Final Report

Retrospective assessment of ITQs to inform research needs and to improve their future design and performance

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FRDC Project No **2017-159**

ISBN 978-1-4863-1228-3

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FRDC 2017-159

2019

The Fisheries Research and Development Corporation plans, invests in and manages fisheries research and development throughout Australia. It is a statutory authority within the portfolio of the federal Minister for Agriculture, Fisheries and Forestry, jointly funded by the Australian Government and the fishing industry.

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Acknowledgments

The authors would like to thank the survey participants for providing the information for the study. Considerable assistance in recruiting survey participants was also provided by fisheries managers and industry representatives across the different jurisdictions. We would also like to thank Sarah Jennings and Emily Ogier for their assistance in developing the survey questionnaire.

Abbreviations

ITQ	Individual transferable (catch) quota
ITE	Individual transferable effort quota
TAC	Total allowable catch
TAE	Total allowable effort
BBN	Bayesian Belief Network
CPT	Conditional probability table

Executive Summary

What the report is about

The use of transferable fishing rights has increased internationally over recent decades with most industrialised countries now using some form of individual transferable catch quota (ITQ) or individual transferable effort (ITE) system for at least some of their fisheries. Australia also has considerable experience in the use of ITQs and ITEs, with examples of ITQ or ITE management in each State and also Commonwealth fisheries.

Perceptions of the success or otherwise of ITQ and ITE fisheries varies, but the key factors underlying success or failure of such programs have not been examined in a systematic way. The purpose in this study is to examine how ITQs and ITEs in Australia have performed relative to sustainability, economic and social criteria, and to determine what may be underlying these successes or failures. The study includes a review of international experiences with ITQ management as well as a description of the key ITQ and ITE fisheries in each jurisdiction. A survey of fishers, scientists and managers was undertaken to determine their perceptions around the performance of ITQs/ITEs, and to estimate what factors may contribute to these perceptions of performance.

Background

ITQs have been used in Australian fisheries since the mid-1980s. By 2000, every fisheries jurisdiction had at least one ITQ or ITE fishery, with most having several fisheries operated using rights-based management at this time.

ITQs have been credited with a number of potential benefits, particularly in relation to fisher incentives and allowing the fishery to adjust in response to changing biological and economic conditions without the need of further actions by managers to reduce fishing effort (i.e. autonomous adjustment). Most Australian ITQ fisheries have seen a reduction in vessel numbers since their introduction, and, where relevant economic data are available, an increase in vessel profitability has been seen in several fisheries.

While these economic benefits have been realised in some ITQ fisheries, others have seen less of an improvement in economic performance. Further, the very mechanism that aims to improve economic performance - autonomous adjustment - is believed to have resulted in adverse social impacts in some cases. For example, the high cost of quota can result in a barrier to entry for some sectors of the community, while concentration of quota ownership and decreasing fleet sizes may result in negative impacts on some regional communities.

Understanding the factors that influence the economic and social outcomes from an ITQ program will help design better programs in the future. This study represents an attempt to identify these key factors.

Aims/objectives

The objectives of the project were to:

1. Identify the extent of use (current and proposed) of ITQs in Australian fisheries;
2. Identify the demonstrable benefits to their use in Australia, and what outcomes have emerged that were largely unintended; and,

3. Identify critical knowledge gaps and further research needed to improve their future design and performance.

Methodology

The study involved several components. The first phase involved a review of international experiences of ITQ management to determine the experiences elsewhere in relation to sustainability, economic and social outcomes. The aim of the review was to identify key areas to explore in the Australian context, and aid the development of a subsequent survey (outlined below).

The second stage involved cataloguing ITQ and ITE fisheries in Australia. This was also largely review based, focusing on documentation produced by each jurisdiction about their fisheries as well as published case study material where available. Three case study fisheries were also examined in more detail: Tasmanian Abalone (ITQ), New South Wales Rock Lobster (ITQ) and the Commonwealth Northern Prawn Fishery (ITE).

The third stage involved a survey of fishers, scientists and managers in ITQ and ITE fisheries across Australia. As noted above, the questionnaire was based on the outcomes from the review of international experiences. Assistance was requested from key management and scientific agencies in each jurisdiction to distribute the questionnaire to an appropriate set of potential respondents. Industry organisations, where these could be identified, were also approached to help distribute the survey to key individuals.

These data were analysed to determine the perceptions of the industry and others about the functioning of the ITQ or ITE fishery that they were involved with. A Bayesian belief network (BBN) model was also developed linking the perceived outcomes of management with the social, economic and governance characteristics of the fishery. The BBN was used to identify which factors most contributed to successful outcomes in terms of sustainability, economic and social performance.

Key Findings

Extent of use

The review of ITQs and ITEs in Australia identified 31 ITQ and 6 ITE fisheries. These ranged in size from a relatively small number of operators (e.g. 4 fishers in the Queensland Bêche-de-mer) to a large number of operators (e.g. 251 in the Queensland Coral Reef Finfish fishery). ITQ fisheries were found in all jurisdictions. Most ITQ fisheries were single species in nature, although several multispecies fisheries were identified. Most ITE fisheries were prawn trawl fisheries.

Benefits and unexpected outcomes

Information on economic performance was limited, although there was some evidence that ITQ fisheries generally performed better in terms of rates of returns to capital than non-ITQ fisheries. Single species ITQ fisheries tended to perform better with respect to economic outcomes than multispecies ITQ fisheries. While few studies were available to test differences in economic performance of different groups of fisheries, qualitative data collected as part of this study (and case study information) suggests that lease dependent fishers were not receiving the same level of benefits as quota-owning fishers. Sustainability issues were not identified for any ITQ fishery although many sustainability-related knowledge gaps, such as lack of species-specific biological data and uncertainty in stock assessments, were identified by respondents.

Perceptions of performance also varied considerably between fisheries and also between individuals within a fishery. Overall, managers' perceived performance of ITQs and ITEs tend to be better than fishers and scientists. Nevertheless, most fishers (65%) believed that sustainability increased as a result of ITQs, with only around 15% believing that sustainability had decreased. Around half of the fishers believed that economic performance had increased as a result of ITQs/ITEs, although around 30% believed that economic performance was worse.

Overall, around 50% of respondents believed that the costs of introducing ITQs/ITEs exceeded the benefits, and only around 35% believed the benefits exceeded the costs. The Northern Prawn Fishery case study illustrated the potential benefits from setting economic targets in the fishery and also the benefits of creating a share system, even if effort based rather than catch based. The share system has enabled the establishment of a co-management arrangement through an industry-owned company to the benefit of the fishery shareholders.

Perceptions of social and governance performance of ITQs/ITEs were the lowest of the outcomes considered, with only around 40% believing that social and governance performance had improved (although only around 20% believed that these performed lower following ITQs/ITEs). Scientists had the lowest perception of social performance. Issues relating to the cost of quota and barriers this created to access the fishery to new fishers ranked relatively high in terms of social concerns associated with ITQs/ITEs, as did the governance concerns related to the uncertainties and potential inaccuracies of stock assessments. For fishers, and to some extent managers, perceptions of the performance of ITQs/ITEs tended to be worse with lower level of experience working in the fishery.

The BBN was used to determine the key drivers of success, and identify any factors that can be targeted to improve perceptions of performance. A key driver of success was the level of satisfaction with fishing, which in turn was influenced by the level of social relations, information sharing between fishers, and enjoyment gained from being part of the industry. Any improvement in these latter three factors can thus influence satisfaction levels and improve perceptions of ITQ/ITE performance, although it is not likely to be an easy task for fisheries managers to influence these social factors. Improving TAC setting process and greater use of economic information in TAC setting was also highly influential in determining overall performance. These two factors might be more easily influenced by fisheries managers. A third key area was the functioning of the quota market (both lease and permanent transfer), which were largely influenced by the accessibility and affordability of quota. The working of the quota market is the result of interactions between buyers and seller, meaning that fisheries managers can only influence the working of the market to a limited extend. They can for instance, provide tools or services that facilitate trade (e.g. the FisherDirect service in NSW) but they cannot directly influence quota price (i.e. affordability).

The key concerns focused on issues related to quota trading (concentration of ownership, investor ownership, foreign ownership, and availability/price of quota) and management (uncertainty in stock assessments, costs of management, and over-governing). The key benefits involved improved sustainability and improved economic efficiency (and higher profits) of the fleet.

The issue associated with separating quota ownership from active participation in fishing/diving was highlighted in the case study of the Tasmanian Abalone Fishery. Abalone divers believed that they were not getting any benefits from the ITQ system, with all the benefits flowing to the quota owners. The ITQ system has not lead to rationalisation of the number of active fishers/divers (because the diver licence is not linked to the quota ownership), just consolidation of quota ownership. An excess of divers competing for lease quota and the development of a power asymmetry between quota owners and leasing fishers, has forced down diver pay rates, with little long-term security of quota access. In contrast, the NSW Lobster Fishery, which has few investor quota owners, has experienced continual growth in economic performance with the benefits accruing mostly to the active fishers. While the fishery has benefited from higher international prices, cost decreases associated with improved stock conditions has been the dominant driver of the increase in fishery profitability.

Knowledge gaps and areas for further research

A range of knowledge gaps were identified by survey respondents and the literature review. From the survey, scientific and related management issues around appropriate data for stock assessments, particularly the availability of fishery independent data, tended to dominate. The need for better economic information, particularly in relation to quota and fish prices, was also strongly proposed by a large proportion of those surveyed. As noted above, the impact of quota ownership and concentration of quota ownership on the functioning of the quota market was not only highlighted as being a concern but also as a significant knowledge gap.

The key knowledge gaps and their associated research needs are summarised in the table below. The study also considered what may be needed to improve ITQ/ITE management in the future based on the outcomes from the survey, case studies and literature review. These key implications and their associated research needs are also included in the table below.

Knowledge gap	Research need
Lack of economic and other data and their appropriate use	• Increased routine collection of economic data (costs, earnings, prices, quota prices); • Cost-effective economic data collection methods; • Increased use of quota trading data to inform management (and development of methods to do so); • Increased use/availability of fishery independent data; • Reduced uncertainty in biological parameters; • Cost effective measures of social and economic management performance; • Collection/identification of appropriate social data; • Inclusion of economic data and social considerations into harvest strategies.

Knowledge gap	Research need
Quota ownership and quota markets	• Improved function of quota markets (identification of constraints, mechanisms that can improve access to quota); • Impact of non-fisher ownership of quota on fishery performance versus social performance (fisher incomes, satisfaction and livelihoods); • Impact of quota-ownership on stewardship and compliance; • Are limits on quota ownership potentially beneficial or counterproductive?
Complementary and conflicting management measures	• What additional management measures are needed to complement ITQs/ITEs; • What additional management measures conflict with ITQ management and produce unintended consequences.
How might we further improve ITQ/ITE management in the future?	• What are the key constraints to autonomous adjustment and can we identify these in a fishery before ITQs are introduced? • Is there a need (or benefits) for excess capacity to be removed before ITQs/ITEs are introduced? • If public funds are used to facilitate adjustment, what is an appropriate community return? • What are the most efficient mechanisms for dealing with discards and over-quota catch? • How do we best allocate quotas across different sectors (e.g. across jurisdictions? Between commercial and recreational fisheries?)

Implications for relevant stakeholders

The positive outcomes of Australian rights-based fisheries management on the environment and sustainability seem to be incontrovertible. The successful sustainability outcomes (and the continuation of stakeholder trust in the TAC setting process) hinges on transparently collected and accurate scientific information (minimising uncertainty and avoiding inaccuracies). Any improvements in the TAC setting process, including greater use of economic information, will be highly influential in determining overall fishery performance.

Similarly, the economic benefits that most directly link to ITQs/ITEs seem to apply to most Australian fisheries, with a high level of agreement between managers, scientists, and fishers on the gains in economic efficiency and profitability. The "T" in ITQ and ITE has proven to be both a key factor affecting economic performance and sustainability of the fishery, but also a key source of contention when quota markets are not efficient. The key indicators of quota market efficiency were availability and affordability of quota, both of which are influenced by concentration of quota ownership, particularly by investors. The relationship between quota concentration and the effectiveness of the quota market was identified as an important knowledge gap and an area for future research.

Negative governance and social outcomes of ITQs/ITEs are often held up as unintended consequences of the ITQ/ITE approach to fisheries management. Although in this study we do not investigate the appropriateness, or not, of allocating private property rights *per se*, we do indeed find that the social and governance outcomes of ITQs/ITEs are not perceived to be as great as the economic and sustainability outcomes. Social relations and fishers' enjoyment from being part of the industry can be influenced by management coordinated processes and cooperative approaches. These processes are also likely to influence information sharing between fishers, which can further improve fisher satisfaction levels.

This study has highlighted that there is much variation in ITQ/ITE management outcomes across Australian fisheries and also between the stakeholders who operate within these fisheries. This variation reflects the diversity of fisheries that are managed with ITQs/ITEs, a characteristic which implies that there is no one approach to ITQ/ITE management that will suit all. However, this study also underscores that it is possible to create management contexts specific to a particular fishery that build on the ITQ/ITE approach. Where issues arise, for instance, when economic, social and/or governance outcomes are not performing as well as expected, or the relative importance of these core objectives vary, other ways could be found to address these issues while maintaining the positive outcomes of ITQ/ITE management.

Keywords

Rights based management; ITQs; ITEs; Australian fisheries, Economic, social and environmental performance

Introduction

Individual transferable quotas (ITQs) have been introduced into a wide range of Australian fisheries. A key perceived advantage of ITQs is that they offer a mechanism for autonomous adjustment, allowing the fishery to adjust in response to changing biological or economic conditions without the need of further actions by managers to reduce fishing effort (e.g. buyback programs). This mechanism also allows the fishers to adjust in response to differences in relative efficiency, with more efficient vessels being able to purchase quota from less efficient vessels; thereby improving the economic performance of the fleet as a whole.

ITQs have also been credited with a number of other potential benefits, particularly in relation to fisher incentives. Foremost of these is a belief that ITQs fosters a change in stewardship of the resource. As ITQs confer a long-term share of the resource to individual fishers, there is a direct benefit to fishers in ensuring these resources improve in the long term. The allocation of a share of catch is also believed to improve the short-term within season incentives of fishers – as fishers know their allocated catch at the start of the season they are better able to make informed decisions rather than “race to fish” to maximise their share of the catch.

While these benefits have been realised in some fisheries through the introduction of ITQs, other fisheries have seen less of an improvement in economic performance, while changes in stewardship are also uncertain. Further, the very mechanism that aims to improve economic performance - autonomous adjustment - is believed to have resulted in adverse social impacts in some cases. For example, the high cost of quota can result in a barrier to entry for some sectors of the community, while concentration of quota ownership and decreasing fleet sizes may result in negative impacts on some regional communities. At the other extreme, imperfections in the quota market may result in autonomous adjustment not being able to achieve improvements in economic performance.

In some fisheries, there have been social, economic and environmental consequences associated with the move to tradeable fishing rights that, even if predictable, may have been unintended. For example, ITQ markets have not always operated as envisaged; thin markets (few buyers and sellers), high transactions costs and the de-coupling of the ownership of quota from fishing practice may have undermined the performance of some ITQ systems. Ownership of quota by processors, exporters and others (including foreign owned business) further along the value chain has also distorted the price incentives in some fisheries. In others, non-fisher quota ownership has resulted in a growing lease-dependent component of the fishery where the fishers are not capturing the benefits generated by the ITQ system. Changing quota ownership characteristics also have an impact on the configuration of industry representatives on co-management committees, with the potential for the development of asymmetric power relationships. It is not yet clear what the longer term impact of this is on stewardship and the decision making process and ultimately on management outcomes.

Globally, ITQs have come under intense scrutiny in the fisheries management and economics literature. Synthesising and critically analysing learnings from these studies, as well as relevant knowledge from individuals/groups/organisations involved in the administration of, or affected by, existing ITQ systems will help identify key issues and, where possible, reforms that through adaptive management can improve the performance of existing markets and inform the design of new tradable rights markets.

As the extension of ITQs in Australia to a greater number of commercial fisheries, and potentially to support inter-sectoral allocations, is contemplated there is a need to learn from experience of ITQs both in Australia and internationally. Over the last two decades (and more), FRDC has invested in considerable research aimed at facilitating the development of ITQ management in a range of fisheries in an aim to capture some of these perceived benefits. These include, for example, studies in the Coral Reef Finfish fishery (2004-030, 2016-134), Rock Lobster fisheries (1999/140, 2010-317), and Abalone fisheries (2013-200) as well as providing assistance in adaption to an ITQ program (2010-229).

Understanding the factors that influence the economic and social outcomes from an ITQ program will help design better programs in the future. To this end, the FRDC Human Dimensions Research Subprogram (HDR) identified the need to review the current experiences with ITQs and quota markets, and identify which factors affect their success or otherwise from an economic and social perspective. This ITQ review aims at supporting two key national strategic priorities, namely ensuring Australian fisheries are sustainable, and improving profitability and productivity of the industry.

Objectives

The objectives of the project were to:

1. Identify the extent of use (current and proposed) of ITQs in Australian fisheries;
2. Identify the demonstrable benefits to their use in Australia, and what outcomes have emerged that were largely unintended; and
3. Identify critical knowledge gaps and further research needed to improve their future design and performance

Method

The project involved four main stages: a desk-based literature review of national and international experiences with ITQs; an inventory of Australian fisheries current under ITQ or ITE management; survey of key stakeholders in each jurisdiction to determine views on the benefits and costs of ITQ/ITE management; and a qualitative modelling stage (using Bayesian Belief Network (BBN) models) to estimate the likelihood of different economic, ecological, social, or governance outcomes from a particular management scheme, and identify which factors may be most influential on producing these outcomes.

These stages are described in more detail in the following sections. The project also considered a number of short case studies for finer detailed analysis. These included the Tasmanian Abalone fishery (an ITQ fishery), the New South Wales Rock Lobster Fishery (an ITQ fishery), and the Commonwealth Northern Prawn Fishery (an ITE fishery).

Literature review

There is considerable literature around the effectiveness of ITQs in individual fisheries and countries (e.g. Annala 1996; Arnason 2005), as well as several past and recent review papers (e.g. Squires *et al.* 1995; Grafton 1996; Chu 2009; Arnason 2012; Thébaud *et al.* 2012). The aim of the literature review in this study was to review national and international experiences with ITQs, particularly factors influencing their economic, ecological, social, and governance performance, as well as unintended consequences where they have been observed. The purpose of the review was help guide the types of questions that need to be asked to assess impacts in Australian fisheries, as well as to support the development of the Bayesian Belief Network (BBN) model used to assess the key drivers of success (or otherwise) in Australian fisheries.

To this end, key literature databases (e.g. Web of Science, Google Scholar, and Scopus) were searched to find both empirical case studies as well as generic review of the effectiveness of ITQs and ITEs in achieving the objective of management.

Cataloguing Australia ITQ and ITE fisheries

The first objective of the project was to identify the extent of use (current and proposed) of ITQs in Australian fisheries. To this end, publically available information produced within each jurisdiction (e.g. web pages, annual reports, management reports, etc.) were reviewed to determine which fisheries are currently managed using ITQs or ITEs in each jurisdiction. In addition, the project team has developed a close working relationship with fisheries managers in most State and Commonwealth fisheries. These individuals were also contacted about potential changes in the fishery.

Stakeholder survey development

A separate survey was developed for fishers, managers and scientists in parallel to the structure of the BBN (see next section). Questions in the survey were asked to ensure appropriate data were available to populate the BBN. Additional questions were also asked that were not related to the BBN, but addressed other objectives of the study. Copies of the surveys are presented in Appendix A.

Given that the different groups have different experience with the different components of the management system, the data collection was broken into three separate surveys - a manager survey; a scientist survey; and a commercial fisher survey. The manager survey focused on the broader "macro" level components of the system, such as how many fishers are operating and how this has changed over time, and how quota is trading in the fishery (individual fishers would not have the same overview as managers have for these factors). Scientists were asked to comment on the scientific input into management i.e. how the TACs are set and the quality and quantity of data used. Industry were asked more operational questions about the fishery.

The surveys had a common first section that asked about their perceptions about the performance of the fishery; and a common last section that asked them to identify key issues (from their perspective) around ITQs/ITEs in their fishery. The middle section included stakeholder specific questions as outlined above.

The target population of the survey was the pool of individuals involved in the management of ITQ or ITE fisheries in Australia. This extends beyond just the formal managers of the fishery to include scientists (including economists) and industry members of management advisory groups. Most jurisdictions have some form of stakeholder advisory groups (e.g. Commonwealth has resource advisory groups (RAGs) involving managers, scientists and industry; Queensland and NSW have fishery working groups with a larger number of participants but similar stakeholder mix). Assistance of the Commonwealth and State management agencies, and in some cases industry associations, was sought to pass on the survey to appropriate individuals. All agencies and associations contacted were willing to assist in this manner.

All responses could only be identify though an ISP address, and this was only used to ensure that multiple responses were not obtained from the same individual. As some agencies have a common IP address, the data for these were examined to see if they represented a duplicate or different response. Similarly, some fishers responded for multiple fisheries using the same IP address. Where duplicate responses were observed, one of these were removed. In most cases, it appeared that the second response was a more complete version of the first (incomplete) response (i.e. in some cases the fisher seemed to start the survey, stop at a point early in the survey and then restart from the beginning). No totally duplicate responses (i.e. answering all the questions the same from the same IP address) were observed.

The survey was conducted online using Survey Monkey. The three surveys were given ethics approval through the CSIRO Human Research Ethics Committee (Project 061/18).

Bayesian Belief Network

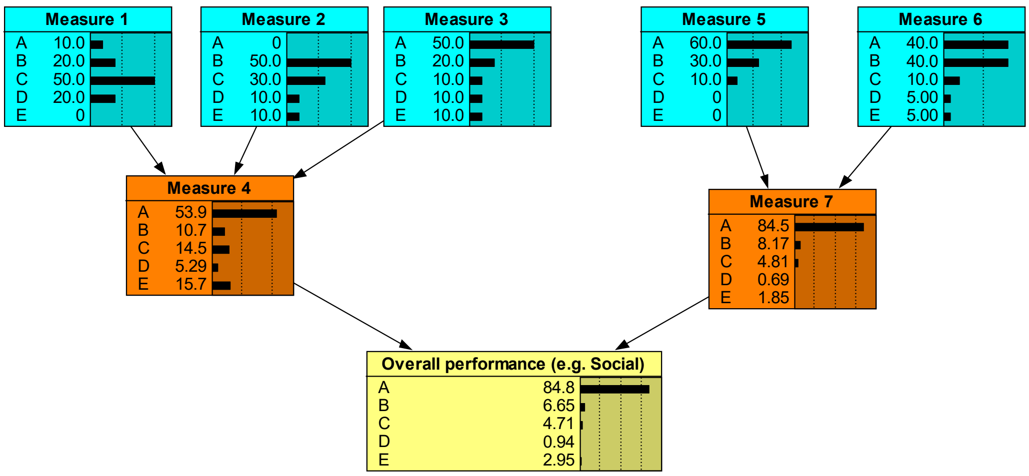
Bayesian Belief Networks (BBNs) are largely qualitative models that do not necessarily model processes, but rather are based on expected probabilities of outcomes given particular combinations of observable events. For example, a classic "textbook" example of a BBN model is one used to estimate the probability that it has rained given that the sky is cloudy (where the alternative is not cloudy) and the grass is wet (where the alternative is dry). Associated with each combination of events (cloudy/clear/wet grass/dry grass) is a probability distribution of rain based on historical observations. BBNs are developed as essentially graphical models in which probabilities of certain outcomes, given certain situations or observations, can be assigned. These probabilities are generally based on combinations of expert opinion, data and previous experiences cited in the literature.

Bayesian networks have been applied to fisheries in numerous cases, particularly when the effects of qualitative as well as quantitative factors are of interest (e.g. Little *et al.* 2004; Pollino *et al.* 2007; Cole 2010; Martin-Ortega *et al.* 2011; van Putten *et al.* 2013b; Pascoe 2018). They have also been applied to consider multi-objective outcomes of coastal resource management, considering social, environmental and economic outcomes (e.g. Healy 1994; Hoshino *et al.* 2016; Pascoe *et al.* 2016).

BBN models provide a probability of an outcome rather than a discrete (deterministic) outcome. From the probability distribution, a mean (expected) outcome and confidence interval can be determined. How each input combines to inform the probability of an outcome is determined through a combination of weighting rather than a numerical estimation process. That is, formal structural relationships do not need to be developed linking different components of the model, enabling non-linear or discontinuous outcomes to occur if considered appropriate.

An illustration of the structure of a typical *converging* BBN is given in Figure 1. Individual measures derived from data or expert opinion are combined at various levels to provide an overall probability of a final outcome. Nodes that influence other nodes are known as *parent* nodes, while the node being affected is a *child* node. In Figure 1, the blue nodes are all parent nodes and the yellow node is a child node, while the intermediate nodes are both parent and child nodes.

Figure 1. Example structure of a BBN model



The nodes are connected through *conditional probability tables* (CPTs). These describe the probability of an outcome for the child node given any combination of inputs from the parent node. For example, the CPT relating the input levels of Measures 1-3 to the output level of Measure 4 in Figure 1 is shown in Figure 2. The CPTs contain one entry for every combination of input levels. For the example in Figure 2, this requires 125 combinations (5*5*5).

Figure 2. Example conditional probability table

Measure 1	Measure 2	Measure 3	A	B	C	D	E
A	A	A	100	0	0	0	0
A	A	B	94	6	0	0	0
A	A	C	88	12	0	0	0
A	A	D	82	18	0	0	0
A	A	E	76	12	12	0	0
A	B	A	90	10	0	0	0
A	B	B	84	16	0	0	0
A	B	C	78	11	11	0	0
A	B	D	72	14	14	0	0
A	B	E	66	17	17	0	0
A	C	A	80	10	10	0	0
A	C	B	74	13	13	0	0
A	C	C	68	16	16	0	0
A	C	D	62	19	19	0	0
A	C	E	0	0	28	20.16	51.84
A	D	A	70	15	15	0	0
A	D	B	64	18	18	0	0
A	D	C	0	0	29	20.59	50.41
A	D	D	0	0	26	19.24	54.76
A	D	E	0	0	23	17.71	59.29
A	E	A	0	0	30	21	49
A	E	B	0	0	27	19.71	53.29
A	E	C	0	0	24	18.24	57.76
A	E	D	0	0	21	16.59	62.41
A	E	E	0	0	18	14.76	67.24
B	A	A	96	4	0	0	0
......							
E	B	B	68	16	16	0	0
E	B	C	62	19	19	0	0
E	B	D	0	0	28	20.16	51.84
E	B	E	0	0	25	18.75	56.25
E	C	A	64	18	18	0	0
E	C	B	0	0	29	20.59	50.41
E	C	C	0	0	26	19.24	54.76
E	C	D	0	0	23	17.71	59.29
E	C	E	0	0	20	16	64
E	D	A	0	0	27	19.71	53.29
E	D	B	0	0	24	18.24	57.76
E	D	C	0	0	21	16.59	62.41
E	D	D	0	0	18	14.76	67.24
E	D	E	0	0	15	12.75	72.25
E	E	A	0	0	22	17.16	60.84
E	E	B	0	0	19	15.39	65.61
E	E	C	0	0	16	13.44	70.56
E	E	D	0	0	13	11.31	75.69
E	E	E	0	0	10	9	81

The CPTs can be derived from expert opinion or from data (where available). Given appropriate data, the Bayesian Network can “learn” from the data by comparing the observed outcomes with the different combinations of inputs, and hence from any combination of inputs one can derive a probability of different outcomes occurring. Ideally, this requires all the data to include all possible combinations of inputs/outputs, although in the absence of these data, estimates of the relationships may still be derived.

In this study, the BBN models were developed using the NETICA (Norsys 2014) software package. NETICA provides two different approaches to learn from the data. The expectation-maximisation (EM) approach is an iterative method for first fitting the model to the existing data (the “expectation” step), then re-estimating the model including the expected values of the missing data based on maximum likelihood estimation (the “maximisation” step). These parameters are then used to determine the distribution of the values in the next estimation step. The process is continued until convergence is obtained. The second approach – the gradient descent approach – is also an iterative machine learning approach which iteratively adjusts the parameter values such that they minimise the negative log likelihood (the objective function). The gradient measures how much the objective function changes as the inputs are changed by a small margin.

Structure of the BBN

The BBN structure was developed based on a combination of literature review and expert opinion, following the best practice guidelines proposed by Marcot *et al.* (2006) and Chen and Pollino (2012b). A BBN model consists of two components: structure and parameters (i.e., conditional probabilities) (Kjærulff and Madsen 2013). The structure of a BBN is often referred to as the qualitative part of the network, developed as an influence diagram, whereas the parameters are often referred to as its quantitative part (Kjærulff and Madsen 2013).

The first stage of the development of a BBN is the development of an influence diagram. This maps the key expected causal relationships in the model without assigning any formal relationship or probability. These relationships can be identified from the literature as well as expert opinion. In the case of this study, the key outcomes of ITQ and ITE programs identified in the literature were used as nodes in the influence diagram. The links between these outcomes and characteristics of the fishery under ITQs/ITEs was also developed through the literature review (based on theoretical relationships and results of empirical studies elsewhere) as well as the previous direct experience of the project team working with ITQ and ITE fisheries.

The project team and other invited fisheries experts reviewed the influence diagrams and agreed on a draft structures of the BBN. This was an iterative process, with the comments of the experts being incorporated into successive drafts of the model until the project team and group of experts were satisfied. The final draft BBN structure was also used in the design of the survey, as it was necessary to ensure that the survey collected data appropriate for use in the BBN.

The results of the survey were used to derive the conditional probabilities in the BBN – the parameters of the model, using the learning features of the NETICA software to derive the quantitative relationships in the model (as described above). Experts were again involved in the review of the model post-parameterisation, and the structure reassessed based on the strengths of the relationships from the survey.

"What if" analyses

BBNs are a modelling tool much like any other tool in that they can be used to answer particular questions. For example, relating to the current project, if we can improve the TAC setting process, how will this improve overall fishery performance? Unlike other modelling approaches, however, BBNs operate in both directions. Using the above example, and assuming that we have several indicators feeding into the TAC setting process node, then by selecting a higher level of outcome for TAC setting, we not only can estimate the probability of an improvement (or otherwise) in performance measures further along the BBN, but also how the inputs into the node will need to change in order to achieve the outcome.

Sensitivity analysis

Sensitivity analysis can be used to measure the degree to which findings at any node (e.g. the indicator measure) can influence the outcomes (or beliefs) at another node (e.g. the child node value), given the set of findings currently entered. That is, the sensitivity relates to what is most likely to affect the outcome of the child node given the current level of all of the parent nodes that feed into it

(Bednarski *et al.* 2004). The results are indicative only, as the sensitivity analysis considers only individual sensitivities – evidence in combination may have a larger impact that the "sum" of the individual impacts (Jensen and Nielsen 2007).

"Evidence" in BBNs is often uncertain in itself, and the cost of increasing the precision may be high (e.g. the cost of collecting more data on all of the variables of interest may be considerable). Sensitivity analysis can also be viewed as a means of determining which variables require the most attention to get accurate data (or at least more precise assessments) as these will be the ones that the outcomes are most sensitive to (Jensen and Nielsen 2007).

Sensitivity analysis can also be used as part of the model evaluation. The sensitivity measures can be compared with *a priori* expectations about importance of particular nodes (indicators) to ensure that the model is behaving as expected (Chen and Pollino 2012a). If the plotted sensitivity function does not behave as expected, this may indicate errors in the network structure or the conditional probability tables (CPTs) (Pollino et al. 2007).

Two forms of sensitivity analysis are available in NETICA (Norsys 2014): mutual information (entropy reduction) and the expected reduction of real variance. Entropy relates to the uncertainty of a variable (Q) characterised by a probability distribution, $P(q)$ (Korb and Nicholson 2003; Pollino et al. 2007). Entropy reduction reports the expected degree to which the joint probability of Q and F diverges from what it would be if Q were independent of F. That is, it is a measure of the mutual information shared between the two nodes. If $I(Q,\mathrm{F})$ is equal to zero, Q and F are mutually independent (Pollino et al. 2007)

The mutual information (I) between Q and F is measured in "bits". The expected reduction in entropy of Q (measured in bits) due to a finding at F[1].

$$I = \sum_q \sum_f \log_2 \left[\frac{P(q)}{P(q)P(f)} \right] \tag{1}$$

where q is a state of the query variable (i.e. the sub-component) and f is a state of the varying variable (the indicator). The measure is logged with a base of 2, which is traditional for entropy and mutual information so that the units of the results will be "bits".

Variance Reduction refers to the expected reduction in variance of the expected real value of Q due to a finding at F.

$$Vr = \sum_q P(q) \left[X_q - \sum_q P(q) X_q \right]^2 - \sum_q P(q|f) \left[X_q - \sum_q P(q|f) X_q \right]^2 \tag{2}$$

where Xq is the numeric "real" value corresponding to state q (i.e. the sub-component). In this case, "real" refers to the expected value of continuous nodes, or discrete nodes which have a real numeric

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[1] http://www.norsys.com/WebHelp/NETICA/X_Sensitivity_Equations.htm

value associated with each state. In our model, all nodes are continuous, with a value ranging from 0 (zero) to 1.

Econometric analyses

An alternative to the BBN analysis to determine factors which affect overall performance of ITQs and ITEs is an econometric analysis, focusing on the key characteristics of the fisheries and also the key management arrangements in place. In particular, the analysis focuses on governance related variables as well as other characteristics of the fishery. The main rationale for this focus is that success of the fishery management plan will depend on the way the plan is implemented, but this may also be influenced by the characteristics of the fishery.

The key governance measures and fishery characteristics to be considered will be based on the results from the survey, and informed by the sensitivity analyses undertaken as part of the BBN analysis. As with the BBN, the variables are qualitative in nature, representing the perceptions of fishers, managers and scientists and represented by relative levels rather than continuous values. An advantage of the econometric analysis is that it enables the contribution of each of the factors to overall fishery performance to be identified separately.

The level of overall performance of the fishery (a continuous variable from 1-10) was regressed against the set of variables identified in the BBN analysis. Most of these variables are ordered categorical variables (i.e. None < Low < Medium < High) so their levels were not independent. Inclusion of ordered categorical into the regression model can be undertaken using polynomial contrasts (Hutcheson 2011). These replace the variable in the model with (N-1) orthogonal combinations of new variables, the values of which reflect the order of the variable. As the categorical variables in the models had four levels (i.e. None < Low < Medium < High), these were replaced by new variables reflecting the linear, quadratic and cubic components of the contrasts. An example of these contrasts is given in Table 1.

Table 1. Polynomial contrasts used for the ordered categorical variables

	Linear (L)	Quadratic (Q)	Cubic (C)
None	-0.6708	0.5000	-0.2236
Low	-0.2236	-0.5000	0.6708
Medium	0.2236	-0.5000	-0.6708
High	0.6708	0.5000	0.2236

An advantage of polynomial contrasts compared with other forms of dummy variable coding is that enables the identification of linear and non-linear trends in the relationship between the ordered explanatory variable and the dependent variable (Hutcheson 2011). The impact of each level of the order categorical variables on overall performance can be derived by the product of the vector of coefficients on the linear, quadratic and cubic terms and the polynomial contrasts used in their estimation.

Given that the relationship between the perception of fishery performance and the characteristics of the fishery may differ by stakeholder group, the analysis was undertaken for each of the key stakeholder groups separately as well as combined.

Results

Literature review of ITQs and ITEs

Individual transferable catch quotas (ITQs) have been applied to a wide range of fisheries since the mid 1970s (Chu 2009). The concept was first introduced in the Netherlands, but New Zealand was the first country to introduce the first major ITQ program in 1986 (Marchal *et al.* 2016). By the early to mid-2000s, ITQs had been implemented in over 20 countries and for over 250 different species (Chu 2009).

ITQs involve the allocation of shares or portions of a total allowable catch (TAC) to individual fishers, vessels, communities or others with an interest in the fishery (e.g. processors). Individual transferable efforts (ITEs) allocate the shares of a total allowable effort (TAE) between individual fishers. The allowable effort into a fishery can be thought of, for instance, as the allowable number of days or hours at sea. Fundamental to both ITQs and ITEs is the “T” – the transferability of the shares.

There is considerable literature around the economic effectiveness of ITQs in individual fisheries and countries (e.g. Annala 1996; Arnason 2005; Gómez-Lobo *et al.* 2011; Grimm *et al.* 2012; Brinson and Thunberg 2016), as well as several past and recent review papers (e.g. Squires et al. 1995; Grafton 1996; Chu 2009; Arnason 2012; Thébaud et al. 2012). It has been theoretically and empirically established that ITQs encourage autonomous adjustment of fleet size, as it provides incentives for inefficient fishers to exit the fishery (Boyce 1992; Grafton 1996). There is also a growing empirical literature around the social, ecological and governance outcomes of ITQs (Nunan *et al.* 2018), which are perhaps less unified in their assessment of ITQ effectiveness.

ITEs, in contrast, have received considerably less conceptual or empirical attention in the literature (Squires *et al.* 2017), although a noted exception is Squires and Maunder (2016) who summarised global experiences of ITE fisheries. The transferability of effort right creates incentives to maximise revenue and catch, allowing more profitable fishers to catch more (Squires et al. 2017) thus illustrating the economic effectiveness of ITEs, although economic incentives are not as strong as catch rights programmes. Like ITQs, there is less concrete evidence of the social, ecological, and governance outcomes of ITEs.

The aim of this section is to review national and international experiences with ITQs, particularly factors influencing their economic, ecological, social, and governance performance, as well as unintended consequences where they have been observed.

Achieving sustainability objectives

ITQs have often been introduced with the primary aim of aiding stock recovery in overexploited fisheries (Chu 2009). Increases in the abundance of target species have been reported globally (e.g. Costello *et al.* 2008; Branch 2009; Chu 2009). It is however, debated whether these abundance increases are in fact attributable to the TACs which goes hand in hand with ITQs. Without a TAC it would not be possible to implement ITQs and the effects of the two may not be easy to separate. Some stocks, however, continued to decline after ITQs were introduced (e.g. Chu 2009; Gardner *et al.*

2015), which may be due to the misspecification of the TAC. Nevertheless ITQs may not always translate into an increased stock biomass if, in parallel, the TAC is not set at the right level for stock recovery. Chu (2009) found improvement in stock biomass in only 12 of 20 stocks examined after a TAC and ITQs were introduced.

While the potential for stock increase may be dependent on an appropriate TAC being set with the objective of stock recovery, ITQs (and the associated TAC) may produce benefits in terms of stock sustainability other than stock increase. For example, using a global data set, Costello et al. (2008) show that ITQs reduce the probability of fisheries collapse. Similarly, a meta-analysis of ITQ fisheries in North America found no changes in stock biomass after the introduction of ITQs but found reduced inter-annual variability in exploitation rate, landings, discard rate, and the ratio of catch to catch quotas (Essington 2010).

Although Essington (2010) found reduced discard rates as a consequence of ITQs for North American fisheries, the impact of ITQs on non-target species and the broader ecosystems remains unclear (Branch 2009). Theoretical studies suggest that ITQ management increases incentives to discard and high-grade (e.g. Copes 1986a; Boyd and Dewees 1992; Anderson 1994; Arnason 1994; Sampson 1994; Vestergaard 1996; Pascoe 1997; Turner 1997), although the empirical evidence is mixed (e.g.Grafton 1996; Branch and Hilborn 2008; Essington 2010; Grimm et al. 2012; Dinesen *et al.* 2018). Mixed discarding outcomes in ITQ managed fisheries are reported for multispecies fisheries, where fishers can discard marketable fish once their quotas have been reached, known as "over-quota discarding." Although empirical evidence of over-quota discarding and high-grading is scarce (Batsleer *et al.* 2015), concerns have led the European Union (EU), where many fisheries are multispecies, to adopt regulations which make high-grading an illegal practice (Batsleer et al. 2015).

Aside from discarding and high-grading, negative ecological impacts of ITQs have been attributed to structural changes in the fleet. Dinesen et al. (2018) found that the introduction of ITQ in the Danish demersal fishery has had indirect negative ecosystem impacts because the fleet changed towards fewer and larger trawl vessels with greater environmental impacts, while reducing the number of smaller less environmentally damaging coastal vessels.

It is common for ITQ managed fisheries to retain some input controls to meet ecosystem-based fisheries management requirements, such as for instance size limits and closed seasons to protect breeding stocks. Emery *et al.* (2012) found that out of 18 ITQ fisheries surveyed worldwide, most of them retain input controls.

Unlike ITQs, ITEs create incentives to expand input use and costs through investment, input substitution, increased input utilization (e.g. fishing time), which make effort rights systems difficult to address overcapacity. Hence, ITEs do not create incentives to overcome biological overfishing or for individuals to adjust harvesting capacity autonomously (Squires et al. 2017). However, various input-based rights management have been implemented worldwide to mitigate ecosystem impacts of fisheries (Squires and Maunder 2016). Programmes have been developed, which create incentives to land or avoid bycatch, such as deemed values in New Zealand, hook decrements in Australia, and individual habitat quota in the USA (Pascoe *et al.* 2010a).

ITQs have sometimes been associated with improved environmental outcomes due to changes in fisher's environmental *stewardship*. The assumption of changed environmental stewardship is founded on the connection between property ownership and stewardship ethics. Although psychological- and stewardship theory suggests that there may be a relationship, there is insufficient evidence to draw the conclusion that improved environmental outcomes in ITQ managed fisheries are attributable to fisher's changing normative values (e.g. van Putten *et al.* 2014).

Achieving economic objectives

An ITQ is primarily an instrument for promoting economic efficiency (Hannesson 1996), rather than environmental outcomes which is achieved separately through a TAC that is introduced in conjunction with ITQs. ITQs are expected to generate a number of economic benefits, including cost reduction and more efficient input choices. Economic efficiency is realised through optimum fleet size and structures achieved through a voluntary exit of less efficient vessels (Squires et al. 1995). In Chile, fleet size for the Southern pelagic fishery fell from 149 active boats in 2000 to 57 in 2004, with estimated discounted net benefits of US$166 million over the 2001-2020 period (Gómez-Lobo et al. 2011).

Studies of ITQ systems around the world show an increased value of landed product. For example, in the Chilean Jack Mackerel ITQ fishery the movement toward higher-value products resulted in increased revenue as well as consolidation of catch on larger vessels, leading to an increase in fishing profits (Kroetz *et al.* 2017). Dupont *et al.* (2005), Herrmann (1996), and Herrmann (2000) found that prices received increased after the introduction of ITQs, largely due to a combination of better quality product being delivered to the market (e.g. fresh rather than frozen) and reduced gluts on the market associated with more derby-style fishing.

Fishing costs can potentially change in ITQ and ITE fisheries for several reasons. In some fisheries, the average number of days at sea has been seen to decline as fishers fill their quota and cease fishing (Ford and Ford 2002). In other fisheries, autonomous adjustment has resulted in few vessels each fishing more days at sea to better utilise their capacity. Individual days at sea increased in the Alaska Pollock and pacific herring fisheries, while at the same time fishing intensity slowed down (Hsueh 2017). Even with more days fished, average costs can decrease as a result of fishery adjustment. Autonomous adjustment has resulted in less efficient vessels exiting the fishery resulting in lower cost per unit catch (Dupont et al. 2005).

The geographical locations fishers operate can also potentially be affected by ITQs, thereby affecting travel time and costs. For example, in the Chilean Jack Mackerel fishery, the introduction of an ITQ system resulted in an influx of larger vessels spending more time at sea per trip and traveling to more distant waters (Kroetz et al. 2017).

ITQs and ITEs can have other impacts on costs, through increased compliance and management costs and potentially higher debt levels through purchasing quota. For lease dependent fishers, lease costs can also increase the total costs of fishing.

The net impact of these factors on the total fishing cost will vary. Larger vessels fishing more days in more distant locations may incur greater costs in absolute levels, but on a cost per kilogram of output basis, they may be lower cost producers.

Worldwide, increased value of the catch, in combination with improvements in cost efficiency and an optimised fleet structure, have contributed to gains in economic efficiency in different fisheries (e.g. Grafton 1996; Arnason 1997; Dewees 1998; Kompas and Che 2005; Gómez-Lobo et al. 2011). While the associated TAC may be a major factor in improving stock sustainability, it is the ITQ that eliminates the wasteful competition in the race to fish and which leads to improved economic performance.

The positive role of ITQs in ending the "race to fish" has been reported in a number of empirical studies (e.g. Grimm et al. 2012; Brinson and Thunberg 2016; Birkenbach *et al.* 2017; Hsueh 2017). A meta-analysis of 39 ITQ-managed fisheries in the USA found strong evidence for ITQs extending fishing seasons (Hsueh 2017) suggesting fishers did not feel the same pressures to fish hard after ITQ introduction. A study examining the impacts of 15 ITQ programmes in the USA and British Columbia also found that the average season had lengthened from 63 days to 245 days (Grimm et al. 2012) evidence that fishers had spread their fishing effort over a longer time period. A similar study in the USA and British Columbia found that economic performance of 16 fisheries had improved profitability and productivity due to reduced capacity, extended fishing seasons, and increased price (Brinson and Thunberg 2016).

Although both theory and empirical evidence suggest a robust link between ITQs and economic performance of the fishery (Grafton *et al.* 2000; Costello et al. 2008), examples of negative impacts also exist. For example, the ITQ-managed Tasmanian Rock Lobster Fishery experienced increased race to fish behaviour during a period of non-binding TAC (Emery *et al.* 2014) resulting in a less economically efficient fishery. An indirectly related economic impact, which is primarily due to regulatory restrictions on the way ITQs could be used as collateral, reduced access to capital. In the Swedish pelagic fishery ITQs could not be used as collateral for loans which reduced the value of the fishing quota, but also made it more difficult for more profitable rights holder to borrow money to buy additional quota (Stage *et al.* 2016).

In multispecies fisheries, so-called "spillover effects" (Squires *et al.* 1998), where ITQs induce negative environmental effects on other species (i.e. non-ITQ species), have been observed (e.g. Asche *et al.* 2007; Hutniczak 2014; Cunningham *et al.* 2016; Blomquist and Waldo 2018). Dupont and Grafton (2000) examined the economic impacts of ITQs on multispecies Nova Scotia Groundfish Fishery in Canada, and found positive economic outcomes in terms of autonomous adjustment of fleet size as well as increased in the prices of ITQ-managed fish. However, they report increased pressure on non-ITQs stocks with related environmental impacts, which have subsequently led to an extension of the ITQ program over additional species (Dupont and Grafton 2000). Blomquist and Waldo (2018) examined the spillover effects of Swedish pelagic ITQ program, which essentially led to fishers shifting fleets. Because the ITQ system was applied to only the pelagic fleet segment, some fishermen sold their quota after ITQ introduction and shifted their effort to another fleet segment which was not part of the pelagic ITQ system. This shifting of effort may have contributed to increased fishing pressure and overcapacity in these other fisheries.

Achieving social objectives

Some of the social impacts of ITQs are associated with the perceived inequitable approach taken in the initial ITQ allocation process (Matulich and Sever 1999; Macinko and Bromley 2002; Copes and Charles 2004; Macinko and Bromley 2004; Bromley 2009). The allocation process can be particularly tricky when there are different stakeholder groups involved who have different interests and hold different values (Plagányi *et al.* 2013; van Putten *et al.* 2013a).

One of the expected social benefits of ITQs include improvement of the quality of fish to consumers. Although the introduction of ITQs may also result in a higher price for product, which may be seen as a negative consumer impact of ITQs. In the British Columbia Halibut Fishery, after the introduction of ITQs almost the entire catch was sold as higher priced fresh fish compared to only half being sold as fresh fish prior to the introduction and the other half being sold as processed fish (Grafton et al. 2000). Similarly, in the Western Australian Western Rock Lobster Fishery, the introduction of quotas has meant that nearly all the catch is exported and has become expensive for local consumers, leading to fears that a black market might develop. A trial allocation of additional quota for sale on the local market was trialled in 2016-17 received public support, particularly in regional communities (Caputi *et al.* 2018).

Because ITQs provide fishers more flexibility in deciding when to fish (e.g. when market is favourable or avoid fishing during adverse weather conditions) this can result in safer fishing operations (Grafton et al. 2000). Prior to ITQ introduction, vessel losses and fatalities associated with the Alaskan Halibut and Sablefish Fishery and the Bering Sea Crab Fisheries were commonplace due to "derby" style prosecution of the fishery. ITQ management of these Alaskan fisheries has improved their safety records (Hughes and Woodley 2007).

Studies of ITQ programmes worldwide have found concentration of fishing power and quota ownership leading to fewer and larger companies or owners, and in some cases, increased levels of vertical integration across harvesting, processing and marketing (e.g. Eythórsson 2000; Stewart *et al.* 2006; Yandle and Dewees 2008; van Putten and Gardner 2010; Olson 2011; Hannesson 2013; Agnarsson *et al.* 2016; Brinson and Thunberg 2016; Gunnlaugsson *et al.* 2018). Concentration of fishery or quota ownership by few large companies can raise potential social concerns. These extensions of corporate control has sometimes been at the expense of small-scale local interests (Pálsson and Helgason 1995; Munk-Madsen 1998; Pálsson 1998; Pinkerton and Edwards 2009). For instance, the development of monopoly powers in the fishery has increased inequality in the distribution of fishery profits, and eroded social norms and cultural heritage in fishing community (McCay 1995; Davis 1996; Sumaila 2010).

Concentration of quota has often been accompanied by an increasing proportion of active fishers who lease their quota. Associated with this, there has been evidence of social stratification and changing social interactions and gender relations (Gerrard 2008), with a clear separation between those who own quota (investors) and those who rely on leasing quota has emerged (e.g. Pinkerton and Edwards 2009; van Putten and Gardner 2010). Sometimes the socio-economic contrast between the owners of quota and those who fish lease quota can become even starker when the quota is owned by large processing companies or part of investment portfolios. In the latter case, the actual fishers may no longer have a financial stake in the fishery and their labour may be paid by the external owners of the fishery.

The distributional concerns has led to restrictions (i.e. in terms of tradability of catch quota) in some ITQ fisheries. A review of right-based fisheries in Europe found that many EU member countries impose transferability restrictions to avoid the concentration of fishing rights (European Commission 2009). For instance, these restrictions in some cases mean that quotas are only allocated to active fishing vessel (or the individuals or firms that own these active vessels). In some other fisheries distributional concerns have been addressed by making quotas transferable only within certain time frames (Da-Rocha and Sempere 2017).

Frequently in well managed ITQ fisheries (and where the TAC is restrictive), increases in resource rents have been followed by increases in the price of quota units. For those fishers who own quota (as well as investors and external owners) this means an increase in the value of their asset. However, the high price of quota has also made it expensive for young fishers to purchase quota and enter ITQ fisheries (Dewees 1998). As a result of the high cost of fishing rights in ITQs fisheries, and because low quantities of quota change hands, it has created financial barriers to enter commercial fisheries for younger generations and consequently the average age of fishers in rural fishing communities in Alaska has increased by 10 years over the past 40 years (Cullenberg *et al.* 2017).

As noted by Flaaten *et al.* (2017), the approach (if any) to capturing and redistributing a fishery's resource rent to society will impact investment in immaterial capital (e.g. quota and licences) and physical capital. Internationally, there have been few attempts by governments to tax and redistribute fishery resource rents to society. Iceland introduced a fishing fee initially to cover management and enforcement costs, but it was soon increased to ensure that a share of rents was being allocated to the public, to encourage public support for the ITQ approach and the sector more generally (Gunnlaugsson et al. 2018). New Zealand also trialled a resource rent tax but it was abandoned (Hannesson 2005). Without redistribution of resource rents, the rents accrue primarily to the quota units, which increases the value of the quota asset (Flaaten et al. 2017).

Nøstbakken (2012) suggests that the typically large resource rents that accrue to incumbent owners of quota relative to the typically low prices they paid for those entitlements means that incumbent owners may not take into account the full opportunity cost of their quota. This can limit the degree to which structural adjustment occurs relative to what the theory would suggest. The accrual of resource rents to quota may also make quota as an investment option, when compared to other investments in the economy, relatively attractive to investors. How resource rent taxation (or the lack thereof) impacts asset prices and the level of external investor interest, however, to the knowledge of the authors, has not generally been explored. Indeed, the interaction between quota scheme design, government policy and quota investment is relatively unexplored (Nøstbakken *et al.* 2011)

Due to potential negative social implications, ITQs remain contentious in fisheries policy worldwide (Birkenbach et al. 2017). For instance, in New Zealand ITQ systems are generally regarded successful with respect to their biological and economic performance, but they have been criticized for disregarding social sustainability (Pinkerton and Edwards 2009; Torkington 2016; Bodwitch 2017; McCormack 2017). Similarly in the US, the Red Snapper (*Lutjanus campechanus*) ITQ program is successful in meeting its major goals of ending derby-style fishing and reducing overcapacity in the harvest sector, but the concerns regarding the social impacts of the program, such as the increased non-fishing quota owners and increased lease-dependent fishers, has led the management agency to initiate discussions to amend their fisheries management plan to deal with these social impacts (Ropicki *et al.* 2018). Concerns over the social and economic effects of ITQ programs led to a moratorium on new ITQ programs in the USA between 1996 and 2002 (Brinson and Thunberg 2016).

ITQs have been introduced into indigenous fisheries or where the fishery is shared between and indigenous and non-indigenous sectors. ITQ introduction has in some cases has been at odds with the culture of particular indigenous communities, for instance, for the Maori in New Zealand (Day 2004; Yandle 2006), and the Mi'kmaq in Canada (Charles 2006). Privatized fisheries rights was in some cases at odds with cultural norms, or were thought to spell the end of a traditional way of life (Sumaila 2010).

Due to the economic efficiency gains observed in many ITQ managed fisheries, the demand for employment has sometimes fallen. In Denmark, Merayo *et al.* (2018) report that full-time employment fell by 68% after the introduction of Danish ITQs, although unemployment rates in the affected fishing communities remained below the national average. Nevertheless there are also examples of fishing communities where quota was sold to non-fishers or "outsiders" (Eythórsson 2000) which manifested in decreased employment (Copes and Charles 2004; Merayo et al. 2018). Despite the fall in employment demand sometimes the fisher's salary can remain largely unchanged (Eythórsson 2000; Merayo et al. 2018). In some ITQ managed fisheries the nature of employment has changed alongside the changing structure of the industry. In some cases, this restructure has negatively affected the availability of full-time equivalent jobs for crew members (Stewart et al. 2006; Sumaila 2010; Olson 2011). In some other fisheries ITQs have led to a decrease in part-time work while an increase in full-time employment was observed (Batstone and Sharp 1999).

Achieving governance objectives

Even though reduced costs and economic efficiency is reported as a positive consequence of ITQs, the management costs of ITQ fisheries can be substantial and thus put downward pressure on profits (e.g. Arnason *et al.* 2000; Hatcher *et al.* 2002; Chávez and Stranlund 2013). In most ITQ fisheries the fees collected are generally well below the actual management costs (Hatcher et al. 2002). The management costs recouped from the fishery under ITQ systems varies substantially from almost nothing to about 3-4% of the fishery's gross revenue.

There is little information on the actual ITQ management cost, and the different cost components, but catch and compliance monitoring are likely to comprise a substantial part of the overall management costs. Catch can in some cases be more challenging to monitor than effort, particularly for multispecies and transboundary species (Squires et al. 2017) and in situations where catch reporting is not traditionally carried out (Plagányi et al. 2013). The effect of ITQs on compliance cost and more generally compliance behaviour is a relatively under researched area. Currently there are indications (albeit scant) that ITQs has had both a positive and negative impact on compliance and quality of reporting (Copes 1986b; Bromley 2009).

In many jurisdictions, ITQs go hand in hand with co-management arrangements, where the fishers and quota owners (in conjunction with scientists, managers and other stakeholders) participate in an often annual process of determining next year's TAC level. Hoefnagel and de Vos (2017) argue that many of the usual negative socio-economic consequences of ITQs mentioned in the literature have been largely absent in the Dutch ITQ system due to the embeddedness of ITQs in co-management arrangements. There is also some evidence of power asymmetries developing in these co-management decision forums (Leal *et al.* 2010; Parslow 2010) due to concentration of quota ownership and some stakeholder (i.e. lease quota fishers) not having a seat at the table (Nunan et al. 2018).

There is a growing literature that examines and highlights the trade-offs between economic and other objectives for different fisheries management approaches, including ITQs (e.g. Costello and Kaffine

2008; Kroetz and Sanchirico 2010; Grainger and Costello 2014; Kroetz *et al.* 2015; Da-Rocha and Sempere 2017). Fisheries management, regardless of the type of management approach, requires trade-offs to be evaluated to inform decisions. Thébaud et al. (2012) noted that most of the existing literature focuses on partial assessments of the economic, social, or ecological impacts of ITQs, rather than on the development of integrated assessments across these three dimensions to allow a full trade-off assessment. Empirically it is obvious that trade-offs occur. For instance, a survey of Icelandic small-boat fishers showed their dissatisfaction with fisheries management because the focus on economic goals tended to overshadow biological and social management goals (Chambers and Carothers 2017). Trade-offs also have to be assessable across fisheries and species. There is currently some research effort going into defining a set of standardised indicators to evaluate the performance of ITQ fisheries to be able to compare evaluations across fisheries (e.g. Brinson and Thunberg 2016).

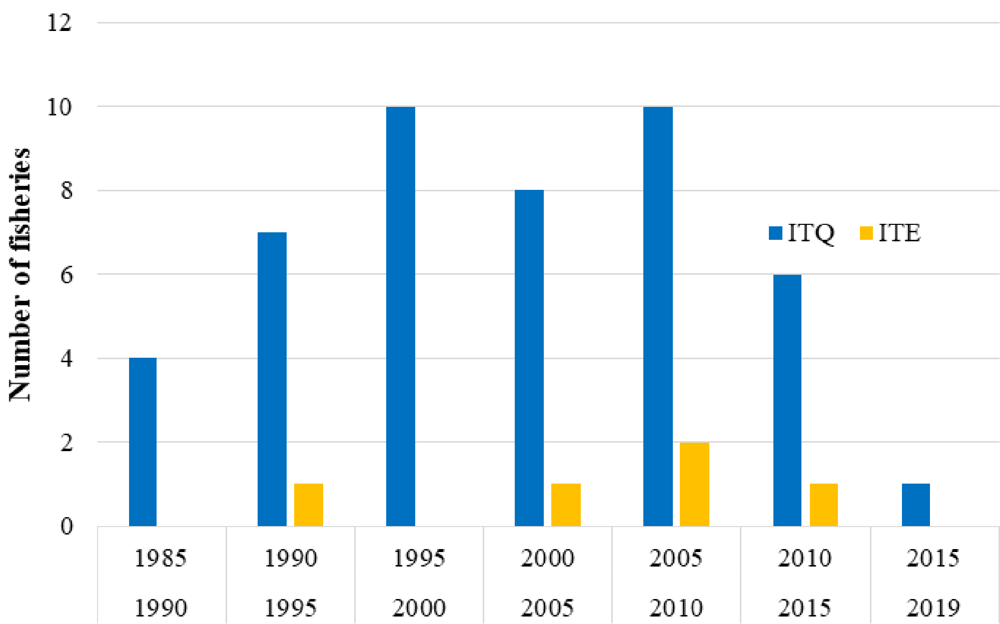
To our knowledge, this current report is the first to evaluate the impacts of ITQ fisheries across the economic, social, ecological and governance dimensions and highlighting the trade-offs and probabilities of meeting those conflicting objectives across a number of fisheries.

ITQs in Australian fisheries

The review of ITQs and ITEs in Australia identified 46 ITQ and 5 ITE fisheries. These ranged in size from a relatively small number of operators (e.g. 4 fishers in the Queensland Bêche-de-Mer Fishery) to a large number of operators (e.g. 251 in the Queensland Coral Reef Finfish fishery). ITQ fisheries were found in all jurisdictions. Most ITQ fisheries were single species in nature, although several multispecies fisheries were identified. Most ITE fisheries were prawn trawl fisheries.

The first ITQs were introduced into Australian fisheries in the mid-1980s, with ITEs first being introduced in the early 1990s (Figure 3). Most current ITQ fisheries were changed to ITQ management between 1995 and 2010, although ITQs have still been introduced in more recent years.

Figure 3. Introduction of ITQ and ITE fisheries into Australia



A summary of the key characteristics of the ITE fisheries is given in Table 2, and ITQ fisheries in Table 3. Estimates of the gross value of product in these fisheries were not available for the same year in all cases. Values for the most recently available year have been indexed up to 2017-18 values using the consumer price index. A key description of these fisheries in each state is presented in the following section.

Table 2. Main ITE fisheries by jurisdiction

Fishery	Fishery type (multi/ single species)	Year ITEs introduced	Number of active vessels	Min market	GVP ($m)
Commonwealth					
Northern Prawn Fishery	Multi	2006	51	Both	$124.0
Torres Strait Prawn Fishery	Multi	1993	20–30	Export	$5.9
Queensland					
East Coast Otter Trawl Fishery	Multi	2000	293	Both	$74.0
South Australia					
Gulf St Vincent Prawn Fishery	Single	2014	10	Domestic	$4.4
Western Australia					
Temperate demersal gillnet/longline	Multi	2009	22	Domestic	$4.8

Description of key ITQ/ITE fisheries by fisheries jurisdiction

Commonwealth fisheries

Australian Fisheries Management Authority (AFMA) manages more than twenty fisheries on behalf of the Australian Government (Newton et al 2007). ITQs are used in 8 Commonwealth fisheries and ITEs are used in 2 Commonwealth fisheries (the Northern Prawn Fishery (NPF) and the Torres Strait Prawn Fisheries (TSPF)). Commonwealth fisheries accounted for 15% of gross value of production (GVP) for Australian wild catch fishing ($438.3 million), accounting for a total of 56,773 tonnes in 2015–16. The NPF, Southern and Eastern Scalefish and Shark Fishery (SESSF), Southern Bluefin Tuna Fishery (SBTF), Eastern Tuna and Billfish Fishery (ETBF) and Torres Strait fisheries accounted for 70% of Commonwealth fisheries GVP in 2015–16 (Patterson *et al.* 2018).

Commonwealth ITE fisheries

The Northern Prawn Fishery (NPF) is the largest ITE-managed fishery in the Commonwealth (detail for this fishery is provided in the case study analysis). ITEs have been in operation in the NPF for over 10 years. After developing rapidly through the 1970s, effort peaked in 1981 with more than 250 vessels in this fishery. Since that time, the fishery has been restructured partly through the structural adjustment and buyback programs, and the implementation of ITEs. The restructure reduced the fleet size to 52 vessels and this has remained relatively stable since then. Stock levels for different prawn species in the NPF mostly fell throughout the 1980s and 90s, but some started trending upwards from around the early 2000s.

Table 3. Main ITQ fisheries by jurisdiction

Fishery	Multi/ single species	Year ITQs introduced	Number of active vessels/ licences	Main market	GVP ($m)
Commonwealth					
Bass Strait Central Zone Scallop Fishery	Single	2006	12	Domestic	$4.6
Eastern Tuna and Billfish Fishery	Multi	2011	37	Export	$35.9
Small Pelagics	Multi	2009	3	Domestic	NA
Southern and Eastern Scalefish and Shark Fishery	Multi	1989	146	Domestic	$72.9
Southern Bluefin Tuna Fishery	Single	1994	25	Export	$35.9
Sub Antarctic fisheries[a]	Multi	2002	4	Export	NA
Torres Strait Rock Lobster Fishery[b]	Multi	2005	11[a]	Export	$14.3
Western Tuna and Billfish Fishery	Multi	2010	3	Export	NA
New South Wales					
Abalone	Single	2000	31	Export	$3.7
Lobster Fishery	Single	2000	102	Export	$11.7
Sea Urchin and Turban Shell Fishery	Multi	2002	17	Export	$0.1
Northern Territory					
Demersal Fishery	Multi	1995	9	Export	$5.1
Timor Reef Fishery	Multi	2015	7	Export	
Coastal Line Fishery	Multi	2015	14	Export	
Queensland					
Beche-de-Mer	Multi	1991	4	Export	$6.7
Coral harvest Fishery	Multi	1995	36	Export	NA
Coral Reef Finfish Fishery	Multi	2004	251	Both	$31.1
Spanner Crab Fishery	Single	1999	61	Domestic	$3.7
Tropical Rock Lobster Fishery	Single	2009	10	Domestic	$7.1
South Australia					
Abalone Fishery	Single	1985	34	Export	$22.2
Australian Sardine Fishery	Single	1995	14	Domestic	$25.9
Blue Swimmer Crab	Single	1996	11	Domestic	NA
Giant Crab	Single	2002	245	Export	NA
Pipi	Single	2007	23	Domestic	NA
Rock lobster southern zone	Single	1993	249	Export	$137.7
Rock lobster northern zone	Single	2003	39	Export	$26.01
Vongole (Mud cockle)	Single	2008	15	Domestic	NA
Tasmania					
Abalone Fishery	Single	1985	120	Export	$79.9
Giant Crab	Single	1999	17	Export	$2.0
Rock Lobster Fishery	Single	1998	173	Export	$92.9
Scallop Fishery	Single	2000	11	Export	$6.0
Victoria					
Abalone Fishery	Single	1988	71	Export	$19.7
Giant Crab	Single	2001	<5	Export	NA
Rock Lobster Fishery	Single	2001	66	Export	$24.5
Scallop Fishery	Single	1998	12-25	Export	NA
Sea Urchin	Single	2014		Export	NA
Western Australia					
Abalone - South Coast Brownlip/Greenlip	Multi	1999	17	Export	$5.1
Abalone - West Coast Roe's	Single	1999	22	Export	$1.2
Gascoyne Demersal Scalefish	Multi	2006/07	17	Export	$1-$5.0
Mackerel Fishery (Statewide)	Multi	2006	10	Both	$2.5-$3
Northern Demersal Scalefish	Multi	2008	17	Export	$10-$20
Shark Bay Crab	Single	2016	30	Export	$2.0
Shark Bay Scallop	Single	2015	20	Export	$8.3
South Coast Purse Seine Managed Fishery	Multi	1994	9	Export	$1.0-$5.0
West Coast Deep Sea Crab Fishery	Single	2013	7	Export	NA
Western Rock Lobster Fishery	Single	2010	226	Export	$424

a) Heard Island and McDonald Island Fishery, and Macquarie Island Fishery; b) Excludes Torres Strait Traditional Inhabitant Fishing Boats (TIB) sector not subject to quota controls.

The Torres Strait Prawn fishery (TSPF) is limited by a Total Allowable Effort (TAE) in the form of transferable fishing days. The decrease in fishing effort in the TSPF has been pronounced from 1999 to 2011, largely as a result of economic conditions in the fishery. In 2017 only 15% of the allowable Australian proportion of the effort was used. Because of the low fishing effort in the TSPF, there is little trade in ITEs. The 2017 fishing season had the lowest catch of Tiger Prawns (*Penaeus esculentus, P. semisulcatus*) and Endeavour Prawns (*Metapenaeus endeavouri*, *M. ensis)* and the lowest fishing effort since 1978 when catch records commenced for this fishery.

Commonwealth ITQ fisheries

The Bass Strait Central Zone Scallop Fishery has a history of boom and bust, with the peaks (1982–1983, 1994–1996, 2003 and 2017) generally becoming progressively smaller. Around 103 vessels were active in the fishery during the 1995 peak. There have been several fishery-wide closures but the fishery reopened in 2009 with 26 active vessels falling to 12 vessels in 2017 (Department of Sustainability 2013). The 2017 fishery opened with a starting TAC of 3,000 t and operators reported Commercial Scallops (*Pecten fumatus*) in good condition but the catch level to trigger a TAC increase was not reached (Patterson et al. 2018).

Five key target species in the Eastern Tuna and Billfish Fishery (ETBF) have been managed using ITQs since 2011 following a transition from ITEs. Australia's catch in the ETBF as a percentage of the total catch from all nations in the Coral and Tasman seas has been declining across the major target species (Swordfish (*Xiphias gladius)* and Yellowfin Tuna (*Thunnus albacares*)). Following a decrease in effort, the total retained catch of all species in the ETBF declined from a high of more than 8,000 t in 2002 to around 4,200 t in 2013 and rising slightly to 4,615 t in 2017 (Patterson et al. 2018). Both the decline in economic conditions and the removal of vessels through a structural adjustment package (Securing our Fishing Future) in 2006–07 are likely to have contributed to the substantial decrease in the number of vessel (from around 150 in 2002 to 39 in 2017) (Vieira *et al.* 2010).

The Southern and Eastern Scalefish and Shark Fishery (SESSF) comprises three separate fishery sectors: the Commonwealth Trawl Sector, the Gillnet, Hook and Trap Sector, and the Great Australian Bight Trawl Sector. The SESSF was the largest Commonwealth fishery in terms of volume caught in the 2016–17 fishing seasons, accounting for 20% ($82 million) of the gross value of production (GVP) of Commonwealth fisheries. Landings in the SESSF have generally decreased over time as a result of reductions in fishing effort. The SESSF was one of the fisheries targeted by the structural adjustment package in 2006–07 (Patterson et al. 2018). For example, reduced effort in the Great Australian Bight Trawl Sector (GABTS) has led to reduced catches of key target species over time. Only four trawl vessels and one Danish-seine vessel operated in GABTS in 2017–18. There are many species for which the TAC in not caught. For instance, only 49 per cent of the TAC for Deepwater Flathead (*Neoplatycephalus conatus*) was caught although this continues to dominate catches in the GABTS, with 548 t landed in the 2017–18 fishing season. Bight Redfish (*Centroberyx gerrardi*) landings in 2017–18 were 308 t, which was 39 per cent of the TAC (Patterson et al. 2018).

The economic condition of the SESSF, the reasons for under-caught TACs, and the potential role quota trade, is currently the subject of a FRDC study (project 2016-146).

The Southern Bluefin Tuna Fishery (SBTF) comprises fishing fleets from a number of nations, both on the high seas and within the Exclusive Economic Zones (EEZs). This fishery is managed jointly under international management arrangements. The reported global catch of Southern Bluefin Tuna (*Thunnus maccoyii*) has declined since the peak catches in the early 1960s, but has been fairly stable since the mid-2000s. The Australian catch and TAC were stable from 1990 to 2009 and were then reduced as part of a global reduction in catch. However, the TAC has been slowly increasing with the implementation of the management procedure in 2011 and positive stock assessment outcomes (Patterson et al. 2018). Currently the catch in this fishery is transferred to aquaculture farming operations off the coast of Port Lincoln in South Australia, where the fish are grown to a larger size to achieve higher market prices. Most of the Australian catch and effort is by purse-seine vessels in the Great Australian Bight and waters off South Australia. The number of longline vessels fishing for southern bluefin tuna off the east coast of Australia has been more variable over time. Effort in the longline sector is largely dependent on available quota. The number of vessels in the purse-seine fishery has been fairly stable, ranging from five to eight since the 1994–95 fishing season (Patterson et al. 2018).

Effort in the Sub Antarctic fisheries of Heard Island and McDonald Islands Fishery (HIMIF) has been fairly stable, with two to four vessels active at any one time since a TAC was introduced (mid 1990s). Catch of Patagonian Toothfish (*Dissostichus eleginoides*) in the HIMIF declined slightly since the late 1990s, but was relatively stable until 2013–14. In 2014–15, seven vessels were active reducing to four vessels in 2016–17. There appears to be a low level of quota latency, which generally go together with positive net economic returns (NER). The catch of Patagonian Toothfish as part of the Macquarie Island Toothfish Fishery (MITF) has been variable over time and generally below the TAC, with a 92 t catch in the 2017–18 season, below the TAC of 450 t (Patterson et al. 2018).

The Torres Strait Tropical Rock Lobster Fishery (TSTRLF**)** is currently managed primarily through input controls. Voluntary buyout of fishing licences for non–Traditional Inhabitants commenced in 2011 (completed in 2012), aimed at increasing the ownership and participation of Traditional Inhabitants in the fishery. In 2016, the Protected Zone Joint Authority (PZJA) released a draft management plan in which a quota-based allocation system (output controls) was proposed (Quotas for Tropical Rock Lobster [Kaiar] Management Plan 2016).[2] The draft plan is not in force but output controls for the non-indigenous sector were proposed, with provisions for leasing quota (Patterson et al. 2018). A process for managing and allocating rock lobster quota within the indigenous sector is still to be determined. Total catch of Tropical Rock Lobster (*Panulirus ornatus*) since 1978 has fluctuated between 122 t and 932 t per year for the Australian sectors and decreased to 283 t in 2016–17 (Patterson et al. 2018). Several studies have outlined potential issues associated with allocating quota to the indigenous sector and increasing indigenous quota ownership (e.g. van Putten et al. 2013a).

The Western Tuna and Billfish Fishery (WTBF) operates in Australia's EEZ and high seas of the Indian Ocean. AFMA first granted statutory fishing rights in 2010 for the four key commercial species: Bigeye Tuna (Thunnus obesus), Yellowfin Tuna (Thunnus albacares), Broadbill Swordfish (Xiphias gladius) and Striped Marlin (*Kajikia audax).* Effort in the WTBF was relatively low (<20

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[2] https://www.pzja.gov.au/sites/g/files/net4491/f/content/uploads/2016/06/I15EF113.v12-TRL-Plan-exposure-draft-PZJA-meeting.pdf

vessels) from the mid-1980s to the mid-1990s and increased in the late 1990s, peaking at 50 active vessels in 2000, but then declined rapidly (Patterson et al. 2018). Since 2005, fewer than five vessels have been active in the fishery each year with three vessels in the 2016 fishing season and four vessels in the 2017 season. The impact of the move to ITQs has not been measured because of the low participation in the WTBF. The very low levels of catch relative to the TAC in the WTBF are unlikely to provide any incentive for quota trade to occur, minimising any efficiency gains (Patterson et al. 2018).

New South Wales

NSW currently has three main ITQ fisheries, namely Eastern Rock Lobster (*Jasus verreauxi*), Blacklip Abalone (*Haliotis rubra*) and Red Sea Urchin (*Heliocidaris tuberculata*). The current ITQ systems for Eastern Rock Lobster and Abalone were implemented in 2000, although TACs and individual allocations (on an equal share basis) were introduced in the mid to late 1990s. ITQs were introduced into both fisheries in response to concerns about declining stock sizes, and both fisheries saw declines in the TAC and fleet rationalisation for several successive years after the introduction of the system. Shareholder numbers and active fishers have stabilised since around 2007, although trading of shares (and leasing of quota) continues to occur. Stock recovery in both fisheries has been observed (Abalone Council of NSW 2018; Liggins *et al.* 2018), although a downturn in abalone stocks has been seen in recent years (believed to be the result of a combination of severe storm conditions, potential local depletion in some areas and a reduction in the productivity of some areas), with a subsequent decline in the Abalone TAC. Vessel level economic information (i.e. cost and earnings data) is not formally collected from these fisheries. Changes in licence trading values over time, however, suggests that profitability in both fisheries has increased substantially over recent years (McKinnon and Foster 2018; Pascoe *et al.* 2019b). Further details on the rock lobster fishery are provided in the case study section of the report. TACs for these two species are set annually by an independent Total Allowable Fishing (TAF) Committee.

The Red Sea Urchin fishery is a component of the broader Sea Urchin and Turban Shell Fishery (SUTS) fishery. Red Urchin is a secondary species in the fishery, with most fishing activity targeting Purple Sea Urchin (*Centrostephanus rodgersii*), a lesser valued but more abundant species. Those who target Red Urchin mostly do so during the winter months, when Purple Urchin have less roe. Fishing activity on the Purple Sea Urchin is not constrained other than through the limit on the number of endorsements. Many SUTS endorsement fishers also operate in the Abalone fishery, and harvest urchin (both species) opportunistically. A 60 tonne TAC for Red Sea Urchin was set in 2002, and this was distributed equally across all (39) endorsements. The Red Sea Urchin quota is not divisible nor separable from the SUTS endorsement, so for a fisher to buy additional quota they need to buy the entire endorsement, effectively buying out another fisher from the broader SUTS fishery. As a result, trade in the fishery is limited, and considerable latent capacity exists, with on average only 6-10 tonnes being caught (from the 60 tonne quota) since 2002. The TAC – unchanged since 2002 – is being reconsidered in 2018 by the TAF Committee, although the outcome from this has not yet been released.

Seventeen other NSW species are being moved to quota management from 2019 as part of a Commercial Fisheries Business Adjustment Program.[3] Around half of these species are fish species caught also in the Commonwealth SESSF, and their management will be in conjunction with that of the SESSF. For the first fishing period (commencing in 2019), the Director General of the Department of Primary Industries (under delegation from the Secretary) has set the TAC for the 17 new species, although subsequent TAC setting is to be referred to the TAF Committee.

Queensland

Queensland has several ITQ fisheries as well as an ITE fishery. The largest ITQ fishery in terms of value is the Coral Reef Finfish Fishery, which operates almost entirely within the Great Barrier Reef Marine Park. This is a multispecies line fishery that includes quotas for two species – Coral Trout (a group of seven species dominated by *Plectropomus leopardus*) and Redthroat Emperors (*Lethrinus miniatus)* – and a large mixed other species (OS) group. Coral Trout – the most valuable species – is exported live to Asian markets. The high value of the species has attracted a number of investors into the industry who purchase and then lease out the quota. In 2011-12, 41% of coral trout quota was owned by participants who did not fish it, and 64% of total Coral Trout landings were made by fishers that owned only 10% of the quota (Innes *et al.* 2014).

ITQs were introduced in to the Queensland Spanner Crab Fishery in 1999, following the introduction of an earlier competitive quota on Spanner Crabs (*Ranina ranina*) in 1986 in response to decline catch rates in the fishery (Dichmont and Brown 2010). The fishery has two regions – one managed using ITQs and the other through trip limits and effort controls. The ITQ region is managed through a simple harvest strategy based on catch rates (catch per unit of effort, CPUE) and fishery independent survey information. The TAC is fixed unless both CPUE and the survey index change by more than a specified proportion (10%), and then the amount of change is limited to half the combined CPUE/index change for an increase, and the full amount in the case of decrease. A maximum TAC is also specified irrespective of the change in CPUE/stock index (Dichmont and Brown 2010; O'Neill *et al.* 2010). Since 2007, the number of active vessels in the fishery has decreased from 72 to 61, while both catches and CPUE has decreased. In 2017, catches in the ITQ region are less than 50% of the TAC (DAF 2018).

The Queensland Tropical Rock Lobster Fishery moved from limited entry to ITQ management in 2009. While 28 vessels hold endorsements to operate in the fishery, only between 7 and 12 active vessels have operated over the last decade, with total catch almost equalling the TAC (99.7%) (DAF 2018). The Bêche-de-Mer Fishery is one of Queensland's oldest commercial fisheries, with harvesting dating back to the 1880s (Roelofs 2004). The fishery is based on a wide range of seas cucumber species, with Blackfish (*Actinopyga palauensis, Actinopyga spinea*), White Teatfish (*Holothuria fuscogilva*) and Sandfish (*Holothuria scabra*) making up most of the harvest. It is harvested by only a small number of fishers, who also process and export the product. Eighteen licences exist for the fishery, but only four are used to harvest the full TAC. The industry has proposed a rotational harvesting system to ensure long term sustainability of the resource (Roelofs 2004).

[3] https://www.dpi.nsw.gov.au/fishing/commercial/reform

The East Coast Otter Trawl Fishery is an ITE fishery targeting predominantly prawn species. ITEs were introduced into the fishery in 2000. Falling prawn prices and higher input prices have resulted in considerable un-utilised effort units (Dichmont *et al.* 2013). Active vessel numbers have declining from 377 in 2007 to 293 in 2018, although total days fished has remained relatively constant over this period (DAF 2018). No information is available about the economic performance of the fishery.

As with NSW, Queensland fisheries are currently undergoing a structural reform review, and ITQs have been proposed for several fisheries currently managed through input controls. As this review has not been finalised or the outcomes implemented it is not feasible to comment which additional fisheries may move to ITQs.

Northern Territory

The NT demersal fishery harvests largely Red Snappers (mainly *Lutjanus malabaricus*) and Goldband Snappers (*Pristipomoides multidens*, *P. typus*), along with a number of associated finfish species. ITQs were introduced into the fishery at the request of the Demersal Fishermen's Association to ensure sustainability and improve economic efficiency and flexibility for the operators (NT Government 2017).

The Timor Reef Fishery is an offshore demersal finfish fishery using traps and lines to target predominantly Goldband Snapper, but also catches significant quantities of Red Snapper. The fishery was originally managed using input controls, but at the request of the licensees, was converted to an ITQ fishery in 2015 (NT Government 2015).

The coastal line fishery harvests mainly Black Jewfish (Protonibea diacanthus, harvested for their swim bladders) and golden snapper. Catch limits for the two main species were put in place in 2010 initially for sustainability reasons, and these were converted to ITQs in 2015 to also ensure ongoing commercial viability of the fishery.[4]

Tasmania

ITQs have been used in Tasmanian fisheries management since 1985. The abalone fishery targeting Blacklip (*Haliotis rubra*) and Greenlip (*Haliotis laevigata*) Abalone was the first ITQ program introduced in Tasmania. Further details on the Tasmanian Abalone Fishery are provided in the case study section of the report.

The Rock Lobster Fishery targeting Southern Rock Lobster (*Jasus edwardsii*) is the largest commercial fishery in Tasmania in terms of the gross value of production, worth $92.9 million in 2015/16 (ABARES 2017b). By the early 1990s, there was growing concern for overfishing and economic inefficiency due to classic race to fish, which has lead the introduction of ITQ in 1998 (Phillips *et al.* 2002). The number of active vessels has declined from 351 in 1994/95 to below 220 in 2007/08 and 2008/09 seasons but since increased to 235 active vessels in 2011/12 season (Hartmann *et al.* 2013). As stocks have declined, vessels and fishers have needed to work more days to take the same catch, which creates an under supply of vessels, improves business conditions for new entrants, hence increased the number of active vessels in the 2011/12 season (Hartmann et al. 2013). However,

[4] http://ntgfia.com.au/wp-content/uploads/2015/03/DPIF-Commercial-Fact-Sheet-print.pdf

the most recent data shows a large decline in the number of active vessels to 173 in 2018/19 season (Klaas Hartmann, personal communication, March 2019). Giant Crabs (*Pseudocarcinus gigas*) had previously been landed as byproduct in the fishery, but became a targeted species in their own right in the mid-1990s, after which catches increased dramatically, but then declined by the late 1990s. At this time quota management was introduced to the Rock Lobster Fishery and there was concern that this would displace effort from the Rock Lobster Fishery to the Giant Crab Fishery. In response, a Giant Crab management plan was introduced and an ITQ system implemented in 1999 (Emery *et al.* 2015).

The Tasmanian Scallop Fishery targets Commercial Scallop (*Pecten fumatus*), one of 3 species naturally occurring in the state. The Tasmanian Scallop Fishery has experienced repeated 'boom and bust" phases, with stock declines resulting in prolonged fishery closures (e.g. 1985-1995, 2000-2002, 2009-2010). Following the introduction of 'bag' quotas in the 1990s, transferable quota units were introduced in 2000 to encourage restructuring in the fishery (Semmens *et al.* 2018). The industry restructuring resulted in a reduction of the number of licenses to 92 by 2005, the most recent available number indicating 72 licenses and 11 active vessels remain in the fishery (Semmens et al. 2018).

South Australia

South Australia has 7 main ITQ fisheries. The ITQs were first introduced into the Abalone Fishery for the Western Zone in 1985, the Southern Zone in 1988 and the Central Zone in 1989 due to concerns of overexploitation for Blacklip and Greenlip Abalone (PIRSA 2015). Commercial access to abalone resources is limited to a total of 34 commercial licenses across the 3 zones (PIRSA 2015). Minimum legal size limits set by each Zone, weight limits, and seasonal closures also apply to the fishery. The Rock Lobster Fishery in South Australia (also targeting Southern Rock Lobster) is divided into two separate management zones: Northern Zone and Southern Zone. The Rock Lobster Fishery went through a number of management measures including winter closure to protect egg bearing females in 1966, limited entry in 1968, government buyback scheme of 40 licenses in 1987, followed by the introduction of an TAC/ITQ system in 1993 for the Southern Zone and in 2003 for the Northern Zone (PIRSA 2015). While the decline in effort has been seen since the introduction of the quota system, there was a marked trend in increased effort between 2000 and 2009 (PIRSA 2015). The TAC for the Northern Zone was not reached for 6 consecutive years after the introduction of the quota system despite TACs being incrementally reduced from 625 t in 2003 to 470 t by 2008, supporting evidence that the resource in the Northern Zone is overfished (PIRSA 2015).

License holders in the Rock Lobster Fishery are also permitted to land and sell Giant Crab. Commercial fishing for Giant Crabs began in South Australian waters in 1992 as a by-product of Rock Lobster fishing operations (PIRSA 2018). A TAC was introduced for commercial harvest of Giant Crab in 1999 and the quota became individually transferable since 2002 (PIRSA 2015). Due to data limitations and contrasting information derived from performance indicators for the fishery, the Giant Crab resource in SA is categorised as undefined (PIRSA 2018).

In 1991, the South Australian Government wrote to Marine Scalefish Fishery license holders seeking expressions of interest in establishing a fishery targeting Australian Sardine (*Sardinops sagax)*, and the first management plan which introduced a transferable quota system was implemented in 1995 (PIRSA 2015). Similarly the Government established a commercial pot fishery for Blue Swimmer Crab (*Portunus armatus*) in 1996, and since the establishment of the fishery, an ITQ system has been in place (PIRSA 2015). Two groups of license holders operate within the Blue Crab Fishery: Blue

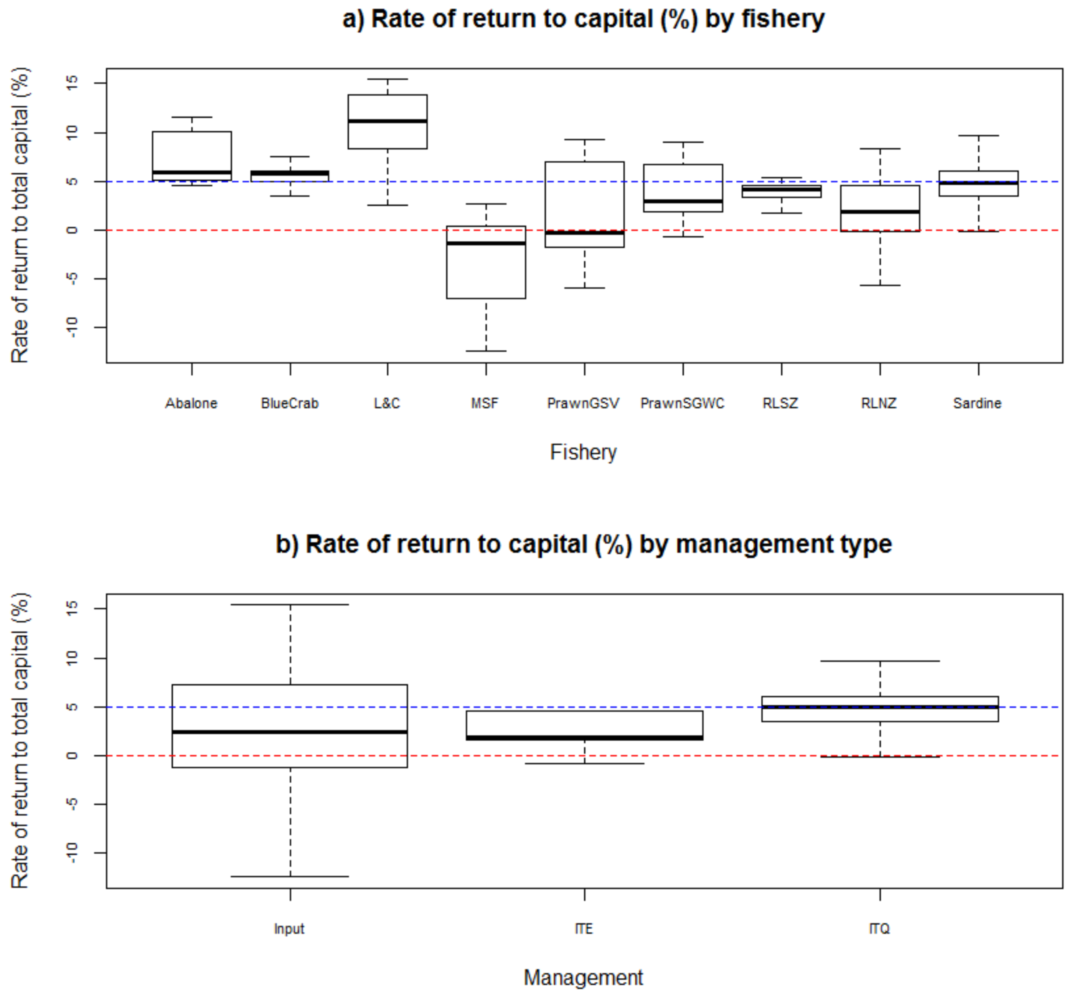
Swimmer Crab license holders and the Marine Scalefish Fishery license holders. Commercial fishers are allocated an agreed level of access to the area defined as the Blue Crab Fishery. This access is provided in units of quota, transferable between the Blue Crab Fishery and Marine Scalefish Fishery. Units are not transferable between Gulf St Vincent and Spencer Gulf fishing zones. Currently the Marine Scalefish Fishery sector holds 1% of TAC for the Blue Crab Fishery. Due to sustainability concerns in Gulf St Vincent, a temporary commercial catch reduction and recreational bag limit reduction was implemented for the 2013/2014 and 2014/15 fishing seasons (PIRSA 2015).

Pipi (*Donax deltoides*) is a small saltwater clam which supports commercial and recreational fishing in SA. The commercial fishery harvest Pipi manually using cockle rakes. The Pipi fishery has expanded rapidly over the last 10 years in response to a growing human consumption market. In response to concerns about the future sustainability of the Pipi fishery, an ITQ was introduced to the commercial fishery in 2007 (PIRSA 2018). The Mud Cockle (also known as Vongole) Fishery in South Australia supports the commercial harvest of three species of the genus *Katelysia*. An ITQ system was introduced in 2008 in response to concerns about future sustainability of stocks (PIRSA 2015).

Gulf St Vincent Prawn Fishery (GSVPF) is a single-species prawn fishery, based on the capture of the Western King Prawn (*Melicertus latisulcatus*) using trawl nets. The commercial prawn fishery began in the Gulf of St Vincent in 1968. The fishery has been temporarily closed on several occasions through its history. In June 1991, the fishery was temporarily closed until February 1994 to enable stock recovery. The GSVPF was again closed in December 2012 at the request of all ten licence holders due to poor economic performance. The economic performance of the fishery had declined due to the declining catches, the high Australian dollar, decreasing prawn prices (largely due to the increasing imports of lower farmed prawns from South East Asia) and increasing costs of operation (PIRSA 2017). The fishery reopened in November 2014. Following the closure of the fishery in 2012 a review of management arrangements in the fishery was conducted, which recommend that fishing access rights be allocated and an ITQ system be implemented via a two stage approach. Stage 1 would use tradable effort units (ITE) and stage 2 would move the fishery to an ITQ system (PIRSA 2017). ITE units were introduced to the fishery in 2014 and are allocated equally between the ten licence holders.

Currently South Australia is the only state that systematically produce economic performance reports for their state-managed fisheries. Based on the most recent report, the total number of active vessels has declined over the last decade, largely driven by declines in Marine Scalefish fishery. The rates of return to total boat capital (licence/quota values and boat capital value) for the different fisheries suggest that the majority of fisheries are earning below normal rate of return (Figure 4). This suggests that either licenses are overvalued relative to the level of profitability that the fishery is consistently performing below its expected long term level of profitability, or that the fishers have a lower discount rate than the risk free rate (Pascoe and Innes 2017). The median rate of return for fisheries managed under ITQs was at the long term risk free rate, while it was less than expected risk free rate for the ITEs and input controlled fisheries (Pascoe and Innes 2017).

Figure 4. Rate of return to capital by a) fishery and b) management type, 1997-98 to 2013-14



Note: The red dotted line indicates "break-even" and the blue dotted line indicates average long run risk-free normal return (Pascoe & Innes 2017).

Victoria

Victoria has 5 main ITQ fisheries. The ITQ system was first introduced in 1988 for the Abalone Fishery to limit the potential for substantial effort increases due to the replacement of older divers with new entrants to the fishery when transferability of licenses was introduced four years previously (Victorian Government 2001). There are 71 fishery access licenses in the Abalone Fishery, which is subdivided into three management zones. Since the beginning of the Commercial Scallop Fishery in the 1970's, catches of Commercial Scallop have varied from tens of tonnes to thousands of tonnes, showing classic sings of boom and bust cycles. Port Phillip Bay was closed to commercial fishing in 1997, and the licenses for Bass Strait and Lakes Entrance were combined in 1998 to be called 'Ocean Scallop'. The Ocean Scallop Fishery has been under ITQ arrangements since 1998. Although there are 91 commercial licenses in the Ocean Scallop Fishery, the number of active vessels was generally between 12 and 25 vessels in any year between 2001/02 and 2008/09 and has been less than 5 vessels in recent years (Victorian Government 2015).

ITQ systems for the Victorian Rock Lobster Fishery (targeting Southern Rock Lobster) and Giant Crab Fishery have been in place since 2001. The two fisheries are divided into two separately managed zones, the Eastern Zone (EZ) and Western Zone (WZ). Currently fishing for Giant Crab only occurs in the Western Zone, and commercial access to the resource is through the issue of a Giant Crab Fishery licence to Western Zone fishers, while in the Eastern Zone access is provide by a general permit and the fishery is managed as a developing fishery (Linnane *et al.* 2015). Prior to 2001, the catch of Giant Crab was reported as the bycatch in the lobster fishery. The number of licenses and vessels has decreased over the last decade, part due to the structural adjustment program undertaken during 2008/2009. Since 2001 (after introduction of ITQs), the number of active licenses/ vessels for the Rock Lobster Fishery in the WZ was reduced from 72 active licenses (83 vessels) in 2001 to 48 licenses (48 vessels) in 2014 (Linnane et al. 2015). Similarly, the EZ saw the reduction from 39 licenses (34 vessels) in 2001 to 27 licenses (27 vessels) in 2014.

The Sea Urchin Fishery, targeting White Sea Urchin (*Heliocidaris erythrogramma*) and Black Sea Urchin (*Centrostephanus rodgersii*), is the newest fishery adapted ITQ in Victoria in 2014. The fishery has been operating as a "developing fishery" under permits since 1998, but following interest by fishers to transition this fishery to a more secure licensing arrangement, a new management framework based on ITQ was introduced in 2014 (Victorian Government 2014).

Western Australia

As of 2016, Western Australia had eleven fisheries under ITQ management and one fishery under ITE arrangements. The Western Australia Abalone Fishery was the first fishery in the state to be managed under ITQs in 1999, after previously being managed under a non-transferable TAC (Hart *et al.* 2017). The fishery is divided into eight spatial zones along the entire Western Australian coastline with TACs set for each zone. Commercial divers target three species: Roe's Abalone (*Haliotis roei*), Brownlip Abalone (*Haliotis conicopora*) and Greenlip Abalone (*Haliotis laevigata*). TAC decision rules were introduced between 2005 and 2009 (Hart *et al.* 2013) and are now captured in a formal fishery harvest strategy (DOF Government of Western Australia 2017). Recent performance in the fishery has been impacted by falling prices (due to competition with cultured abalone) and historically low catches, which are the result of lowered TACs but also decisions by industry not to fish a proportion of their TAC (Gaughan and Santoro 2018). Industry is also considering a move to a different management model for one of the fishery's management areas (Gaughan and Santoro 2018).

The state's largest and most valuable fishery, the Western Rock Lobster (*Panulirus cygnus*) Fishery moved to ITQ management in 2010-11. The fishery has historically been one of Australia's most valuable wild-caught, single-species fisheries. From 1993-94, the fishery had been managed under ITEs (based on pot numbers). Unprecedented falls in the settlement of puerulus (de Lestang *et al.* 2015) caused management to introduce significant effort reductions (with vessel numbers dropping from 460 in to 280 between 2008 and 2010) combined with increasingly complex effort restrictions (Penn *et al.* 2015). Due to this complexity, the Western Australian government made a unilateral decision to move the fishery to ITQs. The reduction in fleet size combined with higher beach prices (due to reduced supply) had already led to increased profits prior to the introduction of ITQs (Reid *et al.* 2013). Further increases in beach prices following ITQs and the adoption of a MEY target in the fishery's harvest strategy in 2014 have further contributed to increased profitability. Increased entitlement values have also resulted but have contributed to a trend of reduced industry ownership (Penn et al. 2015). As noted by Penn et al. (2015), the fishery's transition to ITQs benefited from the relatively simple approach of directly converting ITE units to ITQs and also the fishery's accurate stock prediction model, which was developed under ITEs.

The recent performance of a number of Western Australian quota managed fisheries has been negatively impacted by a marine heat wave that occurred in early 2011 off the Western Australian coast (Caputi *et al.* 2014). Such fisheries included the State's Roe's Abalone Fishery (with mortalities in one management area of the fishery estimated at 99.9 per cent), Shark Bay Scallop and Crab Fisheries and the Abrolhos Islands Scallop Fishery (Gaughan and Santoro 2018). Dramatic management responses including closures were required, with many of the affected stocks still recovering and currently subject to historically reduced catches.

Status of major ITQ/ITE managed stocks in Australia

The information regarding the national assessment of the status of the major fish stocks in Australian is available from two main sources, namely the annual *Fishery Status Reports* published by the Department of Agriculture and Water Resources (ABARES) of the Australian Government (ABARES 2018), and the *Status of Australian Fish Stocks* (SAFS) Reports, published by the Fisheries Research Development Corporation (RFDC) (Stewardson *et al.* 2016). The latter reporting framework was initiated in 2012 to improve the ability to compare the status of fish stocks across Australia.

In our study, we adopted the SAFS 2016 assessment results to compare the sustainability outcomes of the ITQ/ITE fisheries. As SAFS does not provide status summary by fishery, we linked the name of the ITQ/ITE fisheries identified in our desktop review with the stock name appearing in SAFS. Some stocks are exploited in multiple gears/fisheries (technical interactions) and is only partially managed under an ITQ/ITE system. Several smaller ITQ-managed stocks (e.g. sea urchin, Bêche-de-Mer, coral) were not included in the SAFS 2016, hence our summary excludes those fisheries with missing status information.

The status of the key stocks managed under ITQ/ITE systems in Australia by jurisdiction is summarised in Table 4. All jurisdictions had a range of fisheries with different stock status, including several instances of "overfished" and "transitional-depleting". For Australia as a whole, out of 116 ITQ/ITE-managed stocks (including those partially managed by ITQ/ITEs due to technical interactions), the majority (72 stocks or 62.1%) of stocks are classified as "sustainable." However, 26.7% of stocks are classified either "overfished" (17 stocks) or "transitional-depleting" (14 stocks). The result is consistent with the findings from previous review studies (e.g. Chu 2009) that ITQ do not always translate to an increased stock biomass or stock sustainability.

Table 4. Summary of the status of ITQ/ITE-managed stocks in Australia by jurisdiction

Jurisdiction	Stocks fully within an ITQ/ITE fishery		Stocks shared across fisheries, some not ITQ/ITE but with an ITQ or ITE fishery involved	
	ITE	ITQ	ITQ	ITE
Commonwealth	9	33		
Overfished		5		
Sustainable	8	24		
Transitional-depleting		1		
Undefined	1	3		
New South Wales		2		
Sustainable		2		
Northern Territory		7		
Overfished		2		
Sustainable		4		
Undefined		1		
Queensland		8	1	
Sustainable		4		
Undefined		4	1	
South Australia	1	16		
Overfished		1		
Sustainable		8		
Transitional-depleting	1	4		
Undefined		3		
Tasmania		9		
Overfished		1		
Sustainable		3		
Transitional-depleting		4		
Undefined		1		
Victoria		9		
Overfished		2		
Sustainable		3		
Transitional-depleting		2		
Undefined		2		
Western Australia		11	8	2
Negligible		1		
Sustainable		6	8	2
Transitional-depleting		2		
Transitional-recovering		2		
Total	10	95	9	2

Impacts of ITQs – fisher, scientist and manager perceptions

Overview of survey results

Response to the survey was generally good, with responses from each group across all jurisdictions, except for one respondent group in the Northern Territory, where no responses from managers were received (Table 5). Commercial fishers provided the greatest number of responses, although not all responses were usable (usable n=117). In some cases, only the first question (about experience) was answered. Removing these responses from the data set still resulted in a good cross section of data (n=204).

Table 5. Survey response rate by jurisdiction and respondent group (respondent role)

Jurisdiction	Industry		Science		Managers	
	Responses	Usable	Responses	Usable	Responses	Usable
Commonwealth	24	17	11	11	7	7
New South Wales	4	4	3	3	3	3
Northern Territory	3	1	2	2	0	0
Queensland	15	12	3	3	4	4
South Australia	12	10	10	10	4	4
Tasmania	77	60	11	11	2	2
Victoria	10	6	4	4	3	3
Western Australia	8	7	13	12	8	8
Total	153	117	57	56	31	31

The distribution of responses by fishery is presented in Table 6. The number of responses is not included in the table to maintain some degree of confidentiality, as most fisheries only had one or two responses. Analysis is not undertaken at the fishery level, and only basic analysis is undertaken at the jurisdictional level. However, it can be seen from Table 6 that a relatively good distribution of responses was received across the individual fisheries as well as across the different jurisdictions.

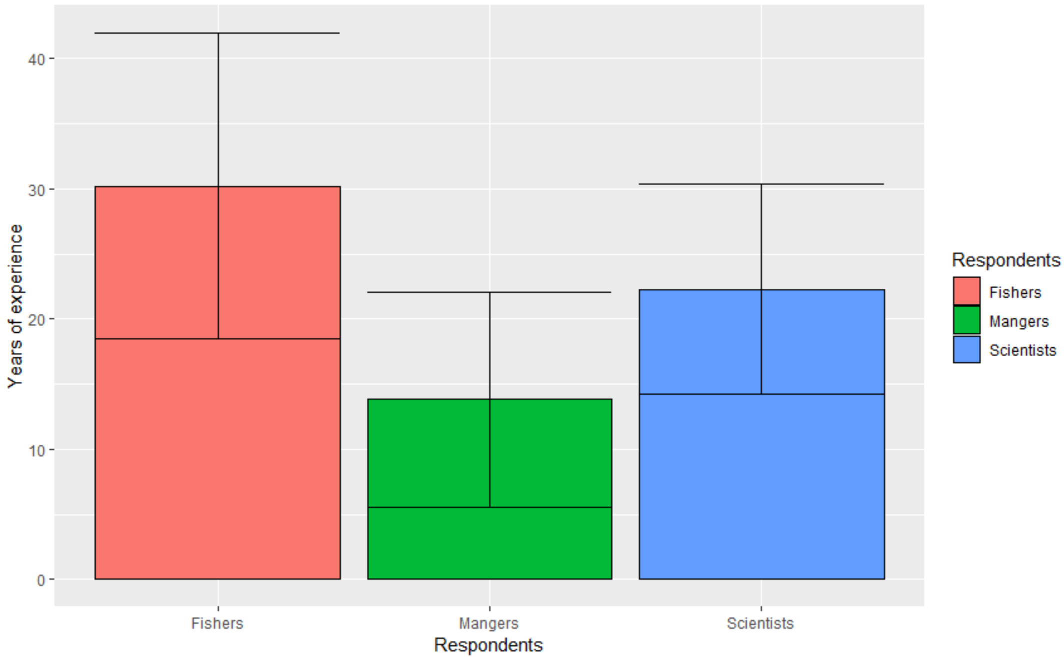
From Table 6, it can be seen that around half of the fisher responses were from Tasmania. Many of these were from one fishery – the Tasmanian abalone fishery. While this was not an explicit sampling strategy, the initial individuals contacted in this fishery felt that a broader response from fishers was warranted. As this was selected as a case study fishery, the project team also felt that a more detailed response from fishers would help better inform the case study. However, given the uneven sample across all fisheries, inclusion of all these responses in the more general national analyses would potentially bias the results. To limit the influence of this one fishery on the overall results, only a subset of data from this fishery was used for most of the subsequent analysis (details of which are given below). The full data from the Tasmanian abalone fishery, however, are used as part of a detailed case study on the fishery.

The level of experience in the industry was collected in order to gain an indication of the potential impact of this on people's perceptions of the outcomes of ITQ/ITE management. All groups included a wide range of experience, with fishers on average having around 30 years of experience in the industry, scientists having around 22 years of experience, while managers averaged around 14 years of experience (Figure 5).

Table 6. Distribution of survey responses by fishery and role

Fishery	Industry		Science		Managers	
	Responses	Usable	Responses	Usable	Responses	Usable
Commonwealth						
Bass Strait Central Zone Scallop	X	X			X	X
Eastern Tuna and Billfish Fishery	X	X	X	X		
Northern Prawn Fishery	X	X	X	X	X	X
Small Pelagics	X	X	X	X	X	X
Southern and Eastern Scalefish and Shark	X	X	X	X	X	X
Southern Bluefin Tuna	X	X	X	X	X	X
Sub Antarctic fisheries	X	X	X	X		
Torres Strait Rock Lobster Fishery						
Western Tuna and Billfish Fishery	X					
Other	X					
New South Wales						
Abalone	X	X	X	X	X	X
Lobster Fishery	X	X	X	X	X	X
Sea Urchin and Turban Shell Fishery	X	X	X	X	X	X
Northern Territory						
Demersal Fishery	X	X	X	X		
Timor Reef Fishery	X		X	X		
Coastal Line Fishery	X					
Queensland						
Aquarium fish	X	X				
Coral harvest fishery	X	X				
Coral Reef Finfish Fishery	X	X	X	X	X	X
East Coast Otter Trawl Fishery	X	X	X	X	X	X
Spanner Crab Fishery	X	X	X	X	X	X
Tropical Rock Lobster Fishery	X	X				
South Australia						
Abalone Fishery	X	X	X	X		
Australian Sardine Fishery			X	X	X	X
Blue Swimmer Crab	X	X				
Giant Crab	X	X	X	X		
Gulf St Vincent Prawn Fishery	X	X	X	X	X	X
Pipi	X	X	X	X		
Rock lobster northern zone			X	X	X	X
Rock lobster southern zone			X	X	X	X
Vongole	X	X	X	X		
Tasmania						
Abalone Fishery	X	X	X	X	X	X
Giant Crab			X	X		
Rock Lobster Fishery	X	X	X	X	X	X
Scallop Fishery	X	X				
Vongole			X	X		
Other			X	X		
Victoria						
Abalone Fishery	X	X	X	X	X	X
Giant Crab			X	X		
Rock Lobster Fishery	X	X	X	X	X	X
Scallop Fishery	X					
Sea Urchin					X	X
Other	X	X				
Western Australia						
Abalone Fishery	X	X	X	X	X	X
Gascoyne Demersal Scalefish	X	X	X	X	X	X
Mackerel Fishery			X	X	X	X
Northern Demersal Scalefish					X	X
Shark Bay Crab			X	X		
Shark Bay Scallop			X	X	X	X
South Coast and West Coast Demersal	X	X	X	X	X	X
South Coast Purse Seine Managed Fishery	X	X	X	X		
Temperate demersal gillnet/longline			X	X		
West Coast Deep Sea Crab Fishery			X	X		
Western Rock Lobster Fishery	X	X	X	X	X	X

Figure 5. Years of experience in the industry: mean values and standard deviations (error bars)



Perceptions of fishery performance

A summary of the average perceptions of fishery performance of each of the groups surveyed is presented in Table 7 and illustrated in Figure 6.

Given the large number of Tasmanian abalone fishers who responded to the survey (with 60 usable responses, comprising nearly half of the total usable observations for the fisher group), only a subset of these were included in the subsequent analysis. The Tasmanian abalone fishers were sorted in order of their perception of overall (combined) performance (from lowest to highest score), and every seventh observation was taken for use in subsequent analysis, resulting in eight observations drawn from this group covering the full range of views.[5] This ensures that the full range of responses are included in the subset of the sample to minimise potential bias. This brings the responses from this fishery closer to the maximum observed from other fisheries.[6] The full set of responses from the Tasmanian abalone fisheries is used in the case study in subsequent sections of the report.

From Table 7 and Figure 6, perceptions of performance of ITQs and ITEs in Australian fisheries varied between the groups, with managers generally giving the highest performance scores against all objectives, and also having the lowest level of variance in these scores across fisheries. Including only

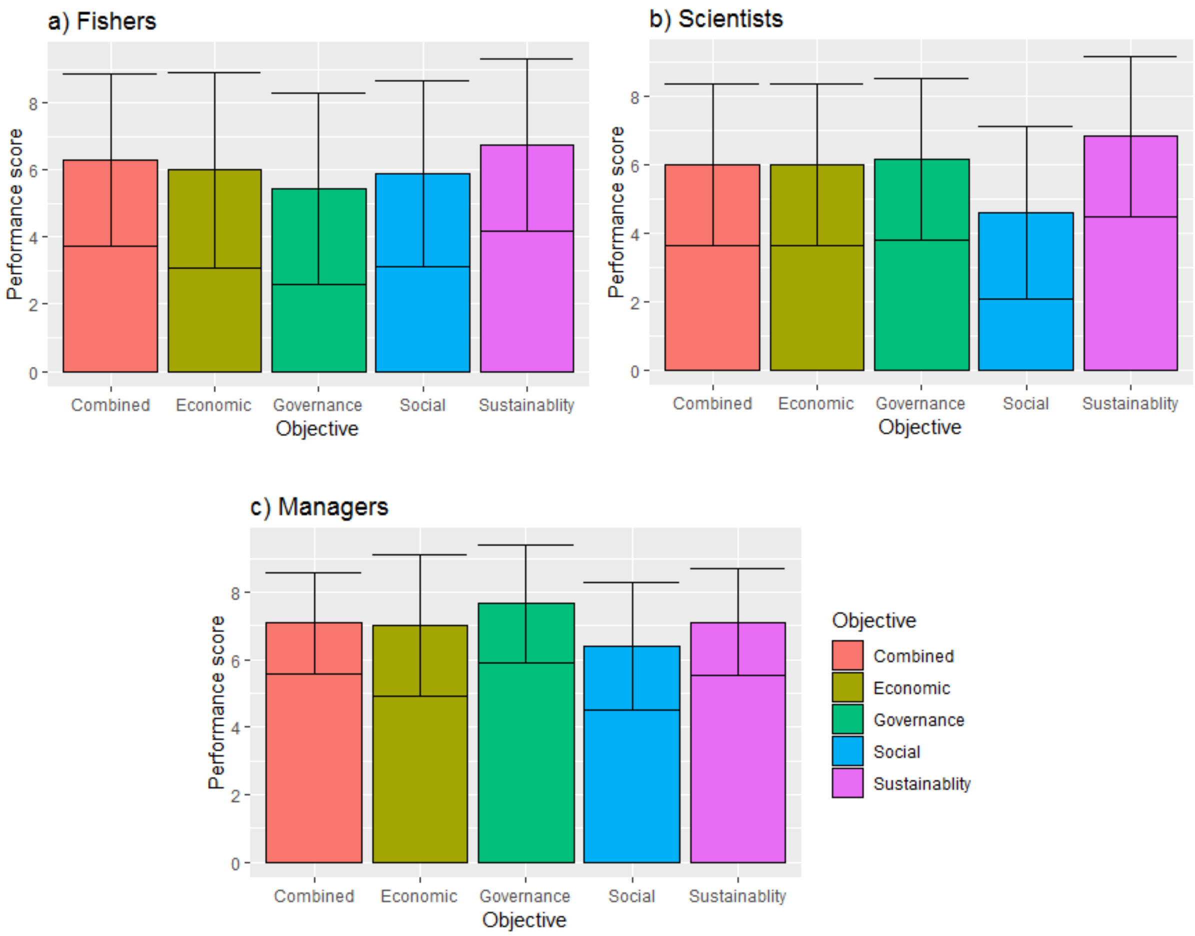
[5] In some parts of the results presented below minor comments are made regarding differences to the full abalone sample.
[6] One other fishery had five usable responses from fishers, three fisheries had four usable responses, while the remainder had three or less, with most fisheries having a single usable response.

a subset of Tasmanian abalone fishers resulted in a slight increase in the mean score for most objectives and the overall combined performance score.

Table 7. Summary statistics for the objective performance scores

	Fishers (all)		Fishers (reduced)		Scientists		Managers	
Objective	Mean	Std	Mean	Std	Mean	Std	Mean	Std
Sustainability	6.52	2.69	6.77	2.57	6.84	2.35	7.10	1.58
Economic	6.00	2.93	6.00	2.90	6.00	2.35	7.00	2.09
Social	5.76	2.78	5.89	2.77	4.60	2.52	6.39	1.89
Governance	5.47	2.91	5.46	2.86	6.18	2.37	7.65	1.76
Combined	5.97	2.72	6.29	2.57	6.00	2.35	7.07	1.51

Figure 6. Perceptions of performance: mean values and standard deviations

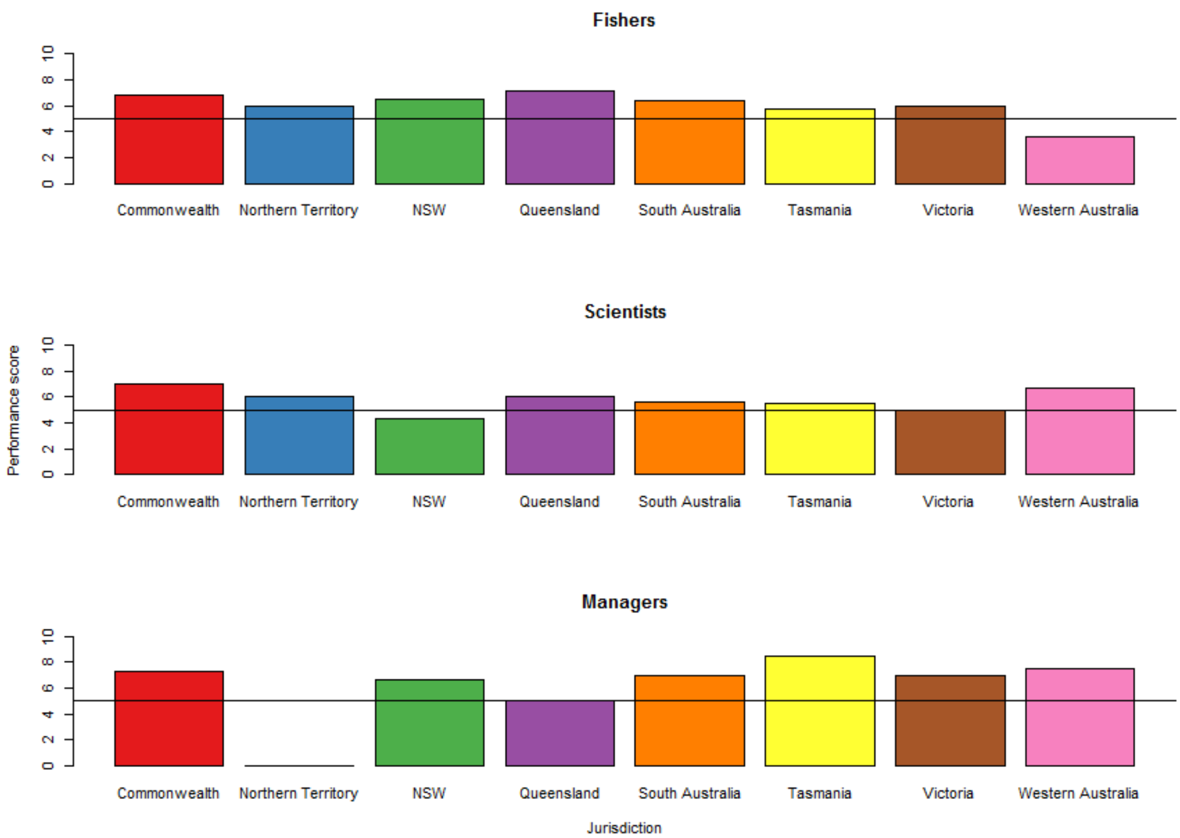


Perceptions of performance against sustainability and economic objectives were generally higher than the other objectives, with the exception that managers scored performance of governance objectives the highest. Performance against social objectives was generally considered low, with scientists considering this objective with the lowest performance. Scientists generally had the lowest perception of overall performance across the three groups.

Overall, respondents did not score the performance of ITQs and ITEs highly, on average. Both fishers and scientists provided an average score of around six out of ten. Managers were more optimistic, but still only scored their performance seven out of ten. Individuals within all the groups had widely varying perceptions (as indicated by the standard deviations in Table 7 and Figure 6), with some individuals scoring performance highly, but others scoring performance as low.

The combined overall performance score also differed across jurisdictions as well as between groups (Figure 7). However, at the jurisdiction level, differences in response rates by each group in each fishery may also affect the mean scores, so this figure needs interpretation with caution. Many fisheries were missing a response from at least one of the three groups (see Table 5 and Table 6). This caveat notwithstanding, scientists were generally more pessimistic about the performance of ITQs and ITEs than the other two groups. A reference line with a score of five has been added in Figure 7 to make comparison easier. Queensland fishers were generally more optimistic about the performance of ITQs and ITEs than most other groups, although, Tasmanian managers had the highest overall performance score across all groups.

Figure 7. Average perception of overall performance score by jurisdiction



Perceptions of performance can also depend on the baseline against which individuals compare the current situation. Studies elsewhere have shown that perceptions of performance can be influenced by the level of experience (Burton *et al.* 2003). A priori, it might be expected that individuals with less experience would be more satisfied with fishery performance, than those with greater experience, as the baselines against which performance is assessed will be further apart. Regressing overall performance against the number of years of experience in the industry suggests a weak negative (non-significant) relationship between the number of years in the industry and the perception of performance (Table 8).

Visual examination of the data suggests that any relationship with years of experience may be limited to fisheries that have an overall lower perceived level of performance. Splitting the data into observations with an overall performance score of 7 or more and those with a score of less than 7 suggests that, for fishers and to some extent managers, adverse perceptions increased (i.e. the performance score gets lower) with the level of experience (Table 8 and Figure 8).

The number of years that the fishery has been under ITQ/ITE management was also considered. A priori, it may be expected that benefits take time to accrue, so that fisheries that had been under ITQ management longer may have higher benefits. At an aggregate level, this appears to hold, with the sign on the years of ITQs coefficient being generally positive and significant at the 10% level of greater. However, sub setting the data into high and low performing fisheries suggests that the latter may be adversely affected by the length of time they management system has been in place.

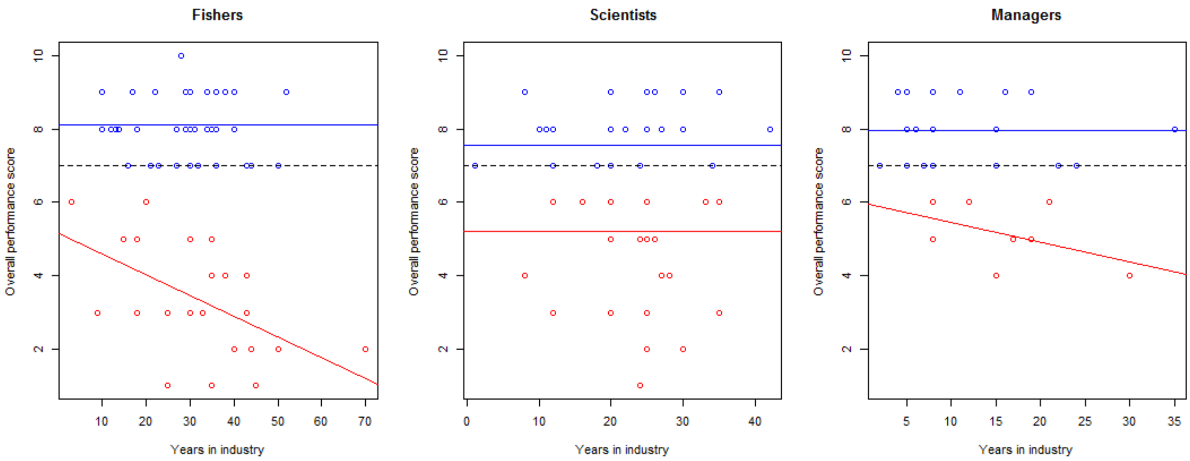
This suggests that a fishery that is seen as performing well is not necessarily one that has had time to "mature", nor one in which fishers have little experience of alternative systems. For fisheries that are seen to be not performing as well, this adverse perception increases with the level of experience, at least for fishers and to some extent managers, and for fishers and scientists also with the length that the management system has been in place. The explanatory power of these models, however, is very low (as indicated by the adjusted R^2 term, which is a measure of the amount of variation in the dependent variable explained by model), so should be considered as indicative only of the possible relationship.

Table 8. Average perception of overall performance score against years in the industry

	All data			Performance>=7			Performance<7		
	Estimate	Std. Error		Estimate	Std. Error		Estimate	Std. Error	
Fishers									
Intercept	3.933	1.177	**	7.613	0.256	***	7.035	1.038	***
Years total	-0.001	0.026	.	0.024	0.007	**	-0.060	0.022	*
Years ITQs	0.122	0.040	**	0.009	0.013		-0.108	0.031	**
$\bar{R}^2$	0.111			0.433			0.366		
Scientists									
Intercept	6.237	0.993	***	8.144	0.124	***	3.720	1.748	*
Years total	-0.063	0.037	.	0.008	0.005		0.048	0.060	
Years ITQs	0.059	0.035	.	-0.011	0.006	.	-0.089	0.040	*
$\bar{R}^2$	0.030			0.064			0.099		
Managers									
Intercept	6.739	0.369	***	8.437	0.156	***	6.261	0.720	***
Years total	-0.013	0.016		-0.001	0.008		-0.069	0.033	.
Years ITQs	0.035	0.019	.	-0.012	0.011		-0.011	0.032	
$\bar{R}^2$	0.016			0.064			0.162		

Significance codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Figure 8. Average perception of overall performance score against years in the industry



Note: Blue dots and lines represent individuals who scored overall performance 7 or higher; red dots and lines represent individuals who scored overall performance less than 7.

Implicit objective weights

The perception of overall performance is essentially a weighted sum of the perception around the performance of the fishery against the four objectives considered: sustainability, economic outcomes, social outcomes, and governance. These weights are implicit, but can be estimated through regressing the overall outcome score against the outcome scores of each of the objectives (Table 9). [7]

From Table 9, fishers appear to give similar weight to sustainability and economic objectives, while slightly higher weight to social objectives. This is in contrast to other studies looking at objective weightings in Australian fisheries, which generally have concluded that fishers have a relatively low weighting attached to social objectives (e.g. Pascoe *et al.* 2013; Jennings *et al.* 2016). Both managers and scientists appear to give a highest weighting to economic objectives and a lower weight to social objectives, with managers giving the lowest weight to social objectives. Both scientists and fishers give a low weight to governance performance. In contrast, managers give a moderate weight to governance performance. Although the adjusted R^2 term is very high in all cases, the absence of an intercept terms in the model makes this measure unreliable.

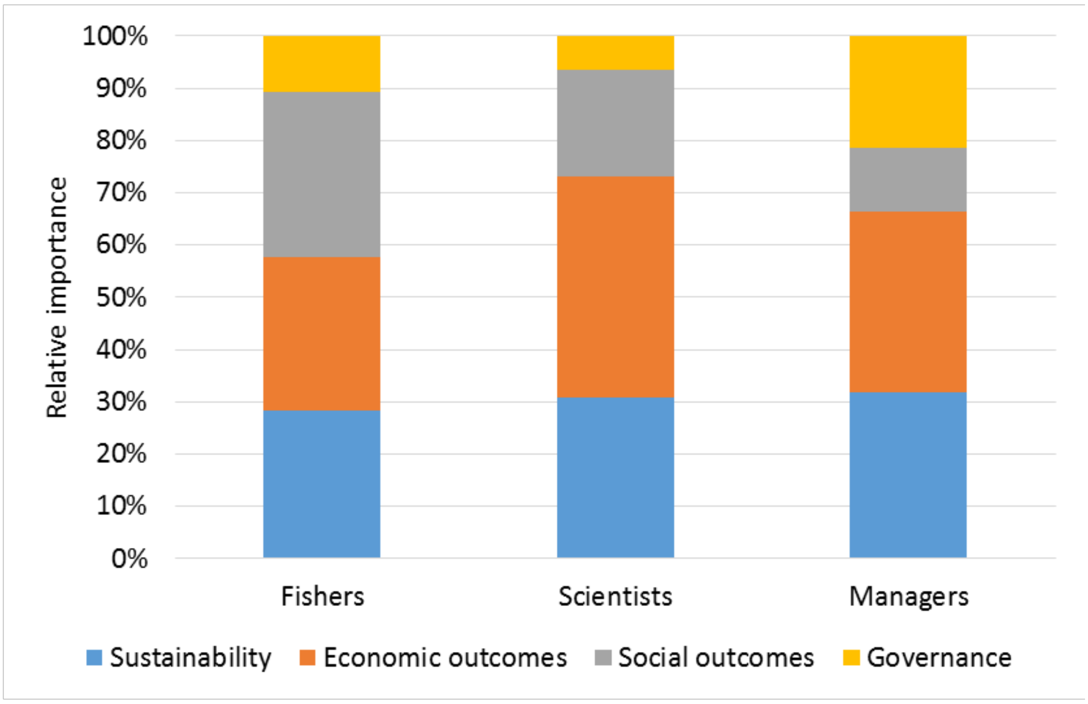
Table 9. Implicit weights for each objective in ITQ/ITE managed Australian fisheries

Objective	Fishers			Scientists			Managers		
	Estimate	Std. Error		Estimate	Std. Error		Estimate	Std. Error	
Sustainability	0.292	0.058	***	0.306	0.077	***	0.327	0.104	**
Economic	0.301	0.092	**	0.422	0.070	***	0.356	0.139	*
Social	0.327	0.085	***	0.204	0.069	**	0.125	0.114	
Governance	0.110	0.056	.	0.064	0.084		0.221	0.116	.
N. Obs	64			54			28		
$\bar{R}^2$	0.979			0.978			0.986		

Significance codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

[7] For clarification, the “outcomes” are a measure of how well an objective has been met.

Figure 9. Implicit relative weights given to each objective in ITQ/ITE managed Australian fisheries



Impact of ITQs/ITEs on objective performance

While the current level of performance is a useful measure, how this has been affected by ITQ/ITE management is of more relevance. Even if performance is seen as low, if it is better than under a previous management system, then this can be interpreted as an improvement.

Fishers were asked to assess how they believed ITQs or ITEs contributed to the current level of performance (i.e. improved it, made it worse, or no change) (Figure 10). Over 60% of fishers believed that ITQs improved sustainability in their fisheries, and over 50 per cent believed that they improved economic performance. In contrast, only around 20 per cent of fishers believed that ITQs or ITEs reduced sustainability, and around 30 per cent believed it reduced economic performance. The perceived impact of ITQs or ITEs on social performance and government was more limited; only around 40 per cent believed they improved outcomes against these objectives, the rest of the group believed they either decreased their performance or had no effect.

Scientists were generally more optimistic about the impact of ITQs and ITEs on the performance against the different fishery objectives (Figure 11), with only around 10 per cent of the scientists believing that ITQs or ITEs made the sustainability, economic and governance objectives worse, and more than half believing that these objectives were improved as a result of ITQs or ITEs. Views on the impact on social performance was mixed, with roughly equal proportions believing it improved them, worsened them or had no impact.

Managers were substantially more optimistic about the impact of ITQs and ITEs on the performance against the different fishery objectives (Figure 12), with around 80 per cent of the managers believing that ITQs or ITEs improved performance against the sustainability, economic and governance objectives. As with the scientists, views on the impact on social performance was mixed, although only a small proportion believed that ITQs or ITEs made the outcome worse.

Figure 10. Fisher perceptions as to how ITQs/ITEs affected the objective performance in Australian fisheries

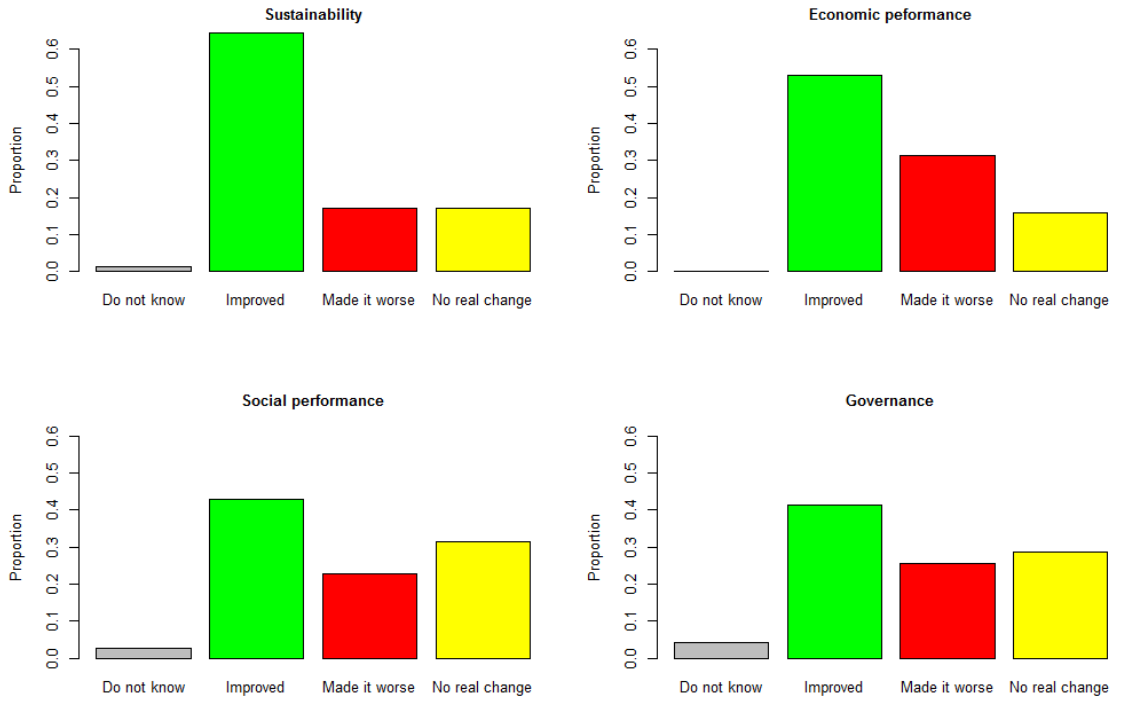


Figure 11. Scientists' perceptions as to how ITQs/ITEs affected the objective performance in Australian fisheries

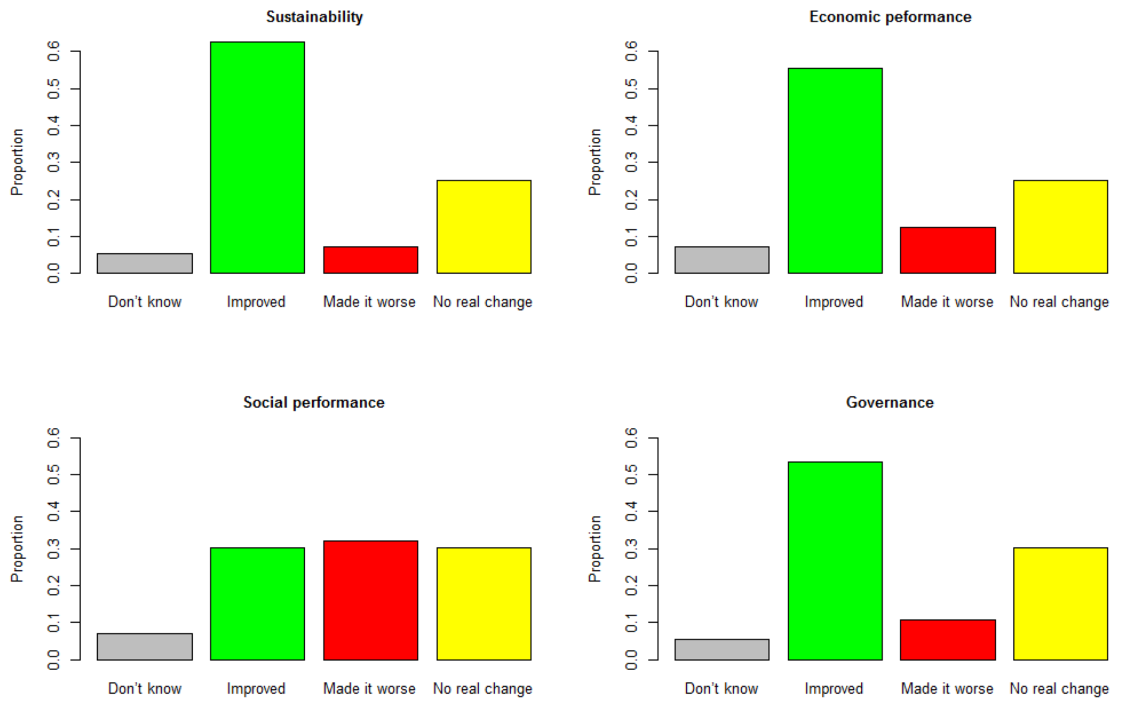
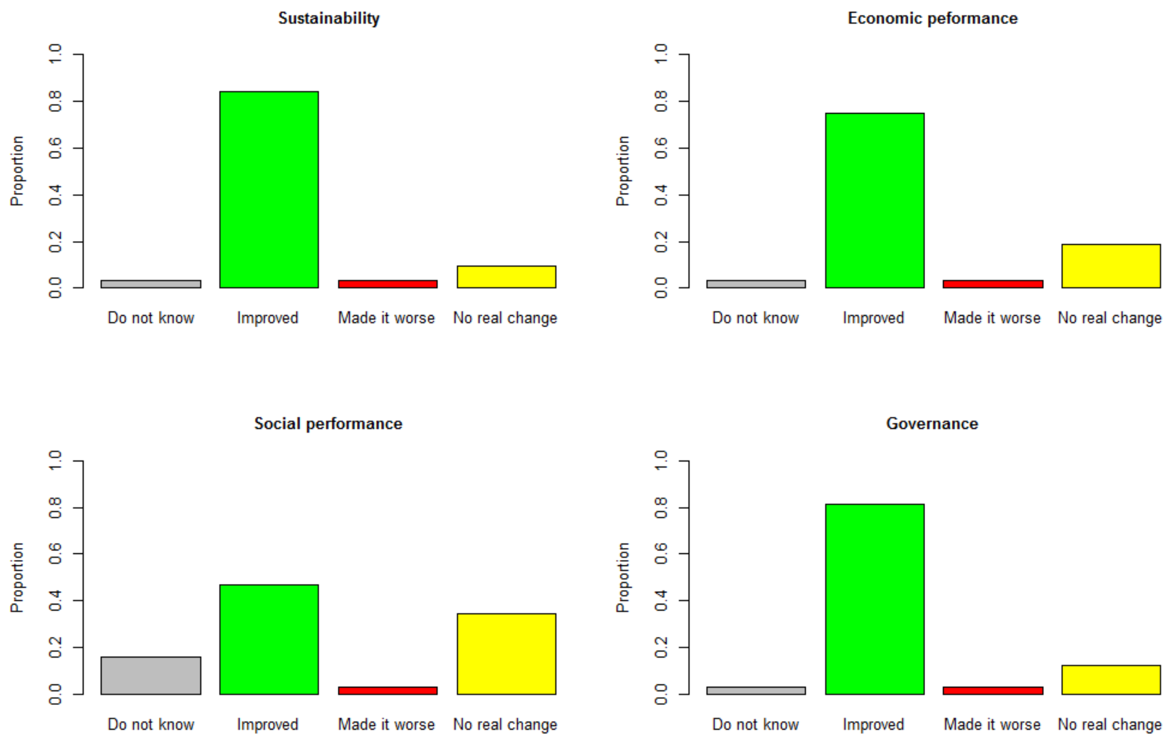


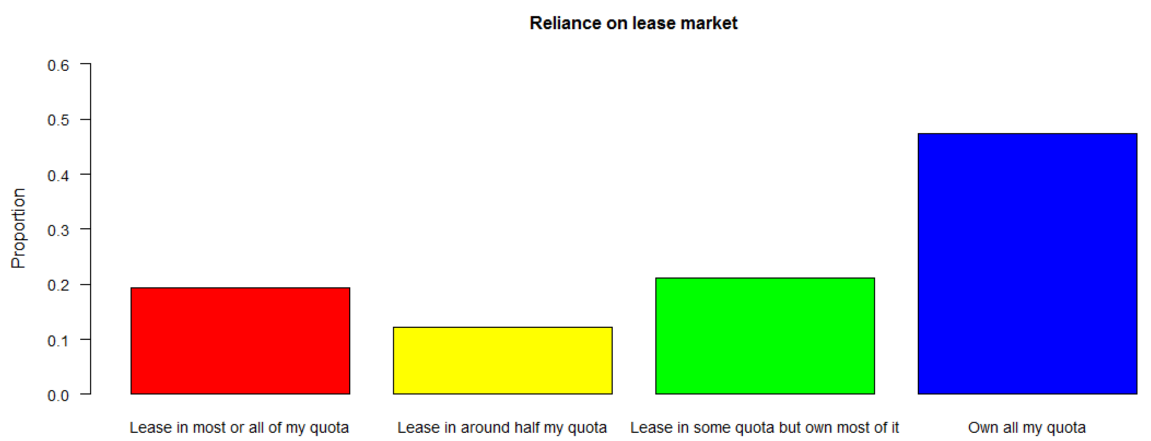
Figure 12. Managers' perceptions as to how ITQs/ITEs affected the objective performance in Australian fisheries



Functioning of the quota markets

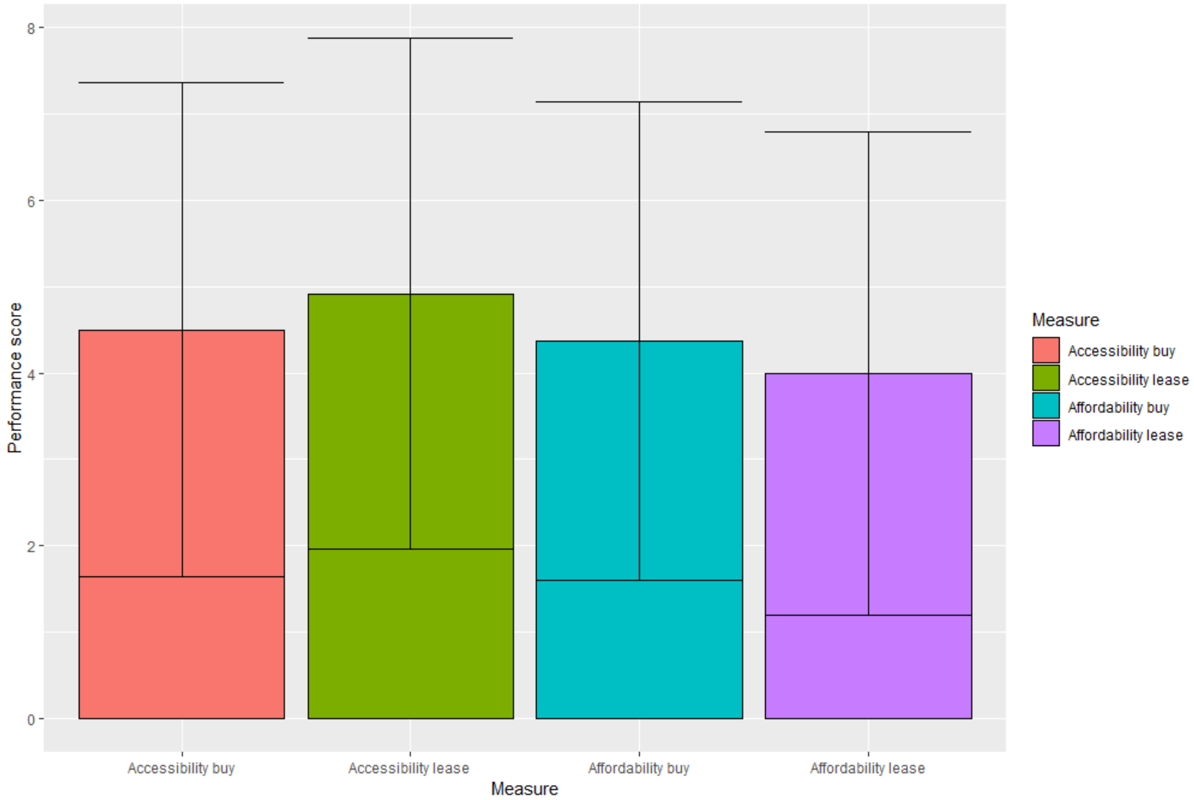
The success or otherwise of an ITQ/ITE system to a large extent relies on the ability of fishers to trade quota. From the survey, around half of the fishers were reliant on leasing quota to some extent, with around 20 per cent highly dependent on leased quota (Figure 13). For these fishers in particular, access to affordable quota is likely to be a priority.

Figure 13. Fishers' reliance on quota leasing in Australian fisheries



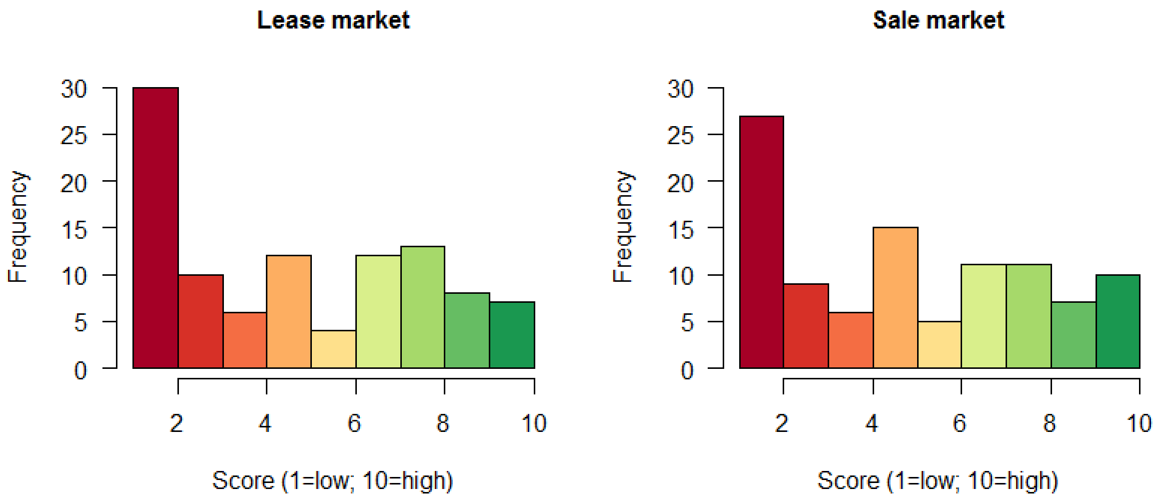
Fishers' perception about accessibility and affordability of quota – either to lease (i.e. a temporary transfer) or buy (i.e. a permanent transfer) – was highly varied, but generally accessibility and affordability were perceived to be low on average (Figure 14). The low accessibility and affordability is represented by the performance score (y-axis in Figure 14) of less than 5 on average. Affordability of leased quota in particular was believed to be low.

Figure 14. Fishers' perception of accessibility and affordability of quota (ranging from 1=low to 10=high): mean and standard deviation



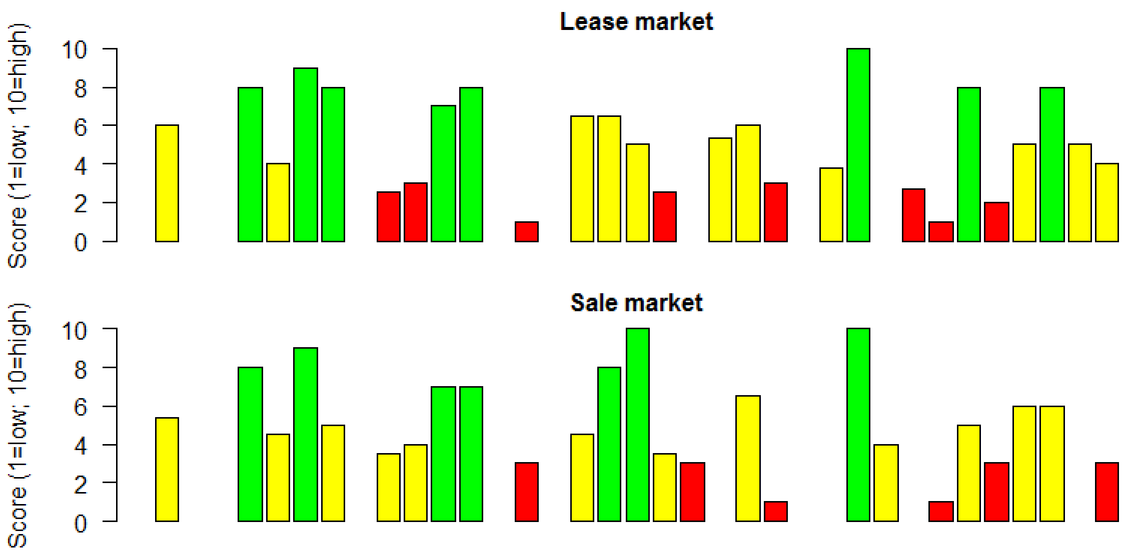
Many fishers were also critical of the overall functioning of the quota market, rating its performance as low (Figure 15). However, as with the other measures, there was a full range of responses, including a roughly equivalent number of fishers rating performance of the markets as good to high (i.e. from 7 to 10).

Figure 15. Fishers' perception of overall functioning of the quota market



The functioning of the quota market is likely to be driven by a number of factors. These factors are explored using the BBN in the subsequent sections of the report. However, these factors are likely to be fishery specific. Comparing the average scores for overall function of the market across fisheries, it can be seen that performance varies by fishery (Figure 16). In Figure 16, a green bar represents an average score of 7 or more; yellow represents an average score of greater than 3 (but less than 7); and red represents an average score of 3 or less. The fisheries in Figure 16 are not identified, but are equally vertically aligned so that the comparison of the lease and sale market in an individual fishery can be seen. For some fisheries, the sale market is believed to be operating effectively but not so the lease market, and vice versa. Only five of the 34 fisheries with usable responses in the survey had a well function sale and lease market.

Figure 16. Average perception of overall functioning of the quota market by Australian fishery



Note: Names of the fisheries have been removed to maintain confidentiality

Perceptions of the impacts of ITQs and ITEs

Markets

Improvements in the prices received by fishers has been identified as a benefit of ITQ management in several fisheries internationally (e.g. Squires et al. 1995; Dupont et al. 2005; Chu 2009; Guldin and Anderson 2018). Slowing down the harvest of fish allows improved quality and also avoids gluts on the market (Squires et al. 1995).

Over half of the fishers responding to the survey believed that both prices and quality of the product improved as a result of ITQ and ITE management, with only a small proportion (less than 10 per cent) believing that these were lower as a result of ITQs (Figure 17).

Perceptions around the supply of the product to the market (i.e. catch) were more evenly distributed, with fairly equal proportions believing that catch had increased, decreased or stayed the same. This may be fishery specific, as in some cases quotas would have reduced output, while stock recovery in other fisheries may have resulted in increased output. However, looking at the responses from individual fisheries (Figure 18), fisheries with multiple responses often included a range of perceptions, with some fishers stating catch increased (or decreased) while others stating it had not changed. In two fisheries, all three options (increased, no change, decreased) were selected perhaps indicating that the fishery had experienced periods of increase, decrease and stability since the introduction of ITQs.

Figure 17. Fishers' perceptions as to how ITQs/ITEs affected the price, quality and supply of Australian product

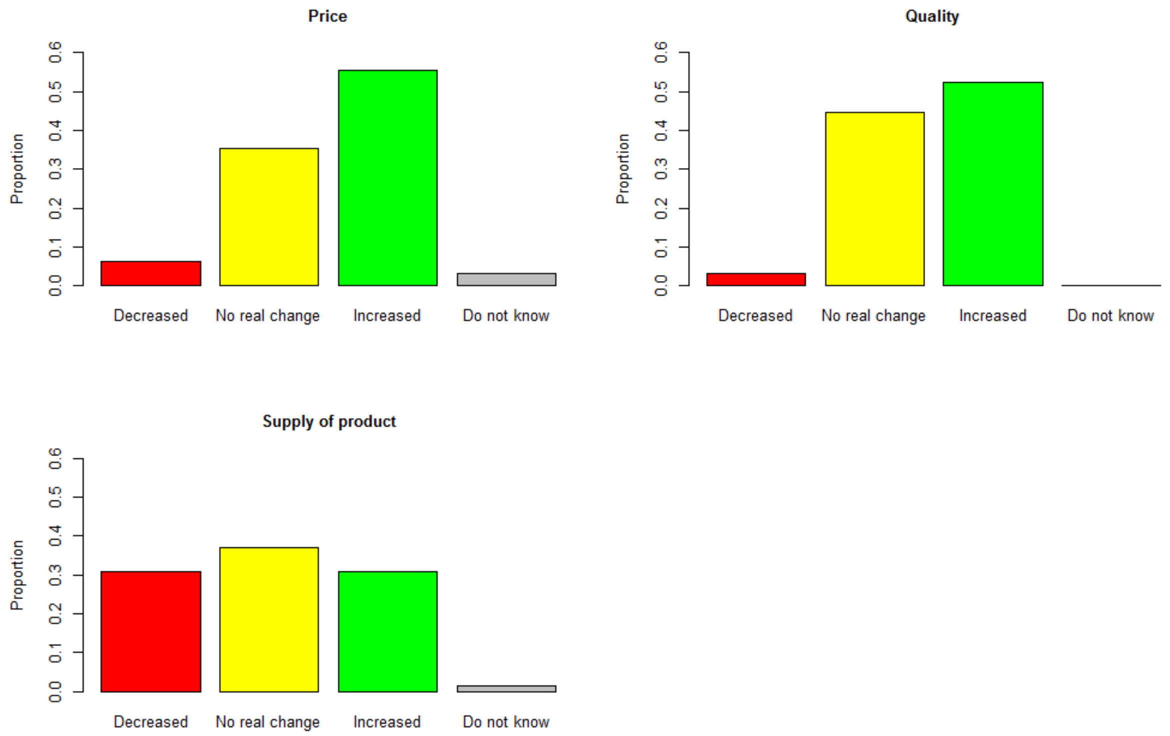
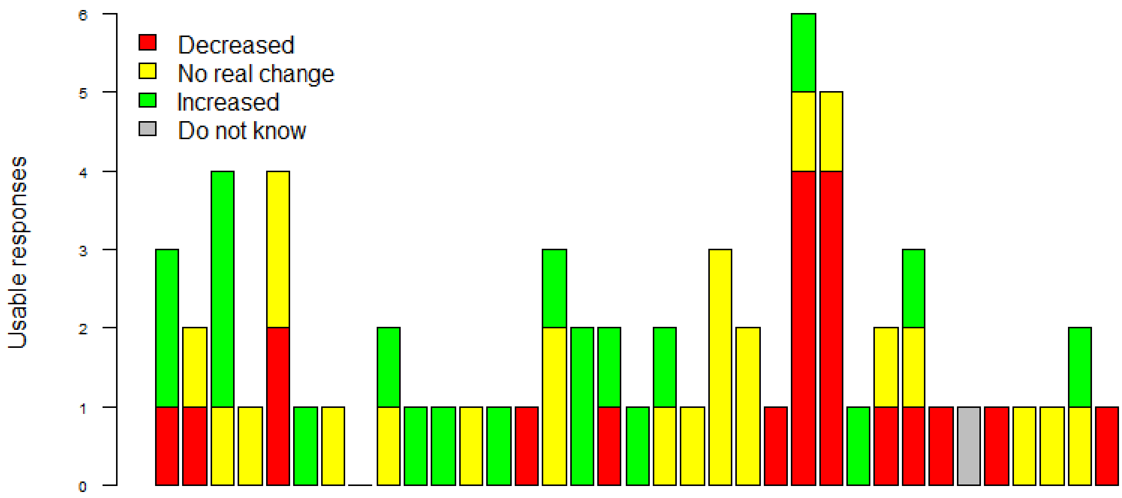


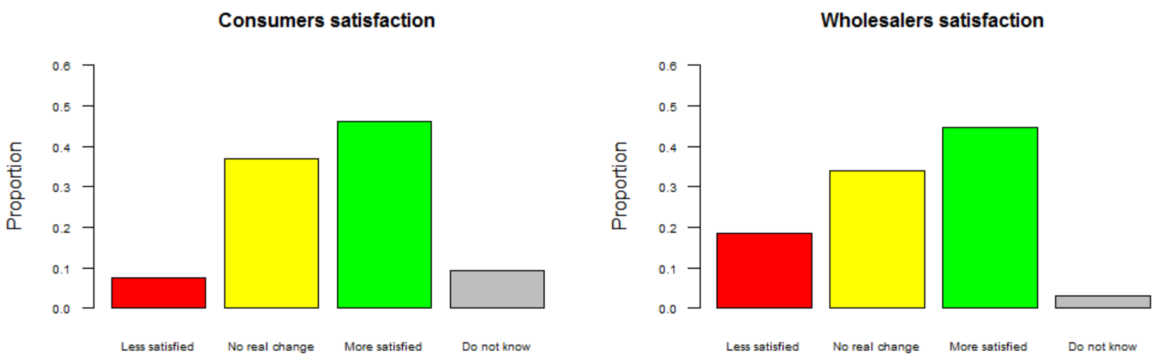
Figure 18. Fishers' perceptions of supply of product from individual fisheries surveyed



Note: Names of the fisheries have been removed to maintain confidentiality

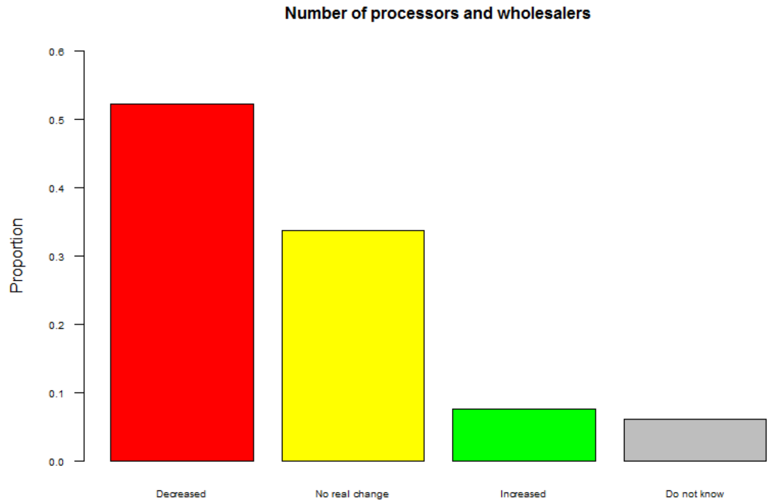
Most fishers believed that consumers and wholesalers were generally more satisfied with the product as a result of ITQs/ITEs (or no worse off), with only 10 per cent believing consumers were worse off, and 20% believing wholesalers and processors were worse off (Figure 19).

Figure 19. Fishers' perceptions of consumer and wholesaler satisfaction as a result of ITQs/ITEs



In some fisheries elsewhere, ITQs have also been associated with a consolidation and reduction in the number of wholesalers and processors (Guldin and Anderson 2018). From the survey, similar perceptions exist in Australian fisheries, with over half of the respondents believing that the number of wholesalers and processors had decreased as a result of ITQs (Figure 20).

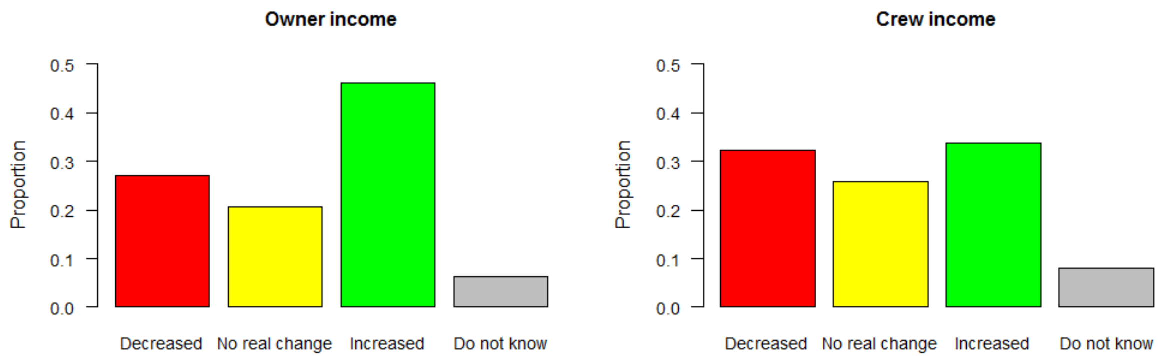
Figure 20. Fishers' perceptions of change in the number of wholesalers and processors as a result of ITQs/ITEs in Australian fisheries



Incomes

Almost half of the fishers who responded believed that their income had increased as a result of ITQs, although almost 30 per cent believed their income had decreased (Figure 21). Perceptions of the impact of ITQs and ITEs on crew income were mixed, with roughly equal proportions of fishers believing that incomes had decreased, increased or stayed the same.

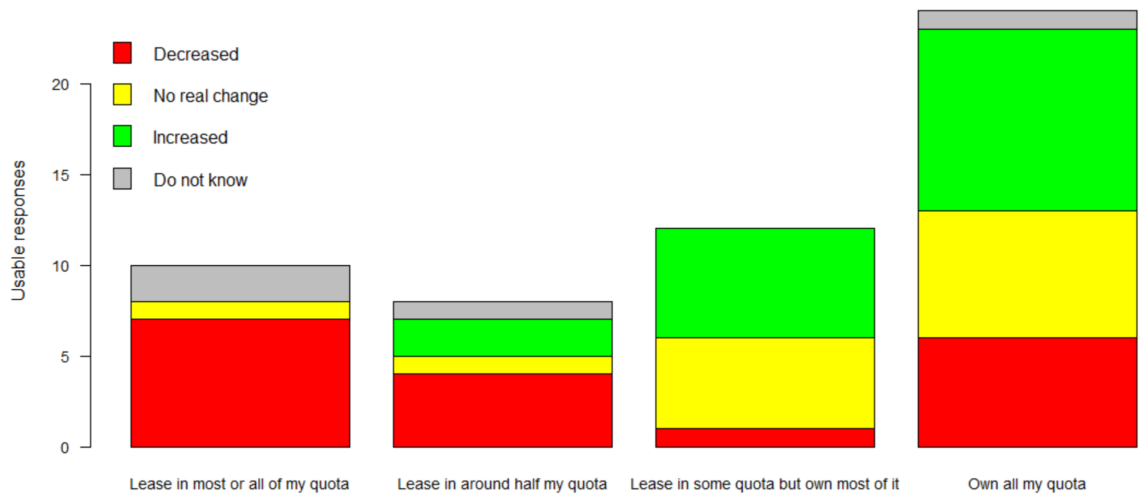
Figure 21. Fishers' perceptions of change in income as a result of ITQs/ITEs in Australian fisheries



Crew in most Australian fisheries, as in many fisheries (McConnell and Price 2006), are paid a share of the revenue, and hence crew incomes will be linked to the change in catch and price of each vessel. Owner incomes, in contrast, is linked to the level of profitability of the vessel. In this regard, the perceptions around owner income are similar to those around economic performance (Figure 10), while perceptions around crew income to some extent also reflect the change in supply from the fishery (Figure 17).

Reductions in crew incomes have also been seen in fisheries where most fishers were lease dependent, as crew were renumerated on the basis of net- rather than gross revenue (Eythórsson 1996; Brandt and Ding 2008). This also seems to be the case for Australian fisheries – crew incomes for fishers who own most or all of their own quota have largely tended to have increase or stay the same, where crew on lease-dependent vessels have tended to have a decreased income (Figure 22).

Figure 22. Relationship between change in crew income and quota ownership in Australian ITQ/ITE managed fisheries



Fishing days and costs

From the survey, most fishers believed that the introduction of ITQs has resulted in fewer days fished or no change, with less than 20 per cent believing that their number of fishing days has increased (Figure 23). Around half of the fishers indicated that the area where they fished had not changed, with roughly equal proportions believing that they had either moved further from, or closer to, their home port as a result of ITQs.

The introduction of ITQs requires fishers to change the way and frequency they report their catch, as well as potentially place other constraints on their activities (i.e. land in designated ports, inspections etc.). Increases in compliance costs have been attributed to the main reason that most small scale fishers left the industry in New Zealand following the introduction of ITQs (Stewart and Walshe 2008). Increased monitoring and enforcement effort in ITQ fisheries, as well as the greater need for accurate stock assessment information, is also generally associated with an increase in management costs (Squires et al. 1995; Grafton 1996).

With many Australian fisheries operating under a cost recovery model, these higher management cost may result in higher costs to industry, with individual costs also being affected with fewer vessels remaining to share these costs. As expected, from the survey, most fishers believed that both management costs and compliance costs increased as a result of the introduction of ITQ/ITE management (Figure 24).

Figure 23. Fishers' perceptions of change in days and area fished as a result of ITQs/ITEs in Australian fisheries

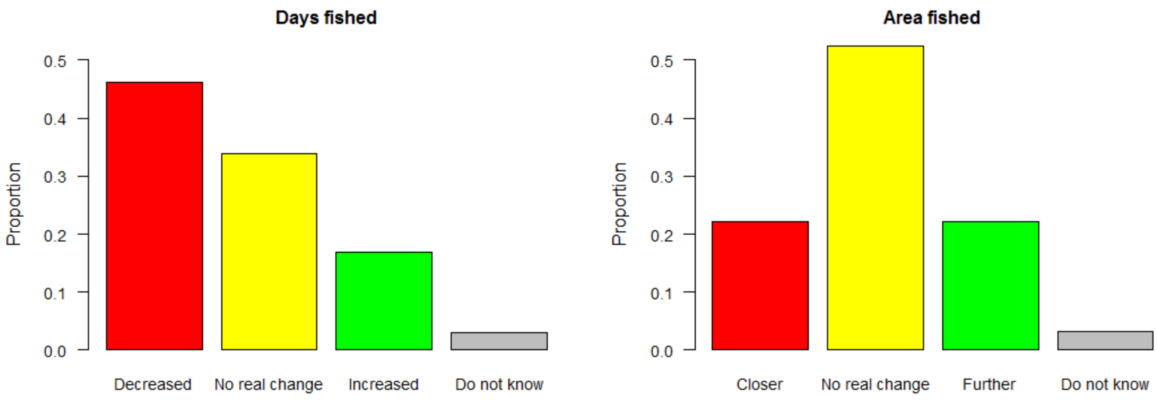
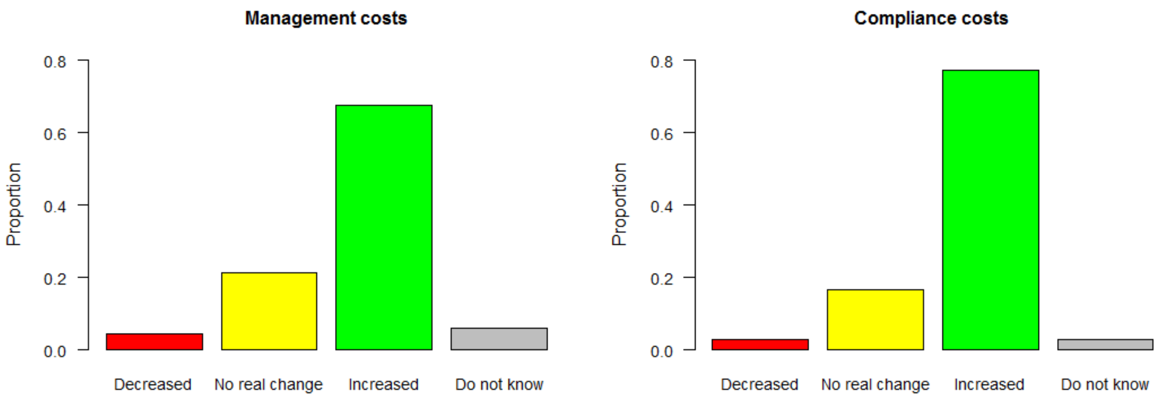
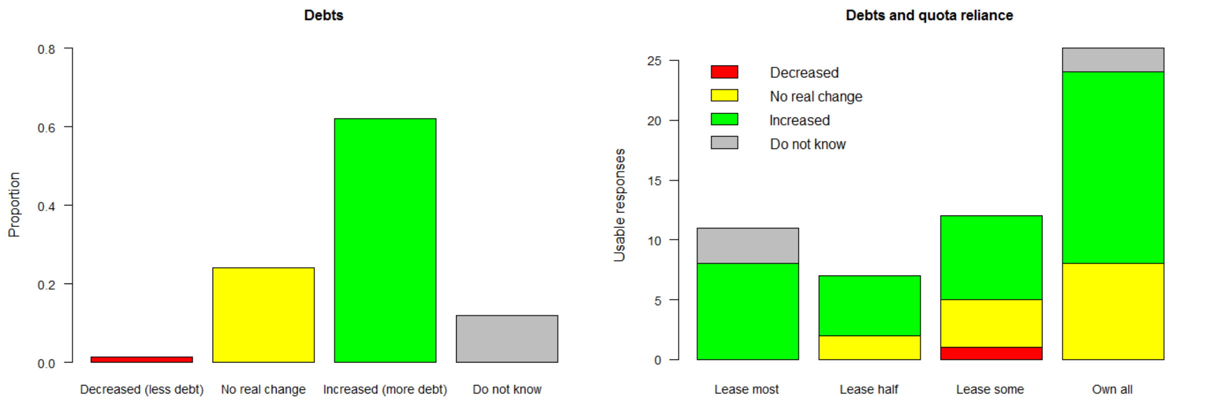


Figure 24. Fishers' perceptions of change in management and compliance costs as a result of ITQs/ITEs in Australian fisheries



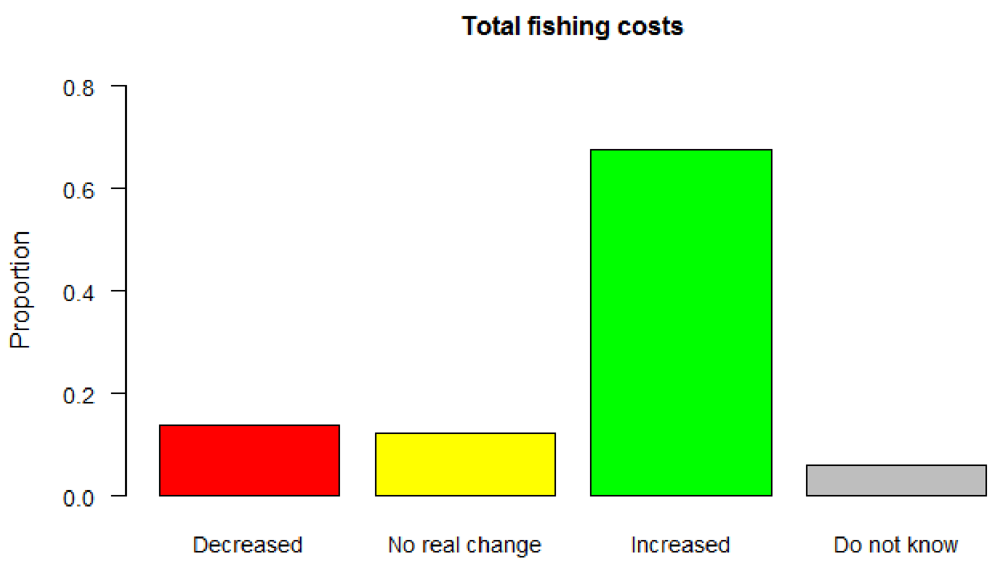
Around 60 per cent of the fishers in the survey believed that their debt level had increased as a result of the introduction of ITQ/ITE management. This debt increase was seen across the board, although was most predominant for quota dependent fishers (Figure 25).

Figure 25. Fishers' perceptions of change in debt levels as a result of ITQs/ITEs in Australian fisheries



Given the changes above, it is unsurprising that most fishers believed that their total fishing costs have increased as a result of ITQ/ITE management (Figure 26).

Figure 26. Fishers' perceptions of change in total fishing costs as a result of ITQs/ITEs in Australian fisheries



Satisfaction with fishing

The increasing incorporation of social objectives into Australian fisheries management requires looking beyond the impacts of ITQs on stocks and economic performance, and also consider the impacts on the broader welfare of the fisher and the local communities. In this context, the survey asked fishers about their level of enjoyment, social interactions and their perception around health and safety. Given this, overall satisfaction with fishing under ITQs was elicited.

Perceptions about the impact of ITQs/ITEs on fishers' enjoyment of being in the commercial fishing industry were fairly evenly split, with a slightly higher proportion believing that their overall satisfaction level had decreased (Figure 27). Similarly, perceptions around social relations between fishers in the fishery (e.g. sense of community, cooperation with other fishers) was also mixed.

In contrast, only around 20 per cent of fishers believed that information sharing and health and safety had decreased as a result of ITQs/ITEs, with a larger percentage believing that these aspects of fishing had increased. Around 40 per cent of fishers believed that health and safety, in particular, had increased as a result of ITQs/ITEs (Figure 28).

Overall, the level of satisfaction with fishing was also mixed, with roughly as many fishers indicating that satisfaction levels with fishing under an ITQ/ITE managed fishery had changed in a positive way as there fishers who indicated their satisfaction had been negative affected (Figure 29).

Figure 27. Fishers' perceptions of change in satisfaction and social relations as a result of ITQs/ITEs in Australian fisheries

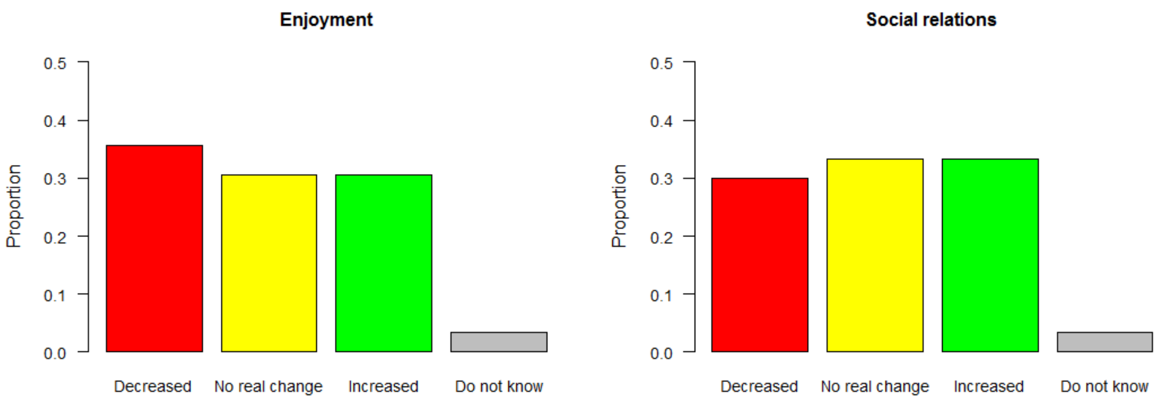


Figure 28. Fishers' perceptions of change in information sharing and health and safety as a result of ITQs/ITEs in Australian fisheries

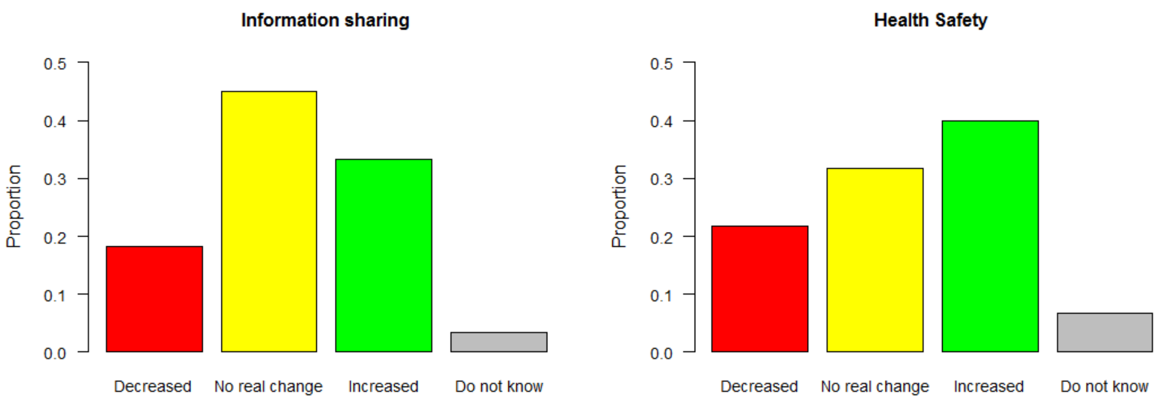
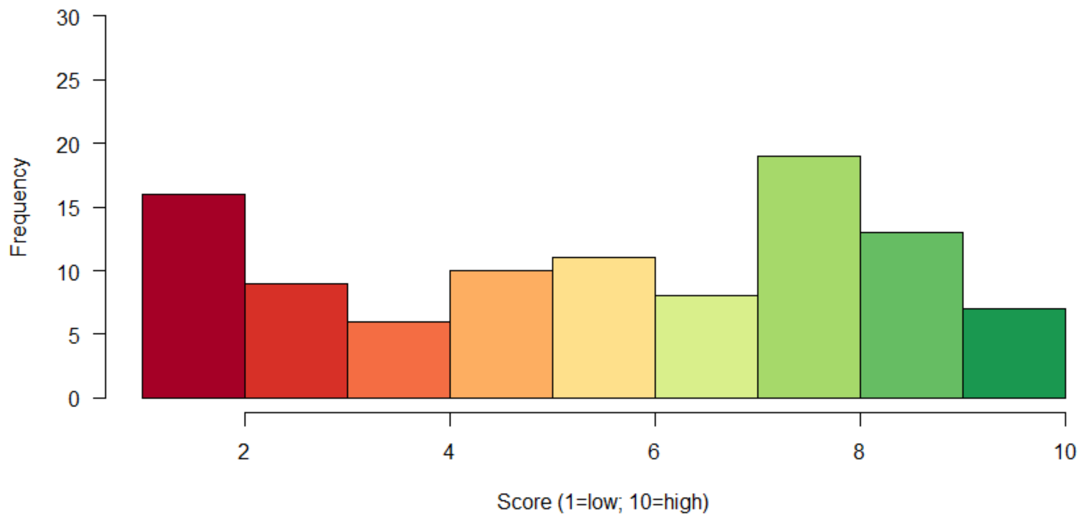


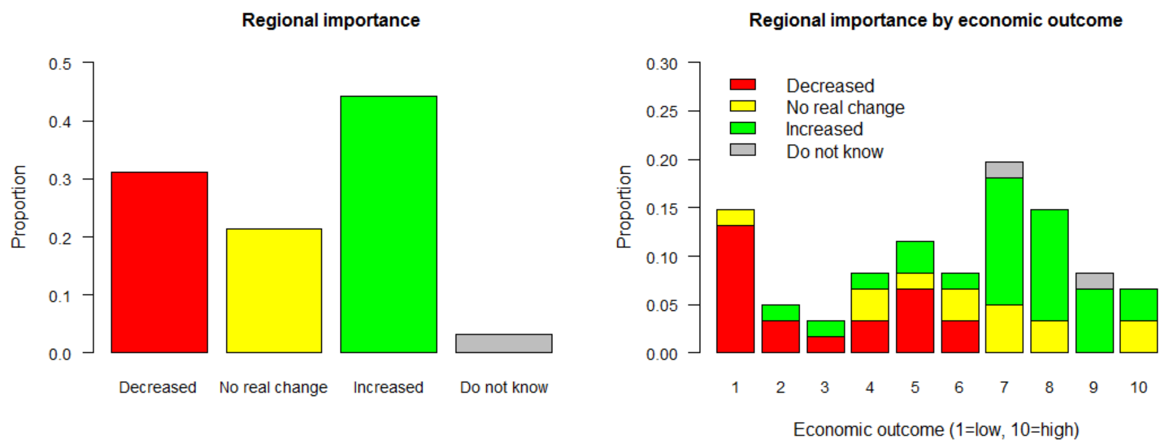
Figure 29. Fishers' overall satisfaction with fishing in the ITQ/ITE Australian fishery



Broader community

The impacts of ITQs and ITEs on the broader community are also an important aspect of the social performance of the management system. Fishers' perceptions of the impact of ITQs/ITEs on the economic importance of the fishery to the local community was mixed, although this also seemed to be related to the perception of the economic outcome under ITQs (Figure 30). Fisheries that were perceived to have had a positive economic outcome were also seen as increasing in importance in the local community, while those that were seen as performing poorly in economic terms were seen to decrease in their regional importance also.

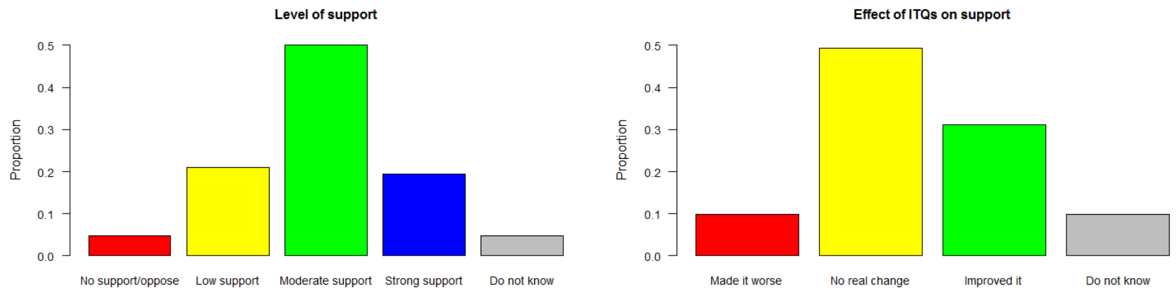
Figure 30. Fishers' perceptions of the economic importance of the fishery to the local community as a result of ITQs/ITEs in Australian fisheries



The need to ensure a social licence to operate is also attracting increasing attention in fisheries management. The term "social licence to operate" is frequently used to refer to the level of social approval that exists in relation to the development of natural resources for private or public purposes (van Putten *et al.* 2018).

In the survey, fishers were asked to provide their views as to the current level of community support for their fisheries and how this has changed as a result of ITQs. Most fisheries were believed to have moderate support, with only around 5 per cent believed to have no support or actively opposed by the local community. Around half the fishers believed ITQs/ITEs had no real impact on this level of support, while around 30 per cent believed ITQs contributed to an improvement in community support. Only 10 per cent of fishers believed ITQs/ITEs were associated with a reduction in community support (Figure 31).

Figure 31. Fishers' perceptions of community support from the local community as a result of ITQs/ITEs in Australian fisheries

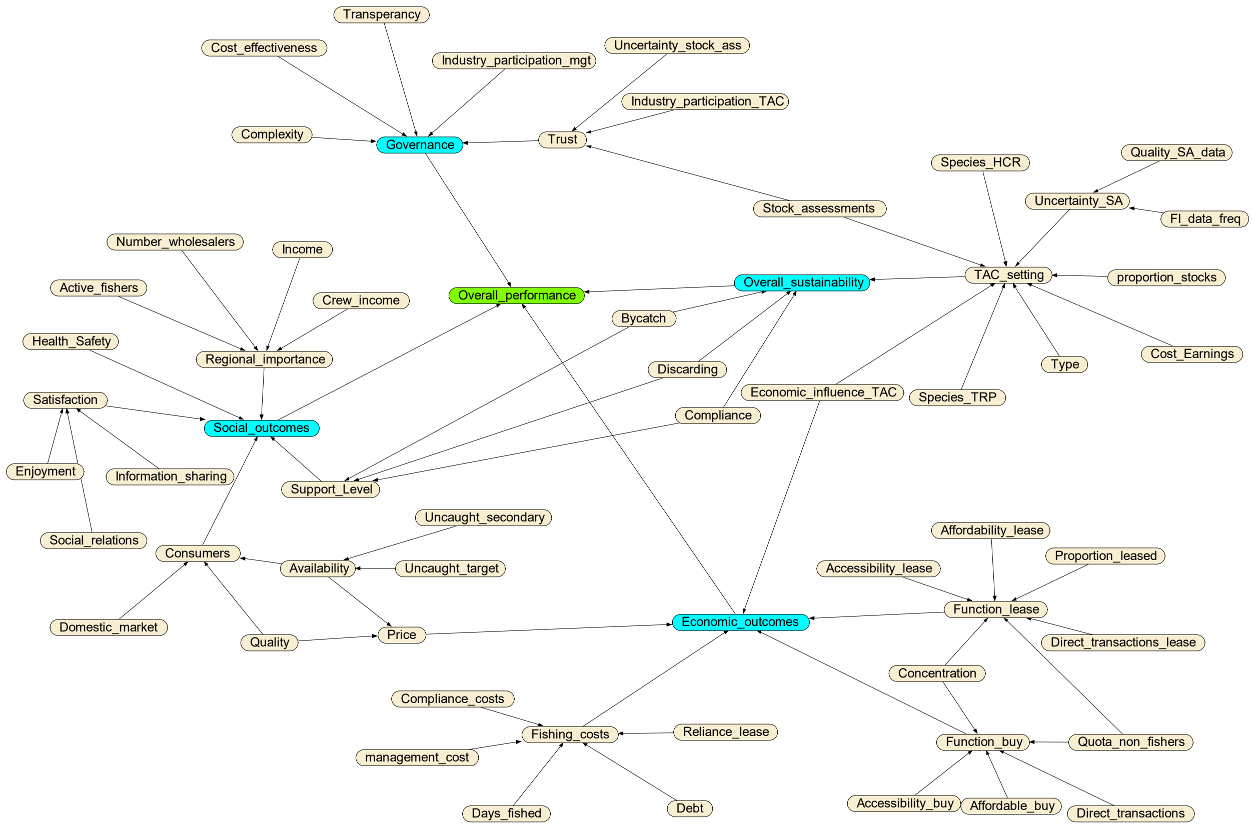


Factors affecting performance of ITQ/ITE systems

The factors affecting the performance of the ITQ/ITE system were assessed using a BBN model. As noted in the methodology, the BBN structure was developed based on a combination of literature review and expert opinion. In the latter case, the project team and other invited experts reviewed draft structures of the BBN (based on theoretical relationships and results of empirical studies elsewhere) and agreed on a final structure. This was also subsequently modified based on the survey results, in particular where no evidence of an assumed relationship was found.

Based on this, the general structure of the final BBN model can be seen in Figure 32. The BBN captures most, but not all, inter-relationships between variables. For example, increased frequency of stock assessments and economic data will also increase the costs of management, although this link is not included in the model. Instead, they are implicit in the management costs input into total fishing costs. A description of each of the nodes is presented in Appendix B.

Figure 32. Diagrammatic structure of the BBN depicting the influence pathways of different variables to the overall performance of ITQs and ITEs (green node in the middle of the diagram)



Estimation of the BBN model and conditional probability tables

The fisher, scientist and manager survey responses were combined at the fishery level, as each provided responses against different criteria. Where multiple responses were obtained at the fishery level, each response was combined with each other response. For example, a fishery with two industry, two scientist and two manager responses would have eight combined responses (i.e. F1+S1+M1; F1+S2+M1;…; F2+S2+M1; F2+S2+M2). The full combined data set had 414 combined "observations", although as not every fishery had a response from all three groups and there were missing data for many observations.

Most variables were measured in terms of three or four levels (e.g. decreased, stayed the same, or increased) although several variables were measured on a 1-10 scale. As this would increase the potential number of combinations if these variables were included as inputs (parent nodes), and the likelihood of reliable probabilities being determined being reduced, the variables were collapsed into three levels (1-5, 5-7, and 7-10).

Given the presence of missing data, the model was estimated using both the expectation-maximisation (EM) approach and the gradient descent approach. The EM learning approach required 283 iterations to fully converge, while the gradient decent approach only required four iterations. However, the log likelihood value for the EM approach was lower (36.8) than that of the gradient decent (37.5), so the former was accepted as the preferred model.

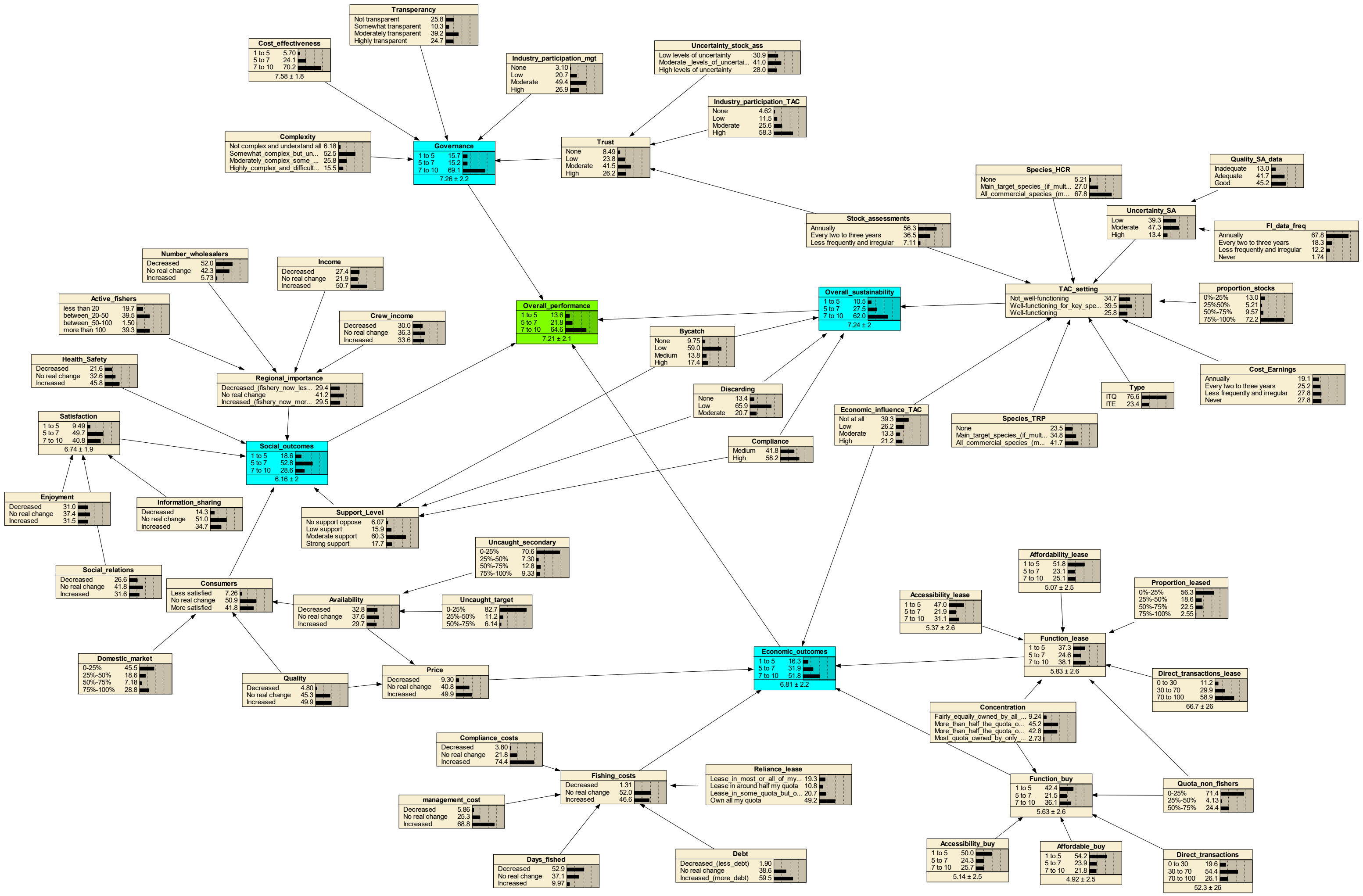
The conditional probability tables were also examined individually for internal consistency. As not all combinations of variable levels were observed in the data, some conditional probability tables contained some inconsistent findings after the EM learning stage. For example, an improvement in the input levels resulted in a decrease in the output level. In some cases, this was an artefact of the limited data, as a combination may have existed but the output (child node) score rated by the fisher/scientist/manager was lower than that given by other peers for similar combinations.

Adjustments to remove inconsistencies were undertaken using two approaches. Where the number of inconsistencies appeared small (a subjective judgement), manual changes were made to the inconsistent probabilities (based on the adjacent probabilities). Where the number of inconsistencies appeared large, regression analysis was undertaken using the original data to derive weights for each of the parent node levels, and these were used to derive a new conditional probability table. Details of the regression model results and their application are given in Appendix C. A summary of the nodes affected and how they were modified is given in Table 10. The final BBN model used for the subsequent analysis is illustrated in Figure 33.

Table 10. Nodes modified post EM learning

Node adjusted	Dimensions	Method of adjustment	Percentage of probabilities adjusted
Governance			
• Governance	4*4*3*4*4=768	Manual (most combinations looked reasonable, only the first few combinations needed adjustment)	8%
• Trust	4*3*3=36	Manual (only the first few combinations and two towards the end)	17%
Social			
• Social	3*3*3*3*4=324	Regression model	100%
• Satisfaction	3*3*3=27	Manual (Small reallocations of probabilities between outcome levels based on adjacent values)	36%
• Consumers	4*3*3=36	Manual (Small reallocations of probabilities between outcome levels to smooth the transition between changes based on adjacent values)	27%
• Regional importance	3*3*3*4=108	Manual (missing combinations in the data resulted in probabilities being assigned fully to one outcome (often counter to expectations). These were reallocated between outcome levels to smooth the transition between changes based on adjacent values and expectations)	51%
Economic			
• Total costs	3*3*3*3*4=324	Regression model	100%

Figure 33. The integrated BBN model estimated using a combination of EM learning and regression analysis



Model results

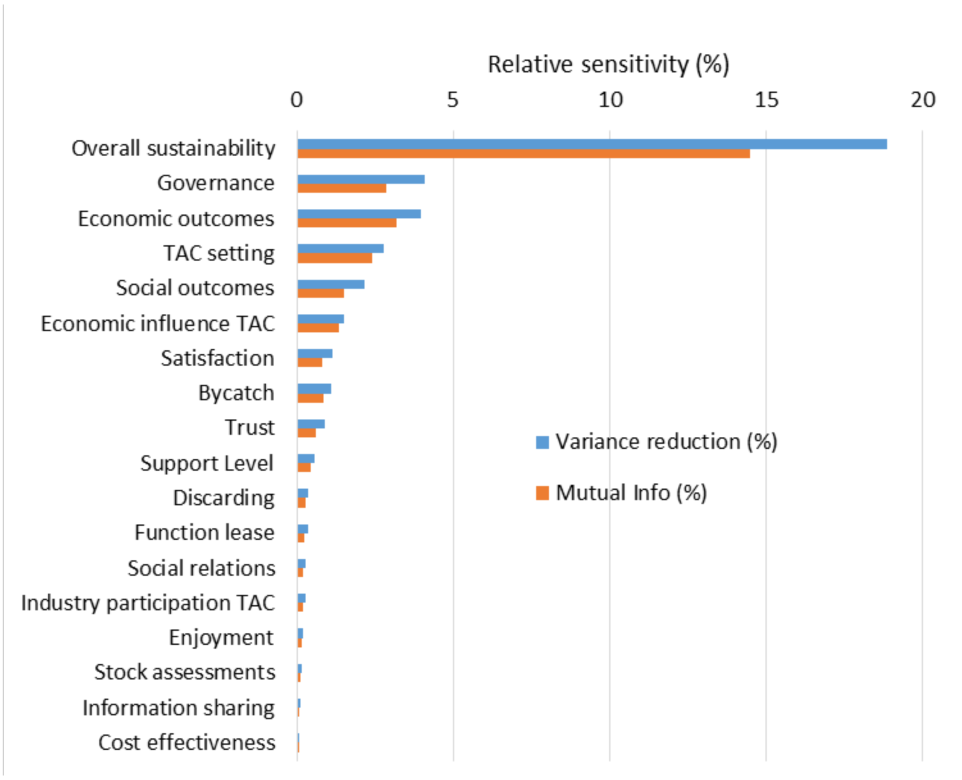
What drives fishery performance?

Sensitivity analysis was undertaken using the model to determine the key factors affecting perceptions of overall fishery performance (Figure 34). The relative sensitivity is a measure of how much the value of the target node could be influenced by a single finding at each of the other nodes in the net. That is, with a change to one node without changing any other component of the BBN. Some of the drivers are nested in other drivers in Figure 34. For example, *Trust* also influences the *Governance* node, *Discarding* affects *Social outcomes* and *Industry participation in the TAC* setting process affects *TAC setting*. Increasing *Trust*, all other things being held constant, will result in an increase in the *Governance* score as well as the overall fishery performance, but by a smaller proportion than if all components of *Governance* was increased.

As expected, the main parent nodes feeding into the measure (the social, governance, sustainability and economic performance measures) were the key measures, with the sustainability performance being the dominant driver. Also significant are the TAC setting process (which affects sustainability) and the influence of economic factors on the TAC setting process.

Industry satisfaction also had a small but significant impact on overall performance (through social performance). Bycatch and discarding, affecting both sustainability and the social licence to operate (community support level) were also key drivers.

Figure 34. Drivers of overall fishery performance

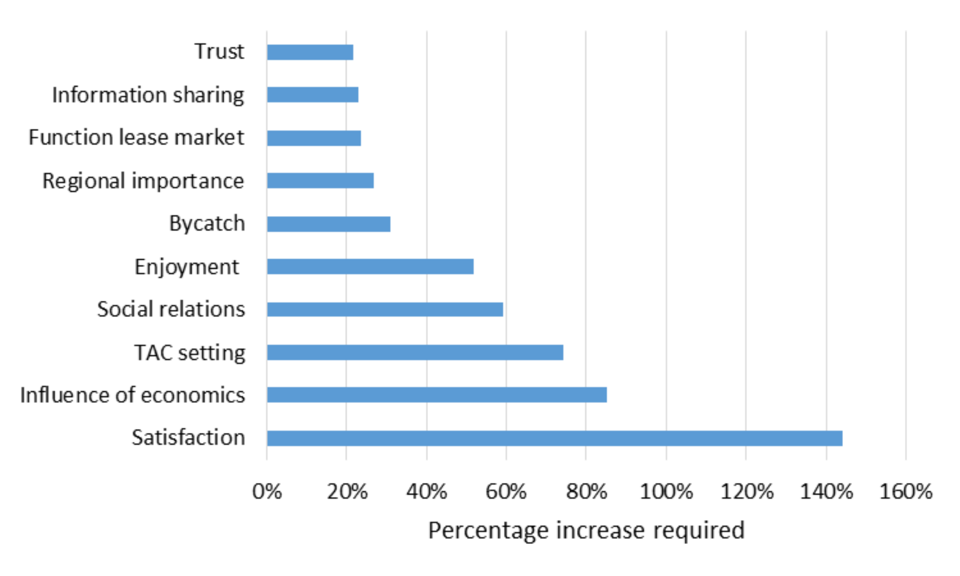


What does a highly performing fishery look like?

The maximum values for the performance measures (economic, social, sustainably, governance and overall performance) were set to 100 per cent in order to assess which factors would most likely need to change to achieve this outcome.

While improvements were required in nearly all nodes, the areas requiring the largest change from their current levels in order to achieve a highly performing fishery are shown in Figure 35 for ITQ fisheries. From this, factors affecting social performance that require the largest absolute increase were, satisfaction with fishing (i.e. job satisfaction), social relations, regional importance, and information sharing. The performance of the TAC setting process also was estimated to require improvement, with increased influence of economic information in the TAC setting process a high priority for improvement. Improved lease market functioning and improved trust in the governance system we also important factors in achieving improved management.

Figure 35. Nodes requiring the largest change to maximise overall fishery performance, ITQ fishery



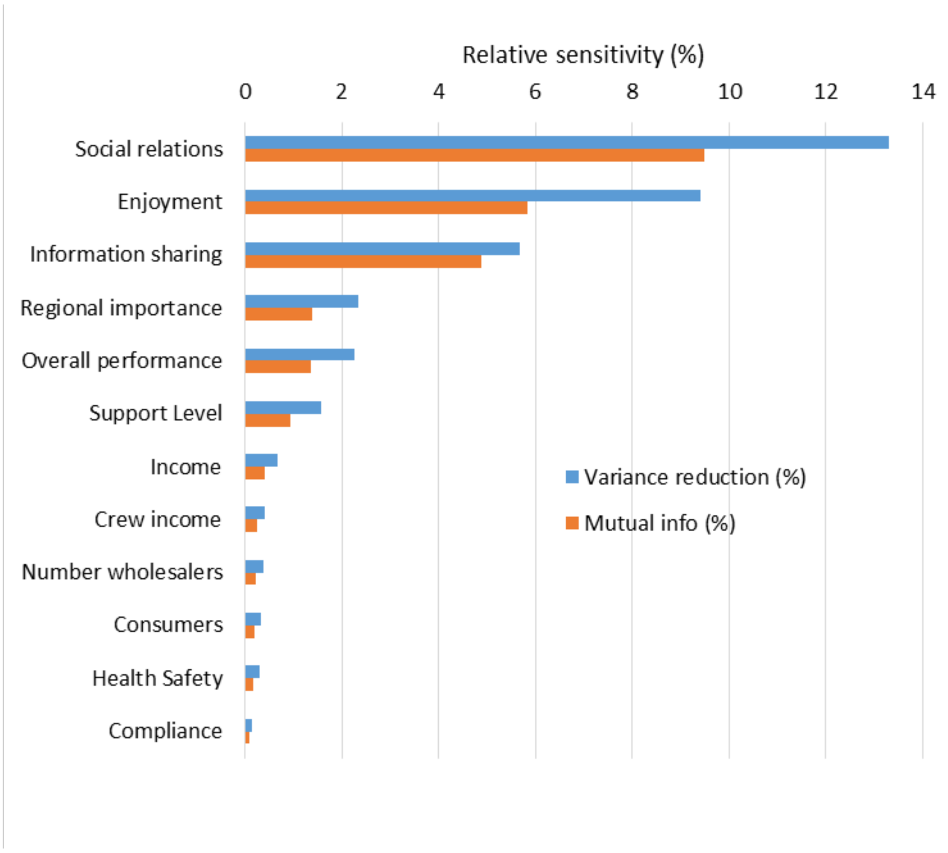
In the model, ITQs only directly affected the fishery differently to ITEs through the TAC setting system, the former requiring TACs for each key species while the latter required a total allowable effort for the fishery as a whole. For ITE fisheries, the factors affecting overall performance were similar to those for ITQ fisheries with the exception that the TAC setting process did not require as much improvement and, as part of this, the influence of economics in the TAC setting process did not need to increase by as much as for ITQs.

What influences satisfaction?

Given the importance of satisfaction in improving overall fishery performance, a sensitivity analysis was undertaken to determine which factors have the greatest influence on the performance measure. Unsurprisingly, the three parent nodes (social relations, enjoyment and information) are the factors that most influence the satisfaction measure. However, satisfaction is also indirectly influenced by regional importance, overall fisheries performance, and the level of community support (social licence to operate). Other factors, such as income levels and customer satisfaction, also have a small influence on the level of satisfaction (Figure 36).

Most of these factors are outside of the direct control of managers, although the use of co-management approaches and the facilitation of industry organisation can positively impact social relations and industry information. The results for the different fisheries with respect to the three main factors were mixed, with roughly equal numbers of fishers believing that ITQs/ITEs have improved these factors as have decreased them (Figure 27).

Figure 36. Satisfaction sensitivity to findings



TAC/TAE setting

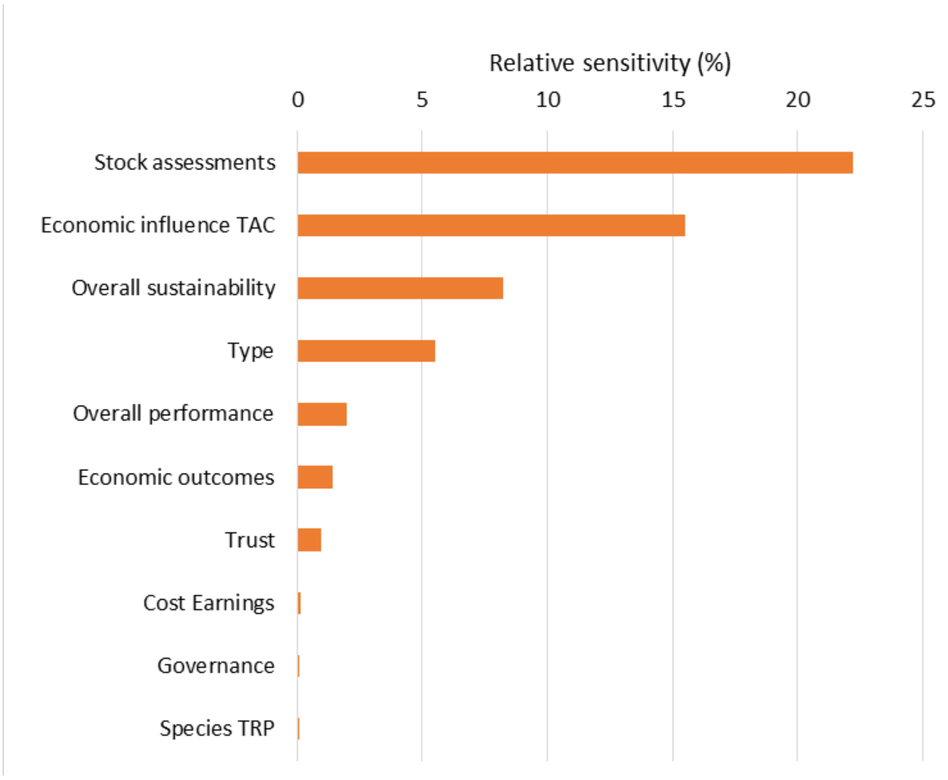
From the data, 40% of respondents believed that the TAC setting process was well functioning for key species, and 25% believed that the process was well functioning for all species. In contrast, 35% believed it did not function well. To increase the belief that the TAC process works well to 100% for all species, the largest impact can be made through increasing the frequency of stock assessments (Figure 37).

Currently, from the survey data, around 56% of stocks have some form of annual assessment, while 37% have an assessment every two to three years, and around 7% have stock assessments less frequently and irregularly. Improving the functioning of the TAC setting process requires different changes for ITQ and ITE fisheries. In ITQ fisheries, the proportion of fisheries with annual assessments needs to increase to 84%, with 16% every two to three years (and none less frequently). For ITE fisheries, assessments every two to three years were believed to be more appropriate – increasing from 37% to 90%. In contrast, annual assessments decreased from 56% to 10%.

The influence of economic considerations on the TAC setting process was also seen to be a significant driver of the functioning of the process (Figure 37), and again this differed between ITQ and ITE fisheries. Currently, economic considerations were believed to have had a high influence on TAC setting in around 21% of responses, and a moderate influence in around 13% of cases. To achieve a well-functioning TAC/TAE setting process for all species, the influence of economic considerations would need to increase to 53% high and 25% moderate for ITQ fisheries, and 44% high and 27% moderate for ITE fisheries.

Achieving a well-functioning TAC/TAE process was also related to achieving a high overall sustainability outcome, while the increased influence of economic considerations also contributed to a higher economic outcome.

Figure 37. TAC/TAE setting sensitivity to findings (mutual information)

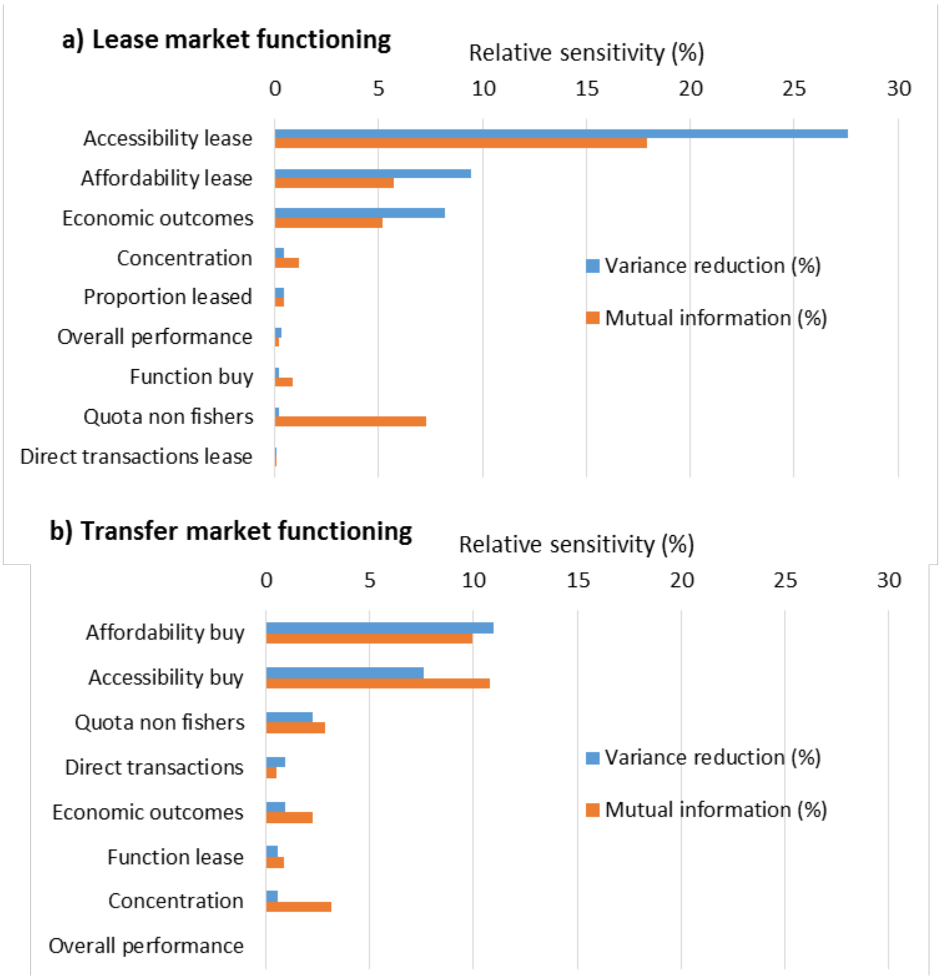


Functioning of the quota transfer and lease markets

The functioning of the quota lease market was also seen as in need of improvement in order to increase overall performance of the fisheries (see Figure 35). As a result, the sensitivity of both the lease market and permanent transfer (buy) market were also examined (Figure 38).

The accessibility and affordability of quota were the key factors affecting the functioning of both markets (Figure 38). These were generally considered low (a score of 1-5 out of 10) in around 50% of responses. For the lease market, only 31% of respondents believed that accessibility of quota was high (7-10), and 25% believed that affordability was also high (when affordability is high this indicates that lease quota is relatively easily obtainable). In contrast, 47% and 52% of respondents believed that accessibility and affordability were low (1-5) respectively. To achieve a well-functioning lease market, accessibility needs to increase to 64% of lease quota becoming highly accessible. Affordability also needs to increase, but by less (35% becoming highly affordable, up from 25%).

Figure 38. Lease and transfer market functioning sensitivity to findings



The sensitivity of the quota transfer market to the factors influencing it was substantially less than for the lease market (Figure 38). Only 26% of respondents believed that accessibility of quota was high (7-10), and 21% believed that affordability was also high. In contrast, 50% and 54% of respondents believed that accessibility and affordability were low (1-5) respectively. To achieve a well-functioning quota transfer market, accessibility needs to increase to 39% highly accessible, a lesser increase than the quota lease market. Similarly, affordability also needs to increase, but by less (28% highly affordable from 21%).

The quota markets are linked also to economic performance. To achieve a high economic performance score, the functioning of the lease market needs to improve to have a probability of well-functioning (i.e. a score of 7-10) of at least 48% (up from 28% currently) and a probability of not well functioning (i.e. a score of 1-5) no higher than 23% (down from 37% currently).[8] Similarly, the functioning of the

[8] The interpretation of these results can be confusing. BBNs are probabilistic models that derive a probability of an outcome. For the quota market functioning, there are three outcome levels based on the scores from the survey which can be roughly interpreted as not functioning (scores 1-5); functioning (scores 5-7) and well-

quota transfer market needs to increase to at least a high score (score 7-10) of 41% (up from 36%), although the proportion of fisheries with a low score for the functioning of the transfer market was similar under the high economic performance scenario (43%) to the current situation (42%).

Fishery characteristics and performance of ITQs and ITEs: econometric analysis

The econometric analysis estimated the relationship between the perceptions of overall fishery performance and perceptions around the governance of the fishery, as well as other fishery-specific characteristics. As noted in the methodology section, the main rationale for this focus is that success of the fishery management plan will depend on the way the plan is implemented, but this may also be influenced by the characteristics of the fishery.

The key governance measures considered were the type of management system (ITQ or ITE), complexity, cost effectiveness of management, perceptions of transparency in decision making, the level of trust in the management system, the level of industry participation in management, the extent to which cost and earnings data is collected and the level of influence of economic considerations in the TAC setting process. The key fishery characteristics were the proportion of quota leased annually, the concentration of quota ownership, the extent to which quota is owned by non-fishers (i.e. investors), the number of active fishers in the fishery, the level of compliance, and the level of bycatch in the fishery.

As with the BBN, the variables are qualitative in nature, representing the perceptions of fishers, managers and scientists and represented by relative levels rather than continuous values. As the categorical variables in the models had four levels (i.e. None < Low < Medium < High), these were replaced by new variables reflecting the linear, quadratic and cubic components of the contrasts.

Initial analyses involving all of these variables resulted in many not being found to be significant. This was to some extent a result in multicollinearity in the models, as some of the variables were found to be correlated despite not being continuous variables. Some of these correlations were not unexpected: For example, the level of quota owned by non-fishers was highly related to the level of leasing (Pr(χ^2_{15DF} =432.01) ≈ 0) and also the level of concentration (Pr(χ^2_{12DF} =293.76) ≈ 0). Similarly, the level of concentration and leasing were also related (Pr(χ^2_{12DF} =293.76) ≈ 0). In other cases, the correlation was an artefact of the data. For example, Industry participation in management and the level of bycatch were correlated (Pr(χ^2_{4DF} =606) ≈ 0), although this was due to fisheries with high bycatch in the data also tending to have high levels of industry participation. Different combinations of the correlated variables were examined, and the final model was determined based on the minimum AIC.

The model results are shown in Table 11. While several of the variables are not significant, removal of these variables resulted in a higher AIC value (suggesting that they were contributing to the overall explanation of the model even though were individually not significantly different from zero). In the

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functioning (scores 7-10). The analysis in this case indicates that we want to increase the probability of a score of 7-10 to 48%, and decrease the probability of a score of 1-5.

results in Table 11, the suffixes ".L", ".C" and ".Q" refer to the linear, quadratic and cubic components of the contrasts. The cubic components for industry participation and bycatch were not estimated due to the collinearity problems identified above. The cubic component of the proportion of quota leased was also not estimated as the data did not include any fisheries identified as having a high proportion of quota leasing, and hence effectively only had three levels (resulting in only two components in the contrasts).

The explanatory power of the model using all the data was relatively low ($\overline{R}^2$=0.21) and many of the variables were not significant. The models were estimated using only the data for the managers, fishers and scientists respectively. These individual sector models performed substantially better ($\overline{R}^2$ ranging from 0.72 to 0.84), with different variables being significant. Also, in some cases, the signs on the coefficients were opposite, so what one group saw as improving fishery performance, other groups though that these factors decreased it.

From Table 11, managers generally perceived that the performance of the fishery was lower if ITEs rather than ITQs were in place, all other things being equal. In contrast, scientist believed that ITE fisheries generally performed better overall than ITQ fisheries. Scientists also believe that fisheries that were managed cost effectively performed worse than fisheries that were managed less cost effectively. The level of cost effectiveness of management for each fishery was determined by the managers in the survey, and potentially lower costs of management may also reflect less scientific input.

Interpretation of the coefficients on the ordered categorical variables in Table 11 are not straightforward. The linear component provides an indication as to how overall performance generally relates to the variable. For example, a positive sign suggests that performance generally increases as the variable moves from None to High, but the overall outcome is also affected by the quadratic and cubic components.

Table 11. Influence of fishery characteristics on perceptions of overall fishery performance

	Combined			Managers			Fishers			Scientists		
	Estimate	Std. Error		Estimate	Std. Error		Estimate	Std. Error		Estimate	Std. Error	
Intercept	5.373	1.714	**	4.645	0.823	***	-1.327	4.337		8.241	1.707	***
ITE	0.760	1.580		-1.656	0.766	*	1.673	5.684		5.333	1.573	**
Cost effectiveness	-0.440	0.359		0.222	0.173		-0.709	0.940		-1.278	0.358	***
Complexity.L	2.190	1.321	.	0.156	0.674		5.629	1.561	**	-0.234	1.379	
Complexity.Q	-0.996	1.027		0.059	0.524		-4.397	1.196	**	0.198	1.074	
Complexity.C	0.518	0.592		0.230	0.299		1.421	0.754	.	-0.291	0.614	
Trust.L	-1.220	2.117		-1.035	1.080		-5.692	2.633	*	-0.620	2.212	
Trust.Q	0.108	1.434		0.626	0.726		1.683	1.934		0.971	1.486	
Trust.C	-0.906	0.639		-0.551	0.321	.	-3.653	0.961	***	-0.357	0.657	
Industry participation in management.L	1.804	1.934		0.934	0.984		8.248	2.563	**	0.584	2.015	
Industry participation in management.Q	0.250	1.122		-0.441	0.571		0.108	1.382		-0.538	1.169	
Cost Earnings data.L	2.420	0.814	**	1.960	0.396	***	-1.181	1.292		4.738	0.818	***
Cost Earnings data.Q	-0.423	0.659		-0.820	0.320	*	-0.246	0.881		1.153	0.665	.
Cost Earnings data.C	0.493	0.625		-0.206	0.299		0.866	1.208		0.615	0.615	
Economic influence TAC.L	-1.213	1.196		-1.729	0.576	**	5.967	2.397	*	-1.755	1.180	
Economic influence TAC.Q	-0.021	0.458		0.077	0.222		-0.427	0.606		0.078	0.456	
Economic influence TAC.C	-1.267	0.778		0.667	0.384	.	-2.507	1.298	.	-4.754	0.789	***
Proportion leased.L	1.831	0.908	*	1.794	0.422	***	-6.810	2.391	**	3.958	0.886	***
Proportion leased.Q	1.900	0.690	**	0.249	0.335		1.141	1.965		3.523	0.687	***
Concentration.L	-2.769	1.344	*	-4.499	0.653	***	5.542	2.849	.	-4.409	1.342	**
Concentration.Q	-11.897	4.690	*	-7.357	2.124	**	-26.313	23.123		-17.811	4.377	***
Concentration.C	-1.830	0.997	.	-2.136	0.484	***	4.947	2.261	*	-3.628	1.010	***
Bycatch.L	-5.079	4.331		-0.721	1.973		-24.183	19.540		-10.328	4.053	*
Bycatch.Q	5.219	2.300	*	3.158	1.024	**	16.772	12.348		5.091	2.103	*
Adjusted R-squared	0.209			0.846			0.727			0.742		
F-statistic:	3		***	15.77		***	6.674		***	8.663		***
No. Obs	175			63			50			62		

Significance codes: ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

The impact of each level of the order categorical variables on overall performance can be derived by the product of the vector of coefficients on the linear, quadratic and cubic terms and the polynomial contrasts. The results of this transformation are given in **Error! Not a valid bookmark self-reference.**. Only coefficients that were significant at the 10% or lower level were used in the derivation. The level of each variable that produces the greatest positive impact on fishery overall performance is shown in bold, while the level that results in the greatest negative performance is shown in italics.

Table 12. Derived impact of different levels of the categorical variables on overall fishery performance

	None	Low	Medium	High
Managers				
• Complexity	0	0	0	0
• Trust	0.123	*-0.369*	**0.369**	-0.123
• Industry participation management	0	0	0	0
• Cost Earnings	*-1.725*	-0.028	0.848	**0.905**
• Economic influence TAC	1.011	**0.834**	-0.834	*-1.011*
• Proportion quota leased	*-1.203*	-0.401	0.401	**1.203**
• Concentration of quota ownership	-0.183	3.252	**4.105**	*-7.174*
• Bycatch	**1.579**	*-1.579*	*-1.579*	**1.579**
Fishers				
• Complexity	*-6.292*	1.893	**2.504**	1.895
• Trust	**4.635**	-1.178	1.178	*-4.635*
• Industry participation management	*-5.533*	-1.844	1.844	**5.533**
• Cost Earnings	0	0	0	0
• Economic influence TAC	*-3.442*	-3.016	3.016	**3.442**
• Proportion quota leased	**4.568**	1.523	-1.523	*-4.568*
• Concentration of quota ownership	*-4.824*	2.079	-2.079	**4.824**
• Bycatch	0	0	0	0
Scientists				
• Complexity	0	0	0	0
• Trust	0	0	0	0
• Industry participation management	0	0	0	0
• Cost Earnings	*-2.602*	-1.636	0.483	**3.755**
• Economic influence TAC	1.063	*-3.189*	**3.189**	-1.063
• Proportion quota leased	-0.894	*-2.646*	-0.876	**4.417**
• Concentration of quota ownership	-5.137	7.458	**10.354**	*-12.675*
• Bycatch	**9.474**	-0.236	*-4.855*	-4.382

From The impact of each level of the order categorical variables on overall performance can be derived by the product of the vector of coefficients on the linear, quadratic and cubic terms and the polynomial contrasts. The results of this transformation are given in **Error! Not a valid bookmark self-reference.**. Only coefficients that were significant at the 10% or lower level were used in the derivation. The level of each variable that produces the greatest positive impact on fishery overall performance is shown in bold, while the level that results in the greatest negative performance is shown in italics.

Table 12, both managers and scientists did not believe that the level of management complexity had any significant impact on overall fishery performance, while fishers believed that a medium level of complexity was important, but a high (and low) level was counterproductive. Any ITQ program would involve some level of management complexity, but getting the balance right is important to fishers.

Managers believed that a medium level of trust from fishers was important, and low trust was detrimental to fisheries performance. Conversely, fishers believed that the fisheries that performed the best where those where they had no trust in management, and high levels of trust were associated with the lowest levels of performance. Potentially related to this result is that both managers and scientists saw no significant relationship between industry involvement in management and fishery performance, whereas fishers saw a high level of involvement in management as essential for high performance (possibly as they have little trust in managers and scientists).

The importance of economic information and use in fisheries management also varied between the groups. Both managers and scientists both saw the collection of economic data as highly important in achieving good overall management performance, but the use of these data to influence catch limits should be limited. Managers believed that best results are achieved if economics has only a low influence on TACs, while scientists believe that economics should only have a medium influence for the best performance. In contrast, fishers did not have any significant connection between the collection of economic data and fisheries performance, but believed that performance was reliant on inclusion of economics into the TAC setting process.

Quota concentration and leasing also had different impact on the perceptions of fishery overall performance between the groups. Both managers and scientists believed that fisheries with high levels of quota leasing were also performing well, while only a medium level of concentration of quota ownership was associated with well performing fisheries. That is, a mix of quota ownership and leasing. In contrast, fishers believed that fisheries that were performing well were those with no leasing and high levels of concentration. That is, relatively few operators in the fishery but which owned all their own quota.

Finally, there was no significant relationship between the level of bycatch and fishery performance from the fishers' perspective, but a strong negative relationship for scientists. From the latter's perspective, fisheries that performed the best where those with no bycatch; while those that performed the worst had high levels of bycatch. The results for managers where more complicated; in some cases no bycatch was desirable and in other cases high bycatch was seen as contributing to overall performance.

Constraints, benefits, concerns and unexpected outcomes

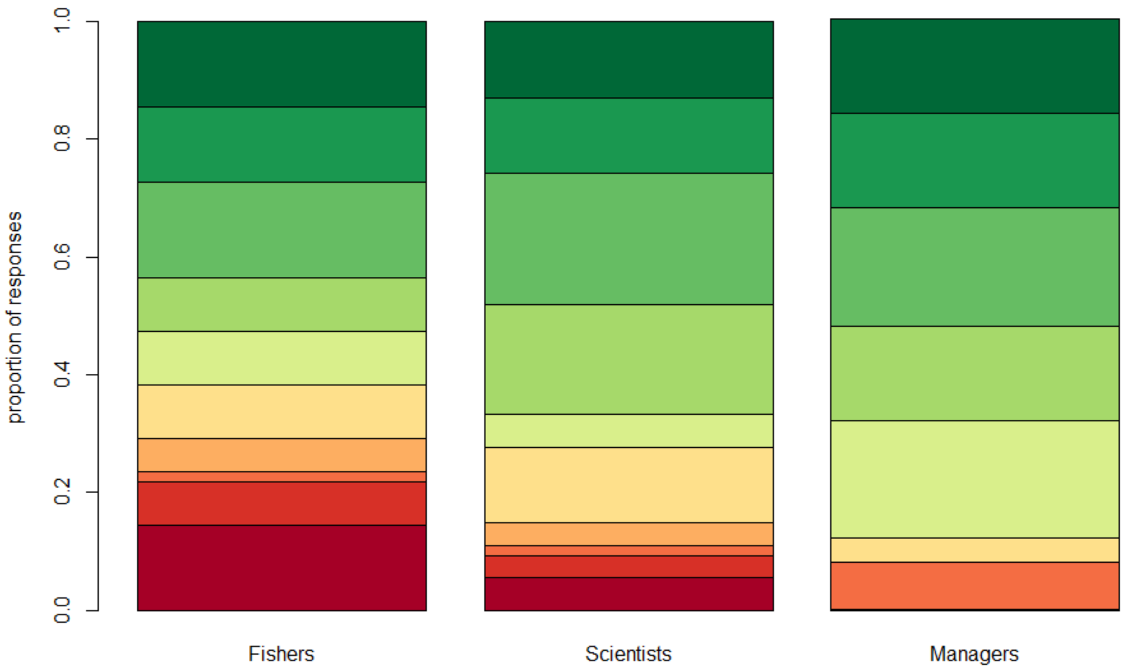
All three respondent groups were asked a common set of questions around constraints to autonomous adjustment, as well as other benefits and concerns they may have around the use of ITQs/ITEs in their fishery. In addition, the groups were asked to identify any unexpected outcomes (both positive and negative) that they may have observed.

Effectiveness of ITQs/ITEs in facilitating autonomous adjustment

One of the perceived advantages of ITQs/ITEs is their ability to facilitate autonomous adjustment in the industry (Grafton 1996). That is, they provide a mechanism for the fleet capacity to adjust to a more efficient configuration, and also allow adjustment in response to changes in economic conditions (which may also be linked to changes in stock size of environmental factors).

Views around effectiveness differed between fisheries, scientists, and managers, with the latter believing that overall ITQs/ITEs had been generally effective in facilitating autonomous adjust (Figure 39). In contrast, around 40% of fishers believed that ITQs/ITEs had not been very effective.

Figure 39. Perceptions of effectiveness of ITQs in facilitating autonomous adjustment in Australian fisheries



Note: red represents ineffective; green represents effective

Respondents were also asked if they observed any constraints to autonomous adjustment in their fisheries. Responses to this question varied considerably. In several cases, fishers who suggested that ITQs/ITEs had been effective in facilitating autonomous adjustment saw this as a negative consequence of the management system. Responses included issues of smaller vessels being "forced out" of the industry, and increased debt for those who remained in the industry. Other responses noted the increased difficulty facing new entrants due to the high cost of obtaining quota, the issue of increased concentration of quota ownership in the industry and the opening it created for investors to enter the industry and purchase the quota, forcing up the price for other fishers.

For those who suggested that ITQs had not been effective in facilitating autonomous adjustment, access to finance and the financial barrier to entry were raised as the main concerns. Several fishers suggested that as adjustment costs were high, government financial assistance was necessary to help facilitate adjustment. Others noted that reductions in TACs have not resulted in autonomous adjustment due to the already poor financial situation of the fishers, and that these TAC reductions have further reduced the financial situation (so no-one can afford to buy quota).

While managers generally perceived ITQs and ITEs to be effective in facilitating autonomous adjustment, many managers also identified some constraints. Foremost of these were perceived financial constraints facing fishers, although several managers also identified lack of availability of quota and imperfections in the quota market. In the case of the former, some managers believed that some ITE owners were not selling based on the hope of a future government buyout. Market imperfections such as a limited number of buyers and sellers and limited divisibility of units in ITE systems was also considered a constraint by some managers.

Several scientist also suggested that the market may be a major constraint on the ability of the fleet to adjust. In particular, the small size of the market, the influence of processors in the market and high transactions costs relative to the value of quota are believed to contribute to reduced market liquidity and hence limited trading. Others suggested that speculation by investors (including superannuation funds) have inflated the cost of quota above a value affordable to the fishers.

Top benefits and concerns (qualitative answers)

The respondents were asked to indicate up to three benefits and concerns they associated with ITQs or ITEs. In total, the respondents identified almost the same number of benefits and concerns (363 benefits and 358 concerns). In total 175 benefits and 196 concerns were identified by fishers, 65 benefits and 54 concerns by managers, and 123 benefits and 108 concerns by scientists. The fishers identified more concerns than benefits, while the managers and scientists identified more benefits than concerns.

The qualitative comments were categorised into theme and subgroups to allow interpretation. There were 8 benefits themes and 23 subgroups, and 9 themes of concerns and 32 subgroups (themes and subgroups are shown in Table 13). These themes and subgroups align with the topics of the quantitative survey components to allow cross interpretation.

Most of the benefits of ITQs and ITEs were related to sustainability, that the catch was controlled, and overfishing was avoided. Some of the benefits as expressed by the respondents were:

- *"Sustainable levels of commercial harvest" (Respondent ID 10101909958)*
- *"Quota - restricting the amount coming out of the water" (Respondent ID 10085623250)*

There remained some sustainability concerns that were reported mainly in relation to the perceptions that the TAC was too high and overfishing still occurred (which manifested itself in decreasing stocks).

- *"Stock has been allowed to decline to such an extent that many fishers are struggling" (Respondent ID 10087747594)*

These comments essentially highlight that catch levels must be set appropriately to ensure that the combined TAC/ITQ system is an effective control (Newton *et al.* 2007).

The second largest group of benefits (17% or 62 responses) associated with ITQs and ITEs were clearly in terms of economic efficiency and greater profitability (15% or 56 responses). Some of the comments were:

- *"Consolidation of quota to fewer more efficient owners" (Respondent ID 10139086843)*
- *"Restructured fleet and potential for higher profitability within industry" (Respondent ID 10099190318)*
- *"Improved economic performance for entire industry" (Respondent ID 10085582361)*

Table 13. Groups and subgroups of qualitative benefits and concern with respect to ITQs/ITEs in Australian fisheries

Benefits	Number of respondents	Concerns	Number of respondents
Sustainability - 121 benefits (33% of total benefits) and 31 concerns (9% of total concerns)			
Controlling catch/ avoid overfishing/ sustainability	105	Decreasing stocks or TAC too high (overfishing)	18
Greater resource stewardship	9	Environmental impacts (external to fishing)	7
End in race to fish	5	Bycatch & discard problems (including lack of data)	6
Bycatch & ecosystem impact reduction	2		
Economic - 62 benefits (17% of total benefits) and 26 concerns (7% of total concerns)			
Economic efficiency	40	Economic inefficiency & overcapitalisation	20
Greater profitability	16	Viability issues and financial constraints (to acquire quota)	6
Less catch variability	6		
Quota - 53 benefits (15% of total benefits) and 80 concerns (22% of total concerns)			
Asset value increase	21	Concentration of quota and quota ownership	24
Flexible and efficient trade in effort and quota units	19	Corporate or investor quota ownership	18
Investment certainty (spreading of risk)	13	Foreign ownership of quota and fishery revenue	16
		Quota retention & limited (thin) market	9
		Quota trade limitations & restrictions	7
		High quota prices	3
		Lack of security on rights & difficulty accessing capital	2
		Low quota prices	1
Management - 51 benefits (14% of total benefits) and 129 concerns (36% of total concerns)			
Flexible, transparent & robust catch setting method	39	Stock assessment methods and data uncertainty and inaccuracies	57
Industry engagement & participation	5	Management ineffectiveness, failure, or over-governing	31
Defined industry stakeholder group	2	High management cost	17
Easy to follow the rules (transparency)	2	Political influence on management & TAC decision	9
Opportunity for zoning	2	Scale-, zoning-, and spatial management issues	8
Improved fishery data	1	Poorly defined management objectives	4
		Lack of stakeholder input & stakeholder apathy	3
Participation - 33 benefits (9% of total benefits) and 44 concerns (12% of total concerns)			
Access certainty	17	Resource access barriers (costs)	26
Equitable access rights	16	High number of fishing entitlements & latent effort	12
		Inequitable allocation of rights & resource sharing issues	6
Market – 20 benefits (6% of total benefits) and 7 concerns (2% of total concerns)			
Higher prices for fish and market control	20	Market access & risk	3
		Lack of integration and opportunity to grow fishery	2
		Low price of fish	1
		High price of fish	1
Social - 19 benefits (5% of total benefits) and 24 concerns (7% of total concerns)			
Choice & timing of effort	10	Community social impact & lack of public benefit	12
Increased health and safety	5	Reduced fishing enjoyment and health impacts	12
Better social outcomes	4		
Industry - 4 benefits (1% of total benefits) and 6 concerns (2% of total concerns)			
Greater industry professionalism & political lobby	4	Short term planning horizons (short term thinking) and limited understanding	5
		Industry image and social licence	1
Employment - 11 concerns (3% of total concerns)			
		Employment losses and lack of job security	11

However, 7% of responses (20) also expressed economic concerns over ITQs and ITEs expressing the opposite of economic efficiency and some also mentioned over capitalisation. For example:

- *"Substantial over-capitalisation with high debts to service" (Respondent ID 10141441353)*

Even though 15% of responses (53) identified quota related benefits, a total of 80 responses (22%) identified quota related concerns. Most of the concerns were related to the concentration of quota ownership (24), corporate quota ownership (18) and foreign ownership (16).

- *"Encourages big businesses to buy out licence holders resulting in less local owner operators and potentially less custodianship over resource" (Respondent ID 10141354507)*
- *"Foreign ownership of a resource owned by State" (Respondent ID 10089487449)*
- *"Concentration of ownership and control by corporations (not fishers)" (Respondent ID 10099241484)*

The greatest number of concerns were related to management (129 responses or 36% of the total concerns identified). The number of management concerns was greater than the perceived benefits attributed to sustainability. The majority of management concerns related to the uncertainties and inaccuracies of stock assessments (57 responses). The second management concern was related to the perceived ineffectiveness or failure of management or the perception the fishery was over-governed (31 responses).

- *"Suitability of commercial catch rates to set quota" (Respondent ID 10101928964)*
- *"Small number of quota holders provide poor data" (Respondent ID 10146293242)*
- *"[need for] Improving the methodology in stock assessment and appropriate quota setting in the longer term." (Respondent ID 10099207448)*
- *"Not enough focus on economics by managers" (Respondent ID 10076548099)*
- *"Not enough focus on limiting catches from the recreational sector"*[9]

In terms of participation in the fishery, 33 benefits were expressed (9% of benefit related responses) and 44 concerns (12% of concern related responses) but some of these were expressing the opposite. For instance, respondents identified equitability of access rights (16) as a benefit but at the same time others identified inequity of access and resource sharing issues (6). A relatively high number of responses expressed resource access concerns (26 responses), but at the same time 17 responses identified the certainty of access as a benefit (although people can be concerned about access but also acknowledge that ones you have access that this access is relatively certain).

- Example of Access certainty: *"Stake in the fishery protected" (Respondent ID 10082201150)*
- Example of resource access barriers (costs): *"Cost to new entrants in the fishery" (Respondent ID 10077127656)*

The number of reported market related benefits outweighed markets related concerns (20 as opposed to 7 respectively). The benefits were all related to the higher prices for fish in the market and having greater control in the market because of the greater flexibility of when to go fishing and thus being able to fish to market. This flexibility is also reflected in the responses that were related to social issues, where choice in timing of effort was identified 10 times as a benefit of ITQs and ITEs. The

[9] From a follow up discussion with fishers and fisher representatives rather than the survey.

main social concerns were related to the lack of public benefit and the social impacts of changing fleet structure (12). For example:

- *"Money not flowing for the benefit of community" (Respondent ID 10092500422)*
- *"Less local based diver/processor, less diversity in fisheries in remote areas" (Respondent ID 10180713288)*

A total of 5 respondent reported better health and safety outcomes associated with ITQs and ITEs, but a total of 12 respondents reported the opposite. For example:

- *"Financial squeeze of lease fishers has increases risk taking, injuries and harms mental health" (Respondent ID 10083706253)*

In terms of the way the industry operates (related to their political influence, social licence and understanding of industry related issues) there were a small number of respondents (4) who thought that the industry showed greater professionalism and had greater influence in the political and decision process. This was, however, also perceived as a concern by some respondents, who saw political influence on management and TAC decisions as a concern (9 shown under the management theme). In addition, a small number of respondents said that the industry was characterised by short term thinking and limited understanding (5).

Lastly, employment issues arising from ITQs and ITEs were only raised as a concern and mainly indicated a reduction in jobs and job security (11).

Overall benefits and costs

All respondents (managers, scientists, and fishers) were asked if they considered that, overall, the benefits of ITQs/ITEs exceeded the costs. These perceptions differed by stakeholder group (Figure 40). Almost half of the fishers believed that the costs of ITQs/ITEs were larger than the benefits they received, with only 30% believing that the benefits exceeded the costs. In contrast, both scientists and managers generally believed that the benefits of ITQ/ITE management outweighed the costs, with only 25 per cent of scientists and 4 per cent of managers believing that the costs outweighed the benefits.

The negative perception held my many fishers largely reflects their views about the economic performance of their fisheries – those fishers who believed that their fishery was performing well economically also tended to believe that ITQs/ITEs provided a net benefit (benefits>costs), or at least did not result in a net loss. In contrast, those fishers who believed that their fishery was performing relatively poorly in terms of economic outcomes tended to also believe that ITQs/ITEs resulted in a net loss (Figure 41).

Figure 40. Perceptions of benefits and costs of ITQs/ITEs in Australian fisheries

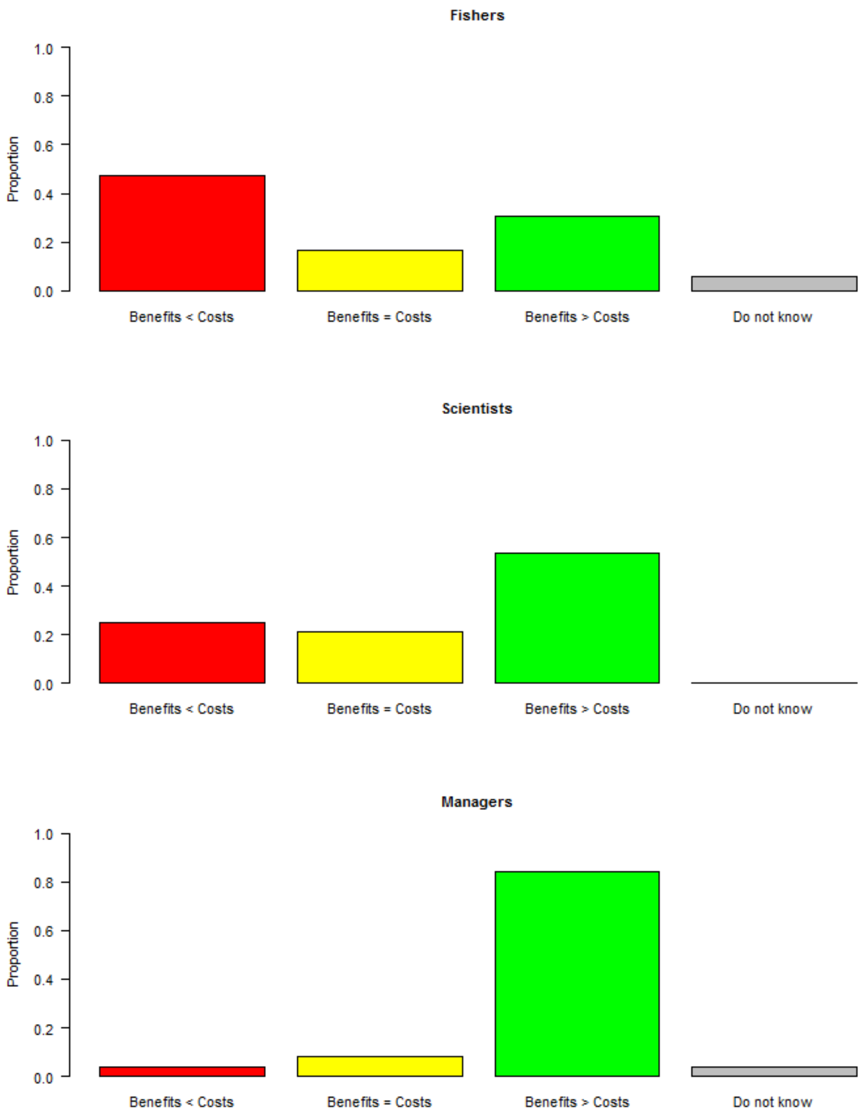
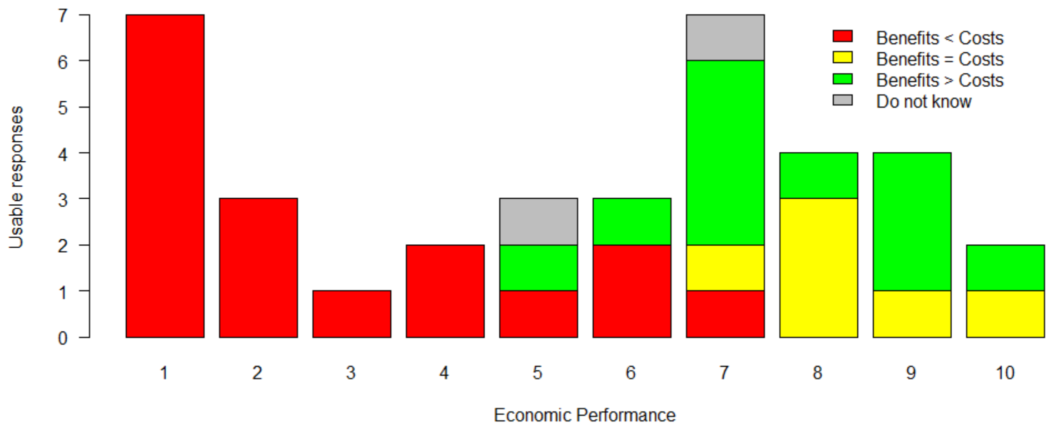


Figure 41. Fishers' perceptions of benefits and costs of ITQs/ITEs compared with fishery economic performance in Australian fisheries



Knowledge gaps

The three survey respondent groups were also asked to identify any knowledge gaps that may be constraining the effectiveness of ITQs/ITEs. A word cloud depicting the frequency of individual words in the responses is shown in Figure 42, and a more detailed breakdown of responses is given in Table 14.

The term "economic" was the most frequently used word in the set of responses across all three groups (Figure 42), although issues around sustainability were the most frequently noted areas where knowledge needs to be improved (Table 14).

Economic knowledge gaps largely related to the lack of economic data for fisheries. Most commonly mentioned by both fishers and managers was the need for more cost and earnings data to assess fishery economic performance. Several fishers, managers and scientists also highlighted the need for a better understanding of fisheries markets, and price-quantity relationships in particular. Other suggestions included greater information on economic performance, targeting behaviour of fishers and productivity measures (effective fishing effort).

The key governance knowledge gaps included how to better incorporate fisher knowledge into management decision making and the greater use of harvest strategies, the former being proposed by fishers and the latter by scientists. A better understanding of how managers should respond to changing conditions in the fishery was also suggested by fishers and scientists. This also relates to the use of harvest strategies, where an appropriate response is determined by the strategy. The need for spatial management was also highlighted by several scientists.

Figure 42. Key knowledge gaps identified by survey respondents

Table 14. Key knowledge gaps identified by survey respondent

Knowledge gap	Fishers	Managers	Scientists	Total
Economic				
Aquaculture impacts	1			1
Bioeconomic model			1	1
Cost benefit analysis		1		1
Economic assessment			1	1
Economic costs	1			1
Economic data	7	6		13
Economic drivers		1	1	2
Economic markets	4	1	2	7
Economic performance	1			1
Economic targets		1		1
Effective effort			1	1
Impact of ITQs			1	1
Targeting behaviour	1			1
Total	15	10	7	32
Governance				
Adaptive management			1	1
Effort allocation	1			1
External impacts	2			2
Fisher knowledge	5			5
Fishery objectives			1	1
Harvest strategies		1	6	7
integrated monitoring			1	1
Manage communicate		1		1
Manage fluctuation		1		1
Management assessment			1	1
Management response	2	1	2	5
Political interferences	1			1
Spatial management	1		4	5
Total	12	4	16	32
Social				
Quota concentration	4			4
Quota ownership	4			4
Recreational fishing	1			1
Research in general	1			1
Social considerations (in general)	10			10
Total	20			20
Sustainability				
Bycatch	1	1		2
Catch rates	1			1
Climate change	4	1	3	8
Connectivity	1			1
Ecological changes	1			1
Environmental data		1		1
External impacts			1	1
Fishery data			2	2
Fishery independent data	3	2	6	11
Illegal catch		1		1
Pollution	2			2
Species biology	11	2	5	18
Stock assessment	7	6	4	17
Sustainability	1			1
Group conservationists	1			1
Total	33	14	21	68
Overall Total	80	28	44	152

Fishers were less clear about social knowledge gaps; interestingly several identified "social" as a knowledge gap but did not provide further information as to what this entailed. This may indicate that there is some uncertainty as to the exact components or factors that are defined as social issues. Where additional information was included, this tended to relate to increasing trust of managers in the information provided by fishers (potentially related to the use of fisher information in the governance domain), or improving the perception of fisheries of the local communities through reducing bycatch. Several fishers also highlighted issues around quota ownership and concentration, and if/how this affects the market for quota (and the prices paid by fishers).

Sustainability-related knowledge gaps raised the most responses across all three groups (Table 14). Fishers in particular were concerned about the lack of species-specific biological data (e.g. growth rates, natural mortality etc.) and the level of uncertainty in stock assessments due to poor data quality (which also included the lack of species-specific biological data). These views were also shared by managers and scientists. In addition, scientists also raised the need for more fishery independent data to assist in stock assessments. The impact of climate change on the fisheries surveyed was also raised by several fishers and scientists.

Many of these knowledge gaps identified by the survey participants are not necessarily unique to ITQ/ITE fisheries, as similar needs could be applied to any fishery. The reliance on an accurate and appropriate TAC/TAE in ITQ/ITE fisheries, however, may make the consequences of inadequate knowledge more severe.

Detailed case study fisheries

There is a wide variety of fisheries that are subject to ITQ and ITE management (as seen in Tables 1 and 2). The previous analyses demonstrated that views of fishers varied considerably across respondent group, across fisheries, and in some cases within fisheries.

Three fisheries were selected for a more detailed examination of the effects of the management system of their operations, profitability, and perceptions of the industry. The first case study is the Tasmanian abalone ITQ fishery. This fishery was selected as it was believed to be facing a number of challenges around the operations of the current ITQ system. The second case study is the NSW Rock Lobster Fishery. This study was chosen as it represents a "success" story in terms of ITQ management. The third case study is of the northern prawn fishery is an ITE fishery. This is also considered a fishery which was relatively successful (Dichmont *et al.* 2016), and illustrates the potential benefits where ITEs are effectively implemented.

Tasmanian abalone

The Tasmanian Abalone Fishery is the largest wild abalone fishery in the world, producing approximately 30% of the global harvest (FAO 2018; Mundy and McAllister 2018). Commercial fishing for abalone in Tasmanian waters commenced in the late 1950s. The fishery has predominantly focused on Blacklip Abalone (*Haliotis rubra*), with Greenlip Abalone (*H. laevigata*) typically accounting for around 5% of the total wild harvest in Tasmania. The fishery operates as a dive fishery with most diving undertaken using 'hookah' gear, whereby compressors pump air through hoses down to the diver. Most divers operate from runabouts or dinghy sized vessels operated from shore or larger mother boats.

Rapid expansion of the fishery led to the first attempt to control effort in 1969 by limiting the number of diving licences (120 licences). Only divers fishing the previous year were licensed to fish in 1969. In 1972 an additional five licenses were issued to the residents of the Furneaux Group. By the early 1980s catch had reached to 4,000 tonnes and there were serious concerns regarding potential overfishing of Tasmania's abalone resource, which led to the introduction of individual transferable quota (ITQ) and a total allowable commercial catch (TACC) in 1985 (Mundy and Jones 2017). The TAC for the commercial abalone fishery was divided into 3,500 equal quota units and each of the registered divers were allocated an equal share of the units (28 units each). The current management measures include mandatory possession of a measuring tool to gauge the various abalone sizes; area closures and sub-block catch caps; rigorous reporting requirements, and the creation of six management zones in State waters, each with an individual TAC.

In 2017, the gross value of production (GVP) of the fishery was estimated to be approximately $70 million from a TAC of 1,561 tonnes. The 2018 TAC of 1,333.5 tonnes is the lowest since TACs were introduced in 1985, down from a high of 3,806 tonnes in that year (Tasmanian Goverment (DPIPWE) 2018) (Table 15).

The beach price of Tasmanian abalone differs across the six Management Zones due to the various markets that the abalone product is suited to. On average across the zones, the nominal beach price has increased from $35/kg in 2010/11 to $45kg in 2015/16 (ABARES 2017b). Abalone quota sale prices are not publically available, but information from quota brokers suggests there is some fluctuation between years due, for instance, to market concerns about risk of possible Abalone Viral Ganglioneuritis (AVG) outbreaks.

Table 15. Catch and value of catch of the Tasmanian Abalone Fishery (both Blacklip and Greenlip combined)

Year	Total catch (tonnes	TACC (tonnes)	% TACC caught	Average beach(?) price, nominal ($/kg)	GVP $m/year
2006	2503	2503	100%	$43	$108
2007	2433	2503	97%	$40	$97
2008	2583	2594	100%	$37	$90
2009	2607	2604	100%	$37	$92
2010	2660	2660	100%	$40	$103
2011	2545	2566	99%	$35	$83
2012	2363	2366	100%	$34	$86
2013	2125	2149	99%	$30	$73
2014	1905	1932	99%	$32	$68
2015	1841	1932	95%	$40	$81
2016	1663	1694	98%	$45	$82
2017	1534	1561	98%	$49	$84
2018	-	1334	-	$54	-

In 1991, a restructure of the industry allowed non-diving investors to purchase abalone quota units (DPIF 1990). A commercial abalone licence was divided into two licences: an Abalone dive entitlement (Fishing License Abalone Dive or FLAD), and an entitlement to hold abalone quota units. Divers do not need to own quota nor FLADs as they can lease both FLAD and abalone quota from those who own them. Based on the definition by Felmingham and van Putten (2009), there are 4 types of abalone divers: (a) Divers who lease in (do not own) both quota and FLAD; (b) Divers who lease in quota (over what they already own or if they do not own any at all) but own FLAD; (c) Divers who own quota but do not own FLAD; (d) Divers who own both quota and FLAD. In 2015, approximately 46.8% of divers either did not own quota or lease in quota more than they owned (a & b above) and only 13.5% of divers owned both quota and FLAD (Ogier *et al.* 2018).

The divers who lease in quota will charge the owner a so-called 'diver charge'. Income for divers who own quota and those who do not own quota differs even though the cost of diving for these two groups is similar (Felmingham and van Putten 2009). For example, in a situation where quota is owned, the diver's profit is the difference between the price of abalone (roughly $35-45 per kg) minus the cost of diving. Where quota is leased, diver profit is the difference between the diver charge (between $7 and $10 per kg) and the cost of diving. The average income for lease-dependent divers (i.e. revenue less diving costs) in 2015 was estimated to be $54,616, based on an average of 110 days of diving per year and catching 24.2 tonnes (Knuckey and Sen 2017). Concerns regarding increasing financial hardship for divers who do not own quota have been raised repeatedly (e.g. Felmingham and van Putten 2009; Knuckey and Sen 2017). A recent review on diver charges by Knuckey and Sen (2017) argues that the number of abalone dive entitlement (FLAD) was based on 1986 participation and is higher than required to catch the current TAC given a 33% drop in TAC since 2001 and that 50% of the current TAC is caught by only 28 divers. The issue of excess diver entitlements has been a topic of discussion, and divisive issue, in this fishery for an extended period of time (at least since the report by Felmingham and van Putten 2009), and was still of relevance of the time of the survey.

Findings from the survey

In total, 54[10] Tasmanian abalone fishers completed the survey, with an average 25 years of working experience as an abalone fisher, and 27 years as a fisher in general. Their perception on overall performance of the ITQ fishery shows mixed results (Figure 43), but average score values suggest that most fisher survey respondents believe ITQs in this fishery have been successful, particularly in terms of sustainability and environmental outcomes (Figure 43, a - c).

Fishers who own quota as opposed to those who lease in quota have more positive views on the ITQ fishery with respect to all nine domains shown in Figure 41 (as the pink colours appear predominantly on the right hand side of each graph). Fishers' satisfaction with the ITQ fishery was also split, with around half of the fishers not satisfied while the other half are satisfied (Figure 43, h).

The question regarding the outcomes of autonomous adjustment, a key perceived advantage of ITQs and ITEs where the fleet size adjusts on its own without the need for government support, was also split. Fishers who own quota tend to believe there was such autonomous adjustment, while others tend to believe there was no such autonomous adjustment (Figure 43, i).

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[10] As noted previously, only seven responses were used in the BBN and survey analysis in which different fisheries, regions and respondent groups were compared to ensure that inter-fishery and inter-regional comparisons were not too heavily biased towards the Tasmanian abalone sector. The seven responses were chosen through sorting the complete set of responses from lowest to highest in terms of their response to the perception of overall fishery performance and taking every seventh response. This group still represents the largest group of responses in the main analysis.

The fisher respondents were divided about whether ITQs have improved the fishery's overall performance with around half of the TAS abalone fishers believe it had improved and the other half believing it made the fishery performance worse (Table 16 and Figure 41, g).

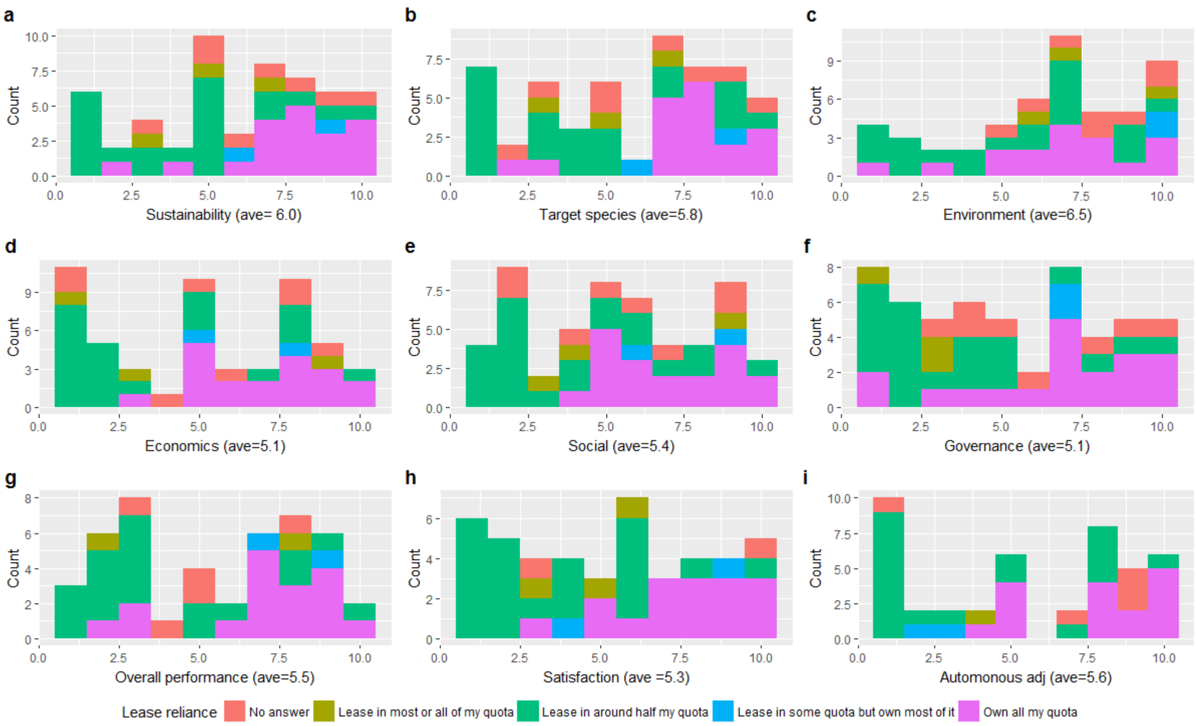
Table 16. Tasmanian abalone fishers' perceptions of how ITQs have affected the performance of their fishery

Outcomes	Made it worse (number of respondents)	No real change (number of respondents)	Improved (number of respondents)	Don't know (number of respondents)
Sustainability	18	6	28	2
Economic	23	5	24	2
Social	18	14	20	2
Governance	17	13	23	1
Total	58	32	67	5

In terms of economics outcomes, the majority of fishers believe ITQ have increased the cost of fishing (67%), cost of management (69%), and compliance cost (65%), while most of them also believe ITQs have improved the quality of catch (52%), and increased the abalone price (72%) (Table 17). In relation to the consumers, nearly half of the fishers believe their customers are more satisfied after ITQ (46%) compared to less satisfied (19%), although many believe availability of fish has decreased (44%).

In terms of social outcomes, the majority of abalone fishers indicated that the employment outcomes, their enjoyment in participating in this fishery, and their social relationships had decreased (54%, 56% and 52% of fishers indicated that ITQ had worsened these outcomes respectively). Many fishers also perceived that the level of information sharing had decreased (43%) but 26% believed this had not changed.

Figure 43. Tasmanian abalone fishers' perceptions on ITQ fishery performance.



Notes: On a scale of 1 to 10 (with 1 being not successful and 10 being very successful), how successful do you think the fishery currently is at achieving? Sustainability = Overall sustainability; Target species = sustainability of target species; Environment = environmental sustainability; Economics = economic outcomes; Social = social outcomes; Governance = fishery governance outcomes; Overall performance = Overall performance of the fisher, Satisfaction = Satisfaction with the ITQ fishery, Autonomous adj = autonomous adjustment.

Table 17. Tasmanian abalone fishers' perceptions of how ITQs have affected key aspects of their fishery

Satisfaction with …	Decreased	No real change	Increased	Don't know
Price of fish	3	3	39	4
Quality of fish	4	13	28	4
Availability of fish	24	12	9	4
Number of wholesalers	27	11	3	8
Days fished	24	11	7	8
Management cost	0	7	37	6
Compliance cost	0	9	35	6
Debt	1	9	31	9
Fishing cost	2	6	36	6
Crew income	29	7	7	1
Employment	25	14	3	4
Enjoyment	29	14	5	4
Social relationship	25	14	3	6
Information sharing	20	12	8	7
Health & safety	20	10	13	5
Regional importance	19	8	19	3
ITQ impact on community support	11	19	10	9
Customer satisfaction	10	8	25	6
Wholesaler satisfaction	15	6	21	7
Area fished	29	11	2	8
Community support (current)	2	13	18	5
Uncertainty in stock assessment	11	15	20	3
TAC setting functioning	20	16	10	3
Degree of …	None	Low	Moderate	High
Complexity	4	18	14	13
Transparency	10	14	19	6
Industry participation TAC	3	13	17	16
Trust	3	17	18	11
Industry participation in management	1	16	20	12

It is evident from this Tasmanian abalone case study that within this fishery – fisher's perceptions on the effectiveness of ITQs vary widely. The ownership of quota has a large impact on the fisher's profitability, and this appears to contribute to different perceptions of the effectiveness of ITQ outcomes, maybe less so with respect to the environment and sustainability but most prominently with respect to the social and economic outcomes. From additional research, some follow up conversations with fishers, and from the qualitative comments provided in the survey it is evident that there is some apparent division in the perceptions in this fishery.

An issue that is laid at the foundation of some of this apparent division is the perception by a proportion of the fishery that there are currently an excess number of diver licences (120) for the available quota. Because the total catch can be caught by a small number of available divers this means that competition for quota puts downward pressure on the prices paid to the abalone divers which can make the profession of abalone diver only marginally profitable if the diver owns no quota themselves. Fierce competition among abalone divers has been reported by Knuckey and Sen (2017), and a further cut in the TAC in recent years may have exacerbate this competition. This was also evident from our results with, for instance, one abalone diver noting

- *“[there are] simply too many divers competing for too little quota. Quota owners/investors shop around (for cheap divers) and there is always someone willing to dive with very little pay. I have no job security because I don’t even know if I can get quota next week”.*

From the survey: *“Constant shifting of boundaries. Plays into the investors hands. Investors have control” (respondent ID 10163414484)*

And listed as a concern: *“Non-fisher ownership of resource” (respondent ID 10163267659)*

As a consequence of the quota ownership characteristics in the Tasmanian abalone fishery, power asymmetries seem to have developed between quota owners and divers who own no (or very little) quota. As noted by, Knuckey and Sen (2017), the lack of quota owned by divers has resulted in increased competition between divers to obtain quota (as compared to increased pressure on the resource). This has put downward pressure on the financial returns to these divers, many of whom indicated experiencing hardship. Fishers also noted that because there is a high level of competition among divers, more divers are willing to operate in unfavourable conditions and safety at sea is worsening. Worsening risk taking and safety outcomes is consistent with ‘race to fish’ type behaviour and contradicts what is generally an expected and observed benefit of ITQs, that is increased safety (e.g. Grafton et al. 2000; Hughes and Woodley 2007).

The separation of quota ownership from the catch sector was identified as a key issue that caused diver competition, financial hardship and increased safety issues in Tasmania. Other states also have abalone fisheries with a diver and quota-owner component, with differing restrictions on quota transfers. For example, separation of abalone quota units from the Abalone Fishery Access Licence (AFAL) has been permitted since 2006 in Victoria, and quota can be permanently transferred to external investors who do not hold an AFAL. However, AFAL license holders are still required to hold a minimum of 5 Blacklip Abalone quota units at all times.[11] In South Australia, quota is transferable between licence holders but quota is attached to licences. Separating quota ownership from the fishing licence reduces the potential for autonomous adjustment in the fishery, one of the key benefits of ITQs.

The perceptions of quota-owners were substantially different to those of the lease dependent divers. Quota owners were generally satisfied with the economic and biological benefits of ITQs. In particular, quota owners noted that ITQs provide business stability and certainty for capital investment, while ensuring and stock conservation.

NSW Rock Lobster fishery

Catches of Eastern Rock Lobster (*Sagmariasus verreauxi*) have been recorded along the coast of New South Wales (NSW), Australia, since the mid-1870s, although were harvested by indigenous Australians before European settlement, and by early settlers from the late 1780s (Montgomery and Liggins 2013). While the stock extends from southern Queensland to Port MacDonnell in South Australia, including around Tasmania, the greatest abundances and the only significant catches occur along the NSW coast (Liggins 2016). Recorded catches fluctuated widely over the next century, with peaks after both the first and second world war with the return of ex-servicemen (and the stock

[11] http://www.environment.gov.au/system/files/pages/fb3d8568-f6d1-4fd4-bd78-180ea31d12eb/files/abalone-status-report-2010.pdf

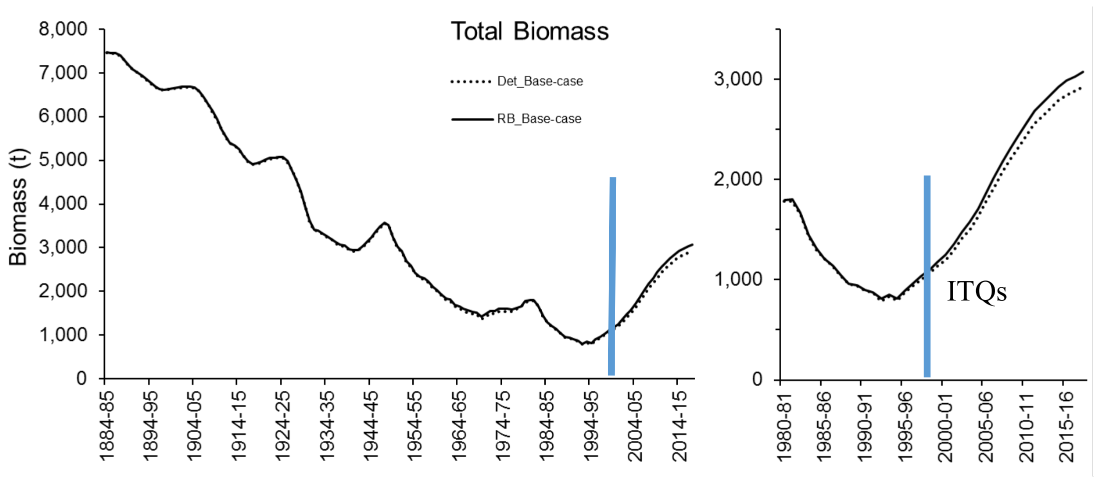
recovery that took place during the wars) (Montgomery and Liggins 2013). Concerns about catches in the fishery emerged in the early 1990s, and the fishery was closed to new entrants in 1993 (i.e. limited entry), with a quota management system introduced in 1994. The initial quota management system involved a total allowable catch (TAC) managed through a tagging system, where the tags were required to be purchased for a fee of (AUD) $2 each. Participants in the fishery were allocated shares in the quota on a provision basis in 1996, and the formal share management plan (i.e. the formal ITQ system currently in place) was implemented in 2000 (Montgomery and Liggins 2013).

The estimated total value of the fishery in 2016-17 was $11.3m (NSW Department of Primary Industries 2018), less than 2% of the total Australian lobster production by value (ABARES 2017b). Around 75% of the catch is sold on the domestic market, unlike lobster fisheries in other Australian States, which are based on different species and are more export focused.[12]

Resource sustainability

Estimates of biomass over time suggest that stock size fell fairly constantly since the fishery opened until the first attempts at quota management in the mid-1990s (Figure 44). The initial TAC introduced in 2000 was higher than the earlier interim TACs in the preceding few years and the observed catches in the years before that. Concerns over falling catch rates and unfilled quota resulted in a substantial cut (around 30%) in the TAC for the 2004-05 fishing season (NSW Department of Primary Industries 2018). Since then, evidence of stock recovery (Montgomery and Liggins 2013) has allowed the TAC to gradually increase. The TAC and catch in 2015/16 and 2016-17 (160t TACC and 160t and 155t respectively) are the largest since the introduction of the ITQ system in 2000 (NSW Department of Primary Industries 2018), and the greatest in the last 34 years (Liggins et al. 2018).

Figure 44. Evolution of the NSW Lobster stock



[12] In 2015-16, over 80% of the landings of Australian rock lobster were exported (ABARES 2017b).

Economic performance

Formal cost and earnings data are not collected for the fishery, but estimates of profits and drivers of profitability were estimated using profit decomposition approaches applied to lease prices as a proxy for profits (Pascoe et al. 2019b). The sales and lease prices for quota (Table 18) are used to derive an implicit cost measure, as well as a series of indexes that indicate what is driving profit change.

From Table 18, unit profit (as indicated by the lease price) has more than doubled in real terms since the early 2000s. The profit index, which represents the change in profit between periods, was greater than one in all but three years of the 15 years of data.

Table 18. Implicit cost and profit decomposition

Fishing period	Lease price (“profit)	Lobster price (output price/kg)	Implicit cost (input price/kg)	Profit index	Price index	Cost index	Key driver
2003-04	$10.17	$55.07	$44.90	-	-	-	-
2004-05	$15.07	$52.99	$37.92	1.48	0.84	1.80	Cost decrease
2005-06	$17.69	$55.57	$37.87	1.17	1.17	1.00	Price increase
2006-07	$20.36	$61.79	$41.43	1.15	1.39	0.83	Price increase
2007-08	$22.65	$57.97	$35.32	1.11	0.84	1.33	Cost decrease
2008-09	$19.40	$66.71	$47.31	0.86	1.52	0.56	Cost increase
2009-10	$17.65	$66.35	$48.70	0.91	0.98	0.93	Cost increase
2010-11	$19.78	$64.21	$44.43	1.12	0.89	1.26	Cost decrease
2011-12	$19.99	$64.98	$45.00	1.01	1.04	0.97	Price increase
2012-13	$21.68	$60.83	$39.15	1.08	0.82	1.33	Cost decrease
2013-14	$22.25	$75.33	$53.08	1.03	1.94	0.53	Price increase
2014-15	$22.92	$79.07	$56.15	1.03	1.18	0.87	Price increase
2015-16	$28.79	$78.70	$49.91	1.26	0.99	1.28	Cost decrease
2016-17	$32.07	$75.14	$43.07	1.11	0.89	1.25	Cost decrease
2017-18	$27.61	$73.40	$45.79	0.86	0.94	0.91	Cost increase

Note: all values in 2017-18 dollars. Source: Pascoe et al. (2019b)

Cost information was not available, although an implicit cost measure could be obtained assuming that the lease price represented the per unit profit, and hence the difference between the lease price and output price represents the cost of fishing (Pascoe et al. 2019b). As the implicit cost measure represents the costs of capture, this will be a composite measure of the impact of changes in input costs as well as changes in the level of inputs required to take a unit of quota. Hence, the impact of changes in stock size (greater availability) and fleet size (reduced competition) on the amount of effort required to take the catch will be captured within this measure. As the index is based on the exponential of a negative cost change, a cost index value greater than one indicates that costs have decreased (and hence positively contributed to profits).

Although the price received has generally increased over the period of the data in real terms, from Table 18, the greatest contributor to improvements in profitability over the period of the data has been cost decreases, most likely due to improvements in biomass, although price increase also played a substantial role. Cost decreases were the key driver in six of the 14 years examined, while price increases were the key driver in five of the years. In the three years when profits appear to have decreases (2008-09, 2009-10 and 2017-18), cost were again the main drivers of these changes, although in this case it was cost increases, with price also being relatively weak in two of these three years.

As seen in Figure 44, biomass has tended to increase since the mid-1990s due to the implementation of the quota system[13] (Liggins et al. 2018). Hence the years in which costs had a negative impact on profits most likely indicate higher than average input prices. While downward pressure on profits due to higher costs was also seen in other years (e.g. 2006-07, 2011-12, 2013-14 and 2014-15), these were more than offset by higher output prices.

Autonomous adjustment and quota trading

Substantial autonomous adjustment has been seen in the fishery, with the number of shareholders decreasing by 41% (174 to 102) since its commencement in 2000 (NSW Department of Primary Industries 2018). Most of this adjustment took place over the first 10 years of the program, with shareholder numbers being relatively stable since 2010-11 (NSW Department of Primary Industries 2018). Of the 102 shareholders, around 70 are active fishers.

The amount of share trading has decreased since the management plan was introduced in 2000, with initial years seeing 7% to 10% of shares traded annually as the fishery adjusted (Table 19). In more recent years, only around 2%-3% of the shares are traded. Information on the price at which shares traded is collected as part of the transfer application. Given that a share represents a proportion of the TAC, the share price in Table 19 has been converted to a price per kg equivalent for comparison with quota lease prices. All prices in Table 19 have been converted to real values, in 2017-18 dollars, using the consumer price index.

Table 19. Lobster price, share and quota trading data, 2000-01 to 2017-18

Fishing	Lobster price	Share transfers		Quota transfers (leases)	
period	($/kg)	% total shares	$/kg	% total TACC	$/kg
2000/01	$66.29	7.2%	$101.04	11%	NA
2001/02	$69.28	9.6%	$83.11	20%	NA
2002/03	$65.05	6.6%	$86.09	33%	NA
2003/04	$55.07	9.3%	$83.72	22%	$10.17
2004/05	$52.99	8.5%	$87.39	34%	$15.07
2005/06	$55.57	6.1%	$125.84	30%	$17.69
2006/07	$61.79	7.2%	$148.02	32%	$20.36
2007/08	$57.97	8.2%	$190.51	34%	$22.65
2008/09	$66.71	3.5%	$184.70	33%	$19.40
2009/10	$66.35	3.1%	$176.92	31%	$17.65
2010/11	$64.21	3.2%	$175.48	28%	$19.78
2011/12	$64.98	5.0%	$171.46	32%	$19.99
2012/13	$60.83	1.2%	$223.92	35%	$21.68
2013/14	$75.33	3.5%	$143.78	30%	$22.25
2014/15	$79.07	1.3%	$309.62	31%	$22.92
2015/16	$78.70	2.1%	$318.34	29%	$28.79
2016/17	$75.14	3.7%	$474.81	31%	$32.07
2017/18	$73.40	2.9%	$616.16	33%	$27.61

Source: Derived from NSW Department of Primary Industries (2018).

Around one third of the annual quota is transferred through leases agreements (Table 19) each year on average. Data on lease prices has been requested on a voluntary basis since 2003-04, with around 30% of quota lease transactions, on average, recording the price (ranging from 18% to 34%) (NSW

[13] As noted previously, initially, quotas operating through a tag-based system was introduced in 1994-95, which was later converted to a full ITQ program in 2000.

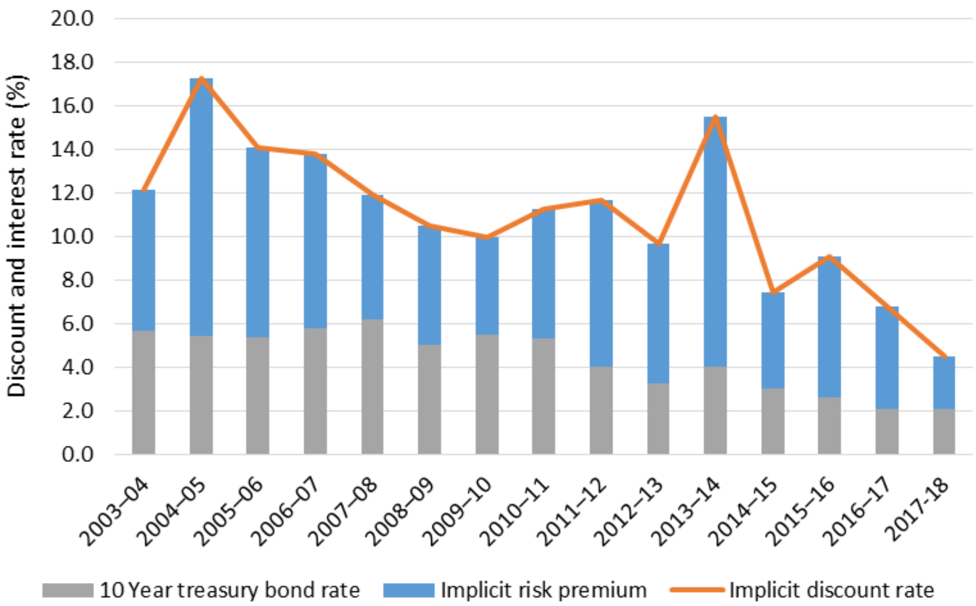
Department of Primary Industries 2018). While this is a small proportion of total transactions, lease agreements can vary through a range of informal arrangements (e.g. "loans", favours for a friend, etc.) that may distort the price.[14] As the share prices and lease prices are generally following a similar (upwards) trajectory, we can assume fishers involved in these informal arrangements are not providing price data, and that the sample of price information received can be considered reasonably representative of the lease prices.

Changes in fishers' confidence in the fishery

The relationship between the annual lease price and the share sale price (on a $/kg basis) provides an indication of the implicit discount rate used by fishers. The implicit discount rate is the rate at which fisher's appear to be willing to trade-off future benefits for current benefits. A high discount rate suggests that fishers prefer benefits now (i.e. have a relatively short time perspective) and are less concerned about future benefits, while a low discount rate suggests fishers take a longer term view about the benefits from fisheries management. Implicit in this also is the level of confidence that longer term benefits will exist. The discount rate also reflects the opportunity cost of capital (in this case, the opportunity cost of holding the quota assets), and hence other factors such as the risk free interest rate can also affect this relationship.

The implicit discount rate derived from Table 19 and the 10 year Treasury bond rate (ABARES 2017a) (representing a risk free interest rate) as shown in Figure 45. The difference between the bond rate and implicit discount rate represents the risk premium required by fishers. Both discount rate and risk premium have generally declined over the period of the data, suggesting that fishers are having greater confidence in the industry and are prepared to take a longer term perspective on its management.

Figure 45. Implicit discount rate, 2003–04 to 2017–18



Source: Pascoe et al. (2019b)

[14] For example, anecdotal evidence (provided by fishers) exist that in some fisheries, quota owned by processors/wholesales is leased at a discounted rate on condition that the catch is supplied to them (at also a discounted price).

Summary

The introduction of ITQs in the NSW lobster fishery, and the associated determination of the TAC, have resulted in an improvement in the stocks and economic performance of the fishery. Further, there is evidence that fishers' confidence in the fishery has also increased, as reflected in the decrease in the implicit discount rate. Autonomous adjustment resulted in a 41% decrease in the total number of shareholders, with most of this adjustment taking place in the first 10 years of the program. The number of shareholders has remained fairly constant since 2010, although share trading has actively taken place in the fishery as individuals adjust their business structure. Quota leasing has also been active, with around one third of quota leased out each year as fishers adjust their short term quota holdings.

Northern Prawn fishery

The Australian Northern Prawn Fishery (NPF), running from the western end of Joseph Bonaparte Gulf in Western Australia to the tip of Cape York Peninsular in Queensland, is one of Australia's most valuable Commonwealth-managed fisheries, with an annual value of production exceeding $120m in recent years (ABARES 2017b). The fishery has two sub-fisheries that are managed using different approaches, but the different species are harvested by the same set of vessels. The Banana Prawn fishery, targeting Common Banana Prawns (*Fenneropenaeus merguiensis*), operates from April to June. The Tiger Prawn fishery, targeting two Tiger Prawn species (*Penaeus esculentus*, *P. semisulcatus)* with Endeavour Prawns (*Metapenaeus endeavouri*, *M. ensis*) caught as byproduct, operates from April to November, with a mid-season closure usually from mid-June to the start of August.[15] The two components are spatially separate, and require different fishing approaches; the banana prawn fishery involves targeting spawning aggregations whereas the tiger prawn fishery involves fishing on more dispersed stocks. Given the shorter nature of the banana prawn season, fishing effort usually focuses on this component at the start of the year, with boats progressively moving onto the tiger prawns as banana prawn catch rates decline (Pascoe *et al.* 2015b).

Since 2004, the fishery has had an objective of achieving maximum economic yield (MEY) (Dichmont *et al.* 2010). The two sub-fisheries are subject to different management approaches to achieve MEY. An individual transferable effort quota system (ITE) in the form of tradeable gear units and seasonal closures was introduced in 2000 (Jarrett 2001). Fishers are allocated statutory fishing rights (SFRs) in the form of a share of the TAE ("gear SFRs") as well as an endorsement to operate in the fishery as a whole (a "boat SFR"). Prior to 2000, management was based on a vessel capacity unit system that was not directly linked to fishing effort.

ITEs are used to manage the Tiger Prawn component, with the total allowable effort (TAE) level (expressed in terms of both season length and gear units available) determined by a bioeconomic model of the fishery (Punt *et al.* 2010; Punt *et al.* 2011). Catch triggers are also available to close the fishery early if average catch rates decline to below a pre-defined level.

While gear SFRs are also in place in the Banana Prawn component (limiting the total amount of gear that can be used), the key mechanism to achieve MEY is through a catch rate trigger and seasonal

[15] A third small sub-fishery targeting Red-legged Banana Prawn (*Penaeus indicus*) in Joseph Bonaparte Gulf is exploited by a small number of NPF vessels between August and November.

closures (i.e. there is no pre-defined TAE for this component of the fishery). The Banana Prawn sub-fishery is characterised by a large recruitment at the start of the year that is largely environmentally driven (Vance *et al.* 1985). This species is fished down over the season until a predefined catch rate triggers the fishery closure, at which time fishers are able to move to the tiger prawn component if they have not already done so (or the mid-season closure is in place which covers the entire fishery). An MEY-based trigger was introduced in 2013 (Pascoe *et al.* 2018a); prior to this the trigger was mainly based on a biological escapement target, with some limited consideration by the industry at the time as to what was profitable at boat level. Fishers must be endorsed to operate in the fishery; the same endorsement as that which is required to operate in the tiger prawn fishery (i.e. limited entry). The number of days fished in this fishery is otherwise not constrained, although there is strong evidence that the level of effort in the fishery is largely influenced by the opportunity cost associated with the tiger prawn fishery (Pascoe et al. 2015b).

ITQs were considered as a management system for both components, but rejected in favour of the current system. Challenges facing ITQ implementation in the fishery included difficulties in setting a TAC for the Banana Prawn component, with the cost of a "wrong" TAC potentially outweighing any potential benefits (Buckworth *et al.* 2013; Buckworth *et al.* 2014). For the Tiger Prawn component, the joint nature of production and the lack of market differentiation between the two tiger prawn species was considered to act as an impediment to the functioning of an ITQ system, again with the benefits not likely to exceed the additional costs involved (Pascoe *et al.* 2010b).

Resource sustainability

Prior to 2006-07, stocks of both Grooved and Brown Tiger Prawns were generally lower than their level at both MSY and MEY, and this situation existed at various times since the 1980s. The fishery was subject to several earlier effort reductions prior to the 2006-07 buyback, but these appeared to have had little impact on the resource base. For example, a series of voluntary buyback programs were undertaken in the mid-1980s to early 1990s that reduced the fleet from 216 vessels to 132 vessels by 1993 while a compulsory surrender of vessel units undertaken in 1994 further reduced the number of vessels by 30%. Despite these effort reductions, stock levels were mostly lower than their targets, although started trending upwards from around 2002 (Figure 46).

Stocks of Brown Tiger Prawns appear to have increased to around or above their target levels since the buyback in 2006-07. Grooved Tiger Prawns, in contrast, have seen substantial fluctuations around their target biomass levels, due largely to fluctuations in recruitment (Hutton *et al.* 2018).

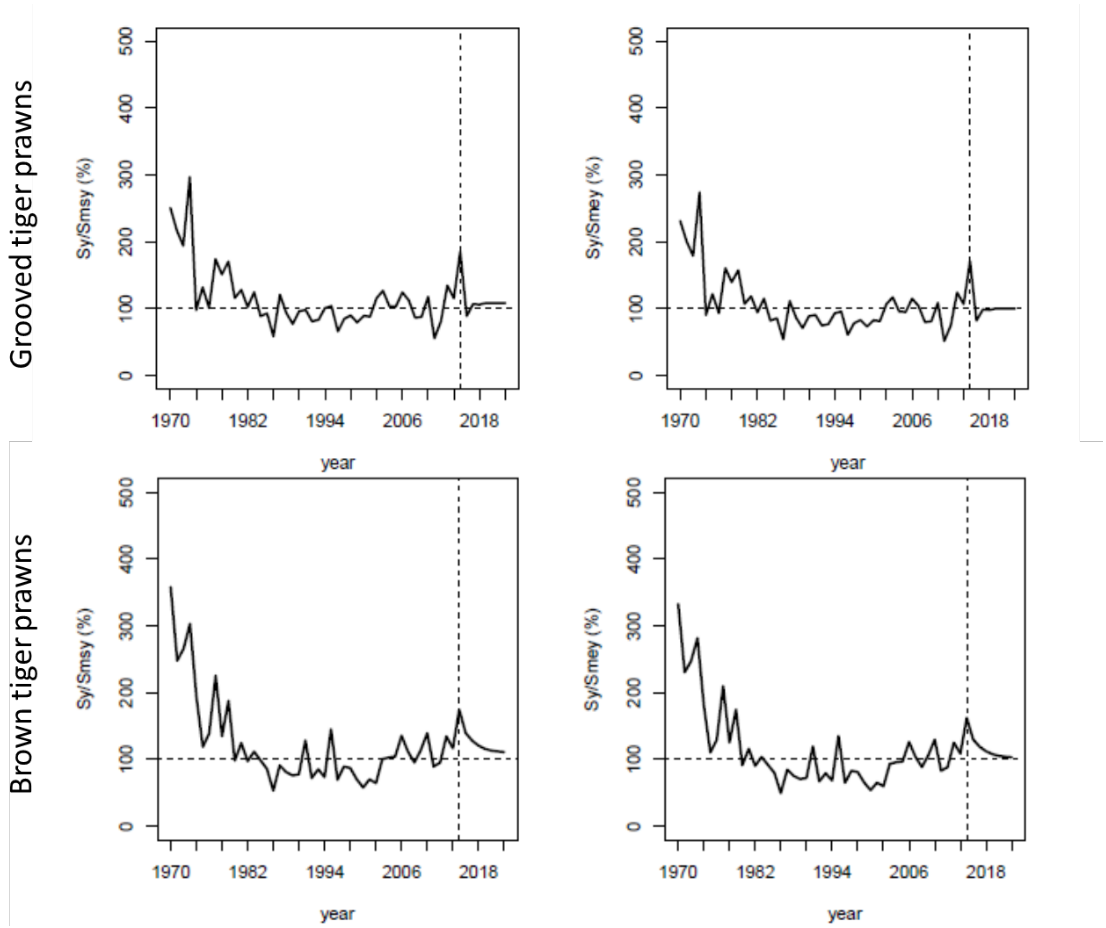
The improvement in the key stocks, and other actions undertaken by the industry to reduce bycatch, has enabled the fishery to receive Marine Stewardship Council accreditation, with the fishery first certified in 2012, and recertified in 2018.

Economic performance and productivity

Profitability in the fishery has remained positive since the buyback in 2006-07 (Figure 47), despite falling prawn prices on the international market and increased input costs. Adjusting the average full equity profit per boat by the terms of trade indicates that higher levels of profits would have been earned under constant input and output price conditions.

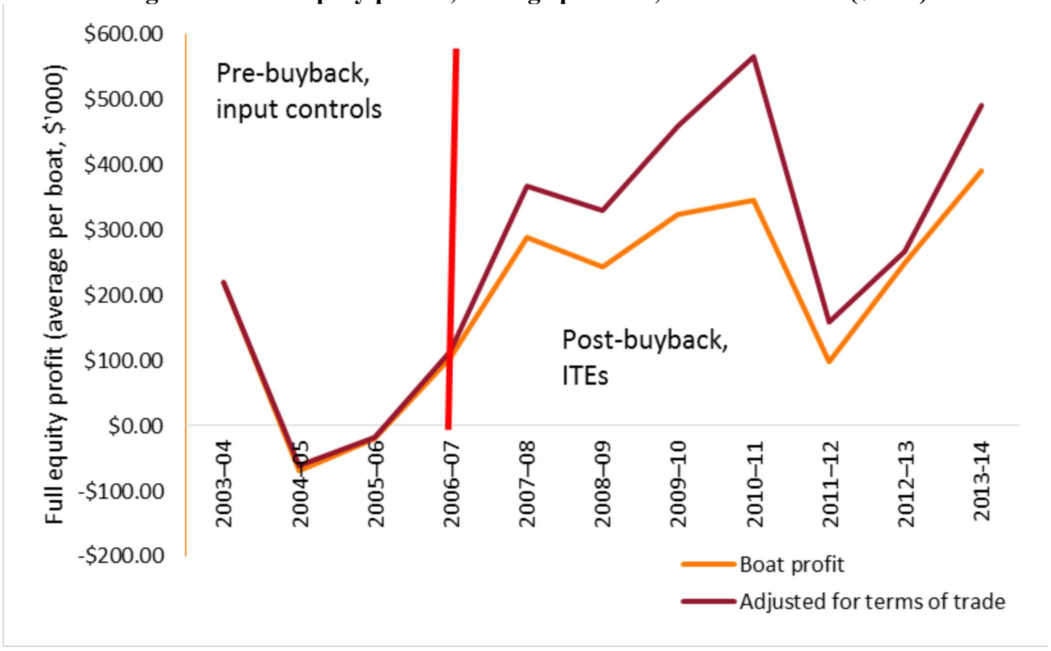
Productivity in the fishery has also increased since the buyback (Figure 48). Much of this productivity change has been driven by the increases in stock size, particularly banana prawns as well as tiger prawns (Figure 49). However, there is also evidence that technical efficiency in the fishery has also increased since the buyback in both the Tiger Prawn and Banana Prawn components of the fishery as a result of fleet rationalisation (Pascoe *et al.* 2012; Pascoe et al. 2018a).

Figure 46. Stocks of the two main Tiger Prawn species relative to MSY and MEY



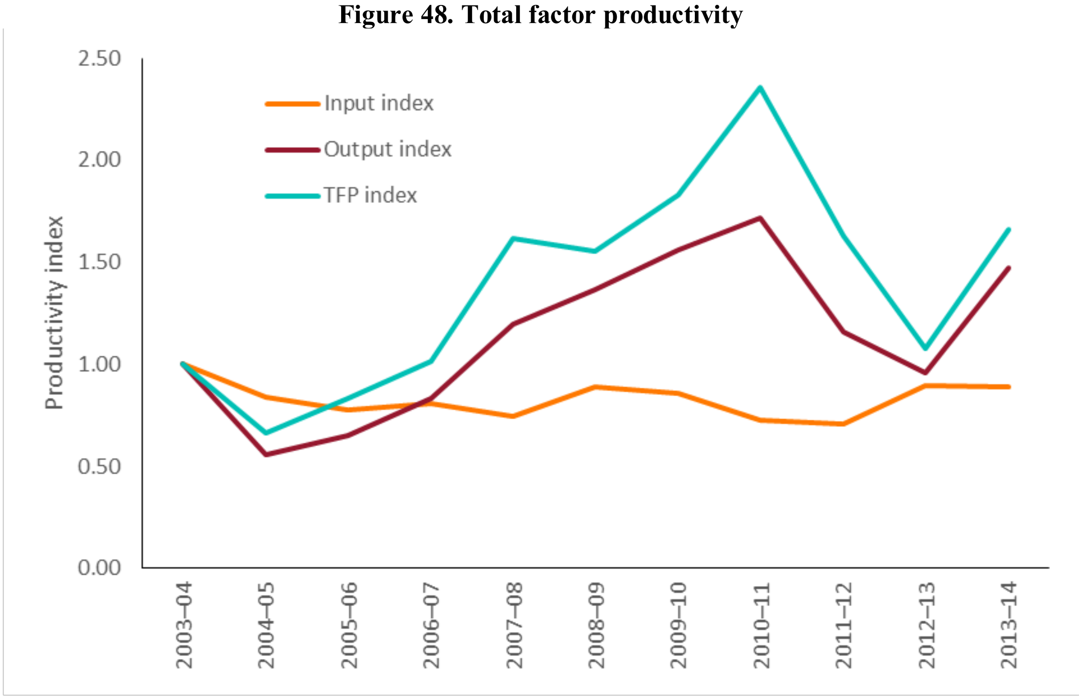
Source: Hutton et al. (2018). The vertical dashed line represents the year of the assessment. Points to the right of the vertical line are model estimates. ITEs have been in place in the fishery since 2000

Figure 47. Full equity profits, average per boat, 2014-15 dollars ($'000)



Source: Bath and Green (2016)

Figure 48. Total factor productivity



Source: Bath and Green (2016)

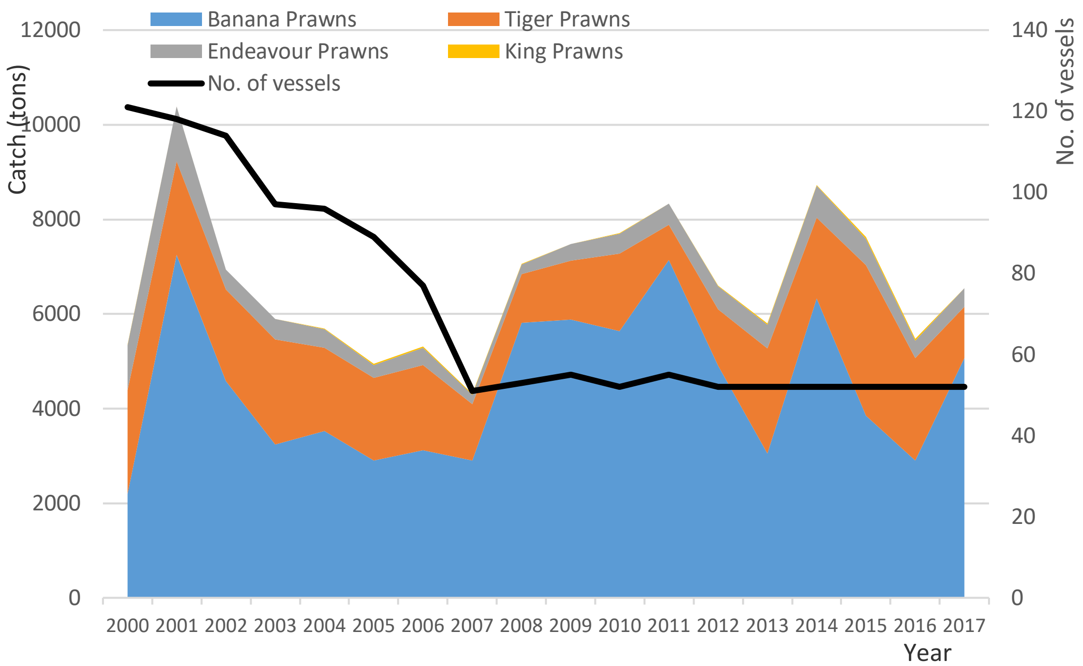
Autonomous adjustment

For ITQ fisheries, improvements in technical efficiency may be viewed as a positive, as a key perceived advantage of ITQ systems is that they facilitate autonomous adjustment. For an effort controlled fishery, however, effort creep is a potential concern if there are no mechanisms to encourage autonomous adjustment; e.g. reduced total allowable effort levels. This was of concern to the AFMA Commission, who requested a review into constraints to autonomous adjustment in the fishery. The concern of managers leading to the review of autonomous adjustment was that effort creep in the form of technological change may result in a divergence between the target effort levels and the effective fishing effort applied.

The review, undertaken by Kompas and Spring (2015), noted that there was evidence that trade in SFRs (both gear and boats) has occurred in the NPF, indicating that concerns over transferability and divisibility are not a binding constraint for the fishery. Moreover, these trades have also been shown to result in productivity gains, increasing overall efficiency in the NPF.

While evidence of autonomous adjustment exists (Kompas and Spring 2015), the extent to which this has resulted in fleet rationalisation has been limited in recent years. The fleet size was reduced from 94 boats to 52 through a buyback in 2006 and 2007 (Figure 49), which also removed an equivalent proportion of gear SFRs. One of the aims of the Commonwealth Structural Adjustment program, under which the buyback took place, was to move the fleet size to roughly that which would achieve maximum economic yield in the fishery. As a consequence, the smaller fleet size was fairly close to optimal at the time (Pascoe *et al.* 2011). The subsequent increase in the tiger prawn stocks has resulted in the total allowable effort being greater than the capacity of the fleet to harvest the resource in recent years, reducing the incentive (and need) for autonomous adjustment.

Figure 49. Catch and vessel numbers, NPF 2000-2017



Source: Laird (2018); Nguyen (2019)

Industry participation in decision making

The reduced fleet size and formal share system helped the establishment of one industry organisation, NPF Industry Pty Ltd (NPFI), to represent NPF SFR owners. NPFI has entered into a co-management relationship with AFMA, and is responsible for data collection (logbook and economic) for the fishery. NPFI also undertakes an active role in promoting and representing the fishery in both domestic and export markets. In addition, the organisation encourages best practice in the fishery in terms of bycatch reduction and broader resource conservation activities, and has also co-ordinated the Marine Stewardship Council accreditation process.

Summary

The NPF is generally regarded as a well-managed fishery. It is managed with an objective of maximising net economic returns, and uses a bioeconomic model to estimate the total allowable effort. Profitability in the fishery in recent years has been high despite adverse changes in terms of trade.

The extent to which these benefits can be attributable to ITEs is unclear. Certainly, the effort reduction through the buyback has played a large role in helping with stock recovery, while the removal of excess capacity has resulted in an improvement in average vessel profitability. However, a common feature of buyback programs internationally is that the benefits they generate are often short term, as incentives exist for remaining fishers to increase their fishing effort, thereby eroding the benefits generated (Curtis and Squires 2007; Squires 2010). This is not the experience of the NPF. In the 12 years since the buyback in the NPF, and despite evidence of technical efficiency change, the benefits of the capacity reduction program are still being realised in the NPF.

The shares established by the ITE system have also allowed the development of an effective industry organisation that plays a role both in management and marketing of the product for the benefit of the shareholders. In this regard, the ITE system has been effective as an ITQ system might have been.

Discussion and conclusions

ITQs and ITEs in Australian fisheries

The survey of managers, scientists and fishers about the outcomes of ITQ and ITE in Australian fisheries raised some interesting issues. First, fisheries managers are generally more positive about the overall outcomes of ITQs and ITEs than the fishers themselves. This may reflect the different focus of the two groups: the managers are responsible for achieving the stated environmental and economic management objectives, and to a large extent ITQs and ITEs appear to achieve these to a reasonable degree. In contrast, fishers have to operate in a fishery that appears to be more constrained by ITQ/ITE management, incurring higher costs and restrictions on their activities even if achieving higher financial benefits. For lease dependent fishers, many of the economic benefits of ITQs are not realised, passing these benefits instead to the quota owners (investors) who, in some cases, may not be actively involved in fishing themselves.

Generally, most fishers believed that most environmental (e.g. sustainability) and individual economic performance metrics (e.g. profitability) had improved with the introduction of ITQs/ITEs, but many did not believe that the benefits exceeded the costs. These high costs were largely social in the form of reduced satisfaction with fishing rather than just economic costs (which also increased).

Scientists tended to be the most pessimistic in terms of their perception of the performance of ITQs, particularly around the social performance. In contrast, managers were generally the most optimistic in terms of all areas of performance of ITQs (e.g. economic, sustainability, governance and social).

The role that different factors played in the perception of overall performance also differed substantially between fishers, managers and scientists (The impact of each level of the order categorical variables on overall performance can be derived by the product of the vector of coefficients on the linear, quadratic and cubic terms and the polynomial contrasts. The results of this transformation are given in **Error! Not a valid bookmark self-reference.**. Only coefficients that were significant at the 10% or lower level were used in the derivation. The level of each variable that produces the greatest positive impact on fishery overall performance is shown in bold, while the level that results in the greatest negative performance is shown in italics.

Table 12). Industry participation in management was seen as a key component of the success of ITQs and ITEs by fishers, but was not a significant factor in the perceptions of managers and scientists. This does not mean to say that the latter groups do not recognise the importance of industry participation in management for a number of other reasons; just that their perceptions of which fisheries are performing well (or not) is not dependent on the level of industry involvement.

The importance of the influence of economics in management also differs between the groups. Managers and scientists place high importance on the collection of economic data (presumably to monitor economic performance), but less so on the *use* of economic information in the TAC setting process. Conversely, fishers were less concerned with the collection of economic data, but saw high value in economic input into the TAC/TAE setting process.

The “vision” as to what a successful fishery looks like in terms of quota ownership and leasing also differed between the groups. The responses from fishers suggest that a smaller (more concentrated) fishery comprised of quota owners with sufficient quota for their own needs (and hence no quota leasing) is a preferred model in terms of overall perceptions of performance. In contrast, managers and scientists see a larger fleet with a combination of quota ownership and leasing, with a high proportion of leasing, as providing the greatest overall performance.

Implications of the results for future ITQ/ITE management

The outcomes from the study provide further evidence that defining objectives is important for the success of management. Most fisheries have strong sustainability objectives, and in many cases specific economic objectives. In contrast, in many cases, social objectives are poorly specified if they exist at all. Where social objectives do exist, these are often focused on the local communities rather than the fishers themselves.

ITQs, and to a large extent ITEs, are generally introduced to achieve economic and sustainability objectives. In this regard, the results from the study suggest that ITQs/ITEs are working effectively in terms of generating economic and sustainability outcomes for most fishers. However, social aspects – particularly satisfaction with being in the industry – are not being achieved to the same degree, and it is these factors that are driving the perception that the benefits of ITQs do not exceed the costs. The BBN results also suggested that to improve fishery performance in ITQ/ITE fisheries, these are the elements that need the most change.

These results are broadly consistent with outcomes elsewhere, and negative governance and social outcomes are often held up as unintended consequences of ITQ/ITE management. Although in this study we do not investigate the appropriateness, or not, of allocating private property rights *per se*, we do indeed find that the social and governance outcomes of ITQs/ITEs are not perceived to be as great as the economic and sustainability outcomes.

Trade-offs between social, economic and sustainability objectives is not uncommon, and it is unlikely that all can be fully achieved simultaneously in any fishery. However, there may be ways to improve social outcomes within an ITQ fishery, even if these are not optimised. For example, social relations and fishers enjoyment from being part of the industry can be influenced by management coordinated processes and cooperative approaches. These processes are also likely to influence information sharing between fishers which can further improve fisher satisfaction levels.

This study has highlighted that there is much variation in ITQ/ITE management outcomes across different Australian fisheries and between the stakeholders who operate within these fisheries. This variation reflects the diversity of fisheries that are managed with ITQs/ITEs, a characteristic which implies that there is no one approach to ITQ/ITE management that will suit all. However, this study also underscores that it is possible to create management contexts specific to a particular fishery that build on the ITQ/ITE approach. Where issues arise, for instance, when economic, social and/or governance outcomes are not performing as well as expected, ways should be found to address these issue while maintaining the positive outcomes of ITQ/ITE management.

How might we improve future ITQ/ITE management?

The results of the study, largely based on the case studies, suggest that consideration should be given to quota ownership in future ITQ and ITE programs. Separating quota ownership from harvesting appears to reduce the potential for autonomous adjustment in the fishery, while diverting economic rents away from the harvest sector to the investment sector. While these transfers may be consistent with ecological and economic sustainability of the fishery, from a social perspective, they potentially lead to dissatisfaction and low incomes in the fishing sector. Most lease dependent fishers indicated that their incomes had declined as a result of the introduction of ITQs, while high levels of leasing were associated with poor overall performance by the industry.

Autonomous adjustment is the main mechanism relied on in ITQ and ITE fisheries to improve economic performance. A constraint to autonomous adjustment identified through the survey was lack of access to financial resources to facilitate adjustment, due to existing low incomes when ITQs or ITEs were introduced. This suggests that other mechanisms to remove excess capacity may be beneficial before ITQs or ITEs are introduced. However, if public funds are to be used to facilitate adjustment to improve economic performance in the fishery, then some form of explicit return to the community should also be considered.

Key knowledge gaps and area for future research

Lack of economic and other data and their appropriate use

The use of economic information in setting TACs/TAEs was identified as a key driver of success in ITQ and ITE fisheries from the BBN analysis. However, from the survey, the lack of economic information was also seen as a key knowledge gap in many fisheries. This included both economic data on the fisheries and also the functioning of the quota markets.

The NSW Lobster fishery case study demonstrated the potential usefulness of quota trading data in providing information about economic performance of a fishery. Extending this type of analysis to multispecies fisheries is an area of potential future research that may provide useful outcomes beyond just a measure of economic performance. For example, an analysis of quota trading (and consideration of quota package trading) may identify critical choke species and the potential economic implications of restrictive catch limits on these species, which in turn may inform future quota setting. The analyses may also provide insights into the efficiency of the quota trading market, and how this affects trading prices.

The development of harvest strategies that consider economic performance information is also an increasing area of importance, particularly given the objective to maximise net economic returns that is adopted in many fisheries. Use of economic information in setting appropriate target reference points in data poor settings has been addressed in recent FRDC studies (e.g. Zhou *et al.* 2012; Pascoe *et al.* 2015a; Pascoe *et al.* 2018b and the current FRDC 2016-213). These studies have focused largely on development of targets, with only limited attempts to develop harvest strategies that respond to changes in economic conditions. The study by Pascoe et al. (2018b) examined a range of harvest strategies and their ability to achieve maximum net economic returns assuming economic conditions were unchanged over time. In contrast, the Northern Prawn fishery harvest strategy allows for changing economic conditions in terms of the trigger catch rate in the banana prawn fishery (Pascoe et al. 2018a) and effort levels determined using the bioeconomic model of the fishery (Hutton et al. 2018). This is the exception rather than the rule, and further research that considered how harvest strategies can be developed that respond to economic conditions is necessary.

The inclusion of social considerations into management was also identified as a key knowledge gap. Again, few attempts have been made to explicitly include social considerations into harvest strategy design (Dichmont et al. 2013; Fletcher *et al.* 2016; Pascoe *et al.* 2019a). These studies have largely tested alternative harvest strategies given social considerations rather than including social indicators as a potential trigger for harvest strategy action. The appropriateness of this approach and the feasibility of social triggers in a harvest strategy is also hence an area for future research.

Many fishers and scientists also believe that more information is needed on species biology to improve the stock assessment process. Species characteristics are often inferred through the stock assessment process rather than fed into the process, and this is believed to contribute to uncertainty in the outcomes. The lack of fisheries independent data was identified by most groups (predominantly scientists) as a key knowledge gap. Unlike economic and social information, harvest strategies (and the underlying models to test them) are generally well established to accommodate new biological information. In this case, the emphasis of future research should be on reducing uncertainty rather than developing new approaches.

Quota ownership and quota markets

Satisfaction in fishing was also identified in the BBN analysis as a key driver of overall performance of the ITQ/ITE fisheries surveyed. From the survey responses, it is likely that quota ownership and quota markets are highly influential on satisfaction, although the relationship is likely to be complicated and is an area for future research.

Issues around quota ownership were identified as a major factor influencing the level of satisfaction and economic performance in the Tasmanian abalone fishery case study, and were also raised as an important consideration by fishers in the assessments of social knowledge gaps. The impact of investors, processors, exporters and other non-fishers owning quota on the distribution of economic benefits from fishing is potentially an important consideration for fisheries moving to ITQs in the future. This is particularly the case if such ownership conflicts with the economic objectives of maximising net economic returns to the broader community as well as potential social objectives of fisheries management. Some of the key issues have been identified in this study, but a more detailed analysis of the relationships between quota ownership and concentration and the social and economic performance of fisheries is warranted.

An issue highlighted in the literature but not raised in the survey was the potential impact of resource rent taxation on the operation of a quota system. Resource rent charges are not commonly applied in Australian fisheries, but were flagged as a potential policy instrument by the Productivity Commission (2016). Where quota entitlements are allocated at no cost (i.e. grandfathering) or at low cost and resource rents increase significantly following the introduction of ITQs, the lack of resource rent redistribution to society in fisheries means that a greater proportion of resource rents accrue to quota owners, increasing the value of the asset. This may impact quota investment, structural adjustment and the entry of new operators. As a result the broader implications of a resource rent tax and how it may affect the operation of the quota market could be further explored.

Complementary and conflicting management measures

Most ITQ and ITE fisheries are subject to a range of other management controls. Some may complement ITQs/ITEs but others may conflict with the operation of the quota market and the ability of operators to balance their quota holdings with their catches. The Tasmanian abalone case study, for example, demonstrated the need to better understand the complications of using quota entitlements combined with other forms of access entitlements (e.g. diver licences) within a fishery and the unintended consequences that can result when the interlinkages are not well understood.

The potential benefits of maintaining some input controls where ITQs do not cover all species has been previously examined in the Australian context (Pascoe 2009) but in other cases input controls may be unduly constraining the operation of the ITQ/ITE system. Other complementary arrangements, such as territorial user rights, may also be beneficial in such cases where the main target species is highly sedentary. Further studies into how ITQs or ITEs are impacted by other management instruments is consequently an area for further research.

The reliance on perceptions

The study has largely been based on perceptions of industry, managers and scientists, primarily as more objective measures of performance and change are not widely available. Despite this, relatively consistent trends in the measures of performance could be derived across the three groups, even though there was substantial individual variability in these measures.

There is a general research need to develop more cost effective measures of fishery management performance. Regular cost and earnings surveys are currently being undertaken for only a relatively small number of fisheries as they are costly and time consuming. While these surveys provide the most reliable estimates of economic performance, alternative approaches may be developed to provide estimates for years in which a survey is not undertaken, or for a fishery where the cost of a survey would far exceed the likely benefits. The NSW Lobster case study illustrated the potential usefulness of quota trading data in assessing economic performance. These data are currently not routinely collected in most jurisdictions, but could provide a cost effective means of assessing changes in economic performance if they were. There is a substantial body of literature on productivity analysis in fisheries which could also potentially provide insights as to economic performance of fisheries (Nguyen 2019), although existing case studies in Australian fisheries are limited. This would require additional research activity to be undertaken, but may be done using existing data and may be more cost effective than frequent cost and earning surveys.

Developing objective measures of social and governance performance is an additional challenge, and will most likely require a mixture of objective and subjective measures as many components are difficult to quantify objectively. Given the importance of social objectives in many jurisdictions, research into developing cost effective measures of performance against these objectives is also an area of potential importance not just related to ITQ and ITE fisheries.

Other questions not addressed in this study

The study considered the broader issues around ITQ and ITE management, although was unable to address some key critical issues that may affect future use of these instruments for Australian fisheries management.

The study considered ITQs as a generic management instrument, although there are a wide range of ways in which ITQs can be implemented. For example, the New Zealand quota management system offers a number of potential "flexible" options for dealing with under and over-quota catch, such as a proportion of the previous year's unused quota to be carried over if uncaught, or a proportion of next year's quota to be "borrowed" if quota is exceeded; or the use of alternative mechanisms such as a penalty system that provides sufficient incentive to land incidental over-quota catch rather than discard it, but not large enough an incentive to encourage the fisher to continue targeting the species (Mace 2013).

The Productivity Commission (2016) also suggested that mechanisms be established to formalise allocations between different sectors (i.e. commercial, recreational and indigenous), as well as between different jurisdictions in the case of shared stocks, and further that mechanisms be developed to allow transfer of quota between these sectors and jurisdictions, which may become particularly pertinent in the context of shifting species under climate changes (Pecl *et al.* 2017). Sectoral allocation is a broader issue that is not necessarily associated with just ITQ or ITE management, so has not been addressed in this study. But it is an issue that has implications for future ITQ and ITE management, and is an area for further examination.

The study identified a number of issues with current ITQ and ITE management that, with hind sight, could have been avoided. The potential for these issues to be rectified ex post raise a number of legal and ethical questions, as well as the economic questions as to whether the cost of retrospectively correcting these issues exceeds the benefits.

Extension and Adoption

Conference presentations

Sean Pascoe, Ingrid Van Putten, Eriko Hoshino, and Simon Vieira, ITQs in Australia: the good, the bad and the ugly, IIFET 2018, U.W., Seattle, July 2018

Abstract: Australia currently has around 45 different fisheries at both State and Commonwealth level managed through individual transferable quotas (ITQs). These range from single species fisheries to complex multi-gear, multi-species fisheries. While in many of these fisheries ITQ management is considered a success, in others the expected economic benefits have not materialised. In this study, we conduct a review of the experiences of managers and fishers across a range of ITQ fisheries to determine what they perceive as the main factors affecting the success or otherwise of ITQ management. We also examine how perceptions of "success" vary between the different stakeholder groups. The results of the analysis provide insights as to how better ITQ systems can be developed in the future.

Journal articles

Papers in preparation:

Sean Pascoe, Ingrid Van Putten, Eriko Hoshino, and Simon Vieira, ITQs in Australia: the good, the bad and the ugly, target journal: Fish and Fisheries (based on the survey results)

Sean Pascoe, Ingrid Van Putten, Eriko Hoshino, and Simon Vieira, Use of economic information in Australian ITQ fisheries, target journal: Marine Policy (based on the links between economic data and performance and also willingness to supply data)

Papers in submission:

Sean Pascoe, Ingrid Van Putten, Eriko Hoshino, and Simon Vieira, Determining key drivers of performance of ITQs fisheries in Australia using a BBN, Submitted to: ICES Journal of Marine Science (based on the BBN modelling results)

Eriko Hoshino, Ingrid Van Putten, Sean Pascoe and Simon Vieira, Implications of ITQs for triple bottom line fisheries objectives: a review. Submitted to: Marine Policy (based on the literature review).

Appendices

A: Survey questionnaires

A.1 Fisher Survey

A.2 Scientist Survey

A.3 Manager Survey

Review of ITQs/ITEs in Australian fisheries - Commercial fishers

Welcome to our Survey

Thank you for agreeing to participate in our survey.

CSIRO, in collaboration with FRDC's Human Dimensions Research Sub-Program and doMar Research, is currently surveying fishers, managers and scientific advisors involved with fisheries that are managed through individual transferable catch (ITQ) or effort (ITE) quotas. The aim of the survey is to identify how successful these management approaches have been, what factors contribute to this success (or otherwise), and what unexpected outcomes, if any, occurred (both positive and negative). Three separate survey questionnaires have been developed – one for fishers, one for managers and one for scientific advisor who provide management advice. These have common elements, but also specific questions for each group.

What is involved?

As a individual identified as having an involvement in providing input into the management of an ITQ or ITE fishery, we would appreciate you providing us with information about your perceptions of the performance of the fishery, plus information around the fishery itself. The survey is completely anonymous. While we request information on the fishery that you are involved with, all data will be pooled to derive a broader overview of the performance of ITQs and ITEs in Australian fisheries.

The survey consists of 3 sections, and takes around 15-20 minutes to complete:

Section 1: Identifies the fishery that you are describing and also asks for your views as to how the fishery is performing;
Section 2: Asks specific questions around your perceptions about the management of the fishery.
Section 3: Involves more open ended questions around adjustment issues and unanticipated outcomes.

There are no right or wrong answers, and all responses will be treated in confidence.

How will my information be used?

The information provided by you to us will be combined with other respondent's answers and statistically analysed to better understand how well ITQs and ITEs have worked under different fishery conditions. The results will not present any individual information. The information will also be used to prepare scientific reports and manuscripts for academic publication. Your personal information will not be identifiable at any stage in these publications.

Review of ITQs/ITEs in Australian fisheries - Commercial fishers

Additional participant information

Participation and withdrawal

Participation in this study is completely voluntary and you are free to withdraw by stopping the survey at any time. Once submitted your answers are anonymised and will not be individually identifiable. As all answers are anonymous it is not possible to withdraw your responses once submitted.

Risks

Aside from giving up your time, there are no foreseeable risks associated with participating in this study. You are free to skip any questions you do not want to answer. If you have any concerns about any aspects of the study, please contact the project leader Dr Sean Pascoe (see below for contact details).

Confidentiality

All individual information collected in this study is confidential and will be assigned a random code. The primary data will only be seen by members of our research team and will be stored in a secure area that is inaccessible to other individuals. Your information will only be used for research purposes.

Will I receive any payment for taking part in the study?

You will not receive any form of direct payment from CSIRO or other project partners for taking part in this survey.

How can I find out more about the study?

Please feel free to contact us at any time during the study (contact details below). This study is being funded by the Fisheries Research and Development Corporation (FRDC) and CSIRO.

Ethical clearance and contacts

This study has been approved by CSIRO's Social Science Human Research Ethics Committee in accordance with the Australian National Statement on Ethical Conduct in Human Research. If you have any questions concerning your participation in the study feel free to contact the researchers involved. Alternatively any concerns or complaints about the conduct of the study can be raised with the Manager of Social Responsibility and Ethics on 07 3833 5693 or by email at csshrec@csiro.au.

Thank you for your help with this important research.

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Review of ITQs/ITEs in Australian fisheries - Commercial fishers

Part 1: Fishery details and performance

This part identifies the fishery that you are describing and also asks for your views as to how the fishery is performing.

The fisheries of interest are those that use either ITQs or ITEs as their main management measure. For clarification, ITQ fisheries involve a total allowable catch which is allocated to individual fishers by means of a transferable share. ITE fisheries are those where there is a total allowable effort level (e.g. days at sea, pot lifts, gear units) that are allocated to individual fishers by means of a transferable share. Transferable licences in a limited entry fishery is not considered an ITE fishery.

We ask you to please answer questions for one fishery at a time. If you are familiar or involved with more than one fishery, we would greatly appreciate you completing a separate survey for each fishery. The link to this survey allows multiple responses.

Which fisheries jurisdiction are you involved with?

Review of ITQs/ITEs in Australian fisheries - Commercial fishers

Commonwealth fisheries

Which Commonwealth fishery does this survey response relate to? (please complete a separate survey for each fishery you are involved in).

- [ ] Bass Strait Central Zone Scallop Fishery
- [ ] Eastern Tuna and Billfish Fishery
- [ ] Northern Prawn Fishery
- [ ] Small Pelagics Fishery
- [ ] Southern and Eastern Scalefish and Shark Fishery
- [ ] Southern Bluefin Tuna Fishery
- [ ] Torres Strait Rock Lobster Fishery
- [ ] Other (please specify)

Queensland fisheries

Which Queensland fishery does this survey response relate to? (please complete a separate survey for each fishery you are involved in).

- [ ] Coral Reef Finfish Fishery
- [ ] East Coast Otter Trawl Fishery
- [ ] East Coast Spanish Mackerel Fishery
- [ ] Tropical Rock Lobster Fishery
- [ ] Spanner Crab Fishery
- [ ] Other (please specify)

Review of ITQs/ITEs in Australian fisheries - Commercial fishers

NSW fisheries

Which NSW fishery does this survey response relate to? (please complete a separate survey for each fishery you are involved in).

- [ ] Abalone Fishery
- [ ] Lobster Fishery
- [ ] Sea Urchin and Turban Shell Fishery
- [ ] Other (please specify)

Victorian fisheries

Which Victorian fishery does this survey response relate to? (please complete a separate survey for each fishery you are involved in).

- [ ] Abalone Fishery
- [ ] Rock Lobster Fishery
- [ ] Scallop Fishery
- [ ] Other (please specify)

Tasmanian fisheries

Which Tasmanian fishery does this survey response relate to? (please complete a separate survey for each fishery you are involved in).

- ☐ Abalone Fishery
- ☐ Rock Lobster Fishery
- ☐ Scallop Fishery
- ☐ Other (please specify)

South Australian fisheries

Which South Australian fishery does this survey response relate to? (please complete a separate survey for each fishery you are involved in).

- [ ] Abalone Fishery
- [ ] Australian Sardine Fishery
- [ ] Blue Swimmer Crab Fishery
- [ ] Giant Crab Fishery
- [ ] Rock Lobster Fishery - Northern Zone
- [ ] Rock Lobster Fishery - Southern Zone
- [ ] Vongole Fishery
- [ ] Pipi Fishery
- [ ] Gulf St Vincent Prawn Fishery (ITE)
- [ ] Other (please specify)

Review of ITQs/ITEs in Australian fisheries - Commercial fishers

Western Australian fisheries

Which Western Australian fishery does this survey response relate to? (please complete a separate survey for each fishery you are involved in).

- [ ] Abalone Fishery
- [ ] West Coast Deep Sea Crab Fishery
- [ ] Western Rock Lobster Fishery
- [ ] Gascoyne Demersal Scalefish
- [ ] Northern Demersal Scalefish
- [ ] South Coast Purse Seine Managed Fishery
- [ ] Mackerel Managed Fishery
- [ ] South Coast and West Coast Demersal Finfish
- [ ] South Coast and West Coast Crustacean
- [ ] Other (please specify)

Review of ITQs/ITEs in Australian fisheries - Commercial fishers

Northern Territory fisheries

Which NT fishery does this survey response relate to? (please complete a separate survey for each fishery you are involved in).

- ☐ Demersal Fishery
- ☐ Timor Reef Fishery
- ☐ Other (please specify)

Involvement with the fishery

How long have you been involved with this fishery? (Years)

How long (number of years) have you been working in fisheries in total (i.e. as a commercial fisher, manager, researcher, or combination of these roles)?

Review of ITQs/ITEs in Australian fisheries - Commercial fishers

Overview of fishery performance

The aim of this section is to ask you to provide your opinion or perceptions about the performance of ITQs/ITEs. These opinions will remain confidential.

Many of the questions just refer to “quota”. For the purposes of the survey, we use this term in the general sense i.e. catch quota or effort quota (i.e. effort units).

On a scale of 1 to 10 (with 1 being not successful and 10 being very successful), how successful do you think the fishery currently is at achieving

	1	2	3	4	5	6	7	8	9	10
Overall sustainability outcomes (i.e. target species as well as broader environment)?	○	○	○	○	○	○	○	○	○	○
- Within this, sustainability of target species?	○	○	○	○	○	○	○	○	○	○
- Broader environmental sustainability (e.g. habitats, bycatch etc.)	○	○	○	○	○	○	○	○	○	○
Economic outcomes (e.g. industry profitability, fisher and crew incomes)?	○	○	○	○	○	○	○	○	○	○
Social outcomes (e.g. community benefits, employment, health and safety, overall satisfaction with fishing, etc.)?	○	○	○	○	○	○	○	○	○	○
5.4. Fishery governance (e.g. participation in decision making, cost effective management, transparency in decision making)?	○	○	○	○	○	○	○	○	○	○

On a scale of 1 to 10 (with 1 being not successful and 10 being very successful), how would you rate the overall performance of the fishery? (i.e. combining sustainability, economic, social and governance considerations)

1	2	3	4	5	6	7	8	9	10
○	○	○	○	○	○	○	○	○	○

In your view, how do you think ITQs or ITEs in the fishery have affected the performance of the fishery?

	Made it worse	No real change	Improved	Don't know
Sustainability outcomes (i.e. target species as well as broader environment)?	○	○	○	○
Economic outcomes (e.g. industry profitability, fisher and crew incomes)?	○	○	○	○
Social outcomes (e.g. community benefits, employment, health and safety and overall satisfaction with fishing)?	○	○	○	○
Fishery governance (e.g. participation in decision making, cost effective management, transparency in decision making)?	○	○	○	○

Review of ITQs/ITEs in Australian fisheries - Commercial fishers

PART 2: Questions for commercial fishers

The following questions are only being asked of commercial fishers and their representatives only.

Markets for fishery products

In these next questions we are interested in how you think ITQs or ITEs have affected the market for your product (e.g., price, quality etc). While there are many other factors which could affect price, availability and quality of your catch, we are only asking about the extent to which you think the use of ITQs/ITEs have produced these effects.

How do you think ITQs/ITEs have affected theprice of the catch from the fishery?

- ◯ Decreased
- ◯ No real change
- ◯ Increased
- ◯ Don't know

How do you think ITQs/ITEs have affected thequality of your landed catch from the fishery?

- ◯ Decreased
- ◯ No real change
- ◯ Increased
- ◯ Don't know

How do you think ITQs/ITEs have affected theoverall availability of catch from the fishery to the market?

- ◯ Decreased
- ◯ No real change
- ◯ Increased
- ◯ Don't know

Generally, how satisfied do you thinkconsumers are with the quality and availability of catch from the fishery?

- ◯ Less satisfied
- ◯ No real change
- ◯ More satisfied
- ◯ Don't know

Generally, how satisfied do you think wholesalers and/or processors are with the quality and availability of catch from the fishery?

- ◯ Less satisfied
- ◯ No real change
- ◯ More satisfied
- ◯ Don’t know

How do you think ITQs/ITEs have affected the number of the wholesalers and/or processors in the fishery?

- ◯ Decreased (fewer wholesales and/or processors)
- ◯ No real change
- ◯ Increased (More wholesales and/or processors)
- ◯ Don’t know

Quota Markets

On the scale from 1 to 10 below, how would you rate:

Accessibility of quota to lease (1= not accessible, 10= easily accessible)?

1	2	3	4	5	6	7	8	9	10
○	○	○	○	○	○	○	○	○	○

Affordability of quota to lease (1=unaffordable, 10 = easily affordable)?

1	2	3	4	5	6	7	8	9	10
○	○	○	○	○	○	○	○	○	○

On a scale of 1 to 10 (1 = not functioning, 10 = well-functioning), how would you rate the overall functioning of the quota lease market?

1	2	3	4	5	6	7	8	9	10
○	○	○	○	○	○	○	○	○	○

Accessibility of quota to buy (i.e. permanent share transfer) (1= not accessible, 10= easily accessible)?

1	2	3	4	5	6	7	8	9	10
○	○	○	○	○	○	○	○	○	○

On a scale of 1 to 10 (1 = not functioning, 10 = well-functioning), how would you rate the overall functioning of the quota share market?

1	2	3	4	5	6	7	8	9	10
○	○	○	○	○	○	○	○	○	○

Affordability of quota to buy (i.e. permanent share transfer) (1=unaffordable, 10 = easily affordable)?

1	2	3	4	5	6	7	8	9	10
○	○	○	○	○	○	○	○	○	○

How reliant are you on quota leasing?

- ◯ Lease in most or all of my quota
- ◯ Lease in around half my quota
- ◯ Lease in some quota but own most of it
- ◯ Own all my quota

Review of ITQs/ITEs in Australian fisheries - Commercial fishers

Fishing costs

How do you think ITQs/ITEs have affected the average number of days fishers need to take their catch?

- ◯ Decreased
- ◯ No real change
- ◯ Increased
- ◯ Don't know

How do you think ITQs/ITQs have affected the areas where fishers take their catch?

- ◯ Fish closer to home (Decreased travel time to grounds)
- ◯ No real change
- ◯ Fish further from home (Increased travel time to grounds)
- ◯ Don't know

How do you think ITQs/ITEs have affected the level of management costs paid by fishers?

- ◯ Decreased
- ◯ No real change
- ◯ Increased
- ◯ Don't know

How do you think ITQs/ITEs have affected the compliance costs incurred by fishers (i.e. costs of providing data, any VMS requirements etc.)?

- ◯ Decreased
- ◯ No real change
- ◯ Increased
- ◯ Don't know

How do you think ITQs/ITEs have affected average debt levels in the fishery?

- Decreased (less debt)
- No real change
- Increased (more debt)
- Don't know

How do you think ITQs/ITEs have affected the overall fishing costs incurred by fishers?

- Decreased
- No real change
- Increased
- Don't know

Fishing incomes

How do you think ITQs/ITEs have affected your take home income from the fishery?

- ◯ Decreased
- ◯ No real change
- ◯ Increased
- ◯ Don't know

How do you think ITQs/ITEs have affected the average income of your crew in the fishery?

- ◯ Decreased
- ◯ No real change
- ◯ Increased
- ◯ Don't know

Review of ITQs/ITEs in Australian fisheries - Commercial fishers

Satisfaction with fishing

On a scale of 1 to 10 (with 10 being the best), how would you rate your overall satisfaction with fishing in the ITQ/ITE fishery?

1	2	3	4	5	6	7	8	9	10
○	○	○	○	○	○	○	○	○	○

How do you think ITQs/ITEs have affected fisher's enjoyment/fulfilment in being in the profession in the fishery?

- ○ Decreased
- ○ No real change
- ○ Increased
- ○ Don't know

How do you think ITQs/ITEs have affected social relations (i.e. sense of community, cooperation with other fishers?) between fishers in the fishery?

- ○ Decreased
- ○ No real change
- ○ Increased
- ○ Don't know

How do you think ITQs/ITEs have affected information sharing between fishers in the fishery (e.g. about catch rates, lease prices etc)?

- ○ Decreased
- ○ No real change
- ○ Increased
- ○ Don't know

How do you think ITQs/ITEs have affected the level of health and safety of fishers in the fishery (e.g. the level of risk taking behaviour; when and where to fish)?

- ◯ Decreased
- ◯ No real change
- ◯ Increased
- ◯ Don't know

Broader community

How do you think ITQs/ITEs have affected the economic importance of the fishery to the regional economy?

- Decreased (fishery now less important)
- No real change
- Increased (fishery now more important)
- Don't know

Taking into consideration community perceptions of discards, bycatch, compliance and other issues in the fishery, what do you think is the current level of support for the fishery by the local communities?

- Strong support
- Moderate support
- Low support
- No support/oppose
- Don't know

How have ITQs/ITEs affected this level of community support?

- Made it worse
- No real change
- Improved it
- Don't know

Review of ITQs/ITEs in Australian fisheries - Commercial fishers

Management decision making

How difficult is it to understand the management arrangements in the fishery? (i.e. the rules as well as reasons why the rules are in place)

- Highly complex and difficult to understand
- Moderately complex, some difficult to understand
- Somewhat complex but understand most
- Not complex and understand all

How transparent is decision making in the fishery? (i.e. how well are decision making processes documented and communicated?)

- Highly transparent
- Moderately transparent
- Somewhat transparent
- Not transparent

What is the level of industry participation in the TAC/TAE setting process?

- High
- Moderate
- Low
- None

What is the level of industry trust in the TAC/TAE setting process?

- High
- Moderate
- Low
- None

How much uncertainty do you think there is in the stock assessment information that feeds into the TAC/TAE setting process?

- High
- Moderate
- Low
- Don't know

Overall, how would describe the TAC/TAE setting process?

- Well-functioning
- Well-functioning for key species
- Not well-functioning
- Don't know

What is the level of industry participation in management decision making in general (not just the TAC/TAE setting process)?

- High
- Moderate
- Low
- None

Review of ITQs/ITEs in Australian fisheries - Commercial fishers

Economic information and knowledge gaps

Improving industry profitability requires accurate economic information from the industry. How willing are you to share with managers:

(Note: you will not be asked to provide data based on your response - this is to determine the general willingness to provide such data in the industry).

	Not prepared to share	May share	Willing to share	Currently do share
Market price information from your sales?	○	○	○	○
Costs and earnings information about your business?	○	○	○	○
Quota lease and share prices?	○	○	○	○

If you answer "Not prepared to share" to any of the above, please indicate why:

Are there any concerns in the fishery about providing accurate economic data to managers?

○ No

○ Yes (please specify)

What are the key knowledge gaps (economic, biological, social or other) that you think currently limit management's ability to improve outcomes for the fishery?

Review of ITQs/ITEs in Australian fisheries - Commercial fishers

PART 3: General questions

These questions are aimed to determining broader benefits and/or costs associated with ITQs or ITEs in the fishery

A key perceived advantage of ITQs and ITEs is that they facilitate autonomous adjustment in the fishery. Autonomous adjustment is where the fleet size adjusts on its own without the need for government support (e.g. a buyback program).

On a scale of 1 to 10, with 1 being not effective (i.e. no adjustment), and 10 being highly effective (lots of adjustment), how effective has ITQs/ITEs been in facilitating autonomous adjustment in the fleet (i.e. allowed capacity to adjust without the need for additional government intervention)

1	2	3	4	5	6	7	8	9	10
○	○	○	○	○	○	○	○	○	○

Do you believe there any constraints to autonomous adjustment in the fishery? (e.g. financial constraints; inability to buy/sell quota units; etc).

○ No constraints

○ Yes (please specify)

What do you see as the top three benefits of ITQs/ITEs in this fishery?

1.

2.

3.

What do you see as the top three remaining concerns of ITQs/ITEs in this fishery?

1.

2.

3.

Overall, do you think the benefits of ITQs/ITEs outweigh the concerns?

- [ ] Concerns outweigh benefits
- [ ] Benefits and concerns balance out
- [ ] Benefits outweigh concerns
- [ ] Don’t know

Do you feel that changes need to be made to the current ITQ/ITE system to improve performance in the fishery?

- ○ No
- ○ Yes - but not sure what
- ○ Yes - Details of my suggested alternative and why I think it would work better are below:

Are there any unexpected outcomes (positive or negative) that ITQs/ITEs have produced?

Review of ITQs/ITEs in Australian fisheries - Commercial fishers

Thank you

Thank you for completing the survey. The results of this survey will help to design better management in the future.

If you would like to make any final comments, or comment on the survey, please do so below:

Review of ITQs/ITEs in Australian fisheries - scientific advisor survey

Welcome to our Survey

Thank you for agreeing to participate in our survey.

CSIRO, in collaboration with FRDC's Human Dimensions Research Sub-Program and doMar Research, is currently surveying fishers, managers and scientific advisors involved with fisheries that are managed through individual transferable catch (ITQ) or effort (ITE) quotas. The aim of the survey is to identify how successful these management approaches have been, what factors contribute to this success (or otherwise), and what unexpected outcomes, if any, occurred (both positive and negative). Three separate survey questionnaires have been developed – one for fishers, one for managers and one for scientific advisors who provide management advice. These have common elements, but also specific questions for each group.

What is involved?

As a individual identified as having an involvement in providing input into the management of an ITQ or ITE fishery, we would appreciate you providing us with information about your perceptions of the performance of the fishery, plus information around the fishery itself. The survey is completely anonymous. While we request information on the fishery that you are involved with, all data will be pooled to derive a broader overview of the performance of ITQs and ITEs in Australian fisheries.

The survey consists of 3 sections, and takes around 15 minutes or less to complete:

Section 1: Identifies the fishery that you are describing and also asks for your views as to how the fishery is performing;
Section 2: Asks specific questions around your perceptions about the management of the fishery.
Section 3: Involves more open ended questions around adjustment issues and unanticipated outcomes.

There are no right or wrong answers, and all responses will be treated in confidence.

How will my information be used?

The information provided by you to us will be combined with other respondent's answers and statistically analysed to better understand how well ITQs and ITEs have worked under different fishery conditions. The results will not present any individual information. The information will also be used to prepare scientific reports and manuscripts for academic publication. Your personal information will not be identifiable at any stage in these publications.

Review of ITQs/ITEs in Australian fisheries - scientific advisor survey

Additional participant information

Participation and withdrawal

Participation in this study is completely voluntary and you are free to withdraw by stopping the survey at any time. Once submitted your answers are anonymised and will not be individually identifiable. As all answers are anonymous it is not possible to withdraw your responses once submitted.

Risks

Aside from giving up your time, there are no foreseeable risks associated with participating in this study. You are free to skip any questions you do not want to answer. If you have any concerns about any aspects of the study, please contact the project leader Dr Sean Pascoe (see below for contact details).

Confidentiality

All individual information collected in this study is confidential and will be assigned a random code. The primary data will only be seen by members of our research team and will be stored in a secure area that is inaccessible to other individuals. Your information will only be used for research purposes.

Will I receive any payment for taking part in the study?

You will not receive any form of direct payment from CSIRO or other project partners for taking part in this survey.

How can I find out more about the study?

Please feel free to contact us at any time during the study (contact details below). This study is being funded by the Fisheries Research and Development Corporation (FRDC) and CSIRO.

Ethical clearance and contacts

This study has been approved by CSIRO's Social Science Human Research Ethics Committee in accordance with the Australian National Statement on Ethical Conduct in Human Research. If you have any questions concerning your participation in the study feel free to contact the researchers involved. Alternatively any concerns or complaints about the conduct of the study can be raised with the Manager of Social Responsibility and Ethics on 07 3833 5693 or by email at csshrec@csiro.au.

Thank you for your help with this important research.

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doMar Research, Perth
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Review of ITQs/ITEs in Australian fisheries - scientific advisor survey

Part 1: Fishery details and performance

This part identifies the fishery that you are describing and also asks for your views as to how the fishery is performing.

The fisheries of interest are those that use either ITQs or ITEs as their main management measure. For clarification, ITQ fisheries involve a total allowable catch which is allocated to individual fishers by means of a transferable share. ITE fisheries are those where there is a total allowable effort level (e.g. days at sea, pot lifts, gear units) that are allocated to individual fishers by means of a transferable share. Transferable licences in a limited entry fishery is not considered an ITE fishery.

We ask you to please answer questions for one fishery at a time. If you are familiar or involved with more than one fishery, we would greatly appreciate you completing a separate survey for each fishery. The link to this survey allows multiple responses.

Which fisheries jurisdiction are you involved with?

Review of ITQs/ITEs in Australian fisheries - scientific advisor survey

Commonwealth fisheries

Which Commonwealth fishery does this survey response relate to? (please complete a separate survey for each fishery you are involved in).

- ◯ Bass Strait Central Zone Scallop Fishery
- ◯ Eastern Tuna and Billfish Fishery
- ◯ Northern Prawn Fishery
- ◯ Small Pelagics Fishery
- ◯ Other (please specify)
- ◯ Southern and Eastern Scalefish and Shark Fishery
- ◯ Southern Bluefin Tuna Fishery
- ◯ Torres Strait Rock Lobster Fishery

Review of ITQs/ITEs in Australian fisheries - scientific advisor survey

Queensland fisheries

Which Queensland fishery does this survey response relate to? (please complete a separate survey for each fishery you are involved in).

- Coral Reef Finfish Fishery
- East Coast Otter Trawl Fishery
- East Coast Spanish Mackerel Fishery
- Tropical Rock Lobster Fishery
- Spanner Crab Fishery
- Other (please specify)

Review of ITQs/ITEs in Australian fisheries - scientific advisor survey

NSW fisheries

Which NSW fishery does this survey response relate to? (please complete a separate survey for each fishery you are involved in).

- Abalone Fishery
- Lobster Fishery
- Sea Urchin and Turban Shell Fishery
- Other (please specify)

Victorian fisheries

Which Victorian fishery does this survey response relate to? (please complete a separate survey for each fishery you are involved in).

- ◯ Abalone Fishery
- ◯ Rock Lobster Fishery
- ◯ Scallop Fishery
- ◯ Other (please specify)

Review of ITQs/ITEs in Australian fisheries - scientific advisor survey

Tasmanian fisheries

Which Tasmanian fishery does this survey response relate to? (please complete a separate survey for each fishery you are involved in).

- ◯ Abalone Fishery
- ◯ Rock Lobster Fishery
- ◯ Scallop Fishery
- ◯ Other (please specify)

Review of ITQs/ITEs in Australian fisheries - scientific advisor survey

South Australian fisheries

Which South Australian fishery does this survey response relate to? (please complete a separate survey for each fishery you are involved in).

- ◯ Abalone Fishery
- ◯ Australian Sardine fishery
- ◯ Blue Swimmer Crab Fishery
- ◯ Giant Crab Fishery
- ◯ Rock Lobster Fishery - Northern Zone
- ◯ Rock Lobster Fishery - Southern Zone
- ◯ Vongole Fishery
- ◯ Pipi Fishery
- ◯ Gulf St Vincent Prawn Fishery (ITE)
- ◯ Other (please specify)

Review of ITQs/ITEs in Australian fisheries - scientific advisor survey

Western Australian fisheries

Which Western Australian fishery does this survey response relate to? (please complete a separate survey for each fishery you are involved in).

- ◯ Abalone Fishery
- ◯ West Coast Deep Sea Crab Fishery
- ◯ Western Rock Lobster Fishery
- ◯ Gascoyne Demersal Scalefish
- ◯ Northern Demersal Scalefish
- ◯ South Coast Purse Seine Managed Fishery
- ◯ Mackerel Managed Fishery
- ◯ South Coast and West Coast Demersal Finfish
- ◯ South Coast and West Coast Crustacean
- ◯ Other (please specify)

Review of ITQs/ITEs in Australian fisheries - scientific advisor survey

Northern Territory fisheries

Which NT fishery does this survey response relate to? (please complete a separate survey for each fishery you are involved in).

- ◯ Demersal Fishery
- ◯ Timor Reef Fishery
- ◯ Other (please specify)

Review of ITQs/ITEs in Australian fisheries - scientific advisor survey

Involvement with the fishery

How long have you been involved with this fishery? (Years)

How long (number of years) have you been working in fisheries in total (i.e. as a commercial fisher, manager, researcher, or combination of these roles)?

Review of ITQs/ITEs in Australian fisheries - scientific advisor survey

Overview of fishery performance

The aim of this section is to ask you to provide your opinion or perceptions about the performance of ITQs/ITEs. These opinions will remain confidential.

Many of the questions just refer to "quota". For the purposes of the survey, we use this term in the general sense i.e. catch quota or effort quota (i.e. effort units).

On a scale of 1 to 10 (with 1 being not successful and 10 being very successful), how successful do you think the fishery currently is at achieving

	1	2	3	4	5	6	7	8	9	10
Overall sustainability outcomes (i.e. target species as well as broader environment)?	○	○	○	○	○	○	○	○	○	○
- Within this, sustainability of target species?	○	○	○	○	○	○	○	○	○	○
- Broader environmental sustainability (e.g. habitats, bycatch etc.)	○	○	○	○	○	○	○	○	○	○
Economic outcomes (e.g. industry profitability, fisher and crew incomes)?	○	○	○	○	○	○	○	○	○	○
Social outcomes (e.g. community benefits, employment, health and safety, overall satisfaction with fishing, etc.)?	○	○	○	○	○	○	○	○	○	○
5.4. Fishery governance (e.g. participation in decision making, cost effective management, transparency in decision making)?	○	○	○	○	○	○	○	○	○	○

On a scale of 1 to 10 (with 1 being not successful and 10 being very successful), how would you rate the overall performance of the fishery? (i.e. combining sustainability, economic, social and governance considerations)

1	2	3	4	5	6	7	8	9	10
○	○	○	○	○	○	○	○	○	○

In your view, how do you think ITQs or ITEs in the fishery have affected the performance of the fishery?

	Made it worse	No real change	Improved	Don't know
Sustainability outcomes (i.e. target species as well as broader environment)?	○	○	○	○
Economic outcomes (e.g. industry profitability, fisher and crew incomes)?	○	○	○	○
Social outcomes (e.g. community benefits, employment, health and safety and overall satisfaction with fishing)?	○	○	○	○
Fishery governance (e.g. participation in decision making, cost effective management, transparency in decision making)?	○	○	○	○

Review of ITQs/ITEs in Australian fisheries - scientific advisor survey

Inputs into management

How frequently are key stocks usually assessed?

- ◯ Annually
- ◯ Every two to three years
- ◯ Less frequently and irregular
- ◯ Never

Roughly what proportion of all species are assessed at least once every three years?(If it is a single species fishery, 100% means the species is assessed at least onece every three year).

- ◯ 0%-25%
- ◯ 25%50%
- ◯ 50%-75%
- ◯ 75%-100%

How would you describe the quality of the data used in the stock assessments?

- ◯ Good
- ◯ Adequate
- ◯ Inadequate
- ◯ Don't know

How frequently are fisheries independent (biological) data collected on the fishery?

- ◯ Annually
- ◯ Every two to three years
- ◯ Less frequently and irregular
- ◯ Never

How much uncertainty do you think there is in the stock assessment process(es) used in the fishery?

- ◯ High
- ◯ Moderate
- ◯ Low
- ◯ Don't know

How many species are subject to harvest control rules?

- ◯ All commercial species (multispecies or single species fisheries)
- ◯ Main target species (if multispecies fishery)
- ◯ None
- ◯ Don't know

How many species have explicit target reference points?

- ◯ All commercial species (multispecies or single species fisheries)
- ◯ Main target species (if multispecies fishery)
- ◯ None
- ◯ Don't know

Review of ITQs/ITEs in Australian fisheries - scientific advisor survey

Role of economic data

The following questions ask about economic data collection and use in the fishery.
For the collection questions, this can relate to any agency (e.g. ABARES) as well as your own organisation.

How frequently are cost and earnings data collected on the fishery

- Annually
- Every two to three years
- Less frequently and irregular
- Never
- Don't know

How frequently are price data collected on the fishery

- Annually
- Every two to three years
- Less frequently and irregular
- Never
- Don't know

How frequently are quota trading price data (i.e. lease prices, share sale prices) collected on the fishery

- Annually
- Every two to three years
- Less frequently and irregular
- Never
- Don't know

To what extent does economic data influence the TAC/TAE setting process?

- High
- Moderate
- Low
- Not at all

What is the level of industry participation in the TAC/TAE setting process?

- High
- Moderate
- Low
- None

Overall, how would you describe the TAC/TAE setting process?

- ◯ Well-functioning for **all** species
- ◯ Well-functioning for **key** species
- ◯ Not well-functioning for any species

What are the key knowledge gaps that you think currently limit your agency's ability to help improve outcomes for the fishery?

Review of ITQs/ITEs in Australian fisheries - scientific advisor survey

PART 3: General questions

These questions are aimed to determining broader benefits and/or costs associated with ITQs or ITEs in the fishery

A key perceived advantage of ITQs and ITEs is that they facilitate autonomous adjustment in the fishery. Autonomous adjustment is where the fleet size adjusts on its own without the need for government support (e.g. a buyback program).

On a scale of 1 to 10, with 1 being not effective (i.e. no adjustment), and 10 being highly effective (lots of adjustment), how effective has ITQs/ITEs been in facilitating autonomous adjustment in the fleet (i.e. allowed capacity to adjust without the need for additional government intervention)

1	2	3	4	5	6	7	8	9	10
○	○	○	○	○	○	○	○	○	○

Do you believe there any constraints to autonomous adjustment in the fishery? (e.g. financial constraints; inability to buy/sell quota units; etc). If yes, please outline these below.

What do you see as the top three benefits of ITQs/ITEs in this fishery?

1.

2.

3.

What do you see as the top three remaining concerns of ITQs/ITEs in this fishery?

1.

2.

3.

Overall, do you think the benefits of ITQs/ITEs outweigh the concerns?

- ◯ Concerns outweigh benefits
- ◯ Benefits and concerns balance out
- ◯ Benefits outweigh concerns
- ◯ Don't know

Do you feel that changes need to be made to the current ITQ/ITE system to improve performance in the fishery?

- ◯ No
- ◯ Yes - but not sure what
- ◯ Yes - Details of my suggested alternative and why I think it would work better are below:

Are there any unexpected outcomes (positive or negative) that ITQs/ITEs have produced? If yes, please detail below:

Review of ITQs/ITEs in Australian fisheries - scientific advisor survey

Thank you

Thank you for participating in the survey. The results of the study will help improve management in the future.

If you wish to make any final comments, or comment about the survey, please do so below:

Review of ITQs/ITEs in Australian fisheries - Managers survey

Welcome to our Survey

Thank you for agreeing to participate in our survey.

CSIRO, in collaboration with FRDC's Human Dimensions Research Sub-Program and doMar Research, is currently surveying fishers, managers and scientific advisors involved with fisheries that are managed through individual transferable catch (ITQ) or effort (ITE) quotas. The aim of the survey is to identify how successful these management approaches have been, what factors contribute to this success (or otherwise), and what unexpected outcomes, if any, occurred (both positive and negative). Three separate survey questionnaires have been developed – one for fishers, one for managers and one for scientific advisors who provide management advice. These have common elements, but also specific questions for each group.

What is involved?

As a individual identified as having an involvement in providing input into the management of an ITQ or ITE fishery, we would appreciate you providing us with information about your perceptions of the performance of the fishery, plus information around the fishery itself. The survey is completely anonymous. While we request information on the fishery that you are involved with, all data will be pooled to derive a broader overview of the performance of ITQs and ITEs in Australian fisheries.

The survey consists of 3 sections, and takes around 15 minutes or less to complete:

Section 1: Identifies the fishery that you are describing and also asks for your views as to how the fishery is performing;
Section 2: Asks specific questions around your perceptions about the management of the fishery.
Section 3: Involves more open ended questions around adjustment issues and unanticipated outcomes.

There are no right or wrong answers, and all responses will be treated in confidence.

How will my information be used?

The information provided by you to us will be combined with other respondent's answers and statistically analysed to better understand how well ITQs and ITEs have worked under different fishery conditions. The results will not present any individual information. The information will also be used to prepare scientific reports and manuscripts for academic publication. Your personal information will not be identifiable at any stage in these publications.

Review of ITQs/ITEs in Australian fisheries - Managers survey

Additional participant information

Participation and withdrawal

Participation in this study is completely voluntary and you are free to withdraw by stopping the survey at any time. Once submitted your answers are anonymised and will not be individually identifiable. As all answers are anonymous it is not possible to withdraw your responses once submitted.

Risks

Aside from giving up your time, there are no foreseeable risks associated with participating in this study. You are free to skip any questions you do not want to answer. If you have any concerns about any aspects of the study, please contact the project leader Dr Sean Pascoe (see below for contact details).

Confidentiality

All individual information collected in this study is confidential and will be assigned a random code. The primary data will only be seen by members of our research team and will be stored in a secure area that is inaccessible to other individuals. Your information will only be used for research purposes.

Will I receive any payment for taking part in the study?

You will not receive any form of direct payment from CSIRO or other project partners for taking part in this survey.

How can I find out more about the study?

Please feel free to contact us at any time during the study (contact details below). This study is being funded by the Fisheries Research and Development Corporation (FRDC) and CSIRO.

Ethical clearance and contacts

This study has been approved by CSIRO's Social Science Human Research Ethics Committee in accordance with the Australian National Statement on Ethical Conduct in Human Research. If you have any questions concerning your participation in the study feel free to contact the researchers involved. Alternatively any concerns or complaints about the conduct of the study can be raised with the Manager of Social Responsibility and Ethics on 07 3833 5693 or by email at csshrec@csiro.au.

Thank you for your help with this important research.

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Review of ITQs/ITEs in Australian fisheries - Managers survey

Part 1: Fishery details and performance

This part identifies the fishery that you are describing and also asks for your views as to how the fishery is performing.

We ask you to please answer questions for one fishery at a time. If you are familiar or involved with more than one fishery, we would greatly appreciate you completing a separate survey for each fishery. The link to this survey allows multiple responses.

The fisheries of interest are those that use either ITQs or ITEs as their main management measure. For clarification, ITQ fisheries involve a total allowable catch which is allocated to individual fishers by means of a transferable share. ITE fisheries are those where there is a total allowable effort level (e.g. days at sea, pot lifts, gear units) that are allocated to individual fishers by means of a transferable share. Transferable licences in a limited entry fishery is not considered an ITE fishery.

Which fisheries jurisdiction are you involved with?

Review of ITQs/ITEs in Australian fisheries - Managers survey

Commonwealth fisheries

Which Commonwealth fishery does this survey response relate to? (please select one only).

- ○ Bass Strait Central Zone Scallop Fishery
- ○ Eastern Tuna and Billfish Fishery
- ○ Northern Prawn Fishery
- ○ Small Pelagics Fishery
- ○ Other (please specify)
- ○ Southern and Eastern Scalefish and Shark Fishery
- ○ Southern Bluefin Tuna Fishery
- ○ Torres Strait Rock Lobster Fishery

Review of ITQs/ITEs in Australian fisheries - Managers survey

Queensland fisheries

Which Queensland fishery does this survey response relate to? (please select one only).

- ◯ Coral Reef Finfish Fishery
- ◯ East Coast Otter Trawl Fishery
- ◯ East Coast Spanish Mackerel Fishery
- ◯ Tropical Rock Lobster Fishery
- ◯ Spanner Crab Fishery
- ◯ Other (please specify)

Review of ITQs/ITEs in Australian fisheries - Managers survey

NSW fisheries

Which NSW fishery does this survey response relate to? (please select one only).

- ◯ Abalone Fishery
- ◯ Lobster Fishery
- ◯ Sea Urchin and Turban Shell Fishery
- ◯ Other (please specify)

Victorian fisheries

Which Victorian fishery does this survey response relate to? (please select one only).

- ◯ Abalone Fishery
- ◯ Rock Lobster Fishery
- ◯ Scallop Fishery
- ◯ Other (please specify)

Review of ITQs/ITEs in Australian fisheries - Managers survey

Tasmanian fisheries

Which Tasmanian fishery does this survey response relate to? (please select one only).

- ◯ Abalone Fishery
- ◯ Rock Lobster Fishery
- ◯ Scallop Fishery
- ◯ Other (please specify)

Review of ITQs/ITEs in Australian fisheries - Managers survey

South Australian fisheries

Which South Australian fishery does this survey response relate to? (please select one only).

- Abalone Fishery
- Australian Sardine Fishery
- Blue Swimmer Crab Fishery
- Giant Crab Fishery
- Rock Lobster Fishery - Northern Zone
- Rock Lobster Fishery - Southern Zone
- Vongole Fishery
- Pipi Fishery
- Gulf St Vincent Prawn Fishery (ITE)
- Other (please specify)

Review of ITQs/ITEs in Australian fisheries - Managers survey

Western Australian fisheries

Which Western Australian fishery does this survey response relate to? (please select one only).

- ◯ Abalone Fishery
- ◯ West Coast Deep Sea Crab Fishery
- ◯ Western Rock Lobster Fishery
- ◯ Gascoyne Demersal Scalefish
- ◯ Northern Demersal Scalefish
- ◯ Other (please specify)
- ◯ South Coast Purse Seine Managed Fishery
- ◯ Mackerel Managed Fishery
- ◯ South Coast and West Coast Demersal Finfish
- ◯ South Coast and West Coast Crustacean

Northern Territory fisheries

Which NT fishery does this survey response relate to? (please select one only).

- ◯ Demersal Fishery
- ◯ Timor Reef Fishery
- ◯ Other (please specify)

Review of ITQs/ITEs in Australian fisheries - Managers survey

Involvement with the fishery

How long have you been involved with this fishery? (Years)

How long (number of years) have you been working in fisheries in total (i.e. as a commercial fisher, manager, researcher, or combination of these roles)?

Review of ITQs/ITEs in Australian fisheries - Managers survey

Overview of fishery performance

The aim of this section is to ask you to provide your opinion or perceptions about the performance of ITQs/ITEs. These opinions will remain confidential.

Many of the questions just refer to “quota”. For the purposes of the survey, we use this term in the general sense i.e. catch quota or effort quota (i.e. effort units).

On a scale of 1 to 10 (with 1 being not successful and 10 being very successful), how successful do you think the fishery currently is at achieving

	1	2	3	4	5	6	7	8	9	10
Overall sustainability outcomes (i.e. target species as well as broader environment)?	○	○	○	○	○	○	○	○	○	○
- Within this, sustainability of target species?	○	○	○	○	○	○	○	○	○	○
- Broader environmental sustainability (e.g. habitats, bycatch etc.)	○	○	○	○	○	○	○	○	○	○
Economic outcomes (e.g. industry profitability, fisher and crew incomes)?	○	○	○	○	○	○	○	○	○	○
Social outcomes (e.g. community benefits, employment, health and safety, overall satisfaction with fishing, etc.)?	○	○	○	○	○	○	○	○	○	○
Fishery governance (e.g. participation in decision making, cost effective management, transparency in decision making)?	○	○	○	○	○	○	○	○	○	○

On a scale of 1 to 10 (with 1 being not successful and 10 being very successful), how would you rate the overall performance of the fishery? (i.e. combining sustainability, economic, social and governance considerations)

1	2	3	4	5	6	7	8	9	10
○	○	○	○	○	○	○	○	○	○

In your view, how do you think ITQs or ITEs in the fishery have affected the performance of the fishery?

	Made it worse	No real change	Improved	Don't know
Sustainability outcomes (i.e. target species as well as broader environment)?	○	○	○	○
Economic outcomes (e.g. industry profitability, fisher and crew incomes)?	○	○	○	○
Social outcomes (e.g. community benefits, employment, health and safety and overall satisfaction with fishing)?	○	○	○	○
Fishery governance (e.g. participation in decision making, cost effective management, transparency in decision making)?	○	○	○	○

What management system is currently in place in the fishery?

- ◯ ITQ
- ◯ ITE

In what year were ITQs/ITEs introduced into the fishery?

What were the main reasons (to the best of your knowledge) that ITQs/ITEs were introduced?

Review of ITQs/ITEs in Australian fisheries - Managers survey

Inputs into management

How frequently are key stocks usually assessed?

- Annually
- Every two to three years
- Less frequently and irregular
- Never

How would you describe the quality of the data used in the stock assessments?

- Good
- Adequate
- Inadequate
- Don't know

How frequently are fisheries independent data collected on the fishery?

- Annually
- Every two to three years
- Less frequently and irregular
- Never

How much uncertainty do you think there is in the stock assessment process(es) used in the fishery?

- High
- Moderate
- Low
- Don't know

How many species are subject to harvest control rules?

- All commercial species (multispecies or single species fishery)
- Main target species (if multispecies fishery)
- None

How many species have explicit target reference points?

- All commercial species (multispecies or single species fishery)
- Main target species (if multispecies fishery)
- None

What proportion of total allowable catch(es) of key species (or effort in ITE fisheries) are generally left uncaught?

- 0-25%
- 25%-50%
- 50%-75%
- 75%-100%
- Don't know

What proportion of total allowable catch(es) of secondary species are generally left uncaught (not applicable for ITE fisheries)

- 0-25%
- 25%-50%
- 50%-75%
- 75%-100%
- Don't know

What is the level of discarding of quota species? (Not applicable for ITE fisheries)

- High
- Moderate
- Low
- None
- Don't know

Review of ITQs/ITEs in Australian fisheries - Managers survey

Role of economic data

The following questions ask about economic data collection and use in the fishery.
For the collection questions, this can relate to any agency (e,g, ABARES) as well as your own organisation.

How frequently are economic cost and earnings data collected on the fishery?

- ◯ Annually
- ◯ Every two to three years
- ◯ Less frequently and irregular
- ◯ Never

How frequently are sales price data collected on the fishery?

- ◯ Throughout the year
- ◯ Annually
- ◯ Every two to three years
- ◯ Less frequently and irregular
- ◯ Never

How frequently are quota trading price data (i.e. lease prices, share sale prices) collected on the fishery?

- ◯ Throughout the year
- ◯ Annually
- ◯ Every two to three years
- ◯ Less frequently and irregular
- ◯ Never

To what extent does economic data influence the TAC/TAE setting process?

- ◯ High
- ◯ Moderate
- ◯ Low
- ◯ Not at all

What is the level of industry participation in the TAC/TAE setting process?

- High
- Moderate
- Low
- None

Overall, how would you describe the TAC/TAE setting process?

- Well-functioning for all species (multispecies or single species fishery)
- Well-functioning for all key species (multispecies fishery)
- Well-functioning for most key species (multispecies fishery)
- Well-functioning for some key species (multispecies fishery)
- Not well-functioning for any species

Review of ITQs/ITEs in Australian fisheries - Managers survey

Quota trading and leasing

To the best of your knowledge, what proportion of permanent quota share trades (including effort units) takes place through the following markets? (Total sums to 100%)

Online trading market [ ]

Brokers [ ]

Direct transactions between buyers and sellers [ ]

Other [ ]

Don't know [ ]

To the best of your knowledge, what proportion of quota leases (including effort units) takes place through the following markets? (Total sums to 100%)

Online trading market [ ]

Brokers [ ]

Direct transactions between buyers and sellers [ ]

Other [ ]

Don't know [ ]

Roughly what proportion of the total quota (including effort units) is leased annually? (Note: quota leasing can exceed 100% if it passes through several holders before final use).

- ◯ 0%-25%
- ◯ 25%-50%
- ◯ 50%-75%
- ◯ 75%-100%
- ◯ more than 100%
- ◯ Don't know

How would you describe the level of concentration of quota ownership in the fishery?

- ◯ Fairly equally owned by all individual quota owners (Little concentration)
- ◯ More than half the quota owned by less than half the individual quota owners (Some concentration)
- ◯ More than half the quota owned by less than one quarter of the individual quota owners (High concentration)
- ◯ Most quota owned by only a few individuals, large number of individuals with little or no quota ownership (Very high concentration)

Over the last 5 years, how has the level of quota ownership<u>concentration</u> changed?

- ◯ Decreased (the number of quota owners has increased)
- ◯ No real change (the number of quota owners is about the same)
- ◯ Increased (the number of quota owners has decreased)
- ◯ Don't know

To the best of your knowledge, what proportion of quota is owned by non-fishers (e.g. investors, retirees, processors etc.)?

- ◯ 0-25%
- ◯ 25%-50%
- ◯ 50%-75%
- ◯ 75%-100%
- ◯ Don't know

Review of ITQs/ITEs in Australian fisheries - Managers survey

Fishing activity

Roughly, how many active fishers currently operate in the fishery?

- ○ less than 20
- ○ between 20-50
- ○ between 50-100
- ○ more than 100

Over the last 5 years, how has the number of active fishers changed

- ○ Decreased
- ○ No real change
- ○ Increased
- ○ Don't know

How would you describe the general level of compliance in the fishery?

- ○ High
- ○ Medium
- ○ Low
- ○ None
- ○ Don't know

How would you describe the general level of bycatch (e.g. TEPS and non-target species) in the fishery?

- ○ High
- ○ Medium
- ○ Low
- ○ None
- ○ Don't know

To the best of your knowledge, what proportion of catch is sold on the domestic market?

- ○ 0-25%
- ○ 25%-50%
- ○ 50%-75%
- ○ 75%-100%
- ○ Don't know

On a scale of 1 to 10 (with 1 not effective and 10 very effective), how would you rate the overall cost effectiveness of the management of the fishery?

1	2	3	4	5	6	7	8	9	10
○	○	○	○	○	○	○	○	○	○

What is the level of industry participation in management decision making (in general, not just the TAC/TAE setting process)?

- ○ High
- ○ Medium
- ○ Low
- ○ None
- ○ Don't know

What are the key knowledge gaps that you think currently limit your agency's ability to improve outcomes for the fishery?

Review of ITQs/ITEs in Australian fisheries - Managers survey

PART 3: General questions

These questions are aimed to determining broader benefits and/or costs associated with ITQs or ITEs in the fishery

A key perceived advantage of ITQs and ITEs is that they facilitate autonomous adjustment in the fishery. Autonomous adjustment is where the fleet size adjusts on its own without the need for government support (e.g. a buyback program).

On a scale of 1 to 10, with 1 being not effective (i.e. no adjustment), and 10 being highly effective (lots of adjustment), how effective has ITQs/ITEs been in facilitating autonomous adjustment in the fleet (i.e. allowed capacity to adjust without the need for additional government intervention)

1	2	3	4	5	6	7	8	9	10
○	○	○	○	○	○	○	○	○	○

Do you believe there any constraints to autonomous adjustment in the fishery? (e.g. financial constraints; inability to buy/sell quota units; etc). If "Yes" please outline these below.

○ No constraints

○ Yes (please specify)

What do you see as the top three benefits of ITQs/ITEs in this fishery?

1.

2.

3.

What do you see as the top three remaining concerns of ITQs/ITEs in this fishery?

1.

2.

3.

Overall, do you think the benefits of ITQs/ITEs outweigh the concerns?

- ◯ Concerns outweigh benefits
- ◯ Benefits and concerns balance out
- ◯ Benefits outweigh concerns
- ◯ Don’t know

Do you feel that changes need to be made to the current ITQ/ITE system to improve performance in the fishery?

- ◯ No
- ◯ Yes - but not sure what
- ◯ Yes - Details of my suggested alternative and why I think it would work better are below:

Are there any unexpected outcomes you are aware of (positive or negative) that ITQs/ITEs have produced?

- ◯ No
- ◯ Yes (please specify)

Thank you

Thank you for participating in our survey. The results of this survey will help to design better management in the future.

If you wish to make any further comments, or comment on the survey, please do so below.

B: Description of the nodes in the BBN

Node name	Description
Accessibility_buy	The relative amount of quota available to purchase. Based on the 1-10 scale in the survey, with 10 indicating no constraints.
Accessibility_lease	The relative amount of quota available to lease. Based on the 1-10 scale in the survey, with 10 indicating no constraints.
Active_fishers	The number of active fishers in the fishery
Affordability_lease	The relative price of quota available to lease. Based on the 1-10 scale in the survey, with 10 indicating no constraints due to price.
Affordable_buy	The relative price of quota available to purchase. Based on the 1-10 scale in the survey, with 10 indicating no constraints due to price.
Availability	The available of fish on the market for purchase by consumers
Bycatch	Incidental catch of non-commercial species
Complexity	The perceived complexity of the management system
Compliance	The level of compliance with management regulations by fishers
Compliance_costs	The cost to fishers of complying with the rules (e.g. completing landings records).
Concentration	The level of concentration of quota ownership in the fishery
Consumers	The level of consumer satisfaction
Cost_Earnings	Economic (cost and earnings data) used in stock assessments
Cost_effectiveness	Perceived cost effectiveness of management
Crew_income	The income received by the crew
Days_fished	The number of days fished
Debt	The level of fisher debt
Direct_transactions	The proportion of quota sold through direct transactions between fishers
Direct_transactions_lease	The proportion of quota leased through direct transactions between fishers
Discarding	The level of discarding of quota species
Domestic_market	The proportion of catch sold through the domestic market
Economic_influence_TAC	The level of influence of economic considerations on the TAC
Economic_outcomes	A relative measure of economic outcomes in the fishery (how well the economic objectives were achieved)
Enjoyment	The level of enjoyments fishers gain from participating in the fishery
FI_data_freq	The frequency that fisheries independent data is used in stock assessment
Fishing_costs	The total cost of fishing
Function_buy	The functioning of the quota trading (sales) market
Function_lease	The functioning of the quota leasing market
Governance	A relative measure of how well the governance objectives were achieved
Health_Safety	The level of health and safety in the fishery
Income	The level of fisher income
Industry_participation_TAC	The degree to which fishers participate in the TAC setting process
Industry_participation_mgt	The degree to which fishers participate in management in general
Information_sharing	The degree to which fishers share information in the fishery
Number_wholesalers	The number of fish wholesalers
Overall_performance	The degree to which all objectives are being met
Overall_sustainability	A relative measure of how well the sustainability objectives were achieved
Price	The price received by fishers

Proportion_leased	The proportion of total quota leased
Quality	The quality of the landed product
Quality_SA_data	The quality of data used in the stock assessments
Quota_non_fishers	The proportion of quota owned by non-fishers
Regional_importance	The regional importance of the fishery
Reliance_lease	The degree to which fishers are reliant on quota leasing to operate
Satisfaction	The level of satisfaction with fishing
Social_outcomes	A relative measure of how well the social objectives were achieved
Social_relations	A measure of how well fishers get along
Species_HCR	The use of species specific harvest control rules when setting TACS
Species_TRP	The use of species specific target reference points when setting TACS
Stock_assessments	The frequency of stock assessments for the main species
Support_Level	The level of support for fishing given by the local community (social licence to operate)
TAC_setting	The level of functioning of the TAC setting process
Transperancy	The level of transparency in management decision making
Trust	The level of trust industry has in managers
Type	Type of management (ITQ or ITE)
Uncaught_secondary	The level of under-caught quota – secondary species
Uncaught_target	The level of under-caught quota – primary target species
Uncertainty_SA	The level of uncertainty in the data used for stock assessments
Uncertainty_stock_ass	The level of uncertainty in the stock assessment results
management_cost	The costs of management
proportion_stocks	The proportion of stocks in a fishery with a TAC

C: Econometric analyses supporting the BBN

Several conditional probability tables required substantial modification from what was estimated using the EM learning. These generally involved tables with a large number of potential combinations (see Table 10). For two of the nodes (social performance and total costs), the number of apparent inconsistencies in their conditional probability tables (CPTs) seemed high, as many combinations did not appear in the data, and in some cases, a low performance score was given by a fisher with a particular combination of contributing factors, while scores given by other fishers with slightly varying factors were substantially higher, resulting in unexpected and unlikely non-transient outcomes. For these two nodes, simple linear regression models were run, and the expected outcome given the combination of the inputs used to derive the new CPTs.

In each case, several different models were run, and the model that performed best in terms of econometric performance and consistency with a priori expectations was used to derive the new CPT (Kennedy 2002).

Social performance

For the social performance measures, several approaches to model development were tested. First, for the purposes of developing the BBN, the social performance and satisfactions measures were aggregated to three levels (1-5, 5-7, 7-10). All other measures feeding into the social performance measure were qualitative (e.g. decreased, stayed the same, or increased). Initial regression models including these qualitative levels suggested that for most inputs (health and safety, consumers, regional importance and level of community support) a "decrease" resulted in decline in the social performance, with no change or an increase having little impact on improving the scores. For the purposes of estimating the probabilities associate with each level of social performance, all variables were converted to a quantitative measure (see Table B1).

Table B1. Variable levels used in the regression analysis: social performance

	Variable level or social performance score (in brackets)		
Measure	Decreased/(1-5)	Stayed the same/(5-7)	Increased/(7-10)
Social performance	-1	0	1
Satisfaction	-1	0	1
Health and Safety	-1	0	0
Consumers	-1	0	0
Regional importance	-1	0	0
Level of Support[a]	-1	0	0

a) For level of support, the variable levels are "no support/oppose" or "low support"; "moderate support"; "strong support"

A simple linear regression model was estimated which explained around 65% of the variation in the social performance measure (Table B2). While most of the individual coefficients were not significant, from the F statistic the coefficients were jointly significant.

Table B2. Linear regression model results: social performance

	Estimate	Std. Error	Significance	Normalised weight used for CPT
Satisfaction	0.677	0.080	***	0.417
Health and Safety	0.070	0.157		0.043
Consumers	0.407	0.255		0.251
Regional	0.096	0.078		0.059
Support	0.374	0.305		0.230
Adjusted R squared	0.649			
F-statistic (5 and 55 DF)	23.19		***	

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

The coefficients of the model were normalised to derive weights associated with each of the factors. These weights were then applied to the data to estimate a relative social performance score (ranging from -100 to +100). From this, the probability of each outcome (1-5, 5-7 or 7-10) was derived:

$$\Pr(1-5) = \begin{cases} -\sum wm \;\; if \sum wm < 0 \\ 0 \end{cases}$$

$$\Pr(7-10) = \begin{cases} 0 \\ \sum wm \;\; if \sum wm > 0 \end{cases}$$

$$\Pr(5-7) = 100 - \Pr(1-5) - \Pr(7-10)$$

where w are the normalised weights associated with each measure (Table B2) and m is the value of each measure (Table B1) multiplied by 100.

Total costs

For the total costs measures, again, several approaches to model development were tested. In the initial analyses, changed in area fished was also considered. However, despite several different approaches, the sign of the coefficient remained negative, counter to expectations, and highly non-significant. This suggests that no relationship between changes in area fished and changes in total costs could be determined from the data even though *a priori* it would be expected that some relationship existed. As a result, the variable was removed from the BBN.

All measures used in the analysis were qualitative (e.g. decreased, stayed the same, or increased). For the purposes of estimating the probabilities associate with each level of total costs, all variables were converted to a quantitative measure (see Table B1). Variations of the model analyses suggested that lease dependence increases costs when fishers were highly dependent (i.e. "Lease in most or all of my quota"), otherwise it had no significant impact on costs.

Table B3. Variable levels used in the regression analysis: social performance

	Variable level or social performance score (in brackets)		
Measure	Decreased	Stayed the same	Increased)
Total costs	-1	0	1
Days fished	-1	0	1
Debt	-1	0	1
Management costs	-1	0	1
Compliance costs	-1	0	1
Lease dependence[a]	0	0	1

a) For Lease dependence, the variable levels are "Lease in some quota but own most of it" or "Own all my quota"; "Lease in around half my quota"; "Lease in most or all of my quota".

The simple linear regression model explained around 57% of the variation in the total cost measure (Table B4). As for the social performance model, while some of the individual coefficients were not significant, from the F statistic the coefficients were jointly significant.

Table B4. Linear regression model results: social performance

	Estimate	Std. Error	Significance	Normalised weight used for CPT
Days fished	0.272	0.114	*	0.204
Debt	0.495	0.137	***	0.371
Management costs	0.136	0.219		0.102
Compliance costs	0.387	0.213	.	0.290
Lease dependence	0.043	0.196		0.032
Adjusted R squared	0.568			
F-statistic (5 and 50 DF)	15.45		***	

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Again, the coefficients of the model were normalised to derive weights associated with each of the factors. These weights were then applied to the data to estimate a relative total cost score (ranging from -100 to +100). From this, the probability of each outcome (decreased, stayed the same, or increased) was derived:

$$\Pr(decreased) = \begin{cases} -\sum wm \;\; if \sum wm < 0 \\ 0 \end{cases}$$

$$\Pr(increased) = \begin{cases} 0 \\ \sum wm \;\; if \sum wm > 0 \end{cases}$$

$$\Pr(stayed\ the\ same) = 100 - \Pr(decreased) - \Pr(increased)$$

where *w* are the normalised weights associated with each measure (Table B4) and *m* is the value of each measure (Table B3) multiplied by 100.

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