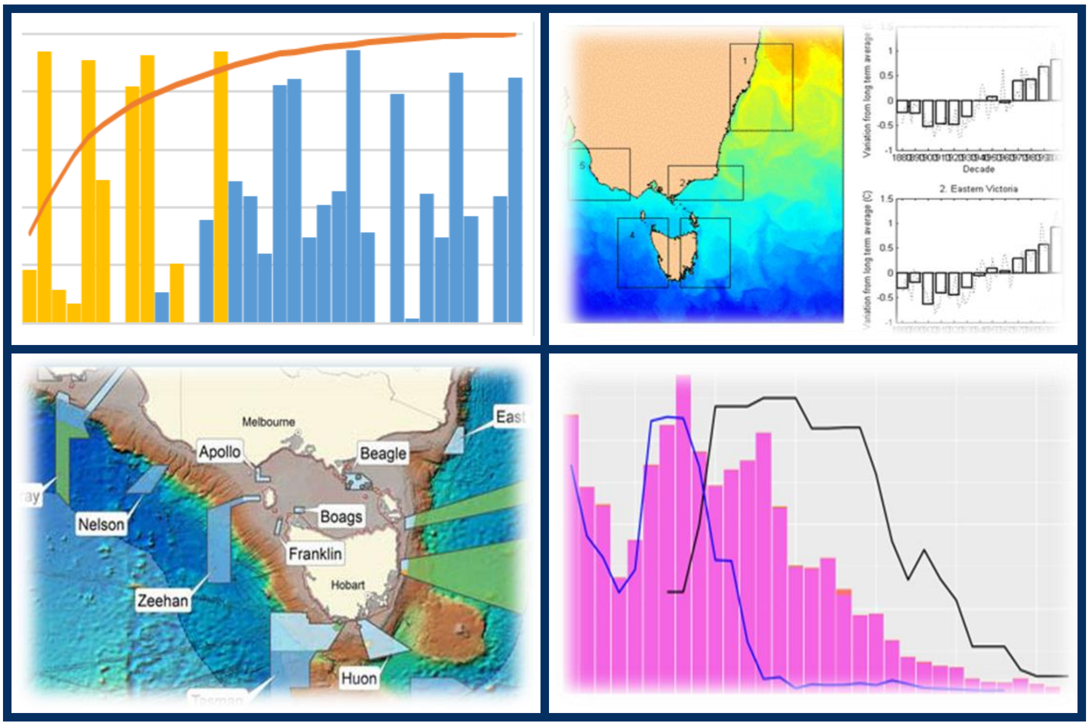
Understanding factors influencing under-caught TACs, declining catch rates and failure to recover for many quota species in the SESSF



Ian Knuckey, Simon Boag, George Day, Alistair Hobday, Sarah Jennings, Rich Little, David Mobsby, Emily Ogier, Simon Nicol and Robert Stephenson

2018

FRDC Project No 2016-146

Australian Government
Australian Fisheries Management Authority

CSIRO

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SETFIA
SOUTH EAST TRAWL FISHING INDUSTRY ASSOCIATION

FRDC
FISHERIES RESEARCH & DEVELOPMENT CORPORATION

Australian Government
Department of Agriculture and Water Resources

ISBN 978-0-9954122-9-3

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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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In submitting this report, the researcher has agreed to FRDC publishing this material in its edited form.

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ACKNOWLEDGEMENTS

The authors would like to thank the Fisheries Research and Development Corporation for funding this project. We would also like to thank those individuals below, who assisted in the input to the individual papers and/or participated in the workshop.

Nigel Abery (AFMA), Tom Bibby (Industry), Simon Boag (Industry), Anthony Ciconte (Industry), Daniel Corrie (AFMA), Robert Curtotti (ABARES), Cathy Dichmont (CDS), Shane Duggins (Industry), Beth Fulton (CSIRO), Gerry Geen (Industry), Beth Gibson (AFMA), David Guillot (Industry), Tony Harman (DAWR), John Jarvis (Industry), Matt Koopman (Fishwell), Tony Lavalle (Industry), Brodie MacDonald (AFMA), Nastaran Mazloumi (ABARES), Sandy Morison (Morison Aquatic), Will Mure (Industry), Erik Poole (Industry), Andrew Powell (AFMA), Nick Rayns (AFMA), Erin Tomkinson (DAWR), Geoff Tuck (CSIRO), Ingrid van Putten (CSIRO).

The work of Dr Paul McShane in compiling and editing the individual papers into the report is much appreciated. Particular thanks for the detailed external review by Dr Andrew Penney, which significantly improved the final report.

ABBREVIATIONS

ABARES	Australian Bureau of Agricultural and Resource Economics and Sciences
AFMA	Australian Fisheries Management Authority
B_{TFP}	Biomass at Maximum Economic Yield
CTS	Commonwealth Trawl Sector
EEZ	Exclusive Economic Zone
ESD	Ecologically Sustainable Development
EPBC	*Environment Protection and Biodiversity Conservation* Act
FRDC	Fisheries Research and Development Corporation
GHTS	Gillnet Hook and Trap Sector
GVP	Gross Value of Production
HSP	Harvest Strategy Policy
IMOS	Integrated Marine Observing System
ITE	Individual Transferrable Effort
ITQ	Individual Transferrable Quota
MAC	Management Advisory Committee
MEY	Maximum Economic Yield
MHW	Marine Heat Wave
MPA	Marine Protected Area
MSC	Marine Stewardship Council
NER	Net Economic Return
NSW	New South Wales
OCS	Offshore Constitutional Settlement
QMS	Quota Management System
RCP	Representative Concentration Pathways
RD&E	Research, Development and Extension
RFMO	Regional Fisheries Management Organisation
SA	South Australia
SESSF	South Eastern Scalefish and Shark Fishery
SETFIA	South East Trawl Fishing Industry Association
SFR	Statutory Fishing Right
TAC	Total Allowable Catch
TACC	Total Allowable Commercial Catch
TAE	Total Allowable Effort
TEPS	Threatened, endangered, and protected species
TFP	Total Factor Productivity
VFA	Victorian Fisheries Authority
VMS	Vessel Monitoring System

EXECUTIVE SUMMARY

Background

Concerns about the ecological and economic sustainability of Australia's Southern and Eastern Scalefish and Shark Fishery (SESSF) prompted major structural readjustment of the fishery in 2006 that significantly reduced the number of operators in demersal trawl, Danish seine and gill net sectors of the fishery. A decade later, many of the ecological sustainability issues have been addressed and despite declining Gross Value of Production (GVP), there has been variable but overall improvement in net economic returns (NER) of the fishery. There remains, however, a number of indicators in the fishery that may point to significant sub-optimal performance in terms of stock sustainability and fishery profitability as outlined below.

Failure to catch TACs

At the end of the 2015/16 year, 23 of the 34 species groups under TACs were less than 50% caught. Of the major quota species, only four had catches above 80% of the TACs (Flathead, Gummy Shark, Pink Ling and School Whiting).

Declining CPUEs

There has been a continual decline in catch rates for many quota species with a range of life histories. Similar trends in decline over the last two decades have been observed for Jackass Morwong, Redfish, Blue Eye Trevalla, Silver Warehou, Blue Warehou, John Dory and Ribaldo, despite the lowest historical effort and catch levels in the fishery. Unstandardised CPUE across the fishery has declined for several years hitting an all-time low in 2015 and has remained at this level in 2016. Moreover, optimised CPUE standardizations for 23 species (including grouped species) and 43 different stocks, methods, or fisheries revealed 29 of the 43 SESSF stocks were found to have declining standardised catch rates.

Lack of recovery of overfished species

Historically overfished species (Eastern Gemfish, School Shark, Blue Warehou and most recently Redfish) have shown little sign of recovery despite over a decade of the lowest catches on record resulting from significant management changes under relevant rebuilding strategies (including bans on targeting, implementation of industry driven avoidance measures, and implementation of spatial closures). The overfishing and subsequent recent recovery of the eastern Orange Roughy stock over the last two decades is well documented – but it is an exception.

There are many and varied reasons to explain these issues in the SESSF, but there has been no attempt at a coordinated approach to identify which factor/s may be the cause, much less how these may be addressed. This project was designed to start this process.

Objectives

1. Provide a range of papers with information on potential causes of under-caught TACs, declining catch rates and non-recovering species
2. Hold a workshop to discuss plausible reasons for under-caught TACs, declining catch rates and non-recovering species
3. Develop strategies to address the under-caught TACs, declining catch rates and non-recovering species-based outputs from Objective 1 and 2.
4. Develop a process for assessing non-rebuilding species.

Methods

A wide range of people with expertise in business, science and management from across all facets of fisheries (sustainability, economics and social) were brought together to consider and prioritise the potential range of underlying factors causing the declining indicators categorised

into seven "issues": 1) legislative or management impediments; 2) fleet capacity and characteristics; 3) fisher behaviour and vessel operation; 4) climate change and oceanographic conditions; 5) costs of production and changing markets; 6) quota ownership and trading; and, 7) the assessment process. These seven issues were explored in separate papers authored by relevant experts and the findings presented and discussed at a workshop involving SESSF fishers and other stakeholders. Workshop outcomes and evaluation of other relevant information is included in the seven papers presented in this report. Collectively, the papers attempt to explore and explain the declining indicators for the SESSF and provide guidance on how to begin to address the potential causes, if indeed this is necessary and/or possible.

Key Results

Legislative/management impediments
Area closures (either by removing productive grounds or by limiting catch) were considered to be major contributors to under caught TACs particularly for Ribaldo, deepwater sharks, Royal Red Prawn, and Silver Trevally. Of other technical measures, day/trip catch limits were also influential but input controls such as gear restrictions less so. Even so, compared with other factors summarised below, legislative and management impediments were not considered to be major issues for declining catch rates, or the ability to catch TACs, and should not have impeded the recovery of overfished species.

Fleet capacity and characteristics
The current trawl fleet is aged and lacking contemporary equipment compared with modern international trawl fleets. However, there is no evidence to suggest that the trawl fleet's ability to catch fish has declined and that this has affected catch rates and the ability to catch TACs. The collective capacity of vessels working together can improve search efficiency (and therefore catch rates). This is aided by modern communication technology including automatic radar plotting aid (ARPA) and mobile telephones. Although there was little evidence of improved search efficiency influencing catch rates, this is most likely because the reduction in fleet capacity following buy-backs reduced total effort (evident across most sectors). Fleet capacity is also influenced by days at sea (uptime). There is evidence to suggest that uptime has increased because the average fishing operations completed per vessel have increased. Nonetheless, there is also evidence that uptime can be increased further across the SESSF (particularly for the gill net sector) and that this may improve catches against the TAC applicable to target species.

Fisher behaviour and vessel operation
Fisher behaviour in the SESSF is influenced by internal drivers such as livelihood choice, fisher experience, preferred targeting of particular species, and external drivers such as market demand/prices. Several hypotheses relating to fisher behaviour including: quota trading, excising and balancing; species targeting and avoidance; livelihood preferences; and vessel operation offer plausible explanations for failure to catch TACs for certain species. For example, spatial closures and regulations on School Shark have affected targeting of Gummy Shark by the gill net fleet. Interactions, particularly with choke species (species that are likely to be caught but for which no or little quota is held) is also a factor. Fleet avoidance of (overfished) species and a mixed-bag targeting strategy were considered by workshop participants as potential causes for declining CPUEs particularly for School Shark, Eastern Gemfish, Redfish and Blue Warehou. However, further information is required to adequately test these hypotheses for declining indicators in the SESSF, in particular, whether there are sub-groups of participants who are operating with different sets of incentives and constraints and whose behaviour is affecting the interpretation of fishery-dependent data, technical efficiency and the liquidity of quota markets. Changes in targeting and avoidance behaviour that affect location, seasonality, depth, and length of trip/shot choices should be incorporated in the stock assessment process.

Climate change and oceanographic conditions

Climate change and related oceanographic conditions have had, and will continue to have, an important influence on the distribution and abundance of key species in the SESSF. Waters off the east coast of Australia region are among the fastest warming in the world. There has been long-term warming at the surface and at depth, and southward transport of warmer waters has increased as the East Australia Current has strengthened and eddies move further south. Other physical variables, such as salinity, and nutrient availability have also changed. These can have various effects either by directly impacting the animal's physiology (particularly on growth and reproduction), affecting their habitat, or a combination of factors. Future projections suggest abundance of some species will decline, some will increase, and some will be largely unchanged. There is a medium to high likelihood that this will negatively affect catch rates, recovery of overfished stocks and under catch of the TAC in the SESSF. However, the confidence (based on available historical evidence) about how this will impact the SESSF is medium or low and there are conflicting drivers (e.g. difficulty locating fish or travelling further out means greater effort (lowered CPUE) and fuel use (also an economic driver)).

Costs of production and changing markets

Economic factors related to market demand influence catch rates and the proportion of the TAC caught for particular species in the SESSF. Workshop participants noted that fish sale prices and changing markets were major factors influencing uncaught TACs. The six species that command the highest prices (priced at or more than $5.99 per kilogram in 2015–16) are Blue-eye Trevalla, John Dory, Deepwater Flathead, Gummy Shark, Tiger Flathead and School Shark. There are therefore financial incentives to target and catch these species. There is no overall single trend for fish prices in the SESSF. The large number of species and variation in price movements makes it difficult to draw conclusions between imports and price changes of SESSF species. Relatively cheaper imported seafood is likely to compete against cheaper alternative protein sources and not directly with higher-value domestically-caught species. Terms of trade (the ratio of output prices to input prices) has been largely neutral in the gillnet and trawl sectors from 2005. Overall terms of trade are therefore unlikely to be a significant cause of quota latency and therefore under caught TACs.

Quota ownership and trading

There was little evidence that quota ownership and trade influenced under caught TACs for a large number of species in the SESSF. Poor market conditions and, lack of suitable fishing capacity were identified as important factors for some species. Similarly, current quota management was not considered to be a major constraint to catching TACs. A key finding is that some TACs will unavoidably remain uncaught in multi-species, multi-gear fisheries when a "one-size-fits-all" Maximum Economic Yield (MEY) target is applied individually to all species in a multi-species fishery. Increasingly it is being recognised that whilst this approach to controlling catches is precautionary, it is inconsistent with a goal of maximising fishery-wide economic yield and can manifest in the form of undercaught TAC for some species. There does seem to be a case, however, for developing a deeper, more nuanced understanding of how well quota markets in the SESSF are working to ensure quota is flowing to the most efficient vessels, and that the under catch of high value quota species in particular is not an artefact of structural, institutional or behavioural features of markets.

The assessment process

Assessment of declining CPUEs in the SESSF is currently affected by the inability to reliably measure and standardise for changing fleet or vessel behaviour, and effects of small catches in logbooks on CPUE standardisations. This may also be a factor affecting the evaluation of the recovery of overfished species. The setting of TACs that are unrealistically high (for the complexity of fleet and quota interactions) is considered to be a factor in undercaught TACs for some species including Jackass Morwong, Silver Trevally, Silver Warehou, and Blue Grenadier.

Prioritisation of issues and mechanisms

Importantly, some indicators (e.g. undercaught TACs) may not necessarily be negative for a stock's status, but nevertheless are seen as a red flag by some groups. Thus, resolving this has important societal consequences for the "social licence" of the fishery. There is considerable interaction among the seven themes summarised above. Fisher behaviour and fleet capacity is related to many factors including livelihood choices, costs of operation, market dynamics, and interaction among fishers. This in turn affects assessment and administration of the sectors within the SESSF i.e. harvest strategies with decision rules which affect catch (and areas fished). Economic issues are clearly important and these need to be incorporated in assessments consistent with policy objectives for ecologically sustainable development of the SESSF.

This project has helped SESSF stakeholder to focus us on the main issues that, if addressed through a targeted RD&E, are most likely to yield benefits to future management of the SESSF. In considering the interplay of the above mechanisms, the following key priority areas (highlighted in green) are recommended for further investigation as to their influence on negative indicators in the SESSF.

Indicator	Mechanism	Issue: Climate / Oceanography	Legislation / Management	Stock Assessment	Cost of Production	Quota & Markets	Fleet Characteristics	Fisher Behaviour
	Uncaught TACs	Minor contribution	Minor contribution	TACs too high Interactions / Choke spp	Fish sale prices and changing markets	Minor contribution	Minor contribution	Choke species
	Declining CPUE	Changing productivity, abundance and distribution	Area closures Catch limits	Not capturing changing behaviour Problem with CPUE standard'n	Not Applicable	Minor contribution	Minor contribution	Avoidance Mixed bag target
	Lack of recovery	Change in productivity	Minor contribution	Not capturing changing behaviour Problem with CPUE standard'n	Not Applicable	Not Applicable	Not Applicable	Not Applicable

Conclusions

The SESSF is a complex multi-species, multi-gear fishery distributed over a large geographical area with a diverse range of vessels and operators. Added to this is the complexity of a quota system which covers 34 species or species groups, with quota held by individuals and companies who are not necessarily fishing concession holders. Thus, there are a large number of inter-related issues and mechanisms which influence catch rates, the recovery of overfished stocks and the capacity to catch TACs in the SESSF. To cap it off, we are endeavouring to manage the fishery in one of the global hotspots, where temperatures are warming at almost four times the global average, greatly influencing habitats, ecosystems and species productivity and distribution. The challenge therefore lies first, in being able to identify and collect the data that is critical to future management of the fishery and second, developing assessments that can quantify each of these aspects and their combined impact on this fishery, and adapt harvest strategies to best manage the fishery taking these factors into account.

To meet the first challenge, we require better data. The highest priority is to cost-effectively collect data that helps us understand the dynamics of fishing operations and their interdependence on markets, costs of production, and most importantly, quota ownership and trading. We also need data that helps us understand the impact that climate change will have on the productivity, abundance and distribution of species we catch and the habitats and ecosystems that support them.

The second challenge is to improve our assessments and management so that they are able to utilise this additional information. This is not a trivial goal, but some of it can start now with incorporation of indicators such as $PUE to better capture economic indicators driving fishing operations and development and inclusion of fishing power time series in CPUE standardisations. Other aspects such as inclusion of the impacts of climate change will take much longer. In the meantime, we need to begin the process of significantly improving our harvest strategies so that they are appropriate with regard to sustainability and maximising economic yield in a multi-species context, but also robust to the uncertainties associated with climate change.

Recommendations

INTRODUCTION

As part of the Australian Government's 'Securing Our Fishing Future' initiative to ensure a sustainable and profitable industry, AFMA was, in 2005, required to end overfishing in Commonwealth fisheries, ensure that other stocks did not become overfished, and minimize fishing impacts on the marine environment. An industry buyback occurred during 2006–07. A decade later, it appears many of the sustainability issues have been addressed and although there is no fish stock solely managed by the Commonwealth that is assessed as being subject to overfishing, seven stocks are still assessed as overfished, having not yet shown significant evidence of recovery. The Southern and Eastern Scalefish and Shark Fishery (SESSF) also experienced significant improvement in net economic returns (NER) although this has declined in recent years.

Most of the SESSF sub-fisheries have suffered from declining Gross Value of Production (GVP), which impacts on vessel profitability. In the Commonwealth Trawl Sector (CTS) alone, GVP has fallen from $97.2 million in 2001–02 (2013–14 dollars) to $57.9 million in 2012–13 and $40.2 million in 2013–14; This has been largely attributed to reductions in catches of Orange Roughy, Blue Grenadier and Silver Warehou, under-catching of other TACs and generally lower fish prices, and has occurred despite increases in the prices of Tiger Flathead and Blue Grenadier. NER in the CTS was negative until 2005–06, rose to a peak of $7.3 million in 2010–11, dropped to $4.2 million in 2012–13, and was projected to fall to $1.4 million in 2013–14 driven by the lower GVP (Skirtun and Green 2015). In the Gillnet Hook and Trap Sector (GHTS), GVP dropped from a peak of $34.7 million in 2008–09 to $22.6 million in 2012–13 from a combination of reducing catch and decreases in the prices of Gummy Shark, saw shark, and various other species. The sector's NER has been negative since 2008–09 and fell further in 2009–10 following the introduction of spatial closures to protect Australian sea lions and dolphins (Skirtun and Green 2015).

There are three concerning trends in the fishery that may be contributing to declining NERs that warrant examination, including:

1. continued long-term CPUE declines for many key species;
2. lack of recovery of most overfished species; and,
3. significant (>50%) under-catch of TACs for most quota species.

Declining CPUEs

There has been a continual decline in catch rates for many quota species with a range of life histories. Similar trends in decline over the last two decades have been observed for Jackass Morwong, Redfish, Blue Eye Trevalla, Silver Warehou, Blue Warehou, John Dory and Ribaldo, despite the lowest historical effort and catch levels in the fishery. Unstandardised CPUE across the fishery has declined for several years hitting an all-time low in 2015 and has remained at this level in 2016. In a recent analysis of optimised CPUE standardizations for 23 species (including grouped species) and 43 different stocks, methods, or fisheries it was revealed that 29 of the 43 SESSF stocks had declining standardised catch rates in the last nine years subsequent to the fishery restructure and introduction of the Harvest Strategy Policy (2007-2015); (Figure 1; from Sporcic and Haddon 2016).

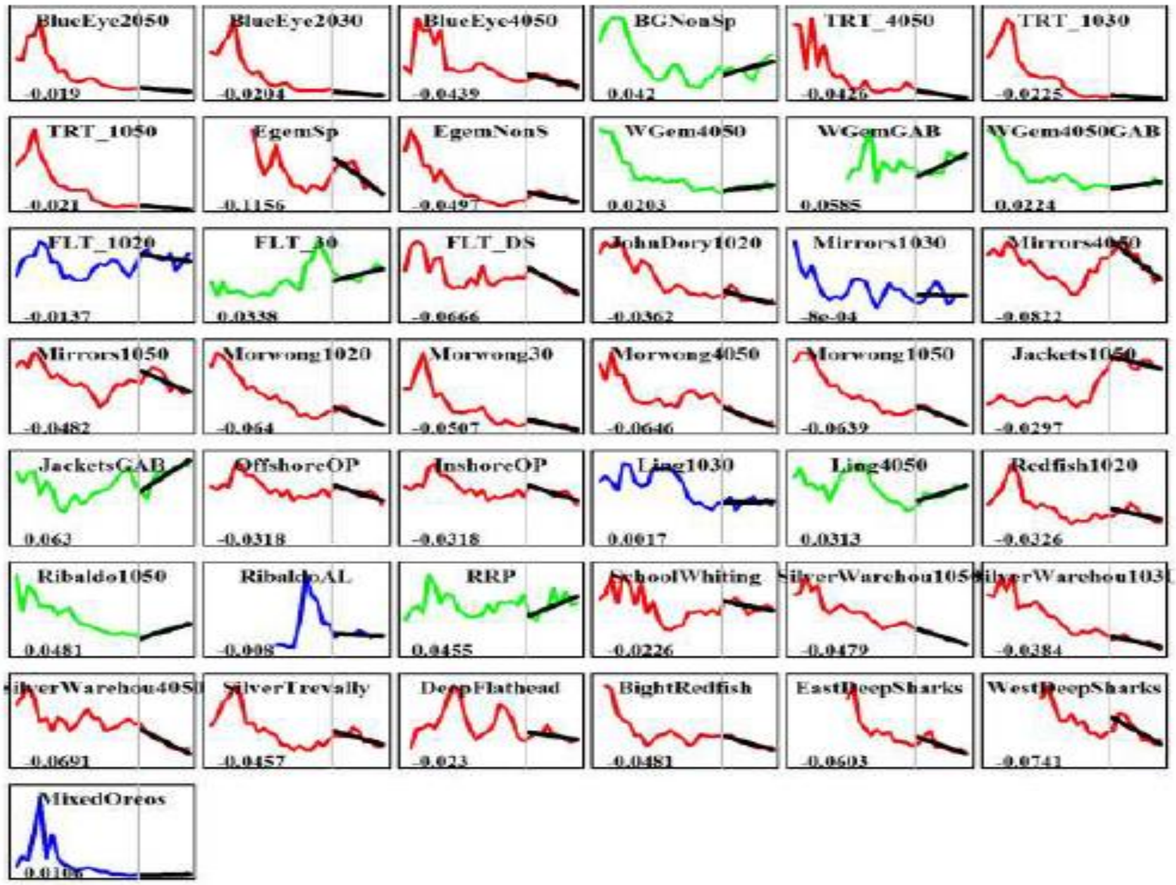

Figure 1. Summary graph of the optimum standardizations for 23 species (including grouped species) and 43 different stocks, methods, or fisheries, each with a linear regression across the last nine years (2007-2015). The gradient is at bottom left in each graph and the line colour reflects the gradient: green indicates a positive gradient > 0.015, blue a flat line with a gradient between 0.0149 and – 0.0149, and red indicates a negative gradient < -0.015. From Sporcic and Haddon (2016).

Lack of recovery of overfished species

The overfishing and subsequent recent recovery of the eastern Orange Roughy stock over the last two decades is well documented – but it is an exception. In contrast, other historically overfished species (Eastern Gemfish, School Shark, Blue Warehou and most recently Redfish) have shown little sign of recovery despite significant management changes under relevant rebuilding strategies (e.g. including bans on targeting, implementation of industry driven avoidance measures, and implementation of closures).

Failure to catch TACs

Finally, there is a failure to catch the TACs for many quota species. At the end of the 2015/16 year, 23 of the 34 species groups under TAC were less than 50% caught. Of the major quota species, only four had catches above 80% of the TACs (Flathead, Gummy Shark, Pink Ling and School Whiting).

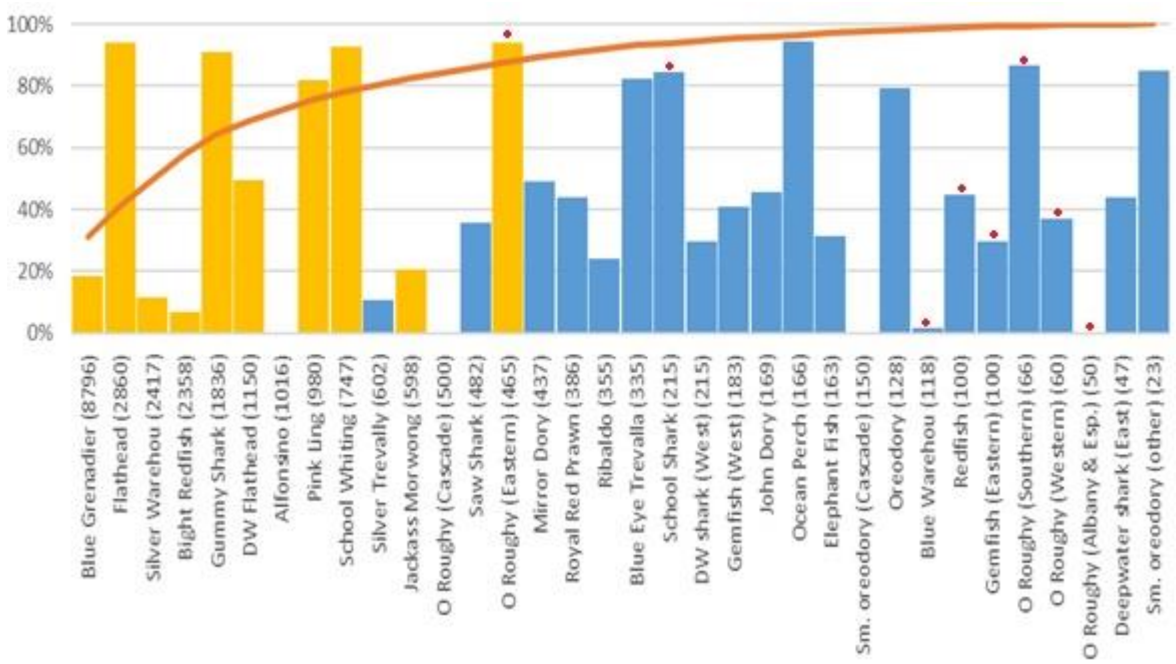

Figure 2. Percentage of the catch (t) versus TAC (tonnes in parentheses) for SESSF quota species during 2016, in order of TAC amount (high to low). Key commercial species (yellow) are contrasted with byproduct species (blue) with species under recovery plans highlighted (•). The orange line represents the cumulative catch. Data source – AFMA.

There are many and varied reasons put forward to explain these issues in the SESSF, but there has been no attempt at a coordinated approach to actually identify which factor/s may be the cause, much less how it may be addressed. This project has been designed to start this process by using the wide range of expertise (business, science, management) available across all facets of fisheries management (sustainability, economics and social) to consider and prioritise the potential range of underlying factors for under-caught TACs, declining catch rates and the failure of stocks to recover).

OBJECTIVES

1. Provide a range of papers with information on potential causes of under-caught TACs, declining catch rates and non-recovering species
2. Hold a workshop to discuss plausible reasons for under-caught TACs, declining catch rates and non-recovering species
3. Develop strategies to address the under-caught TACs, declining catch rates and non-recovering species-based outputs from Objective 1 and 2.
4. Develop a process for assessing non-rebuilding species.

METHODS

Highlighted as a priority over four years ago, this project has been a long time in development because different factions involved in the fishery had different – and strongly held – beliefs/opinions about the reasons underlying the negative indicators in the SESSF. This created a stalemate in proceeding (and obtaining support and funding for) any one particular area of research to address the issues. It became apparent that the only way to break this stalemate was to consider all of the potential reasons and have an independent/objective means of establishing which (one or more) may be the most likely cause, worthy of further research.

A workshop was held during 2015 to discuss the range of potential causes of the negative indicators. Acknowledging that there are considerable overlaps, seven main areas were identified – a brief description of each is provided below.

During the development of the proposal it was agreed that a team of authors would use a common template (Appendix 1) to produce a short paper on each of the potential causes described below. Once compiled, each of these papers was presented at the workshop where Ian Knuckey and an independent facilitator (Robert Stephenson) worked with the expert participants to prioritise the likely causes and develop an approach to begin to better understand and (hopefully) address the issues.

A brief summary of each of the issues and the authorship team is provided below. Coordination across these papers was facilitated by a Steering Committee consisting of Ian Knuckey (Fishwell), Simon Nicol (ABARES), George Day (AFMA), Rich Little (CSIRO), Simon Boag (SETFIA) and Nick Rayns (AFMA), with assistance from Nastaran Mazloumi (ABARES).

Legislative / management impediments

Lead author:	George Day
Co-authors / Industry advisors:	Simon Boag, Gerry Geen, Tony Harman, Beth Gibson, Geoff Tuck

The recent Productivity Commission (2016) report into fisheries revealed that policy settings are not maximising the value of fisheries to the community. In particular, most commercial fisheries are managed primarily though controls over fishing methods, which can inhibit fishers from introducing more innovative and cost-effective practices. Differences between the fishery management techniques adopted by Commonwealth and State governments add to the costs faced by fishers operating in cross-jurisdictional fisheries and to risks in managing the sustainability of stocks. In addition to output controls, the SESSF has a range of input controls that restrict fishing activities for various reasons. These include minimum mesh sizes, size limits, various spatial and temporal closures, bycatch reduction devices, bycatch limits, limited entry etc. Does the combination of these additional controls mean the fleet is unable to catch the TACs? Even if we just consider output controls managed by TACs, the different stock status of species in a multi-species fishery means that the low or bycatch TACs introduced for overfished or recovering species may significantly limit the fleets ability to target other quota species that are abundant in the same region.

Fleet capacity and characteristics

Lead author: Simon Boag
Co-authors / Industry advisors: Will Mure, Shane Duggins, Matt Koopman, Andrew Powell

The numbers of vessels in the fleet and associated fishing effort has reduced considerably since the 1980's particularly as part of the 2006 buyback. In the past, with many vessels operating out of each port, it is possible that fleets had more capacity to search and find aggregations of fish that all operators could then target. With many ports now only holding a few vessels, this searching capacity may be much reduced.

Fisher behaviour and vessel operation

Lead author: Emily Ogier

Co-authors / Industry advisors: Matt Koopman, Simon Boag, David Guillott, John Jarvis, Tom Bibbey, Gus Dannon, Will Mure

Increasingly, skippers now report that they are endeavouring to catch a "mixed bag" of fish to suit the market, or targeting particular species based on demand, rather than large catches by weight. This helps to maximise the value of the catch back to the boat. To this end, they are deploying generalist nets and spreading their effort across different depths and areas within their trips. Alternatively, they may target a particular species based on time year or market conditions.

Climate change and oceanographic conditions

Lead author: Alistair Hobday
Co-authors / Industry advisors: Rich Little, Ian Butler

Recent modelling of the oceanic conditions including movement of the East Australian Current and water temperature in south eastern Australia shows it to be one of the rapidly changing regions in the world. Fishermen know that temperature and oceanographic conditions affect where fish congregate and can be caught. There are very specific temperature-depth profiles at which some species are found in an otherwise highly variable oceanic region - are these changing to an extent where some species preferred habitat/conditions is moving outside the fishery? What is the likely impact of climate change on distribution, productivity and trophic structure shifts in the SESSF and is this causing the negative indicators?

Costs of production and changing markets

Lead author: Dave Mobsby

Co-authors / Industry advisors: Robert Curtotti, Anthony Ciconte, John Jarvis, Nigel Abery, Ingrid van Putten

Australia now imports 80% of its seafood. There is an abundance of low-priced aquaculture and/or imported fish available on the market. It has already been mentioned above that skippers now report fishing for a "mixed bag" of fish to suit the market. As a fishery that typically produced high volume, low-priced fish to the Melbourne and Sydney markets, is the SESSF suffering from this competition to an extent where the markets are impacting the level of catch that is economically caught by a vessel. These issues have been compounded by the misuse of Australian fish names with significant volumes of imported fish now being passed off as Australian species.

Quota ownership and trading

Lead author:	Sarah Jennings
Co-authors / Industry advisors:	Ingrid van Putten and Abul Bari / David Guillott, Gus Dannoun, John Jarvis, Tom Bibbey and Will Mure

Since the introduction of output controls through TACs and ITQs, the nature of quota ownership, trade and leasing has changed considerably and this in turn, has changed the nature of the fishery. At the outset, quota was almost exclusively held by owners and operators of fishing vessels. Over time there is a perception that there has been an aggregation of quota ownership as companies have become more vertically integrated and endeavoured to shore-up their access to supply. This movement, if it is occurring, means that less quota is now held directly by the harvesting sector. It may be that significant amounts of quota are owned by companies other than those who operate fishing vessels. The costs of quota leasing, and the efficiency of the market, may have impacted on access of the catching sector to quota.

The assessment process

Lead author:	Rich Little
Co-authors / Industry advisors:	Simon Boag; Tony Lavalle, Daniel Corrie, Geoff Tuck

Overarching all of the above issues is that current stock assessments may not have information available that enables them to consider the potential impact of the above factors on assessment results. A number of projects have endeavoured to look into some of these issues separately but without much success. Further, many of the lower tier (Tier 4) stock assessments have reference years that relate to a period over two decades ago, since which time the conditions in the fishery have changed considerably, potentially impacting on the suitability of such targets for the current fishery. The time-series catch rate index of abundance for some species such as School Shark and eastern Gemfish has been lost as fisheries no longer target the species and actively avoid areas where they might be caught. How much is this affecting the stock assessments and TACs that are derived from this assessment process?

A workshop involving researchers, managers and members of industry was held April 11+12, 2018. Participants are listed in the acknowledgements to this report. The seven research papers had been distributed in draft form prior to the workshop. Summaries of each paper, focusing on key questions were presented and discussed as follows:

- Authors of each paper put forward mechanisms by which their topic could contribute to each of the declining indicators
- Proposed mechanisms were discussed and clarified in discussion
- Participants ranked each proposed mechanism in an on-line survey using survey-monkey (Format and questions in Appendix 1)

In a facilitated discussion, the workshop participants then attempted to prioritize the seven themes and to rank the relative contributions of mechanisms in relation to the declining indicators.

RESULTS AND DISCUSSION

Legislative / Management Impediments

George Day, Simon Boag, Gerry Geen, Tony Harman, Beth Gibson, Geoff Tuck

SCOPE OF THE ISSUE

Legislative / management requirements have been implemented in the SESSF under a regulatory and policy regime that seeks to pursue AFMA's objectives including ensuring ongoing sustainability and maximising economic returns for the Australian community.

However, these technical management measures (gear restrictions) and input controls such as limited entry, trip limits and closures impact to some extent on SESSF operators' ability to catch Total Allowable Catches (TACs).

To investigate this issue, this paper outlines significant management changes implemented in the SESSF from 2005, before a period of structural adjustment in 2006, to 2017 in the context of changes in under-caught TACs over that period. Several under-caught TAC scenarios are outlined, recognising that some quota stocks are targeted whereas others are secondary stocks that are often not targeted.

Annual effort in terms of number of boats, hours trawled, hooks and net length set may be impacted by legislative / management requirements but are covered in the *Fleet capacity and characteristics* workshop paper and not addressed here.

The key management changes over the period are summarised in Table 1 and Figure 3**.** A more complete description of management events in the SESSF, along with current closures and indicative maps, is available here: http://www.afma.gov.au/fisheries/southern-eastern-scalefish-shark-fishery/.

IMPACT ON UNDER-CAUGHT TACS

Total catches of quota stocks in the SESSF have been between 30 per cent and 60 per cent below the fishery wide TACs during the period 2005-06 to 2016-17 (Figure 4. TACs (blue), catches (red) and under-caught TACs (green) in the SESSF 2005-2017.Figure 4). There was a marked increase in the total under-caught TACs over four fishing seasons from 32 per cent in 2011-12 to 58 per cent in 2014-15, stabilising at around this level over the last three seasons.

Table 1. Attachment A: Management Events Timeline

Date	Key management event (for a more complete list please refer to [AFMA website])
4 May 2005	Closure direction implementing: Murat Bay netting closure, 41° South, Victorian Marine Parks, East Coast Deepwater Sector trawl Exclusion Zone, shark pupping area closures (Head of the Bight, Seal Bay and Pages Island) and fisheries closures (Cascade Plateau, St Helens Hill)
14 January 2006	Trawl cod end to reduce bycatch (excluding Danish seine): 90mm single twine mesh; or double twine mesh of at least 102mm (4 inch) or greater; or 90mm double twine mesh with a bycatch reduction device.
June 2006	Structural adjustment: Australian Government *Securing our Fishing Future* voluntary fishing concession buyback.
June 2007	Batemans Marine Park from the high-water mark to 3nm. Approximately 850km^2.
28 June 2007	South East Commonwealth Marine Reserves network establishing 14 Commonwealth marine reserves covering approximately 388 464 km^2.
13 July 2007	• South East Trawl Deepwater Closure (waters generally deeper than 700m) closed to trawl fishing primarily to protect Orange Roughy. • Outside183m closure for gillnet and shark hook • Inside 183m closure for automatic longline • Shark hook and gillnet closures including Backstairs Passage, Kangaroo Island, West Coast Tasmania • Initial gulper shark closures (Southern Dogfish Closure of 1339 km^2 off Coffin Bay, the Endeavour Dogfish Closure of 507 km^2 off Sydney and the Harrisson's Dogfish closure of 1231km^2 off Flinders Island).
26 June 2010	Australian sea lion management strategy implemented with gillnet closures around colonies (6 300km^2) with additional triggered closures under the strategy.
December 2010	Additional Upper Slope Dogfish Management Closures: extension to the Sydney Endeavour Dogfish Closure and new closures: Babel Closure, Cape Barren Closure, Port MacDonnell Closure.
2011	Maximum gillnet length increased to 6 000m .
1 May 2011	Closed additional areas for Australian sea lions around colonies (18 500km2), allowed gillnet to hooks.
1 May 2011	School shark 20% ratio introduced.
22 September 2011	Dolphin gillnet Coorong closure and observation zone implemented.
January 2012	Lowered bycatch trigger levels for Australian sea lions.
6 February 2012	Australian sea lion adaptive management zone A closed for 18 months.
5 March 2012	Australian sea lion adaptive management zone B closed for 18 months.

6 April 2012	Australian sea lion adaptive management zone D closed for 18 months.
28 August 2012	Three-month Pink Ling spawning closures implemented in: Seiners Horseshoe, Everard Horseshoe, Ling Hole and Maria Island.
February 2013	Increased spatial closures to provide additional protection for upper slope dogfish. • New closures: Queensland and Brittania seamounts, Derwent Hunter Seamount, Murray Dogfish Closure. • Amendments: Endeavour Dogfish Closure, Harrison's Dogfish Closure, Barcoo and Taupo, Port MacDonnell. • Babel and Cape Barren closures connected to form the extended Flinders Research Zone closure.
10 April 2013	Western deep-water shark area adjacent to western King Island / western Tasmania opened with a 25 tonne Orange Roughy trigger.
1 July 2013	Maria Island Canyon, Seiner's Horseshoe and Everard Horseshoe closed to prevent targeting of Pink Ling.
26 September 2013	50kg Pink Ling daily limit implemented.
1 May 2014	250kg Pink Ling daily limited implemented (reduced to 50kg from 12 February 2015 – 19 May 2015)
6 September 2014	Gillnet Dolphin Strategy implemented allowing operators into the Coorong Zone under conditions.
1 May 2015	Requirement that live School Shark must be released.
1 May 2015	Targeted fishing for Orange Roughy eastern
1 May 2015	Hydraulic hand reel droplining allowed without a trigger on St Helens, Freycinet, Murray, Barcoo and Taupo, Murray Dogfish
20 May 2015	175kg eastern Pink Ling allowance.
27 May 2015	Implements eastern Pink Ling area closures for Maria Island, Seiner's Horseshoe, Everard Horseshoe unless boats have opted in to individual 25% eastern Pink Ling TAC limit.
16 January 2016	Australian sea lion adaptive management zone C closed for 18 months.
1 May 2016	Eastern Pink Ling daily catch allowance removed subject to SETFIA catch restrictions or opted in to individual 25% eastern Pink Ling TAC limit.
1 May 2016	• Shark hook allowed outside 183m. • West coast Tasmania shark hook and gillnet closure (130m - 183m) removed.
10 May 2017	Gillnet net length restrictions removed.
10 May 2017	Gillnet Dolphin Mitigation Strategy implements an individual accountability approach for dolphin interactions across the whole gillnet fishery, with management responses escalating to closures for fishers who are unable to minimise their interactions.
11 September 2017	Australian sea lion adaptive management zone D closed for 18 months.

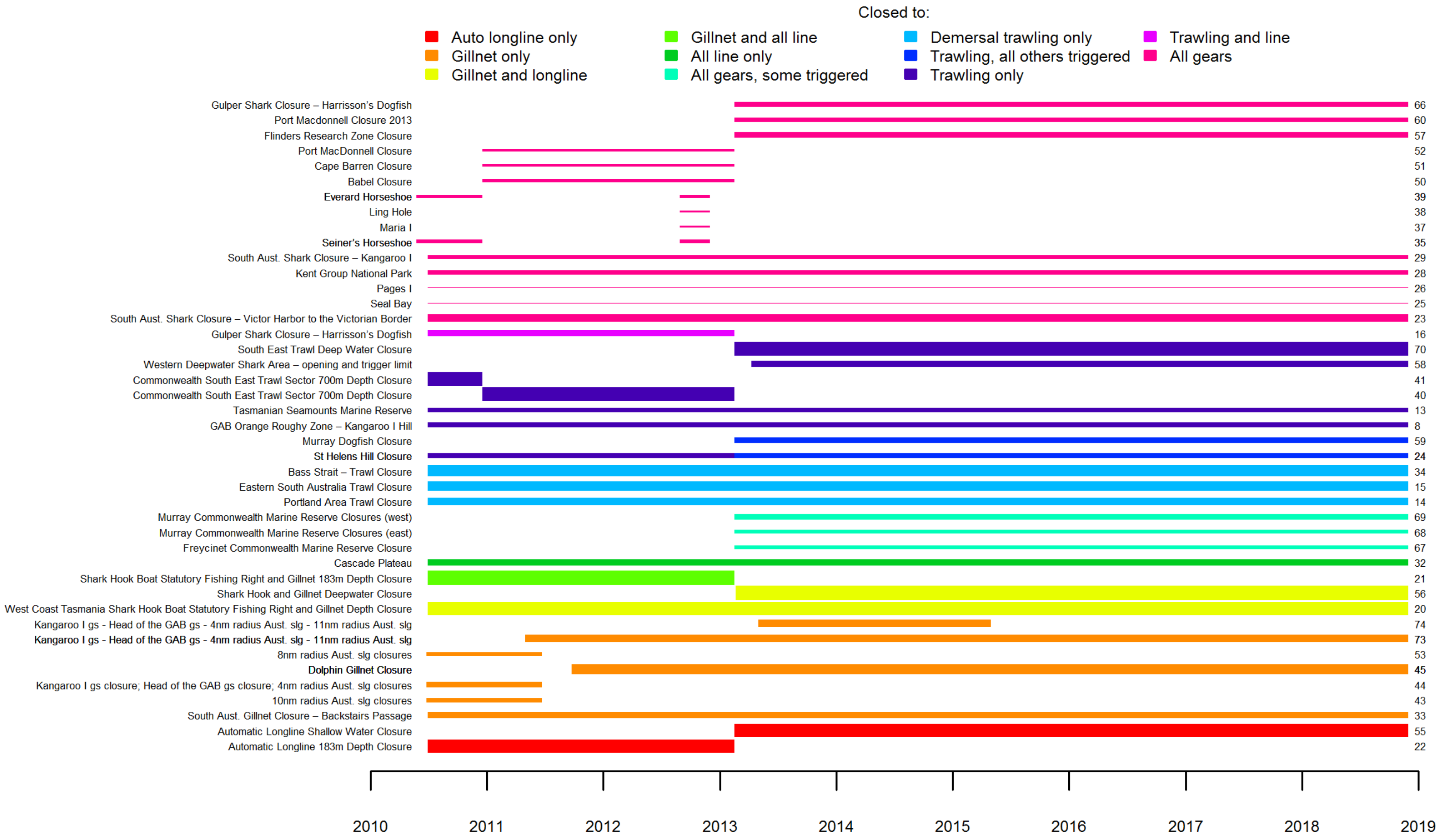

Figure 3. Attachment B: SESSF closures since 2010 (Pitcher 2015)

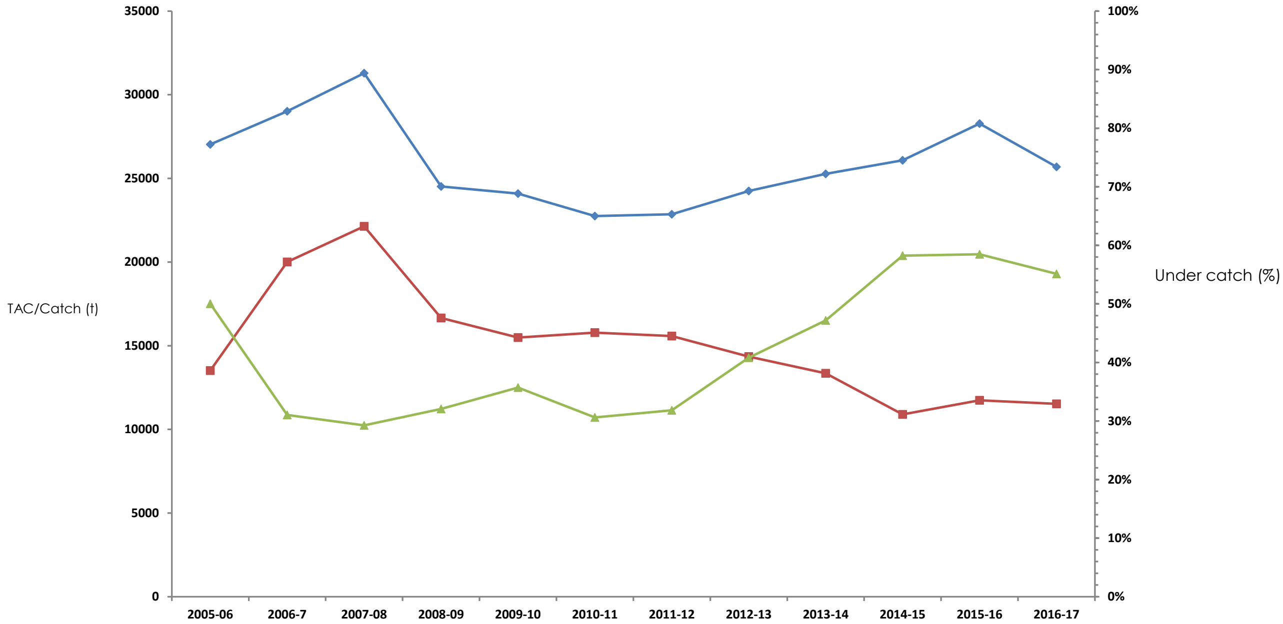

Figure 4. TACs (blue), catches (red) and under-caught TACs (green) in the SESSF 2005-2017.

The total under-caught TACs in the SESSF, and particularly the increase in under-catch from 2011/12 - 2014/15, is significantly driven by Blue Grenadier. The TAC of this stock is variable, driven by strong recruitment pulses, with high recent TACs of 8 765 tonnes, more than three times the next highest TAC in the SESSF of 2 712 tonnes for Flathead. Further, catches of Blue Grenadier are heavily influenced by operational and financial considerations and whether a foreign factory freezer vessel is available to fish the winter spawning fishery. Excluding Blue Grenadier from the analysis reduces the period of increasing under-caught TAC from four to three seasons (the under-caught TAC in 2014-15 reducing) and shows a reducing under-caught percentage over the last four seasons (Figure 5).

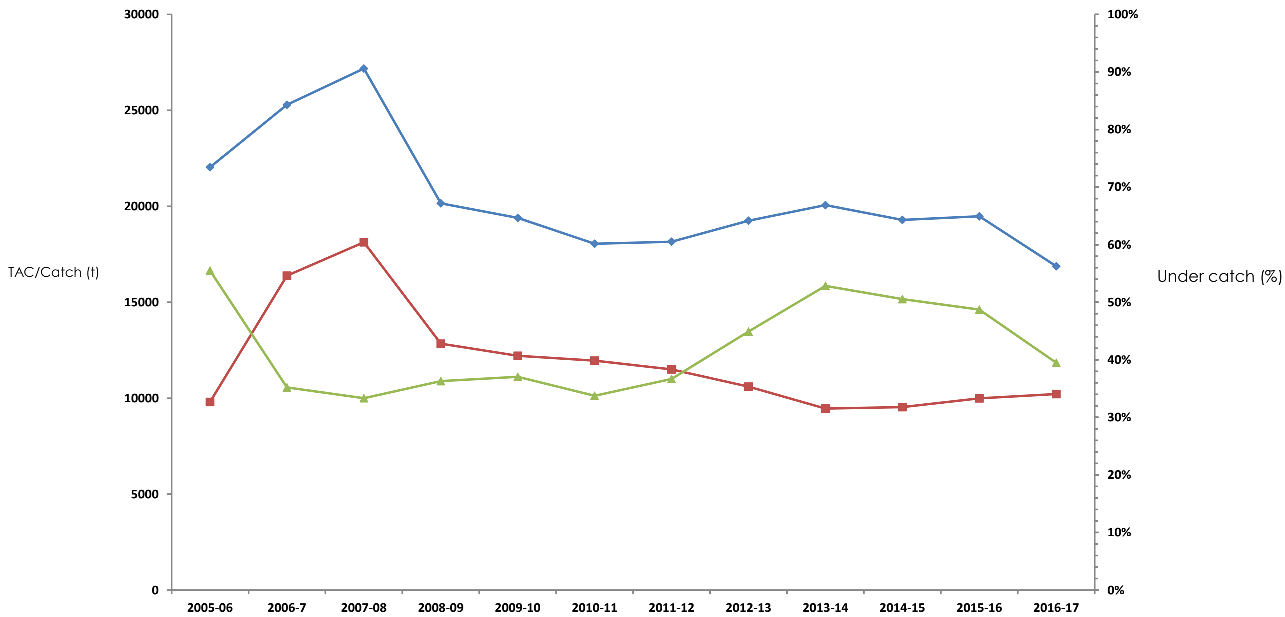

Figure 5. TACs (blue), catches (red) and under-caught TACs (green) in the SESSF 2005-17 excluding Blue Grenadier (recognising that Blue Grenadier under-catch is primarily for operational and financial reasons).

Focussing only on key economic stocks as proposed by the SESSF Monitoring and Assessment Project (Flathead, Gummy Shark, Pink Ling, Deepwater Flathead, Blue Eye Trevalla, Orange Roughy (eastern stock only), Eastern School Whiting, Bight Redfish and Silver Warehou but excluding Blue Grenadier) shows a lower average under-caught TAC over the period of 35 per cent (Figure 6). There is a still an increase in under-catch over three seasons from 2011-12 to 2013-14 but this is less pronounced with a reduction in under-catch in recent years and 2016-17 showing the lowest under-catch over the period of 23 per cent.

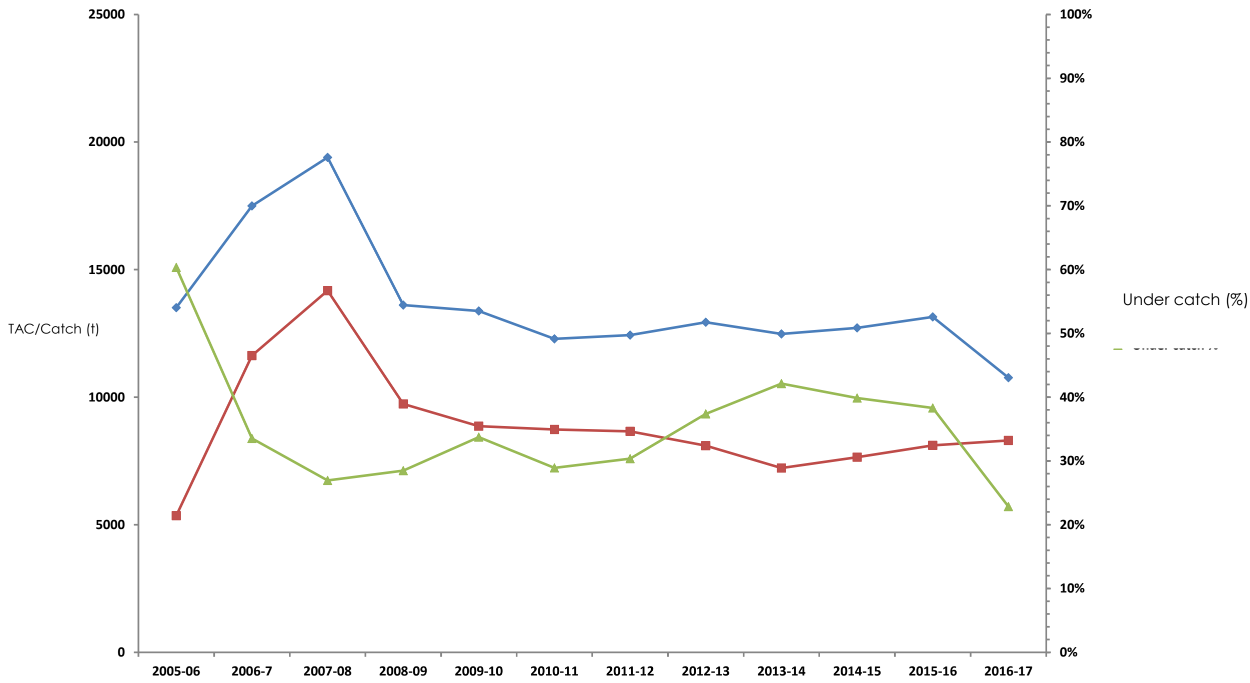

Figure 6. TACs (blue), catches (red) and under-caught TACs (green) for primary stocks (as proposed by the SESSF Monitoring and Assessment Project) in the SESSF 2005-17 (excluding Blue Grenadier): Flathead, Gummy Shark, Pink Ling, Deepwater Flathead, Blue Eye Trevalla, Orange Roughy (eastern stock only), Eastern School Whiting, Bight Redfish and Silver Warehou. Note that Orange Roughy eastern has only been targeted since 2015-16.

The under-catch of non-primary stocks shows an upward trend from 2005-2014 to a maximum of 71 per cent under-caught in 2014-15, levelling out in the most recent four seasons (Figure 7). As secondary species, however, the negative economic impact of this would be less than might be expected This suggests increased emphasis on primary target species, with reduced catches of the secondary species. Thus, the economic impact is less than might be thought from all species catch trends.

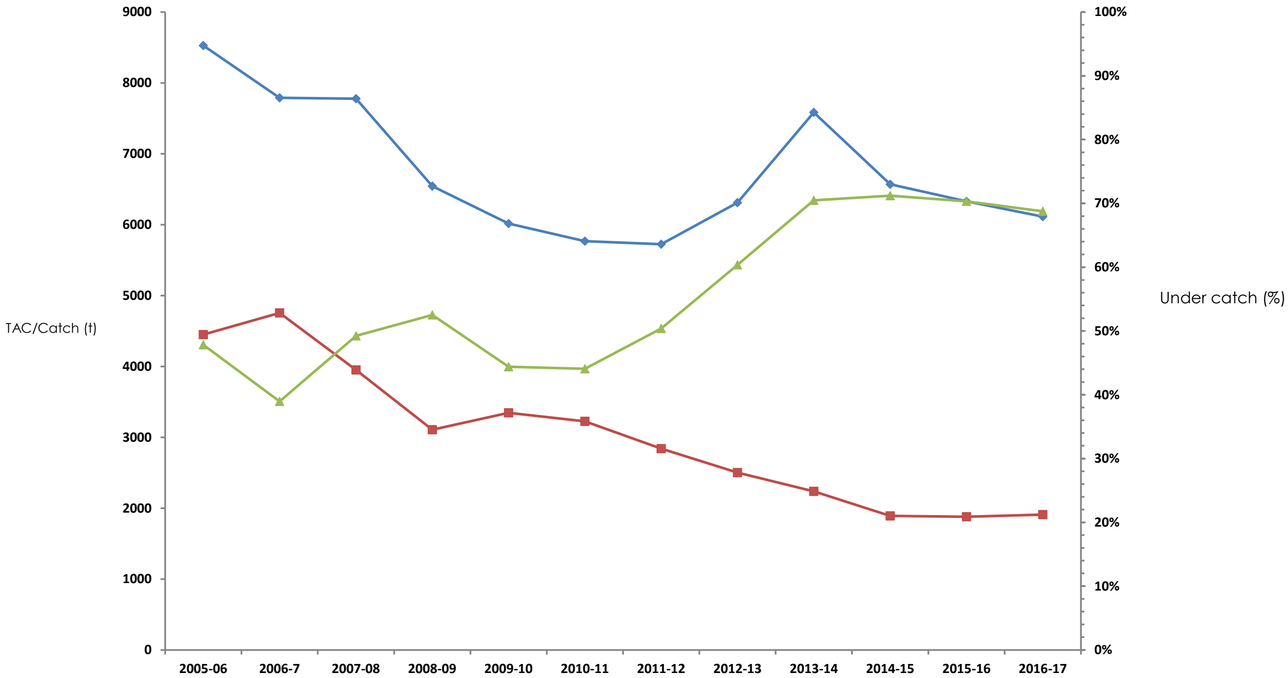

Figure 7. TACs (blue), catches (red) and under-caught TACs (green) for non-primary stocks (as proposed by the SESSF Monitoring and Assessment Project) in the SESSF 2005-17.

FISHERIES CLOSURES AND MARINE PROTECTED AREAS

The period between 2007 and 2013 saw significant areas of the SESSF closed through Commonwealth marine protected areas and fishery closures. An analysis of trawl closures in fishable depths (to 1500m), accounting for overlaps, was undertaken for closures up to 2013 (Pitcher *et al* 2016) finding:

- for the South East Trawl sector: approximately 46.7 per cent is closed (41.3 per cent by fishery closures and 8.5 per cent by marine protected areas)
- for the Great Australian Bight Trawl: approximately 21.9 per cent is closed (11.2 per cent by fishery closures and 12.3 per cent by marine protected areas).

In the Gillnet, Hook and Trap Sector considerable permanent closures have been adopted for gillnets around Australian sea-lion colonies (initially 6 300 km^2 in 2010 and then increasing to 18 500 km^2 in 2011), to protect dolphins (approximately 27 000 km^2 closed to gillnets from 2011 to 2014 off the Coorong) and Upper Slope Dogfish closures in 2010 and 2013 impacted line fishing.

In addition, adaptive management has led to temporary closures at both a fishery and boat level for interactions with Australian sea lions off South Australia (18 month triggered closures), interactions with dogfish in defined areas (12-month closures for automatic longline boats) and individual responses under the Gillnet Dolphin Strategy.

Key closures impacting the SESSF between 2005-17 were:

- June 2007 South East Commonwealth Marine Reserves Network (388,464km^2) (Figure 8).
- July 2007:
  - South East Trawl Deepwater Closure (waters generally deeper than 700m) closed to trawl fishing primarily to protect Orange Roughy.

  - Outside 183m closure for gillnet and shark hook.
  - Inside 183m closure for automatic longline.
  - Shark hook and gillnet closures including Backstairs Passage, Kangaroo Island, West Coast Tasmania.
  - Initial gulper shark closures (off Coffin Bay, Sydney and Flinders Island).
- December 2010: additional Upper Slope Dogfish Management closures: Babel Closure, Cape Barren Closure, Port MacDonnell Closure. Extension to the Sydney Endeavour Dogfish Closure.
- June 2010: gillnet spatial closures around Australian sea lion colonies covering 6 300km^2.
- April 2011: gillnet spatial closures around Australian sea lion colonies increased to 18,500km^2.
- September 2011: Dolphin gillnet Coorong closure and observation zone implemented.
- February 2012 - 17: a series of triggered 18-month gillnet zone closures to protect Australian sea lions (Figure 9):
  - 6 February 2012-15 May 2013 – Zone A
  - 5 March 2012 – 10 August 2013 - Zone B
  - 6 April 2012-23 August 2013 - Zone D
  - 16 January 2016 -18 June 2017- Zone C
  - 11 September 2017-9 March 2019– Zone D.
- February 2013: increased spatial closures to provide additional protection for upper slope dogfish. Babel and Cape Barren closures connected to form the Flinders Research Zone closure.

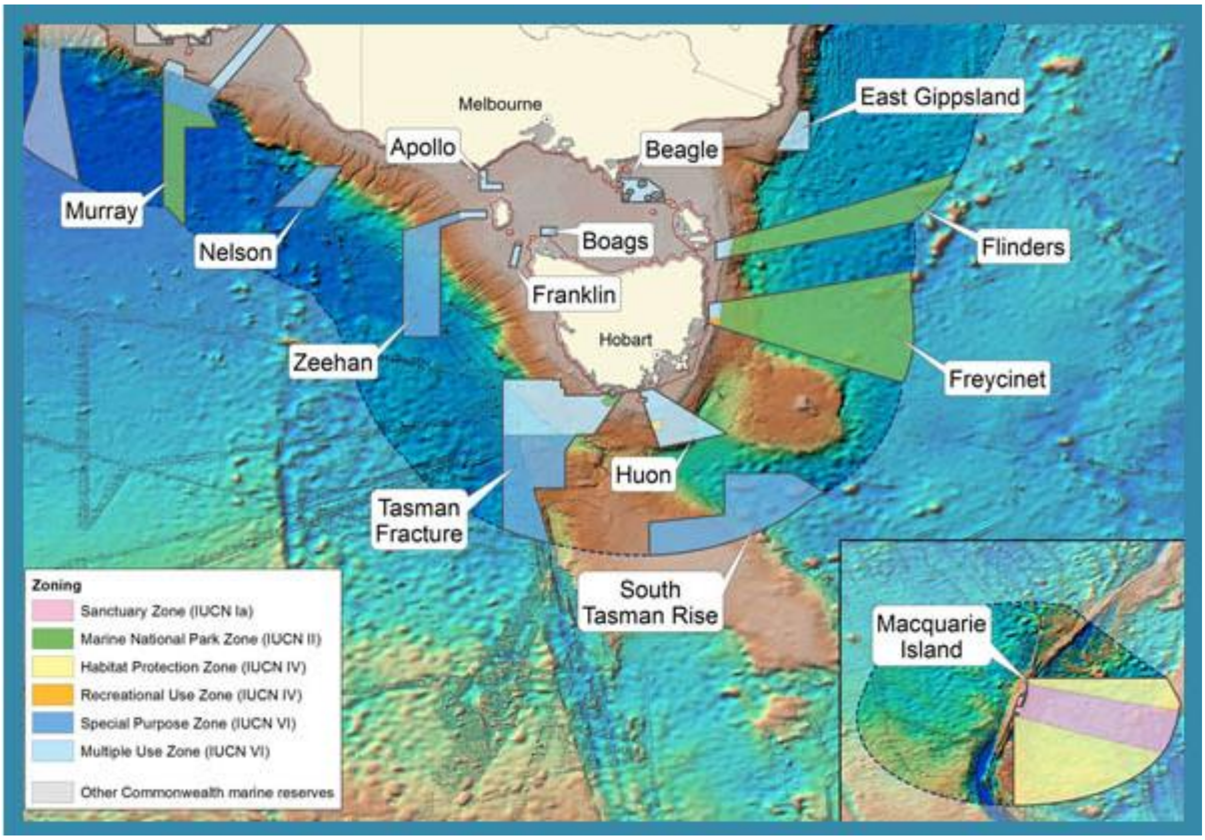

Figure 8. Closures applying under the South east Commonwealth Marine Reserves Network.

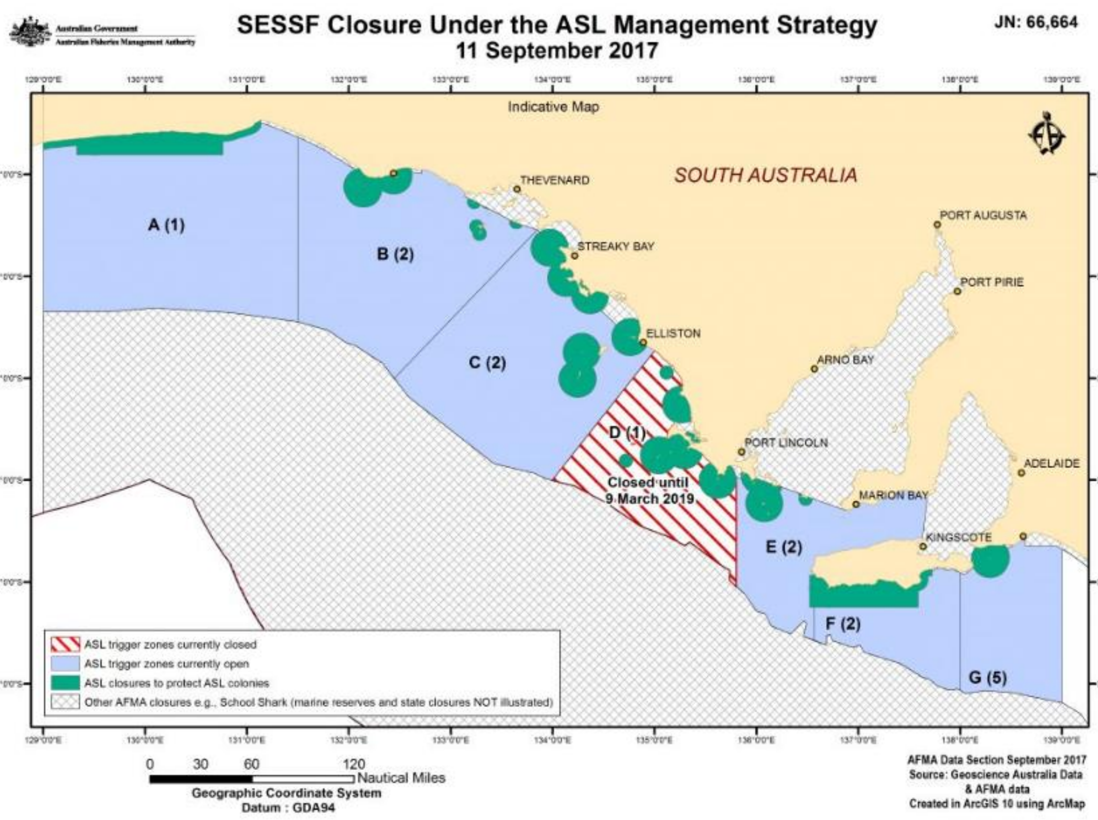

Figure 9. Australian sea lion trigger zones (Zone D is currently closed until 9 March 2019).

Area closures may impact under-caught TACs by:

- Reducing effort, with operators fishing less or ceasing to operate in the fishery (refer to *Fleet capacity and characteristics* workshop paper).
- Affecting the TAC level by biasing data used in assessment (refer to *The assessment process* workshop paper).
- Reduce CPUE, where productive grounds are closed or effort is concentrated in open areas leading to lower catch rates.
- Reducing catch, where, depending on mixing rates between open and closed areas, some fish will no longer be available to the fishery.

Across all quota stock categorisations (Figure 4 - Figure 7), the four seasons from 2010-11 to 2013-14 show a decrease in the proportions of TACs caught. This increase is primarily driven by the trawl stocks because:

- gillnet closures for Australian sea lions and dolphins impacted the GHTS in the waters off South Australia. However, there was limited impact in terms of under-catch of the key target stock Gummy Shark during this period with under-catch at 15 per cent for 2011-12 and 2012-13 and 18 per cent for 2013-14
- auto-longline closures in 2013, expanding the 2010 closures, impacted on areas available to target Blue Eye Trevalla and Pink Ling. However, both these stocks remained close to fully caught during these three seasons.

The biggest contributions to under-catch during this period are outlined in Table 2. Given that there was an increase in under-catch for all quota stocks except for Gemfish (western) and School Shark, it is possible that the extended upper slope dogfish closures affecting trawl during this time may have impeded catches of the TACs. However, it is unlikely to be the only reason; not all the species occur in these depths and the current TACs for the top two contributors to under-catch are now markedly lower than 2013-14 because of changes to the assessment:

- Bight Redfish TAC (now 800 tonnes) was reduced as a result of a revised assessment. The previous base case stock assessment (Klaer 2012) gave a much higher unfished female spawning biomass of 26,000 tonnes compared to the 2015 estimate of 5,451 tonnes because of a lack of contrast in available data
- Silver Warehou TAC (now 605 tonnes) was reduced as a result of a revised assessment using a low recruitment scenario.

Table 2. Stocks contributing to under-catch during three seasons from 2011-12 to 2013-14

2010-11 to 2013-14	Total undercatch	Increase undercatch
Bight Redfish	6,763,749	1,343,107
Silver Warehou	6,255,181	1,225,344
Blue Grenadier	4,057,623	871,240
Alfonsino	2,819,772	500,000
School Whiting	1,122,459	456,370
Redfish	967,636	393,765
Orange roughy (Cascade Plateau)	1,836,346	349,409
Royal Red Prawn	644,975	286,860
Gummy Shark	988,695	158,462
John Dory	567,125	147,854
Smooth Oreos (Cascade Plateau)	596,370	147,056
Deepwater Flathead	1,612,813	138,848
Silver Trevally	1,696,715	129,449
Pink Ling	74,674	91,398
Oreos	118,619	88,248
Flathead	464,681	81,151
Mirror Dory	2,287,658	76,294
Ocean Perch	181,739	66,212
Deepwater Sharks East	226,551	52,088
Jackass Morwong	660,036	51,253
Orange Roughy (Albany and Experance	200,000	50,000
Deepwater Sharks West	428,913	47,125
Smooth Oreos (other)	133,674	44,907
Blue Warehou	197,447	38,758
Blue Eye Trevalla	81,738	34,029
Orange Roughy (Western)	111,437	32,352
Orange Roughy (Eastern)	56,293	23,282
Saw Shark	231,617	19,634
Orange Roughy (Southern)	67,519	19,270
Ribaldo	148,465	17,271
Gemfish (Eastern)	115,504	9,530
Elephant Fish	80,311	5,183
Gemfish (Western)	220,518	-13,673
School Shark	40,859	-17,292

Of the non-primary stocks, the largest contributor to under-catch over the period 2005-17 was alfonsino with 7,369 tonnes of under-catch (Table 3). This stock has not been targeted, with zero catches in the last three years and reports from industry that this is for operational and financial reasons precluding them going out to the main fishing grounds. Redfish (4,416 tonnes under-caught) and mirror dory (4,355 tonnes under-caught) are the next largest contributors, each with large TACs set during the early years of the period which were not caught. It is worth noting that over the last decade, both of these assessments have had difficulties with conflicts between ageing data and CPUE data and therefore the results of Tier 3 and Tier 4 assessments, respectively. A significant portion of the undercatch over the last decade has resulted from Tier 3 assessments (based on age) suggesting much higher TACs (ultimately undercaught) than those derived from the Tier 4 assessments (based on CPUE). Such conflicts can only really be dealt with when a Tier 1 assessment is applied, enabling comparison and appropriate consideration of the conflicting data. For example, in the 2011 stock assessment of Redfish, the Tier 3 method yielded a 1569 t TAC whereas the Tier 4 assessment projected an RBC of zero. Only when a Tier 1 assessment was carried out in 2017 was this conflict able to be reconciled (e.g. Tuck et al 2017) leading to a zero RBC.

Table 3. Non-primary stock contribution to under-catch over the period 2005-17 in kilograms

Species	Undercatch 2005-17
Alfonsino	7,369,450
Redfish	4,415,870
Mirror Dory	4,355,630
Orange roughy (Cascade Plateau)	4,273,830
Silver Trevally	4,174,349
Royal Red Prawn	2,980,782
Jackass Morwong	2,939,507
Saw Shark	1,620,099
Ocean Perch	1,464,789
John Dory	1,458,502
Smooth Oreos (Cascade Plateau)	1,320,859
Blue Warehou	1,279,425
Ribaldo	1,113,676
Gemfish (Western)	1,051,339
Deepwater Sharks West	946,379
Orange Roughy (Western)	750,928
Oreos	635,047
Orange Roughy (Albany and Experance)	574,544
Elephant Fish	476,477
Deepwater Sharks East	439,078
Gemfish (Eastern)	399,512
Smooth Oreos (other)	368,869
School Shark	346,409
Orange Roughy (Southern)	204,831

OTHER INPUT CONTROLS AND TECHNICAL MEASURES

Input controls other than closures and technical measures are included in Table 1. The impact of limited entry and structural adjustment will be considered in the workshop paper *Fleet capacity and characteristics.*

Size limits and the majority of gear requirements (e.g. mesh size) had been implemented before 2005. However, in 2006 cod end requirements implemented for trawl fishing changed from 90mm to: 90mm single twine mesh; or double twine mesh of at least 102mm (4 inch) or greater; or 90mm double twine mesh with a bycatch reduction device. These were implemented particularly to reduce the wasteful practice associated with discarding (and hence mortality) of undersized quota species and other bycatch (Knuckey and Ashby 2009; Walker et al. 2010).

The changes to input controls and technical measures most likely to have impacted TAC under-catch over the period 2005-17 are:

- arrangements for rebuilding School Shark:
    - in May 2011 the maximum ratio of 20% School Shark to Gummy Shark restriction was implemented
    - from May 2015 all live School Shark were required to be returned to the water
- arrangements to limit catches of eastern Pink Ling: in additional to closures in areas to limit targeting:
    - October 2013: daily catch limit of 50kg
    - July 2014: daily catch limit of 250kg (reduced to 50kg from 12 February 2015 – 19 May 2015) or opt in to eastern Pink Ling catch limit of 25% of their individual quota
    - May 2015: daily catch limit of 175kg or opt in to individual 25% eastern Pink Ling TAC limit
    - May 2016: eastern Pink Ling daily catch allowance removed subject to SETFIA catch restrictions or opt in to individual 25% eastern Pink Ling TAC limit.

IMPACT ON DECLINING CPUES

Legislative / management restrictions could reduce CPUE where productive grounds are closed or effort is concentrated in open areas leading to lower catch rates. Management restrictions, for example preventing targeting of some stocks, may also be impacting CPUE as a reliable index of abundance where this behaviour cannot be accounted for in standardisation.

An empirical examination of the effect of marine closures on CPUE standardisation has been undertaken by Haddon (in prep)for Tiger Flathead, Pink Ling and John Dory. This work found barely any impact of closures on standardisation approaches for these stocks, primarily because the closures considered represented only a small proportion of the catching area and an equivalently small proportion of the catch (see Table 4 - Table 8).

Haddon also considered the auto-longline fishery for Blue Eye Trevalla where closures such as the Flinders Research Zone had more impact, accounting for 20% of the catch in Zones 20 and 30. Again the impact of closures on CPUE was limited, and it appeared that vessels and their skippers were capable of rapidly adapting to the advent of even effectively large closures so that any potential effects they might have are masked by the vessels altering their fishing behaviour and moving to alternative fishing grounds.

IMPACT ON LACK OF RECOVERY OF OVERFISHED STOCKS

In some circumstances, technical gear requirements and management arrangements that permit the catch and discarding of overfished quota stocks may impact on their recovery. However, advice from Resource Assessment Groups using available assessments and indicators is that current levels of fishing mortality have been reduced to very low levels and arenot preventing recovery.

Advice from the South East Management Advisory Committee in February 2018 was that, if fishing mortality is required to be reduced further to allow recovery, the most appropriate mechanism to achieve this is through input controls or technical measures rather than reductions in the incidental bycatch TAC.

WORKSHOP FEEDBACK AND CONCLUSIONS

Area closures (either by removing productive grounds or limiting catch) were considered to be major contributors to under-caught TACs (Figure 10, Figure 11). The impact was thought to be greatest for Ribaldo, deepwater sharks, royal red prawn and Silver trevally (Figure 12). Of other technical measures, day/trip catch limits were also considered to be a likely contributor, but gear controls less so.

Technical measures (allowing discards and bycatch) and insufficient area closures were seen as potential mechanisms for the lack of recovery of over-fished species, but workshop participants assessed the potential impact as moderate (Figures 14-16).

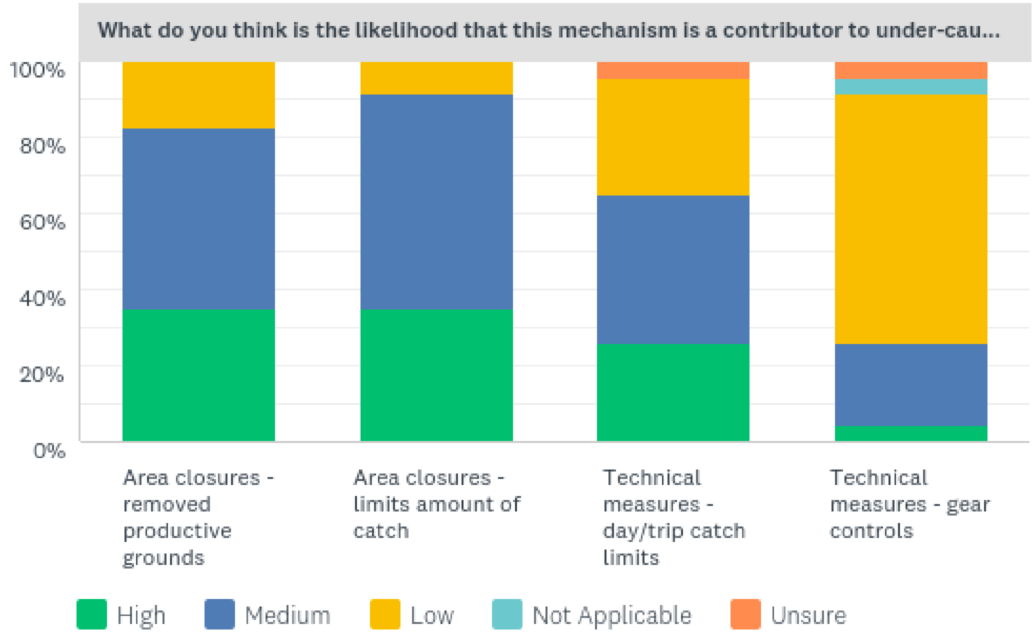

Figure 10. Workshop participant assessment of the likelihood that these management mechanisms are contributors to under-caught TACs.

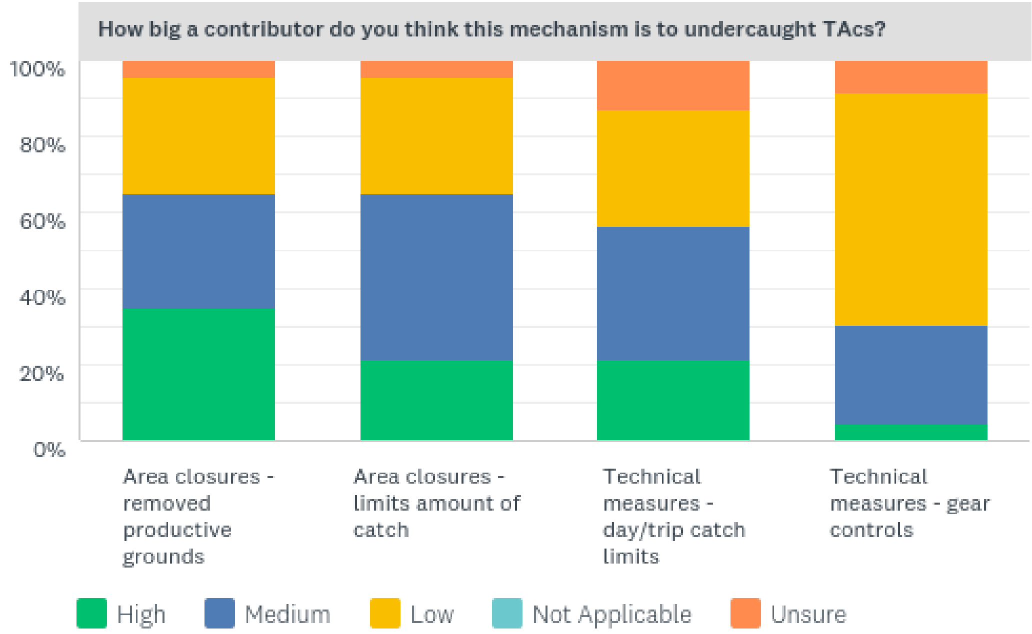

Figure 11. Workshop participant assessment of how big a contributor these management mechanisms are to under-caught TACs.

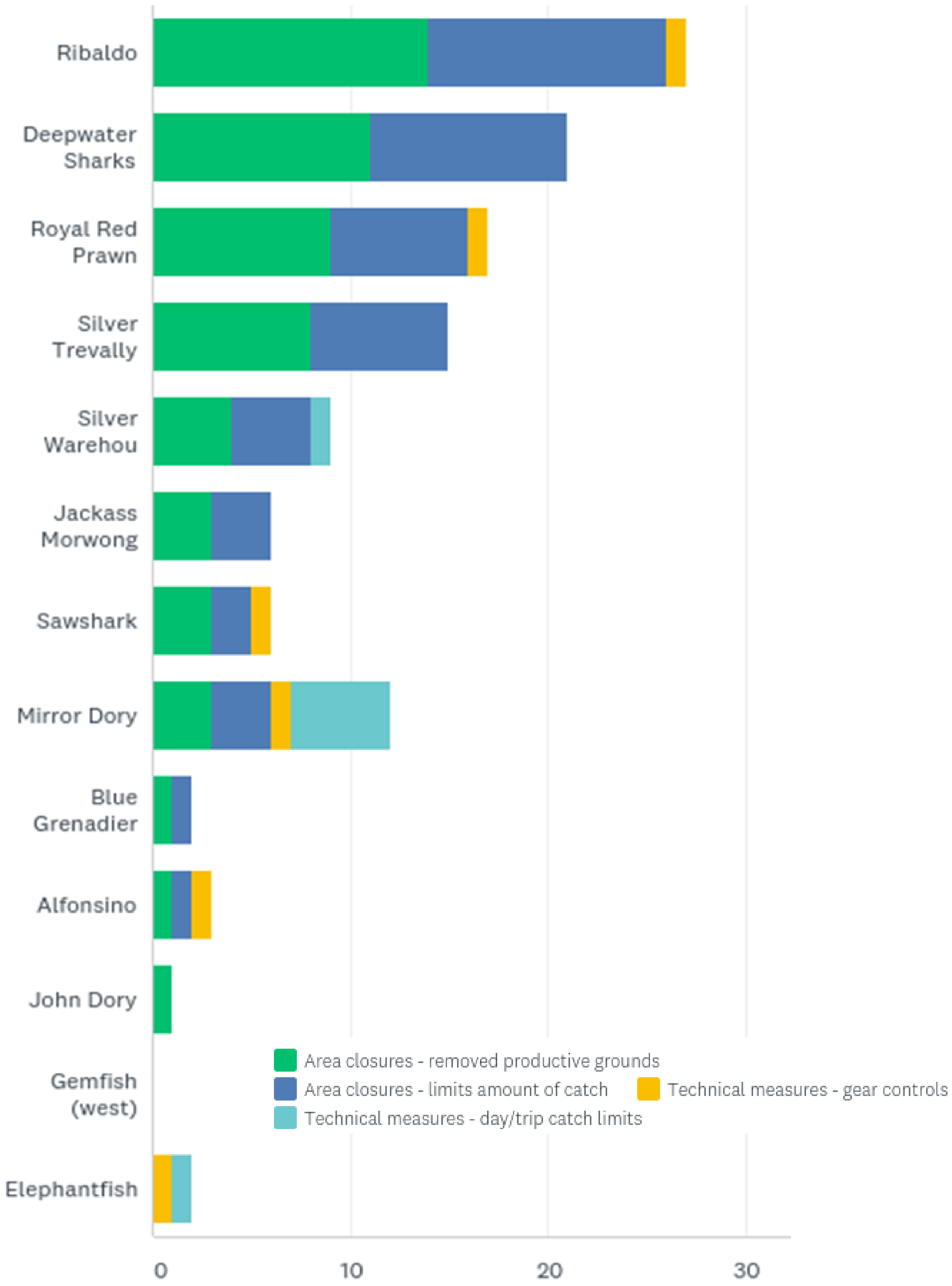

Figure 12. Workshop participant assessment of which particular mechanism are relevant to the under-caught TACs of specific species.

Participants considered that area closures (by concentrating effort, removal of productive grounds, or limiting the amount of catch) and that day trip catch limits were the most likely mechanisms that might impact declining CPUE (Figure 13, Figure 14) and that this would be most relevant to Silver trevally and Ribaldo (Figure 15).

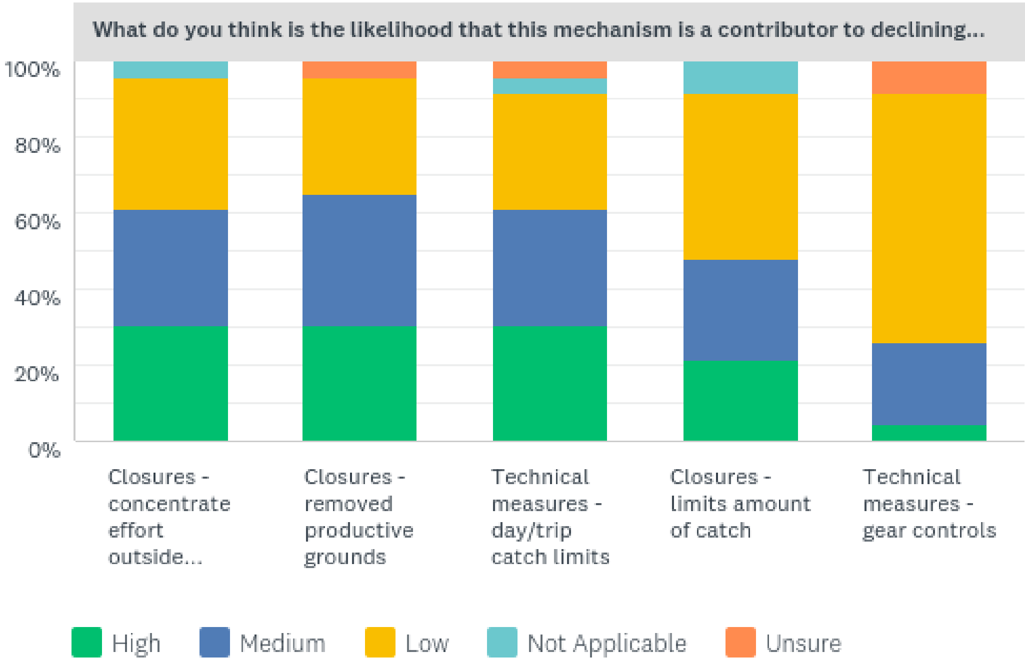

Figure 13. Workshop participant assessment of the likelihood that these management mechanisms are contributors to declining CPUEs.

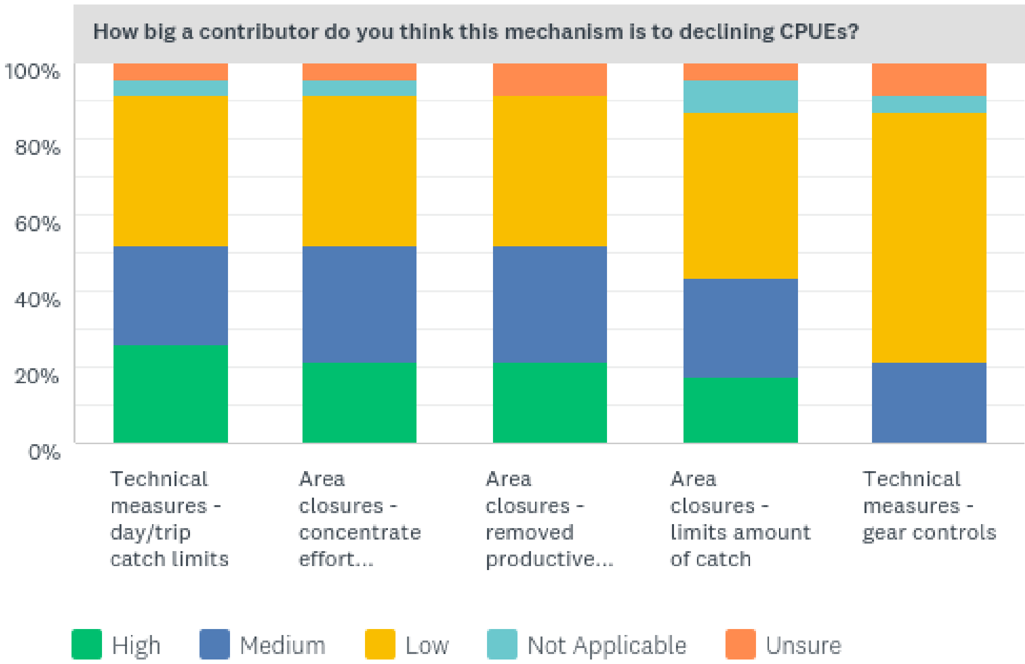

Figure 14. Workshop participant assessment of how big a contributor these management mechanisms are to declining CPUEs.

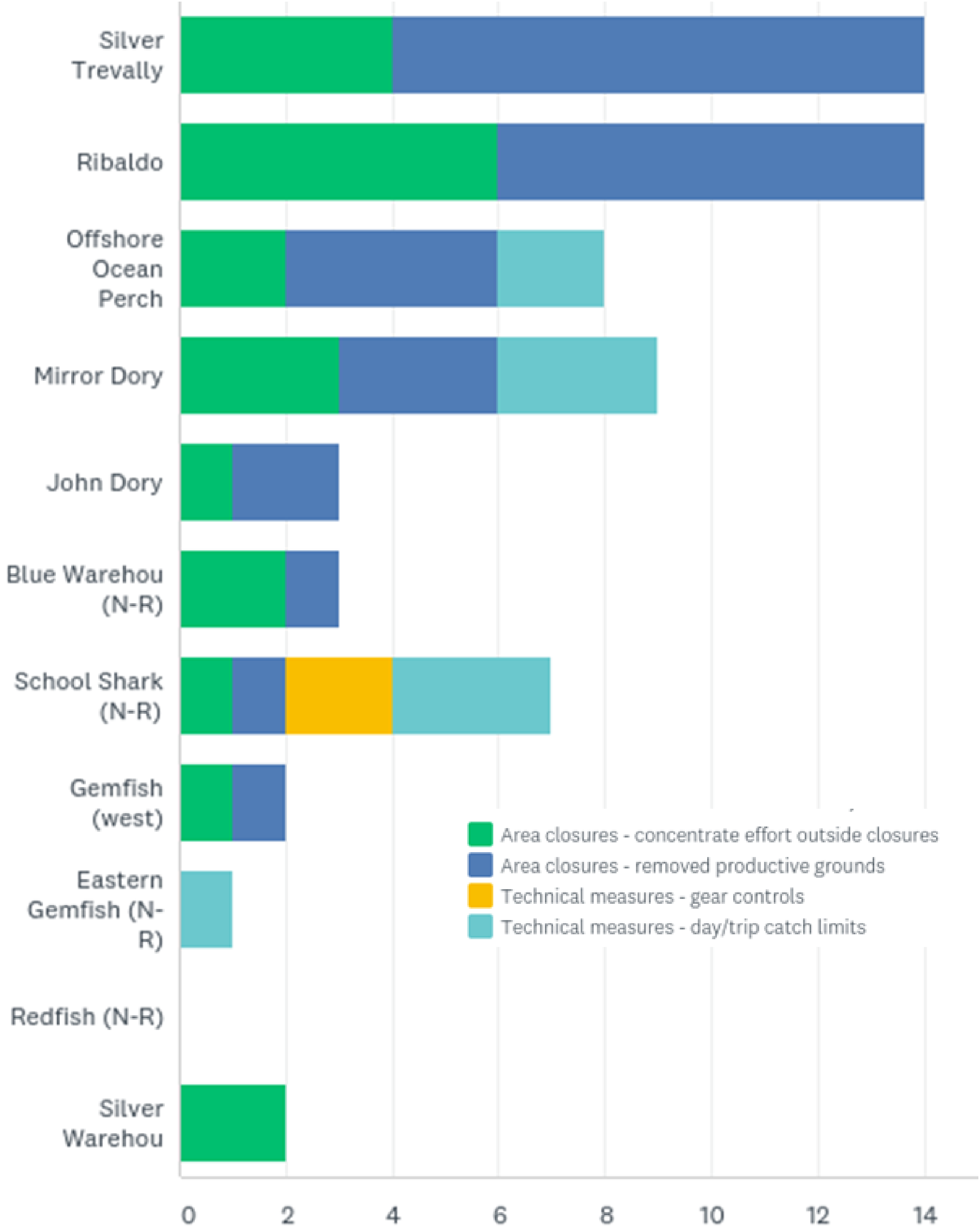

Figure 15. Workshop participant assessment of which particular mechanism are relevant to the declining CPUEs of specific species (N-R = Non-recovering).

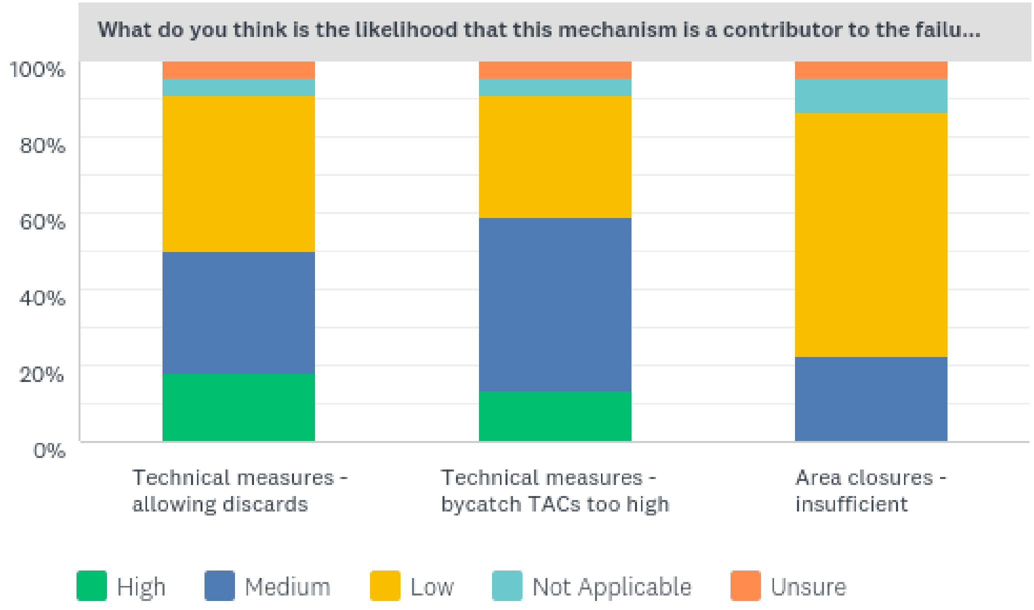

Figure 16. Workshop participant assessment of the likelihood that these management mechanisms are a contributor to the lack of recovery of over-fished species.

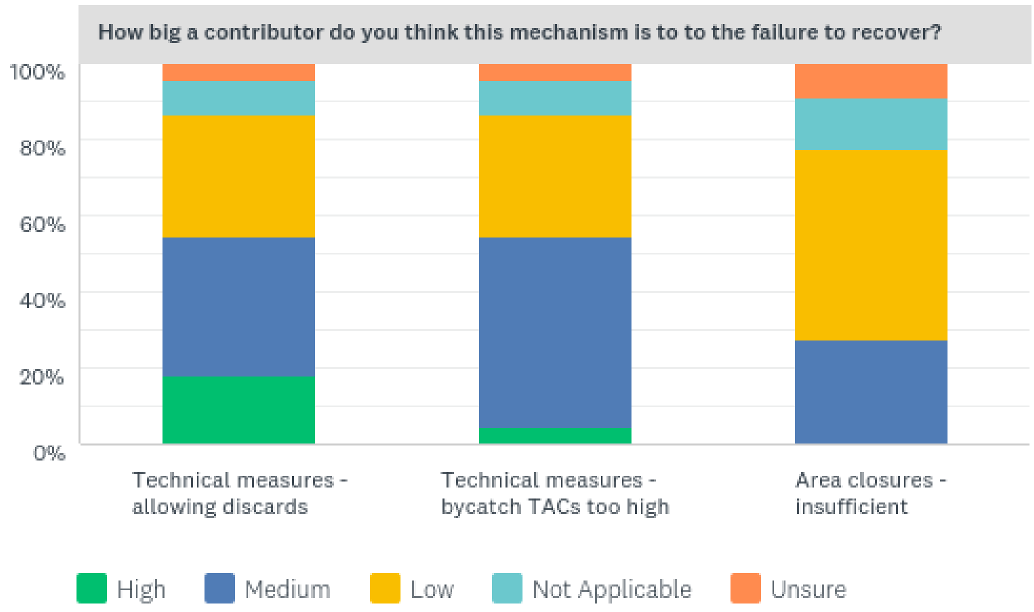

Figure 17. Workshop participant assessment of how big a contributor these management mechanisms are to lack of recovery of over-fished species.

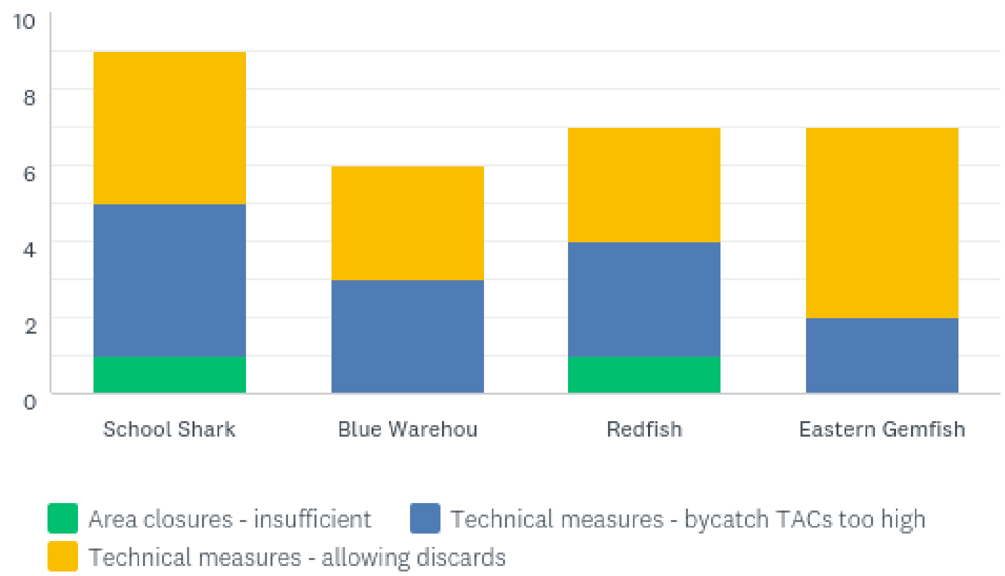

Figure 18. Workshop participant assessment of which particular mechanism are relevant to the lack of recovery of over-fished species.

Of the potential mechanisms in this section, the impact of area closures on CPUE was deemed most likely by workshop participants (see Figures 17 to 24). Some assessment methods (eg. Tier 4) have been modified to take this effect into account through filtering of the data, including closure in the standardisation, and a combination of both (e.g. the impact of the 700m closure on deep-water sharks; Sporcic and Haddon 2018).

The input controls and technical measures introduced over the period 2005-17, however, do not have a clear link to increases in under-catch in the SESSF with the timing of most large fishery closures and marine protected areas not aligning with increased under-catch. This is supported by an empirical examination of the effect of marine closures on CPUE standardisation on four stocks in the SESSF which found no evidence of a substantial impact of closures on CPUE or catch (Haddon in press). The period of increasing under-catch (2010-11 to 2013-14), however, did see an increased under-catch for all species except Gemfish (western) and School Shark. This may indicate that extended closures for the protection of upper slope dogfish during this period led to increased under-catch in the trawl sector. There are likely to be a combination of reasons for the under-catch; not all species affected are caught at the relevant depths and the under-catch associated with some species is likely the result of changing assessment methods resulting in higher TACs.

Separate consideration of primary stocks and secondary stocks indicates that the SESSF operators have become more focussed on economic drivers with secondary stocks becoming further under-caught over the period from 2005-17. In this context, the upcoming review of the SESSF Harvest Strategy Framework should consider the appropriateness of TAC setting for secondary stocks and whether the risk-catch-cost trade-off is being appropriately applied.

Consideration should be given to stocks for which no plausible explanation of under-catch has yet been identified (e.g. royal red prawn, saw shark, ribaldo, Gemfish west and deep water shark west). It may be appropriate to highlight these species for further consideration.

Fishery closures by sector

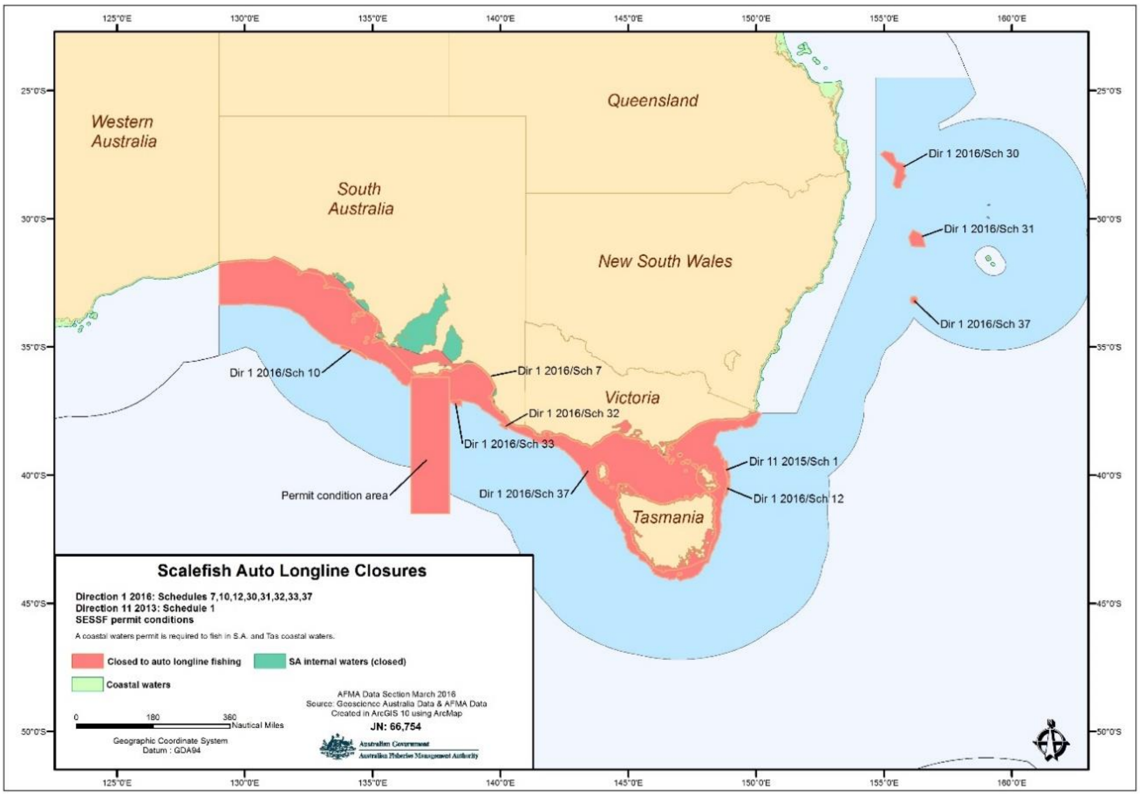

Figure 19. SESSF Scalefish autolongline closures

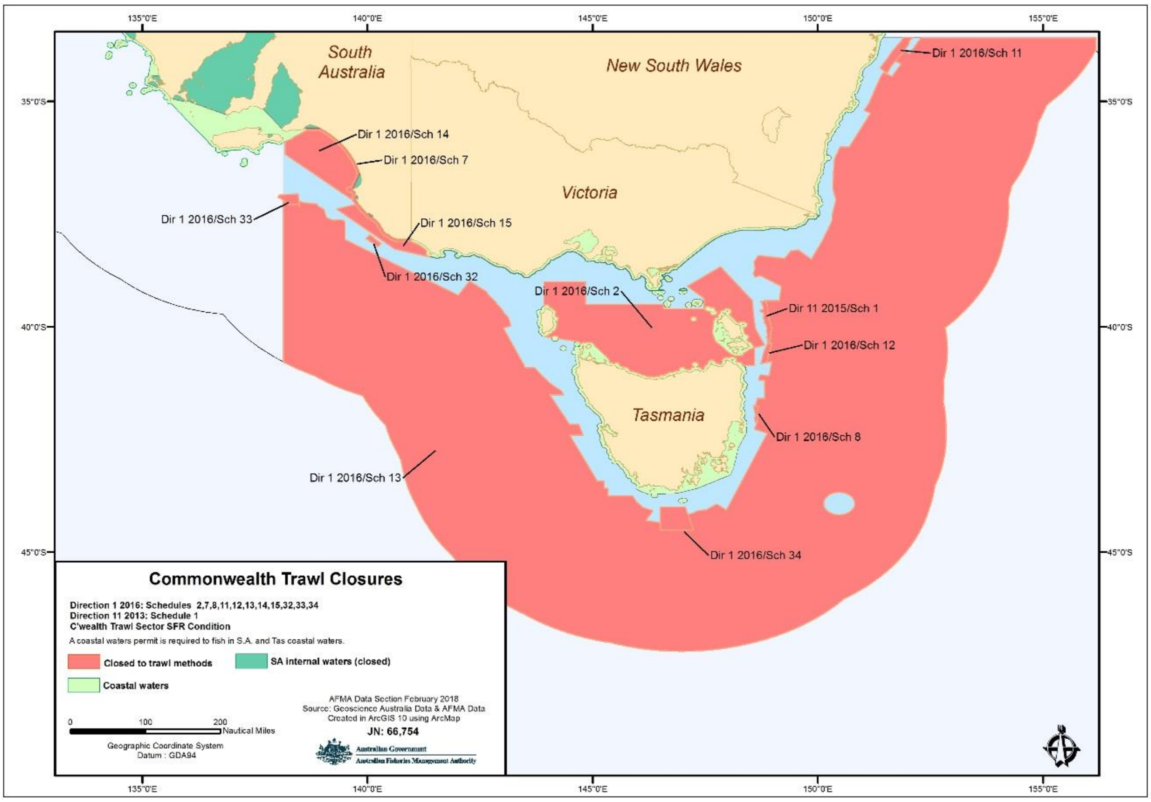

Figure 20. SESSF Commonwealth Trawl closures

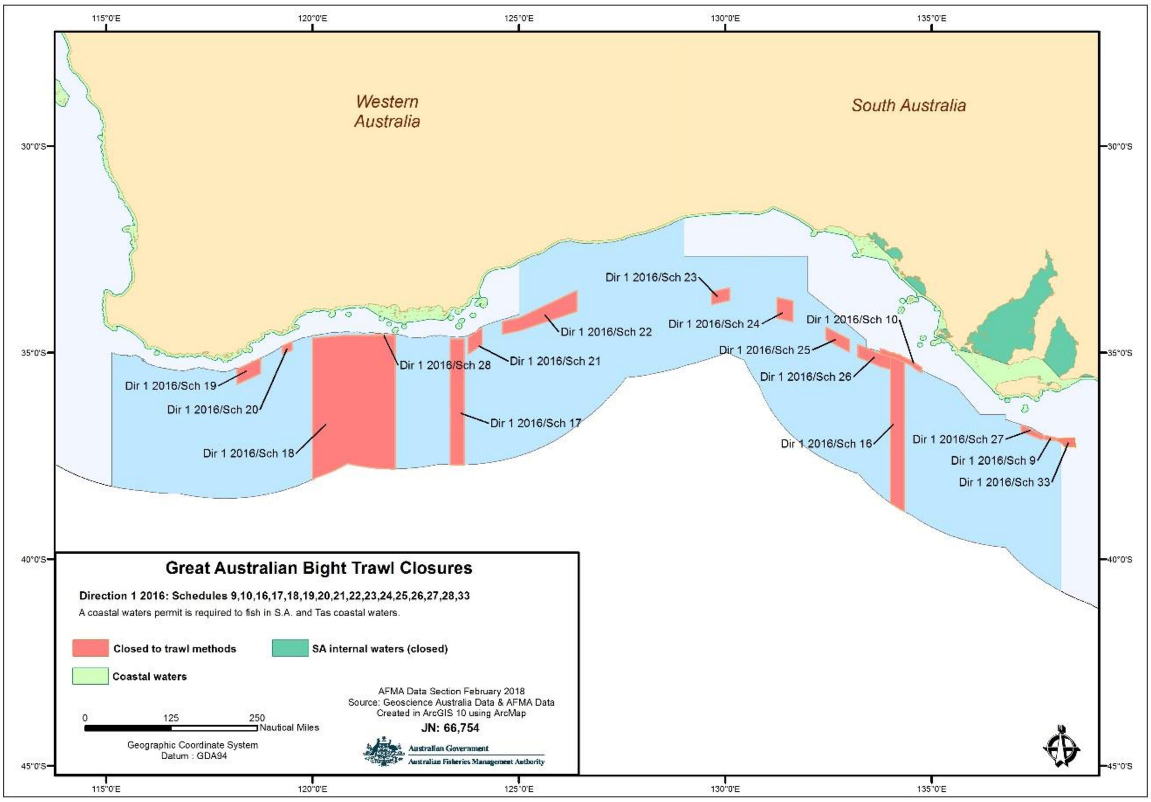

Figure 21. SESSF Great Australian Bight Trawl closures

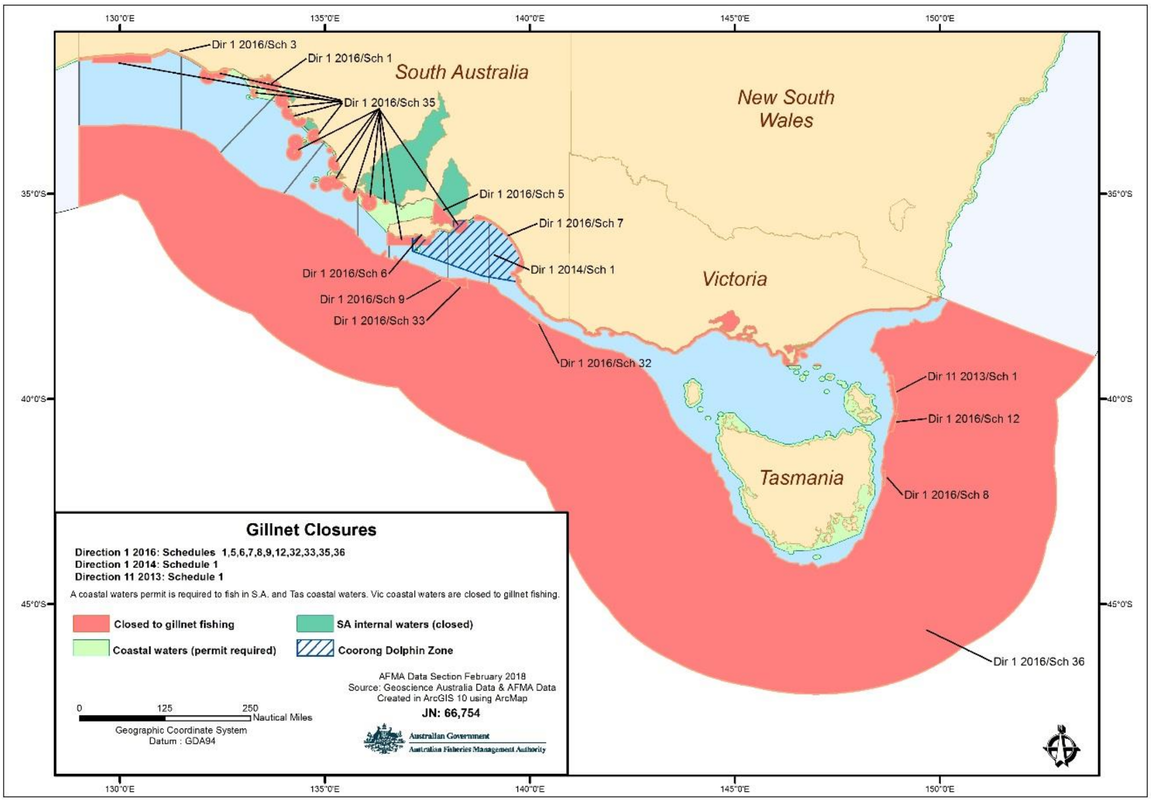

Figure 22. SESSF Gillnet closures

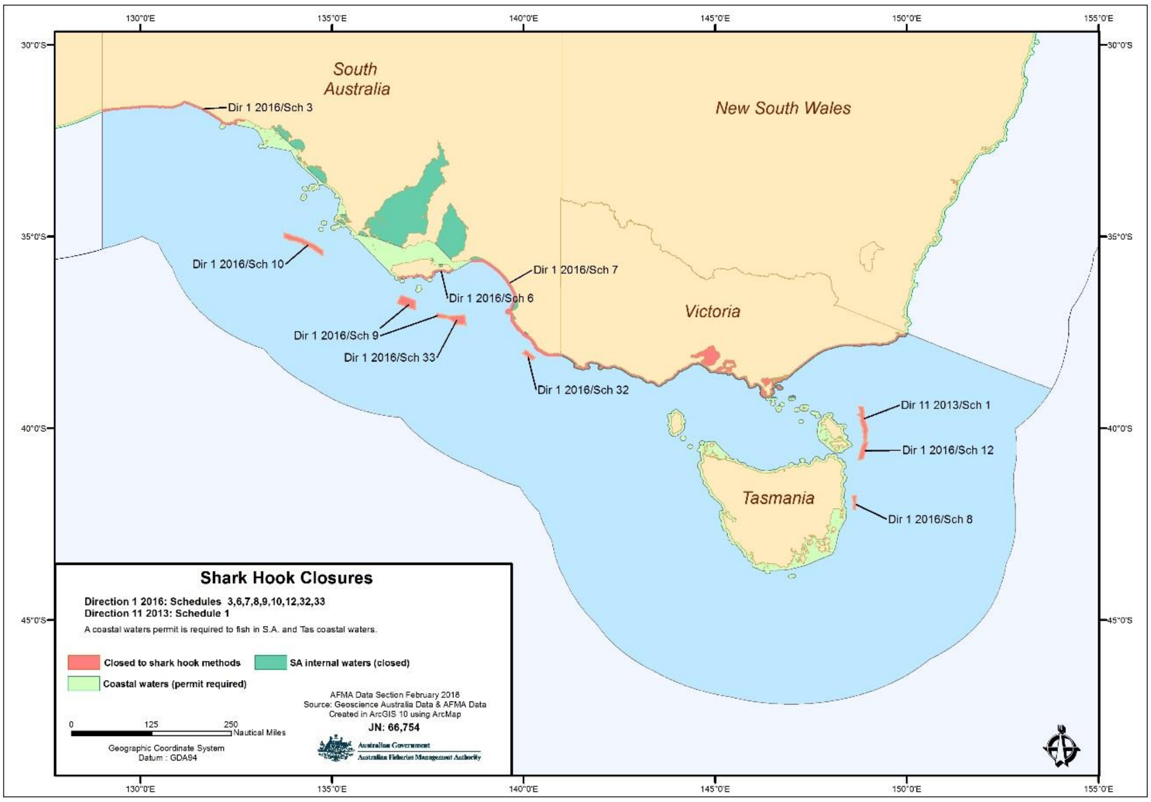

Figure 23. SESSF Shark Hook closures

Figure 24. SESSF Scalefish hook closures

Table 4. The total number of records and catches in the open areas and closures for Flathead in Zones 10-20 from 1986-2015 (Haddon in press).

Closure Name	Records	Catch (t)	%Catch
Open	271003	33501.460	99.26
Endeavour	289	26.095	0.077
FlindersRZ	332	46.275	0.137
EastGippland	223	27.353	0.081
Flinders	261	46.745	0.138
Seiners	405	95.146	0.282
Everard	58	8.305	0.025
Total	272571	33751.383	100
Total Out	271003	33501.464	99.26
Total In	1568	249.919	0.74

Table 5. The total number of records and catches in the open areas and closures for Flathead in Zone 30 from 1986-2015 (Haddon in press).

Name	Records	Catch	pCatch
Open	21838	4000.664	95.4
StHelens	77	6.221	0.1
Huon	560	82.762	2.0
Freycinet	516	96.227	2.3
Flinders	45	7.812	0.2
MariaIsland	6	0.335	0.0
Total	23042	4194.021	100.0
Total Out	21838	4000.664	95.39
Total In	1204	193.357	4.61

Table 6. The total number of records and catches in the open areas and closures for Pink Ling taken by trawl in depths of 250-600m in Zones 10-30 from 1986-2015 (Haddon in press).

Closure	Records	Catch	% Total Catch
Open	96034	12060.157	95.72
Endeavour	941	17.526	0.14
StHelens	28	1.599	0.01
FlindersRZ	479	35.067	0.28
Huon	81	5.120	0.04
Freycinet	454	48.062	0.38
EastGippland	286	55.082	0.44
Flinders	719	73.472	0.58
MariaIsland	56	3.993	0.03
Seiners	805	155.589	1.24
Everard	774	143.883	1.14
Total	100657	12599.550	100.00
Total Out	96034	12060.157	95.72
Total In	4623	539.393	4.28

Table 7. The total number of records and catches in the open areas and closures for John Dory in Zones 10-20 from 1986-2015 (Haddon in press).

Name	Records	Catch	pCatch
Open	141812	3488.839	99.84
Endeavour	2	0.110	0.00
FlindersRZ	34	0.755	0.02
EastGippland	103	2.576	0.07
Flinders	56	0.202	0.01
Seiners	72	1.691	0.05
Everard	21	0.370	0.01
Total	142100	3494.543	100.00
Total Out	141812	3488.839	99.84
Total In	288	5.704	0.16

Table 8. The total number of records, catch and percent of total catch reported by auto-line outside closures and within particular closures from 1986-2015 (Haddon in press).

Name	Records	Catch	%Catch
Outside	2549	1127.624	70.04
StHelens	182	128.935	8.01
FlindersRZ	368	206.116	12.80
Huon	68	59.241	3.68
Freycinet	87	15.571	0.97
EastGippland	1	0.03	0.00
Flinders	165	40.876	2.54
MariaIsland	22	3.624	0.23
Seiners	84	12.556	0.78
Everard	101	15.329	0.95

Fleet Capacity and Characteristics

Simon Boag, Matt Koopman, Will Mure, Shane Duggins, Andrew Powell

SCOPE OF THE ISSUE

The aim of this paper is to investigate whether the SESSF fleet's capacity ("fleet capacity") is a significant factor influencing catch rate and failure to catch TACs across sectors (trawl, Danish seine, gill net).

Data were analysed from three sources:

1) During March and April 2018 an online survey of SESSF fishers from the Gillnet Hook and Trap (GHTS), Commonwealth Trawl Sector (South-East Trawl or CTS which included Danish seine and trawl methods), Great Australian Bight Trawl Sector (GAB) and East Coast Deepwater Trawl Sector (ECDT) was undertaken. SMSs and emails were sent to all SESSF vessel SFR holders and other stakeholders. Further to this, an article appeared in SETFIA's April newsletter inviting SESSF fishers to participate in the survey. Non-responsive fishers were telephoned and encouraged to complete a survey on line or verbally. Fishers from non-SESSF fisheries were excluded even if they attempted the survey (3% of all respondents) and multiple surveys from single vessels were also corrected.

   The survey asked fishers about their vessel, their fishing gear, their hold capacity, limitations on seadays, limitations on fish age before landing, and normal steaming distances to grounds. The average time taken to complete the survey was 16 minutes.

   By July 2018, 83 responses had been received (38 GHTS, 39 CTS and 4 GAB).

2) Data from a historical series of audits conducted by NSW Fisheries were used (Graham, 1998).
3) Data requests were submitted to AFMA and these data were analysed. Only data from the GHTS-gillnet, CTS-demersal trawl, and CTS-Danish seine were requested.

   Data were not requested from the GAB, GHTS-auto-longline, GHTS-pot, GHTS-other-longline because:

   - the relatively low number of vessels in those sectors meant that confidentiality rules complicated provision of the data;
   - in the context of this high-level analysis the catches from those sectors were negligible;
   - there was a low number of survey responses.

We addressed five hypotheses relating to fleet capacity and its impact on under-caught TACs and catch rates. Recovery of overfished species was not considered.

IMPACT ON UNDER-CAUGHT TACS

H1: The fleet is aging and this has reduced 'uptime' (including value adding activities) due to breakdown and maintenance so less fish will be caught

Uptime is the percentage of functional time available for vessels at sea. It includes steaming, fishing, choosing not to fish, or processing catch. Conventional downtime includes breakdown and maintenance activities such as slipping, reactive repairs, steaming home early after breakdown and preventative servicing. However, other downtime including unloading, port movements, bunkering, waiting to unload, waiting for crew, resting crew, waiting for weather, crew injury, holidays, regulatory intervention, no available quota, and waiting for markets is often hidden. Hidden downtime may be greater than conventional downtime and fishers consider such downtime as an unavoidable part of the fishing business.

No data were available on the fleet uptime but survey data revealed that constraints were weather, quota availability, market price and crew availability. Further to these constraints, 25% of operators believed that breakdown/maintenance was a constraint on their business, not unexpectedly in an ageing fleet.

Survey data revealed that most SESSF voyages are of 4 ½ days duration and that most businesses complete 50 voyages per year. This suggests that the average SESSF fishing vessel has at most 62% uptime (225 days at sea).

In the gillnet sector 35 vessels are completing a total of 4,500 seadays or 129 sea days per annum per vessel (35% uptime). Gillnetters work lunar cycles which might explain the low uptime to some extent. Some operators suggested that there was underutilised capacity in the gill net fleet.

Trawl vessels in the SESSF cost about $6-8,000/seaday to operate and have revenues of $8-10,000/seaday. This suggests that the cost of downtime on a trawler is $300-400 per hour. However, trawlers also have fixed costs (overheads) regardless of operating time. Variable costs include wages, freight and market commissions. The opportunity cost of the investment in a fishing operation (vessel, equipment, quota) can be considerable. At the very least, the return on investment through fishing operations should exceed the opportunity cost.

Compared with large freezer trawlers typical of major international fisheries, vessels in the SESSF have lower operating costs. Perhaps this explains the relative disregard for downtime or uptime in the SESSF. However, there may be cultural or lifestyle issues which influence uptime. The average vessel age has increased over time for Danish seine, gillnet and trawl vessels in the SESSF (Figure 26) and this may affect uptime and therefore total catches. Changes to time management e.g. by decreasing "hidden" downtime and improving uptime (e.g. for the gill net fishery) may require a cultural shift. There is evidence (from increasing fishing activities per vessel) that such a cultural shift is already occurring (Figure 30). Perhaps this relates to changes in operators following structural adjustment in the SESSF.

H2: There are fewer vessels in the fleet so less fish will be caught and TACs will not be taken.

The number of fishing permits in the SESSF has reduced over time with buy-outs accompanying structural adjustments in 2005 -2006. the most dramatic changed being from 240 to 118 in 2006 so there are indeed fewer vessels. Table 20 shows that effort in the "post buy-back" era in the Danish seine fishery has remained relatively stable at high levels. Table 20 also shows that catch rates in the Danish seine fishery have declined for primary stocks and increased only slightly for by-product stocks. The sector has been able to maintain total catches by slightly increasing the catch rates of secondary stocks and increasing shots per vessel (Figure 25) which maintained total effort. This does not support the hypothesis.

For the demersal trawl sub-sector effort has declined significantly. Catch rates decreased before increasing in the post buy-back era (Table 21). Even so, the trawl sector has not been able to maintain its total catches because of the loss of vessels. This supports the hypothesis.

Vessel numbers in the gill net sector are about a third of historical numbers but total effort (sets) has only decreased by 50% indicating that vessels are working harder (Figure 25). Catch rates have risen around 25%, which supports the hypothesis.

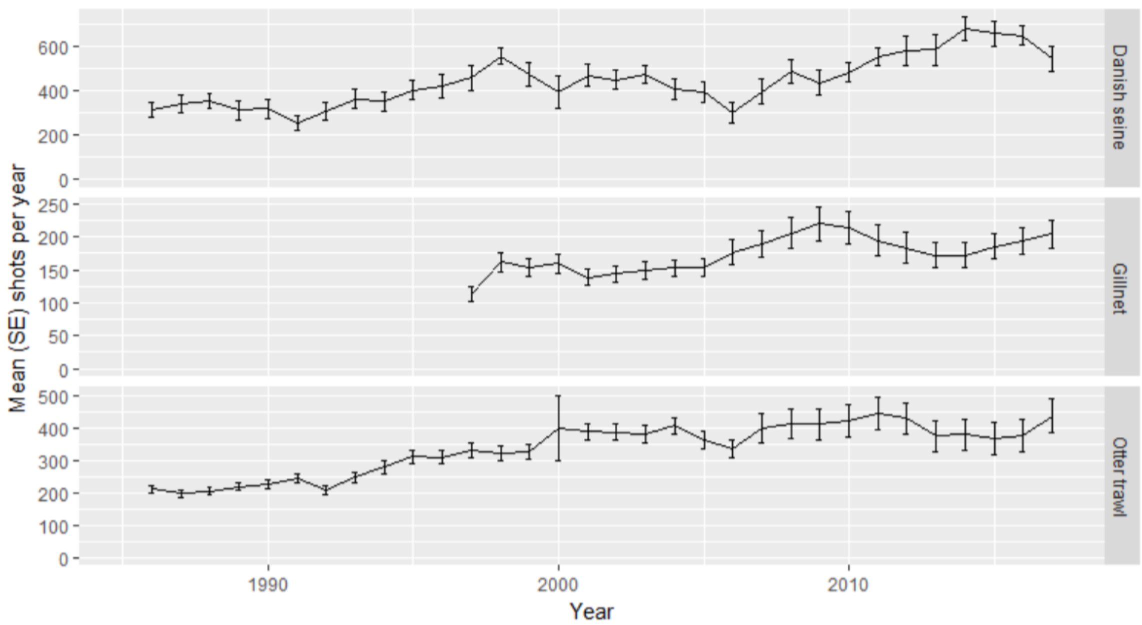

Figure 25. Variation in the number of shots per vessel for Danish Seine, Trawl, and Gill net sectors of the SESSF. Data are means ± SE

H3: The fleet's fish carrying capacity has reduced increasing the number of trips made per vessel. This has led to fewer fishing days and the fleet cannot catch TACs.

Hold capacity is poorly recorded in AFMA's database. There is evidence that trawler length has increased over time (Figure 28). Accordingly, it is unlikely that hold capacity has decreased and this hypothesis is therefore rejected.

IMPACT ON DECLINING CPUES

H4: The fleet is aging causing its catching power to reduce and this has reduced catch rates

Through discussions with fishers and fleet managers across Australasia characteristics of a contemporary fishing vessel were identified (Table 9). The average SESSF vessel includes some contemporary features like hull construction, refrigeration, 3D mapping and Kort nozzle presence. However, electronic equipment was either outdated or lacking, fish chilling equipment was inadequate, fish handling equipment and a general lack of self-tensioning winches were inconsistent with modern fishing vessels.

The average age of SESSF vessels (36 – 39 years) has increased over time for Danish seine, gillnet and trawl vessels (Figure 26 and Table 10 below) and may be considered very old for a fishing vessel. Features of older fishing vessels do not include contemporary features of modern vessels e.g. offal discharge to reduce seabird interactions, energy efficiency, or crew health and safety. The rate of vessel aging shows that there is some renewal with newer vessels arriving but in general, the SESSF fleet is generally old and outdated.

Engine horsepower is an important variable in fish capture for trawlers. Data reveal an increase in the variation of horsepower across the SESSF fleet but no clear increase or decrease (Figure 27) even though there has been an apparent increase in the size of trawlers since 2000 (Figure 28). Survey data revealed an average trawl door spread of 104 m. However, these data are estimates as only two vessels have door spread sensors.

Although the SESSF fleet has aged and many vessels lack the features of contemporary fishing vessels, there is little evidence in support of this reducing catch rates. Only the catch rates of Danish seiners have declined (Table 20) whereas gill net and trawl vessels show increased catch rates (Table 21, Table 22). The hypothesis is therefore rejected.

Table 9. Analysis of a contemporary fishing vessel vs SESSF performance (red = not widely present, amber = present to some extent, green = widely present).

Attribute	Survey result in SESSF	Reference
steel or perhaps fibreglass hull	75% of vessels have steel hull, a few fibreglass but 15% are still wooden hull vessels	Table 11
refrigerated hold	71% of vessels have a refrigerated hold	Table 12
stores fish on board in a method best for that species – probably not bulk stored	22% of vessels bulk store their fish on board in ice	Table 13
modern electronics (sounder, plotter, GPS, radar) less than 5 years old, preferably newer	25% of electronics less than 3 years old 20% are 3-7 years old 55% of electronics are more than 8 years old including 15% that are more than 18 years old	Table 14
have sounders with advanced capabilities such as multi-beam, multi-frequency, broadband (CHIRP) and sonar	43% of vessels have multi-frequency sounders 15% do not know	Table 15
is able to produce 3D maps using its own data	50% of sounders link to the GPS to create and display 3D images	Table 16
has the ability to interpret historical catches by time and space	26% of vessels have the ability but do not use it only 4% use this function	Table 17
ARPA radar which allows it to track and record the fishing patterns and locations of other vessels	41% have ARPA radar	Table 18
(trawlers may have other catching including: catch sensors, headline monitor, door spread sensors, net geometry sensor).	trawlers: 21% have catch sensors, 10% door spread sensors, 37% headline monitors, 16% geometry sensors	Table 19
if dealing with large delivery volumes of fish technology that allows the fish to be chilled while it is being sorted and stored	not present in the fleet	
(trawlers have a Kort nozzle)	83% of trawl vessels have a Kort nozzle	
(larger trawlers have self-tensioning winches)	not present in the fleet	

Table 10. Analysis of age of vessels by sector in the SESSF.

	Danish Seine (CTS)	Trawl (CTS	Gillnet (GHTS)
Average Age	39	36	36
Rate of aging (years per annum)	0.85	0.88	0.87

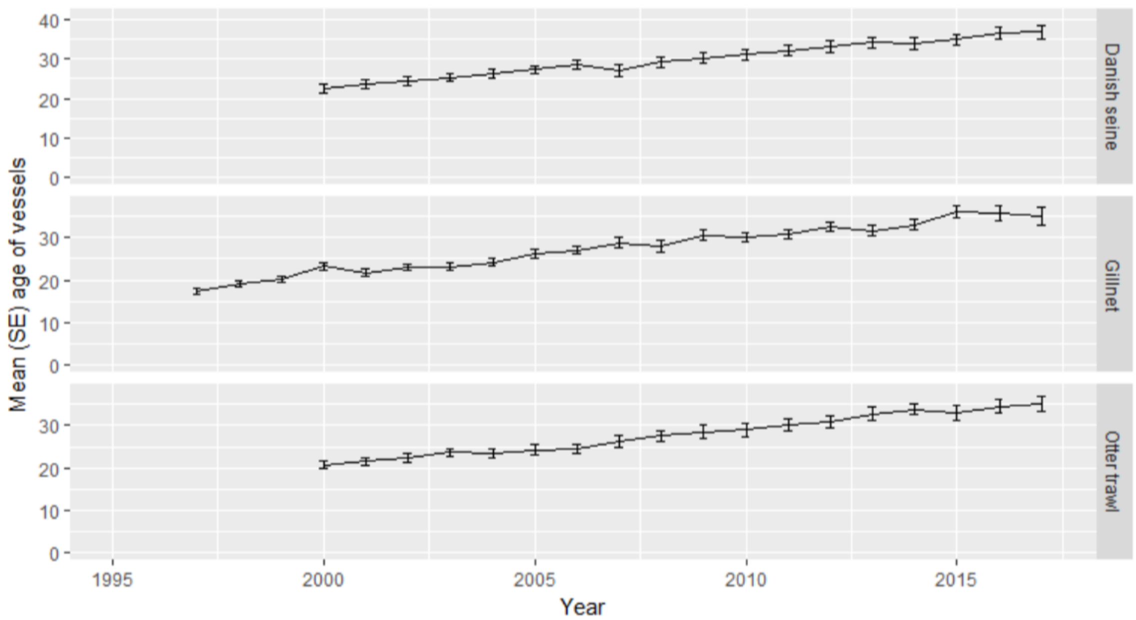

Figure 26. SESSF average vessel age over time for Danish seine, gill net and Otter trawl sectors (Data are from AFMA).

Table 11. Survey responses for hull material.

ANSWER CHOICES		RESPONSES	
Wood		14.29%	7
Steel		75.51%	37
Fibreglass		10.20%	5
Aluminium		0.00%	0
Other (please specify)	Responses	0.00%	0
Total Respondents: 49			

Table 12. Survey responses for hold refrigeration

ANSWER CHOICES	RESPONSES	
Yes	71.74%	33
No	28.26%	13
Total Respondents: 46		

Table 13. Survey responses for storage of catch

ANSWER CHOICES		RESPONSES	
Iced fish cases		53.06%	26
Iced bulk bins ("bulkies")		10.20%	5
In a tank with chilled seawater (brine)		12.24%	6
In a tank with chilled brine		0.00%	0
Frozen		0.00%	0
Bulked (in ice in a hold)		22.45%	11
Other (please specify)	Responses	2.04%	1
TOTAL			49

Table 14. Survey responses for vessel electronics including manufacturer and equipment age.

Manufacturer	SIMRAD	FURUNO	LOWRANCE	OTHER	DON'T KNOW	TOTAL
Sounder	13.04% 6	71.74% 33	0.00% 0	13.04% 6	2.17% 1	46
Radar	6.67% 3	80.00% 36	0.00% 0	11.11% 5	2.22% 1	45
GPS	8.70% 4	78.26% 36	0.00% 0	13.04% 6	0.00% 0	46

Year of manufacture	BEFORE 2000	2001-2005	2006-2010	2011-2015	2015-NOW	DON'T KNOW	TOTAL
Sounder	10.26% 4	15.38% 6	30.77% 12	15.38% 6	25.64% 10	2.56% 1	39
Radar	21.05% 8	15.79% 6	10.53% 4	21.05% 8	28.95% 11	2.63% 1	38
GPS	13.89% 5	13.89% 5	22.22% 8	25.00% 9	22.22% 8	2.78% 1	36

Table 15. Survey responses for vessel echo-sounder capabilities.

ANSWER CHOICES	RESPONSES	
Multi-beam (includes WASP technology)	4.35%	2
Multi-frequency - operate with one or two frequencies at once	43.48%	20
Broadband (CHIRP) - pulses through various frequencies	2.17%	1
Sonar - forward or side looking	0.00%	0
Not sure	15.22%	7
No	39.13%	18
Total Respondents: 46		

Table 16. Survey responses: GPS link to vessel echo-sounder to create 3D charts.

ANSWER CHOICES	RESPONSES	
Yes	52.17%	24
No	47.83%	22
Total Respondents: 46		

Table 17. Survey responses: e-log software with capacity to spatially analyse catch over time. If so, is this capacity used?

ANSWER CHOICES	RESPONSES	
I'm not sure	21.74%	10
No and no	43.48%	20
My eLog software does not have that capacility or I haven't paid for that version	4.35%	2
My eLog software does have that capability but I've never used it	26.09%	12
My eLog software does have that capacility and I do use it	4.35%	2
TOTAL		46

Table 18. Survey responses: Vessel has Automatic Radar Plotting Aid (ARPA).

ANSWER CHOICES	RESPONSES	
Yes	41.30%	19
No	58.70%	27
Total Respondents: 46		

Table 19. Survey responses: Vessel catching aids.

ANSWER CHOICES		RESPONSES	
Catch sensors		33.33%	4
Door spread sensors		16.67%	2
Third wire headline monitor		0.00%	0
Acoustic headline monitor		58.33%	7
Net geometry sensors		25.00%	3
Other (please specify)	Responses	16.67%	2
Total Respondents: 12			

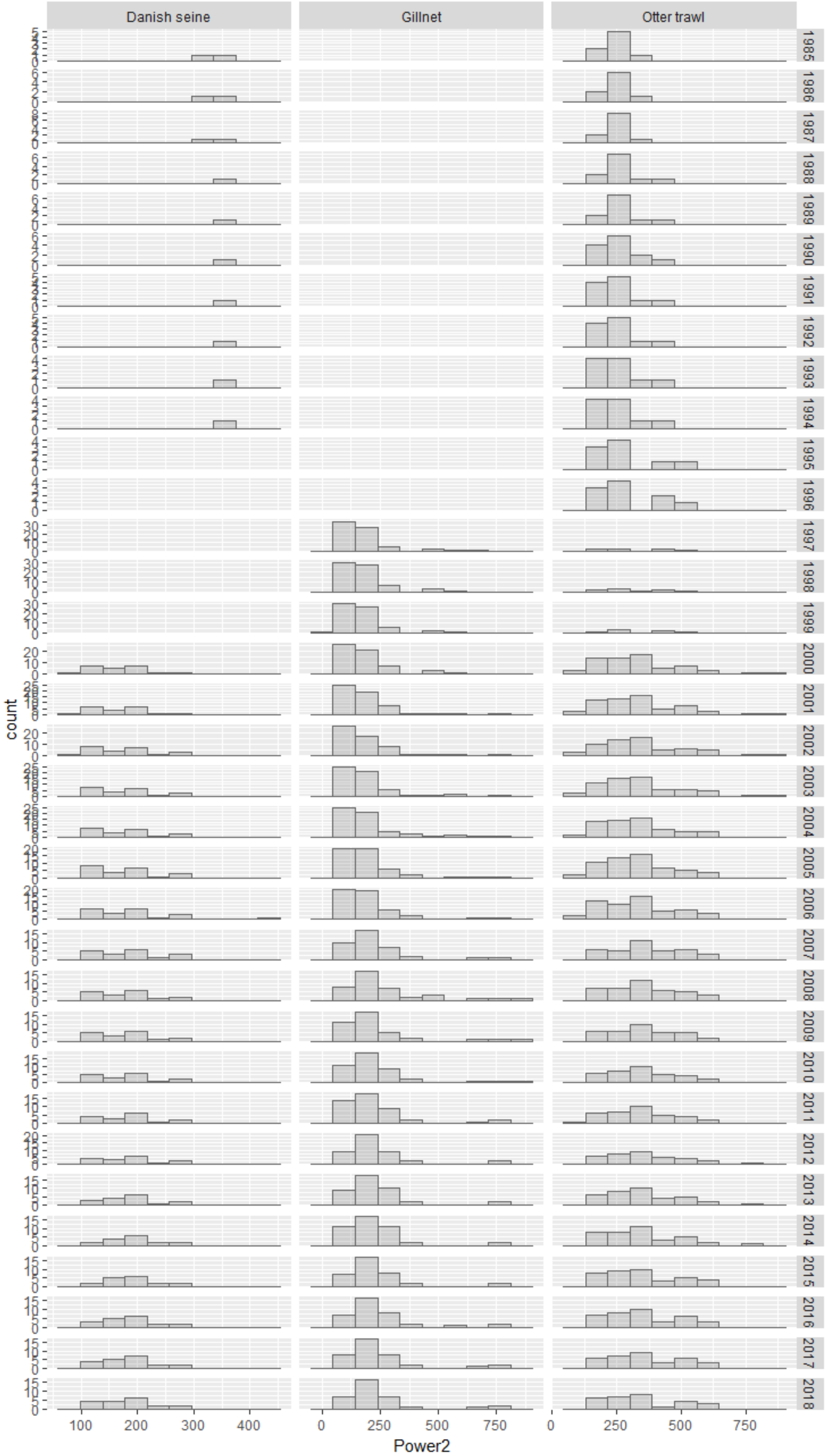

Figure 27. Engine horsepower for SESSF vessels by sector. Data are from AFMA.

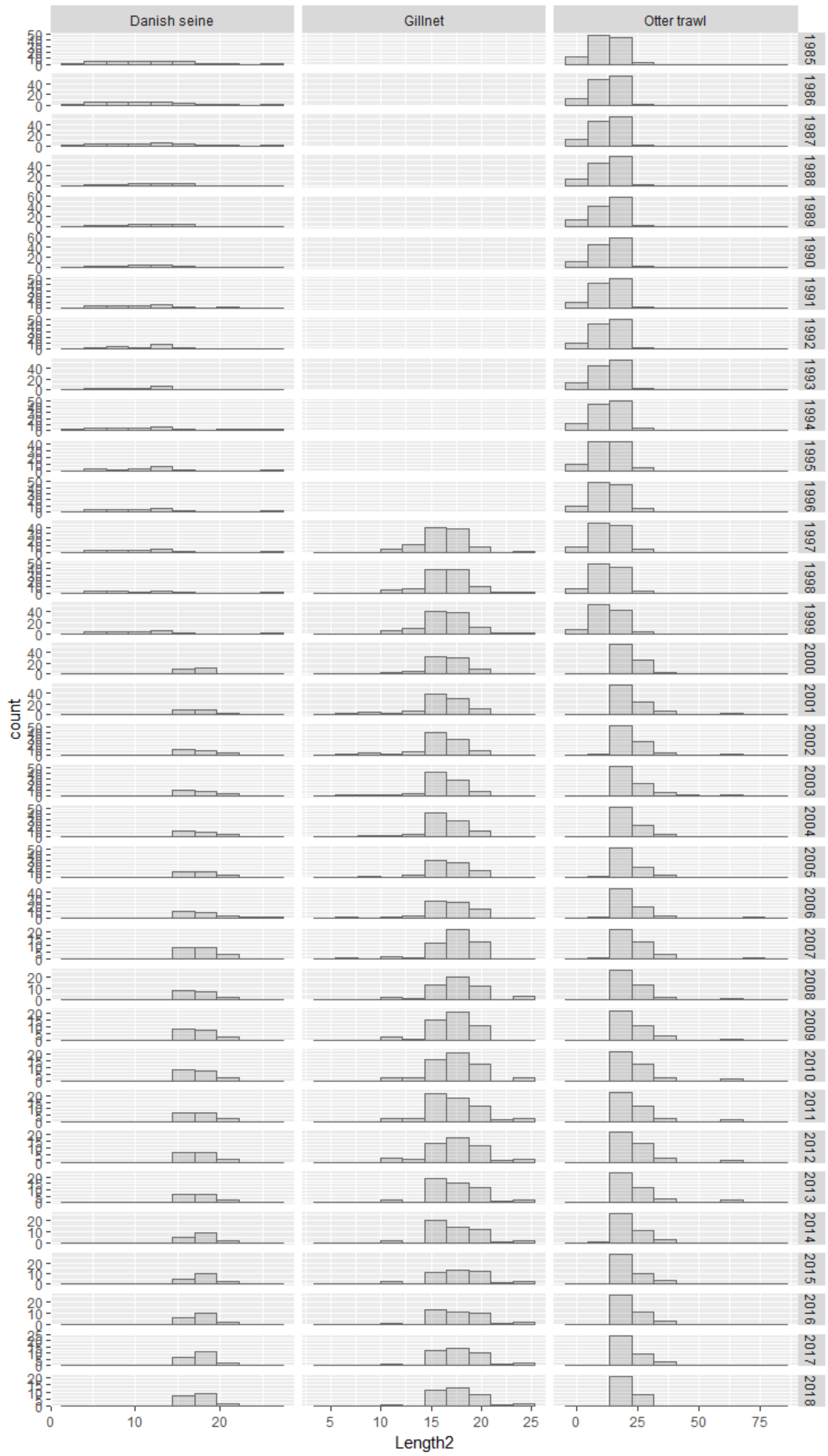

Figure 28. Length distribution for SESSF vessel by sector. Data are from AFMA.

H5: The number of vessels in the fleet has declined meaning vessels have less ability to work together to find fish and this has reduced catch rates.

There is evidence that vessels working together have greater search efficiency (and therefore catch rates) compared with vessels operating alone. Survey data included responses from 50 vessels operating from 17 ports. Vessels were concentrated (58%) in four ports but the number of vessels has decreased across all sectors (Figure 29, Figure 30, Figure 31). This reflects the buy-back of fishing concessions associated with structural adjustments undertaken by the Commonwealth government. In 2006, concessions in the trawl sector decreased from 118 to 59 and concessions in the Gill net sector reduced from 122 to 59.

Data presented in Table 20, Table 21, and Table 22 show changes in catch rates following structural adjustments (eras in the fishery). For the Danish Seine sector, the expansion era was characterised by high catch rates, high vessel numbers, high effort and high catches. Catch rates then dropped but then increased following the structural adjustment. Vessel numbers remained high in the trawl sector but following the buy-back in 2006 effort per vessel increased and catches decreased. Similarly, effort per vessel for the Gillnet sector increased following the buy-back but catch rates increased. The concentration of vessels in a relatively small numbers of ports is a factor influencing search efficiency. ARPA radar allows vessels to identify the location of other vessels operating within 50 km potentially improving search efficiency. Similarly, vessel to vessel communication via telephone or SMS typically occurs for vessels collocated in ports. Such changes in communication technology allow private conversations among operators (compared with publicly available information via radio contributing to search efficiency).

The catch rate results do not show a strong effect related to catch efficiency. The reduction of total effort (following buy-out of fishing concessions in the SESSF) and possible increase in fish stocks has potentially masked effects of searching efficiency. Reduced searching efficiency is likely to be real and related to fleet dynamics but other factors (e.g. decrease in fleet size) have had a greater influence on catch rates in the SESSF.

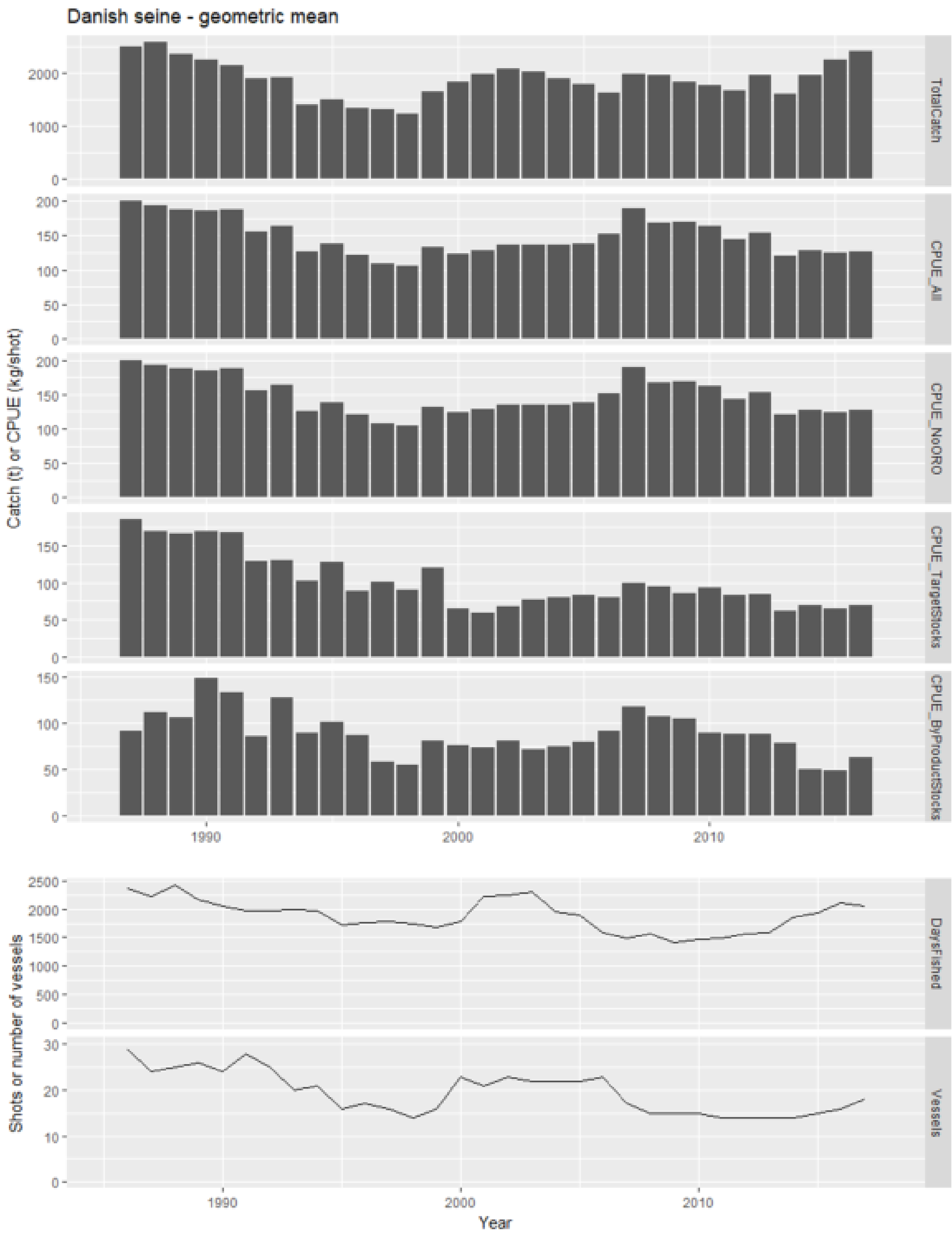

Figure 29. Catch and catch rate data over time (top panels) and days fished/ vessels reporting (bottom panels) for the SESSF Danish Seine sector. Data are geometric means.

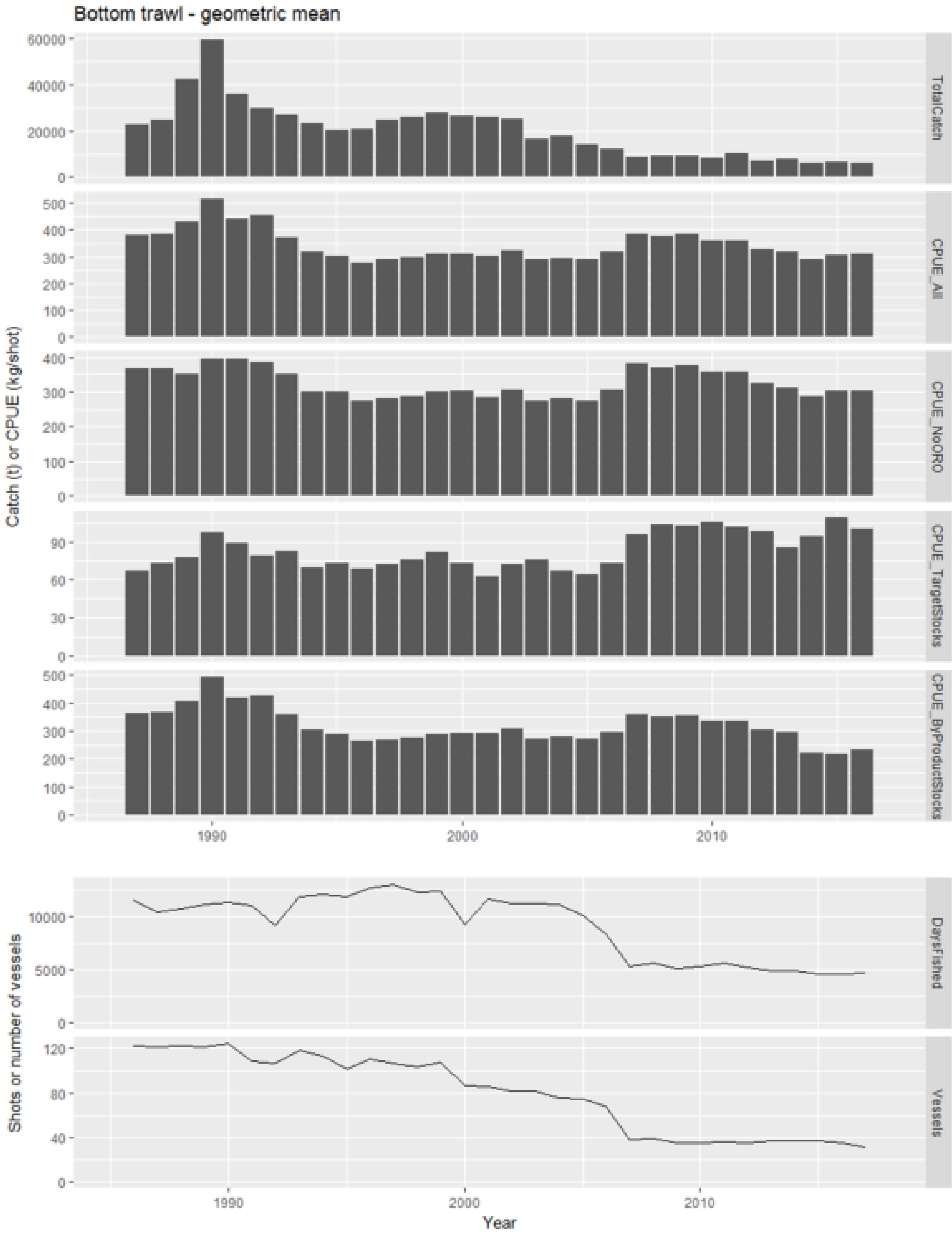

Figure 30. Catch and catch rate data over time (top panels) and days fished/ vessels reporting (bottom panels) for the SESSF Trawl sector. Data are geometric means.

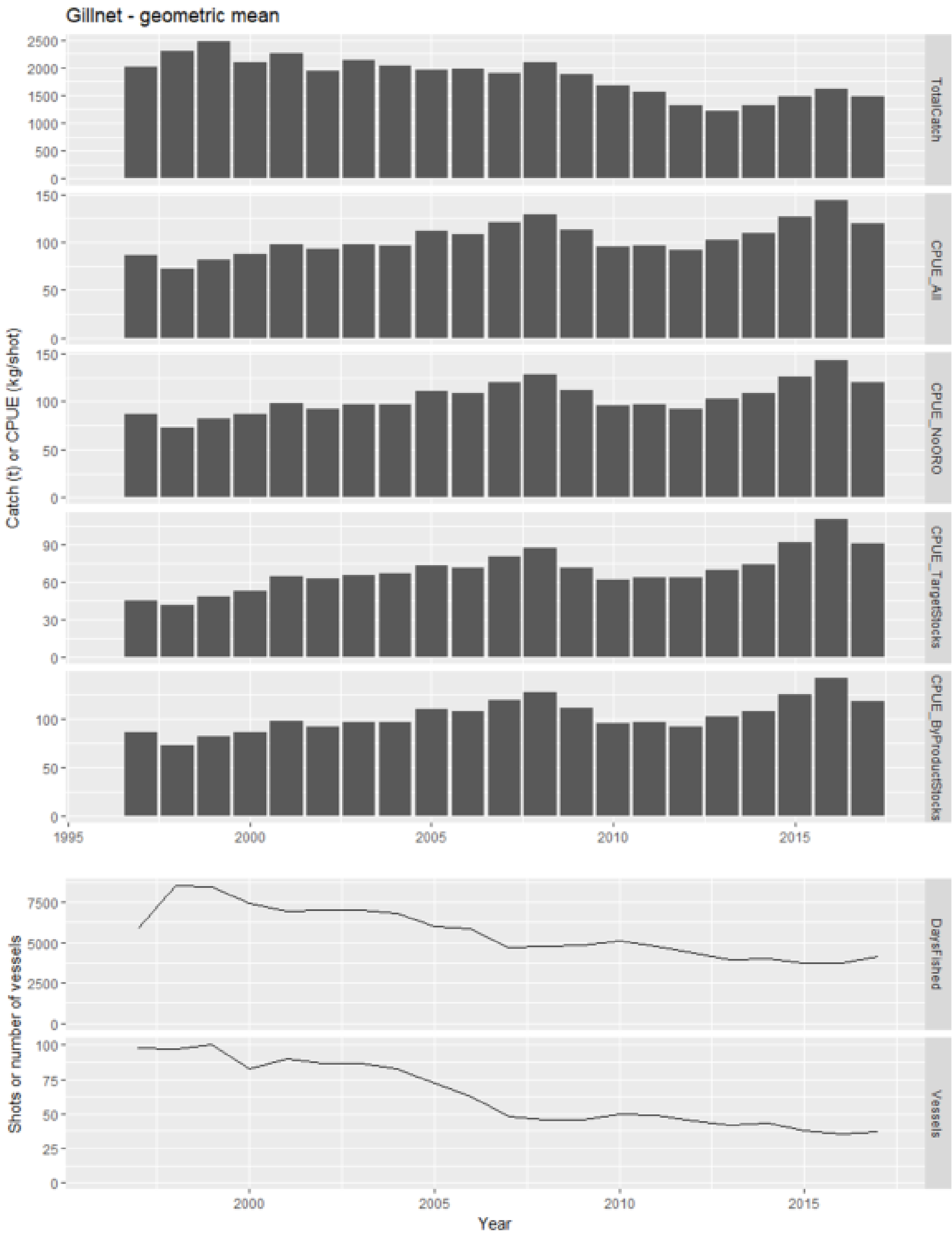

Figure 31. Catch and catch rate data over time (top panels) and days fished/ vessels reporting (bottom panels) for the SESSF Gill net sector. Data are geometric means.

Table 20. Analysis of catch rates over time for the Danish seine sector of the SESSF.

Era	Period years	Catch rates ALL STOCKS (kg/shot)	Catch rates BY-PRODUCT STOCKS	Catch rates PRIMARY STOCKS (kg/shot)	Vessel numbers	Total Effort (shots)	Effort per vessel (shots)	Total Catches
Expansion	1985-1991	High (175-200)	High (125-175)	High (175)	High (25-30)	High	Increasing	High
Post-expansion	1992-2005	Low (125-150)	Low (50-75)	Low (75-125)	Mod-High (15-20)	High	Increasing	Mod-High
Post buy-back	2006-present	Low-*improved*	Moderate (75-125)	Very low (75-100)	Moderate (15-17)	High	Increasing	Mod-High

Table 21. Analysis of catch rates over time for the Trawl sector of the SESSF.

Era	Period years	Catch rates ALL STOCKS (kg/shot)	Catch rates BY-PRODUCT STOCKS (kg/shot)	Catch rates PRIMARY STOCKS (kg/shot)	Vessel numbers	Total Effort (shots)	Effort per vessel (shots)	Total Catches
Expansion	1985-1991	High (400-500)	High (350-450)	Moderate (75)	High (110-120)	High	Increasing	High
Post-expansion	1992-2005	Low (300-350)	Low (250)	Low (60-75)	High (90-100)	High	Increasing	Moderate
Post buy-back	2006-present	Moderate (350-400)	Moderate (300-350)	High (80-100)	Low (50)	Moderate	Increasing	Very Low

Table 22. Analysis of catch rates over time for the Gill net sector of the SESSF.

Era	Period years	Catch rates ALL STOCKS (kg/shot)	Catch rates BY-PRODUCT STOCKS (kg/shot)	Catch rates PRIMARY STOCKS (kg/shot)	Vessel numbers	Total Effort (sets)	Effort per vessel (shots)	Total Catches
Pre buy-back	Pre-2005	Moderate (75-100)	Moderate (75-100)	Moderate (50-70)	High	High	Increasing	High
Post buy-back	2006-present	High (100-125)	High (100-125)	High (70-90)	Low	Low	Increasing	Moderate

WORKSHOP FEEDBACK AND CONCLUSIONS

Participants felt that of the three proposed mechanism (fewer vessels, insufficient fleet carrying capacity and more down time), only reduction in vessels would be a likely contributor to under-caught TACs (Figure 32, Figure 33). Participants felt that fewer vessels working together would be more likely cause of undercaught TACs than reduced catching power of an ageing fleet, but this was not considered a major mechanism. Reduced fleet capacity would be most relevant for Blue grenadier and Mirror Dory (Figure 34).

The mechanisms of fewer vessels working together and ageing fleet were not considered large contributors to the lack of recovery (Figure 35, Figure 36, Figure 37).

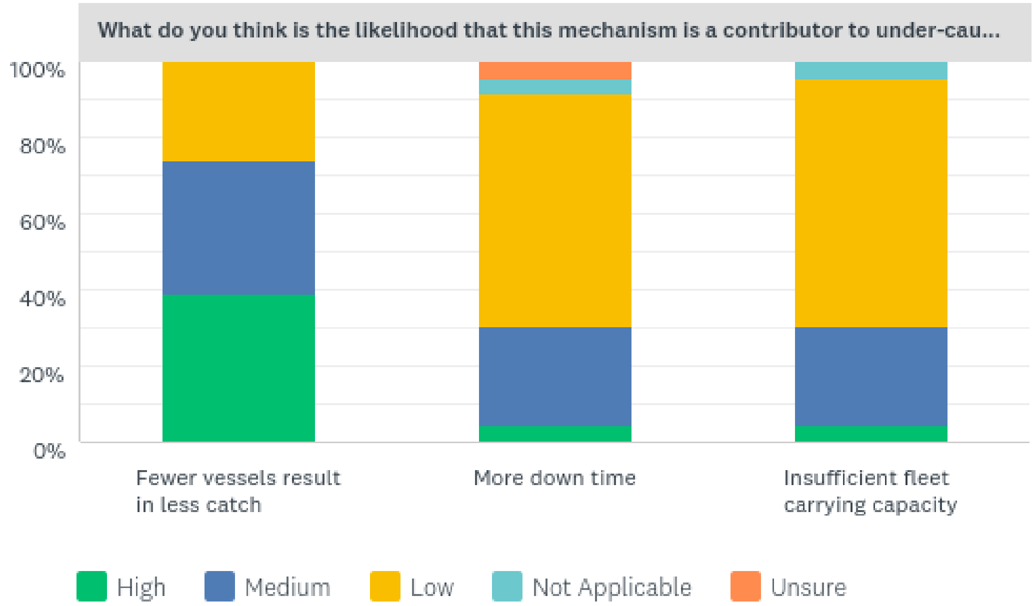

Figure 32. Workshop participant assessment of the likelihood that these fleet capacity mechanisms are a contributor to under-caught TACs.

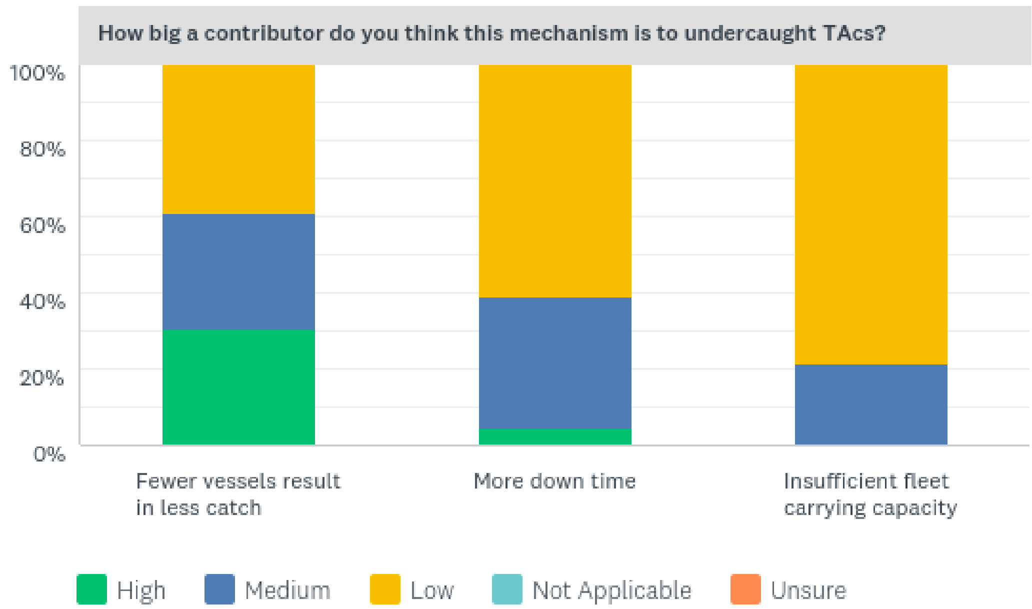

Figure 33. Workshop participant assessment of how big a contributor these fleet capacity mechanisms are to under-caught TACs.

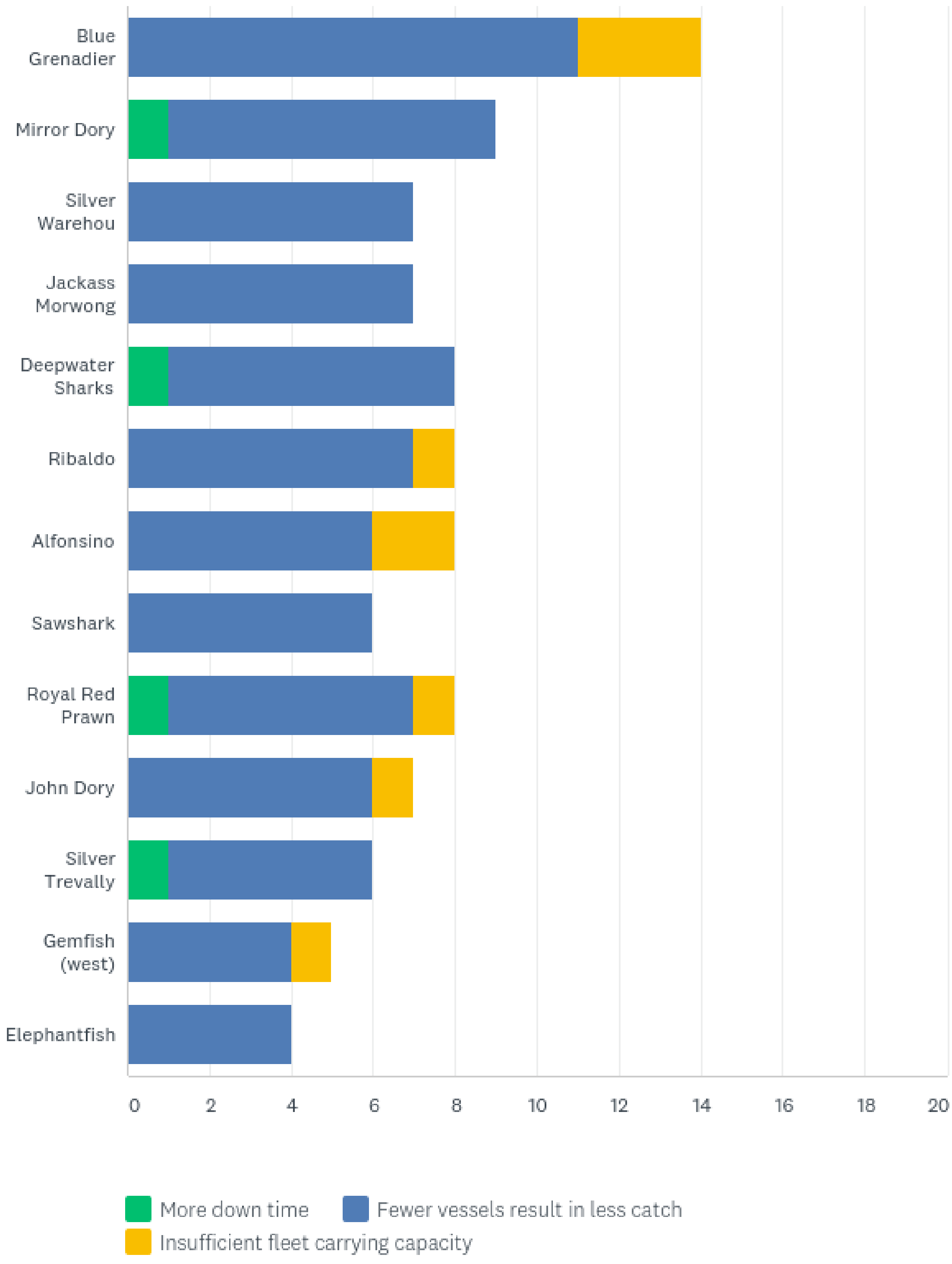

Figure 34. Workshop participant assessment of how big a contributor fleet capacity mechanisms are to under-caught TACs of specific species.

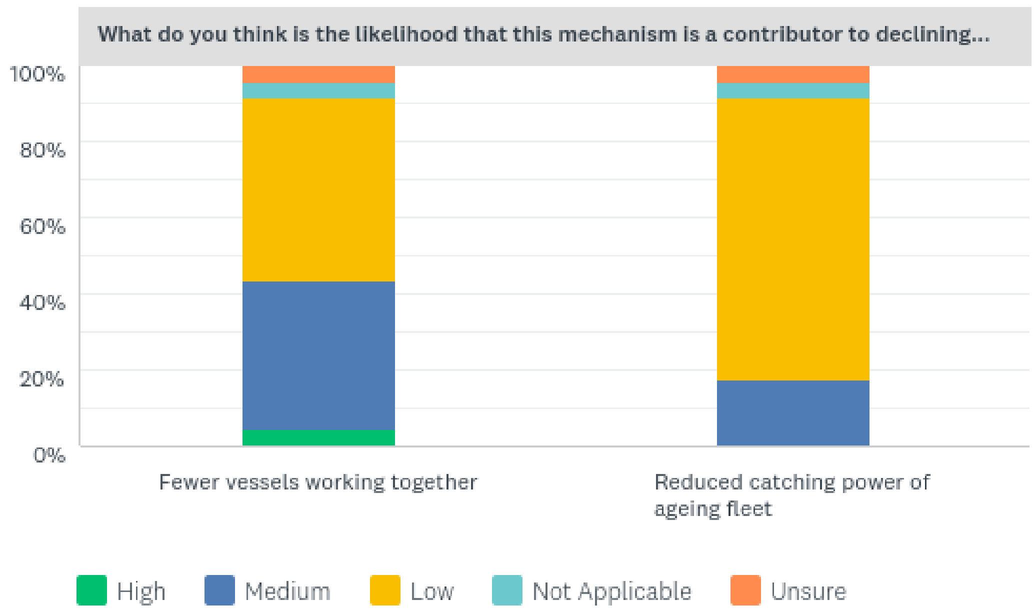

Figure 35. Workshop participant assessment of the likelihood that these fleet capacity mechanisms are a contributor to declining CPUEs.

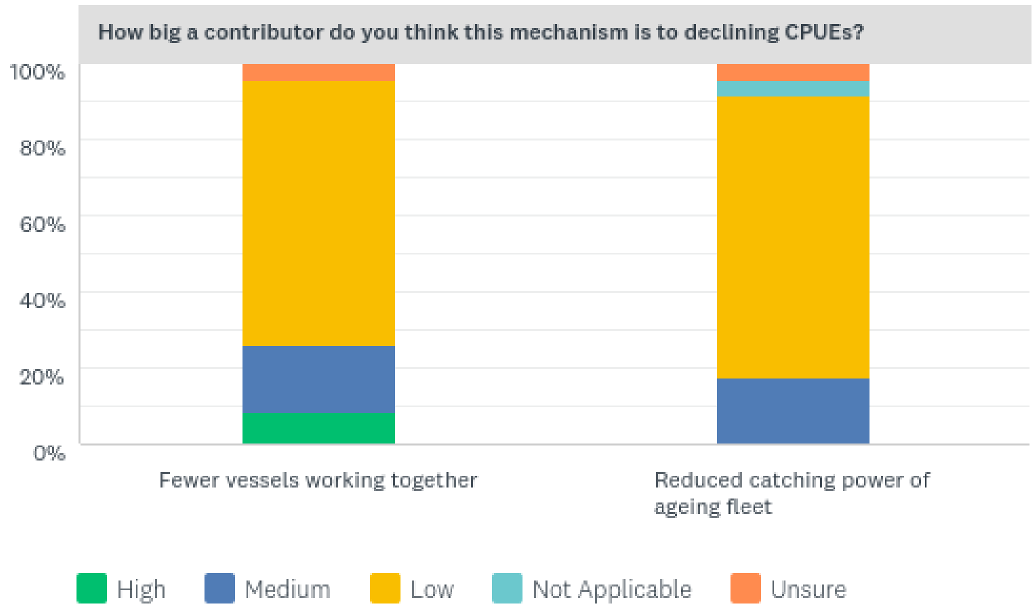

Figure 36. Workshop participant assessment of how big a contributor these fleet capacity mechanisms are to declining CPUEs.

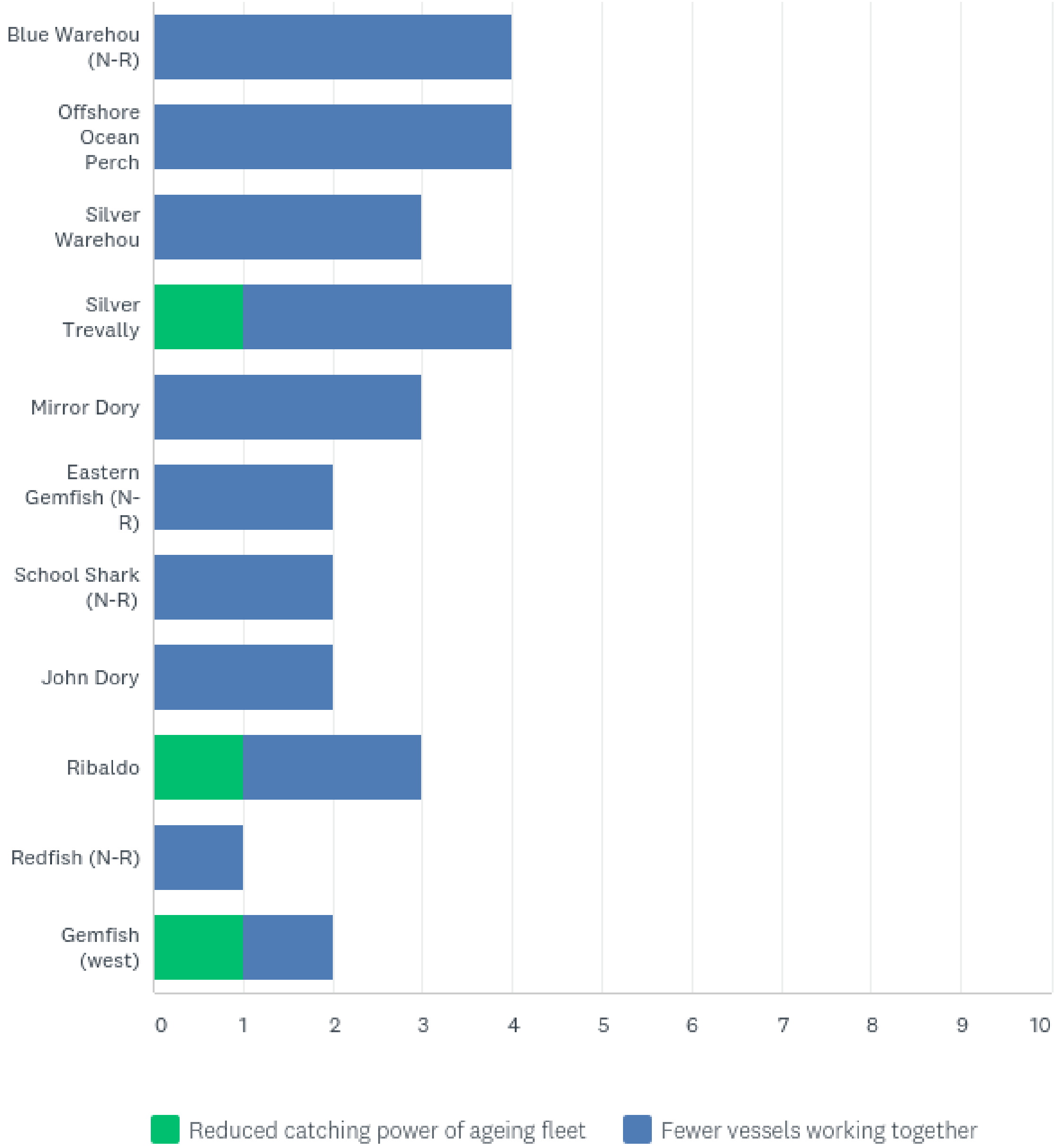

Figure 37. Workshop participant assessment of which particular fleet capacity mechanisms are relevant to declining CPUEs.

Fisher Behaviour and Vessel Operation

Emily Ogier, Matt Koopman Simon Boag, David Guillott, John Jarvis, Tom Bibby, Gus Dannoun and Will Mure

SCOPE OF THE ISSUE

The purpose of this paper is to:

- Identify which types of fisher behaviour and vessel operation are occurring that provide possible explanations for declines in key Fishery Indicators for performance of the SESSF
- Examine what data are available to assess the prevalence of behaviours
- Identify further analyses and/or applied model development required for establishing causality and for decision support

Understanding what drives fisher behaviours and vessel operations, and the ways these in turn affect fleet dynamics and catch, is critical to achieving effective management of fishing activities and therefore sustainability of the resource. It is now widely recognised that for multi species fisheries interpreting changes in performance indicators of both stock (such as catch rates or other measures of fishing efficiency) and management (such as TACs) requires understanding and assessing changes in quota market participation, fishing targeting, effort and distribution of that effort, because of their influence on fishery-dependent data and incentives for levels of extraction (Coglan et al. 2007, Branch et al. 2008, Pascoe et al. 2010, Dowling et al. 2015).

Changes in fisher behaviour and vessel operations arise from a suite of choices or decisions made by the relevant decision unit (individual fisher or wider groups of fishery participants) concerning how much to fish, what to target, with what gear, where and when (Eggert et al. 2004, Salas et al. 2004, van Putten et al. 2012, Girardin et al. 2017).

Fishers are necessarily required to respond to external factors such as changing market and environmental conditions as well as management arrangements. However, the set of decisions available to fishers to choose between and the choices/behaviours they then make in response to these external factors are constrained or influenced by a number of drivers that are internal to the fisher or decision unit. There has been increasing recognition of the role these internal drivers have in influencing choices and behaviours of fishers, and their response to complex management regimes (Pollnac et al. 2008, van Putten, Kulmala et al. 2012, Wise et al. 2012, Boonstra et al. 2016, Girardin, Hamon et al. 2017).

We define fisher behaviour and vessel operation as compromising three components:

- The domain of behaviour or decision (e.g. targeting/avoidance; quota trading)
- Types of observable behaviours (e.g. gear choice - increasing use of generalist nets)
- The factors driving what choices fishers have (external factors – e.g. market demand), and the drivers influencing what choices fishers make (internal drivers – e.g. livelihood/income strategies, risk preference)

For the purposes of this paper we have selected domains of fisher behaviour (Table 23) on the basis that they are: identified in theory; supported by empirical studies of other fisheries; demonstrated to influence fleet dynamics, fishing efficiency and catch levels relative to TACs; and, viewed as relevant to the SESSF by industry advisors. Using the same criteria, we have then defined the internal drivers that are understood to influence fisher behaviour and vessel operation (Table 24).

Table 23. Domains and types of behaviours
(*addressed by other papers and partially addressed in this paper; **addressed by other papers and no coverage in this paper)

Domain of behaviour	Indicators of observable behaviour
1. Quota trading, excising and balancing*	Purchasing / Leasing,
	Excising /Non-excising
	Balancing
2. Species targeting/avoidance	Intended targeting
	Composition of landed catch
	Discarding
3. Vessel operation	Location choice
	Gear choice
	Timing and intensity of effort
4. Technical innovation**	Improvements in On-board technology; Boat capacity
5. Compliance**	Compliance with reporting requirements

We also identified the types of participants in the SESSF who are making the decisions/behaviours by classifying their characteristics as firms (i.e. ownership, level of vertical integration, principal-agent arrangements) (Table 25).

Table 24. Types of internal drivers that influence fisher choice between available behaviours (Sources: Holland et al. (2000), Pascoe et al. (2002), Salas and Gaertner (2004), Coglan and Pascoe (2007), Branch and Hilborn (2008), Pollnac and Poggie (2008), van Putten, Kulmala et al. (2012), Wise, Murta et al. (2012), Dowling, Wilcox et al. (2015), Boonstra and Hentati-Sundberg (2016), Girardin, Hamon et al. (2017)).

Internal driver	Indicators used in other studies
Livelihood preferences	Inferred from socio-demographic characteristics of skippers
	Also inferred from response to variability in expected catch and revenue
Economic opportunity	Quota unit ownership
	Vessel ownership
	Principal-agent arrangements
	Past gross value
Risk preferences	Adherence to past fishing strategies/tactics ('tradition')
	Response to variability in expected catch and revenue, inferred from quota lease, targeting/avoidance and other effort behaviours
Level of experience, education and skill	Time in the fishery
	Family history in the fishery
	Vocational and other training undertaken
Information processing and technological capability	Use of on-board technology
	Response to fishing activities of others

Table 25. Types of participants (decision units) in the SESSF.

	Vertically-integrated company	Post-harvest company	Harvesting company – Land based	Harvesting company – Vessel-owner operated	Quota Investor	Quota Trader
Vessel ownership	Yes	No	Yes	Yes	No	No
Skipper/crew employee arrangement	Hired skipper and crew - Share catch	Skipper is quota lessee. Hired crew - Share catch	Hired skipper and crew - Share catch	Skipper is owner. Hired crew - Share catch	n/a	n/a
Quota lease in	As needed to supplement	As needed to supplement	As needed to supplement	As needed to supplement	No	Yes
Quota lease out	Only when surplus	Only when surplus	Only when surplus	Only when surplus	Yes	Yes
Internal processing	Yes	Yes	No	No	n/a	n/a
Internal sales	Yes	No	No	No	n/a	n/a
External sales to customers	Yes	Yes	Yes	Yes	n/a	n/a
External sales - fish market	No	Yes	Yes	Yes	n/a	n/a

Fisher behaviour and operation of vessels is an outcome of the interactions between individual fisher characteristics and preferences that guide fishers' choices, and external factors that determine what choices fishers have to choose between (Figure 38). The external factors identified in other studies and by industry contributors are examined in this paper as well as in other papers in this project (Table 26).

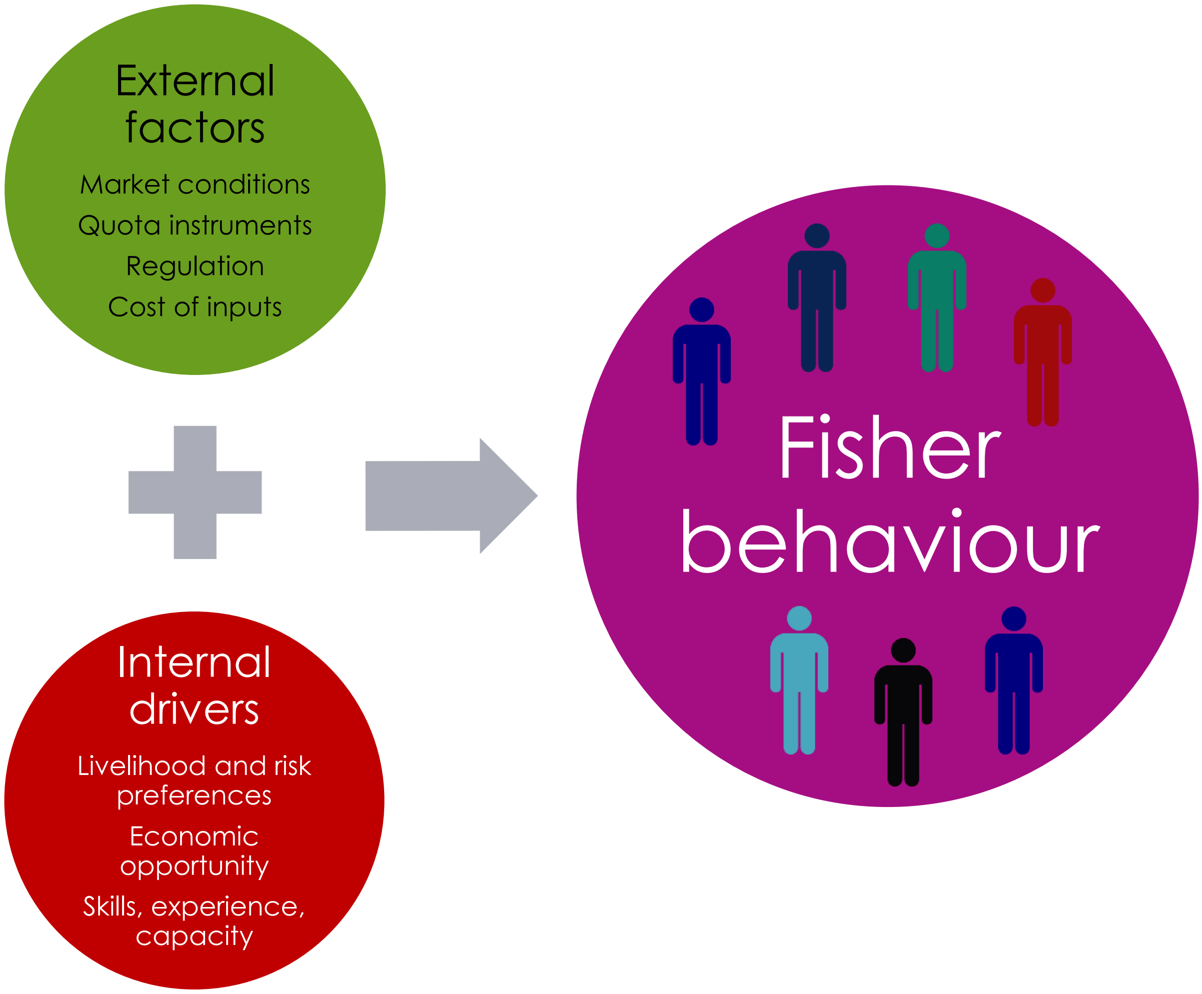

Figure 38. Conceptual model of fisher behaviour and internal and external drivers.

Table 26. External factors that influence the sets of choices of behaviours fishers have available to them.

Domain of behaviour	External factors	Investigated in other project papers
1. Quota trading, excising and balancing	Design of quota/SFR system	Paper E
	Design of quota markets	Paper E
	Design of balancing mechanisms	Paper E
2. Species targeting/avoidance	Input controls (regulation of fishing capacity, effort, spatial distribution)	Paper A
	Output controls (TACC setting)	Paper A
	Market conditions (demand and price)	Paper F
	Vessel capacity	Paper B
3. Vessel operation	Input controls (regulation of fishing capacity, effort, spatial distribution)	Paper A
	Cost of diesel and other inputs	Paper F
	Vessel capacity	Paper B
4. Technical innovation*	Market availability of new technology	Paper B
	Cost of new technology	Paper B
	Compliance requirements or other barriers to uptake of new technology	Paper A
5. Compliance*	Design of compliance regime	Paper A
	Level of compliance monitoring and enforcement effort	Paper A
	Types and severity of penalties	Paper A

Sources for quantitative data presented in this paper include the following existing data sets and analyses: Green (2016); Klaer et al. (2012); Klaer et al. (2014) Mobsby et al. (2017); Bath et al. (2018); and logbook and landings data provided by AFMA.

Sources of qualitative data include observations reported by identified industry contributors spoken to in the course of drafting the paper.

We examine the following for each of the domains of fisher behaviour and vessel operation:

- *Relevancy* – do any of the domains and types of behaviours we defined have any relevance to the Fishery Indicator?
- *Potential Explanations* – how the types of behaviour may influence the indicator (a summary is provided in Table 27)
- *Supporting Data and Analysis* – describes the data or existing studies that may provide evidence of relationships between the type of behaviour, any observed changed in that behaviour, drivers of the behaviour, and the Fishery Indicator; and
- *Solutions* – describes how incorporating analysis of fisher behaviour and vessel operation into stock assessment, quota market review and TAC setting processes may improve accuracy of interpretation of performance against Fishery Indicators

Table 27. Summary of potential explanations for Fishery Indicators arising from fisher behaviours and vessel operations.

Mechanism	Fishery Indicators and hypothetical explanations (H)	
	Declining CPUEs	**Under caught TACs**
1. Quota trading, excising and balancing		**H.6**: Inability of lessee fishers to meet up-front costs of leasing in quota that becomes available intra-season has contributed to the non-excising of quota (see also Paper E) **H.7**: Tactical non-excising or trade of quota due to livelihood preferences and failure to take account of opportunity cost has contributed to under catch of quota species (see also Paper E) **H.8**: Strategic use of quota balancing options has contributed to increased levels of non-excising of quota and therefore of under catch of quota species (see also Paper E) **H.9**: Strategic concentration and non-excising of quota to ensure scarcity of fish product and thereby higher prices has contributed to increased levels of under catch of quota species (see also Paper E)
2. Species targeting and avoidance	**H.1:** Levels of targeting of mixed catches or single species of smaller volumes but larger sized fish have increased relative to levels preceding reported CPUE declines, and that this has distorted CPUE trends (see also Paper G) **H.2:** Active avoidance of low value /catch-restricted species, results in changes in estimated catchability (see also Paper G)	**H.10**: Active avoidance of low value species or species with catch-restricted companion species has contributed to non-excise of quota and therefore under catch of quota species
3. Vessel operation	**H.3:** Levels of deployment of different gear types to target/avoid certain types of catches/species have changed relative to levels preceding reported CPUE declines, and that this has distorted estimates of catchability (see also Paper G) **H.4**: Spatial and seasonal distribution of effort (areas, depths, length of shots and trips) has changed as fishers target smaller volumes of larger fish rather than high catch rates, relative to distribution of effort preceding reported declines in CPUE, and that this has distorted estimates of catchability (see also Paper G) **H.5:** Levels of fishing efficiency of skippers due to higher proportion of new entrants has decreased relative to levels preceding reported declines in CPUE, and that this has distorted estimates of catchability (see also Paper G)	**H.11**: Spatial closures requiring skippers to fish for species in areas with lower abundance have contributed to under catch **H.12**: Levels of fishing efficiency of skippers due to higher proportion of new entrants has decreased, and that this has contributed to under catch

IMPACT ON UNDER-CAUGHT TACS

There is a continued and significant (>50%) under catch of TACs for many quota species. At the end of the 2015/16 year, 23 of the 34 species groups under TAC were less than 50% caught. Of the major quota species, only four had catches above 80% of the TACs (Flathead, Gummy Shark, Pink Ling and School Whiting). It is not clear whether this is reflecting:

- declining stock abundance or availability (addressed in Papers G and D);
- decreased fleet capacity (addressed in Paper B);
- inappropriate TACs (addressed in Papers E, F and G);
- low demand and unfavourable product market conditions (addressed in Paper F);
- quota market design and performance (addressed in paper E)
- interdependencies between multiple quota species (addressed in this paper and in Papers F and G); and/or
- tactical and strategic behaviours of quota trade participants (addressed in this paper and in Paper E).

For this analysis, potential explanations arising from fisher behaviour and vessel operation were investigated generally for the SESSF as well as specifically for three species: Gummy shark; School whiting; Blue grenadier (Table 28). Long-term trends in the catch relative to the TAC for these three species are presented in Figure 40.

Table 28. Selected species with under caught TACs.

Species	Sub-sector	Primary gear type	Target / Secondary / Non-target	Companion spp. (Klaer and Smith 2012)	Relative market value	Recovering spp.
Gummy shark	GHTS, but also CTS	Gillnet (also Line, then Trawl, then Danish Seine)	Target and Secondary	Caught as a companion species to Flathead School shark a commonly-occurring incidental (non-target) catch	High	No
School whiting	CTS	Danish Seine	Target and Secondary	Also caught as a companion species to Flathead	Medium	No
Blue Grenadier	CTS	Trawl	Targeted		Low	No

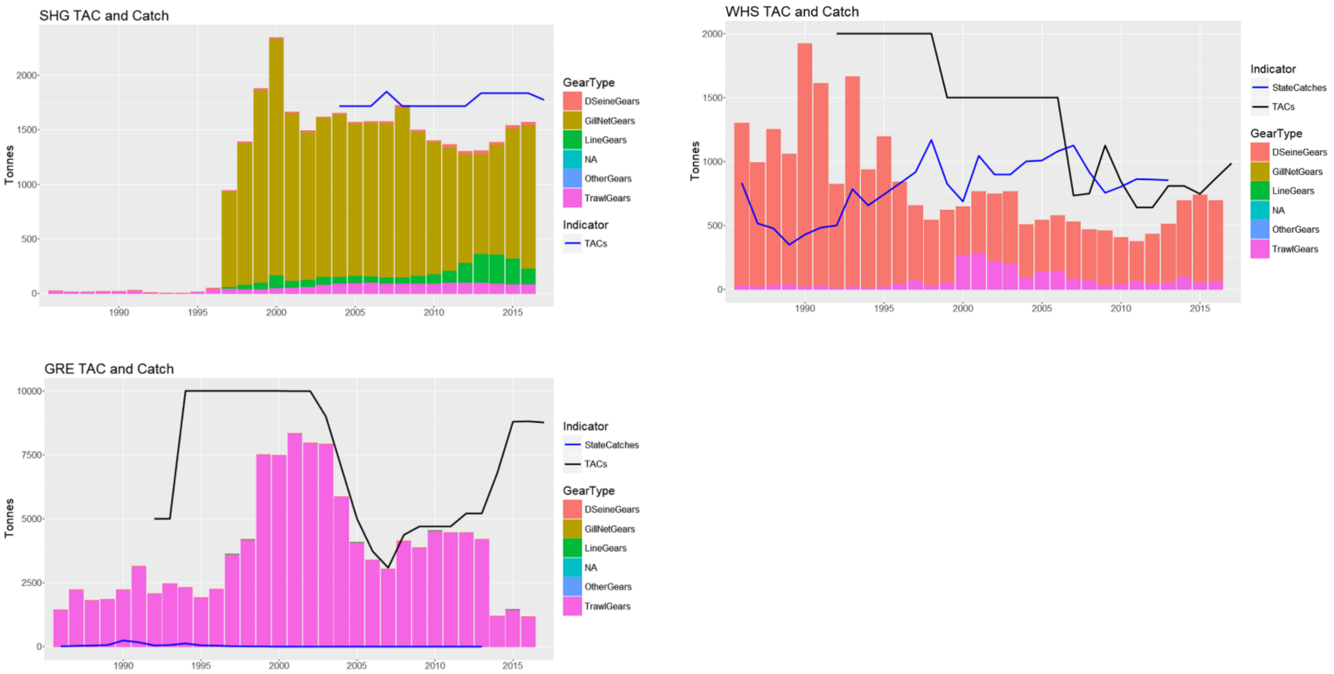

Figure 39. Catch relative to the TAC by gear type for Gummy shark (SHG), School Whiting (WHS) and Blue Grenadier (GRE).

QUOTA TRADING, EXCISING AND BALANCING BEHAVIOURS

The behaviour of individual decision units (skippers, companies – see Table 25) in quota trade and balancing behaviours is directly relevant to the issue of under caught TACs in the SESSF.

H1: Inability of lessee fishers to meet up-front costs of leasing in quota that becomes available intra-season has contributed to the non-excising of quota (see also Paper E)

Skippers are reporting that if they cannot get access to quota early on in the quota season, then they make decisions to target other species in other areas. This limits their ability to make intra seasonal adjustment to their fishing strategy in the event that cheaper quota becomes available.

Quota investors are reported to be offering units for lease at the start of the season at high prices, limiting quota leasing behaviour. However, when as yet un-traded or excised quota becomes available at cheaper prices later in the season, operators are not always able to adjust their fishing strategy to take up the opportunity, and so quota is left uncaught. This has been cited as a potential explanation for recent under catch of School Whiting.

Evidence that would support or refute this explanation is not currently available and would require analysis of quota trades and market prices. Reporting by ABARES (Bath, Mobsby et al. 2018) on levels of quota latency does not include analysis of such market factors.

H2: Tactical non-excising or trade of quota due to livelihood preferences and failure to take account of opportunity cost has contributed to under catch of quota species (see also Paper E)

Some participants, particular those to whom quota units were "gifted" in the initial allocation, are reported to not perceive any lost opportunity or benefit foregone in not excising quota units, either though trade or fishing. A number of internal behavioural drivers have been suggested as explanatory variables:

- Because of livelihood preferences which place higher value on lifestyle factors, the transaction costs of participating in the broader quota market to lease out quota units for low value species are perceived to be too high;
- Because of these livelihood preferences plus informational processing capacity, these participants may not recognise or value the cost of not excising quota relative to other input costs, i.e. fuel cost, or the implications of under caught TACs on quota unit value longer term.

Evidence that would support or refute this explanation is not currently available and would require analysis of livelihood preferences of active skippers and quota holders. Reporting by ABARES (Bath, Mobsby et al. 2018) on levels of quota latency does not include analysis of such behavioural factors.

H3: Strategic use of quota balancing options has contributed to increased levels of non-excising of quota and therefore of under catch of quota species (see also Paper E)

Some industry participants are reporting that quota units are being leased at low cost late in the season for certain species and, rather than catch it in that quota year, the leased-in quota is intentionally being 'banked', or 'rolled over' to the following year as an investment strategy via quota balancing administrative arrangements. This results in under catch being reported for that quota year. AFMA's quota balancing provisions currently limit the number of units that can be 'rolled over' each year, and so this behaviour can only potentially account for a small proportion of the under catch for any given species.

Evidence that would support or refute this explanation is not currently available and would require analysis of quota trades and market prices, and interviews with quota traders and fishing firms to determine extent of these behaviours.

H4: Strategic concentration and non-excising of quota to ensure scarcity of fish product and thereby higher prices has contributed to increased levels of under catch of quota species (see also Paper E)

Integrated companies who participate in both quota and product markets are reported to be purposefully not trading or excising quota units in certain species to prevent competition in product supply and sales, prevent oversupply / ensure scarcity of fish product, and thereby keep product prices high. This behaviour has been anecdotally reported for School Whiting.

Evidence that would support or refute this explanation is not currently available and would require analysis of quota trades, quota holdings and market prices. Reporting by ABARES (Bath, Mobsby et al. 2018) on levels of quota latency does not include analysis of such market (demand, supply, price) factors.

No data or analyses concerning livelihood preferences and strategies are available for participants in the SESSF. Data on age structure and levels of experience of skippers in the SESSF (Figure 45, Figure 46) suggest that nearly 50% of skippers in the CTS have been in the fishery for 11 or more years and were likely to have been "gifted" a portion of their quota units in the initial allocation. These may indicate a sub-group of fishers who operate with a different set of incentives and livelihood preferences in the fishery.

In his analysis of boat-level technical efficiency of vessels in the CTS, Green (2016) included reports of substitution between species targeted in response to changing market conditions - a behaviour that may influence levels of reported under catch for these species. Green (2016) also noted that the assumption that fishers are price 'takers', rather than 'makers' may be violated should fishers choose to limit output levels (catches) of selected species in order to influence market prices through scarcity.

Analysis of available AFMA SFR/ITQ transaction data is addressed in Paper E.

Further research needs and possible solutions in relation to the design of the quota market and balancing arrangements are discussed in Paper E.

Alternative payment options for lessees to reduce pressure to fish early in the season to meet costs of upfront quota lease fees could be considered by industry.

SPECIES TARGETING AND AVOIDANCE BEHAVIOURS

The choice of fishing strategy, based on decisions concerning which species to target and which to avoid, is directly influenced by quota availability, as well as expected revenue (Branch and Hilborn 2008, Girardin, Hamon et al. 2017).

H5: Active avoidance of low value species or species with catch-restricted companion species has contributed to non-excise of quota and therefore under catch of quota species

Skippers have reported intentional leasing then non-excising of quota units where those quota units are for low value species that were attached to units for high value species (i.e. Tiger Flathead), only offered in the quota market as part of "packages" of units.

During times when fuel prices are high relative to revenue, skippers have been choosing not to operate their vessels to catch un-used quota for low value species, as the opportunity cost of un-excised quota is lower than the input cost of fuel. For example, skippers report that Blue grenadier cannot be caught by non-factory freezer boats without financial cost to the operator, due to competition from imported product.

Evidence that would support or refute this explanation is not currently available and would require analysis of quota trades and market prices for low value species, as well as an updated analysis *as per* Klaer et al. (2012) of targeting/avoidance, catch composition and inter-dependence in catches of different species in the SESSF and the implications of their analysis for TAC setting.

School shark is listed as a conservation dependent species under the *EPBC Act* and has been managed under a rebuilding strategy since 2008 which has prevented targeted fishing for this species and restricted catches to incidental catches only. School shark was previously targeted and continues to be incidentally caught by fishers targeting Gummy shark. Fishers are now actively avoiding targeting School shark (AFMA 2015). Internal behavioural drivers that may be relevant include risk preferences of skippers, wherein skippers who are risk adverse are more likely to avoid targeting Gummy shark also to reduce the risk of catching School shark.

Constraints imposed on fishers due to spatial closures and catch restrictions are limiting the choices fishers can make with regard to location choice and species targeting strategies. These constraints and avoidance behaviours are likely to be reducing fishing efficiency and economic incentives to target Gummy shark.

Evidence that would support or refute this explanation is not currently available and would require analysis of risk preferences of active skippers. The influence of catch-restricted companion species on under caught TACs is addressed in more detail in Papers by E, F and G.

The effect of production costs and market conditions on the under catch of low value quota species is addressed in Paper F.

Klaer and Smith (2012) applied the concept of 'companion' species to their analysis of targeting, catch composition and inter-dependence in catches of different species in the SESSF and examined the implications of their analysis for TAC setting. They found that in 2006 Gummy shark was the target fish for only 7% of the landed catch of that species while 45% of this species catch was taken as a companion species to Flathead, and 48% as an incidental catch of shots targeting a range of other species. School whiting was the target fish for 68% of its catch that year, and the companion species to shots targeting Flathead for 23% of its catch. Blue grenadier was the target species for 88% of its catch (Klaer and Smith 2012: 611).

More recent analysis has been undertaken by Smith et al. (2017) on the impact of technical interactions on catches relative to TACs in multi species fisheries and is discussed and fully citied in Paper G.

Refer to Species targeting and avoidance behaviour (above). Solutions are directly addressed by Papers A, G and F.

VESSEL OPERATION

Stock availability of the major species targeted in the SESSF is area specific, therefore location choices can potentially affect which species are caught and how much, thereby influencing levels of over/under catch of specific quota species (Klaer and Smith 2012, Green 2016).

H6: Spatial closures requiring skippers to fish for species in areas with lower abundance have contributed to under catch

Extensive spatial closures put in place since 2003 have reduced the extent of grounds available for gillnetting to target Gummy shark (Skirtun and Green 2015). As a result, fishing effort is highly spatially concentrated. Constraints imposed on fishers due to spatial closures are limiting the choices fishers can make with regard to location choice. These constraints, combined with avoidance behaviours associated with catch restrictions on companion species, are likely to be reducing fishing efficiency and economic incentives to target Gummy shark.

Levels of quota latency for Gummy shark are reported by ABARES in the 2017 *Financial and Economic Indicators Report for the SESSF* (Bath, Mobsby et al. 2018) and are indicatively attributed to the establishment of spatial closures and subsequent re-distribution of effort.

H7: Levels of fishing efficiency of skippers due to higher proportion of new entrants has decreased, and that this has contributed to under catch

This is discussed under Hypothesis 10.

We have not established whether any analysis has been undertaken to assess the effect on targeting and excise of quota for Gummy shark of spatial closures in addition to observations made by Skirtun and Green (2015), above.

Potential solutions include reviewing the TAC settings for Gummy shark in light of the extent of spatial closures and continued under catch. This is addressed by Papers A and G.

IMPACT ON DECLINING CPUES

There has been an apparent continual decline in catch rates for many quota species with a range of life histories across the last two decades, despite the lowest historical effort and catch levels in the fishery. In a recent analysis of CPUE trends of 43 SESSF stocks, 29 were found to have declining catch rates. Unstandardised CPUE across the fishery has declined for several years hitting an all-time low in 2015 and has remained at this level in 2016. It is not clear whether this is:

- a real trend in relative biomass (addressed in Papers G and D);
- a real trend reflecting increased inefficiency of individual fishers (addressed in this paper and in Paper B); or
- biased by the data collected or method adopted for the catch rate standardisation itself which may be failing to account for changes in targeting and avoidance behaviours (addressed both in this paper and in Paper G).

For this analysis, potential explanations arising from fisher behaviour and vessel operation were investigated generally for the SESSF as well as specifically for four species: Silver Warehou; Redfish; Jackass Morwong; Eastern Gemfish (Table 29), all of which are caught with trawl gear types.

Table 29. Selected species with declining CPUE.

Species	Sub-sector	Primary gear type	Target / Secondary / Non-target	Companion spp. (Klaer et al. 2012)	Relative market value	Recovering spp.
Silver Warehou	CTS	Trawl	Target and Secondary	Also caught as a companion spp. to Blue Grenadier	Low	No
Redfish	CTS	Trawl	Non-target (incidental catches only)	Caught as a companion spp. to Flathead and Morwong	Medium-Low	Yes - catch restrictions apply
Jackass Morwong	CTS	Trawl	Target and Secondary	Caught as a companion spp. to Flathead	Medium-Low	No
Eastern Gemfish	CTS	Trawl	Non-target (incidental catches only)	Caught as a companion spp. to Mirror Dory	Low	Yes - catch restrictions apply

Long-term trends in the standardised CPUE for these four species are presented in the latest stock assessment report (Tuck 2016). Of greater relevance, given the limitations of CPUE data in revealing either stock abundance or economic performance in multi species fisheries, is the trend in Value Per Unit Effort (VPUE). This trend reveals the economic performance of selected species, potentially explaining increased targeting behaviour (Davie et al. 2015). Presentation of VPUE has not been completed as part of this scoping paper although it is a recommendation that it be undertaken.

QUOTA TRADING, EXCISING AND BALANCING BEHAVIOURS

This not directly relevant to this issue

SPECIES TARGETING AND AVOIDANCE BEHAVIOURS

Targeting behaviour is a recognised factor affecting standardisation and interpretation of CPUE in multi species fisheries (Salas and Gaertner 2004, Branch and Hilborn 2008, Pascoe, Punt et al. 2010).

H8: Levels of targeting of mixed catches or single species of smaller volumes but larger sized fish have increased relative to levels preceding reported CPUE declines, and that this has distorted CPUE trends (see also Paper G)

Skippers report that they are endeavouring to catch a "mixed bag" of larger fish to suit the market, or targeting particular species based on demand. This helps to maximise the value of the catch back to the boat. Evidence to support this hypothesis requires analysis of logbook and landings data at the trip level for the proportion of catch of separate species over minimum weight over time, to establish whether catch composition and fish weight relative to number has varied significantly compared with levels preceding the reported decline in catch rates. Further evidence of the incentives and disincentives for difference volumes of catch arising from market conditions for these species could be obtained from analysis of CPUE trends.

H9: Active avoidance of low value /catch-restricted species, results in changes in estimated catchability (see also Paper G)

Skippers are reported to be avoiding targeting and retaining large volumes or smaller-sized fish of these species. This choice is reported to be driven by product market factors (low price/demand in the first instance, and the potential to drive beach prices down further by flooding the market with large volumes) and management restrictions (catch restrictions applied to recovering/rebuilding stocks – see Table 29).

Klaer et al. (2012) examined targeting, catch composition and inter-dependence in catches of different species in the SESSF and explored the implications of their analysis for TAC setting. They define ‘companion species’ as “species that should be considered when setting the TAC of the primary [i.e. targeted] species, because a considerable proportion of the primary species catch is taken with the companion species as a non-target catch” (2012: 607). Their analysis required target assignment of the sample of trawl shots analysed, and their assumptions included that fishers target “according to the [market value] of the species in the catch rather than the weight, and that targeting is informed by prior knowledge of where and when certain species may be caught” (Klaer and Smith 2012: 607). However, they acknowledge that multiple species may be targeted by fishers in a single shot, and that the exact proportion of random “prospect” fishing that occurs is not known. It should be noted that evidence to support their assumption that most fishing in the SESSF is based on fisher’s prior knowledge of where and when fish are available is based on analyses published in 2000 and 2001 and has not been recently reviewed. If levels of “prospect” fishing relative to targeted fishing have changed significantly, this may influence estimated catch rates.

They found that in 2006 Silver Warehou was the target fish for 61% of the landed catch of that species and that 23% of its catch was as the companion fish to Blue grenadier; Eastern Gemfish was the target fish for 75% of the landed catch of that species; Jackass Morwong was the target fish for 40% of the landed catch while 32% of the catch of this species was an a companion to Flathead; and that Redfish was the target fish for 47% of the catch and 21% of the catch was as the companion species to Flathead (Klaer and Smith 2012: 611).

In the recent ABARES analysis of boat-level technical efficiency of vessels in the CTS, Green (2016) highlighted difficulties in designating effort to a single species and thereby measuring performance using indicators such as CPUE or any form of efficiency, based on the nature of trawl fisheries. Conventionally, for such fisheries, the proportion of different species caught is a function of stock availability (rather than stock abundance, due to changing annual migratory patterns) and the types of technology (gear) used. However, this convention is itself subject to question, for as Green (2016: 14) points out, the level of variation in stock availability may be of such significance that these species are targetable using area selection, rather than technology(there areanecdotal accounts that a small number of vessels are able to specialise in particular species through area selection).

Analysis of aggregate catch composition by Klaer et al (2014) indicates that the proportion of the total catch for the CTS comprising ‘other’ species has increased since the restructure in 2006, supporting the “mixed bag” hypothesis for the trawl fisheries (Figure 40), noting that these are aggregate data rather than an analysis of catch composition of landings of individual trips. At the same time, there is an indication of substitution of key species and increasing reliance on new key species (declines in volumes of and dominance of the total catch by Silver Warehou and Blue Grenadier and increases in Tiger Flathead and School Whiting).

Analysis of AFMA landings data for the CTS shows that the mean number of species landed per individual trip increased significantly from 2000 to 2002, and has stayed at a mean of between 12-16 species per trip from 2002 to 2017 (Figure 41). For the GHT, the mean number of species landed per trip has ranged between 6 to 8 since 1998 (Figure 41).

While analysis of mean number of species landed per trip appears to refute the hypothesis, analysis of logbook and landings data at the individual trip level for the proportion of catch of separate or individual species over minimum weight over time is required to establish or refute whether species composition of landed catches has varied significantly to levels preceding the reported decline in catch rates.

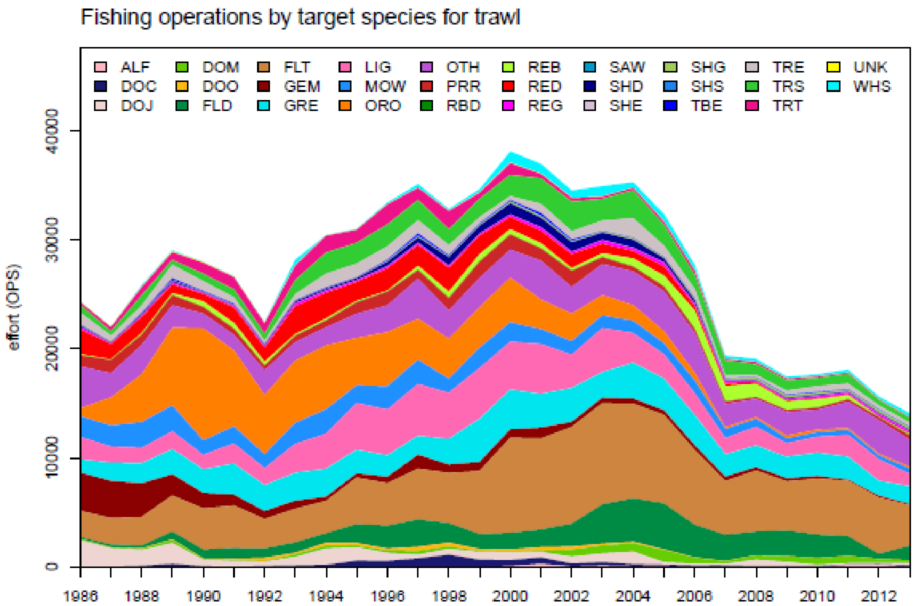

Figure 40. Number of fishing operations targeting species using trawl gears 1986-2013 (Source: Klaer et al. 2014).

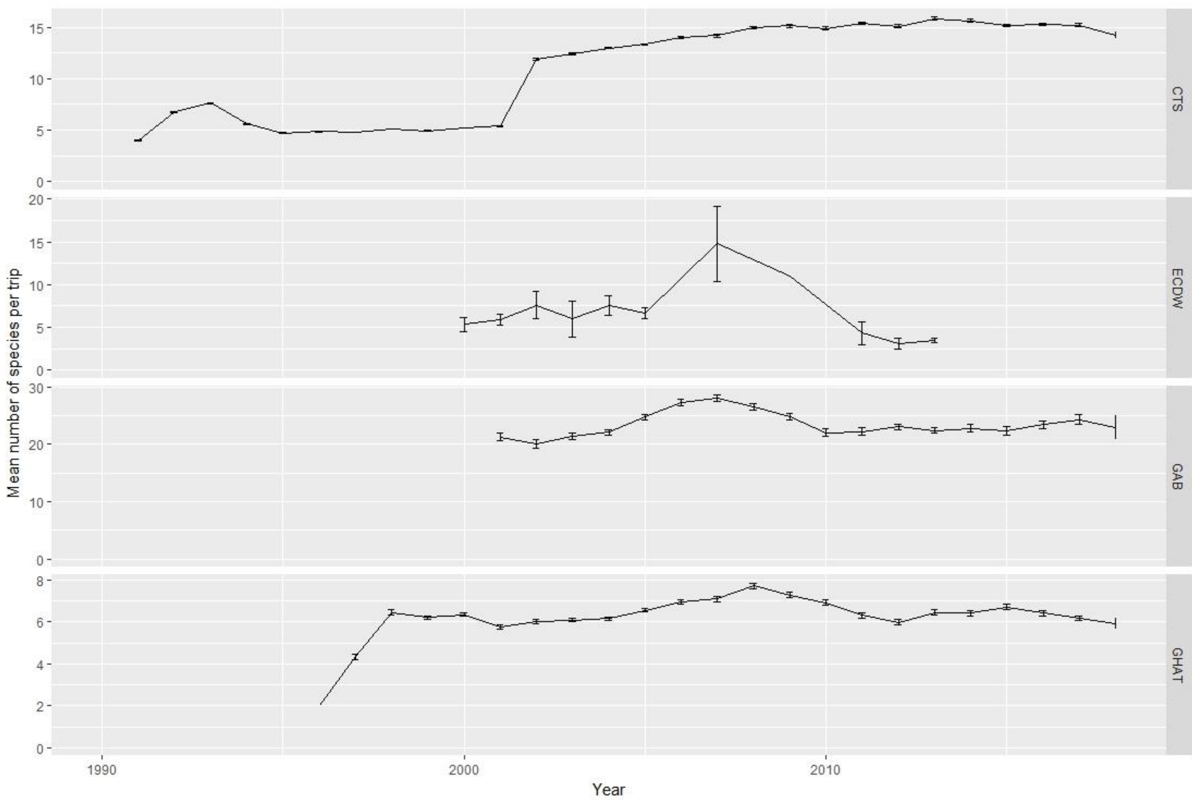

Figure 41. Mean number of species landed per trip for different sub-sectors of the SESSF, 1988-2017 (Source: AFMA landings data).

Currently, targeting behaviour can only be inferred from catch and effort data. Improvements in collection of skippers' stated targeting strategy (species, sizes and catch ratios of these) in logbook records would support definition of targeting for stock assessment purposes. Presentation of CPUE trends may also reveal changes in the scale of incentives and disincentives to target or avoid specific species, which may in turn affect estimates of catch rates.

Klaer and Smith's analysis of targeting and catch inter-dependence could be updated, using the algorithm they developed to identify targeting behaviour.

Pascoe, Punt et al. (2010) examined the degree to which fishers had the ability to target individual species in the NPF. A multi-output distance function was used to examine fishers' ability to control output mix in a fishery about to move to ITQ management. They concluded that analyses of targeting behaviour in similar multi species fisheries with TACs and ITQ management should use a profit, rather than distance, function. They note that in such an analysis "both the ability to target and the incentives to target need to be considered simultaneously" (Pascoe, Punt et al. 2010: 329).

Girardin, Hamon et al. (2017) highlight developments in fleet dynamics modelling using discrete-choice models and the use of these to understand and predict location and gear choice and targeting behaviours in fishers.

VESSEL OPERATION

Location and gear selection are key behaviours in determining skippers' ability to influence catch composition in multi species fisheries, both in terms of species and fish size (Holland and Sutinen 2000, Branch and Hilborn 2008, Pascoe, Punt et al. 2010, Green 2016). Levels of human capital (experience, skill) have also been positively associated with fishing efficiency in the English Channel trawl fisheries (Coglan and Pascoe 2007).

H10: Levels of deployment of different gear types to target/avoid certain types of catches/species have changed relative to levels preceding reported CPUE declines, and that this has distorted estimates of catchability (see also Paper G)

Skippers are reporting that they are deploying generalist nets more frequently, and at the same time sub-groups of skippers are becoming specialists. Generalist nets result in smaller catches composed of mixed species. This helps to maximise the value of the catch back to the boat by responding to market demand and higher beach prices. Unstandardized single species catch rates for these shots are therefore low. Evidence that would support this hypothesis includes time series analysis of logbook data concerning gear deployment to determine if changes in prevalence of this behaviour (use of generalist nets) have occurred in parallel with declines in catch rates.

H11: Spatial and seasonal distribution of effort (areas, depths, length of shots and trips) has changed as fishers target smaller volumes of larger or higher value fish rather than high catch rates, relative to distribution of effort preceding reported declines in CPUE, and that this has distorted estimates of catchability (see also Paper G)

Skippers are actively choosing to not fish in areas where spawning aggregations of lower value species are occurring to avoid large catches of small fish of single species. This avoidance behaviour is also affecting length of shot and trip. These reported behaviours are driven by low market demand (and therefore, prices) for such catches. Instead, fishers are choosing locations and depths where larger fish of more than one species are available, though less aggregated. This behaviour is reported for Eastern Gemfish and Blue grenadier in particular. Evidence that would support this hypothesis includes time series analysis of logbook data concerning location, seasonality, shot length and trip length to determine if changes in prevalence of these avoidance behaviours have occurred in parallel with declines in catch rates.

H12: Levels of fishing efficiency of skippers due to higher proportion of new entrants has decreased relative to levels preceding reported declines in CPUE, and that this has distorted estimates of catchability (see also Paper G)

Industry advisers report that a sub-group of skippers are fishing far less efficiently, deploying additional, un-targeted 'exploratory' or random prospect shots which are landing lower catches, relative to targeted shots by more experienced skippers. This is despite reported increases in fishing power generally. This may be lowering estimates of catch rates for single species if this sub-class of skippers is increasing as a proportion of overall skippers. This sub-group comprises recent entrants who are employed by companies (i.e. hired skippers, see Table 25) who have no family history or prior knowledge of the fishery. In contrast, other new entrants who have a family history of fishing are reported to be comparatively efficient, due to the advantage of shared local knowledge about effective targeting strategies and vessel operation (time of day, location choice).

Furthermore, changes in the types of companies and their principal-agent arrangements with hired skippers may be influencing the types of incentives under which skippers operate and their choices between alternate fishing strategies and tactics. Skippers report that those skippers who are entirely dependent on acquiring leased quota are choosing fishing strategies in which they fish early in the season to service upfront quota lease payments, regardless of whether those times are optimal for catch rates and targeting larger, higher value fish. Evidence that would support this hypothesis includes time series analysis of both logbook and licensing data concerning average levels of experience (number of years in the fishery as a skippers) of skippers active in the fishery each year, to determine whether average levels of experience behaviours have declined in parallel with declines in catch rates. Further analysis could determine whether a sub-class of skippers with less than 5 years' experience has been associated with lower catch rates compared with the overall skipper population.

Data are available from AFMA logbook data concerning gear type used which indicates no substantial changes in general gear type deployed to catch Silver Warehou, Redfish, Jackass Morwong and Eastern Gemfish over the last two decades (Figure 42). However, this analysis does not specify the types of nets being used.

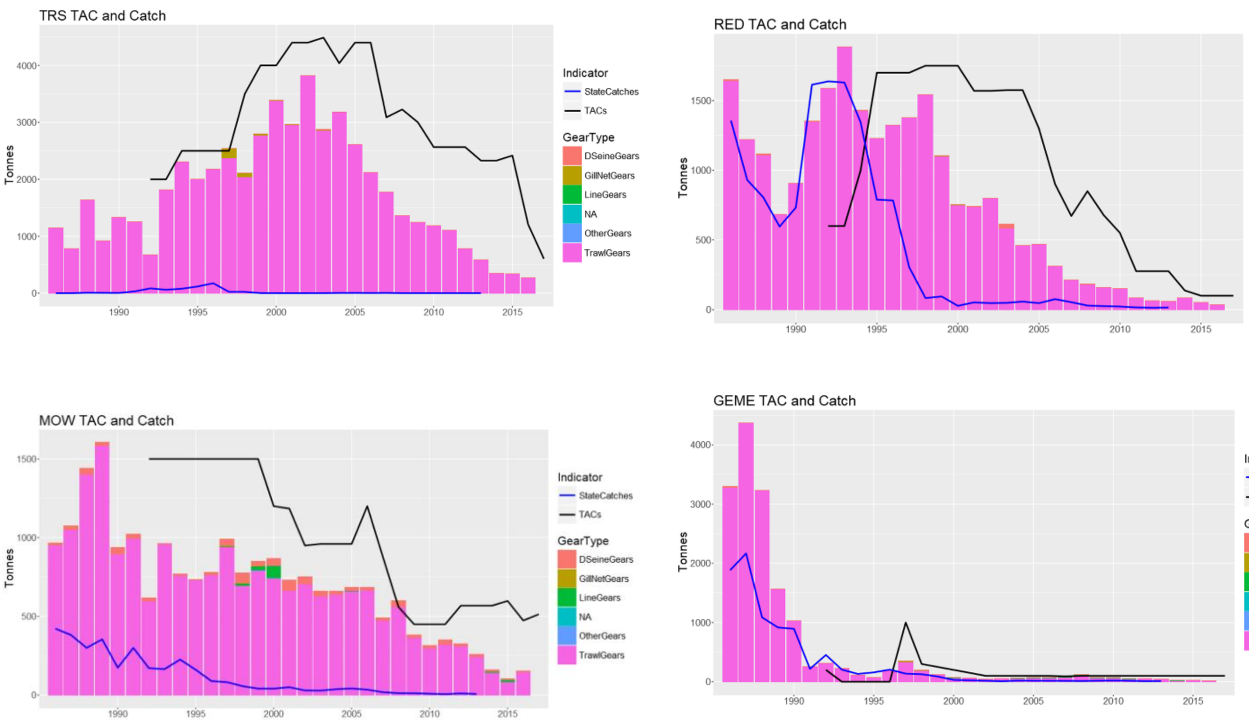

Figure 42. Changes in gear type used to catch Silver Warehou (TRS), Redfish (RED), Jackass Morwong (MOW), Eastern Gemfish (GEME).

Data available from AFMA logbook data concerning depth of fisher effort by gear type does not indicate substantial increase in the range of depths at which shots are occurring for the trawl gears (Figure 43), although the resolution of the analysis may be too low to pick up this change in vessel operation. Historical analysis by Klaer et al (2014: 3) indicates that at the aggregate level (all gear types), a higher proportion of effort has been located in shelf depth zones, with a subsequent minor decline in the proportion of effort in the slope depth zone and a significant decline in the deep-water depth zone.

When these data was broken down into depth by zone, it appears that variation in depths at which different types of gear are shot is at least partially determined by zone, and that there appears to be no consistent trend in the depths at which different gear types are shot across zones across time (Figure 44). Analysis at higher resolutions in both depth ranges and sub-zones for the period preceding reported declines in catch rates as well proceeding is needed to establish whether re-distribution of effort at different depths and in different zones is an explanatory factor accounting for such declines. Changes in the distribution of shots across depths and zones at this level of resolution is likely to be confounded by the re-distribution of effort caused by the introduction of Commonwealth marine reserves.

Green (2016) found a statistically significant level of technical inefficiency in the CTS from 2002-3 to 2012-13. Silver Warehou and Jackass Morwong were species included in the output index. Peak efficiency was estimated to be in 2009 and has since declined. He concludes that this peak was attributable to changes in the composition of the fleet, rather than improved efficiency by fishers. He also found that, according to most model specifications, "boats that expend more fuel are those searching for, and failing to find, fish". Whether this reveals a sub-population of highly technically inefficient fishers or an issue with model specification is not established but warrants resolving (Green 2016: 23). Sources of inefficiency that need incorporating into further analysis include: skipper characteristics (age, experience) and vessel characteristics (length, engine power, year of manufacture) (Green 2016: 23).

Data obtained from the AFMA Licensing database (Figure 45 and Figure 46) show that of active skippers in 2017, 49% of skippers in the GHTS and 37% of skippers in the CTS had 0-5 years' experience in the fishery. For the CTS, a high proportion of skippers have over 11 or more years' experience in the fishery (48%) while in contrast only 23% of GHTS skippers have this many years' experience. For the CTS this suggests two major sub-groups in the fishery; the inexperienced new entrants and the highly experienced operators. However, without being able to compare these proportions of experienced with inexperienced skippers in the fishery in 2017 to previous years (2007, 1997, 1987, for example), this analysis can't support the H.5 hypothesis.

No analysis is currently available concerning the catch rates of newer entrants compared with established skippers, although this analysis is possible using AFMA licensing and logbook data. No data are currently available concerning the proportion of skippers under different types of principal-agent arrangements.

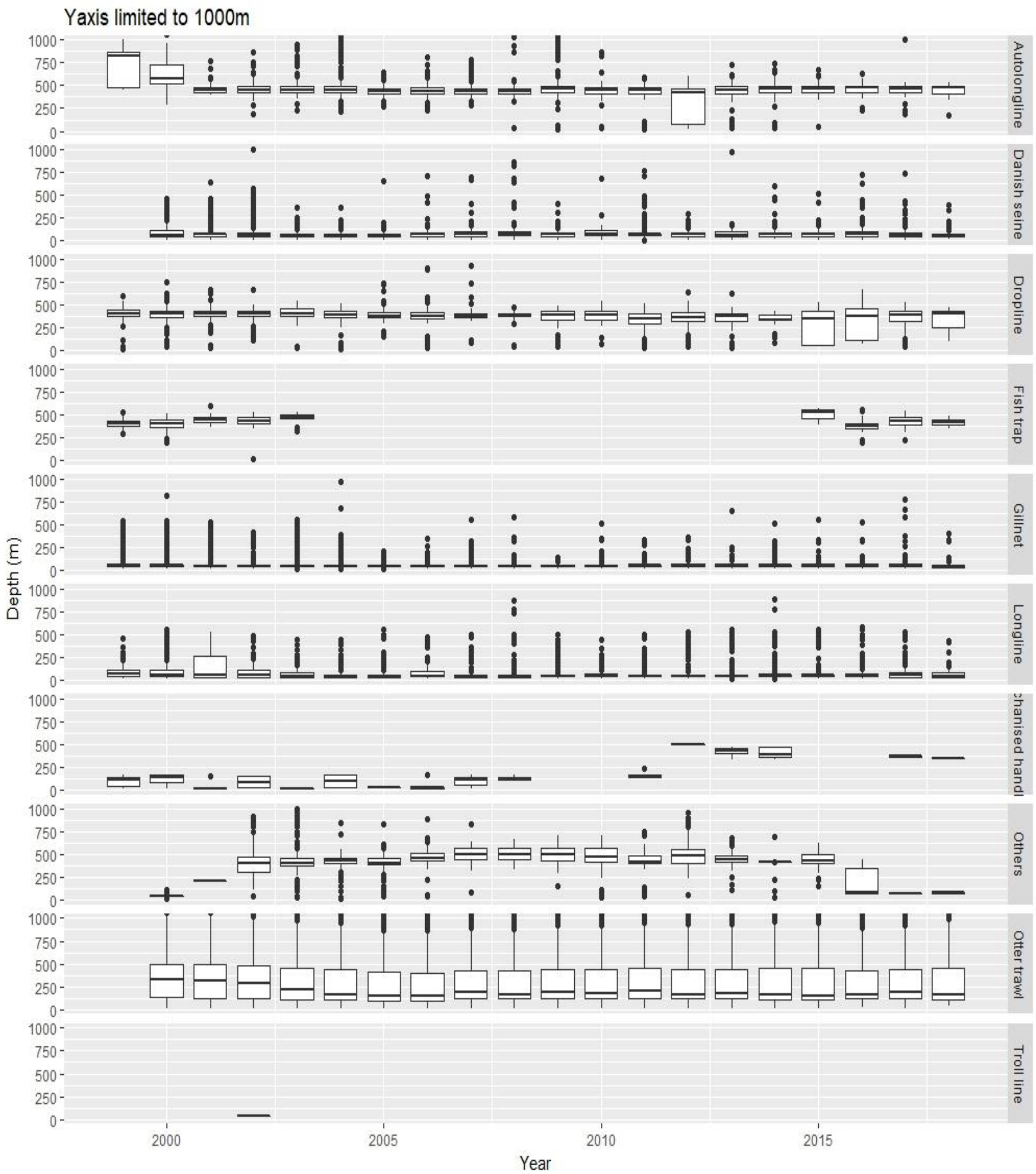

Figure 43. Depth box plot by gear type, Y axis limited to 1000m.

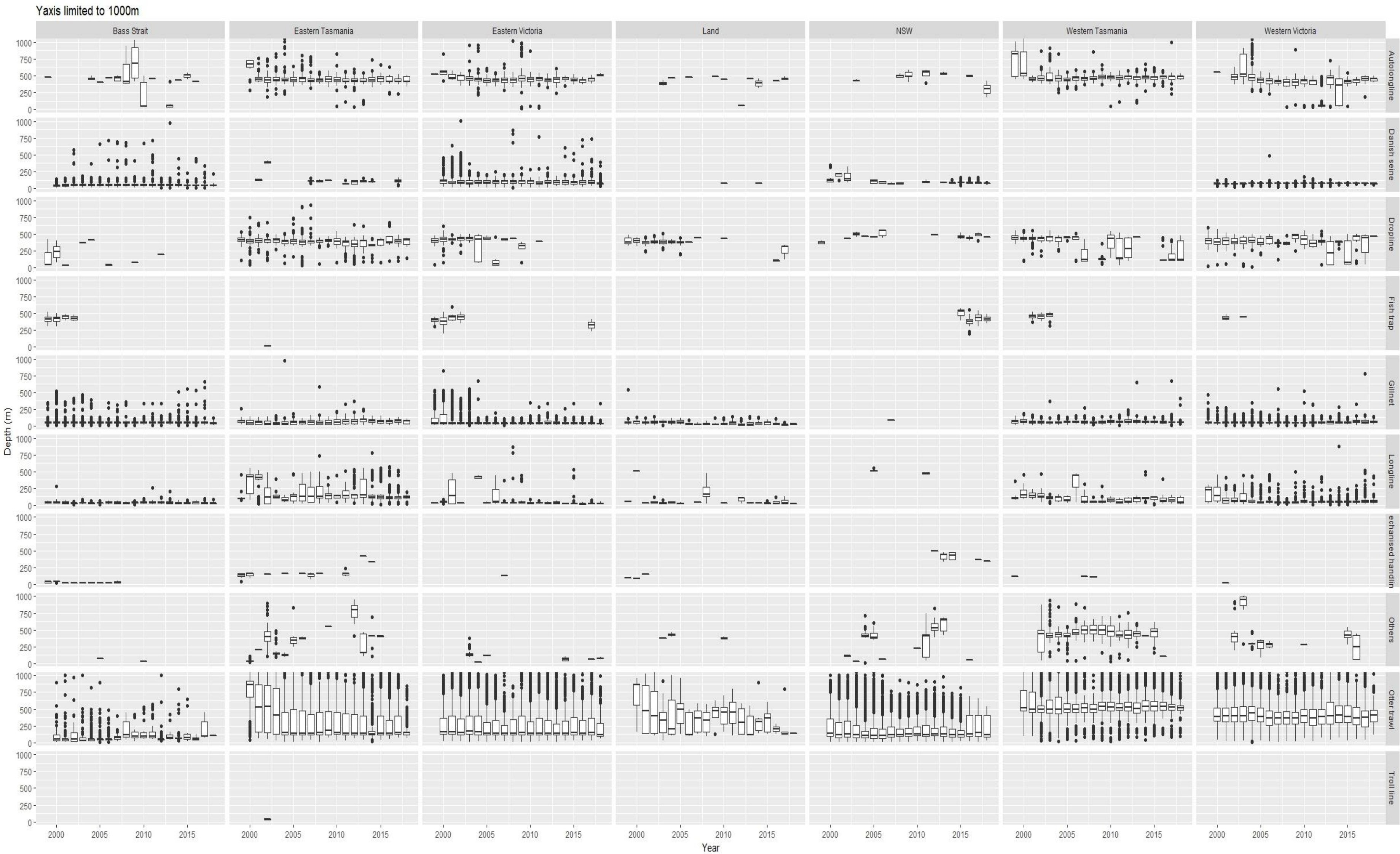

Figure 44. Depth box plot by gear type by zone, Y axis limited to 1000m.

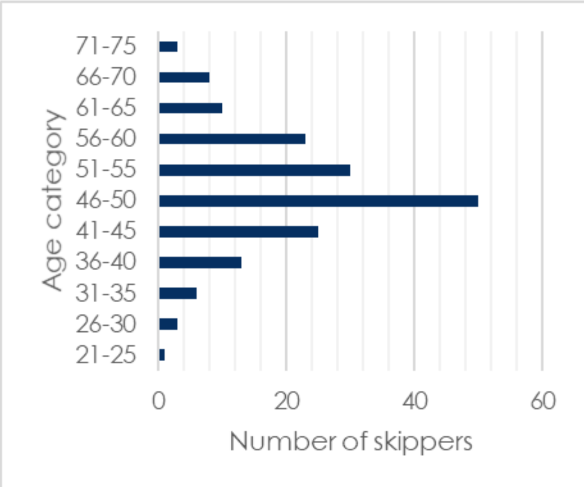

Figure 45. Age structure of skippers in the SESSF in 2014. (Source: ABARES, Skirtun et al. (2015).

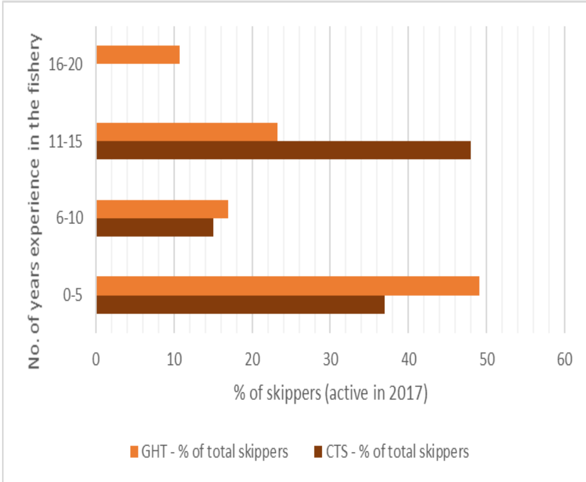

Figure 46. Years of experience of skippers active in 2017, as a proportion of total number of skippers active in 2017. (Source: AFMA licensing data).

The Assessment Process paper (Paper G) considers the supporting evidence and potential solutions from recent analyses concerning improvements in targeting and catch rate definition and standardisation to more accurately account for effort parameters (gear, depth, location and seasonality choice behaviours), as well as landings parameters (weight/size of landed fish, composition of catches).

Resolving the sources of detected technical inefficiency in the fleet, as identified by Green (2016), would then make it possible to identify further solutions and effective interventions.

IMPACT ON LACK OF RECOVERY OF OVERFISHED SPECIES

Industry advisors did not identify any potential explanations or mechanisms directly related to fisher behaviour and vessel operation, other than avoidance behaviours towards these species and the resulting changes in estimated catchability (and thereby, abundance estimates) which are discussed in the previous and following sections. This hypothesis is also directly address by Paper G (Assessment Process). Fisher avoidance of overfished species should have contributed to their recovery. That it appears to have had negligible effect suggests another mechanism likely played a more important role.

It is understood that this Fishery Indicator issue concerns Eastern Gemfish, Blue Warehou, Redfish, Jackass Morwong, Silver Warehou, and School shark, of which all but School shark are considered in this section (Impact of Declining CPUEs) of this paper.

- (including preceding reported declines in catch rates), and how this can be more accurately reflected in the stock assessment process.

WORKSHOP FEEDBACK AND CONCLUSIONS

Workshop participants suggested that there were several contributing mechanisms for the impact of fishery behaviour and vessel operation on under-caught TACs. Choke species was considered to be the most likely mechanism and largest contributor to this, but livelihood preferences, quota balancing, concentration of quota and seasonal inflexibility were also considered to be mechanisms (Figure 47, Figure 48). In considering the species most affected by these mechanisms, Mirror Dory was a clear standout compared to other under-caught species. In addition to being a choke species, seasonal inflexibility and quota balancing were highlighted as important mechanisms (Figure 49)

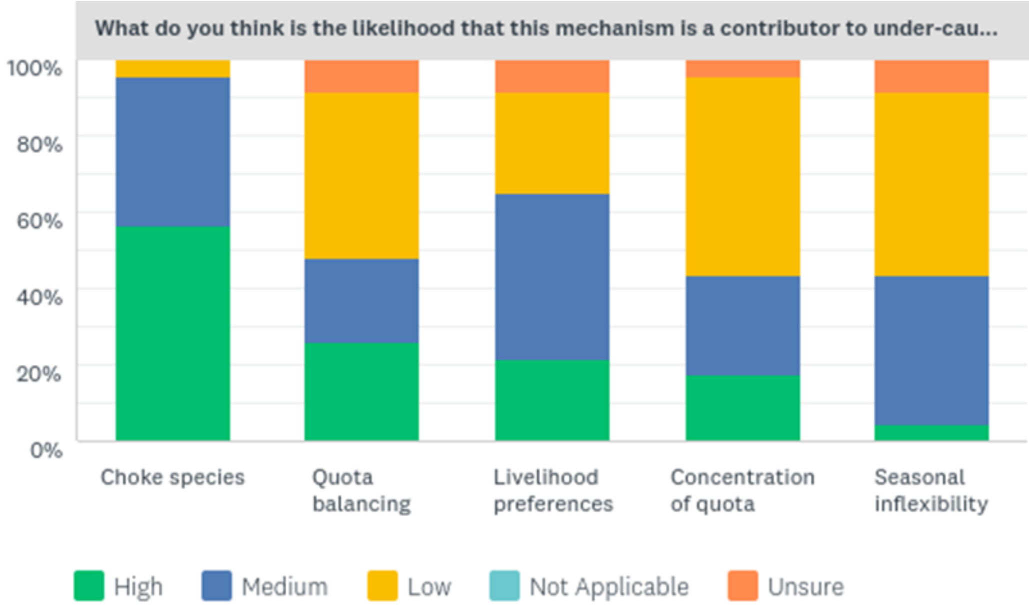

Figure 47. Workshop participant assessment of the likelihood that these fisher behaviour mechanisms are a contributor under-caught TACs.

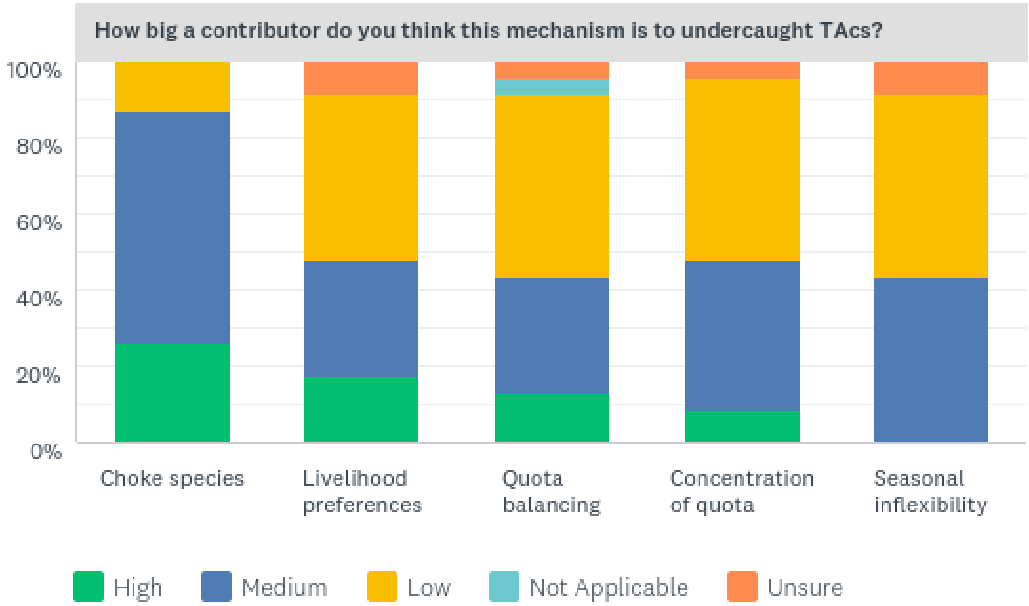

Figure 48. Workshop participant assessment of how big a contributor these fisher behaviour mechanisms are to under-caught TACs.

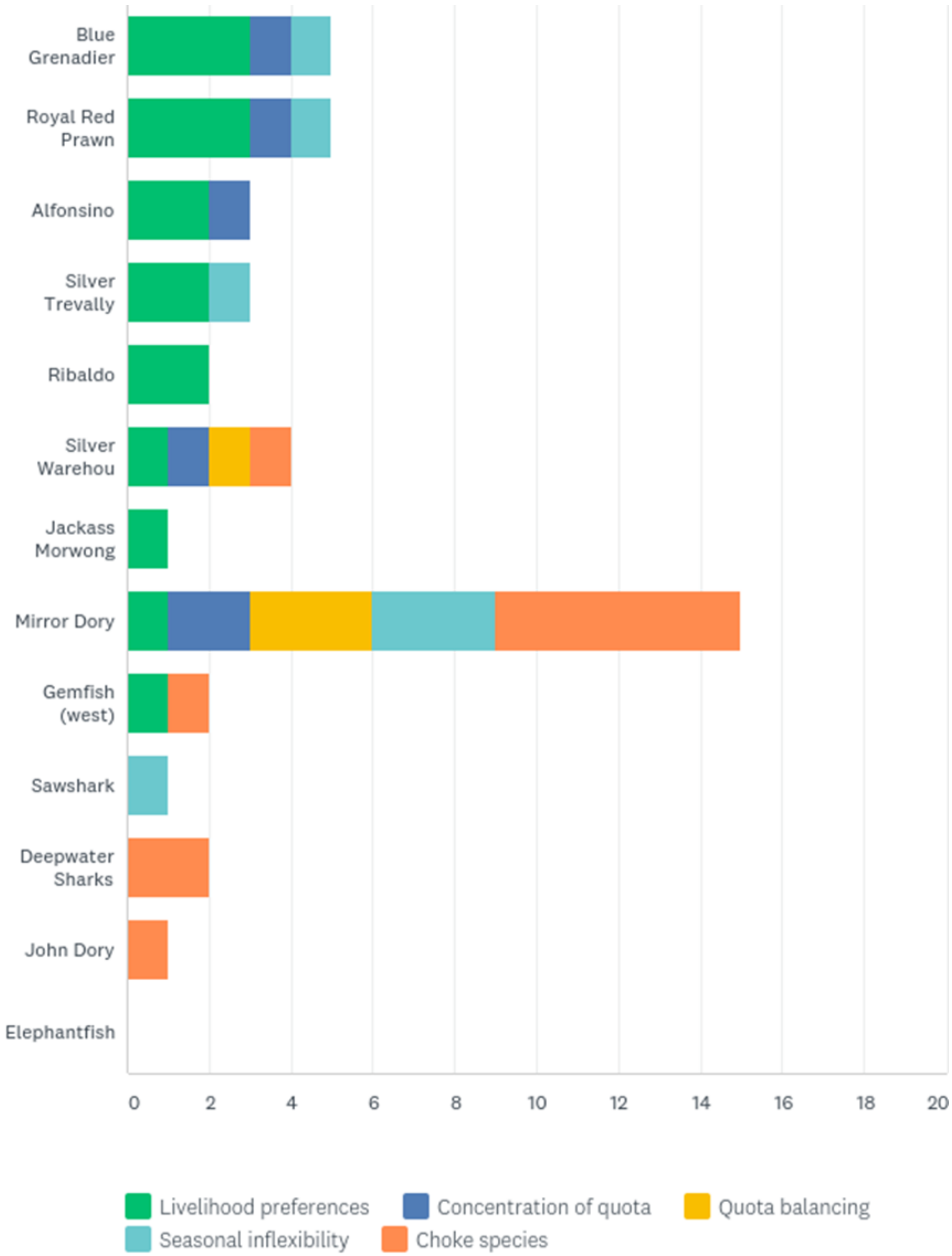

Figure 49. Workshop participant assessment of which particular fisher behaviour mechanisms are relevant to the under-caught TACs of specific species.

Fleet avoidance of species and a mixed-bag targeting strategy were considered to be prominent mechanisms for apparent declining CPUEs (Figure 50, Figure 51) Avoidance was especially important for the non-recovering species (School Shark, eastern Gemfish, Redfish and Blue Warehou) which are all under rebuilding strategies. (Figure 52).

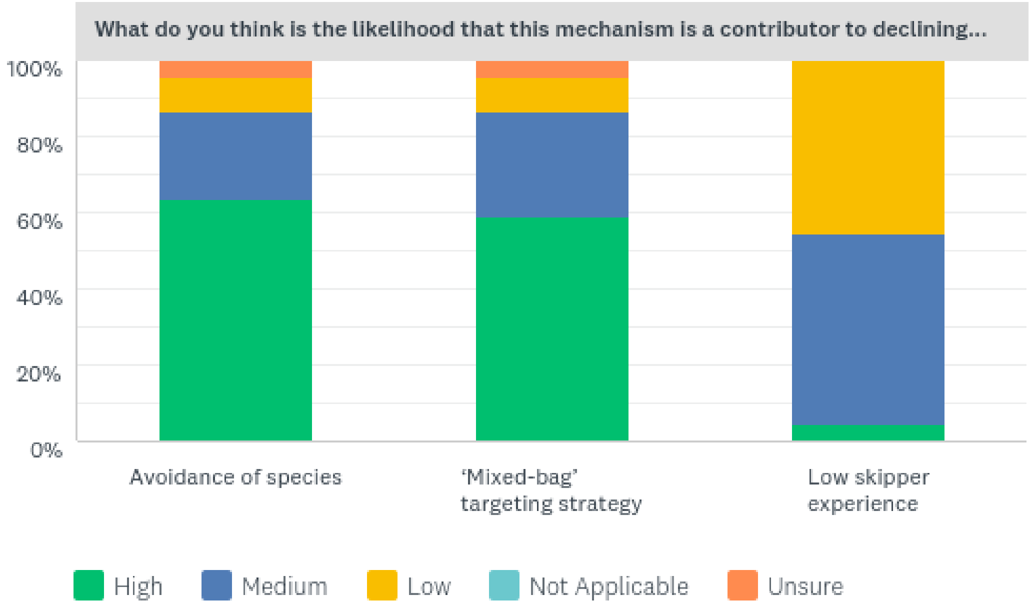

Figure 50. Workshop participant assessment of the likelihood that these fisher behaviour mechanisms are a contributor to declining CPUEs.

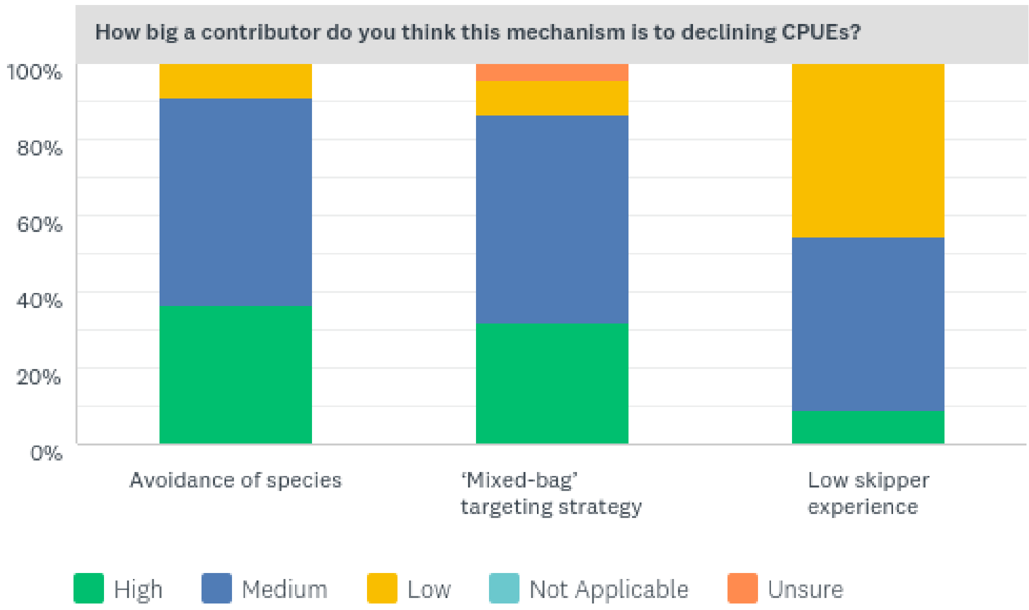

Figure 51. Workshop participant assessment of how big a contributor these fisher behaviour mechanisms are to declining CPUEs.

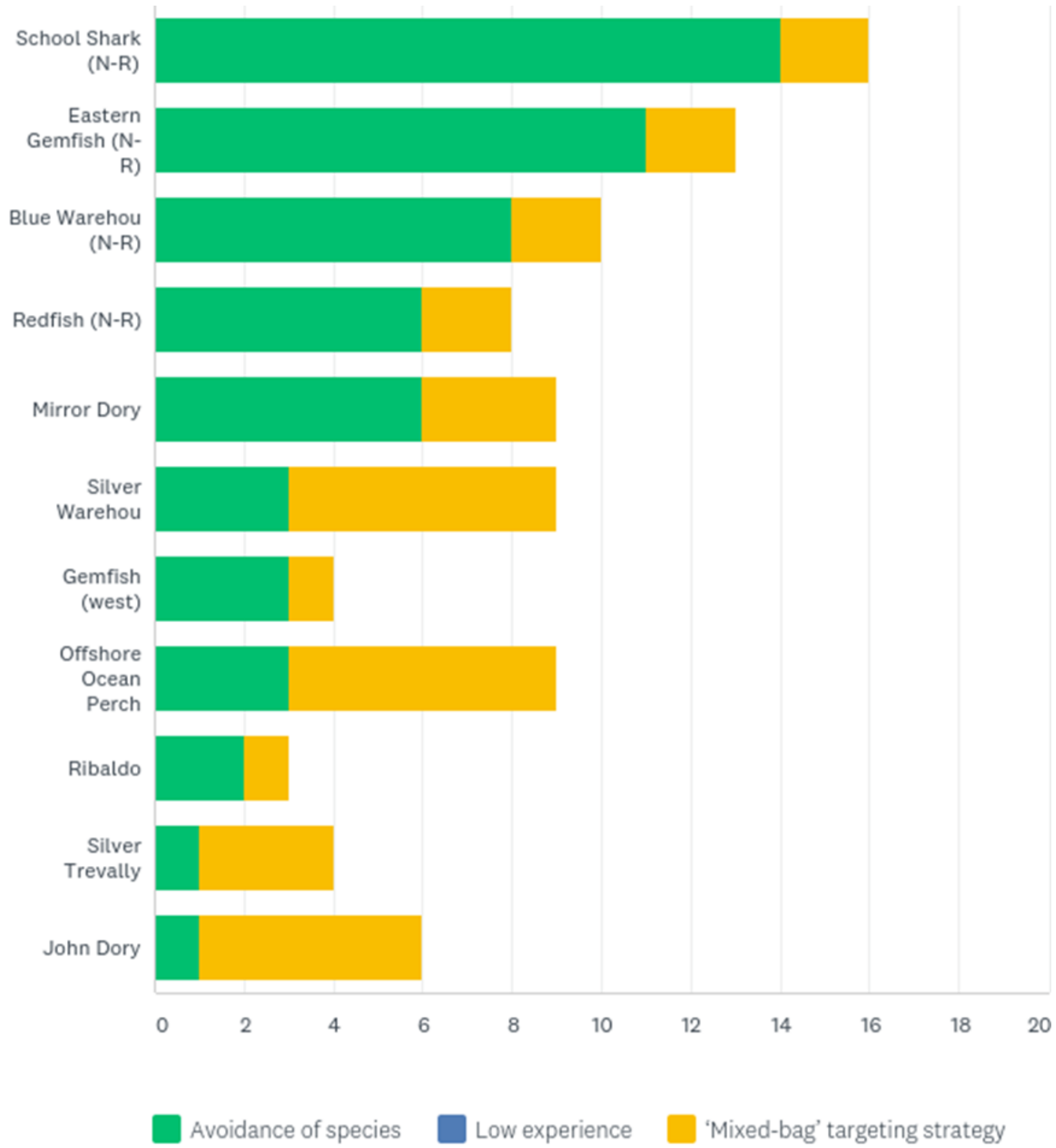

Figure 52. Workshop participant assessment of which particular mechanism are relevant to the declining CPUEs of specific species (N-R = Non-recovering).

None of the mechanisms was considered to rate highly as a mechanism preventing recovery of the overfish species (Figure 53, Figure 54). Avoidance was considered the most relevant mechanism for lack of recovery of each species (Figure 55) largely because of the influence that avoidance has on (reducing) CPUE which is used as an index of abundance).

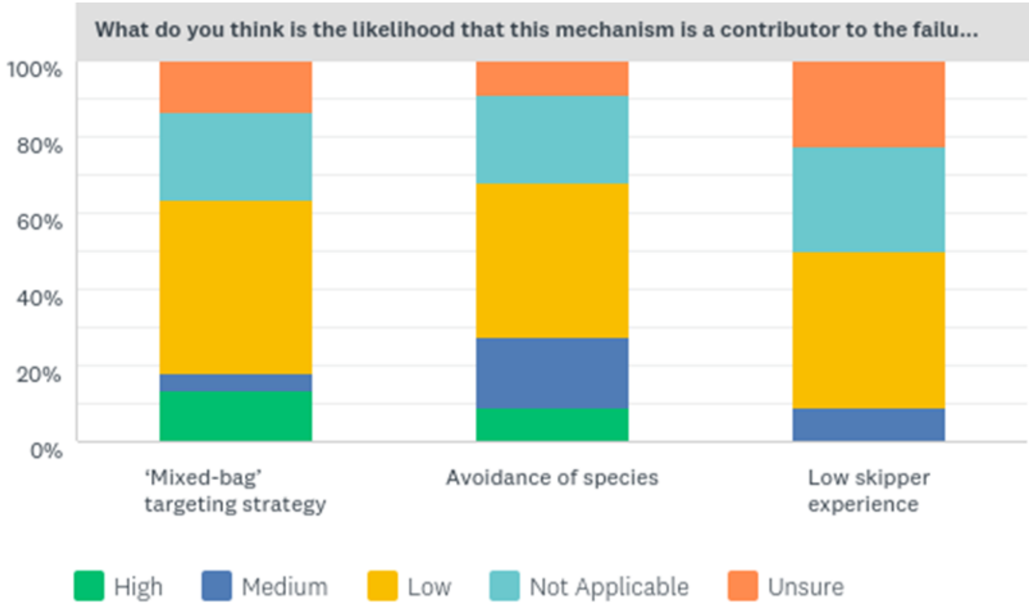

Figure 53. Workshop participant assessment of the likelihood that these fisher behaviour mechanisms are a contributor to declining CPUEs.

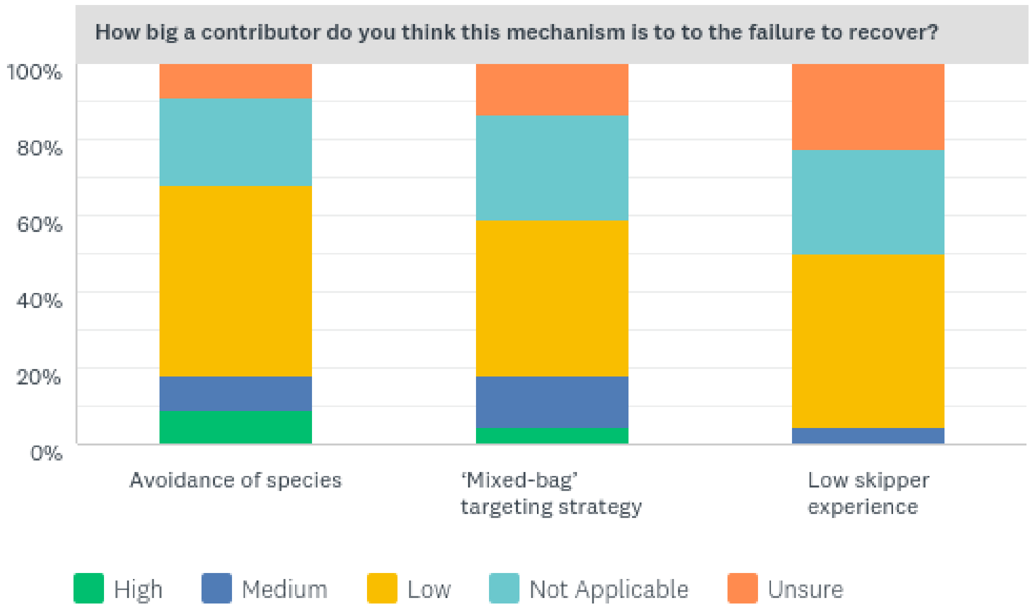

Figure 54. Workshop participant assessment of how big a contributor these fisher behaviour mechanisms are to lack of recovery of over-fished species.

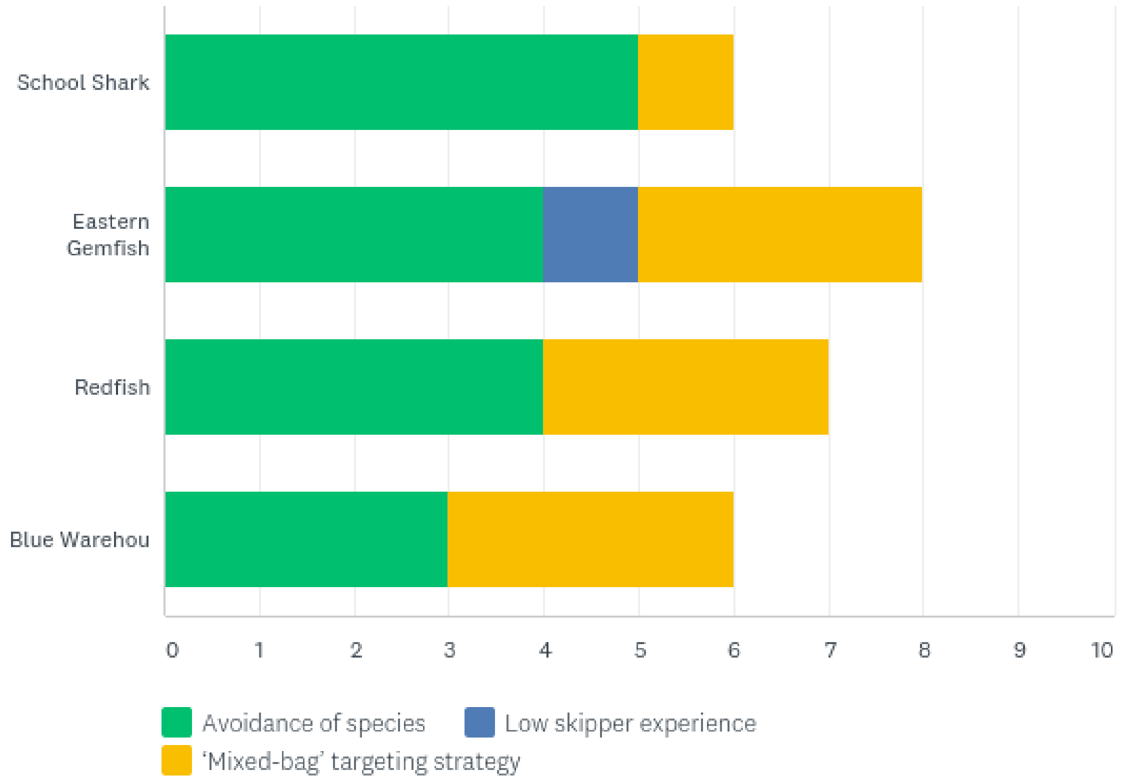

Figure 55. Workshop participant assessment of which particular fisher behaviour mechanisms are relevant to the lack of recovery of over-fished species.

Further research is required to understand:

- Whether there are sub-groups of participants in the SESSF who are operating with differing sets of incentives and constraints and whose behaviour is affecting interpretation of fishery-dependent data, technical efficiency and the liquidity of quota markets.

The degree of change in targeting and avoidance behaviour and therefore location, seasonality, depth, and length of trip and shot choices and behaviours across time

Climate Change and Oceanographic Conditions

Alistair Hobday, Rich Little and Ian Butler

SCOPE OF THE ISSUE

There are long-term trends in the temperature and currents of the oceans around Australia that are already leading to substantial changes in associated marine ecosystems; these trends are projected to continue and to have greater impact in the future. Temperatures are warming at almost four times the global average off south-east Australia; ecological and fishery impacts are compounded as the currents are also changing. There have been extensive climate-related changes in distribution of sea urchins, intertidal molluscs, seaweeds and many coastal fish species over the last few decades. Long-term change and extreme events, such as marine heatwaves and cyclones, have impacted commercial fish habitat such as mangroves, kelp beds and coral reefs, and reduced populations of important commercial species around Australia (e.g. Hobday et al. 2016; Oliver et al. 2017).

Productivity and biomass of marine resources is intrinsically linked to ocean conditions. In favourable environmental conditions, recruitment, growth, and survival are high, and the focal stock size can increase, and sustainable fishing levels may be higher. The converse is true in periods of unfavourable conditions, and the total biomass supported by the environment in the absence of fishing (e.g. dynamic B_0) may be lower. Understanding the state of the environment with respect to biomass and productivity of a particular species or ecosystem is thus critical for fisheries management. Environmental variation between favourable and unfavourable conditions can occur on a range of time scales (Figure 56) which will influence the three negative indicators (uncaught TACs, apparent declining CPUE, and lack of recovery of some stocks).

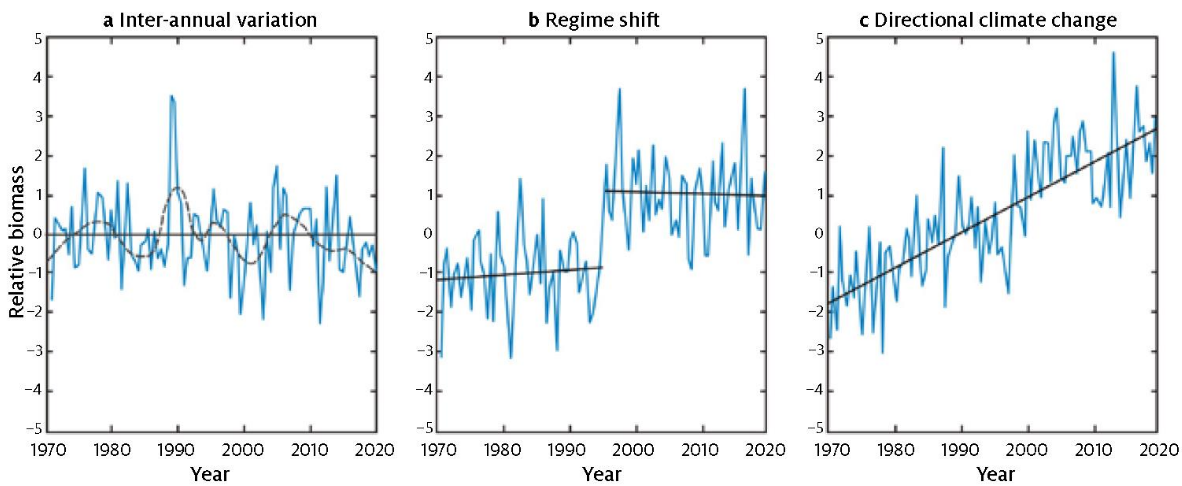

Figure 56. Illustration of environmental variability (a) inter-annual (b) regime shifts (c) directional climate change.

- **Inter-annual environmental variability** operates typically at time scales of 1-5 years. Inter-annual variability can manifest itself either as unpredictable noise, or relatively predictable episodic or periodic cycles (Figure 56a). The former is exhibited in species such as squid, prawns, scallops, small pelagic fishes, while the latter in stocks such as Blue Grenadier.
    - <u>Inter-annual variability can lead to short-term variation in the negative indicators</u>.

- **Regime shifts**. Marine ecosystems are occasionally subject to sudden, dramatic, long-lasting changes in ecosystem structure and function (Figure 56b). Regime shifts operate at large spatial scales (e.g., regional to basin scales) and are characterized by temporal variability that is coherent across multiple taxa and trophic levels within a community. Regime shifts can occur as responses to natural (e.g. low-frequency climate variability) or anthropogenic causes (e.g. overfishing, eutrophication, habitat loss). Regime shifts are best known from the North-east and South-east Pacific Ocean, where spatially extensive, multi-decadal observational time series allow changes in ecological structure to be documented. No regime shift has been reported at an ecosystem level (Litzow et al. 2015). Long-term biological observations are scarce in most marine ecosystems globally, which may make the formal detection of regime shifts difficult or impossible on a time scale that is useful for management (i.e., if only identified many years later).
    - Regime shifts can lead to a step change in the negative indicators.
    - No regime shift has been reported at an ecosystem level in southeast Australia (Litzow et al. 2015).
- **Long-term sustained environmental change** is occurring or is projected to occur over many decades (Figure 56c). This may be due to anthropogenic climate change, resulting in long-term warming and acidification of the ocean. Long time series may be needed to detect these changes.
    - Sustained change in the negative indicators is a consistent with long term change.

There have been observed oceanographic and environmental changes in the SESSF region, in sea surface temperature, temperature at depth, currents, chlorophyll (productivity). These patterns are described in the following sections, along with some projected changes for the region.

SEA SURFACE TEMPERATURE (SST)

Sea surface temperatures have been steadily rising in the southeast region (Figure 57). It is one of the fastest warming in the global ocean with observed temperature increases approaching 2°C over the past 80 years (Hobday and Pecl, 2014). Inter-annual variation over the past decade is apparent and overlays the overall warming trend (Figure 58). Annual climatologies show the pattern of SST each year, such as the warm period at the end of 2017 (Figure 59).

Sea surface temperatures around Australia are projected to be approximately 2.0°C warmer in the south within the next 100 years under RCP 2.6, or 5.0°C warmer in the south within the next 100 years under RCP 8.5 (Lenton et al. 2015). This warming is likely to result in increased stratification, which has also been associated with declining oxygen concentrations (Thompson et al. 2009).

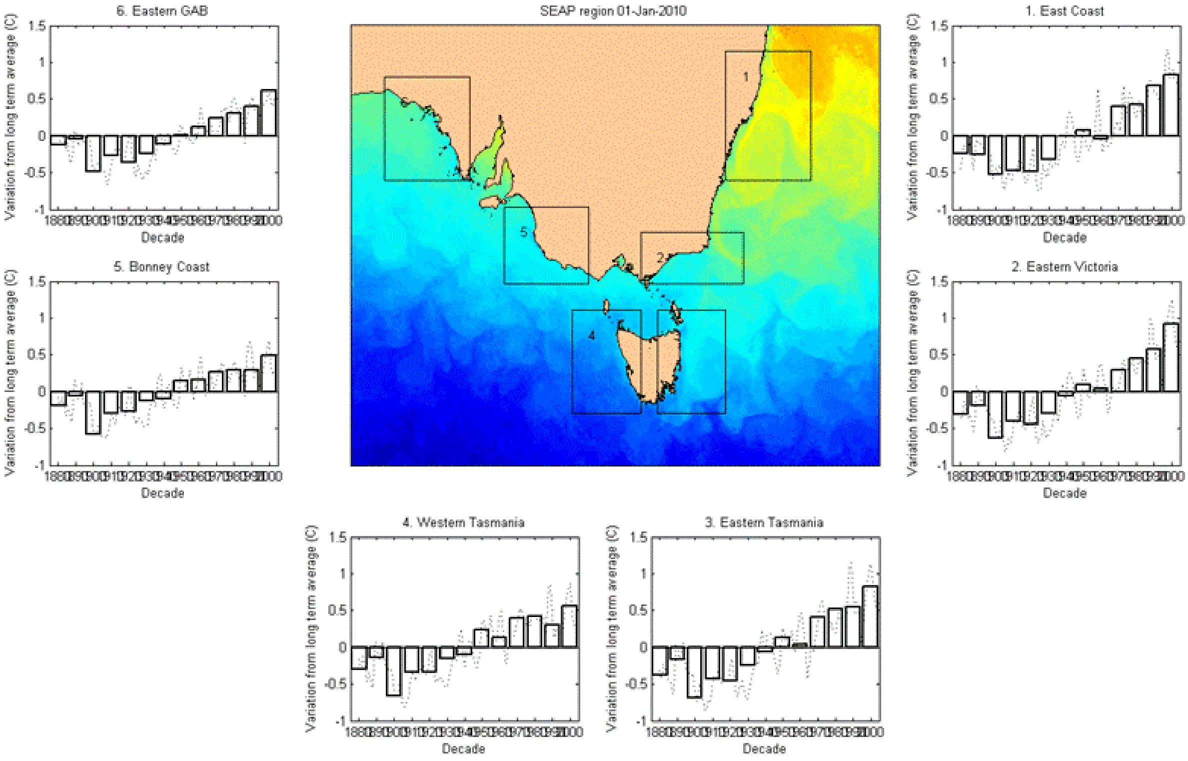

Figure 57. Long term SST patterns in regions of the SESSF.

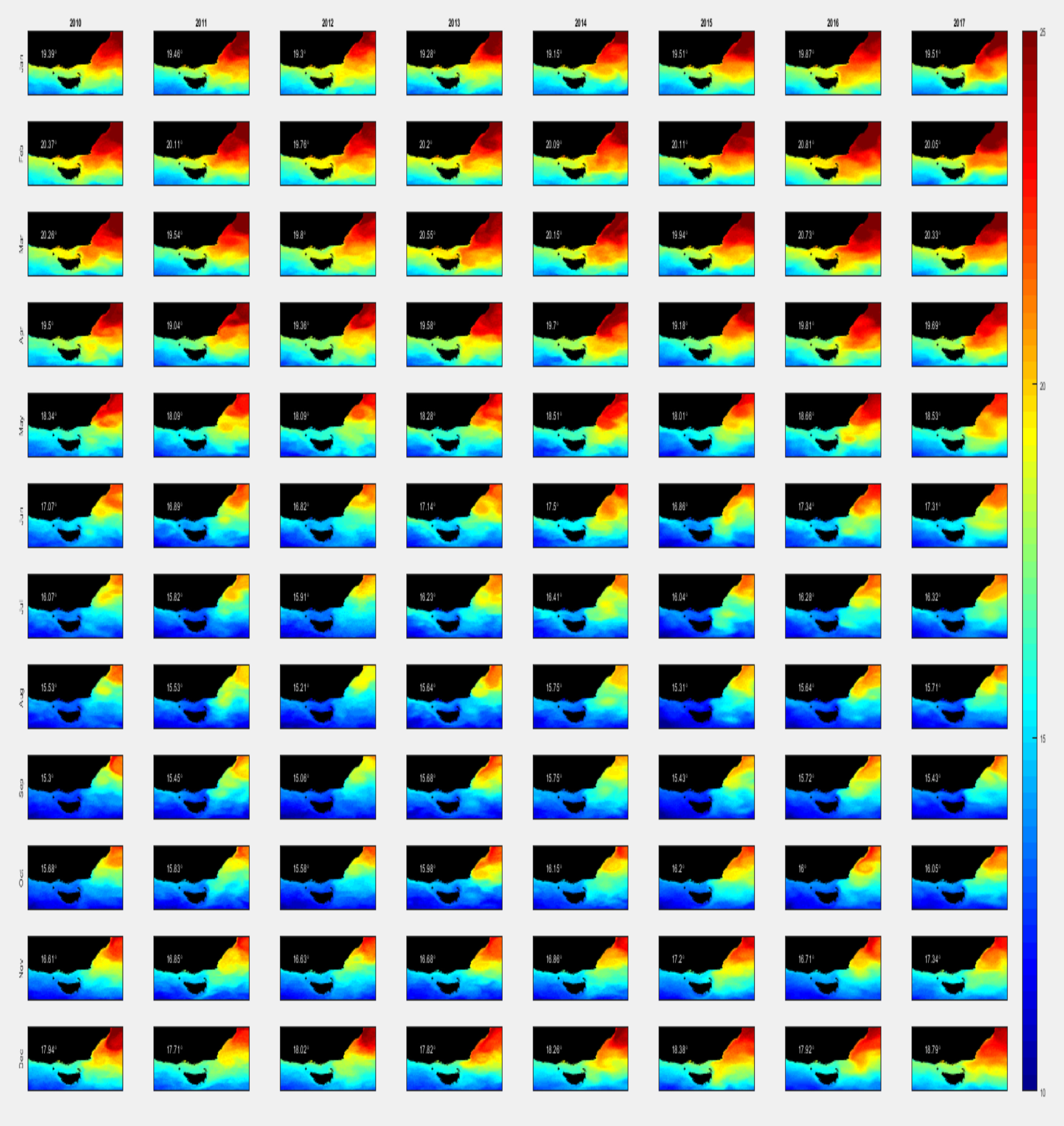

Figure 58. Sea surface temperature in south-east Australia.

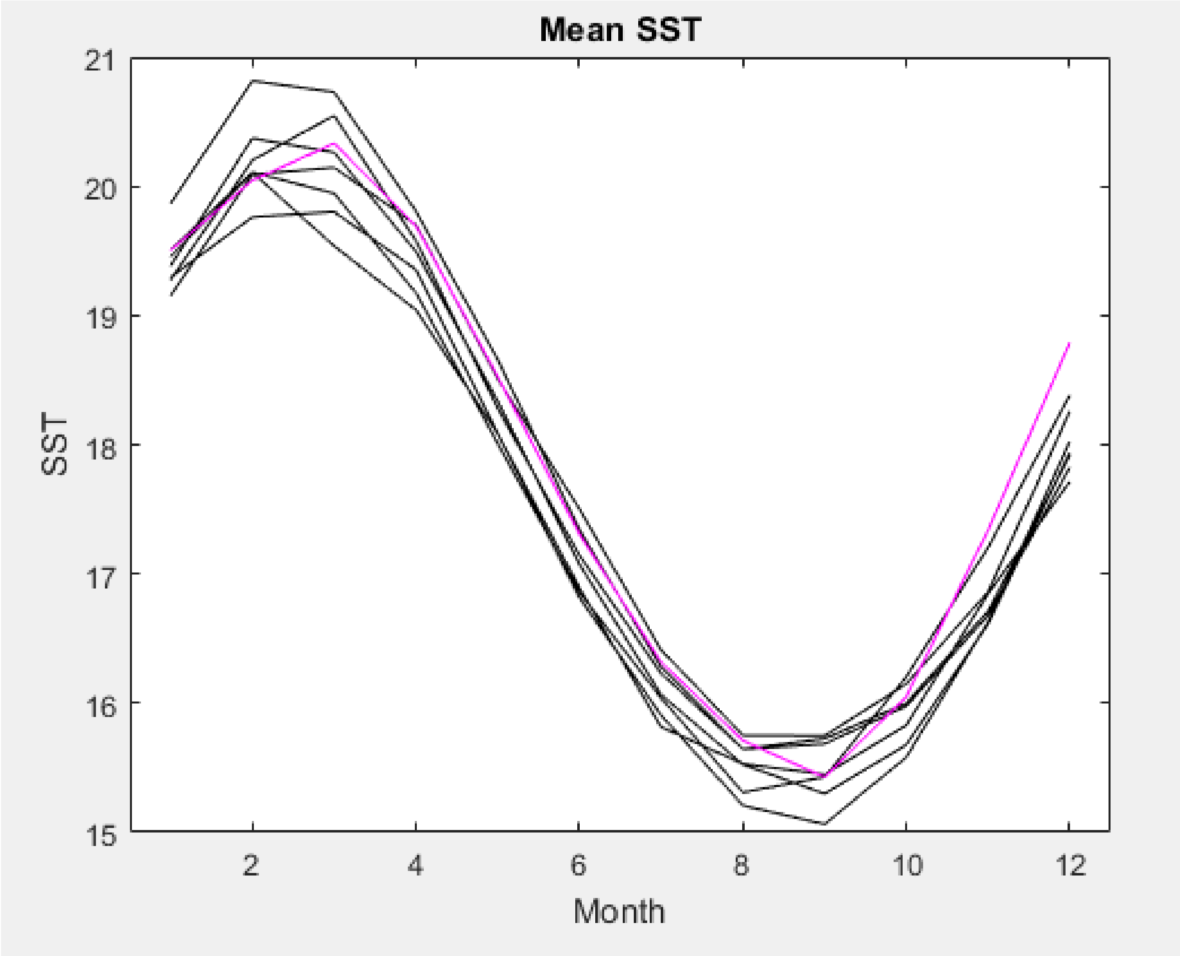

Figure 59. Recent (2010-2017) annual SST climatologies for the region shown in Figure 3 (2017 in magenta).

SALINITY

Increases in salinity have been reported in the south-east marine region, associated with a strengthening East Australia Current (EAC, Ridgway 2007; Hill et al 2008; Figure 60). These salinity changes are relatively small in the open ocean, however, and thus do not directly affect biology, but are an indicator of changing ocean conditions.

OCEAN pH

Changes in water chemistry, as a result of the oceans absorbing CO_2, are not well documented around Australia, but are not substantially different from the pH decrease of 0.1 reported for the global ocean (Lenton et al. 2015). Projections of pH change under RCP 8.5 are the largest, with a decrease of 0.68 (0.61-0.73) by 2050, doubling to 1.35 (1.24-1.44) in 2090, relative to the historical period (Lenton et al. 2015).

In terms of pH risk to species in general (and not specifically to the south-east), there is mounting evidence that declining pH reduces the ability of plankton to precipitate carbonate shells, although most experiments have been performed at pH levels not expected until the year 2100 or after. There is also evidence of acidification impacting the growth and behaviour of other marine life – corals, sponges, rock lobster, shellfish, and fish (Munday et al 2013) although the impacts of temperature increase are seen as more important (Watson et al 2018).

NUTRIENTS

The availability of nutrients is important for phytoplankton growth. One of the most important is nitrate, which has shown an increasing trend in south-east Australia and levels are now more enhanced in winter (Thompson et al 2009). The changing nutrient concentrations are due to changes in circulation of currents (tropical water is nutrient-poor) and stratification of the ocean due to warming, which reduces mixing of nutrient-rich deep water to the surface where there is light to support phytoplankton growth.

TEMPERATURE AT DEPTH AND OXYGEN CONCENTRATION

The warming of ocean waters also extends to deeper waters (Lenton et al 2015). Evidence for the warming at depth comes from ARGO float profiles (Figure 60).

Oxygen changes in the south-east have not been detected.

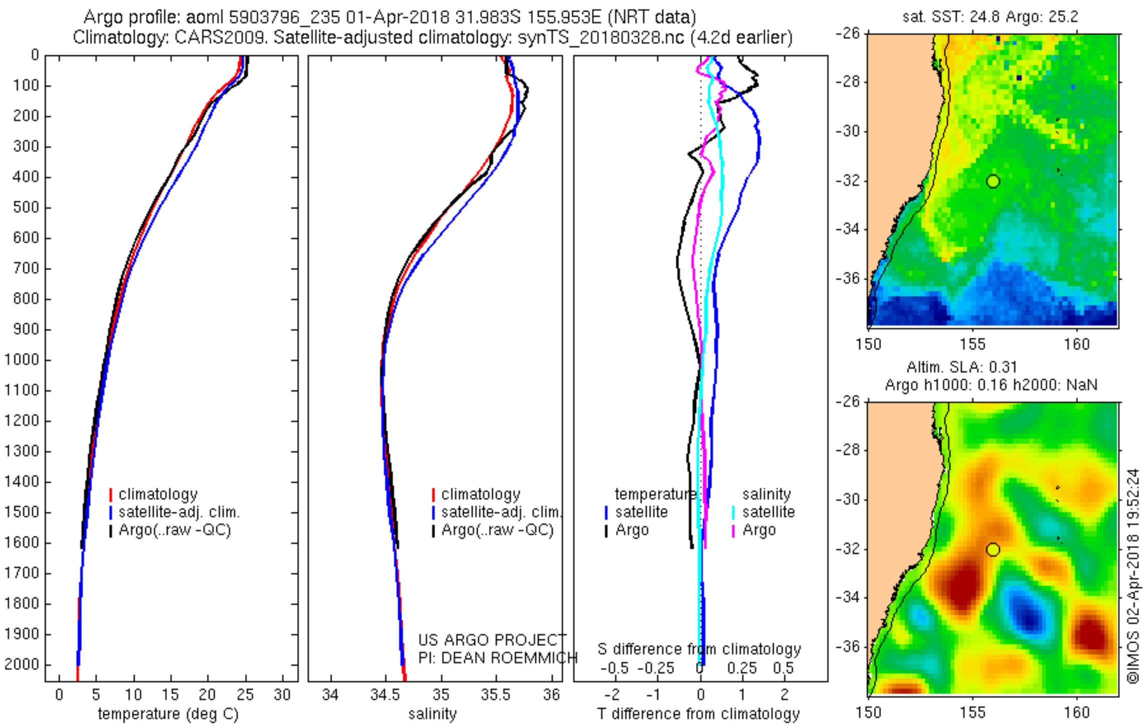

Figure 60. Argo data. Example from http://oceancurrent.imos.org.au/profiles/profile.php?link=5903796/20180401_5903796_235.html.

CURRENTS - EAC TRANSPORT

The region of the SESSF is the intersection of three major currents (Figure 61).

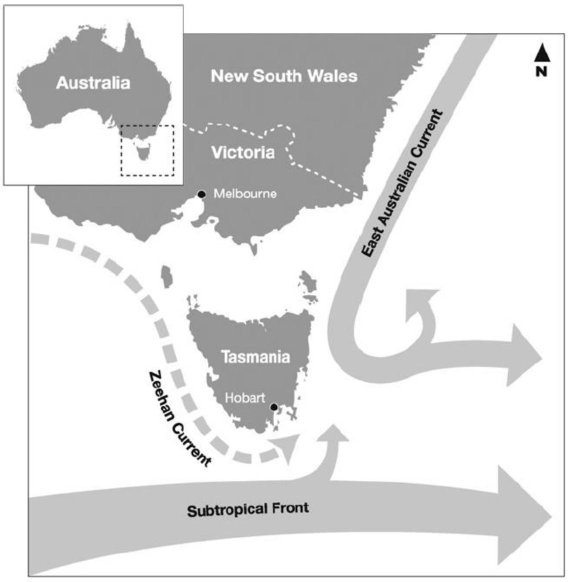

Figure 61. Currents of south-east Australia. Source Wayte 2013.

The southern component of the EAC has steadily increased in strength (Ridgway 2007; Hill et al 2008) (Figure 62) despite little change in the overall volume of the core EAC region (Sloyan and O'Kane 2015). Climate models suggest that there will be an increase in strength of 12% in the EAC core area, and 35% in the EAC poleward extension by 2060 (Sun et al. 2012). This poleward extension is expressed in longer lasting and stronger eddies moving south.

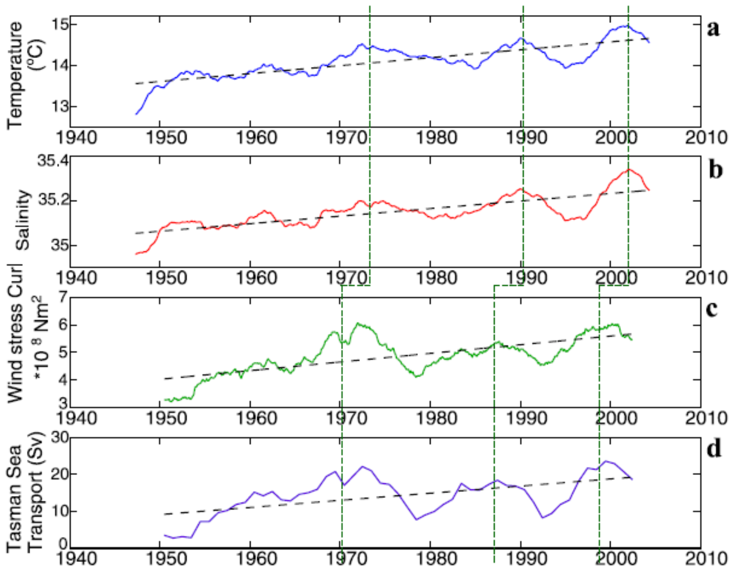

Figure 3. Low-pass filtered (a) sea surface temperature at MITS, (b) surface salinity at MITS, (c) South Pacific regional mean wind stress curl (20–50°S, 180–280°E), (d) net transport through the Tasman Sea, calculated using the Island Rule [*Godfrey*, 1989]. Black dashed lines show the linear trend. Green dashed lines illustrate the time lag between MITS T/S and South Pacific winds/Island rule transports.

Figure 62. Source: Hill et al 2008.

Connectivity and larval transport have also changed and will continue to change

As a result of the changing currents around Australia, transport pathways for larvae have been projected to change (Tracey et al. 2011). Strengthened currents for example, have been shown to override the effect of warming on lobster larval dispersal and survival along the east coast of

Australia (Cetina-Heredia et al. 2015). Species with long-larval lifetimes are likely to be impacted in the south-east region, but direct evidence is lacking due to lack of larval studies in the region.

PRIMARY PRODUCTIVITY – THE BASE OF THE FOOD CHANGING

Primary productivity can be approximated by satellite measurements of chl-a, but long time-series of *in situ* measurements (flow cytometry, pigment analysis, etc.) are needed. Some excellent time series are now becoming available from the national reference stations maintained by IMOS (Lynch et al 2014). Changes in the species of phytoplankton in south-east Australia are also reported. For examples, Thomson and Pattiartatchi (2018) showed an increased abundance of tropical picoplankton in southern Australian waters, and these species do not support the same fish biomass. Unpublished work by Karlie McDonald (CSIRO) suggests that in south-east Australia, there have been declines in the strength of the spring blooms (thus less food at the base of the food chain) and increases in winter phytoplankton biomass. More research is needed on the productivity of the region. New ocean models now include phytoplankton and nutrients, so new information should be available soon.

- *Is there a relationship between climate change and another issue?*

In addition to climate change, extreme events such as heatwaves do impact the SESSF region, but with limited known biological effects to date. There is no evidence of a sudden regime shift.

In addition to long term change, there are environmental impacts on species in the SESSF region as a result of extreme events, such as marine heatwaves (e.g. Tasman Sea marine heatwave (MHW)of 2015/16 (Figure 63); Oliver et al 2017, Oliver et al 2018). These can have a dramatic effect on local abundance of some species and in other regions (such as abalone, kelp and seagrass die-offs in the 2011 Western Australian MHW), but have not been shown to affect deeper living fishes in south-east Australia.

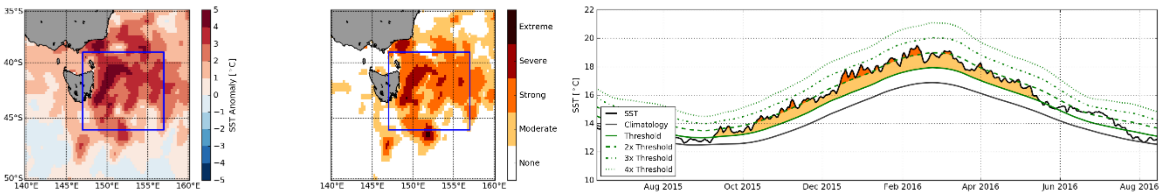

Figure 63. The 2015-16 Tasman Sea Marine Heatwave lasted more than 250 days. Source Hobday et al 2018a.

There has been no ecosystem-wide regime shift detected in south-east Australia, despite an attempt to find one (Litzow et al 2016). The authors concluded that the nature of ecological variability in the region cannot be determined with available data. The development of additional long-term biological observations is needed for understanding change in southeast Australia and in many other marine ecosystems globally. With regard to a single species shift in productivity, Klaer et al (2015) propose a range of criteria, many of which have been met for the SESSF species. Additional work is needed in this area.

Regime shifts in other ocean regions, such as the north-east Pacific, have led to dramatic catch differences as species abundances have changed

Climate change is leading to changes in distribution, abundance, phenology and productivity in many regions around the world. Australia is not alone, but changes in the south-east are rapid compared to some other locations.

A new FAO report details climate change impacts in other regions for the world (Barange et al 2018) and includes a chapter for Australia (Hobday et al. 2018b) which highlights the following key message:

- There are long-term trends in the temperature and currents of the oceans around Australia that are already leading to substantial changes in associated marine ecosystems; these trends are projected to continue and to have greater impact in the future.
- Temperatures are warming at almost three and four times the global average off Southwest and Southeast Australia respectively; ecological and fishery impacts are compounded in these locations as the currents are also changing.
- There have been extensive climate-related changes in distribution of sea urchins, intertidal molluscs, seaweeds and many coastal fish species over the last few decades.
- Long-term change and extreme events, such as marine heatwaves and cyclones, have impacted commercial fish habitat such as mangroves, kelp beds and coral reefs, and reduced populations of important commercial species. The coral reef systems of Australia have experienced severe and extensive bleaching, multiple times and over large areas, in recent years.
- Multiple assessment approaches suggest that invertebrates are most at risk from climate change, and pelagic fishes the least. Australia's most valuable fisheries target invertebrate species.
- Adaptation options are being considered by fishery managers in Australia, particularly around access rights and spatial management. Although research to underpin adaptation efforts is underway, much remains to be done.

IMPACT ON UNDER-CAUGHT TACS

Climate-related changes in dozens of fish and invertebrate distributions have been reported around Australia (Hobday et al. 2018b), particularly along the eastern coastline, and are primarily because of increases in water temperature and changes in ocean currents (Last et al 2011; Sunday et al. 2015, Robinson et al. 2015). Changes at the southern edges of the boundary currents appear to have reduced productivity and degraded the state of temperate ecosystems in New South Wales (Verges et al. 2016) and Tasmania (Johnson et al. 2011).

Impacts span a range of trophic levels (Frusher et al. 2014). At the base of the food chain, a 50% decline in phytoplankton biomass during the spring bloom has been reported from eastern Tasmania (Thompson et al. 2009), where cold water zooplankton have also become less common (Johnson et al. 2011), and a change in small pelagic fish composition has occurred (McLeod et al. 2012). Growth of southern rock lobster (*Jasus edwardsii*), positively related to water temperature, has increased in southern Tasmania (Johnson et al. 2011). Declining growth rates in coastal fish (e.g. banded Morwong, *Cheilodactylus spectabilis*), particularly at the warm end of their range may lead to declining productivity in the north and range contraction towards the southern limit in Tasmania (Neuheimer et al. 2011). Regime shifts in productivity have already been recognised for some key target species (e.g. Jackass Morwong, *Nemadactylus macropterus*; Wayte 2013). Importantly, impacts have largely been described at the single-species level, with comparatively fewer investigations exploring the interactive effects of multiple species shifts in the region, or impacts at the ecosystem level (Marzloff et al. 2015).

Vulnerability assessments have been developed to identify Australian fished species likely at risk from climate change (Pecl et al. 2014), and updated by Fulton et al (2018). Scoring of traits that indicate sensitivity to distribution, abundance and phenological change allows for relative ranking of species (Figure 64). Generally demersal invertebrates are likely more sensitive than pelagic fishes.

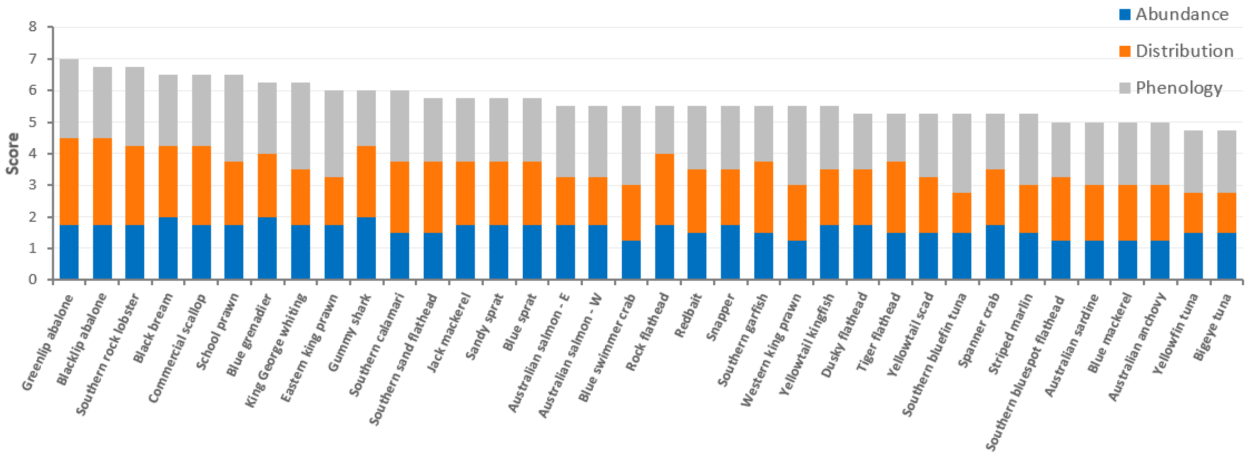

Figure 64. Example of a sensitivity assessment of fished species in south-east Australia (modified from Pecl et al. 2014). Higher scores indicate greater sensitivity, with a maximum score of 3 for each of the Distribution, Abundance and Phenology categories, and a combined maximum score of 9. (Source Fulton et al. 2018).

Trends in SESSF species from recent models and sensitivity assessment show that south-east species are projected to be vulnerable to climate change (Fulton et al. 2018) and there are some common patterns between the sensitivity assessments and the model results (Table 30). These can be due to various causes such as direct impact on the animal's physiology (particularly on growth and reproduction) and therefore its fitness and survivorship, affecting their habitat or a combination of factors (Koehn et al 2011).

Declines in CPUE can occur if density of species is declining due to changes in environmental conditions.

Undercaught TAC can occur if changes in environmental conditions means that species are more difficult to find by fishers, or less days are fished if storminess has increased

Lack of recovery could be due to changed environmental conditions. This means that spawning areas could no longer be suitable, currents could have modified dispersal pathways.

It is not possible to distinguish between these causes with the current information available. Many of the changes are consistent with what is expected under climate change.

Table 30. Summary of information from other assessments, for the 28 SESSF species. Projected trends are based on results from the south-east Atlantis model, for climate only impacts (dynamic fishing) on biomass. Species included in the same functional group in the model will have the same trend as another species. Species with no entry are not included as they are not a major species in a particular functional group. Source (Fulton et al 2018).

Species	Sensitivity score (Total)	Atlantis SE trend Biomass projections to Climate RCP8.5[1] only; dynamic fishing[2]; at 2050
1. Blue Warehou	5.00	Slight increase (+7%)
2. School Shark	6.50	No change
3. Redfish	4.50	Increase (+10%)
4. Eastern Gemfish	6.25	Decline (-10%)
5. Blue Eye Trevalla	5.50	Slight decline (-8%)
6. Silver Warehou	5.00	Increase (+12)
7. Jackass Morwong	4.50	No change (+4%)
8. Silver trevally		See Blue Eye Trevalla
9. Bight Redfish	6.00	See Redfish
10. Blue grenadier	6.25	No change (+2%)
11. Tiger Flathead	5.25	Increase (+10%)
12. School whiting		Increase (+10%)
13. Pink Ling	5.25	No change (+4%)
14. Orange roughy	5.50	Increase (+10%)
15. Gummy Shark	6.00	No change (+2%)
16. Smooth Oreo		See John Dory
17. Offshore Ocean Perch		
18. Alfonsino		
19. Mirror Dory		See John Dory
20. Flathead		Increase (+10%)
21. John Dory		Slight increase (+5%)
22. Ribaldo		Slight decline (-5%)
23. Oreodory		Slight increase (+5%)
24. Royal Red Prawn		Decline (-10%)
25. Saw Shark		
26. Elephant Fish		
27. Deepwater Flathead		See Flathead
28. Deepwater shark (East)		No change (-2%)

[1] RCP stands for 'Representative Concentration Pathway'. RCP8.5 is a future with little curbing of emissions, with a CO_2 concentration continuing to rapidly rise, reaching 940 ppm by 2100.

[2] "Dynamic Fishing" refers to his simulations include full feedback management decision processes and active effort and species targeting decisions by the modelled fishers.

WORKSHOP FEEDBACK AND CONCLUSIONS

Workshop participants concluded that climate change and oceanographic conditions were likely to have contributed to under-caught TACs due to changes in abundance, changes in productivity, change in species distribution or climate sensitivities[3] of the species (Figure 65, Figure 66). This is especially the case for Jackass Morwong and Silver Warehou (Figure 67).

Climate and oceanographic conditions are considered to be a potential factor in declining CPUEs (Figure 68, Figure 69,) for several species including eastern Gemfish, Redfish, Silver and Blue Warehou (Figure 70).

Participants felt there was a high probability of major impact of climate on recovery of overfished species due to changes in productivity, abundance, distribution or species sensitivity (Figure 71, Figure 72), especially Blue Warehou, Eastern Gemfish, School Shark and Redfish (Figure 71, Figure 72, Figure 73).

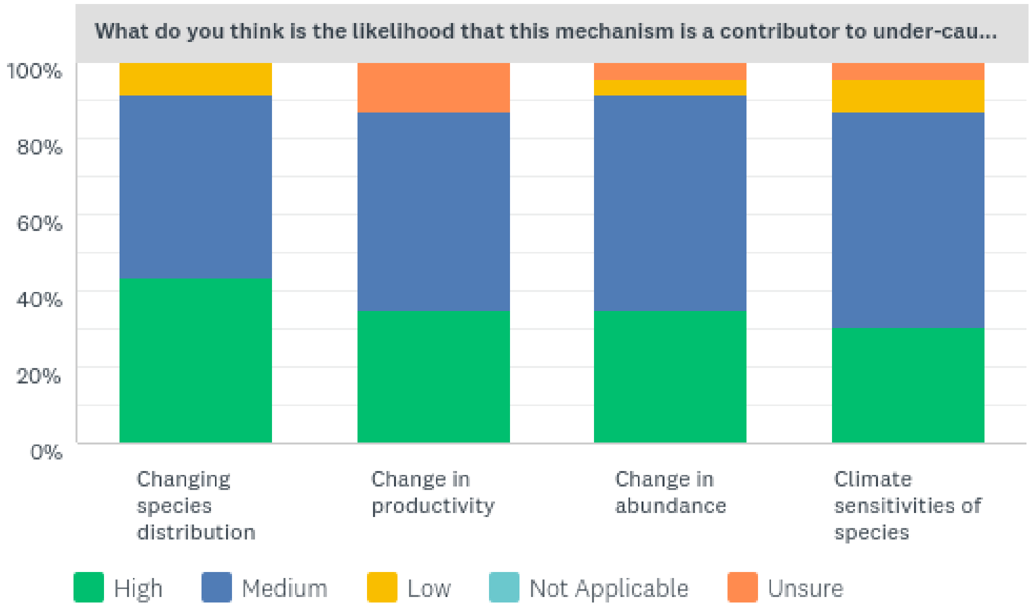

Figure 65. Workshop participant assessment of the likelihood that these climate change mechanisms are a contributor under-caught TACs.

[3] Climate change sensitivity assessments consider three aspects of the biology of exploited species that are relevant to fishers and resource managers: changes in distribution, abundance and phenology.

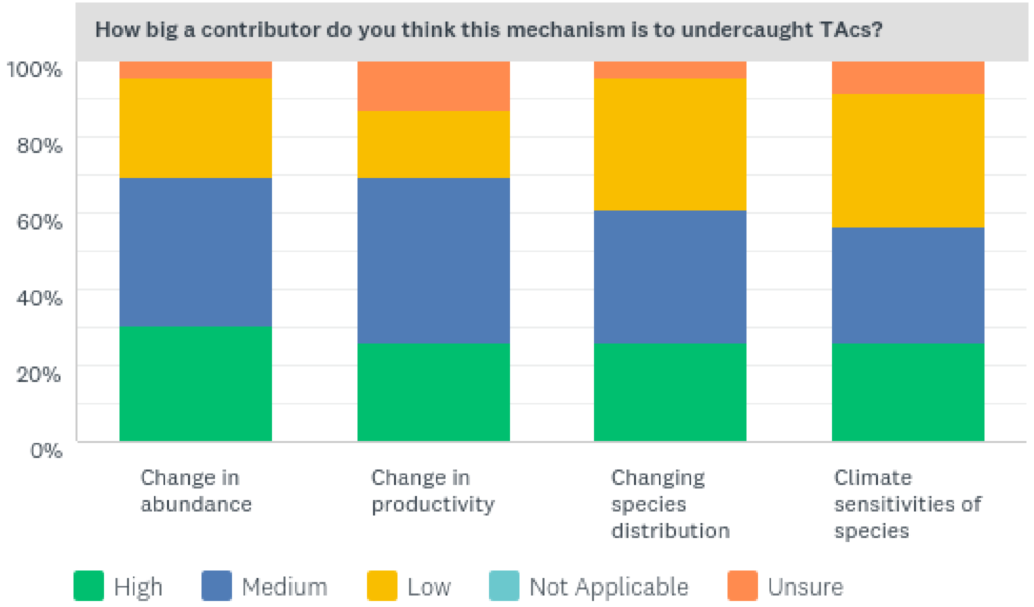

Figure 66. Workshop participant assessment of how big a contributor these climate change mechanisms are to under-caught TACs.

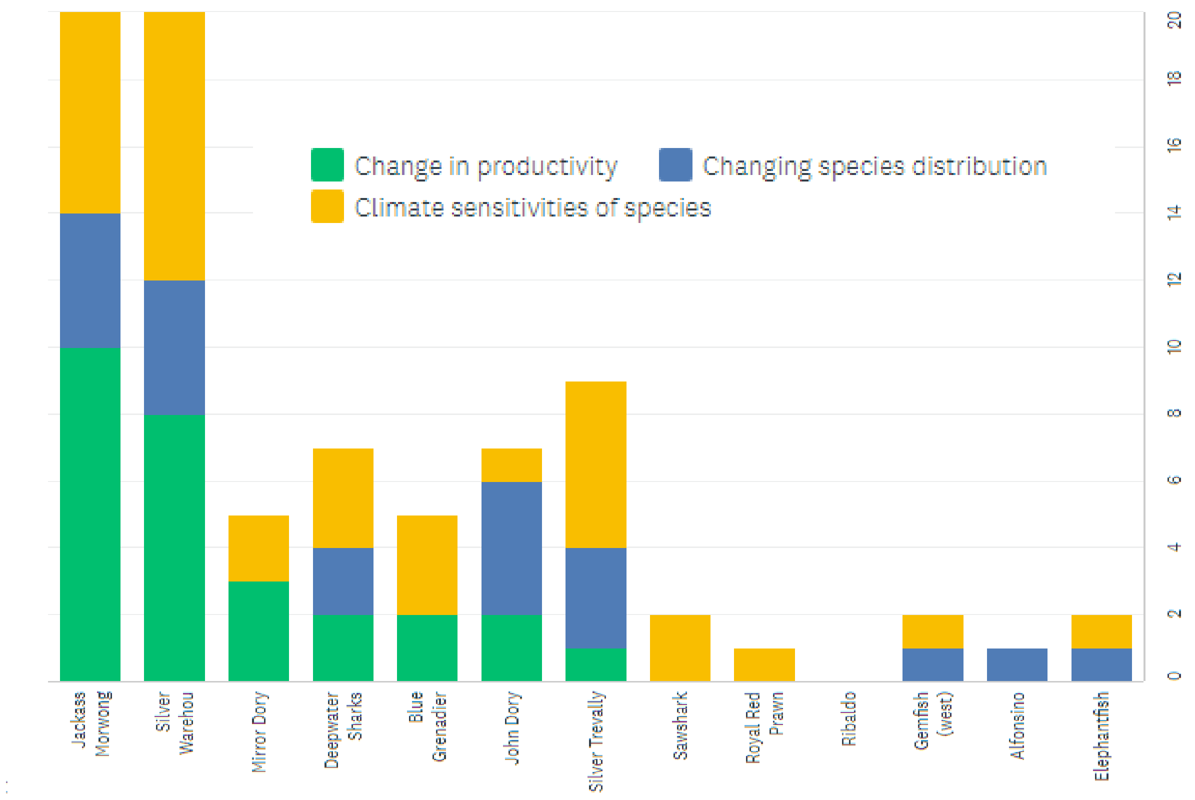

Figure 67. Workshop participant assessment of which particular climate change mechanisms are relevant to the under-caught TACs of specific species.

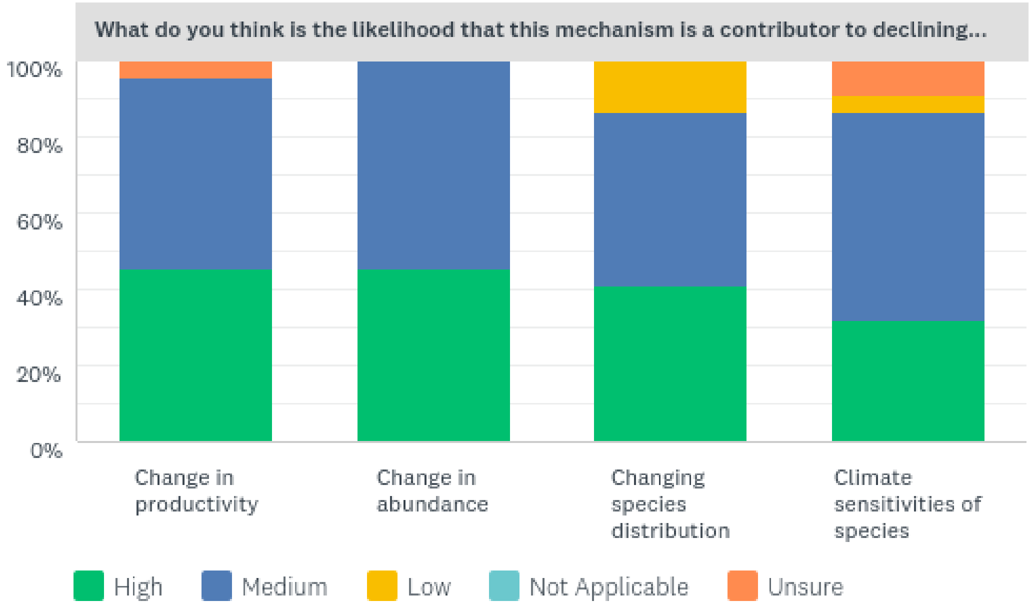

Figure 68. Workshop participant assessment of the likelihood that these climate change mechanisms are a contributor declining CPUEs.

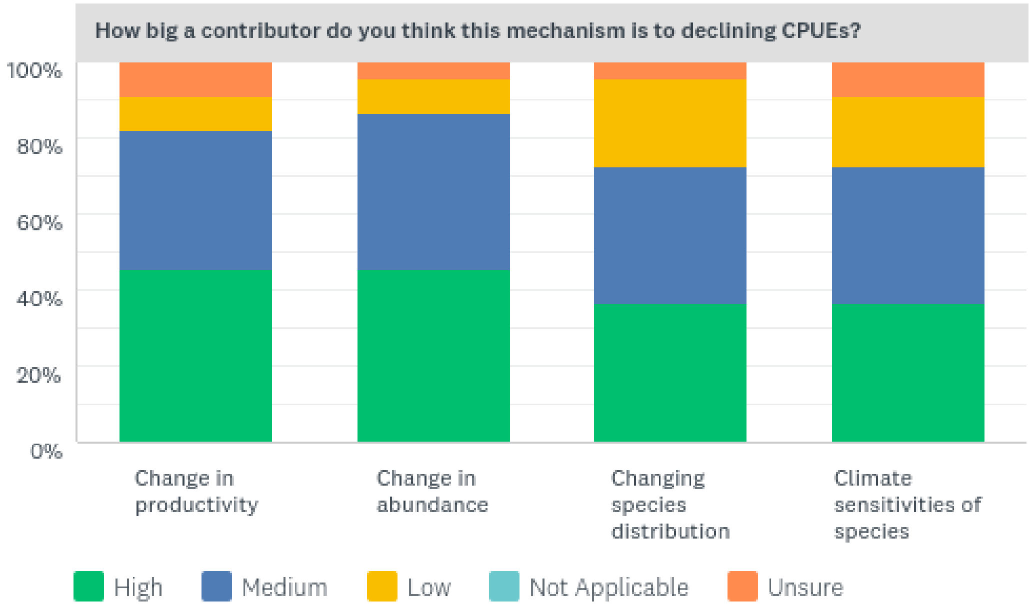

Figure 69. Workshop participant assessment of how big a contributor these climate change mechanisms are to declining CPUEs.

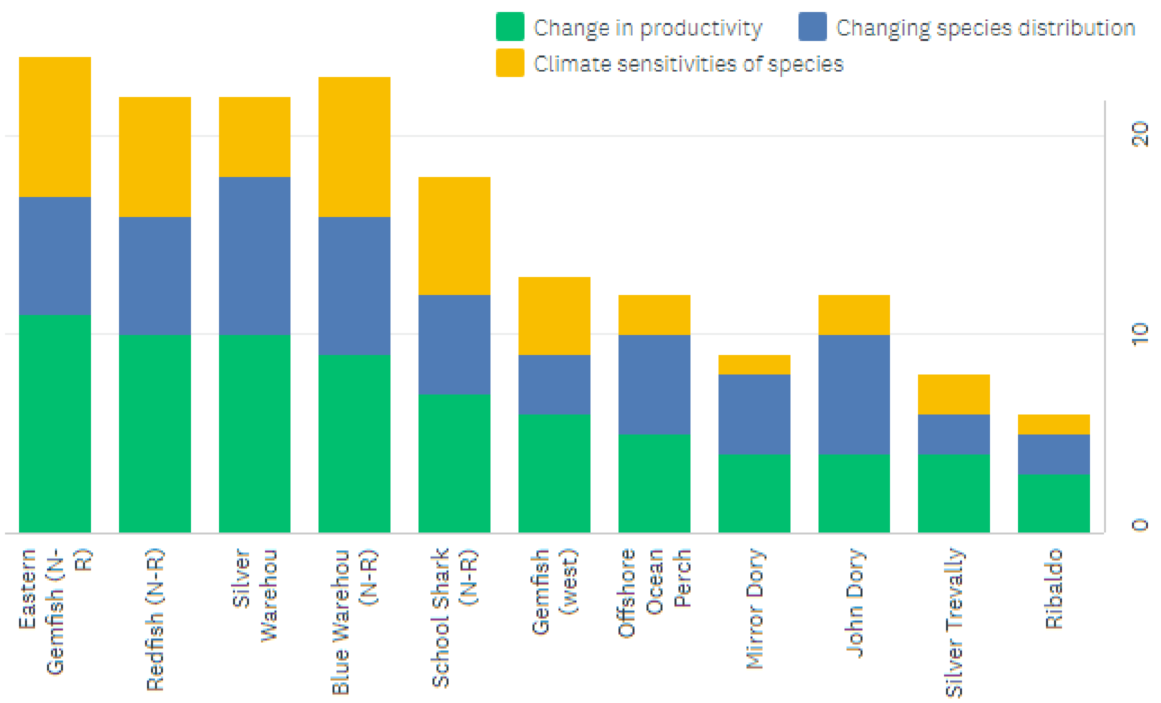

Figure 70. Workshop participant assessment of which particular climate change mechanisms are relevant to the declining CPUEs of specific species (N-R = Non-recovering).

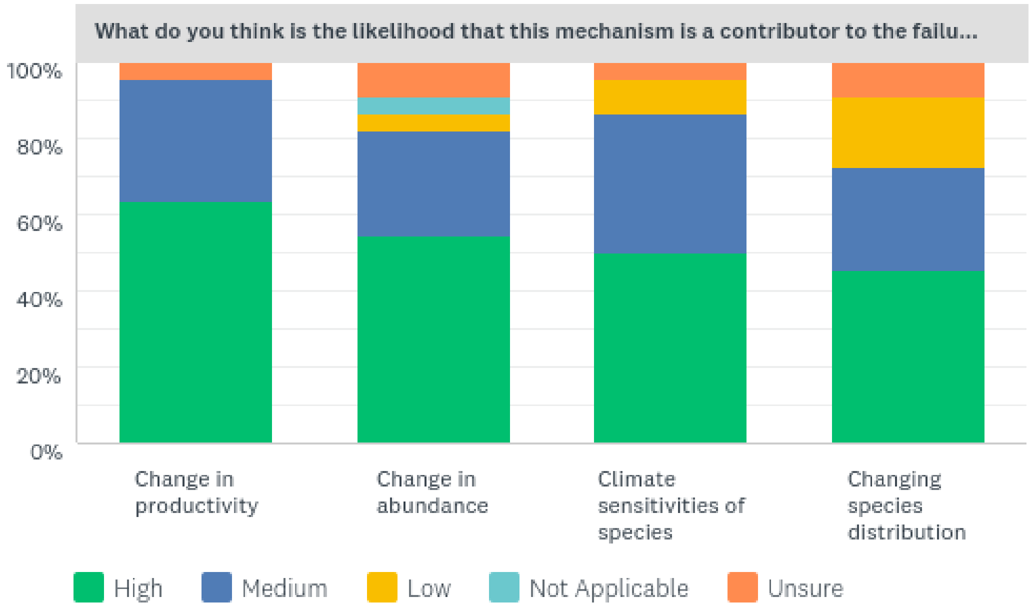

Figure 71. Workshop participant assessment of the likelihood that these climate change mechanisms are a contributor the lack of recovery of over-fished species.

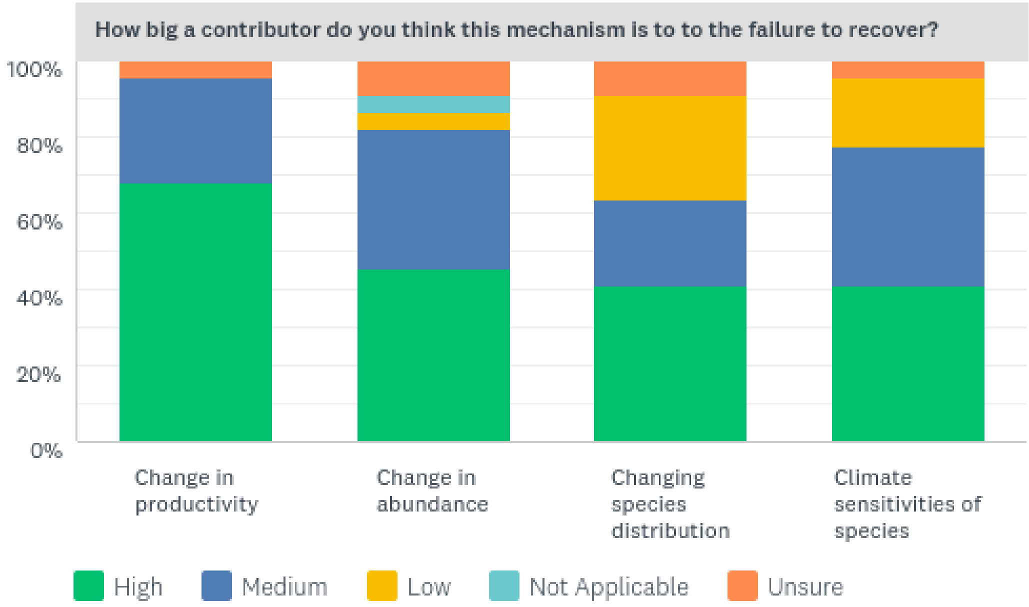

Figure 72. Workshop participant assessment of how big a contributor these climate change mechanisms are to lack of recovery of over-fished species.

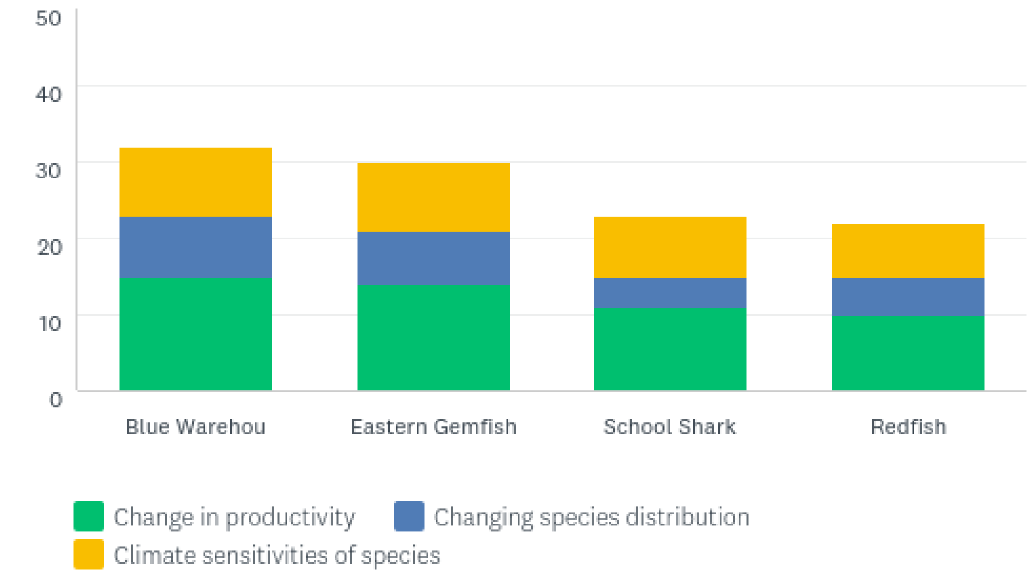

Figure 73. Workshop participant assessment of which particular climate change mechanisms are relevant to the lack of recovery of over-fished species.

The south-east coast of Australia region is one of the fastest warming in the world. There has been long-term warming at the surface and at depth and southward transport of warmer waters has increased as the East Australia Current has strengthened. Other physical variables, such as salinity, and nutrient availability have also changed. The range of many species of commercial and non-commercial fish has increased to the south over the past 40 years. The climate sensitivity of many species in the SESSF is high and future projections suggest abundance of some species will decline, some will increase, and some will be largely unchanged (Table 30).

The observed changes in these indicators in the past are likely to be a combination of climate and other cumulative or synergistic drivers It is difficult to separate climate change impacts from the other factors explored in this project, but climate is a definite contributor to the observed changes. With regard to the effect of climate change on the three indicators, environmental suitability can influence all three negative indicators

(i) under-caught TAC; likelihood of climate change contributing MED

- confidence LOW

(ii) declining CPUE; likelihood of climate change contributing MED

- confidence MED

(iii) lack of recovery; likelihood of climate change contributing HIGH

- confidence MED

Overall, we find that there is a high likelihood of impacts of climate change on marine ecosystems and SESSF stocks based on model projections, however, the confidence (based on available historical evidence) is medium or low and there are conflicting drivers (e.g. difficulty locating fish or travelling further out means greater effort (lowered CPUE) and fuel use (also economic driver).

Costs of Production and Changing Markets

Dave Mobsby, Robert Curtotti, Anthony Ciconte, John Jarvis, Nigel Abery, Ingrid van Putten

SCOPE OF THE ISSUE

INTRODUCTION

This chapter has an economics focus and largely explores how trends in fisher's terms of trade, fleet productivity, fish prices and consumer markets might contribute to under-caught TACs. The chapter takes a data driven approach by exploring available datasets on fleet revenue and costs and market trends that affect the prices received for fisher output and prices paid for inputs. The rationale is that net economic return (NER) (and latency) can be affected by terms of trade (fisher costs and market prices) and fleet productivity (doing better with less).

The failure to catch the TAC in a given season is referred to as quota latency. The reason for quota latency in not always clear, but could be related to fishing conditions, stock availability, a change in market conditions or more profitable opportunities from other fisheries. Another possibility is that the target reference point is set too high given the market fundamentals of the fishery. This chapter looks only at the impact that market conditions, fleet productivity and finfish consumption trends may have on latency.

The SESSF is characterised by multiple fleets and multiple species, which means that identifying why some individual species quota latency is high is difficult. The analysis presented here indicates that high priced species have generally low levels of quota latency and lower priced (non-target) species higher latency.

According to ABARES economic survey of the SESSF, which covers the Commonwealth Trawl Sector (CTS) and the Gillnet, Hook and Trap Sector (GHTS), net economic returns to the CTS and GHTS has improved since 2014-15 (Bath et al 2018). This has occurred despite high quota latency amongst a number of species. The CTS achieved a positive NER in 2014-15, while GHTS NER remained negative, but improved its economic performance compared to recent past surveys. Both sectors are estimated (using non-survey methods) to achieve positive NER in the 2015-16 and 2016-17 financial years.

The structure of this chapter is organised as follows: Section one reviews changes to the prices of SESSF species between 2005-06 and 2015-16. Section two examines fisher's terms of trade in two sectors of the SESSF (CTS & GHTS). This provides an overview of how input and output prices have varied in these sectors which is a starting point for discussing the economic incentives to fish in these sectors. Section 3 briefly reviews total factor productivity in the CTS and GHTS. Section 4 reviews changing markets of seafood in Australia with a focus on consumption and imports. For each section key findings from the analysis are highlighted.

Review of SESSF species prices

Prices of SESSF species vary from low to high price with some species falling and some increasing in the past ten years.

For most higher priced species (those species priced at or over $4.49 per kilogram in 2015-16) more than 75 per cent of TAC is caught.

For most lower priced species (less than $4.49 per kilogram in 2015-16) less than 50 per cent of the TAC is caught (see chapter on fisher behaviour).

The six species that fetch the highest prices (priced at or over $5.99 per kilogram in 2015–16) are Blue-eye Trevalla, John Dory, Deepwater Flathead, Gummy shark, Tiger Flathead and School Shark (Table 31). Only two of the top six priced species are under caught and for the remainder more than 75 per cent of the TAC is caught. Two high priced species that are under caught are John Dory (46 per cent caught) and Deepwater Flathead (50 per cent caught). Four of the 10 higher priced species (priced at or over $4.49 per kilogram in 2015–16) are also high volume (Deepwater Flathead, Gummy Shark, Tiger Flathead and Pink ling). Two high volume species (Blue Grenadier and Eastern School Whiting) fetch some of the lowest prices ($1.30 a kilogram and $3.00 a kilogram respectively).

Just under half of the species in the SESSF have seen real prices increase over the past 10 years (Table 31). For four of the highest priced species real prices fell over the past 10 years (John Dory, Pink Ling, Gummy Shark, and School Shark), while seven of the highest priced species real prices increased (Blue-eye Trevalla, Deepwater Flathead, Tiger Flathead, Orange Roughy, Bight Redfish, Ocean Perch and Silver trevally). Prices have varied most for Ocean perch (Standard deviation of $1.33 per kilogram) and least for Mirror Dory (standard deviation of $0.54 per kilogram) between 2005–06 and 2015–16.

Table 31. Species prices, TACs and catch, 2015–16

Species across all SESSF sectors	2015–16 price per kg	2016 Actual TAC (t)	2016 Catch (t)	% change in real price between 2005-06-2015-16	Price standard deviation 2005-06-2015-16	Proportion of TAC caught 2016
Blue-eye trevalla	$9.06	363	299	14%	$0.60	82%
John dory	$8.66	189	87	-17%	$1.05	46%
Deepwater flathead	$7.11	1,265	627	37%	$0.82	50%
Gummy shark	$6.29	1,978	1,799	-8%	$0.69	91%
Tiger flathead	$6.18	3,092	2,909	107%	$0.92	94%
School shark	$5.99	215	181	-6%	$0.85	84%
Pink ling	$5.73	1,006	825	-15%	$1.00	82%
Orange roughy (eastern)	$5.59	465	436	63%	$1.07	94%
Bight redfish	$5.31	2,594	180	66%	$0.84	7%
Ocean perch	$5.09	179	169	92%	$1.33	95%
Silver trevally	$4.49	662	72	67%	$1.06	11%
Royal red prawn	$4.01	414	183	97%	$0.60	44%
Redfish	$3.43	111	50	49%	$0.54	45%
Jackass morwong	$3.36	654	136	47%	$0.64	21%
Mirror dory	$3.15	514	252	-1%	$0.54	49%
Blue warehou	$3.06	118	2	31%	$0.62	2%
Eastern school whiting	$3.05	790	733	10%	$0.36	93%
Gemfish (western)	$2.43	200	82	-44%	$0.86	41%
Sawshark	$1.88	522	187	-37%	$0.58	36%
Blue grenadier	$1.30	9,411	1,754	-43%	$1.32	19%
Silver warehou	$1.15	2,643	303	-31%	$0.52	11%
Elephantfish	$0.69	172	54	-54%	$0.54	32%

Note: No regional price information was available so only eastern Orange roughy western Gemfish were included. Price information was also not available for Ribaldo and Oreo dory. Species for which price information was available but catches were not available were "other species" other shark angel shark leatherjacket, Yellow spotted boarfish, squid, knifejaw, blue Morwong. All these species were excluded from the analysis.

Sources: AFMA 2016, ABARES

TERMS OF TRADE (TOT)

Profitability of fishing is linked to both input prices and output prices. All else being equal an improvement in the fisher's terms of trade, for example through an increase in the price of fish and a decrease in input costs, would be expected to result in more fishing and lower quota latency. At constant fleet productivity an improvement in the fisher terms of trade is associated with the fisher becoming more profitable and the incentive to increase fishing effort.

In the Australian fisheries economic indicators report series ABARES constructs a terms of trade index for surveyed fisheries (Bath et al. 2018). Over the period 2002–03 to 2014–15 fisher's terms of trade for both the CTS and GHTS has reduced slightly, however there have years of increasing or declining TOT during this period. The input price index has generally been rising in the CTS and GHTS since 2009–10 suggesting added cost pressure. While fleet productivity has been variable, there are signs of an overall increase in recent years which is likely to have offset increased fishing costs all else being held equal over this period (see total factor productivity section below).

If TOT had been declining significantly in both sectors, then increased quota latency could be the result of adverse movements in market prices for inputs and output. A significant rise in the terms of trade would be expected to lead to increased fishing effort and lower quota latency. A neutral to slightly increasing or decreasing TOT movement indicates that movements in both input and output prices have been largely balanced and quota latency is generally not a result of changes to input and output prices.

In the CTS the terms of trade index declined by 9 per cent between 2002–03 and 2014–15 (Figure 74). It was most favourable for fishers in 2009–10, when the input price index declined and output prices were high. Since 2009–10 terms of trade have generally declined in the CTS and has mirrored movements in the output price index. For the GHTS, terms of trade index was 5 per cent lower in 2014–15 compared with 2002–03, although variable within that period, there has been no strong trend in the longer term movement of the terms of trade index in the GHTS.

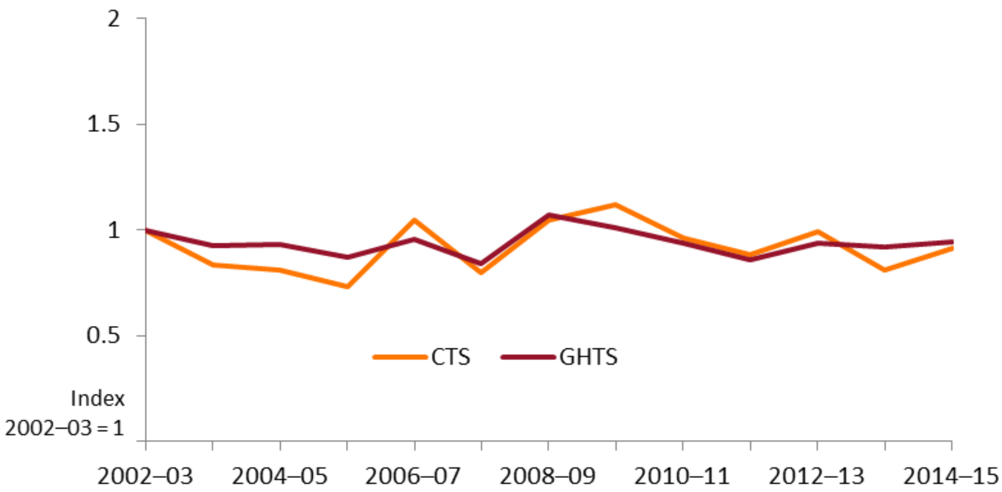

Figure 74. Terms of trade CTS and GHTS, 2002–03 to 2014–15 normalised to start at 1.

Source: Bath et al 2018

Input and output price indexes in the GHTS AND CTS

The input price index has generally been rising in the CTS and GHTS suggesting that cost pressure has been increasing in these sectors since around 2009–10 (Figure 75). Offsetting this cost pressure, has been a trend in rising total factor productivity. However, changes in fisher behaviour should also be accounted for. For example, the number of days fished per active vessel declined in the CTS and the GHTS between 2007–08 and 2014–15 which would be expected to reduce operating costs.

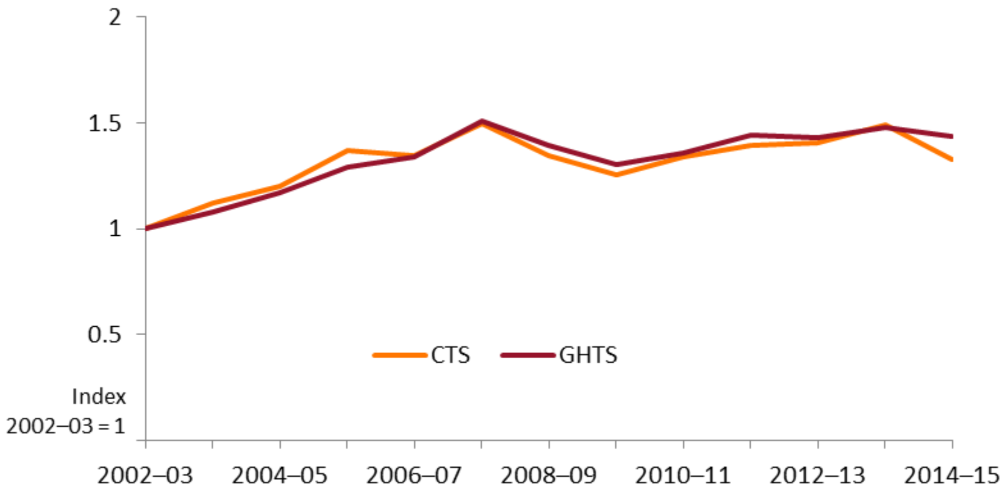

Figure 75. Input price index CTS and GHTS, 2002–03 to 2014–15

Source: Bath et al 2018

The output price index for the CTS has declined slightly in recent years in the CTS, but has increased in the GHTS (Figure 76). However, the output price index was higher in 2014–15 compared with 2002–03 for both sectors. Changes to individual SESSF fish prices have been mixed which could be the result of a number of factors. Imports of 'other finfish' increased since the early 2000s, notably from Vietnam. These may be competing against lower priced species in the SESSF. It is unclear to what extent to the movement in SESSF prices has been influenced by these imports since there have been mixed movements in the price of relatively lower valued SESSF species.

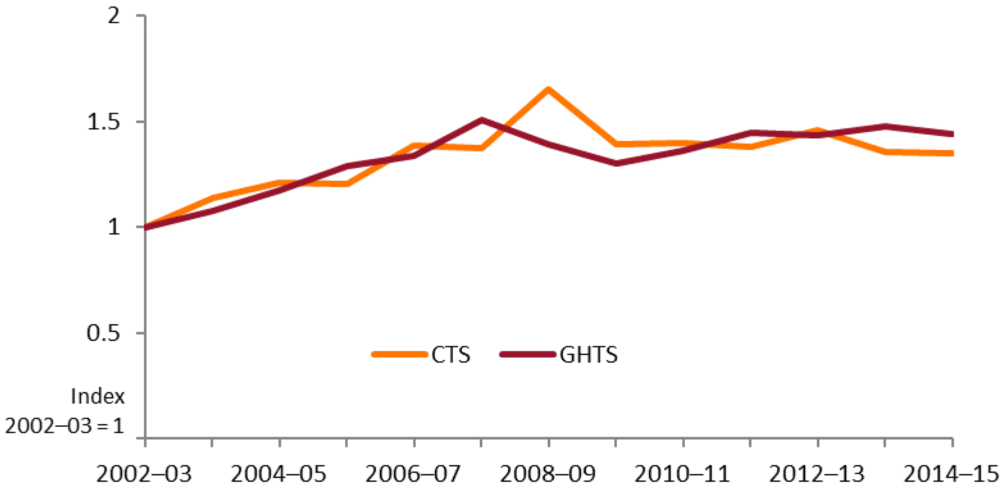

Figure 76. Output price index CTS and GHTS, 2002–03 to 2014–15

Source: Bath et al 2018

TOTAL FACTOR PRODUCTIVITY

Total factor productivity (TFP) of a fishery represents the fishers' ability to convert inputs into outputs over time by comparing the quantity of inputs to the quantity of outputs. Results from this type of analysis assist in evaluating a fishery's economic performance and provide insight into the factors driving changes in productivity. While TFP in the CTS and GHTS has increased over the longer term (2002-03 to 2014-15), TFP in both sectors has been marked by periods of increasing and decreasing TFP.

If movements in the terms of trade have been largely neutral, then a change in TFP (effectively doing more with less) could provide evidence as to why latency has declined or increased. Periods of declining total factor productivity during unchanged terms of trade would suggest an increasing cost of fishing and possibly be a cause for increased quota latency.

TFP in the CTS was 29 per cent higher in 2014-15 compared with 2002-03 (Figure 77). From 2002–03 to 2005–06 TFP in the CTS grew at a modest rate because the input and output indexes declined at similar rates. However, TFP fell between 2010-11 and 2013-14 before rising in 2014–15. TFP in the GHTS was 43 per cent higher in 2014-15 compared with 2002-03. From 2002–03 to 2007–08 productivity rose before declining through to 2009–10. Between 2010–11 and 2014–15 productivity in the fishery increased. The output index has decreased steadily since 2007–08, so an increase in the productivity index is mainly attributable to a lower use of inputs, as indicated by a falling input index over the period 2009-10 to 2014-15. The input index follows effort levels in the fishery over time for example, a fall in the input index from 2002-03 to 2007-08 and subsequent increase reflected changing numbers of days fished.

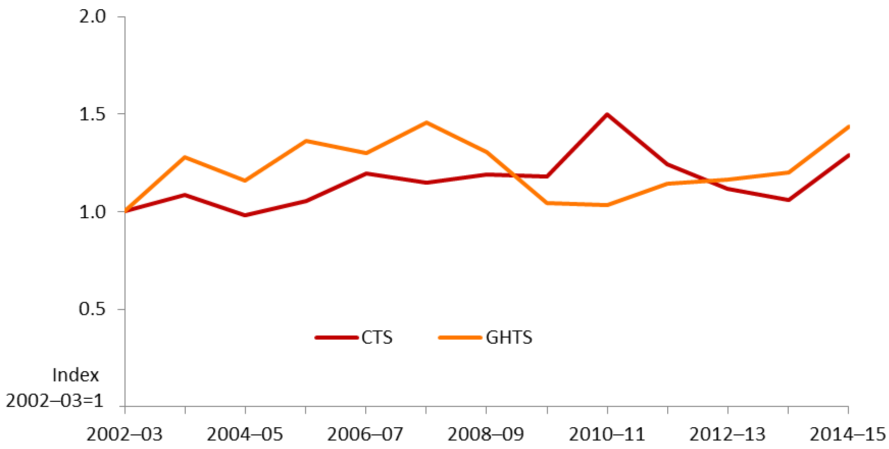

Figure 77. Total factor productivity in the CTS and GHTS, 2002–03 to 2014–15

Source: Bath et al 2018

TRENDS IN AUSTRALIAN FINFISH CONSUMPTION

Fish protein consumption

In 2015–16 Australians got most of their meat and seafood consumption from poultry (39 per cent), followed by pig meat (22 per cent) and beef and veal (20 per cent). Australians consumed slightly more seafood (11 per cent) than sheep and lamb (at 7 per cent) in 2015-16 (Figure 78).

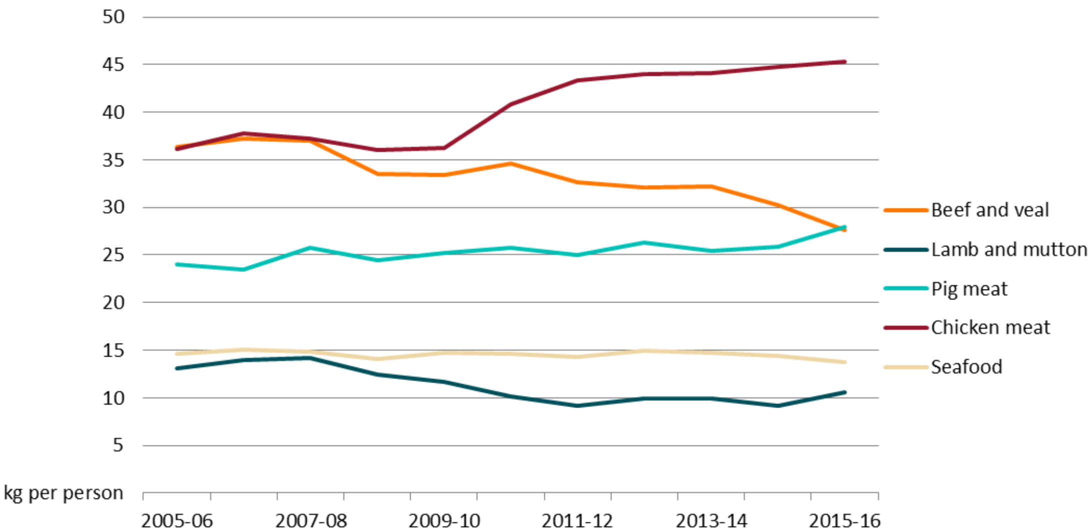

Figure 78. Australian per-person apparent consumption of meats and seafood, 2005–06 to 2015–16

Source: ABARES 2017

In 2015-16 Australians consumed on average 6 per cent less seafood compared to the five-year average to 2014-15. They also consumed less beef and veal (-17 per cent) and lamb and mutton (-6 per cent) but consumed more animal protein in the form of poultry (9 per cent) and pig meat (7 per cent).

Australian seafood and finfish consumption

Total apparent consumption of seafood in Australia increased, on average, at an annual rate of 1.1 percent between 2005–06 and 2015–16, from an estimated 298,968 tonnes in 2005–06 to 333,321 tonnes in 2015–16. Over the same period, domestic seafood supply remained steady at around 110,000 tonnes. Imports of seafood and salmonoid mariculture have increased to fill the gap between seafood consumption and local seafood supply. Imports of seafood into Australia increased, on average, at an annual rate of 1.7 per cent, from 188,312 tonnes in 2005-06 to 222,778 tonnes in 2015–16. The largest categories of imported products by value over this period were prepared and preserved fish (mostly canned fish such as tuna), frozen fish, frozen prawns and prepared and preserved prawns. In 2015–16, imports accounted for 67 percent of Australia's total apparent consumption of seafood, compared with 63 percent in 2005–06.

The decline in apparent seafood consumption[4] in Australia in 2015–16 (Figure 78) was the result of an increase in exports (Figure 79) and a decline in imports more than offsetting an increase in domestic seafood production. Around two-thirds of seafood consumed in Australia is imported, and an increase in average seafood import prices could have been a cause for reduced import volumes (Figure 80). However, because of the large variety of seafood products produced and traded in Australia, it is difficult to identify a single cause for the decline in import volume in 2015–16.

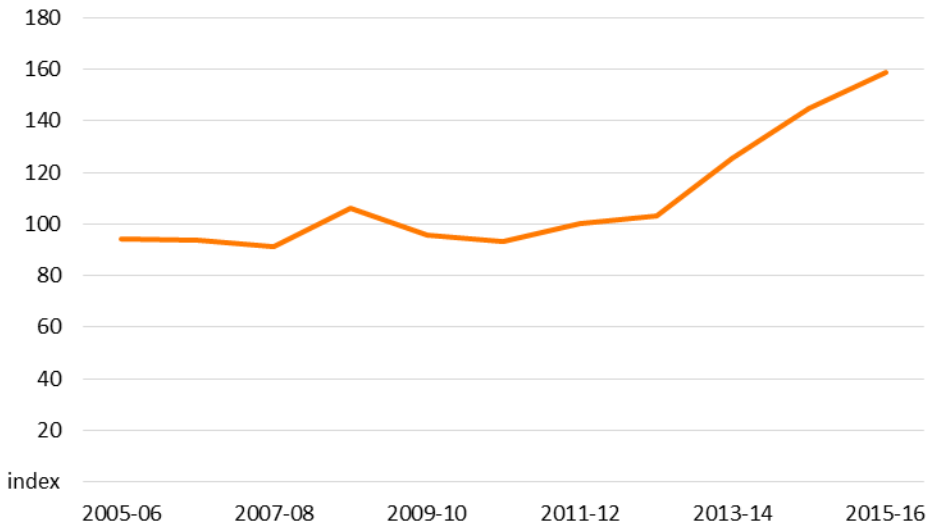

Figure 79. Seafood import price index Australia, 2000–01 to 2015–16

Note: 2011–12 = 100. Seafood is defined as products included in division 3 of the Standard International Trade Classification.
Source: ABS 2017

[4] Apparent consumption is the mathematical sum of production plus imports minus exports. The difference between 'apparent' consumption and 'real' consumption is that the latter definition also recognises changes in stock levels. The phrase 'apparent consumption' is often used interchangeably with 'apparent domestic consumption'.

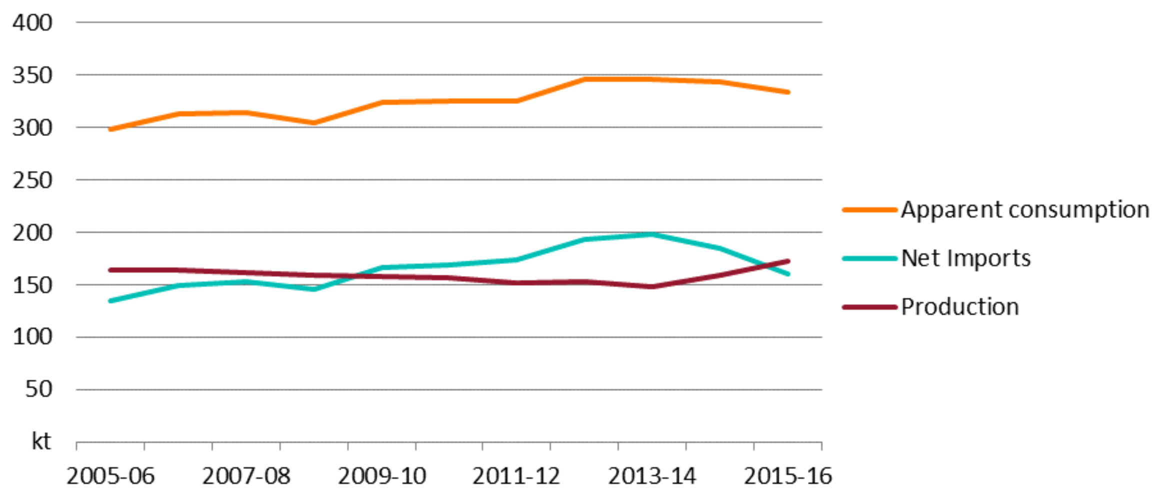

Figure 80. Apparent consumption, production and net imports of seafood, Australia, 2000–01 to 2015–16

Source: ABARES 2017

For the five years to 2015–16 finfish constituted 64 per cent of all apparent seafood consumption in Australia by volume. Based on per person finfish consumption estimates and the estimated Australian population, total estimated finfish consumption for the three fish categories that fall under finfish (salmon, tuna and other finfish) (Figure 81). Between 2012–13 and 2015–16 consumption of 'other finfish' fell by 13 per cent. Similarly, tuna consumption has dropped by 7 per cent. In contrast to tuna and other finfish, Salmonid consumption has increased by 19 per cent to around 51,000 tonnes in 2015–16 and is now estimated to be higher than the consumption of Tuna (at 45,875 tonnes).

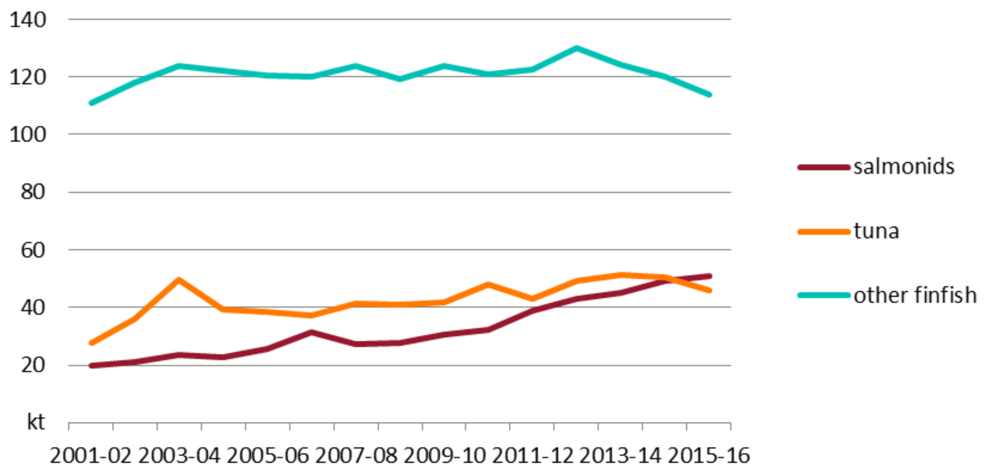

Figure 81. Apparent finfish consumption in Australia.

Source: ABARES 2017

Note: these estimates are based on average per capital consumption and population size estimates.

Salmon

Contrasting against a largely static trend in total seafood consumption in Australia, salmonid (largely farmed Atlantic salmon) consumption has trended upwards. Consumption has largely been met by an increase in domestic production, but has been supplemented by significant volumes of imported salmonids (largely in a smoked, prepared and preserved product form). Between 2005–06 and 2015–16 Australian salmonid production increased from 20,976 tonnes to 56,319 tonnes with the increase in production having largely been consumed domestically (Figure 82). A focus on quality management, new product development and promotion are suggested reasons explaining the growth of the domestic salmon industry in Australia (DIIS 2007).

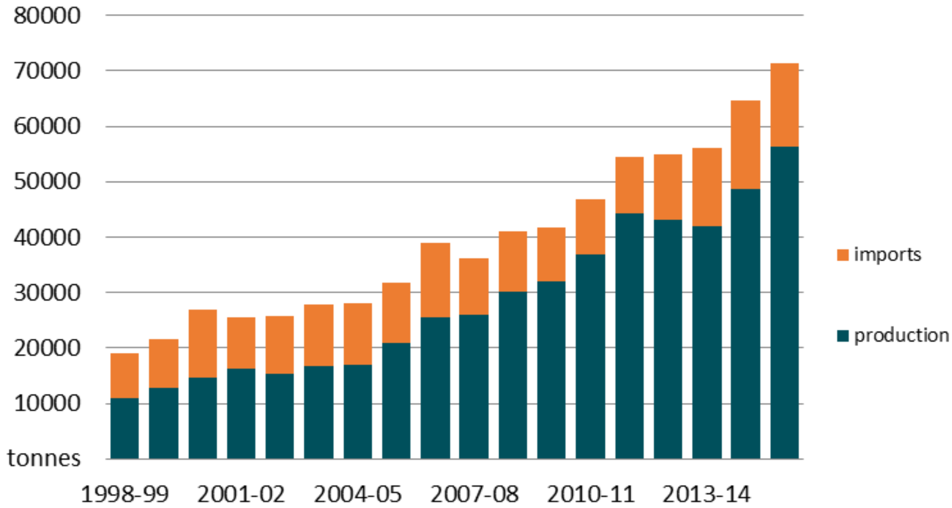

Figure 82. Australian salmonid production and import volume, 1998–99 to 2015–16.

Source: ABARES

Imports

The total value of fishery and aquaculture product imports increased by 4 per cent in 2016–17 to $2.18 billion. Edible finfish imports increased by 6 percent to $1.13 billion to account for around half of total fishery and aquaculture product import value in 2016–17. The total value of crustacean and mollusc imports increased by 7 per cent in 2016–17 to $768 million.

Finfish imports typically account for around 60 per cent of Australian seafood imports by value. Between 2006–07 and 2016–17 the real value of finfish imports increased by $236 million (in 2016–17 dollars) (Figure 83). This increase was driven by tuna and salmonids imports, which increased in real terms (2016–17 dollars) by $123 million and $87 million, respectively. Significant rises in import value also occurred for a number of other fish species and product forms during that period while the real value of a number of other species groups declined.

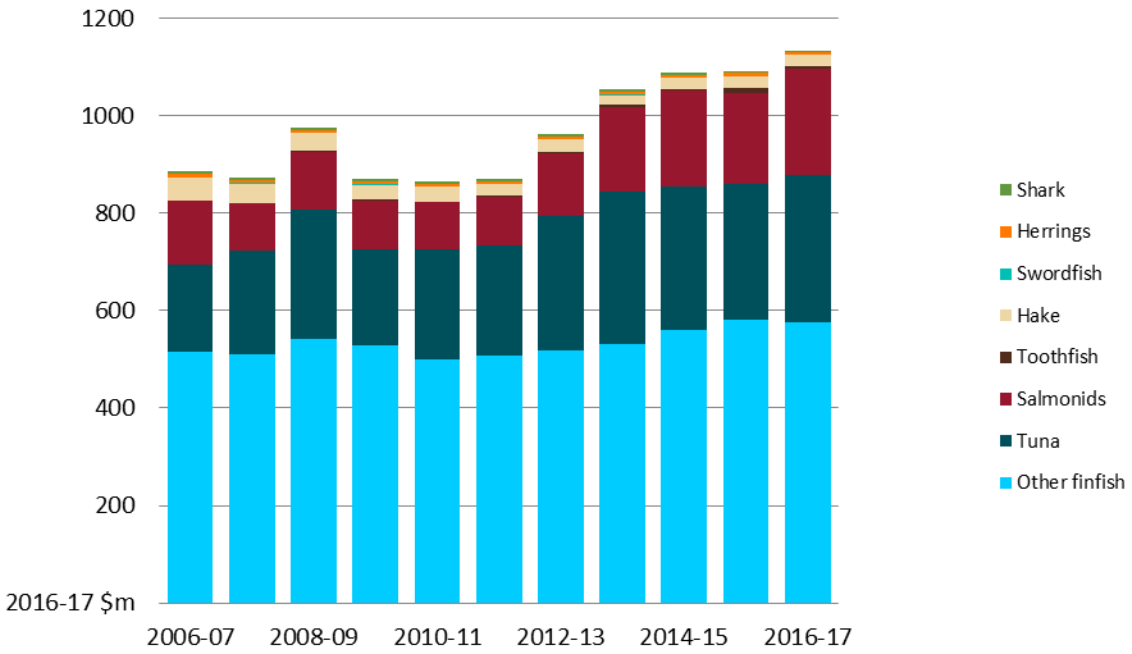

Figure 83. Value of finfish imports by species, 2005–06 to 2015–16

Sources: ABS 2018, ABARES

SESSF species that would most likely have close substitute species would be found in the 'other fish' category in Figure 84. The majority of fish imported under this category is imported as fresh, chilled or frozen product. The majority of the 'other fish' is imported from New Zealand and Vietnam together representing 57 per cent of import value for the five years to 2016–17. Hoki (from New Zealand) and basa (from Vietnam) are major species Australia imports from these countries (DIIS 2017). The total volume of 'other fresh, chilled or frozen fish' steadily increased from 1990–91 to reach a peak of 61,238 tonnes in 2012–13. However, since 2012–13 import volume for this category has declined annually and import volume in 2016–17 was 7 per cent lower than 2012–13. Conversely between 2012–13 and 2016–17 the value of these imports increased by 10 per cent in real terms suggesting an increase in average import prices and/or a change in the composition of imports to relatively higher value species.

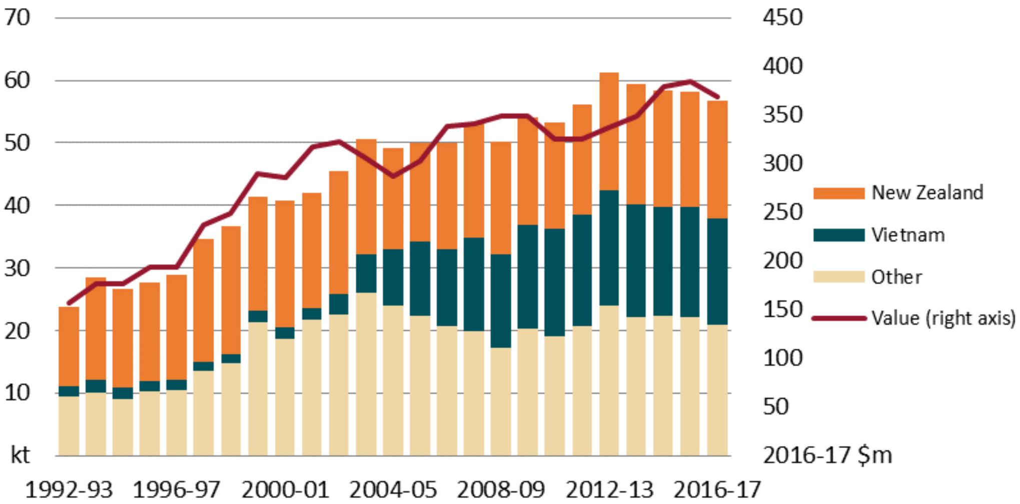

Figure 84 Imports of fresh, chilled and frozen 'other' finfish

Sources: ABS 2018, ABARES

The degree of competition with relatively high value domestically produced seafood is uncertain with imports of low cost seafood (Figure 84) competing with other cheap protein products such as chicken or mince and not directly with higher valued Australian white flesh fish (DIIS 2017). If direct competition is occurring, then is likely to be occurring mainly for the lower priced SESSF species.

IMPACT ON UNDER-CAUGHT TACS

This chapter focused on fisher terms of trade, fleet productivity and trends in Australian finfish consumption and how these may contribute to the under-caught TAC issue.

The relative stability of the terms of trade indices for the CTS and GHTS of the SESSF since 2002–03 indicate that TOT movement is unlikely to be influencing the level of under caught TAC. While a general increase in fleet total factor productivity in two major sectors of the SESSF mean that higher latency is unlikely to be caused by productivity effects.

Relatively cheaper imported seafood is likely to compete against cheaper alternative protein sources and not directly with higher valued domestically caught species. The large number of species and variation in price movements in the SESSF makes it difficult to draw conclusions between imports and price changes of SESSF species. Anecdotally, skippers do report that prices for some SESSF species do drop when large volumes are landed within a short period of time. The volumes of finfish expected to compete most with those species caught in the SESSF have been declining since 2012–13.

From an economic perspective the existence of under caught total allowable catches (TACs) (especially for lower priced non-target species) is not always a 'negative' indicator for a fishery. Given that latency in the SESSF seems to be highest for lower priced species it could be the case that latency in this fishery for those species could arise as the result of a misalignment of TAC settings with economic incentives to fish, that is, the TAC for some SESSF species is not reflective of "true" maximum economic yield (MEY). As noted in Patterson et al 2017 the MEY target for a particular species can be set higher than the optimum level for a number of reasons. These reasons include:

- estimating MEY targets requires investments in data collection and modelling that are constrained by available resources; managers therefore frequently use proxy targets that may not be optimal for a given species or multispecies stock;
- market conditions, such as fish prices or input prices for fuel and labour, may have changed, making a model-derived MEY target and/or proxy inaccurate;
- a stock may be less abundant than anticipated, or located further afield, and thus more costly to catch; and,
- regulatory changes in gear or spatial restrictions may mean that it is no longer economically profitable to catch to the previous MEY target.

WORKSHOP FEEDBACK

Participants felt that 'fish sale prices and changing markets' was a major contributor to uncaught TACs, followed by 'changing demand - imports and consumption' (Figure 85, Figure 86). This was seen as impacting the uncaught TACs of several species, particularly Silver Warehou, Blue Grenadier, sawshark and royal red prawn (Figure 87). The same mechanisms could have impacted the apparent drop in CPUE (Figure 88, Figure 89), especially for Silver Warehou, Mirror Dory, Eastern Gemfish, and Ocean Perch (Figure 90).

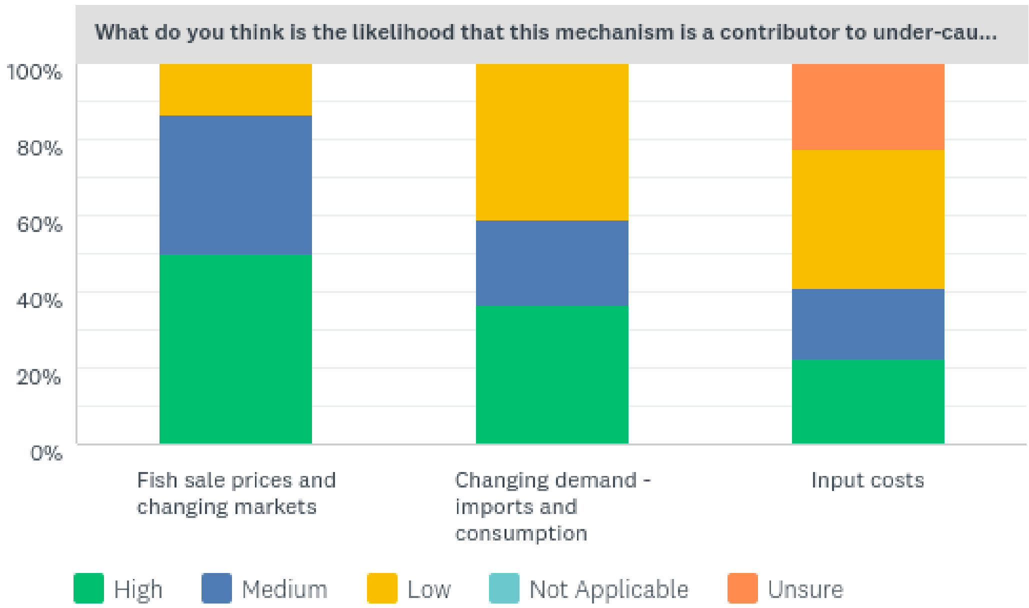

Figure 85. Workshop participant assessment of the likelihood that these production/marketing mechanisms are a contributor under-caught TACs.

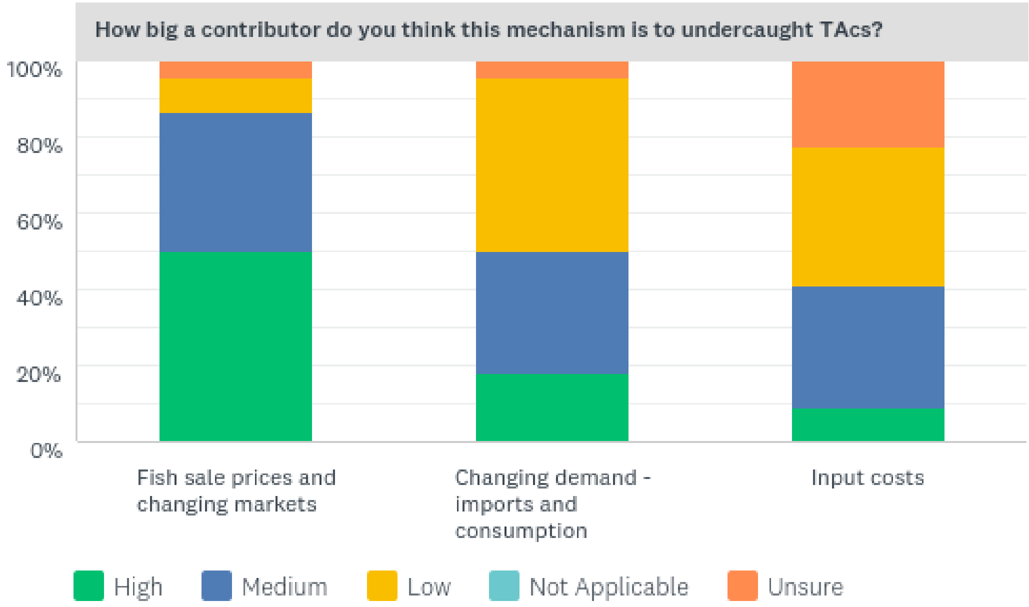

Figure 86. Workshop participant assessment of how big a contributor these production/marketing mechanisms are to under-caught TACs.

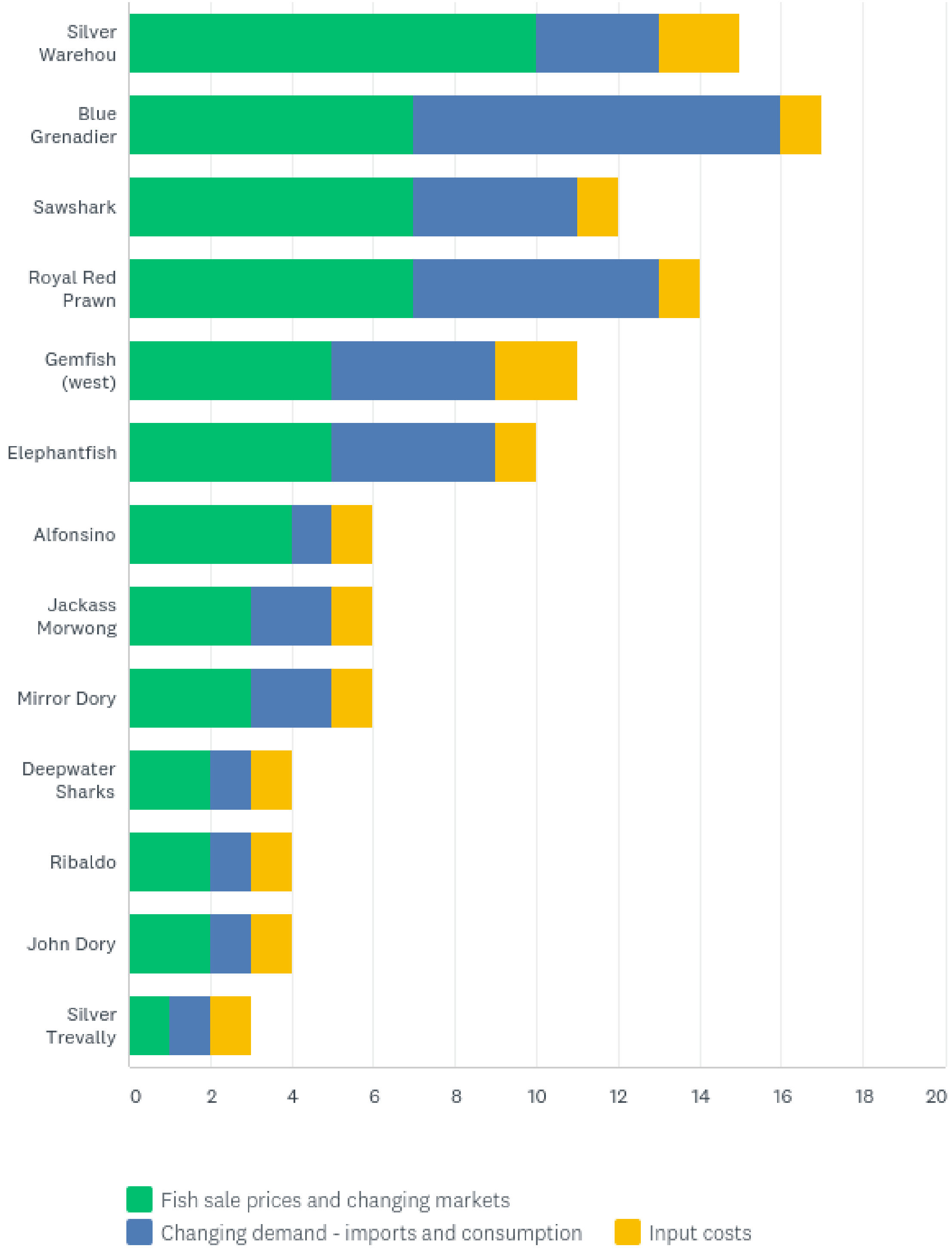

Figure 87. Workshop participant assessment of which particular production/marketing mechanisms are relevant to under-caught TACs of specific species.

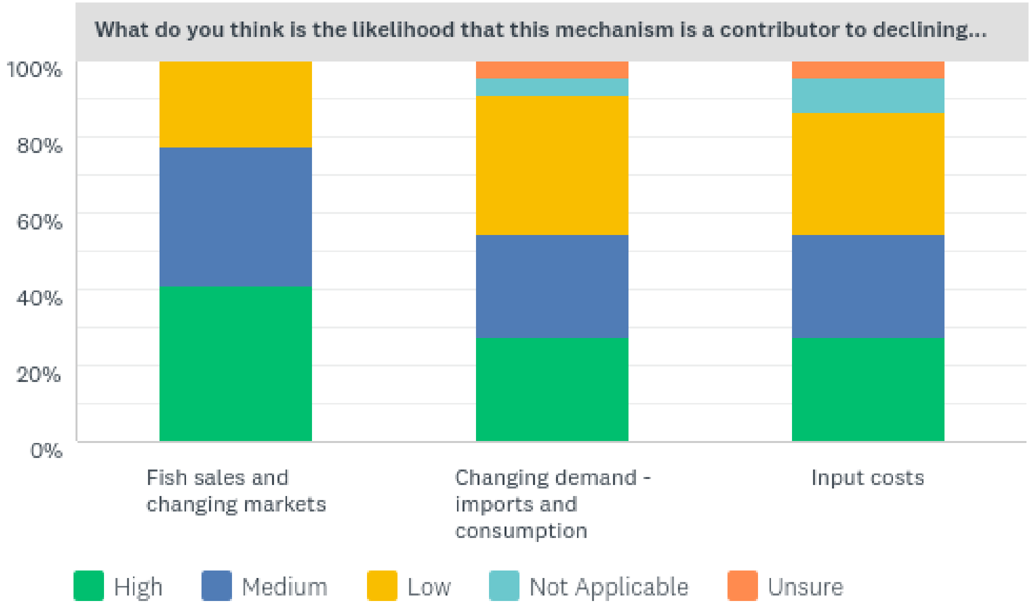

Figure 88. Workshop participant assessment of the likelihood that these production/marketing mechanisms are a contributor declining CPUEs.

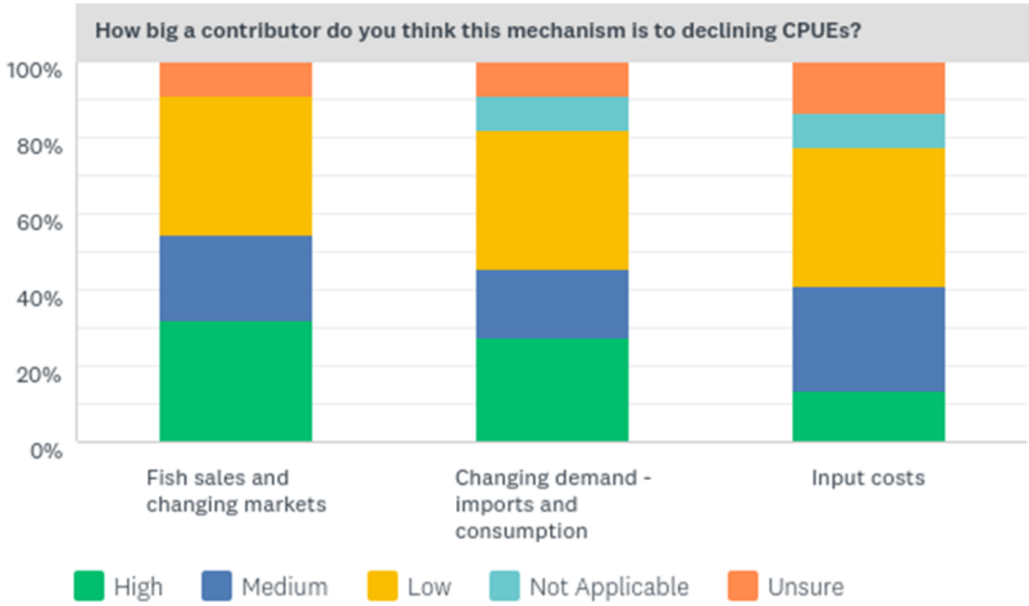

Figure 89. Workshop participant assessment of how big a contributor these production/marketing mechanisms are to declining CPUEs.

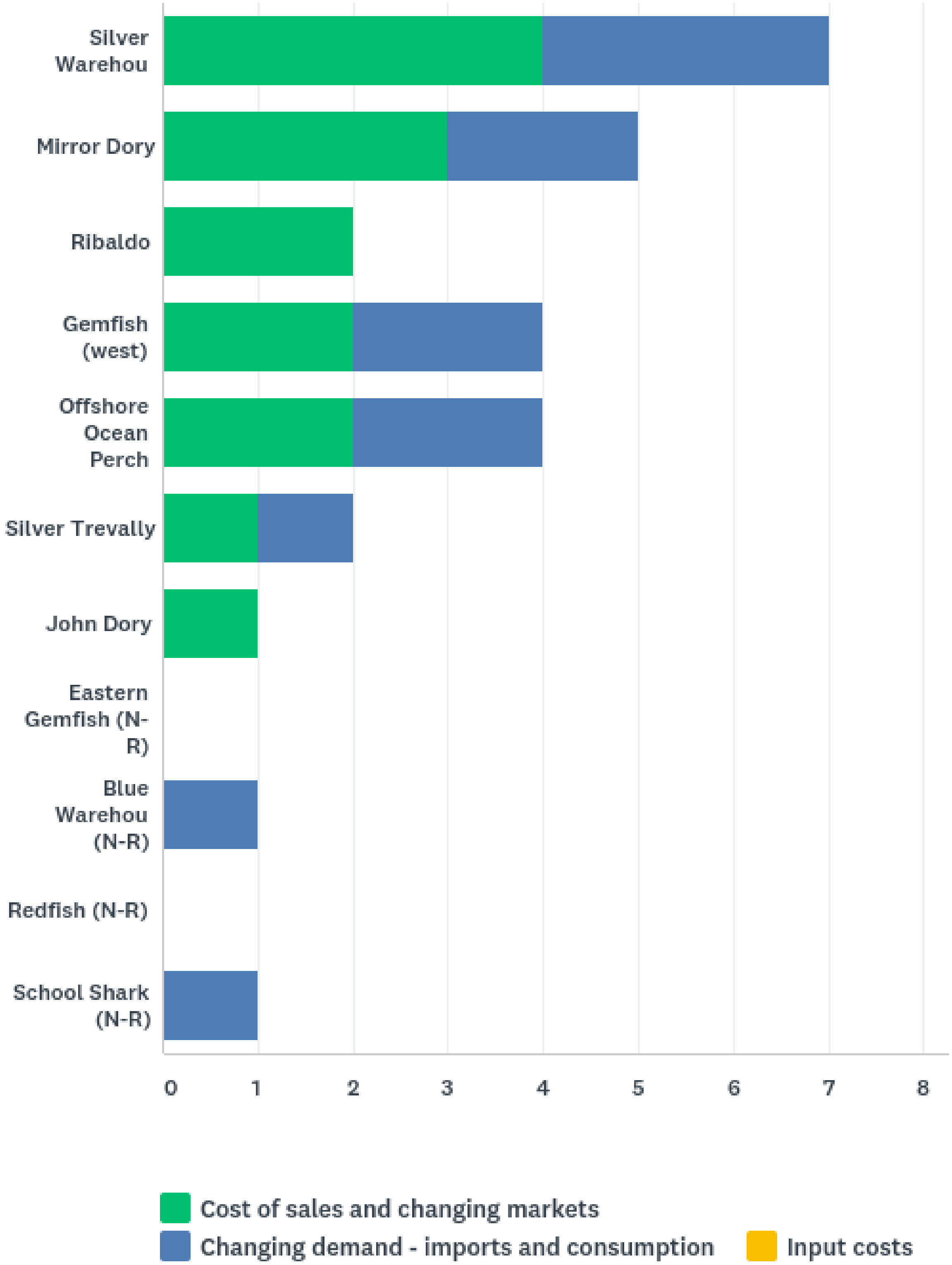

Figure 90. Workshop participant assessment of which particular production/marketing mechanisms are relevant to the declining CPUEs of specific species (N-R = Non-recovering).

Quota Ownership and Trading

Sarah Jennings, Ingrid van Putten, Abul Bari, David Guillot, Gus Danoun, John Jarvis, Tom Bibby and Will Mure

SCOPE OF THE ISSUE

In the case of the issue addressed in this paper (Quota ownership and trading) the overlap/linkages with other domains of interest is likely to be substantial (Table 32). Additionally, there will be feedbacks between performance indicators and issues, such as when declining performance trend undermines confidence in long term prospects for the fishery, altering investment decisions and prompting greater focus on short term gains. Alternatively, if expected to be transitory or to prompt appropriate regulatory change, these may signal a positive investment opportunity.

In this paper we examine the possible relationship between the SESSF quota system and only one of the performance indicators, namely under caught TACs on the grounds that it was thought to be of limited direct relevance to declining CPUEs and to the lack of recovery of some species. Possible links between various aspects of the SESSF quota system and persistent under catch are drawn from the description of the issue as defined in this project,[5] a scan of the ITQ literature, and from anecdotal evidence. Available evidence related to each link is then described. We draw on three evidence streams. These are a review of relevant empirical research, the experiences and views of several domain experts elicited through informal, unstructured interviews and the results of some additional preliminary analysis of quota ownership and trading data. We then identify possible actions that could immediately address any substantiated problems and identify research and data gaps that need to be addressed to rigorously and systematically understand causality and to design effective and efficient responses.

Individual transferable quotas (ITQs) are a popular form of fisheries management in output-managed fisheries where aggregate catch is capped. When catch is controlled by creating individual harvesting rights such that quota holders have access to a guaranteed share of the TAC, ITQs have the potential over time to reduce the excess competition and investment that is common in limited entry and open-access fisheries. Transferability of individual quotas via quota markets fosters economic efficiency because more efficient fishers tend to harvest a greater share of the total allowable catch (TAC) and because it provides incentives for inefficient fishers to exit the fishery.

The autonomous adjustment properties of an ITQ system, whereby the fishery will move to a more efficient position without the need for active management intervention, makes it very attractive and the Australian Government has had a long-standing preference for managing Commonwealth fisheries using statutory fishing rights (SFRs) in the form of ITQs (AFMA, 2013).

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[5] *"Since the introduction of output controls through TACs and ITQs, the nature of quota ownership, trade and leasing has changed considerably and this in turn, has changed the nature of the fishery. At the outset, quota was almost exclusively held by owners and operators of fishing vessels. Over time, as companies became more vertically integrated, and processors and wholesalers wanted to shore-up their access to supply, less quota has been held directly by the catching sector. Now, very significant amounts of quota are owned by companies other than those who operate fishing vessels. The costs of leasing and the efficiency of the market has impacted on access of the catching sector to quota."* FRDC 2016-146 Understanding factors that may influence ongoing negative indicators in the SESSF

For the purpose of this paper we apply a broad lens to the ITQ system, breaking it into three components, namely the *catch control*, the *quota market(s)* via which harvesting rights are redistributed and the *quota management system*.[6] Each component is described by sub-elements (Table 33).

Table 32. Selected examples of linkages between Quota ownership and trading and other issues

From issue:	***To issue:***	***Description of link***
Legislative/management impediments	Quota ownership and trading	The use of input controls, including marine reserves, in an ITQ fishery acts to reduce the security (and hence value) of quota holders' assets, which can in turn weaken stewardship.
Quota ownership and trading	Legislative/management impediments	Implementation of ITQ can increase the incentive to discard (in order to high grade and/or to balance catch against quota holding), undermining sustainability and requiring greater regulation, monitoring and enforcement.
Quota ownership and trading	Fisher behaviour and vessel operation	An increasing proportion of quota lessee fishers has been shown to increase the propensity to take risks (e.g., fish in more dangerous weather conditions) in order to ensure adequate revenue to cover fixed costs.
Climate change and oceanographic conditions	Quota ownership and trading	Perceptions of environmental change can impact expectations of future management, including TACs. Depending on whether TACs are currently binding, this may lead to expectations of either higher or lower quota values.
Fleet capacity and characteristics	Quota ownership and trading	Gains realised from the introduction of an ITQ system in terms of industry profit will only be partially realised where fishers do not have the capacity to improve their technical efficiency by altering their catch composition.

[6]The process by which harvest rights are allocated initially is also of great importance in an ITQ system, particularly to the way in which benefits are shared both among fishers and between various communities of interest. ITQs have however been in place for SESSF species for at least a decade for all species and much longer for most and it is assumed that any legacy effects of the manner in which quota was initially allocated is not playing out in current markets still. Note though, where new species are put under quota or where administrative reallocation of existing quota is contemplated, the allocation/reallocation method may become relevant to understanding fishery trends.

Table 33. ITQ system components and component elements

ITQ system component	*Sub-elements*
Catch control	Total allowable catch (TAC)
Quota market(s)	Ownership
	Nature of rights (lease vs transfer; package vs single species)
	Restrictions on trade
	Liquidity
	-Transactions costs
	-Social behaviour
	-Number buyers and seller
	-Information
	Quota price
	Quota latency
Quota management system	Quota reconciliation
	Overcatch/under-catch provisions

IMPACT ON UNDER-CAUGHT TACS

There is a continued and significant (>50%) under catch of TACs for many quota species. At the end of the 2015/16 year, 23 of the 34 species groups under TAC were less than 50% caught. Of the major quota species, only four had catches above 80% of the TACs (Flathead, Gummy Shark, Pink Ling and School Whiting).

Under caught TACs have been a feature of the SESSF over a long period of time, and concern over this indicator is not new. For example, in reference to the SETF, Kompas and Gooday (2007) noted that catch levels rarely met targets set for ITQ managed species over the period 1992–2005, with the harvest of some species caught as low as 30% of TAC. While the structural adjustment package and substantial reductions in TACs being implemented at the time were expected to go some way towards removing the problems of overfishing and overcapacity, it was noted that success would also require AFMA to set “targets and policies that guarantee economic efficiency”, possibly including some form of MEY target.

For the full benefits of ITQs to be realised, the aggregate catch or TAC must be set at a level such that it is constraining at least some of the time. If it is not the price of quota fails to provide the signals needed to ensure effort levels are constrained and economic returns will be eroded. In short, quota plays the role of allocating catch in a limited-user open access fishery, and not of the autonomous adjustment mechanism that underpins anticipated efficiency gains as intended.

QUOTA SYSTEM COMPONENT: CATCH CONTROL

The Commonwealth Fisheries Harvest Strategy Policy (HSP) and Guidelines (DAFF 2007) requires that “fisheries harvest strategies for key commercial stocks should be designed to pursue maximising the economic yield from the fishery, and ensure stocks remain above the levels at which the risk to the stock is unacceptably high”. With these objectives in mind, the target biomass is that which produces MEY, or BMEY. By and large this is achieved in the SESSF by applying a default, proxy target reference point of BMEY = 1.2BMSY. Individual species RBCs/TACs are all then set with reference to a common proxy target biomass.

The problem of setting TACs to maximise fishery-wide returns in multi-species fisheries such as the SESSF is challenging conceptually, but even more so in practice. That said, recent work based on fisheries in the SESSF have made quite substantial progress in this area. Pascoe et al. 2015 demonstrated that using a common proxy target reference point (i.e. BMEY=1.2BMSY) for all key commercial species leads to catch controls that both fail to maximise the fishery-wide economic yield and are infeasible. Smith et al. 2017 also showed that multi-species fisheries cannot maintain the range of key commercial and by product species at the same target because of different catchabilities, as a result of technical or ecosystem interactions, and cite possible sub-fisheries in the SESSF where the constraining (or close to constraining) TAC on one species may effectively 'choke' fisher's ability to catch TACs on another special (see Paper G Assessment process). Pascoe et al. 2018 also show that having quota on too many species in the fisheries may be counterproductive in fisheries like the SESSF due to choke effects. Limiting quota to only those species that make an important contribution to revenue was found to increase profitability, result in fewer discards and, importantly, result in lower levels of under catch.

Previous modelling work on the setting of targets and associated TACs in multi species fisheries provides a strong basis for ongoing research aimed at developing and trialling the use of multispecies MEY targets (and associated TACs) in the SESSF. Enabled by recent changes to the Commonwealth HSP, an FRDC project (Development and evaluation of multi-species harvest strategies in the SESSF) has been proposed in which some of these issues will be progressed through the MSE testing of a range of multi species fisheries harvest strategies. However, there is a need to also consider some of the broader governance issues that would arise if effectively dealing with these issues were to require changes to supporting legislation and regulations, management arrangements and harvest rights, or result in outcomes that have consequences for the distribution of benefits from the fisheries.

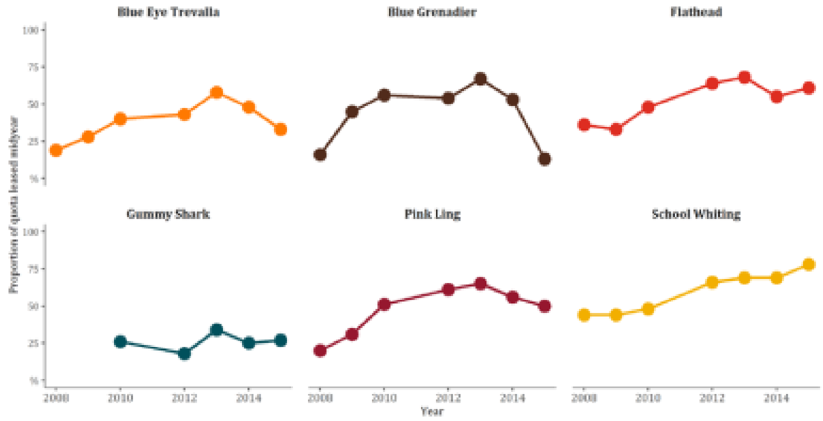
QUOTA MARKET(S)

The markets in which quota are transferred (either permanently or temporarily) are the life blood of any ITQ system, and without well-functioning markets harvest rights may not end up in the hands of operators/vessels who are best able to take the catch, or best motivated to optimise efficiency and profitability (see chapter on fisher behaviour). This may lead to poor current performance in the fishery (low returns and under caught TACs) which may then also prevent the longer-term adjustments required in fisher/vessel/fleet composition and characteristics that are needed to ensure continued economic efficiency in the face of changing biological, environmental, market (both inputs and outputs) and technological conditions.

The relationship between well-functioning quota markets and under caught TACs was shown in a recent study (FRDC Project No 2015-202). Pascoe et al. (2018) use a suite of models of a SESSF-like fishery to (among other things) demonstrate the relationship between the incidence of under catch and the efficiency of the quota market under a range of TAC-setting rules and harvest strategy settings. Two extreme, stylised quota market efficiency scenarios were considered; a perfect market where quota was permitted to move permanently both within and between fishing metiers in response to profitability, and an imperfect market in which the reallocation of quota was restricted to within fishing metiers and occurred on an annual lease basis only. While theoretical, results reinforce the importance of a well-functioning quota market for realising the full economic potential of the fishery under all management arrangements investigated involving TACs and ITQs. Of direct relevance here is that, in general, simulations with restricted quota trading (imperfect market) resulted in substantially higher levels of under catch (and discarding) as well as lower profits than simulations with a perfect market.[7]

The performance of Commonwealth ITQ markets was recently reviewed by ABARES in a submission to the Productivity Commission from the Department of Agriculture and Water Resources (DAWR) as part of the Inquiry into regulation of the Australian marine fisheries and aquaculture sectors (Australian Government, 2016). Some key points relevant to the SESSF were:

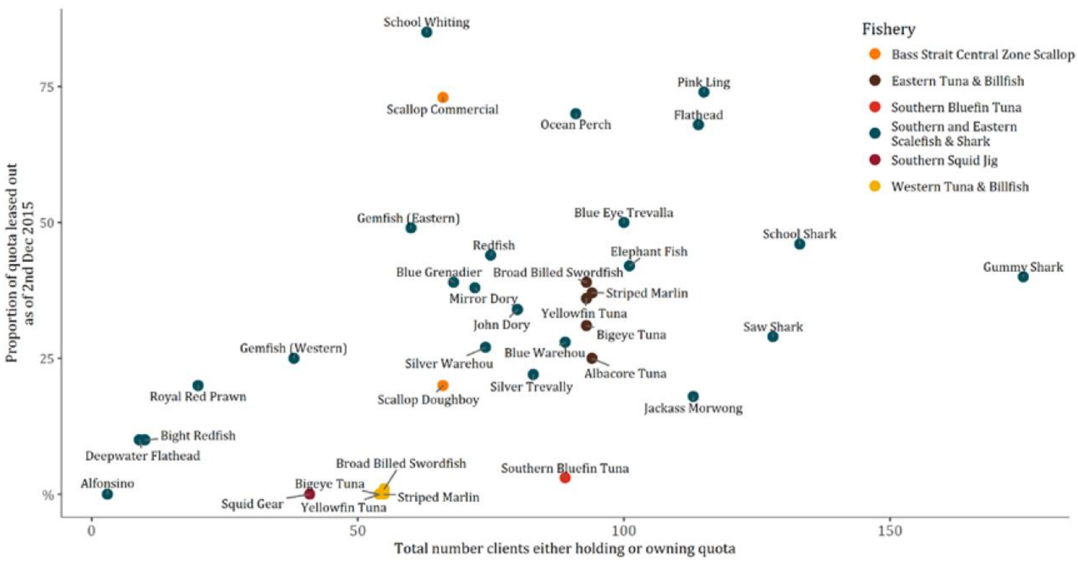
- Most targeted stocks in the SESSF have demonstrated an increasing proportion of leased quota over time (Figure 91), with over two thirds of Flathead and Pink Ling quota held by someone other than the owner in December 2015. There is also a positive relationship between the total number of clients either holding or owning quota and the proportional role of the quota lease market (Figure 92. Relationship between number of clients and proportion of quota leased for SESSF species).



Source: Derived from AFMA data by ABARES Note: Data unavailable for 2010. Data is for early July for all years except 2009, which is early June. Some leasing activity may be between entities controlled by the same person or persons.

Figure 91. Proportion of quota leased for key SESSF species. Note that the 2015 drop in Blue grenadier was a direct result of the absence of a freezer trawler coming into the winter spawning fishery (see chapter on fleet capacity).

[7] However, even with a perfect quota market some under catch was predicted to occur regardless of the management conditions and ability for fleet restructuring simulated. This result highlights the challenge of designing management systems that simultaneously address sustainability and economic objectives in multi-species fisheries.



Source: Derived from AFMA data by ABARES Note: Some leasing may be between entities controlled by the same person or persons.

Figure 92. Relationship between number of clients and proportion of quota leased for SESSF species

- Ownership concentration for five commercially important SESSF species (Blue-eye Trevalla, Blue grenadier, Flathead (including deep water), Gummy shark and Pink Ling) as measured by the proportion of quota held by the top three owners as at 2nd December 2015 ranged between 23% (Flathead) and 46% (Blue grenadier) (Table 34). Furthermore, ownership concentration has remained steady at these levels over the period 2008 – 2015. Concentration in quota holdings has also remained steady for all but a few stocks, such as Blue grenadier which is subject to changes in operating conditions and for which concentration in holdings have varied over time.[8]

Table 34. Measures of ownership concentration for selected species in the SESSF

Stock	Herfindahl Index	Gini Coefficient	Proportion owned by top owner	Proportion owned by top three owners	No. of Owners	GVP 2013–14 ($m)
Swordfish (ETBF)	0.09	0.72	0.26	0.39	80	$7.2
Blue Eye Trevalla	0.07	0.78	0.18	0.35	83	$3.3
Blue Grenadier	0.11	0.81	0.21	0.46	50	$6.4
Flathead	0.04	0.71	0.11	0.23	92	$13.6[a]
Gummy Shark	0.04	0.77	0.12	0.26	134	$13.5
Pink Ling	0.08	0.83	0.16	0.41	98	$4.3
Southern Bluefin Tuna	0.04	0.73	0.09	0.22	89	$39.5
Yellowfin Tuna (ETBF)	0.04	0.68	0.13	0.25	54	$14.4

Source: Derived from AFMA data by ABARES **a** includes deepwater flathead

- For most species concentration in holdings exceeds concentration in ownership (Table 35, Figure 93) for important SESSF species and is taken as evidence that the increase in the number of non-fishing quota owners (such as institutional investors) is not leading to

[8] Note that this is consistent with ownership of quota becoming more consolidated (i.e. fewer owners each with larger holdings) over the same period as was noted during the workshop).

greater quota concentration. Notable exceptions to this in the SESSF are Mirror dory, School shark and Gummy shark – a major target species.

Table 35. Comparison of concentration in holding and ownership for selected species in the SESSF.

difference in concentration by....	Gini coefficient	Herfindahl index	Proportion held/owned by top holder/owner	Proportion held/owned by top 3 holders/owners	GVP (2013–14 fishing season)
Notably more concentrated in holding than ownership					
Blue Eye Trevalla	-0.03	-0.03	-8%	-7%	$3.3 million
Blue Grenadier	-0.06	-0.11	-21%	-19%	$6.4 million
Flathead	-0.06	-0.04	-9%	-14%	$13.6 million a
Pink Ling	-0.01	-0.05	-9%	-12%	$4.3 million
Eastern School Whiting	-0.15	-0.2	-31%	-40%	$2.0 million
Notably more concentrated in ownership than holding					
difference in concentration by....	**Gini coefficient**	**Herfindahl index**	**Proportion held/owned by top holder/owner**	**Proportion held/owned by top 3 holders/owners**	**GVP (2013–14 fishing season)**
Gummy Shark	0.04	0.01	5%	8%	$13.5 million
Mirror Dory	0.06	0.08	13%	13%	$0.6 million
School Shark b	0.03	0.02	4%	13%	$1.8 million

Source: Derived from AFMA data by ABARES Note: For all four measures a higher number indicates higher concentration, so in the table a positive number indicates higher measured concentration in ownership rather than holding **a** Includes deepwater flathead **b** Incidental catch allowance only a includes deepwater flathead

- Overall quota lease market activity is successful in reallocating the use of quota, at least on a temporary basis, and growth in this activity indicates falling transactions costs as the market has matured.
- Overall the contention of increasing concentration of ownership is not supported by the data.
- Overall the increase in non-fishing quota owners is not thought to be resulting in the excise of market power through increased concentration of ownership, and the lease market is working to direct quota to a smaller number of efficient fishers.

The DAWR submission also addresses the question of whether poor quota market performance contributes to observed under catch in the SESSF. Their conclusion is that it does not, citing product market conditions and rising costs due to more constraining management as more plausible explanations for under catch of some species. The strategic hoarding of unused quota is also dismissed by ABARES on the basis that it would be economically irrational to do so in anticipation of capital gains, when the option for leasing exists. Similarly, suggestions that quota holders may deliberately withhold quota from use in order to increase prices and reduce per unit fishing costs through stock rebuilding are dismissed by ABARES on the basis that this would be unnecessary in an ITQ system where catches are capped at their appropriate MEY levels. (Note however the earlier discussion that suggests that targets and TACs are not currently set at levels that maximise fishery-wide MEY and further that the use of proxy targets fails to account for the responsiveness of market prices to catch levels.)

While the ABAREs analysis notes a number of reassuring patterns and trends in quota ownership and performance, there remain a number of questions regarding the functioning of the current system for which sound evidence does not exist, some of which may best be addressed at the sub-fishery or regional level. For example:

- As the ITQ system has evolved, so too has the number and diversity of types of trading entities. In addition to fishers (quota owners/lessees or mixed), non-fishing institutional owners (individual and corporate), and integrated fisheries companies now all participate. The resources, objectives and behavioural drivers of these groups differ and may not always align with those implicit in the design of an ITQ system. Lease quota fishers for example are not guided by the same incentive structure generated by ITQ management that theoretically regulates the behaviour of quota owners (Bradshaw 2004; Gibbs 2009) (see Paper C: Fleet behaviour and vessel operation). Lease fishers may for example display low flexibility in changing their fishing activities during the season due to the need to lock plans in early in the season to ensure sufficient revenue to cover quota lease costs which are generally incurred and must be paid early in the season. This may result in lost trading/fishing opportunities if some groups wanting to lease quota see an advantage in not offering quota at a reasonable price until late in the season. Lack of understanding of the asset value of quota may also be a factor, particularly with quota owners who have been allocated or bequeathed their quota. Failure to recognise the opportunity cost of not exercising this right annually (foregone lease revenue) and the potentially negative effect on quota asset values (due to the link between non-binding TACs and poor economic performance) may lead to sleeper quota.
- There is anecdotal evidence of personal/social relationships underpinning much of the trading patterns in the SESSF quota lease market. While many lessee fishers rely on well-established trading relationships (thereby reducing transaction costs) there was also the suggestion that some trading opportunities were ruled out because of poor relationships and/or experiences between entities. Despite the emergence of a quite healthy brokerage system some smaller quota owners may remain disconnected from the market, leading to unused quota or transactions that are not optimal in terms of fishery wide efficiency.
- Theoretical and experimental work on quota market auction design in multi-species fisheries suggests there are benefits to trading in packages rather than single species trading (Tisdell et al. 2013). Further evidence of package trading emerging in quota markets where there is no central trading platform is taken as further evidence of its benefits (in lowering transactions costs and the need for ex ante quota balancing) and an indicator of market maturity (Innes, 2014).
  Experts interviewed indicated the dominance of package trading in the SESSF markets, also noting a trend towards larger packages comprising a greater number of species. An initial analysis of the data for the period 2007 – 2017 (Figure 93, Figure 94, Figure 95, Figure 96) confirms the importance of package trades in both lease and transfer markets, with between 40% and 50% of total lease trades comprising packages over the entire period. While this proportion has remained fairly steady, the proportion of package trades in the transfer market has declined, with this form of transaction dominating the market (>50%) prior to 2012 but now (2017) comprising only 35% of transfer transactions. Over the period 2007 – 2017 the average number of species included in lease packages has risen (from 10 to 14), but it has fallen (from 5 – 3) in transfer packages. Industry experts suggested that lease packages offered on a take it or leave it basis now contain a large proportion of quota species that remain unfished as lessees do not on-sell them due to their low value and/or the high transactions costs of doing so. Rather than representing a desirable response to high transactions costs, observed trends in package trading may indicate an imbalance of market power between lessors and lessees.

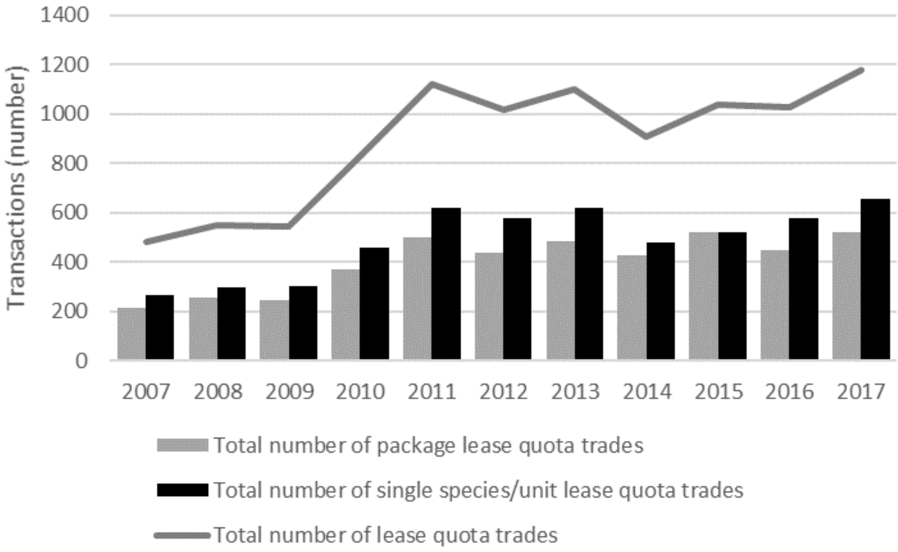


Figure 93. Total, package and single species quota lease transactions from 2007-2017.

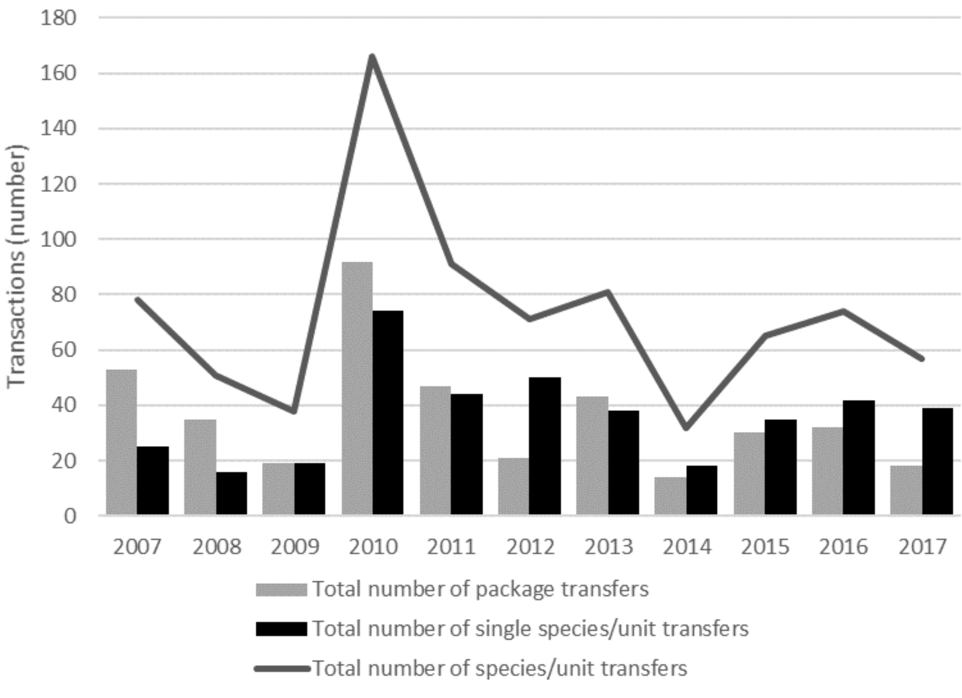


Figure 94. Total, package and single species quota transfer transactions from 2007-2017.

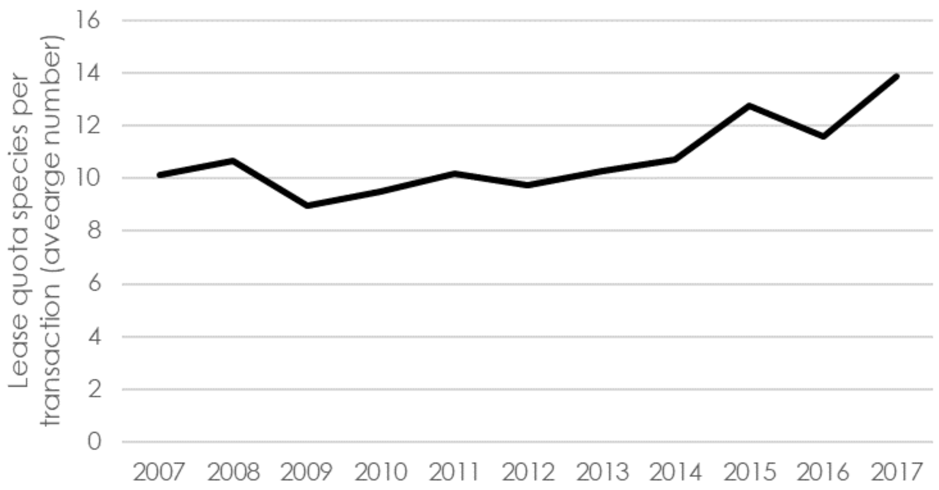


Figure 95. Average number of quota species per lease package per annum for all SESSF species (based on seller information)

Figure 96. Average number of quota species per transfer package per annum for all SESSF species (based on seller information)

It has not been possible in this brief review paper to draw any strong overall conclusions about the degree to which the market for quota in the SESSF is well-functioning, or the extent to which the operation of the market is contributing to under caught TACs. While the extent of quota latency is often taken as an indicator of a well-functioning quota market (by which account the SESSF market would be deemed inefficient), it is possible that some observed market behaviours and practices are symptomatic (rather than causal) of a fishery in which persistent under caught TACs (and other poor performance indicators) feedback to alter the incentives driving quota market participant's behaviour and in turn manifest as market inefficiencies.

Analysis of quota ownership/market data to create an accurate snapshot of exactly where unexercised quota is sitting in specific sub-fisheries, and what type of entities own unexercised quota would help in understanding whether the causes are for example behavioural, institutional, or technical and could help focus future research. For example, data on sleeper-holdings in the SETF in Connor and Alden (2001) suggested that by volume these were quite small, and underpinned by a large tail of small holdings. The continued growth in the lease market, and in the heterogeneity of quota participants suggest this exercise is worth repeating/updating.

In-depth analysis, using network analysis, of selected regional/sub fishery quota markets would help build an understanding that is currently largely anecdotal of how, and how well, quota markets in the SESSF are functioning, and potentially of the extent to which this issue is contributing to declining indicators. Investigation of the fine structure and performance of these markets will complement previous high-level analysis of these markets and contribute to evidence-based decision-making regarding possible future management actions, such as providing quota price information and/or creating a centralised quota trading mechanism/marketplace. A network analysis would also be able to identify areas of the SESSF quota market where industry-led solutions might be possible.

All transfers of quota SFR's and ITQs (permanent or temporary) must be recorded with AFMA. This includes the identity of both seller and buyer, or lessor and lessee, the quantity of SFR's traded and the transaction date. Access to data at this level of detail is governed by the AFMA's legal obligations as articulated in their Information disclosure policy, although periodic snapshots of SFR and ITQ ownership is publicly available.

In the past, analysis based on this data has been subject to the caveat that quota owners and holders are often legal persons or partnerships, such that a given person may hold or own quota under several different names. In addition, the intra-entity movement of quota will be recorded as a transfer or lease transaction if different parts of an integrated company trade under different names. This confounds estimates of ownership and market activity. Further work is needed on the database before strong evidence on this issue can be produced.

There is no central quota trading board/platform in the SESSF and AFMA have not historically required quota price information to be provided as part of its quota reporting. Consequently, the prices at which quota are traded (transferred and leased) in the SESSF are not available, other than anecdotally. Note though that as from July 3, 2017, concession holders must report the prices of all transferred quota and gear SFRs and disclose intra-entity transfers. Future disclosure of individual's SFR prices will be subject to AFMA's Information disclosure policy and SFR price data in aggregated form will not be published prior to 1 July 2019.

QUOTA MANAGEMENT

While market trade (both permanent and temporary) in quota enables fishers to adjust their quota portfolio to match catch, critics of multispecies ITQ systems have described catch-quota balancing as an insurmountable problem (Copes 1986). Quota management systems have therefore also evolved in parallel to quota markets to address this challenge and are intended to complement quota trading. They may play a particularly important role in fisheries where TACs are out of balance with average catch ratios. In such cases, non-trading mechanisms might enable fishers to more fully utilize the TAC of the species that would otherwise have been constrained by the TAC of the jointly caught species.

Current quota balancing arrangements in the SESSF comprise two main measures as set out in the Management Arrangement Booklet 2017 (AFMA, 2017). These are the quota reconciliation process and under catch and over catch provisions.

The requirement for fishers to balance catch with quota holdings involves a rolling 28-day reconciliation process. That is, fish landed above quota can be retained/sold and fishing can continue, so long as quota is secured to cover the exceeded amount within a 28-day period. Failure to reconcile over-catch quota within this period will trigger compliance action.

Continuous reconciliation reduces periodic spikes in quota demand and lessens the opportunity for price gouging.

Over catch-under catch provisions allow fishers who have exceeded their allocated or purchased quota at the end of a fishing season to reallocate quota from the subsequent season or carry over part of their quota to the next season if they have unused quota. Such over/undershooting can occur for a number of reasons, including uncertainty about fishing and market conditions. To prevent overfishing, there is a limit on the level of over catch (based on a % of the TAC) and undercatch is not transferable.

Over catch provisions means fishers do not have to seek quota on the quota market to avoid compliance procedures for relatively modest overshoots, and by reducing the risk to fishers can prevent deliberate under catch. Under catch provisions mean fishers have the flexibility to use quota in a subsequent season if they feel operating/economic and fish market conditions will serve them better in the next season.

While administratively-based quota reconciliation arrangements are intended to complement quota markets (in particular the lease market) as a means of balancing catch against quota (particularly where such markets may be illiquid), they also have the potential to erode the benefits of ITQ systems by undermining their effectiveness in constraining global catches, encouraging price gouging by quota sellers and by crowding out quota market transactions.

Quota administrative arrangements in Commonwealth fisheries have been subject to a lengthy review in accordance with the Quota Administrative Policy (QAP). One of the guiding principles for this review was to “minimise distortion of operation of the quota market”. This review resulted in the introduction of the current continuous reconciliation arrangements, replacing the previous system of quarterly reconciliation. Under catch-over catch arrangements are currently under review by AFMA with analysis indicating that this provision (in some form) is on balance desirable, particularly where quota markets are illiquid.

Quota administration arrangements were not identified as a serious impediment to the operation of quota markets in the SESSF by any of the experts interviewed in the process of preparing this paper. However, examples of quota market participants purchasing quota at the end of the season when prices were low with the specific intent of making maximum use of under catch carry forward provisions, and of multiple entity market participants shuffling quota holdings internally in order to maximise their eligible carry forward, were cited.

AFMA’s review of quota administration arrangements is ongoing and is guided by the need for this component of the quota system to complement and not impede the ability of the quota market to reallocate quota to fishers who are best able to catch the TAC. That said, there is a need to monitor the level of use of administrative quota balancing mechanisms as changes occur in the fishery and to better understand the conditions that might lead quota market participants to use these provisions in ways that do negatively impact quota market performance and fishery sustainability goals.

WORKSHOP FEEDBACK AND CONCLUSIONS

Of the six potential mechanisms, workshop participants felt that only multi-species catch controls could be a major contributor to under-caught TACs (Figure 97, Figure 98, Figure 99). No potential mechanisms were identified between quota ownership/trading and declining CPUEs or failure to recover of overfished species.

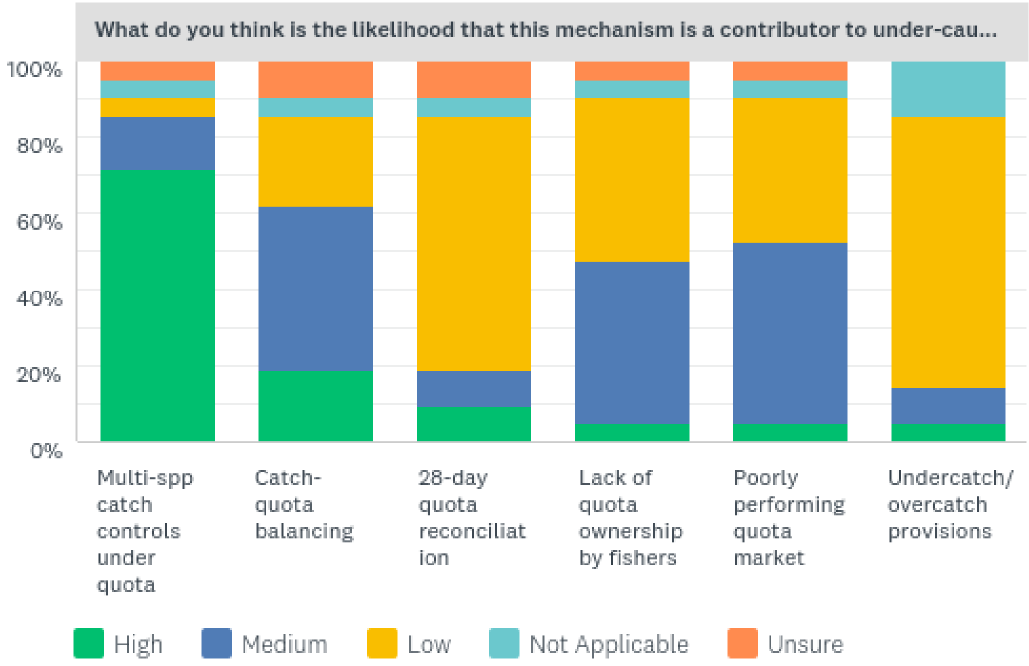


Figure 97. Workshop participant assessment of the likelihood that quota ownership/trading mechanisms are a contributor under-caught TACs.

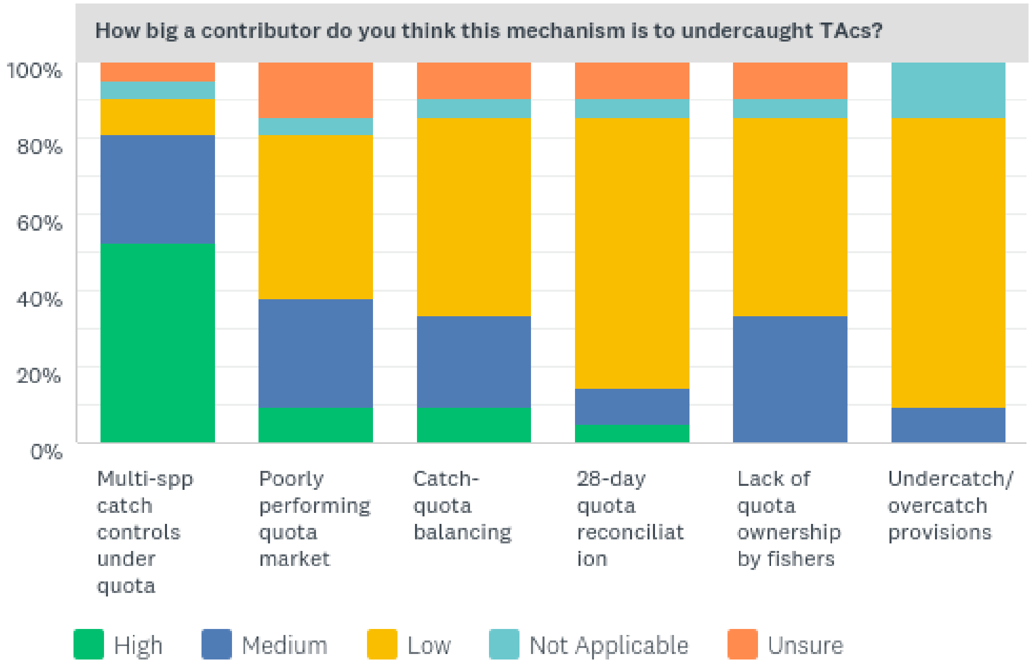


Figure 98. Workshop participant assessment of how big a contributor these quota ownership/trading mechanisms are to under-caught TACs.

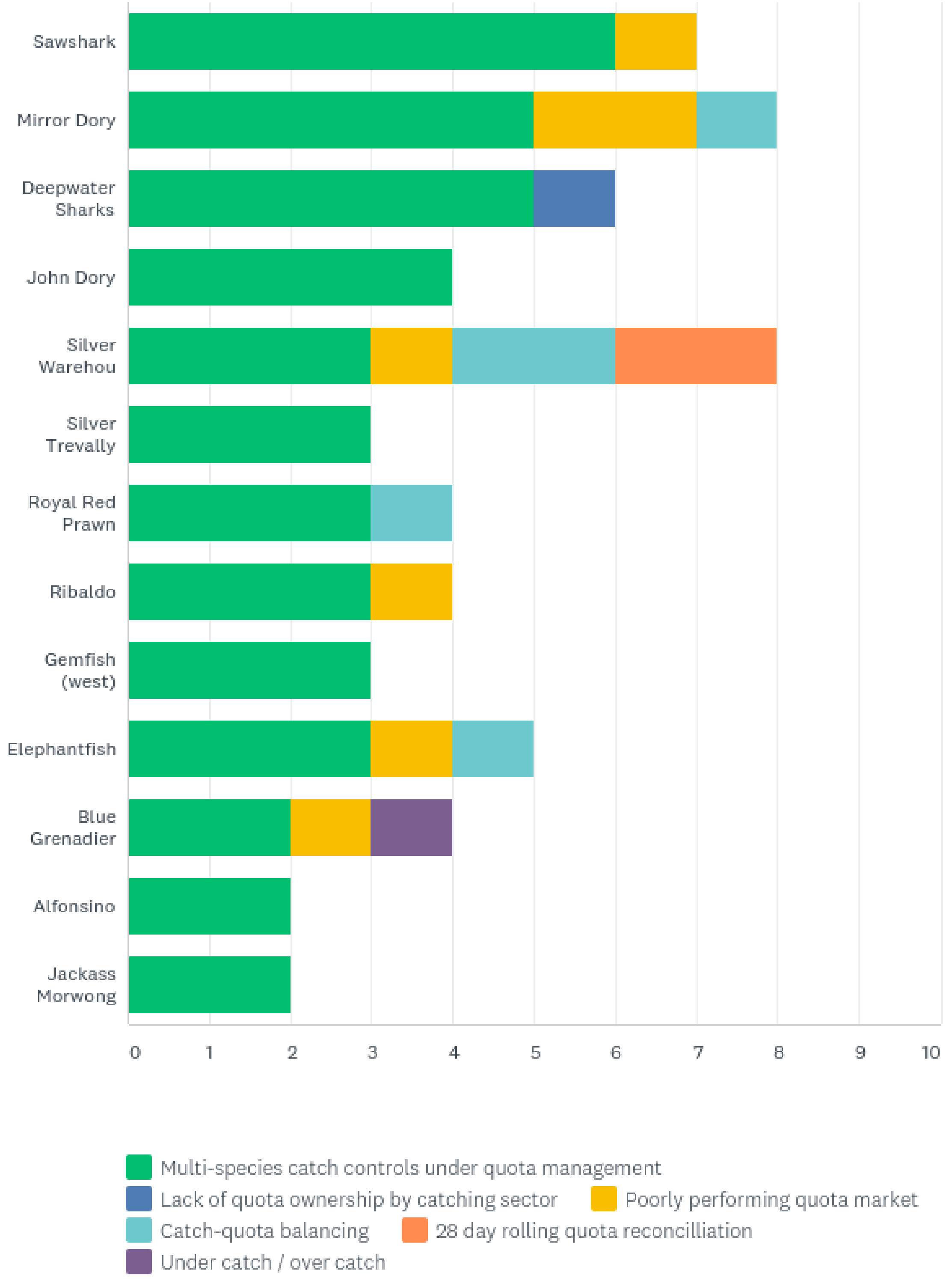


Figure 99. Workshop participant assessment of which particular quota ownership/trading mechanisms are relevant to the under-caught TACs of specific species.

CONCLUSIONS

Overall, none of the industry experts consulted as part of this process indicated that they believed the *Quota ownership and trade issue* was a strong driver in explaining the persistence of under caught TACs for a large number of species in the SESSF, although one expert thought TACs were 'too high'. Instead, they variously cited poor market conditions, lack of suitable fishing capacity, environmental change and marine reserves as being of greater overall importance.

Our brief review of evidence of the extent to which current *quota management* may be leading to underperformance of the quota system suggests that this is not currently of great concern. In fact, the presence of such arrangements in ITQ-managed, multi-species fisheries is generally thought to be essential, particularly where TACs may not align well with average catch ratios and where quota markets (transfer and lease) may not be liquid. Furthermore, AFMA's review process of quota administration provisions is well positioned to monitor the use of these provisions to identify any emerging issues.

The question of whether observed under catch for many species is the product of TACs that are incorrectly set remains. A key point is that there is mounting evidence that some TACs will unavoidably remain uncaught in multi-species, multi-gear fisheries when a one-size-fits-all target is applied across all species, and that this approach to controlling catches is inconsistent with a goal of maximising fishery-wide economic yield. Some modelling-based evidence of a SESSF-like fishery suggests that current TACs for many species may well be higher than optimal while other may be lower, and that this manifests in terms of lower profitability and higher levels of under catch. The tractability of the challenge of setting TACs that are constraining at least some of the time for all species is compounded as the number of species that are managed to quotas increases. A system in which TACs based on MEY targets are applied to a small number of the highest value species would probably improve fishery performance. The TAC is important to ensuring an ITQ system delivers the best outcome in terms of economic efficiency as well as being central to ensuring fisheries sustainability. The proposed FRDC research project (FRDC Project 2018-021 – Development and evaluation of multi-species harvest strategies in the SESSF) should build on previous work to deliver practical and cost-effective solutions to target and TAC-setting in the SESSF that are responsive to changing economic, market, technological and environmental over time.

Overall, existing evidence of *quota market performance* is inconclusive and raises more questions than it resolves. While industry experts noted specific instances where they experienced or were aware of problems with sourcing quota and gave examples where market liquidity was inhibited due to personal/social factors, strategic behaviours, diverse participant behavioural drivers and levels of understanding and lack of information, quota markets overall appeared to function reasonably well for them. However, there does seem to be a case for developing a deeper, more nuanced understanding of how well quota markets in the SESSF are working to ensure quota is flowing to the most efficient vessels, and that the under catch of high value quota species in particular is not an artefact of structural, institutional or behavioural features of markets. With some further data preparation and linking, quota ownership and trading data could be used to further unpack a number of trends (e.g. increased lease activity, package trading), at the level of important species groupings and to identify trading patterns across time and types of market participant behaviours that might be contributing to declining fisheries performance indicators. We suggest using network analysis to identify a set of existing and emerging features of both lease and transfer markets, that can then be prioritised for further analysis. As an important indicator of quota market performance, the future availability of quota price data offers the prospect of being able to evaluate market behaviour and performance more thoroughly, and so improve management and policy, but also to reduce information and transaction costs for market participants. The type of research proposed would help predict and quantify the potential benefit of establishing a centralised, double blind marketplace for quota which has also been raised as a possible action, but would need to be subject to a cost-benefit analysis. It may also identify alternative, lower cost options to improving quota market performance.

The Assessment Process

Rich Little, Simon Boag; Tony Lavalle, Daniel Corrie, Geoff Tuck

SCOPE OF THE ISSUE

The Assessment process has several stages, with the Assessment stage representing the culmination of previous stages. We have defined the stages as:

1. Setting Data Collection Targets

In the assessment process, data target setting usually pertains to specification of:

   a. the sampling location and sample size for observer data collection,
   b. a model-based procedure to inform the sampling activity of the fishery independent survey (FIS).

2. Data collection

Data collection occurs three ways in the SESSF through

   a. sampling by observers,
   b. Fishery Independent survey (FIS)
   c. Logbooks
   d. Industry observations of length composition data

3. CPUE standardization

CPUE standardisation involves analysis of fishery dependent catch and effort from logbooks.

4. Assessment

The Assessment stage usually integrates or analyses across one or more of the data sources. It is likely that if the Assessment stage affects a Fishery Indicator (Declining CPUEs, Lack of Recovery, under caught TACs), then some element of the process leading to the Assessment, could do so as well.

In the remainder of this document, across the stages of the Assessment Process we have defined, for each Fishery Indicator we examine the:

- Relevancy – does the stage have any relevance to the fishery indicator
- Potential Explanations – lists the potential explanations of how the assessment stage may influence the indicator
- Supporting Data and Analysis – describes the data or existing studies that may provide evidence of relationships between the assessment stage and the indicator; and
- Solutions – describes how changes to the assessment process may reduce any biases or uncertainties to the indicators introduced by the assessment stages.

A summary of this is outlined in Table 36.

Table 36: Summary of hypothetical explanations relating to the effect of the stages of the Assessment Process on the Fishery Indicators.

Issue	**Fishery Indicators**			
Assessment Process	**Declining CPUEs**	**Lack of Recovery**	**Under caught TACs**	**Possible Solutions**
Data collection targets		H: lack of data collection from recovering stocks H: active avoidance of recovering stocks, results in changes in catchability		Targeted survey for recovering stocks More frequent FIS Redirection of observer resources
Data collection routines	H: Human error in entry of logbook data			Automated VMS, and e-logbook
CPUE standardization	H: Inability to capture changing behaviour or management changes (Working Group C) H: including or exclusion of small catches in the logbook data.	H: Inability to capture changing behaviour or management changes (Working Group C) H: including or exclusion of small catches in the logbook data.	H: Inability to capture changing behaviour or management changes (Working Group C) H: including or exclusion of small catches in the logbook data.	Has been attempted with limited success
Assessment	Analytical procedure tends to *use* CPUE, not influence it. Thus, this stage is unlikely to contribute to Declining CPUEs.	Analytical procedure measures recovery, not influence it. Thus, this stage is unlikely to contribute to lack of recovery.	H: TAC may be set too high. H: Under caught TACS may be result of choke factor on primary species resulting from technical interactions.	Harvest strategy amendment to adjust targets for non-target species.

IMPACT ON DECLINING CPUES

It is expected that data collection and CPUE standardisation stages of the Stages of the Assessment Process are relevant for the Declining CPUE indicator. It is important to define the concern with declining CPUE. A decline in catch rates for many quota species should not be surprising if the entire exploitation history is relatively recent, since the decline would reflect the reduction in abundance from close to pre-exploitation levels. The declines should be more concerning if they have occurred relatively recently, compared to a long exploitation history, especially if it has occurred after the implementation of the Commonwealth Harvest Strategy Policy.

Nearly all quota stocks in the SESSF have experienced a reduction in observed catch rates to some extent since the mid-1980s when logbook data recording began (Figure 100). The greater concern is that, despite low effort and catches, for seven species, the catch rate has continued to decline in recent years, and not stabilised at reasonable levels or increased. These species are: Jackass Morwong, Redfish, Blue Eye Trevalla, Silver Warehou, Blue Warehou, John Dory and Ribaldo. The question then becomes whether this is a real trend in relative biomass (see Lack of Recovery section) or biased by either the data going in to the catch rate analyses or the method adopted for the catch rate standardisation itself. The following sections discuss how, if the observed declining catch rates are due to a bias, this might have occurred and what can be done to remedy this situation. Figure 100 puts into perspective recent CPUE trend (boxes) in relation to longer term trends since 1985 and highlights these species.

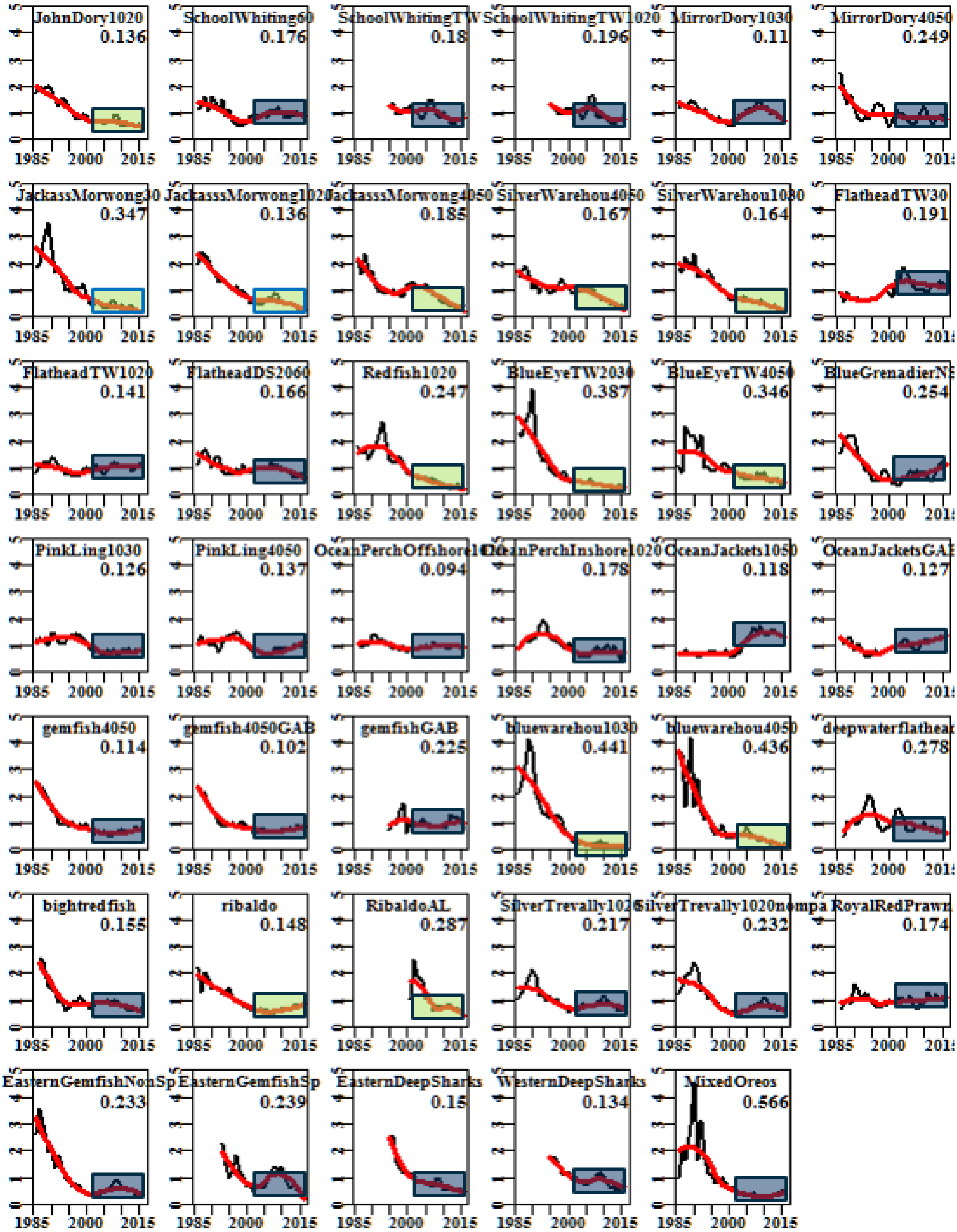


Figure 100. CPUE standardisation by Haddon (in prep) with trend since 2000 highlighted by boxes (yellow signify species previously highlighted for concern)

DATA COLLECTION

The Data Collection Stage of the Assessment process is relevant to Declining CPUE indicators. Potential explanations for Declining CPUEs at the Data collection stage of the Assessment Process are:

H1: Likely effect CPUE through human error of logbook data

This is a data quality issue. Catch recorded by skippers is done so with varying degrees of accuracy. Catch recorded in the logbook is often underestimated.

Operators are required to record fishing effort information in the daily fishing logbooks. The instructions (Figure 101) may be interpreted differently by some operators. Often logbook data cannot be read.

Start and end shot times

Start times are when the gear setting has stopped. End time is when hauling begins. Please record all times using the 24-hour clock (e.g. 1:00pm = 1300).

Start and end position

Start position is the position of the vessel when the gear setting has stopped. End position is the position of the vessel when gear hauling begins.

Average trawl depth

This is the average depth at which the net is towed during a shot. Please circle m (metres) or fath (fathoms) depending on which unit you are using.

Average temperature (N/A?)

This is the average temperature recorded at trawl depth during the shot. Please record it in degrees Celsius. If you do not have a net monitor that records temperature put a dash in this space.

Shot valid

Circle 'Yes' if the gear was deployed successfully or 'No' if you had gear problems, ie. net was pinned up.

Figure 101. Instructions for filling out logbooks in the South East Trawl Fishery (EFT01B).

H2: Inability to capture changing behaviour

This includes possibly the advent of major management changes such as the shift to a quota management system (QMS) in 1992 (1997 for GHTS) and the structural adjustment aligned with the HSP and is likely to be part of other working groups and not considered here.

There is no applicable supporting research we know of concerning human error in the collection of logbook data.

Automated e-logbook could reduce some of the human error associated with logbooks such as consistent use of common names, however this is unlikely to result in improved estimates of catch and discards. Moving to e-logbooks will also not rectify or correct any historical inadvertent recording errors in the data.

The introduction of electronic monitoring, for example hydraulic sensors on net drums, could allow for standardised recording of fishing effort for methods such as trawl where the location, start, duration and end of a shot are automatically recorded and not left to skipper judgement.

DATA TARGETING SETTING

Because the Data Collection target setting stage of the Assessment Process does not involve setting catch or effort, this stage of the Assessment Process is not relevant to the Declining CPUE indicator.

CPUE STANDARDISATION

The CPUE Standardisation Stage of the Assessment process is relevant to Declining CPUE indicators.

Potential explanations for Declining CPUEs this stage of the Assessment Process are:

H3: Including small shots from the logbook data in CPUE standardisation.

The concern and reasons for questioning the ability of CPUE, and standardisation methods to improve the representation of underlying biomass is well established in fisheries science. A decade ago the concern with the increasing prevalence of small shots motivated an investigation (Day 2006) (Figure 102).

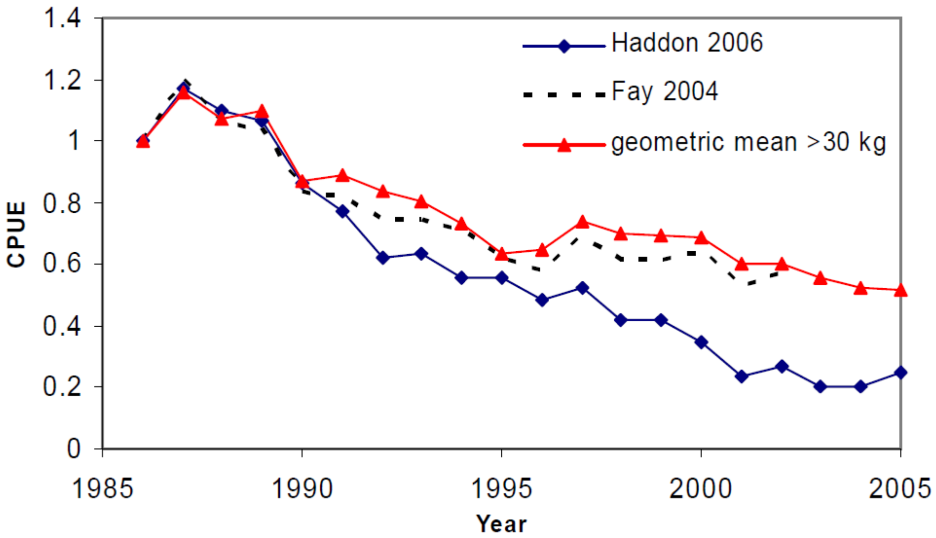


Figure 17.1. Three different standardised CPUE series where the series all equal 1 in the year to which they are standardised: the Fay series (tows with > 30kg morwong only), data to 2005 the Haddon series (all tows catching morwong, with vessel restrictions as noted above) data to 2005; and the geometric mean (not standardised) of catches >30kg, data to 2005. This graph is from Fay (2006).

Figure 102. Figure from 2006 SESSF stock assessment report (Day 2006).

The decision to include or exclude small shots in the standardisation does not affect whether the series trend declines or not, i.e. they both still decline, however the effect of including "small shots" exacerbates the degree of decline. This motivated the investigation by Bravington and Foster (2015) concerning whether zero-shot data should be included when doing CPUE standardizations.

Bravington and Foster (2015) observed that CPUE in the multi-species SESSF is standardized on species-by-species basis, and investigated appropriate data sub-setting methods, and whether long-term changes in targeting behaviour have distorted the CPUE trend. The standardisation model they developed was complicated but did not suggest markedly different trends in CPUE compared with a standard species-by-species standardization, even though the estimated effects of the various types on catch were significant, and there were apparent trends in targeting.

One of the motivations behind this study was the lengthy and unresolved debate about whether zero catch shots of a species should be included when doing single-species CPUE standardization. This has broad implications when considering targeting in multi-species fisheries and has some implication in single species fisheries. The model developed, which the authors did not recommend for use in assessments, resolved the issue by using all the data, zeros included, but it did not make much difference (see Figure 103 for example) in solving the problem of declining CPUEs. In fact, including zeroes did not necessarily lead to a greater decline in the catch rate series.

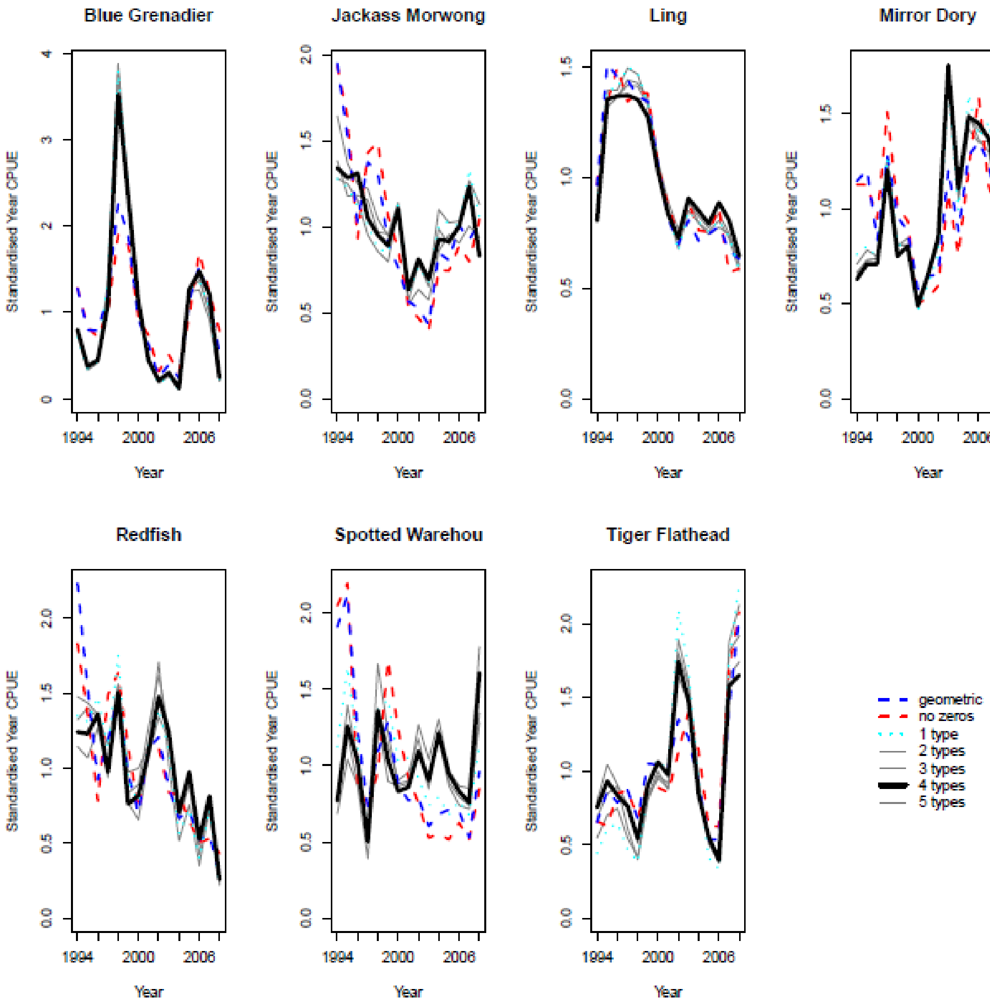


Figure 103: Relative abundance series estimated by different models (Bravington and Foster 2015).

More recently, Malcolm Haddon is also currently leading a project to improve catch rate standardizations by accounting for changes in targeting (2012-201). The final report is currently pending, but some conclusions from the recent standardisation report (Haddon and Sporcic 2017) preview some of the issues (Figure 100):

John Dory

A potential change in fishing behaviour is suggested to have occurred since about 2014, which is evidenced by changes in the distribution of log-transformed CPUE each year. From 2014 a number of widely spread spikes in the histograms have become apparent, most especially in 2015 and 2016. The underlying driver for these changes is not immediately apparent.

Morwong

The vessel factor in zones 40 and 50, changed its influence from 2001 onwards reflecting the increase in catches from 2001 and suggesting the fishery changed markedly at that time. The reasons behind this change should be explored and explained in more detail.

In zones 10 and 20, the structural adjustment altered the effect of the vessel factor on the standardized result. However, log (CPUE) has also changed in character from 2014 - 2016, with spikes of low catch rates arising.

Silver Warehou

In zones 10,20 and 40,50 the period around 1999 - 2006 appears exceptional, or at least contains exceptional vessels, all of which left the fishery after the structural adjustment. This suggests that there have been transitional periods in the time-series of CPUE. This urgently needs more attention because this may imply that CPUE may no longer be acting as a valid index of relative abundance through time, especially across the structural adjustment boundary at Nov 2006.

Redfish

Catches in zones 10 and 20 by year and vessel, in the period around 1993 - 2006 appear to be different to other years. This suggests that there have been transitional periods in the time-series of CPUE, likely driven by discard practices (Tuck, 2017). This urgently needs more attention because of the potential implications this has for the index of relative abundance through time.

Blue-eye

Given the on-going low catches taken by trawl, and the recent even lower catches, the major changes in the fleet contributing to the fishery, the dramatically changing character of the CPUE data itself, and the recent disjunction between the nominal catch rates and the standardised catch rates it is questionable whether this time-series of trawl CPUE is indicative in any useful way of the relative abundance of Blue-Eye Trevalla.

Blue Warehou

Exploration of the early CPUE data could be made to examine whether there are obvious or consistent errors leading to mean CPUE values 4 times greater than the long-term average.

Further investigation into the CPUE data were recommended by Haddon and Sporcic (2017).

ASSESSMENT

Because the Assessment stage tends to *use* CPUE, not influence CPUE, it is likely that this stage of the Assessment Process is not relevant to the Declining CPUE indicator.

If the assessments and associated Harvest Control Rules for Tier 1 (fully quantitative stock assessment) and Tier 4 (Standardised CPUE analysis) assessments use catch rates that are biased low, this could lead to unnecessarily low TACs, such that vessels may need to avoid the stock so as to not exceed their individual quota holdings. This combined behavioural interaction between the quota setting process and the operators could lead to an iterative decline in apparent catch rate trends.

IMPACT ON LACK OF RECOVERY OF OVERFISHED SPECIES

The assessment process has little effect on recovery of stocks but will influence the perception and ability to determine recovery or not. Thus, because it is a matter of perception, the effect manifests itself mainly at the Assessment stage.

This fishery indicator relates to eastern Gemfish, Blue Warehou, Redfish, Jackass Morwong, Silver Warehou, and School Shark.

The Data Collection Stage of the Assessment process is relevant to the Lack of Recovery indicator. The potential explanations include those for the previous Declining CPUE indicator.

H4: Limited harvest reduces the opportunity to collect fishery dependent data (reduced shots and catches).

This is a *data quantity* issue.

H5: In addition, because the commercial fleet tends to actively avoid recovering stocks, fishing behaviour will have changed rendering potential inconsistency with previous data series.

This is a *data quality* issue.

The result is that the uncertainty associated with the stock state is usually higher for recovering stocks. Supporting data and analysis also relate to the previous Declining CPUE indicator, as well as has flow on implications to the Assessment stage. Wetzel et al. (in press) performed a simulation analysis on rockfish, under three data availability scenarios (Figure 104). They found that decreased availability of data during rebuilding resulted in increased variation in spawning biomass estimates (Figure 105). The addition of a survey index and composition data led to less variability and reduced bias (Figure 106; note scale change).

A dedicated targeted survey for recovering stocks, or more frequent and greater statistical power for the fishery independent surveys could provide data needed to more accurately and precisely capture the state of recovering stocks.

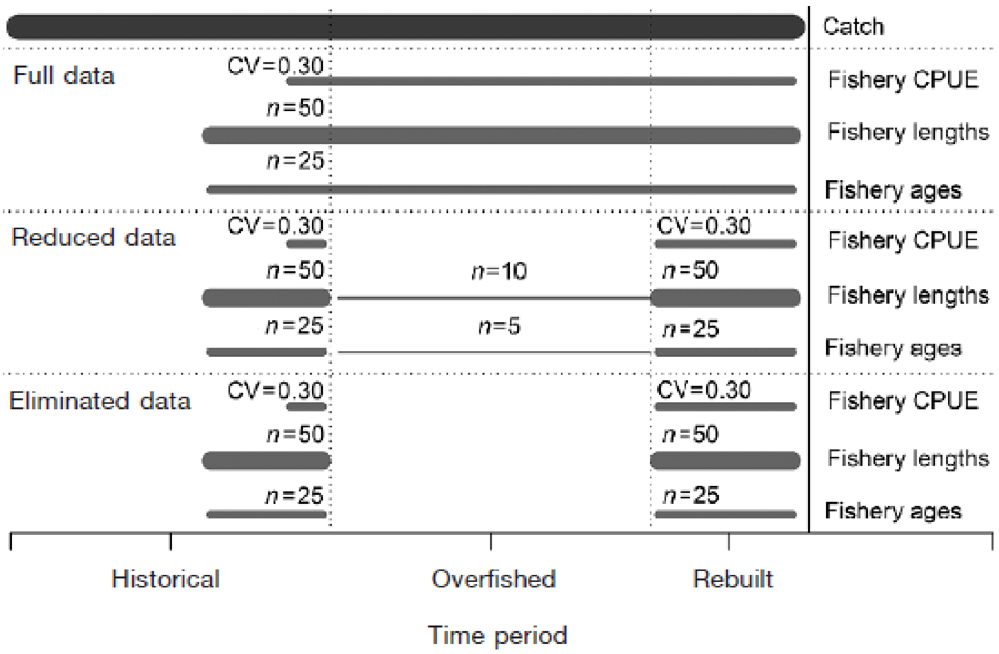


Figure 2

Summary of the data available for each of the 3 data scenarios (full data, reduced data, and eliminated data) created to explore the impact of data availability on the ability to monitor rebuilding of an overfished stock of rockfish species: coefficient of variation (CV) and number of samples (n) for catch per unit of effort (CPUE), lengths, and ages from the fishery. Historical length and age data from the fishery begin in year 35, 15 years before the first assessment, and the fishery CPUE data start in year 45. The management period begins in year 50 when data quantity and quality change by data scenario. Data quantity and quality return to historical levels when the simulated stock has been estimated to be rebuilt to the target biomass. Thickness of the horizontal lines reflects the different sample sizes; all fishery data are shown in dark gray and catches are shown in black. Catches were known without error and were available for all data scenarios.

Figure 104. Data scenarios for simulation study performed by Wetzel et al. (in press).

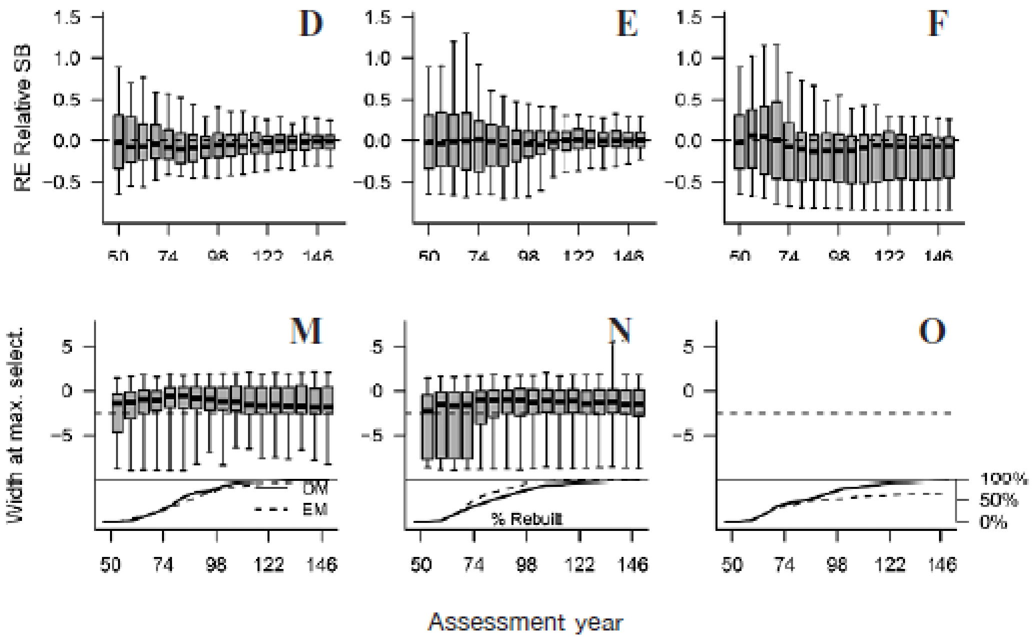


Figure 105. Relative error of the depletion estimates by assessment year on the top panels, and operation model (OM) depletions and estimation model (EM) depletion indicated in the bottom panels.

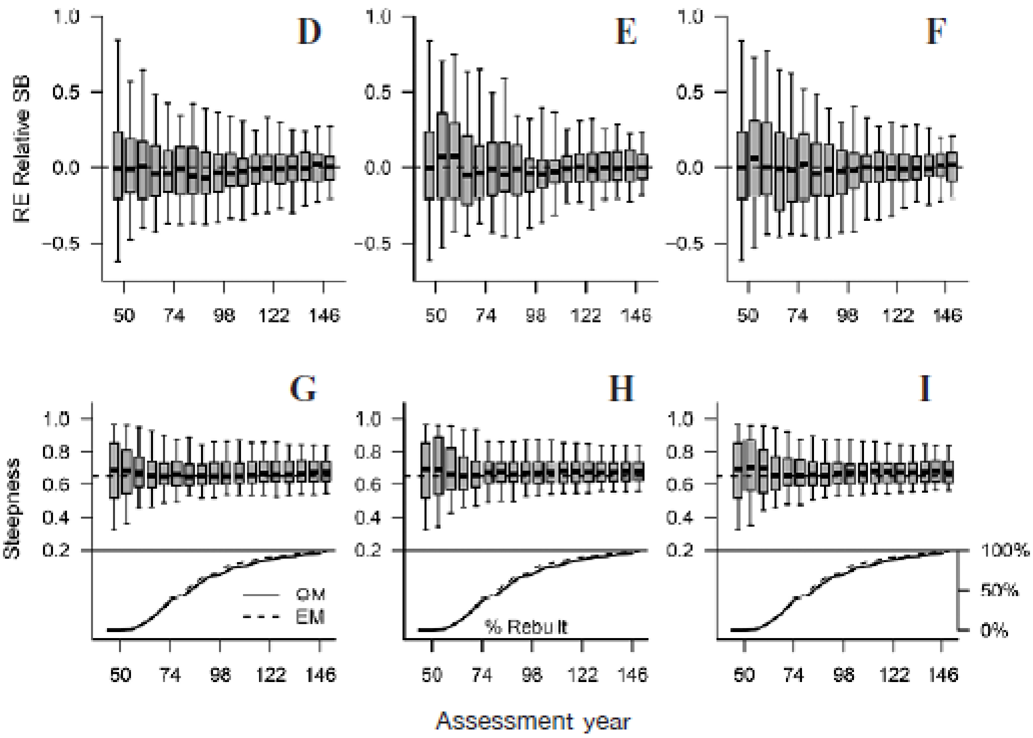


Figure 106. Relative error of the depletion estimates by assessment year on the top panels, and operation model (OM) depletions and estimation model (EM) depletion indicated in the bottom panels.

DATA TARGETING SETTING

Because the commercial fleet tend to avoid recovering stocks, there is a lack of data in the Data target setting stage of the Assessment Process, and thus it too is relevant, but is addressed above.

CPUE STANDARDISATION

The CPUE Standardisation Stage of the Assessment process is relevant to the Lack of recovery indicator, because of flow on implications from the data collection stage. The catch rate series provides a relative abundance index that will influence interpretations of recovery, whether used solely as an indicator, or within an assessment.

ASSESSMENT

Because the Assessment stage tends to *use* the data to derive a stock status, this stage of the Assessment Process is highly relevant to the Lack of Recovery indicator. However, the Assessment stage really basically integrates across different data sources, using the principles of population dynamics, and thus mainly reflects the quality and quantity of data collected, and hence data collection, data targeting and CPUE standardisation all affect the outcome of the Assessment.

An assessment is largely where the determination of a lack of recovery occurs. Therefore, if there is any bias in the data, CPUE or assessment method, then this has the potential to flow into this determination.

IMPACT ON UNDER-CAUGHT TACS

All stages of the Assessment Process are relevant to the Undercaught TAC indicator. For Data collection, Data target setting, and CPUE standardisation stages, many of the explanations for the other two fishery indicators (Declining CPUEs, and Lack of Recovery) are relevant for the same reasons. However, it is at the Assessment stage of the Assessment process that TACs (or rather RBCs) are set. Setting TACs include application of the Harvest Control Rule, and reference points.

As previously mentioned, at the end of the 2015/16 year, 23 of the 34 species groups under TAC were less than 50% caught (Figure 107). Blue Grenadier is the standout primary target species, followed by the Deepwater Flathead fishery, while most of the others are considered byproduct species.

DATA COLLECTION

The failure to catch TACs is indirectly relevant through the previous indicators, but because the TAC is mainly set at the Assessment stage, we believe the Data Collection stage is not directly relevant to the Undercaught TAC indicator.

DATA TARGETING SETTING

The failure to catch TACs is indirectly relevant through the previous indicators, but because the TAC is mainly set at the Assessment stage, we believe the Data targeting stage is not directly relevant to the Undercaught TAC indicator.

CPUE STANDARDISATION

The failure to catch TACs is indirectly relevant through the previous indicators, but because the TAC is mainly set at the Assessment stage, we believe the CPUE standardisation stage is not directly relevant to the Under-caught TAC indicator. If the catch rate is over-estimating abundance relative to the target reference period, then the TAC may be set too high and lead to an inability (or lack of market) to catch the quota.

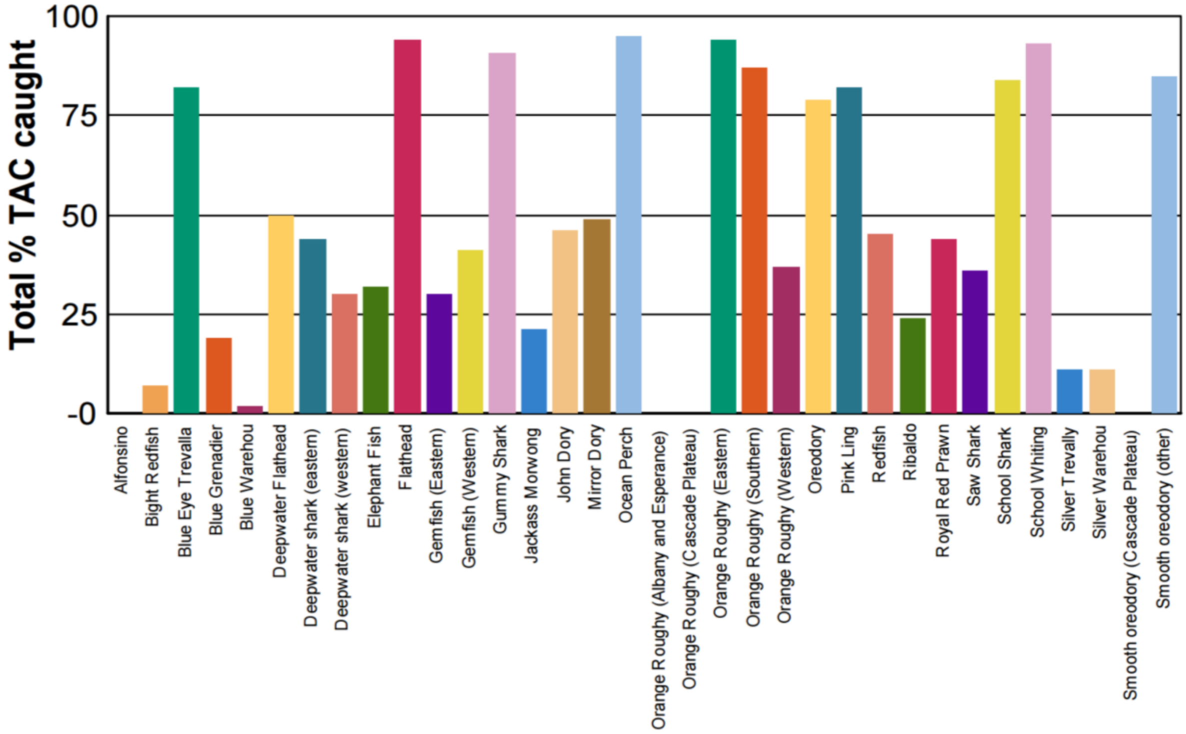


Figure 107. Catches of SESSF species relative to TAC.

ASSESSMENT

The Assessment stage of the Assessment process is relevant the Undercaught TAC indicator.

For the Assessment stage the following explanations are possible:

H6: TAC may be set too high

This explanation implies reference points are incorrectly specified or the assessment is overly optimistic about recent stock status and/or the magnitude of current spawning biomass. For Tier 4 this includes defining reference period and relation between Catch and CPUE. For Tier 1 the inability to estimate steepness (productivity) could lead to incorrect reference points. For Deepwater Flathead for example, only recently after some intensive fishing that the data became more informative and more realistic TACs though smaller were provided (Haddon 2015).

H7: Undercaught TACS may be result of choke factor resulting from technical interactions, and thus not considered in RBC/TAC calculation.

This would be due to a key primary targeted species being fully or near caught and an associated stock, with lower catchability not able to be caught as the TAC tightens on the primary targeted stock, and not economically justified to be targeted itself.

Supporting Data and Analysis

Recent research (Smith et al. 2017) has shown that multi-species fisheries cannot maintain the range of key commercial and byproduct species at the same target because of different catchabilities, as a result of technical or ecosystem interactions.

Comparing the SESSF species catches relative to TAC in three sub-fisheries considered by Smith et al. (2017) the

1. **Upper slope trawl – primary: ling; by-product: blue-eye trevalla and ocean perch**
   - Choke factors on Ocean Perch could contribute since Ling TAC is around 80% caught (Figure 8).
2. **Shelf – primary: tiger flathead; by-product: jackass morwong, John dory and silver trevally**
   - Choke factors could occur since Tiger flathead TAC is close to 100%, while John dory and Silver trevally are less than 25% (Figure 8).
   - Alternatively, John Dory may be depleted. A data-poor analysis for John Dory came out very close to the limit reference point.
3. **Blue grenadier spawning fishery – primary: blue grenadier; by-product: silver warehou**
   - Choke factors between these two species is unlikely to occur as both have less than 25% of the TAC caught (Figure 8)

An FRDC project has been proposed to investigate the multi-species MEY issues, including differential target reference points.

WORKSHOP FEEDBACK AND CONCLUSIONS

IMPACT ON DECLINING CPUES

Consultation by the expert panel suggested that the most important mechanism to Declining CPUEs in the Assessment Process is the inability to capture changing fleet or vessel behaviour. Despite a number of projects that have endeavoured to understand and capture the influence fisher behaviour and targeting on CPUE [9] this remains a very difficult area to address because many of the factors that influence fisher and fleet behaviour are not captured in logbook or auxiliary data. Problems with CPUE standardisation such as small catches in the logbooks (Figure 108, Figure 109) were also believed to be a problem. The least important mechanism was thought to be human error in logbook entry. Other explanations for declining CPUEs is that it represents the declining biomass resulting from TACs being set too high. Further analysis was suggested to examine effort creep and fishing power, although this is part of Working Groups B (Fleet Capacity) and C (Fleet behaviour) focus. Alternative approaches to assessments that do not use CPUE such as close-kin analysis are considered worth investigating, as would be the use of fishery independent data.

LACK OF RECOVERY

Consultation by the expert panel suggested that the most important mechanism to Lack of Recovery in stocks in the Assessment Process was the lack of fishery data from infrequently caught species. Problems with CPUE standardisation outlined in the previous section were also considered an important mechanism. These, and reduced fishery data could be impacting the evaluation of the recovery of overfished species (Figure 110). Inconsistent and changing behaviours were also considered a third priority mechanism. Inability of the assessment to capture changing behaviour and problems with CPUE standardization may be contributing to lack of recovery of overfished species.(Figure 111, Figure 112, Figure 113).

[9] E.g. Tuck unpublished FRDC Project 2012-201 Improve catch rate standardizations to account for changes in targeting.

It was strongly agreed that fishery independent data is needed to overcome it. Besides fishery independent information, further analysis was suggested to examine alternative indices to more accurately measure stock status, such as close-kin genetics.

There was a suggestion that technical interactions, potentially through bycatch, might be limiting a stock ability to recovery, but this is not part of the Assessment Process. No other mechanisms were suggested to cause Lack of Recovery in stocks due to the Assessment Process, but it was noted that the issue is one of ability to monitor and perceive the stock status rather than actually directly influence the state of the stock.

UNDERCAUGHT TACS

The possibility of TACs set too high as a result of biased inputs into the assessment (often related to CPUE or productivity) producing unrealistically high RBCs was considered a large potential contributor to under-caught TACs by all participants (Figure 114, Figure 115). This generally meant that the target reference point was set too high, which could be the result from an inaccurate reference period in Tier 4 assessments, or invalid productivity assumption in Tier 1 assessments. This is thought to be important to TAC performance for several species including Jackass Morwong, Silver trevally, Silver Warehou and Blue Grenadier (Figure 116). Technical interactions, particularly choke species was also considered a probable and important mechanism, but secondary to the above. There were no other mechanisms offered for why the Assessment Process may be lead to Undercaught TACs.

Despite the fact that choke species were deemed of secondary importance, a lot of follow-up on the subject was suggested. First, a revisit of the companion species project was suggested as a further analysis. Second, the proposed multi-species MEY project was suggested could accurately set differential reference points that factor in technical interactions, mainly of non-target species. These reference points would represent how the fleet currently operates, and could possibly be dynamic and recalculated periodically as the fleet behaviours change. It was suggested that such reference points needed to be MSE tested before being implemented.

Reconsideration and more careful consideration of the Tier 4 reference period was suggested could more accurately reflect the target reference point, since several stock rely on it for assessment purposes. This interacts strongly with the Declining CPUE fishery indicator, and the associated problems identified with it. No further analyses were suggested on how the reference point calculation using the current Assessment Process and Tiered assessments could improve.

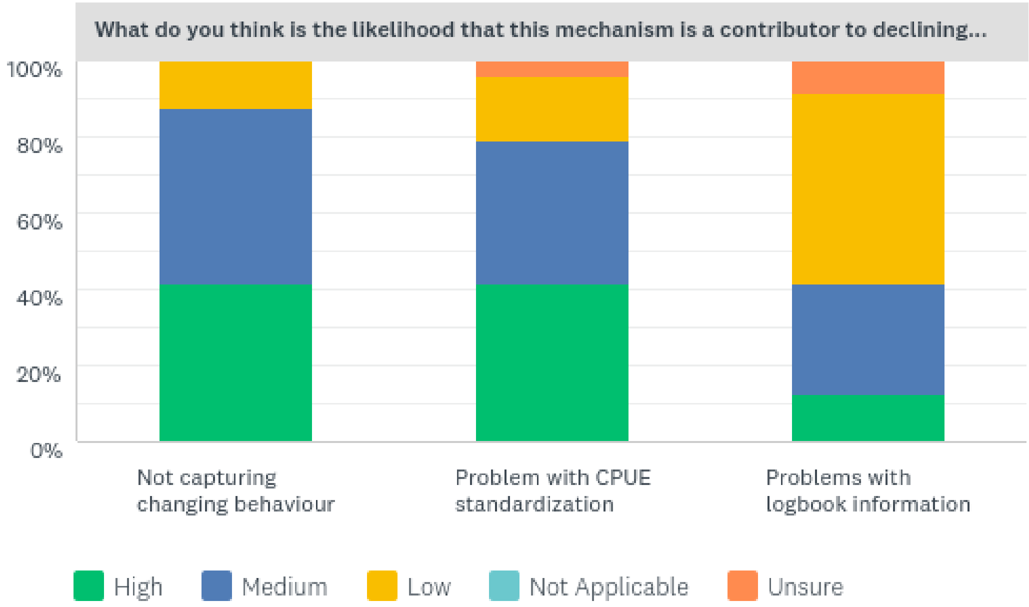


Figure 108. Workshop participant assessment of the likelihood that this issue is a contributor declining CPUEs.

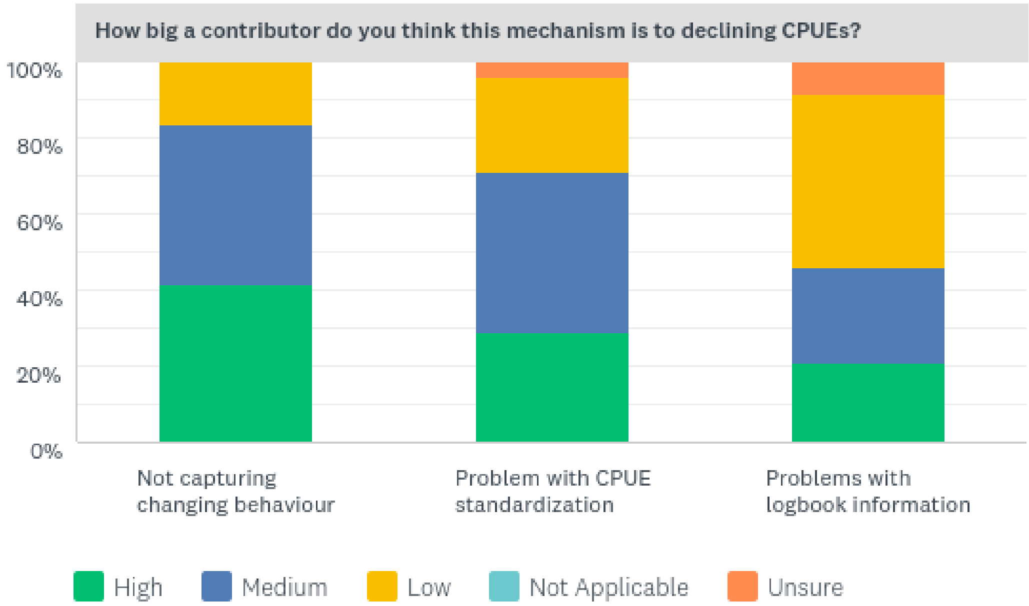


Figure 109. Workshop participant assessment of how big a contributor this issue is to declining CPUEs.

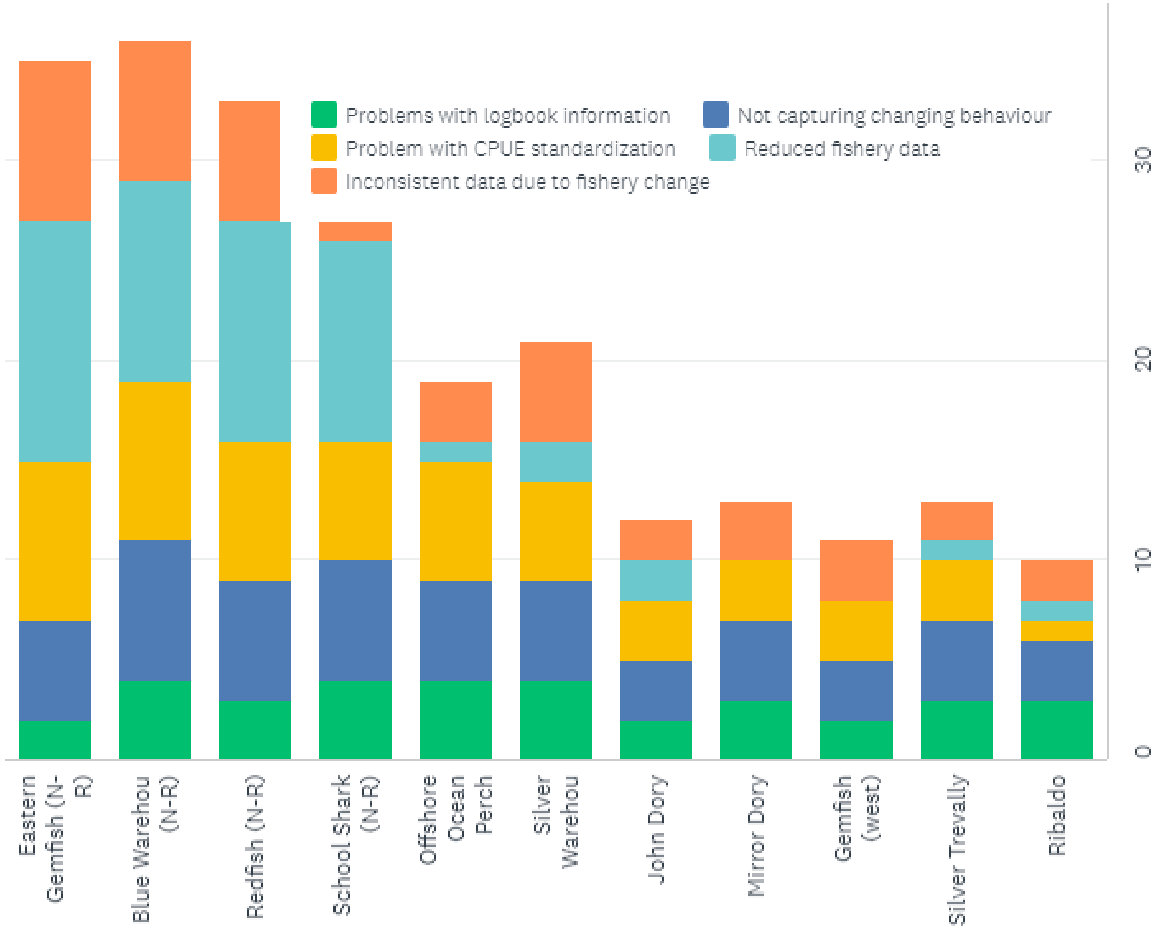


Figure 110. Workshop participant assessment of which particular assessment mechanisms are relevant to the declining CPUEs of specific species (N-R = Non-recovering).

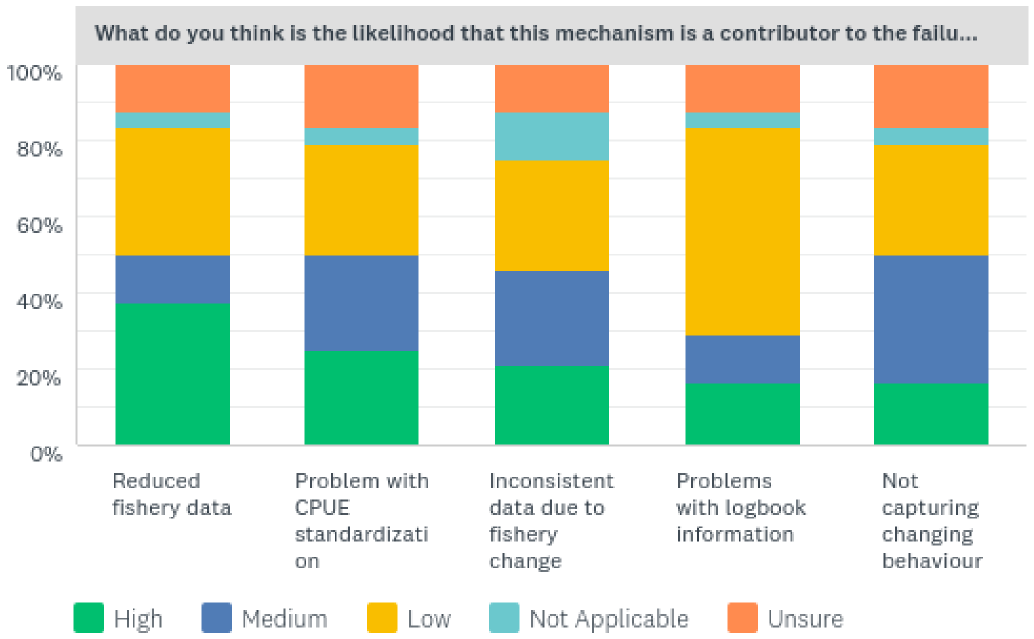


Figure 111. Workshop participant assessment of the likelihood that this issue is a contributor the lack of recovery of over-fished species.

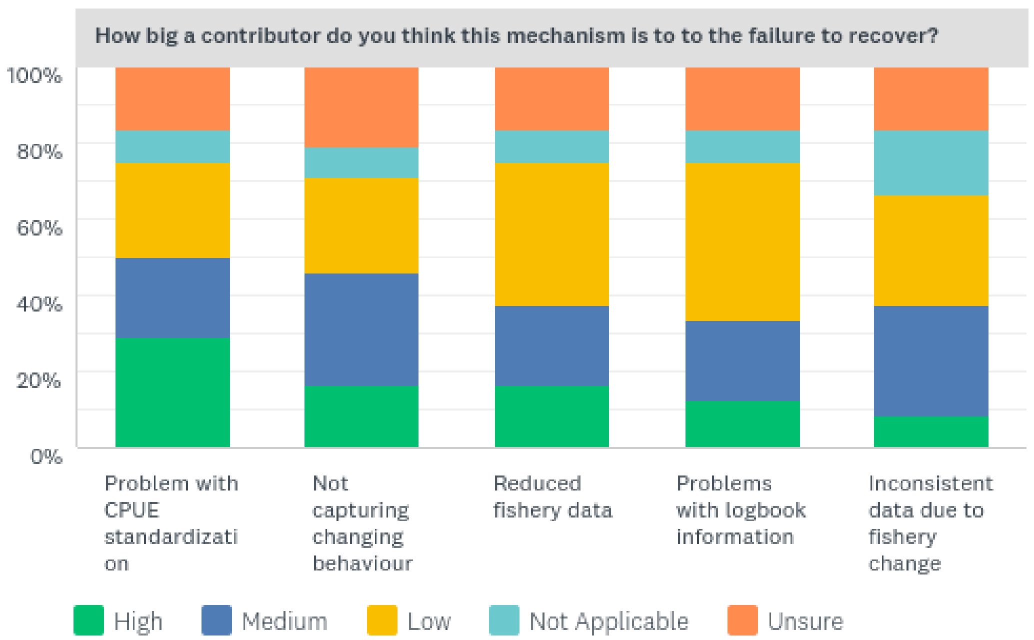


Figure 112. Workshop participant assessment of how big a contributor this issue is to lack of recovery of over-fished species.

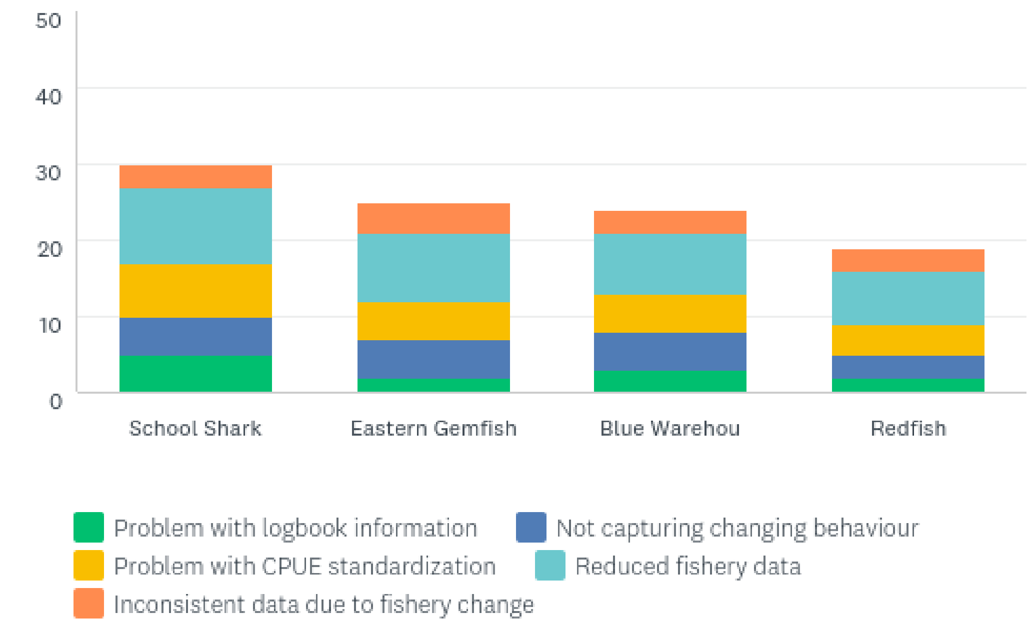


Figure 113. Workshop participant assessment of which particular mechanism are relevant to the lack of recovery of over-fished species.

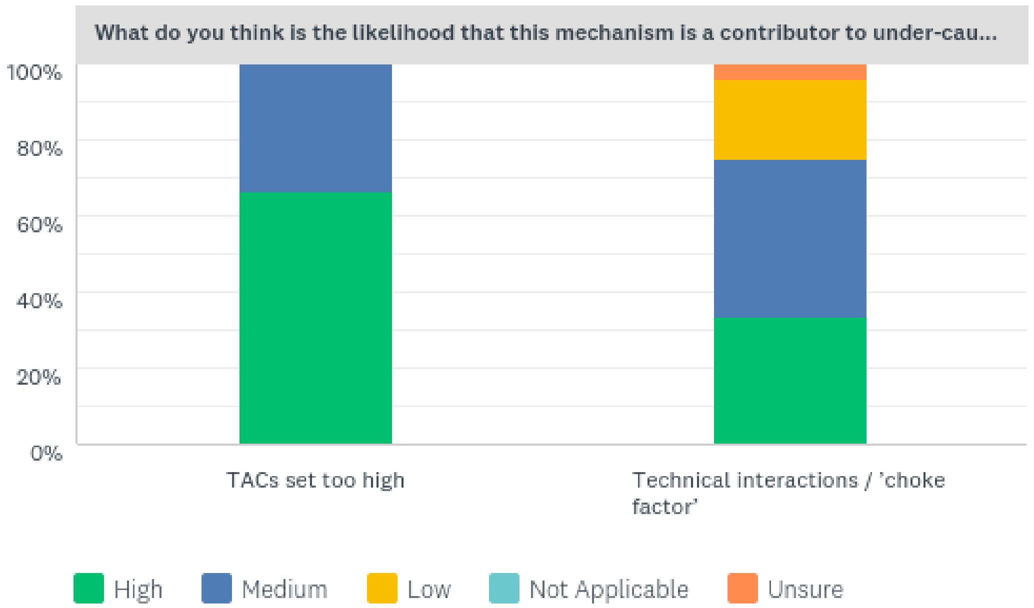


Figure 114. Workshop participant assessment of the likelihood that either assessment mechanism is a contributor under-caught TACs.

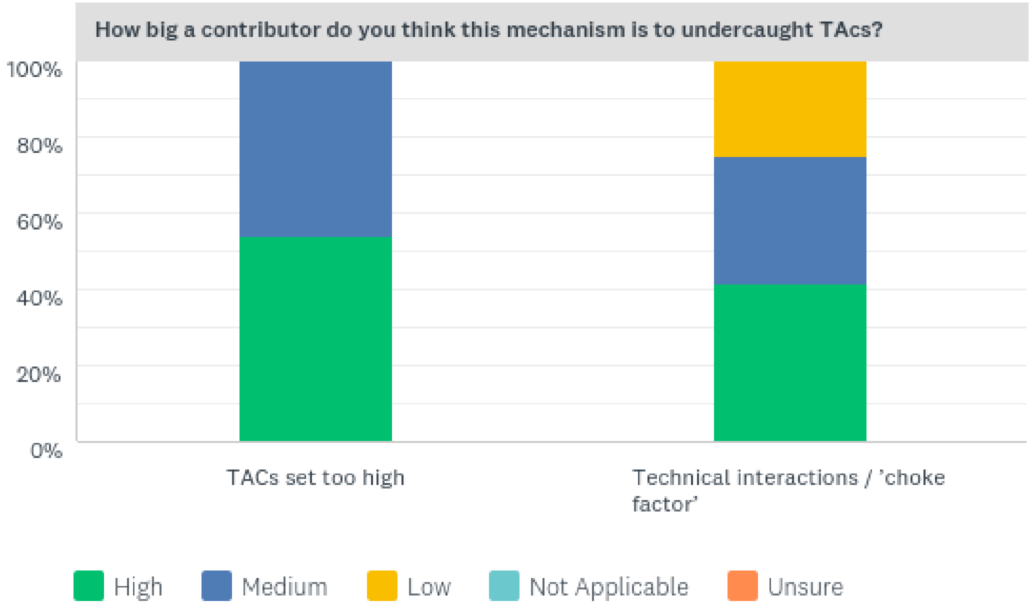


Figure 115. Workshop participant assessment of how big a contributor either assessment mechanism is to under-caught TACs.

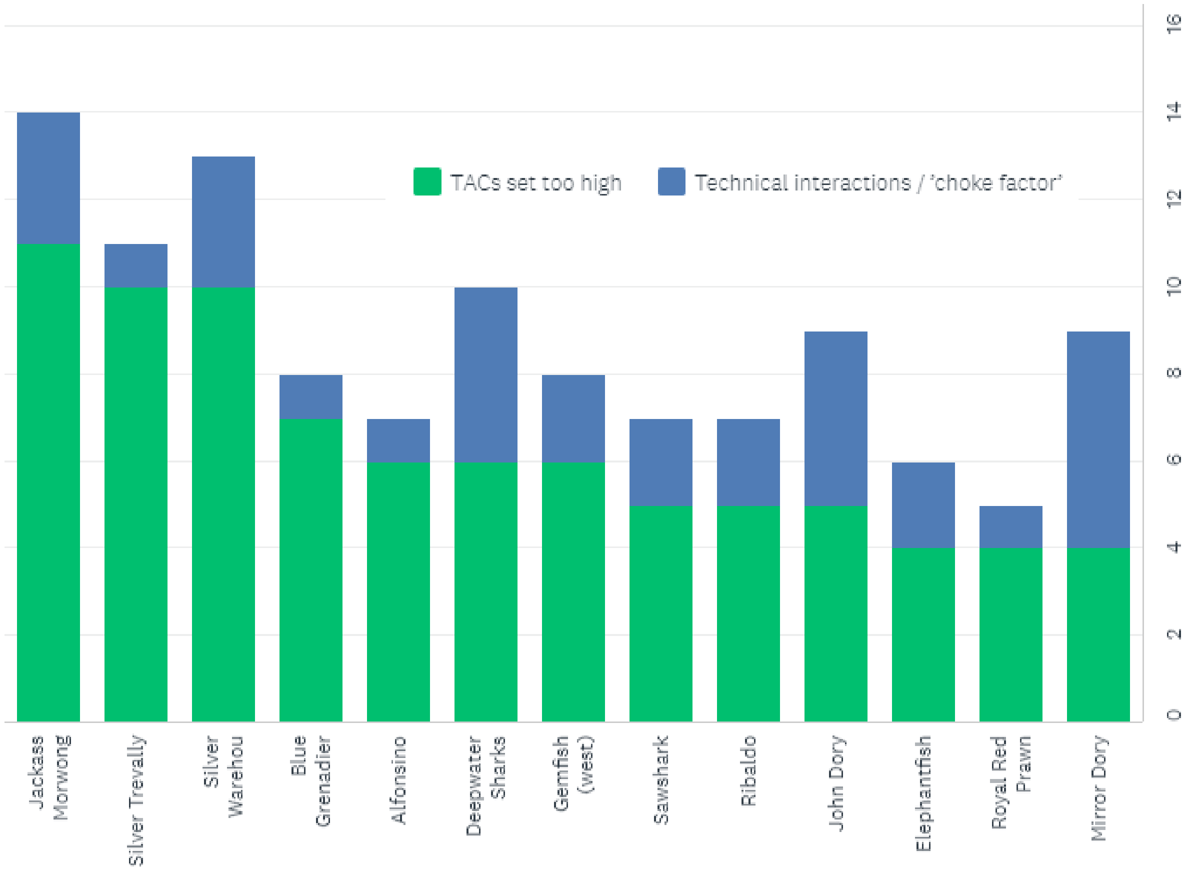


Figure 116. Workshop participant assessment of which particular assessment mechanisms are relevant to the under-caught TACs of specific species.

Discussion and prioritisation of issues and mechanisms

Following presentation of all of the papers and individual feedback from workshop participants, we then focussed on discussion and prioritisation of the issues and mechanisms that may be influencing each of the declining indicators.

UNDER-CAUGHT TACS

Diverse mechanisms across the various issues were proposed for under-caught TAC's (Figure 117). Workshop participants considered fisher behaviour, costs and markets had the most impact overall, but the assessment process was also considered to be a key driver.

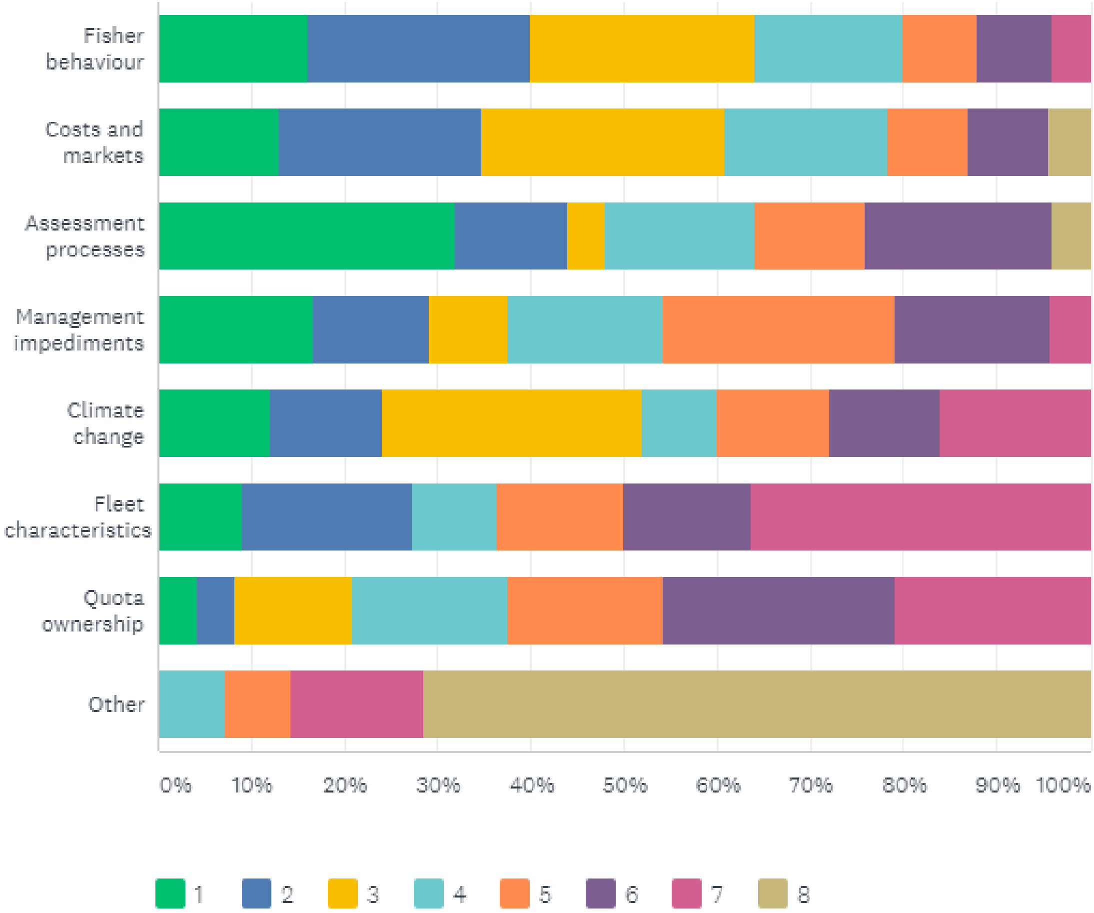


Figure 117. Workshop participant assessment of priority issues impacting on under-caught TACs (1 – High priority to 8 – Low priority). Issues are in descending order of priority with the highest weighted priority at the top.

The main mechanism highlighted that relates to the assessment process and under-caught TACs is the difficult aspect of implementing MEY-based harvest strategies in a multi-species fishery. It was generally recognised that it was unrealistic to think that a high percentage of all TACs would be taken each year in a multi-species, multi-gear fishery. As to why the under-catch is so high for so many species, however, needs further investigation. Although a fishery-wide MEY is the goal for the SESSF, it is currently only achieved by conducting multiple individual stock assessments, each with an individual MEY target. There are many shortfalls in this approach. In the HSP guidelines several forms of interactions are recognised that should be considered when determining MEY-based target reference points within a multi-species fishery. Technical interactions (the catch of a mix of species with a non-selective gear in a specific time and place) are important, as are ecosystem interactions where there is a direct or indirect effect of the catch of one stock on the abundance or distribution of another (e.g. a habitat forming or prey species). Ecosystem interactions are also impacted by environmental conditions and so any changes to that condition, can have impacts for the interactions between stocks and ecosystem structuring". In this respect, the importance of incorporating the impact on climate change in stock assessments is obvious and needs to be addressed.

In short, there are recognised problems in developing a multi-species harvest strategy appropriate for the SESSF that complies with the HSP but takes account of technical interactions and the influences of climate change. These issues currently play out in a sub-optimal stock assessment and TAC-setting process. FRDC project 2018-021 "Development and evaluation of multi-species harvest strategies in the SESSF" has only recently been approved (September 2018) and is designed specifically to review and (hopefully) address this situation.

Recommendation 1. Support research to develop multi-species harvest strategies for the SESSF, particularly for the Commonwealth Trawl Sector.

The TAC assemblage includes 'primary' and 'non-primary' stocks and catches are influenced by fish price (markets), behaviour and quota markets. There are differences in the degree of targeting for various species and the influence of choke species on fisher behaviour and catches was considered an important mechanism.

Some respondents proposed that mainly economic factors were driving under-catch of most species. The factors are not easily separated. For example, fisher behaviour is responsive to changing costs of production and changing market conditions, which in turn influence targeting behaviour.

Some participants felt that TACs are set above true MEY given market conditions and that the assessment process was not capturing market dynamics adequately. It was apparent that despite MEY being a key target indicator for stock levels in the Commonwealth Harvest Strategy Policy, people have very different interpretations of MEY and how it should be operationalised in the fishery, particularly influenced by their consideration of relative importance of the economic value of the fishery compared to the economic value of the quota. This is discussed in greater detail in the section on quota ownership and trading.

Considering the extensive amount of data available on the SESSF, there is a paucity of information on fisher behaviour, quota ownership and trading and to a lesser extent, costs and markets. It is becoming very apparent that deficiencies in the quality and availability of this type of social and economic information is significantly undermining our ability to (quantitatively) understand fishery dynamics and manage key aspects of this quota-based fishery. Some of this information is likely to be difficult to obtain but a significant effort needs to be made to determine what information can be feasibly collected and how it can be used to improve assessments and harvest strategies.

Recommendation 2. Determine what data can be feasibly collected to better understand the links between fisher behaviour, vessel operations, costs / markets and quota ownership / trading, and their impact on the dynamics of the fishery.

Recommendation 3. Investigate options to incorporate these key social and economic factors into future harvest strategies.

Major changes to the SESSF coincided with a structural adjustment in 2006 which considerably reduced the fleet size particularly in the trawl and gill net sectors of the SESSF. Despite the restructure, typical vessels now operating in the SESSF are relatively old, lack or have outdated equipment (including electronic catching aids), and are generally underutilised (particularly in the gill net sector). Nevertheless, the reduced fleet size and an ageing fleet is suggested to only have limited impact on catch rates and the ability to catch TACs. Under-caught TACs were thought to be impacted primarily by fisher behaviour, fishing costs/markets, but these are also confounded by aspects of implementing single species assessments and harvest strategies in a multi-species fishery. This is particularly the case where potential interactions with other species (including companion species which may be threatened, endangered or protected) or choke species (those species which are likely to be caught but for which little or no quota is held) influence the spatial dynamics of fishery operations, and inhibit the potential of fishers to catch quota.

There is a difference in the considerations of total catch and economic value of catch which may vary from sector to sector depending on the main target species. While TAC is set at a maximum in relation to ecological sustainability and economic yield from the fishery as a whole, individual fishers (and quota owners) have profitability as a primary objective: increased catch is only good if it increases profitability. Accordingly, quota latency is not necessarily a problem. There are many legitimate business and market reasons — underpinned by the economics of the fishery and the quota market — why people may choose not to catch their quota. Thus, on its own, undercaught TACs are not necessarily a negative indicator.

There is a need to determine in what situations are under-caught TACs a problem. In a multi-species fishery, it is impossible to maintain each individual species at B_{MEY} and, where individual assessments set each individual TAC, undercaught TACs may be commonplace and represent and economically rational fisher response — not an indicator of foregone fishery income/profit. On the other hand, if, given the current status of a stock, an inappropriately high TAC has been derived through assessment bias or failure to capture changed productivity in its harvest strategy target, then that represents a significant problem.

Overall, the issue of under-caught TACs are interpreted differently by different people, and there was generally agreement that, depending on the reasons, uncaught TACs are not necessarily a "negative" indicator. There is a need to distinguish the relevance of these indicators ecologically and (or versus) what they mean economically (to both fishers and to quota investors). There is a need for consideration of the impact of future pressures (state of the stocks, TAC's, climate change) on catch. We need improved understanding of fish populations and ensure that key species have relevant and conservative TACs. It was suggested that there may be value in considering alternate administrative / management strategies in relation to TAC's. For example, consideration of regional/stock TACs, notional TAC's, or investigate strategies for "basket" TACs.

Importantly, based on the input from the workshop, some indicators (e.g. undercaught TACs, but also declining CPUEs for some species) may not necessarily be negative for a stock's status, but nevertheless are seen as a red flag by some groups. Thus, resolving this has important societal consequences for the "social licence" of the fishery.

Recommendation 4. Explicitly determine under what circumstances under-caught TACs are a "negative indicator" and when are they not. Consider the merits of using under-caught TACs as an indicator in future harvest strategies.

DECLINING CPUES

Notably, the same mechanisms highlighted as most important for under-caught TACs were also highlighted for declining CPUEs. Similar to under-caught TACs, the explanations put forward for declining CPUEs were diverse and indicate compounding and interactions among contributing factors (Figure 118), particularly related to the mechanisms of avoidance in mixed target fisheries, complex area closures and catch limits, changing productivity, abundance and distribution, and not capturing fisher behaviour in CPUE standardization. Many of these factors influence fisher behaviour which is in turn feeding back to affect effort and CPUE. Changing fisher behaviour may be the mechanism, but fisher behaviour may be both a causal factor of and a response to undercaught TACs. Important factors likely vary between species, and especially differ between target stocks (where CPUE probably reflects biomass declines) and bycatch species (where market issues are probably more important).

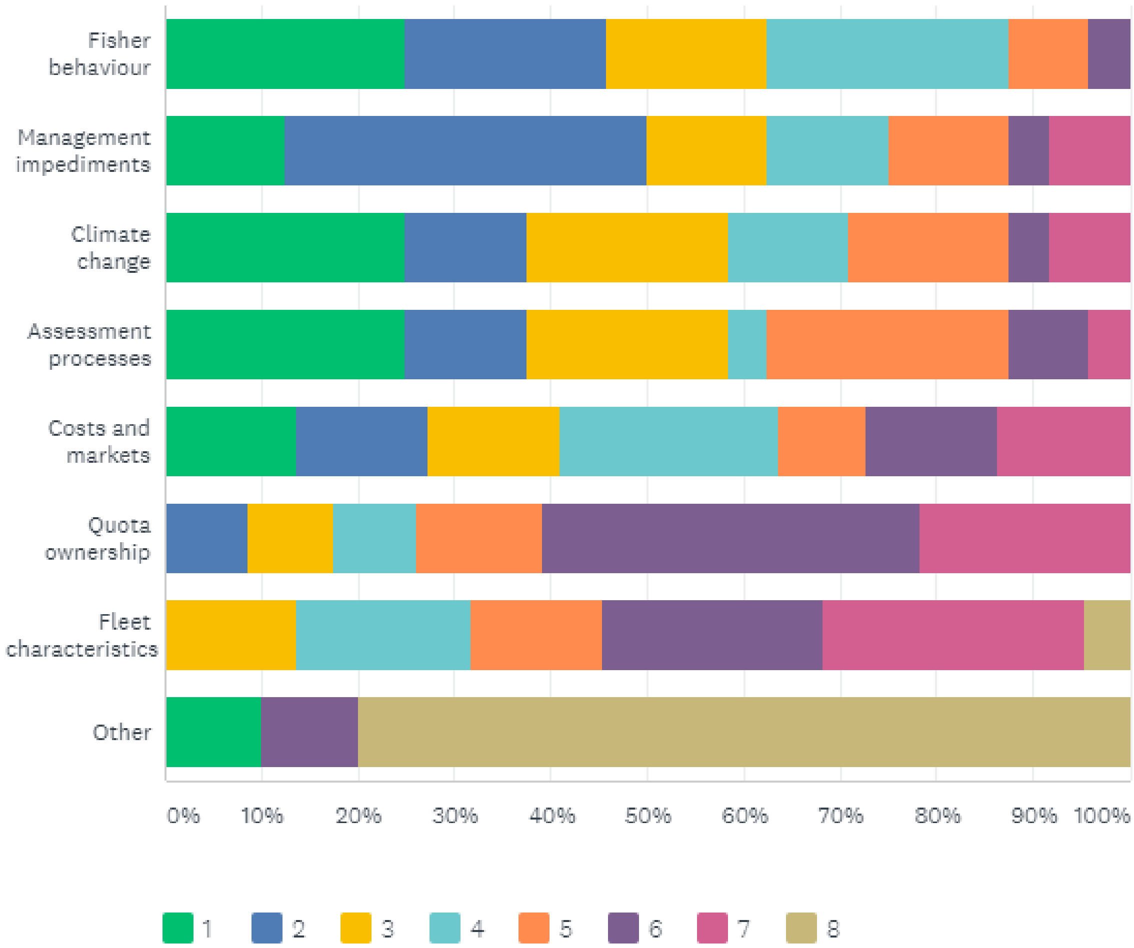


Figure 118. Workshop participant assessment of priority issues impacting on declining CPUEs (1 – High priority to 8 – Low priority). Issues are in descending order of priority with the highest weighted priority at the top.

One particular area highlighted for further attention is that currently our assessments assume efficiency of a unit of fishing effort (eg. trawl-hour, km-net-lift for gillnet, shot for Danish seine) has not changed since the implementation of logbooks despite significant improvements in the technology available to vessels in terms of GPS, sounders, communications, fishing gear construction and materials etc over this time. Increase in efficiency or “fishing power” is a critical input to stock assessments in other commonwealth fisheries[10] but has been largely overlooked in the SESSF, possibly because it is output-controlled. If indeed there has been some (even low) improvement in fishing efficiency in the SESSF since 1986, lack of recognition of this in CPUE analyses would yield overly optimistic stock levels and unduly high TACs. This could therefore be a critical factor in under-caught TACs that warrants further investigation.

CPUE time series are critically important to many assessments as the primary indicator of stock abundance. Importantly, if increased fishing efficiency has in fact occurred over time in the SESSF as detailed in the section above, it needs to be included in CPUE standardisations to ensure that actual decline in abundance are not masked.

Recommendation 5. Investigate changes of fishing efficiency in the various SESSF sub-fisheries and the potential inclusion of fishing power time series in CPUE analyses.

Recommendation 6. Based on the above fishing power investigation, ensure appropriate data is collected in the future to enable fishing power to be included as a factor in CPUE standardisations.

Separate to improving CPUE as an indicator, it was also highlighted that CPUE may not be the most relevant fishery indicator to reflect fisher behaviour. Workshop participants discussed changing markets and prices and the need to incorporate economic information into assessments. The fishery will be expected to fish for dollars, and to avoid volume in favor of higher valued fish and price. Some low value species with declining indicators were previously important parts of the fishery. There have been (and will continue to be) large changes in fish markets and in demographics that will affect market value for a wider range of species. SESSF species are competing with imports, changing markets, and can suffer from mis-labelling. As a product from a wild-caught sustainable fishery, SESSF species could be in a high-value "niche" category compared with many other products/imports. A continuing focus on fidelity of labelling and consumer awareness of ecologically sustainable practices in the seafood industry could benefit the SESSF.

It was recommended that additional relevant indicators especially relating to markets and economics be considered. To this end it was specifically recommended that "$PUE" (dollar per unit effort) be evaluated as an indicator and potentially built into assessments. There was discussion of the evaluation of the fishery (including economic performance) as well as of the stock. It was suggested that there is a need to incorporate other considerations such as market aspects and other economic factors into the evaluation/assessment. There is also need to consider data requirements relevant to the mechanisms and issues identified above. What additional information is needed to clarify and inform management in relation to declining CPUE and uncaught quotas?

Recommendation 7. Explore the potential to develop additional indicators that are relevant to markets and economics and ensure adequate information is collected to support the use of these indicators in assessments and harvest strategies.

Recommendation 8. Develop a "$PUE" indicator or similar to be used as a performance indicator for the fishery.

[10] In the NPF for example, fishing power analyses are critical because it is an input-controlled fishery and have revealed a five-fold increase in annual fishing power over the last 40 years (3-4% per year).

The potential impact of climate change was ranked as a more important mechanism for the CPUE declines than for under-caught TACs but there is a potential relationship between the two. All participants acknowledged the south-east coast of Australia region is one of the fastest warming in the world and the impact that this can have on species productivity (growth, reproduction, recruitment) and physical variables, such as salinity, temperature and nutrient availability, increasing the range of many commercial species further to the south. Future projections suggest abundance of some species will decline, some will increase, and some will be largely unchanged but this has yet to be addressed in the stock assessments and harvest strategy. This has particular importance in harvest strategies that seek to achieve some proportion of a historical biomass level regardless of any climate-induced change in productivity that may have occurred. The observed changes in these indicators in the past are likely to be a combination of climate and other cumulative or synergistic drivers but are difficult to separate from the other factors explored in this project. At the moment, the primary management response to declining CPUEs is a reduction in TACs in the expectation that this will lead to stock recovery. If climate change is a key contributor to the observed changes then such a management response may not lead to any recovery in the long term. Overall, based on model projections there was at least medium confidence that there is a medium-high likelihood of impacts of climate change on marine ecosystems and SESSF stocks.

Compared with the factors discussed above, legislative and management issues were considered to have less effect on declining CPUE. Of the management mechanisms discussed, area closures have had the greatest impact particularly for Gummy Shark and deepwater species but overall, the impact has been minor for the SESSF.

Recommendation 9. Determine and implement biological and oceanographic data collection processes necessary to detect climate-driven changes in the fishery.

Recommendation 10. Develop methods to incorporate the potential impacts of climate change on species distribution, abundance and productivity in both stock assessments and harvest strategies.

LACK OF RECOVERY OF OVERFISHED SPECIES

Climate change was attributed as the highest priority mechanism responsible for lack of recovery (Figure 119). There was general agreement that there is an environmental aspect to the failure of some species to recover that could likely be due to a change in productivity involving changes in preferred habitats and food webs[11]. It appeared that two main insights underpin this conclusion: 1) a range of significant management controls have been introduced over the last 15 years to minimise fishing mortality on overfished species to an extent where recovery should have occurred but hasn't; 2) impacts of climate change appear to be having a detrimental effect on some SESSF species. Participants were well aware that this conclusion could be viewed (both internally and externally) as a "cop out", endeavouring to move the blame away from historical overfishing to something now out of the control of fisheries management. There is ongoing pressure to achieve/allow recovery of any overfished species, and a reluctance to accept altered states or ongoing impacts.

If SESSF stakeholders believe that climate change is the prime factor for lack of recovery, then there is a need to scientifically demonstrate it as a reason rather than use it as an excuse. In reality, the lack of recovery indicator is a particular case of the declining CPUE indicator except

[11] The 'Others' category in the survey of participants included ecosystem interactions, climate and oceanography.

that significant and targeted management efforts have been made to reverse the declining trend. To date, there has only been one stock (eastern Jackass Morwong) out of 29 declining SESSF quota stocks for which a change in productivity has been demonstrated and accepted.

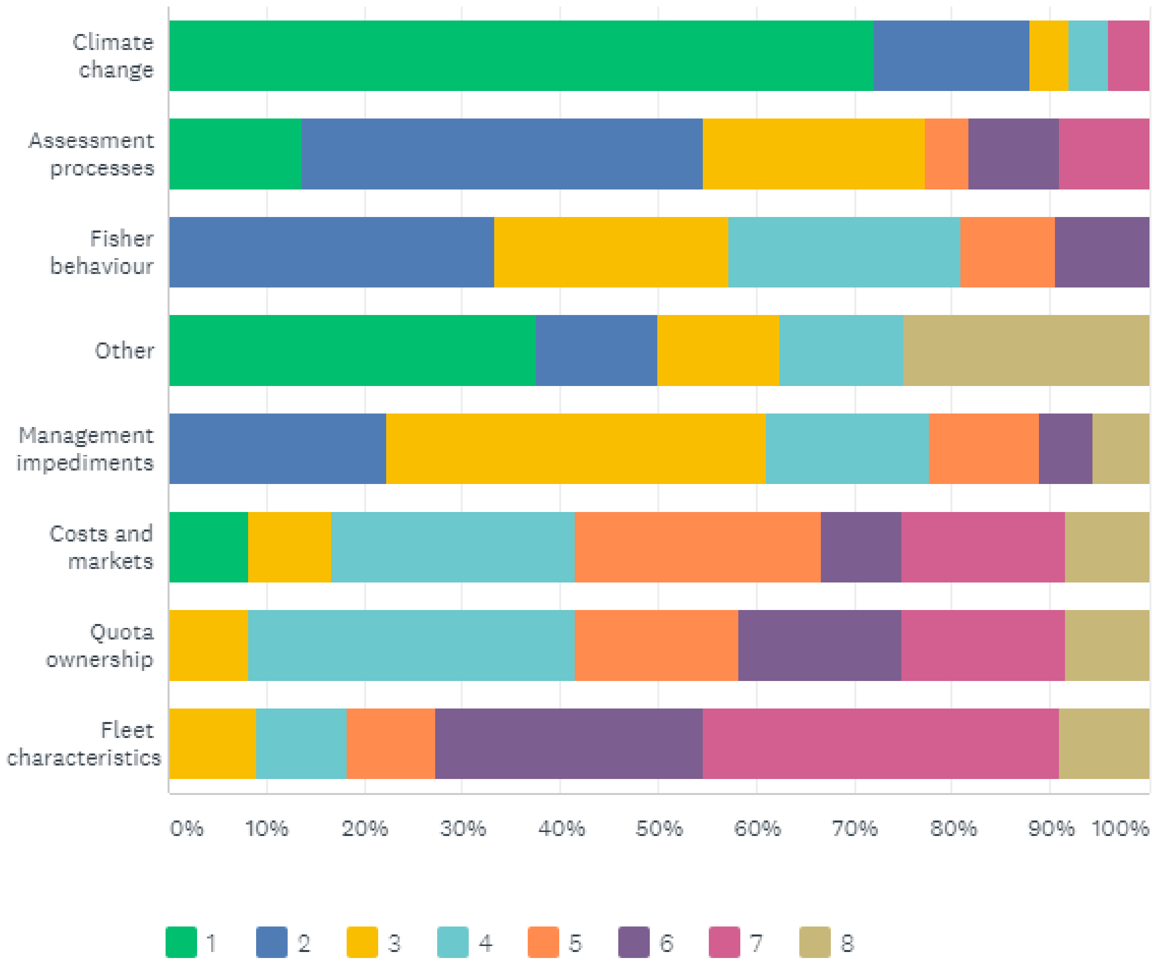


Figure 119. Workshop participant assessment of priority issues impacting on lack of recovery of overfished species (1 – High priority to 8 – Low priority). Issues are in descending order of priority with the highest weighted priority at the top.

It seems obvious that there is a need for further investigation of this aspect, not only in relation to the failure of some species to recover, but also in relation to the future expectations of productivity of other species. There is a tension in objectives regarding the impacts on major and minor species. Management is now trying to do a bit of both focusing on maximizing attention on key species while also safeguarding productivity of all species to preserve broader ecosystem function. There in a need to synthesize and track information related to changes in species abundance, distribution and timing of major life history events (e.g. spawning and migration) and to consider the mechanisms related to recovery of species and the potential relationship with the management of other species. What does a change in productivity imply, not only for potential recovery of species, but for the entire fishery? What is the expectation for recovery of depleted species? How will recovery be measured and monitored? Are additional indicators required? Is it worthwhile investing in recovery?

Management is required to monitor recovery and to have rebuilding plans for overfished species. At the same time, loss of indicators (particularly commercial CPUE) affects ability to track any recovery. This is the reason that the assessment process was highlighted as the other main mechanism underpinning lack of recovery (Figure 119). In effect, this mechanism relates to concern about the reliance on commercial CPUE as an indicator of stock abundance of overfished species, when it is compromised by recovery management measures that cause fisher avoidance. In the bigger picture, there may be depensation, therefore a greater probability that it will happen in other species as well. Does this mean that we need to be more precautionary with other species? There is a need to understand the mechanisms and the changes in productivity of the depleted species, and a better understanding of critical life history stages of species. There is a need to monitor changes in phenology (timing), range and productivity. We need to answer which of these are important, and to determine what questions would help managers the most?

Recommendation 11. Compile available information and develop a feasible and scientifically defensible method to determine the extent of productivity change (positive or negative) for SESSF species, and the implications this has on stock assessments and harvest strategies — including rebuilding plans.

Recommendation 12. Synthesize and monitor information related to SESSF species life histories, phenology, productivity, distribution and key determinants of major life history events (e.g. spawning, recruitment and migration).

PRIORITY AREAS

Based on the process above conducted for each indicator, workshop participants identified priority areas on which to focus future work (Figure 120). Participants reviewed and discussed the cells that were most highly ranked in the prioritisation exercise. There was considerable discussion of the interaction between the seven theme topics presented here, and the complexity caused by this interaction. Fisher behaviour, for example, and to some extent fleet capacity, is related to many factors such as market conditions and costs of operation. These issues in turn, impact assessments.

		Issue						
	Mechanism	**Climate / Oceanography**	**Legislation / Management**	**Stock Assessment**	**Cost of Production**	**Quota & Markets**	**Fleet Characteristics**	**Fisher Behaviour**
Indicator	**Uncaught TACs**	Minor contribution	Minor contribution	TACs too high Interactions / Choke spp	Fish sale prices and changing markets	Minor contribution	Minor contribution	Choke species
	Declining CPUE	Changing productivity, abundance and distribution	Area closures Catch limits	Not capturing changing behaviour Problem with CPUE standard'n	Not Applicable	Minor contribution	Minor contribution	Avoidance Mixed bag target
	Lack of recovery	Change in productivity	Minor contribution	Not capturing changing behaviour Problem with CPUE standard'n	Not Applicable	Not Applicable	Not Applicable	Not Applicable

Figure 120. Priorities identified from participant feedback (green cells were rated priority 1 by some and priority 1 + 2 by greater than 30% of participants).

CONCLUSIONS

This project has helped SESSF stakeholders to focus us on the main issues that, if addressed through a targeted RD&E, are most likely to yield benefits to future management of the SESSF.

The SESSF is a complex multi-species, multi-gear fishery distributed over a large geographical area with a diverse range of vessels and operators. Added to this is the complexity of a quota system which covers 34 species or species groups, with quota held by individuals and companies who are not necessarily fishing concession holders. Thus, there are a large number of inter-related issues and mechanisms which influence catch rates, the recovery of overfished stocks and the capacity to catch TACs in the SESSF. To cap it off, we are endeavouring to manage the fishery in one of the global hotspots, where temperatures are warming at almost four times the global average, greatly influencing habitats, ecosystems and species productivity and distribution. The challenge therefore lies first, in being able to identify and collect the data that is critical to future management of the fishery and second, developing assessments that can quantify each of these aspects and their combined impact on this fishery, and adapt harvest strategies to best manage the fishery taking these factors into account.

To meet the first challenge, we require better data. The highest priority is to cost-effectively collect data that helps us understand the dynamics of fishing operations and their interdependence on markets, costs of production, and most importantly, quota ownership and trading. We also need data that helps us understand the impact that climate change will have on the productivity, abundance and distribution of species we catch and the habitats and ecosystems that support them.

The second challenge is to improve our assessments and management approaches so that they are able to utilise this additional information. This is not a trivial goal, but some of it can start now with incorporation of indicators such as $PUE to better capture economic indicators driving fishing operations and development and inclusion of fishing power time series in CPUE standardisations. Other aspects such as inclusion of the impacts of climate change will take much longer. In the meantime, we need to begin the process of significantly improving our harvest strategies so that they are appropriate with regard to sustainability and maximising economic yield in a multi-species context, but also robust to the uncertainties associated with climate change.

EXTENSION AND ADOPTION

This project has necessarily involved a broad range of SESSF stakeholders including industry (fishermen, quota owners and investors), managers, social scientists, economists, climatologists and fish biologists, to get the extent of input and expertise required to shed light on potential reasons for the declining SESSF indicators. It has been useful to identify and prioritise mechanisms that may explain these indicators and the need for further investigation.

In conjunction with the current project, there has been other recent strategic projects which elucidate current issues in the SESSF and their potential to be addressed in future SESSF management: FRDC 2014-203 'SESSF Monitoring and Assessment – Strategic Review' (Knuckey et. al 2017); FRDC 2016-139 'Decadal scale projection of changes in Australian fisheries stocks under climate change' (Fulton et al. 2018); and 'FRDC 2016-059 Adaptation of Commonwealth fisheries management to climate change' (Rayns et al, underway). There is a need for the outcomes and recommendations of all of these project to be considered together to inform future management of the SESSF and in particular to help inform the design of the upcoming project: FRDC 2018-021 'Development and evaluation of multi-species harvest strategies in the SESSF'.

Recommendation 13. Consider and integrate the results and recommendations of the four recent SESSF-related projects (FRDC 2014-203, FRDC 2016-139, FRDC 2016-059 and the current project FRDC 2016-146) in light of the recently released revised Commonwealth Harvest Strategy Policy and Bycatch Policy to inform directions for future management of the SESSF and in particular, the development and evaluation of multi-species harvest strategies in the SESSF (FRDC 2018-021).

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APPENDIX 1 GENERIC AUTHOR TEMPLATE

Scope of the Issue

- Try to describe the breadth/detail of the issue you are considering and how it might relate to the three negative indicators: declining CPUE; lack of recovery; and, failure to catch TAC) (what is in, what is out and why).
- Where possible, provide quantitative evidence that demonstrates the impact of the issue on one or more of the indicators (Graphs and/or tables).
- Is there a relationship between this and another issue? (if yes – explain).
- Is there some other jurisdiction in Australia or internationally where this is a problem?

Impact on declining CPUEs

- Is the issue relevant to this indicator? (yes / no / unsure – why?)
- What is the potential explanation? (mechanisms and hypotheses)
- Is there any available/supporting data? (examples)
- Has there been any analysis of data? (has anything been analysed)
- Can this issue be addressed by management or industry? (if so – how?)
- Is further research is required? (objectives and methods)

Impact on lack of recovery of overfished species

- Is the issue relevant to this indicator? (yes / no / unsure – why?)
- What is the potential explanation? (mechanisms and hypotheses)
- Is there any available/supporting data? (examples)
- Has there been any analysis of data? (has anything been analysed)
- Can this issue be addressed by management or industry? (if so – how?)
- Is further research is required? (objectives and methods)

Impact on failure to catch TACs

- Is the issue relevant to this indicator? (yes / no / unsure – why?)
- What is the potential explanation? (mechanisms and hypotheses)
- Is there any available/supporting data? (examples)
- Has there been any analysis of data? (has anything been analysed)
- Can this issue be addressed by management or industry? (if so – how?)
- Is further research is required? (objectives and methods)

Conclusions

Summary

References

APPENDIX 2 WORKSHOP AGENDA

SESSF Declining Indicators Workshop

11-12th April 2018, Holiday Inn – Melbourne Airport (03) 9933 5111

Day 1	Item	Presenter
9:00	**Welcome and background** • Introductions and house keeping • Project overview – The three declining indicators – The seven papers on potential issues • What we want to achieve in the workshop?	Ian Knuckey Rob Stephenson
9:30	**Workshop methods** • Presentation of papers • Participant feedback – Trial feedback game • Prioritising future R&D directions	Ian Knuckey Rob Stephenson
10:00	**Morning Tea**	
10:30	**Fisher behaviour and vessel operation** • Summary of paper (25 minutes) • Q & A (15 minutes) • Workshop participant feedback (20 minutes)	Emily Ogier Group
11:30	**Fleet capacity and characteristics** • Summary of paper • Q & A • Workshop participant feedback	Simon Boag Group
12.30	**Lunch**	
13:30	**Quota ownership and trading** • Summary of paper • Q & A • Workshop participant feedback	Sarah Jennings Group
14:30	**Costs of production and changing markets** • Summary of paper • Q & A • Workshop participant feedback	Robert Curtotti Group
15:30	**Afternoon Tea**	

SESSF Declining Indicators Workshop

16:00	**Assessment processes** • Summary of paper findings • Q & A • Workshop participant feedback	**Rich Little** **Group**
17:00	**Day 1 Wrap up**	**Ian Knuckey** **Rob Stephenson**

Day 2	Item	Presenter
08:45	**Outline for Day 2**	**Ian Knuckey** **Rob Stephenson**
09:00	**Legislative / management impediments** • Summary of paper • Q & A • Workshop participant feedback	**George Day** **Group**
10:00	**Climate change and oceanographic conditions** • Summary of paper findings • Q & A • Workshop participant feedback	**Alistair Hobday** **Group**
11:00	**Morning Tea**	
11:30	**Prioritisation of issues** • Description of process • Workshop participant feedback	**Rob Stephenson** **Ian Knuckey** **Group**
1:00 pm	**Lunch**	
2:00 pm	**Prioritisation of issues (contd….)** • Analysis of feedback • Presentation and discussion of results	**Rob Stephenson** **Ian Knuckey** **Group**
2:30 pm	**Next Steps?** • Finalisation of papers based on feedback • Compilation of papers and workshop results • Process for implementation	**Rob Stephenson** **Ian Knuckey**
4:00pm	**Meeting Close**	