FISHERIES RESEARCH & DEVELOPMENT CORPORATION

Economics into Fisheries Management

Building economics into Fisheries Management decision making - to utilise a suite of SA case studies

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Contents

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Abbreviations

AARES	Australian Agricultural and Resource Economics Society
AFMA	Australian Fisheries Management Authority
AFMF	Australian Fisheries Management Forum
AIASA	Abalone Industry Association of South Australia
BC	Blue Crab
CBA	Cost benefit analysis
CPI	Consumer Price Index
CPUE	Catch Per Unit Effort
FIS	Fisheries Independent Survey
FRDC	Fisheries Research and Development Corporation
GOS	Gross Operating Surplus
GSV	Gulf St Vincent
GVP	Gross Value of Production
IIFET	International Institute of Fisheries Economics & Trade
MEY	Maximum Economic Yield
NER	Net Economic Return
NPV	Net Present Value
PIRSA	Primary Industries and Regions South Australia
SA	South Australia
SARDI	South Australian Research and Development Institute
TACC	Total Allowable Commercial Catch

Executive Summary

This project, undertaken by BDO EconSearch, investigated fisheries management decision making by analysing South Australian fishery case studies to assist in preparing a checklist and user guide for Fishery Managers to incorporate economic metrics into harvest strategies.

Fisheries management decision making involves a complex mix of biological, economic and social considerations. Formal harvest strategies have been developed for many fisheries across Australian management jurisdictions over the past decade, as a way of establishing a formal and structured framework to make management decisions to achieve biological stock sustainability. When these harvest strategies (or other fishery management decision making processes) have incorporated the use of economic information, it has traditionally been based on the use of complex and expensive bioeconomic models to pursue maximum economic yield management targets.

There is a need to identify and explore more cost-effective and efficient ways to incorporate economic information in harvest strategies and decision making processes that aim to achieve maximum economic yield. The report on FRDC project 2010/061 on the National Guidelines to Develop Fishery Harvest Strategies identified this as a gap that requires further work.

The aim of this project was to develop a set of economic analysis guidelines that can be used at an individual fishery level to aid harvest strategy and other fisheries management decision making by demonstrating how economics can be incorporated in fisheries management frameworks in lower value fisheries, with less resources to collect and model economic data than would be required to develop a full bioeconomic model.

Three working papers were developed in the initial stages of the project. The first, a literature review, was conducted to review both national and international literature on current and previous attempts to incorporate economic information in harvest strategies and decision making processes. The second considered different types of economic information, different approaches and decision making processes in fisheries management. The final working paper considered the sources of economic information that are relevant to fisheries management decision making, the processes of collecting that information and providing a discussion and general guidelines.

Three case studies were designed and chosen based on Working Paper Three and a workshop was held with fishery managers and industry representatives. These were:

- Case Study 1: Restructure and harvest strategy options in the South Australian Western Zone Abalone fishery
- Case Study 2: Summer fishing trial in the South Australian Gulf St Vincent Blue Crab Fishery
- Case Study 3: Alternatives to the current fishery independent survey regime in the South Australian Central and Western Zone Abalone fisheries.

The results of these case studies allowed for the creation of a fisheries managers checklist and user guide which examined the types of calculations or considerations which need to be made in a partial budgeting and discounted cash flow approaches.

There are significant challenges to the implementation and ongoing use of economic analyses in most Australian fisheries. Many of these challenges initially arise from an absence of clearly identified and prioritised objectives within overarching legislation and management plans. Once objectives are prioritised, limited resources can be allocated more efficiently to improve data collection, economic analysis and increase awareness as well as education of managers and industry.

There often appears to be some confusion among those involved in fisheries management as to the way economic data and economic indicators fit into the process. The case studies and guidelines developed for this report have illustrated how important it is for fisheries managers to work closely with industry groups and the scientific community when developing, for example, a draft harvest strategy. The development of a checklist and a practical User Guide for fisheries managers that contains a set of steps to develop a cost effective economic model, adjust the model, collect necessary data, and generate results for practical application in relevant fishery's harvest strategy, will allow for cost effective techniques to be implemented and incorporate economic considerations into harvest strategies.

In the fishery independent survey case study there are some implicit bounds on the analysis that are worth stating for general application. For example, it was implicit that the starting point for the analysis was to use existing data where possible rather than needing to embark on new data collection programs. Not all fisheries have access to economic data and it is rarely used to full value in decision making.

Within this case study, the issues/decisions that could be analysed are quite restricted in fisheries like this because more complex interactions between biology and economics could not be modelled with the tools available. A solution here is at least have a small number of clear good indicators so adaptive management can be effective.

The outcomes could only be assessed in terms of producer surplus, i.e. private net present value of fishers, meaning that PIRSA cannot meet their legislative obligation to manage the fishery to the benefit of the South Australian community. There are a few ways this could be addressed in the general case: (i) use a performance indicator that does capture all stakeholders in the community, (ii) report outcomes for more than one indicator, and/or (iii) use private net present value but note its limitations.

It was important to use a measure of profit like private net present value or gross operating surplus as the economic performance indicator, not gross value of production. Gross value of production is emphasised as a formal and informal performance indicator in fisheries management/assessments in Australia. However, this case study showed that managers need to switch focus away from gross value of production and towards private net present value if they want to make better decisions. Sometimes fishery performance can only be improved by reducing gross value of production, challenging the mindset that higher gross value of production is good for profit.

A cost benefit analysis is a basic approach likely to be useful for many other fisheries although the fishery independent survey case study illustrated limitations. The same is true in many biological analyses and demonstrates the need for future reviews and adaptive management, which is more effective with good performance indicators.

Cost benefit techniques can be applied to give more informed management decisions even in fisheries without complicated stock assessment models. Cost benefit is a basic technique and was applied in the case studies where some information was lacking. Based on the available data, these were imperfect analyses, yet were still more informed than proceeding with just opinion. It enabled pre-conceptions to be tested and gave useful guidance. Sometimes best guesses were used as inputs and these were then subject to sensitivity testing. This is more transparent and objective than typical processes like "expert opinion".

A potential set of Draft Harvest Strategy steps incorporating decision rules using economic data and indicators have been recommended. The steps include:

- identify optimal and equitable economic performance indicators for the management of the fishery
- agree on how this is to be measured and reported
- discuss if there are any trade-offs that affect structure of the harvest
- discuss and define reference points; discuss decision rules

- test the harvest strategy against a range of possible scenarios.

Economic information can be used to improve management decision-making across far more than the traditional domain of fisheries economics, which is Total Allowable Catch setting. For example, in the fishery independent survey case study efficiencies of different research data collection programs were explored.

Including economics in fisheries decision making is worthwhile because the cost of this research is often small compared to the gains in profit that could occur. Most fisheries incur large ongoing costs for biological monitoring, yet forgo opportunities for higher profits by not testing whether management tweaks could raise economic returns to fishers. This is possible through the application of relatively inexpensive and intuitive economic modelling techniques.

Keywords

Fisheries, fisheries management, economic analysis, South Australian Commercial Fisheries, Abalone, Blue Crab, user guide.

1. Introduction

Fisheries management decision making involves a complex mix of biological, economic and social considerations. Formal harvest strategies have been developed for many fisheries across Australian management jurisdictions over the past decade, as a way of establishing a formal and structured framework to make management decisions to achieve biological stock sustainability. When these harvest strategies (or other fishery management decision making processes) have incorporated the use of economic information, it has traditionally been based on the use of complex and expensive bioeconomic models to pursue maximum economic yield (MEY) management targets.

There is a need to identify and explore more cost-effective and efficient ways to incorporate economic information in harvest strategies and decision making processes that aim to achieve MEY. The report on FRDC project 2010/061 on the National Guidelines to Develop Fishery Harvest Strategies (Sloan et al. 2014) identified this as a gap that requires further work.

The aim of this project was to develop a set of economic analysis guidelines that can be used at an individual fishery level to aid harvest strategy and other fisheries management decision making. Specifically, the objective was to demonstrate how economics can be incorporated into fisheries management frameworks in lower value fisheries, with less resources to collect and model economic data than would be required to develop a full bioeconomic model.

This project has been based around a set of three case studies.

- Case Study 1: Restructure and harvest strategy options in the South Australian Western Zone Abalone fishery
- Case Study 2: Summer fishing trial in the South Australian Gulf St Vincent Blue Crab Fishery
- Case Study 3: Alternatives to the current fishery independent survey regime in the South Australian Central and Western Zone Abalone fisheries.

The results of these case studies allowed for the creation of a fisheries managers checklist and user guide which examine the types of calculations or considerations that need to be made in partial budgeting and discounted cash flow approaches.

The project team has worked directly with those fisheries, involving industry and managers – those involved in decision making. In this way the conduct of the project has comprised an extension of the project outcomes as the decision makers in the case study fisheries have been directly involved in the development and testing of the analytical tools.

2. Objectives

The objectives for the project were as follows:

1. The development of cost effective techniques to incorporate economic considerations into harvest strategies.
2. The preparation of a check list/self-assessment tool to guide fisheries managers in determining whether or not a fishery is suitable for economic modelling using one of the cost effective techniques developed as part of the project.
3. The development of a practical User Guide for fisheries managers that contains a set of steps to develop a cost effective economic model, adjust the model, collect necessary data, and generate results for practical application in relevant fishery's harvest strategy.

3. Method & Structure of this Report

This project was undertaken in a series of stages, each resulting in standalone papers or case studies. These have been presented as a series of Chapters in this report.

Each Chapter contains a background section to provide context as well as a discussion of the specific outcomes of the Chapter and how they relate to the overall project. The three Chapters reporting on the case studies also include a methods and results section specific to the research undertaken in the case study.

These Chapters proceed a summary of the User Guide and Checklist for fisheries managers “Is your Fishery Suitable for Low Cost Economic Modelling?”, which is followed by Conclusions relevant to the overall Objectives of the project and Recommendations.

Inception Meeting

The inception meeting between the project investigators was pivotal to the success of the project. The objectives of this meeting were to:

- Confirm the scope and goals of the research project and the expectations of stakeholders
- Identify and discuss key issues in relation to the project, particularly any sensitivities associated with the project
- Discuss and agree on the research and consultation approach
- Discuss and agree on the frequency and timing of project deliverables
- Discuss any other issues

Develop initial principles and guidelines

The first step was to conduct a literature review presented in **Chapter 4**. The aim of this paper was to review both national and international literature on current and previous attempts to incorporate economic information in harvest strategies and decision making processes. The review incorporated by peer-reviewed and ‘grey’ literature, i.e. model specific references and reports.

Secondly, **Chapter 5** was drafted to consider different types of economic information that are relevant to fisheries management decision making, different approaches to incorporating economic information in harvest strategies and decision making processes, and the strengths and weaknesses of the relevant indicators and approaches.

Chapter 6 was developed building on the previous two Working Papers and considers the sources of economic information that are relevant to fisheries management decision making, the processes of collecting that information and providing a discussion and general guidelines about different approaches to incorporating economic information in harvest strategies and decision making processes.

Workshop

Prior to the workshop, a set of candidate fisheries to discuss at the Workshop was compiled by liaising with managers and industry representatives across a range of fisheries. The Workshop, held on 20 April 2017 at SARDI Aquatic Science West Beach, involved the project team and candidate fishery industry members, managers of the three fisheries and scientists. It focussed on a discussion of the candidate fisheries and development of recommendations.

Case studies (Chapters 7 to 9)

Based on the outcomes of the **Workshop** and **Section 6**, three case study fisheries were selected:

- **Restructure and harvest strategy options in the South Australian Western Zone Abalone fishery (Chapter 7)**

  For the fishery restructure study, the strategies were considered at two different time scales. The time scales reflect the 12-month season currently fished for both species, based on the fishing pattern observed in 2016, and a six-month season aimed at harvesting both species at their optimum time.

  After investigating different options SARDI, Abalone Industry Association of South Australia (AIASA) and BDO EconSearch decided to contrast three fishery restructure scenarios against the baseline (status quo) scenario. The results were presented in *Western Zone Abalone Fishery Restructure and Fishing Strategy Options* (BDO EconSearch 2019c).

- **Summer fishing trial in the South Australian Gulf Saint Vincent Blue Crab Fishery (Chapter 8)**

  A key objective of this study was to estimate net benefits of the Blue Swimmer Crab (*Portunus armatus*, BC) Gulf St Vincent (GSV) summer fishing trial. Two proposed scenarios were compared against a base case scenario within the framework of a cost benefit analysis (CBA). The standard CBA method involves the specification of a base case against which scenarios are compared. The analysis was conducted over a 10-year period and results were expressed in terms of net benefits, that is, the incremental benefits and costs of the scenarios relative to those generated by the base case. The results were presented in *Gulf St Vincent Blue Crab Fishery Summer Fishing Trial* (BDO EconSearch 2020b).

- **Alternatives to the current fishery independent survey (FIS) regime in the South Australian Central and Western Zone (CZ and WZ) Abalone fisheries (Chapter 9)**

  Cost benefit analysis was used as the analytical framework for the case study including net present value (NPV) calculation and threshold analysis. A 20-year time horizon was selected to allow time for the 6-year transition under data logger scenarios, the subsequent 10-year assumed response to changed TACC and multiple survey cycles under each scenario. The results were presented in *Cost Benefit Analysis of Alternatives to Current FIS Program at Tiparra Reef* (BDO EconSearch 2020a).

Checklist and User Guide for Fisheries Managers (Chapters 10 and 11)

Drawing on the conclusions of the case studies, a user guide (Chapter 10) and checklist (Chapter 11) were compiled to examine the types of calculations or considerations which need to be made in a partial budgeting and discounted cash flow approaches. This is an indication of the logical flow of elements to consider in such an analysis. It is in the context of considering change to current management arrangements or considering alternative actions within a harvest strategy, the focus is on identifying the gains coming from the existing arrangements and comparing these to the possible gains from new arrangements which might replace those currently in place.

4. A Literature Review on Current and Previous Attempts to Incorporate Economic Information in Harvest Strategies and Decision Making Processes

Presented below is a review of both national and international literature on current and previous attempts to incorporate economic information into harvest strategies and decision making processes. There are many model-specific references/reports that are not part of the academic literature that were also reviewed. In the more formal, peer-reviewed literature there were a vast array of papers to review.

National Literature

Commonwealth Fisheries Harvest Strategies

In 2018, the Australian Government released the *Commonwealth Fisheries Harvest Strategy Policy and Guidelines* (DAFF 2018) to ensure that key commercial fish species are managed for long–term biological sustainability and economic profitability. The guidelines state that MEY should be a clear objective for Commonwealth fisheries.

Bioeconomic models have been developed for the Northern Prawn Fishery (NPF) and the Southern and Eastern Scalefish and Shark Fishery. A review of the Commonwealth Fisheries Harvest Strategies has been undertaken to determine what economic indicators or target reference points relating to economic information have been included in the harvest strategies. This is detailed by fishery below. Only five of the 13 fisheries with harvest strategies consider economic indicators, all with target reference points relating to MEY.

Northern Prawn Fishery (Dichmont et al. 2019) – The harvest strategy was developed in line with the CFHSP. There is consideration for sustainable and profitable utilisation of the resource in perpetuity. Similarly the harvest strategy aims for an exploitation rate that keeps fish stocks at a level equal to MEY and ensure stocks remain above a limit biomass level at least 90 per cent of the time. The NPF was the first major fishery in the world for which the goal of MEY was implemented (Pascoe et al. 2016).

Southern and Eastern Scalefish and Shark Fishery (AFMA 2020) – The harvest strategy includes biological, socio-economic and ecosystem objectives. The socio-economic objectives relate to:

- maintain stocks at (on average), or return to, a target biomass point equal to the stock size that aims to maximise net economic returns for the fishery as a whole.
- maximise the profitability of the fishing industry and the net economic returns to the Australian community.
- minimise costs to the fishing industry, including consideration of the impacts on the industry of large or small changes in TACs and the appropriateness of multi-year TACs.

Whilst both biological and economic targets have been explicitly considered in developing the reference points and decision rules, economic indicators and parameters are still under development.

Bass Strait Central Zone Scallop Fishery (AFMA 2015a) – The primary objective of the harvest strategy is to maximise the economic returns to the Australian community whilst keeping stocks at ecologically sustainable levels. However, there is no qualitative or quantitative target reference points for MEY.

Coral Sea Fishery – Aquarium Sector (AFMA 2019) – The harvest strategy includes biological, economic and ecosystem objectives. The primary economic objective of the harvest strategy is to maximise net economic returns to the Australian community from management of Australian fisheries, always in the context of maintaining commercial fish stocks at sustainable levels. However, there is no qualitative or quantitative target reference points for MEY.

Coral Sea Fishery – Lobster and Trochus Sector (AFMA 2008b) – Although the harvest strategy suggests the use of triggers in optimising the potential for yield, there is no indication of the use of MEY as a trigger point.

Coral Sea Fishery – Line, Trawl and Trap Sector (AFMA 2008c) – No qualitative or quantitative target reference points for MEY due to the developmental status of the fishery and its temporally variable species composition.

Coral Sea Fishery – Sea Cucumber (AFMA 2008d) – There is as yet no qualitative or quantitative notion of target or limit reference points in terms of MEY. Assessing stock status for this sector is expensive and problematic; consequently, it is difficult to conclusively demonstrate that catch is sustainable. However the sea cucumber sector's small size, low GVP and effectiveness of existing management arrangements negates the need for a more complicated harvest strategy. The conservative TACs and trigger points, together with the spatial closures, move-on provisions and size limits should mitigate against overexploitation while enabling controlled expansion of the fishery and hence the potential for yield to be optimised.

Eastern Tuna and Billfish Fishery (AFMA 2021) – The harvest strategy includes economic objectives relating to:

- maximise net economic returns to the Australian community—always in the context of maintaining commercial fish stocks at sustainable levels
- maintain key commercial fish stocks, on average, at the required target biomass to produce maximum economic yield from the fishery
- maintain all commercial fish stocks, including by-product, above a biomass limit where the risk to the stock is regarded as unacceptable, at least 90 per cent of the time;

Western Deepwater Trawl Fishery and North West Slope Trawl Fishery (AFMA 2011b) – Due to spatially extensive fishing grounds in remote areas that encompass a range of marine bioregions and ecosystems, the small number of operators and low GVP reference points and triggers relate to biological aspects only (e.g. catch and CPUE).

Skipjack Tuna Fishery (AFMA 2011c) - No qualitative or quantitative target reference points for MEY. Management of the fishery centres around catering for the unique and highly variable nature of the fishery, the lack of concern regarding the overall stock status of skipjack, the international nature of the fishery and managing the potential for localised depletion.

Small Pelagic Fishery (AFMA 2017) – This harvest strategy is based on a fishery-independent stock assessment technique and does not include any quantitative economic information.

Arrow Squid Fishery (AFMA 2014) - This harvest strategy is based on recent catch history and does not include any quantitative economic information. MEY is not a relevant reference point for this fishery given its high variability but the supposed minimal impact of current levels of effort on the stock would suggest that current (as at 2007) exploitation levels are well below that which would correspond to a theoretical MEY.

Western Tuna and Billfish Fishery - The Western Tuna and Billfish Fishery uses the same harvest strategy framework as the Eastern Tuna and Billfish Fishery Harvest Strategy. However, due to the low effort and catch, there was insufficient data to operate the harvest strategy in the fishery. AFMA is in the process of developing a new Australian Tuna and Billfish Fishery harvest strategy that will be able to assess by-product and major by-catch species in addition to the main target species.

State Fisheries Harvest Strategies

Most state fisheries have included economic objectives in their harvest strategies but not have formally adopted an objective of MEY as a key target reference point (Pascoe et al. 2016). This has led to the development of numerous bioeconomic models over the past ten years. As with the Commonwealth fisheries, a review of the State fishery harvest strategies has been undertaken to determine what economic indicators or target reference points relating to economic information have been included in the harvest strategies. This is detailed by state and fishery below.

Western Australia

The *Harvest Strategy Policy and Operational Guidelines for the Aquatic Resources of Western Australia* (WA Department Fisheries 2015a) states that for fisheries that target solely or largely a single commercial species, a target level or target range of stock abundance (that is above the stock Fisheries sustainability threshold level generate more optimal levels of economic efficiency) could be established. In addition, the guidelines recommend considering unwanted effects on social outcomes, broader community concerns and overall return to the community if adoption of an MEY strategy involves significant reductions in catch levels, shifts in fishing methods or other practices.

Bioeconomic models have been developed for the Exmouth Gulf Prawn Fishery (Ye et al. 2005), the Abalone Fishery and the Western Rock Lobster Fishery (Caputi et al. 2015; Reid et al. 2013) but have not been used in harvest strategy decisions. Described below by fishery are the economic objectives that are included in the harvest strategies. Of the nine publically available harvest strategies, only three consider economic indicators, two relating to GVP and one to MEY.

North Coast Demersal Scalefish (WA Department of Fisheries 2017a) – The harvest strategy includes one economic objective which is to provide flexible opportunities to ensure fishers can maintain or enhance their livelihood, within the constraints of ecological sustainability. The economic and social objectives do not currently have explicit performance measures within this harvest strategy.

Gascoyne Demersal Scalefish (WA Department of Fisheries 2017b) – Similar to the North Coast Demersal Scalefish the harvest strategy includes one economic objective which is to provide flexible opportunities to ensure fishers can maintain or enhance their livelihood, within the constraints of ecological sustainability. Gross value of production (GVP) has been chosen as a performance indicator to evaluate whether fishers in the GDSMF have been able to maintain or enhance their livelihood.

Pearl Oyster Fishery (WA Department of Fisheries 2016a) - The harvest strategy includes once economic objective which is to optimise economic returns to the State through the production of pearls from the pearl oyster resource. Performance against the economic objective is assessed by monitoring changes in the annual GVP of the industry.

Estuarine and Nearshore Finfish Managed Fishery (WA Department of Fisheries 2020b) - The harvest strategy includes one economic objective which is to provide commercial fisheries with reasonable opportunities to maximise their livelihood in supplying seafood to the community, within the constraints of ecological sustainability. The economic objective for this fishery does not have explicit performance measures within the harvest strategy.

Blue Swimmer Crab Managed Fishery South-West (WA Department of Fisheries 2020c) - Similar to the North Coast Demersal Scalefish and the Gascoyne Demersal Scalefish fisheries the harvest strategy includes one economic objective, which is to provide flexible opportunities to ensure fishers can maintain or enhance their livelihood, within the constraints of ecological sustainability. The economic objective for this fishery does not have an explicit performance measure within the harvest strategy.

Blue Swimmer Crab Managed Fishery Shark Bay (WA Department of Fisheries 2020d) - Similar to the blue swimmer crab fishery in the South-West, the harvest strategy includes economic objectives. These are to provide flexible opportunities to ensure fishers can maintain or enhance their livelihood and maintain or provide opportunity to maximise the flow of commercial fishing related economic benefit to the broader community, within the constraints of ecological sustainability. The economic objective for this fishery does not have an explicit performance measure within the harvest strategy.

West Coast Deep Sea Crustacean Managed Fishery (WA Department of Fisheries 2020a) – Similar to a number of other fisheries the harvest strategy includes one economic objective which is to provide flexible opportunities to ensure fishers can maintain or enhance their livelihood, within the constraints of ecological sustainability. The performance indicator for this objective looks at whether fisheries management arrangements impose constraints, for reasons other than ecological sustainability, on access to livelihood opportunities. The main way this is achieved is by providing fishers the opportunity to increase the TAC by up to 10 per cent annually, subject to targets for ecological objectives being met or exceeded.

Shark Bay Prawn Managed Fishery (WA Department of Fisheries 2014a) – The harvest strategy describes one economic objective which is to provide industry the opportunity to optimise the economic returns within a sustainable fishery framework. The target for this objective is no impediments to industry optimising efficiency identified or raised.

Exmouth Gulf Prawn Managed Fishery (WA Department of Fisheries 2018) – Similar to the Shark Bay Prawn Managed Fishery the harvest strategy describes one economic objective, which is to provide industry the opportunity to optimise the economic returns within a sustainable fishery framework. The target for this objective is no impediments to industry optimising efficiency identified or raised.

West Coast Rock Lobster Fishery (WA Department of Fisheries 2013) - The harvest objective is to determine the maximum legal proportion harvested for the fishery based on MEY.

South Australia

The *Guidelines for implementing the South Australian fisheries harvest strategy policy* (PIRSA 2015) recommend incorporating all aspects of Ecologically Sustainable Development (ESD) in accordance with the national ESD framework (Fletcher et al. 2002). This will ensure the economic and social performance of each fishery is considered along with the ecological performance. Conducting an ESD risk assessment will help identify and prioritise all ecological, economic and social issues in the fishery.

In South Australia, models have been developed for the Northern Zone Rock Lobster Fishery and the Southern Zone Rock Lobster Fishery (Gardner et al. 2015, Green et al. 2012, Hamon et al. 2014, McGarvey et al. 2014). Most recently, bioeconomic models were developed for the South Australian Prawn fisheries (Spencer Gulf Prawn Fishery and Gulf St Vincent Prawn Fishery) (Noell et al. 2015).

A Fishery Gross Margin modelling framework has been developed to aid the harvest strategy in the Lakes and Coorong Pipi fishery. The model was proposed as an alternative to more complex bioeconomic models that enable calculation of Maximum Economic Yield. BDO EconSearch has been commissioned annually by PIRSA to update the model and analysis to assist in the implementation of the harvest strategy for the Lakes and Coorong Pipi fishery.

The reference points and decision rules have been developed to guide the TACC setting process to ensure the Pipi resource is harvested within ecologically sustainable limits and also to maximise economic returns from the fishery within those limits.

Lakes and Coorong Fishery (PIRSA 2016) – As described above the Pipi Fishery does use economic references points in the implementation of the harvest strategy. Although it does not target MEY it is the only State based fishery in Australia to use economic objectives in setting a TACC.

For the finfish section of the fishery there is one economic objective stated in the harvest strategy. This is to improve economic efficiency and financial returns to commercial fishery. However, there are no trigger points or decision rules relating to the economic objective.

Marine Scalefish Fishery (PIRSA 2013a)

Southern Garfish harvest strategy – There is one economic objective, which is to improve economic efficiency and financial returns to the commercial fishery. This objective and managing this fishery to achieve MEY has been identified as a medium to long-term goal. Developing meaningful MEY performance indicators will require additional resources in order to integrate the current biological and economic information for the fishery. In order to improve the suite of performance indicators currently available, future Marine Scalefish Fishery Economic Indicators Reports will aim to report on indicators specifically associated with the haul net fishery component of the MSF. These indicators include:

- Gross Operating Surplus (GOS)
- Profit at full equity
- Rate of return on total boat capital

In addition, price per kilogram provides a simple yet effective indicator of economic performance.

Snapper and King George Whiting Harvest Strategies **-** The objective of improving economic efficiency and financial returns to the commercial sector needs to be achieved within the bounds of sustainability imperatives and the existing management framework. Like the Garfish Fishery performance indicators will include GOS, profit at full-equity and rate of return on total boat capital.

Southern Calamari and Vongole Harvest Strategies **-** The objective of improving economic efficiency and financial returns to the commercial sector needs to be achieved within the bounds of sustainability imperatives and the existing management framework. No specific indicators apply to measure the economic performance of the Southern Calamari and Vongole fisheries.

Northern Zone Rock Lobster Fishery (PIRSA 2020b) - The harvest strategy objectives relate to optimum utilisation of the stocks but no specific reference is made to economic objectives. The key indicator for the TACC setting decision rules is CPUE. The influence of various external factors (exchange rate, product price, fuel price, etc.) on fishery performance is recognised in the harvest strategy and industry is given an opportunity to provide evidence to support the impacts of these external factors on performance indicators each year in the TACC decision making process.

Southern Zone Rock Lobster Fishery (PIRSA 2020a) – As above for the Northern Zone Rock Lobster Fishery.

Sardines (PIRSA 2014b) - Optimise economic returns within these sustainability imperatives. However, there are no trigger points or decision rules relating to the economic objective.

Spencer Gulf & West Coast Prawn Fisheries (PIRSA 2020d, 2019b) - The Harvest Strategy includes an economic objective, which is to achieve an economically efficient fleet, without compromising sustainability objectives. The performance indicators for this objective include:

- Gross value of production (GVP)
- Return on investment (ROI)
- Gross Operating Surplus (GOS)
- Economic indicators report
- Number of full time equivalent (FTE) positons directly and indirectly employed

Gulf St Vincent Prawn Fishery (PIRSA 2017) - The Harvest Strategy includes an economic objective, which is to optimise economic performance within biologically sustainable limits. The performance indicators for this objective include:

- Gross value of production (GVP)
- Return on investment (ROI)
- Gross Operating Surplus (GOS)
- Economic indicators report

Blue Crab Fishery (PIRSA 2020c) - The Harvest Strategy includes economic objectives, which are to maintain a flow of economic benefit from the fishery to the broader community, and also maintain the stock at or above a level that will support commercial catch rates within the historical range. The performance indicators for these objectives include:

- Gross value of production (GVP)
- Total economic impact

For the remaining SA fisheries, including Abalone Fishery (PIRSA 2012a) and Charter Boat Fishery (PIRSA 2019a) there are no economic objectives in the current harvest strategies.

Victoria

Whilst there is no published overarching harvest strategy policy and guidelines the Fishery Management Plans identify policies and strategies for the ecologically sustainable development of Victoria's fisheries.

Wild Harvest Abalone Fishery (Victorian Department of Economic Development, Jobs, Resources and Transport (DEDJTR) 2015) – Whilst the fishery's management plan outlines one objective relating to enabling improvements in economic productivity there are no economic objectives in the current harvest strategy.

Eel Fishery (Victorian Department of Natural Resources and Environment (Victorian DNRE) 2002) – No qualitative or quantitative target economic reference points. The management plan does include the objective to provide for the expansion of eel production through stock enhancement and aquaculture. However, no economic data or analysis has not been identified as a strategy for this objective.

Giant Crab Fishery (Victorian Department of Primary Industries (Victorian DPI) 2003) – No qualitative or quantitative target economic reference points. The management plan does include the objective of encouraging economic efficiently.

Victorian Pipi Fishery (Victorian Fisheries Authority 2018) – The fishery's management plan indicates that the TACC will be set on the basis of available biological, economic and social information. However the plan does not provide or discuss any qualitative or quantitative target economic reference points.

Rock Lobster Fishery (Victorian DPI 2003) – No qualitative or quantitative target economic reference points. The management plan does include the objective of encouraging economic efficiently. The management plan has identified fishery weaknesses, particularly the availability of little economic research upon which management can draw. Consequently, the management plan seeks to obtain information on the social and economic consequences of trends in the fishery and aims to develop robust performance indicators and reference points related to management objectives. This task has been given a high priority with regards to future research and monitoring needs of the fishery.

Sea urchin Fishery (Victorian Department of Environment and Primary Industries (DEPI) 2014) - No qualitative or quantitative target economic reference points. The Fishery has been operating as a 'developing fishery' since 1998, prior to this it ran under various exploratory fishing under permits. The management arrangements aim for economic efficiency by adopting flexible, tradeable and divisible entitlements which support adjustments in effort over time in response to changes in market and other operating conditions.

Tasmania

In Tasmania, a number of bioeconomic models have been developed for the Rock Lobster Fishery (Gardner et al. 2015, Green et al. 2012, Hamon et al. 2014, McGarvey et al. 2014).

Abalone Fishery (Tasmanian Department of Primary Industries, Parks, Water & Environment (DPIPWE) 2018) - Each year the abalone TAC, must be set for the next quota year (by calendar year), an abalone fishery operational information paper published by DPIPWE provides details on fishing zones, allowable catch, size limits. No qualitative or quantitative target economic reference points are named.

Commercial dive fishery (Tasmanian Department of Primary Industries, Water & Environment (DPIWE) 2005) – The fishery's aims to optimise the yield from the resource by requiring or encouraging appropriate fishing practices. Relevant to economic data and analysis, is the strategy to identify the most appropriate TACs and size limits, which will benefit both the industry and the environment. However, no specific qualitative or quantitative target reference points are acknowledged.

Giant Crab Fishery (DPIPWE 2013) - Each year the giant crab TAC must be set for the next quota year. There is no specific qualitative or quantitative target reference points are acknowledged in the fishery rules.

Rock Lobster Fishery (DPIPWE (draft) 2016a) - There is no specific qualitative or quantitative target reference points are acknowledged in the draft fishery rules.

Scalefish Fishery (Institute for Marine and Antarctic Studies (IMAS) 2015) – The fishery's rules (the management plan) provides the regulatory framework, covering commercial and recreational components. However, the objectives, strategies and performance indicators, relating to the fishery are to be contained in a policy document currently in preparation. Relating to economics of the fishery's management is the major objectives to optimise yield and/or value per recruit and to mitigate any adverse interactions from competition between different fishing methods or sectors.

Although no specific qualitative or quantitative target reference points are acknowledged, the fishery assessment does specify a primary strategy to monitor the performance of the fishery over time, inclusive of biological reference points for key scalefish species.

Scallop Fishery (DPIPWE 2016b) – The fishery remains closed following the Scallop Fishery Advisory Committee's consideration of surveys commenced on April 2016. There is no specific qualitative or quantitative target reference points are acknowledged in the fishery rules.

Shellfish Fishery (Tasmanian Department of Primary Industries & Water (DPIW) 2007) and (DPIPWE 2017) – The fishery's aims to optimise the yield from the resource by requiring or encouraging appropriate fishing practices. Relevant to economic data and analysis, is the strategy to identify the most appropriate TACs and size limits, which will benefit both the industry and the environment. Additionally, the policy document includes the objective to mitigate conflict resulting from competition between different fishing methods for access to shared fish stocks/fishing grounds.

Under the proposed harvest strategy (IMAS recommendations), the framework of the Commonwealth Harvest Strategy would adopted and use empirical evidence (previous catch levels and TACC) from the fishery so as to provide a baseline harvest strategy, which is useful now and whose values can be modified in future assessments. MEY is identified as the point at which sustainable catch or effort level across the whole fishery maximises profits. Guidelines around how BMEY might be estimated are provided, i.e. BMEY = 1.2*BMSY.

New South Wales

In NSW, a bioeconomic model of the State's Prawn Fisheries has been developed (Ives et al. 2013). Despite the majority of the NSW fisheries management plans promoting economic objectives, none include target reference points for MEY. A harvest strategy policy has been drafted (NSW DPI 2020) and harvest strategies are currently being developed for the Rock Lobster, Trawl Whiting and Spanner Crab fisheries. The draft policy (p. 11) refers to target reference points which define the value of an indicator for a fish stock or management unit that are desirable or ideal and at which fisheries management should aim. These may refer to "the required target biomass to produce maximum sustainable yield (MSY) from each fishery, or in certain fishery circumstances, maximum economic yield (MEY), as may be required to suit the individual circumstances of the fishery". In cases where MSY or MEY are not currently estimated, or are not reliably estimated, a suitable proxy may be used where required.

Abalone Fishery (NSW Total Allowable Fishing Committee (TAFC) 2018) – no formal (or informal) economic objective for the fishery, nor an economically based target level of biomass and catch. No qualitative or quantitative target reference points for MEY. The TACC is set each year by the statutory and independent TAFC. Part of TAFC's process involves economic considerations for the fishery. This includes the analysis of economic indicators of gross revenue, export prices and catch per unit effort. Additionally, the financial performance of the fishery, based on a 2011/12 survey conducted by BDO EconSearch is considered; however, this is to a limited extent due concerns relating to the age of the surveyed data.

Ocean Trap and Line Fishery (NSW Department of Primary Industries (NSW DPI) 2006) – No qualitative or quantitative target reference points for MEY. However, the management plan includes the objective to consider economic and social factors affecting the fishery, and the effects of management changes on fishing businesses and communities. In line with this, DPI has identified economic research as a priority for the fishery. Particularly there is need to assess the economic viability of businesses within the fishery, and to quantify the flow-on effects from fishing activities to regional communities.

Ocean Hauling Fishery (NSW Fisheries 2003a) – No qualitative or quantitative target reference points for MEY. However, the management plan includes the objectives to promote the long-term economic viability of ocean hauling and to improve knowledge of social and economic aspects of the fishery. Accordingly, the development of a performance measure for economic viability at both individual fishing business and fishery wide level and accessing the feasibility of gathering additional information on social and/or economic aspects of the fishery are priorities.

Ocean Trawl Fishery (NSW DPI 2007) – No qualitative or quantitative target reference points for MEY. However, the management plan includes the objective to manage harvesting to achieve the best outcome in terms of optimising biological yield and maximising economic return. Additional objectives are to consider economic and social factors affecting the fishery, and the effects of management changes on fishing businesses and communities.

In line with this, DPI has identified economic research as a priority for the fishery. Particularly there is need to assess the economic viability of businesses within the fishery, and to quantify the flow-on effects from fishing activities to regional communities.

Lobster Fishery (TACSRC 2016b) – No formally derived target reference points for MEY. An implicit target reverence point of 0.5 of the unfinished biomass has been used by the committee for reporting stock status.

The committee believes that the setting of the TACC for MEY remains unanswered whilst information regarding economic data and industry operations are limited. DIP has started discussions with industry regarding the collection of economic analysis of the fishery. The committee is of view that calculation of net return would be the best start for economic analysis of the fishery, and that deployment of a bioeconomic model of the fishery would provide substantial benefits.

General Fishery (NSW Fisheries 2003b) & Estuary Prawn Fishery (NSW Fisheries 2003c) – These fisheries management strategies were developed together, and include no qualitative or quantitative target reference points for MEY. However, an economic survey was carried out in 2001. The results showed that only 20% of the Estuary General Fishery are making an economic surplus, and 10% of the Estuary Prawn Fishery had a long run economic surplus.

The management plan for both fisheries includes the objectives to promote the long term economic viability of fishing within the fishery and to improve knowledge of social and economic aspects of the fishery. Accordingly, the development of a performance measure for economic viability at both individual fishing business level and accessing the feasibility of gathering additional information on social and/or economic aspects of the fishery are priorities.

Queensland

In Queensland, bioeconomic models of the Eastern King Prawn Fishery (Courtney et al. 2014 and O'Neill et al. 2014) and Moreton Bay Prawn Fishery (Wang et al.2014) have been developed. Since 2019, Fisheries Queensland has been working with stakeholders to develop draft harvest strategies for most of Queensland's fisheries. Harvest strategies for the reef line and spanner crab have been approved and drafts are currently available for many of the state's other fisheries.

The majority of the fisheries' harvest strategies were developed together, all with the same primary objective. These fisheries are Blue Swimmer Crab Fishery (Queensland Department of Agriculture and Fisheries (Queensland DAF) (draft) 2020a), Mud Crab Fishery (Queensland DAF (draft) 2020b), Spanner Crab Fishery (Queensland DAF 2020c), East Coast Inshore Fishery (Queensland DAF (draft) 2020d), Marine Aquarium Fish Fishery (Queensland DAF (draft) 2020e), Queensland Coral Fishery (Queensland DAF (draft) 2020f), Sea Cucumber Fishery (Queensland DAF (draft) 2020g), Fin Fish Trawl (stout whiting) Fishery (Queensland DAF (draft) 2020h), Southern, Moreton Bay, Central and Northern Trawl Fishery (Queensland DAF (draft) 2020i), Lobster Fishery (Queensland DAF (draft) 2020j) and Reef Line Fishery (Queensland DAF (draft) 2020k).

The main objective of these fisheries is to maintain the target species resource at, or returned to, a target exploitable biomass level that achieves MEY for the fishery. A target reference point of 60 per cent of the exploitable biomass (for key target species) being the relative biomass level the harvest strategy aims to achieve. This is also considered a proxy measure of the biomass at MEY for the purposes of the harvest strategy. This is to be achieved while maximising profitability for the commercial sector and monitoring the social and economic benefits of the fisheries to the community. Performance indicators include:

- Capacity utilization
- CPUE (average per day)
- Costs, earnings and net financial and economic profit
- Quota sale and lease price
- Profit decomposition (using profit or lease price) income generated (crew plus profit—gross value added)
- Fisher satisfaction (with their fishing experience – commercial and recreational)
- Percent of quota/licences that are owned (rather than leased)
- Percent of total costs/inputs purchased from local businesses/residents
- Income generated (crew plus profit – gross value added)
- Proportion of catch sold locally
- Fish prices
- Number of platforms/number of active licenses/total capacity
- Target species prices

Northern Territory

All Fisheries – No qualitative or quantitative target reference points for MEY found in the fisheries' various Environmental Management System (EMS) documents. Notwithstanding specific indicators, the EMS vision does include the objective of ensuring economic viability.

Other Literature

Roadblock to the adoption of economics in fisheries policy (Emery et al. 2015)

The paper identifies challenges and opportunities associated with implementing bioeconomic approaches and stock enhancement within fisheries management frameworks. The opportunities and challenges identified has led to the development of three journal articles, summarised below.

Article one – Emery et al. (2017) Incorporating economics into fisheries management frameworks

The paper discusses closing the gap between current and optimal economic performance of Australian wild catch fisheries. Arguably, the sole use of economic instruments, such as ITQs are insufficient in accomplishing this goal. One issue highlighted was the initial deployment of ITQ solely to achieve ecological targets.

The paper suggests bioeconomic model uptake to facilitate the task of optimising economic performance. This follows the view that although economic objectives are generally prevalent within Australian fishery legislation, there is a lack of routine economic data collection and analysis which is inconstantly applied across jurisdictions.

The article highlights challenges of bioeconomic model implementation, specifically categorised as the following:

- short terms transition cost and trade-offs between stakeholder objectives,

- logistical and financial capacity to collect and analyse economic data,
- lack of desire among industry to transition to economic targets, and
- level of economic illiteracy among fisheries managers and industry.

A case study analysis presents how bioeconomic models have been deployed and the following outcomes. The case studies focused on three large scale fisheries[1] and two small scale fisheries[2].

The continued adoption of bioeconomic models and other economic analysis can result in improved fishery management. There is potential to foster greater understanding of the associated trade-offs within fishery management (e.g. economic, ecological and social goals) and to encourage greater economic literacy of managers and education for industry. Analysis can also assist development of measurable targets and reference points, and may encourage further innovation for data collection and use proxy values.

Article two – Emery et al. (2015) The role of government in pursuit of economic objective in fisheries management

Although ITQs are increasingly being adopted to rebuild stocks and improve economic efficiency the paper argues that an economic optimal outcome may not be possible with sole use of ITQs. These limitations are evident in the form of residual externalities, occurring when the costs of a fisher's behaviour is not fully borne by the individual.

Given the ITQs are a right to access a shared resource, as opposed to full property rights, there is no assurance that fishers will refrain from actions that reduce the profitability of other ITQ holders. Although ITQs may promote economic rationality at the individual level, such may not be the case for the whole. For example competition may encourage fishers to overexploit productive fishing grounds or fish areas at sub optimal times (i.e. in order to be the first to access the resource). Additionally ITQs do not provide incentive to share information such as location of productive fishing grounds.

The paper highlights the potential of self-governing fishing cooperatives to resolve these issues through collective action. Specifically, cooperatives may serve to reduce economic rent dissipation by coordinating fishing effort and harvest times to maximise profit. Examples of cooperation include rotation of fishing grounds and the pooling and sharing of income, which has been utilised by fisheries in Japan and Turkey.

Specific attributes were identified in cooperative fisheries, which may server as requirements for encouraging self-governance. These were the following:

- homogeneity among fishers (likelier in small fisheries),
- sedentary target species, and
- geographical isolation, with high transaction cost to commercialisation.

Where these key requirements are absent, the paper recommends swift action by government in making appropriate management framework and decisions. This involves the implementation of meaningful economic objectives relative to other objectives, and may require the implementation of management changes in lack of fishers' consensus.

Article three - (Hart 2015) Commercial scale invertebrate fisheries enhancement in Australia: experiences, challenges and opportunities

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[1] The Tasmanian Southern Rock Lobster, Western Australian Rock Lobster, and Commonwealth Northern Prawn Fisheries.

[2] The Lakes and Coorong Pipi and Western Australian Shark Bay Prawn Trawl Fisheries.

The paper discusses the use of stock enhancement or assisted recruitment and how it may interact with fisheries management. If successful[3] there is potential to provide management substantial control over the recruitment side of the fisheries equation, rather than just production.

Generally, the track record for marine enhancement has been broadly unsuccessful, as there remains a legacy for a quick fix. However since stock enhancement is a multi-disciplinary task, it will encourage greater diversity in understanding fisheries management.

One such complexity is the interaction between a given stock's self-correcting mechanism and assisted recruitment. Using the North Sea Cod (*Gadus morhua*) model, the paper concludes that enhancement will always result in increased biomass at low spawning stock, but might not necessarily provide for a comparable increase at high spawning stock. Accordingly, there is emphasis on the need to predict environmental conditions and accept stochastic elements of recruitment. This results in what can be consider a calculated gamble approach to recruitment enhancement.

Although no major advance towards commercialising stock enhancement has resulted to date, the analysis does outline a couple promising developments.

- Tasmanian Southern Rock Lobster: Translocation of species from low to high growth areas resulted in an additional catch of 50 tonne per annum.
- Western Australian Greenlip Abalone: Significant attempt to commercialise in 2011/12, although this was ultimately unsuccessful, it lead to Australia's first commercial scale sea ranching lease for *Haliotis laevigata.*

There are challenges for enhanced recruitment however. The first issue relates to economic inequality of natural requirement and stock enhancement. Specifically there is a lack of market-based mechanisms to separate out the value of enhancement from wild catch fisheries. The second issue relates to self-replenishing natural populations, specifically from an evolutionary viewpoint. There is importance to maintain sufficient genetic variability in the wild stock, in order to preserve potential for adaptive evolution in the species (and hence the sustainability of the wild catch fishery)

Technical reviews for the Commonwealth Fisheries Harvest Strategy Policy 2007: technical overview (Penney et al. 2013)

At the time of publication, MEY targets had been estimated for the Northern Prawn and Great Australia Bight Fisheries. For all other Commonwealth fisheries, a proxy reference target (1.2BMSY or 0.48B0) was used. The report stated that the main complication with estimating MEY for other species had been the difficulty in getting the necessary representative cost data to enable bioeconomic modelling. It was recommended that better guidance is required on economic objectives and how they can be best achieved for different fisheries, such as highly variable fisheries and those where market process can be controlled by adjusting catch volumes.

A more practical approach is required to using existing economic data and incorporating economic parameters into current stock assessments to estimate MEY, as opposed to developing separate bioeconomic assessments. There should be further exploration of alternative indicators and reference points for MEY, including those based on optimal fishing capacity and catch rates, and more appropriate proxies for different fisheries and gear types.

[3] i.e. the implementation of stock enhancement is still within the research and development phase for many fisheries.

Technical reviews for the Commonwealth Harvest Strategy Policy: economic issues (Vieira & Pascoe 2013)

Fishery-wide targets have only been quantitatively estimated for two fisheries. Most Commonwealth fisheries apply the proxy target values defined in the policy. Rebuilding the seven overfished stocks that were depleted prior to the policy's development has also been problematic.

This paper was a collaboration between ABARES and CSIRO. Issues relating to the implementation of economics within the Commonwealth Harvest Strategy Policy are detailed, including challenges to estimation and operationalising MEY in the context of issues such as data-poor fisheries, multi-species fisheries, variable stocks, market power and internationally managed fisheries. The nature of the more common issues are elaborated upon below.

- Data-poor species – the harvest strategy policy was developed with a focus on biomass reference points which makes the application of the policy to data-poor fisheries difficult. Because data-poor fisheries are often of low value, careful consideration needs to be given to the relative costs and benefits of reducing management uncertainty through any application of the policy.
- Multi-species fisheries – the harvest strategy policy recognises that in multi-species fisheries MEY should be applied to the fishery as a whole and not necessarily to individual species. However, while this can be done well where data and resources are available (e.g. Northern Prawn Fishery), it can be difficult in situations where there are a large number of species and limited biological information.
- Variable stocks – the optimal harvest strategy for short-lived (generally annual) species is to fish down the stock available until it is unprofitable, provided recruitment and sustainability are not affected. It rarely happens that fishing stops when it is optimal to do so and the high profits at the beginning of the season will attract excess capital into the fishery. Assessing the level of excess capacity to improve MEY management is an option but generally complicated to do.

The report concluded that due to the large amount of data required, both biological and economic, to calculate MEY that proxies have often been used instead (e.g. a target biomass that is a fixed percentage above the biomass associated with maximum sustainable yield (B_{MSY})). Further research is underway to look at proxy measures for MEY in multi-species fisheries when there is not enough information for bioeconomic models. The aim of this project was to develop rules of thumb that will allow better estimates of MEY to be made in the absence of complete data.

International Literature

"Bioeconomic models have been developed in most countries around the world for a wide range of fisheries and to assess a wide range of issues… Rarely, however, have these models been used to provide tactical management advice such as target effort or catch levels" (Pascoe et al. 2016).

A report previously cited in this report and titled *Experiences with the use of bioeconomic models in the management of Australian and New Zealand fisheries* (Pascoe et al. 2016) examines the use of bioeconomic models in Australian and New Zealand fisheries. The report describes only a few published bioeconomic models developed for New Zealand fisheries. These include the bioeconomic analyses of management strategies for:

- Rock Lobster (Breen et al. 2000 and Holland et al. 2005)
- Orange Roughy (Armstrong and Kahui 2012 and Hilbornet al. 2006)
- Scallops (Bisack and Sutinen 2006)
- Abalone (Kahui and Alexander 2008)
- Hoki (Marchal et al. 2009)

- Sea Lion bycatch (Kahui 2012).

Two more bioeconomic models were developed for the evaluation of fisheries self-governance for the Bluff Oyster fishery (Yanget al. 2010) and multi-species finfish fisheries (Sinclair 2014).

Despite the development of these models in recent years there has been no use of the models in the setting of TACs of New Zealand fisheries. The report does note that economic information and objectives are considered in the decision making process but there is a major focus on maximum sustainable yield (MSY).

This report also outlines viability analysis as an alternative approach that is gaining increasing attention in Australia and NZ (Péreau et al. 2012). These models assess the probability that a given harvest strategy can consistently achieve at least minimum levels of each objective over time. Viability analysis models have been developed for the NPF and some NZ fisheries.

A report titled *A Review of EU Bio-economic Models for Fisheries: the Value of a Diversity of Models* (Prellezo et al. 2012) examines how effective thirteen existing European bioeconomic models are in the evaluation of EU policies. The bioeconomic models, listed below, differ in terms of policy objectives, simulation/optimisation models, input/output controls, short-term/long-term behaviour, single targeted species fisheries/multi-specie fisheries, region and etc.

Notwithstanding differences between the bioeconomic models, the analysis discusses three component considered common to the economic side of the models; these being (i) price dynamics, (ii) fleet and effort dynamics, and (iii) cost dynamics. The orientation of the models, such as simulation vs optimisation, or long vs short term focus will determine how these components are structured. For example, optimised models are generally based on fixed prices and optimise fishing effort to maximise profits. Conversely, simulation models typically incorporate price changes and effort dynamics through specific functions such as elasticity assumptions. This follows the 'what if' and 'what's best' approach of simulation and optimisation models respectively.

Similarly, long and short time frames can be modelled by making distinction between tactical (e.g. days fished, gear usage) and strategic (e.g. capital investment) elements of fleet and effort dynamics. Regarding costs dynamics, all of the models reviewed utilised linear relationships, however to varying levels of detail.

The following list the thirteen bioeconomic models discussed in the analysis.

- The Dynamic Capacity Change Model
- Methodological Support for a Bioeconomic Model of Population Analysis of Demersal Resources
- Bioeconomic Modelling of Mediterranean Fisheries
- A Dynamic bioeconomic model of the fisheries of the South West to determine the costs and benefits of sustainable fisheries management
- Economic effects of the cod recovery plan on the mixed fisheries in the North Sea
- Bioeconomic multispecies model of the Barnet Sea fisheries
- Economic Interpretation of ACFM[4] advice
- Economic Management Model of Fisheries in Denmark

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[4] The Advisory Committee on Fishery Management (ACFM) operates in the International Council for the Exploration of the Sea (ICES) framework and provides the advice and information on fisheries, living resources and their exploitation and the interaction between fisheries and the ecosystem as requested by North Atlantic Fisheries Commission (NEAFC), International Baltic Sea Fishery Commission (IBSFC), NASCO, European Commission and Member Countries of ICES.

- Fisheries Library in R
- Mediterranean Fisheries Simulation Tool
- Models for Optimal Sustainable Effort in the Seas
- Swedish Resource Rent Model for Commercial Fishery
- A fleet-based bioeconomic simulation soft-ware for management strategies accounting for fishers behaviour

The analysis showed the models were able to handle the specific tasks for which they were originally created, for example, to address specific management scenarios. However, the majority of the models were developed as part of research projects and not directly to be used within a fishery management framework, i.e. the analyses are retrospective, exploring the efficacy of already imposed management frameworks, as opposed to directing future management action. As such, the models cannot be easily updated with new information. The models also require significant knowledge of the programming language which, depending on the language and associated documentation, can be a limitation. These factors together have made it difficult to apply the models within fishery management policy.

The structures of bioeconomic models generally reflect the main features of the fisheries under analysis which implies limited transferability between fisheries. As Prellezo et al. (2012) point out, fisheries in the EU are very heterogeneous. Single species and multi-species (mixed) fisheries, pelagic and demersal fisheries, single gear and multi-gear fisheries need different modelling approaches. Moreover, different management regimes are in force in different areas and for different fisheries. The modelling approaches used to simulate the effects of output control measures, such as Total Allowable Catch (TAC), diverge substantially from those used to simulate input control measures (e.g. fishing effort limitations) or technical measures (e.g. mesh size restrictions, or area and season closures) (Prellezo et al. 2012, p. 4).

A trade-off between model simplicity and usefulness emerges when integrated models are used. Conversely, the Economic Interpretation of ACFM advice (EIAA) model was identified as a potential exception to the complexity involved in altering bioeconomic models. As a Microsoft Excel based model it should provide practicality for development and as a modelling tool for other fisheries. Additionally the EIAA model is relatively flexible with biological inputs, requiring input from an external assessment. The EIAA model was specifically developed to calculate the economic effects of different TACs within the European fishing fleet, and which can therefore be used relatively quickly, compared to the other models, if a specific question needs to be addressed (Prellezo et al. 2012, p. 18).

5. Different Approaches to Incorporating Economic Information in Harvest Strategies and Decision Making Processes

Economic Indicators within a Harvest Strategy

The development of harvest strategies has led to the creation or adoption of formal economic indicators which has been a positive step in management of fisheries. However, the process of developing economic indicators is much newer and less developed than for biological indicators.

Many of the fisheries use multiple indicators of economic performance and these are often highly correlated. If they were biological indicators they would be pragmatically narrowed down and the most relevant used to drive decisions. For example, either CPUE or model estimated biomass as an index of stock size would be chosen, but not both. Likewise, in the case of economic indicators it would be good to eliminate weaker performance indicators and focus in on those that are most important and directly relevant to the objective of management plans and ultimately the legislation.

Generally, there seems to be a need for deeper consideration of legislative objectives in selecting economic indicators for harvest strategies. This is evident in the long list of indicators for most South Australian fisheries and in the fact that so many reference points are countervailing (e.g. employment and economic rent). This reduces the ability of the harvest strategy to target objectives.

The choice of some indicators also seem strange given that the decision has already been made to manage the fishery with ITQs and TACCs. For example, it is hard to understand the use of GVP or employment as economic indicators when there has been a decision to reduce both GVP and employment with ITQs and TACCs.

Most fisheries list “optimal utilisation” as a goal of management yet it is hard to see the logical link between this goal and the strategy or performance indicators of the harvest strategy, other than through allowing the operators flexibility to trade ITQ units (which is thought to increase technical efficiency). Fisheries economics more typically involve strategies of targeting optimal sustainable economic yield through the setting of the TACC and other regulations (size, season) and this implies the use of an economic yield or proxies as indicators.

In some of the fisheries, for example the Spencer Gulf Prawn Fishery (SGPF), economic indicators are listed but they are “work plan” objectives, not management objectives.

To explain, if the economic objective were “to maximise gross state product” then “gross state product (GSP)” would be the logical performance indicator and the harvest strategy could set a limit reference point for GSP of say $20 million. So if GSP fell below $20 million a review would be triggered and management would decide if something could be done to restore the contribution of the fishery to state production.

Instead of this approach, the SGPF has limit reference points of simply monitoring the GSP. So if GSP is measured and reported, the economic performance is considered acceptable. This does not seem to be a good structure for the harvest strategy because it does not drive the fishery towards the relevant objectives defined in legislation, which are:

> (b) access to the aquatic resources of the State is to be allocated between users of the resources in a manner that achieves optimum utilisation and equitable distribution of those resources to the benefit of the community; and

(d) recreational fishing and commercial fishing activities are to be fostered for the benefit of the whole community.

These objects of the Act emphasise benefit to the community, which is most directly measured with GSP. Economic rent (ER) is also relevant, especially where some of this is returned to the whole community with royalties. Measuring performance with GSP or ER is a simpler approach than the long list of performance indicators used in most fisheries especially where the selected performance indicators are countervailing or unclear.

Using South Australian examples this Chapter will present different types of economic information that are relevant to fisheries management decision making, different approaches to incorporating economic information in harvest strategies and decision making processes, and the strengths and weaknesses of the relevant indicators and approaches.

There is a need to identify and explore cost-effective and efficient ways to incorporate economic information in harvest strategies and decision making processes, particularly those that aim to achieve MEY. Regardless of the complexity or otherwise of the bioeconomic models, there is a clear gap in the collection and publication of baseline economic data that support the MEY-based approaches and associated target reference points that are increasingly being incorporated in fisheries management plans and harvest strategies.

This section discusses potential economic indicators that could be considered for these purposes. They are grouped into:

- financial indicators
- economic indicators
- other indicators.

The discussion is based on a review[5] of the economic indicator work of ABARES for major AFMA managed fisheries[6], work done by EconSearch for PIRSA managed fisheries[7] and for the Pacific Islands Forum Fisheries Agency as part of the development and implementation of economic indicators for the Pacific Island Nations' tuna fisheries.

Financial Indicators

Financial indicators are indicators that have a direct bearing on the financial performance of vessels in the fishery.

Some of the financial indicators are used as input into bioeconomic or other models used to estimate MEY; and input into some of the economic indicators.

Primarily, the financial indicators will be those that are relevant to operators of fishing vessels. For these commercial businesses their principal objective will generally be to maximise returns to their investments. For this reason the costs and returns to the business are of primary importance. In many fisheries the fishing concession or access right to the fishery is in the form of a tradeable right that has a commercial value.

The three main financial indicators considered here are:

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5 Drawn from EconSearch (2015).
6 See for example, Skirtun, Stephan & Mazur (2014).
7 See for example, EconSearch 2017, *Economic Indicators for the SA Abalone Fishery, 2015/16*, prepared for Primary Industries and Resources South Australia.

- product prices and income
- operating costs
- vessel profitability.

It should be noted that in preparing their respective economic indicator reports ABARES and EconSearch take a slightly different approach to the scope of income and costs included within their financial indicators. ABARES includes all income, costs and capital associated with the fishing business, including in cases where fishing businesses have operated in a number of fisheries. EconSearch only considers income from the fishery under consideration, related costs and the share of capital employed in that fishery. Both approaches are valid, with the ABARES approach being more appropriate in fisheries where there is significant employment of capital in other fisheries (e.g. the Northern Prawn Fishery, where most businesses operate in other state-based prawn or trawl fisheries). The EconSearch approach is more appropriate where most fishing businesses operate discretely within individual fisheries and where a comparison of financial performance across fisheries is desired. The main consideration is to keep to one method, otherwise boat profitability will be under or over-estimated.

Product prices and income

Product price is an obvious indicator and an important determinant in calculating a number of other potential economic indicators (e.g. total value of catch, value of exports, vessel profitability and economic rent).

If a significant proportion of the catch from the fishery is exported, the value of the Australian dollar relative to the trading currency can have a considerable impact on the economic performance of the fishery, and exchange rate data are useful to collect as well.

The ABARES financial indicator for income is **Total Cash Receipts**. Total cash receipts represent returns from the sale of fish, from non-fishing activities, including charter operations, and from other sources (insurance claims and compensation, quota and/or endorsements leased out, government assistance and any other revenue) in the financial year (Skirtun 2014). For consistency, marketing charges may need to be added back into fishing receipts for some boats to give a gross value. Where this is necessary, these selling costs are also added into the cost estimates to offset the new revenue figure. Receipts also include amounts received in the survey year for fish sold in previous years (Skirtun 2014).

The EconSearch financial indicator for income is **Total Boat Income.** Total boat income refers to the cash receipts for fishing received by an individual firm and is expressed in dollar terms. Total boat income is generally calculated as catch (kg) multiplied by 'beach price' ($/kg). In the case of the charter boat sector, total boat income is calculated as number of clients multiplied by average price ($/person). Total boat income is the contribution of an individual licence holder to the GVP of a fishing sector or fishery.

Beach price refers to the price received by commercial fishers at the 'port level' for their catch, and is generally expressed in terms of $/kg. Processing costs are not included in the beach price, as processing operations are assumed to occur further along the value chain. The use of beach prices also removes the effect of transfer pricing by the firm if it is vertically integrated into the value chain.

Vessel operating costs

Detailed vessel operating costs (fuel, labour, repairs and maintenance, provisions, etc.) are useful indicators in their own right but are also important in calculating other indicators such as vessel profitability, fishery resource rents and contribution of the fishery to the regional/state/national economy.

Some costs, or at least indicators of the main costs, can be collated from readily available sources and used as proxies for actual vessel operating costs. While such proxies may be useful for indicating trends in the main fishing costs, the only way to collect a comprehensive set of fishing costs is through a survey of concession holders.

ABARES estimates **Total Cash Costs.** Total cash costs include payments made for both permanent and casual hired labour and payments for materials and services (including payments on capital items subject to leasing, rent, interest, licence fees and repairs and maintenance). Capital and household expenditures are excluded (Skirtun 2014).

Labour costs are often the highest cash cost in the fishing operation. Labour costs include wages and an estimated value for owner/partner, family and unpaid labour. Labour costs cover the cost of labour involved in boat-related aspects of the fishing business, such as crew or onshore administration costs, but do not cover the cost of onshore labour involved in processing fisheries products. On many boats, the costs of labour are reflected in the wages paid by boat owners and/or in the share of the catch they earn. However, in some cases, such as where owner–skippers are involved, or where family members work in the fishing operation, the payments made can be low or even nil, which will not always reflect the market value (opportunity cost) of the labour provided. To allow for this possible underestimation, all owner/partner and family labour costs are based on estimates collected at the interview of what it would cost to employ someone else to do the work (Skirtun 2014).

EconSearch's approach in terms of cost items under consideration is the same, however the costs are split into variable and fixed costs.

Total Boat Variable Costs: are costs which are dependent upon the level of catch or, more commonly, the amount of time spent fishing. As catch or fishing time increases, variable costs also increase. Variable costs are measured in current dollar terms and include the following individual cost items:

- fuel, oil and grease for the boat (net of diesel fuel rebate)
- bait
- ice
- provisions
- crew payments
- fishing equipment, purchase and repairs (nets, pots, lines, etc.)
- repairs & maintenance: ongoing (slipping, painting, overhaul motor).[8]

Total Boat Fixed Costs: are costs that remain fixed regardless of the level of catch or the amount of time spent fishing. As such these costs, measured in current dollar terms, are likely to remain relatively constant from one year to the next. Examples of fixed cost include:

- insurance
- licence and industry fees
- office & business administration (communication, stationery, accountancy fees)
- interest on loan repayments and overdraft
- leasing.

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[8] Some components of repairs and maintenance may be better classified as fixed costs (e.g. regulated maintenance). If operating costs are separated into fixed and variable categories then it is desirable to separate repairs and maintenance similarly, where possible.

Total Boat Cash Costs (TBCC): defined as *Total Boat Variable Costs* plus *Total Boat Fixed Costs*.

Likewise, the EconSearch approach estimates a value for **Owner-operator and Unpaid Family Labour.** This imputed labour cost can be included simply as another cost so that Gross Operating Surplus takes account of this cost. Alternatively, it can be deducted from GOS to give a separate indicator called Boat Cash Income (Section 3.1.3 provides a description of GOS and BCI). Owner-operator and unpaid family labour is separated into variable labour (fishing and repairs and maintenance) and overhead labour (management and administration).

Vessel profitability

As with any business, there are a number of ways to measure fishing boat profitability, which are discussed below. As is the case with vessel operating costs, the measures of vessel profitability can only be effectively collected via a survey of concession holders.

In addition to operating costs, information is required on depreciation of all capital items and any labour costs that are not part of normal operating costs (such as the boat owner and family members who are not paid a regular wage).

These indicators are on a per vessel basis. The data set would allow ready calculation of profitability in terms of other units, e.g. gross margin/tonne, EBIT[9]/tonne.

EconSearch uses the following profitability indicators:

Boat Gross Margin: is defined as Total Boat Income less Total Boat Variable Costs. This is a basic measure of profit which assumes that capital has no alternative use and that as fishing activity (days fished) varies there is no change in capital or fixed costs.

Gross Operating Surplus: (GOS) is defined as *Total Boat Income* less *Total Boat Cash Costs* and is expressed in current dollar terms. GOS may be used interchangeably with the term *Gross Boat Profit*. A GOS value of zero represents a breakeven position for the business, where TBCC equals TBCR. If GOS is a negative value the firm is operating at a cash loss and if positive the firm is making a cash profit. GOS does not include a value for owner/operator wages, unpaid family work, or depreciation.

Boat Cash Income: is defined as *Gross Operating Surplus* less *imputed wages for owner- operator and unpaid family labour*.

Boat Capital: includes capital items that are required by the licence holder to earn the boat income. It includes boat hull, engine, electronics and other permanent fixtures and tender boats. Other capital items such as motor vehicles, sheds, cold-rooms, and jetty/moorings can be included to the extent that they are used in the fishing business. The fishing licence/permit value is included in **Total Boat Capital**.

Depreciation: Depreciation refers to the annual reduction in the value of boat capital due to general wear and tear or the reduction in value of an item over time.

Boat Business Profit: is defined as *GOS* less *Depreciation* less *Owner-operator and Unpaid Family Labour*. Boat Business Profit represents a more complete picture of the actual financial status of an individual firm, compared with GOS, which represents the cash in-cash out situation only.

Profit at Full Equity: is calculated as *Boat Business Profit* plus *rent, interest and lease payments*. Profit at Full Equity represents the profitability of an individual licence holder, assuming the licence holder has full

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[9] Earnings before interest and tax.

equity in the operation, i.e. there is no outstanding debt associated with the investment in boat capital. Profit at Full Equity is a useful absolute measure of the economic performance of fishing firms.

Rate of Return to Capital: is calculated as *Profit at Full Equity* divided by *Boat Capital* multiplied by *100*. This measure is expressed in percentage terms and is calculated for an individual licence holder. It can be estimated as two indicators: rate of return to boat capital (fishing gear and equipment) and rate of return to total boat capital (fishing gear, equipment, quota and licence). It refers to the economic return to the total investment in capital items, and is a useful relative measure of the performance of individual firms. Rate of return to capital is useful to compare the performance of various licence holders, and to compare the performance of other types of operators, and with other industries.

ABARES reports a subset of the above indicators, namely boat cash income, boat business profit, profit at full equity, rate of return to boat capital and rate of return to full equity (equivalent to rate of return to total boat capital).

Economic Indicators

In addition to ensuring that the exploitation of fisheries resources is conducted in a manner consistent with the principles of ecologically sustainable development, the charter for most agencies responsible for fisheries management will generally be concerned with:

- maximising economic efficiency in the exploitation of fisheries resources
- implementing efficient and cost-effective fisheries management.

These broader considerations give rise to a number of indicators additional to those referred to in Section 0. These include:

- gross value of production
- cost of management
- economic rent or net economic return (NER)
- productivity analysis
- profitability indexes
- entitlement values
- lease values.

Gross value of production

GVP is a commonly reported indicator and is used in the calculation of a number of other economic indicators.

Gross value of production (GVP): refers to the value of the total annual catch for individual fisheries, fishing sectors or the fishing industry as a whole, and is measured in dollar terms. GVP, generally reported on an annual basis, is the quantity of catch for the year multiplied by the average monthly landed beach prices. GVP is generally reported with the two components from which it is derived, namely average price and catch.

Cost of management

An objective of many jurisdictions is to achieve recovery of the costs of the agency or authority responsible for the management of the jurisdiction’s fisheries. Because the management of the resource benefits the resource users, a strong argument can be made that the users should contribute to the cost of management.

In a commercial fishery management services will generally include biological monitoring and reporting; policy, regulation and legislation development; compliance and enforcement services; licensing services; and research. Where a commercial fishery operates under full cost recovery, licence fees will be set to cover the cost of managing the fishery or at least the commercial sector's share of the resource.

In fisheries where there is full cost recovery, it can be assumed that the cost of providing these management services to the commercial sector will be equal to the gross receipts from licence fees in the fishery. With information on licence fee receipts, GVP, catch and the number of commercial fishers in the fishery, the following indicators can be readily calculated:

- aggregate licence fee receipts for the fishery ($)
- licence fee/GVP (%)
- licence fee/catch ($/kg)
- licence fee/licence holder ($/licence holder).

In fisheries where there is not full cost recovery from licence holders, then it is more appropriate to estimate both the recovered management costs (i.e. licence fees and other recovered costs) and non-recovered management costs and to present the above indicators in terms of total management costs (i.e. recovered management costs plus non-recovered management costs).

Net economic return

Net economic return (NER) is also known as economic rent. NER is defined as the difference between the price of a good produced using a natural resource and the costs of turning that natural resource into the good. In this case the natural resource is the fishery and the good produced is the landed fish.

The long term costs all need to be covered if the concession holder is to remain in the fishery. These long-term costs include direct operating costs, the opportunity cost of family and owner labour, fishery management costs, depreciation and the opportunity cost of capital. What remains after the value of these inputs (labour, capital, materials and services) has been netted out is the value of the natural resource itself, i.e. net economic return (the economic rent).

The following discussion is based on Skirtun (2014).

Economic performance, measured through the NER indicator shows the return to the community from harvesting the fishery resource. Although estimates of NER do not reveal how a fishery has performed relative to the maximum potential (i.e. maximum economic yield) in a given period, interpretation of NER trends and drivers, together with other economic indicators, can assist in assessing the fishery's performance against the objective of maximising economic efficiency in the exploitation of fisheries resources.

A fishery's net economic return for a given time period can be defined as:

$$NER = R - CC - OWNFL + ILR - OppK - DEP + recMC - totMC$$

Where:

NER = net economic returns

R = total cash receipts attributable to the fishery, excluding leasing income i.e. fish sale receipts

CC = total cash costs attributable to the fishery

OWNFL= imputed cost of owner and family labour

ILR = interest and quota/permit leasing costs

OppK = opportunity cost of capital

DEP = depreciation

recMC = recovered management costs

totMC = total management costs.

Note that recovered management costs are those management costs paid by industry through management fees and are included in total cash costs (CC). These costs are removed (as indicated by '+ recMC') to prevent double counting given that these costs are a component of total management costs. Similarly, interest and quota/permit leasing costs are removed (indicated by '+ ILR') as these costs at the fishery level represent revenues that have been redistributed to external investors in the fishery.

Fish sale receipts are usually taken from fishers' financial accounts. Where a fisher operates in more than one fishery, they are asked to indicate what proportion of total fish sales is attributable to the fishery being surveyed. Any freight or marketing costs must also be deducted. This provides an estimate of net fishing receipts that incorporates only the 'beach price' that has been received for the catch; that is, the price received for fish at its first landing point.

Incomes received from leasing out quota and licences are not included as income in calculating net economic returns. This item represents a redistribution of profits among investors in the fishery. Also, the amount a fisher earns from leasing out quota and licences relates to the amount of pro0fits the fishery is generating. Including leasing revenue would therefore result in double counting.

Operating costs include day-to-day operational expenses incurred to harvest fish in the fishery. Cash costs are a component of operating costs that includes those cost items that are easily identified in fishers' accounts, such as fuel, repairs and gear replacement.

Labour costs are often specified in fishers' accounts as wages. However, in calculating net returns, an estimate of the opportunity cost of labour is needed. The opportunity cost of labour is the wage that could have been earned performing a similar role elsewhere. Where a market wage is paid, it is assumed to represent the opportunity cost of labour and is included in the cash costs component of operating costs. The opportunity cost of owner and family labour is not easily identifiable in fishers' accounts. Often owners and their families are involved in operating a boat, either as skippers and crew or onshore as accountants and shore managers. While some will be paid market value for their labour, some will not be paid at all and others paid very high amounts, often as 'director fees' or 'manager fees'. In these cases, survey respondents are asked to estimate the market value of owner and family labour—that is, the amount that would need to be paid to employ a non-family member to fulfil the same position. This amount is entered as a component of operating costs (OWNFL). Note that EconSearch take a different approach to calculating OWNFL. Respondents are asked to estimate the hours of unpaid labour used in various categories of labour and a market-based wage rate is applied to each category.

Quota and licence leasing costs and interest expenses are included in cash costs. However, these costs must be removed from calculation of net returns for the same reason they are excluded from income.

Capital costs calculation requires an estimate of the value of capital. Fishers are asked to provide information for all capital items associated with the fishing business (including hull, engine, on-board equipment, vehicles and sheds). Information collected for each item includes the year the capital item was manufactured and an estimate of what it would cost to replace that item with a new equivalent item. By accounting for previous depreciation and inflation, these data are used to estimate the total value of capital invested in the fishery for the survey year.

Capital costs include the opportunity cost of capital (OppK) and depreciation (DEP). The opportunity cost of capital is the return that could have been earned if capital was invested elsewhere, rather than in the fishery. This cost is not identifiable in fishers' accounts. A real interest rate that represents the long-term average rate of return that could be earned on an investment elsewhere is applied to the value of capital in the fishery. For fisheries surveys, ABARES uses a rate of 7 per cent per year, EconSearch use 10 per cent per year[10].

Depreciation expense is the cost of capital becoming less valuable over time as a result of wear and tear and obsolescence. Depreciation expense is not consistently identifiable in fishers' accounts, so the annual depreciation of boats is calculated based on the capital inventory list collected during the surveys (described above) and predetermined depreciation rates for each capital item type.

Management costs are incurred to ensure the fishery continues operating and are therefore costs associated with harvesting fish in the fishery. Management costs are made up of two components: recovered management costs and non-recovered management costs. Recovered management costs (recMC) are those costs recovered from fishers and appear in the accounts of fishers as payments of management fees or levies. Non-recovered management costs are those management costs not charged to fishers, but instead are covered by the managing body or government. Calculation of net economic returns requires deduction of total management costs, which is the sum of these two components.

Total cash costs (CC) includes an estimate of recovered management costs based on management levy expenses contained in fishers' accounts. As this estimate of recovered management costs is based only on a sample of the fishery, it may not be consistent with the actual value of management costs recovered from the entire fishery. Fishery managers are able to provide an estimate of total management costs for each fishery—that is, the sum of both recovered and non-recovered management costs. For these reasons, recovered management costs from fishers' accounts are ignored (as indicated by +recMC in the net returns equation). Then, total management costs (totM) are used to estimate net economic returns.

Fishery gross margin

The development of fully specified bioeconomic models often requires a large quantity of data which are often difficult and costly to collect, especially with a small number of participants (to share the cost) and where data collection requires industry cooperation. The economic information needed will include that described above to enable calculation/prediction of NER over time. As well, the biology of the fishery needs to be well developed (e.g. known stock recruitment and growth rates) and, where changes in biomass from year to year are affected by natural growth (recruitment less natural mortality) and fishing, these factors can be difficult to measure/predict.

In small fisheries which are subject to environmental variability, a simpler and less costly approach may be warranted. The calculation of a fishery gross margin (FGM) is an example. FGM is calculated as total fishery income less total variable costs, where variable costs are proportionate to fishing effort. .This approach will be particularly suitable relevance where changes in supply (catch) have a measurable impact on price. It is also applicable in fisheries where capital outlays and overhead costs are a relatively small proportion of total costs. For a short to medium term perspective, the focus is on variable costs (short run marginal costs) and price (marginal revenue).

Of course there are alternatives to the relatively atypical and specialised FGM approach that could be considered an intermediate or halfway house to a fully specified bioeconomic model. These might include partial budgeting approaches that could be used for incremental or relatively simple changes to a harvest

[10] Composed of the long term (10 year) real rate of return on government (treasury) bonds of 5 per cent and a risk premium of 5 per cent.

strategy. In comparison to the FGM approach, the partial budgeting method would take account of changes in capital requirements, consider changes in costs and revenues over time, and evaluate changes in asset values over time.

Productivity analysis

In recent years ABARES has applied productivity analysis in its reporting on economic performance of major Commonwealth fisheries. Using boat level data collected in the surveys, total factor productivity (TFP) analysis looks at the ability of fishers in a fishery in converting inputs into outputs over time. Results from this analysis can assist in the evaluation of a fishery's economic performance and provide understanding to the factors driving changes in productivity. Changes in productivity generally reflect changes in a fishery's operating environment, such as management settings that regulate technology choice of fishers, or changing market conditions. Therefore, fishery managers can gain some understanding on the factors driving productivity change and effectiveness of various management decisions (Skirtun 2014).

Market conditions range from variations in input costs, import competition, changes in Australia's terms of trade (appreciation or depreciation of the Australian dollar). Both changes in a fishery's operating environment and market conditions can provide fishers with incentives to pursue vessel level productivity improvements. This may be required in order to keep the business financially viable, for example, to offset any negative effects on profitability from adverse market conditions such as increasing input costs or competition. Adverse market conditions can also help drive autonomous structural adjustment within the industry. In fisheries, this is often characterised by fishing rights moving to the most profitable fishers and the least efficient or least profitable vessels exiting the industry, resulting in a more productive residual fleet (Skirtun 2014).

There are various methods developed to quantitatively assess TFP trends for industries, and individual enterprises within industries. ABARES uses the Fisher quantity index to construct productivity indices for major Commonwealth fisheries. The Fisher quantity index is well suited to handling the range of inputs and outputs recorded in ABARES fisheries economic survey data. As with other index number approaches that measure productivity, the Fisher quantity index enables measurement of productivity trends with multiple inputs and outputs. The prices paid for inputs and received for outputs are used as weights to derive aggregations of outputs and inputs, which are expressed in index form. Output and input indexes are estimated using both a Laspeyres and a Paasche index approach. A geometric mean of these indexes is derived to determine the Fisher output and input indexes. Total factor productivity is measured as the ratio of the Fisher output and Fisher input indexes. For further description of the method and interpretation of results, see Skirtun (2014).

Profitability indexes

Another useful economic analysis that relies on the data collected from fishery surveys is the index profit decomposition used by ABARES in the analysis of Commonwealth fisheries. It is an approach that isolates relative contributions of different factors to changes in vessel-level profit over time and can help evaluate whether changes in fishery management have improved profitability in the fishery by looking at how the factors driving fishery profitability have responded following policy changes. These factors can be within the influence of management (such as productivity and stock biomass) while others lie outside management control (such as catch prices and input costs).

The method uses index numbers to decompose and quantify the relative contribution of drivers to a firm's profitability. It does so by examining the variable's share of profit for one firm and compares it with the share of profit of the same variable for a reference or benchmark firm. In the case of a fishery, a firm is represented by a vessel and the key variables that contribute to a vessel's profit include output price, prices of inputs (labour and fuel prices), productivity and fixed capital. The reference vessel is normally selected based on the vessel that is the most profitable over the period of the analysis. However, ABARES has defined the reference vessel as the average vessel in the most profitable year. For further description of the method and interpretation of results, see Skirtun and Vieira (2012).

Entitlement values

Entitlement values reflect underlying beliefs about the health of the fishery's stock and expected prices for that stock. In general, entitlement values reflect expected vessel profitability in the fishery. Over time, changes in entitlement values can provide an indication of economic performance in the fishery. However, it is important to note that for entitlement values to accurately reflect expectation of future profits, an efficient market system must exist for entitlement trade. That is, a quota market with many buyers and sellers, and low transaction costs (Skirtun 2014). Entitlement values can also vary due to factors unrelated to fishery performance such as the availability of finance or yield expectations from alternate investments. Nonetheless, entitlement values are a low cost indicator of fishery economic performance.

Entitlement values are ideally reported as the aggregate value (i.e. total number x average price) as this provides a measure of market capitalisation, a measure widely used in finance for reporting on size and trend in the value of companies.

Lease values

In fisheries where there is an efficient market for leasing of annual catch allocations, the lease price provides insight into the economic yield of the fishery. Aggregate lease value (total catch x lease price per unit weight) provides a market-revealed measure of economic yield from the fishery. Lease values are generally very easy to obtain from brokers and provide a low-cost proxy for economic yield.

Note that in a few instances fisheries contribute to the community through payment for access, such as with a royalty payment. These payments direct some of the lease price from the fishery to the community so that the private quota owner receives a lower price. This means the royalty payment needs to be added back into the aggregate lease value, as it is a part of the total economic yield from the fishery.

A variant on the lease market that exists in some fisheries is where quota owners pay a catching fee to the fisher. In these fishery the market is for labour and catching costs, not economic rent from the fishery. Economic rent can still be estimated easily in these fisheries as price – (catching cost + license fees + transaction costs).

Return on investment (ROI)

All economic indicator reports for South Australian commercial fisheries provide commentary on ROI although the concepts are not always clear. The issue here is that value of the licence is generally considered "investment" by private operators. If licence value is included as part of investment, "return on investment" will fall if the licence value increases at a faster rate than net revenue.

A fall in ROI can occur if a problem occurs in the fishery, for example a crash in price. However, ROI can also fall in response to positive change in the industry that leads to growth in licence value, for example if interest rates fall or if the market becomes more optimistic about the future. Salient points to note here are that:

(i) calculation of ROI should be clearly defined; and

(ii) ROI where licence value is included is meaningless as a performance indicator for tracking a fishery and should not be used in harvest strategies. This is in contrast to licence value (i.e. the entitlement value or the lease value) which is a market-based measure of performance of the fishery.

A low ROI is typically cast as a sign of poor performance within harvest strategies but it may well be a sign of high licence value in an industry that is doing well.

Other Indicators

A fishery is a common property resource and, as such, can be thought of as being owned by the broader community, not just the fishers who have access to the resource. The management of the fishery will be on behalf of this broader community and will generally include a range of social and economic objectives that are wider in scope than the indicators described above. Indicators reflecting these broader community objectives might include:

- Employment – direct and indirect
- Provision of services to the fishing industry
- Contribution of the fishery to gross domestic product
- Exports.

Employment

A commonly asked question is 'how many people are actually being employed as a result of fishery X?'

The employment question is generally in two parts:

- direct employment – this includes jobs directly in fishing operations (i.e. skipper, crew and management) and may be extended along the seafood industry supply chain to include fish processing, transport, retailing and food service (restaurants, etc.) sectors; and
- indirect employment – this is the flow-on or multiplier employment generated in the regions under consideration and represented by jobs in the seafood industry support sectors, e.g. fuel and provision suppliers, fishing gear and equipment manufacturers and retailers, business support services (accountants, lawyers), jobs in the businesses that provide jobs to the support services and employment in the businesses where the skipper and crew and others directly engaged in the seafood industry spend their money, e.g. local supermarket, restaurants, hotels, etc.

The only way to collect direct employment in the fishing industry is through a survey of fishing concession holders and other businesses in the seafood supply chain.

The estimation of indirect employment is usually made using some form of national or regional economic model (e.g. input-output model, computable general equilibrium model). Consequently, the capacity to estimate indirect employment will be constrained by the existence of such economic models and the additional fishing industry data that would be required by the models.

Employment in a fishing business (and other businesses along the supply chain, if relevant) should include a measure of the number of working proprietors, managers, directors and other employees, in terms of the number of full-time equivalent (fte) jobs. While total number of jobs may be of interest and can be reported, the number of fte jobs should be calculated or estimated as best as is possible as it will provide a consistent and comparable data series over time.

Provision of services to the fishing industry

In a way identical to that described for employment, the value of fishing industry activity can be categorised as either direct activity (i.e. part of the fishing industry supply chain) or indirect activity (i.e. services to the fishing industry). Such activity can be measured by its value in dollar terms, and is usually expressed as the value of output. This indicator needs to be used with care as it includes elements of double counting (e.g.

the value of output of the fish processing sector includes the value of the raw product). Direct and indirect output are defined as follows:

- direct output – this includes fishing GVP and may be extended along the seafood industry supply chain to include the value of fish processing, transport, retailing and food service (restaurants, etc.) sectors; and
- indirect output – this includes the services to the fishing industry as represented by output in the seafood industry support sectors, e.g. fuel and provision suppliers, fishing gear and equipment manufacturers and retailers, and business support services (accountants, lawyers, etc.).

Contribution to gross domestic product (GDP) or gross regional product (GRP)

Contribution to GDP is a measure of the net contribution of an activity to the national economy (GRP is the equivalent for a region). Contribution to GDP is measured as value of output less the cost of goods and services (including imports) used in producing the output.

It can also be measured as household income plus other value added (gross operating surplus and all taxes, less subsidies). By this definition it represents payments to the primary inputs of production (labour, capital and land). Using contribution to GDP as a measure of economic impact avoids the problem of double counting that may arise from using value of output for this purpose.

Like employment and output, contribution to GDP can be categorised as either direct activity (i.e. contribution to GDP by businesses along the fishing industry value chain) or indirect activity (i.e. contribution to GDP by services to the fishing industry).

Exports

Because exports and balance of trade considerations have a direct effect on the macroeconomic performance of any country, detailed reporting of export statistics is highly desirable, and should include the following where possible:

- Value (free-on-board (fob)) and quantity
- Processed and unprocessed – this may include a distinction between chilled, frozen, cooked, etc.
- Country of destination – tracking the relative size of major markets over time is extremely useful and the value and quantity data can sometimes be reported for each country.

Concluding Comments

Most industries in the wider economy operate with zero rent (net economic return) but the SA commercial fisheries surveyed generally have positive rent[11]. This occurs because the number of licences and the catch is limited so that new firms cannot enter the fishery without purchasing a licence from an existing operator. The fact that licences have value is market-based evidence of the large positive rent received by licence owners of many SA fisheries.

Each fishery in SA has an objective of being managed to *maintain a flow of economic benefit from the fishery to the broader community*. Indicators for this objective have been selected by the SA Government and reported in the BDO EconSearch economic indicator reports.

[11] See, for example, BDO EconSearch (2020, p. 181).

However, many of the economic indicators selected do not appear well matched to the objective. This is a problem because indicators should guide management decisions. There are two problems with the indictors of most fisheries:

a) *Many of the indicators do not necessarily measure economic benefit.* For example, most fisheries include the indicator of GVP but this does not indicate profitability or economic benefit from the fishery. Revenue and profit are two very different things. The decision to use GVP appears strange because information relevant to measuring economic benefit are reported in the BDO EconSearch reports. Better indicators for the management objective include profit at full equity, licence value, value of quota units, NER (or economic rent), and gross state product.

b) *Whether the indicator measures benefit to the community*. Not all indicators measure benefit to the community. For example, NER would not measure community benefit where there is ownership of quota units by investors outside SA. SA does not charge any access fee or royalty on their fisheries, so all of the rent is paid to quota owners. If quota owners live or invest their rent outside SA, it is possible for community benefit from the fishery to decline at the same time as NER increases. Other indicators like gross state product may be better aligned with the objective.

6. Processes for Data Collection and Presentation

Presented in this chapter are the sources of economic information that are relevant to fisheries management decision making and the processes of collecting that information. Also provided is a discussion and general guidelines about different approaches to incorporating economic information in harvest strategies and decision making processes.

Source and Collection Methods of Economic Indicators

In this section, the source and collection methods for each of the potential economic indicators (canvassed in Chapter 5) are discussed, drawing on EconSearch (2015). Although some indicators are simply secondary data that are published elsewhere, some indicators are primary data while others are either derived or estimated values utilising the primary and secondary data. Since these calculated indicators are derived or dependent in some way on other indicators, it is very important that the primary data are as precise and reliable as possible.

For each potential indicator this section provides a brief description of the source of the data or the suggested collection or calculation method. Comments relevant to the source or collection method are also provided.

The information is provided in three tables:

- Source and collection methods for financial indicators – Table 1
- Source and collection methods for fishery indicators – Table 2
- Source and collection methods for other indicators – Table 3.

Table 1 Source and collection methods for financial indicators

Financial indicator	Source and collection method	Comments
Product prices and income		
Landed 'beach' price	For some jurisdictions, monthly price data are available (e.g. from SARDI, ABARES), otherwise price data can be collected monthly from fish processors and Sydney and Melbourne market data	Used to estimate GVP. Can be used to estimate income for individual fishers if they are reluctant to provide revenue data through the survey. Used in non-survey years to update income estimates.
Catch	Catch data sourced from fishery manager	
Operating costs		
Comprehensive boat - level cost data (primary)	Periodic survey of fishers, updated between surveys with update data in a vessel cost model	
Update data (secondary)	Fishery catch, effort, price of fuel, labour, bait (where relevant), interest, CPI	Fishery catch and effort data sourced from fishery manager, fuel - ABS transportation index, labour - ABS wage price index, interest - RBA indicator lending rate for small business, CPI - ABS consumer price indices. If bait is a significant component of cost, sourcing prices for baitfish is advised.
Vessel profitability	Calculated from fisher survey data or from vessel cost model in non-survey years.	The elements that comprise the calculation of vessel profitability are also necessary to estimate economic rent

Table 2 Source and collection methods for economic indicators

Economic Indicator	Source and collection method	Comments
Gross value of production		
Landed 'beach' price	See Table 1	
Catch	See Table 1	
Cost of management	Cost of management data sourced from fishery manager	
Economic rent	Calculation of economic rent requires information on: cost of labour, other cash costs, depreciation, opportunity cost of capital (sourced from fisher survey data), GVP and cost of management.	Need to adjust for known biases in the survey data to fishery total
Productivity analysis	Require information collected through the fisher survey and update data.	
Profitability indexes	In addition to information collected through the fisher survey, data on boat length required	
Entitlement values	Entitlement value (licence and quota) trading data if available, otherwise collected through fisher survey. Data on trade in entitlements sourced from fishery manager	
Annual lease value	Lease values are generally very easy to obtain from brokers.	Where fisheries contribute to the community through payment for access (e.g. royalties), the access payment needs to be added back into the aggregate lease value to more accurately estimate the total economic yield from the fishery.

Table 3 Source and collection methods for other indicators

Other Indicator	Source and collection method	Comments
Employment		
Direct employment	Estimate of employment in fishery is based on survey data. In non-survey years employment can be estimated on the the basis of the change in the number of active concession holders. Estimates of employment in other parts of the seafood industry supply chain requires data from a value chain analysis. Data may be available from existing value chain analyses (e.g. PIRSA Value-added Scorecard series in South Australia).	This includes jobs directly in fishing and may be extended along the seafood industry supply chain to also include fish processing, transport, retailing and food service (restaurants, etc.) sectors. Employment should be expressed in terms of full-time equivalent (fte) jobs to provide a consistent and comparable data series over time.
Indirect employment	Estimates of indirect employment generally made using some form of regional, state and/or national economic model (e.g. input-output (IO) model). These are generally updated and available through government agencies in most jurisdictions, such as Dept of Premier and Cabinet in SA and the Department of Jobs, Precincts and Regions in Victoria . Indirect employment estimation also requires the detailed fishing industry cost and supply chain data that would be used in the models .	Indirect employment is the flow-on or multiplier employment generated in the region represented by jobs in the seafood industry support sectors, e.g. fuel and provision suppliers, fishing gear and equipment manufacturers and retailers, business support services (accountants, lawyers), jobs in the businesses that provide jobs to the support services and employment in the businesses where the skipper and crew and others directly engaged in the seafood industry spend their money, e.g. local supermarket, restaurants, hotels, etc.
Provision of services		
Direct output	As per discussion regarding direct employment. In non-survey years output could be estimated on the basis of the change in fishery GVP.	
Indirect output	As per discussion regarding indirect employment	Measures of indirect output should be treated with caution as they include elements of double counting. GSP is a preferred indicator of contribution to economic activity.
Contribution to GSP		
Direct contribution	As per discussion regarding direct employment. In non-survey years output could be estimated on the basis of the change in fishery GVP and input costs.	
Indirect contribution	As per discussion regarding indirect employment	
Exports		
Export volumes and prices (fob)	Available from Australian Bureau of Statistics by request	
Exchange rates	RBA Exchange rates - Daily Bulletin	

This section discusses some of the key considerations in collecting, managing and presenting data for economic indicators.

Survey of Concession Holders in the Fishery

Most economic indicators discussed in Section 5 require an estimate of fishing business costs to be calculated. To assess these costs with reasonable accuracy requires a survey of concession holders in the fishery.

This section discusses some of the key considerations in undertaking a surveys, namely:

- survey frequency
- support from concession holders
- sample size
- questionnaire design
- privacy of information provided.

Survey frequency

South Australian fisheries are surveyed every three years. Some fisheries have been surveyed from the mid 1990's. These surveys allow the update of financial performance indicators for the fishery at a frequency sufficient to capture the structural changes in the operational style of the fishery. In the intervening two years economic performance indicators are updated based on fishery and state level data.

ABARES has undertaken economic surveys of selected Commonwealth fisheries since the early 1980s. These have been done on a regular basis for particular fisheries since 1992. The current fisheries survey program involves surveying major Commonwealth fisheries every few years; or more frequently where the fishery is undergoing major changes and monitoring is particularly important. The aim is to develop a consistent time series of economic information for each fishery (see, for example, Stephan (2013) where economic time series data have been used to analyse trends in total factor productivity of five key Commonwealth managed fisheries). The major fisheries[12] have in recent years been surveyed every two years, with two years of financial information collected from respondents.

Surveying fisheries annually is likely to be too costly and may result in survey fatigue amongst survey respondents. From BDO EconSearch's experience, a survey interval beyond three years may be too infrequent to capture the structural changes in the operational style of the fishery.

Support from concession holders

To achieve a high level of cooperation in undertaking the financial surveys, the data collection team would preferably have experience in working with the target fishery and have positive relationships with those industries. Critical to this, however, will be the ongoing support of the fisheries and any representative association that may exist in the fishery. It is vital to work closely with such organisations to ensure that their needs are being met. Ideally, this would involve regular meetings, a reporting schedule and an annual review.

Sample size

In conducting any survey, and in choosing an appropriate sample size in particular, there is inevitably a need to balance accuracy and reliability against the constraints of budget and time. Given some information about the population to be sampled (the standard deviation of the parameter to be estimated), the required sample size can be determined for a given level of confidence and an acceptable sampling error.

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[12] Northern Prawn Fishery, Eastern Tuna and Billfish Fishery and the Commonwealth Trawl and Gillnet, Hook and Trap Sectors of the Southern and Eastern Scalefish and Shark Fishery.

Survey work conducted by BDO EconSearch in preparing Economic Indicators reports in South Australia allowed such estimates of sample size to be made for the larger fisheries (i.e. those with over 30 licence holders). The survey results allowed estimation of the mean and standard deviation of operator income in each fishery. Given these values and a desire to estimate the population mean to within ±10 per cent (±15 per cent for multi-species fisheries[13]) and to be 95 per cent confident of correctly estimating the true mean, the required sample size was calculated[14]. Because there is likely to be greater variability in operating costs between licence holders (than the variability in income), the sample size may need to be slightly larger to achieve the same level of reliability for cost estimates.

This analysis indicated a wide ranging sampling level from just 14 per cent in the South Australian Southern Zone Rock Lobster fishery, where there is relatively high uniformity of operator income (population = 180, thus required sample size = 26), to over 60 per cent in the lakes and Coorong fishery where there is a high level of variation in boat earnings (population = 36, thus required sample size = 22). Other things being equal, it will be necessary to have a relatively large sample in the fisheries with a small number of licence holders. For the smaller fisheries (less than 30 vessels) it is expected that at least 50 per cent of vessels would need to be surveyed to achieve an acceptable level of accuracy.

Questionnaire

To be able to report on the required range of financial indicators, the structure and content of the questionnaire will be similar for most fisheries, although for all fisheries there will be some differences according to the nature of the specific fishing operations. The questionnaire used in the survey will need to ask for information on all major categories of operating costs (variable and fixed), as well as investments in the business, fishing-related income and employment.

While the data collected may be similar between fisheries, the method of collection could vary significantly. The timing of the survey, the stratification of licence holders and the way in which licence holders are approached (on-line, mail and telephone surveys, one-on-one personal interviews, or combinations of these and other approaches) would need to be negotiated with each of the fisheries.

From BDO EconSearch’s experience, better quality and more complete survey responses are achieved through mail-out of forms (post or e-mail) followed by interview (in person or by phone).

Privacy of information provided

Survey respondents, who divulge their businesses financial data, are providing information that is commercially sensitive. It is important that data is not presented in a manner that could expose individual information provided. This can be avoided by presenting the data as averages or in aggregate. Where stratification of the data is sought (e.g. reporting against different gear types), care must be taken to ensure that the sub-samples are large enough to maintain anonymity of data.

It is also important that the data are used for the purposes that it was collected and that agreement has been obtained from the fisher for the data to be used for that purpose. If new uses of the data are sought from what was originally intended, agreement should be sought from the fisher.

Once data are collected they should be entered into the database in an anonymised manner (i.e. survey data should not be kept with information that identifies the respondent unless agreement to hold identified data has

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13 A small error margin in the highly variable multi-species fisheries would significantly increase the required sample size.

14 Based on the following equation $n = \frac{z^2\sigma^2}{e^2}$ where n = the sample size required; Z = the confidence level desired; e = the sampling error permitted; and σ = the standard deviation.

been previously obtained[15]). To the authors' knowledge, there is no generic database that has been developed for this purpose.

Update Survey Data

Once a set of economic indicators have been developed for a fishery, between survey years they can be readily updated using a range of primary and secondary data as well as survey–based indicators. The following information would be used to adjust the survey year indicators to reflect the fishery's performance in the update year.

- Update year catch and price data is used to reflect changes in both catch size and its value between survey and update years. Where necessary these data can be adjusted with other information such as Sydney or Melbourne fish market data. Catch and price data are used to determine the GVP in the fishery.
- Change in the number of concession holders in the fishery needs to be collected from the fisheries agency. This information is used to update and present performance indicators on a 'per licence holder' basis.
- Change in fishing effort (typically the number of days fished) between the survey year and the update year. This is used to adjust the costs of inputs that vary with fishing effort. These inputs included fuel, repairs and maintenance, bait and provision costs.
- Price information from input suppliers or published data are used to adjust prices that may have changed, for example, fuel and bait. The ABS transportation index and wage price index can be used to adjust prices for fuel and labour respectively. The RBA's data on indicator lending rate for small businesses can be used to adjust interest.
- The consumer price index (CPI) is used to adjust the cost of inputs to reflect local levels of inflation.
- If relevant, information on new boat registrations in the fishery during the update year and information from the survey year on the value of vessels. This information is used to compare the value of new capital entering the fishery with the value of capital depreciation in the fishery.

Data security

The key data include financial information provided by licence holders in the surveys and various other data sets provided by fishery managers. These data are commercially sensitive or are not available publically. Furthermore, they are used in time series analysis (e.g. the South Australian fishery trends are presented over periods up to 20 years). It is important to maintain the integrity of the data and systems should be put in place to:

- avoid loss of the data through theft, viral attack or other malicious activity
- avoid accidental loss
- avoid corruption of data or obsolete storage technology.

Therefore, consideration of appropriate property and IT security systems is essential. No specific recommendations are made in this regard as it will depend on the individual organisation's existing systems, protocols and software.

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[15] For example, bioeconomic modelling requires matching of individual fishing businesses catch data with their financial data, and this should be anticipated in the data collection and storage program.

7. Case Study 1: Western Zone Abalone Fishery Restructure and Fishing Strategy Options[16]

Method

A key objective of this study was to estimate net benefits of the Western Zone Abalone Fishery restructure and fishing strategy options. The proposed options were compared against a baseline scenario within the framework of a cost benefit analysis (CBA). The standard CBA method involves the specification of a base case (baseline scenario) against which options are compared. The CBA conducted for this project conforms to South Australian and Commonwealth Government guidelines for conducting evaluations of public sector projects (Department of Treasury and Finance (2008) and Department of Finance and Administration (2006)).

The starting point for the CBA was to develop the 'baseline' scenario, that is, the benchmark against which the alternative scenarios were compared. It is important to note that the baseline scenario is not a 'spend nothing' or 'do nothing' scenario. Given that costs and benefits were specified in real terms (i.e. constant 2018 dollars), future values were converted to present values by applying a discount rate of 6 per cent. The choice of discount rate is consistent with the rate commonly used by the South Australian Government in this type of analysis.

The analysis was conducted over a 10-year period and results were expressed in terms of net benefits, that is, the incremental benefits and costs of the options relative to those generated by the 'baseline' scenario.

The evaluation criterion employed for this analysis is the present value (PV) of net economic return (NER) estimated over a 10-year period. The NER is defined as the difference between the price of a good produced using a natural resource and the unit cost of turning that natural resource into the good. In this case the natural resource is the SA Western Zone Abalone Fishery and the good produced is the landed Abalone. The unit costs or long term costs all need to be covered if a licence holder is to remain in the fishery. These long-term costs include direct operating costs such as fuel, labour (including the opportunity cost of a self-employed fisher's own labour), ice, overheads such as administration and licences and the cost of capital invested in the boat and gear (excluding licence). Capital costs includes depreciation and the opportunity cost of the capital applied to the fishery. The opportunity cost is equivalent to what the fisher's investment could have earned in the next best alternative use.

Determining the opportunity cost of capital involves an assessment of the degree of financial risk involved in the activity. For a risk-free operation, an appropriate opportunity cost of capital might be the long-term real rate of return on government bonds. The greater the risks involved, the greater is the necessary return on capital to justify the investment in that particular activity. For this analysis the long term (10-year) real rate of return on government (treasury) bonds of 5 per cent has been used and a risk premium of 5 per cent has been applied.

Under this decision rule, an option was considered to be potentially viable if the NER was greater than zero. The NER for option *i* has been calculated as an incremental NER, using the formulation:

PV of NER_i = (PV ($option_i$ income – 'baseline' income) – (PV ($option_i$ costs – 'baseline' costs))

Fishery Baseline

BDO EconSearch has been reporting economic indicators for the SA Abalone Fishery for the last 20 years. This has provided a consistent time series of economic information for the fishery. Data from the most recent

[16] The full case study is reported in BDO EconSearch (2019c).

report titled *Economic and Social Indicators for the South Australian Abalone Fishery 2017/18* (BDO EconSearch 2019a) has been utilised for the purpose of this report.

The average financial performance per boat for the Western Zone Abalone Fishery in 2017/18 was used as the baseline against which the fishery restructure and fishing strategy options were compared (Table 4). These estimates were derived using survey-based 2017/18 indicators (licence holder survey undertaken in 2018).

Table 4 Financial performance in the Western Zone Abalone Fishery, 2017/18 [a]

		Fishery Total
(1)	**Total Fishery Income**	**$16,017,000**
	Variable Costs	
	Fuel	$312,493
	Repairs & Maintenance [b]	$519,791
	Ice	$5,725
	Provisions	$0
	Labour - paid	$5,003,678
(2)	Labour - unpaid [c]	$99,032
	Other	$693,695
(3)	**Total Variable Costs**	**$6,634,414**
	Fixed Costs	
	Licence Fee	$1,446,999
	Insurance	$122,092
(4)	Interest	$483,573
(5)	Labour - unpaid [c]	$211,303
	Leasing	$694,578
	Legal & Accounting	$264,622
	Telephone etc.	$60,291
	Slipping & Mooring	$19,246
	Travel	$35,544
	Office & Admin	$238,865
(6)	**Total Fixed Costs**	**$3,577,111**
(7)	**Total Fishery Cash Costs (3 + 6)**	**$10,211,526**
	Fishery Gross Margin (1 - 3)	**$9,382,586**
(8)	**Total Unpaid Labour (2 + 5)**	**$310,335**
	Gross Operating Surplus (1 - 7 + 8)	**$6,115,810**
(9)	**Fishery Cash Income (1 - 7)**	**$5,805,474**
(10)	**Depreciation**	**$720,248**
(11)	**Fishery Business Profit (9 - 10)**	**$5,085,227**
(12)	**Profit at Full Equity (11 + 4)**	**$5,568,800**
	Boat Capital	
(13)	Fishing Gear & Equip	$5,914,018
	Licence Value	$83,831,639
(14)	**Total Boat Capital**	**$89,745,657**
	Rate of Return on Fishing Gear & Equip (12 / 13 * 100)	**94.2%**
	Rate of Return on Total Boat Capital (12 / 14 * 100)	**6.2%**

[a] Financial performance estimates for were based on the 2018 licence holder survey. All figures are in nominal terms.

[b] Repairs and maintenance costs have been classified as variable although it is noted that some of these costs may be fixed.

[c] Unpaid labour was divided between variable (time spent on fishing and repairs and maintenance) and fixed (management and administrative duties) costs based on survey responses.

Source: BDO EconSearch (2019a)

The average financial performance per boat for the Western Zone Abalone Fishery in 2017/18 was then used to estimate the net economic return (NER) for the whole fishery. The choice of basing the analysis on the fishery rather than individual vessel was because this is the scale at which management decisions and harvest strategy operate. The average financial performance per boat was scaled up to the fishery total using the number of active vessels (22 boats) and adjusted for sample bias. The estimated NER for the Western Zone Abalone Fishery is presented in Table 5.

Table 5 Net economic return, Western Zone Abalone Fishery, 2017/18 [a]

	Fishery Total $m
Gross Income	16.0
Less Labour	5.3
Less Cash Costs	3.7
Less Depreciation	0.7
Less Opportunity Cost of Capital (@10%)	0.6
Net Economic Return	**5.7**

[a] Adjusted for sample bias.

Source: BDO EconSearch (2019a) and BDO EconSearch analysis

Fishery Restructure and Fishing Strategy Options

As previously mentioned, the optimum time to harvest Blacklip Abalone (*Haliotis rubra*) is from January to March (Stobart and Mayfield in prep), while Greenlip Abalone (*H. laevigata*) is best harvested between April and June (Stobart et al. 2015). The model developed during these studies is used to explore two different fishing strategies: (FS1) maintain the current TACC and evaluate the change in number of Abalone harvested; or (FS2) maintain the current number of Abalone harvested and evaluate the change in landed catch. Both of these strategies provide benefits that are: (1) that FS1 reduces the risk to the fishery by enabling the extraction of the current TACC with fewer abalone; and (2) that FS2 improves economic return because a higher TACC can be achieved with the same number of abalone currently extracted, with no apparent increase in risk to the fishery.

For this fishery restructure study, these strategies were considered at two different time scales. The time scales reflect the 12-month season currently fished for both species, based on the fishing pattern observed in 2016, and a six-month season aimed at harvesting both species at their optimum time (Table 6).

After investigating different options SARDI, Abalone Industry Association of South Australia (AIASA) and BDO EconSearch decided to contrast three fishery restructure scenarios against the baseline (status quo) scenario, as outlined in Table 7.

Scenario 4 was added after discussions with industry. Industry indicated that it would be unlikely that 14 boats could catch the TACC within 6 months. They indicated it was more realistic that 17 boats could catch the TACC within 6 months.

Scenarios 1, 3 and 4 were then analysed using two different fishing strategies, as follows.

Fishing strategy 1 (FS1) No change to the TACC but number of Abalone decreases as the average weight per abalone increases.

Fishing strategy 2 (FS2) Increase the TACC so the number of Abalone caught is the same as the Baseline.

Table 6 Proportion of catch by month for the 12 month and 6 month baseline fishing seasons

	12 month season [a]			6 month season	
	BL	GL		BL	GL
Month/Proportion of catch	2016	2016			
Jan	0.20	0.13		0.30	
Feb	0.10	0.09		0.30	
Mar	0.15	0.18		0.20	0.10
Apr	0.10	0.12		0.07	0.30
May	0.01	0.13		0.07	0.30
June	0.06	0.09		0.06	0.30
Jul	0.03	0.05			
Aug	0.06	0.08			
Sept	0.02	0.03			
Oct	0.08	0.02			
Nov	0.14	0.05			
Dec	0.06	0.02			
OUTPUTS					
TACC [b](Kg)	74,580	73,010	**FS1**	74,580	73,010
No. abalone	378,196	279,543		362,763	256,947
Value (AU$)	7,085,100	9,180,522		7,085,100	9,296,389
Difference in No. abalone				-15,433	-22,596
Difference in value (AU$)				0	115,867
Difference in TACC (Kg)				0	0
TACC [b] (Kg)			**FS2**	77,753	79,431
No abalone				378,196	279,543
Value (AU$)				7,386,518	10,113,918
Difference in No. abalone				0	0
Difference in value (AU$)				301,418	933,396
Difference in TACC (Kg)				3,173	6,421

[a] Totals may not sum due to rounding.

[b] Meat weight, approximately one-third the whole weight.

Source: SARDI

Table 7 Western Zone Abalone Fishery restructure scenarios

Scenario	Description
Baseline	22 boats fishing a 12-month season
Scenario 1	Same number of boats to fish a 6-month season (22 boats, 6-month season)
Scenario 2	Remove 8 boats from the fishery with the remaining 14 boats to fish a 12-month season (14 boats, 12-month season)
Scenario 3	Remove 8 boats from the fishery with the remaining 14 boats to fish a 6-month season (14 boats, 6-month season)
Scenario 4	Remove 5 boats from the fishery with the remaining 17 boats to fish a 6-month season (17 boats, 6-month season)7

The fishery restructure and fishing strategy options assumptions are summarised in Table 8. It was assumed these changes would occur within one year.

Prices were sourced from industry with an average price for Blacklip Abalone of $31.67/kg whole weight and $54.44/kg whole weight for Greenlip Abalone.

Table 8 Fishery restructure and fishing strategy options

	Baseline	Scenario 1		Scenario 2	Scenario 3		Scenario 4	
Boats (no.)	22	22		14	14		17	
Season Length (mths)	12	6		12	6		6	
		FS1	FS2		FS1	FS2	FS1	FS2
Total days fished (no.)	1,364	1,285	1,364	1,364	1,285	1,364	1,285	1,364
Catch/TACC (t) [a]	443	443	472	443	443	472	443	472

[a] Whole weight.

Source: SARDI

Fishing costs for each scenario were adjusted from baseline values as follows:

- Paid labour costs varied with the change in income.
- Other variable costs varied with days fished.
- Fixed costs and depreciation varied with the number of boats.

Costs associated with each fishery restructure scenario would be incurred but are unknown at this stage of the analysis. These costs would include, but not be limited to, costs associated with changing the regulations, management plan and harvest strategy plus any other costs incurred by the fleet or management that would not be incurred under the baseline management of the fishery. Any projected benefits of the scenarios will need to be considered against these unknown costs.

Results

The results of the analysis are presented in Table 9. In summary, each scenario will result in net economic return (NER) over 10 years additional to the Baseline Scenario of:

- Scenario 1: $0.7m under Fishing Strategy 1 and $7.8m under Fishing Strategy 2
- Scenario 2: $10.3m
- Scenario 3: $11.0m under Fishing Strategy 1 and $18.1m under Fishing Strategy 2
- Scenario 4: $7.1m under Fishing Strategy 1 and $14.2m under Fishing Strategy 2

Table 9 Results summary

	Baseline	Scenario 1		Scenario 2	Scenario 3		Scenario 4	
Boats (no.)	22	22		14	14		17	
Season Length (mths)	12	6		12	6		6	
		FS1	FS2		FS1	FS2	FS1	FS2
Total days fished (no.)	1,364	1,285	1,364	1,364	1,285	1,364	1,285	1,364
Catch/TACC (t) [a]	443	443	472	443	443	472	443	472
Incremental NER ($m)[b]		0.7	7.8	10.3	11.0	18.1	7.1	14.2

[a] Whole weight.

[b] Incremental net economic return calculated as a present value.

Source: BDO EconSearch analysis

Under the assumptions described in the methods section above, the incremental NER is significantly improved by reducing the number of boats from 22 to 14 (Scenarios 2 and 3). This is due to reduced fixed costs, depreciation and opportunity cost of capital. Even reducing the number of boats to 17 (Scenario 4) significantly improves the incremental NER. Furthermore, shortening the season length from 12 to 6 months (Scenarios 1, 3 and 4) increases the incremental NER among the options. This is due to higher revenue (compared to Scenario 2) from the better weight expected in the January to June period.

For Scenarios 1, 3 and 4, the incremental NER is higher for Fishing Strategy 2, where the TACC is increased to a level where the same number of Abalone are caught as under the Baseline.

The improvement in NER under Scenario 2 ($10.3m) results from savings in fixed costs, depreciation and opportunity costs of capital for the eight boats removed because the season length remains at 12 months.

Therefore, among the specified scenarios, the most profitable course of action for the fishery would be to reduce the number of boats to 14, reduced the season length to 6 months and increase the TACC to 472t (Scenario 3, Fishing Strategy 2). It is important to note, however, this analysis excludes fishery restructure adjustment costs and social costs (especially of the reduced boat scenarios) which could potentially change these results. It is also worth noting that over time there could be added benefits of FS1 where the TACC remains the same but the number of Abalone taken is lower. Fewer Abalone being taken could lead to an increase in the biomass for the fishery. This could lead to increased catching capacity (CPUE) or the potential for future increases in TACC.

Sensitivity Analysis

The results of the analysis were re-estimated using values for key variables that reflect the uncertainty of those variables. The sensitivity analysis included the following:

- discount rate
- moderate price reduction
- extreme price reduction

The range of values used for each uncertain variable and detailed results of the sensitivity analysis are set out below with some interpretation of the results. Note that each sensitivity analysis for each variable was undertaken by holding all other variables constant at their 'expected' values. The assumptions and results of the sensitivity analysis are summarised and described in the following sections.

Discount rate

The incremental NER is specified in real terms (i.e. constant 2018 dollars) and future values are converted to present values by applying a discount rate of 6 per cent. A sensitivity analysis was conducted using discount rates of 4 and 8 per cent (Table 10).

Table 10 Sensitivity analysis for discount rate - incremental NER a ($m)[b]

Discount rate	Scenario 1		Scenario 2	Scenario 3		Sceanrio 4	
	FS1	FS2		FS1	FS2	FS1	FS2
4%	0.8	8.5	11.1	11.9	19.6	7.7	15.4
6%[c]	0.7	7.8	10.3	11.0	18.1	7.1	14.2
8%	0.7	7.3	9.5	10.2	16.8	6.6	13.2

[a] Incremental net economic return calculated as a present value.

[b] In 2018 dollars.

[c] Expected value.

Source: BDO EconSearch analysis

As expected, the incremental NER improves with the lower (4 per cent) discount rate. This occurs because the benefits that accrue over later years are greater, in present value terms, when the discount rate is lower. However, the results of the analysis are shown to be insensitive to the discount rate, principally the result of the analysis being undertaken over a 10-year period.

Moderate price reduction

Under Scenarios 1, 3 and 4, the fishing season would be shortened from 12 to 6 months. A sensitivity analysis was undertaken to illustrate the effect of a moderate (10 per cent) decrease in monthly prices. The results of this sensitivity analysis are summarised as follows:

Scenario 1: Incremental NER (present value over 10 years) would decline from $0.7m to -$10.3m under Fishing Strategy 1 and from $7.8m to -$4.0m under Fishing Strategy 2.

Scenario 2: No change as season length remains at 12 months, incremental NER of $10.3m.

Scenario 3: Incremental NER would decline from $11.0m to $0m under Fishing Strategy 1 and from $18.1m to $6.3m under Fishing Strategy 2.

Scenario 4: Incremental NER would decline from $7.1m to -$3.9m under Fishing Strategy 1 and from $14.2m to $2.4m under Fishing Strategy 2.

The result of the sensitivity analysis changes the order of the Scenarios as the incremental NER under Scenarios 1, 3 and 4 fall below that projected for Scenario 2.

Clearly, the results for the scenarios involving a shortening of the season are very sensitive to price which would need to be carefully considered prior to introducing such changes. Regardless of price responsiveness, however, the results indicate that scenarios involving a reduction in the number of active boats (Scenarios 2, 3 and 4) have the potential to significantly improve net returns to the fishery.

This sensitivity analysis was undertaken in order to show what affect a change in price would have on the results. However, this fishery is based on product that is shucked bled meat weight that is frozen, dried, canned, preserved and not as susceptible to price variations as fresh product.

Threshold price reduction

Discussion with industry and management raised the question about how the results might be affected under a severe price reduction caused, for example, by loss of market access. This type of market impact would, however, be felt under the base case as well as the three scenarios and therefore not affect the ranking of the scenarios. Table 9 shows that all scenarios would be preferable to the base case and that Scenario 3 (FS2) is the most preferred. Although the dollar values would change under a severe price reduction, the rankings would remain the same.

More interesting are circumstances where the scenarios could differentially impact the price of Abalone. One potential situation is where Scenarios 1, 3 and 4 impact the market price (differently from Scenario 2 and the base case) because of the shortened fishing season (from 12 to 6 months). In this situation it would be useful to know the price impact that would make the scenario a marginal investment, i.e. reduce the net economic return to zero (compared to the base case).

This sensitivity analysis was undertaken to illustrate the effect of a more significant and sustained price reduction and to identify the price reduction that would yield an NER (present value over 10 years) of zero. The results of this analysis are summarised as follows:

Scenario 1: Incremental NER (present value over 10 years) would decline from $0.7m to $0.0m under Fishing Strategy 1 with a price decline of 0.66 per cent, and from $7.8m to $0.0m under Fishing Strategy 2 with a price decline of 6.65 per cent.

Scenario 2: No change as season length remains at 12 months, incremental NER of $10.3m.

Scenario 3: Incremental NER would decline from $11.0m to $0.0m under Fishing Strategy 1 with a price decline of 9.96 per cent and from $18.1m to $0.0m under Fishing Strategy 2 with a price decline of 15.33 per cent.

Scenario 4: Incremental NER would decline from $7.1m to $0.0m under Fishing Strategy 1 with a price decline of 6.47 per cent and from $14.2m to $0.0m under Fishing Strategy 2 with a price decline of 12.07 per cent.

Although the fishery is not susceptible to significant price variations, particularly variations induced by changes in the length of the fishing season, the threshold price analysis does demonstrate the robustness of proposed scenarios. For example, Scenario 3 under either fishing strategy could suffer a 25 per cent price decline and still generate a higher economic return for the fishery compared to the baseline scenario under existing prices.

Implications/Conclusions for Industry and Fisheries Management

The purpose of this analysis was to assess the economic benefit of a range of strategies for the Western Zone Abalone Fishery compared to a base case of continuing current management arrangements. Among the specified scenarios, the most profitable course of action for the fishery would be to adopt Scenario 3. This would involve

- reducing the number of boats to 14
- reducing the season length to 6 months
- increasing the TACC to 472t (Scenario 3, Fishing Strategy 2).

While this scenario is projected to generate the highest incremental NER of all the scenarios, the analysis excludes fishery restructure adjustment costs and possible social costs (especially of the reduced boat scenarios) which could potentially influence the preferred option. Furthermore, discussions with industry suggested that it may be difficult to catch the total fishery quota with just 14 boats and that around 17 boats might be needed to be confident that the full quota could be harvested in most years.

The sensitivity analysis showed:

- the ranking of the scenarios does not change with variations in the discount rate. The benefits of all the scenarios are positive and significant compared to the base case

- the scenarios involving a shortening of the season (to 6 months) are very sensitive to price. Clearly this would need to be carefully considered prior to the introduction of such changes.
- that regardless of price responsiveness, the scenarios involving a reduction in the number of active boats (Scenarios 2, 3 and 4) have the potential to significantly improve net returns to the fishery.

For industry to take advantage of these potential improvements in the economic performance of the fishery some incentives for the necessary adjustments to take place will be required. For a shorter fishing season these could include, for example:

- quota penalty in the following year for taking quota outside predefined ‘desirable’ months (e.g. January to June)
- licence fee rebate/penalty for taking quota outside predefined ‘desirable’ months

A number of different approaches could be taken to encourage amalgamation or consolidation of licences including a licence buyback or a licence amalgamation program.

Licence buybacks in fisheries are a key management tool used to, among other things, remove excess fishing capacity and transition to more rationalised fishery management arrangements

Reducing fishing capacity, through removing vessels and licences, and relieving pressures on fish stocks should allow vessel profits and resource rents to improve as demonstrated in the preceding analysis, and fish stocks to recover. Distribution of income and wealth will also change through the redistribution of access and the result of any compensation and transfer payments.

These impacts on profits and on the distribution of income and wealth are largely influenced by the design and structure of the buyback/licence amalgamation program. Although licence buybacks are widely used and considerable funds expended, there is often insufficient attention given to evaluation prior to their implementation, consideration of their strengths and weaknesses, consideration of the best circumstances for their implementation or how best to design them so they can be applied in a cost-efficient manner.

In principle, there may be clear benefits of a buyback/amalgamation program, but it will result in changes to vessel level behaviour that could generate both intended and unintended results. Some examples are discussed briefly below.

- *Short-run advantages to remaining licence holders*: If stocks rebuild, there are likely to be additional profits for the remaining vessels, in the short-term at least.
- *Increased investment by remaining licence holders*: The short-run lift in profits can create incentives to invest in more capital and adopt new technologies. In this way a buyback program can be self-defeating over the longer period, although the existing quota system in the fishery should work against this happening.
- *Exiting vessels may be the least efficient*: under a well-designed program this is what would be expected. However, it may be that some of the participating vessels would have exited the fishery anyway (without the cost and inconvenience of a buyback/amalgamation program) and the program would simply accelerate their departure.
- *Improved attitudes in a transition stage*: Experience elsewhere has shown that prior to a significant capacity reduction fisheries are often characterised by low profitability or losses, attitudes border on desperation or despair and are more likely to be contentious and highly competitive, and incentives favouring cooperation are impaired. Lower vessel numbers, following a buyback/amalgamation program, contribute to higher vessel profits, and the remaining licence holders are more likely to be committed and receptive to alternative management regimes. Having fewer licence holders in general favours cooperation.

- *Not everyone benefits*: Buyback/amalgamation programs can create distributional impacts, with gainers and losers. Setting aside the question of who funds the program, it is generally the case that crew members or other participants in the fishery are usually ineligible for payments under a licence buyback/amalgamation program. The licence owner is usually the only recipient of any available funds.

The many intended and unintended consequences of a fishery restructure will naturally be affected by the design of the restructure. For example, determining who will be exiting (who the sellers are) will be a critical aspect of the program design. There are methods in which the sellers are determined by an *administrative approach* and other methods in which sellers are determined in a *market–based process*.

Administrative processes, of the sort currently used by PIRSA to allocate aquaculture tenure, rely on administrative discretion in either formal or informal settings. The main advantages of this method are that it can be quick and potentially has a low administrative cost.

In contrast to administrative processes, formally designed auctions (market-based approach) have the advantage of being based on a large body of systematic scientific research. Well-designed auctions can promote efficient acquisition of licences without requiring the entity financing the program to have prior knowledge of licence values or costs. Compared with administrative processes, auctions are more transparent and less dependent on subjective judgment, and can yield cost savings to whoever is financing the program. There are, however, drawbacks with auctions that need to be recognised. In some circumstances administrative processes can be quick and be implemented at low cost.

Another important consideration would be around how many vessels/licences should be removed? The analysis reported in this paper considered a reduction from 22 to 14 (Scenarios 2 and 3) and a reduction from 22 to 17 (Scenario 4). However, neither of these may be the optimal number or the best performing of possible options. Further analysis of what is the optimal outcome under what conditions would be required.

8. Case Study 2: Gulf St Vincent Blue Crab Fishery Summer Fishing Trial

Method

A key objective of this study was to estimate net benefits of the BC GSV summer fishing trial. Two proposed scenarios were compared against a base case scenario within the framework of a cost benefit analysis (CBA). The standard CBA method involves the specification of a base case against which scenarios are compared.

The CBA conducted for this project conforms to South Australian and Commonwealth Government guidelines for conducting evaluations of public sector projects (Department of Treasury and Finance (2008) and Department of Finance and Administration (2006)).

The starting point for the CBA was to develop the 'base case' scenario, that is, the benchmark against which the summer fishing scenarios were compared. It is important to note that the base case is not a 'spend nothing' or 'do nothing' scenario. Given that costs and benefits were specified in real terms (i.e. constant 2019 dollars), future values were converted to present values by applying a discount rate of 6 per cent. The choice of discount rate is consistent with the rate commonly used by the South Australian Government in this type of analysis.

The analysis was conducted over a 10-year period and results were expressed in terms of net benefits, that is, the incremental benefits and costs of the scenarios relative to those generated by the base case.

The evaluation criterion employed for this analysis is the present value (PV) of net economic return (NER) estimated over a 10-year period. The NER is defined as the difference between the price of a good produced using a natural resource and the unit cost of turning that natural resource into the good. In this case the natural resource is the Blue Crab Gulf St Vincent Fishery and the good produced is the landed Blue Crab. The unit costs or long term costs all need to be covered if a licence holder is to remain in the fishery. These long-term costs include direct operating costs such as fuel, labour (including the opportunity cost of a self-employed fisher's own labour), ice, overheads such as administration and licence fees, and the cost of capital invested in the boat and gear (excluding licence). Capital costs includes depreciation and the opportunity cost of the capital applied to the fishery. The opportunity cost is equivalent to what the fisher's investment could have earned in the next best alternative use.

Determining the opportunity cost of capital involves an assessment of the degree of financial risk involved in the activity. For a risk-free operation, an appropriate opportunity cost of capital might be the long-term real rate of return on government bonds. The greater the risks involved, the greater is the necessary return on capital to justify the investment in that particular activity. For this analysis the long term (10-year) real rate of return on government (treasury) bonds of 5 per cent has been used and a risk premium of 5 per cent has been applied.

The decision rule for a CBA is that a scenario, or option, is considered to be potentially viable if the NER is greater than zero. In this analysis, the NER of the options (Scenarios 1 and 2) are calculated and compared to the NER of the Base Case scenario. The NER for scenario i has been calculated as an incremental NER, using the formulation:

PV of NER_i = (PV (scenario$_i$ income – 'baseline' income) – (PV (scenario$_i$ costs – 'baseline' costs))

Summer Fishing Trial Scenarios

Scenario description

The summer fishing trial enables the continuation of commercial fishing during the regulated seasonal closure in GSV by Blue Crab licences holders. The summer fishing trial has been in place for the 2015/16 to 2018/19 years.

Base Case: No summer fishing

Scenario 1: With summer fishing

Scenario 2: With summer fishing as under Scenario 1 and target months with highest CPUE.

Data

As previously mentioned, BDO EconSearch has been reporting economic indicators for the SA Blue Crab Pot Fishery for the last 20-years. This has provided a consistent time series of economic information for the fishery. Data from the most recent report titled *Economic and Social Indicators for the South Australian Blue Crab Fishery 2017/18* (BDO EconSearch 2019b) has been utilised for the purpose of this report.

The total financial performance for the SA Blue Crab Fishery in 2017/18 (Table 11) was used to derive financial performance estimates per boat and per pot lift (also shown in Table 11). These estimates were derived using a range of primary and secondary data and survey-based 2016/17 indicators (licence holder survey undertaken in 2018). The following information was used to adjust the survey-based indicators to reflect the fishery's performance in 2017/18:

- SARDI data were used to reflect changes in catch and its value between years. Catch and price data were used to estimate the average total boat income in the fishery.
- Information on change in fishing effort (number of days fished) between years was used to adjust the cost of inputs that were assumed to vary with fishing effort. These inputs included fuel, repairs and maintenance, ice and provisions.
- The consumer price index (CPI) for Adelaide and components of the CPI were used to adjust the cost of inputs to reflect local levels of inflation (ABS 2019).

Table 11 Financial performance in the Blue Crab Fishery, 2017/18 [a]

		Fishery Total	Per Pot Lift
(1)	**Total Fishery Income**	$7,831,463	$50.61
	Variable Costs		
	Fuel	$470,572	$3.04
	Repairs & Maintenance [b]	$421,366	$2.72
	Ice	$106,069	$0.69
	Provisions	$37,191	$0.24
	Labour - paid	$1,597,514	$10.32
(2)	Labour - unpaid [c]	$58,917	$0.38
	Other	$7,633	$0.05
(3)	**Total Variable Costs**	$2,699,261	$17.44
	Fixed Costs		
	Licence Fee	$286,718	$1.85
	Insurance	$179,500	$1.16
(4)	Interest	$362,390	$2.34
(5)	Labour - unpaid [c]	$15,687	$0.10
	Leasing	$45,844	$0.30
	Legal & Accounting	$40,838	$0.26
	Telephone etc.	$12,191	$0.08
	Slipping & Mooring	$89,462	$0.58
	Travel	$11,302	$0.07
	Office & Admin	$88,931	$0.57
(6)	**Total Fixed Costs**	$1,132,864	$7.32
(7)	**Total Fishery Cash Costs (3 + 6)**	$3,832,125	$24.77
	Fishery Gross Margin (1 - 3)	$5,132,203	$33.17
(8)	**Total Unpaid Labour (2 + 5)**	$74,604	$0.48
	Gross Operating Surplus (1 - 7 + 8)	$4,073,942	$26.33
(9)	**Fishery Cash Income (1 - 7)**	$3,999,338	$25.85
(10)	**Depreciation**	$1,098,514	$7.10
(11)	**Fishery Business Profit (9 - 10)**	$2,900,824	$18.75
(12)	**Profit at Full Equity (11 + 4)**	$3,309,059	$21.39
	Boat Capital		
(13)	Fishing Gear & Equip	$5,628,834	$36.38
	Licence Value	$30,688,025	$198.33
(14)	**Total Boat Capital**	$36,316,859	$234.70
	Rate of Return on Fishing Gear & Equip (12 / 13 * 100)	58.8%	58.8%
	Rate of Return on Total Boat Capital (12 / 14 * 100)	9.1%	9.1%

[a] Financial performance estimates for 2017/18 were based on the 2018 licence holder survey. All figures are in nominal terms.

[b] Repairs and maintenance costs have been classified as variable although it is noted that some of these costs may be fixed.

[c] Unpaid labour was divided between variable (time spent on fishing and repairs and maintenance) and fixed (management and administrative duties) costs based on survey responses.

Source: BDO EconSearch (2019b)

Additional data on Blue Crab catch, price and CPUE were sourced from SARDI for the 11-year period, 2007/08 to 2017/18.

Total catch was held constant under the Base Case and both scenarios (TACC of 245t).

Average price and CPUE across the 11 years (2007/08 to 2017/18), as detailed in Table 12, was also held constant under the Base Case and both scenarios.

Table 12 Average monthly price and CPUE for Blue Crab (2007/08 to 2017/18)

	Price ($/kg) [a]	CPUE (kg/pot lift)
July	8.34	2.89
August	8.73	3.06
September	8.70	3.15
October	8.94	2.39
November	9.45	2.32
December	11.99	2.34
January	9.06	3.82
February	8.08	4.32
March	8.43	3.86
April	9.08	3.44
May	8.53	2.89
June	8.29	2.51

[a] Real 2017/18 terms.
Source: SARDI

Monthly catch under the scenarios, as detailed in Table 13, was as follows:

Base Case: No summer fishing. Average monthly catch pattern over the period before summer fishing was trialled (2007/08 to 2014/15).

Scenario 1: With summer fishing. Taking an equal amount of catch from the 10 months under the Base Case and allocate this catch evenly across November and December.

Scenario 2: With summer fishing as under Scenario 1 and target months with highest CPUE (January to April).

Monthly catch patterns (Table 13) and average prices (Table 12) were used to calculate monthly gross value of production (GVP). This information was then used to calculate income and costs that vary with income (i.e. paid labour).

Monthly catch per unit effort (CPUE) and catch were used to calculate number of pot lifts. This information was then used to calculate costs that vary by pot lift (i.e. fuel and bait and ice).

Fixed costs, depreciation and value of capital are fixed per boat and were evenly divided across the 12 months.

This information was used to estimate the incremental net economic return (NER) for each scenario.

Table 13 Monthly catch, Base Case and Scenarios 1 and 2

	Price ($/kg) [a]	CPUE (kg/pot lift)
July	8.34	2.89
August	8.73	3.06
September	8.70	3.15
October	8.94	2.39
November	9.45	2.32
December	11.99	2.34
January	9.06	3.82
February	8.08	4.32
March	8.43	3.86
April	9.08	3.44
May	8.53	2.89
June	8.29	2.51

Source: SARDI

Results

Scenario 1, allowing summer fishing, will result in net economic return (NER) over 10 years additional to the Base Case of $0.35m.

Scenario 2, allowing summer fishing and targeting months with highest CPUE, will result in NER over 10 years additional to the Base Case of $0.58m.

The results show that it is a worthwhile option to permanently allow summer fishing. Furthermore, by targeting effort in months when CPUE is the highest will result in the most benefit for the fishery. Note costs involved with changing the regulations to permanently allow summer fishing have not been included, but these are likely to be minor.

Sensitivity Analysis

The results of the analysis were re-estimated using values for key variables that reflect the uncertainty of those variables. The sensitivity analysis included the following:

- discount rate
- price
- variable costs

The range of values used for each uncertain variable and detailed results of the sensitivity analysis are set out below with some interpretation of the results. Note that each sensitivity analysis for each variable was undertaken by holding all other variables constant at their ‘expected’ values. The assumptions and results of the sensitivity analysis are summarised and described in the following sections.

Discount rate

The incremental NER is specified in real terms (i.e. constant 2019 dollars) and future values are converted to present values by applying a discount rate of 6 per cent. A sensitivity analysis was conducted using discount rates of 4 and 8 per cent (Table 14).

Table 14 Sensitivity analysis for discount rate - present value of incremental NER [a]

Discount rate	Scenario 1 NER ($m)	Scenario 2 NER ($m)
4%	0.38	0.63
6% [b]	0.35	0.58
8%	0.32	0.54

[a] In 2019 dollars.

[b] Expected value.

Source: BDO EconSearch analysis

As expected, the incremental NER for each scenario improves with the lower (4 per cent) discount rate. This occurs because the benefits that accrue over later years are greater, in present value terms, when the discount rate is lower. However, the results of the analysis are shown to be insensitive to the discount rate. This is principally because the analysis has been undertaken over a relatively short 10-year period and the flow of benefits and costs are constant over that period, i.e. there is no significant investment at the start of the period (both scenarios involve a change in regulation) and future stream of net benefits are neither increasing nor decreasing over time.

Price

One uncertainty in this analysis is the price received for Blue Crabs over the summer months. This sensitivity analysis was undertaken to identify the how the incremental NER would change with a 10 per cent increase or decrease in average price between November and January (Table 15).

Table 15 Sensitivity analysis for summer price - present value of incremental NER [a]

Percentage change in average price	Average Price ($/kg)	Scenario 1 NER ($m)	Scenario 2 NER ($m)
-10%	9.15	0.04	0.17
0% [b]	10.17	0.35	0.58
10%	11.18	0.65	1.00

[a] In 2019 dollars.

[b] Expected value.

Source: BDO EconSearch analysis

The results of the analysis are quite sensitive to changes in the average price received for Blue Crabs over the summer months. If there was a 10 per cent decrease in average price over these months, both scenarios of summer fishing would still be preferable to the Base Case of no summer fishing however, Scenario 1 would be only just preferred.

Note that average monthly prices provided by SARDI are based on wholesale prices received at the Adelaide market. Evidence from licence holders suggests a large proportion of the catch is marketed either at the Sydney or Melbourne markets, where prices received are considerably higher than can be obtained at the Adelaide market. However, a reasonable amount of product in still marketed in Adelaide.

Variable costs

A further uncertainty in this analysis is the cost of operation during the summer months, November to January. Difficulties were encountered relating to the rules of the trial regarding no fishing on weekends and public holidays and no baiting of pots during these times. These requirements made it more difficult to fish in a cost effective manner (SABCPFA pers. comm.). The inconvenience of complying with the requirements of summer fishing is difficult to quantify and was not costed in the analysis. For this reason a sensitivity analysis was undertaken to identify how the incremental NER would change with modelled increases in variable fishing costs.

The results of the analysis are shown in Table 16 for 10 and 20 per cent increases in variable costs. Variable labour costs were excluded from the sensitivity analysis as these are directly related to value of catch. However, fuel, repairs and maintenance, bait and ice, provisions and other variable costs were all included.

Table 16 Sensitivity analysis for summer cost of fishing - present value of incremental NER [a]

Percentage change in summer month non-labour variable costs [b]	Summer month non-labour variable costs ($/pot lift)	Scenario 1 NER ($m)	Scenario 2 NER ($m)
0% [c]	$6.74	0.35	0.58
10%	$7.41	0.24	0.45
20%	$8.09	0.14	0.32

[a] In 2019 dollars.

[b] Non-labour variable costs include fuel, repairs and maintenance, bait and ice, provisions and other variable costs.

[c] Expected value.

Source: BDO EconSearch analysis

The results of the analysis are moderately sensitive to changes in the average variable cost of fishing for Blue Crabs over the summer months. However, even with a 20 per cent increase in average costs over these months, both scenarios of summer fishing are still preferable to the Base Case of no summer fishing.

The analysis was extended to identify the “threshold” increase in variable costs that would deem each scenarios break even, i.e. the point at which the incremental NER would be equal to $0.0m. Scenario 1 would be breakeven if the costs of fishing during the summer months were 33 per cent higher than expected. For Scenario 2, the breakeven increase in non-labour, variable fishing costs was found to be 44 per cent.

Implications for Industry and Fisheries Management

Clearly As stated in the *Management Plan* for the fishery, the economic objective of managing the fishery is to *maintain a flow of economic benefit from the fishery to the broader community* (PIRSA 2018).

The purpose of this analysis was to assess the economic benefit of permanently allowing summer fishing in GSV compared to a base case of continuing current management arrangements. This analysis is a relatively simple application of including economic analysis in fisheries management decision making, to shed light on the implications of management change. It requires only limited data (namely catch and effort by month separated for GSV) in addition to that which is already collected as part of the annual economic indicators report (BDO EconSearch 2019b).

The framework is standard cost benefit analysis (CBA). The key features of which are:

- defined base case and options.
- Analysis undertaken over time. The time period for this analysis is 10 years but this can vary according to the issue. The time period was not so important in this analysis because there are no large investment costs at the beginning and the stream of benefits and costs are constant over time.

- Method for comparing different options, in this case management changes to a base case or status quo.

The results show that it is a worthwhile option to permanently allow summer fishing. Furthermore, by targeting effort in months when CPUE is the highest will result in the greater benefit for the fishery. The sensitivity analysis suggests that these conclusions hold while varying key assumptions across a reasonable range.

Note that the costs involved with changing the regulations to permanently allow summer fishing have not been included, but these are likely to be minor in this case. Also, the “inconvenience” of complying with the requirements of summer fishing (not fishing on weekends and public holidays, etc.) was not costed although this was addressed in the sensitivity analysis which showed that a significant increase in operating costs during the summer months would be required to change the overall results.

9. Case Study 3: Cost Benefit Analysis of Alternatives to Current FIS Program at Tiparra Reef[17]

Method

Cost benefit analysis provides the framework for the analysis. This section describes the scenarios and base case in terms of the activities that take place under each and the associated costs and benefits.

The following assumptions are consistent across all scenarios:

- Price is independent of catch volume.
- Response of biomass to reduced TACC (see Table 21).
- FIS method and locations.

The current FIS program is considered to generate data with a high level of confidence.

- Choosing an alternative would reduce confidence in the data for stock assessment in most cases.
- Reduced confidence in the data would lead to a more uncertain assessment and more conservative TACC.
- Increased confidence in the data would lead to a less uncertain assessment and a less conservative TACC.
- Lower TACC means lower GVP and harvest cost in the short-run (assume lower gross operating surplus (GOS)).
- Reduced catch leads to increased biomass in the long-run, allowing a decrease in variable harvest cost i.e. lower cost to harvest a given volume.

These assumptions are considered reasonable and valid. However we note the confidence in the results is dependent on the degree of confidence in the assumptions on which they are based.

While the cost of collecting and analysing data (data cost) varies across scenarios, the lowest cost doesn't necessarily have the greatest net economic value as the benefits also need to be considered. There are two alternate ways of comparing the scenarios that will be used in the analysis: net present value (NPV) and threshold analysis.

Net Present Value (NPV)

Considered positive if the *present value of cost savings is greater than the present value of the associated reduction in GOS over the period of analysis*. r is the discount rate and Δ represents change relative to the base case in the same year.

$$NPV = \sum_{t=1}^{20}\left(\frac{\Delta GVP_t - \Delta Harvest\ Cost_t - \Delta Data\ Cost_t}{(1+r)^t}\right)$$

A 20-year time horizon was selected to allow time for the 6-year transition under data logger scenarios, the subsequent 10-year response to changed TACC and multiple survey cycles under each scenario.

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[17] The full case study is reported in BDO EconSearch (2020b).

Threshold Analysis

Threshold analysis fixes the NPV at zero under each scenario and allows an assumption to vary to identify the value necessary to achieve an NPV of zero (i.e. the 'break-even' value for the variable). The assumption that was allowed to vary in this analysis was the reduction in TACC relative to the base case under each scenario. This was included as there is substantial uncertainty around the value of logger data for stock assessment. The threshold analysis allows the following type of statement to be made about each scenario:

- *Scenario A* will produce a positive NPV as long as TACC reduces by less than x%.
- *Scenario B* will produce a positive NPV as long as TACC increases by at least x%.

This gives useful context to the uncertainty around changes to TACC under each scenario.

As TACC changes over time under most scenarios, the assumption was varied by multiplying the TACC reduction for all years of each scenario by a single multiplier and varying that. The resulting threshold value for that multiplier determines whether the direction and/or size of the effect described by the assumption needs to be changed to achieve an NPV of zero (break-even). The resulting multiplier values can be interpreted as follows:

Less than 0	The direction of the effect needs to be reversed.
Value of 0	The effect needs to be removed.
Between 0 and 1	The size of the effect needs to be reduced.
Value of 1	The effect already achieves an NPV of zero so doesn't need to change.
Over 1	The size of the effect needs to be increased.

For example, the Ind scenario has an expected TACC value of 80 per cent relative to the base case in all years (Table 20). If threshold analysis produced a multiplier value of 0.5 then the effect on TACC would need to be halved (so TACC reduces to 90 per cent of the base case) in order to achieve an NPV of zero. If threshold analysis produced a value of 1.5 then the effect would need to be increased to 150 per cent of the assumed value (so TACC reduced by 70 per cent relative to the base case).

Scenarios

Eight scenarios were analysed and compared to the base case (BC). They fit within three categories:

- **Use of data loggers** – the suitability of logger data for stock assessment is uncertain and the subject of ongoing research. Loggers were used in conjunction with FIS data in the successful recovery of the Victorian Western Zone Abalone Fishery following the 2006 AVG outbreak and were subsequently incorporated (alongside FIS and all other available data) into the regular TACC decisions (FRDC 2012). However, it is uncertain whether logger data can replace data from FIS entirely, or whether they need to be supplemented by a schedule of FIS. For example, they have been used in Tasmania for some time but are not yet able to be used directly in TACC setting (Caleb Gardner pers. comm.). Data logger scenarios with no supplementary FIS (DL), biennial FIS (DL2), triennial FIS (DL3) and quinquennial FIS (DL5) are included in this analysis to ensure that, given future gains in knowledge, at least one workable logger data scenario is included. In addition, a second DL2 scenario (DL2*) was added to include a more favourable assumption about the value of logger data for stock assessment.
- **Use of industry equipment and labour** – two scenarios are included for integration of industry equipment and labour into the survey: complete replacement (Ind) and partial replacement (I+S).
- **Less frequent FIS** – reducing the frequency of the FIS is a simple modification of the base case and one scenario with triennial FIS is analysed (FIS3).

Table 17 Timeline for each scenario [a]

Year	BC	DL2*	DL2	DL3	DL5	DL	Ind	I+S	FIS3
2018/19	FIS	DL+FIS •	DL+FIS	DL+FIS	DL+FIS	DL+FIS	Survey •	Survey •	FIS
2019/20		DL	DL	DL	DL	DL			
2020/21	FIS	DL+FIS	DL+FIS	DL+FIS	DL+FIS	DL+FIS	Survey	Survey	•
2021/22		DL	DL	DL	DL	DL			FIS
2022/23	FIS	DL+FIS	DL+FIS	DL+FIS	DL+FIS	DL+FIS	Survey	Survey	
2023/24		DL	DL	DL	DL	DL			
2024/25	FIS	DL+FIS	DL+FIS •	DL •	DL •	DL •	Survey	Survey	FIS
2025/26		DL	DL	DL+FIS	DL	DL			
2026/27	FIS	DL+FIS	DL+FIS	DL	DL	DL	Survey	Survey	
2027/28		DL	DL	DL	DL+FIS	DL			FIS
2028/29	FIS	DL+FIS	DL+FIS	DL+FIS	DL	DL	Survey	Survey	
2029/30		DL	DL	DL	DL	DL			
2030/31	FIS	DL+FIS	DL+FIS	DL	DL	DL	Survey	Survey	FIS
2031/32		DL	DL	DL+FIS	DL	DL			
2032/33	FIS	DL+FIS	DL+FIS	DL	DL+FIS	DL	Survey	Survey	
2033/34		DL	DL	DL	DL	DL			FIS
2034/35	FIS	DL+FIS	DL+FIS	DL+FIS	DL	DL	Survey	Survey	
2035/36		DL	DL	DL	DL	DL			
2036/37	FIS	DL+FIS	DL+FIS	DL	DL	DL	Survey	Survey	FIS[a]
2037/38		DL	DL	DL+FIS[a]	DL+FIS[a]	DL			

[a] The cost of FIS is scaled down to compensate for the fact that only one year of benefit is realised from this cycle. For example, with a triennial FIS there is a cost every three years and benefits arise for three years. If the cycle is cut short by the period of analysis, then the cost needs to be adjusted proportionally. This is equivalent to including a residual value of capital at the end of the period of analysis where the FIS is considered capital that is replaced every survey period.

• First year that TACC has the potential to be affected under this scenario.

Base Case (BC)

SARDI carries out a biennial FIS over the 20-year period of analysis. The FIS includes: survey design, data collection and analysis. Each FIS collects data from 55 locations around Tiparra Reef, the locations are the same each time the FIS is carried out. At a high-level, data collection at each location includes the following:

1. lay a 100m leaded line on the ocean floor using a specified start point and direction
2. two divers swim along the line (one each side) and count and measure the Abalone lying within one meter of the line, measuring instruments and well-defined rules are used to ensure consistency
3. move to a new location and repeat steps 1 and 2.

The time taken to complete all 55 locations varies each FIS as a result of varying conditions but SARDI divers usually complete at least 8 locations per day. As this CBA focuses on the 'cost to industry', the component that is cost-recovered from industry though licence fees is used in the analysis.

Data Loggers (DL)

Data loggers are provided, maintained and replaced by SARDI and operated by Abalone divers in year 1 and continuously thereafter. SARDI develops and operates analysis based on data from data loggers. FIS is carried out by SARDI biennially for a period of 6 years (3 surveys) and SARDI uses it to validate (or modify) the new analysis and provide input to the harvest decision for those 6 years. Subsequently, in this scenario, it is assumed that data loggers will replace FIS completely in the harvest decision from year 7 so any effect on TACC will begin in year 7. This represents the scenario where confidence in the use of data loggers for stock assessment increases rapidly over the next few years such that it is considered to be sufficient without a regular supplementary FIS, but with the reduced confidence in stock assessments reflected in reduced TACC.

Data Loggers and Biennial FIS (DL2)

Data loggers are provided, maintained and replaced by SARDI and operated by Abalone divers in year 1 and continuously thereafter. SARDI develops and operates analysis based on data from data loggers. FIS is carried out by SARDI biennially, as with the base case. For the first 6 years, the logger program is focused on developing and validating a method for integrating logger data into stock assessment. Subsequently, in this scenario, FIS and data logger data will be used together in the harvest decision. Any effect on TACC will occur from year 7. This represents a scenario where confidence in data loggers for stock assessment does not increase enough over the next few years for use without a regular supplementary FIS but does increase enough to increase confidence in stock assessment overall, reflected in high TACC.

Data Loggers and Biennial FIS – Higher Value of Logger Data (DL2*)

As with DL2 except that some additional information is incorporated from logger data immediately increasing the value of data available for stock assessment. Subsequently, in this scenario, FIS and data logger data will be used together in the harvest decision. Any effect on TACC will occur immediately and will increase after the first 6-year validation period. This represents a scenario where confidence in data loggers for stock assessment does not increase enough over the next few years for use without a regular supplementary FIS.

Data Loggers and Triennial FIS (DL3)

Data loggers are provided, maintained and replaced by SARDI and operated by Abalone divers in year 1 and continuously thereafter. SARDI develops and operates analysis based on data from data loggers. FIS is carried out by SARDI biennially for a period of 6 years (3 surveys) and SARDI uses it to validate the new analysis and provide input to the harvest decision for those 6 years. Subsequently, in this scenario, it is assumed that FIS frequency will reduce to every 3 years from year 7 and FIS and data logger data will be used in the harvest decision. Any effect on TACC will occur from year 7. This represents the scenario where confidence in data loggers for stock assessment does not increase enough over the next few years for use without a regular supplementary FIS.

Data Loggers and Quinquennial FIS (DL5)

Data loggers are provided, maintained and replaced by SARDI and operated by Abalone divers in year 1 and continuously thereafter. SARDI develops and operates analysis based on data from data loggers. FIS is carried out by SARDI biennially for a period of 6 years (3 surveys) and SARDI uses it to validate the new analysis and provide input to the harvest decision for those 6 years. Subsequently, in this scenario, it is assumed that FIS frequency will reduce to every 5 years from year 7 and FIS and data logger data will be used in the harvest decision. Any effect on TACC will occur from year 7. This represents the scenario mid-way between DL and DL3 – confidence in data loggers for stock assessment increases a little over the next few years, sufficient for use with occasional (quinquennial) supplementary FIS.

Biennial Industry Survey (Ind)

SARDI designs the survey the same as under the base case but industry carries out data collection with industry boats and divers. The data are used for the harvest strategy in the same way currently planned for FIS data. Some initial investment in training of industry divers by SARDI divers will be required. SARDI will also carry out data validation by re-sampling some of the locations.

Biennial Industry+SARDI Survey (I+S)

SARDI designs the survey the same as under the base case but shares the task of data collection with industry by using industry boats and coordinated data collection between industry and SARDI divers. SARDI divers will provide ongoing training to industry divers during data collection. The data are used for the harvest strategy in the same way currently planned for FIS data. Some initial investment in training of industry divers and boat survey upgrade will be required.

Triennial FIS (FIS3)

FIS modified by reducing the frequency to triennial. Everything else remains the same as under the base case.

Costs and Benefits

Each scenario uses different combinations of data inputs leading to different levels of confidence in the results. Collecting and analysing different sets of data would incur different costs, such as one-off investment, labour, maintenance, data entry and analysis costs. In addition, if the TACC changes under a scenario then variable harvest costs would also change. Table 18 lists the costs and benefits that vary across the scenarios and are quantified in the analysis.

Table 18 Costs and benefits

Scenario(s)	Investment cost (agent[a])	Ongoing cost (agent[a])	Benefit (agent[a])
BC FIS3	None	FIS design (SARDI) FIS data collection (SARDI) FIS data entry, validation and analysis (SARDI) Variable harvest costs (Industry)	GVP (Industry)
DL[b] DL2* DL2 DL3 DL5	Data logger purchase and setup (SARDI)	Data logger program and maintenance (SARDI) FIS design (SARDI) FIS data collection (SARDI) FIS data entry, validation and analysis (SARDI) Variable harvest costs (Industry)	GVP (Industry)
Ind	Diver training on FIS data collection (SARDI)	FIS data collection (Industry) FIS data analysis (SARDI) Variable harvest costs (Industry)	GVP (Industry)
I+S	Diver training on FIS data collection (SARDI) Industry boat survey upgrade costs (Industry)	FIS design (SARDI) FIS data collection (SARDI) FIS data entry, validation and analysis (SARDI) Variable harvest costs (Industry)	GVP (Industry)

[a] Given the cost-recovery arrangements in the fishery, the costs attributed to SARDI above are ultimately incident on industry through cost recovery.

[b] FIS costs are only during transition (6 years) under the DL scenario (see Table 17).

Data and Assumptions

Data used to quantify the costs and benefits described above were collected from a variety of sources. Each is described in this section.

Data cost estimates

Estimates of the data costs identified in Table 18 were directly made by the agent identified in the table. For example, SARDI provided data logger program and FIS costs, industry provided costs for using industry capital and people to carry out the survey. The estimated data collection costs under each scenario are presented in Table 19.

Table 19 Assumed data collection costs and data sources

Scenario(s)	Summary of costs (with data source in brackets)
BC	**Every two years** FIS design ($3,865) (SARDI) FIS data collection by SARDI ($67,395) (SARDI) FIS data entry, validation and analysis ($11,277) (SARDI) *TOTAL: $82,537*
FIS3	*As for BC but with FIS occurring every 3 years rather than 2.*
DL[a] DL2* DL2	**Every year** Data logger program ($44,789) (SARDI) Data logger replacement ($20,000 every fifth year and $2,000 every other year) (SARDI) Data logger operation cost to diver (negligible - part of a normal fishing day) (CZ and WZ) *TOTAL: $64,789 every fifth year and $46,789 every other year* **Every two years** FIS design ($3,865) (SARDI) FIS data collection by SARDI ($67,395) (SARDI) FIS data entry, validation and analysis ($11,277) (SARDI) *TOTAL: $82,537*
DL3 DL5	*As for DL2 but with FIS occurring every 3 (DL3) and 5 (DL5) years rather than 2.*
Ind	**One-off cost** SARDI cost to train industry divers ($35,967) (SARDI) *TOTAL: $35,967* **Every two years** FIS design ($3,865) (SARDI) FIS data collection by industry ($35,700) (CZ and WZ industry)[b] Validation of FIS data collection by SARDI ($25,706) (SARDI) FIS data entry, validation and analysis ($11,277) (SARDI) *TOTAL: $76,548*
I+S	**One-off cost** SARDI cost to train industry divers ($35,967) (SARDI) Industry vessel upgrade cost ($100,000) (SARDI) *TOTAL: $135,967* **Every two years** FIS design ($3,865) (SARDI) FIS data collection by industry ($27,200) (CZ and WZ industry)[b] FIS data collection and validation by SARDI ($26,814) (SARDI) FIS data entry, validation and analysis ($11,277) (SARDI) *TOTAL: $69,156*

[a] FIS costs are only during transition (6 years) under the DL scenario (see Table 17).

[b] The CZ and WZ estimates were very similar with ranges overlapping. The CZ estimate was used directly in the analysis and the sensitivity analysis covers the WZ estimates.

Assumed TACC under different scenarios

Perceptions of the likely TACC setting relative to the base case were collected from SARDI, fishery management and industry for each scenario. The values selected for the analysis are presented in Table 20 They result from the following factors:

1. combined estimates from SARDI and fishery management determine the final TACC values as they will likely determine the actual outcome (industry estimates are explored in sensitivity analysis)
    - under the DL scenarios this was a combination of confidence gained from adding DL information to stock assessment and confidence being lower from reduced frequency of FIS (other than under DL2* and DL2 where FIS frequency is unchanged). As the BC had TACC at 100% in all years, DL2 and DL2* had TACC >100% in some years as this was the most practical way to account for increased assessment confidence.
    - under the FIS3 scenario this was a due to reduced confidence due to less frequent FIS.

- under Ind and I+S scenarios this was due to lower confidence in data collected by industry divers rather than research divers with the confidence being lower in Ind due to the low level of data collected by research divers (limited to infrequent validation).

2. any decrease is gradual as data become older, increasing uncertainty over time
3. the change for logger scenarios is affected by a 5 per cent 'learning dividend', TACC increases by 5 percentage points relative to the base case after 5 years of use in the TACC decision
4. the change under a given scenario and year must equal the change in any other scenario that shares the same data collection history, other than DL2*.

Table 20 TACC under each scenario (% of base case TACC)

Year	BC	DL2*	DL2	DL3	DL5	DL[a]	Ind	I+S	FIS3
2018/19	100%	105%	100%	100%	100%	100%	80%	90%	100%
2019/20	100%	105%	100%	100%	100%	100%	80%	90%	100%
2020/21	100%	105%	100%	100%	100%	100%	80%	90%	85%
2021/22	100%	105%	100%	100%	100%	100%	80%	90%	85%
2022/23	100%	105%	100%	100%	100%	100%	80%	90%	85%
2023/24	100%	110%	100%	100%	100%	100%	80%	90%	85%
2024/25	100%	110%	105%	90%	90%	90%	80%	90%	85%
2025/26	100%	110%	105%	90%	85%	85%	80%	90%	85%
2026/27	100%	110%	105%	90%	85%	85%	80%	90%	85%
2027/28	100%	110%	105%	90%	85%	80%[a]	80%	90%	85%
2028/29	100%	110%	105%	90%	85%	80%[a]	80%	90%	85%
2029/30	100%	110%	110%	95%	90%	85%	80%	90%	85%
2030/31	100%	110%	110%	95%	90%	85%	80%	90%	85%
2031/32	100%	110%	110%	95%	90%	85%	80%	90%	85%
2032/33	100%	110%	110%	95%	90%	85%	80%	90%	85%
2033/34	100%	110%	110%	95%	90%	85%	80%	90%	85%
2034/35	100%	110%	110%	95%	90%	85%	80%	90%	85%
2035/36	100%	110%	110%	95%	90%	85%	80%	90%	85%
2036/37	100%	110%	110%	95%	90%	85%	80%	90%	85%
2037/38	100%	110%	110%	95%	90%	85%	80%	90%	85%

[a] The profile of TACC reduction for the DL case requires some explanation. Between 2024/25 and 2026/27, the DL case is constrained by the DL5 case as the data activities are identical, so their effect on TACC must be too. In 2027/28 and 2028/29, the profile reaches its full reduction to 80 per cent. In 2028/29, the TACC reduction moderates by 5 percentage points due to the 'learning dividend'.

Source: BDO EconSearch analysis based on consultation with SARDI and PIRSA Fisheries and Aquaculture

Assumed response of biomass to reduced TACC

Accurately determining the improvement in the biomass that would result from a decrease in TACC would require scientific modelling that is beyond the scope of this study. In place of this type of model, a survey of perceptions of people familiar with the fishery was taken including SARDI, fishery management and industry. A schedule of response was estimated for various TACC reductions over 10 years. That is, how much larger would the biomass be in 10 years if TACC was reduced by a given amount? The data collected were similar across respondents. The assumed schedule of response is presented in Table 21.

Table 21 Assumed response of biomass to 10 year sustained TACC reduction

TACC Reduction	Biomass Response After 10 Years
0%	0%
10%	10%
20%	20%
30%	30%
40%	40%
50%	45%

Source: BDO EconSearch analysis based on consultation with industry and SARDI and PIRSA Fisheries and Aquaculture

Assumed effect of improved biomass on the fishery

The effect of an improved biomass on the fishery was modelled by assuming that CPUE increases by 50% of the improvement in the biomass. For example, reducing TACC by 20 per cent for 10 years would improve the biomass by 20 per cent at the end of the period and increase CPUE by 10 per cent for subsequent years. This was modelled by reducing variable harvest cost by 10 per cent. This is a conservative estimate for increase in CPUE due to an improved biomass.

Industry harvest cost estimates

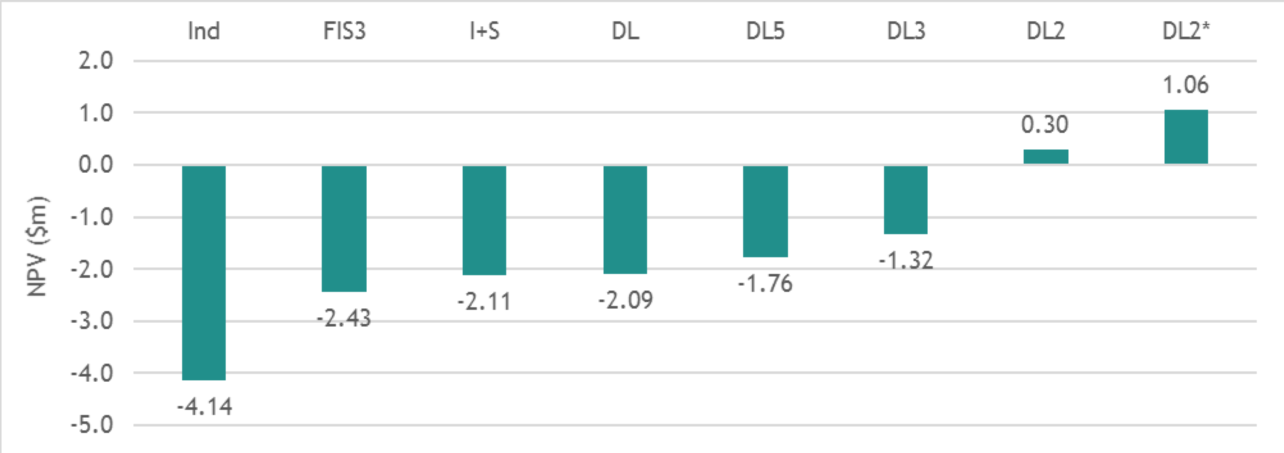
Estimates of the fixed costs of running an Abalone fishing business in the CZ and of the variable harvest cost for Abalone at Tiparra Reef were estimated using data from BDO EconSearch (2017) and Burnell & Mayfield (2017). The fixed cost attributable to Tiparra Reef ($577,000/yr) was estimated by multiplying the total fixed cost for CZ Abalone fishing businesses in 2016/17 by the 10-year average contribution to total CZ catch taken at Tiparra Reef (36.7 per cent). The variable harvest cost ($4.65/kg) was estimated by dividing the total variable cost of CZ Abalone fishing businesses in 2016/17 by the total catch in the CZ in the same year.

Results

Net Present Value

The NPV for each of the eight scenarios is presented in Figure 1. The results show, with a 20-year time horizon and 7 per cent discount rate, only DL2 and DL2* represent a positive net economic benefit compared to the base case. The NPV is negative for the remaining scenarios, indicating that the base case is preferred to each.

Figure 1 **Net present value (NPV) under each scenario**

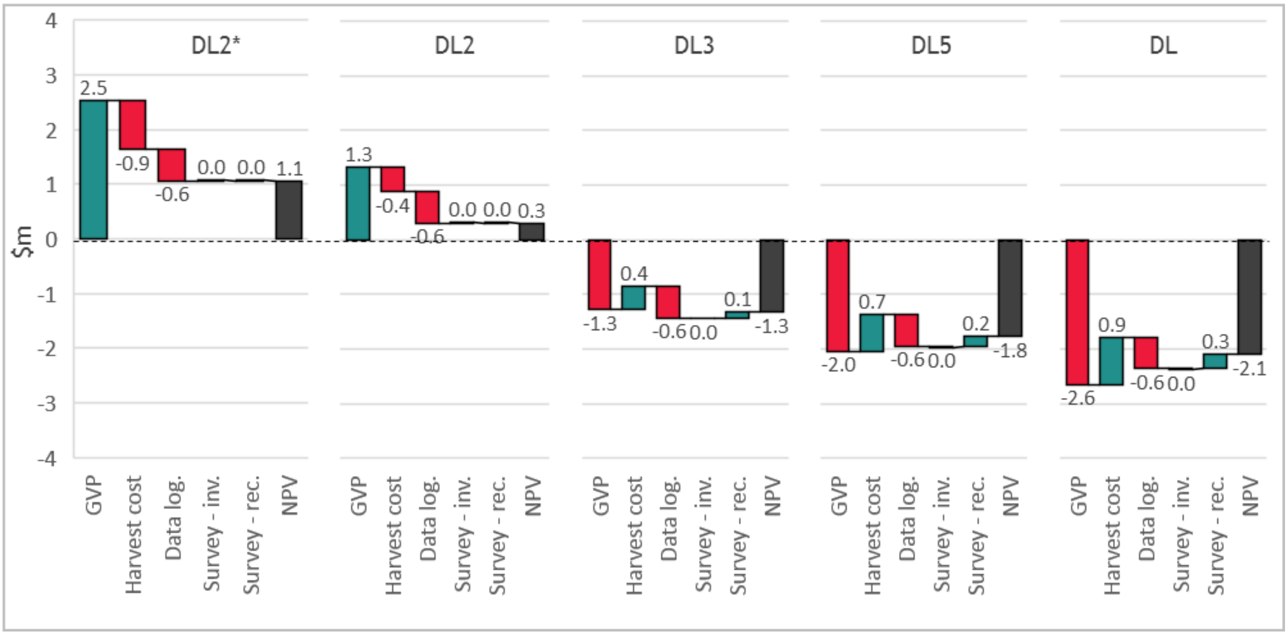


Source: BDO EconSearch analysis

The NPV for each scenario is deconstructed in Figure 2 (for data logger scenarios) and Figure 3 (for other scenarios) to illustrate the factors that determine these results. Each of the charts shows the NPV in grey on the right-hand side and the contribution of six different components towards it (GVP, harvest cost, data logger cost, survey investment cost and recurring survey cost). A green bar indicates a positive contribution to NPV, a red bar indicates a negative contribution and the cumulative sum is represented by the black joining line (as components are added from left to right). Each contribution can be interpreted as the present value over 20 years relative to the base case, discounted with a 7 per cent discount rate.

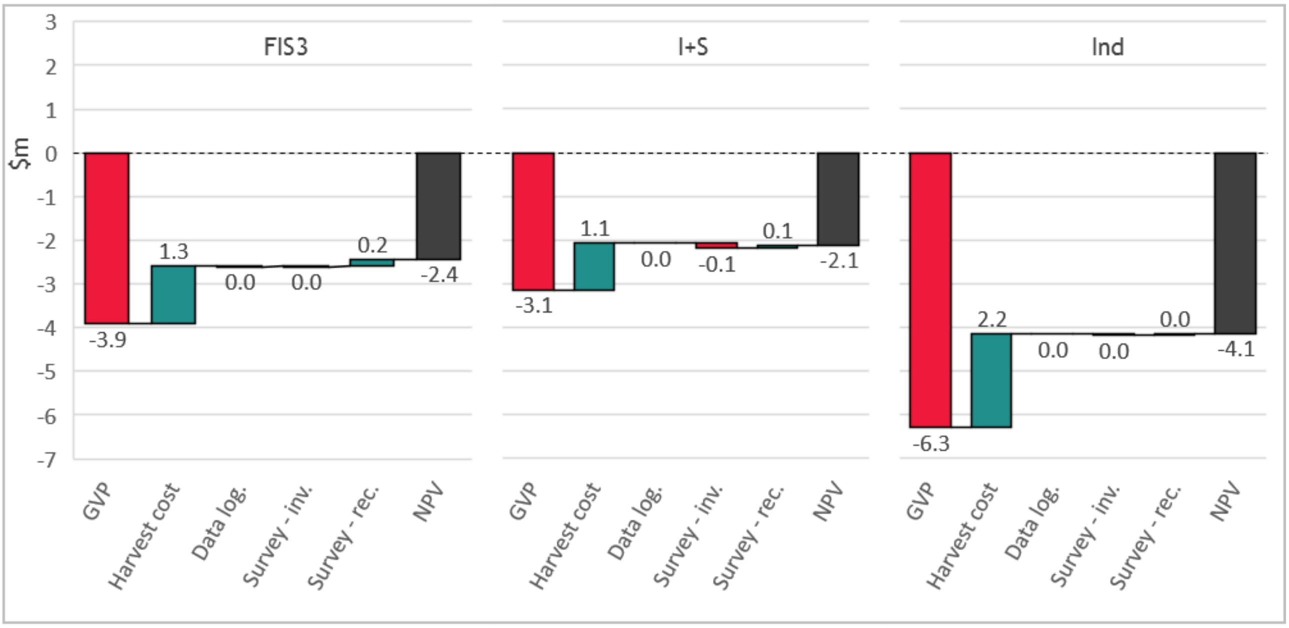
For example, DL3 has an NPV of -$1.3m as the negative contributions from decreased GVP (-$1.3m) and data logger costs (-$0.6m) outweigh the positive contributions from decreased harvest cost ($0.4m) and decreased recurring survey cost ($0.1m). DL2* has an NPV of $1.1m as the positive contribution from increased GVP ($2.5m) outweighs the negative contributions from increased harvest cost (-$0.9m) and data logger costs (-$0.6m) (Figure 2).

Figure 2 **Deconstruction of net present value ($m) under data logger scenarios**



Source: BDO EconSearch analysis

Figure 3 Deconstruction of net present value ($m) under industry and modified FIS scenarios



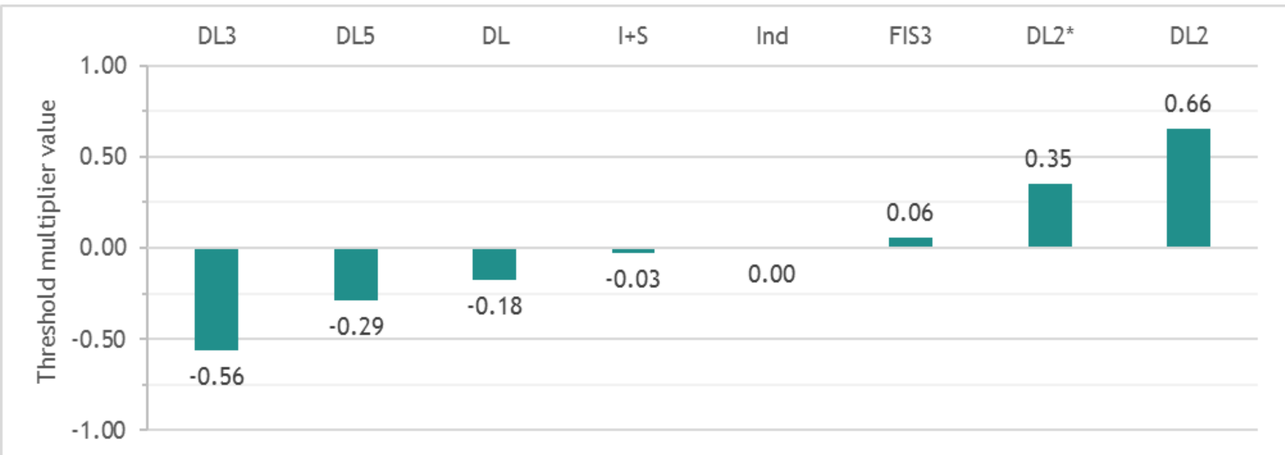
Source: BDO EconSearch analysis

Threshold Analysis

The threshold TACC multiplier values are presented in Figure 4. The following observations can be made:

1. Under the DL3, DL5, DL and I+S scenarios the negative effect on TACC needs to be reversed to reach an NPV of zero. This means that these scenarios would be preferred to the base case only if TACC increased. It is assumed to decrease due to a loss of information in the model.
2. Under the Ind scenario an NPV of zero is reached if the effect on TACC is removed. This is due to the data collection costs being very similar to those under the Base Case.
3. Under the FIS3 scenario the negative effect on TACC needs to be reduced substantially (to 6 per cent of its assumed magnitude) to reach an NPV of zero. The TACC can still be slightly negative as data collection costs are lower under the FIS3 scenario than under the Base Case.
4. Under the DL2* and DL2 scenarios the positive effect on TACC could decrease to 35 per cent and 66 per cent of its magnitude (respectively) before the NPV reduces to zero. This is because these scenarios have positive NPVs.

Figure 4 Threshold value for TACC reduction multiplier under each scenario



Source: BDO EconSearch analysis

The interpretation of the multiplier values in Figure 4 is non-intuitive as the multipliers affect a varying profile of effect on TACC over time, rather than a single value. The profiles of effect on TACC relative to the base case implied by the TACC multiplier thresholds in Figure 4 are presented Table 22 to illustrate the implications of the threshold multiplier values for each scenario. For example, scenario DL2* is preferred to the base case if TACC increases to 102 per cent of the base case in year one and to 103 per cent of the base case in year 6.

Table 22 ‘Break-even’ TACC profile under each scenario (% of base case TACC)

Year	BC	DL2*	DL2	DL3	DL5	DL	Ind	I+S	FIS3
2018/19	100%	102%	100%	100%	100%	100%	100%	100%	100%
2019/20	100%	102%	100%	100%	100%	100%	100%	100%	100%
2020/21	100%	102%	100%	100%	100%	100%	100%	100%	99%
2021/22	100%	102%	100%	100%	100%	100%	100%	100%	99%
2022/23	100%	102%	100%	100%	100%	100%	100%	100%	99%
2023/24	100%	104%	100%	100%	100%	100%	100%	100%	99%
2024/25	100%	104%	103%	106%	103%	102%	100%	100%	99%
2025/26	100%	104%	103%	106%	104%	103%	100%	100%	99%
2026/27	100%	104%	103%	106%	104%	103%	100%	100%	99%
2027/28	100%	104%	103%	106%	104%	104%	100%	100%	99%
2028/29	100%	104%	103%	106%	104%	104%	100%	100%	99%
2029/30	100%	104%	107%	103%	103%	103%	100%	100%	99%
2030/31	100%	104%	107%	103%	103%	103%	100%	100%	99%
2031/32	100%	104%	107%	103%	103%	103%	100%	100%	99%
2032/33	100%	104%	107%	103%	103%	103%	100%	100%	99%
2033/34	100%	104%	107%	103%	103%	103%	100%	100%	99%
2034/35	100%	104%	107%	103%	103%	103%	100%	100%	99%
2035/36	100%	104%	107%	103%	103%	103%	100%	100%	99%
2036/37	100%	104%	107%	103%	103%	103%	100%	100%	99%
2037/38	100%	104%	107%	103%	103%	103%	100%	100%	99%

Source: BDO EconSearch analysis

Sensitivity Analysis

The sensitivity of the NPV under each scenario to key assumptions is presented in Table 23. The green shaded ‘Mid’ rows show the assumed value for each variable. Alternative discount rates (a) were selected based on other commonly used values. Coefficients (b, c and d) were varied up and down by 50 per cent. Number of days to complete survey under I+S and Ind scenarios (e) was selected based on the current SARDI days (6.9 days), mid-point of industry expectations (8.5 days) and upper bound of industry expectations (11 days). Assumed vessel survey upgrade cost under Ind scenario (f) was varied by 100 per cent.

Two additional cases were tested to remove two assumed effects entirely:

- Assume the TACC is unchanged between the scenarios and base case (bottom row of panel b ‘zero’). This assumption removes all benefits and only compares the cost of data collection.
- Assume the biomass is not affected by the change in TACC (bottom row of panel c ‘zero’). This removes the moderating effect on NPV of TACC reductions leading to reduced harvest costs through improved biomass.

Table 23 Sensitivity analysis – net present value ($m)

(a) Discount rate

	Discount rate	DL2*	DL2	DL3	DL5	DL	I+S	Ind	FIS3
High	10%	0.84	0.15	-1.05	-1.37	-1.59	-1.79	-3.46	-1.94
Mid	7%	1.06	0.30	-1.32	-1.76	-2.09	-2.11	-4.14	-2.43
Low	4%	1.38	0.53	-1.71	-2.33	-2.82	-2.56	-5.09	-3.11

(b) Multiplier for TACC reduction assumption

	Multiplier value	DL2*	DL2	DL3	DL5	DL	I+S	Ind	FIS3
High	150%	1.87	0.74	-1.75	-2.45	-2.99	-3.15	-6.25	-3.74
Mid	100%	1.06	0.30	-1.32	-1.76	-2.09	-2.11	-4.14	-2.43
Low	50%	0.25	-0.14	-0.90	-1.08	-1.20	-1.08	-2.05	-1.13
Zero	0%	-0.58	-0.58	-0.47	-0.39	-0.31	-0.06	-0.00	0.15

(c) Multiplier for assumed response of biomass to TACC reduction

	Multiplier value	DL2*	DL2	DL3	DL5	DL	I+S	Ind	FIS3
High	150%	1.00	0.28	-1.31	-1.74	-2.06	-2.04	-4.01	-2.35
Mid	100%	1.06	0.30	-1.32	-1.76	-2.09	-2.11	-4.14	-2.43
Low	50%	1.13	0.32	-1.34	-1.79	-2.13	-2.18	-4.26	-2.50
Zero	0%	1.19	0.35	-1.36	-1.82	-2.16	-2.25	-4.39	-2.58

(d) Assumed response of harvest costs (or CPUE inversely) to biomass improvement

	Response	DL2*	DL2	DL3	DL5	DL	I+S	Ind	FIS3
High	75%	1.00	0.28	-1.31	-1.74	-2.06	-2.04	-4.01	-2.35
Mid	50%	1.06	0.30	-1.32	-1.76	-2.09	-2.11	-4.14	-2.43
Low	25%	1.13	0.32	-1.34	-1.79	-2.13	-2.18	-4.26	-2.50

(e) Assumed number of days to complete survey under Ind and I+S scenarios

	Days	DL2*	DL2	DL3	DL5	DL	I+S	Ind	FIS3
High	11.0	-	-	-	-	-	-2.20	-4.20	-
Mid	8.5	-	-	-	-	-	-2.11	-4.14	-
Low	6.9	-	-	-	-	-	-2.05	-4.10	-

(f) Assumed vessel survey upgrade cost under I+S scenario

	Cost	DL2*	DL2	DL3	DL5	DL	I+S	Ind	FIS3
High	$150,000	-	-	-	-	-	-2.21	-	-
Mid	$100,000	-	-	-	-	-	-2.11	-	-
Low	$50,000	-	-	-	-	-	-2.01	-	-

Source: BDO EconSearch analysis

NPV remains negative (red font) under all scenarios other than DL2 and DL2* (black font) across almost all sensitivities tested and is most sensitive to the TACC reduction assumption (b). NPV for the DL2 and DL2* scenarios remains positive across all assumptions other than a low or zero increase in TACC. The order and sign of NPVs across the scenarios remains unchanged under the zero biomass response case (bottom row of panel c).

Conclusions

Consistent with other cost-benefit analyses, the analyses undertaken in this report relied on numerous assumptions. While these assumptions are considered reasonable and valid, confidence in the results is dependent on the degree of confidence in the assumptions on which they are based. Given the assumptions, this analysis concludes that incorporating data loggers into the stock assessment and TACC decision for Tiparra reef would lead to a positive net economic benefit if the outcome was that logger data reduced assessment uncertainty and this was reflected in an increase in TACC of around 2 per cent for the first 5 years, and 4 per cent (relative to the base case) thereafter, assuming no change to current FIS data collection (DL2 and DL2*). This is because the modelled outputs show that the increase in TACC is sufficient to cover the cost of the data logger program, after accounting for the harvest cost increase associated with the TACC increase.

The use of data loggers in the recovery of the Victorian Western Zone Abalone Fishery following the 2006 AVG outbreak and their subsequent incorporation (alongside FIS and all other available data) into the regular TACC decision (FRDC 2012) suggests that their application for tracking changes in biomass may be possible. However, logger data have been collected in Tasmania for a decade but are not yet able to be used directly or indirectly in TACC setting (Caleb Gardner pers. comm.). An FRDC-funded project has been developed to quantify relationships among logger metrics, CPUE and FIS that will, in part, enable the use of biomass from loggers to be thoroughly tested and validated. Additional research into the value of logger data in stock assessment and the TACC decision process is recommended to improve knowledge of this key variable thereby strengthening the conclusions of this analysis.

This analysis also concludes that, since all other scenarios (DL3, DL5, DL, Ind, I+S and FIS3) have a negative NPV, the base case is preferred to each of them. This is because the cost of alternative data collection methods under each scenario (other than FIS3) is estimated to be greater than that under the base case. Further, each of these scenarios included an assumed decrease in TACC, which further decreased the NPV. For any of these scenarios to be preferred to the base case, the cost of collecting data would need to decrease and/or improvements made to reduce the negative impact on TACC.

The sensitivity analysis suggests that these conclusions hold while varying key assumptions across a reasonable range.

10. User Guide For Fisheries Managers - Is Your Fishery Suitable For Low Cost Economic Modelling?

Background

This project, *Building Economics into Fisheries Management Decision Making* (FRDC project: 2016-213), aims to develop a set of economic analysis guidelines that can be used at an individual fishery level to aid harvest strategy and other fisheries management decision making. A large gap has been identified between the current and optimal economic performance of wild-capture commercial fisheries in Australia. Economic approaches have the potential to assist fisheries to bridge this gap, such as bioeconomic models that combine biology with fishing costs to evaluate the economic performance of a broad range of management measures.

Although there is evidence that quantifiable economic benefits have accrued from applying formal bioeconomic models in Australian fisheries (Emery et al. 2017), there remain significant challenges to the implementation and ongoing use of economic analyses in most Australian fisheries. These include:

(i) short-term transition costs and associated trade-offs between ecological, economic, social and political objectives

(ii) scarce logistical and financial capacity to collect and analyse economic data

(iii) a lack of desire among industry to change and transition to economic targets such as maximum economic yield (MEY), particularly when it is associated with lower catches

(iv) a lack of economic literacy among fisheries managers and industry.

Bioeconomic models can be used to determine MEY and a trajectory for reaching this target reference point. For this a large dataset of biological and economic information is required and the industry needs to be profitable enough to continually revise and re-evaluate the MEY target as the industry cost structure and market price change through time.

In calculating MEY the use of complex bioeconomic models are often required. Key model parameters include biological carrying capacity (biomass at no fishing), biomass growth rate, fishing mortality rate, revenue and costs. Limitations of MEY models include:

- The need for a large quantity of data which are often difficult and costly to collect, especially with a small number of participants (to share the cost) and where data collection requires industry cooperation.
- Biology of the fishery needs to be well understood (e.g. known stock recruitment and growth rates).
- Changes in biomass from year to year are affected by natural growth (recruitment less natural mortality) and fishing. This can be difficult to measure/predict in fisheries with high environmental influence.
- Models are not always accurate in their predictions (even where good data exist) and even models that may be able to explain the past well may not be able to predict the future (a potential limitation of all models).
- Working in a multi-species fishery can add a significant degree of complexity to the modelling.

The aim of this project has been to demonstrate how economics can still be incorporated in fisheries management frameworks in lower value fisheries, with less resource to collect and model economic data than would be required to develop a full bioeconomic model.

This project has been based around a set of three case studies. The project team has worked directly with those fisheries, involving industry and managers – those involved in decision making. In this way the conduct of the project has comprised an extension of the project outcomes as the decision makers in the case study fisheries have been directly involved in the development and testing of the analytical tools.

Framework for Economic Analysis

Introduction

The importance of economics in explaining fisher behaviour and the overexploitation of fisheries resources has been well established. Fishing in anything other than a subsistence-based economy is an economic activity. The species that fishers target, the level of exploitation, and the gear that they use are all influenced by the benefits they receive (i.e. the revenue) and the costs they incur.

Fisheries management changes the set of incentives facing fishers, and in doing so changes their behaviour. In some cases, management imposes additional costs on their operation directly (e.g. limiting output, or inefficient technology mixes arising from input controls), while in other cases, costs are imposed indirectly through a new set of incentives created (e.g. displacement of fishers from one area has an impact on other fishers already operating in the areas to which they move). Changes in fisher behaviour not only influence the costs to the industry, but also may reduce the effectiveness of management itself when the expected outcomes are not achieved. As a result, assessment of the economic consequences of changes in fisheries management is becoming commonplace internationally.

Fisheries management is concerned with the optimal allocation of marine resources for the benefit of society. Economics provides a framework for such an optimal allocation of resources. It provides an approach to valuing the different activities, allowing trade-offs between activities to be assessed and impacts to be measured in a consistent manner.

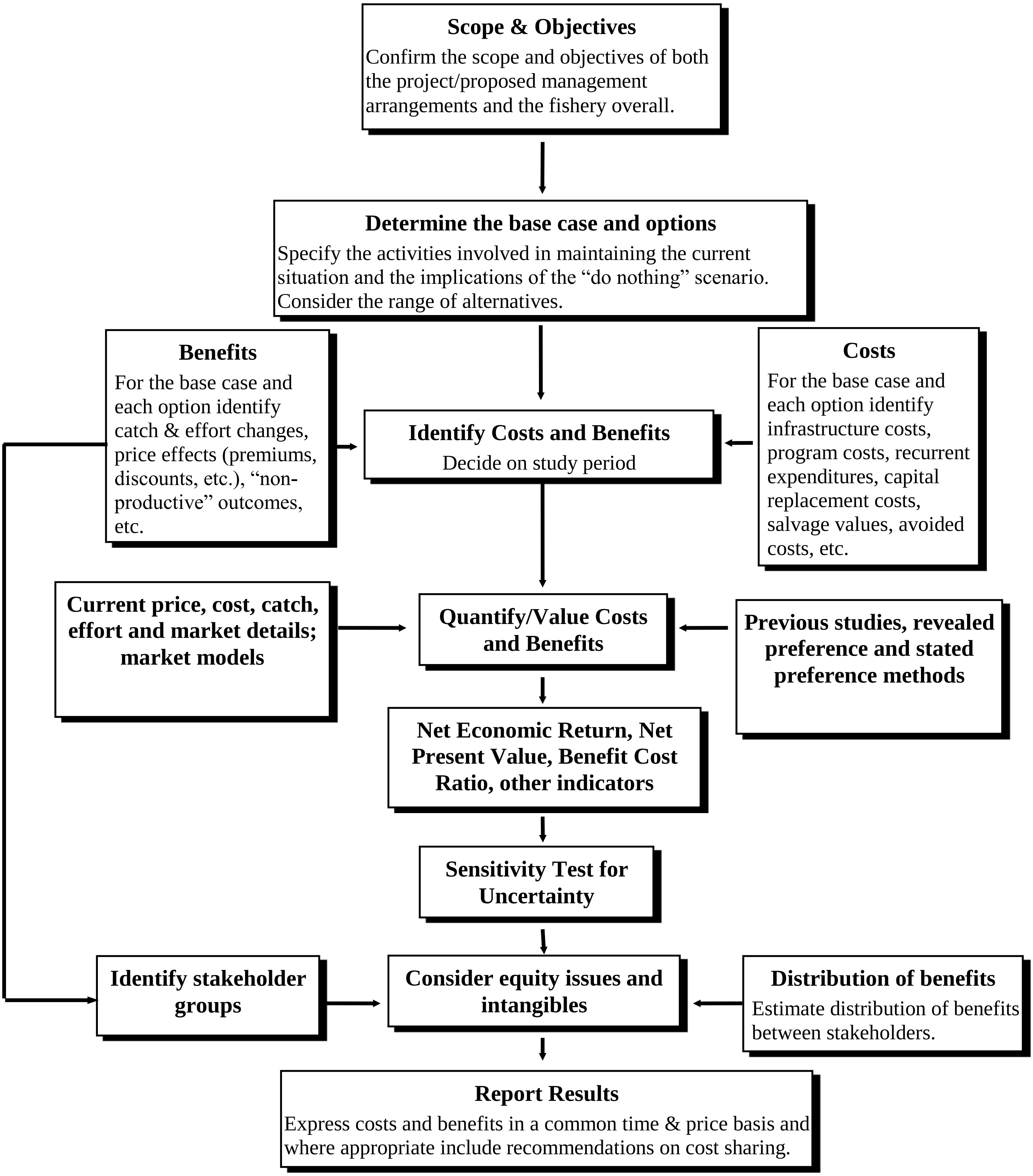
Economics can play a role in assessing the likely outcomes of different management options on the varied groups, based on the incentives they create. Further, economic instruments (e.g. rights-based management, user charges) may provide an appropriate means of ensuring efficient allocation of the resources between such competing groups.

There are a number of reasons why the successful inclusion of economic analysis has been constrained in practical fisheries management decision making. Many of these challenges (short-term transition costs, limited capacity to collect and analyse economic data initially, lack of desire among industry to change and transition to economic targets, etc.) arise from an absence of clearly identified and prioritised economic objectives within overarching legislation and management plans. Once economic objectives are prioritised, limited resources can be allocated more efficiently to improve data collection, economic analysis and increase awareness as well as education of managers and industry (Emery et al 2017).

Basic Framework

The idea that most people, much of the time, make decisions based on their evaluation of the benefits and costs of alternatives is central to economic thinking. This thinking is equally relevant when we think more broadly about how society's limited resources should be allocated. Cost benefit analysis (CBA) provides a structured framework for comparing the economic effects of different allocations of resources, and can provide useful input to the decision making process. The basic steps in a CBA are outlined in Figure 5.

Figure 5 Basic steps in cost benefit analysis



Economic analysis for decision making only needs to be undertaken to the depth necessary to accurately represent the issue in question. For example, three depths (gross margins, partial budget and discounted cash flow) are described below and are appropriate for three different types of decisions.

Fishery Gross Margin (FGM)

Gross margins provide a simple method for measuring the performance of an individual enterprise (or a fishery). A gross margin refers to the total income derived for an individual fishing business or the fishery as whole for a given period of time (usually one year) less the variable costs incurred in the enterprise. Gross margins are appropriate for short-term (i.e. daily, monthly, annual) decision making about small adjustments that do not affect the structure of a fishery.

Partial Budget

There are alternatives to the relatively atypical and specialised FGM approach. These approaches could be considered intermediate or halfway houses between the FGM model and a fully specified bioeconomic model. Partial budgeting approaches, for example, could be used for incremental or relatively simple changes to a harvest strategy. In comparison to the FGM approach, the partial budgeting method would take account of changes in capital requirements, consider changes in all costs and revenues, evaluate changes in asset values, and include indicators such as return on investment and change in net economic return (economic rent). A partial budget approach is appropriate for decision making where there are structural, but relatively short-term (i.e. one or two years), implications for a fishery.

Discounted Cash Flow (Cost Benefit Analysis)

More complex changes are likely to be characterised by longer time frames, more significant changes in the level of capital and labour employed in the fishery and have significant implications for the way the fishery operates. In these circumstances, a discounted cash flow analysis may be a more appropriate approach as it includes a formal consideration of time and the 'money value of time', enabling the direct comparison of multiple options that have different timelines (such as different transition periods). The typical discounted cash flow analysis will have a number of indicators or evaluation criteria to compare alternative management actions. These include:

- Net present value (NPV) – discounted[18] option benefits less discounted option costs. Under this decision rule an option is considered to be potentially viable if the NPV is greater than zero. The NPV for option *i* is calculated as an incremental NPV, using the standard formulation[19]:

  $NPV_i = (PV\ (option_i\ benefits - \text{'base case' } benefits) - (PV\ (option_i\ costs - \text{'base case' } costs))$

- Benefit-cost ratio (BCR) – the ratio of the present value of benefits to the present value of costs. Under this decision rule option *i* is considered to be potentially viable if the BCR is greater than one. The ratio is expressed as:

  $BCR_i = PV\ (option_i\ benefits - \text{'base case' } benefits) / PV\ (option_i\ costs - \text{'base case' } costs)$

- Internal rate of return (IRR) – the discount rate at which the NPV of a project is equal to zero. Under this decision rule an option is considered to be potentially viable if the IRR is greater than the benchmark discount rate.

Net present value can be expressed as:

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18 Discounting refers to the process of adjusting future benefits and costs to their equivalent present-day values (Sinden and Thampapillai 1995).

19 Base case represents the costs and benefits of the existing activity in the fishery involved in maintaining the current management arrangements.

$$NPV = \sum_{n=0}^{N} \frac{B_n - C_n}{(1+r)^n}$$

where B_n = benefits in year n expressed in constant[20] dollars

C_n = costs in year n expressed in constant dollars

r = real discount rate

N = number of years that costs and/or benefits are produced

Discounting recognises that there is value in receiving an amount of money today, as opposed to receiving it in, say, 5 years. Likewise, incurring a cost today is more costly than incurring the same cost in the future as the money could be put to other productive uses in the meantime. The sum of the discounted costs and benefits in a cash stream is the net present value (NPV) of the cash stream – that is, the net value of the cash stream over its life, in today's dollars.

The rate at which costs and benefits are discounted is a subject of ongoing debate as it can have a significant impact of evaluation results. A standard rate of 7 per cent is currently used by the Commonwealth and most State Governments for public sector project appraisals. The standard rate used by Government is set at a level to maintain a 'level playing field' between public and private sectors, so that public sector investment does not displace higher-yielding private investment. This method of 'setting' the discount rate is based on the concept of the 'social opportunity cost' of capital. An alternative concept for setting the discount rate is to use the concept of a 'social time preference' rate, which represents society's preference for present as against future consumption.

When private decisions are made which fail to take account of the needs of future generations the social time preference rate will be lower than the private time preference rate (Department of Finance and Administration (2006) and Department of Treasury and Finance (2008)). Fisheries management typically focuses on the long-term sustainability of marine resources and implicitly on the needs of future generations. In the context of these analyses, it may be appropriate to use a discount rate based on a social time preference rate rather than one based on the social opportunity cost. A discount rate of 3 or 4 per cent is often used in a sensitivity analysis as the lower end value, although some analysts have argued it may be justifiable to use these values (rather than 6 or 7 per cent) as the default rate in the analyses regarding the long-term sustainability of natural resources such as fisheries.

Guidelines

The types of calculations or considerations which need to be made in a partial budgeting and discounted cash flow approaches are listed below. This is a guide only, not a recipe, simply an indication of the logical flow of elements to consider in such an analysis. In the context of considering change to current management arrangements or considering alternative actions within a harvest strategy, the focus should be on: (i) identifying the gains coming from the existing arrangements; and (ii) comparing these to the possible gains from new arrangements which might replace those currently in place.

General steps might include:

1. Establish economic objectives and indicators
2. Identify the base case and options
3. Identify costs and benefits

[20] Constant dollars means the values have been adjusted for any effects of inflation, i.e. any changes in prices, for example, will be separate from the effects of inflation (real price changes).

4. Establish the time frame
5. Quantify the costs and benefits
6. Calculate the indicators
7. Conduct sensitivity analysis
8. Take account of intangible factors
9. Rank the options
10. Reporting

Step 1: Establish Economic Objectives and Indicators

Establish a clear understanding of the economic objectives for the fishery and what indicator(s) or measure(s) will best reflect the objectives.

- What are the objectives set by legislation?
- What are the economic performance indicators of optimal and equitable management in the fishery?

The first step involves a description of the fishery in question, in qualitative and quantitative terms. What is its scale, and what are its key economic and biological characteristics? You may want to describe for the most recent year and for up to ten years (if data are available):

- species targeted in the fishery and annual catch
- number of licence holders (active and total)
- the condition of the fish stock
- its location
- broad management arrangements – types of input and output control methods (where relevant).

This process will involve reviews of the management plan, harvest strategy, stock assessment reports, economic reports and discussions with experts in the field. In determining the appropriate boundaries of the fishery in question, you may need to consider the underlying economic and biological processes; how 'connected' is the area in question to whole fishery and to local, regional and state economies. Do they need to be considered together?

You will also need to consider any 'gaps' or uncertainties in knowledge of the environmental asset, and whether these are likely to be important to the analysis.

The idea here is to gain a good understanding of the asset in question and, by considering how it links in with other parts of the natural and man-made environment, determine the appropriate scope for the analysis of impacts.

Step 2: Identify the Base Case and Options

What problem are you trying to solve? Describe the fishery and relevant characteristics. How has it changed over time? How has it come to this?

This step requires you to provide a clear specification of the activities involved in maintaining the current arrangements (the base case). Although the base case may involve no change to the current arrangements, it does not mean the fishery will continue to "perform" at its current level. Further, the base case is unlikely to be a 'do nothing' scenario as maintaining current arrangements will likely involve continuing various programs and projects.

Consider the range of alternatives. What is the nature of the alternative management arrangements? How will they affect the performance of the fishery? Are they expected to change key variables such as harvest levels, catch rates, vessel numbers, fishing effort, cost of fishing, product prices and target markets?

For analysis of state or territory fisheries, the scope of the assessment of costs and benefits should extend to the entire state or territory. However, where there are likely to be flow-on effects to interstate businesses, consumers, governments or the wider community, including environmental spill overs, these should be taken into consideration. For example, increasing production in a fishery that exports through a port in a neighbouring state could lead to a positive impact on exporters in the export port state (from handling a greater volume) and a negative impact on other states that produce the same product (increased supply in their market, reducing price). The parties ultimately included in the scope of the assessment should be clearly identified.

Step 3: Identify Costs and Benefits

For the base case and each option, identify catch and effort, relevant price (premiums, discounts, etc.) and "non-productive" and intangible outcomes. Costs and benefits should be identified for all parties affected by the proposed option (i.e. industry, government, local community, etc.). It is useful to compile a table identifying the benefits under the base case and those under each of the options. Many of the quantifiable benefits, in particular gross income, will be relevant to both the base case and options but at different levels.

A useful presentation format for benefits is a table with the following column headings:

- Options
- Description of benefits
- Beneficiary
- Valued in $ terms
- Source of information.

A similar table can be constructed for costs with the second and third columns being 'Description of costs' and 'Bearer of costs', respectively. For the base case and each option identify infrastructure costs, program costs, recurrent expenditures, capital replacement costs, salvage values, avoided costs, etc.

Step 4: Establish the Time Frame

The total period over which impacts should be analysed needs to be sufficient to capture all potential costs and benefits of the proposed change. This will depend on the purpose of the change in management arrangements. For changes which will last in perpetuity it is suggested that the time frame be no longer than 20 years due to the difficulty of making informed estimates this far in advance (some environmental regulation and complex transitions may have longer time horizons and as such may be an exception to this generalised rule). For transitional arrangements the time frame should be the period up to when the new measures come into effect.

In some circumstances the changes may be relevant for only a single year. The fishery gross margin model applied in the SA Lakes and Coorong Pipi fishery has a one-year time horizon and is re-run annually.

Step 5: Quantify Costs and Benefits

The next step is to consider whether the cost and benefit estimates can be:

- valued in monetary terms; or
- estimated as quantity measures, where it is not possible to monetise; or
- qualitatively described, where quantification of any kind is not possible.

It is important to value as many of the impacts in monetary terms as possible. Monetised values will form the basis of the indicator calculations (such as NPV).

Where costs and benefits cannot be measured in dollar terms then the indicator calculations will need to be supplemented with further information about non-monetised costs and benefits.

Once all costs and benefits have, as far as possible, been converted into monetary values they should be entered into a spreadsheet and allocated to time periods taking into account how each cost and benefit will change over the time frame chosen at Step 4.

Determine as best as possible the relevant physical information and assumptions regarding catch and catch rate for the base case and alternatives. As noted earlier, this framework for economic analysis is relevant for fisheries where bioeconomic models are either unavailable or the capacity to maintain and update them is limited. In these circumstances there may still be stock assessment models, good quality data and analytical capacity available to provide any necessary information regarding catch and catch rates.

In any analysis it is important to separate operational from capital costs. Many management changes will involve some form of investment up front, whether it be in physical infrastructure, human capital (training and education) or the time and cost involved in developing and implementing new management arrangements.

Working closely with industry and scientific researchers/advisors is essential in this step.

Step 6: Calculate the Indicators

Calculate the relevant indicator(s) (specified at Step 1) reflecting the objectives e.g. establish the return on capital invested (including the costs associated with the alternative arrangements) and, if relevant, compare with other opportunities for investment.

Apply the indicator calculations to all the monetised impacts described in Step 5. In a cost benefit analysis, the NPV calculation allows the stream of costs and benefits calculated over the lifetime of the proposal to be converted to a single figure which demonstrates whether the proposal results in a net benefit to the community (subject to assessment of any costs and benefits which are not able to be monetised).

In order to be able to compare the different regulatory options the key economic indicator (e.g. NPV in a cost benefit analysis) is calculated for each option. Guidance on how to calculate the NPV of a proposal is provided in sub-section above entitled *Discounted Cash Flow*.

If, in the case of a cost benefit analysis, the NPV is positive, the policy improves community welfare. If the NPV is negative, the policy lessens community welfare. If not all costs and benefits can be valued in dollars, the NPV result for each option will need to be supplemented with information analysing the effects of non-monetised costs and benefits, as described above.

Step 7: Conduct Sensitivity Analysis

There may be considerable uncertainty about predicted impacts and their appropriate monetary valuations. Sensitivity analysis provides information about how changes in different variables will affect the overall costs and benefits of the regulatory proposal. It shows how sensitive calculated indicator values are to different values of uncertain variables and to changes in assumptions. It tests whether the uncertainty over the value of certain variables matters, identifying the critical assumptions.

Sensitivity analysis helps assess uncertainties in the regulatory proposal and determines reasonable expected values for costs and benefits. The process of considering and trying to quantify uncertainties is essential. It identifies risks to policy success, allowing decision makers to focus more attention on reducing those risks by reducing the uncertainty about them.

The first step in a sensitivity analysis is to substitute the estimates you have made for each cost and benefit item with the most pessimistic estimates you can justify. This should be done for each variable simultaneously to see how much the net present value is affected. If the decision rule for the indicator is still satisfied (e.g.

the NPV is still positive), then it may be concluded that even under worst case assumptions, the analysis supports the proposal.

The second step is to try to assess how risky the proposal is, that is, which variables significantly affect the economic indicators and which do not. This can be established by varying each variable one at a time, holding all other variables unchanged, and seeing which has the greatest effect on the indicator values.

Step 8: Take Account of Intangible Factors

The analysis of costs and benefits in a CBA (and in a fisheries gross margin or partial budget) sums the costs and benefits across individuals without regard to the distribution. This aspect of the analysis is directed at whether the proposal delivers a net benefit to society as a whole, rather than who receives the benefits or who pays the costs.

The way in which costs and benefits are distributed among various groups can also be important to decision makers. While the net benefit analysis cannot resolve equity issues, it can draw attention to them by describing the impacts of proposed policies on different groups. Agencies may choose to further analyse the regulatory impacts by sub-groupings, for example, it may be appropriate to group impacts by the size of business or community group, or different locations such as urban or rural.

If the information is available, a CBA and other forms of economic analysis can identify potential winners and losers and the magnitude of their gains and losses. It is then up to decision makers to decide whether distributional impacts or equity issues are important and need addressing. For example, the decision maker may decide to reject an option with the largest net benefit in NPV terms if it has significant adverse equity impacts. The reasons should be made explicit.

A single monetary value cannot be placed on the “cost” of less equitable outcomes or the “benefit” of more equitable outcomes. However, if information is available, the impacts may be able to be quantified and even monetised for each group (e.g. the cost to those in the bottom 20 per cent of the income distribution is $20 per week, whereas for those in the top 20 per cent of the income distribution it is $5 per week).

Before rejecting a proposal with adverse equity impacts, however, some consideration by decision makers may be given to the relative ease or difficulty of addressing the distributional issues through other means. If there are existing mechanisms which are able to significantly and relatively easily address inequities created by the most beneficial regulatory option, then that option should not be rejected immediately on the grounds of equity but given further due consideration.

Step 9: Rank the Options

Generally, the preferred option will be the one with the largest positive net benefit (NPV in the case of discounted cash flow analysis), subject to consideration of non-monetised costs and benefits and distributional issues.

While maximising the net benefits to the community (in NPV terms) is the primary objective, managers should be mindful also of the government’s objectives to reduce regulatory costs imposed on business. If two (or more) options have a similar net benefit NPV result, but the costs imposed on business vary considerably, consideration could be given to the lowest cost option even if not the option which maximises the net social benefit.

Furthermore, the sensitivity analysis might suggest that the option with the largest NPV is not necessarily the best under all circumstances. For example, proponent agencies might be more confident in recommending the option with a lower expected value of net benefits, but with a smaller chance of imposing a significant net cost on the community (lower ‘downside risks’).

Step 10: Reporting

Carefully explain the method, data and assumptions. Results (costs and benefits) of the base case and alternatives need to be expressed in a common time and price basis and, where appropriate, include recommendations on cost sharing. Calculated values for indicators should be interpreted and the results of the sensitivity analysis presented and interpreted. Providing context to recommendations is important, particularly where there are significant intangible or distributional factors that influence the ranking of options.

11. Checklist For Fisheries Managers - Is Your Fishery Suitable For Low Cost Economic Modelling?

The following check list is designed for use by fisheries managers to ascertain the suitability of their fishery for low cost economic modelling.

1. Are there clear economic objectives for the fishery and what measure(s) will best reflect the objectives?
2. Is there a clear picture of a proposal or option(s) for changing management arrangements to be considered? Has or can the problem to be addressed be clearly articulated? Is there agreement among industry, scientific community and other relevant stakeholders that the problem exists?
3. Is it possible to work with industry and the scientific industry to develop or refine the proposed options?
4. Is there available or does there exist relevant physical information (assumptions on catch and catch rate) that might vary between the current arrangements and the proposed, alternative arrangements?
5. Would it be possible to collect (or develop through informed assumptions) relevant prices and costs, particularly those that would be likely to vary between the current arrangements and the proposed, alternative arrangements?
6. Is it possible to identify (and value) any significant investment or changes in capital associated with the option or alternative arrangements?
7. Is there capacity and expertise available to undertake the analysis/modelling as outlined in the Guidelines (Chapter 10)?

12. Conclusion

There are significant challenges to the implementation and ongoing use of economic analyses in most Australian fisheries. Many of these challenges initially arise from an absence of clearly identified and prioritised objectives within overarching legislation and management plans. Once objectives are prioritised, limited resources can be allocated more efficiently to improve data collection, economic analysis and increase awareness as well as education of managers and industry (Emery et al. 2017).

There often appears to be some confusion among those involved in fisheries management as to the way economic data and economic indicators fit into the process. The case studies and guidelines developed for this report have illustrated how important it is for fisheries managers to work closely with industry groups and the scientific community when developing, for example, a draft harvest strategy.

The following general discussion points can be made from the conduct of this study and the three case studies in particular:

1. It was important to use a measure of profit like net present value (NPV) or gross operating surplus (GOS) as the economic performance indicator, rather than gross value of production (GVP). GVP is emphasised as a formal and informal performance indicator in fisheries management/assessments in Australia. However, the FIS case study showed that managers need to switch focus away from GVP and towards NPV if they want to make better decisions. Sometimes fishery performance can only be improved by reducing GVP so the mindset that higher GVP is always good for profit needs to be challenged.
2. Cost benefit techniques can be applied to better inform management decisions even in fisheries without complicated stock assessment models. Cost benefit is a basic technique and was applied in the case studies where some information was lacking. These were imperfect analyses yet still more informed than proceeding with only opinion. It enabled pre-conceptions to be tested and gave useful guidance. Sometimes best guesses were used as inputs and these were then subject to sensitivity testing. This is more transparent and objective than typical processes like "expert opinion".
3. Economic information can be used to improve management decision-making across far more than the traditional domain of fisheries economics, which is TACC setting. For example, in the FIS case study efficiency of different research data collection programs was explored.
4. Including economics in fisheries decision making is worthwhile because the cost of this research can be small compared to the gains in profit that could occur. Most fisheries incur large ongoing costs for biological monitoring yet forgo opportunities for higher profits by not testing whether management tweaks could raise economic returns to fishers.

The User Guide for fisheries managers provides a guide to the logical flow of elements to be considered in an economic analysis. The Guide can be used at an individual fishery level to aid harvest strategy and other fisheries management decision making.

A large gap has been identified between the current and optimal economic performance of wild-capture commercial fisheries in Australia. Economic approaches have the potential to assist fisheries to bridge this gap, and the User Guide provides a framework to incorporate economics into fishery management decision making, where a full bioeconomic model is not available.

13. Implications

The development of a checklist and a practical User Guide for fisheries managers will allow for cost effective techniques to be implemented and incorporate economic considerations into harvest strategies and other management decisions. As noted above, most fisheries incur large ongoing costs for biological monitoring yet forgo opportunities for higher profits by not testing whether management tweaks could raise economic returns to fishers. This is possible through the application of relatively inexpensive and intuitive economic modelling techniques.

14. Recommendations

The following are a potential set of Draft Harvest Strategy steps incorporating decision rules using economic data and indicators. These recommendations are made in the context of the principal aim of this project, namely to develop a set of economic analysis guidelines that can be used at an individual fishery level to aid harvest strategy and other fisheries management decision making. This is particularly relevant for lower value fisheries, with less resource to collect and model economic data than would be required to develop a full bioeconomic model.

1. If we assume we follow the objective set by legislation, what are the economic performance indicators of optimal and equitable management in the fishery? (and any other objectives like efficient management).
2. Agree on how this is to be measured and reported (this could be as simple as saying the existing surveys continue to measure and report indicators X, Y and Z).
3. Discuss if there are any trade-offs that affect the structure of the harvest strategy (for example, people tend to worry that decisions based on economic indicators may jeopardise sustainability, or what does the indicator mean for jobs?). Does the harvest strategy need some meta-statements? (like "biological limit reference points take precedence in harvest decisions").
4. Discuss and define reference points. This could lead to harvest strategies that depart considerably from the existing Commonwealth approach, which is mainly about biomass proxies for maximum economic yield (MEY). It may be reasonable to decide that reference points for economic indicators are not necessary, and that the test is simply whether the indicator can be increased. In this case the target reference point could be a rate of change, e.g. increase in economic yield of 2 per cent per annum above CPI.
5. Discuss decision rules. For example, a review of options to improve the fishery if the indicator declines by x% would be, in many circumstances, a useful decision rule. It would initiate discussion where no action would otherwise occur.
6. Test the harvest strategy against a range of possible scenarios. For example, does it promote change in-line with, for example, managing for continuity of supply, matching landings with transport availability, etc. Also, consideration needs to be given to some extreme situations and how the harvest strategy would deliver. For example, does maximising economic yield meet this objective if the fishery licences were foreign owned? What if production crashed with a disease? What if the exchange rate changed dramatically?

Perhaps finally worth noting that the development of harvest strategies for data-poor fisheries represents a significant challenge, namely reconciling available information and capacity against a formal and defensible harvest strategy that achieves the desired objectives for the resource and fishery (Dichmont et al. 2011; Dowling et al. 2011). The challenge, therefore, is developing harvest strategies that reconcile the reality and limitations of these fisheries with fishery objectives or policy (Emery et al. 2017). The judicious collection and analysis of economic data can guide decision making, even in an imperfect way, to better align outcomes with management objectives.

15. Extension and Adoption

SARDI was heavily involved and informed throughout the project. Dr Stephen Mayfield of SARDI was a co-investigator on the project along with Sean Sloan of PIRSA (at the time). The findings and outcomes will be presented at the International Institute of Fisheries Economics & Trade (IIFET) conference (2022), the Australian Agricultural and Resource Economics Society (AARES) conference (2022) and the National Seafood Directions conference (2021). A presentation will also be made at the World Fisheries Congress 2021, under the theme 'Public perception, social licence and economic value'.

Appendices

Investigators

- Dr Julian Morison, BDO EconSearch – Principle Investigator
- Associate Professor Caleb Gardner, University of Tasmania – Co-Investigator
- Dr Stephen Mayfield, SARDI – Co-Investigator
- Mr Roger Edwards, CORVEL Marketing and Management – Co-Investigator
- Mr Sean Sloan, PIRSA – Co-Investigator

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