives were first identified in a workshop setting with the assistance of recreational fishers experienced in targeting the three stocks in NSW waters. A statewide survey of randomly selected RF licence holders (telephone survey) and a self-selecting group of NSW residents (online survey delivered in 6 languages) was then used to elicit preferences among those objectives. Potential differences in objectives preferences among stocks, respondent groups and RF subgroups identified by their demographic and operational characteristics were explored.

Three desktop reviews were undertaken to develop a holistic understanding of RF inclusion in HSs. Firstly, we reviewed the type and extent of RF inclusion in 339 HSs for multi-sector fisheries across 11 nations, focusing on the HS components (e.g. data collection) included for the RF sector compared to commercial and small-scale sector (i.e., artisanal, cultural, or subsistence). Australian HSs were then reviewed in August, 2020, and a national database of HSs was developed, providing a searchable electronic resource for interested stakeholders tasked with developing HSs. Finally, a detailed review of RF data and monitoring in NSW over the past 20 years was completed. RF data sources were linked to RF objectives where they could be used to monitor fishery performance.

The content and functionality of the FishPath HS development Tool was reviewed from the RF perspective and revised to better characterize and integrate RF information into HS development for multi-sector fisheries. Four scientists specialising in recreational fisheries reviewed the options, questions, criteria, and caveats in the Tool and proposed additions to better service RF. A workshop was first run to familiarize reviewers with the Tool and a second workshop was held to consolidate and discuss review findings and recommendations with the FishPath Core Team (including representatives from The Nature Conservancy). Required revisions were made to the Tool (following TNC approval), including the development of a RF 'filter' capable of removing questions and options within the Tool that are not relevant for the RF sector of any specific fishery.

Guidelines and recommendations to inform HS development for multi-sector fisheries that include RF were developed using the information obtained throughout the project. The guidelines cover steps for identifying, prioritising and consolidating RF objectives, and steps for linking those objectives to data sources and performance indicators for monitoring. The guidelines include some steps which should also be undertaken prior to formal HS development. The guidelines also address management control of RF and formulation of the relevant harvest control rule (HCR). We identified four technical approaches for achieving RF objectives within multi-sector HSs via combinations of specific HS components. A HS template for multi-species fisheries was developed, to help visualize and ogranise HS components within an overall strategy.

Knowledge acquired during the project was used to develop example HSs for three recreationally-important stocks in NSW – Mulloway, Yellowtail Kingfish and Snapper. A set of conceptual and operational objectives was developed with all sectors in a working-group setting and the FishPath Tool was used to characterize each fishery and identify suitable HS components. NSW data sources, including both current and emerging RF data sources, were used to develop performance indicators (PIs), along with reference points that, when applied in the HS framework, could achieve the fishing objectives of all sectors. Empirical and model-based assessments were designed in accordance with available PIs and the life-history of each stock. HCRs were developed to provide dynamic management of both the RF and commercial sectors in accordance with assessment outcomes and selected reference points. Additional static management measures were identified that provide control not afforded by dynamic management.

Key results

A list of RF objectives suitable for inclusion in HSs was produced for Mulloway, Yellowtail Kingfish and Snapper in NSW. These spanned ecological, economic and social aspects of sustainability and provide a reference for future HS development in the state and elsewhere where similar RF groups are recognised within the management framework of the fishery. Preferences among these objectives elicited from the statewide survey were generally similar among stocks and respondent groups, with ecological objectives found to be most important, particularly maintaining enough fish overall and regionally to ensure a healthy stock and avoid localised declines. Social objectives were found to be more important than economic objectives in two out of three respondent groups, although contrary to expectation, an objective regarding ‘trophy-sized’ fish was considered less important than other social objectives. While recreational fishers in the survey clustered into four distinct ‘types’ according to operational and demographic differences, these did not substantially influence objective preferences.

The international review indicated that RF inclusion in HSs was more similar to the small-scale sector than the commercial sector, with explicit operational objectives, data collection, performance indicators, reference points, and management controls lacking in many regions. The limited inclusion of RF in HSs, together with the fact that RF plays a significant and often increasing role in the harvest of marine resources, raises uncertainty regarding the sustainability and management of marine multi-sector fisheries.

The review of Australian HSs in 2020 revealed that 49% were developed for multi-sector fisheries that included an RF sector at that time. HS elements (e.g. fishing objectives, PIs, reference points) were included less frequently for the RF sector than the commercial sector when both sectors were involved in a fishery, indicating relatively lower likelihood of achieving fishery performance for the RF sector. Most objectives specified for both the RF and commercial sectors were biological/ecological; however, a greater proportion of RF objectives were social (14%) compared to the commercial sector (5%). A searchable electronic database has been developed that currently includes all HSs that were publicly available by the time of review (August, 2020). A primary feature of the database is the ability to search according to a range of fisheries attributes, including sector, gear type, jurisdiction, species and environment. The database is fully updatable and can be hosted online for general use (hosting location pending at time of publication).

A total of 21 RF data sources were identified in NSW over the past two decades, spanning all major aquatic environments and 146 fished species. Numerous data sources were available to monitor ecological objectives, providing time-series and potential reference points for key indicators such as catch-per-unit-effort. Few data sources were available for social, economic, and institutional objectives, consistent with a global paucity of these data. We found that most social objectives of RF lie outside the scope of traditional HSs, although some are linked to underlying ecological performance. Social data sources are still required to confirm that fisheries performance against social objectives is being achieved through ecological objectives. Such monitoring may not need to contribute to assessment and subsequent harvest control, providing that social performance is being achieved indirectly.

Expert reviews of the FishPath HS development tool highlighted existing capability for the RF sector and also opportunities for enhancement. The latter spanned areas of content (e.g. addition of data collection options specific to RF), functionality (e.g. comparison of questionnaire responses across sectors), minor clarifications (e.g. ‘not applicable’ responses for RF), and broader considerations (e.g. considering distinction between shore-based and boat-based RF). Related revisions of the Tool were completed, including updating of 19 questions, creation of a comparison matrix of questionnaire responses and HS options across sectors, and the addition of an RF ‘filter’ that allows the practitioner to remove irrelevant questions, or pre-answer overly technical questions, prior to engagement with a recreational stakeholder group whilst allowing outcomes from those actions to be transparent to the group. An RF ‘translation’ was also developed, which reduces the technical language within the questionnaire, aiding comprehension and engagement of the RF sector.

Development of example HSs for Mulloway, Yellowtail Kingfish and Snapper in NSW highlighted the need to consider what data must be RF-specific, how these data might contribute to a common assessment and what options are available for dynamic and static management of the RF sector in response to assessment outcomes. Accurate data on RF harvest was identified as an important addition to the total catch series for each of the three stocks, given the large proportion of total mortality arising from RF. For monitoring and assessment of fishery performance against common biological/ecological objectives, it was recognized that RF-specific PIs may not be required when a suitable alternative was available from either the commercial sector or independent survey. Some RF-specific objectives (e.g. ensuring large fish in the population) can either be achieved directly in the HS, via inclusion of length-based PIs in the assessment and HCR, or indirectly via primary biomass objective and associated PIs. If the latter approach is taken, there is a need to establish and monitor RF-specific PIs outside of the control rule, so that putative indirect fishery performance can be tested. Lastly, gradated dynamic control of RF is challenging without real-time (within-season) reporting of RF harvest or effort. This is likely to remain an issue for many recreational fisheries due to the logistic challenges associated with establishing real-time reporting across a larger number of individual recreational fishers.

Key recommendations

Guidelines and recommendations for the integration of recreational fishing information into harvest strategies for multi-sector fisheries were developed throughout the project and outlined in detail in Objective 4. They are organised according to a four-phase harvest strategy (HS) development process, along with an additional period prior to Phase 1, during which prerequisite legislation, regulation and supporting policies (e.g. allocation policy) should be established:

Prior to Phase 1 - before pre-engagement for a specific HS

- Establish allocation policy to support resource sharing between the RF and other sectors within HSs.
- Establish HS policy and guidelines that explicitly acknowledge RF and the need to include the sector in HSs.
- Review existing RF monitoring to identify potential data gaps for common fishing objectives. Early commencement may allow timely establishment of essential monitoring.

Phase 1 – Pre-engagement, definitions and scoping for specific fishery HS

- Establish an equitable process for HS development, where the RF sector is afforded inclusion in all engagement, provision of information, and meetings relative to other sectors.
- Define the type, magnitude and extent of RF activity related to the stock(s), as well as the role of RF representatives.
- Review existing management measures for RF and note which, if any, are effective at controlling total harvest. Instigation of effective mechanisms for controlling total harvest, if not already available, are likely to

Phase 2 - Identifying objectives and options for HS components

- Elicit fishing objectives from RF representatives and prioritise them, noting those objectives that are not within the scope of a HS and need to be addressed via alternative management processes.
- Consolidate objectives across fishing sectors and within the RF sector itself, noting instances where objectives are common among sectors but target reference points are not.
- Identify options for the three main HS components - data collection, assessment, management measures – and where these may differ to those of other sectors.

Phase 3 – Linking components together into a functioning HS

- Identify PIs suitable for quantitative monitoring of fishery performance relative to specific RF objectives.
- Use a HS template to visualize linkages between alternative data collection options across sectors, their combination into a common assessment, and the range of separate management measures required.
- Determine reference points for each PI that reflect RF objectives. Compromise on reference points among sectors may be required, even when objectives themselves are common.

Phase 4 – HS evaluation

- Use quantitative management strategy evaluation (MSE) where possible, but alternatives including retrospective analyses or expert consultation may be required due to data-limitations.
- Evaluate HS performance against the PIs corresponding to each RF objective. This is critical where RF objectives have not been explicitly incorporated within the assessment and HCR.

Keywords

Harvest strategies, fishing objectives, recreational fishing, Mulloway, Yellowtail Kingfish, Snapper

Introduction

Importance and limited governance of recreational fishing

Recreational fishing (RF) is an important component of fisheries globally, particularly in high-income nations. The activity is distinguished from other types of fishing through the primary motivation of leisure rather than sale or subsistence. While participation varies considerably among regions, approximately 10% of the developed world fishes recreationally (Arlinghaus et al., 2015, 2019). Retained catch by recreational fishers has been estimated at 17 billion fish per year, or 12% of total global fisheries harvest by weight (Cooke & Cowx, 2004). For numerous stocks, recreational harvest represents a significant proportion of the total catch (Brown, 2016; Coleman et al., 2004; Cooke & Cowx, 2006; Hyder et al., 2018; Ihde et al., 2011; Lewin et al., 2006, 2019; Radford et al., 2018), highlighting the need to account for RF with respect to resource sustainability (Ihde et al., 2011; McPhee et al., 2002; Post et al., 2002; Radford et al., 2018). The socio-economic scale of RF is also substantial; ∼190 billion USD is spent on RF per year (World Bank, 2012) with approximately 1 million jobs attributable to the activity worldwide (Arlinghaus et al., 2002; Cisneros-Montemayor & Sumaila, 2010; Hyder et al., 2018; Steinback et al., 2004).

Despite its importance, recognition and governance of RF remains underdeveloped, particularly when compared to the commercial sector (Arlinghaus et al., 2019; Potts et al., 2020). A recent survey of fisheries experts identified ineffective management of the activity in 89% of the 28 countries surveyed, with respondents noting that management of RF was “worse” than that for industrialized and small-scale fisheries (Potts et al., 2020). This likely stems from: (i) an entrenched focus on commercial fishing, which historically accounted for greater catch, (ii) a historic perception that recreational fisheries were inconsequential (McPhee et al., 2002), and (iii) the logistical challenges associated with controlling the activity of a diverse sector consisting of a large number of individual fishers, fishing methods, platforms, waterbodies, access points, and target species (Iversen, 1996). A particular challenge is the right of access of recreational fishers and the associated limitations this places on management controls (e.g. limited entry) (Kearney, 2000). More recent recognition of the size and importance of RF means that integration of the sector into legislation, policy, and management strategies is essential for ensuring sustainability of the activity, while securing associated socio-economic benefits.

Recreational fishing and harvest strategies

Harvest strategies (HS) offer a means to integrate RF into the monitoring, assessment and management of fisheries that also include a commercial or small-scale sector (hereafter termed ‘multi-sector fisheries’). Sometimes referred to as management strategies (Butterworth & Punt, 1999; Dichmont et al., 2020), HSs are increasingly being used to manage fisheries because they are an improvement on previous approaches that were associated with fishery collapses (Dowling et al., 2020; Sainsbury et al., 2000). They are a formal and pro-active method for sustainable fisheries management, specifying the management actions needed to achieve stakeholder objectives, as well as the stock monitoring and assessment required to measure fishery performance against those objectives.

HSs lie at the centre of the fisheries management framework and consist of three core components data collection, assessment and management controls – along with numerous other elements (Figure 1, Sloan et al. 2014). Performance indicators, either empirical or arising from a model-based assessment, are compared to reference points that identify both a desirable fishery state (target reference point) and an unacceptable fishery state (limit reference point). Trigger reference points may also be used between the target and limit reference points to facilitate early intervention

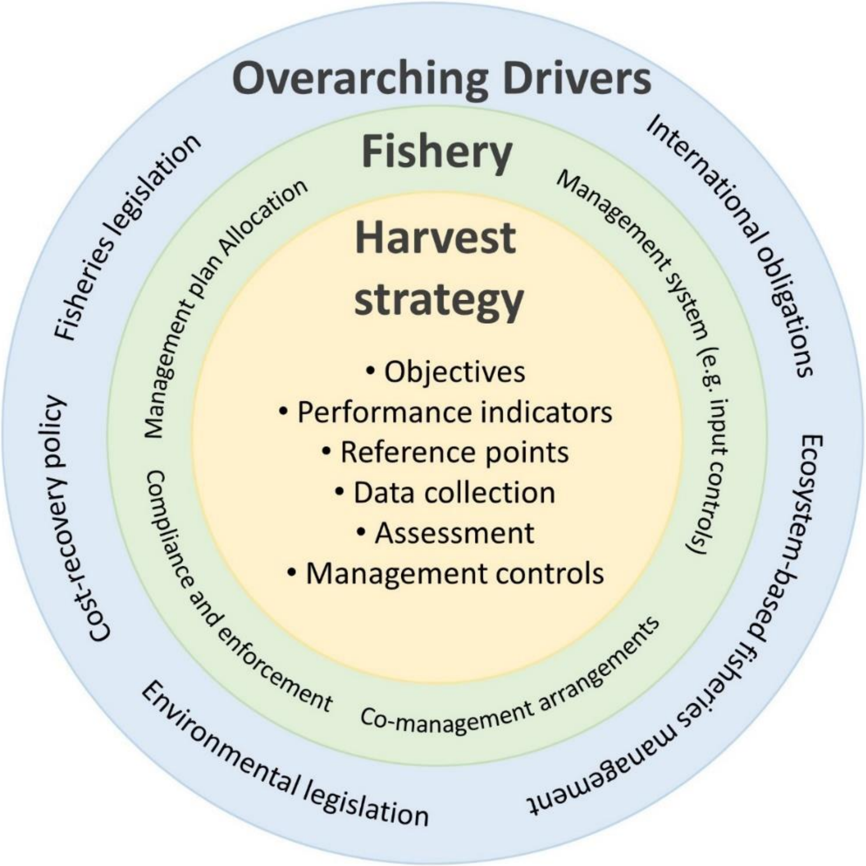


Figure 1 Diagram showing the main elements of a harvest strategy and where they fit within an overall fisheries management framework (figure adapted from Sloan et al. 2014).

before the limit is reached. By having pre-specified management controls that are explicitly linked to performance measures (the value of indicators relative to reference points) and drive a fishery towards its target, HSs are more likely to achieve desirable outcomes compared to previous management approaches (Dowling et al., 2015a; Froese et al., 2011).

HSs are developed to achieve fishing objectives and they must therefore consider the objectives of all stakeholder groups to ensure equitable outcomes. While the objectives of the commercial fishing sector are relatively well-understood, recreational fishing objectives are not. This is due to the diversity of motivations for RF and the large number of individual fishers, which complicates efforts to understand these motivations (Arlinghaus, 2006; Young et al., 2016; Tweedley et al., 2023). Objectives for RF may differ to those of other sectors (Pascoe et al., 2009). Commercial fishers, for example, are primarily motivated by the monetary value and profitability of their business operation, while recreational objectives are often social in nature and relate to the quality of the fishing experience; for example, the probability of encountering trophy-sized fish, enhancing social capital, and the aesthetic appeal of the fishing location (Young et al., 2016; Magee et al., 2018; Pascoe et al., 2019). The extent to which fishing objectives align among sectors is likely driven by the interaction of numerous factors at the individual fishery level. Recreational objectives may also differ among subgroups of the recreational sector, for example, sports fishers relative to consumptive fishers.

The Australian and New South Wales contexts

Australia supports diverse fisheries that vary greatly in their characteristics, both among and within jurisdictions. While numerous fisheries are large commercial operations that target one or a few key stocks, the majority are smaller scale, include multiple sectors and harvest a range of stocks. Despite lower financial value, small-scale fisheries often have high social and cultural significance.

RF is an important component of Australian fisheries. The activity increased rapidly following the advent of trailer boats during the 1960s (Frawley 2015), and by the year 2000, the national participation rate was estimated at 19.5%, with 3.36 million residents aged five or older fishing at least once in a 12-month period (Henry and Lyle, 2003). Most fishers at this time resided in the nation's most populous state of New South Wales (NSW), and although participation in NSW has declined since that time (11.7% in 2013, West et al. 2015), the most recent survey conducted in 2019/20 found that 321,115 residents fished at least once in NSW during a 12-month period, with a total estimated fishing effort of 1,653,531 days (Murphy et al. 2022). These fishers caught 7,849,661 individual organisms and 53% of those were retained.

HSs are now increasingly being applied to Australian fisheries in response to the demand for fisheries management that is transparent, decisive, consistent and effective. Uptake has been fostered by the development of specific policies and guidelines over the past two decades. In 2007, the establishment of the *Commonwealth Fisheries Harvest Strategy: Policy and Guidelines* (Australian Government 2007) greatly advanced the development of HS for Commonwealth fisheries. In 2014, the *National Guidelines to Develop Fishery Harvest Strategies* (Sloan et al. 2014) aimed to provide a unified approach across jurisdictions. At that time, no states or territories had formal HS policies and few had active HSs. The *National Guidelines* provided high-level technical advice on a range of common challenges encountered when developing HSs.

HS development has recently commenced in NSW and will include fisheries with a substantial RF component, both in terms of fisher participation and total catch. The *NSW Fisheries Management Act 1994* ("The Act") includes the object, "...to promote quality recreational fishing opportunities", and the NSW Harvest Strategy Policy (HSP) states,

> "Where stocks are shared among sectors (e.g. commercial, recreational, Aboriginal cultural fishing) this should be explicitly recognised in the management approach. Harvest strategies offer a mechanism to manage the overall extraction by all sectors, rather than having separate sector-specific processes."

To meet the requirements of The Act and the HSP, HSs in NSW will need to include RF for stocks where the sector has a substantial interest. NSW is following a formal Working Group process to develop HSs sequentially for key stocks and fisheries. The Working Groups include stakeholder representatives from those sectors involved in the fishery, as well as fisheries scientists, managers and economists.

Stakeholder participation in HS development

HS development for multi-sector fisheries requires a transparent and defensible process, due to complexities in addressing diverse objectives and apprehension of fisheries management processes among stakeholder groups. Structured workshops that use easily understandable, interactive decision support tools and involve independent experts and stakeholder representatives are likely to provide best outcomes. Broad stakeholder representation is essential to ensure the interests of the range of RF sub-groups (e.g. anglers and spearfishers) are adequately addressed. Broader consultation with more fishers is required to determine whether outcomes from workshops are generally representative of RF views within a fishery.”

FishPath is a leading HS decision support tool and ‘bottom-up’ engagement philosophy that allows experts and stakeholders to interactively contribute to HS development in a transparent workshop setting (Dowling et al. 2016, https://tool.fishpath.org/). It consists of three components: the FishPath Tool, the FishPath Process and the FishPath Network. The FishPath Tool uses a diagnostic questionnaire to elicit information on fishery characteristics and circumstances, specifically: 1) the biology of the species of interest, (2) the fishery operational characteristics, (3) the availability and types of data, 4) the socioeconomic context and (5) the governance systems and policies affecting the fishery (Figure 2; Dowling et al. 2016). Fishery characteristics are then compared to the requirements of the three core HS components – data collection, assessment, and management measures. The user is then presented with a list of options for which minimum criteria have been met, along with a range of caveats regarding their use. The Tool provides specific, stepwise advice on how to narrow down the list of options to a shortlist for consideration by stakeholders (Working Groups in NSW). The Tool does not specify the form of the control rule(s), just the management measures that may be viable. Although the Tool was originally developed for data and capacity-limited (DCL) fisheries, it can potentially be applied to any fishery.

The FishPath Tool sits within a broader approach for HS development – the FishPath Process (Dowling et al. 2023). The core of the Process is stakeholder participation, with participants guided through, and contributing to, the development of a HS. The benefits of this approach are enhanced when combined with training and capacity building. The Process comprises four phases that span an initial application of the FishPath Tool in a group setting, through data exploration and analysis, to integration of FishPath Tool options into a HS, and finally implementation and refinement (Figure 3). The FishPath Network comprises a global network of practitioners that are trained in applying the Tool and the Process.

Project need

Integration of RF in HSs is necessary for many fisheries in Australia, to account for catches that can equal or exceed commercial catch for some key species and to address biological and experiential objectives of the RF sector. Both the Productivity Commission’s report Marine Fisheries and Aquaculture (2016) and the ICES Report from the Working Group Recreational Fishing Surveys (2018) recommend formal integration of RF into stock assessments and harvest strategies. Failure to do so puts sustainable management goals and legislated state and Commonwealth fisheries requirements at risk.

Equitable and quantitative inclusion of RF in HSs is rare. It is therefore unclear: 1) what types of RF data and monitoring best service stock assessments, (2) which data also track indicators of recreational objectives (often related to the fishing experience), and (3) how to integrate HS components for multiple sectors. The need to address these knowledge gaps was highlighted by the FRDC priority research call in 2018 - “Integrating recreational fishery data into harvest strategies for multi-sector fisheries in New South Wales”. NSW provides an important test case for addressing issues around RF integration that are faced by most jurisdictions.

The FishPath Tool and Process offer the means to develop an effective multi-sector HS via ‘bottom-up’ stakeholder engagement and participation, including RF representatives. However, additional development in recreational and multi-sector contexts would improve application, enhance stakeholder engagement and likely provide better outcomes.

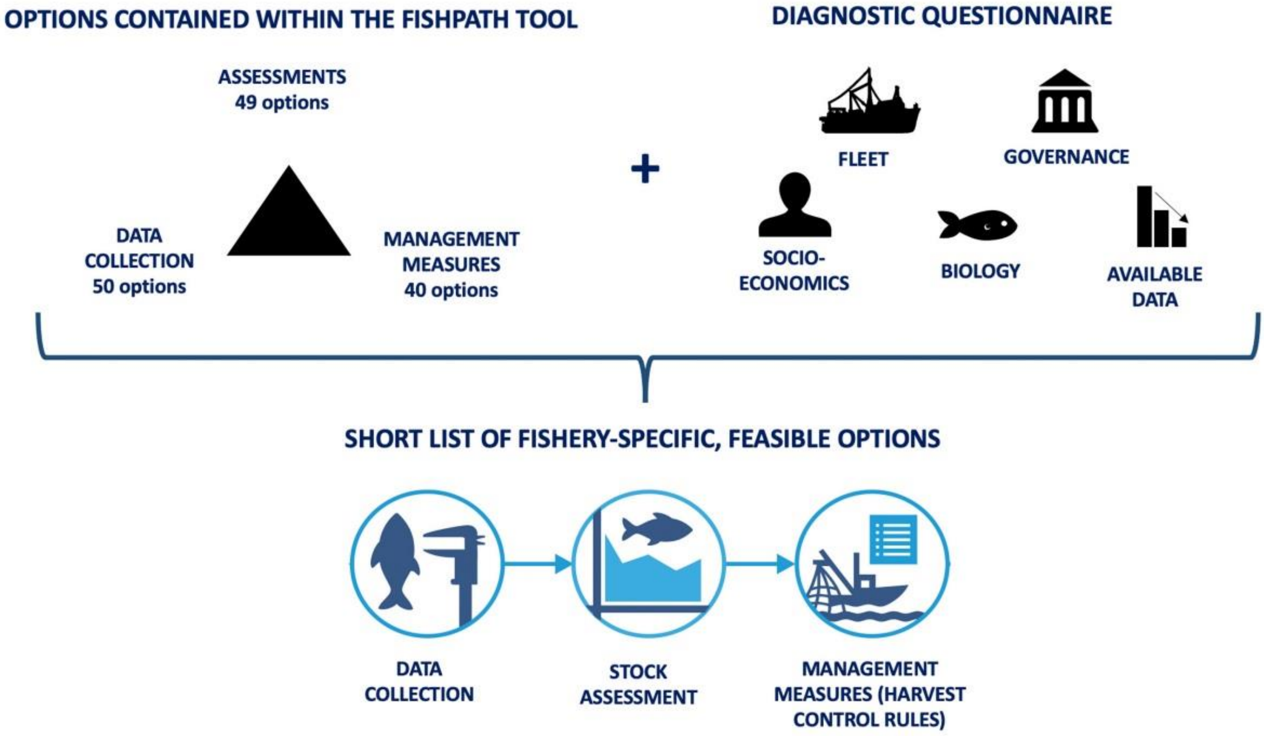


Figure 2 Conceptual diagram of the FishPath Tool showing the elements of the diagnostic questionnaire for the three HS components – Data Collection, Assessment and Management Measures. Answers to the questions are then used to tailor a shortlist of feasible options for the fishery. Figure reproduced from Dowling et al. 2023.

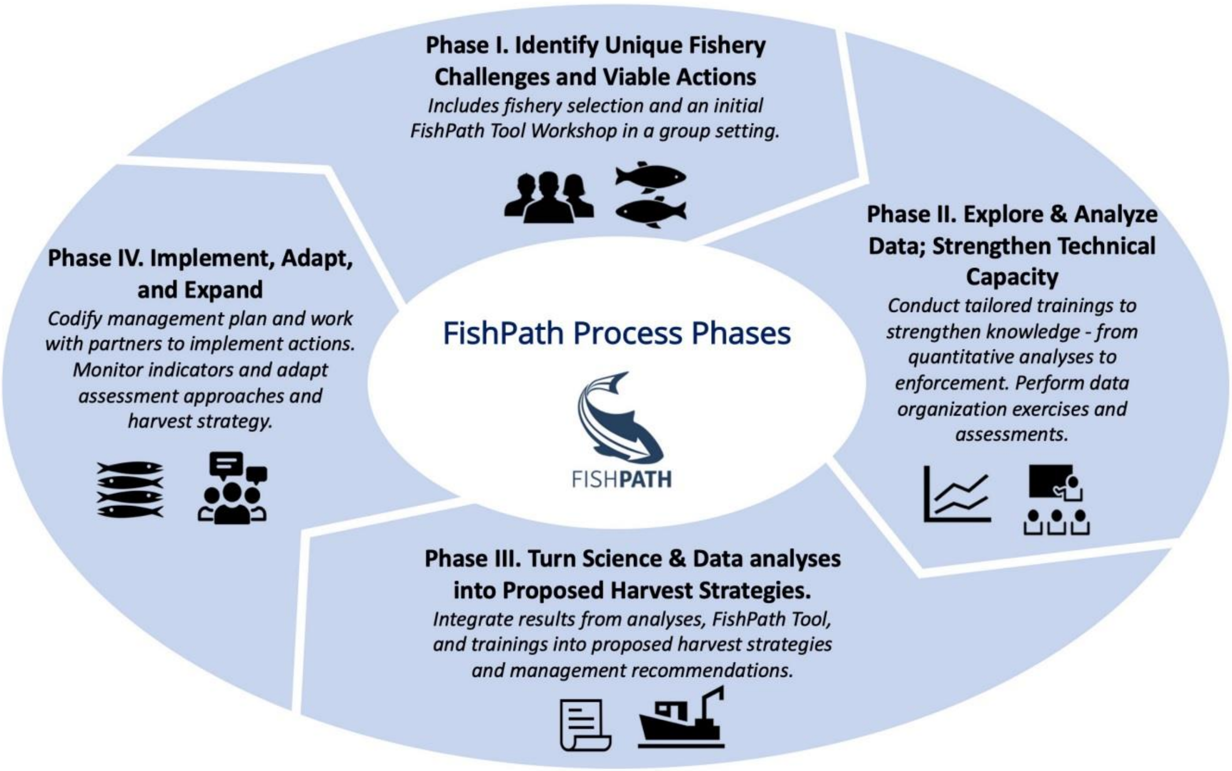


Figure 3 The four phases of the FishPath Process. Figure reproduced from Dowling et al. 2023.

Project objectives

Original objectives

1. Obtain information on recreational fishing objectives and facilitate improved understanding among recreational fishers of the role of harvest strategies.

2. Identify types of recreational fishing data and monitoring that provide reliable measures of both the biological and experiential performance of fished populations.

3. Interrogate and extend the FishPath decision support software tool to better characterise and integrate recreational fishing information into harvest strategy development for multi-sector fisheries.

4. Develop guidelines and recommendations for the integration of recreational fishing information into harvest strategies for multi-sector fisheries.

5. Develop draft harvest strategies for key multi-sector fisheries using outcomes from Objectives 1-4.

Project modifications and additional research and development

An unanticipated change to workshop methodology during the initial stages of the project resulted in significant cost savings that were used for additional research and development to enhance project outcomes. Workshops with recreational fishers in NSW (see Methods) were initially planned to be face-to-face. However, in response to the COVID-19 pandemic, restrictions were placed on travel, group events, and social interaction by the NSW State Health Department. The Recreational Fishing Research Workshops (RFRWs) were therefore held online, which eliminated budgeted expenditure on travel, accommodation and venue hire.

All additional research and development using project funds was approved by FRDC. Additional work included:

1) <u>A statewide survey of recreational fishing objectives</u> – this was undertaken to obtain information on priority fishing objectives from a broader spectrum of recreational fishers in NSW. The survey greatly expanded the information obtained from participants in the RFRWs. Survey results contributed to Objective 1.

2) <u>Development of a national HS database</u> – this work extends the review of Australia HSs undertaken for Objective 1. Data collected from published Australian HSs was used to build a searchable online database. The database allows practitioners to search for HSs developed for particular environments, types of fisheries or stocks and those that include specific components or elements.

3) <u>Development of a recreational fishing filter for FishPath</u> – this work extends the review and revision of the FishPath Tool conducted for Objective 3. The filter allows a workshop facilitator to customise the questionnaire, including only those questions they consider relevant for a particular recreational fishery, without compromising the Tool’s functionality. The filter aims to increase stakeholder engagement and understanding by reducing questionnaire burden.

Steering Committee

A Steering Committee (SC) was established to evaluate progress of the project relative to objectives and provide advice on future direction. The SC initially consisted of scientific experts but was later broadened to include recreational and commercial fishers, with both NSW and national experience. The SC met annually throughout the life of the project.

Report structure

The report is structured around the objectives. Methods are first presented for each objective, then results, discussion and, where necessary, conclusions are presented. Methods and results for Objective 5 were omitted at the time of first publication because they included confidential information from ongoing HS development via formal Working Groups.

Methods

Objective 1 - Obtain information on recreational fishing objectives and facilitate improved understanding among recreational fishers of the role of harvest strategies

Recreational Fishing Research Workshops

Workshops are an effective method for obtaining detailed operational and social information from fishery stakeholders while also providing information on fisheries research and management processes that affect stakeholders. While stakeholder workshops are typically undertaken for management purposes, they can also be effective for collecting fishery data, particularly where variables of interest are related to stakeholder interests and experiences (Yochum et al. 2011). Workshops ideally include stakeholders, managers, and scientists within a fishery, to ensure a holistic and balanced process. While harvest strategy workshops typically include all stakeholder groups within a fishery, preliminary workshops with individual groups can be useful for identifying sector-specific objectives and priorities.

Selection of stocks

Fishing objectives may differ among stocks, due to their inherent characteristics and the interests of fishers that target them. Objectives are therefore best developed at the stock level.

Three fin-fish stocks were identified as both important to recreational fishers in NSW and of interest for harvest strategy development in the near-term: Mulloway (*Argyrosomus japonicus*), Yellowtail Kingfish (*Seriola lalandi*), and Snapper (*Chrysophrys auratus*).

All three stocks are distributed throughout coastal NSW. They inhabit all saline waters, from estuaries through to coastal offshore, depending on season and life-cycle stage. Mulloway in NSW has declined since the mid-1970s and was classified as depleted at the time of the workshops (Hughes 2021). Yellowtail Kingfish are highly mobile and move between NSW and multiple other jurisdictions in Eastern Australia. Fish in this region are therefore considered a single biological stock which was classified as sustainable in the most recent assessment (Hughes and Stewart 2021). Stock assessment for Snapper is conducted at the jurisdictional level, with the NSW assessment at the time of the workshops indicating the NSW component of the stock was sustainable (Stewart et al. 2020).

All three species are prized sportfish with excellent eating qualities. Mulloway are often targeted in estuaries in NSW, where large individuals can be accessed using small boats or from shore. Yellowtail Kingfish and Snapper are primarily targeted on coastal reefs, with larger Yellowtail Kingfish typically found offshore. The most recent statewide RF survey (2017/18) at the time of the workshops found that recreational harvest of Mulloway, Yellowtail Kingfish and Snapper in NSW was estimated at 90 t, 129 t, and 106 t, respectively (Murphy et al. 2020). The recreational harvest of both Mulloway and Yellowtail Kingfish exceeded the commercial harvest in that time period (56 and 58%, respectively), with the recreational harvest of Snapper comprising 38% of total harvest.

Ethics

This study was approved through the NSW DPI Fisheries Research Human Ethics process in accordance with the National Statement on Ethical Conduct in Human Research 2007 (“National Statement”, updated 2018, www.nhmrc.gov.au). Participation in this study was voluntary and participants could opt out at any time. The identities of participants are kept confidential, consistent with the National Statement.

Workshop process

Participation

Fishing objectives were elicited from RF stakeholders in NSW during workshops held by NSW DPI Fisheries in March, 2021. Workshops were held online, after normal working hours, to increase participation of fishers located throughout the state, and to comply with COVID-19 restrictions. Twenty active RF stakeholders were invited to attend the workshops based on their knowledge and experience targeting the selected stocks in NSW. Some RF attendees had expertise across all three stocks while others specialised in one of the three. Other attendees included fisheries scientists and managers from NSW DPI Fisheries, and fisheries scientists from CSIRO, University of Wollongong, and University of Tasmania. Workshops were facilitated by an independent scientist specialising in recreational fisheries.

Sessions

Workshops consisted of a series of short (1.5-2 hours) sessions designed to accommodate personal schedules and minimise stakeholder fatigue (Figure 4). They involved a combination of presentations from scientists and managers, and group discussions. Sessions commenced with an Information Session for all stocks combined, which included: 1) an outline of the project and purpose of the workshops, 2) a presentation on harvest strategies, and 3) presentations on current stock status, assessment and management for each of the three stocks. RF stakeholders were then asked to consider their preliminary objectives for each stock in preparation for the next session.

Objectives Sessions were held separately for each of the three stocks (Figure 4). In Objectives Session 1, facilitated group discussions were used to build a preliminary list of objectives for each stock. A generic list of RF objectives sourced from the scientific literature was provided as a guide (Table 1). Generic objectives were organised into three tiers – broad, sub-, and specific. The broad tier reflected the four major categories of fishing objectives – ecological/biological, economic, social, and managerial (Stephenson et al. 2018). Objectives then became increasingly specific through the lower two tiers. Not all sub-objectives required further specification.

RF stakeholders were first divided into small separate groups online (2-4 person) to consider which of the generic objectives were appropriate for the particular stock under consideration and which were not, while also adding objectives required for the specific stock. Findings from the small groups were then reported to all workshop participants by a spokesperson, discussed and combined. Between sessions, scientists and managers consolidated objectives that were similar and classified them according to whether they were suitable for inclusion in a harvest strategy. This decision was purely technical and based on whether the objective could be achieved through control of harvest. Three categories of suitability were used – “in scope”, “in scope but difficult to measure”, and “out of scope”. Wording of objectives was also refined, to ensure consistency, brevity and precision.

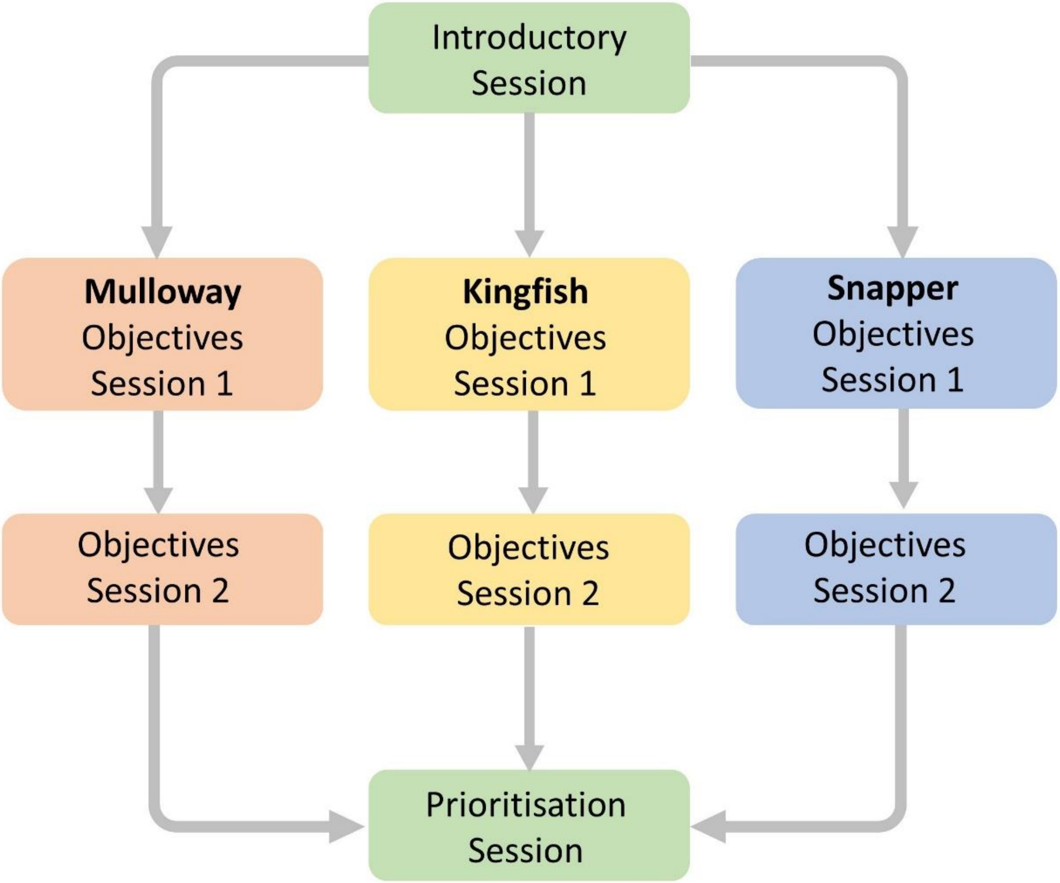


Figure 4 Arrangement of the separate workshop sessions.

Table 1 Generic list of RF objectives developed from a review of the scientific literature and provided to workshop participants as a base to assist their development of objectives specific to Mulloway, Yellowtail Kingfish, and Snapper in NSW. Objectives are organised into three tiers of specificity; broad objectives (bold headings), sub-objectives (left column), and specific objectives (right column).

Ensure ecological sustainability	
Catch fish	Reduce the number of fishless trips Maximise the number of fish caught per fisher day
Receive bites or strikes	Maximise the number of strikes or bites per fisher day
Obtain food	Maximise the number of legal-sized fish caught per fisher day
Catch large or 'trophy' fish	Ensure 'trophy' fish are available in the fishery Increase the chance of catching large fish
Ensure a sustainable fishery	Maintain sustainable stock biomass Increase fisher awareness of sustainable fishing practices Increase RF understanding of population biology and stock assessment Reduce fishing infringements
Avoid environmental impacts of fishing	Minimise mortality of bycatch species Minimise mortality of undersized fish Minimise interactions with Threatened, Endangered, Protected (TEP) species Minimise pollution generated by RF Reduce habitat damage Limit the transfer of aquatic pest species
Enhance economic performance	
Maximise the value of the recreational experience	Maximise the value of the recreational experience
Generate economic value for the RF industry	Maximise profit for RF charter industry Maximise profit for RF tackle industry
Generate economic value for communities	Maximise flow-on economic benefits to local communities
Minimise financial costs	Minimise cost of managing the fishery Minimise cost of compliance for charter industry

Maximise social outcomes	
Easy access to fishing locations	Improve physical access to fishing locations Optimise the number, size and quality of boat ramps
Improve participation in RF ('grow the sport')	Increase the number of individuals participating in RF each year Increase time spent fishing
Compete against other fishers	Increase opportunities to compete in fishing tournaments
Equitable access to fish stocks	Maintain equitable allocation of catch among fishing sectors
Enhance social networks, or social capital	Increase networking opportunities within the RF community
Foster a positive public image of RF	Minimise negative public perception of environmental impacts Improve public understanding of socio-economic benefits of RF Minimise negative interactions with other aquatic users
Improve fishing knowledge	Increase knowledge of fishing techniques Increase knowledge of fishing locations Increase knowledge of target species
Enjoy the outdoors/nature	Maintain/improve the aesthetic beauty of fishing locations
Spend time with friends and family	Increase the time spent fishing with friends and family
Relaxation, or to reduce stress	Enhance the relaxative effect of fishing
To be on your own	Avoid interactions with other people
Enhance management performance	
Flexible management to meet RF needs	Broaden the range of rec-specific harvest strategy components used Optimise the period between harvest strategy reviews Include 'breakout' rules for RF in harvest strategies
Transparent management	Increase consultation periods on management changes Improve the clarity of fisheries management documentation Improve the distribution of fisheries management information

	Simplify fishing regulations
Involvement in fisheries management processes	Increase recreational representation in fisheries management advisory processes Improve partnerships between recreational fishers and fisheries management Provide opportunities for co-management

In Objectives Session 2, the refined objectives and suitability classifications were presented to RF stakeholders and further refinements were made through group discussion. Potential management measures and considerations suggested by RF stakeholders were also discussed, including the fishing sectors that might be involved. Following the session, scientists translated objectives in the harvest strategy shortlist (see below) into non-technical language, to increase comprehension within the statewide survey component of the project.

The final Prioritisation Session was combined across all stocks. It included presentations on prioritising fishing objectives using stakeholder preferences and a survey designed to elicit those preferences from RF stakeholders attending the workshops. The survey was anonymous and completed online following the workshops. Survey results from workshop participants will be compared to those from a broader survey of RF objectives throughout NSW (a later component of this project) and are therefore not reported in this document.

Identifying priority RF objectives

This study aimed to extend the outcomes of the Recreational Fishing Research Workshops (RFRWs) by determining whether some of the RF objectives identified are considered more important than others (hereafter ‘priority’ or ‘preferred’ objectives) by recreational fishers in NSW. If recreational fishers prefer some objectives over others, this information can be used to prioritise them for inclusion in HSs – an essential step given that HSs function best with a small number of objectives. Prioritisation of objectives is particularly important when developing HSs for multisector fisheries, because each sector may have its own suite of fishing objectives, thereby increasing the total number of objectives that must be considered for a single strategy.

This study also aimed to determine if objective preferences differed among the three fish stocks examined, the three respondent groups in the survey, or subsets of the recreational fishing community as defined by their demographic and fishing operational characteristics (see below).

Ethics

This study was approved through the NSW DPI Fisheries Research Human Ethics process in accordance with the National Statement on Ethical Conduct in Human Research 2007 (“National Statement”, updated 2018, www.nhmrc.gov.au). Participation in this study was voluntary and participants could opt out at any time. The identities of individuals contacted for the random survey component (see below) are kept confidential, consistent with the National Statement. Online surveys were completed anonymously.

Survey design and implementation

Preferences among objectives were elicited from recreational fishers in NSW using online surveys. Three groups of fishers were surveyed: 1) a random spatially-stratified sample of NSW residents that hold either a one- or three-year recreational fishing licence (hereafter 'random' group), 2) a self-selecting group that accessed the survey via the NSW DPI Fisheries website (hereafter 'self-selecting' group), and 3) the participants of the RFRWs (hereafter 'workshop' group). The random group were 'long-term' licence holders, as opposed to one- or three-day licence holders. Fishers from this group were sampled using a two-step telephone-online approach, where initial contact was made via telephone (mobile or landline) and a weblink to one of the three online surveys was then provided to the respondent if they: a) indicated willingness to complete the survey, and b) had fished for at least one of the three stocks of interest (see below) in the previous 12 months. A random sample of 20,000 fishers was drawn from the database of NSW licence holders. The sample was spatially stratified across nine residential survey strata defined by the Australian Bureau of Statistics (Figure 5), with the number of individuals selected from each stratum weighted according to the relative proportion of fishers located in each stratum. Due to the much larger number of fishers within the metropolitan Stratum 1 (greater Sydney, 49% of fishers), the number of individuals sampled from this stratum was down-weighted by two-thirds. This allowed greater sampling effort in other strata, increasing the chance of identifying target respondents in less populated areas. Stratum 10 was excluded from the survey because this represents a separate jurisdiction from NSW, the Australian Capital Territory (ACT).

Surveys were initially completed by the workshop group who were provided with weblinks to electronic versions following completion of the RFRWs in March, 2021. In the following year, social media posts on fishing-specific pages were used to communicate the survey and provide weblinks to recreational fishers throughout NSW (self-selecting group). A weblink to the surveys was also provided on the recreational fishing homepage on the NSW DPI Fisheries website. The survey commenced on 14th Mar 2022, at which time phone calls for the random group were initiated. The survey remained open for six weeks. Surveys were provided in six different languages, including English, and were mobile-compatible. Surveys were produced using Qualtrics software.

Survey content and calculation of preferences

Non-technical methods summary

- Separate surveys were used to obtain information on fishing practises, fishing objectives and fisher characteristics for each stock.
- Preferences among fishing objectives were calculated for each survey respondent using their scores provided in Part 2 of the survey.
- Sub-groups (or clusters) of RF fishers were identified using responses on demographics (e.g. age) and fishing operations (e.g. gear type).
- Preferences were compared between fishing objectives, the three fish stocks, the three survey respondent groups and the RF subgroups (clusters).

A separate survey was used for each of the three fish stocks considered in the workshops - Mulloway, Yellowtail Kingfish and Snapper – due to the minor differences in the objectives identified for each stock during the RFRWs (see Tables 6, 7 and 8). Separate surveys were also used because preferences among objectives may differ among stocks, even when the objectives themselves are common. Surveys consisted of three parts, outlined below:

Part 1 – "Fishing practices" – contained questions about the respondent's fishing background, experience and operations as they related to the specified stock within NSW waters.

Part 2 – "Recreational fishing objectives" – asked respondents to score the relative importance of RF objectives for the specified stock within NSW waters.

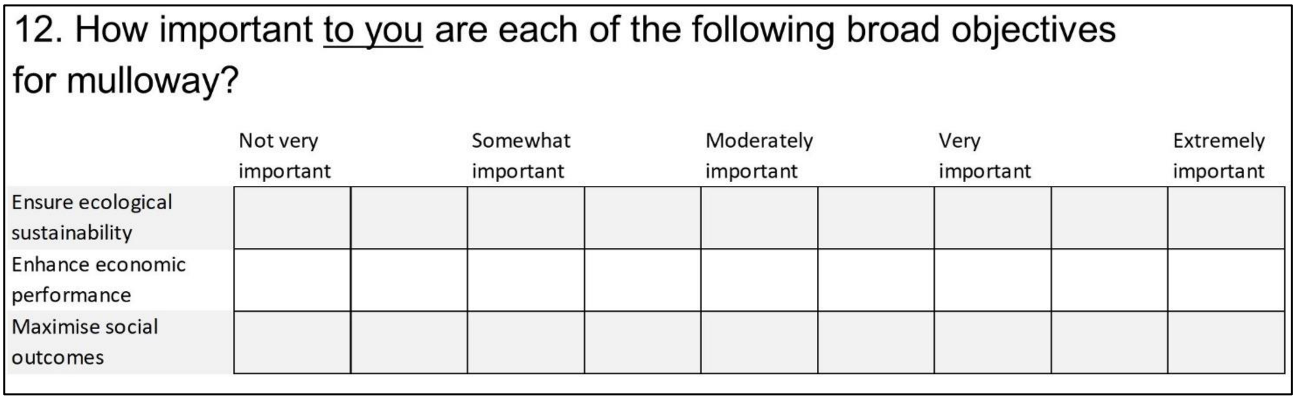
Part 3 – "About you" – contained questions on demographic characteristics of the respondents, including age and gender.

Multiple-choice responses were provided for questions in Parts 1 and 3. The objectives used in Part 2 were those from the shortlists of HS-specific objectives identified during the RFRWs (Tables 6, 7 and 8). The hierarchy from broad to specific objectives was maintained in the survey by grouping objectives according to their position in the hierarchy. The three broad types of objectives (ecological, economic, and social) were presented to the respondent first (Figure 6), then the sub-objectives within each broad group were compared, then the specific objectives within each sub-objective. Respondents were asked to score objectives according to their relative importance on a nine-point Likert-like scale, from "extremely important" ('9') through to "not very important" ('1'). To force a distinction regarding relative importance, respondents were unable to give the same importance score to objectives within a hierarchical group.

Preferences among objectives were quantified from the scoring data and converted into a scale of priority weightings using Analytical Hierarchy Process (AHP). AHP is a method of Multi-Criteria Decision Analysis (MCDA) that uses a series of pairwise comparisons to determine a weighting for each criterion (Saaty 1987). In the current study, the criteria were the numerous alternative RF objectives that may be used in a HS. AHP has been applied extensively in environmental decision-making (Schmoldt 2001, Kiker et al. 2005, Dos Santos et al. 2019), and has previously been used to determine stakeholder preferences among fishery objectives (Mardle et al. 2004, Pascoe et al. 2009, Pascoe et al. 2019). In addition to determining overall objectives preferences for recreational fishers in NSW, AHP weightings were used to quantitatively examine potential differences in preferences among RF sub-groups (see below).

The structure of the preference survey component (Part 2) and the AHP calculations of Pascoe et al. (2019) were followed, to limit issues associated with remote completion of surveys by respondents and the unintentional inconsistencies that can arise from repeated pairwise comparisons in traditional AHP. All objectives within a hierarchical group were presented together to the respondent, rather than presenting every pairwise combination separately (see Figure 6). This allows the respondent to retain some understanding of broader relativity when making preference decisions, while still being blinded to the entire hierarchy of objectives. The latter property of AHP testing is important to retain, because it reduces the ability of the respondent to engineer a desired result ('gaming'). The method of presenting multiple objectives simultaneously eliminates the need to test for inconsistency and thereby avoids arbitrary decisions with respect to whether inconsistency in a survey meets a suitable standard (Pascoe et al. 2019).

Figure 5 ABS-based strata used to weight the random telephone sample for the survey of RF objectives in NSW. Strata 6a and 6b were combined for the survey and Stratum 10 (ACT) was not included. Figure reproduced from West et al. 2015.



12. How important to you are each of the following broad objectives for mulloway?

	Not very important		Somewhat important		Moderately important		Very important		Extremely important
Ensure ecological sustainability									
Enhance economic performance									
Maximise social outcomes									

Figure 6 Example question from Part 2 of the survey, showing three RF objectives the respondent was asked to compare with respect to their relative importance.

In the current approach, a separate importance score is obtained for each objective (1 to 9). Relative scores between pairs of objectives are estimated by subtracting one from the other, according to:

$$a_{i,j} = \begin{cases} a_i - a_j + 1 \; if \; a_i - a_j > 0 \\ \frac{-1}{a_i - a_j - 1} \; if \; a_i - a_j \leq 0 \end{cases} \quad and \; a_{j,i} = \frac{1}{a_{i,j}} \tag{1}$$

where a_i and a_j are the scores for two objectives (*i* and *j*). Derived scores were assumed to be symmetrical, such that a score of 9 when considering Objective 1 relative to Objective 2, would be 1/9 when considering Objective 2 relative to Objective 1. A matrix of relative scores could therefore be produced for each set of objective comparisons within a hierarchical group:

$$A = \begin{bmatrix} 1 & a_{12} & \dots & a_{1n} \\ a_{21} & 1 & \dots & a_{2n} \\ \dots & \dots & \dots & \dots \\ a_{n1} & a_{n2} & \dots & 1 \end{bmatrix} \tag{2}$$

Weights for each objective (w_i) were then calculated using the geometric mean method (GMM, Crawford and Williams 1985), which performs better than the original method based on eigenvalues with respect to the influence of extreme preferences (Pascoe et al. 2019):

$$\omega_i = \frac{\left(\prod_{j=1}^{n} a_{i,j} \right)^{1/n}}{\sum_i \left(\prod_{j=1}^{n} a_{i,j} \right)^{1/n}} \tag{3}$$

Where $\prod_{j=1}^{n} a_{i,j}$ is the product of relative scores across row i and *n* is the total number of objectives being compared within a hierarchical group.

The GMM was applied within each group of objectives within each level of the hierarchy (e.g. Figure 6). Weights for the three broad objectives were calculated together in a single GMM analysis. Then, weights were calculated for the sub-objectives within each broad objective, for example, weights were calculated for 'ensure a sustainable fishery' and 'minimise lost fishing gear…' within the 'ecological' broad objective. Finally, weights for the specific objectives were calculated within each of the sub-objectives. Final weights for each objective were obtained by multiplying up through the objectives hierarchy, such that the final weight for a specific objective was obtained by multiplying the specific weight by the weight of the overlying sub-objective and then by the weight of the overlying broad objective ($w_{specific} \times w_{sub} \times w_{broad}$).

Statistical analyses

Respondent characteristics were first explored to identify potential sub-groups of recreational fishers that do not necessarily relate to the stock of interest. Responses regarding fishing operations and demographics from the random group were pooled across the three stocks and explored together using multivariate distance-based hierarchical clustering on nominal data types. The continuous variables of age, years of fishing experience and days fished per year were converted to categorical variables for the cluster analysis by dividing the data range into seven categories of 10 units each.

Clustering was done using the *nomclust* package (Šulc et al. 2022) in R (v. 4.3.1), with the 'Lin' dissimilarity measure (Lin 998) combined with the average linkage method. Lin is based on the relative frequencies of the observed categories, assigning higher weights to more frequent categories in the case of a match and lower weights to less frequent categories in the case of a mismatch. The average linkage method uses the average pairwise dissimilarity between objects in two merged clusters, which differs to other linkage methods that use only a single dissimilarity value to determine the distance between clusters. The combination of Lin dissimilarity and average linkage has been found to provide the most coherent clusters (Šulc and Rezanková 2019). Evaluation of the optimal number of clusters was done using a suite of methods that differ in how cluster quality is determined. Methods were: the pseudo-F index based on entropy (PSFE), the pseudo-F index based on mutability (PSFM), the BK index, the modified AIC and BIC indices, and the silhouette index (SI). PSFE, PSFM, BK determine cluster quality based on the degree of within-cluster variability, BIC and AIC are likelihood-based, and SI determines cluster quality using within- and between-cluster distances. The optimal number of clusters was determined according to majority consensus across these methods (Šulc et al. 2022). Dendrograms of three- and five- cluster scenarios were also produced to visually examine cluster integrity.

To identify specific variables contributing to cluster separation in the optimal scenario, each operational and demographic variable was compared between the four clusters using univariate statistical methods. ANOVA was used for the original continuous data for age, years fished and days while chi-squared tests were used for the nominal variables (targeting, habitat, region, method, fishing platform, and gender).

Preference weights were compared among objectives, stocks and respondent groups using generalised linear mixed models (GLMMs; Bolker et al. 2009). Each level of the objectives hierarchy was analysed separately; for example, broad objectives were analysed separately from specific ecological objectives. This was done because final preference weights are determined by multiplying individual weights through the hierarchy, such that final weights tend to become smaller at lower hierarchical levels that are subject to greater multiplication. All three respondent groups (random, self-selecting and workshop) were included in each analysis. All three stocks were included where possible, i.e. where each stock had the same objectives within a level of the hierarchy. The full model structure, when all stocks were included, was (in script notation):

```
Weight ~ Objective + Stock + Objective:Stock + Group + Group:Objective + (1|Respondent)
```

Key model terms relevant to the study aims were Objective, which tested for differences in preference weights among objectives within a level of the hierarchy, Objective:Stock, which tested whether the pattern of weights across objectives differed among stocks, and Objective:Group, which tested whether the pattern of weights across objectives differed among respondent groups. The Respondent term was a unique identifier for each survey respondent, treated as a random effect to address the fact that each respondent provided data for multiple objectives. This term was included in all models.

Preference weights were also compared among the clusters identified within the random respondent group using the same GLMM approach as above. The full model structure[1] was (in script notation):

Weight ~ Objective + Cluster + Objective:Cluster + (1|Respondent)

The best combination of fixed effects was identified using model selection based on relative model fit and parsimony determined by Akaike's Information Criterion (AIC). Maximum likelihood (ML) estimation was used for model comparisons. The best model was then rerun using restricted maximum likelihood (REML) to produce unbiased parameter estimates. Efron's pseudo-r^2 was calculated for each model, which is a suitable metric for examining variance explained in logistic models (Efron, 1978). Tukey's tests adjusted for multiple comparisons were used to compare means among objectives within respondent groups.

Data were explored prior to analysis using boxplots, Cleveland plots and scatterplots following the protocol of Zuur et al. (2010). Given that the response variable (Weight) was continuous and bounded by 0 and 1, the ordered beta distribution with logit link was used (Kubinec 2023). The suitability of this distribution was confirmed visually using standard model diagnostic plots, including Q–Q plots of residuals.

Modelling was done in R (ver. 4.3.1, R Foundation for Statistical Computing, Vienna, Austria) using the *glmmTM*B function from the 'glmmTMB' package (Brooks et al. 2023). Model diagnostics were produced using the 'DHARMa' package (Hartig 2022).

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[1] Note that data were pooled across stocks for cluster analysis, so a Stock term was not included within these models. The focus of these analyses was to test whether the preference weights among objectives differed among clusters, hence the focal term was Objective:Cluster.

Objective 2 - Identify types of recreational fishing data and monitoring that provide reliable measures of both the biological and experiential performance of fished populations

This objective was addressed using three separate desktop reviews aimed at developing a holistic understanding of RF inclusion in HSs to date, including the types of data and monitoring used and their potential to measure fisheries performance across a range of objective types. The first review explored the type and extent of RF inclusion in HSs internationally, including recreational data collection. The second provided a detailed examination of the objectives included for commercial and recreational sectors in Australian HSs, the indicators used to measure fishery performance against these, and the management measures enacted when reference points are reached. This, and additional information on other HS components, were used to develop a searchable electronic database of HSs in Australia. The third review examined specific data sources and monitoring programs in a case-study jurisdiction (NSW) and linked these to RF objectives they may be used to monitor fishery performance for.

Review 1: International inclusion of RF in HSs

Nations were selected on the basis of an ‘average’ or ‘good’ score regarding the efficacy of RF management, as determined by Potts et al. (2020), and the availability of suitable experts (see below). We focused on nations with relatively good RF management because HSs from these nations are most likely to include RF where the sector is present within a multi-sector fishery. Canada was included despite a ‘poor’ score being recorded for the province of British Columbia because of the explicit incorporation of RF in fisheries policy at multiple jurisdictional levels (Potts et al., 2020). Two additional inclusions were the United Kingdom (UK) and São Paulo State, south-eastern Brazil; the former provides a contrasting case study of emerging RF management in a high-income country, while the latter provides a case study of high RF participation in a low- or middle-income country.

Expert knowledge was used to obtain information on HSs because these documents are often not publicly available or are contained within ‘grey’ literature that is difficult to locate using internet searches. Terminology for the same HS components also varies among regions, which may be misinterpreted by external practitioners, and language barriers provide additional challenges to HS interpretation. An expert can be defined as anyone with relevant and extensive or in-depth knowledge of a topic of interest that is not widely held by others (Krueger et al., 2012; Martin et al., 2012). Experts for the current study were mostly identified from the primary literature on RF. Some of these individuals identified additional experts in their nation to assist with specific regions. Based on expert recommendation, two nations were divided into separate regions for analysis; the United States (U.S.) was divided into four regions (NW, NE, SW, SE), and Spain was divided into two regions (Atlantic and Mediterranean). Experts included fisheries scientists, managers, and economists with 6–36 years of experience within their nation, as well as some with extensive international experience in fisheries research. All had experience with RF, and most experts indicated additional experience with either commercial or small-scale fisheries.

We used a multiple-round expert elicitation process based on the approach outlined in Martin et al. (2012). A questionnaire was used to elicit knowledge in three main areas: (1) the characteristics of multi-sector marine fisheries that involve the RF sector in the expert's region or nation; (2) the elements of a HS that have typically been specified for each fishing sector; and (3) the types of RF objectives addressed by HSs and the nature of any stated conflicts between sectors. Three fishing ‘sectors’ were considered – recreational, commercial, and small-scale. Recreational fishing is defined as ‘fishing of aquatic animals (mainly fish) that do not constitute the individual's primary resource to meet basic nutritional needs and are not generally sold or otherwise traded on export, domestic or black markets' (FAO, 2012; Hyder et al., 2020). While it is acknowledged that small-scale fisheries are diverse and an all-encompassing definition is challenging (Kurien & Willmann, 2009), for the purposes of this study we consider the small-scale 'sector' to encompass typically traditional fishing involving households (as opposed to commercial companies), using a relatively small amount of capital and energy, relatively small fishing vessels (if any), making short fishing trips, close to shore, and mainly for local consumption (Di Cintio et al., 2022; FAO, 1999). Small-scale fishing includes subsistence, cultural, and artisanal activities, where catch from the latter may be sold but only in small quantities to local markets. Commercial fishing was considered to be any fishing activity where the catch is sold and the operation is more substantial in scale than that encompassed by our small-scale definition.

The HS elements evaluated were those identified by Sloan et al. (2014) and are outlined in Table 2. Both conceptual (qualitative) and operational (quantitative) objectives were examined to distinguish between qualitative consideration of RF objectives and their explicit operationalisation within a HS framework. Management controls (decision rules) were specifically examined, to distinguish whether these were dynamic, that is, adjusted in response to assessment outcomes (e.g., increase and decrease of total allowable catch [TAC]), or merely statically applied (e.g., gear restrictions).

Following the initial elicitation round of the questionnaire, responses were screened for potential errors related to misinterpretation, and experts were individually contacted to clarify their responses. Experts were then provided with the preliminary results and given the opportunity to modify their responses.

Responses to most questions were provided on an ordinal five-point scale; 'almost never' (1), 'rarely' (2), 'often' (3), 'mostly' (4), and 'almost always' (5). This standardised the responses and facilitated direct comparison among sectors. Approximate proportional values were also assigned for each response category (e.g., mostly: ~75% of the time) to assist comprehension and reduce procedural variability among experts. A small number of responses were in short-answer format. When answering questions, experts were asked to consider all HSs for multi-sector fisheries that involve the RF sector in their region or nation. HSs are not necessarily developed for all multisector fisheries, so the number of HSs in a region is a subset of the number of multi-sector fisheries.

To limit misinterpretation biases, experts were provided with a defined scope and instructions for completing the questionnaire, including definitions of terms and a worked example. To ensure a focus on true HSs, experts were asked to avoid high-level management plans that provide only broad (conceptual) objectives, lack other HS components, are not stock-specific, and do not explicitly aim to control harvest. The questionnaire was distributed via email and completed remotely rather than in a shared environment, reducing the influence of group-based biases, including dominant personalities, subset polarisation, and 'group-think' (Martin et al., 2012). A comments section was provided, allowing experts to clarify responses if they thought it necessary.

Questionnaire data were explored using a combination of summary statistics and quantitative analyses. Medians and interquartile ranges were used to facilitate comparisons among groups based on ordinal scores. Permutational Multivariate ANOVA (PERMANOVA+, PRIMER-E) was used to test for differences in the suite of specified HS elements between sectors and principal coordinates analysis (PCO) was used to visualise the separation (Anderson et al., 2008). Permutations were based on a Euclidean distance matrix. Namibia was excluded from statistical analyses because only one HS has been developed for a multi-sector fishery that involves the RF sector.

Table 2 Elements of a harvest strategy considered in the questionnaire, including fishing objectives and quantities enabling their achievement.

HS component	Description
Conceptual objective	A high-level objective that guides fisheries management in a manner consistent with overarching legislation. Conceptual objectives sit above operational objectives and are typically too broad to define specific measures of fishery performance.
Operational objective	A precise objective that has a direct and practical interpretation in the context of a fishery and against which performance can be directly measured. These are typically specified for individual stocks and should link to performance indicators, reference points, and management controls.
Performance indicator (PI)	A quantity that can be measured and used to track changes in the fishery with respect to achieving an operational objective.
Limit reference point (LRP)	The value of a performance indicator below which fishery performance is no longer considered acceptable.
Target reference point (TRP)	The value of a performance indicator that represents a desired level of fishery performance and should be aimed for.
Trigger reference point	A value between the LRP and TRP that triggers a management control designed to prevent further decline of the indicator toward the LRP.
Management control	Also referred to as 'decision rules', these are pre-defined and specific management actions. Dynamic management controls vary according to the value of the PI relative to the reference points. This may be continuous, such that the level of management control is a function of the PI, or stepped, such that the management control is invoked when a specific value of the PI is reached; e.g. the LRP. Management controls may also be static, and implemented irrespective of the value of the PI.

Review 2: HSs in Australia and development of a national database

We reviewed HSs within Australia to: 1) identify the types of objectives included for the RF sector, 2) determine whether suitable HS elements have been included to achieve fishery performance against RF objectives, and 3) compare the extent of inclusion of the RF sector to that of the commercial sector within multi-sector HSs.

All publicly available HS documents were accessed through websites of fisheries management organisations in each Australian jurisdiction during August, 2020. Information was collected on the presence and type of HS components and other elements included for each sector (see Table 2). This information was examined at the level of individual objectives and their associated HS elements, so the ability to monitor and assess fisheries performance against specific objectives, and control harvest levels accordingly, could be evaluated. This reduced the need to precisely define a 'complete' HS for the purpose of analyses in the current study, which was challenging given the varied HS structure and terminology across jurisdictions, and the absence of explicit linkages between objectives and core HS elements in numerous cases (e.g. operational objectives without PIs or control rules). Comparisons between sectors also did not require an absolute number of complete HS.

A holistic approach was used to determine the fishing sectors for which objectives and HS elements had been applied within each HS. Primary biological objectives and associated HS elements are often common to all sectors of a fishery, even though each sector may not be explicitly mentioned against them. To avoid 'false negatives' for a sector, i.e. noting that an objective or HS element was not included for the RF sector despite the HS being implicitly developed for all sectors within a fishery, we examined related documentation, where possible, to understand the sectoral scope of each HS. For example, the HS for the Blue Crab Fishery in SA is detailed within a broader Management Plan for the fishery (PIRSA, 2018) which articulates objectives for all sectors - commercial, recreational and Aboriginal traditional fishing. Sectors are then not specified again with regard to objectives, data collection is completed via a fishery-independent survey, and a TACC is used as the primary management control. While the method of data collection and management are not specific to the RF sector, they may still be suitable HS elements for achieving fishery performance against RF objectives (see Aim 2, above). Hence, in this example, we argue that objectives, data collection and management controls have been included for the RF sector.

Occasionally, objectives were described as operational, but were really conceptual, being of a general nature and represented by numerous different types of indicator. We classified such objectives as conceptual. While classification of objective types is somewhat subjective, the same approach was taken for the RF and commercial sectors, hence comparisons between sectors are unlikely to be affected by the inherent subjectivity.

Database development

The preliminary database contained over 50 HSs extracted from 45 management documents. The data was transformed into a database structure and uploaded into Airtable (Formagrid Inc., see below). In July 2023, another review of the Australian fishery management organisations was conducted for new or updated harvest strategies. 22 of the harvest strategies from the preliminary database have had an updated plan published. 30 newly published harvest strategies were also identified for a future update of the database.

The choice of the database software platform was driven by three main considerations. First, the primary use case is to provide a resource for fisheries managers who are going through the process of designing a harvest strategy. The manager can search the database for commonalities based on fishery characteristics and find harvest strategies for fisheries with similar characteristics. A secondary use case is for fisheries researchers to conduct more in-depth analyses of the type and function characteristics of harvest strategies in Australia.

The second major design consideration was to have the ability to make changes relatively easily, quickly and inexpensively. A technology that allows for quick iteration and incorporation of user feedback ensures that this resource can be useful and relevant over time without requiring substantial investment of time or resources.

Finally, we sought a technology that could be maintained and updated by the NSW DPI Fisheries Research staff without frequent consultation of software developers. This is especially important during the initial stages of release while the exact requirements of the end users are not entirely clear. It was also desired to minimize the ongoing hosting costs as much as possible.

Airtable was chosen as the preferred option to meet all design requirements. For data, Airtable provides the structure of a relational database, but a user interface that resembles a spreadsheet. This makes it approachable and easy to use for non-technical users when compared to a relational database that requires knowledge of SQL. Airtable also provides a no-code data visualisation designer that allows for the quick development of dashboards that the end users will interact with.

Review 3: Data and monitoring approaches for RF in NSW

Knowledge of existing datasets and collection programs available to monitor RF objectives is a prerequisite for effective inclusion of the sector within harvest strategies. We therefore reviewed RF data and monitoring in NSW over the past two decades, with the specific aims: (i) determine the characteristics of RF data sources, including the spatial scale, temporal extent, and species; (ii) examine the utility of data for assessment, particularly the availability of extended time-series; (iii) identify potential RF objectives and link performance indicators from NSW data sources to those objectives; and (iv) identify data gaps that need to be addressed. The study demonstrates the first steps necessary for operationalising management of the RF sector within harvest strategies, using NSW as a case study. Knowledge of RF objectives and the potential for harvest strategies to achieve them is an essential precursor to development of harvest strategies for specific fisheries. The approach of linking objectives with existing data sources will also improve monitoring efficiency by indicating RF data types that are, and are not, required for harvest strategies.

Background on RF in NSW

RF comprises a broad range of activities undertaken throughout the state (approximately 800,000 km^2, Figure 7), including all aquatic environments from freshwater streams through to offshore marine waters. The sector includes private individuals and "for hire" charter fishing operators. Over 140 species of bony fish, sharks, rays, crustaceans, molluscs, and polychaete worms are caught recreationally each year (West et al., 2015; Murphy et al., 2020); however, <20 species comprise most of the catch based on the number of individuals (Lynch et al., 2020a). RF methods include line fishing, spear fishing, trapping, and bait netting, with substantial shore and boat-based effort reported (Murphy et al., 2020).

The recreational fishery is open access, although recreational fishers require a licence and must adhere to numerous static management controls, including gear restrictions and species-specific bag and size limits (Lynch et al., 2020a). Those exempt from the licence requirement include individuals under the age of 18, Aboriginal people, and various concession holders. Amateur recreational fishers are not required to report their activity, so catch and effort are primarily monitored through a statewide telephone-diary survey that is now conducted biennially (see

Results, Murphy et al., 2020). The sample frame for the survey only includes long-term (1–3 year) licence holders, because short-term (1 day and 1 week) holders and exempt individuals are not required to provide their contact information. The Recreational Charter Fishery is required to report catch and effort through a logbook reporting system (Lynch et al., 2020b). Compliance is actively enforced through patrols by fisheries officers who are authorized to issue fines and seize catch and fishing equipment in accordance with fishing regulations.

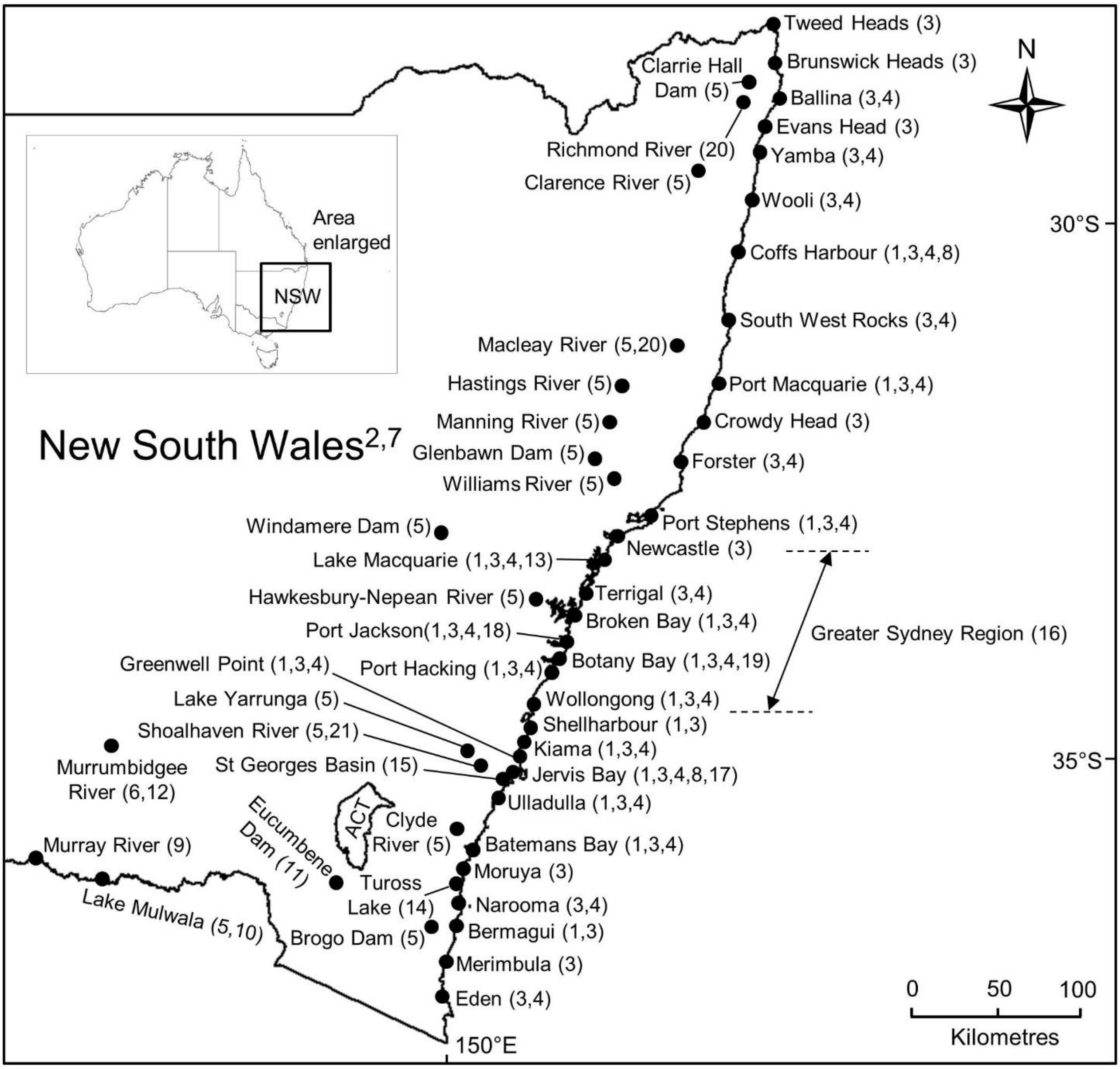


Figure 7 Collection locations of RF data in NSW, Australia, during 1999-2020. Numbers in parentheses indicate the data sources from Table 3 that collected data at each location.

NSW data sources

We considered all studies conducted on RF by NSW Department of Primary Industries—Fisheries (NSW DPI), or including NSW DPI as a collaborator, between the years 1999 and 2020. We focused on these studies because they represent most of the research conducted on RF within NSW, including all long-term, spatially expansive monitoring. Data from these studies are also readily available to service state-based harvest strategies. Studies included both regular monitoring programs and temporal "snapshot" surveys conducted at a range of spatial scales. Metadata categories were used to summarize the data sources and determine their operational characteristics. These included the aquatic environment and fish species covered, the spatial and temporal extent of data collection, and the variables measured. To aid in identifying potential time-series, data sources were organized by collection method and location, and similar studies conducted in different years were combined. We distinguished those data sources that could already provide a time-series (referred to as "ongoing time-series") and those that may provide a time-series if data collection is continued (referred to as "emerging time-series"). Data sources were also evaluated for their potential to inform reference points in HSs. Evaluation was qualitative and based on the temporal extent of data collection. Data sources commencing within the last 5 years were not considered suitable to inform target reference points, under the assumption that past fishery performance was likely more indicative of target performance. However, in some cases, recent performance may be considered an adequate target by stakeholders. Further descriptions of data categories are provided in Table 3. Studies prior to 1999 were not evaluated, because the underlying data were often inaccessible.

Linking data sources to RF objectives

To generate a list of potential objectives for NSW recreational fishers, we reviewed previous surveys of RF motivations in the state and published studies on RF conducted elsewhere in Australia and internationally. Primary sources in NSW were the attitudinal survey ("wash-up") component of the state-wide telephone-diary surveys conducted by NSW DPI during 2013/2014 and 2017/2018 (West et al., 2015; Murphy et al., 2020), and a dedicated survey of RF motivations in NSW conducted during 2016 (McIlgorm et al., 2016; Magee et al., 2018). The attitudinal survey is conducted after the diary period and aims to capture the opinions and attitudes of diarists (1257 and 1681 in 2013/2014 and 2017/2018, respectively) using a range of structured and unstructured questions (West et al., 2015; Murphy et al., 2020). Diarists are presented with eight motivational factors, representing both catch- and non-catch-related components of the RF experience and asked to rate each on a five-point scale. Both the attitudinal surveys (West et al., 2015; Murphy et al., 2020) and dedicated survey of RF motivations in 2016 (McIlgorm et al., 2016; Magee et al., 2018) focused on objectives that are typically referred to as motivations and often considered at the level of an individual fisher (e.g. "catch large or 'trophy' fish", Table 4). To ensure a comprehensive list, we also included objectives linked to RF at a sector-wide level (e.g. "ensure a sustainable fishery"). These were primarily identified from investigations of recreational stakeholder priorities in Australian fisheries, for example, a survey of stakeholder preferences in the Coral Reef Fin Fish Fishery (CRFFF) in Queensland that included the recreational sector (Pascoe et al., 2019). A complete list of sources is provided in Table 4.

Table 3 Operational characteristics of recreational fishing (RF) data sources in NSW between 1999 and 2020, including the type of monitoring conducted, the spatial and temporal scale, and species included. Harvest strategy utility relates to the potential provision of time-series (ongoing or emerging), or reference points (RPs), or both.

ID	Monitoring type	Harvest strategy utility	RF sub-group	Variables (units)	Aquatic environment	Spatial scale	Location	Regularity	Collection years	Number of taxa	Taxa name	Primary publications
1	On-site interviews, voluntary tournament reporting	Ongoing time-series, RPs	Gamefish tournament anglers	Catch (no.) Effort (boat hrs) CPUE (no./boat hr) Participation (no. of boats) Body length (cm)	Marine	Statewide	15 coastal locations from Mooloolaba to Bermagui	Periodic (local scale) Regular (statewide scale)	Annual: 1993-present	15	Top 10 spp. by recorded catch: Yellowfin Tuna, Striped Marlin, Mahi Mahi (Dolphin Fish), Black Marlin, Albacore, Mako Shark, Blue Marlin, Striped (Skipjack) Tuna, Yellowtail Kingfish, Blue Shark.	Murphy et al. 2002; Lowry and Murphy 2003; Park 2007; Ghosn 2016
2	Off-site survey: telephone and diary	Emerging time-series, RPs	All sub-groups	Catch (no., kg [est]) Zero catch events (no.) Effort (no. of events, hrs, days) CPUE by method (no./hr, no./day) Participation (no. of fishers/households) Released fish (no.) Reason for release (categorical) Motivation for fishing (categorical) Satisfaction (score) Dissatisfaction reason (categorical) Fishers in a household (no., demographics)	Marine Estuarine Freshwater	Statewide	N/A	Regular	Biennial (from 2017/18): 2000/01, 2013/14, 2017/18, 2019/20	>50	Top 10 spp. by recorded catch: Bream spp, Dusky Flathead, Sand Flathead, Luderick, Snapper, Tailor, Sand Whiting, European Carp, prawns, nippers	Henry and Lyle 2003; West et al. 2015; Murphy et al. 2020; Lynch et al., 2020b

3	Mandatory logbook: NSW Recreational Charter Fishery	Ongoing time-series, RPs	Charter operators	Catch (no. retained) Effort (fisher hrs) CPUE (no./fisher hr and no./boat hr) Participation (no. of fishers) Location (spatial coordinates) Interactions with TEP spp. (no.) Lost and found fishing gear (categorical)	Marine Estuarine	Statewide	36 ports throughout the state	Regular	Annual: 2000-present	146	Top 10 spp. by reported catch: Bluespotted Flathead, Snapper, Grey Morwong, Blue Mackerel, Flathead (other), Ocean Jacket, Sweep, Yellowtail Scad, Yellowtail Kingfish, Redfish	Gray and Kennelly 2016; Gray and Kennelly 2017; Hughes et al 2021b; Lynch et al., 2020b
4	Observer program: NSW Recreational Charter Fishery	Emerging time-series	Offshore charter operators	Catch (no. retained and released) Effort (fisher hrs) CPUE (no./fisher hr and no./boat hr) Participation (no. of fishers) Body length (cm, retained and released) Location (spatial coordinates) Vessel parameters (various) Depth (m) Water temperature (degrees C) Current velocity (m/s) Bottom type (categorical) Weather conditions (various) Releases (no., spp.) Reason for release (categorical) Condition of released fish (score) Interactions with TEP spp. (no. per unit time) Client demographics (age, residence, participation [charter and private])	Marine	Regional and statewide	2014-2016: 6 ports in 3 regions (30-35°S) 2017/18: 13 ports in southern half of the state (33-36°S) 2019/20: 18 ports throughout the state (28-37°S)	Periodic	Biennial (from 2017/18): 2014-2016, 2017/18, 2019/20	105	Top 10 spp. by recorded catch: Bluespotted Flathead, Blue Mackerel, Snapper, Longspine Flathead, Yellowtail Scad, Grey Morwong, Sergeant Baker, Redfish, Silver Sweep, Ocean Jacket	Gray and Kennelly 2016; Gray and Kennelly 2017; Hughes et al 2021b
5	Voluntary tournament reporting	Ongoing time-series, RPs	Tournament anglers	Catch (no. released) Effort (fisher hrs) CPUE (catch-and-release) Zero catch events (no.) Participation (no. of fishers) Body length (cm)	Freshwater	Statewide	15 locations throughout the state	Regular	Annual: 1988 - present	1	Australian Bass	Ghosn 2009

6	Voluntary tournament reporting	Emerging time-series	Tournament anglers	Catch (no. released) Effort (fisher hrs) CPUE (catch-and-release) Zero catch events (no.) Participation (no. of fishers) Body length (cm)	Freshwater	Local (moving to statewide)	Murrumbidgee River	Regular	Annual: 2019 - present	6	Murray Cod, Trout Cod, Golden Perch, Redfin, River Blackfish, European Carp	NSW DPI unpublished
7	Voluntary tag-recapture program		Gamefish anglers	Catch locations Recapture locations Recapture rate (%) Movement (km, km/day) Growth rate (cm/day, kg/day)	Marine	Statewide and national	Statewide	Regular	Annual: 1973-present	41	Top 10 species tagged: Black Marlin, Yellowfin Tuna, Yellowtail Kingfish, Sailfish, Mahi Mahi (Dolphinfish), Mackerel Tuna, Striped Marlin, Striped Tuna, Albacore, Bonito	Pepperell 2007
8	On-site survey: access point boat-based fisheries		Boat-based fishers	Motivations for fishing (categorical) Awareness of Commonwealth Marine Parks (categorical) Attitudes towards Commonwealth Marine Parks (categorical) Perceptions of Commonwealth Marine Park impacts on marine ecosystems and fishing (categorical)	Marine	Local	Jervis Bay Coffs Harbour	Snapshot	2019/20	NA	Catch data not collected	-
9	On-site survey: roving shore-based and roving boat-based fisheries		Boat-based and shore-based anglers	Catch (no., kg) Effort (fisher hrs and boat hrs) CPUE (no./ fisher hr and no./boat hr) Body length (cm)	Freshwater	Local	Murray River	Snapshot	2018/19	5	Murray Cod, Trout Cod, European Carp, Golden Perch, Silver Perch	NSW DPI unpublished
10	On-site survey: access point		Boat-based and shore-based anglers	Catch (no., kg) Effort (fisher hrs and boat hrs) CPUE (no./ fisher hr and no./boat hr) Body length (cm)	Freshwater	Local	Lake Mulwala	Snapshot	2015/16	5	Murray Cod, Trout Cod, European Carp, Golden Perch, Silver Perch	Forbes et al. 2020

11	On-site survey: roving shore-based and access boat-based fisheries		Boat-based and shore-based anglers	Catch (no., kg) Effort (fisher hrs and boat hrs) CPUE (no./ fisher hr and no./boat hr) Body length (cm)	Freshwater	Local	Lake Eucumbene	Snapshot	2015/16	2	Rainbow Trout, Brown Trout	Forbes et al. 2017
12	On-site survey: access point	RPs	Boat-based and shore-based anglers	Catch (no., kg) Effort (fisher hrs and boat hrs) CPUE (no./ fisher hr and no./boat hr) Body length (cm)	Freshwater	Local	Murrumbidgee River	Snapshot	2012-2013	5	Murray Cod, Trout Cod, European Carp, Golden Perch, Silver Perch, Murray Crayfish	Forbes et al. 2015
13	On-site survey: roving and access-point, shore and boat-based fisheries	Emerging time-series, RPs	Boat-based and shore-based fishers	Catch (no., kg [not in 2011]) Effort (fisher hrs) CPUE (no./fisher hr) Body length (cm)	Estuarine	Local	Lake Macquarie	Periodic	1999/00, 2003/04, 2011	39	Top 10 spp. by recorded catch: Blue Swimmer Crab, Luderick, Yellowfin Bream, Dusky Flathead, Common Squid, Sand Mullet, Trumpeter Whiting, Yellowfin Leatherjacket, Snapper, Tailor.	Steffe and Chapman 2003; Steffe et al. 2005a; Ochwada-Doyle et al. 2014a; Ochwada-Doyle et al. 2014b
14	On-site survey: roving and access-point, boat-based fisheries	Emerging time-series, RPs	Boat-based anglers	Catch (no., kg [not in 2011]) Effort (fisher hrs) CPUE (no./fisher hr) Body length (cm)	Estuarine	Local	Tuross Lake	Periodic	1999/00, 2003/04, 2011	26	Top 10 spp. by recorded catch: Dusky Flathead, Yellowfin Bream, Sand Whiting, River Garfish, Sand Mullet, Luderick, Tailor, Large-toothed Flounder, Sea Garfish, Yelloweye Mullet, Blue Swimmer Crab	Steffe et al. 2005b; Ochwada-Doyle et al. 2014a; Ochwada-Doyle et al. 2014b

15	On-site survey: roving and access-point, shore and boat-based fisheries		Boat-based and shore-based anglers	Catch (no.) Effort (fisher hrs) CPUE (no./fisher hr) Body length (cm)	Estuarine	Local	St. Georges Basin	Snapshot	2011	13	Top 5 spp. by recorded catch: Bream spp, Dusky Flathead, Sand Whiting, Yellowfin Leatherjacket, Snapper	Ochwada-Doyle et al. 2014a; Ochwada-Doyle et al. 2014b
16	On-site survey	RPs	Boat-based and shore-based fishers	Catch (no., kg) Effort (fisher hrs) CPUE (no./fisher hr); Body length (cm)	Marine Estuarine	Regional	Greater Sydney Region (Newcastle to Illawarra)	Snapshot	2007-2009	>50	Top 10 spp. by reported catch: Yellowfin Bream, Dusky Flathead, Yellowtail Scad, Sand Whiting, Sand Mullet, Tailor, Blue Swimmer Crab, Silver Trevally, Luderick , Yellowfin Leatherjacket	Steffe and Murphy 2011
17	On-site survey: roving and access-point, shore and boat-based fisheries		Boat-based and shore-based fishers	Effort (fisher hrs)	Marine	Local	Jervis Bay	Periodic	1999-2009		Catch data not collected	Lynch 2006; Lynch 2014
18	On-site survey: boat-based roving, shore and boat-based fisheries	RPs	Boat-based and shore-based fishers	Catch (no., kg) Effort (fisher hrs) CPUE (no./fisher hr); Body length (cm)	Estuarine	Local	Sydney Harbour	Snapshot	2007/08	33	Top 10 spp. by recorded catch: Yellowtail Scad, Yellowfin Bream, Snapper, Tailor, Dusky Flathead, Yellowtail Kingfish, Trumpeter Whiting, Blue Mackerel, Sand Whiting, Yellowfin Leatherjacket.	Ghosn et al. 2010

19	On-site survey: access point	RPs	Boat-based anglers	Catch (no., kg) Effort (fisher hrs, boat hrs) CPUE (no./fisher hr and no./boat hr) Body length (cm)	Estuarine	Local	Botany Bay	Periodic	2000, 2007	7	Yellowfin Bream, Dusky Flathead, Yellowfin Leatherjacket, Silver Trevally, Tailor, Snapper, Sand Whiting	Isaacson 2000; Bogg 2007
20	On-site survey: roving and access-point, shore and boat-based fisheries	RPs	Boat-based and shore-based anglers	Catch (no.) Effort (fisher hrs) CPUE (no./fisher hr) Body length (cm)	Estuarine	Regional	Richmond River Macleay River	Snapshot	2001	3	Luderick, Yellowfin Bream, Dusky Flathead	Steffe and Macbeth 2002; Steffe et al. 2007
21	On-site survey: roving shore-based and roving boat-based fisheries		Boat-based and shore-based anglers	Catch (no., kg) Effort (fisher hrs, boat hrs) CPUE (no./ fisher hr and no./boat hr) Body length (cm)	Estuarine	Local	Shoalhaven River	Snapshot	2009/10	32	Top 10 spp. by recorded catch: Yellowfin Bream, Dusky Flathead, Snapper, Luderick, Tailor, Sixspine Leatherjacket, Sea Mullet, Sand Whiting, Estuary Perch, Tarwhine	Miles and West 2011

Table 4 Potential objectives of recreational fishers in NSW. Broad objectives were identified from the literature (see footnotes) and translated into operational objectives, where required. Objectives were classified according to the four pillars of fisheries sustainability (Stephenson et al., 2018), and whether they were catch-oriented or not. The most appropriate management level for each objective is indicated, following Sloan et al. (2014). A dash indicates an objective did not clearly sit within an existing management level.

Catch orientation	**Type of objective (pillar of sustainability)**	**Broad objective, motivation or need**	**Derived operational objective**	**Management level**
Catch-oriented (activity specific)	Ecological/Social	1. Catch fish [a,b,g,h,j,k,q]	1.1 Maximise the number of trips where a fish is caught	Harvest strategy
			1.2 Maximise the number of fish caught per fisher day	Harvest strategy
	Ecological/Social	2. Receive bites or strikes [b]	2.1 Maximise the number of strikes or bites per fisher day	Harvest strategy
	Ecological/Social	3. Obtain food [a,b,e,g,h,i,j,k,m,q,s,t]	3.1 Maximise the number of legal-sized fish caught per fisher day	Harvest strategy
	Ecological/Social	4. Catch large or 'trophy' fish [a,b,g,h,k,n,q]	4.1 Maximise the size of fish caught	Harvest strategy
			4.2 Maximise the likelihood of encountering large fish	Harvest strategy
	Ecological	5. Ensure a sustainable fishery [e, n, p]	5.1 Maintain stock biomass above the minimum sustainable limit	Harvest strategy
			5.2 Increase fisher awareness of sustainable fishing practices	Management plan
			5.3 Increase RF understanding of population biology and stock assessment	Management plan
			5.4 Minimise fishing infringements	Compliance and enforcement
	Ecological	6. Avoid environmental impacts of fishing [e, n, p]	6.1 Minimise bycatch mortality	Harvest strategy
			6.2 Minimise interactions with TEP spp.	Harvest strategy
			6.3 Minimise pollution generated by RF	Management plan
	Economic	7. Generate economic value for the RF industry [e,p]	7.1 Maximise profit for RF charter industry	Harvest strategy

		7.2 Maximise profit for RF tackle industry	Harvest strategy
	8. Enhance the value of the fishing experience [p]	8.1 Maximise monetary value of the fishing experience, direct to participant	Harvest strategy
Social	9. Easy access to fishing locations [b,d,n,o,u]	9.1 Maximise access to fishing locations	Management plan
		9.2 Optimise the number, size and quality of boat ramps	Management plan
Social	10. Improve participation in RF ('grow the sport') [l]	10.1 Increase the number of individuals participating in RF each year	-
		10.2 Increase time spent fishing	-
Social	11. Compete against other fishers [b,i,j,s]	11.1 Maximise opportunities to compete in fishing tournaments	-
Social	12. Equitable access to fish stocks [d, o, p, r]	12.1 Maintain equitable allocation of catch among fishing sectors	Allocation policy
Social	13. Enhance social networks, or social capital [l,t]	13.1 Maximise networking opportunities within the RF community	-
Social	14. Foster a positive public image of RF [c,e,n]	14.1 Minimise negative public perception of RF impacts	Management plan
		14.2 Maximise public understanding of socio-economic benefits of RF	Management plan
		14.3 Minimise negative interactions with other aquatic users	Management plan
Social	15. Improve fishing knowledge [g,k,m,q,t]	15.1 Increase knowledge of fishing techniques	-
		15.2 Increase knowledge of fishing locations	-
		15.3 Increase knowledge of target species	-
Institutional	16. Flexible management to meet RF needs [d]	16.1 Increase the range of rec-specific harvest strategy components used	Management system
		16.2 Optimise the period between harvest strategy reviews	Management system
		16.3 Include 'breakout' rules for RF in harvest strategies	Management system
Institutional	17. Transparent management [d, o]	17.1 Increase consultation periods on management changes	Management system

			17.2 Increase detail in fisheries management documents	Multiple levels/types
			17.3 Increase the distribution of fisheries management information	-
	Institutional	18. Involvement in fisheries management advisory processes [d, o]	18.1 Increase representation in fisheries management advisory processes	Management system
			18.2 Increase opportunities for stewardship/co-management	Management system
Non-catch-oriented (activity general)	Social	19. Enjoy the outdoors/nature [b,f,g,i,j,k,m,s,t]	19.1 Increase aesthetic beauty of fishing locations	-
	Social	20. Spend time with friends and family [b,f,g,i,j,k,m,q,s]	20.1 Increase the time spent fishing with friends and family	-
	Social	21. Relaxation, or to reduce stress [b,d,g,l,k,m,o,q,s,t]	21.1 Maximise the relaxative effect of fishing	-
	Social	22. To be on your own [g, i, j, q, s]	22.1 Minimise interactions with other people	Harvest strategy

[a]Anderson et al. 2007, [b]Arlinghaus 2006, [c]Arlinghaus et al. 2012, [d]Brooks et al. 2015, [e]Cowx and Van Anrooy 2010, [f]Driver and Cooksey 1977, [g]Fedler and Ditton 1994, [h]Graefe 1980, [i]Henry and Lyle 2003, [k]Magee et al. 2018, [l]McPhee 2017, [m]Ormsby 2004, [n]Pascoe et al. 2013, [o]Pascoe et al. 2014, [p]Pascoe et al. 2019, [q]Schramm and Gerard 2004, [r]Stephenson et al. 2017, [s]West et al. 2015, [t]Young et al. 2016, [u]Young et al. 2020

Objectives were classified according to whether they were specific to the activity of RF ("catch-oriented") or associated with numerous outdoor activities ("non-catch-oriented"; Arlinghaus, 2006). Objectives were also classified according to the "four pillars of sustainability" in fisheries management—ecological, economic, social, and institutional (Stephenson et al., 2017). Ecological objectives are also referred to as biological objectives and typically relate to aspects of stock sustainability, optimal yields, fishing impacts, and broader ecosystem integrity (Stephenson et al., 2018). Economic objectives relate to the financial value of fishing, which may be realized directly through the sale of catch, or indirectly through expenditure on fishing activity or the personal value placed on the fishing experience (Pascoe et al., 2019). Social objectives relate to human interactions and community effects associated with fishing (Pascoe et al., 2014), and institutional objectives relate to legal obligations, governance structure, and management processes (Stephenson et al., 2018). The management level most appropriate for each objective in the current study was identified according to the management levels specified in Sloan et al. (2014), including allocation, compliance and enforcement, management system, and the broader management plan. Classification of objectives with respect to catch orientation, the pillars of sustainability, and management levels were based on the original source of each objective, where these distinctions were evident, or the judgement of the authors of the current study when not provided.

We derived operational objectives from broad objectives identified in the literature. Operational objectives allow for monitoring using specific performance indicators. We then linked these operational objectives to variables from NSW RF data sources that may act as performance indicators (Table 5). The RF data sources that supply specific variables were identified and grouped by primary aquatic environment (marine, estuarine, or freshwater). Links between data sources and objectives were made qualitatively, based on the general utility of particular data types. Quantitative investigation of data suitability for monitoring fishery performance against objectives was beyond the scope of the current study, given the large number of objectives, data sources, and stocks involved. However, we demonstrate the potential of RF data sources for quantitative monitoring using an example stock in NSW. Ocean jacket (*Nelusetta ayraud*) is a large monacanthid species inhabiting coastal waters throughout the southern half of Australia. The species is one of the most common monacanthids caught in Australia (Miller et al., 2010) and prominent in recreational catches from estuaries and nearshore reefs of NSW (Murphy et al., 2020). The steps for linking harvest strategy objectives to empirical performance indicators and their data sources were followed for the ocean jacket stock in NSW (see Figure 23). The broad objective "catch fish" (Objective 1) and the derived operational objective "maximize the number of fish caught per fisher day" (Objective 1.2) were selected (Table 4) based on their likely importance to the RF sector. An empirical performance indicator was then developed from a NSW RF data source linked to the operational objective (Table 5). Ocean Jacket is not currently managed using a harvest strategy in NSW.

Table 5 Operational objectives and the variables available from RF studies in NSW that may be used to monitor them. ID numbers indicate the data sources in Table 3 that provide those variables, with data sources grouped according to aquatic environment: "M": marine, "E": estuarine, "F": freshwater. Objective numbers refer to those displayed in Table 4.

Derived operational objective (from Table 4)	**Variables from RF studies** (from Table 3)	**ID of RF data source** (from Table 3)
1.1 Maximise the number of trips where a fish is caught	Zero catch events (no.)	**M**: 2; **E**: 2; **F**: 2,5
1.2 Maximise the number of fish caught per fisher day	Catch (no.), CPUE	**M**: 1-4,16; **E**: 2-3,13-16,18-21; **F**: 2,5-6,9-12
2.1 Maximise the number of strikes or bites per fisher day	Catch (no.), CPUE	**M**: 1-4,16; **E**: 2-3,13-16,18-21; **F**: 2,5-6,9-12
3.1 Maximise the number of legal-sized fish caught per fisher day	Catch (no. retained) OR catch (no.) AND body length (cm)	**M**: 1-4,16; **E**: 2-3,13-16,18-21; **F**: 2,5-6,9-12
4.1 Maximise the size of fish caught	Catch (kg) OR Catch (no.) AND body length (cm)	**M**: 1,4,16; **E**: 13-16,18-19,21; **F**: 5-6,9-12
4.2 Maximise the likelihood of encountering large fish	Effort (hrs) AND body length (cm)	**M**: 1,4,16; **E**: 13-16,18-21; **F**: 5-6,9-12
5.1 Maintain stock biomass above the minimum sustainable limit	Catch (no.), effort (hrs, days), CPUE, releases (no.), body length (cm)	**M**: 1-4,16-17; **E**: 2-3,13-16,18-21; **F**: 2,5-6,9-12
5.2 Increase fisher awareness of sustainable fishing practices	Reason for release (categorical)	**M**: 2,4; **E**: 2; **F**: 2
5.3 Increase RF understanding of population biology and stock assessment	-	
5.4 Minimise fishing infringements	-	
6.1 Minimise bycatch mortality	Releases (no., spp.), condition of released fish (score)	**M**: 2,4; **E**: 2; **F**: 2,5-6
6.2 Minimise interactions with TEP spp.	Interactions with TEP spp. (no.)	**M**: 3,4; **E**: 3; **F**: -
6.3 Minimise pollution generated by RF	Lost and found fishing gear	**M**: 3; **E**: 3; **F**: -

7.1 Maximise profit for RF charter industry	-	-
7.2 Maximise profit for RF tackle industry	-	-
8.1 Maximise monetary value of the fishing experience, direct to participant	-	-
9.1 Maximise access to fishing locations	-	-
9.2 Optimise the number, size and quality of boat ramps	-	-
10.1 Increase the number of individuals participating in RF each year	Participation (no. of fishers/boats)	**M**: 1-4; **E**: 2-3; **F**: 2,5-6
10.2 Increase time spent fishing	Effort (hrs, days)	**M**: 1-4,16-17; **E**: 2-3,13-21; **F**: 2,5-6,9-12
11.1 Maximise opportunities to compete in fishing tournaments	Participation (no. of fishers/boats)	**M**: 1; **E**: - ; **F**: 5-6
12.1 Maintain equitable allocation of catch among fishing sectors	Catch (kg)	**M**: 2,16; **E**: 2,13-14,16,18-19,21; **F**: 2,9-12
13.1 Maximise networking opportunities within the RF community	-	-
14.1 Minimise negative public perception of RF impacts	-	-
14.2 Maximise public understanding of socio-economic benefits of RF	-	-
14.3 Minimise negative interactions with other aquatic users	-	-
15.1 Increase knowledge of fishing techniques	-	-
15.2 Increase knowledge of fishing locations	-	-
15.3 Increase knowledge of target species	-	-
16.1 Increase the range of rec-specific harvest strategy components used	-	-
16.2 Optimise the period between harvest strategy reviews	-	-
16.3 Include 'breakout' rules for RF in harvest strategies	-	-
17.1 Increase consultation periods on management changes	-	-

17.2 Increase detail in fisheries management documents	-	-
17.3 Increase the distribution of fisheries management information	-	-
18.1 Increase representation in fisheries management advisory processes	-	-
18.2 Increase opportunities for stewardship/co-management	-	-
19.1 Increase aesthetic beauty of fishing locations	-	-
20.1 Increase the time spent fishing with friends and family	Fishers in a household (no., demographics)	**M**: 2; **E**: 2; **F**: 2
21.1 Maximise the relaxative effect of fishing	-	-
22.1 Minimise interactions with other people	-	-

Objective 3 - Interrogate and extend the FishPath decision support software tool to better characterise and integrate recreational fishing information into harvest strategy development for multi-sector fisheries

Interrogation of the FishPath decision support tool

The FishPath tool (tool.fishpath.org) is designed to assist development of key harvest strategy (HS) components - data collection, assessment and management controls. It engages stakeholders to characterise the fishery of interest through a series of questionnaires and guide decision making on viable component options, given answers to the questionnaires, providing detailed information on a comprehensive series of minimum criteria and caveats for stakeholder consideration. The Tool does contain technical language and was primarily designed around the commercial sector. Given potential differences in HS components among sectors, and to support the Tool's relevance and contribution to engage the recreational fishing sector in HS development, a review of the Tool's content and functionality, from a recreational fishing (RF) perspective was initiated.

Four scientists specialising in the field of monitoring and assessment of recreational fisheries were engaged to review the Tool. Following an introductory workshop (7-8th Dec 2020), the four reviewers conducted separate reviews of the Tool from the recreational perspective. The workshop ran online for 1.5 days and aimed to rapidly introduce reviewers to the Tool, prior to their review. In addition to the reviewers, participants in the workshop included staff from CSIRO, NSW DPI Fisheries and the FishPath Core Development Team from the USA.

The reviews aimed to address the options, questions, criteria, and caveats in the Tool, and reviewers were encouraged to suggest additions to the Tool where they felt these were required. A guide and minimum review criteria were provided to reviewers (see below - *Reviewers Guide*). This guide was to provide consistent background information to reviewers and help standardise and focus the review process, whilst also encouraging reviewers to develop and extend comments and recommendations to areas they considered relevant to better engage the recreational fishing sector and integrate RF information into HS development.

Reviewers Guide

Background

NSW DPI Fisheries is currently using the FishPath tool (tool.fishpath.org) to assist development of harvest strategy (HS) components for a range of fisheries in NSW. A number of these fisheries are shared among the commercial, recreational and Aboriginal sectors, with the recreational sector in particular now taking substantial catches of numerous stocks. Although FishPath can be applied to any sector/fishery, it was primarily designed around the commercial sector. Given potential differences in monitoring, assessment and harvest controls among sectors, there may be an opportunity to improve FishPath for non-commercial sectors.

To assist development of HS for shared (multi-sector) fisheries, NSW DPI has commenced a research project entitled "Integrating recreational fishing information into harvest strategies for multi-sector fisheries". One objective is to interrogate and extend the FishPath tool to better characterise and integrate recreational fishing information into harvest strategy development for multi-sector fisheries. Leading scientists in the field of monitoring and assessment of recreational fisheries will be consulted to: (1) determine the current strengths and limitations of the FishPath software for recreational fisheries, (2) suggest refinements to the questionnaire component of the software to address the specific characteristics of recreational fisheries, and (3) add additional monitoring components and harvest control options suited to recreational fisheries.

A previous Peer Review Panel of 13 global fisheries science and management experts has reviewed the general content and logic matrices of the FishPath Tool (Sept-Oct 2020). Their feedback centred around improvements to the questionnaire, caveats, and options, as well as tool functionality and improvements to the results page. Synthesized suggestions from this Peer Review Panel have been prioritized for action and implementation by the FishPath Team, and input regarding use of the tool in the recreational sector will be synthesized and prioritized relative to these edits.

Recreational fishing review

The recreational review of FishPath followed a similar structure to the previous global review. Following an introductory workshop (7-8th Dec 2020), reviewers each separately conducted a review of FishPath from the recreational fishery perspective. The reviews addressed the options, questions, criteria, and caveats, as well as suggested new additions for each. Below are a series of questions provided to guide reviewers, although reviewers were not limited to these. To best interact with the tool, and thereby answer the questions below, it was requested that reviewers attempt to complete a FishPath analysis of a recreational fishery known to them, or recreational sector within a shared fishery. The priority was to complete one fishery in depth, with additional fisheries welcomed using any spare time within the agreed work period. The general ability/potential for FishPath to integrate results for the recreational sector with those from other sectors within shared fisheries was also to be considered.

When evaluating FishPath, distinction was made between issues arising from language and those related to actual content. While language issues are important to note, particularly when considering applicability of language to recreational contexts, it was also important to determine whether the underlying meaning was still sound or not. This distinction may have considerable bearing on the effort required to update the tool.

Reviewers were asked to provide a series of recommendations that would allow FishPath to be refined in light of their findings. Recommendations were formulated to provide greatest ease/utility for FishPath refinement. This was achieved by providing specific recommendations that indicated the exact location of the refinement within the tool, while also taking into account any flow-on effects. For example, a recommendation to add a question would have most benefit if the options impacted were also specified.

Questions to guide the review

<u>The goal of FishPath is:</u>

To support users in understanding and navigating the universe of options available for fishery data collection, assessment, and management measures, refining these to identify those best suited to the user’s specific circumstances. Tool users complete each section’s questionnaire, consider specific reasons why options are or are not good matches (i.e. options, criteria and caveats), then narrow appropriate options to a shortlist of “narrowed options” that are best suited for their fishery.

<u>Questions, with respect to recreational fisheries</u>

1. Is the FishPath Tool content significantly supportive of reaching the stated goal for recreational sector/fisheries? *While trained scientists or practitioners can facilitate the experience of using the tool with stakeholders, we are also interested in whether the content is sufficient to significantly help users identify appropriate data collection, stock assessment, and management measures options for specific situations.*

2. Are there missing or redundant questions from the recreational perspective? *Please outline these*.
3. Are there missing or redundant options from the recreational perspective? *Please outline these*.
4. Within the subset of relevant options, please outline key criteria or caveats that require revision for relevance to the recreational sector/fisheries. *An exhaustive review of criteria and caveats is beyond the scope of the review. Please limit review to those that are deemed by the reviewer as central to the recreational utility of the tool.*
5. How easy is it to integrate the recreational sector with other sectors within a shared (multi-sector) fishery? If not, how could this be improved? *When answering, consider areas of major divergence in responses to questions among sectors, potentially different options that are generated, and how a user might best achieve an integrated set of options for the fishery as a whole.*
6. Please provide general comments on the functionality of the FishPath tool and your user experience from the recreational fishing perspective.
7. Are there any other major areas for improvement or anything else you would like to add?

Extension and integration of RF information into the FishPath decision support tool - Expert Input Workshop

Extension and integration of the expert review findings into the FishPath decision support tool was done in three phases. Phase 1 involved a post-review discussion of the review findings and conclusions among members of the current project team (NSW DPI, CSIRO) and the expert reviewers. This was to ensure expert reviewer findings were understood and interpreted correctly by the current project team, the reviewers were aware that the intent of any recommendations to change the Tool remained within the scope and context of the Tool and where any comments or recommendations were considered out of scope. Phases 2 and 3 delivered outputs against the 6 sub-objectives (listed below). Phase 2 included a review of the content of the Tool, documenting proposed specific changes, including rewording or removal of content (sub-objective 1), a scope of work to implement changes to improve relevance to the RF sector and implementing changes to the Tool, where possible (sub-objectives 2 and 5). Phase 3 focused on improving functionality of the Tool, including a matrix of question responses and HS component options (for short-listed options) with associated caveats and user specified notes (sub-objective 3), the addition of standard outputs (automated reports) from the Tool, allowing comparisons of outcomes from alternate scenarios/fisheries/sectors (sub-objective 4) and a scope of work to 'filter' questions and options within the Tool relevant to recreational fishers/fisheries (sub-objective 6).

Sub-objectives:

1. Identify and list questions/component options that would benefit from rewording or removal.
2. Develop a scope of work for changes required to address issues identified in sub-objective 1, including, but not limited to, providing original and alternate wording to relevant questions/component options, introducing a response option of 'NA' or 'unknown' to relevant questions and, implementing changes in the FishPath tool.
3. Develop a scope of work and implement the generation of a report presenting a matrix of options versus question responses invoking caveats, and notes, for short-listed options.
4. Develop a scope of work and implement side-by-side comparisons of multiple 'fisheries' for a) alternative answers; and b) alternative options.
5. Develop a scope of work for the inclusion of recreational fishing relevant options for Data Collection and Management Measures.

6. Develop a scope of work (concept diagram or outline) for achieving a ‘filtered’ FishPath series of reduced questions and options relevant to recreational fishers.

Phases 2 and 3 involved the development of a body of work by the current project team with members of the FishPath Core Team, including Brain Snouffer leading and delivering a series of outputs against each of the sub-objectives (Upwell Solutions LLC). These outputs and others, including functional changes to the Tool (FishPath Tool) are presented and summarised in the section ‘Results and discussion - Objective 3’.

Summary findings and recommendations from this work, specifically any proposed changes to the Tool, were presented to FishPath Core Team members from The Nature Conservancy (TNC) and National Oceanic and Atmospheric Administration (NOAA), along with a discussion about how best to achieve the recommendations. Adoption of recommendations was subject to the governance requirements, and at the discretion of the FishPath Core Team, The Nature Conservancy and associated organisations.

Objective 4 - Develop guidelines and recommendations for the integration of recreational fishing information into harvest strategies for multi-sector fisheries

The information obtained from the workshops, review and consultations under Objectives 1, 2, 3 and 5 was used to develop guidelines and recommendations to inform HS development for multi-sector fisheries that include a recreational component.

The guidelines are organised according to a four-phase harvest strategy (HS) development process (see Dowling et al. 2023). These include: Phase 1 – Pre-engagement, definitions and scoping for a specific HS, Phase 2 - Identifying objectives and options for HS components, Phase 3 – Linking components together into a functioning HS, and Phase 4 – HS evaluation. We also include guidelines for a period prior to Phase 1, when prerequisite legislation, regulation and supporting policies (e.g. allocation policy) should be established. The guidelines cover steps for identifying, prioritising and consolidating recreational fishing (RF) objectives, which should commence prior to formal HS development, and steps for linking RF objectives to data sources and performance indicators for monitoring, some of which should also be undertaken prior to formal HS development. The guidelines also address management control of RF and formulation of the harvest control rule (HCR).

In addition to specific guidelines, we outline four technical approaches for achieving RF objectives within multi-sector HSs (see break-out box). These indicate performance indicators, assessments, and methods of management control that potentially combine to achieve fisheries performance for the sector, alongside other sectors involved in a fishery.

Lastly, we provide a template that can be used to visualise the overall structure of the HS and linkages between components (monitoring, assessment and management controls) and other elements for a multi-sector fishery. Application of this template is demonstrated in Objective 5 (Appendix 6).

Results, discussion and conclusion

Objective 1 - Obtain information on recreational fishing objectives and facilitate improved understanding among recreational fishers of the role of harvest strategies

Recreational Fishing Research Workshops

Eight workshop sessions were completed, involving a total of 14 hours contact time with participants. Workshops were generally well-attended, with more than 10 RF stakeholders participating in most sessions. Objectives sessions for Snapper were attended by six RF stakeholders.

The shortlists of objectives considered suitable for inclusion in harvest strategies (HS), based on whether they could be achieved via harvest control, are presented in Tables 6-8 and outlined in the section "HS objectives" below. The objectives are phrased in non-technical language, to ensure comprehension by a wider audience potentially involved with HS development and the broader group of recreational fishers involved in future surveys of objectives preferences. The complete lists of all objectives developed within the workshops, including those not considered addressable within a HS, are presented in Tables A1 1-3 (Appendix 1) and outlined in the section "Complete list of objectives". Note that the complete lists include the technical language originally used for HS objectives (in bold).

HS objectives

HS objectives were similar among stocks and included 20-21 sub- or specific objectives. They spanned three of the four broad categories - ecological, economic, and social (Tables 6-8); none of the managerial objectives were considered suitable for inclusion in a HS because they were unlikely to be achieved by controlling harvest. Ecological objectives primarily related to aspects of sustainability, such as maintaining healthy stocks and ensuring a reasonable proportion of fish reached legal size. Economic objectives included maximising the value of the RF experience, generating revenue for RF industries and promoting quality regional fisheries. Social objectives included growing the sport, increasing time spent with friends and family, and improving recreational experiences. Numerous social objectives were related to ecological objectives, for example, the social objective "Ensure a decent proportion of the stock can reach trophy size" relates directly to the ecological objective "Ensure a decent proportion of the stock can reach maximum size". Maintaining stock biomass was considered an ecological objective in the context of stock sustainability, but also a social objective from the perspective of ensuring quality fishing.

Table 6 Recreational fishing objectives hierarchy for Mulloway (*Argyrosomus japonicus*) in NSW. Objectives here are considered suitable for inclusion in a harvest strategy and represent a subset of the full list (see Table A1-1). Bold indicates differences with other species.

Broad objective	Sub-objectives	Specific objectives
Ensure ecological sustainability	Ensure a sustainable fishery	Maintain enough fish overall to ensure a healthy stock
		Maintain enough fish regionally to avoid local declines in numbers
		Ensure a decent proportion of the stock can reach maximum size
		Ensure a decent proportion of the stock can reach legal size
		Ensure protection of spawning aggregations
		Ensure released fish have a high chance of survival
	Minimise lost fishing gear and other waste	
Enhance economic performance	Maximise the dollar value of your recreational fishing experience	
	Generate economic value for the recreational fishing industry	Maximise the dollar return for the charter fishing industry
		Maximise the dollar return for the fishing tackle industry
	Increase development of quality regional fisheries to promote tourism	
	Minimise the cost of adhering to management regulations for the charter fishery	
	Increase investment in the fishery to obtain best management outcomes	
Ensure social outcomes	Increase the number of individuals participating in recreational fishing each year	
	Increase time spent fishing (with family and friends)	
	Ensure that the share of catch between sectors is fair, according to pre-agreed proportions	
	Improve recreational fishing experiences	Ensure a decent proportion of the stock can reach a trophy size
		Maintain enough fish overall to ensure quality fishing
		Maintain enough fish regionally to ensure quality fishing in local areas
		Ensure a good chance of encountering fish

Table 7 Recreational fishing objectives hierarchy for Yellowtail Kingfish (*Seriola lalandi*) in NSW. Objectives here are considered suitable for inclusion in a harvest strategy and represent a subset of the full list (see Table A1-2). Bold indicates differences with other species.

Broad objective	Sub-objectives	Specific objectives
Ensure ecological sustainability	Ensure a sustainable fishery	Maintain enough fish overall to ensure a healthy stock
		Maintain enough fish regionally to avoid local declines in numbers
		Ensure a decent proportion of the stock can reach maximum size
		Ensure a decent proportion of the stock can reach legal size
		Ensure protection of spawning aggregations
	Minimise lost fishing gear and other waste	
Enhance economic performance	Maximise the dollar value of your recreational fishing experience	
	Generate economic value for the recreational fishing industry	Maximise the dollar return for the charter fishing industry
		Maximise the dollar return for the fishing tackle industry
	Increase development of quality regional fisheries to promote tourism	
	Minimise the cost of adhering to management regulations for the charter fishery	
	Increase investment in the fishery to obtain best management outcomes	
Ensure social outcomes	Increase the number of individuals participating in recreational fishing each year	
	Increase time spent fishing (with family and friends)	
	Increase opportunities to compete in fishing tournaments	
	Ensure that the share of catch between sectors is fair, according to pre-agreed proportions	
	Improve recreational fishing experiences	Ensure a decent proportion of the stock can reach a trophy size
		Maintain enough fish overall to ensure quality fishing
		Maintain enough fish regionally to ensure quality fishing in local areas
		Ensure a good chance of encountering fish

Table 8 Recreational fishing objectives hierarchy for Snapper (*Chyrsophrys auratus*) in NSW. Objectives here are considered suitable for inclusion in a harvest strategy and represent a subset of the full list (see Table A1-3). Bold indicates differences with other species.

Broad objective	Sub-objectives	Specific objectives
Ensure ecological sustainability	Ensure a sustainable fishery	Maintain enough fish overall to ensure a healthy stock
		Maintain enough fish regionally to avoid local declines in numbers
		Ensure a decent proportion of the stock can reach maximum size
		Ensure a decent proportion of the stock can reach legal size
		Ensure protection of spawning aggregations
		Rebuild stocks in habitats previously known to support fish
	Minimise lost fishing gear and other waste	
Enhance economic performance	Maximise the dollar value of your recreational fishing experience	
	Generate economic value for the recreational fishing industry	Maximise the dollar return for the charter fishing industry
		Maximise the dollar return for the fishing tackle industry
	Increase development of quality regional fisheries to promote tourism	
	Minimise the cost of adhering to management regulations for the charter fishery	
	Increase investment in the fishery to obtain best management outcomes	
Ensure social outcomes	Increase the number of individuals participating in recreational fishing each year	
	Increase time spent fishing (with family and friends)	
	Increase opportunities to compete in fishing tournaments	
	Ensure that the share of catch between sectors is fair, according to pre-agreed proportions	
	Improve recreational fishing experiences	Ensure a decent proportion of the stock can reach a trophy size
		Maintain enough fish overall to ensure quality fishing
		Maintain enough fish regionally to ensure quality fishing in local areas
		Ensure a good chance of encountering fish

Minor differences in ecological and social objectives were observed among stocks (Tables 6-8). Concern regarding post-release mortality of Mulloway led to the inclusion of an additional sustainability objective, "Ensure released fish have a high chance of survival". Tournament fishing was also not considered an objective for this stock, hence the social objective "Increase opportunities to compete in fishing tournaments" was omitted. A desire to recover localised populations of Snapper led to the inclusion of the ecological objective "Rebuild stocks in habitats previously known to support fish".

Complete list of objectives

An additional 20-26 objectives were included in the complete list for each stock (Tables A1 1-3). While considered worthy of retention by workshop participants, the additional objectives were deemed to be outside of the scope of a HS, because they were unlikely to be achieved by controlling harvest.

The additional objectives were primarily social and managerial, and were similar among stocks. Differences included: 1) increasing knowledge of the benefits of releasing large fish for Yellowtail Kingfish (Social, Table A1-2), 2) improving public education regarding the use of whole fish, to avoid waste and more generally respecting and valuing the fish, for Snapper (Social, Table A1-3), and 3) ensuring clarity of regulations for a Snapper HS (Management, Table A1-3).

Objectives considered during the workshop mostly require dynamic harvest control, where the amount of harvest is set in response to the performance of the fishery relative to the objective. However, numerous objectives were identified that could be achieved using fixed (static) management measures (Tables A1 1-3). These included the ecological objectives of coordinating with other sectors to minimise bycatch mortality of juvenile fish, particularly when setting catch and effort quotas in other fisheries, and protecting larger Snapper while retaining smaller fish for consumption. Ensuring protection of spawning aggregations for Snapper and Yellowtail Kingfish could be achieved via both dynamic controls and fixed measures, depending on whether spawning aggregations differ through time and space or remain in the same locations, respectively.

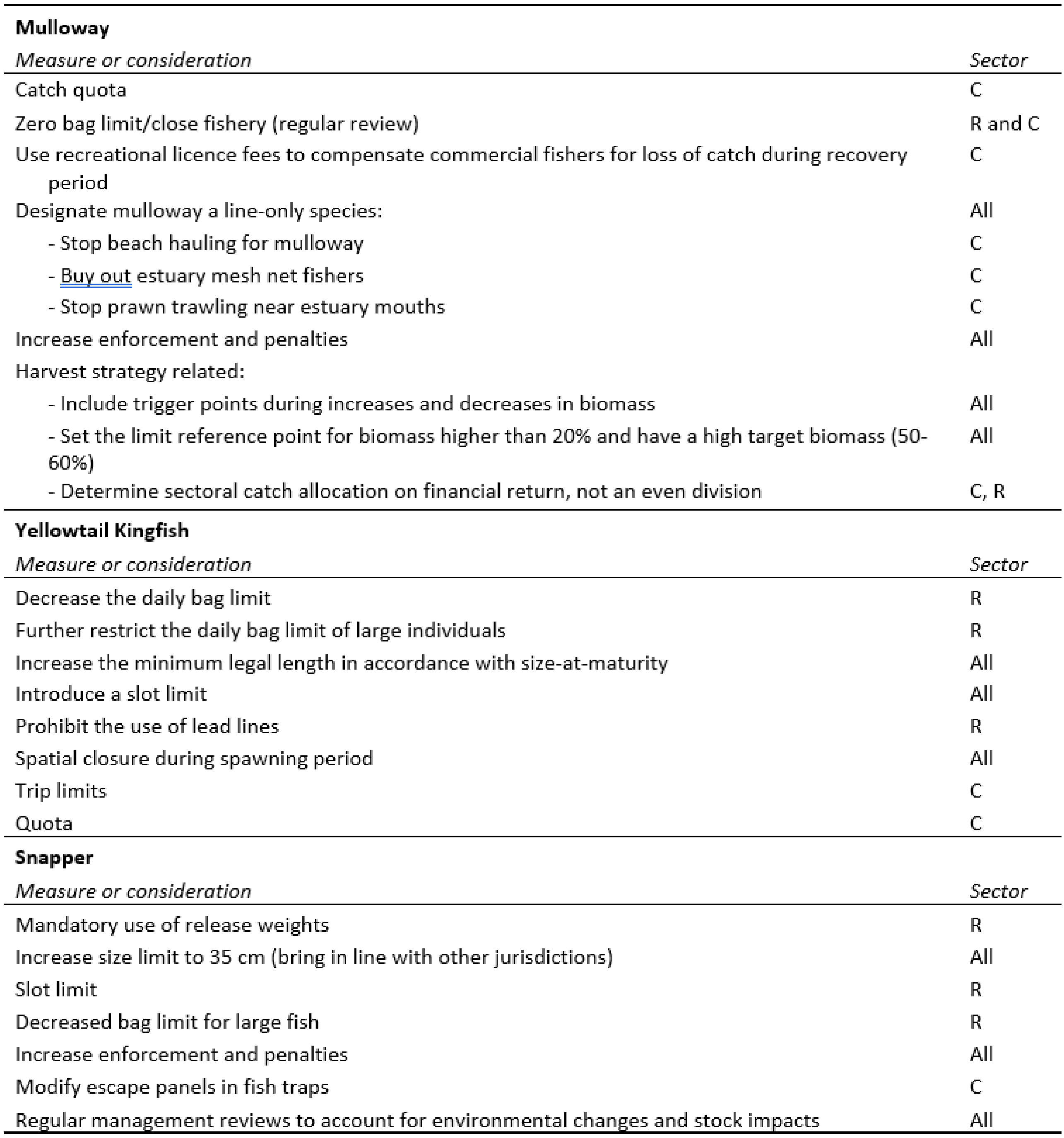
Social objectives potentially achieved using fixed management measures included minimising negative interactions with other aquatic users and avoiding interactions with other people generally. Management objectives focused on the development and review of HSs, specifically, broadening the range of RF-specific HS components, optimising the frequency of HS reviews, and including breakout rules for RF (Tables A1 1-3).

Potential management measures and considerations suggested by participants

Numerous measures and considerations were suggested for each stock (Table 9). These primarily related to limiting harvest, either through reductions in bag limits for the recreational sector or introducing catch quotas for the commercial sector. Harvest controls for particular size classes were also suggested, including slot limits and increasing the minimum legal length for both Yellowtail Kingfish and Snapper for all sectors. Increased enforcement and penalties were also suggested for Mulloway and Snapper for all sectors.

Suggested measures for Mulloway were more numerous and more substantial (Table 9), because participants identified that immediate and drastic management action is required for this stock until rebuilding has been achieved. Suggestions included a zero bag limit for the recreational sector, line-only status, and a closed fishery for the commercial sector, including ceasing commercial mesh netting and beach hauling for that species. The line-only measure reflects the fact that this method can be conducted with minimal mortality through catch-and-release, which is not possible with other methods. Suggestions were also provided for other HS components, including the use of trigger reference points during both increases and decreases in biomass. Setting the limit reference point higher than 20% of unfished biomass, setting a target biomass of 50-60% unfished biomass, and determining sectoral catch allocation on financial return were all suggested for this stock.

Table 9 Management measures or considerations suggested by workshop participants for each stock. The sector(s) that would be affected by each proposed measure are indicated. C: commercial, R: recreational. 'All' refers to commercial, recreational and Aboriginal customary fishers.



Mulloway

Measure or consideration	*Sector*
Catch quota	C
Zero bag limit/close fishery (regular review)	R and C
Use recreational licence fees to compensate commercial fishers for loss of catch during recovery period	C
Designate mulloway a line-only species:	All
- Stop beach hauling for mulloway	C
- Buy out estuary mesh net fishers	C
- Stop prawn trawling near estuary mouths	C
Increase enforcement and penalties	All
Harvest strategy related:	
- Include trigger points during increases and decreases in biomass	All
- Set the limit reference point for biomass higher than 20% and have a high target biomass (50-60%)	All
- Determine sectoral catch allocation on financial return, not an even division	C, R

Yellowtail Kingfish

Measure or consideration	*Sector*
Decrease the daily bag limit	R
Further restrict the daily bag limit of large individuals	R
Increase the minimum legal length in accordance with size-at-maturity	All
Introduce a slot limit	All
Prohibit the use of lead lines	R
Spatial closure during spawning period	All
Trip limits	C
Quota	C

Snapper

Measure or consideration	*Sector*
Mandatory use of release weights	R
Increase size limit to 35 cm (bring in line with other jurisdictions)	All
Slot limit	R
Decreased bag limit for large fish	R
Increase enforcement and penalties	All
Modify escape panels in fish traps	C
Regular management reviews to account for environmental changes and stock impacts	All

Discussion and conclusions

Recreational fishers identified a broad range of objectives for stocks of Mulloway, Yellowtail Kingfish and Snapper in NSW, indicating the sector has diverse interests in these stocks. While numerous ecological and economic objectives were identified, including those often associated with maintaining viable stocks and generating revenue for RF-related industry, many social and managerial objectives were also retained from the generic list provided to participants. This finding suggests that maximising fishery performance for the NSW RF sector will require consideration of objectives that extend beyond the objectives typically addressed in HSs. The finding in NSW is consistent with investigations into RF motivations globally, which have shown that satisfaction of recreational fishers is linked to both catch- and non-catch-related motivations (Arlinghaus 2006).

HSs have the potential to deliver considerable improvements in fishery performance for the RF sector in NSW, given that all ecological objectives and most economic objectives identified during workshops were considered suitable for inclusion in HSs. Decisions regarding suitability for inclusion were based on whether objectives were likely to be influenced by harvest – a prerequisite for achieving an objective through harvest control (Deroba and Bence, 2008). The effect of this control was expected to be indirect for some objectives, for example, it was still considered possible for harvest control to promote tourism, by assisting the development of quality regional fisheries through increases in fish abundance.

Many objectives identified in the workshops are likely shared with other fishing sectors, providing opportunities for development of mutually beneficial HSs in NSW. Examples include maintaining stock biomass, rebuilding depleted stocks and increasing investment in fisheries management. However, while the objectives themselves may be similar among sectors, the degree of fishery performance considered acceptable to meet these objectives may differ considerably. For example, HSs for commercial fisheries often aim for a stock biomass that provides maximum sustainable yield (B_{MSY}), yet this biomass is likely to be considerably lower than the 50-60% biomass target suggested for Mulloway by recreational fishers during the workshops. Determining levels of fishery performance that are acceptable to all sectors, or at least optimising the trade-offs for conflicting objectives, is essential for development of equitable HSs.

The similarity of objectives among the stocks examined suggests that RF objectives, while broad, may be relatively uniform across fin-fish stocks subject to similar fisheries activity in NSW. Similarity likely also arose from the fundamental nature of many objectives, for example, the need for sustainability. Other objectives lie at the sector or fishery level, rather than at the stock level, and lie outside the scope of HSs; for example, maintaining catch allocation among sectors and providing opportunities for co-management. Numerous social objectives relate to the fishers themselves, not the stock, for example, spending time with friends and family. The few differences that were observed among stocks tended to relate to stock-specific biological traits or requirements. For example, potentially high mortality of Mulloway following release (largely related to barotrauma effects) prompted the inclusion of an objective regarding ensuring survival of released individuals. The similarity of most objectives among the three stocks suggests that the lists generated in the current study may provide a useful base for development of objectives for other stocks.

Although ecological and economic objectives of recreational fishers are potentially achievable using HSs, many social and all management objectives from the complete lists were not considered suitable for inclusion. Despite this, a comparable number of social objectives, relative to other types of objectives (ecological, economic), were retained within the HS-specific lists. The links identified between social and ecological objectives suggest that some additional social performance may be achieved via ecological objectives that are included. Social monitoring would be required to confirm that fishery performance against social objectives is being achieved through ecological objectives. If social performance is being adequately achieved via ecological objectives, this would help to reduce the complexity of HSs and the resources required to service them. However, if social and management objectives are considered priorities for recreational fishers (see below), HSs alone may not achieve adequate fishery performance for the sector. In such circumstances, social and management objectives should be considered within the broader management regime, along with methods of monitoring and assessing success.

Objectives developed in the current study must be reduced in number for effective HS development, either by prioritisation or combination. While numerous objectives can simultaneously be included within HSs, each additional objective increases the complexity of the harvest control response (Dowling et al. 2020). It is extremely challenging to accommodate the sheer number of objectives developed in the workshops (even at the sub-objective level) within a HS framework, particularly given that other sectors will likely contribute separate and potentially competing objectives. Each objective also requires monitoring and assessment to evaluate its performance, increasing the resourcing required to maintain the HS. Prioritising RF objectives will focus HS development on the most important goals of the sector and increase the likelihood that each will be achieved. Workshop participants were surveyed to elicit their preferences among objectives developed in the workshop. Results from this elicitation will be compared to those from a broader survey of recreational fishers in NSW, under development as part of this project, and will be reported at a later date. If a small number of priority objectives are identified from the surveys, this will provide an objective base for selection of RF objectives. If not, consideration should be given to combining objectives of a similar nature where possible.

Identifying priority RF objectives

Survey responses

In total, 562 complete survey responses were received (Table 10). The greatest number was received from the random group (321), followed by the self-selecting group (224) and then the workshop group (17). Survey responses were spread relatively evenly across the three stocks (30-39% each). Given the relatively few surveys available from workshop participants (17 completed), information on demographics and fishing practices below are not presented for this group. This group is, however, included in analyses of preference weights. Nearly all respondents indicated they were independent recreational fishers with no other type of involvement in the fishery (Table 10). A small proportion (1.3%) of respondents indicated their main involvement was as charter operators and a single respondent indicated their main involvement related to the tackle industry.

Across both the random and self-selecting surveys, the average age of respondents was 47 years and 94% were male. Respondents had an average of 19 years’ experience fishing for the stock they elected to complete a survey for (Mulloway, Yellowtail Kingfish, or Snapper) and had spent an average of 29 days per year fishing for that stock during the previous three years.

Table 10 Summary of demographic and fishing operational characteristics reported by survey respondent from the random and self-selecting groups. Percentage values for operational characteristics were calculated within each respondent group.

	Random			**Self-selecting**		
	Mulloway	Yellowtail Kingfish	Snapper	Mulloway	Yellowtail Kingfish	Snapper
Complete responses	111	98	112	49	118	57
Main type of involvement in the fishery:						
- Independent recreational fisher (%)	99	99	98	100	96	98
Age (mean [range])	49 (21-78)	46 (21-82)	53 (20-85)	49 (21-87)	40 (14-75)	45 (18-83)
Gender (% male)	95	91	87	100	97	100
Years fished for target stock (mean [range])	26 (2-45)	15 (1-30)	18 (4-40)	20 (10-35)	21 (7-45)	10 (1-20)
Days fished per year (mean [range])	24 (3-40)	14 (4-30)	11 (1-30)	45 (15-100)	40 (2-100)	47 (8-156)
Region (% of respondents)						
- North	42	17	37	42	19	28
- Central	46	60	24	52	64	49
- South	12	22	39	6	17	23
Habitat (% of respondents)						
- Estuary	45	6	16	64	13	5
- Coast	51	60	41	32	65	61
- Offshore	4	34	42	4	22	33
Targeting (% of respondents)						
- Sole target	11	11	3	28	14	19
- Primary target	28	33	24	46	53	51
- Numerous target	61	56	73	26	33	30
Fishing platform (% of respondents)						
- Land	48	20	20	48	26	14
- Boat	52	80	80	52	74	86
Main method (% of respondents)						
- Live bait	41	39	5	20	46	0
- Lure	20	37	16	44	29	40
- Fly	0	2	0	0	2	0
- Spear	4	5	1	0	16	2
- Dead bait	36	17	77	36	8	58

Respondent clusters and characteristics

Based on the operational and demographic variables pooled across the three stocks, four clusters within the random respondent group were determined to be optimal by the majority of cluster evaluation methods (PSFE, PSFM, BIC, and BK, Figure A2-1 Appendix 2). The remaining two methods, AIC and SI, identified six and two clusters, respectively. The agglomerative coefficient was 0.85.

Primary cluster separation within the optimal scenario (four clusters) occurred between a small group of respondents and the remainder (Panel B, Figure 8). This small cluster was maintained across the lower and higher cluster scenarios (Panels A and C, Figure 8). Remaining respondents in the optimal scenario were then separated into three larger clusters, with one cluster (light blue, Panel B) being maintained in the three-cluster scenario (green, Panel A), and the other two clusters (red and green, Panel B) being maintained in a five-cluster scenario (red and yellow, Panel C).

Univariate comparisons indicated that age, years fished, and days fished per year all differed among clusters in the optimal (four cluster) scenario (ANOVA: Age – $F_{3,291} = 14.63$, $p < 0.001$, Years - $F_{3,291} = 9.96$, $p < 0.001$, Days - $F_{3,291} = 4.39$, $p = 0.005$; Figure 9). Respondents in Cluster 2 were the oldest, while respondents in Cluster 3 were the youngest (Tukey's HSD: $p < 0.05$; Figure 9). Respondents in Clusters 1 and 2 spent more years fishing for one of the three target stocks than respondents in Clusters 3 and 4 (Tukey's HSD: all $p < 0.05$; Figure 9), with mean years' experience in Cluster 2 more than double that of Cluster 4. Respondents in Cluster 1 spent more days per year fishing for one of the three target stocks than respondents in Clusters 3 and 4 (Tukey's HSD: all $p < 0.05$; Figure 9).

The proportion of respondents fishing in each region did not differ significantly among clusters (χ^2 (6, 295) = 9.43, $p = 0.151$), with a relatively even spread of respondents among North, Central and South regions (Figure 10a). A greater proportion of respondents in Cluster 2 fished offshore compared to other clusters (χ^2 (6, 295) = 88.99, $p < 0.001$; Figure 10b). With respect to targeting behaviour, a large proportion of respondents in Cluster 1 considered the stock in question to be a primary target, whereas most respondents in other clusters considered the stock to be one of numerous targets (χ^2 (6, 296) = 69.79, $p < 0.001$; Figure 10c). Most respondents in Cluster 3 fished from land whereas most respondents in other clusters fished from a boat (χ^2 (3, 295) = 127.87, $p < 0.001$; Figure 10d). A greater proportion of respondents in Cluster 1 used live bait compared to other clusters; the majority of respondents in other clusters used a spear (χ^2 (12, 301) = 100.88, $p < 0.001$; Figure 10e). All respondents in Cluster 4 were female whereas all, or nearly all, respondents in other clusters were male (χ^2 (3, 298) = 223.59, $p < 0.001$; Figure 10f).

Although the proportion of respondents completing surveys for each of the three stocks also differed significantly among clusters (χ^2 (6, 295) = 48.12, $p < 0.001$), clusters were not aligned with single stocks and all three species were represented in each cluster (Figure 10g). Clusters 1 and 3 had similar composition to each other, as did Clusters 2 and 4.

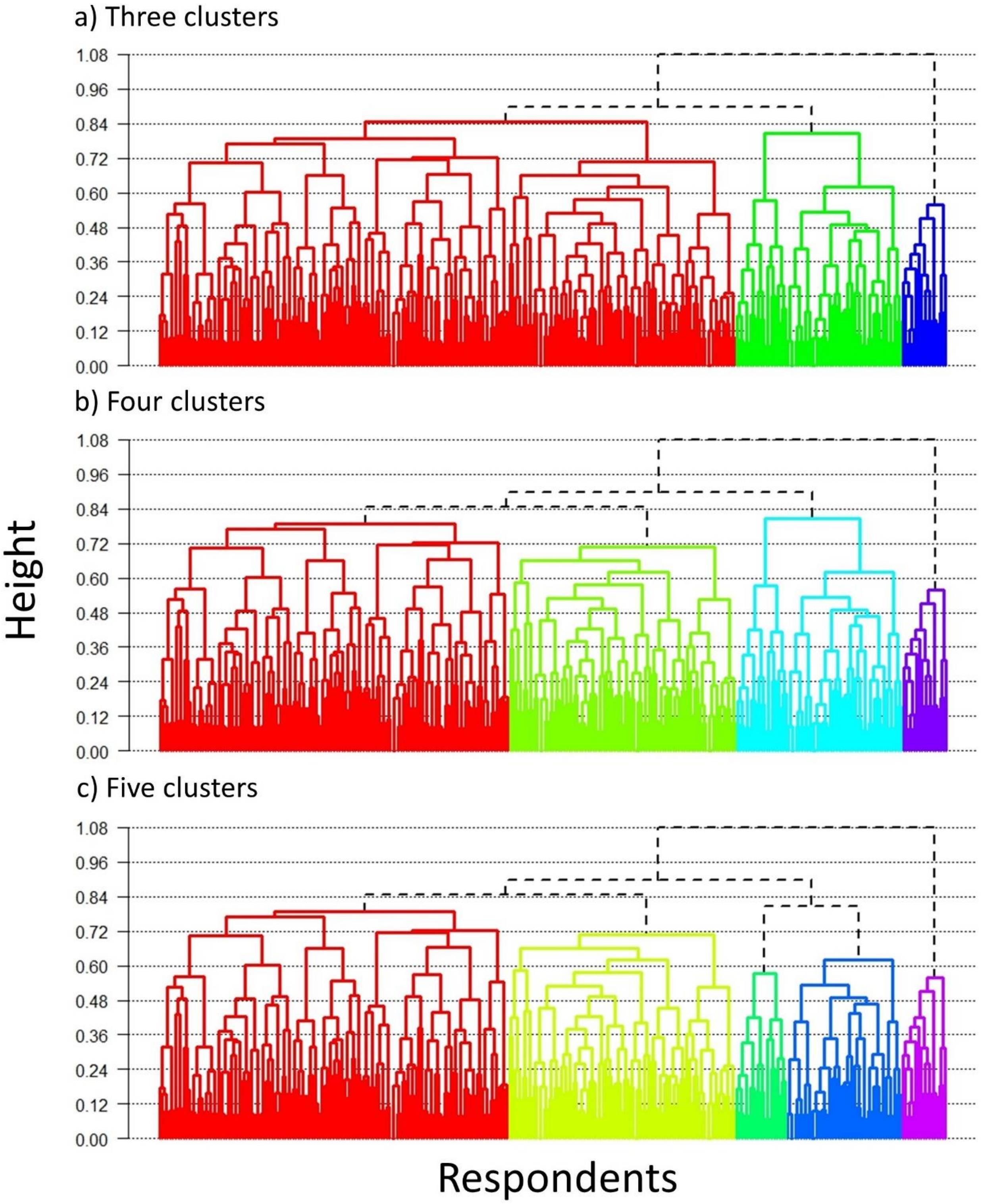


Figure 8 Dendrograms of survey respondents (random group) produced from clustering of operational and demographic characteristics. The result for the optimal number of clusters is shown in Panel b, while results for lower and higher cluster scenarios are shown in Panels a and c, respectively. Colours indicate separate clusters. The height represents the distance between clusters, with most distance observed between the smallest cluster and all other clusters.

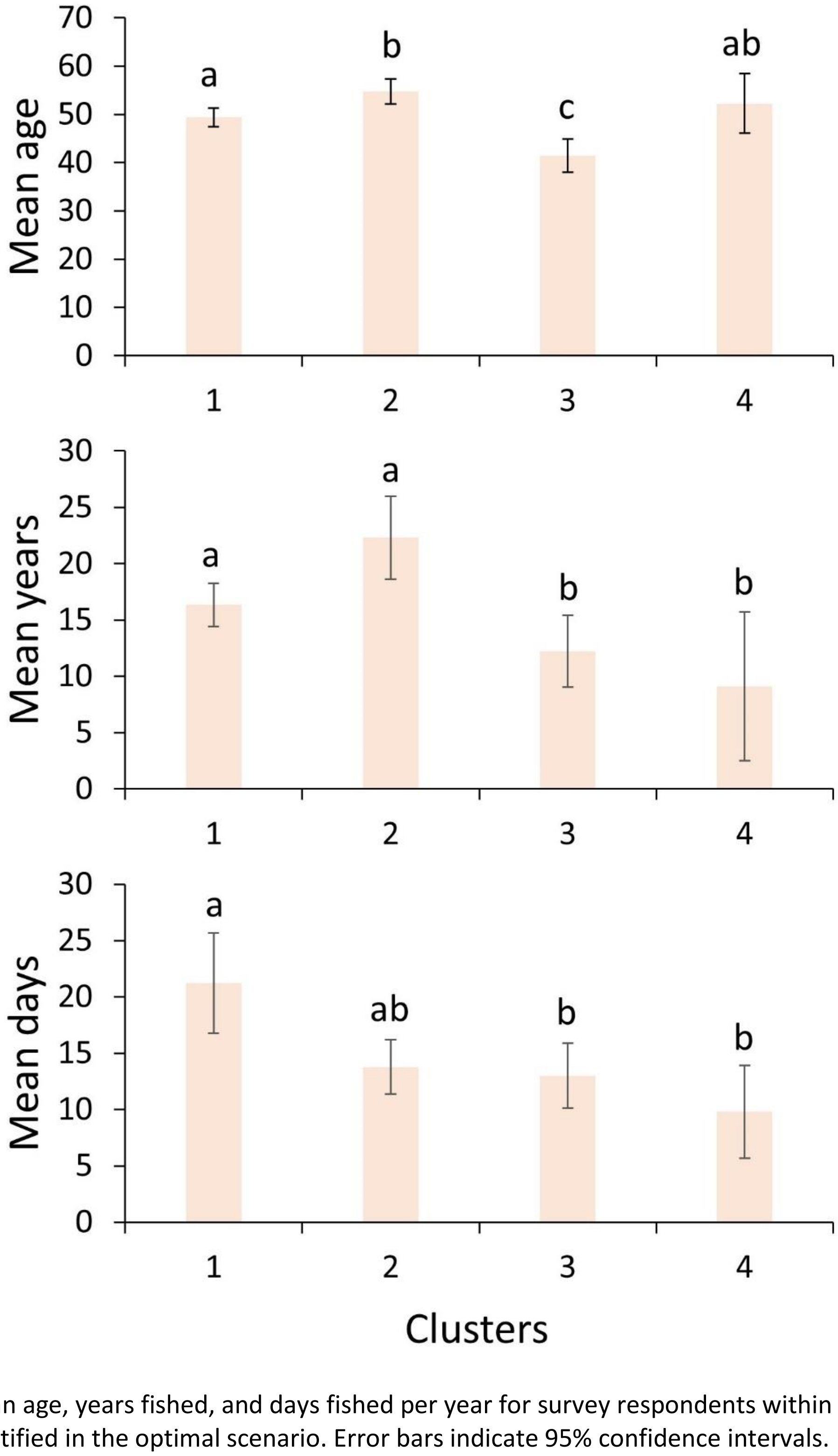


Figure 9 Mean age, years fished, and days fished per year for survey respondents within the four clusters identified in the optimal scenario. Error bars indicate 95% confidence intervals.

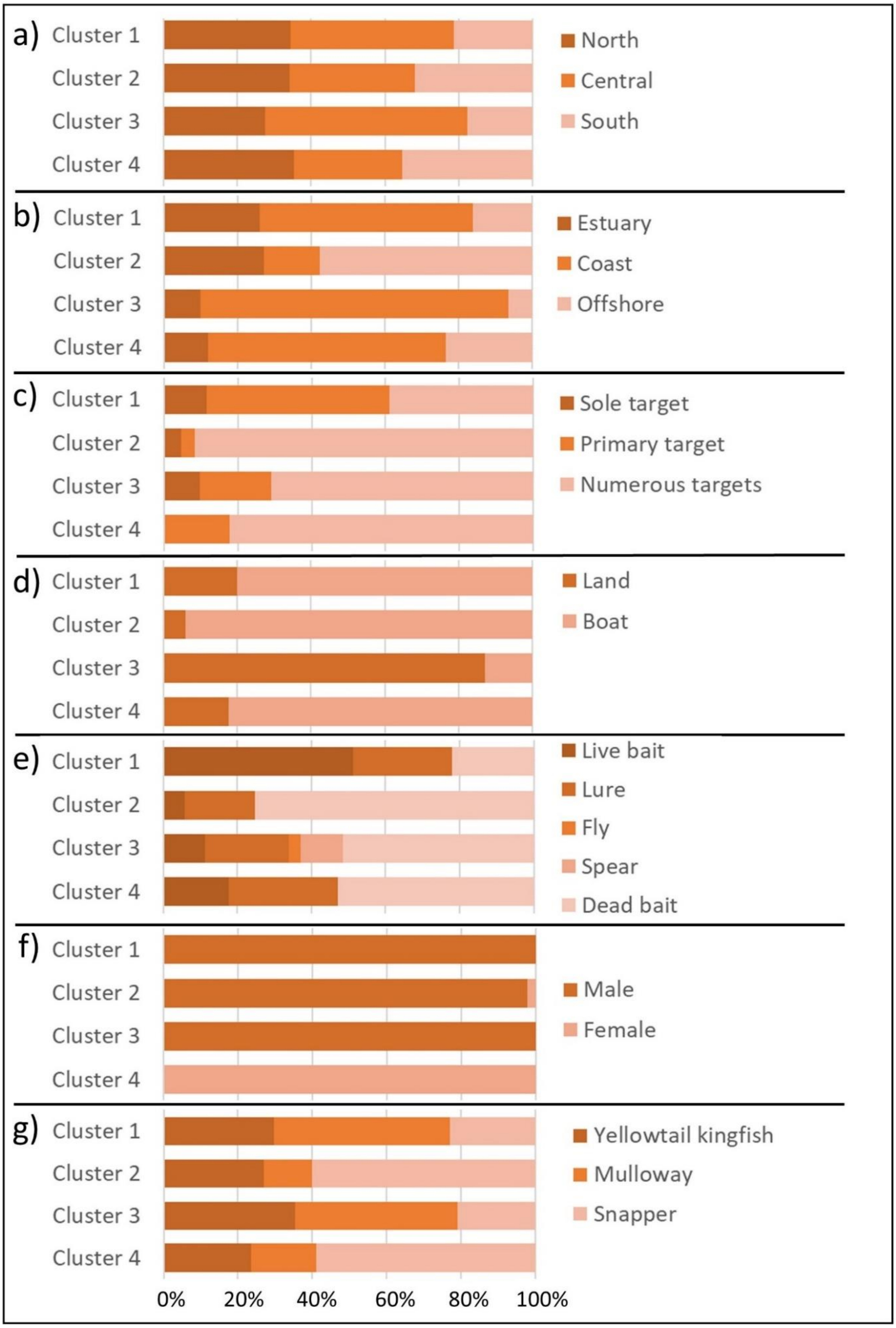


Figure 10 Proportional composition of clusters according to seven respondent characteristics: a) region fished, b) habitat fished, c) targeting behaviour, d) fishing platform, e) fishing method, f) gender, and g) target species.

Preference weightings – comparisons among objectives, stocks and respondent groups

The best model identified for most levels of the objectives hierarchy included the terms Objective, Group, and the interaction between Objective and Group, but did not include Stock or the associated interaction term (Table 11). There were only two departures from this; the best model for specific ecological objectives for Snapper did not include the interaction between Objective and group, and the best model for specific social objectives included all terms, including Stock and the interaction between Objective and Stock. Models explained between 24 and 80% of variability in preference weights (Table 11).

For the analysis of broad objective types (Analysis 1, Table 11), preference weights for ecological objectives were higher than those for either economic or social objectives in all respondent groups (Figure 11). Preference weights for social objectives were higher than those for economic objectives, except in the workshop group where these did not differ. For ecological sub-objectives (Analysis 2, Table 11), preference weights for ensuring a sustainable fishery were higher than those for minimising lost fishing gear and other waste in all respondent groups.

Analyses for specific ecological objectives were completed separately for each stock due to the slightly different objectives among them (Analyses 3-5, Table 11). Despite the selection of an interaction term for Mulloway and Yellowtail Kingfish, patterns of preference weights across objectives were relatively consistent among respondent groups and stocks (Panels 3-5, Figure 12). Preference weights for maintaining enough fish overall to ensure a healthy stock were generally the highest, while those for ensuring protection of spawning aggregations and ensuring released fish have a high chance of survival were generally the lowest (Panels 3-5, Figure 12). Preference weights for other objectives were typically intermediate and rarely differed from each other. Preference weights from the workshop group had a greater range and variance than other groups.

For economic sub-objectives (Analysis 6, Table 11), preference weights were highest for increasing investment in the fishery to obtain best management outcomes, except for the workshop group which also highly weighted increasing development of quality regional fisheries to promote tourism (Panel 6, Figure 13). The objective of minimising the cost of adhering to management regulations for the charter fishery received the lowest weights.

For specific economic objectives (Analysis 7, Table 11), preference weights were higher for maximising the dollar return for the fishing tackle industry than the charter fishing industry, and this pattern was consistent across all respondent groups (Panel 7, Figure 13).

For social sub-objectives for Mulloway (Analysis 8, Table 11), preference weights were highest for the objectives of ensuring that the share of catch between sectors is fair, according to pre-agreed proportions, and improving recreational fishing experiences (Panel 8, Figure 13). Increasing the number of individuals participating in recreational fishing each year received consistently low weights across respondent groups (Panel 8, Figure 13). Increasing the time spent fishing with family and friends also received a lower weighting from the self-selecting and workshop groups. Results for Yellowtail Kingfish and Snapper (Analysis 9, Table 11) were similar to those for Mulloway, with the additional objective of increasing opportunities to compete in fishing tournaments also receiving relatively low weight (Panel 9, Figure 14).

For specific social objectives (Analysis 10, Table 11), most objectives received similar preference weights, except for ensuring a decent proportion of the stock can reach a trophy size, which received the lowest weights across all stocks (Panel 10a, Figure 14) and the lowest weight from

Table 11 Best models identified from GLMM analyses of preference weights among objectives, stocks and respondent groups. Separate analyses were conducted for each level of the objectives hierarchy (see Tables 6-8). Separate analyses were conducted for stocks where their objectives differed within a level of the hierarchy. Model selection was based on Akaikes's Information Criterion (AIC). Dark grey indicates the comparison of broad objective types (ecological, economic, social), moderate grey indicates comparisons for lower-level ecological objectives, light grey indicates the comparisons for lower-level economic objectives and white indicates the comparisons for lower-level social objectives. Respondent was included as a random effect in all models.

Analysis description	**Model structure/terms**	**Pseudo r^2 (Efron's)**	**Model description**
1. Broad objectives - *All stocks included*	Weight ~ Objective + Group + Objective:Group + (1|Respondent)	0.53	Objectives, respondent groups and their interaction
2. Ecological sub-objectives - *All stocks included*	Weight ~ Objective + Group + Objective:Group + (1|Respondent)	0.24	Objectives, respondent groups and their interaction
3. Specific ecological objectives - *Mulloway*	Weight ~ Objective + Group + Objective:Group + (1|Respondent)	0.42	Objectives, respondent groups and their interaction
4. Specific ecological objectives - *Yellowtail Kingfish*	Weight ~ Objective + Group + Objective:Group + (1|Respondent)	0.52	Objectives, respondent groups and their interaction
5. Specific ecological objectives - *Snapper*	Weight ~ Objective + Group + (1|Respondent)	0.47	Objectives and respondent groups, no interaction
6. Economic sub-objectives - *All stocks included*	Weight ~ Objective + Group + Objective:Group + (1|Respondent)	0.47	Objectives, respondent groups and their interaction
7. Specific economic objectives - *All stocks included*	Weight ~ Objective + Group + Objective:Group + (1|Respondent)	0.80	Objectives, respondent groups and their interaction
8. Social sub-objectives - *Mulloway*	Weight ~ Objective + Group + Objective:Group + (1|Respondent)	0.43	Objectives, respondent groups and their interaction
9. Social sub-objectives - *Yellowtail Kingish and Snapper*	Weight ~ Objective + Group + Objective:Group + (1|Respondent)	0.52	Objectives, respondent groups and their interaction
10. Specific social objectives - *All stocks included*	Weight ~ Objective + Stock + Objective:Stock + Group + Objective:Group + (1|Respondent)	0.66	Full model

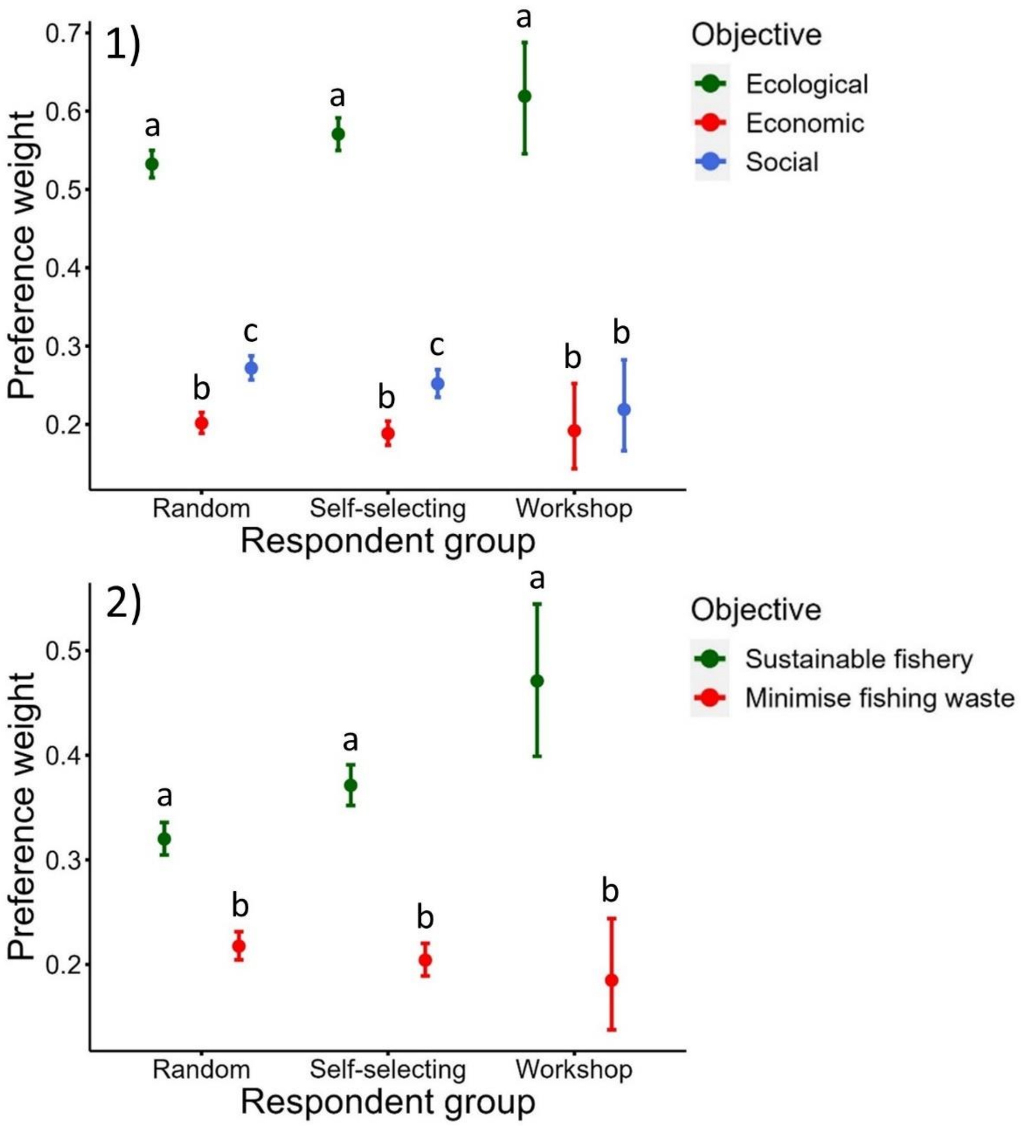


Figure 11 Mean preference weights (marginal effects) from GLMM analyses of: 1) broad objectives and 2) ecological sub-objectives (analysis numbers relate to Table 11). Weights are displayed for objectives within each respondent group. If values share a lower-case letter within a respondent group, they were not significantly different according to Tukey's tests adjusted for multiple comparisons.

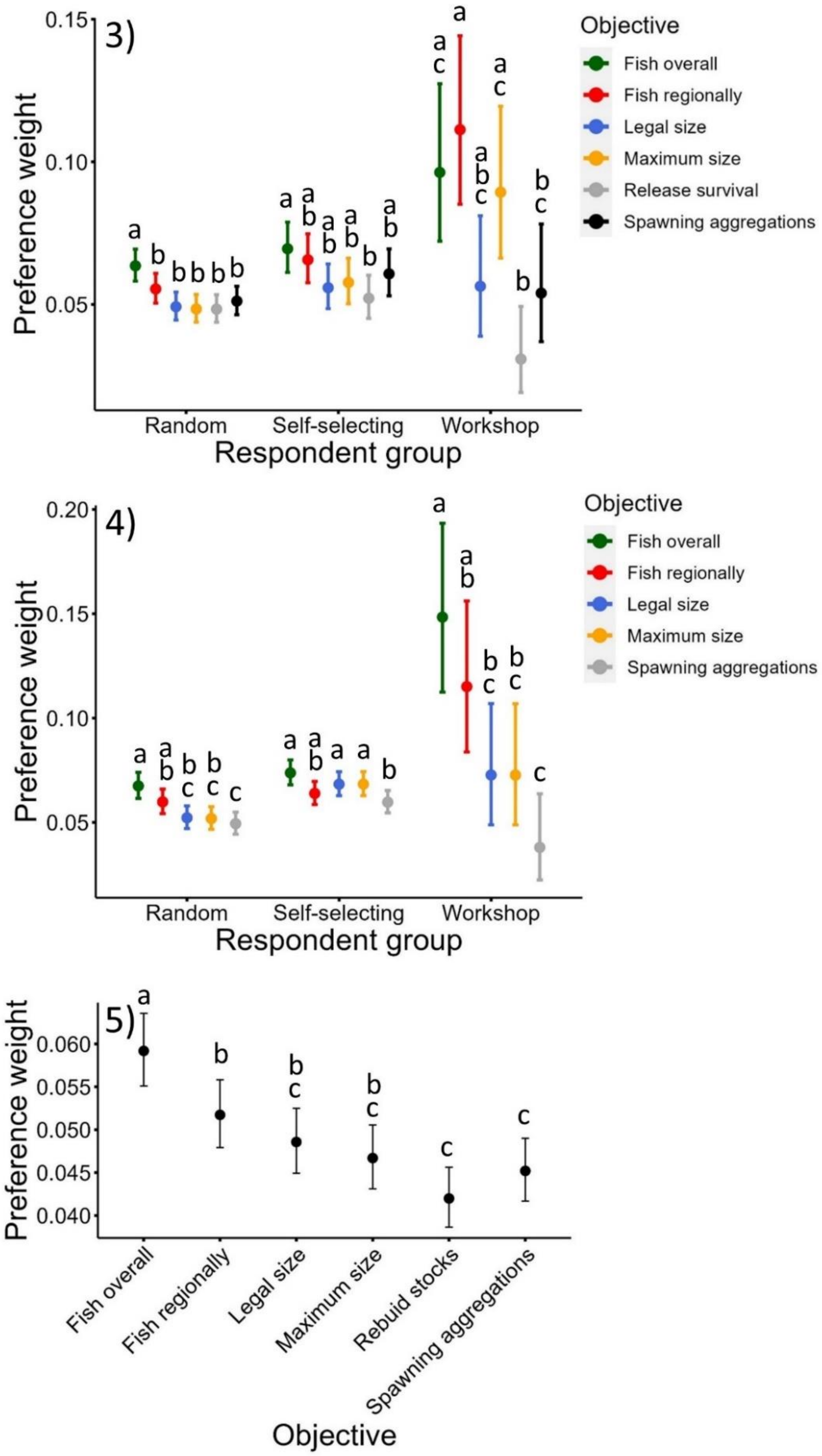


Figure 12 Mean preference weights (marginal effects) from GLMM analyses of specific ecological objectives for: 3) Mulloway, 4) Yellowtail Kingfish, and 5) Snapper (analysis numbers relate to Table 11). Weights are displayed for objectives within each respondent group, except for Snapper, where an interaction between Objective and Group was not included in the best model. If values share a lower-case letter within a respondent group, they were not significantly different according to Tukey's tests adjusted for multiple comparisons.

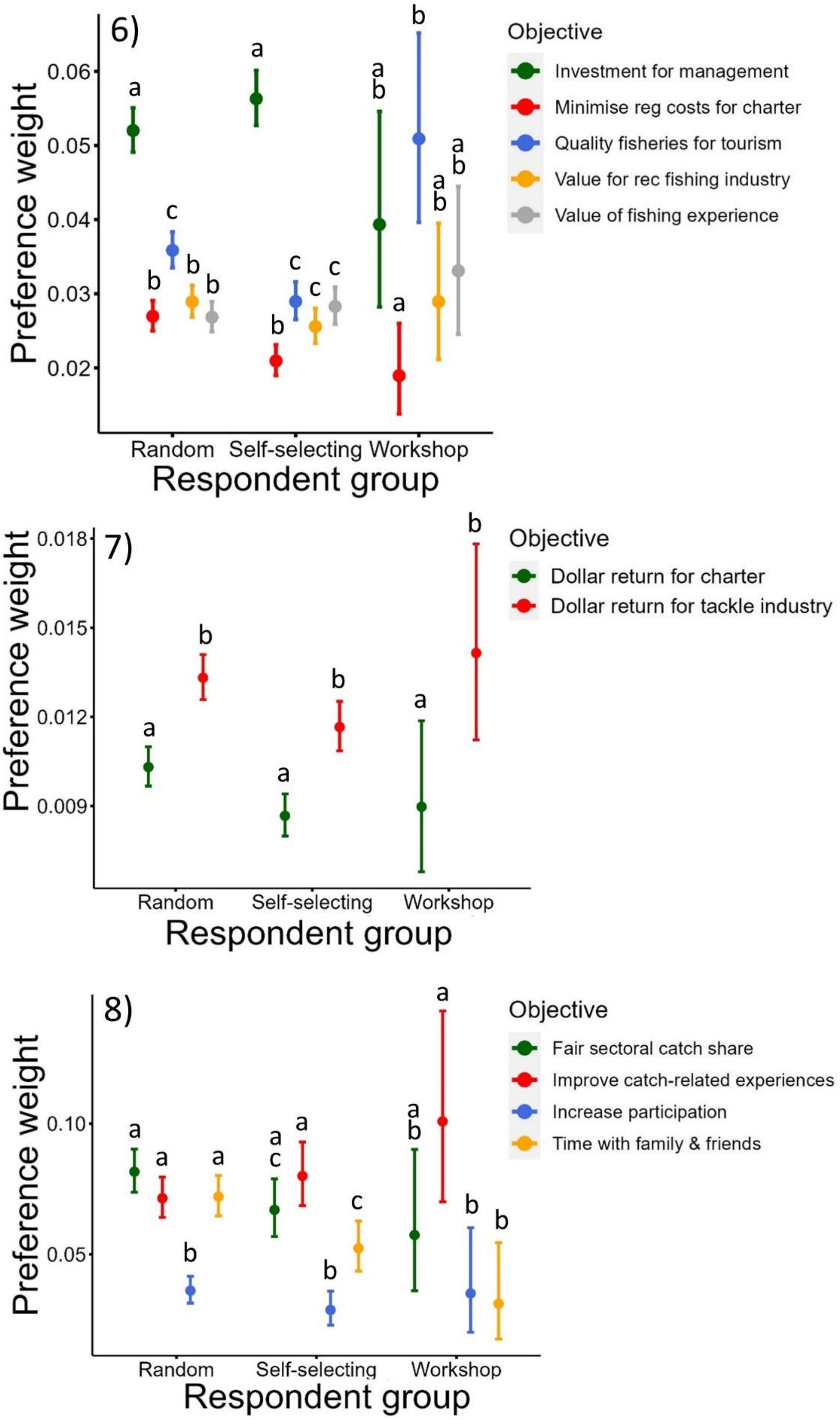


Figure 13 Mean preference weights (marginal effects) from GLMM analyses of: 6) economic sub-objectives, 7) specific economic objectives, and 8) social sub-objectives for Mulloway (analysis numbers relate to Table 11). Weights are displayed for objectives within each respondent group. If values share a lower-case letter within a respondent group, they were not significantly different according to Tukey's tests adjusted for multiple comparisons.

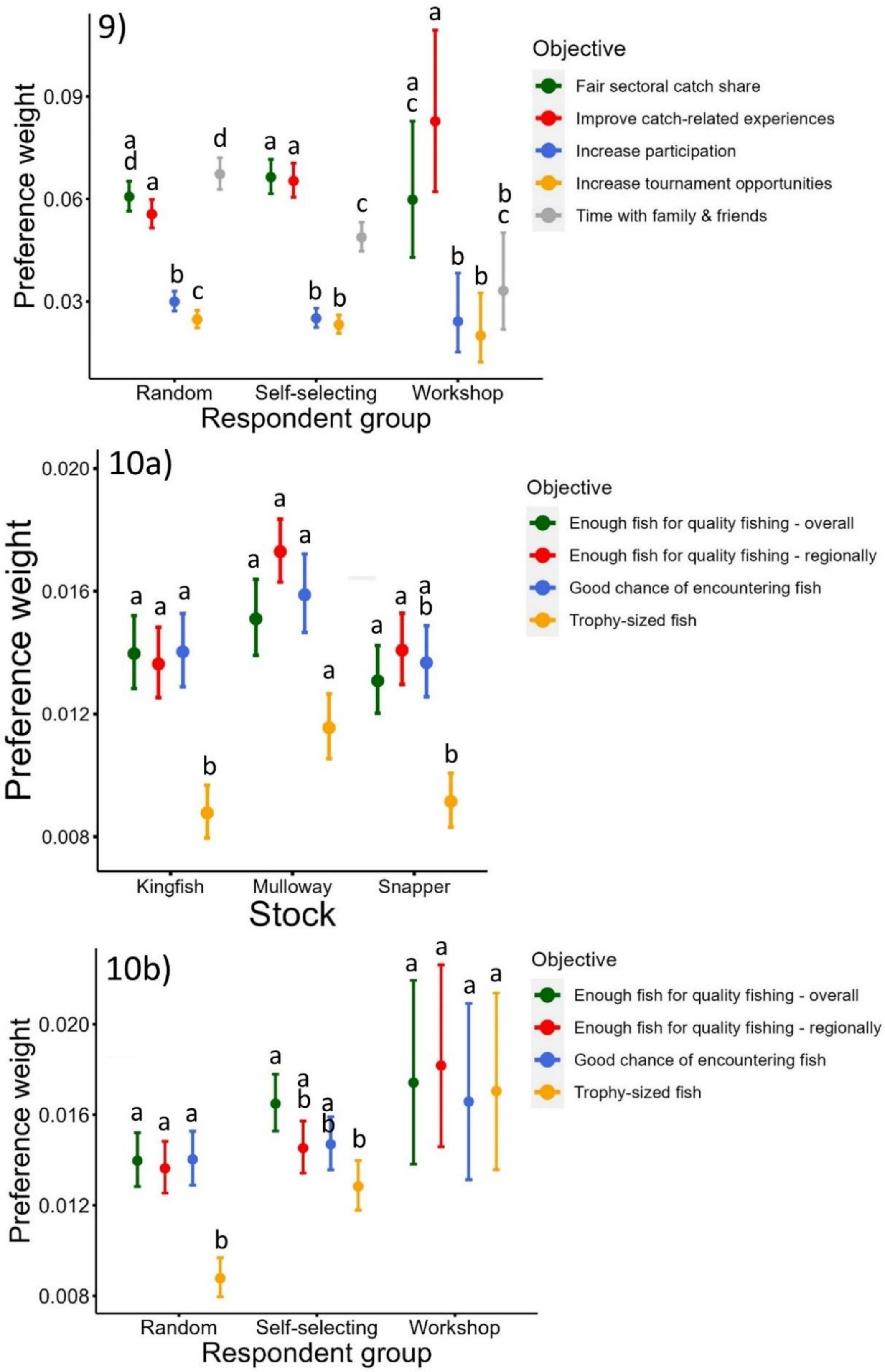


Figure 14 Mean preference weights (marginal effects) from GLMM analyses of: 9) social sub-objectives for Kingfish and Snapper combined and 10) specific social objectives (analysis numbers relate to Table 11). Panel 10a shows the interaction between Objective and Stock, while Panel 10b shows the interaction between Objective and Group. Weights are displayed for objectives within each respondent group (or stock). If values share a lower-case letter within a respondent group, they were not significantly different according to Tukey's tests adjusted for multiple comparisons.

the random and self-selecting respondent groups (Panel 10b, Figure 14). Trophy-sized fish received a similar weight to other objectives from the workshop group.

Preference weightings – comparisons among objectives and clusters

The best model identified for most levels of the objectives hierarchy included only the Objective term, not Cluster (Table 12). There were two departures from this: the best models for specific economic objectives (Analysis 7) and specific social objectives (Analysis 10) both included Cluster and the interaction between Objective and Cluster. Models explained between 14 and 79% of variability in preference weights (Table 12). The effect of Objective on preference weights is already outlined in the preceding section and visualised in Figures 11-14. Below, the effect of the interaction between Objective and Cluster is outlined for those analyses where the best model included the interaction term.

For specific economic objectives (Analysis 7, Table 12), preference weights were higher for maximising the dollar return for the fishing tackle industry than the charter fishing industry for Clusters 1 and 2 (Panel 7, Figure 15). In contrast, no difference in preference weights between the two objectives was observed for Clusters 3 and 4.

For specific social objectives (Analysis 10, Table 12), preference weights were similar among objectives, except for ensuring a decent proportion of the stock can reach a trophy size, which received the lowest weights across all clusters (Panel 10, Figure 15).

Discussion and conclusions

Our findings suggest that the RF sector within NSW has distinct priorities regarding fishing objectives that are relatively consistent across fish stocks and subsets of the RF community. Stock was only included in one of the ten statistical models across the objectives hierarchy, and although the best performing models typically included interactions with respondent group, the pattern of preferences among objectives was mostly consistent across the three groups examined. Objective preferences also rarely differed among subsets (or clusters) of recreational fishers defined by their demographic and fishing operational characteristics. The preferred objectives identified in the current study may therefore represent the core interests of a broad range of recreational fishers in the state and should be considered when developing HSs for the three stocks examined. The objectives may also provide a useful reference when developing HSs for other stocks in the region, although the extent to which the three stocks examined represent the breadth of stocks fished recreationally in NSW is unknown.

While considerable research has been conducted on the interests, motivations and objectives of recreational fishers, this has rarely been in the context of HS development. It is therefore unclear whether previously determined preferences for the sector are suitable for identifying priority objectives for HSs. For broad types of HS objectives, our findings are similar to those identified for recreational fishers in the Coral Reef Finfish Fishery (CRFFF) in Queensland, Australia, where ecological objectives received higher preference weights than economic, social and managerial objectives (Pascoe et al. 2019). A recreational preference for ecological objectives potentially simplifies HS development for multi-sector fisheries, because these are likely to be shared with other sectors to a large extent. Maintaining a sustainable stock biomass, for example, is a prerequisite for all forms of fishery performance and therefore represents a common objective, although the preferred amount of biomass (i.e. target reference point) may differ among sectors. Common objectives among sectors will help limit the total number of objectives that need to be included in multi-sector HSs, which will reduce the complexity associated with developing control

Table 12 Best models identified from GLMM analyses of preference weights among objectives and clusters of recreational fishers within the random respondent group. Separate analyses were conducted for each level of the objectives hierarchy (Tables 6-8). Separate analyses were conducted for stocks where their objectives differed within a level of the hierarchy. Model selection was based on Akaikes's Information Criterion (AIC). Dark grey indicates the comparison of broad objective types (ecological, economic, social), moderate grey indicates comparisons for lower-level ecological objectives, light grey indicates the comparisons for lower-level economic objectives and white indicates the comparisons for lower-level social objectives. Respondent was included as a random effect in all models.

Analysis description	Model structure/terms	Pseudo r^2 (Efron's)	Model description
1. Broad objectives - *All stocks included*	Weight ~ Objective + (1|Respondent)	0.50	Objectives
2. Ecological sub-objectives - *All stocks included*	Weight ~ Objective + (1|Respondent)	0.14	Objectives
3. Specific ecological objectives - *Mulloway*	Weight ~ Objective + (1|Respondent)	0.39	Objectives
4. Specific ecological objectives - *Yellowtail Kingfish*	Weight ~ Objective + (1|Respondent)	0.52	Objectives
5. Specific ecological objectives - *Snapper*	Weight ~ Objective + (1|Respondent)	0.50	Objectives
6. Economic sub-objectives - *All stocks included*	Weight ~ Objective + (1|Respondent)	0.47	Objectives
7. Specific economic objectives - *All stocks included*	Weight ~ Objective + Cluster + Objective:Cluster + (1|Respondent)	0.79	Objectives, clusters and their interaction
8. Social sub-objectives - *Mulloway*	Weight ~ Objective + (1|Respondent)	0.37	Objectives
9. Social sub-objectives - *Yellowtail Kingish and Snapper*	Weight ~ Objective + (1|Respondent)	0.50	Objectives
10. Specific social objectives - *All stocks included*	Weight ~ Objective + Cluster + Objective:Cluster + (1|Respondent)	0.71	Objectives, clusters and their interaction

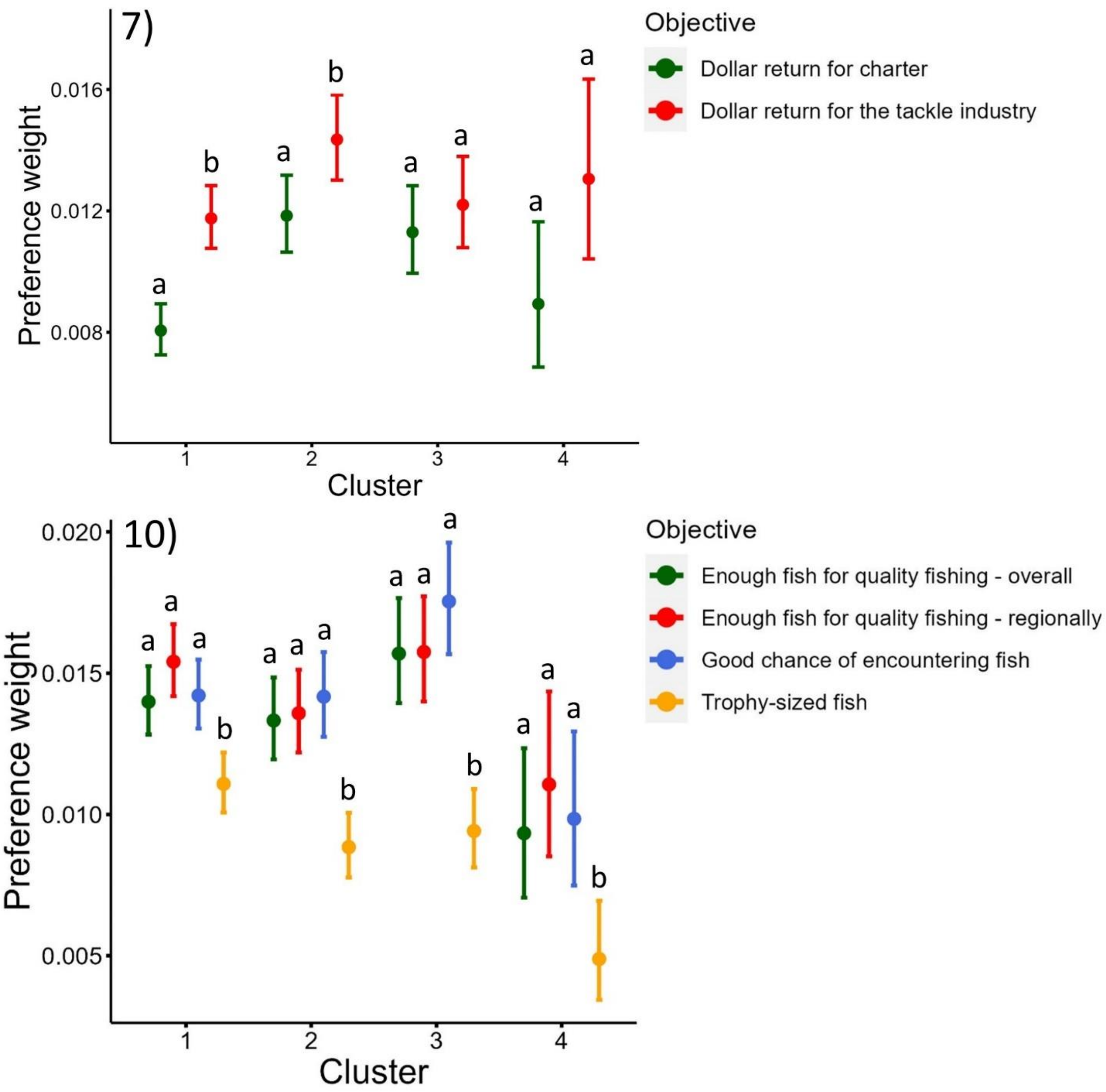


Figure 15 Mean preference weights (marginal effects) from GLMM analyses of: 7) specific economic objectives and 10) specific social objectives (analysis numbers relate to Table 12). An interaction between Objective and Cluster was observed for these two analyses. If values share a lower-case letter within a respondent group, they were not significantly different according to Tukey's tests adjusted for multiple comparisons.

rules that optimise trade-offs among competing objectives (Dowling et al. 2020). Prioritisation of ecological objectives may also reduce the number of economic and social objectives that need to be included within HSs, further limiting the complexity and data limitations often associated with addressing the Triple Bottom Line (Elkington 2006, Dowling et al. 2020). Considerably more RF data is available in NSW to monitor fisheries performance against ecological objectives than either economic or social objectives (Fowler et al. 2022).

The preference for specific ecological objectives related to maintaining "enough fish" might be expected, given that alternative objectives were related to more specific aspects of stock biology and ecology (e.g. "Ensure released fish have a high chance of survival"). The finding suggests that survey respondents possessed an understanding of the general benefit to fishery performance arising from sufficient stock biomass. The minimal differences in preference weights among most specific ecological objectives in the current study is likely due in part to the "dilution" of weightings at lower levels of the objectives hierarchy (Pascoe et al. 2019). This arises from the distribution of higher-level objective weights over many specific objectives during the final weight calculation. However, the variance of preference weights relative to the mean for specific objectives was greater than that for broad objectives, potentially indicating greater differences in opinion among respondents regarding the relative importance of specific objectives.

The preference for social objectives ahead of economic objectives in two out of three respondent groups in the current study suggests that social objectives should be given priority after ecological objectives when developing HSs that include the RF sector in NSW. While this finding differs to that of Pascoe et al. (2019) for recreational fishers and other stakeholder groups in the Qld CRFFF, it is consistent with a meta-analysis of recreational preferences from surveys conducted in Commonwealth, Queensland and southern fisheries in Australia (Pascoe and Dichmont 2017). These surveys all used similar methodology for preference elicitation to the current study – the Analytical Hierarchy Process (AHP, Saaty 1987). Findings for sub- and specific social objectives in the current study highlight the importance placed on catch-related experiential objectives, for example, "Ensure a good chance of encountering fish". The result is consistent with previous findings regarding the importance of quality recreational fishing experiences (García-Asorey et al., 2011; Young et al., 2016; Magee et al., 2018). Such preferences offer further potential for simplification of HSs that include the RF sector, because fishery performance for numerous catch-related experiences is likely to be achieved indirectly via ecological objectives related to stock biomass and distribution. The lower weighting given to an experiential objective relating to trophy-sized fish by the randomly-selected respondent group, a pattern not observed in the workshop group, suggests that catching trophy-sized fish may be less of a priority for the broader, potentially less-specialised fisher base in NSW. The low weight given to increasing RF participation may highlight a disparity between individual and collective desires regarding the number of RF fishers. At the individual level, more fishers may not be desirable given limited resources, yet at a collective level, more RF stakeholders may increase the prominence of the activity and the strength of the sector.

The objectives preferences determined in the current study are likely to benefit HS development in NSW beyond simply identifying priority objectives for inclusion. Firstly, they highlight aspects of RF data and monitoring that require consideration when developing HSs for the stocks examined. For example, the relatively high weight given to objectives regarding regional fishery performance indicates a potential need to develop regional monitoring of the RF sector. The primary data source for recreational catch in NSW includes a regional component, but divisions are coarse (three marine regions across 1000 km of coast) and do not necessarily reflect the spatial scale of population structure or fishing operations for specific stocks. Secondly, preference weights from the current study can be used to weight the contribution of performance indicators to a harvest control rule in a multi-indicator framework. This would eliminate arbitrary weighting decisions required in the absence of quantitative information on relative indicator importance. Thirdly, preference weights may indicate additional management processes required to support HS development or implementation. For example, the relatively high weight given to an objective relating to maintaining pre-agreed sectoral catch shares suggests that allocation policy may be an important prerequisite for HS success in NSW. At the time of writing, NSW does not have a policy for allocating catch among sectors within multi-sector fisheries.

As far as the authors are aware, this is the first attempt to representatively elicit objectives preferences for HSs within an entire fisheries management jurisdiction. The primary challenge was obtaining a sufficient number of responses from individuals who fished for at least one of the three target stocks within the previous 12 months. This is a recognised issue when targeting specific types of fishers while adhering to an appropriate random stratified sampling design (Tracey et al. 2022) that is amplified in regions like NSW with many recreationally-fished species (Murphy et al. 2023). The only suitable database of recreational fishers in NSW includes every long-term licence holder in the state (approximately 460, 000 individuals), without information on targeting preferences, requiring considerable survey effort to reach suitable respondents. Given the small number of complete responses from the random group (321) relative to the number of recreational fishers who likely target the three stocks in NSW, it is unclear how representative the views of this group are, despite the use of an appropriate sampling design. However, in support of the potential generality of our findings, objectives preferences were mostly similar across the three respondent groups. Each group had considerably different selection biases, e.g. random selection via telephone compared to self-selection via a website. A known source of potential bias, irrespective of the number of fishers surveyed, relates to the database only including long-term (1- and 3-year) licence holders. Preferences of short-term licence holders may differ to some degree, driven by operational characteristics potentially linked to licence duration, e.g. avidity and specialisation. Partial validation of the preferences identified in the current study might be achieved by including a short series of repeat questions within the ‘wash up/attitudinal’ survey within the statewide offsite-telephone diary survey of RF participation, catch and effort (Murphy et al. 2023). The biennial frequency of the survey may also allow for ongoing monitoring of potential changes in objectives preferences.

Given the challenges involved with development of efficient and effective multi-sector HSs, we recommend a flexible approach to inclusion of the RF objectives preferences identified in the current study. Explicit monitoring, assessment, and harvest control for numerous separate objectives across sectors may be impractical, due to data limitations and the difficulty in constructing control rules that effectively accommodate many performance indicators (PIs), particularly when trade-offs are required among completing objectives (Dowling et al. 2020). Initially, potential alignment of priority RF objectives with those of other sectors should be explored, to allow consolidation of objectives where possible. If RF objectives are distinct from those of other sectors, potential correlation of PIs across objectives should be considered that would allow the use of a subset for monitoring, assessment and harvest control (Dowling et al. 2020). For example, recreational strike rates are likely positively related to stock biomass, with the latter more readily monitored and assessed using non-recreational data. If discrete PIs are required for RF objectives, these may jointly inform harvest control, along with other indicators, via the use of a multi-indicator framework (Harford et al. 2021). Such a framework can still be implemented when a primary PI originates from a model-based stock assessment. If RF-specific PIs are distinct from those of other sectors, and these are not included within the assessment, performance of the HS against these PIs may still be evaluated using management strategy evaluation (MSE). Research that explores the various options for quantitative inclusion of RF objectives and tests resulting HSs would assist with practical implementation of the findings in the current study. Prioritisation, consolidation and quantitative inclusion of RF objectives should be considered a goal for HS development, because qualitative and potentially superficial inclusion risks antagonising RF stakeholders, particularly if a more structured and quantitative process is followed for the commercial sector. An important first step to such an equitable and quantitative process would be to eliminate RF objectives that cannot be achieved within a HS, regardless of the quantity and quality of data. The current study focused on RF objectives that lie within the scope of a HS, yet many RF objectives must be pursued through alternative resource management process.

Objective 2 - Identify types of recreational fishing data and monitoring that provide reliable measures of both the biological and experiential performance of fished populations

Review 1: International inclusion of RF in HSs

RF in marine multi-sector fisheries

The RF sector shares removals from marine stocks with both commercial and small-scale sectors in nearly all regions examined, but the relative extent varies considerably (Figure 16). In most regions, the RF sector shares stocks more often with the commercial sector than the small-scale sector. This is 'almost always' the case in Spain –Atlantic, the UK, and Canada, and 'mostly' the case in Japan, Australia, and the eastern regions of the U.S. The opposite was reported in Germany, São Paulo –Brazil, Namibia, and Spain –Mediterranean, where the RF sector more commonly shares marine stocks with the small-scale sector. In the Bahamas and Norway, the RF sector shares marine stocks equally with the commercial and small-scale sectors.

RF, as a component of multi-sector marine fisheries, was reported to be more prevalent in the coastal nearshore environment and estuaries than offshore (Table 13). However, there were numerous exceptions; for example, RF in the Bahamas was more prevalent offshore and within estuaries than nearshore. Shore-based fishing was generally more prevalent than boat-based fishing, except in Canada and São Paulo –Brazil, where the opposite was reported. Both types were equally prevalent in Norway (Table 13).

As expected, the range of fishing gear types used by the RF sector within multi-sector fisheries was considerably narrower than other sectors (Figure 17). Hook-and-line was 'almost always' used, with spear, pot or trap, and hand collection methods receiving median scores between 'often' and 'rarely' (2.0–2.5, Figure 17). The recreational use of mesh/gill nets, dip nets, and cast nets was reported from some regions.

HS elements specified for each fishing sector

In total, experts considered 339 harvest strategies (HSs) for marine multi-sector fisheries with a RF sector. Regions with the greatest number of HSs considered were the U.S. - SE, Norway, and Japan, while those with the fewest were Germany, São Paulo - Brazil, and Namibia (Figure 16).

The combined suite of HS elements specified for the RF sector differed to those from the commercial sector (pseudo-t = 2.638, p = 0.009) but was similar to those from the small-scale sector (pairwise PERMANOVA, pseudo-t = 1.674, p = 0.090; Figure 18). A breakdown of scores for individual HS elements (see definitions in Table 2) indicated that all elements were more frequently specified for the commercial sector than either the RF or small-scale sector (Figure 19). RF was "almost never" (1) or "rarely" (2) mentioned in HSs from 40% (6 out of 15) of regions. In contrast, the commercial sector was at least "often" (3) mentioned or "almost always" (5) mentioned in 73% (11 out of 15) of regions (Figure 19). Exceptions were the four U.S. regions, which reported identical inclusion of all HS elements for both the RF and commercial sectors. Excluding the U.S., the least frequently specified HS elements (scoring "almost never" [1]) for RF were the three types of reference points (Limit, Trigger and Target), followed by operational objectives and dynamic management controls. These elements relate to quantitative monitoring and management, the associated values of which can be challenging to specify for RF. These HS elements were also the least frequently specified for the small-scale sector. Target reference points and management controls were the least frequently specified elements for the commercial sector.

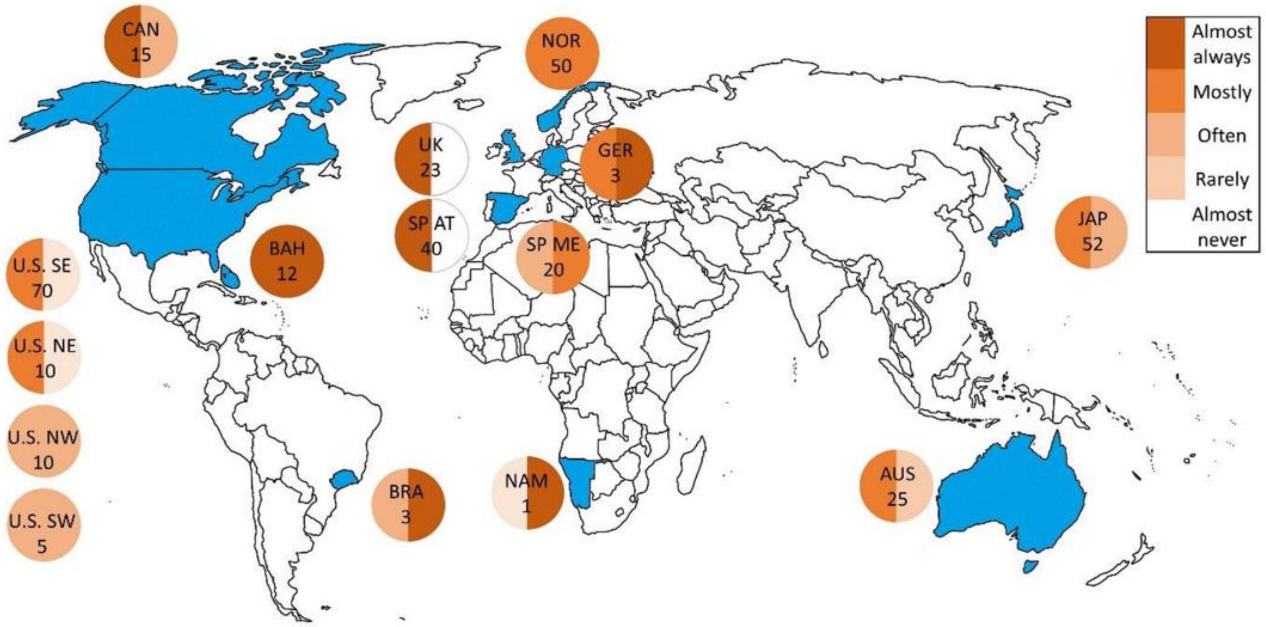
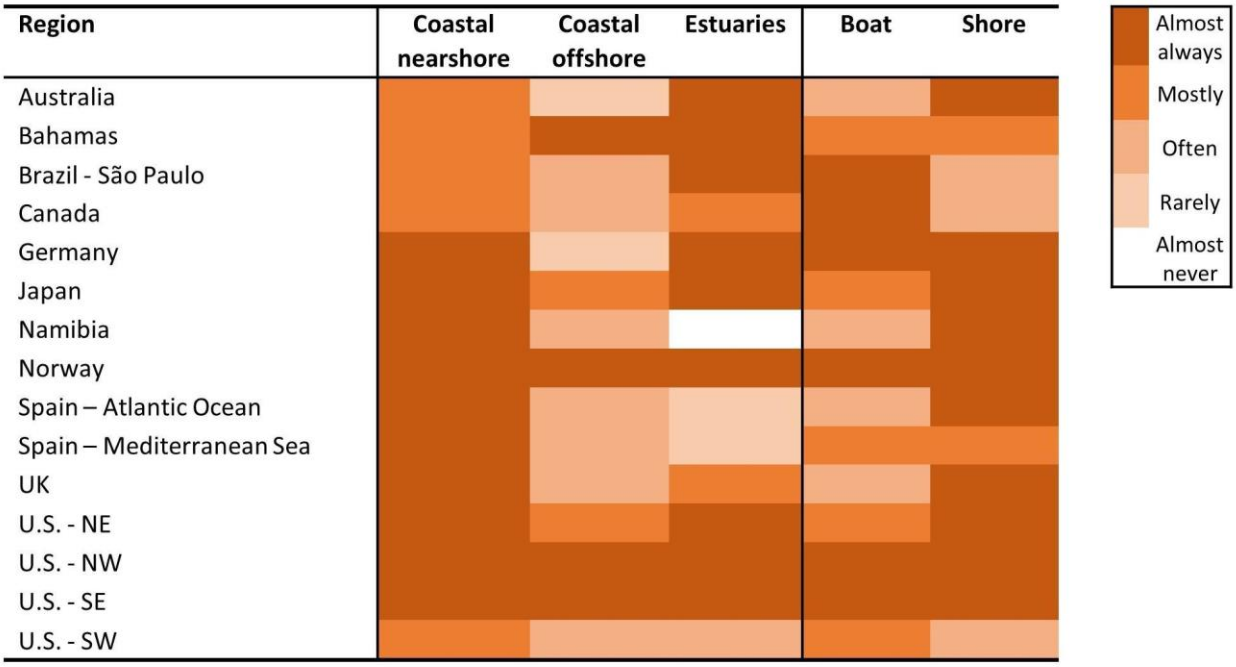


Figure 16 Regions included in the study (blue – abbreviated names for nations and regions fully described in Table 13). The colour scale indicates expert knowledge on the extent to which the RF sector is involved with marine fisheries that also include the commercial sector (left half of the circle) and the small-scale sector (right half of the circle) in each region. Numbers within circles indicate the approximate number of HSs considered, which is a subset of multi-sector fisheries in each region (see methods). Four regions are considered separately within the United States ("U.S.") and two regions are considered separately within Spain ("SP").

Table 13 Prevalence of RF by environment and fishing platform (boat vs shore) within multi-sector fisheries in each region. Colours indicate expert knowledge on the prevalence of RF in each environment and platform.



Region	Coastal nearshore	Coastal offshore	Estuaries	Boat	Shore
Australia	▓	░	█	▒	█
Bahamas	▓	█	█	▓	▓
Brazil - São Paulo	▓	▒	█	█	▒
Canada	▓	▒	▓	█	▒
Germany	█	░	█	█	█
Japan	█	▓	█	▓	█
Namibia	█	▒	□	▒	█
Norway	█	█	█	█	█
Spain – Atlantic Ocean	█	▒	░	▒	█
Spain – Mediterranean Sea	█	▒	░	▓	▓
UK	█	▒	▓	▒	█
U.S. - NE	█	▓	█	▓	█
U.S. - NW	█	█	█	█	█
U.S. - SE	█	█	█	█	█
U.S. - SW	▓	▒	▒	▓	▒

█	Almost always
▓	Mostly
▒	Often
░	Rarely
□	Almost never

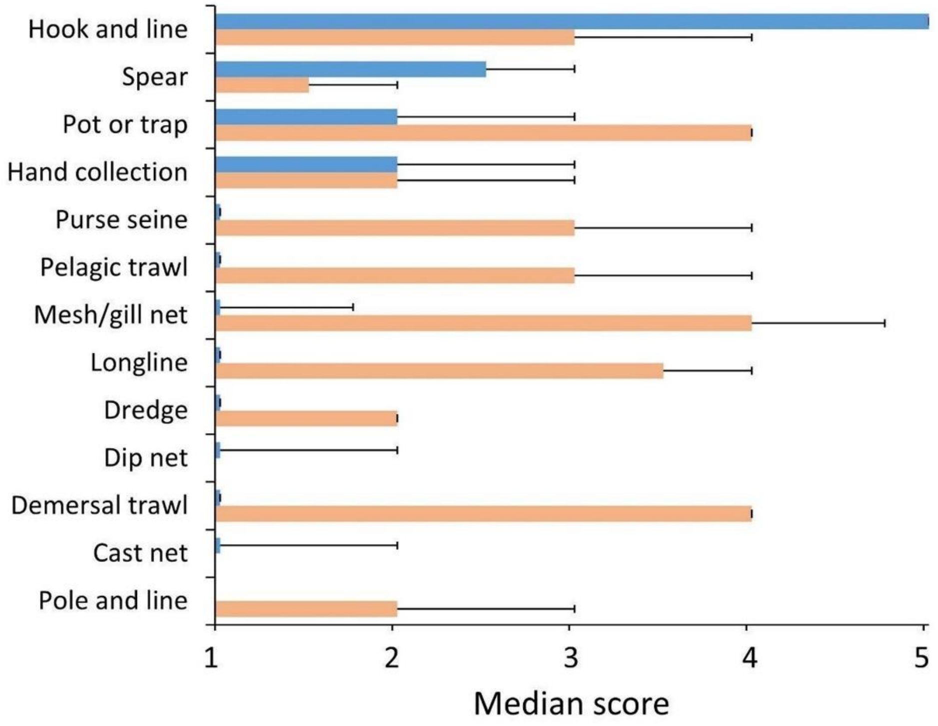


Figure 17 Types of fishing gear used by the RF (blue) and other (orange) sectors in marine multi-sector fisheries, expressed as a median score across 14 regions. Scores reflect expert knowledge on the prevalence of gear types used within each region, ranging from 5 ('almost always') through to 1 ('almost never'). Error bars indicate third quartiles. Namibia was excluded from this analysis because only one HS for a multi-sector marine fishery was reported.

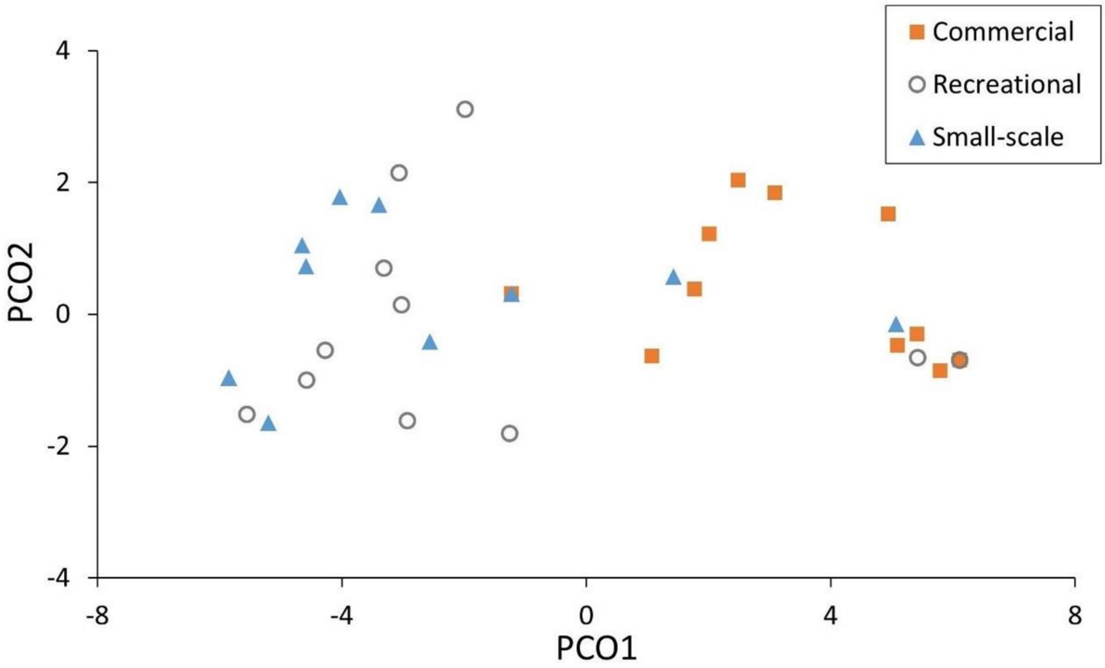


Figure 18 Principal coordinates analysis (PCO) comparing HS elements among sectors using expert scores on the extent to which each element was specified in the expert's region. Scores ranged from 5 ("almost always") through to 1 ("almost never"). Namibia was excluded from this analysis because only one HS for a multi-sector marine fishery was reported.

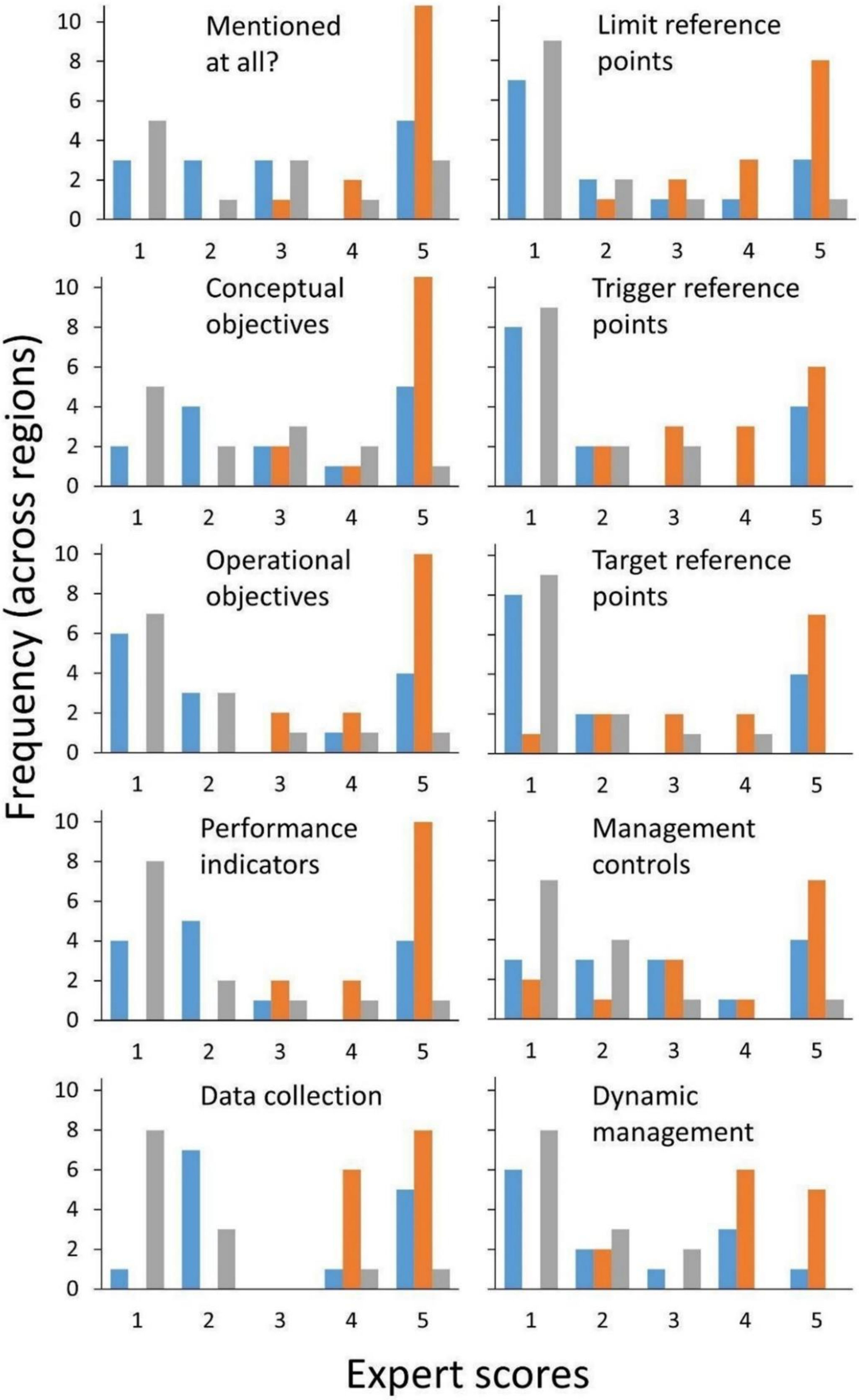


Figure 19 Expert scores indicating the degree to which each HS element was included for each fishing sector in 14 regions. Scores ranged from 5 ('almost always') through to 1 ('almost never'). Blue: RF sector, orange: commercial sector, grey: small-scale sector. Namibia was excluded from this analysis because only one HS for a multi-sector marine fishery was reported.

The lowest scores for the RF sector across all HS elements were reported from the two case study regions of the UK and São Paulo, Brazil (Table A3-1, Appendix 3). Elements were “almost never” (1) specified for RF in HSs in these regions, with the exception of data collection in the UK, which was “almost always” (5) specified, and management controls in São Paulo, which were “rarely” (2) specified. These scores contrasted strongly with those for the commercial sector in the same regions, with HS elements “almost always” specified in the UK and “rarely” to “mostly” specified in São Paulo.

Despite the relatively infrequent inclusion of RF in HS, experts from 87% (13 out of 15) of regions reported that inclusion has increased through time. Two exceptions were Namibia, where inclusion has reportedly decreased, and the U.S. – SW, where RF inclusion has reportedly been stable for the past decade.

Types of objectives specified for the RF sector in HSs

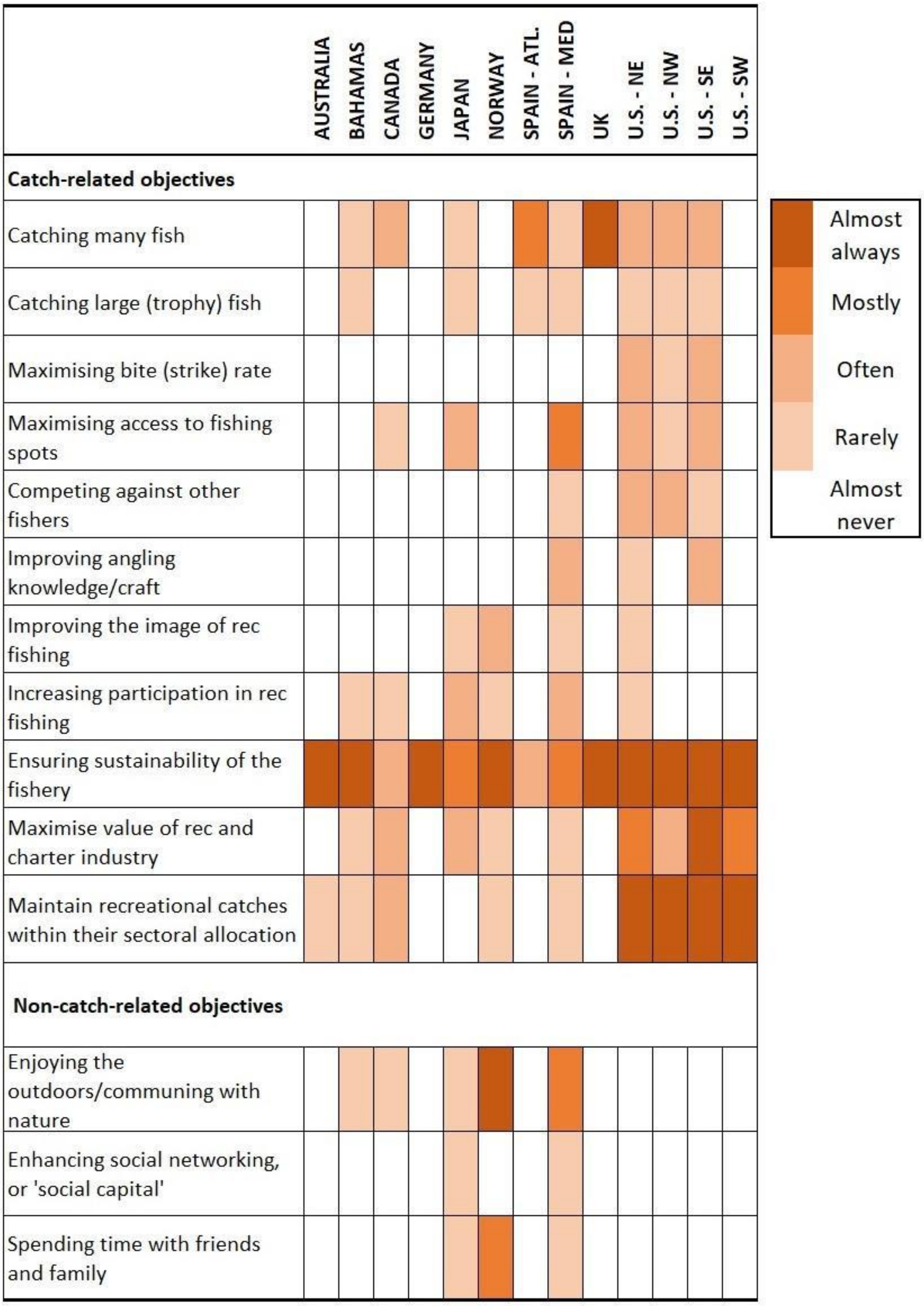
Fishery sustainability was the most frequently specified objective for RF and was included in HSs from all regions that reported specific objectives for the sector (13 regions, Table 14). The next most frequently specified objectives were maintaining catches within the RF sector allocation, maximising RF value, and catching many fish. Few regions reported social objectives that were unrelated to catch, such as enhancing social networking and spending time with friends and family. Exceptions to this were Norway and Spain – Mediterranean, which indicated that the objective “enjoying the outdoors/communing with nature” was “almost always” (5) and “mostly” included in HSs from these regions, respectively. Norway also listed “spending time with friends and family” as “mostly” included.

The breadth of RF objectives included in HSs varied considerably among regions (Table 14). Spain – Mediterranean included all objectives for the sector at least “rarely” (2), with the exception of maximising bite (strike) rate. The U.S. – NE included all catch-related objectives but none of the non-catch-related objectives. Regions with fewer RF objectives focused on fisheries sustainability, maintaining catches within the RF sector allocation, maximising RF value, and catching many fish (e.g., Australia, UK).

Conflicts specified in HSs

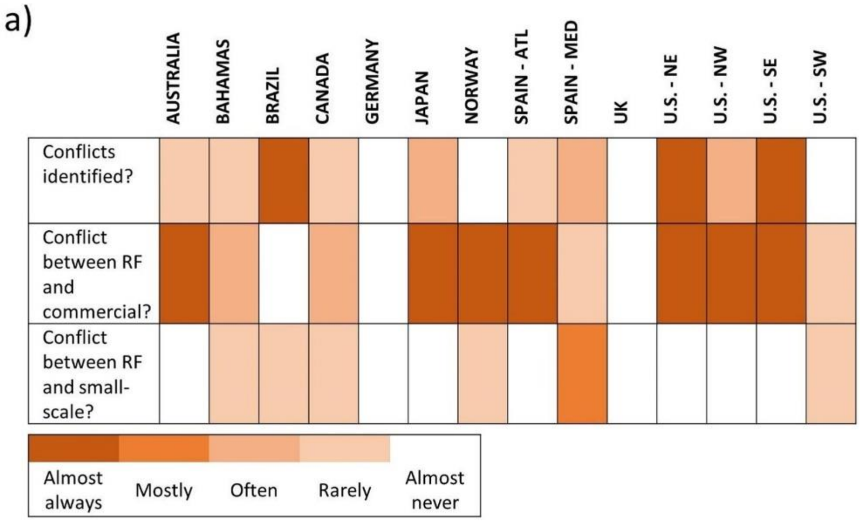
The inclusion of known conflicts between sectors in HSs also varied considerably among regions (Figure 20a). Even within the U.S., conflicts were “almost always” included in HSs from the U.S. – NE and U.S. – SE but rarely in HSs from the U.S. – SW. Conflicts were mostly between the RF and commercial sectors, rather than the RF and small-scale sectors (Figure 20a). Conflicts with the RF sector were mostly related to competition for a limited resource, especially with respect to allocation of that resource (Figure 20b). Other conflicts included different regulations between sectors and perceptions of unfairness, access rights, and a lack of appreciation for subsistence fisheries. Note that many of these cannot be directly addressed within a HS, but an inclusive HS may mitigate these conflicts to some extent.

Table 14 Objectives specified for RF in HSs for marine multi-sector fisheries in 13 regions. Colours indicate expert knowledge on the prevalence of each objective within HSs, ranging from 'almost always' (dark orange) through to 'almost never' (white). The prevalence of specific RF objectives was not reported for São Paulo, Brazil. Namibia was excluded because only one HS was reported.



	AUSTRALIA	BAHAMAS	CANADA	GERMANY	JAPAN	NORWAY	SPAIN - ATL.	SPAIN - MED	UK	U.S. - NE	U.S. - NW	U.S. - SE	U.S. - SW
Catch-related objectives													
Catching many fish		Rarely	Often		Rarely		Mostly	Rarely	Almost always	Often	Often	Often	
Catching large (trophy) fish		Rarely			Rarely		Rarely	Rarely		Rarely	Rarely	Rarely	
Maximising bite (strike) rate										Often	Rarely	Often	
Maximising access to fishing spots			Rarely		Often			Mostly		Often	Rarely	Often	
Competing against other fishers								Rarely		Often	Often	Rarely	
Improving angling knowledge/craft								Often		Rarely		Often	
Improving the image of rec fishing					Rarely	Often		Rarely		Rarely			
Increasing participation in rec fishing		Rarely	Rarely		Often	Rarely		Often		Rarely			
Ensuring sustainability of the fishery	Almost always	Almost always	Often	Almost always	Mostly	Almost always	Often	Mostly	Almost always	Almost always	Almost always	Almost always	Almost always
Maximise value of rec and charter industry		Rarely	Often		Often	Rarely		Rarely		Mostly	Often	Almost always	Mostly
Maintain recreational catches within their sectoral allocation	Rarely	Rarely	Often			Rarely		Rarely		Almost always	Almost always	Almost always	Almost always
Non-catch-related objectives													
Enjoying the outdoors/communing with nature		Rarely	Rarely		Rarely	Almost always		Mostly					
Enhancing social networking, or 'social capital'					Rarely			Rarely					
Spending time with friends and family					Rarely	Mostly		Rarely					

🟧	Almost always
🟧	Mostly
🟧	Often
🟧	Rarely
⬜	Almost never



b)

Description of the conflict	**Frequency**
Competition for a limited resource especially with respect to allocation of that resource	11
Lack of appreciation for subsistence fisheries	2
Differential regulations and perceptions of unfairness	2
Restricted access to fishing areas	2
Inequity of size limit between sectors	2
Lack of knowledge of fisheries	1
Blurred lines between commercial and recreational	1

Figure 20 Conflicts between RF objectives and those of other sectors in HSs for marine multi-sector fisheries: a) the extent to which known conflicts are explicitly stated in HSs and which sectors are involved in each region, and b) the frequency of specific types of conflicts, as reported by experts. Namibia was excluded because only one HS for a multi-sector marine fishery was reported.

Discussion and conclusions

The limited inclusion of RF in HSs identified in the current study, together with the fact that RF plays a significant and often increasing role in the harvest of marine resources, raises uncertainty regarding the sustainability and management of marine multi-sector fisheries. Experts from numerous regions reported that RF was not even mentioned in HSs for fisheries where the activity was undertaken. The risks of not effectively including the RF sector in HSs are ecological, social and economic, stemming from: 1) reduced likelihood of achieving fishery performance for the RF sector, to the point of systematic disadvantage, 2) uncertainty regarding the impacts of RF on target stocks and the broader ecosystem, and 3) inequity among sectors, including reduced accountability of the RF sector for its contribution to fishing mortality. Given our focus on nations with relatively efficient RF governance (Potts et al., 2020), the issue is likely widespread and potentially more severe in nations with less effective policy and legislation regarding RF.

Omitting or only partially including RF in HSs reduces the likelihood of delivering optimal fisheries performance because the processes required to achieve fishing objectives are not established. For HSs to function effectively, conceptual objectives must be translated into operational objectives, against which the performance of a fishery can be monitored using indicator metrics. Yet, operational objectives were one of the least frequently specified HS elements for the RF sector. Compounding this issue was the lack of reference points specified for the RF sector in many regions. Reference points provide both a target to aspire to and a limit below which fisheries performance is considered unacceptable. Without reference points, fishery performance cannot be explicitly assessed against the level required to achieve objectives. The risk of shifting baselines is also heightened because a reference of past performance is not formally retained (Pauly, 1995). Critically, the absence of a limit reference point for ecological objectives risks management inaction during a period when overfishing may be occurring (see Post et al. 2002, for example). While management decisions can be made ad-hoc, their pre-emptive development and automatic application at particular levels of fishery performance is a requirement of HSs that provides certainty for stakeholders, rights-holders, and user groups while also optimising resource protection. It also avoids the need to reactively develop socio-economically detrimental management measures during periods of poor fishery performance that could disproportionately penalize one sector.

As stated, the formal incorporation of RF objectives into HSs necessitates the translation of each conceptual recreational objective to an operational objective, associated with a quantitative performance indicator. These may be either directly (empirically) measured, or analytically derived from a quantitative stock assessment. They can then either directly inform a harvest control rule, and the resultant adjustment of management measures, or they can be used to evaluate the performance of the HS. For example, a performance indicator of strike rate might be compared to a target and limit reference point value, and this performance measure combined with others to inform an adjustment to the total allowable catch (TAC), and hence, the recreational bag limit. On the other hand, a time-series of strike rate might not contribute to a harvest control rule, but be used to determine whether a HS is performing well against this objective. Operationalising RF objectives explicitly within a HS can directly address certain forms of inter-sectoral conflict, either qualitatively by enabling trade-offs to be explicitly identified and discussed, or quantitatively, by each sector weighting the performance indicators and having these contribute to a sector-specific objective function, where the management outcome is adjusted until a cross-sector overall optimum is achieved (Dowling et al., 2020).

We identified significant cross-sectoral inequities in HS development for multi-sector fisheries that may lead to inequities in fishery performance and resource accountability. The more frequent inclusion of HS components for the commercial sector relative to the RF and small-scale sectors delivers fishery performance in favour of the commercial sector. While some degree of fishery performance for other sectors is likely to be achieved with commercial objectives, this will depend on the overlap among sectors, and the scale of RF relative to commercial. For example, increasing stock biomass from a low level is likely to benefit all sectors initially, but some recreational fishers may desire a ‘trophy’ fishery with a high likelihood of encountering large fish and thus a higher stock biomass and age structure. However, the great diversity within the RF sector itself means the objectives of at least some RF groups will be met at a stock biomass consistent with achieving commercial objectives (see Fowler et al., 2022). Small-scale fishers may want more medium-sized fish to efficiently feed community groups, while commercial fishers for the same stock are likely to value catches that maximise profit which may be achieved at a lower stock biomass (Hilborn, 2007). The rates of fishing mortality required to achieve these objectives are different, hence a compromise (trade-off) on exploitation rates would likely be required to balance the objectives of all sectors. The more frequent inclusion of HS components for commercial fishing also places primary accountability for the resource on that sector, which may not appropriately reflect contributions to fishing mortality from other sectors.

The need for explicit compromise between commercial, small-scale and RF sectors is likely to increase for marine fisheries, given HSs are being applied to more complex multi-sector scenarios (Dichmont et al., 2020) and recreational fishers share many stocks with other sectors (Figure 16). Increasing consideration of triple-bottom-line objectives (ecological, economic, and social) within HSs will also likely increase explicit trade-offs with the RF sector, given that a large proportion of RF objectives are social (Fowler et al., 2022) and will likely conflict with other types of fishing objectives, particularly economic ones (Dowling et al., 2020). The limited inclusion of known sectoral conflicts in HSs from numerous regions suggests that objectives requiring compromise, and their implications for achieving equitable fishery performance, are likely not fully realised. While the most common source of conflict between recreational and commercial fishers – resource allocation – is outside of the scope of a HS, the maintenance of those sectoral allocations, once decided upon, can be achieved within a HS.

The limited data collection specified for both recreational and small-scale fishing suggests uncertainty in the assessment of fishery performance and indicates that target stocks in numerous regions may be at increased risk of overexploitation. Sector-specific monitoring of retained catch is obviously required to understand total fishing mortality in multi-sector fisheries. Monitoring of each sector is also required to account for additional sources of mortality that are sector-specific, for example, discarding of undersized fish by the commercial sector and post-release mortality from the recreational sector, which can be substantial relative to retained catch. Underestimating mortality may lead to overestimation of future biomass in HSs that rely on model-based stock assessment. Knowledge of sector-specific harvest is required to specify effective management measures within HSs, to collectively reduce or increase fishing mortality in line with achieving fishery objectives. While the extent of these issues clearly depends on the relative magnitude of harvest among sectors, data on sector-specific harvest are at least initially required to make this determination. Although the collection of representative RF data is challenging, it is essential given that mortality from RF equals or exceeds that of commercial fishing in many marine fisheries (Coleman et al., 2004; Cooke and Cowx, 2006; Ihde et al., 2011; Brown, 2016; Hyder et al., 2018; Radford et al., 2018; Lewin et al., 2006, 2019).

In our analysis, we focused on federal fisheries in the U.S., which are all subject to the Magnuson-Stevens Fishery Conservation and Management Act (MSA, 2007). The equal inclusion of RF and commercial fishing in HSs in the U.S. is largely driven by the MSA. The MSA requires consideration of resource use for both sectors, operating under the premise that, "…fishery resources must be conserved and managed in such a way as to assure that an optimum supply of food and other fish products, and that recreational opportunities involving fishing are available on a continuing basis and that irreversible or long-term adverse effects on fishery resources are minimized" (Cloutier, 1996; Dell'Apa et al., 2012). Fisheries managers are also directed to achieve optimum yield for a fishery, defined in Section 3(33) as "the amount of fish which—(A) will provide the greatest overall benefit to the Nation, particularly with respect to food production and recreational opportunities…(B) is prescribed as such on the basis of the maximum sustainable yield from the fishery, as reduced by any relevant economic, social, or ecological factor…" However, other regions investigated in the current study also have legislation mandating consideration of RF opportunities (e.g., Australia), so it is unclear why such legislation has not resulted in greater inclusion of the RF sector within HSs in those regions, as it has in the U.S.

HSs in most U.S. regions also included a range of catch-related objectives likely to be of direct importance to the RF sector (e.g., catching many fish). While a number of these objectives may be indirectly achieved in other regions via more commonly applied ecological objectives related to stock biomass, their explicit inclusion in U.S. HSs, via the optimum yield mandate, at least facilitate some level of direct monitoring and assessment of success. Importantly, the focus on federal fisheries in the U.S. tends to depict the best cases for RF inclusion within HSs, as few coastal states have statutes similar to the MSA that guide fisheries management at the state level. Fisheries that primarily operate in state waters were included in some regions in the current study, but only fisheries that are managed through cooperative state/federal plans and, therefore, fall under MSA (e.g., summer flounder, black sea bass, and scup in the Northeast; salmon on the West Coast). Exclusion of most state-level fisheries likely increased the RF inclusion scores relative to a more exhaustive treatment of all U.S. fisheries.

Results from the two case-study regions of the UK and São Paulo (Brazil) indicate that poor inclusion of the RF sector in HSs can occur irrespective of the prominence of RF and developed governance structures. Although the per capita participation rate for marine RF in the UK is moderate relative to other European nations, the UK has the second highest number of recreational fishers and number of days fished per year in the Atlantic, as well as the highest annual average expenditure per marine recreational fisher in Europe (Hyder et al., 2018). Commercial fisheries governance in the UK is also well developed, as evidenced by our finding that HS components of the commercial sector are "almost always" included in HSs. The UK therefore provides a stark example of the HS gap that can develop between sectors, even where developed governance structures for fishing exist. This situation may have arisen through a common view in the UK that RF is a right, rather than an extractive activity to be regulated and managed alongside commercial fishing (Pawson et al., 2008). However, this situation is changing rapidly with the implementation of the UK Fisheries Act (2020), which has embedded recreational fisheries into the fisheries management process. Within this, there is the provision for the development of Fisheries Management Plans for many stocks that are co-designed by all sectors. This means that recreational fisheries are fully embedded and can engage in the fisheries management process. The process had not commenced when our initial survey was distributed, so these changes are not captured in the current analysis. At the time of writing, it was too early to identify outcomes from the development of Fisheries Management Plans, but early indications are positive with good engagement with recreational fishers (e.g. for European sea bass). In the state of São Paulo, Brazil, poor inclusion of RF in HSs likely stems from the limited capacity of fisheries management to keep pace with a rapidly growing sector (Barcellini et al., 2013; Arlinghaus et al., 2021). Catches for particular stocks in the state of São Paulo now already exceed those of the commercial sector, and small-scale fishers are transitioning to RF guiding services (Freire et al., 2016; Motta et al., 2016). Research and data collection for RF are also considerably lagging that for the commercial sector (Freire et al., 2016), presenting challenges for development of RF-specific HS components. The HS gap between the RF and commercial sectors was less severe in São Paulo than in the UK, due to only moderate inclusion of HS components for the commercial sector in São Paulo.

Identifying the cause(s) of limited RF inclusion in HSs is a critical first step toward addressing the issue. There are numerous potential and interrelated explanations, including: 1) a legacy of focusing on the historically more regulated commercial sector; 2) a lack of sectoral acknowledgement and thus lack of policy goals for RF in fisheries governance structures; 3) an assumption that the objectives of all sectors will be met by achieving those of the commercial sector; 4) a misconception that RF catch is insignificant and that catch-and-release has little or no impact; 5) challenges involved with regular and accurate monitoring of RF, together with limited ability to control total catch in response to assessment outcomes due largely to the open-access nature of most RF; 6) failure to address socio-economic aspects of sustainability; 7) a primarily harvest-based approach to decisions regarding the exclusion of sectors from HSs (e.g., prior resource allocation); and 8) limited organisation of the RF sector (e.g., lack of a 'peak body') and resulting challenges with representative engagement in management processes. Decisions to exclude a sector from a HS are often made via management processes that precede HS development and may be based on a limited range of criteria, most commonly an arbitrary threshold of harvest that is considered significant. Such an approach already fails to consider social and non-harvest-related economic aspects of sustainability, because the fishery objectives of the RF sector are often socio-economic and decoupled from retained catch. A continued focus on ecological sustainability in HSs, potentially at the expense of socio-economic considerations (Cevenini et al., 2023), is clear from the types of objectives specified for the RF sector in HSs considered in the current study (Table 14), although objectives regarding value for recreational and charter fishers were often included in numerous regions. The focus on ecological objectives for the RF sector likely mirrors a broader issue regarding limited implementation of the TBL to fishery HSs (Dowling et al., 2020), because articulating operational social objectives is challenging, as is relating economic objectives to the level of harvest.

While all fisheries have unique characteristics that limit generalisations, knowledge of operational scenarios that commonly involve RF will assist planning for HSs applied to multi-sector fisheries. Unsurprisingly, our results indicate that RF is more likely a consideration in HSs for nearshore rather than offshore multi-sector fisheries, due to ease of access. However, this may not be the case for island nations with a relatively narrow continental shelf, such as the Bahamas in our study (Sahoo et al., 2019). In these circumstances, RF may be more prevalent in offshore areas and HSs may need to integrate the objectives and activities of the RF sector with those of large, valuable and often international commercial fleets. Development of such HSs would particularly benefit from pre-established resource allocation between sectors, with allocation based on factors beyond mere harvest fraction, particularly given the prevalence of catch-and-release in offshore game fisheries (Whitelaw, 2003).

The prominence of shore-based RF in most regions raises issues regarding the capacity to monitor and assess the sector within HSs, which may affect the achievement of fishing objectives. While RF is generally challenging to monitor, shore-based catch and effort are particularly difficult to quantify due to the large and often unknown number of access points and broad spatial scale of potential effort. The activity is therefore frequently overlooked or omitted from stock assessments and HSs (Hartill et al., 2012; Hyder et al., 2014; 2018; 2020; Smallwood et al., 2012; Tate et al., 2020). Remote monitoring methods, including cameras and drones, may offer cost-effective solutions for ongoing monitoring of shore-based effort, but not catch (Smallwood et al., 2012; Desfosses et al., 2019). Novel approaches using smartphone apps could also be used (Skov et al., 2021), but the issues around bias also need to be assessed (Venturelli et al., 2017). Offsite surveys are not affected by the number of access points, but data may not be precise enough to determine fishery performance relative to predetermined reference points, e.g. target or limit reference points. Ultimately, the type of RF monitoring required will be dictated by the objectives and performance indicators. Whole-of-stock monitoring and assessment are not necessarily required to achieve objectives within a HS and a relative comparison of metrics obtained from smaller-scale on-site surveys through time may be sufficient to monitor fishery performance and support management measures for the RF sector.

The narrow range of gear types reported for RF in multi-sector fisheries suggests relative gear efficiency should be considered when attempting to achieve objectives for the sector within HSs. Common RF gear types, including hook-and-line and spear, are generally less efficient than nets and longlines that are more commonly used by the commercial sector. Such inefficiencies may result in poorer fishery performance for the RF sector relative to other sectors at the same level of stock biomass. For example, a stock at low biomass may still be viable for boat-based commercial fishers using nets, but too depleted to deliver an adequate strike rate for shore-based recreational fishers using hook-and-line (but see Kleiven et al., 2020). Differential management controls between sectors may exacerbate gear-based fisheries performance inequity, for example, lower minimum size limits for the commercial sector compared to the RF sector. Differential fishery performance among sectors may be addressed in HSs via a compromise on reference points; for example, adopting a higher limit reference point for stock biomass in the previous example, to ensure that unacceptable performance for the RF sector is not reached without substantial management intervention. Importantly, for the RF sector more than others, care must be taken when attempting to interpret fishery performance in relation to efficiency. Considerable fishery performance may be realised by recreational fishers at low efficiencies depending on other objectives that relate to the fishing experience (e.g., scenic beauty of the fishing location). In fact, primacy of non-catch-related objectives in some fisheries may drive continued RF effort at low stock biomass, maintaining RF satisfaction to the potential detriment of other sectors that rely on yield. Controlling total RF effort is challenging but likely essential for achieving fishery performance for, and accountability of, all sectors within multi-sector fisheries (Post et al., 2002).

The use of expert knowledge in the current study allowed an efficient international exploration of HSs, their elements, and the relative inclusion of the different fishing sectors. However, as with all elicitations of expert knowledge, our results were potentially influenced by respondent and procedural biases that cannot be fully accounted for (Martin et al., 2012). Although a range of bias control procedures was used (see Methods), only 1-3 experts could be engaged from each region and their responses may have been biased by their particular area of expertise and the completeness of their knowledge of HSs, among other things. Despite this, we believe it unlikely that biases substantially affected the findings of the current study, given the consistent results among most nations whose experts completed their questionnaires separately.

The substantial gap between sectors with respect to their inclusion in HSs risks the ecological and socio-economic sustainability of marine fisheries and we recommend it be addressed as a matter of urgency. RF stakeholder groups are becoming more engaged with fisheries management and are increasingly demanding such inclusion, recognizing that exclusion can lead to systemic disadvantage of the sector. Fisheries organisations should undertake a review of RF at the fishery level, to evaluate the magnitude of sustainability risk posed by the sector's partial or total exclusion from HSs. This may require establishment or improvement of RF data collection, both with respect to catch and effort, but also social and economic aspects. Consideration should also be given to management measures that can control total mortality arising from RF, something that cannot be achieved via the typical daily bag limits applied to open-access fisheries with a large number of recreational fishers that may engage in catch-and-release. In parallel, existing HSs should be revised with engagement of RF representatives, to ensure that the objectives of the sector are accurately captured and that suitable HS components and additional elements are established to achieve those objectives. To avoid future perpetuation of sectoral inequality in HSs, we recommend that nations establish legislation and policy that precisely specifies the requirements for inclusion of each sector within HSs, along with additional management policies, goals, and procedures that support the development of HSs, such as allocation policy and processes. The power imbalance between the RF and commercial sectors should also be acknowledged and controlled for during the HS development process, to ensure equitability of stakeholder input and the resulting outcome.

Review 2: HSs in Australia and development of a national database

Results and discussion

As of August, 2020, 49% of HSs in Australia explicitly mentioned both RF and commercial sectors. Most of these were for fisheries in SA (52%) and WA (32%), with the remaining few strategies spread across Qld, Tas and Vic. Only one HS was recreational-only ("Harvest Strategy for the South Australian Recreational Fishery") and one HS was charter-only ("Charter Fishery Harvest Strategy" in SA). At the time of this review, NSW had not completed a HS.

All HS elements were included more frequently for the commercial sector than the RF sector in HSs that included both sectors (Table 15a, Table A4-1 Appendix 4). Conceptual objectives were the most frequently included element for the RF sector (44% of HSs); however, these were less frequently supported by operational objectives or HS elements that would allow monitoring, assessment and control of fisheries performance to achieve those objectives. This indicates a greater risk of failing to achieve RF objectives than commercial objectives within existing multi-sector HSs.

For both sectors, performance indicators (PIs), reference points, assessments and management controls were more frequently articulated in HSs than operational objectives (Table 15a). This was unexpected, given that operational objectives are typically articulated first and functional HS elements (PIs, reference points, etc.) are then developed to address those objectives. Operational objectives are required for this purpose because conceptual objectives do not contain sufficient detail about the nature of fishery performance that is desired. The finding suggests reduced clarity regarding exactly what aspects of fishery performance are being achieved in Australia and to what degree that performance is addressing fishing objectives. Greater focus on articulating operational objectives within HSs would reduce uncertainty regarding fishery performance in future.

When objectives were specified for a sector, much greater equity was observed regarding articulation of associated HS elements (Table 15b). PIs and assessments were mostly articulated for objectives (89-91%), and to a lesser extent, management controls (72-77%). The most infrequently specified HS elements were reference points (target, trigger and limit), which is somewhat surprising given the requirement for PIs to be compared to reference points within the assessment. For the commercial sector, limit reference points were the most frequently articulated type of reference point (69% of objectives), presumably because of the severe consequences of breaching them. In contrast, trigger reference points were the most frequently articulated type of reference point (65% of objectives) for the RF sector, potentially because of the secondary nature of numerous PIs for the sector. For example, in the Qld Reef Line Fishery Harvest Strategy, a trigger reference point was included for an objective regarding "maintaining sectoral allocations for all coral reef fin fish species" (Queensland Government, 2020). When breached, an adjustment of the recreational catch limit is triggered, to return catch back to the allocated share. Target reference points were the least commonly articulated reference point for both sectors.

Most objectives articulated for the RF sector were biological (86%), which was similar to the commercial sector (82% of objectives). This resulted from the commonality of biological objectives regarding stock sustainability between sectors. Other biological objectives articulated for the RF sector included avoiding the impacts of fishing on bycatch species, Threatened and Protected Species (TEPS), habitats and ecological processes, as well as maximising the fishing experience within ecologically sustainable limits and share allocation (Table A5-1 Appendix 5). The latter objective might also be considered social. Interestingly, objectives regarding fish size were specified in only one HS (Blue Crab Fishery; PIRSA, 2018), and only then with respect to maintaining the proportion of legal-sized crabs, as opposed to achieving a 'trophy' size. This is consistent with preferences elicited from recreational fishers in NSW, where an objective about ensuring a decent proportion of the stock can reach trophy size received relatively low preference weight (see Objective 1).

No economic objectives were specified for the RF sector while 12% of objectives for the commercial sector were economic. While a lack of economic objectives might be considered intuitive for a recreational stakeholder group, there are numerous potential economic objectives that might be considered for the sector, including maximising the dollar value of the RF experience, generating economic value for the charter or tackle industries, and increasing development of quality regional fisheries to promote tourism (Tables 6-8). Including economic objectives for the RF sector in HSs should be given greater consideration, particularly when such objectives are included for the commercial sector. While explicit monitoring and assessment may be challenging, indirect fishery performance against economic objectives for the RF sector can likely be achieved via linked biological objectives, similar to the economic performance achieved for the commercial sector by achieving B_{mey} (biomass that delivers maximum economic yield).

Social objectives accounted for 14% of RF objectives, but only 5% of commercial objectives. Most of the social objectives related to maintaining catches within agreed sectoral allocations, which aligns with the preferences elicited from recreational fishers in NSW (Objective 1). Additional social objectives for the RF sector included improving lifestyle benefits, maximising the flow of recreational fishing (and charter) tourism-related economic benefit to the broader community, and providing flexible opportunities to ensure charter operators can maintain or enhance their livelihood (both economic and social; Appendix 5).

Findings from the current study indicate reduced inclusion of the RF sector relative to the commercial sector in HSs for multi-sector fisheries in Australia. This appeared to stem from an inequity regarding specification of objectives, because other HS elements tended to be equivalently specified for both sectors once an objective had been explicitly stated. When evaluating the objectives articulated for the RF sector, the authors took care not to exclude biological objectives that are typically common across all sectors (e.g. those relating to stock sustainability), where explicit mention of the RF sector may simply have been neglected. We therefore consider it unlikely that our findings reflect incomplete documentation of sectoral inclusion within published HS. The limited inclusion of the RF sector in Australian HSs is consistent with our findings from other regions of the globe, with the causes of such a pattern potentially numerous, entrenched and therefore challenging to address (see Review 1). We recommend an objective and considered approach to HS development for multi-sector fisheries, where sectoral equivalency is explicitly evaluated at each step of the development process, and for each HS element commencing with fishing objectives.

Table 15 Frequency of HS elements articulated for commercial and RF sectors at the level of a) harvest strategies and b) individual objectives.

a)

HS element	Commercial (%)	Recreational (%)
Conceptual objectives	63	44
Operational objectives	53	11
Performance indicators (PIs)	86	22
Reference points	86	19
Assessments	86	33
Management controls	86	19

b)

HS element	Commercial (%)	Recreational (%)
Performance indicators (PIs)	89	91
Target reference points	43	27
Trigger reference points	59	65
Limit reference points	69	51
Assessments	89	91
Management controls	72	77

Database

A searchable electronic database has been developed for HSs in Australia. The database is fully functional, updatable, includes all existing data collected from HSs in Australia and can be hosted online for general use once an appropriate server location can be determined.

Database schema

The developed schema focuses on the characteristics of the fishery and the individual HS components. Each HS component, i.e. objectives, indicators and management actions, is stored in a separate table. This allows for better organization, searching and filtering among the components, and allows for each to contain the data most pertinent to it.

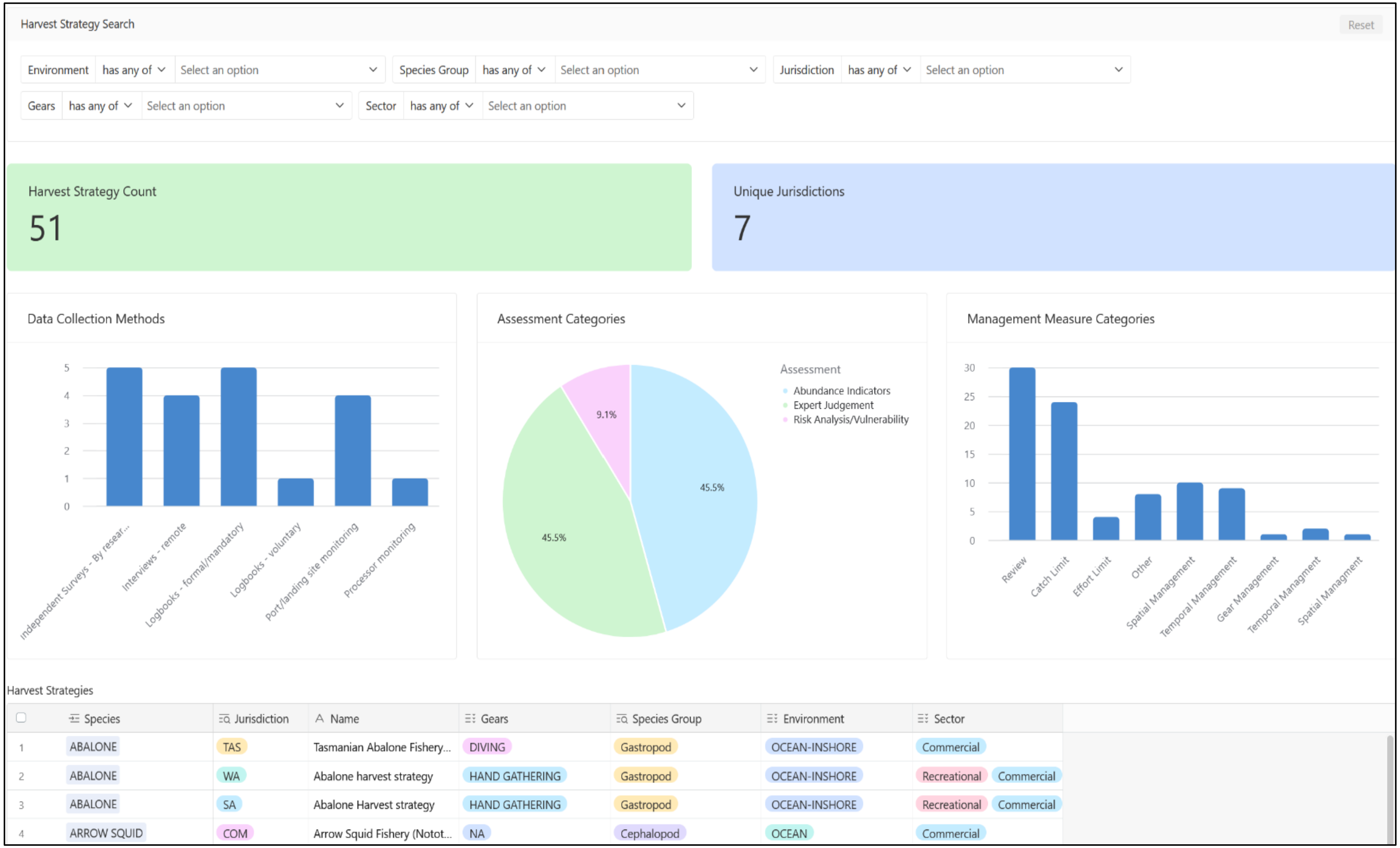
The review highlighted the wide variety of HS structures that have been implemented throughout Australia. For example, complete linkages of HS components, i.e. operational objective linked to specific performance indicator linked to control rule, were often not discernible. For this reason, the database does not currently display existing linkages (those that could be discerned), making it challenging for the user to rapidly understand how the HS functions. An area of future development is to provide a brief summary of the HS structure and function on the detail page (see below).

Search and visualisation functionality

The user interface (UI) facilitates a rapid search of the database for relevant HSs and visualisation of results based on the user's search and filter choices. The database can be explored from three different perspectives: 1) fishery characteristics, 2) goals, objectives and indicator characteristics, and 3) HS components (data collection, assessment and management actions). The visualisation 'dashboard' associated with each of these options displays the range of filters that can be applied for the search, summary counts (e.g. number of HSs returned from a search), summary charts for rapid visualisation of search results (e.g. the number of different types of management controls), and a list of HSs returned from a search including their key characteristics (e.g. fishery name, jurisdiction, gear types, stock(s), etc.; Figure 21). Users can then select a specific harvest strategy and open a page that provides further detail on HS components and a link to download the HS document (Figure 22).

Database updates

Ongoing addition of HSs to the database presents a logistical challenge, owing to the time required to extract the full range of data elements from each strategy. A previously developed application that uses generative AI was adapted by the developer (Upwell Solutions LLC) to extract relevant data from HS documents (pdfs) in the format required for the database. While imperfect, the extraction greatly reduces the amount of time taken to input a new HS into the database. This application interfaces with Airtable and the reviewed output can be uploaded directly into the database. NSW DPI staff have been trained to update the database, reducing the need for external technical support.



Environment has any of Select an option

Species Group has any of Select an option

Jurisdiction has any of Select an option

Gears has any of Select an option

Sector has any of Select an option

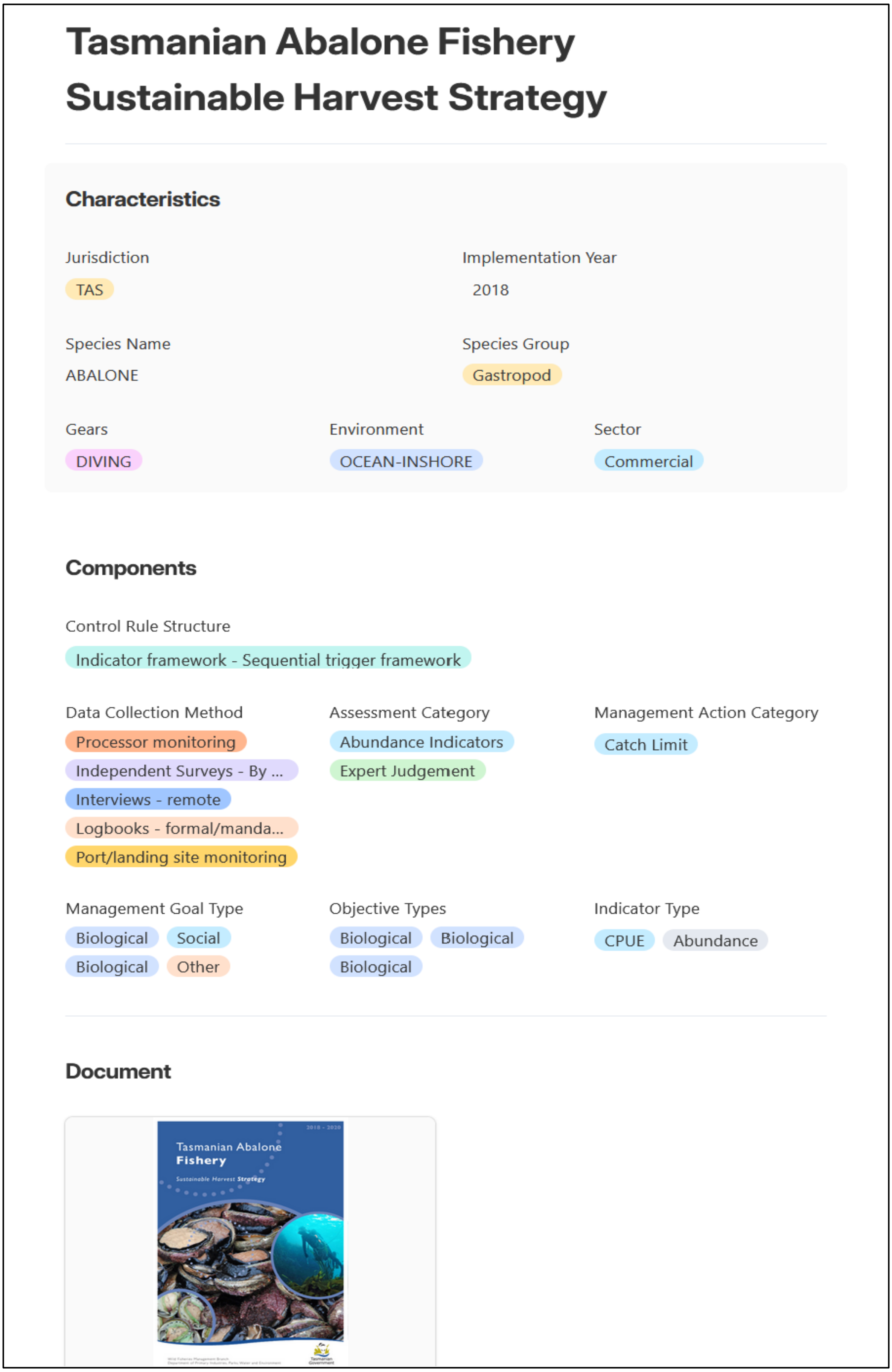
Harvest Strategy Count
51

Unique Jurisdictions
7

Harvest Strategies

☐	Species	Jurisdiction	Name	Gears	Species Group	Environment	Sector
1	ABALONE	TAS	Tasmanian Abalone Fishery...	DIVING	Gastropod	OCEAN-INSHORE	Commercial
2	ABALONE	WA	Abalone harvest strategy	HAND GATHERING	Gastropod	OCEAN-INSHORE	Recreational Commercial
3	ABALONE	SA	Abalone Harvest strategy	HAND GATHERING	Gastropod	OCEAN-INSHORE	Recreational Commercial
4	ARROW SQUID	COM	Arrow Squid Fishery (Notot...	NA	Cephalopod	OCEAN	Commercial

Figure 21 One of the visualisation dashboards allowing users to search and filter the database based on fishery characteristics. The list at the bottom of the page allows users to open up a detailed information page for each HS.



Tasmanian Abalone Fishery Sustainable Harvest Strategy

Characteristics

Jurisdiction: TAS

Implementation Year: 2018

Species Name: ABALONE

Species Group: Gastropod

Gears: DIVING

Environment: OCEAN-INSHORE

Sector: Commercial

Components

Control Rule Structure: Indicator framework - Sequential trigger framework

Data Collection Method:
- Processor monitoring
- Independent Surveys - By ...
- Interviews - remote
- Logbooks - formal/manda...
- Port/landing site monitoring

Assessment Category:
- Abundance Indicators
- Expert Judgement

Management Action Category:
- Catch Limit

Management Goal Type:
- Biological
- Social
- Biological
- Other

Objective Types:
- Biological
- Biological
- Biological

Indicator Type:
- CPUE
- Abundance

Document

Figure 22 Detail page for an example HS. From here, users can download a copy of the complete HS document.

Review 3: Data and monitoring approaches for RF in NSW

RF data sources in NSW

Twenty-one RF data sources were identified in NSW between the years 1999 and 2020, spanning all major aquatic environments and providing data on at least 146 fish species caught by recreational fishers in the state (Table 3, Figure 7). The majority of data sources were from a single waterbody and consisted of 'snapshot' on-site surveys, for example, a roving shore and roving boat-based survey of catch and effort in the freshwater Murray River during 2018/19 (Data Source ID 9, Table 3). This type of survey typified freshwater data sources, nearly all of which were developed in the last six years and therefore do not currently provide substantial time-series that can inform reference points. An exception is the ongoing tournament monitoring of Australian Bass (*Percalates novemaculeatus*) through the Basscatch Program (ID 5, Table 3), which has been operating annually since 1988 and collects data on a range of catch-related variables in 15 rivers and stocked impoundments across the state. Indicators include catch-per-unit-effort (CPUE), fisher participation rates, and fish length (Table 3). Similar tournament monitoring commenced in the Murrumbidgee River during 2019 for other freshwater species (ID 6, Table 3).

More RF data sources were identified from estuarine and marine environments than fresh water. Although many were local in scale, most commenced over a decade ago and were sometimes repeated, providing potential reference periods and emerging time-series. For example, on-site surveys of both shore- and boat-based fishing in Lake Macquarie commenced during 1999/00, with surveys repeated during 2003/04 and 2011 (ID 13, Table 3).

RF data sources that reliably survey many species and provide data at a state-wide scale are likely of greatest value for HS development, because they provide monitoring efficiencies across stocks and match the jurisdictional scale of HSs. Two data sources in NSW provide 'ready-made' long-term time-series and state-wide coverage for many recreational species: i) mandatory logbooks from the Recreational Charter Fishery; and ii) voluntary tournament reporting from the NSW Gamefish Tournament Monitoring Program (IDs 3 and 1, respectively, Table 3). Charter logbooks provide annual data since 2000 on catch-related indicators, as well as fisher participation and interactions with Threatened, Endangered and Protected (TEP) species, across 36 locations in marine and estuarine waters in NSW. Logbooks include at least 146 species, although 95% of the retained catch comes from ~30 species (Hughes et al., 2021). Logbooks are also a licensing requirement for charter operators, ensuring ongoing availability of this data.

Gamefish tournament monitoring may complement data from the Recreational Charter Fishery by providing time-series for a range of large offshore species that would otherwise be difficult to obtain (e.g. billfishes, tuna). Charter vessels in NSW primarily operate in nearshore areas and mostly catch small-bodied demersal species, so are unlikely to provide consistent data on large pelagics (Hughes et al., 2021). Gamefish tournament monitoring has provided data on catch-related variables and body length annually since 1993 for 15 species across 15 locations in the marine environment (ID 1, Table 3). A voluntary gamefish tag-recapture program has also been active since 1973, providing data on catch locations, fish movement and growth – the NSW Gamefish Tagging Program (ID 7, Table 3). However, the use of these variables for more traditional performance indicators within HSs is less clear than the use of indicators such as catch or fishing effort.

Notable emerging data sources include a state-wide telephone-diary survey and an on-board observer program for the marine NSW Recreational Charter Fishery (IDs 2 and 4, Table 3). Despite only providing four temporal data points to date, the telephone-diary survey is probably the most valuable RF data source for HS development in NSW (Data Source ID 2, Table 3, Murphy et al., 2020). The survey currently provides data on more than 50 fished species across marine, estuarine and freshwater environments. Data include estimates of total recreational catch and effort in NSW, and data on social aspects of fishing, including motivations and satisfaction. The time-series commenced in 2000 as part of the National Recreational and Indigenous Fishing Survey, was repeated in 2013/14, and is now run biennially from 2017/18.

The on-board Recreational Charter Fishery observer program provides 17 indicators on fishing activity in NSW marine waters (ID 4, Table 3). Catch-related data are available for 105 species, with data also collected on social variables including participation rates and fishing motivations, and environmental variables including depth, bottom type and water temperature. The program commenced statewide in 2014, was repeated in the southern half of the state during 2017/18, and is expected to continue biennially at a statewide scale from 2019/20.

Fishing objectives

From our review of the literature, we identified 22 broad objectives proposed for RF that may apply to the sector in NSW (Table 4). These were further articulated to produce 41 operational objectives, 37 of which were catch-oriented (activity specific) and 4 which were non-catch-oriented (activity general). Classification according to the four pillars of sustainability was not always discrete, with some objectives spanning multiple categories. For example, fishing motivations such as “maximise the number of fish caught per fisher day” (Objective 1.2) and “maximise the size of fish caught” (Objective 4.1) have both ecological and social relevance. Sector-wide objectives such as “maintain stock biomass above the minimum sustainable limit” (Objective 5.1) and “minimise bycatch mortality” (Objective 6.1) were considered purely ecological. Most objectives within the ecological pillar could be addressed within a HS; however, some (e.g., “increase fisher awareness of sustainable fishing practices” [Objective 5.2]) need to be addressed through other fisheries management processes.

Many objectives identified for the RF sector were classified as social, covering a broad range of fishing interests including “easy access to fishing locations” (Objective 9), “improved participation in RF” (Objective 10), and “equitable access to fish stocks” (Objective 12). All the social operational objectives except one were found to lie outside the scope of a HS and need to be addressed using other fisheries management processes, potentially alleviating concern regarding the challenges involved with including such objectives in HSs. For example, the objective “maximise access to fishing locations” (Objective 9.1) was considered better addressed within broader fisheries management plans, given it is not influenced by harvest activity or biological aspects of the stock, and is therefore unlikely to be achieved using typical harvest control rules (Table 4). The exception was “minimise interactions with other people” (Objective 22.1) which could potentially be addressed in a HS with ‘move on’ management controls.

Numerous institutional objectives were identified as potentially applying to the RF sector in NSW, for example “increase detail in fisheries management documents” (Objective 17.2) and “increase representation in fisheries management advisory processes” (Objective 18.1, Table 4). None of the derived operational objectives were considered addressable within a HS and are primarily dictated by the design of management systems or processes themselves.

Economic objectives identified for the RF sector included generation of profit for the two primary industries involved - charter and tackle (Objectives 7.1 and 7.2, respectively, Table 4), as well as “maximise the monetary value of the recreational experience” at the individual fisher level (Objective 8.1). All economic objectives could be addressed within a HS.

Linking data sources to fishing objectives

The process for linking RF data sources with objectives and developing quantitative monitoring is outlined in Figure 23. Each operational objective within a HS must correspond to a performance indicator supplied by a data source, so that fishery performance for that objective can be monitored and assessed through time. We linked indicators from RF data sources in NSW (Table 3) with specific operational objectives identified in our literature review (Table 4). These links were made at the level of data sources, not individual stocks; an example for a specific stock is provided below.

RF data sources in NSW yielded 14 variables that could serve as performance indicators for the operational objectives identified (see "Variables from RF studies", Table 5). Similar to other fishing sectors, ecological objectives for RF were the most readily linked to indicator variables, with indicators available for all but two operational objectives of this type. Data sources for ecological objectives were also generally available in all three environments – marine, estuarine, and fresh water (see "ID of RF data source", Table 5). Exceptions were the objectives "increase RF understanding of population biology and stock assessments" (Objective 5.3) and "minimising fishing infringements" (Objective 5.4), with no data sources across all three environments, although these objectives lie outside the scope of HSs. No data sources were identified for "minimise interactions with TEP species" (Objective 6.2) and "minimise pollution generated by RF" (Objective 6.3) in freshwater systems.

Few data sources were identified for non-ecological objectives (Table 5). Performance against the social objectives "improve participation of RF" and "compete against other fishers" (Objectives 10 and 11) could potentially be monitored using variables of participation (number of fishers/boats) and effort (hours/days fished). Data for such variables are available from numerous sources in all three environments. The performance against objective "maintain equitable allocation of catch among fishing sectors" (Objective 12.1) could potentially be monitored using data on catch (kg), which is also available in all three environments. Lastly, the performance against the non-catch-oriented objective "increase the time spent fishing with friends and family" (Objective 20.1) could be monitored using data on the number of fishers per household. The latter data is available in all three environments from the state-wide telephone-diary survey (Data Source ID 2, Table 3). No data sources in NSW were clearly applicable to any of the economic or institutional operational objectives, although this does not necessarily reflect the difficulty of such monitoring.

Numerous additional variables were available from RF data sources in NSW (Table 3); however, these were not clearly applicable to the objectives identified (Table 5). For example, annual data on catch locations, growth and movement of recreationally-important species is available from 1973 to present through a voluntary gamefish tag-recapture program (Data Source ID 7, Table 3), yet it was unclear how these data might serve as performance indicators for any of the recreational objectives identified (Table 5). Data on fisher satisfaction is also available through the state-wide telephone-diary survey (ID 2, Table 3) and onsite surveys of boat-based fisheries in Jervis Bay and Coffs Harbour (ID 8, Table 3), yet the nature of such data are currently too imprecise to apply to any specific operational objective. Satisfaction data are also not stock-specific, limiting their utility within HSs.

Quantitative monitoring using RF data – an example

The linked data sources and objectives from the current study facilitated development of a quantitative monitoring approach for Objective 1.2 "maximise the number of fish caught per fisher day" for Ocean Jacket in NSW (Figure 23). Catch-per-unit-effort (CPUE) was identified as a potential performance indicator for Objective 1.2 (Table 3) and mandatory logbooks from the

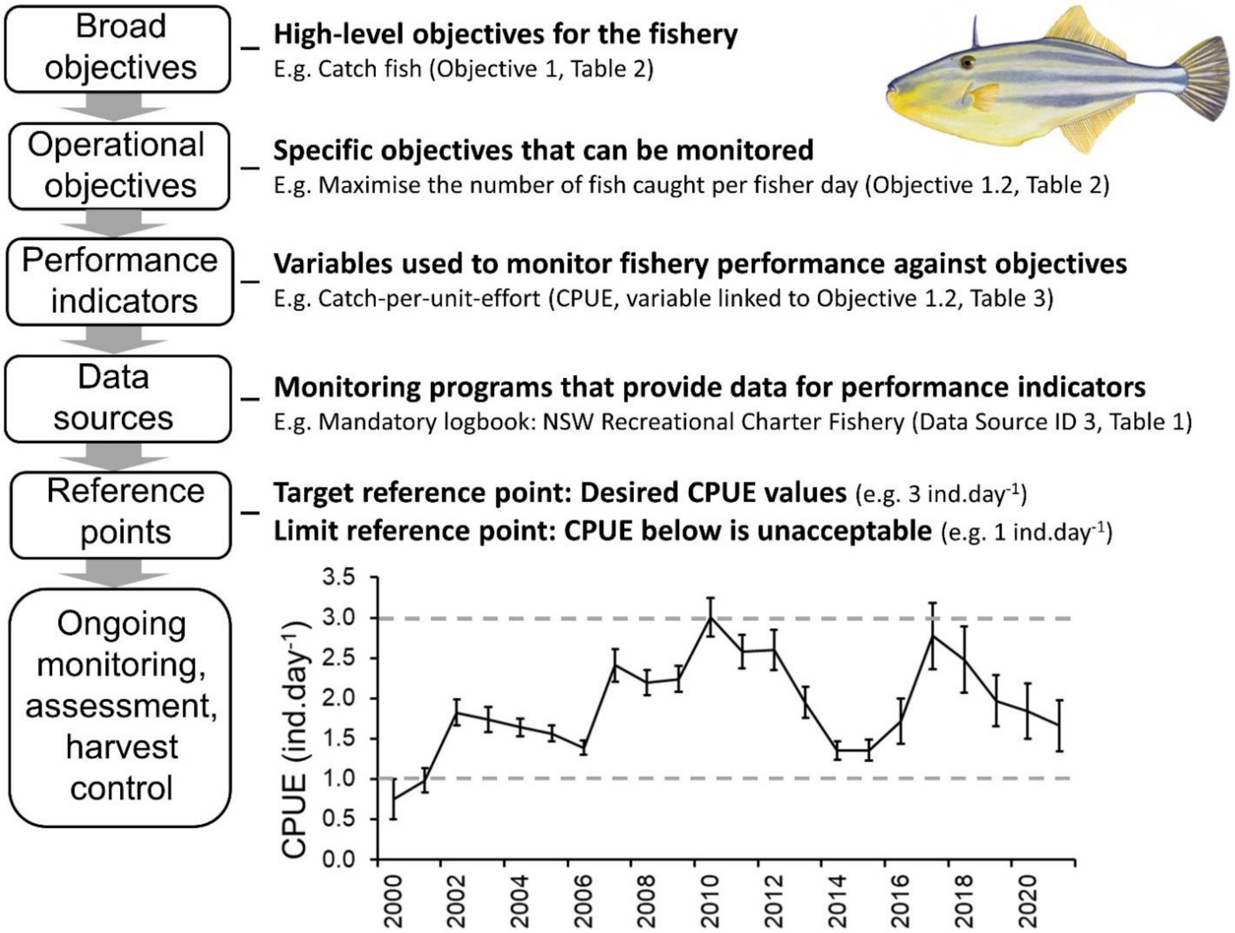


Figure 23 Steps for developing quantitative monitoring and assessment of recreational fishing objectives using empirical performance indicators within harvest strategies. The process is demonstrated using a species fished recreationally in NSW and not currently managed using a harvest strategy - Ocean Jacket (*Nelusetta ayraud*). An example objective from Table 4 is linked to a potential performance indicator and NSW data source identified in Table 5. Catch-per-unit-effort (CPUE) values are the mean number of individual fish caught per fisher per day (ind.day^{-1}) on recreational charter vessels in NSW reported in mandatory logbooks during 2000-2021. Grey dashed lines indicate example target (upper) and limit (lower) reference points. Error bars indicate 95% confidence intervals. Image credit: Bernard Yau.

NSW Recreational Charter Fishery were identified as a potential data source (Data Source ID 3, Tables 3 and 5). The CPUE metric available from logbooks - number of individuals caught per fisher per fishing event (day) – directly addresses Objective 1.2. A 21-year time-series of CPUE (2000-2021) was available for Ocean Jacket, with values ranging between 0.8 and 3.0 individuals.day-1 (Figure 23). The time-series provides an indication of past CPUE performance that can be used to inform reference points for assessment and harvest control (see examples, Figure 23).

Discussion and conclusions

The current study demonstrates the first steps and highlights various challenges for formal inclusion of the recreational fishing (RF) sector in HSs. We identified broad sectoral objectives from the literature, refined them to operational objectives that can be measured, linked operational objectives to potential data sources that could be used to monitor them in a case-study jurisdiction (NSW, Australia), and demonstrated the utility of an RF data source for quantitative monitoring using an example stock. We also evaluated whether RF objectives lay within the scope of a HS. Our review identified numerous RF data sources that could be used to monitor ecological objectives in NSW, offering both 'ready-made' time-series and potential reference points for a range of performance indicators. Performance indicators offer a means of achieving RF objectives through dynamic control of harvest; for example, if the number of zero catch events reaches an undesirable level, then bag limits could be reduced until an acceptable number of successful trips is achieved. Linking indicators to objectives is a necessary step for explicit inclusion of the RF sector in HSs, rather than relying on commercial or fishery-wide objectives and indicators that may not be relevant to RF. The objectives and linked data sources from the current study provide a base from which to develop HSs for specific fisheries, through direct consultation with recreational fishers.

RF data sources

To our knowledge, this is the first study to characterise and synthesise all available RF data sources in a management jurisdiction, and to explore their potential utility for HS development. Our approach for reviewing RF data sources is useful for four main reasons. Firstly, organisations with a long history of monitoring and research may accumulate many datasets, some of which may fall into obscurity following their immediate purpose. Our research suggests that audits of disparate datasets may discover they have both intrinsic and combined value for use within HSs, and indeed broader fishery management application. Such audits may also identify redundant or imprecise data that do not serve an assessment purpose. Secondly, fisheries data often come from the commercial sector and may be unsuitable for monitoring recreational fishery performance of objectives that are specific to the sector. This is especially true when gear types or fishing locations differ between the two sectors. Knowledge of the type and extent of existing RF data is essential for understanding which RF objectives can currently be addressed within a HS, and which require development of new data sources. Thirdly, the use of existing data sources avoids the need for new data collection programs, which are costly to implement and maintain, and may not provide useful data series for many years. Fourthly, our approach allows for identification of data gaps prior to commencement of HSs and therefore facilitates timely establishment of new data collection programs, or the modification of existing programs, to monitor RF objectives.

Several RF data sources identified in the current study provide opportunities for monitoring of ecological objectives within NSW HSs. They are well-established, ongoing, provide long time-series, include many target species, and are collected at a broad scale relevant to statewide HSs. Development of HSs has only recently commenced in the state and will progressively cover a range of fisheries and stocks relevant to the RF sector (NSW DPI, 2020). While this situation provides an opportunity for RF inclusion from the outset, the timelines commonly associated with changes in fisheries management may result in a default to the status quo of commercial-centric HSs (Charles, 1998; Abbott et al., 2018), despite the dominance of the RF sector in NSW. Our approach will help avoid this scenario by expediting development of performance indicators and reference points for the RF sector. The general dearth of such information has contributed to the qualitative approach to RF inclusion often seen within HSs and the reliance on commercial fishery data for monitoring and assessing fishery performance (Griffiths and Fay, 2015). Ultimately, the usefulness of RF data sources for HSs will depend on their applicability to the objectives developed for specific fisheries through stakeholder consultation. However, the catch-related variables (e.g. CPUE) for RF identified in NSW data sources are likely relevant to key RF objectives (Birdsong et al., 2021), and similar variables have already been used successfully as performance indicators for the commercial sector (Little et al., 2011; Dowling et al., 2015b).

Off-site surveys like the NSW telephone-diary survey are commonly used to monitor RF worldwide (Holdsworth et al., 2018; Hyder et al., 2018; Brownscombe et al., 2019), because they provide cost-effective data for numerous variables over the broad spatial scales typical of fisheries assessment and management (Pollock et al., 1994; Lyle et al., 2002). However, despite these advantages, such surveys are logistically demanding and may therefore only be completed infrequently (Hartill et al., 2012). To be effective within a HS, the frequency of off-site surveys must be considered with respect to the desired frequency of assessment and harvest control. For example, if off-site surveys are only conducted every few years, an annual assessment schedule would require a secondary indicator(s) to be used in a HS in non-survey years. Off-site surveys also often yield imprecise data for less commonly-caught species, due to the lower incidence of such species within the sample frame (West et al., 2015; Murphy et al., 2020). An acceptable level of precision for these data would have to be determined prior to their inclusion as a monitoring method within HSs. If the error associated with data and the indicators derived from them (e.g. catch, catch rate) is too great, performance of the recreational fishery may not be readily distinguishable from reference points with acceptable certainty.

Few alternatives to offsite surveys exist for broad-scale monitoring of RF. Emerging methods for RF monitoring include smartphone applications (‘angler apps’), drones, and boat ramp cameras (Venturelli et al., 2017; Dutterer et al., 2020; Hartill et al., 2020; Provost et al., 2020). However, only angler apps allow for broad-scale and frequent data collection at low cost (Venturelli et al., 2017), and like other citizen science approaches, they suffer from a range of biases and data quality issues (Hyder et al., 2015; Bradley et al., 2019; Cooke et al., 2021). Despite this, mandatory catch and effort reporting using smartphone applications has potential to considerably improve the quality of broad-scale RF data (Arlinghaus et al. 2019), depending on the willingness of recreational fishers to report accurately. Smartphone applications can be combined with websites to improve functionality and expand content and interactivity for recreational fishers; for example, the Fangstjournalen citizen science platform that allows anglers to submit catch-related trip data and also receive information on fishing regulations and other developments (Gunderlund et al. 2020). An alternative to sector-wide monitoring of RF is to monitor a representative subset of recreational fishers. In NSW, the Recreational Charter Fishery is considered a subset of the broader RF sector and offers an established, consistent, and low-cost data source for catch-related indicators (Hughes et al., 2021). Using Ocean Jacket in NSW as an example, we have demonstrated that CPUE data from charter logbooks may be useful for monitoring and assessing fishery performance against recreational catch-related objectives within a HS. However, charter fishing may not be representative of amateur RF, given charter operators are professional fishers that may fish similar areas, but have greater knowledge and experience (Lynch, 2008). If charter CPUE is indicative of the abundance of Ocean Jacket, then the performance indicator may also be useful for monitoring sustainability objectives (e.g. Objective 5.1 “maintain stock biomass above the minimum sustainable limit”, Table 4).

More localised ecological data sources, such as ‘snapshot’ on-site surveys (see Table 3), may be useful in combination to inform HSs, particularly for freshwater stocks that inhabit multiple river systems separated by large (100s of km) distances. While labour-intensive, on-site surveys are commonly used to obtain high-resolution data on recreational fishing over small spatial scales (Pollock et al., 1994; Holdsworth et al., 2018; Vølstad et al., 2020). They also allow collection of accurate length and weight data, which is rarely possible with off-site surveys (Hartill et al., 2012) but vital for stock assessment models. Localised RF data sources may also be useful for monitoring stocks with restricted distributions, those not well represented in broader off-site monitoring due to a smaller number of specialist fishers (e.g. Eastern Rock Lobster, *Sagmariasus verrauxi*, West et al., 2015), or for areas of particular interest (Lynch, 2014; Ochwada-Doyle et al., 2014). However, we found that most on-site surveys of RF in NSW were conducted irregularly and in isolation. Data collected were also primarily biological/ecological and currently provide little scope to address social, economic, or institutional objectives. The use of multiple on-site surveys as an ongoing monitoring approach to service HSs would likely require the establishment of a coordinated program, to ensure efficiencies across stocks, fisheries and locations. The need for such a program could be explored through an audit of stocks that are not well monitored using other more efficient RF data sources.

Biases associated with RF data sources should be considered when using them to monitor fishery performance within HSs. Coverage and non-response biases can potentially render off-site surveys unsuitable for monitoring fishery performance for particular subgroups of the recreational sector (Teixeira et al., 2016; Lewin et al., 2021). For example, the NSW telephone-diary survey may not provide representative catch rates for short-term licence holders, because only long-term licence holders are surveyed (Murphy et al., 2020). Catch rates may be over-estimated if fisher skill is related to the duration of licence purchased. Biases associated with self-reporting may also affect the accuracy of performance indicators derived from off-site surveys and fisher diaries. Prestige bias, where fishers report events more favourably than they occurred, may artificially inflate catch and catch rate (Cooke et al., 2000). Similarly, recall bias may affect indicators through accidental omission of particular data, such as underreporting of zero catch events (Hartill and Edwards, 2015).

While generally more reliable than off-site surveys (Hartill and Edwards, 2015), on-site surveys could potentially overestimate fishery performance in a HS through the disproportionate inclusion of avid, and potentially more skilful, fishers (length-of-stay bias and trip-frequency bias, Thomson, 1991; Lewin et al., 2021). Performance indicators derived from tournament monitoring may be affected by tournament rules, including selective catch based on size, while voluntary gamefish tag-recapture data may be affected by participation bias if spatio-temporal patterns of fishing activity differ between participants and non-participants (Hughes et al. 2022). Despite numerous potential biases, data sources that provide relative indicators of fishery performance may still be useful for HSs if biases are constant through time and are not so severe that they obscure trends relevant to objectives.

Further development of socio-economic data sources will be required to monitor RF objectives, both in NSW and elsewhere. The limited social and economic data for RF in NSW reflects a global dearth of such data across all fishing sectors, due to a historical focus on stock biology and sustainability (Hilborn, 2007; Dichmont et al., 2020; Dowling et al., 2020). Recognition of this failure to address the 'human dimension' of fisheries sustainability has led to the recent development of lists of social and economic indicators, for example, those within the Fisheries Performance Indicators (FPI) tool (Anderson et al., 2015) and the Canadian Fisheries Research Network (CFRN) framework (Stephenson et al., 2018). However, the applicability of these sector-general indicators to recreational fisheries requires further evaluation, and the extent to which such indicators have been operationalised within fisheries monitoring programs to date is unclear. Social indicators for RF may also be of limited use within a HS framework, given that nearly all social objectives we identified for RF lie outside the scope of a HS (see below), although we found that some social objectives may be indirectly monitored via related ecological indicators (Table 4). Establishing data sources for social indicators will require knowledge of the management context within which they will be used.

RF objectives

We provide a list of objectives specific to the RF sector, to assist explicit inclusion of RF interests in HSs. The objectives offer a starting point for the RF sector when developing HSs for specific fisheries, prior to cross-sectoral engagement. Identification of fishing objectives during HS development is often done with multiple stakeholder groups simultaneously (e.g. Pascoe et al., 2013; Pascoe et al., 2019), due to the cost and logistical burden of separate consultation. While objectives shared by all sectors may be covered using such an approach (e.g. "ensuring a sustainable fishery"), some sector-specific objectives may be overlooked due to the dominance of a particular sector in the fishery or the meetings themselves, or a limited understanding of the HS development process. A comprehensive exploration of sector-specific objectives prior to HS development is therefore useful in multi-sector fisheries (Fedler and Ditton, 1994; Young et al., 2016).

Our list of objectives draws together RF interests, motivations and objectives identified in numerous investigations that have often only considered these in specific contexts (see Table 4 and references therein). Motivations for recreational fishing, such as 'catching trophy fish' or 'obtaining a family meal', are typically the domain of human dimensions research and are often overlooked in fisheries management (Hunt et al., 2013; Young et al., 2016). Yet, they are directly linked to satisfaction with the fishing experience (Arlinghaus, 2006). To date, explicit consideration of such motivations within HSs is uncommon (Brooks et al., 2015; Fletcher et al., 2016; Pascoe et al., 2019; Dowling et al., 2020). This may be because motivations are often social and therefore rarely lie within the scope of a HS (Table 4). However, numerous catch-related motivations identified in the current study are both measurable and are likely some function of harvesting activity or stock abundance (e.g. "receive bites or strikes"). Such motivations should therefore be considered during HS development. Our list of objectives was compiled from published literature that explicitly stated motivations or objectives specific to the RF sector. The list is therefore not exhaustive, and like any pre-emptive set of fishing objectives, will require further development through stakeholder consultation.

RF is often omitted from HSs due to the perceived challenges involved, particularly the incorporation of additional objectives and resulting conflicts with the commercial sector. HSs with many objectives are challenging to put into practice, because objectives are likely to compete, generating numerous trade-offs that are difficult to optimise (Pascoe et al., 2009; Dowling et al., 2020). This is particularly the case when social and economic objectives are included alongside core ecological objectives in Triple Bottom Line (TBL) HSs (Elkington, 2006; Dichmont et al., 2020; Dowling et al., 2020). Yet, despite the broad range of objectives identified for RF, our results suggest that inclusion of the sector in HSs may not greatly increase their complexity. We found that many RF objectives lie outside the scope of a HS, particularly social and institutional objectives such as maintaining equitable access to fish stocks, maximising access to fishing locations, and increasing flexibility and transparency of fisheries management, all of which need to be addressed within the broader management regime. Objectives that are within scope are mostly ecological, and likely consistent with those of other sectors, potentially reducing the total number of objectives required across sectors. These include stock sustainability, high catch rates and generating economic value. Numerous social objectives of RF are also linked to the underlying performance of the stock, including key catch-related objectives. This may reduce the number of indicators required to monitor RF objectives and limit the need to develop social data sources that are currently unavailable. However, some form of social monitoring would ultimately be required to confirm fishery performance against social objectives. Finally, those objectives that are identified as less important through consultation with the RF sector may be omitted from further consideration. While the preceding points indicate potential consolidation of RF objectives in HSs, thereby limiting complexity, they highlight the need to address social objectives through other management processes (see Sloan et al., 2014). Failure to do this risks fishery underperformance for the RF sector, given that most objectives we identified for RF are social.

Further research is required to clarify and prioritise RF objectives in NSW. Fishing objectives are likely to vary among regions, fisheries and stocks. The applicability of objectives identified from the literature to NSW therefore requires validation. This could be achieved through a combination of stakeholder workshops and surveys with recreational fishers in the state. Workshops with active fishers would allow detailed information on objectives to be collected, potentially at a fishery or stock level. The relative importance of objectives could then be quantified using surveys that elicit pairwise comparisons between objectives; for example, the survey of objective preferences conducted on stakeholders in the Coral Reef Fin Fish Fishery in Queensland, Australia (Pascoe et al. 2019). Such investigations could be used to develop a 'short-list' of objectives that is broadly representative of recreational fishers in NSW and would provide an objective basis for reducing the number of objectives included within HSs.

Inclusion of RF in HSs also requires consideration of conflicts within the sector, not just those with other sectors. The diversity of RF objectives at the sector level arises from the diversity of recreational fishers themselves, even within the same fishery (Johnston et al. 2010, Arlinghaus et al. 2019, Grilli et al. 2019). For example, fishers wanting to catch trophy fish may conflict with those attempting to catch fish for food, given the greater restriction of harvest likely required to increase the incidence of large fish in the population (Arlinghaus, 2005; García-Asorey et al., 2011). Similarly, objectives relating to sport fishing and associated catch-and-release practices are likely to conflict with objectives relating to recreational harvest (Arlinghaus, 2005; Arlinghaus, 2007; García-Asorey et al., 2011). The potential extent of conflict within the RF sector suggests that developing equitable HSs may even be challenging in RF-only fisheries. Conflicts between RF objectives could potentially be addressed using trade-off analyses (multi-criteria decision analysis [MCDA]) that compare multiple HS options based on stakeholder input (Dichmont et al. 2020), or a multi-indicator optimisation model (Dowling et al. 2020).

Effective operationalisation of RF objectives will require the development of suitable harvest control rules, ideally those that can respond dynamically to a breach of reference points. Dynamic control of fish mortality arising from RF is challenging, due to the large number of fishers each taking a small proportion of total catch and the difficulty in informing and enforcing changes in regulations across a diffuse sector (Arlinghaus and Cooke, 2009). Intermittent data collection and lagged reporting typical of RF limit the frequency and temporal relevance of dynamic control, respectively. The coarse nature of harvest controls typically applied to the RF sector also hinders fine-scale adjustment of fishing mortality (e.g. bag limits).

We have presented a range of operational objectives for RF and identified numerous data sources that may be used to monitor them in a jurisdiction of globally high RF participation. Yet considerable development is still required to produce quantitative recreational performance indicators and reference points, and integrate them with those of other fishery sectors in HSs. An assessment of data for individual stocks is required, given that data availability and quality is likely to vary considerably among stocks, even within the same data source.

We also provide evidence of limited capacity to monitor social, economic and institutional objectives of RF. While reflective of a general dearth of such fisheries data, this may not present a substantial issue for the RF sector if such objectives can be addressed indirectly through more readily-measurable objectives with established data sources. The fact that most RF objectives lie outside the scope of a HS leads us to caution against hasty development of additional indicators and data sources for HS development. Consideration must first be given to the most appropriate management level for addressing RF objectives and how performance is measured therein.

The ability of performance indicators proposed in the current study to monitor operational objectives requires verification. The linkages between performance indicators and objectives in the current study were made with knowledge of the general utility of data types, but may not be suitable for particular circumstances or stocks. The meaning and intent of objectives may also be refined through stakeholder consultation during HS development, potentially affecting the suitability of linked performance indicators. Once clarified, RF data collection programs can be configured to better service the data requirements of HSs. HSs provide an opportunity for much needed integration of RF into the management of multi-sector fisheries. However, if RF objectives are not linked to data sources that can effectively monitor them, truly equitable HSs are unlikely to be achieved.

Objective 3 - Interrogate and extend the FishPath decision support software tool to better characterise and integrate recreational fishing information into harvest strategy development for multi-sector fisheries

FishPath is seen as a valuable tool to support the development of a harvest strategy (HS), providing an inclusive series of options across the components of Data Collection, Assessment and Management Measures. However, some content and functionality, and the absence of some more relevant recreational fishing options limits engagement with the recreational fishing sector, particularly within a HS development process for a multi-sector fishery. Expert review of the Tool identified a number of opportunities to address these limitations.

Interrogation of the FishPath decision support tool

Independent reviews of the Tool (supported by the reviewers guide - see Methods Objective 3) were submitted to the project lead from each of the four specialist, recreational fisheries scientists. Key points and recommendations from these independent reviews were collated into six categories (outlined below). Category 1 sought to capture comments and recommendations regarding content. Categories 2 and 3 address issues of functionality. Category 4 highlighted some potential minor errors within the Tool or issues with familiarity of the user with the Tool. Category 5 highlighted comments regarding broader changes to the structure and function of the Tool and Category 6 captured issues relevant to HS development, and of particular interest to the recreational sector, but that are outside the scope of the Tool.

Key points by category

1. Content - tailoring FishPath to the recreational sector
    - Filtering questionnaires for recreational relevance
        - insert a series of questions at the beginning of the questionnaires that filter out redundant questions/options/caveats
    - Expand the use of “not-applicable” responses
        - Numerous questions require an N/A response from the recreational perspective, without that option currently being available. This offers a solution while a recreational specific filtering option is considered/developed
        - Some questions are still relevant to the recreational sector (i.e. not filtered out), but not to specific recreational fisheries) e.g. spearfishing), hence still requiring N/A
    - Additional options of particular relevance to the recreational sector (e.g. tag-recapture, fishing club records) and questions
    - Improve comprehension for recreational fishers (potentially enacted within the recreational sector filter)
        - Simplify terminology and descriptions
        - Reduce length of descriptions
        - Use RF-specific language
        - Adapting existing questions to better suit RF (e.g. effort series)
        - Provide a set of simplified/shortened results that can be viewed instead of the full output (user selection).
2. Functionality - assistance/increased guidance with narrowing options
    - Semi-automated options narrowing, using:
        - Auto-starring of ‘best’/higher tier option(s)
        - Prioritisation of options based on caveats
    - Narrowing options based on available resources, or more broadly, capacity (invoked with a question at the end of questionnaire)

- Linking user notes to criteria and caveats, which will assist with understanding/transparency regarding the retention of options that appear unsuitable
- Modify options ‘narrowing’ steps:
    - sort by category and then type of option before examining caveats (more user-friendly)

3. Functionality - side-by-side comparisons of questions, results and notes
    - Comparisons of responses and options across multiple ‘Fisheries’ within the Tool (e.g. different sectors or gear types within the same fishery) would assist evaluation and understanding of similarities and differences

4. Potential errors within the FishPath Tool
    - Divergence in responses provided and results recorded (‘no’ becoming a ‘yes’)
    - Options at bottom of active web page not displayed/accessible

5. Broader considerations
    - Options could vary according to:
        - spatial scale
        - Recreational fishing ‘platform’ e.g. shore based vs boat (within sector)
    - Adding a more detailed introductory ‘front end’ to the Tool that forces the user to endure an explanation on the scope of FishPath and the Tool within broader process of harvest strategy development

6. Harvest strategy related but outside the scope of the FishPath Tool
    - Pre- and post- use of the Tool in development of a harvest or management strategy
        - resource allocation (between and even among sectors)
        - development of operational objectives and the challenges of developing recreational fishery objectives measurable through a harvest strategy as opposed to broader RF objectives (e.g. social and economic objectives – some of which may be addressed through biological/sustainability objectives)

Extension and integration of RF information into the FishPath decision support tool - Expert Input Workshop

Summary outputs and outcomes

Phase 1: Expert review findings were reviewed by the project team. Post-review discussion with the reviewers resulted in minor agreed changes to some specific comments. Reviewers were provided with an overview of the body of work planned to address content and functionality (and errors) of the Tool addressing their comments and recommendations, and informed of other recommendations being provided to the FishPath Core Team for ongoing consideration of changes to the Tool and beyond the scope of this body of work.

Phase 2: FishPath content review. Within the Tool, 19 questions were updated, 3 questions drafted and under review by the FishPath core team, 2 options drafted and under review by the FishPath core team, and a number of caveats revised.

Pages 3: FishPath functionality. Three new reports were added to the Tool. First is a csv matrix of questions by options showing all the caveats for any given fishery. Second, is two ways of comparing Tool outputs across multiple fisheries, a first within FishPath. One report allows for comparison of answers and question notes, while the other allows for comparison of summaries of results between fisheries. Finally, concept diagrams were created for ways to allow for filtering out redundant questions from the questionnaire when answering in various settings (i.e., recreational fisheries).

Outputs and outcomes

Phase 1

Phase 1 involved a review of the review findings and recommendations by the project team (NSW DPI, CSIRO). Reviewers considered 116 questions within the Tool questionnaire, and typically completed the questionnaire for Data monitoring, Assessment and Management measures, for the recreational component of a fishery known to them. All reviews adhered to the minimum criteria prescribed in the 'Reviewers guide' and provided detailed comments and recommendations, some including the addition of new, or proposed modification to existing options within Data monitoring and Management measures. Post-review discussion between the project team and reviewers clarified some review comments and consolidated some consistent responses among some reviewers.

Phase 2

Sub-objective 1. Identify and list questions/component options that would benefit from rewording or removal.

Output 1: List of existing questions/component options that require either rewording or removal in order to best pertain to the recreational sector

- Completed review of all comments from recreational expert reviews including documenting if changes would be required to address, or a response if it was determined that changes would not be made to address the comment
- Compiled all question specific comments into a spreadsheet along with suggested follow up and potential actions to address
- 8 questions were suggested to be redundant for the recreational sector and were suggested to have a 'Not Applicable' answer option added
- Adding an NA answer option was approved by FishPath Core Team for 1 question, consistent with an independent TNC led peer review response
- 1 question was determined to include an answer option "Unknown" instead of "Not Applicable"
- Rationale was provided for why the inclusion of a NA answer was rejected for each of the other 6 questions
- 2 were determined to be included in a 'filter' list for recreational fisheries (if developed, subject to consideration beyond this project)
- Facilitation guidance should be written for each of these 6 questions to help guide facilitators during recreational sector facilitated workshops
- Compiled questions to be considered to be filtered for the recreational sector

Sub-objective 2. Develop a scope of work for changes required to address issues identified in sub-objective 1, including, but not limited to, providing original and alternate wording to relevant questions/component options, introducing a response option of 'NA' or 'unknown' to relevant questions and, implementing changes in the FishPath tool.

Output 2: Scope of work for Objective 2 (changes to address issues in Objective 1), including implementing changes in the FishPath tool

- Each question specific comment from each expert review has been reviewed and determined if/what action is needed to address
- 20 questions had specific reviewer comments
- Collaboratively, B. Snouffer and N. Dowling wrote edits to questions for 19 of the 20 comments and a response as to why no changes were suggested for the 20th
- Reviewed all edits with The Nature Conservancy - FishPath Core Team representative (S. Lominico) for inclusion in Tool
- Final edits are now live in the FishPath Tool
- Fully drafted 3 new questions and associated caveats. Recommendations sit with the FishPath Core Team regarding inclusion into the Tool
- To what extent are any recreational fishing activities catch and release? (Data Collection and Management Measures components)
- What time series of social indicator data exists? (Assessment component)
- What time series of economic indicator data exists? (Assessment component)
- Added 8 terms to the glossary

Sub-objective 5. Develop a scope of work for the inclusion of recreational fishing relevant options for Data Collection and Management Measures.

Output 5: Scope of work for revision and addition of component options more sympathetic and relevant to the recreational sector

- Compiled all reviewer feedback that pertains to specific options or inclusion of new options
- Fully drafted a proposed new data collection option ‘Tagging’.
- Proposing this option for 3 of 4 categories (Biological information, Temporal trend analysis, and To inform model-based stock assessments)
- Drafted all caveats for each category
- Recommendations sit with the FishPath Core Team regarding inclusion into the Tool
- Fully drafted proposed new management measure option: Catch and release.
- Two proposed options are: Stocking and Citizen Science.
- Drafted all caveats for each
- Recommendations sit with the FishPath Core Team regarding inclusion into the Tool

Phase 3

Sub-objective 3. Develop a scope of work and implement the generation of a report presenting a matrix of options versus question responses invoking caveats, and notes, for short-listed options.

Output 3: Facility within the FishPath tool to obtain a matrix of options versus question responses invoking caveats, and notes for shortlisted options

- Completed software development to add the ability for users to download the option by question csv matrix for specific fishery results into the Tool. This is live and available for access for user described ‘fisheries’ at FishPath Tool.
- Export is accessed by navigating, in the Tool, to the results page, then clicking ‘Export CSV’ -> ‘Download Results’. This is live and available for access for user described ‘fisheries’ at FishPath Tool.

Sub-objective 4. Develop a scope of work and implement side-by-side comparisons of multiple ‘fisheries’ for a) alternative answers; and b) alternative options.

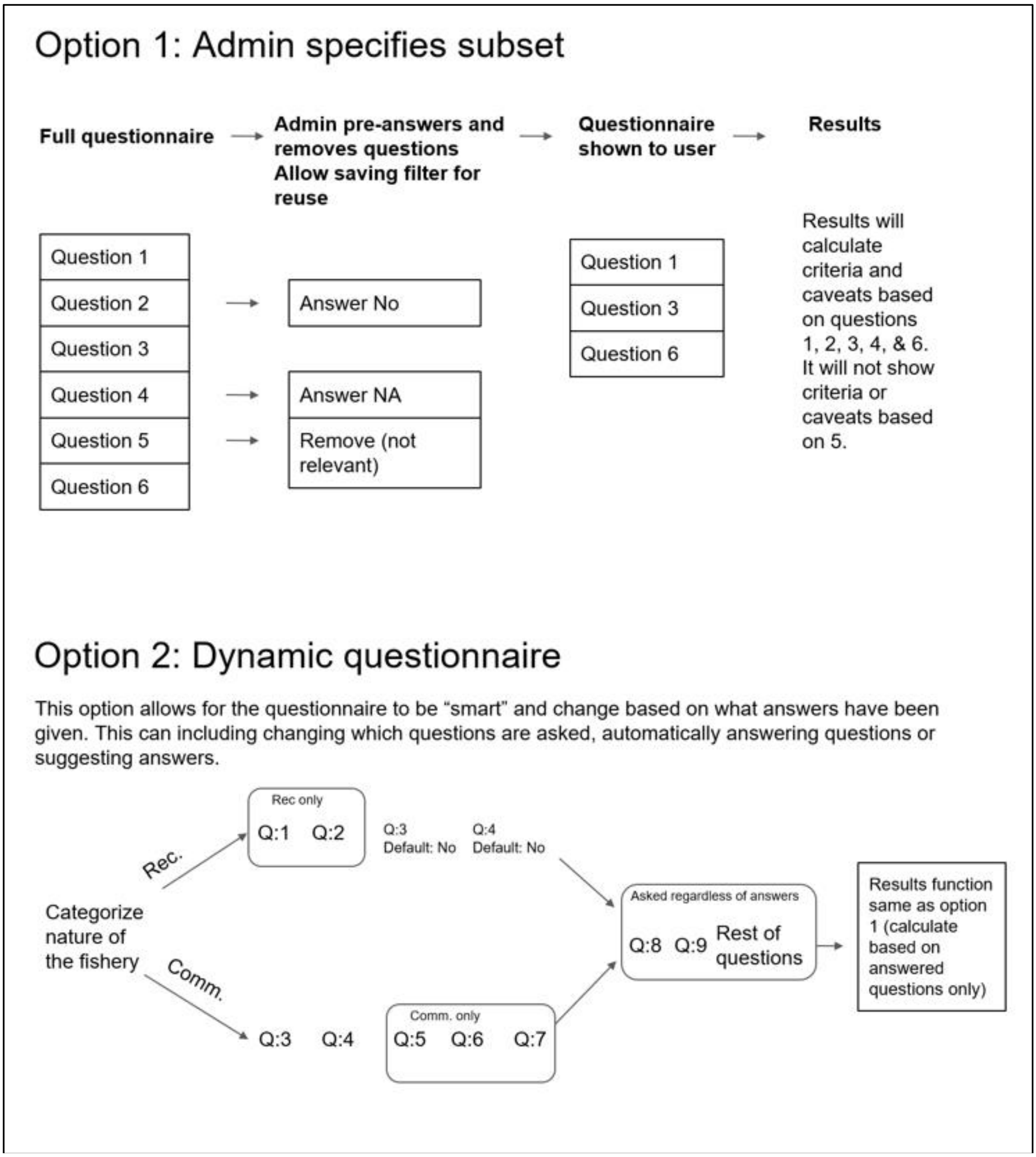
Output 4: Scope of work for implementing changes in the FishPath tool to facilitate side-by-side comparison of a) alternate answers to questions, and b) alternative options, for multiple ‘fisheries’

- Developed two new csv reports to compare summary of fishery questionnaires and results side by side
- Multiple fishery answer summary shows comparison of the answers, notes and bookmarks for multiple fisheries
- Multiple fishery options summary shows a comparison of the number of criteria and each type of caveats for each option, as well as notes and if an option is flagged as a top option
- Export is accessed by navigating, in the Tool, to the results page, then clicking ‘Multiple Fisheries CSVs’, choosing to export ‘Answers’ or ‘Options’, selecting the ‘fisheries’ to compare, then -> ‘Generate report’. This is live and available for access for user described ‘fisheries’ at FishPath Tool

Sub-objective 6. Develop a scope of work (concept diagram or outline) for achieving a ‘filtered’ FishPath series of reduced questions and options relevant to recreational fishers.

Output 6: Concept diagram or outline, including filter logic, potentially in FishPath tool development environment, for achieving a “filtered” tool of reduced questions and (potentially) options relevant to the recreational sector

- Completed concept diagrams for two software design paradigms that would allow for filtering in the FishPath Tool (Figure 24)
- Compiled list of design considerations that will need to be taken into account when finalising the user interface and software design for this functionality



Option 1: Admin specifies subset

Results will calculate criteria and caveats based on questions 1, 2, 3, 4, & 6. It will not show criteria or caveats based on 5.

Option 2: Dynamic questionnaire

This option allows for the questionnaire to be “smart” and change based on what answers have been given. This can including changing which questions are asked, automatically answering questions or suggesting answers.

Results function same as option 1 (calculate based on answered questions only)

Figure 24 Concept diagram for software design paradigms, Option 1 (Admin specified answers) and Option 2 (Dynamic questionnaire), allowing ‘filtering’ of questions for different groups/sectors. Noting, implications on stakeholder engagement and results outcomes, including reduced (loss of ‘irrelevant’) criteria and caveats.

Option 1 was adopted for further development and implementation (Upwell Solutions 2023). Development and Tool functionality has been completed and is available in a beta version of the Tool. However, full implementation to the online Tool requires approval from the core FishPath team at The Nature Conservancy.

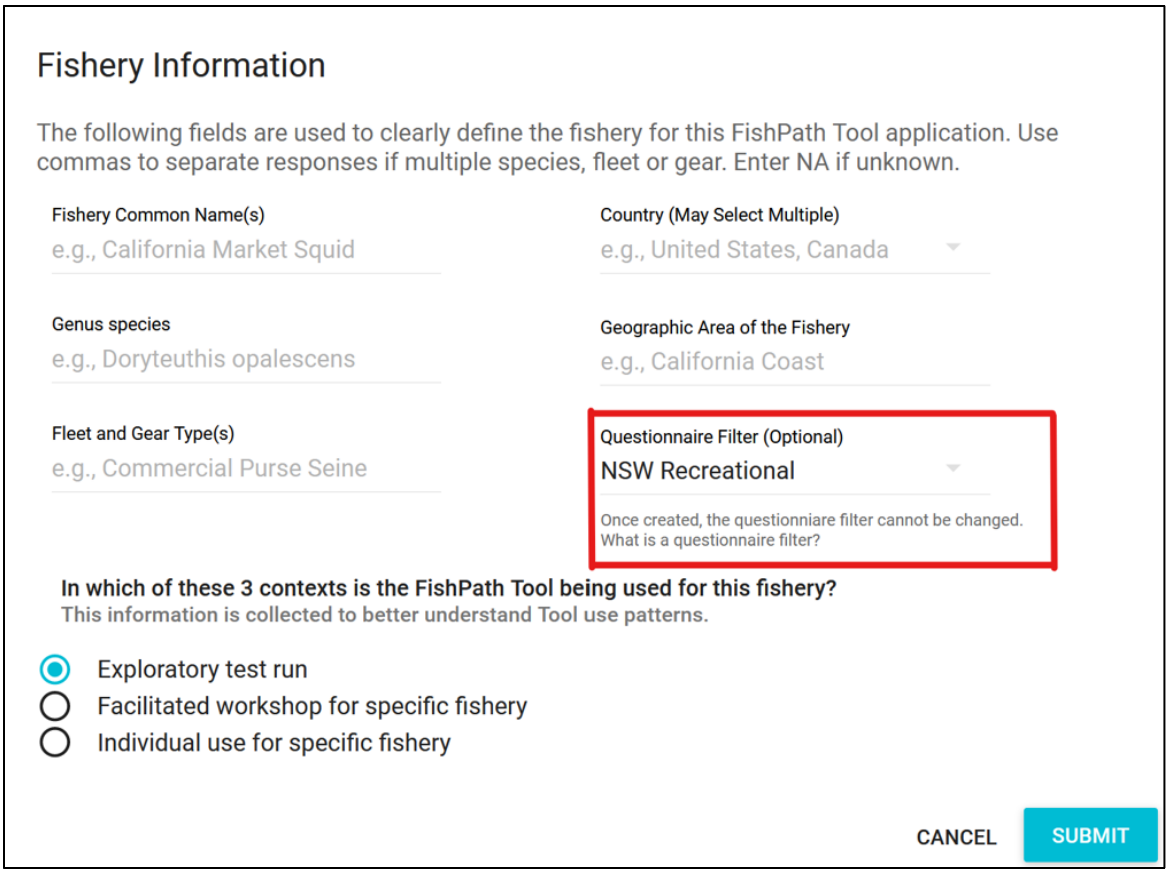
Overview of filtering functionality

The new functionality adds the ability for Tool administrators to create a "filter" for the FishPath Tool questionnaire. This filter is applied to the questionnaire before starting the questionnaire. A filter is created to be specific to a given context (Figure 25, e.g. NSW Recreational). The filter gives the administrator three choices for each question:

1. Leave the question as is (i.e., no change). This will keep the question for it to be displayed as normal when going through the questionnaire.
2. Filter the question out of the questionnaire. This is done when it is determined the question is irrelevant to this context. This removes the question from the questionnaire and the calculation of the results. It can be thought of as the equivalent of selecting a "Not Applicable" answer even if that question does not provide "Not Applicable" as an answer choice.
3. Pre-select an answer. This allows admins to choose answers that are certain and won't likely elicit useful stakeholder discussion. For example, a NSW recreational filter may pre-select "recreational fishing" for the sector. The question and answer will be used in the calculation of the results.

Options 2 & 3 both remove the questions from the list of questions displayed to users going through the questionnaire. This reduces the amount of time needed to answer and can reduce questionnaire fatigue and the time burden for users and allows facilitators and stakeholders to be able to focus on the questions of most interest. These choices also allow for the administrator to add a note to be automatically applied for that question.

Importantly, questions that have been filtered or pre-answered are still displayed in the answer section of the results (Figure 26). Users can see the impact these questions have on the results and are able to change the answers as needed. This is in keeping with a core tenant of the Tool to provide transparency in the decision-making process.



Fishery Information

The following fields are used to clearly define the fishery for this FishPath Tool application. Use commas to separate responses if multiple species, fleet or gear. Enter NA if unknown.

Fishery Common Name(s): e.g., California Market Squid

Country (May Select Multiple): e.g., United States, Canada

Genus species: e.g., Doryteuthis opalescens

Geographic Area of the Fishery: e.g., California Coast

Fleet and Gear Type(s): e.g., Commercial Purse Seine

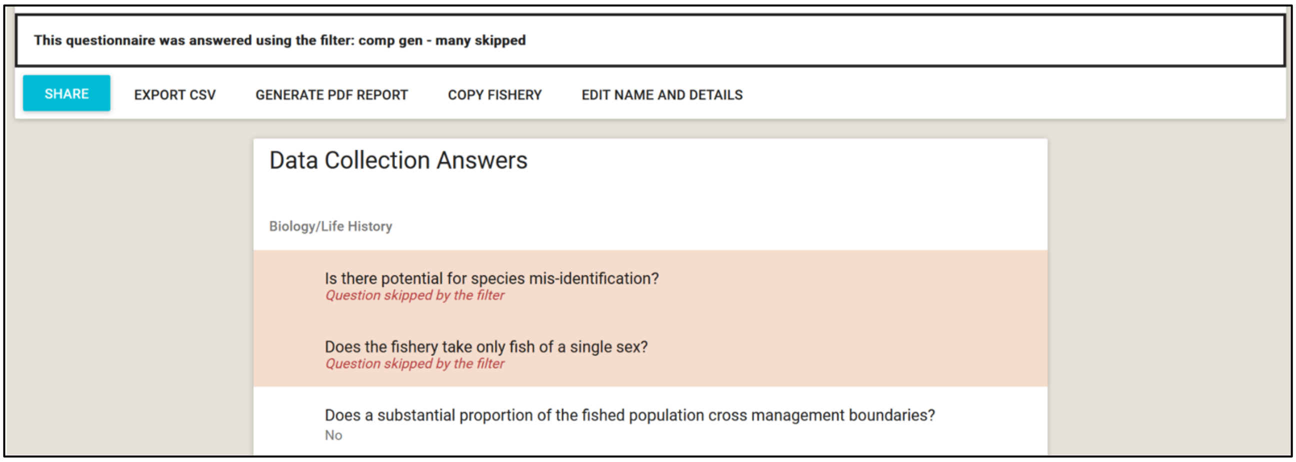
Questionnaire Filter (Optional): NSW Recreational

Once created, the questionniare filter cannot be changed. What is a questionnaire filter?

In which of these 3 contexts is the FishPath Tool being used for this fishery?
This information is collected to better understand Tool use patterns.

● Exploratory test run
○ Facilitated workshop for specific fishery
○ Individual use for specific fishery

Figure 25 The fishery information screen when starting a new questionnaire in the FishPath Tool. The area outlined in red shows where to apply a filter for the new questionnaire.



This questionnaire was answered using the filter: comp gen - many skipped

Data Collection Answers

Biology/Life History

Is there potential for species mis-identification?
Question skipped by the filter

Does the fishery take only fish of a single sex?
Question skipped by the filter

Does a substantial proportion of the fished population cross management boundaries?
No

Figure 26 Example highlighting questions that were skipped by the filter. The banner at the top displays which filter was applied to the questionnaire. Users are able to click on a question to change the answer or add a note.

NSW Recreational Filter and ‘Translation’

Functionality of the filter process has been developed to be generic and universally usable by all users of the Tool. This is needed for the update to be considered for inclusion in the online Tool by the core FishPath team within The Nature Conservancy. Functionality to the FishPath Tool is under constant review and development (beyond this project), included in its added functionality has been ‘custom translations’ for the questions. When developing the filter, this functionality was leveraged by writing question ‘translations’ for the ‘recreational fisher’. This ‘translation’ results in a softening preface being included for all technical questions and more lay language being applied to the questions in the Tool. For example, the question ‘*Do you have the life history ratio (M/k) for the species? Select the answer that best describes the source and uncertainty.’* would have a softening preface and lay language added to result in the question ‘*This is a technical question about our understanding of the species biology and is required for certain types of stock assessments. Do you know the ratio of the natural mortality (death rate, known as "M") and population growth rate (known as "k") for the species, to calculate the ratio M/k?*"

The inclusion of both the recreational questionnaire filter and translation should provide a greatly improved FishPath Tool experience when used in recreational fishing engagements.

Objective 4 - Develop guidelines and recommendations for the integration of recreational fishing information into harvest strategies for multi-sector fisheries

The guidelines are organised according to a four-phase harvest strategy development process (see Dowling et al. 2023). A detailed diagram of the phases is provided in Figure 27, which builds on the original diagram from Dowling et al. (2023). These guidelines focus on the RF sector and therefore extend, rather than duplicate, non-sector-specific guidelines already provided for HS development (e.g., Dowling et al. 2015, Dowling et al. 2023). While some of the current guidelines have previously been articulated by Sloan et al. (2014), we indicate when each should be considered throughout the HS development process. We also outline numerous considerations that should be made prior to Phase 1. This should inform timely commencement of activities, e.g. establishment of monitoring programs. We also provide four approaches to HS development that can assist with achieving RF objectives in multi-sector fisheries (see breakout box). These address the potential trade-offs that arise from multiple competing objectives, both across and within sectors.

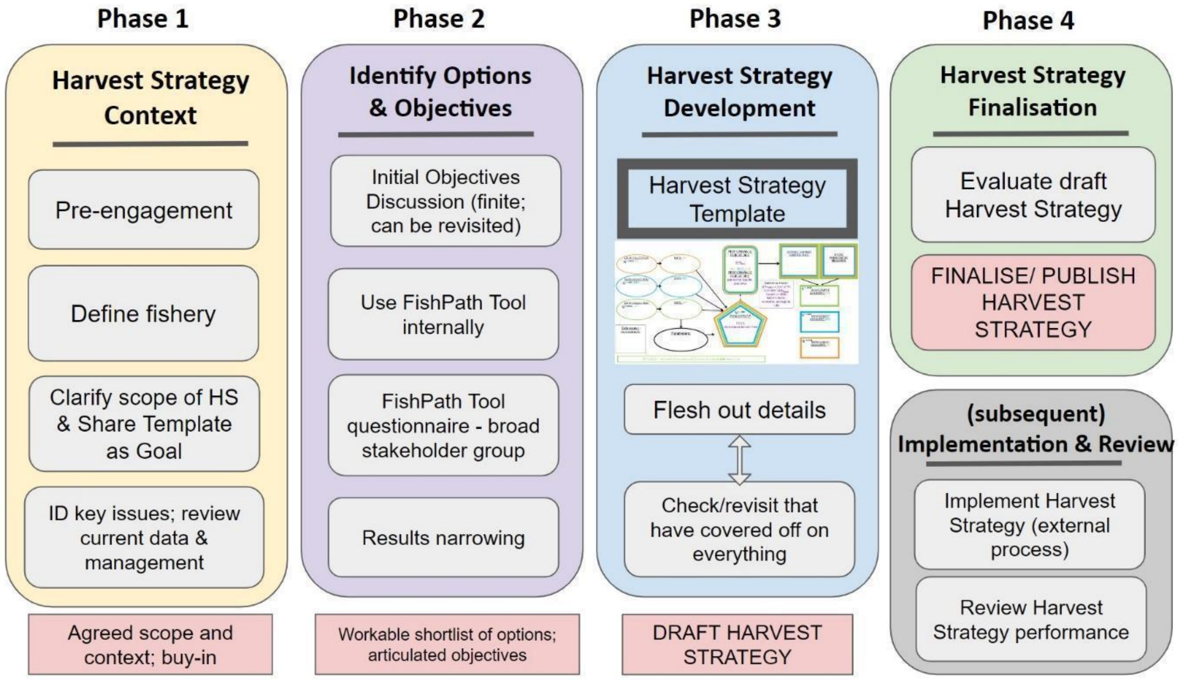


Figure 27 Steps within each of the four phases of the harvest strategy development process (adapted from Dowling et al. 2023). Pink boxes indicate the expected outcomes of each phase.

Prior to Phase 1 - before pre-engagement for a specific HS

0.1 Review existing legislation and regulation of RF and identify any barriers to HS development, including legal risks involved with applying management controls to the sector.

0.2 Establish allocation policy to support resource sharing between the RF and other sectors within HSs.

0.3 Establish HS policy and guidelines that explicitly acknowledge RF and the need to include the sector in HSs.

0.4 Define appropriate criteria for inclusion of the RF sector in HSs. Contribution to fishing mortality alone is insufficient for the RF sector, particularly for stocks with a significant catch-and-release component.

0.5 Conduct research to understand RF operations and objectives. While these topics will be considered in Phases 1 and 2 for specific HSs, prior knowledge of the type, magnitude and extent of RF is essential for HS planning. A general understanding of RF objectives in isolation, prior to joint meetings, will also reduce the likelihood of overlooking a potentially less dominant sector. Consideration must be given to economic and social objectives, as well as biological, to facilitate 'triple-bottom-line' (TBL) sustainability.

0.6 Review existing RF monitoring to identify potential data gaps for common fishing objectives. Substantial gaps at this stage can inform timely establishment of new monitoring programs, noting that exact objectives and associated data requirements will not be confirmed until Phases 2 and 3. Also consider non-RF data sources for potential monitoring of RF objectives.

0.7 Identify RF organisations and individuals that may act as suitable representatives for the sector during HS development and establish good working relationships. This may be challenging if a single organisation (or 'peak body') does not exist.

Phase 1 – Pre-engagement, definitions and scoping for specific fishery HS

1.1 Identify RF sub-groups that are involved in the specific fishery scheduled for HS development. These may be distinguished by numerous characteristics, including avidity, gear preference, socio-economic status and location of residence relative to fishing areas. Sub-group composition may differ among stocks and fisheries.

1.2 Establish an equitable process for HS development, where the RF sector is afforded inclusion in all engagement, provision of information, and meetings relative to other sectors. Although inclusion in the process should be equal, membership and voting rights within the HS Development Committee may be unequal among sectors, depending on prior resource allocation outcomes.

1.3 Ensure RF representatives are provided with information on the relevance of HSs to the sector, their scope and limitations, and the expected HS development process. RF representatives may be less familiar with formal stakeholder engagement processes than others, particularly commercial fishers.

1.4 Define the type, magnitude and extent of RF activity related to the stock(s), as well as the role of RF representatives. This will help define the scope of the HS from the RF perspective.

1.5 Review existing RF data sources to identify those that may be suitable for monitoring RF objectives for the specific fishery and stock(s) under development, and to identify potential data gaps that need to be addressed. Monitoring programs for RF often cover many stocks, with fishers being the primary sampling unit, such that quality data may only be available for the most common stocks.

1.6 Review existing management measures for RF and note which, if any, are effective at controlling total harvest. Most measures are ineffective, due to the large number of individuals each responsible for a small fraction of total harvest.

Phase 2 - Identifying objectives and options for HS components

2.1 Elicit fishing objectives from RF representatives and prioritise them. Elicitation should consider the full suite of TBL objectives. Separate meetings with RF representatives may be required, due to the extent and complexity of RF objectives, particularly if preliminary research has not been conducted (see Guideline 0.5). Objective preferences may differ among RF sub-groups and elicitation methods should be structured to capture preference weightings.

2.2 Determine whether RF objectives can be achieved within the scope of a HS or need to be addressed using other management processes. Objectives in a HS must be either directly or indirectly influenced by harvest level, stock abundance, or life-history parameters responsive to fishing. Many RF objectives are social and many of these may not be achievable by adjusting harvest.

2.3 Consolidate objectives across fishing sectors and within the RF sector itself. Consolidation is a critical step because it is challenging to construct a HS that addresses a large number of objectives simultaneously, and the RF sector has a broad range of ecological, economic and social objectives. Some objectives may be common among sectors, particularly those that relate to ecological sustainability. Ecological objectives for the RF sector (e.g. achieving target biomass) may indirectly achieve at least some economic and social objectives (e.g. a ‘trophy’ fishery), further reducing the number of separate objectives required within a HS. Fishery performance against objectives must be quantifiable, such that specific values of an indicator can be used to define reference points. Specific RF indicators may or may not be required within the assessment (see the Assessment section in Phase 3 and the breakout box).

2.4 Discuss with RF representatives what optimal and poor outcomes would be for each objective. This provides a focus on achieving objectives when developing HSs and is a precursor to selection of reference points for performance indicators (PIs; see Guideline 3.2).

2.5 Identify options for the three main HS components - data collection, assessment, management measures - efficiencies can be gained through a structured, comprehensive approach such as use of the FishPath questionnaire. The questionnaire should initially be completed separately for the RF and other sectors. Data collection and management options for RF often differ to those for other sectors, while the assessment may be common.

Phase 3 – Linking components together into a functioning HS

3.1 Populate the HS Template (Figure 28) with the most suitable options for the RF and other sectors identified in Phase 2. Consider how multiple options within a HS component type, e.g. management measures, may combine to achieve objectives. Also consider linkages between HS components, e.g. the multiple types of data required to support a particular assessment.

3.2 Identify PIs suitable for quantitative monitoring of fishery performance relative to specific RF objectives (Guideline 2.1). This draws from the RF data sources already identified in previous phases (Guidelines 0.6 and 1.5).

3.3 Determine reference points for each PI that reflect RF objectives. Each PI should have a target and a limit reference point. For PIs that are common to multiple sectors (e.g., biomass depletion), a compromise on the target reference point may be required to ensure equity with respect to achieving the objectives of all sectors. This can be achieved by either applying preference weightings to target values and producing a weighted average value, or non-quantitatively by establishing an agreed compromise value among stakeholder groups.

3.4 When finalising each HS component:

Data Collection

- Tailor data collection options specifically to the RF sector, given the differences in operational characteristics and data types between the RF and other sectors.
- Confirm whether existing monitoring programs collect the necessary data to inform PIs. If not, design improved, additional or replacement data collection protocols. Considerations include data representativeness and potential biases, along with

precision of estimates throughout the time-series (the FishPath tool provides advice in these contexts).

- Consider the utility of voluntary data collection by recreational fishers given their large number and typically broad spatio-temporal coverage.

Assessment

- Consider a broader definition of 'assessment', beyond a model-based estimate of stock status, particularly where RF objectives are not clearly linked to biomass. For example, multi-indicator decision frameworks, that may or may not be inclusive of a model-based stock assessment, may be considered an 'assessment'.
- Determine the extent to which the assessment will explicitly incorporate RF-specific PIs. RF objectives may be achieved by directly including RF indicators within the assessment (e.g., multi-indicator frameworks), or by using proxies (e.g., biomass indicators) and evaluating performance against RF objectives. See the breakout box.
- Include the mortality resulting from RF in model-based assessment, particularly if this represents a significant proportion of the total fishing mortality. Both retained catch and estimates of post-release mortality should be included.
- Consider the spatial distribution of biomass in addition to whole-of-stock status. Recreational fishers may be primarily concerned with fishery performance at a local scale. Higher target reference points for whole-of-stock biomass, or regionalised monitoring, assessment and harvest control, may be required to achieve this.

Management Measures:

- These are often different for the RF sector than for the commercial sector.
- Measures may be fixed (static), or dynamically adjusted (scaled response, open/close) in response to assessment outcomes via a harvest control rule (HCR)
- Methods for controlling total harvest should be carefully considered for RF, given typical measures are applied on a per-fisher basis with unknown total effect (e.g., daily bag limits).
- Consider primary and secondary measures to achieve all fishing objectives (e.g., a TAC shared among the sectors may be the primary measure, but local spatial closures may be a secondary measure).
- Ensure that the types of management measures selected for each sector allow for shared accountability for the resource.
- Ensure the measures are enforceable. Compliance is likely to be more challenging for the RF sector given the large number of individuals, the challenge of educating all participants as to the value of HSs, and the broad scale of operation.

3.5 Formulating the HCR:

- Ensure these result in shared accountability across sectors. For example, dynamic harvest control is applied to all sectors, such that increases and decreases in allowable catch are shared through time.
- Be conscious of the limitations of common RF harvest control. Some measures can only provide discrete, coarse stepped control (e.g., changing bag limit from 2 individuals to 1 individual) and thus potentially compromise shared accountability, particularly if other sectors have a continuous scaled response (e.g., TAC adjustment)
- Ensure the frequency of harvest control is consistent with monitoring and assessment capability. For example, real-time catch monitoring of the RF sector is often challenging, such that within-year control of harvest (e.g., dynamic closed season) may not be possible.

- Consider the spatial scale at which harvest control is required (to achieve objectives). There may be a primary HCR (say, to adjust TAC throughout the entire fishery), as well as augmentary HCRs that apply at a finer scale to address local RF objectives.

Phase 4 – HS evaluation

4.1 Use quantitative management strategy evaluation (MSE) where possible, but alternatives may be required given typical data limitations and the types of assessment used for multi-sector HSs that include the RF sector. Alternatives include retrospective analyses and expert consultation.
4.2 Select an evaluation method capable of accommodating potential trade-offs between sectors, as well as within sectors.
4.3 Evaluate HS performance against the PIs corresponding to each of the RF objectives. This is critical where RF objectives have not been explicitly incorporated within the assessment and HCR.
4.4 Trade-offs may be resolved either quantitatively (e.g., objective function optimisation) or in a formal qualitative process (e.g., via consultation).

Breakout box: approaches for achieving RF objectives within HSs

Direct

- Use a multi-indicator framework that includes PIs specific to RF objectives. These indicators would directly influence the control rule and sit alongside, secondary to, or replace a biomass-based stock assessment. For example, a hierarchical decision tree for TAC determination, where an initial catch is set via a primary biomass indicator and an adjustment to that catch is then made based on the value of a secondary length-based indicator.
- Include multiple performance indicators, each of which is used in an objective function that is weighted according to a stakeholder group's preferences (Dowling et al. 2020). Quantitative preference weightings can be elicited directly from RF representatives, or a broader sample of the RF community, using a multi-criteria decision analysis approach (e.g. Analytical Hierarchy Process). The RF sector would have its own objective function that is a weighted sum of all the (normalised) PIs, which may differ to the objective functions for other sectors. The management measure (e.g., TAC) is then adjusted to achieve the overall optimum across all the objective functions. The approach provides a formal method for 'trading off' RF objectives against those of other stakeholder groups, where differences occur, resulting in the best compromise for all groups.
- Address RF objectives using augmentary management measures, such as spatial or seasonal closures or exclusive local access rights. These measures could be dynamically invoked at trigger values of a primary indicator, or sit outside the HCR as static measures.

Indirect

- Use a biomass-based stock assessment under the assumption that improved biomass will also achieve fisheries performance against a range of other objectives, then evaluate the performance of the strategy against all objectives (using MSE testing). If necessary, adjust the control rule to achieve an acceptable trade-off in performance across the objectives. Reference points for biomass may need to be more conservative than typical benchmarks (e.g., B_{mey}) to achieve additional recreational objectives.

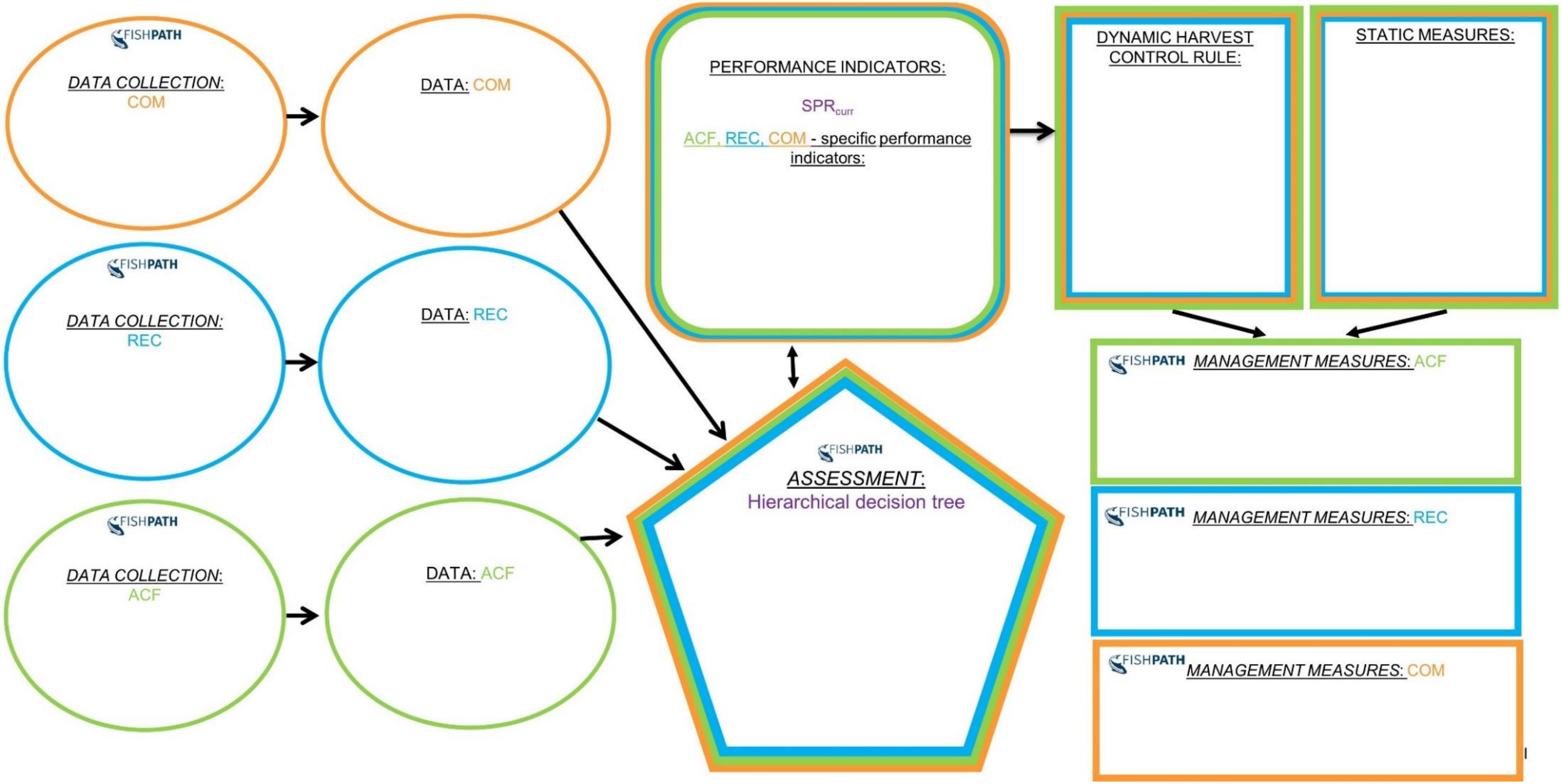


Figure 28 HS template for a multi-sector fishery including the RF sector (blue). Options for data collection and management measures are separate for each sector, as are the performance indicators, but the assessment is common to all sectors. The control rule consists of dynamic management measures (HCR), with static measures potentially providing additional types of control. 'REC': Recreational Fishing Sector, 'ACF': Aboriginal Cultural Fishing, 'COM': Commercial Sector (figure: Dowling, pers. comm.)

Implications

The current project has highlighted and detailed the limited inclusion of recreational fishing (RF) in harvest strategies (HSs), both nationally and globally, and provides approaches and recommendations to help fisheries practitioners address this issue. Integration of RF is necessary for many multi-sector fisheries, to account for catches that can equal or exceed commercial harvest and to achieve biological, social and economic objectives of the RF sector. Inadequate integration of RF in HSs therefore risks fisheries sustainability.

While there are numerous causes of limited RF integration to date, key drivers include a lack of knowledge about RF-specific HS components and how to integrate them with those of other sectors. Prior to this project, minimal information was available on: 1) types of RF data and monitoring that best serve assessments, (2) variables that can also be used as performance indicators (PIs) for recreational objectives, which are often related to the fishing experience, and (3) how to integrate HS components for multiple sectors into a common HS framework. To address these knowledge gaps, the current project has provided:

- Information on the specific HS elements that remain underdeveloped for the RF sector, most notably operational objectives, reference points to assess fisheries performance against those objectives and dynamic management controls required to achieve them
- A broad list of RF objectives that can be used as a base for more specific consultation, along with a specific list of objectives for each of three stocks of importance to the RF sector in NSW – Mulloway, Yellowtail Kingfish, Snapper. The latter were co-developed with experienced NSW recreational fishers in a workshop setting
- Preferences among those objectives from workshop participants and a broader cross-section of NSW recreational fishers via a statewide survey. The preferences can be used to identify priority RF objectives for inclusion in HSs and also weight the contribution of different PIs to a multi-indicator harvest control rule (HCR), if such a control is desirable.
- Refinements to the interactive HS development tool, FishPath, to better characterize RF when developing HSs that include the sector and to increase engagement of RF stakeholders via improved comprehension.
- A searchable online database of HSs in Australia to help fisheries practitioners find example strategies developed for specific scenarios of relevance, including multi-sector fisheries with an RF sector.
- Guidelines and recommendations for integrating RF into HSs. These are provided for each phase of HS development to assist with timely development of RF components. Four technical approaches for achieving RF objectives in HSs are also provided.
- An example multi-sector HS for each of the three stocks of interest, demonstrating the development process and methods for integrating RF with other sectors, particularly the commercial sector.

Together, the above developments advance the knowledge base, approaches and tools available for integrating RF in HSs. While these are useful contributions, their acceptance and implementation likely requires other barriers to be overcome. These include:

- A lack of sectoral acknowledgement and thus lack of policy goals for RF in fisheries governance structures
- A primarily harvest-based approach to decisions regarding the exclusion of sectors from HSs (e.g., prior resource allocation)

- A legacy of focusing on the historically more regulated commercial sector
- The misconception that RF catch is insignificant and that catch-and-release has minimal impact
- The assumption that objectives of all sectors will be met by achieving minimum biological sustainability targets often associated with commercial fishing
- Failure to address socio-economic aspects of sustainability
- Limited organisation of the RF sector (e.g., lack of a 'peak body') and resulting challenges with representative engagement in management processes
- Challenges involved with regular and precise monitoring of RF, together with limited management measures to dynamically control total RF harvest in response to assessment outcomes

Progress across all these areas is required to bridge the gap between sectors and develop truly inclusive, equitable and effective HSs. Not to do so risks the ecological and socio-economic sustainability of marine fisheries and we recommend it be addressed as a matter of urgency.

Further development

The HS database will require regular updates to remain current, particularly given the recent expansion of HS development in Australia. The utility of the database is also likely to be improved with the addition of a brief summary of the structure and function of each HS on the detail page. This will help the user quickly grasp overall HS architecture and the links between core components, e.g., separate management controls for each sector informed by a common assessment. Succinctly summarizing all HSs included in the database is a substantial undertaking that will require experienced personnel.

Scenario testing of the three example HSs will help determine whether they are likely to function as intended. Such testing is a significant task and beyond the scope of the current project. Given the data-limited nature of the example Mulloway HS, quantitative Management Strategy Evaluation (MSE) may not be possible and retrospective scenario testing using historic data may be required.

More generally, improved methods of monitoring and controlling total harvest of the RF sector are required to facilitate effective integration of the activity into HSs. The large number of individual fishers, each responsible for a small proportion of catch, presents a significant challenge for precise estimation of total harvest. Methods capable of estimating total RF harvest across an entire fishery, e.g., offsite surveys, typically involve considerable error. This increases uncertainty regarding assessment outcomes and the efficacy of resulting harvest control. Efficacy of harvest control is further hampered by the limited range and coarse nature of management measures that can be dynamically applied to the RF sector. Per-person daily bag limits are one of the few RF controls that can be dynamically adjusted in response to assessment outcomes, yet their ability to predictably control total harvest (across many fishers) is not well understood. Dynamic controls that can be reliably implemented at a sector, rather than individual, level would likely improve certainty regarding control of RF harvest.

The integration of RF into HSs represents one of numerous complexities that increase the difficulty of HS development. Others include multiple target stocks, multiple gear types and multiple jurisdictions. The various combinations of these and other complexities produces a spectrum of fisheries scenarios, each of which is seemingly unique and intractable. This apparent lack of precedent may delay HS development or force the development of overly simplistic HSs that do not address all fisheries management objectives or stakeholder expectations. Research that reviews the nature and range of fisheries complexities in Australia, identifies common scenarios and provides standard templates to guide HS development for those scenarios is needed, particularly for data-limited fisheries where model-based assessments and quantitative HCRs are not possible.

Extension and adoption

The extension plan for this project aimed to: 1) develop understanding of harvest strategies in the RF community and promote the benefits of harvest strategies for sustainable fisheries management, 2) increase knowledge and build capacity of fisheries scientists and managers to effectively monitor the performance of recreational fisheries and incorporate these data streams into harvest strategies for multi-sector fisheries, and 3) broaden the use/uptake of decision support tools for harvest strategy development, such as FishPath, in response to demand from state fisheries agencies.

Aim 1 was achieved through direct communication with RF representatives and fishers in the Recreational Fishing Research Workshops (RFRWs), the statewide survey of RF objectives and Harvest Strategy Working Groups (HSWGs). In the RFRWs, fisheries scientists, managers and independent experts from NSW DPI, UTAS, and CSIRO presented information on HSs and their relevance to 20 experienced and influential recreational fishers from NSW. The statewide survey directly engaged over 550 recreational fishers in NSW and communicated information on HSs and their relevance to recreational fishing. Information on fishing objectives reached a far greater number of recreational fishers in the state via promotion of the survey through NSW DPI social media accounts and hosting of the survey on the NSW DPI website. The HSWGs for Mulloway, Yellowtail Kingfish and Snapper directly engaged RF representatives via completion of FishPath questionnaires and discussion of results. Presentations from the project team were also used to communicate the methods by which RF might be integrated into HSs for the shared fisheries under consideration.

Aims 2 and 3 were achieved through publications in peer-reviewed scientific journals, presentations at national and international scientific conferences, an FRDC ‘webinar’ on HSs, workshops for other RF-related FRDC projects, and presentations to RFNSW and RFSTEC. Peer-reviewed articles published to date include a review linking RF data sources to fishing objectives in NSW and a high-impact review of the inclusion of RF in HSs globally. Project developments were the subject of a keynote address at the World Fisheries Congress (WFC) in 2021, and a keynote address at the Australian Society for Fish Biology (ASFB) Conference in 2022. Project outcomes were also presented to numerous fisheries practitioners throughout Australia at an FRDC-hosted webinar on HSs in late 2023. An additional presentation on identifying priority RF objectives was given to the World Fisheries Congress in 2024. Within NSW, presentations on RF data, sector monitoring and their importance for achieving the sector’s objectives have been given to the Recreational Fishing NSW Advisory Council (RFNSW) and the Recreational Fishing Saltwater Trust Expenditure Committee (RFSTEC). An overview of integrating RF into HSs and project outcomes to date was presented to RF representatives throughout Australia at a meeting for FRDC Project 2021-124 - *Partnering to deliver national research, development and extension for Australia’s recreational fishing sector: management project 2022-2024*. A similar presentation was given to fisheries practitioners via a workshop for FRDC Project 2022-001 - FRDC Project 2022-001 –

Exploring changes in recreational fishing participation and catch due to COVID-19 – A WA case study.

Extensive communication of approaches for integrating RF in HSs, from data collection through to management options, has occurred within the project team consisting of fisheries scientists and managers from multiple organisations throughout Australia.

Project materials developed

Publications resulting from this project include:

Fowler, A. M., Dowling, N. A., Lyle, J. M., Alós, J., Anderson, L. E., Cooke, S. J., Danylchuk, A. J., Ferter, K., Folpp, H., Hutt, C. and Hyder, K., Lew, D. K., Lowry, M. B., Lynch, T. P., Meadows, N., Mugerza, E., Nedreaas, K., Garrone-Neto, D., Ochwada-Doyle, F. A., Potts, W., Records, D., Steinback, S., Strehlow, H. V., Tracey, S. R., Travis, M. D., Tsuboi, J., Volstad, J. H. and Chick, R. C. 2023. Toward sustainable harvest strategies for marine fisheries that include recreational fishing. Fish and Fisheries, 24(6): 1003-1019.

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Fowler, A. M, Chick, R. C., Bolton, P., Folpp, H., Harnwell, J., Lowry, M., Lyle, J. M., Lynch, T. P., McIlgorm, A., Nichols, R., Ochwada-Doyle, F. A., Pepperell, J., Dowling, N. A. 2021. Recreational fishing objectives in NSW: An interim report on the outcomes of stakeholder workshops for Mulloway, Yellowtail Kingfish and Snapper. NSW DPI Fisheries, 24 pp.

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Appendix 1

Table A1 1 Complete list of recreational fishing objectives developed for Mulloway (*Argyrosomus japonicus*) in NSW. Bold indicates those objectives considered suitable for inclusion in a harvest strategy. Note: language here differs to the non-technical language used for objectives in Table 6.

	Specific objectives (or sub-level objectives where no further specification occurred)	**Further detail**	**Objectives addressed by fixed management measures**
ECOLOGICAL/BIOLOGICAL	**Maintain stock biomass at target level**	To provide resilience	Coordinate with other sectors to minimise bycatch mortality of juvenile mulloway in other fisheries
	Maintain regional biomass at target levels per region	To avoid localised depletion	Acknowledge mortality of juvenile mulloway when setting catch or effort quotas in other fisheries
	Maintain the encounter rate at a target level	This is an abundance proxy	
	Maintain a target proportion of the stock that reaches maximum size		
	Maintain a target proportion of the stock that reaches legal size		
	Ensure protection of spawning aggregations		
	Minimise mortality of released fish	Also influenced by extent of education	
	Minimise impacts of lost fishing gear and other discarded waste	To avoid environmental impacts of fishing	
ECONOMIC	**Maximise the financial value of the recreational experience**	What the fishing experience is worth to the participant	
	Increase investment in the fishery to obtain best management outcomes		
	Minimise cost of compliance for charter industry	E.g. licence fees	
	Maximise revenue for RF charter industry	Helps maximise flow-on economic benefits to local and regional communities	
	Maximise revenue for RF tackle industry	Helps maximise flow-on economic benefits to local and regional communities)	
	Increase development of quality regional fisheries to promote tourism	The component of fishing quality linked to harvest control	
	Optimise efficiency of RFL spending through consultation with RF		
	Improve methods for evaluation of RF experience		
SOCIAL	**Increase the number of individuals participating in RF each year**	To 'grow the sport'	Avoid interactions with other people
	Maintain equitable share of catch among fishing sectors, according to allocation policy	Sectoral allocation policy does not currently exist	Minimise negative interactions with other aquatic users
	Increase time spent fishing (with family and friends)		
	Maintain stock biomass at target level	To ensure a good fishing experience and catch sufficient to feed family	
	Maintain regional biomass at target levels per region	To ensure good catches and strike rates	
	Maintain the encounter rate at a target level	To ensure a good fishing experience and strike rate for fishers of all skill levels	
	Maintain a target proportion of the stock that reaches trophy size		
	Improve physical access to fishing locations		
	Optimise the number, size and quality of boat ramps		
	Increase networking opportunities within the RF community		
	Increase knowledge of fishing techniques		
	Increase knowledge of fishing locations		
	Increase knowledge of target species		
	Maintain/improve the aesthetic beauty of fishing locations		
	Enhance relaxative effect of fishing		
	Contribute to sense of wellbeing through education to improve handling practices and minimise mortality of released fish	Both target and bycatch species	
	Improve public understanding of socio-economic benefits of RF	By improved public education, encourage efficiency of yield by taking fewer fish of a larger size, rather than many fish of smaller size	
MANAGEMENT	Avoid undue complexity and redundancy in regulations		Broaden the range of rec-specific harvest strategy components used
	Increase consultation periods on management changes		Optimise the period between harvest strategy reviews
	Increase transparency of public information regarding catch and stock status		Include 'breakout' rules for RF in harvest strategies
	Improve the clarity of fisheries management documentation		
	Improve the distribution of fisheries management information		
	Increase recreational representation in fisheries management advisory processes		
	Improve partnerships between recreational fishers and fisheries management		
	Provide opportunities for co-management		
	Increase penalties for infringement		
	Increase financial investment in management of the fishery		
	Increase fisher awareness of sustainable fishing practices	Including knowledge of population biology and stock assessment, the benefits of releasing large fish, best-practise fish handling, and catch-and-release)	

Table A1 2 Complete list of recreational fishing objectives developed for Yellowtail Kingfish (*Seriola lalandi*) in NSW. Bold indicates those objectives considered suitable for inclusion in a harvest strategy. Note: language here differs to the non-technical language used for objectives in Table 7.

	Specific objectives (or sub-level objectives where no further specification occurred)	**Further detail**	**Objectives addressed by fixed management measures**
ECOLOGICAL/BIOLOGICAL	**Maintain stock biomass at target level**	To provide resilience	Increase protection of spawning aggregations
	Maintain regional biomass at target levels per region	To avoid localised depletion	
	Maintain the encounter rate at a target level	This is an abundance proxy	
	Maintain a target proportion of the stock that reaches maximum size		
	Maintain a target proportion of the stock that reaches legal size		
	Ensure protection of spawning aggregations		
	Minimise impacts of lost fishing gear and other discarded waste	To avoid environmental impacts of fishing	
ECONOMIC	**Maximise the financial value of the recreational experience**	What the fishing experience is worth to the participant	
	Increase investment in the fishery to obtain best management outcomes		
	Minimise cost of compliance for charter industry	E.g. licence fees	
	Maximise revenue for RF charter industry	Helps maximise flow-on economic benefits to local and regional communities	
	Maximise revenue for RF tackle industry	Helps maximise flow-on economic benefits to local and regional communities)	
	Optimise efficiency of RFL spending through consultation with RF		
SOCIAL	**Increase the number of individuals participating in RF each year**	To 'grow the sport'	Avoid interactions with other people
	Maintain equitable share of catch among fishing sectors, according to allocation policy	Sectoral allocation policy does not currently exist	Minimise negative interactions with other aquatic users
	Increase time spent fishing (with family and friends)		
	Increase opportunties to compete in fishing tournaments		
	Maintain stock biomass at target level	To ensure a good fishing experience	
	Maintain regional biomass at target levels per region	To ensure good catches and strike rates	
	Maintain the encounter rate at a target level	To ensure a good fishing experience	
	Maintain a target proportion of the stock that reaches trophy size		
	Improve physical access to fishing locations		
	Optimise the number, size and quality of boat ramps		
	Increase networking opportunities within the RF community		
	Increase knowledge of fishing techniques		
	Increase knowledge of fishing locations		
	Increase knowledge of target species		
	Maintain/improve the aesthetic beauty of fishing locations		
	Enhance relaxative effect of fishing		
	Contribute to sense of wellbeing through education to improve handling practices and minimise mortality of released fish	Both target and bycatch species	
	Improve public understanding of socio-economic benefits of RF	By improved public education, encourage efficiency of yield by taking fewer fish of a larger size, rather than many fish of smaller size	
	Increase knowledge of benefits of releasing large fish		
MANAGEMENT	Avoid undue complexity and redundancy in regulations		Broaden the range of rec-specific harvest strategy components used
	Ensure clarity of regulations for kingfish HS		Optimise the period between harvest strategy reviews
	Increase consultation periods on management changes		Include 'breakout' rules for RF in harvest strategies
	Improve the clarity of fisheries management documentation		
	Improve the distribution of fisheries management information		
	Increase recreational representation in fisheries management advisory processes		
	Improve partnerships between recreational fishers and fisheries management		
	Provide opportunities for co-management		
	Maximise penalties for infringement		

Table A1 3 Complete list of recreational fishing objectives developed for Snapper (*Chyrsophrys auratus*) in NSW. Bold indicates those objectives considered suitable for inclusion in a harvest strategy. Note: language here differs to the non-technical language used for objectives in Table 8.

	Specific objectives (or sub-level objectives where no further specification occurred)	**Further detail**	**Objectives addressed by fixed management measures**
ECOLOGICAL/BIOLOGICAL	**Maintain stock biomass at target level**	To provide resilience	Coordinate with other sectors to minimise bycatch mortality of juveniles in other fisheries
	Maintain regional biomass at target levels per region	To avoid localised depletion	Acknowledge mortality of juveniles when setting catch or effort quotas in other fisheries
	Maintain the encounter rate at a target level	This is an abundance proxy	Increase protection of spawning aggregations
	Maintain a target proportion of the stock that reaches maximum size		Protect larger fish and maintain best eating Snapper in catch
	Maintain a target proportion of the stock that reaches legal size		
	Ensure protection of spawning aggregations		
	Rebuild stocks in habitats previously known to support fish		
	Minimise impacts of lost fishing gear and other discarded waste	To avoid environmental impacts of fishing	
ECONOMIC	**Maximise the financial value of the recreational experience**	What the fishing experience is worth to the participant	
	Increase investment in the fishery to obtain best management outcomes		
	Minimise cost of compliance for charter industry	E.g. licence fees	
	Maximise revenue for RF charter industry	Helps maximise flow-on economic benefits to local and regional communities	
	Maximise revenue for RF tackle industry	Helps maximise flow-on economic benefits to local and regional communities	
	Increase development of quality regional fisheries to promote tourism	The component of fishing quality linked to harvest control	
	Optimise efficiency of RFL spending through consultation with RF		
	Improve methods for evaluation of RF experience		
SOCIAL	**Increase the number of individuals participating in RF each year**	To 'grow the sport'	Avoid interactions with other people (i.e. recreational fishers)
	Maintain equitable share of catch among fishing sectors, according to allocation policy	Sectoral allocation policy does not currently exist	Minimise negative interactions with other aquatic users (i.e. other sectors/users)
	Increase time spent fishing (with family and friends)		
	Increase opportunties to compete in fishing tournaments		
	Maintain stock biomass at target level	To ensure a good fishing experience and catch sufficient to feed family	
	Maintain regional biomass at target levels per region	To ensure good catches and strike rates	
	Maintain the encounter rate at a target level	To ensure a good fishing experience and strike rate for fishers of all skill levels	
	Maintain a target proportion of the stock that reaches trophy size		
	Improve physical access to fishing locations		
	Optimise the number, size and quality of boat ramps		
	Increase networking opportunities within the RF community		
	Increase knowledge of fishing techniques		
	Increase knowledge of fishing locations		
	Increase knowledge of target species		
	Maintain/improve the aesthetic beauty of fishing locations		
	Enhance relaxative effect of fishing		
	Contribute to sense of wellbeing through education to improve handling practices and minimise mortality of released fish	Both target and bycatch species	
	By improved public education, encourage efficiency of yield	By only taking enough plate size fish to feed a family - fewer fish of a larger size, rather than many fish of smaller size	
	Improve public education to use whole fish to avoid waste and more generally respecting and valuing the fish.	e.g. use of head and frames	
MANAGEMENT	Avoid undue complexity and redundancy in regulations		Broaden the range of rec-specific harvest strategy components used by explicitly capturing recreational objectives in development of a harvest strategy
	Ensure clarity of regulations for Snapper HS		Optimise the period between harvest strategy reviews
	Increase consultation periods on management changes		Include 'breakout' rules for RF in harvest strategies
	Increase transparency of public information regarding catch and stock status		
	Improve the clarity of fisheries management documentation		
	Improve the distribution of fisheries management information		
	Increase recreational representation in fisheries management advisory processes		
	Improve partnerships between recreational fishers and fisheries management		
	Provide opportunities for co-management		
	Increase penalties for infringement		
	Increase financial investment in management of the fishery		
	Increase fisher awareness of sustainable fishing practices	Including knowledge of population biology and stock assessment, the benefits of releasing large fish, best-practise fish handling, and catch-and-release)	

Appendix 2

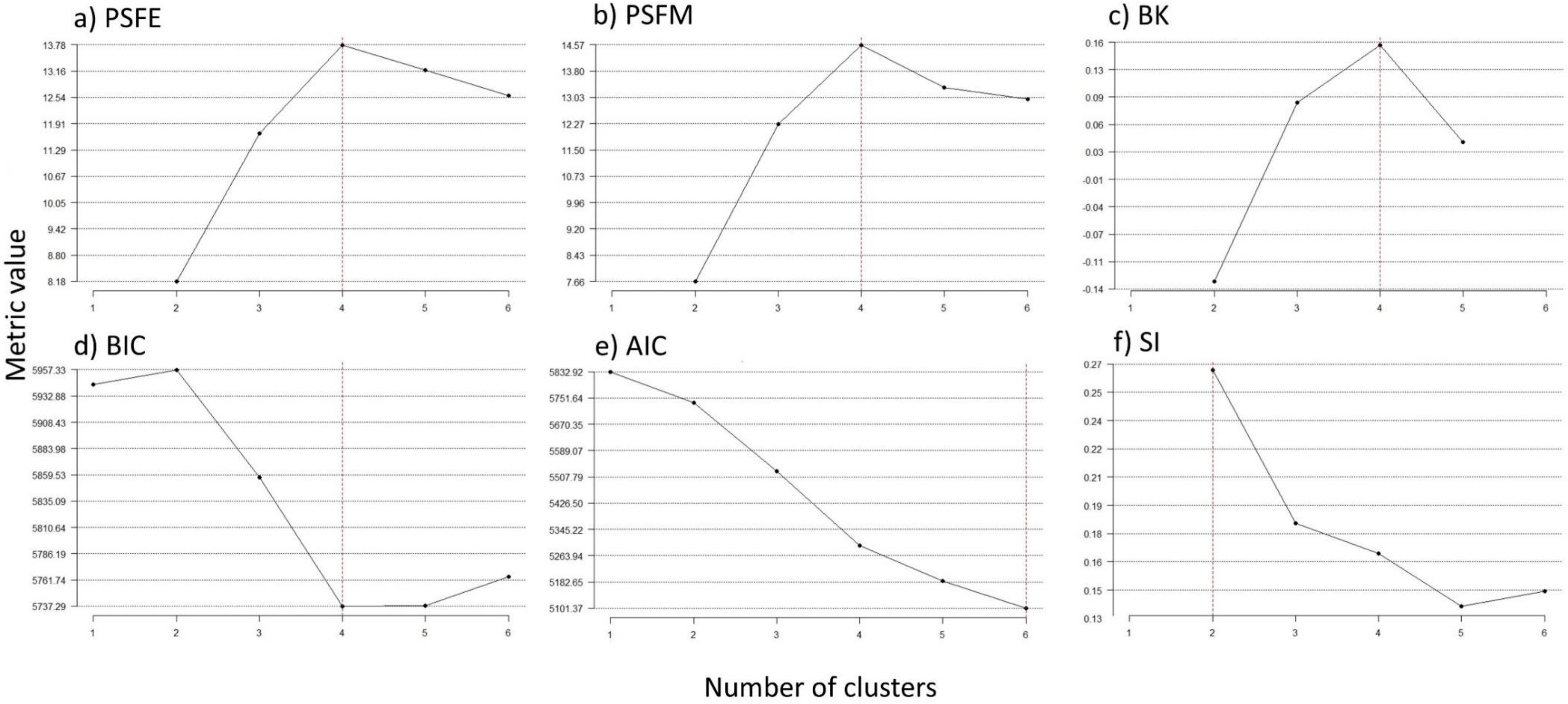

Figure A2 1 Optimal number of clusters identified by the six evaluation methods used.

Appendix 3

Table A3 1 Expert scores indicating the degree to which each HS element was included for each fishing sector in 14 regions. Scores ranged from 5 ('almost always') through to 1 ('almost never'). Namibia was not included because only one HS was reported.

	AUSTRALIA	BAHAMAS	BRAZIL	CANADA	GERMANY	JAPAN	NORWAY	SPAIN - ATL.	SPAIN - MED.	UK	U.S. - NE	U.S. - NW	U.S. - SE	U.S. - SW
Recreational sector														
Is this sector mentioned at all?	3	5	1	2	2	3	1	3	2	1	5	5	5	5
Are conceptual objectives specified?	3	4	1	2	5	3	2	2	2	1	5	5	5	5
Are operational objectives specified?	2	4	1	1	1	2	1	2	1	1	5	5	5	5
Are performance indicators specified?	2	2	1	2	1	2	2	3	1	1	5	5	5	5
Is formal data collection specified?	2	2	1	2	5	2	2	2	2	5	5	5	5	4
Are limit reference points specified?	1	1	1	2	1	1	1	3	2	1	5	5	5	4
Are trigger reference points specified?	1	1	1	2	1	1	1	2	1	1	5	5	5	5
Are target reference points specified?	1	1	1	2	1	1	1	2	1	1	5	5	5	5
Are management controls specified?	3	1	2	3	1	3	2	4	2	1	5	5	5	5
Are management controls dynamic?	1	1	1	2	1	3	1	1	2	0	4	4	4	5
Commercial sector														
Is this sector mentioned at all?	5	5	3	5	5	4	5	4	5	5	5	5	5	5
Are conceptual objectives specified?	5	5	3	5	5	4	5	3	5	5	5	5	5	5
Are operational objectives specified?	5	5	3	4	5	4	5	3	5	5	5	5	5	5
Are performance indicators specified?	5	5	3	3	5	4	5	4	5	5	5	5	5	5
Is formal data collection specified?	4	5	4	4	5	4	5	4	5	5	5	5	5	4
Are limit reference points specified?	5	4	2	4	5	3	3	4	5	5	5	5	5	5
Are trigger reference points specified?	4	3	2	4	5	3	3	2	4	5	5	5	5	5
Are target reference points specified?	5	1	2	4	5	3	3	2	4	5	5	5	5	5
Are management controls specified?	5	3	2	1	1	3	3	4	5	5	5	5	5	5
Are management controls dynamic?	5	4	2	4	5	5	4	2	5	0	4	4	4	5
Small-scale sector														
Is this sector mentioned at all?	3	3	3	2	1	4	1	5	1	1	1	5	1	5
Are conceptual objectives specified?	3	2	3	3	1	4	1	5	1	1	1	2	1	4
Are operational objectives specified?	1	2	3	2	1	2	1	5	1	1	1	1	1	4
Are performance indicators specified?	1	1	3	2	1	1	2	5	1	1	1	1	1	4
Is formal data collection specified?	1	1	4	2	1	1	1	5	1	1	1	2	1	2
Are limit reference points specified?	1	1	2	2	1	1	1	5	1	1	1	1	1	3
Are trigger reference points specified?	1	1	2	2	1	1	1	3	1	1	1	1	1	3
Are target reference points specified?	1	1	2	2	1	1	1	4	1	1	1	1	1	3
Are management controls specified?	1	1	2	2	1	2	2	5	1	1	1	1	1	3
Are management controls dynamic?	1	1	2	2	1	2	1	3	1	1	1	1	1	3

Appendix 4

Table A4 1 HS elements included for the RF and commercial sectors in Australian HSs. HS documents were accessed during August, 2020.

Havrest strategy informaiton		**Recreational sector**							**Commercial sector**						
Jurisdiction	Harvest strategy	Conceptual objectives	Operational objectives	Indicator(s)	Limit reference	Target reference	Trigger reference	Control rules	Conceptual objectives	Operational objectives	Indicator(s)	Limit reference	Target reference	Trigger reference	Control rules
SA	Recreational Fishery	YES	NO	PARTIAL	PARTIAL	PARTIAL	PARTIAL	PARTIAL	NO	NO	NO	NO	NO	NO	NO
SA	Secondary and tertiary species	NO	NO	NO	NO	NO	NO	NO	YES	YES	YES	YES	YES	YES	NO
SA	Southern Garfish	NO	NO	NO	NO	NO	NO	NO	YES	YES	YES	YES	NO	YES	YES
SA	Snapper	NO	NO	NO	NO	NO	NO	NO	YES	YES	YES	YES	NO	YES	YES
SA	King George Whiting	NO	NO	NO	NO	NO	NO	NO	YES	YES	YES	YES	NO	YES	YES
SA	Southern Calamari	NO	NO	NO	NO	NO	NO	NO	NO	YES	YES	YES	NO	YES	YES
SA	Vongole (Mud cockle)	NO	NO	NO	NO	NO	NO	NO	NO	YES	YES	NO	NO	YES	YES
SA	Abalone	NO	NO	NO	NO	NO	NO	NO	YES	NO	YES	YES	NO	YES	YES
SA	Blue Crab	NO	NO	NO	NO	NO	NO	NO	YES	YES	YES	YES	YES	YES	YES
SA	Giant Crab	NO	NO	NO	NO	NO	NO	NO	YES	YES	YES	YES	YES	YES	YES
SA	Charter Fishery	YES	NO	NA	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
SA	Gulf St Vincent Prawn	NO	NO	NO	NO	NO	NO	NO	YES	YES	YES	YES	YES	YES	YES
SA	Lakes and Coorong Pipi	NO	NO	NO	NO	NO	NO	NO	NO	YES	YES	YES	YES	YES	YES
SA	Lakes and Coorong Finfish	YES	NO	NO	NO	NO	NO	NO	YES	NO	YES	YES	YES	YES	YES
SA	West Coast Prawn Fishery	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
SA	Northern Zone Rock Lobster Fishery	NO	NO	NO	NO	NO	NO	NO	YES	NO	YES	YES	YES	YES	YES
SA	Southern Zone Rock Lobster Fishery	NO	NO	NO	NO	NO	NO	NO	YES	NO	YES	YES	YES	YES	YES
SA	Sardine Fishery	NO	NO	NO	NO	NO	NO	NO	YES	NO	YES	YES	YES	YES	YES
SA	Spencer Gulf Prawn Fishery	NO	NO	NO	NO	NO	NO	NO	YES	YES	YES	YES	YES	YES	YES
SA	Lake Eyre Basin	YES	NO	YES	YES	NO	NO	YES	YES	NO	YES	YES	NO	NO	YES
WA	Abalone	YES	YES	YES	NO	NO	YES		YES	YES	YES	YES	YES	YES	YES
WA	Sea Cucumber Resource	NO	NO	NO	NO	NO	NO	NO	YES	YES	YES	YES	YES	YES	YES

Table A4 1 continued

Havrest strategy informaiton		**Recreational sector**							**Commercial sector**						
Jurisdiction	Harvest strategy	Conceptual objectives	Operational objectives	Indicator(s)	Limit reference	Target reference	Trigger reference	Control rules	Conceptual objectives	Operational objectives	Indicator(s)	Limit reference	Target reference	Trigger reference	Control rules
WA	Octopus Resource	YES	NO	NO	NO	NO	NO	NO	YES	YES	YES	YES	YES	YES	YES
WA	North Coast Demersal Scalefish Resource	YES	NO	NO	NO	NO	NO	NO	YES	YES	YES	YES	YES	YES	YES
WA	Gascoyne Demersal Scalefish Resource	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
WA	Blue Swimmer Crab Resource of the Peel-Harvey Estuary	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
WA	Silver-lipped Pearl Oyster Resource	NO	NO	NO	NO	NO	NO	NO	YES	YES	YES	YES	YES	YES	YES
WA	Finfish Resources of the Peel-Harvey Estuary	YES	NO	NO	NO	NO	NO	NO	YES	YES	YES	YES	YES	YES	YES
WA	West Coast Deep Sea Crustacean Resources	NO	NO	NO	NO	NO	NO	NO	YES	YES	YES	YES	YES	YES	YES
WA	Shark Bay Prawn Managed Fishery	NO	NO	NO	NO	NO	NO	NO	YES	YES	YES	YES	YES	YES	YES
WA	Exmouth Gulf Prawn Managed Fishery	NO	NO	NO	NO	NO	NO	NO	YES	YES	YES	YES	YES	YES	YES
WA	West Coast Rock Lobster	NO	NO	NO	NO	NO	NO	YES	NO	YES	YES	YES	YES	YES	YES
NT	Northern Territory Offshore Net and Line Fishery	NO	NO	NO	NO	NO	NO	NO	YES	YES	YES	YES	YES	YES	YES
TAS	Abalone Fishery	YES	NO	NO	NO	NO	NO	NO	YES	YES	YES	YES	YES	NO	YES
VIC	Rock Lobster	NO	NO	NO	NO	NO	NO	NO	NO	YES	YES	YES	YES	NO	YES
VIC	-	NO	NO	NO	NO	NO	NO	NO	NO	NO	YES	YES	YES	YES	YES
VIC	Victorian Wrasse (Ocean) Fishery	NO	NO	NO	NO	NO	NO	NO	YES	NO	YES	YES	YES	YES	YES
QLD	Reef Line Fishery	YES	NO	YES	NO	YES	YES	YES	YES	NO	YES	YES	YES	YES	YES

Table A4 1 continued

Havrest strategy informaiton		**Recreational sector**							**Commercial sector**						
Jurisdiction	Harvest strategy	Conceptual objectives	Operational objectives	Indicator(s)	Limit reference	Target reference	Trigger reference	Control rules	Conceptual objectives	Operational objectives	Indicator(s)	Limit reference	Target reference	Trigger reference	Control rules
QLD	Spanner Crab Fishery	YES	NO	YES	NO	NO	NO	NA	YES	YES	YES	YES	YES	NO	YES
COM	Bass Strait Central Zone Scallop Fishery	NO	NO	NO	NO	NO	NO	NO	YES	NO	YES	YES	YES	YES	YES
COM	Coral Sea Fishery Aquarium Sector	NO	NO	NO	NO	NO	NO	NO	YES	NO	YES	YES	NO	YES	YES
COM	Coral Sea Fishery Hand Collection Sector: lobster and trochus	NO	NO	NO	NO	NO	NO	NO	NO	NO	YES	NO	NO	YES	YES
COM	Coral Sea Fishery Hand Collection Sector: sea cucumber	NO	NO	NO	NO	NO	NO	NO	NO	NO	YES	YES	NO	YES	YES
COM	Coral Sea Fishery Line, Trawl and Trap Sector Sub-fisheries	NO	NO	NO	NO	NO	NO	NO	NO	NO	YES	YES	NO	YES	YES
COM	Eastern Tuna and Billfish Fishery	NO	NO	NO	NO	NO	NO	NO	NO	YES	YES	NO	YES	NO	YES
COM	Northern Prawn Fishery	NO	NO	NO	NO	NO	NO	NO	NO	YES	YES	YES	YES	YES	YES
COM	Western Deepwater Trawl Fishery and North West Slope Trawl Fishery	NO	NO	NO	NO	NO	NO	NO	NO	YES	YES	YES	YES	NO	YES
COM	Skipjack Tuna	NO	NO	NO	NO	NO	NO	NO	YES	NO	YES	NO	NO	YES	YES
COM	Small Pelagic Fishery	NO	NO	NO	NO	NO	NO	NO	YES	YES	YES	YES	YES	YES	YES
COM	Southern and Eastern Scalefish and Shark Fishery	NO	NO	NO	NO	NO	NO	NO	YES	YES	YES	YES	YES	YES	YES
COM	Arrow Squid Fishery	NO	NO	NO	NO	NO	NO	NO	NO	NO	YES	YES	NO	YES	YES

Appendix 5

Table A5 1 Objectives and indicator types identified for the RF sector within HSs in Australia. HS documents were accessed during August, 2020.

Jurisdiction	Harvest strategy	Objective type	Conceptual Objective	Operational Objective	Indicator/Assessment type
SA	Recreational Fishery	Biological	Ensure long-term sustainable harvest of recreational species.	-	
SA	Recreational Fishery	Social	Maintain recreational catches within the allocated shares.	-	
SA	Recreational Fishery	Biological	-	-	
SA	Recreational Fishery	Biological	Maximise fishing experience within ecological sustainable limits and allocated shares.	-	
SA	Charter Boat Fishery	Biological	Ensure long-term sustainable harvest of recreational species.	-	
SA	Charter Boat Fishery	Social	Maintain recreational catches within the allocated shares.	-	
SA	Charter Boat Fishery	Biological	-	-	
SA	Charter Boat Fishery	Biological	Maximise fishing experience within ecological sustainable limits and allocated shares.	-	
SA	Abalone	Biological	Maintain the stocks above ecologically sustainable levels for both species	-	Total catch
SA	Abalone	Biological	Maintain the stocks above ecologically sustainable levels for both species	-	Percentage large or Grade 1
SA	Abalone	Biological	Maintain the stocks above ecologically sustainable levels for both species	-	CPUE
SA	Abalone	Biological	Maintain the stocks above ecologically sustainable levels for both species	-	Density of legal size
SA	Abalone	Biological	Maintain the stocks above ecologically sustainable levels for both species	-	Density of pre recruits
SA	Abalone	Biological	Maintain the stocks above ecologically sustainable levels for both species	-	Total mortality
SA	Secondary and tertiary species	Biological	Ensure long-term sustainable harvest of secondary and tertiary species	-	Egg production
SA	Secondary and tertiary species	Biological	Ensure long-term sustainable harvest of secondary and tertiary species	-	Exploitation rate
SA	Secondary and tertiary species	Biological	Ensure long-term sustainable harvest of secondary and tertiary species	-	Exploitation rate
SA	Secondary and tertiary species	Biological	Ensure long-term sustainable harvest of secondary and tertiary species	-	Recruitment

Table A5 continued

Jurisdiction	Harvest strategy	Objective type	Conceptual Objective	Operational Objective	Indicator/Assessment type
SA	Secondary and tertiary species	Biological	Ensure long-term sustainable harvest of secondary and tertiary species	-	Age structure
SA	Secondary and tertiary species	Social	Maintain catches within agreed allocations for each sector	-	Commercial catch estimate
SA	Secondary and tertiary species	Social	Maintain catches within agreed allocations for each sector	-	Targeted effort
SA	Secondary and tertiary species	Social	Maintain catches within agreed allocations for each sector	-	Targeted CPUE
SA	Blue Crab	Biological	Define biological performance indicators that align to national status classifications	Maintain the legal size portion of the Blue Swimmer Crab biomass in FIS in Gulf St Vincent above the trigger of 0.8 kg/potlift	Density of legal size
SA	Blue Crab	Biological	Define biological performance indicators that align to national status classifications	Maintain the legal size portion of the Blue Swimmer Crab biomass in FIS in Spencer Gulf above the trigger of 1.7 kg/potlift and	Density of legal size
SA	Blue Crab	Biological	Define biological performance indicators that align to national status classifications	-	Density of pre recruits
SA	Blue Crab	Biological	Define biological performance indicators that align to national status classifications	-	CPUE of legal sized
SA	Blue Crab	Biological	Define biological performance indicators that align to national status classifications	-	Daily pot sampling data
SA	Vongole (Mud cockle)	Biological	-	Maintaining total commercial catches at or below 7.5% of the biomass estimate	Exploitation rate
SA	Southern Garfish	Biological	Ensure long-term sustainable harvest of Southern Garfish by rebuilding stocks during the specified timeframes	Reduce harvest fraction to trigger reference points within set timeframes	Exploitation rate
SA	Southern Garfish	Biological	Ensure long-term sustainable harvest of Southern Garfish by rebuilding stocks during the specified timeframes	Reduce harvest fraction to trigger reference points within set timeframes	Exploitation rate
SA	Southern Garfish	Biological	Ensure long-term sustainable harvest of Southern Garfish by rebuilding stocks during the specified timeframes	Reduce harvest fraction to trigger reference points within set timeframes	Exploitation rate
SA	Southern Garfish	Biological	Ensure long-term sustainable harvest of Southern Garfish by rebuilding stocks during the specified timeframes	Increase egg production to trigger reference points within set timeframes	Egg production

Table A5 continued

Jurisdiction	Harvest strategy	Objective type	Conceptual Objective	Operational Objective	Indicator/Assessment type
SA	Southern Garfish	Biological	Ensure long-term sustainable harvest of Southern Garfish by rebuilding stocks during the specified timeframes	Increase egg production to trigger reference points within set timeframes	Egg production
SA	Southern Garfish	Biological	Ensure long-term sustainable harvest of Southern Garfish by rebuilding stocks during the specified timeframes	Increase the proportion of fish ≥ 3yrs of age between each stock assessment report	Egg production
SA	Southern Garfish	Biological	Ensure long-term sustainable harvest of Southern Garfish by rebuilding stocks during the specified timeframes	≥ 13% haul net effort reduction by June 2014	Total effort
SA	Southern Garfish	Social	Maintain catches within agreed allocations for each sector	-	Total catch
SA	Southern Garfish	Social	Maintain catches within agreed allocations for each sector	-	CPUE
SA	Southern Garfish	Biological	Ensure long-term sustainable harvest of Southern Garfish by rebuilding stocks during the specified timeframes	-	Fishable biomass
SA	Southern Garfish	Biological	Ensure long-term sustainable harvest of Southern Garfish by rebuilding stocks during the specified timeframes	-	Recruitment
SA	Snapper	Biological	Rebuilding Snapper stocks in Spencer Gulf to at or above sustainable levels. Maintaining, at or above sustainable levels, the Snapper stocks in Gulf St Vincent and other regions of the fishery	-	Targeted effort
SA	Snapper	Biological	Rebuilding Snapper stocks in Spencer Gulf to at or above sustainable levels. Maintaining, at or above sustainable levels, the Snapper stocks in Gulf St Vincent and other regions of the fishery	-	CPUE
SA	Snapper	Biological	Rebuilding Snapper stocks in Spencer Gulf to at or above sustainable levels. Maintaining, at or above sustainable levels, the Snapper stocks in Gulf St Vincent and other regions of the fishery	-	Proportion of trips reaching 250 kg
SA	Snapper	Biological	Rebuilding Snapper stocks in Spencer Gulf to at or above sustainable levels. Maintaining, at or above sustainable levels, the Snapper stocks in Gulf St Vincent and other regions of the fishery	Maintain proportion of fish older than 10, above 20% of the fished population	Age structure

Table A5 continued

Jurisdiction	Harvest strategy	Objective type	Conceptual Objective	Operational Objective	Indicator/Assessment type
SA	Snapper	Biological	Rebuilding Snapper stocks in Spencer Gulf to at or above sustainable levels. Maintaining, at or above sustainable levels, the Snapper stocks in Gulf St Vincent and other regions of the fishery	-	Fishable biomass
SA	Snapper	Biological	Rebuilding Snapper stocks in Spencer Gulf to at or above sustainable levels. Maintaining, at or above sustainable levels, the Snapper stocks in Gulf St Vincent and other regions of the fishery	Maintain harvest fraction at ≤ 32% (international standard)	Exploitation rate
SA	Snapper	Social	-	-	Total catch
SA	Snapper	Biological	Rebuilding Snapper stocks in Spencer Gulf to at or above sustainable levels. Maintaining, at or above sustainable levels, the Snapper stocks in Gulf St Vincent and other regions of the fishery	-	CPUE
SA	Snapper	Biological	Rebuilding Snapper stocks in Spencer Gulf to at or above sustainable levels. Maintaining, at or above sustainable levels, the Snapper stocks in Gulf St Vincent and other regions of the fishery	-	Proportion of trips reaching 250 kg
SA	Snapper	Biological	Rebuilding Snapper stocks in Spencer Gulf to at or above sustainable levels. Maintaining, at or above sustainable levels, the Snapper stocks in Gulf St Vincent and other regions of the fishery	-	Egg production
SA	Snapper	Biological	Rebuilding Snapper stocks in Spencer Gulf to at or above sustainable levels. Maintaining, at or above sustainable levels, the Snapper stocks in Gulf St Vincent and other regions of the fishery	-	Recruitment
SA	King George Whiting	Biological	-	Maintaining the primary performance indicators within acceptable trigger reference points described	Total effort
SA	King George Whiting	Biological	-	Maintaining the primary performance indicators within acceptable trigger reference points described	Cpue
SA	King George Whiting	Biological	-	Maintaining the primary performance indicators within acceptable trigger reference points described	Age structure
SA	King George Whiting	Biological	-	Maintaining the primary performance indicators within acceptable trigger reference points described	Fishable biomass

Table A5 continued

Jurisdiction	Harvest strategy	Objective type	Conceptual Objective	Operational Objective	Indicator/Assessment type
SA	King George Whiting	Biological	-	Maintain harvest fraction at ≤ 28% (international standard)	Exploitation rate
SA	King George Whiting	Social	-	-	Total catch
SA	King George Whiting	Biological	-	-	Recruitment
SA	Southern Calamari	Biological	-	Maintaining performance indicators within the trigger reference points described	CPUE
SA	Southern Calamari	Biological	-	Maintaining performance indicators within the trigger reference points described	Total catch
SA	Southern Calamari	Biological	-	Maintaining performance indicators within the trigger reference points described	Total effort
SA	Lakes and Coorong Pipi	Biological	-	Maintain a target Pipi relative biomass above the target reference point of 11 kg/4.5 m^2 and not less than the limit reference point of 4 kg/4.5 m^2	Relative biomass of legal sized (fishery-independant survey)
SA	Lakes and Coorong Pipi	Biological	-	-	Presence/absence of pre-recruits
SA	Lakes and Coorong Pipi	ECO0MIC	-	To maximise Fishery Gross Margin.	Fisheries gross margin
SA	Lakes and Coorong Pipi	Biological	-	-	Catch vs TACC
SA	Lakes and Coorong Pipi	Biological	-	-	CPUE
SA	Lakes and Coorong Pipi	Biological	-	-	Pre-recruit relative abundance index
SA	Lakes and Coorong Pipi	Biological	-	-	Seasonality and spatial abundance
SA	Lakes and Coorong Finfish	Biological	Monitor the Lower Lakes and Coorong environmental conditions to set an appropriate TACE	-	Mean annual water level
SA	Lakes and Coorong Finfish	Biological	-	-	Amount of available habitat (%)
SA	Lakes and Coorong Finfish	Biological	-	-	Amount of available habitat (%)
SA	Northern Zone Rock Lobster	Biological	Sustainability of the Northern Zone Rock Lobster Fishery To promote stock recovery and management decisions that are responsive to changes in catch rates	-	CPUE

Table A5 continued

Jurisdiction	Harvest strategy	Objective type	Conceptual Objective	Operational Objective	Indicator/Assessment type
SA	Northern Zone Rock Lobster	Biological	Sustainability of the Northern Zone Rock Lobster Fishery To promote stock recovery and management decisions that are responsive to changes in catch rates	-	Pre-recruit index
SA	Southern Zone Rock Lobster	Biological	Sustainability of the Southern Zone Rock Lobster Fishery To promote stock recovery and management decisions that are responsive to changes in catch rates	-	CPUE
SA	Southern Zone Rock Lobster	Biological	Sustainability of the Southern Zone Rock Lobster Fishery To promote stock recovery and management decisions that are responsive to changes in catch rates	-	Pre-recruit index
SA	Lake Eyre Basin	Biological	Recreational fishing catches are ecologically sustainable	-	Population structure
SA	Lake Eyre Basin	Biological	Adverse external impacts on ESD objectives minimised	-	Presence/absence of invasive species
SA	Lake Eyre Basin	Biological	Adverse external impacts on ESD objectives minimised	-	Total freshwater flow
WA	Abalone Resource	Biological	To maintain spawning stock biomass of each target species (i.e. Roe's, Greenlip and Brownlip abalone) at a level where the main factor affecting recruitment is the environment	To manage the recreational catch to the TARC of the Resource / Asset.	Total catch
WA	Gascoyne Demersal Scalefish Resource	Biological	To maintain spawning stock biomass of each retained species above B_{MSY} to maintain high productivity and ensure the main factor affecting recruitment is the environment.	Maintain each resource or component above the threshold level (and, where relevant, close to the target range or level), or to rebuild the resource if it has fallen below the threshold or the limit levels.	Spawning biomass estimate
WA	Gascoyne Demersal Scalefish Resource	Biological	To maintain spawning stock biomass of each retained species above B_{MSY} to maintain high productivity and ensure the main factor affecting recruitment is the environment.	Maintain each resource or component above the threshold level (and, where relevant, close to the target range or level), or to rebuild the resource if it has fallen below the threshold or the limit levels.	Spawning biomass estimate
WA	Gascoyne Demersal Scalefish Resource	Biological	To maintain spawning stock biomass of each retained species above B_{MSY} to maintain high productivity and ensure the main factor affecting recruitment is the environment.	Maintain each resource or component above the threshold level (and, where relevant, close to the target range or level), or to rebuild the resource if it has fallen below the threshold or the limit levels.	Periodic risk assessment

Table A5 continued

Jurisdiction	Harvest strategy	Objective type	Conceptual Objective	Operational Objective	Indicator/Assessment type
WA	Gascoyne Demersal Scalefish Resource	Biological	To ensure fishing impacts do not result in serious or irreversible harm to bycatch species' populations.	Maintain each resource or component above the threshold level (and, where relevant, close to the target range or level), or to rebuild the resource if it has fallen below the threshold or the limit levels.	Periodic risk assessment
WA	Gascoyne Demersal Scalefish Resource	Biological	To ensure fishing impacts do not result in serious or irreversible harm to Endangered, threatened and protected (ETP) species' populations	Maintain each resource or component above the threshold level (and, where relevant, close to the target range or level), or to rebuild the resource if it has fallen below the threshold or the limit levels.	Periodic risk assessment
WA	Gascoyne Demersal Scalefish Resource	Biological	To ensure the effects of fishing do not result in serious or irreversible harm to habitat structure and function.	Maintain each resource or component above the threshold level (and, where relevant, close to the target range or level), or to rebuild the resource if it has fallen below the threshold or the limit levels.	Periodic risk assessment
WA	Gascoyne Demersal Scalefish Resource	Social	To maintain or improve lifestyle benefits for recreational fishing participants within the constraints of ecological sustainability and while having regard for the objectives of other fishing sectors	Maintain each resource or component above the threshold level (and, where relevant, close to the target range or level), or to rebuild the resource if it has fallen below the threshold or the limit levels.	Fisher participation
WA	Gascoyne Demersal Scalefish Resource	Social	To provide flexible opportunities to ensure charter operators can maintain or enhance their livelihood (eco0mic and social), within the constraints of ecological sustainability and while having regard for the objectives of other fishing sectors.	Maintain each resource or component above the threshold level (and, where relevant, close to the target range or level), or to rebuild the resource if it has fallen below the threshold or the limit levels.	Fisher participation
WA	Gascoyne Demersal Scalefish Resource	Social	Maintain and provide opportunity to maximise the flow of recreational fishing (and charter) tourism related eco0mic benefit to the broader community within the constraints of ecological sustainability and while having regard for the objectives of other fishing sectors.	Maintain each resource or component above the threshold level (and, where relevant, close to the target range or level), or to rebuild the resource if it has fallen below the threshold or the limit levels.	Fisher satisfaction

Table A5 continued

Jurisdiction	Harvest strategy	Objective type	Conceptual Objective	Operational Objective	Indicator/Assessment type
WA	Gascoyne Demersal Scalefish Resource	Biological	To ensure the effects of fishing do 0t result in serious or irreversible harm to ecological processes.	Maintain each resource or component above the threshold level (and, where relevant, close to the target range or level), or to rebuild the resource if it has fallen below the threshold or the limit levels.	Periodic risk assessment
WA	Blue Swimmer Crab Resource of the Peel-Harvey Estuary	Biological	To maintain spawning stock biomass of each retained species at a level where the main factor affecting recruitment is the environment.	Maintain each resource or component above the threshold level (and, where relevant, close to the target range or level), or to rebuild the resource if it has fallen below the threshold or the limit levels.	Total catch
WA	Blue Swimmer Crab Resource of the Peel-Harvey Estuary	Biological	To maintain spawning stock biomass of each retained species at a level where the main factor affecting recruitment is the environment.	Maintain each resource or component above the threshold level (and, where relevant, close to the target range or level), or to rebuild the resource if it has fallen below the threshold or the limit levels.	Periodic risk assessment
WA	Blue Swimmer Crab Resource of the Peel-Harvey Estuary	Biological	To ensure fishing impacts do not result in serious or irreversible harm to bycatch species populations.	Maintain each resource or component above the threshold level (and, where relevant, close to the target range or level), or to rebuild the resource if it has fallen below the threshold or the limit levels.	Recreational catch and discards
WA	Blue Swimmer Crab Resource of the Peel-Harvey Estuary	Biological	To ensure fishing impacts do not result in serious or irreversible harm to bycatch species populations.	Maintain each resource or component above the threshold level (and, where relevant, close to the target range or level), or to rebuild the resource if it has fallen below the threshold or the limit levels.	Periodic risk assessment
WA	Blue Swimmer Crab Resource of the Peel-Harvey Estuary	Biological	To ensure fishing impacts do not result in serious or irreversible harm to endangered, threatened and protected (ETP) species populations.	Maintain each resource or component above the threshold level (and, where relevant, close to the target range or level), or to rebuild the resource if it has fallen below the threshold or the limit levels.	Periodic risk assessment
WA	Blue Swimmer Crab Resource of the Peel-Harvey Estuary	Biological	To ensure the effects of fishing do not result in serious or irreversible harm to habitat structure and function.	Maintain each resource or component above the threshold level (and, where relevant, close to the target range or level), or to rebuild the resource if it has fallen below the threshold or the limit levels.	Periodic risk assessment

Table A5 continued

Jurisdiction	Harvest strategy	Objective type	Conceptual Objective	Operational Objective	Indicator/Assessment type
WA	Blue Swimmer Crab Resource of the Peel-Harvey Estuary	Biological	To ensure the effects of fishing do not result in serious or irreversible harm to ecological processes.	Maintain each resource or component above the threshold level (and, where relevant, close to the target range or level), or to rebuild the resource if it has fallen below the threshold or the limit levels.	Periodic risk assessment
VIC	Rock Lobster	Social	-	-	-
VIC	Rock Lobster	Social	-	-	-
QLD	Reef Line Fishery	Biological	Maintaining sectoral allocations for all coral reef fin fish species	-	Allocation of shares
QLD	Reef Line Fishery	Biological	Maintaining sectoral allocations for all coral reef fin fish species	-	Change of possession limit
QLD	Reef Line Fishery	Biological	Maintain all species in the reef line fishery at, or returned to, a target spawning biomass level that aims to maximise eco0mic yield (MEY) for the fishery	-	Fishing mortality
QLD	Spanner Crab Fishery	Social	Monitor the social and eco0mic benefits of the fishery to the community	-	Fisher satisfaction
QLD	Spanner Crab Fishery	Biological	Maintaining sectoral allocations for spanner crab	-	Allocation of shares